IUCAA

36th ANNUAL REPORT 2023-24

अंतर–विश्वविद्यालय केंद्र : खगोलविज्ञान और खगोलभौतिकी

INTER-UNIVERSITY CENTRE FOR ASTRONOMY AND ASTROPHYSICS

(An Autonomous Institution of the University Grants Commission)

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Secretary,
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Shantanu Rastogi
D.D.U. Gorakhpur University

Rajbir Singh,
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Rohtak

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R. Srianand,
Director
(Chairperson) (from 01 December 2023)

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(Convener) (till 06 December 2023)

A. N. Ramaprakash
(Convener) (from 07 December 2023)

Ranjeev Misra

Anupam Bhardwaj
(from 01 March 2024)

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(till 26 July 2023)

Debarati Chatterjee

Subhadeep De

Gulab Chand Dewangan

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(from 03 July 2023)

Neeraj Gupta

Shasvath Kapadia

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(from 01 December 2023)

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UGC

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A. N. Ramaprakash,
IUCAA
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Centre Director,
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Niranjan V. Abhyankar,
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(Chairman) (till 30 November 2023)

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Dean,
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Ranjeev Misra,
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(from 07 December 2023)

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(until 06 December 2023)

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Dean,
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N.V. Abhyankar, SAO
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(Officiating from 01.01.2023
till 30.11.2023)

R. Srianand
Dean,
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(from 01.04.2022 till 06.12.2023)

A. N. Ramaprakash
Dean,
Core Academic Programmes
(from 07.12.2023)

A. N. Ramaprakash
Dean,
Visitor Academic Programmes
(from 01.10.2022 - 06.12.2023)

Ranjeev Misra
Dean,
Visitor Academic Programmes
(from 07.12.2023)

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Sukanta Bose (till 26.07.2023)
Debarati Chatterjee
Subhadeep De
Gulab C. Dewangan
Rajeshwari Dutta (from 03.07.2023)
Tarun Souradeep (On Deputation)
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Shasvath J. Kapadia
Sanjit Mitra
Surhud S. More
Dipanjan Mukherjee
Sowgat Muzahid
Vaidehi S. Paliya
Aseem S. Paranjape
Kanak Saha
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T. P. Singh
Shamin Padalkar

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Varun Sahni
Kandaswamy Subramanian

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Deepak N. Bankar
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Rani S. Bhandare
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Samir A. Dhurde
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Santosh B. Jagade
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Shivaraj Kandhasamy
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Deepa Modi
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Savita K. Dalvi
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Sandeep L. Gaikwad
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Bhimpuri S. Goswami (till 31.03.2024)
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Senith S. Samuel
Rohan K. Shelar
Shahish K. Sukale
Varsha R. Surve
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Shashank S. Tarphe
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Kalidas P. Wavhal

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Sajad Ahmad Bhat (from 01.08.2023)
Souradeep Bhattacharya
Swadesh Chand
Atrideb Chatterjee
Jaiverdhan Chauhan (from 15.09.2023)
Sujaya Das Gupta (till 31.03.2024)
Sharmistha Chatterjee
Akash Garg
Tanuman Ghosh (from 01.08.2023)
Edmund Christian Herenz (from 01.11.2023)
Annu Jacob (till 13.10.2023)
Stanley Johnson
Anisha R. Kashyap (from 01.08.2023)
Saikruba Krishnan
Moupiya Maji
Preetish Kumar Mishra (till 31.08.2023)
Sapna Mishra (till 25.08.2023)
Ayan Mitra (till 11.12.2023)
Abhishek Mohapatra (till 31.01.2024)
Chayan Mondal
Vibhore Negi (from 01.03.2024)
Prasia P.
Sneha V. Pandit (from 12.02.2024)
Dhruv Pathak
Divya Rawat (till 18.10.2023)
Shouvik Roy Choudhury (till 28.06.2023)
Shilpa Sarkar (till 08.08.2023)
Suchira Sarkar
Mayur B. Shende
Srishti Tiwari
Chiranjeeb Singha (from 23.11.2023)
Subhashree Swain (from 05.01.2024)

RESEARCH STUDENTS

Linn Abraham (from 01.05.2023)
Deepali Agarwal (till 08.09.2023)
Bhaskar Arya
Eshita Banerjee
Sankalpa Banerjee
Nilaksha Barman
Ranit K. Behera
Rajendra P. Bhatt
Nishad Prashant Kumar Bunnelal (from 03.08.2023)
Suvas C. Chaudhary
Navin L. Chaurasiya
Rajesh Chell (till 15.07.2023)
Sourav Das (joined 01.08.2023)
Partha P. Deka
Saee M. Dhawalikar
Suraj Dhiwar
Sayak Dutta
Piyali Ganguly
Aman Gangwar (till 27.07.2023)
Priyanka Gawade
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Ankush Mandal
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Rajesh Mondal
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Pushpak Pandey
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Dhruv Pandya (till 30.09.2023)
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Avinash Tiwari
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Dhanraj Borgaonkar (till 06.09.2023)
Kshitij Chavan (from 15.06.2023)
Mahanthesha D.
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Vithal S. Savaskar
Balaji V. Sawant
Priyanka P. Shelke (from 01.01.2024 till 31.03.2024)
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Nived V. N. (from 30.06.2023)

VISITING ASSOCIATES OF IUCAA

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44. Suchetana Chatterjee, Department of Physics, Presidency University, Kolkata.
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46. Pradip Kumar Chattopadhyay, Department of Physics, Coochbehar Panchanan Barma University, Cooch Behar, West Bengal.

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48. Raghavendra Chaubey, DST Centre for Interdisciplinary and Mathematical Sciences, Banaras Hindu University, Varanasi.
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60. Sukanta Deb, Department of Physics, Cotton College State University, Guwahati.
61. Dipak Debnath, Institute of Astronomy Space and Earth Science, West Bengal.
62. Partha S. Debnath, Department of Physics, A. P. C. Roy Government College, Siliguri.
63. Ujjal Debnath, Department of Mathematics, Indian Institute of Engineering Science and Technology, Howrah.
64. Shantanu Desai, Department of Physics, IIT, Hyderabad.
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88. Umananda D. Goswami, Department of Physics, Dibrugarh University, Dibrugarh.
89. Aruna Govada, Department of Computer Engineering, Government Polytechnic, Daman & Diu.
90. Shivappa B. Gudennavar, Department of Physics, Christ (Deemed to be) University, Bangalore.
91. Sarbari Guha, Department of Physics, St. Xavier's College, Kolkata.
92. Mamta Gulati, School of Mathematics, Thapar Institute of Engineering and Technology, Patiala.
93. Priya Hasan, Department of Physics, Maulana Azad National Urdu University, Hyderabad.
94. Golam M. Hossain, Department of Physical Sciences, IISER, Kolkata.

95. Joe Jacob, Department of Physics, Newman College, Thodupuzha, Kerala.
96. Rinku Jacob, Department of Basic Sciences and Humanities, Rajagiri School of Engineering and Technology, Kakkanad, Kochi, Kerala.
97. Chetana Jain, Department of Physics, Hansraj College, Delhi.
98. Deepak Jain, Department of Physics, Deen Dayal Upadhyaya College, New Delhi.
99. Rajeev K. Jain, Department of Physics, IISc, Bangalore.
100. Charles Jose, Department of Physics, Cochin University of Science and Technology, Kochi, Kerala.
101. Jessy Jose, Department of Physics, IISER, Tirupati.
102. Minu Joy, Department of Physics, Alphonsa College, Pala, Kerala.
103. Jeena K., Department of Physics, Providence Women's College, Kozhikode, Kerala.
104. Sathya Narayanan K., Department of Physics, The Cochin College, Kochi, Kerala.
105. Md. Mehedi Kalam, Department of Physics, Aliah University, Kolkata.
106. Sanjeev Kalita, Department of Physics, Gauhati University, Guwahati.
107. Nagaraja Kamsali, Department of Physics, Bangalore University, Bangalore.
108. Pralay Kumar Karmakar, Department of Physics, Tezpur University, Assam.
109. Sreeja S Kartha, Department of Physics & Electronics, Christ (Deemed to be University) Bangalore, Karnataka.
110. Pradeep Kumar Kayshap, VIT Bhopal University, Bhopal.
111. Arun Kenath, Department of Physics & Electronics, Christ (Deemed to be University), Bangalore.
112. Nishikanta Khandai, School of Physical Sciences, NISER, Bhubaneswar.
113. Ram Kishor, Department of Mathematics, Central University of Rajasthan, Ajmer.
114. Newton Singh Kshetrimayum, Department of Physics, National Defence Academy, Khadakwasla, Pune.
115. Arun V. Kulkarni, Department of Physics, BITS - Pilani, Goa.
116. Bharat Kumar, Department of Physics & Astronomy, National Institute of Technology, Rourkela, Orissa.
117. Nagendra Kumar, Department of Mathematics, MMH College, Ghaziabad.
118. Rajesh Kumar, Department of Mathematics and Statistics, DDU Gorakhpur University, Uttar Pradesh.
119. R.K. Sunil Kumar, Department of Information Technology, Kannur University, Kerala.
120. Sanjay Kumar, PG Department of Physics, Patna University, Patna.
121. Suresh Kumar, Department of Mathematics, Indira Gandhi University, Meerpur, Haryana.
122. Richa Kundu, Department of Physics, University of Delhi, Delhi.
123. Badam Singh Kushvah, Indian Institute of Technology, Indian School of Mines Dhanbad, Jharkhand.
124. Vinjanampaty Madhurima, Department of Physics, Central University of Tamil Nadu, Thiruvarur.
125. Smriti Mahajan, Department of Physics, IISER, Mohali.
126. Bibhas R. Majhi, Department of Physics, IIT, Guwahati.
127. Liton Majumdar, Department of Physics, NISER, Bhubaneswar.
128. Shiva K. Malapaka, Department of Physics, IIIT, Bengaluru.
129. Manzoor A. Malik, Department of Physics, University of Kashmir, Srinagar.
130. Soma Mandal, Department of Physics, Government Girls' General Degree College, Kolkata.
131. Tuhina Manna, St. Xaviers College (Autonomous), Kolkata, West Bengal.
132. Titus K. Mathew, Department of Physics, Cochin University of Science and Technology, Kochi, Kerala.
133. Ram A. Maurya, Department of Physics, NIT – Calicut, Kozhikode, Kerala.
134. Biman J. Medhi, Department of Physics, Gauhati University, Guwahati.
135. Irom A. Meitei, Department of Physics, Manipur University, Imphal.
136. Manesh Michael, Department of Physics, Bharata Mata College, Kochi, Kerala.
137. Hameeda Mir, Department of Physics, Government Degree College, Srinagar.
138. Mubashir H. Mir, Department of Physics, Government Degree College, Bandipora, Jammu and Kashmir.
139. Bivudutta Mishra, Department of Mathematics, BITS - Pilani, Hyderabad.
140. Sourav Mitra, Department of Physics, Surendranath College, Kolkata.
141. Kamakshya P. Modak, Department of Physics, Brahmananda Keshab Chandra College, Kolkata.
142. Sajahan Molla, Department of Physics, New Alipore College, Kolkata.
143. Aditya S. Mondal, Department of Physics, Visva-Bharati University, Santiniketan.
144. Saptarshi Mondal, Department of Physics, Bethune College, Kolkata.
145. Soumen Mondal, Department of Physics, Jadavpur University, Kolkata.

146. Mahadevappa Naganathappa, Gitam (Deemed to be University) Hyderabad Campus, Telangana.

147. Hemwati Nandan, Department of Physics, Gurukula Kangri University, Haridwar.

148. Rajesh K. Nayak, Department of Physical Sciences, IISER, Kolkata.

149. Rahul Nigam, BITS Hyderabad, Telangana.

150. Chandrachani Devi Ningombam, Physics Department, Manipur University, West Manipur.

151. Sachin P.C., Department of Physics, Fatima Mata National College, Kollam, Kerala.

152. Prince P. R., Department of Physics, University College, Thiruvananthapuram.

153. Sreejith Padinhatteeri, Manipal Centre For Natural Sciences, Manipal Academy of Higher Education, Udupi, Karnataka.

154. Barun K. Pal, Department of Physics, Netaji Nagar College for Women, Kolkata.

155. Main Pal, Sri Venkateswara, College University of Delhi, Delhi.

156. Biswajit Pandey, Department of Physics, Visva-Bharati University, Santiniketan.

157. Sanjay K. Pandey, Department of Mathematics, L.B.S. Degree College, Gonda, Uttar Pradesh.

158. Mahadev B. Pandge, Department of Physics, Dayanand Science College, Latur, Maharashtra.

159. Uma Papnoi, Department of Physics, Gurukul Kangri (Deemed to be University), Vishwavidyalaya, Haridwar.

160. Rutu M. Parekh, Dhirubhai Ambani Institute of Information & Communication Technology, Gandhinagar, Gujarat.

161. Amit Pathak, Department of Physics, Banaras Hindu University, Varanasi.

162. Kishor D. Patil, Department of Mathematics, Vivekanand Science College, Buldhana, Maharashtra.

163. Madhav K. Patil, School of Physical Sciences, Swami Ramanand Teerth Marathwada University, Nanded, Maharashtra.

164. Bikash C. Paul, Department of Physics, University of North Bengal, Siliguri.

165. Surajit Paul, Manipal Center for Natural Sciences, Manipal Academy of Higher Education, Manipal, Karnataka.

166. Devraj D. Pawar, Department of Physics, RJ College, Mumbai.

167. Ninan S. Philip, Artificial Intelligence Research and Intelligent Systems, Thelliyoor, Kerala.

168. Ananta C. Pradhan, Department of Physics and Astronomy, NIT, Rourkela.

169. Anirudh Pradhan, Department of Mathematics, GLA University, Mathura.

170. Ram Prasad Prajapati, School of Physical Sciences, Jawaharlal Nehru University, New Delhi.

171. Anisur Rahaman, Durgapur Government College, Durgapur, West Burdwan.

172. Farook Rahaman, Department of Mathematics, Jadavpur University, Kolkata.

173. Nisha Rani, Miranda House University of Delhi, Delhi.

174. Rakhi R., Department of Physics, N. S. S. College, Pandalam, Kerala.

175. Rajesh S.R., Department of Physics, Sanatana Dharma College, Alappuzha, Kerala.

176. Chayan Ranjit, Department of Mathematics, Egra S.S.B. College, Purba, Medinipur, West Bengal.

177. Shantanu Rastogi. Department of Physics, DDU. Gorakhpur University, Gorakhpur.

178. CD Ravikumar, Department of Physics, University of Calicut, Kozhikode, Kerala.

179. Saibal Ray, Centre for Cosmology, Astrophysics & Space Science (CCASS) University Mathura, Uttar Pradesh

180. Biplab Raychaudhuri, Department of Physics, Visva-Bharati University, Santiniketan.

181. Pramit Rej, Department of Mathematics, Sarat Centenary College, Hooghly, West Bengal.

182. Rupak Roy, Manipal Center for Natural Sciences, Manipal Academy of Higher Education, Manipal, Karnataka.

183. Prabir Rudra, Department of Mathematics, Asutosh College, Kolkata.

184. Aswathy S., Department of Physics, Providence Women's College, Kozhikode, Kerala.

185. Sunil Kumar S., Department of Physics, IISER, Tirupati.

186. Anirban Saha, Department of Physics, West Bengal State University, Kolkata.

187. Sanjay K. Sahay, Department of Computer Science and Information Systems, BITS - Pilani, Goa.

188. Sandeep Sahijpal, Department of Physics, Panjab University, Chandigarh.

189. Pradyumn Kumar Sahoo, BITS-Pilani, Hyderabad Campus, Hyderabad, Telangana.

190. Eeshankur Saikia, Department of Applied Sciences, Gauhati University, Assam.

191. Gauranga C. Samanta, PG Department of Mathematics, Fakir Mohan University, Balasore, Orissa.

192. Prasant Samantray, Department of Physics, BITS - Pilani, Hyderabad.

193. Biplob Sarkar, Department of Applied Sciences, School of Engineering, Tezpur University, Tezpur.

194. Prakash Sarkar, Kashi Sahu College Seraikella Dist - Jharkhand.

195. Rathin Sarma, Department of Physics, Rabindranath Tagore University, Hojai.

196. Saumyadip Samui, Department of Physics, Presidency University, Kolkata.

197. Subrata Sarangi, Department of Physics, Centurion University of Technology and Management, Bhubaneswar.

198. Tamal Sarkar, High Energy and Cosmic Ray Research Centre, University of North Bengal, Siliguri.

199. Anjan A. Sen, Centre for Theoretical Physics, Jamia Millia Islamia, Delhi.

200. Asoke K. Sen, Department of Physics, Assam University, Silchar, Assam.

201. Somasri Sen, Department of Physics, Jamia Millia Islamia, Delhi.

202. Anand Sengupta, Department of Physics, IIT, Gandhinagar, Gujarat.

203. T.R. Seshadri, Department of Physics and Astrophysics, University of Delhi, Delhi.

204. Kannabiran Seshasayanan, Department of Physics, Indian Institute of Technology Kharagpur West Bengal.

205. Geetanjali Sethi, Department of Physics, St. Stephens College, University of Delhi, Delhi.

206. Mohd Shahalam, Integral University, Lucknow.

207. Aishawnnya Sharma, Department of Physics, Bahona College, Jorhat.

208. Ranjan Sharma, Department of Physics, Cooch Behar Panchanan Barma University, West Bengal.

209. Umesh K. Sharma, Department of Mathematics, GLA University, Mathura.

210. Md. Salim Md. Harun Shekh, S. P. M. Science and Gilani Arts Commerce College, Yavatmal.

211. Amit Shukla, Discipline of Astronomy, Astrophysics and Space Engineering, IIT, Indore.

212. Ashutosh Singh, Centre for Cosmology, Astrophysics and Space Science GLA University Mathura, Uttar Pradesh.

213. Alkendra Singh, Department of Physics, Institute of Science, Banaras Hindu University, Varanasi.

214. Dharm Veer Singh, Department of Physics, GLA University Mathura, Uttar Pradesh.

215. Gyan P. Singh, Department of Mathematics, Visvesvaraya National Institute of Technology, Nagpur.

216. Harinder P. Singh, Department of Physics and Astrophysics, University of Delhi, Delhi.

217. Heisnam S. Singh, Department of Physics, Rajiv Gandhi University, Arunachal Pradesh.

218. Suprit Singh, Department of Physics, Indian Institute of Technology, New Delhi.

219. Monika Sinha, Department of Physics, IIT, Jodhpur.

220. Surendra N. Somala, Department of Civil Engineering, IIT, Hyderabad.

221. Sourav Sur, Department of Physics &Astrophysics, University of Delhi (North Campus), New Delhi.

222. Parijat Thakur, Department of Basic Sciences and Humanities, Guru Ghasidas Central University, Bilaspur.

223. Arun V. Thampan, Department of Physics, St. Joseph's College, Bangalore.

224. Vithal P. S. Tilvi, Department of Physics, Government College of Arts, Science and Commerce, Khandola, Goa.

225. Sunil K. Tripathy, Department of Physics, Indira Gandhi Institute of Technology, Orissa.

226. Vinutha Tummala, Department of Applied Mathematics, Andhra University, Visakhapatnam.

227. Rashmi Uniyal, Department of Physics, Government Degree College, Narendranagar, Uttarakhand.

228. Sanil Unnikrishnan, Department of Physics, St. Stephen's College, Delhi.

229. Sudhaker Upadhyay, Department of Physics, KLS College, Nawada, Bihar.

230. Anisul A. Usmani, Department of Physics, Aligarh Muslim University, Aligarh.

231. Jithesh V, Department of Physics and Electronics, Christ (Deemed To Be University) Bengaluru.

232. Nilkanth D. Vagshette, Department of Physics and Electronics, Maharashtra Udaygiri Mahavidyalaya, Udgir, Maharashtra.

233. Deepak Vaid, Department of Physics, NIT, Surathkal, Karnataka.

234. Bhargav P. Vaidya, Discipline of Astronomy, Astrophysics and Space Engineering, IIT, Indore.

235. Murli M. Verma, Department of Physics, University of Lucknow, Lucknow.

236. Jaswant K. Yadav, Department of Physics, Central University of Haryana, Haryana.

237. Nitin Yadav, Department of Physics, Indian Institute of Science Education and Research Thiruvananthapuram, Kerala.

238. Lalthakimi Zadeng, Department of Physics, Mizoram University, Aizawl.

The Thirty-fourth batch (2023) of Visiting Associates, who were selected for a tenure of three years, beginning August 1, 2023.


Abisa Sinha Adhikary


Aditi Agarwal


Faizuddin Ahmed


Musavvir Ali


Dipankar Bhattacharya


Mridusmita Buragohain,


Luke Chamandy


Pradip Kumar Chattopadhyay


Ankan Das


Dipak Debnath


Praveen Kumar Dhankar


Mansi Dhuria


Sakshi Gautam


Pralay Kumar Karmakar


Sreeja S Kartha


Pradeep Kumar Kayshap


Rajesh Kumar


Richa Kundu


Badam Singh Kushvah


Rahul Nigam


Main Pal


Nisha Rani


Pramit Rej


Rupak Roy


Prakash Sarkar


Kannabiran Seshasayanan


Mohd Shahalam


Md. Salim Md. Harun Shekh


Ashutosh Singh


Jithesh V.


Mrs. Nitin Yadav

Appointment of the following visiting associates of the thirtieth batch was extended for three years from August 2023

Bijan Kumar Bagchi, Arunima Banerjee, Sarmistha Banik, Priya Bharali, Rashmi Bharadwaj, Srijit Bhattacharjee, Subhra Bhattacharya, Nand Kumar Chakradhari, Hum Chand, Ramesh Chandra, Suresh Chandra, Suchetana Chatterjee, Ritaban Chatterjee, Ayan Chatterjee, Surajit Chattopadhyay, Asis Kumar Chattopadhyay, Raka Vasant Dabhade, Shyam Das, Sudipta Das, Ujjal Debnath, Shantanu Desai, Abhik Ghosh, Gaurav Goswami, Naseer Iqbal Bhat, Sathya Narayanan K., Arun Venkatesh Kulkarni, Sanjay Kumar, Suresh Kumar, R.K. Sunil Kumar, Smriti Mahajan, Liton Majumdar, Manzoor A. Malik, Soma Mandal, Titus K. Mathew, Ram Ajor Maurya, Irom Ablu Meitei, Hameeda Mir, Saptarshi Mondal, Mahadev Baburao Pandge, Kishor Dnyandeo Patil, Surajit Paul, Ninan Sajeeth Philip, Rakhi R., Shantanu Rastogi, Saibal Ray, Prabir Rudra, Sunil Kumar S., Gauranga Charan Samanta, Saumyadip Samui, Anand Sengupta, T.R. Seshadri, Umesh Kumar Sharma, Heisnam Shanjit Singh, Gyan Prakash Singh, Monika Sinha, Arun Varma Thampan, Sunil Kumar Tripathy, Vinutha Tummala, Rashmi Uniyal, Deepak Vaid.

ORGANISATIONAL STRUCTURE OF IUCAA'S ACADEMIC PROGRAMMES

(As on March 31, 2024)

The Director

R. Srianand

(from December 01, 2023)

(Officiating Director from 01.01.2023 till 30.11.2023)

Dean, Core Academic Programmes


R. Srianand **A. N. Ramaprakash**

Head, Computing Facilities

Sanjit Mitra

Head, Publications

Dipanjan Mukherjee

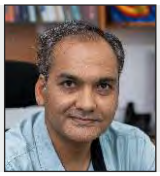
Head, Instrumentation & IGO

A.N. Ramaprakash

Head, Teaching Programmes

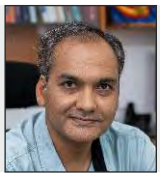

Gulab C. Dewangan **Aseem Paranjape**

Head, Library




Durgesh Tripathi **Kanak Saha**

Head, Rajbhasha Committee




Durgesh Tripathi **Vaidehi Paliya**

Head, Infrastructural Facilities

R. Srianand

Head, Grievance Cell

Gulab C. Dewangan

Chairperson, IUCAA Committee Against Sexual Harassment (ICASH)

Nirupama Bawdekar

Chairman, Special Cell for Scheduled Cast and Scheduled Tribes

Nitin Ohol

Dean,
Visitor Academic Programmes

A. N. Ramaprakash

Ranjeev Misra

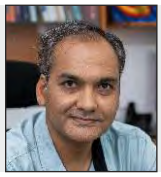
Head,
Observing Programmes (IGO and SALT)

R. Srianand

Gulab C. Dewangan

Head,
Scientific Meetings and ICARDs

Ranjeev Misra



Durgesh Tripathi

Head,
Public Outreach Programmes

Nishant Singh

DIRECTOR'S REPORT

The main objectives of IUCAA are to provide a centre of excellence within the university sector for teaching, research and development in Astronomy & Astrophysics (A&A), as well as to promote nucleation and growth of active groups in this area in the universities. The aim is to provide researchers from universities access to state-of-the-art astronomical instrumentation, theoretical know-how, well-equipped laboratories, data centre and high-quality computing facilities. For more than three decades, IUCAA has not only achieved these objectives but has maintained the emphasis on fundamental research and innovative teaching in a wide range of areas of A&A. Over this period, IUCAA's interactions with universities have also evolved as per the demands of the changing research and technology landscape in the country and abroad.

At present, IUCAA's academic staff consists of 24 faculty members (including Emeritus Professors), 4 Adjunct faculty members, 47 PhD students, 20 Post-Doctoral fellows, 41 Scientific and technical staff and 5 project students. The high level of science productivity of IUCAA academic staff is reflected in the fact that during this academic year, they have published about 173 papers in peer-reviewed journals. The average impact factor for these publications is 5.19 Our M. Sc Physics (Astrophysics) programme in collaboration with the SPPU-Physics department continues to attract young students across the country, and we are happy to see a good fraction of students graduating from this programme are taking up PhD admissions in different astronomy institutions in the country and abroad. This year, we have initiated the setting up of an introductory-level laboratory for gravitational science. A first school for Master's students using this laboratory is planned for the winter months of 2024.

This year, we have re-established the Scientific Advisory Committee (SAC) of IUCAA, consisting of domain experts from India and abroad. The main activities of the SAC are to submit its report, after a thorough review of IUCAA's activities and advice on future directions and developments, to the Governing Board, which will in turn take it to the University Grants Commission. The first meeting of the new SAC was held from April 22-26, 2024. The committee has gone through a detailed review of all activities of IUCAA and engaged with all stakeholders. Their valuable suggestions will soon be incorporated into the activities of IUCAA.

The number of IUCAA associates also shows a steady increase over the period. Now, the total number of associates stands at 237. This year, we have re-established the "Users' Committee" nearly after a decade. The Users' Committee is expected to provide recommendations to the Governing Board of IUCAA for optimal and effective utilisation of the IUCAA's facilities by visiting university scientists. The Users' Committee will have the responsibility of devising methods for obtaining feedback from the users and may comment on Visitor Academic Programmes such as schools, courses, workshops etc.,

conducted by IUCAA. We are in the process of setting up various research theme-based working groups consisting of IUCAA faculty and associates to plan and carry out various activities, including the upgradation and effective utilisation of various IUCAA programmes and facilities. IUCAA has established about 24 IUCAA Centre for Astronomy Research and Development (ICARD). These were established to contribute to the development of up-to-date course structures and new kinds of experiment / data analysis sessions, which can be a part of a starting or existing Astronomy course in universities. The next call for proposals for establishing new ICARDs will be released soon and we hope to establish more ICARDs, in particular, covering the regions and states that are not well geographically represented at present.

SARATHI, a powerful HPC facility at IUCAA, is dedicated to LIGO data analysis and is IUCAA's contribution to the International Gravitational Wave Observatory Network (IGWN). SARATHI accounts for about 15% of IGWN computing resources. PEGASUS HPC cluster is a dedicated facility made available to the general users of IUCAA and researchers from Indian universities. We are enhancing the computing power of PEGASUS by 25%. We have also established a usage policy document and set up a Time Allocation Committee and usage monitoring committee to maximise the efficient usage of HPC. Efforts are on to secure a much larger computing facility to accommodate every growing computing needs of IUCAA users.

This year, two major events grabbed the attention of astronomers in the country. The first one is the formal approval of the LIGO-INDIA project from the Government of India. The LIGO-India project received cabinet approval in April 2023 and is expected to start operating in the year 2030. The project is being led by four lead institutions: Directorate of Construction Services and Estate Management (DCSEM), Mumbai, Institute of Plasma Research (IPR), Gandhinagar, Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune and Raja Ramanna Centre for Advanced Technology (RRCAT), Indore. IUCAA is the key science stakeholder in the project and leading the computing and data management, human resource development, education and public outreach activities. IUCAA also has the responsibility to build a commissioning team and initiate a detail project proposal for the operations and maintenance (O&M) phase that will follow after the initial science runs of LIGO-India. IUCAA is planning various activities to bring gravitational wave science to teachers and students from universities, colleges, and schools as well as to the general public.

The second important development is the ISRO's Launch of ADITYA-L1, our first space solar mission. IUCAA has played an important role in this mission by delivering the Solar Ultraviolet Imaging Telescope (SUIT). We are happy to note that the telescope is performing very well and initial science verification and calibration observations are going on as per the plan. IUCAA is hosting the Payload Operations Centre (POC) for the SUIT instrument. This POC will benefit from the vast experience we have gained in operating the Astrosat Science Support Cell (ASSC) and POC for the CZTI instrument onboard Astrosat. In this regard, it is gratifying to note that the number of papers published using Astrosat data and the number of individual users of Astrosat continue to increase this year, too. In particular, about 30% of these papers have emerged from authors from the university sector. We hope to achieve similar success for the data obtained using the SUIT instrument as well.

IUCAA continue to spread Astronomy & Astrophysics to different sections of the community. The Astronomy Centre for Educators (ACE) of IUCAA includes the Teaching Learning Centre (TLC), National Resource Centres (NRC) and the International Astronomical Union's Office of Astronomy for Education (IAU-OAE). Their activities focused on spreading Astronomy activities to students and teachers from colleges and schools. As a part of LIGO-India activities, IUCAA is involved in different Education and Public Outreach (EPO) programmes focusing on gravitational wave science. As usual, more than 8000 people have visited IUCAA during Science Day celebrations. We have welcomed students of varying age groups and from distant locations like Ghodegaon, Hingoli and Parbhani. This year, IUCAA focused on showcasing various in-house research activities. Models of various upcoming mega-science projects were displayed for the general public. All the exhibits and demonstrations were very well received. As usual, the centre of attraction was the "Ask the Scientist?" event, where Professor Narlikar and others enthusiastically answered interesting questions from the general public. I use this opportunity to thank all the volunteers from IUCAA, Ferguson College and other institutes in Pune for their contribution to making the event successful.

Finally, I take this opportunity to thank my colleagues and seniors at IUCAA for their help in performing my duties as the Director of IUCAA. I would also like to express thanks to our mentors, our Governing Board with Hon'ble Dr K. Kasturirangan as Chair, and our Council, chaired by Hon'ble Dr M. Jagadesh Kumar, Chairman, University Grants Commission (UGC). I also acknowledge the help, advice and support from the UGC and its officers and staff, and from the Ministry of Education of the Government of India.

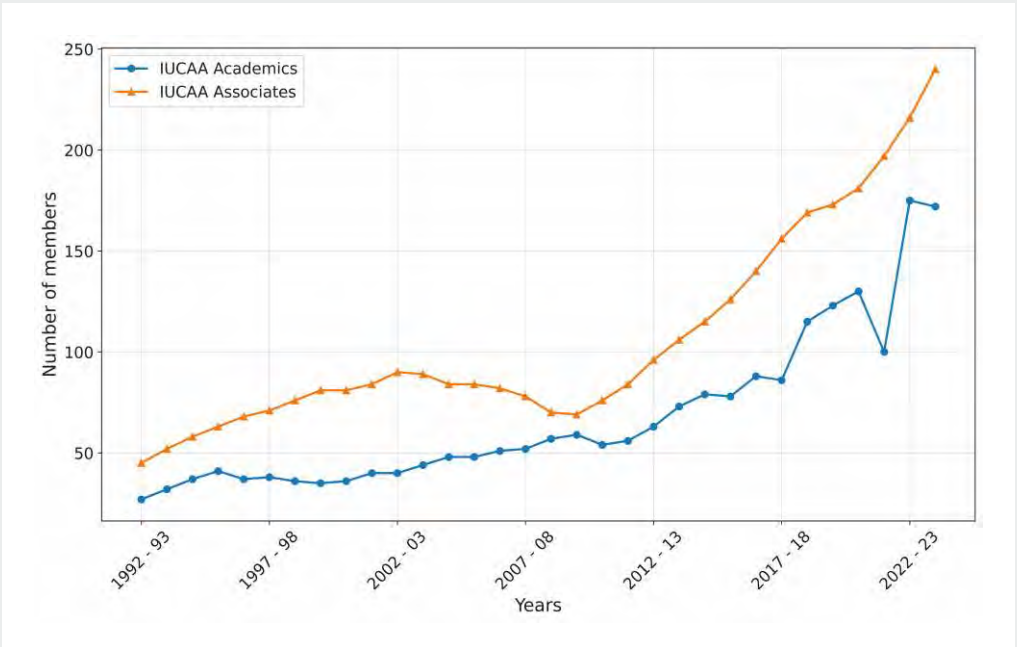
R. SRIANAND

Director, IUCAA

IUCAA IN NUMBERS

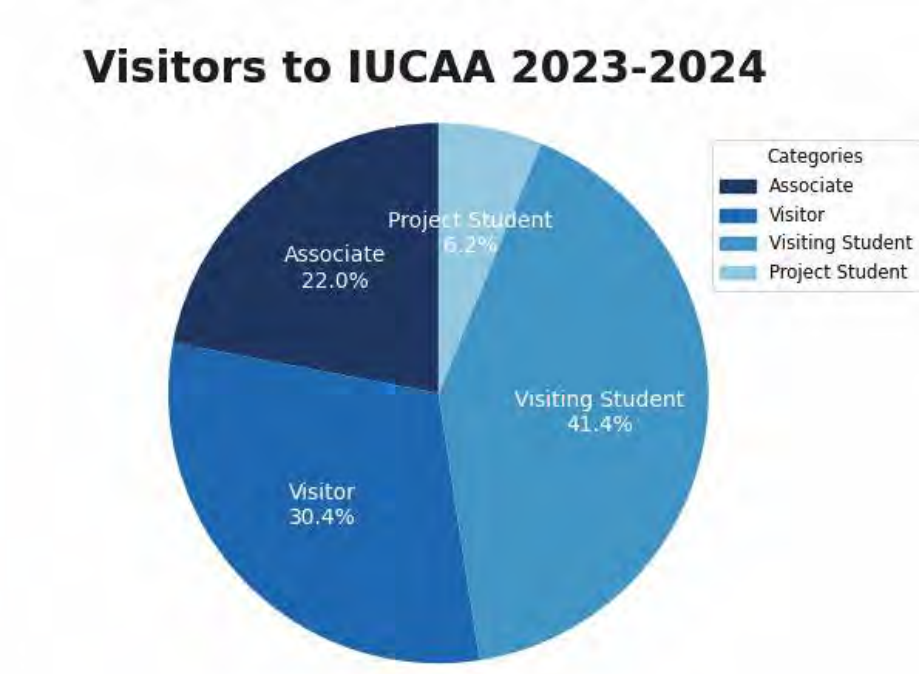
IUCAA Family

The graph depicts the three-fold growth of the academic strength and the IUCAA extended family of Visiting Associates since its inception.



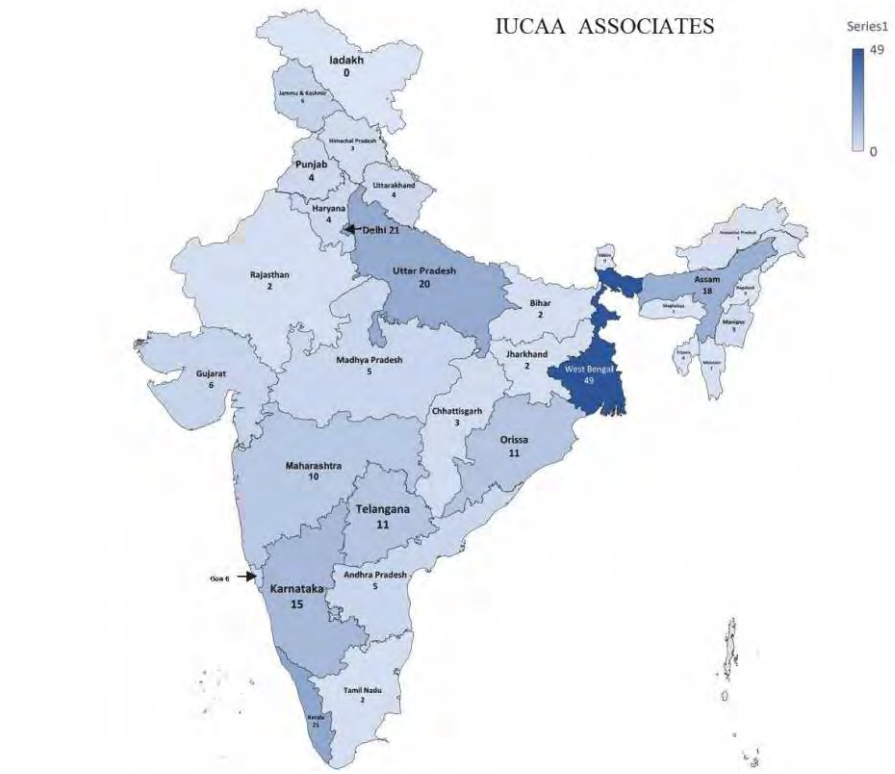
Visitors to IUCAA

In addition to hosting Visiting Associates (22%), IUCAA hosted official visitors comprising university academics (30.4%), students (41.4%) pursuing their Ph.Ds. from other universities/institutes, and project students (6.2%) working on projects supervised by IUCAA faculties. The total number of visitors in the period 2023-24 comprising the above-mentioned categories was 677.



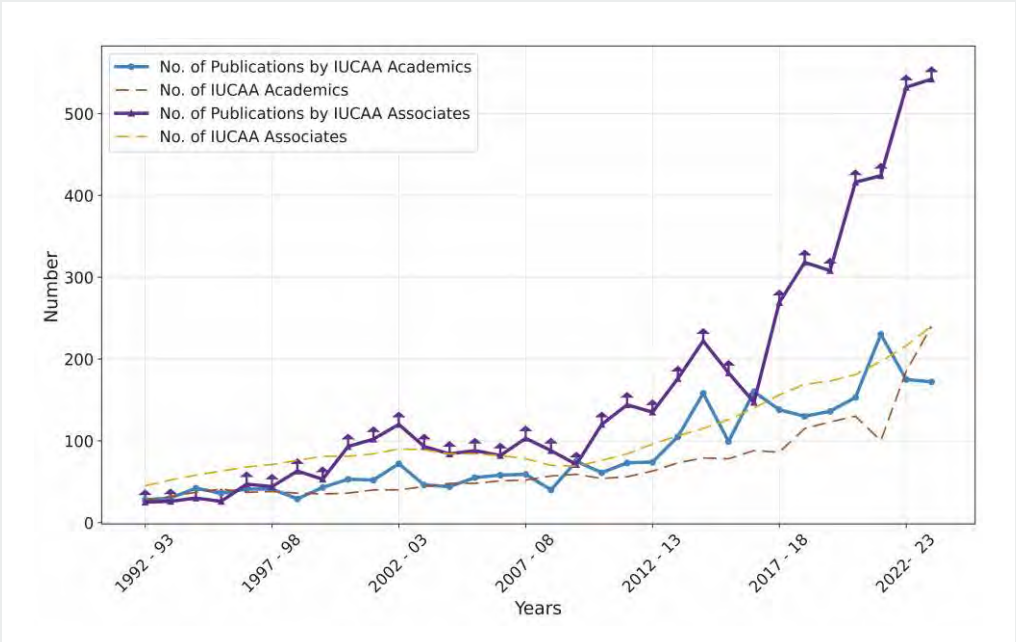
IUCAA Visiting Associates across India

The number of IUCAA Visiting Associates has continued to expand in numbers and geographically, with significant representation today from the remotest part of the country. The state wise distribution of IUCAA Associates is depicted in the map. The number of Visiting Associates across India during 2023-24 was 238.

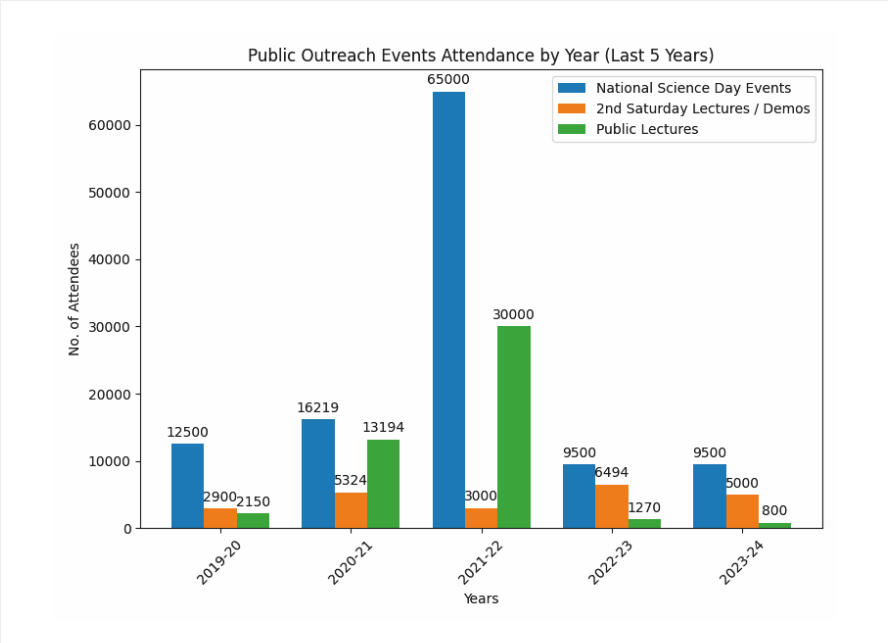


Publications across the year

The increasing academic strength has gone hand-in-hand with a corresponding increase in scientific output.

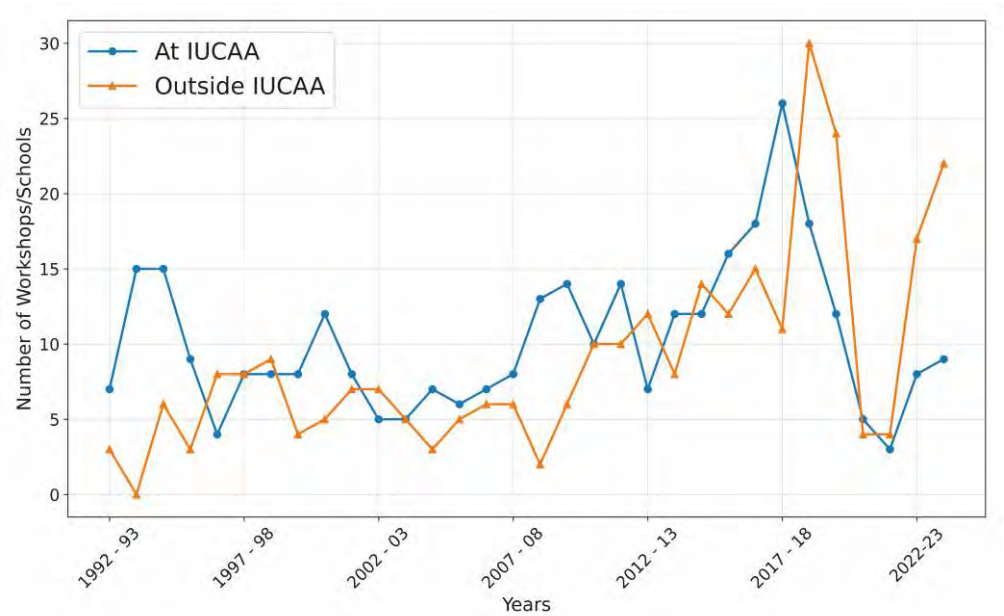


Public Outreach Events at IUCAA



Workshops/ Schools in IUCAA and Outside IUCAA

IUCAA is committed to fostering astronomy and astronomy in universities, primarily through an increasing frequency of workshops and schools, both at and outside IUCAA. The graph shows the distribution of workshops/schools held at IUCAA and outside IUCAA during 2023-24.



IUCAA has perhaps the largest research group in gravitational waves (GW) in India. Consequently the research work done here spans a vast range of areas, namely, data analysis, signal modelling, astrophysics, cosmology, detector characterization, instrumentation, etc., leading to several publications every year. The research outcome is highly regarded worldwide, often for introducing ideas that have made significant impact in the field. In this article, we highlight several research achievements that happened in the past few years.

Searches

Compact Binary Coalescence (CBC)

- **Hierarchical search:** Matched Filtering is the primary method that is used to find GW signals buried in noisy data. The analysis has to be conducted to search for lakhs of model waveforms (templates), making the process computationally expensive. At this point, due to computational limitations, one needs to invoke major assumptions to reduce the dimensionality and size of the search parameter space. Kanchan Soni, Sanjeev Dhurandhar and Sanjit Mitra have developed a two stage (coincident) hierarchical search, which speeds up the search by more than one order of magnitude [Phys. Rev. D 105, 064005 (2022)]. The search was applied to real data and it recovered all the events published in the LIGO-Virgo-KAGRA (LVK) collaboration's first transient catalogue (GWTC-1) with approximately the same significance. They have also developed a novel technique of determining the significance of an event accurately yet fast, without which the computational efficiency would be lost [Phys. Rev. D 109, 024046 (2024)].

- **Towards a Machine Learning based search:** While Machine Learning based algorithms are progressively being introduced for GW data analysis for various tasks, and Sanjit Mitra and his group at IUCAA made the first successful implementations of it on real GW data, as of now, the primary algorithm to search for CBCs is matched filtering. Shreejit Jadhav, Mihir Srivastava (IIT Kharagpur) and Sanjit Mitra have recently developed a method towards that goal. While the method is not yet as efficient as Matched Filtering, it is a big step towards making a primarily Machine Learning based search. Also, this has the potential to work with the present Matched Filtering based analysis to perform a deeper search (that is, to find low significance events). [Mach. Learn.: Sci. Technol. 4 (2023) 045028]

- **Sigmanet - A neural network to distinguish Binary Black Holes (BBH) vs glitches:** Sunil Choudhary, Anupreeta More, Sudhagar S and Sukanta Bose designed SiGMaNet, a neural network, initially, to distinguish massive BBH from Blip glitch, a type of transient non-gaussian feature. This is done by generating projection maps of cross-correlations of triggers (either a BBH or a Blip glitch) with Sine-Gaussian functions. Since the projections of BBH and Blip glitches are different, they could successfully identify BBH from Blip glitches far better than traditional methods [Phys. Rev. D, 107, 024030 (2023)] . In the extension of this work, with SiGMaNet-2, they are broadening its applicability to a wider class of glitches and by training a new neural network on much larger samples [Narayan, More et al. in prep].

Gravitational Wave Background (GWB)

- **Pipeline development for GWB searches:** Until now, the LVK collaboration has been using mainly Matlab-based codes for isotropic GWB searches. The collaboration has now developed a Python-based search library for GWB searches [ApJ 952 25 (2023)]. This new code is faster and also easier to use. This will be useful for the wider GWB community outside of LVK. Much documentation has also been produced for this new code base to support that effort [JOSS 9(94), 5454 (2024)]. This code is now publicly available. Shivaraj Kandhasamy was one of the lead developers of the new pipeline. Sukanta Bose and Sanjit Mitra were part of the LVK team that reviewed the code.

- **Effect of calibration uncertainties on GWB searches:** With the ongoing improvements in the detector sensitivities, the detection of GWB is on the horizon. However, much work still needs to be done to extract all the information from the detected signal. The calibration process, which converts photo-detector signals at the output to GW strain, can affect such parameter estimation. Shivaraj Kandhasamy (IUCAA) and Junaid Yousuf (Univ. Kashmir) studied such effects quantitatively and showed that for the current generation of detectors with calibration uncertainties less than 10%, such effects are negligible [Phys. Rev. D 107, 102002 (2023)].

- **All-Sky All-Frequency (ASAF) analysis:** Sanjit Mitra and his group developed an analysis pipeline, PyStoch, to search for anisotropic GWB, which utilised years worth of data folded to one sidereal day utilising a mathematical symmetry, which was also developed by the same group. The folded data not only made the present LVK analysis hundreds of times faster, but enabled making skymaps at every frequency bin. The LVK collaboration devoted a full publication on All-Sky All-Frequency (ASAF) analysis, where Deepali Agarwal was the lead analyst, Sanjit Mitra led the search. Sukanta Bose and Shivaraj Kandhasamy were part of the LVK review team. [Phys. Rev. D 105, 122001 (2022)]

Time Delay Interferometry (TDI) for LISA

- Ground-based interferometric detectors of GW have taken great strides in detecting nearly a hundred binary mergers, and more detections are in the offing. However, these detectors are sensitive in the high-frequency range above 10 Hz. Because of various noise sources, it is impossible

to go below this lower limit. However, there are interesting astrophysical sources emitting GW at low frequencies. The solution is to go into space. The Laser Interferometer Space Antenna (LISA) is a space-based gravitational wave detector that is sensitive in the low-frequency band from 10^-5 Hz - 10^-1 Hz. However, LISA is plagued by laser frequency noise about 6 or 7 orders above the other ambient noises. Time-delay interferometry (TDI) is a technique in which the data streams are combined with appropriate time delays so that the laser frequency noise is cancelled or suppressed. Sanjeev Dhurandhar and his collaborators have used algebraic-geometric methods to find TDI combinations of data streams - an exact solution - the null space, namely, the module of syzygies (terminology by David Hilbert) is obtained for the static case. Since the arm-lengths are mildly time-varying, they Taylor-expanded the time-delay operators and obtained approximate solutions at the required order. Matrix methods have also been found to be useful. [M. Tinto and S. Dhurandhar, Living Reviews in Relativity (Springer), Vol. 24, article 1, (2021); M. Tinto, S. Dhurandhar and P. Joshi, Phys. Rev. D 104, 044033 (2021); S. Dhurandhar, P. Joshi and M. Tinto, Phys. Rev. D 105, 084063 (2022); M. Tinto, S. Dhurandhar and D. Malakar, Phys. Rev. D 107, 082001 (2023); M. Tinto and S. Dhurandhar, Phys. Rev. D 108, 082003 (2023)]

Parameter Estimation (PE)

- **Relative BInning in Bilby:** Parameter estimation of gravitational-wave signals is a computationally expensive process which increases with longer signal durations. Relative binning is a promising solution to accelerate the likelihood evaluations, which uses the smooth variation (in frequency) of the ratio of neighbouring waveforms in the parameter space. This approximation reduces the number of frequency points at which the waveform needs to be evaluated while sampling, thus reducing the computation time. Apratim Ganguly, along with his collaborators, has implemented his method in Bilby, an open-source Bayesian inference package. [arXiv: 2312.06009]

Rates & Populations (R & P)

- **Detectability of hyperbolic interactions of black holes:** Sajal Mukherjee, Sanjit Mitra and Sourav Chatterjee (TIFR) showed that the hyperbolic encounters of black holes may be detected by the next generation GW detectors. Even multiple present generation detectors observing for several years have non-negligible chances for detection of these events. Since GWs only from coalescing binaries have so far been detected, discovery of new types of events will be highly exciting. Moreover, these events can complement the CBC detections (which probe blackholes in binaries) in obtaining more precise estimates of the population of Black Holes in the universe. [MNRAS 508, 5064–5073 (2021)]

- **Probing the formation channels of CBCs with their centre-of-mass acceleration:** Avinash Tiwari and Shasvath J. Kapadia, in collaboration with Aditya Vijaykumar (CITA), Sourav Chatterjee (TIFR) and Giacomo Fragione (Northwestern University) are exploring the possibility of constraining line-of-sight acceleration (LOSA) of the centre of mass of CBCs. Detectors sensitive at low frequencies, such as proposed space-based detectors LISA and DECIGO, are best suited to observe this acceleration, although sufficiently large accelerations may also be detectable in future ground-based detectors such as Cosmic Explorer and Einstein Telescope. Avinash et al are also investigating how LOSA and its higher time derivatives can be used to probe the gravitational potential of the CBC's environment, thus determining their formation channel on a single-event basis. Avinash, Aditya and Shasvath will be contributing to the LVK Collaboration with analyses related to this work. [MNRAS, 527, 3, (2024), Astrophys. J., 954, 105 (2023)]

Gravitational Lensing

- **Strong lensing rates and constraints on merger rate density models:** Anupreeta More computed the fraction of the GW events that are expected to be strongly lensed for different types of lenses where the deflector is either an individual galaxy or a cluster of galaxy. The unlensed to lensed rates are -
  - Galaxy ~ 1 : O(1000)
  - Galaxy-clusters ~ 1: O(1000) but rarer than galaxy-scale lenses by a factor of 2

  The binary black hole merger rate density model determines the strong lensing rates. Thus, (non-)detection of strong lenses in the GW data can constrain the underlying family of merger rate density models. [Lensing LVK collaboration: Abbott et al. ApJ, Vol 923, Issue 1, id.14, 24 pp. 2021, Abbott et al. 2023 - arXiv:2304.08393]

- **Microlensing by isolated point-mass lens:** Isolated point-mass Microlensing introduces frequency dependent modulations in the GW signals. Anuj Mishra, Anupreeta More, Sukanta Bose and collaborators showed that if

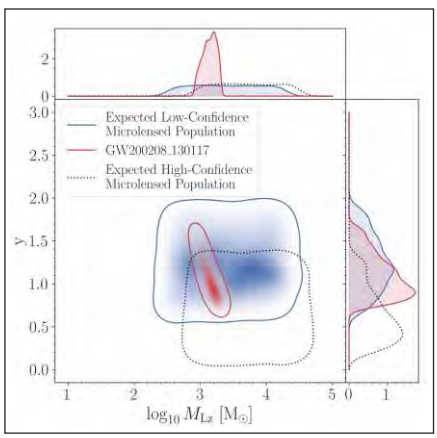


Fig: Microlensing parameters of GW200208_130117 overlap with low to high confidence regions of detectable microlensed signals which needs further investigation.

microlensing effects are ignored, it can cause bias in the inference of various parameters of binary black holes, for example, their distances, masses, spins and so on. We have identified which part of the microlensing parameters space is easier to be detected in the observations. A GW event called GW200208_130117 seems to arise from this detectable part of the microlensing parameter space. However, due to the low SNR of the GW event, one cannot be confident of its nature and needs to do further investigation. [MNRAS, In press (2024)]

- **Microlensing by population of stars and stellar remnants embedded in strong lensing galaxy:** Anuj Mishra, Anupreeta More, Sukanta Bose and collaborators developed a framework to determine microlensing by population of stellar/stellar remnant population embedded in strong lenses. The strong lensing magnification was found to be the most important parameter that affected the severity of microlensing distortions in the lensed GW signals [MNRAS, 508, 4869 (2021)]. Essentially, all lensed GW signals with strong lensing magnification <10 showed no deviation from unlensed signals [MNRAS, 517, 872 (2022)]. In subsequent studies, we also showed that if strong lensing + microlensing effects are not accounted for during the strong lensing searches in GW data, then this can adversely affect detection of lensed GW signals [MNRAS, In press (2024)].

- **Improving the ranking statistics of strongly lensed signals:** Anupreeta More and Surhud More proposed using joint distributions of strongly lensed image properties such as the time delays and relative magnifications to better select pairs of strongly lensed gravitational wave events in the data. The improvement was demonstrated by generating a mock sample of lensed and unlensed gravitational events. Furthermore, the new ranking statistics called Mgal was also applied to the known GW events which improved their significances, in particular for GW190731-GW190803 which seemed to be more consistent with a lensed population [MNRAS, 515, 1044 (2023)]. The importance of using joint distributions, which relies on a specific lens mass model, was further tested by Anupreeta More and collaborators to show that there was more benefit in using Mgal when searching for strongly lensed pair of candidate events [MNRAS 519, 2046 (2024)].

- **Rapid detection of strongly lensed GW signals with machine learning:** Sourabh Magare, Anupreeta More and collaborators have developed the SLICK pipeline which uses a neural network to analyse a pair of GW events and decide whether these are likely to be strongly lensed. In this work, the signals are cross-correlated with Sine-Gaussian functions and the resulting projection maps for the pair of events seen in two LIGO detectors are analysed simultaneously. For a lensed pair of events, we expect similar projections compared to a random pair of unlensed events. We find that our network is able to show good performance on a mock sample of lensed and unlensed events as well as the real known GW events from the third observing run of LIGO-Virgo data [arXiv:2403.02994].

- **Early-Warning with Gravitational-Lensing:** Sourabh Magare, Shasvath J. Kapadia and Anupreeta More have developed a method to alert electromagnetic telescopes of the merger of a binary neutron star, well before it merges, provided the BNS is gravitationally lensed. This method will enable telescopes to capture electromagnetic emissions before the merger, resulting in highly exciting and potentially ground-breaking observations. [Astrophys. J. Lett., 955, L31 (2023)]

- **Constraints on compact dark matter from gravitational wave microlensing:** If a significant fraction of dark matter is in the form of compact objects, they will cause microlensing effects in the GW signals observable by the ground-based detectors. Apratim Ganguly, Shasvath J. Kapadia and their collaborators have developed a method to constrain the fraction of compact dark matter to be less than $\simeq$ 50-80 % in the mass range 10^2-10^5 $M_\odot$ from the (non-)observation of microlensing signatures in the LIGO-Virgo observing runs. These modest constraints will be significantly improved in the next few years with the expected detection of thousands of binary black hole events, providing a new avenue to probe the nature of dark matter. [Astrophys. J. Lett. 926 L28 (2022)]

- **Detection and parameter estimation challenges of type-II lensed signals:** Type-II lensed GW signals introduce additional distortions in the strains of the BBH signals depending on various morphologies. Apratim Ganguly and his collaborators investigated the potential applicability of these distortions in helping identify Type-II signals from a single detection. They also investigated the systematic biases that could arise in the inference of their parameters if they are unknowingly recovered with gravitational-wave templates that do not take the distortion into account. It can be shown that the lensing distortions will allow to confidently identify Type-II images for highly inclined binaries: at network signal-to-noise ratio (SNR) $\rho = 20$ (50), individual Type-II images should be identifiable with log Bayes factor $\ln \mathcal{B} > 2$ for inclinations $\iota > 5\pi/12$ ($\pi/3$). [Phys. Rev. D 108, 043036 (2023)]

Cosmology

- **Expansion rate of the Universe:** The Hubble constant measures the local expansion rate of the Universe. As part of the LVK Collaboration, IUCAA researchers used 47 gravitational wave sources from the Third LVK Gravitational Wave Transient Catalog (GWTC-3) to estimate the Hubble constant H_0. Each GW signal provides the luminosity distance to the source, and researchers

estimated the corresponding redshift of the GW events using two methods: the redshifted masses and a galaxy catalogue. Using the binary black hole (BBH) redshifted masses, they simultaneously inferred the source mass distribution and the Hubble constant. Their results show that the source mass distribution displays a peak around $34M_{\odot}$, followed by a drop-off. Assuming this mass scale does not evolve with the redshift results in a measurement of the Hubble constant, the H0 measurement from the binary neutron star GW170817 and its electromagnetic counterpart. In the second method the researchers associated each GW event with its probable host galaxy in a galaxy catalogue, statistically marginalising over the redshifts of each event's potential hosts and could obtain tighter constraints, however those constraints can be strongly impacted by the assumption about the unknown mass distribution of the BBH sources. [Astrophys. J., 949, 76 (2023)]

- **Expansion rate from Binary black holes:** The statistical host identification method used to infer the expansion rate of the Universe with the help of binary black hole events suffers from galaxy catalogues whose incompleteness increases as we go to higher and higher redshifts, severely affecting the constraints. IUCAA researchers have developed methods to utilise the clustering of the visible population of brighter galaxies with the gravitational wave events in order to infer the Hubble constant from data at higher redshifts. [arXiv:2312.16305].

Testing General Relativity (TGR)

- **Biases in tests of GR due to microlensed signals:** Anuj Mishra and Apratim Ganguly have developed a method to investigate how isolated microlensed GW signals can introduce biases in tests of general relativity due to the non-inclusion of lensing effects in waveform models. The absence of lensing in the models can lead to a false deviation in GR tests using lensed signals. We restricted our results for the IMR consistency test and parameterised tests. [arXiv 2311.08446]

- **Addressing issues in defining the Love numbers for black holes:** In their recent work [Phys. Rev. D 108, 084013 (2023); arXiv:2306.13627 [gr-qc]], Rajendra Prasad Bhatt, Sumanta Chakraborty, and Sukanta Bose presented an analytic method for calculating the tidal response function of non-rotating and slowly rotating black holes from the Teukolsky equation in the small frequency and the near horizon limit. They also pointed out the two possible ways to define the tidal Love numbers and dissipative part from the tidal response function (in relativistic context), and calculated them for non-rotating and slowly rotating black holes. They also discussed a procedure to calculate the tidal response function and consequently the tidal Love numbers for an arbitrary rotating black hole. For future work, they proposed an interesting exercise of finding the effect of the tidal response function of a black hole (or compact objects in general) to the inspiral part of the gravitational wave waveform from Weyl scalar. Which will allow us to directly relate the tidal Love numbers and the dissipative part to the gravitational wave signal.

Extreme Matter

- **Constraining Neutron Star Equations of State with Gravitational Waves:** Neutron stars are among the densest objects in the Universe and serve as astrophysical laboratories for testing properties of extreme matter. In a series of recent investigations, information from multi-disciplinary physics (nuclear theory at low densities, heavy-ion data at intermediate densities, electromagnetic + gravitational wave astrophysical data at high densities) was imposed on the composition of the neutron star interior for
  1. nucleonic matter only [S. Ghosh, D. Chatterjee+ EPJA 58,37 (2022)]
  2. matter composed of strange baryons ("hyperons") [S. Ghosh, B.K. Pradhan, D Chatterjee+ FrASS 9,864294 (2022)]
  3. matter with phase transition to deconfined quarks, the fundamental constituents of matter [S. Shirke, S. Ghosh, and D. Chatterjee ApJ 944, 7 (2023)]

- **Effect of NS viscosity on the Gravitational wave and tidal heating of NS in binary:** The presence of hyperon matter in the NS interior can lead to a substantial effect heating the NS to temperatures of up to 1MeV by damping the tidally excited modes in binary and introduce an additional phase shift in the GW waveform which is relevant for upcoming next-generation detectors. This was shown by S. Ghosh, B.K. Pradhan and D. Chatterjee [Accepted in Phys. Rev. D (2024)].

- **Neutron Star oscillation modes to study NS interior as well as effects on GWs:** The effect of the Neutron star interior composition on fluid oscillation modes is being studied extensively. Using future GW detection from unstable oscillation modes, the NS interior models can be constrained. Exotic matter in NSs can lead to changes in oscillation modes which impact the observed GW frequencies. The effect of hyperons on f-mode oscillations of neutron stars was studied by B. K. Pradhan & D. Chatterjee [Phys. Rev. C 103, 035810 (2021)] using Cowling approximation. This was extended to include general-relativistic effects in B. K. Pradhan, D. Chatterjee, M. Lanoye and P. Jaikumar [Phys. Rev. C 106, 015805 (2022)]. The effect of the admixture of dark matter in NSs on these oscillation modes was then explored in detail in S. Shirke, B. K. Pradhan, D. Chatterjee, L. Sagunski, and J. Schaffner-Bielich [arXiv:2403.18740 (2024)]. Its impact on r-mode oscillations, interesting for continuous waves, was explored by S. Shirke, S. Ghosh, D. Chatterjee, L. Sagunski, and J.

Schaffner-Bielich [JCAP 12, 008 (2023)]. It was shown how nuclear parameters can be constrained from next-generation detectors using gravitational waves from glitch-powered f-mode oscillations in Neutron Stars by B K. Pradhan, D. Pathak and D. Chatterjee [Astrophys. J. 956, 38 (2023)]. An additional tidal contribution comes from the higher-order tidal terms and can impact the GW waveform. The following works have been done in this direction by B. K. Pradhan, A. Vijaykumar, and D. Chatterjee [Phys. Rev. D 107, 023010 (2023)], who investigated the impact of URs and the tidal corrections on the NS properties inferred from GW170817 as well as from future binary events. B K. Pradhan, T. Ghosh, D. Pathak and D. Chatterjee [Astrophys. J. 966, 79 (2023)] investigated the effect of the dynamical tidal correction on the inferred nuclear physics from a binary system

- **Distinguishing Strange Stars (SSs) using Gravitational Waves:** NSs and SSs follow a different relation between f-mode frequency and tidal deformability (f-Love relation). B.K. Pradhan, S. Shirke, and D. Chatterjee [arXiv:2311.15745 (2023)] outlined the methodology and showed that the next-generation GW detectors will be able to gather "substantial evidence" for or against the existence of strange stars in a single GW170817-like event, demonstrating the potential of GW to settle the long-standing fundamental physics problem of the true ground state of matter.

Continuous Waves

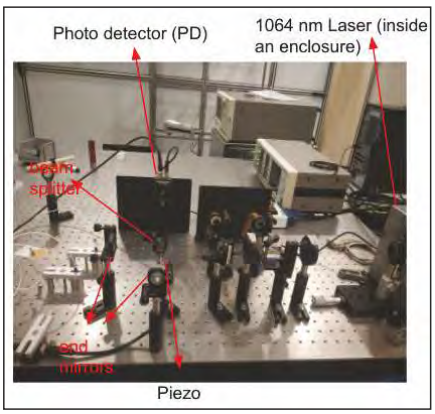
- **Constraining Neutron Star Physics:** Unstable rotational r-modes can also be sources of continuous GW from isolated pulsars. The frequency of the emitted GW depends on the compactness of the star but it is universal i.e. independent of neutron star EOS. The Universal relation updated in Ghosh et al. [ApJ 944, 53 (2023)] determines the search parameters from known pulsars to be implemented in the O4 run. From a future detection, measurement of frequency and spin down can give independent measurements of Compactness and moment of inertia which was shown to be useful in constraining the dense matter EOS inside a neutron star. [MNRAS 525, 448 (2023)]

- **Improving the spin-down limits for the continuous gravitational waves:** Recently, Abbott et al. ApJ 935, 1 (2022) gave spin-down limits for a set of 237 pulsars out of which only 144 were corrected for dynamical effects in spin frequency derivative, that too using an inexact traditional approach. D. Pathak and D. Chatterjee [A&A 679, A17 (2023)] improved the values of the spin-down limit of the continuous gravitational wave strain (assuming pulsars as triaxial rotators) for the set of pulsars given in Abbott et al. (2022) by using 'GalDynPsr', a python-based public package used to calculate more realistic values of intrinsic spin frequency derivatives, on which the spin-down limit depends. It was found that for 2 pulsars [PSRs J2222-0137 and J1400-1431] percentage increase in spin-down limit values was greater than 100% and for 3 pulsars [PSRs J2322-2650, J1709+2313, and J2010-1323], the percentage increase in spin-down limit values was between 20% and 100%.

- Gopalkrishna Prabhu and Shasvath J. Kapadia, in collaboration with Aditya Sharma and R. Prasad at ICTS-TIFR constrained the abundance of spinning, deformed, isolated compact objects (such as highly elliptical neutron stars) in our Milky Way Galaxy, from the non-detection of continuous gravitational waves. They are working on constraining other interesting physics from these non-detections. [arXiv:2403.00502 (2024)].

Instrumentation

- **LIGO control system:** Shivaraj Kandhasamy, along with other IUCAA members, set up a LIGO-like but smaller-scale Control and Data System (CDS) using hardware and software used in LIGO. It was also interfaced with a small rigid Michelson interferometer. The Michelson interferometer was locked using the built CDS (see figure), and the interferometer output was calibrated to physical units. This was a significant milestone in understanding and using the LIGO CDS, one of the critical subsystems in LIGO. The experience gained from such a system will be helpful for LIGO-India operations.



- **Seismic isolator and sensor development:** Suresh Doravari has developed a novel single-stage seismic isolator based on a well known mechanical linkage known as "Roberts Linkage". The seismic isolator (presently under fabrication) acts as a low pass filter with a tunable corner frequency of about 0.1 Hz in all the six degrees of freedom of motion. A multiple-input-multiple-output (MIMO) feedback control system utilising

custom built sensors and actuators are also developed. The horizontal sensors use a Folded Pendulum Sensor (FPS) design and the vertical sensors use a Geometric Anti-Spring (GAS) design. These sensors have been fabricated and are being tested at present and show promising results. Displacement sensors (OSEMs) which are used in LIGO detectors have been adapted for use in these seismic sensors. Work is ongoing to improve the signal to noise ratio of these sensors in the 0.1-10 Hz frequency band where these sensors suffer from high 1/f noise. Exploration of isolator design, sensing and actuation in this integrated facility forms one of the training modules for LIGO-India commissioning and operation.

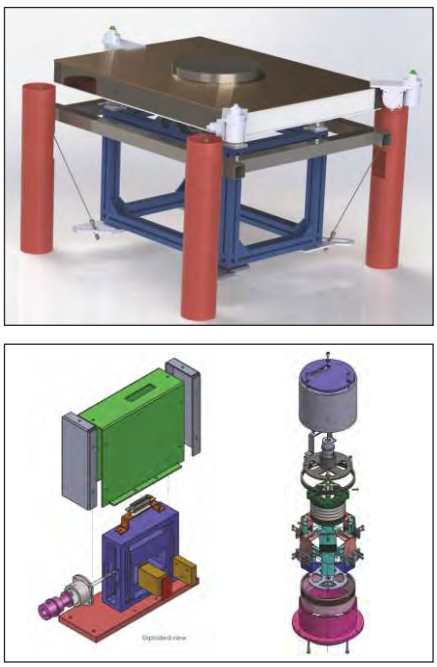


Figure showing a CAD rendering of the Roberts Linkage seismic isolator, Folded Pendulum Seismometer and the Low Frequency Geophone designs.

There are many more instrumentation modules and experiments are being developed at IUCAA for human resource development, which also have strong research potential, which can mature in the next few years. This program is however evolving to cater to the needs of the LIGO-India project.

LIGO-India

- The LIGO-India project received approval by the Union Cabinet last year which created a lot of excitement in the country. The project is funded by the Department of Atomic Energy (DAE) and the Department of Science and Technology (DST), Government of India, with a Memorandum of Understanding (MoU) with the National Science Foundation (NSF), USA, along with several national and international research and academic institutions. IUCAA is one of the four lead institutions executing the project. IUCAA is responsible for computing facilities and human resource development for the project. IUCAA is also the key science stakeholder for the project and interface to the national and international scientific communities. It is playing a major role in growing the community. The observatory aims to start science operations by 2030

1. **Gravitational lensing helps scientists see dark matter**
   The Times of India, Pune, April 4, 2023, Page no. 4

2. **Scientists, IUCAA team map dark matter in the Universe using gravitational lensing**
   Indian Express, Pune, April 5, 2023, Page no. 7

3. **What LIGO-India will do**
   The Indian Express, Pune, April 10, 2023, Page no. 12

4. **Quantum computers and India**
   The Indian Express, Pune, April 26, 2023, Page no. 14

5. **The death of another Nehruvian idea**
   The Hindu, Mumbai, May 2, 2023

6. **Designed by Pune centre, ISRO gets a SUIT-able telescope for its first observatory studying the Sun**
   Indian Express, Pune, June 17, 2023, Page no. 1-2

7. **IUCAA delivers telescope for solar mission**
   The Times of India, Pune, June 17, 2023, Page no. 2

8. **आदित्य एल- १ साठी 'सूट' सज्ज : 'आयुका' ने निर्माण केलेले उपकरण इस्रोकडे**
   सकाळ, पुणे, जून १७, २०२३, पान नं. ८

9. **'आयुका' चा टेलिस्कोप 'इस्रो'कडे सुपूर्द**
   महाराष्ट्र टाइम्स, पुणे, जून १७, २०२३, पान नं. २

10. **IUCAA develops space telescope to capture ultraviolet imaging of Sun**
    Hindustan Times, Pune, June, 17, 2023, Page no. 4

11. **'आदित्य एल-१' ला आयुकाचे पाठबळ**
    प्रभात, पुणे, जून १७, २०२३, पान नं . १-२

12. **कृष्णविवरांच्या चकतीच्या रहस्य उघड: पुण्यातील 'आयुका'चे संशोधन**
    सकाळ, पुणे, जून ११, २०२३, पान नं . ६

13. **'चांद्रयान' मोहीम हा भारताचा अभिमान : डॉ. जयंत नारळीकर**
    प्रभात, पुणे, ऑगस्ट २३, २०२३, पान नं . ३

14. **Feet on Moon, eyes on Sun**
    The Indian Express, Pune, August 29, 2023, Page no. 14

15. **Why India wants to take a closer look at the Sun**
    The Times of India, Pune, August 29, 2023, Page no.

16. **Pragyan skirts 4m crater, continues with moonwalk**
    The Times of India, Pune, August 29, 2023, Page no. 18

17. **शनिवारी सूर्याकडे प्रयाण !**
    लोकसत्ता, पुणे, ऑगस्ट २९, २०२३, पान नं . १

18. **After Moon, India will shoot for Sun on Sept 2**
    The Times of India, Pune, August 29, 2023, Page no. Cover Page

19. **Space, Sunny Side Up**
    The Times of India, Pune, August 31, 2023, Page no. 12

20. **Mission to study Sun: ISRO wraps up launch rehearsal, internal checks**
    Indian Express, Pune, August 31, 2023, Page no. 11

21. **Smooth operation of 'LAM' critical to Aditya-L1 success**
    The Hindu, Mumbai, August 31, 2023, Page no. 12

22. **Solar mission Aditya L-1 in position, set for launch**
    Hindustan Times, Pune, August 31, 2023, Page no. 1 & 7

23. **Pune Scientist wait for decade- long effort to bear fruit**
Indian Express, Pune, September 01, 2023, Page no. 09

24. **'इस्रो'ला 'आदित्य 'च्या उड्डाणाचे वेध**
सकाळ, पुणे, ऑगस्ट ३१, २०२३, पान नं . ८

25. **इस्रोचे आता 'आदित्याय नमः '**
सकाळ, पुणे, सप्टेंबर ०१, २०२३, पान नं . ४

26. **Aditya will shape the next phase of our space forays**
Hindustan Times, Pune, September 02, 2023, Page no. 08

27. **Aditya-L1 to launch today**
Hindustan Times, Pune, September 02, 2023, Page no. 02

28. **The Sun, and how it has fuelled humanity's curiosity, knowledge**
Hindustan Times, Pune, September 02, 2023, Page no. 02

29. **India's first solar observatory mission to be launched today**
The Hindu, Mumbai, September 02, 2023, Page no. 05

30. **European agency to support Aditya-L1**
The Hindu, Mumbai, September 02, 2023, Page no. 05

31. **The Sun up close: Aditya-L1 mission and its objectives**
Indian Express, Pune, September 02, 2023, Page no. 14

32. **An eye on the universe from Hingoli, Maharashtra**
Indian Express, September 02, 2023, Page no. 10

33. **India's Shot At The Sun Today**
Indian Express, Pune, September 02, 2023, Page no. 1

34. **IISER Pune scientist helps build solar wind spectrometer for Aditya L1 task**
Times of India, Pune, September 02, 2023, Page no. 4

35. **Aditya-L1 begins 1.5 million-km trek to solar vantage point today**
Times of India, Pune, September 02, 2023, Page no. 1

36. **Aditya-L1 among longest PSLV mission to be taken**
Times of India, Pune, September 02, 2023, Page no. 7

37. **भारताची आज सूर्याकडे झेप**
लोकसत्ता, पुणे, सप्टेंबर ०२, २०२३, पान नं . ०१

38. **अतिनील किरणांच्या अभ्यासासाठी 'सूट ' दुर्बीण**
लोकसत्ता, पुणे, सप्टेंबर ०२, २०२३, पान नं . ०२

39. **'आयुका 'तील शास्त्रज्ञांची भावना ; 'सूट 'च्या निर्मितीमध्ये सहभाग : दशकभराची मेहनत सार्थकी**
सकाळ, पुणे , सप्टेंबर ०२, २०२३, पान नं . ०४

40. **'आदित्य' च्या निर्मितीत महाराष्ट्राच्या तरुणांचा झेंडा**
पुढारी, पुणे, सप्टेंबर ०२, २०२३, पान नं . ०४

41. **After Moon landing, India kicks off journey to explore the Sun**
Sunday Times, Pune, September 03, 2023, Page no. 1

42. **Mission over, Vikram, Pragyan to put to sleep**
Sunday Times, Pune, September 03, 2023, Page no. 11

43. **Scientists shunned perfume for months to put Aditya on path**
Sunday Times, Pune, September 03, 2023, Page no. 11

44. **Aditya to start 125 days journey to L1 point: ISRO**
Sunday Times, Pune, September 03, 2023, Page no. 14

45. **After Moon landing, ISRO launches its first solar mission**
The Sunday Express, Pune, September 03, 2023, Page no. 1-2

46. **IUCAA scientists on cloud nine as Aditya-L1 heads to the Sun**
The Sunday Express, Pune, September 03, 2023, Page no. 5

47. **Aditya-L1 lifts off to study the Sun**
The Hindu, Mumbai, September 03, 2023, Page no. 1

48. **Aditya-L1 begins its long solar voyage**
Hindustan Times, Pune, September 03, 2023, Page no. 04

49. **An ISRO Sunrise**
Hindustan Times, Pune, September 03, 2023, Page no. 01

50. **Aditya satellite healthy & operating nominally: ISRO**
The Times of India, Pune, September 04, 2023, Page no. 12

51. **Young Scientists Get their Place in the Sun with Aditya-L1 Launch**
Economics Times, Pune, September 04, 2023, Page no. 11

52. **Aditya-L1 'healthy' in the orbit: ISRO**
The Hindu, Mumbai, September 04, 2023, Page no. 12

53. **Aditya-L1 completes key orbit manoeuvre**
Hindustan Times, Pune, September 04, 2023, Page no. 01

54. **Aditya glances back at Earth**
Times of India, Pune, September 08, 2023, Page no. 01

55. **Aditya-L1's first pics: Earth, Moon & selfie**
Times of India, Pune, September 08, 2023, Page no. 01

56. **Aditya-L1 takes selfie, snaps Earth, Moon**
Indian Express, Pune, September 08, 2023, Page no. 13

57. **55 from Pune ranked in Stanford varsity's list of world's top 2% scientists**
Indian Express, Pune, September 10, 2023, Page no. 05

58. **'आयुका ' चे उपकरण सक्रिय**
महाराष्ट्र टाइम्स , पुणे , नोव्हेंबर २१, २०२३, पान नं . ०२

59. **'आयुका 'च्या संचालकपदी प्रा. रघुनाथ श्रीआनंद**
सकाळ, पुणे, डिसेम्बर ०२, २०२३, पान नं . २

60. **'आयुका 'च्या संचालकपदी प्रा. आर. श्रीआनंद यांची नियुक्ती**
लोकसत्ता, पुणे, डिसेम्बर ०२, २०२३, पान नं . ३

61. **'आयुका 'च्या संचालकपदी प्रा. रघुनाथ श्रीआनंद**
महाराष्ट्र टाइम्स, पुणे, डिसेम्बर ०२, २०२३, पान नं . ४

62. **Prof. R Srianand is New Director of IUCAA, Pune**
Hindustan Times, Pune, December 02, 2023, Page no. 04

63. **R Srianand appointed Director of IUCAA**
Indian Express, Pune, December 03, 2023, Page no. 03

64. **खगोलभौतिकातील 'तारा'**
सकाळ, पुणे, डिसेम्बर ०४, २०२३, पान नं . ०६

65. **'आदित्य-एल १' ने टिपली सूर्याची प्रतिमा**
सकाळ, पुणे, डिसेम्बर ०९, २०२३, पान नं .

66. **Aditya-L1 telescope built by IUCAA takes sun's 1st image**
The Times of India, Pune, December 09, 2023, Page no. 6

67. **'आदित्य-एल १' च्या दुर्बिणीकडून सूर्याची प्रकाशचित्रे**
लोकसत्ता, पुणे, डिसेंबर ११, २०२३, पान नं . ०६

68. **Aditya L1's SUIT gives first ever full images of Sun**
Indian Express, Pune, December 11, 2023, Page no. 09

69. **' आयुका ' च्या दुर्बिणीने टिपली सूर्याची पाहिली छबी**
लोकसत्ता, हॅलो पुणे, डिसेंबर ०९, २०२३

70. **स्वदेशी तंत्रज्ञानातूनच अर्थव्यवस्था**
सकाळ, पुणे, डिसेम्बर ३०, २०२३, पान नं. ३

71. **Aditya L1, ISRO's mission to study Sun, set to be placed in final orbit tomorrow**
Indian Express, Pune, January 05, 2024, Page no. 01 & 02

72. **' आदित्य- एल १ ' यानाची आज अंतिम कक्षेत प्रस्थापना**
लोकसत्ता , जानेवारी ६, २०२४, पान नं . १६

73. **यानाचा १२५ दिवसांमध्ये १५ लाख किलोमीटरचा प्रवास**
महाराष्ट्र टाइम्स, जानेवारी ०६, २०२४, पान नं . ०२

74. **Aditya-L1, ISRO's first mission to study Sun, in final orbit; another landmark: PM**
Indian Express, Pune, January 07, 2024, Page no. 01

75. **Actual science observations may take another 3 months'**
Indian Express, Pune, January 07, 2024, Page no. 06

76. **India basks in Sun's glory as Aditya reaches vantage point**
Times of India, Pune, January 07, 2024, Page no. 01

77. **India creates another landmark: PM Modi on success of Adotya-L1**
Times of India, Pune, January 07, 2024, Page no. 15

78. **मानवाच्या कल्याणासाठी सौरअभ्यास आवश्यक**
सकाळ, पुणे, जानेवारी ०७, २०२४, पान नं . १०

79. **' आदित्य - एल १ ' साठी विद्यापीठाणाही प्रशिक्षण**
सकाळ, पुणे, जानेवारी ०७, २०२४, पान नं . १०

80. **India's solar observatory to reach its destination today**
Hindustan Times, Januray 6, 2024, Page no. 02

81. **ISRO tests fuel cell to potentially power space missions**
Indian Express, January 6, 2024, Page no. 13

82. **Open Campus Day to be held at IUCAA tomorrow**
The Indian Express, Pune, February 27, 2024, Page no. 04

83. **असा साजरा करा विज्ञान दिन**
सकाळ टुडे , पुणे , फेब्रुवारी २७, २०२४, पान नं . ०१

84. **Exhibitions, spl talks, quiz mark National Science Day**
The Indian Express, February 29, 2024, Page no. 04

85. **Curious minds mill around exhibits, listen to lectures & pitch questions**
Times of India, Pune, February 29, 2024, Page no. 03

86. **विज्ञान जाणून घेण्याची उत्सुकता**
लोकसत्ता, पुणे, फेब्रुवारी २९, २०२४, पान नं . १५

87. **वैविध्यपूर्ण उपक्रमांनी विज्ञान दिन उत्साहात**
महाराष्ट्र टाइम्स , पुणे, फेब्रुवारी २९, २०२४, पान नं . ०३

88. **पुणे झाले ' विज्ञानमय '**
सकाळ, पुणे, फेब्रुवारी २९, २०२४, पान नं . ०३

89. **संस्कृतीसोबत ज्ञान - तंत्रज्ञानाचाही माहेर पुणे**
लोकमत, पुणे, मार्च ७, २०२४, पान नं . ०२

90. **संशोधनातील मराठमोळ्या ' ती ' चा सन्मान**
सकाळ, पुणे, मार्च ०७, २०२४, पान नं . २

91. **Telescope capture escaping ionising photons fron galaxies**
Hindustan Times, Pune, March 07, 2024, Page no. 04

92. **नऊ अब्ज प्रकाशवर्षे अंतरावरील दहा आकाशगंगांचा शोध**
पुढारी, माझे पुणे, मार्च ०९, २०२४, पान नं . ०३

93. **ऐन तारुण्यात १० दीर्घिकांचा शोध**
सकाळ, पुणे, मार्च ०९, २०२४, पान नं . ०१

IUCAA ACADEMIC CALENDAR

Annual Events at IUCAA 2023-24

Introductory Summer School in Astronomy & Astrophysics 2023
Date: May 15 to June 16, 2023

Refresher Course on Astronomy and Astrophysics
Date: May 15 to June 16, 2023

Vacation Students' Programme
This is an ongoing programme

Foundation Day
Date: December 29, 2023

National Science Day
Date: February 28, 2024

Events at IUCAA - 2023-24

Workshop on the limiting compactness objects: Black holes and Buchdahl stars
Date: October 30 - November 03, 2023
Coordinators: Naresh Dadhich

Indo-French Astronomy School (IFAS 8) 3D Spectroscopy
Date: November 06 - 12, 2023
Coordinators: Kanak Saha

Radio Astronomy Winter School 2023
Date: December 12 - 22, 2023
Coordinators: Rajeshwari Dutta | D. J. Saikia

Data Science Meeting
Date: December 12 - 14, 2023
Coordinators: Surhud More | Ashish Mahabal

Teachers Training Workshop, OAE, India
Date: February 16 - 17, 2024
Coordinators: Surhud More | Moupiya Maji

OSMU24 (Octonions, Standard Model, and Unification [Online]
Date February 16 - December 13, 2023
Coordinators: T.P. Singh | Durgesh Tripathi

Mumbai-Pune Cosmology meeting at IUCAA
Date: February 23 - 24, 2024
Coordinators: Surhud More | Aseem Paranjape

Events outside IUCAA - 2023-24

Workshop on Python Programming in Astronomy, Astrophysics & Cosmology
Date: April 07 - 08, 2023
Place: The Department of Applied Sciences of G. H. Raisoni College of Engineering, Nagpur
Coordinators: Saibal Ray | Praveen Kumar Dhankar | Bhagwat Thakran.

Summer School in Theoretical Physics 2023
Place: The Department of Physics and Electronics, St Xavier's College (Autonomous), Ahmedabad,
Date: May 29 - June 09, 2023
Coordinators: Gurudatt Gaur (SXCA) | Ranjeev Misra, IUCAA

Beginning Astronomy v2: Start a Data Driven Journey
Place: Central University of Himachal Pradesh
Date: July 06 - 08, 2023
Coordinators: Hum Chand | Souradeep Bhattacharya | Preetish Kumar Mishra | Chayan Mondal | Megha Anand

Workshop on Python Programming in Astronomy, Astrophysics & Cosmology
Place: GLA University, Mathura
Date: July 20 - 22, 2023
Coordinators: Saibal Ray | Ranjeev Misra

Himalayan Meet of Astronomers
Place: Islamic University of Science and Technology, Awantipora Pulwama (IUST), Kashmir (J&K)
Date: September 25 - 26, 2023
Coordinators: Naseer Iqbal | Hum Chand

INDO-South Africa Workshop on Astrophysics (ISAWA 2023)
Place: Centre for Theoretical Physics, Jamia Millia Islamia
Date: September 27 - 29, 2023
Coordinators: Sushant Ghosh | Tabish Qureshi

Statistical Techniques in Astrophysics and Cosmology Using Python
Place: Bharathidasan University, Tiruchirappalli,
Date: October 16 - 20, 2023
Coordinators: T. R. Seshadri | V. Madhurima | P. Muruganandam

Radio Astronomy Fundamentals for Engineering Students
Place: RSET, Kakkanad, Kerala
Date: 28 October 2023
Coordinators: R. Jacob | J. Jacob | Neeraj Gupta

Pedagogic Workshop on Astronomy, Astrophysics and Cosmology
Place: St. Stephen's College, Delhi
Date: November 06 - 10, 2023
Coordinators: G. Sethi | V. Paliya | D.J. Saikia

North-East Meet of Astronomers (NEMA) - IX
Place: Mizoram University
Date: November 20 - 22, 2023
Coordinators: Lalthakimi Zadeng | Ranjeev Misra

Workshop on Gravitational Waves and LIGO India
Place: Goa University
Date: November 27 - 01 December, 2023
Coordinators: R.R. Raut | Sanjit Mitra | Apratim Ganguly

Meghnad Saha Memorial Workshop on Solar Astronomy focused on "Aditya -L1 Mission"
Place: Department of Physics, University of Allahabad
Date: December 04 - 06, 2023
Coordinators: V. K. Tiwari | U. Kushwaha | Durgesh Tripathi

Beginning Astronomy v3: Start a Data-driven Journey
Place: IIT, Hyderabad
Date: December 11 - 13, 2023
Coordinators: Mayukh Pahari | Shantanu Desai | Ranjeev Misra | Souradeep Bhattacharya | Chayan Mondal | Megha Anand

Workshop on Gravitation: Theory and Observation
Place: Department of Physics, Cooch Behar Panchanan Barma University (CBPBU)
Date: January 03, 2024
Coordinators: Ranjan Sharma | Kanak Saha

Pedagogic Workshop on Astronomy, Astrophysics and Cosmology: A Faculty Development Programme
Place: Gauhati University
Date: January 04 - 10, 2024
Coordinators: S. Kalita | S. Muzahid | D.J. Saikia

Research in Astronomy: Opportunities and Challenges - RAM IX
Place: Manipal Centre for Natural Sciences, Manipal Academy of Higher Education (MAHE), Manipal
Date: January 10 - 11, 2024
Coordinators: Debbijoy Bhattacharya | Ranjeev Misra

Two-day exhibition: Evolution of Astronomy
Place: Fergusson College, Pune
Date: January 2024
Coordinators: R. Dabhade | D. Tripathi

X-ray workshop -- Astrosat and XpoSat
Place: Department of Physics, Providence Women's College, Malaparamba, Kozhikode
Date: February 28 - March 03, 2024
Coordinators: Gireesh V. | Jeena K. | Ranjeev Misra

Conference on Relativistic Astrophysics and Cosmology
Place: Department of Physics, Malda College, Malda, West Bengal
Date: February 29 - March 01, 2024
Coordinators: Shyam Das | Ranjeev Misra

Workshop on SUIT Science and Data Analysis
Place: Department of Physics, Tezpur University
Date: March 06 - 07, 2024
Coordinators: G. Ahmed | J. Sarkar | D. Tripathi

Workshop on Gravity, Cosmology and Raychaudhuri's Equation
Place: Jadavpur University, Kolkata
Date: March 13 - 14, 2024
Coordinators: A. Mukherjee | S. Mondal | R. Misra

Frontiers in Physics XVIIth
Place: Fergusson College, Pune
Date: March 13 - 14, 2024
Coordinators: R. Dabhade | D. Tripathi

Workshop on Formation and Evolution of Galaxies
Place: Central University of Haryana, Mahendragarh
Date: March 18 - 20, 2024
Coordinators: J. Yadav | A. Paranjape

Workshop on Advancement in AGN, Galaxy, Cluster and IGM Research
Place: Central University of Himachal Pradesh Dharamshala, H.P.
Date: March 29 - 31, 2024
Coordinators: Hum Chand | Sowgat Muzahid

AWARDS AND DISTINCTIONS

Shasvath Kapadia

- Awarded the SERB Startup Grant, and the SERB MATRICS grant.
- The following collaborative work with colleagues at ICTS-TIFR was selected as the Editor's Suggestion in Physical Review Letters (PRL).
  Souvik Jana, Shasvath J. Kapadia, Tejaswi Venumadhav, Parameswaran Ajith, *Cosmography using strongly lensed gravitational waves from binary black holes*, arXiv:2211.12212, PRL, 130, 261401, (2023).

Surhud More

- Best paper award for 2023 by the Publications of the Astronomical Society of Japan: *Cosmological constraints from cosmic shear two-point correlation functions with HSC survey first-year data.* Takashi Hamana, et al. Publ Astron Soc Jpn (2020) 72 (1): 16, doi.org/10.1093/pasj/psz138.

J. V. Narlikar

- Rashtriya Gunakar Muley Award (2021) from the Madhya Pradesh Government, Culture Department, September 14, 2023.
- Fellowship of the Gwalior Academy of Mathematical Sciences, Gwalior, December 11, 2023.

Durgesh Tripathi

- Vishal Upendran was the recipient of the K.D Abhyankar Best Thesis Presentation Award for his thesis Heating and Dynamics of the Solar Atmosphere.
- Janmejoy Sarkar, Senior Research Fellow (SRF) of the Department of Physics, Tezpur University, Assam, was felicitated with the Distinguished Student Achiever Award 2023 for his contribution in developing the SUIT module of India's space mission ADITYA-L1.

RESEARCH GRANTS AND FELLOWSHIPS

Souradeep Bhattacharya

- DST-INSPIRE Faculty Fellowship.

Subhadeep De

- DST grant for the project: *DST - Quantum Information Technologies with ion-trap and optical-lattice devices of Interdisciplinary Cyber Physical Systems (ICPS).*
- *Sub-micron resolution imaging system to detect individual ions/ atoms* - Project funded by the DAE Board of Research in Nuclear Sciences (BRNS) (2021-24)
- I-HUB Chanakya Doctoral Fellowship (2022-27) - *Synchronization of the optical atomic clocks located at IUCAA and IISER Pune by ultra-stable fiber optic channel.*

Samir Dhurde

- International Astronomical Union (OAO Grant).

Shasvath Kapadia

- SERB Start-up grant.
- SERB MATRICS grant.

Ajit Kembhavi

- Pune Knowledge Cluster (PKC):
- National Centre for Biological Science.
- BASF Chemicals India grant:
- For a mentoring and scholarship program for women in chemistry and sustainability - WEnyan.
- A platform for Gamified Learning in Chemistry and STEM Education.
- Lenovo India grant for Teach with Tech.
- PKC Tree Project.

Ranjeev Misra

- ISRO Grant to set up the AstroSat Science Support Cell (ASSC).

Sanjit Mitra

- LIGO India TDCB and DAE.
- LIGO India SEED and DST.

- **Anupreeta More**
  - DST SERB Power (Promoting Opportunities for Women in Exploratory Research) Grant.

- **Dipanjan Mukherjee**
  - Indo-French Centre for the Promotion of Advanced Research (IFCPAR) Grant for the project: Resolving the impact of AGN feedback on gas and star formation through simulations and observations.
  - DST sponsored Indo-Italian grant for the exchange of researchers.

- **Sowgat Muzahid**
  - DST grant - The Role of Gaseous Halos in Galaxy Evolution.

- **A.N. Ramaprakash**
  - Participation Grant in Thirty Metre Telescope (TMT) Project at Mauna Kea, Hawaii, USA.
  - Institute of Plasma Physics Crete WALOP N.
  - Infosys Foundation Grant for Resurgent Caltech – IUCAA Collaboration for Advanced Instrument Development and Scientific Discoveries.
  - Institute of Arizona LBT1.

- **Kanak Saha**
  - Grant for the project: Exploring the Nature of Lyman Continuum Emitting Sources in the AstroSat-UV Deep Field (AUDF).

- **Dhruba J. Saikia**
  - UGC Malaviya Mission Teachers Training Grant.

- **Durgesh Tripathi**
  - ISRO Solar Flares P&F.
  - Indo-French grant for 'Investigating the origin of switchbacks in the solar corona via interchange reconnection -- A statistical and multi-instruments approach including machine learning'.

PUNE KNOWLEDGE CLUSTER

About Pune Knowledge Cluster

The Pune Knowledge Cluster (PKC) is one of the six S&T clusters established by the Office of the Principal Scientific Adviser to the Government of India under The City Knowledge and Innovation Cluster Initiative (CKIC). PKC aims to create, enable and nurture a collaborative S&T ecosystem for various stakeholders, including Industry, Academia, Government, and Citizens. PKC is hosted by the Inter-University Center for Astronomy & Astrophysics (IUCAA), a UGC-supported government institution in Pune.

Since July 2022, PKC is registered as a private (not-for-profit) company – Pune Knowledge Cluster Foundation, under the section 8 of The Companies Act 2013.

Vision

The Pune Knowledge Cluster (PKC) aims to bring together academia, R & D institutions, and the Industry of Pune and its surrounding areas, to address challenging problems of the region through innovative means, using scientific knowledge and engaging highly skilled human resources.

Mission

To act as a catalyst to bring together the large talent pool present in Industry, Academia, Government, and non-Governmental organizations of Pune to brainstorm, discuss and identify projects of importance and value to the region and to execute them through collaborative efforts.

Key Achievements (since April 2023)

- PKC has signed MoUs with 15 organizations including academia, R&D labs, industries, NGOs, and incubation centres.
- PKC has conducted 18 training programs (incl. workshops and courses), 9 citizen-centric talks, 8 industry visits and 34 program awareness sessions, benefitting a total of 5000 individuals
- PKC has hosted a total of 10 stakeholder meetings, conferences and roundtables/panel discussions to foster and strengthen collaborations as well as build new programs
- PKC has hosted as well as been a part of international delegations to foster collaborations in the areas of water and wastewater management, and energy.

PKC Focus Areas

I. Health

PKC's Health vertical aims to build collaborations across academic and industry, NGOs, and Govt departments in generating data critical for public health decisions such as serosurveys, clinical, immunological, and environmental surveillance etc., and creating an epidemiological database with comprehensive health information for Pune and access to real-time data. Projects supported under PKC's health vertical align with the **Integrated Disease Surveillance Project (IDSP)** and the **National Health Mission .**

Projects: PKC has the following ongoing programs under this vertical:

- COVID-19 Genomic Surveillance
- COVID-19 Environmental Surveillance
- Retrospective clinical study for COVID-19 (Supported by Rockefeller foundation)
- COVID-19 Long Term Immunogenicity Study (Supported by Hindustan Unilever)
- COVID-19 Clinical Database
- Dengue Incidence study
- Anti-microbial Resistance (AMR) study
- Saksham: A series of Workshops on Vector-Borne Diseases for Healthcare Workers

Partners: Projects are implemented in a collaborative manner between the hospitals, R&D labs and city administration. Key partners include – IISER Pune, CSIR-NCL, BJMC, KEM, Symbiosis, Genepath, Noble Hospital, STRAND life sciences, EPIC-HIM, ARTPARK, PMC, PCMC, NCBS, Ashoka University, MUHS

Key Future plans: Infectious Disease Platform - Building a platform for multi-institutional collaborations for data-driven policies for infectious diseases.

II. Sustainability & Environment

Aligned to the National Action Plan on Climate Change, PKCs Sustainability and Environment vertical currently has the following ongoing projects:

- **Technology-driven Urban Forestry Programs** such as ConnecTree and TreeVerse, to preserve and improve tree cover in Pune City. PKC is working to create technology platforms to automate tree census, improve citizen engagement in tree plantation and adoption and build a computational platform for carbon sink estimation.
- **Carbon Accounting in Campuses:** Through this program, PKC encourages academic campuses and Industry premises to account for their Carbon emissions through efficient data collection; and imbibe practises enabling Carbon Neutrality.
- **Sustainable Afforestation Programs:** Through these programs, PKC aims to initiate forest landscape restoration projects designed to provide a sustained livelihood by meeting raw material requirements of industry on a short, medium as well as long term basis. PKC currently plans to

undertake these programs at three different locations in and around Pune.

- **Biomass white paper:** PKC, along with partner organizations is in a process of creation of white paper for increasing biomass on degraded and fallow lands, to augment the green energy demands of the nation. The aim is present this white paper to relevant stakeholders for conversion into a policy document.
- **Water Action Plan for Pune Metropolitan Region:** Aligned to the National Water Mission, PKC is preparing a sustainable water Management Plan for the Pune Metropolitan Region, comprising of comprehensive information on priority issues, and available resources (human, technical and financial), and mapped solutions. A digital decision-making support system will also be created using time-series and real-time absolute data, GIS maps, and analytics.
    - For this, a feasibility study has been started for PCMC, in collaboration CPC analytics.
- **Hydrogen Valley in Pune region:** PKC is working towards developing a Hydrogen Cluster in Pune region to foster collaborations between industries and R&D organizations for developing technologies for Green Hydrogen production, storage, transport and capacity building.

Work with local administration: PKC works actively with PMC, PCMC and Pune Zilla Parishad to serve as a knowledge partner for technology evaluation, project feasibility studies, and creating plans for implementing water conservation, and bio-energy projects in Pune and its surrounding villages.

Partners: Pune Smart City, CEE India, WRCS, Genesys, Maharashtra Forest Department, Samuchit Environment, Gokhale Institute of politics and economics (GIPE), CPC Analytics, Kishore Pumps, Biofuel circle, Bhartiya Agro Industries Foundation (BAIF), CSIR-NCL, IORA Ecological Solutions Pvt. Ltd., CDSA, ACWADAM, DHI (Denmark), Water Valley Denmark, Clean Cluster, DTU (Denmark)

Key Future plans:

- **Centre for Water** – Building a Centre for water management, technology deployment, and policy in collaboration with Water Valley, Denmark
- **CoE for Carbon Sequestration & Renewable Energy** – Building a centre of excellence focused on increasing urban/peri-urban and rural vegetation cover for carbon sequestration, developing technology-based plantation models and citizen engagement programs, piloting technologies for biofuels production

III. Sustainable Mobility

PKC's Sustainable Mobility vertical aims to apply scientific and technical tools to address the rapidly growing and changing mobility requirements of the city. We wish to support the development of sustainable solutions toward carbon-neutral transportation.

Working towards the **Smart City Mission** of GoI, the Pune City administration is encouraging and enabling sustainable modes of mobility in the city. In this regard, PKC has the following programs in the pipeline.

- **Vehicle E-Waste Recycling** –Projects are being conceptualized with technology providers and the auto industry to pilot novel technologies for vehicle E-waste recycling at the city level through public-private partnership models.
- **Charging Infrastructure Mapping using Pune Digital Twin** – In partnership with TCS Pune Digital Twin, PKC wishes to map and plan locations for EV charging infrastructure in the city.
- **Behavioural Nudges for Sustainable Transportation** – In Partnership with PMPML, this program aims towards increasing the ridership of public transport in Pune, in order to combat traffic congestion and air pollution

Partners: Automotive Research Association of India (ARAI), Center for Materials for Electronics Technology (CMET), C4i4, Society of Automotive Engineers, Pune Mahanagar Parivahan Mahamandal Limited (PMPML)

IV. BIG Data & Artificial Intelligence

This vertical enables the development of various AI-driven platforms for basic and applied research. Large-scale citizen science programs are being developed to involve citizens in analyzing BIG scientific data to foster scientific temper. One such program is called One-Million Galaxies where 1700+ citizens have analyzed over 2 GB of data (images of galaxies) on PKC's platform. PKC is also trying to develop AI algorithms based on citizens' response.

Apart from this, PKC is building collaborative projects between BIG Data and AI experts, chemists, and biologists to encourage inter-disciplinary research; and building an open-access dataset where capabilities of differently abled citizens will also be leveraged to collect scientific data.

Partners: CODATA, IUCAA, Univ. of Southampton, IIA Bangalore, HBCSE Mumbai, Nehru Planetarium Mumbai, Jawaharlal Nehru Planetarium Bangalore, Jyotirvidya Parisanstha Pune, Khagol Vishwa Pune

V. Capacity Building

Aligned with the **Skill India Mission,** the capacity-building vertical of PKC aims to provide new opportunities to students,

young researchers, and professionals to improve their knowledge base and acquire advanced skills through the following programs

- Interdisciplinary Training Programs & Courses – Contemporary skill-building and knowledge enhancement
- Citizen centric science talks by experts

Over the past year, PKC has conducted over 18 inter-disciplinary training programs and workshops with over 1300 beneficiaries, and 9 citizen-centric talks with over 500 beneficiaries.

STEM Education: Aligned with the **National Education Policy 2020**, PKC's STEM education vertical focuses on promoting STEM education through technology-enabled training programs for school teachers and students, scholarship programs for women in STEM, gamification of learning, and setting up of STEM Labs.

Projects: PKC has 3 ongoing STEM projects:

- Teach with Tech (supported by Lenovo India)
- WEnyan – a mentoring and scholarship program for women in chemistry and sustainability (supported by BASF Chemicals India)
- Platform for Gamified Learning in Chemistry and STEM Education (supported by BASF Chemicals India).

Partners: Icertis, Infosys Springboard, IBM, DY Patil Engineering, SPPU, District Institute of Education and Training, Pune Zilla Parishad, Agarkar Research Institute, CODATA, Persistent Systems, Serum Institute of India.

Key Future plans:

CoE for STEM Education: Centre with a focus on innovation in school education, gamification in learning, STEM labs, girl education, and Math Circles.

Classical and Quantum Gravity

Theoretically motivated dark electromagnetism as the origin of relativistic MOND

T. P. Singh and collaborators [Felix Finster (U. Regensburg), Jose M. Isidro (U. Valencia), Claudio F. Paganini (U. Regensburg)] have made a modest attempt to initiate the research program outlined as follows. They propose that General Relativity (GR) and relativistic MOND (RelMOND) are analogues of the broken electroweak symmetry. That is, SU(2)R×U(1)YDEM→U(1)DEM (DEM stands for Dark ElectroMagnetism), and GR is assumed to arise from the broken SU(2)R symmetry, and is analogous to the weak force. RelMOND is identified with dark electromagnetism U(1)DEM, which is the remaining unbroken symmetry after spontaneous symmetry breaking of the dark electro-grav sector SU(2)R×U(1)YDEM. This sector, as well as the electroweak sector, arise from the breaking of an E8×E8 symmetry in a recently proposed model of unification of the standard model with pre-gravitation, this latter being an SU(2)R gauge theory. The source charge for the dark electromagnetic force is square-root of mass, motivated by the experimental fact that the square-roots of the masses of the electron, up quark, and down quark, are in the ratio 1:2:3, which is a flip of their electric charge ratios 3:2:1. The introduction of the dark electromagnetic force helps understand the weird mass ratios of the second and third generation of charged fermions. They also note that in the deep MOND regime, acceleration is proportional to square-root of mass, which motivates them to propose the relativistic U(1)DEM gauge symmetry as the origin of MOND. They explain why the dark electromagnetic force falls inversely with distance, as in MOND, and not as the inverse square of the distance. They conclude that dark electromagnetism is a good mimicker of cold dark matter (CDM), and the two are essentially indistinguishable in those cosmological situations where CDM is successful in explaining observations, such as, CMB anisotropies and gravitational lensing.

Causal fermion systems and octonions

T. P. Singh and collaborators [Felix Finster (U. Regensburg), Niels G. Gresnigt (U. Xian Jiaotong-Liverpool), Jose M. Isidro (U. Valencia), Antonino Marciano (U. Fudan), Claudio F. Paganini (U. Regensburg)] compared the structures and methods in the theory of causal fermion systems with approaches to fundamental physics based on division algebras, in particular the octonions. They found that octonions and, more generally, tensor products of division algebras come up naturally to describe the symmetries of the vacuum configuration of a causal fermion system. This is achieved by associating the real and imaginary octonion basis elements with the neutrino and charged sectors of the vacuum fermionic projector, respectively. Conversely, causal fermion systems provide octonionic theories with spacetime structures and dynamical equations via the causal action principle. In this way, octonionic theories and causal fermion systems complement each other.

Two dark clouds on the space-time horizon

T. P. Singh has proposed that there are currently two strong indicators that our knowledge of gravitation and spacetime structure is incomplete. (i) Investigations of stellar systems known as wide binaries suggest that Newton's law of gravitation breaks down at low accelerations. This can be explained by proposing a fifth force with U(1) gauge symmetry, whose corresponding gauge boson is the sought for dark matter candidate. (ii) Relativistic causality (i.e., no faster than light signalling) permits nonlocal correlations stronger than those permitted by quantum mechanics. This can be explained if our universe possesses a second 4D spacetime with a signature opposite to ours. He argued that such a fifth force, and a second spacetime, arise naturally in a recently proposed theory of unification based on an E8 × E8 symmetry. Our spacetime arises from breaking of an SU(2)R × U(1)Y DEM symmetry, and the second spacetime arises from broken electroweak symmetry.

Gravitation and quantum theory as emergent phenomena

T. P. Singh is writing a book on his research on octonionic unification, with the same title. The book will have fifteen chapters describing the so-called aikyon theory of unification, and will cover topics including quantum foundations, trace dynamics, noncommutative geometry, division algebras, Clifford algebras and elementary particles, unification of forces, derivation of fundamental constants, quantum nonlocality, origin of dark matter, and experimental predictions of the octonionic theory. The book will be published by Springer Nature in their series 'Fundamental Theories of Physics' and is expected to be released in late 2025.

Cosmology and Structure Formation

Testing ΛCDM with eBOSS data using a model independent diagnostic

Varun Sahni, jointly with Arman Shafieloo, Sangwoo Park and Alexei Starobinsky, used the Model independent Om3 diagnostic to test the ΛCDM model using the latest eBOSS data set. The Om3 diagnostic tests the consistency of the cosmological constant as a candidate for dark energy using baryon acoustic oscillation (BAO) data. An important feature of Om3 is that it is independent of any parametric assumption for dark energy, neither does it depend upon the dynamics of the Universe during the pre-recombination nor those during the post-recombination eras. In other words, Om3 can be estimated using BAO observables and used either to confirm or falsify the cosmological constant independent of the value of the Hubble constant H0 (expansion rate at z = 0) and the comoving sound horizon at the baryon drag epoch (which is a function of the physics of the Universe prior to recombination). Consequently, Om3 can play a key role in identifying the nature of dark energy regardless of the existing tensions in the standard model of cosmology and the possible presence of systematics in some of the data sets. They revisit Om3 using the most recent BAO observables from the eBOSS survey in order to test the consistency of the cosmological constant with these data. The results show the consistency of dark energy being the cosmological constant. Moreover, with eBOSS data, they have achieved a precision of 1.5% for this three-point diagnostic. This demonstrates that Om3 can be a potent diagnostic of dark energy when used in conjunction with the high precision data expected from forthcoming large-scale structure surveys such as the Dark Energy Spectroscopic Instrument (DESI) and Euclid.

GPR-based parameter exploration using SCRIPT

A. Paranjape and his collaborators, B. Maity & T. R. Choudhury (NCRA-TIFR), have used the Gaussian Process Regression (GPR) algorithm that is part of the PICASA package described in arXiv:2205.07906 to obtain a factor ∼ 30 speed-up in MCMC analysis using the semi-numerical reionization model SCRIPT. The idea is to interpolate the likelihood function in reionization parameter space for a given data set, so that the interpolator (or 'emulator') can replace the actual likelihood evaluation in an MCMC analysis. The emulator is built by training a Gaussian Process (GP), which is one of the simplest and most transparent machine learning techniques available in the literature. Their technique takes advantage of the fact that the output of SCRIPT at large length scales and for 1-point quantities such as the UV luminosity function and integrated electron scattering optical depth to last-scattering is well-converged as a function of simulation resolution. This allows them to run a full MCMC (∼ 100,000 likelihood evaluations) using SCRIPT with a coarse-resolution simulation, which in turn accurately defines a much smaller 'training sample' of ∼few × 1000 parameter vectors that are used to set up the likelihood emulator at high resolution. In other words, the number of function calls to the high-resolution SCRIPT simulation is only ∼ few × 1000, which is more than an order of magnitude smaller than the number required for a converged MCMC at high resolution. By testing against the actual output of a full, high-resolution MCMC (which is of course more expensive), they have demonstrated that this approach successfully captures not only the best- t but also the 68% and 95% pairwise contours in parameter space. They have further set up the framework to operate at resolutions required for upcoming 21-cm observations with the SKA, for which a full MCMC is unfeasible.

Impact of tidal environment on galaxy clustering in GAMA

A. Paranjape and collaborators S. Alam (TIFR, Mumbai) and J. A. Peacock (ROE) have constrained models of the galaxy distribution in the cosmic web using data from the Galaxy and Mass Assembly (GAMA) survey. They model the redshift-space behaviour of the 2-point correlation function (2pcf) and the recently-proposed Voronoi volume function (VVF) – which includes information beyond 2-point statistics. They extend the standard halo model using extra satellite degrees of freedom and two "assembly bias" parameters which correlate the occupation numbers of central and satellite galaxies with their host halo's tidal environment. They measure non-zero values of these parameters using a combination of 2pcf and VVF measurements, representing a detection of assembly bias at the 3.3 sigma (2.4 sigma) significance level for satellite (central) galaxies. This result remains robust to possible anisotropies in the halo-centric distribution of satellites as well as technicalities of estimating the data covariance. They show that the growth rate ($f\sigma_8$) deduced using models with

assembly bias is about 7% (i.e., 1.5 sigma) lower than if assembly bias is ignored. When projected onto the $\Omega_m - \sigma_8$ plane, the model constraints without assembly bias overlap with Planck expectations, while allowing assembly bias introduces significant tension with Planck, preferring either a lower Ω_m or a lower σ_8. Finally, they find that the all-galaxy weak lensing signal is unaffected by assembly bias, but the central and satellite sub-populations individually show significantly different signals in the presence of assembly bias. Their results illustrate the importance of accurately modelling galaxy formation for cosmological inference from future surveys.

Model-agnostic cosmological constraints from the BAO feature in redshift space

A. Paranjape & R. K. Sheth (U. Penn) have extended the Gaussian-smearing approximation of the baryon acoustic oscillation (BAO) feature to describe the anisotropies of the galaxy 2-point correlation function (2pcf) in redshift space, namely its multipoles $\ell = 0, 2, 4$. One issue with the description of the monopole ($\ell = 0$) in the literature (as well as the authors' earlier work) is that the smearing scale σ_v must be known a priori. Their extension to describing *all* multipoles is a major step forward, since it allows σ_v to be simultaneously estimated from the data, along with the shape of the linear theory BAO feature. Moreover, the analysis now also becomes sensitive to the value of the linear growth rate $f = \mathrm{d}\ln D/\mathrm{d}\ln a$. Thus, the same analysis which allows one to estimate the shape of the BAO feature (e.g., by measuring its so-called 'linear point' $r_{\rm LP}$, Anselmi et al. 2016) additionally constrains the cosmological parameters σ_v and f. Tests using mock data sets indicate that this approach is accurate enough for unbiased parameter recovery with current surveys such as BOSS DR12, but is not accurate enough for upcoming surveys like DESI. The authors are currently working on improving the approximation for non-linear growth, so as to allow for a more accurate treatment of the effects of non-linearities such as scale-dependent bias on the shape of the BAO feature. If successful, this would allow for a novel treatment of the parameter subspace $\{f, \sigma_v, r_{\rm LP}\}$ as a potentially powerful, model-agnostic testing ground for a variety of cosmological models such as ΛCDM, dynamical dark energy, modified gravity and beyond.

Constraints on the Cosmic Expansion History from Hyper Suprime-Cam Year 3 results

Weak gravitational lensing can be used to map out the matter distribution in the Universe and its evolution. In a series of 5 papers prepared under the leadership of **Surhud More** from IUCAA and his counterpart Hironao Miyatake at Nagoya University, the Subaru Hyper Suprime-Cam (HSC) survey collaboration presented the latest results from Year 3 cosmological analysis. The first two papers measured the correlation of the distortion of shapes of millions of background galaxies imprinted as they get (weakly) gravitationally lensed as the light from these galaxies traverses the Universe on its way to us. These correlations, called cosmic shear, were analyzed in Fourier space and configuration space in the first two papers, respectively. The next set of three papers presented the measurements and the analysis of the cosmic shear signal, the clustering of galaxies and the galaxy–galaxy lensing signal, the so called 3×2 point statistics that characterizes the cosmological information. All these cosmological analyses were carried out in a blind fashion to avoid confirmation bias. The results indicate a value of S_8, that characterizes the amplitude of density fluctuations, to be about $2 - \sigma$ lower than that expected from the cosmic microwave background experiment Planck. The HSC survey is a precursor to the Rubin Observatory's Legacy Survey of Space and Time which will start in 2025, and thus is important to establish the challenges that cosmologists will face in the upcoming decade.

Joint cosmological and gravitational-wave population inference using dark sirens and galaxy catalogues

In the absence of numerous gravitational-wave detections with confirmed electromagnetic counterparts, the "dark siren" method has emerged as a leading technique of gravitational-wave cosmology. The method allows redshift information of such events to be inferred statistically from a catalogue of potential host galaxies. Due to selection effects, dark siren analyses necessarily depend on the mass distribution of compact objects and the evolution of their merger rate with redshift. Informative priors on these quantities will impact the inferred posterior constraints on the Hubble constant (H_0). It is thus crucial to vary these unknown distributions during an H_0 inference. This was not possible in earlier analyses due to the high computational cost; restrictions by either excluding galaxy catalogue information, or fixing

the gravitational-wave population mass distribution, risks introducing bias to the H_0 measurement. In this paper, an international collaboration of scientists including **Surhud More and Tathagata Ghosh** from IUCAA, introduced a significantly enhanced version of the Python package GWCOSMO, which allowed a joint estimation of cosmological and compact binary population parameters, thereby ensuring a robust cosmological analysis. The gravitational-wave events from the Third Gravitational-Wave Transient Catalogue were reanalysed with the GLADE+ galaxy catalogue, and an updated, more reliable measurement of $H_0 = 69^{+12}_{-7} kms^{-1}Mpc^{-1}$ was found (maximum a posteriori probability and 68% highest density interval). This improved method will enable cosmological analyses with future gravitational-wave detections to make full use of the information available (both from galaxy catalogues and the compact binary population itself), leading to promising new independent bounds on the Hubble constant.

Identification of Superclusters and Their Properties in the Sloan Digital Sky Survey Using the WHL Cluster Catalog

Superclusters are the largest massive structures in the cosmic web, on tens to hundreds of megaparsec scales. They are the largest assembly of galaxy clusters in the Universe. Apart from a few detailed studies of such structures, their evolutionary mechanism is still an open question. In order to address and answer the relevant questions, a statistically significant, large catalog of superclusters covering a wide range of redshifts and sky areas is essential. In this work, together with an international team of collaborators, **Surhud More** of IUCAA, presented a large catalog of 662 superclusters identified using a modified friends-of-friends algorithm applied on the WHL (Wen-Han-Liu) cluster catalog within a redshift range of $0.05 \leq z \leq 0.42$. The most massive supercluster was identified at $z \sim 0.25$ as the Einasto Supercluster. The median mass of superclusters found was $\sim 5.8 \times 10^{15}$ $M_\odot$ and the median size was ~ 65 Mpc. The supercluster environment was shown to slightly affect the growth of clusters. A comparison of the properties of the observed superclusters with the mock superclusters extracted from the Horizon Run 4 cosmological simulation showed broad agreement.

Optical Cluster Cosmology with SDSS redMaPPer clusters and HSC-Y3

The abundance of galaxy clusters in the Universe is sensitive to the cosmological parameters. In this paper, the Subaru HSC collaboration, together with **Surhud More** from IUCAA, presented the cosmology results obtained from a blind joint analysis of the abundance, projected clustering, and weak lensing of galaxy clusters measured from the Sloan Digital Sky Survey (SDSS) redMaPPer cluster catalog and the Hyper-Suprime Cam (HSC) Year3 shape catalog. A full-forward model for the cluster observables, which includes empirical modeling for the anisotropic boosts on the lensing and clustering signals of optical clusters, was used to analyse the observables. The analysis was validated via mock cluster catalogs which include observational systematics, such as the projection effect and the effect of baryonic feedback, to show that robust constraints on cosmological parameters can be obtained. The joint analysis in the context of the flat ΛCDM model resulted in cosmological constraints for $S_8 \equiv \sigma_8 \sqrt{\Omega_{\rm m}/0.3} = 0.816^{+0.041}_{-0.039}$, a result consistent with the S_8 inference from other cosmic microwave background- and large scale structure-based cosmology analyses, including the result from the *Planck* 2018 primary CMB analysis.

On the feasibility of primordial black hole abundance constraints using lensing parallax of GRBs

Primordial black holes, which could have formed during the early Universe through overdensities in primordial density fluctuations during inflation, are potential candidates for dark matter. In this paper led by graduate student **Priyanka Gawade** together with **Surhud More** from IUCAA, the use of lensing parallax of gamma-ray bursts (GRBs), which results in different fluxes being observed from two different vantage points, was used to probe the abundance of primordial black holes in the unexplored mass range of 10^{-15} to 10^{-11} $M_\odot$. The optical depth for the lensing of GRBs with a distribution of source properties and realistic detector sensitivities was derived. The paper also explored the ability of the proposed Indian twin satellite mission Daksha in its low Earth orbit to conduct this experiment. If the two Daksha satellites observe 10,000 GRBs simultaneously and the entirety of dark matter is made up of 10^{-15} to 10^{-12} $M_\odot$ black holes, Daksha will detect non-zero lensing events with a probability ranging from 80 to 50 per cent at the bin edges, respectively. Non-detections

will not conclusively rule out primordial black holes as dark matter in this mass range. However, it was shown that meaningful constraints can be obtained in such a case if the two satellites are separated by at least the Earth-Moon distance.

Computational Astrophysics

Small-scale dynamo with nonzero correlation time

The small-scale dynamo is typically studied by assuming that the correlation time of the velocity field is zero. Some authors have used a smooth renovating flow model to study how the properties of the dynamo are affected by the correlation time being nonzero. In this work, IUCAA PhD student **Kishore Gopalakrishnan** and **Nishant Singh** derive the lowest-order corrections to the evolution equation for the two-point correlation of the magnetic field in Fourier space by assuming that the velocity is an incompressible Gaussian random field (which need not be smooth). Using this, they obtain the evolution equation for the longitudinal correlation function of the magnetic field (ML) in nonhelical turbulence, valid for arbitrary Prandtl number. The non-resistive terms of this equation do not contain spatial derivatives of ML of order greater than two. They further simplify this equation in the limit of high Prandtl number, and find that the growth rate of the magnetic energy is much smaller than previously reported. Nevertheless, the magnetic power spectrum still retains the Kazantsev form at high Prandtl number.

Mean-field dynamo due to fluctuating turbulent diffusivity

In systems where the standard α-effect is inoperative, one often explains the existence of mean magnetic fields by invoking the 'incoherent α effect', which appeals to fluctuations of the mean kinetic helicity. Previous studies, while considering fluctuations in the mean kinetic helicity, treated the mean turbulent kinetic energy as a constant, despite the fact that both these quantities involve second-order velocity correlations. The mean turbulent kinetic energy causes both turbulent diffusion and diamagnetic pumping of the mean magnetic field. In this work, IUCAA PhD student **Kishore Gopalakrishnan** and **Nishant Singh** use a double-averaging procedure to analytically show that fluctuations of the mean turbulent kinetic energy (giving rise to η-fluctuations, where, η is the turbulent diffusivity) can lead to the growth of a large-scale magnetic field even when the kinetic helicity is zero pointwise. These fluctuations tend to reduce the overall turbulent diffusion. It was also found that the diamagnetic pumping, which arises due to inhomogeneities in the turbulent kinetic energy, leads to growing mean field solutions even when the η-fluctuations are isotropic. Our results suggest that fluctuations of the turbulent kinetic energy may be relevant in astrophysical contexts.

A model for transitions between steady states of sub-Keplerian accretion discs: Implication for spectral states and hot corona above the disc

Together with an IUCAA associate Dr S R Rajesh from Kerala and his student Ms Arunima Ajay, **Nishant Singh** worked on an analytical hydrodynamic model based on a sequence of steady states of the inner sub-Keplerian accretion disc to understand its different spectral states. Correlations between different hydrodynamic steady states were studied to understand the origin of various astrophysical observables such as aperiodic variabilities. The plausible source of corona/outflow close to the central compact object is shown to be a consequence of steady state transition in the underlying accretion flow. They envisage that this phenomenological model can give insight on the influence of viscosity, efficiency of energy advection, nature of the background flow and environment, on the evolution of the inner sub-Keplerian accretion disc.

Implementing a self-gravity module in PLUTO code and its application on AGN feedback studies

Researchers at IUCAA have developed a novel numerical scheme to solve the Poisson equation for self-gravitating systems and incorporated it into the well-known PLUTO astrophysical code. The method involves a V-cycle based multi-grid solver, where starting from a fine grid, the Poisson equation is iteratively solved on coarser grids and the results are interpolated back to the original grid. Such a cyclic method traversing different levels of grid refinement is efficient in yielding quicker convergence of solutions. For the finer grids, a Gauss-Seidel method has been employed and for the coarsest grid, a new iterative scheme based on the Runge-Kutta-Legendre (RKL) algorithm has been implemented. The above combination of techniques has been demonstrated to provide a very fast, highly parallelisable and accurate

Poisson solver, which has been tested on a wide variety of problems (see Fig. 1). The research was led by **Mr. Ankush Mandal**, a PhD student at IUCAA along with **Prof. Dipanjan Mukherjee** (IUCAA) and Prof. Andrea Mignone (University of Torino). The results have been published in Mandal et al. 2023, MNRAS. Using the newly developed self-gravity module, IUCAA researchers have carried out a large suite of high-resolution simulations of dense inhomogeneous clouds of gas being stripped by fast winds from an Active Galactic Nuclei (AGN). In one of the first of its applications, the impact of self-gravity in such clouds being impacted by the winds has been tested (see Fig. 7. The study demonstrated that self-gravitational forces prevent ablation of the cloud, with the cloud cores collapsing unto themselves, forming highly dense structures that are further resilient to destruction by AGN winds. The above depends on the power of the wind, with higher power winds being more efficient in disrupting the clouds. The results have been communicated to the MNRAS journal.

Impact of turbulent magnetic fields on the polarisation of synchrotron emission from young jets

Researchers at IUCAA have carried out a series of high-resolution simulations of relativistic jets evolving into the ambient medium of galaxies. A novel feature in these simulations was the inclusion of turbulent magnetic fields in the ambient gas around the galaxies, which is swept up by the evolving forward shock driven by the jet. As the external field gets stretched and wraps around the cocoon, it can strongly affect the degree of polarisation of the synchrotron emission expected from such systems. The simulations show that for lower power jets, there indeed is significant de-polarisation due to the swept up magnetic field. For higher power jets with strong internal magnetic fields, the emission from the cocoon dominates over that from the forward shock and hence the impact of the turbulent magnetic fields from the environment is less. The simulations additionally demonstrate that MHD instabilities can cause filamentary structures in the jet's cocoon as well as multiple hotspot complexes, which have also been observed in several systems. The research has been led by **M. Meenakshi**, a PhD student at IUCAA, in collaboration with **Prof. Dipanjan Mukherjee** (IUCAA) and researchers from the Observatory of Torino. The results have been published in Meenakshi et al. 2023, MNRAS.

Galactic and Extragalactic Astronomy

The cosmic web of X-ray active galactic nuclei seen through the eROSITA Final Equatorial Depth Survey (eFEDS)

Determining which galaxies in the general population turn into active galactic nuclei (AGNs) is a keystone of galaxy formation and evolution studies. Thanks to SRG/eROSITA's contiguous 140 square degree pilot survey field, we constructed a large, complete, and unbiased soft X-ray flux-limited ($F_X > 6.5\times 10^{-15}$ erg s^{-1} cm^{-2}) AGN sample at low redshift, $0.05 < z < 0.55$. Two summary statistics, the clustering using spectra from SDSS-V and galaxy-galaxy lensing with imaging from HSC, are measured and interpreted with halo occupation distribution and abundance matching models. Both models successfully account for the observations. **Surhud More** and collaborator obtain an exceptionally complete view of the AGN halo occupation distribution. The population of AGNs is broadly distributed among halos with a mean mass of $3.9^{+2.0}_{-2.4}\times 10^{12}\ M_\odot$. This corresponds to a large-scale halo bias of $b(z=0.34) = 0.99^{+0.08}_{-0.10}$. The central occupation has a large transition parameter, $\sigma_{\log_{10}(M)} = 1.28 \pm 0.2$. The satellite occupation distribution is characterized by a shallow slope, $\alpha_{\rm sat} = 0.73\pm0.38$. We find that AGNs in satellites are rare, with $f_{\rm sat} < 20\%$. Most soft X-ray-selected AGNs are hosted by central galaxies in their dark matter halo.

The eROSITA Final Equatorial-Depth Survey (eFEDS) - Splashback radius of X-ray galaxy clusters using galaxies from HSC survey

The splashback radius is a measure of the size of the dark matter halos of astrophysical objects. In this paper, **Divya Rana**, a graduate student at IUCAA together with **Surhud More** and collaborators, presented measurements of the splashback radius around the SRG/eROSITA eFEDS X-ray selected galaxy clusters by cross-correlating them with HSC photometric galaxies. The X-ray selection is expected to be less affected by systematics related to projection that affects optical cluster finder algorithms. Using a nearly volume-limited sample of 109 galaxy clusters selected in $0.5-2.0$ keV band, having luminosity $L_X > 10^{43.5}\,{\rm erg\,s^{-1}h^{-2}}$ within the redshift $z < 0.75$, they obtained measurements of the projected cross-correlation with a signal-to-noise of 17.43. They infer the value of the 3D splashback radius to be $1.45^{+0.30}_{-0.26}\,{\rm h^{-1}}$ Mpc. These constraints on

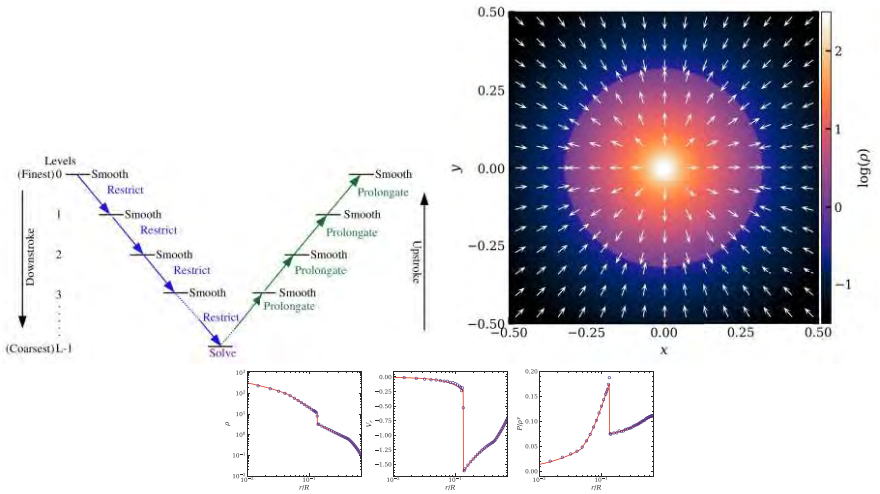


Figure 1: Top left: A schematic diagram of the multigrid V-cycle algorithm for the Poisson solver. Top Right: A slice of the density distribution for the adiabatic collapse test problem. The white arrows indicate velocity vectors. Bottom panel: The evolution of the density, radial velocity and entropy as a function of time, with the semi-analytical solution overplotted in red. The solutions from the simulations show remarkable match with the semi-analytic results, indicating the accuracy of the implemented numerical schemes.

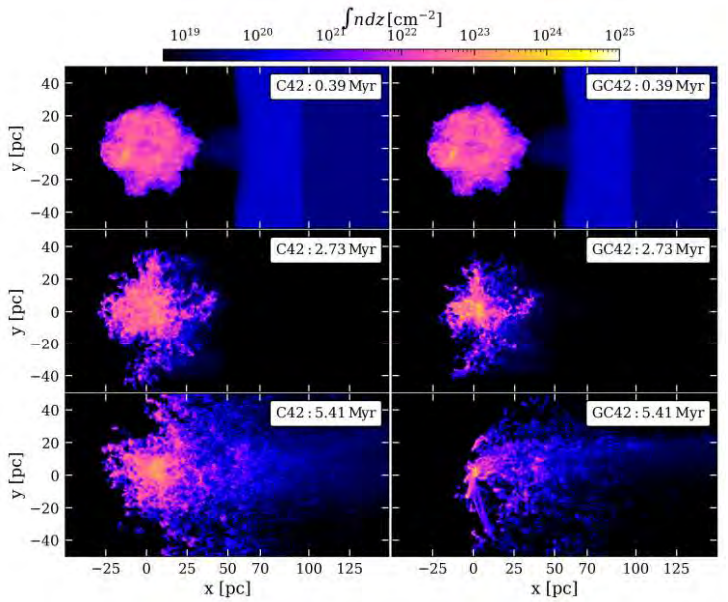


Figure 2: Time evolution (row-wise) of the projected number density along the z-axis of the simulations without self-gravity (left) and with self-gravity (right). The power of the wind for both simulations is $10^{42}\,\mathrm{erg\ s^{-1}}$. It is evident that in the absence of self-gravity (left), the cloud undergoes expansion after the initial compression. Whereas in the self-gravity case (right) global collapse takes place.

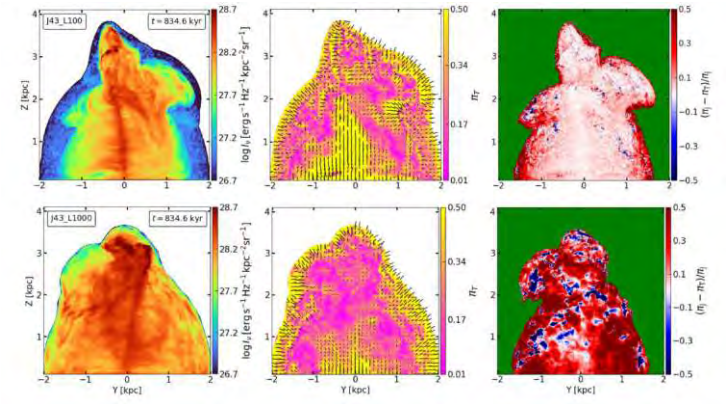


Figure 3: Top:Logarithmic total synchrotron emission, polarization fraction (π_T and π_J) for a jet of power $\sim 10^{43}$erg s^{-1} at $\theta_I = 45^\circ$ at different times. **Bottom:** Same as above for jet in an environment with longer correlation lengths of magnetic field lines. **H3** shows hotspot complexes in J43 with three hotspots, and **R3** shows arc-like features.

the splashback radius, although broad, are the best measurements thus far obtained for an X-ray selected galaxy cluster sample.

Stellar mass dependence of galaxy size-dark matter halo radius relation probed by Subaru-HSC survey weak lensing measurements

In this paper, IUCAA postdoctoral fellow **Preetish Mishra**, together with **Divya Rana and Surhud More** of IUCAA, investigated the stellar mass dependence of the 'galaxy size'-'dark matter halo radius' relation for low-redshift galaxies using weak gravitational lensing measurements. Their sample consisted of 38000 galaxies more massive than $10^8 M_\odot h^{-2}$ and within $z < 0.3$, drawn from the overlap of Galaxy And Mass Assembly survey data release 4 and HSC-SSP PDR2. They divided the galaxy sample into a number of stellar mass bins and measured the stacked weak lensing signals and modeled it using a conditional stellar mass function to infer the stellar mass-halo mass relation. They further fit a single Sersic model to HSC i-band images of those galaxies to obtain their three-dimensional half-light radii and infer the median galaxy size-mass relation. A combination of these relations allowed them to infer the galaxy size-halo radius relation. They confirmed the linear nature of this relation, given the statistical errors, and showed that the ratio of galaxy size to halo radius remains constant over two orders of magnitudes for stellar mass above $10^9 M_\odot h^{-2}$.

Galaxy-dark matter connection of photometric galaxies from the HSC-SSP Survey: galaxy-galaxy lensing and the halo model

In this paper, IUCAA graduate student **Navin Chaurasiya**, together with **Surhud More**and an international team of collaborators, inferred the connection between stellar mass of galaxies from Subaru Hyper Suprime-Cam (HSC) survey and their dark matter halo masses in two bins of redshifts between [0.3, 0.8]. They used measurements of the weak lensing of background galaxies from Year-1 shape catalogue from the HSC survey. By binning lens galaxies in stellar mass with varying thresholds ranging from $8.6 \leq \log[M_*/(h^{-2}M_\odot)] \leq 11.2$ and using stringent cuts in the selection of source galaxies, they measured a robust weak lensing signal and modeled it in the halo occupation distribution framework. The results demonstrate that the lensing measurements are best able to constrain average central halo masses, $\langle Mcen \rangle$. The results show that the galaxy-dark matter connection does not vary significantly in the Universe between the large period explored in the study.

Over-abundance of orphan galaxies in the UNIVERSEMACHINE empirical galaxy formation model

Orphan galaxies that have lost a large fraction of the dark matter subhaloes have often been invoked in semi-analytical as well as empirical models of galaxy formation. However, observations have not yet constrained the distribution of orphan galaxies in such models. In this study, IUCAA graduate student

Amit Kumar, together with **Surhud More** from IUCAA, ran a mock cluster finder that mimics the optical cluster finding technique of the redMaPPer algorithm on a catalogue of galaxies with quenched star formation from one such empirical model, the UNIVERSEMACHINE, to obtain the prevalence of orphan galaxies in these clusters as a function of their cluster-centric distance. This allowed for a direct comparison of the fraction of orphan galaxies with the upper limits derived based on their prior observations of the weak lensing signals around satellite galaxies from SDSS redMaPPer clusters. In the manuscript, they showed that the orphan fraction from the UNIVERSEMACHINE is only marginally consistent with the upper limits in the innermost regions of galaxy clusters spanning $[0.1, 0.3]h^{-1}$Mpc, and observed that the orphan fractions are substantially larger than the upper limits in the outer regions of galaxy clusters beyond $0.3h^{-1}$Mpc. In the paper, the authors discussed the reasons, plausible improvements to the model and how observations can be used to constrain such models further.

Lyman Continuum Leakers in the AstroSat Ultraviolet Deep Field: Extreme-ultraviolet Emitters at the Cosmic Noon

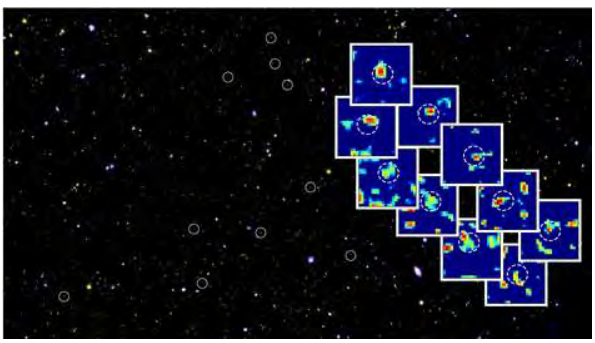


Figure 4: Background image is a portion of the AstroSat UV Deep Field North (AUDF-north) field made using UVIT filters. Circles denote the position of 10 LyC leakers discovered in the field in the redshift range z∼1 - 2. In inset-boxes are shown the far-UV (F154W filter) image of the LyC leakers probing rest-frame wavelength ∼600Å.

Within the first billion years after the Big Bang, our Universe went through a major phase transition known as reionization, a process in which neutral hydrogen atoms dissociated into protons and electrons when they are struck by high energy UV radiation with wavelengths less than 912 Åoe energy greater than 13,6 eV - known as Lyman Continuum emission. Understanding the cosmic reionization and the sources responsible for this process remains one of the frontier problems in astronomy. The Lyman continuum emission can be easily absorbed or scattered by the interstellar medium or the circumgalactic medium of their host galaxies. Even when some of these ionizing photons manage to come out of the galaxy's environment, they maybe absorbed by the vast intergalactic medium between us and the galaxy. This is what makes their discovery a rare event in astrophysics. In the current discovery, **Suraj Dhiwar**, project student (funded by ISRO and registered under S.P. Pune University and **Kanak Saha** from IUCAA have found 10 Lyman continuum emitting galaxies from the peak era of cosmic star formation history, making it the first coherent sample of Lyman continuum leakers at this epoch. More interestingly, these Lyman Continuum photons have wavelength ∼600 Å, falling in the Extreme Ultraviolet regime, the shortest ultraviolet wavelength with which a galaxy has been imaged so far. These galaxies are about 8 - 9 billion light years away from the Earth and have intense star formation rates, with some of them forming massive young stars at a rate 100 times higher than our Milky Way Galaxy. The discovery would fill an important niche in understanding the evolution of these rare objects. This work will be a part of the PhD thesis of **Suraj Dhiwar**.

Mapping the distribution of neutral hydrogen around low-redshift galaxies

It is now well established that the luminous parts of galaxies are surrounded by a large reservoir of low-density, diffuse gas called the circumgalactic medium (CGM). The CGM serves as a bridge between galaxies and the intergalactic medium (IGM). Although CGM is believed to play a crucial role in regulating star formation inside galaxies, the emission from this medium is difficult to observe due to its tenuous nature. Alternatively, absorption line spectroscopy of bright background sources has paved the way to probe this medium. However, in order to probe the CGM in this manner, a large statistical sample of galaxy-quasar pairs with a dynamic range of galaxy properties is required. The lack of such a sample has restricted the study of cool neutral gas around the galaxies and its connection to the host galaxy properties.

In this work, **Sayak Dutta** and collaborators present a detailed study of cool, neutral gas traced by Lyman-

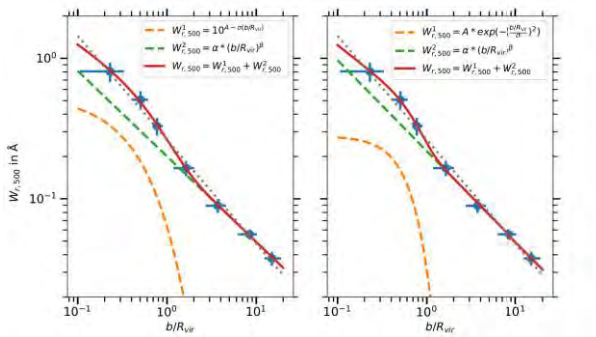


Figure 5: Modeling the observed Lyman-α rest-frame equivalent width ($W_{r,500}$) profile with two components. The data points show $W_{r,500}$ plotted against $b/R_{\rm vir}$ from this work. A log-linear (left, orange dashed) or a Gaussian (right, orange dashed) and a power-law component (green dashed, both panels) are used as shown by the legends. The solid red line is the combined best-fit model in both panels. The small-scale and power-law components represent the 1-halo (coming from the CGM of the individual galaxies) and 2-halo terms (coming from the large-scale clustering between galaxies and Lyman-α absorbers), respectively.

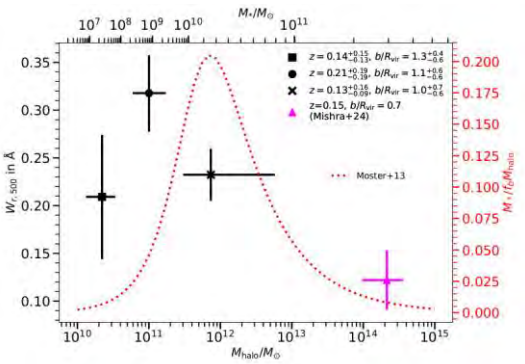


Figure 6: The Lyman-α $W_{r,500}$, measured within $2R_{\rm vir}$, as a function of stellar/halo mass is plotted with black symbols. All galaxies with $0.25 < b/R_{\rm vir} < 2$ are selected and split into 3 stellar mass bins with $\log_{10}(M_*/{\rm M}_\odot)< 8$, $8 <\log_{10}(M_*/{\rm M}_\odot)< 9.5$ and $\log_{10}(M_*/{\rm M}_\odot)> 9.5$ to produce the Lyman-α stacks. The magenta triangle represents the median $W_{r,500}$ for stacked Lyman-α absorption in low redshift ($z < 0.5$) cluster outskirts ($b/R_{500} < 1.5$) by Mishra et al. (2024). The x-error bars show the 68% range of M_* in each bin, y-error bars are 68% confidence intervals of the median $W_{r,500}$. The median $b/R_{\rm vir}$ and z (along with 68% confidence intervals) of each bin are given in the legends. The overlaid red dotted line showing the star-formation efficiency (SFE, defined as stellar mass to the baryonic mass in the halo) corresponds to the right y-axis. The similarity in the SFE and the Lyman-α $W_{r,500}$ may suggest that the cool neutral gas and the efficiency of star formation are linked.

α around 4595 $z < 0.5$ galaxies using stacks of background quasar spectra. The galaxies are selected from their MUSEQuBES low-z survey along with data from the literature. These galaxies, with a median stellar mass of $\log_{10}(M_*/{\rm M}_\odot) = 10.0$, are probed by 184 background quasars giving rise to 5054 quasar-galaxy pairs. They find excess absorption out to a transverse distance of at least 15 times the virial radius and $\approx \pm$ 600 km s^{-1} along the line of sight. They show that the median stacked profile for the full sample, dominated by the pairs with transverse distance beyond the virial radius can be explained by a galaxy-absorber two-point correlation function. There are strong indications that the inner regions (inside the virial radius) of the rest equivalent width (a measure of Lyman-α absorption) profile are better explained by a log-linear (or a Gaussian) relation whereas a power-law, consistent with galaxy-absorber large-scale clustering well describe the outer regions. Using a sub-sample of 339 galaxies with star formation rate measurements, they find that the Lyman-α absorption is significantly stronger for star-forming galaxies compared to passive galaxies, but only within the virial radius. The Lyman-α absorption at $\approx$ virial radius for a redshift-controlled sample peaks at $M_* = 10^9\,M_\odot$ ($M_{\rm halo} = 10^{11}\,M_\odot$). This work is a part of the Ph.D. thesis of Sayak Dutta and was published in the Monthly Notices of Royal Astronomical Society **(Dutta et al. 2024, MNRAS, 528, 3745-3766)**.

Probing coherence in metal absorption towards multiple images of strong gravitationally lensed quasars

Studying the distribution and mixing of metals around galaxies is crucial to understand the star formation history and chemical enrichment of galaxies. Due to its low density, the diffuse gas in the halos around galaxies is most effectively probed in absorption against bright background sources such as quasars. The major limitation of absorption line studies is that they probe the gas only along a pencil-beam sightline towards the background point source, and hence cannot directly map the spatial distribution of the gas. Gravitationally lensed quasars or quasar pairs enable spatially resolved studies of the halo gas in absorption. However, such systems are rare. **Rajeshwari Dutta** and collaborators have used integral field spectroscopic observations, using

Multi Unit Spectroscopic Explorer (MUSE) on the Very Large Telescope (VLT), of two gravitationally lensed quasar systems to conduct a tomographic analysis of the structure of metal-enriched cool gas in the halos around galaxies at redshifts $z < 2$. These are two of the few currently known quasars with multiple images due to strong gravitational lensing by galaxy clusters at $z \sim 0.5 - 0.6$. The diffuse gas from the halos of intervening galaxies is detected in absorption in the spectra of the multiple images of the background quasars at $z \sim 2 - 3$. The angular separations between different pairs of quasar multiple images facilitate probing the absorption over transverse physical separations of $0.4 - 150$ kpc. The MUSE observations of these quasar fields enable study of the galaxies associated with the absorbing gas. The results of this study indicate that the metal-enriched gaseous structures around galaxies become less coherent with increasing physical separation, with a likely coherence length scale of $\sim$ 10 kpc. The high-ionization gas phase traced by CIV absorption shows a higher degree of coherence than the low-ionization gas phase traced by MgII absorption.

Hunting gamma-ray-emitting FR0 radio galaxies in wide-field sky surveys

The latest entry in the jetted active galactic nuclei (AGN) family is the Fanaroff–Riley type 0 (FR0) radio galaxies. They share several observational characteristics, e.g., nuclear emission and host galaxy morphology, with FR I sources, however, they lack extended, kiloparsec-scale radio structures, which are the defining features of canonical FR I and II sources. Meghana Pannikkote, **Vaidehi S. Paliya and Dhruba J Saikia** report the identification of seven γ-ray-emitting AGN as FR0 radio sources by utilizing the high-quality observations delivered by the ongoing multiwavelength wide-field sky surveys, e.g., Very Large Array Sky Survey. The broadband observational properties of these objects are found to be similar to their γ-ray undetected counterparts. In the γ-ray band, FR0 radio galaxies exhibit spectral features similar to more common FR I and II radio galaxies, indicating a common γ-ray production mechanism and the presence of misaligned jets. Although the parsec-scale radio structure of FR0s generally exhibits a wide range, with about half having emission on opposite sides of the core, the γ-ray-detected FR0s tend to have dominant cores with core-jet structures. They conclude that dedicated, high-resolution observations are needed to unravel the origin of relativistic jets in this enigmatic class of faint yet numerous population of compact radio sources.

A giant radio galaxy with three cycles of episodic jet activity from LoTSS DR2

The excellent sensitivity and optimum resolution of LoTSS DR2 at 144 MHz has enabled the discovery of a giant radio galaxy (J1225+4011) with three distinct episodes of jet activity by **Kshitij Chavan**, Pratik Dabhade and **Dhruba J Saikia**, making this source a member of a class of objects called triple-double radio galaxies (TDRGs). The source extends overall up to 1.35 Mpc in projected size, with the second episode extending to 572 kpc, and the inner episode to 118 kpc. J1225+4011 is only the fourth radio source showing a triple-double radio structure. All four sources have overall sizes greater than 700 kpc, making them giants. They have summarized and discussed the radio properties of all TDRGs for the first time to understand their growth and evolution. They suggest that the power of the jets may decrease with time. Kshitij Chavan was awarded the Astronomical Society of India New Discovery Award for the year 2023 for the discovery of this galaxy.

Star formation in the dwarf Seyfert galaxy NGC 4395: evidence for both AGN and SN feedback?

Payel Nandi, C. S. Stalin, **Dhruba J Saikia** and collaborators present a detailed multi-wavelength study of star formation in the dwarf galaxy NGC 4395 which hosts an active galactic nucleus (AGN). From their observations with the Ultra-Violet Imaging Telescope, they have compiled a catalogue of 284 star forming (SF) regions, out of which they could detect 120 SF regions in Hα observations. Across the entire galaxy, they found the extinction corrected star formation rate (SFR) in the far ultra-violet (FUV) to range from 2.0×10^{-5} $M_{\odot}yr^{-1}$ to 1.5×10^{-2} $M_{\odot}yr^{-1}$ with a median of 3.0×10^{-4} $M_{\odot}yr^{-1}$ and age to lie in the range of $\sim$ 1 to 98 Myr with a median of 14 Myr. In Hα they found the SFR to range from 7.2×10^{-6} $M_{\odot}yr^{-1}$ to 2.7×10^{-2} $M_{\odot}yr^{-1}$ with a median of 1.7×10^{-4} $M_{\odot}yr^{-1}$ and age to lie between 3 to 6 Myr with a median of 5 Myr. The stellar ages derived from Hα show a gradual decline with galactocentric distance. They found three SF regions close to the center of NGC 4395 with high SFR both from Hα and UV which could be attributed to feedback effects from the AGN. They also found six other SF regions in one of the spiral arms having higher SFR. These are

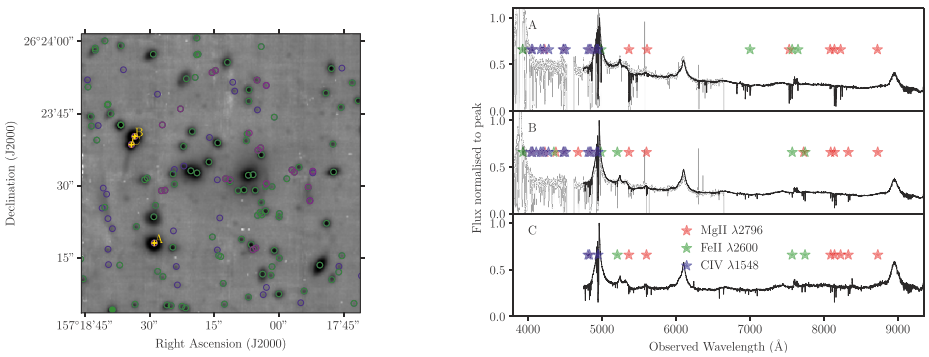


Figure 7: The left panel shows the MUSE image of one of the lensed quasar fields studied by Dutta et al., 2024. The three multiple images, A, B, and C, of the quasar are marked with '+'. The circles identify all the detected sources. The right panel shows the spectra of the three quasar multiple images obtained using MUSE and UVES. The stars mark the MgII (red), FeII (green), and CIV (blue) absorption lines detected in the spectra.

very close to supernovae remnants which could have enhanced the SFR locally. They obtained a specific SFR (SFR per unit mass) of 4.64×10^{-10} yr^{-1} for the whole galaxy.

Evidence for low-power radio jet-ISM interaction at 10 pc in the dwarf AGN host NGC 4395

Black hole driven outflows in galaxies hosting active galactic nuclei (AGN) may interact with their interstellar medium (ISM) affecting star formation. Such feedback processes, reminiscent of those seen in massive galaxies, have been reported recently in some dwarf galaxies. However, such studies have usually been on kiloparsec and larger scales and our knowledge on the smallest spatial scales to which these feedback processes can operate is unclear. Payel Nandi, C. S. Stalin, **Dhruba J Saikia** and collaborators including **Vaidehi S. Paliya** demonstrate radio jet−ISM interaction on the scale of an asymmetric triple radio structure of $\sim$ 10 parsec size in NGC 4395. This triple radio structure is seen in the 15 GHz continuum image and the two asymmetric jet-like structures are situated on either side of the radio core that coincides with the optical *Gaia* position. The high resolution radio image and the extended [OIII]λ5007 emission, indicative of an outflow, are spatially coincident and are consistent with the interpretation of a low power radio jet interacting with the ISM. Modelling of the spectral lines using `MAPPINGS`, and estimation of temperature using optical integral field spectroscopic data suggest shock ionization of the gas. The continuum emission at 237 GHz, though weak, was found to spatially coincide with the AGN. However, the CO(2−1) line emission was found to be displaced by around 20 parsec northward of the AGN core. The spatial coincidence of molecular $H_2\lambda2.4085$ along the jet direction, the morphology of ionised [OIII]λ5007 and displacement of the CO(2−1) emission argues for conditions less favourable for star formation in the central $\sim$ 10 parsec region.

LeMMINGs. VI. Connecting nuclear activity to bulge properties of active and inactive galaxies: radio scaling relations and galaxy environment

Multiwavelength studies indicate that nuclear activity and bulge properties are closely related, but the details remain unclear. To study this further, B. T. Dullo, J.. H. Knapen, R. J. Beswick and collaborators including **D. J. Saikia** combine Hubble Space Telescope bulge structural and photometric properties with 1.5 GHz e-MERLIN nuclear radio continuum data from the LeMMINGs survey for a large sample of 173 'active' galaxies (LINERs and Seyferts) and 'inactive' galaxies (H IIs and absorption line galaxies, ALGs). Dividing their sample into active and inactive, they define distinct (radio core luminosity)-(bulge mass), $L_{\rm R,core}-M_{*,\rm bulge}$, relations, with a mass turnover at $M_{*,\rm bulge} \sim 10^{9.8\pm0.3}M_\odot$ (supermassive black hole mass $M_{\rm BH} \sim 10^{6.8\pm0.3}M_\odot$), which marks the transition from AGN-dominated nuclear radio emission in more massive bulges to that mainly driven by stellar processes in low-mass bulges. None of their 10/173 bulge-less galaxies host an AGN. The AGN fraction increases with increasing $M_{*,\rm bulge}$ such that $f_{\rm optical\_AGN} \propto M_{*,\rm bulge}^{0.24\pm0.06}$ and $f_{\rm radio\_AGN} \propto M_{*,\rm bulge}^{0.24\pm0.05}$. Between $M_{*,\rm bulge} \sim 10^{8.5}$ and $10^{11.3}$ M$_\odot$, $f_{\rm optical\_AGN}$ steadily rises from 15 $\pm$ 4 to 80 $\pm$ 5

per cent. They find that at fixed bulge mass, the radio loudness, nuclear radio activity, and the (optical and radio) AGN fraction exhibit no dependence on environment. Radio-loud hosts preferentially possess an early-type morphology than radio-quiet hosts, the two types are however indistinguishable in terms of bulge Sérsic index and ellipticity, while results on the bulge inner logarithmic profile slope are inconclusive. They finally discuss the importance of bulge mass in determining the AGN triggering processes, including potential implications for the nuclear radio emission in nearby galaxies.

Narrow-line Seyfert 1 galaxies in Sloan Digital Sky Survey: a new optical spectroscopic catalogue

Narrow-line Seyfert 1 (NLSy1) galaxies are an enigmatic class of active galactic nuclei (AGN) that exhibit peculiar multiwavelength properties across the electromagnetic spectrum. For example, these sources have allowed us to explore the innermost regions of the central engine of AGN using X-ray observations and have also provided clues about the origin of relativistic jets considering radio and gamma-ray bands. Keeping in mind the ongoing and upcoming wide-field, multifrequency sky surveys,**Vaidehi S. Paliya**, C. S. Stalin, C. S., Alberto Domínguez and **D. J. Saikia** present a new catalogue of NLSy1 galaxies. This was done by carrying out a detailed decomposition of >2 million optical spectra of quasars and galaxies from the Sloan Digital Sky Survey Data Release 17 (SDSS-DR17) using the publicly available software 'Bayesian AGN Decomposition Analysis for SDSS Spectra'. The catalogue contains 22656 NLSy1 galaxies which is more than twice the size of the previously identified NLSy1s based on SDSS-DR12. As a corollary, they also release a new catalogue of 52273 broad-line Seyfert 1 (BLSy1) galaxies. The estimated optical spectral parameters and derived quantities confirm the previously known finding of NLSy1 galaxies being AGN powered by highly accreting, low-mass black holes. They conclude that this enlarged sample of NLSy1 and BLSy1 galaxies will enable them to explore the low-luminosity end of the AGN population by effectively utilizing the sensitive, high-quality observations delivered by ongoing/upcoming wide-field sky surveys.

Characterizing the outskirts of galaxy clusters

Owing to the lack of sensitive diagnostics to probe the cool/warm-hot gas that prevails in the cluster outskirts (i.e., $\rho > R_{500}$) in emission, the outskirts of galaxy clusters remained poorly understood. In an earlier work, they showed that quasar absorption line spectroscopy can be used to probe these unexplored regions of the Universe **(Mishra & Muzahid, ApJ, 933, 229, 2022)**. More recently, by cross-matching the Hubble Spectroscopic Legacy Archive quasar catalogue with optically- and SZ-selected cluster catalogues, they presented the first detection of cool, neutral gas in the outskirts of low-z galaxy clusters using a statistically significant sample of 3191 $z \approx 0.2$ background quasar–foreground cluster pairs **(Mishra et al., MNRAS, 527, 3858, 2024)**. The median cluster mass of their sample is $\approx 10^{14.2}$ $M_{\odot}$ with a median impact parameter of ≈ 5 pMpc. They detected significant Lyman-α , marginal C IV, but no O VI absorption in the signal-to-noise ratio weighted mean stacked spectra with rest-frame equivalent widths of 0.096 ± 0.011 Å, 0.032 ± 0.015 Å, and < 0.009 Å (3σ), respectively, for their sample. The Lyman-α REW shows a declining trend with increasing ρ (ρ/R_{500}), which is well explained by a power-law with a slope of -0.79 (-0.70). The covering fractions measured for Lyman-α (21 per cent), C IV (10 per cent), and O VI (10 per cent) in cluster outskirts are significantly lower than those measured in the circumgalactic medium (CGM) of galaxies at similar redshifts. They also found that the CGM of galaxies that are closer to cluster centres or those in massive clusters is considerably deficient in neutral gas (see Figure 8). The low covering fraction of the Lyman-α along with the non-detection of Lyman-α signal when the strong absorbers ($> 10^{13}$ cm^{-2}) are excluded, indicate a patchy distribution of cool gas in the outskirts. We argue that the cool gas in cluster outskirts in combination arises from the circumgalactic gas stripped from cluster galaxies and from large-scale filaments feeding the clusters with cool gas. Our observations indicate that gas (CGM) stripping is important out to large clustocentric distances ($> 3R_{500}$).

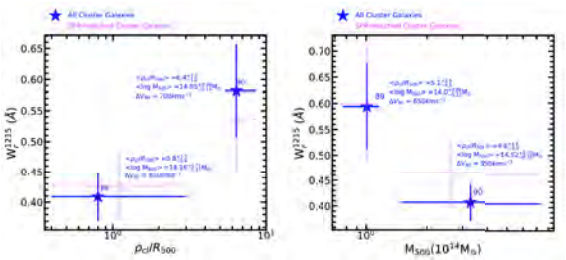


Figure 8: `Left:` Rest-frame equivalent width (REW) of Lyman-α for cluster galaxies (blue stars) as a function of cluster normalized impact parameter (ρ/R_{500}). The median values of cluster mass, normalized clustocentric impact parameter, and Δv_{90} of the stacked profile are indicated near each of the data points. The REW of Lyman-α as a function of ρ/R_{500} for the SFR and stellar mass-matched cluster galaxies are shown with open magenta circles. The number of galaxies contributing to each bin of ρ/R_{500} for both samples are also indicated near the data points in respective colours. `Right:` Similar to the left but as a function of M_{500}. It is evident that the CGM is deficient in cool gas for galaxies residing close to cluster centers (`left`) or galaxies residing in massive clusters even at large clustocentric distances (`right`).

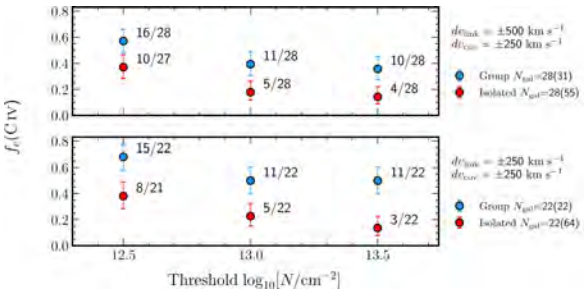


Figure 9: The C IV covering fractions for different threshold column densities for the isolated and pair/group subsamples. Isolated galaxies do not have any companions within the MUSE field of view and within the line of sight velocity window ($dv_{\rm link}$), as mentioned in the legends. Group galaxies exhibit higher C IV covering fraction for all threshold column densities.

MUSEQuBES: The relation between Ly-α emitters and C IV absorbers at $z \approx 3.3$

The circumgalactic medium (CGM) is a dynamic, complex, multiphase gaseous region enveloping galaxies, and extending out to $\sim$ few 100 kpc. It contains the imprints of crucial processes such as galactic-scale winds and the accretion of intergalactic baryons via the "hot mode"/"cold mode" along cosmic filaments. It is widely believed that these processes played a crucial role in determining the evolution of the cosmic star formation rate density (SFRD) which shows a peak at redshift of $z \approx 2-3$. Therefore, studying the CGM of galaxies at $z \approx 3$ is of utmost importance. Utilizing absorption spectra from bright background quasars, **Eshita Banerjee** and collaborators performed a comprehensive study of the column density and covering fraction profiles of C IV absorption around 86 Lyα emitters (LAEs) at $z \approx 3.3$. This study was part of the MUSEQuBES survey, covering 8 Multi-Unit Spectroscopic Explorer (MUSE) fields, each $1' \times 1'$ in size and centered on 8 UV-bright background quasars. Using Voigt profile fitting of all the C IV absorbers detected in the 8 quasar spectra, we generated a "blind" absorber catalog consisting of 489 C IV absorption components. We cross-matched this blind C IV catalog with the MUSE-detected LAE catalog and found significant enhancement of C IV components within $\approx \pm 400$ km s^{-1}of the systemic redshifts of the LAEs. Neither the C IV column density (N) nor the Doppler parameter (b) of individual C IV components shows any significant anti-correlation with impact parameter (ρ) of the LAEs in the 68 percentile range of $90 \leq \rho \leq 230$ physical kpc (pkpc). We find a covering fraction of $\approx 60\%$ for a threshold N(C IV) of $10^{12.5}$ cm^{-2}, which is roughly twice as high as in random regions. The C IV covering fraction remains constant at $\approx 50\%$ for impact parameters in the range 150–250 pkpc ($\approx 3-6R_{200}$). Using the covering fraction profile, we constrain the LAE–C IV absorber two-point correlation function, and obtain $r_0 = 3.4^{+1.1}_{-1.0}$ comoving Mpc (cMpc) and $\gamma = 1.2^{+0.2}_{-0.3}$ for a threshold N(C IV) of $10^{13.0}$ cm^{-2}. The C IV covering fraction is found to be enhanced for the LAEs that are part of a "pair/group" compared to the isolated ones (see Fig. 9). This work is part of the thesis of Eshita Banerjee and is published in **Banerjee et al. 2023, MNRAS, 524, 5148**. They defined a galaxy-pair/group in such a way that each member of a pair/group has at least one companion within MUSE field-of-view ($\approx$ 320 pkpc) and LOS velocity window, $dv_{\rm link}$, as mentioned in the plot. The "Pair/group" LAEs exhibit consistently higher C IV covering fractions than the "isolated" ones (ref. Figure 9).

Gravitational Waves and Gravitational Lensing

Hierarchical search strategy in searching for compact binary coalescences

An important idea that needs investigation is employing hierarchical search algorithms in gravitational wave searches. Such strategies save on the computational cost in searching for signals, such as, compact coalescing binary stars. Saving on computational cost will free CPU time for searches of other astrophysical sources. Recently an improved detection statistic has been proposed — the phase-time statistic. This statistic has a Bayesian flavour to it, because it incorporates information about the detectors and also of astrophysical source parameters. The hierarchical search strategy is applied to the phase-time statistic where a gain factor of about 20 has been obtained. A pipeline for the LIGO software library is expected to be added in the near future. An important issue here is the statistical significance of the detection obtained by the hierarchical search method. The key question is that of estimating the background noise distribution. This must be achieved without losing out on the computational gain factor. The main idea investigated here is to estimate the background with smaller number of time slides so that the computational gain is not very much compromised, and then, extrapolate the empirically obtained results to the normal operating points. The paper has been published. **Ms. Kanchan Soni** is the IUCAA student involved in this work under the joint guidance of **Sanjeev Dhurandhar** and **Sanjit Mitra**.

Second generation and higher order time-delay interferometry for space-based detectors of gravitational waves.

Work by M. Tinto and **Sanjeev Dhurandhar**
Time-Delay Interferometry (TDI) is the data processing technique that cancels the large laser phase fluctuations affecting the heterodyne Doppler measurements made by unequal-arm space-based gravitational wave interferometers. One obtains the entire space of all TDI combinations for stationary arrays. In this case, the three time-delay operators commute and any element of the TDI space can be written as a linear combination of four TDI variables, the generators of the first-generation TDI space. Here, the problem of exactly canceling the residual laser noise, due to terms linear in the inter-spacecraft velocities, is analysed. The procedure for obtaining elements of the second generation TDI space can be generalized in an iterative way. This allows the "lift-up" of the generators of the first generation TDI space and construct elements of the higher order TDI space with identical gravitational wave sensitivities. This approach is extended to higher order TDI that cancel higher order time derivatives of the arm-length variations. This is achieved by showing that the number of loops made by each beam before interfering corresponds to a specific higher-order TDI space. Similar to what was achieved for the second-generation TDI space, elements of a specific higher-order TDI space can be obtained by first "lifting" up the first generation TDI space to the higher-order space of interest and then taking linear combinations. Higher-Order TDI might be required by future interplanetary gravitational wave missions whose inter-spacecraft armlengths vary appreciably with time. Two papers have been published. A student Ms. Dishari Malakar from IISER, Kolkata was involved with one of the works.

Improved binary black hole searches through better discrimination against noise transients

Work by S. Choudhary, T. Ghosh, P. Joshi. S. Bose and **Sanjeev Dhurandhar**
The short-duration noise transients in LIGO and Virgo detectors significantly affect the search sensitivity of compact binary coalescence (CBC) signals, especially in the high mass region. In the previous work by the authors, a chi-squared statistic was proposed to distinguish them from CBCs. This work is an extension of the improved noise-discrimination of the optimal chi-squared statistic in real LIGO data. The tuning of the optimal chi-squared statistic includes accounting for the phase of the CBC signal and a well informed choice of sine-Gaussian basis vectors. This procedure allows one to discern how CBC signals and some of the most worrisome noise-transients project differently. Real blip glitches (a type of short-duration noise disturbance) are considered from the second observational run (O2) of LIGO-Hanford and LIGO-Livingston detectors. The binary black hole signals were simulated using IMRPhenomPv2 waveform and injected into real LIGO data from the same run. It is shown that in comparison to the traditional chi-squared and the sine-Gaussian chi-squared statistics, the optimal chi-squared statistic improves the signal detection rate remarkably. This work is in progress. The students involved in this work are **Sunil Choudhary and Tathagata Ghosh** from IUCAA, and Prasanna Joshi formerly from IISER, Pune is now a Ph.D. student in Max Planck Insti-

tute, Hannover, Germany.

R-modes as a New Probe of Dark Matter in Neutron Stars

Debarati Chatterjee and her research group are studying Neutron Stars (NS) which are perfect astrophysical laboratories to study cold and dense nuclear matter. The interior densities in NSs can surpass several times normal nuclear matter densities encountered in terrestrial (nuclear and heavy-ion) experiments. The motivation for studying NS is that the ultradense matter environment in its core allows us to probe physics under the most extreme conditions. Further, it is expected that strangeness, in the form of hyperons or deconfined quark matter, can exist as stable constituents of the inner NS core. Until recently, NSs were only observed using electromagnetic radiation at multiple wavelengths, from which their astrophysical observables could be indirectly deduced. The detection of gravitational waves (GW) from NSs in binary mergers have allowed us to directly probe their interior composition. Isolated neutron stars could also be important sources of GWs, either as burst sources (triggered by rotational glitches, flares), continuous wave sources (mountains, oscillation modes) or stochastic background. Unstable oscillation modes (such as f-,p-g- or r-modes), excited in isolated or binary mergers, could also contain signatures of its interior composition. **Debarati Chatterjee** and her research group (NSGW) at IUCAA develop complex theoretical models incorporating state-of-the-art information from nuclear physics, particle physics, heavy-ions, condensed matter physics as well as multi-messenger (electromagnetic and GW) observations to investigate how the interior composition of neutron stars influences its global properties and GW emission.

Constraining nuclear parameters using Gravitational waves from F-modes in Neutron Stars

The evidence for the fact that Dark Matter (DM) is about five times as prevalent as ordinary nuclear matter, ranges from astrophysical observations (dwarf galaxies rotation curves or the mass distribution of the Bullet cluster) to cosmological observations (structure formation and the cosmic microwave background). However, the particle nature of DM is still unknown. It is conjectured that DM could also be present in NSs, accreted into its interior forming a DM core or as DM halo beyond its radius. If DM exists in NSs, it could affect gravitational wave emission through its effects on the global properties such as NS mass and radius, or its effect on unstable oscillation modes such as rotational r-modes. In a recent publication (Journal of Cosmology and Astroparticle Physics 12, 2023, 008), **Debarati Chatterjee** along with her Ph.D. students **Swarnim Shirke and Suprovo Ghosh** and collaborators from J.W. Goethe University of Frankfurt, Germany, performed the first systematic investigation of the effects of the presence of dark matter on r-mode oscillations in NSs. Using a self-interacting DM model based on the neutron decay anomaly, they imposed constraints on the DM self-interaction strength and DM fraction using recent NS multi-messenger astrophysical observations, which was then used to calculate shear and bulk viscosity. The study concluded that DM shear and bulk viscosity may significantly modify the r-mode instability window compared to normal matter, depending on the thermal behaviour of the dark decay. The study also found that for compatibility with the X-ray and pulsar observational data, the rate for the dark decay process must be fast enough. With the increasing sensitivity of the current GW detectors (A+) or with the next-generation GW detectors such as Einstein Telescope (ET), Cosmic Explorer (CE), and the Neutron Star Extreme Matter Observatory, the NS stellar oscillation modes could be detectable, which will provide an excellent opportunity to investigate the complex interiors of NSs. In a recent work (The Astrophysical Journal, 956, 2023, 38), **Debarati Chatterjee** along with her Ph.D. student **Bikram K. Pradhan** and postdoctoral fellow **Dhruv Pathak**, demonstrated within a Bayesian formalism how future f-mode observations can be used to constrain the nuclear parameters and the NS interior composition. They used inverse NS asteroseismology, the idea of NS asteroseismology in which NS global properties are inferred from the observation of mode characteristics using universal relations independent of the NS composition. The study showed that, considering multiple glitch observations, it is possible to constrain all the nuclear parameters to high precision both in A+ and ET configurations. This study was also extended to binary NS (BNS) systems, in collaboration with IUCAA PhD student **Tathagata Ghosh** (arXiv:2311.16561 (2023), accepted in the Astrophysical Journal).Recent investigations showed that the ignorance of higher-order f-mode dynamical tidal corrections in the gravitational waveform model in BNS systems can lead to substantial bias in the inference of NS properties and composition. In this work, the bias in the nuclear parameters resulting from the ignorance of dynamical tidal correction was investigated. This

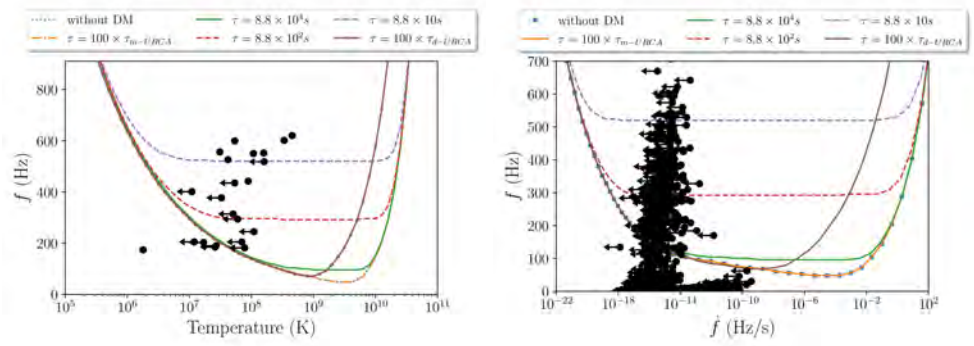


Figure 10: R-mode instability window in (i) the frequency-temperature plane along with the X-ray data (left panel) and (ii) in the frequency-frequency derivative plane (right panel) along with the pulsar timing data from the ATNF catalogue for different scenarios (marked by the different lines) of the dark decay process for a canonical NS.

work also demonstrated the sensitivity of f-modes in BNS systems to nuclear parameters and the estimated constraints on their values using future GW observations.

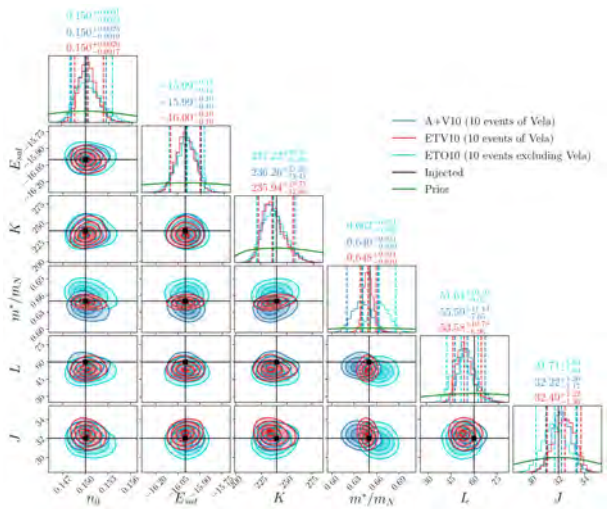


Figure 11: Joint posterior distributions of nuclear parameters (top panel) and 90% credible intervals for NS EoS and mass-radius relation (bottom panels) reconstructed using the parameters constrained for future detections in A+ and ET configurations with multiple events

Accelerated binary black holes in globular clusters: forecasts and detectability in the era of space-based gravitational-wave detectors

The motion of the center of mass of a coalescing binary black hole (BBH) in a gravitational potential imprints a line-of-sight acceleration (LOSA) onto the emitted gravitational wave (GW) signal. The acceleration could be sufficiently large in dense stellar environments, such as globular clusters (GCs), to be detectable with next-generation space-based detectors. In this work, **Shasvath Kapadia** and Collaborators use outputs of the cluster monte carlo (cmc) simulations of dense star clusters to forecast the distribution of detectable LOSAs in DECi-hertz Interferometer Gravitational wave Observatory (DECIGO) and Laser Interferometer Space Antenna (LISA) eras. They study the effect of cluster properties — metallicity, virial and galactocentric radii — on the distribution of detectable accelerations, account for cosmologically-motivated distributions of cluster formation times, masses, and metallicities, and also incorporate the delay time between the formation of BBHs and their merger in our analysis. They find that larger metallicities provide a larger fraction of detectable accelerations by virtue of a greater abundance of relatively lighter BBHs, which allow a higher number of GW cycles in the detectable frequency band. Conversely, smaller metallicities result in fewer detections, most of which come from relatively more massive BBHs with fewer cycles but larger LOSAs. They similarly find correlations between the virial radii of the clusters and the fractions of detectable accelerations. Their work, therefore, provides an important science case for space-based GW detectors in the context of probing GC properties via the detec-

tion of LOSAs of merging BBHs.

Constraining the abundance of Galactic compact objects with continuous gravitational waves

Galactic, spinning compact objects (COs) with non-zero ellipticity are expected to be sources of continuous gravitational waves (CGWs). Certain classes of hypothetical COs, such as neutron stars with quark cores (hybrid stars), and quark stars, are thought to be capable of sustaining large ellipticities from theoretical considerations. Such exotic COs (eCOs) with large ellipticities should produce CGWs detectable by the current LIGO-Virgo-Kagra GW detector network. Since no detections for CGWs, from searches in LIGO-Virgo data, have so far been reported, we place constraints on the abundance of highly elliptical eCOs in our Galaxy. We formulate a Bayesian framework to place upper limits on the number count N_{tot} of highly deformed Galactic eCOs. We divide our constraints into two classes: an "agnostic" set of upper limits on N_{tot} evaluated on a CGW frequency and ellipticity grid that depend only on the choice of spatial distribution of COs; and a model-dependent set that additionally assumes prior information on the distribution of frequencies. We find that COs with ellipticities $\epsilon \gtrsim 10^{-5}$ have abundance upper limits, at 90% confidence, of $N_{tot}^{90\%} \lesssim 100$, and those with $\epsilon \gtrsim 10^{-6}$ have $N_{tot}^{90\%} \lesssim 10^4$. We additionally place upper-limits on the ellipticity of Galactic COs informed by our choices of spatial distributions, given different abundances N_{tot}.

SLICK: Strong Lensing Identification of Candidates Kindred in gravitational wave data

By the end of the next decade, we hope to have detected strongly lensed gravitational waves by galaxies or clusters. Although there exist optimal methods for identifying a lensed signal, it has been shown that machine learning (ML) algorithms are orders of magnitude faster than non-ML methods, while giving comparable performance. **Sourabh Magare and Anupreeta More** present the SLICK pipeline which comprises a parallel network based on deep learning. They analyse the Q-transform maps (QT maps) and the Sine-Gaussian maps (SGP maps) generated for the binary black hole signals injected in Gaussian as well as real noise. They compare their network performance with the previous work and find that the efficiency of their model is higher by a factor of 5 at a false positive rate of 0.001. Further, they show that including SGP maps with QT maps data results in a better performance than analysing QT maps alone. When combined with sky localisation constraints, they hope to get unprecedented accuracy in the predictions than previously possible. They also evaluate their model on the real events detected by the LIGO–Virgo collaboration and find that their network correctly classifies all of them, consistent with non-detection of lensing.

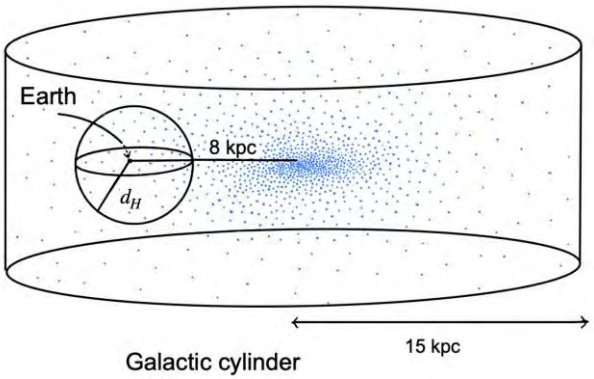


Figure 12: Illustration of the mean number of Galactic compact objects that lie within the horizon sphere with radius $r = d_H(\epsilon, f_{GW})$, where $\epsilon and f_{GW}$ are, respectively, the ellipticity and the gravitational-wave frequency of the spinning compact object. This number is proportional to the probability volume of the 3D spatial distribution that lies within this sphere.

Identifying noise transients in gravitational-wave data arising from nonlinear couplings

Noise in various interferometer systems can sometimes couple non-linearly to create excess noise in the gravitational wave (GW) strain data. Third-order statistics, such as bicoherence and biphase, can identify these couplings and help discriminate those occurrences from astrophysical GW signals. However, conventional analysis can yield large bicoherence values even when no phase-coupling is present, thereby, resulting in false identifications. Introducing artificial phase randomization in computing the bicoherence reduces such occurrences with negligible impact on its effectiveness for detecting true phase-coupled disturbances. **Anupreeta More, Sukanta Bose** and collaborators demonstrate this property with simulated disturbances in this work. Statistical hypothesis testing is used for distinguishing phase-coupled disturbances from non-phase coupled ones when employing the phase-randomized bicoherence. They also

obtain an expression for the bicoherence value that minimizes the sum of the probabilities of false positives and false negatives. This can be chosen as a threshold for shortlisting bicoherence triggers for further scrutiny for the presence of non-linear coupling. Finally, the utility of the phase-randomized bicoherence analysis in GW time-series data is demonstrated for different scenarios.

Exploring the Impact of Microlensing on Gravitational Wave Signals: Biases, Population Characteristics, and Prospects for Detection

In this study, **Anuj Mishra, Anupreeta More, Sukanta Bose** and collaborators investigate the impact of microlensing on gravitational wave (GW) signals in the LIGO−Virgo sensitivity band. Microlensing caused by an isolated point lens, with (redshifted) mass ranging from $M_{\rm Lz} \in (1,\ 10^5)$ $M_\odot$ and impact parameter $y \in (0.01,\ 5)$, can result in a maximum mismatch of $\sim 30\%$ with their unlensed counterparts. When $y < 1$, it strongly anti-correlates with the luminosity distance enhancing the detection horizon and signal-to-noise ratio (SNR). Biases in inferred source parameters are assessed, with in-plane spin components being the most affected intrinsic parameters. The luminosity distance is often underestimated, while sky-localisation and trigger times are mostly well-recovered. Study of a population of microlensed signals due to an isolated point lens primarily reveals: (i) using unlensed templates during the search causes fractional loss (20% to 30%) of potentially identifiable microlensed signals; (ii) the observed distribution of y challenges the notion of its high improbability at low values ($y < 1$), especially for $y < 0.1$; (iii) Bayes factor analysis of the population indicates that certain region in $M_{\rm Lz} - y$ parameter space have a higher probability of being detected and accurately identified as microlensed. Notably, the microlens parameters for the most compelling candidate identified in previous microlensing searches, GW200208_130117, fall within the 1-sigma range of the aforementioned higher probability region. Identifying microlensing signatures from $M_{\rm Lz} < 100$ $M_\odot$ remains challenging due to small microlensing effects at typical SNR values. Additionally, they also examined how microlensing from a population of microlenses influences the detection of strong lensing signatures in pairs of GW events, particularly in the *posterior-overlap* analysis.

A Bayesian Approach to Strong Lens Finding in the Era of Wide-area Surveys

The arrival of the Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST), Euclid-Wide and Roman wide area sensitive surveys will herald a new era in strong lens science in which the number of strong lenses known is expected to rise from $10^3 - 10^5$. However, current lens-finding methods still require time-consuming follow-up visual inspection by strong-lens experts to remove false positives which is only set to increase with these surveys. In this work, **Anupreeta More** and collaborators demonstrate a range of methods to produce calibrated probabilities to help determine the veracity of any given lens candidate. To do this, they use the classifications from citizen science and multiple neural networks for galaxies selected from the Hyper Suprime-Cam (HSC) survey. Our methodology is not restricted to particular classifier types and could be applied to any strong lens classifier which produces quantitative scores. Using these calibrated probabilities, they generate an ensemble classifier, combining citizen science and neural network lens finders. They find such an ensemble can provide improved classification over the individual classifiers. They find a false positive rate of 10ˆ3 can be achieved with a completeness of 46%, compared to 34% for the best individual classifier. Given the large number of galaxy-galaxy strong lenses anticipated in LSST, such improvement will still produce significant numbers of false positives, in which case using calibrated probabilities will be essential for population analysis of large populations of lenses.

Survey of Gravitationally lensed Objects in HSC Imaging (SuGOHI) – X. Strong Lens Finding in The HSC-SSP using Convolutional Neural Networks

Anupreeta More and collaborators apply a novel model based on convolutional neural networks (CNNs) to identify gravitationally-lensed galaxies in multi-band imaging of the Hyper Suprime Cam Subaru Strategic Program (HSC-SSP) Survey. The trained model is applied to a parent sample of 2350061 galaxies selected from the a 800 deg^2 Wide area of the HSC-SSP Public Data Release 2. The galaxies in HSC Wide are selected based on stringent pre-selection criteria, such as multiband magnitudes, stellar mass, star formation rate, extendedness limit, photometric redshift range, etc. Initially, the CNNs provide a total of 20,241 cutouts with a score greater than 0.9, but this number is subsequently reduced

to 1522 cutouts by removing definite non-lenses for further inspection by human eyes. They discover 43 definite and 269 probable lenses, of which 97 are completely new. In addition, out of the 880 potential lenses, they recovered 289 known systems in the literature. They identify 143 candidates from the known systems that had higher confidence in previous searches. Their model can also recover 285 candidate galaxy-scale lenses from the Survey of Gravitationally lensed Objects in HSC Imaging (SuGOHI), where a single foreground galaxy acts as the deflector. Even though group-scale and cluster-scale lens systems were not included in the training, a sample of 32 SuGOHI-c (i.e., group/cluster-scale systems) lens candidates was retrieved. Their discoveries will be useful for ongoing and planned spectroscopic surveys, such as the Subaru Prime Focus Spectrograph project, to measure lens and source redshifts in order to enable detailed lens modelling.

Exploring the hidden Universe: a novel phenomenological approach for recovering arbitrary gravitational-wave millilensing configurations

Since the first detection of gravitational waves in 2015, gravitational-wave astronomy has emerged as a rapidly advancing field that holds great potential for studying the cosmos, from probing the properties of black holes to testing the limits of our current understanding of gravity. One important aspect of gravitational-wave astronomy is the phenomenon of gravitational lensing, where massive intervening objects can bend and magnify gravitational waves, providing a unique way to probe the distribution of matter in the universe, as well as finding applications to fundamental physics, astrophysics, and cosmology. However, current models for gravitational-wave millilensing — a specific form of lensing where small-scale astrophysical objects can split a gravitational wave signal into multiple copies — are often limited to simple isolated lenses, which is not realistic for complex lensing scenarios. In this paper, **Anupreeta More** and her collaborators present a novel phenomenological approach to incorporate millilensing in data analysis in a model-independent fashion. Their approach enables the recovery of arbitrary lens configurations without the need for extensive computational lens modeling, making it a more accurate and computationally-efficient tool for studying the distribution of matter in the universe using gravitational-wave signals. When gravitational-wave lensing observations become possible, their method can provide a powerful tool for studying complex lens configurations, including dark matter subhalos and MACHOs.

Follow-up analyses to the O3 LIGO-Virgo-KAGRA lensing searches

Along their path from source to observer, gravitational waves may be gravitationally lensed by massive objects. This results in distortions of the observed signal which can be used to extract new information about fundamental physics, astrophysics, and cosmology. Searches for these distortions amongst the observed signals from the current detector network have already been carried out, though there have as yet been no confident detections. However, predictions of the observation rate of lensing suggest detection in the future is a realistic possibility. Therefore, preparations need to be made to thoroughly investigate the candidate lensed signals. In this work, **Anupreeta More, Anuj Mishra** and collaborators present some of the follow-up analyses and strategies that could be applied to assess the significance of such events. They also ascertain what information may be extracted about the lens-source system from such candidate signals by applying them to a number of O3 candidate events, even if these signals did not yield a high significance for any of the lensing hypotheses. For strongly-lensed candidates, they verify their significance using a background of simulated unlensed events and statistics computed from lensing catalogs. They also look for potential electromagnetic counterparts. In addition, they analyse in detail a candidate for a strongly-lensed sub-threshold counterpart that is identified by a new method. For microlensing candidates, they perform model selection using a number of lens models to investigate their ability to determine the mass density profile of the lens and constrain the lens parameters. They also look for millilensing signatures in one of the lensed candidates. Applying these additional analyses does not lead to any additional evidence for lensing, in the candidates that have been examined. However, it does provide important insight into potential avenues to deal with high-significance candidates in future observations.

Gear Up for the Action Replay: Leveraging Lensing for Enhanced Gravitational-wave Early Warning

Pre-merger gravitational-wave (GW) sky-localisation of binary neutron star (BNS) and neutron star black hole (NSBH) coalescence events, would enable telescopes to capture precursors and electromagnetic

(EM) emissions around the time of the merger. **Sourabh Magare, Shasvath Kapadia and Anupreeta More** propose a novel astrophysical scenario that could provide early-warning times of hours to days before coalescence with sub-arcsecond localisation, provided that these events are gravitationally lensed. The key idea is that if the BNS/NSBH is lensed, then so must the host galaxy identified via the EM counterpart. From the angular separation of the lensed host galaxy images, as well as its redshift and the (foreground) lens redshift, they demonstrate that they can predict the time delays, assuming a standard lens model. Encouraged by the non-trivial upper limits on the detection rates of lensed BNS/NSBH mergers that they estimate for upcoming observing runs of the LIGO-Virgo-Kagra and third-generation networks, they assess the feasibility and benefits of their method. To that end, they study the effect of the limited angular resolution of the telescopes on the ability to predict time delays. They find that with an angular resolution of 0.05 arcsec, they can predict time delays of > 1 day, with 1σ error-bar of order of hours at best. They also construct realistic time delay distributions of detectable lensed BNSs/NSBHs to forecast the early-warning times they might expect in the observing scenarios they consider.

High Energy Astrophysics

A multi-wavelength study of a blackhole X-ray binary

In "A multi-wavelength study of the hard and soft states of MAXI J1820+070 during its 2018 outburst", **Srimanta Banerjee & G. C. Dewangan** along with their collaborators performed comprehensive analysis of the 2018 outburst of MAXI J1820+070 using AstroSat's far UV, soft and hard X-ray data alongside quasi-simultaneous observations from Las Cumbres Observatory (optical) and NICER (soft X-ray). They found that, in the hard state, the accretion disk recedes significantly from the black hole, making way for a structured corona comprising two distinct components with unique physical properties. Conversely, during the soft state, the disk moves closer to the black hole, while the coronal emission diminishes. Notably, the study reveals a perplexing emission component in the soft state, identified as residual emission cascading into the black hole. They also employed advanced techniques to measure the black hole's spin, one of its two fundamental properties (alongside mass), revealing the black hole to be moderately to highly spinning. Their study also revealed a captivating connection between the X-ray emission from the inner regions near the black hole and the optical/UV emission from the outer region of the accretion disk. They found that X-rays undergo substantial reprocessing in the outer accretion disk, representing the primary mechanism for generating optical/UV photons in this system. Importantly, the proportion of reprocessed radiation is notably higher in the hard state, suggesting the existence of a warped or convex outer disk during this phase.

Studying the accretion disc emission in Seyferts using UV and X-rays

Shrabani Kumar and G. C. Dewangan, along with their collaborators, utilised UVIT Grating data and X-ray spectral data from SXT, LAXPC and CZTI from AstroSat observations of Active Galactic Nuclei. They studied accretion disk emission from eight Seyfert-type Active Galactic Nuclei (AGN) using far-ultraviolet (FUV; 1300-1800 Å...) slit-less grating spectra acquired with the AstroSat/UVIT. They corrected for the Galactic and intrinsic extinction, contamination from the host galaxies, narrow and broad-line regions, Fe II emission, and Balmer continuum, and derived the intrinsic continua. They also used Hubble Space Telescope COS/FOS spectra to account for the emission/absorption lines in the low-resolution UVIT spectra. They found generally a redder power-law in the FUV band than predicted by the standard accretion disk model in the optical/UV band. They fitted accretion disk models such as the multi-temperature disk blackbody (DISKBB) and relativistic disk (ZKERRBB, OPTXAGNF) to the observed intrinsic continuum emission. They measured the inner disk temperatures using the DISKBB model for seven AGN. These temperatures in the range $\sim 3.6 - 5.8$ eV are lower than the peak temperatures predicted for standard disks around maximally spinning supermassive black holes accreting at Eddington rates. The inner disks in two AGN, NGC 7469, and Mrk 352, appear truncated at $\sim 35 - 125$ and $\sim 50 - 135$ gravitational radii, respectively.

Connections between the UV and X-ray variability of an AGN NGC 4051

Kavita Kumari, G. C. Dewangan and their collaborators studied the connection between the variations in the far-ultraviolet (FUV), near-ultraviolet (NUV), and X-ray band emission from NGC 4051, using 4-day-long AstroSat observations performed during 5–9 June 2016. NGC4051 showed rapid variability in all three bands with the strongest variability am-

plitude in the X-ray band ($F_{var} \sim 37\%$) and much weaker variability in the UV bands ($F_{var} \sim 3-5\%$). Cross-correlation analysis performed using interpolated cross-correlation functions and discrete cross-correlation functions revealed a robust correlation (~ 0.75) between the UV and the X-ray light curves. The variations in the X-ray band lead those in the FUV and NUV bands by ∼7.4 ks and ∼24.2 ks, respectively. The UV lags favour the thermal disc reprocessing model. The FUV and NUV bands are strongly correlated and the variations in the FUV band lead those in the NUV band by ∼13 ks. Comparison of the UV lags found using the AstroSat observations with those reported earlier and the theoretical model for thermal reverberation time-lag suggested a possible change in either the geometry of the accretion disc/corona or the height of the corona.

X-ray polarisation studies of Cygnus X-1

Cygnus X-1, the well-known accreting black hole system, exhibits several observational features hinting at an intricate interplay between the accretion disk, its atmosphere known as the corona, and the putative relativistic jet. It has been extensively studied using all available observational methods, including the newly available technique of sensitive X-ray polarimetry. X-ray polarization characteristics are distinct for coronal and jet emissions. The low X-ray polarization measured below ∼100 keV is understood as arising from the corona. In contrast, the high polarization measurements reported above ∼400 keV required a separate jet-dominated spectral component, which spectroscopy does not demonstrate conclusively. The AstroSat CZTI team, including **G. C. Dewangan**, reported precise polarization measurements in the $100-380$ keV range made during three different subclasses of spectral states of the source using the CZTI instrument onboard AstroSat. A high polarization ($23 \pm 4\%$) is found mainly in the intermediate hard state of the source, and the energy-resolved measurements smoothly connect the coronal and the jet regimes. When high polarization is observed, the simultaneous spectral data hints at a separate power-law component above 100 keV. We examine the possible sources of this energy-dependent high polarization in Cygnus X-1.

Spectral and timing characteristics of 1A 1744-361

Aditya S. Mondal and Biplab Raychaudhuri, in collaboration with **G. C. Dewangan**, studied the spectral and timing characteristics of the accreting neutron star 1A 1744-361 using the Nuclear Spectroscopic Telescope Array observations, performed during its 2022 outbursts. They found that the source was in the banana branch of the atoll track. The source spectrum exhibited relativistic disc reflection and clear absorption features while an absorbed blackbody and cut-off power-law model described the continuum emission well. With detailed spectral modelling, they found the inner-disc radius, Rin, to be in the range of $8.4-14.9$ gravitational radii or $17.6-31.2$ km for a $1.4\,M_{\odot}$ NS). This measurement allowed them to further constrain the magnetic field strength to $B \lesssim 0.94 \times 10^9$ Gauss. They also found strong absorption features at ~ 6.91 keV and ~ 7.99 keV due to highly ionized absorbing material, with a column density $N_H \sim 3 \times 10^{22}$ cm^{-2}. These features emanate from the accretion disc in the form of disc wind with an outflow velocity of about $0.021c \simeq 6300$ km s^{-1}.

Very High-energy (>50 GeV) Gamma-Ray Flux Variability of Bright Fermi Blazars

Understanding the high-energy emission processes and variability patterns are two of the most challenging research problems associated with relativistic jets. In particular, the long-term (months to years) flux variability at very high energies (VHE; >50 GeV) has remained an unexplored domain so far. **Vaidehi S. Paliya** has recently conducted the most comprehensive search using the gamma-ray data provided by the Fermi Large Area Telescope that has led to, for the first time, the detection of significant VHE flux variations in five blazars at the >99% confidence level, whereas eight of them exhibit variability, albeit at a lower confidence level (∼95%–99%). These results open up a new dimension to unravel the VHE emission processes operating in relativistic jets, hence sowing the seeds for their future observations with the upcoming Cherenkov Telescope Array.

Leptohadronic multi-messenger modeling of 324 gamma-ray blazars

The origin of the diffuse astrophysical neutrino flux observed by the IceCube experiment is still under debate. Multiple associations have been reported between high-energy neutrino events and individual blazars. From a theoretical perspective, the properties of these sources as neutrino emitters are not yet well understood. Xavier Rodrigues, **Vaidehi S. Paliya**, and collaborators have recently used a self-consistent numerical radiation model applied to a large sample of gamma-ray-detected blazars and

estimated the diffuse neutrino flux from gamma-ray blazars by extrapolating the result to the blazar population. They showed that it may be at the level of ∼20% of the diffuse neutrino flux observed by IceCube, which is in agreement with current limits from stacking analyses.

Constraints on redshifts of blazars from extragalactic background light attenuation using Fermi-LAT data:

Distance measurements are of fundamental importance, yet for BL Lacartae objects, they are challenging because the non-thermal emission from the jet may outshine any spectral signature from the host galaxy. Alberto Dominguez, Maria Lainez, **Vaidehi S. Paliya**, and collaborators recently published a method to constrain redshifts for these sources that rely only on data from the Large Area Telescope on board the Fermi Gamma-ray Space Telescope. This method takes advantage of the signatures that the pair-production interaction, between photons with energies larger than approximately 10 GeV and the extragalactic background light, leaves on gamma-ray spectra. Stringent upper limits were obtained for the distances of 303 γ-ray blazars, classified as 157 BL Lacertae objects, 145 of uncertain class, and 1 flat-spectrum-radio quasar, whose redshifts are otherwise unknown. These results are also applied to estimate the detectability of these blazars with the future Cherenkov Telescope Array, finding that at least 21 of them could be studied in a reasonable exposure of 20 hours.

A new derivation of the Hubble constant from γ-ray attenuation using improved optical depths for the Fermi and CTA era:

Alberto Dominguez and collaborators, including **Vaidehi S. Paliya**, published γ-ray optical-depth calculations from an extragalactic background light (EBL) model built from multiwavelength galaxy data from the Hubble Space Telescope Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey (HST/CANDELS). From these newly calculated optical depths, the team derived the cosmic γ-ray horizon and measured the Universe's expansion rate and matter content.

Quantum Technologies

Precision & Quantum Measurement laboratory (PQM-lab: https://pqmlab.iucaa.in/)

Present team members – **Venu Jangam** (UG student), **M Gautham Upadhyaya** (PG student), **Sankalpa Banerjee** (doctoral student), **Arinjit Mondal** (research fellow), **Stanley Johnson** (research associate), **Sujaya Das Gupta** (research associate), **Sankar Majhi** (scientific officer) and **Subhadeep De** (project investigator)

Research

The Precision & Quantum Measurement Laboratory (PQM-lab) is developing an optical atomic clock based on the highly forbidden octupole transition of Ytterbium-ion ion (171Yb+) at a 467 nm wavelength. This particular clock transition has the highest sensitivity for the measurement of the temporal constancy of the fine structure constant and possible violations of Lorentz symmetry. The entire experimental setup includes a range of sophisticated technologies like ion trapping, generation of narrow linewidth ultra-stable lasers, optical frequency synthesis, and phase-preserved dissemination of reference photons; therefore, it involves sophisticated instrumentation, most of which needs to be engineered in-house. Here, we are describing some such instruments which we developed in the last year and will be used in our optical clock experiment.

A) Fiber stabilized laser:

We have developed a novel technique for stabilization of the laser frequencies that uses a standalone spool of optical fiber providing the reference analogous to the Fabry-Perot cavity. This setup is easy to set up and cost-effective. For this, a commercially available laser having a few kHz of linewidth and a 22 km long optical fiber spool as a reference are used. As shown in(Figure: 13) (a), the acousto-optic modulator (AOM1) is used to correct for the laser frequency noise. The Faraday mirror (FM1) provides a carrier signal for interference with the light making the round-trip through the fiber spool, AOM2, and FM2. This interference signal is captured by photodiode (PD1) and sent to the field-programmable gate array (FPGA) for signal processing. The FPGA generates and applies a suitable frequency correction factor to the AOM1. The beat signal between the

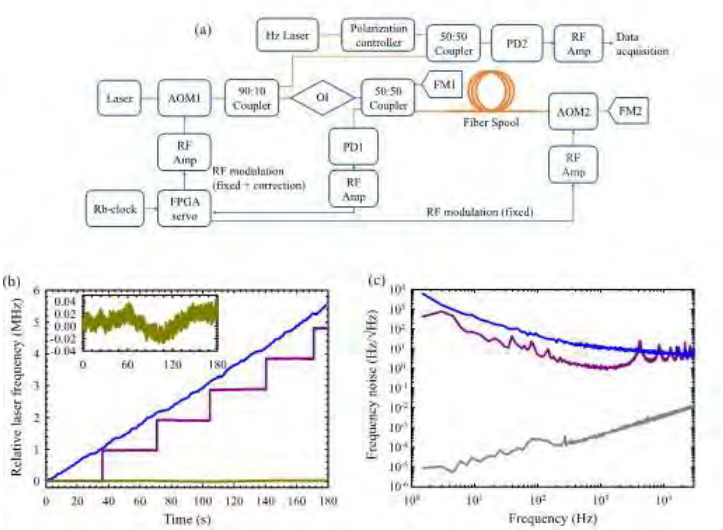


Figure 13: (a) Experimental setup for the fiber stabilized laser, OI - optical isolator, AOM1 and 2 - acousto-optic modulators, FM1 and 2 - Faraday mirrors, PD1 and 2 - Photodiodes, RF Amp - RF amplifier, Hz laser - Hz-linewidth laser. (b) Laser frequency relative to the Hz linewidth laser - purple: fiber stabilized laser servo active; blue: fiber stabilized laser servo inactive; dark yellow: data synthesized by removing frequency steps from the purple trace, the inset shows this synthesized data in greater detail with the inset axes units staying the same as the main figure, (c) Laser frequency noise spectrum - purple: fiber stabilized laser servo active; blue: fiber stabilized laser servo inactive; gray: instrument noise floor.

corrected laser and the in-house available ultra-stable Hz-linewidth laser incident on PD2 is recorded on a frequency counter. (Figure: 13)(b) shows this time-domain frequency noise for 180 s. When the servo is inactive, the laser drifts linearly (blue curve), while when the servo is active, the laser drift is suppressed to give nearly flat segments (purple curve) until the frequency correction limit of the AOM1 is reached (the AOM has a bandwidth of around ±1 MHz). The frequency correction limit of the AOM1 is the reason for the 1 MHz frequency steps seen when the servo is active (purple curve). The beat signal at PD2 is also recorded for 2 seconds on an oscilloscope. This recorded data is processed to extract the frequency noise spectrum of the corrected laser light, depicted in Fig. 1 (c). Here, we see that when the servo is active (purple curve), the laser noise is generally reduced compared to when the servo is inactive (blue curve). The free-running laser linewidth of 1.37 kHz can be reduced to 89 Hz when the servo is active for 10 ms integration time; here, the beta separation method is used for laser linewidth estimation. The linewidth reduction is less effective at larger integration times due to residual low-frequency fiber noise.

B) Atomic clock stabilized multi-channel RF source:

The accurate generation and distribution of stable radio-frequency signals has always been in high demand for various applications such as precision frequency and phase meteorology, quantum information processing, qubit control, and quantum communication. We demonstrated a highly stable dual-channel digitally controlled oscillator (DCO) integrated with direct digital synthesis (DDS) technology, referenced externally to a rubidium atomic clock, as shown in (Figure: 14). This system offers low noise, accurate, sub-Hz frequency resolution signal generation across a broad frequency spectrum (1 MHz to 300 MHz), with stability of 10-11 at 1s and a noise floor ¡ -140 dBc. Each channel of the DCO exhibits a maximum frequency deviation of 8 µHz and an inter-channel frequency drift of 1.3 mHz from the mean at a carrier frequency of 10 MHz, indicating precise frequency control. The maximum phase deviation between channels is observed to be 3 milli-radians. Additionally, it exhibits excellent noise performance with a Spurious Free Dynamic Range (SFDR) exceeding -40 dBc and a noise floor below -140 dBc. Such exceptional stability and low noise characteristics are crucial for maintain-

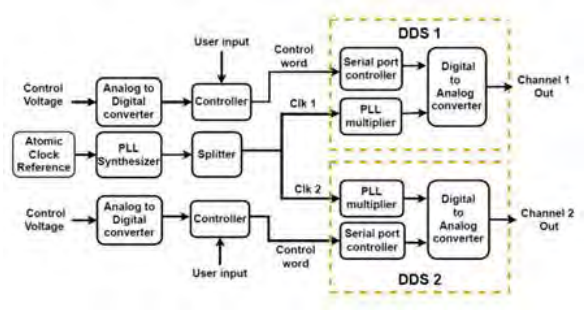


Figure 14: Block diagram of the digitally controlled oscillator (DCO)

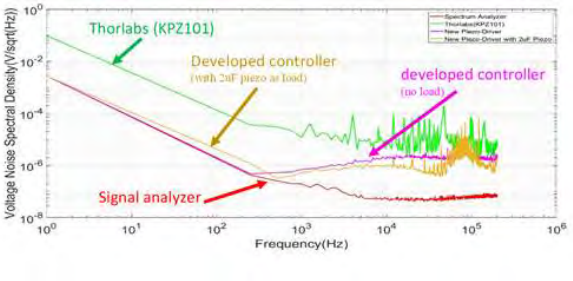


Figure 15: Reported stabilities of FP cavities around the world at room temperature (red), cryogenic (blue) and present simulation with dielectric and crystalline mirrors (green and magenta respectively).

ing shot-to-shot redundancy in time-sequenced experiments, ensuring reliable and accurate results. Our system utilizes a Raspberry Pi 4 board as the controller, connected to the DDS block via a Serial Peripheral Interface port (clocked with a 31 MHz source) for the frequency (via a 48-bit tuning word), phase (via a 14-bit tuning word), and amplitude control of the generated output RF waveform. To simplify its operation and enable remote control, our system features a user-friendly graphical interface developed in-house.

Piezo driver for diode laser frequency tuning

A piezo driver controls the mechanical displacement of piezoelectric actuators by tuning the applied voltage on them. Piezo controllers find applications in a diverse range of fields like frequency tuning of extended cavity diode lasers, interferometers, laser beam steering, optics alignment, etc., where precision and controlled positioning are crucial. We have developed a low-cost piezo controller, tested, characterized, and benchmarked its performance. The developed hardware has mainly three subsections: (i) high voltage amplifier section, (ii) bias control section, and (iii) scan generator section. The heart of the circuit is the high voltage amplifier section, which defines the bandwidth of the controller. The performance of the controller in terms of bandwidth, noise floor, bias stability, etc., is better than some of the commercially available controllers (such as Thorlabs MDT694B, KPZ101). The small signal bandwidth is approximately 500 kHz at no load and 3 kHz with a 2 uF piezo as the load. The maximum power bandwidth of the controller is approximately 35 kHz (calculated using the slew rate of the amplifier, the maximum operating frequency of the scan, and the maximum peak-to-peak scan voltage). The system's noise floor of the controller is measured using a Tektronix real-time signal analyzer as shown in Fig. 3. The voltage noise power spectral density (PSD) at 1 kHz is is $610^{-7}\ \nu/\sqrt{Hz}$ (without load) and $410^{-7}\ \nu/\sqrt{Hz}$ (with the piezo as the load). The voltage noise PSD with the piezo is lower due to the capacitive effect of the piezo. The bias voltage stability of the controller is around 2 mV recorded over a 3-day period measured using a Keysight 6.5-digit DMM. The added scan generator can generate triangle, sawtooth, square, and sinusoidal signals of a frequency range from 0.01 Hz to 30 kHz. Precision, ultra-low noise, highly stable electronic components are used to develop the controller, which will be used for controlling our home-made ECDL laser systems.

Solar and Stellar Physics

Research in Solar Astrophysics

Accurate measurement of plasma parameters in various structures is one of the prime goals for understanding the heating and dynamics of the solar corona. The plasma parameters are temperature, densities, and thermal & non-thermal velocities. Sharma and **Durgesh Tripathi** have performed measurements of the variation of temperature and non-thermal velocity with height, in fan loops (Figure 16), by using observations recorded by the Extreme Ultraviolet Imaging Spectrometer (EIS) onboard Hinode. They employed the emission measure (EM)-loci method to estimate the temperature profiles of different coronal fan loops and then used the obtained temperatures at different locations along the fan loops to estimate the thermal width of the spectral lines and thereby derive the non-thermal velocities. The non-

thermal velocities are obtained in Si VII 275.35 Å and Fe VIII 185.21 Å lines to which the fan loops are most sensitive. The EM-loci analysis provides nearly isothermal temperature along the fan loops (Figure 17). They obtained the peak temperatures in the range $\log T(\mathrm{K}) = 5.85$–$5.95$ for fan loops, and the subtraction of thermal broadening gives the non-thermal velocities in the range $\approx$ 5–15 and $\approx$ 11–29 km/s for Si VII 275.35 Å and Fe VIII 185.21 Å, respectively (Figure 18). Their method provides quantitative accuracy in the measurement of non-thermal velocity, which is an important parameter in understanding the dynamics of heating of the solar atmosphere.

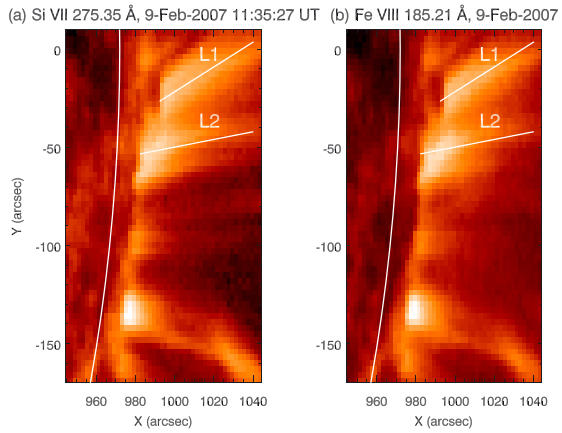


Figure 16: Intensity map obtained for Si VII 275.35 Å (left panel) and Fe VIII 185.21 Å (right panel). The two loops studied here are marked as L1 and L2.

High-precision distances to nearby dwarf spheroidal galaxies

Dwarf galaxies are the most numerous galaxy types in the Universe and among the best astrophysical laboratories to study the structure of dark matter halos and the nature of dark matter. Dwarf spheroidal galaxies are low-luminosity, low-mass early-type dwarf galaxies that host dominant old and intermediate-age stellar populations including a large fraction of variable stars. The nearby dwarf spheroidal galaxies are the most interesting because we can probe the kinematics and chemical abundances of their individual stars up to the faint main sequence evolutionary phases. The analysis of internal stellar kinematics can be used to infer the amount of dark matter in these dwarf spheroidal galaxies. Draco dwarf spheroidal galaxy is one of the nearest and the most dark matter dominated satellites of our Milky Way galaxy. In collaboration with an international team of astronomers, IUCAA faculty **Dr. Anupam Bhardwaj** used 4-m class Canada-France-Hawaii Telescope to monitor stellar variability in Draco for the first time at near-infrared wavelengths. This study obtained homogeneous light curves of more than 200 RR Lyrae variable stars, which are excellent distance indicators at infrared wavelengths. High-precision photometric data provided luminosity-metallicity distributions of RR Lyrae stars in Draco, and resulted in the most precise (1.5% uncertainty) distance to the Draco dwarf spheroidal. This study was done within the Stellar VAriability and Distance Indicators in the Near-infrared (SVADhIN) project. The SVADhin project is targeting several nearby dwarf spheroidal galaxies to determine their high-precision distance, which is a fundamental ingredient for modelling dynamical history, formation and evolution, and constraining the dark matter content of these stellar systems.

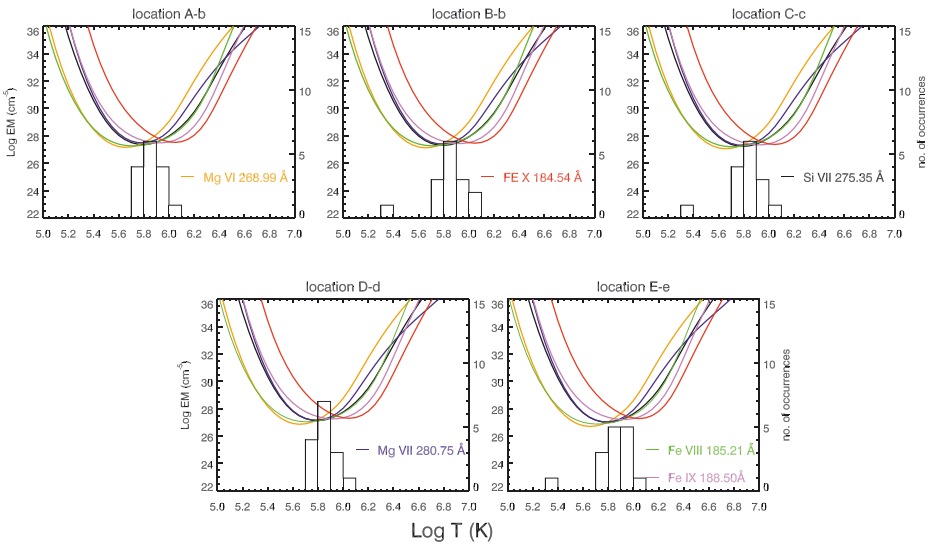


Figure 17: EM-loci plots using different line as labelled for various locations along the loop L1. Each panels show the histograms of the number of crossings.

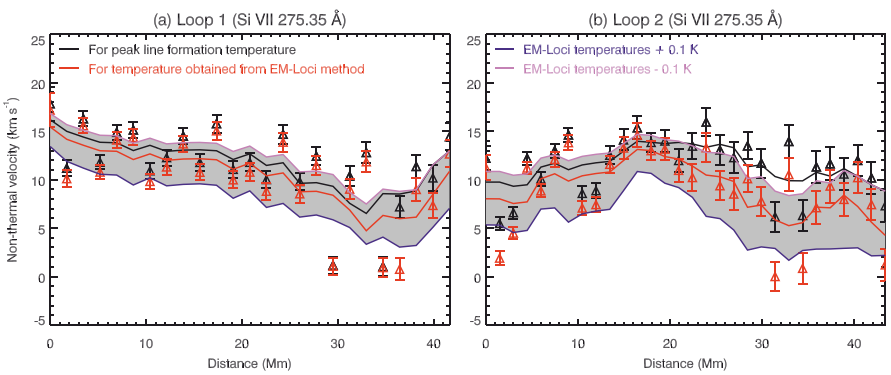


Figure 18: Variation of the non-thermal velocities in Si VII 275.35 Å line obtained using peak formation temperature (black) and the temperature obtained using that obtained using EM-loci analysis for loops L1 (Left panel) and L2 (right panel).

PEDAGOGICAL

(a) IUCAA-NCRA GRADUATE SCHOOL

Debarati Chatterjee:

Quantum and Statistical Mechanics I (August 07 - October 06, 2023)

Rajeshwari Dutta:

Interstellar Medium (March 11 - May 10, 2024)

Surhud More:

Extragalactic Astronomy I (January 02 - March 01, 2024)

Aseem Paranjape/ Subhadeep De:

Research Methods and Statistical Techniques (January 02 - March 01, 2024)

Aseem Paranjape:

Quantum and Statistical Mechanics II (October 16 - December 15, 2023)

A.N. Ramaprakash:

Astronomical Techniques - I (March 11 - May 10, 2024)

Kanak Saha:

Introduction to Astronomy and Astrophysics (August 07 - October 06, 2023)

Nishant Singh:

Electrodynamics and Radiative Processes I (August 07 - October 06, 2023)

T. P. Singh:

Methods of Mathematical Physics II (October 16 - December 15, 2023)

Durgesh Tripathi:

Introduction to Astronomy and Astrophysics II (October 16 - December 15, 2023)

(b) SPPU-IUCAA JOINT M.Sc. (PHYSICS WITH ASTROPHYSICS) PROGRAMME and The DEPARTMENT OF PHYSICS, SPACE SCIENCES, SPPU, M.Sc. (ASTRO) Lectures

Gulab C. Dewangan:

High-Energy Astrophysics (January – May 2024)

Neeraj Gupta/Sowgat Muzahid:

Astronomical Techniques (July - December 2023)

Neeraj Gupta/Sowgat Muzahid:

Astrophysics Laboratory I (July - December 2023)

Shasvath Kapadia:

General Relativity and Cosmology (January – May 2024)

Sanjit Mitra:

Relativistic Electrodynamics and Radiation Processes (July - Nov 2023)

Dipanjan Mukherjee:

Astrophysical Dynamics (January – May 2024)

Sowgat Muzahid:

Astrolab-II (January – May 2024)

Vaidehi Paliya:

Introduction to Astronomy and Astrophysics I and II (July - December 2023)

(c) B.Sc. INTERDISCIPLINARY SCHOOL OF SCIENCE (IDSS) Savitribai Phule Pune University (SPPU)

D. J. Saikia

Introductory Astronomy and Astrophysics (12 lectures) (April 2023)

(d) SUPERVISION OF Ph. D. THESES (IUCAA)

(Degrees Awarded)

Sanjit Mitra

Title: *Algorithms for Gravitational Wave Data Analysis and Detector Controls Based on Modern Techniques.*

Student: Sreejith Jadhav

Title**:** *Radiometer Searches for Persistent Sources of Gravitational Waves using Ground-based Detectors*

Student: Deepali Agarwal

Surhud More

Title: *Probing cosmology using large scale structure correlations*

Student: Divya Rana

Aseem Paranjape

Title: *Exploring the nature of dark matter using astrophysical and cosmological probes.*

Student: Bhaskar Arya

R. Srianand

Title:*Probing the Nature, Environment, and Evolution of Ultrastrong Mg II Absorption Systems.*

Student: Labanya Kumar Guha

Title: *Probing ultra-fast outflows in BAL quasars using multi-epoch spectroscopy.*

Student: Aromal P.

(e) SUPERVISION OF Ph. D. THESES (IUCAA)

(Ongoing)

Debarati Chatterjee

Title: *Consistent finite temperature models of Neutron Stars for studies of Gravitational Wave emission.*

Student: Nilaksha Barman

Title: *Constraining Neutron Star Equation of State using Multi-disciplinary Physics and its Application in studying various aspects in Gravitational Wave Emission.*

Student: Suprovo Ghosh

Title: *The Implications of Fundamental Physics on Neutron Star Properties and associated Gravitational Wave Emission (tentative).*

Student: Rajesh Maiti

Title: *Study of the effect of Neutron Star composition on fluid oscillation modes and Gravitational Wave emission.*

Student: Bikram K. Pradhan

Title: *Probing exotic matter in Neutron Stars using Multi-Messenger Astronomy.*

Student: Swarnim Shirke

Title: *Role of Bulk Viscosity in Gravitational Wave Emission from Neutron Stars.*

Student: Pranjal Tambe

Gulab C. Dewangan

Title: *AstroSat view of accretion discs in Active Galactic Nuclei.*

Student: Shrabani Kumar

Title: *Accretion disk-corona interplay in Active Galactic Nuclei.*

Student: Kavita Kumari

Title: *Active Galactic Nuclei and bright UV sources in the AstroSat/UVIT fields.*

Student: Piyali Ganguli

Neeraj Gupta

Title:*An unbiased view of cold atomic gas associated with radio loud AGNs.*

Student: Partha P. Deka

Shasvath Kapadia

Title: *Prospects for probing dense stellar environments with gravitational waves emanated by accelerated compact binary coalescences.*

Student: Avinash Tiwari

Title: *Observing lensed and unlensed gravitational-waves with current and future-generation detectors.*

Student: Sourabh Magare

Title: *Astrophysical Inference Using Continuous Gravitational Waves and Gravitational Lensing Of Gravitational Waves.*

Student: Gopalkrishna Prabhu

Title: *Searches for Lensed Gravitational Waves and Overlapping Gravitational Wave Signals.*

Student: Sudhir Gholap

Supervisor of Sajad Bhat, post-doctoral fellow

Sanjit Mitra

Title: *Efficient Searches for Compact Binary Coalescences and Science in the LIGO-India Era.*

Student: Kanchan Soni

Title: *Searches and astrophysical implications of gravitationally lensed gravitational waves.*

Student: Anirban Kopty

Anupreeta More

Title: *Using Gravitational waves from compact binary coalescences to probe gravitational lensing (strong and micro) and the magnetic Penrose processes.*

(co-supervised with Sukanta Bose).

Student: Anuj Mishra

Surhud More

Title: *Gravitational lensing in Galaxy clusters*

Student: Amit Kumar

Title: *Weak gravitational lensing: galaxy-dark matter connection and cosmology*

Student: Navin Chaurasiya (co-supervised with Anupreeta More)

Title: *Gravitational Lensing Probes of Dark Matter*

Student: Priyanka Gawade (co-supervised with Anupreeta More)

Title: *Measuring Cosmological Parameters with Gravitational-Wave Observations*

Student: Tathagata Ghosh

Dipanjan Mukherjee

Title: *Modelling the impact of AGN-driven outflows on the star formation activity in galaxies.*

Student: Ankush Mandal

Title: *Simulating effects of AGN-driven outflows on galactic scales and predicting their observable signatures.*

Student: M. Meenakshi

Title: *Simulations of various aspects of extra-galactic, relativistic jets.*

Student: Prathamesh Ratnaparkhi

Title: *Magnetic fields of Accreting Neutron Stars.*

Student: Saurabh Yeole

Title: *Modelling Time-Dependent Accretion and Outflow for supermassive black holes*

Student: Raghav Gogia

Sowgat Muzahid

Title: *Gaseous atmospheres of high redshift Lyman-alpha emitters.*

Student: Eshita Banerjee

Title: *Probing the CGM of low redshift galaxies*

Student: Sayak Dutta

Aseem Paranjape

Title: *Interplay of galaxy formation and the evolution of dark matter haloes in cosmic web.*

Student: Premvijay Velmani

Title: *Cosmic velocity flows: from theory to observations.*

Student: Saee Dhawalikar

Kanak Saha

Title: *Dark matter in Low-mass Compact galaxies.*

Student: Jyoti Prakash

Title: *Probing the ionizing radia/on of high-redshi3 galaxies using AstroSat.*

Student: Soumil Maulick

Title: *Probing the assembly of galaxies in high-z universe.*

Student: Manish Kataria

Title: *Clump dynamics of Star-forming galaxies at intermediate redshift.*

Student: Pushpak Pandey

Nishant Singh

Title: *Aspects of Turbulent Convection: Implications for Solar Differential Rotation and Small-Scale Dynamos.*

Student: Kishore Gopalakrishnan

Title: *Interaction between Seismic Modes and Magnetic fields in the Solar Atmosphere in presence of Turbulence.*

Student: Rajesh Mondal

R. Srianand

Title: *Exploring the metals in the Intergalactic Medium.*

Student: Sukanya Mallik

Title: *Physics of galaxy formation and evolution at the cosmic dawn.*

Student: Ranit Kumar Behera

(f) SUPERVISION OF Ph. D. THESES (Other than IUCAA)

(Ongoing)

Gulab Dewangan

Student: Pravin Patole (Ph. D. student at SRTM University Nanded, ongoing)

Student: Shammi Kamal (Ph. D. student at Jamia-Millia University New Delhi, started)

Neeraj Gupta

Student: Eric Maina, SARAO, South Africa (co-supervisor, 2019-2024)

Student: Jonah Wagenveld - MPIfR, Germany (mentor, since 2019 - 2024)

Vaidehi Paliya (Co-supervisor)

Title: *Energy-Dependent Flux Variations of Bright Fermi Blazars: Clues to the Radiative Processes*

Student: Naseef Mohammed (faculty at Farook College, Calicut and registered at the University of Calicut for a PhD).

Nishant Singh (Co-supervisor)

Title: *Magnetic fields of disc galaxies.*

Student: Subah Sharma (PhD student from Thapar Institute of Engineering and Technology, Patiala)

(g) SUPERVISION OF PROJECTS

Debarati Chatterjee

- Rajesh Maiti (IUCAA-NCRA Graduate School) *Investigating the model dependence of correlation between nuclear parameters and neutron star properties.*

- Kartav Kesri (BS-MS student, IISER Bhopal) *Study of Compact stars in the Buchdahl limit. (co-supervised with Naresh Dadhich)*

S. V. Dhurandhar

- Devashree Kulkarni (B.Sc. final year project, Fergusson College, Pune) completed her project on Special and General Relativity and Applications. The application of relativity chosen for the project was the *Global Positioning System (GPS)*.
- Gautam Singh and Dalika Joshi (B.Sc. third-year project, Fergusson College, Pune). Both are working on Special and General Relativity and Applications. The application is Shapiro time-delay and gravitational lensing.

Neeraj Gupta

- Shashank Soni (IISER, Pune) January – December 2024
- Trishala Majumdar (SPPU-IUCAA M.Sc.) *Properties of young radio loud AGN in MALS.*
- Soubhik Pramanik (SPPU-IUCAA M.Sc.) *Multiwavelength properties of galaxies in MALS.*

Sanjit Mitra

- Sakshi Kumar (IIT, Kharagpur, M.Tech Project, July 2023 - April 2024)

Anupreeta More

- Arshi Ali (SPPU M. Sc.) *Gravitational Lensing and Precision with GW +EM Lensed Signals.*
- Abhinandan Saha (IISER, Tirupati) *A Search for Quadruply Lensed Quasars from the HSC Survey.*
- Prajakta Mane (IISER, Mohali), *Strategies to identify strongly lensed type Ia supernovae in Rubin LSST* (co-supervised with Surhud More).
- Soorya Narayan (IISER Pune) *Machine learning algorithm to identify gravitational lensing and gravitational wave sources.*
- Alwin Andrews (NIT, Meghalaya) *Effects of lens model systematics on the constraints on H0*
- Siddhant Shrivastava (NSUT, Delhi) *Study of eccentric, precessing and microlensed GW signals with machine learning.*
- Anirban Kopty (IUCAA Graduate student project) *Exploring direct cross-correlation analysis of GW data for identification of lensing candidates.*

Surhud More

- Parmeshwar Dewangan (SPPU-IUCAA M.Sc.) *A search for infalling groups into galaxy clusters.*
- Prajakta Mane (IISER, Mohali) *Strategies to identify strongly lensed type Ia supernovae in Rubin LSST* (co-supervised with Anupreeta More)
- Devesh Yadav (SPPU-IUCAA M.Sc.) *Determining Hubble constant from Gravitational wave data.*

Sowgat Muzahid

- Mrinmoy Karmakar (SPPU-IUCAA M.Sc.*) Survey of emission line galaxies using MUSE.*
- Rajdeep Nandi (SPPU-IUCAA M.Sc.) *Exploring galaxy scaling relations using SDSS and DESI.*
- Subhadip Bhattacharjee (SPPU M.Sc.) *MUSE Survey of Lyman-alpha emitters at high redshifts.*
- Sukanya Mallik (IUCAA PhD student – Project to fulfil the requirement of a 'Topical Course') *Understanding the curious over density of Lyman-alpha absorbers at z = 0.3 towards QSO 3C 57.*

Vaidehi Paliya

- Moumita Pal (SPPU-IUCAA M.Sc.) *Hunting BL Lacertae Objects Among Fermi Blazar Candidates of Uncertain Type.*
- Suptotthita Ghosh (SPPU-IUCAA M.Sc.) *Identifying blazar candidates among gamma-ray sources: a multi-wavelength approach.*
- Srijita Hazra (M.Sc. Physics, St. Xaviers College, Mumbai) *A Broadband Study of the Most Distant Gamma-ray Emitting BL Lacertae Object.*

Aseem Paranjape

- Aryan Singh (SPPU-IUCAA M.Sc.) *Cosmological N-body simulations.*
- Payaswinee Dhoke (M.P. Deo Memorial College, Nagpur) ongoing long-term project on *Excursion set techniques for alternate dark matter models.*

Kanak Saha

- Mayank Sekhar Singh (MS final year thesis (ongoing), IISER, Pune) *UV image processing using Lucy's algorithm*

Dhruba J. Saikia

- Kshitij Chavan (IUCAA) *Double-double radio galaxies* (co-supervised by Pratik Dabhade).
- Rushikesh N. Bhutkar (University of Manitoba, Canada) *Compact Steep Spectrum Radio Sources and Unification Scheme* (co-supervised by Yogesh Chandola).
- Rahul Musale (Kr. V.N. Naik Shikshan Prasarak Sanstha's Arts, Commerce and Science College, Nashik) *Compact Steep Spectrum Radio Sources and Unification Scheme* (co-supervised by Yogesh Chandola).

Nishant Singh

- Abinash Dehuri (SPPU-IUCAA M.Sc.) *Solar f mode using data from Helioseismic and Magnetic Imager onboard SDO*

- Snehil Pandey [Graduate School Project - ongoing]
- Biplab Sarkar [Graduate School Project - ongoing]

T. P. Singh

- Arvinder Singh [IISER, Mohali, Master's Thesis]*An algebraic approach to unification.*

(h) SEMINAR / COLLOQUIA / LECTURES / POSTERS

Debarati Chatterjee

Gravitational Waves from Neutron Star as probes of Fundamental Physics, Nicholas and Lee Begovich Center for Gravitational Wave Physics and Astronomy [GWPAC], California State University Fullerton, USA, March 22, 2024.

Constraining Nuclear Parameters using Gravitational Waves from F-mode Oscillations in Neutron Stars" [online], Modular Unified Solver of the Equation of State [MUSES] collaboration, March 18, 2024.

Gravitational waves from Neutron Stars as probes of Fundamental Physics, Physics Department, Washington University in St. Louis, USA, March 07, 2024.

Constraining nuclear and particle physics using multi-messenger data, invited talk delivered at the conference "GW-EM-Nu-2023: Role of India in Multi-Messenger Astrophysics and Cosmology" at the Tata Institute of Fundamental Research, Mumbai on November 21, 2023.

Probing hyperons in Neutron Stars using Multimessenger data, keynote talk at the conference "ROCKSTAR: Towards a ROadmap of the Crucial measurements of Key observables in Strangeness reactions for neutron sTARs equation of state" at the European Centre for Theoretical Studies in Nuclear Physics and Related Areas [ECT*] in Trento, Italy on October 10, 2023.

R-modes to probe the presence of Dark Matter in Neutron Stars, [remote], workshop on Bridging the Gaps: Interdisciplinary Collaborations in Constraining the Physics of Finite Nuclei, Neutron Stars, and Dark Matter, organised by NIT Rourkela, July 07, 2023.

Gravitational waves to probe Dark Matter in Neutron Stars, [contributed talk] 'Dark Matter and Stars" conference in Lisbon, Portugal on May 04, 2023.

Neutron stars as probes of Fundamental Physics in light of multi-messenger astronomy, colloquium delivered at the Department of Physics, Ashoka University, Sonipat, April 04, 2024.

Gravitational Waves from f-modes as a tool to probe the Neutron Star Interior, colloquium, Department of Physics and Astronomy, California State University Long Beach, USA, March 27, 2024.

Hints from Multi-disciplinary Physics to probe dense matter in Neutron Stars, Invited colloquium at the National Centre for Radio Astrophysics [NCRA], Pune, June 10, 2022.

Gravitational Waves from Neutron Stars to probe Extreme Physics, invited talk, ECU2023 [The 2nd Electronic Conference on Universe] Session 2: Women Scientists in Astronomy, Astrophysics and Cosmology, live on YouTube, February 27, 2023.

Compact Stars and Gravitational Waves [invited], ISSAA2023 [IUCAA Summer School / Refresher Course in Astronomy & Astrophysics] on June 02, 2023.

Compact stars and Multi-messenger Astronomy and *Continuous Gravitational Waves,* [02 lectures], Workshop on Gravitational Waves and LIGO-India, Goa University, November 29 and December 01, 2023.

Kalpesh Chillal

Performance validation of the IUCAA Digital sampler array controller, paper presented at the Modern Engineering Trend in Astronomy [META2023] conference, Raman Research Institute, Bangalore, October 31 - November 05, 2023.

Subhadeep De

Quantum clock form quantum metrology" INSQT 24, PRL Ahmedabad, March 20 – 22, 2024.

Quantum clock for ultra-sensitive metrology" TC 2024, PRL 2024, February 15 – 17, 2024.

Developing ytterbium-ion based quantum clock" by Subhadeep De, QIPA 23, HRI, Allahabad, December 03 – 10, 2023.

Indigenization of optical clock, colloquium at ISRO-ISTRAC Bangalore, November 21, 2023.

Optical clock sub-systems" by Stanley Johnson, Quantum technologies for ultra-cold atoms, IISER Pune, November 17, 2023.

Ultra-stable optical clock, QETCI, August 21, 2023.

Quantum clock for quantum metrology and fundamental science, colloquium at IIT Bombay, August 17, 2023.

Atomic clock for testing fundamental science, colloquium at Presidency University, Kolkata, August 02, 2023.

Introduction to atomic clock, PMQM workshop by Subhadeep De, ICTS Bangalore, July 10 – 21, 2023.

Gulab C. Dewangan

Multi-wavelength View of Accreting Compact Objects with AstroSat, Seminar, IIA, Bangalore, August 03, 2023.

Data-driven High Energy Space-based Astronomy, Seminar, IIT, Hyderabad, December 12, 2023.

Multi-wavelength spectral study of hard and soft states of MAXI J1820+070, [online], 4th China-India workshop, Fudan University, China, October 21, 2023.

Neeraj Gupta

The MeerKAT Absorption Line Survey: overview and results, MeerKAT@5 conference in Stellenbosch to celebrate 5 years of the MeerKAT telescope, South Africa, February 2024.

Ranjan Gupta

Regolith-related experiments & India's Mega Projects in Astronomy, IRAP, Toulouse, France, April 4, 2023.

A Career in Astronomy & Astrophysics and the latest Asteroid, Nehru Planetarium, Mumbai, on May 09, 2023.

Photometry & Spectroscopy, Introductory Summer School on Astronomy and Astrophysics, IUCAA, Pune, May 15 - 16, 2023.

Introduction to Spectroscopy, IFAS8, IUCAA, Pune, November 06 – 12, 2023.

Careers in Astronomy, IOP, Bhubaneshwar, January 14, 2024.

Regolith Research and Recent Asteroid Return Missions, Exploring the Universe from Near to Far - Astronomy and Astrophysics Conference 2024, ICSP, Kolkata, February 16, 2024.

Shasvath Kapadia

Gravitational Lensing of Gravitational-Waves, Seminar, Tokyo Institute of Technology, Tokyo, Japan, September 2024.

Ranjeev Misra

Soft excess of Mark 335, 4th Indo-China Workshop on High Energy Astrophysics, Fudan Univ., October 2023.

Seminar on "X-ray Variability of Black Hole Systems: The AstroSat Advantage", MAHE, Manipal, October 2023.

The Nobel Road to observing black holes, (online colloquium), SRM University, Sikkim, September 2023.

Using X-ray variability to distinguish between spectrally degenerate models, International Symposium in Relativistic Astrophysics, Gangtok, December 2023.

Sanjit Mitra

Gravitational Waves & The LIGO-India Project, Workshop on Gravitational Waves and LIGO India, November 30, 2023.

Science with LIGO-India: Stochastic Gravitational Wave Background, (invited), GW-EM-NU meeting, TIFR, Mumbai, November 23, 2023.

Presentation on motivation for an Indian deci-Hertz GW detector (panel discussion on space-based facilities), GW-EM-NU meeting, TIFR, Mumbai, November 23, 2023.

Binary Neutron Star mergers and LIGO-India (invited), IIT, Indore, November 16, 2023.

Science with LIGO-India: Immediate Opportunities & Exciting Possibilities, (invited colloquium), RRI, Bangalore, October 26, 2023.

Science with LIGO-India: Stochastic Gravitational-Wave Background, (invited lecture), LIGO-India meeting, ICTS-TIFR, October 27, 2023.

Stochastic GW background in the decihertz band, (invited lecture), Lunar Gravitational-Wave Detection meeting, ICTS-TIFR, April 20, 2023.

Anupreeta More

Gravitational lensing and transient science, Rubin LSST Strong lensing Workshop, Oxford, UK, March 2024.

Towards the first detection: combining the messengers, (plenary + panellist), The Theo Murphy meeting, The Royal Society, Manchester, UK, March 2024.

Detection of lensed GW and impact on cosmology, (seminar), Niels Bohr Institute, Copenhagen, Denmark, March 2024.

Glitch classification, search and parameter estimation for gravitational waves, (talk), Data Science Workshop, IUCAA, Pune, India, December 2023.

Gravitational lensing of Gravitational waves as a cosmological probe, (talk), GW-EM-Nu-2023, TIFR, Mumbai, India, November 2023.

Gravitational waves and Gravitational lensing, (colloquium), Presidency University, Kolkata, India, October 2023.

Gravitational waves meet Cosmology (talk), Mumbai-Pune Astroparticle and Cosmology Meeting, IISER Pune, India, August 2023.

Strong gravitational lensing, (lecture), ISSAA 2023, IUCAA, Pune, India, June 2023.

Surhud More

Cosmological constraints from Year 3 data from the Subaru Hyper Suprime Cam Survey, World-wide-web seminar, April 2023.

Cosmological constraints from Year 3 data from the Subaru Hyper Suprime Cam Survey, Frontiers in Physics XVI, April 2023.

Measuring the Universe: Expansion rate and the clumpiness in the matter distribution, BHU Varanasi, April 2023.

Cosmological constraints from Year 3 data from the Subaru Hyper Suprime Cam Survey, NCRA colloquium, May 2023.

Latest developments in Astronomy and plans for the next decade for India, BRICS meeting, South Africa, October 2023.

Hands-on session for the Data Science in Astronomy workshop, IUCAA, December 2023.

Cosmological constraints from large optical surveys, WHEPP XVII, IIT Gandhinagar, January 2024.

Office of Astronomy for Education Center India, Astronomical Society of India meeting plenary on ASI Public Outreach and Education, February 2024.

On the subhalos of satellite galaxies and primordial black hole abundance, Seminar, Nagoya University, March 2024.

Dipanjan Mukherjee

Jet-feedback on kpc scale: a review", invited talk review, international conference on AGN on the Beach, Tropea, Italy, September 10 - 15, 2023.

Spatially resolved simulations of Jet-ISM interaction", invited talk, workshop on Importance of jet-induced feedback on galaxy scales, Lorentz Centre, University of Leiden, from October 23 - 27, 2023.

Role of relativistic jets in Galaxy evolution, workshop on Advances in Relativistic Astrophysics, ARIES, Nainital from November 02 - 04, 2023.

Interpreting X-ray polarisation Data: requirement for modelling, Second XPoSat Users meet, URSC, Bangalore, 18 - 19 December 2019.

AGN feedback, workshop on Galaxy formation and evolution, Central University, Hyderabad, March 20, 2024.

Chayan Mondal

AstroSat UV Deep Field – A unique view of the distant galaxies, [contributed talk], Network of Ultraviolet Astronomy [NUVA] eMeeting, October 24 – 26, 2023.

A Decade of ESO Wide-field Imaging Surveys [contributed talk], Conference held at ESO Garching, Germany during October 16 – 20, 2023.

Contributed as one of the primary resource persons in a national workshop on 'Data-driven Astronomy v2' during July 06 - 08, 2023, at CUHP, Shahpur, India.

Contributed as one of the primary resource persons in a national workshop on 'Data-driven Astronomy v3' during December 11 - 13, 2023, at IIT Hyderabad, India.

Sowgat Muzahid

Connecting galaxies and clusters and cool gas surrounding them, June 2023, University of Milan, Biccoca, Italy.

Vaidehi Paliya

Gamma-ray Emission from Cosmic Beacons, National Conference on REcent Trends in the study of Compact Objects (RETCO-V): Theory and Observation conference, Kodaikanal Solar Observatory, India, April 03 – 05, 2023.

The Central Engines of Fermi Blazars, [invited talk], Advances in Relativistic Astrophysics, Aryabhatta Research Institute of Observational Sciences, Nainital, November 02 – 04, 2023.

Active Galactic Nuclei: Introduction and Latest Advancements [02 lectures], Artificial Intelligence in Astronomy & Astrophysics, Department of Physics, University of Calicut, January 18 - 20, 2024

Aseem Paranjape

Model-agnostic cosmological constraints from the baryon acoustic oscillation feature in redshift space, IFPU, Trieste, Italy, April 13, 2023.

Chaitanya Rajarshi

Confronting Challenges in Design and Development of the Wide Area Linear Optical Polarimeter -South, 42nd meeting of the Astronomical Society of India, Bengaluru, January 31 – February 04, 2024.

Overcoming Assembly, Integration, and Testing Challenges in WALOP-South, Modern Engineering Trends in Astronomy (META-2023) conference, Raman Research Institute, Bengaluru, November 01 – 04, 2023.

Kanak Saha

How do galaxies grow their mass? Invited talk, Gravitation: Theory and observation, a workshop organised at the Cooch Behar Panchanan Barma University, Cooch Behar, January 03, 2024.

Searching for the galaxies that reionized the universe, invited talk, Meghnad Saha Memorial International Conference on Frontiers of Physics, Department of Physics, University of Allahabad, November 22 - 24, 2023.

Galaxy dynamics in the IFU era, invited talk, IFAS 8, IUCAA, Pune, November 06 - 12, 2023.

AstroSat UV Deep Field: key results, invited colloquium, NCRA-TIFR, Pune, May 19, 2023.

UV deep surveys using INSIST, invited talk, INSIST meeting, IIA, Bengaluru, April 12, 2023.

Dynamics and orbital structures: application to planetary system and our galaxy, invited talk,

IWCMDA, Central University of Rajasthan, January 06 - 07, 2024.

Dhruba J. Saikia

The Milky Way and HI observations, Horn antenna workshop, IUCAA, Pune, April 03, 2023.

Breakthrough contributions in astronomy: reflections on building inclusive societies, Inaugural talk, Frontiers in Physics XVI, Fergusson College, Pune, April 11, 2023.

Select breakthrough contributions in astronomy and the importance of building inclusive societies, Indian Association of Physics Teachers, Goa RC 21, Carmel College Nuvem, Goa, April 15, 2023.

Our home, our Galaxy and our place in the Universe, MSFDA and ACE IUCAA workshop on Astronomy, Science and Society, MSFDA, Pune, September 08, 2023.

Role of technology in a multi-messenger view of our Universe, Vishwakarma Institute of Technology, Pune, October 05, 2023.

Black holes in our Universe: an observational perspective, The Physics Society, St. Stephen's College, New Delhi, November 07, 2023.

Academic leadership, governance and management: an overview, (online) NEP Orientation and Sensitization Program, IUCAA, Pune, November 07, 2023.

Overview of multi-messenger astronomy, Pedagogic workshop on Astronomy, Astrophysics and Cosmology, St. Stephen's College, New Delhi, November 08, 2023.

Galaxies and active galactic nuclei (AGN), Pedagogic workshop on Astronomy, Astrophysics and Cosmology, St. Stephen's College, New Delhi, November 09, 2023.

Active galaxies, Ashoka Student Astronomy Conference 2023, Ashoka University, Sonipat, November 11, 2023.

Reflections on holistic and multidisciplinary education, (online) NEP Orientation and Sensitization Program, Mizoram University, Aizawl, November 21, 2023.

Higher education and society: social justice and building equitable societies, (online) NEP Orientation and Sensitization Program, Mizoram University, Aizawl, November 21, 2023.

Reflections on academic leadership, governance and management, (online) NEP Orientation and Sensitization Program, National Institute of Educational Planning and Administration, New Delhi, December 20, 2023.

Radio emission from galaxies, IUCAA-NCRA Radio Astronomy Winter School 2023, IUCAA, Pune, December 21, 2023.

An overview of multi-messenger astronomy and recent results, Pedagogic workshop on astronomy, astrophysics and cosmology, Gauhati University, Guwahati, January 04, 2024.

Galaxies and their circumnuclear activity, Pedagogic workshop on astronomy, astrophysics and cosmology, Gauhati University, Guwahati, January 06, 2024.

Black holes in our Universe: stellar mass to supermassive ones, Diving Deep into Physics Colloquium Series, IIT Jodhpur, January 12, 2023.

Radio and x-ray astronomy: an overview and recent developments in India, MSFDA and ACE IUCAA workshop on Astronomy, Science and Society, Maratha Vidya Prasarak Samaj's Commerce, Management & Computer Science (C. M. C. S.) College, Nashik, January 19, 2024.

Building inclusive societies: a few lessons from astronomy, MSFDA and ACE IUCAA workshop on Astronomy, Science and Society, Maratha Vidya Prasarak Samaj's Commerce, Management & Computer Science (C. M. C. S.) College, Nashik, January 20, 2024.

Academic leadership, governance and management: Forms of governance and reflections on the Cotton University experience, (online) NEP Orientation and Sensitization Program, IUCAA, February 04, 2024

Indian higher education in global context, Panel discussion, IIT Bombay, February 28, 2024.

Active galaxies and their recurrent nuclear activity, Keynote address, International Conference on Frontiers in Physics and Applied Physics, University of Science and Technology Meghalaya (USTM), Ri Bhoi district, Meghalaya, March 01, 2024.

Academic leadership, governance and management: Forms of governance and institutional research, (online) NEP Orientation and Sensitization Program, North-Eastern Hill University, Shillong, March 04, 2024

A multi-messenger view of our Universe, Plenary talk, National Symposium on Astronomy and Space Technology, Assam down town University, Guwahati, March 06, 2024.

Reflections on academic governance, Special lecture, Cotton University, Guwahati, March 07, 2024.

A journey through the Universe, Assam Don Bosco University, Tepesia, Guwahati, March 08, 2024.

Higher education and society: Creating inclusive societies and university social responsibility, (online) NEP Orientation and Sensitization Program, IUCAA, Pune, March 16, 2024.

Holistic and multidisciplinary education: Towards a holistic curriculum, (online) NEP Orientation and Sensitization Program, Tezpur University, Tezpur, March 20, 2024.

Higher education systems and institutions: An overview, (online) Faculty Induction Program, National Institute of Educational Planning and Administration, New Delhi, March 23, 2024.

Governance and Management of Higher Educational Institutions: Perspectives from the North-East region, (online) National Institute of Educational Planning and Administration, New Delhi and North-Eastern Hill University, Shillong, March 27, 2024.

Higher education and society: University social responsibility, (online) NEP Orientation and Sensitization Program, Mizoram University, Aizawl, March 28, 2024.

Nishant Singh

Delivered an invited talk at the Department of SPASE, IIT Kanpur, 04 April 2024.

Solar Physics (online), a program jointly organised by VIIT, Pune and IUCAA.

On Magnetic Fields and Surface Gravity Mode of the Sun (online), invited talk, Leibniz Institute for Solar Physics, Freiburg, February 05, 2024.

Solar Magnetic Fields and Convective Conundrum, invited talk, NISER-Bhubaneswar, November 01, 2023.

Delivered a talk at the Conference on Plasma Simulation (CPS-2023), Raman Science Centre, Leh, Indian Institute of Astrophysics (IIA), July 13 - 15, 2023.

Delivered an invited talk at the meeting on 'Statistical Physics and Complex Systems'

Magnetic fields and convection in turbulent systems: some

challenges (e.g., convective conundrum), meeting on Statistical Physics and Complex Systems, IIT, Kharagpur, June 05 - 07, 2023.

T. P. Singh

Trace dynamics, octonions and unification, OSMU23 online lecture, June 2023.

The exceptional Jordan algebra and its implications for our understanding of gravitation and the weak session, [online], Session on `Clifford Algebras and the fundamental forces of nature', 13th International Conference on Clifford Algebras and their applications in Mathematical Physics', Holon, Israel, June 4 - 9, 2023.

Durgesh Tripathi

Coronal Heating and Origin of Solar Wind", Durgesh Tripathi, Vishal Upendran, V N Nived, Sami Solanki, Multi-scale Phenomena on the Sun: Present Capabilities and Future Challenges, April 3 - 5, 2023.

Solar Ultraviolet Imaging Telescope [SUIT] on board Aditya-L1 mission", Durgesh Tripathi, A N Ramaprakash, P. Sreejith and SUIT team, Multi-scale Phenomena on the Sun: Present Capabilities and Future Challenges, April 3 - 5, 2023.

Multi-scale processes in Coronal Transients", Durgesh Tripathi, Multi-scale Phenomena on the Sun: Present Capabilities and Future Challenges, April 3 - 5, 2023.

Aditya-L1 mission, Durgesh Tripathi, Frontiers in Physics, Fergusson College, April 12, 2023.

Solar wind prediction using deep learning, Vishal Upendran, Mark Cheung, Shravan Hanasoge, Ganapathy Krishnamurthi, Science from In-situ measurements of Aditya-L1 (SIMA-01), Space Physics Laboratory, Vikram Sarabhai Space Center, Thiruvananthapuram, India, April 11 - 13, 2023.

Center-to-limb variation of the Mg II intensities in quiet Sun and active regions from IRIS, Megha Anand, Pradeep Kayshap, Durgesh Tripathi, The many scales of the magnetic Sun, Potsdam, Germany, May 8 - 12, 2023.

Building of the Solar Ultraviolet Imaging Telescope (SUIT) on board Aditya-L1: why and how?", Durgesh Tripathi, IIT-BHU, May 29, 2023.

Mega Science Talk on Aditya-L1, Durgesh Tripathi, IUCAA Summer School, June 2, 2023.

Solar Ultraviolet Imaging Telescope, Durgesh Tripathi and A. N. Ramaprakash with the SUIT team, Aditya-L1 support Cell Workshop, ARIES, June 28- July 7, 2023.

Introduction to Solar Physics, Megha Anand, Beginning Astronomy v2: Start a data-driven journey, Central University of Himachal Pradesh, Shahpur from July 5 - 8, 2023.

Reaching for the Sun, Durgesh Tripathi, NCERT, Listening to Learn Program, New Delhi, August 18, 2023.

Science Objectives of Aditya-L1, Megha Anand, Fergusson College, Pune, September 25, 2023.

Statistical constraints on impulsive heating of solar corona, Vishal Upendran, Durgesh Tripathi, Mithun N.P.S, Santosh Vadawale, Anil Bhardwaj. Solar and cosmic plasma seminar, Kyoto University, Kyoto, Japan, October 2, 2023.

Mg II index from SUIT in different chromospheric features, Megha Anand, Pradeep Kayshap, Vishal Upendran, Pranava Seth, Janmejoy Sarkar, Soumya Roy, Durgesh Tripathi, Third SUIT Science Meeting [online], October 10 - 12, 2023.

Observatory class mission for Solar Studies, Durgesh Tripathi, Beyond Aditya-L1: Exploring the future of Indian Solar Physics from Space, November 7 - 9, 2023.

Introduction to the Sun and Aditya-L1 mission, Durgesh Tripathi, Meghnad Saha Memorial Workshop on Solar Astronomy Focused on Aditya -L1 Mission, December 3 - 5, 2023.

Solar Ultraviolet Imaging Telescope [SUIT] on-board Aditya-L1, Soumya Roy on behalf of the SUIT team, Lockheed Martin Advanced Technology Center, Palo Alto, USA, December 7, 2023.

Solar Physics for Beginners, Megha Anand, Beginning Astronomy v3: Start a data-driven journey, Indian Institute of Technology, Hyderabad, India December 11 - 13, 2023.

Thermal and non-thermal energy evolution in solar flares, Soumya Roy, S. Musset, K. Reeves, Durgesh Tripathi and C. Moore, presented in AGU 2023, San Fransisco, December 11 - 15, 2023.

India's first Solar Observatory in Space: The Aditya-L1, Durgesh Tripathi, Frontier Symposium, IISER Thiruvananthapuram, January 19 - 21, 2024.

The Sun through the eyes of India's Aditya-L1, Durgesh Tripathi, Astronomical Society of India meeting 2024, IISc, Bangalore, India, January 31 – February 04, 2024.

Pre-launch Photometric calibration and Spectral validation of the SUIT payload onboard Aditya L1, Janmejoy Sarkar, Soumya Roy, Rushikesh Deogaonkar, A.N. Ramaprakash, Durgesh Tripathi et al., National Space Science Symposium 2024, Goa University, February 26 – March 1, 2024.

Science with SUIT, Durgesh Tripathi, 6th Aditya-L1 Support Cell Workshop, February 6 - 8, 2024.

Aditya Calling Aditya, Durgesh Tripathi, Frontiers in Astronomy - New Challenges in the Careers in Astronomy and Astrophysics, in association with the Centre for Extra-Mural Studies (CEMS), Mumbai University., February 10 - 11, 2024.

Introduction to our own Star: The Sun, Durgesh Tripathi, IMPRESS program, IIG Mumbai, February 12 - 15, 2024.

Aditya Calling Aditya, Durgesh Tripathi, Bahona College, Jorhat, March 05, 2024.

The Sun through the Eyes of SUIT/Aditya-L1, Durgesh Tripathi, CESSI@10, annual Physics Day, IISER Kolkata, March 8 - 10, 2024.

Exploring the formation of solar wind, switchbacks and Quiet Sun

heating (poster), Vishal Upendran & Durgesh Tripathi, Solar Wind 16 conference in Monterey, CA, USA, June 12 - 16, 2023.

Statistical impulsive heating signatures in the solar corona (poster), Vishal Upendran, Durgesh Tripathi, Mithun N.P.S, Santosh Vadawale, Anil Bhardwaj, Hinode 16 / IRIS 13 meeting in Niigata, Japan, September 25 - 29, 2023.

Flux emergence thermodynamics in Coronal Holes and Quiet Sun (poster), Vishal Upendran, Durgesh Tripathi, Bhargav Vaidya, Mark Cheung, Takaaki Yokoyama, Hinode 16 / IRIS 13 meeting in Niigata, Japan, September 25 - 29, 2023.

An Artificial Intelligence-based chromospheric feature extractor and classifier for SUIT (poster), Pranava Seth, Vishal Upendran, Megha Anand, Soumya Roy, Janmejoy Sarkar, Durgesh Tripathi, Astronomical Society of India meeting 2024, IISc, Bangalore, India, January 31 – February 4, 2024.

Energetics of the November 29th, 2020 limb event (poster), Soumya Roy, K. Reeves, Durgesh Tripathi, C. Moore, S. Musset and T. Hernandez; presented in Hinode-16/IRIS-13, Niigata, Japan, September 2023.

Interpretable Deep Learning for Solar Flare Predictions (poster), Linn Abraham, Vishal Upendran, Durgesh Tripathi, Ninan Sajeeth Philip, Nandita Srivastava, A. Ramaprakash, Sreejith Padinhatteeri, Annual Meeting of Astronomical Society of India, IISc. Bangalore, January 31 – February 4, 2024.

In-Lab Photometric Calibration of the SUIT Payload on-board Aditya L1 (poster), Janmejoy Sarkar, Soumya Roy, Rushikesh Deogaonkar, A.N. Ramaprakash, Durgesh Tripathi et al., Annual Meeting of Astronomical Society of India, IISc. Bangalore, January 31 – February 4, 2024.

Observations of the flare on the 5th of August 2023 (poster), Deepak Kathait, Soumya Roy, Vishal Upendran, Durgesh Tripathi, Sreejith Padinhatteeri, Nandita Srivastava, A. N. Ramaprakash, Annual Meeting of Astronomical Society of India, IISc. Bangalore, January 31 – February 4, 2024.

(I) LECTURE COURSE/ WORKSHOP

Prakash Arumugasamy

Electromagnetic theory of the horn, (one lecture), Horn Antenna Workshop, IUCAA, April 3 - 6, 2023.

Positional astronomy using interactive Web applications, (one lecture), ISSAA 2023, IUCAA, May 15 to June 16, 2023.

Experiments with pulsar data, (one lecture), Workshop on Astronomy-Themed Experiments, IUCAA, August 8 – 12, 2023.

Positional astronomy using Stellarium, (one lecture), Workshop on Astronomy-Themed Experiments, IUCAA, August 8 – 12, 2023.

Simulating experiments in Stellarium, (one lecture), Workshop on Astronomy-Themed Experiments, IUCAA, August 8 – 12, 2023.

Positional astronomy using Stellarium, (1 lecture), Pedagogic workshop on Astronomy, Astrophysics, and Cosmology, St. Stephen's College, Delhi, November 6 – 10, 2023.

Detecting a pulsar in Ooty Radio Telescope voltage data, (1 lecture), Pedagogic workshop on Astronomy, Astrophysics, and Cosmology, St. Stephen's College, Delhi, November 6 – 10, 2023.

Pulsars, (one lecture), IUCAA–NCRA Radio Astronomy Winter School 2023, IUCAA, Pune, December 12 – 22, 2023.

Information and Communication Technology, (one lecture), NEP Orientation and Sensitization Programme, (online), March 14 – 29, 2024.

Subhadeep De

Convener of the workshop Introduction to Precision Measurements and Quantum Metrology (PMQM 2023) held at ICTS, Bangalore, July 10 - 21, 2023.

Rajeshwari Dutta

Lecture on "Gas in Galaxies" in the IUCAA-NCRA Radio Astronomy Winter School, December 10 – 12, 2023.

Surhud More

Cosmology, Orientation cum Selection camp for International Astronomy Olympiad, HBCSE, May 2023.

Lectures on Gravitational lensing at the IUCAA Summer School cum Refresher Course, IUCAA, June 2023.

Cosmology, pre-departure camp for International Astronomy Olympiad, HBCSE, August 2023.

Dipanjan Mukherjee

Four lectures on Radiative Transfer and one lecture on Computational Astrophysics, Introductory Summer School in Astronomy and Astrophysics, IUCAA, Pune, May 15 to June 16, 2023.

One lecture in the Radio Astronomy Winter School at IUCAA, December 12 – 22, 2023.

Three lectures on Computational Fluid Dynamics at the Computational Astrophysics workshop, IISc Bangalore, July 10 – 14, 2023.

Sowgat Muzahid

Lectures delivered at the Advancements in AGN, Galaxy, Cluster, and IGM Research, CUHP, Dharamshala, March 2024.

Lectures delivered during the Pedagogic workshop on Astronomy, Astrophysics and Cosmology: A Faculty Enrichment Programme, Gauhati University, January 2024.

Lectures delivered during the Indo-French School (IFAS8), IUCAA, November 2023.

Lectures delivered during the Introductory Summer School in

Astronomy and Astrophysics, IUCAA, Pune, May 15 to June 16, 2023.

Vaidehi Paliya

Three lectures on Stellar Structure and Evolution, Introductory Summer School in Astronomy and Astrophysics, IUCAA, Pune, May 15 to June 16, 2023.

Two lectures on Active Galactic Nuclei, Introductory Summer School in Astronomy and Astrophysics, IUCAA, Pune, May 15 to June 16, 2023.

Kanak Saha

Three lectures on Galaxies: Dynamics and Evolution, Introductory Summer School in Astronomy and Astrophysics, IUCAA, Pune, May 15 to June 16, 2023.

Dhruba J. Saikia

The Milky Way and Galaxies, (online, three lectures) Introductory course on astronomy and astrophysics for college teachers, Central University of Himachal Pradesh and ACE, IUCAA, April 2023.

Relativistic jets, (three lectures), Introductory Summer School in Astronomy and Astrophysics, IUCAA, Pune, May 15 to June 16, 2023.

Nishant Singh

Three lectures on Fluids and Plasma Physics were delivered during the Introductory Summer School in Astronomy and Astrophysics, IUCAA, Pune, May 15 to June 16, 2023.

Resource person for the HPC workshop held from May 22 - 25, 2023, Kashmir University.

Delivered a set of lectures at a school organised by IIT Kharagpur during June 08 - 10, 2023.

Resource person for the Meghnad Saha Memorial Workshop on Solar Astronomy Focused on Aditya-L1 Mission, Department of Physics, University of Allahabad, Prayagraj, December 03 - 07, 2023.

T. P. Singh

General Relativity and Cosmology, (four lectures), Introductory Summer School in Astronomy and Astrophysics, IUCAA, Pune, May 15 to June 16, 2023.

Co-host for the online Lecture Series `Octonions, elementary particles, and the Standard Model' February 16 - December 15, 2024 (Event organized outside IUCAA)

Durgesh Tripathi

Four lectures on Solar Astrophysics, May 24-29, 2023, Introductory Summer School in Astronomy and Astrophysics, IUCAA, Pune, May 15 to June 16, 2023.

(j) POPULAR/PUBLIC LECTURE

Prakash Arumugasamy

Physical scales in the Universe, (one lecture), Astronomy, Science and Society, MSFDA, Pune, September 6, 2023.

Exoplanets, (one lecture), The Physics Society, St. Stephen's College, Delhi, November 9, 2023.

Scales of the Universe, (one lecture), Astronomy, Science and Society, Commerce, Management & Computer Science College, Nashik, January 19, 2024.

Debarati Chatterjee

LIGO-India: A Gravitational Wave detector on Indian soil, invited talk, Frontiers in Physics XVI at Fergusson College, Pune on April 12, 2023.

LIGO-India: A Gravitational Wave observatory on Indian soil, online invited talk, Basic Astronomy Course organised by Jyotirvidya Parisanstha (JVP), May 30, 2023.

Gravitational Wave Astronomy: a new window to the invisible Universe, invited talk, Interdisciplinary School of Science (IDSS) Space Society, Savitribai Phule Pune University (SPPU) on the occasion of the World Space Week on October 4, 2023.

Gravitational Waves: the game changer in Compact Star Astrophysics, invited public talk, Aakashganga, Astro club of IISER Pune, January 24, 2024.

Gravitational Waves and LIGO-India: a New Frontier in Indian Science, guest speaker, PHYL-79 Award Distribution Function and Inauguration of Cultural Event RESONANCE FEST, Physics Association of the Department of Physics, Abasaheb Garware College on February 7, 2024.

Gravitational Waves: the game changer in Compact Star Astrophysics, Department of Physics and Astronomy, California State University Long Beach, USA, March 26, 2024.

Gravitational Waves: the game changer in Compact Star Astrophysics, Annual Science Festival Spacecraft 2.0, Ashoka University Sonipat, April 3, 2024.

S.V. Dhurandhar

Ripples in Spacetime: Gravitational Wave Astronomy, (invited talk), Frontiers in Physics, Fergusson College, March 14, 2024.

Neeraj Gupta

Driving innovations in radio astronomy, Podcast with Rebecca Parson and Prem Chandrasekaran, September 2023.

https://www.thoughtworks.com/insights/podcasts/technology-podcasts/driving-innovation-radio-astronomy

Sanjit Mitra

The Future of Gravitational Wave Astronomy, IIT, Bombay, March 31, 2024.

LIGO India Challenges and Opportunities, Goa Science Centre, November 30, 2023.

Anupreeta More

Citizen Science: Gravitational lens discoveries at your fingertips, (public talk), National Science Day, IUCAA, Pune, India, February 2024.

Gravitational lensing Experiments, (talk), Astronomy Themed Experiments, IUCAA, Pune, India, August 2023.

A series of Public Talks on "*LIGOand role of LIGO-India*" in the region of Satara, Islampur and Kolhapur, India, March 2023.

Nishant Singh

Fluid Dynamics: Astrophysical Flows and Magnetic Fields, Frontiers in Physics XVII, Fergusson College, Pune, March 14, 2024.

T. P. Singh

Is there dark matter in the universe? (online) Symposium on space physics and astrophysics, St. Teresa College, Ernakulam, December 14 - 15, 2023.

Flat galaxy rotation curves: dark matter, or a new law of gravitation? (online) Workshop on Cosmology, Kerala University, August 3 - 4, 2023 (online talk); SVNIT Surat, October 2023.

Gravitation and quantum theory as emergent phenomena, Bharata Mata College, Kochi, (online talk in a one-day meeting on `Life and Science of Thanu Padmanabhan'), March 23, 2024.

(k) RADIO/TV PROGRAMME

Surhud More

Difference between Astronomy and Astrology, 'Soppa Karun Sangto with Suvrat, VishayKhol', (in Marathi) February 2024, https://www.youtube.com/watch?v=SKc7UhK5nQI.

[l] PROFESSIONAL ACHIEVEMENTS / DISTINCTIONS

Debarati Chatterjee

Work featured along with an invited article published in the special issue (Jan-June 2023) of Physics News, showcasing the cutting-edge research of young women physicists in India. Physics News is a newsletter published by the Indian Physics Association (IPA). The special issue can be found at:

https://www.tifr.res.in/~ipa1970/news/V53-12/PN_V53-12.html

S. V. Dhurandhar

International Detection Committee for Pulsar Timing Array groups:

Gravitational waves (GW) have been detected by ground-based laser interferometric detectors in 2015. The astrophysical sources detected so far are mergers of stellar-mass black holes or neutron star binary systems. These detectors observe GW in the high-frequency band of tens of Hz to kHz.

However, there are other possible methods to detect and observe gravitational waves. The Pulsar Timing Array (PTA) consists of monitoring the timing residuals of nearby millisecond pulsars using radio telescopes to detect gravitational waves. The waves PTA can observe are of very low frequencies in the range of 10 - 100 nano-Hz. The specific source the PTA groups are targeting is the stochastic background of gravitational waves from supermassive black holes. So far there is no confirmed detection, although there is possible evidence for such sources. However, it is believed that confirmed detection is not far off.

I (by nomination) am part of the International Detection Committee consisting of 8 members from various countries around the world. The International Pulsar Timing Array (IPTA) Consortium currently consists of four PTAs: (i) the North American PTA (NANOGrav) (ii) the Australian PTA (PPTA), (iii) the European PTA (EPTA) and (iv) the Indian PTA (InPTA).

The task of the Detection Committee was to provide support and advice relating to claims of gravitational wave background detection to the PTA groups belonging to the IPTA. The detection committee has prepared a checklist of requirements any claims of detection must fulfil. The committee was tasked with vetting the papers from the different PTA groups and scrutinising them if any detection claims could be made.

Rajeshwari Dutta

Awarded 100 Hubble Space Telescope orbits for the program "Characterizing Lyman-Alpha emitters with Snapshot Survey (CLASS)" (Principal Investigator: Rajeshwari Dutta).

Neeraj Gupta

Principle Investigator: MeerKAT Absorption Line Survey (MALS).

Co-Chair of the SKA International HI Working Group.

Co-Chair of the Pulsars and HI Absorption Science Working Group: Hydrogen Intensity and Real-time Analysis eXperiment (HIRAX).

Member of the Pipeline Calibration and Science Verification Working Group: 4MOST AGN survey.

Member of the SKA India HI working group.

Shasvath Kapadia

The following collaborative work with colleagues at ICTS-TIFR was selected as the Editor's Suggestion in Physical Review Letters (PRL).

Souvik Jana, Shasvath J. Kapadia, Tejaswi Venumadhav, Parameswaran Ajith, *Cosmography using strongly lensed gravitational waves from binary black holes*, arXiv:2211.12212, PRL, 130, 261401, (2023).

Varun Sahni

Member of the International Organizing Committee of the fifth Zeldovich Meeting, Yerevan, Armenia, June 2023.

SCIENTIFIC MEETINGS AND OTHER EVENTS

Introductory Summer School in Astronomy & Astrophysics 2023

The Introductory Summer School in Astronomy & Astrophysics (ISSAA) 2023 was conducted at IUCAA from 15 May to 16 June 2023. It is an annual IUCAA event that introduces senior undergraduate and postgraduate students to the exciting fields of astronomy and astrophysics. The school consisted of lectures covering the fundamentals and latest advancements in astronomy and astrophysics. ISSAA was coordinated by Vaidehi S. Paliya, IUCAA.

[For details see Khagol 130, January - October 2023]

Refresher Course on Astronomy and Astrophysics

The Refresher Course on Astronomy and Astrophysics 2023 was held online from the 15th of May to the 16th of June. It was held concurrently with the Summer School on Astronomy and Astrophysics offline. There were about thirty participants from higher educational institutions from across the country.

The lectures covered a wide range of topics, introducing the basic important topics of the field, which included radiative processes, stellar structure and evolution, the Sun, compact objects, galaxies, galactic dynamics, active galactic nuclei and jets, gravitational lensing, x-ray astronomy, fluids and plasmas, general theory of relativity and cosmology, structure formation, photometry and spectroscopy as well as recent advances.

Vaidehi Paliya and Team ACE IUCAA coordinated the Refresher Course.

[For details see Khagol 130, January - October 2023].

The Thirty-Fifth Foundation Day Lecture Innovate to Transform: Prosperity through Science and Technology

The 35th Foundation Day lecture was delivered on Friday, December 29, 2023, by Padma Bhushan Dr. Jyeshtharaj B. Joshi, DAE-Homi Bhabha Chair Professor, Homi Bhabha National Institute, Anushaktinagar Mumbai, President, Marathi Vidnyan Parishad, Mumbai and Emeritus Professor of Eminence, Institute of Chemical Technology, Mumbai. The lecture ended with a lively discussion with the audience and questions taken online over YouTube. The recorded lecture is available at the

YouTube link:https://www.youtube.com/live/Fa_jcLmY3YA?si=af8sRQ-HoplulfygYou

[For details see Khagol 131, January 2024]

NATIONAL SCIENCE DAY 2024

The National Science Day was celebrated with an Open Day on 28th February 2024 at IUCAA and other events throughout February. Like every year, IUCAA responded to people's enthusiasm to associate better with Science and Scientists. The celebrations attracted numerous students from Pune and other parts of Maharashtra, including teachers, parents, and the public.

[For details see Khagol 132, April 2024]

Workshop on the limiting compactness objects: Black holes and Buchdahl stars

The workshop on the limiting compactness objects: Black holes and Buchdahl stars was held from 30 October 2023 to 03 November 2023 at IUCAA, Pune. The workshop was organised as a compact discussion/discourse meeting with a threadbare exposition and discussion of the various aspects and the questions arising. It was occasioned by the visit of Professor Håkan Andreasson of the Gothenburg Technical University, Sweden. The workshop was organised by Naresh Dadhich, IUCAA, Pune.

[For details see Khagol 130, January - October 2023].

Indo-French Astronomy School (IFAS 8) 3D Spectroscopy

The Indo-French Astronomy School (IFAS 8) 3D Spectroscopy was held from November 06 - 12, 2023 at IUCAA, Pune. The IFAS8 school gathered 20 student participants from different parts of India and abroad to expose them to high-level lectures on spectroscopy and dynamical modeling and proposed they carry on a week-long research project. The school was focused on "Spectroscopy and Spectrographs." It covered a wide range of topics in observational astronomy using 3D integral-field spectroscopy. One of the major highlights of the IFAS school is its intense

research-based project. The school was organised by Kanak Saha, IUCAA, Pune.

[For details see Khagol 131, January 2024].

Radio Astronomy Winter School 2023

IUCAA and NCRA–TIFR jointly organised the 16th Radio Astronomy Winter School 2023 (RAWS2023) from 12th to 22nd December 2023. In its present format, RAWS invites student participants and college and university faculty members to mentor the student groups formed for the school's activities. This year, 24 student participants and seven faculty mentors participated in the programme. The organising team comprised of Rajeshwari Dutta, Ashish Mhaske, Avinash Deshpande, Jameer Manur, Prakash Arumugasamy and Dhruba J. Saikia from IUCAA and Subhashis Roy from NCRA-TIFR.

[For details see Khagol 131, January 2024]

Data Science in Astronomy

A meeting geared towards young researchers on Data Science in Astronomy was held from 12 to 14 December 2023 at IUCAA, Pune, to address the challenges of integrating traditional scientific domains with state-of-the-art computational techniques that revolutionise research paradigms. With its rich datasets, astronomy has already taken advantage of many machine-learning techniques and statistical methodologies, but much more can be accomplished. Ninety participants at various career stages attended the

meeting. The meeting was organised by Surhud More, IUCAA, and Ashish Mahabal, Caltech, USA.

[For details see Khagol 131, January 2024]

Office of Astronomy for Education (OAE) Center, India

The Office of Astronomy for Education (OAE) Center India organised a two-day Teacher's Training Workshop on 16 and 17 February 2024. The workshop was targeted towards school teachers who teach grades 5 - 10. The core idea of the workshop was to revisit the various astronomy concepts taught in schools, discuss pedagogical approaches, and explore the basics of astronomy. The sessions were delivered by various resource persons from IUCAA and Homi Bhabha Centre for Science Education (HBCSE - TIFR). The workshop was coordinated by Moupiya Maji and Surhud More.

[For details see Khagol 132, April 2024]

Pune-Mumbai Cosmology Meeting at IUCAA

A two-day meeting, 'Pune-Mumbai Cosmology Meeting,' was held at IUCAA, Pune, on February 23 and 24, 2024, that brought together scientists working in theoretical, numerical and observational aspects of cosmology from the Pune Mumbai region. The meeting was coordinated by Surhud More and Aseem Paranjape.

[For details see Khagol 132, April 2024]

PUBLIC OUTREACH HIGHLIGHTS

50th Rashtriya Bal Vaigyanik Pradarshani (RBVP) 2023:

The IUCAA Inter-University Centre for Astronomy & Astrophysics Scipop team had put up a stall at RBVP from 26 to 31 December 2023. Posters mentioning information about IUCAA and its academic activities were displayed. Astronomy Concept models and our iconic "Velo-Gyaneshwari" bicycle, which consists of 40 hands-on experiments, were also displayed. A telescope made at the IUCAA was displayed as a part of the IUCAA Telescope-making workshop.

A sky-observation session was conducted with Pimpri Chinchwad Science Park for around 500 RBVP attendees. We received many visitors, approximately 20,000 students from 200 Schools with 1000 teachers and 3000 general Public.

Science Toys Demonstrations and Basic Astronomy Sessions

5th October: Dyanaganga Vishwa Vidyalaya, Shirur, Pune, 100 students, five teachers, conducted by Prasad Adekar and Shivani Pethe.

10th October: Tara Mobile Creche, Pune, 40 students, four teachers, conducted by Shivani Pethe.

12th October: Balavantrao Zele School, 50 students, five teachers, conducted by Rupesh Labde.

17th October: Manvya Sanstha, Kothrud, 25 students, five teachers, conducted by Prasad Adekar.

17th October: Dattakala Shikshan Sanstha Daund, 104 students, 12 teachers, conducted by Rupesh Labde.

19-20 October: Ryan International School, Bhavdhan Pune, 145 students, ten teachers, conducted by Rupesh Labde.

26th October: Dapodi Kanya Shala No. 31, Dapodi Pune, 85 students and four teachers, conducted by Shivani Pethe.

21st November: Vibgyor Rise, Chinchwad, 45 students, two teachers, conducted by Rupesh Labde.

23rd November: New English School, Landewadi, 100 students, six teachers, conducted by Prasad Adekar and Rupesh Labde.

7th December: St Mary's College Thoothukudi, Tamil Nadu, 44 students, six teachers, conducted by Prasad Adekar.

12th December: Bhartiya Jain Sanghtana School, Wagholi, 90 students, three teachers, conducted by Rupesh Labde.

19th December: Saraswati Vishwavidyalay, Talwade, 60 students, three teachers, conducted by Rupesh Labde.

21st December: Tara Mobile Creche, 90 students and three teachers, conducted by Shivani Pethe.

22nd December: Dnyanganga Vishwavidyalaya Shirur, 150 students, ten teachers, conducted by Rupesh Labde and Tushar Purohit.

28th December: Chandranarayan Balwade English School, Jaysingpur, 88 students and eight teachers, conducted by Prasad Adekar.

Teacher Training:

- **6th November:** Agastya International Foundation, Baramati, 80 teachers, conducted by Rupesh Labde.
- **14th December:** SVS High School, Khadi, 300 teachers, conducted by Rupesh Labde.

Science toys demonstration, Astronomy workshops, and Skywatch events:

- Science Toys and Skywatching session at Junnar Taluka Science Exhibition (2 January) Venue: Samarth Engineering College, Belhe. Participants: 300.
- The skywatching event at Andur, Tuljapur. (4 January) About 200 school students, their parents and teachers got a lot of information during this event at Gramin Vidnyan Kendra, Andur.
- Science Club Talk at S P College. (4 January) A talk on Basic Astronomy and Careers. Avasara Academy, Lavale Workshop - (12 January)
- Science Toys Demonstration session and Skywatching for students and teachers. About 120 students attended the session.
- Skywatching Event and Basic Astronomy Session - (17 January) Venue: SBES College, Chatrapati Sambhaji Nagar. About 250 students and the public attended the event.
- Skywatching Event at Indapur - (23 January) The Panchayat Samiti office in Indapur arranged the event. About 1600 students and 60 teachers attended the event.

Telescope Making Workshop:

22nd December: A telescope-making workshop was conducted by Tushar Purohit and Maharudra Mate for participants from IIT Gandhinagar.

Regular Friday Skywatching sessions saw an attendance of 150, while a special sky session organised for Foundation Day had about 200 people enjoying viewing the sky with telescopes.

Telescope Making Workshop at GLA University, Mathura: (1-2 February)

The event was organised at the Centre for Cosmology, Astrophysics and Space Science (CCASS) in GLAU, also an I-CARD. The workshop's target audience was school students and volunteers from the GLA Astronomy Club, who will carry out regular public outreach with the two telescopes made.

Telescope Making Workshop at MVPS, Nashik (27-28 March)

IUCAA and MVPS, Nashik, jointly arranged the workshop, and 25 teachers participated in this training.

2nd Saturday lectures:

14th October: "Formation of Black Holes" by Prof. Surhud More (Marathi) and Dr. Moupiya Maji (English).

11th December: "Detecting the Invisible through Gravitational Waves" by Dr. Pushpa Khare (English and Marathi).

Public Talks in Chandrasekhar Auditorium:

13th December: A Public lecture was organised by IUCAA Scipop on "ZARTH: How to catch a Supernova". The speaker was Dr. Ashish Mahabal.

29th December: The 35th IUCAA Foundation Day Lecture titled "Innovate to Transform" was delivered by Padma Bhushan Prof. Jyeshtharaj Bhalchandra Joshi, a well-known chemical engineer and nuclear scientist.

NATIONAL SCIENCE DAY 2024

The National Science Day was celebrated with an Open Day on 28th February 2024 at IUCAA and other events throughout February. Like every year, IUCAA responded to people's enthusiasm to associate better with Science and Scientists. The celebrations attracted numerous students from Pune and other parts of Maharashtra, including teachers, parents, and the public.

As per tradition, there were also events for school students before the open day. IUCAA Public Outreach personnel conducted a science quiz, essay writing, and drawing competitions for the rural students of the Ambegaon Taluka on February 17, 2024.

Prajakta Mane, Rutuja Pilgar, Jitendra Joshi, Ravi Kesharwani and the SciPop Team (all from IUCAA) enthusiastically encouraged students from 15 rural schools, who competed at the venue generously provided by the Government Polytechnic, Awasari.

On February 24, 2024, about 180 students from 36 schools in Pune City responded to IUCAA's invitation and participated in another set of inter-school competitions. Students from classes VIII to X participated in the drawing, essay, model making, and science quiz competitions.

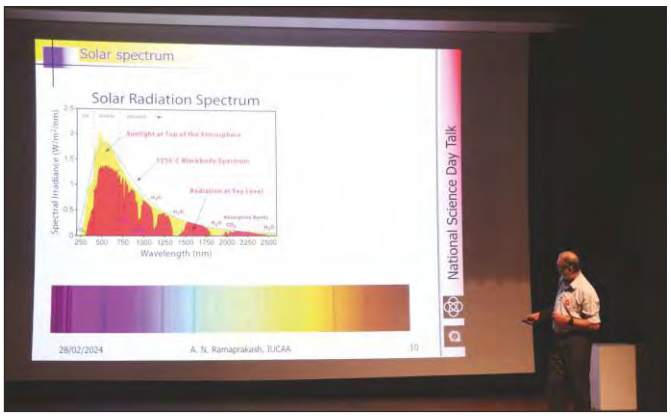
The coordinators were Vaidehi Paliya, Rajeshwari Dutta, Anupreeta More, Manasadevi T., and Shivaraj Kandaswamy. During the first round of Quiz, Moupiya Maji gave a fascinating talk to the teachers, who

accompanied the students.

After the finals of the quiz competition, all winning students received prizes from the IUCAA Director, including the students from the rural schools who were specially invited to IUCAA for a visit that day.

All the students were pleased to have a chance to interact with the IUCAA scientists during these National Science Day celebrations.

[For details see Khagol 132, April 2024]



OAE-India Teachers Training Workshop (16-17 February)

The OAE-India Node organised the training at IUCAA; 51 teachers (local and from other states) participated in this training.

(The above sessions had various members of the IUCAA Scipop Team as organisers or resource persons.)

Ph.D. DEGREES AWARDED

PH. D. PROGRAMME

During the year of this report, six IUCAA Research Scholars, namely **Deepali Agarwal** [Guide: Sanjit Mitra], **Sunil Choudhary** [Guide: Sukanta Bose], **Labanya Kumar Guha** [Guide: R. Srianand], **Shreejit Jadhav** [Guide: Sanjit Mitra], **P. Aromal** [R. Srianand] and **Divya Rana** [Surhud More] have defended their Ph.D. theses. The Jawaharlal Nehru University, New Delhi, has awarded their Ph.D. degrees.

The synopses of their theses are given below:

Deepali Agrawal

Radiometer Searches for Persistent Sources of Gravitational Waves using Ground-based Detectors

A collection of unresolvable sub-threshold gravitational wave (GW) sources may produce a detectable Stochastic Gravitational Wave Background (SGWB). The GWs originated during the early universe, such as slow-roll inflation, first-order phase transition, cosmic strings, primordial black holes, etc., are buried under the foreground from astrophysical sources such as compact binary systems. Enriched with astrophysical and cosmological information, the SGWB intensity may have an intrinsic or extrinsic anisotropic distribution from the sources in the nearby universe. This thesis presents detection methods and analyses for such an anisotropy using the GW radiometer algorithm.

Firstly, we use the radiometer method to perform an all-sky unmodeled search for point-like narrowband sources of SGWB, which is performed by exploiting the advantage of the recent improvements in search algorithms such as data folding and `PyStoch`. This search is sub-optimal for the known sources of continuous waves, such as spinning neutron stars in isolated or binary systems for which the phase evolution can be modeled with manageable parameter space. This search complements the match-filtering-based searches for continuous GW being robust to poorly modeled sources such as accreting neutron stars in X-ray binaries. The angular power spectrum is a good proxy for probing the extended anisotropy of statistically isotropic Gaussian background. We use the narrowband maps created on a pixel basis to extract the narrowband angular power spectrum and develop a method to use the spectrum's signal-to-noise ratio (SNR) as the detection statistic. The constraints from our search can be used to constrain theoretical models which predict the SGWB angular power spectra and for estimating or constraining the corresponding parameters.

This thesis's second part focuses on mapping the anisotropy of the broadband SGWB sources. The imaged sky maps are convoluted with the detectors' response. The maximum likelihood estimation for the unbiased anisotropy involves the inversion of the pixel-to-pixel noise covariance matrix, which is numerically challenging due to an ill-conditioned matrix. Previous searches either accounted for angular correlations in the map using the spherical harmonic basis, where regularization was relatively easier, or ignored the pixel correlation. Using singular-value decomposition and Bayesian regularization schemes, we explore various ways to account for the pixel-to-pixel Fisher information matrix (FIM). Through an injection study, we account for their ability to distinguish the signal from the noise and set upper limits. Remarkably, we find that, due to nuances involved in the regularization schemes, the simplest method of using the convolved (dirty) map with a normalized variance, which was used in the LIGO-Virgo-KAGRA (LVK) Collaboration analysis, provides reasonable upper limits as the elaborate schemes with the full noise covariance matrix. Hence, we recommend using this simple method, though

more regularization schemes may be explored to obtain more substantial upper limits.

The standard searches for the broadband SGWB model spectral dependence by a power law characterized by the spectral index α. Since SGWB sky is populated with the GW sources having distinct spectral indices and the detector observes a convoluted effect of these populations, it is necessary to account for the spectral indices correlations. Here, we develop a maximum likelihood-based statistic and demonstrate its capability of producing unbiased results with injection study. Then, we set joint constraints on the all-sky flux of broadband SGWB using real data.

Finally, using a targeted search, we set constraints on the ensemble properties, such as the number of sources and ellipticity of galactic millisecond pulsars, assuming that their spatial and spectral features are known a priori from electromagnetic observations. Being a forward modeling problem, such a search is immune to the deconvolution problem.

Sunil Choudhary

Analytical and machine-learning solutions for hunting binary black holes and dark matter constituents

This dissertation primarily focuses on enhancing the sensitivity of LIGO-Virgo's search for gravitational wave signals originating from compact binary coalescences (CBCs). It addresses a significant challenge posed by short-duration noise transients, also known as blip glitches, present in the LIGO-Virgo data, which adversely affect the sensitivity of the compact binary coalescence searches, especially in the high mass region of the parameter space. Additionally, the dissertation investigates GW signals from binary black holes (BBHs) surrounded by scalar field clouds, using chirping sine-Gaussian waveforms to model the ringdown phase and constrain parameters of the surrounding cloud, such as the mass of constituent particles and the field strength.

In Chapter Two, the dissertation discusses efforts to develop a χ^2 statistic using a unified χ^2 formalism, aiming to improve the sensitivity of searches in the high mass region of CBC parameter space. This includes formulating a χ^2 statistic by utilizing morphologies of both signal and glitches, using sine-Gaussian projection maps to select appropriate basis vectors, and incorporating phase information into the basis vectors. The effectiveness of the approach is demonstrated by applying it to real data from LIGO-Hanford and LIGO-Livingston detectors, showing improvements in sensitivity compared to traditional methods. Complementing the above method, Chapter Three focuses on identifying and vetoing blip glitches using machine learning techniques. The study constructs a deep-learning neural network trained on the sine-Gaussian projection maps of simulated BBH signals and real noise data to efficiently distinguish between BBH signals and blip glitches. Results show significant improvements in sensitivity, with the network outperforming traditional methods in identifying BBH signals and mitigating false positives. When tested on real GW events, it correctly identifies 95% of the events in the third Gravitational-wave Transient Catalog (GWTC-3).

Finally, the dissertation delves into the analysis of BBH systems surrounded by scalar field clouds, aiming to constrain the physical characteristics of these clouds through GW observations. Numerical simulations are used to study the gravitational-wave signals emitted during the merger-ringdown phase, revealing insights into the

effects of scalar field clouds on BBH waveforms. The study models the merger-ringdown signal using a chirping sine-Gaussian waveform, enabling constraints on the mass and strength of ultra-light bosons constituting the scalar field clouds. Overall, the dissertation presents a comprehensive approach to improving GW signal detection, addressing challenges posed by noise transients, and advancing our understanding of astrophysical phenomena involving BBH systems and scalar field clouds. Sine-Gaussian waveforms are central to the analysis presented in the thesis.

Labanya Kumar Guha

Probing the Nature, Environment, and Evolution of Ultrastrong Mg II Absorption Systems

According to the modern theoretical paradigm, galaxies evolve by means of a slowly varying equilibrium between gas accretion, galactic-scale winds, and in-situ star-formation in the galactic disks (Ref. 1). Galactic-scale outflows with velocities of 100-1000 $\mathrm{km\,s^{-1}}$, probed by "down-the-barrel" low-ionization (e.g., Na I, Mg II and Fe II) absorption lines, are ubiquitous in galaxies (Refs. 9,11,4,7,8,3). *While the presence of winds in down-the-barrel studies is well-established, their locations (important for deriving wind parameters such as the mass outflow rate) with respect to the stellar disks cannot be constrained.*

Quasar absorption line studies, on the other hand, have established the presence of a cool circumgalactic medium (CGM) around galaxies out to projected distances of a few 100 kpc (Refer to references 2,10,12). It is now well recognized that the kinematically complex, multi-phase CGM plays a crucial role in regulating gas flows in and out of galaxies. *In CGM studies using background quasars, unlike the down-the-barrel experiments, the distance of the absorbing gas with respect to the host galaxy is well measured. Nevertheless, it is difficult to establish a direct link between host galaxy properties like star formation and absorbing gas, especially at large impact parameters.* Probing star-forming galaxies using background quasar sight lines at very low impact parameters (e.g., within the regions influenced by winds over a characteristic time-scale of star formation) can provide vital clues on the role played by large-scale winds in shaping the physical conditions of the CGM. For example, an outflow moving with a speed of 200 $\mathrm{km\,s^{-1}}$ can influence a region out to $\sim$20 kpc surrounding galaxies in about 100 Myr [i.e., comparable to the time-scale for UV continuum-based SFR][Ref. 6].

In this thesis, by utilizing two distinct classes of Mg II absorption systems: (i) Ultra-Strong Mg II absorption systems (USMg II) and (ii) Galaxies On Top Of Quasars (GOTOQs), we study the largest sample of quasar-galaxy pairs at very small impact parameters (within a few tens of kpc) to investigate the nature large scale gas flows operating at disk-halo interface of galaxies and its connection to the host galaxy properties. The organization of the thesis is as follows:

Host Galaxies of ultrastrong Mg II absorbers at $z \sim 0.5$: From a sample of 109 candidates USMg II systems at $0.4 \leqslant z \leqslant 0.6$, we confirm 27 and identify host galaxies of 20 systems based on associated nebular line emission from our SALT observations or from SDSS fiber spectra. The measured impact parameter, [O II] luminosity, star formation rate, B-band luminosity, and stellar mass are in the ranges $7.3 \leq \mathrm{D[kpc]} \leq 79$, $0.2 \leq \mathrm{L_{[O\ II]}[10^{41}\ ergs^{-1}]} \leq 4.5$, $2.59 \leq \mathrm{SFR[M_\odot yr^{-1}]} \leq 33.51$, $0.15\mathrm{L_B^*} \leq \mathrm{L_B} \leq 1.63\mathrm{L_B^*}$ and $10.21 \leq \mathrm{log[M_*/M_\odot]} \leq 11.62$ respectively. The impact parameters found are larger than predicted by the W_{2796} vs. D relationship of the general population of Mg II absorbers. At a given D, USMg II host galaxies are more luminous and massive than typical

Mg II absorbers. However, the measured SFRs are slightly lower than that of main-sequence galaxies with the same $M_\star$ at $z \sim 0.5$. We report a correlation between $L_{[O\ II]}$ and W_{2796} for the full population of Mg IIabsorbers, driven mainly by the host galaxies of weak Mg II absorbers that tend to have low $L_{[O\ II]}$ and large impact parameters. We find at least ∼33% of the USMg II host galaxies (with a limiting magnitude of $m_r < 23.6$) are isolated, and the large W_{2796} in these cases may originate from gas flows (infall/outflow) in single halos of massive but not starburst galaxies. We also find galaxy interactions could be responsible for large velocity widths in at least ∼17% cases.

Host Galaxies of ultrastrong Mg II absorber at $z \sim 0.7$: With the success of our USMg II survey at $z \sim 0.5$, we proceed further with a slightly higher redshift ($z \sim 0.7$) sample to identify any redshift evolution associated with these systems. We report spectroscopic identification of the host galaxies of 18 USMg II systems at $0.6 \leqslant z \leqslant 0.8$. Combining these with twenty host galaxies at $0.4 \leqslant z \leqslant 0.6$ reported in our previous survey, we compile the largest sample of USMg II absorbers with host galaxy identification. The measured impact parameters (D) are found to be larger than expected ($6.3 \leqslant D[\mathrm{kpc}] \leqslant 120$ with a median value of 19 kpc), and the USMg II host galaxies do not follow the canonical $W_{2796} - D$ anti-correlation. We show that the presence and significance of this anti-correlation may depend on the sample selection. The USMg II absorbers are at the upper frontier of the W_{2796} vs D diagram. The $W_{2796} - D$ anti-correlation seen for the full sample of Mg II absorbers does show a mild evolution at low W_{2796} end over the redshift range $0.4 \leqslant z \leqslant 1.5$ with an increase of the impact parameters. Compared to the host galaxies of normal Mg II absorbers, USMg II host galaxies are brighter and more massive for a given impact parameter. Also, these systems preferentially pick star-forming galaxies with a higher [O II] luminosity than the field galaxies. However, USMg II host galaxies have slightly lower ongoing star-forming rates than the main sequence galaxies with the same stellar mass and redshift, indicating that these galaxies are transitioning from star-forming to quiescent galaxies. For a limiting magnitude of $m_r < 23.6$, we find that at least 29% of the USMg II host galaxies are isolated, and the large widths of the Mg II absorption in these cases may be the result of gas flows (infall/outflow) in isolated haloes of massive star-forming but not starbursting galaxies. We also discover that, in at least 21% of cases, we can associate more than one galaxy with the absorber where interactions may cause wide velocity spread.

Spectroscopic follow-up of the GOTOQ sub-sample using SALT : Obtaining the impact parameters of the foreground galaxies in GOTOQs straight from the SDSS fiber-fed spectroscopy is challenging. To constrain the impact parameter as well as to identify the signatures of the disk-halo interaction, like the presence of inflows and outflows around the galactic disk, we consider a sub-sample of the GOTOQ sample created by Joshi et al [Ref. 5]. Thus, we consider systems with higher star-formation activity as one expects the 'galactic fountains' to be manifested better with higher starburst-driven feedback. Since the ongoing SFR of a galaxy is directly related to the nebular emission lines present in its spectrum, we use the [O II] emission line luminosity above a certain threshold to select for systems with higher SFR. A sub-sample of 20 systems out of 55 GOTOQs accessible to SALT is finally followed up spectroscopically using SALT. Using long-slit spectra obtained at different position angles, we could constrain the impact parameter for 16 of these systems in the range $4.8 \leqslant D(\mathrm{kpc}) \leqslant 16.3$. Using a statistically significant number of the QGPs with $\lesssim 10$ kpc at high redshift, we confirm the flattening of the $W_{2796} - D$ anticorrelation at small D. We also confirm that the visible photometric extensions around the GOTOQs are associated with the foreground galaxies, and the D in these cases can be directly obtained from the broadband images.

Nature of the Galaxies On Top Of Quasars producing Mg II absorption: Quasar-galaxy pairs at small separations are important probes of gas flows in the disk-halo interface in galaxies. We study host galaxies of 198 Mg II absorbers at $0.36 \leq z_{\mathrm{abs}} \leq 1.05$ that show detectable nebular emission lines in the SDSS spectra. We report measurements of impact parameter ($5.9 \leq D[kpc] \leq 16.9$) and absolute B-band magnitude ($-18.7 \leq M_B \leq -22.3$ mag) of host galaxies of 74 of these absorbers using multi-band images from the DESI Legacy Imaging Survey, more than doubling the number of known host galaxies with $D \leq 17$ kpc. This has allowed us to quantify the relationship between Mg II rest equivalent width (W_{2796}) and D, with best-fit parameters of $W_{2796}(D = 0) =$

3.47 ± 0.22Å and an exponential scale length of 22.8$\pm$2.4 kpc. We find a significant anti-correlation between M_B and D, and M_B and W_{2796}, consistent with the brighter galaxies producing stronger Mg II absorption. We use stacked images to detect average emissions from galaxies in the full sample. Using these images and stacked spectra, we derive the mean stellar mass ($9.4 \leq \log(M_*/M_\odot) \leq 9.8$), star formation rate ($2.3 \leq \mathrm{SFR}[M_\odot \mathrm{yr}^{-1}] \leq 4.5$), age (2.5$-$4 Gyr), metallicity (12+log(O/H)$\sim$8.3) and ionization parameter (log q[cm s^{-1}]$\sim$ 7.7) for these galaxies. The average M_* found is less than that of Mg II absorbers studied in the literature. The average SFR and metallicity inferred are consistent with that expected in the main sequence and the known stellar mass-metallicity relation, respectively. High spatial resolution follow-up spectroscopic and imaging observations of this sample are imperative for probing gas flows close to the star-forming regions of high-z galaxies.

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Sreejith Jadhav

Algorithms for Gravitational Wave Data Analysis and Detector Controls Based on Modern Techniques

Since the observation of the first gravitational-wave (GW) signal by the twin advanced LIGO detectors on 14th September 2015, the advanced LIGO and advanced Virgo detectors have observed over 90 events so far, firmly establishing the field of observational GW astronomy. Along with providing an excitingly new perspective to astrophysics, the field also poses unique challenges in data analysis and instrumentation. In this thesis, we have explored the applications of machine learning (ML) techniques to solve some of these problems more eciently, with a particular emphasis on implementing the solutions on real data and actual lab-based experiments.

The sensitivity of GW searches is marred by noise transients of terrestrial origin (glitches). We demonstrate that integrating deep learning (DL) methods with conventional search pipelines can significantly improve effective search sensitivity. Apart from recovering all the events from the first GW transient catalogue (GWTC-1), especially the low significance events GW151012 and GW170729, our analysis detected an additional GW signal, strongly supporting the claimed sensitivity gains. To improve the reliability of DL approaches and, thus, our confidence in the accuracy of their results, we propose an elaborate strategy for their development. We build a new metric that captures the visible strength of compact binary coalescence (CBC) features and allows a faithful generation of large volumes of training data. We employ a denoising variational auto-encoder to obtain a reduced and smooth representation of the CBC features in the input. We build a classifier which maps this encoding to the binary output corresponding to CBC and noise classes through densely connected layers. We probe the failure modes of this classifier using adversarial attacks and introduce a novel first step towards increasing the robustness of the model by employing generative adversarial networks (GANs). We present the search results along with the sensitivity estimates from the search of real LIGO data.

As the technology of the GW detectors evolves increasingly complex, the control systems are expected to get overwhelmingly involved. Using Genetic Algorithms, we automate the procedure of aligning the input beam into the optical cavities, which are the fundamental units of GW detectors. It is otherwise a tedious manual task due to the extreme sensitivity of these cavities to misalignments. Our tool reaches the ideal alignment of the experimental setup within 11.5 minutes.

Aromal P.

Probing ultra-fast outflows in BAL quasars using multi-epoch spectroscopy

Strong outflows with velocities reaching up to a few 10,000 km s^{-1} are seen in quasar spectra as blue-shifted broad absorption lines (BALs) with velocity widths of several 1000 km s^{-1}. Associated quasars are commonly known as 'BAL' quasars. These powerful outflows can carry a significant amount of mechanical energy and momentum which can in principle contribute to AGN feedback mechanisms, regulating the central black hole growth

and the host galaxy evolution. They might interact with the inter-stellar medium of the host galaxies which can result in quenching or enhancement of star formation. If these outflows can escape the galactic potential wells they can also contribute to the chemical enrichment of the intergalactic medium (IGM) in the vicinity of galaxies.

The time variability of BAL profiles is a powerful tool for studying the origin and evolution of BAL outflows. Monitoring BAL variability over different time scales can put tight constraints on the BAL lifetime, location of the outflow, etc., and provide significant insights on the origin and physical mechanisms driving the flow. The time variability of C IV, Si IV and Mg II BAL profiles have been studied extensively in the literature. BAL variability includes extreme optical depth variations like emergence, disappearance and kinematic shift of BALs. Possible reasons for these variations include : (i) fluctuations in quasar ionizing flux, (ii) changes in covering fraction of the outflow with respect to the central source, (iii) bulk motion of the outflow. It has been found that significant changes in the equivalent width and/or shape of the BAL trough occur typically on time scales of a few months to years in the quasar rest frame.

One of the most interesting aspects of ultra-fast outflows (UFO) is the presence of absorbing atoms that have reached very high kinetic energies despite the presence of strong gravitational potential of the central supermassive black hole (SMBH). Their high velocities can be attributed to the fact that these outflows originate from within a few hundred gravitational radii of the central engine. Since the UFOs are believed to be located very close to the accretion disk after its formation, ionization changes can occur rapidly as its distance from the central ionizing source (i.e accretion disk) changes by an appreciable factor even if the quasar radiation does not vary considerably. The X-ray UFOs are defined as highly ionized absorbers with blue-shifted Fe XXV and Fe XXVI (H- and He- like Fe) K-shell absorption lines having velocities $v > 10^4\, kms^{-1}$. There is a considerably higher detection rate of X-ray UFOs ($\sim$ 35%) and the variability time scales of these absorption lines range from a few years to less than $\sim$ 100 ks. Hence, it is essential to study in detail the time variability of UFOs as seen in BALs as well at both short- and long-time scales with more frequent spectroscopic monitoring of their rest-frame UV spectra.

For this, we have created a sample of 64 UFO BAL sources which has been spectroscopically monitored using the Southern African Large Telescope (SALT) in addition to the already publicly available SDSS data (**?**). This sample contains quasars with r-band magnitude $I_{r-band} < 18.5$ to ensure good SNR and also a redshift cut of z > 2 so that we can probe both C IV and Si IV BALs in the SALT wavelength range. We observed the sources in long-slit configuration with moderate resolution spectroscopy. We have obtained 164 SALT spectroscopic data for the 64 sources (almost all of them having at least two epochs with a few months' separations in the rest-frame) in the sample by the end of the 2022-2 SALT observing cycle. This leads to a total of 375 spectra (after adding 211 SDSS spectra) in our sample with a median of 4 for the total number of spectroscopic epochs per source. In this thesis we summarize our main finding based on statistial analysis of this sample. The organization of the thesis is as follows.

Chapter 1 - Introduction : This chapter provides an overview of the structure of AGNs and different types of AGN outflows which is the main focus of the thesis.

Chapter 2 - Time variability of ultra-fast BAL outflows using SALT: C IV equivalent width analysis : We study the time variability (over $\leq$7.3 yrs) of ultra fast outflows (UFOs) detected in a sample of 64 C IV broad absorption line (BAL) quasars (with 80 distinct BAL components) monitored using the Southern African Large Telescope. By comparing the properties of the quasar in our sample with those of a control sample of non-BAL quasars we show that the distributions of black hole mass are different and the bolometric luminosities and optical photometric variations of UFO BAL quasars are slightly smaller compared to that of non-BAL quasars. The detection fraction of C IV equivalent width (W) variability ($\sim$95%), the fractional variability amplitude ($\frac{\Delta W}{W}$) and the fraction of "highly variable" BAL (i.e., $\left|\frac{\Delta W}{W}\right|$>0.67) components ($\sim$ 33%) are higher in our sample compared

to the general BAL population. The scatter in $\frac{\Delta W}{W}$ and the fraction of “highly variable" BALs increase with the time-scale probed. The $\frac{\Delta W}{W}$ distribution is asymmetric at large time scales. We attribute this to the BAL strengthening time scales being shorter than the weakening time scales. The BAL variability amplitude correlates strongly with the BAL properties compared to the quasar properties. BALs with low W, high-velocity, shallow profiles, and low-velocity width tend to show more variability. When multiple BAL components are present a correlated variability is seen between low- and high-velocity components with the latter showing larger amplitude variations. We find an anti-correlation between the fractional variations in the continuum flux and W. While this suggests photoionization-induced variability, the scatter in continuum flux is much smaller than that of W (these results are published in Aromal et al 2023).

Chapter 3 - Pixel-based variability analysis of C IV absorption in UFO BAL quasars : In this chapter we complement the equivalent width based analysis presented in the previous chapter using transmitted flux based analysis. Initially, we study the pixel-based analysis of BAL variability in our UFO BAL sample by splitting the BAL region in each source into 2000 km s^{-1} velocity bins and quantifying variability at each velocity bin averaged over all sources. We find a strong monotonic increase in the strength of variability as the outflow velocity increases. For each source in our sample, we also identify “variable regions" as those regions inside a BAL trough where the flux difference ($\Delta F = F_2 - F_1$) between two epochs is greater than 0.1 for a velocity width of at least 500 km s^{-1}. It is observed that the total number of variable regions per BAL increases with longer time scales, but their relative size remains only a few tenths of the entire width of the BAL. We find that the width of the variable regions is smaller at short time scales but later increases as the time scale increases with typical widths of the order of $\sim$ 2000 km s^{-1}for time scales more than 2 years in the rest-frame. The same trend is true for the fraction of the total width of the variable regions with respect to the velocity width of the BAL (f$_{var}$) and also for the maximum change in flux inside the variable region ($\Delta d_{var,max}$). We notice that the distributions of the absolute velocity of the variable regions with respect to $z_{\rm em}$ and the relative position of the variable region with respect to BAL profile remain the same irrespective of the time scale. We also study the connection between "variable region" properties and overall equivalent width variations shown by the BAL troughs. Our analysis also identify that $\sim$17% of the UFO BALs show uncorrelated variability within the BAL trough.

Chapter 4 - Correlated time variability of multicomponent high-velocity outflows in J162122.54+075808.4 : Here, we focus on the BAL variability of an individual source named J162122.54+075808.4 from the UFO BAL sample which has been spectroscopically well-monitored as part of our SALT observing program. We present a detailed analysis of time variability of two distinct C IV broad absorption line (BAL) components seen in the spectrum of J162122.54+075808.4 ($z_{\rm em}$= 2.1394) using observations from SDSS, NTT and SALT taken at seven different epochs spanning about 15 years. The blue-BAL component (with an ejection velocity, $v_{\rm e} \sim 37,500$ km s^{-1}) is an emerging absorption that shows equivalent width variations and kinematic shifts consistent with acceleration. The red-BAL component ($v_{\rm e} \sim 15,400$ km s^{-1}) is a three component absorption. One of the components is emerging and subsequently disappearing. The two other components show kinematic shifts consistent with acceleration coupled with equivalent width variability. Interestingly, we find the kinematic shifts and equivalent width variability of the blue- and red-BAL components to be correlated. While the C IV emission line flux varies by more than 17% during our monitoring period, the available light-curves (covering rest frame 1300-2300Å) do not show more than a 0.1 mag variability in the continuum. This suggests that the variations in the ionizing flux are larger than that of the near-UV flux. However, the correlated variability seen between different BAL components cannot be explained solely by photoionization models without structural changes. In the framework of disk wind models, any changes in the radial profiles of density and/or velocity triggered either by disk instabilities or by changes in the ionizing radiation can explain our observations. High-resolution spectroscopic monitoring of J1621+0758 is important to understand the physical conditions of the absorbing gas and thereby to constrain the parameters of disk-wind models (these results are published in Aromal et al 2021).

Chapter 5 - Coordinated time variability of multi-phase ultra-fast outflows in J132216.25+052446.3 : We present a time variability analysis of broad absorption lines (BAL; spread over the velocity range of 5800-29000 km s^{-1}) seen in the spectrum of J132216.25+052446.3 ($z_{\rm em}$ = 2.04806) from the UFO BAL sample at ten different epochs spanning over 19 years. The strongest absorption component (BAL-A; spread over 5800-9900 km s^{-1}) is made up of several narrow components having velocity separations close to C IV doublet splitting. The C IV, N V and Si IV absorption from BAL-A show correlated optical depth variability without major changes in the velocity structure. A very broad and shallow absorption (BAL-C; spread over the velocity range 15000-29000 km s^{-1}) emerged during our monitoring period coinciding with a dimming episode of J1322 + 0524. All the identified absorption lines show correlated variability with the equivalent widths increasing with decreasing flux. This together with the C IV emission line variability is consistent with ionization being the main driver of the correlated variability. The observed UV-continuum variations are weaker than what is required by the photo-ionization models. This together with a scatter in the C IV equivalent width at a given continuum flux can be understood if variations of the C IV ionizing photons are much larger than that of the UV continuum, the variations in the ionizing photon and UV fluxes are not correlated and/or the covering factor of the flow varies continuously. We suggest BAL-A is produced by a stable clumpy outflow located beyond the broad emission line region and BAL-C is a newly formed wind component located near the accretion disk and both respond to changes in the ionizing continuum (these results are published in Aromal et al 2022).

Chapter 6 - Summary & Future directions : In the final chapter, we summarize the main results of the thesis and also provide future directions based on the thesis work. The thesis focuses on the detailed analysis of the time variability in UFO BAL sample as a whole and also on two particular sources which are well-monitored and show extreme variability events during our monitoring period.

Divya Rana

Probing cosmology using large scale structure correlations

The statistics of large-scale structure of the matter distribution in the Universe reflect the cosmological initial conditions and their evolution with time. The cross-correlations of various tracers of the matter density distribution thus contain important astrophysical as well as cosmological information. In this thesis, we will use such cross-correlations in order to address three topics of contemporary interest: a) the connection between galaxies and galaxy groups to their dark matter halos, b) the structure of dark matter halos of galaxy clusters, c) and, the inference of the Hubble constant from observations of gravitational wave mergers. Using weak gravitational lensing from the Subaru Hyper Suprime-Cam (HSC), we will present the tightest constraints on the group observable halo mass relations of galaxy groups from the Galaxy And Mass Assembly (GAMA) survey, as well as the first results from weak lensing on the galaxy size-halo size relation of GAMA galaxies. Combining cluster-galaxy cross-correlations with weak lensing, we will present the tightest constraints on the location of the halo edges of X-ray clusters selected from the eFEDS survey. Finally, we will also present a method to constrain the Hubble constant based on the cross-correlation between galaxies and gravitational wave events and discuss its practical implementation.

Computing Facility

The IUCAA Computing Facility offers state of the art computing hardware and technology rich environment for IUCAA members, associates and visitors. It also extends an array of specialized High-Performance Computing (HPC) environments to the academic community for their research.

The hardware and devices currently managed by the computing facility include about 350+ servers and desktops, 100+ laptops, 80+ printers and scanners, three large High-Performance Computing systems and over 9.5 PiB of storage, in addition to diverse equipment deployed for an extensive, high throughput wired and wireless campus-wide network. The number of registered Wi-Fi devices are over 900 and e-mail accounts served by the computing facility are nearly 825.

IUCAA provides e-mail services to its members and associates, the total number of accounts being nearly 825. IUCAA has its own registered domain name as "iucaa.in", "associates.iucaa.in", "ligo-india.in" and "mailman.gw.iucaa.in". The WAN services are provided by the National Knowledge Network over a 1 Gbps fibre connectivity, with a fall back arrangement over a 50 Mbps line from BSNL.

In the year April 2023- March 2024 emphasis was given to implementation of:

1) **Expansion of the Pegasus cluster**
The Pegasus cluster deployed in 2019 consists of two head nodes, four login nodes, two graphics nodes, four GPU nodes, 2560 compute cores, and 2PiB Parallel File System (PFS) storage. Several new users have been added in the last two years, and all users use the cluster extensively. The average cluster utilisation is more than 90%, resulting in a considerable wait time for many jobs. To cater for the ever-increasing need of computational power for large-scale computational jobs and reduce the computational job's wait time, the Pegasus cluster will be augmented by adding 20 compute nodes.

2) **Replacement of 40KVA UPS system with 60 KVA modular UPS**
IUCAA has a 40 KVA UPS dedicated to supporting the Rack LCPs, Chiller pumps, BMS utilities, Carel setup and power supply to the Utility room and data centre. Due to the increasing load, we needed a Higher-capacity modular UPS system. The old 40 KVA UPS has been replaced with a new 60 KVA UPS system to support the expanding load.

3) **Installation of 200 TB Unified storage**
IUCAA has dedicated 200TB enterprise class storage for the virtualization infrastructure(VI) setup (Server Virtualisation and Virtual Desktop Infrastructure). This storage is more than nine years old and has reached the end of life and support with more than 80% of storage capacity utilised, affecting the storage performance. To enable the smooth functionality of the VI setup, better support and performance, the storage has been replaced with the new 200TB unified storage.

4) **Expansion of MALS archival storage by 1PiB**
e next phase of MALS observations focusing on the UHF band (remaining ~1100 hrs) was scheduled to start in 2023. To process MALS data, we have procured 4PB PFS storage (hot), 1PB (archival storage), and 1PB tape storage(cold). Till now, we have received about 150 tapes containing L band data. We expect 81 tapes containing UHF band data by next month and will receive around 250 in the near future. We have moved about 1PB of processed L band data to archival storage, and still, 1.5PB of the processed data is on PFS storage. Hence, the archival storage is expanded by an additional 1 PiB, so processed L-band data may be moved from the PFS storage to archival storage, enabling the processing of UHF datasets.

5) **Network monitoring and Analysis Software setup**
IUCAA has an extensive network (wired LANS and W-LAN). As the number of users increases, the network complexity increases, and keeping the network system secure and running is paramount. A new network monitoring and management software, has been procured that helps in monitoring, manage, and providing ease of maintenance, reducing significant network issues and to ensure the utmost uptime.

6) **Replacement of existing Email Servers hardware**
IUCAA hosts Zimbra email services on the two dedicated servers with the warranty is about to expiring. Two new servers have been procured to ensure uninterrupted mail services.

7) **Renewal of Astronomical software services.**
Scientists at IUCAA carry out research in a wide range of Astronomy and Astrophysics, such as Classical and quantum gravity, Cosmic magnetic fields, cosmology, large-scale structure, Galactic and extragalactic astronomy, Gravitational waves, High energy astrophysics, Instrumentation for astronomy, Observational Astronomy (Optical, UV, X-ray, and Radio), Quantum metrology for precision measurements, Solar Physics, and many more. Many of these fields require high-level data visualizations out of complex numerical data. To help create such meaningful visualizations, IUCAA procured the licenses for Mathematica, Matlab, and IDL software services.

The Computer Centre continues to provide technical support to IUCAA associates, project students as well as visitors from universities and institutions within India and abroad.

Work done by personnel at the Computing Facility

The Computing facility employs 10 personnel, who carry out the daily functions that include:

1. Architecting overall IT solution /

technologies required for IUCAA and present it to the Computer Facilities Committee for consensus.

2. Framing policy documents and finalizing them in consultation with the Computer Facilities Committee members.

3. Drawing up specification of the RFP (Request For Proposal) tender document for IUCAA IT required to be purchased and oversee all purchase related procedure and follow up.

4. Maintenance of IT hardware in the campus including servers, desktops, mobile computing equipment, printers etc.

5. Providing in-house design, development and maintenance support to the Administrative Office automation software (iOAS) and IUCAA website. (Designed web portals consisting online application module for various workshops.)

6. Maintaining Zimbra email servers and mirror sites hosted at IUCAA, and their day-to-day administration.

7. Configuration and management of data backups.

8. Design, management and administration of network topology and firewall rules.

9. Administration of Ruckus wireless network covering the entire office as well as residential campus. Providing end users support for Wi-Fi devices such as laptops, mobile devices.

10. Day to day administration of Virtualization infrastructure and various servers catering to Administration such as AD, etc.
11. Maintenance of Video Conferencing equipment and end user support.

12. Management of inventory of computer center consumable items and Assets and Furniture and its tracking.

13. Procurement of SSL certificates and software for all the relevant web servers at IUCAA.

14. End user service support to Administrative staff, Academic Visitors and Associates.

15. Infrastructure, management and coding support to IT intensive projects such as LIGO, MALS, SUIT, AstroSat, Big Data etc.

16. Procurement, installation and periodic upgradation of mathematical software such as Matlab, IDL, Mathematica meant for general IUCAA users and cluster users.

17. Procurement of Printers (Qty. 10), All in one Desktops (Qty 20), Laptops (Qty. 3), MacOS devices (Qty. 8) for the academic community, visitors and administrative officers.

18. Hardware Maintenance and General System Administration of clusters in IUCAA in coordination with OEM.

19. Assisting Library department to maintain their IT infrastructure.

20. Hosted GitLab for IUCAA users and associates.

21. Architecting new hardware solutions to address operational needs.

High Performance Computing

IUCAA currently has three major independent HPC clusters dedicated to different applications, namely Pegasus, SARATHI and VROOM.

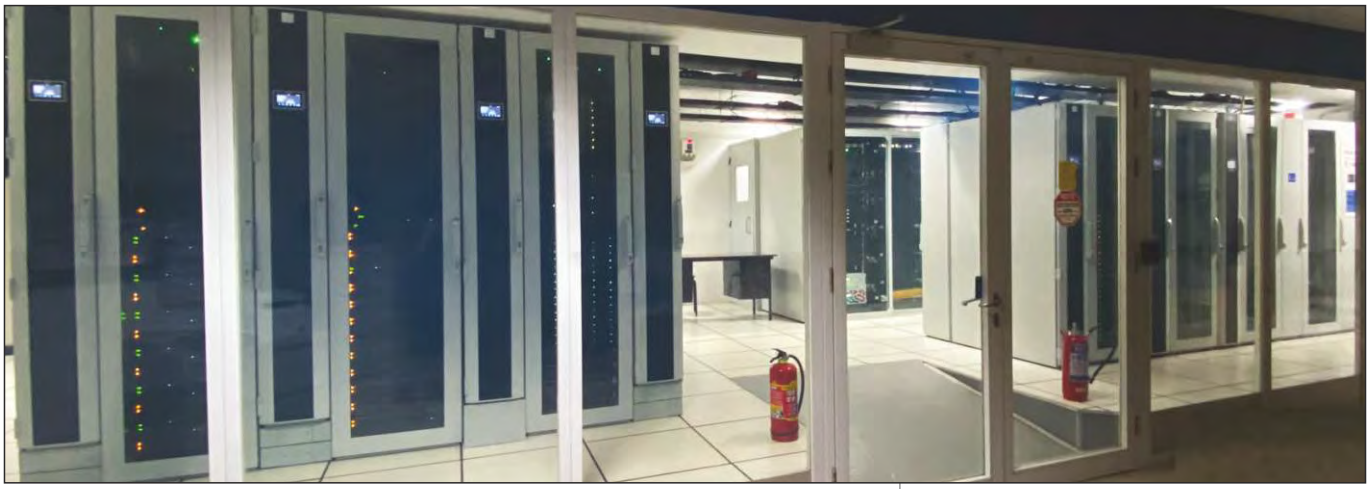
The **Pegasus Cluster** is to serve the general computing requirement of the astronomy community associated with IUCAA. It has 80 compute nodes, 4 gpu nodes with 32 cores and 384 GB (on old) & 512GB RAM (on new). It uses InfiniBand EDR (100Gbps) as an inter-connect, and Portable Batch System (PBS) as a job scheduler. For visualisation purposes, there are two dedicated graphics nodes equipped with NVIDIA Tesla P100 GPU cards. The cluster consists of more than 2600 Physical cores. The cluster is attached to a 2 PiB parallel file system (Lustre), which is capable of delivering 15 Gbps throughput. Theoretical computing speed of the Pegasus Cluster is 150 TF. The Pegasus cluster has been utilized by about 70 high volume users from IUCAA and various Indian Universities, running applications for Molecular Scattering, Molecular Dynamics, Stellar Dynamics, Gravitational N-Body Simulations, Cosmic Microwave Background Evolution, Fluid Mechanics, Magnetohydrodynamics, Plasma Physics, and the analysis of diverse astronomical data.

The **Sarathi Cluster** is primarily used for gravitational wave research and is mostly used by national and international members of the LIGO Scientific Collaboration (LSC), which includes many IUCAA members and Associates. The cluster is comprised of heterogeneous compute servers, it is built in three phases. The cluster consists of more than 8000 Physical cores. The theoretical peak performance of the compute node CPUs of the cluster is nearly 530 TFlops. The cluster has 2PiB PFS storage with 30Gbps write and read (1:1) throughput.

The **Vroom cluster** is used solely for the MeerKAT Absorption Line Survey (MALS). This cluster has 21 compute nodes, 2 MDS nodes, 4 GPU notes and 2 head node which delivers 25 TF computing speed and has a parallel file system of 3.5 PiB usable capacity attached to it. The cluster is also attached to 2 PiB archival storage for archiving/serving the processed data to international community.

HPC clusters listed in Top Supercomputers in India

Sarathi Cluster Phase III, Pegasus Cluster, and Sarathi Cluster Phase II are listed at 36th, 50th and 53rd rank respectively in the list of top Supercomputers in India published on January 31, 2024. The list is maintained and supported by CDAC's Terascale Supercomputing Facility (CTSF), CDAC, Bangalore. The list is available at https://topsc.cdacb.in/filterdetailstry?page=60&slug=January2024



IUCAA High-Performance Computing clusters, namely Pegasus and Sarathi.

(Picture Credit: Mr. Shashank Tarphe)

The staff of the Computing Facility at IUCAA.

(Picture Credit: Mr. Shashank Tarphe)

Chiller plant assembly for IUCAA Data Centre.

(Picture Credit: Mr. Shashank Tarphe)

Power conditioning room for IUCAA Data centre with UPS, battery banks and control panels

(Picture Credit: Mr. Shashank Tarphe)

IUCAA Library

The IUCAA library provides users access to a comprehensive collection of books and journals in astronomy, astrophysics, and related areas. The library acquired 64 new print titles and 361 eBooks from the Springer Physics and Astronomy collection for 2023-24 and renewed the subscription to Annual Reviews. The library maintained its renewals to the Grammarly Premium software and Overleaf, the collaborative cloud-based LaTeX editor for writing, editing and publishing scientific documents. The library renewed its subscriptions to 63 journals for 2023.

In addition to e-journal subscriptions, the library continued to receive access to seven e-resources, courtesy of the E-Shodh Sindhu Consortium for Higher Education Electronic Resources, MHRD, Government of India and two NDL e-resources as listed below:

1. American Institute of Physics
2. American Physical Society
3. Institute for Studies in Industrial Development (ISID) Database
4. JGate Plus (JCCC)
5. Springer Link 1700 Collection and Nature Journal
6. Taylor and Francis
7. Web of Science

NDL e-Resources

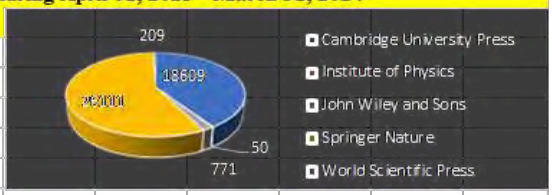
1. World e-Book Library (Now available through NDLI only)
2. South Asia Archive (SAA) (Under National Licensing (Perpetual)

The library has deployed the Remotlog access and authentication software to facilitate off-campus access to all the e-resources it subscribes to. Users, including Visiting Associates of IUCAA, have accessed the following e-resources.

- **American Association of Physics Teachers**

E-Books usage during April 01, 2023 - March 31, 2024

Publisher	Count
Cambridge University Press	18609
Institute of Physics	50
John Wiley and Sons	771
Springer Nature	26111
World Scientific Press	209



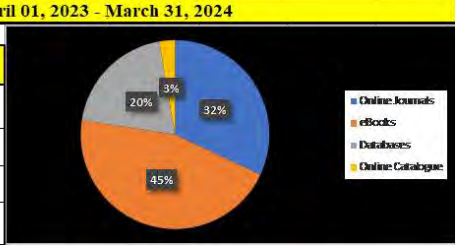
E-Journals usage during April 01, 2023 - March 31, 2024

Publisher	Count
American Institute of Physics	1708
American Physical Society	10637
Institute of Physics	9510
Nature	8336
Science Direct	3593
Springer	8495
Taylor and Francis	294

- **American Institute of Physics**
- **American Scientist**
- **Annual Review of Astronomy and Astrophysics**
- **Applied Optics**
- **American Physical Society**
- **Cambridge University Press**
- **EDP Sciences**
- **Institute of Physics**
- **Nature**
- **New Scientist**
- **Physics Today**
- **Physics Education**
- **Popular Science**
- **Science Direct**
- **Springer Nature**
- **Taylor and Francis**
- **Web of Science**
- **World Scientific**

Remotlog usage during April 01, 2023 - March 31, 2024

Resource	Count
Online Journals	735
eBooks	1043
Databases	456
Online Catalogue	62



In addition to the usual library business, the library team of five professionals and one library intern facilitated the following activities and services:

- **VIDWAN:** Created IUCAA faculty profiles on the VIDWAN portal (https://vidwan.inflibnet.ac.in/), which is developed and maintained by the Information and Library Network Centre (INFLIBNET) with financial support from the National Mission on Education through ICT (NME-ICT).

- **IRINS: The Indian Research Information Network System** is a web-based Research Information Management (RIM) service developed by the Information and Library Network (INFLIBNET) Centre. The portal facilitates the academic, R&D organisations,

faculty members, and scientists to collect, curate and showcase scholarly communication activities and provides an opportunity to create a scholarly network. The IUCAA faculty profiles are available at https://iucaa.irins.org.

- **Open Journal System (OJS):** Manage and maintain the IUCAA Annual Report, Khagol and Vyom issues on the IUCAA website using OJS (http://publication.iucaa.in/).
- **Document Delivery Service:** Fulfilled 173 article requests from 92 users.
- **Inter-library Loan Service:** Facilitated the loan of six books to three libraries.
- **Publication Charges and Memberships:** Processed seventeen publication charge requests and renewed one arXiv membership for 2023-24.
- **Plagiarism Reports:** Provided plagiarism reports for research papers using Ouriginal software (until 30.09.2023) and DrillBit-Extreme software (01.10.2023 onwards).
- **YouTube Channel:** The library's YouTube channel had 174 videos with 8.07K subscribers and 615,733 views during the period.
- **Publication Assistance:** Assistance to the Publications Department in compiling lists of publications by IUCAA Academics and Visiting Associates and compiling ICARD reports for the 35th Annual Report.

N. Nageswaran,
Shashikant Mirkute,
Hemant Sahu,
Kanak Saha (Head, Library),
Vijay Rai,
Nirupama Bawdekar

(Picture Credit: Mr. Shashank Tarphe)

Horn Antenna Workshop

A workshop on fabricating a horn antenna was organised for teachers by ACE IUCAA from the 3rd to the 6th of April 2023. The resource persons were Avinash Deshpande (IUCAA), Prakash Arumugasamy (IUCAA), Jameer Manur (IUCAA), Ashish Mhaske (IUCAA), Dhruba J Saikia (IUCAA), Neeraj Gupta (IUCAA), Ruta Kale (NCRA), and Bhal Chandra Joshi (NCRA).

On the first day, lectures covered the basic principles of antennas, radio astronomy, receiver chain, and observations using the horn antenna and HI observations of the Milky Way galaxy. On the second day participants assembled the horn antenna and tested the receiver chain in the ACE Astro Lab. On the third day participants took the observations of the HI line of the Milky Way galaxy using the horn antenna they had assembled, and also installed the software required for the observations and analyses. These were followed by semi-informal discussion sessions with experts on the Giant Metrewave Radio Telescope and radio astronomy techniques and instrumentation. The workshop's hands-on activities included:

- Assembling the pre-fabricated parts of the horn antenna and its receiver chain;
- Observing neutral atomic hydrogen (HI) in emission from the Galactic plane;
- Analyzing the data to obtain the Galactic rotation curve.

Participants seen assembling the horn antenna and working on the electronics

A group photograph of the participants of the horn antenna workshop

There were 12 participants from different parts of the country who worked together in groups, actively interacting and learning. The participants presented their analysis and results and shared their experiences in a follow-up presentation session held after the workshop on 3rd June 2023. The ACE IUCAA Team coordinated the Horn Antenna Workshop.

Workshop on Astronomy-Themed Experiments

A workshop on astronomy-themed experiments for faculty members of colleges and universities interested in exploring, creating and sharing laboratory experiments based on concepts in astronomy for teaching at the undergraduate and postgraduate levels was organized from 8th to 12th August 2023 at IUCAA. The long-term goal was to produce an open-source repository of astronomy-themed experiments covering diverse topics. There were about 30 participants from over a dozen institutions presenting a wide range of experiments. The workshop started with a presentation of a very

A group photograph of the participants of the Workshop on Astronomy-Themed experiments

Dipankar Bhattacharya describing the experiments developed at Ashoka University

creative set of experiments at the undergraduate level developed by Dipankar Bhattacharya and his team at Ashoka University. The workshop covered a wide range of experiments including optical data analysis using archival data as well, such as from GAIA, a number of radio-astronomy related experiments including determining the rotation curve of the Galaxy from observations of neutral atomic hydrogen and analysis of pulsar data, planetary data analysis, cometary data and astrometry, stellarium-related experiments, gravitational lensing, gamma ray astronomy, gravitational waves, and on the Sun and stars. Many of the experiments have also been written up and will soon be put in the repository. The workshop was organized by Team ACE IUCAA.

Radio Astronomy Winter School 2023

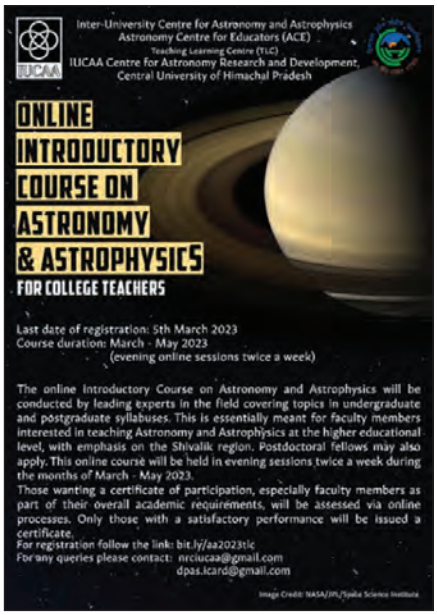
IUCAA and NCRA–TIFR jointly organised the 16th Radio Astronomy Winter School 2023 (RAWS2023) from 12th to 22nd December 2023. RAWS in its present format invites both student participants and college and university faculty members to mentor the student groups formed for the school's activities. This year, 24 student participants and 7 faculty mentors participated in the programme. The lecture sessions started with an introduction to the radio Universe and future prospects, followed by single dish radio telescopes and radio interferometry. The later lecture sessions covered radiative processes, error analysis, positional astronomy, solar radio astronomy, Aditya L1 and beyond, pulsars, millisecond pulsars and gravitational waves, radio transients, our Galaxy and its constituents, gas in galaxies, radio emission from galaxies and cosmology and its present status, and the Giant Metrewave Radio Telescope (GMRT) and highlights of recent results. The main emphasis of RAWS is on hands-on radio astronomy related experiments. The participants worked in groups with their faculty mentors on experiments characterizing detector noise, gain, and directionality, and worked on a super-heterodyne receiver system. They determined the transmission cable characteristics and also used a horn antenna to observe the 21-cm Hydrogen emission to obtain Galaxy rotation curves. A highlight of the school was a day trip to the GMRT, where the participants got a guided tour of the observatory's design and functioning by Kaushal Buch, Shubendu Joarder, Subhashis Roy and Dhruba J Saikia. On the final day, the student groups

Group photograph and glimpses from RAWS2023

presented one of their chosen experiments and competed in a game-style quiz on the topics taught in the school. In addition to the organizers listed below, the resource persons included

Nissim Kanekar, Divya Oberoi, Bhal Chandra Joshi, Ruta Kale, Yogesh Maan and Tirthankar Roychoudhury (all from NCRA-TIFR) and Neeraj Gupta, Dipanjan Mukherjee, Ranjeev Misra and Durgesh Tripathi (all from IUCAA). The students' and faculty's enthusiasm and active participation helped make this an enjoyable educational event. The organizing team comprised of Rajeshwari Dutta, Ashish Mhaske, Avinash Deshpande, Jameer Manur, Prakash Arumugasamy and Dhruba J. Saikia from IUCAA and Subhashis Roy from NCRA-TIFR.

Introductory Course on Astronomy and Astrophysics for College Teachers



An introductory course on astronomy and astrophysics for college teachers in collaboration with the IUCAA Centre for Astronomy Research and Development at the Central University of Himachal Pradesh started on the 22nd of March and ended on the 27th of May. The resource persons were Sarita Vig (IIST Trivandrum) who spoke on stars and stellar evolution, Dhruba J Saikia (IUCAA) who spoke on multi-messenger astronomy and the Milky Way, Prakash Arumugasamy (IUCAA) who conducted a number of discussion and tutorial sessions, Hum Chand (Central University of Himachal Pradesh) who spoke on positional and observational astronomy, Jasjeet S Bagla (IISER Mohali) who spoke on cosmology and structure formation, and Dipankar Banerjee (ARIES) who spoke on the Sun.

There were about thirty participants in the Introductory Course. The course was coordinated by Hum Chand along with Team ACE IUCAA. An online quiz was held after the Course and Certificates of participation were given to those who performed satisfactorily. The Introductory Course was coordinated by Hum Chand and Team ACE IUCAA.

Refresher Course on Astronomy and Astrophysics

The Refresher Course on Astronomy and Astrophysics 2023 was held online from the15th of May to the 16th of June. It was held concurrently with the Summer School on Astronomy and Astrophysics which was held offline. There were about thirty participants from higher educational institutions from across the country.

The lectures covered a wide range of topics introducing the basic important topics of the field which included radiative processes, stellar structure and evolution, the Sun, compact objects, galaxies, galactic dynamics, active galactic nuclei and jets, gravitational lensing, x-ray astronomy, fluids and plasmas, general theory of relativity and cosmology, structure formation, photometry and spectroscopy as well as recent advances. The latter included the exciting field of gravitational wave astronomy and LIGO, machine learning, quantum clocks, and the mega projects such as the Thirty Meter Telescope, LIGO, Aditya-L1 and the Square Kilometre Array.

An online quiz was held after the Course and Certificates of participation were given to all those who performed satisfactorily. The Refresher Course was coordinated by Vaidehi Paliya and Team ACE IUCAA.

Pedagogic Workshop on Astronomy, Astrophysics and Cosmology: St. Stephen's College, Delhi University

A five-day workshop titled "Pedagogic Workshop on Astronomy, Astrophysics and Cosmology" was organized from 6th – 10th November, 2023 for teachers teaching astronomy and astrophysics to undergraduate students in the northern part of India. The workshop was jointly organized by the Astronomy Centre for Educators, Malaviya Mission Teacher Training Centre, IUCAA, Pune and Physics Department, St. Stephen's College, University of Delhi, at St. Stephen's College. The workshop was attended by around 30 teachers and 15 resource persons. The Principal, St. Stephen's College inaugurated the workshop and the inaugural lecture was delivered by Dipankar Bhattacharya, Ashoka university. The main purposes of the workshop were to (i) explore innovative teaching methodologies and strategies that can improve student learning experiences in the field of astronomy and astrophysics, (ii) expand subject knowledge of key concepts in core areas of astronomy, astrophysics and cosmology, (iii) develop resource materials that teachers can utilize to enhance their instructional practices and engage their students effectively, and (iv)

A group photograph of the participants in the workshop on Astronomy, Astrophysics and Cosmology at St. Stephen's College

equip teachers with practical tools and hands-on activities that they can implement in their classrooms, fostering active learning and critical thinking among students. The topics covered included stars and stellar evolution, multi-messenger astronomy, astronomical experiments, galaxies and active galactic nuclei, x-ray astronomy, pulsars and radio astronomy, dark matter, cosmic distance ladder, and cosmology. There were hands-on sessions every day and presentations by the teacher participants. The resource persons were Dipankar Bhattacharya and Philip Cherian (Ashoka University), T. R. Seshadri and Darshan Beniwal (Delhi University), Aru Beri (IISER Mohali), Chetana Jain (Hansraj College), Suprit Singh (IIT Delhi), Main Pal (Sri Venkateswara College), Deepak Jain (Deen Dayal Upadhyaya College), Geetanjali Sethi, Akshay Rana, Shruti Thakur and Sanil Unnikrishnan (St. Stephen's College) and Prakash Arumugasamy and Dhruba J. Saikia (IUCAA). The coordinators of the workshop were Geetanjali Sethi, Vaidehi S. Paliya and Team ACE, IUCAA.

Pedagogic Workshop on Astronomy, Astrophysics and Cosmology: A Faculty Development Programme at Gauhati University

A Pedagogic Workshop on Astronomy, Astrophysics and Cosmology was organized by ICARD, Gauhati University (GU) in collaboration with the Malaviya Mission Teacher Training Centre of the Astronomy Centre for Educators, IUCAA during 4th to 10th January, 2024. The major goals of the workshop were to (a) enrich college and university teachers with new developments in astronomy, astrophysics and cosmology, (b) familiarize them with methods of teaching various topics on astronomy and astrophysics included in the newly introduced syllabuses while implementing the National Education Policy, and (c) build long-term academic relationships between the participants and resource persons of various fields delivering talks in the workshop. The workshop brought together 30 participants involved in astronomy teaching and research in various colleges

Group photograph of the participants in the workshop on Astronomy, Astrophysics and Cosmology held at Gauhati University

and universities of the North-Eastern region and nearby states. The inaugural talk of the workshop was delivered by Dhruba J Saikia of IUCAA which covered recent advances and prospects in the era of multi-messenger astronomy. It was attended by Hiralal Duorah, retired Professor of Physics, GU and the former Vice-Chancellor of the University who founded the GU Observatory and introduced astronomy and astrophysics in colleges of Assam and in the University. Resource persons from Gauhati University, IUCAA, Assam

University, Dibrugarh University, Tezpur University and Cotton University delivered interactive talks on stellar astrophysics, observational astronomy, solar system, galaxies and the intergalactic medium, gravitation and cosmology. The workshop had rigorous hands-on sessions which included usage of Stellarium, analysis of astronomical data through SDSS Sky Server and other virtual observatory tools and visualization of concepts in stellar astrophysics through Modules for Experiments in Stellar Astrophysics (MESA). An observation session in the Gauhati University Observatory was also organized. Another interesting component of the workshop was a series of short talks delivered by the participants on topics which they are teaching. These talks were presented in front of the resource persons who interacted with the participants. The workshop was coordinated by Sanjeev Kalita (ICARD Coordinator, GU), Dhruba J Saikia (MMTTC, ACE, IUCAA) and Sowgat Muzahid (IUCAA).

National Education Policy (NEP) Orientation and Sensitization Programme: 2023 November

The NEP Orientation and Sensitization Programme under the Malaviya Mission Teacher Training Programme was held online from 1st to 10th November 2023. The resource persons included Malhar A. Kulkarni, Cell for Indian Science and Technology in Sanskrit, who spoke on Indian Knowledge Systems; Malish C. M., Ashank Desai Centre for Policy Studies who spoke on Student Diversity and Inclusive Education; Milind Sohoni, Centre for Technology Alternatives for Rural Areas and Anush Kapadia, Department of Humanities and Social Sciences, both of whom spoke on Higher Education and Society; Sarmistha Pattanaik, Department of Humanities and Social Sciences, who spoke on Research and Development. They are all from IIT Bombay. Narayan Sharma, Cotton University and Aniket Sule, Homi Bhabha Centre for Science Education spoke on Holistic and Multidisciplinary Education; Garima Malik, National Institute of

A screen shot showing a section of the participants of the NEP Orientation and Sensitization programme held in 2023 November

Educational Planning and Administration and Dhruba J. Saikia, IUCAA, spoke on Academic Leadership, Governance and Management. Bhupendra N. Goswami, Cotton University, spoke on Research and Development, Yogendra Pal, NIIT University on Information and Communication Technology for higher education, while Santosh Mehrotra, Jawaharlal Nehru University discussed Skill Development. The Programme was attended by about 30 participants, who each wrote two essays on any two of the presentations as part of their evaluation.

National Education Policy (NEP) Orientation and Sensitization Programme: 2024 February

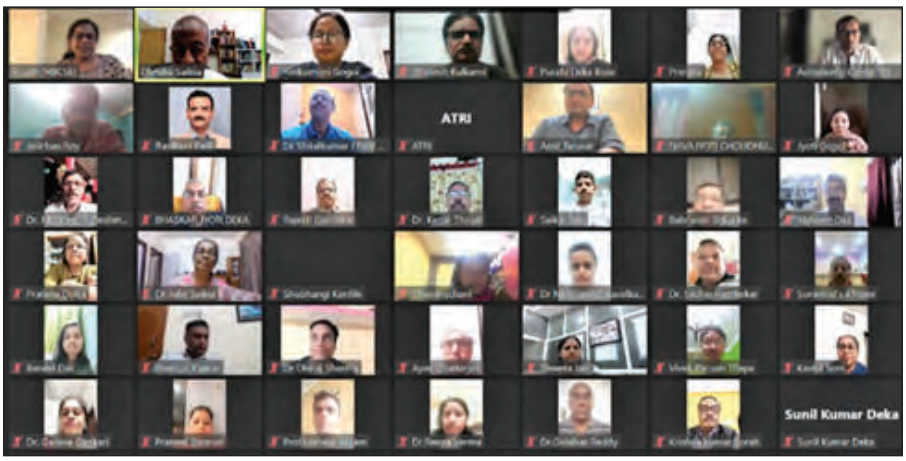
An NEP Orientation and Sensitization Programme under the Malaviya Mission Teacher Training Programme was held online from 1st to 15th February 2024. For the February programme, the resource persons were G. Nagarjuna, IISER Pune, on holistic and multi-disciplinary education; Mayank N Vahia, TIFR Mumbai, on Indian knowledge systems; Narayan C Talukdar, Assam down town University and K J George, IIT Jodhpur, on higher education and society; Dhruba J Saikia, IUCAA and Soumendra M Patnaik, University of Delhi, on academic leadership, governance and management; Sameer S Sahasrabudhe and Rohan Dasgupta, IIT Gandhinagar, on

A screen shot showing a section of the participants of the NEP Orientation and Sensitization programme held in 2023 November

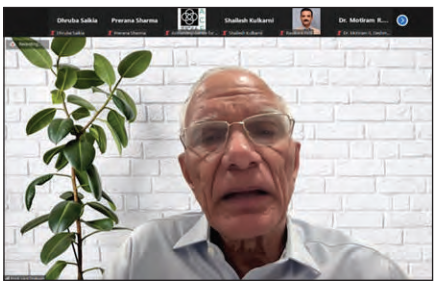
information and communication technology; Nilika Mehrotra, JNU, New Delhi and Deepa Chari, HBCSE, TIFR Mumbai, on student diversity and inclusive education; Farhat Naz, IIT Jodhpur and Sourav Pal, Ashoka University, Sonepat, on research and development; and N V Varghese, NIEPA, New Delhi and Mekin Maheshwari, Founder, Udhyam Learning Foundation, Bengaluru, on skill development.

National Education Policy (NEP) Orientation and Sensitization Programme: 2024 March

The third NEP Orientation and Sensitization Programme of the year was held from 14th to 29th March 2024. The resource persons for this programme were Hiten Choudhury, Cotton University and Prakash Arumugasamy, IUCAA, on information and communication technology; Sushruti Santhanam, Musician and Music Historian, and Vijay Singh, CEBS, Mumbai, on Indian knowledge systems; Ayush Gupta, HBCSE, TIFR Mumbai, on student diversity and inclusive education; Dhruba J Saikia, IUCAA and K J George, IIT Jodhpur, on higher education and society; Somak Raychaudhury, Ashoka University, Sonepat and Padma Sarangapani, TISS, Mumbai, on holistic and multi-disciplinary education; Maithreyi Ravikumar, Karnataka Health Promotion Trust, Bengaluru and C M Malish, IIT Bombay, on skill development; Javed Iqbal, former Director, Dr Reddy's Institute of Life Sciences, Hyderabad and Vijay Singh, CEBS, Mumbai on research and development; Ved Prakash, former Chairperson, University Grants Commission, and Furqan Qamar, former Secretary General, Association of Indian Universities, on academic leadership, governance and management.



A screen shot showing a section of the participants of the NEP Orientation and Sensitization programme held in 2024 March.



Professor Ved Prakash, former Chairperson of the University Grants Commission delivering a lecture on Academic Leadership, Governance and Management as part of the MMTTC, ACE, IUCAA programme on the National Education Policy Orientation and Sensitization on 20th March 2024

Astronomy, Science and Society: 2023 September at MSFDA, Pune

A workshop on the theme of Astronomy, Science and Society, was organized from 6th to 8th September by the Maharashtra State Faculty Development Academy (MSFDA) and the Astronomy Centre for Educators of IUCAA, at MSFDA, Pune. The objectives of these workshops which are often held in smaller towns of Maharashtra are to bring the excitement of astronomy and science to faculty members across disciplines and also discuss broader issues related to science and society such as inclusiveness and non-discrimination. During this workshop Pramod Kale (ISRO and Savitribai Phule Pune University) traced the history of India's space programme and discussed the recent Chandrayaan Mission,

A group photograph of the participants of the workshop Astronomy, Science and Society at MSFDA, Pune

while Durgesh Tripathi (IUCAA) brought forward the excitement of the Sun and the Aditya-L1 Mission. The physical scales in the Universe were lucidly described by Prakash Arumuasamy (IUCAA), while Jameer Manur (IUCAA) presented fun astronomy-themed experiments. The recent exciting discovery of nano Hertz gravitational waves and pulsars was presented by one of the discoverers, Bhal Chandra Joshi (NCRA-TIFR). Images in the sky caused by gravitational lensing were beautifully described by Anupreeta More (IUCAA). The workshop concluded with a discussion and presentation on the theme of our home, our Galaxy and our place in the Universe by Dhruba J Saikia (IUCAA). The workshop included a visit to the Giant Metrewave Radio Telescope near Narayangaon where Shubendu Joardar, Kaushal Buch and colleagues described the telescope and its working. The workshop which had about fifty participants including resource persons was organized by Apurva Barve and Ajay Padvi from MSFDA and Team ACE IUCAA.

The participants of the Astronomy, Science and Society workshop at the Giant Metrewave Radio Telescope

Astronomy, Science and Society: 2024 January at MVPS's CMCS College, Nashik

A workshop on the theme of Astronomy, Science and Society, was organized on 19th and 20th January 2024 at the Maratha Vidya Prasarak Samaj's Commerce, Management & Computer Science (C. M. C. S.) College, Nashik, by the Maharashtra State Faculty Development Academy (MSFDA) and the Astronomy Centre for Educators of IUCAA. The objectives of these workshops which are often held in smaller towns of Maharashtra are to bring the excitement of astronomy and science to faculty members across disciplines and also discuss broader issues related to science and society such as inclusiveness and non-discrimination. During this workshop Prakash Arumugasamy described the scales of the Universe, Moupiya Maji recounted the story of black holes, Jameer Manur introduced them to the night sky, while Dhruba J Saikia gave an overview of radio and x-ray astronomy and highlighted recent developments in India. In a separate talk, he spoke on the importance of building inclusive societies drawing lessons from the history of astronomy. There was a night sky watching session led by Jameer Manur, and a bird watching session early in the morning led by Dhruba J Saikia. The participants enthusiastically took part in all the events. The workshop which had about fifty participants including resource persons and organizers was organized by Apurva Barve and Ajay Padvi from MSFDA and Team ACE, IUCAA.

A group photograph of the participants and glimpses of the bird watching and sky watching sessions at MVPS's C.M.C.S. College, Nashik

SPONSORED MEETINGS AND EVENTS OUTSIDE OF IUCAA

Workshop on Python Programming in Astronomy, Astrophysics & Cosmology

The Department of Applied Sciences of G. H. Raisoni College of Engineering, Nagpur, organised a two-day workshop on Python Programming in Astronomy, Astrophysics & Cosmology on 07 and 08 April 2023. The workshop was funded by the Inter-University Center for Astronomy and Astrophysics (IUCAA), Pune, where forty participants from all over India, viz. thirty undergraduates and post-graduates, five faculty members and five PhD scholars participated.

The keynote speakers were Professor S.N. Hasan, Dr. Priya Hasan (MANU University, Hyderabad) and Mr. D.K. Beniwal (Delhi University). The chief guest of the inaugural function was Dr. G.P. Singh, Head & Professor, Department of Mathematics, VNIT, Nagpur, where the organisers of the workshop were Professor Saibal Ray, Dr Praveen Kumar Dhankar and Professor Bhagwat Thakran. The workshop was organised by Professor Saibal Ray (CCASS, GLA University, Mathura and IUCAA Associate), Dr Praveen Kumar Dhankar (Dept of Applied Mathematics, G. H. Raisoni College of Engineering, Nagpur) and Professor Bhagwat Thakran (Dept of Applied Mathematics, G. H. Raisoni College of Engineering, Nagpur).

[For details, see Khagol no. 130, January-October 2023]

Summer School in Theoretical Physics 2023

The Department of Physics and Electronics, St Xavier's College (Autonomous), Ahmedabad, in association with Kshama Ahmedabad Academy of Sciences, Ahmedabad, organised a two-week Summer School in Theoretical Physics 2023 from 29 May to 09 June 09 2023. A primary objective of the School was to offer a unique opportunity for the participants to expand their knowledge and engage with leading experts in the field. The workshop had forty lectures, each one of an hour and a half duration, delivered by eight experts. In total, thirty-eight offline and forty-two online participants attended the School. The participants were provided with a certificate for attending the School.

[For details, see Khagol no. 130, January-October 2023]

Workshop on Python Programming in Astronomy, Astrophysics & Cosmology

A three-day workshop on Python Programming in Astronomy, Astrophysics & Cosmology was organised from 20 - 22 July 2023 at the Centre for Cosmology, Astrophysics and Space Science (CCASS), GLA University, Mathura, Uttar Pradesh. The workshop was organised by Professor Saibal Ray and Dr Ashutosh Singh (Centre for Cosmology, Astrophysics and Space Science (CCASS), GLA University, Mathura).

[For details, see Khagol no. 130, January-October 2023]

Himalayan Meet of Astronomers

A 'Himalayan Meet of Astronomers' conference was held from 25 to 26 September 2023 at the Islamic University of Science and Technology, Awantipora Pulwama (IUST), Kashmir (J&K). The conference brought together researchers, astronomers, and astrophysicists from various research institutes and universities in Northern India to delve into various aspects of astrophysics and discuss the present status of the subject in these institutes and universities. The conference was strategically organised into six sessions, each focusing on distinct cosmic entities and phenomena: Blazars, X-ray binaries, AI and ML in Astrophysics, and Galaxies. Approximately sixty participants from various institutes attended the conference.

The conference was organised by Professor Naseer Iqbal (University of Kashmir) and Professor Hum Chand (Central University of Himachal Pradesh) supported by the Islamic University of Science and Technology Awantipora Pulwama (IUST), Kashmir (J & K), Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune, the University of Kashmir, Srinagar (KU) and the Central University of Himachal Pradesh (CUHP).

[For details, see Khagol no. 130, January-October 2023]

INDO-South Africa Workshop on Astrophysics (ISAWA 2023)

The INDO-South Africa Workshop on Astrophysics (ISAWA 2023) was hosted at the Centre for Theoretical Physics, Jamia Millia Islamia. Inauguration: PVC, JMI inaugurated ISAWA-2023 from 27 - 29 September 2023. The workshop was supported by ICARD, Centre for Theoretical Physics, Jamia Millia Islamia, Delhi.

[For details, see Khagol no. 130, January-October 2023]

Statistical Techniques in Astrophysics and Cosmology Using Python

An Introductory School on Statistical Techniques in Astrophysics and Cosmology Using Python (STACUP) was organised by the Central University of Tamil Nadu (CUTN). The school was held at Bharathidasan University, Tiruchirappalli, from 16 to 20 October 2023. The school was the second in a series of schools organised by CUTN to bolster the presence of astrophysics and cosmology research in the southern region

of India. The school was organised by T. R. Seshadri (Delhi University), V. Madhurima (Central University of Tamilnadu) and P. Muruganandam (Bharatidasam University).

[For details, see Khagol no. 131, January 2024]

ASTROCOSMOCON: Fusing Astronomy, Cosmology, and Atmospheric Research

A three-day workshop from 26-28 October 2023 sponsored by IUCAA and CCSP, SGT.

A three-day workshop on Astronomy, Cosmology, and Atmospheric research was organised from 26 to 28 October 2023 by the Centre for Cosmology and Science Popularization, SGT University, Gurgaon. The workshop was intended for the graduate and post-graduate students from

India. The workshop was coordinated by Aditi Agarwal (CCSP, Gurgaon) and T. R. Seshadri (University of Delhi).

[For details, see Khagol no. 131, January 2024]

Radio Astronomy Fundamentals for Engineering Students

A one-day seminar on Radio Astronomy Fundamentals for Engineering Students, sponsored by IUCAA, Pune, was jointly organised by the Department of Basic Sciences and Humanities, Rajagiri School of Engineering and Technology (RSET), Kakkanad, Kerala, on October 28, 2023. Neeraj Gupta (IUCAA, Pune), Rinku Jacob (RSET, Kerala) and Joe Jacob (Visiting Associate of IUCAA and former Head, Department. of Physics, Newmann College, Thodupuzha) coordinated the seminar.

[For details, see Khagol no. 131, January 2024]

North-East Meet of Astronomers (NEMA) - IX

The North East Meet of Astronomers (NEMA)-IX was conducted successfully at Mizoram University from November 20 to 22, 2023. During the three-day event, experts from all over North-Eastern states gave talks on various topics of Astronomy and Astrophysics.

The meeting was coordinated by Lalthakimi Zadeng (Mizoram University) and Ranjeev Misra (IUCAA).

[For details, see Khagol no. 131, January 2024]

Workshop on GRAVITATIONAL WAVES and LIGO INDIA

The workshop on Gravitational Waves and LIGO India, jointly organised by the Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune and the School of Physical and Applied Sciences at Goa University, was held over five days from 27 November to 01 December 2023 at Goa University, Goa.

The workshop was coordinated by R. R. Raut (Goa University, Goa), S. Mitra (IUCAA, Pune) and A. Ganguly (IUCAA, Pune).

[For details, see Khagol no. 131, January 2024]

Meghnad Saha Memorial Workshop on Solar Astronomy focused on "Aditya -L1 Mission"

The Department of Physics, University of Allahabad, organised a three-day Meghnad Saha Memorial Workshop on Solar Astronomy focused on the Aditya L1 Mission from 04 - 06 December 2023. IUCAA, Pune, funded the workshop. The participants comprised fifty undergraduate, post-graduate and PhD students, including twenty students from different institutions in India and thirty student participants from

Prayagraj and nearby areas. The workshop aimed to generate trained human resources for a career in solar Physics.

[For details, see Khagol no. 131, January 2024]

Beginning Astronomy v3: Start a Data-driven Journey.

The Beginning Astronomy v3: Start a Data-Driven Journey was conducted from 11th to 13th December 2023 at IIT Hyderabad and was jointly hosted by IIT Hyderabad and IUCAA. BSc and BTech students in their 2nd year or higher, along with MSc and MTech students, were eligible, and 366 students applied from all over India. Forty students were selected. Dr Mayukh Pahari coordinated from IIT Hyderabad along with Dr Souradeep Bhattacharya, Dr Chayan Mondal, Dr Megha Anand, Mr Pushpak Pandey and Prof. Ranjeev Mishra from IUCAA, Pune. 13 MSc and BTech students from the Nakshatra Astronomy Club at the IIT Hyderabad were part of the Local Organizing Committee, who assisted in effective coordination.

[For details, see Khagol no. 131, January 2024]

Workshop on Gravitation: Theory and Observation

A workshop titled "Gravitation: Theory and Observation" was held at the IUCAA Centre for Astronomy Research and Development (ICARD), Department of Physics, Cooch Behar Panchanan Barma University (CBPBU) on 03 January 2024. The Hon'ble Vice-Chancellor, Prof. Nikhil Chandra Roy, inaugurated the programme. The university registrar, Dr. Abdul Kader Safily, was present at the programme. The workshop was organised by Ranjan Sharma (CBPBU) and Kanak Saha, IUCAA, Pune.

[For details, see Khagol no. 132, April 2024]

Research in Astronomy: Opportunities and Challenges - RAM IX

The ninth Regional Meeting on 'Research in Astronomy and Challenges' (RAM 2024) was held at the Manipal Centre for Natural Sciences, Manipal Academy of Higher Education (MAHE), Manipal, from January 10-12, 2024, jointly organised and funded by MAHE and IUCAA. The meeting was organised by Debbijoy Bhattacharya (MAHE) and Ranjeev Misra, IUCAA.

[For details, see Khagol no. 132, April 2024]

X-ray workshop -- Astrosat and XpoSat

The AstroSat Science Support Cell (ASSC), IUCAA, ISRO and Department of Physics, Providence Women's College, organised a five-day workshop for Research Scholars and motivated M.Sc students from 28 February to 03 March 2024 at the Department of Physics, Providence Women's College, Malaparamba, Kozhikode. The workshop was organised for the benefit of research scholars and postgraduate students in X-ray astronomy.

The workshop was coordinated by Gireesh V., ISRO, Jeena K, Providence Women's College, and Ranjeev Misra, IUCAA.

[For details, see Khagol no. 132, April 2024]

Conference on Relativistic Astrophysics and Cosmology

The Conference on Relativistic Astrophysics and Cosmology was held from 29 February to 01 March 2024 at the Department of Physics, Malda College, Malda, West Bengal. The participants expressed their heartfelt gratitude and appreciation for the meeting organisers. Dr. Shyam Das, Convenor of the conference, expressed sincere gratitude to the Principal, Malda College, invited speakers, participants, students, and others for their support at various stages from the commencement to the conclusion of the Conference. The conference was organised

by Shyam Das (Malda College) and Ranjeev Misra (IUCAA).

[For details, see Khagol no. 132, April 2024].

Workshop on SUIT Science and Data Analysis

The Department of Physics, Tezpur University, in collaboration with IUCAA, Pune, conducted a two-day workshop entitled ADITYA-L1: Workshop on SUIT Science and Data Analysis from 6-7 March 2024. The workshop was organised by Gazi Ameen Ahmed, Tezpur University, in coordination with Janmejoy Sarkar, IUCAA & Tezpur University and Durgesh Tripathi, IUCAA.

[For details, see Khagol no. 132, April 2024].

Workshop on Formation and Evolution of Galaxies

A Workshop on Formation and Evolution of Galaxies was held from 18 to 20 March 2024 at the Central University of Haryana, Mahendragarh. Sixty participants including masters and research scholars from different universities participated in the workshop. The workshop was coordinated by Jaswant Yadav, CUH, and Aseem Paranjape, IUCAA.

[For details, see Khagol no. 132, April 2024].

Workshop on Advancement in AGN, Galaxy, Cluster and IGM Research

A workshop on Advancements in AGN, Galaxy Cluster and IGM Research was held at the Dharamshala Campus of the Central University of Himachal Pradesh Dharamshala, H.P. from 29 to 31 March 2024. The conference hosted around twenty-one participants, including 11 students from the university sector. IUCAA provided financial support for this workshop. The workshop was coordinated by Hum Chand (CUHP) and Sowgat Muzahid, IUCAA.

[For details, see Khagol no. 132, April 2024].

Aditi Agarwal

AAnalysis of the intra-night variability of BL Lacertae during its August 2020 flare

We present an analysis of the BVRI photometry of the blazar BL Lacertae on diverse timescales from mid-July to mid-September 2020. We have used 11 different optical telescopes around the world and have collected data over 84 observational nights. The observations cover the onset of a new activity phase of BL Lacertae started in August 2020 (termed as the August 2020 flare by us), and the analysis is focused on the intra-night variability. On short-term timescales, (i) flux varied with $\sim$ 2.2,mag in R band, (ii) the spectral index was found to be weakly dependent on the flux (i.e., the variations could be considered mildly chromatic) and (iii) no periodicity was detected. On intra-night timescales, BL Lacertae was found to show bluer-when-brighter chromatism predominantly. We also found two cases of significant inter-band time lags of the order of a few minutes. The duty cycle of the blazar during the August 2020 flare was estimated to be quite high ($\sim$ 90% or higher). We decomposed the intra-night light curves into individual flares and determined their characteristics. On the basis of our analysis and assuming the turbulent jet model, we determined some characteristics of the emitting regions: Doppler factor, magnetic field strength, electron Lorentz factor, and radius. The radii determined were discussed in the framework of the Kolmogorov theory of turbulence. We also estimated the weighted mean structure function slope on intra-night timescales, related it to the slope of the power spectral density, and discussed it with regard to the origin of intra-night variability. This work has been done in collaboration with Aditi Agarwal, B. Mihov, Vipul Agrawal, S. Zola, Aykut Ozdonmez, Ergun Ege et al.

Classification of Blazar Candidates of Unknown Type in Fermi 4LAC by Unanimous Voting from Multiple Machine-learning Algorithms

The Fermi fourth catalog of active galactic nuclei (AGNs) data release 3 (4LAC-DR3) contains 3407 AGNs, out of which 755 are flat spectrum radio quasars (FSRQs), 1379 are BL Lacertae objects (BL Lac objects), 1208 are blazars of unknown (BCUs) type, while 65 are non-AGNs. Accurate categorization of many unassociated blazars still remains a challenge due to the lack of sufficient optical spectral information. The aim of this work is to use high-precision, optimized machine-learning (ML) algorithms to classify BCUs into BL Lac objects and FSRQs. To address this, we selected the 4LAC-DR3 Clean sample (i.e., sources with no analysis flags) containing 1115 BCUs. We employ five different supervised ML algorithms, namely, random forest, logistic regression, XGBoost, CatBoost, and neural network with seven features: photon index, synchrotron-peak frequency, pivot energy, photon index at pivot energy, fractional variability, ν F ν, at synchrotron-peak frequency, and variability index. Combining results from all models leads to better accuracy and more robust predictions. These five methods together classified 610 BCUs as BL Lac objects and 333 BCUs as FSRQs with a classification metric area under the curve >0.96. Our results are significantly compatible with recent studies as well. The output from this study provides a larger blazar sample with many new targets that could be used for forthcoming multiwavelength surveys. This work can be further extended by adding features in X-rays, UV, visible, and radio wavelengths.

Faizuddin Ahmed

Nonrelativistic quantum particles interacting with pseudoharmonic-type potential under flux field in a topological defect geometry

In this work, we investigate the quantum motions of nonrelativistic particles interacting with a potential in the presence of the Aharonov-Bohm (AB) flux field within a topological defect geometry, for example space–time with a distortion of a vertical line into a vertical spiral. We begin by deriving the radial Schrödinger wave equation, incorporating an anharmonic oscillator potential, which is a superposition of a harmonic oscillator and an inverse square potential, along with a constant term. The eigenvalue solution is obtained through the confluent Heun equation focusing on the ground state energy level and the radial wave function for the radial mode $n = 1$ as an example and analyze the results. Subsequently, we use these results to molecular potential models, considering pseudoharmonic and shifted pseudoharmonic potentials. The derived eigenvalue solutions provide insights into the behavior of particles within these potentials. Expanding our exploration, we study the quantum system featuring only an inverse square potential in the presence of the quantum flux field in the same

geometry background. Employing the same procedure, we determine the ground state energy level and the radial wave function. Notably, our findings reveal that the eigenvalue solutions are significantly influenced by the topological defect characterized by the parameter β, and the quantum flux field $\Phi_A B$. This influence manifests as a shift in the energy spectrum, drawing parallels to the gravitational analog of the AB effect. This work has been done in collaboration with Prabir Rudra, Faizuddin Ahmed, Houcine Aounallah.

Cosmological constant Petrov type-N space-time in Ricci-inverse gravity

Our focus is on a specific type-N space-time that exhibits closed time-like curves in general relativity theory within the framework of Ricci-inverse gravity model. The matter-energy content is solely composed of a pure radiation field, and it adheres to the energy conditions while featuring a negative cosmological constant. One of the key findings in this investigation is the non-zero determinant of the Ricci tensor ($R_{\mu\nu}$), which implies the existence of an anti-curvature tensor ($A^{\mu\nu}$) and, as a consequence, an anti-curvature scalar ($A \neq R^{(} - 1)$). Furthermore, we establish that this type-N space-time serves as a solution within modified gravity theories via the Ricci-inverse model, which involves adjustments to the cosmological constant (Λ) and the energy density (ρ) of the radiation field expressed in terms of a coupling constant. As a result, our findings suggest that causality violations remain possible within the framework of this Ricci-inverse gravity model, alongside the predictions of general relativity. This work has been done in collaboration with J. C. R. de Souza, A. F. Santos.

Gouri Ambika

Vedang Tamhane and G. Ambika , Structure and Stability of the Indian Power Transmission Network

We present the study on the Indian power transmission network using the framework of a complex network and quantify its structural properties. For this, we build the network structure underlying the Indian power grid, using two of its most prevalent power lines. We construct an equivalent model of an exponential network and study its structural changes with changes in two parameters related to redundancy and dead-ends. Then we analyze its stability against cascading failures by varying these two parameters using the link failure model. This helps to gain insight into the relation of network topology to its stability, and indicates how the optimum choice of these parameters can result in a power grid structure with minimum failed links. We apply the same model to study the robustness of the Indian power grid against such failures. In this case, we find that when a link connected to a generator fails, it results in a cascade that spreads in the grid until it is split into two separate stable clusters of generators and consumers, with over one-third of its nodes nonfunctional.This work has been done in collaboration withVedang Tamhane.

Early warning signals for critical transitions in complex systems

In this topical review, we present a brief overview of the different methods and measures to detect the occurrence of critical transitions in complex systems. Westart by introducing the mechanisms that trigger critical transitions, and how they relate to early warning signals (EWS) and briefly mention the conventional measures based on critical slowing down, as computed from data and applied to real systems. We then present in detail the approaches for multivariate data, including those defined for complex networks. More recent techniques like the warning signals derived from the recurrence pattern underlying the data, are presented in detail as measures from recurrence plots and recurrence networks. This is followed by a discussion on how methods based on machine learning are used most recently, to detect critical transitions in real and simulated data. Towards the end, we summarise the challenges involved while computing the EWS from real-world data and conclude with our outlook and perspective on future trends in this area. This work has been done in collaboration with Sandip V. George, and Sneha Kachhara.

Arunima Banerjee

Analyzing the cosmic web environment in the vicinity of grand-design and flocculent spirals with local geometric index

We explore the environment of a combined set of 367 grand-design and 619 flocculent spiral galaxies. We introduce a novel estimator called the *local geometric index* to quantify the morphology of the local environment of these 986 spirals. The local geometric index allows us to classify the environment of galaxies into voids, sheets, filaments, and clusters. We find that grand-designs are mostly located in dense environments

like clusters and filaments ($\sim 78\%$), whereas the fraction of the flocculents lying in sparse environments like voids and sheets is significantly higher ($> 10\%$) than that of the grand-designs. A p-value $< 10^{-3}$ from a Kolmogorov-Smirnov test indicates that our results are statistically significant at 99.9% confidence level. Further, we note that dense environments with large tidal flows are dominated by the grand-designs. On the other hand, low-density environments such as sheets and voids favor the growth of flocculents. This work has been done in collaboration with Suman Sarkar, ; Ganesh Narayanan.

HI 21cm observations and dynamical modelling of the thinnest galaxy: FGC 2366

Superthin galaxies are bulgeless low surface brightness galaxies with unusually high major-to-minor axes ratio of the stellar disc, i.e.,$10 < a/b < 20$. We present Giant Metrewave Radio Telescope (GMRT) $H\,I$ 21cm radio-synthesis observations of FGC 2366, the thinnest galaxy known with $a/b = 21.6$. Employing the 3-D tilted-ring modelling using Fully Automated TiRiFiC (FAT), we determine the structure and kinematics of the $H\,I$ gas disc, obtaining an asymptotic rotational velocity equal to $100kms$ and a total $H\,I$ mass equal to $10^9 M_\odot$. Using z-band stellar photometry, we obtain a central surface brightness of 22.8 mag arcsec^{-2}, a disc scale length of 2.6 kpc, and a scaleheight of 260 pc. Next, we determine the dark matter density profile by constructing a mass model and find that an NFW dark matter halo best fits the steeply-rising rotation curve. With the above mass inventory in place, we finally construct the dynamical model of the stellar disc of FGC 2366 using the stellar dynamical code "AGAMA". To identify the key physical mechanisms responsible for the superthin vertical structure, we carry out a Principal Component Analysis of the data corresponding to all the relevant dynamical parameters and a/b for a sample of superthin and extremely thin galaxies studied so far. We note that the first two principal components explain 80% of the variation in the data, and the significant contribution is from the compactness of the mass distribution, which is fundamentally responsible for the existence of superthin stellar discs. This work has been done in collaboration with K. Aditya, Peter Kamphuis, Aleksandr Mosenkov, Dmitry Makarov, Sviatoslav Borisov.

Indrani Banerjee

Imprints of Einstein-Maxwell dilaton-axion gravity in the observed shadows of Sgr A and M87**

Einstein-Maxwell dilaton-axion (EMDA) gravity provides a simple framework to investigate the signatures of string theory. The axion and the dilaton fields arising in EMDA gravity have important implications in inflationary cosmology and in addressing the late time acceleration of the universe. It is therefore instructive to explore the implications of such a model in explaining the astrophysical observations. The Kerr-Sen metric represents the exact, stationary and axisymmetric black hole solution of EMDA gravity. Such a black hole is characterized by the angular momentum a acquired from the axionic field and the dilatonic charge r_2 arising from string compactifications. We study the role of spin and the dilaton parameter in modifying the shape and size of the black hole critical curve, which is associated with the projection of the spherical null geodesics on the sky. We compare the theoretically derived critical curve with the EHT results related to the images of M87* and Sgr A* to obtain constraints on the dilaton parameter r_2. We take into account the errors in mass and distance of M87* and Sgr A* while deriving their theoretical critical curve. Our analysis reveals that the image of M87* exhibits a preference towards the Kerr scenario when the critical curve angular diameter is calculated with the central value of mass and distance. When errors in mass and distance are taken into account the allowed range of r_2 turns out to be $0 \lesssim r_2 \lesssim 1$. For Sgr A*, the preferred range of r_2 is $0.1 \lesssim r_2 \lesssim 0.4$ when central values of mass and distance are used to calculate the theoretical critical curve. When error bars in mass and distance are used to calculate the theoretical critical curve of Sgr A*, the preferred range of r_2 turns out to be: $0 \lesssim r_2 \lesssim 0.5$. Thus the image of M87* favors the Kerr scenario and allows the Kerr-Sen scenario only when errors in the mass and distance are taken into consideration while the image of Sgr A* favors the Kerr-Sen scenario and allows when errors in the mass and distance are taken into account. This work has been done in collaboration with Siddharth K. Sahoo, and Neeraj Yadav.

Prasad Basu

Detectability of gas-rich E/IMRI's in LISA band: observable signature of transonic accretion flow

Real extreme/intermediate-mass ratio inspiral (E/IMRI) systems are likely to contain large accretion discs which could be as massive as the central supermassive black hole. Therefore, contrary to its ideal model, a real E/IMRI system contains a third important component: the accretion disc. We study the influence of these discs on the emitted gravitational wave (GW) profile and its detectability through proposed LISA observation. We use a semirelativistic formalism in the Kerr background for the case of transonic accretion flow which is a potential candidate to describe the accretion flows around active galactic nuclei. The hydrodynamic drag of the discs modified the motion of the companion as a result of the emitted wave changes in amplitude and phase. We found that these changes are detectable through the last few years of observation by LISA (in some cases as small as 6 months) for EMRIs

residing within redshift $z = 1$ from the detector and for the accretion rate of the primary black hole of the order of $\dot{M} = 1\dot{M_{Edd}}$. These choices of parameter values are consistent with real systems. The drag effect and hence the detectability of the emitted GW is sensitive to the hydrodynamical model of the disc. Therefore, we vary the disc parameters, accretion rate, and duration of observation of E/IMRIs, and find that in comparison with other disc models, transonic solution offers relatively better observable signatures in detecting the gas-rich E/IMRIâ€™s within the LISA band. Such observations will help one to probe the nature of the accretion flow and verify various paradigms of accretion physics. This work has been done in collaboration with Sangita Chatterjee1,and Soumen Mondal.

Aru Beri

The accretion/ejection link in the neutron star X-ray binary 4U 1820-30 I : A boundary layer-jet coupling

The accretion flow / jet correlation in neutron star (NS) low-mass X-ray binaries (LMXBs) is far less understood when compared to black hole (BH) LMXBs. In this paper we will present the results of a dense multi-wavelength observational campaign on the NS LMXB 4U 1820-30, including X-ray (Nicer, NuSTAR and AstroSAT) and quasi-simultaneous radio (ATCA) observations in 2022. 4U 1820-30 shows a peculiar 170 day super-orbital accretion modulation, during which the system evolves between "modes" of high and low X-ray flux. During our monitoring, the source did not show any transition to a full hard state. X-ray spectra were well described using a disc blackbody, a Comptonisation spectrum along with a Fe K emission line at 6.6 keV. Our results show that the observed X-ray flux modulation is almost entirely produced by changes in the size of the region providing seed photons for the Comptonisation spectrum. This region is large (about 15 km) in the high mode and likely coincides with the whole boundary layer, while it shrinks significantly (¡10 km) in low mode. The electron temperature of the corona and the observed RMS variability in the hard X-rays also exhibit a slight increase in low mode. As the source moves from high to low mode, the radio emission due to the jet becomes about 5 fainter. These radio changes appear not to be strongly connected to the hard-to-soft transitions as in BH systems, while they seem to be connected mostly to variations observed in the boundary layer. This work has been done in collaboration with A Marino, T D Russell, M. Del Santo, A. Sanna, F. Coti Zelati, N. Degenaar et al.

Modelling neutron-star ocean dynamics, Universe, 2023, 9(5), 226

We re-visit the calculation of mode oscillations in the ocean of a rotating neutron star, which may be excited during thermonuclear X-ray bursts. Our present theoretical understanding of ocean modes relies heavily on the traditional approximation, commonly employed in geophysics. The approximation elegantly decouples the radial and angular sectors of the perturbation problem by neglecting the vertical contribution from the Coriolis force. However, as the implicit assumptions underlying it are not as well understood as they ought to be, we examine the traditional approximation and discuss the associated mode solutions. The results demonstrate that, while the approximation may be appropriate in certain contexts, it may not be accurate for rapidly rotating neutron stars. In addition, using the shallow-water approximation, we show analytically how the solutions that resemble r-modes change their nature in neutron-star oceans to behave like gravity waves. We also outline a simple prescription for lifting Newtonian results in a shallow ocean to general relativity, making the result more realistic. This work has been done in collaboration with Nils Andersson, Fabian Gittins and Thomas Celora.

Piyali Bhar

Dark energy stars and quark stars within the context of f(Q) gravity

In this work, we investigate the relativistic structure of compact stars within the framework of $f(Q)$ gravity, where Q is the nonmetricity scalar. In particular, we focus on the $f(Q) = \alpha Q + \beta$ gravity model, with α and β being free parameters of the theory. This study is split up into: 1. Models of dark energy stars by using metric potentials of Tolman-Kuchowicz type which are free of singularity. It considers the stellar fluid to be made up of both ordinary matter along with dark energy, where the constants in the metric are determined from observational measurements of some well-known compact stars. Part 2 deals with quark stars where their masses and radii are a consequence of integrating the stellar structure equations given a specific equation of state (EoS) for the dense matter involved. We use the pulsar SAX J1808.4-3658, which has a known mass and radius of $M = 0.9^{+0.3}_{-0.3}\,M_{\odot}$, and 7.95^{+1}_{-1} km respectively, to explain the physical characteristics of the dark energy star. For various values of α, the causality criteria and the model's dynamical stability are discussed. In light of the discovery of gravitational waves GW190814, we also investigate the possibility of characterizing the secondary component of such an event as a stable dark energy star in the presence of anisotropy using the $M - R$ relation, which characterizes a dark energy star with mass $2.57\,M_{\odot}$ and associated radius 9.3 km. Furthermore, in the case of quark stars with MIT bag model EoS, we find that both the radius and the mass increase with increasing α for fixed $\beta = 0$. Meanwhile, the effect of the parameter β is a substantial increase in the maximum-mass values as β becomes more negative for a fixed value of α. This work has been done in collaboration with Juan M.Z. Pretel.

Singularity Free Star Model Characterized by Quintessence Field in Quadratic f(Q) Gravity

In the context of the $f(Q)$ theory of gravity, we offer a spherically symmetric quintessence dark energy star model in this article. For this reason, we take into account that $f(Q)$ has the formula $f(Q) = aQ^2 + Q$, where Q stands for the non-metricity scalar and 'a' is the coupling constant for modified gravity. We suppose that the quintessence field defined by the parameter ω_q, where $\omega_q \in \left(-1, -\frac{1}{3}\right)$, controls the energy-momentum tensor of the underlying fluid distribution. We investigated the relationship between several physical parameters for the selected values of 'a', by choosing the metric potentials suggested by the Krori-Barua [Krori and Barua; *J. Phys. A, Math. Gen.* **8**: 508, 1975]. Further, we have carried out several analyses in detail to examine the physical validity of the proposed stellar model. We have succinctly described the consequences of the compact star system caused by the connection of matter and geometry. The maximum allowable mass and radius for our present model for different values of 'a' have been studied by $M - R$ and $M - \rho_c$ curve. One can recover the usual general relativity (GR) standard results for $a = 0$.

Naseer I. Bhat

Can FSRQ 3C 345 be a very high energy blazar candidate ?

The recent detection of very high energy (VHE) emissions from flat spectrum radio quasars (FSRQs) at high redshifts has revealed that the universe is more transparent to VHE γ-rays than it was expected. It has also questioned the plausible VHE emission mechanism responsible for these objects. Particularly for FSRQs, the γ-ray emission is attributed to the external Compton (EC) process. We perform a detailed spectral study of Fermi -detected FSRQ 3C 345 using synchrotron, synchrotron self-Compton, and EC emission mechanisms. The simultaneous data available in optical, ultraviolet, X-ray, and γ-ray energy bands is statistically fitted under these emission mechanisms using the χ^2-minimization technique. Three high flux states and one low flux state are chosen for spectral fitting. The broad-band spectral energy distribution during these flux states is fitted under different target photon temperatures, and the model VHE flux is compared with the 50 h Cherenkov Telescope Array sensitivity. Our results indicate a significant VHE emission could be attained during the high flux state from MJD 59635 -59715 when the target photon temperature is within 900–1200 K. Furthermore, our study shows a clear trend of variation in the bulk Lorentz factor of the emission region as the source transits through different flux states. We also note that during high γ-ray flux states, an increase in external photon temperature demands high bulk Lorentz factors, while this behaviour reverses in case of low γ-ray flux state. This work has been done in collaboration with Athar A. Dar, Sunder Sahayanathan, and Zahir Shah.

Broad-band spectral and temporal study of Ton 599 during the brightest 2023 January flare.

In this work, we provide a detailed analysis of the broad-band temporal and spectral properties of the blazar Ton 599 by using observations from the Fermi Large Area Telescope (LAT) and Swift X-Ray Telescope (XRT)/Ultraviolet–Optical Telescope (UV O T), during its brightest γ-ray flaring. The one-day bin γ-ray light curve exhibits multiple substructures with asymmetric and symmetric profiles. Notably, the γ-ray light curve shows a maximum flux of 3. 63 × 10-6 photon cm -2 s -1 on MJD 59954.50, which is the highest flux ever observed from this source. The correlation between the γ-ray flux and γ-ray spectral indices suggests a moderate 'harder when brighter' trend. Taking the γ-ray light curve as the reference, a strong correlation is observed with X-ray, optical, and UV energies. Additionally, the γ-rays and optical/UV emission exhibit higher variability compared with X-rays. To understand the parameter variation during the active state of the source, we conducted a statistical broad-band spectral modelling of the source in 10 flux intervals of equal duration. A one-zone leptonic model involving synchrotron, synchrotron-self-Compton, and external Compton processes successfully reproduces the broad-band spectral energy distribution (SED) in each of these flux intervals. We observed that flux variation during the active state is associated mainly with variation in the magnetic field and particle spectral indices. This work has been done in collaboration with Zahoor Malik, Sundar Sahayanathan , Zahir Shah, and Aqqib Manzoor.

Srijit Bhattacharjee

Slowly evolving horizons in Einstein gravity and beyond

We study event horizon candidates for slowly evolving dynamical black holes (BHs) in General Relativity and Einstein–Gauss–Bonnet (EGB) gravity. Such a type of horizon candidate has been termed as slowly evolving null surface (SENS). It signifies a near-equilibrium state of a dynamic BH. We demonstrate the time evolution of such surfaces for three different metrics. First, we locate such a surface for a charged Vaidya metric and show that the parameter space of the BH gets constrained to allow a physically admissible SENS. We then consider a supertranslated Vaidya solution that contains a non-spherical horizon and study the properties of the SENS. This spacetime generates a non-vanishing shear at the SENS due to the presence of the supertranslation field. The SENS for a spherically symmetric Vaidya-like solution in EGB gravity yields a bound on the accretion rate that depends on the size of the horizon. We also show that the first

and second laws of BH mechanics can be established for these slowly evolving surfaces. This work has been done in collaboration with Ayon Tarafdar.

Soft theorems and memory effects at finite temperatures

We study the soft theorems for photons and gravitons at finite temperatures using the thermofield dynamics approach. The soft factors lose universality at finite temperatures as the soft amplitudes depend on the nature (or spin) of the particles participating in the scattering processes. However, at low temperatures, a universal behavior is observed in the cross-section of the soft processes. Further, we obtain the thermal contribution to the electromagnetic and gravitational memory effects and show that they are related to the soft factors consistently. The expected zero temperature results are obtained from the soft factors and memories. The thermal effects in soft theorems and memories seem to be sensitive to the spin of the particles involved in scattering. This work has been done in collaboration with Divyesh N. Solanki.

Dipankar Bhattacharya

Fast-varying time lags in the Quasi-periodic Oscillation in GRS 1915+105

The properties of sub-second time variability of the X-ray emission of the black-hole binary GRS 1915+105 are very complex and strictly connected to its patterns of variability observed on long time scales. A key aspect for determining the geometry of the accretion flow is the study of time lags between emission at different energies, as they are associated to key time scales of the system. In particular, it is important to examine the lags associated to the strong low-frequency Quasi-periodic Oscillations (QPOs), as the QPOs provide unambiguous special frequencies to sample the variability. We have analyzed data from an observation with the AstroSat satellite, in which the frequency of the low-frequency QPO varies smoothly between 2.5 and 6.6 Hz on a time scale of ∼10 hours. The derived phase lags show the same properties and evolution of those observed on time scales of a few hundred days, indicating that changes in the system geometry can take place on times below one day. We fit selected energy spectra of the source and rms and phase-lag spectra of the QPO with a time-variable Comptonization model, as done previously to RossiXTE data of the same source, and find that indeed the derived parameters match those obtained for variations on much longer time scales. This work has been done in collaboration with Tomaso M. Belloni, Mariano Mendez, and Federico Garcıa.

High hard X-ray polarization in Cygnus X-1 confined to the intermediate hard state: evidence for a variable jet component

Cygnus X-1, the well-known accreting black hole system, exhibits several observational features hinting at an intricate interplay between the accretion disk, its atmosphere known as the corona and the putative relativistic jet. It has been extensively studied using all available observational methods, including using the newly available technique of sensitive X-ray polarimetry. X-ray polarization characteristics are distinct for coronal and jet emissions. The low X-ray polarization measured below ∼100 keV is understood as arising from the corona. In contrast, the high polarization measurements reported above ∼400 keV required a separate jet-dominated spectral component, which spectroscopy does not demonstrate conclusively. Here we report precise polarization measurements in the 100–380 keV region made during three different sub-classes of spectral states of the source using the CZTI instrument onboard *AstroSat*. A high polarization (23±4 %) is found mainly in the Intermediate Hard State of the source, and the energy-resolved measurements smoothly connect the coronal and the jet regimes. When high polarization is observed, the simultaneous spectral data hints at a separate power law component above 100 keV. We examine the possible sources of this energy-dependent high polarization in Cygnus∼X-1. This work has been done in collaboration with Tanmoy Chattopadhyay, Abhay Kumar, A. R. Rao, Yash Bhargava and et al.

Subhra Bhattacharya

Complexity factor parameterization for traversable wormholes

It is known that static traversable wormholes in Einstein gravity are supported by matter that violates null energy conditions (NEC). Essentially, such wormholes will be characterized by a central throat with anisotropic matter lining the throat that violates NEC. This, in turn, provides viable geometry for the wormhole to sustain. In 2018, Herrera [Phys. Rev. D 97, 044010 (2018)] introduced a new classification for spherically symmetric bodies called "complexity factor." It was proposed that a spherically symmetric non-trivial geometry can be classified as complex or non-complex based on the nature of the inhomogeneity and anisotropy of the stress–energy tensors with only homogeneous and isotropic matter distribution leading to null complexity. Mathematically, there was also another way of obtaining zero complexity geometry. In this context, since static traversable wormholes, by default, are characterized by anisotropic and inhomogeneous matter stress tensors, the question we answer is whether it is possible to obtain zero complexity class of wormholes supported by exotic matter. This work has been done in collaboration withSubhasis

Nalui.

Ritabrata Biswas

Dynamical System Scenario for Accretion Discs: Dark Energy Acting through the Space Time Metric

Studies of accretion towards black holes are found in literature where dark energy is chosen to act as the accreting agent. Studies of a dynamical system related to such a phase portrait are also available. In this article, the central engine is opted to be embedded in a dark energy universe. Footprints of the dark energy equation of state are found in the black hole's metric chosen by us. Using the pseudo Newtonian method, the force complexity due to relativity is replaced with simplified terms. Dynamical system for a viscous accretion is constructed. Each point of this said system is a three coordinated tuple presenting radial inward speed, sonic speed and specific angular momenta one after the other. A bent curve of center equilibrium is found. Two planes are seen which are respectively attractor and repeller. Every case is physically interpreted. For a viscous accretion onto a dark energy embedded black hole, it is followed that the center equilibrium points are forming a closed curve taking the origin on its own plane. Though the orbit of such a center equilibrium curve keeps only a part of it in the space of discussion. This work has been done in collaboration with Giridhari Deogharia.

Nuclear matter equation of state and stability of charged compact stars embedded in $f(T)$ modified gravity, under cosmic acceleration

This work mainly focuses on modeling the charged compact stars and investigating their properties in the framework of $f(T)$ modified gravity, under the accelerated phase of the universe. In this study, we have introduced the modified gravity and dark matter to culture the evolution of the charged neutron stars by considering the present situation. True knowledge and proper study on the macroscopic parameters of the compact stars are very much needed to realize the microscopic properties and behavior of the core nuclear matter at very high density and pressure. The existence of modified Chaplygin gas as an exotic fluid inside the core of these stars in $f(T)$ gravity plays a very important role inside the stars. We have found out that exotic fluid has a great impact on the equation of state of the core nuclear matter and even on the stability of the compact stars. Pressure anisotropy reduces the tidal deformability of the charged stars in an appreciable amount and helps to get a more compact structure. But surprisingly, the compact stars are still able to maintain their spherically stable and equilibrium configuration. Further, we can put constraints on several macroscopic parameters of the compact stars and can investigate their evolution from our present investigation. This work has been done in collaboration with Mayukh Bandyopadhyay.

Chandrachur Chakraborty

Magnetic Penrose process in the magnetized Kerr spacetime

It is well-established that the magnetic Penrose process (MPP) could be highly efficient (efficiency can even exceed 100%) for extracting the energy from a Kerr black hole, if it is immersed in a mG order magnetic field. Considering the exact solution of the magnetized Kerr spacetime, here we derive the exact expression of efficiency ($\eta_{\rm MPP}$) for MPP, which is valid for both the Kerr black hole (BH) as well as Kerr superspinar (SS), and also from the weak magnetic field to an ultra-strong magnetic field (B) which can even distort the original Kerr geometry. We show that although the value of $\eta_{\rm MPP}$ increases upto a certain value of ultra-strong magnetic field (B_p), it decreases to zero for $B > B_p$, in case of the Kerr BHs. On the other hand, $\eta_{\rm MPP}$ shows the opposite behavior in case of the Kerr SSs. One intriguing feature that emerges is, $\eta_{\rm MPP}$ acquires the maximum value for the Kerr parameter $a_* \approx 0.786$ (unlike $a_* = 1$ for the ordinary PP), decreases for the range $0.786 < a_* \leq 1$, and reaches to 20.7% for $a_* = 1$ with a few limitations. This indicates that the BH starts to expel the effect of magnetic field for $a_* > 0.786$, and is fully expelled from the extremal Kerr BH due to the gravitational Meissner effect. As a special case of MPP, we also study the ordinary Penrose process (PP) for the magnetized Kerr spacetime. We show that the efficiency of PP decreases with increasing the magnetic field for the Kerr BH. In case of the Kerr SS, the efficiency of PP decreases from 10^3% to 0 for increasing the value of magnetic field from 0 to a specific value of ultra-strong magnetic field. Thus, the MPP for Kerr BHs, Kerr SSs and the ordinary PP for Kerr SSs can be superefficient for the astrophysical applications to powering engines in the high-energy sources like active galactic nuclei and quasars, in the weak magnetic fields. Our strong magnetic field result of MPP could be important to the primordial BHs in the early Universe immersed in the primordial magnetic fields, and to the transmuted BHs which are formed by collapsing and/or by merging of the magnetized progenitors. It is almost impossible to extract the energy from a BH (SS) through MPP (PP) in the ultra-strong magnetic fields. This work has been done in collaboration with P. Patil, G. Akash.

Black holes shielded by magnetic fields

Black holes (BHs) formed by collapsing and/or merging of magnetized progenitors, have magnetic fields penetrating the event horizon, and there are several possible scenarios. Thus, the no-hair theorem that assumes the outside medium is a vacuum, is not applicable in this case. Bearing this in mind

and considering a Schwarzschild BH of mass M immersed in a uniform magnetic field B, we show that all three frequencies related to the equatorial circular orbit of a test particle become imaginary for the orbits of radii $r_B > 2B^{-1}$. It signifies that if a BH is surrounded by a magnetic field of order $B \sim R_g^{-1}$ (where R_g is the gravitational radius of the BH), a test particle could unable to continue its regular geodesic motion from/at $r > r_B$, hence the accretion disk could not be formed, and the motion of other stellar objects around the BH could be absent. As the BHs are generally detected by watching for their effects on nearby stars and gas, a magnetic field of order $B \sim R_g^{-1}$ could be able to shield a BH in such a way that it could remain undetectable. Motivated with this theoretical investigation and considering the sphere (of radius r_f) of magnetic influence around an astrophysical BH, we constrain B, above which a magnetized BH could remain undetectable. For example, $M = 10^9 M_\odot$ BH surrounded by $B > 10^6$ G and $M = 10 M_\odot$ BH surrounded by $B > 10^{14}$ G could remain undetectable for $r_f \sim 10^5 R_g$. In other words, our result also explains why a *detected* SMBH has surprisingly weak magnetic field.

Subenoy Chakraborty

The classical and quantum implications of the Raychaudhuri equation in $f(T)$-gravity

The present work deals with the classical and quantum aspects of the Raychaudhuri equation (RE) in the framework of $f(T)$-gravity theory. n the background of homogeneous and isotropic Friedmann Lemaitre Robertson Walker space time, the RE has been formulated and used to examine the focusing theorem and convergence condition for different choices of $f(T)$. Finally in quantum cosmology, the wave function of the Universe has been shown to be the energy eigen function of the time-independent Schrodinger equation of a particle. Also probability measure on the minisuperspace has been examined at zero volume for singularity analysis in the quantum regime. Lastly, the Bohmian trajectory for the present quantum system has been explicitly determined for some particular choices. This work has been done in collaboration with Madhukrishna Chakraborty.

Raychaudhuri equation from Lagrangian and Hamiltonian formulation: A quantum aspect

The paper deals with a suitable transformation related to the metric scalar of the hyper-surface so that the Raychaudhuri Equation (RE) can be written as a second order nonlinear differential equation. A first integral of this second order differential equation gives a possible analytic solution of the RE. Also, it is shown that construction of a Lagrangian (and hence a Hamiltonian) is possible, from which the RE can be derived. WheelerDewitt equation has been formulated in canonical quantization scheme and norm of its solution (wave function of the universe) is shown to affect the singularity analysis in the quantum regime for any spatially homogeneous and isotropic cosmology. Finally Bohmian trajectories are formulated with causal interpretation and these quantum trajectories unlike classical geodesics obliterate the initial big-bang singularity when the quantum potential is included. This work has been done in collaboration with Madhukrishna Chakraborty.

Nand K. Chakradhari

Weak secondary cyclotron line in eclipsing high-mass X-ray binary Cen X-3

We report the time-resolved spectroscopy results from two observations of Centaurus X-3, over one binary orbit with *AstroSat* and two binary orbits with *Nuclear Spectroscopic Telescope Array (NuSTAR). NuSTAR* covered two intensity states where the light curve showed transition in count rate from first to second binary orbit by a factor of ~ 3. A phenomenological model comprising of partially absorbed power law with smoothed high energy cutoff, cyclotron absorption ~ 24 and 6.4 keV iron emission gave good fit for *AstroSat* observation. *NuSTAR* spectra required two additional emission components, a broad one ~ 5.7 keV and a narrow one ~ 6.9 keV. A weak secondary absorption feature at ~ 11.6 and ~ 14.5 keV was seen in the residuals of the spectral fit for *AstroSat* and *NuSTAR* data, respectively. The secondary absorption energy showed no correlation with the cutoff energy. Its strength varied within 0.1–0.6 keV with its width ~ 1.6 keV. Its energy and optical depth showed linear positive correlation with the fundamental cyclotron line energy and depth, respectively. The cyclotron line energy showed anticorrelation to flux described by a power law with negative index and the secondary absorption also showed similar trend to flux. Depth of secondary absorption was ~ 45 per cent and centroid energy was ~ 54 per cent of fundamental. Depth and energy ratio of secondary to fundamental lied within 2σ deviation from 0.5. We suggest this secondary absorption to be a redshifted dipolar cyclotron resonance feature exhibiting sub-harmonic behaviour. This is a collaborative work of Pravat Dangal, Ranjeev Misra, N. K. Chakradhari and Yashpal Bhulla.

Type Ia supernovae SN 2013bz, PSN J0910 + 5003, and ASASSN-16ex: similar to 09dc-like?

We present optical photometric and spectroscopic studies of three supernovae (SNe): SN 2013bz, PSN J0910 + 5003, and ASASSN-16ex (SN 2016ccj). UV–optical photometric data of ASASSN-16ex obtained with the *Swift* Ultraviolet/Optical Telescope (UVOT) are also analysed. These objects were initially classified as 09dc-like type Ia SNe. The decline-rate parameters ($\Delta m_{15}(B)_{true}$) are derived as 0.92 ± 0.04 (SN 2013bz), 0.70 ± 0.05 (PSN J0910+5003) and 0.73 ± 0.03 (ASASSN-16ex). The estimated B-band absolute

magnitudes at maximum: -19.61 ± 0.20 mag for SN 2013bz, -19.44 ± 0.20 mag for PSN J0910+5003 and -19.78 ± 0.20 mag for ASASSN-16ex indicate that all the three objects are relatively bright. The peak bolometric luminosities for these objects are derived as $\log L_{\rm bol}^{\rm max} = 43.38 \pm 0.07$, 43.26 ± 0.07, and $43.40 \pm 0.06\,{\rm erg\,s^{-1}}$, respectively. The spectral and velocity evolution of SN 2013bz is similar to that of a normal SN Ia, hence it appears to be a luminous, normal type Ia supernova. On the other hand, the light curves of PSN J0910 + 5003 and ASASSN-16ex are broad and exhibit properties similar to 09dc-like SNe Ia. Their spectroscopic evolution shows similarity with 09dc-like SNe: strong C II lines are seen in the pre-maximum spectra of these two events. Their photospheric velocity evolution is similar to SN 2006gz. Further, in the UV bands, ASASSN-16ex is very blue, like other 09dc-like SNe Ia. This is a collaborative work of Shrutika Tiwari, N. K. Chakradhari, D.K. Sahu, G. C. Anupama, Brajesh Kumar and K.R. Sahu.

Hum Chand

Intranight optical variability of TeV blazars with parsec-scale jets dominated by slow-moving radio knots

BL Lac objects detected at TeV energies preferentially belong to the subclass called 'high-frequency-peaked' BL Lacs (HBLs). Parsec-scale radio jets in these TeV-HBLs often show dominant, slow-moving radio knots that are at most mildly superluminal. We report the first systematic campaign to characterize the intranight optical variability (INOV) of TeV-HBLs using a representative sample of six such sources, all showing a fairly high degree of optical polarization. Our campaign consists of high-sensitivity monitoring of this sample in 24 sessions of more than 3 h duration each. For these TeV-HBLs, we find a striking lack of INOV and based on this, we discuss the importance of superluminal motion of the radio knots vis-a-vis the optical polarization, as the key diagnostic for INOV detection. This work has been done in collaboration with Vibhore Negi, Gopal-Krishna.

Intranight optical variability of blazars and radio-quiet quasars using the ZTF survey

We explore the potential of the ongoing Zwicky Transient Facility (ZTF) survey for studying intranight optical variability (INOV) of active galactic nuclei (AGNs), in particular for picking rare events of large INOV amplitudes, whose detection may require extensive temporal coverage. For this, we have used the available high cadence subsets of the ZTF data base to build a well-defined large sample of 53 blazars and another sample of 132 radio-quiet quasars (RQQs), matched to the blazar sample in the redshift-magnitude plane. High-cadence ZTF monitoring of these two matched samples is available, respectively, for 156 and 418 intranight sessions. Median durations for both sets of sessions are 3.7 h. The two classes of powerful AGNs monitored in these sessions represent opposite extremes of jet activity. The present analysis of their ZTF light curves has revealed some strong INOV events that, although not exceptionally rare for blazars, are indeed so for RQQs, and their possible nature is briefly discussed. This work has been done in collaboration with Vibhore Negi, Gopal-Krishna, Ravi Joshi et al.

Ramesh Chandra

Observational Characteristics of solar EUV waves

Extreme-ultraviolet (EUV) waves are one of the large-scale phenomena on the Sun. They are defined as large propagating fronts in the low corona with speeds ranging from a few tens km/s to a multiple of 1000 km/s. They are often associated with solar filament eruptions, flares, or coronal mass ejections (CMEs). EUV waves show different features, such as, wave and nonwave components, stationary fronts, reflection, refraction, and mode conversion. Apart from these, they can hit the nearby coronal loops and filaments/prominences during their propagation and trigger them to oscillate. These oscillating loops and filaments/prominences enable us to diagnose coronal parameters such as the coronal magnetic field strength. In this article, we present the different observed features of the EUV waves along with existing models. This work has been done in collaboration with Pooja Devi, P. F. Chen, Brigitte Schmieder, Reetika Joshi, Bhuwan Joshi, and Arun Kumar Awasthi.

Interaction of solar jets with filaments: Triggering of large-amplitude filament oscillations

Context. Large-amplitude oscillations (LAOs) are often detected in filaments. Using multi-wavelength observations, their origin can be traced back to the interaction with eruptions and jets. Aims: We present two different case studies as observational evidence in support of 2.5D numerical magnetohydrodynamics (MHD) experiments that show that the LAOs in the filament channels can be initiated by solar jets. Methods: We use longitudinal magnetic field observations using the Helioseismic Magnetic Imager to study the evolution of the filament channels. The LAOs in the filaments are analysed using two techniques. The first is time-distance diagnostics with extreme-ultraviolet (EUV) and Hα datasets. In the second method, the oscillations in different parts of the filaments are examined using Fourier analysis of the brightness variations of all pixels in Hα observations. Results: In the two studied events, we can identify a quadrupolar configuration with an X-point at the top of the parasitic region suggestive of a classical null-point. The X-point evolves into a flat structure suggestive of a breakout current sheet. A reconnection flow emanates from this structure, leading to a jet that propagates along

the filament channel. In both cases, we can identify the quiescent and eruptive phases of the jet. The triggered LAOs have periods of around 70-80 min and are damped after a few oscillations. The minimum magnetic field intensity inferred with seismology for the filament turns out to be around 30 Gauss. Conclusions: We conclude that the two case studies are consistent with a recently published numerical model in which the LAOs are initiated by jets. The relationship between the onset of the jet and filament oscillations is straightforward for the first case but is less clear for the second case. In the second event, although there is some evidence for a relationship, we cannot rule out other possibilities such as activity unrelated to the null-point or changes in the magnetic structure of the filament. Both jets are associated with very weak flares that did not launch any EUV waves. Therefore, a role of EUV waves in triggering the filament oscillations can be eliminated for these two cases. This work has been done in collaboration with Reetika Joshi, Manuel Luna, Brigitte Schmieder, and Fernando Moreno-Insertis.

Suresh Chandra

Potential spectral lines of ethanimine (CH_3CHNH) - an important possible precursor of amino acids

Accurate computational characterization of ethanimine (CH_3NH), considered as an important possible precursor of amino acids, is now available. Ethanimine has two E and Z isomers and each isomer has two A and E substates. Some lines of Green Bank Telescope PRIMOS radio astronomy survey spectra in Sagittarius B2 North (Sgr B2(N)) have been assigned to the ethanimine. For known values of accurate energies of rotational levels in the ground vibrational state, and the spectroscopic data (rotational and centrifugal distortion constants, and electric dipole moment), we have calculated Einstein A and B coefficients (radiative transition probabilities) for rotational transitions for each substate. These radiative transition probabilities along with collisional rate coefficients are calculated using a scaling law have been used for solving a set of statistical equilibrium equations coupled with the equations of radiative transfer for each substate. We have found a number of weak MASER lines and anomalous absorption lines for each substate. These lines may play important role for identification of ethanimine in a cosmic object. Corresponding lines in two substates in a isomer have been found to show similar behaviour, except different values of their frequencies. This work has been done in collaboration with Mohit K. Sharma, and Mattia Melosso.

Sobolev analysis of methanimine with large number of levels: Requirement of collisional rate coefficients

Methanimine in gas phase has been a subject of interest because of its role as precursor of glycine. Recently, methanimine has been analyzed using accurate collisional rate coefficients for collisional transitions between 15 lower rotational levels, having energy up to 28.3 cm^{-1}. Since kinetic temperature in some molecular regions is several tens of Kelvin, it is required to consider large number of levels in an analysis. But, the collisional rate coefficients are not available for methanimine when large number of levels are considered; whether it is worth to go for calculation of collisional rate coefficients considering large number of levels of methanimine. To understand this situation, we have performed the Sobolev Large Velocity Gradient (LVG) analysis of methanimine considering 140 levels, having energy up to 303 cm^{-1}. Using accurate rotational and centrifugal distortion constants, energies of rotational levels, and radiative transition probabilities for radiative transitions between the levels have been calculated. These radiative transition probabilities in conjunction with the scaled values of collisional rate coefficients have been used in the Sobolev LVG analysis of methanimine and we have found encouraging results. Hence,the calculation of collisional rate coefficients between large number of levels is desirable. This work has been done in collaboration with Mohit K. Sharma,and Heena Luthra.

Ritaban Chatterjee

Correlated Short Time-Scale Hard-Soft X-Ray Variability of the Blazars Mrk 421 and 1ES 1959+650 Using AstroSat

We study simultaneous soft ($0.7-7$ keV) and hard ($7-20$ keV) X-ray light curves at a total of eight epochs during $2016-2019$ of two TeV blazars Mrk 421 and 1ES 1959+650 observed by the SXT and LAXPC instruments onboard *AstroSat*. The light curves are $45-450$ ks long and may be sampled with time bins as short as $600-800$ sec with high signal to noise ratio. The blazars show a harder when brighter trend at all epochs. Discrete cross-correlation functions indicate that the hard and soft X-ray variability are strongly correlated. The time lag is consistent with zero in some epochs, and indicates hard or soft lag of a few hours in the rest. In the leptonic model of blazar emission, soft lag may be due to slower radiative cooling of lower energy electrons while hard lag may be caused by gradual acceleration of the high energy electrons emitting at the hard X-ray band. Assuming the above scenario and the value of the Doppler factor (δ) to be $10-20$, the hard and soft lags may be used to estimate the magnetic field to be ~ 0.1 Gauss and the acceleration parameter to be $\sim 10^4$ in the emission region. Due to the availability of the high time resolution ($\sim$ minutes to hours) light curves from *AstroSat*, the value of the illusive acceleration parameter could be estimated, which provides a stringent constraint on the theories of particle acceleration in blazar jets. This work has been done in collaboration with Susmita Das.

Multi-Year Characterisation of the Broad-Band Emission from the Intermittent Extreme BL Lac 1ES 2344+514

Aims: The BL Lac 1ES 2344+514 is known for temporary extreme properties characterised by a shift of the synchrotron spectral energy distribution (SED) peak energy $\nu_{synch,p}$ above 1 keV. While those extreme states have only been observed during high flux levels thus far, additional multi-year observing campaigns are required to achieve a coherent picture. Here, we report the longest investigation of the source from radio to very high energy (VHE) performed so far, focussing on a systematic characterisation of the intermittent extreme states.
Methods: We organised a monitoring campaign covering a 3-year period from 2019 to 2021. More than ten instruments participated in the observations in order to cover the emission from radio to VHE. In particular, sensitive X-ray measurements by XMM-Newton, NuSTAR, and AstroSat took place simultaneously with multi-hour MAGIC observations, providing an unprecedented constraint of the two SED components for this blazar.
Results: While our results confirm that 1ES 2344+514 typically exhibits $\nu_{synch,p} > 1$ keV during elevated flux periods, we also find periods where the extreme state coincides with low flux activity. A strong spectral variability thus happens in the quiescent state, and is likely caused by an increase in the electron acceleration efficiency without a change in the electron injection luminosity. On the other hand, we also report a strong X-ray flare (among the brightest for 1ES 2344+514) without a significant shift of $\nu_{synch,p}$. During this particular flare, the X-ray spectrum is among the softest of the campaign. It unveils complexity in the spectral evolution, where the common harder-when-brighter trend observed in BL Lacs is violated. By combining Swift-XRT and Swift-UVOT measurements during a low and hard X-ray state, we find an excess of the UV flux with respect to an extrapolation of the X-ray spectrum to lower energies. This UV excess implies that at least two regions significantly contribute to the infrared/optical/ultraviolet/X-ray emission. Using the simultaneous MAGIC, XMM-Newton, NuSTAR, and AstroSat observations, we argue that a region possibly associated with the 10 GHz radio core may explain such an excess. Finally, we investigate a VHE flare, showing an absence of simultaneous variability in the $0.3 - 2$ keV band. Using time-dependent leptonic modelling, we show that this behaviour, in contradiction to single-zone scenarios, can instead be explained by a two-component model. This work has been done in collaboration with Abe, H., et al.

Asis Kumar Chattopadhyay

Investigation of the effect of bars on the properties of spiral galaxies: a multivariate statistical

Subjective classification of spiral galaxies is not sufficient for studying the effect of bars on their physical characteristics. In reality the problem is to comprehend the complex correlations in a multivariate parametric space. Multivariate tools are the best ones for understanding this complex correlation. In this work an objective classification of a large set (26,089) of spiral galaxies was compiled as a value added galaxy catalogue from sdss DR 15 virtual data archive. Initially for dimensionality reduction, Independent Component Analysis is performed to determine a set of Independent Components that are linear combinations of 48 observed features (namely ionized lines, Lick indices, photometric and morphological properties). Subsequently a K-means cluster analysis is carried out on the basis of the 14 best chosen Independent Components to obtain 12 distinct homogeneous groups of spiral galaxies. Amongst these, 3 groups are the oldest ones, while 5 groups fall in the medium aged category , 2 groups consist of only unbarred spirals, 1 group is the youngest one and the remaining one is an outlier. In many groups there are clear indication of recurrent bar formation phenomena which is consistent with few previous simulation works. In order to study the robustness of the clusters with respect to the method of clustering, a second method of clustering by Gaussian Mixture Modeling Method (GMMBC) is applied. This work has been done in collaboration with Prasenjit Banerjee, Tanuka Chattopadhyay.

Comparison among different Clustering and Classification Techniques:Astronomical data-dependent study

In the field of Astrostatistics, clustering and classification of different astronomical objects play a very important role. In cluster analysis, the objective is to group the items such that items in the same cluster are more closely related than those assigned to different clusters. The total number of clusters in the data set may be known in some cases and maybe unknown in others. There are different methods available for clustering, which can be further categorized under supervised and unsupervised learning techniques. In the case of supervised learning, there are some model assumptions but in the case of unsupervised learning, there are no such assumptions. Under both the above-mentioned categories, for clustering and classification, various methods have been developed depending on the nature of the data sets. However, generally, it is difficult to compare the performances of the different techniques. Here we have tried to compare the applicability of some of the clustering techniques on a galaxy data set. To justify the robustness of the variety of unsupervised methods

used in our work, a few post-classification techniques are used as supervised learning. Finally, the comparability of clusters, obtained by different techniques, is studied with respect to an ad-hoc techniqueand they are further justified in terms of astrophysical properties of the galaxies. Our main focus is on unsupervised machine learning algorithms, which are used to perform dimensionality reduction, cluster analysis, visualization and to get an idea regarding the best-unsupervised technique that is appropriate for a galaxy data set. It is found that K-means performs best for the galaxy data set under consideration. This work has been done in collaboration with Prasenjit Banerjee, and Tanuka Chattopadhyay.

Pradip Kumar Chattopadhyay

New mass limit of a strange star admitting a colour flavor locked equation of state

A class of strange stars is analysed in the present article in hydrostatic equilibrium, whose state is defined by a CFL phase equation of state. We have compared our results with those obtained from the MIT equation of state for strange quark matter, which is regarded as free particles. We have noted that if we consider quarks to form a cooper pair and if their description is made by the CFL equation of state, the maximum mass of strange star reaches a value as high as 3.61 $M_{\odot}$. This value is well above the value of 2.03 $M_{\odot}$ obtained by using the MIT bag equation of state for massless free quarks. Both the maximum masses are determined by solving the TOV equation for different values of the strange quark mass m_s . Thus, the inclusion of the possibility of quark pair formation in the theory permits us to accommodate a wider class of compact objects such as PSR J1614-2230, PSR J0740+6620, PSR J0952-0607 etc. and the mass of the companion star in the GW190814 event in our model. The consideration of such a high value of mass is hardly theoretically obtainable from normal strange star models in general relativity even with a fast rotation effect. The object PSR J0952-0607 is found to be the fastest and heaviest pulsar in the disk of Milky Way Galaxy, having a mass of 2.35 $M_{\odot}$, which may be predicted in our model, as observational evidence supports the existence of strange quark matter in its composition. This work has been done in collaboration with K. B. Goswami, A. Saha1, and S. Karmakar.

New gravastar model in generalised cylindrically symmetric spacetime and prediction of mass limit

We present a class of new Gravastar solutions following the works of Mazur and Mottola for a Gravitational BoseEinstein Condensate (GBEC) star in generalised cylindrically symmetric spacetime. A stable gravastar consists of 3 distinct regions, namely: (i) an interior de-Sitter space ($p = -\rho$), which exerts an outwards repulsive force at all points on the thin shell, (ii) an intermediate thin shell with a slice of finite length separating the interior and exterior regions is supposed to be consisting of an ultra-relativistic stiff fluid, with the equation of state $p = \rho$ and (iii) an exterior vacuum region. This thin shell, which is considered as the critical surface for the quantum phase transition, replaces both the classical de-Sitter space and Schwarzschild event horizon. The new solutions are free from any singularities. The energy density, total energy, proper length, and the entropy of this shell are explored in this model. From the thin shell solution and using Lanczos equations for stress energy density, we have predicted the mass contained into the gravastar shell. The stability of the gravastar model is analysed through the consideration of gravitational surface redshift and entropy calculation. We have also obtained a constraint on the possible mass of the thin shell without violating the condition for stable gravastar configuration. All these features indicate that the present model is physically viable. This work has been done in collaboration with Debadri Bhattacharjee, and Bikash Chandra Paul.

Surajit Chattopadhyay

A truncated scale factor to realize cosmological bounce under the purview of modified gravity

The present paper reports a study on bounce realization with a truncated scale factor and the holographic fluid taken in the form of Holographic Ricci Dark Energy. This work is inspired by the work of Nojiri et. al. *Nuclear Physics B*, **Vol** 949, Article ID 114790 (2019). We have investigated the realization of bounce as a result of the application of holographic fluid in the early scenario of the universe. In our study, we have started with a de-Sitter scale factor and derived two modified forms using Taylor's series expansion. After studying the behaviour of the resulting Hubble parameter, we identified $a(t) = a_0\left[1 + H_0(t-t_0) + \frac{H_0^2}{2}(t-t_0)^2\right]$ as the suitable form of the scale factor to realize the bounce. It satisfied the conditions $H < 0$, $H = 0$, and $H > 0$ before, at, and after the turn-around point. We have also observed that the resulting Equation Of State(Eos) parameter violates the null energy condition required by the bounce realization. We have further studied the bounce scenario in a modified $f(T)$ gravity framework and derived the slow roll parameters. We have studied the behaviour of the potential along with the slow-roll parameters in this bouncing scenario. This work is carried out with Khandro K. Chokyi.

A study on the various aspects of bounce realisation for some choices of scale factors

The current study examines the realisation of cosmic bounce in two situations involving two distinct scale factor

selections, one of which is a scale factor already developed for bouncing and the other is a scale factor created by truncating a series expansion of a de-Sitter scale factor. Generalised Chaplygin gas (GCG) is assumed to be the background fluid in both situations. When the scale factor is set to the first kind, the pre-bounce scenario's GCG energy density decreases due to contraction, reaches its lowest point at $t = 0$ during the bounce, then rises as a result of expansion following the bounce. However, it has been noted that the truncation has an impact on the density evolution from pre-bounce in the other scale factor scenario. The influence of bulk viscosity has been shown in all circumstances, in addition to non-viscous, and the test for stability using squared speed of sound. At the turn-around places, the null energy criterion has also been violated. The final stage of the study included cosmographic analysis and a demonstration of the Hubble flow dynamics. In the conclusion, we found that inflationary cosmology can also be realised with GCG as the background fluid for the two scale factor options. When the equivalent cosmic parameter is examined for pre-bounce and post-bounce scenarios, a symmetry is frequently seen. The symmetry occurs near the point of bouncing or turning. This work is carried out in collaboration with Sanghati Saha, and Ertan Gudekli.

Bhag Chand Chauhan

Leptogenesis and neutrinoless double beta decay in the scotogenic hybrid textures of neutrino mass matrix

In our recent work, we identified the hybrid textures that simultaneously account for dark matter (DM) and neutrinoless double beta decay ($0\nu\beta\beta$). We also obtained bounds on dark matter mass and effective Majorana mass. However, on the same lines, in this work, we explored common parameter spaces amongst the baryon asymmetry of the universe Y, dark matter mass M_1, and effective Majorana mass $|M_{ee}|$. We use experimental bounds on the relic density of dark matter (Ωh^2) and baryon asymmetry of the universe to identify the suitable hybrid textures. We found that out of the five hybrid textures only three simultaneously satisfy the physics observations of the DM, $0\nu\beta\beta$, and leptogenesis. It is interesting to note that these three hybrid textures give a lower bound to the effective Majorana mass $|M_{ee}|$, which can be probed in current and future experiments like SuperNEMO, KamLAND-Zen, NEXT, and nEXO (5 years) that have sensitivity reaches of 0.05 eV, 0.045 eV, 0.03 eV, and 0.015 eV, respectively. This work has been done in collaboration with Ankush Choudhary, Rishu Verma, Sahil Kumar.

Dark Matter and Muon $(g-2)$ from a discrete Z_4 Symmetric Model

The non-zero neutrino mass and nature of Dark Matter (DM) is still unknown within Standard Model (SM). In 2021, there was 4.2σ discrepancy with SM results in the measurement of muon magnetic moment reported by Fermilab. Recently, Fermilab released its precised results for muon's magnetic moment and it shows 5.1σ discrepancy. In this work, we study the co-relation between neutrino masses, muon $(g-2)$ anomaly and Dark Matter within a framework based on Z_4 extension of the scotogenic model, in which the neutrino masses are generated at one loop level. We extend the model with a vector like lepton (VLL) triplet in order to explain muon $(g-2)$. Here, the coupling of VLL triplet ψ_T to inert doublet η provides positive contribution to muon anomalous magnetic moment. We also studied the DM phenomenology of ψ_T by considering the neutral component of ψ_T as the lightest DM candidate. We show that, for mass of VLL triplet M_ψ in TeV scale, the model can well explain muon $(g-2)$ anomaly and also gives required relic density. This work has been done in collaboration with S. Arora.

Himadri Sekhar Das

Probing the magnetic field and dust grain properties of two dark clouds L1495 and L1498 through photopolarimetry

We present the R-band polarimetry of two low latitude Lynd's clouds L1495 and L1498 acquired with AIMPOL at Aryabhatta Research Institute of Observational Sciences, Nainital, India. The estimated polarization across the regions of L1495 and L1498 is typically in the range of $\sim$ 1-5 percent and the position angle is typically in the range of $\sim$ 100-137 degrees from which we infer the morphologies of the corresponding magnetic field in the envelope region (θ_B^{env}). In both clouds, the magnetic fields are found to be aligned with the galactic field (θ_{GP}). Due to their close proximity to the galactic plane, we incorporate the values of offset ($\theta_{off} = |\theta_B^{env} - \theta_{GP}|$) from this study into our previously established geometrical correlation between the variation in relative orientation with the galactic longitude. We find that the offsets estimated for two clouds L1495 and L1498 in this investigation are consistent with the offsets predicted by our previous study. We also generate the extinction map for the two clouds using the NICE technique and the extinction structure is found to be analogous to the dust structure at the denser region of the cloud as obtained from the 500 μm dust continuum emission maps of *Herschel* SPIRE. Three distinct cores with high extinction are detected in L1495, and two such cores are also detected in L1498. We also estimate the mean particle density ($< n_{H_2} >$) at the peripheral region as well as the high extinction cores of the clouds. This work has been done in collaboration with G. B. Choudhury, B. Goswami, B. J. Medhi,and J. C. Pandey.

A study of the correlation between polarization maximum to minimum ratio and scattering parameters in a spheroid dust model

This paper investigates the correlation between the ratio of polarization maximum to polarization minimum (P_z) and different scattering parameters such as complex refractive indices ($m = n+ik$), effective radius (r_{eff}), effective variance (v_{eff}), and axial ratio (E) for spheroidal particles. The simulations are executed using the double-precision T-matrix code for randomly oriented spheroidal particles, considering different sets of scattering parameters. For a specific range of n, k, E, r_{eff}, and v_{eff}, a strong correlation between P_z and other scattering parameters is observed in all cases, which can be fitted by a second-degree polynomial equation. The simulations are conducted at two wavelengths ($\lambda = 0.50\mu m$ and $0.65\mu m$). Additionally, we compare our results obtained from numerical simulation with the experimental data for a few forsterite samples conducted by Muñoz et al. (2021). A set of conclusions is presented based on our work. This work has been done in collaboration with B. Goswami.

Prasanta Kumar Das

Jet substructure probe to unfold singlet-doublet dark matter in the presence of non-standard cosmology

We examine the singlet-doublet fermionic dark matter model, where the non-thermal production of the dark matter in light of a non-standard cosmology demands a significantly larger interaction rate than the typical radiation-dominated Universe. Despite Being a model of freeze-in light dark matter and heavy mediator, the characteristic long-lived particle searches at the collider experiment and the displaced vertex signature do not help in probing such a dark sector since this non-standard interaction mandates nearly prompt decay. We make a counterproposal to probe such a signal with di-fat-jets generated from the boosted decays of massive vector bosons and Standard Model Higgs, along with the substantial missing transverse momentum to probe the dark matter at LHC. Interestingly,substructure variables associated with these fat jets have an additional handle to tackle the extensive QCD background as it encodes implicit footmarks of their origin. We adopt the multivariate analysis with the boosted decision tree to constrain the measured relic density allowed parameter space of dark matter in the presence of the modified cosmological scenario. Our study shows how the non-trivial expansion affects dark matter production in the early Universe and alters the required search strategies at colliders. This probe provides the best discovery prospect at the HL-LHC for extended parameter space now opened up in the dark sector. This work has been done in collaboration with Partha Konar, Saumyen Kundu Sudipta Show.

Inflationary cosmology with a non-minimal curvature and scalar mixing $\xi R\phi^2$ term

We use the PLANCK 2018 and the WMAP data to constraint inflation models driven by a scalar field in the presence of the non-minimal scalar-curvature mixing term ξ R $\phi^2/2$. We consider four distinct scalar field potentials $\phi^p exp$ (-$\lambda\phi$), $(1 - \phi^p)$ exp(-$\lambda\phi$), (1-$\lambda\phi$)p̂ and $\alpha\phi^2/(1+\alpha\phi^2)$ to study inflation in the non-minimal gravity theory. We calculate the potential slow-roll parameters, predict the scalar spectral index n_s , tensor-to-scalar ratio r , leading and higher order non-Gaussianity parameters (f_NL, τ_NLandg_NL) and the amplitude of the scalar spectrum A_s in the parameter space (λ, p, α) of the potentials corresponding to different values of the non-minimal coupling parameter ξ . We have compared our results with the ones existing in the literature, and this indicates the present status of non-minimal inflation after the release of the PLANCK 2018 data. This work has been done in collaboration with Payel Sarkar, Ashmita Rai.

Shyam Das

Compact stellar model with vanishing complexity under Vaidya-Tikekar background geometry

We make use of the condition of vanishing complexity, based on the current definition proposed by L. Herrera (Phys. Rev. D 97: 044010, 2018), to find exact interior solutions to the Einstein equations for describing compact stellar objects. In the framework of general relativity, the complexity factor is an outcome of the orthogonal splitting of the Riemann tensor from which structure scalars are obtained. By using the Vaidya-Tikekar (V-T) metric ansatz (J. Astrophys. Astron. 3:325, 1982) for the spacetime of a static spherically symmetric matter distribution, we model superdense, relativistic stars. The interior spacetime is matched to the exterior Schwarzschild solution across the boundary of the star where the radial pressure vanishes. The physical viability of the model has been tested following the current data corresponding to the pulsar $4U1820 - 30$. The stability of the model fulfilled the given criteria, namely the Tolman-Oppenheimer-Volkoff equation, the adiabatic index and the causality conditions. This work has been done in collaboration with Megandhren Govender, Robert S. Bogadi.

Anisotropic compact stellar objects with a slow rotation effect

A new class of exact solutions depicting anisotropic compact objects is presented in the current work. This spherically symmetric matter distribution assumes a specific form of anisotropy to obtain the exact solution for the field equations. The obtained interior solutions are smoothly matched with the Schwarzschild exterior metric over the bounding surface of a compact star and together with the

condition that the radial pressure vanishes at the boundary, the form of the model parameters are attained. One of the interesting features of the obtained solutions is the codependency of the metric potentials. We have considered the pulsar 4U1608−52 with its current estimated data (mass $= 1.57^{+0.30}_{-0.29}\ M\odot$ and radius $= 9.8 \pm 1.8\ km$) to study the model graphically. Moreover, we have studied the physical features and some important stability conditions for the model. Tabular comparison with other known pulsars infers that the obtained model represents a compact star within a radius of 8 to 12 km. Finally, we have found the angular momentum that causes the dragging of inertial frames of the slowly rotating equilibrium compact objects. This work has been done in collaboration with Lipi Baskey,and Farook Rahaman.

Ujjal Debnath

Gravitational Lensing of Acoustic Charged Black Hole

We study the Gravitational Lensing of the acoustic charged black hole in strong and weak-field limit approximations. For this purpose, we first numerically obtain the deflection limit coefficients and deflection angle in the strong field limit. We observe that strong deflection angle α_D increases with the increasing magnitude of charged parameter Q and the strong deflection angle for α_D for an acoustic charged black hole with tuning parameter $\xi = 4$ is greater than standard Reissner-Nordström black hole ($\xi = 0$). We also study the astrophysical consequence via strong gravitational lensing by taking the example of various supermassive black holes in the centre of several galaxies and observe that the acoustic charged black hole could be quantitatively distinguished from the standard Reissner-Nordström ($\xi = 0$) and standard Schwarzschild black hole ($\xi = 0$,$Q = 0$). Furthermore, by using the Gauss -Bonnet-theorem, we derive the weak deflection angle in the background of acoustic charged black hole in curved spacetime. We find that for the fixed value of charged parameter Q and tuning parameter ($\xi = 0$ *or* 4) weak deflection angle σ_D decreases with the impact parameter b. We also observe that weak deflection angle σ_D decreases with the increasing magnitude of charged parameter Q for the fixed value of tuning parameter ($\xi = 0$ *or* 4). Our results suggest that the observational test for an acoustic charged black hole is indeed feasible, and it is generalized to the case of acoustic Schwarzschild ($Q = 0$), standard Reissner-Nordström ($\xi = 0$) and standard Schwarzschild ($\xi = 0$,$Q = 0$) black hole. This work has been done in collaboration with Niyaz Uddin Molla.

Possible Existence of Traversable Wormhole in Finsler-Randers Geometry

In the present article, we have explored the possible existence of a traversable wormhole in the framework of Finsler-Randers (F-R) geometry. In order to achieve this goal, first, we have constructed gravitational field equations for static, spherically symmetric spacetime with anisotropic fluid distribution in F-R geometry. Next, we have written the deduced form of field equations in the background of Morris-Thorne wormhole geometry. To visualize the shape of the wormhole, we have selected exponential shape function $b(r) = \frac{r}{exp\left(\eta\left(\frac{r}{r_0}-1\right)\right)}$ with the constant parameter η and the throat radius r_0 and depicted 2-dimensional and 3-dimensional embedding diagrams corresponding to some considered values of η and r_0. Moreover, all essential requirements to build a wormhole shape have been examined for the reported shape function. Next, We have analyzed wormhole configuration for three cases (I, II, III) corresponding to three selected redshift functions. Furthermore, each case is analyzed by dividing it into two models such as (i) *Model-1* (for general anisotropic EoS $p_t = \chi p_r$) and (ii) *Model-2* (for linear phantom-like EoS $p_r + \omega\rho = 0$). In each model of three cases, we have verified the validity of the wormhole solution in F-R geometry by considering null, weak, strong and dominant energy conditions. Also, the total amount of averaged NEC-violating matter near the wormhole throat has been analyzed by computing volume integral quantifier. This work has been done in collaboration with Krishna Pada Das.

Shantanu Desai

title dont know

The Indian Pulsar Timing Array (InPTA) collaboration has recently made its first official data release (DR1) for a sample of 14 pulsars using 3.5 years of uGMRT observations. We present the results of single-pulsar noise analysis for each of these 14 pulsars using the InPTA DR1. For this purpose, we consider white noise, achromatic red noise, dispersion measure (DM) variations, and scattering variations in our analysis. We apply Bayesian model selection to obtain the preferred noise models among these for each pulsar. For PSR J1600−3053, we find no evidence of DM and scattering variations, while for PSR J1909−3744, we find no significant scattering variations. Properties vary dramatically among pulsars. For example, we find a strong chromatic noise with chromatic index ~ 2.9 for PSR J1939+2134, indicating the possibility of a scattering index that doesn't agree with that expected for a Kolmogorov scattering medium consistent with similar results for millisecond pulsars in past studies. Despite the relatively short time baseline, the noise models broadly agree with the other PTAs and provide, at the same time, well-constrained DM and scattering variations. This work has been done in collaboration with ??

Galaxy clusters could produce gamma-rays from inverse Compton scattering of cosmic ray electrons or hadronic

interactions of cosmic ray protons with the intracluster medium. It is still an open question on whether gamma-ray emission (> GeV energies) has been detected from galaxy clusters. We carry out a systematic search for gamma-ray mission based on 300 galaxy clusters selected from the 2500 deg.^{2} SPT-SZ survey after sorting them in descending order of M_{500}/z^2, using about 15 years of Fermi-LAT data in the energy range between 1-300 GeV. We were able to detect gamma-ray emission with significance of about 6.1σ from one cluster, viz SPT-CL J2012-5649. The estimated photon energy flux from this cluster is approximately equal to 1.3×10^{-6} MeV cm^{-2} s^{-1}. The gamma-ray signal is observed between $1-10$ GeV with the best-fit spectral index equal to -3.61 ± 0.33. However, since there are six radio galaxies spatially coincident with SPT-CL J2012-5649 within the Fermi-LAT PSF, we cannot rule out the possibility this signal could be caused by some of these radio galaxies. Six other SPT-SZ clusters show evidence for gamma-ray emission with significance between $3-5\sigma$. None of the remaining clusters show statistically significant evidence for gamma-ray emission. This work has been done in collaboration with ???

Shanti Priya Devarapalli

Photometric and Period Variation study of two contact binaries ASAS J034931-0431.2 and KIC 11413213.

We present the first photometric analysis of ASAS J034931-0431.2 and KIC 11413213, two short-period eclipsing contact binaries. Photometric analysis using the Wilson-Devinney method was performed using TESS, Kepler 2, and Gaia DR3 data available. Based on the collected times of minima, period variation studies were carried out and the orbital period was found to show a secular period decrease in both the variables. This can be inferred due to mass transfer or Angular momentum loss in the systems and the same are discussed. From the results obtained, ASAS J034931-0431.2 is an A-type marginal contact binary system with a low mass-ratio of q $\sim$ 0.2, while KIC 11413213 is W-type marginal contact with a high mass-ratio of q $\sim$ 1.2. The evolutionary status of the variables in the study is discussed using the Mass-Radius diagram, the long-time period decrease, the marginal-contact configuration, and the astrophysical parameters of these systems. This work has been done in collaboration with Dereje Wakgari, Rukmini Jagirdar.

First investigations of 14 neglected, late-type contact binaries

In the current work we present the first investigations of 14 neglected, late-type, short period contact binaries using period variation, photometric and spectroscopic analysis performed on long term space and ground based observations. The binaries in study belong to spectral classes F to K. In this study the two contact binaries TIC 242100930 and TIC 332918217 are suggestive to be precursors to merger candidates since they showed highest period decreasing rates 10-6 day/yr. Preliminary photometric analysis using PHOEBE revealed 9 of them to be in marginal, 4 in over and 1 in deep contact configuration. The evidence of magnetic activity is observed in 6 of the contact binaries either by presence of spots in their photometric solution or photospheric and chromospheric lines in their spectra from LAMOST/VBT/HCT, suggesting such activity to be an inherent feature in these binaries, irrespective of their evolutionary stages. The equivalent widths of Na and Hα lines, in the spectra taken from VBT and HCT for TIC 7022755 and TIC 20572196, show strong phase dependent variability. Additionally a strong correlation is found between equivalent widths of Na and Hα lines throughout the observed phases, for the high mass ratio contact binary TIC 7022755. TIC 50717816 is found to be a deep overcontact binary (f $\geq$ 50%) with extreme low mass ratio (q 0.22), showing a long term period decrease, which may further evolve into a progenitor to blue straggler, due to merger of its components. Using the collective results from current study, an attempt is made to explain the evolution of the 14 contact binaries via AML and TRO models. This work has been done in collaboration with R. Jagirdar.

Anoubam Senorita Devi

Spectral study of the Ultraluminous X-ray sources in M51 at different epochs of Chandra observation

In the present work we mainly study the spectral properties of the Ultraluminous X-ray sources in the face-on spiral galaxy M51(NGC 5194/5195) at different epochs of *Chandra* observation that covers a period of nearly 21 years . M51 is located at a distance of $\sim$8.58 Mpc. From a total of 23 *Chandra* Observations during the year 2000 to 2021, 43 X-ray sources with net source counts > 100 were considered for the present spectral study. Spectra of all the sources were fitted with two empirical models - an absorbed power law & an absorbed disk black-body in the 0.3-10.0 keV energy range. 29 X-ray binaries and 14 Ultraluminous X-ray sources (ULXs) were identified. Most of the X-ray binaries are in the low/hard state while few of them were also there in the soft state. Out of the 14 ULXs detected, only two ULXs, CXOU J132943.3+471135 (src18) & CXOU J132940.0+471237 (src25), were found to be in soft spectral state. CXOU J132953.3+471043 (src9) showed a transient nature by increasing its luminosity by a factor of around 6.7 during a period of one month. CXOU J133007.5+471106 (src13) is one of the brightest source with its bolometric luminosity even going upto Extremely luminous X-ray sources (ELXs) range ($> 10^{40}$ erg s^{-1}) in few of its Chandra epoch. There is a clear signature of spectral state transition in CXOU J133007.5+471106 (src13) from a hard state with KT$_{in}$ $\sim$ 1.25 keV/powerlaw photon index Γ $\sim$ 2.0 to a relatively

soft state with $KT_{in} \sim 0.63/0.67$ keV and powerlaw photon index, $\Gamma > 3.0$ in the year 2021 observations. Remarkable emission lines of certain ionized species were detected in the spectra of CXOU J132950.7+471155 (src23) in two Chandra observations. CXOU J132943.3+471135 (src18) is the softest and extremely luminous source in M51 with an inner disk temperature of $\sim 0.10 - 0.19$ keV with a steep powerlaw photon index $\Gamma > 4$. Its bolometric luminosity $L_x \sim 6.91 \times 10^{40}$ erg s^{-1} in its softest epoch with $kT_{in} \sim 0.1$ keV is consistent with the system harboring an Intermediate mass black hole with mass, $M_{BH} \sim 10^4 M_\odot$. Even with extreme beaming, with beaming factor, $\eta \sim 5$ the black hole mass, $M_{BH} \sim 10^3 M_\odot$. Another soft ULX, CXOU J132940.0+471237 (src25) with $kT_{in} \sim 0.35$ keV, in its softest state is consistent to be accreting on to a black hole of mass $\lesssim 100 M_\odot$ at its sub-Eddington limit. However, anisotropic emission by a stellar mass black hole can't also be totally ruled out for such sources. Other hard ULXs spectra may be explained due to inverse comptonization of soft photons in the hot plasma near the disk. This work has been done in collaboration with Thokchom Sanatombi, K. Yugindro Singh.

Spectral study of X-ray sources in some galaxies recently observed by Chandra

With the aim to study the spectral properties of some X-ray sources from recently observed *Chandra* data, 9 galaxies which have been observed by *Chandra* ACIS-S during the year 2018 to 2022 have been considered for the present work. 27 sources with net source counts ≥ 100 have been considered. The spectra of all the sources were fitted using two empirical models- an absorbed powerlaw and an absorbed disk blackbody. From their estimated bolometric luminosities, the 27 X-ray sources are categorized as 6 X-ray binaries (XRBs) and 21 Ultraluminous X-ray sources (ULXs). All the six XRBs are found to be in the spectrally hard state ($\Gamma \sim 1.52 - 2.29$) which indeed may be due to thermal comptonization. Only one ULX - CXOUJ032251.2-370950 (X-5) was found to be spectrally soft while the remaining 20 ULXs were spectrally hard. The spectral parameters of X-5 with an inner disk temperature (kT_{in}) ~ 0.5 keV and an estimated bolometric luminosity, $L_X \sim 3.26 \times 10^{39}$ erg s^{-1} requires a black hole of mass, $M_{BH} \sim 137.86^{+66.62}_{-47.41} M_\odot$ accreting at ~ 0.19 times its Eddington limit. 8 ULXs - X-4, X-8, X-9, X-10, X-11, X-12, X-20 and X-21 were found to be in the Extremely luminous X-ray sources (ELXs) regime with even their lower limit of luminosity $> 10^{40}$ erg s^{-1}. Softening/Hardening of spectra with or without changes in the luminosity were also observed in some ULXs/ELXs. In the hard ELX, X-8, spectral softening with almost consistent luminosity was observed. While in the ULXs - X-20 and X-25 spectral softening with increasing luminosity was observed. However spectral hardening with increase in luminosity were observed in the ULXs - X-21 and X-26. This work has been done in collaboration with Amom Lanchenbi Chanu.

Moon Moon Devi

Investigating the effects of Lorentz Invariance Violation on the CP–sensitivities of the Deep Underground Neutrino Experiment

The phenomena of neutrino oscillations offer a great potential for probing new-physics beyond the Standard Model. Any additional effects on neutrino oscillations can help understand the nature of the non-standard effects. The violation of fundamental symmetries may appear as a probe for new-physics in various neutrino experiments. Lorentz symmetry is one such fundamental symmetry in nature and the breakdown of spacetime is a possible motivation for a departure from the standard Lorentz symmetry picture. The Lorentz Invariance Violation (LIV) is intrinsic in nature and its effects exist even in a vacuum. Neutrinos can be an intriguing probe for exploring such violations of Lorentz symmetry. The effect of violation of Lorentz Invariance can be explored through its impact on the neutrino oscillation probabilities. The effect of LIV is treated as a perturbation to the standard neutrino Hamiltonian considering the Standard Model Extension (SME) framework.

In this work, we have probed the effects of LIV on the measurement of neutrino oscillation parameters considering Deep Underground Neutrino Experiment (DUNE) as a case study. The inclusion of LIV affects the measurements of various neutrino oscillation parameters as it modifies the standard neutrino oscillation probabilities. We looked into the capability of DUNE in constraining the LIV parameters and then explored the impact of CPT-violating LIV terms on the mass-induced neutrino oscillation probabilities. We have also probed the impact of LIV parameters on the CP-measurement sensitivities at DUNE. This work has been done in collaboration with Arnab Sarkera, Abinash Medhi.

Archana Dixit

Observational constraints for an axially symmetric transitioning model with bulk viscosity parameterization

In this paper, we have analyzed the significance of bulk viscosity in an axially symmetric Bianchi type-I model to study the accelerated expansion of the universe.We have considered four bulk viscosity parameterizations for the matter dominated cosmological model. The function of the two significant Hubble $H(z)$ and deceleration parameters are discussed in detail. The energy parameters of the universe are computed using the most recent observational Hubble data (57 data points) in the redshift range $0.07 \leq z \leq 2.36$. In this model, we obtained all feasible solutions with the viscous component and analyzed the universe expansion history. Finally, we analyzed the statefinder diagnostic

and found some interesting results. The outcomes of our developed model now properly align with observational results This work has been done in collaboration with A. Pradhan b, V.K. Bhardwaj , A. Beesham.

Observational constraints in general class of Bianchi models of f (R, T) gravity

In the $f(R,T)$ modified theory of gravity, where R, T denote the curvature scalar and the trace of the stress-energymomentum tensor, respectively, the work is concerned with the general class of Bianchi cosmological models with perfect fluid and time-dependent cosmological constant Λ. To achieve a deterministic solution, we consider the time-dependent scale factor$a(t) = \alpha_1 exp[1\beta(2\beta t + \alpha)]$ where $\alpha_1 > 0$ $\alpha > 0$,$\beta > 0$ are arbitrary constants. Using the Bayesian analysis and likelihood function in conjunction with the Markov Chain Monte Carlo method, we obtained the model parameters $H_0 = 71.23080 \pm 0.00010$ and $\beta = 0.008054 \pm 0.000093$ by using $H(z)+BAO+Pantheon$ data. We obtained that Λ, a candidate for dark energy, is positive and decreases with redshift, eventually reaching a very small positive value near zero at late time, which is consistent with current observations of $H(z) + BAO + Pantheon$. We also perform the Om diagnostic to identify the quintessence and phantom region. The energy conditions and adiabatic squared speed of the sound are used to test the stability of the model. This work has been done in collaboration with M. Zeyauddin Anirudh Pradhan.

Broja Gopal Dutta

First detection of Soft-lag in GRS 1915+105 at HFQPO using AstroSat observations

The Galactic black hole GRS 1915+105 exhibits generic High-Frequency Quasi-periodic Oscillations (HFQPOs) at $\sim$ 67 Hz only during the radio-quiet 'softer' variability classes. We present the time-lag properties associated with HFQPOs in the wide energy band (3−60 keV) using all *AstroSat* observations. For the first time, we detect soft-lag of 6−25 keV band w.r.t 3−6 keV band for all 'softer' variability classes (δ, ω, κ and γ). Moreover, our findings reveal that soft-lag increases gradually with the energy of the photons. These features are entirely opposite to the previous report of hard-lag obtained with the *RXTE* observations. The energy-dependent time-lag study exhibits a maximum soft-lag of $\sim$ 3 ms and $\sim$ 2.5 ms for the δ and ω classes respectively, whereas the κ and γ classes both exhibit a maximum soft-lag of $\sim$ 2.1 ms. We find a coherent lag-energy correlation for all four variability classes, where the amplitude of soft-lag increases with energy and becomes maximum at $\sim$ 18 keV. We interpret this observed soft-lag as the reflection of hard photons in the 'cooler' accretion disc. A generic lag-rms correlation implies that the soft-lag increases with the rms amplitude of the HFQPO. The wideband (0.7−50 keV) spectral study suggests a high value of the optical depth ($\tau \sim 6.90-12.55$) of the Comptonized medium and the magnitude of the soft-lag increases linearly with the increase in optical depth (τ). We explain the observed time-lag features at the HFQPOs in the context of a possible accretion disc scenario. This work has been done in collaboration with Prajjwal Majumder, Anuj Nandi

Jibitesh Dutta

Global phase space analysis for a class of single scalar field bouncing solutions in general relativity

We carry out a compact phase space analysis of a non-canonical scalar field theory whose Lagrangian is of the form $F(X) - V(\phi)$ within general relativity. In particular, we focus on a kinetic term of the form $F(X) = \beta X^m$ $(m \neq 1/2)$ with power-law potential $V_0\phi^n$ and exponential potential $V_0 e^{-\lambda\phi/M_{Pl}}$ of the scalar field. The Cuscuton case $m = 1/2$ where the scalar field is non-dynamical is left out of consideration.The main aim of this work is to investigate the genericity of nonsingular bounce in these models and to investigate the cosmic future of the bouncing cosmologies when they are generic. A global dynamical system formulation that is particularly suitable for investigating nonsingular bouncing cosmologies is used to carry out the analysis. We show that when $F(X) = \beta X^m$ $(\beta < 0)$, nonsingular bounce is generic for a power law potential $V(\phi) = V_0\phi^n$ only within the parameter range $\left\{\frac{1}{2} < m < 1,\, n < \frac{2m}{m-1}\right\}$ and for an exponential potential $V(\phi) = V_0 e^{-\lambda\phi/M_{Pl}}$ only within the parameter range $\left\{\frac{1}{2} < m \leq 1\right\}$. Except in these cases, nonsingular bounce in these models is not generic due to the non-existence of global past or future attractors. Our analysis serves to show the importance of a global phase space analysis to address important questions about nonsingular bouncing solutions, an idea that may and must be adopted for such solutions even in other theories. This work has been done in collaboration with A. S. Agrawal, Saikat Chakraborty, B. Mishra.

Sudip Kumar Garain

Multidimensional Generalized Riemann Problem Solver for Maxwell's Equations

Approximate multidimensional Riemann solvers are essential building blocks in designing globally constraint-preserving finite volume time domain and discontinuous Galerkin time domain schemes for computational electrodynamics (CED). In those schemes, we can achieve high-order temporal accuracy with the help of Rungeâ€“Kutta or ADER time-stepping. This paper presents the design of a multidimensional approximate generalized Riemann problem (GRP) solver for the first time. The multidimensional Riemann solver accepts as its inputs the four states

surrounding an edge on a structured mesh, and its output consists of a resolved state and its associated fluxes. In contrast, the multidimensional GRP solver accepts as its inputs the four states and their gradients in all directions; its output consists of the resolved state and its corresponding fluxes and the gradients of the resolved state. The gradients can then be used to extend the solution in time. As a result, we achieve second-order temporal accuracy in a single step. In this work, the formulation is optimized for linear hyperbolic systems with stiff, linear source terms because such a formulation will find maximal use in CED. Our formulation produces an overall constraint-preserving time-stepping strategy based on the GRP that is provably L-stable in the presence of stiff source terms. We present several stringent test problems, showing that the multidimensional GRP solver for CED meets its design accuracy and performs stably with optimal time steps. The test problems include cases with high conductivity, showing that the beneficial L-stability is indeed realized in practical applications. This study has been done in collaboration with Arijit Hazra, Dinshaw S. Balsara ,Praveen Chandrashekar.

Sakshi Gautam

Estimation of the slope of nuclear symmetry energy via charge radii of mirror nuclei

Charge radii of mirror nuclei are calculated by implementing pairing effects with the Hartree-Fock Bogoliubov approximation. Correlations between the difference of charge radii (ΔR_{ch}) and slope of nuclear symmetry energy (L) are examined for different mirror nuclei pairs of varying masses using 40 different Skyrme energy density functionals. $\Delta R_{ch} - L$ correlations are found to be robust for the binding constraints imposed on density functionals. We observe that ΔR_{ch} and L show better correlations in relatively heavier pairs than those obtained in the lighter pairs. Our calculations impose a constraint on the slope of nuclear symmetry energy as -20 MeV $\leq L \leq$ 55 MeV with 68% confidence band using available measurements on charge radii. This is a moderately soft symmetry energy, in contrast to stiff and soft symmetry energy indicated by PREX-II and CREX measurements of neutron skin thickness in ^{208}Pb and ^{48}Ca, respectively. Our result is also in agreement with celestial constraints obtained from observational data for neutron stars. This work has been done in collaboration with Anagh Venneti, Sarmistha Banik , B. K. Agrawal.

Probing onset of nuclear vaporisation in heavy-ion collisions

A detailed analysis on onset of vaporization using Isospin dependent Quantum Molecular Dynamics (IQMD) model supplemented by Minimum Spanning Tree (MST) algorithm is present. The system size effects on onset of vaporization is studied using four symmetric reaction pairs (a) ^{40}Ca + ^{40}Ca, (b) ^{84}Kr + ^{84}Kr, (c) ^{132}Xe + ^{132}Xe and (d) ^{197}Au + ^{197}Au using gas-liquid content and probability of vaporization versus incident energy behaviour. Further, isospin effects are also probed taking different systems having variant N/Z ratios. The influence of different nuclear equation of state (Soft/Hard) and momentum dependent interactions on onset of vaporization are investigated too. This work has been done in collaboration with Navjot K Dhillon, Rajat Rana, Sucheta, and Rajeev K Puri.

Prabir Gharami

Tidal Angular Momentum in Close Binary Systems in Presence of Wind Driven Non-conservative Mass Transfer with Uniform Mass Accretion Rate

A very well-known property of close binary stars is that they usually rotate slowly than a similar type single star. Massive stars in close binary systems are supposed to experience an exchange of mass and angular momentum via mass transfer and tidal interaction, and thus the evolution of binary stars becomes more complex than that of individual stars. In recent times, it has become clear that a large number of massive stars interact with binary companions before they die. The observation also reveals that in close pairs the rotation tends to be synchronized with the orbital motion and the companions are naturally tempted to invoke tidal friction. We here introduce the effect of tidal angular momentum in the model of wind driven non-conservative mass transfer taking mass accretion rate as uniform with respect to time. To model the angular momentum evolution of a low mass main sequence companion star can be a challenging task. So to make the present study more interesting, we have considered initial masses of the donor and gainer stars at the proximity of bottom line main sequence stars and they are taken with lower angular momentum. We have produced a graphical profile of the rate of change of tidal angular momentum and the variation of tidal angular momentum with respect to time under the present consideration.

Statistical Investigation of Self -Similarity and Scaling Analysis of Daily Sunspot Data

Sunspot is an important feature in the study of solar physics as it depicts the singularity in the magnetic field around the solar surface. In other words, by studying sunspot numbers we can have an idea about the distribution of the solar magnetic field as well as the structure of the solar surface. Here in the present work, we have studied the self-similarity and performed a scaling analysis of daily sunspot data observed by the Royal Observatory of Belgium, Brussels. The data covers a range from 26th November, 1954 to 31st December, 2022 with the data size of 74875. On these data we have first investigated the self-similarity by Higuchi method and obtained its fractal dimension. This

study clearly reveals a fractal nature of the present data. Next, we perform the scaling analysis of these data using Finite Variance Scaling Method (FVSM) and obtained its Hurst Exponent. It is established from the study that the present data possibly exhibits a short memory with a hint of randomness. In fine, the present study possibly indicates a self-similar and short memory distribution of singularity in the magnetic field about the solar surface.

Abhik Ghosh

Towards 21-cm intensity mapping at $z = 2.28$ with uGMRT using the tapered gridded estimator II:Cross-polarization power spectrum

Neutral hydrogen $H\,I$ 21-cm intensity mapping (IM) offers an efficient technique for mapping the large-scale structures in the universe. We introduce the 'Cross' Tapered Gridded Estimator (Cross TGE), which cross-correlates two cross-polarizations (RR and LL) to estimate the multi-frequency angular power spectrum (MAPS) Cl. We expect this to mitigate several effects like noise bias, calibration errors etc., which affect the 'Total' TGE which combines the two polarizations. Here we apply the Cross TGE on a 24.4, MHz bandwidth uGMRT Band 3 data centred at 432.8, MHz aiming H_I IM at $z = 2.28$, and demonstrate an improvement over our earlier results based on the Total TGE. The measured Cross Cl is modelled to yield maximum likelihood estimates of the foregrounds and the spherical power spectrum $P(k)$ in several k bins. Considering the mean squared brightness temperature fluctuations, we report a 2σ upper limit $\Delta^2_{\rm UL}(k) \leq (58.67)^2, {\rm mK}^2$ at $k = 0.804{\rm Mpc}^{-1}$, which is a factor of 5.2 improvement on our previous estimate based on the Total TGE. Assuming that the H_I traces the underlying matter distribution, we have modelled Cl (δ (ν)) to simultaneously estimate the foregrounds and $\Omega_{HI} b_{\rm HI}$, where $\Omega_{\rm HI}$ and —$b_{\rm HI}$ are the H_I density and linear bias parameters, respectively. We obtain a best-fitting value of $[\Omega_{\rm H,I} b_{\rm H,I}]^2 = 7.51 \times 10^{-4} \pm 1.47 \times 10^{-3}$ that is consistent with noise. Although the 2σ upper limit $[\Omega_{\rm H\,I} b_{\rm H\,I}]_{\rm UL} \leq 0.061$ is ~ 50 times larger than the expected value, this is a considerable improvement over earlier works at this redshift. This work has been done in collaboration with Kh.Md.Asif Elah, Somnath Bharadwaj, Srijita Pal, et al.

Towards 21-cm intensity mapping at $z = 2.28$ with uGMRT using the tapered gridded estimator III: Foreground removal

Neutral hydrogen ($H\,I$21-cm intensity mapping (IM) is a promising probe of the large-scale structures in the Universe. However, a few orders of magnitude brighter foregrounds obscure the IM signal. Here we use the Tapered Gridded Estimator (TGE) to estimate the multi-frequency angular power spectrum (MAPS) $C_\ell(\Delta\nu)$ from a 24.4 MHz bandwidth uGMRT Band 3 data at 432.8 MHz. In $C_\ell(\Delta\nu)$ foregrounds remain correlated across the entire $\Delta\nu$ range, whereas the 21-cm signal is localized within $\Delta\nu \leq [\Delta\nu]$ (typically $0.5 - 1$ MHz). Assuming the range $\Delta\nu > [\Delta\nu]$ to have minimal 21-cm signal, we use $C_\ell(\Delta\nu)$ in this range to model the foregrounds. This foreground model is extrapolated to $\Delta\nu \leq [\Delta\nu]$, and subtracted from the measured $C_\ell(\Delta\nu)$. The residual $[C_\ell(\Delta\nu)]_{\rm res}$ in the range $\Delta\nu \leq [\Delta\nu]$ is used to constrain the 21-cm signal, compensating for the signal loss from foreground subtraction. $[C_\ell(\Delta\nu)]_{\rm res}$ is found to be noise-dominated without any trace of foregrounds. Using $[C_\ell(\Delta\nu)]_{\rm res}$ we constrain the 21-cm brightness temperature fluctuations $\Delta^2(k)$, and obtain the 2σ upper limit $\Delta^2_{\rm UL}(k) \leq (18.07)^2\,{\rm mK}^2$ at $k = 0.247\,{\rm Mpc}^{-1}$. We further obtain the 2σ upper limit $[\Omega_{HI} b_{HI}]_{\rm UL} \leq 0.022$ where $[\Omega_{HI}]$ and b_{HI} are the comoving H_I density and bias parameters respectively. Although the upper limit is nearly 10 times larger than the expected 21-cm signal, it is 3 times tighter over previous works using foreground avoidance on the same data. This work has been done in collaboration with Kh. Md. Asif Elah,Somnath Bharadwaj, Srijita Pal.

Suman Ghosh

Signature quasinormal modes of Ellis-Bronnikov wormhole embedded in warped braneworld background

We examine the quasinormal modes of Ellis-Bronnikov wormholes embedded in a warped five dimensional braneworld background and compare with its four-dimensional counterpart. These scalar quasinormal frequencies are obtained using the WKB formula, Prony method, and the direct integration method. The signature of the warped extra dimension shows up as two distinct quasinormal ringing eras, characterized by two distinct dominant quasinormal modes. Features of the latter region are similar to that observed earlier for massive scalar fields in the black hole background, particularly the existence of arbitrarily long-lived quasinormal modes. We also discuss the how steepness of the neck of the wormhole effects the quasinormal frequencies. This work has been done in collaboration with Antariksha Mitra.

Tuhin Ghosh

Statistical properties of Galactic synchrotron temperature and polarization maps - a multi-frequency comparison

Understanding the statistical properties of synchrotron emission from our Galaxy is valuable from the perspective of observations targeting signals of cosmological origin, as well as for understanding physical processes in our Galaxy. In this work, we extend the analysis of *Rahman et al. 2021* to - (a) all-sky observed maps of total foreground emissions

at different frequencies provided by WMAP, Planck and Stockert-Villa, (b) component separated synchrotron temperature maps provided by WMAP, Planck and BeyondPlanck, and (c) component separated polarization maps provided by WMAP and Planck. The tools we use are Minkowski functionals and tensors. Our main goals are twofold. First, we determine the variation of morphological properties of the total foreground maps with observing frequency and compare with simulations. This study elucidates how the morphology varies with frequency due to the relative dominance of different foreground components at different frequencies. Secondly, we determine the nature of non-Gaussianity and statistical isotropy of synchrotron fluctuations towards smaller scales using various component separated synchrotron temperature and polarization maps. We find that all maps exhibit kurtosis-type non-Gaussianity, in agreement with the Haslam map. This result can be an important input for modelling of small-scale synchrotron fluctuations for component separation pipelines. This also suggests that residual synchrotron contamination in CMB will manifest as kurtosis and will not be captured by three-point statistics. From a comparison of the different component separated maps, we find that BeyondPlanck and WMAP MCMC-e agree well with Haslam at all scales. The other maps show differences of varying statistical significance. Our analysis suggests a combination of residual AME and/or free-free emissions and point sources as contributing to these differences, and underscores the need for further improvement of the pipelines. This work has been done in collaboration with Fazlu Rahman, and Pravabati Chingangbama.

Importance of High-Frequency Bands for Removal of Thermal Dust in ECHO

The Indian Consortium of Cosmologists has proposed a Cosmic Microwave Background (CMB) space mission, Exploring Cosmic History and Origin (ECHO). A major scientific goal of the mission is to detect the primordial B-mode signal of CMB polarization. The detection of the targeted signal is very challenging as it is deeply buried under the dominant astrophysical foreground emissions of the thermal dust and the Galactic synchrotron. To facilitate the adequate subtraction of thermal dust, the instrument design of ECHO has included nine dust-dominated high-frequency bands over the frequency range 220-850 GHz. In this work, we closely re-examine the utility of the high-frequency ECHO bands in foreground subtraction using the Needlet Internal Linear Combination component separation method. We consider three dust models: a physical dust model, a dust spectral energy distribution (SED) with a single modified black body (MBB) emission law and a multilayer dust model with frequency-frequency decorrelation. We consider eleven ECHO bands in the $28-190$ GHz range as our baseline configuration and investigate the changes in the level foreground and noise residuals as subsequent dust-dominated high-frequency bands are added. We find that adding the high-frequency bands leads to a consistent decrease in the level of residual foreground and noise, and the sensitivity of r measurement improves. Most of the reduction in both residual levels and enhancement in the sensitivity is achieved in the $28-600$ GHz frequency range. Negligible change in residual levels is seen by extending the frequency range from 600 GHz to 850 GHz. We find that extending the ECHO frequency bands from 190 GHz to 340 GHz leads to a $40-50\%$ reduction in the foreground and noise residual levels in the recovered CMB map. Correspondingly the sensitivity of ECHO towards r also improves by a similar amount. Furthermore, incorporating higher frequencies up to 600 GHz yields an additional reduction of $12-15\%$ in the residual levels and uncertainty on r. However, extending observations up to the 850 GHz frequency band only leads to a marginal improvement in sensitivity, ranging from $3-7\%$. This work has been done in collaboration with Aparajita Sen, Soumen Basak, Debabrata Adak, Srijita Sinha.

Ankur Gogoi

Role of optically active defects in photoluminescence properties of diatom frustules

Diatoms are a group of unicellular photosynthetic algae having intricately patterned silica cell wall called frustules made of amorphous silica. These frustules exhibit strong visible photoluminescence (PL) property when exposed to radiation of suitable frequency. Although silanol could be the one of the major sources of the observed PL for high energy irradiation ($>$ 5 eV), its origin for low energy excitation is still debatable. In this work, PL spectroscopy of the diatom frustules were carried out using low energy ($<$4.2 eV) excitation and correlated with UV-vis and Fourier Transform Infrared (FTIR) spectroscopy to analyse the role of various optically active defects and impurity groups responsible for diatom frustules PL. Theoretical calculations based on density functional theory was also conducted the verify the experimental findings. This work has been done in collaboration with Jayur Tisso, Surajit Konwer, Gazi A. Ahmed, and Nirmal Mazumder.

Facile construction of a laser scanning optical beam induced current microscope

We report on the design and construction of a laser scanning optical beam-induced current (OBIC) microscope by assembling cost-effective commercial optical and electronic hardware components and developing data acquisition and control software in LabVIEW. A preliminary OBIC image of a Si photodetector acquired by the developed microscope is presented to demonstrate its operational capability. The versatility of the design will allow for the construction of other scanning microscope modalities on the same platform.

This work has been done in collaboration with Ankita Buragohain, Nayan M. Kakoty, Guan-Yu Zhuo, Gazi A. Ahmed et al.

Umananda D. Goswami

Weak gravitational lensing and shadow cast by rotating black holes in axionic Chern-Simons theory

We investigate the impact of the axionic coupling parameter on the bending angle of light and the shadow cast by slowly rotating black holes in Chern-Simons modified gravity. We utilize the Ishihara et al. method to derive the deflection angle of light for an observer and source located at finite distances from a lens object in an asymptotically flat spacetime, using the Gauss-Bonnet theorem. The deflection angle exhibits an increasing trend up to a certain point, followed by a decrease as a function of the impact parameter, with the presence of the axion matter field causing the observed increase. Additionally, we calculate the Einstein ring radius as a direct application of the weak deflection angle. We also investigate the effect of the axion matter field on the time delay of light and analyze its impact on the shadow cast by slowly rotating black holes. Our findings reveal a significant effect of the axionic coupling parameter on the black hole's shadow. This work has been done in collaboration with Nashiba Parbin, Dhruba Jyoti Gogoi.

Galactic rotation dynamics in a new $f(\mathcal{R})$ gravity model

We propose to test the viability of the recently introduced $f(\mathcal{R})$ gravity model in the galactic scales. For this purpose we consider test particles moving in stable circular orbits around the galactic center. We study the Palatini approach of $f(\mathcal{R})$ gravity via Weyl transformation, which is the frame transformation from the Jordan frame to the Einstein frame. We derive the expression of rotational velocities of test particles in the new $f(\mathcal{R})$ gravity model. For the observational data of samples of high surface brightness and low surface brightness galaxies, we show that the predicted rotation curves are well fitted with observations, thus implying that this model can explain flat rotation curves of galaxies. We also study an ultra diffuse galaxy, AGC 242019 which has been claimed in literature to be a dark matter dominated galaxy similar to low surface brightness galaxies with a slowly rising rotation curve. The rotation curve of this galaxy also fits well with the model prediction in our study. Furthermore, we studied the Tully-Fisher relation for the entire sample of galaxies and found that the model prediction shows the consistency with the data. This work has been done in collaboration with Nashiba Parbin.

Shivappa B. Gudennavar

NuSTAR and AstroSat observations of GX 9+1: spectral and temporal studies

We have studied the spectro-temporal properties of the neutron star low mass X-ray binary GX 9+1 using data from *NuSTAR*/Focal Plane Module and *AstroSat*/ Soft X-ray Telescope and Large Area X-ray Proportional Counter (LAXPC). The hardness-intensity diagram of the source showed it to be in the soft spectral state (banana branch) during both observations. *NuSTAR* spectral analysis yielded an inclination angle (θ) = $29^{+3^{\circ}}_{-4}$ and inner disc radius (R_{in}) $\leq$ 19 km. Assuming that the accretion disc was truncated at the Alfvén radius during the observation, the upper limit of the magnetic dipole moment (μ) and the magnetic field strength (B) at the poles of the neutron star in GX 9+1 were calculated to be 1.5×10^{26} G cm^3 and 2.1×10^8 G, respectively (for k_A = 1). Furthermore, the thickness of the boundary layer was found to be $\simeq$ 7.5 km, which yielded the radius of the neutron star to be $\leq$11.5 km. Flux resolved spectral analysis with *AstroSat* data showed the source to be disc dominated (F_{disc}/F_{total} $\sim$0.9) with a monotonic increase in mass accretion rate ($\dot{m}$) along the banana branch. The analysis also showed the presence of absorption edges at $\sim$1.9 and $\sim$2.4 keV, likely due to Si XIII and S XV, respectively. Temporal analysis with LAXPC-20 data in the 0.02 $-$ 100 Hz range revealed the presence of noise components, which could be characterized with broad Lorentzian components. This work has been done in collaboration with Neal Titus Thomas, and S. G. Bubbly.

Spectral and temporal features of GX 13+1 as revealed by AstroSat observations

GX 13+1, a neutron star low mass X-ray binary that exhibits the properties of both atoll and Z sources, is studied using data from Soft X-ray Telescope and Large Area X-ray Proportional Counter (LAXPC) onboard *AstroSat*. The source traces a ν shaped track in its hardness-intensity diagram (HID). Spectral modelling of the data in the 0.7$-$30.0 keV energy range, with the model - `constant` $\times$ `tbabs` $\times$ `thcomp` $\times$ `bbodyrad` + `relxillNS`, yields orbital inclination angle (θ) of $77^{+10^{\circ}}_{-8}$. Flux resolved spectral analysis reveals the ν shaped pattern in the plots of spectral parameters kT_e, kT_{bb} and Γ versus F_{bol}, closely resembling the pattern traced in LAXPC HID. This indicates changes in the spectral properties of the corona and the boundary layer/accretion disc. Assuming that the accretion disc was truncates at the Alfvén radius, the upper limit of the magnetic field strength (B) at the poles of neutron star in GX 13+1 was calculated to be 5.10×10^8 G (for k_A = 1 and η = 0.1), which is close to that of atoll sources. Furthermore, thickness of the boundary layer is estimated to be 5.70 km, which results in the neutron star radius value of $\lesssim$14.50 km. Quasi-periodic oscillations (QPOs) at 56$\pm$4 and 54$\pm$4 Hz

are detected in Regions D and E of HID, respectively. The frequencies of these QPOs are similar to the characteristic frequency of horizontal branch oscillation and these do not exhibit a positive correlation with mass accretion rate. This work has been done in collaboration with L. Giridharan, Neal Titus Thomas, S. G. Bubbly.

Golam Mortuza Hossain

Origin of primeval seed magnetism in rotating astrophysical bodies

We show that a primeval seed magnetic field arises due to spin-degeneracy breaking of fermions caused by the dragging of inertial frames in the curved spacetime of rotating astrophysical bodies. This seed magnetic field would arise even due to electrically neutral fermions such as neutrons. As examples, firstly we show that an ideal neutron star rotating at 500 revolutions per second, having mass 0.83 $M_\odot$ and described by an ensemble of degenerate neutrons, would have 0.12 Gauss seed magnetic field at its center arising through the breaking of spin-degeneracy. Secondly, similar seed field at a proto-galactic stage for the Milky Way galaxy as implied by its observed rotation curve is estimated to be between $10^{-19} - 10^{-24}$ Gauss, a field strength which is known to be sufficient to produce presently observed microgauss magnetic field. This work has been done in collaboration with S. Mandal.

Chetna Jain

A comprehensive study of orbital evolution of LMC X–4: Existence of a second derivative of the orbital period

We report here results from pulse arrival time delay analysis of the eclipsing high mass X-ray binary pulsar LMC X–4 using observations made with the Rossi X–ray Timing Explorer, XMM-Newton, NuSTAR and AstroSAT. Combining the orbital parameters determined from these observations with the historical measurements dating back to 1998, we have extended the $T_{\pi/2}$ epoch history of LMC X–4 by about 4600 binary orbits spanning about 18 years. We also report mid-eclipse time measurements (T_{ecl}) using data obtained from wide-field X-ray monitors of *MAXI*-GSC and *Swift*-BAT. Combining the new $T_{\pi/2}$ and T_{ecl} estimates with all the previously reported values, we have significantly improved the orbital evolution measurement, which indicates that the orbital period is evolving at a time scale ($P_{\rm orb}/\dot{P}_{\rm orb}$) of about 0.8 Myr. For the first time in an accreting X-ray pulsar system, we confirm the existence of a second derivative of the orbital period, having an evolution time scale ($\dot{P}_{orb}/\ddot{P}_{orb}$) of about 55 yr. Detection of a second derivative of the orbital period in LMC X–4 makes its orbital evolution timescale more uncertain, which may also be true for other HMXBs. Independent solutions for the orbital evolution measurement using the mid-eclipse data and the pulse timing data are consistent with each other, and help us put an upper limit of 0.009 on the eccentricity of the binary system. This work has been done in collaboration with Rahul Sharma and Biswajit Paul.

4U 1626-67 returns to spin-down: timing features toe the line

We present a comprehensive analysis of X-ray pulsar 4U 1626-67 during its current spin-down (2SD) state, following a recent torque reversal. Since its discovery, this ultra-compact binary has experienced multiple torque states, transitioning from spin-up (1SU) during 1977-1990 to spin-down (1SD) during 1990-2008, and again spin-up (2SU) until 2023. From Nuclear Spectroscopic Telescope ARray observation of May 2023, we have investigated the timing and spectral properties of this pulsar during its 2SD phase, while also comparing them with previous spin-up-down states. For energies up to 8 keV, a distinct bi-horned pulse profile was observed during the spin-up phase, while several substructures emerged during spin-down. Beyond 8 keV, a broad asymmetric peak was consistently observed across all torque states. The pulse fraction during the 2SD phase was higher than that during 2SU phase. A prominent ∼46.8 mHz quasi-periodic oscillation has been exclusively detected during the spin-down phase. The broad-band spectrum during the 2SD phase is described by empirical Negative and Positive power-law with Exponential cutoff model, cyclotron absorption feature and its first harmonic. The spectrum during 2SU phase requires an additional blackbody component and asymmetry in the cyclotron absorption line. A significant flux drop by a factor of ∼3 in the 2SD was observed. This work has been done in collaboration with Rahul Sharma and Biswajit Paul.

Deepak Jain

Gamma Rays Bursts: A Viable Cosmological Probe?

In this work, our focus is on exploring the potential of current GRB measurements to provide reliable constraints on cosmological model parameters at high redshift. This work is divided into two parts. First, we calibrate the Amati relation in a model-independent way by using Hubble parameter measurements obtained from the differential ages of the galaxies. We further check if the Amati relation parameters evolve with the GRB's redshift or not, using the data of Old Astrophysical Objects. The results indicate that GRBs do seem to evolve with redshift. In the second part, we test different cosmological models with the calibrated GRB data obtained by using constant and dynamical Amati relation. Our results indicate that the present quality of GRB data is not good enough to put tight constraints on the cosmological parameters. Hence we perform a joint analysis with the combined data of GRBs and Type Ia Supernovae (SNe) and find that this can considerably

enhance cosmological constraints in contrast to solely relying on GRBs. This work has been done in collaboration with Darshan Kumar, Nisha Rani, Shobhit Mahajan, Amitabha Mukherjee.

Constraints on the transition redshift from the calibrated Gamma-ray Burst E_p - E_{iso} correlation

We constrain the deceleration-acceleration epoch, namely the transition redshift z_{tr}, adopting model-independent techniques that utilize a calibrated $E_p - E_{iso}$ correlation for gamma-ray bursts (GRBs). To do so, in addition to real data points, we employ up to 1000 simulated observational Hubble data (OHD) points. We then calibrate the $E_p - E_{iso}$ correlation by means of the well-consolidate BÃ©zier polynomial technique, interpolating OHD up to the second order. Once GRB data have been calibrated, we consider two strategies of cosmographic expansions, i.e., first we take a direct Hubble rate expansion around z_{tr}, and second the expansion of the deceleration parameter around the same redshift, but with a different order. Employing type Ia supernovae, baryonic acoustic oscillations and GRB data sets, from Monte Carlo analyses we infer tight constraints on z_{tr} and the jerk parameters at z_{tr}, namely j_{tr}. Our results are extremely compatible with previous outcomes and confirm the ΛCDM predictions, being slightly different in terms of the jerk parameter. In this respect, we conjecture which extensions of the concordance paradigm are possible and we compare our findings with expectations provided by generic dark energy models. This work has been done in collaboration with Marco Muccino, Orlando Luongo.

Jessy Jose

Search for brown dwarfs in IC 1396 with Subaru HSC: interpreting the impact of environmental factors on substellar population

Young stellar clusters are predominantly the hub of star formation and hence, ideal to perform comprehensive studies over the least explored substellar regime. Various unanswered questions like the mass distribution in brown dwarf regime and the effect of diverse cluster environment on brown dwarf formation efficiency still plague the scientific community. The nearby young cluster, IC 1396 with its feedback-driven environment, is ideal to conduct such study. In this paper, we adopt a multiwavelength approach, using deep Subaru HSC along with other data sets and machine learning techniques to identify the cluster members complete down to $\sim 0.03\ M\odot$ in the central 22 arcmin area of IC 1396. We identify 458 cluster members including 62 brown dwarfs which are used to determine mass distribution in the region. We obtain a star-to-brown dwarf ratio of ~ 6 for a stellar mass range 0.03-1 $M\odot$ in the studied cluster. The brown dwarf fraction is observed to increase across the cluster as radial distance from the central OB-stars increases. This study also compiles 15 young stellar clusters to check the variation of star-to-brown dwarf ratio relative to stellar density and ultraviolet (UV) flux ranging within 4-2500 stars pc^{-2} and 0.7-7.3 G_0, respectively. The brown dwarf fraction is observed to increase with stellar density but the results about the influence of incident UV flux are inconclusive within this range. This is the deepest study of IC 1396 as of yet and it will pave the way to understand various aspects of brown dwarfs using spectroscopic observations in future. This work has been done in collaboration with S. Gupta.

An outburst and FU Ori-type disc of a former low-luminosity protostar

Strong accretion outbursts on to protostars are associated with emission dominated by a viscously heated disc, which is characterized by high luminosities. We report the discovery and characterization of a strong mid-IR (3.4, 4.6 μm) outburst in the embedded protostar SSTgbs J21470601+4739394 (hereafter SSTgbsJ214706). SSTgbsJ214706 has steadily brightened in the mid-infrared by 2 mag over the past decade, as observed by NEOWISE. Follow-up investigations with the Gemini near-IR spectrograph reveal that SSTgbsJ214706 is a binary system with a spatially extended outflow. The outburst is occurring on the more embedded south-east (SE) component, which dominates the mid- and far-infrared emission from the source. The outbursting component exhibits a spectrum consistent with an FU Ori-type outburst, including the presence of enhanced absorption observed in the molecular bands of CO. The luminosity of the SE component is estimated to be $\sim 0.23\ L\odot$ before the outburst and $\sim 0.95\ L\odot$ during the outburst, which is one to two orders of magnitude fainter than bonafide FU Ori outbursts. We interpret this eruption as an FU Ori-type outburst, although the possibility of brightening following an extinction episode cannot be ruled out. We discuss the implications and potential explanations for such a low-luminosity eruption. This work has been done in collaboration with M. Ashraf, H. Lee, et al.

Minu Joy

Primordial gravitational waves by chaotic potential with a sharp step

The primordial gravitational wave spectrum observed today, $\Omega_0^{gw}(f)$ produced by a chaotic inflationary model featuring a step in its potential is studied. Employing the slow-roll approximation, we analyze the scalar and tensor power spectra and found oscillatory density fluctuations within a specific range of wavenumbers around the feature. Localized small anomalies are observed in the tensor power spectrum also. We estimate the observational parameters, including the scalar spectral index (n_s), tensor tilt (n_t) and tensor-to-scalar ratio (r), which are found to be consistent

with Planck satellite results. Additionally, by employing the relation between $\Omega_0^{gw}(f)$ and r, we determine the effective equation of state parameter $\hat{w}(f)$ at the end of inflation. Evolution of $\hat{w}(f)$ from 0.2 to 0.33, followed by constancy is obtained in the $n_t\hat{(f)} - \hat{w}(f)$ plot. This evolution of $\hat{w}(f)$ is attributed to the reheating process, which is crucial for transitioning from the inflationary phase to the subsequent radiation-dominated era. This work is done in collaboration with Rinsy Thomas and Jobil Thomas.

Gravitational wave production after inflation for a hybrid inflationary model.

We studied the stochastic background of gravitational waves sourced by the tensor perturbation due to a hybrid inflationary model with cubic potential. The tensor-to scalar ratio for the present hybrid inflationary model is obtained as $r \approx 0.0006$. Gravitational wave spectrum of this stochastic background, for large-scale CMB modes, $10^{-4}Mpc^{-1}$ to $1Mpc^{-1}$ is studied. The present-day energy spectrum of gravitational waves $\Omega_0^{gw}(f)$ is sensitively related to the tensor power spectrum and r which is, in turn, dependent on the unknown physics of the early cosmos. This uncertainty is characterized by two parameters: $n_t\hat{(f)}$ logarithmic average over the primordial tensor spectral index and $w\hat{(f)}$ logarithmic average over the effective equation of state parameter. Thus, exact constraints in the $n_t\hat{(f)}$-$w\hat{(f)}$ plane can be obtained by comparing theoretical constraints of our model on r and $\Omega_0^{gw}(f)$. We obtain a limit on $\hat{w}(10^{-15}Hz) < 0.33$ around the modes probed by CMB scales. This work is done in collaboration with Rinsy Thomas, J. Thomas and S. P. Surendran.

Mehedi Kalam

Lorentzian wormhole in the framework of loop quantum cosmology

In this paper, we construct a traversable static Lorentzian wormhole in the effective scenario of Loop Quantum Cosmology (LQC), where the field equations are modified due to the ultraviolet (UV) corrections introduced at large space-time curvatures. A stable wormhole can be constructed in the effective scenario without the violation of Null energy condition (NEC) by physical matter at the throat. The NEC is effectively violated due to the corrections in the field equations from LQC, resolving the Weyl curvature singularity at the throat. However, the physical matter does violate the Strong energy condition (SEC), suggesting the interesting possibility that dark energy can be harnessed into a wormhole. A possible explanation for this is the presence of inherent pressure isotropy in the UV-corrected field equations (discussed and compared to braneworld wormholes in the discussion). No additional exotic ingredient (violating NEC) is required, avoiding quantum instabilities. The tidal forces at the throat do not diverge and also the throat is found to be stable. The wormhole features an attractive geometry. LQC can resolve both types of curvature singularities appearing at the black hole centre and wormhole throat, without exotic matter. This work has been done in collaboration with Rikpratik Sengupta, and Shounak Ghosh.

Traversable Lorentzian wormhole on the Shtanov-Sahni braneworld with matter obeying the energy conditions

In this paper we have explored the possibility of constructing a traversable wormhole on the Shtanov-Sahni braneworld with a timelike extra dimension. We find that the Weyl curvature singularity at the throat of the wormhole can be removed with physical matter satisfying the NEC $\rho + p \geq 0$, even in the absence of any effective Λ-term or any type of charge source on the brane. (The NEC is however violated by the effective matter description on the brane arising due to effects of higher dimensional gravity.) Besides satisfying NEC the matter constituting the wormhole also satisfies the Strong Energy Condition (SEC), $\rho + 3p \geq 0$, leading to the interesting possibility that normal matter on the brane may be harnessed into a wormhole. Incidentally, these conditions also need to be satisfied to realize a non-singular bounce and cyclic cosmology on the brane where both past and future singularities can be averted. Thus, such a cyclic universe on the brane, constituted of normal matter can naturally contain wormholes. The wormhole shape function on the brane with a time-like extra dimension represents the tubular structure of the wormhole spreading out at large radial distances much better than in wormholes constructed in a braneworld with a spacelike extra dimension and have considerably lower mass resulting in minimization of the amount of matter required to construct a wormhole. Wormholes in the Shtanov-Sahni (SS) braneworld also have sufficiently low tidal forces, facilitating traversability. Additionally they are found to be stable and exhibit a repulsive geometry. We are left with the intriguing possibilty that both types of curvature singularity can be resolved with the SS model, which we discuss at the end of the concluding section.This work has been done in collaboration with Rikpratik Sengupta, Shounak Ghosh .

Sreeja S Kartha

Disentangling the association of PAH molecules with star formation: Insights from JWST and UVIT

Polycyclic Aromatic Hydrocarbons (PAHs) are ubiquitous complex molecules in the interstellar medium and are used as an indirect indicator of star-formation. On the other hand the ultraviolet (UV) emission from the young massive stars directly traces the star formation activity in a galaxy. The James Webb Space Telescope (JWST), along with the UltraViolet Imaging Telescope (UVIT), opened up a new window of opportunity to make a better understanding of

the properties of the PAH molecules associated with the star-forming regions. In this study, we investigate how the resolved scale properties of PAH molecules in nearby galaxies are affected by star-formation. We analyze the PAH features observed at 3.3, 7.7, and 11.3 μm using F335M, F770W, and F1130W images obtained from JWST. Additionally, we utilize UVIT images to assess the star formation associated with these PAH emitting regions. Our study focuses on three galaxies, namely NGC 628, NGC 1365, and NGC 7496, selected based on the availability of both JWST and UVIT images. Based on the resolved scale study on the PAH bright regions using JWST and UVIT images, we found that the fraction of ionized PAH molecules is high in the star-forming regions with high ΣSFR. We observed that emission from smaller PAH molecules is more in the star-forming regions with higher ΣSFR. Our study suggests that the PAH molecules excited by the photons from SF regions with higher ΣSFR are dominantly smaller and ionized molecules. UV photons from the star-forming regions could be the reason for a higher fraction of the ionized PAHs. We suggest that the effect of high temperature in the star-forming regions and the formation of smaller PAH molecules in the star-forming regions might also be resulting in the higher fraction of emission in the F335MPAH band. This work has been done in collaboration with Ujjwal Krishnan, Akhil Krishna R, Blesson Mathew, Smitha Subramanian, Sudheesh T P, and Robin Thomas.

DES J024008.08-551047.5: A new member of the polar ring galaxy family

This study presents the discovery of a new polar ring galaxy (PRG) candidate and highlights its unique features and characteristics. We provide evidence from photometric analysis that supports the inclusion of galaxy DES J024008.08-551047.5 (DJ0240) in the PRG catalogue. We have discovered the galaxy DJ0240, a PRG candidate with a ring component positioned almost perpendicular to the host galaxy. The position angles of the ring and host components are ∼80 and ∼10 degrees, respectively, indicating that they are nearly orthogonal to each other. The extension of the ring component is three times greater than that of the host galaxy and shows a distinct colour separation, being bluer than the host. The estimated g - r colour values of the host and ring components are 0.86±0.02 and 0.59±0.10 mag, respectively. The colour value of the ring component is similar to those of typical spiral galaxies. The host galaxy's colour and the presence of a bulge and disc components indicate that the host galaxy may be lenticular. Our findings reveal a subtle yet noticeable colour difference between the host and ring components of PRGs and RTGs. We observe that both the host and ring components of DJ0240 align more closely with PRGs than with RTGs. Furthermore, we compared the Sersic index values of the ring component (n_{ring}) of galaxy DJ0240 with a selected sample of PRGs and Hoag-type galaxies. The results show that DJ0240 has a remarkably low n_{ring} value of 0.13, supporting the galaxy's classification as a PRG. Hence, we suggest that the ring galaxy DJ0240 is a highly promising candidate for inclusion in the family of PRGs. This work has been done in collaboration with Akhil Krishna R, Blesson Mathew, Ujjwal Krishnan, Savithri H Ezhikode, and Robin Thomas.

Arun Kenath

Primordial Planets with an Admixture of Dark Matter Particles and Baryonic Matter

It has been suggested that primordial planets could have formed in the early universe and the missing baryons in the universe could be explained by primordial free-floating planets of solid hydrogen. Many such planets were recently discovered around the old and metal-poor stars, and such planets could have formed in early epochs. Another possibility for missing baryons in the universe could be that these baryons are admixed with DM particles inside the primordial planets. Here, we discuss the possibility of the admixture of baryons in the DM primordial planets discussed earlier. We consider gravitationally bound DM objects with the DM particles constituting them varying in mass from 20 to100 GeV. Different fractions of DM particles mixed with baryonic matter in forming the primordial planets are discussed. For the different mass range of DM particles forming DM planets, we have estimated the radius and density of these planets with different fractions of DM and baryonic particles. It is found that for heavier-mass DM particles with the admixture of certain fractions of baryonic particles, the mass of the planet increases and can reach or even substantially exceed Jupiter mass. The energy released during the process of merger of such primordial planets is discussed. The energy required for the tidal breakup of such an object in the vicinity of a black hole is also discussed. This work has been done in collaboration with O. V. Kiren,and Chandra Sivaram.

Gammaless gamma-ray bursts?

One of the possible resolutions of the compactness problem in gamma-ray bursts (GRBs) is by invoking the Lorentz factors associated with the relativistic bulk motion. This model applies to GRBs where sufficient energy is converted to accelerate the ejected matter to relativistic speeds. In some situations, this may not be a possible mechanism, and as a result, the gamma rays are trapped in the region. In this work, we look at such possible scenarios and where the neutrino pair production process can dominate. As a result, the neutrinos can escape freely. This could give rise to a scenario where the release of neutrinos precedes the gamma-ray emission that is much attenuated. This model can thus possibly explain why fewer GRBs are observed than

what is expected. This work has been done in collaboration with Chandra Sivaram.

Nishikanta Khandai

Halo Mass Function in Scale Invariant Models

Sheth-Tormen mass function has been widely used to quantify the abundance of dark matter halos. It is a significant improvement over the Press-Schechter mass function as it uses ellipsoidal collapse in place of spherical collapse. Both of these mass functions can be written in a form that is universal, i.e., independent of cosmology and power spectrum when scaled in suitable variables. However, cosmological simulations have shown that this universality is approximate. In this paper, we investigate the power spectrum dependence of halo mass function through a suite of dark-matter-only N-body simulations of seven power-law models in an Einstein-de Sitter cosmology. This choice of cosmology and a power-law power spectrum ensures the self-similar evolution of dark matter distribution, allowing us to isolate the power spectrum dependence of mass function. We find that the mass function shows a clear non-universality. We present fits for the parameters of the Sheth-Tormen mass function for a range of power-law power-spectrum indices. We find a mild evolution in the overall shape of the mass function with the epoch. Finally, we extend our result to LCDM cosmology. We show that the Sheth-Tormen mass function with parameter values derived from a matched power-law EdS cosmology provides a better fit to the LCDM mass function than the standard Sheth-Tormen mass function. Our results indicate that an improved analytical theory is required to provide better fits to the mass function. This work has been done in collaboration with SwatiGavas, JasjeetBagla, and Girish Kulkarni.

Role of Ionizing Background on the Statistics of metal Absorbers in Hydrodynamical Simulations

We study the statistical properties of OVI CIV, and $NVIII$ absorbers at low-z (i.e., $z < 0.5$) using Sherwood simulations with "WIND" only and "WIND+AGN" feedback and Massive black-II simulation that incorporates both "WIND" i.e. outflows driven by stellar feedback and AGN feedbacks. For each simulation, by considering a wide range of metagalactic ionizing UV background (UVB), we show the statistical properties such as distribution functions of column density (N), b-paramerer and velocity spread (ΔV_{90}), the relationship between N and b-parameter and the fraction of Lyα absorbers showing detectable metal lines as a function of N HI are influenced by the UVB used. This is because UVB changes the range in density, temperature, and metallicity of gas contributing to a given absorption line. For simulations considered here, we show the difference in some of the predicted distributions between different simulations is similar to the one obtained by varying the UVB for a given simulation. Most of the observed properties of OVI absorbers are roughly matched by Sherwood simulation with "WIND+AGN" feedback when using the UVB with a lower OVIionization rate. However, this simulation fails to produce observed distributions of CIV and fraction of HI absorbers with detectable metals. Therefore, in order to constrain different feedback processes and/or UVBs, using observed properties of HI and metal ions, it is important to perform simultaneous analysis of various observable parameters. This work has been done in collaboration with Sukanya Mallik,; Raghunathan Srianand, ; Soumak Maitra, ; Prakash Gaikwad.

Ram Kishor

Nonlinear stability of triangular equilibrium points in non-resonance case with perturbations

The present study deals with the normalisation of Hamiltonian for the nonlinear stability analysis in non-resonance case of the triangular equilibrium points in the perturbed restricted three-body problem with perturbation factors as radiation pressure due to first oblate-radiating primary, albedo from second oblate primary, oblateness and a disc. The problem is formulated with these perturbations and Hamiltonian of the problem is normalised up to fourth order by Lie transform technique consequently a Birkhoffâ€™s normal form of the Hamiltonian is obtained. The Arnoldâ€“Moser theorem is verified for the nonlinear stability test of the triangular equilibrium points in non-resonance case with the assumed perturbations. It is found that in the presence of radiation pressure, stability range expanded, significantly with respect to the classical range of stability; however, because of albedo, oblateness and the disc, it contracted gradually. Moreover, it is observed that alike to the classical problem, in the perturbed problem under the impact of the assumed perturbations, there always exist one or more values of the mass ratio within the stability range at which discriminant , which means the triangular equilibrium points are unstable in nonlinear sense.This work has been done in collaboration with Poonam Meena.

On the periodic motion in the photo-gravitational planar elliptic restricted four body problem

Since, orbital analysis in the vicinity of an equilibrium point of a dynamical system is a fundamental key to explore and understand about its dynamical behaviour. This paper contains orbital study of an infinitesimal mass under the frame of a photo-gravitational planar elliptic restricted four body problem (RFBP) in the context of long periodic and short periodic orbits near the equilibrium points in the presence of perturbation in the form of radiation pressure effect due to two primaries. The long periodic and short periodic orbits about each equilibrium points are

obtained followed by the effect of radiation pressure force due to radiating primaries and impact due to variation of mass parameter are analysed. It is noticed that radiation parameter and mass parameter both have considerable influence on the orbital parameters (i.e. on the eccentricity, frequency, time period, semi-major and semi-minor axes) of the long as well as short periodic orbits near equilibrium points. To observe the nature of the orbits in the vicinity of respective equilibrium points, Poincare surface of sections are estimated at different values of radiation parameter and mass parameter and then visualized the chaotic and quasi periodic nature of the orbits. These results will be helpful to study the more generalized problem with different kinds of perturbations. This work has been done in collaboration with Poonam Meena.

Nagendra Kumar

Temporal and spatial variability of EUV flux at 094*Å and its relationship with sunspot activity*

We study temporal and spatial variability of coronal EUV flux/emission/intensity at 094 Ã... and investigate latitudinal profiles of the EUV flux from centre to poles of solar disc based on daily image obtained from the SDO/AIA for the period from 10 February, 2011 to 20 November, 2021. Solar coronal activities (regions of high EUV flux) patterns of latitudinal EUV flux, latitudinal north-south asymmetry of EUV flux and relationship between EUV flux and sunspot numbers are discussed. The disc-integrated normalized EUV flux is found positive correlated with SDO/EVE normalised solar irradiance. It is shown that there are two kinds of migration of solar coronal activities in distribution of EUV flux at 094 $Å$ during the rising phase of solar cycle 24: one towards the equator and another towards the poles in both hemispheres. The peaks of EUV flux occur in the region -25° to $+25^\circ$ solar latitudes in the years 2011 and 2014. The latitudinal EUV flux in northern and southern hemispheres have asymmetrical behaviour. The dominancy of EUV flux in northern hemisphere is found only at 5°, 15°, and 75° solar latitudes whereas the dominancy of EUV flux in southern hemisphere is found at the rest of the solar latitudes. We found that the dominancy of EUV flux in both the hemispheres is a function of time and solar latitude. The EUV flux is dominated in the southern hemisphere during the entire period. The EUV flux is positive correlated with sunspot numbers for full disc, northern and southern hemispheres and their relationship is found linear and significant. This work has been done in collaboration with Avneesh Kumar, Jaidev Sharma and Hari Om Vats.

Rajesh Kumar

Black hole formation in gravitational collapse and their astrophysical implications

In this study, we have explored the process of black hole (BH) formation occurring in the collapse of a self-gravitating configuration using an innovative approach. The exact solution of the Einstein field equations is obtained in a model-independent way by considering a parametrization of the expansion scalar (Θ) in the background of spherically symmetric space-time geometry governed by the FLRW metric. Smooth matching of the interior solution with the Schwarzschild exterior metric across the boundary hypersurface of the star, together with the condition that the mass function $m(t, r)$ is equal to Schwarzschild mass M, is used to obtain all the physical and geometrical parameters in terms of the stellar mass. The four known massive stars namely $R136a3$, $Melnick$, $R136c$, and $R136b$ with their known astrophysical data (mass, radius, and present age) are used to study the physics of the model both numerically and graphically. We demonstrate that the formation of the apparent horizon occurs earlier than the singular state that is, the collapse of massive stars in our model results in the eventual formation of black holes as their final state. We have conducted an analysis indicating that the lifespans of massive stars are closely related to their respective masses. Our findings demonstrate that more massive stars exhibit considerably shorter lifespans in comparison to their lighter counterparts. Thus, the presented model corresponds to the evolutionary stages of astrophysical stellar objects and theoretically predicts their possible lifespan. We have also shown that our model satisfies the energy conditions and stability requirements via Herrera's cracking method. This work has been done in collaboration with Annu Jaiswal, S.K. Srivastava, M. Govender and S.K.J. Pacif.

Eternal gravitational collapse in f (R) theory of gravity and their astrophysical implications

The present investigation explores a novel facet of gravitational collapse, surpassing conventional notions of black holes and naked singularities. In this work, we explore a new aspects on the final fate of Gravitational Collapse of a stellar system within the framework of $f(R)$ gravity and find the continued homogeneous gravitational collapse: an eternal collapsing phenomenon. The exact solutions of field equations have been obtained in an independent way by the parameterization of the expansion scalar (Θ) governed by the interior spherically symmetric FLRW metric. We impose the Darmois junction condition required for the smooth matching of the interior region to the Schwarzschild exterior metric across the boundary hypersurface of the star. The junction conditions demand that the pressure is non-vanishing at the boundary and is proportional to the non-linear terms of $f(R)$ gravity, and

the mass function $m(t,r)$ is equal to Schwarzschild mass M. The eight massive stars, namely $Westerhout49-2, BAT99-98, R136a1, R136a2, WR24, Pismis24-1$, $\lambda - Cephei$, and $\beta - CanisMajoris$ with their known astrophysical data (masses and radii) are used to estimate the numerical values of the model parameters which allows us to study the solutions numerically and graphically. Here we have discussed two $f(R)$ gravity models describing the collapse phenomenon. The singularity analysis of models is discussed via the apparent horizon and we have shown that stars tend to collapse for an infinite co-moving time in order to attain the singularity (an eternal collapsing phenomenon). We have also shown that our models satisfy the energy conditions and stability requirements for stellar systems. This work has been done in collaboration with Annu Jaiswal, S.K. Srivastava and M. Govender.

Sanjay Kumar

Magnetohydrodynamics simulation of magnetic flux rope formation in a quadrupolar magnetic field configuration

Magnetic flux ropes (MFRs) play an important role in high-energetic events like solar flares and coronal mass ejections in the solar atmosphere. Importantly, solar observations suggest an association of some flaring events with quadrupolar magnetic configurations. However, the formation and subsequent evolution of MFRs in such magnetic configurations still need to be fully understood. In this paper, we present idealized magnetohydrodynamics (MHD) simulations of MFR formation in a quadrupolar magnetic configuration. A suitable initial magnetic field having a quadrupolar configuration is constructed by modifying a three-dimensional linear force-free magnetic field. The initial magnetic field contains neutral lines, which consist of X-type null points. The simulated dynamics initially demonstrate the oppositely directed magnetic field lines located across the polarity inversion lines (PILs) moving towards each other, resulting in magnetic reconnections. Due to these reconnections, four highly twisted MFRs form over the PILs. With time, the foot points of the MFRs move towards the X-type neutral lines and reconnect, generating complex magnetic structures around the neutral lines, thus making the MFR topology more complex in the quadrupolar configuration than those formed in bipolar loop systems. Further evolution reveals the non-uniform rise of the MFRs. Importantly, the simulations indicate that the pre-existing X-type null points in magnetic configurations can be crucial to the evolution of the MFRs and may lead to the observed brightenings during the onset of some flaring events in the quadrupolar configurations. This work has been done in collaboration with Avijeet Prasad, Sushree S. Nayak, Satyam Agarwal and R. Bhattacharyya.

Formation of an observed eruptive flux rope above the torus instability threshold through tether-cutting magnetic reconnection

Erupting magnetic flux ropes (MFRs) are believed to play a crucial role in producing solar flares. However, the formation of erupting MFRs in complex coronal magnetic configurations and the role of their subsequent evolution in the flaring events are not fully understood.
Aims. We perform a magnetohydrodynamic (MHD) simulation of active region NOAA 12241 to understand the formation of a rising magnetic flux rope during the onset of an M6.9 flare on 2014 December 18 around 21:41 UT (SOL2014-12- 18T21:41M6.9), which was followed by the appearance of parallel flare ribbons.
Methods. The MHD simulation was initialised with an extrapolated non-force-free magnetic field generated from the photospheric vector magnetogram of the active region taken a few minutes before the flare.
Results. The initial magnetic field topology displays a pre-existing sheared arcade enveloping the polarity inversion line. The simu- lated dynamics exhibit the movement of the oppositely directed legs of the sheared arcade field lines towards each other due to the converging Lorentz force, resulting in the onset of tether-cutting magnetic reconnection that produces an underlying flare arcade and flare ribbons. Concurrently, a magnetic flux rope above the flare arcade develops inside the sheared arcade and shows a rising motion. The flux rope is found to be formed in a torus-unstable region, thereby explaining its eruptive nature. Interestingly, the location and rise of the rope are in good agreement with the corresponding observations seen in extreme-ultraviolet channels of the Atmospheric Imaging Assembly (AIA) of the Solar Dynamics Observatory (SDO). Furthermore, the foot points of the simulations flare arcade match well with the location of the observed parallel ribbons of the flare.
Conclusions. The presented simulation supports the development of the MFR by the tether-cutting magnetic reconnection inside the sheared coronal arcade during flare onset. The MFR is then found to extend along the polarity inversion line (PIL) through slip- running reconnection. The MFRâ€™s eruptive nature is ascribed both to its formation in the torus-unstable region and also to the runaway tether-cutting reconnection. This work has been done in collaboration with Avijeet Prasad, A. C. Sterling, R. L. Moore, G. Aulanier, R. Bhattacharyya, and Q. Hu.

Suresh Kumar

Effects of type Ia supernovae absolute magnitude priors on the Hubble constant value

We systematically explore the influence of the prior of the peak absolute magnitude (M) of type Ia supernovae (SNe Ia) on the measurement of the Hubble constant (H_0) from SNe

Ia observations. We consider five different data-motivated M priors, representing varying levels of dispersion, and assume the spatially-flat ΛCDM cosmological model. Different M priors lead to relative changes in the mean values of H_0 from 2% to 7%. Loose priors on M yield H_0 estimates consistent with both the Planck 2018 result and the SH0ES result at the 68% confidence level. We also examine the potential impact of peculiar velocity subtraction on the value of H_0, and show that it is insignificant for the SNe Ia observations with redshift z>0.01 used in our analyses. We also repeat the analysis in the cosmography model and find very similar results. This suggests that our results are robust and model independent. This work has been done in collaboration with Yun Chen, Bharat Ratra, and Tengpeng Xu.

Vinjanampaty Madhurima

Unravelling hydrogen bond network in methanol-propanol mixtures via molecular dynamics simulation and experimental techniques

Hydrogen-bonded networks in 1-propanol-methanol binary mixture are studied using molecular dynamics simulation along with experimental techniques (FTIR, dielectric spectroscopy and refractive index measurements) for the entire concentration range. The structure of hydrogen-bonded networks is studied through radial distribution function, hydrogen bond statistics and graph theoretical analysis from molecular dynamics. It is observed that the probability of hydrogen bonding is maximum in methanol molecules followed by hydrogen bonding between methanol and 1-propanol molecules and minimum among 1-propanol molecules, as the concentration changes. The graph theory results show the formation of linear chain hydrogen bond networks, with no caged structures, which is validated from the experimental results. Further, the deconvolution of the FTIR OH peak suggests the presence of linear multimers in all concentrations of the binary system. Average degree of the hydrogen-bonded networks from graph theory indicates a complex networks among pure alcohols and dimers between methanol and 1-propanol in their binary mixtures at all concentrations. The negative values of excess permittivity indicate that the components of the mixture interact in a manner such that the net dipole polarisation decreases. This work has been done in collabration Ajmal Rahman M K, K Saishree, Swathi P V, and Abdulkareem U.

Understanding complexity of hydrogen-bonded liquids through Voronoi entropy

In this paper we study the short order of liquids using Voronoi entropy (SVor), computed using Voronoi Polyhedra (VP) tessellations. Voronoi tessellations partition a plane with n seeds into polyhedrons, in which each polyhedron has exactly one seed and every location within a given polyhedron is nearest to its generating seed, rather than to any other seed. The distribution of these VP is used to determine the Voronoi entropy (SVor), which shares similarities with the Shannon measure of information (H). Such studies, however, have been largely restricted to two-dimensional analysis. In this study SVor is used to quantify the orderliness of the three-dimensional structures of hydrogen-bonded systems (water, methanol, ethanol, and 1-propanol), as well as binary mixtures (methanol-ethanol, methanol-1-propanol, and ethanol-1-propanol) through molecular dynamics simulations. SVor is calculated for the VP considering all atom types and oxygen atoms to exclusively study the hydrogen bonds. The SVor for all atoms shows that the smaller molecules have a more ordered structure than the larger ones whereas the SVor calculated considering only oxygen atoms decreases as the alkyl chain length of the molecules increases indicating the smaller molecules have more ways to form hydrogen bonds than the larger ones. SVor calculated for binary mixtures for varying concentrations shows a similar trend. This work has been done in collabration with Abdulkareem U.

Smriti Mahajan

AstroSat /UVIT study of galaxies in the cluster Abell ∼ 2199

We present the newly acquired data for an *AstroSat*/UVIT field centred on a face-on spiral starburst galaxy UGC 10420, located in the X-ray bright cluster Abell 2199 ($z = 0.031$). We have analysed the *FUV* BaF_2 data for this field along with the archival *FUV* and *NUV* data from the *GALEX* mission, optical photometric data from the SDSS, spectroscopic data from the literature, and low-frequency radio data from the LoTSS survey, respectively. The stars were separated from the galaxies using the SDSS photometric pipeline classification, while the spectroscopic redshifts available for 35% of the detected UVIT sources were used to identify member galaxies of the cluster Abell. We find that (a) the non-cluster galaxies are on average fainter than the cluster galaxies at fixed magnitude, (b) stars and galaxies are indistinguishable in the r vs $NUV - r$ plane, and (c) bright stars are $\sim$ 1.5 mag bluer than the galaxies in the $FUV - r$ vs $NUV - r$ colour-colour plane. Besides UGC ∼10420 which is the only known cluster galaxy with an extended-UV disk, we identify five more galaxies with asymmetric *FUV* morphology and extended radio emission in this field. All the asymmetric member galaxies of Abell, lie within the virial boundaries of the cluster. This observation, together with the fact that these asymmetric cluster galaxies have low-frequency radio tails or *FUV* emission pointing away from the cluster centre leads us to hypothesise that these galaxies are likely undergoing ram-pressure stripping (RPS) under the influence of cluster-environment related mechanisms. A comparison of optical and *FUV* star formation rate of UVIT detected galaxies shows enhanced star formation in half of the RPS candidates, suggesting

that environment-related mechanisms may lead to a burst of star formation in RPS galaxies. Our analysis indicates the presence of at least two more groups or clusters at $z \sim 0.077$ and 0.260, coincident with Abell along the line of sight of the field of view studied here. This work has been done in collaboration with Kulinderpal Singh, Somak Raychaudhury.

Manzoor A. Malik

Effects of calibration uncertainties on the detection and parameter estimation of isotropic gravitational-wave backgrounds

Gravitational-wave backgrounds are expected to arise from the superposition of gravitational-wave signals from a large number of unresolved sources and also from the stochastic processes that occurred in the early Universe. So far, we have not detected any gravitational-wave background, but with the improvements in the detectors sensitivities, such detection is expected in the near future. The detection and inferences we draw from the search for a gravitational-wave background will depend on the source model, the type of search pipeline used, and the data generation in the gravitational-wave detectors'. In this paper, we focus on the effect of the data generation process, specifically the calibration of the detectors' digital output into strain data used by the search pipelines. Using the calibration model of the current LIGO detectors as an example, we show that for power-law source models and calibration uncertainties $\leq$ 10%, the detection of isotropic gravitational-wave background is not significantly affected. We also show that the source parameter estimation and upper limit calculations get biased. For calibration uncertainties of $\leq 5\%$, the biases are not significant ($\leq 2\%$), but for larger calibration uncertainties, they might become significant, especially when trying to differentiate between different models of isotropic gravitational-wave backgrounds This work has been done in collaboration with Junaid Yousuf, Shivaraj Kandhasamy.

The Role of Convectively-Generated Gravity Waves in Poleward Propagation of MSTIDs Over Srinagar

We report the influence of the atmospheric gravity waves on medium scale traveling ionospheric disturbances (MSTIDs) that are observed during the month of September 2020, using an airglow imager over Srinagar, Kashmir. Several cases of nighttime MSTIDs at $\sim$ 250 km altitude are presented which propagate either in northwestward, northward or northeastward direction. Either the phase fronts of the observed MSTIDs are not aligned in the NW-SE direction, or the MSTIDs are not propagating in the southwest direction, these are believed to be non-electrified MSTIDs which are generally associated with gravity waves (GWs). The average horizontal wavelengths of these MSTIDs range from 185 to 469 km, horizontal phase speeds of about 162 -"521 m/s while the time periods range from 13 to 24 min considered as very short-period ionospheric disturbances. The detection of GWs at $\sim$ 97 and $\sim$ 85 km heights during the nights of MSTID detection leads to the inference that there is a strong correlation between the occurrences of these MSTIDs with mesospheric GWs. By using satellite data, including INSAT-3DR and the Atmospheric Infrared Sounder, the detection of convective clouds near the locations of the imager is observed, and by utilizing the kinetic temperature data from the Sounding of the Atmosphere using Broadband Emission Radiometry satellite, the presence of GWs near the convective systems is also seen. Such GWs are also observed in the vicinity of the imager location and it is concluded that the lower atmospheric convectively-generated GWs could be a leading factor for the generation of poleward propagating MSTIDs. This work has been done in collaboration with Aashiq Hussain Bhat, Mohammad Rafeeq Rather, T. K. Ramkumar.

Soma Mandal

Spectral and timing evolution of GX 340+0 along its Z-track

We present the results from spectral and timing study of the Z source GX 340+0 using *AstroSat*'s SXT and LAXPC data. During the observation the source traced out the complete Z-track, allowing for the spectral evolution study of the Horizontal, Normal and Flaring branches (HB, NB and FB) as well as the hard and soft apexes (HA and SA). The spectra are better and more physically described by a blackbody component and a hot Comptonizing corona with a varying covering fraction, rather than one having a disc component. Along the track, the Comptonized flux (as well as the covering fraction) monotonically decreases. It is the blackbody component (both the temperature and radius) which varies non-monotonically and hence gives rise to the Z-track behaviour. Rapid timing study reveals a prominent Quasi-periodic Oscillation (QPO) at $\sim$ 50 Hz at the HB, HA and upper NB, while a QPO at $\sim$ 6 Hz is seen for the other branches. The fractional r.m.s of the QPOs increase with energy and exhibit soft lags in all branches except SA and FB. This work has been done in collaboration with Suchismito Chattopadhyay, Yashpal Bhulla, Ranjeev Misra.

Ram Ajor Maurya

Dynamics of a quiescent prominence observed by IRIS and SDO/AIA

We studied the dynamical properties of a quiescent prominence using high-resolution observations provided by the Interface Region Imaging Spectroscopy (IRIS) and Atmospheric Imaging Assembly (AIA) onboard Solar Dynamics Observatory (SDO). The prominence is found to be shaped by two rotating magnetic structures. Both

structures were formed after a EUV brightening followed by magnetic flux emergence and cancellation. We computed the prominence's Doppler velocities using the spectroscopic observations provided by IRIS. The temperature maps in the prominence regions are estimated using the Differential Emission Measure (DEM) of observations in the six Extreme Ultra-Violet (EUV) wavelengths obtained from SDO/AIA. The prominence has an average temperature of 9.8×10^4K. The non-thermal velocity in the prominence was estimated between 8 – 40 $\mathrm{km\,s^{-1}}$. We employed the Local Correlation Tracking (LCT) to find the plane-of-sky motions in the prominence. Thus the measurements of plasma motions in two normal directions such as in the line-of-sight and in the plane-of-sky helped us to investigate the anti-clockwise rotation of the prominence's leg with a period of around 60 minutes when viewed from the top of it. We found dynamical motions of 20 to 60 $\mathrm{km\,s^{-1}}$ in the prominence regions. On the other hand, one of the prominence's legs was rotating in front of the other first in the clockwise and after half an hour in the counter-clockwise directions. We also found a sizable helical motion in the upper part of the prominence with a linear speed of 6.71 $\mathrm{km\,s^{-1}}$. Further, the prominence was found to have significant oscillations in the frequency band 1.5 - 2.5 mHz, corresponding to a period range of 7 - 11 minutes. This work has been done in collaboration with Jain Jacob P. T.,and Safna Banu K.

Flare-Induced Transverse Oscillations of Coronal Loops and Propagating EUV Waves

We study an X1.5 class solar flare observed from an active region NOAA 13006 on May 10, 2022. This flare was accompanied by other energetic activities such as the propagation of an Extreme Ultraviolet (EUV) wave, coronal loop oscillations, Coronal Mass Ejections (CMEs), etc. We analyze this event using high spatial and temporal resolution observations from the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Observatory (SDO), Extreme-Ultraviolet Imager (EUVI) of the Solar Terrestrial Relations Observatory-Ahead (STEREO-A), and the Large Angle and Spectrometric Coronograph (LASCO) within the Solar and Heliospheric Observatory (SOHO) satellites. We found that the EUV waves are initiated at the start of the flare, i.e., they are driven by the solar flares. It consisted of both fast and slow wave components. These shock wave fronts create oscillations in the coronal bundle of loops. One of the loops studied further to estimate the oscillation parameters. This loop oscillated with a period of 5.3 minutes with a damping time of 14±1 minutes. After that, we evaluated the oscillated coronal loop length by combining observations from AIA/SDO and EUVI/STEREO-A. Then, we estimated the magnetic field strength as 68 G with the help of coronal seismology. This work has been done in collaboration with Safna Banu K.

Biman Jyoti Medhi

Statistical and Multiwavelength Photometric Analysis of a Young Embedded Open Star Cluster: IC 1590

e present a statistical and multiwavelength photometric studies of young open cluster IC 1590. We identified 91 cluster members using *Gaia* DR3 astrometry data using ensemble-based unsupervised machine learning techniques. From *Gaia* EDR3 data, we estimate the best-fitted parameters for IC 1590 using the Automated Stellar Cluster Analysis package (ASteCA) yielding the distance $d \sim 2.87 \pm 0.02$ Kpc, age $\sim 3.54 \pm 0.05$ Myr, metallicity $z \sim 0.0212 \pm 0.003$, binarity value of ~ 0.558, and extinction $A_v \sim 1.252 \pm 0.4$ mag for an R_v value of $\sim 3.322 \pm 0.23$. We estimate the initial mass function slope of the cluster to be $\alpha = 1.081 \pm 0.112$ for single stars and $\alpha = 1.490 \pm 0.051$ for a binary fraction of ~ 0.558 in the mass range 1 $\mathrm{M_\odot} \leq \mathrm{m(M_\odot)} \leq 100$ $\mathrm{M_\odot}$. The G-band luminosity function slope is estimated to be $\sim 0.33 \pm 0.09$. We use $(J-H)$ versus $(H-K_s)$ color-color diagram to identify young stellar objects (YSOs). We found that all the identified YSOs have ages $\leq$ 2 Myr and masses $\sim$ 0.35 - 5.5 $\mathrm{M_\odot}$. We also fit the radial surface density profile. Using the galpy we performed orbit analysis of the cluster. The extinction map for the cluster region has been generated using the PNICER technique and it is almost similar to the dust structure obtained the dust structure from the 500 μm dust continuum emissions map of *Herschel* SPIRE. We finally at the end discussed the star formation scenario in the cluster region. This work has been done in collaboration with A H Sheikh.

Irom A. Meitei

Hawking radiation of rotating BTZ black hole based on modified dispersion relation and Rarita-Schwinger equation

In this paper, tunneling of fermions from rotating BTZ black hole is investigated using modified dispersion relation (MDR) and Rarita Schwinger equation. The effect of MDR on the tunneling of fermions raises the Hawking temperature of rotating BTZ black hole. It is observed that the modified Hawking temperature of the black hole depends not only on the radial parameters of the black hole but also on the angular parameters of the black hole and the coupling constant σ. Further, the entropy and the heat capacity of the black hole are also studied. This work has been done in collaboration with S. Gayatri Devi, T. Ibungochouba Singh, A. Keshwarjit Singh and K. Yugindro Singh.

Modified Hawking temperature and entropy of Kerr-de Sitter black hole in Lorentz symmetry violation theory

In this paper, we discuss the tunneling of scalar particles near the event horizon of stationary and nonstationary Kerr-de

Sitter black hole using Lorentz violation theory in curved spacetime. The modified form of Hamilton-Jacobi equation is derived from the Klein-Gordon equation by applying Lorentz violation theory. The Hawking temperatures derived from stationary and nonstationary Kerr-de Sitter black holes are modified due to Lorentz violation theory. It is noted that the change in Bekenstein-Hawking entropy and modified Hawking temperatures of stationary and nonstationary Kerr-de Sitter black hole not only depend on the black hole parameters but also on ether-like vectors u^{α}. This work has been done in collaboration with Y. Onika Laxmi and T. Ibungochouba Singh.

Hameeda Mir

Quantum Theory Of 3+1 Dimensional Einstein Gravity, Dilatons And Dark Matter

Gravitons and four dimensional dilatons play an important role with regards to dark matter. Here, by appeal to developments of Gupta and Feynman and using a novel mathematical theory based on Ultrahyperfunctions [1] , we are able to provide an exact, quantum relativistic expression for the gravitons and dilatons self-energies. For a complete explanation of Ultrahyperfunctions and their uses in Quantum Field Theory see [2]. Ultrahyperfunctions (UHF) are the generalization and extension to the complex plane of Schwartz 'tempered distributions. This manuscript is an application to Einstein's Gravity and Dark Matter (EG) of the mathematical theory developed by Bollini et al [3, 4, 5, 6]. We will quantize EG using the most general quantization approach, the Schwinger-Feynman variational principle [15], which is more appropriate and rigorous than the popular functional integral method (FIM). FIM is not applicable here because our Lagrangian contains derivative couplings. We use the Einstein Lagrangian as obtained by Gupta [16, 17, 18], but we add a new constraint to the theory. Thus the problem of lack of unitarity for the S matrix that appears in the procedures of Gupta and Feynman disappear Our theory is obviously non-renormalizable. However, this inconvenience is solved by resorting to the theory developed by Bollini et al. [3, 4, 5, 6] We give here explicit formulas for the self-energy of the graviton, interacting with dilatons. Also, for the first time in the literature, we present 7 graphs corresponding to those self energies. This work has been done in collaboration with A. Plastino, M.C.Rocca.

Measurement of Atmospheric Neutrino Cross-Sections on Oxygen, Water and Argon using Nuwro Event Generator

Neutrinos were produced immediately after Big-bang. These are the most abundant particles after photons. Neutrinos are literally jam packing the Universe and are associated with some of the deepest mysteries of nature. These are excellent carriers of information from the past of Universe through sources like bursting stars and black holes which we do not have a direct access to. Consequently, there has been a surge in the study of neutrinos and their interaction with matter. However, since neutrinos are very weakly interacting particles, these have feeble cross-sections. Nonetheless, cross-section measurement is the basic ingredient for any higher order neutrino studies. Therefore, in this work we report the cross-section measurements of neutrino interactions with three atmospheric gases viz; Oxygen, Water and Argon. This study is done using NuWro event generator. Nuwro is a Polish code developed by some eminent researchers at Wroclaw University of Poland. It is configured using well known physical models of neutrino interaction. The cross-section measurements are taken in an energy interval of hundreds of MeV to a few GeV, which is also best suited to study neutrino oscillations. We also try a novel way to define the scattering potential for neutrino interactions as a function of initial neutrino flux. This work has been done in collaboration with Iflah Rasool Shaik, Qudsia Gan.

Bivudutta Mishra

Observational constrained $F(R, \mathcal{G})$ gravity cosmological model and the dynamical system analysis.

TIn this paper, we have analyzed the geometrical and dynamical parameters of $\mathcal{F}(R, \mathcal{G}) = \alpha R^2 \mathcal{G}^{\beta}$ cosmological model, (R, $\mathcal{G}$ being the Ricci scalar and Gauss-Bonnet invariant respectively), constraining the parameters through the cosmological data sets. It is exhibited that the model admits a viable radiation era, and early deceleration followed by late-time acceleration in the matter-dominated era. From the phase-space, portrait stability criterion has been analysed, restricting the parameter β, different from $\beta = -1$. Additionally, we have explored the stability of the model from the behavior of critical points and obtained the present value of the density parameter for matter-dominated and dark energy components, which are identical to those obtained through cosmological data sets. This work has been done in collaboration with Santosh V. Lohakare, Krishna Rathore.

Dynamical complexity in Teleparallel Gauss-Bonnet gravity

The stable critical points and their corresponding cosmology are derived in the teleparallel gravity with an added Gauss-Bonnet topological invariant term. We have analyzed the dynamics of the Universe by presenting two cosmological viable models, showing the potential to describe different phases of the evolution of the Universe. The value of the deceleration parameter (q), total equation of state parameter (ω_{tot}) and dark energy equation of state parameter (ω_{DE}) have been presented against each critical point. The existence and stability conditions are also presented. We

study the behavior of the phase space trajectories at each critical point. Finally, the evolutionary behavior of the deceleration parameter and the equation of state parameters have been assessed with the initial condition of the dynamical variables, and compatibility has been observed in connection with the present cosmological scenario. This work has been done in collaboration with S.A. Kadam, Santosh V Lohakare.

Aditya Sow Mondal

The complex spectral behavior of the newly discovered neutron star X-ray binary Swift J1858.6-0814

We report on the NuSTAR observation of the newly discovered neutron star X-ray binary Swift $\sim$ J1858.6-0814 taken on 23rd March 2019. The light curve of the source exhibits several large flares during some time intervals of this observation. The source is softer in the high-intensity interval where the large flaring activity mainly occurs. We perform time-resolved spectroscopy on the source by extracting spectra for two different intensity intervals. The source was observed with a $3-79$ keV luminosity of $\sim 9.68\times10^{36}$ ergs/s and $\sim 4.78\times10^{36}$ ergs/s for high and low-intensity interval, respectively assuming a distance of 15 kpc. We find a large value of the absorbing column density ($N_H \sim 1.1\times10^{23}$ cm^{-2}), and it appears to be uncorrelated with the observed flux of the source. Each spectrum shows evidence of Fe Kα emission in the $5-7$ keV energy band, an absorption edge around $\sim 7-8$ keV, and a broad Compton hump above 15 keV, indicating the presence of a reflection spectrum. The observed features are well explained by the contribution of a relativistic reflection model and a partially covering absorption model. From the best-fit spectral model, we found an inner disc radius to be $4.87^{+1.63}_{-0.96}$ R_{ISCO} (for the high-intensity interval) and $5.68^{+9.54}_{-2.78}$ R_{ISCO} (for the low-intensity interval), indicating a significant disc truncation. The disk inclination is found to be relatively low, $i < 33^0$. We further place an upper limit on this source's magnetic field strength considering the disc is truncated at the magnetospheric radius. This work has been done in collaboration with B. Raychaudhuri, and G. C. Dewangan.

Relativistic X-ray reflection and highly ionized absorption in the spectrum of NS LMXB 1A 1744-361

We present the results from the spectral and timing analysis of the accreting neutron star 1A 1744-361 from the NuSTAR observation performed in its 2022 outbursts. The unabsorbed bolometric X-ray luminosity during this observation in the energy band $0.1-100$ keV is 3.9×10^{37} erg s^{-1}, assuming a distance of 9 kpc. During this observation, the source was in the banana branch of the atoll track. The source spectrum exhibits relativistic disc reflection and clear absorption features when an absorbed blackbody and cut-off power-law model describes the continuum emission. The $3-50$ keV source spectrum is well fitted using a model combination consisting of an absorbed single-temperature blackbody and a reflection model along with the addition of a warm absorber component. The inner-disk radius, R_{in}, obtained from the reflection fit is $\sim (1.61-2.86)R_{ISCO} = (8.4-14.9)R_g$ ($17.6-31.2$ km for a 1.4 M$\odot$ NS). This measurement allowed us to further constrain the magnetic field strength to $B \lesssim 0.94\times10^9$G. The strong absorption features ~ 6.91 keV and ~ 7.99 keV imply the presence of highly ionized absorbing material with a column density N_H of $\sim 3\times10^{22}$ cm^{-2}, emanating from the accretion disk in the form of disc wind with an outflow velocity of $v_{out} \simeq 0.021c \simeq 6300$ km s^{-1}. This work has been done in collaboration with B. Raychaudhuri, and G. C. Dewangan.

Mahadevappa Naganathappa

Theoretical study of amines containing molecules in the gas and water solvent

The present study reports the infrared and electronic absorption spectra of amines containing molecules of neutral in the gas and astrophysical H2O ice and their ionic forms. These are prebiotic molecules such as propargylamine single isomer of C3H5N, four isomers of C3H7N (1-aminopropene, 2-propanamide, allylamine, and cyclopropylamine), and two isomers of C3H9N (n-propylamine and 2-aminopropane) considered for the study. We have reported the geometrical parameters such as bond length, bond angle and optimized energy, electron affinity, and dipole moment of all molecules in the gas phase, water solvent, and ionic states. Coupled-cluster method (CCSD) with a 6-311++G** basis set has been implemented for these studies. The vibrational frequencies of these molecules are well matching with the available experimental determination at the CCSD/6-311++G** level of theory. The IEFPCM model has been used to study solvent effect at this same level of theory. The equation of motion coupled cluster theory (EOM-CCSD) has been used to study the electronic absorption spectra of all these molecules at the CCSD/6-311++G** level of theory. We have reported the HOMO-LUMO gap, electronic transitions, and oscillator strength of these transitions. The AOMix has been used to find the transitions. We have also suggested the best lines to observe these molecules in interstellar environments. Though there are more than single isomers for the above molecule they can be differentiated by their peaking wavelength, intensities, and modes. All these calculations have been performed using Gaussian 16 program package. This work has been done in collaboration with Venkata Lakshmi Karri, Sumalya Kaluva.

Understanding Diazirine Oligomers: A Theoretical Investigation of Solvent Effects and Molecular Properties

Diazirines have captured significant attention in the scientific community, particularly in the field of biology, owing to their diverse applications. In this study, we explore diazirine oligomers ranging from monomers to pentamers, organized in linear, ladder, and cyclic clusters, under both gas and water solvent conditions. Notably, dimers within cyclic, hexamer, and larger clusters are shown to be unstable. To investigate weak interactions in diazirine oligomers, we employ the dispersioncorrected B3LYP-D3 method using a 6-311++G (d, p) basis set with diffused and polarized functions. The comparison of geometrical properties and vibrational modes of monomeric diazirine against existing experimental results reveals good agreement. Among all stretch and bend modes, the N-N stretch mode and the C-H wag mode stand out as the most intense. Further, we employ time-dependent density functional theory (TD-DFT) to determine the excited-state electronic absorption spectra of diazirine oligomers at the same level of theory. Key properties such as the wavelength of electronic transitions, oscillator strength, and HOMO to LUMO gaps are reported. Additionally, we calculate the first ($\hat{I}^2$) and second ($\hat{I}^3$) hyperpolarizabilities of diazirine using the finite field method. Interestingly, the diazirine monomer displays higher responsiveness to the first hyperpolarizability than the second. To gain insights into the interaction energies, we utilize the many-body analysis technique. Our findings show that two-body interactions play a dominant role in contributing to the binding energy. Lastly, we investigate hydrogen-bonded cooperativity in diazirine oligomers across all cluster types. Our study contributes to a deeper understanding of diazirine oligomers' solvent effects and molecular properties, shedding light on their potential applications in various fields. This study has been done in collaboration with Sumalya Kaluva.

P. R Prince

Investigation of random noise in SYM-H and Dst during intense geomagnetic storms and solar quiet days of SC 23 using the method of potential analysis

Potential analysis (PA) method is used to investigate the randomness or stochastic noise in 1-minute Dst and SYM-H data during highly disturbed as well as solar minimum quiet periods. This method is helpful in understanding the behaviour of a system whose internal parameters are unknown. The eAect of random noise is exhibited in the number of wells in the potential function and in the bifurcation of states. Higher the number of state, higher the eAect of random noise in the system. Our study focuses on PA of 12 intense geomagnetic storms of solar cycle (SC) 23 with peak Dst B â€“200 nT and 12 quiet events with Dst C â€“50 nT during solar minimum periods, using 1-minute Dst and SYM-H data for a period of 10 days each. Storm phases were least aAected by random noise, while undisturbed periods were episodes of higher noisy states. Random noise in the indices can be attributed to different factors, including the eAect of solar wind dynamic pressure on Dst estimation, contribution of different ion species to ring current, storm time super substorms, etc. Role of other factors is subjected to further analysis. This work has been done in collaboration with Devi R. Nair.

Biswajit Pandey

Separating the blue cloud and the red sequence using Otsu's method for image segmentation

The observed colour bimodality allows a classification of the galaxies into two distinct classes: the 'blue cloud' and the 'red sequence'. Such classification is often carried out using empirical cuts in colour and other galaxy properties that lack solid mathematical justifications. We propose a method for separating the galaxies in the 'blue cloud' and the 'red sequence' using Otsu's thresholding technique for image segmentation. We show that this technique is insensitive to the choice of binning. It provides a robust and parameter-free method for the classification of the red and blue galaxies based on the minimization of the intra-class variance and maximization of the inter-class variance. We also apply an iterative triclass thresholding technique based on Otsu's method to improve the classification. The galaxy colour is known to depend on the stellar mass and the luminosity of galaxies. We obtain the dividing lines between the two populations in the colour-stellar mass plane and the colour-absolute magnitude plane by employing these methods in a number of independent stellar mass bins and absolute magnitude bins.

The correlations between galaxy properties in different environments of the cosmic web

We study the correlations between $(u - r)$ colour, stellar mass, specific star formation rate (sSFR) and metallicity of galaxies in different geometric environments of the cosmic web using a volume limited sample from the SDSS. The geometric environment at the location of each galaxy is determined using the eigenvalues of the tidal tensor in three dimensions. We use the Pearson correlation coefficient (PCC) and the normalized mutual information (NMI) to quantify the correlations between these galaxy properties in sheets, filaments and clusters after matching the stellar mass distributions of the galaxies in these environments. A two-tailed t-test assesses the statistical significance of the observed differences between these relations in different geometric environments. The null hypothesis can be rejected at $> 99.99\%$ significance level in most of the cases, suggesting that the scaling relations between the observable galaxy properties are susceptible to the geometric environments of

the cosmic web. This work has been done in collaboration with Anindita Nandi,and Prakash Sarkar

Amit Pathak

Theoretical microwave spectra of interstellar nitrogen-containing PAHs

The recent discovery of naphthalene (C10H8) in cyano-substituted polycyclic aromatic hydrocarbon (CN-PAH) form in the Taurus molecular cloud (TMC-1) has sparked curiosity regarding the search for other nitrogen-containing naphthalenes in similar interstellar environments. In this light, naphthalenes having N atoms in the structure are promising candidates to be searched for in cold, dark molecular clouds such as TMC-1. Since obtaining data on such samples in the laboratory is complicated, the present work reports theoretical microwave spectra of naphthalene in all N-substituted forms. Density functional theory (DFT) calculations are employed to calculate the spectroscopic constants and simulate the rotational spectra with hyperfine splitting. For cold temperature regions such as TMC-1 (about 5 K), the considered N-naphthalene species show the strongest transition around centimetre wavelengths, a typical range for PAH-related species in dark molecular clouds. Accurate rotational data provided here may act as a guide for laboratory experiments and astronomical searches. This work has been done in collaboration with Akant Vats, Satyam Srivastav,and Anshika Pandeya.

C-H Stretch Vibrational Modes: Tracers of Interstellar PAH Geometries?

Polycyclic aromatic hydrocarbon (PAH) molecules have long been adjudged as carriers of the frequently detected interstellar emission features in the 3-20 μm region. In the present work, PAHs with straight edges having solo-duo (PAHD) and solo-duo-trio (PAHT) C-H modes along with PAHs with irregular edges (PAHI) have been studied theoretically to understand the effect of molecular geometry on the interstellar C-H stretch vibrations at 3.3 μm. The C-H out-of-plane bending vibrations at 11.2 and 12.7 μm are also included for completeness. Using the NASA Ames PAH IR Spectroscopic Database, the mid-infrared spectra have been studied for 125 PAH molecules of varying molecular geometries, sizes, charge states, and symmetries. Results show that the individual solo, duo, and trio C-H stretches follow an order in the peak wavelength ($\lambda_{3.3}$ (solo) > $\lambda_{3.3}$ (duo) > $\lambda_{3.3}$ (trio)) and intensity ($I_{3.3}$ (solo) < $I_{3.3}$ (duo) < $I_{3.3}$ (trio)). If only PAHD's are considered, the contribution of each charge state is required to account for the observed peak wavelength of the 3.3 μm band, or if only neutrals are contributors, PAHD and PAHT neutrals can explain the 3.3 μm band variations. The observed emission at 11.2 and 12.7 μm is found to match effectively with PAHD with increasing size, and the 11.2 μm band is present at longer wavelengths for PAHT contributing to the red wing. When the solo to duo hydrogen ratio is nearly equal to or greater than 1.0, PAHD neutrals yield better 3.3 μm peak positions. The ratio has a lower limit of 0.8 for the 11.2 μm band and converges at 1.5, indicating a size range of PAHD neutrals with 80 to larger numbers of carbon atoms. The present work examines the presence of solo, duo, and trio modes in the C-H stretching band, which must be taken into consideration when interpreting accurate data from James Webb Space Telescope (JWST) to further explain the observed variations in the interstellar 3.3 μm. This work has been done in collaboration with Akant Vats,Takashi Onaka, Itsuki Sakon, and Izumi Endo.

Bikash C. Paul

Gaussian black holes in brane-world model

Regular black hole solutions in the framework of Brane-world gravity sourced by a Gaussian matter distribution is obtained. We note black hole metric that permits the common features of a regular black holes in the modified General Relativity (GR) with some exciting features. The energy momentum tensor for an isotropic fluid on the brane is considered in the modified Einstein field equation which is identified with an effective energy momentum tensor that describes an anisotropic fluid as a function of the brane world parameters. The effective transverse pressure is found to behave differently although the effective radial pressure and energy density satisfy a vacuum energy condition. Here the Gaussian black hole (GBH) solutions are obtained from a Gaussian matter distribution. A new class of GBH solutions are obtained in the brane-world gravity in the presence of an effective normal matter in addition to exotic matter distribution. The mass of a GBH depends on the brane tension and that a massive GBH is permissible compared to a GBH that formed in a low energy limiting case (i.e., GR). We study the trajectories of the massive and the massless particles that can be trapped around a GBH for a set of model parameters. The radii of the photon spheres around the GBH and the condition for the stability of the trajectories of the photon spheres are determined. The properties of the GBHs are studied in detail, including their possible observable features.

Study of Gravastars in Rastall Gravity

We study Gravastar in the framework of Rastall gravity. Rastall gravity is a popular alternative to GR. Stellar model is proposed here making use of the Mazur-Mottola's conjecture. The three regions that are assumed in a gravastar, *viz.*, (i) Interior region, (ii) Intermediate shell region, and (iii) Exterior region. The pressure within the interior core region is assumed with a constant negative matter-energy density which provides a repulsive force over

the entire thin shell region. The shell is assumed to be made up of fluid of ultra-relativistic plasma which follows the Zel?dovich?s conjecture of stiff fluid. It is also assumed that the pressure is proportional to the matter-energy density according to Zel?dovich?s conjecture, which cancel the repulsive force exerted by the interior region. The exterior region is completely vacuum described by the Schwarzschild de Sitter solution. Under this conditions, we obtain a set of exact and singularity-free solutions of the gravastar model presenting several physically valid features within the framework of Rastall gravity. The physical properties of the shell region namely, the energy density, proper length, total energy and entropy are studied. The stability of the gravastar model is investigated using the surface redshift against the shell thickness and maximizing the entropy of the shell. This Work has been done in collaboration with S. Ghosh, S. Dey, A. Das, A. Chand,

Ninan Sajeeth Philip

Detection of Rings in SDSS Galaxies Using Deep Learning

In a collaboration involving Linn Abraham, Sheelu Abraham, Professor Ajit Kembhavi and Ninan Sajeeth Philip, a deep learning classifier that can learn the visual morphological features of galaxies was developed. In an earlier work, the bar structures in galaxies were identified in a similar manner. The goal this time was to focus on galactic rings that are seen predominantly around disc galaxies. Rings are important features that help understand galaxies' evolution and dynamics. These ring galaxies include normal or "resonance" rings as well as "cataclysmic" rings formed due to collisions, mergers etc. Existing catalogues from archives were used to prepare the labelled training data for the deep learning model. A CNN architecture called AlexNet was used as the deep learning model. The choice of the AlexNet model was that it has fewer trainable parameters compared to many other models and hence shows better resilience to overfitting when trained with a limited number of labelled catalogue data. In addition, a method known as image augmentation, where one creates new synthetic data from the existing data by applying plausible modifications such as scaling, translation, rotation etc to help the network capture the actual phenomena that we are interested in capturing. The trained classifier was used to create a catalogue of rings and non-rings. The classifier was applied to a catalogue of barred galaxies to identify a set of barred rings that contain both a bar and a ring. The work is under review in the Astrophysical Journal.

Detecting HI Galaxy Sources from Radio Data Using Deep Learning

Hydrogen is the most abundant element in the universe. However, it is mostly found in the ionized state in plasma or as molecular hydrogen. Understanding the distribution of neutral atomic hydrogen or HI is important because of its connection to star formation in galaxies. In conditions found in the interstellar medium, it cannot be observed in the optical band. However, HI can be detected using radio astronomy since it emits a characteristic hyperfine spectral line at 21cm. Finding these galaxy sources from radio cubes, especially at low SNR values, is challenging. The current state of the art is the SoFiA, which needs human intervention at certain stages. In the study involving Linn Abraham, Kshitij Thorat, Arun Kumas and Ninan Sajeeth Philip, the use of a 3-dimensional CNN architecture called V-Net showed promising results. Radio data cubes obtained from the WHISP radio survey and the ground truth (labels) for training were prepared using two methods. The first uses ordinary sigma clipping, and the second uses the output of SoFiA as ground truth source masks. After training, benchmarking the predictions of the model with SoFiA demonstrated that the machine learning model performed about four times better and faster than the SoFiA model. The work is in progress.

Anirudh Pradhan

The reconstruction of constant Jerk parameter with $f(R,T)$ gravity

In this work, we have developed an FLRW type model of a universe which displays transition from deceleration in the past to the acceleration at the present. For this, we have considered field equations of f(R,T) gravity and have taken $f(R,T) = R + 2\lambda T$, λ being an arbitrary constant. We have estimated the λ parameter in such a way that the transition red shift is found similar in the deceleration parameter, pressure and the equation of state parameter ω. The present value of Hubble parameter is estimated on the basis of the three types of observational data set: latest compilation of 46 Hubble data set, SNe Ia 580 data sets of distance modulus and 66 Pantheon data set of apparent magnitude which comprised of 40 SN Ia bined and 26 high redshift data's in the range $0.014 \leq z \leq 2.26$. These data are compared with theoretical results through the χ^2 statistical test. Interestingly, the model satisfies all the three weak, strong and dominant energy conditions. The model fits well with observational findings. We have discussed some of the physical aspects of the model, in particular the age of the universe. This work has been done in collaboration with G.K. Goswami and A. Beesham.

Effects of anisotropic pressure on interacting quark star structure

Perturbative Quantum Chromodynamics (pQCD) corrections and color superconductivity predict that strongly interacting matter can reveal new physical phenomena under extreme conditions. Taking into account these interaction

effects, we investigate the role of anisotropic pressure in quark stars composed of interacting quark matter. Adopting two physically well-motivated anisotropy profiles, we numerically solve the stellar structure equations in order to explore the consequences of anisotropic pressure on various macroscopic properties such as radius, gravitational mass, surface redshift, moment of inertia, tidal Love number and oscillation spectrum. Remarkably, for both anisotropy models, negative anisotropies increase the radial stability of interacting quark stars, while the opposite occurs for positive anisotropies. However, for the Bowers-Liang profile, the central density corresponding to the maximum-mass point does not coincide with the central density where the squared oscillation frequency vanishes, indicating that the existence of stable anisotropic interacting quark stars is possible beyond the maximum mass for negative anisotropies. Additionally, we compare our theoretical predictions with several observational mass-radius measurements, which suggest that both strong interaction effects and anisotropy effects play a crucial role in describing compact stars observed in the Universe. This work has been done in collaboration with Jaun M.Z. Pretel, T. Tangphati, A, Banerjee.

Ram Prasad Prajapati

Rayleigh-Taylor instability in compressible ultra-relativistic degenerate strongly coupled plasma

Dense stars (e.g., white dwarfs) are composed of mainly ultra-relativistic degenerate electrons and strongly coupled ions subjected to a gravitational field. Considering the physical conditions of such systems, in this paper, we investigate the linear Rayleigh-Taylor (R-T) instability in a compressible ultra-relativistic degenerate strongly coupled plasma (SCP) using the generalized hydrodynamic fluid model. The electron f luid is assumed to be inertialess, ultra-relativistic degenerate, and weakly coupled, while the ion fluid is treated as non-degenerate and strongly coupled. The compressibility effects are considered for the ion fluid in terms of the Coulomb coupling parameter and internal energy. The dispersion properties of the R-T instability have been analyzed using the normal mode analysis. For short wavelength perturbations, the R-T instability excites in the presence of compressibility and degeneracy of ultra-relativistic electrons; otherwise, the characteristic internal wave propagates in the plasma medium. The compressibility and strong coupling effects play a decisive role in suppressing the R-T modes in dense degenerate SCP. In the high-frequency kinetic limit, the instability region is observed to be shorter than the low-frequency hydrodynamic limit. The effects of ultra-relativistic degenerate electrons are almost negligible on the growth rates. However, they significantly modify the dispersion properties and R-T instability criterion. The astrophysical applications of the present work have been discussed in the high-density ultra-relativistic plasmas in the finite flame thickness near the center of white dwarfs. This work has been done in collaboration with Ravinder Bhambhu .

Wave modes and instabilities in gravitating magnetized polytropic quantum plasmas including viscosity tensor and FLR corrections

The present analytical study extends the problems of pressure anisotropy-driven instabilities and gravitational instability in space plasmas to mixed quantum polytropic gas in the interior of dense stars accounting for the effects of viscosity, finite Larmor radius (FLR) and self-gravitational effects. The generalized polytrope pressure laws are considered as adiabatic equations in which the pressure components depend upon the plasma density, magnitude of the magnetic field, and the polytrope indices. The modified properties of waves and instabilities in gravitating quantum plasmas have been analysed using the quantum magnetohydrodynamic (QMHD) fluid description in the magnetohydrodynamic (MHD) and Che-W-Goldberger-Low (CGL) limits. In the parallel propagation, the Jeans instability modified by quantum diffraction parameters and firehose mode modified by FLR parameter is obtained separately. The Jeans instability condition depends upon the quantum diffraction term and polytrope index, and it remains unaffected due to viscosity and ion Larmor frequency. The growth rate of the Jeans instability decreases due to viscosity and quantum diffraction parameters, while the growth rate of the firehose instability increases due to FLR corrections. In the transverse mode, a similar nature is observed in the growth rates; however, the instability region decreases significantly due to polytrope indices and different dispersion properties of MHD and CGL viscous quantum plasmas. The analytical results have been applied in dense degenerate stars to measure the characteristic parameters and understand the MHD wave propagation, pressure anisotropy-driven, and gravitationally driven instabilities. This work has been done in collaboration with Vinesh Kumar Sangwan

Rakhi R.

UVIT view of NGC 5291: Ongoing star formation in tidal dwarf galaxies at $\sim$ 0.35 kpc resolution

NGC 5291, an early-type galaxy surrounded by a giant H I ring, is believed to be formed from collision with another galaxy. Several star forming complexes and tidal dwarf galaxies are distributed along the collisional ring which are sites of star formation in environments where extreme dynamical effects are involved. Dynamical effects can affect the star formation properties and the spatial distribution of star forming complexes along the tidal features. To study and quantify the star formation activity in the main body and in the ring structure of the NGC 5291 system, we use

high spatial resolution FUV and NUV imaging observations from the Ultraviolet Imaging Telescope onboard AstroSat. A total of 57 star-forming knots are identified to be part of this interacting system out of which 12 are new detections (star forming complexes that lie inside the H I contour) compared to the previous measurements from lower resolution UV imaging. We estimate the attenuation in UV for each of the resolved star-forming knots using the UV spectral slope β, derived from the FUV-NUV colour. Using the extinction corrected UV fluxes, we derive the star formation rate of the resolved star forming complexes. The extinction corrected total star formation rate of this system is estimated as 1.75 $\pm$ 0.04 M$\odot$/yr-1. The comparison with dwarf galaxy populations (BCD, Sm, and dIm galaxies) in the nearby Universe shows that many of the knots in the NGC 5291 system have SFR values comparable to the SFR of BCD galaxies.

Anisur Rahaman

The fermionic greybody factor and quasinormal modes of hairy black holes, as well as Hawking radiation's power spectrum and sparsity

A hairy black hole (HBH) emerges due to matter surrounding the Schwarzschild metric when using the Extended Gravitational Decoupling (GD) approach. The fermionic greybody factors (GFs) and quasinormal modes (QNMs) as well as Hawking spectra and sparsity of HBH solutions are investigated. We consider massive and massless spin-1/2 fermions, along with massless spin-3/2 fermions. The equations of the effective potential for fermions with different spins are derived in HBH spacetime. Then, the rigorous bound method is used to calculate the fermionic spin-1/2 and spin-3/2 GFs. With the time domain integration method at our disposal, we illustrate the impact of additional parameters on the ringdown waveform of the massless fermionic spin-1/2 and spin-3/2 fields and, in turn, on their quasinormal modes. We then delve into investigating the Hawking spectra and sparsity of the radiation emitted by an HBH. Hairy parameters significantly affect the sparsity of Hawking radiation as well. We observe that the total power emitted by the BH increases both with α and Q but decreases with l0. Our study conclusively shows the significant impact of the additional parameters on important astrophysical phenomena such as quasinormal modes, Hawking spectra, and sparsity. This work has been done in collaboration with Ahmad Al-Badawi, Sohan Kumar Jha .

Study of superradiance phenomena and shadow cast by the Simpson-Visser black hole in a non-commutating environment

We consider non-commutating Simpson-Visser spacetime and study the superradiance phenomena and the shadow cast by the back hole associated with it. We extensively study the different aspects of the black hole associated with the metric endowed with the corrections linked with non-commutative properties of spacetime. We study the superradiance effect, deviation of shape, size of the ergosphere, and the shadow of the black hole in this extended situation and look into their variation taking different values Simpson-Visser parameter ℓ and non-commutative parameter b We have made an attempt to constrain the parameter ℓ using the data available from the Event Horizon Telescope (EHT) collaboration for 87* black hole. Our study reveals that black holes are associated with non-commutative Simpson-Visser spacetime may be a suitable candidate for an astrophysical black hole. This work has been done in collaboration with Sohan Kumar Jha.

Farook Rahaman

Deflection of massive body around wormholes in Einstein–Kalb–Ramond spacetime

It is known that the deflection of massive body around a gravitating body (say, black hole or wormhole) can be used as a test of gravity, like deflection of light (bending of light i.e. gravitational lensing). In this study, we have used the Jacobi metric, which can be obtained from the usual spacetime metric, in order to study the angle of deflection of a massive body around wormholes in Einstein–Kalb–Ramond spacetime, considering two different models of wormholes corresponding to two different expressions of shape and redshift functions. We have used two approaches to our calculation of the angle of deflection, first according to the method proposed by Rindler and Ishak (2007); and second by employing the Gauss–Bonnet theorem. We have also compared the deflection angle obtained using the two approaches for the two wormhole models graphically. For the first model of the wormhole, we observed similar results for greater values of the impact parameter, whereas for the second model of the wormhole, the two approaches produced nearly identical results for smaller values of the impact parameter and larger values of velocity of the massive body. This work has been done in collaboration with A Aziz, T Manna, A Islam, N Pundeer, S Islam .

Traversable wormholes supported by dark matter and monopoles with semiclassical effects

We present a new traversable wormhole explication of Einstein's field equations supported by the prof ile of Einasto Dark Matter densities (Einasto in Trudy Inst Astrofiz Alma-Ata51:87,1965; PTarO36:414,1968;Astron Nachr 291:97, 1969) and global monopole charges along with semiclassical effects in the local universe as the galactic halo. The Einasto DM density profile produces a suitable shape function that meets all the requirements for presenting the wormhole geometries. The Null Energy Condition

(NEC) is violated by the obtained solution with different redshift functions i.e. the Einasto profile representing DM candidate within the wormholes gives the fuel to sustain these wormhole structures in the galactic halo. Moreover, the reported wormhole geometries are getting asymptotically flat and non-flat depending only on the choices of redshift function whereas all the wormhole structures are maintaining their balance of equilibrium under the action of different forces. This work has been done in collaboration with B Samanta, N Sarkar, B Raychaudhuri, B Sen.

Nisha Rani

Gamma rays bursts: a viable cosmological probe?

In this work, our focus is on exploring the potential of current GRB measurements to provide reliable constraints on cosmological model parameters at high redshift. This work is divided into two parts. First, we calibrate the Amati relation in a model-independent way by using Hubble parameter measurements obtained from the differential ages of the galaxies. We further check if the Amati relation parameters evolve with the GRBs' redshift or not, using the data of Old Astrophysical Objects. The results indicate that GRBs do seem to evolve with redshift. In the second part, we test different cosmological models with the calibrated GRB data obtained by using constant and dynamical Amati relation. Our results indicate that the present quality of GRB data is not good enough to put tight constraints on the cosmological parameters. Hence we perform a joint analysis with the combined data of GRBs and Type Ia Supernovae (SNe) and find that this can considerably enhance cosmological constraints in contrast to solely relying on GRBs. This work has been done in collaboration with Darshan Kumar, Deepak Jain, Shobhit Mahajan and Amitabha Mukherjee.

Chayan Ranjit

Cosmological effects on $f(\tilde{R},\tilde{T})$ gravity through a nonstandard theory

This study aims to investigate the impact of dark energy in cosmological scenarios by exploiting $f(\bar{R},\bar{T})$ gravity within the framework of a nonstandard theory, called K-essence theory, where $\bar{R}$ represents the Ricci scalar and $\bar{T}$ denotes the trace of the energy-momentum tensor associated with the K-essence geometry. The Dirac-Born-Infeld (DBI) nonstandard Lagrangian has been employed to generate the emergent gravity metric $\bar{G}\mu\nu$ associated with the K-essence. This metric is distinct from the usual gravitational metric ($g\mu\nu$). It has been shown that under a flat Friedmann-Lemaître-Robertson-Walker (FLRW) background gravitational metric, the modified field equations and the Friedmann equations of the $f(\bar{R},\bar{T})$ gravity are distinct from the usual ones. In order to get the equation of state (EoS) parameter ω, we have solved the Friedmann equations by taking into account the function $f(\bar{R},\bar{T}) \equiv f(\bar{R}) + \lambda\bar{T}$, where λ represents a parameter within the model. We have found a relationship between ω and time for different kinds of $f(\bar{R})$ by treating the kinetic energy of the K-essence scalar field (ϕ^2) as the dark energy density which fluctuates with time. Surprisingly, this result meets the condition of the restriction on (ϕ^2). By presenting graphical representations of the EoS parameter with time, we show that our model is consistent with the data of $SNIa + BAO + H(z)$ within a certain temporal interval. This work has been done in collaboration with Arijit Panda, Saibal Ray, Goutam Manna, Surajit Das,

A supply-chain of coastal biomass incorporating fuzzy deterioration and freshness under dynamic unit price

In this study, a wholesaler-retailer supply chain(SC) of coastal biomass in an imprecise environment is developed incorporating the effect of the freshness of the units on the consumers' demand under promotional cost sharing. Due to the imprecise nature of the rate of deterioration, the deterioration rate and the expiration time of the units are considered fuzzy numbers. As the freshness of the units depends on the expiration time, its nature is also imprecise and decreases with time. So, the seller normally decreases the unit selling price with time to boost the demand for biomass. The demand for the item is influenced by the unit selling price and freshness of the units, and hence its nature is also fuzzy. Due to the impreciseness of the rate of demand and deterioration, the model is mathematically formulated using fuzzy differential equations and fuzzy Riemann integration. The credibility measure of the fuzzy objective(average profit) with respect to a properly defined fuzzy goal is optimized for determining the marketing decision. Also, fuzzy simulation algorithms are presented for determining the said credibility measure. The models are studied in both the non-coordination scenario and the coordination scenario. In the non-coordination scenario, the retailer is the leader and the wholesaler is the follower, i.e., the retailer determines the marketing decision independently, and following the decision of the retailer the wholesaler determines his/her marketing strategy. In the coordination scenario, they make a joint decision for better performance by sharing the promotional cost incurred by the retailer by reducing the selling price to boost the demand. The model is illustrated using a set of hypothetical test data and it is established that the individual profits, as well as the channel profit, improve if the decision is made jointly. In a particular case the model is solved for the rough estimations of some problem parameters and an approach is proposed for the mathematical formulation and decision making. The trust measure on a rough goal is defined for the formulation of the model and a corresponding rough simulation algorithm is proposed for the determination

of the same. As the simulation approaches are used for decision-making in imprecise environments, the basic particle swarm optimization algorithm is slightly modified, implemented, tested, and used for the determination of the marketing decision for the different models. This work has been done in collaboration with Rumpa Sau, and Manas Kumar Maiti.

Shantanu Rastogi

PAH emission features in star-forming regions and late type stars

Mid-infrared emission spectra, obtained from ISO archive, of thirteen astrophysical objects as well as computed spectra of 27 polycyclic aromatic hydrocarbon (PAH) molecules are studied. All the objects show strong aromatic infrared band (AIB) features with variations that correlate with object type. Based on AIB peak positions, the features for IRC 10216, Monoceros R2, and IC 5117 and PN-SwSt1 are classified as type A, B or C for the first time. The AIBs at 6.2, 7.7 and 11.2 microns are used to obtain band intensity ratios for 6.2/7.7 and 11.2/6.2, which respectively indicate PAH size as number of carbon atoms and the ionization conditions of the medium. The smaller value of 6.2/7.7 points towards the presence of large PAH molecules, while higher value of 11.2/6.2 ratio relates to harsh conditions around the object. In general, for star-forming regions, the 6.2/7.7 band ratio obtained is >1 and the 11.2/6.2 ratio is >2, while for late type carbon stars, these values are <1 and <. This indicates that small/medium-sized ionized PAHs are likely in star-forming regions and large PAHs in evolved stars. For each of the 27 plain PAH molecules, the integrated intensity in these bands is obtained from the computed infrared spectra and the band ratios are calculated. The ratio 6.2/7.7 in several computed medium and large sized PAH cations is in the range of observed ratio in most objects, but some molecules show large variations in band ratios, indicating that PAHs possible in interstellar medium could be more complex and with irregular structures. This work has been done in collaboration with Rahul Kumar Anand, and Brijesh Kumar.

Investigating changes in atmospheric aerosols properties over the Indo-Gangetic Plain during different phases of COVID-19-induced lockdowns

Impact of COrona VIrus Diseases 2019 (COVID-19) restrictive measures on aerosol optical depth (AOD) and black carbon (BC) concentration is investigated for the western, central, and eastern Indo-Gangetic Plain (IGP) using satellite-based observations. Due to COVID-19-induced lockdown measures, a noticeable decline in AOD and BC concentrations was observed across the IGP when compared to pre-lockdown period of 2020 and the lockdown concurrent period of 2015-2019. During the total lockdown period, a maximum drop in AOD and BC was observed in the central IGP (26.5 % and 10.1 %), followed by western IGP (24.9% and 5.2%) and eastern IGP (23.2 % and 4.9 %) with respect to the same period of 2015-2019. We have removed seasonal influences on aerosol properties during the COVID-19 lockdown, by taking average seasonal variations during the period of 2015-2019 as reference and projecting the hypothetical AOD and BC for the lockdown period under normal scenario. The difference between the hypothetical AOD and BC (under normal scenario) and the retrieved AOD and BC for the lockdown period is the absolute percentage change in AOD and BC concentration due to the lockdown alone. This elimination of seasonal influence is a novel approach. Central IGP showed an absolute decrease in AOD and BC of 38.5% and 18.2% during the lockdown period followed by western IGP (34.6% and 7.7%) and eastern IGP (25.9% and 11.5%). The observed absolute reduction in AOD, 26-39 %, is significantly higher than the global average reduction in AOD of 2-5%. CALIPSO-derived aerosol sub-types over major location of the western, central, and eastern IGP suggests prevalence of anthropogenic activities during pre- and post-lockdown periods. During the lockdown, IGP was influenced by aerosols from natural sources, with mineral dust and polluted dust in the western and central IGP, and aerosols from marine regions in the eastern IGP. Replenishment of aerosols within the boundary layer were far quicker when compared to total column during post-lockdown. Overall, the study reveals a reduction in anthropogenic emissions during the COVID-19-induced lockdowns, leading to temporary improvements in air quality over the IGP. Our study presents a comprehensive analysis of COVID-19 lockdown impact on aerosols properties over the IGP and highlights unprecedented reductions in AOD (about 40%) and BC (about 20%), due to imposition of lockdown and subsequent cessation of aerosol sources, by removing seasonal influences. This work has been done in collaboration with Prayagraj Singh, Aditya Vaishya.

C.D. Ravikumar

Connections between central intensity ratio and hot gas properties of early-type galaxies

Vinod, K. T. , Baheeja, C. and Ravikumar, C. D.report strong connections between central intensity ratio (CIR) and hot gas properties of Early-type galaxies (ETGs) in the nearby (D < 30Mpc) Universe. We find new strong correlations between (optical) CIR and X-ray gas luminosity ($L_{X,GAS}$) as well as X-ray gas temperature (T_{GAS}). These correlations suggest that higher the central gas temperature lower will be the (central) star formation process in ETGs. Correlations of CIR separately with K-band magnitude and age of the sample galaxies further support suppression of star formation in the central region of ETGs as they grow in mass and age. The systematic and tight variation of

CIR with $L_{X,GAS}$ not only shows its remarkable potential to estimate $L_{X,GAS}$ from simple photometry but also helps in transforming the core-coreless dichotomy into a gradual one.

Understanding the broad-band emission process of 3C 279 through long term spectral analysis

The long term broad-band spectral study of Flat Spectrum Radio Quasars during different flux states has the potential to infer the emission mechanisms and the cause of spectral variations. To scrutinize this, we performed a detailed broad-band spectral analysis of 3C 279 using simultaneous Swift-XRT/UVOT and Fermi-LAT observations spanning from 2008 August to 2022 June. We also supplement this with the simultaneous NuSTAR observations of the source. The optical/UV, X-ray, and γ-ray spectra were individually fitted by a power law to study the long term variation in the flux and the spectral indices. A combined spectral fit of simultaneous optical/UV and X-ray spectra was also performed to obtain the transition energy at which the spectral energy distribution is minimum. The correlation analysis suggests that the long term spectral variations of the source are mainly associated with the variations in the low energy index and the break energy of the broken power-law electron distribution which is responsible for the broad-band emission. The flux distribution of the source represents a lognormal variability while the γ-ray flux distribution showed a clear double lognormal behaviour. The spectral index distributions were again normal except for γ-ray which showed a double-Gaussian behaviour. This indicates that the lognormal variability of the source may be associated with the normal variations in the spectral index. The broad-band spectral fit of the source using synchrotron and inverse Compton processes indicates different emission processes are active at optical/UV, X-ray, and γ-ray energies.

Pramit Rej

Charged strange star model in Tolman–Kuchowicz spacetime in the background of 5D Einstein–Maxwell–Gauss–Bonnet gravity

In this article, we provide a new model of static charged anisotropic fluid sphere made of a charged perfect fluid in the context of 5D Einstein-Maxwell-Gauss-Bonnet (EMGB) gravity theory. To generate exact solutions of the EMGB field equations, we utilize the well-behaved Tolman-Kuchowicz (TK) *ansatz* together with a linear equation of state (EoS) of the form $p_r = \beta\rho - \gamma$, (where β and γ are constants). Here the exterior space-time is described by the EGB Schwarzschild metric. The Gauss-Bonnet Lagrangian term $\mathcal{L}_{GB}$ is coupled with the Einstein-Hilbert action through the coupling constant α. When $\alpha \to 0$, we obtain the general relativity (GR) results. Here we present the solution for the compact star candidate EXO 1785-248 with mass= $(1.3 \pm 0.2)M_{\odot}$; Radius = 10^{+1}_{-1} km. respectively. We analyze the effect of this coupling constant α on the principal characteristics of our model, such as energy density, pressure components, anisotropy factor, sound speed etc. We compare these results with corresponding GR results. Moreover, we studied the hydrostatic equilibrium of the stellar system by using a modified Tolman-Oppenheimer-Volkoff (TOV) equation and the dynamical stability through the critical value of the radial adiabatic index.The mass-radius relationship is also established to determine the compactness factor and surface redshift of our model. In this way, the stellar model obtained here is found to satisfy the elementary physical requirements necessary for a physically viable stellar object. This work has been done in collaboration with Abdelghani Errehymy, and Mohammed Daoud.

Charged strange star coupled to anisotropic dark energy in Tolman–Kuchowicz spacetime

The concept of dark energy can be used as a possible option to prevent the gravitational collapse of compact objects into singularities. It affects the universe on the largest scale, as it is responsible for our universe's accelerated expansion. As a consequence, it seems possible that dark energy will interact with any compact astrophysical stellar object [Phys. Rev. D 103, 084042 (2021)]. In this work, our prime focus is to develop a simplified model of a charged strange star coupled to anisotropic dark energy in Tolman-Kuchowicz spacetime (Tolman, Phys Rev 55:364, 1939; Kuchowicz, Acta Phys Pol 33:541, 1968) within the context of general relativity. To develop our model, here we consider a particular strange star object, Her X-1 with observed values of mass = $(0.85 \pm 0.15)M_{\odot}$ and radius = $8.1^{+0.41}_{-0.41}$ km. respectively. In this context, we initially started with the equation of state (EoS) to model the dark energy, in which the dark energy density is proportional to the isotropic perfect fluid matter-energy density. The unknown constants present in the metric have been calculated by using the Darmois-Israel condition. We perform an in-depth analysis of the stability and force equilibrium of our proposed stellar configuration as well as multiple physical attributes of the model such as metric function, pressure, density, mass-radius relation, and dark energy parameters by varying dark energy coupling parameter α. Thus after a thorough theoretical analysis, we found that our proposed model is free from any singularity and also satisfies all stability criteria to be a stable and physically realistic stellar model. This work has been done in collaboration with Akashdip Karmakar.

Prabir Rudra

Ricci-Cubic Holographic Dark Energy

In this work, we propose the Ricci-cubic holographic dark energy model. The model is inspired by the cubic curvature

invariant formed by the contraction of three Riemann tensors. A combination of Ricci scalar and the cubic invariant is used to describe the infrared cutoff of the holographic dark energy. Such a construction is extremely useful since the evolution does not depend on the past or future features of the universe, but completely on its present features. Moreover, the use of invariants makes the theory more fundamental in nature. We have constructed the model and studied its cosmological features. The analytical solutions of various cosmological parameters such as the density parameter, equation of state parameter, and deceleration parameter are extracted and their behaviour is studied. It is seen that the holographic dark energy model can exhibit all the cosmological epoch, sequentially starting from radiation in the early universe, followed by matter, and finally the dark energy dominated epoch at late times. The equation of state parameter shows that the model can exhibit quintessence nature, phantom-divide crossing, and even phantom nature depending on the choice of parameter spaces.

Gravitational Collapse in Energy-momentum squared gravity: Nature of singularities

In this paper we explore a collapsing scenario in the background of energy-momentum squared gravity (EMSG). EMSG claims to have terms that originate from the quantum gravity effects mimicking loop quantum gravity. As a result the framework admits a bounce at a finite time thus avoiding a singularity. So the question that naturally arises : Is there any realistic chance of formation of a black hole or the quantum gravity effects are strong enough to totally avoid such a pathology? Motivated from this we are interested in studying a gravitational collapse mechanism in the background of EMSG and investigate the fate of such a process. We model the spacetime of a massive star by the Vaidya metric and derive the field equations in EMSG. Then using the equations we go on to study a gravitational collapse mechanism, on two specific models of EMSG with different forms of curvature-matter coupling. The prime objective is to probe the nature of singularity (if formed) as the end state of the collapse. We see that none of the models generically admit the formation of black holes as the end state of collapse, but on the contrary they support the formation of naked singularities. This can be attributed to the quantum fluctuations of the gravitational interactions at the fundamental level.

Sunil Kumar S.

Unraveling the mystery of solvation-dependent fluorescence of fluorescein dianion using computational study

Fluorescein, one of the brightest fluorescent dye molecules, is a widely used fluorophore for various applications from biomedicine to industry. The dianionic form of fluorescein is responsible for its high fluorescence quantum yield. Interestingly, the molecule was found to be nonfluorescent in the gas phase. This characteristic is attributed to the photodetachment process, which out-competes the fluorescence emission in the gas phase. In this work, we show that the calculated vertical and adiabatic detachment energies of fluorescein dianion in the gas and solvent phases account for the drastic differences observed in their fluorescence characteristics. The functional dependence of these detachment energies on the dianions microsolvation was systematically investigated. The performance of different solvent models was also assessed. The higher thermodynamic stability of fluorescein dianion over the monoanion doublet in the solvent phase plays a crucial role in quenching photodetachment and activating the radiative channel with a high fluorescence quantum yield. This work has been done in collaboration with A. Roy, S. Samanta, S. Ray, S. Sunil Kumar, and P. Mondal

A versatile 16-pole ion trap setup for investigating photophysics of biomolecular ions

A linear 16-pole ion trap-based experimental setup has been designed, implemented, and characterized to investigate the photophysics of biomolecules in the gas phase. Electrospray ionization is employed to generate the ions in the gas phase at atmospheric pressure. The voltage configuration on the ion funnel, the ion optic device in the first vacuum interface, is used to control the energy of the ions. A home-built quadrupole mass-filter is utilized for the mass-selection of the ions of interest. A 16-pole ion trap designed and built in-house is implemented for ion trapping. The instrument's versatility and capability are showcased by demonstrating the fragmentation patterns of protonated and deprotonated tryptophan, as well as describing the photodetachment decay of deprotonated indole. This work has been done in collaboration with M. Salvi, N. N. Uma, H. Dinesan, A. Roy.

Sanjay K. Sahay

An Investigation of Two-Step Cascaded CNN for the Detection of Gravitational Wave Signal from Two Different Astronomical Sources

Recently, Convolutional neural network (CNN), a class of deep neural network, has been widely used for processing images and video data. The reason that CNN performs better than the classic neural network on images and video is basically because convolutional layers take advantage of the inherent properties of images. Therefore, in this paper, we propose and investigate two-step a cascaded classification model using CNN for the detection of gravitational wave (GW) signals emitting from the two different heavenly astronomical objects in the noisy time-series data. To build a robust model for the detection of GW waves, we considered

prominent binary black holes (BBH) and binary neutron stars (BNS). In the proposed model, first, we used CNN to know whether in the noisy data stream, the considered GW signal is present or not. While in the second step, we further applied CNN to know that the present GW signal in the stream is BBH or BNS. The analysis shows that the proposed two-step cascaded classification model can detect not only the presence of the signal but also able to distinguish between the type of signal i.e., whether the gravitational wave signal is from BBH or BNS. This work has been done in collaboration with Lokesh Kumar, and Hrishikesh Govindrao Kusneniwar.

Gravitational wave: Generation and detection techniques

In this paper, we review the theoretical basis for generation of gravitational waves and the detection techniques used to detect a gravitational wave. To materialize this goal in a thorough way, we first start with a mathematical background for general relativity from which a clue for gravitational wave was conceived by Einstein. Thereafter, we give the classification scheme of gravitational waves such as (i) continuous gravitational waves, (ii) compact binary inspiral gravitational waves and (iii) stochastic gravitational wave. Necessary mathematical insight into gravitational waves from binaries is also dealt with which follows detection of gravitational waves based on the frequency classification. Ground-based observatories as well as space borne gravitational wave detectors are discussed in a length. We have provided an overview on the inflationary gravitational waves. In connection to data analysis by matched filtering there are a few highlights on the techniques, e.g. (i) random noise, (ii) power spectrum, (iii) shot noise and (iv) Gaussian noise. Optimal detection statistics for a gravitational wave detection is also in the pipeline of the discussion along with detailed necessity of the matched filter and deep learning. This work has been done in collaboration with Saibal Ray, R. Bhattacharya, Abdul Aziz, and Amit Das

Pradyumn Kumar Sahoo

Constraining $f(T, \mathcal{T})$ Gravity with Gravitational Baryogenesis

Gravitational baryogenesis is one of the mechanisms which help us to explore more about our early universe, especially baryon-anti-baryon asymmetry. As we know, modified theories of gravity are very successful in describing the present accelerated scenario of the universe. Therefore, in this letter, we aim to constrain the generalized torsion-based modified theory of gravity, namely, $f(T, \mathcal{T})$ gravity with gravitational baryogenesis, where T, $\mathcal{T}$ are the torsion scalar, trace of the energy-momentum tensor, respectively. For this, we examine how the various Lagrangian forms of $f(T, \mathcal{T})$ affect the baryogenesis. We also impose the constraints on the extra degrees of freedom induced by modified theory with the observational values of the baryon-to-entropy ratio. In addition, we further explore how more generalized gravitational baryogenesis can attribute in a physically viable and consistent way to the cosmologies of the modified theory of gravity. This work has been done in collaboration with Sai Swagat Mishra, Sanjay Mandal.

Cosmological Reconstruction and ΛCDM Universe in $f(Q, C)$ Gravity

Symmetric Teleparallel Gravity allows for the reformulation of gravity in the form of nonmetricity by vanishing the contorsion term in the generic affine connection. Our focus is in investigating a recently proposed extension of this theory in which the Lagrangian has the form $f(Q, C)$ by incorporating the boundary term C. In this work, we first use a reconstruction approach in $f(Q, C)$ gravity that might admit the ΛCDM expansion history. Furthermore, we perform a novel approach for cosmological reconstruction of $f(Q, C)$ gravity in terms of e-folding, and it shows how any FLRW cosmology can arise from a specific $f(Q, C)$ gravity. A variety of instances are provided using this approach in which $f(Q, C)$ gravity is reconstructed to yield the well-known cosmic evolution: ΛCDM era, acceleration/deceleration era which is equivalent to the presence of phantom and non-phantom matter, late-time acceleration with the crossing of phantom-divide line and transient phantom era. This work has been done in collaboration with Gaurav N. Gadbail, Avik De.

Eeshankur Saikia

An innovative tool for automating classification of stellar variability through nonlinear data analytics

Though Classical Cepheids, δ-Scuti, Eclipsing Binary, Long-Period variables, and RRLyraes are abundant in most of the clusters, automating the classification of the objects faces challenges. Since the rate at which the data has been getting accumulated is enormous, this automation of classification is paramount for carrying out appropriate analysis of the objects depending on the class it belongs to. Our results prove that the proposed tool for automating stellar classification not only reduces misclassification by up to 94.79% (in case of classification between multimode subclass of δ-Scuti and Mira subclass of Long-Period variables) but also improves reliability by as high as 78.35% (in case of conventionally misclassified pair of RRab subclass of RRLyrae and Fundamental Mode subclass of Classical Cepheids). Our random forest model has achieved a cross-validation accuracy of 0.88 with conventional statistical parameters coupled with tools of Nonlinear Dynamical Theory. It has achieved the highest precision and recalls for Long-Period variables of the Mira subclass (i.e., 0.99 &

0.99) and the lowest for Eclipsing Binary of subclass contact (i.e., 0.81 & 0.77). A positive improvement in accuracy rate by 7.3% is observed when compared with a model based on a conventional statistical platform. This proves the significance of introducing the proposed tools in devising an automated classification model for stellar variables.

Can cloud images help in predicting geomagnetic storms?

Solar activity and Cosmic Ray particles are known to have an effect on the formation of structural clouds through changes in temperature. With an increase in solar activity, coronal mass ejection increases, leading to an increase in temperature in the Earthâ€™s atmosphere. The change in temperature is related to the change in cloud formation and rainfall distribution, and hence the change in climate pattern. This prompts us to analyse terrestrial cloud images for robust processing of underlying information or patterns. Geometrical exploration of cloud properties using Multi-Fractal Analysis (MFA) is given preference over standard statistical tools for devising an improved weather prediction platform in the future. For the first time, MFA is reported to be used successfully to analyse cloud properties using images obtained from satellites to predict geomagnetic storms.

Biplob Sarkar

Study of Properties of Active Galactic Nuclei and Observational Findings

Active Galaxies Nuclei (AGNs) are some of the most violent sources in the universe. Several ongoing studies are trying to explain the underlying physical processes of enormous energy emission and the particle acceleration to very high energies in the jet. However, ongoing debates remain regarding its unification scheme based on the properties of radio emission and orientation. Here we present a review work that primarily includes a historical overview and discusses various AGN regions from the unification scheme. We have also incorporated some of the current observational statuses by different missions worldwide with some underlying problems and research scope in the study of AGNs. This work has been done in collaboration with Hritwik Bora, Niranjan Gogoi, , Sree Bhattacherjee, and Rupjyoti Gogoi.

Science, Technology and Development: Relationship, Challenges and Opportunity

This chapter gives an idea of how Science and Technology (S&T) are interconnected though they are distinct in their way. Science is a systematic study through observation and experiment that provides a basis for Technology; without Technology, Science is worthless, and similarly, Technology is impossible without Science. However, there are some instances where Technology sustains without deep knowledge of Science. S&T has a significant role in the Development of a nation. Here we are interested in discussing Sustainable Development. In general, S&T in Development offers numerous benefits and is something to be admired, but there are also some unpleasant difficulties brought on by Development's only objective, which is also described here. If we look optimistically, these challenges are also an opportunity for a new field of Research and Development (R&D). The goal of Sustainable Development has shaped Development, which traditionally started with Industrialization. Initially, Development was only related to a nation's economic growth, which led to many unavoidable circumstances in the world. The importance of policies and investments in S&T in leading R&D toward Sustainable Development is briefly examined in the context of India. Wide-ranging opportunities and exposure for the disciplines of Technology, society, economy, and the environment have been made possible by S&T in Development. We conclude that recognizing innovation and progress in space exploration, Information and Communication Technology, or Information Technology, is essential. This work has been done in collaboration with Arbind Pradhan, and Gyan Prakash Bharti.

Geetanjali Sethi

Multifunctional composite materials for electromagnetic interference shielding

Increasing dependence and usage of electronic devices has raised the concern for electromagnetic (EM) shielding. This review article is an overview of ongoing cutting-edge research on electromagnetic shielding materials, their applications, advantages and shortcomings. The article highlights doping of polypyrrole(PPy) with different components to achieve desired properties. The work focusses on methods of achieving desired properties of PPy through doping. We have summarized results of doping it with Graphene, Nickel, MXene, Iron Oxide and CNT to achieve desired properties like better electrical conductivity, flexibility and lighter material, greater tensile strength, biocompatibility, better microwave absorption and better magnetic properties. The review presents compilation of most recent ongoing research in the field of electromagnetic shielding. We have also discussed existing limitations and possible future prospects in the ongoing research. This work has been done in collaboration with Annu Malhotra, Sangeeta Sachdeva, Payal Mehrotra, Yoshit Bargla. et al.

Variable Chaplygin Gas: Constraints from Supernovae, GRB and Gravitational Wave Merger Events

We investigate the cosmological constraints on the Variable Chaplygin gas model from the latest observational data: SCP Union 2.1 compilation dataset of Type Ia supernovae

(SNe Ia), Pantheon sample of SNe Ia, Platinum Sample of Gamma Ray Bursts (GRB) and GWTC-3 of gravitational wave merger events. Variable Chaplygin gas is a model of interacting dark matter and dark energy, which interpolates from a dust-dominated era to a quintessence-dominated era. The Variable Chaplygin gas model is shown to be compatible with Type Ia Supernovae and gravitational merger data. We have obtained tighter constraints on cosmological parameters B_s and n, using the Pantheon sample. By using the Markov chain Monte Carlo (MCMC) method on the Pantheon sample, we obtain B_s=0.108 ± 0.034, n=1.157 ± 0.513 and H_0=70.020 ± 0.407, for GRBs, we obtain B_s=0.20 ± 0.11, n=1.45 ± 1.40 and H_0=70.41 ± 0.67 and on GWTC-3, we obtain B_s=0.130 ± 0.076, n=0.897 ± 1.182 and H_0=69.838 ± 3.007. The combined constraints from the above data sets are B_s=0.11 ± 0.03, n=1.14 ± 0.36 and H_0=70.34 ± 0.61. This work has been done in collaboration with Ashley Chrayaa, Yuvraj Muralichandran.

Aishawnnya Sharma

Variation of temperature and non-thermal velocity with height in fan loops

We study the variation of temperature and non-thermal velocity with height in fan loops. For this purpose, we have used the observations recorded by the Extreme Ultraviolet Imaging Spectrometer (EIS) on board *HINODE*. We have employed the Emission Measure (EM)-loci method to estimate the temperatures of different coronal fan loops and then compute the non-thermal velocities using the obtained temperatures in Si VII 275.35 Å and Fe VIII 185.21 Å lines.The EM-loci analysis provides nearly iso-thermal temperature along the fan loops. We obtain the peak temperatures in the range $\log T[K] = 5.85$–5.95 for fan loops, and the subtraction of thermal broadening gives the non-thermal velocities in the range ≈ 5–15 km s^{-1} and 11–29 km s^{-1} for Si VII 275.35 Å and Fe VIII 185.21 Å, respectively. Our method provides quantitative accuracy in the measurement of non-thermal velocity, which is an important parameter in understanding the dynamics of heating of the solar atmosphere. This work has been done in collaboration with Durgesh Tripathi.

Ranjan Sharma

Electromagnetic extension of Buchdahl bound in $f(R,T)$ gravity

The compactness of a relativistic star provides valuable insight into the star's equation of state (EOS) vis-a-vis the nature of particle interactions under extreme conditions. To get an estimate of the maximum compactness bound in modified gravity, we develop a stellar model in $f(R,T)$ gravity. The modification is assumed to be linear in T, the trace of the energy-momentum tensor. The exterior spacetime of the star is described by the Reissner-Nordström metric metric. The interior solution is obtained by invoking the Buchdahlâ€“Vaidyaâ€“Tikekar ansatz, for the metric potential g_{rr}, which has a clear geometric interpretation. A detailed physical analysis of the model clearly shows physical behaviour that is distinct from general relativity. We find the maximum compactness bound for such a class of compact stars in $f(R,T)$ gravity which is an extension of Buchdahl bound in modified gravity. The estimated upper bound on compactness is also shown to be a generalization of the earlier results obtained within the framework of GR by Giuliani and Rothman. This work has been done in collaboration with Soumik Bhattacharyaa, and Sunil D. Maharaj.

Properties of relativistic star in 5-D Einstein-Gauss-Bonnet gravity

In recent years, there has been a growing interest in stellar modelling in the framework of Einstein-Gauss-Bonnet gravity. In this paper, for a relativistic star in static equilibrium, we invoke the 5 dimensional Einstein-Gauss-Bonnet gravity and solve the system by assuming an anisotropic matter distribution that admits a linear equation of state (EOS). For the assumed matter distribution, we make the EGB field equations tractable by introducing a particular coordinate transformation and closing the system in terms of a single generating function. We solve the system by specifying the generating function and show that the generated solution is regular, well behaved and the energy conditions are satisfied. We fix the model parameters by matching the interior solution to the exterior Boulware-Deser metric, which facilitates physical analysis of the resultant configuration. We analyze the star's gross physical properties, which brings to attention the role of the Gauss-Bonnet coupling parameter α in fine-tuning the values of the matter variables. This work has been done in collaboration with Soumik Bhattacharya, Suntharalingam Thirukkanesh.

Ashutosh Singh

Varying vacuum models with spatial curvature: a dynamical system perspective

We investigate the qualitative cosmic dynamics of varying vacuum models with the non-flat, homogeneous and isotropic background. In these models, the dark matter interacts with the vacuum energy. We utilize the dynamical system technique to explore the existence and stability of fixed points. The existence of radiation and matter dominated decelerating phase of the universe may be explained in these models. The accelerating universe expansion may also be explained due to the existence of an attractor in these models. Further, the numerical solution technique is incorporated to solve the autonomous systems. These solutions are utilized to illustrate the

evolution of cosmographic and statefinder parameters along with the energy conditions. The Milne universe solution exists in the model which is a consequence of spatially curved geometry. The stability criterion of the fixed points reveals that the cosmic history in the considered models may be observationally viable. Furthermore, the strength of interaction terms are constrained using the observational estimates of the cosmographic parameters. This work has been done in collaboration with S. Krishnannair.

Cosmic dynamics of isotropic models with inhomogeneous EoS: a dynamical system perspective

We examine the homogeneous and isotropic models sourced by the fluid having an inhomogenous equation of state (EoS) using qualitative methods. The flat Friedmann-Lemaitre-Robertson-Walker (FLRW) model explains the accelerating universe expansion of the present era having past of decelerating era dominated by radiation and matter. The open FLRW model incorporates the radiation, matter and dark energy dominated era in order with the spatial curvature playing role just before the accelerated universe evolution. The dominating behaviors of radiation, matter and spatial curvature affect the evolution trajectories of the deceleration and effective EoS parameter, which are obtained by the numerical solutions of autonomous system. The model parameters affect the nature of dark energy and therefore the EoS parameter may also lie in the quintessence or phantom regions. The closed FLRW model having constant positive curvature may yield the bouncing and turnaround universe evolution with dark energy-dominated phase at late-times. The application of statefinder diagnostic in the cosmological dynamical systems highlights that the universe may approach the Λ cold dark matter (ΛCDM) universe as a particular case in the future.

Dharm Veer Singh

Shadows and quasinormal modes of the Bardeen black hole in cloud of strings

We investigate the black hole solution of Einsteinâ€™s gravity coupled with non-linear electrodynamics (NED) source in the background of a cloud of strings. We analyze the horizon structure and optical features of the black hole. The photon radius and shadows are obtained as a function of black hole parameters. We observe that the size of the shadow image is bigger than its horizon radius and photon sphere. We also study the quasi-normal modes using WKB formula for this black hole. The dependence of shadow radius and quasi-normal modes on black hole parameters reflects that they are mimicker to each other. This work has been done in collaboration with Bijendra Kumar Vishvakarma, and Sanjay Siwach.

Parameter estimation of the Bardeen-Kerr black hole in cloud of strings using shadow analysis

We consider the rotating generalization of the Bardeen black hole solution in the presence of a cloud of strings (CoS). The parameter space for which the black hole horizon exists is determined. We also study the static limit surface and the ergo-region in the presence of the CoS parameter. We consider photon orbits and obtain the deformation of black hole shadows due to rotation for various values of the CoS parameter. The shadow deformation is used to determine the black hole spin for different values of the black hole parameters. This work has been done in collaboration with Bijendra Kumar Vishvakarma, Sanjay Siwach.

Gyan P. Singh

Cosmic dynamics with late-time constraints on the parametric deceleration parameter model

We investigate the evolution of a flat Friedmann-Lemaitreâ-Robertson-Walker (FLRW) model equipped with the matter content induced by the fluid having equation of state depending on the parametric deceleration parameter. We reconstruct the universe which is composed of the dark energy and the non-relativistic matter. The universe transits from the decelerated phase dominated by the non-relativistic matter into an accelerated phase dominated by the dark energy. We single out the physically reasonable cases by checking the compatibility of the model to the observations. The model parameters are constrained by χ^2 minimization technique. Based on the best fit values of the model parameters, evolution of the equation of state parameter, energy density, cosmographic parameters along with the role of the energy conditions are investigated in detail. The phantom dominated evolution may be realized during the future in reconstructed universe having the present age compatible with the model dependent estimates and the cold dark matter model, subjected to the best fit values of the model parameters. And, the universe may lead to the little-rip. singularity as $z \to -1$ in the remote future. This work has been done in collaboration with Ashwini R. Lalke, and Ashutosh Singh.

Late-time acceleration from ekpyrotic bounce in $f(Q,T)$ gravity

In this paper, we investigate the late-time accelerated universe evolution in a flat, homogeneous and isotropic model in the context of $f(Q,T)$ gravity, where Q and T are non-metricity scalar and trace of energy-momentum tensor, respectively. The scale factor, by construction, yields ekpyrotic contraction era followed by a non-singular bounce. The expanding era of the universe yields late-time dark energy era preceded by matter-dominating decelerating era. The model unifies an ekpyrotic, non-singular bounce

with the present dark energy-dominated epoch. The model parameters in the functional form of $f(Q,T)$ gravity affect the dynamical evolution of the equation of state (EoS) parameter. The theoretical value of EoS parameter is found to be $\omega = -1.0136, -1.0273$ for $n = 0, 1$ respectively, and it lies in range of the estimated value of EoS parameter from the Planck+SNe+BAO observational data. Different aspects of this bouncing model including behavior of geometrical and physical quantities along with energy conditions have been discussed in detail. This work has been done in collaboration Ashwini R. Lalke, and Ashutosh Singh.

Monika Sinha

Fast neutron star cooling in light of PREX-2 experiment

During very early age of neutron stars, the core cools down faster compared to the crust creating a large thermal gradient in the interior of the star. During years, a cooling wave propagates from the core to the crust causing the interior of the star to thermalize. During this duration thermal properties of the core material is of great importance to understand the dynamics of the interior of the star. The heat capacity and thermal conductivity of the core depends on the behaviour of matter inside the core. We investigate these two properties in case of magnetars. Due to presence of large magnetic field, the proton superconductivity is quenched partially inside the magnetars depending upon the comparative values of upper critical field and the strength of the magnetic field present. This produces non-uniformity in the behaviour of matter throughout the star. Moreover, such non-uniformity arises from the variation of nature of the pairing and values of the pairing gap energy. We find that the heat capacity is substantially reduced due to the presence of superfluidity. On the other hand, the thermal conductivity of neutron is enhanced due to proton superconductivity and gets reduced due to neutron superfluidity. Hence, the variation of the thermal properties due to superfluidity in presence of magnetic field is different at different radius inside the star. However, in all the cases the maximum variation is of the order one. This affects the thermal relaxation time of the star and eventually its the thermal evolution. This work has been done in collaboration with Trisha Sarkar, Shalu Yadav.

Fast neutron star cooling in light of PREX-2 experiment

The nuclear symmetry energy and its behaviour with density has been recently evaluated with enhanced value by PREX-2 experiment. This new values enables direct Urca neutrino emission process to be functioning in the dense matter inside neutron stars. With this new outlook we study the cooling rate of canonical mass neutron stars and compare with available observational cooling data. We find most of the isolated neutron star thermal profile is compatible with the cooling of canonical mass star including superfluidity suppression. This work has been done in collaboration with Trisha Sarkar, and Vivek Baruah Thapa.

Parijat Thakur

Further Probe of TTV and Its Cause in the Exoplanetary System Qatar-1 with New TESS Data

Prof. Parijat Thakur with his PhD student Mr. Vineet Kumar Mannaday and other collaborators further explored the cause of transit timing variation (TTV) of hot-Jupiter extra-solar planet Qatar-1b. Qatar-1b is a Jupiter size transiting exoplanet for which the previous study reported variation in the transit arrival times. The line-of-sight acceleration of the system away from the Earth was suggested to be the possible cause of the TTV. However, the actual cause of TTV is still unclear. Since Transiting Exoplanet Survey Satellite (TESS) has observed 67 new transits of Qatar-1b in its multiple sectors, it would be interesting to further look for the cause of the TTV in the Qatar-1 system by considering large number of transit time-data. For this work, they have collected all new TESS transit light curves and determined precise mid-transit times by analyzing them through a uniform procedure. In order increase the base line of transit observations for TTV analysis, 184 precise mid-transit times available in the literature were combined with newly determined mid-transit times. From the timing analysis, they found an indication for increasing orbital period of Qatar-1b that can not be produced due to tidal orbital decay. Since observed period change can be induced due to presence of additional companion in the system, the possibilities of close-in additional body, apsidal precession, and the line-of-sight acceleration of the system are also examined. However, except the line-of-sight acceleration of the system, none of these possibilities were found responsible for the observed TTV. In order to confirm our findings, future radial velocity and transit observations of Qatar-1 system are required.

Probing the Cause of Transit Timing Variation of hot-Jupiter Extra-solar Planet TrES-5b with Ground and Space Based Transit Data

Prof. Parijat Thakur with his PhD student Mr. Vineet Kumar Mannaday and other collaborators analyzed the cause of transit transit timing variation (TTV) of hot-Jupiter extra-solar planet TrES-5b. For this work, they utilized 88 new transit light curves of TrES-5b observed during 2014-2022 using the ground based and space based TESS telescopes. Apart from these, 26 more transit light curves available in literature were also combined with the new light curves to perform the precise timing analysis. A linear ephemeris model fitted to the mid-transit times determined from the above considered transit light curves provides the refine transit ephemeris for orbital period and mid-transit

time to be P =1.4822466 ± 0.000000048 day and T_0 =2456944.768716 ± 0.000064 BJD_{TDB}, respectively. The derived ephemeris are consistent the results available in literature but are estimated with improved precision. Using the above derived ephemeris, they obtained the timing residuals (i.e., O-C) as a function of epoch E. The obtained timing residuals indicate downward departure from linear ephemeris model. To probe the origin of this departure, the possibilities of additional close-in planet, orbital decay, apsidal precession and the line-of-sight acceleration of the system are explored. The frequency analysis suggests that the observed departure from the linear ephemeris model may not be originated due to presence of close-in additional planet in the TrES-5 system. The orbital decay study reports the orbital decay rate of $\dot{P}_q \sim -10.56 \pm 3.25$ ms yr^{-1} for TrES-5b. By assuming that this obtained $\dot{P}_q$ is caused by the tidal dissipation within the host-star, they have estimated the tidal quality factor $Q'_* \sim 3.5 \times 10^4$ for the host-star, which is an order smaller than the lower limit of its theoretically predicted typical range of $10^5 - 10^{10}$. Therefore, the observed departure from linear ephemeris model cannot be explained by the orbital decay scenario. In addition to this, the apsidal precession phenomenon cannot be the possible explanation for observed TTV of TrES-5b as the estimated planetary tidal Love of $k_p = 7.55 \pm 0.14$ corresponding to the observed apsidal precession rate is an unphysical. The line-of-sight acceleration of the system towards the Earth appears to be the most possible explanation for the observed period TTV. This is because the the estimated linear trend of $\dot{\nu} \pm_{RV}$= -0.07 ± 0.02ms^{-1} day^{-1} corresponding to the above observed $\dot{P}_q$ is found to be consistent within 1σ limit of its observational value of $\dot{\nu} \pm_{RV}$ = -0.12 ± 0.20 ms^{-1} day^{-1} available in literature. Since this observed $\dot{\nu} \pm_{RV}$ is found to be statistically less significant, further high-precision radial velocity observations of TrES-5 are required to confirm this possibility.

S. K. Tripathy

Casimir wormhole with GUP correction in extended symmetric teleparallel gravity

Quantum mechanical concept such as the Casimir effect is explored to model traversable wormholes in an extended symmetric teleparallel gravity theory. The minimal length concept leading to the generalized uncertainty principle (GUP) is used to obtain the Casimir energy density. The effect of the GUP correction in the geometrical and physical properties of traversable Casimir wormholes are investigated. It is noted that the GUP correction has a substantial effect on the wormhole geometry and it modifies the energy condition. From a detailed calculation of the exotic matter content of the GUP corrected Casimir wormhole, it is shown that, a minimal amount of exotic matter is sufficient to support the stability of the wormhole. This work has been done in collaboration with A. Sahoo, B. Mishra, Saibal Ray.

Existence of non-exotic traversable wormholes in squared trace extended gravity theory

An extended gravity theory is used to explore the possibility of non-exotic matter traversable wormholes. In the extended gravity theory, additional terms linear and quadratic in the trace of the energy momentum tensor are considered in the Einstein-Hilbert action. Obviously, such an addition leads to violation of the energy-momentum tensor. The model parameters are constrained from the structure of the field equations. Non-exotic matter wormholes tend to satisfy the null energy conditions. We use two different traversable wormhole geometries namely an exponential and a power law shape functions to model the wormholes. From a detailed analysis of the energy conditions, it is found that, the existence of non-exotic matter traversable wormholes is not obvious in the model considered and its possibility may depend on the choice of the wormhole geometry. Also, we found that, non-exotic wormholes are possible within the given squared trace extended gravity theory for a narrow range of the chosen equation of state parameter. This work has been done in collaboration with D. Nayak, B. Mishra, D. Behera and S. K. Sahu.

Sudhaker Upadhyay

Non-perturbative correction on the black hole geometry

In this paper, we use the holographic principle to obtain a modified metric of black holes that reproduces the exponentially corrected entropy. The exponential correction of the black hole entropy comes from nonperturbative corrections. It interprets as a quantum effect which affects black hole thermodynamics especially in the infinitesimal scales. Hence, it may affect black hole stability at the final stage. Then, we study modified thermodynamics due to the non-perturbative corrections and calculate thermodynamics quantities of several non-rotating black holes. This study has been done in collaboration withB. Pourhassan, H. Farahani, F. Kazemian, ˙Izzet Sakall.

Non-perturbative correction to thermodynamics of conformally dressed 3D black hole

We extend the study of corrected thermodynamics for the 3D black holes conformally coupled to scalar field up to non-perturbative level. We calculate the exponential correction to entropy arises due to the microstate counting for quantum states on the boundary. This exponential correction in entropy attributes to the other thermodynamical quantities also. We study the stability and phase transition for this system of black hole under the influence of non-perturbative correction. We also discuss the quantum work associated with exponential corrected entropy. Finally, we justify the results from the view point

of thermodynamic geometry. This study has been done in collaboration with S. Soroushfar, H. Farahani.

Anisul Ain Usmani

Theoretical studies on structural properties and decay modes of $^{284-375}119$ isotopes

Within the axially deformed relativistic mean field with NL3* parametrisation, the different bulk properties like binding energy, quadrupole deformation parameter, separation energies, density profile and shape co-existence for Z = 119 isotopic chain within the mass range $284 \leq A \leq 375$ are computed. Further, a competition between possible decay modes such as $\alpha-$decay, and spontaneous fission (SF) of the isotopic chain of Z = 119 superheavy nuclei under study is systematically analysed within self-consistent relativistic mean field model and a close agreement is noticed among the calculations performed using various semi-empirical formulae and also with the estimations made by finite range droplet model (FRDM) wherever available. Our analysis confirmed that $\alpha-$decay is restricted within the mass range $284 \leq A \leq 375$ and thus being the dominant decay channel in this mass range and there is no possibility of $\beta-$decay for the considered isotopic chain. In addition, we forecasted the $\alpha-$decay chain of fission survival nuclides, i.e. $^{284-296}119$ and found as one α chain from $^{284}119$ and $^{296}119$, 2α chains from $^{285}119$ and $^{295}119$ consistently, 3α chains from $^{286}119$ and $^{294}119$ consistently, 4α chains from $^{287}119$ consistently, six consistent α chains from $^{288-293}119$. A comparative study of SF and $\alpha-$decay half-live computed using the formula of Santhosh et. al. and Coulomb proximity potential model (CPPM), respectively, for the fission surviving isotopic chain reveals that $^{288-293}119$ isotopes exhibit 6α chains followed by SF, $^{295,296}119$ isotopes exhibit 4α chains followed by SF, and the rest of the nuclei show continuous α chains. This study has also established that the alpha half-life values computed using Q_α (RMF) agree with half-life values computed using experimental Q_α values within 1 order difference. Thus, such studies can be of great significance to the experimentalists in very near future for synthesizing the isotopes of Z = 119 superheavy nuclei. This work has been done in collaboration with Asloob A. Rather, M. Ikram, Ishfaq A. Rather, M. Imran, et al.

Jithesh V

Extreme photometric and polarimetric variability of blazar S4 0954+65 at its maximum optical and γ-ray brightness levels

In 2022 the BL Lac object S4 0954+65 underwent a major variability phase, reaching its historical maximum brightness in the optical and γ-ray bands. We present optical photometric and polarimetric data acquired by the Whole Earth Blazar Telescope (WEBT) Collaboration from 2022 April 6 to July 6. Many episodes of unprecedented fast variability were detected, implying an upper limit to the size of the emitting region as low as 10^{-4} parsec. The WEBT data show rapid variability in both the degree and angle of polarization. We analyse different models to explain the polarization behaviour in the framework of a twisting jet model, which assumes that the long-term trend of the flux is produced by variations in the emitting region viewing angle. All the models can reproduce the average trend of the polarization degree, and can account for its general anticorrelation with the flux, but the dispersion of the data requires the presence of intrinsic mechanisms, such as turbulence, shocks, or magnetic reconnection. The WEBT optical data are compared to γ-ray data from the *Fermi* satellite. These are analysed with both fixed and adaptive binning procedures. We show that the strong correlation between optical and γ-ray data without measurable delay assumes different slopes in faint and high brightness states, and this is compatible with a scenario where in faint states we mainly see the imprint of the geometrical effects, while in bright states the synchrotron self-Compton process dominates. This work has been done in collaboration with C M Raiteri, M Villata, M I Carnerero, S S Savchenko, S O Kurtanidze et al.

Flares during eclipses of high-mass X-ray binary systems Vela X-1, 4U 1700-37, and LMC X-4

In eclipsing X-ray binary systems, the direct X-ray emission is blocked by the companion star during the eclipse. We observe only reprocessed emission that contains clues about the environment of the compact object and its chemical composition, ionization levels, etc. We have found flares in some X-ray binaries during their eclipses. The study of eclipse flares provides additional clues regarding the size of the reprocessing region and helps distinguish between different components of the X-ray spectrum observed during the eclipse. In the archival data, we searched for flares during eclipses of high-mass X-ray binaries and found flares in three sources: Vela X-1, LMC X-4, and 4U 1700-37. Comparing spectral properties of the eclipse flare and non-flare data, we found changes in the power-law photon index in all three sources and multiple emission lines in Vela X-1 and 4U 1700-37. The fluxes of prominent emission lines showed a similar increase as the overall X-ray flux during the eclipse flare, suggesting the lines originate in the binary environment and not in the interstellar medium. We also observed a soft excess in 4U 1700-37 that remains unchanged during both eclipse flare and non-flare states. Our analysis suggests that this emission originates from the extremely thin shell of the stellar wind surrounding the photosphere of its companion star. The detection of short (100-200 seconds) count-rate doubling timescale in 4U 1700-37 and LMC X-4 indicates that the eclipse reprocessing occurs in a region larger than, but comparable to the size of the companion star. This work

has been done in collaboration with Ketan Rikame, Biswajit Paul, Rahul Sharma, and K T Paul.

Murli M. Verma

Scalar modes of polarization and speed of gravitational waves in $f(R)$ gravity

We explore the gravitational waves (GWs) within the framework of the $f(R)$ gravity model represented by $f(R) = \frac{R^{1+\delta}}{R_c^{\delta}}$ in the weak field approximation. In this scenario, gravitational waves exhibit an additional polarization mode beyond the standard transverse-traceless (TT) tensor modes. We show that the polarization characteristics of these waves are connected to the scalaron mass and the effective potential derived from the function $f(R)$. Furthermore, the study of the speed of gravitational waves (c_g) within the Horndeski theory, particularly using the $f(R)$ model, reveals an intriguing feature about the equality of the speed of gravitational waves to that that of electromagnetic waves. This equivalence arises due to the modification introduced in the Ricci scalar within the $f(R)$ model. This work has been done in collaboration with Utkal Keshari Dash, Bal Krishna Yadav.

Probing massive gravitons in $f(R)$ with lensed gravitational waves

We investigate the novel features of gravitational wave solutions in $f(R)$ gravity under proper gauge considerations in the shifted Ricci scalar background curvature ($R^{1+\epsilon}$). The solution is further explored to study the modified dispersion relations for massive modes at local scales and to derive constraints on ϵ. Our analysis yields new insights as we scrutinize these dispersion effects on the polarization (modified Newman-Penrose content) and lensing properties of gravitational waves. It is discovered that the existing longitudinal scalar mode, and transverse breathing scalar mode are both independent of the mass parameter for $\epsilon << 1$. Further, by analysing the lensing amplification factor for the point mass lens model, we show that lensing of gravitational wave is highly sensitive to these dispersion effects in the milli-Hertz frequency (wave optics regime). It is expected that ultra-light modes, having mass about $O(10^{-15})$ eV for $\epsilon << 1 (\approx 10^{-7})$ lensed by $(10^3 \leq M_{Lens} \leq 10^6) M_{\odot}$ compact objects are likely to be detected by the advanced gravitational wave space-borne detectors, particularly within LISA's (The Laser Interferometer Space Antenna) sensitivity band. This work has been done in collaboration with Vipin Kumar Sharma, Sreekanth Harikumar, Margherita Grespan, Marek Biesiada.

ICARD Department of Physics, Aliah University, Kolkata
Activities from 1st April 2023 to 31st March 2024

Coordinator:
Professor Md. Mehedi Kalam

Areas of Research:

General Relativity, Theoretical Astrophysics, Compact stars, Dark matter, Alternative Theory of Gravity, Wormhole Physics, Cosmology

The Department of Physics, Aliah University, started functioning as a host of ICARD on and from 14 September 2022 after receiving approval from the competent authority. The Department has enhanced its Astrophysics program, introducing General Relativity, Astrophysics, and Cosmology courses in the new CBCS curricula. This shift offers M.Sc. students a comprehensive 12-credit course alongside a 4-credit project in Astrophysics and Cosmology, starting from the 2022-23 academic session. Prof. Md. Mehedi Kalam coordinates ICARD, supported by Prof. Debades Bandopadhyay (Honorary Visiting Professor and Former Head Astro-particle Physics Division, SINP) and Dr. Sajahan Molla (a visiting associate of IUCAA), other associates of nearby institutions along with the research scholars of Astrophysics group are among others. The involvement of experienced professionals and active members from neighbouring institutions enriches the research environment. This transition has seen the enrollment of 17 students in 2022-23 and 14 in 2023-24, reflecting a growing interest in these specialised fields

Research work done in ICARD

(Activities from 01 April 2023 to 31 March 2024)

The members associated with ICARD, Aliah University, have worked on different issues related to Astrophysics and Cosmology. Together with other associates and members, we consider an exotic matter source with a nonlinear Equation of state (EoS) and a minimally coupled scalar field with two different potentials that produce a closed inflationary emergent universe in the relativistic context. Also, we have computed quasi-normal modes of Ayon-Beato Garcia (ABG) Regular Black Holes (which have a non-linear electrodynamical source) using the WKB methods and AIM. A comparison has been made between the spectrum of QNMs calculated by both methods. We analyse how the spectrum of QNMs depends on the black hole parameters, multipole number and overtone number and establish that the ABG black hole is stable against the scalar field.

Also, we construct a traversable static Lorentzian wormhole in the effective scenario of Loop Quantum Cosmology (LQC), where the field equations are modified due to the ultraviolet (UV) corrections introduced at large space-time curvatures. A stable wormhole can be constructed in an effective scenario without violating the null energy condition (NEC) by physical matter at the throat. The NEC is effectively violated due to the corrections in the field equations from LQC, resolving the Weyl curvature singularity at the throat. However, the physical matter violates the strong energy condition (SEC), suggesting the interesting possibility that dark energy can be harnessed into a wormhole. A possible explanation for this is the presence of inherent pressure isotropy in the UV-corrected field equations (discussed and compared to braneworld wormholes in the discussion). No additional exotic ingredient (violating NEC) is required, avoiding quantum instabilities. The tidal forces at the throat do not diverge, and the throat is found to be stable. The wormhole features an attractive geometry. LQC can resolve both the types of curvature singularities appearing at the black hole centre and wormhole throat without exotic matter.

In another article, we explored the possibility of constructing a traversable wormhole on the Shtanov-Sahni braneworld with a time-like extra dimension. We find that the Weyl curvature singularity at the throat of the wormhole can be removed with physical matter satisfying the NEC $\rho + p \geq 0$, even in the absence of any effective Λ-term or any charge source on the brane. (The NEC is violated by the effective matter description on the brane arising due to effects of higher dimensional gravity.) Besides satisfying NEC, the matter constituting the wormhole also satisfies the Strong Energy Condition (SEC), $\rho + 3p \geq 0$, leading to the interesting possibility that normal matter on the brane may be harnessed into a wormhole. Incidentally, these conditions must also be satisfied to realise a non-singular bounce and cyclic cosmology on the brane where both past and future singularities can be averted. Thus, such a cyclic universe on the brane, constituted of normal matter, can naturally contain wormholes. The wormhole shape function on the brane with a time-like extra dimension represents the tubular structure of the wormhole spreading out at large radial distances much better than in wormholes constructed in a braneworld with a spacelike extra dimension and have considerably lower mass, resulting in minimisation of the amount of matter required to construct a wormhole. Wormholes in the Shtanov-Sahni (SS) braneworld also have sufficiently low tidal forces, facilitating traversability. Additionally, they are found to be stable and exhibit a repulsive geometry.

Colloquia/Seminars organised by ICARD

(Activities from 01 April 2023 to 31 March 2024

Colloquium lecture delivered by Dr Nazma Islam, Assistant Research Scientist, NASA Goddard Space Flight Center Greenbelt, USA, on Friday, 09 February 2024, at 2.30 p.m. at the Seminar Room, Department of Physics, Aliah University, New Town campus.
Title of the talk: Exploring the Hot and the Energetic Universe.

Outreach programme organised by ICARD

(Activities from 01 April 2023 to 31 March 2024):

We organised a one-day public outreach programme on astronomy and astrophysics for the students of Baruipur High School, P.O.+P.S.-Baruipur, Dist.- South 24 Parganas, West Bengal, on 08 January 2024, at noon.

Speakers:

1. Prof. Prabir Kr. Haldar, Cooch Behar Panchanan Barma University, Cooch Behar, West Bengal.
   Topic: Recent Advances in Astroparticle Physics.

2. Prof. Md. Mehedi Kalam, Coordinator, ICARD, Aliah University, Kolkata
   Topic: Introduction to Einstein's Theory of Relativity.

Publications using ICARD facilitie

(Activities from 01 April 2023 to 31 March 2024)

The members of ICARD, Aliah University have published articles in the following journals:

1. Non-singular flat universes in braneworld and loop quantum cosmology by R Sengupta, BC Paul, M Kalam, P Paul, A Aich, The European Physical Journal Plus 138 (10), 1-16 (2023), https://doi.org/10.1140/epjp/s13360-023-04541-w

2. Lorentzian wormhole in the framework of loop quantum cosmology by Rikpratik Sengupta, Shounak Ghosh and Mehedi Kalam The European Physical Journal C 83 (9), 830 (2023), https://doi.org/10.1140/epjc/s10052-023-12002-y

3. Traversable Lorentzian wormhole on the Shtanov-Sahni braneworld with matter obeying the energy conditions by Rikpratik Sengupta, Shounak Ghosh and Mehedi Kalam, Journal of Cosmology and Astroparticle Physics 09, 018 (2023), https://doi.org/10.1088/1475-7516/2023/09/018

4. Quasi-normal modes of Ayon–Beato Garcia regular black holes for scalar field by Masum Murshid, Farook Rahaman and Mehedi Kalam, Indian J.Phys. 97, no. 1, 295-305 (2023), https://doi.org/10.1007/s12648-022-02374-4

Honours/distinctions/awards, etc.

Prof. Mehedi Kalam, Coordinator, ICARD, Aliah University, has been awarded Life Membership of the Astronomical Society of India (ASI).

Colloquium lecture delivered by Dr Nazma Islam, Assistant Research Scientist, NASA Goddard Space Flight Center Greenbelt, USA, on Friday, 09 February 2024, at 2.30 p.m. at the Seminar Room, Department of Physics, Aliah University, New Town campus.

Public Outreach Programme

ICARD, Aliah University organised a one-day public outreach programme on Astronomy and Astrophysics for Baruipur High School students, P.O.+P.S.-Baruipur, Dist.- South 24 Parganas, West Bengal, on 08 January 2024, from noon onwards.

Prof. Prabir Kr. Haldar, Professor, Cooch Behar Panchanan Barma University, Cooch Behar, W.B., delivering his lecture.

Prof. Mehedi Kalam, Coordinator, ICARD, Aliah University, was felicitated by the Head Master, Baruipur High School, Baruipur.

The audience of the one-day public outreach programme on Astronomy and Astrophysics Baruipur High School students, Baripur, 24 Pgs(S), West Bengal on 08 January 2024

ICARD- Department of Applied Mathematics, University of Calcutta (Activities from 01 April 2023 to 31 March 2024)

Coordinator:
Asis Kumar Chattopadhyay

Areas of Research

In the period under review, the main focus of the research work was on the investigation of the effect of bars on the properties of spiral galaxies, Clustering of eclipsing binary light curves, Exploration of the origin of galactic and extragalactic star clusters, Completeness study on the astronomical sample, Statistical data analysis related to astronomical objects etc. Some large-scale simulation studies have been carried out. Some scholars and faculty members of different colleges and universities in and around Kolkata are involved in using mathematical and statistical software and developing computer programs for the appropriate analysis of astronomical data.

Research work

(Activities from 01 April 2023 to 31 March 2024)

Subjective classification of spiral galaxies is not sufficient for studying the effect of bars on their physical characteristics. In reality, the problem is to comprehend the complex correlations in a multivariate parametric space. Multivariate tools are the best ones for understanding this complex correlation. In this work, an objective classification of a large set (26,089) of spiral galaxies was compiled as a value-added galaxy catalogue from the SDSS DR 15 virtual data archive. For dimensionality reduction, Independent Component Analysis is performed to determine a set of Independent Components that are linear combinations of 48 observed features

(ionised lines, Lick indices, photometric and morphological properties). Subsequently, a K-means cluster analysis is carried out based on the 14 best chosen Independent Components to obtain 12 distinct homogeneous groups of spiral galaxies. Amongst these, 3 groups are the oldest ones, while 5 groups fall in the medium-aged category, 2 groups consist of only unbarred spirals, 1 group is the youngest one, and the remaining one is an outlier.

There are clear indications of recurrent bar formation phenomena in many groups, consistent with a few previous simulation works. To study the robustness of the clusters with respect to the method of clustering, a second method of clustering by Gaussian Mixture. In another work, we revisit the problem of clustering 1318 new variable stars found in the Milky Way. Our recent work distinguishes these stars based on their light curves which are univariate series of brightness from the stars observed at discrete time points. This work proposes a new approach to look at these discrete series as continuous curves over time by transforming them into functional data. Then, functional principal component analysis is performed using these functional light curves. Clustering based on the significant functional principal components reveals two distinct groups of eclipsing binaries with consistency and superiority compared to our previous results. This method is established as a new powerful light curve-based classifier, where implementing a simple clustering algorithm is effective enough to uncover the true clusters based merely on the first few relevant functional principal components. Simultaneously, we discard the noise from the data study involving the higher-order functional principal components. Thus, the suggested method is very useful for clustering big light curve data sets, verified by our simulation study.

Another study examines the effect of dark matter halos on the orbital and escape dynamics of stars in the central region of barred galaxies. A three-dimensional gravitational model with a central bulge, bar, disc, and dark matter halo (or simply dark halo) has been set up and analysed from the viewpoint of escape in open Hamiltonian systems. Additionally, this model has been examined separately for the dark halo profiles, oblate and NFW. In both circumstances, an escape mechanism, which corresponds to the bar ends, has been identified near the saddle points of the phase space. The escaping motion of stars is seen using orbital maps and Poincare´e surface section maps generated in various phase planes. Finally, the relationship between chaos and dark halo parameters such as mass, size, circular velocity, and nature has been studied. Our findings suggest that oblate dark halos are preferred over NFW dark halos for justifying the formation of full-fledged spiral arms and extended distribution of dark halos in giant spiral galaxies with supermassive black holes (SMBHs) at their centers. Again, the oblate dark halos will justify the emergence of less prominent or poor spiral arms and the core-dominated distribution of dark halos in dwarf and LSB galaxies in the absence of central SMBHs. On the other hand, extreme central baryonic feedback is required for the NFW halos to generate spiral patterns and such dark halos should be preferred for galaxies with extremely energetic centers.

Publications using ICARD facilities

(Activities from 01 April 2023 to 31 March 2024)

1. Dependence of Star formation rate on different properties of molecular clouds, Ashok Mondal and Tanuka Chattopadhyay, New Astronomy, 2024, 108. https://doi.org/10.1016/j.newast.2023.102182

2. Investigation of the effect of bars on the properties of spiral galaxies: a multivariate statistical analysis, Prasenjit Banerjee, Tanuka Chattopadhyay and Asis Kumar Chattopadhyay, Communications in Statistics- Simulation and Computation, 2024, 53(3), 1216-1246 https://doi.org/10.1080/03610918.2022.2039198

3. A new approach to Astronomical data analysis based on multiple variables, Prasenjit Banerjee, Asis Kumar Chattopadhyay and Soumita Modak, Advances in Astronomy, 2023, Article ID 8682054. https://doi.org/10.1155/2023/8682054

4. Star formation histories of dwarf and giant galaxies with different supernovae-driven outflows: NGC 2403, NGC 628, Suparna Sau, Tanuka Chattopadhyay and Pratap Ray, New Astronomy., 2023, 100. https://doi.org/10.1016/j.newast.2022.101992

5. Effect of dark matter holes on barred galaxies' orbital and escape dynamics, Debasish Mondal and Tanuka Chattopadhyay, The European Physical Journal-Plus, 2023, 138, 1144. https://doi.org/10.1140/epjp/s13360-023-04715-6

6. Comparison among different clustering and classification techniques: Astronomical data-dependent study, Prasenjit Banerjee, Tanuka Chattopadhyay and Asis Kumar Chattopadhyay, New Astronomy, 2023, 100. https://doi.org/10.1016/j.newast.2022.101973

Lectures organised by the ICARD CentreD

1. Dipankar Banerjee: Variability of our nearest star, the Sun and its impact, M.K. Dasgupta Birth Centenary Celebration, Rajabazar Science College, University of Calcutta, September 01, 2023.

2. Ajit Kembhavi: The James Webb Space Telescope, M.K. Dasgupta Birth Centenary Celebration, Rajabazar Science College, University of Calcutta, September 01, 2023.

3. Tanuka Chattopadhyay: Clustering & Classification of Galaxies: A Multivariate Data Base Approach, M.K. Dasgupta Birth Centenary Celebration, Rajabazar Science College, University of Calcutta, September 01, 2023.

Token of Honour received by Prof. Tanuka Chattopadhyay for delivering the M.K. Dasgupta birth centenary celebration lecture at the Meghnad Saha Auditorium of the University of Calcutta on 01 September 2023.

Token of Honour received by Prof. Ajit Kembhavi for delivering the M.K. Dasgupta birth centenary celebration lecture at the Meghnad Saha Auditorium of the University of Calcutta on 01 September 2023.

ICARD- Department of Physics and Electronics, CHRIST University, Bangalore. (Activities from 01 April 2023 to 31 March 2024)

Coordinator:
Professor Shivappa B. Gudennavar

Areas of Research

Stellar Physics; High-Energy Astrophysics - X-ray Astronomy; Cosmology - Dark Matter and Dark Energy; Extragalactic Astronomy; Astronomical Instrumentation and Radio Astronomy; Interstellar Medium.

Research Work and Collaborations

Faculty members, PhD students and post-docs of the Department are involved in collaborative research work with IUCAA, IIA, RRI and TIFR faculty members through joint supervision and research projects.

Conference organised by the Department PhD scholars:

Young Astronomers' Meet (YAM) 2024 was held at CHRIST University from 06-09 March 2024.

Publications:

The Department's faculty members have published about twenty articles during the reporting period in the abovementioned areas. These are all the outcomes of funded projects and collaborations by the faculty members.

Talks delivered/organised.

All the faculty members of the Department working in Astronomy have delivered invited talks at the regional and state-level meetings. The Department has also organised regularly the weekly Guest Lectures and Colloquia on recent developments in Astronomy and Astrophysics.

ICARD- Department of Physics, Cooch Behar Panchanan Barma University (CBPBU), West Bengal (Activities from 01 April 2023 to 31 March 2024)

Coordinator:
Dr Ranjan Sharma

Areas of Research

Primary areas: Astro-particle physics and Cosmology.

Thrust areas: Studies of compact stars; gravitational collapse, dark matter and dark energy, tidal effects in extreme gravity, studies of higher-derivative and extended theories of gravity. through BAO scales; Kalita, S. & Rabha, C., The European Physical Journal C, 83 (7), 671 (2023) (27th July 2023).

Workshops/schools organised

ICARD, CBPBU organised an international seminar, "*Physics in curved spacetime*", in hybrid mode on 07 July 2023. The seminar was attended by more than 75 participants from Spain, South Africa, Sri Lanka, and UAE, as well as research scholars, students, and faculty members from different provinces of India. Prof. Luis Herrera, Universidad de Salamanca, Spain; Dr Arunava Bhadra, High Energy and Cosmic Ray Research Centre, University of North Bengal; Dr Koushik Chakraborty, Government College of Education, Burdwan, West Bengal; Prof. Megandhren Govender, Durban University of Technology, Durban, South Africa participated in the seminar as invited speakers. Selected research scholars also presented their research articles.

A workshop titled "*Gravitation: Theory and Observation*" was held at the IUCAA Centre for Astronomy Research and Development (ICARD), Department of Physics, Cooch Behar Panchanan Barma University (CBPBU) on 03 January 2024. Prof. Kanak Saha, IUCAA, Dr Arunava Bhadra, High Energy and Cosmic Ray Research Centre, University of North Bengal and Dr Tamal Sarkar, High Energy and Cosmic Ray Research Centre, University of North Bengal participated as resource persons at the workshop. The speakers discussed various aspects of current research initiatives in astrophysics and cosmology. The main thrust of the workshop was to provide hands-on training on SciLab in astronomy. The workshop was a huge success in terms of the active participation of more than eighty participants (post-graduate students, research scholars and faculty members) from nearby colleges and universities. The workshop was coordinated by Dr Ranjan Sharma, Coordinator, ICARD (CBPBU) and Prof. Kanak Saha, IUCAA, Pune.

Publications using ICARD facilities

1. Core-envelope model of an anisotropic strange star with density-dependent Bag(B) parameter, B. Das, K. B. Goswami, P. K. Chattopadhyay, Ranjan Sharma, Indian J of Phys., 2023; https://doi.org/10.1007/s12648-023-02586.

2. An insight on the origin of half-metallicity of new equi-atomic quaternary Heusler alloys PtRuTiZ (Z=Al/Si):GGA and GGA+U approaches, Kunal Labar, A. Shankar, M. Das and Ranjan Sharma, Computational Materials Science, 220 (2023) 112039.

3. Properties of relativistic star in 5-D Einstein-Gauss-Bonnet gravity, Soumik Bhattacharya, Suntharalingam Thirukkanesh and Ranjan Sharma, Mod. Phys. Lett. A 38 (2023) 2350018.

4. Stiffness, complexity, cracking and stability of relativistic compact stars, Ranjan Sharma and Satarupa Barman, Acta Phys. Polon Supp 16 (2023), 6,7.

5. A physically viable model for a compact star and its compactness bound, S. Thirukkanesh, Arpita Ghosh and Ranjan Sharma, Eur. Phys. J. Plus, (2023) 138:588

6. Critical compactness bound of a class of compact stars, Satarupa Barman and Ranjan Sharma, Gen. Relativ. Grav. (2023)55:99.

7. Electromagnetic extension of Buchdahl bound in f(R,T) gravity; Soumik Bhattacharya, Ranjan Sharma and Sunil D. Maharaj, Eur. Phys. J C (2024)84(1),64.

8. Impact of spacetime curvature on the physical behaviour of Vaidya and Tikekar (VT) type anisotropic compact objects, Lipi Baskey, Shyam Das, Ranjan Sharma and Farook Rahaman, New Astronomy (2024); 108, 102164.

9. Compactness bound of Buchdahl-Vaidya-Tikekar anisotropic star in D ≥ 4-dimensional spacetime, Samstuti Chanda and Ranjan Sharma, Gen. Relativ. Grav. (2024) 56:41.

10. A. Hakim, K. B. Goswami and P. K. Chattopadhyay, Strange Quark Mass (m_s) dependent model of anisotropic Strange Quark Star, Chin. Phys. C (2023) 47(9), 095103.

11. D. Bhattacharjee and P. K. Chattopadhyay, Stable charged gravastar model in cylindrically symmetric space-time, Physica Scripta (2023) 98, 085013.

12. A. Saha, K. B. Goswami, R. Roy and P. K. Chattopadhyay, Maximum mass of charged strange quark star in presence of Strange Quark Mass (m_s), Physica Scripta (2023) 98, 105012.

13. K. B. Goswami, A. Saha, P. K. Chattopadhyay and S. Karmakar, New mass limit of a strange star admitting a colour flavour locked equation of state, Eur. Phys. J. C (2023). 83, 1038 (2023).

14. B. Das, K. B. Goswami, A. Saha and P. K. Chattopadhyay, Anisotropic strange stars and its maximum mass in Finch-

Skea geometry in dimensions D ≥ 4, Physica Scripta (2023) 98, 125004.

15. D. Bhattacharjee, P. K. Chattopadhyay and B. C. Paul, New gravastar model in generalised cylindrically symmetric space-time and prediction of mass limit, Phys. Dark Univ. (2024) 43, 101411.

16. D. Bhattacharjee and P. K. Chattopadhyay, Maximum mass of an anisotropic compact object admitting the modified Chaplygin equation of state in Buchdahl-I metric, Eur. Phys. J. C (2024) 84, 77.

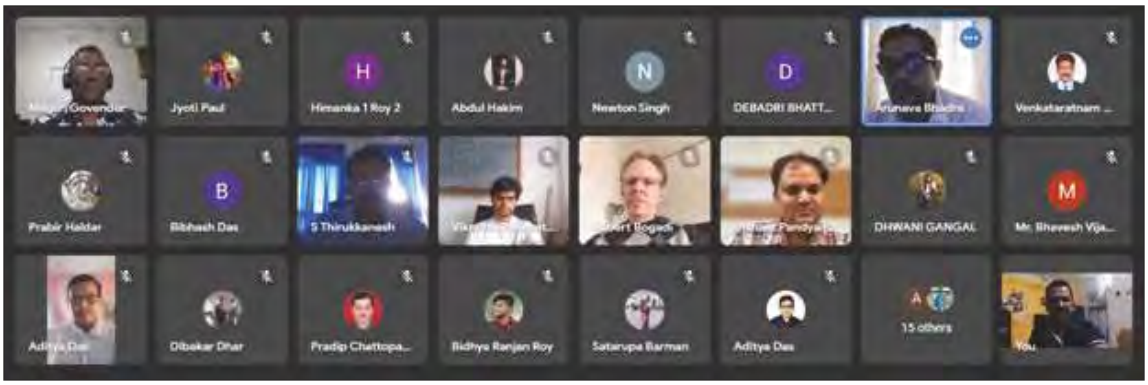
17. S. Sarkar, D. Bhattacharjee, K. B. Goswami, and P. K. Chattopadhyay, New class of anisotropic charged strange quark star in Durgapal IV metric and its maximum mass, Astrophys. Space Sci. (2024) 369, 19.

18. B. Das, K. B. Goswami, A. Saha and P. K. Chattopadhyay, A comparative study on the maximum mass and radius of compact stars from Heintzmann geometry and the TOV approach, Int. J. Geom. Methods Mod. Phys. (2024), DOI: http://doi.org/10.1142/S0219887824501792).

Outreach programmes, including public lectures/sky watch arranged by ICARD:

Prof. Kanak Saha, IUCAA, continues to serve as a Visiting Professor in the Department of Physics, CBPBU

A workshop titled "Gravitation: Theory and Observation" was held at ICARD, CBPBU, on 03 January 2024



A glimpse of the international hybrid seminar "Physics in curved spacetime" organised by the ICARD, CBPBU on 07 July 2023

ICARD - Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi (Activities from 01 April 2023 to 31 March 2024)

Coordinator:
Professor Sushant G. Ghosh

Areas of research:

Cosmology: The Cosmology group is currently actively involved in the issues relates to Cosmological Tensions, e.g the Hubble Tension, S_{8} tension and anomalies in JWST observations for abundances of massive galaxies at high redshifts compared to concordance LCDM model.

Black Hole Shadow and Event Horizon Telescope (EHT) Results: Research in this area centres on understanding theoretical predictions of black hole shadows and comparing them with EHT observational data. Constraints derived from EHT results on deviation parameters offer crucial insights into the validity of black hole and gravity theories.

Gravitational Lensing by Black Holes: Extensive studies explore gravitational lensing in black hole contexts, aiding in inferring black hole properties such as mass, spin, and accretion disk structure. This phenomenon also serves as a tool to probe dark matter and test alternative gravity theories.

Black Hole Thermodynamics: Interest in black hole thermodynamics spans entropy, temperature, and evaporation processes, with recent advances shedding light on entropy behaviour in diverse gravitational theories. These findings impact fundamental physics, including the holographic principle and quantum spacetime nature.

Quasinormal Modes (QNMs): QNMs are pivotal in understanding black hole stability, structure, and interactions with matter and gravitational waves. Ongoing research refines QNM calculations for various black hole types and explores their connections with broader aspects of black hole physics.

Research Work and Collaborations

1. We have proposed a model with ADS behaviour in the Dark Energy Sector, an interesting model for resolving the Hubble tension. Subsequently, we study the abundance of high redshift galaxies in such modes in light of JWST observations. We also studied the forecast of such models for post-ionisation 21cm signals in future SKA-Mid observations.

2. We have also studied the role of GRB observations in the context of cosmological tensions due to low-redshift and CMB observations. We propose a technique using EHT observables to estimate parameters of SMBHs described by the Kerr metric, explicitly accounting for measurement uncertainties. Modelling Kerr–Newman and three rotating regular spacetimes for M87* and Sgr A*, we estimate charge parameters and spin. Our method aligns with existing formalisms and applies to general, non-circular shadow shapes.

3. We also investigate gravitational lensing in the strong deflection regime by loop quantum gravity (LQG)-motivated rotating black hole (LMRBH) metrics, characterised by parameters l, mass M, and rotation a. Using SMBHs Sgr A* and M87* as lenses, we compare LMRBH signatures with Kerr black holes. For Sgr A*, the angular position θ_{∞} ranges from 16.4 to 39.8 μas, and for M87* from 12.33 to 29.9 μas. Angular separation s ranges from 0.008 to 0.376 μas for Sgr A* and from 0.006 to 0.282 μas for M87*. Deviations in observables $\Delta \theta_{\infty}$ and Δs for LMRBH ($a=0.80,l=2.0$) from Kerr black holes can reach up to 10.22 μas and 0.241 μas for Sgr A*, and 7.683 μas and 0.181 μas for M87*. Relative magnitude r_{mag} ranges from 0.047 to 1.54. EHT results for Sgr A* impose stricter limits on LMRBH parameter space than those for M87*.

4. We analysed the restricted phase space thermodynamics (RPST) of Kerr-Sen-AdS black holes with the central charge C and its conjugate chemical potential μ but excluded the familiar PdV term in the first law of black hole thermodynamics. That gives rise to a new perspective on the thermodynamics of black holes. We investigate the first law and the corresponding Euler formula using the scaling properties. Such formalism has its beauty; for example, the mass is considered to be a homogeneous function of the extensive variables in the first order. In contrast, the intensive variables are of zeroth order. Because of the complicated expressions of the metric, we numerically calculate the critical values of the thermodynamic quantities. We find the phase transition behaviour of the free energy and other thermodynamic conjugate variables that appear in the first law.

5. We analysed the restricted phase space thermodynamics (RPST) of Kerr-Sen-AdS black holes, focusing on the central charge C and its conjugate chemical potential μ, excluding the PdV term. This provides a novel perspective on black hole thermodynamics. By examining scaling properties, we derive the first law and Euler formula, treating mass as a homogeneous function of extensive variables of the first order. In contrast, intensive variables are of zeroth order. Due to complex metric expressions, we numerically calculate critical thermodynamic values, revealing phase transition behaviour in free energy and other thermodynamic variables.

6. Considering the cosmological constant as the positive pressure of the system and volume as its conjugate variable, we analyse the thermodynamics of various black holes in the extended phase space. Owing to the deviation parameter from the modified theories, we analyse the Hawking temperature, entropy and specific heat. We also investigate the relationship between the photon sphere radius and the phase transition AdS black holes. We can regard both the changes of photon sphere radius and impact parameter before and after phase transition as the order parameter; their critical exponents near the critical point are equal to the same value 1/2, just like ordinary thermal systems. These indicate that a universal relation of gravity may exist near the crucial point in a black hole thermodynamic system.

Workshops/schools organised

1. Indo-South Africa Workshop on Astrophysics September 27-29, 2023.
2. National Science Day February 28, 2024
   - Poster Display with Explanation by PhD scholars
   - Talks by Eminent Speakers
3. Special Lecture Series on Cosmology and Astrophysics. The inaugural by Prof M Sami, Director, CCSP], SGT University -February 20, 2024, at 3:30 pm

Publications using ICARD facilities

The publications are included under 'Publications by Visiting Associates'.

Outreach programmes, including public lectures/sky watch arranged by ICARD

1. National Science Day February 28, 2024
2. Poster Display with Explanation by PhD scholars - February 28, 2024

Honours/distinctions/awards, etc.
Prof Anjan Sen is elected the General Secretary of IAGRG.

ICARD - Department of Physics, Gauhati University, Gauhati (Activities from 01 April 2023 to 31 March 2024)

Coordinator:
Dr. Sanjeev Kalita

Areas of Research

The ICARD at the Department of Physics, Gauhati University, was active from October 2022. It hosts research activities in gravitation & cosmology, as well as observational astronomy. The ICARD has two permanent faculty members in Astronomy & Astrophysics – Sanjeev Kalita and Biman J Medhi.

Sanjeev Kalita's research studies include testability of modified gravity theories near the Galactic Centre black hole through upcoming Extremely Large Telescopes, expansion history of the universe outside Lambda CDM cosmology, formation of massive black holes in the high redshift universe and early universe physics. He also carries out historical research studies on astronomy.

Biman J Medhi is involved in the observational studies of active galactic nuclei through X-ray astronomy, star formation and star clusters and polarimetric studies of galactic dust clouds and comets. He is also interested in studying exoplanets and their connection with host star properties.

Research

A possible combination of early universe physics and late-time cosmologies in gravitation and cosmology has been investigated with the observed BAO scales. It is found that cosmological models with curvature and departure from general relativity are promising with BAO alone. Age has been found to be elevated in some of these alternatives to Lambda CDM and is found compatible with available reports of very old star clusters. The possibility of the formation of massive black hole seeds in the pre-quasar era has been investigated through the accretion of Self Interacting Dark Matter. f[R] gravity scalarons and Primordial Black Hole mass have been constrained through observed bounds on primordial helium abundance.

A Kerr metric was constructed in these theories with the NJA algorithm to study the testability of f[R] gravity theories near the Galactic Centre black hole. Astronomical consequences such as effects on black holes shadows, Lense-Thirring precession of compact stellar orbits and Schwarzschild precession were studied. It has been reported that scalaron degrees of freedom with masses 10 – 17 - 10 – 16 eV are consistent with general relativity.

In observational astronomy, observations from XMM Newton, Swift and NuSTAR were used to study X-ray/UV correlation in Seyfert galaxies. Through Gaia DR 3 astrometric data of stars in open clusters, a statistical and multiwavelength study was carried out for the open cluster IC 1590. With the help of AIMPOL at ARIES, Nainital, the magnetic field and dust grain properties of two galactic dust clouds L 1495 and L 1498 were studied through photopolarimetry.

Workshop/School Organised

An astronomy workshop for college and university teachers titled 'Pedagogic

Workshop on Astronomy, Astrophysics and Cosmology - A faculty enrichment program' was organised from 04-10 January 2024, was organised by ICARD, Gauhati University and TLC-ACE, IUCAA, Pune.

Coordinators: Sanjeev Kalita, Gauhati University, Dhruba J Saikia, IUCAA, TLC and Sowgat Muzahid, IUCAA

Publications using ICARD facilities

1. Possible combinations of early and late time cosmologies through BAO scales; Kalita, S. & Rabha, C., The European Physical Journal C, 83 (7), 671 (2023) (27th July 2023).

2. Immanuel Kant in the universe; Sanjeev Kalita, Astronomy & Geophysics, 64 (5), 5.29-5.33 (2023) (1st October 2023) (related to historical research in astronomy).

3. Formation of Massive Black Holes with M=(103–108) M⊙ at Pre-quasar Epochs through Hoyle–Lyttleton–Bondi Accretion of Self-interacting Dark Matter onto a Moving Seed; Das, N. and Kalita, S., The Astrophysical Journal, 961 (1), 105 (2024) (17th January 2024).

4. Constraining primordial black hole masses through f (R) gravity scalarons in Big Bang Nucleosynthesis; Talukdar, A., Kalita, S., Das, N. and Lahkar, N., Journal of Cosmology and Astroparticle Physics, 2024 (02), 019 (2024) (9th February 2024).

5. Kerr-scalaron Metric and Astronomical Consequences near the Galactic Center Black Hole; Paul, D., Bhattacharjee, P. and Kalita, S., The Astrophysical Journal, 964, 127 (2024) (22nd March 2024).

6. A Search for X-Ray/UV Correlation in the Reflection-dominated Seyfert 1 Galaxy Markarian 1044; Barua, S. et al., The Astrophysical Journal, 958 (1), 46, 2023 (10th November 2023).

7. Probing the magnetic field and dust grain properties of two dark clouds L1495 and L1498 through photopolarimetry; Choudhury, G.B. et al., Monthly Notices of the Royal Astronomical Society, 528 (4), 7156 (2024) (9th February 2024).

8. A statistical and multiwavelength photometric analysis of a young embedded open star cluster: IC 1590; Sheikh, A. H. and Medhi, B.J., Monthly Notices of the Royal Astronomical Society, 528 (4), 7037 (2024) (13th February 2024).

Outreach programmes, including public lectures/skywatch

The ICARD, Gauhati University, runs the Gauhati University Observatory, which hosts two operating telescopes. One is a 9.25-inch Schmidt Cassegrain (motorised), and the other is a 6-inch Galilean (motorised). The observatory is used for M.Sc training in observational astronomy as part of the M.Sc physics course and for public outreach events.

List of public events at the observatory

ICARD, Gauhati University, organised a Citizen Science Hackathon in July 2023. The mission was to identify MilkyWay-type galaxies from the images released by space telescopes and to extract possible techno-signature of Extra-terrestrial Civilizations from a list of radio signals. The best performers were awarded prizes at the department premises.

The three winners (3rd, 4th and 5th from right) with the astronomy team (left panel) and the first prize winner holding the prize distributed by Dr Sanjeev Kalita (right panel)

A public outreach event named " Realm of the Solar System and the Stars" was organised on 18 March 2024 for school and college students, teachers and parents in collaboration with Gauhati Planetarium. The programme components were (i) Sky viewing of celestial objects through telescopes, (ii) an Astronomy presentation by the A & A team (teachers and research scholars) and (iii) a poster presentation on the solar system by MSc physics students of the ICARD.

Sanjeev Kalita is talking to the public about the solar system's formation

Kids looking through a telescope eyepiece

Research scholars interact with school students and teachers by presentation of planets

Honours/distinction/awards

ICARD Coordinator Dr Sanjeev Kalita was elected as a Fellow of the Royal Astronomical Society (FRAS), UK, in October 2023

ICARD - Centre for Cosmology, Astrophysics and Space Science, GLA University, Mathura (Activities from 01 April 2023 to 31 March 2024)

Coordinator:
Professor Anirudh Pradhan

Areas of Research

Astronomy, Astrophysics, Cosmology, History and the Philosophy of Science

Research

The faculties in the CCASS, GLA University, are working in the fields of cosmology, general and modified theories of gravity, astrophysics, astronomy, and the history and philosophy of science.

Workshops/School organised

A three-day workshop on "*Python Programming in Astronomy, Astrophysics and Cosmology (PPAAC)*" was held at CCASS, GLA University, Mathura from 20-22 July 2023. The speakers were Prof. S. N. Hasan (MANUU, Hyderabad), Dr. Priya Hasan (MANNU, Hyderabad), Dr. Akshay Rana (Delhi University, Delhi), Mr. Darshan Kumar (Delhi University, Delhi) for providing opportunities to UG/PG students, Research Scholars, PDF and newly joined faculties to get an exposure on the data analysis related works in the field of astronomical sciences.

A two-day workshop on "Basic Astronomy and Telescope Making for School-College University Teachers and students" was held at CCASS, GLA University, Mathura from 01-02 February 2024. The speakers were Mr Samir Dhurde (IUCAA, Pune) and Mr Tushar Purohit (IUCAA, Pune) for hands-on training for students, research scholars, and faculties for amateur astronomy.

Publications using ICARD facilities

1. T. Tangphati, G. Panotopoulos, A. Banerjee, A. Pradhan, Charged compact stars with color–flavor-locked strange quark matter in f(R,T) gravity, Chinese Journal of Physics, 82 (2023) 62-74

2. L. Baskey, S. Ray, S. Das, S. Majumder, A. Das, Anisotropic compact stellar solution in general relativity, Eur. Phys. J. C 83 (2023) 307

3. S. Das, A. Panda, G. Manna, S. Ray, Raychaudhuri Equation in K-essence Geometry: Conditional Singular and Non-Singular Cosmological Models, Fortschritte der Physik 71 (2023) 2200193

4. A. Pradhan, G. Goswami, S. Krishnannair, The reconstruction of constant jerk parameter with f(R, T) gravity in Bianchi-I spacetime, Eur. Phys. J. Plus 138 (2023) 451

5. S.K. Maurya, A. Errehymy, B. Dayanandan, S. Ray, N. Al-Harbi, A.-H. Abdel-Aty, Role of vanishing complexity factor in generating spherically symmetric gravitationally decoupled solution for self-gravitating compact object, Eur. Phys. J. C}, 83 (2023) 532

6. R. Kundu, U. Debnath, A. Pradhan, Gravitational lensing: dark energy models in non-flat FRW Universe, Eur. Phys. J. C 83 (2023) 553

7. K.P. Das, U. Debnath, S. Ray, Dark Energy Star: Physical Constraints on the Bounds, Fortschritte der Physik 71 (2023) 2200148

8. A. Singh, Homogeneous and anisotropic cosmologies with affine EoS: a dynamical system perspective, Eur. Phys. J. C 83 (2023) 696

9. D.C. Maurya, J. Singh, L.K. Gaur, Dark Energy Nature in Logarithmic f(R,T) Cosmology, Int. J. Geom. Methods Mod. Phys., 20 (2023) 2350192

10. F. Tello-Ortiz, A. Rincon, A. Alvarez, S. Ray, Gravitationally decoupled non-Schwarzschild black holes and wormhole space–times, Eur. Phys. J. C 83 (2023) 796

11. A. Dixit, A. Pradhan, V.K. Bhardwaj, A. Beesham, Observational constraints for an axially symmetric transitioning model with bulk viscosity parameterization, Astronomy and Computing, 45 (2023) 100768

12. T. Tangphati, A. Errehymy, A. Banerjee, A. Pradhan, Anisotropic quark stars in energy-momentum squared gravity, Journal of High Energy Astrophysics, 40 (2023) 68-75

13. S. Ray, Soham Ray, I.S. Al-Amri, S.K. Maurya, K.P. Manith Banula, Drake equation of search for extraterrestrial intelligence: A proposal for modification in the light of Dirac's large number hypothesis, Int. J. Mod. Phys. D, 32 (2023) 2350094

14. S. Ray, U. Mukhopadhyay, S. Dhurde, IUCAA: genesis of a unique research centre, Eur. Phys. J. H 48 (2023) 1

15. S.K. Maurya, K.N. Singh, M. Govender, G. Mustafa, S. Ray, The Effect of Gravitational Decoupling on Constraining the Mass and Radius for the Secondary Component of GW190814 and Other Self-bound Strange Stars in f(Q) Gravity Theory, ApJS 269 (2023) 35

16. T. Tangphati, C.R. Muniz, A. Pradhan, A. Banerjee, Traversable wormholes in Rastall-Rainbow gravity, Physics of the Dark Universe, 42, (2023) 101364

17. D.C. Maurya, Constrained ΛCDM dark energy models in higher derivative $f(R, L_m)$-gravity theory, Phys. Dark Uni., 42 (2023) 101373

18. P. Bhar, A. Errehymy, S. Ray, Constraining physical parameters of DESs via the secondary component of the GW190814 event and other self-bound NS pulsars in f(Q)-gravity theory, Eur. Phys. J. C, 83 (2023) 1151

19. S.K. Maurya, K.N. Singh, A. Aziz, S. Ray, G. Mustafa, Compact stars with dark matter induced anisotropy in complexity-free background and effect of dark matter on GW echoes, Mon. Not. R. Astron. Soc., 527 (2024) 5192–5205

20. J.M.Z. Pretel, T. Tangphati, A. Banerjee, A. Pradhan, Effects of anisotropic pressure on interacting quark star structure, Physics Letters B, 848, (2024) 138375

21. D.C. Maurya, J. Singh, Modified f(Q)-gravity string cosmological models with observational constraints, Astronomy and Computing, 46 (2024) 100789

22. J. Bhadra, U. Debnath, A. Pradhan, Amended FRW universe: thermodynamics and heat engine, Eur. Phys. J. C, 84, (2024) 131

23. A. Singh, Qualitative study of anisotropic cosmologies with inhomogeneous equation of state, Chinese J. Phys., 88, (2024) 865-878

24. A. Singh, Lyra cosmologies with the dynamical system perspective, Phys. Scr., 99, (2024) 045011

25. G. Mustafa, F. Javed, S.K. Maurya, S. Ray, Possibility of stable thin-shell around wormholes within string cloud and quintessential field via the van der Waals and polytropic EOS, Chinese Journal of Physics}, 88, (2024) 32-54

Outreach programme, including public lecture/sky-watch

1. A popular talk entitled "*Expanding universe: cosmic time and cosmic redshift*" by Dr Dinesh Chandra Maurya (Centre for Cosmology, Astrophysics and Space Science, GLA University, Mathura) was organised for students and faculties on 30 September 2023.

2. A popular talk entitled "*Black hole vs black hole shadow*" by Dr Dharm VDr Singh (Department of Physics, GLA University, Mathura) was organised for students and faculties on 04 November 2023.

3. A popular talk entitled "*Scientific Legacy of Stephen Hawking*" by Dr Shobhit Sachan (Department of Physics, GLA University, Mathura) was organised for students and faculties on 01 December 2023.

4. A popular talk entitled "*Celestial Object Classification in the Sloan Digital Sky Survey using Machine Learning Algorithms*" by Prof. Syamala Krishnannair (University of Zululand, South Africa) was organised for students and faculties on 16 January 2024.

5. A sky-watching event was organised for students and faculties on 17 February 2024 in the evening.department interacted with the students by illustrating on the naked eye planets.

ICARD - School of Physical and Applied Sciences Goa University, Goa (Activities from 01 April 2023 to 31 March 2024)

Coordinator:
Dr. Reshma Raut Dessai

Workshop/School organised

(Activities from 01 November 2023 to 31 March 2024)

National Workshop

Workshop on Gravitational waves and LIGO India

A five-day workshop on Gravitational Waves and LIGO India was held from 27 November to 01 December 2023 at Goa University. The workshop gave the participants an understanding of gravitational wave physics and data analysis techniques, equipping them with the skills to understand and explore these groundbreaking discoveries. The workshop comprised the theory of gravitational wave physics, which includes general relativity, source modelling, basics of search, and parameter estimation and detectors. It gave participants a profound understanding of the theoretical foundations and cutting-edge methodologies underpinning gravitational wave research. The data analysis and instrumentation sessions gave

skills to contribute meaningfully to ongoing and future research. Forty-three participants from the Masters and Engineering branch attended the workshop.

Public Talks organised

A talk titled '*The Sources of Gravitational Waves*' by Prof. Nigel T. Bishop, University of Rhodes, South Africa, was organised on 28 November 2023 at the Conference Room, Goa University.

Prof. Nigel Bishop delivering a talk at Goa University

A talk titled '*LIGO India and Opportunities*' by Prof. Sanjit Mitra was organised on 30 November 2023 at the Goa Science Centre, attended by School students and teachers.

The Director of Goa Science Centre welcomes Prof. Sanjit Mitra

Outreach Activities

Delivered a talk on '*Observation Astronomy and Career in Science*' during the pre-science day celebration activity at Triump School, Pundalik Nagar, Porvorim, on 23 February 2024. An astronomy quiz was also held as a part of the celebration activity.

Pre-science Day celebration activities at Triump School, Pundalik Nagar, Porvorim, Goa, on 23 February 2024

A skywatch session using a 6-inch reflector telescope and ZSO Seestar Smart telescope was organised for the general public on 16 February 2024 at the School of Physical and Applied Sciences, Goa University.

Skywatch session using a 6-inch reflector telescope and ZSO Seestar Smart Telescope

A skywatch session, along with a talk on Observational Astronomy, was held on 13 February 2024 at Bamanbhat Cujira, Santa Cruz, Goa.

Skywatch session at the Goa University campus

ICARD - Department of Physics, DDU Gorakhpur University (Activities from 01 April 2023 to 31 March 2024)

Coordinator:
Professor Shantanu Rastogi

Areas of Research

The ICARD members at Gorakhpur and surrounding areas, including Varanasi and Lucknow, mainly work in the areas of infrared observations of stars, Circumstellar and Interstellar Medium, Molecules of Astrophysical importance, Star clusters, Gravity and Dark Matter, Atmospheric aerosols, Trace gases in planetary atmospheres etc.

Research

Amit Pathak, BHU and Shantanu Rastogi, DDUGU, have studied various aspects of astrophysical infrared emission features and their possible carrier polycyclic aromatic hydrocarbon (PAH) molecules. Amit Pathak also participated in JWST data analysis. A study of Globular Clusters using observations from ARIES, Nainital, and GAIA data is being carried out by Apara Tripathi, DDUGU. Alka Mishra, LU is doing theoretical studies on the chemistry of the formation of pre-biotic molecules in the interstellar medium. Rajesh Kumar, DDUGU, studies gravitational collapse and interacting models of dark matter and dark energy. Analysis of Astrosat observations by Sanjay Pandey, LBS Gonda. Continuous monitoring of atmospheric aerosols at Gorakhpur and study of satellite data on atmospheric trace gases are being carried out by Prabhunath Prasad and Shantanu Rastogi, DDUGU.

Publications using ICARD facilities

1. A far-ultraviolet-driven photoevaporation flow observed in a protoplanetary disk; O. Berne, ... A. Pathak, ... et al.; Science 383 (6686), 988-992, 2024.

2. C–H Stretch Vibrational Modes: Tracers of Interstellar PAH Geometries?; A. Vats, A. Pathak, T. Onaka, I. Sakon, I. Endo; ACS Earth and Space Chemistry 7 (7), 1350-1364, 2023.

3. Infrared spectra of protonated and deuteronated C60 in interstellar environments; A. Vats, A. Pathak; Journal of Astrophysics and Astronomy 44 (1), 32, 2023.

4. Rotational spectroscopy of 1-pyrroline: A theoretical study; A. Pandey, A. Pathak, K.A.P. Singh; Journal of Astrophysics and Astronomy 44 (1), 33, 2023.

5. Interstellar branched chain molecules: A theoretical-rotational study; S. Srivastav, A. Vats, A. Pandey, A. Pathak; Journal of Astrophysics and Astronomy 44 (1), 31, 2023.

6. Theoretical microwave spectra of interstellar nitrogen-containing PAHs; A. Vats, S. Srivastav, A. Pandey, A. Pathak; Physical Chemistry Chemical Physics 25 (28), 19066-19072, 2023.

7. A comprehensive rotational study of astronomical iso-pentane within 84 to 111 GHz; A. Pandey, S. Srivastav, A. Vats, A. Pathak, K.A.P. Singh; Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 290, 122299, 2023.

8. An Eternal gravitational collapse in f (R) theory of gravity and their astrophysical implications; A. Jaiswal, R. Kumar, S. K. Srivastava, M. Govender, Chinese Journal of Physics 89, 325-339, 2024.

9. Black hole formation in gravitational collapse and their astrophysical implications, A. Jaiswal, R. Kumar, S. K. Srivastava, M. Govender, S. K. J. Pacif; Physica Scripta, 99(3), 035307, 2024.

10. Dynamics of uniformly collapsing system and the horizon formation; A. Jaiswal, S. K. Srivastava, R. Kumar; International Journal of Geometric Methods in Modern Physics, 20(07), 2350114, 2023.

11. Astrophysical implications of an eternal homogeneous gravitational collapse model with a parametrization of expansion scalar; A. Jaiswal, R. Kumar, S. K. Srivastava, S. K. J. Pacif; The European Physical Journal C, 83(6), 490, 2023.

12. Optical intraday variability of the blazar S5 0716+ 714; T. Tripathi, ... S. Rastogi, ... et al.; Monthly Notices of the Royal Astronomical Society, 527 (3), 5220-5237, 2024.

13. Insights of Boundary Layer Turbulence Over the Complex Terrain of Central Himalaya from GVAX Field Campaign, A. Rajput, N. Singh, J. Singh, S. Rastogi; Asia-Pacific Journal of Atmospheric Sciences, 60, 143, 2023.

14. Investigating changes in atmospheric aerosols properties over the Indo-Gangetic Plain during different phases of COVID-19-induced lockdowns, P. Singh, A. Vaishya, S. Rastogi, Environmental Science and Pollution Research, 30, 100215–100232, 2023.

15. Photometric and kinematic studies of open cluster NGC 1027, A. Tripathi, N. Panwar, S. Sharma, B. Kumar, S. Rastogi, Journal of Astrophysics and Astronomy, 44, 61, 2023.

16. PAH emission features in star-forming regions and late-type stars, R. K. Anand, S. Rastogi, B. Kumar, Journal of Astrophysics and Astronomy, 44, 47, 2023.

Activities/Outreach programmes

1. Dr. Tapas Kumar Das, HRI, Prayagraj, visited ICARD on 11 April 2023 and delivered a popular lecture on 'Supermassive Black Holes'.

2. Prof. Shantanu Rastogi, DDU Gorakhpur University, delivered a popular lecture

for school students at Air Force School, Gorakhpur, on 2 Aug 2023 on 'The Moon and its Exploration (Chandrayan -3)'.

3. Dr. Apara Tripathi and Dr. Prabhunath Prasad, DDU Gorakhpur University, organised a Quiz and demonstration for Astronomy popularisation on 23 Sep 2023, celebrating International Astronomy Day.

4. 4.M.Sc. and B.Sc. students organised a Science Fair with Models, Posters and Lab visits to celebrate the Birthday of Sir C.V. Raman on 7 Oct 2023. (Mentors: Research students of the Physics Department).

5. Science Day was celebrated with Lectures, Models and Posters by students of the University, local

Explanation of Sunspots during Solar Maxima on Science Day, 28 Feb 2024

Engineering Colleges, and other Affiliated Colleges on 28 Feb 2024.

6. Dr. Indraneel Chattopadhyay, ARIES, Nainital, visited ICARD on 1 Mar 2024 and had a discussion class on 'Cosmology and CMBR' with MSc final (Astrophysics) students.

ICARD - Manipal Centre for Natural Sciences (MCNS), Centre of Excellence, Manipal Academy of Higher Education (MAHE) (Activities from 01 April 2023 to 31 March 2024)

Coordinator:
Dr Debbijoy Bhattacharya

Area of Research:

MCNS researchers are involved in theoretical studies, multi-wavelength observation and associated modelling in various fields of astrophysics, which include cosmic inflation, cosmic microwave background anisotropy, dark matter, primordial black holes, High Energy Astrophysics, transient phenomena and exotic objects such as X-ray binaries, AGN, supernova and gamma-ray burst, black hole physics and astrophysical jets, solar physics and space instrumentation.

Research

TThe astrophysics and cosmology group at MCNS is actively involved in theoretical and observational research. Researchers from this group extensively use observational data from various national and international observatories (e.g., JCBT-Kavalur, HCT-Hanle, ASTROSAT, Fermi, Swift, Planck, SDSS, etc). MAHE became a member of the SKA-India Consortium in November 2023. Faculty from MCNS are actively involved in developing and characterising SUIT payload onboard India's space-based Solar observatory ADITYA-L1.

Two projects received external funding during this period (details in Annexure II). The total number of research grants (sanctioned/ongoing) was five last year.

Dr Suvedha Suresh Naik (presently a Postdoctoral fellow at IIA) was awarded a PhD

Publications using ICARD facilities

During the last year, sixteen papers were published by the astrophysics group at MCNS.

1. Particle production during inflation: constraints expected from redshifted 21 cm observations from the epoch of reionization by Suvedha Suresh Naik, Pravabati, Chingangbam and Kazuyuki Furuuchi, 2023, Journal of Cosmology and Astroparticle Physics, 4, 058.

2. Gravitational Larmor precession by Chandrachur Chakraborty and Parthasarathi Majumdar, 2023, The European Physical Journal C, 83, 714.

3. Geometric phase in Taub-NUT spacetime by Chandrachur Chakraborty and Banibrata Mukhopadhyay, 2023, The European Physical Journal C, 83-937.

4. Adaptive friend-of-friends algorithm for identifying gravitationally bound cosmological structures", Prateek Gupta, and Surajit Paul, 2023, Physical Review D, 108, 103509.

5. The Solar Ultra-Violet Imaging Telescope (SUIT) Onboard Intelligence for Flare Observations by Manoj Varma, Sreejith Padinhatteri, Sakya Sinha et al., 2023, Solar Physics, 298, 2, 16.

6. A Kpc-scale radio polarization study of

PG BL Lacs with the uGMRT by Baghel, Janhavi; Kharb P.; Hovatta T.; Gulati S.; Lindfors E.; Silpa S., A Kpc-scale radio polarization study of PG BL Lacs with the uGMRT, 2024, Monthly Notices of the Royal Astronomical Society, 527, 1, 672 – 688.

7. Unravelling the nuclear dust morphology of NGC 1365: a two-phase polar–RAT model for the ultraviolet to infrared spectral energy distribution by Subhashree Swain, P. Shalima and K. V. P. Latha, 2024, Monthly Notices of the Royal Astronomical Society, 527, 3592–3601.

8. Black holes shielded by magnetic fields by Chandrachur Chakraborty, 2024, Physics Letters B. 849, 138437.

9. A New Enigmatic Radio Relic in the Low-mass Cluster Abell 2108 by Chatterjee, Swarna; Rahaman, Majidul; Datta, Abhirup; Kale, Ruta; Paul, Surajit, 2024, Monthly Notices of the Royal Astronomical Society, 527, 4, 10986 – 1099.

10. AT2020ohl: its nature and probable implications by Rupak Roy, Samir Mandal, D. K. Sahu, G. C. Anupama, Sumana Nandi and Brijesh Kumar, 2024, Monthly Notices of the Royal Astronomical Society, 528, 4, 6176 –6192.

11. A VLBA-uGMRT search for candidate binary black holes: Study of six X-shaped radio galaxies with double-peaked emission lines by Biny Sebastian, Anderson Caproni, Preeti Kharb, Nayana A.J., Arshi Ali, K, Rubinur, Christopher P. O'Dea, Stefi Baum, Sumana Nandi, 2024, Monthly Notices of the Royal Astronomical Society, 530, 4902–4919.

12. A Large Jet Narrow-line Seyfert 1 Galaxy: Observations from Parsec to 100 kpc Scales by Sina Chen, Preeti Kharb, Silpa Sasikumar, Sumana Nandi et al.", 2024, Astrophysical Journal, [Supplement Series], 963, 32.

13. Magnetic Penrose process in the magnetized Kerr spacetime by Chandrachur Chakraborty, Parth Patil and G. Akash, 2024, Physical Review D, 109, 064062.

14. Search for interacting galaxy clusters from SDSS DR-17 employing optimized friends-of-friends algorithm and multimessenger tracers by Oak, Tejas; Paul, Surajit, 2024, Monthly Notices of the Royal Astronomical Society, 528,4,5924 – 5951.

15. Multiwavelength Study of Radio Galaxy Pictor A: Detection of Western Hotspot in Far-UV and Possible Origin of High Energy Emissions by Gulati, S.; Bhattacharya, D.; Ramadevi, M. C.; Stalin, C. S.; Sreekumar, P. Monthly Notices of the Royal Astronomical Society, 2023, 521 (2), 2704–2715.

16. Multiwavelength Study of NGC 1365: The Obscured Active Nucleus and off-Nuclear Compact X-Ray Sources by Swain, S.; Dewangan, G. C.; Shalima, P.; Tripathi, P.; Latha, K. V. P. Monthly Notices of the Royal Astronomical Society, 2023, 520 (3), 3712–3724.

Seminar/Colloquium/Public Talks

MCNS organised 29 seminars / colloquiums / popular talks from 01 April 2023 to 31 March 2024. Eminent researchers from various institutes and universities delivered seminars to students and researchers from MAHE and neighbouring colleges.

1. Dr Hideo Furugori, Postdoctoral Fellow Kyoto University, gave a talk on the theme - From Fundamental Physics to the Universe, titled *Infrared Triangle: Insights from Dressed State Formalism in QFT,* on 06 March 2024.

2. Dr Keisuke Izumi, Lecturer Kobayashi-Maskawa Institute for the Origin of Particles and the Universe and Nagoya University, gave a talk on the theme - From Fundamental Physics to the Universe, titled *Gravity, Mass and Surface* on 06 March 2024.

3. Dr Toshifumi Noumi, Associate Professor at The University of Tokyo, gave a talk on the theme - From Fundamental Physics to the Universe, titled *Wave-packet Approach: Cosmic Infation and Quantum Gravity,* on 06 March 2024.

4. Dr Kenji Nishiwaki, Assistant Professor Shiv Nadar University, gave a talk on the theme - From Fundamental Physics to the Universe, titled *Wave-packet Approach: A full-fledged way to clarify quantum nature*" on 06 March 2024.

5. Ms Kaho Yoshimura, M Sc. Scholar, Kobe University, gave a talk on the theme - From Fundamental Physics to the Universe, titled *Black Hole Evaporation and the Weak Gravity Conjecture,* on 02 March 2024.

6. Mr Noel Jonathan Jobu, PhD Scholar, Shiv Nadar University, gave a talk on the theme - From Fundamental Physics to the Universe, titled *Neutrinos: A portal into Beyond Standard Model Physics,* on 02 March 2024.

7. Mr. Sota Sato, PhD Scholar, Kobe University, gave a talk on the theme - From Fundamental Physics to the Universe, titled *Dark Matter and Quantum Gravity*, on 02 March 2024.

8. Mr Kanji Nishii, PhD Scholar at Kobe University, gave a talk on the theme - From Fundamental Physics to the Universe, titled *Black Holes and Thermodynamics*, on 02 March 2024.

9. Dr Daisuke Yoshida, Designated Assistant Professor at Nagoya University, gave a talk on the theme - From Fundamental Physics to the Universe, titled *Initial Singularities of the Universe,* on 02 March 2024.

10. Dr Vivek Kumar Jha, Research Associate, MCNS, gave a seminar on *Unveiling the diverse nature of the inner regions of AGNS through variability* on 19 Jan 2024.

11. Ms Nigar Shaji, Programme Director at the U.R.Rao Satellite Centre & Project Director of the Aditya-L1 mission Indian Space Research Organization (ISRO),

gave a Public Lecture on the *Technology Challenges of Aditya-L1 mission* on 12 January 2024 (Ninth Regional Astronomy Meeting 2024 at Manipal).

12. Prof. B. Eswar Reddy, Programme Director of the India TMT Coordination Center (ITCC) Dean, Indian Institute of Astrophysics, gave a Public Lecture on *The Thirty Meter Telescope - A New Window to the Universe* on 10 January 2024 (Ninth Regional Astronomy Meeting 2024 at Manipal).

13. Dr Joby Kochappan, a Postdoctoral Fellow, gave a seminar on *Observational evidence for Early Dark Energy as a solution to the Hubble tension* on 5 January 2024.

14. Prof. Tarun Souradeep, Director, Raman Research Institute, gave a talk on *Quests & Conquests: Gravitational Wave Science* on 28 December 2023.

15. Prof. Tirthankar Roy Choudhury, National Centre for Radio Astrophysics, Tata Institute of Fundamental Research, gave a talk on *Cosmic Neutral Hydrogen as a Probe of the First Stars in the Universe* on 21 December 2023.

16. Prof. A. Gopakumar, TIFR, Mumbai, India Chair, Indian Pulsar Timing Array, gave a talk on the *Murmuring of the fabric of our Universe* on 19 December 2023.

17. Dr. Debanjan Bose, School of Astrophysics, Presidency University, Kolkata, gave a talk on *Probing High Energy Universe with Gamma-rays and Neutrinos* on 22 November 2023.

18. Dr. Murthy Dharmapura, Associate Professor, Department of Chemistry, Coordinator, Center for Renewable Energy, Manipal Institute of Technology, MAHE, gave a talk on *Prospects and Challenges in sunlight-driven H 2 generation via water splitting*" on 15 November 2023.

19. Prof. B. S. Acharya, former Senior Professor at Tata Institute of Fundamental Research (TIFR), Mumbai, gave a talk on *Ground-based Gamma-ray Astronomy* on 08 November 2023.

20. A popular talk on "*Seminar on Quantum Mechanics of Inflationary Cosmological Perturbations*" by Dr Rathul Nath Raveendran, Research Associate, Indian Association for the Cultivation of Science, Kolkata, at MCNS on 16 October 2023.

21. A popular talk on "*Search for candidate binary black holes*" by Dr. Sumana Nandi, Assistant Prof, MCNS, MAHE, Manipal at MCNS on 11 October 2023.

22. A popular talk on *X-ray Variability of Black Hole Systems: The AstroSat Advantage* by Prof. Ranjeev Misra, IUCAA, Pune, at MCNS on 04 October 2023.

23. A popular talk on *Magnetic Instabilities and Dynamics in Compact Stars* by Dr. Prasanta Bera, Open University of Israel, Ra'anana, Israel, at MCNS on 27 September 2023.

24. A popular talk on *Nuclear Transients – their complexity & environment* by Dr. Rupak Roy, Assistant Professor, MCNS, MAHE, Manipal at MCNS on 20 September 2023.

25. Popular talk on *Grouping with the measure of increased tie with gravity order: An adaptive friend-of-friend group finder* by Dr Surajit Paul, Associate Professor, MCNS, MAHE, Manipal at MCNS on 06 September 2023.

26. A popular talk on *The Giant Metrewave Radio Telescope: A Technological and Scientific Milestone in Indian Science* by Prof. Ishwara Chandra C. H., Professor & Dean, GMRT Observatory, NCRA-TIFR, Pune, at MCNS on 29 June 2023.

27. A popular talk on *Space Science Programs of ISRO* by Dr. V. Girish, Deputy Director, Science Program Office, ISRO, Bangalore, at MCNS on 09 June 2023.

28. A popular talk on *X-ray Study of the Sun – My experiences with sounding rockets* by Dr P. S. Athiray, University of Alabama, Huntsville Center for Space Plasma and Aeronomic Research, NASA Marshall Space Flight Center, USA, at MCNS on 02 June 2023

29. A popular talk on *X-ray imaging spectroscopy to study solar active region heating*, by Dr P. S. Athiray, University of Alabama, Huntsville Center for Space Plasma and Aeronomic Research, NASA Marshall Space Flight Center, USA, at MCNS on 01 June 2023

Workshop/School Organised

The ninth Regional Astronomy meeting on 'Research in Astronomy: Opportunities and Challenges' was held at the Manipal Centre for Natural Sciences, Manipal Academy of Higher Education (MAHE), Manipal, from 10-12 January 2024, jointly organised and funded by MAHE and IUCAA. The regional astronomy meeting is an annual program that aims to provide a platform for researchers from universities and institutes, primarily from Kerala, Karnataka and Tamil Nadu, to showcase their work and encourage future collaboration. 122 researchers from various universities and institutes participated in the meeting. Out of 54 abstracts submitted for the meeting, 29 were selected for oral presentation and 14 abstracts were selected as posters. In addition to the student/young researcher talks on their present research work, there were dedicated discussion sessions on establishing a roadmap for inter-institutional collaborative research work, which is the key to addressing important science problems. The meeting was coordinated by Debbijoy Bhattacharya, MCNS, MAHE and Ranjeev Misra, IUCAA.

Honours/distinctions/awards, etc.

1. A recipient of the ASI Zubin Kembhavi Award for Global elemental mapping of lunar surface by payloads on Chandrayaan-2 team (Dr P. Sreekumar as one of the members).

2. C. Chakraborty, Individual Member, International Astronomical Union (IAU).

ICARD - Newman College, Thodupuzha, Kerala (Activities from 01 April 2023 to 31 March 2024)

Coordinator:
Dr Joe Jacob

Research:

The research scholar Aparna Raj devised a new method for identifying restarted radio sources from all available sky radio surveys. Using the spectral curvature calculated from the multi-frequency data obtained by cross-matching the flux data from the various surveys, she could build a catalogue of 9407 candidates for restarted radio sources. She has submitted her results as a paper to the Journal of Astronomy and Astrophysics (JOAA). Her proposal to observe selected sources using GMRT has been accepted. Neha, P. R. has been continuing her studies on the X-ray data from SWIFT on variable source ARK 564 and consolidating her findings as a research paper.

Seminars/Colloquia organised by ICARD

1. In collaboration with ICARD Newman College, Kerala, the Department of Physics, Cochin College, Kochi organised a one-day 'Regional Seminar in Physics and Astronomy' on 16 October 2023 at Cochin College, Kochi. Forty-four students from twelve colleges (affiliated with MG University and the University of Calicut, Kerala) participated in the programme. Dr Geetha M, Principal of Cochin College, delivered the presidential address. Prof. K. A. Solaman, a retired professor of the Department of Physics at St. Michael's College, Cherthala, inaugurated the event, followed by a felicitation address by Dr. Joe Jacob. Dr Sibi K. S. (Assistant Professor, Dept. of Physics, University of Kerala) engaged in the morning sessions. Dr Mathew George, Assistant Professor, Sacred Heart College, Thevara, started the afternoon session with a talk on 'Basics of Hydrogen Line Detection with a DIY Amateur Radio Telescope'. This is followed by a live demonstration of radio detection from the Milky Way galaxy using a radio telescope. The final session was on 'Aditya L1- in search of secrets of the Sun' by Dr Joe Jacob, ICARD Coordinator, Newman College.

2. The Research & Post Graduate Department of Physics and ICARD of Newman College organised a two-day workshop on Astronomical Data Processing from 01-02 March 2024 for the UG and PG students. The programme consisted of talks on the fundamentals of optical astronomy and hands-on sessions on astronomical data analysis. Dr Arun Roy (Post-doctoral fellow, IIA, Bangalore), Ms Nidhi Sabu (Research Fellow, Christ University, Bangalore), and Dr Sreedharan Bhaskaran (Post-doctoral fellow, TIFR, Mumbai) were the resource persons. Forty-eight students participated in the programme.`

3. The Bharata Mata College, Thrikkakara, Kochi, organised a one-day colloquium as a tribute to the legacy of Professor Thanu Padmanabhan on 23 March 2024. The colloquium served as a platform for research scholars and students to engage with the insights and experiences of Professor Padmanabhan's students, shedding light on their collaborations, research endeavours, and personal reflections on their journey alongside him. S. Shankaranarayanan (IIT Bombay), Archana Pai (IIT Bombay), Titus Mathew (CUSAT), Tejinder Singh (IUCAA), Jasjeet Singh Bagla (IISER Mohali), Dawood Kothawala (IIT Madras), Sanved Kolekar (IIA Bangalore), Suprit Singh (IIT Delhi), and, Krishnamohan Parattu (IIT Mandi) were the resource persons.

4. ICARD Newman College, Thodupuzha, conducted a one-year Active Research Training program in collaboration with Kerala Theoretical Physics Initiative (KTPI), a collective comprising of Faculty, Post Doctoral Fellows and PhD Students in the field of Theoretical Physics worldwide, with roots in Kerala. The programme conducted at the Cochin University of Science and Technology provided post-graduate students with an opportunity to collaborate with KTPI Members and engage in research projects spanning an academic year under their mentorship. A student-scientist

interaction program was conducted to provide training for the current and upcoming batches on April 12, 2024. Prof. Indumathi D. (IMSC Chennai), Dr Charles Jose (CUSAT), Dr Krishnamohan Parattu (IIT Mandi), and Dr Rathul Nath Raveendran (IISc Bangalore) were the resource persons.

Outreach Activities

A three-day science camp for school students was conducted from 22 to 24 May 2023 at the Carmel CMI Public School, Vazhakulam, in the joint auspices of the ICARD, Newman College unit and the Block Panchayat, Muvattupuzha, to impart science awareness and education for the selected students of standard 8 -10 studying in seven Gram Panchayats under the Block Panchayat. Sixty participants from various schools were selected in a novel manner involving their teachers and the respective grama panchayat people's representatives. In the sessions that followed during the three days, fifteen eminent resource persons dealt with various subjects in science with an emphasis on astronomy. A skywatch programme was organised on 23 May 2023 as a part of the Science camp. Dr Joe Jacob (Coordinator, ICARD, Newman College) and Mrs Jossy Jolly (Member, Block Panchayath, Muvattupuzha) coordinated the programme.

The following programs were also conducted:

1. Moon Day celebrations, 20 July 2023.
2. Moon Quiz, 19 September 2023.
3. Observation of Sunspots, 25 January 2024.
4. Skywatch program, 27 January 2024.
5. National Science Day-seminar Competition, 14 March 2024.

ICARD - Department of Physics, University of North Bengal, Siliguri, West Bengal (Activities from 01 April 2023 to 31 March 2024)

Coordinator:
Professor B. C. Paul

Research Area

Relativistic Astrophysics, Cosmology, Compact Objects, DATA analysis of X-ray Sources,
Non-linear Dynamics

Research Activities of the Data Centre

A group of four students, one post-doctoral fellow and three other SRFs are engaged in analysing the X-ray Pulsar DATA archived on the NASA website. The group is constantly vigilant of the new results in X-ray pulsars, and several papers have been published reporting their findings.

Anisotropic Universe with Barrow Holographic Dark Energy

Research cholars are engaged in the analysis of X-ray Data of NASA to investigate different X-ray emitting Pulsars. Presently, four research scholars are involved in doing research using the facilities of the ICARD DATA Centre. It is proposed to use ASTROSAT data from IUCAA soon.

Seminars/Colloquia organised by ICARD

ICARD NBU and Malda College Joint Program

The National Conference on Relativistic Astrophysics and Cosmology (NCRAC) at Malda College, Malda, was organised on 29 February and 01 March 2024. Dr B. C. Paul, Dr Shyam Das and Dr Ranjeev Sharma were the Joint Coordinators of the program. The conference was attended by invited speakers from India and abroad. Surhud S. More, IUCAA, Pune delivered an invited talk online in the session on "Subaru Hyper Suprime Cam Survey Report: Cosmological constraints from weak lensing observations" focusing on the detection of dark matter using various techniques.

A. K. Raychaudhuri Centenary Special Lecture

Prof. Sailojananda Mukherjee, Former Professor of Physics, North Bengal University delivered the 'A. K. Raychaudhuri Centenary Special Lecture' on 21 December 2023. The participants were M. Sc. students of Mathematics and Physics, Research Scholars, Faculties and former students of Prof. Mukherjee (retired from university, namely, Dr D. P. Datta, Dr R. Samanta) and others. A total of 95 head gathered. The topic of discussion was "The story of stars".

Outreach Activities

1. Outreach Program by Prof. B. C. Paul, *Cosmology: Present status. Exploring the Cosmos* at HECRC, NBU on 15 February 2023.

2. Prof. B.C. Paul delivered a talk titled '*Astrophysics: Chandrayaan and Aditya L1?*' on 04 October 2023 for the Salesian College, Siliguri undergraduate students.

3. Prof. B.C. Paul delivered a talk titled '*The Moon and Mission: Chandrayaan-3*' on 23 August 2023 at the Physics Department, North Bengal University—all the M. Sc. students of Physics and mathematics. Research Scholars and faculties attended the popular talk on the eve of the success of Chandrayyan-3.

4. Prof. B.C. Paul delivered a popular talk titled '*Astrophysics: Chandrayaan and Aditya L1?* on 19 September 2023 at the Physics Department, Raiganj University, for B. Sc and M. Sc. students.

5. Prof. B.C. Paul delivered a talk titled '*Indian Missions to the Moon & the Sun and Astrophysics*' on 28 November 2023 at the HRDC, NBU.

6. Prof. B.C. Paul delivered a talk titled '*Black Holes: The Final State of a Luminous Massive Star*' on 28 November 2023 at the HRDC, NBU.

7. Prof. B.C. Paul delivered a talk titled, '*The Moon: Its Missions-Chandrayan?* on 13 January 2024 at HRDC, NBU.

8. Prof. B.C. Paul delivered a talk titled, '*Indian Missions to the Moon & the Sun and Astrophysics*' on 15 January 2024 at the West Bengal Science Congress, A. C. College, Jalpaiguri.

Publications using ICARD facilities

1. B Rai, B Paul, M Tobrej, M Ghising, R Tamang, B. C. Paul, Spectral properties of the BE/X-ray pulsar 2S 1553- 542 during Type II outbursts arXiv:2211.09082 (2022), J. Astrophysics & Astronomy (accepted) (2023).

2. Md. Tobrej, Bi. Rai, M. Ghising, R. Tamang, Bikash Chandra Paul, A high-mass X-ray binary pulsar 4U 1907+09 with multiple absorption-line features in the spectrum Mon. Not. Roy. Astron. Soc. (MNRAS) 518, 4861-4869 (2023).

3. M. Ghising, R. Tamang, Md Tobrej, B. Rai, B. C. Paul, Super-critical accretion in BeXRB SXP 15.3 Mon. Not. Roy. Astron. Soc. (MNRAS) 520, 3396-3404 (2023).

4. A. Chanda, A. Halder, A. S. Majumdar, B. C. Paul, Late time cosmology in f(R; G) gravity with exponential interactions Euro. Phys. Journal C 83, 23 (2023).

5. R. Sengupta, B. C. Paul, M. Kalam, Lorentzian wormholes in an emergent universe Class. Quantum Grav. 40, 095009 (2023).

6. M. Ghising, Ruchi Tamang, M. Tobrej, Binay Rai, B. C. Paul, Spectral & Timing Analysis of BeXRB eRASSU J050810.4-660653 recently discovered in the Large Magellanic Cloud (LMC) Mon. Not. Roy. Astron. Soc. (MNRAS) 518, 893-899 (2023).

7. S. Ghosh, A. Chanda, S. Dey, B. C. Paul Barrow Holographic Dark Energy in Brane - World Cosmology, Class. Quantum Grav. 41 035004 (2024).

8. Binay Rai, Biswajit Paul, Manoj Ghising, Md. Tobrej, Ruchi Tamang, Bikash Chandra Paul, Luminosity dependent cyclotron line in Swift J 1626.6-5156 - JOAA 45, 7 (2024).

9. M. Tobrej, Binay Rai, Manoj Ghising, Ruchi Tamang, B. C. Paul, Spectral Study of Neutron Star low mass X-ray binary Source 1A 1744-361 - Mon. Not. Roy. Astron. Soc., 526, 2032-2038 (2024).

10. M. Ghishing, Md.Tobrej, B. C. Paul The ongoing spin-down episode of 4U 1626-67 - Mon. Not. Roy. Astron. Soc 528 3550?3558 (2024).

11. D Bhattacharjee, P K Chattopadhyay, B. C. Paul New gravastar model in generalized cylindrically symmetric spacetime and prediction of mass limit - Physics of the Dark Universe 43, 101411(2024).

12. B. C. Paul, Gaussian Black Hole in Brane-World - Euro Phys. J C 84, 309 (2024).

ICARD - School of Studies in Physics and Astrophysics, Pt. Ravishankar Shukla University, Raipur
(Activities from 01 April 2023 to 31 March 2024)

Coordinator:
Dr N. K. Chakradhari

Research Area

Supernovae, X-ray Binaries, GRBs and Galaxies

Research work

The spectral and timing study of X-ray Binaries was conducted by Pravat Dangal (Thesis submitted) with N.K. Chakradhari in collaboration with Ranjeev Misra (IUCAA, Pune).

UV-optical photometric and spectroscopic study of supernovae is being carried out by Shritika Tiwari (Thesis to be submitted), Kripa Ram Sahu (Thesis work ongoing) and Mulchand Kurre (Thesis work ongoing) with N.K. Chakradhari in collaboration with G.C. Anupama and D.K. Sahu (IIA, Bengaluru).

A study of early-type/lenticular galaxies was carried out by Mahendra Kumar Verma (PhD awarded) and Amit Kumar Tamrakar (PhD awarded), with S.K. Pandey and Laxmikant Chaware in collaboration with S. Barwey (IIA Bengaluru) and Kanak Saha (IUCAA, Pune).

A study of GRBs – on aspects of multi-wavelength emission, environment and host galaxies was carried out by Ankur Ghosh (PhD awarded) with Amitesh Omar, Kuntal Misra (ARIES, Nainital) and N.K. Chakradhari (co-supervisor).

Publications using ICARD facilities

1. Weak secondary cyclotron line in eclipsing High Mass X-ray Binary Cen X-3, Pravat Dangal, Ranjeev Misra, N. K. Chakradhari, Yashpal Bhulla, 2024, MNRAS, 527, 6981.

2. Search for merger ejecta emission from late-time radio observations of short GRBs using GMRT, Ghosh Ankur, Vaishnava C. S., Resmi L., Misra Kuntal, Arun K. G., Omar Amitesh, Chakradhari N. K., 2024, MNRAS, 527, 8068.

3. Type Ia supernovae SN 2013bz, PSN J0910+5003 and ASASSN-16ex: similar to 09dc-like? Tiwari S., Chakradhari N. K., Sahu D. K., Anupama G.C., Kumar B., and Sahu K.R., 2023, MNRAS, 521, 5207.

The following papers were presented at the 42nd annual meeting of the Astronomical Society of India (ASI 2024), hosted jointly by IISc, ISRO and JNP, Bengalufrom, from 31 January to 04 February 2024.

a) Normal Type Ia Supernova SN 2010ju, Shrutika Tiwari, N.K. Chakradhari, K.R. Sahu, Mulchand Kurre, D.K. Sahu, G.C. Anupama.

b) Optical Studies of Type Ic Supernova SN 2020akf in galaxy KUG 0925+387B, K.R. Sahu, Yogita Patel, Mulchand Kurre, Shrutika Tiwari, N.K. Chakradhari, G.C. Anupama, D.K. Sahu.

c) Photometric and Spectroscopic Studies of Supernova SN 2021mxx, Mulchand Kurre, D.K. Sahu, G.C. Anupama, Yogita Patel, N.K. Chakradhari.

Outreach Activities

Skywatch programmes were organised at the following places using the ICARD facilities.

1. NIT Raipur, 26 and 27 October 2023.

2. Government School, Dhanora, 25 November 2023.

3. NSS Camp, PRSU Raipur, 17 February 2024.

4. BCS PG College, Dhamatari, 23 February 2024.

5. Govt Science College, 24 February 2024.

6. Rungta Public School, 15 March 2024.

We coordinated interactive sessions and discussions with experts, facilitating arrangements for students and staff to witness the live launch of Chandrayaan-3 (14 July 2023), its soft landing (23 August 23 2023), and the Aditya-L1 mission (02 September 2023). Interviews were given to the press on various news channels and newspapers.

ICARD - University of Kashmir, Srinagar (Activities from 01 April 2023 to 31 March 2024)

ICARD Coordinator:
Professor Manzoor A. Malik

Research Area

Theoretical Astrophysics, Cosmology, Galaxy Clusters, X-ray Astronomy, Blazers

Research

Several PhD students and faculty members in universities and colleges are working and publishing in diverse areas of Astronomy and Astrophysics. Several projects funded by SERB (DST), ISRO, DRDO, etc. are ongoing.

Publications (selected) using ICARD facilities

1. Effects of calibration uncertainties on the detection and parameter estimation of isotropic gravitational-wave backgrounds Junaid Yousuf, K. Shivaraj, Manzoor A. Malik; Physical Review D, 107(10), 2023.

2. Time-resolved spectroscopy of a GRS 1915 + 105 flare during its unusual low state using AstroSat, S Boked, B Maqbool, J V, R Misra, NI Bhat, Y Bhulla Monthly Notices of the Royal Astronomical Society 528 (4), 7016-7026.

3. Broadband spectral and temporal study of Ton 599 during the brightest January 2023 flare A Manzoor, Z Shah, S Sahayanathan, N Iqbal, AA Dar Monthly Notices of the Royal Astronomical Society, 529(1), 41–50, 2024.

4. Can FSRQ 3C 345 be a Very High Energy blazar candidate? AA Dar, S Sahayanathan, Z Shah, N Iqbal Monthly Notices of the Royal Astronomical Society 527 (4), 10575-10583.

5. Understanding the very high energy γ-ray excess in nearby blazars using leptonic model Manzoor, S Sahayanathan, Z Shah, S Bhattacharyya, N Iqbal, Z Malik; MNRAS 525 (3), 3533-3540, 2023.

6. Large scale structure formation for conformal theory of gravity AW Khanday, S Upadhyay, N Iqbal, PA Ganai; General Relativity and Gravitation 55 (9), 101, 2023.

7. Statistical description of galaxy clusters in Finzi model of gravity AW Khanday, S Upadhyay, N Iqbal, PA Ganai Physica Scripta 98 (6), 065019, 2023.

8. Development of general functional form of the gravitational potential: Addressing the Flatness Problem in Galactic Rotation Curves Hameeda Mir, DA Qadri; Journal of Holography Applications in Physics 3 (4), 1-4, 2023.

9. Comparative analysis of thermodynamic quantities of galaxy clustering through different approaches under the modified potential HA Bagat, D Shahwar, M Hameeda, PF Shah, PA Ganai; Physics of the Dark Universe 40, 101191, 2023.

10. Generalized statistical mechanics of Newtonian Gravity Mir Hameeda et al; Physica A, 624, 128803, 2023.

11. Measurement of Atmospheric Neutrino Cross-Sections on Oxygen, Water and Argon using Nuwro Event Generator IR Shaik, Q Gani, M Hameeda, Iranian Journal of Astronomy and Astrophysics, 11(1), 17-30, 2024.

12. Development of general functional form of the gravitational potential: Addressing the Flatness Problem in Galactic Rotation Curves H Mir, DA Qadri Journal of Holography Applications in Physics 3 (4), 1-4.

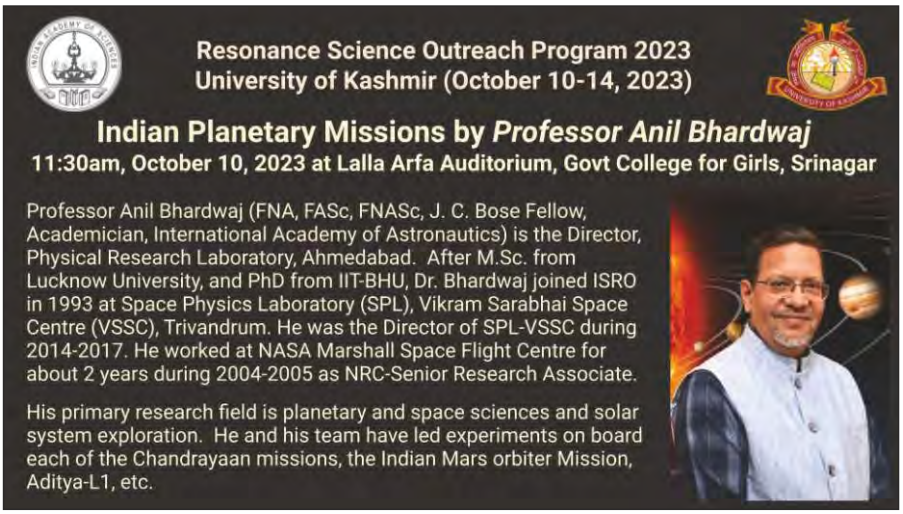
Seminars/Colloquia organised by ICARD

Himalayan Meet of Astronomers (25 and 26 September 2023)

The Islamic University of Science and Technology (IUST), Kashmir and Kashmir University jointly organised a two-day programme in collaboration with the Inter-University Centre for Astronomy and Astrophysics, IUCAA, Pune and the Central University of Himachal Pradesh. The purpose was to bring researchers from Northern India together to discuss the recent developments, opportunities and challenges in the field of Astronomy and Astrophysics with an emphasis on regional advancement in astronomy and astrophysics. The event was coordinated by Naseer Iqbal, University of Kashmir and Ranjeev Misra, IUCAA.

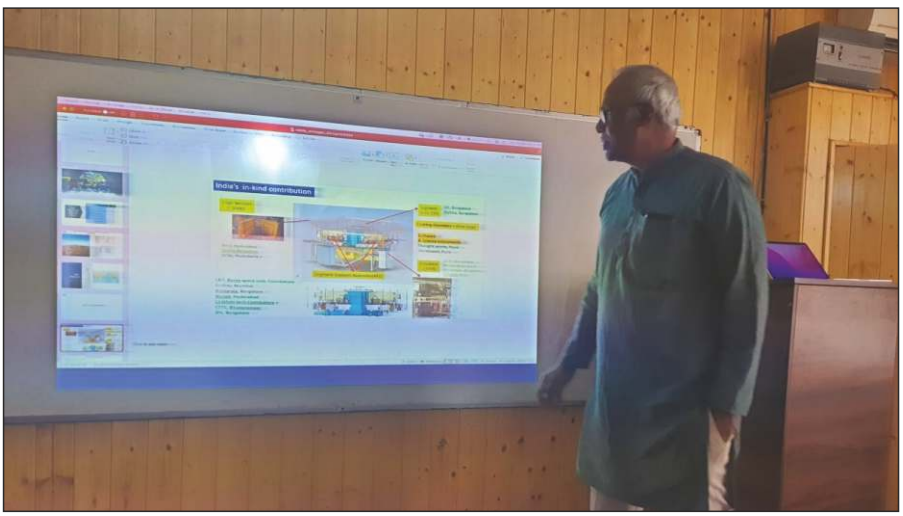
Science Outreach Program (10 to 14 October 2023)

Although not an ICARD activity, several talks covering astronomy and space science in India were delivered. There was also a demonstrative session on daytime astronomy. The Program was organized by Manzoor Malik, University of Kashmir and Jasjeet Bagla, IISER, Mohali.



Seminar

A seminar titled, '*The Thirty Meter Telescope - A New Window to the Universe*' was delivered by Professor B. Eswar Reddy, Dean, Faculty of Sciences, IIA, Bangalore and the Programme Director, India TMT Coordination Center, on 22 March 2024 in the Department of Physics, Kashmir University.



Professor B. Eswar Reddy delivering his talk

PUBLICATIONS BY IUCAA MEMBERS

1. R. Abbott, ..., **D. Agarwal, D. Bankar, A. V. Bhandari, B. Biswas, S. Bose, Debarati Chatterjee, S. Choudhary, M. Deenadayalan, S. Dhurandhar, S. Doravari, A. Ganguly, S. G. Gaonkar, T. Ghosh, S. P. Jadhav, S. Kandhasamy, A. Mhaske, A. Mishra, S. Mitra, A. More, S. More, S. Ponrathnam, D. Rana, T. R. Saravanan, V. Savant, H. L. Sawant, K. Soni, T. Souradeep, S. Sudhagar, M. P. Thirugnanasambandam, Srishti Tiwari**, et al. (The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration) (2023) *Open data from the third observing run of LIGO, Virgo, KAGRA and GEO*, ApJS, **267**, 29.

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Circular

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c) Books (Authored/Edited)

Debarati Chatterjee

Invited to contribute a chapter on "*Equations of state*" to the book "*New Frontiers in GRMHD Simulations*", Editors: Cosimo Bambi (Fudan University, China), Yosuke Mizuno (Shanghai Jiaotong University, China), Swarnim Shashank (Fudan University, China), Feng Yuan (Shanghai Astronomical Observatory/CAS, China). d) Book Reviews]

Popular Science/Technical Articles

Debarati Chatterjee

Invited to contribute an article to the special issue (Jan-June 2023) of Physics News (PN), *Showcasing the cutting-edge research of young women physicists in India*. PN is a newsletter published by the Indian Physics Association (IPA) https://www.tifr.res.in/~ipa1970/

Tejinder P. Singh

Quantum theory could have been different, relativity could have been different; https://forums.fqxi.org/d/3975-quantum-theory-could-have-been-different-relativity-could-have-been-different

Others

Nishant Kumar Singh

Computing time:
Together with Kishore Gopalakrishnan and collaborators from Germany, Dr Petri Kaepylae and Dr Markus Roth, we successfully wrote a proposal for HPC usage at SuperMUC-NG at LRZ, Munich. We have been granted over 40 Million CPU hours for the project "Detection of magnetic signatures with helioseismic techniques from ab initio simulations of turbulent convection" for the period Jan-Dec 2024.

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15. N. T. Thomas, M Varun, Navya T. Jacob, **S. B. Gudennavar** and S. G. Bubbly (2023) *Spectral studies of 4U 1636-536 using AstroSat,* National Conference on REcent Trends in the Study of Compact Objects (RETCO-V): Theory and Observation held during April 3 - 5, 2023 at Kodaikanal Solar Observatory, Tamil Nadu, India.

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20. S. S. Anurag, S. L. Aswini Thampi and **P. R. Prince** (2023) *Study of Vertical Distribution of Ozone using Ozonesonde*, 60th Annual Convention of Indian Geophysical Union 22-24 Nov.2023, Department of Marine Geology and Geophysics, Cochin University of Science and Technology, Kochi, Kerala.

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28. Utkal Keshari Dash and **M. M. Verma** (2024) *Polarization of gravitational waves in f(R) gravity and their lensing near massive objects***,** Astronomical Society of India, ASI 2024, 31 January- 04 February 2024, Indian Institute of Science (IISc), Bengaluru.

29. Vipin Kumar Sharma and **M. M. Verma** (2023) *Characterizing ultralight scalarons in f(R) gravity using gravitational lensing of GWs***,** Cosmology 2023 in Miramare, 28 August- 02 September, 2023, SISSA, Trieste, Italy.

30. **Murli Manohar Verma** (2023) *Scalaron as dark matter in modified gravity*, XXIII International Meeting on Physical Interpretations of Relativity Theory (PIRT-2023), July 3-6, 2023, Bauman Moscow State University, Moscow, Russia.

The Bombay Public Trust Act, 1950

SCHEDULE - VIII
[Vide Rule 17 (1)]

Name of the Public Trust **Inter-University Centre for Astronomy and Astrophysics**

Registration No. : **F-5366**
Dated : 27.01.1989

Balance Sheet As At : 31.03.2024

FUNDS & LIABILITIES	Schedule no	Rs.	Current year 01.04.2023 to 31.03.2024 Rs	Previous year 01.04.2022 to 31.03.2023 Rs
Trusts Funds or Corpus :-	6			
Balance as per last Balance Sheet		2,45,95,413		
Adjustment during the year (give details)		21,80,154		
Schedule No. 6			2,67,75,567	2,45,95,413
Other Earmarked Funds :-	7			
(Created under the provisions of the trust deed or scheme or out of the Income)			12,25,95,552	11,44,03,826
Balance as per last Balance Sheet		**Opening Balance**		
Grant in Aid - 2 MTR (CAPITAL)			11,90,80,000	11,90,80,000
Grant in Aid BUILDING			11,97,49,000	11,97,49,000
Capital Grant to the Extent of Depriciation		(1,78,20,29,910)		
Additions during the year		(13,64,89,046)	(1,91,85,18,956)	(1,78,20,29,910)
Grant in Aid General (Capital) from UGC		2,57,12,56,873		
Additions during the year		18,00,00,000		
Add: Interest				
Less : Subtraction/reversed		(10,81,894)		
Schedule No. 7			2,75,01,74,979	2,57,12,56,873
Any Other Fund - Project Grants	8			
Schedule No. 8			36,99,34,793	36,63,77,901
Loans (Secured or Unsecured) :-				
From Trustees				NIL
From Others				NIL
Liabilities :-	10 & 10 A			
For Expenses and other liabilities			26,07,52,379	33,10,67,752
For Projects and Other Payables			7,22,57,553	9,03,36,338
For Rent & Other Deposits, duties and taxes			1,15,937	9,69,781
For Sundry Credit Balances			35,634	1,01,50,538
Schedule No. 10 &10 A				
Income and Expenditure Account :-	14			
Balance as per last Balance Sheet		(42,55,93,470)		
Less : Appropriation, if any		4,06,48,292		
Add : Deficit during the year		(7,80,54,688)		
Less Surplus				
Schedule No. 14			(46,29,99,865)	(42,55,93,470)
Total Rs.....			1,45,99,52,573	1,54,03,64,042

PROPERTY & ASSETS	Schedule no	Rs.	Current year 01.04.2023 to 31.03.2024 Rs	Previous year 01.04.2022 to 31.03.2023 Rs
Immovable Properties :- (At Cost)	11			
Balance as per last Balance Sheet		67,07,52,839		
Additions during the year		17,33,96,560		
Less : Sales /written off during the year		0		
Depreciation up to date		13,21,42,273		
Schedule No. 11			71,20,07,125	67,07,52,839
Investments :-	12			
Note : The market value of the above investment is Rs.				
Schedule No. 12			47,81,33,500	63,91,85,527
Furniture & Fixtures :-	11		1,84,46,643	2,09,48,145
Balance as per last Balance Sheet		2,09,48,145		
Additions during the year		18,45,271		
Less : Sales /written off during the year		0		
Depreciation up to date		43,46,773		
Schedule No. 11				
Loans (Secured or Unsecured) :				
Good/doubtful				NIL
Loans Scholarships				
Other Loans				NIL
Advances :-	13			
To Trustees				NIL
To Employees and other			1,36,90,907	1,12,70,286
To Suppliers/Security Deposits/Prepaid Exp.			2,27,96,595	1,46,78,136
To Lawyers				NIL
To Project and Other Receivables			12,02,633	46,03,786
Schedule no. 13 & 13A				
Income Outstanding :-				
Rent				
Interest				
Other Income				
Cash and Bank Balances :-	13			
(a) In Savings Account with Bank of Baroda				
In Fixed Deposit Account with				
(b) With the Trustee				
(c) With the Manager				
Schedule no. 13 B			21,36,75,171	17,89,25,324
Total Rs.....			1,45,99,52,573	1,54,03,64,042

As per our report of even date,

For Kirtane & Pandit LLP
Chartered Accountants
Firm Registration No. 105215W/W100057

KIRTANE & PANDIT LLP ★ FRN 105215W/W100057 ★ Chartered Accountants

Parag Pansare
(Partner)
Membership No. 117309

The above Balance Sheet to the best of my/our belief contains a true account of the Funds and Liabilities and of the Property and Assets of the Trust.

For Inter-University Centre for Astronomy and Astrophysics

M.S. Sahasrabudhe
Admin. Officer (Accounts)

N.V. Abhyankar
(Sr. Admin. Officer)

Prof. R. Srianand
Director / Trustee

Chairperson/Trustee
Governing Board

Place : Pune
Dated : 29.05.2024

matchstickds@gmail.com

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