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IUCAA

Editor
T. Padmanabhan
(e-mail : paddy@iucaa.ernet.in)

Design, Artwork and Layout
Santosh Khadilkar
(e-mail : snk@iucaa.ernet.in)

No. 36

A Bulletin of the
Inter-University Centre for Astronomy and Astrophysics
(An Autonomous Institution of the University Grants Commission)

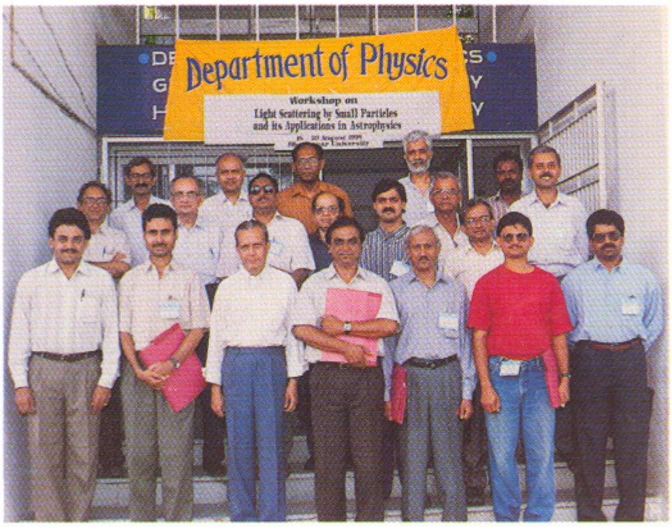
October 1998

Workshop on Light Scattering by Small Particles and Its Applications in Astrophysics

This workshop, sponsored by IUCAA, was organized at the Department of Physics, Bhavnagar University, during August 18-20, 1998. The aim of the workshop was to provide a platform to scientists working on different aspects of light scattering and to put together their expertise for astrophysical applications. Researchers from across the country participated very actively in this workshop.

J.V. Narlikar (IUCAA) provided the initial impetus by his ideas on whiskers in the interstellar dust. N.C. Wickramasinghe (University of Wales, Cardiff) discussed his revolutionary ideas of having biological molecules in the space among galactic dust. J.N. Desai (PRL, Ahmedabad) discussed about the results from various laboratory studies of light scattering and their possible application in astrophysical context. B.G. Anandrao talked about the recent developments in infrared emissions from circumstellar dust. H.C. Bhatt (IIA, Bangalore) lucidly described details of HII regions in space. A.K. Sen (Assam University, Silchar) talked on recent observations of molecular clouds and their dust scattering properties. The scattering properties of porus grains were brought out in detail by D.B. Vaidya (PRL). Ranjan Gupta (IUCAA) gave a talk on interstellar extinction and IUE observations. R.V. Mehta (Bhavnagar University) discussed the various experiments of light scattering using magnetic fluids and their possible extensions. K.S. Baliyan (PRL) talked on recent observations of cometary dust grains, while S.K. Sharma (S.N. Bose National Centre, Calcutta) discussed his work on phase functions for scattering of light.

All the talks were delivered in a very cordial atmosphere and everyone participated actively. Participants came from various colleges of Gujarat, and included research students and post-doctoral fellows from PRL, scientists from Remote Sensing Applications area. Expressing their thoughts at the concluding session of the workshop, the participants expressed satisfaction and thanked IUCAA and Bhavnagar University for providing this opportunity to interact with prominent scientists. A few scientists who had earlier worked on light scattering applied to paints showed keen interest to utilize their experience in astrophysics.



Participants of this workshop

Inside...

IUCAA *Preprints*

Listed below are the IUCAA preprints released during July - September 1998. These can be obtained from the Librarian, IUCAA (library@iucaa.ernet.in).

Valerio Faraoni and Edgard Gunzig, *Tales of tails in cosmology*, IUCAA-23/98; **Valerio Faraoni**, Edgard Gunzig and Pasquale Nardone, *Conformal transformations in classical gravitational theories and in cosmology*, IUCAA-24/98; **Ali Nayeri** and **T. Padmanabhan**, *A possible Newtonian interpretation of relativistic cosmological perturbation theory*, IUCAA-25/98; **Sumati Surya** and Sachindeo Vaidya, *Global anomalies in canonical gravity*, IUCAA-26/98; Fay Dowker and **Sumati Surya**, *Topology change and causal continuity*, IUCAA-27/98; **Sumati Surya** and Donald Marolf, *Localized branes and black holes*, IUCAA-28/98; **K. Srinivasan** and **T. Padmanabhan**, *Facets of tunneling : Particle production in external fields*, IUCAA-29/98; **Valerio Faraoni**, *Does the non-minimal coupling of the scalar field improve or destroy inflation?*, IUCAA-30/98; **Valerio Faraoni** and F.I. Cooperstock, *When a mass term does not represent a mass*, IUCAA-31/98; **Varun Sahni** and Salman Habib, *Does inflationary particle production suggest $\Omega_m < 1$?*, IUCAA-32/98; **Sushan Konar** and Dipankar Bhattacharya, *Magnetic field evolution of accreting neutron stars - II*, IUCAA-33/98; **Sukanta Bose** and **Naresh Dadhich**, *On the Brown-York quasilocal energy, gravitational charge, and black hole event horizons*, IUCAA-34/98; and **A. Pai, S.V. Dhurandhar**, P. Hello and J-Y. Vinet, *Radiation pressure induced instabilities in laser interferometric detectors of gravitational waves*, IUCAA-35/98.

Congratulations to...

R.P. BAMBAH
Chairperson, Governing Board of IUCAA, for being awarded the **Aryabhata Medal,** by INSA

J.V. NARLIKAR
for being awarded the
Punya Bhushan Award
(great personalities of Pune) by Tridal, Pune, and the **N.C. Kelkar Award**
by Dainik Kesari, Pune,
for his book *Akashashee Jadale Nate,*

J.V. NARLIKAR
and ASHOKE SEN,
Mehta Research Institute of Mathematics and Mathematical Physics, Allahabad,
for jointly being awarded the
R.D. Birla Award
by the Indian Physics Association,

K.D. ABHYANKAR
for being awarded the
INSA-Vainu Bappu Award

Refresher Course in Astronomy and Astrophysics

(May 17 - June 18, 1999)

IUCAA will conduct a Refresher Course in Astronomy and Astrophysics for teachers in universities and colleges. The topics will include observational and theoretical aspects of astronomy. In addition to lectures, the course will emphasise problem solving sessions and experiments; approximately two hours a day will be devoted to one of these two activities.

The number of participants for the course will be 20. Interested persons should apply on plain paper, giving their curriculum vitae, and their experience of teaching and research in astronomy over the last five years. Applications should be forwarded through the Head of the Department, or Principal of the College/Institution, so as to reach the **Coordinator, Core Programmes, IUCAA**, by **January 20, 1999**. The candidates will be informed of their selection for the course by **March 1, 1999**.

Vacation Programme for University Students (VPUS)

IUCAA invites applications for the Vacation Programme for University Students (VPUS). Students selected under this programme will spend six weeks at IUCAA to work on specific research projects under the supervision of the IUCAA Faculty. The time of the year when the project is to be taken, is flexible and may be chosen by the student as per his/her vacation and availability of Faculty in IUCAA. Those who perform well will be pre-selected to join IUCAA as Research Scholars to do Ph.D. in Astronomy and Astrophysics, after completing the prescribed evaluation procedure and satisfactory completion of their degree requirements.

Students who are in the pre-final year of the M.Sc. (Physics/ Applied Mathematics / Astronomy / Electronics) / B.Tech./ B.E. (any branch) and have motivation to do research in Astronomy and Astrophysics, are eligible to apply. Applications, in plain papers, giving the academic record (from class X onwards) of the applicant as well as two letters of Confidential recommendations from teachers, should reach the **Coordinator, Core Programmes, IUCAA**, Post Bag 4, Ganeshkhind, Pune 411 007, by December 15, 1998.

This programme is, in additiion to the usual Vacation Students' Programme, planned to suit some of the university/college students. The selected students will be provided with travel support and free hospitality at IUCAA during the period of this programme.

IUCAA Observing Programmes

IUCAA has ongoing observing programmes for interested persons from universities and colleges. The programmes involve observing with small and large optical telescopes, through proposals submitted to various observatories in India and abroad, under their Guest Observing Programmes. Observations with the Ooty Radio Telescope and analysis of archived data obtained from various terrestrial and space based telescopes are also possible. Intending observers may work either individually or in collaboration with each other and with IUCAA faculty. Interested persons may write to the Coordinator, Core Programmes, IUCAA, in this regard.

2nd Level 1 Workshop on Astronomical Photometry

(during January 25-29, 1999, at IUCAA)

The **2nd Level 1 Workshop on Astronomical Photometry** will be held at IUCAA during January 25-29, 1999. The workshop will focus on the light pollution of the night sky and elementary astronomical photometry. The participants of the workshop will make a photometer to observe the brightness of the night sky and stars using small telescopes developed in IUCAA's Instrumentation Laboratory. Participation to this workshop is limited to 18. Limited funding for travel is available and local hospitality will be provided to all the participants. The participants should be prepared to work for extra hours in the Electronics Laboratory to build their own photometers and to take observations in the night. Interested persons may apply to the **Coordinator, Core Programmes**, IUCAA, before November 10, 1998, with a brief bio-data and a note (not exceeding 500 words) about what they understand by light pollution, astronomical photometry and how they wish to use the photometer.

Workshop on Introductory Image Processing and Astronomical Applications

(during February 1999, at Tezpur University)

A workshop on Introductory Image Processing and Astronomical Applications will be held in Tezpur University, Assam, during February 1999. The dates will be shortly announced. The workshop will cover various elementary aspects of image processing and related areas and is mainly meant for people from the north-eastern region of India. Those interested may write to **Professor A. Choudhury**, Professor and Head, Department of Physics, Tezpur University, Tezpur 784 001, Assam, by November 30, 1998.

Seminar on Science and the Media

(during March 1-2, 1999, at IUCAA)

IUCAA will be holding a two day seminar on Science and the Media during March 1-2, 1999. The purpose is to bring together a variety of persons engaged in taking science to the masses. The seminar is being organized after the National Science Day celebrations at IUCAA, so that the participants for the seminar would be able to experience for themselves the efforts taken by IUCAA for popularization of science, if they desire to do so. Interested persons may apply (in plain papers), giving their name, organization, address, etc. to the **Coordinator, Core Programmes,** IUCAA, before October 31,1998.

Other Forthcoming Events

November 9-13, 1998, **Introductory School on Astronomy and Astrophysics,** at Indira Gandhi Science Complex-Planetarium, Patna; *Contact person:* **Shri B.K. Sinha**, Project Director, Indira Gandhi Science Complex-Planetarium, Adalatganj, Patna-800001, Bihar. FAX: 0612-230432.

January12-16, 1999, **Introductory School on Astronomy and Astrophysics,** at G.C. College, Silchar; *Contact Person:* **Dr. Asoke K Sen,** Department of Physics, P.B. 63, Assam University, Silchar-788001, Assam. FAX: 03842-32779

January 18-19, 1999, **Orientation Meeting on Exact Solutions in Relativity and Cosmology,** at Department of Physics, D.D.U..Gorakhpur University, Gorakhpur-273009, U.P.; *Contact Person:* **Dr. D.C. Srivastava** at the above address. FAX: 0551-340459/332398

We are happy to note that

Professor J.V. Narlikar has taken up the first Homi Bhabha Professorship of the Department of Atomic Energy from July 19, 1998. Till such time as he is the Director of IUCAA, he will hold this professorship in an honorary capacity.

The Discovery Of Quasi-Stellar Objects

Perhaps the event which contributed most towards enlivening extragalactic astronomy this century was the discovery in 1963 of the quasi-stellar objects.

As the adjective 'quasi-stellar' suggests, these objects have a star-like appearance (in contrast to the fuzzy appearance of galaxies), and they had earlier been mistaken for stars. The appreciation of their rather extraordinary nature came about, thanks to a cooperation between optical and radio astronomers.

Radio astronomers C. Hazard, M.B. Mackay and A.J. Shimmins took the first step in this venture in 1962, when they used the then new method of lunar occultation. The radio source 3C 273 was going to be occulted by the Moon and the drop in its radio flux during the period of occultation could be used to pin point the position of the source very accurately. These observations were carried out by the trio at Parkes Radio Astronomy Observatory.

The accurate position coordinates of the source were conveyed to the optical astronomers using the then largest telescope of 5 metres on the Palomar Mountain. With the help of optical plates, the source was identified with a 13th magnitude star. However, it was only when Maarten Schmidt at the Palomar Observatory took the spectrum of the object that its extraordinary nature became clear. The spectrum had emission lines, which are somewhat unusual for a star, but even more importantly, they showed a redshift of 0.158, *which was unheard of for a star*. Thus the source was not a star. What was it?

Shortly thereafter, another radio source 3C 48 was identified with another starlike object and this one had a redshift even higher, of 0.367. Astronomers realized that they were finding a new population of sources. What was the cause of their high redshifts?

Assumptions that the redshift was Doppler or gravitational in origin were tried, but they placed almost impossible constraints on the early models. The third option, that of cosmological redshift (due to expansion of the universe), was known for galaxies and could be applied to these sources. This placed them well beyond the Galaxy and, therefore also demanded that they were as powerful emitters of light as the typical galaxy.

This requirement coupled with the compact size of the source meant that it had its energy reservoir within a very tiny volume compared to a galaxy. In the early part of 1963, Fred Hoyle and William Fowler proposed that the energy source lay in the gravitational field of a compact supermassive object, later to be identified with the name 'black hole'.

Today, around 10,000 quasars have been found and they have provided a wealth of menu to astronomers and astrophysicists. The former have to contend with multi-wavelength observations ranging from radio to X-rays, while the latter have to provide models of high energy astrophysics using at times, inputs from general relativity.

UPDATE

The IUCAA Telescope Project

The overall progress during the last one year has been slow. The work on the telescope has suffered due to delays at RGO (UK), and on the basis of a recent review, we have been informed that the telescope is expected to be ready by June 2000. The process of aquiring the land is in its final phases and the construction of the observatory is expected to commence soon.

The progress on the instrumentation has been more encouraging. The proposal to develop a versatile faint object imager spectrograph, in collaboration with the CSIO, Chandigarh and Copenhagen University Observatory, has received funding from the CSIR and DST, and the design work on the optics as well as the mechanics is over. The optics is under fabrication at CSIO and the mechanical fabrication, along with the controls and electronics, is being done at the Copenhagen University Observatory. This instrument is expected to be ready well before installation of the telescope.

Gravitational Collapse and Critical Phenomena

1. Introduction

Since Schwarzschild's pioneering work in 1916, several types of black holes have been found to arise as solutions in general relativity. Since general relativity has a well posed initial value formulation (see, e.g., Wald (1984)), it is of interest to ask if black holes can be formed by evolving non-singular initial data that respect reasonable energy conditions on matter. Related to such a time-evolution is the issue of the (non)-validity of the cosmic censorship hypothesis (Penrose (1979)), which opposes the formation of naked singularities (i.e., singularities uncloaked by an event horizon) from generic initial data.

Several authors have studied the gravitational collapse of matter fields, primarily in spherically symmetric and axisymmetric cases, and have attempted to classify the initial data into sets that evolve to form (i) a black hole, (ii) a naked singularity, or (iii) non-singular future spacetime regions. Recent reviews of the status of this field are given by Clarke (1993), Joshi (1993), Singh (1996).

In this summary, we will discuss the evolution of only fundamental matter fields, such as the Klein-Gordon scalar field (as opposed to macroscopic fluid distributions) under gravitational interaction. The evolution of a spherically symmetric configuration of massless scalar fields under self-gravity is the simplest matter configuration one can study, for, as a result of Birkoff's theorem, such systems have no physical gravitational degrees of freedom. This is the first case we discuss below.

2. Collapse of spherically symmetric scalar fields

Analytically, the evolution of spherically symmetric scalar massless, minimally coupled matter fields in Einstein gravity has been studied notably by Christodoulou (1984 - 1996). He showed that in such systems, if the initial data is sufficiently weak in a well defined way, it evolves to a Minkowski-like spacetime (Christodoulou (1993)); otherwise it forms a black hole (1991). Heuristically, the evolution of such systems is governed by a competition between the kinetic energy of the scalar field (which tends to disperse the field to infinity) and its self-induced gravitational potential energy (which tends to trap some mass to form a black hole). Depending on which of these two effects dominates, one of the two end states results.

The main issue in these studies was to seek an answer to the following question (Choptuik (1994)): Consider a generic smooth one-parameter family of initial data such that for large (or supercritical) values of the parameter p, a black hole is formed, and no black hole is formed for small (or subcritical) p. Then, if one searches the solution space near the critical value p^* at which a black hole is barely formed, does it have an infinitesimal mass or a finite mass? Alternatively stated, one seeks if the phase transition from non-black hole to black hole solutions is of second order or first order, respectively. The latter situation pertains to the existence of a "mass gap".

A conclusive answer to this question proved elusive until 1993, when Choptuik employed advanced numerical methods (which recursively refine the numerical grid) to provide convincing evidence for a second-order phase transition in spherically symmetric collapse of scalar matter fields. More surprisingly, the near-critical solution of an infinitesimally small black hole exhibited the following phenomena. First, the black hole mass scales as $M \propto (p - p^*)^\gamma$. Second, the solution is scale periodic. That is, there exists a certain foliation of such a spacetime in terms of spacelike slices such that a region of any slice is a scaled image of that on a previous slice. The logarithmic scale period of this solution is denoted as Δ. Interestingly, the critical exponent γ and the scale period Δ remain unchanged for all such one-parameter families of initial data sets. This aspect is often termed as "universality". The above features associated with these infinitesimal black hole solutions together constitute critical phenomena. The critical solution in the spherically symmetric Einstein-scalar field system is called the "choptuon".

3. Gravitational collapse of other fields

The critical phenomena found by Choptuik are not limited to the collapse of scalar matter fields. Similar features were found in the following systems. Collapse of radiation was studied by Evans and Coleman (1994). The collapse of a massive scalar field was simulated by Choptuik (1994) and Brady et al. (1997); the critical solution in such a collapse was also analysed by Gundlach and Martin-

Garcia (1996), and Hara et al. (1996). The case of scalar electrodynamics was dealt by Hod and Piran (1997). It may be noted that in the case of collapsing dust, the initial data can be used to determine the full spacetime solution in closed form. This is the Tolman-Bondi solution (Tolman (1934), Bondi (1947)). Barring shell-crossing singularities, the space of initial data can be divided into two categories: one in which a naked singularity is formed at the centre, and the other in which a black hole is formed. In this case, the end state of evolution is determined solely by the leading terms in the expansion of the initial data around the centre of symmetry (Christodoulou (1984); Jhingan et al. (1996)). This aspect of the fluid models is considered by some to reveal the unphysical nature of associated collapse scenarios (Gundlach (1998c)).

In the context of lower dimensional gravity, such as the two-dimensional sigma models, such critical phenomena have been shown to exist in the collapse of complex scalar fields (Hirschmann and Eardley (1995); Gundlach (1997)), axion-dilaton fields (Eardley et al. (1995); Hamade et al. (1996)) and the scalar-Brans-Dicke field (Liebling and Choptuik (1996)).

4. Non-spherical collapse

In all of the above cases, spherical symmetry was assumed. Do Choptuik's results hold in the collapse of more generic field configurations? This is an area in need of some exploration. The only works available are of two types. First, soon after Choptuik's work (1993), such critical phenomena were observed in the axisymmetric collapse of gravitational waves in pure gravity by Abrahams and Evans (1993, 1994). The only other type of collapse scenarios studied are the ones obtained by introducing non-spherical perturbations about critical solutions corresponding to some spherically symmetric collapses (Gundlach (1998a)). In these limited contexts, critical phenomena do persist.

5. Systems with type I phase transition

It has been known that in the space of initial data, type I black hole phase transitions are expected to occur in the context of the instability that arises in sequences of static stellar models parametrized, e.g., by the central density. In the context of collapse of fundamental fields, a similar transition has been reported to occur by Choptuik et al. (1996) in the spherically symmetric SU(2) Yang-Mills field. Brady et al. (1997) have shown that such a transition is also found in the massive scalar field system.

6. Choptuik scaling of angular momentum

Since, all classical asymptotically flat stationary black hole solutions can be characterized completely by their mass, charge, and angular momentum, it is logical to ask if scaling relations (akin to that for the mass) also exist for the remaining two black hole parameters. In fact, *a priori* the possibility remains that introducing charge and angular momentum in the initial data may lead to a violation of Choptuik's scaling law for the black hole mass. In his study of collapse with non-spherical perturbations, Gundlach (1998b) investigated the behaviour of the leading non-spherical mode that contributes to the angular momentum of the system and found such a scaling law to exist. Similarly, in a perturbative approximation, Gundlach and Martin-Garcia (1996) have shown a power-law scaling for the black hole charge. However, whether these laws hold for more generic initial conditions is yet to be investigated.

7. Explaining the origin of critical phenomena

This remains an open problem till date, although some suggestions have been offered. To explain the power-law scaling of the black hole mass, Argyres (1994) and Koike et al. (1995), among others, have noted that the time - evolution near the critical solution can be explained as a renormalisation group flow on the space of initial data. The computation of the critical exponent γ should then be similar to that for the critical exponent governing the correlation length near the critical point of statistical systems.

On the other hand, Garfinkle (1997) has pointed out that the self-similarity of the critical solution could be linked to the scale invariance of the Einstein field equation. He defines "scale invariant" variables in terms of the phase space variables of the Einstein theory. The field equations are then recast as time-evolution equations for the scale-invariant parts and that for the scale part. He suggests that when the scale-invariant variables are periodic, the spacetime is discretely self-similar. This must happen when the parameter obeys $p = p^*$. For scale-invariant systems, one would have to find a mechanism for the "dissipation" of energy so as to evolve the system towards a limit cycle. On the other hand, for initial data sets corresponding to parameter values away from criticality, this mechanism should drive the system away from this cycle. It must, however, be noted that these suggestions have not yet been borne out by any conclusive demonstrations.

8. Status of the cosmic censorship hypothesis

Although "bets" have been won and lost among prominent researchers over the supposed demise of this hypothesis in the wake of the Choptuik phenomena (see New York Times (1997)), it must be made amply clear that this hypothesis is more robust now than ever before (Wald (1997)). Essentially, the hypothesis says that for all physically reasonable spacetimes, with suitable matter (that is, for matter obeying reasonable energy conditions), and arising from generic initial data, no singularity is ever "visible" to any observer. Although, this hypothesis has never been proven, there is enough evidence in its support. It has been shown that different types of black holes are stable under perturbations (Vishveshwara (1970), Price (1972), Whiting (1989)). Studies of certain collapses of fluid matter, which conclude that naked singularities are formed, can be shown to employ either non-generic initial data or non-suitable matter (Wald (1997)). Moreover, any attempt to provide counterexamples (Gibbons (1972), Penrose (1973)) to disprove the hypothesis has failed. More recently, after the advent of Choptuik's work, Christodoulou (1994) has investigated the global behaviour of spherically symmetric Einstein-scalar field system analytically and showed that there exist suitable matter corresponding to certain choices of initial data that evolve to form naked singularities, which are similar to the naked singularities in the near-critical solutions of the Choptuik type. However, Christodoulou (1998) has now analytically demonstrated the non-generic nature of these naked singularities. All these analyses only work towards increasing the longevity of the cosmic censorship hypothesis!

9. The Quantum story

Choptuik's work of 1993 has certainly opened up a Pandora's box. However, the novel phenomenology of the critical classical solutions notwithstanding, it is pertinent to ask about the odds of such phenomena manifesting themselves in nature. We saw that the critical solutions already suffer from the non-generic character of the initial data. That apart, there is a possibility of quantum effects playing truant in modifying the beautiful critical features. It must be noted that the surface gravity at the horizon of, say, the Schwarzschild black hole, diverges as its size becomes infinitesimal. This indicates the breakdown of the classical theory in such regimes of the solution space. To wit, in these cases, the role of quantum effects can not be ignored. In this regard, a few groups (Strominger and Thorlacius (1994), Bose et al. (1996), Peleg et al. (1997), Ayal and Piran (1997)) have analysed "toy" models in effectively lower-dimensional gravity. There, one quantizes the scalar matter fields propagating on a classical dynamical spacetime, which in turn responds to the back reaction of these quantized matter fields through the semiclassical equations of motion. Although, the results obtained are model dependent, Peleg et al. have demonstrated that the Choptuik scaling, which is manifested in their classical near-critical solutions, breaks down when quantum corrections are taken into account. Moreover, the 2nd order phase transition, which occurs for the classical case, appears to become 1st order in the quantum picture. The associated mass gap depends on the initial data and is, therefore, non-universal. Heuristically, the mass gap can be understood to arise from the quantum pressure created by the vacuum polarisation effect, which tends to disperse the matter to infinity unless it is of a minimum mass determined by the Planck's constant.

10. Conclusion

Although, only half a decade has passed after Choptuik's discovery, the volume of related work that has followed in the aftermath bears testimony to its significance. Recently, a couple of reviews have arrived that describe in greater detail some of the material presented in this summary. These are by Gundlach (1998c) and Choptuik (1998) himself.

Before Choptuik's work, numerical computations in relativity were mostly relegated to the role of quantifying aspects that were already understood qualitatively. The critical phenomena associated with gravitational collapse, on the other hand, has unearthed unanticipated solutions which analysts will be busy explaining quantitatively for at least a few years to come.

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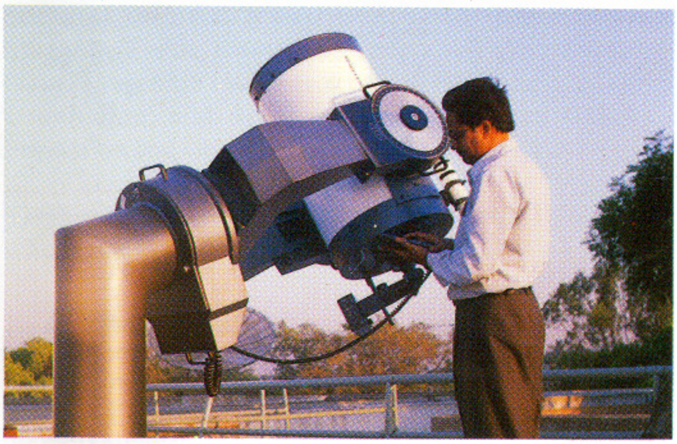
Observations with IUCAA Meade Telescope

Recent advances in astronomical instrumentation have placed efficient computer controlled telescopes, CCD imaging cameras and sophisticated photometers within the modest budgets of small observatories. Now, students and amateur astronomers have a chance to observe with high quality instruments. In order to make these facilities available to observers, IUCAA has initiated an observing programme. IUCAA has acquired one 16" Meade LX-200 telescope, ST-7 CCD camera and SSP 3A photoelectric photometer. During the previous observing season, we thoroughly tested the performance of the telescope and its accessories.

Telescope and its Accessories

IUCAA Meade Telescope is mounted on the terrace of the IUCAA main building, Aryabhatta, on a permanent metallic pier attached to an equatorial mount. The telescope is a 16" Meade LX-200 Schmidt Cassegrain, focal ratio f/10, manufactured by Meade Instruments Corporation, USA. The motion of the telescope as well as tracking and focusing can be achieved either by using a key-pad or through a PC. For astronomical imaging, a ST-7 CCD camera manufactured by Santa Barbara Instrumentation Group, USA is available. The CCD is of array size 760 X 510 pixels. The telescope CCD combination gives a fine resolution of 0.5 X 0.5 arcsecond per pixel. CCD camera is equipped with Bessell's BVRI standard filters for use in scientific observations and RGB interference filter for colour imaging. An important scientific use of the small telescope is for photoelectric photometry of variable stars and other astronomical objects and that can be done using the SSP-3A solid state photoelectric photometer. Filters mounted on the SSP-3A photometer are standard broad band Johnson filters. The photometer has been interfaced with the computer and digital output can be stored on the computer for further reduction and analysis.



IUCAA 16" Meade Schmidt Cassegrain telescope mounted on the top of the IUCAA Building

Research Projects Using the Telescope

Variable star observation

The study of variable stars is one of the most popular and dynamic fields of modern astronomical research. With the development of new astronomical tools and techniques, classical variables are being studied in novel ways. At the same time new types of variable stars are being discovered. As a branch of astronomical research, the study of variable stars is one where amateur astronomers can make a significant contribution to frontier research. Professional astronomers using the most sophisticated instruments of ground and space based astronomy, collaborate with amateur (and some professional) astronomers using small telescopes to probe the mystery of stellar variability. Their work is very important for the study of stellar structure and evolution. Variable star astronomy is one of the few fields in astronomy where amateurs are not only encouraged but are also vital to the scientific process. Earlier this year, several groups including amateur astronomers and college teachers, observed variable stars using the IUCAA telescope. One set of observations of the light curve of δ Scuti type variable star γ Crb (Fig. 1) was obtained by three amateur astronomers from Dombivli near Mumbai. The cause of periodic light variation in δ Scuti is the pulsation of the outer stellar envelope in a very complicated fashion, in radial and non-radial modes. Astronomers around the globe are paying much attention to investigate the pulsation of δ Scuti stars, which is one of the best diagnostic tools to explore the interiors of stars. After white dwarfs,

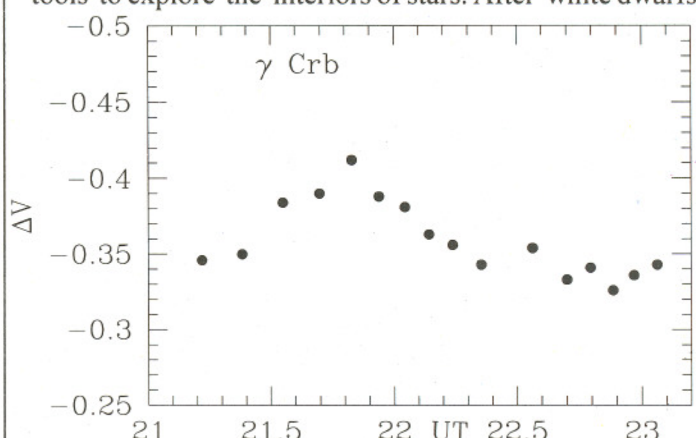
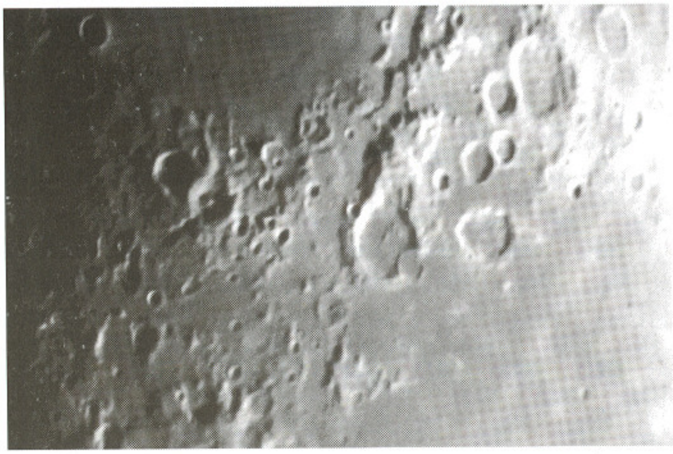


Fig 1. Light curve of the short period Delta Scuti Gamma Crb, observed by amateur astronomers from Dombivli.

δ Scuti stars are the second most abundant pulsating variable in our Galaxy. Because of their short light variation period, one can cover many cycles within a single night. Apart from observation of these classical variables, the telescope has been used to carried out fruitful work on RS CVn binaries which is one of the most attractive and challenging fields in variable star astronomy.

CCD Imaging and Astrophotography

Advent of the electronic imaging CCD camera started a new era in astronomical observation. The use of CCD cameras allows access to faint objects which previously could be observed only using big telescopes. Our small format SBIG ST-7 CCD camera, provides imaging as well as tracking facility. In the last observing run, we tested the CCD camera and got some fine images of the moon and some planets. One CCD image of the Moon's south-west part recorded on March 3, 1998 has been shown in the photograph. We used red interference filter to enhance contrast between lunar features and their backgrounds. Exposure time was 20 seconds. A useful project could involve broad band CCD imaging of planets and compact deep sky objects like globular clusters and bright galaxies. A SLR camera and black and white film processing lab are available for astrophotography.



Cratered south-west surface of the Moon recorded on March 3, 1998, using ST-7 CCD camera on the IUCAA Meade telescope.

Measuring Atmospheric Extinction

High quality astronomical observation requires a considerable amount of technical skill that can be developed only by training and practice. An excellent exercise in observation involves measurement of atmospheric extinction at a site.

Light coming from stars and other astronomical objects travels through the Earth's atmosphere before it reaches us. While passing through the Earth's atmosphere, star light is scattered as well as absorbed. This leads to dimming of star light which is called extinction. Loss of star light is measured by extinction coefficients, which depend on various factors such as atmospheric conditions, altitude of the observatory, and wavelength of the incoming light. Meteorological conditions strongly affect extinction coefficients, so atmospheric extinctions vary a lot. Each observation needs to be corrected for atmospheric extinction so that two different observations can be effectively compared. We carried out extensive observations of atmospheric extinction from February to April 1998. Distribution of the extinction coefficients during this period have been shown in Fig. 2. Our extinction results show that though Pune is a very large city with severe light pollution, its atmospheric conditions are favourable from the astronomical point of view and one can make useful observations using the IUCAA telescope.

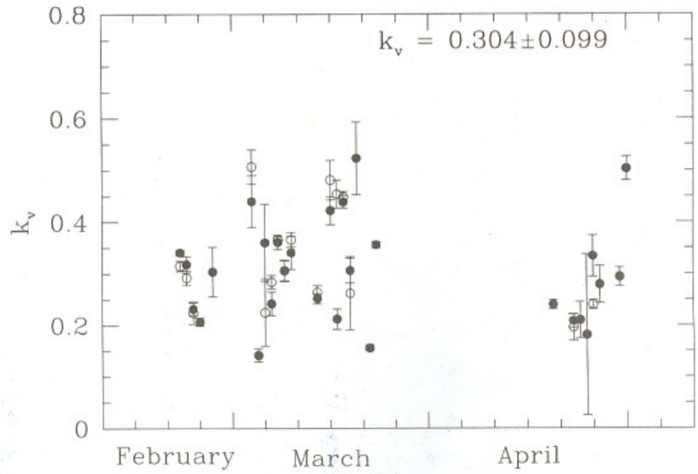


Fig 2. Distribution of atmospheric extinction coefficients observed at IUCAA during February to April 1998. The filled and open circles represent observations of two different stars.

Observing Opportunity with IUCAA Meade Telescope

IUCAA offers observing opportunity to people, from universities, colleges and other organisations as well as interested individuals, who have keen interest in observational astronomy. Serious amateur astronomers are also encouraged to use this facility. The observing season will commence in the first week of October (weather permitting) and it will continue till April 1999. Those having access to the Internet can visit our web Page at **http://www.iucaa.ernet.in/smalltelescope.shtml** for details of this programme and the telescope. An observing proposal form can be downloaded from this web page or requested for by writing to The Dean, Visitor Academic Programmes, IUCAA. Persons alloted telescope time will perform their observation under guidance of a skilled person from IUCAA. Outstation observers will be be provided lodging and boarding facilities at IUCAA, with prior arrangement.

Roses Roses All The Way!

IUCAA's rose garden was judged the *best institutional garden* in the Monsoon Rose Show organised by the Rose Society of Pune, held during September 19-20, 1998.

IUCAA has also won the following prizes in the Poona Women's Council Flower and Vegetable Show held during September 26-27, 1998: (i) *1st prize for cut flower single bloom - variety Paradise*, (ii) *1st Prizze Armaity J. Sukhiya Trophy for best entry of miniature roses*, and (iii) *1st prize for best entry in class VII miniature roses.*

Welcome to...

Joydeep Bagchi, who has joined as a core faculty. His research interests are Radio Astronomy, X-ray Studies of Galaxy Clusters and High Energy Radiative Processes.

Sushan Konar, Mohammad Nouri-Zonoz and **Boudewijn F. Roukema**, who have joined as post-doctoral fellows. Konar's research interests are Magnetic Fields, Compact Systems and related areas, Nouri's research interests are General Relativity and Gravitation, and Roukema's interessts are Galaxy Formation and Observational Cosmological Topology.

Tirthankar Roy Choudhury and **Jatush V. Sheth**, who have joined as research scholars.

... Farewell to

Valerio Faraoni, who has joined the Universite' Libre de Bruxelles.

Sayan Kar, who has joined the Indian Institute of Technology, Kharagpur.

Sumati Surya, who has joined the Tata Institute of Fundamental Research, Mumbai.

Rainer Wichmann, who has returned to Hamburg, Germany.

Colloquia

3.8.98 S.B. Patel *on* Extremes of nuclear structure; 10.8.98 S.G. Dani *on* Some questions in diophantine approximation; 21.9.98 A.K. Kamra *on* Thunderstorm electrification; and 28.9.98 J. Nandi *on* Infection by HIV versus life in space: The unlikely comrades?.

Vacation Students' Programme 1998

The 6 week long Vacation Students' Programme (VSP) for students in their penultimate year of their science or engineering degree course was held during June 1 - July 10, 1998. Of the 10 students selected to participate from over 100 applicants, 8 were from the IITs and 2 were from Delhi University. The lecture programme, which in the first week overlapped with the Summer School, included 5 lectures each of Cosmology (J.V. Narlikar), Radiative Processes and General Relativity (T. Padmanabhan), Physics of Interstellar Medium (R. Nityananda, RRI) and Gas Dyanmics and MHD (A. Mangalam). There were lectures on special topics including Galactic Dynamics (S. Raychaudhury), Gravitational Waves (S. Dhurandhar), Structure Formation (V. Sahni), Pulsars (R. T. Gangadhara, NCRA) and Aspects of Optical and Radio Astronomy (S. Tandon, R. Gupta, V. Kapahi (NCRA)) and evening talks by S. Engineer, F. Sutaria, T. Saini, R. Wichmann and G. Swarup (NCRA). A trip to see the working of the GMRT was arranged on one Saturday.

The projects involved topics in Quantum GR, Lensing and Cosmology guided by a subset of the lecturers and Sukanta Bose. Five students, were pre-selected for admission to the graduate school 1999 and offered research scholarships. Arun Mangalam was the coordinator of this programme.

Seminars

14.7.98 A. Ambastha *on* Recent developments in the understanding of solar flares; 30.7.98 Valerio Faraoni *on* When Brans-Dicke gravity does not reduce to Einstein's theory; 5.8.98 A. Mitra *on* Gamma ray bursts, gravitational collapse, black hole and other stories; 7.8.98 B. Irkaev *on* International programme of searching delta scuti stars; 13.8.98 N.C. Wickramasinghe *on* Spectroscopic identifications of interstellar grains; 24.8.98 N. Sambhus *on* Stellar orbits near the centres of galaxies; 16.9.98 S. Sethi *on* CMP Polarization: Foregrounds and cosmological parameter; 18.9.98 A. Patnaik *on* Milliarcsec-scale structure in gravitational lenses; 24.9.98 R.S. Kaushal *on* Quantum analogue of Ermakov systems; and 30.9.98 R. Nityananda *on* Gravitational clustering at long and short wavelengths.

PEP Talks

7.7.98 Rajaram Nityananda *on* Some fibre bundles I have known; and 6.8.98 Bahor Irkaev *on* Modern state of astronomy in Tajikistan.

IUCAA is happy to announce the publication of the *Proceedings of the 15th Meeting of the International Society on General Relativity and Gravitation (GR 15)* entitled **Gravitation and Relativity: At the turn of the Millennium**, edited by Naresh Dadhich and Jayant Narlikar. The other details of this publication are as follows:

ISBN
81-900378-3-8

Price
India : Library: Rs.750/-, Individual: Rs.500/-, IAGRG Members: Rs.300/-
International: US $50 (inclusive of postage)

For details about the payments contact **Naresh Dadhich** (e-mail: nkd@iucaa.ernet.in) at IUCAA.

Visitors

during July-September 1998

R. Nityananda, S.K. Sahay, A. Pradhan, J. Vijapurkar, A. Ambastha, D.C. Srivastava, S.N. Biswas, B.B. Sanwal, K.P. Singh, A. Ray, D. Bhattacharya, C.S. Shukre, S. Sampemane, P.S. Parihar, T.N. Rengarajan, V. Aiyagiri, P.C. Agrawal, U.C. Joshi, B.G. Anandarao, S.K. Pandey, P.S. Wamane, G. Garge, A. Mitra, S.B. Patil, B. Irkaev, D.B. Vaidya, N.C. Wickramasinghe, R. Tikekar, P. Rajaratnam, P. Bhargava, S. Ramadurai, Shyam Lal, S.P. Khare, D. Mitra, R.T. Patel, A.J. Shroff, H. Knutsen, S.M. Chitre, A. Mahabal, N. Hathi, Juan Jose Ortuno, C.V. Vishveshwara, H.P. Singh, P.C. Vaidya, A.K. Raychaudhuri, P.N. Bhat, S.D. Verma, Thant Zin Naing, K.S.V.S. Narasimhan, B.S. Rautela, G.C. Joshi, Jitendra Singh, Rajesh Deo, T.R. Seshadri, S. Rastogi, S. Sethi, R.S. Kaushal, A. Patnaik, R.G. Vishwakarma, P. Gandhi, P. Thakur, S. Barway, A. Banerjee, G.K. Sasidharan, S. Singh, K.Sankara Sastry, R. Ramakrishna Reddy, and A.K. Sen.

Visitors Expected

October: T. Singh, Benares Hindu University; S.R. Kulkarni, Caltech; M. Tobar, High Energy Accelerator Reseach Organization, Japan; S. Chatterjee, New Alipore College; S.N. Karbelkar, College of Engineering and Technology, Akola; A. Zdziarski, N. Copernicus Astronomical Centre, Warsaw; J. Mikolajewska, N. Copernicus Astronomical Centre, Warsaw; D.B. Vaidya, Gujarat College; S. Chakravarti, Visva Bharati, Shantiniketan; 70-80 participants attending the Total Solar Eclipse Workshop.

November: S. Odewahn, Caltech, USA; J. Starck,Cenre d'Etudes de Saclay, France; F. Ochsenbein, Observatoire Astronomique de Strasbourg; participants of the Workshop on Databases, Data Visualization and Image Processing.

December: K. Yugindro Singh, Manipur University; V.B. Johri, Lucknow University.

Science Popularisation and One-Way Traffic

The Albemarle Street in the West End of London was the first street in the world to be made into a one-way street. The reason?

The famous Royal Institution is located in the Albemarle Street. The RI organized popular lectures in science which the general public of London greatly appreciated. In particular, Michael Faraday was a great crowd puller during the last century. His lectures attracted so much crowd that the horse drawn carriages blocked the traffic flow in Albemarle Street. Which is why it was made one-way.

The tradition of science popularization continues at the Royal Institution, and Albemarle Street continues to have one-way traffic.

[-Based on the D.S. Kothari Memorial Lecture by John Kendrew]

Erratum

The place where Professor Abdus Salam made his speech in 1967 [vide title : "An IAU-General Assembly Circa 767 A.D.?", Khagol, issue No. 35 of July 1998] should have been Dhaka, East Pakistan rather than Dhaka, Bangladesh. (Bangladesh came into existence as a nation in 1971.) We thank Dhananjay Gadre for pointing out this correction.

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

IUCAA, Post Bag 4, Ganeshkhind,
Pune 411 007, India

Phone (0212) 351414
e-mail PUBL@iucaa.ernet.in
Fax (0212) 350760
Telex 0145 7658 GMRT IN

Universal Resource Locator : **http://www.iucaa.ernet.in/**