Annual Report

(April 1, 1994 - March 31, 1995)

of the

INTER-UNIVERSITY CENTRE FOR ASTRONOMY AND ASTROPHYSICS

An Autonomous Institution of the University Grants Commission

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till 31.12.94

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5. Fred Hoyle
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   Gujarat University, Ahmedabad

* *deceased (14.3.95).*

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till 31.12.94

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C. Boily
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Y. Wadadekar

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A. Bhave (Office Automation)
K. Dande (Office Automation)
V. Mahabal (Office Automation)
S. Menon (DST Project) (till 9.5.94)
G. Molakala (ERNET Project)
R.K. Parui (Project Scientist) (till 31.10.94)
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Department of Physics
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(S.N. Tandon)

Head, Instrumentation Laboratory
(S.N. Tandon)

Head, Post-Doctoral Research
(S.V. Dhurandhar)

Head, Computer Centre
(A.K. Kembhavi)

Head, Library & Documentation
(A.K. Kembhavi)

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(T. Padmanabhan)

Head, Publications
(T. Padmanabhan)

Dean, Visitor Academic Programmes
(N.K. Dadhich)

Head, Associates & Visitors
(N.K. Dadhich)

Head, Workshops & Schools
(S.V. Dhurandhar)

Head, Guest Observer Programmes
(A.K. Kembhavi)

Head, Science Popularization & Amateur Astronomy
(N.C. Rana)

Director's Report

During 1994-95, IUCAA's academic activities included several highlights. During October 25-28, 1994, the Astronomical Society of India organised its Sixteenth Meeting at IUCAA. Of the total participants numbering 171, 40 came from the University Sector. As IUCAA's impact grows we hope that the participation of this sector in the national Astronomy and Astrophysics (A & A) activities will grow. The Second Indo-US Workshop in the 3-workshop series was held from November 28 - December 10, 1994, on Array Detectors and Image Processing. 7 participants came from the USA and their inputs into the area of astronomical instrumentation were very valuable indeed. There were two international meetings in the field of cosmology and large scale structures, one a workshop in July 1994, to which foreign participants came from Europe and the USA and the other, an Indo-French School in February 1995.

IUCAA's last Regional Meeting was held in Muzaffarpur in Bihar in October 1994. This filled an important gap in our coverage of different parts of the country by regional meetings. The enthusiasm generated by this meeting has led to the planning of a specialized workshop on "Space Dynamics and Celestial Mechanics" during 1995-96. It will help in growing the already existing expertise in this field in this region.

The Scientific Advisory Committee (SAC) met in July 1994 over three days. The members spent considerable time and effort in discussions, visits to IUCAA facilities and attending presentations of research by the academics at IUCAA and by the associates. The SAC felt that with the impact of IUCAA already becoming noticeable, the university sector will gain considerably if IUCAA acquires and manages a 1.5 metre optical telescope dedicated to certain frontier projects. Attempts have begun to acquire such a facility. A new SAC-IUCAA took over on January 1, 1995 and will have its first meeting in December 1995.

In the meantime, guest observership of other telescopes under the IUCAA auspices is growing. For the first time, member of a university in India could use a telescope in Chile under this programme. Similarly, other telescopes in South Africa and the USA have been used. These efforts have been very worthwhile and I hope that more opportunities will come by to enlarge IUCAA's efforts in observational astronomy.

IUCAA's international reputation as a research centre for A & A is steadily growing. One indication was the large number of applications received in response to its announcement of post-doctoral openings. There are now formal, semi-formal and informal collaborations between IUCAA and scientists from the USA, UK, France, Australia, Japan, China and South Africa.

The in-house academic research, seminar and colloquium activity and other informal discussions, works carried out by users from universities and colleges, the instrumentation programme, etc. are described in detail elsewhere in this report.

A 20-minute film on IUCAA called *Spaces and Interactions* was made by Arun Khopkar. It gives the visitor a glimpse into IUCAA - its history, architecture, environment and last but not the least its scientific activities.

The usage of IUCAA by visitors is growing as is indicated from Figure 1. Figure 2 likewise shows the status regarding publications from IUCAA. There are 58 associates currently on the IUCAA rolls. We would wish that they came more frequently and for longer duration. I do hope that Vice-Chancellors, Principals and other concerned authorities will make it easier for the associates from their institutions to visit IUCAA, treating their visits as on duty.

To make visitors more at home, IUCAA has now a full-fledged Recreation Centre named Chittaranjan. It has a covered badminton court, two tennis courts, a gymnasium, a lounge to relax and facilities for chess, cards and carrom. There is also a library and a tea room.

Ashok Ganguly from Unilever, London, was our Foundation Day Speaker. Talking on *Who Should Look at Stars?,* he made a strong case for frontier research in A & A and went on to advocate enlightened support for science in the country. His talk is printed in this report.

It was a pleasure to welcome Antony Hewish, one of our Honorary Fellows. He delivered a very informative public lecture on *The Excitement of Pulsars* on January 23, 1995. Barely two months later, we heard the sad news of the passing away of another Honorary Fellow, Willy Fowler on March 14, 1995. Many of us recall his scintillating visit five years ago when we were still housed in the Aditi shed. All of us at IUCAA deeply mourn the loss of a friend and well wisher.

While concluding this report, I wish to record my thanks to the University Grants Commission for giving me the opportunity to be with IUCAA for a second term. On behalf of IUCAA, I express our gratefulness to G. Ram Reddy for his guidance and help as the head of our statutory bodies. After his retirement we now welcome his successor Armaity Desai, the new Chairperson of the UGC. We also welcome Naresh Mathur as the Vice-Chairperson of the UGC. He was earlier a member of our Scientific Advisory Committee.

It is also a pleasure to thank the UGC staff for help in processing all IUCAA's papers. And, last but not the least, I thank all my colleagues in IUCAA for taking on many responsibilities on my behalf and thus lightening my load as Director.

J.V. Narlikar

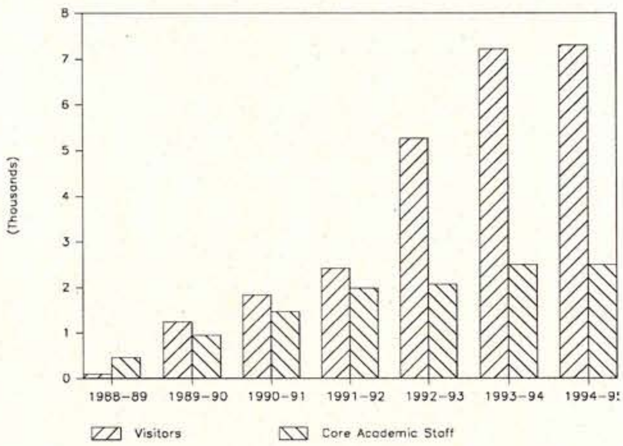


Fig. 1 : Visitor man-days in comparison with Core Academic Staff man-days

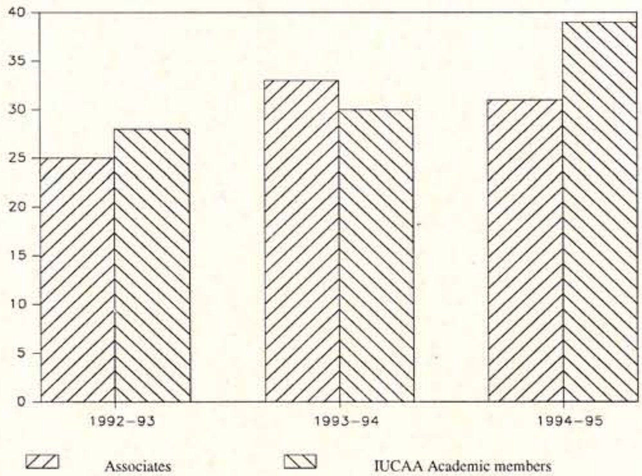


Fig. 2 : Number of Publications in refereed journals by Associates in comparison with Academic members of IUCAA

Awards and Distinctions

IUCAA Members

S.V. Dhurandhar

Elected Fellow of the Maharashtra Academy of Sciences.

D Duari

Best thesis presentation award at the XVIth Meeting of the Astronomical Society of India held at Pune during October 25-28, 1995.

T.S. Ghosh

Certificate of Appreciation, Rotary Club of Pune, Rotary International, dist:3130.

J.V. Narlikar

Rotary Excellence Award for 1994-95 for recognition of the excellence achieved by eminent personalities in their field of vocation, Rotary Club of Pune.

Godavari Gaurav 1994 by Kusumagraj Pratishthan for the excellent work done in the field of science, Nashik.

Elected President of Cosmology Commission (47) of the International Astronomical Union for 1994-1997.

S.N. Tandon

Elected Fellow of the Maharashtra Academy of Sciences.

Associates/Senior Associates

Ashok Goyal

Elected Fellow of the National Academy of Sciences (Allahabad).

T. Singh

Selected for Post Doctoral Fellowship of European Commission at Queen Mary and Westfield College, University of London, for the period March-September 1995.

S.K. Srivastava

Meghnad Saha Award for research in theoretical sciences (UGC-Hari Om Ashram Trust Awards in Science, 1993)

Calendar of Events

April 4-8	Workshop on Astronomy Curriculum in Schools
April 18-21	Workshop on Sky Globe Making at N.E.S. Science College, Nanded, sponsored by IUCAA, in joint collaboration with Department of Physics, N.E.S. Science College
April 25-28	Workshop on Two Years After COBE
April 29-May 3	Workshop on Making a Sky Globe and a Simple Telescope, for School Science Teachers of Pune
May 2-June 10	Summer Programme for School Students
May 21	IUCAA-NCRA Graduate School : Second Semester ends
May 23-June 11	Introductory Summer School on Astronomy and Astrophysics, hosted by IUCAA and NCRA, sponsored by DST
June 1-July 15	Vacation Students' Programme
July 1	Selection of Fifth Batch of Associates and Senior Associates
July 20-26	Workshop in memory of Late Professor Ya B. Zeldovich, on Large Scale Structure Beyond N-body Simulations
July 27-29	Fourth Scientific Advisory Committee Meeting
August 1-4	Young Astronomers' Meet
August 16	IUCAA-NCRA Graduate School : Start of First Semester
September 13-17	Second Workshop on Experimental Techniques in Space Sciences and Astronomy, at Gujarat University, Ahmedabad, in collaboration with Physical Research Laboratory and Space Applications Centre
September 26-30	Introductory School on Astronomy and Astrophysics, at Gulbarga University, Gulbarga
October 3-4	Regional Meeting for Universities of Eastern India, at B.R. Ambedkar Bihar University, Muzaffarpur
October 3-7	Preparatory Workshop on Total Solar Eclipse of October 24, 1995
October 25-28	Sixteenth Meeting of the Astronomical Society of India

October 31-November 4	Workshop on the Heritage of Ancient Indian Astronomy
November 21-December 10	Inter-University Graduate School on Large Scale Structure in the Universe, at Mysore University, sponsored by IUCAA and UGC
November 28-December 10	Second Indo-US Workshop on Array Detectors and Image Processing
December 5-24	Introductory School on Astronomy, for IIT students
December 23	IUCAA-NCRA Graduate School : End of First Semester
December 29	Sixth Foundation Day; Completion of Phase IV, Staff Housing and Recreation Centre
January 2-13	Workshop on Computer Networks, co-sponsored by NCST, Bombay and ICTP, Italy
January 16	IUCAA-NCRA Graduate School : Start of Second Semester
January 30-February 3	Discussion Meeting on Group and Singularity Analysis in Differential Equations
January 30-February 20	Indo-French School on Understanding Large Scale Structures in the Universe, sponsored by IFCPAR, New Delhi
February 15-18	Mini-workshop on Solar Physics, at Meerut University, Meerut
February 28	National Science Day

(I) RESEARCH AT IUCAA

The following description relates to research work carried out at IUCAA by the core academic staff, post-doctoral fellows and research scholars. The next section describes the research work carried out by associates of IUCAA using the Centre's facilities.

Quantum Theory and Gravity

Bringing together the principles of quantum theory and gravity is probably the outstanding problem in theoretical physics today. Since a frontal attack on this problem leads to serious conceptual and mathematical complications, it is usual to approach this subject with more limited goals. Several such investigations were carried out in the last year.

Decoherence in quantum cosmology:

Quantum cosmology attempts to provide a quantum mechanical description of classical cosmological solutions. It is based on the hypothesis that, for such a description, it is adequate to concentrate on a small number of degrees of freedom of gravity. For example, a quantum cosmological model describing Friedmann universe will only deal with the expansion factor as the relevant degree of freedom and will attempt to provide a quantum mechanical description of it. The theory will be based on a Schrodinger-like equation [called "Wheeler-DeWitt equation"] and is mathematically tractable.

Conceptually, however, it is not easy to understand the solutions to this equation. The equation, for example, allows the universe to be in a coherent superposition of two macroscopically distinct states - say one in which it is expanding and the other in which it is contracting. To reconcile this theoretical possibility with our ordinary experience of perceiving the universe to be in a definite state, one needs a mechanism for producing classical behaviour from quantum cosmology. *T. Padmanabhan* and J.J. Halliwell independently suggested, in 1989, such a mechanism for quantum cosmology, based on the earlier work by Zeh and coworkers in the area of quantum measurement theory. They showed that if the system of interest interacts with an "environment" consisting of a large number of unobserved degrees of freedom, then (under certain conditions) the quantum interference effects can be suppressed as a consequence of this interaction. The system is then said to "decohere" and it can be described in terms of classical concepts.

S. Sinha has now studied aspects of decoherence in a cosmological model called "Gowdy T^3 Universe" which describes a closed, anisotropic, spatially inhomogeneous, empty cosmology. Treating the homogeneous modes as the "system" interacting with the "environment" of the inhomogeneous modes, she has shown that decoherence occurs at late times and is insensitive to the initial conditions. This process also generates some amount of entropy as a consequence of averaging over the environment. This can be calculated explicitly and is shown to be directly related to the number of gravitons created.

The spectral distance between two universes :

The classical general relativity describes the dynamics of (local) metric geometry, while assuming a fixed (global) topology. In the case of quantum gravity, it is possible that not only the metric but also the topology can undergo fluctuations. If that is the case, one has to consider the possibility that the quantum state of the universe might be a superposition of different topologies. This will make the mathematical structure of the theory very complicated.

In particular, one can then ask why we do not experience the space around us to have fluctuating macroscopic topologies? The concept of decoherence described in the previous work could possibly provide an answer. In the original attempt to introduce decoherence in quantum cosmology, *T. Padmanabhan* introduced a concept of "distance between two different geometries". Roughly speaking, this is a way of quantifying which two spaces are almost similar to each other and which are very different. This attempt, however, did not take into account the difference in the topology. Recently, *M. Seriu* has pursued the idea of generalising this concept to include both spatial geometry and topology. Such a quantitative measure of "distance between two spaces" with different topologies [called the "spectral distance"] is useful to discuss quantum cosmological problems in which topological aspects of the universe takes part.

M. Seriu has investigated several properties of the spectral distance. First, he has shown that the spectral distance is finite only when the spaces have the same dimension and total volume. In other words, whenever dimensions and volumes differ, they behave as 'far-away' spaces and there is very little quantum interference between them. Secondly, he showed that one can modify the definition of the spectral distance and define a "scale-dependent distance" in a natural manner. It is often conjectured in quantum gravity that the space will behave like a "foam" with complex topological properties at small scales but could appear to be simple at large scales. The new concepts *M. Seriu* has introduced could help in providing a quantitative description of these features. Finally, to get more insight into the various aspects of this distance, *M. Seriu* studied several 2-dimensional models and calculated the spectral distances between them. Specifically, he has analysed both orientable and non-orientable spaces to find out whether two universes with different orientabilities are far apart or close together. He finds that it is possible to have an orientable space "fairly close" to a nonorientable space. This surprising result raises the question as to why we do not see quantum interference between such spaces and suggests that there could be some other mechanism causing orientable and non-orientable universes to decohere.

Stochastic effects in semiclassical gravity:

One possible way of exploring the issues which arise when quantum theory and gravity are brought face to face is to study the so called "semiclassical gravity" in which quantum fields are coupled to a classical metric. Such an approximation is supposed to provide a link between classical gravity and the yet undiscovered quantum theory of gravity. In this approximation, one has to use some suitable set of equations to describe the effect of quantum fields on the background metric. This is usually done by using the mean values [or "expectation" values] of quantum mechanical operators. One necessary feature of such a description is that the quantum fluctuations of the fields are not incorporated properly in the evolution of the metric.

Recently, Calzetta, Hu, Matacz and *S. Sinha* have looked at this question from the point of view of quantum Brownian motion. The equations describing Brownian motion of a particle in a liquid does contain a fluctuating force term arising from the random collisions with the molecules. In a similar manner, these authors suggest that a description of semiclassical gravity must, in general, use an extra stochastic force term arising from quantum fluctuations of the matter field. The description of the semiclassical gravity using the average values of quantum operators, according to Calzetta et. al., is only a mean field theory. They, in fact, show that the analogy with Brownian motion is fairly deep and that the modified description [in terms of what is called an Einstein-Langevin equation] requires a "noise term " and a "dissipation term", the two being linked through a generalized fluctuation-dissipation relation. The usual semiclassical equations are regained as a result of averaging over the noise distribution.

It is widely expected that the evaporation of a black hole will lead to changes in the metric which can be understood at some level by semiclassical gravity. *S.Sinha*, Raval and Hu have now undertaken an investigation of these effects in the context of black hole evaporation using their approach. The analysis of the full back-reaction problem leading to an Einstein-Langevin equation and its solution is in progress.

Back-reaction on topological degrees of freedom:

In classical gravity, both the topology of spacetime and the local geometry of spacetime play an important role. For example, the spatial sections of a universe could be closed [like a surface of a sphere] or open [like an infinite sheet of paper]. In studying the semiclassical gravity, most of the attention in the past was concentrated on the geometrical aspects. One often assumed that the topology of the spacetime was fixed and inviolable.

It was, however, known that the nature of the topology can have important effect on the quantum fields. For example, the zero-point energy of a quantum field, which arises due to the quantum fluctuations, depends on the topology of space. This energy will have a dynamical effect on the system and could, in turn, affect the topology. *M. Seriu* has recently examined the back-reaction of a scalar matter field in a torroidal spacetime using a toy 2 + 1 model for gravity. He has constructed a (2+1)-dimensional spacetime in the shape of a torus, which can be described by certain finite number of parameters, and investigated the effect of the quantum field on the dynamical evolution of the spacetime. He finds that back-reaction affects the dynamics of the global geometry in several interesting ways: For instance, the back-reaction causes the torus to be unstable, stretching the torus such that it gets ever thinner while simultaneously its volume increases.

Black hole evaporation :

Path integrals provide a simple way of proceeding from classical physics to quantum physics. The quantum mechanics of a nonrelativistic particle can be obtained by a path integral prescription using the classical action. Last year, *T. Padmanabhan* showed that it is possible to adopt a similar procedure for obtaining the quantum field theory from the action for a relativistic particle. He has now investigated the generalisation of this result to more complex spacetimes in order to understand the behaviour of quantum fields in these spacetimes. For example, a spacetime describing a blackhole has a region from which no signal can escape. It is usual to say that such a spacetime possesses a "horizon" which limits the region with which communication is possible. The quantum field theory in spacetimes with horizons lead to several interesting effects and usually it is possible to attribute a temperature to such spacetime like the Hawking temperature for the blackhole. *T. Padmanabhan* finds that, using the path integral approach, it is possible to provide a simple formula relating the behaviour of the metric near the horizon and the temperature of the thermal radiation detected by an observer. This formula is quite general and provides an interesting connection between the properties of the infinite redshift surface and the semiclassical propagator.

Response of finite-time detectors :

One may naively imagine that whether a particle exists or not in some region of spacetime could be determined by purely local measurements. It turns out that, this is not strictly true. Two observers moving with respect to each other will not, in general, agree as to what a vacuum state is: that is, when one observer sees no particles, the other one will see some. This feature arises because of the global nature of the quantum mechanical description. In the attempts to reconcile the principles of quantum theory and gravity, one has to tackle this issue that quantum field theory uses global concepts to define physical states while general relativity is based on a local approach to spacetime. This dichotomy creates several difficulties in the formulation of the semiclassical limit to quantum gravity.

L. Sriramkumar and *T. Padmanabhan* have attempted to provide a local description for quantum theory based on the response of model detectors which probe only a local region in both space and time. They studied the response of some simple physical systems [usually called "Unruh-DeWitt particle detector"] which are supposed to "click" in the presence of particles. They assumed that the detector was kept switched on only during a finite proper time interval so that the clicking of the detector will indicate the presence of the particle during that time interval.

It turns out that such a detector will click even while on an inertial trajectory due to the transient effects arising from switching on the detector. Further, the actual response of the detector will also depend on the manner in which the detector is switched on and off. [These aspects were not recognised properly in the previous published literature in the subject]. *L. Sriramkumar* and *T. Padmanabhan* have obtained a general formula for the response of the detector when its coupling is specified, and worked out the response in detail for some specific cases. A detailed discussion of both short time and long time response is analysed and several subtleties in the limiting procedures are clarified. This analysis could provide some insight into the problem of defining the semiclassical limit of gravity.

Classical Gravity

Several aspects of classical general relativity were investigated during the current year.

Non-singular cosmological models :

One of the outstanding problems in classical cosmology is that currently popular models describing the universe have a "singular" beginning. That is, these models predict an epoch in the past at which physical variables, like density, temperature, etc., were infinitely large. Such an event is, of course, physically unacceptable and it would be interesting to see whether one can find other solutions to Einstein's equations which are non-singular.

N.K. Dadhich and two of IUCAA associates, L.K. Patel and R.S. Tikekar have been investigating such non-singular family of models which might have relevance to cosmology. In an earlier work, they found a family of non-singular models which were cylindrically symmetric. They have now attempted to address the following question: Is cylindrical symmetry singled out by the singularity free character of models? Such a question cannot be tackled for a general metric without any symmetry and the original solution they found assumes some special feature for the metric - they have taken a general orthogonal metric and assumed it to be separable in space and time in the comoving coordinates.

This assumption forces the anisotropy of the spacetime to be permanent. That is, if the universe starts out being anisotropic, it will never become isotropic. Through a detailed analysis, they have filtered out a set of differential equations, which are being subjected to Lie analysis by P.G.L. Leach and K.S. Govinder. They believe that they are now on the verge of proving a general theorem : For an orthogonal spacetime metric separable in space and time in comoving coordinates, the requirement of perfect fluid satisfying the strong energy condition and non-singularity singles out the already identified family of cosmological models.

The application of these non-singular models to practical cosmology is severely hampered by the fact that they are anisotropic at all times while the observed universe exhibits high degree of isotropy at least during late stages of evolution. It will be quite exciting to find a non-singular model that starts out as anisotropic but becomes more and more isotropic as time progresses. In view of the above conjecture it seems one has to give up either orthogonalilty or separability of the metric tensor to achieve this. In either case, it becomes mathematically formidable to obtain a solution.

Gravitational potential in Newtonian gravity and general relativity :

In Newtonian gravity, the Poisson equation determines the gravitational potential only upto a constant. The question arises: Does Einstein's theory of gravitation allow this arbitrariness in the value of potential?

N.K. Dadhich has investigated this question for the case of spherically symmetric, vacuum spacetimes. In these spacetimes, Einstein's field equations reduce to two equations; one is the well-known Laplace equation and the other is the first integral of Laplace equation which actually sets the constant of integration to zero. Thus general relativity, unlike the Newtonian theory, does not permit the arbitrariness in the value of the potential. The absence of gravitational field in general relativity is characterised by the vanishing of potential as well.

Thus, general relativity seems to define the absolute zero of gravitational potential at least in the spherically symmetric case. Even though this is restricted to spherical symmetry, it is an important feature. One may then ask, what kind of spacetime in general relativity corresponds to a constant gravitational potential in the Newtonian limit. It turns out that such a spacetime has only one curvature component non-zero. Since Newtonian gravity is annulled out, this spacetime can be said to be "minimally" curved. Further, this spacetime requires a non-zero energy distribution which is precisely that of a global monopole resulting from global breaking of symmetry 0(3) into U(1) in a gauge theory.

Quasi local energy in general relativity :

In general relativity, gravitational field is replaced by the curvature of the spacetime. Because of this reason, it is not easy to define the concept of energy for the gravitaional field in a purely local manner. Recent investigations in blackhole physics have, however, revealed that variables such as energy can be specified by fixing certain components of the gravitational field on the spatial boundary. As a concrete example, consider the gravitational field contained inside a two-dimensional sphere at an instant of time. By considering how this region appears in the spacetime as time goes on, it is possible to derive an expression for the quasilocal energy of the system. The adjective "quasilocal" is used because the sphere may be arbitrarily small. This quasilocal energy can be expressed as a (suitably defined) time derivative of the action for gravitational field. In this sense the definition is completely analogous to how energy is defined in ordinary classical mechanics.

S. Lau has extended the theory of quasilocal energy in three regards. First, he has examined, with J. D. Brown and J. W. York, how the quasilocal energy behaves under generalized "boosts" - crudely speaking this is like calculating the quasilocal energy in a moving frame. Secondly, he has completely reformulated the theory of quasilocal energy (fully addressing the issue of generalized boosts) in terms of the canonical Ashtekar variables. Ashtekar variables are a set of variables related to geometry of the spacetime which were discovered in the mid 1980s. They can be used to provide a new formulation of Einstein's theory of gravity. Thirdly, he has established a close connection between quasilocal energy and certain mathematical techniques which are useful in proving the positive energy theorem in Einstein's theory of gravity.

Radiation reaction in curved space :

An accelerated charged particle will emit electromagnetic radiation. The energy for this emission has to come from the source which is accelerating the particle. In other words, the source which is pushing the charge has to do work against a resistive force and supply extra energy. This resistive force is usually called the "radiation reaction" force.

This phenomenon takes an interesting turn when viewed from a noninertial frame of reference in which the charge is at rest. Since physical phenomena are independent of the frames of reference, one could study the Maxwell's equations in the accelerated frame as well. It is, however, difficult to understand the origin of radiation reaction in the rest frame of the charge. *T. Padmanabhan* has investigated this problem and find that the radiation reaction is intimately connected with the apparent horizon which arises when the charge is moving noninertially. This horizon behaves as though it is endowed with a charge density and the electrostatic interaction between the charged particle and the charge density on the horizon correctly accounts for the radiation reaction force in the rest frame of the charge.

Measurement of frequency by accelerated observers:

In relativity, one tries to provide operational definitions for all physical quantities which one is interested in. When the observers are moving with respect to each other with uniform velocity, it is fairly easy to arrive at an acceptable set of definitions for physical quantities. The situation, however, becomes more complicated if the observers are accelerated.

One may, for example, ask the question as to how accelerated observers should perform a measurement of some quantity which is considered by at least one of them to be the 'time-period' [or frequency] of some event occurring at regular intervals of proper time in one frame of reference. To answer this, *B. Bhawal* has studied a uniformly accelerating observer who sends light pulses at regular intervals in his proper time and investigated how other accelerating observers moving in the same (or some other) direction detect these successive pulses and measure the proper time interval between them.

Only when both the emitter and detector belong to the same family of observers having a common event horizon 'line', the intrinsic pulse period can be measured upto a proportionality constant. If the detector is moving at some angle with the emitter, it will never be able to receive more than two pulses, in case all the pulses are emitted in the same direction. In this and all other cases, the measured time-interval has a complicated nonlinear relationship with the intrinsic time-period.

Cosmology and Structure Formation

During the last decade, there has been tremendous advance in both theoretical and observational cosmology. These advances have helped detailed comparisons between models and observations and have helped to put severe constraints on the models. Several aspects of these developments were investigated during the last year.

Quasi-steady state cosmology :

Further developments have taken place, during the last year, in the new cosmological model (QSSC in brief) proposed by F. Hoyle, G. Burbidge and *J.V. Narlikar*. This model was suggested to bring high energy astrophysics closer to cosmology through a physical description of the phenomenon of creation of matter in mini-explosions, which not only conserve matter and energy but also generate negative stresses on the geometry of spacetime so as to make it expand. As its name implies, the QSSC has the universe expanding exponentially with a long timescale of around 1000 billion years together with short period cycles of expansion and contraction of around 40 - 50 billion years.

The astrophysical implications of this cosmology include a derivation of the temperature of the microwave background in terms of thermalized starlight of preceding cycles, the interpretation of dark matter as either very low mass stars (which have very low luminosity), or brown dwarfs/jupiters, or very old debris of burnt out stars. The production of light nuclei is from the decay products of the primary particle to be created, which has the characteristic Planck mass of about a few micrograms.

Further work on this cosmology now includes scenarios of structure formation from the primary mini-creation events together with the growth of perturbations. The latter is certainly helped along during the contracting phase of an oscillatory cycle. Some progress has also been made in relating the timescales of exponential expansion and cycles respectively to the fundamental constants of the underlying theory and the perturbations of the simplest models will next be looked at from the point of view of structure growth to galaxies, clusters and superclusters.

Action-at-a-distance electromagnetism and cosmology :

In a recent review in the Reviews of Modern Physics that marks the 50th year of the important 1945 paper in the same journal by John A. Wheeler and Richard P. Feynman on the absorber theory of radiation, F. Hoyle and *J.V. Narlikar* have proposed a novel solution to the problem of infinities in classical and quantum electrodynamics.

These awkward infinities typically arise in the quantum field theory when one discusses the electrodynamic effects of electric charges acting on themselves or with the so called virtual pairs in the vacuum. In the absence of any analytical solution to the problem of infinities, the "renormalisation programme" is introduced to "subtract" one infinity from another and arrive at a finite solution. The sole justification of this procedure is that the finite residue agrees with the observed or measured quantities like the Lamb shift, the anomalous magnetic moment of the electron, etc.

In the action-at-a-distance version, the Wheeler and Feynman theory had demonstrated that at the classical level, the concept of self action of a charge is replaced by the response of the universe. In subsequent works by J.E. Hogarth and by F. Hoyle and *J.V. Narlikar* in the early 1960s, it was shown that the response is of the required magnitude and sign provided suitable cosmological boundary conditions are satisfied. In the late 1960s, F. Hoyle and *J.V. Narlikar* quantized the Wheeler-Feynman theory to show that provided the same boundary conditions are met, the full quantum electrodynamic phenomena are describable in the action-at-a-distance framework.

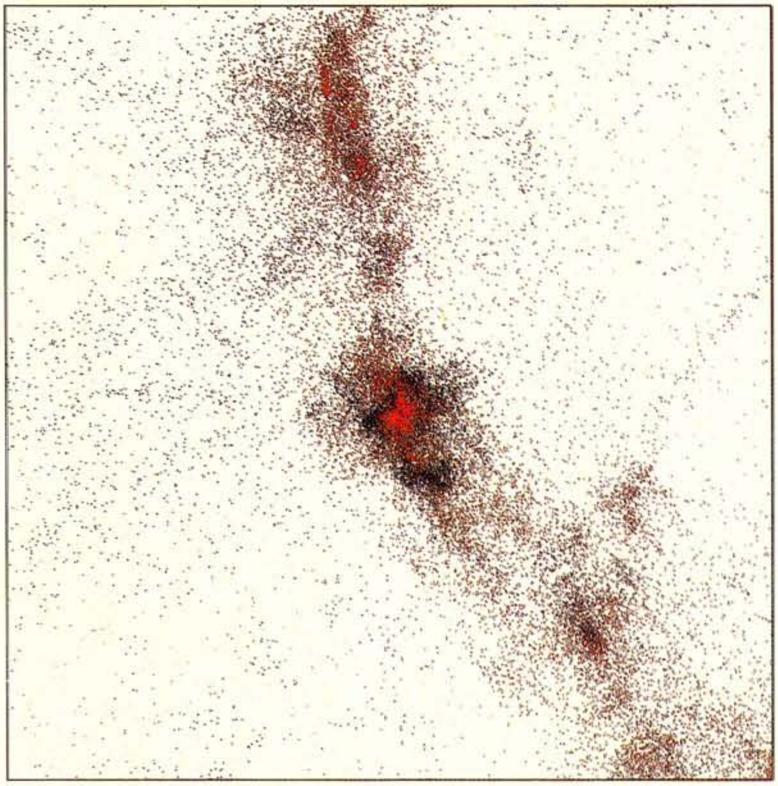
The recent work further shows that while calculating the response of the universe the event horizon like the one that exists in the steady state theory or the QSSC, cuts off the contributions of waves beyond a finite but high frequency. This results in converting all those integrals which were turning out to be infinite in the field theoretic calculations into finite ones. Thus quantities like the bare mass and bare charge of the electron remain finite.

It may be mentioned that none of the standard hot big bang models have the right cosmological boundary conditions either to generate the correct response or to make the above integrals finite.

N-body simulations and structure formation :

It is generally believed that structures like galaxies, clusters, etc., grew out of small perturbations in the early universe through gravitational instability. When these perturbations become significantly large, it is difficult to understand their evolution by analytic methods and one has to rely on computer simulations. These simulations are also important in testing the accuracy of approximation schemes and semianalytic models.

Cosmological N-body codes differ from other types of N-body codes in many ways, and so different numerical techniques have to be used. *J.S. Bagla* and *T. Padmanabhan* have written a code [usually known as "Particle Mesh code"] to study the nonlinear evolution of dark matter distribution. These simulations start with small perturbations described by a Gaussian random field. Then the system is evolved by solving the equations of motion for particles and the Poisson equation for the gravitational field simultaneously. The motion of the particles changes the gravitational potential and one needs to recalculate the forces at each time step. This force recalculation is done by smoothing the density field onto a regular mesh and solving Poisson equation in the Fourier space, using techniques like fast Fourier transforms to speed up the calculation. The gain in



Close up of a cluster in a CDM simulation

speed allows running simulations with a large number of particles (10^6). By testing all the components of the code independently, *J.S. Bagla* and *T. Padmanabhan* have been able to pick the ideal set of components for any given context or model. They have carried out tests to evaluate accuracy of the full code in many situations. A comparison of simulation results with scaling solutions shows good agreement. They have also compared the results of their simulations with results from high resolution simulations carried out on GRAPE machine by the Princeton group. The comparison shows remarkable agreement over the entire range of scales. They have used this code to investigate several interesting issues of dynamics described below:

(a) Coupling between small and large scales: One of the assumptions that form the basis of study of gravitational clustering by simulations is that nonlinearities at small scales do not influence the dynamics of large scales. This hypothesis allows one to study large scale dynamics by analytic methods even when small scales have gone nonlinear. *J.S. Bagla* and *T. Padmanabhan* have tested this hypothesis by simulating toy models with initial fluctuations that were limited to a small range of scales. As a first step, they considered a narrow Gaussian as the initial power spectrum. The simulation followed the linear evolution correctly and it produced the spectral "tail" at large scales which was predicted theoretically. To understand influence of nonlinearities at small scales on fluctuations at large scale they studied evolution of a model with power concentrated around two scales, in the initial power spectrum. Amplitudes of the two scales were adjusted so that small scales became nonlinear well before the large scales. Results from this simulation were compared with results obtained without any small scale power. The evolved power spectra were found to be similar at large scales showing that the small scale nonlinearities do not affect the large scales. They are pursuing this study further to understand interaction of different scales.

(b) A new statistics for nonlinear epochs: Comparison of different models for structure formation with observations in the nonlinear regime is complicated by many factors. First among these is that simulations give us distribution of dark matter whereas observations

provide the distribution of light sources viz. baryons. To make a comparison, we need a technique to separate out regions where baryonic structures can form. There is a general belief that these are regions which are strongly nonlinear and the question arises as to how one can choose them in a simulation.

It is possible to pick out nonlinear structures by imposing a density threshold but the density in quasilinear phase depends on the local symmetry of collapse. One statistical measure that is independent of local symmetry, is suggested by *J.S. Bagla* and *T. Padmanabhan*. This is based on the deviation of peculiar velocities from the local gravitational acceleration. It turns out that these vectors are proportional to each other in the linear regime, and this alignment is destroyed when particle trajectories cross significantly [called "shell crossing"]. The difference between the two vectors is very large after shell crossing. *J.S. Bagla* and *T. Padmanabhan* show that these facts can be used to identify regions which are highly nonlinear in a systematic way. Assuming that galaxy formation takes place in such highly nonlinear regions, one can calculate how "biased" the galaxy formation is at different scales.

(c) Evolution of gravitational potential: When gravitational clustering takes place in an expanding universe, the density inhomogenieties change by a large factor but the gravitational potential fluctuations change only marginally. This feature is prominent in models like the one with cold dark matter. *J.S. Bagla* and *T. Padmanabhan* have investigated the origin of this feature using N-body simulation results. Their analysis shows that some spectra evolve at the linear rate even in quasilinear and nonlinear regime. It also shows that for CDM like spectra, the evolution is almost linear on all scales as far as the gravitational potential is concerned. This happens because of a conspiracy of amplitude and local index of the power spectrum.

Nonlinear clustering and scaling relations :

The nonlinear clustering of dark matter particles in an expanding universe is usually studied by N-body simulations. At the other extreme, when the perturbations are small, one can obtain analytic results using perturbation theory. One can gain valuable insight into this complex problem if simple relations between physical quantities in the linear and nonlinear regimes can be extracted from the results of N-body simulations. Last year, *T. Padmanabhan* and R. Nityananda made a hypothesis to relate the mean relative pair velocities of particles to the mean correlation function in a useful manner. This relation helps one to obtain results in the nonlinear epoch from that of linear theory, in an approximate manner.

Recently, *T. Padmanabhan* (in collaboration with R. Cen, J.P. Ostriker and F. Summers) have investigated this relation and other closely related issues further. The idea was to check the validity of the original hypothesis for widely different models using accurate state-of-the-art simulations. They have studied six different cosmological models which cover most of the popular ones. The simulations were done in NCSA Convex-3880 supercomputer, and have extremely high resolution and range. Their results throw light on several aspects of dynamics:

To begin with, they find that the evolution of clustering in an expanding universe is self-similar if there are no scales involved in the problem. This result is expected but settles some doubts raised by previous workers in this field. Secondly, they find that clustering does not, in general, stabilise to a bunch of virialised, gravitationally bound objects. Merging and fragmentation of structures continue to play an important role in most cosmological models. The hypothesis of such "stable clustering" seems to be a better approximation in the case of open universe in which structure formation freezes out at some low redshift. Finally, they find that the original hypothesis of R. Nityananda and *T. Padmanabhan* is only approximately valid though it is a fairly good approximation. The deviation from the original relation depends on the amount of small scale power in the universe and *T. Padmanabhan* et. al. have been able to provide a quantitative interpretation of the same.

Approximations to gravitational instability :

Gravitational instability in an expanding universe is fairly straightforward to study, by means of perturbative methods, when the density contrast is small. In the nonlinear regime, the situation is more complex and an exact analytical treatment has so far eluded researchers. In the absence of an exact treatment, several approximations attempting to mimic the effects of nonlinear gravity have been proposed in recent years. *D. Munshi, V. Sahni* and A.A. Starobinsky have compared the accuracy of approximations such as the Zel'dovich approximation, the linear potential approximation, etc. using as a comparative statistics, the evolution of non-Gaussianity in the density and velocity fields in these approximations.

A non-Gaussian distribution can be characterized by its moments such as the skewness, kurtosis, etc. Generalizing the earlier work by Bernardeau, done in 1992, *D. Munshi, V. Sahni* and A.A. Starobinsky developed an anzatz to evaluate all the moments characterising a given approximation by means of a generating function which, remarkably, was shown to satisfy the equations of motion of a homogeneous spherical density enhancement in that approximation. On the basis of the analysis they showed that approximations formulated in Lagrangian space (such as the Zel'dovich approximation and its extensions) were considerably more accurate than approximations formulated in Eulerian space such as the frozen flow and linear potential approximations when tested in the weakly nonlinear regime. They also evaluated the density probability distribution function for the different approximations in the quasi-linear regime and compared their results with an exact analytical treatment in the case of the Zel'dovich approximation (ZA).

The weakly nonlinear regime is, however, inadequate if one wishes to study highly evolved structures such as galaxies and groups and clusters of galaxies. Extending the above work of *D. Munshi, V. Sahni* and Starobinsky, *B.S. Sathyaprakash, V. Sahni* and *D. Munshi*, in collaboration with D. Pogosyan and A. L. Melott have studied the development of gravitational instability in the strongly non-linear regime. Using a number of statistical indicators such as filamentary statistics, spectrum of overdense/underdense regions and the void probability function, each of which probes a particular aspect of gravitational clustering, they discriminate between different approximations to gravitational instability and test them against N-body simulations. The approximations tested are, the truncated Zel'dovich approximation (TZ), the adhesion model (AM), and the frozen flow (FF) and linear potential (LP) approximations. The main conclusion of their work is that FF and LP break down relatively early, soon after the non-linear length scale exceeds the mean distance between peaks of the gravitational potential. The reason for this break down is clear: Particles in FF are constrained to follow the streamlines of the initial velocity field, the initial flow being potential, shell crossing is absent in this case and structure gradually freezes as particles begin to collect near minima of the gravitational potential. In LP, on the other hand, particles follow the lines of force of the primordial potential, oscillating about its minima at late times when the non-linear length scale reaches the mean distance between the peaks of the gravitational potential. Unlike FF and LP, the AM (and to some extent TZ) continues to give accurate results even at late times. This is because both AM and TZ use the presence of long range modes in the gravitational potential to move particles. Thus, as long as the initial potential has sufficient long range power to initiate large scale coherent motions, TZ and AM will remain approximately valid.

In relation to AM, TZ suffers from a single major drawback; it underestimates the presence of small clumps. Similarly, it predicts the right mean density in large voids but misses subcondensations within them. The reason for this is clear: TZ is an improvement over the ZA, in which power is surgically removed on length scales which have already gone nonlinear. This removal of power guarantees that pancakes remain thin in TZ rendering this approximation more effective than ZA at late times. However, the removal of power on nonlinear scales designed to prevent shell crossing, causes a substantial fraction of matter (which would have been clustered in N-body simulations) to lie within low density regions at all epochs. As a result, voids are more thickly populated in TZ than N-body simulations seem to show. The main advantage of TZ is that it is very fast to implement and accurately predicts the location of large objects such as clusters of galaxies.

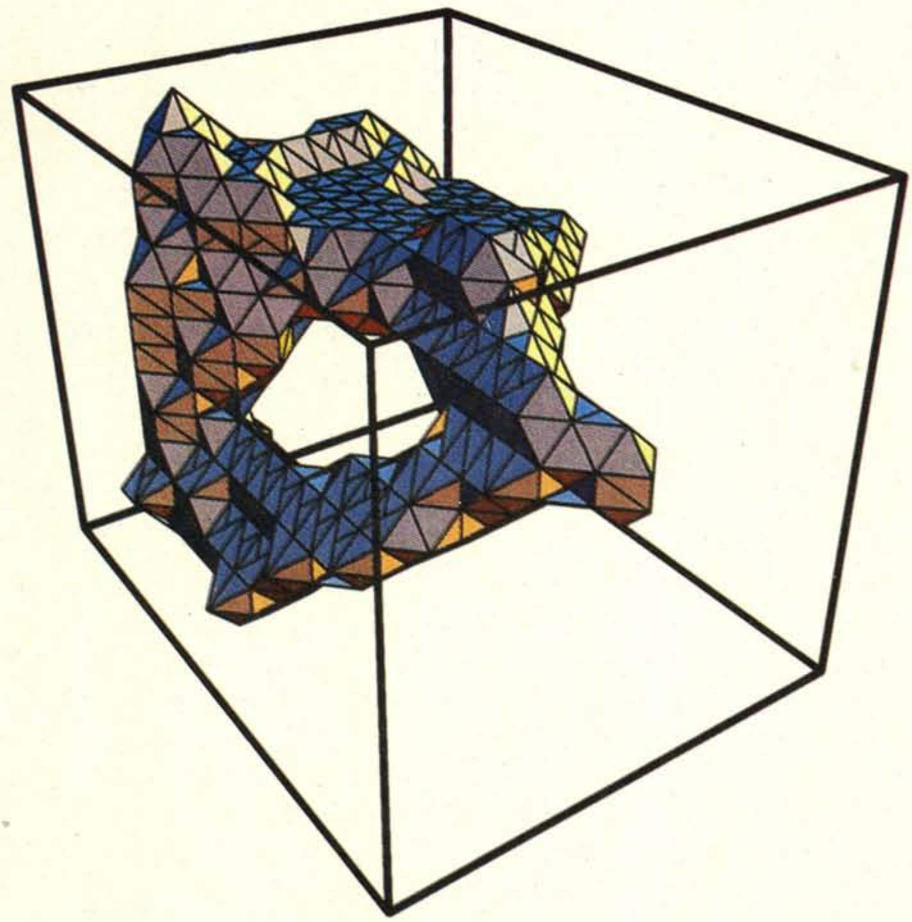
For the standard CDM model, the adhesion model and, to some extent, the TZ approximation appear to be more realistic approximations to apply to the study of large scale structure in the Universe than either FF or LP.

Shapes of clusters and superclusters :

B.S. Sathyaprakash, V. Sahni and Sergei Shandarin are applying statistics sensitive to shape of a region to study the form and evolution of overdense and underdense regions in N-body simulations and in galaxy catalogues. In three dimensions, the degree of prolateness or oblateness of structures appears to depend upon the initial spectrum of density perturbations. They propose to combine the shape statistic with percolation and topology to provide a clearer picture of the evolution of large scale structure during nonlinear gravitational clustering.

Fluctuations in the cosmic microwave background :

Measurements of temperature anisotropies in the Cosmic Microwave Background (CMB) probe primordial "seed" perturbations which later give rise to the large scale structure of the universe. The



A void from numerical simulations with the topology of a torus. The void is plotted in initial (i.e. Lagrangian) space. In the physical (i.e. Eulerian) space such a void is not wholly empty but has a mini-pancake running through it.

amplitude and shape of the power spectrum of the CMB anisotropy appears to be consistent with predictions of the inflationary scenario made over a decade ago. Inflationary models generically predict that the underlying statistics of primordial density perturbations will be Gaussian; these fluctuations, in turn, induce fluctuations in the Microwave Background Radiation (MBR) at the time of recombination. On their way to the observer, microwave photons travel through a gravitational potential which is perturbed by the presence of density inhomogenieties (precursors of clusters and superclusters), as a result the CMB anisotropy becomes slightly non-gaussian when measured on earth.

T. Souradeep Ghosh, D. Munshi and A.A. Starobinsky, have made careful estimates of the skewness in CMB anisotropy maps. Extending earlier work by *D. Munshi, V. Sahni* and Starobinsky, *T. Souradeep Ghosh, D. Munshi* and A.A. Starobinsky show that the MBR skewness arises due to small non-linear corrections to the gravitational potential which induce fluctuations in the MBR through the Sachs-Wolfe effect. They find that, for the standard CDM model, the skewness appears to be smaller than previously expected and is lower than the cosmic variance limit even at small angular scales. However, though small for the cold dark matter model, the skewness in CMB maps could be substantially larger in other scenarios of structure formation such as models which incorporate a cosmological constant in addition to normal matter. Work is currently in progress to make more quantitative analysis of non-Gaussianity of the MBR in such models.

D. Munshi and *T. Souradeep Ghosh*, in collaboration with Somnath Bharadwaj, are also studying non-Gaussian features induced in the CMB anisotropy maps due to stochastic gravity waves arising during inflation.

Neutral hydrogen at high redshifts :

In the standard cosmological models, the universe was in plasma state at very high redshifts. At a redshift of about thousand or so, it would have cooled sufficiently to allow the formation of neutral hydrogen and helium. It is, however, possible that these get ionised again when the structure formation proceeds. While observations show evidence for bound systems of neutral hydrogen, there does not seem to exist any neutral hydrogen in the intergalactic medium (IGM). The detailed distribution of neutral hydrogen at high redshifts can provide important clues to the formation of structures and the Giant Meterwave Radio Telescope (GMRT), currently under construction, may be able to detect the protocondensates with neutral hydrogen.

Over the last two years, *T. Padmanabhan* and his collaborators have been studying the ionisation history of the universe in the redshift range of $z < 10$. Such a study is important in understanding the formation and abundance of quasar absorption systems and in determining possible signal due to neutral hydrogen. The N-body code developed by *J.S. Bagla* and *T. Padmanabhan*, in combination with a model that can predict the neutral fraction of hydrogen by mass in galaxies/ protogalaxies, can be used to study the neutral hydrogen fraction in different models of structure formation. *J.S. Bagla, T. Padmanabhan* and *B. Nath* are working on an algorithm for coupling the N-body code with a model for computing the neutral fraction of hydrogen. This technique could allow them to bypass the complications of a hydrodynamical simulation and, at the same time, provide reasonable answers.

IGM and unstable neutrinos :

The ionisation history of the IGM, mentioned above, depends on the details of the physical processes which take place in these redshifts. For example, the gaseous species can get reionized again if the formation of various structures in the universe, like quasars and galaxies, can emit enough ultra-violet radiation. Thus observation of ionization states of hydrogen and helium can be used to study the intensity and spectrum of the background ultra-violet source at high redshifts.

It is, however, not clear whether conventional sources like quasars and young galaxies can explain the ionization state of hydrogen, which is found to be highly ionized upto a redshift of 5. In recent years, observations of two ionization states of helium, neutral and singly ionized helium, have revealed certain trends: There is almost no neutral helium in the intergalactic medium; but strong absorption due to singly-ionized helium is seen. These observation can point to a unique spectrum of the background ionizing source.

S. Sethi has studied the cosmological consequences of a radiatively decaying neutrino providing the source of ionising photons. In this scenario, a massive neutrino decays into a photon and a massless neutrino with a small branching ratio. He has investigated the evolution of ionization states of hydrogen, neutral helium, and singly-ionized helium in this model, with the radiatively decaying source as the source of ultraviolet radiation and taking into account the effect of absorption due to diffuse background and the Lyman-alpha systems. He has also incorporated the constraints due to spectral distortion of the CMBR, closure density, cooling of red giants, diffuse UV background, and astrophysical constraints imposed by observations of SN1987A. It is shown that simultaneous observation of small optical depth due to neutral hydrogen and large optical depth due to singly-ionized helium forces the mass of neutrino to be above and about 110 eV, independent of other parameters. This constraint, combined with constraints due to closure density and cooling of red giants, rules out all of the parameter space. So an inescapable conclusion of his analysis is that neutrinos which decay with a lifetime less than the age of universe cannot be a dominant source of ultraviolet radiation at high redshifts. Further, the ionization state of singly-ionized helium puts very stringent constraints on the parameters of the model; these constraints are more stringent than the ones from other astrophysical phenomena.

Gravitational Waves

One of the definitive predictions of general relativity is the existence of gravitational waves and as such the detection of these waves will go a long way in strengthening our understanding of general relativity. The funding of large scale detectors for gravitational waves, namely the LIGO and the VIRGO and the medium scale detectors such as GEO, has provided added impetus to groups working in the area of gravitational detection and observation. In this world wide effort, India is collaborating with Australia (the AIGO project) which has recently received seed funding. IUCAA is responsible for the theoretical aspects in the experiment which involves essentially gravitational wave data analysis and computer modelling of the laser interferometric gravitational wave detector. Specifically, in the last year, the thrust in IUCAA has been on the data analysis of two important astrophysical sources, the coalescing binaries and pulsars, and modelling the optics of giant laser cavities which form an integral part of the detector. This last mentioned work is being carried out in collaboration with the French under the Indo-French Centre for the Promotion of Advanced Research (IFCPAR) programme.

Coalescing binaries :

Compact coalescing binary stars are the most promising sources for the LIGO/VIRGO detectors. Although PSR 1913+16 will coalesce in about 10^8 years, several events per week are likely to be seen with these large scale interferometers which have ranges upto 1 Gpc or so. Weiner filtering a signal from a noisy detector output is a well known technique and is envisaged to be used in the detection and analysis of binary merger events. A bank of filters is used to extract the signal from the noise and the result is the filtered output which depends on parameters such as the masses of the stars, the time of arrival, phase, etc. The problem is to analyse the distribution of the peak of the filtered output. This however is a daunting task. *S.V. Dhurandhar* and B.F. Schutz had investigated the one dimensional case, the parameter in question being the time of arrival of the signal and obtained thresholds, sampling rates, etc. *R. Balasubramanian, B.S. Sathyaprakash* and *S.V. Dhurandhar* have carried out simulations in the general case to determine the accuracies with which the parameters of the coalescing binary system can be determined from the gravitational wave signal emitted during inspiral of the binary system. The analysis is carried out using the actual noise curves of the initial LIGO with a lower frequency cut-off of 40 Hz. The signal waveform used is correct upto the 1.5 post-Newtonian order. The signal analysis techniques are recast in the language of differential geometry which enables one to characterize the errors in the measurement of the parameters in a coordinate independent way. In addition, they have extended the analysis carried out by *B.S. Sathyaprakash* earlier at first post-Newtonian order and have shown that even at the 1.5 post-Newtonian order the signal can be detected by using essentially only a one-dimensional lattice of templates. Consequently, inclusion of higher order corrections up to 1.5 post-Newtonian order does not lead to any extra burden on data analysis.

(a) Differential geometry and data analysis: The idea is to employ the powerful techniques available in geometry to develop efficient data analysis algorithms to detect and analyse very weak gravitational wave signals. *B. Bhawal, S.D. Mohanty* and *S.V. Dhurandhar* have analysed this problem in general but have mainly concentrated the study to coalescing binary waveforms.

In the geometrical picture, matched filtering is equivalent to taking the inner product of the detector output vector with a filter vector. Any given filter will pick out signals lying in a small neighbourhood around itself on the signal manifold with a sufficiently high signal-to-noise ration (SNR). The required number of filters, therefore, depends on the extrinsic geometry of the signal manifold. So, in some cases, for example, in the case of detection only, it may be possible to achieve a reduction in the number of filters by placing them outside the manifold. Two different algorithms are being considered to achieve an optimal placement of filters around the signal manifold.

It has been found that the Newtonian as well as post-Newtonian signal manifold (obtained by stationary phase approximation) are intrinsically flat. Efforts are on to fix criteria for the good coordinates to describe the manifold, placement of filters and to give geometrical interpretation to several physical and statistical quantities.

(b) The periodogram technique for data analysis: Even though a Weiner filter is the most optimal linear filter, there is a necessity for the development of computationally less intensive and/or statistically independent strategies of detection. *S.D. Mohanty* and *B.S. Sathyaprakash* have investigated the feasibility of using a technique called, ``Periodogram'' analysis, vis-a-vis, the above criteria.

Amplitude and frequency of an inspiral wave form from a binary system of stars increases with time. By switching over to a new time variable which is proportional to the phase of the signal, one obtains a periodic wave form. Fourier transforming the transformed data, or simply folding it over every period, facilitate concentrating the signal energy at the expense of noise. The latter method was studied in detail by them, who assessed the effectiveness of the periodogram when compared with matched filtering. They find that two techniques (i) yield the same SNR, (ii) are computationally equally expensive and (iii) are statistically independent. The first point implies that in the detection problem, either the periodogram technique or Weiner filtering can be used and the second point implies that if a signal is detected by both these techniques, then we can be more confident about its presence.

(c) Testing general relativity: In collaboration with Luc Blanchet (Observatoire de Paris, France), *B.S. Sathyaprakash* has now refined the estimates of minimal SNRs required to unambiguously detect general relativistic nonlinear effects like tails of gravitational waves that are imprinted

in the radiation emitted by compact coalescing binary systems. In particular, they have shown that the detection of the tail effect could be achieved in future gravitational wave experiments, at least in the case of blackhole coalescences. For a blackhole binary with a total mass of $20 \sim M_{\odot}$ they obtain a minimal SNR of 35 and for a neutron star binary with a total mass of $2.8 \sim M_{\odot}$, they obtain 250, to confirm the presence of tails. They caution that the minimal SNR depends on the number of independent parameters that are used in the filtering process: a larger value being needed for a higher number of parameters.

Gravitational waves from pulsars :

An interesting question can be posed: Can we detect gravitational waves from millisecond pulsars by resonant bar detectors before the large scale interferometers go into operation? This question has become relevant especially since the bar detectors have reached high sensitivities approaching the quantum limit. The feasibility of this idea has been examined by *S.V. Dhurandhar*, D.G. Blair and M.E. Costa in the context of the millisecond pulsar PSR 437 - 4715, which is the nearest pulsar discovered so far, and the resonant bar detector at Perth, Australia. Since it is possible to tune the bar to frequencies ranging from 500 Hz - 1200 Hz several millisecond pulsars can be subjected to scrutiny by the different bar detectors around the globe. A list of such pulsars has been provided and a viable data analysis scheme proposed.

Another problem under investigation is the all sky all frequency search for pulsars. Earlier analysis has shown that the problem is highly computer intensive if one adopts the straightforward approach of scanning over all the directions in the sky. However, D.C. Srivastava, S. Prasad, R. Valluri and *S.V. Dhurandhar* have opted for a novel approach of estimating the number of degrees of freedom in the function space of signals. The preliminary results, taking into account only the rotational motion of the earth, are encouraging.

Coincident observation by a network of detectors:

In the next few years, altogether five interferometric gravitational wave detectors are planned at five different locations (2 LIGOs, VIRGO, GEO, AIGO). These will have different sensitivities arising mainly due to different arm lengths. Coincident observation by such a network will help in eliminating rare and unmodelled noise sources.

B. Bhawal has investigated the problem of setting a threshold for observations against a background of Gaussian noise, when one allows for the time delay windows within which coincidences will be accepted. The noise generated events within this window of time-delays in separated detectors will contribute to the false alarm rate, thus raising the threshold level. Thresholds for several different combinations of detectors at various sites have been computed by evaluating the volume of the time-delay window and assuming statistical independence in the noise.

Modelling the interferometer:

S.V. Dhurandhar and *B.S. Sathyaprakash* in collaboration with J.Y. Vinet and P. Hello of Linear Accelerator Laboratory, University of Orsay, France, have been funded by the IFCPAR to model interferometric gravitational wave detectors that employ very high laser power in their giant cavities. The scope of the present project is to carry out theoretical investigations regarding onset of nonlinearities in high power laser cavities. When high power lasers are employed in interferometric cavities that contain mirrors that are freely suspended, one can envisage the following physical effects to be important:

(i) radiation pressure on the mirrors and its fluctuation due to quantum uncertainty and due to intrinsic variations in the laser power,

(ii) deformations in the mirrors caused by absorption of the intra-cavity light field and the input light field,

(iii) generation of photon modes in the substrate of the material of the mirror and consequent efficient absorption of the light field,

(iv) thermal lensing introduced in the substrate of the mirror, etc.

This is, therefore, a coupled nonlinear problem and the group has started investigating the problem, to begin with, under certain simplifying assumptions.

The nonlinearities in high power laser cavities may be worked out numerically in the following three stages of development:

(i) an optical code that can accurately determine the intra-cavity light field in the presence of imperfections in the alignment of the mirrors and/or of the laser beam, deformations in the surface of the mirrors, nonideal modes of the beam, etc,

(ii) an algorithm capable of determining the transient temperature field in the laser cavity, in particular on the mirror surfaces, given the input laser power, and,

(iii) an algorithm to compute the transient deformations of the mirrors and possibly other components, given the transient temperature field.

The three codes together can then be used to iteratively study the quality of the intra-cavity light field, and to study the onset of instability in the intra-cavity light power when either the input laser power is high or the finesse of the cavity is large or both. An optical code capable of computing the intra-cavity light field when subject to small perturbations has already been developed by the group.

Before venturing upon the other problems, the problem of the effect of a fluctuating light beam incident on the mirrors has been considered. In this case, one can envisage two different kinds of mirror deformations: small scale deformations that occur locally and may disappear in course of time and large scale deformations that tend to expand the mirror surfaces globally and that remain forever. The latter effects are easy to model, given the thermal properties of the material of the substrate of the mirrors and of the mirror coating. What could be potentially a source of major problem is the transient, local deformation. The smallest physical size of such fluctuations to be considered will clearly depend on the time scale in the problem. The relevant scales in the problem have been estimated by assuming that the input laser power fluctuates at a certain fiducial frequency. Analytical solutions of the heat equation have been obtained and it has been shown that the boundary conditions are unimportant when the frequency of fluctuations is greater than 10 Hz. This simplifies the problem considerably since imposing the boundary conditions at the rim of the mirror is very awkward. Analytical solution to the deformation of mirrors is now being sought.

Squeezing the noise :

Squeezed states of light may be used to reduce the photon shot noise in the laser interferometric gravitational wave detector. The photon shot noise at low input laser power far exceeds the noise due to motion of mirrors by radiation pressure fluctuations. By appropriately squeezing the vacuum field at the output port, it is possible to reduce the photon counting noise, thus increasing the sensitivity of the detector. Another technique to increase the sensitivity is to increase the effective laser power by recycling the light coming out of the laser port. *V. Chickarmane* and *B. Bhawal* showed that both these techniques could be used in conjunction in a single pass interferometer to enhance the sensitivity. Later *V. Chickarmane* and *S.V. Dhurandhar* have extended this work to Fabre-Perot cavities. The effect of losses is also being included which is very crucial, since it is known that losses are detrimental to squeezed state technique. However, optimal solutions may be found if the losses are small.

B. Bhawal has written a programme to describe the build up of the intra-cavity fields in light recycling scheme. The programme will be useful to study transients, which arise in actual operation of an interferometer.

Quasars and Extragalactic Astronomy

Extragalactic astronomy has made considerable progress in the last decade or so with increased input from the observational side. Several theoretical and observational aspects of this field were investigated last year.

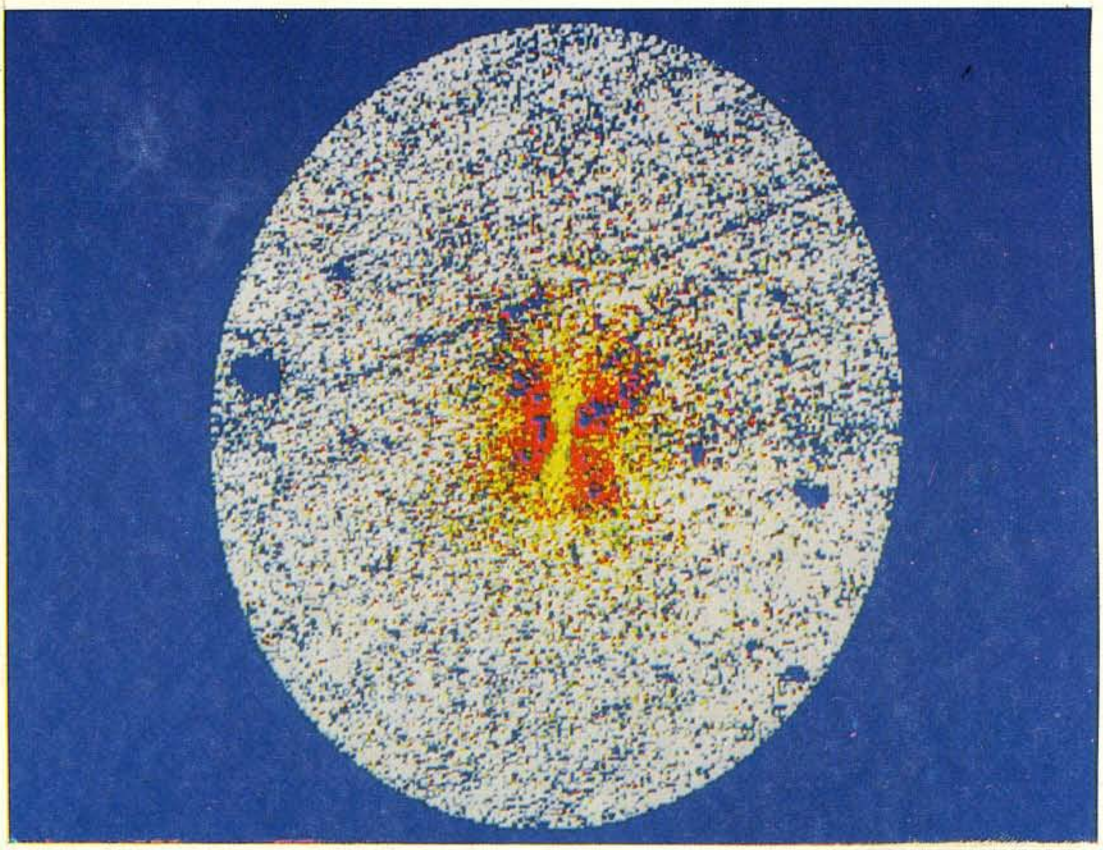
Imaging of galaxies :

IUCAA has an extensive programme for the imaging of galaxies using charged coupled device (CCD) cameras. Compared to photographic plates, CCDs have very high efficiency for photon detection and a high dynamic range. It is, therefore, possible to use them on telescopes of relatively small aperture (1 to 2 meters) to map in detail the distribution of light in galaxies. Using sophisticated image processing techniques and fast computers, it is possible to use this data to study the large and small scale structures in galaxies to very faint levels.

Elliptical galaxies have simple structures and their light distribution is on the whole fairly smooth. It is, therefore, possible to study the faint structures in these galaxies. Such structures are expected to be produced as a result of interaction of elliptical galaxies with other galaxies, mergers between galaxies, the cannibalising of dwarf galaxies by ellipticals, inflow of gas and so on.

A major observing project in IUCAA is the study of powerful radio galaxies, which are all elliptical, from the Molongolo radio catalogue. This work is being done by *A.K. Kembhavi* and *A. Mahabal* in collaboration with Patrick McCarthy. Broad band data in the optical and infra-red has been obtained on a number of galaxies from a sample using telescopes of the Carnegie Observatory at Las Campanas in Chile and analysis is in progress.

A.K. Kembhavi and *A. Mahabal* have



Major axis dust lane in the radio galaxy 3C270 analysed a small sample of radio ellipticals observed with the Vainu Bappu Telescope (VBT) in collaboration with K.P. Singh, P.N. Bhat and T.P. Prabhu. The most interesting outcome of this has been a detection of a dust lane in the radio galaxy 3C-270 (NGC 4261). The VBT observations have established that the relatively large scale dust lane is aligned very close to the major axis of the galaxy, and normal to the direction of the radio source. The presence of the lane has important implications for the structure of the galaxy, the origin of the dust and the nature of the radio source.

As a part of the university's observing programmes, S.K. Pandey and Devendra Sahu of Pt. Ravishankar Shukla University, Raipur, have been studying shells, arcs and other such internal structures in elliptical galaxies, in collaboration with *A.K. Kembhavi*. Considerable amount of data has recently been obtained in collaboration with P. McCarthy from Las Campanas. The astronomers from Pt. Ravishankar Shukla University have also been studying spiral galaxies using data obtained from the Uttar Pradesh State Observatory (UPSO) in collaboration with V. Mohan.

Spiral galaxies have very complex structures and a great deal of star forming activity. In some galaxies, star formation occurs in bursts involving 10^8 solar masses in the nuclear regions of the galaxies. *A.K. Kembhavi* and *A. Mahabal* have undertaken the imaging of a sample of star burst galaxy in narrow and broad band filters centered on various prominent emission lines. Data for the project has been obtained using telescopes belonging to the South African Astronomical Observatory and Kitt Peak National Observatory in Arizona. This work is being done in collaboration with Prabhakar Gondhalekar. Narrow band photometry will be used to study the distribution of stellar masses in the bursts, the distribution of the bursts in the nuclear region and so on. The star burst galaxies are also being studied at X-ray energies using archival data by *A.K. Kembhavi, D. Duari* and Varsha Chitnis.

A.K. Kembhavi and *G.C. Anupama* have been studying Seyfert galaxies with a view to determining the optical luminosity distribution in nuclear, bulge and discomponents. This work is being done in collaboration with M. Elvis and Rick Edleson.

Cooling flows in compact groups :

Cool gas and dust have been observed in elliptical galaxies in clusters, which until recently, were believed to be gas free. The origin of the dust and gas, both the warm ionised component and the cold atomic component, is still quite uncertain. Some observations indicate that the cooler interstellar component is associated with the cooling flows in these galaxies, while others suggest the gas has an external origin, and has been accreted from a late type companion. Observations of emission lines have shown the presence of ionised gas disks in ellipticals. The source of energy required to keep the gas ionised is, in several cases, highly uncertain.

The most widely accepted theory to explain both the origin and excitation of the ionised gas is the "cooling flow model". In this model the hot X-ray emitting plasma cools radiatively in less than a Hubble time and settles to the centre of the galaxy potential as a cooling flow. Radiative cooling of the hot gas gives rise to the optical emission as it cools. However, in several cases the ionised gas appears to be associated with dust lanes and shells which are evidence of a recent tidal interaction or merger. Some authors have argued that thermal conduction from the hot X-ray emitting gas to the cold gas accreted from outside heats and evaporates the cold gas to a stable temperature of about 10^4K, which then forms the emission line region.

Recent ROSAT observations have shown, for the first time, the existence of giant X-ray halos, which appear to be associated with the group as a whole. In one of these, HCG62, the soft X-ray spectrum indicates that the gas temperatures decrease towards the centre indicating the presence of a cooling flow centred on the group. The existence of a cooling flow would imply that warm, ionised gas could also exist in the centre of this galaxy. HCG62 has four members, all early-type galaxies (E/S0) at a mean redshift $z = 0.03$. The brightest two members of the group HCG62a and HCG62b seem to be interacting.

M. Valluri and *G.C. Anupama* have imaged Hickson's compact group HCG62 in broad band *VR* and narrow band Hα filters. They have detected Hα emission in three of the group members HCG62a, HCG62b and HCG62c, which could be associated with the X-ray cooling flow gas. The Hα luminosity is of the order of 10^{38} ergs/s. They also make an estimate of the density and hydrogen mass in the gas ($n_e \sim 30\ \mathrm{cm}^{-3}$; $M_H \sim 10^5\ M_\odot$ for a filling factor of 10^{-5}). Three different mechanisms for ionisation sources, namely, (a) ionization by hot young stars, (b) ionization by the hot X-ray gas and (c) g-mode gravity waves, have been examined. The most plausible source of ionization which explains the observed luminosity, density and mass values turns out to be the hot X-ray gas.

Radio lobes of giant galaxies

The lobes of giant radio sources, of mega-parsec length, have been used earlier by several researchers to estimate the physical properties of the intergalactic medium, in which the lobes are embedded. Assuming pressure balance between the lobes and the intergalactic medium, one can obtain the pressure of IGM from the estimated pressure in the observed lobes. However, it has been shown that the pressure of the intergalactic medium estimated in this way is too large to be comfortable with other observations, such as the spectral distortion of the cosmic microwave background radiation through the interaction of photons with the ionised IGM.

In a recent work, *B. Nath* has emphasised that the assumption of the pressure balance between the lobe and the intergalactic medium is incorrect. This is because, there exists the cocoon-like region surrounding the giant radio sources, of which the lobes are a part, which is over pressured compared to the intergalatic medium. Using a model of such over pressured cocoons, as worked out by various people recently, *B. Nath* has devised a method to estimate the density (rather than the pressure) of the intergalactic medium from the observations of these lobes. He finds that the density of the IGM is of the order of a few percent of the closure density of the universe. He has also calculated the radio power of the over pressured cocoons surrounding the light jets of the radio sources as a function of time and the ambient density.

Evolution of Galaxies and Clusters

Galactic collisions and star clusters :

Star clusters include some of the oldest stellar associations in the universe. This has led some people to even conjecture that star clusters were the first entities to condense out in the post-recombination era. In this picture, all galaxies form by collecting gas and star clusters out of the cosmic fabric. However, it has become clear since the early 1980's that this scenario needs refinement. For instance, it is known that the number of star clusters differs for galaxies of different Hubble type but with similar dynamical masses. On the other hand, HST observations of galactic merger candidates have led to the discovery of several bright, blue sources that may well be star clusters in the making. The possibility of forming star clusters in galactic mergers is all the more important, given the likelihood of merger events at high redshifts. But how can the collision of two galaxies trigger the formation of star clusters?

One sine qua non condition is that gas be available to form new stars. Most spiral galaxies have copious amounts of gas and so presumably colliding spirals result in the formation of many new stars. In this situation, star clusters would form where star formation is more efficient. This view has received much observational impetus lately through spectroscopic studies; however, one aspect of the scenario that has attracted little attention concerns the morphology (or, dynamics) of star clusters formed in galactic mergers. Groups of stars formed by shock-compression of interstellar gas should not be (dynamically) cold and spherically symmetric initially, two assumptions often implemented in stellar cluster studies. More likely, the stellar systems will show odd shapes and high velocity dispersion at the time of formation. What can we say of young stellar systems of this sort?

C.M. Boily, C.J. Clarke and S.D. Murray have completed a study of elliptical star clusters through N-body simulations. They imagined clusters formed by head-on collisions of interstellar gas clouds being flat, axisymmetric structures which then evolve dissipationlessly. Two parameters are used to characterise the clusters initially, namely their aspect ratio (or, ellipticity) and the ratio of kinetic to gravitational energies. The global shape of clusters during collapse is well described by adiabatic invariants provided only a small but finite amount of kinetic energy is present initially. When the amount of kinetic energy is reduced, it was found that inhomogenieties develop rapidly which give rise to nucleated subsystems.

While the core of star clusters gets round in just a few crossing times, the envelope retains elliptical shape for much longer periods: clusters that started out the flattest remain the most elliptical. Large ellipticities are obtained at radii well within the truncation radius measured for the galactic and Magellanic star clusters. Consequently, one would expect an age-ellipticity relation as reported for instance for the globular clusters of the Large Magellanic Clouds.

Gas in the clusters :

X-ray observations reveal the existence of hot gas in the intracluster medium (ICM). However, there is no single model that simultaneously explains the amount of the hot gas and its metallicity. The models usually invoke galactic winds, gas ejected by galaxies when supernovae in the galaxies provide the gas with thermal energy and the gas attains escape velocity. But these models of galactic winds from large ellipticals, that abound in clusters, can explain the iron content of ICM, but not the total amount of the hot gas.

There has been a suggestion recently that, dwarf spheroidals in clusters can provide the required amount of hot gas, owing to the large amount of gas expelled from these galaxies because of their small binding energy. *B. Nath* and Chiba have recently calculated the metallicity of the resulting ICM gas in this scenario in detail. They find that the gas is ejected too early from dwarf spheroidals and is not enriched enough to account for the amount of iron in the ICM.

Chemical evolution of the galaxy :

N.C. Rana and his collaborators continued to investigate several aspects of chemical evolution of the galaxy and star formation.

He and Pushpa Tantry investigated the consistency of an empirical formula for the star formation rates in about 60 nearby spiral galaxies. The results based on this formula agreed with the expected dependence on the amount of dust grains in those galaxies. The indicators of the star formation rate were gauged both from infrared and blue band flux.

N.C. Rana and Mridula Chandola are working on a model to account for the excess of iron in the hot intracluster medium based on vigorous starburst activities occurring in a very short period. The starburst would serve for creation of iron in the form of dust grains and efficient ejection out of the galaxies due to the radiation pressure. A narrow range of parameters can explain the fact that giant ellipticals are devoid of O-B stellar associations and gas at the very early stage of their evolution, and thus justifying the presence of giant ellipticals in those hot clusters of galaxies.

A detailed model for the formation of interstellar grains from a given seed nucleus originating from the atmosphere of the cool red giants is being studied by *N.C. Rana* in collaboration with an IUCAA associate, D.B. Vaidya. It seems that the gap between the formation of grains from seeds to their observed properties in the interstellar medium can be explained by this model.

A new form for the initial mass function and the present day mass function of the stars in the solar neighbourhood are derived from a very careful study of the physical binaries and multiple stellar systems by *N.C.Rana*, K. Rajeev and Mridula Chandola. The results indicate that there are weak signatures of stellar burst activities under different chemical environments, but reasonably following a power-law form only for the stars of the intermediate mass range extending to the most massive ones with a slope of about -2.7 (in comparison with -2.3 due to Salpeter).

Stellar Physics

Gas flows and star formation :

The origin of stars has ever been a puzzle to scientists. Although they are the bread and butter of astronomers, no consensus has yet been reached regarding this issue. Recent progress in this area has come from numerical calculations, but these are hardly substitutes for the theoretical insight provided by analytic solutions. Of these, self-similar flows derived from dimensional analysis are especially important, being exact, non-linear time-dependent solutions. Now, *C.M. Boily* and D. Lynden-Bell have introduced a two-parameter family of self-similar collapse and accretion flows in spherical symmetry. They constructed their solutions by taking the gas emission rate to be a product of powers of the density and temperature. The power indices so introduced help to define the time-dependencies of all physical scales. *C.M. Boily* and D. Lynden-Bell have extended previous similarity solutions for isothermal gas, to specific emission processes allowing for radial variations of the temperature. Most flows develop strong density gradients and supersonic infall. All solutions assume power-law form away from the centre of condensation. More exotic type of solutions exist, when a dense shell develops on a sphere converging toward the origin: thus the maximum density need not be located at the centre of gravity.

Collapse solutions are continued in time when accretion by a central mass begins. The freedom in the choice of emission process (or, power indices) allows for solutions where accretion by the star does not proceed at a constant rate. This concurs with numerical studies of others who found decreasing accretion rates with time. The case of accretion from a 'dusty' envelope is treated in greater details as an example.

Further hydrodynamical similarity solutions describe the expansion of a mass distribution with excess pressure: the expansion give rise to a rarefied region ever bigger and sparse. This 'bubble' can be thought of as the expanding envelope of a Type II supernova.

Gas outflows surrounding young stellar objects have for several years challenged the wits of theorists. The problem is easily perceived when contrasting, on the one hand, the theoretical bias for tractable, isotropic outflows, and on the other, the commonly observed collimated or otherwise anisotropic gaseous structures expanding about a central hot source. Models of the phenomena have invariably fallen into either of two categories, one based on hydrodynamics, the other on magnetohydrodynamics. Recent observations of strong magnetic field lines in the atmosphere of T Tauri stars appear to tilt the balance in favour of the MHD camp. Motivated by such observations, *C.M. Boily* extended the work of D. Lynden-Bell on scale-free, wound magnetostatics, to the case of collimated quadrupolar configurations. These are configurations of nearly cylindrical geometry. The quadrupolar field is rooted on the inside of a sphere which is then blown up to fill the entire space. Near the pole, the foot-points are twisted and the field lines wind up about the axis. The lines of constant flux describe cylindrical surfaces which open up at large z. The toroidal flux initially concentrated at the pole is released after a mean twist of $141^\circ.5$. When a dipolar field is substituted for the quadrupole, the solutions remain cylindrical everywhere and are known in algebraic form.

C.M. Boily's solutions offer a means to confine gas outflows, however he did not include any gas in his calculations. Is it possible to construct wound collimated fields that carry currents away from the source? R.V.E. Lovelace and *C.M. Boily* have constructed such scale-free magnetostatic solutions, based on the 'small p' solution of D. Lynden-Bell. Here an open magnetic field reverses across a neutral layer of conical shape carrying current loops. When a poloidal current component is added, the surface bends in until it becomes a cylinder away from the source. The radius of the cylinder is fixed by the intensity of the poloidal current. Such collimated open structures have applications to outflows observed around young stars and also to galactic jets.

Star formation in galaxies :

When a starburst occurs in a galaxy, ultraviolet (UV) radiation from young massive stars can compress gas in the surrounding regions, triggering further star formation. A wave of star formation, therefore, propagates through regions containing adequate amount of gas. The process is self-regulating because as the flux of UV radiation increases to a critical value, clouds in which further star formation can take place are destroyed. The result of these complex processes is that the properties of the star bursts region are quite different from those expected if the star bursts occurred without any propagation or regulation. V. Korchagin in collaboration with *A.K. Kembhavi*, T.P. Prabhu and Y.D. Mayya, has carried out a detailed study of self regulated star formation and shown that the evolution of the colour of such regions is consistent with observations.

Pulsar simulations :

Radio pulsars and neutron stars which rotate very rapidly have very strong magnetic fields. The rotation leads to emission of radio waves and a small fraction of this energy is beamed in a narrow cone which sweeps the sky. Hundreds of pulsars are now known and their statistical study leads to important inferences about the intrinsic properties of pulsars as well as their distribution in the Galaxy. One of the important questions related to the magnetic field is whether this decays with time, and if it does, whether there is any value at which it becomes constant. It is possible to simulate the population of pulsars under different assumptions about the magnetic field as well as other parameters, and to compare this statistically with the observed population. The parameter values which produce the best coincidence with the simulated and observed population are then taken to be the right ones. *A.K. Kembhavi* has been collaborating with Soma Mukherjee on a project where such simulations are carried out using different statistical techniques in one or two dimensional parameters base.

It is believed that the progenitors of binary and millisecond pulsars are X-ray binary systems. A number of scenarios have been developed which lead to the evolution of massive and low mass X-ray binaries to different such states. There are, however, a number of shortcomings to the scenarios and there is a need to look for other progenitors. It has been suggested that triple systems, which are fairly common, can provide the basis for additional scenarios which could be more consistent with observations. If a third body moves around an X-ray binary, it can produce fluctuations in the separation between the components of the binary, which leads to a fluctuation in the observed X-ray intensity. *A.K. Kembhavi* and *C.M. Boily* in collaboration with Rosanne di Stefano have been using numerical codes to study triple systems over the long period of time. Calculations show that semi analytical inferences which have been made before by different investigations are correct only for small regions of the total available parameter space. The numerical calculations lead to new patterns of behaviour.

Photospallation and pulsar companions :

The process of photospallation, in which high energy photons spallate heavy nuclei down to lighter elements, has been shown to be important in the regions near active galactic nuclei, and in cosmological nucleosynthesis. *B.Nath* and Eichler have found that photospallation can also be relevant in the vicinity of pulsars with companion stars. High energy photons emitted by a pulsar impinging on the surface of its companion can alter the abundances of light elements of the latter.

The exact nature of the high energy emission from pulsars, and what fraction of the total spin down power is emitted in high energy photons (MeV), are still unknown. These authors have studied the effects of high energy radiation (with energy more than 20 MeV) from pulsars on the surface abundances of their companions, if any, and found that the light element abundances of the companions can be useful diagnostics of the high energy emission of pulsars.

Neural networks and stellar physics :

The concept of stellar populations in our Galaxy and nearby stellar systems relies on basic stellar properties, which in turn can be determined from photometric and spectroscopic observations of individual stars.

R. Gulati and *R. Gupta* are involved in continuing effort to determine these properties in a homogeneous and efficient way. As a part of this project, they have now explored the potential of artificial neural networks (ANN) for classification of stellar spectra in optical and ultraviolet domain. Further optimisation of ANN architectures have been tried in collaboration with the neural network group of ISI, Calcutta, in collaboration with U. Bhattacharya, Soma Mukherjee and S. Parui.

They are extending this scheme to a large database acquired from a French group who have observed about 10,000 spectra for about 3,000 stars with Marly spectrograph attached to their 1.2 metre telescope at the Observatoire De Haute Provence (OHP), Saint Michel, France. Since these spectra were obtained to complement radial velocity information to accurate measurements of parallaxes with Hipparcos astrometry mission, there is a need to include MK templates in order to classify them in terms of MK classes and to identify peculiar stars. Observations of these templates have been planned for this summer which will be done at the OHP. Classification of this large sample together with their accurate distances will allow R. Gulati, R. Gupta and their collaborators to distribute them on the HR diagram and to constrain stellar evolutionary models.

Another aspect of this study is to tie information on stellar atmospheric parameters and this can be done by comparing an observed spectrum with one generated by using theoretical stellar model atmospheres. This aspect is being pursued by making spectroscopic observations of cool stars for which atmospheric parameters have been compiled in the Cayrel catalogue. First phase of the observations were done from the 2.3 m VBT at VBO, Kavalur. The data is reduced and automated procedure is being developed to determine atmospheric parameters in homogeneous way. Second phase of observations will be carried out in March 1995. This work is carried out by *R. Gulati, R. Gupta* and N. K. Rao.

In collaboration with Gerbaldi and Faraggiana, a systematic study of physical properties of peculiar stars has been initiated in order to understand their evolutionary status. The ground work on this project has already been done and towards this direction, a library of these objects observed with the International Ultraviolet Explorer at low and high dispersion is set up. Theoretical tools involving Kurucz stellar model atmospheres and spectrum synthesis using his exhaustive line list have been tested on the standard star Vega.

Past interest on synthesis of spectral indices diagnostic of stellar populations in early type stellar systems has been pursued in collaboration with Miguel Chavez (SISSA).

Instrumentation

Imaging polarimeter :

The polarisation of light emitted by astronomical objects can serve as an important diagnostic regarding the properties of the source. However, such measurements used to be difficult and time consuming because of the low levels of polarisation found in astronomical objects. Modern CCDs with excellent stability and high quantum efficiency make it possible to tackle this difficult task comparatively easily. An Imaging Polarimeter (IMPOL) is being developed at IUCAA, which should allow linear polarization studies of extended astrophysical sources like dark molecular clouds, reflection nebulae. *R. Gupta, A.N. Ramaprakash, S.N. Tandon* and A.K. Sen are involved in the project. The instrument offers a field of view corresponding to 30 mm diameter at the focal plane of the telescope ($\phi \sim 3$ arcminutes for a 1.2 m, f/13 telescope) and should be capable of measuring polarisation as low as one percent. To enable long exposures, an integrated telescope guidance system, which is capable of looking for a guide star within a field corresponding to 100 mm $\times$ 40 mm, at the focal plane of the telescope, will also be included.

The design of the optical system of the instrument was completed during the early part of last year. The various optical elements required for the instrument had been procured and tests to verify the performance of these elements had been carried out in the laboratory. The IMPOL optical system was set up on the optical bench in the laboratory and the various tests and optimisations were carried out.

The electronic hardware for instrument control is now being assembled and tested in the laboratory. The instrument control system is based on a 8051 microcontroller card, which receives commands from a PC and carries out the various low-level control tasks. All the control operations are executed in closed-loop mode to ensure accuracy and reliability.

The detailed engineering drawings for the mechanical structure have been prepared and the fabrication is underway. Since the mechanical structure of the instrument is as crucial in determining the instrument performance as any other part, extreme care has been given to its design and rigid tolerances have been prescribed for the fabrication. The various tools required for assembling and testing the instrument in the laboratory are also being fabricated.

The work on writing the instrument control software has begun. This software, which is being written in Turbo C, provides the user interface through a PC, and generates the sequence of commands which are transmitted to the microcontroller card through an asynchronous serial interface.

The CCD camera system to be used for data acquisition in the instrument, is also being developed at IUCAA. The progress in this work is given elsewhere in this report.

Automated Photoeletric Telescope (APT) :

One of the ways of increasing efficiency of routine tasks is automation under the control of a computer. Thus, photometric observations of selected stars can be carried out very efficiently by an automated telescope. Motivated by the need to provide an efficient tool for photometric observations to the interested groups at our universities, IUCAA has taken up the development of a small APT. The telescope is built around the 14 inch aperture optical tube of Celestron's C14 telescope and it is designed to carry out observations under computer control. The APT passed through several important stages in its development during the last year. *R. Gupta, A.N. Ramaprakash* and *S.N. Tandon* are involved in the programme.

The writing of the code for the APT instrument control software has been completed. (This work was mainly done by Ratnakar Deo, as part of his M. Tech. project and by Sumesh Jaiswal, from IIT, Kanpur.) The software allows the telescope to be used in two modes, manual and automatic. At present, the various operations of the manual mode have been field tested and are working satisfactorily.

The photometer to be used in the telescope is fully operational now. In addition to an online display of the photometric counts, this photometer also has a signal outlet, which can be used for data-acquisition with a PC. The photometer is designed in such a way that a beam-splitter can be introduced into the beam path. This facility is used in the APT to divert 10% of the incoming beam to the CCD camera used for guiding the telescope.

The telescope guiding system has been incorporated into the APT system and its performance tested. This unit is capable of acquiring the star from within a field of view of about an arcminute in diameter, and centering it in the field with an accuracy of about 10 arcseconds.

Currently, field tests are being carried out to determine the pointing accuracy of the instrument. Initial results indicate that the pointing accuracy is worse than the expected 2 arcminutes, by a factor of about 3. This is mainly attributed to the fact that, the instrument being a prototype, there have been some flaws in the design and fabrication of the mechanical structure. These problems have now been identified, and have been rectified in the version of the APT to be built by the university groups. Meanwhile, steps are being taken to improve the performance of the prototype unit itself.

M.N. Anandaram, a senior associate of IUCAA, and his collaborators from the Bangalore University have got financial support from the Department of Science and Technology to develop a telescope for their own use. They have successfully completed the assembling of the photometer and have started work on assembling the telescope in IUCAA's laboratory.

(II) RESEARCH WORK BY ASSOCIATES

S.M. Alladin: In collaboration with V.R. Venugopal and K.S.V.S. Narasimhan, the relationship between tidal effects and radio activity in compact groups of galaxies, was empirically investigated. It is found that the tidal effects of the group as a whole, are more important than the tidal effect of the nearest neighbour in enhancing the radio activity of a galaxy in the group. With S.G. Tagare and N. Hasan, he studied analytically the scattering phenomena in parabolic encounters of a single star with a binary.

R.E. Amritkar has shown that the adaptive control procedure where a parameter is changed can be used to synchronize different chaotic signals. This was done by introducing a proper damping mechanism. A control mechanism was found to enhance the efficiency of mixing in chaotic flows. The control mechanism uses small changes in system parameter in regions of phase space where the local Lyapunov exponent is small. A substantial enhancement of mixing efficiency was obtained even when the parameter change is small.

M.N. Anandaram and B.A. Kagali have completed the contruction of a stellar photometer at the IUCAA Instrumentation Laboratory and have found its performance in lab tests to be satisfactory. Its filter slide assembly was also completed. The mechanical assembly of the base support and polar shaft assembly have also been completed. The task of attaching the fork arm and the optical tube will now be taken up.

A. Banerjee: The major part of his work was devoted to the study of inhomogeneous perfect fluid cosmological models with or without cosmological constant in five dimensional spacetime. Here, the standard three space is assumed to be isotropic and homogeneous, while the fifth dimension depends on both space and time coordinates. Such higher dimensional spacetime at late stage becomes effectively the usual four dimensional spacetime in the sense that the extra dimension becomes unobservably small as a consequence of the dimensional reduction.

S. Banerji has considered the model of a spherical void containing low density heat conducting fluid surrounded by a thick spherical shell of radiation embedded in a Robertson-Walker universe with flat space sections. He assumes the R-W universe to be filled with a perfect fluid with a linear equation of state. The matching conditions indicate that the void goes on contracting as the universe expands until it collapses to a point. However, if the pressure in the external universe vanishes, the void remains static.

D.K. Chakraborty: The images of several galaxies, obtained in V, R and I photometric bands, using 1m UPSO telescope, were analysed. He also studied some general relativistic effects on the dynamics of fluid disks rotating around a Schwarzschild black hole and stability of rotating fluid disks using a variational principle.

Suresh Chandra has been working on the molecules observed in the interstellar molecular clouds and circumstellar envelopes of evolved stars. In particular, he has been working on CS molecule found in IRC +10216, both in the ground and vibrationally excited states.

P. Das Gupta: The electric and magnetic duality that is exhibited by the extended Maxwell equations is gauged by introducing a complex scalar field, and it is shown that if there is a spontaneous symmetry breaking in the scalar field sector, one recovers the standard electrodynamics without magnetic charges. In this model, electric charge arises by virtue of symmetry breaking. In the framework of extended inflation, it is shown that by including accretion of matter by primordial blackholes, significant amount of excess baryons can be generated after the electroweak phase transition. It is also argued that collision of bubble walls can lead to formation of primordial blackholes that have relativistic speeds immediately after their births.

S.S. De: By incorporating the "changing gravity approach", he has shown that the "zero" cosmological constant is a natural consequence of the present approach of the very early cosmological history where matter has been originated from the initial anisotropic perturbation of the Minkowski spacetime.

M.C. Durgapal studied the problem of shear-free structures in GR. He has shown that if the uniform density sphere is isentropic or (and) the temperature at the surface remains constant, the pressure must vanish. If the sphere is neither isentropic nor it has a constant surface temperature, then the solutions are not consistent with the baryon-conservation law and no-heat-flow condition. The other problem under study is of isentropic fluids in general. The preliminary results show that isentropic fluid represents either FLRW type cosmological model or static structures.

D.P. Dutta: The work on the project 'Berry phase in semiclassical gravity' has been successfully generalized. Several issues related to the origin and validity of the semiclassical Einstein equations, the concept of time and decoherence in quantum cosmology, particle production and the corresponding back reactions in a cosmological background are considered and interpreted from a new angle. Interesting new light is shed on the gravitational properties of the vacuum energy. It is pointed out that some of the predictions made in this context may even be experimentally testable in atomic/molecular physics.

A. Goyal: Bounds on neutrino mass and magnetic moment from SN1987A have been computed by assuming exotic core composition namely, (a) presence of quasi-free pions, (b) neutral and charged pion condensate and (c) strange quark matter. Bulk properties of strange matter like viscosity and stability under strong magnetic field have been studied. The former is important in studying the damping of pulsations of newly formed neutron stars and leads to the maximum rotation rate of the pulsar.

P. Khare: Models for galactic halos giving rise to quasar absorption lines at redshifts between 1.0 and 2.0 were studied. A detailed comparison between model predictions and observed statistical properties of absorption lines was made. High resolution observations of Lyman alpha absorption lines of 8 quasars were analysed. It was shown that Lyman alpha forest absorption lines cluster at scales of few hundred kms. per sec. It was further shown that lines of sight passing through H II regions in absorbing galaxies can atmost produce 10% of the observed absorption systems.

P.S. Naik has designed and constructed low noise amplifying circuitary (Analog Card) with variable time constants and tested for its RMS noise current in collaboration with Instrumentation Laboratory of IUCAA. It is observed that the noise current is of the order of expectation value of 10 FA. Further, a digital display board has been fabricated in order to digitise the output and converting it to suitable frequency using VFC. Display card and analog card were together tested and callibrated for 1 second and 8 seconds integration and they were found working satisfactorily. As per his proposal, it is necessary to procure 8" - C8 plus Celestron telescope with standard accessories, ST-4 CCD camera and a personal computer AT 386 for CCD camera imaging analysis. Of these three permanent equipments, the first two have already been procured through IUCAA.

U. Narain: An update entitled "Chromospheric and coronal heating mechanicsm II" in collaboration with P. Ulmschneider (University of Heidelberg, Germany) has been completed and submitted to the Space Science Reviews. It reviews the literature from January 1990 to December 1994. Part of this work was done at IUCAA during September 1994, when P. Ulmschneider visited IUCAA.

S.K. Pandey: The research programme on surface photometric studies of galaxies is an ongoing collaborative activity with A.K. Kembhavi of IUCAA, V. Mohan of UPSO, and other colleagues and students at Pt. Ravishankar Shukla University, Raipur. This programme received a big boost with the installation of a SUN Sparc workstation at the university for the purpose of data analysis. The main emphasis of the work has been on the detailed investigations of isophotal shapes of elliptical galaxies to examine the presence of dustlanes, shells, ripples, tidal interactions, etc. embedded in otherwise smooth galaxies using various techniques. The analysis of isophotes of several elliptical galaxies led to detection of new faint features in some of them. Galaxy-galaxy interactions are known to cause dramatic changes in morphological structures and often induce large bursts of star formation activity. Imaging of the interacting ellipticals as well as spirals included in the existing data set with narrow band filters, e.g., H-alpha, and also in near infra-red band is proposed during the next observing session.

Observations of several early-type galaxies and low red shift radio-sources drawn from MRC were carried out at Las Campanas Observatory (Chile) of the Carnegie Institution of Washington during September 1994, using 1m & 2.5m telescopes equipped with CCD/IR camera in B-, R- and near - IR K - bands. The visit was jointly sponsored by IUCAA and Carnegie Institution of Washington. The near-IR images often reveal features in the galaxies that are hidden in optical images due to obscuring effects of the dust. By combining the near-IR and optical images, we hope to obtain the spatial colour distribution within the galaxies. Patrick McCarthy of the Carnegie Institute is also a collaborator in this programme.

U.S. Pandey: Tidal interaction of a central object in a binary system is studied. An object like a neutron star, which in close orbit, gets deformed and breaks and/or fractures due to tidal interaction of the companion. The equation of geodesic deviation for an infinitesimal, compressible, inhomogeneous self-gravitating object is considered in a slightly generalised form. Assuming the validity of Newtonian theory for the elastic structure of the orbiting body, a second order inhomogeneous differential equation is derived. The solution of this equation has also been obtained under slow rotation limit. This work is done in collaboration with the another associate S.S. Prasad.

S.S. Prasad has obtained two exact non-static solutions of Einstein's field equations for higher dimensional perfect fluid spheres admitting a one-parameter group of conformal motions. The first solution refers to 'n' dimensional spacetime which reduces to solution 1 of Herrera and Leon (J.Math.Phys. **26**, 778 (1985)) for $n = 4$. The solution is homogeneous and represents stiff matter with oscillatory matter variables. The other solution is for five dimensional spacetime. Both the solutions are shearing and fulfill the dominant energy condition.

A.K. Ray: Neutrino properties like its mass, magnetic moment and number of families have profound impact in understanding the solar neutrino deficit, atmospheric neutrinos, hot dark matter, primordial nucleosynthesis and the formation of large scale structures in the universe. Recently, it has been pointed out that the deficits in the solar and atmospheric neutrino fluxes and a need for significant component of hot dark matter can be simultaneously reconciled with three light neutrinos if they are almost degenerate with mass of about 2.5 eV. To obtain degenerate neutrino masses it has been shown that the mass matrix M_ν in the basis ν_L, ν_R^c, is given by

$$M_\nu = \begin{bmatrix} m_L & m_D \\ m_D & m_R \end{bmatrix}$$

In a recent work, he has achieved the same scenario of neutrino masses in the context of an extended partially ununified model (PUM) based on the gauge group $SU(2)_{qL} \times SU(2)_{lL} \times U(1)_Y$ including with $Z_3 \times Z_4$ discrete symmetries with appropriate Higgs fields. The model yields Majorana neutrinos of almost degenerate masses of the order of 4 eV and transition magnetic moment of the order of $10^{-11}{}_{\mu B}$. In another work, he has demonstrated that almost degenerate Dirac neutrinos of mass of the order of a few eV can be obtained in a left-right symmetric model (LRM) based on the gauge group $SU(2)_L \times SU(2)_R \times U(1)_{B-L}$ with a discrete symmetry and appropriate Higgs fields. These results are interesting in view of the fact that both the models PUM and LRM, including the proposed symmetries, have an intermediate mass scale of a few TeV contrary to 10^{12} - 10^{13} GeV required in the GUT type models.

K. Shankara Sastry has been working on the formulation of a classification scheme for galactic collisions based on the observable and measurable parameters to give an observational tinge to the qualitative classification. This work is being done in collaboration with K.S.V.S. Narasimhan. The observational data required for the above work is being collected from the Astronomical Data Centre, IUCAA.

D.C. Srivastava: Pulsars are one of the important and interesting objects among continuous sources of the gravitational radiation (GR). The GR emitted by a pulsar is about two orders of magnitudes smaller than the sensitivity of present day laser interferometric detectors. However, one can achieve an enhancement of signal to noise ratio (SNR) of the detector by extending the observations for a longer time, say, for about a year. Besides optically active pulsars, there may be old pulsars which are optically unknown and whose number is estimated to be about a thousand corresponding to a currently known active pulsar and that too at a distance of about 10 parsecs. The search of these pulsars over all sky and all frequency is an important problem in the context of the detection of GR.

In order to achieve larger SNR, the observations are made for about a year and accordingly the motion of Earth viz., its rotation about its axis, revolution around the Sun and about the Moon becomes important and results in the appreciable Doppler shift of the GR. Because of this, the angular resolution of the pulsar results into a patch on the sky about the source direction so as to have the same Doppler correction. The problem of all sky search concerns in knowing the minimum number of such patches so as to cover the whole sky. An estimate of independent patches, as made by B.F. Schutz (1991) is 1.3×10^{13}.

S.K. Srivastava: A study of higher - derivative gravity shows that, at high energy level, the Ricci scalar behaves like a spinless matter field in addition to its usual nature as a geometrical field. Material aspect of Ricci scalar is manifested through scalar fields representing spinless particles, called Riccions.

R.K. Thakur: Work on the gravitational collapse, the origin of the big-bang and the horizon problem in cosmology were continued. The relevance of Pauli's exclusion principle and the uncertainty principle has been discussed in this connection.

L.K. Patel and R. Tikekar: A study of inhomogeneous cosmological models filled with a non-thermalised perfect fluid has been undertaken. Assuming that the background spacetime admits two space-like commuting Killing vector fields, endowed with metric coefficients as separable functions of space and time variables, a general class of such models has been obtained, which has a rich singularity structure that depends on the choice of the parameters and the metric functions. A number of previously known perfect fluid models such as those obtained by Ruiz and Senovilla, Dadhich, Patel and Tikekar follow as particular cases of this class.

Spacetime metrics corresponding to radiating blackholes with global monopole in Einstein's Universe and the de Sitter universe complying with the requirements of Einstein's field equations have been obtained and their geometrical and physical features have been examined.

D.B. Vaidya: Dust grains nucleating in a stellar atmosphere are subject to outward acceleration and due to grain-grain collisions are likely to arrive in the interstellar medium with a distribution of sizes. Using a radiative model, he has analysed the IRAS data on a few oxygen-rich (AGB) Mira variable stars and have estimated the grain size distributions in the circumstellar dust shells of these stars. His results show that the size distributions in the circumstellar dust shells of these stars follow the power law [i.e. $n(a) \propto a^{-p}$, with $p = 3.0$ to 3.5]. This is consistent with the size distribution found for the interstellar as well as the interplanetary dust. Further analysis on few more stars is in progress. He has analysed extinction curves of 30 stars, derived from the low dispersion IUE spectra. In this analysis, he compares the values of the colour excesses and the shapes of the extinction in the visual, the 2200 A hump and the FUV region. Further, using the discrete dipole approximation, he calculates the extinction for the graphite particles to model the 2200 A hump. From the analysis of the extinction curves he finds that the 2200 A hump is well correlated with the visual extinction but there is no correlation between the FUV extinction and the 2200 A hump or the visual extinction. This suggests that several dust components are required to explain the extinction in this region. His calculations on the extinction show that small graphite particles do not produce the 2200 A hump satisfactorily. It seems likely that very special types of particles (porous or fluffy) are required to produce the 2200 A hump and the FUV extinction. These calculations are in progress.

P.C. Vinodkumar: Based on a relativistic confinement model for coloured quarks and gluons, hadronic masses in the open flavour are successfully calculated. The original model has been modified to incorporate the heavier sector also. From the successful predictions of the hadronic masses, the model parameters are related to the running coupling constant as expected heuristically for any confinement mechanism.

(III) Ph.D. THESES

Two of our first batch of research scholars, *Debiprosad Duari* and *Kanti Jotania*, have submitted their Ph.D. theses to the University of Pune. The abstracts of the theses are given below:

Statistical studies of the redshifts of spectral lines of quasi-stellar objects

by *Debiprosad Duari*

In 1929, Edwin Hubble found his velocity-distance relation for extragalactic nebulae, which soon became the foundation of modern observational cosmology. The velocity of recession of an extragalactic object , which can be measured in terms of the redshift, became a distance indicator of these objects, with the standard interpretation that the redshift arises from the expansion of the universe. This principle has often been referred to as the Cosmological Hypothesis (CH).

An alternative hypothesis has always existed, as a minority opinion that has consistently argued against the cosmological nature of QSO redshifts. This point of view is based on certain observations which go against the CH. The minority opinion is, therefore, that the QSO redshifts are not of cosmological origin. We may term this as the Local Hypothesis (LH).

This viewpoint has motivated a number of people to analyse the redshift distributions of QSOs, both emission and absorption, thereby checking the discrepancies between the observations and the theoretical predictions based on the CH, but the arguements between the proponents of the CH and the LH have continued to remain inconclusive. Keeping these arguements and controversies in the background, this thesis tries to investigate the various observational results regarding QSO redshifts and tries to verify the theoretical predictions of the CH vis-a-vis the observations.

The thesis consists of two sections. The first section is devoted to the statistical study of the emission redshifts of QSOs. In the second section, the question of the origin of the absorption features found in a typical QSO spectra is dealt with, by means of various statistical tests performed on the latest compilation of QSO absorption systems.

There have been claims from time to time that there are periodicities in the redshift distribution of QSOs. These claims are examined here using various statistical tests on the 2164 QSO redshifts from Hewitt-Burbidge catalogue '93. The tests include the power spectrum analysis, the generalized Rayleigh test and the Kolmogorv-Smirnov test and a specially constructed new test, the 'Comb-Template' test. All the above four tests reveal strong evidence, in terms of various statistical significance levels, for periodicities of ξ = 0.0565. When the redshift values are transformed into the galacto-centric frame, it is found that the confidence level of the periodicity $\xi = 0.0565$ marginally increases.

We have also performed a large number of Monte Carlo simulations of the QSO redshift distribution and the result shows that the presence of the periodicity being a chance is very remote. The presence of this periodicity is very puzzling in view of the cosmological principle, according to which the universe is not only isotropic but homogeneous also over a large distance scale.

Next we have considered the metal line absorption systems found in the spectra of QSOs and analysed their redshifts to examine the hypothesis that the heavy element absorption line systems in QSO spectra originate through en-route absorption by intervening galaxies, halos, etc. Statistical tests are applied, mainly in two different ways to compare the predictions of the intervening galaxies hypothesis (IGH) with the actual observations (Junkkarinen, Hewitt and Burbidge 1991). In one method, the expected frequency distribution of multiple line systems is compared. In the other, the expected redshift distributions of CIV and MgII systems are examined. On both these counts, considerable gap is found between the predictions of the IGH and the actual observations even after considering any effect of clustering of absorbers, invoking evolution in the number density of the absorbers, allowing for the inhomogenity of samples examined and possible selection effects.

In the second part of the work, the question of the origin of the absorption features that are commonly seen in QSO spectra is examined. Statistical tests carried out here to test the intervening galaxies hypothesis are those proposed by Bachall and Peebles (1969). In this section, each of the 208 QSO spectrum has been examined for determining the redshift coverage while performing the statistical tests. Here we have examined CIV absorption systems and used the data in two statistical tests to check the hypothesis that the absorption system arises in the intervening material along the line of sight to the QSO.

The various tests carried out in this section bring out the fact that although the IGH is a natural explanation to account for the absorption features, it does not seem to account for the effect entirely.

The present statistical tests applied on the emission and absorption redshift distributions of QSOs, therefore, highlights to the fact that all is not well with the general consensus regarding the CH and the IGH, and that some new inputs to the QSO-astronomy are needed. Any theory of redshifts, whether intrinsic or cosmological, will find in these results a stiff challenge.

Some aspects of gravitational wave signal analysis from coalescing binaries and pulsars

by *Kanti Jotania*

This thesis presents some aspects of gravitational wave (GW) data analysis for ground based highly sensitive laser interferometric detectors like LIGO, VIRGO, AIGO, etc. for two important astrophysical sources,: (i) coalescing binaries, and (ii) pulsars.

The signal to noise ratios (SNRs) are

computed for GW signals from coalescing binary in the post-Newtonian (PN) approximation using matched filtering techniques. It is shown that up to the first PN order, on the whole, the SNRs are reduced for white noise and power recycling noise of the detectors for a wide range of parameters for arbitrary orientations of the detector and source.

However, to take full advantage of this technique, it is necessary that the coalescing binary waveform be known to a very high degree of accuracy. This means, one should include as many PN terms as possible in constructing the templates. When PN corrections are included, the function space of waveforms acquires an extra dimension. Our study shows that when first PN corrections are included in the phase of the waveform it is possible to make a judicious choice of the parameters so that the *effective dimension* of the parameter space remains unchanged.

Since the typical pulsar source has low GW amplitude for getting an appreciable SNR, one needs long integration times ($T_{obs} = 10^7$ secs). This implies that the motion of the detector is important and should be included in the response. In this thesis, the noise free response of an arbitrary oriented detector has been calculated for the GW emitted by an arbitrarily oriented pulsar. There are two modulations appearing in the noise free response of the detector, namely, frequency modulation (FM) and amplitude modulation (AM). The FM smears out a monochromatic signal into a small bandwidth around the signal frequency of the monochromatic waves. In general, the AM results in about 40% drop in the amplitude of the signal as compared to the optimal incidence of the wave.

The effect of FM on the FT of signal is much more severe compared to AM. Analytical approximations to FT of the pulsar are also given.

(IV) PUBLICATIONS

• by IUCAA Academic Staff

[The publications are arranged alphabetically by the name of the IUCAA staff member, which is highlighted in the list of authors. When a paper is co-authored by an IUCAA staff member and an Associate/Senior Associate of IUCAA, the name of the latter is displayed in italics.]

a) Journals

Stirpe, G.M., C. Winge, B. Altieri, D. Alloin, E.L. Aguero, **G.C. Anupama**, R. Ashley, R. Bertram, H.J. Calderon, R.M. Catchpole et. al. (1994) Steps toward determination of the size and structure of the broad-line region in active galactic nuclei. VI. Variability of NGC 3783 from ground based data, Ap. J., **425**, 609.

Anupama, G.C. and S. Sethi (1994) Spectroscopy of the Recurrent Nova V3890 Sagittarii 18 days after the 1990 outburst, MNRAS, **269**, 105.

Balasubramanian, R. and **S. V. Dhurandhar** (1994) Performance of Newtonian filters for searching gravitational wave signals from coalescing binaries, Phys. Rev. **D 50**, 6080.

Chickarmane, V. and **Biplab Bhawal** (1994) Squeezing and recycling in laser interferometric gravitational wave detector, Phys. Lett., **A190**, 22.

Lynden-Bell, D. and **C.M. Boily** (1994) Self-similar solutions up to flashpoint in highly wound magnetostatics, MNRAS, **267**, 146.

Tikekar, R., L.K. Patel and **N. Dadhich** (1994) A class of cylindrically symmetric models in string cosmology, Gen. Rel. Grav. **26,** 647.

Daftardar, V. and **N. Dadhich** (1994) Gradient conformed killing vectors and exact solutions, Gen. Rel. Grav. **26,** 859.

Dadhich, N. (1994) On active and passive mass of a fluid sphere, J. Ind. Math. Soc. **64,** 68.

Dhurandhar, S.V. and B. F. Schutz (1994) Filtering coalescing binary signals: Issues concerning narrow banding, thresholds and optimal sampling, Phys. Rev. **D 50**, 2390.

Jotania, K. and **S. V. Dhurandhar** (1994) Noise-free response of a laser interferometric detector to gravitational waves from pulsars, Bull. Astr. Soc. India, **22**, 303.

Gulati, R.K., **R. Gupta**, P. Gothoskar and S. Khobragade (1994) Stellar spectral classification using automated schemes, Ap. J., **426**, 340.

Srivastava, N., **R.K. Gulati** and **N.C. Rana** (1994) Test of evolutionary models for stellar population studies, J. Astroph. Astron., **15**, 187.

Gulati, R.K., **R. Gupta**, P. Gothoskar and S. Khobragade (1994) Ultraviolet stellar spectral classification using multilevel tree neural network, Vistas in Astronomy, **38 (3)**, 293.

Frittelli, S., **S. Koshti**, E.T. Newman. and C. Rovelli (1994) Classical and quantum dynamics of the Faraday lines of force, Phys. Rev. **D 49**, 6883.

Munshi, D. and A.A. Starobinsky (1994) Nonlinear approximations to gravitational instability: A comparison in second-order perturbation theory, Ap. J., **428**, 433.

Munshi, D., **V. Sahni** and A.A. Starobinsky (1994) Nonlinear approximations to gravitational instability: A comparison in the quasi-linear regime, Ap. J., **436**, 517.

Narlikar, J.V. (1993) The role of mathematics in physical sciences, Bangladesh Journal of Mathematical and Physical Sciences, **2**, 19.

- (1994) Spectral shifts in general relativity, American J. of Phys. , **62**, No. 10, 903.

- (1995) How universal is Hubble's law?, Journal of the Indian Mathematical Society, **61**, 13.

Hoyle, F., G. Burbidge and **J.V. Narlikar** (1994) Astrophysical deductions from the quasi-steady-state cosmology, MNRAS, **267**, 1007.

- Further astrophysical quantities expected in a quasi-steady state universe, Astron. Astrophys. **289**, 729.

- (1995) The basic theory underlying the quasi-steady state cosmology, Proc. Roy. Soc. Lond. **A**, **448**, 191.

Hoyle F. and **J.V. Narlikar** (1995) Cosmology and Action at a distance electrodynamics, Rev. Mod. Phys. **61**, 113.

Nath, B. B. and P.L. Biermann (1994) Gamma radiation from stellar winds in Orion complex, MNRAS, **270**, L33.

Chiba, M., **B.B. Nath** (1994) Effects of photoionization on galaxy formation, Ap. J., **436**, 618.

Padmanabhan, T. (1994) Path integral for relativistic particle and harmonic oscillator, Found. Physics, **24**, 1543,

Nityananda R. and **T. Padmanabhan** (1994) Scaling properties of nonlinear gravitational clustering, MNRAS, **271**, 976.

Kumar A., **T. Padmanabhan** and K. Subramanian (1995) Neutral hydrogen at high redshifts as a probe of structure formation. II Line profiles of a protocluster, MNRAS, **272**, 544.

Rana, N.C. and M. Chandola (1994) Mass-luminosity ratio of nearby stars and its relation to baryonic dark matter, J. Astrophys. Astron. **15**, 193.

Rana, N.C. and A.D. Jana (1994) Metallicity distribution of F-dwarf stars in the solar neighbourhood, J. Astrophys. Astron. **15**, 197.

Mathew, T.K., S. Ramani and **N.C. Rana** (1994) The effect of enhanced ^{8}Li (α,n) ^{11}B reaction rate on primordial abundance of ^{7}Li, Ind. J. Phys. **67B** (2), 99.

Rana, N. C. and B. Gajria (1994) Stellar multiplicities and signatures of supernova-induced star formation in the Eta Carinae Nebula, Bull. Astron. Soc. Ind. **22**, 415.

Chakrabarty, S. and **N.C. Rana** (1994) Electron capture rates of light elements of astrophysical interest in the presence of a non-thermal tail of electron plasma, J. Phys. G: Nucl. Part. Phys. **20**, L117.

Sahni, V., B.S. Sathyaprakash, and Shandarin, S.F. (1994) The evolution of voids in the adhesion approximation, Ap. J., **421**, 20.

Blanchet, L. and **B.S. Sathyaprakash** (1994) Signal analysis of gravitational wave tails, Class. and Quant. Grav., **11**, 2807.

Sathyaprakash, B.S. (1994) Filtering post-Newtonian gravitational waves from coalescing binaries, Phys. Rev. **D 50**, R7111.

Blanchet, L. and **B.S. Sathyaprakash** (1994) Detecting a tail effect in gravitational wave experiments, Phys. Rev. Lett., **74**, 1067.

Seriu, M. and T.P. Singh (1994) On the relation between causality and topology in the semiclassical universe, Phys. Rev. **D 50**, 6165.

Majumdar, A., **S. Sethi**, S. Mahajan, A. Mukherjee, *N. Panchapakesan* and R. P. Saxena (1994) RG-improved bounds on Higgs Boson and top quark masses from electroweak baryogenesis, Mod. Phys. Lett. **A9**, 459.

Hu, B.L. and **S. Sinha** (1995) Fluctuation-dissipation relation for semiclassical gravity, Phys. Rev. **D51**, 1587.

Verma, R.P., R.S. Bisht, S.K. Ghosh, K.V.K. Iyengar, T.N. Rengarajan and **S.N. Tandon** (1994) Far-Infrared observations of three galactic star-forming regions, Astron. Astrophys., **284**, 936.

Valluri, M. (1994) A model for the declining rotation curves of cluster spiral galaxies, Ap. J., **430**, 101.

b) Proceedings

Gulati, R.K. (1994) Evolutional population models, *in* Abstracts of Dissertations for the "Dottorate" in Astronomy, Eds. M. Capaccioli and R. Fanti, 205 (La Citta Del Sole).

Malagnini M.L., C. Morossi, and **R.K. Gulati** (1994) Molecules in cool stars: an Atlas of synthetic spectra, *in* IAU Colloquium 146 : Molecular opacities in the stellar environment, Eds. Peter Thejll and Uffe G. Jorgensen, 79 (Springer-Verleg).

Jotania, K., S.V. Dhurandhar and S.R. Valluri (1994) Signal analysis of gravitational waveform of pulsars, *in* Proceedings of the Fifth Canadian Conference on General Relativity and Relativistic Astrophysics, Waterloo, May 13-15, 1993, Eds. R.B. Mann and R.G. McLenaghan, 406 (World Scientific Publishing).

G. Burbidge, F. Hoyle and **J.V. Narlikar** (1994) Quasi-steady state cosmology, *in* IAU Symposium 159 : Active Galactic Nuclei across the Electromagnetic Spectrum, Geneva, Switzerland, August 30 - September 3, 1993, Eds. T.J.-L. Courvoisier and A. Blecha, 293 (Kluwer Academic Publishers).

Narlikar, J.V. (1995) Bhutas: Some reflections on modern scientific concepts and traditional Indian thoughts, *in* Prakriti: The Integral Vision (The Nature of Matter), Ed. J.V. Narlikar, 1, **4** (Indira Gandhi National Centre for the Arts, New Delhi).

- (1995) Man, Nature and the Universe, *in* Prakriti: The Integral Vision (Man in Nature), Ed. B. Saraswati, 9, **5** (Indira Gandhi National Centre for the Arts, New Delhi).

Rana, N. C. and T. Mathews (1994) A comparison of the calculated and observed primordial abundances of the light elements, *in* Physics and Astrophysics of Quark-Gluon Plasma, ICPA-QGP'93, 215 (World Scientific Publishing).

c) Books

Authored/Edited

Narlikar, J.V. "Time machinechi kimaya" (1994) (in Marathi) [published by Sri Vidya Prakashan, Pune].

- "Vidnyangangechi Avakhal Valane" (1995) (in Marathi) [published by Manovikas Prakashan, Bombay].

- "Srushti vidnyan gatha : Ekvisavya Shatakacha Sangati" (1994) (in Marathi) [edited by **Narlikar, J.V.**, published by Rajhans Prakashan, Pune].

- "Prakriti : The Integral Vision in the Nature of Matter" (1995) [Vol. 4, edited by **Narlikar, J.V.**, published by Indira Gandhi National Centre for the Arts, New Delhi].

Narlikar, M.J. **and Narlikar, J.V.** "Ganitachi Gosht" (1994) (in Marathi) Samaj Shikshan Mala, 529, [published by Sarojini Babar, Pune].

Kochhar, Rajesh and **Narlikar, J.V.** "Astronomy in India - A perspective" (1995) [A diamond jubilee publication, Indian National Science Academy, New Delhi].

Vayada, N., Gandhi, S. and **Rana, N.C.** (1994) "Nightfall on a Sunny Morning" [Confederation of Indian Amateur Astronomers, Pune].

d) Book Reviews

Padmanabhan T. (1994) The Physics of Astrophysics (Vol. I and II) by F.H. Shu (Foundations of Physics, **24**, 3).

Narlikar, J.V. (1994) Home is Where the Wind Blows *by* Fred Hoyle (Times of India, August 13)

e) Popular Science Articles

Mahabal, A. (1994), When SL9 collides with Jupiter, (Hitavada, Nagpur, July 10).

Narlikar, J.V. (1994), Parsecstones in astronomy-6: The universality of the law of gravitation, (Khagol, No. 18, April).

- Secrets of the universe, was there a Big Bang?, (The Times of India, April 23).

- The Inter-University Centre for Astronomy and Astrophysics, (Southern Sky Magazine, May/June, 22).

- Jenva chakachi hava jate, (Tonic-94, 12).

- Parsecstones in astronomy-7: From Laplace to Leverrier: Further checks on Newton's gravity, (Khagol No. 19, July).

- Conformism vs originality : The dilemma of modern science, (The Times of India, July 30).

- A pattern of resistance - New ideas in astronomy, (The Statesman, Festival'94, Calcutta, 109).

- Fred Hoyle : Reaching for the stars, (The Times of India, August 13).

- Parsecstones in astronomy-8: The discovery of binary stars, (Khagol, No. 20, October)

- Signs in the sky - The irrationality of astrology, (The Times of India, October 22).

- Abbe' Georges Lemaitre : Father of the Primeval Atom, (Current Science, 67, 950).

- Mediocrity to the fore - Why scientists suffer in India, (The Times of India, November 26).

- Committee work in lieu of science, (The Times of India, December 12).

- Srishtividnyan gathechi gatha, (Ravivar Sakal, December 18).

- Srishtividnyan gathemagachi bhumika, (Maharashtra Times, Bombay, December 28).

- Parsecstones in astronomy-9: Stellar studies in bulk, (Khagol, No. 21, January)

- Eka udar manavatawadi sahityikachya sannidhyat, (Sakal, January 25, 4)

- Age of the universe - Did it have a beginning?, (The Times of India, New Delhi, January 30).

- Declining standards - The law of social thermodynamics, (The Times of India, February 22).

- An all-rounder, (Education, science and human values, Essays in honour of Professor D.S. Kothari, Eds. - R.C. Mehrotra, Ramesh K. Arora, published by Wiley Eastern Limited).

- Vaidnyanik drishtikonacha prasar, (9th Vidnyan Lekhak Shibir-93, 20).

- Jidnyasapurtisathi mahiticha bhandar, (Maharashtra Times, October 16).

- Cambridge : A tradition of excellence, (Science Reporter Festival Issue - 1994, 30).

- Recreational aspects in the study of mathematics, (Ramanujam birth anniversary programme souvenir, Date with Maths by Maths lovers, Pune, December 22, 9).

- The concept of a university, (India 2000 - Global Civilization and Cultural Roots, Wiley Eastern Ltd., New Delhi, February 5, 42).

- Vidnyangangechi avakhal valane, (Maharashtra Times, March 12).

- Ajachya Bharatat Agarkaranchi bhumika, (Lokasatta, Pune, March 19).

Nath, B. B. (1995) On the Hubble constant, (Sunday Review, The Times of India, February 12).

Padmanabhan T. (1994 & 1995) Windows to the sky, Cosmic Canvas - 16, (Economic Times, April 16).

- Seeing is believing, Cosmic Canvas - 17, (Economic Times, May 14).

- Heat in the sky, Cosmic Canvas - 18, (Economic Times, June 11).

- Celestial symphony, Cosmic Canvas - 19, (Economic Times, July 9).

- At the fringe of vision, Cosmic Canvas - 20, (Economic Times, August 13).

- The see-through universe, Cosmic Canvas - 21, (Economic Times, September 10).

- Tracking scintillating sparks, Cosmic Canvas - 22, (Economic Times, October 15).

- Bonfires in the sky, Cosmic Canvas - 23, (Economic Times, November 12).

- Time keepers of heaven, Cosmic Canvas - 24, (Economic Times, December 17).

- How I wonder what you are, Cosmic Canvas - 25, Economic Times, January 14).

- Black is not black, Cosmic Canvas - 26 (Economic Times, February 25).

- Jets in space, Cosmic Canvas - 27 (Economic Times, March 18).

A. Paranjpye Star Gazing, (Monthly feature, Indian Express, Pune, April 1994 to March 1995).

- Sky Corner, (Monthly feature, Science Reporter, Delhi, April 1994 to January 1995).

- Hya Mahinyache Akash, (Loksatta, Pune and

Bombay, February and March 1995)

- Shoemaker Levy 9 chi guru la bhet, (Sakal, June 25).

• by Associates/Senior Assosciates

[Publications co-authored by Associates/Senior Associates and a member of IUCAA staff appear in the previous section and are not repeated here].

a) Journals

John, J.K. and **R.E. Amritkar** (1994) Synchronization of unstable orbits using adaptive control, Phys. Rev. **E 49**, 4843.

Amritkar, R.E. (1994) Fractals and growth processes, Indian J. Pure Appl. Phys. **32**, 595.

Chatterjee, S., D. Panigrahi and **A. Banerjee** (1994) Inhomogeneous Kaluza Klein cosmology, Class. Quant. Grav., **11**, 371.

Banerjee, A., D. Panigrahi and S. Chatterjee (1994) A class of inhomogeneous cosmological models in Kaluza Klein space time, Class. Quant. Grav., **11**, 1405.

Banerjee, A., A. Sil and S. Chatterjee (1994) Gravitational collapse of inhomogeneous dust sphere in higher dimensional space time, Ap. J., **422**, 681.

- Motion of particles in five dimensional Kaluza Klein space time, J. Math. Phys., **35**, 2423.

Banerjee, A., S. Chatterjee, A. Sil and N. Banerjee (1994) Relativistic plasma in a homogeneous cosmological background, Phys. Rev. D., **50**, 1161.

Chakrabarty, S. (1994) Effect of strong magnetic field on the stability of dense nuclear and quark matter, Astrophys. and Space Sci., **213**, 121.

- On the possibility of stable droplets of strange quark matter at the core of neutron stars, Mod. Phys. Lett. A9, 187.

- On the possibility of low mass quark droplet stars, Mod. Phys. Lett. **A9**, 2691.

Chandra, S. and Lalan Prasad (1994) Magnetohydrostatic equilibrium in solar coronal arcades, Bull. Astron. Soc. India, **22**, 149.

Chandra, S. (1994) On collisional vibrational deexcitation rate constants $k_{1 \rightarrow 0}$ of diatomic molecules, Astrophys. and Space Sci., **218**, 29.

Chandra, S. and A.K. Sharma (1994) Einstein A-coefficients for rotational transitions in the HN^{+}_{20} , Pramana, **43**, 487.

Datta, D.P. (1994) Geometric gauge fields, particle production and time, Phys. Rev. **D 50**, 2605.

Goyal, A. and S. Dutta (1994) Flipped neutrino emissivity in strange quark matter, Phys. Rev. **D 49**, 3910.

- Flipped neutrino emissivity of hot plasma in supernova core, Phys. Rev. **D 49**, 5593.

Goyal, A., V.K. Gupta, J.D. Anand and Pragya (1994) Bulk viscosity of strange quark matter, Z.fur Physik, **A349**, 93.

Srianand, R. and **P. Khare** (1994) Halo model for intermediate redshift QSO absorption systems, Ap. J., **428**, 82.

- Evolutionary properties of Lyman alpha lines, MNRAS, **271**, 81.

Vaidya, P.C. and **L.K. Patel** (1995) A radiating Schwarzschild interior solution, J. Indian Math. Soc., **61**, 87.

Patel, L.K. and N.P. Mehta (1995) An exact solution for a static charged fluid sphere, J. Indian Math. Soc., **61**, 95.

Patel, L.K. and N.R. Pandya (1994) An inhomogeneous viscous-fluid cosmological model with heat flux, Maths Today, **12**, 19.

Patel, L.K. and Laxmi Desai (1994) Plane symmetric viscous-fluid cosmological models with heat flux, Int. J. Mod. Phys. **D3**, 639.

Reddy, R.R. (1994) The correlation between average nuclear effective charge, refractive index, standard heat of atomization and melting point in tetrahedral semiconductors, Journal of Physics & Chemistry (Great Britain), **55**, 523.

Reddy, R.R. (1995) Relationship between refractive index, optical electronegativities and electronic poolarizability in alkali halides, III-V, II-VI group semiconductors, Crystal Research Technology (Berlin) **30**, 263.

Singh, T. (1994) A unified approach to charged fluid distributions in general relativity, Nuove Cimento B (Italy), **109B**.

- Exact solutions for homogeneous time dependent magneto fluids, Hadronic J. (USA), **17**, 441.

- Stationary universes in general relativity and Lyra's geometry forts, Phys. (Germany), **42**, 71.

Tikekar, R. (1994) A class of exact solutions of Einstein equations in higher dimensional space times, J. Ind. Math. Soc. **61**, 37.

Vinodkumar, P.C. and S.B. Khadkikar (1994) Gauge constraints : A probable basis for phenomenological confinement models, Physics Lett. **B 329**, 81 [Errata in **340**, 264].

b) Proceedings

Roy, M. and **R.E. Amritkar** (1994) Boundary effects in Z-dimensional coupled map lattices, *in* Proceedings of seminar on computational aspects in chaos and non-linear dynamics, Eds. G. Ambica and V.M. Nandakumaran, 151 (Wiley Eastern).

(V) PEDAGOGICAL ACTIVITIES

a) IUCAA-NCRA Graduate School

S.V. Dhurandhar	Mathematical Physics
A.K. Kembhavi	Galactic and Interstellar Medium
T. Padmanabhan	(a) Aspects of Quantum Field Theory, (b) Advanced Astrophysical Processes
V. Sahni	Extragalactic Astronomy and Cosmology
B.S. Sathyaprakash	Mathematical Physics
S.N. Tandon	Observational Astronomy

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

J.V. Narlikar	Astrophysics I
S. Sinha	Astrophysics II
R. Gupta	*Practicals*
G.C. Anupama	Astrophysics I
S.V. Dhurandhar	Astrophysics II

c) Supervision of Projects

G.C. Anupama	R. Indira (VSP) *Space density of galactic novae*
	S.V. Singasane (B.Sc.) D.K. Trivedi (M.Sc.) *Accretion discs*
B. Bhawal	V. Aji (M.Sc.) *Gravitational radiation from binary pulsars*
S.V. Dhurandhar	A. Oke (VSP) *Signal analysis*
	K. Dave (M.Sc.) S. Das (M.Sc.) *Gravitational waves*

R. Mukund (M.Sc.)
Gravitational waves

Trushant (M.Sc.)
Optimum orientation of the resonant bar antenna for a pulsar source

D. Bhoite, P. Deshpande (School Students Summer Programme)
Making a carbon microphone

R.K. Gulati

A. Dixit, S. Chatterjee (B.Tech.)
Stellar spectral classification of ultraviolet spectra using neural networks

A.A. Mahabal

D.S. Deshpande, J.V. Gokhale, P.P. Dhere, S.R. Pawar (School Students' Summer Programme)
Solar system

B.B. Nath

E.R. Binu (M.Sc.)
Physical state of the intergalactic medium and COBE measurements

T. Padmanabhan

N. Shah (M.Sc.)
Path integrals

S. Jha (VSP)
Effective action in quantum mechanics

S. Sankararaman (B.Sc.)
Interesting optical phenomena in the atmosphere

N.C. Rana

P. Tantry (VSP)
A study of star formation rates in 62 nearby spiral galaxies

A. Apte (M.Sc.)
Entropy content of the nuclear species and the radiation just before the primordial nucleosynthesis

H. Deshpande (M.Sc.)
Characteristics of main-sequence and post-main-sequence stars from their model evolutions

D. Agashe (B.Sc.)
A study of the p-p chain reactions in the context of stellar nucleosynthesis

A. Athani (B.Sc.)
A study of the Balmer discontinuity in a sample of nearby stars

B.S. Sathyaprakash

A. R. Oke (B.Tech.)
Chirplets - A wavelet basis for the detection of gravitational waves from coalescing binaries

S. Sinha

S. Gupta (DST)
Manisha Marathe (DST)
Cosmological models

R. Khshirsagar (VSP)
Particle production in cosmological spacetimes

S.N. Tandon

S. Jaiswal (Summer Research Fellow, JNC, Bangalore)
Development of software for scheduling and controlling an automatic photoelectric telescope

	A. Saxena (VSP) *CCD - defects and parameters*
M. Valluri	N. Kakatdar (B.E.) S.G. Kakati (M.Sc.) *Gravitational N-body problem*

d) Supervision of Thesis

J.V. Narlikar

D. Duari (1995) qualified for the Ph.D. degree of Pune University for his thesis on *Statistical Studies of the Redshifts of Spectral Lines of Quasi-Stellar Objects*

e) Tutorial Assistantship

J.S. Bagla

Astrophysics I, M.Sc. (Physics), University of Pune (for J.V. Narlikar).

Electrodynamics and Radiative Processes, IUCAA-NCRA Graduate School (for M. Vivekanand, NCRA).

R. Balasubramanian

Mathematical Physics, IUCAA-NCRA Graduate School (for S.V Dhurandhar and B.S Sathyaprakash).

C. Boily

Galactic and Interstellar Medium, IUCAA-NCRA Graduate School (for A.K. Kembhavi).

V. Chickarmane

Quantum and Statistical Mechanics, IUCAA-NCRA Graduate School (for K. Subramanian, NCRA).

S. Sethi

Extragalactic Astronomy and Cosmology, IUCAA-NCRA Graduate School (for V. Sahni).

(VI) IUCAA Colloquia, Seminars, etc.

a) Colloquia

S. Modak: *Encyclopedia genetica*, April 7.

S.R. Gadre: *Molecular electrostatics*, April 18.

D.D. Bhawalkar: *Laser fusion*, May 2.

B. Jones: *The origin of large scale cosmic structures*, July 26.

D. Lynden-Bell: *Mach's principle*, August 8.

T. Padmanabhan: *What is the problem in quantizing gravity?*, August 29.

P. Ulmschneider: *Is there intelligent life outside the solar system?*, September 12.

V. Sitaramam: *Why does the sperm die?*, October 17.

S.B. Ogale: *Superconductivity and magnetism - a strange relationship!*, December 5.

K.R. Parthasarathy: *Brownian motion and some applications*, December 12.

K. Wali: *Non-commutative geometry: Is it the Riemannian geometry of particle physics?*, December 26.

A. Ashtekar: *Glimpses in quantum geometry*, December 28.

D. Lal: *Cosmic rays and planetary sciences*, January 19.

S.V. Damle: *Ways and means of space research :*

Scientific balloon - A poor man's satellite, February 20.

b) Seminars

T.K. Menon: *Galaxy interactions and origin of radio sources*, April 21.

Supurna Sinha: *Brownian motion and magnetism*, May 4.

S. Joseph: *Fractional spin from gravity*, May 10.

N. Ratnashree: *Approach to stability of radio pulsar profiles*, May 17.

Sukanya Sinha: *A fluctuation-dissipation relation for semiclassical cosmology*, May 19.

S.D. Mohanty: *Non-locality of the Lagrangian evolution of the Weyl tensor*, May 26; *A modified periodogram analysis of the gravitational wave signal from a coalescing binary*, May 27.

A. Goyal: *Bounds on neutrino mass and magnetic moment from SN1987A*, June 21.

V.I. Korchagin: *Sites of massive star formation in disk galaxies*, June 30.

B.S. Sathyaprakash: *A report on the 6th Asia Pacific Physics Conference* - Gravitational Astronomy Workshop, July 13; *Filtering post-Newtonian gravitational waves from coalescing binaries*, August 11.

M. Varadarajan: *A curious property of the gravitational Hamiltonian*, August 12.

U. Chattopadhayay: *The challenge of network reliability*, August 18.

P. Bellanca: *Fractal spacetime, quantum mechanics and scale relativity*, August 22.

P. Ulmschneider: *Why do almost all stars have hot outer shells?*, September 15.

R. Gupta: *A new approach to stellar spectral classification*, October 4.

P.R. Pisharoty: *Magnetic phenomena during total solar eclipse*, October 6.

S.V. Dhurandhar: *Detecting gravitational waves from pulsars by resonant bar antennae*, October 11.

J.V. Narlikar: *New determinations of Hubble's constant*, November 17.

S.S. De: *Particle masses : Entropy and particle production in the very early universe*, December 1.

S. Sarkar: *Weak interaction rates for presupernova stars*, December 13.

Rosanne Di Stefano: *Binary stellar systems in globular clusters*, January 5.

A. Borde: *Did the inflationary universe have a beginning?*, January 6.

J. Pati: *Unity of forces and understanding the origin of families and mass scales*, January 6.

S. Mathur: *Absorption in AGN*, January 10.

N. Dadhich: *Gravitational Casimir effect*, January 12.

M. Thompson: *Helioseismology : Probing the interior of a star*, February 1.

Jean-Yves Vinet: Virgo : *A first step toward gravitational wave astronomy*, February 2.

P.G.L. Leach: *The in-channel evolution of the Mixmaster universe*, February 8.

A.A. Rangwala: *Nonlinear evolution equations, Baiklund transformations and solitons*, February 10.

S. Chakrabarty: *Quark bubble nucleation in neutrons in presence of strong magnetic fields*, March 2.

G.D. Love: *Progress in adaptive optics and liquid crystal wavefront correctors*, March 9.

S.Chakrabarty, *Electron capture rates of light elements of astrophysical interest in the presence of a non-thermal tail of electron plasma*, March 14.

c) Public Lecture

A. Hewish, University of Cambridge: *The excitement of pulsars*, January 22.

d) PEP talks

By Locals...

S. Sinha : *Some aspects of transition from quantum to classical physics*, April 22.

T. Padmanabhan : *Some aspects of classical electrodynamics*, July 1.

B. Phookan (NCRA) : *Looking for radio emission from low surface brightness galaxies*, July 25.

T. Saini : *Berry's phase in quantum mechanics*, August 19.

P. Gothoskar (NCRA) : *Jupiter SL9 collision*, September 16.

S. Engineer : *Neural networks and artificial stupidity*, September 30.

C.R. Subrahmanya (NCRA) : *Understanding the skies with radio surveys*, October 7.

S.D. Mohanty : *Statistical theory of hypothesis testing*, December 2.

C. Boily : *Collimated, highly wound magnetostatic fields*, December 23.

A.N. Ramaprakash : *Thermal equilibrium in emission nebulae*, March 3.

T. Padmanabhan : *Some curiosities in Newtonian gravity and classical mechanics*, March 31.

By Visitors...

J. Samuel : *Theory of falling cats*, May 9.

B. Jones : *Astrophype*, July 27.

R. Cannon : *Multi object spectroscopy, an update*, July 28.

B. Pascal : *Fermat's last theorem, proof for n=4*, August 26.

Y.D. Mayya: *Disks of spiral galaxies : transparent or opaque*, December 7.

A. Saha : *HST and the measurement of Ho*, December 8.

A. Ashtekar : *Geometry in Physics - some unexpected applications*, December 29.

R. Schaeffer: *Fractals, Percolation, Genus and all that*, February 7.

Y. Mellier : *Observing faint objects*, February 15.

e) IDG (Informal Discussion Group) Meetings

G.C. Anupama : *Early UV spectral evolution of a classical nova*, April 28.

D.J. Saikia (NCRA) : *On problems with unification scheme for powerful radio sources*, April 28.

T. Padmanabhan : *Primordial deuterium at high redshifts*, May 3.

A. Kshirsagar (RRI) and S. Sethi : *Discovery of top quark?*, May 3.

J.S. Bagla : *The clustering properties of IRAS galaxies*, September 22.

S. Upreti (NCRA) : *Memory storage and neural systems*, September 22.

A. Mahabal : *Radio jets and optical features*, September 29.

R. Malik (NCRA) : Possibility of search for planets at low radio frequencies, September 29.

A.N. Ramaprakash : *Photoionization equilibrium in emission nebulae*, October 10.

S. Koshti : *Actions for gravity and generalizations*, October 20.

B. Nath : *X-ray flare in zeta orionis*, October 20.

L. Sriramkumar : *Recent work on the Unruh thermal spectrum*, November 24.

S. Jeyakumar (NCRA) : *Energetics and evolution of asymmetric radio sources*, November 24.

B. Bhawal : *Observational constraints on the neutron star mass distribution*, December 8.

V.K. Kulkarni (NCRA) : *Discovery of a VLBI counter-jet in NGC 1275 (3C84)*, December 8.

R. Balasubramanian : *Alternative methods of detecting gravity waves*, December 22.

B. Phookun (NCRA) : *What's in a halo?*, December 22.

N.C. Rana (IUCAA) : *Total solar eclipse*, March 16.

T. Sakurai (NCRA) : *Polarization measurements with the VLBI*, March 16.

f) Lecture Series

R.M. Vivekananda, NCRA, Pune: *Physics of pulsars*, January 11-17, 1995 (6 lectures).

Igor Novikov, Theoretical Astrophysics Centre, Copenhagen : *Can we see what happens inside a black hole?*, February 17; *Astrophysics of black holes*, February 20; *Can we change the past? (Physics in the presence of a time machine)*, February 21.

(VII) TALKS AT WORKSHOPS OR AT OTHER INSTITUTIONS

a) Seminars, Colloquia and Lectures

G.C. Anupama

Recent trends in recurrent novae, (Invited Review, Padova-Abano Conference on Cataclysmic Variables: Inter Class Relations, Abano, Italy, June 22).

The recurrent nova RS Ophiuchi at quiescence, (Observatorio di Roma, Rome, Italy, June 27).

J.S. Bagla

Gravitational dynamics in expanding universe, (BCSPIN Summer School, Kathmandu, Nepal, May 27).

Frozen potential approximation, (Workshop on Large scale structure beyond N-body simulations, IUCAA, July 22).

Gravitational dynamics in expanding universe, (YAM, IUCAA, August 3).

Gravitational dynamics and clustering in an expanding universe, (IIA, Bangalore, TPSC Seminar, November 17).

Gravitational dynamics and nonlinear clustering, (IISc, Bangalore, Submarine : a forum for informal pedagogic talks, November 18).

Gravitational dynamics and clustering in the nonlinear regime, (Indo-French school on Understanding large scale structure in the universe, IUCAA, February 17).

R. Balasubramanian

Techniques of data analysis of gravitational wave signals, (YAM, IUCAA, August 4).

Detection of gravitational waves, (University of Pune, Raman Mini Symposium, Department of Physics, University of Pune, November 23).

B. Bhawal

Hulse Taylor Binary Pulsar, (Introductory school on Astronomy and astrophysics, IUCAA, June 8; Mehta Research Institute of Mathematics and Mathematical Physics, Allahabad, October 22; Physics Department, North Bengal University, Siliguri, March 2).

Gravitational waves, (Two lectures for VSP, IUCAA, June 29 and 30).

Testing theories of gravitation using binary pulsars, (YAM, IUCAA, August 1).

Squeezing and recycling in laser interferometric gravitational wave detectors, (Mehta Research Institute of Mathematics and Mathematical Physics, Allahabad, October 24).

Binary pulsars, (Introductory school on Astronomy for IIT students, IUCAA, December 15).

Gravitational waves and their detection, (Physics Department, North Bengal University, Siliguri, March 10)

C.M. Boily

Wound magnetostatics and flaring, (IAU Coll. 154: Solar and Planetary Transients, NCRA, Pune January 23).

V. Chickarmane

Experimental techniques in the detection of gravitational waves, (YAM, IUCAA, August 4).

N. Dadhich

On manipulations of Einstein's equations, (Workshop on Chaos and Ordinarily Differential Equations, University of Durban, Westville, Durban, April 23).

Black holes and their energetics, (University of Zululand, Zululand, South Africa, May 23).

Inhomogeneity and non-singularity in cosmology, (University of South Africa, Pretoria, South Africa, June 13).

Singularity free cosmological models, (University of Witwatersrand, Johannesburgh, South Africa, June 15).

On characterisation of perfect free cosmological models, (Conference on gravitation and cosmology, University of Aegean, Greece, September 5).

On way to the uniqueness of non-singular cosmological models, (ERE-94, Spanish Relativity Meeting, Menorca, Spain, September 12).

Energetics of black holes and their gravitational charge, (University of Bilbao, Spain, September 22).

On non-singular cosmological solutions of Einstein's equations, (University of Gottenburgh, Sweden, September 28).

Towards the uniqueness of non-singular family of cosmological models, (University of Stockholm, Sweden, October 5).

On inhomogeneous non-singular cosmological models, (Institute of Astrophysics, Neils Bohr Institute, Copenhagan, Denmark, October 7).

On characterisation of perfect fluid free cosmological models, (Queen Mary Westfield College, London, October 16).

Rotating black holes in magnetic field, (University of Southumpton, UK, October 21).

On black hole energetics, (University of Portsmouth, UK, October 25).

Gravity : Einstein versus Newton, absolute zero of gravitational potential, Jamia Millia University, Jamia Millia, Delhi, February 14).

S.V. Dhurandhar

Detecting gravitational waves from PSR 0437 by the Perth Bar, (Department of Physics, University of Western Australia (UWA), Perth, August 22).

Gravitational waves from coalescing binary neutron stars and blackholes, (Department of Physics, UWA, Perth, August 25).

The search for gravitational waves : current status, (Sydney University, Sydney, August 30).

The search for gravitational waves, (Mount Stromlo and Sliding Spring Observatories, Canberra, September 1).

Gravitational wave detection: current status and future prospects, (XVI meeting of the ASI, IUCAA, October 26).

Detection of gravitional waves, (Indian Mathematical Society, University of Pune, Pune, December 28).

Geometric and differential geometric techniques in the detection of gravitational waves, (Indian Mathematical Society, University of Pune, Pune, December 28).

D. Duari

Quasar redshift distribution, (University of Amsterdam, Amsterdam, August 30).

Periodicity in quasar redshift, (Royal Observatory, Edinburgh, UK, September 14).

Peaks and periodicities in the redshift distribution of quasars, (Queen Mary and Westfield College, London, September 16).

Absorption spectra of QSOs and the intervening galaxies hypothesis, (Conference on Large scale structure of the universe, Potsdam, Germany, September 22).

Statistical studies of the redshifts of spectral lines of quasi-stellar objects, (XVI Meeting of the ASI, IUCAA, October 26).

T.S. Ghosh

Relating cosmology to the CMBR anisotropy spectrum, (Workshop on Two years after COBE, IUCAA, April 25).

Cosmological clues in the CMBR, (YAM, IUCAA, August 4)

The cosmic script: cosmological clues in the CMBR anisotropy, (Raman Mini symposium, Department of Physics, University of Pune, November 23).

Inflation after COBE, (XI DAE symposium on High Energy Physics, Santi Niketan, December 30).

Secondary skewness in the CMBR, (Indo-French School on Understanding large scale structures in the universe, IUCAA, February 15).

R.K. Gulati

Stellar spectroscopy, (Introductory summer school in Astronomy and astrophysics, IUCAA, May 25).

Stellar evolution, (2 lecutres, VSP, IUCAA, June 14-15).

Synthesis of stellar spectral features, (Department of Astronomy, University of Michigan, Ann Arbor, USA, October 3).

Tools to understand stellar populations, (Department of Astronomy, University of Toronto, Toronto, Canada, October 14).

Employing an artificial brain to stellar spectral classification, (Institut D'Astrophysique, Paris, France, December 16).

R. Gupta

Optical techniques I & II, (Introductory summer school in Astronomy and astrophysics, IUCAA, May 24-25).

Photometry; Photometer, (IInd Workshop on Experimental techniques in space science and astronomy, Department of Physics, Gujarat University, Ahmedabad, September 14).

Stellar spectral classification by artificial neural network techniques, (Physical Research Laboratory, Ahmedabad, September 19).

Telescope and human eye; Atmospheric effects; Astronomical photometry; Astronomical Spectroscopy, (Introductory school on Astronomy and astrophysics, Department of Physics, Gulbarga University, Gulbarga, September 26-30).

Observational astronomy I & II, (Introductory school on Astronomy for IIT students, IUCAA, December 7-8).

K. Jotania

Detection of gravitational waves, (YAM, IUCAA, August 4).

Some aspects of gravitational wave signal analysis from coalescing binaries and pulsars, (XVI Meeting of the ASI, IUCAA, October 28).

Gravitational wave data analysis from coalescing binaries and pulsars, (Raman Research Institute, Bangalore, February 10).

Search for gravitational waves, (Raman Research Institute, Bangalore, February 14).

Coalescing binaries in post-Newtonian approximation, (Raman Research Institute, Bangalore, February 16).

Filtering post-Newtonian chirp, (Raman Research Institute, Bangalore, February 18).

Gravitational radiation from pulsars, (Raman Research Institute, Bangalore, February 20).

A.K. Kembhavi

Birth and death of stars, (MACS Exploratory, Maharashtra Association for Cultivation of Science, Pune, May 14).

Galaxies - Shapes, cores and dust, (IIA, Bangalore, May 28).

Compact objects, (VSP, IUCAA, June 15).

Dust in the elliptical galaxy 3C270, (Anglo Australian Observatory, Australia, June 20).

Dust in the elliptical galaxy 3C270, (Mount Stromlo Observatory, Perth, June 22).

The shapes of ellipticals, (University of Melbourne, Melbourne, June 28).

Compact objects : white dwarfs, neutron stars and blackholes, (Department of Physics, IIT, Kanpur, August 25).

Elliptical galaxies, (Department of Physics and Astronomy, University of Kentucky, Lexington, September 20).

The elliptical galaxy 3C270, (Carnegie Institution, Pasadena, September 30).

Surface photometry of galaxies, (2 lectures, Indo-US Workshop on Array detectors and image processing, IUCAA, November 28, December 10).

Compact objects, (2 lectures, Introductory school on Astronomy for IIT students, IUCAA, December 8, 9).

Astrophysics research in India, (Inter-University Consortium for DAE Facilities, Indore, December 14).

Galaxy morphology : Observations and theory, (India-Japan Seminar on Astronomy and Astrophysics, IIA, Bangalore, January 19).

Computer networking and internet, (Bioinformatics, Pune, January 23).

Image processing, (Institute of Radio Physics, Calcutta, March 12).

Pulsars, (Jadavpur University, Calcutta, March 14).

A. Mahabal

Image processing , (2 lectures, Second Workshop on Experimental techniques in space science and astronomy, Gujarat University, Ahmedabad, September 13-14).

Elliptical galaxies, (Kutuhal, Nagpur, July 7).

Image processing techniques in astronomy, (YAM, IUCAA, August 3).

D. Munshi

Comparing approximations to gravitational instability, (BCSPIN Summer School, Kathmandu, Nepal, May 30).

Approximations to gravitational instability, (YAM, IUCAA, August 3).

Gravitational instability in the quasilinear regime, (Workshop on Large scale structure beyond N-body simulations, IUCAA, July 22).

Comparing approximations to gravitational instability, (Indo-French school on Understanding large scale structures in the universe, IUCAA, February 14).

J.V. Narlikar

What is the interpretation of COBE findings?, (Workshop on Two years after COBE, IUCAA, April 27).

The quasi-steady state cosmology and its interface with particle physics, (Tata Institute of Fundamental Research, Bombay, April 20; University of California at San Diego, USA, May 10; Syracuse University, Syracuse, USA (PASCOS 1994), May 20).

The quasi-steady state cosmology : Achievements and challenges, (Center for Astrophysics (CfA), Cambridge, USA, May 17; C.I.T.A. Toronto, Canada, May 23; Tokyo University, Tokyo, Japan, March 6; Yukawa Institute, Kyoto University, Kyoto, Japan, March 9).

The quasi-steady state cosmology: An alternative to the Big Bang, (Stanford University, USA, June 2).

General relativity, (VSP, IUCAA, June 23).

Theoretical foundations of the quasi steady state cosmology, (IAU Symposium No. 168, The Hague, Netherlands, August 26).

Some conceptual problems in general relativity and cosmology, (BSPS Conference on Physical interpretations of relativity theory, Imperial College, London, September 11).

Quantum cosmology, (ISYA, Cairo, Egypt, September 18).

Cosmological debate, (ISYA, Cairo, Egypt, September 18).

Quasi-steady state cosmology, (Indian Institute of Astrophysics, Bangalore, November 11).

IUCAA : A facility within the university sector, (Vice-Chancellors' meeting in the University of Pune, Pune, November 13).

Overview of astronomy and astrophysics, (Introductory school on Astronomy for IIT students, IUCAA, December 5).

Recreational aspects in the study of mathematics, (Maths Lovers, Pune, December 22).

Sources of gravitational waves, (Indian Mathematical Society, University of Pune, Pune, December 28).

Challenges in Astronomy and Cosmology, (Indian Science Congress 1995 - Calcutta, January 4).

Absorber theory of radiation in expanding universes, (Indo-Japan Seminar on Astronomy and astrophysics, IIA, Bangalore, January 17).

Challenges and puzzles in astronomy: The problems of origin, age and nature of matter in the universe, (Tokyo University, Tokyo, Japan, March 3).

B.B. Nath

Cocoons of radio galaxies and intergalactic matter, (NCRA, Pune, August 26).

T. Padmanabhan

COBE and its aftermath, (Workshop on Two years after COBE, IUCAA, April 25).

Universality in nonlinear gravitational clustering, (Workshop on Large scale structure beyond N-body simulations, IUCAA, July 21).

Scaling in nonlinear clustering, (Department of Astrophysical Sciences, Princeton University, Princeton, November 10).

Structure formation in the universe, (Pennsylvania State University, November 19).

Modelling the universe, (Indo-Japan Seminar on Astronomy and astrophysics, IIA, Bangalore, January 19).

A. Paranjpye

Observing with small telescopes, (II Workshop on Experimental techniques in space science and astronomy, Gujarat University, Ahmedabad, September 14).

Spherical astronomy, (Introductory school on Astronomy and astrophysics, Gulbarga University, Gulbarga, September 26).

Observing with small telescopes, (Introductory school on Astronomy and astrophysics, Gulbarga Universisty, Gulbarga, September 27).

Astronomical photography, (Preparatory Workshop on Total solar eclipse 1995, IUCAA, Pune, October 5).

Photographing Total Solar Eclipse, (Preparatory Workshop on Total solar eclipse 1995, IUCAA, Pune, October 5).

Astronomical observations, (Introductory school on Astronomy for IIT students, IUCAA, Pune, December 9).

Photometry with low cost photometer, (V All India Amateur Astronomers Meet, Bhubaneswar, January 16).

A.N. Ramaprakash

Imaging Polarimeter, (YAM, IUCAA, August 8).

V. Sahni

Inflation, gravity waves and the cosmic microwave background, (Workshop on Two years after COBE, IUCAA, April 25).

Voids and adhesion theory, (Conference: Birth of the universe and fundamental physics, Rome, Italy, May 19).

Voids in the adhesion approximation, (Los Alamos National Laboratory, Los Alamos, USA, June 1).

Simulating big nothings: voids in the adhesion model, (University of California, Berkeley, USA, June 3).

Comparing dynamical approximations in the quasi-linear regime, (Workshop on Large scale structure, Aspen, USA, June 7).

The formation and evolution of voids, (Harvard Smithsonian Center for Astrophysics, Harvard, USA, June 15).

Gravity waves and the early universe, (Tufts University, Medford, USA, June 21).

A study of voids using the adhesion approximation, (Workshop on Large scale structure beyond N-body simulations, IUCAA, July 22).

Voids and their evolution in the adhesion model, (Workshop on Large scale structure in the universe, Potsdam, Germany, September 19).

The large scale structure of the universe and Burgers equation, (Theoretical Astrophysics Center, Copenhagen, Denmark, September 20).

The large scale structure of the universe, (Sixteenth meeting of the Astronomical Society of India, IUCAA, October 25).

Voids in the adhesion model, (Indo-French school on Understanding large scale structures in the universe, IUCAA, February 13).

B.S. Sathyaprakash

Large scale structure in the universe, (VSP, IUCAA, June 30).

Choice of filters for detecting gravitational waves from coalescing binaries: Inclusion of post-Newtonian effects, (Gravitational Astronomy Workshop, 6th Asia Pacific Physics Conference, Brisbane, Australia, July 5).

Data analysis of coalescing binaries, (Gravitational Astronomy Workshop, 6th Asia Pacific Physics Conference, Brisbane, Australia, July 6).

Australian International Gravitational Observatory - Indian Participation, (Gravitational Astronomy Workshop, 6th Asia Pacific Physics Conference, Brisbane, Australia, July 7).

Comparison of approximations to gravitational clustering: The strongly nonlinear regime, (Workshop on Large scale structure beyond N-body simulations, IUCAA, July 22).

Comparison of nonlinear approximations to gravitational instability, (International Workshop on *Large scale structure in the universe - Observational and theoretical aspects*, (Potsdam, Germany, September 23).

Detection of gravitational waves from coalescing binaries and testing general relativity, (University of Orsay, Paris, October 17).

Filtering gravitational waves from coalescing binaries and testing general relativity, (Raman Research Institute, Bangalore, December 8).

Signal analysis, (Introductory school on Astronomy for IIT students, IUCAA, December 19).

Statistical estimation, (Indian Mathematical Society, University of Pune, Pune, December 28).

Understanding gravitational instability, (Nonlinear Dynamics Seminar, Physics Department, University of Pune, Pune, January 21).

Morphology of large scale structure, (Indo-French school on Understanding large scale structures in the universe, IUCAA, February 16).

A.K. Sen

An imaging polarimeter for observational astronomy, (Indian Institute of Astrophysics, Bangalore, August 30).

S. Sethi

Cosmological consequences of radiatively decaying neutrino, (Workshop on Large scale structure beyond N-body simulations, IUCAA, July 22).

S. Sinha

Early universe, (Introductory summer school on Astronomy and astrophysics, IUCAA, June 6).

Cosmology, (VSP, IUCAA, June 27).

A fluctuation-dissipation relation for semiclassical cosmology, (Raman Research Institute, Bangalore, November 28).

S.N. Tandon

Samrat Yantra, (Workshop on Heritage of ancient Indian astronomy, IUCAA, October 31).

Limitations on use of fibres in spectroscopy, (Indo-US Workshop on Array detectors and image processing, IUCAA, December 2).

Infrared astronomy with balloon-borne telescopes in India, (Indo-Japan Seminar on Astronomy and astrophysics, IIA, Bangalore, January 19).

Technological challenges of HIROT, (HIROT Meeting, IIA, Bangalore, March 11).

M. Valluri

Galaxies, (Introductory summer school on Astronomy and astrophysics, IUCAA, 2 lectures, May 31, June 1).

Normal galaxies, (VSP, IUCAA, June 16).

b) Lecture Courses

N.K. Dadhich

Non-singular cosmological models, (Hanno Rund Workshop on Relativity and cosmology, University of Natal, South Africa, April-June), 6 lectures.

S.V. Dhurandhar

Gravitational wave detection, squeezed states and interferometry, (SERC School on Coherence and correlations in optics and quantum physics, Institute of Mathematical Sciences, Madras, February 6-8), 3 lectures.

D. Duari

Observational cosmology, (Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, sponsored short course at Shivaji University, Kolhapur, February 2-3), 2 lectures.

T.S. Ghosh

CMBR anisotropy, (Inter-university graduate school on Large scale structure formation in the universe, Department of Physics, University of Mysore, Mysore, December 2-3), 3 lectures.

A.K. Kembhavi

Tidal capture, (Department of Physics, University of Pune, Pune, April 19 - May 4), 3 lectures.

D. Munshi

Large scale structure formation, (Inter-university graduate school on Large scale structures in the universe, Department of Physics, University of Mysore, Mysore, November 28 - December 9), 10 lectures.

J.V. Narlikar

Standard big bang cosmology, (ISYA, Cairo, Egypt, September 17-23), 5 lectures.

Introduction to cosmology, (Inter-university graduate school on Large scale structures in the universe, Department of Physics, University of Mysore, Mysore, November 23-26), 6 lectures.

Introduction to cosmology, (Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, sponsored short course at Shivaji University, Kolhapur, January 29-February 2), 3 lectures.

T. Padmanabhan

Cosmology, (Introductory summer school on Astronomy and astrophysics, IUCAA, June 2-3), 3 lectures.

Radiation processes, (VSP, IUCAA, June 13, 14), 3 lectures.

Cosmology, (Introductory school on Astronomy for IIT Students, IUCAA, December 8-9), 3 lectures.

Linear perturbation theory and CMBR, (Indo-French school on Understanding large scale structures in the universe, January 30 - February 20, 1995), 5 lectures.

V. Sahni

Structure formation in the universe, (Inter-university graduate school on Large scale structures in the universe, University of Mysore, December 5-9), 7 lectures.

B.S. Sathyaprakash

Large scale structure - observations, (Inter-university graduate school on Large scale structures in the universe, Department of Physics, University of Mysore, Mysore, November 21 - December 10), 6 lectures.

S. Sethi

Genera l theory of relativity, (Inter-university graduate school on Large scale structures in the universe, Department of Physics, University of Mysore, November 20 - December 9), 7 lectures.

Astro-particle physics, (Inter-university graduate school on Large scale structure formation in the Universe, Department of Physics,University of Mysore, November 20 - December 9), 5 lectures.

S.N. Tandon

CCD fundamentals; Sources of error and noise in CCDs, (IInd Workshop on Experimental techniques in space science and astronomy, Gujarat University, Gujarat, September 13-17) 2 lectures.

Invisible universe; Detection of light, (Introductory school on Astronomy and astrophysics, Gulbarga University, Gulbarga, September 26 - 30) 2 lectures.

c) Popular Lectures

B. Bhawal

Nobel Prize 1993: Hulse Taylor Binary Pulsar, (Jawharlal Nehru Planetarium, Allahabad, October 23).

N.K. Dadhich

Path dependence of time, (Springfield College, Durban, South Africa, May 20).

Space, time and gravity, (University of Zululand, Zululand, South Africa, May 24).

S.V. Dhurandhar

Introduction to gravitational waves, (Perth Astronomical Research Group Meeting, Department of Physics, UWA, Perth, August 26).

Gravitational wave detection, (Department of Physics, University of Pune, Pune, October 1).

R. Gupta

Galileo mission and images of Comet Shoemaker Levy 9 collision with Jupiter - a slide show, (Vikram A. Sarabhai Community Science Centre, Ahmedabad, September 17).

Our universe, (Department of Physics, Gulbarga University, September 28).

A.K. Kembhavi

Suryamaletil grah (in Marathi), (Exploratory, MACS, Pune, April 23).

CCD cameras, (Electronics Department, University of Pune, Pune, June 16).

Computer communication, (Department of Physics, Marathwada University, Aurangabad, July 16).

Computer (in English and Marathi), (Maharashtra Vidya Mandal, Pune, January 11).

J.V. Narlikar

New challenges in astronomy, (Doon School, Dehra Dun, April 1).

A frontier between physics and astronomy, (Doon School, Dehra Dun, April 2).

Vigyan samaj aur patrakarita (in Hindi), (Makhanlal Chaturvedi National University of Journalism, Bhopal, April 4).

Chandravaril manavache padarpan (in Marathi), (Dnyan Prabodhini School, Pune, July 20).

Vidnyan ani adhyatma : Virodh ki samanvay? (in Marathi), (Ramakrishna Math, Pune, July 25).

New challenges of astronomy - The Indian experience, (Nehru Centre, London, September 14).

Vishwarachanechya kalpana (in Marathi), (Galaxy Astronomical Society - Amateur Astronomers' Group, Pune, November 17).

The search for extra-terrestrial intelligence, (Mysore University, Mysore, November 25).

National Defence Academy Graduation Address, (National Defence Academy, Pune, December 1).

Pruthvipalikadil jeevsrishticha shodh (in Marathi), (Abhijat Kala Mandal, Pune, January 15).

Khagolshastratale anuttarit prashna (in Marathi), (Muktangan Autonomous Rural University Centre and Kavi Anantaphandi Vyakhanmala, Sangamner, January 27).

Khagolshastratun ghadanare vishwarup darshan (in Marathi), (Sanskrit Bhasha Sabha, Nasik, January 27).

Khagolshastrachi navi kshitije (in Marathi), (Marathi Vidnyan Parishad & Rotary Club of Kolhapur, Kolhapur, February 2).

Vidnyan gangechi avakhal valane - Kahi aitihasik udaharane (in Marathi), (Rajaram Seetaram Dixit Vachanalaya, Nagpur, February 25).

Vidnyan gangechi avakhal valane - Vartamanatun bhavishyakade (in Marathi), (Rajaram Seetaram Dixit Vachanalaya, Nagpur, February 26).

Historical and new challenges in astronomy, (S.P. College, Pune, February 28).

Exciting developments in astronomy, (IUCAA, Indo-American Chamber of Commerce members, March 16).

Aajachya Bharatat Agarkaranchi bhumika (in Marathi), (Agarkaranche vichar va aajachi paristhiti, Tilak Smarak Mandir, Pune, Agarkar Smruti Shatabdi Samiti, March 19).

The role of media in covering scientific and other developments, (Symbiosis Institute of Journalism and Communication, Pune, March 28).

T. Padmanabhan

Understanding our universe, (Science, Technology and Environment Department, Thiruvananthapuram, February 28).

A. Paranjpye

Six inch "eff" eight : an astronomical telescope, (College of Military Engineering, Pune, July 23).

How to make a telescope, (Jyotirvidya Parisanstha, Pune, September 3).

Collision of Shoemaker-Levy 9 with Jupiter, (II Workshop on Experimental techniques in space science and astronomy, Ahmedabad, September 14).
Shoemaker - Levy 9, (Department of Physics, Gulbarga University, Gulbarga, September 26).

Our universe, (Department of Physics, Gulbarga University, Gulbarga, September 27).

Wonders of the sky, (Spicer Memorial College, Pune, October 24).

Total Solar Eclipse October 24, 1995, (Rotary Club of Pune, Kothrud, February 14).

How to photograph Total Solar Eclipse, (Jyotirvidya Parisanstha, Pune, March 11).

d) Radio / TV Programmes

J.V. Narlikar

Interview with Fred Hoyle, (Broadcast on several occasions on Doordarshan's educational channel).

Brahmand, (a 17 episode Science Serial broadcast on Doordarshan Channel - I, May 9 onwards).

Maza chhand maza anand, (All India Radio, Pune, October 27).

Aflatoon toli ani time machine, (Radio play, All India Radio, Pune, February 6).

A. Paranjpye

Ulka varsha, (All India Radio, Pune, January 8).

Extramural Activities

Ruchika Theatre Group, New Delhi : *Drama - Odhni*, December 13.

Ratan Thiyam and Group : *Dramas - Chakravyuha*, December 24; *Andha Yug*, December 25.

Gloria Maddox, USA : *One Act Play - Sweet dreams and oddly shaped rooms*, January 11.

Vinay Kulkarni, Pune: *Talk - AIDS : How it concerns you?*, February 7.

WORKSHOPS

Workshop on Two Years After COBE

A workshop on Two Years After COBE was held during April 25-28, 1994. It brought together about twenty people to discuss various aspects of cosmology and structure formation related to the COBE discovery of anisotropy in the microwave background. Most of the lectures were of pedagogical kind.

Speakers included T.S. Ghosh, J.V. Narlikar, T. Padmanabhan, V. Sahni, T.P. Singh, R. Sinha, K. Subramanian and M. Vivekanand. *T. Padmanabhan* was the organizer of this workshop.

Workshop on Making a Sky Globe and a Simple Telescope for School Science Teachers of Pune

This workshop was organised at IUCAA during April 29 - May 3, 1994. An enthusiastic response from 55 schools made the workshop most lively and fruitful. Under skillful supervision, each teacher made a sky globe and a small astronomical telescope during the workshop. The cost per set of sky globe and telescope turned out to be as low as Rs.125 and they were presented to the teachers. *N.C. Rana* was the organizer of this workshop.

Workshop on Astronomy Curriculum in Schools

IUCAA had organised in its campus a workshop on Astronomy Curriculum in Schools during April 4-8, 1994. About 20 teachers from different parts of India attended and presented the astronomy portions of the existing curricula in various states. This has been collated in the form of a recommendation for possible action to be taken up by the NCERT. The teachers also took part in an astrophotometry practical session with a piggy-mount telescope and a simple photometer. *N.C. Rana* was the organizer of this workshop.

Workshop on Sky Globe Making

IUCAA had sponsored a workshop on Sky Globe Making at Nanded in joint collaboration with Department of Physics, N.E.S. Science College, during April 18-21, 1994. The teachers and students from colleges in and around Nanded as well as from local high schools participated in the workshop. The participants completed the job of sky globe making within the period of four days. The technical assistance was provided by N.C. Rana of IUCAA. Special lectures by N.C. Rana, L.K. Kulkarni and N.G. Phatak were organised. A practical sky watching programme was also organised for the participants. *N.C. Rana* was the organizer of this workshop.

Workshop on Large Scale Structure Beyond N-body Simulations

A workshop on Large Scale Structure Beyond N-body simulations, dedicated to the memory of the outstanding Russian physicist Ya. B. Zeldovich was organised in IUCAA during July 20-26, 1994. The workshop dealt with frontier issues in cosmology, which were vigorously debated both formally during the workshop and after "office" hours. The topics discussed included: the Cosmic microwave background, Reionisation of the intergalactic medium, Scaling and universality in gravitational clustering, Non-linear approximations to gravitational instability, N-body and gas dynamical simulations of large scale structure, Statistics of gravitational clustering, etc. Fifteen Indian and ten foreign scientists participated in this workshop. *V. Sahni* and S. Shandarin were the organizers of this workshop.

2nd Workshop on Experimental Techniques in Space Science and Astronomy

This workshop, sponsored by IUCAA, was conducted at the Department of Physics, Space Sciences and Electronics, Gujarat University, Ahmedabad, in collaboration with Physical Research Laboratory (PRL) and Space Application Centre (SAC) during September 13-17, 1994. The main objective of this workshop was to introduce the concept of CCD, photometry, image processing, and its various applications in space sciences and astronomy to university/college teachers and research scholars. George Joseph, Director, SAC, was kind enough to inaugurate the workshop and O.P.N. Calla, Deputy Director, SAC, gave the key note address.

There were 18 lectures by invited speakers from IUCAA, SAC, PRL, Gujarat University and Gujarat College, 5 demonstrations and 3 visits. Three days programme was arranged in the university campus and remaining two days programme was held at SAC and PRL. There were 30 participants from different parts of the country, including 5 from Nepal. *R. Gupta* was the organizer of this workshop.

Second Indo-US Workshop on Array Detectors and Image Processing

The second Indo-US workshop on Array Detectors and Image Processing was held at IUCAA during November 28-December 10, 1994. Out of a total of 39 participants, 7 were from USA. The topics included were (i) technology of CCDs and near and mid-infrared arrays, (ii) controllers for these, (iii) optimisation of and noise reduction in controllers, (iv) instrumentation for astronomical photometry and spectroscopy and (v) reduction and analysis of photometric and spectroscopic data in astronomy. Through informal discussions, many details and ideas were communicated, which are not available in literature, and this exchange is expected to give a boost to the research efforts of the participants. *S.N. Tandon* and G. Fazio were the organizers of this workshop.

Preparatory Workshop on Total Solar Eclipse 1995

A Preparatory workshop on Total Solar Eclipse (October 24 1995) was held at IUCAA during October 3-7, 1994. About forty participants, mostly amateur astronomers and college teachers attended it. Lectures and practical demonstrations with camera and telescope for shooting and safe viewing were arranged. About thirty amateur clubs participated in it. Due to the fear of the plague epidemic, some of the lecturers could not turn up, but many participants opted for discussions about their own programmes. *N.C. Rana* was the organizer of this workshop.

Participants of the Second Indo-US Workshop on Array Detectors and Image Processing

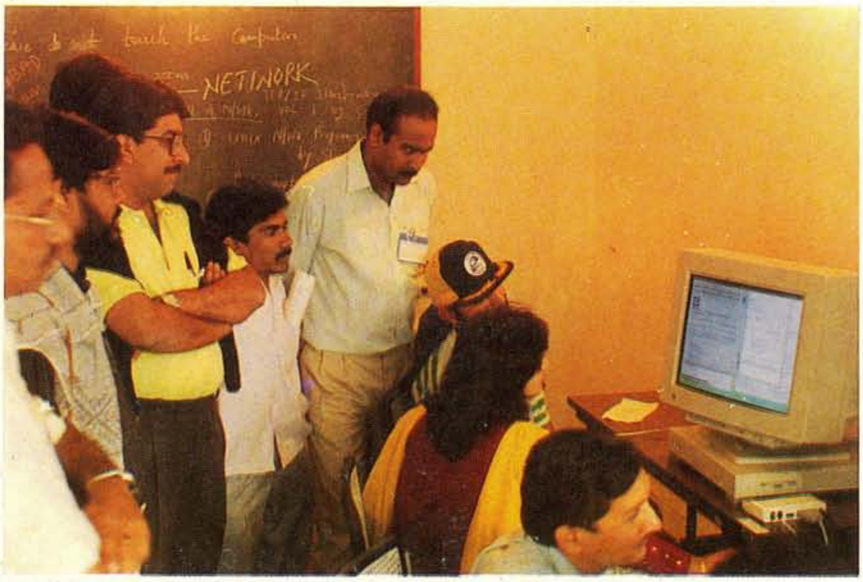
Workshop on the Heritage of Ancient Indian Astronomy

A workshop on the Heritage of Ancient Indian Astronomy was held at IUCAA during October 31-November 4, 1994. About 50 participants, mostly college and university teachers, amateur astronomers and learned scholars of history and astronomy, attended it. There were about 25 scholarly lectures delivered by the distinguished speakers. The proceedings of the same will be brought out as a special supplement to the Bulletin of the Astronomical Society of India. *N.C. Rana* was the organizer of this workshop.

Participants of the Workshop on the Heritage of Ancient Indian Astronomy

Workshop on Computer Networks

A workshop on Computer Networks was held at IUCAA during January 2-13, 1995. The workshop was co-sponsored by NCST, Bombay and ICTP, Italy. A number of invited speakers from India and abroad spoke on the principles and practices of computer networking. The topics included: TCP/IP networking technology; Messaging systems; Network security; User services - Network news, Archie, WAIS, Gopher, WWW, Xmosaic.



Demonstration during the Workshop on Computer Networks

Lectures were held in the morning and the afternoons were devoted to computer laboratory sessions. Fifty-six participants from universities/colleges and research institutions attended the workshop. During informal discussions, computer networking problems of the participants were discussed and solutions were proposed. *A.K. Kembhavi* and *A.M. Kane* were the organizers of this workshop.

SCHOOLS

Summer School

An Introductory Summer School on Astronomy and Astrophysics, funded by DST and hosted by IUCAA and NCRA, was held at IUCAA during May 23 - June 11, 1994. This was the fifth in the series of schools, the venue for which alternates between Pune and Bangalore. About 35 students of physics and engineering from all over the country took part in the school.

There were 50 lectures on various topics in A & A, which were delivered by leading scientists from different A & A centres in the country. In addition, the students also took part in individual projects under suitable supervision. Observations through an optical telescope, a visit to the GMRT site and computer demonstrations were also some of the activities arranged during the school. The school provided adequate exposure to A & A and emphasized the thrust areas in the field.

Introductory School on Astronomy and Astrophysics

The Introductory School on Astronomy and Astrophysics, sponsored by IUCAA and Gulbarga University was conducted by the Department of Physics, Gulbarga University, during September 26-30, 1994. The School was inaugurated by S.M. Yahya, Hon'ble Minister for Higher Education, Government of Karnataka. There were about 60 participants from Post Graduate Department of Physics, Gulbarga University, Undergraduate Colleges and Institutions in the region of north Karnataka. The subject experts were invited from IUCAA and Bangalore University. Lectures were given on the following topics: Non optical universe, Light detectors, Telescope and human eye, Atmospheric effects, Astronomical photometry, Astronomical spectroscopy, Radio astronomy, Relativity and astrophysical consequences, Stellar evolution, Stellar structure, Atmosphere of stars, Spherical astronomy, Galaxy structure, and Sky observation. There were two discussion and four night sky observations.

During this school, it was proposed to start an Amateur Astronomers club in Gulbarga to kindle interest in the subject and to make night watching as hobby among students. On the concluding day, A.C. Hiremath, Dean of Science and Technology, Gulbarga University, was the Chief Guest and M.T. Lagare, Chairman, Department of Physics, presided over the valedictory function. In conclusion, the School was a grand success and the participants felt that many more such meetings should be arranged, particularly at district level, involving high school students. The school served the purpose of exposing the participants to basics of Astronomy and Astrophysics.

Inter-University Graduate School on Large Scale Structures in the Universe

An Inter-University Graduate School on Large Scale Structures in the Universe, jointly sponsored by the UGC and IUCAA, was conducted in Mysore University during November 21-December 10, 1994. *V. Sahni* and Gopala Rao were the Directors of this school. The school offered refresher courses in General Relativity and Cosmology and also focussed on advanced topics in Cosmology such as: Astroparticle physics: the early universe, phase transitions, topological defects, inflation and baryogenesis; Structure formation in the universe: correlation functions, hot and cold dark matter models, the Press-Schechter formalism, the Zeldovich approximation and N-body simulations; Cosmic microwave background; High redshift universe: QSO's, radio galaxies and the intergalactic medium; Clusters of galaxies; Gravitational lensing by clusters, etc.

Participants to the school included graduate students, post-docs and lecturers from different parts of the country. Also present were participants from Nepal, Jordan and Germany.

Introductory School on Astronomy for IIT Students

The Introductory School on Astronomy for IIT Students was held at IUCAA during December 5-24, 1994. *S. V. Dhurandhar* was the director of this school. In the school, several lectures were arranged in various areas of astrophysics and astronomy providing basic exposure to the subject and to convey the excitement in the frontier areas. Eleven students from the IITs participated in the school. The students took projects with the faculty and gave presentations at the end of the school. In addition, the students were taught to handle an optical telescope at IUCAA to perform astronomical observations. A visit to the GMRT site was also arranged.

Indo-French School on Understanding Large Scale Structures in the Universe

The first Indo-French School on Understanding Large Scale Structures in the Universe sponsored by Indo-French Centre for Promotion of Advanced Studies was held at IUCAA, Pune, during January 30 - February 20, 1995. *T. Padmanabhan* and F. Bouchet were the Directors of this school. This was the first school which was organised in the area of Astrophysics, a thrust area identified under the Indo-French collaboration.

Six speakers from France and three from India delivered forty two lectures while twelve scientists delivered fifteen seminars. The following topics were covered: Observational review of large scale structures, Standard big bang cosmology, Linear perturbation theory and CMBR, Observational aspects of CMBR anisotropy, Population synthesis, Star formation and hydrodynamic processes, Weakly and strongly nonlinear regime and statistics of density fields.

A book containing the lecture notes of this school will be brought out in about a year's time and this publication will be edited by T. Padmanabhan and F. Bouchet.

MEETINGS

Scientific Advisory Committee Meeting

The fourth meeting of the Scientific Advisory Committee (SAC) of IUCAA was held on the IUCAA premises from July 27 to 29, 1994. Seven out of ten members came for the meeting: from within the country, K.D. Abhyankar (Osmania University), N. Kameswara Rao (Indian Institute of Astrophysics), N.V.G. Sarma (Raman Research Institute) and B.V. Sreekantan (National Institute of Advanced Studies) and from abroad D. Lynden-Bell (Institute of Astronomy, Cambridge), J.R. Bond (Canadian Institute of Theoretical Astro-

Participants of the first Indo-French School on Understanding Large Scale Structures in the Universe physics, Toronto) and R. Cannon (Anglo-Australian Observatory, Sydney).

The SAC visited IUCAA facilities and attended long sessions on the research work carried out by IUCAA members and associates, besides having discussions with the Director and the faculty. They left with good impressions of the progress made by IUCAA for its relatively short age but they also gave constructive criticism and practical advice for its efforts to attain a world class reputation.

The Sixteenth Meeting of the ASI

The sixteenth meeting of the Astronomical Society of India (ASI) was held at IUCAA during October 25-28, 1994. A total of 171 participants attended the meeting, of these 58 were from Pune; there were 40 participants from universities and other educational institutions.

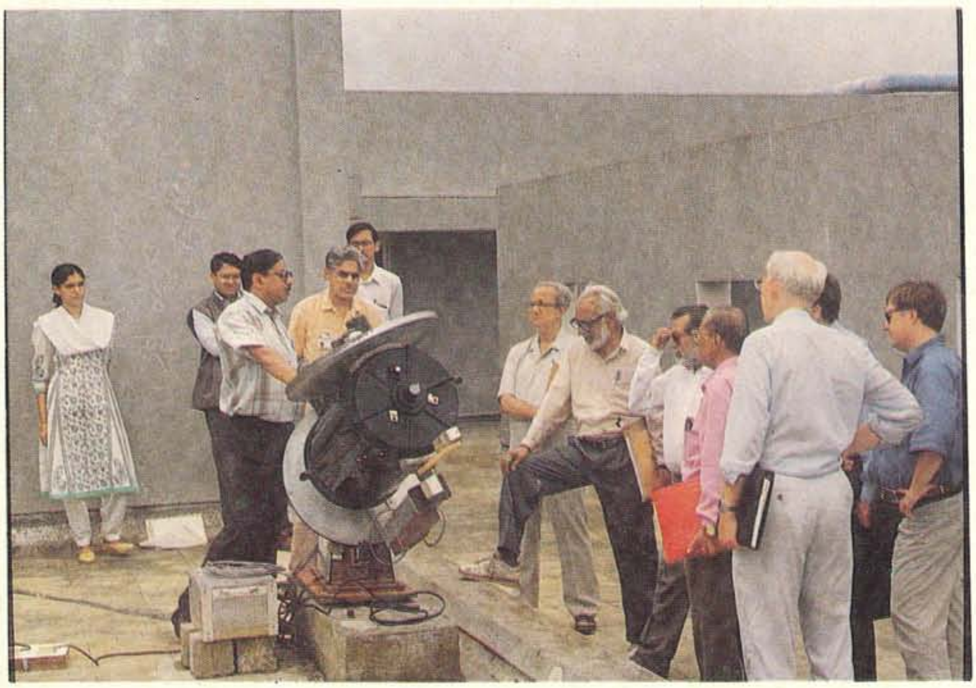
The academic programme began with the address by S.M. Chitre, President of the Society, on Probing the solar interior. There were fifteen invited talks which covered a range of observational and theoretical topics. There were two special sessions on Comet Shoemaker Levy 9 and Jupiter collision and Science with GMRT and twelve oral presentations of contributed papers, but most of the contributed papers were presented as posters. The ninety poster papers were summarised in seven rapporteur talks on the following areas: Sun and solar system astronomy, Stars and stellar astronomy, Galactic astronomy, Galaxies and AGN, Cosmology and early universe, and High energy astrophysics and Pulsars.

There were seven presentations of recent theses works, and of these, two were chosen as outstanding: (i) Statistical studies of the redshifts of spectral lines of QSOs by D. Duari, and (ii) IPS observations of variability in the solar wind by P. Gothoskar. They were given awards.

There was a visit to the GMRT site on October 27, 1994. The proceedings ended with the general body meeting of the Society which also gave its approval to the election of the next Executive Council with K. Kasturirangan as its President, and Vinod Krishan as the Editor of the Bulletin of ASI.

Regional Meeting for Universities of Eastern India

This meeting was sponsored by IUCAA and held at the Department of Mathematics, B.R. Ambedkar Bihar University, Muzaffarpur, during October 3-4, 1994. The main objective of the meeting was to



SAC members inspecting the Automated Telescope built at IUCAA promote research work in Astronomy and Astrophysics amongst university/college teachers and research workers in the region. Altogether 44 participants including Orissa (5), Uttar Pradesh (4). Bihar (13), and 22 local teachers attended the meeting. J.V. Narlikar, Director, IUCAA, gave the key note address while Vice-Chancellor of B.R.A. Bihar University presided over it. B. Ishwar, Coordinator, presented a brief report about the utility and different academic programmes of the meeting.

Participants of the Sixth Meeting of the Astronomical Society of India

There were 10 lectures by invited resource persons from IUCAA, B.R.A. Bihar University, T.M. Bhagalpur University, Gorakhpur University and Utkal University. There was an open general discussion and J.V. Narlikar encouraged the participants to use the facilities at IUCAA, including the Library, Computer Centre, Data Centre, E-mail and interactions with faculty members. A visit to Vaishali, an ancient democratic state, was arranged for the participants.

Participants of the Regional Meeting for Universities of Eastern India

J.V. Narlikar and S.N. Tandon were guests of the Governor of Bihar and had discussions with him at dinner on October 4, 1994. They also visited Nalanda and Rajgir on October 2, 1994.

Young Astronomers' Meet (YAM) 1994

YAM'94 was held during August 1-4, 1994 at IUCAA and it was jointly organised by research scholars at IUCAA and the National Centre for Radio Astrophysics, Pune. The event was funded by the Department of Science and Technology. K. Aswathanarayan, *J.S. Bagla, A. Mahabal, D. Munshi, A.N. Ramaprakash and L. Sriramkumar* organised this meet.

SENIOR ASSOCIATES of IUCAA



B. CHAKRABORTY **M.C. DURGAPAL** **A.K. RAY**

ASSOCIATES of IUCAA



S.S. DE **B.N. DWIVEDI** **P.S. NAIK**



V.M. NANDAKUMARAN **R.R. RAUSARIA** **P.C. VINODKUMAR**

Participants of the Introductory School on Astronomy and Astrophysics held at Gulbarga University, Gulbarga

Forty five research scholars from all over the country, including 16 locals, participated in the meet. Seminars by participants, in which they presented their work and discussions on a few selected topics comprised the academic programme. Presentations covered the entire range of topics from solar physics to structure formation in the universe. In addition, there were invited lectures by scientists from the local institutes and some visiting scientists.

The interaction of students from different fields has led to a better understanding and perspective of the research work being done in the country. It was decided to enlarge the scope of YAM by starting a quarterly newsletter. This should lead to an enhanced scientific interaction among the students working in astronomy and astrophysics.

Discussion Meeting on Group and Singularity Analysis in Differential Equations

N.K. Dadhich, P.G.L. Lesch and K.S. Govinder were the organizers of this meeting. Peter Lesch and Kesh Govinder from the University of Natal, Durban (South Africa), conducted a weeklong course on manipulating differential equations by using the techniques of Lie and Painleve analysis with special reference to Einstein's equations. It was attended by about 25 colleagues from universities. The participants had an opportunity to have hands-on experience of using Lie analysis software package. The lecture notes as well as the Lie package was provided to the participants so that they could actually use it in their places of work. The topics discussed included : Symmetry and invariance under transformation, Symmetries of differential equation, Computer methods, Algebraic properties of symmetries of ordinary differential equations (ode) and their first integrals, Similarity reductions of partial differential equations (pde) and Painleve analysis of ode and pde.

(IX) Vacation Students' Programme 1994

The VSP-94 was conducted during June 1 - July 15, 1994. 9 students, selected from various universities and IITs, participated in this programme. There were 25 lectures, covering all aspects of Astronomy and Astrophysics as well as a project work by each student. The students were graded based on their performance in the project work and the written test conducted at the end of the programme. In this year, no student was pre-selected for the Research Scholarship, starting from August 1995. T. Padmanabhan was the coordinator of this programme.

The IUCAA Creche

The efforts of some members of the IUCAA staff and the support of the Director led to the establishment of the IUCAA Creche. It started functioning at # 9, Akashganga housing complex in July 1994. Since July 1995, it has shifted to its permanent venue at Aditi. The creche is open 6 days a week, from 0900 to 1745 hrs.

The creche is open to the children of IUCAA staff, NCRA staff and visitors.

Currently, it entertains 15 children, (the optimal number that can be handled with the current creche staff strength) of all age groups (6 months young to 8 years young).

IUCAA has provided all the infrastructural facilities (utensils, gas connection, beds, mattresses etc.). Any subsequent requirement will be met through equal contribution from IUCAA and the beneficiaries.

Facilities

(I) Computer Centre

The IUCAA Computer Centre has an ever increasing number of sophisticated workstations to keep with the growing demand from within the institute as well as users who are spread in different university departments and colleges. During 1994-95 the emphasis has been on making high end computing services available. This has culminated in the acquisition of fast computers including a Silicon Graphics Power challenge system which provides ~ 0.5 Gflop computing speed, as well as very fast input and output and a large memory. This will be suitable for high speed computations of different varieties. It is hoped that in the near future the capabilities of this machine will be further enhanced. The Computer Centre has a great variety of software and hardware, so that the diverse needs of the many visitors to IUCAA are readily satisfied. The Computer Centre also provide software services and consultancy on hardware and networking solutions to other institutions and departments.

(II) Astronomical Data Centre

The Astronomical Data Centre (ADC) at IUCAA which is funded by the Department of Science & Technology, now has a collection of hundreds of astronomical catalogues together with sophisticated software which allows to catalogues' very easy retreat and study. The ADC also has data from various missions on CD ROMS, the digitized sky survey, various stellar libraries, etc. Access to these is provided remotely to those have the telnet facility. Others can send the request by mail or E-mail, and also visit IUCAA for extensive reference. Recently, programmes have been developed in the 'C' language which allows specific catalogues to be very easily accessed. These programmes and data are highly potable and can be provided on floppy disks or tapes. In the near future, more such programmes can be developed for the convenience of users and closer liaison will be established with foreign databases so that Indian users can have access to them more easily than at present.

(III) Library

The IUCAA Library now has about 12,000 volumes and the collection is converging towards reasonable completeness. Back volumes of important journals have been obtained either on paper or micro-film. Many individuals through kind donations have helped in building up the collection of back volumes as well as older books which are now out of print. The Library now receives quite a lot of material in electronic format which makes it rapidly accessible. The Library continues to provide different services to users from within the institute as well as to those spread in different universities and colleges. It is hoped that as computer communication improves in the country, the Library will be able to provide more sophisticated services to the users scattered far and wide.

(IV) Instrumentation Laboratory

The laboratory has developed two types of photometers, both based on photodiodes and it provides support to interested parties in developing photometers for their own use. One of the photometers is suitable for observations with telescopes of size 20 cm to 40 cm and having motorised tracking arrangement. The second photometer is very small and it can be used with smaller telescopes (e.g. 7.5 cm aperture telescopes); the laboratory provided support to several students and teachers from colleges, etc. to develop their photometers.

The laboratory has provided technical support to Gulbarga University in the acquisition and testing of their 20 cm telescope and its accessories.

Several advanced instruments are under development in the laboratory — Automated Photoelectric Telescope, CCD Camera and Imaging Polarimeter — for which details can be seen elsewhere in this report.

(V) Recreation Centre

The Recreation Centre building was ready by the end of the year 1994 and it was a pleasure to have Professor P.C. Vaidya with us to christen the building as Chittaranjan (recreation for the mind) on December 29, 1994, the IUCAA Foundation Day. The Chittaranjan hosts a library, a covered badminton court, table tennis table, chess and card tables, and a modern gym equipment. A Television set has been acquired and is set up in the lounge. The existing tennis courts adjacent to the building also form part of the facility. We hope that the visitors will make ample use of Chittaranjan.

Science Popularization Programmes

(I) National Science Day

School students demonstrate the model for Lunar and Solar Eclipse during National Science Day Celebrations

IUCAA celebrated the National Science Day on February 28, 1995, with a participation of about 500 school students. The main theme of this year's celebration was the total solar eclipse to be seen on October 24, 1995. Fifteen schools had participated in model making competition on how to demonstrate the phenomenon of eclipse. There were a couple of entries which were very innovative in design. Another eye-catching item was the Astro-ballet, performed by the students of the Sanjeewan Vidyalaya, Panchgani, based on the theme of the myths and legends about the eclipses that are practiced by about twenty different communities in the world. A video film on total solar eclipse of February 16, 1990 was shown. It ended with a quiz contest in which about 80 schools participated. The ceremony concluded with the Director giving away the rotating Trophy and Cup, and a retainable plaque to the winning teams.

(II) Popularization of Astronomy and IUCAA Telescopes

3-inch telescopes

Two of IUCAA's 3-inch telescopes, made by CSIO, Chandigarh, were given on loan to Jyotirvidya Parisanstha (JVP), an association of amateur astronomers in Pune. These telescopes were being used for showing heavenly bodies to general public.

They were also used by JVP during their star parties to give training in polar alignment, finding faint objects using star maps, etc.

A low cost photometer that was developed last year in the instrumentation laboratory of IUCAA was being used for estimating the brightness of the night sky. One M.Sc. student is taking the observations from her residence using the 3-inch telescope and the photometer. This student had demonstrated the same during the Vth All India Amateur Astronomers' Meet at Bhubaneshwar in January 1995.

The other 3-inch telescope is being used for timing lunar occultations.

8-inch telescope

An 8-inch Celestron telescope is also being taken for star parties for advance training and for demonstrations. N.C. Rana was invited for a star party atop Sinhagadh, the Lion fort, about 1317 meters above m.s.l.) south-west of Pune city. A lively discussion and observing continued for the full night. At another star party R. Gupta, B.S. Sathyaprakash and R. Gulati gave talks on various astronomy related topics and answered questions during the tea breaks between the observations.

Students demonstrating parallel transport on a football

Programme for School Students

As a part of the ongoing science popularization programme, IUCAA has started two programmes for the school students of Pune, in order to motivate and train a selected number of students towards opting for a research career in astronomy and astrophysics. The response was overwhelming.

(I) Summer Programme for School Students

From May 2 to June 10, 1994 (six weeks), 126 students from 63 schools participated in this programme. Each school from Pune city was asked to depute 2 students from standards VIII to X for a week. They interacted with IUCAA research scholars, post-doctoral fellows and faculty members and did a project. Projects included, the symmetries in physics, the number theory and group, introduction to the celestial sphere, interior of the Sun/neutron star, rising and setting of astronomical objects, construction of optical periscope and kaleidoscope, making sky globes, determining latitude of a place and the radius of the earth, structures in the universe, the world of dimension 4, measuring solar constant, properties of wave, basic principles of geometrical optics, projectile motion, etc. Students were encouraged to acquire 'do-it-yourself' attitude towards scientific activities. All facilities of IUCAA were extensively used in this programme.

(II) Lecture Demonstrations for School Students

For conveying the excitement of doing science to secondary school students, this programme was instituted. This is being held on the second Saturday every month during June-February. Under this

4th Friday Sky Watching Programme

This year also, people in large number attended the Sky Watching Programme, using IUCAA's 14-inch telescope on the 4th Friday of every month. There are now requests for group showing of the sky by various organisations. A programme was arranged at the Spicer Memorial College, Pune, using 8-inch telescope. IUCAA Graduate Students helped a 300 strong crowd to identify some bright constellations. The public announcement system was used.

Rains and cloudy weather, during 1994, continued till the end of October. These conditions limited the use of telescopes for popularizing astronomy. It had quite disappointed local enthusiasm during the comet Shoemaker-Levy 9's impact on Jupiter in July 1994.

During PEC-94 (Physics, Electronics and Computers-94) exhibition, organised at Fergusson College, Pune, from January 24, 1995, a 3-inch telescope and photometers were exhibited to the students. On the second day, a 8-inch telescope was exhibited. P. Chordia (IUCAA) demonstrated the working of the photometer with the telescope.

programme, the following lecture demonstrations were conducted:

R. Gupta

Comet Shoemaker Levy 9 and Jupiter collision, (in English) September 10.

A.K. Kembhavi

Computer (in English and Marathi), January 14.

J.V. Narlikar

Nature of the universe (in English), July 23; *Vishwat itar thikhani jeevsrishticha shodh* (in Marathi), December 10.

A. Paranjpye

Dhumaketu Shoemaker Levy 9 chi Guru la dhadhak (in Marathi), September 10.

N.C. Rana

Foucault pendulum (in English), August 13; *Total Solar Eclipse* (in English), October 8.

S.N. Tandon

Light pollution (in Hindi), February 11.

All these lecture demonstrations were conducted in the IUCAA Auditorium, with a capacity of nearly 500. The response from the city schools has been overwhelming; on most occasions, some students had to sit on the carpet. On a few occasions, IUCAA was forced to decline admission to late-comers because of insufficient sitting space.

The role of administration has been defined in IUCAA's Project Report as supportive to the Academic Programmes. With a view to ensure that the quality of services being rendered by the administrative and support staff are of the highest standards, the staff are being trained by deputing them for short courses/conferences relating to administration.

During the year, the following staff were deputed for various courses/programmes as mentioned against their names :

N.V. Abhyankar : Attended a Six days Intensive Programme on Central Excise and Union Budget 1994-95 during June 13-18, 1994, conducted by the Indian Institute of Materials Management, Pune.

K.C. Nair : Attended the Western Regional Conference on the theme 'Excellence in Materials Management' during August 12-13, 1994, conducted by the Indian Institute of Materials Management at Hotel Blue Diamond, Pune.

S.N. Khadilkar : Attended a workshop on Microsoft Solutions for the New Business Paradigm on December 21, 1994 organised by the Microsoft Corporation and Software Consultancy Group at Hotel Aurora Towers, Pune.

R.D. Pardeshi : Attended an Intensive Certificate Programme on HRD from December 17 to 30, 1994 organised by Symbiosis Centre for Management and Human Resource Development at Symbiosis College, Pune.

E.M. Modak : Attended a Five Day Workshop on Administrative Vigilance for Inquiry/Presenting/ Investigating Officers from January 16 to 20, 1995 conducted by the Centre for Management, Training and Social Service at New Delhi.

These exposures have certainly contributed in improving effective administrative support to various workshops/seminars arranged by the Centre during the year.

The IUCAA Corpus Fund

During 1994-95 a beginning was made to build up a corpus fund to support IUCAA's scientific activities and visitor programmes not normally covered by the various funding agencies of the Government of India. Since the donations to IUCAA qualify for 100% deduction from taxable income an appeal was made to the various industrial houses to make donations to IUCAA. The goal is to have a fund of Rs 1 crore.

A modest beginning has been made towards this goal and during the period of this Annual Report donations of Rs 7,50,500/- have been received. The detailed list of contributors to the Fund will be published from next year (1995-96).

IUCAA thanks all the donors for their handsome contributions and invites other industrial houses, institutions and individuals to contribute generously to the corpus fund.

Jayant Narlikar
Director

Sixth IUCAA Foundation Day Lecture

WHO SHOULD LOOK AT STARS?

by
Dr. Ashok S. Ganguly
Director, Unilever PLC, London

In January 1994, I met Professor Jayant Narlikar on a flight from Calcutta to Bombay. He then reminded me of an earlier occasion when (in a weak moment), I had agreed to deliver a Foundation Day lecture at his Institute in Pune. I tried to wriggle myself out of the commitment, firstly, by reminding Jayant that I would have nothing meaningful to say to what was likely to be a distinguished gathering of scholars, and secondly, because my daughters were discouraging me from being typecast as a Foundation Day fixture. Both attempts failed, as you will notice from my presence here today.

Having made the commitment to speak, I spent many agonized evenings trying to focus on a suitable topic. Finally, I drew inspiration from my association with Professor Narlikar as a member of the Science Advisory Council to the Prime Minister (1986-89) and settled on a 'Blue Sky' approach. More of that shortly.

A few recent events spurred me to put down some initial thoughts on paper before I lost track of them. A very close friend and his wife were visiting us in London. While we were driving to Glyndebourne to attend a performance of the Opera, Don Giovani, I shared with them my dilemma about the Foundation Day lecture. My friend's wife, a well-known physician from Bombay in her own right, asked me, "Why should a poor country like India, with its impoverished millions, fund research to watch stars?" For the best part of the two hour car ride, we had a series of disagreements on the subject. These disagreements ranged from the concept of curiosity, through the nature of the Indian mind and the need to be part of the international community in leading-edge science, to the origin of the universe and life on Earth. I could not convince her that curiosity-driven exploration was at the heart of human civilisation, starving or otherwise. Finally, the arguments ended inconclusively when I raised a rhetorical question, "What was the level of poverty and deprivation in Italy in the days of Galileo Galilei?" I asked, feeling that would end the debate amicably. Neither of us knew for sure, but she promptly shot back that it really did not matter, since Galileo's star gazing was not funded by the State.

GALILEO - THE STAR GAZER

Her reply had me stumped, until just a few days later when I came across a review by A.C. Grayling of Galileo: A Life, a new book by James Reston Jr. If any one man acted as a doorman to the modern world, Galileo Galilei has an excellent claim to the title. The publication of this latest biography is timely because Reston has hooked his tale firmly to events in the contemporary world: the flight of the space craft Galileo to Jupiter, still taking place as I speak to you, and the decision of the Vatican in 1992 to acknowledge its fault in ill-treating Galileo three and a half centuries ago by dragging him before the Inquisition, humiliating and imprisoning him.

Indeed, Galileo's story is a microcosm of the epic struggle between science, religion and society. Galileo was inquisitive, inventive, and mathematically adept. He was fascinated by the view above him in the clear Italian night sky. He perfected the telescope, and terrified the Church by revealing more stars than had been guessed before, hitherto unseen satellites orbiting other planets, valleys and mountains on the surface of the moon.

Because Christian scriptures taught that the Earth sits immovably in the centre of the Universe, whose celestial spheres are driven round by angels, the Church could not tolerate this new cosmology.

By threats and intimidation, Pope Urban VIII forced Galileo to recant his espousal of the Copernican system. That the Church should come to its own recantation in 1992, speaks volumes for the conflict between faith and reason. Therefore, I cannot consider my friend's wife's question of whether Astronomy research is really needed in a poor country like India unusual.

Galileo not only made discoveries of prime importance in astronomy and physics - especially in the laws of motion, thus breaking the stranglehold of Aristotelian ideas - he was also an inventive genius. He devised, amongst other things, pendulums for clocks, ways of improving telescopes and instruments for measuring pulse rates and temperatures. Despite disgrace by the Inquisition, his telescopic discoveries made him a star all over Europe.

While I have not been able to locate evidence of State support for his experimental pursuits, I am reliably informed that there were many poor people in Italy at the time Galileo gazed at the stars.

From star-gazing Galileo to the man behind the comet, EDMUND HALLEY

Soon after the book on Galileo, I came across an excellent piece by Dr. Allan Chapman of Wadham College, Oxford, on a remarkable man.

Dr. Chapman avers that scientific research has always been expensive, but in the past, the real cost was not so much the hardware, as paying for the scientists' time. This is why so many discoveries between the 17th and 19th centuries have been made by clergymen, semi-retired professionals and businessmen, and people of private means - individuals who were in command of their own time. But while the cash was not entirely certain, if one had the ability to wear many hats and cultivate friends across the whole spectrum of potential influence, then one might enjoy a career similar to that of Edmund Halley (1656-1742). This immediately brought to my mind some eminent Indians who fit parts of this description, like Ramanujam, Sir C V Raman and Homi Bhabha, to name just three.

Edmund Halley's work was funded by, to begin with, family money. When that ran out, he worked as a clerk at the Royal Society, then took a job with the Royal mint, and later joined the Royal Navy. At the age of 48, he became a professor at Oxford and, at 64, the Astronomer Royal. Edmund Halley was clearly capable of living with uncertainty.

Though primarily an astronomer, what is most impressive about Halley's approach to science is his awareness of how the great 'systems' of nature are interconnected. Geomagnetism was such a system. Halley published major papers in 1683 and 1692 in which he collected and analyzed a growing body of data on the subject. He created the geomagnetic chart and then, in 1716, he was the first to recognise the interconnection between the Earth's magnetic field and the aurora borealis.

Halley was a man of vast interests, ranging from pure science to a whole series of practical applications in marine engineering.

I imagine in modern parlance one would find comparable traits in the venture entrepreneurship of many famous American academics and Nobel Laureates. But where are the young Bhabhas and Ramans, I wonder.

FRED HOYLE - THE ASTROBIOLOGIST

No address in an institute headed by Jayant Narlikar would be complete without reference to his Guru, Fred Hoyle, the Astrobiologist.

Being somewhat of an amateur biologist myself, Hoyle's 'origin of life' hypothesis intrigues me. In his autobiography, `Home Is Where The Wind Blows', Hoyle is sanguine about the chances of acceptance of his idea that life began in the vast expanses of space. "'Finding glycine is about five per cent of the way to proving the idea", says Hoyle, 'It's the right way, but it's only five per cent."

The glycine discovery certainly bolsters Hoyle's thesis that the first organic matter rained down on Earth from space. According to Hoyle, it was such a comet which struck Earth about four billion years ago, depositing its cargo of primitive cells - the forerunners of all life today.

It is a rather controversial view, although the idea that organic material - the 'feedstock of life' - came from space is gaining wider acceptance. One is, however, faced with the moral and philosophical dilemma about the true origin of the living form. Hoyle acknowledges that the riddle will not be solved in his lifetime. However, he has been proved right before. In 1940, he had suggested that molecular hydrogen was widespread in space and was greeted with wide disbelief. He subsequently published his views in a science fiction book, 'The Black Cloud'. Since the book was published, more than 100 molecules have been detected in space, including molecular hydrogen, which is now known to be the most abundant molecule in the Universe.

Marcus Chown (New Scientist, September 10th, 1994) writes, "Hoyle believes that, if a problem has an orthodox solution, the scientific community would already have found it, so he looks for the unorthodox solution."

This unorthodox approach has proved Hoyle right on a number of predictions and wrong in just as many, such as the making of the Sun or the explanation of binary stars.

But as the saying goes, "If you have not made mistakes, you have really not tried." I hope the adage applies to this institute also.

I was pleased to learn that, since 1988 Hoyle has developed the 'quasi-steady-state theory' jointly with Burbridge and Jayant Narlikar. The three of them believe that the creation tap opened in one part of the Universe 15 billion years ago, unleashing a flood of matter and causing the expansion of galaxies we observe all about us. Who knows they may be right!

Finally, I feel much comforted by Hoyle's view that "a little bit of God operates in all of us. We are his observing instruments. He observes the Universe through us." No matter where you are, whether in Cambridge or California or Pune, it all happened together.

"HAS SCIENCE LOST ITS WAY?"

While I was warming up to the theme of science for curiosity's sake, I was crestfallen to read Bernard Levin's essay titled 'Has Science Lost Its Way?'. Even if I were to ignore Levin's levity, in the UK, observations on science such as his, fall under the classification of, "Have you beaten your wife today?". Like it or not, some of this reflects contemporary lay thinking.

Bernard Levin's motto seems to be 'Beware of scientists claiming breakthroughs'. He then goes on to observe, "If the boffins do have a fault, it is their conviction that any amount of money required for their work should be immediately provided." In this essay, Levin chose the Quarks as his centrepiece to critique the nature of scientific enquiry and quotes a neat example of his odd but touching belief from a recent breakthrough in science. The last quark had been spotted (or rather not spotted. The thing is invisible). Professor Arie Bodek from Chicago said that his discovery had saved scientists from an intellectual crisis, "since failure to discover the top quark would have shattered decades of research worth billions of pounds." Levin asks, if the quark cannot even be seen, "What is in it for us?" The moot question is, what can discovery of quarks do for the common man? To Levin's queries, the only response he was able to elicit is that there are six quarks named respectively, UP, DOWN, CHARM, STRANGE, TOP and BOTTOM, and that 493 scientists were enlisted to find the last quark, going about the search "smashing protons and antiprotons in a four-mile circular accelerator" and on top of that "the two particles annihilate each other as they collide."

Bernard Levin then moves on to compound his confusion by relating the discovery of a new planet

7000 trillion miles away. Hitherto, "in every case, the putative planets had either proved impossible to confirm, turned out to be something else, or shown to be a product of error." Now, however, Professor Wolszczan's team, "has bolstered its original findings with three more years of even more finely nuanced data designed to eliminate any explanation other than planets". And this statement is backed by Professor Kulkarni, a pulsar expert at the California Institute of Technology, who says, "It should convince even diehard sceptics that planets exist outside the solar system."

Amongst other things, Levin concludes by noting that, whereas the common man may not very much be grudge the scientists the millions and millions of pounds needed to peep beyond the solar system 'where God resides!' while millions and millions may starve and suffer from malnourishment around the world, surely the tax-payers have a right to better understand where all these discoveries are leading.

Well, there we go! In quick succession, the wife of one of my best friends from India and the well known columnist Bernard Levin, two persons from two totally different societies, asking very similar questions. Then interesting events started happening in July.

SHOEMAKER-LEVY 9

My interest perked up on reading the news that the comet, Shoemaker Levy 9, was moving as a funeral procession of 21 fragments of ice and rock after its break up two years ago. Their eventual collision with Jupiter was being described by Astronomers as, "a once in a millennium opportunity". The subsequent pictures and descriptions of the collision were widely reported around the world by the media. I am told that it will take years before the explanation of the events leading up to this collision are well understood. But the pictures and descriptions of the events started making sense to the common man as to why we stare at the night sky. This has been further encouraged by the fact that, unlike the Shoemaker couple who are professional astronomers, Levy is an amateur.

Suddenly Big Bang is back on the agenda and the question on everyone's lips is, "If it could happen to Jupiter, can it not happen to Earth?"

Comets are celestial bodies, believed to be the relics of the birth of the solar system. A thousand or so of them have had their orbits well plotted. But for every comet which is confirmed to exist, there are thought to be at least ten others that have eluded detection. And billions more may reside in a halo beyond Pluto. Comets have collided with Earth before, and scientists insist that more collisions are probable, making it vital to overcome complacency about the threat to Earth from cosmic debris.

If a comet, streaming along at 50,000 miles per hour, were to crash into Earth in the wrong place at the wrong time - London, Bombay or New York at rush hour it could cause a disaster of monstrous proportions. These thoughts were expressed in the editorials of the serious London Times. There is a school of serious Astronomers, aptly known as, 'catastrophists' which is convinced that within the celestial procession of comets lie the seeds of Armageddon. They attribute the death of the dinosaurs, 65 million years ago, to a comet which ploughed into the planet triggering either a nuclear-style winter or uncontrollable fires. The serious question is; If the comet could wipe out the mighty Tyrannosaurus Rex, what chance does puny homo sapiens have?

Thus, contemplating the impact of the 21 fragments of Shoemaker Levy 9 on collision with Jupiter in our lifetime has raised modern Astronomy from the preoccupation of the specialists to a concern for all living and thinking mankind, starving or not.

Such an extraordinary astral event then starts stretching the mind and arouses the interest of the layman in Astronomy, as indeed it did mine. I then began to think that although man has the technology needed to detect and track threatening celestial objects, there is yet no global chain of telescopes.

And research has still to be aimed at defending the Earth from 'asteroid attack', including the possible redeployment of nuclear warheads to shatter incoming projectiles and the use of propulsion units to divert or steer them away. None of these, however, will protect us from every conceivable threat, nor can they whet our awe at the immensity of space. The 'black that remains beyond our blue' seems destined to remain a mystery to all but our telescopes.

THE SOCIAL RELEVANCE

No matter how awestruck I am, I cannot avoid relating all of this to developments in India. I hope I have provided a reasonable, layman's support to the need for the pursuit of the planets even in Pune. The statistical probability is that, next to China, India should have the largest number of curious people. This does not necessarily mean that we should have the second largest population of astronomers peeping through a chain of telescopes across the Indian sub-continent.

However, in Astronomy we have a history of interest as recorded in the Puranas, through the Middle Ages, and now this world class centre in Pune. There is, thus, a tradition in mathematics and physics which links the ancient with the leading edge in India.

This unfortunately is not the case in most other areas of modern science and technology. Although we talk of modernising and globalising India, in lay terms what we really mean is a growth in production and consumption in our lifetime rather than a change in the fundamentals of looking and doing for a better future. I am, therefore, proud that India is considered to be a world player in Astronomy and Astrophysics, if not in any other sphere of science and technology.

Following our independence after over a thousand years of enslavement, Nehru, Bhabha, Bhatnagar, Meghnad Saha and many others inspired my generation to believe that science and technology held the key to traverse the path from backwardness to modernity and provide social justice for all. History will record that, for the first three decades, this promise at least seemed to begin to materialise. The role of science and technology in India achieving self-reliance was indeed significant. India thus achieved a critical mass as a democracy with a viable economy, although the problems of social inequity remained.

At a time when we are ready to integrate India's economic developments with the rest of the world, the same science and technology institutions which helped in achieving self-reliance may now turn out to be the major source of competitive disadvantage. Any attempt to revive them may be futile, as many of them may have outlived their utility. What is necessary is to take drastic steps to restructure and modernise the old and, in addition, create new institutions for the future.

Who should be concerned about this vital problem? The Government, Indian Industry, NGOs, the media, the intellectuals, or whoever? Since 1990 even the interest and vibrancy in the Science and Technology community that one felt and saw in the 1980s seems to have dangerously waned. Unusual and dangerous priorities have overtaken the Nation, such as disputes regarding places of worship, the revival of the caste conflict, the drive for instant gratification and enrichment, multinational baiting, the 'back to primitive roots movement', etc. There is not even lip service paid to the social and economic imperative to modernise our institutes of higher education and those institutions dedicated to advanced research in different areas of S&T. Every country, other than India, seems to be deeply engaged in addressing these vital issues. China is set to revamp its total research base, from one which had remained isolated and totally dependent on the State, towards one which is more autonomous, modern and globally relevant. There is a similar reassessment of the science base in the USA and Japan. In the UK, the 1993 white paper on the need to choose areas of science in which to lead and its relevance to that country's global competitiveness was articulated. The key was that not every country could afford to be outstanding in every discipline of science. What a nation needs is a solid foundation in basic and higher education and then the ability to choose areas of science to excel in, by the combined efforts of the Government, Academia and Industry.

As an Indian, it frightens me today that, as we enter the most complex and competitive period in human history, we in India, seem to adopt a policy of benign neglect of higher education and leading edge S&T. Probably the only other tragedy that this policy can be compared with is the disarray in the once powerful S&T culture of the former Soviet Union with its devastating consequences.

India does not have a choice. All of us must raise our voices against this benign neglect, in which lie the seeds of economic impoverishment and social disarray. Just talking about liberalisation, economic development and poverty alleviation will not do. There are limits to foreign investment and export growth. Without overhauling our S&T base, India faces a finite economic horizon.

I, therefore, disagree with my friend's wife and with people like Bernard Levin. Just because we are unable to comprehend science-speak or because many mediocre practitioners may have given science a poor image, it does not mean that there are better alternatives to achieve excellence in science. For there are none. More people will die of starvation and malnourishment without scientific advances and more nations will face decline and catastrophe without the pursuit of scientific knowledge. I am, therefore, thrilled that Professor Narlikar and his dedicated colleagues have built this world class facility in Pune. Could this be the faint glimmer of light at the end of the tunnel? We need a few more of these, and soon. I am encouraged by developments in massively parallel computing, also in Pune, advances in complex materials in the Institute of Science in Bangalore, the modernisation of NCL and a few other such developments. They cost very little money. What they need is a few great minds. As an Indian, I am grateful that we have a fair number of excellent minds. Let us create the environment in which they can flourish to prepare India for the next century. Jayant and I had the privilege of being members of Rajiv Gandhi's Science Advisory Council. In every meeting we had with him, we enjoyed inspirational debates on the choice of blue sky priorities. True, even then, everyone was aware of India's day to day problems, but it was not a question of either/or. Such debates have now waned. I hope Narlikar and his dedicated group will help revive the debates, even beyond blue skies. I sometimes wonder, if only we could divert a fraction of the energy of our people away from breaking down places of worship or participating in caste riots, towards the pursuit of scientific enquiry, could we transform our nation and start realising our potential?

I am now pleased about the brief encounter Jayant and I had in January 1994.

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BALANCE SHEET AS AT MARCH 31, 1995

ASSETS AND PROPERTIES	SCHEDULE	AMOUNT (RS.)
1. FIXED ASSETS	[1]	133,560,470
2. OTHER PROJECT ASSETS	[2]	1,270,742
3. DOE ERNET ASSETS	[3]	357,006
4. INVESTMENTS		1,703,239
5. CURRENT ASSETS		
A) STOCKS ON HAND	[4]	869,581
B) CASH & BANK BALANCES	[5]	4,156,027
C) AMOUNTS RECEIVABLE	[6]	1,218,135
D) LOANS & ADVANCES	[7]	5,730,217
E) DEPOSITS	[8]	618,878
6. DEFERRED REVENUE EXPENDITURE	[9]	245,347
7. INCOME & EXPENDITURE ACCOUNT		106,612,689
OPENING DEBIT BALANCE		74,458,326
ADDITION DURING THE YEAR		32,154,363
TOTAL (RS.)		256,342,331
REPRESENTED BY FUNDS & LIABILITIES	**SCHEDULE**	**AMOUNT (RS.)**
1. TRUST FUND OR CORPUS	[10]	147,262,412
2. OTHER EARMARKED FUNDS	[11]	107,827,554
3. CURRENT LIABILITIES		
A) CREDITORS	[12]	212,973
B) OTHER LIABILITIES	[13]	1,039,392
TOTAL (RS.)		256,342,331

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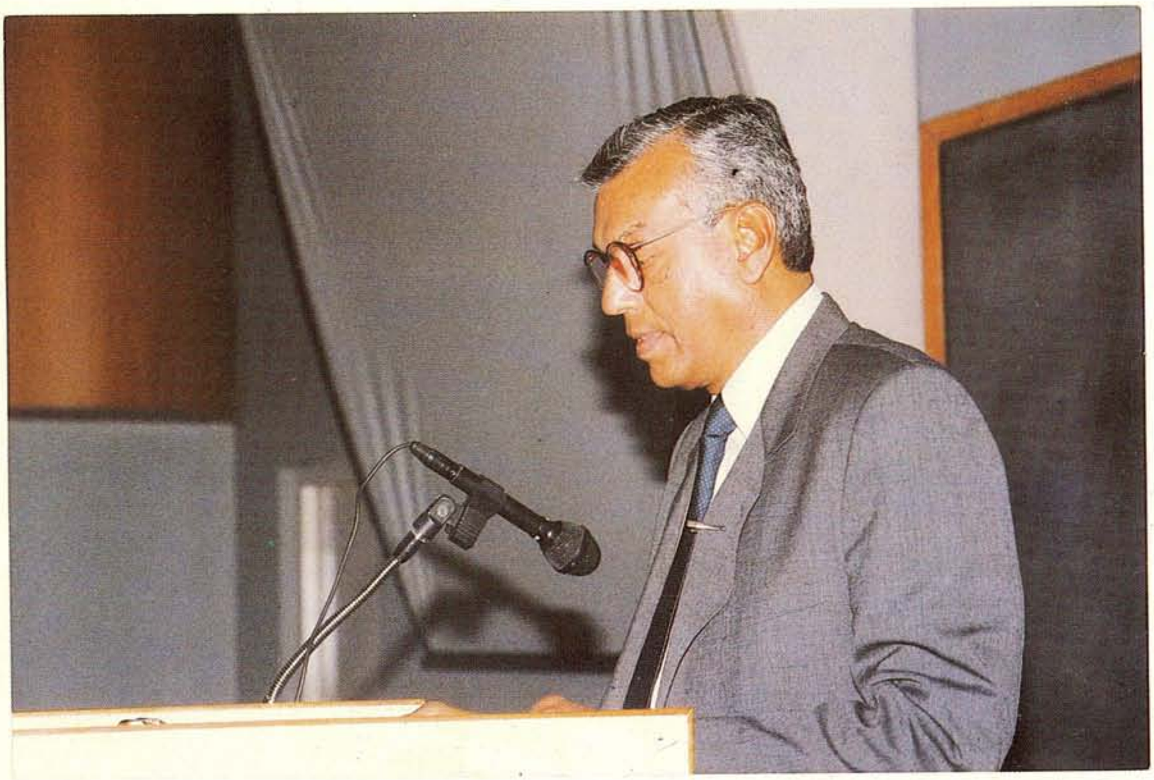

Ashok S. Ganguly delivering the
6th IUCAA Foundation Day Lecture