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. 35

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

July 1998

Introductory Summer School on Astronomy and Astrophysics

A DST sponsored introductory school on Astronomy and Astrophysics, jointly organized by IUCAA and National Centre for Radio Astrophysics (NCRA), was held in IUCAA during May 18 to June 5, 1998. Twenty four students (second and third year B.Tech. as well as final year B.Sc. and first year M.Sc.) from around the country attended the school. Different topics in A&A were taught in a more elementary level. The lectures were split into two broad classes (a) lectures on *'the physics of astrophysics'* and (b) a *'phenomenological introduction to astronomy'*. In addition to these courses, each student was also assigned a project. Students made a visit to GMRT during one of the weekends. R. Srianand (IUCAA) and Jayaram Chengalur (NCRA) coordinated the academic activities of the school.

Participants of the Introductory Summer School on Astronomy and Astrophysics

Inside...

Welcome to the IUCAA family

IUCAA is happy to announce the selection of the ninth batch of its Associates and Senior Associates, who are selected for a tenure of three years, beginning July 1, 1998.

Extension of the sixth batch of Associates/Senior Associates

G. Ambika
Maharajas College, Cochin (*)

Narayan Banerjee
Jadavpur University (A)

Subenoy Chakraborty
Jadavpur University (*)

D.P. Datta, NERIST
Arunachal Pradesh (SA)

Ashok K. Goyal, Hans Raj College
University of Delhi (SA)

V.H. Kulkarni
University of Mumbai (SA)

G.P. Malik
Jawaharlal Nehru University, New Delhi (SA)

S.N. Paul
Serampore Girls' College, Hooghly (SA)

R.P. Saxena
University of Delhi (SA)

H.P. Singh
Sri Venkateswara College, New Delhi (*)

The (*) indicates that they were Associates (A) and now they are made Senior Associates (SA).

New Associates/Senior Associates

Associates

Kalyani Desikan
M.O.P. Vaishnav College for Women, Chennai

Sukanta Dutta
S.G.T.B. Khalsa College, Delhi

Kanti R. Jotania
St. Xavier's College, Ahmedabad

Torun Chandra Phukon
Pandu College, Guwahati

Shantanu Rastogi
Lucknow University

Pradeep K. Srivastava
DAV (PG) College, Kanpur

Senior Associates

Farooq Ahmad
University of Kashmir, Srinagar

S. Biswas
University of Kalyani

Soumya Chakravarti
Visva-Bharati, Santiniketan

Sarbeswar Chaudhuri
Gushkara Mahavidyalaya, Burdwan

Chanda J. Jog
Indian Institute of Science, Bangalore

R.S. Kaushal
University of Delhi

Kamal K. Nandi
University of North Bengal, Darjeeling

P.N. Pandita, North Eastern Hill University, Shillong

K. Yugindro Singh,
Manipur University, Imphal

Seminars

21.4.98 K.S. Balasubramanian *on* Solar pores: The smallest visible magnetic elements on the Sun; 28.4.98 Sayan Kar *on* Ripples and kinks on strings and branes; 15.6.98 S. Shankara Narayanan *on* Nature of associated CIV absorption system in NGC5548; and 24.6.98 R.P. Saxena *on* Nucleation in ϕ^4 theory in the thin wall limit and beyond.

Colloquia

6.4.98 A. Khare *on* Exact ground state of a class of N-body problems; 13.4.98 P. Majumdar *on* Quantum characteristics of black holes; 27.4.98 P. Ganguly *on* Atoms in molecules; and 12.5.98 J. Maharana *on* String cosmology.

PEP Talks

27.5.98 Debojyoti Dutta *on* Exposing the ultrafast morons; 1.6.98 Debojyoti Dutta *on* Connecting the ultra fast morons; 19.6.98 Sayan Kar *on* Uses and abuses of traversable wormholes; 25.6.98 Debojyoti Dutta *on* Introduction to algorithms for scientific computing; and 29.6.98 Hydrogen atom as harmonic oscillator.

School Students' Summer Programme

Every year IUCAA conducts a summer programme for the school students from class eighth to tenth. The schools in and around Pune are asked to send two motivated students to participate in this programme. About 75 schools responded and around 150 students attended the summer programme. This year the programme started on April 13 and ended on May 22. Every student was assigned to one of the IUCAA members. Each student spent a week doing their projects and assignments. Some of them made models of the solar system, sun dials, measured the rotation of the Earth by the Foucault Pendulum; some of them calculated radiation from the sun, distance between stars, etc. The instructions were given in Marathi, English and Hindi.

Welcome to...

Firoza K. Sutaria, who has joined as a post-doctoral fellow. Her research interests are Supernovae, Nuclear and Neutrino Astrophysics, and the applications.

... Farewell to

A.N. Ramaprakash, who has joined the Institute of Astronomy, Cambridge University, UK, as a post-doctoral fellow.

IUCAA Preprints

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

S. Sridhar, *Turbulent transport of a tracer : An electromagnetic formulation*, IUCAA-12/98; **R. Srianand** and P. Petitjean, *Molecules in the Z_{abc} = 2.8112 damped system toward PKS 0528-250*, IUCAA-13/98; **S.D. Mohanty** et. al., *A search for gravitational waves from the millisecond pulsar PSR 0437-471*, IUCAA-14/98; **S. Engineer, K. Srinivasan** and **T. Padmanabhan**, *Formal analysis of two dimensional gravity*, IUCAA-15/98; A.K. Raychaudhuri, *Rotation, closed timelike curves and a singularity theorem*, IUCAA-16/98; **N.K. Dadhich**, *On electrogravity duality*, IUCAA-17/98; **A. Mahabal, A. Kembhavi** and P.J. McCarthy, *Effective radii and colour gradients in radio galaxies*, IUCAA-18/98; **R. Misra** and **F.K. Sutaria**, *Comparisons of various model fits to the Iron line profile in MCG-6-30-15*, IUCAA-19/98; Reza Mansouri and **Ali Nayeri**, *Gravitational coupling constant in arbitrary dimensions*, IUCAA-20/98; **Varun Sahni**, *The inflationary universe - from theory to observations*, IUCAA-21/98; and **Valerio Faraoni**, *The w (tends to infinity) limit of Brans-Dicke theory*, IUCAA-22/98.

Talks during visits abroad

Valerio Faraoni: *Gravitational waves: a new kind of gravitational lenses*, University of Udine, Italy, April 28.

A.K. Kembhavi: *Pulsars*, Institute of Advanced Studies in Basic Sciences, Zanjan, Iran, April 11-12 (2 lecutres); *The red and blue centres of radio galaxies*, Sterrenwacht, Leiden, Netherlands, June 9; and *The optical morphology of radio galaxies*, Kapetyn Institute, Groningen, Netherlands, June 15.

Ranjeev Misra: *Accretion disks around black holes*, University of Krakow, Krakow, Poland, June 18; and *Evidence for advective flow from multi-wavelength observations of X-ray Novae*, Nicholaus Copernicus Astronomical Center, Warsaw, Poland, June 22.

J.V. Narlikar: *Quasi-steady State Cosmology: An alternative to Big Bang*, Institut d'Astrophysique, Paris, April 2-3; *Quasi-steady State Cosmology*, University de Liege, Belgium, April 5; *Quasi-steady State Cosmology*, Max-Planck Institute for Gravitational Physics, Potsdam, Germany, April 16; *Structure formation in the Quasi-steady State Cosmology*, Institute of Astronomy, Cambridge, April 22; and *Astronomy in India: Past, present and future*, LGED Auditorium, Dhaka, Bangladesh, June 26.

Sumati Surya: *Causal discontinuity and topology change*, Syracuse University, Syracuse, NY, May 26; Tufts University, Boston, June 3; University of Wisconsin, Milwaukee, June 11.

The Cosmic Microwave Background

In 1964, Arno Penzias and Robert Wilson at the Bell Telephone Laboratory, Holmdale, New Jersey made an unexpected discovery while testing their horn shaped antenna for some galactic observations in the microwaves. Working at 7.35 cm wavelength, they found that after subtracting contributions from all known sources, there still remained an isotropic background of radiation. If the radiation were in thermal equilibrium, its equivalent black body temperature came to around 3.5K. What was this radiation due to?

In Parsecstone 22, we described the primordial nucleosynthesis theory of George Gamow and his collaborators. A by-product of that work was a deduction, first published by Gamow's students Ralph Alpher and Robert Herman in *Nature* in 1948, that the early hot era of nucleosynthesis would leave behind a relic radiation background. Alpher and Herman estimated the present temperature of the background at around 5K, although in later publications Gamow himself estimated higher values. However, as described there, the primordial nucleosynthesis idea lost its charm with the realization that it could deliver only the very light nuclei and that the bulk of chemical elements have been synthesized in stars. Thus this prediction of relic radiation had been sidelined by the developments in stellar astrophysics during the 1950s.

The Gamow idea on primordial nucleosynthesis and relic radiation was, however, independently resurrected in the early 1960s by R.H. Dicke and P.J.E. Peebles in Princeton and by Ya.B. Z'eldovich in Moscow. The Princeton group had in fact begun to set up an antenna to detect the radiation, when the news of the discovery by Penzias and Wilson reached them. They could interpret the isotropic background found by Penzias and Wilson as the relic of big bang.

The Dicke-Peebles paper followed immediately after the Penzias-Wilson paper, both appearing in the volume 142 of the *Astrophysical Journal* in 1965. This discovery of an isotropic microwave background radiation (MBR) has been considered the most significant discovery in cosmology since Hubble's Law. Moreover, it was considered the strongest support for the big bang hypothesis. In 1978, Penzias and Wilson were awarded a Nobel Prize for this discovery. The strength of this evidence grew as further observations led to a confirmation that the spectrum of MBR is indeed that of a black body with a presently estimated temperature of 2.73K. We will return to the present status of MBR in a later Parsecstone.

In retrospect, however, one must recall an earlier discovery of this radiation by A. McKellar in 1941. McKellar had noticed that the CN molecules in the interstellar space in our Galaxy are found in rotationally excited states, a fact which could be accounted for only by assuming that a radiation background in the microwaves was present. This discovery had come during World War II and in a relatively obscure Canadian publication. So it did not attract the attention it so richly deserved.

Gravitational Lensing

1. Background

Einstein's general theory of relativity predicts a deflection θ for a light ray passing a mass M at a minimum distance b given by the formula, (valid for $b \gg GM/c^2$), $\theta = 4GM/c^2 b$ This amounts to 1.75 arc seconds for a light ray passing close to the edge of the sun. This classic test of general relativity was carried out in 1919, and today, the accuracy attainable is one per cent of this value [1]. In fact, even a light ray reaching us 90^0 away from the Sun is deflected by four and a half milliarcseconds, a large enough value to be routinely incorporated as a correction by astronomers who need high accuracy angular positions.

"Gravitational Lensing", the theme of this resource summary, is a broad term which includes all applications of the light bending phenomenon in contemporary astronomy. These range from the study of dark matter in the halo of our own galaxy to scales larger than clusters of galaxies, and we discuss them in the order of increasing scale rather than historically, starting with a section on the optics of gravitational lenses. This topic, as well as the astronomical applications upto about 1992, are described in the comprehensive monograph by Schneider, Ehlers, and Falco [2], which has become the basic general reference in the field. Blandford [3] gives a stimulating personal view of the important unsolved problems as of 1995.

2. Gravitational lens optics

The basic problem involves a source S, a deflector or lens L, and an observer at O. Since the "lens" was not designed to bring all rays to a single focus, the analysis is rather different from what one is used to. Some possible cases and terminology are illustrated in Fig. 1, using

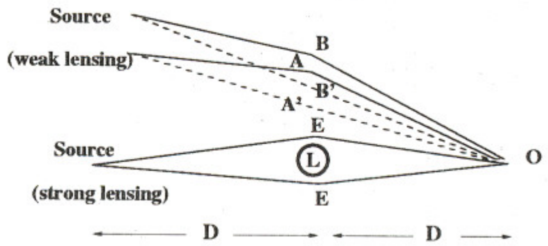


FIGURE 1A

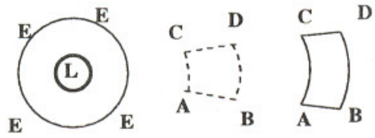


FIGURE 1B

a compact spherical mass for simplicity. Two sources send rays (shown by dashed lines) which would reach the observer via A' and B' on the reflector plane, if the lens were absent (Fig. 1A). The actual rays are shown by the full lines passing through A and B. We note an outward displacement, which is greater for the ray A that has undergone a larger deflection. This means that lensing has moved a given piece of sky $A'B'$ outwards and compressed it radially to AB (Fig. 1B). Now consider rays C and D just above A and B out of the plane of the figure, These too are displaced outward from $C'D'$ due to lensing. In the simple case of a cicularly symmetric lens, the geometry of these rays is identical but in a plane rotated about OL. As shown in Fig. 1(B), the outward displacement elongates AC with respect to $A'C'$.

It is a basic principle, that the specific intensity I, defined as the energy per unit time per unit frequency interval per unit area per unit solid angle, is preserved by optical systems using reflection and refraction. For an extended source, the total intensity received by the detector is, therefore, magnified by the same factor as the ratio of the solid angles ($ABCD$ to $A'B'C'D'$) with and without lensing. (Absorption, laser amplification, and scattering are excluded, and moving optical elements, sources and observers and time varying gravitational fields can shift the frequency ν, in which case the quantity preserved is I/ν^3.)

Noitce that apart from magnification, there is a change in shape as well, known as "shear". When the magnification is close to unity and the shear is small, one speaks of weak lensing. For example, in the original eclipse experiment to test general relativity, the shear was a few parts in a thousand and the magnification was unity plus a few parts in a million. Let us now increase either the deflection or the source-to-lens and/or the lens-to-observer distances ($\sim$ D). We can have multiple rays reaching the observer, and large magnification – in short, "strong lensing" An extreme example is the Einstein ring, which occurs for perfect alignment of source, lens and observer and circularly symmetric deflections. This is illustrated in Figs. 1A and 1B by the family of rays labelled E. From the geometry, the linear and angular radii of the ring are given by $b_E^2 = 2GMD/c^2$, $\theta_E^2 = 2GM/c^2D$

Technically, the magnification is infinite as rays along a circle are being brought to a single point. (Taking an extended source, or detector, or finite wavelength removes this unphysical infinity). The angular scale θ_E and the associated linear scale b_E continue to be useful measures of the cross section for strong lensing effects, even if we do not have perfect symmetry and alignment.

Of course, realistic galaxy potentials produce more complicated and less symmetric deflections than a point mass. The qualitative and quantitative analysis of the generic situation is greatly facilitated by constructing wavefronts normal to the family of rays [4] and using the principle of least time [6]. (see also the brief reviews [7]). These principles and ideas are the legacy of Huyghens, Fermat and Hamilton, but unraveling the full implications needed the modern mathematics of singularity theory, also known as catastrophe theory. (See [7] for further references). One astronomically important observable is the time delay between the different rays – (again in contrast to the laboratory lens which is designed for zero time delay) and this is best pictured in terms of wavefronts [4].

3. Gravitational microlensing in our galaxy

The two decade old problem of the nature of dark matter in the halos of galaxies is still unsolved [5]. The models based on particle physics, e.g., massive neutrinos, would predict a smooth potential. But models which postulate planet like objects, very low mass stars, or dead stars filling the halo predict detectable lensing effects for background stars belonging to the Magellanic Clouds [8-9]. The hypothetical massive compact halo objects are sometimes known as "machos" and MACHO is also the acronym for one of the large experimental teams assembled to detect these lensing effects, the others being EROS, OGLE and DUO. (This maximally politically incorrect choice of nomenclature will no doubt be understood by social psychologists one day. My own interpretation is that we are witnessing a subconscious tribute to the steadily increasing impact of contributions made by women to astronomical research!)

The Einstein rings of these $\sim 10^{12}$ hypothetical $\lesssim M_\odot$ objects subtend only a milliarcsecond (hence the "micro") and would cover of the order of a millionth of the sky even if they made up the entire dark matter of the halo. Hence, several million stars in the Magellanic Clouds are monitored, and a similar number toward the galactic bulge. The data generated over a year is nearly a terabyte! Relative motions of source, lens and deflector perpendicular to the line of sight result in microlensing events which are distinguished from other kinds of variability by a characteristically symmetric, wavelength independent rise and fall of the measured flux, the timescale being mass dependent and of the order of months. Of the order of a dozen such events have been recorded, and detailed modeling of systematic and statistical effects has been carried out. The compact object model for the dark matter has not been decisively ruled out but indications are that there is a shortfall of at least a factor of two compared to expectations for a halo fully made up of compact objects. The error bars will, of course, shrink in a few years time.

4. Lensing by galaxies

Zwicky (1937) realised that the probability of light from one galaxy being strongly lensed by another was not as small as in the case of stars in our galaxy $\theta_E \sim 1''$. He had the foresight to suggest that this would become a tool both for weighing the foreground object and viewing the background one at high magnification. Forty two years later, in 1979, Walsh, Carswell and Weymann [10] discovered 0957 + 561 (the numbers refer to right ascension and declination), which is a pair of quasar images with identical spectra, at redshift 1.4, with a separation of 6 arcseconds. An elliptical galaxy at redshift 0.36 proved to be the culprit, aided and abetted by an associated cluster. This discovery spurred systematic searches which have now discovered nearly twenty cases of multiple imaging of quasars and radio sources. When the redshifts (i.e., distances) of the lens and source are known, it is possible to construct models for the underlying mass distribution. Having many images or better still, an extended source, part of which is multiply imaged helps to constrain model parameters. One goal driving these searches is Refsdal's proposal, made as early as 1964 [11]. There is a time delay between the different paths from source to observer, which could be measured if the source varies in intensity, as quasars do. With redshifts and angles coming from observations, the size of the time delay is inversely proportional to Hubble's constant H_o. This sets the scale for the universe since it converts measured recession velocities to distances. Difficulties with this method include extracting the time delay from noisy data and non uniqueness in modeling. These issues, as well as other applications to cosmology are discussed in [12]. The great attraction is that this distance measurement is entirely independent of the improving but still shaky ladder of successively poorer methods applied to successively greater distance scales [13].

One implication of lensing by galaxies is that at least some quasars might have been significantly affected by lensing so that the statistics of their luminosities may be distorted, especially at the bright end. There is also work on the probabilities of lensing in different cosmological models, with suitable assumptions about the masses of the galaxies. The hope is to constrain cosmological parameters like q_0 (a measure of the deceleration of the expansion), or Ω_Λ (a measure of the cosmological constant, i.e., vacuum energy density [14] in units of the current closure density) though precise measurement is more difficult.

5. Strong cluster lensing

The criterion for strong lensing can be converted to a requirement on the surface density within the Einstein ring, which depends only on the distances $M/\pi b_E^2 \sim c^2/2\pi GD$. This is of the order of 1 g cm^{-2} for D of the order of a gigaparsec. Early theoretical estimates of the surface density in the inner parts of clusters of galaxies assumed smooth behaviour in a central core of several hundred kiloparsecs and hence, fell short of this critical value. The situation changed dramatically in 1987 with the discovery of giant luminous arcs in Abell 370 [15], [16]. It was soon realised that the arcs were highly tangentially elongated images of background galaxies. This made it possible to estimate core radii of clusters and even fulfil Zwicky's dream of a cosmic telescope [17].

6. Weak lensing

With improved telescopes and detector technology even from the ground [18] and then the Hubble Space Telescope, it has become possible to detect the elongation of a large statistical sample of images of background galaxies even when it is weak, in the outer regions of a cluster. It was proposed in 1993 that one could use these elongations to map out the surface density of the dark matter responsible [19]. We can look forward to yet another independent view of the masses associated with clusters, complementary to those already available from the motions of galaxies, the temperature of hot X-ray emitting gas, and strong lensing.

7. Conclusion

This Resource Summary is basically a pointer to the extensive literature and increasing current activity in this field. The approach has been to cite a few early papers and some recent reviews. The reader who finds gravity and dark matter attractive and optics enlightening is urged to follow further the multiple paths of gravitational lensing.

References

(1) C.M. Will, 'Was Einstein Right?', p.86 Oxford University Press, (1986)

(2) P. Schneider, J. Ehlers, E. Falco, 'Gravitational Lenses' (Springer-Verlag, Heidelberg, 1992)

(3) R. Blandford, 'Gravitation Lensing' in 'Unsolved Problems in Astrophysics, p.93 J.N. Bahcall and J.P. Ostriker eds. (Princeton University Press, 1997)

(4) R. Kayser, S. Refsdal Astron. Astrophys **128** 156 (1983)

(5) S. Sridhar, Resource Summary, Khagol, April 1997.

(6) R. Blandford, R. Narayan, Ap.J. **310** 568 (1986)

(7) R. Nityananda, 'Gravitational Lensing', Y. Mellier et al. p 3 (Springer 1990), Curr. Sci. **59** 1044 (1990),

(8) B. Paczynski, Ap. J. **304** 1 (1986)

(9) B. Paczynski, Ann. Rev. Astron. Astrophys. **34** 419 (1996)

(10) D. Walsh, R. Carswwell, R. Weymann, Nature **279** 381 (1979)

(11) S. Refsdal, Mon. Not. Roy. Astron. Soc. **128** 307 (1964)

(12) R. Blandford, R. Narayan Ann. Rev. Astron. Astrophy. **30**, 311 (1992)

(13) P.W. Hodge, Ann. Rev. Astron. Astrophy. **19** 357 1981

(14) S. Carroll, W. Press, E. Turner, Ann. Rev. Astron. Astrophy. **30** 499 (1992)

(15) G. Soucail et al., Astron. Astrophy **172** L14 (1987)

(16) R. Lynds, V. Petrosian, Bull Am. Astron. Soc. **18** 1014 (1986)

(17) B. Fort, Y. Mellier, A & A Reviews **5** 239 (1994)

(18) A. Tyson, F. Valdes, R. Wenk, Ap.J. Lett. **349** L1 (1990)

(19) N. Kaiser, G. Squires, Ap.J. **404** 441 (1993)

Meteor Showers and Observing them

The bright streak of light in the sky, lasting for less than a second, called shooting star in common language, is a phenomenon astronomers call **meteor**.

The meteor phenomenon occurs when an interplanetary dust particle traveling at high speed enters into the atmosphere of the Earth and ablates due to energy produced by its friction with the atmospheric constituents. Such a dust particle, called **meteoroid**, is about as large as a pea, a few millimeters in diameter. Smaller grains may produce meteors so faint that they can be seen only through a telescope. On the other hand, a bigger meteoroid can produce a meteor as bright as Venus. This phenomenon is then called **fireball.** A bright fireball can be seen in broad day light. (Venus can be seen when the Sun is above the horizon.) Sometimes, a fire ball also makes noise as it rushes through the atmosphere of the Earth. A fireball may explode in the sky - it is then called **bolide.**

Normally, a meteoroid completely burns out in the atmosphere of the Earth as meteor, fireball or bolide. But, sometimes it may survive the plunge and can be picked up. It is then called **meteorite**, once called **uranolith** - the mineral that fell from the sky.

It is believed that meteoroids were formed at the time of the formation of the solar system and meteorites can give us clues of the condition prevailing during that period. Meteorites are classified into three broad categories: *stones, irons* and *stony irons*.

Stony meteorites account for nearly 93 percent of all meteoritic fall, but owing to their close resemblance to the terrestrial stones they are difficult to discover. A freshly fallen stony meteorite may have a fusion crest produced when its outer surface melted during the plunge.

Iron meteorites account for about 6 percent of meteorites. It contains about 90 percent iron and about 9 percent nickel. In 1620, an iron meteorite was picked up near Jalandhar, Punjab. It weighed about 1.6 kilograms. Emperor Jahangir asked his artisan to make weapons out of it. The artisan found that the composition of the meteorite was rather *less dense* and added one part of iron to three parts of meteoritic material to make two swords, one knife and one dagger.

Stony iron meteorites consists equal amounts of rock and iron. They look small pieces of stones set in iron. Without going any further on this topic we end it with the information that carbonaceous chondrites, a type of stony meteorite, also contain amino acids, the building blocks of life sustaining proteins and it is debated that they may have played a role in the appearance of simple organisms on our planet, about 4 billion years ago.

Coming back to the observations, a meteoroid starts burning at the height of about 140 km. above the surface of the Earth and by the time it reaches 50 km it burns out completely. It would have traveled about 300 km in the atmosphere by then.

Meteoric phenomenon lasts from a fraction of a second to a few seconds. A meteor may leave behind a trail of ionised gas. This trail can be seen for as much as half an hour under undisturbed atmospheric conditions.

Velocity of a typical meteor in the Earth's atmosphere can range from 12 km per second to 72 km per second. This is explained in the figure. We can see that evening meteors are slow moving, lasting for long time and the morning ones are swift and short lived.

On any dark clear night one is expected to see one meteor every few minutes coming from a random direction in the sky. However, there are times when meteors can be seen coming from a particular direction in the sky.

Four hours before the dawn on November 13, 1833 people of eastern North America saw the skies lit up by meteors - some thing no one knew would happen. Among those who witnessed the display was Denison Olmsted. He observed that meteors were coming from a particular point in the Leo constellation. He further investigated observations of this extraordinary display at other places and presented his results in January 1834. He suggested, rightly, that the meteors had originated from a cloud of particles in the space but could not comment on the nature of the cloud. It was reported that about 2,40,000 meteors showered in just one hour.

Later, astronomers discovered that the events of November 13, 1833 repeats if not with the same intensity, every 33 years or so and occurs close to the perihelion passage of comet Tempel-Tuttle. They also discovered the connection between meteoric activity and comets. This started a new astronomy *-the astronomy of meteor showers*.

When a comet approaches Sun, material trapped inside its stony shell sublimates and comes out of it by breaking the shell. This forms the coma of the comet. As the distance between the comet and Sun decreases, the activity inside the comet increases. The shell is broken at various places. Some tiny particles break loose from the comet. This cometory debris forming its tail follow almost the same path as that of the comet. Some get shot up in front of the comet and some lie behind it. Over a period of time, a ribbon of debris is formed along the orbit of the comet.

If the orbit of a comet and the Earth intersect or lie close to each other, then every year when the Earth passes through the point of intersection it would experience a shower of meteors. However, the probability of the Earth comet collision may itself be very negligible.

The point in the sky from where the meteor appears to be originating from, is called the radian of the shower and the shower itself is recognised by the name of the constellation in which the radiant lies. The meteor shower of November (every year) due to comet Tempel-Tuttle is know as Leonide.

Observations of meteor showers is ideally suited for those with the lack of funds to invest in instrumentation. This is very nearly zero initial investment astroproject. All you need is a one good eye. Then there are about a dozen meteor showers which we know are good to observe and so you can make your plans well in advance. Now, before going into the how and dos and don'ts of meteor shower observations, let me tell you the express purpose of this article.

The comet Tempel-Tuttle passed its perihelion on February 28, 1998. Thus, during the current year and in the next year the leonides are expected to be very active. The last year's observations were washed out by bright moon light. This year, the Moon will not interfere in the observation.

The Earth enters the swarm on November 14 and leaves it on November 21. The radiant of leonides rises by about midnight. The peak of the shower is expected to be at half past midnight on November 17, which is quite good for us in India.

This project can have varying degree of complexities of observations starting with visual counting to usage of video cameras. Here, we shall highlight the basic visual method of meteor shower observations. A more detailed booklet is under preparation. For the booklet, write to Science Popularization Committee, c/o IUCAA. The table gives the list of some regular meteor showers and you may start off with the next one available to you.

The golden rule to observe the meteor showers is to be comfortable. Have an easy chair, wear enough warm clothes, have a blanket ready and keep some hot drink to keep you awake. Don't go for alcoholic drinks; they reduce sensitivity of your eyes. Warm milk, flavored if you like, is the best. Do not forget insect (mosquito) repellents. Although insects won't let you sleep, you will not be comfortable either!

You will require a torch which is covered with red gelatin paper, a note book and a pencil/pen, a watch set to the standard time to the accuracy of a minute and a sky map. You should also find out the latitude and longitude of your observing site and record it in you note book.

You are not to watch in the direction of the radiant but about 40 degrees away from it. Before you start observing let your eyes get adapted to the darkness. This will take about 15 minutes. Estimate and note the limiting magnitude of the sky for your observations. It is the faintest star that you can see. Write the time when you start observing.

Every time you see a meteor, trace its path backwards. If it reaches the radiant then it is a shower meteor, else it is a sporadic one. You may write 'S' for shower and 'N' for sporadic or non-shower, or make a tic mark for shower and cross for a sporadic one. When you are about to get tired or would like to relax - stop. Record the time when you stopped observing. In any case take a few minutes break every 30 minutes. You may also write any remarks on the brightness and trail that might have been left behind. After the observations, add up all the sporadic and shower meteors for every observing interval.

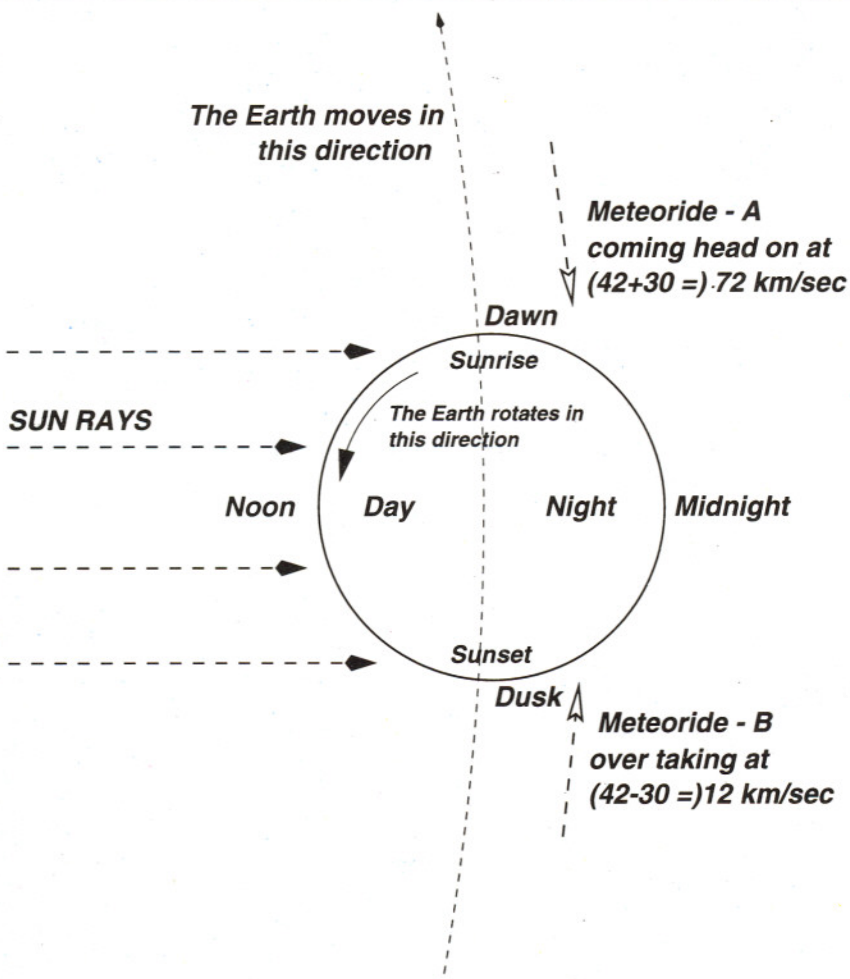
Your observations will be very useful to the International Meteor Organization (IMO). You can send them directly to Rainer Arlt of IMO (e-mail: visual@imo.net) or to me (e-mail: arp@iucaa.ernet.in) and I will in turn forward your observations to IMO.

You can help yourself by having a partner. One of you watch the sky while the other takes the notes. This way, one need not shift one's gaze back and forth from the sky to paper. You may also use a tape recorder. Tape all your observations and time. You can then play back the tape at some suitable time later on.

If you form a team of about 10 people, then you can work in 5 pairs and select different patches of the sky to observe.

Visit these sites for more information:
http://www.imo.net/
http://www.skypub.com/meteors/meteors.html

Shower name	Peak on	Active between from to	RA	DEC	v km/s	Notes
Quadrantids	03/01	01/01 - 06/01	15 28	+50	42	Blue and yellow meteors
Lyrids	22/04	19/04 - 25/04	18 16	+34	48	Moderately active shower
Eta-Aquarids	04/05	24/04 - 25/05	22 27	00	65	Multiple radiant broad Maximum
Delta Aquarids	28/07	15/07 - 20/08	22 38	-16	41	Double radiant, faint meteors
Perseids	12/08	23/07 - 20/08	03 06	+58	60	Rich shower, with bright meteors
Orionids	22/10	16/10 - 27/10	06 22	+16	66	Fast meteors
Taurids	03/11	20/10 - 30/11	03 44	+14	28	Slow and bright meteors
Leonids	17/11	14/11 - 20/11	10 08	+22	71	Fast meteros Storms expected in 1998
Geminids	14/12	07/12 - 16/12	07 28	+32	35	Rich shower of medium speed meteors



At the Earth's distance from the Sun, the parabolic velocity of a meteoride is about 42 km/sec
And the Earth's orbital velocity is 30 km/sec

Figure

Visitors during April-June 1998

R. Nityananda, Sanjiv Kumar, Piyali Banerjee, Suresh Chandra, Moncy John, S.N. Karbelkar, R.V. Saraykar, A. Khare, P. Majumdar, G. Yellaiah, A. Kothare, K. Jotania, G.P. Pimpale, T. Subba Rao, V.S. Kale, G.P. Singh, D.B. Vaidya, R.R. Reddy, Y. Nazeer Ahmed, R. Tikekar, S.H. Sarma, S.P. Bhatnagar, N.K. Jadeja, S. Mohanty, S. Mukherjee, D. Dutta, Renuka Datta, B.R. Iyer, H.P. Singh, E. Saikia, D.A. Choudhary, A.P. Kamble, V.C. Kuriakose, S.G. Tagare, J. Maharana, Prashant, T. Ghosh, V.H. Kulkarni, L.K. Patel, M. Shukla, K.R. Balaji, J. Deepa, P. Arora, R. Jotania, A. Gupta, D.J. Rosario, S. Sanjuktha, K. Chatterjee, K. Bhattacharya, D. Maiti, T. Kotoch, V. Vidwans, S. D'Souza, A. Juneja, P. Trivedi, P. Mehta, P. Ojha, J. Sreeguru Raj, K. Joshi, V. Gupta, A. Morarka, M. Gad, M. Wyawahare, B. Lokanadham, S. Nanavati, M.K. Das, S.D. Sharma, S. Vaishampayan, Y. Ravi Kiron, S.J. Devasagayam, A.K. Goswami, B.A. Kagali, M. Khan, M.N. Anandaram, B. Datta, K.N. Joshipura, L.M. Saha, A.L. Choudhari, V.O. Thomas, P. Dasgupta, V. Venugopal, P.K. Srivastava, N. Rooprai, S. Gahlaut, A. Batra, S. Sharma, P.C. Vinodkumar, S. Mohanty, N. Vasudevan, R. Guruprasad, P. Singh, G. Soni, M. Sethi, B. Karthikeyan, A. Kolarkar, R. Gopal, V. Ramanan, R. Deo, Asoke Sen, S.N. Paul, Santokh Singh, S. Singh, I. Chakrabarty, V.K. Gupta, R.P. Saxena, D. Roychaudhury, R. Hablani, P. Khare, J.D. Anand, M. Dahiya, S.S. Prasad, D. Chandra, S. Konar, Sanjay Pandey, Ng. Ibohal, K. Azad Singh, B. Ishwar, U. Narain, P. Agarwal, R. Sharma, S. Bharadwaj, and A Ambastha.

Visitors Expected

July : D.C.Srivastava, Gorakhpur University; Sanjay Kumar Sahay, Gorakhpur University; Anirudh Pradhan, Hindu Degree College, Ghazipur; S.N. Biswas; I. Bardoloi, Handique Girls' College, Guwahati; K.P. Singh, TIFR; and K. Yugindro Singh, Manipur University.

August: H. Knutsen, Stavenger College, Norway.

September: The Governing Board and Council members of IUCAA will be visiting.

Erratum

The Fifth Workshop on High Energy Physics Phenomenology (WHEPP-5), which was held at IUCAA during January 11-25, 1998, was mainly funded by the S.N. Bose National Centre for Basic Sciences. This fact was inadvertently missed out in the last issue of Khagol.

An IAU-General Assembly Circa 767 A.D.?

Almost exactly twelve hundred years ago, Abdullah Al Mansur, the second Abbasid Caliph, celebrated the founding of his new capital, Baghdad, by inaugurating an International Scientific Conference. To this Conference were invited Greek, Nestorian, Byzantine, Jewish as well as Hindu scholars. From this Conference, the first International Conference in an Arab country, dates the systematic renaissance of science associated with Islam. The theme of the conference was Observational Astronomy. Al Mansur was interested in more accurate astronomical tables than available then. He wanted, and he ordered at the Conference, a better determination of the circumference of the Earth. No one realised it then but there was read at the Conference a paper destined to change the whole course of mathematical thinking. This was a paper read by the Hindu astronomer, Kankah, on Hindu numerals, then unknown to anyone outside India.

[from a speech delivered in 1967, at Dhaka, Bangladesh, by the late Professor Abdus Salam]

Absolutely Wrong!

In this column in the last issue we quoted Agnes Clerke on nebulae with a year 1945; it should have been 1905. We regret this typo, but thank the readers who pointed it out.

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/**