INTER-UNIVERSITY CENTRE FOR ASTRONOMY AND ASTROPHYSICS

(An Autonomous Institution of the University Grants Commission)

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Highlights of 2010-2011

This annual report covers the activities of IUCAA during its twenty-third year, April 2010- March 2011.

The research activities and endeavours of IUCAA span different fronts, and are outlined in the pages of this report. Here, a quick summary and highlights are provided.

IUCAA has an academic strength of 15 core faculty members (academic), 10 post-doctoral fellows and 29 research scholars. The core research programmes by these academics span a variety of areas in astronomy and astrophysics. These topics include quantum theory and gravity, classical gravity, gravitational waves, cosmology and structure formation, cosmic microwave background radiation, observational cosmology and extragalactic astronomy, active galaxies, quasars and IGM, magnetic fields in astrophysics, high energy astrophysics, stars and the interstellar medium, and instrumentation. These research activities are summarised in pages 19 - 38. The publications of the IUCAA members, numbering to about 75 in the current year are listed in pages 39 - 41. IUCAA members also take part in pedagogical activities like lectures, seminars, popularisation of science, etc., the details of which are given in pages 42 - 51 and 65 - 66 of this Report.

The extended academic family of IUCAA consists of about 75 Visiting Associates, who have been active in several different fields of research. Pages 67 - 74 of this report highlights their research contributions. The resulting publications, numbering to about 130 are listed in pages 75 - 79 of this report. A total of about 1324 person-days were spent by Visiting Associates at IUCAA during this year. In addition, IUCAA was acting as host to about 700 visitors through the year. During the current year the Visiting Associates were drawn from 56 universities and colleges from all over India. The visitors to IUCAA came from over 160 institutions, universities and colleges which indicates the extent of participation of the university sector in IUCAA's activities.

IUCAA conducts its graduate school jointly with the National Centre for Radio Astrophysics, Pune. Among the research scholars, one student has successfully defended his thesis and obtained Ph.D. degree from the University of Pune during the year 2010 - 2011. Abstract of his thesis appears in page 55.

Apart from these activities, IUCAA conducts several workshops, schools, and conferences each year, both at IUCAA and at different university/college campuses. During this year, there were 11 such events in IUCAA and 10 were held at other universities/colleges under IUCAA sponsorship.

Another main component of IUCAA's activities is its programme for Science Popularisation. On the National Science Day, several special events were organised, which included a special workshop on making simple spectroscopes. There were posters displayed by the academic members of IUCAA, which elaborated on the research work at IUCAA and topics in the field of astronomy. There were public lectures given by the faculty members and programmes for school students consisting of quiz, essay and drawing competitions. During the Open Day, about 6500 people visited IUCAA.

The activities carried out by IUCAA were ably supported by the scientific and technical, and administrative staff (27 and 31 in number respectively) who should get the lion's share of the credit for the successful running of the programmes of the centre. The scientific staff also looks after the major facilities like library, computer centre, IUCAA Girawali observatory and instrumentation lab. A brief update on these facilities is given on pages 56 - 61 of this Report.

Swara Ravindranath
Editor

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The Council and the Governing Board

The Council (As on March 31, 2011)

President

SUKHADEO THORAT, Chairperson, University Grants Commission, New Delhi (till February 2011)

Vice-President

VED PRAKASH, Vice-Chairperson, University Grants Commission, New Delhi.

Members

Anil Kakodkar, (*Chairperson, Governing Board*), DAE Homi Bhabha Chair Professor, Bhabha Atomic Research Centre, Mumbai.
P. C. Agrawal, Mumbai.
Geeta Bali, Vice-Chancellor, Karnataka State Women's University, Bijapur.
Samir K. Brahmachari, Director General, Council of Scientific And Industrial Research, New Delhi.
Mihir K. Chaudhuri, Vice-Chancellor, Tezpur University.
Praveen Chhadah, Director, UGC-DAEF Consortium for Scientific Research, Indore.
Swarna Kanti Ghosh, Centre Director, National Centre for Radio Astrophysics, Pune.
J.N. Goswami, Director, Physical Research Laboratory, Ahmedabad.
Chanda Jog, Indian Institute of Science, Bengaluru.
Niloufer Kazmi, Secretary, University Grants Commission, New Delhi.
Devang V. Khakhar, Director, Indian Institute of Technology, Mumbai.
M. Basheer Ahmed Khan, Vice-Chancellor, Sido Kanhu Murmu University, Jharkhand.
Parthasarathi Majumdar, Saha Institute of Nuclear Physics, Kolkata.
Ram Rajesh Misra, Vice-Chancellor, Rani Durgavati Vishwavidyalaya, Jabalpur.
T. V. Shivshankara Murthy, Vice-Chancellor, Mangalore University.
K. Ramamurthy Naidu, Hyderabad.
K. Radhakrishnan, Chairman, Indian Space Research Organization, Bengaluru.
T. Ramasami, Secretary, Department of Science And Technology, New Delhi.
R. K. Shevgaonkar, Vice-Chancellor, University of Pune
H. P. Singh, University of Delhi
Kandaswamy Subramanian, Inter-university Centre for Astronomy and Astrophysics, Pune.
J. A. K. Tareen, Vice-Chancellor, Pondicherry University

Member Secretary

Ajit K. Kembhavi, Director, IUCAA, Pune.

The Following Members Have Served On The Council For Part Of The Year

G. Baskaran, The Institute Of Mathematical Sciences, Chennai.
Sanjay G. Dhande, Director, Indian Institute of Technology, Kanpur.
N. S. Gajbhiye, Vice-Chancellor, Dr. Harisingh Gour University, Madhya Pradesh.
A. M. Pathan, Vice-Chancellor, Central University of Karnataka, Gulbarga.
A. N. Rai, Vice-Chancellor, Mizoram University, Aizawl.
G. Thiruvasagam, Vice-Chancellor, University of Madras, Chennai.
G. Sarojamma, Vice-Chancellor, Sri Padmavati Mahila Visvavidyalayam, Tirupati.
M. Sami, Head, Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi.

The Governing Board

Chairperson

Anil Kakodkar

Members

P.C. Agrawal	**Mihir K. Chaudhuri**	**Praveen Chhadah**	**Swarna Kanti Ghosh**
J.N. Goswami	**Niloufer Kazmi**	**K. Ramamurthy Naidu**	**R.K. Shevgaonkar**
Kandaswamy Subramanian	**J.A.K. Tareen**		

Member Secretary

Ajit K. Kembhavi, Director, IUCAA, Pune.

The following member has served on the Governing Board for part of the year

S.S. Hasan, Director, Indian Institute of Astrophysics, Bangalore.

Honorary Fellows

E. Margaret Burbidge, Centre for Astronomy and Space Sciences, University of California, USA.
Russell Cannon, Anglo-Australian Observatory, Australia.
E.P.J. van den Heuvel, Astronomical Institute, University of Amsterdam, The Netherlands.
Antony Hewish, University of Cambridge, UK.
Gerard 't Hooft, Spinoza Institute, The Netherlands.
Donald Lynden-Bell, Institute of Astronomy, University of Cambridge, UK.
Yash Pal, Noida, India
Allan Sandage, (Expired on November 14, 2010) The Observatories of the Carnegie Institution of Washington, USA.
Govind Swarup, (from May 18, 2010) Emeritus Professor, National Centre for Radio Astrophysics, Pune

Statutory Committees

The Scientific Advisory Committee (SAC)

P.C. Agrawal, Mumbai.
Abhay Ashtekar, Director, Institute for Gravitation and the Cosmos, USA.
Deepak Dhar, Tata Institute of Fundamental Research, Mumbai.
Andrew C. Fabian, University of Cambridge, UK.
Yashwant Gupta, National Centre for Radio Astrophysics, Pune.
Romesh Kaul, The Institute of Mathematical Sciences, Chennai.
P.N. Pandita, North-Eastern Hill University, Shillong.
Martin M. Roth, Astrophysikalisches Institut Potsdam (AIP), Germany.
Ajit K. Kembhavi, Director, IUCAA, Pune.

The Users' Committee

Ajit K. Kembhavi, (Chairperson, Ex-officio Member), Director, IUCAA, Pune.
Sanjeev Dhurandhar, IUCAA, Pune.
Dipankar Bhattacharya, IUCAA, Pune.
Mihir K. Chaudhuri, Vice-Chancellor, Tezpur University.
Indra Vardhan Trivedi, Vice-Chancellor, Mohanlal Sukhadia University, Udaipur.
T. Ramachandran, Vice-Chancellor, Cochin University of Science and Technology (CUSAT), Kochi.
M.K. Patil, Swami Ramanand Teerth Marathwada University, Nanded.
Sarbari Guha, St. Xavier's College, Kolkata.

The following member has served on the Committee for part of the year

Arpana Arora, Vice-Chancellor, Mohanlal Sukhadia University, Udaipur.

The Academic Programmes Committee

Ajit K. Kembhavi (Chairperson)
Dipankar Bhattacharya
Ranjan Gupta
A.N. Ramaprakash
Tarun Souradeep
T. Padmanabhan (Convener)
Gulab C. Dewangan
Ranjeev Misra
Swara Ravindranath
R. Srianand
Joydeep Bagchi
Sanjeev V. Dhurandhar
Maulik Parikh (resigned on 29/10/2010)
Varun Sahni
Kandaswamy Subramanian

The Standing Committee for Administration

Ajit K. Kembhavi (Chairperson)
K.C. Nair (retired 31.12.2010)
(Member Secretary)
T. Padmanabhan
E. M. Modak
(Member Secretary) (from 31.01.2011)
Sanjeev V. Dhurandhar

The Finance Committee

A. Kakodkar (Chairperson)
K. Subramanian
T. R. Kem
A. K. Kembhavi
A. K. Dogra
K.C. Nair (retired 31.12.2010)
(Non-member Secretary)
N. A. Kazmi
S. K. Ghosh
E.M. Modak
(Non-member Secretary) (from 31.01.2011)

Members of IUCAA

Academic

Ajit K. Kembhavi (Director)

Joydeep Bagchi
Ranjan Gupta
A.N. Ramaprakash
Tarun Souradeep

T. Padmanabhan
(Dean, Core Academic Programmes)
Dipankar Bhattacharya
Ranjeev Misra
Swara Ravindranath
R. Srianand

Sanjeev V. Dhurandhar
(Dean, Visitor Academic Programmes)
Gulab C. Dewangan
Maulik Parikh (resigned on 29/10/2010)
Varun Sahni
Kandaswamy Subramanian

Emeritus Professors

Jayant V. Narlikar
Naresh K. Dadhich
Shyam N. Tandon

Scientific and Technical

Prafull S. Barathe
Santosh S. Bhujbal
V. Chellathurai (retired on 30.4.2010)
Hillol K. Das
Sudhakar U. Ingale
Shashikant G. Mirkute
N. Nageswaran

Swapnil M. Prabhudesai
Chaitanya V. Rajarshi
Nirupama U. Bawdekar
Mahesh P. Burse
Kalpesh S. Chillal
Samir A. Dhurde
Abhay A. Kohok

Deepa Modi
Arvind Paranjpye
Sujit P. Punnadi
Hemant Kumar Sahu
Rani S. Bhandare
Shanker B. Chavan
Pravinkumar A. Chordia

Gajanan B. Gaikwad
Vilas B. Mestry
Vijay Mohan
Sarah Ponrathnam
Vijay Kumar Rai
Yogesh R. Thakare

Administrative and Support

E. M. Modak
(Senior Administrative Officer)
Sandeep L. Gaikwad
Baban B. Jagade
Santosh N. Khadilkar
Kumar B. Munuswamy
Mukund S. Sahasrabudhe
Snehalata Shankar (retired on 31.01.2011)
Sadanand R. Tarphe

Niranjan V. Abhyankar

Bhagiram R. Gorkha
Sandip M. Jogalekar
Susan B. Kuriakose
K. C. Nair (retired on 31.12.2010)
Vyankatesh A. Samak
Deepak R. Shinde
Shankar K. Waghela

Vijay P. Barve

Bhimpuri S. Goswami
Nilesh Kadam
Neelima S. Magdum
Rajesh D. Pardeshi
Senith S. Samuel
Varsha R. Surve
Kalidas P. Wavhal

Savita K. Dalvi

Ramesh S. Jadhav
Swati D. Kakade
Manjiri A. Mahabal
Rajesh V. Parmar
Balaji V. Sawant
Deepika M. Susainathan

Post-doctoral Fellows

Bhaswati Bhattacharyya
Surajit Paul
Radouane Gannouji

Kinjal Banerjee
Harsha Raichur
Prakash Sarkar

Jayanti Prasad
Sanil Unnikrishnan
Bibhas Majhi

Project Scientist

Rizwan Ansari

Research Scholars

Moumita Aich
Saugata Chatterjee
Mohammad Hasan
Dawood Kothawala
Sowgat Muzahid
Suprit Singh
Pritesh Randive

Maryam Arabsalmani
Santanu Das
Charles Jose
Sandeep Kumar
Hadi Rahmani
Mudit Kumar Srivastava
Krishanamohan P.

Bruce Cabral
Tuhin Ghosh
Nisha Katyal
Sibasish Laha
Aditya Rotti
Kaustubh Vaghmare
Vikram Khaire

Luke Chamandy
Gaurav Goswami
Sanved Kolekar
Dipanjan Mukherjee
Prashant Kumar Samantray
Pallavi Bhat
Nagendra Kumar
Mainpal Rajan

Temporary/Project/Contractual Appointments

Tushar Agrawal
Santosh Jagade
Manish Kharade
Sharmad D. Navelkar

Ashok Rupner
Rucha Sule
Neelam S. Bhujbal
Jeetendra S. Joshi

Shrirang Zodage
Manish Karjule
Sagar Shah
A.K. Tamrakar
V. Chellathurai

Aparna Joshi
Maharudra Mate
Nilesh Pokharkar
Sakya Sinha
Sangita Thakare
Kirti Tonpe

Part-time Consultant

Vidula Mhaiskar

Vitthal Savaskar

N. V. Nagarathnam

Long Term Visitors

Arvind Gupta

P.P. Divakaran

Pushpa Khare

R. Tikekar

Ninan Sajeeth Philip

Visiting Associates of IUCAA

Sk. Saiyad Ali	Department of Physics, Jadavpur University, Kolkata.
G. Ambika	Department of Physics, Indian Institute of Science Education and Research, Pune.
B.R.S. Babu	Department of Physics, University of Calicut, Kozhikode.
N. Banerjee	Department of Physical Sciences, Indian Institute of Science Education and Research, Kolkata,
S.K. Banerjee	Department of Mathematics, University of Petroleum and Energy Studies, Dehradun
Vasudha Bhatnagar	Department of Computer Science, University of Delhi.
Gour Bhattacharya	Department of Physics, Presidency College, Kolkata.
S.N. Borah	Department of Physics, DKD College, Dergaon.
Somenath Chakrabarty	Department of Physics, Visva Bharati, Santiniketan.
Pavan Chakraborty	Robotics and AI Division, Indian Institute of Information Technology, Allahabad.
Subenoy Chakraborty	Department of Mathematics, Jadavpur University, Kolkata.
Suresh Chandra	School of Physics, Shri Mata Vaishno Devi University, Kakryal-Katra.
Asis Kumar Chattopadhyay	Department of Statistics, Calcutta University, Kolkata.
Tanuka Chattopadhyay	Department of Applied Mathematics, Calcutta University, Kolkata.
Ajay S. Chaudhari	School of Physical Sciences, Swami Ramanand Teerth Marathwada University, Nanded.
Rabin Kumar Chhetri	Department of Physics, Sikkim Government College, Gangtok.
H.S. Das	Department of Physics, Assam University, Silchar.
Ujjal Debnath	Department of Mathematics, Bengal Engineering and Science University, Howrah.
Jishnu Dey	Department of Physics, Presidency College, Kolkata.
Mira Dey	Department of Physics, Presidency College, Kolkata.
Anjan Dutta	Department of Physics and Astrophysics, University of Delhi.
Sushant Ghosh	Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi.
P.S. Goraya	Department of Physics, Punjabi University, Patiala.
Sarbari Guha	Department of Physics, St. Xavier's College, Kolkata.
K.P. Harikrishnan	Department of Physics, The Cochin College, Kochi.
N. Ibohal	Department of Mathematics, University of Manipur, Imphal.
Naseer Iqbal Bhat	P.G. Department of Physics, University of Kashmir, Srinagar.
S.N.A. Jaaffrey	Department of Physics, University College of Science, M.L. Sukhadia University, Udaipur.
Joe Jacob	Department of Physics, The Newman College, Thodupuzha.
Deepak Jain	Department of Physics and Electronics, Deen Dayal Upadhyaya College, Delhi.
Sanjay Jhingan	Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi.
Kanti Jotania	Department of Physics, The M.S. University of Baroda, Vadodra.
Minu Joy	Department of Physics, Alphonsa College, Pala.
Nagendra Kumar	Department of Mathematics, M.M.H. College, Ghaziabad.
V.C. Kuriakose	Department of Physics, Cochin University of Science and Technology, Kochi.
Manzoor A. Malik	Department of Physics, University of Kashmir, Srinagar.
Mamta	Department of Physics and Electronics, SGTB Khalsa College, Delhi.
Pradip Mukherjee	Department of Physics, Barasat Government College, Barasat
K.K. Nandi	Department of Mathematics, North Bengal University, Siliguri.
Sanjay Pandey	Department of Mathematics, L.B.S. (P.G.) College, Gonda.
S.K. Pandey	Vice-Chancellor, Pt. Ravishankar Shukla University, Raipur.
P.N. Pandita	Department of Physics, North Eastern Hill University, Shillong.
K.D. Patil	Department of Mathematics, B.D. College of Engineering, Sevagram.

M.K. Patil	School of Physical Sciences, Swami Ramanand Teerth Marathwada University, Nanded.
B.C. Paul	Department of Physics, North Bengal University, Siliguri.
Ninan Sajeeth Philip	Department of Physics, St. Thomas College, Kozhencherri.
Farook Rahaman	Department of Mathematics, Jadavpur University, Kolkata.
S. Rastogi	Department of Physics, D.D.U. Gorakhpur University.
C.D. Ravikumar	Department of Physics, University of Calicut, Kozhikode.
Saibal Ray	Department of Physics, Government College of Engineering and Ceramic Technology, Kolkata.
Biplab Raychaudhuri	Department of Physics, Visva Bharati, Santiniketan.
Anirban Saha	Department of Physics, West Bengal State University, Barasat.
Sandeep Sahijpal	Department of Physics, Panjab University, Chandigarh.
E. Saikia	Department of Physics, Inderprastha Engineering College, Ghaziabad.
Sanjay Baburao Sarwe	Department of Mathematics, St. Francis De Sales College, Nagpur.
Anjan Ananda Sen	Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi.
Asoke Kumar Sen	Department of Physics, Assam University, Silchar.
T.R. Seshadri	Department of Physics and Astrophysics, University of Delhi.
K. Shanthi	Academic Staff College, University of Mumbai.
Ranjan Sharma	Department of Physics, P.D. Women's College, Jalpaiguri
H.P. Singh	Department of Physics and Astrophysics, University of Delhi.
M. Sivakumar	School of Physics, University of Hyderabad.
Pranjal Trivedi	Department of Physics, Sri Venkateswara College, Delhi.
Paniveni Udayashankar	Department of Physics, NIE Institute of Technology, Mysore.
A.A. Usmani	Department of Physics, Aligarh Muslim University.

Till July 31, 2010

Ranabir Dutt	Department of Physics, Visva Bharati, Santiniketan.
Chanda Jog	Department of Physics, Indian Institute of Science, Bengaluru.
Pradeep K. Srivastava	Department of Physics, D.A.V. (P.G.) College, Kanpur.

From August 1, 2010

Farooq Ahmad	Department of Physics, University of Kashmir, Srinagar.
Tanwi Bandyopadhyay	Department of Mathematics, Shri Shikshayatan College, Kolkata.
Bhag Chand Chauhan	Department of Physics, Government College, Karsog, Mandi.
K. Indulekha	School of Pure and Applied Physics, Mahatma Gandhi University, Kottayam.
Md. Mehedi Kalam	Department of Physics, Aliah University, Kolkata.
Archana Pai	Indian Institute of Science Education and Research, Thiruvananthapuram
Anirudh Pradhan	Department of Mathematics, Hindu Post-Graduate College, Ghazipur.
Tarun Deep Saini	Department of Physics, Indian Institute of Science, Bengaluru.
Pramoda Kumar Samal	Department of Physics, Utkal University, Bhubaneswar.

The twenty-first batch of Visiting Associates, who were selected for a tenure of three years, beginning August 1, 2010

Farooq Ahmad

Bhag Chand Chauhan

Md. Mehedi Kalam

Tanwi Bandyopadhyay

K. Indulekha

Archana Pai

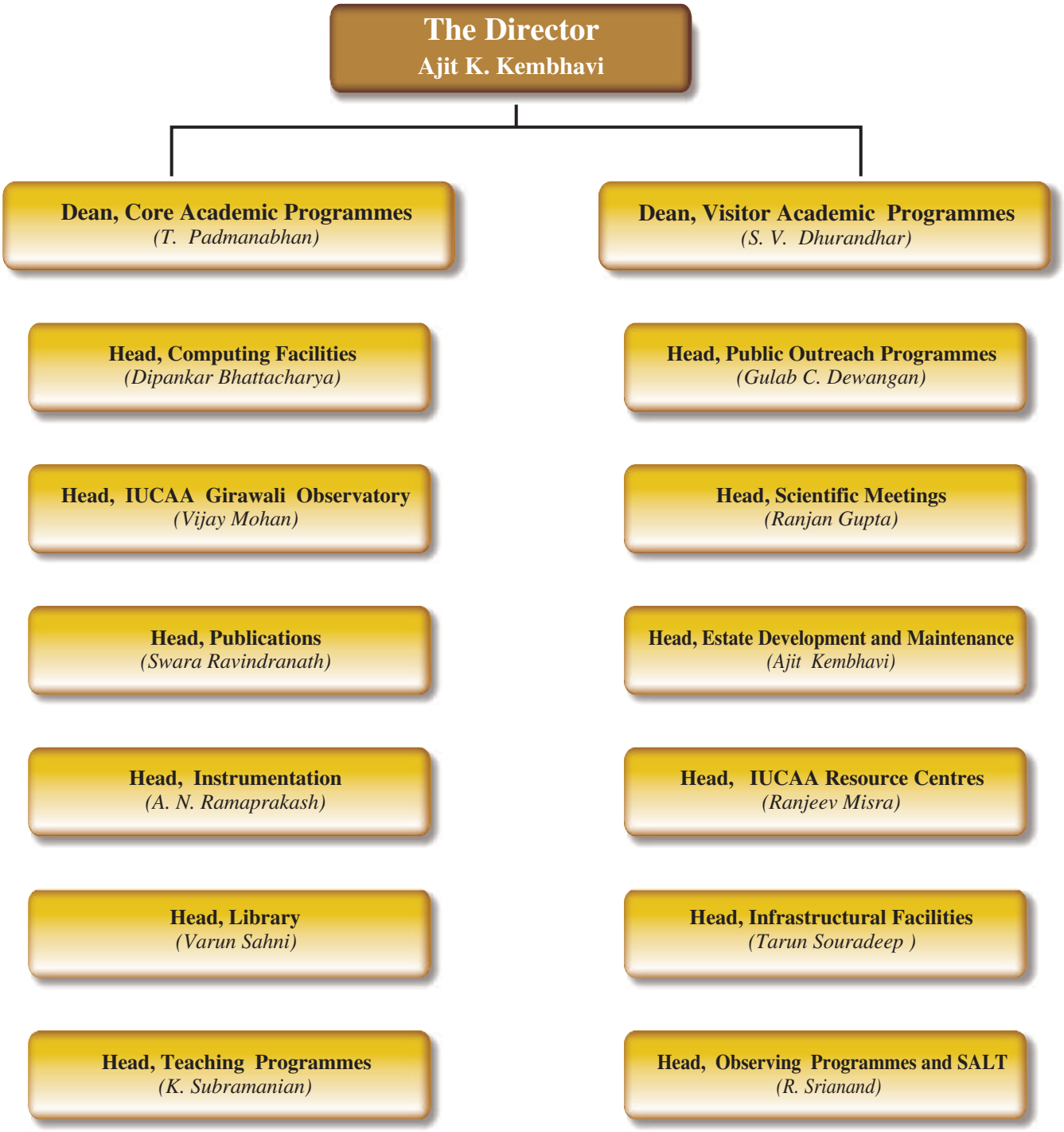
Anirudh Pradhan

Pramoda Kumar Samal

Tarun Deep Saini

Appointments of the following Visiting Associates from the eighteenth batch were extended for three years : G. Ambika, Narayan Banerjee, Pavan Chakraborty, Subenoy Chakaraborty, Himadri Sekhar Das, Sushant G. Ghosh, K.P. Harikrishnan, S.N. A. Jaffrey, Sanjay Jhingan, Kanti R. Jotania, Nagendra Kumar, P.N. Pandita, Madhav K. Patil, Biplab Raychaudhuri, Anirban Saha, Anjan Ananda Sen, Harinder Pal Singh, Paniveni Udayashankar, and Anisul Ain Usmani.

Organizational Structure of IUCAA's Academic Programmes (From August 1, 2010)



DIRECTOR'S REPORT

The year covered by this report has been one of consolidation as well as planning at IUCAA. Some projects which were started sometime ago have now come to fruition, while several new projects, which could have a major impact on the work done at IUCAA are in progress.

The academic and technical staff at IUCAA have been active as ever, and significant theoretical, observational and instrumentation projects have been completed. Five research scholars and three post-doctoral fellows have joined IUCAA during the year, and Professor Govind Swarup, FRS, has accepted an invitation to be an Honorary Fellow of IUCAA.

The performance of the 2 metre telescope at IUCAA Girawali Observatory (IGO), and observing conditions there have been excellent, so that very useful data have been obtained. The technical problems which plagued the 10 metre Southern African Large Telescope (SALT), in which IUCAA has a share, have now been resolved satisfactorily, and data of excellent quality have been obtained in test runs. The first general call for observing proposals for SALT is expected to be put out in June 2011.

The instrumentation group has been working on the very exciting Robo-AO project in collaboration with California Institute of Technology (Caltech). The goal of the project has been to fabricate a low cost, dynamic, laser-guide-star adaptive optics system. Important components of the system have been developed in the IUCAA instrumentation laboratory, and IUCAA staff have made regular visits to Caltech and the Palomar Observatory for integration and testing. The system is expected to be ready in the second half of 2011. The instrumentation group has also completed a data acquisition and handling system for the near-infrared arm of the Robert Stobie spectrograph for SALT. This project has been carried out in collaboration with the University of Wisconsin, and IUCAA will receive a certain number of observing nights on SALT using the instrument. There has been significant progress in the fabrication of Ultra Violet Imaging Telescope (UVIT) for ASTROSAT, with the work being carried out in collaboration with the Indian Institute of Astrophysics (IIA) in that Institute's laboratories in Bengaluru.

The computer centre at IUCAA has acquired GPGPU (General Purpose Graphics Processing Units) to purely fulfill its high performance computing needs. The system offers a very cost effective solution with 6 Tflop/s. In order to meet the demand for connectivity in IUCAA, a campus-wide Wireless Local Area Network (WLAN) has been implemented in both residential and office premises. IUCAA now acquired 1 Gbps connectivity through National Knowledge Network (NKN). Steps are being taken to develop the technical infrastructure required for installing a high performance computer and data centre.

Much progress has been made with the planned new construction work at IUCAA, which consists of extensions to the computer centre and instrumentation laboratories, a new guest house and additional quarters for staff and visitors. The designs for the new buildings have been completed by Architect Charles Correa and his team, and the required municipal clearances and permissions have been obtained. The process for identifying a contractor has begun and it is expected that a contract will be awarded by the end of August 2011.

The thirteenth meeting of the Scientific Advisory Committee (SAC) of IUCAA took place during January 6-11, 2011. Committee members present at the meeting were Professors P.C. Agrawal, Abhay Ashtekar, Andrew C. Fabian, Yashwant Gupta, Romesh Kaul, P.N. Pandita, and Martin M. Roth. Professor Craig Mackay of the Institute of Astronomy, Cambridge, was a special invitee and Professor Andrew Fabian chaired the meeting. The committee had expressed satisfaction at the active research being carried out by the academic members, observations being carried out at IGO, and the progress made with the instrumentation laboratory, and the computing facilities. The SAC had made specific recommendations for increase in the faculty, post-docs and students numbers and made suggestions for identifying good candidates for faculty positions at IUCAA. The committee had expressed appreciation of IUCAA's participation in projects like ASTROSAT, TMT, SALT, and IndIGO consortium.

A number of programmes have been carried out for universities and colleges at IUCAA, as well as many other campuses. The data centres set-up at the six IUCAA Resource Centres (IRCs) at Siliguri, Kolkata, Delhi, Raipur, Udaipur, and Kochi are now fully operational. These are being used to train young faculty and students in techniques of data analysis. Virtual Observatory tools are increasingly being used in these exercises. The IRCs have been organizing a number of workshops, seminars and training sessions built around specific research topics, which have led to an increase in the number of students carrying out research in astronomy in university departments and colleges. A large number of university faculty and students have been visiting IUCAA for their research work and to attend workshops and conferences during the year. There were around 80 Visiting Associates from universities and colleges, many of whom have spent significant periods at IUCAA for their research work using the facilities at IUCAA. Majority of these Visiting Associates collaborate with IUCAA faculty and bring their research scholars to use the facilities. Students from various universities also visit IUCAA in large numbers and some of these students have been guided for their thesis work by IUCAA faculty.

Of the many workshops and meetings conducted at IUCAA during the year, special mention could be made of a Conference on Wideband X-ray Astronomy, Frontiers in Timing and Spectroscopy, which was attended by leading astronomers in the field from India and abroad. One of the aims of this conference was to discuss scientific projects, which could be carried out using ASTROSAT after its launch. Another interesting workshop on the World Wide Telescope and Virtual Observatory was organized, as a part of the Public Outreach activities at IUCAA, in collaboration with Microsoft Research, and was widely attended by high school and college teachers, and students in and around Pune.

IUCAA has been involved in the formulation of plans to participate in some major international projects. One of these is the Thirty Metre Telescope (TMT), which is proposed to be built by an international consortium. The TMT which will be located in Hawaii is expected to be ready towards the end of this decade, and will be one of the largest optical and infrared telescopes. Operating over the next few decades, IUCAA together with IIA, Bangalore and ARIES, Nainital has received a grant from the Department of Science and Technology (DST) to develop prototypes of various hardware sub-systems and software for this telescope. After official approval is received from concerned departments of the Government, India will become a partner in the Consortium, fully participate in the development of the telescope, and acquire observing rights on it. IUCAA, together with other members of the Indian Initiative in Gravitational-Wave Observations (IndIGO) Consortium is in discussion with American counterparts about setting up a gravitational wave data analysis centre at IUCAA. The possibility of locating an advanced LIGO gravitational wave detector in India is also under consideration.

During the year, there have been some important changes in the administration at IUCAA. Mr. K.C. Nair, Senior Administrative Officer had retired from service on December 31, 2010 and Mrs. S. Shankar, who was the Administrative Officer (Visitor Services), had taken voluntary retirement w.e.f. January 31, 2011. Both these people had provided excellent and efficient services to IUCAA during their long tenure. Mrs. Shankar, in particular, had helped to create and sustain the complex Visitor Programmes at IUCAA and her services have been appreciated by everyone in the institute, as well as the many visitors who benefitted from her help over the years. Mr. E.M. Modak, who was an Administrative Officer at IUCAA, was selected through an open interview to be the next Senior Administrative Officer. Because of the two vacancies created, a number of administrative staff in IUCAA have benefitted through promotions. The IUCAA administration has been known for the excellent support that it provides for all the activities including the extensive Visitor Programmes. I am glad to say that inspite of the departure of very senior staff from the administration, it has been possible to provide all services at the very high levels expected from the IUCAA administrative staff.

I wish to thank the Governing Board and in particular, the Chairperson Dr. Anil Kakodkar for the constant support and encouragement provided to IUCAA and to me personally. Likewise the Council too has been always very encouraging and supportive. The President of the Council, Professor Sukhadeo Thorat demitted office as Chairperson of the University Grants Commission and consequently as the President of the Council in February 2011. On behalf of all my colleagues at IUCAA, and on my own behalf, I wish him every success in his new responsibilities. Our work would not have been possible without the great support provided by the University Grants Commission and its officers, and most importantly, the scientific, technical and administrative staff of IUCAA.

Ajit Kembhavi
(Director)

Congratulations to ...

JAYANT NARLIKAR,
on being conferred with

S.L. Kirloskar Achievement Award from the People's Art Centre, Mumbai, May 3.

Distinguished Lecture Medal from College de France, Paris, June 24.

Baroda Sun Lifetime Achievement Award from the Bank of Baroda, July 20.

Shri. Naresh Mehta Smriti Vangmaya Samman from the Madhya Pradesh Rashtrabhasha Prachar Samiti, Bhopal, January 29.

Maharashtrabhushan Puraskar

by the Government of Maharashtra.

Honors

D. Litt. Tilak, Maharashtra Vidyapeeth, Pune.

ARVIND PARANJPYE, on being conferred with the ***Vocational Excellence Award*** by The Rotary Club of Gandhi Bhawan, Pune.

VARUN SAHNI was elected Fellow of the Indian National Science Academy.

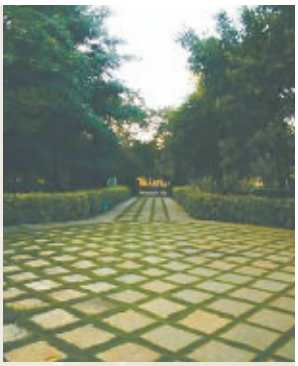
ARVIND GUPTA,

on being conferred with the ***Professor T. Navaneeth Rao's Best Teacher Award*** by A.V. Rama Rao Research Foundation in association with Indian Institute of Chemical Technology (IICT), Hyderabad, for 2010.

on being conferred with the ***TWAS Regional Prize*** for Public Understanding and Popularization of Science by the TWAS Regional Office for Central and South Asia (TWAS-ROCASA), Bengaluru.

on being conferred with the ***Sri Chandrasekarendra Saraswati National Eminence Award*** in the field of Science and Technology by the South Indian Education Society (SIES), Mumbai.

IUCAA ACADEMIC CALENDAR 2010-11



2010

April 1 - 30
IGO Training School in Observational Astronomy
at IUCAA

April 5 - 9
Advanced Workshop on Astronomy: Observations, Theory, and Interpretations
at IRC, North Bengal University, Siliguri

April 12 - May 21
School Students' Summer Programme
at IUCAA

May 7
IUCAA-NCRA Graduate School
Second semester ends

May 10 - June 11
Introductory Summer School on Astronomy and Astrophysics (for College /University students)
at IUCAA

May 10 - June 25
Vacation Students' Programme
at IUCAA

August 9
IUCAA - NCRA Graduate School
First semester begins

September 4
Workshop on World Wide Telescope and Virtual Observatory
at IUCAA

October 4 - 8
Workshop on Advanced Statistical Techniques for Astronomy
at IUCAA

October 26 - 29
Workshop on Optical and Infrared Astronomy
at D.D. U. Gorakhpur University

November 12 - 13
Workshop on Laboratory Astrophysics: Applications to Cosmic Dust
at M. G. Science Institute, Ahmedabad

November 23 - 25
Workshop on Data Analysis Techniques in Astronomy
at Burdwan University

November 26 - 28
Workshop on Astrophysics and Cosmology
at IRC, West Bengal State University, Barasat

December 6 - 10
Workshop on Photometer Fabrication
at IUCAA

December 6 - 17
IndIGO School on Gravity Wave Astronomy
at IRC, University of Delhi

December 10
IUCAA - NCRA Graduate School
First semester ends

December 15 - 17
Workshop on Compact Objects (in collaboration with University of Kwazulu-Natal, South Africa)
at IUCAA

December 15 - 17
Introductory Workshop on Astronomy and Astrophysics (with one day on Star Formation)
at NECRD/ IGNOU, Guwahati

December 20, 2010 - January 15, 2011
IGO Training School in Observational Astronomy
at IUCAA

December 29
Foundation Day

2011

January 3
IUCAA-NCRA Graduate School
Second semester begins

January 13 - 16
International Conference on Wideband X-ray Astronomy, Frontiers in Timing and Spectroscopy
at IUCAA

February 21 - 26
School on Recent Advances in Cosmology
at North Bengal University, Siliguri

February 28
National Science Day

March 3 - 7
Workshop on X-ray Astronomy
at Tezpur University,

March 15 - 18
IUCAA School on Gravitation and Astrophysics
at Centre for Theoretical Physics, Jamia, Millia Islamia New Dehli

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RESEARCH AT IUCAA

Quantum Theory and Gravity

On the measure of spacetime and gravity

By following the general guiding principle that nothing should be prescribed or imposed on the universal entity, spacetime, **Naresh Dadhich** established that it is homogeneity (by which, it is meant homogeneity and isotropy of space and homogeneity of time) that requires not only a universally constant invariant velocity but also an invariant length given by its constant curvature, Λ . This is a 'free' state of spacetime, which is completely free of all forces and their dynamics. It is the state characterized by Newton's First Law.

Since both space and time are homogeneous they could be freely interchanged without affecting the 'free' state of spacetime. Although, their dimension does not match, however, the requirement of homogeneity has to be met. Thus, an universal constant velocity c, has to be brought in as a fundamental new constant of spacetime structure, as requirement of the general concept of homogeneity of space and time. Adhering to the general principle of no imposition or prescription for spacetime, since spacetime is homogeneous, its curvature must also be homogeneous, which means, it should be covariantly constant, $\nabla_e R_{abcd} = 0$. The only thing that is constant relative to covariant derivative is the metric, hence, homogeneous curvature is given by $R_{abcd} = \Lambda (g_{ac} g_{bd} - g_{ad} g_{bc})$, where Λ is a constant, the measure of curvature of spacetime. Like c, Λ thus, emerges as another natural constant of spacetime structure. These are the only two most fundamental constants that are the part of spacetime structure, and no other constant could claim being fundamental to this degree.

Thus, the geometry of homogeneous spacetime, which is the analogue of Newtonian free space is in general curved and has constant curvature and includes the zero curvature flat spacetime as a special case. In special relativity, geometry of spacetime was assumed to be flat described by the Minkowski metric, while the dynamical characterization of *free* (homogeneous) spacetime would have determined it to have constant curvature and not necessarily zero curvature. Minkowski geometry was, therefore, a prescription imposed on spacetime, it is not the natural and general geometry of free spacetime. What it means is that without any imposition from outside, the *free spacetime* has homogeneous (constant) curvature with Λ as its measure. It would be described by dS/AdS metric depending upon the curvature being positive or negative, and when it is zero, it is the flat Minkowski spacetime.

As homogeneity characterized absence of dynamics, inhomogeneity would imply the presence of dynamics.

Again, nothing to be imposed from outside, it should be given by the Riemann curvature of spacetime. It satisfies the Bianchi differential identity, which on taking trace lead to the Einstein equation for gravity with Λ. Here, the only thing we have to put from outside is the identification of the source for gravity with the energy momentum distribution. It is the inhomogeneity of spacetime that drives gravity and hence, it has to be an universal force linking to everything that physically exists. Since, its linkage is universal, its source should be a universal property, which is shared by all, and that is energy-momentum. The gravitational dynamics is, thus, part of inhomogeneous spacetime structure.

The association of Λ with the vacuum energy is not quite valid. Note that vacuum energy, a secondary effect caused by the presence of matter and that is what should appear in the equation as a source. It is like gravitational field energy, which is never included as a source. How does then it gravitate, and if it gravitates it must like everything else? In GR, it gravitates through enlargement of the spacetime framework from flat to curved, its contribution gets automatically taken care of. This is what should precisely happen for the vacuum energy, which unfortunately would be exposed only when there emerges a full quantum theory of gravity - only then would the enlargement of framework become visible. Hence, for gravitational understanding of vacuum energy, there seems no short cut but to wait for quantum theory of gravity.

Since Λ has nothing to do with the vacuum energy, it is free to have any value like any other constant. It offers the simplest and clearest explanation of the observations of the accelerating universe without any recourse to exotic dark energy. The observations are, in fact, measuring the new constant of spacetime as envisaged in the equation of motion for gravitation. Interestingly, the embarrassment of great mismatch of numbers could be turned into a virtue by turning the argument on its head, it could as well be envisioned that in terms of the Planck area, the universe measures 10^{120} units!

As velocity of light binds space and time into spacetime, Λ curves the spacetime and prepares it for the description of gravitational dynamics. Then gravity does not produce a discontinuous change from flat to curved in the spacetime structure, because it only makes the homogeneous spacetime inhomogeneous.

Gravity hydrodynamics of spacetime

The view that gravity is an emergent phenomenon is one which has been gaining ground over the last decade. In this paradigm, one considers the field equations of gravity as having the same status as the equations of elasticity or fluid mechanics. One could use the latter to study the vibrations of a steel rod or a steam engine without ever worrying about the microscopic molecular structure of the materials involved. In the same way, gravitational field equations describe the

behaviour of continuum spacetime even though the microscopic structure of spacetime could be discrete and made up of, as yet, unknown 'atoms of spacetime'.

In the case of normal material, the existence of thermal phenomena provides a bridge connecting microscopic and macroscopic behaviour. As first pointed out by Boltzmann, matter cannot be heated up if it has no microscopic structure; in fact, the heat content of a body is a direct measure of the microscopic dynamics (e.g., the random motion of the molecules in a gas) of its constituents. The number of microscopic degrees of freedom N required to store a given amount of energy E at temperature T is given by the equipartition law $N = E/[(1/2)kT$, which gives a microscopic, discrete, quantity N in terms of macroscopic thermodynamic variables E and T. As described in the last annual report, **T. Padmanabhan** has been able to show that a similar relation holds in gravitational theories, thereby providing a firm basis for the emergent paradigm. Given these results, it seems reasonable to expect that one should be able to explicitly rewrite the field equations of gravity in a manner similar to the equations of fluid mechanics and **Padmanabhan** has shown that it is instead the case.

At any event in the spacetime, there are null rays which criss-cross at that event, thereby forming a null surface. These surfaces have the property that no material body can cross this surface, because nothing can travel faster than light. In other words, null surfaces act as one-way-membranes blocking the flow of information. Since information is closely related to entropy, the null surfaces play a key role in the thermodynamic approach to gravity. It turns out that, if one projects the Einstein field equations on to a null surface in any spacetime around an event, then the form of the resulting equations become identical in form to the Navier-Stokes equations of fluid mechanics! Such a result was derived decades ago by Damour in the specific context of black hole horizons (which are special class of null surfaces) but **Padmanabhan's** work now shows that the result is far more general and far more fundamental. The fact that gravitational field equations reduces to Navier-Stokes equations in any spacetime and around any event allows an equivalent description of spacetime dynamics in terms of the fluid mechanical equations. This is precisely what one would have expected if gravity is an emergent phenomenon and the current result provides yet another evidence in support of this paradigm.

Ideal gas in a strong gravitational field: Area dependence of entropy

It is known from earlier works in the literature that all horizons can be attributed a temperature, which is independent of the field equations of the theory, whereas the entropy attributed to a horizon, in sharp contrast, depends explicitly on the gravitational theory. In a situation involving both matter sources and gravity, it is not quite clear what precisely is the inter-relationship between the usual thermodynamic entropy of matter and the entropy of the horizon. The two extreme views which are possible would be:

(i) The entropy of the horizon is the same as the entropy of the matter source, the gravity of which leads to the formation of the horizon .

(ii) The horizon entropy arises from microscopic quantum structure of spacetime and the matter fields inherits the thermodynamic variables just as material kept in a hot oven inherits its temperature. As usual, there are open questions in both points of view and it could very well be that neither approach fully captures the reality. There are at least two more facts, which we need to keep in mind while studying a situation in which both normal matter and gravity are present.

First, we know that the temperature, attributed to the vacuum state of the theory is observer dependent. In flat spacetime, an inertial observer would attribute zero temperature to the vacuum state, while a uniformly accelerating Rindler observer will attribute a non-zero temperature to the vacuum state. This result continues to hold in an approximate sense for more realistic non-inertial trajectories, and indicates that vacuum fluctuations can mimic thermal fluctuations in certain contexts. Also, the thermodynamical properties of a highly excited state (which could, for example, represent a quantum gas of particles) will also be viewed differently by inertial and non-inertial observers. In other words, once the thermodynamic properties of vacuum state have become observer dependent, the thermodynamic properties of *any system* becomes observer dependent. We can no longer attribute to a box of gas a temperature or entropy, say, in an observer independent fashion. This situation is peculiar and requires deeper understanding.

Second, the co-existence of matter and gravitational field can lead to both kinematic and dynamical effects depending on whether we take into consideration the self-gravity of matter or not. For example, consider a spherical cloud of gas which collapses to form a black hole under its own gravity. It will be interesting to understand how the "normal" entropy of the gas cloud is related to the entropy of the black hole, both with respect to an observer collapsing with the cloud and with respect to an outside observer (who will see the black hole formation only at asymptotic infinity). On the other hand, we can also ask a purely kinematical question of what happens to a cloud of gas, as regards to its thermodynamical properties when it is located in a spacetime with horizon. In this case, the gas is *not* self-gravitating and the horizon is produced by an external source or could even be due to the acceleration of the observer.

In a recent paper, **Sanved Kolekar** and **T. Padmanabhan** have analyzed the last aspect mentioned above, in the context of the thermodynamical behaviour of a box of gas, treated as a test system located in an external spacetime with horizon, neglecting its self-gravity. Such a study is important to distinguish sharply between the kinematical and dynamical

effects when both matter and gravity are present. It also reinforces the essential observer dependence of thermodynamics arising principally through Davies-Unruh effect.

Specifically, they have studied a box containing a gas of indistinguishable particles in a static background spacetime having a horizon. They then calculate the entropy of the gas when the box is situated far away and near the horizon and obtain the relevant expressions in two different independent ways of (i) statistical mechanics of a canonical ensemble and (ii) thermodynamics. They have analyzed the thermal behaviour in various background spacetimes having a horizon for which the near horizon limit of the metric is the Rindler metric.

Their analysis shows that far away from the horizon, the entropy of the gas depends on volume of the box with negligible corrections due to the background geometry. As one moves towards the horizon, in general, entropy, etc., depends on the location of the box in a way dictated by the background metric (and in general, is not a function of its volume alone, because of finite size effects in an external geometry). In spherically symmetric spacetimes, the transverse directions are unaffected and quantities such as transverse pressure take their usual Minkowski form. However, when the leading edge of the box is about Planck length L_p away from the horizon, the entropy depends on a smaller volume $A_\perp L_p/2$ instead of the total volume V of the box, upto an order $O(L_p/K)$, where $A_\perp$ is the transverse area of the box and K is the (proper) longitudinal size of the box related to the distance between leading and trailing edge in the vertical direction (i.e., in the direction of the gravitational field). Thus, the contribution to the entropy comes from only a fraction $O(L_p/K)$ of the matter degrees of freedom and the rest are suppressed when the box approaches the horizon. Near the horizon, all the thermodynamical quantities behave as though the box of gas has a volume $A_\perp L_p/2$ and is kept in a Minkowski spacetime. Since all these effects are true in a Rindler spacetime, they argued that (i) they are purely kinematic in their origin and independent of spacetime geometry, and (ii) observer dependent. When the equilibrium temperature of the gas is taken to be equal to the horizon temperature, they then get the familiar $A_\perp/L_p^2$ dependance in the expression for entropy. All these results hold in a Schwarzschild-like spherically symmetric background metric in D+1 dimensions.

Gravitational Waves

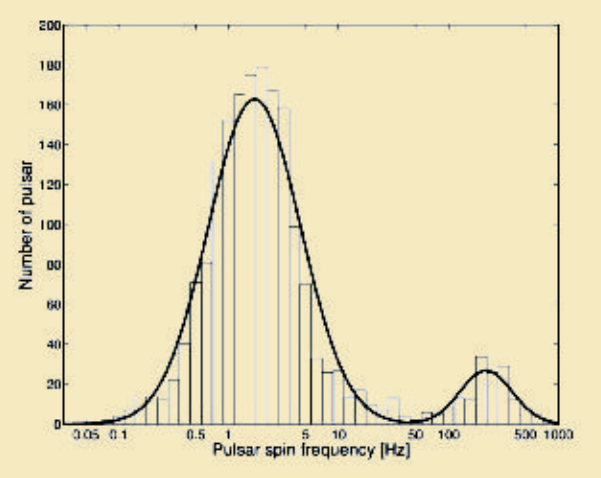
Introduction

The existence of gravitational waves (GW) predicted by the theory of general relativity, has long been verified 'indirectly' through the observations of Hulse and Taylor, who then won the Nobel prize for physics in 1993. The inspiral of the members of the binary pulsar system named after them has been successfully accounted for in terms of the back-reaction due to the radiated gravitational waves - the observational results and the theory agree with each other within a fraction of a percent. However, detecting such waves directly with the help of detectors based either on ground or in space has not been possible so far.

Several observatories have sprung up around the globe to detect GW. These are the LIGO (US) at Hanford (H) and Louisiana (L), Virgo (France-Italy), GEO (Germany-UK) and TAMA (Japan). There are also plans to build future ground-based detectors in Australia (AIGO) and LCGT in Japan. Following its 20 year old legacy of GW data analysis and waveform modeling, India has recently initiated experimental effort in GW. After the successful stint of the initial detectors, advanced detectors are being constructed and should begin operating in this decade. Apart from the ground-based detectors, there are plans also to build detectors in space - the Laser Interferometric Space Antenna (LISA) is one such project.

The cross-correlation search for a hot spot of gravitational waves

The cross-correlation search has been previously applied to map the gravitational wave stochastic background in the sky and also to target gravitational waves from rotating neutron



The distribution of observed radio pulsars from the ATNF Pulsar database. The horizontal axis is $log_{10}(f_r)$, where f_r is the rotational frequency of pulsars. The histogram is the observed number. The solid line is the two component Gaussian model of the distribution.

stars/pulsars. **S. V. Dhurandhar** and the Japanese team consisting of H. Tagoshi, Y. Okada, N. Kanda, and H. Takahashi have investigated how the cross-correlation method can be used to target a small region in the sky spanning atmost a few pixels, where a pixel in the sky is determined by the diffraction limit which depends on (i) the baseline joining a pair of detectors, and (ii) detector

bandwidth. Here, as one of the promising point sources, the Virgo cluster is targeted - a "hot spot" spanning few pixels - which could contain, as estimates suggest ~ 10^{11} neutron stars, of which a small fraction - namely millisecond neutron stars - would continuously emit GW in the bandwidth of the detectors. Assuming the same distribution for the neutron stars as the pulsar distribution in our galaxy, one estimates about 40,000 millisecond neutron stars per Milky Way type of galaxy. For the baselines, advanced detector pairs among

ρ_{1yr}	LIGO-H	Virgo	LCGT	AIGO
LIGO-L	11.3	3.54	3.36	13.2
LIGO-H	-	2.63	3.21	9.12
Virgo	-	-	1.90	3.51
LCGT	-	-	-	3.84

$T_{obs}^{\rho=3}$ (in days)	LIGO-H	Virgo	LCGT	AIGO
LIGO-L	25.8	262	291	18.9
LIGO-H	-	474	319	39.5
Virgo	-	-	907	266
LCGT	-	-	-	223

The Tables show (i) the signal-to-noise ratio $_{1yr}$, which can be obtained with 1 year observation time and (ii) the observation time $T_{obs}^{\rho=3}$ required to achieve $\rho=3$ for each combination of the noise power spectral density (PSD) of the detectors. Ellipticity of $\varepsilon = 10^{-5}$ is assumed. Noise PSD of AIGO is assumed to be the same as that of LIGO noise PSD.

LCGT, LIGO, Virgo, ET, etc. are considered. The results show that sufficient signal to noise can be accumulated with integration times of the order of a year. This analysis could as well be applied to other likely hot spots in the sky and other possible pairs of detectors. This work is being done in collaboration with the Japanese under the Indo-Japanese DST-JSPS project.

These results have been extended to multiple baselines of a network of detectors with improved performance.

Time-delay interferometry for LISA: numerical simulations

In LISA (Laser Interferometric Space Antenna), the laser frequency noise dominates the other secondary noises, such as optical path noise, acceleration noise by 7 or 8 orders of magnitude, and must be removed if LISA is to achieve the required sensitivity of $h \sim 10^{-22}$, where h is the metric perturbation caused by a gravitational wave. In LISA, six data streams arise from the exchange of laser beams between the three spacecraft approximately 5 million km apart. These six streams produce redundancy in the data, which can be used to suppress the laser frequency noise by the technique called time-delay interferometry (TDI), in which the six data streams are combined with appropriate time-delays. A rigorous mathematical foundation for the TDI problem for static LISA was given previously by **S. V. Dhurandhar**, R. Nayak and J-Y Vinet, where it was shown that the data combinations cancelling laser frequency noise formed the *module of syzygies* over the polynomial ring of time-delay operators. In the general case of time varying armlengths, the polynomial ring is in six variables (the six optical links) but now it is non-commutative. There is still a linear system, which leads to a module (a left module), but it seems difficult to obtain its generators in general.

Dhurandhar, Ni and Wang consider the case of one of LISA's arms being dysfunctional. One must envisage the possibility that not all optical links of LISA will be operating at all times for various reasons like technical failure for instance or even because of high operating costs. The problem can be reduced to that of only one linear constraint on two polynomials, although the equation is still non-commutative. It is shown that an infinity of solutions can be generated using a combinatorial algebraic approach, which lists all such solutions in a systematic way. Numerical simulations are performed to estimate the path difference taking into account an optimal model of LISA for a three year period. The important point is that the perturbing effects of all planets and also the main asteroids are taken into account. It is found that for the first 14 such solutions, the residual path length is well within the tolerance limit.

A fast transform for periodic waves from pulsars and rotating neutron stars

The all sky all frequency search for pulsars or rotating neutron stars is an extremely computationally intensive problem. The reason for this is that, the signal is very weak and requires long integration times of the order of a few months to build up an acceptable signal-to-noise-ratio. In this period of time, the detector executes complex motion as it is carried by the rotating and revolving Earth. Thus, if the source direction and frequency of the source is unknown, one must demodulate the signal for each direction and then search over the frequency. In a simple model, in which the source is assumed to be monochromatic, a Fourier transform after the demodulation can be performed to reveal the signal. Even in this simple case, ignoring spindowns, for a years worth of data over a kHz bandwidth, one must search over 10^{13} directions leading to 10^{25} computer operations!

Several schemes involving alternately coherent and incoherent stages of data processing have been developed but they do not come anywhere near solving the problem - that is, perform the data analysis with the current computer resources in reasonable time. **S. V. Dhurandhar** and Badri Krishnan from AEI, Potsdam, Germany have come up with a completely different approach based on group theory. The idea is to exploit the symmetries in the problem to reduce the computational cost. Groups are a precise way to describe a symmetry. The procedure sought is analogous to the procedure followed in the fast Fourier transform. The

stepping around the sky approach of Schutz seems to be useful in formulating the problem. For the simple case of one circular motion, the demodulation over the azimuth can be performed very efficiently by using the fast Fourier transform, that is, in order of $B\log_2\mathbf{B}$ operations, where B is the number of frequency bins the signal is spread into by Doppler modulation. The brute force method on the other hand leads to order of B^2 operations, which is far more. The results so far obtained seem encouraging and one expects this approach to yield rich dividends.

Vetoes for a coherent search with a network of detectors for inspiraling binaries

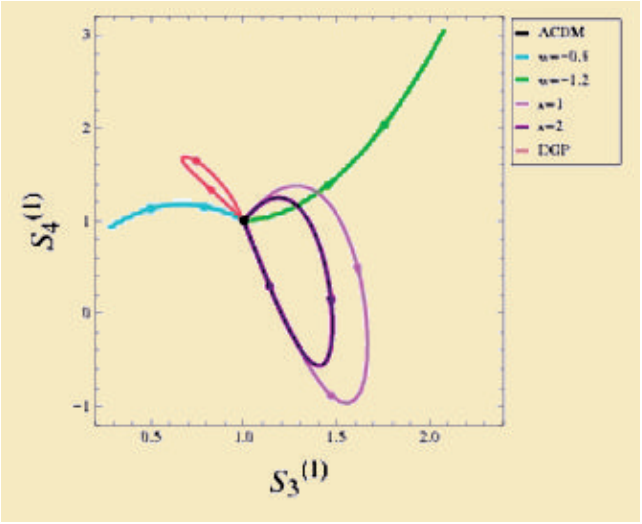
Two strategies currently exist in searching for inspiraling binary sources with a network of detectors: the coherent and the coincident. The coherent strategy involves combining data from different detectors phase coherently, appropriately correcting for time-delays and polarisation phases and obtaining a single statistic for the full network, that is optimized in the maximum likelihood sense. On the other hand, the coincident strategy matches the candidate event lists of individual detectors for consistency of the estimated parameters of the GW signal. However, the phase information is ignored and also the detectors are considered in isolation.

It is however, felt that for real data, the coincidence strategy acts as a powerful veto for fake events arising from the presence of non-Gaussian noise. In coincidence detection, the requirement of the consistency of estimated parameters in an error window acts as a powerful veto, to weed out fake events generated from non-Gaussian noise. On the other hand, in coherent detection as yet no such obvious veto has been developed. This, however, does not rule out the possibility that a powerful veto cannot be constructed for the coherent strategy. This will form the main thrust of future work. The idea is to use the χ^2 statistic and formulate χ^2 test(s) analogous to the test proposed by Bruce Allen for a single detector. A preliminary result is that the statistic is the sum of squares of four terms, analogous to the F-statistic. This will help in the construction of the veto.

Cosmology and Structure Formation

The Statefinder hierarchy: An extended null diagnostic for concordance cosmology

There is mounting observational evidence in support of a universe that is currently accelerating. The reason behind cosmic acceleration is currently unknown and different theoretical models are usually clubbed together and called 'Dark Energy'. Because of its elegance and simplicity, the cosmological constant, Λ, occupies a privileged place in the burgeoning pantheon of DE models. Although, the reasons behind the extremely small value of Λ remain unclear, concordance cosmology (ΛCDM) does appear to provide a very good fit to current data. Given the success and simplicity of concordance cosmology, it is perhaps natural to discuss diagnostic measures, which can be used to compare a given DE model with ΛCDM.



Statefinders $S_4^{(1)}$ and $S_3^{(1)}$ are shown for DE models possessing the equation of state w = - 0.8 (blue), phantom with ω = - 1.2 (green), Chaplygin gas (purple) and DGP (red). The fixed black point at {1,1}is ΛCDM. The arrows show the time evolution and the present epoch in the different models is shown as a dot. ($\Omega_m = 0.3$ is assumed.) Details provided in *Phys. Rev. D* **83**, 043501 (2011).

Maryam Arabsalmani and **Varun Sahni** have shown how higher derivatives of the expansion factor can be developed into a null diagnostic for concordance cosmology. It is well known that the Statefinder -- the third derivative of the expansion factor written in dimensionless form, $a^{(3)}/aH^3$, equals unity for Λ CDM. **Arabsalmani and Sahni** generalize this result and demonstrate that the hierarchy, $a^{(n)}/aH^n$, can be converted to a form that stays *pegged at unity* in concordance cosmology. This remarkable property of the Statefinder hierarchy enables it to be used as an extended null diagnostic for the cosmological constant. The Statefinder hierarchy combined with the growth rate of matter perturbations defines a *composite null diagnostic,* which can distinguish the evolving dark energy from ΛCDM. The accompanying figure illustrates how the Statefinder hierarchy can successfully differentiate between dark energy models as diverse as (i) The cosmological constant (w = - 1), (ii) Phantom DE (w < -1), (iii) Quiessence (ω > -1), (iv) The Chaplygin gas, (v) The Dvali-Gabadadze-Porrati (DGP) braneworld.

Generalizing the cosmic energy equation

Ever since its discovery, the cosmic energy equation $\dot{E} = -(2K + U)\, H$, $(E = K + U)$ has been one of the bulwarks of modern cosmology, and its many applications include estimates of the matter density, its gravitational binding energy, etc. Once the clustering has entered a stationary regime, the condition $\dot{E} = 0$ results in the virial relation $2K+U=0$. A breakdown of this equation for galaxies belonging to the Coma cluster led Zwicky to suggest that a large amount of dark matter might dominate the dynamics of Coma. While dark matter appears to be ubiquitous, its nature remains elusive. Our current theoretical understanding of dark matter (DM) and dark energy (DE) include the possibility of an interaction between DM/DE as well as the even more radical possibility of a breakdown of Newtonian/Einsteinian gravity on large scales. **Varun Sahni** and Yuri Shtanov (BITP, Kive) show how the cosmic energy equation can be generalized to incorporate more flexible forms of the gravitational interaction of dark matter, some of which have been suggested in the literature.

They generalize the cosmic energy equation to the case when massive particles interact via a modified gravitational potential of the form $\phi\,(a, |\mathbf{r_1} - \mathbf{r_2}|)$, where ϕ is allowed to explicitly depend upon the cosmological time through the expansion factor $a(t)$. Using the nonrelativistic approximation for particle dynamics, they then derive the equation for the cosmological expansion, which has the form of the Friedmann equation with a renormalized gravitational constant. The generalized Layzer-Irvine cosmic energy equation and the associated cosmic virial theorem are applied to some recently proposed modifications of the Newtonian gravitational interaction between dark-matter particles. Shtanov and **Sahni** draw attention to the possibility that the cosmic energy equation may be used to probe the expansion history of the universe, thereby throwing light on the nature of dark matter and dark energy.

Weighing neutrinos using high redshift galaxy luminosity functions

Laboratory experiments measuring neutrino oscillations, indicate small mass differences between different mass eigenstates of neutrinos. The absolute mass scale is, however, not determined, with the present strongest upper limits coming from astronomical observations rather than terrestrial experiments. The presence of massive neutrinos suppresses the growth of perturbations below a characteristic mass scale, thereby leading to a decreased abundance of collapsed dark matter halos. **Charles Jose, Saumyadip Samui, Kandaswamy Subramanian** and **Raghunathan Srianand** showed that this effect can significantly alter the predicted luminosity function (LF) of high redshift galaxies. In particular, they have demonstrated that a stringent constraint on the neutrino mass can be obtained using the well-measured galaxy LF and their semi-analytic structure formation models. Combining the constraints from the Wilkinson Microwave Anisotropy Probe 7 year (WMAP7) data with the LF data at $z = 4$, they get a limit on the sum of the masses of 3 degenerate neutrinos $\Sigma\, m_\nu < 0.52$ eV at the 95% CL. The additional constraints using the prior on Hubble constant strengthens this limit to $\Sigma\, m_\nu < 0.29$ eV at the 95% CL. This neutrino mass limit is a factor of order 4 improvement compared to the constraint based on the WMAP7 data alone, and as stringent as known limits based on other astronomical observations. As different astronomical measurements may suffer from different set of biases, the method presented here provides a complementary probe of $\Sigma\, m_\nu$. Repeating this exercise on well measured luminosity functions over different redshift ranges can provide independent and tighter constraints on $\Sigma\, m_\nu$.

Cosmic Microwave Background

As regularly reported in previous annual reports, **Tarun Souradeep**, his students, and collaborators, have maintained a successful research programme related to the cosmic microwave background (CMB) anisotropy and polarization.

Odd parity non-Gaussianity

Measurement of the CMB bispectrum, or three-point correlation function, has now become one of the principle efforts in early-universe cosmology. Recently, Marc Kamionkowski (Caltech) and **Tarun Souradeep** have showed that there is a parity-odd component of the CMB bispectrum that has been hitherto unexplored. Parity-odd temperature-polarization bispectra can arise, in principle, through weak lensing of the CMB by chiral gravitational waves or through cosmological birefringence, although the signals will be small even in the best-case scenarios. Measurement of these bispectra requires only modest modifications to the usual data-analysis algorithms. Hence, they should also be useful as an important consistency test in searches for the usual bispectrum, in addition to the search for surprises in the data.

Statistical isotropy of the CMB sky

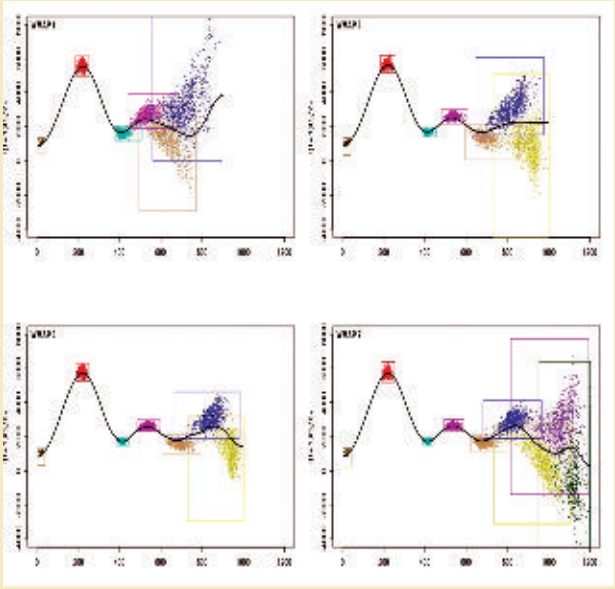
Increasingly more attention is being paid to emerging avenues of fruitful research on subtle 'anomalous' cosmic signatures, of ten referred to as 'CMB anomalies'. The Bipolar Spherical Harmonic (BipoSH) representation has been proposed and established by the group in IUCAA as a robust measure of violation of statistical isotropy in the CMB anisotropy. The most recent data released by the Wilkinson Microwave Anisotropy Probe (WMAP) team in January 2010 devotes a separate paper to the CMB anomalies and have invoked the bipolar representation of Amir Hajian and **Tarun Souradeep** to quantify them. The IUCAA group has published further studies on the origin and characterization of the subtle signatures of statistical isotropy violation in the CMB sky maps.

Recently, IUCAA associate, Sanjay Jhingan, and his student, Nidhi Joshi, and **Souradeep** have published a comprehensive study relating the bipolar observables to stepwise symmetry breakdown of statistical isotropy to smaller symmetry sub-groups. The CMB anisotropy and polarization power, measured at all angular scales arise from free-streaming of anisotropy power at very low multipoles (essentially, the monopole, dipole and quadrupole) in the baryon-photon plasma at the epoch of last scattering. **Moumita Aich** and **Souradeep** have published a complete formalism to relate violation of statistical isotropy in the photon distribution function at the last scattering surface to non-zero BipoSH coefficients in the present observed CMB .

Joshi and **Aditya Rotti** have recently completed an analytical derivation of the underlying statistics of BipoSH coefficients. They are also engaged in measuring the BipoSH observable from the WMAP-7 data. In particular, the odd-parity bispectrum was motivated by work on odd-parity BipoSH coefficients that has been missed by the WMAP team and others in their application of BipoSH to the data. **Souradeep,** Marc Kamionkowski and their students have shown that the odd-parity BipoSH probe the curl part of a deflection field in weakly lensed CMB maps. Further work on estimation of BipoSH from data is ongoing.

WMAP CMB angular power spectra

Tuhin Ghosh and **Tarun Souradeep** have developed, and now implemented, DAPSE - an improved method that employs a clever strategy to alleviate the bias arising in IPSE due to the co-dominance of foregrounds and noise on intermediate angular scales. This allows a more robust estimation of the CMB polarization power spectra from the WMAP seven year data .



The angular power spectrum, C_l suggested by minimum risk, non-parametric REACT fit. Risk minimization involves a trade-off between the least square minimization and a bias 'penalty' function that prevents over-fitting using an expansion in an appropriate basis functions. The best-fit nonparametric C_l curve obtained and the uncertainties on the peak and dip locations and heights for WMAP 1 year- (top left), 3 years- (top right), 5 years - (bottom left), and 7-years (bottom right) data is represented by the peaks of 5000 sample fitting functions randomly drawn 95% CL error ball surface of the fitting function coefficients. The sustained improvement in resolving the peak locations over the years of WMAP data is evident in the plots. At present, WMAP-7 data resolves the first three peaks and dips of the CMB power spectrum in a model independent manner.

The university collaboration between Mihir Arjunwadkar, Centre for Modeling and Simulations, University of Pune, and **Souradeep** with their joint student, Amir Aghamousa has recently estimated the CMB power spectrum from WMAP-7 data using a non-parametric estimation based on risk minimization. The best fit C_l spectrum is close to, but not the same, as that obtained through cosmological parameter estimation based model fitting. The non-parametric analysis provides an estimate of the peak location and heights with corresponding confidence level error balls, independent of theoretical biases. The analysis also reveals the sustained improvement in the peak localization in WMAP data. The scatter plot of points of different colours represent the 95% CL scatter in the localization of the peaks. This analysis is now being extended to include data-sets at larger multipole values, such as obtained from the ACBAR, QUad and ACT experiments.

Diffuse foreground emission from WMAP

Tuhin Ghosh was selected for the prestigious Indo-French Sandwich PhD fellowship to visit IAP, Paris. During this collaboration with French scientists, **Ghosh** and **Tarun Souradeep** have published this work on constructing the 'best available' foreground emission maps from WMAP data. These foreground galactic emission maps at the five WMAP frequencies ranging from 22-94 GHz, now publicly available, are expected to provide very useful information about galactic physics, as well as, help in cleaner extraction of the CMB signal in upcoming experiments.

On another front, an ongoing collaboration of **Ghosh** and **Souradeep** with scientists at IAP, Paris, involves characterizing the statistics of foreground maps in the needlet (wavelet) basis, based on ideas used in the wavelet analysis of natural images.

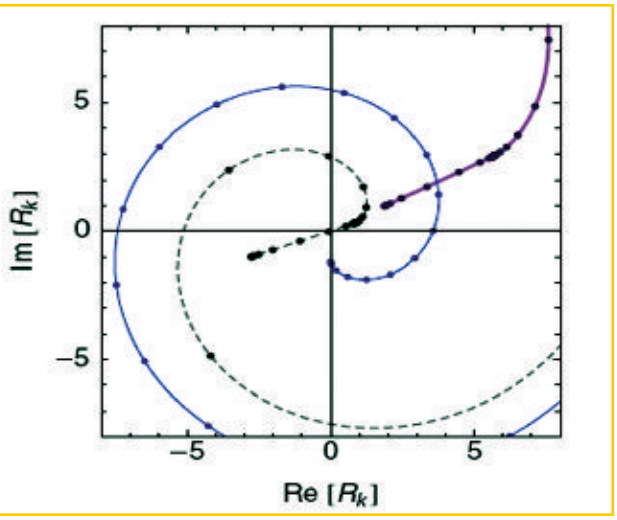
Systematic effects in CMB maps

In this era of high precision CMB measurements, systematic effects are beginning to limit the ability to extract more information. The non-circularity of the experimental beam has become progressively important as CMB experiments strive to attain higher angular resolution and sensitivity. **Santanu Das** and **Tarun Souradeep** have recently estimated the effect of non-circular beam profiles of WMAP and Planck on the leakage of power from dipole to quadrupole

and octupole anisotropy in CMB measurements. This appears to be an non-negligible effect that may be relevant to the peculiar suppression observed in the CMB anisotropy quadrupole and can also explain part of the anomalous correlation seen between the quadrupole and octupole.

Early universe from CMB

In collaboration with L. Sriramkumar's group at HRI, **Moumita Aich** and **Tarun Souradeep** have analyzed scenarios of inflation that lead to features in the primordial power spectrum of the kind favoured by data. The collaboration has compared the CMB predictions of a suit of models with the currently available CMB measurements from experiments such as WMAP, ACBAR and QuaD



The trajectories of mode function of comoving curvature perturbation (R) in complex plane. The dots on the trajectory are uniform in expansion e-folds, crowding of dots indicates that R freezes.The thin (blue) trajectory corresponds to power law inflation which never crosses the origin. The other two trajectories show the behavior of R in the complex plane for two different modes in the punctuated inflation model. The mode denoted by the continuous (thick) purple curve freezes once, then unfreezes, evolves radially in and freezes again before crossing the origin. The dashed gray curve corresponds to a mode with larger wavenumber, it undergoes large radial super-Hubble evolution, crosses the origin and then freezes undergoing super-Hubble enhancement of power compared with the other mode that undergoes suppression. In between would lie a mode (not shown) that ends up right at the origin leading to a null in PPS.

Recently, **Gaurav Goswami** and **Souradeep** have provided a clear understanding of power spectrum nulls arising in the punctuated inflation scenario proposed earlier by the IUCAA and HRI collaboration. The salient aspects of mode evolution that come into play in these phenomena are illustrated in the Figure. The modes that have once frozen in amplitude and phase after being stretched to super-Hubble radius scales can be made to undergo a short phase of evolution even while they are super-Hubble radius scale, to another frozen state. The super-Hubble scale modes are then constrained to evolve along an incoming radial trajectory in the complex plane. Interestingly enough, if any mode evolves past the origin, then the radial evolution demands that there

exists a wave-number for which the amplitude of the scalar perturbation mode is exactly frozen at zero amplitude leading to nulls in the primordial power spectrum.

Aditya Rotti and **Souradeep**, have been working on establishing upper limits on cosmological / astrophysical gravity wave backgrounds from the current experimental upper bounds on the CMB B-polarization measurements.

Cosmological parameter estimation

Finding a set of cosmological parameters consistent with the available observational data sets is a computationally challenging task, mainly due to high dimensionality of the parameter space and large volume of data. Traditionally Markov Chain Monte Carlo (MCMC) methods, which are stochastic, have been used to find cosmological parameters from the data sets obtained from various CMB experiments such as, WMAP, QUaD, ACBAR, etc. Particle Swarm Optimization (PSO), is another stochastic, population based optimization scheme, that can be used for parameter estimation. In some cases of very high dimensionality of parameter space, large number of local minima, etc., it is known to perform better than MCMC. In an ongoing study, **Jayanti Prasad** and **Tarun Souradeep** have demonstrated the use of PSO for cosmological parameter estimation using WMAP data. They show that a very simple implementation of PSO, which is easy to parallelize on a cluster system, can provide best fit cosmological parameters in a relatively short time.

Primordial magnetic field limits from the CMB bispectrum of magnetic passive scalar modes

Primordial magnetic fields lead to non-Gaussian signals in the cosmic microwave background (CMB) even at the lowest order, as magnetic stresses and the temperature anisotropy they induce depend quadratically on the magnetic field. In contrast, CMB non-Gaussianity due to inflationary scalar perturbations arises only as a higher order effect. Apart from a compensated scalar mode, stochastic primordial magnetic fields also produce scalar anisotropic stress that remains uncompensated till neutrino decoupling. This gives rise to an adiabatic-like scalar perturbation mode that evolves passively, thereafter called the passive mode.

Kandaswamy Subramanian, along with IUCAA associates Pranjal Trivedi, and T.R. Seshadri has computed the CMB reduced bispectrum ($b_{l_1 l_2 l_3}$) induced by this passive mode, sourced via the Sachs-Wolfe effect, on large angular scales. For any configuration of bispectrum, taking a partial sum over mode-coupling terms, the have found a typical ø value of $l_1(l_1 + 1)\, l_3\,(l_3 + 1)\, b\, l_1 l_2 l_3 \sim 6\text{-}9 \times 10^{-16}$ for a magnetic field of $B_0 \sim 3$ *nG,* assuming a nearly scale-invariant magnetic spectrum. the have also evaluated, in full, the bispectrum for the squeezed collinear configuration over all angular mode-coupling terms and found $l_1(l_1+1)\, l_3\,(l_3+1)\, b\, l_1 l_2 l_3 \approx 1.4 \times 10^{-16}$.

These values are more than $\sim 10^6$ times larger than the previously calculated magnetic compensated scalar mode CMB bispectrum. Observational limits on the bispectrum from WMAP-7 data allow us to set upper limits of $B_0 \sim 2$ nG on the present value of the cosmic magnetic field of primordial origin. This is over 10 times more stringent than earlier limits on B_0 based on the compensated mode bispectrum.

Observational Cosmology and Extragalactic Astronomy

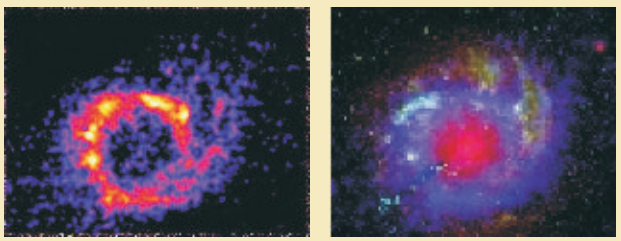
Cosmic ray transport in galaxy clusters: Implications for radio halos, gamma-ray signatures, and cool core heating

Kandaswamy Subramanian, in collaboration with Torsten Ensslin, Christoph Pfrommer, and Francesco Miniati, has investigated the interplay of cosmic ray (CR) propagation and advection in galaxy clusters. Propagation in the form of CR diffusion and streaming tends to drive the CR radial profiles towards being flat, with equal CR number density everywhere. Advection of CR by the turbulent gas motions tends to produce centrally enhanced profiles. They have assumed that the CR streaming velocity is of the order of the sound velocity. This is motivated by plasma physical arguments. The CR streaming is then usually larger than typical advection velocities and becomes comparable or lower than this, only for periods with trans and super-sonic cluster turbulence. As a consequence, a bimodality of the CR spatial distribution results. Strongly turbulent, merging clusters should have a more centrally concentrated CR energy density profile with respect to relaxed ones with very subsonic turbulence.

This translates into a bimodality of the expected diffuse radio and gamma-ray emission of clusters, since more centrally concentrated CR will find higher target densities for hadronic CR proton interactions, higher plasma wave energy densities for CR electron and proton re-acceleration, and stronger magnetic fields. Thus, the observed bimodality of cluster radio halos appears to be a natural consequence of the interplay of CR transport processes, independent of the model of radio halo formation, be it hadronic interactions of CR protons or re-acceleration of low-energy CR electrons. Energy dependence of the CR propagation should lead to spectral steepening of dying radio halos. Furthermore, they have showed that the interplay of CR diffusion with advection implies first order CR re-acceleration in the pressure-stratified atmospheres of galaxy clusters. Finally, they have argued that CR streaming could be important in turbulent cool cores of galaxy clusters since, it heats preferentially the central gas with highest cooling rate.

Star formation in nuclear rings

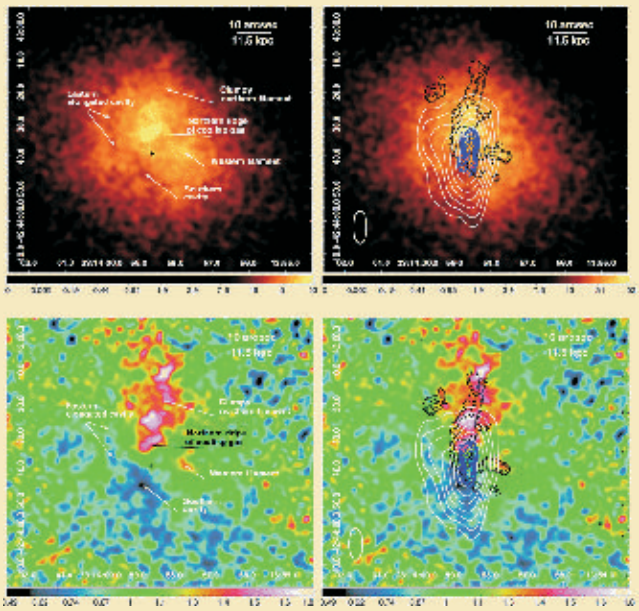
Starbursts are extreme environments, where the bulk of star formation takes place with high efficiency, and they play a major role in galaxy formation and evolution. At high redshifts, intense starbursts are dominant, but these distant systems are often dust-enshroudded. The inferences about their nature and evolution rely on diagnostics available for similar systems at lower redshifts. Local analogs of starbursts are found in the nuclear resonance rings of barred galaxies. The kiloparsec-sized nuclear rings are the result of bar-driven gas inflow toward the inner lindblad resonance, yielding a large concentration of gas in a small region surrounding the nucleus. The intense star formation that is triggered in the nuclear rings is a key component in the process of pseudobulge formation via secular evolution. Hubble Space Telescope (HST) imaging of nuclear rings have shown that they are composed of super star clusters (SSCs), which are extremely luminous (M_V = -14 to -15 mag), and compact (2 - 4 pc); likely to be young globular clusters. A number of issues about the evolution of SSCs in circumnuclear rings remain unsolved : (1) Does star formation proceed by sequential triggering of intense bursts, or is it a continuous process depending on the gas supply? (2) Do the older clusters dissolve to form part of the bulge stellar population? (3) What fraction of pseudobulges are the result of secular evolution? (4) Over what timescales can the gas inflow, and starburst episodes build up the pseudobulges observed in galaxies? **Swara Ravindranath** and collaborators are using the panchromatic data from the HST, along with the mid-IR images, from the TReCS instrument on Gemini-South telescope, to study the evolution of star clusters in the nuclear rings of the nearby galaxies. They use the mid-IR image, which traces the emission at 11.3 microns from dust heated by the massive stars to reveal the locations of the *current or on-going* star formation. The youngest and most obscured clusters with ages (< 6 - 8 Myrs) and extinction $A_V > 3$ mag can only be traced by radio and mid-IR emission. The optical images trace the intermediate age (9-20 Myrs) starbursts in regions of relatively less obscuration ($A_V \sim 1$ mag). In the galaxy NGC 2997, the mid-IR emission is found to arise from a nearly circular ring of radius 320 parsecs, located within the ring seen at optical wavelengths, which has a radius of 540 parsecs. The star formation proceeds radially outward, rather than azhimuthally along the ring. For the star formation rate measured from the mid-IR emission, the circumnuclear ring is $\sim 0.1\ M_\odot$ /yr, and is found to be about 2.5 times that measured using the UV luminosity.



(*Left)* The 11.3 μm image of the central 28" x 21" of NGC 2997. (*Right*) A three colour composite of the central region, which combines I-band (F814W; red), U-band (F330W; green), and 11.3 μm (blue) images. The mid-IR ring of 320 parsecs radius is located within the larger optical ring.

Evolution of massive galaxies at 1.5 < z < 3.0

Recently, a deep near-infrared survey targeting regions around the massive galaxies ($M_* > 10^{11}$ $M_\odot$) at $1.5 < z < 3.0$ within the Great Observatories Origins Deep Survey (GOODS) was completed using the NICMOS instrument on the Hubble Space Telescope. Based on the new data, the team including **Swara Ravindranath** has argued that major mergers alone are not sufficient for driving the evolution of massive galaxies at $z < 3.0$. Other mechanisms, such as, minor mergers, star formation driven by gas accretion at various stages are key components of the galaxy mass build-up. Also, the colour-magnitude bimodality that defines the red and blue sequence of low redshift galaxies is already in place at $z < 2$. They also discuss the evolution in the number density of massive galaxies as a function of redshift or cosmic time. The massive galaxy density is found to be roughly constant, similar to the value at $z = 0$ up to $z = 1.5$, and thereafter, shows a significant decline. The number density of massive galaxies grows by a factor of eight between $z = 3.0$ and $z = 1.5$. This implies that the epoch between $z = 3.0$ and 1.5 is a period when there is significant growth in galaxy mass, resulting in almost a factor of eight increase in the number of galaxies with $M_* > 10^{11}$ $M_\odot$ during the relatively short period of ~ 2 Gyrs.



Top-left panel: background-subtracted, flat-fielded Chandra X-ray image of the core of Sérsic 159−03 in the 0.5 –7.5 keV band. The cross indicates the position of the central radio source. Top-right panel: the same Chandra image with overplotted contours of the 8.4 GHz (blue) and 1.4 GHz (white) radio emission, and with the contours of the Hα+[NII] line emission (black). The beam size of the 1.4 GHz radio emission is indicated by the white ellipse in the bottom-left corner. The outermost radio contour is at 0.3 mJy beam−1 and the levels increase logarithmically to the innermost contour which is at 137.7 mJy beam−1. The contours of the 8.4 GHz radio emission are the same as in the other Figure The dense cooling gas is displaced to the north of the centre of the galaxy and the region within r ~ 7.5 kpc is void of the dense gas. Lower-left panel: the Chandra image divided by the best-fitting 2D elliptical double beta model. Note the clear structure to the north. Lower-right panel: the same ratio image with the contours of the radio and Hα+[NII] emission overplotted. The images have been smoothed with a Gaussian kernel.

Violent interaction between the active galactic nucleus and the hot gas in the core of the galaxy cluster Sérsic 159−03

Supermassive black holes (SMBHs) play a crucial role in galaxy formation. The correlation between the mass of the central SMBH and the bulge mass of their host galaxies suggests that their evolution is tightly coupled. Outbursts of accreting SMBHs (referred to as active galactic nuclei or AGN) disturb and heat the surrounding gas, lowering the accretion rate and, in some cases, driving so much gas out of the galaxy that the star formation is drastically reduced. This AGN feedback mechanism plays an extremely important role in galaxy formation and it could strongly affect the central region of galaxy clusters.

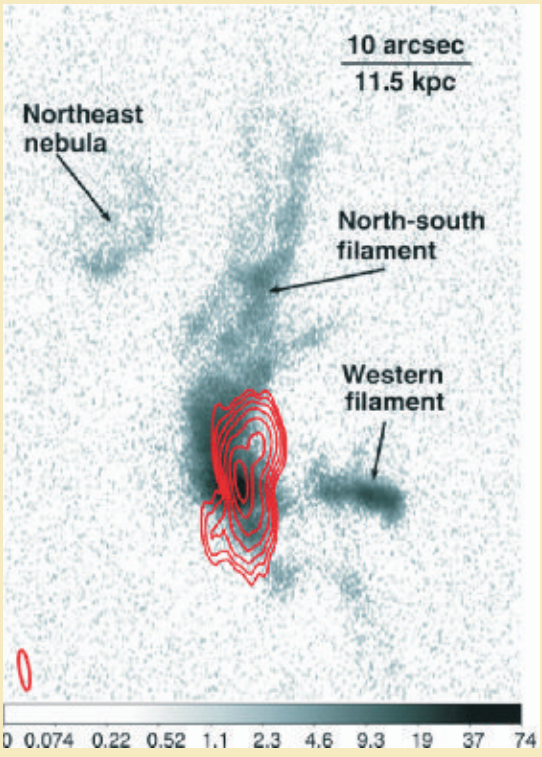
Joydeep Bagchi and his collaborators (N. Werner, M. Sun, S.W Allen, G.B. Taylor, S. Sirothia, A. Simionescu, E.T. Million, J. Jacob and M. Donahue) have uncovered striking evidences of this powerful AGN feedback occurring in the massive galaxy cluster Sérsic 159−03. This cluster harbours a giant cD galaxy at the centre which also is a strong radio source, suggesting an active nuclear black hole. X-ray data from Chandra, high-resolution X-ray spectra and ultraviolet (UV) images from XMM–Newton, Hα images from the Southern Astrophysics Research Telescope (SOAR), Hubble Space Telescope optical imaging, and Very Large Array (VLA) and Giant Metrewave Radio Telescope (GMRT) radio data were used by them for a detailed multi-wavelength study. The main conclusions from their study are the following :

(i) Powerful 'radio-mode' AGN feedback and possible ram pressure of jets have cleared the central region of the cD galaxy ($r < 7.5$ kpc) of the cooling low-entropy X-ray gas.

(ii) This low-entropy, high-metallicity, relatively cool X-ray gas lies along the bright, 44 kpc long Hα+[N II] filament extending from the centre of the cD galaxy to the north.

(iii) As indicated by the observed dust lanes seen in Hubble Space Telescope images, molecular and ionized emission-line nebulae, and the excess UV emission; part of this displaced gas, which is removed from the direct influence of the AGN, cool and form stars.

(iv) The pressure map shows evidence for an AGN-induced weak shock at a radius of $r = 15$ kpc and the X-ray images reveal dark cavities indicating past powerful AGN activity with an energy input of $\sim 7 \times 10^{58}$ erg. At low frequencies, the radio source has an unusually steep spectrum with spectral slope $\alpha = 1.5$, indicating aging and confinement by the ambient gas.



Hα+[N ii] emission line image of the central cD galaxy obtained with the 4.1-m SOAR Telescope. The image shows a large 44 kpc long north-south filament, a smaller western filament, and a separate nebula at the north-east. The northern end of the large filament separates into two parallel structures. The contours of the 8.4 GHz (VLA) radio emission are overplotted in red and the beam size is indicated by the red ellipse in the bottom-left corner. The outermost radio contour is at 0.12 mJy beam^{-1} and the levels increase logarithmically to the innermost contour which is at 4.0 mJy beam^{-1}. The radio source has an S-shaped structure, which might indicate precession of the radio jets.

Active Galactic Nuclei, Quasars, and Intergalactic Medium

The ionized environment of the Seyfert 1 galaxy Mrk ~ 704

Sibasish Laha, Gulab Dewangan and **Ajit Kembhavi** have done a detailed study of the ionized environment of the Seyfert 1 galaxy Mrk~704 using medium and high resolution X-ray spectra obtained with a long XMM-Newton observation. They found clear signatures of two components of warm absorbing medium outflowing at different velocities and having different ionisation parameters and column densities. They also detected signatures of weak emission lines of He-like triplets from OVII and NVI ions, thus making Mrk~704 a Seyfert 1 galaxy with both warm absorption and warm emission. The physical conditions of warm emitters and warm absorbers suggest that these clouds are similar but observed in absorption along our line of sight and in emission at other lines of sight. The unique line of sight passing close to the torus opening angle is likely responsible for the neutral partial covering absorption and the view of emission lines due to the suppressed continuum in this polar scattered Seyfert 1 galaxy.

Identifying binary black holes using X-ray spectra

The hierarchical models of galaxy formation and evolution imply that when two galaxies merge, dynamical friction will bring their central black holes closer, and they will form a massive black hole binary system. These massive binary black holes will eventually spiral in and merge to form a single central supermassive black hole of the new galaxy. While observations have revealed the presence of black holes separated by thousands of light years, evidence for close binary systems with separations less than the sizes of the optical broad-line regions (a few light days to several light years) is lacking. **G. C. Dewangan** and **R. Misra** have devised a new technique, which can unambiguously identify close binary systems, irrespective of their separation, using their broad band X-ray emission. If one of the sources is highly absorbed, the system will have unique X-ray spectrum and variability signatures, which can be distinguished from any other possible scenarios. They have applied this technique to the Suzaku and XMM-Newton X-ray observations of several active galactic nuclei and found that X-ray properties of PDS456 are consistent with that expected from a binary supermassive black holes. PDS456 is the most luminous quasar (bolometric luminosity ~ 10^{47} ergs/s, z = 0.184) in the nearby universe. The high luminosity of PDS456 implies a black hole mass of about a billion solar mass from the Eddington limit. A detailed analysis of the Suzaku X-ray observations of the luminous quasar PDS~456 showed that the X-ray emission from the quasar is consistent with the presence of a close binary system of supermassive black holes with 900 and 100 million solar masses with a separation less than 0.75 parsec.

Average Lyman - α emission from DLAs

Using a spectral stacking technique, **Hadi Rahmani** and **R. Srianand** and their collaborators (P. Noterdaeme and P. Petitjean) have searched for the average Lymanα emission from high-z damped Lyα (DLA) galaxies detected in the Sloan Digital Sky Survey quasi-stellar object (QSO) spectra.

They used a sample of 341 DLA galaxies of mean redshift $<z>=2.86$ and log~N(HI)$\geq$ 20.62 to place a 3σ upper limit of 3.0×10^{-18} ergs $^{-1}$ cm $^{-2}$ on the Lyα flux emitted within ~ 1.5 arcsec (or 12kpc) from the QSO line of sight. This corresponds to an average Lyα luminosity of $\leq 2 \pm 10^{41}$ ergs^{-1} or 0.03L$_*$ (Lyα). This limit is deeper than the limit of most surveys for faint Lyα emitters. The lack of Lyα emission in DLA galaxies is consistent with the in situ star formation, for a given N(HI), being less efficient than what is seen in local galaxies. Thus, the overall DLA population seems to originate from the low-luminosity end of the high-redshift Lyα emitting galaxies and/or to be located far away from the star-forming regions. The latter may well be true, since they detect strong O_{VI} absorption in the stacked spectrum, indicating that DLA galaxies are associated with a highly ionized phase, possibly the relics of galactic winds and/or originating from cold accretion flows. They have found the contribution of DLA

galaxies to the global star formation rate density to be comparatively lower than that of Lyman break galaxies.

X-ray emission from BAL QSOs

Broad absorption line QSOs, are usually X-ray quiet. In order to probe the X-ray weakness of low luminosity QSOs **R. Srianand** and collaborators (Stalin and P. Petitjean) have carried out an optical followup (using AAOMEGA/AAT multiple fibre spectroscopy) of all the QSO candidates detected in the CFHT deep field that also has deep XMM observations. They have reported 9 BAL QSO with X-ray emission and confirmed lack of X-ray emission in most of the BAL QSO which is related to X-ray weakness and not to X-ray absorption.

Nature of low η IGM

Sowgat Muzahid, R. Srianand and P. Petitjean have estimated the He II to H I column density ratio, η = N(He II)/N(He I), in the intergalactic medium towards the high-redshift (z_{em}= 2.885) bright quasar QSO HE 2347-4342 using Voigt-profile fitting of the H I transitions in the Lyman series and the He II Lyman- α transition as observed by the FUSE satellite. They have established a connection between the O~IV absorption and low η regions. They favoured a multiphase model in which most of the gas is at a high temperature (>10^5 K), but the metals, and in particular C IV, are due to a lower-temperature (few 10^4 K) photoionized gas.

An example of Translucent clouds at high-z

R. Srianand and his collaborators (P. Noterdaeme, Ledoux, Petitjean and Lopez) have presented the analysis of a sub-damped Lyman- α system with neutral hydrogen column density, log N(H^0) (cm^{-2}) = 20.0 ± 0.15 at z_{abs} = 2.69 toward SDSS J123714.60+064759.5 (z_{em}=2.78). Using the VLT/UVES and X-shooter spectrographs, they detect H_2, HD, and CO molecules in absorption with log N(H_2, HD, CO) (cm^{-2}) = $19.2^{+0.13}_{-0.12,}$ 14.48±0.05 and 14.17±0.09 respectively. The overall metallicity of the system is super-solar ([Zn/H] = +0.34 relative to solar) and iron is highly depleted ([Fe/Zn] = -1.39), revealing metal-rich and dusty gas. Three H_2 velocity components spanning ~ 125 km s^{-1} are detected. The strongest H_2 component, at z_{abs} = 2.68955, with log N(H_2) = 19.20, does not coincide with the centre of the HI absorption. This implies that the molecular fraction in this component, f_{H2} = $2N(H_2)/(2N(H_2)+N(H0)$, is higher than the mean molecular fraction $<f_{H2}>$ = 1/4 in the system. They also have found the Cl^0 associated with this H_2 component to have N(Cl^0)/N(Cl^+) > 0.4, which points in the same direction. Cl^0 is tied to H_2 by charge exchange reactions, this means that the molecular fraction in this component is not far from unity. The kinetic temperature derived from the J = 0 and 1 rotational levels of H_2 is T=108^{+84}_{-33} K and the particle density derived from the C^0 ground-state fine structure level populations is n^0_H ~ 50 - 60 cm^{-3}. They have derived an electronic density < 2 cm^{-3} for a UV field similar to the galactic one and show that the carbon-to-sulphur ratio in the cloud is close to the solar ratio. The size of the molecular cloud is probably smaller than 1 pc. Both the $CO/H_2 = 10^{-5}$ and CO/C^0 ~ 1 ratios for f H_2 > 0.24 indicate that the cloud classifies as translucent, i.e., a regime where carbon is found both in atomic and molecular form. The corresponding extinction, A_V = 0.14, albeit lower than the definition of a translucent sightline (based on extinction properties), is high for the observed H^0 column density. This means that intervening clouds with similar local properties but with higher column densities (i.e., larger physical extent) could be missed by current magnitude-limited QSO surveys.

The excitation of CO is dominated by radiative interaction with the cosmic microwave background radiation (CMBR) and they have derived Tex(CO) = $10.5^{+08}_{-0.6}$ K, when T_{CMB}(z = 2.69) = 10.05 K as expected, and measured $N(HD)/2N(H_2) = 10^{-5}$. This is about 10 times higher than what is measured in the galactic ISM for f_{H2} = 1/4 but similar to what is measured in the galactic ISM for higher molecular fractions. The astration factor of deuterium with respect to the primordial D/H ratio is only about 3. This can be the consequence of accretion of unprocessed gas from the intergalactic medium onto the associated galaxy.

In the future, it will be possible to search efficiently for molecular-rich DLAs/sub-DLAs with X-shooter, but detailed studies of the physical state of the gas will still need UVES observations.

Mini-survey of QSO-galaxy pairs

R. Srianand and his collaborators (Neeraj Gupta, Don York, David Bowen and Yogesh Wadadekar) have conducted a mini-survey of 21-cm absorption for a sample of five quasar-galaxy pairs (QGPs), with the redshift of the galaxies in the range $0.03 \leq z_g \leq 0.18$, selected from the Sloan Digital Sky Survey (SDSS). The HI 21-cm absorption was searched towards the nine sightlines with impact parameters ranging from 10 to 55 kpc using the Giant Metrewave Radio Telescope (GMRT).

21-cm absorption was detected only in one case, i.e, towards the quasar (z_q= 2.625 SDSS J124157.54+633241.6)-galaxy (z_g = 0.143 SDSS J124157.26+633237.6) pair with the impact parameter ~ 11 kpc. The quasar sightline in this case pierces through the stellar disc of a galaxy having near solar metallicity [i.e., (O/H)+12 = 8.7] and star formation rate uncorrected for dust attenuation of 0.1 $M_\odot yr^{-1}$. The quasar spectrum reddened by the foreground galaxy is well fitted with the Milky Way extinction curve (with an A_V of 0.44) and the estimated HI column density is similar to the value obtained from 21-cm absorption, assuming a spin temperature (T_S) of 100 K.

In the remaining cases, their GMRT spectra provide upper limit on N(HI) in the range (10^{17}-10^{18}) × T_S cm^{-2}. Combining their sample with the z ≤ 0.1 data available in the literature, the have found the detectability of 21-cm absorption with integrated optical depth greater than 0.1 km s^{-1} to be 50% for

the impact parameter less than 20 kpc. Using the surface brightness profiles and a well-established relationship between the optical size and extent of the HI disc known for nearby galaxies, they conclude that in most of the cases of 21-cm absorption non-detection, the sightlines may not be passing through the HI gas (1 column density of a few times 10^{19} cm^{-2}). They also find that in comparison to the absorption systems associated with these QGPs, $z < 1$ damped Lyman- α absorbers with 21-cm absorption detections have lower CaII equivalent widths despite having higher 21-cm optical depths and smaller impact parameters. This suggests that the current sample of DLAs may be a biased population that avoids sightlines through dusty star-forming galaxies. A systematic survey of QGPs over a wider redshift range using a large sample is needed to confirm these findings and understand the nature of 21-cm absorbers. This group is conducting such a survey with WSRT and GMRT.

A high-z 21-cm absorber with H_2 detections

A DLA with both 21-cm absorption and H_2 molecule is very rare and none was known at $z \geq 2$. **R Srianand** and his collaborators (Neeraj Gupta, P. Petitjean, Ledoux, and P. Noterdaeme) have reported the detection of 21-cm and molecular hydrogen absorption lines in the same damped Lyman - α system (DLA; with log N(HI) = 21.36 ± 0.10) at z_{abs} = 3.17447 towards SDSSJ133724.69+315254.55 (z_{em} ~ 3.174). They estimate the spin temperature of the gas to be $T_S = 600^{+222}_{-159}$ K, ntermediate between the expected values for cold and warm neutral media. This suggests that the HI absorption originates from a mixture of different phases. The total molecular fraction is low, ~ 10^{-7}, and H_2 rotational level populations are not in equilibrium. The average abundance of the α -elements is [S/H] = -1.45 ± 0.22. Nitrogen and iron are found underabundant with respect to α-elements by ~ 1.0 and ~ 0.5 dex, respectively. Using photoionization models, they conclude that the gas of mean density $n_H \sim 2$ cm^{-3} is located more than 270 kpc away from the quasi-stellar object. While the position of the 21-cm absorption line coincides with the H_2 velocity profile, its centroid is shifted by ~ 2.7 ± 1.0 kms^{-1} with respect to the redshift measured from the H_2 lines. However, the position of the strongest metal absorption component matches the position of the 21-cm absorption line within 0.5 kms^{-1}. From this, they constrain the variation of the combination of fundamental constants $x = \alpha^2 G_p/\mu$, $\Delta x/x = (1.7 \pm 1.7) \times 10^{-6}$, This system is unique as one can at the same time have an independent constraint on μ using H_2 lines. However, as the H_2 column density is low, only Werner band absorption lines are seen and, unfortunately, the range of sensitivity coefficients is too narrow to provide a stringent constraint: $\Delta\mu/\mu \leq 4.0 \times 10^{-4}$. The Ultraviolet and Visual Echelle Spectrograph spectrum reveals another DLA at z_{abs} = 3.16768 with log N(HI) = 20.41 ± 0.15 and low metallicity, [Si/H] = -2.68 ± 0.11, in which [O/C] ~ 0.18 ± 0.18 and [O/Si] ~ 0. This shows that even in the very early stages of chemical evolution, the carbon or silicon to oxygen ratios can be close to solar. Using Voigt profile fitting they derive log(N(DI)/N(HI)) = -(4.93 ± 0.15) in this system. This is a factor of 2 smaller than the value expected from the best-fitting value of Ω_b from the Wilkinson Microwave Anisotropy Probe 5-yr data. This confirms the presence of astration of deuterium even at very low metallicity.

Emission line galaxies detected in QSO spectra:

P. Noterdaeme, **R. Srianand** and **Vijay Mohan** have presented a sample of 46 [OIII]-emitting galaxies at $z < 0.8$ detected in the fibre spectra of quasars from the Sloan Digital Sky Survey, Data Release 7 (SDSS-DR7) through an automatic search procedure. They have also detected [OII] and Hβ emission lines from most of these galaxies in the SDSS spectra. They have studied both the emission and absorption properties of a subsample of 17 galaxies in the redshift range z = 0.4 - 0.7, where Mg II lines are covered by the SDSS spectra.

The measured lower limits on the star formation rates of these galaxies are in the range 0.2 - 20 $M\odot yr^{-1}$. The emission-line luminosities and (O/H) metallicities from R_{23} measured in this sample are similar to what is found in normal galaxies at these redshifts. Thus, this constitutes a unique sample of intermediate-redshift star-forming galaxies, where they can study the quasi-stellar object (QSO) absorber-galaxy connection. Strong Mg II (Wλ 2796≥ 1Å) as well as Mg I absorption lines are detected in the QSO spectra at the redshift of most of these galaxies. Strong Fe II (Wλ 2600 > 1Å) absorption lines are also generally detected whenever the appropriate wavelength ranges are covered. This suggests that most of these systems could be bona fide damped Lyman-α systems. They have investigated various possible relations between the Mg II rest equivalent widths and the emission-line properties.

They find a possible (2σ) correlation between the emission-line metallicity of the galaxies and the Mg II rest equivalent width of the absorbers [log(O/H) + 12 = 0.1Wλ2796 + 8.27], which could be a consequence of an underlying mass-metallicity relation. However, [OIII]-selected Mg II systems represent only a minor fraction of the strong Mg II absorbers.

They have found that cannot be attributed to biases related either to the spectral signal-to-noise ratio or to the brightness of the QSOs.

They have measured the average observed fluxes (collected into the SDSS fibre) of the [OII] and [OIII] lines associated to Mg II-selected systems through stacking technique. They find that the average luminosities of emission lines are higher for systems with larger Wλ 2796. The stacked luminosities are found to be below the typical detection limit in individual spectra, indicating that faint galaxies can contribute appreciably to the observed population of strong Mg II absorbers at intermediate redshifts.

They have also presented the long-slit spectroscopic observations of SDSSJ113108+202151, the most luminous line-emitting galaxy in our $z \geq 0.4$ sample obtained with IGO. Surprisingly, they find that the line-emitting region does not coincide with the nearby extended bright galaxy with

consistent photometric redshift seen inthe SDSS image.

CMB Temperature: A prediction of the standard hot big-bang model is the linear increase with redshift of the black-body temperature of the CMB (T_{CMB}). This radiation excites the rotational levels of some interstellar molecules, including carbon monoxide (CO), which can serve as cosmic thermometers. Using three new and two previously reported CO absorption-line systems detected in quasar spectra during a systematic survey carried out using VLT/UVES, **R. Srianand** and his collaborators (P. Noterdaeme, C. Ledoux, P. Petitjean and S. Lopez) have constrained the evolution of T_{CMB} to $z \sim 3$. Combining their precise measurements with previous constraints, they obtain $T_{CMB}(z) = (2.725 \pm 0.002) \times (1+z)^{1-\beta}$ K with $\beta = -0.007 \pm 0.027$, which is more than two-fold improvement in precision. The measurements are consistent with the standard (i.e., adiabatic, $\beta = 0$) big-bang model and provide a strong constraint on the effective equation of state of decaying dark energy (i.e., $w_{eff} = -0.996 \pm 0.025$).

High Energy Astrophysics

The black hole GRS 1915+105 is an enigmatic system exhibiting chaotic temporal behaviour. K. P. Harikrishnan, **R. Misra,** and G. Ambika have undertaken an comprehensive non-linear time-series analysis of its X-ray light curve. They are also developing a scheme to compute the fractal dimension of a system based on box-counting techniques, which is significantly more reliable and computationally more efficient than earlier methods.

Cyg X-1 is a well known black hole system, which has been extensively studied by the Rossi X-ray Timing Experiment (RXTE). S. Rizwan, **R. Misra,** and S. N. A. Jaaffrey have analyzed more than 500 pointed RXTE observations of the source using recent spectral models to obtain a consistent picture of the spectral changes that take place in the system. They have obtained correlations between the spectra components as the sources spectra evolve, which are overall consistent with the scenario, where the standard disk moves inwards and recedes.

Several X-ray binaries exhibit different kinds of long term temporal behaviour including long term secular evolution and super-orbital oscillation. These are thought to be related to instabilities in the accretion disk perhaps due to the hydrogen ionization instability. B. Maqbol, **Misra,** and N. Iqbal are investigating the effect on the structure and stability of X-ray irradiated outer accretion disks, and are trying to obtain global self-consistent time dependent solutions.

Active galactic nuclei (AGN) and X-ray binaries typically show hard X-ray lags, which means that the hard X-ray emission is delayed with respect to the soft X-ray emission. Analysis of XMM-Newton data of the AGN, NGC 1040, S. Tripathi, **Misra, G. C. Dewangan,** and S. Rastogi have discovered that this AGN shows the opposite trend of a soft lag. This will have important implications regarding the dominant radiative process and geometry of AGNs. They are also analyzing the Suzaku and XMM-Newton data analysis of Mrk 110 and Ark 564. These narrow-line Seyfert I, have markedly different high energy spectral indices, which may be analogous to the hard and soft states of X-ray binaries. The broadband Suzaku data will allow us to confirm the distinct spectra of the sources.

Chandra has discovered ultra-luminous X-ray (ULX) sources in nearby galaxies that are bright ($> 10^{39}$ ergs/s) and off centre. Jitesh V., Jeena K., **Misra, S. Ravindranath, Dewangan,** C. D. Ravikumar, B. R. S. Babu, and P. Shalima have undertaken a campaign to study the multi-wavelength properties of these sources. Using multiple epoch HST images of these galaxies, they are trying to identify those X-ray sources, which exhibit long term optical variability. These may be background AGN or more interestingly, episodic variability in the accretion disks. They have undertaken analysis of Spitzer data, to identify the infra-red counterparts of X-ray sources in nearby galaxies. The infra-red colour is known to distinguish AGN, and hence, infra-red emission is expected to identify background AGN and provide valuable information regarding nature of these sources.

S. Mondal and **Misra** are analyzing Chandra data of thirty nearby galaxies to study the long term temporal properties of the X-ray sources. They find that the bright ULX are less variable in ksec time-scale than the regular luminosity X-ray sources.

Cyclotron line spectra from X-ray pulsars

D. Bhattacharya and his Ph.D. student **Dipanjan Mukherjee** have been engaged in modeling the structure and stability of accretion mounds at the magnetic poles of accretion-powered X-ray pulsars and the cyclotron line spectra expected from these mounds. It has been found that a maximum of $\sim 10^{-13}$ solar mass of material can be magnetically confined in the polar mound for a typical dipole field strength of $\sim 10^{12}$ G. The distortions of the magnetic field, required to support the mound, leaving their signature in the cyclotron lines found in their X-ray spectra. The change in the magnetic field across the mound could range up to a factor of 4.

Discovery of three millisecond pulsars using GMRT within FERMI LAT error boxes

Bhaswati Bhattacharyya and her collaborators (Jayanta Roy, Yashwant Gupta, Dipankar Bhattacharya) has been working in the project of searching for millisecond pulsars within the error boxes of Fermi LAT sources using the GMRT. In order to systematize the search for millisecond pulsars in the error box of Fermi LAT sources, a Pulsar Search Consortium (PSC) is formed consisting of representatives of major radio observatories as well as members of the Fermi team, and has discovered 35 new millisecond pulsars (MSPs) in the galactic disk till date (including our discoveries), which is 30% of the total disk MSP population. They have started the pulsar search using the GMRT as a member of the PSC from the end of 2010. They have discovered three interesting millisecond pulsars from our current search processing. These are the first discoveries of galactic disk millisecond

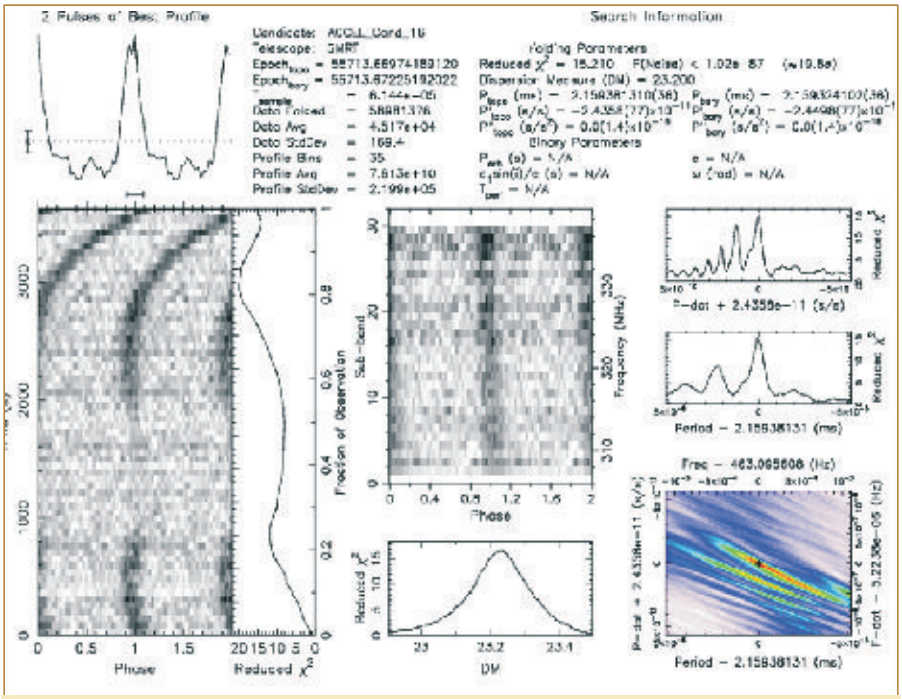
pulsations at the GMRT. The GMRT has joined the PSC a year before, and already contributed 11% of the total Fermi MSP discoveries in only 9 months, and contributed about 36% to enhance the MSP population. Due to steep spectral nature of the pulsars, lower frequencies are the better choice to look for them. The error boxes of the Fermi LAT sources are typically about 20'-30', hence, the larger beam-width of the GMRT at lower frequencies is of considerable help. We have developed the search pipeline tuned to look for these nearby fast MSPs in exotic binary system using the IUCAA HPC cluster. The full three dimensional search is very computationally expensive, uses upto 7.5 Tflops of compute power, e.g., the search analysis for one of our binary MSP took around 1280 CPU hours on the IUCAA HPC cluster. Two of these pulsars are discovered at 610 MHz and the third one is discovered at 325 MHz. All the three MSPs are found to be nearby object within a distance of 1.5 kpc.

One of these MSPs seems to have significant evolution of period and its higher derivatives over the span of observations. They could estimate the orbital period of 2.8 hrs, which is the shortest among the Fermi binary MSPs and second shortest among the full disk MSP population (based on the ATNF pulsar catalog database). The minimum companion mass is around 0.018 M⊙. Interestingly, we have found this pulsar eclipses about 10% of its orbit by this very low-mass companion. This indicates that this pulsar can be one of the "missing link" between the isolated and fully recycled pulsars, where the pulsar is ablating its companion creating significant amount of intrabinary material to obscure the pulsar emission, similar to the system of PSR B1957+20. Such systems are called "Black Widow". There are only 4 such system known in galactic disk till now. Discovery of such exotic binary system allows to study the special evolutionary phases of MSP formation.

They are in the process of following up all the three MSPs to derive initial timing solutions, including orbital parameters and companion types. Detection of gamma-ray pulsations using the radio ephemeris from our initial timing solution will help to understand the radio and gamma-ray emission mechanism.

Low mass X-ray binary (LMXB)

Broad-band spectral study of a low mass X-ray binary (LMXB) was done using X-ray data from the Rossi X-ray Timing Explorer (RXTE) and the Suzaku observatories. **Harsha Raichur** has found that the source was observed in two spectral state during its 2007 outburst, namely in the high luminosity/soft spectral state (high/soft) and the low luminosity/hard spectral state (low/hard). The two component model consisting of soft multi-colour blackbody emission from the accretion disk and a harder Comptonized emission from the neutron star boundary layer best describe the observed spectra in both high/soft and low/hard state. There was evidence, during the high/soft state, for a transient hard tail (extending to ~ 50 keV) and contributing 1.5% of the total source luminosity, which is modelled as a power-law. Aql X-1 is only the second Atoll LMXB after GX 13+1 to show this high energy tail. There was further evidence during all spectral states of the presence of a weak but broad Fe-line.



Discovery plot for one of the binary MSP, significant evolution of period and its derivatives seen with an eclipse.

It was found that as the source changed from high/soft state to the low/hard state, the temperature of the boundary layer changed from ~2 keV to ~20 keV.

She has also demonstrated that for eclipsing binaries (EB), it is possible to evaluate the temperature of both the stars if there are radial velocity data, and absolute light curves, which can be matched to an absolute flux model. The accuracy with which these temperatures can be evaluated is restricted only by the accuracy with which band to band flux calibration ratios are known. Hence, improved band to band flux calibration ratios will lead to improved temperature accuracy. Since, distance is correlated with temperature, improved temperature estimates will eventually lead to better estimates of distances to EBs. **Raichur** has simultaneously analysed the two-component RV curves and absolute light curves taken in different bands of three eclipsing binaries, namely V1143 Cyg, Eps CrA, and ER Vul, using the Direct Distance Estimation (DDE) algorithm, which is the latest version of Wilson-Devinney EB modeling and analysis computer programme.

She has found that the distances measured using DDE are in good agreement with the HIPPARCOS parallaxes and alsod the temperatures of the EB stars measured are consistent with the spectral types of the respective component stars.

Stars and Interstellar Medium

Analytical fits to interstellar extinction curves

Ashim Roy, Subodh K. Sharma, and **Ranjan Gupta** have recently developed analytical formulas for extinction by PAHs. The figure shows one such plot for the UV and FUV regions. such plots can be merged with the already developed silicate and graphite curves to provide better fits to the averaged observed galactic extinction curves and also possibly extend to the sister galaxies LMC and SMC interstellar extinction curves.

Composite dust model fits to interstellar extinction curves in various sight lines in our galaxy

Under the ongoing ISRO-RESPOND project, entitled 'Interpretation of the observed extinction in the optical-UV region from TAUVEX and ASTROSAT-UVIT satellite database', **Nisha Katyal, Ranjan Gupta** and D.B. Vaidya have compared the composite grain model based extinction curves with various directions in our galaxy. The variation in the strength and width of the 2174Å feature is clearly seen for various environments, i.e., from dense regions and reflection nebulae to diffuse clouds. The main conclusions of this study are:

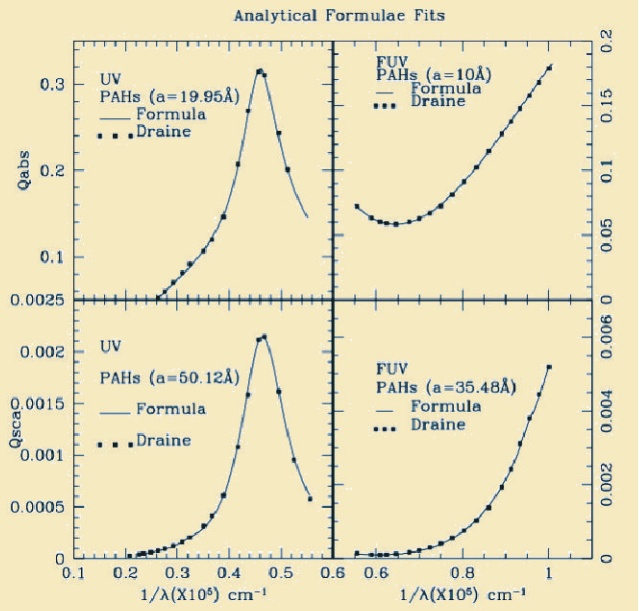
(i) The extinction properties of the composite grains vary considerably with the variation in the volume fraction of the inclusion, viz., the extinction peak at '2175 Å'. shifts and broadens with variation in the graphite inclusions.

(ii) Our composite grain models, with axial ratios 1.33 -2.00 and volume fraction of inclusions 0.1 - 0.3, fit the observed extinction curves reasonably well. However, the composite grain models with inclusions of other carbonaceous materials (silicon carbide, PAHs) might help to obtain better fits.

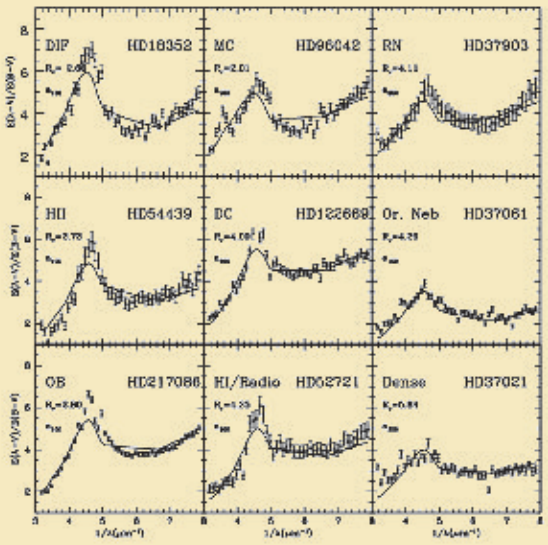
(iii) From the sample of 48 observed IUE stars, about 77% (37 nos.) fit the model curves with smaller size distribution, a = 0.001 - 0.100μ.

(iv) The ratio R_V =A(V)/E(B-V) i.e., visual extinction to the total extinction towards the direction for these observed IUE stars is well correlated with the '2175Å' feature. The 'peak' is higher for small value of R_V (= 2-3) and it gets lower for large value of R_V (=4-6). However, more sample of stars need to be analyzed with the composite grain models to understand the extinction properties in the UV region.

(v) Broader bumps of larger widths are produced in the extinction curves of the stars lying in the dense environments such as dense clouds and reflection nebulae (RN) whereas narrower bumps of average widths are produced in extinction curves of stars lying in the diffuse environments. A more systematic study with a larger sample of stars in all the environments are required to be compared with the dust models to infer the dust properties in various dust environments.



Analytical fits in the UV and FUV region using PAHs



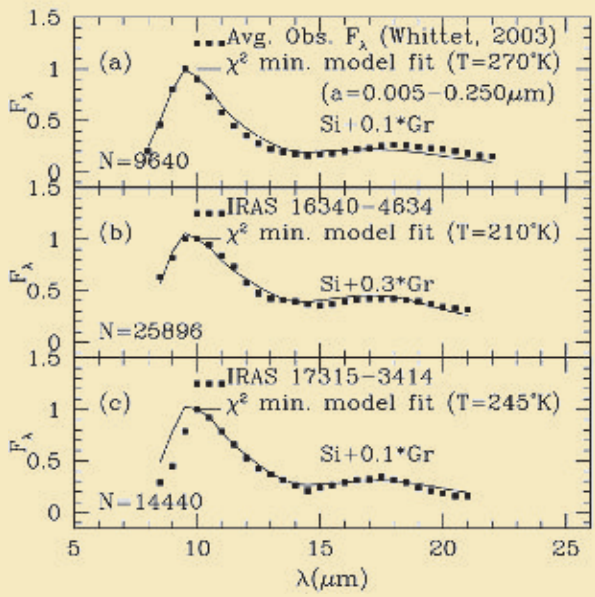
Model fitting for stars with different environments. DIFF, HII, OB, MC, DC, HI/Radio, RN, Or.Neb, dense refers to diffuse medium, HII region, OB type stars, molecular cloud, dense cloud, HI/Radio sources, reflection nebulae, orion nebulae complex and dense environment respectively. It can be seen for most of the stars that dense regions and stars present in dense cloud, nearby HI/Radio sources, Orion Nebula, reflection nebulae and dense mediums have broader peak, whereas the peak is narrower for diffuse regions, OB and HII regions. a_{100} and a_{250} mentioned in the panels are the best fit size for that particular star, which signifies the size range 0.001 - 0.100μ and 0.005 - 0.250μ respectively.

Composite dust grains and circumstellar IR emissions

D.B. Vaidya and **Ranjan Gupta** have studied the effects of inclusions and porosities on the emission properties of silicate grains and compare the model curves with the observed infrared emission from circumstellar dust. The results on the composite grains clearly indicate that the silicate feature at 10 mm shifts with the volume fraction of graphite inclusions. The feature does not shift with the porosity. Both the features do not show any broadening with the inclusions or with porosity. The absorption efficiencies of the composite grains calculated using DDA and effective medium approximation (EMA) do not agree. The composite grain models presented in this study need to be compared with the observed IR emission from the circumstellar dust around a few more stars.

Correlation of colour excess and polarization in dark star forming clouds

Star forming regions of dark clouds CB3, CB25 and CB39 were studied by A. K. Sen, V. F. Polcaro, I. Dey, and **R. Gupta** in details after obtaining the photometric observations with the 2 m. Himalayan Chandra Telescope, India, and 1.52 m. Cassini Telescope, Loano, Italy, and comparing with the earlier photo-polarimetric observations carried out by this group in 2000. The major conclusions from



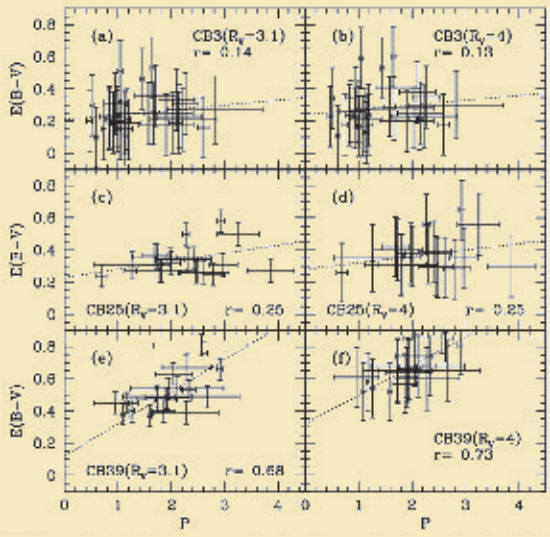
Best fit χ^2 minimized composite grain models (silicates with graphite inclusions) plotted with the average observed infrared flux for the IRAS-LRS curve and the two stars, IRAS 16340-4634 and IRAS 17315-3414.

this study are listed below:

(i) The three clouds under observation show different degrees of correlation between polarization and extinction. The correlation does not appear to be related to the turbulence or other parameters within the clouds.

(ii) The correlation seems to be dependent on the degree of grain alignment (expressed as a function of dust and gas temperatures) as estimated using a Davis Greenstein type mechanism. However, for any future work to study this possibility, recent alignment models should be included.

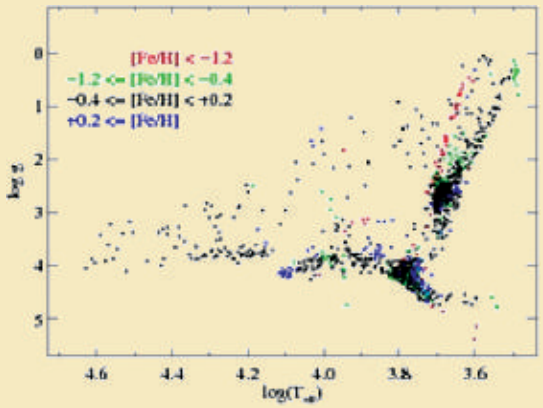
(iii) For any future studies, one should also determine E (B - V) more accurately with spectroscopy and perform polarimetry at much higher extinction in the infrared,



Extinction E(B-V) vs. polarization p for the clouds CB3, CB25, and CB39 for RV = 3.1 and 4.0 are shown.

Cross-calibration and stellar atmospheric parameters from CFLIB and ELODIE spectral libraries

The CFLIB spectral library has been now compared with the Elodie spectral library and the atmospheric parameters have been cross-calibrated and published. This work has been carried out by Yue Wu, Harinder P. Singh, Philippe Prugniel, **Ranjan Gupta,** and Mina Koleva.



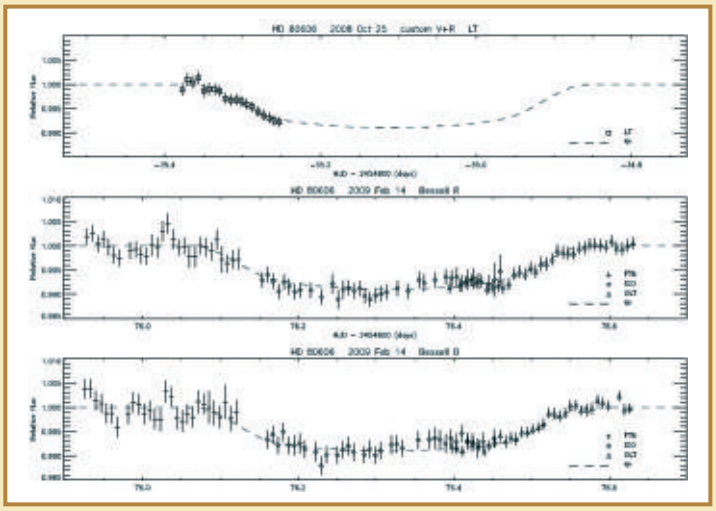
Distribution in the log(Teff) - log g plane of the adopted atmospheric parameters for the 1271 CFLIB stars. The colour of the symbols distinguishes the different metallicity classes and the comparison of the atmospheric parameters determined by the authors (ordinates, upper panels) with those from ELODIE 3.2 (abscissas).

Very old stars

Although, a study of CMDs of stars in the LMC suggests a population of 20 Gyr age the uncertainties in the data cannot rule out the alternative of interstellar reddening. Further work, including spectroscopy is needed for a definitive conclusion. This study has been carried out by **Vijay Mohan, Jayant Narlikar** from IUCAA, Ferdinando Patat from ESO, and Ken Freeman from ANU, Canberra.

Transit of a planet across the star HD80606

A. N. Ramaprakash and collaborators used four telescopes at different longitudes to obtain near-continuous light curve coverage of the star HD 80606 as it was transited by its ~4-MJup planet. The observations were performed during the predicted transit windows around the 25th of October 2008 and the 14th of February 2009. Their data set is unique in that it simultaneously constrains the duration of the transit and the planet's period. The Markov-Chain Monte Carlo analysis of the light curves, combined with constraints from radial-velocity data, yields system parameters consistent with previously reported values. They find a planet-to-star radius ratio marginally smaller than previously reported, corresponding to a planet radius of Rp = 0.921 ± 0.036RJup.

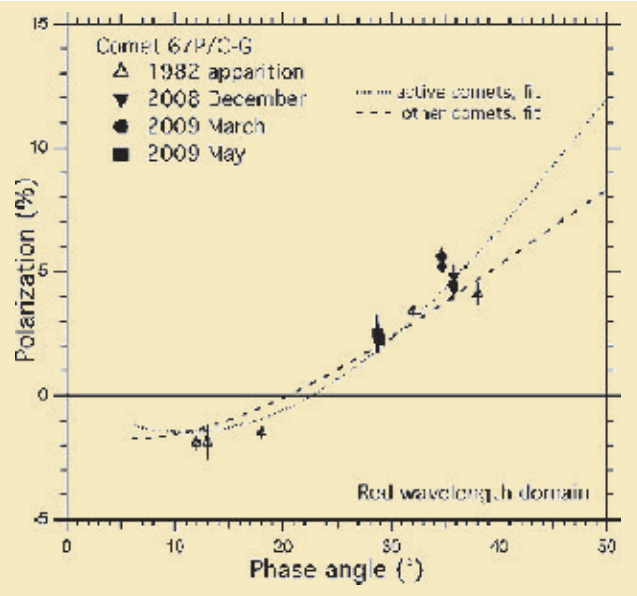


A transit ingress of HD 80606 b observed with the Liverpool telescope (LT, top panel), and the following transit observed by the Faulkes Telescope North (FTN), the IUCAA Girawali Observatory's 2 m telescope (IGO), and the Oskar-L¨uhning Telescope (OLT). Close-up of the data used in the fit, along with the best-fit model obtained from MCMC simulations. The error bars indicate the weights used in the fit, i.e., they include the statistical uncertainty as well as the read noise estimate.

Parameter	Median	Uncertainty
Scaled semi-major axis, a/R*	101.2	-5.5, + 6.9
Orbital period, P (days)	111.4273	± 0.0031
Orbital eccentricity, e	0.93369	± 0.00068
Epoch of periastron T*p* (HJD)	2454424.8575	± 0.0040
Argument of periastron, ω (deg)	300.53	± 0.19
Orbital, inclination, *i* (deg)	89. 341	-0.063, + 0.073
Planet/ star radius ratio R_p/R_*	0.0967	-0.0035, + 0.0032
Planet radius, R_p[a] (R_{Jup})	0.921	± 0.036
Epoch of mid-transit (HJD)	2454876.3173	± 0.0036
Complete transit duration (t_4 - t_1, hours)	12.14	± 0.36
Ingress / egress duration (t_2 - t_1, hours)	2.33	± 0.37

[a] **Using $R_* = 0.978 \pm 0.015 R_\odot$ (?).**

The physical parameters of the HD 80606 b system obtained from the MCMC fit.



Comet 67P/C-G polarization observations on 2008-2009 return, as compared to its 1982 apparition and to synthetic polarization phase curves for other comets.

Sun and Solar system

Scale-dependence of magnetic helicity in the solar wind

Kandaswamy Subramanian, in collaboration with Axel Brandenburg, Andre Balogh, and Melvyn L. Goldstein determined the magnetic helicity, along with the magnetic energy spectra of the solar wind, at high latitudes using data from the Ulysses mission. The data set spans the time period from 1993 to 1996. The basic assumption of the analysis is that the solar wind is homogeneous. Because the solar wind speed is high, they follow the approach first pioneered by Matthaeus, et al., by which, under the assumption of spatial homogeneity, one can use Fourier transforms of the magnetic field time series to construct one-dimensional spectra of the magnetic energy and magnetic helicity under the assumption that the Taylor frozen-in-flow hypothesis is valid. That is, a well-satisfied assumption for the data used in this study. The magnetic helicity is derived from the skew-symmetric terms of the three-dimensional magnetic correlation tensor, while the symmetric terms of the tensor are used to determine the magnetic energy spectrum.

Their results show a sign change of magnetic helicity at wavenumber $k \sim 2$ AU^{-1} (or frequency $\nu \sim 2$ uHz) at distances below 2.8 AU and at $k \sim 30$ AU^{-1} (or $\nu \sim 25$ uHz) at larger distances. At small scales, the magnetic helicity is positive at northern heliographic latitudes and negative at southern latitudes. The positive magnetic helicity at small scales is argued to be the result of turbulent diffusion reversing the sign relative to what is seen at small scales at the solar surface. Furthermore, the magnetic helicity declines toward solar minimum in 1996. The magnetic helicity flux integrated separately over one hemisphere amounts to about 10^{45} Mx^2/cycle at large scales and to 3 times lower value at smaller scales.

Polarisation on observations of comet 67P

Remote observations of the light scattered by comet 67P/Churyumov-Gerasimenko dust coma are of major importance to determine the physical properties of the particles and prepare the rendezvous with the ESA/Rosetta spacecraft in 2014. Polarization and intensity variations in the coma of the comet are reminiscent of those noticed for some comets such as comet 81P/Wild 2 and 9P/Tempel 1. The presence of rather large dust particles can, thus, be suggested before and just after perihelion and ejection of smallest grains, eventually in fluffy aggregates post-perihelion. An important seasonal effect related to the obliquity of the comet suggests that the different grains originate from different hemispheres of the nucleus. The observations were carried out at the Haute-Provence Observatory (France) during March 17-19, 2009 at 35^0 phase angle and at IUCAA Girawali Observatory during December 25-27, 2008 at 36^0 phase angle, and during April 30-May 1, 2009 at 29^0 phase angle, by Edith Hadamcik, Anny-Chantal Levasseur-Regourd, Asoke K. Sen, **Ranjan Gupta** and Jeremie Lasue.

Instrumentation

Ultra Violet Imaging Telescope (UVIT) on ASTROSAT

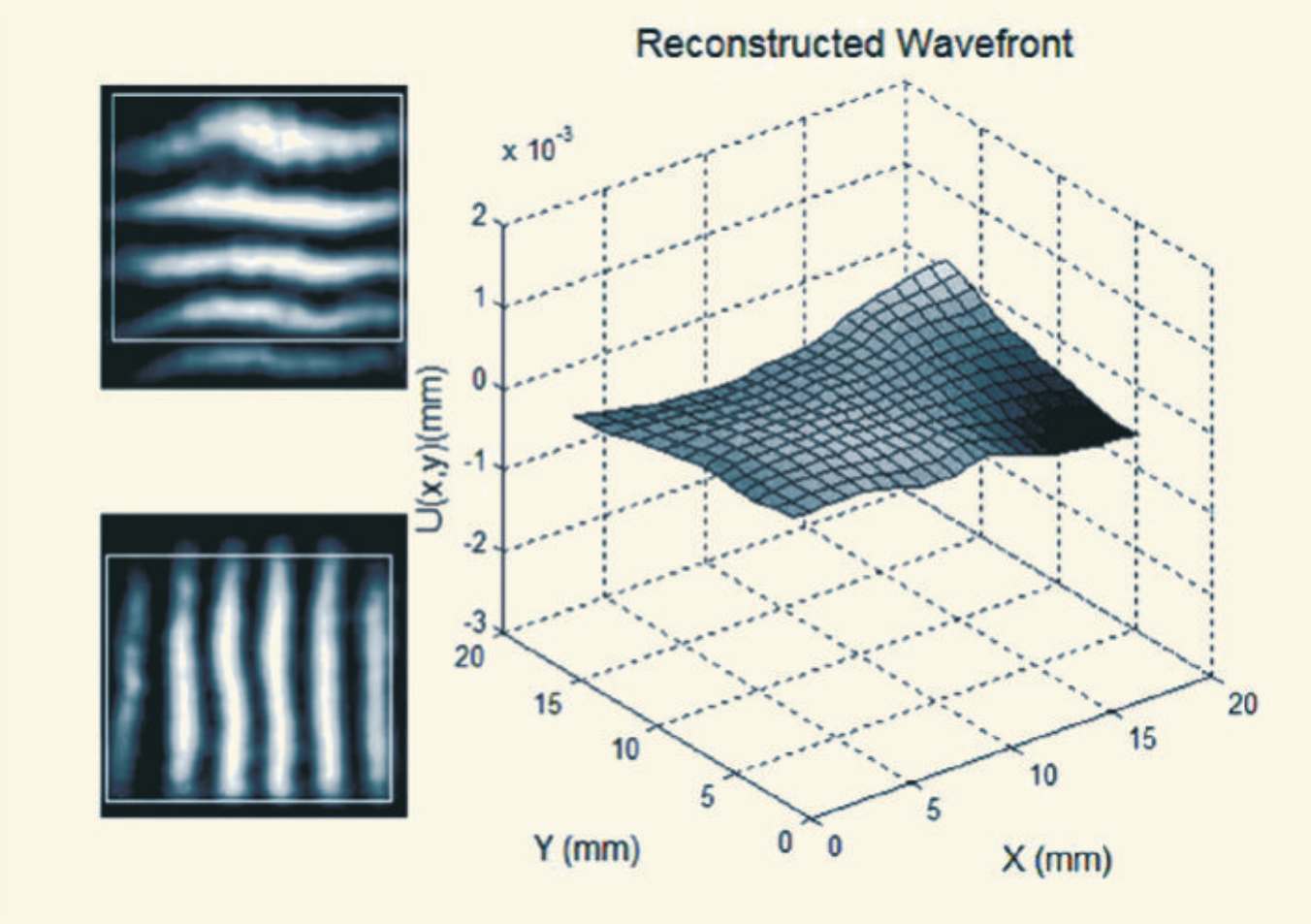
UltraViolet Imaging Telescope (UVIT) is one of the 5 instruments to go on the first Indian astronomy satellite ASTROSAT; the other 4 instruments are X-ray telescopes. UVIT consists of two telescopes, each of aperture 380 mm. The two telescopes make images in a field of ~ 28' with a resolution of < 1.8", simultaneously in three channels: 1300 - 1800 A, 2000 - 3000 A, and 3200 - 5300 A. UVIT is being developed through a collaboration between several Indian institutions: IIA, ISRO, IUCAA, and TIFR, and Canadian Space Agency. **Shyam Tandon** has been coordinating this development as Programme Manager for the project.

This year, the various subsystems of the payload were extensively tested and calibrated. The engineering model of the payload was assembled at IIA, and it was tested at ISAC, ISRO for vibration loads (expected during the launch), and for thermal/vacuum conditions as per the protocol of ISRO. With successful testing of the engineering model, design of the payload is checked. Assembly of the flight model is to begin in the next year. It is expected that the payload would be ready for delivery to ISAC, ISRO for integration with the satellite by the end of year 2011.

A two channel wave-front sensor using moire's deflectometry

In another work by **A. N. Ramaprakash** and collaborators, they constructed an adjustable, high sensitivity, wide dynamic range two channel wave-front sensor based on moir´e deflectometry, for measuring distortions of light wave-front transmitted through the atmosphere.

In this approach, a slightly divergent laser beam is passed through the turbulent ground level atmosphere and then a beam-splitter divides it into two beams. The beams pass through a pair of moir´e deflectometers, which are installed parallel and close together. From deviations in the moir´e fringes they calculated the two orthogonal components of angle of arrival at each location across the wave-front. The deviations have been deduced in successive frames which allows evolution of the wave-front shape to be determined. The dynamic range and sensitivity of detection are adjustable by merely changing the separation of the gratings and the angle between the rulings of the gratings in both the channels. The spatial resolution of the method is also adjustable by means of bright, dark, and virtual traces for given moir´e fringes without paying a toll in the measurement precision.



Results from a wavefront sensor based on moire fringes and Talbot effect. The wavefront reconstructed from two orthogonal fringe patterns generated by a plane wavefront passing through a turbulent medium.

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(b) Proceedings

Bhaswati Bhattacharyya, Geoffrey Wright, Yashwant Gupta, Patrick and Weltevrede (2010) *Discovery of phase related drift regions in PSR B1039-19*, AIP Conference Proceedings of Pulsar Conference *Radio Pulsars: A key to unlock the secrets of the Universe*, Sardinia, October 2010.

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(c) Books (authored/edited)

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J. V. Narlikar (2010) *Shake-Up India*, Global Vision Press, New Delhi

T. Padmanabhan (2010) *Astronomy in India: A Historical Perspective,* Springer, Delhi (Editor: Indian National Science Academy, Platinum Jubilee special volume.)

Pedagogical Activities

(a) IUCAA-NCRA Graduate School

Dipankar Bhattacharya	Quantum and Statistical Mechanics II (14 lectures) (October –December 2010)
Gulab Dewangan	Electrodynamics and Radiative Processes I (August - September 2010)
Sanjeev Dhurandhar	Methods of Mathematical Physics I (21 lectures) Courses taught at M.Sc., Pune University (August - October 2010)
Ranjeev Misra	Electrodynamics and Radiative Processes II (October – December 2010)
Swara Ravindranath	Introduction to Astronomy and Astrophysics I (14 lectures) (August - October 2010)
Varun Sahni	Extragalactic Astronomy I (January – February 2011)
Tarun Souradeep	Methods of Mathematical Physics II (October -December 2010)
Kandaswamy Subramanian	Quantum and Statistical Mechanics I (14 lectures) (August - September 2010)
R. Srianand	Galaxies: Structure, Dynamics and Evolution (January – February 2011)

(b) University of Pune, M.Sc. (Physics)

Ranjan Gupta	Astronomy and Astrophysics (Theory 10 lectures), and Laboratory course for III and IV semester courses (10 sessions and night experiments)
J.V. Narlikar	Astronomy and Astrophysics II
T. Padmanabhan	*Astrophysics* February-April 2011.

(c) Supervision of Projects

Bhaswati Bhattacharya	IUCAA School Students Summer Programme 2010 – 1 week, Project on *Pulsars* (for six students) IUCAA School students summer program 2010 – 6 weeks *Exploring single pulse properties of pulsars* (for five students)
Dipankar Bhattacharya	I.S. Shabnam (VSP-2010) *Polarization due to Compton drag in relativistic flows* Devraj Pawar (Academy Summer Fellowship 2010) *Timing properties of low-mass X-ray binaries* Gayathri Raman (Pune University M.Sc.) *Observational determination of magnetic field in intermediate polars* Shweta Attiwilli (Pune University M.Sc.) *Seismological signatures in flares of soft gamma repeaters*
Sanjeev Dhurandhar	Swetha Bhagwat (IISER, Pune) *General relativity and gravitational waves*
Gulab Dewangan	Sibasish Laha (Ph. D. project) *Warm absorption and emission from Seyfert 1 galaxies* Bruce Cabral (Graduate school project)*Suzaku X-ray spectral study of narrow-line Seyfert 1 galaxy Ton~S180* Sukhdeep Singh (VSP project)*Variable X-ray absorption and broad iron Kα line*

Ajit Kembhavi	Chandrashekar Murugesan (St. Joseph's College, Bengaluru, Academy Summer Fellow) *A study of the fundamental plane of galaxies*
	Mohit Tanga (IISER, Mohali) (Jointly with Ranjeev Misra) *Compton drag model for gamma-ray bursts*
Ranjeev Misra	Fency. M., and Minu V. (M.Sc., Dept. of Physics, Calicut Univ.) *Accretion disks around compact objects*
J.V. Narlikar	School Students' Summer Programme (2010) *Foucault Pendulum*
T. Padmanabhan	Aditya Bawane (BITS-Pilani) (August - December 2010) *Quantum field theory and horizon thermodynamics*
	Alexander Yale (Perimeter Institute, Canada) (Jan 2010 - June 2010) *Structure of Lanczos-Lovelock Lagrangians in critical dimensions*
Surajit Paul	Ashmeet Singh (Integrated M.Sc., IIT Roorkee) *Understanding SZ effect in context to galaxy-cluster physics Co-guide* (with Joydeep Bagchi)
Tarun Souradeep	Shireen Gangal (Univ. Pune, M.Sc. Thesis) *Reconstruction of inflaton potential* (Co-supervised by Gaurav Goswami.) (From September 2010- May 2011).
	Santanu Das (Graduate school project) *Detour into the relic radiation,* (May-July, 2010)
	Nawaf Nazir (NIT, Srinagar) *SI violation simulation* (February 2010)
Kandaswamy Subramanian	Suvodip Mukherjee (VSP - 2010) *Reionization of the universe*
R. Srianand	*Observational training project* for 6 students (IISER, Pune) and 3 students (IIST, Thiruvanandapuram)

(d) Supervision of Ph.D. Thesis

T. Padmanabhan (Guide)	Gaurang Mahajan, *Nature and evolution of quantum states in non-trivial external backgrounds*

Pedagogical Articles in Physics

T. Padamanabhan

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Archimedes, Resonance, **15**, 774, 2010.

The Healing Art, Resonance, **15**, 870, 2010.

The Arab Legacy, Resonance, **15**, 1009, 2010.

The Indo-Arabic Numerals, Resonance, **15**, 1062, 2010.

The Printed Page, Resonance, **16**, 6, 2011.

The Conquest of the Seas, Resonance, **16**, 110, 2011.

The Rise of Modern Medicine, Resonance, **16**, 274, 2011.

Talks by IUCAA Academic Members at IUCAA and Other Institutions

(a) Seminars, Colloquia, and Lectures

Bhaswati Bhattacharyya

Single pulse studies of pulsars, Max Plank Institute for Radio Astronomy, Bonn, Germany, October 2010.

Discovery of phase related drift regions in PSR B1039-19, Jodrell Bank Centre for Astrophysics, University of Manchester, UK, October 2010.

Search for millisecond pulsations from Fermi LAT unassociated sources, Workshop on Compact Objects held in IUCAA, December, 2010.

Dipankar Bhattacharya

Evolutionary processes in neutron star binaries, Astrophysics of Neutron Stars 2010, Cesme, Turkey, August 2, 2010.

Neutron star studies with Astrosat, Astrophysics of Neutron Stars 2010, Cesme, Turkey, August 6, 2010.

Some examples of HPC applications in astrophysics, Indo-Russian HPC Workshop, C- DAC/NCRA, November 19, 2010.

Data-enabled research in astronomy and the role of US-India collaboration, US-India Network-Enabled Research Collaboration Meeting, New Delhi, December 6, 2010.

Beyond the Chadrasekhar limit: The structure and formation of compact stars, The Chandrasekhar Centenary Symposium, Indian Institute of Astrophysics, Bengaluru, December 10, 2010.

Observational constraints on compactc star equation of state, Workshop on Compact Objects, IUCAA, December 16, 2010.

Cyclotron line studies with Astrosat, International Conference on Wideband X-ray Astronomy, Frontiers in Timing and Spectroscopy, IUCAA, January 13, 2011.

Hard X-ray studies of the magnetic fields of neutron stars, Astronomical Society of India Meeting, Raipur, February 23, 2011.

Gamma ray bursts: Echoes in the embers, Indo-Russian Bilateral Workshop on Supernovae and Gamma Ray Bursts, ARIES, Nainital, March 2, 2011.

Survey of astronomy (2 lectures), Vacation Students' Programme, IUCAA, May 10-11, 2010.

Gamma ray bursts, Vacation Students' Programme, IUCAA, May 27, 2010.

Monte Carlo techniques in astrophysics (2 lectures), Workshop on Advanced Statistical Techniques for Astronomy, IUCAA, October 5-6, 2010.

Magnetic field evolution in neutron star interiors, Colloquium, NCRA, July 19, 2010.

Structure and stability of accretion mounds on the polar caps of strongly magnetized neutron stars, Astronomical Institute Anton Pannekoek, University of Amsterdam, March 23, 2011.

Naresh Dadhich

Gravity (2 lectures), Vacation Students' Programme, IUCAA, June 2-3, 2010.

Chaired the Workshop on Cosmology, 19th International Conference on General Relativity and Gravitation (GR-19), Mexico, July 4-9, 2010.

Characterization of the Lovelock gravity by the Bianchi derivative, 19th International Conference on General Relativity and Gravitation (GR-19), Mexico, July 4-9, 2010.

Gravity in higher dimensions, Harish-Chandra Research Institute, Allahabad, September 23.

Characterization of the Lovelock gravity by the Bianchi derivative, Feza Gursey Institute, Istanbul, Turkey, October 18, 2010.

Why Einstein (Had I been born in 1844!)?, Canakkale Onsekiz Mart University, Turkey, October 20, 2010.

Universalization as a physical guiding principle, Akdeniz University, Antalya, Turkey, October 25, 2010.

Gravity in higher dimensions, 13th Regional Conference on Mathematical Physics, Antalya, Turkey, October 2010.

Gravity in higher dimensions, South African Mathematical Society's 53rd Annual Congress, University of Pretoria, South Africa, November 2010.

Why Einstein (Had I been born in 1844!)?, Pt. Ravishankar Shukla University, Raipur, December 5, 2010.

A unified view of the basic forces, Pt. Ravishankar Shukla University, Raipur, December 6, 2010.

Some universal features of gravity in higher dimensions, Chandrayana 2011 Conference, The Institute of Mathematical Sciences, Chennai, January 4, 2011.

Gravity, for M.Sc. students of Presidency College and the West Bengal State University, IUCAA, January 28, 2011.

On the measure of spacetime and gravity, Indian Institute of Technology, Kharagpur, March 2011.

Gulab Chand Dewangan

Partial covering absorption and variability in AGN, International Conference on Wideband X-ray Astronomy, Frontiers in Timing and Spectroscopy, IUCAA January 13-16, 2011.

X-ray emission from radio-quiet active galactic nuclei, Astronomical Society of India Meeting, Raipur, February 23-25, 2011.
Active galactic nuclei, Tezpur University, March 4, 2011.

Sanjeev Dhurandhar

Mathematical structures underlying LISA time-delay interferometry, One day symposium, Mathematics Department of North Bengal University, Siliguri, October 9, 2010.

The IndIGO project, 26th Meeting of the IAGRG, HRI, Allahabad, January 20, 2011.

Data analysis for LIGO-Australia, IndIGO Meeting, Jamia Millia Islamia, New Delhi, February 8 - 10, 2011.

Gravitational wave astronomy, CEBS, Kalina, Mumbai, April 5, 2010.

Ranjan Gupta

Artificial neural networks - a robust tool for astronomy applications, CALTECH, Pasadena, USA, June 18, 2010.

Modeling of interstellar dust, University of Minnesota, USA, June 22, 2010.

Composite grains in circumstellar dust, Workshop on Dusty Visions 2010, Gottingen, Germany July 14 - 16, 2010.

Artificial neural networks: Application to astronomical spectra, NISTADS, New Delhi, September 7, 2010.

Bidirectional surface scattering experiment for solar system regolith analogs, Workshop on Laboratory Astrophysics: Application to Cosmic Dust, M.G. Science Institute, Ahmedabad, November 12 - 13, 2010.

Funding opportunities for Indian researchers in astronomy area, Planetarium and The Outreach Activities Conference, Thiruvananthapuram , November 18-21, 2010.

Interstellar dust and its properties, CPS, Kobe University, Japan, March 9, 2010.

Light scattering properties of nano sized dust grains, Centre for Excellence in Nano-Technology, AIT, Bangkok, March 19, 2011.

Ajit Kembhavi

Radiative processes (2 talks), Advanced Workshop on Astronomy: Observations, Theory and Interpretations, IUCAA Resource Centre, North Bengal University, Siliguri, April 5 and 6, 2010.

Large telescopes – From Galileo's time to the 21st century, KVPY Summer Programme, IISER, Pune, June 2, 2010.

Big data – Is the end of observational astronomy in sight? Twenty-first Mid-year Meeting of Indian Academy of Sciences, Indian Institute of Science, Bengaluru, July 2, 2010.

Virtual observatory and world wide telescope (WWT), Workshop on World Wide Telescope, IISc., Bengaluru, September 2, 2010.

Virtual observatories and world wide telescope, Workshop on WWT and VO, IUCAA, Pune, September 4, 2010.

White dwarf stars and Professor S. Chandrasekhar, St. Joseph's College, Bengaluru, September 15, 2010.

"E", KRM 2010, Information resources, services and practices, Tata Memorial Hospital, Mumbai, September 29, 2010.

Chi^2 Distribution, confidence intervals and regression problems, Workshop on Advanced Statistical Techniques for Astronomy, IUCAA, Pune, October 4 and 6, 2010.

Real and virtual observatories, Mindspark' 10, College of Engineering, Pune, October 8, 2010.

Supermassive black holes, IISER, Thiruvananthapuram, October 19, 2010.

Telescopes, Workshop on Optical and Infrared Astronomy, DDU Gorakhpur University, October 26, 2010.

Photometry, Workshop on Optical and Infrared Astronomy, DDU Gorakhpur University, October 26, 2010.

The IUCAA Story, South African Astronomical Observatory, Cape Town, South Africa, November 4, 2010.

Fitting a straight line: Is that so simple? Workshop on Data Analysis Techniques in Astronomy, Burdwan University, November 25, 2010.

Universal galaxies (two talks), Workshop on Astrophysics and Cosmology West Bengal State University, Barasat, November 26, 2010.

Virtual observatories, US-India Workshop on Network Enabled Research Collaboration, ERNET India, New Delhi, December 6, 2010.

Galaxy morphology and supermassive black holes, Chandrayana 2011, The Institute of Mathematical Sciences, Chennai, January 3, 2011.

Mega projects in astronomy – Opportunities for the Indian software industry, Centre for Research in Engineering Sciences and Technology, KPIT Cummins Infosystems Ltd., Hinjewadi, Pune, January 20, 2011.

Astronomy with the virtual observatory and large telescopes, Workshop on Astronomy with Virtual Observatory, Sri Venkateswara College, New Delhi, January 25, 2011.

Extremely large optical telescopes, Frontiers in Physics – 2011, Fergusson College, Pune, February 7, 2011.

Kepler: The astronomer and Kepler the mission, Meghnad Saha Lecture, University of Allahabad, February 22, 2011.

Electronic access to scientific literature, 8th International Caliber 2011, Goa University, March 2, 2011.

Nature of galaxies, Workshop on Optical Astronomy, Data Mining and Analysis, CUSAT, Kochi, March 3, 2011.

Astronomical data through arXives, Workshop on Optical Astronomy, Data Mining and Analysis, CUSAT, Kochi, March 4, 2011.

Kepler: The astronomer and the mission, Aligarh Muslim University, March 14, 2011.

Stellar mass and supermassive black holes (two talks), IUCAA School on Gravitation and Astrophysics, Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi, March 15, 2011.

Ranjeev Misra

Radiative and accretion processes in astrophysics (2 lectures) Workshop on Astrophysics and Cosmology, West Bengal State University, Barasat, November 2010.

Accretion processes in astrophysics (2 lectures) Workshop on Data Analysis Techniques in Astronomy, Burdwan University, November 2010.

ASTROSAT: A forthcoming Indian astronomy mission, Conference on Accretion and Outflow in Black Hole Systems, Kathmandu, Nepal, October 11-15, 2010.

Timing properties of accreting black hole systems, Internatioal Conference on Wideband X-ray Astronomy, Frontiers in Timing and Spectroscopy, IUCAA, January 2011.

Vijay Mohan

Observational astronomy, Homi Bhabha Centre for Science Education, Indian National Astronomy Olympiad (INAO), Mumbai, May 2010.

Observational astronomy, West Bengal State University, Barasat, April 19 to 30, 2010.

Observational astronomy and demos in image processing, Introductory Summer School on Astronomy and Astrophysics, IUCAA, May-June 2010.

Observational astronomy, Workshop on Data Analysis and Data Mining, CUSAT, Kochi , March 3 - 5, 2011.

Jayant Narlikar

Searches for extraterrestrial life, Maulana Azad Institute of Technology, Bhopal, April 12, 2010.

A search for very old stars, IUCAA, Pune, April 15, 2010.

A search for micro-organisms in the stratosphere, Max Planck Institut fur Astrophysik, Germany, April 28, 2010.

Some conceptual problems in general relativity and cosmology, Institute of Cosmology and Gravitation, University of Portsmouth, U.K., May 11, 2010.

A search for very old stars, Institute of Astronomy, U.K., June 2, 2010.

A search for micro-organisms in the Earth's atmosphere, College de France, Paris, June 24, 2010.

A search for very old stars, Canadian Institute for Theoretical Astrophysics (CITA), Toronto, September 20, 2010

A search for very old stars, University of Western Ontario, London, Canada, September 23, 2010.

Searches for microlife in the Earth's atmosphere, Origins Institute, Hamilton, Canada, September 27, 2010.

A search for very old stars, Origins Institute, Hamilton, Canada, September 28, 2010.

A search for very old stars, Queen's University, Kingston, Canada, September 30, 2010.

A critique of standard cosmology, Queen's University, Kingston, Canada, October 1, 2010.

A search for very old stars, Syracuse University, U.S.A., October 4, 2010.

A search for very old stars, Department of Astronomy, University of Maryland, U.S.A., October 6, 2010.

The IUCAA Story, Department of Physics, University of Maryland, U.S.A., October 7, 2010.

Some conceptual problems in general relativity and cosmology, Department of Physics, University of Maryland, U.S.A., October 8, 2010.

Quantum cosmology via path integrals, Institute for Gravitation and the Cosmos, Penn State University, U.S.A., October 11 and October 12, 2010.

Chandra's impact on Indian astronomy, Chandrasekhar Centennial Symposium, University of Chicago, U.S.A., October 16, 2010.

Searches for microlife in the Earth's atmosphere, California State University, Northridge, U.S.A., October 27, 2010.

Cosmology, Fred Hoyle and I, California Institute of Technology, U.S.A., October 28, 2010.

A critique of standard cosmology, University of Washington, U.S.A., November 10, 2010.

Searches for microlife in the Earth's atmosphere, School of Pure and Applied Physics, Mahatma Gandhi University, Kottayam, December 7, 2010.

Chandra's influence on Indian astronomy, Chandrayana 2011 Conference, The Institute of Mathematical Sciences, Chennai, January 3

A critique of standard cosmology, Indian Institute of Technology Bombay, Mumbai, January 21, 2011.

A critique of standard cosmology, for the M.Sc. students of Presidency College, Kolkata and the West Bengal State University, IUCAA, January 27, 2011.

Analytical reasoning, Indian Institute of Science Education and Research, Pune, February 26, 2011.

Some conceptual problems in general relativity and cosmology, IUCAA School on Gravitation and Astrophysics, Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi, March 17, 2011.

T. Padmanabhan

Gravity: A different perspective, Perimeter Institute, Canada, June 2, 2010.

Gravity: A new perspective, Indian Academy of Sciences, Bengaluru , July 2, 2010.

What does classical gravity tell us about quantum structure of spacetime?, Gravity as a Crossroad in Physics - Spanish Relativity Meeting ERE 2010, Granada, September 6, 2010.

Lessons from classical gravity about the quantum structure of spacetime, Spacetime-Matter: Current Issues in Quantum Mechanics and Beyond, Fifth International Workshop DICE 2010 (Keynote Address), Castiglioncello (Tuscany), September 13, 2010.

Statistical mechanics of gravitating systems, Chandra Centenary Conference, IIA, Bengaluru, December 8, 2010.

Gravity: An emergent phenomenon, Mini-Symposium on the Quest for Quantum Gravity? INSA Anniversary General Meeting, Indian Institute of Science, Bengaluru, December 29, 2010.

What does classical gravity tell us about quantum structure of spacetime?, Chandrayana 2011, The Institute of Mathematical Sciences, Chennai, January 6, 2011.

A new perspective on gravity, C.V. Raman Award Lecture of Indian Physics Association, Khalsa College, Mumbai, February 11, 201.

Lessons from classical gravity about the quantum structure of spacetime, QFT Conference, IISER, Pune, February 23, 2011.

Gravity: An emergent phenomenon, School of Mathematics, Statistics, and Operations Research, Victoria University of Wellington, New Zealand, March 8, 2011.

Gravity: An emergent phenomenon, NCRA, Pune, January 31, 2011.

Gravity: An emergent phenomenon, Research School of Astronomy and Astrophysics, Mount Stromlo Observatory, The Australian National University, Canberra, March 10, 2011.

Gravity: An emergent phenomenon, University of Queensland, Brisbane, March 14, 2011.

Surajit Paul

Evolution of shocks and turbulence in the formation of galaxy clusters embedded in Megaparsec-scale filaments, Conference on Non-thermal Phenomena in Colliding Galaxy Clusters, NtGC 2010, Nice, France, November 15-18, 2010.

Role of major galaxy-cluster mergers in distribution of energy in filamentary inter cluster medium, Conference on Exploring the Cosmos, NBU, West Bengal, India, January 27 & 28, 2011.

Evolution of turbulence and shocks in major merging clusters and the role of filaments in this event, Institut fur Astro und Teilchenphysik (IAT), Universitat Innsbruck, Austria, November 22, 2010.

Diffuse radio emission in merging clusters of galaxies: observations and simulation, Department of Physics, Institute for Astronomy, ETH, Zurich, Switzerland, November 25, 2010.

Role of major galaxy-cluster mergers in distribution of energy in filamentary inter cluster medium, SAC meeting, IUCAA, Pune, January 10, 2011.

A.N. Ramaprakash

Technology for astronomy in the next decade: Challenges for India, VSP Special Lecture, IUCAA, June 8, 2010.

TMT-India:Instrumentation, SPIE Meeting, San Diego, USA, June 26, 2010.

SALT-India:Instrumentation, SPIE Meeting, San Diego, USA, June 30, 2010.

Adaptive Optics – Requirements and Challenges, Institute for Advanced Studies in Basic Sciences, Zanjan, Iran, August 17, 2010.

IUCAA Girawali Observatory, Institute of Physics and Mathematics, Tehran, Iran, August 18, 2010.

ARIES-IUCAA synergies in instrumentation, 1.3 m Telescope Inaugural Symposium, ARIES, Nainital, December 18, 2010.

David vs. Goliath, *Can small beat the big?*, Symposium on Small and Medium Telescopes, Kish, Iran, December 20, 2010.

India's participation in TMT, TIFR Tuesday Seminar, TIFR, Mumbai, February 8, 2011.

Participation in TMT, Technological Challenges for India, Meeting of the Astronomical Society of India, February 23, 2011.

IUCAA Girawali Observatory, Meeting of the Astronomical Society of India, February 25, 2011.

TMT AO and first light instruments, TMT-India Meeting, Delhi University, March 3, 2011.

Astronomy ahead: Technology challenges and opportunities, IIST, Thiruvananthapuram, March 16, 2011.

Astronomy ahead: Technology challenges and opportunities, IISER, Thiruvananthapuram, March 17, 2011.

Astrotechnology! Why not?, National Workshop on Recent Trends in Theoretical Physics, CUSAT, Kochi, March 20, 2011.

TMT-India:Instrumentation Interests, TMT Science and Instrumentation Meeting, Victoria, Canada, March 30, 2011.

Swara Ravindranath

Galaxy morphology and mass build-up seen with CANDELS, National Radio Astronomy Obsevatory, Charlottesville, Virginia, USA, February 28, 2011.

Galaxy morphology and sizes at high redshift, University of California, Riverside, California, USA, June 15, 2010.

Gaining weight and getting in shape? HST/WFC3 observations of galaxies at z = 2, Gemini Science Centre, La Serena, Chile, June 2, 2010.

The world of galaxies (2 lectures), Introductory Workshop on Astronomy and Astrophysics, IGNOU, Guwahati, December 2010.

Star formation in galaxies, Introductory Workshop on Astronomy and Astrophysics, IGNOU, Guwahati, December 2010

Varun Sahni

Exploring braneworld cosmology, CITA Reunion meeting (19th Kingston meeting), CITA, Toronto, Canada, May 12-16, 2010.

The accelerating universe, XIX DAE BRNS High Energy Physics Symposium, LNMIIT, Jaipur, December 13-18, 2010.

The accelerating universe and dark energy, Silver Jubilee Jawaharlal Nehru University, JNU School of Physical Sciences, New Delhi, March 10-11, 2011.

Tarun Souradeep

Beyond the standard cosmological model with CMB, (Review talk), ASI meeting, Raipur, February 22-25, 2011.

Advances in cosmology, Workshop on Recent Advances in Cosmology, North Bengal University, February 2011.

Cosmogenesis scripted in the cosmic glow, Invited talk, The First Foundation Day, NISER, Bhubaneshwar, December 29, 2010.

Cosmology: CMB and LSS, IUCAA-NCRA Radio Astronomy School, NCRA, Pune December 22, 2010,

Odd parity CMB correlations, PFNG-2009 International Meeting on Primordial Features and Non-Gaussianity, HRI, Allahabad, India, December 13-18, 2010.

Statistics of the perturbed universe 1 &2, Workshop on Advanced Statistical Techniques for Astronomy, IUCAA, October 4 - 8, 2010.

Minimizing foregrounds in CMB maps, Caltech-JPL (CaJaGWR) Seminar, Pasadena, USA, August 10, 2010.

Evolution of Statistical Isotropy violation of CMB fluctuations, Seminar, Caltech Astronomy, August 4, 2010.

Standard cosmology and beyond with CMB, Plenary talk, GR-19, Mexico City, Mexico July 5, 2010.

Standard cosmology and beyond with CMB, Colloquium, University of Texas, Brownsville, USA, July 12, 2010.

Evolution of statistical isotropy violations of CMB fluctuations, Institute of Astronomy,Cambridge, UK, June 9, 2010.

Searching beyond `Standard' cosmology in the CMB, ICG, Portsmouth, UK, June 7, 2010.

Subtle signatures beyond `Standard' cosmology in the CMB, University of Sussex, UK, June 11, 2010.

Statistical isotropy of CMB fluctuations, CITA@25/Bond@60: The Theory of the Universe and Everything in It, CITA, Toronto, Canada, May 12 - 16, 2010.

R. Srianand

QSO-Galaxy connection using 21-cm absorption lines, The International Conference, Marshelle, France, 2010.

Astronomical spectroscopy (2 talks), Workshop on Optical and Infrared Astronomy, D.D.U. Gorakpur University, November 2010.

Observational astronomy (2 talks), Kochi, IUCAA Workshop, February 2011.

K. Subramanian

Magnetizing the universe, Colloquium, IISER, Pune, October 2010.

Magnetizing the universe, Indian Academy of Sciences Annual Meeting, Goa, November 2010.

Models of origin of extragalactic magnetic fields, Astroparticle Physics Centre Meeting, Paris, France, December 2010.

Batteries and dynamos in the universe (2 lectures), IISER, Pune, April 2010.

(b) Lecture Courses

Bhaswati Bhattacharya

Heat and thermodynamics (part of the course), IISER, Pune.

Dipankar Bhattacharya

Survey of astronomy and astrophysics (15 lectures), SERC School on Astronomy and Astrophysics, NCRA, June 14-30, 2010.

Fluids in astrophysics (3 lectures), Vacation Students' Programme, IUCAA, May 12-14, 2010.

Naresh Dadhich

General relativity (3 lectures), IUCAA School on Gravitation and Astrophysics, Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi, April 15 – 18, 2011.

Gulab Chand Dewangan

Active galactic nuclei (3 lectures), Introductory Summer School on Astronomy and Astrophysics/Vacation Students' Programme, IUCAA May 24-26, 2010.

Observational techniques 2: High energy radiation and cosmic rays (3 tutorials), The SERC School on Astronomy and Astrophysics, NCRA, June 14 - July 10, 2010.

Sanjeev Dhurandhar

Black holes and gravitational waves (3 lectures) Introductory Summer School on Astronomy and Astrophysics /Vacation Students' Programme, IUCAA in May-June 2010.

General relativity, black holes and gravitational waves (6 lectures), IRC, North Bengal University, October 6 – 10, 2010

General relativity, and gravitational wave data analysis (5 lectures), IRC, New Delhi, December 13 – 24, 2010.

General relativity and gravitational waves (3 lectures), IRC, Calcutta University, Kolkata January 16 – 19, 2011.

Ranjan Gupta

Spectroscopy - Basics, instruments and analysis tools (3 lectures), Introductory Summer School on Astronomy and Astrophysics/Vacation Students' Programme, IUCAA, May 19-21, 2010.

Spectroscopy basics, Astronomical spectroscopy, and Career and funding opportunities (3 lectures) Introductory Workshop on Optical and Infrared Astronomy, Dept. of Physics, DDU Gorakhpur University, October 28-29, 2010.

Basic concepts of photometry I and II, CCDs in astronomy, and Upcoming large optical telescope facilities (4 lectures), Workshop on Photometer Fabrication, IUCAA, Pune. December 6 - 10, 2010,

Astronomical spectroscopy I and II, Interstellar dust (3 talks), Introductory Workshop on Astronomy and Astrophysics, IGNOU, NECRD, Guwahati , December 15-17, 2010.

Observational astronomy (15 lectures), at CSSTEAP, International School, PRL, Ahmedabad, February 1-13, 2011.

Basics of astronomy (5 lectures), Advance Meteorological Training Course, Central Training Institute, Pune, February 21-23, 2011.

Ajit Kembhavi

*Stellar structure (*3 talks*),* (to students of West Bengal State University visiting IUCAA), IUCAA, April 27 – 29, 2010.

*Stellar structure and evolution (*3 talks*),* Introductory Summer School on Astronomy and Astrophysics/Vacation Students' Programme, IUCAA, May 10 – 12, 2010.

*Stellar structure and evolution (*8 talks*),* (to students visiting from Presidency college and West Bengal State University), IUCAA, January 21 – 30, 2011.

*Radiative processes (*2 lectures*), Vacation Students' Programme/ Summer School,* IUCAA, May 13 – 14, 2010.

Ranjeev Misra

Accretion processes in astrophysics (4 lectures), Introductory Summer School on Astronomy and Astrophysics /Vacation Students' Programme, IUCAA, May 2010.

Radiative and accretion processes in astrophysics (4 lectures), IUCAA sponsored workshop in Astronomy and Astrophysics, North Bengal University, Siliguri, March 2010.

T. Padmanabhan

General relativity and cosmology (30 lectures), IISER, Pune, August - November 2010.

Special and general relativity (4 lectures), Introductory Summer School on Astronomy and Astrophysics /Vacation Students' Programme, IUCAA, May-June, 2010

A. N. Ramaprakash

Charge coupled devices in astronomy, Institute of Physics and Mathematics, Tehran, Iran, August 15, 2010.

*Astronomical techniques tutorial*s, SERC School on Astronomy and Astrophysics, NCRA, Pune, June-July, 2010.

Detectors and instrumentation, Introductory Summer School on Astronomy and Astrophysics /Vacation Students' Programme, IUCAA, May-June, 2010.

Swara Ravindranath

Galaxies (3 lectures), Introductory Summer School on Astronomy and Astrophysics/Vacation Students Programme IUCAA, May-June, 2010.

Tarun Souradeep

Cosmology with CMB and LSS, (4 lectures), Introductory Summer School on Astronomy and Astrophysics/Vacation Students' Programme, IUCAA, May – June 2010.

Cosmology with CMB and LSS (3 lectures), IUCAA School on Gravitation and Astrophysics, Jamia Milla Islamia, New Delhi, May 15-17, 2011.

R. Srianand

Observational cosmology (6 lectures), Summer School, Harish-Chandra Research Institute.

Introduction to stellar structure (10 lectures), IISER, Pune

Introduction to astronomical spectroscopy (5 lectures), IGO Observational Astronomy School,

Kandaswamy Subramanian

Magnetohydrodynamics (3 lectures), *Cosmology* (2 lectures), Introductory Summer School on Astronomy and Astrophysics Vacation Students' Programme, IUCAA, May 2010.

Magnetohydrodynamics (3 lectures), IISER, Pune, October 2010.

SCIENTIFIC MEETINGS AND OTHER EVENTS at IUCAA

Introductory Summer School on Astronomy and Astrophysics was conducted by IUCAA during May 10 - Jun, 11, 2010, for Collge/University Students. **The Vacation Students' Programme** (VSP) was also simultaneously conducted during May 10 - June 25, 2010. The Summer School was coordinated by Swara Ravindranath and Ajit Kembhavi and the VSP was coordinated by K. Subramanyam.

[Khagol, Issue No 83, July 2010]

IUCAA Girawali Observatory Training School in Observational Astronomy was conducted at IUCAA, during April 1 - 30, 2010. The school was coordinated by Vijay Mohan and R. Srianand**.**

[Khagol, Issue No 83, July 2010]

A novel workshop on the working of the new software **World Wide Telescope** (WWT) by Microsoft was conducted at IUCAA, on September 4, 2010 in collaboration with the California Institute of Technology (Caltech), USA, and Microsoft Research.

[Khagol, Issue No 84, October 2010]

Workshop on Advanced Statistical Techniques for Astronomy

[October 4 - 8 , 2010 at IUCAA]

The Workshop was coordinated **Asis Kumar Chattopadhyay** (Calcutta University) and **Ajit Kembhavi** (IUCAA)

[Khagol, Issue No. 85, January 2011.]

Workshop on Compact Objects

[December 15 - 17, 2010 at IUCAA]

Subharthi Ray (University of KwaZulu-Natal) and **Ajit Kembhavi** and **Ranjeev Misra** (IUCAA) coordinated the Workshop.

[Khagol, Issue No. 85, January 2011.]

An international conference on **Wideband X-ray Astronomy, Frontiers in Timing and Spectroscopy** was held at IUCAA during January 13 - 16, 2011

[Khagol, Issue No. 86, April 2011.]

[Soft copies of all the above workshops/schools are available at http://ojs.iucaa.ernet.in]

The 22nd IUCAA Foundation Day
[December 29, 2010]

The 22nd IUCAA Foundation Day lecture titled, "Biotechnology and Development: Potential Impact and Concerns" was delivered by M.K. Bhan, Secretary, Department of Biotechnology, Government of India

The 22nd IUCAA foundation day lecture titled, `Biotechnology and Development: Potential Impact and Concerns' was delivered by M.K. Bhan, Secretary, Department of Biotechnology. In his talk, Bhan gave an overview of biotechnology research and its role in the betterment of human life through the influence of biotechnology on agriculture, human health, bioresource conservation and use, clean manufacturing, etc. He highlighted the recent developments in biotechnology that have led to new drug discovery, diagnosis, and predictive and personalized medicine. New innovations, and promotion of new sciences, such as, genomics, RNA biology, proteomics, stem cell biology, were also discussed. The speaker also presented India's achievements in the area of vaccines, and the new directions in biotechnology research in India, which includes major capacity building in genomics and designer breeding. Bhan also emphasized the future of nanobiotechnology, which is emerging with enormous potential by bringing together nanosciences and biotechnology.

The lecture was well attended and appreciated.

[For details please refer to Khagol, Issue No. 85, January 2011. Soft copy available at http://ojs.iucaa.ernet.in]

The IUCAA- NCRA Graduate School

Ph.D. Programme

IUCAA Research Scholar, **Gaurang Mahajan** has defended his Ph.D. thesis submitted to the University of Pune. Professor **T. Padmanabhan** was his thesis supervisor.

Title of the thesis :
Nature and evolution of quantum states in non-trivial external backgrounds

Abstract:
The thesis explores some of the several conceptual questions arising in a *semi-classical* approximation, which involves coupling a quantum system with a time-dependent classical one. In particular, the question of defining a general, time-dependent notion of 'particle', and the conditions for emergence of 'classical' behaviour through time evolution, are addressed. The detailed analysis of toy models, as well as the examples drawn from QFT in time-dependent external backgrounds help to clarify the issues relating to the interpretation of classicality based on the Wigner distribution. A simple and intuitive measure for classicality has been proposed, on the basis of which, a very general result linking strong particle production to a growth of classicality has been obtained. The work has implications for a better understanding of the physics of the early universe, and of the validity of semi-classical equations in calculations of 'back-reaction'.

FACILITIES at IUCAA

(i) Computing Facility

The year 2010 – 2011 had been a fulfilling year as far as computing facility related activities are concerned.

General Purpose computing on Graphics Processing Units (GP-GPU) has been dramatically changing the landscape of high performance computing in Astronomy and Astrophysics. The modern graphics processing units (GPUs) from Nvidia and ATI, are inexpensive commodity hardware that offer Tflop/s of theoretical computing capacity. In order to fulfill the growing demand for GP-GPU, the four node GP-GPU cluster named "Hyades" has been added in February 2011, offering 6 Tflop/s peak performance. Each node consists of 2 x Intel 6 core Westmere CPUs @ 2.93 GHz, 24 GB RAM, 2 x 146 GB SAS hard disks, QDR IB HCA interconnect and 3 x Tesla M2050 series GPUs.

In July 2010, FAS 2020 NAS (Network Attached Storage) from Netapp was commissioned, as it offered data deduplication in block level for better utilization of space and snapshot facility for backup and restoration. It is an appliance that supports network filesystems CIFS and NFS to suit MS windows environment and UNIX environment respectively.

Internet bandwidth is now being served from more than one ISP (Internet Service Provider), other than ERNET. In June 2010, a 10 Mbps link from BSNL, funded by UGC- Infonet programme was commissioned. Since IUCAA has been associated with ERNET from its inception and various web servers have been hosted on ERNET network, it was decided to continue to be a part of ERNET and to upgrade the bandwidth from 1 Mbps to 4 Mbps. In September 2010, the much awaited 1Gbps NKN (National Knowledge Network) was deployed successfully at IUCAA.

In May 2010, a Sonicwall UTM (Unified Threat Management) device was deployed as a Next-Generation Firewall solution. Its underlying SonicOS operating system combines deep packet inspection technology with a multi-core architecture to scan all network traffic while delivering high performance and low latency. This powerful architecture serves as the foundation for application intelligence, control and visualization, intrusion prevention, anti-malware, SSL inspection, high-speed virtual private networking (VPN) technology, and other robust security capabilities.

During April 2010, twenty Sun Ray 270 virtual display thin clients replaced the commodity desktops in the Computer Lab, used for conferences, workshops and training programmes. It is an all-in-one unit that offers a secure, resilient desktop environment in a small foot print, when used in conjunction with redundant powerful back end Sun servers,

The IUCAA Computer Centre continues to cater to the growing needs of IUCAA users as well as IUCAA associates and visitors from the universities / colleges, and institutions in India and abroad.

ii) Library and Publications

During this year, the library has added 222 books and 400 bound volumes, taking the total collection to 23,657. At present, 126 journals were subscribed by the library, and 143 books were added to the Muktangan Library. The activities initiated by the library during this period are described below :

Library Trainee Programme: A trainee programme was initiated by the library during the year 2010. Four candidates having a Masters Degree in Library and Information Science (M.LISc) have been selected to work in the IUCAA library for a period of one year. The traineeship helps them in gaining practical knowledge of library housekeeping tasks, as well as digital library initiatives.

· Recording of Lectures: The library has recorded the lectures delivered by Samir Mathur on the topic "The Black Hole Information Paradox" during July 7- 30, 2010. The recording was done by using a system known as 'Enhance Your Audience' (EyA) (An innovative automated audio/video/slide recording system developed by the Scientific Dissemination Unit of the International Centre for Theoretical Physics (I.C.T.P.), Italy). The recorded lectures can be accessed at the link ttp://www.iucaa.ernet.in/~archives/index.htm.

·Under the UGC-INFONET programme, the IUCAA library has received access to the following e-resources:

a) American Institute of Physics (18 titles) **b)** American Physical Society (10 titles) **c)** Emerald Database (29 titles) **d)** JCCC Database (Journal Custom Content for Consortia, an e-journal gateway for universities and colleges) **e)** Science Direct (1036 titles) **f)** Springer Llink (1389 titles) **g)** Taylor and Francis (1173 titles) **h)** Web of Science (1 citation database)

IUCAA has a publications department which brings out the Annual report, and newsletters. "Khagol" is the quarterly newsletter which covers the news updates on events held at IUCAA and Universities, information about conferences, meetings, and workshops, and snippets on interesting scientific topics. "Vyom" (The Sky) is a Marathi quarterly newsletter published by IUCAA. The aim of the newsletter is to create interest in Astronomy and Astrophysics among the schools in rural regions of Maharashtra. The first issue was published in July 2010.

The Annual report, Khagol, and Vyom are made available online within a week of their publication.

(iii) Instrumentation Laboratory

Excellent progress has been made in the IUCAA-Caltech collaboration for developing a low cost, robotic, queue-scheduled adaptive optics (AO) system for small and medium class (primary mirror diameter of 1-3 m) telescopes. Several engineering runs have been carried out on the telescope and a full scale peformance demonstration is planned to be carried out over the next few months. Plans are also afoot to build a near-IR arm for RoboAO, in the near future. As a follow up of the above programme, a low order adaptive optics fed near-infrared imager is being built in the laboratory for use on one of the side ports of IUCAA Girawali Observatory telescope. Design work for a high order AO test bench is currently underway.

Under an MoU signed with the University of Wisconsin-Madison (UW), the laboratory has developed a detector control and data acquisition system for the near-IR arm of the Robert-Stobie Spectrograph, which is being built for the Southern African Large Telescope (SALT). The IUCAA controller system is based on an initial version of the next generation focal plane array controller system (NGFPAC), which is being developed in the laboratory.

The FPGA-based controller of the NGFPAC system has been delivered to UW under this collaboration. SIDECAR is an ASIC developed by Teledyne Scientific & Imaging (TS&I), USA, as a low power, compact "controller in a chip" for interfacing with the HAWAII series of near-IR detectors, also developed by the same company. IUCAA laboratory has developed the capability to handle SIDECAR driven HAWAII detectors from a Linux-platform. The system called IUCAA SIDECAR Drive Electronics Card (ISDEC), which will be used in the Canarias InfraRed Camera Experiment (CIRCE), being built by the Univeristy of Florida (UF) for the 10.4 m Gran Telescopio Canarias (GTC) on La Palma. An MoU has been signed with UF for this collaboration and the work on designing, assembling and testing ISDEC is currently underway in the laboratory.

IUCAA laboratory is collaborating in a project led by the Tata Institute of Fundamental Research (TIFR), Mumbai, to build the InfraRed Spectroscopic Imaging Survey (IRSIS) satellite. The project has got initial funding from the Indian Space Research Organization (ISRO) for developing the design and a laboratory model for the instrument. IUCAA laboratory has been leading the optical design of the spectrograph, which has two arms covering a wavelength range of about 1.7 to 6 microns.

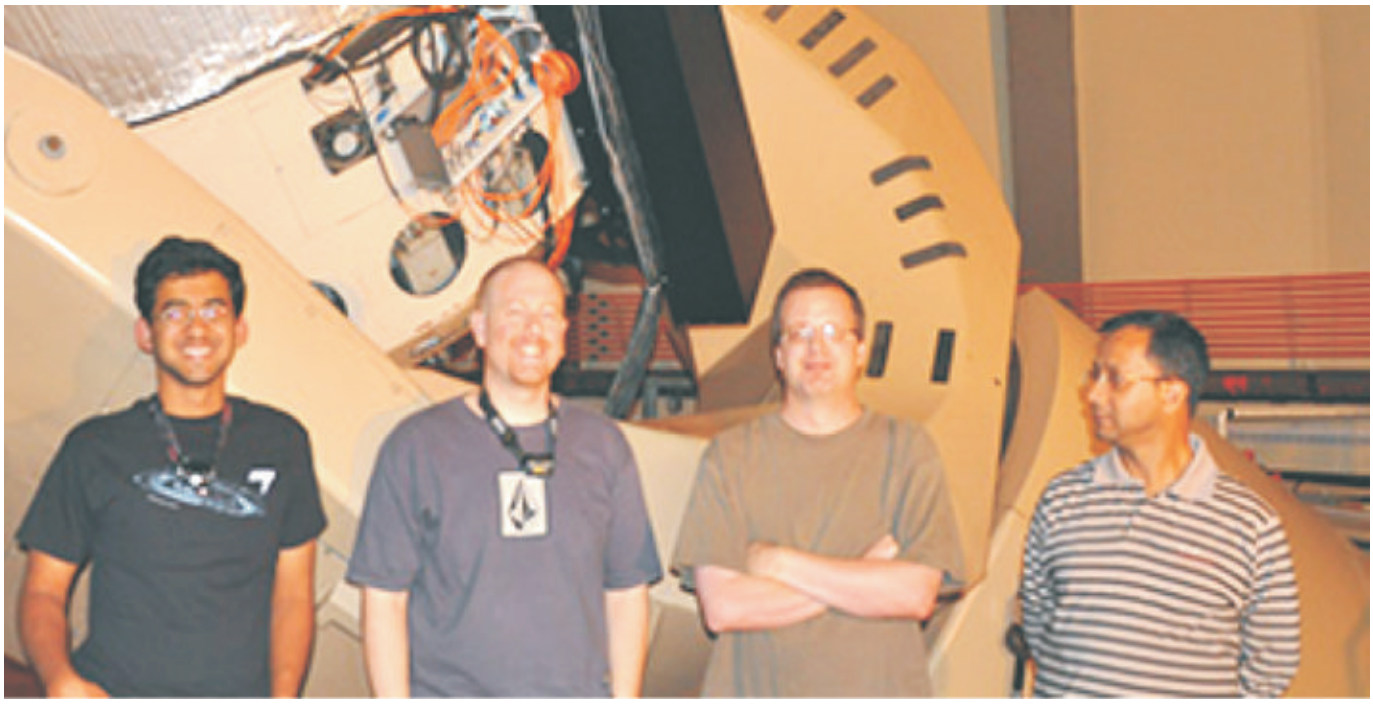
This project employs SIDECAR ASIC driven HAWAII detectors.

(iv) IUCAA Girawali Observatory (IGO)

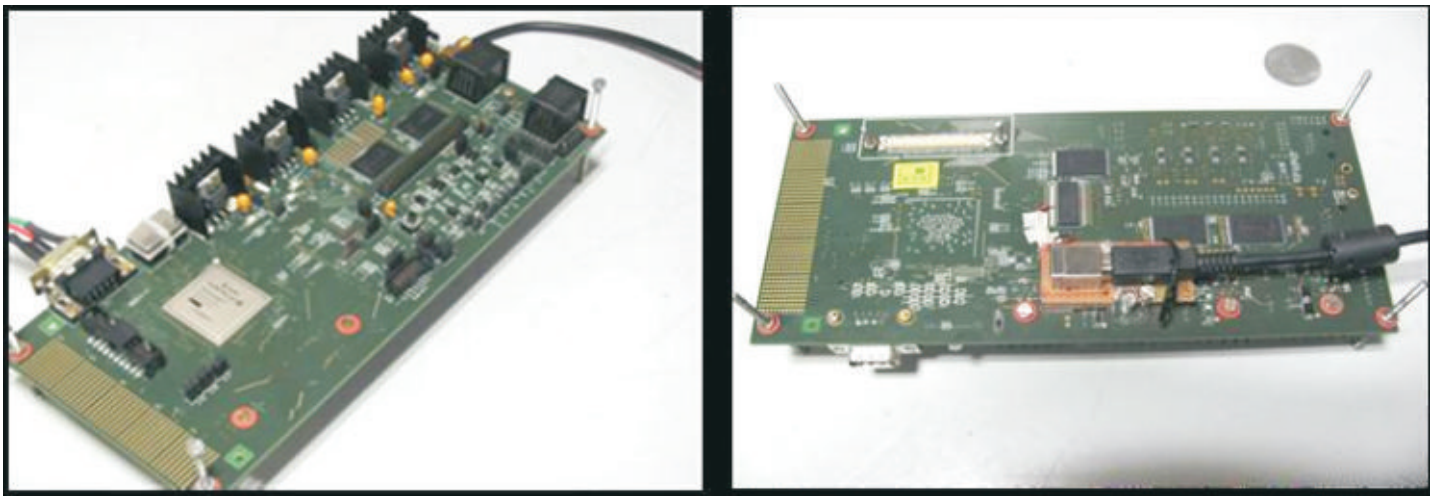
During this year telescope operations were relatively smooth Observations could be made on 150 nights involving 26 proposals, approved by the IGO Time Allocation Committee. About 35 nights were allotted to TIFR for testing their new IR instrument. Two IGO training schools, each of one month duration, were organised in April and December 2010 to train prospective researchers in observational astronomy.

An generic control and monitoring system for observatory is being developed through a joint project between IUCAA and NCRA. It is envisaged that the system will be initially deployed at the IUCAA Girawali Observatory, as well as the 15 m radio observatory, which NCRA is building. Coding work for the system is being carried out through Persistent Systems Limited, a Pune based software development firm.

A fibre-fed integral field unit (IFU) was installed on one of the side ports of the IGO telescope as the part of the Ph. D. project of Mudit Srivastava. Commissioning and performance verification observations were carried with the instrument on the telescope during the early part of last year. A full data reduction pipe line for the instrument was developed and tested on real astronomical data .

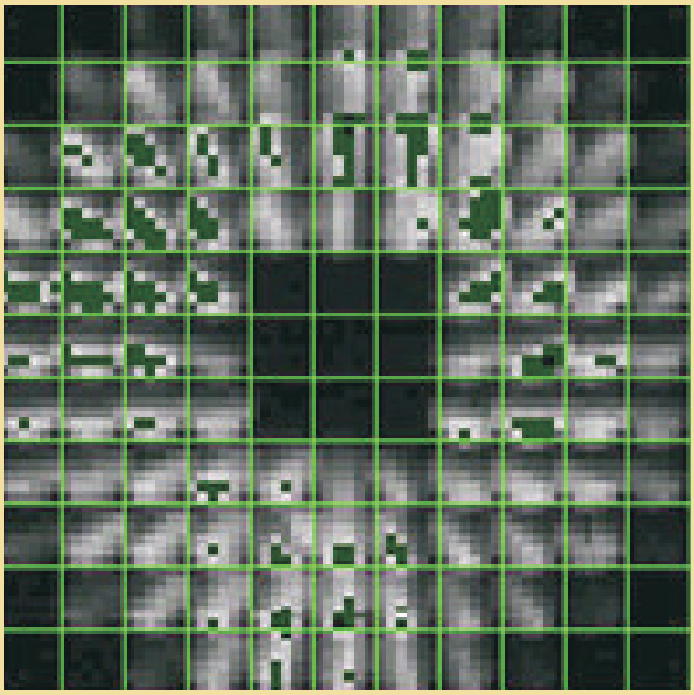


Robo-AO team members (l-r: S. Tendulkar, C. Baranec, R. Reed, and H. Das) at the Palomar 60 inch telescope after successful tests of the laser facility.



Views of the IUCAA Focal Plane Array Controller card which uses Virtex 5 series FPGA. Versions of this card are being integrated into the RSS-NIR instrument being built by the University of Wisconsin for the 11m SALT.

Laser beacon guide star being test fired from the Palomar 60 inch telescope during an engineering run in September 2010.



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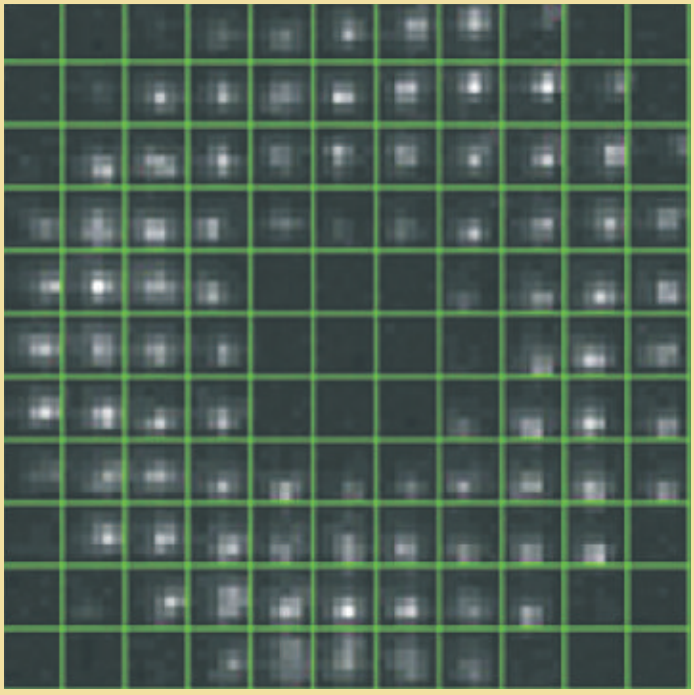

With range-gate

(v) Virtual Observatory India – Phase II

VOI-Phase II is the third generation of VOI project hosted at IUCAA in collaboration with Persistent Systems Ltd (PSL). This project carries forward the excellent model for collaboration between experts from academic fields and from the information technology industry, already established by the earlier VOI project.

The aim of VOI-Phase II is to utilize the most recent advances in computer hardware and software technology to develop a new generation of data analysis, visualization and mining tools, using state-of-the art computer clusters, grid computing and machine learning techniques.

New applications developed in the first year of VOI-Phase II include a Universal VOI Portal and Pymorph. VOI Portal is an entry point to all VOI web services. It will ease the adoption of VO technology by end users, by providing easy access to different VO sites and VO facilities in a unified manner. It provides core VO packages and applications as gadgets, and allows the user to customize them to suit their needs. It also provides users space on the server side to store their data and results. VOI Portal incorporates standards and protocols laid down by IVOA wherever they are applicable. Pymorph is a Galaxy Morphology Service, which allows users to derive morphological parameters for galaxy images. It is a software pipeline, which computes non-parametric and parametric morphological parameters of galaxies. This service exists as a separate application as well as it is now integrated to the VOI Portal. VOI Application Framework implements single point authentication and registration for all VOI web services. The users will now be able to register once and use all VOI web services with the same login account.

During the 2010-2011 period, VOI has also made upgrades to several existing applications and services. VOPlot, the VOI plotting and visualization tool, has undergone a major revamp. A better ASCII file parser module is implemented and integrated into VOPlot. Support for plotting data from different files against each other is a major new addition. The user interface is redesigned to be more users friendly. Dynamic Plot interlinking has been introduced, which makes the tool much more intuitive to user's actions. VOI Mosaic Service allows users to make mosaic of images retrieved from image servers spread worldwide. This has been upgraded and now supports High–Level Science Products (HLSP), which are identified as Level 5 data products from Hubble Legacy Archive (HLA). The various Proposal Management and Data Archive Systems developed under previous VOI projects are being provided with support to enhance their functionality based on user feedback.

As a part of the VOI Public Outreach programme, a workshop on World Wide Telescope (WWT) India was conducted on September 4, 2010 at IUCAA in collaboration with the California Institute of Technology (Caltech), USA, and Microsoft Research. Participant from various IRCs, universities, outreach departments, planetaria were present, along with students and astronomy enthusiasts. Another workshop on Astronomy with Virtual Observatories was also held at the Shri Venkateshwara College, Delhi, for school and college students.

VOI-Phase II will be a good example of the use of Indian scientific and information technology expertise to make important contributions to a worldwide effort, and to strengthen the role that India has already played as one of the pioneers of the Virtual Observatory movement.

Public Outreach Activities

The annual School Students' Summer Programme was held from April 19 to May 28, 2010.

[Khagol, Issue No 83, July 2010]

The National Science Day - 2011 was celebrated on February 26 and February 28, 2011 at IUCAA.

[Khagol, Issue No 86, April 2011]

[For soft copies : http://ojs.iucaa.ernet.in]

Workshop on Photometer Fabrication
was conducted at IUCAA, during
December 6 - 10, 2010.

[Khagol, Issue No 85, January 2011]

Highlights of the Muktangan Vidnyan Shodhika

State Level Camp for College Students (SLCCS), initiated by Rajiv Gandhi Science and Technology Commission (RGSTC), Mumbai, Government of Maharashtra, and catalyzed and supported by Rashtriya Vigyan Evam Prodyogiki Sanchar Parishad (RVPSP), DST, New Delhi, was conducted by IUCAA, during January 14 – 16, 2011. The camp was conducted in Manchar town in Pune district, which is about 65 kilometre from Pune on the Pune–Nasik highway. Thirty two students from Pune, Ahamadnagar, Thane, Mumbai, Raigad, Ratnagiri, Satara, Solapur, Sangli, Sindhudurg and Kolhapur, were invited to participate.

Ranjan Gupta inaugurated the camp and gave a lecture on Large Optical Telescopes. Vijay Mohan and Chaitanya V. Rajarshi gave lectures on A Journey Through the Universe. Solanki (NCRA) talked on Giant Meterwave Radio Telescope and Sudhanshu Barway (South African Astronomical Observatory) talked on Virtual Observatories and gave hand-on demonstrations. The students were also invited to attend the lecture by Giuseppina Fabbiano (Senior Astrophysicist at the Harvard-Smithsonian Center for Astrophysics, Cambridge, USA), on the Chandra X-ray.

The students observed the passage of the Hubble Space Telescope and the International Space Station. They also observed and recorded occultation of 47 Ari (mag 5.8) by the moon. They were given firsthand experience in using a 150 mm Newtonian telescope for observations of Orion Nebula, Jupiter, Saturn, Venus, Omega Centauri, M13, M44, M67, binary stars Alcor and Mizar.

International Year of Astronomy 2009- State Level Camp for College Students

An astronomy quiz competition was conducted for the participants. The first prize was won by Pankaj Udayshankar Yadav, and second and third prizes by Vishar Vijay Bhogate and Sujay Sudhir Olkar respectively.

Nilesh Pokharkar (at IGO) assisted in conducting the camp. Samir Dhude and Arvind Paranjpye coordinated the camp. They interacted with the students and gave them lectures and hand-on practice on using astronomical telescope, and conducted interactive session with students on debunking astrology.

Public Lecture on ***The Chandra X-ray Observatory*** delivered by **Giuseppina Fabbiano** on January 16, 2011

Fabbiano talked about NASA's advanced X-ray Astrophysics satellite that was launched on July 23, 1999 and was named the Chandra X-ray Observatory in honour of Subrahmanyan Chandrasekhar, the great astrophysicist. Chandra has imaged spectacular, glowing remains of exploded stars, and obtained spectra showing the dispersal of chemical elements. Chandra has observed the region around the supermassive black hole in the centre of our Milky Way, and also found black holes in galaxies across the universe.

She concluded her talk by stating that *".. over its mission, Chandra will continue to discover startling new science about our high-energy universe."*

The talk was well received by the audience.

Popular Talks

Dipankar Bhattacharya

Origin of the moon, Pu La Deshpande Science Week, IUCAA, November 8, 2010.

Naresh Dadhich

The challenge of global and local synthesis, World Universities Congress 2010, Turkey, October.

Science and society and their interaction, Durban University of Technology, South Africa, November 10.

Science: Method and vision, Pt. Ravishankar Shukla University, Raipur, December 6.

Gulab Dewangan

X-ray astronomy, Radio Astronomy Winter school, IUCAA/NCRA, December 2010.

Sanjeev Dhurandhar

The story of gravity, Siliguri , October 13, 2010.

Ajit Kembhavi

Modern telescopes: From Galileo to the E-ELT, Advanced Workshop on Astronomy: Observations, Theory and Interpretations, IUCAA Resource Centre, North Bengal University, Siliguri, April 6.

Extra solar planets : World beyond the solar system, Tezpur University, April 8.

The new planets : Are there many earths in our galaxy? Deenanath Mangeshkar Hospital, Pune, May 2.

Large telescopes : From Galileo's time to the 21st century, Nehru Planetarium, New Delhi, July 7.

Life of Chandrasekhar (English), School Students Lecture Programme, IUCAA, July 10. *Life of Chandrasekhar (Marathi), School Students Lecture Programme,* IUCAA, July 10.

Ranjeev Misra

Black holes in the universe, Tezpur University, March 2011.

Black holes in the universe Radio Astronomy Winter school, IUCAA/NCRA, December, 2010.

J. V. Narlikar

Khagolatil ghatana : Andhashradha – virudh – vaidnyanik drushtikon (Superstitions vs. the scientific temper) (in Marathi), Dadar Bhagini Samaj, Dadar, Mumbai, August 19.

Building institutions, Semco Electric Pvt. Ltd., MIDC, Chakan, Pune, August 23.

Searches for extraterrestrial life, Tata Consultancy Services, Pune, August 25.

A search for very old stars, Nehru Planetarium, Mumbai, September 15.

Searches for micro-organisms in the Earth's atmosphere, The Elizabeth Laird Memorial Lecture, University of Western Ontario, London, Canada, September 22.

Aapan vishwat ekate aahot ka? (Are we alone in the universe) (in Marathi), Maharashtra Mandal, U.S.A., October 30.

Khagolshastra ka shikave? (Why study astronomy?), (in Marathi), Dayanand College. Latur, January 15.

Antaralatil jeevshrusti (Life in space), (in Marathi), Dayanand College, Latur, January 16.

Convocation address, Dhirubhai Ambani Institute of Information & Communication Technology, Gandhinagar, January 22.

Dnyan vidnyan ke shetra mein Hindi (Hindi in the areas of science and knowledge), (in Hindi), Hindi Bhawan, Bhopal, January 29.

Why study astronomy?, Indian Institute of Science Education and Research, Pune, February 26.

Khagol vidnyan ka shikave? (Why study astronomy?),Giant Metrewave Radio Telescope, Khodad, March 1.

Searches for microlife in the Earth's atmosphere, Institute of Technology, Banaras Hindu University, Varanasi, March 3.

T. Padmanabhan

Story of the Calendar, Department of Physics, University of Delhi, August 5.

Our Changing View of the Cosmos, Centre for Earth Science Studies, Akkulam, Trivandrum, August 13. (Prof. C. Karunakaran endowment Lecture)

Gravity and the Cosmos, KVPY VIJYOSHI Camp, 2010, IISC, Bangalore, December 6.

Many faces of gravity, 3rd Science Conclave: A Congregation of Nobel Laureates, Indian Institute of Information Technology, Allahabad, December 13.

Surajit Paul

Understanding the Universe using Computer Simulations, IUCAA National Science day, 28.02. 2011

Kandaswamy Subramanian

Large scale structure of the universe, IIT Madras , October 2010.

Popular Articles

Narlikar, J.V. *LHC : The large hype creator*, The Asian Age, April 28 (2010).

Microbes in the stratosphere, Scientific American India, April, 36 (2010).

P.C. Vaidya (1918 – 2010), Current Science, **98**, 10, 1389 (2010).

Are we alone in this universe?, The Asian Age, May 26 (2010).

Streets echo the culture of a city, The Asian Age, June 23 (2010).

The curious child, The Asian Age, July 28 (2010).

Use time as a tool, not as a crutch, The Asian Age, August 25 (2010).

Big bang and other prejudices, The Asian Age, September 22 (2010).

Geoffrey Ronald Burbidge, Physics Today, October, 65 (2010).

The sum of ego & challenges, The Asian Age, October 27 (2010).

Fred Hoyle : A scientist of multi-faceted talents, Resonance, October, 865 (2010).

We still lack the urge, The Asian Age, November 24 (2010).

Tilak and the star of the Vedas, The Asian Age, December 22 (2011).

Sky-gazing for survival, The Asian Age, January 19 (2011).

Deemed unfit, The Asian Age, March 16 (2010).

Khagol shastra kyon seekhe?, (in Hindi) [Why study astronomy?], Srot, June (2010).

Vidnyan, main aur vidnyan ka romanch, (in Hindi) [Science, I and excitement of it all], *Shaishanik Sandarbha, May-June, 5* (2010).

P.C. Vaidya, (in Hindi)[P.C. Vaidya], Srot, September (2010).

Vidnyan, samaj aur patrakarita, (in Hindi) [Science, Society and Journalism], Hindi Patrakarita ke nutan kshitij, 3 (2010).

Durbininchya purvi, (in Marathi) [Before the telescopes arrived], Learn More, May 15, 5 (2010).

Yala jevan aise naav, (in Marathi) [This is what is called a meal], Panchavati Patrika, May (2010).

Nicolaus Copernicus, (in Marathi) [Nicolaus Copernicus], Learn More, June 15, 5 (2010).

Bahurangi pratibhecha vaidnyanik, (in Marathi) [Fred Hoyle : Scientist of Multi-Faceted Talents], Learn More, July 15, 5 (2010).

Nate akashashi…, (in Marathi) [Relationship to the sky], Learn More, August 1, 5 (2010).

Vidnyanacha sandesh : vividhatetil ekata, (in Marathi) [Unity amongst diversity : The message of science], Vidnyan Vedh, 58 (2010).

Mahan ganiti 'Gauss', (in Marathi) [Great mathematician 'Gauss'], Learn More, September 1, 7 (2010).

Chakravuha, (in Marathi) [Mazes], Learn More, October 1, 5 (2010).

Me vaidnyanik kasa zalo?, (in Marathi) [How I became a scientist?], Learn More, November 1, 14 (2010).

Apaharan, (in Marathi)[Kidnapped], Dhananjay, Diwali Issue, 129 (2010).

Gangatiri aani grantakathi, (in Marathi) [From Ganges to Granta], Sadhana, Diwali Issue, November 6, 20 (2010).

Aakadyanche chamatkar, (in Marathi) [Fun with numbers], Learn More, December 1, 6 (2011).

Vidnyanachya aika haka, (in Marathi) [Listen to the call of science], Sakal, January 1 (2011).

Vidnyanachya aika haka, (in Marathi) [Listen to the call of science], *Shikshan Sankraman*, February, 5.

Associateship Programmes

Research by IUCAA Visiting Associates

Tanwi Bandyopadhyay

Modified holographic dark energy and phantom behaviour of Randall-Sundrum brane

The evolution of modified holographic dark energy (HDE) derived from the UV/IR cutoff in the Randall-Sundrum II (RS-II) braneworld scenario has been discussed. Choosing future event horizon as the IR cutoff, it is seen that the equation of state parameter for the modified HDE can cross the phantom crossing line for $\omega = -1$.

Subenoy Chakraborty

The generalized second law of thermodynamics and the nature of the entropy function

In black hole physics, the second law of thermodynamics is generally valid whether the black hole is a static or a non-static one. Considering the universe as a thermodynamical system, the second law of black hole dynamics extends to the non-negativity of the sum of the entropy of the matter and the horizon, known as generalized second law of thermodynamics (GSLT). In this work, it is assumed that the universe is to be bounded by the event-horizon, where Bekenstein entropy-area relation and Hawking-temperature are not applicable. Thus, considering entropy to be an arbitrary function of the area of the event-horizon, Subenoy Chakraborty and collaborators (Nairwita Mazumdar and Ritabrata Biswas) have tried to find the nature of the entropy-function for the validity of the GSLT, both in quintessence-era and in phantom-era. Some graphical representation of the entropy-function has been presented, in their published paper.

Suresh Chandra

Anomalous absorption in thioformaldehyde

Absorption against the Cosmic Microwave Background (CMB), called the anomalous absorption, is an unusual phenomenon. The transition 1_{11} - 1_{10} at 4.829 GHz of formaldehyde (H_2CO) was the first one showing the anomalous absorption. The $C - C_3H_2$ is the second molecule showing anomalous absorption through its transition 2_{20} - 2_{11} at 21.590 GHz. Structure of thioformaldehyde (H_2CS) is very similar to that of the H_2CO. Therefore, Suresh Chandra and collaborators (Amit Kumar and M.K. Sharma) have investigated about the physical conditions under which the transition 1_{11} - 1_{10} at 1.0465 GHz of H_2CS would be found in anomalous absorption in cool cosmic objects. As in case of H_2CO, the anomalous absorption of 1_{11} - 1_{10} of H_2CS is found sensitive to the relative collisional rates and it requires that the collisional rate for the transition $1_{11} - 2_{11}$ must be smaller than that for the transition $1_{10} - 2_{12}$.

Suggestion for the search of H_2CC in cool cosmic objects

The structure of H_2CC is very similar to that of H_2CO and H_2CS. Both H_2CO and H_2CS have already been identified in a number of cosmic objects. Though H_2CC is not yet identified in the cosmic objects, Suresh Chandra and collaborators (Amit Kumar and M.K. Sharma) propose that H_2CC may be identified in cool cosmic objects through its transition 1_{11} - 1_{10} at 4.85 GHz in anomalous absorption.

Asis Chattopadhyay and Tanuka Chattopadhyay

Structures in the fundamental plane of early-type galaxies

The fundamental plane of early-type galaxies is a rather tight three-parameter correlation discovered more than 20 yr ago. It has resisted both a global and precise physical interpretation despite a consequent number of works, observational, theoretical or using numerical simulations. It appears that its precise properties depend on the population of galaxies in study. Instead of selecting a priori these populations, T. Chattopadhyay and A.K. Chattopadhyay and collaborators proposed to objectively construct homologous populations from multivariate analyses. They have undertaken multivariate cluster and cladistic analyses of a sample of 56 low-redshift galaxy clusters containing 699 early-type galaxies, using four parameters: effective radius, velocity dispersion, surface brightness averaged over effective radius and Mg2 index. All the analyses are consistent with seven groups that define separate regions on the global fundamental plane, not across its thickness. In fact, each group shows its own fundamental plane, which is more loosely defined for less diversified groups. They conclude that the global fundamental plane is not a bent surface, but made of a collection of several groups characterizing several fundamental planes with different thicknesses and orientations in the parameter space. Their diversification scenario probably indicates that the level of diversity is linked to the number and the nature of transforming events and that the fundamental plane is the result of several transforming events. They also show that their classification, not the fundamental planes, is universal within the redshift range (0.0070.053). They find that the three groups with the thinnest fundamental planes presumably formed through dissipative (wet) mergers. In one of them, this(ese) merger(s) must have been quite ancient because of the relatively low metallicity of its galaxies, Two of these groups have subsequently undergone dry mergers to increase their masses. In the k-space, the third one clearly occupies the region where bulges (of lenticular or spiral galaxies) lie and might also have formed through minor mergers and accretions. The two least diversified groups probably did not form by major mergers and must have been strongly affected by interactions, some of the gas in the objects of one of these groups having possibly been swept out. The interpretation, based on specific assembly histories of galaxies of the seven groups, shows that they are truly homologous.

They were obtained directly from several observables, thus independently of any a priori classification. The diversification scenario relating these groups does not depend on models or numerical simulations, but is objectively provided by the cladistic analysis. Consequently, the proposed classification is more easily compared to models and numerical simulations, and this work can be readily repeated with additional observables.

Ajay Chaudhari

Infrared and electronic absorption spectra of formaldehyde in gas phase and astrophysical H_2O ice

The vibrational frequencies at B3LYP/6-311++G** level are in agreement with the experimental determinations. The gas phase dipole moment of neutral formaldehyde 2.4 D is in excellent agreement with the experimental value of 2.33 D. An influence of ice on vibrational frequencies of neutral formaldehyde molecule has been obtained using Self Consistence Isodensity Polarizable Continuum Model (SCI-PCM) with dielectric constant 78.5. Significant shift in vibrational frequencies for neutral formaldehyde molecule when studied in H_2O ice and upon ionization has been observed. All the vibrational modes in cation and anion of formaldehyde in gas phase are more red shifted than the corresponding modes in neutral formaldehyde. Two vibrational modes are blue shifted and all other modes are red shifted for neutral formaldehyde in H_2O ice. Time dependent density functional theory (TDDFT) is used to study electronic absorption spectrum of neutral formaldehyde and its charged states. It is found that like neutral formaldehyd***e,*** its cation and anion also display strong $\sigma \rightarrow \sigma^*$ electronic transitions in vacuum and far UV regions. This study by Ajay Chaudhari in collaboration with Mahadevappa Naganathappa, and Shivaji Waghmare should help in detecting formaldehyde molecule and its ions in gas phase and in H_2O ice in different astronomical environment.

Infrared and electronic absorption spectra of n-butyronitrile and its ions using Møller Plesset method

The coupled cluster theory (CCSD) and second order Møller-Plesset perturbation (MP2) theory with TZVP basis set are used for the study. Vibrational frequencies of gauche and anti conformers of neutral n-butyronitrile at MP2/TZVP and CCSD/TZVP levels are in agreement with the experimental determinations. Rotational and distortion constants are also in good agreement with the available experimental values. Time dependent density functional theory is used to study the electronic absorption spectra of gauche and anti- conformers, their ions and an isomer of butyronitrile. All the electronic transitions of gauche and anti- conformers of neutral n-butyronitrile, and 2-methylpropanenitrile are $\sigma \rightarrow \sigma^*$ transitions whereas ions of n-butyronitrile show both $\sigma \rightarrow \sigma^*$ as well as $\pi \rightarrow \pi^*$ transitions, in vacuum UV, far UV and visible regions. This study by Ajay Chaudhari in collaboration with Mahadevappa Naganathappa helps in detection of neutral gauche and anti-conformer and their ions in interstellar medium.

H.S. Das

Polarisation properties of comet NEAT C/2001 Q4

Comets exhibit high (up to 25 %) amount of optical polarization when they are observed through ground based or space telescopes. These polarizations are caused due to the scattering of cometary dust. The observed linear polarisation of comets is generally a function of the wavelength of incident light (λ), the scattering angle (θ), the geometrical shape and size of the particle, and the composition of dust particles in terms of the complex values of the refractive index. The scattering properties of cometary dust will help to know the nature of cometary dust. The observed linear polarization data of Comet NEAT have been studied through simulations using Ballistic Particle-Cluster Aggregate (BPCA) and Ballistic Cluster-Cluster Aggregate (BCCA). Using superposition T-matrix code, the best-fitting values of complex refractive indices are calculated, which can well fit the observed polarization data of Comet NEAT C/2001 Q4. The best fitting values of complex refractive indices from the present analysis correspond to mixture of both silicates and organics. This work was done in collaboration with S.R. Das D. Paul, and A. K. Sen.

Ujjal Debnath

Thermodynamical properties of dark energy filled universe

The flat FRW model of the universe, which is filled with only dark energy has been studied. The general descriptions of first and second laws of thermodynamics have been investigated on the apparent horizon and event horizon of the universe. He has considered tachyonic field, phantom field and scalar field in both interacting and non-interacting situations and investigated the validity of the generalized second law of thermodynamics in a flat FRW universe. It has been found that in all cases, excepting the phantom field dominated universe, the derivative of the entropy remains at negative level, and is increasing with the decrease in the redshift. The validity of the generalized second law (GSL) of thermodynamics has been examined in the presence of interaction between DBI-essence and other three candidates of dark energy namely, modified Chaplygin gas, hessence, tachyonic field and new agegraphic dark energy. It has been observed that the GSL breaks down in the presence of the interactions.

Sarbari Guha and Subenoy Chakraborty

Brane cosmology and motion of test particles in five-dimensional warped product spacetimes

In the braneworld scenario, ordinary standard model matter and non-gravitational fields are confined by some trapping

mechanism to the 4-dimensional universe constituting the D3-branes, which are embedded in a (4 + n)-dimensional manifold referred to as the 'bulk' (n being the number of extra dimensions). The notion of particle confinement is necessary for theories with non-compact extra dimensions, otherwise, the particles would escape from the 4-dimensional world along unseen directions. S. Guha and S. Chakraborty have considered a five-dimensional warped product spacetime having an exponential warping function, which depends on time as well as on the extra coordinates and a non-compact fifth dimension. Assuming that the lapse function may either be a constant or a function of both time and the extra coordinates, they have studied the nature of the geodesics of test particles and photons and have analyzed the conditions of stability in this geometrical framework. They have also discussed the possible cosmology of the corresponding (3 + 1)-dimensional hypersurfaces.

Ng. Ibohal

Hawking's radiation in non-stationary rotating de Sitter background

Ng. Ibohal and T. Ibungochouba have investigated the Hawking's radiation effect of Klein-Gordon scalar field, Dirac particles and Maxwell's electromagnetic field in the non-stationary rotating de Sitter cosmological spacetime by using a method of generalized tortoise co-ordinates transformation. The locations and the temperatures of the cosmological horizons of the non-stationary rotating de Sitter model have been derived. It is found that the locations and the temperatures of the rotating cosmological model depend not only on the time but also on the angle. The stress-energy regularization techniques are applied to the two dimensional analog of the de Sitter metrics, and the calculated stress-energy tensor contains the thermal radiation effect.

Charged black holes in Vaidya backgrounds: Hawking's Radiation

Ng Ibohal and L. Kapil propose a class of embedded solutions of Einstein's field equations describing non-rotating Reissner-Nordstrom-Vaidya and rotating Kerr-Newman-Vaidya black holes. The Reissner-Nordstrom-Vaidya metric is obtained by embedding Reissner-Nordstrom solution into non-rotating Vaidya metric. Similarly, Kerr-Newman solution has been embedded into the rotating Vaidya solution to obtain Kerr-Newman-Vaidya balck hole. The Reissner-Nordstrom-Vaidya solution is type D, whereas Kerr-Newman-Vaidya metric is algebraically special type II of Petrov classification of spacetime. These embedded solutions can be expressed in Kerr-Schild ansatze on different backgrounds. The energy momentum tensors for both non-rotating as well as rotating embedded solutions satisfy the energy conservation equations, which show that they are solutions of Einstein's field equations. The surface gravity, area, temperature, and entropy are also presented for each embedded black hole. It is observed that the area of the embedded black holes is greater than the sum of the areas of the individual ones. By considering the charge to be a function of radial coordinate, it is shown that there is a change in the masses of the variable charged black holes. If such radiation continues, the mass of the black hole will evaporate completely, thereby forming 'instantaneous' charged black holes and creating embedded 'negative mass naked singularities' describing the possible life style of radiating embedded black holes during their continuous radiation processes.

Deepak Jain

Constraints on dark energy and modified gravity models by the cosmological redshift drift test

Deepak Jain and S. Jhingan have studied cosmological constraints on the various accelerating models of the Universe using the time evolution of the cosmological redshift of distant sources. The important characteristic of this test is that it directly probes the expansion history of the Universe. They have analyzed the various models of the Universe, which can explain the late time acceleration, within the framework of general theory of relativity (GR) (XCDM, scalar field potentials) and beyond GR (f(R) gravity model).

Constraints on dark energy from the lookback time versus redshift test

Deepak Jain and collaborators (Lado Samushia, Abha Dev, and Bharat Ratra) have used the lookback time versus redshift data from galaxy clusters and passively evolving galaxies and applied a Bayesian prior on the total age of the Universe based on WMAP measurements, to constrain dark energy cosmological model parameters. Current lookback time data provide interesting and moderately restrictive constraints on cosmological parameters. When used jointly with current baryon acoustic peak and Type Ia supernovae apparent magnitude versus redshift data, lookback time data tighten the constraints on parameters and favour slightly smaller values of the non-relativistic matter energy density.

Minu Joy

Minu Joy has used a perturbative approach for studying inflation models with soft departures from scale free spectra of the power law model. In the perturbed power law (PPL) approach, at the leading, one obtains both the scalar and tensor power spectra with the running of their spectral indices. In contrast to the widely used slow roll expansion method, for which ε and δ have to be small, PPL can look also at models with comparatively larger ε and δ with the condition that $(\varepsilon + \delta)$ is small. The PPL spectrum is confronted with data and it has been shown that the PPL parameters are well estimated from WMAP-7 data.

Kanti Jotania

Some exact Bianchi type-V perfect fluid cosmological models with heat flow and decaying vacuum energy density : Expressions for some observable quantities

Kanti Jotania and Anirudh Pradhan have obtained some new exact solutions of Einstein's field equations in a spatially homogeneous and anisotropic Bianchi type-V spacetime with perfect fluid distribution along with heat-conduction and decaying vacuum energy density Λ, by applying the variation law for generalized Hubble's parameter that yields a constant value of deceleration parameter. It is found that the constant value of deceleration parameter is reasonable for the present day universe. The variation law for Hubble's parameter generates two types of solutions for the average scale factor, one is of power-law type and other is of the expotential form. Using these two forms, Einstein's field equations are solved separately, that correspond to expanding singular and non-singular models of the universe respectively. The cosmological constant Λ is found to be a decreasing function of time and positive, which is corroborated by results from recent supernovae Ia observations. Expressions for lookback time-redshift, neoclassical tests (proper distance d (z)), luminosity distance red-shift and event horizon are derived and their significances are described in detail. This work discusses physical and geometric properties of spatially homogeneous and anisotropic cosmological models.

Magnetized string cosmology in anisotropic Bianchi-II spacetime with variable cosmological term

This study deals with a spatially homogeneous and anisotropic Bianchi-II cosmological models representing massive strings by applying the variation law for generalized Hubble's parameter that yields a constant value of deceleration parameter. K. Jotania and collaborators (Padmini Yadav and S.A. Faruqi) have found that the constant value of deceleration parameter is reasonable for the present day universe. The energy-momentum tensor for such string as formulated by Letelier is used to construct massive string cosmological models for which, they assume that the expansion (θ) in the model is proportional to the component σ^{11} of the shear tensor σ^{ji}. This condition leads to $A = (BC)^m$, where A, B and C are the metric coefficients and m is proportionality constant. These models are in accelerating phase, which is consistent to the recent observations. The cosmological constant Λ is found to be a decreasing function of time and it approaches a small positive value at present epoch, which is in good agreement by the results from recent supernovae observations.

Anirudh Pradhan and Kanti Jotania

A class of new LRS Bianchi type-I perfect fluid universes with decaying vacuum energy density Λ

A class of new LRS Bianchi type-I cosmological models with a variable cosmological term is investigated in the presence of perfect fluid. A procedure to generate new exact solutions to Einstein's field equations is applied to LRS Bianchi type-I spacetime. Starting from some known solutions, a class of new perfect fluid solutions of LRS Bianchi type-I is obtained. The cosmological constant Λ is found to be positive and a decreasing function of time which is supported by results from recent supernovae Ia observations. The physical and geometric properties of spatially homogeneous and anisotropic cosmological models are discussed in their paper.

Pradip Mukherjee

Poincaré gauge theory from higher derivative matter Lagrangians

Starting from matter Lagrangians containing a higher order derivative than the first order, the Poincaré gauge theory is constructed by localizing the Poincaré symmetry of the matter theory. The construction is shown to follow the usual geometric procedure of a gravitational coupling, thereby buttressing the geometric interpretation of the Poincaré gauge theory.

P. N. Pandita

Phenomenology of neutralinos and charginos in different supersymmetry breaking models

P.N. Pandita and collaborators (Katri Huitu, Jari Laamanen, and Paavo Tiitola) have considered different patterns of supersymmetry breaking gaugino masses, and implications of these patterns for the phenomenology of neutralinos and charginos in models of low energy supersymmetry. They have evaluated an upper bound on the mass of the lightest neutralino that follows from the structure of the mass matrix in different models for the gaugino mass parameters. Using the experimental lower limit for the chargino mass, the lower bound for the neutralino masses has been obtained. They have used the sum rule for the squared masses of charginos and neutralinos to distinguish between different models for the supersymmetry breaking gaugino masses. Their analysis shows that by measuring the masses and decay properties of the neutralinos, one can distinguish between different patterns of supersymmetry breaking in the gaugino sector. Finally, they have compared the dark matter characteristics that arise in different models for the supersymmetry breaking gaugino mass parameters.

Ninan Sajeeth Philip

A learning algorithm based on primary school teaching wisdom.

A learning algorithm based on primary school teaching and

learning has been implemented in classifying data using neural network. The methodology is to continuously evaluate the performance of the network and to train it on the examples for which they repeatedly fail, until all the examples are correctly classified. Empirical analysis on UCI data show that the algorithm produces good training data and improves the generalization ability of the network on unseen data. The algorithm has interesting applications in data mining, model evaluations and rare objects discovery.

Anirudh Pradhan

An interacting two-fluid scenario for dark energy in FRW universe

Anirudh Pradhan and collaborators (Hassan Amirhashchi and Bijan Saha) have studied the evolution of the dark energy parameter within the scope of a spatially flat and isotropic Friedmann-Robertson-Walker (FRW) model filled with barotropic fluid and dark energy. To obtain the deterministic solution they choose the scale factor $a(t) = \sqrt{te}$ which yields a time dependent deceleration parameter (DP). In doing so, they have considered the case minimally coupled with dark energy to the perfect fluid as well as direct interaction with it.

Dark energy model in anisotropic Bianchi type-III spacetime with variable EoS parameter

To get the deterministic model, A. Pradhan and H. Amirhashchi consider that the expansion in the model is proportional to the eigen value $\sigma^2_{\sim 2}$ of the shear tensor $\sigma^i_{\sim i}$. The Equation of State (EoS] parameter ω is found to be time dependent and its existing range for this model is in good agreement with the recent observations of SNe Ia data, and SNe Ia data with CMBR anisotropy and galaxy clustering statistics. It has been suggested that the dark energy that explains the observed accelerating expansion of the universe may arise due to the contribution to the vacuum energy of the EoS in a time dependent background.

C. D. Ravikumar

Black hole mass limits for optically dark X-ray bright sources in elliptical galaxies

C. D. Ravikumar and collaborators (V. Jithesh, K. Jeena, R. Misra, S. Ravindranath, G. Dewangan and B.R.S. Babu) analyze *HST* ACS and WFPC2 images to search for optical counterparts of 84 point-like X-ray sources detected with *Chandra* in thirteen nearby elliptical galaxies. They have used a novel technique to search for faint optical counterparts in the *HST* images, whereby they subtract the bright galaxy light based on isophotal modeling of the surface brightness. They have identified optical counterparts for 56 sources, and the remaining 28 sources do not have any detectable optical emission at 3σ level. These optically dark sources cannot be foreground stars or background active galactic nuclei, and hence must be accreting systems residing within their host galaxies. They have placed tight upper limits on the black hole masses of these sources, based on the upper limits to their optical emission and assuming that these sources have standard accretion disks. For several of these optically dark ultra-luminous X-ray sources (ULX), they constrain their black hole masses $M_{BH} < 5000\ M_{\odot}$. In particular, an ULX in NGC~4486 has $M_{BH} < 1244\ M_{\odot}$. These limits are nearly two orders of magnitude smaller than previous estimates based on dynamical friction arguments. The potential of this method will provide stringent constraints on the black hole masses, and the implications on the physical nature of these sources.

Saibal Ray

Charged anisotropic matter with linear or nonlinear equation of state

Saibal Ray and collaborators (I.V. Varela, F. Rahaman, K. Chakraborty and M. Kalam) deal with self-gravitating, charged, anisotropic fluids and get even more flexibility in solving the Einstein-Maxwell equations. In order to discuss analytical solutions, they have extended the Krori and Barua method to include pressure anisotropy and linear or non-linear equations of state. The field equations are reduced to a system of three algebraic equations for the anisotropic pressures as well as matter and electrostatic energy densities. Combined with specific equations of state, the field equations imply quadratic polynomial equations satisfied by matter density. Attention is paid to compact sources characterized by positive matter density and positive radial pressure. The resultant solutions satisfy the energy conditions of general relativity. For the considered values of mass, charge and radius, different equations of state lead to similar configurations. Spheres with vanishing net charge contain fluid elements with unbounded proper charge density located at the fluid-vacuum interface. Notably, the electric force acting on these fluid elements is finite, although the acting electric field is zero. Net charges can be huge (10^{19} C) and maximum electric field intensities are very large (10^{23} -10^{24} statvolt/cm) even in the case of zero net charge. Inward-directed fluid forces caused by pressure anisotropy may allow equilibrium configurations with larger net charges and electric field intensities than those found in studies of charged isotropic fluids. These results are connected to that with charged strange quark stars as well as models of dark matter including massive charged particles. The van der Waals equation of state leading to matter densities constrained by cubic polynomial equations is briefly considered. The fundamental question of stability is left open.

Singularity-free solutions for anisotropic charged fluids with Chaplygin equation of state

Saibal Ray and collaborators (F. Rahaman, A. K. Jafry and K. Chakraborty) extend the Krori-Barua analysis of the static, spherically symmetric, Einstein-Maxwell field equations and consider charged fluid sources with anisotropic stresses. The inclusion of a new variable (tangential pressure) allows the

spherically symmetric, Einstein-Maxwell field equations and consider charged fluid sources with anisotropic stresses. The inclusion of a new variable (tangential pressure) allows the use of a non-linear, Chaplygin-type equation of state with coefficients fixed by the matching conditions at the boundary of the source.

A. K. Sen

A more exact expression for the gravitational deflection of light, derived using material medium approach

The deflection of a ray of light passing close to a gravitational mass is generally calculated from the null geodesic which the light ray (photon) follows. However, there is an alternate approach, where the effect of gravitation on the ray of light is estimated by considering the ray to be passing through a material medium.

Using this approach A.K. Sen has estimated the amount of deflection due to a static non-rotating mass. The refractive index of such a material medium, has been calculated in a more rigorous manner, and the final expression for the amount of deflection calculated is claimed to be more exact than all other expressions derived so far, using material medium approach.

Based on this expression, the amount of deflection for a sun grazing ray has also been calculated. The exact amount of deflection can be performed in a number of ways, without the material medium approach.

However, the method using the material medium approach and without any weak field approximation is believed to be original.

Photopolarimetric study of star forming clouds CB3, CB25, and CB39.

A. K. Sen, in collaboration with V. F. Polcaro, I. Dey and R. Gupta has found that the background star polarization when studied together with extinction is expected to help to understand various grain properties and the role of polarimetry as a tracer of magnetic field in these star-forming clouds. With this idea, polarization and colour excess $E\,(B-V)$ values for a set of background stars have been studied together to understand various astrophysical process in some star-forming dark clouds. Optical photometric observations of the three clouds CB3, CB25, and CB39 were carried out at the 2 m Himalayan Chandra Telescope, India, to determine the colour excess $E\,(B-V)$ of the background stars by following a technique adopted by Bernabei and Polacaro. These three clouds were selected from a set of eight clouds previously observed by the team in optical polarimetry. Further, independent spectroscopic measurements of a few selected sample stars were recently carried out during February and March 2010 from 1.52 m Cassini Telescope, Loinao, Italy, to confirm the correctness of estimated $E\,(B-V)$ values obtained by this photometric technique.

The colour excess $E\,(B-V)$ values so obtained were compared with optical polarization values obtained for the same set of stars. It has been found that the measured extinction values increase with the increase in percentage polarization for the cloud CB39 and to some extent for CB25. However, for cloud CB31, no such correlation is observed. It is normally expected that the grains causing extinction should also cause polarization of the light from background stars. Any possible deviation from this under different circumstances has been examined in the light of the ongoing physical processes in the star-forming clouds.

T. R. Seshadri

Accelerated expansion of our universe

One of the very intriguing features of our universe is that it is undergoing an accelerated expansion. While several approaches have been tried to investigate this feature there is not yet a good understanding of the reason for this behaviour. T. R. Seshadri and collaborators (Shruti Thakur and Anjan A. Sen) have attempted to understand this behaviour in models, in which gravity is described by a non-minimal action. It has been shown that the Hubble parameter evolves more slowly in the case of non-minimal coupling as compared to the minimal case. As in the minimal coupling in this case too, the universe accelerates around the present time, and makes a transition to the decelerating regime in the past. Using the Union 2 dataset for supernova Type Ia as well as the data for baryon acoustic oscillation (BAO) from SDSS observations, they place constraints on the parameters of Linder exponential model in the two different approaches. It is shown that there is an upper bound on model parameter in minimal coupling. But for non-minimal coupling case, there is wide range of allowed values for the model parameter.

H.P. Singh

Physical parameters of 62 eclipsing binary stars using the All Sky Automated Survey-3 data – I

H. P. Singh and Sukanta Deb have carried out light-curve analysis of publicly available V-band observations of 62 binary stars, mostly contact binaries, obtained by the All Sky Automated Survey (ASAS)-3 project between 2000 and 2009. Eclipsing binaries are important astronomical targets for determining the physical parameters of component stars from the geometry of their orbits. They provide an independent direct method of measuring the radii of stars. They have improved the ASAS determined periods and ephemerides, and obtained the Fourier parameters from the phased light curves of these 62 stars. These Fourier parameters were used for preliminary classification of the stars in the sample. The phased light curves were then analysed with the aid of the Wilson-Devinney light-curve mass ratios as determined from the radial velocity measurements available in the literature were used as one of the inputs to the light-curve modelling technique in order to

obtain various geometrical and physical parameters of these binaries. The spectroscopic mass ratios as determined from the radial velocity measurements available in the literature were used as one of the inputs to the light-curve modelling. Thus, reliable estimations of parameters of these binaries were obtained with combined photometric and spectroscopic data, and error estimates were made using the heuristic scan method. For several systems in the sample, the solutions were obtained for the first time and would serve as a good source in the future for light-curve analysis based on more precise follow-up CCD photometric observations. Out of 62 stars in the sample, photometric analysis of 39 stars is presented here for the first time using the ASAS photometry and precise spectroscopic mass ratios. From the analysis, they have found 54 contact binaries, six semidetached binaries and two detached binaries. The Fourier parameters in the a2-a4 plane were used for preliminary classification, and the final classification was done based on the Roche lobe geometry obtained from the light-curve modelling.

Physical parameters of the Small Magellanic Cloud RR Lyrae stars and the distance scale

H.P. Singh and Sukanta Deb have done a careful and detailed light curve analysis of RR Lyrae stars in the Small Magellanic Cloud (SMC), discovered by the Optical Gravitational Lensing Experiment (OGLE) project. Out of 536 single-mode RR Lyrae stars selected from the data base, they have investigated the physical properties of 335 'normal-looking' RRab stars and 17 RRc stars, that have good quality photometric light curves. They have also been able to estimate the distance modulus of the cloud, which is in good agreement with those determined from other independent methods. The Fourier decomposition method has been used to study the basic properties of these variables. Accurate Fourier decomposition parameters of 536 RR Lyrae stars in the OGLE-II data base are computed. Empirical relations between the Fourier parameters and some physical parameters of these variables have been used to estimate the physical parameters for the stars from the Fourier analysis. Further, the Fourier decomposition of the light curves of the SMC RR Lyrae stars yields their mean physical parameters as MV = 0.78 +/- 0.02 for 335 RRab variables and MV = 0.76 +/- 0.05 for 17 RRc stars. Using the absolute magnitude together with the mean magnitude, intensity-weighted mean magnitude and the phase-weighted mean magnitude of the RR Lyrae stars, the mean distance modulus to the SMC is estimated to be 18.86 +/- 0.01, 18.83 +/- 0.01 and 18.84 +/- 0.01 mag, respectively, from the RRab stars. From the RRc stars, the corresponding distance modulus values are found to be 18.92 +/- 0.04, 18.89 +/- 0.04 and 18.89 +/- 0.04 mag, respectively. Since, the Fourier analysis is a very powerful tool for the study of the physical properties of the RR Lyrae stars, they emphasize the importance of exploring the tool for the study of the physical properties of the RR Lyrae stars, and the reliability of the calculation of Fourier parameters together with the uncertainty estimates keeping in view the large collections of photometric light curves that will become available from variable star projects of the future.

Ranjan Sharma

Geometry, equation of state and the collapse of a star

Ranjan Sharma and Ramesh Tikekar have examined the evolution of the gravitational collapse of a spherically symmetric star accompanied with heat flux on the background of spacetimes of Vaidya-Tikekar ansatz, prescribing 3-spheroidal geometry for the physical 3-space of the collapsing configuration. It is found that initially, the static configurations having same mass and size proceed towards the ultimate end-state almost at the same rate irrespective of their material compositions or equation of state (EOS).

A class of solutions for anisotropic stars admitting conformal motion

Ranjan Sharma and collaborators (Farook Rahaman, Mubasher Jamil, and Kaushik Chakraborty) have provided a new class of interior solutions for anisotropic stars admitting conformal motion. The Einstein's field equations in this construction are solved for specific choices of the density/mass functions. They have analyzed the behaviour of the model parameters, like radial and transverse pressures, density and surface tension.

Pranjal Trivedi

Primordial magnetic field limits from cosmic microwave background bispectrum of magnetic passive scalar modes

An interesting possibility for the large scale magnetic fields seen in galaxies and clusters of galaxies is that they are of primordial origin. One consequence of such a cosmic magnetic field would be to introduce fluctuations in the CMB that are completely non-Gaussian, because magnetic field effects are non-linear.

Pranjal Trivedi, in collaboration with T. R. Seshadri, K. Subramanian, has investigated this non-Gaussian imprint on the CMB, taking into account the effect on neutrinos on the behaviour of the magnetic scalar anisotropic stress. They have calculated the bispectrum of the CMB, which is a simple measure of non-Gaussianity. The CMB bispectrum due to magnetic scalar anisotropic stress turns out to be a million times larger than that due to magnetic energy density, calculated earlier.

The current most sensitive observations of the CMB (WMAP7 data) allow them to compare the observed upper limits of non-Gaussianity with their predictions due to a cosmic magnetic field. They have related these two to obtain a limit that a tangled cosmic magnetic field must be less than 2 nano Gauss in strength at the current epoch on scales of 1 Megaparsec.

This limit is ten times better than the earlier limit from magnetic energy density. It is also as strong a constraint on the cosmic magnetic field, at a Megaparsec scale, as is known from all other techniques.

Paniveni Udayashankar

Activity dependence of supergranular fractal dimension

P. Udayashankar has studied the complexity of supergranular cells using the intensity patterns obtained at the Kodaikanal Solar Observatory during the solar maximum. This data consist of visually identified supergranular cells, from which a fractal dimension D for supergranulation is obtained according to the relation $P \alpha A^{D/2}$, where A is the area and P, the perimeter of the supergranular cells. It is found that the fractal dimension is about 1.12 for active region cells and about 1.25 for quiet region cells, the difference that could be attributed to the inhibiting effect of the magnetic field.

A. A. Usmani

Thin shell wormholes from charged black holes in general dileton-axion gravity

A. A. Usmani and collaborators (Z. Hasan, F. Rahaman, Sk. A. Rakib, Saibal Ray, and Peter K.F. Kuhfittig) have found a new type of thin-shell wormhole constructed by applying the cut-and-paste technique to two copies of a charged black hole in generalized dilaton-axion gravity, which was inspired by low-energy string theory. After analyzing various aspects of this thin-shell wormhole, they find its stability to linearized spherically symmetric perturbations.

Time variable lambda and the accelerating universe

A. A. Usmani and collaborators (U. Mukhopadhyay, Saibal Ray, and P.P. Ghosh) have performed a deductive study of accelerating universe and focus on the importance of variable time-dependent Λ in the Einstein's field equations under the phenomenological assumption, $\Lambda = \alpha H^2$, for the full physical range of α. The relevance of variable Λ with regard to various key issues like dark matter, dark energy, geometry of the field, age of the universe, deceleration parameter and barotropic equation of state has been trivially addressed. The deceleration parameter and the barotropic equation of state parameter obey a straight line relationship for a flat universe described by Friedmann and Raychaudhuri equations. Both the parameters are found identical for $\alpha = 1$.

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A. Pradhan (2011): Thesis titled *"On higher dimensional cosmology with decaying vacuum density: expressions for some observable quantity"*, by ***Deepak Srivastava*** , *submitted to* V.B.S. Purvanchal University, Jaunpur.

Saibal Ray (2010) : Thesis titled *"Some aspects of static charged fluid spheres in general relativity,"* by ***Basanti Das,*** submitted to Jadavpur University, Kolkata.

Asoke Kumar Sen (2010) : Thesis titled *"Wavelet based intelligent methods in image processing",* by **Sudipta Roy,** submitted to Assam University, Silchar.

IUCCA Sponsored Meetings and Events at Various Universities in India

An **Advanced Workshop on Astronomy: Observation, Theory and Interpretations,** was held during April 5-9, 2010 at IUCAA Resource Centre (IRC), Physics Department, North Bengal University, Siliguri. B.C. Paul from NBU and G. C. Dewangan from IUCAA coordinated the programme.

[Khagol, Issue No. 83, July 2010.]

A Workshop on Optical and Infrared Astronomy was held at Department of Physics, DDU Gorakhpur University, during October 26 - 29, 2010. Shantanu Rastogi and D.C. Srivastava from (DDU Gorakhpur University) and Vijay Mohan and Ranjan Gupta from IUCAA coordinated the programme.

[Khagol, Issue No. 85, January 2011]

The Workshop on Laboratory Astrophysics : Applications to Cosmic Dust, was held at M. G. Science Institute, Ahmedabad, during November 12 - 13, 2010. C. V. Pandya from M.G. Science University, and Ranjan Gupta from IUCAA coordinated the programme.

[Khagol, Issue 85, January 2011]

Introductory *Workshop in Astronomy and Astrophysics* *(With one day on Star Formation)* was held at: North East Centre for Research and Development (NECRD) IGNOU, Guwahati, during December 15 - 17, 2010. Anil C. Bora from NECRD, IGNOU, and Ranjan Gupta from IUCAA coordinated the programme.

[Khagol, Issue No. 85, January 2011]

The Physics Department, Tezpur University, organised an **Adanced Workshop on X-ray Astronomy** during March 3 -7, 2011. The workshop was coordinated by Nilakshi Das, Physics Department, Tezpur University and Ranjeev Misra, IUCAA.

[Khagol, No. 86, April 2011.]

A two-days UGC Seminar on **Recent Advances in Relativity, Cosmology and Astrophysics** was held at the Department of Physics, North Bengal University (NBU), Siliguri, jointly organised by IUCAA Resource Centre (IRC) and Physics Department, NBU, on February 28 and March 1, 2011. The seminar was coordinated by B.C. Paul and M.K. Das , NBU.

[Khagol, Issue No. 86, April 2011.]

Introductory Workshop on Astrophysics and Cosmology co-sponsored by IUCAA and West Bengal State University, Barasat, was jointly organised by the Department of Physics, West Bengal State University, Barsat, and IRC, Kolkata during November 26 - 28, 2010 and held at WBSU Campus. The workshop was jointly coordinated by Anirban Saha from the Department of Physics, WBSU and Ranjeev Misra from IUCAA.

[Khagol Issue No. 86, April 2011]

A School on **Recent Advances in Cosmology** was held during February 21 - 26, 2011 at IUCAA Resource Centre, Physics Department, North Bengal University, Siliguri. The school was coordinated by T. Souradeep from IUCAA and B.C. Paul from NBU.

[Khagol Issue No. 86, April 2011]

[Soft copy available at http://ojs.iucaa.ernet.in]

IUCAA Resource Centre

Department of Physics, Cochin University of Science and Technology, Kochi 682022

Coordinator: V. C. Kuriakose
Jt.Coordinator: Ramesh Babu T.

Highlights

The data centre was inaugurated on March 4, 2011 by Ramachandran Thekkedath, Vice-Chancellor of the University in the presence of A. Kembhavi, Director, IUCAA. The data centre is being now used by M.Sc. and M. Phil. students for doing projects and research students for their research work. The IRC possesses a 6" telescope and two 2.5" telescopes. The data centre is also housed in the IRC. Using the 6" telescope given by IUCAA the IRC has introduced two experiments in astrophysics for the MSc. students namely Determination of apparent magnitude of a star and Measurements of lunar topography.

Research

The thrust areas of research are: Physics of black holes, Extended theories of Gravity, Observational astronomy, Nonlinear dynamics, Bose-Einstein condensates and quantum optics. There are eleven research students doing research work in these areas.

Workshops and meetings

(a) IRC Meeting on X-ray Astronomy. A meeting on X-ray astronomy was held during April 21 - 24, 2010 at the Department of Physics. This meeting was attended by researchers (faculty and research scholars), who were actively involved in X-ray astronomy research. There were 14 outstation and 3 local participants. All the participants presented their work and R. Misra (IUCAA) coordinated this meeting.

(b) Introductory Level Workshop on General Relativity and Data Analysis Techniques in Astronomy
IRC in collaboration with the Department of Physics, University of Calicut, organized a workshop for post-graduate students at the Department of Physics, Providence College, Calicut, during September 8-10, 2010. There were about thirty five participants. The resource persons were C. G. Stalin, IIA, Bangalore; B. R. S. Babu, Calicut University; C. D Ravikumar, Calicut University; and V. C. Kuriakose, CUSAT. K. Jeena, V. Jithesh, P. Shalima, Veena S. Parvati (Research Scholars of Calicut University) gave training in astronomical data analysis. B. R. S. Babu was the coordinator of this workshop.

(c) Workshop on Optical Astronomy, Data Mining and Data analysis
IRC organized a workshop on optical astronomy, data mining and Data analysis at the Department of Physics, CUSAT during March 3-5, 2011. The resource persons of the workshop were A. Kembhavi, R. Srianad, Vijay Mohan, Anand Narayanan, Ninan Sajeeth Philip and V. C. Kuriakose. There were about 55 outstation participants and 15 local participants. Student participants were given hands-on experience on astronomical data mining and data analysis, using the facility of the data centre. Vivek M., Bhavya B., and Sheelu Abraham (Research Scholars) led the hands-on Data analysis sessions.

(d) IRC Sponsored Programmes

School of Pure and Applied Physics, M. G. University, Kottayam organised two workshops :

I) *On Tour Making,* held during October 18-19, 2010 and

ii) *On E- Astronomy and Statistics,* held during January 17-19, 2011. K. Indulekha of M.G. University was the Coordinator of these workshops.

Publications

a. Elements of optical solitons: An overview, V. C. Kuriakose, and K. Porsezian, Resonance – Journal of Science Education, 15, 643 (2010).

b. Variational method in optical solitons, V. C. Kuriakose, and C P Jisha, The proceedings of Sixth National Conference on Nonlinear Systems and Dynamics, January, 27-31, 2011, Tiruchirapalli.

Seminars/colloquia

(a) IRC Colloquia

A one day colloquium series was held on October 30, 2010 at the Department of Physics, CUSAT. This was attended by the local IUCAA Associates and their students. In this series the following talks were presented.

i) Time variability of broad absorption quasars, by Vivek M.

ii) QNMs of black holes, by Nijo Varghese

iii) Entanglement entropy of black holes by R. Tharanath

iv) Gravity as an Entropic force, by Saneesh Sebastian

v) Modified de-Broglian mechanics and some insights into quantum probability, by Moncy V. John.

(b) IRC Seminars

i) V. C. Kuriakose on Seeing the universe, July 27, 2010.

ii) Arvind Pranjpye on World wide telescope tour for educational purpose, October 20, 2010.

iii) P. Ajith on Gravitational wave astronomy: Opening a new window onto the universe, January 10, 2011.

Public Outreach Programmes

(a) Telescope making and sky watching for the school students

Department of Physics, CUSAT, organized a workshop for school students during April 19-29, 2010, in collaboration with IRC, Kochi. These students were given training in making small telescopes, and they constructed their own telescopes. There were lectures on astronomy and astrophysics and related topics. In addition, there were lectures on other topics in physics, and the students were given training on doing experiments and they were given opportunity to visit different research laboratories in the department. There were 45 students from different schools in Kerala.

(b) Lectures, telescope making and sky watching programmes at schools:

The IRC users have visited the following village schools and colleges and conducted telescope making and sky watching programmes for the benefit of the students.

(i) Government Model Technical Higher Secondary School, Kaprassery, December 17, 2010, (ii) Government Higher Secondary School, Chembuchira, Kodakara, January 11, 2011, (iii) MAP School, Mechira, Chalakudy, February 8, 2011, (iv) Christ College, Irinjalakuda, March 10, 2011, (v) Alphonsa College, Pala, March 14, 2011. Lectures in general astronomy were also given. The programmes were conducted in the local language Malayalam.

The research scholars of the astronomy and astrophysics group: Nijo Varghese, R. Tharanath, Saneesh Sebastian, Vivek M, Bhavya B and Pressia P. have rendered valuable services in making the public out-reach programme great a success.

IUCAA Resource Centre

Department of Physics and Astrophysics, University of Delhi , Delhi

Coordinator : T. R. Seshadri

The IRC Delhi has organized the IndIGO School on Gravitational Wave Astronomy 2010, during December 13-24, 2010. [For a detailed report, please check Khagol, Issue No. 86, published in April 2011 as well as@ojs.iucaa.ernet.in.]

In addition, the Data Centre has been set up with the computers and equipments provided by IUCAA. Several college, and university students have started using these for doing projects under the guidance of university and college teachers.

Talks and Journal Club

The following talks were arranged:

S.Shankaranarayanan, IISER, Thiruvananthapuram, *Spinor driven inflation,* April 27, 2010.

Kumar Atmjeet, University of Delhi, *Magnetic field generation in Higgs inflation model,* September 16, 2010.

Pranjal Trivedi, University of Delhi, *Dark matter candidates from particle physics and methods of detection,* September 23, 2010.

Sampurnanand, University of Delhi, *How exactly did the universe become neutral,* November 19, 2010.

Public Lectures

T. Padmanabhan, IUCAA, *The story of the calendar,* August 5, 2010 (organised jointly with Centre for Science Education and Communication, Delhi University).

B. S. Sathyaprakash, University of Cardiff, UK, *Listening to the symphony of black holes,* December 14, 2010. (As part of the ISGWA 2010)

IUCAA Resource Centre

Department of Statistics, Calcutta University, Kolkatta

Coordinator: Asis K. Chattopadhyay

Highlights

During this year, the activities of the data centre have started by the installation of server, terminals and UPS. The centre is now ready for use with all the scientific softwares and data structure and archives. The students, research, scholars and faculty members of different colleges, universities and institutes are using the facilities.

Research Areas

The principal area of interest in IRC Kolkata is Astrophysics and related data analysis. Some of the research scholars and faculty members are involved in the use of statistical tools and techniques for the analysis of astronomical data. Theoretical research work, related to theory of relativity and cosmology is also a major area of focus.

Workshops and Meetings

(a) Workshop on ***Data Analysis Techniques for Astronomy***, November 23-25, 2010 Sponsored by IUCAA, and organized by IUCAA Resource Centre, Kolkata and Conducted at, Burdwan University,W.B.

(b) Workshop on ***Astrophysics and Cosmology***, November 26-28, 2010. Sponsored by IUCAA, Pune and organized by IUCAA Resource Center, Kolkata and Department of Physics, West Bengal Barasat State University.

(c) Workshop on ***Statistical Data Analysis***, December 30-31, 2010 organized by IUCAA Resource Centre, Kolkata, and Department of Statistics, Calcutta University.

Publications

(a) *Structures in the fundamental plane of early-type galaxies* (2010), D Fraix-Burnet, M. Dugue, T. Chattopadhyay AS.K.Chattopadhyay and E. Davoust, *Mon. Not. R. Astron. Soc*, **407**, 2207.

(b) *Statistical analysis of the dwarf galaxies and their globular clusters in the local volume* (2010), T. Chattopadhyay, M Sharina, and P. Karmakar, *Astrophysical Journal*, 724, 628.

Seminars and Colloquia

(a) Jishnu Dey , Presidency College, Kolkata on *The importance of being strange,* April 24 , 2010.

(b) Tapomoy Guha Sarkar, (affiliation) on *The post- reionization redshifted 21-cm signal and its cross correlations*, August 7, 2010.

(c) Wei-Tou Ni,Centre for Gravitation and Cosmology, Department of Physics, National Tsing Hua University Hsinchu, Taiwan 30013 Republic of China on *Gravitational waves : Classification and detection methods*, January 14, 2011; and on *Probing cosmology and galaxy co-evolution with black holes via gravitational wave observations*, January 18, 2011.

(d) Sanjeev V. Dhurandhar, IUCAA, Pune, (two seminars) on *Introduction to general relativity , black holes and gravitational waves*, January 17, 18, 2011.

IUCAA Resource Centre

North Bengal University, Siliguri

Coordinator : B. C. Paul

The faculty members, research scholars and M. Sc. students of the department, as well as visitors from different colleges, universities and institutes, use the facilities available at the IRC, Physics Department, NBU. Eight computers and storage devices were provided by IUCAA, Pune, to set up a high speed computing facility for astronomical data analysis . A data centre is being set up with the help of IUCAA. It will cater the need for the researchers in the North Eastern part of India. IRC, NBU has organized a number of seminars during the year. an advanced Data Analysis workshop during the period one school and three workshops have been organized with the speakers from IUCAA, different universities and institutes in India . T. Souradeep from IUCAA, and B. C. Paul, NBU coordinated the School on Recent Advances in Cosmology held during February 21-26, 2011 at IRC, NBU. A pedagogical lecture series has been arranged during October 6-14, 2010 for the M. Sc. students and young college teachers. S. V. Dhurandhar from IUCAA delivered the lectures.

Visitors

A. K. Kembhavi (IUCAA), R. Misra (IUCAA), G. Dewangan (IUCAA), S. V. Dhurandhar (IUCAA), T. Raychaudhuri (HRI, Allahabad) S. Majumdar (TIFR, Mumbai), S. Bharadwaj (IIT, Kharagpur), L. Sriramkumar (HRI, Allahabad), S. Mukherjee (Kolkata), N. K. Dadhich (IUCAA), C. S. Unnikrishnan (TIFR, Mumbai), R. Tikekar (IUCAA), D. Majumdar (SINP, Kolkata), D. P. Duari (MPBP, Kolkata), B. Modak (Kalyani University), P. Bhakta (Sikkim Govt. College, Gangtok), R. Chhetri (Sikkim Govt. College, Gangtok), P. Chattopadhyay (Alipurduar College), P. Thakur (Alipurduar College), P. Pradhan (St. Joseph's College, Darjeeling), S. Mandal (Taki Govt. College, North 24 Parganas), S. Chakraborty (Jadavpur University), P. K. Roy (Presidency College, Kolkata), S. K. Manna (Dinhata College), A. Kumar (BHU, Varanashi), Wei-Tou Ni (Tsing Hua Unversity, China), and P. S. Debnath (A B N Seal College, Coochbehar).

Seminar/ Workshop organized

1. Data Analysis Workshop during April 5-9, 2010

2. A School on Recent Advances in Physics (SRAC-2011) was held during February 21 -26, 2011 The school was organized by T. Souradeep from IUCAA and B. C. Paul from NBU. There were 30 participants from different Institutes and universities in India. The speakers of the school were: T. Souradeep, B. C. Paul , T. Raychaudhuri, and S. Majumdar, S. Bharadwaj, L. Sriramkumar, S.Mukherjee. The main objective of the school was to expose the research scholars to the recent research frontiers in cosmology. A number of lectures have been delivered by the active workers in the field, mostly young faculties of different Institutes in India, to introduce the area of cosmology namely, overview of cosmology and structure formation, basic cosmology, inflation, density perturbation and observational cosmology including dark matter. The emerging area of research has also been discussed thereafter.

3. A two days UGC Seminar on Recent Advances in Relativity, Cosmology and Astrophysics during February 28 - March 1, 2011 was held at Physics Department, NBU jointly organized by IRC and Physics Department, NBU. The seminar was coordinated by B. C. Paul and M.K. Das, NBU. The seminar was organized to expose the recent developments in the fields of cosmology and a strophysics for the PG students of NBU including other universities. There were 100 participants. The speakers were N. K. Dadhich (IUCAA), C. S. Unnikrishnan (TIFR), R. Tikekar (IUCAA), D. Majumdar (SINP), D. P. Duari (MPBP), B. Modak (KU), S.K. Ghosal (NBU), S. Mukherjee (IRC). A public talk (Why Einstein : Relativity for Everyone) by N.K. Dadhich was organized on February 28, 2011. It was attended by 25 school students, the participants of the seminar and people from other departments. A popular talk entitled Voyage to the Cosmos was delivered by D. P. Duari on March 01, 2011.

4. IRC, North Bengal University (NBU) and Department of Mathematics, NBU have organized a one day seminar on NONLINEAR DYNAMICS and ASTROPHYSICS on October 9, 2010. About 38 participants from different colleges attended the seminar. The speakers were S. V. Dhurandhar (IUCAA) , S. Chakraborty (JU), P. Chatterjee (Santiniketan), B.C. Paul (NBU), D.P. Datta (NBU), K. Mondal (Alipurduar), A. Palit (Siliguri), P. Bhakta (Sikkim), R.Tiwari (Darjeeling). Dhurandhar gave a talk entitled "Mathematical structures underlying LISA time delay interferometry". Non-linear theories in different fields of research discussed in the seminar.

5. IRC,NBU also organized a one day Workshop on Advances in Physics and Astrophysics at Siliguri B. Ed. College, Shivmandir on October 13, 2010. The speakers are S. V. Dhurandhar, B.C. Paul, S.K.Ghosal and P. Mandal. Fifty participants attended the seminar.

6. S. V. Dhurandhar gave a series of lectures on gravitation at Physics Department, NBU during October 6- 14, 2010. Post graduate students and college teachers from neighbouring colleges attended the pedagogical lectures.

List of Publications using the facilities of IRC.

1. B. C. Paul, S. Ghose and P. Thakur (2011) *Emergent Universe from A composition of Matter, Exotic Matter and Dark Energy, MNRAS,* 413, 1, 686690

2. B.C. Paul, P. Chattopadhyay, S. Karmakar and R. Tikekar (2011) *Relativistic Strange Star with Anisotropy* , Mod. Phys. Letts. A 26, 575

3. B. C. Paul and A. Saha (2010) *Singular Instanton in R4 Gravity for Open Inflation*, Class. Quantum Grav. 27, 215004 .

4. B. C. Paul, P. Thakur and S. Ghose (2010) *Constraints on Exotic Matter needed for an Emergent Universe*, Mon. Not. Roy. Astron. Soc. 407, 415

5. B. C. Paul and S. Ghose (2010) *Emergent Universe Scenario in the Einstein-Gauss-Bonnet Gravity with Dilaton*, Gen. Rel. Grav. 42, 795 (2010), arXive : 0809.4131

6. P. K. Chattopadhyay and B. C. Paul (2010) *Relativistic Star Solutions in Higher Dimensional Pseudo-spheroidal Space-time*, Pramana, Journal of Physics 74, 513 .

7. A. Bhadra, S. Biswas and K. Sarkar (2010) *Gravitational deflection of light in the Schwarzschild-de Sitter space-time*, Phys. Rev. D. 82, 063003

8. F. Rahaman, K K Nandi, A. Bhadra, M. Kalam, K. Chakraborty (2010) *Perfect fluid dark matter, A Phase Space Analysis*, Physics Letters B, 694, 10 .

9. R. K. Dey, A. Bhadra and J. N. Capdevielle (2011) *Behaviour of the EAS Age Parameter in the Knee Energy Region*, Proc. ISVHECRI , (arXiv:1009.5396)

10. A. Bhattacharya, G M Garipova, A. A Potapov, A. Bhadra, K. K. Nandi (2011) *The Vacuole Model Revisited: New Repulsive Terms in the Second Order Deflection of Light*, JCAP 028.

11. S Raut and D P Datta (2010) *Scale invariance and Cantor sets*, Fractals !8 (1), 111-118.

12. D P Datta, and A. Raychoudhuri (2010) *Scale Invariant Analysis and Prime Number Theorem*, Fractals 18 (2), 171-184.

13. A. Palit and D P Datta (2010) *The existence of exactly N limit cycles in Lienard systems*, Int. J. Pure and Applied math, 59 (4), 469-488.

IUCAA Resource Centre

Department of Physics Pt. Ravishankar Shukla University, Raipur

Coordinators : S. K. Pandey and R. C. Agrawal

Highlights

Data Centre: The new data centre at IRC, is now ready. M.Sc. students and research scholars are making use of the facility.

Research activities

The faculty members, and research scholars in the university as well as visitors from other universities/colleges in this region made use of the facilities (data centre, library, etc.) provided by IUCAA at the centre to strengthen their research activities. Some of the important activities of the centre during the year are listed below.

D. K. Chakraborty and his research students continued their work on the projected properties of a family of triaxial mass models. They have extended their work on the mass models with central cusp to investigate the effect of the inclusion of high order residuals on intrinsic shapes of elliptical galaxies.

S. K. Pandey continued the collaborative research programme with A. K. Kembhavi, on Multiwavelength photometric study of dusty early-type galaxies, which constitutes the thesis work of Samridhi Kulkarni. A paper entitled "Study of dust and ionized gas in early type galaxies" reporting the results is under preparation.

Also, the programme of studying faint outermost region of the galaxies from the Large Format Camera (LFC) field was continued during the year. A paper entitled "Isophotal shapes of early-type galaxies to very faint isophotal levels" reporting our findings is being sent for publication. This is a collaborative research programme involving A. K. Kembhavi, Russell Cannon, and Ashish Mahabal, and this work constitutes the thesis work of Laxmikant Chaware. Sheetal Sahu, research student of S. K. Pandey started working on the project "Multiwavelength study of a sample of radio loud elliptical galaxies" and is using the 2 m telescope at IUCAA Girawali Observatory for the observations.

Nand Kumar Chakradhari, Lecturer in the department, is actively involved with his research work on supernova and short period variability in chemically peculiar stars.

Research project

A research project entitled "Photometric and spectroscopic studies of galaxies in deep survey fields" approved by ISRO, Bengaluru under RESPOND programme, with S. K. Pandey as PI and A. K. Kembhavi as Co-PI entered into its third year.

Publication :

Intrinsic shapes of very flat elliptical galaxies, D. K. Chakraborty, A. K. Diwakar, and S. K. Pandey, MNRAS, **412**, 585.

Poster/paper presentation

1. Search for P-mode pulsations in late type chemically peculiar stars, S. Joshi, and N.K. Chakradhari, Paper presented at an International Conference, AOGS 2010, held at Hyderabad, during 5-9 July, 2010.
2. Poster entitled "Study of dust properties in early type galaxies", Samridhi Kulkarni, Laxmikant Chaware, D. K. Sahu, N. K. Chakradhari, and S. K. Pandey, was presented in the conference, "Wittfest: Origins and evolution of dust", held at University of Toledo, Toledo, Ohio, during October 10-12, 2010 .
3. Poster entitled "Multiwavelength investigation of dusty E/SO galaxies", Samridhi Kulkarni, Laxmikant Chaware, D. K. Sahu, N. K. Chakradhari, and S. K. Pandey, won best poster prize at the ASI-2011, held at Pt. R. S. University, Raipur, during February 23-25, 2011.
4. Poster entitled "Photometric and spectroscopic study of the So galaxy, NGC 1266", Sheetal Kumar Sahu, S. Ravindranath, and S.K. Pandey, was presented in ASI-2011, held at Pt.R. S. University, Raipur, during February 23-25, 2011.

Lectures

S K Pandey

"*Teaching of astronomy*" an invited contribution at ASI-2011 held at Raipur during February 23-25, 2011

"*The dynamic universe*" an invited lecture at the Young Scientist Meet organized by Bastar University, Jagdalpur, during February 28- March 1, 2011.

"*A glimpse of the universe*" special lecture at the workshop organized at Govt. College, Abikapur on March 4, 2011.

N. K. Chakradhari

"Telescopes and multiwavelength universe" an invited lecture in Teachers Training Programme at SCERT, Raipur, on April 22, 2010. Lectures to the INSPIRE participants and school students of the Chhattisgarh State during December 2 - 6 2010, December 15 - 19, 2010, June 4 – 8, 2010 and June 10 – 14, 2010.

TV / Radio Program

N. K. Chakradhari was invited as an expert for a discussion on "The end of the world on December 21, 2012: A mis-conception among the common people" in a TV programme broadcasted by *Zee-Chhattisgarh 24 hour* TV channel in November 2010.

Visitors

J. V. Narlikar (IUCAA), M. K. Patil (SRTM Univ., Nanded), Ajit Kembhavi, (IUCAA), Gulab Dewangan (IUCAA), D. K. Sahu (IIA, Bangalore), Sudhanshu Barway (SAAO, South Africa), Pushpa Khare (Utkal University, Bhub aneshwar), and Rajaram Nityananda (NCRA, Pune)

Workshop / Conference

1. Astronomical Society of India Meeting was organized at the university during February 23- 25, 2011. Eminent scientists and research students from all over India participated.

Sky gazing programme

- Astronomical lecture, telescope demonstration, and sky watching programme at a camp organized by Directorate of Sports and Youth Welfare, Chhatisgarh at Barnawapara/Turturiya on February 17, 2011.
- **Astronomy Week**: Astronomical lectures, telescope demonstration and sky watching programme at various colleges and schools from 9th to 18thJan 2011 (Digvijay College Rajnandgaon, Dumartarai School; Raipura School; Radiant Public School, Nimora; Ramsagar Para School; Kalyan College, Bhilai, and Mujgahan School).
- Telescope demonstration, and sky watching programme for the INSPIRE participants during December 2 – 6, 2010 and December 15 – 19, 2010.
- Sky gazing programme on September 21 2009 for the University teachers and NAAC Peer Team.

Along with these events, the regular sky gazing programme for students of the department/university, students from local schools/colleges as well as for the general public were organized.

Students' seminars

M. Sc., and M. Phil. students of the department made use of IRC facilities for the preparation/presentation of weekly seminars organized in the department.

Balance Sheet 2010-11

The Bombay Public Trust Act, 1950. Schedule VIII [Vide Rule (1)]

Name of the Trust : INTER-UNIVERSITY CENTRE FOR ASTRONOMY & ASTROPHYSICS

Address: Post Bag-4,Ganeshkhind, Pune-7. Registration No. :F-5366 (PUNE) dated 27.1.1989.

BALANCE SHEET AS AT 31ST MARCH 2011

Sr No.	FUNDS & LIABILITIES	Schedule No.	31.03.2011 Rs.
1	Trust Fund / Corpus	6	3,77,30,731
2	Grant-In-Aid from UGC	7	103,48,12,079
3	Other Project Grants	8	2,94,39,073
4	Projects and Other Payable(Net)	9	46,45,870
5	Current Liabilities	10 & 10A	71,18,845
6	Income and Expenditure a/c	14	(4,03,79,273)
	Total		107,33,67,325

Sr No.	ASSETS & PROPERTIES	Schedule No.	31.03.2011 Rs.
1	Fixed Assets (At cost)	11	76,34,86,285
2	Investments / Deposits	12	24,73,16,733
3	Project & Other Receivables(Net)	13	2,00,73,026
4	Current Assets -	13	
	a) Cash, Bank balances & Revenue Stamps		16,89,152
	b) Loans and Advances	13A	92,82,225
	c) Deposits		14,17,761
	d) Prepaid Expenses		66,52,147
	e) Advance to Suppliers	13B	2,34,49,996
	Total		107,33,67,325

For Inter-University Centre for Astronomy & Astrophysics

N. V. Abhyankar
Admn.Officer (Accounts)

E.M.Modak
(Sr.Admn.Officer)

Prof. A.K.Kembhavi
(Director / Trustee)

As per Report of even date
For Kirtane & Pandit
Chartered Accountants
FRN-105215W

Parag Pansare
(Partner)
Membership No.117309

Chairperson
Governing Board

Place : Pune
Date : 12.08.2011.