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IUCAA

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July 2000

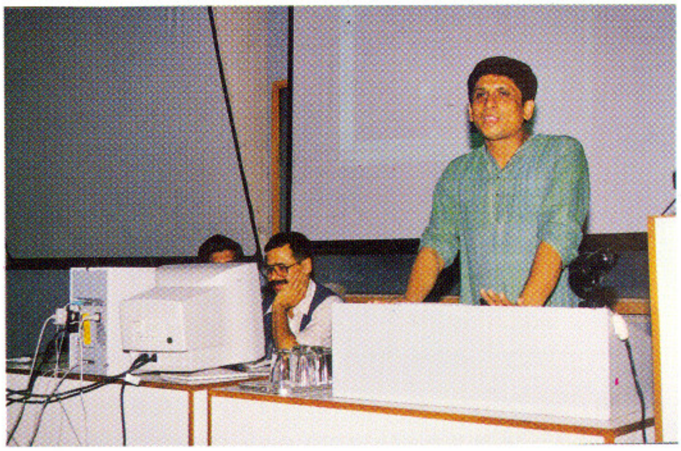
School Students' Summer Programme 2000

Some of the participants of the School Students' Summer Programme 2000

The School Student's Summer Programme was held from April 10 to May 19, 2000. Invitation for participation in this programme was sent to all the schools in Greater Pune and the schools were requested to nominate two students from 8th or 9th class. Seventy five schools responded to our invitation. A batch of 28 students was invited to work at IUCAA from Monday to Friday each week for 6 weeks. Sub-groups of 4 to 6 students were formed from this batch and each sub-group worked under the guidance of a member of IUCAA. No set syllabus or course guideline was made for this programme. The students and the guide worked out the schedule for each week. The students also had a free access to the IUCAA library.

In addition to their programme with the guides,

Contents...



Nail biting moment for the young astronomers as they wait for the light from M51, the Whirlpool Galaxy, which had travelled 15 million light years to make another 14,000 kilometer journey. Jayant Narlikar is all smiles at the excitement and Somak Raychaudhury is giving vital statistics of the galaxy.

some common activities were also planned for them. They were shown scientific films, a lecture was arranged and were taken to the Science Park. A question and answer session was also conducted for the students with Jayant Narlikar answering their questions.

On Thursday, May 4, at 2 p.m., a 14" telescope and a CCD camera, which is halfway across the world in California, was operated through the Internet in the presence of that week's school students and several members of IUCAA. This innovative telescope was made by a group called TIE (Telescope in Education) at Mt. Wilson. Using an interface supplied by the Mt. Wilson group, it was possible to move the telescope to several targets, take exposures with a CCD camera, and download and display the images in real time. The objects observed were M87, M83, M51, M101, etc. This was the beginning of a collaboration between IUCAA and the Outreach group at Mount Wilson to use telescopes at each others' institutions for "daytime observing". The terminology arises from the fact that when it is daytime (2 p.m.) here, it is about 1 a.m. at California.

On Fridays, the students were asked to give an oral presentation of their work, in addition to submitting a report of their work. Based on last year's experience, the students were given instructions as to how to present their work. Barring one or two cases, all presentations were in true scientific spirit.

Those who contributed to this programme by guiding students were Tarun Saini, Yogesh Wadadekar and S. Shankarnarayanan (Research Scholars); Subhash Karbelkar (Associate); Firoza Sutaria, Arun Thampan, Sushan Konar (Post-Docs); Ranjan Gupta, Somak Raychaudhury, S. N. Tandon, Jayant Narlikar (Faculty); V. Chellathurai, Dhananjay V. Gadre (Scientific staff) and Vinaya Kulkarni (Science Popularization Laboratory). Arvind Paranjpye was the co-ordinator of this programme.

Some of the projects undertaken by the students were - Rotation of the Earth : Foucault's pendulum, Measuring time : Samrat Yantra, the sun dial; Solar system, Astronomy and Astrophysics: Kepler's laws, calculating masses of planets, law of gravitation, scale model of the solar system, Doppler effect, luminosity and temperature, Hubble's law; Understanding paradoxes : Olber's, Achilles and a tortoise; Mathematics : Non - Euclidean geometry, Combinotrics, works of Fermat, Pascal, Gauss, Riemann, Discovery of calculus - Newton and Leibeniz; Computer Programming : understanding and writing computer programme; Evolution of life : Darwin's theory. Most of the students also read introductory books in astronomy.

The friendly atmosphere at IUCAA made students bold enough to make constructive suggestions. The most voiced criticism was lack of books in Marathi and Hindi and the short duration of the programme.

Gilber Clark, Director of the TIE project, is the brain behind the "web-driven" telescope. He has received many awards in the last three years, including the NASA Exceptional Achievement Medal and the Rolex Award for Enterprise for Applied Science and Invention. We acknowledge his kind cooperation in giving us the telescope time. We also thank Steve Goldent, Mary Cragg and Gary Creason of TIE, and Sarah Ponrathnam, Vijay Upreti, Sunu Engineer and Vinaya Kulkarni at IUCAA for their help in remote viewing through telescope possible.

Workshop on Stellar Structure and Evolution at St. Berchman's College, Changanacherry.

An introductory workshop on Stellar Structure and Evolution will be organized at St. Berchman's College in early October, 2000. Those interested may write to George Varghese, Dept. of Physics, St. Berchman's College, Changanacherry, Kerala 696 101; e-mail: sbclib@vsnl.com

Welcome to ...

A. N. Ramaprakash, who has joined as a core faculty member. His research interests are in astronomical instrumentation and observation.

Workshop on Nuclear Astrophysics at IUCAA

A workshop on Nuclear Astrophysics will be held at IUCAA during September 20-22, 2000. The workshop will deal with topics like stellar nucleosynthesis, neutron rich nuclei and their importance in astrophysics, neutron star magnetic fields, equation of state for dense stellar matter and neutrino astrophysics, etc. Those who are interested to participate in the workshop may kindly write to Somenath Chakrabarty, Dept. of Physics,University of Kalyani, Kalyani 741 235, West Bengal; e-mail: somenath@klyuniv.ernet.in; Fax: (033) 5828282.

Workshop on Observations with Small Telescopes

A workshop on Observations with Small Telescopes will be jointly organised by Bhavnagar University and IUCAA, during November 2 - 4, 2000, at Bhavnagar. Resource persons will be from PRL, Ahmedabad, IUCAA, IIA, Bangalore and Bhavnagar University. Lectures on topics covering photometry, spectroscopy and related backend instrumentation for small telescopes will be delivered.

Persons working in this field or planning to initiate teaching / research in this area may contact S.P. Bhatnagar, Department of Physics, Bhavnagar University, Bhavnagar-364002, Gujarat. (email: spb@bhavuni.ren.nic.in). Participation to this workshop will only be by invitation.

IUCAA is happy to announce the selection of the eleventh batch of its Visiting Associates , who are selected for a tenure of three years, beginning July 1, 2000. The Governing Board has decided that with effect from this year (2000), all Associates and Senior Associates will be designated together as , **"Visiting Associates".**

Extension to the eighth batch of Associates / Senior Associates

Moncy John, St. Thomas College, Kozhencherri.
Manoranjan Khan, Jadavpur University.
Udit Narain, Meerut College.
R. Ramakrishna Reddy, Sri Krishnadevaraya University, Anantapur.
Asoke Kumar Sen, Assam University, Silchar.
G.P. Singh, Visvesvaraya Regional College of Engineering, Nagpur.
Santokh Singh, Deshbandhu College, New Delhi.
S.K. Srivastava, Noth-East Hill Unversity, Shillong.

New Visiting Associates

S.K. Banerjee, Mody College of Engineering and Technology, Lakshmangarh.
Anil Ch. Borah, Assam University, Silchar.
K.N. Iyer, Saurashtra University, Rajkot.
Ashok Kumar Mittal, Allahabad University.
Bijan Modak, University of Kalyani.
B.C. Paul, North Bengal University, Siliguri.
Sandeep Sahijpal, Panjab University, Chandigarh.
M. Sami, Jamia Millia Islamia, New Delhi.
K. Shanthi, Mumbai University.
P.K. Suresh, University of Hyderabad.

Cosmology with the Cosmological Constant

1 The early universe and Λ

The cosmological constant was introduced in 1917 by Einstein who decided to modify his equations of general relativity to include a '$\Lambda - term$',

$$R_{ik} - \frac{1}{2}\, g_{ik}R - \Lambda g_{ik} = \frac{8\pi G}{c^4} T_{ik}. \qquad (1)$$

The Λ term is equivalent to an ideal fluid with the (Lorenz invariant) equation of state $P = -\rho = -\Lambda/8\pi G$ and led to the possibility that the universe could be spatially closed (a 3-sphere) and static, which Einstein felt was compatible with Mach's inertia principle. In 1917 the existence of galaxies other than our own had not yet been firmly established and the concept of a static universe was entirely plausible. The situation underwent a radical change when Hubble discovered that the universe was expanding and Friedmann showed that an expanding matter dominated universe could be constructed on the basis of the Einstein equations without introducing Λ. Although abandoned by Einstein (who later referred to it as his biggest mistake) the cosmological constant was not forgotten and even came to occupy the cosmological centre-stage on several occasions including the present (for reviews of the cosmological constant see [17, 4, 15]).

In a homogeneous and isotropic universe, the Einstein equations can be recast to resemble the equation of motion of a point particle on the surface of a sphere of radius R

$$\ddot{R} = -\frac{GM}{R^2} + \frac{\Lambda}{3}\, R. \qquad (2)$$

The total 'gravitating mass' $M = \frac{4\pi}{3}R^3(\rho + 3P)$ reflects the fact that 'pressure carries weight' in Einstein's theory of gravity. A particle on the sphere clearly feels both attractive and repulsive forces. When $\Lambda > 0$, the force of repulsion $F_{rep} = \frac{\Lambda}{3}\, R$ is caused by the cosmological constant and increases with distance. In the absence of matter, the repulsive effects of Λ cause the universe to expand exponentially, $R \propto \exp[(\Lambda/3)^{1/2}t]$, once the effects of spatial curvature have been diluted. An exponentially expanding universe was discovered by de Sitter in the same year that Einstein introduced Λ. The de Sitter solution subsequently played an important role in several developments in cosmology, including the steady state theory and inflationary models of the early universe.

The cosmological constant has been in the news for almost two decades. Developments in high energy physics during the late 1970's and early 1980's demonstrated that an effective cosmological Λ-term could be generated both with and without spontaneous symmetry breaking. Interest in Λ-based 'inflationary' models grew when it was discovered that they could resolve the horizon and flatness problems as well as generate primordial 'seed' fluctuations responsible for galaxy formation. A positive Λ-term might also explain why our universe is so remarkably uniform on large scales. It is well known that Λ 'irons out' wrinkles in the universe and that a large class of inhomogeneous and anisotropic cosmological models homogenises and isotropises under its influence [8]. This remarkable property (sometimes called 'Cosmic Baldness') generalises to cosmology the famous 'no-hair theorems' originally formulated in connection with black holes and could well explain why we live in a universe which is so uniformly homogeneous and isotropic on very large scales.

2 Is the universe Λ dominated ?

While a large value of Λ is preferred in the very early universe, a much smaller value of Λ at the present time is indicated by observations of high redshift Type Ia supernovae (SNe Ia). SNe Ia are widely believed to be 'standard candles' since:

1. Their high absolute luminosity ($M_B \simeq -19.5$ mag) implies that they can be seen out to large distances making them ideal candidates for measuring and constraining cosmological parameters [5, 3, 7, 13].

2. Their variability at maximum light is small.

3. The decline in the SNe Ia light curve is strongly correlated with its peak luminosity: a brighter supernova fades more slowly.

Using SNe Ia one can learn about the geometry of the universe and its matter content (for recent reviews see [7, 13]). The luminosity flux reaching our present location from a supernova at a redshift z is $\mathcal{F} = \mathcal{L}/4\pi d_L^2$. The quantity $d_L(z)$ is the 'luminosity distance' to the supernova, it depends upon the curvature of space as well as the dimensionless matter density $\Omega_m = 8\pi G\rho_m/3H^2$ and the dimensionless density in the cosmological constant $\Omega_\Lambda = \Lambda/3H^2$

($H = \dot{a}/a$ is the Hubble parameter). Since the presence of Λ *increases* the luminosity distance to a given object supernovae appear dimmer in a universe with Λ. For instance a supernova at a redshift of three will appear 9 times brighter in a flat matter dominated universe with $\{\Omega_m, \Omega_\Lambda\} = \{1, 0\}$ than it will in de Sitter space $\{\Omega_m, \Omega_\Lambda\} = \{0, 1\}$.

Observations of Type Ia supernovae carried out by two teams: the Supernova Cosmology Project [9, 10] and the High-Z Supernova Search Team [12] indicate that a positive Λ-term dominates the energy density of the universe as demonstrated in figure 1. From figure 1, we also see that a considerable degeneracy exists in the parameter space $\{\Omega_m, \Omega_\Lambda\}$. (A degeneracy arises when a result remains unaffected by a specific combination of parameter changes.) Fortunately this degeneracy can be broken and much tighter constraints on the parameter pair $\{\Omega_m, \Omega_\Lambda\}$ obtained by combining SNe Ia observations with those of the Cosmic Microwave Background (CMB).

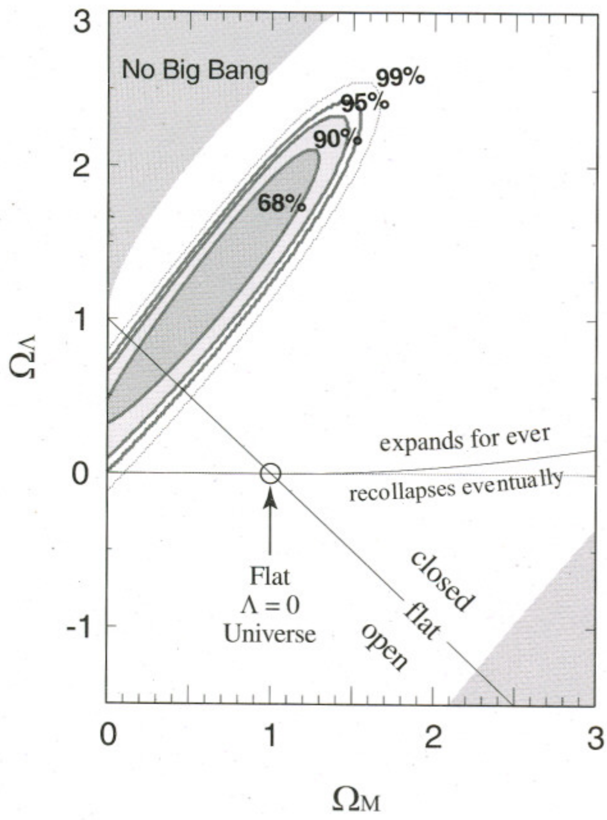


Figure 1: Best-fit confidence regions in the $\Omega_m - \Omega_\Lambda$ plane obtained from the analysis of 42 Type Ia high redshift supernovae with $z \leq 0.83$ by Perlmutter et al. (1999).

The CMB temperature fluctuations expanded on the celestial sphere have the form

$$\frac{\delta T}{T}(\theta, \phi) = \sum_{l=2}^{\infty} \sum_{m=-l}^{l} a_{lm} Y_l^m(\theta, \phi), \qquad (3)$$

where the coefficients a_{lm} are statistically independent and distributed in the manner of a Gaussian random field with zero mean. Of considerable interest is the angular power spectrum of fluctuations $C_l \equiv \langle |a_{lm}|^2 \rangle$. On large angular scales $\theta \gtrsim 1^\circ$ photons of the cosmic microwave background (travelling to us unhindered from the recombination epoch when matter and radiation last scattered off each other) probe scales that were causally unconnected at the time of recombination. (The horizon at recombination subtends an angle $\theta \simeq 2^\circ$ at our location.) On these scales the angular power spectrum measured by the COBE satellite has been successfully used to determine the amplitude and spectrum of primordial density perturbations and gravity waves. Hydrogen in the universe recombined a few hundred thousand years after the big bang when the temperature had fallen to $\sim 4000^\circ$ K. Prior to recombination, electrons and baryons were tightly coupled to photons due to Thompson scattering and electromagnetic interactions. Acoustic oscillations (sound waves) in the photon-baryon fluid give rise to features in the CMB on subdegree scales. On these scales the form of C_l is characterised by a series of peaks and troughs – imprints of acoustic oscillations (sound waves) in the photon-baryon plasma at the time of the cosmological recombination of hydrogen. The position of the first peak is related to the maximum distance sound waves have travelled at the time of recombination (sound horizon). The angular scale of the peak is determined by the angle subtended by the sound horizon and can be used to constrain the geometry of the universe and its total energy density characterised by $\Omega_{\rm total}$ [6].

The first peak in the CMB has recently been measured by the BOOMERANG balloon-borne experiment and occurs at $l_{\rm peak} = 197 \pm 12$ ($\theta \sim 1^\circ$) [2]. In adiabatic structure formation models with $\Omega_{\rm total}$ close to unity the location of the first peak is predicted to occur at $l_{\rm peak} \sim 200\Omega_{\rm total}^{-1/2}$, one therefore obtains $0.88 \leq \Omega_{\rm total} \leq 1.12$ at the 95% confidence level [2]. Combining measurements of CMB anisotropies with high redshift supernovae data one gets [1],

$$\Omega_m = 0.375 \pm 0.125, \quad \Omega_\Lambda = 0.58 \pm 0.18 \qquad (4)$$

at the 95% confidence level. Thus CMB + SNe Ia measurements strongly favour a flat universe with $\Omega_m + \Omega_\Lambda \simeq 1$.

Knowing the values of Ω_m and Ω_Λ, we can determine: (i) the redshift z_a when the universe began to accelerate and (ii) the redshift z_Λ when the universe became Λ-dominated. For $\Omega_m \simeq 0.28$, $\Omega_\Lambda \simeq 0.72$, we obtain $z_\Lambda \simeq 0.37$, $z_a \simeq 0.73$. Since $z_\Lambda < z_a$ we reach the interesting conclusion that the universe begins to accelerate even *before* its density becomes Λ-dominated !

The existence of Λ has other important consequences:

1. The age of the universe is enhanced in the presence of Λ.

2. Structure formation takes place at a slower rate in a Λ-dominated universe. As a result, one expects to find fewer high redshift galaxy clusters in the standard Cold Dark Matter model (CDM) than one would in a ΛCDM cosmology. X-ray observations of the cluster population at high redshifts from satellites such as XMM are likely to yield useful information about Λ in the near future.

3. If $\Lambda > 0$ and $\Omega_{\rm total} \simeq 1$ the universe will soon enter an epoch of exponential expansion, $a \propto e^{\sqrt{\frac{\Lambda}{3}}t}$ as the Hubble parameter freezes to a constant value: $H = H_\infty = \sqrt{\Lambda/3} = H_0\sqrt{1-\Omega_m}$. Density perturbations will stop growing if they are in the linear regime but gravitationally bound systems such as galaxies and galaxy clusters will remain unaffected. As a result, the universe will soon become a desolate sea of ever expanding vacuum energy Λ sparsely peppered by isolated islands of matter.

   Another fascinating property of a universe dominated by a positive cosmological constant is that the volume of space from which an observer is able to receive signals begins to shrink in size and contract. Additionally, the coordinate volume of space which could be directly influenced by our civilization in the entire conceivable future is finite. It can be easily shown that for $\Omega_m \simeq 0.3$ and $\Omega_\Lambda \simeq 0.7$, observers located beyond the redshift surface $z_H \simeq 1.8$ will forever remain inaccessible to signals emitted by our civilization and "comoving observers once visible to us will gradually disappear from view as light emitted by them gets redshifted and declines in intensity [15]." These properties are related to the presence of a de Sitter-like (future) event horizon in a universe which begins to expand exponentially in the future. An analogous process is observed for objects falling through the horizon of a black hole. More discussion of these issues can be found in [15] and references therein.

3 Theoretical implications

The cosmological constant was given a theoretical basis by Zeldovich who showed that the energy-momentum tensor evaluated for one-loop quantum vacuum effects in an expanding universe had the form of a cosmological Λ-term $\langle T_{ik}\rangle_{vac} = \Lambda_{vac}g_{ik}$ [18]. The value of Λ_{vac} is formally divergent: $\Lambda_{vac} \propto k^4$. An ultraviolet cutoff at the Planck scale ($l_{Pl} \sim 10^{-33}$ cm) gives rise to a vacuum energy density in the universe which is 123 orders of magnitude larger than the currently observed value, $\rho_\Lambda \sim 10^{-29}$g/cm^3. This is frequently referred to as the 'cosmological constant problem' [17]. Sine fermions and bosons contribute to the vacuum with opposite signs, it was, hoped during the seventies that supersymmetric theories might reduce the value of Λ_{vac} due to the cancellation of bosonic and fermionic infinities [20]. However, supersymmetry is broken on scales $< 10^3$ GeV and one cannot appeal to this mechanism to generate a small cosmological constant at the present epoch. A more speculative possibility of generating Λ is provided by the observation that in some models the SUSY breaking scale is rather low, $M_{\rm SUSY} \sim 10^3$ GeV. On the logarithmic scale, the value of $\rho_{\rm SUSY} \sim M^4_{\rm SUSY}$ lies midway between the Planck value $\rho_{Pl} \sim (10^{18}GeV)^4$ and the observed value of the vacuum energy $\rho_\Lambda \sim (10^{-3}eV)^4$. This might indicate that the present value of the cosmological constant is provided by a theory in which the effective energy scale of the vacuum was given by, $M_X = M^2_{\rm SUSY}/M_{Pl} \sim 10^{-3}eV$ so that $\rho_\Lambda = M_X^4 \sim 10^{-29}$g/cm^3.

A small value of Λ can also be generated by vacuum polarization associated with an extremely light non-minimally coupled scalar field, as demonstrated in [14].

If Λ is held constant then one runs into the 'fine tuning problem' – the value of $\rho_\Lambda = \Lambda/8\pi G$ has to be set 123 magnitudes smaller than the radiation density at the Planck time ($\sim 10^{-34}$ sec after the big bang) in order that Λ dominates the cosmological mass density at *precisely* the present epoch. One might try to minimise this problem by making Λ a function of time. Since scalar fields are so successful at generating a large Λ-term during an early 'inflationary' epoch, it is conceivable that they might also generate a small Λ today. The energy density ρ and pressure P of a scalar field rolling down a potential $V(\phi)$ is given by,

$$\begin{aligned} \rho &= \frac{1}{2}\dot{\phi}^2 + V(\phi) \\ P &= \frac{1}{2}\dot{\phi}^2 - V(\phi). \end{aligned} \tag{5}$$

The Λ-term equation of state $P \simeq -\rho$ arises if $\dot{\phi}^2 \ll V(\phi)$. The simplest models based on the potential $V \propto m^2\phi^2, \lambda\phi^4$ run into the fine tuning problem encountered by the cosmological constant. However, in models in which the scalar field rolls down a potential which is initially steep $V(\phi) = k/\phi^\alpha$ ($\alpha > 0$), the condition $P \simeq -\rho$ arises only at late times when the field has grown to large values and encounters a potential which is flat. In this manner one can arrive at a small value of ρ_Λ today from much larger initial values of ρ_ϕ, thereby significantly increasing the ratio $\rho_\phi/\rho_{\rm rad}$ at early times and reducing the fine tuning between ρ_ϕ and $\rho_{\rm rad}$ [11]. This property is also shared by Λ-models based on exponential potentials [16, 19]. It is encouraging that field theory models are successful in generating a small Λ at the present epoch. However, the following questions must be answered before a firm theoretical basis for Λ is established: (i) Why are the following (seemingly unrelated) quantities: $\Omega_{\rm baryon}, \Omega_m, \Omega_\Lambda$, of the same magnitude ? (ii) Is the small current value of Λ related to the large Λ driving inflation ? (iii) Is the *cosmological constant problem* linked to the small cosmological constant observed today ?

On the observational front, we need to understand better the physical nature of Type Ia supernovae together with the role of environmental effects, obscuration, evolution, etc. It is encouraging that the supernova inventory is growing rapidly with close to a dozen new SNe Ia events added each year. Fresh SNe Ia data and CMB observations by MAP and PLANCK are bound to provide the definitive answer to whether the universe is accelerating fuelled by a Λ-term.

References

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IUCAA Preprints

Listed below are the IUCAA preprints released during April - June 2000. These can be obtained from the Librarian, IUCAA (library@iucaa.ernet.in).

R. Srianand and **Patrick Petitjean**, *Physical conditions in broad and associated narrow absorption-line systems toward APM 08279+5255*, IUCAA-14/2000; **Subharthi Ray**, **Jishnu Dey** and **Mira Dey,** *Density dependent strong coupling constant of QCD derived from compact star data*, IUCAA-15/2000; **T. Roy Choudhury**, **T. Padmanabhan** and **R. Srianand**, *Semi analytic approach to understanding the distribution of neutral hydrogen in the universe*, IUCAA-16/2000; **Ignazio Bombaci**, **Arun V. Thampan** and **Bhaskar Datta**, *Rapidly rotating strange stars for a new equation of state of strange quark matter*, IUCAA-17/2000; **Patrick Petitjean**, **Bastien Aracil**, **R. Srianand** and **Rodrigo Ibata,** *Structure of the Mg II and damped Lyman-a systems along the line of sight to APM 08279 + 5255*, IUCAA-18/2000; **S. V. Dhurandhar,** *Searching for gravitational waves from rotating neutron stars*, IUCAA-19/2000; **Sushan Konar,** *Magnetic field evolution of accreting neutron stars - IV effect of the curvature of space-time*, IUCAA-20/2000; **T. Padmanabhan** and **T. Roy Choudhury,** *The issue of choosing nothing: What determines the low energy vacuum state of nature?*, IUCAA-21/2000; **S.G. Ghosh, R.V. Saraykar** and **A. Beesham**, *Collapsing shells of radiation in higher dimensional spacetime and cosmic censorship conjecture*, IUCAA-22/2000; **L. Sriramkumar** and **T. Padmanabhan,** *Probes of the vacuum structure of quantum fields in classical backgrounds*, IUCAA-23/2000; **Anirudh Pradhan** and **Ambarish Kumar,** *LRS Bianchi I cosmological universe models with varying cosmological term l*, IUCAA-24/2000; **Varun Sahni** and **Alexei Starobinsky,** *The case for a positive cosmological L -term*, IUCAA-25/2000.

Colloquiua

3.4.2000 D. Lynden-Bell *on* From Newton to NUT Space via the Quantum N-Body Problem; 10.4.2000 Palash B. Pal *on* Pulsar Kicks and Neutrinos; 24.4.2000 C.V. Vishveshwara *on* Leaves from an Unwritten Diary - Subrahmanyan Chandrasekhar - Reminiscenes and Reflections; 1.5.2000 R. Ramachandran *on* Dualities in String Theories and 22.5.2000 Somak Raychaudhury *on* The First Results from Chandra and XMM-Newton

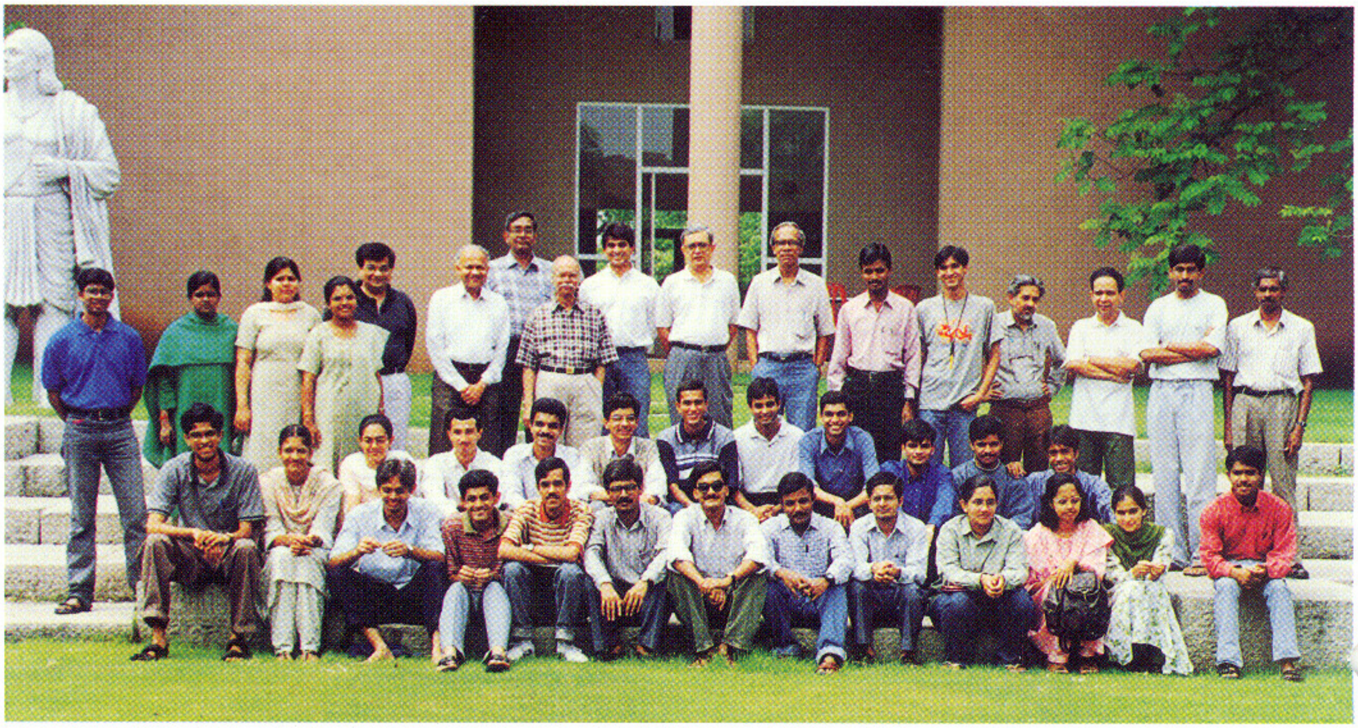
Seminars

6.4.2000 Diego Malquori *on* The Role of Interactions in Galaxy and Quasar Evolution; 19.4.2000 Prasenjit Saha *on* Gravitational Lenses: Some Theory, Some Mass Maps, and Some Inferences about H_0; 20.4.2000 C.V. Vishveshwara *on* Black Holes in Non-Flat Backgrounds; 26.4.2000 Srabani Datta *on* Structure of Molecular Clouds: A Fractal Description; 12.6.2000 Suketu Bhavsar *on* The Magnitude Distributions of First-Ranked Cluster Galaxies.

21st Meeting of the IAGRG and Discussion Conference on Cosmology

The 21st Meeting of the Indian Association for General Relativity and Gravitation will be held during January 30 - February 1, 2001, at the Central India Research Institute (CIRI), Nagpur. On this occasion, a Discussion Conference on Cosmology : Aspects of Standard Model vis-a-vis Alternatives, organized jointly by IUCAA, Pune and CIRI, Nagpur, will also be held during January 28 - 29, 2001. Participation to this Meeting and the Discussion Conference is by invitation. Those who are interested in participating, as well as who wish to present paper(s)/thesis may contact Sanjay M. Wagh: CIRI, Post Box 606, Laxminagar, Nagpur 440 022, Maharashtra, India. (e-mail : ciri@vsnl.com).

Introductory Summer School on Astronomy and Astrophysics held at IUCAA from May 22 to June 23



Students and the lecturers of the Summer School on Astronomy and Astrophysics

A summer school for students of the B.Sc. final year and M.Sc.first year was organized jointly by IUCAA and National Centre for Radio Astrphysics (NCRA) at Pune during May 22 to June 23, 2000. The school is part of an annual series of Summer Schools on Astronomy and Astrophysics, sponsored by the Department of Science and Technology under which, the schools are conducted alternatively at Bangalore and Pune. The school extended over a period of five weeks and lectures covering different theoretical, observational and instrumental aspects of astronomy and astrophysics were given by people from IUCAA, NCRA and TIFR, Mumbai. There were a few problem solving sessions and special discussions including one on careers in astronomy. A few students voluntarily took on projects under the supervision of IUCAA or NCRA faculty. Students of the school visited the GMRT site and also had a day's excursion to Sinhagad fort. Altogether 33 students from throughout India attended this school. Ajit Kembhavi from IUCAA and Vasant Kulkarni from NCRA were the school coordinators.

Indo-French workshop on Star Bursts and the Structure and Evolution of Galaxies

An Indo-French Workshop on Star Bursts and the Structure and Evolution of Galaxies will be organized during December 10 - 20, 2000. The organizers of this workshop are Ajit Kembhavi from IUCAA and Bruno Guiderdoni from Institut d'Astrophysique de Paris. Those interested may write to Susan B. Kuriakose, IUCAA, Post Bag 4, Ganeshkhind, Pune 411 007; e-mail: susan@iucaa.ernet.in.

Update on the IUCAA 2 metre Telescope Project

As reported in the July 1999 issue, this telescope is being made at Liverpool, UK by Telescope Technologies Ltd., under a contract from PPARC of UK. The primary mirror and its cell, the azimuth base-box and forks, and the Cassegrain focal plane assembly are ready; the secondary mirror assembly is yet to be fabricated. While many items are yet to be made, the company has informed IUCAA that they are confident of supplying the telescope by the end of this year, after carrying out all the necessary tests with the fully assembled telescope.

The first light instrument is going to be a spectrographic camera of a design based on EFOSC. The optics has already been integrated with the mechanical structure at the Copenhagen University Observatory, and the final tests on the fully assembled instrument would be carried out at Copenhagen in the month of August, 2000. A calibration unit has been constructed in IUCAA laboratory, for spectral and flat field calibrations of this instrument.

The road at the site has been completed and the buildings as well as the dome are under construction. It is expected that the installation of the telescope, which would take about 3 months, can start in the month of February 2001.

Visitors Expected

July

P.N. Pandita, NEHU; N. Surchandra Singh, Gauhati University, Murli Manohar Verma, Institute of Engineering and Technology, CSJM University, Kanpur; S. Chandra, SRTMU, Nanded; H.P. Singh, Sri Venkateswara College, Delhi; R. Ellis, Caltech, USA; E. van den Heuvel, University of Amsterdam; K. Babu Joseph, CUSAT; Ram Sagar, UPSO, Nainital; S.K. Trehan, Chandigarh; S. Mukherji, North Bengal University, M. Dey, Presidency College, Calcutta; J. Dey, Maulana Azad College, Calcutta; S.K. Pandey, Pt. Ravishankar Shukla University, Raipur; M.K. Das, Sri Venkateswara College, Delhi; R. Ramakrishna Reddy, Sri Krishnadevaraya University, Anantapur; A. Goyal, Hans Raj College, Delhi; V.C. Kuriakose, CUSAT, Kochi; P. Petitjean, Institute of Astrophysics, Paris; P.J. Lavakare, H. Jassal, Delhi University; B.B. Walwadkar, Walchand College of Engineering, Sangli; S. Kar, IIT, Kharagpur.

September

K.S.V.S. Narasimhan, Chennai.

Visitors during April - June 2000

D. Lynden Bell, S.N. Biswas, K. Indulekha, G.V. Vijayagovindan, S. Ray, J. Dey, H.P. Singh, P. Pal, P. Saha, G.P. Singh, A. Sarma, N. Upadhyay, C.V. Vishveshwara, S. Rastogi, M.L. Kurtadikar, K. Jotania, R. Tikekar, R. Ramachandran, C.D. Ravikumar, K.K. Nandi, S.N. Karbelkar, M.K. Das, K. Chhaya, S.K. Pandey, L.M. Saha, T. P. Sarma, S.G. Ghosh, R.V. Saraykar, C. Jog, P. Subramanian, M.K. Patil, S.P. Bhatnagar, U.V. Dodia, M.N. Anandaram, Y. Narasimha Murthy, P. Abdul Azeem, K. Ramagopal, V.H. Kulkarni, D. Lohiya, N. Rooprai, S. Chakraborty, A. Pradhan, R.R. Reddy, R. Datta, A.C. Kumbharkhane, S. Kaushik, Deepak Chandra, B. Chakraborty, S. Chaudhuri, P.K. Srivastava, A.K. Sen, K. Desikan, S. Banerji, H.S. Das, T.K. Dey, V.O. Thomas, P.C. Vinodkumar, S. Mukherjee, B. Ishwar, L.K. Jha, G. Prasad, B.K. Sinha, L. Prasad, D.P. Datta, R. Sharma, U. Narain, P. Agarwal, R.K. Sharma, P.N. Bhat, K.P. Singh, D.K. Chakraborty, S.K. Pathak, N. Philip, S. Ramadurai, P. Rajaratnam, P. Bhargava, R. Bali, R.D. Upadhyay, D.C. Srivastava, S.K. Sahay, M. Sami, R. Nayak, S.N. Paul, S. Bhattacharya and T. Singh

Apart from this 41 students attended the Introductory Summer School on Astronomy and Astrophysics and the Vacation Students' Programme.

A Narrow Miss!

A passenger jet was traversing Arizona on a clear day. The copilot was bombarding passengers with remarks about landmarks over the PA system. "Coming up on the right side of our cabin, you can see Meteor Crater. A major tourist attraction in northern Arizona, it was formed when a lump of nickel and iron weighing 300,000 tons, 150 feet across, struck the earth at 40,000 miles an hour, scattering white-hot debris for miles in every direction. The hole measures nearly a mile across and is 570 feet deep."

From the cabin, a passenger looking out of the window, was heard to exclaim, "Wow! It just missed the highway!"

Khagol (the Celestial Sphere) is the quarterly bulletin of IUCAA. We welcome your responses at the following address:

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Pune 411 007, India

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