KHAGOL
खगोल
IUCAA

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

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

No. 38

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

April 1999

Thank You

My second term as Director of IUCAA comes to an end at the end of May this year. The Chairperson, University Grants Commission, in her capacity as President of the Council of IUCAA, requested me to continue with this assignment for a third term till the age of sixty five. I have agreed to carry on with this responsibility and wish to thank all my colleagues at IUCAA for their help and loyal cooperation which has made IUCAA prosper.

Since the announcement of this news, I was deeply touched to receive several letters from friends, colleagues and well-wishers, expressing their appreciation for the past and conveying encouragement for the future. It has not been possible for me to respond to them individually, but through this note I wish to express my gratefulness for these sentiments.

Jayant V. Narlikar

Congratulations!

...to **Suresh Chandra**, Senior Associate of IUCAA, for being selected Associate Member of the Third World Academy of Sciences (TWAS).

National Science Day at IUCAA

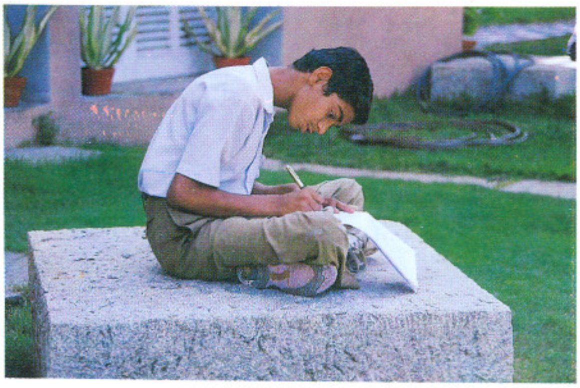
The annual National Science Day was celebrated at IUCAA over the weekend of February 27-28, 1999. The Science Festival on Saturday 27th comprised of various competitions for high school students. On Sunday 28th, IUCAA was open to the general public, when visitors could view special displays on exciting new research areas in Astrophysics, and meet many of the academic and scientific staff. This was followed by night-sky viewing for members of the public till midnight.

The Inter-school Science Festival

The Science festival consisted of several inter-school science competitions for students upto Class X. About 500 students from 80 schools in the Greater Pune area (English, Marathi and Hindi medium) participated in a Science Quiz contest, two Essay competitions (in English

Visitors enjoying the exhibits at the IUCAA Science Park on the Open Day

Contents...



There was one participant from each school in the Science Essay and Drawing Competitions.

IUCAA members presented their work and described exciting research in their field to the visitors.

and in Marathi) and a Drawing competition on scientific themes. This day also saw the finale of the inter-school science project competition. In addition, there was a science crossword contest for the teachers who had accompanied the students.

One student from each school took part in the Drawing competition, The first prize was awarded to Kavita Bhandari (St. Joseph's High School, for her imaginary portrait of a scientist), while the second and third prizes were given to Shivkumar Ranabhor (Panditrao Agashe High School, for his depiction of a city street in the 22nd century) and to Chirag Baljekar (Symbiosis Secondary School, for his drawing of the world through X-ray eyes) respectively.

The participants in the Essay competitions were asked to write, in English or in Marathi, on any one of the topics given. The first prize winners of both the Marathi (Nilkantha Wani, Modern High School) and the English (Shalmali Bodas, Muktangan School) sections wrote essays on *"Industrial age, Computer age, what next?"*. The above topic was chosen also by the second prize winner in English, Abha Dhupkar (Rewachand Bhojwani Academy) and the third prize winner in Marathi, Anupama Kulkarni (Jnana Prabodhini Navnagar Vidyalaya). Bhargavi Venugopal (St. Joseph's High School) won the third prize for her English essay on *"What if our ancestors were not apes?"*, while Anand Godse (Jnana Prabodhini Prashala) won the second prize for his Marathi essay on *"Life in a two-dimensional world"*

Students from Jnana Prabodhini School won the N.C. Rana Memorial trophy for the best all-round performance

The qualifying round of the Science Quiz lasted an hour, in which each team had to answer 25 objective type questions in physics, astronomy, mathematics, chemistry and biology. In this event, each school was represented by a team of three students. Six teams were chosen to compete in the final round of the Science Quiz, which took place in the afternoon of the same day, in the Chandrasekhar Auditorium, in front of a capacity crowd of 550. There were four rounds of questions, many involving slides and pictures, conducted in English, with Marathi surtitles. The team from Sou. Vimlabai Garware High School was the clear winner of the Quiz first prize trophy. Symbiosis Secondary School and Jnana Prabodhini Prashala won the second and third places respectively.

Before lunch, when the judges were busy with the various entries, T. Padmanabhan talked about exciting new discoveries in astronomy to the assembled students and teachers.

The science crossword competition was won by Kalpana Ramakrishnan, who is a science teacher at the Kendriya Vidyalaya, Range Hills.

The N.C. Rana Memorial trophy for the best overall performance was won by Jnana Prabodhini Prashala for the second year in a row. While the winning schools get to keep the trophies for the year, the individual winners were awarded prizes (book tokens) as well. J.V. Narlikar gave away the prizes.

The Science Project Competition

This year, for the first time, IUCAA had organized an inter-school Science Project Competition with the active collaboration of the Jnana Prabodhini Foundation. The programme had been started in August last year, with a workshop on possible research projects that students could undertake. Over 100 high school science teachers from the Pune area attended this workshop. Schools had then been asked for plans of projects that three-member teams of students may undertake, from which 25 had been selected for the final round. Three months later, on January 30, 1999, these teams had given 15-minute seminars to the judges. On February 27 and 28, they had set up their displays on the IUCAA grounds, where judges graded them on their innovation, creativity and ability to explain their work to the public.

The prize for the best project went to the three-girls' team from Kai. Sou. Sunderbai Rathi Prashala for their model of *"The human eye and some of its defects"*. The second and third prizes were won by the teams from Kendriya Vidyalaya, CME (*"The effect of naturally occurring substances on acid-base titrations"*) and Shri Fattechand Jain Vidyalaya (*"The amount of water needed for different house plants"*) respectively.

Open Day for the Public

An unseasonably hot sun could not deter any of the 6000 visitors to IUCAA as it was open to the general public on February 28, 1999 from 11 a.m. to 6 p.m. This was followed by night sky viewing till midnight, attended by more than a thousand enthusiasts.

Many of the academic members (including students and visitors) of IUCAA were present during the day to discuss their research work with the Open Day visitors; many of them had put up posters showing exciting results from their area of research. In the Instrumentation Laboratory, one could witness the current status of the automated telescope and low-cost photometer projects, plus various demonstrations involving lasers and CCD cameras. The Computer Centre provided demonstrations of the working of the Internet, and of samples of the Astronomical Data Centre at IUCAA, and of the image processing research that has been carried out at IUCAA.

Almost all visitors spent a considerable time with the interactive outdoor exhibits in the IUCAA Science Park. In the shade, series of half-hour lectures (in English, Hindi and Marathi) were given by IUCAA scientists to capacity audiences all through the day in parallel at two different locations. The lecturers found themselves surrounded by members of the audience with questions for long times outside the lecture halls. Video films on astronomy and space programmes were also shown at yet another location. The library's display included an account of C.V. Raman's work, which is commemorated by the National Science Day each year.

From 7 p.m. till midnight, hundreds of visitors viewed features of the almost full moon, and other objects of astronomical interest, like the Orion nebula, through six and eight-inch telescopes set up by IUCAA members led by Arvind Paranjpye, with the help of those who made telescopes at IUCAA. Almost all the telescopes used had been made at IUCAA by various amateur astronomers as part of our year-long mirror-grinding and telescope making programme.

Students participating in the Science Project Competition confront the public on the Open Day

Workshop on New Trends in IR Astronomy

A workshop on **New Trends in IR Astronomy** is being jointly organised by Physical Research Laboratory (PRL), Ahmedabad and IUCAA, during August 17-20, 1999 at PRL, Ahmedabad. Three resource persons, two from Ohio State University (Jay Frogel and Darren DePoy) and one from South African Astronomical Observatory (Ian Glass) are expected to deliver lectures on various aspects of IR Astronomy, like thrust areas of astrophysical interest, instrumentation and observational techniques and data analysis procedures, etc. Persons working in this field or interested to initiate research in this area may contact U.C. Joshi at the PRL, Navrangpura, Ahmedabad-380009 (e-mail: joshi@prl.ernet.in) before June 5, 1999. Participation in this workshop will be only by invitation.

Dark Matter in the Universe

Back in 1933, Fritz Zwicky had, on the basis of his studies on galaxies, argued for the existence of dark matter in the universe. By studying the dynamics of galaxies, he concluded that the mass to light ratio of galaxies and clusters of galaxies required far more mass than explained on the basis of stellar origin of their light.

Although the evidence was there, it took some decades for astronomers to appreciate the significance of dark matter. By the 1970s, the feeling that dark matter might easily exceed visible matter was strengthened mainly by evidence on two counts.

First, the astronomy with waves of 21-cm wavelength arising from internal changes in the hydrogen atom revealed that there are clouds of neutral hydrogen circling around galaxies at distances much in excess of their visible boundaries. Had all mass of a galaxy been confined to its visible part, the rotational speed of the cloud should have dropped in inverse proportion to the square root of its distance from the galactic centre. This does not happen; the rotation curves are flat, i.e., the rotational velocity more or less stays constant out to distances twice or thrice the visible radius of the galaxy. Unless one is prepared to modify the laws of motion and gravitation suitably, the conclusion has to be that there is extra matter present beyond the visible boundary, matter that can't be seen.

The second line of evidence, also noted by Zwicky, concerns the motions of galaxies in clusters. If in a self gravitating system of galaxies, a state of statistical equilibrium is reached, then there should be an approximate equipartition between the kinetic and potential energies. In actual clusters, the kinetic energy far exceeds the potential energy. This discrepancy can be resolved either by assuming that the clusters are not relaxed (i.e., in equilibrium), or by postulating a large amount of dark matter at rest, which contributes to potential energy but not the kinetic one.

Today, experts may disagree in their estimates of how much dark matter there is, but all would agree that a major component of the universe is simply not visible. Attempts to locate and estimate dark matter in the form of small sub-stellar objects in the halo of our Galaxy by gravitational micro-lensing are underway. A major issue currently being debated is whether all dark matter is baryonic (i.e., made of ordinary particles like the neutrons and protons) or non-baryonic (i.e., made of as yet unfamiliar species like massive neutrinos, axions, photinos, etc. whose existence has been conjectured by particle physicists). In the big bang scenario, this issue is very important particularly for understanding the growth of large scale structure in the universe.

Vijay Kumar Kapahi

1944 - 1999

We are grieved to learn of the passing away of VIJAY KUMAR KAPAHI on March 16, 1999, after a brief period of illness. He is survived by his wife and two sons.

Professor Kapahi, born on January 21, 1944, was a founder member of the Radio Astronomy Group at TIFR. In his 36 years long career at the Tata Institute of Fundamental Research, he played a key role in all-round development of Radio Astronomy in the country, including the construction of the Ooty Radio Telescope and the Giant Metrewave Radio Telescope at Khodad, Narayangaon. He was the Director of National Centre for Radio Astrophysics at Pune since 1994. He has received numerous distinctions and awards during his illustrious career and was elected the President of the Astronomical Society of India last year.

Surface Photometry of Galaxies

Galaxy surface photometry deals with the observed two dimensional distribution of the intensity of light across galaxies. Two major galaxy types are the *ellipticals* and the *spirals*. The former have isophotes (i.e., equal intensity contours) which are elliptical in shape. The observed distribution of galaxy light is the projection onto the plane of the sky of a three dimensional ellipsoid. In the most general case, the ellipsoid is triaxial, but in many cases the ellipsoid has approximate axial symmetry and is oblate in shape. Very few elliptical galaxies which are prolate ellipsoids are known. The spiral galaxies have two components: a *bulge* which has properties similar to that of an elliptical galaxy and a thin extended disk. There are also conspicuous spiral arms, which give this galaxy type its name. Another major galaxy type are the class of *lenticulars* which have large dominant bulges, along with a structureless disk-like component. The spirals and lenticulars occur in the *normal* and *barred* varieties, the latter having a conspicuous bar like structure through the centre. The three types mentioned here represent only gross divisions, and there are many subclasses and intermediate types as well as galaxies with highly irregular morphology. A clear discussion on the matter can be found in Binney and Merrifield (1998). A more elementary account is available in Tayler (1993).

The more subtle aspects of galaxy morphology, which are not immediately obvious in photographs, can be discerned after careful processing which highlights features with properties different from their surroundings, or the galaxy as a whole. Galactic morphology can develop distortions, due to internal processes or interaction with other galaxies, which appear as faint large scale features. An extreme case of galactic interaction is where two or more galaxies merge, a process which is believed to lead to the formation of elliptical galaxies, starting from spirals. If some ellipticals are indeed formed in this manner, one should be able to see evidence of the event in present day ellipticals, and perhaps even set up a time sequence of structural evolution after the merger(s). Galaxies have an interstellar medium which consists of gas in various phases, often contain dust, which has to be studied through its absorption features, or star forming regions containing recently formed massive stars. These features are indicative of past or ongoing processes and interactions. A small fraction of galaxies host an active galactic nucleus (AGN), in which occur thermal and nonthermal processes which are distinct from the stellar activity in the galaxy. The nucleus can be so luminous as to outshine the whole galaxy, as in quasars, and can give rise to emission structures which are far bigger than the host itself, as in radio galaxies. The nucleus can affect the host in various ways, like producing starbursts. An account of AGN and quasars can be found in Kembhavi and Narlikar (1999).

We shall in this brief resource summary consider just a few aspects of morphology, with no pretense at completeness, and provide references. These will principally be to basic papers, reviews and books, which it is hoped will lead interested persons to the rest of the literature. The summary is biased by the authors' own work and interests, which have primarily to do with elliptical galaxies, and the limited space available.

Image Analysis

Images of galaxies are at the present time obtained primarily with Charged Coupled Devices (CCD) in the optical band (~ 3500 Å to ~ 10000 Å) and with infrared arrays in the near IR band (~ 22000 Å). These detectors have a linear response, high dynamical range and provide data in a digitized form, which make it easy to handle. Images obtained with these detectors have to be processed to remove various signatures of the detector itself, and photometric calibration has to be done so that counts obtained by the detector can be expressed in terms of the actual intensity of light, which is usually expressed in units of magnitudes per unit angular area (CCD preprocessing is described e.g., in Mclean 1997). This procedure is now largely standardized, and can be quickly carried out using standard image processing packages like IRAF (this is distributed free by the National Optical Astronomy Observatories; the package along with extensive documentation, can be downloaded from the IRAF Home page http://iraf.noao.edu/).

An ellipsoidal galaxy produces an image with elliptical isophotes. When the ellipsoid has rotational symmetry, the ellipses have their major axes aligned in the same direction, and non-aligned ellipses can be a sign of triaxiality. The ellipticity can change with distance from the centre. In the case of spiral galaxies, the bulge has elliptical projections, as does the thin disk, with the ellipticity of the latter depending solely on the angle of inclination of the disk with the line of sight (assuming that the disk is circular). Through much of the galaxy, either the bulge or the disk dominates, so that the net intensity distribution can be fairly well approximated by elliptical isophotes. The shape can be non-elliptical when the bulge as well as the disk contribute substantially, since each can have a different ellipticity. Distortions can also be produced by the presence of structures like spiral arms and bars. In addition to all this, there is noise in the data, which gives the isophotes a ragged appearance. The effects of atmospheric seeing spread out an ideal point image (of a star, say) into an extended shape, called the *point spread function* (psf), which can usually be approximated by a two dimensional Gaussian. This typically has a full width at half maximum (fwhm) of ~ 1 arcsec. Due to the psf, isophotes of small angular size acquire the shape of the psf itself, while large isophotes are spread out somewhat, depending on their angular size.

As a first step in the analysis of a galaxy image, it is useful to fit ellipses to the observed isophotes. This is done by staring with a trial ellipse, expanding the intensity differences between this and the isophote in question in the form of a Fourier series,

$$I(\phi) = a_0 + a_1 \sin(\phi) + b_1 \cos(\phi) + a_2 \sin(2\phi) + b_2 \cos(2\phi) + \ldots, \quad (1)$$

and minimizing the coefficients. When the fitting is complete, a_0 provides the average intensity distribution over the isophotes, and the other coefficients provide estimates of the misalignment between the best fit ellipse and the isophote. Due to the form of the stellar orbits in an elliptical galaxy, it is possible for the isophotes to become slightly boxy in shape. If an elliptical galaxy has a faint disk observed edge on, then the isophotes would appear to be somewhat pointed. These departures from perfectly elliptical shapes are small, about ~ 1 percent or so, but can nevertheless be detected by examining the higher Fourier coefficient b_4, with $b_4 > 0$ indicating boxiness and $b_4 < 0$ indicating diskiness. These departures are discernible in elliptical galaxies because of their overall smooth distribution of light, unlike spirals which have a complex morphology due to the spiral arms and continuing star formation. The analysis described here can be performed using routines in IRAF, and is based on techniques developed and described, amongst others, by Kent (1984, 1985), Jedrzejewski (1987) and Lauer (1985). A summary of the techniques, and further references to the literature can be found in Mahabal (1998).

Intensity Distribution

The Fourier decomposition described above provides a march of the average intensity as a function of the isophotal semi-major axis length r. It is known that the intensity distribution in elliptical galaxies and bulges of spirals can be described by the famous de Vaucouleurs' 1/4 law, while disks have an exponential intensity distribution. The net bulge and disk intensity is, therefore, given by

$$I(r) = I_b(0)10^{-3.33(r/r_e)^{1/4}} + I_d(0)\, e^{-(r/r_d)}, \quad (2)$$

where r_e is the effective radius within which is contained half the total light from the bulge, and the other symbols have obvious meaning. When an AGN is present, it makes an additional contribution at the centre. To find the parameters, a model galaxy with the above intensity distribution and trial values of the parameters is generated, convolved with the observed psf, and the resulting intensity distribution is compared with the observed intensity distribution. The best fit parameters are determined by minimizing an appropriately defined χ^2 function. A computer program for obtaining the galaxy parameters has been developed by Kembhavi, and can be obtained by writing to the authors of this article.

The above decomposition technique depends upon comparing the one dimensional distribution in Equation 2 with the observed distribution obtained by fitting ellipses to isophotes. However, it is not always possible to fit ellipses successfully, particularly when the bulge and disk components are both strong, and the disk is highly inclined to the line of sight. Techniques which directly compare a convolved model galaxy with the observed two dimensional light distribution have been developed by Byun and Freeman (1995) and by Wadadekar, et al. (1999). The last authors also consider a generalized form of de Vaucouleurs' law, in which the 1/4 power in Equation 2 is replaced by $1/n$, with n obtained from the best fit. Though such a law has been considered before (see e.g., Andredakis, et al. 1995), the distribution of n amongst different kinds of galaxies, and the implications remain to be satisfactorily explored. We have shown in Figure 1, the dependence of n on the effective radius and central

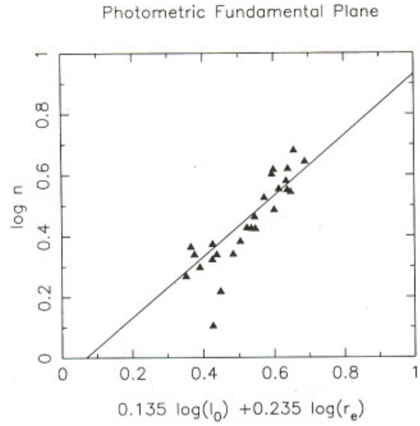


Fig.1

n as a function of bulge central intensity and scale length

bulge intensity for the bulges of a sample of disk galaxies observed by Andredakis, et al. (1995). The two dimensional fitting programmes described in Wadadekar, et al. (1999) can be obtained by writing to the authors of this article.

Dust in Ellipticals

Dust in a galaxy can be detected by using the property that it absorbs more of the blue light than the longer wavelength radiation. So if the image of a galaxy is obtained in the *B* band and another in the *R* band, then the *B-R* colour map, obtained by dividing the shorter wavelength image by the longer wavelength one, provide a trace of the regions of the galaxy containing dust. A *B-K* image provides an even better map, and it helps to smooth the longer wavelength image before the division. It is possible to deduce from the colour map the optical depth of the absorbing column of dust, and making some assumptions about the nature of the dust, to estimate its mass and that of the neutral hydrogen gas which goes with it. The physics of dust in a galactic environment has been described, e.g., in Whittet (1992).

In his classification of galaxies, E. Hubble excluded from the class of ellipticals any galaxy which betrayed the presence of dust; such galaxies were classified as lenticulars or later types. But sensitive observations, especially with CCD detectors have shown that even ellipticals contain dust. Van Dokkum and Franx (1995) have found from a Hubble Space Telescope (HST) study of early-type galaxies that ~ 78 percent of them contain nuclear dust. A detailed study of dusty ellipticals may be found in Goudfrooij (1994) and in Sahu (1998; this thesis contains an exhaustive list of references). The mass of the dust in ellipticals estimated from colour maps is typically in the range 10^5 - 10^6 $M_\odot$. Dust in ellipticals has also been observed through infrared observations with *IRAS*; the mass determined in this manner can be higher than the mass determined from optical colour maps because the latter can only see dust which has sufficiently high optical depth to produce obscuration, while the infrared observations reveal even dust which is thinly spread out.

The dust in ellipticals can be produced through mass loss from evolved stars, or it may be of external origin, being captured during interaction with other galaxies, or during mergers which lead to the formation of the elliptical. The nature, mass and distribution of dust in the galaxy is thus crucial to the understanding of the history of elliptical galaxies. An external origin for the dust is favoured by the observation that the the motion of the dust, and the cold gas associated with it, is often found to be decoupled from the motion of stars in the galaxy. The manner in which dust settles in a galaxy is related to its geometry. In the simplest case of a non-rotating axially symmetric spheroid, the dust settles in the equatorial plane. So if a dust lane is found along the major axis of an elliptical galaxy, it could be an oblate spheroid, while a dust lane along the minor axis would point to a prolate spheroid. In this simple picture, the three-dimensional shape of the ellipsoid can be inferred from the dust configuration (Bertola and Galletta 1978). However, this simple picture is no longer valid when the galaxy is triaxial, or if it rotates round an axis and one has to use photometric as well as dynamical (spectroscopic) data to model the shape of the galaxy (see Kormendy and Djorgovski, 1989 and de Zeeuw and Franx, 1991 for reviews of these topics).

Radio Galaxies

A small fraction of galaxies have a luminosity in the radio band which is comparable to or greater than the luminosity in the optical band. These *radio galaxies* often display characteristic radio structures which are much larger than the optical size of the galaxy. The radio galaxies are believed to be powered by narrow jets of energetic charged particles, which arise from an AGN. An interesting observation, for which presently there is no accepted explanation, is that all radio galaxies are found to be ellipticals or lenticulars.

It is of great interest to see in what manner these radio ellipticals are different from normal elliptical galaxies. This question may be found to be discussed, amongst others, by Heckman et al. (1986), Lilly and Prestage (1987), Baum, Zirbel and O'Dea (1995), Mahabal (1998) and Mahabal, Kembhavi and McCarthy (1999). A summary of the results may be found in Mahabal (1998), who showed from detailed surface photometric study of a sample of radio galaxies that they are bluer in colour towards the centre than normal ellipticals. Though the overall morphology was found to be much like that of a normal elliptical, small and large scale disk like structures were found in some cases, there was departure from de Vaucouleurs' law towards the centre, and often dust was present in the form of lanes (which are taken to be disks observed edge on) or patches at the centre. It has been found (Mahabal, et al. 1996) from the colour map of the radio galaxy 3C 270 (NGC 4261) that it has a large dust lane situated along its major-axis. This lane, which again may be taken to be the edge on projection of a disk, is nearly collinear with a much smaller scale disk discovered in observations with the HST (Jaffe, et al. 1994). The lane is also nearly perpendicular to the direction of a large scale radio jet, making it plausible that the jet direction is being determined by the rotational axis of the disk. It is difficult to see whether this holds for other galaxies from the sample of Mahabal (1996), since the radio structures in that case have not been mapped with adequate resolution.

Obtaining Data

An increasing amount of imaging data on galaxies is now publicly available (eg. de Jong 1996; Peletier & Balcells 1997, http://www.elsevier.nl/locate/newast/) on the Internet. The large and rapidly growing Hubble Space Telescope Data Archive (http://archive.stsci.edu/) contains imaging data in ultraviolet, visible and infrared bands for thousands of galaxies.

References

Andredakis, Y.C., Peletier, R.F., & Balcells, M. 1995, MNRAS, **275**, 874

Baum, S.A., Zirbel, E.L. & O'Dea, C.P. 1995, ApJ, **451**, 88

Bertola F. & Galletta G. 1978, ApJL, **226**, L115

Binney, J. & Merrifield, M. 1998, Galactic Astronomy (Princeton: Princeton University Press)

Byun, Y.I., & Freeman, K. 1995, ApJ, **448**, 563

de Jong R. S. 1996, A&AS, **118**, 557

de Zeeuw, T. & Franx, M. 1991, ARAA, **29**, 239

Goudfrooij, P. 1994, Ph.D. thesis, University of Amsterdam

Heckman et al. 1986, ApJ, **311**, 526

Jaffe, W. et al. 1994, AJ, **108**, 1567

Jedrzejewski, R. I. 1987, MNRAS, **226**, 747

Kembhavi, A. & Narlikar, J. 1999, Quasars and Active Galactic Nuclei: an Introduction (Cambridge: Cambridge University Press)

Kent, S.M. 1984, ApJS, **56**, 105

Kent, S.M. 1985, ApJS, **59**, 115

Kormendy, J. & Djorgovski, S.G. 1989, ARAA, **27**, 235

Lauer T.R. 1985, MNRAS, **216**, 429

Lilly, S.J. & Prestage, R. M. 1987, MNRAS, **225**, 531

Mclean, I. 1997, Electronic Imaging in Astronomy (Wiley-Praxis)

Mahabal, A. A., et al. 1996, ApJ, **457**, 598

Mahabal, A. A. 1998, Ph.D. thesis, University of Pune

Mahabal, A. A., Kembhavi, A. & McCarthy P.J. 1999, ApJL, **516**, May 10 issue

Peletier, R.F., & Balcells, M. 1997, New Astronomy, **1**, 349

Sahu, D.K., 1998, Ph.D. thesis, Pt. Ravishankar Shukla University, Raipur

Tayler, R.J. 1993, Galaxies: Structure and Evolution (Cambridge: Cambridge University Press)

Van Dokkum, P. G. & Franx, M. 1995, AJ, **110**, 1027

Wadadekar, Y., Robbason, B. & Kembhavi, A. 1999, AJ, **117**, March 1999 issue

Whittet, D.C.B. 1992, Dust in the galactic Environment (Bristol: Institute of Physics Publishing)

Under the cloudy sky : My Weather Observatory

It is not very uncommon to observe that when one part of our town was soaked wet, there was no rain in some other area. Under such circumstances, if you are a regular listener of weather reports on the Radio or TV channels, you would wonder what all that report means. So why not do some thing different and observe weather this time?

Weather observatories or weather stations, as these are sometimes called, have very sophisticated instruments to monitor weather, a very complex way of interpreting the weather data and forecasting. However, you can build a satisfactory weather observatory with some reasonable expenditure and some discarded material. With a Do-It-Yourself weather observatory in your physics laboratory, keeping a regular record of weather observation, can become an absorbing activity. Comparison of your data with that announced by your local observatory can be very educative. You can add better equipments to your observatory or perfect your instruments as your interest developes.

To setup your weather observatory, you must select a place free from obstructions, such as trees or buildings. Terrace of your school or college might just be ok.

In this article, we shall see how to make a rain gauge to measure rain fall. I am preparing a hand out on measuring or estimating other weather related parameters such as temperature, humidity, wind speed and direction, cloud cover, etc. Please do write to me if you would like to receive a copy of this hand out.

Rain Fall

With a little care, you can make a very good rain gauge for measuring rain fall. In its very simple form, if you keep any vessel with uniform cross section along its vertical side and then the measure of the height of the water gives the amount of the rain fall. You can see that the shape of the rain collector is not important as long as its horizontal cross section is uniform throughout.

Those mathematically minded would take a step further and say that it is not even important to have a uniform cross section as long as we know the water collecting area. The area of collecting water and the amount of water collected can give us the amount of rain fall.

For the practical usages, however, taking into account some simple guide lines can make observations very easy.

One simple way of making the rain gauge is using an empty white transparent distilled water bottles or similar bottles. Cut the upper one third portion. It can be easily done with heated nicrome wire wrapped around the bottle. It is beyond the scope of this article on this issue, but if you do not know how then ask around someone, such as a glass cutter is bound to know about it.

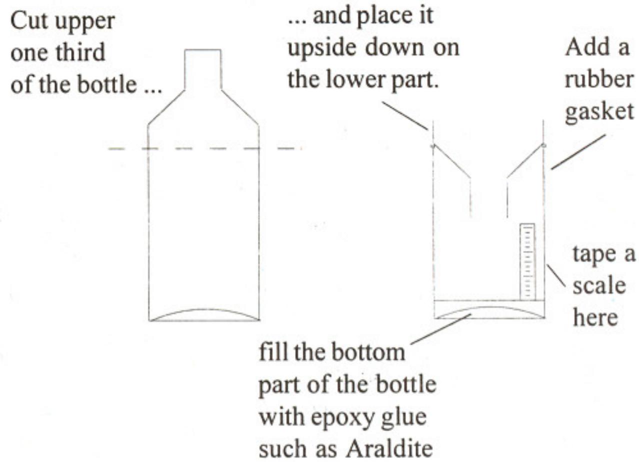
This upper portion is to be inverted and kept over the lower portion as shown in the figure. Cover the edges of the lower part of the bottle with a plastic or rubber bidding. It will provide cushion.

The bottom part of these bottles are not flat. One solution could be to fill it up with wax added with equal amount of rosin. Better still carefully pour in epoxy glue such as Araldite. Having done that, simply stick a good plastic or metal scale to this lower part of the bottle. Note that often scales have extra length before the graduation starts. Either cut this portion off or add this length in to the final reading.

Keep the arrangement in an open space for collecting the rain drops. Now, after the rain you simply read the height of the water (and apply correctin if necessary). This is the amount of rain fall.

You may put the whole assembly into a box or support it from sides so that even strong winds will not topple it down. You must also take care that no rain water from elsewhere splash into your rain gauge. You should also remember that under windy conditions or torrential rains, your reading will not be accurate.

The basic simplicity of this instrument reflects the fact that of all the weather elements, rainfall was probably the first to be measured accurately.



IUCAA Preprints

Listed below are the IUCAA preprints released during January-March 1999. These can be obtained from the Librarian, IUCAA (library@iucaa.ernet.in).

Mohammad Nouri-Zonoz, *Gravoelectromagnetic approach to the gravitational Faraday rotation in stationary spacetimes*, IUCAA-01/99; **R. Srianand** and **S. Shankaranarayanan**, *Probing the BLR in AGNs using time variability of associated absorption*, IUCAA-02/99; **B.F. Roukema**, D. Valls-Gabaud, B. Mobasher and S. Bajtlik, *Galaxy clustering at Z ~ 2 and halo radii*, IUCAA-03/99; Jean-Pierre Luminet and **B.F. Roukema**, *Topology of the universe: Theory and observation*, IUCAA-04/99; **N.K. Dadhich** and A.K. Raychaudhuri, *Oscillating non-singular relativistic spherical model*, IUCAA-05/99; P. Petitjean and **R. Srianand**, *The Z abs~Z em absorption line systems toward QSO J2233-606 in the Hubble Deep Field South: Ne VIII lambda lambda770, 780 absorption and partial coverage*, IUCAA-06/99; **Sushan Konar**, *Whither strange pulsars?*, IUCAA-07/99; **N.K. Dadhich**, *Dual spacetimes, Mach's principle and topological defects*, IUCAA-08/99; **S.K. Banerjee** and **J.V. Narlikar**, *The quasi-steady state cosmology: A study of angular size against redshift*, IUCAA-09/99; **B.F. Roukema** and S. Bajtlik, *Transverse galaxy velocities from multiple topological images*, IUCAA-10/99; P. Lundqvist, J. Sollerman, A. Ray, B. Leibundgut and **F.K. Sutaria**, *Deep optical observations at the position of PSR1706-44 with the VLT-UT1*, IUCAA-11/99; **F.K. Sutaria**, A. Ray, J.A. Sheikh and P. Ring, *Nuclear properties in early stages of stellar collapse*, IUCAA-12/99; A. Mahabal, **A.K. Kembhavi** and P.J. McCarthy, *Effective radii and color gradients in radio galaxies*, IUCAA-13/99; and **N.K. Dadhich** and L.K. Patel, *A simple shear-free non-singular spherical model with heat flux*, IUCAA-14/99.

Introductory School on Astronomy and Astrophysics

An Introductory School on Astronomy and Astrophysics sponsored by IUCAA, Pune was held at G.C. College, Silchar (Assam) during January 12-16, 1999. Experts delivered lectures to the student participants on various subjects in astronmy. They include: J.V. Narlikar, IUCAA (Cosmology); Ranjan Gupta, IUCAA (Observational Astronomy and Astronomical Techniques); H.P. Singh, SVC, New Delhi (Star and Stellar evolution); K.S.V.S. Narasimhan, Chennai (Time and Co-ordinate System); U.C. Joshi, PRL, Ahmedabad (Extragalactic Astronomy) and A.K. Sen, Assam University, Silchar (Polarimetry). There were 64 registered participants, out of which, there were three persons, one each from Kalyani University, West Bengal and Kerala University. Rest of the participants were from Assam and adjoining north-eastern states. There were two university/college lecturers, three research scholars, 32 M.Sc. (Physics, Maths, Computer Science, etc.) students; and 27·third year B.Sc. students. The classes were very interactive and students showed a lot of enthusiasm towards astronomy.

Proposals for holding Workshops/Schools Outside IUCAA

Proposals to conduct workshops/schools in Astronomy and Astrophysics or related areas are invited from university departments/affiliated colleges and the same may be sent to the Dean, Visitor Academic Programmes (VAP), IUCAA with a copy to the Chairman, Workshop Committee, IUCAA by May 1, 1999 (for events during August 1999 - January 2000) so as to be included in the academic calendar for the next academic year.

The following details should be given while sending the proposals: **the title (topic), duration of the workshop/school, topics to be covered and number of lectures in each topic, the level of audience and their number, the number of resource persons available locally and the number of resource persons expected from IUCAA, a description of the facilities available and the budget estimates (clearly stating the support offered by the host university/institute).**

It is generally expected that accommodation to the participants as well as the resource persons will be provided by the host institution. Other expenses will be borne by IUCAA. The coordinators are encouraged to consult IUCAA faculty while framing the workshop/school proposal.

Once the workshop/school is approved, IUCAA will nominate a coordinator from its faculty, who will interact with the organiser in relation to academic programme, budget and identifying and approaching the resource persons.

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 Head, Guest Observing Programmes, IUCAA (e-mail: rag@iucaa.ernet.in).

IUCAA Telescope Update

The Particle Physics and Astronomy Research Council of UK, who are the main contractors for the telescope, have assigned the work on fabrication of the telescope to Telescope Technologies Ltd., Liverpool. The design of the telescope is nearly complete and fabrication of major mechanical parts has been started. It is expected that bulk of the parts would be ready before the end of this year.

The land for the observatory has been acquired and construction of the approach road would soon start. The construction of the buildings would start after this.

Orientation Meeting on Exact Solutions in Relativity and Cosmology

An Orientation Meeting on Exact Solutions in Relativity and Cosmology was organised by D.C. Srivastava during January 18-19, 1999, at the Department of Physics, D.D.U. Gorakhpur University. This meeting was sponsored by IUCAA and was coordinated by N.K. Dadhich. The meeting had discussion sessions on (i) *Physical properties of solutions*, (ii) Inhomogeneous cosmological solutions, (iii) Klauza Klein theory, and (iv) Cosmic strings. These sessions were coordinated by experts in the field who have presented review of current work, relevant problems, new methods and techniques. The participation was by invitation only. The importance of the meeting was availability of distinguished foreign scientists viz. A. Krasinski (Polland), H. Knutsen (Norway) and B. Nolan (Ireland). The keynote address was delivered by P.C. Vaidya. The meeting was attended by about twenty outstation participants. The meeting was preceded by the 20th Meeting of the Indian Association for General Relativity and Cosmology, which was held during January 20-21, 1999. An excursion trip to Kushinagar, a place about 50 kms from Gorakhpur, was also arranged.

Workshop on Introductory Image Processing and Astronomical Applications

A Workshop on Introductory aspects of image processing was organised by the Department of Physics, Tezpur University and IUCAA at Tezpur during February 9 - 11, 1999. Short lecture courses on different topics in the area including elements of image processing, Fourier transforms, segmentation, morphological image processing, etc., with special emphasis on astronomical applications were conducted.

The lecturers included Ranjan Gupta, Ajit Kembhavi, Yogesh Wadadekar (IUCAA), Ashoke Sen (University of Assam, Silchar) and A. Choudhury (Tezpur University). There were about 25 participants at the workshop besides the lecturers. A number of practical demonstrations and discussions were conducted.

Science and the Media - A seminar

A seminar on Science and the Media was organised at IUCAA during March 1-2, 1999. The seminar brought together a wide cross-section of people including scientists, journalists and others concerned with propagating science to the public through the printed, audio and visual media.

The deliberations were divided into: (a) Experiences in popularizing science in the developing world; (b) Science coverage in Indian newspapers, magazines, radio, television, etc. (c) Science in the hands of non-scientists; (d) Science communication through means other than mass media and (e) Changing face of science communication

Invited talks which came under these categories were presented by a number of experts. Many participant of the seminar also had the opportunity to interact with visitors to the Science Day at IUCAA on February 28, 1999.

IUCAA-Visva Bharati School on Astrophysics for Physicists

The joint IUCAA-Visva Bharati School on Astrophysics for Physicists was held at the Physics Department of Visva Bharati, in Santiniketan, West Bengal, during March 6-10, 1999. The purpose of the school was to highlight that the basic physics that is taught in university honours courses is directly applicable to frontline research in astrophysics. Thirty students from various parts of West Bengal, Orissa, Assam and Bihar attended this school, intended for M.Sc./B.Tech. students and young research scholars of physics, mathematics and engineering, studying or working in Eastern India. The Upacharya of Visva Bharati, D.K. Sinha, inaugurated the school on the evening of March 5th and hosted a welcome dinner for all participants.

The lecturers were A.K. Kembhavi (IUCAA, *on* High energy radiative processes), Kamales Kar (SINP Calcutta, *on* Neutrino astrophysics), Soumya Chakravarti (Visva Bharati, *on* Nuclear astrophysics), Ranjan Gupta (IUCAA, *on* Observational astrophysics), Somenath Bharadwaj (IIT, Kharagpur, *on* Newtonian Cosmology), Sushan Konar (IUCAA, *on* Statistical physics of compact objects) and Somak Raychaudhury (IUCAA, *on* Stellar dynamics). Evening lectures were given by Kembhavi and Sayan Kar (IIT, Kharagpur). Lectures were supplemented with tutorials (conducted by Dipanjan Mitra, RRI, Bangalore) for interactively solving problems related to these lectures. The school was coordinated by Soumya Chakravarti of the Department of Physics, Visva Bharati, who is also a senior Associate of IUCAA, and Somak Raychaudhury of IUCAA, with financial support from IUCAA, Visva Bharati and the CSIR.

Participants of the IUCAA-Visva Bharati School on Astrophysics for Physicists

2nd Level 1 Workshop on Astronomical Photometry

The 2nd Level 1 Workshop on Astronomical Photometry was held at IUCAA during January 25-29, 1999. There were 12 participant (10 teachers and 2 amateur astronomers) from different parts of India. Ranjan Gupta, Hillol Das and Arvind Paranjpye (all from IUCAA) gave talks on topics related to astronomical photometry. All the participants built their own low cost photometers at IUCAA. Pravin Chordia and Vilas Mistry (both from IUCAA) gave lectures on electronics related to the photometer. Participants were allowed to take the photometers made by them to their institutions.

Tycho Brahe's Nose

The famous Danish astronomer Tycho Brahe, whose meticulously collected data on planets helped Kepler to formulate his laws of planetary motion, had a whimsical and uncertain temper. As a young student in Rostock, Germany, Tycho picked up a quarrel with a Danish nobleman, which finally ended in a duel in which Tycho lost part of his nose. In those days prior to plastic surgery, he had to replace the lost piece by an artificial one made of gold and silver. Tycho's portraits suggest something peculiar about his nose for this very reason. This episode was immortalized in the famous 'Astronomer's Drinking Song', which Augustus de Morgan quoted in his 'Budget of Paradoxes':

The noble Tycho placed the stars
Each in its due location;
He lost his nose by spite of Mars,
But that was no privation:
Had he but lost his mouth, I grant
He would have felt dismay, sir,
Bless you! he knew what he should want
To drink his bottle a day sir!

Seminars

25.1.99 Jeffery Lewins *on* Variational principle for generalised Markov systems; 28.1.99 K. Shivanandan *on* Space technology transfer for industrial and medical applications; 28.1.99 Jerry Sellwood *on* Dynamical constraints on disk masses; 16.2.99 Guy Pelletier *on* The link between accretion, ejection and high energy radiation in AGN physics; 23.2.99 Alexander Boksenberg *on* What the quasar absorption lines tell us about the universe?; 24.2.99 E.A. Speigel *on* Vortices of disks; 3.3.99 Tapas Kumar Das *on* On the mass outflow from matter accreting onto compact objects; 17.3.99 Arun Thampan *on* KHz QPOs in X-ray binaries and their implications on neutron star structure; 22.3.99 Aparna Chitre *on* Photometric studies of Markarian starburst galaxies; 23.3.99 Watson Varricatt *on* Near IR photometric studies of algol light curves; and 24.3.99 U.S. Kamath *on* Optical and near-infrared studies of novae.

Colloquia

25.1.99 Jeffery Lewins *on* Variational Monte Carlo; and 18.2.99 David Malin *on* Faint features of bright galaxies.

Public Lecture

18.2.99 David Malin *on* A universe revealed: Modern astronomical photography.

PEP Talks

4.3.99 B. Roukema *on* A global constitution for the 21st century; and 19.3.99 & 25.3.99 T.D. Saini *on* How to get more when you have little?

Visitors

during January-March 1999

H. Knutsen, R. Jorgensen, J. Sellwood, D.B. Vaidya, Rajesh Deo, J. Lewins, P.S. Negi, S. Kamat, D. Demble, F. Ahmad, D.A. Choudhary, A.P. Kamble, S.S. Patil, A.C. Kumbharkane, A. Goyal, P.M. Savant, A.B. Bhise, A. Krasinski, A.R. Sahaf, K. Shivanandan, S. Masood, M.A. Shah, J. Batt, S. Sampemane, P. Mahajani, P.P. Hallan, P.K. Srivastava, D. Singh, B. Saxena, G. Pelletier, D. Malin, S.S. Aundhkar, A. Rao, A. Boksenberg, E.A. Spiegel, T.K. Das, R.J. Rayner, J.E.S. Singh, S.S. De, M. Chakrabarty, K.R.K. Mohan, J. Grygar, G.P. Thatte, J. Singh, A. Chandel, L. Londhe, A.P. Deshpande, B. Basu, G.S. Kundapur, B.S. Shylaja, H.R. Madhusudan, D. Salwi, D.K. Satpathy, S. Anil Kumar, S. Mahanti, J. Vadhvana, P.C. Patel, G. Durairaj, R. Ramkarishna Reddy, G. Pimpale, K. Manjula, A. Bandyopadhyay, R. Kochar, R. Ramachandran, V. Sidhartha, S.S. Barve, M.M. Chaudhri, J. Chordia, Vithal Nadkarni, Suhas Naik-Satam, A.D. Jayaraman, J.J. Rawal, P.S. Chaudhari, S. Arunachalam, G.S. Rautela, M. Rao, P. Sheth, N.K. Sehgal, P. Pathak, A. Ray, K. Jotania, A. Thampan, Watson Varricatt, U.S. Kamath, A. Chitre, E. Saikia

Visitors Expected

April: S. Chakraborty, Jadavpur University; S.N. Karbelkar, College of Engineering, Akola; D. B. Vaidya, Gujarat College; S.P. Bhatnagar, Bhavnagar University; N.K. Jadeja, Bhavnagar University; D. Thatte, Mumbai; J.C. Bhattacharya, Bangalore; Z. Ahsan, Aligarh Muslim University.

May: G. Efstathiou, Institute of Astronomy, Cambridge; R. Tikekar, Sardar Patel University, Vallabh Vidyanagar; P.K. Srivastava, Chanda Jog, Indian Institute of Science; G.P. Singh, Visveswarya Regional College of Engineering; Suchita Ghosh, Rajendra College; M. Khan, Jadavpur University; P.C. Vinodkumar, Sardar Patel University; K. Jotania, St. Xavier's College; A. Goyal, Hans Raj College; S. Chaudhuri, Gushkara Mahavidyalaya; T. Subba Rao, Kakatiya University; K.N. Joshipura, Sardar Patel University; S. Chatterjee, New Alipore College; R.S.Kaushal, Delhi University; S. Vaishampayan, North Maharashtra University; L.P. Singh, Utkal University; S. Chakrabarti, Kalyani University; R. Ramakrishna Reddy, Sri Krishnadevaraya University; S.K. Pandey, Pt. Ravishankar Shukla University; S. Banerji, Burdwan University; V.H. Kulkarni, Bombay University.

June: A. Pradhan, Hindu Degree College, Ghaziabad; S.P. Khare, Ch. Charan Singh University, Meerut; T. Singh, Benaras Hindu University; U. Narain, Meerut College; R. Bali, University of Rajasthan; K.Y. Singh, Manipur University; P. Khare, Utkal University; K. Desikan, M.O.P. Vaishnav College for Women; R. Datta, Bethune College; K.K. Nandi, North Bengal University.

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 (020) 351414
e-mail publ@iucaa.ernet.in
Fax (020) 350760
Telex 0145 7658 GMRT IN

Web page : **http://www.iucaa.ernet.in/**