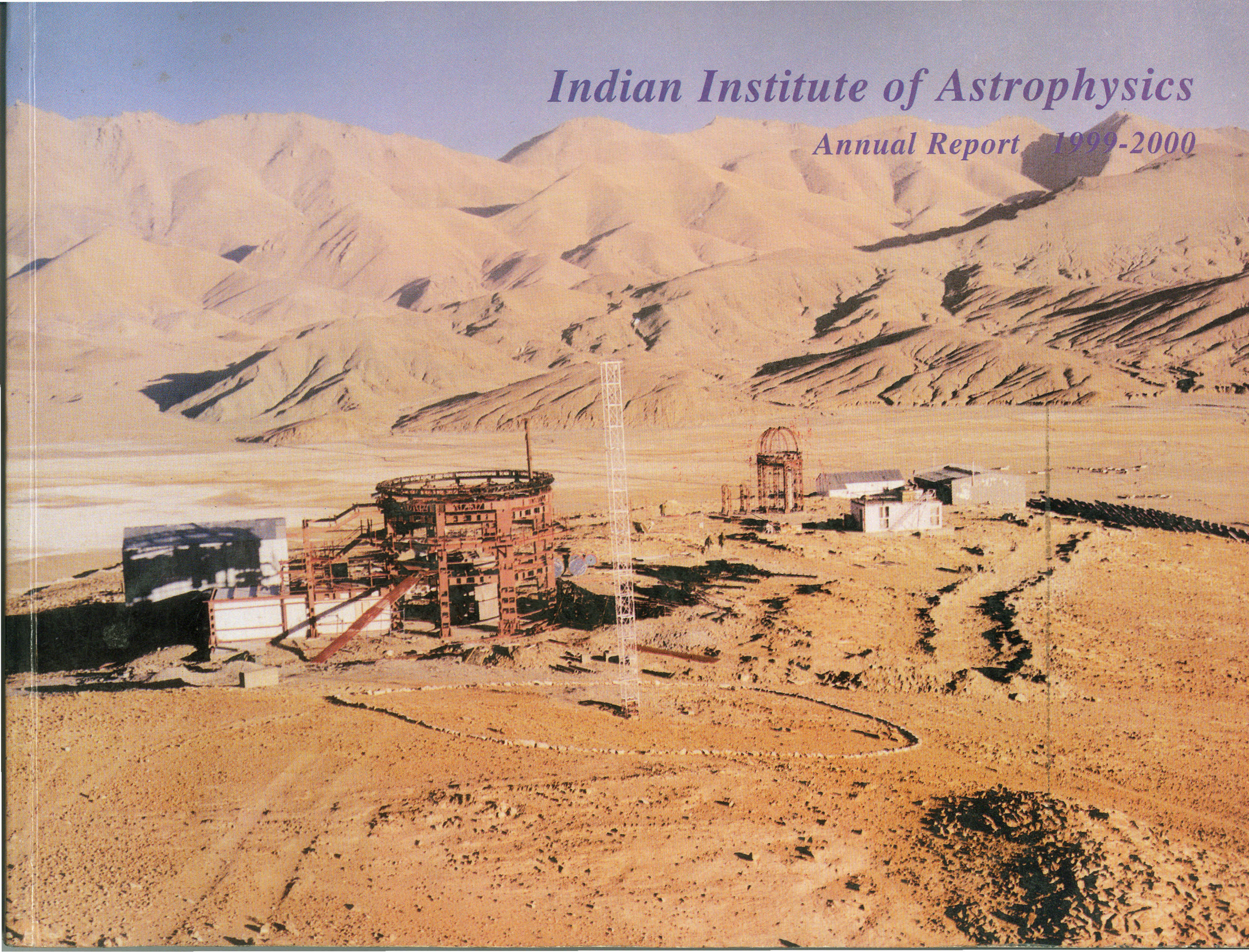
Indian Institute of Astrophysics

Annual Report 1999-2000



INDIAN INSTITUTE OF ASTROPHYSICS

ANNUAL REPORT
1999-2000

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Editorial Assistance :

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Front Cover : The dome of the 2-m telescope under construction at the Indian Astronomical Observatory (IAO) site on Mt. Saraswati, Hanle, Ladakh.

Back Cover : Solar power panels at IAO.

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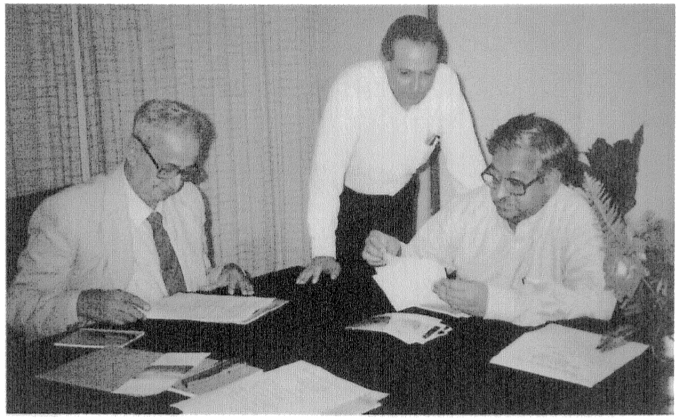
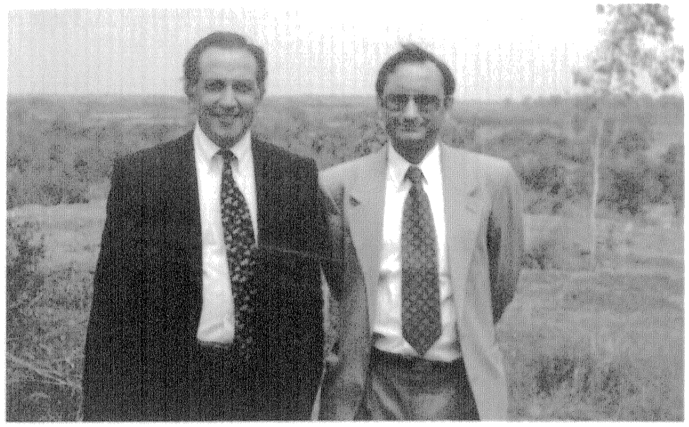
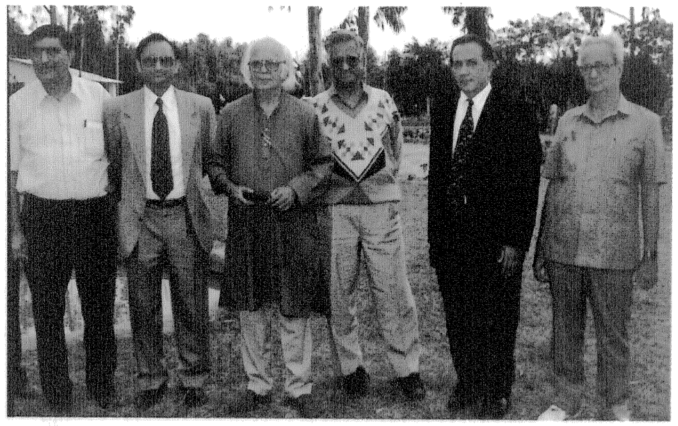


Prof. R. Cowsik with Prof. B.V. Sreekantan and Prof. V.S. Ramamurthy.



Prof. R. Cowsik with Mr. Rahul Sarin, IAS, Joint Secretary and Financial Advisor, DST, during Governing Council meeting at CREST Campus, Hosakote.



Some members of the Governing Council : (L to R) Prof. S.K. Sikka, Mr. Rahul Sarin, IAS, Prof. Yash Pal, Prof. V.S. Ramamurthy, Prof. Ramanath Cowsik and Prof. B.V. Sreekantan (Chairman of the council).

Prof. V.S. Ramamurthy

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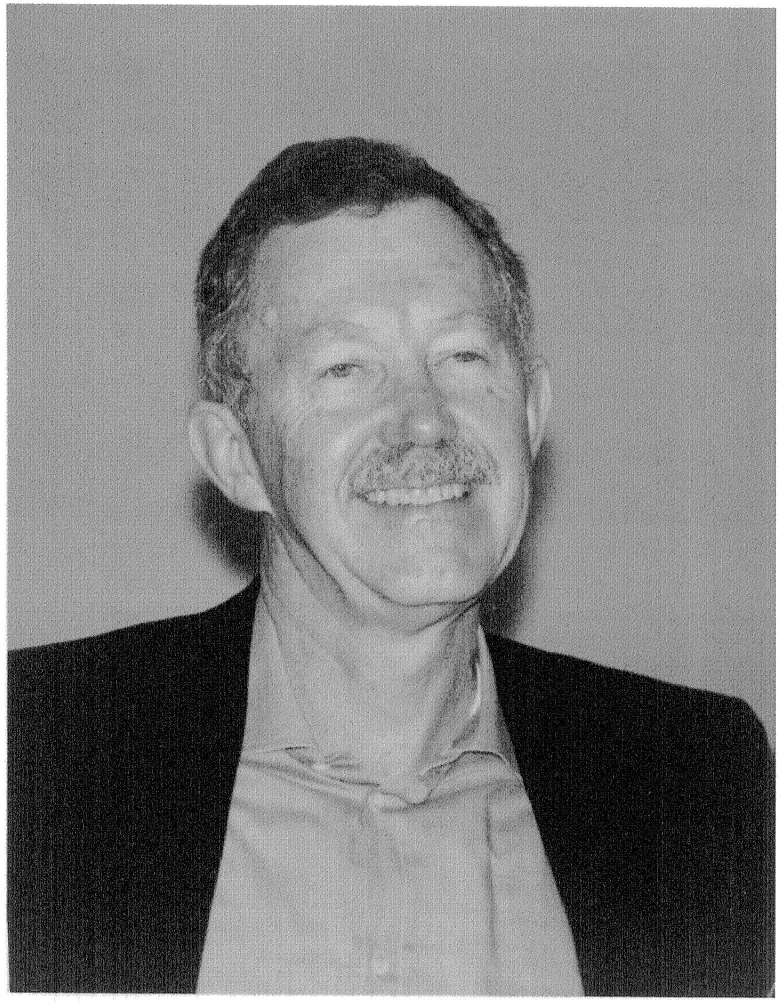
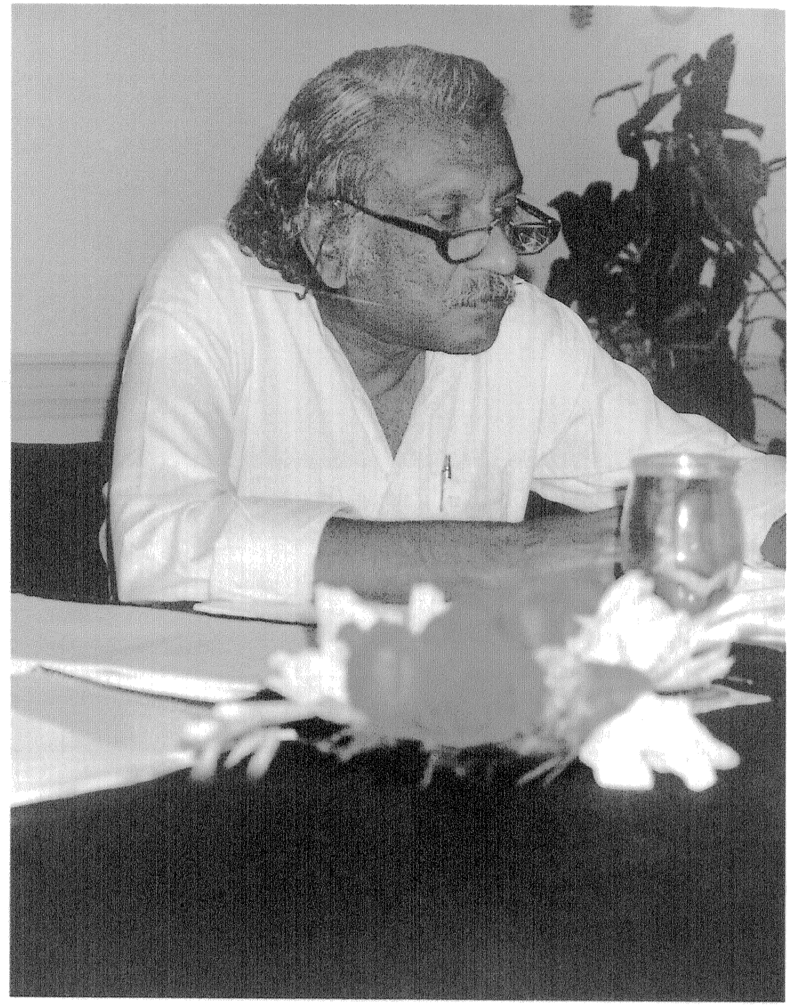
Professor Ramanath Cowsik, Director, Indian Institute of Astrophysics, Bangalore 560 034.	Member
The Administrative Officer, Indian Institute of Astrophysics, Bangalore 560 034.	Non-member secretary to Council.



Professor P. Buford Price



Professor V. Radhakrishnan,

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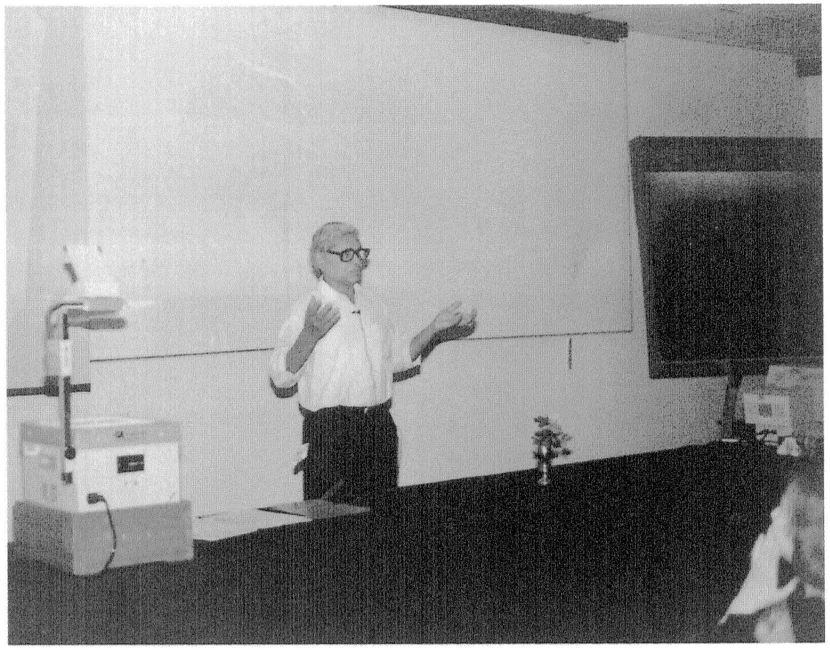
Bangalore 560 080.

High level Bangladeshi delegation on a visit to IIA, Bangalore during 2 - 4 March 2000. At the centre is Lt. Gen. Md. Noor Uddin Khan, Minister of Science and Technology, Govt. of Bangladesh.

Honours & Awards :

Ram Sagar	:	Elected Fellow, National Academy of Sciences, India.
C. Sivaram	:	Received Honourable Mention for his paper "A non-anthropic origin for a small cosmological constant" from the Gravity Research Foundation, Massachussetts, USA.
R. Cowsik	:	Elected Secretary to the Cosmic Ray Commission (C4) of the International Union of Pure and Applied Physics (1999-2002).
		K.R. Ramanathan Memorial Lecture Award, Physical Research Laboratory, Ahmedabad, February 2, 2000.
R. Ramesh	:	Received the young scientist award of the International Union of Radio Science during its XXVIth General Assembly in Canada, August 1999.
K.P. Raju	:	Received the Japan Society for the Promotion of Science (JSPS) Invitation Fellowship at National Astronomical Observatory of Japan at Mitaka, Tokyo, Japan.



Prof. Vinod Gaur delivering the 14th IIA Bicentennial Commemorative Public Lecture on "Natural hazards : prediction and mitigation of their impacts", 16 March, 2000.

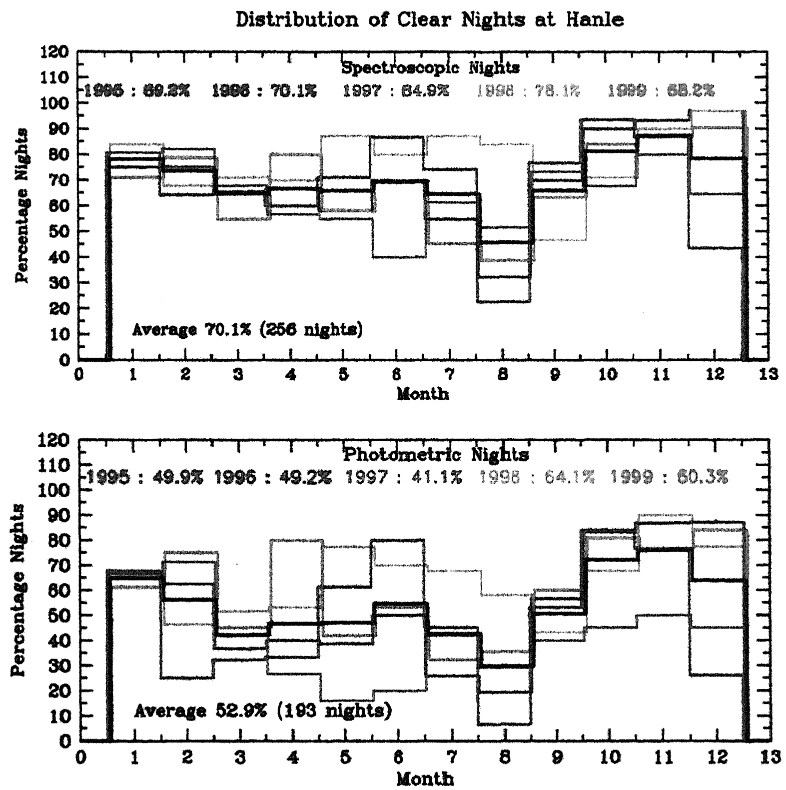
A Panoramic view of Indian Astronomical Observatory on Mt. Saraswati, Hanle, Ladakh.

The Year in Review

The Indian Astronomical Observatory (IAO) at Hanle in Ladakh, at an altitude of 15000 feet above mean sea level, the highest in the world, had to be prepared in every respect for the installation of the Optical/Infrared Telescope of 2-meter aperture. This telescope being capable of remote operation, the Satellite Communication and Control Station had to be established at the Centre for Research and Education in Science & Technology (CREST) campus of the Institute at Hosakote near Bangalore. These challenging and multifaceted tasks were accomplished with speed, economy and efficiency by the dedicated team of scientists and engineers of the Indian Institute of Astrophysics working in close cooperation with various agencies of the Government and institutions in the private sector. Amongst these I would like to make a special mention of the teams led by Dr. R. Srinivasan and Professor T. P. Prabhu of our Institute and the cooperation extended by Dr. K. Kasturirangan, Dr. S. Rangarajan and Mr. S. B. Iyer of the Indian Space Research Organization.

The photograph on the left, showing a panoramic view of the IAO on Mount Saraswati, clearly brings out the remarkable features of this astronomical site — clear skies, dry conditions, thin mountain air of high altitude — all of which make this one of the finest sites for astronomy in the world. It may be worth recalling here the intellectual struggle and the sheer physical effort needed to discover such a superlative site in India, an extended land mass that enjoys both the summer and the winter monsoons. How do we find in such a land a site which has cloudless skies during 250 or more nights? In such a densely populated country, how do we find a location which is several hundreds of kilometers distant, away from man-made lights and other aspects of human activity which will tend to obfuscate the observations of faint stars and galaxies which may even be 1,000,000,000,000,000,000,000,00 kilometers away, deep in the intergalactic space?

The strategy adopted by the IIA team in the discovery of Hanle rests on the geography of India which clearly indicates the presence of rain-shadow regions beyond the Himalayan ranges. Moreover, the high altitude of the mountains provides several attractive features: (a) with a smaller overburden of air, the light from the stars are absorbed less and the rays are not deflected from their rectilinear path, thus allowing sharp images to be obtained; (b) of particular importance is the fact that the amount of precipitable water vapour above the site tends to be substantially smaller than at most other sites, which is of great advantage for astronomy in the infrared; (c) such regions situated far away from concentrations of human population are free from man-made light, aerosols etc.; (d) we will be able to go above the tree-line, so that density of pollen is very low. With such ideas a mammoth effort was launched all across the Himalayan ranges to identify suitable sites. After an effort lasting several years the team of scientists and engineers from IIA proclaimed Hanle as the winner. The Figure below shows the distribution of the photometric and spectroscopic nights at the Hanle site.



The fraction of photometric and spectroscopic nights each month at Hanle.

The characteristics of Hanle as an astronomical site are summarized below based on measurements being made since January 1995.

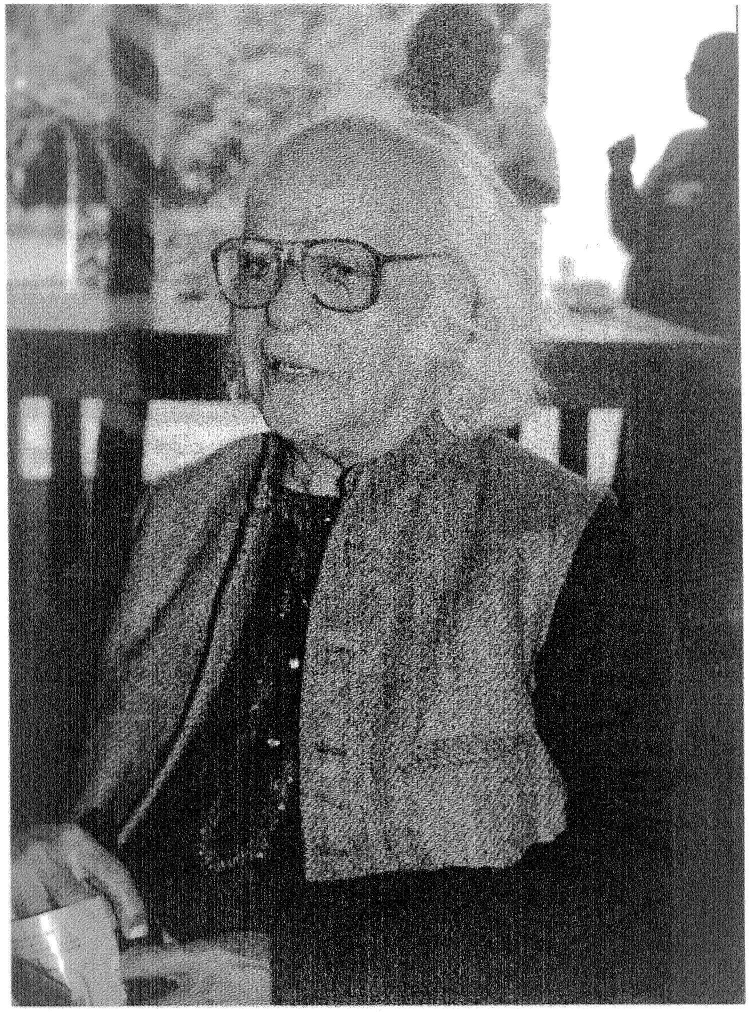
- Good accessibility round the year.
- Number of spectroscopic nights: 256 per year.
- Number of photometric nights: 193 per year.
- Precipitable water vapour: < 2 mm between October and April.
- Annual precipitation of rain and snow: < 10 cm.
- Low ambient temperature and very low humidity.
- Low concentration of atmospheric aerosols.
- Extinction in V band: ~ 0.1 mag / airmass.
- Sky brightness: 21.5 (V) mag/arcsec^2.
- Median Seeing: < 1 arcsec.
- Right Ascension advantage: Uniform distribution of useful nights round the year.
- Longitudinal advantage (78°.5 E): Canary Islands (20° W); Eastern Australia (157° E).
- Latitude advantage (32°.8 N): Other similar sites in southern hemisphere (Atacama desert in Chile).
- Low seismicity.

Hanle can be reached through two alternative routes, either from Srinagar via Kargil and Zojilla pass or from Simla via Manali and Upshi. These roads are open to public transportation from June through October each year and is likely to be snow-bound during the rest of the year. Once Leh is reached the drive thereafter to Hanle is along the river Indus. The narrow black-top road follows the river for 210 km up to Loma where the river is crossed by a well maintained bridge and the road turns south and enters the Hanle valley at Rongo. In the vast valley of flat compactified sand the road peters out into tracts left by the vehicular traffic. Despite the extreme cold, reaching occasional minima close to –30°C, the road between Leh and Hanle is open round the year — there is neither snow nor rain in the Hanle valley. Scientists and engineers may reach the site at any time during the year by flying from Delhi to Leh and taking a jeep therefrom to Hanle.

The following facilities were established at Hanle to be in readiness to install the telescope that was expected to arrive there in the summer of 2000:

- Solar Power Plants, 2 Nos., each of 30 KW peak power with adequate storage for operating the telescope for 3-nights without additional input.
- Liquid nitrogen plant, for cooling the CCD cameras.
- Satellite based communication links (2 Nos.) to the remote control and operation station at Hosakote, one 2 Mbps duplex and one 64 kbps duplex.
- Dome of 10.5m diameter and 16m height with innovative design (by IIA), capable of automatic operation.
- Computational facilities for a variety of purposes such as, control of power, the focal plane instruments, the dome, communication system etc..
- Facilities for scientists, engineers and technicians to stay.
- Facilities for archiving the data.
- Power and communication cables interconnecting the various units.
- The road from the valley to Mt. Saraswati.

It should be noted that such work which involves working with metal objects and with cement, concrete etc., had to be carried out only during the months of June through August when even the night temperatures stay above freezing. It may not be inappropriate to mention here that the air pressure on Mt. Saraswati being about one half of that at sea level, the team had to contend with the low oxygen levels during their work and had to take the requisite precautions. And what is remarkable and praiseworthy is that this immense and formidable task of great difficulty was accomplished on schedule. Since every piece of equipment, the building materials and other components had to be transported across high mountain routes, this accomplishment bears elegant testimony to the foresightedness, planning, dedication, technical competence and grit of the team, and gives us every confidence that indeed the final phase of the task of installing and commissioning of the telescope will also be accomplished with the same level of attention to detail.



Professor Yash Pal, Chairman of the Himalayan Infra Red and Optical Telescope (HIROT) Project Management Board.

The CREST on the land donated by the Government of Karnataka in Hosakote, was equipped to complement the infrastructure at Hanle. The control and operation centre at Hosakote was equipped with communication equipments, computers and office space for round the clock activities. Suitable facilities are also created for archiving the astronomical data. Thus the Indian Institute of Astrophysics is in full readiness for the final phase of this exciting project.

Remote control and data acquisition centre at Hosakote

The infrastructural facilities have been utilized also for a variety of scientific activity other than astronomy by several research institutions in the country including IIA. I would like to draw attention here to the work of Prof. Gaur of our Institute pertaining to the mechanism of continental deformation. Making a series of accurate measurements with global positioning systems from Hanle and other places in India, Professor Gaur and his collaborators find that the intracontinental region in Ladakh, bound by the Great Himalayas in the south and the Karakoram fault in the north, does not deform as an elastic solid plate, but as a viscous continental plate possessing a layered-cake rheology.

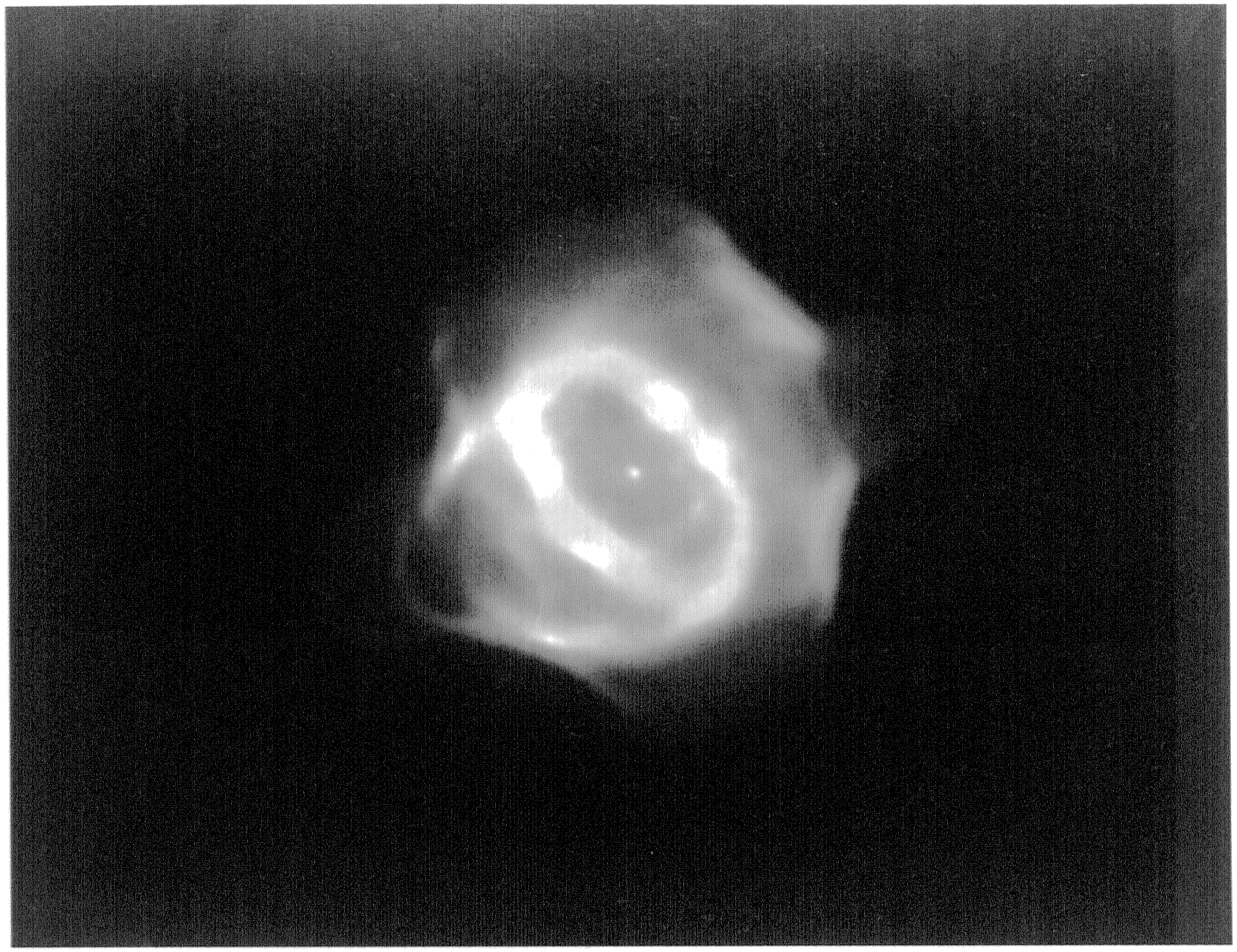
The Vainu Bappu Observatory (VBO) made important observations during the year and new facilities were commissioned at the Observatory. The Liquid Nitrogen Plant installed on the Observatory grounds provides more than 5 liters of LN_2 per hour and all the requirement of the coolant for the CCD-cameras. A new medium-resolution spectrograph commissioned to work with the Vainu Bappu Telescope is functioning satisfactorily.

The readiness of the facilities at VBO may be seen from the recent multi-band observations from VBO of the after-glow of the gamma ray burst GRB000301c, which was detected by the All-Sky Monitor on board the Rossi X-ray Timing Explorer on 2000 March 1, 4108 UT (universal time) and also by Ulysses and NEAR. The coordinates of the event, R. A.=$16^h\ 20^m\ 21^s.5$ and declination = $+29^{\circ}24'56''.37$ within an error box of $50'' \times 50''$, was communicated internationally to all observers, and within three hours of the receipt of the electronic-mail the multi-band photometric observations were commenced by Ms. Bhargavi and collaborators at VBO, and these provided important anchor points for delineating the light-curve of the after-glow of the gamma ray burst.

We may see how a decade of observations, both spectroscopically and photometrically with the Vainu Bappu Telescope in Kavalur, of the recurrent novae T-Coronae Borealis, RS Ophiuchi and others during their quiescent phase, have indicated that the hot sources in these binary systems are accreting white-dwarfs embedded in an optically thick envelope of the wind from the giant companion; see Dr G.C. Anupama's paper for details. It is, therefore, clear that VBO will continue to serve the astronomical community in decades to come, especially for spectroscopic studies.

The astronomers of the Institute have access to the observational facilities across the globe and indeed even from space-borne telescopes. In an extensive study of the R-Coronae Borealis stars, Professor N. K. Rao and collaborators obtained their spectra with the Cassegrain echelle spectrograph on the CTIO 4-m reflector at Cerro Tololo in Chile. Whereas one may refer to the paper by them (A&A, **353**, 287, 2000), it is worth noting here that many of these enigmatic stars are born-again giants, formed either through a final He-shell flash in a post-AGB star or through a merger of two white dwarfs.

The Stingray nebula shows all the characteristics of a newly born planetary nebula. It has become ionized only within the past few decades, the mass loss



Hubble Space Telescope narrow-band high resolution image of Stingray nebula (Hen - 1357). This high-resolution image was obtained in nebular emission lines of H-alpha, H-beta and [OIII] 5007 Å with the Wide Field Planetary Camera-2 (WFPC2). The emission appears most strongly concentrated in an ellipse with its major axis subtending 1.6″ from northeast to southwest. The equatorial ring has dimensions of 1.67″ x 0.92″. This is the youngest planetary nebula discovered so far. It has evolved into a photoionized planetary nebula within the past 20 years and the central star is rapidly evolving into a DA white dwarf. The HST WFPC2 images revealed not only the collimated outflows but also the companion to the central star. The companion lies 0.4″ from the central star, at a position angle of 60″ and its V magnitude is 17. It is 1.6 magnitude fainter than the central star. The companion star is dynamically distorting the gas in this newly-born planetary nebula.

from the central star has ceased only within the last 7 or 8 years and the central star is becoming hotter and fainter as expected of a star on its way to becoming a white dwarf. Professor Parthasarathy of our Institute obtained access to the Hubble Space Telescope in collaboration with an international team and observed this most exciting phase in the evolution of a star, a rare event indeed, to discover that the ejected matter surrounding the central star appears to have been processed perhaps due to the presence of a binary companion.

Ever since Megh Nad Saha revolutionized our understanding of the abundances of the elements in stellar atmospheres, one of the main objectives of astronomy has been to perform spectroscopic studies on stars, obtain the abundances from the data and compare them with theoretical studies of nucleosynthesis and so on. Indeed the Institute participates in such an effort and the astronomers of the Institute have made several significant contributions in this field, as may be seen from the list of publications given in Appendix A of this Annual Report. Recently there has also been an attempt to understand how our Milky Way Galaxy as a whole evolves chemically both in the halo and in the disc.

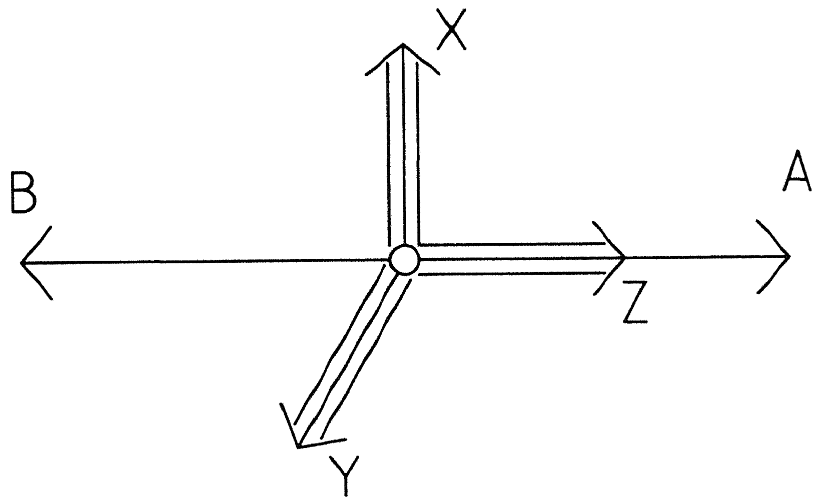
The Institute has a long tradition of research in solar astronomy and solar system studies. In this brief review I would like to highlight just two papers to exemplify the research activity in this field. The scientists of the Institute have searched for waves in the solar corona, waves that might be responsible for heating the corona to millions of degrees celsius, even though the solar photosphere is at a mere 6000^{0} C. Such waves have been searched for through microphotometry of the corona during total solar eclipses. In a recent paper Professors Hasan and Kalkofen have suggested that such waves are generated when the magnetic flux tubes that thread the photosphere are buffeted by the granules or cells on the solar surface which are in rapid random motion. This theoretical suggestion is very timely and will be kept in mind in the ongoing experimental efforts to observe the solar oscillations, especially during the total solar eclipse of June 2001 in southern parts of Africa. In an exhaustive work which extended over several years, Professor Sivaraman and his collaborators have used pairs of temporally simultaneous spectroheliograms in the CaII-K line and have found spatial correlation between CaII-K bright points and the magnetic elements (which are often bipolar regions approaching each other) at the photospheric level, suggesting very strongly that magnetic fields play a crucial role in the heating of the solar chromosphere by providing the source of energy and its transport.

The study of cosmic rays has been called corpuscular astronomy and one of the mysteries of this field is the fact that the energy spectrum of the particles extends beyond 10^{20}eV, quite contrary to the theoretical expectation that the spectrum is expected to cut off progressively beyond $\sim 5 \times 10^{19}$eV due to the interaction of these particles with the radiation fields in the Universe. This cut-off in the spectrum can be avoided if the sources of these highest energy particles are within our own Galaxy or within about 10 megaparsecs (3×10^{19} km) from us. On the other hand the conditions needed for the acceleration of such particles are not observed astronomically in these nearby regions. Dr. P. Bhattacharjee has suggested several ways to resolve this puzzle which include the possibility that they arise in the decay of metastable massive particles or in the annihilation of cosmic strings and other topological defects.

About three decades ago, when I had suggested that "dynamical discrepancies observed in galactic systems were due to the presence of dark matter consisting of weakly interacting particles which were relicts of the big-bang origin of the Universe", it was considered a very daring and esoteric suggestion. Today this has become an accepted paradigm and many equally exciting possibilities are suggested. In two recent papers entitled "Relics of the cosmological QCD phase transition" (Bhattacharyya et al, *Phys. Rev.* D **61**, 083509, 2000) and "Cosmological QCD phase transition and dark matter" (Bhattacharyya et al, *Nucl. Phys.* **A 661**, 629, 1999), it has been suggested by a consortium of scientists from across India that the dark matter could be "quark nuggets" or massive quark condensates which in principle could also be relics of the big bang. If this is correct, dedicated experiments launched from Hanle will be able to detect them.

Turning our attention to the kind of Universe we live in, I would like to draw attention to the paper by S. Majumdar of IIA and R. Subrahmanyan of RRI where they estimate the anisotropy in the universal microwave background imposed on it through its interaction with hot plasma in clusters of galaxies. Comparison of the theoretically expected level of anisotropy based on "cold dark matter" models with that of the observed background shows that such models are not tenable unless the mean density of the Universe is below the critical density needed for closure.

How contrary are the predictions of quantum mechanics to the concept of reality abstracted from our every day experiences is highlighted in the Einstein-Podolsky-Rosen (EPR) paradox. Einstein argued that all responses are local in the sense that matter responds to the forces at the location where it is situated. And we attribute an element of physical reality if we can predict with certainty the value of a physical quantity before actually making a measurement of it. The following quantum mechanical system seems to be contrary to this expectation. Consider a spin-0 state decaying and emitting two photons in opposite directions. Since each of the photons carries a spin 1, their spins have to be oppositely directed. Thus if one photon has spin component (along any particular cartesian axis) +1, we may predict with certainty that the other photon has spin component -1 along the same axis. This is not surprising (see Fig. below).



What is amazing is the predictions of quantum mechanics. The experimenters at A and B may choose to measure the spin component along $\hat{z}$, $\hat{x}$, $\hat{y}$, or any angle θ in the xy plane. Then the following are the predictions of quantum mechanics:

- If A measures s_z and B measures s_x, the two measurements are completely randomly correlated.
- If A measures s_x and B also measures s_x, there is 100% (opposite sign) correlation.
- If A makes no measurement, B's measurement will yield random results.
- Suppose A measures the spin polarization to be along θ_A, then the probability that B will find the polarization to be along θ_B is given by $P(\theta_A, \theta_B) = \sin^2 [(\theta_A - \theta_B)/2]$.

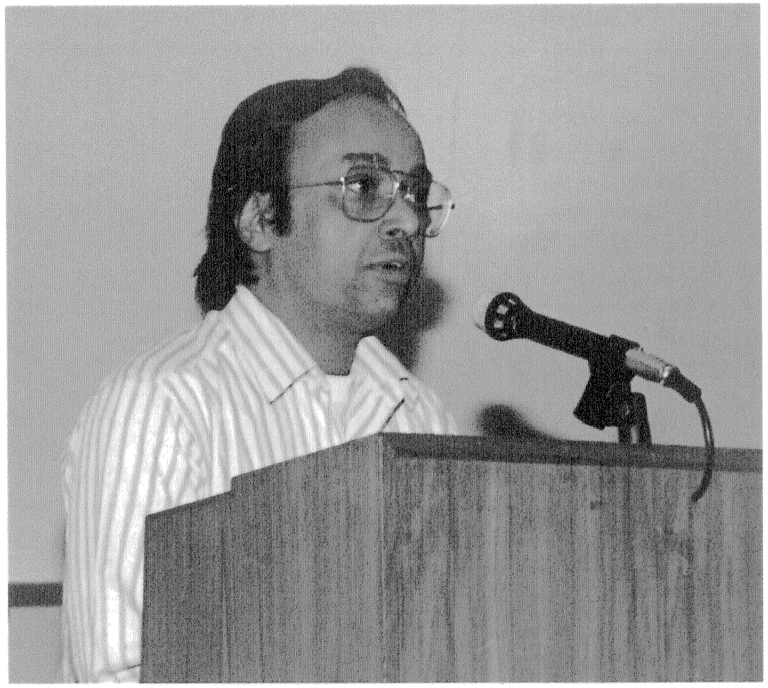
These results show that the measurements carried out at A predicts correctly the results of measurements at B, even if B is outside the light-cone of A. Dr. Unnikrishnan has developed a consistent prescription for calculating these correlations, starting from only local probability amplitudes. This resolves a longstanding paradox of non-locality in the foundations of quantum mechanics.

Theoretical work has also been carried out in many fields of astrophysics and there have been many suggestions for probing the nature of gravitation and other force fields of nature. The essay on the possible reasons for the smallness of the cosmological constant by Professor C. Sivaram received an honourable mention by the Gravity Research Foundation; this is a very important subject and the correct explanation of the value of the cosmological constant is bound to involve ideas of unification of all the forces of nature including gravity and also fundamental issues of cosmology.

More details of the scientific research and development activities during the year, various honours and awards received by Institute's scientists, conferences held at the Institute, lectures given by visitors, etc., are given in the accompanying pages. By all considerations, I would say we have had a very good and productive year.

But what is constantly present in my mind as I write this review of the academic activities of the year is the sad and untimely demise of my dear friend and colleague Professor Bhaskar Datta in December 1999. He was a brilliant scientist, well-known for his contribution to the physics of nuclear matter and pulsars. More than anything else he was a thorough gentleman and a wonderful human being. I am sure there are many besides me who will miss his warm and friendly presence amongst us.

Ramanath Cowsik
Director



Professor Bhaskar Datta (1949 — 1999)

SCIENTIFIC RESEARCH

1. Sun and The Solar System

1.1 Solar Physics

The study of the physical phenomena occurring in the Sun continues to be one of the major areas of scientific research activity in the Institute.

The Kodaikanal Solar Observatory operated by the Institute has a large database consisting of daily full disk white light solar images over a period of several decades (1906 – 1987). The long term programme of analyzing these images is continuing. Recently, Institute's scientists in collaboration with scientists from some other institutions in the world have succeeded in measuring the positions and areas of all sunspots (numbering 332620) to an accuracy of about 0.5 arcsec from 18,900 images covering the 82 year period. Two important measurable quantities have been extracted from this data set, namely, (i) the solar rotation rates at different solar latitudes and the variation of the rotation rate with the solar cycle, and (ii) the tilt angles of spot groups (i.e., the angle between the line joining the centroids of the Leading and the Following spots in the group and the local parallel of latitude). From the measurements of the rotation rates of the spots two important results have been established, namely (a) bigger spots generally rotate slower than the smaller spots and (b) the residual rotation rate (in degree per day) of all spots shows that the rotation during the years of solar minimum is faster than that during the solar maximum years. These results as well as those of the tilt angle measurements of the spot groups have important implications for the dynamics of the solar interior, in particular, for the structure and dynamics of the solar magnetic field, which are being studied in details.

For a complete understanding of the nature of Sunspots, it is necessary to measure not just the strength of the local magnetic field but also their local orientation. Towards this goal, Institute's scientists have developed a Stokes Polarimeter to study the vector magnetic field of the sunspots and have successfully installed it at the Kodaikanal Tower Telescope. A sunspot KKL 21263 (NOAA 8516) was observed with this instrument and the associated magnetic field parameters were successfully determined. This instrument is expected to provide many valuable data pertaining to solar magnetic fields in the years to come.

Another issue pertaining to the sunspots is the question of why some but not all sunspots are observed to have the so-called "EUV plumes", the regions of enhanced emission in the extreme ultraviolet, extending to altitudes of several thousand kilometers above the photosphere, with temperatures of one to two orders of magnitude lower than the surrounding corona. The preliminary results of work done in the Institute suggest that plumes appear to be present only in magnetic bipolar sunspots, particularly during their dynamic phase of activity, and efforts are on to confirm this finding by combing data from the Solar Heliospheric Observatory (SOHO) for EUV emission and the data from Kodaikanal Observatory for the activity phases of the sunspots.

In addition to the Kodaikanal data on sunspots, Institute's scientists have also used sunspot group data from other observatories such as the Greenwich data (1874 – 1981) and NOAA/USAF data (1977 – 1981) to study a variety of topics on solar physics, e.g., (i) study of the dependence of the meridional motions of sunspot groups on the phase of solar cycle, (ii) searching for the 22-year periodicity in the solar differential rotation, (iii) studying the correlation between solar differential rotation and meridional motion, and so on.

A continuing puzzle in solar physics is the unknown mechanism by which the Sun is able to maintain a very hot atmosphere (called "chromosphere") above its surface without losing the heat through conduction to the surface. The main sites in the chromosphere where the heat is thought to be generated are the so-called "bright points". There are generally two opposing schools of thought regarding the nature of these bright points, one claiming association of these bright points with magnetic phenomena and the other modeling them as purely of hydrodynamic origin. In this context, recent work by Institute's scientists have provided strong support to the magnetic association hypothesis by firmly establishing the association of the bright points in the interior of the Calcium II K line network in the solar chromosphere with the underlying sub arc sec magnetic elements at the photospheric level.

In another piece of work on solar chromosphere, by analyzing data provided by the SOHO, Institute's scientists have found evidence for the existence of the so-called ``meso-scale granulation" in the solar upper chromosphere, of roughly the same size as observed earlier in the photosphere and lower chromosphere. These meso-granulations, which are convective cells arising from the solar convection zone and having horizontal sizes in the "medium" range of few thousand kilometers, are found mostly in the photosphere and are generally not seen to extend to the chromosphere. Thus, this new result, if confirmed by future detailed studies, has important implications for the energetics of solar convection process.

There have also been important theoretical work done in the Institute on the problem of solar chromospheric heating with the aim of identifying the precise mechanism by which energy is transported from the photosphere to the chromosphere through the magnetic flux tubes. In this direction work has been done to study the excitation of oscillations in the magnetic network of the Sun through the footpoint motion of photospheric magnetic flux tubes located in the intergranular lanes. Result of this study shows that in order to transport enough energy on a sufficiently steady time scale to account for chromospheric heating, one needs to include the effect of turbulent convective flows on flux tubes in intergranular lanes. Work has also been done to study the radiative effects on the convective stability of the magnetic flux tubes.

If one goes outward beyond the chromosphere one encounters the Corona, visible to the naked eye during a total solar eclipse, which is even hotter than the chromosphere. The problem of explaining the heating of the corona and maintaining it at a temperature of ~ a million degrees constitutes one of the most enigmatic of all the major unsolved problems in solar physics. Institute's scientists have used the coronal spectroscopic data from the ground-based Norikura Solar Observatory of National Astronomical Observatory of Japan and the space-based SOHO images to throw light on this problem. From the power spectral analysis of the time-series of line intensity, line width and Doppler velocity data obtained from the time sequences of the coronal emission line spectra in Fe X 6374 Å and Fe XIV 5303 Å, strong evidence for coronal oscillations with periodicities in the range of a few minutes to a few tens of minutes has been established. In particular, a 3-minute periodicity is consistently seen in both green and red line spectra reported earlier by scientists elsewhere using independent data. These results lend strong support to the hypothesis that magnetohydrodynamic (MHD) waves of short periods (~ minutes) are responsible for the energy transport to and heating of the corona.

In another piece of work, Institute's scientists have discovered interesting correlationship between the magnetic activity in some persistent active regions of the Sun and the enhancement of the 5303 Å coronal green line emission, a result that might have important bearing on the role of magnetic fields in the coronal heating problem.

While short period MHD waves are widely believed to play important role in the coronal heating mechanism, Institute's scientists have also found tentative evidence for the existence of MHD waves of "long" periods, ranging from about 20 days to about 276 days in some frequency ranges in the mean solar radio flux data. The possible role, if any, of these long period MHD waves in the coronal heating mechanism is also being studied in order to have a complete understanding of the problem.

Study of the Sun in radio wavelengths is continuing in the Institute using the Gauribidanur radio telescope operated by the Institute. Radio emission associated with transient Extreme Ultraviolet (EUV) jets from polar regions of the Sun was identified for the first time with the Gauribidanur radioheliograph. This instrument has also provided important data on the coronal mass ejection events of April 13, 1997 and September 12, 1998.

Scientists of the Institute are also involved in several major international space missions studying the macroscopic as well as microscopic physical characteristics of the Sun. One such mission is the SOLARNET interferometric space mission, which will be able to provide detailed information, with high spatial and temporal resolution, about the structure and evolution of the solar magnetic field; scientists of the Institute are involved in the detailed design and modeling of the principal scientific instruments of the mission. Another such project is the PICARD Microsatellite Program, which will provide high resolution measurements (from space), over a period of 2 to 6 years, of the two important macroscopic properties of the Sun, namely, the Solar diameter and the Solar Constant (the total amount of solar radiation received per unit time and unit area at the mean Sun-Earth distance in the absence of Earth's atmosphere). These measurements will allow one to investigate the nature of the relationship, if any, between the two, and their variabilities. The Solar diameter and the Solar Constant are fundamental quantities for the understanding of the internal structure of the Sun and the Solar-Terrestrial relation (e.g., the influence of the Sun on the Earth's climatic conditions).

The Sun, while being the dominant object in the solar system, is, of course, not an isolated object, and as such there is a possibility that there may exist interesting connection between the Sun's internal dynamics and the orbital dynamics of its planetary system. Sun has a large number of internal gravity modes of oscillation with frequencies close to the reciprocal of $\tau_J \sim 43$ min, which, interestingly, happens to be the average time of propagation of gravitational effects between Sun and its largest planet, Jupiter. Institute's scientists are investigating if there could be any observable consequences of the effects of the perturbations due to Jupiter's motion on the Sun's internal gravity modes.

1.2 Solar Terrestrial Physics

The Solar Terrestrial Physics (STP) group of the Institute participated in the *Equatorial Spread F* (ESF) campaign held during April 1999 under the Indian Solar-Terrestrial Energy Program (I-STEP). Regular data acquisition in the monitoring mode continued with the experimental facilities (IPS42 digital ionosonde, HF Doppler Radar and Magnetometer) at Kodaikanal Observatory.

A comprehensive study of the ionospheric storm of November 4, 1993 in the Indian equatorial region was undertaken in the Institute because of the absence hitherto of an assessment of the response of equatorial upper atmosphere to this magnetic storm. The study, based on data from the ionosonde and magnetometer networks in the country, brought to light several new facets of the storm-time behavior of the equatorial ionosphere, indicating, in particular, a significant electrodynamic coupling between high- and low latitude ionosphere.

Work is continuing in the Institute on the inter-relationships between solar wind, magnetosphere and ionosphere. The global manifestation of the waveform of the geomagnetic storm sudden commencement (SC) of November 18, 1993 has been evaluated using high time resolution data of several magnetometer networks coupled with HF Doppler Radar measurements at Kodaikanal. The work revealed that the dip equatorial appearance of the preliminary reverse impulse (PRI) of the SC deviated quite significantly from the pattern established by previous statistical studies as well as the one predicted by currently available theoretical models of SC.

Institute's scientists are also involved in detailed study of the effects of meteor showers on the ionosphere. In particular, the effect of Leonid meteor showers during the years 1996 through 1998, on the characteristics of sporadic-E layers at equatorial latitudes, has been studied using data of rapid ionospheric soundings at several stations in the country. The results showed an increase in the occurrence of Es layers at altitudes in the range 100-140 km throughout the equatorial region at the times of peak shower activity. The finding underscores the need for further studies to ascertain the origin of the observed changes in Es behavior, in particular the relative roles of deposition of metallic ions due to shower activity and the physical mechanism(s) that cause ion-convergence and lead to Es layers.

1.3 Solar System Objects

Following the earlier observations of the Comet Hale-Bopp at the Vainu Bappu Observatory (VBO), Institute's scientists are currently involved in determining the physical nature of the cometary grains in this comet. The porosity and organic fraction of the grains have been determined by comparing the computed variation of polarization of the light scattered by an ensemble of grains of various different assumed porosity and organic fraction with observational data. In addition, by modeling the spectro-polarimetric observations of the Comet Hale-Bopp done earlier at VBO, new information on the grain composition, namely, the proportion of glassy versus crystalline silicates, has been obtained.

2. Stars and Stellar Systems

2.1 Stars

The study of stars of various types – their composition, structure and evolution – constitutes a subject of intense research activity in the Institute.

Important new insights have been obtained on the nature of the so-called R Coronae Borealis (RCB) stars. These stars are photometrically distinct from other stars by their decline at unpredictable times by one to several magnitudes, as a cloud of carbon soot obscures the stellar photosphere for weeks to months. Spectroscopically, the distinctive signature of an RCB is weak Balmer lines which indicate an atmosphere deficient in hydrogen. What are the evolutionary paths by which some stars with their normal hydrogen-rich atmospheres are converted to RCBs with helium-rich atmospheres? And what are the physical processes that trigger and control the development of the unpredictable photometric decline of these stars? These are two of the fundamental questions about RCB stars that researchers are currently trying to answer.

A set of high-resolution optical spectra of R CrB star acquired before, during and after its 1995–96 decline has been analyzed by Institute's scientists in collaboration with scientists from several other Institutions in the world in order to attempt to answer the second of the above questions. This novel data set provides new information on the decline of the star. This includes the discovery that the onset of the decline is marked by distortions of high-excitation absorption lines, and quickly followed by emission in these and in low-excitation lines. This 'photospheric trigger' implies that dust causing the decline is formed close to the star. An outcome of the above analysis is that R CrB might have a compact companion surrounded by an accretion disk. This suggestion has been submitted as a proposal to the Hubble Space Telescope (HST) for high resolution UV spectroscopy in collaboration with scientists from several other Institutions in the world. The proposal has been accepted and 13 orbits have been allocated for this study.

Among other works on RCrB stars, the surface abundance analysis of 18 R CrB stars has been completed. In an interesting piece of work, the presence of cool gas ($T \sim 1100$ K) in the atmosphere of the R CrB star V854 Cen during a deep minimum has been detected by the analysis of C2 molecular lines. This is an important observation which indicates that dust nucleation occurs in the atmospheres of these hot stars ($T_{eff} \sim 7000$ K) after passage of a shock wave.

In the context of stellar evolution, work on the atmospheric abundances and physical properties of intermediate temperature He stars is being pursued in the Institute using high resolution spectroscopy and model atmospheres exclusively developed for this programme.

Another area of stellar astronomy in which significant new results have been obtained by Institute's scientists is the so-called post-AGB (post-asymptotic giant branch) phase of stellar evolution. During this phase in the advanced stage of evolution of typically low-mass stars, substantial mass loss occurs from the outer envelop of the star. The ejected mass, which forms a shell around the hot central star, is ionized by the radiation from the hot central star and is visible as a planetary nebula. The central star subsequently cools, contracts and ends up as a white dwarf.

One of Institute's scientists in collaboration with a team of international scientists has studied the rapid evolution of a newly born planetary nebula – the so-called Stingray Nebula – by analyzing the images of this nebula obtained with the Hubble Space Telescope. This study has provided new insights on the early structure and evolution of planetary nebulae. Other related work on Planetary Nebulae and the Post-AGB stellar phase done in the Institute during the past year includes (i) a high resolution spectroscopic study of the rapidly evolving post-AGB star SAO 85766, (ii) analysis of the UV (IUE) spectrum of the planetary nebula PC 11, (iii) determination of the spectral types of 40 IRAS sources which have far-infrared colours similar to planetary nebulae and are thought to be low mass stars in the post-AGB stage of evolution, (iv) IUE and ISO observations of the bipolar proto-planetary nebula Hen 401, (v) $BVRIJHK$ photometric study of 27 post-AGB candidates, (vi) determination and analysis of abundances of elements in the atmospheres of several post-AGB candidates, and so on.

Other than post-AGB stars and Planetary Nebulae, a host of other kinds of stars have been studied and new results obtained. These include, to mention a few, (i) polarization measurements of the luminous blue variable HR Carinae, (ii) the photometric, spectroscopic and polarimetric observations of the isolated T Tauri binary star V4046 Sgr, (iii) abundance analysis of several SRD variable stars, (iv) search for lithium-rich stars among G-K giants with IR excess, (v) polarization measurements of Vega-like stars, and (vi) a study of the evolution of Li abundance in Pop I giant stars by using the moderately high resolution CCD spectra (in the Li I region) of a sample of 109 subgiants, giants and supergiants of spectral types F3 to M2 obtained with the Coude Echelle Spectrograph at the 1m telescope at VBO, Kavalur.

2.2 Interstellar Medium

Leaving individual stars, as one goes out into the Interstellar Medium (ISM) of the Galaxy, there is a wide variety of astrophysical processes occurring in the ISM on which Institute's scientists are engaged in active research work.

Work is being done on the so-called Young Stellar Objects (YSOs). Stars are born in the cores of interstellar molecular clouds. In their early pre-main-sequence phase, these "stars" or YSOs are still surrounded by their parent cloud envelop and often have circumstellar disks that drive bipolar jets and outflows and also cause polarization of star light by scattering. Institute's scientists are studying YSOs in several star forming regions by emission-line imaging, spectroscopy and polarimetry, and have so far observed about 25 of these objects. This study is likely to yield important insight into the process of star formation.

In another work, the galactic distribution of the high-latitude molecular clouds has been studied. It has been found that the majority of these clouds are clustered in two large shells around the two closest OB associations (i.e., associations of stars of spectral types O–B2), namely, Per OB3/Cas-Tau and Sco OB2. The implication of this result is that these molecular clouds are probably linked with stellar winds emanating from, and supernova explosions of, stars belonging to the above OB associations.

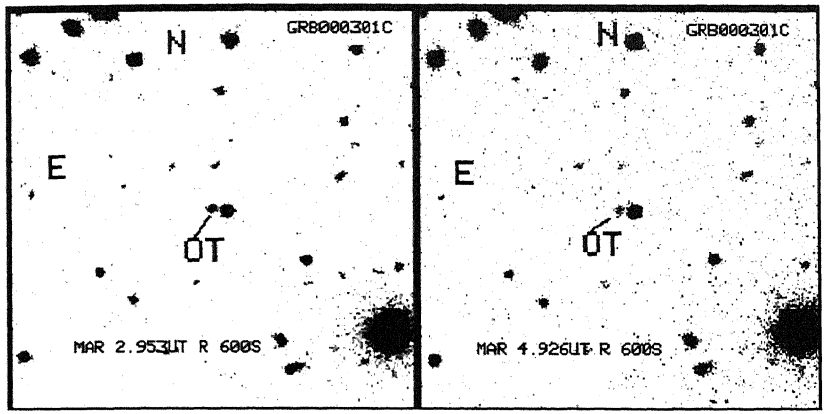
2.3 Galaxies

Coming to the study of individual galaxies, a detailed study of the optical and X-ray properties of the nuclear region of the post-starburst galaxy KUG 1259+280 has been done. The results indicate the presence of a previously undetected active nucleus of the galaxy.

In another work, the distribution of stellar light in some lop-sided (asymmetric) galaxies is being studied in order to obtain the underlying disk mass distribution and the distribution of different stellar components, which will allow one to study the correlation between lop-sidedness and recent star formation in these galaxies. Data have been obtained so far for three such galaxies with the VBT at Kavalur and the analysis of these data is in progress.

2.4 Gamma Ray Bursts

Sustained efforts over the past few years fructified this year when Institute's scientists were able to make early observations of the afterglow of the Gamma Ray Burst (GRB) GRB000301c. Multiband observations of the Optical Transient (OT) associated with GRB000301c was carried out between 2–4 March 2000 using the 2.34-m Vainu Bappu Telescope (VBT) at Kavalur. When combined with other reported data, the initial decline in the R-band magnitude



The R-band images of GRB000301C field of exposure 600s each taken on Mar 2.9953 UT and Mar 4.9257 UT where the fading of the Optical Transient (OT) is clearly seen. Each image portion shown here is of size 2′.6 x 2′.6. North is up and East is to the left.

with log $(t - t_0)$, the time since the burst, is fit with a slope $\alpha_1 = -0.70 \pm 0.07$ which steepens after about 6.0 days to a slope of $\alpha_2 = -2.44 \pm 0.29$. It is found that this change in slope does not occur smoothly; rather there is an indication of a possible bimodal distribution. The available measurements of the evolution of (B–R) color do not show any discernible evolution in the first 12 days. These observations have important implications for the GRB models which are currently under investigation.

On the phenomenological side, clustering of GRBs on the sky was studied. The two-point correlation of the 4th (current) BATSE catalog (2494 objects) has been calculated. The correlation function is found to be consistent with zero at nearly all angular scales of interest. Assuming that GRBs trace the large scale structure in the universe the angular correlation function for the standard cold dark matter (CDM) (sCDM) model was also calculated. It is found to be $\leq 10^{-4}$ at $\theta \simeq 5^{\circ}$ if the BATSE catalog is assumed to be a volume-limited sample up to $z \simeq 1$. Combined with the error analysis on the BATSE catalog this suggests that nearly 10^5 GRBs will be needed to make a positive detection of the two-point angular correlation, if there is any, at this angular scale.

3. Theoretical Astrophysics

3.1 Radiative Transfer

Radiative transfer continues to be one of the major areas of research activity in Theoretical Astrophysics in the Institute.

Using detailed radiative transfer calculations, the Institute's scientists had shown in the previous year that the observed linear polarization in the molecular lines of C_2, MgH, etc in the spectrum of the quiet sun is caused by coherent scattering processes in the solar atmosphere as in the case of atomic lines. Extending that work further, the parameters such as the oscillator strengths, the inelastic collision rates, and depolarizing elastic collision rates for a number of observed molecular transition lines in the solar atmosphere have now been obtained, which have important implications for the states of various molecules in the solar atmosphere.

Radiative transfer calculations were used to understand the nature of the recently discovered brown dwarf Gliese 229B. In particular, the formation of methane line at 2.3 micron in Brown Dwarf Gliese 229B was studied. By fitting the synthetic continuum spectra with the observed spectra at a wide range of wavelengths, the physical properties of the object such as the effective temperature and surface gravity were determined.

Substantial progress has been made in further developing the new operator perturbation method developed in the Institute in the previous year for studying polarized line transfer for the case of Hanle effect which now incorporates various Quantum Electrodynamic effects.

Other works done in the area of radiative transfer include a study of the radiative transfer processes in planetary nebulae, a study of the radiative transfer in the dusty, irradiated expanding atmospheres of close binary components, and so on.

3.2 Magnetohydrodynamics (MHD)

A remarkable fact about the large-scale magnetic field in the Sun is that it is mostly concentrated in isolated magnetic flux tubes at the visible surface and also in the form of coronal loops where the field strengths are of order 1500 Gauss. Why flux tubes rather than uniformly distributed magnetic field? Institute's scientists are engaged in attempts to answer this question by studying the relaxation of a compressible plasma to equilibrium configuration with flow. Three classes of equilibrium solutions corresponding to energy extrema satisfying the constraints of conservation of mass, energy, angular momentum, cross helicity and relative magnetic helicity, have been found. One of these solutions with increasing radial density profile has been identified to be relevant for solar flux tubes. Further studies exploring the stability of these solutions are in progress.

Other works done in MHD include (i) a study of the non-parallel propagation of hydromagnetic surface waves in presence of steady shear-flows relevant for solar coronal loops as well as for photospheric magnetic flux tubes, (ii) a study of the properties of propagating hydromagnetic waves in solar wind flow structures, (iii) deriving the pressure, magnetic field and the flow field structure of solar coronal loops using the statistical theory of MHD turbulence, and so on.

3.3 Plasma Physics and Accretion Process

A kinetic theory of the Jeans instability of a dusty plasma has been developed. The effect of grain charge fluctuations due to the attachment of electrons and ions to the grain surface has been considered. It is demonstrated that the grain charge fluctuations alter the growth rate of the gravitational collapse of the dusty plasma.

It is shown that a certain class of flare models for variability from accretion disk coronae are subject to beam-plasma instabilities. These instabilities can prevent significant direct acceleration and greatly reduce the variable X-ray emission argued to arise via inverse Compton scattering involving relativistic electrons in beams and soft photons from the disk.

The process of formation of quasar black holes from magnetized accretion of a collapsed disk has been studied. It is shown that, in a self-similar accretion flow model, for typical halo parameters, about $10^8 M_\odot$ accretes (thus forming a black hole) via small magnetic stresses (or alternatively by self-gravity induced instability) in $\sim 10^8$ years. A model of self-gravitating evolution of a compact magnetized disk has also been studied. The formalism can be applied to other contexts like formation of protostellar disks as well, and has important implications for dwarf galaxy formation and a residual large scale seed magnetic field.

3.4 Galactic Dynamics

It is known that more than 90% of the material content of the Universe is in the form of some unknown, invisible matter. The nature and distribution of this so-called "dark matter" in the Universe is one of the major unsolved problems of contemporary cosmology. This dark matter, widely believed to be constituted of some unknown weakly interacting particles of small mass, is a major component of the total masses of individual galaxies, including that of our own Galaxy, the Milky Way, as well as the masses of clusters of galaxies. Institute's scientists are engaged in trying to decipher the phase space distribution of these dark matter particles in our Galaxy from various observational data. An efficient Poisson Equation solver for axisymmetric mass distributions has been developed for this purpose using the method of spherical harmonics expansion of the gravitational potential of dark matter in the Galaxy. This code has been used to self-consistently solve the phase space distribution of the dark matter coupled to the visible matter in the Galaxy. The results show that in order to explain the Galactic rotation curve data and the dynamics of the dwarf spheroidals in the outskirts of the Galaxy, the velocity dispersion of the dark matter particles in the solar neighbourhood has to be $\gtrsim 570$ km s^{-1}, a value significantly larger than the usually *assumed* value of ~ 270 km s^{-1}. This result is important in the context of interpretation of the data from various experiments that are currently underway at various laboratories in the world to directly detect the dark matter particles in cryogenic detectors, and implies important constraints on the nature of the dark matter particles.

Important new results have also been obtained in the study of galaxy dynamics by means of numerical N-body simulations. These include a study of the tidal effects on a satellite galaxy caused by a centrally concentrated massive perturber, an investigation of oscillations of galaxies, a study of the process of violent relaxation in elliptical galaxies, and several other related issues.

3.5 Atomic Astrophysics

Atomic Astrophysics is another branch of Theoretical Astrophysics in which important work has been done in the Institute in the past year. A knowledge of excitation energies and oscillator strengths of allowed as well as forbidden transitions is crucial for the determination of abundances and temperatures of a variety of astronomical objects. Relativistic many-body calculations of the oscillator strengths of the allowed, intercombination and magnetic quadrupole transitions of the berrylium sequence have been done using the multi-configuration Dirac-Fock approach. This work highlights the significance of electron correlation in these studies. Using a variant of the multi-reference many-body perturbation theory known as the effective valence Hamiltonian method, the excitation energies, ionization potential, electric dipole moments and oscillator strengths for cyclic and linear isomers of the C3H radical were calculated. This radical is present in the interstellar medium like the dark molecular cloud TMC1 and in the circumstellar shell of highly evolved carbon star IRC+10216.

4. High Energy Astrophysics, Astroparticle Physics and Cosmology

4.1 Neutron Stars and Pulsars

Neutron Stars and Pulsars is an area of research in which Institute's scientists have made major contributions over the years. The main theme of the work done in this area in the past year has been the study of General Relativistic effects pertaining to physics in and around pulsars which are strongly magnetized rotating neutron stars.

By studying the General Relativistic effects on the propagation of light in the vicinity of pulsars, it has been shown that the spacetime curvature introduces a shrinking of the magnetic field lines towards the magnetic poles by a small magnitude. This tends to overcome the divergence of the pulsar beam caused by the light bending effect. The formalism developed can be used for arbitrary emission altitudes in the pulsar and for all inclination angles between the magnetic and rotation axes of the pulsar. It is proposed that these relativistic effects may be observable in the case of millisecond pulsars. In addition, it has been shown that these relativistic effects, together with various observational constraints on pulsars, put severe constraints on the equation of state (EOS) of the neutron star matter. In particular, very soft EOS's are preferred, as would be the case, for example, if the radio pulsars were actually the so-called "strange stars" made up of u, d, and s quarks instead of neutron matter.

Important constraints on the EOS of neutron star matter have also been obtained by studying the properties of accretion disks around rapidly rotating neutron stars with low surface magnetic fields in Low Mass X-ray Binaries (LMXBs) including the full General Relativistic effects. In particular, using the EXOSAT data on the X-ray spectrum of Cygnus X-2, it has been inferred that the neutron star in Cygnus X-2 rotates close to the centrifugal mass-shed limit.

The General Relativistic effects on Joule heating of neutron stars have also been studied. It is found that, although the effect of space-time curvature produced by the intense gravitational field of the star slows down the decay rate of the magnetic field, the modification of the initial magnetic field configuration and the initial field strength by the space-time curvature results in increasing the rate of Joule heating. This gives strong support to the hypothesis that Joule heating is responsible for maintaining a relatively high surface temperature which is consistent with the observation.

Work has also been done on various observational and phenomenological aspects of pulsars. In particular, the distribution of the polarization modes at different pulse longitudes for the pulsars PSR B0301+19 and B0355+54 has been studied by analyzing the single pulse data of these pulsars at 1.41 GHz taken by the 100-m Effelsberg radio telescope of MPIfR. Evidence has been found for depolarization, and it has been shown that most of the pulsar radiation depolarizes due to superposition of orthogonal polarization modes. Other related works done on pulsar include (a) a study of the origin of the orthogonal polarization modes and (b) various propagation effects such as the effect of stimulated Raman scattering on polarization of pulsar radio emission.

4.2 Astroparticle Physics, Cosmology and Early Universe

A model for the origin of MeV emission from blazars has been developed, that involves the production of MeV gamma rays through Inverse Compton (IC) scattering of electrons in the blob of the blazar jet with the UV photons of the accretion disk around the central supermassive black hole. The OSSE and the COMPTEL spectra of the blazar PKS 0528 + 134 have been fitted with the computed MeV gamma ray fluxes of this model. Possible emission of TeV energy photons through synchrotron self compton (SSC) processes in this model has also been suggested.

Stringent constraints on the mass and charge of photon were put based on the arrival times of radiation at different wavelengths (radio, optical and gamma rays) from the gamma ray burst GRB 990123. Also, limits on certain parameters (such as the string scale) relevant to quantum gravity theories were obtained. Analogous to the situation in SN 1987A, from the various delay times, stringent limits were put on deviations from the validity of the Einstein equivalence principle for photons over a wide (12 orders of magnitude) energy range.

Recently there have been attempts to revive alternative cosmological models different from the standard Big Bang model, which are supposedly able to account for both the microwave background and light element abundances. Theoretical work done in the Institute has, however, shown that the cosmic neutrino background in these alternative models would be vastly different both in energy and number density from that predicted in the standard Big Bang model. One can thus envisage future neutrino based observations which can differentiate between these models.

Important theoretical work has been done in the Institute on the process of black hole evaporation. By applying ideas of non-equilibrium thermodynamics initially developed for glassy systems, this work has shown that the Hawking temperature of the primordial black holes formed in the early Universe would always be much lower than the corresponding ambient temperature, which would inhibit the evaporation of these black holes. This result has important implications for observability of primordial black holes through the Hawking radiation process.

The abundance and the size distribution of the so-called "quark nuggets" (QNs), a possible relic from a first order phase transition from quark-gluon matter to hadron in the early Universe, have been calculated. It is found that a significant fraction of QNs may have been formed with initial baryon number large enough that they survive through their subsequent evolution, so that QNs may significantly contribute to a baryonic component of the dark matter in the Universe.

A stringent constraint on the total mass density of the Universe has been derived from the Sunyaev-Zel'dovich (SZ) effect — the distortion of the Cosmic Microwave Background (CMB) due to scattering with the hot electrons in a cluster of galaxies. It is found that a low matter density (including dark matter) Universe is favored, indicating that there may be significant amount of "vacuum energy" (contributing as a cosmological constant term in the Einstein equation) for a critical Universe. In addition, the effect of cooling flows in clusters of galaxies on the determination of the Hubble constant from SZ effect, as well as SZ distortions of the CMB due to galactic winds at high redshifts have been studied.

An impressive variety of recent observations which include luminosity evolution of high red shift supernovae strongly suggest that the cosmological constant (Λ) is not zero. Even though the Λ-term may dominate cosmic dynamics at the present epoch, such a value for the vacuum energy is actually unnaturally small, and is difficult to explain. Theoretical work done in the Institute, based on ideas of phase transitions in the early Universe, has shown how such a small residual cosmological constant term of the correct magnitude can arise from fundamental physics. In addition, the role of gravitational spin interactions in generating a residual cosmological term has also been explored.

5. Physics

5.1 Optics

Experimentation on Adaptive Optics is in progress in the Institute. The piezo tilt mirror has been calibrated in the laboratory using the Zygo Interferometer. The algorithm to measure the centroid correction has been tested. The calibration of the CMOS CCD is in progress. Efforts are on to procure a Shack Hartmann sensor to develop the laboratory Adaptive Optics system.

Work is also being done on wavefront sensing. The algorithm to retrieve the phase from a single shearing interferometric record is being developed. The results from different approaches are being compared for their efficiency in terms of minimum duty cycle per operation. In the mean time efforts are on to build a Shack Hartmann sensor to compare the two methods.

In theoretical optics, scattering of light by a rough phase grating has been studied. Light scattered by a pure phase grating is known to have a periodic structure with respect to the angle of scattering. In the present work it is shown that while roughness smears out the sharpness of this structure, the broadening of the peaks is dependent on the nature of the randomness (whether Gaussian or Cauchy type, etc.). Thus the hidden periodic structure can be detected by observing the pattern at different wavelengths. Detectibility of such periodic structures hidden behind randomness is one of great importance, e.g., in remote sensing.

5.2 Foundations of Quantum Theory

A resolution of the celebrated Einstein-Podolsky-Rosen (EPR) nonlocality puzzle in quantum mechanics has been proposed. The EPR puzzle is one of the most discussed fundamental problems in physics. A seemingly inescapable feature of the standard version of quantum mechanics is its nonlocality – it seems to require the existence of apparently superluminal and mysterious communication between the space-like separated subsystems of an initially correlated, entangled quantum system. The present work has shown that the quantum correlations of space-like separated entangled particles can be reproduced starting from local probability amplitudes, quantities that preserve the relative phase information. Use of complex number amplitudes circumvents the widely discussed Bell's theorem on the impossibility of a local realistic description of quantum correlations. The objective reality in this formulation is at the level of initial phases that cannot be measured, and there is no determinism. The result implies that there is no 'spooky action-at-a-distance' in the correlations and resolves the EPR nonlocality puzzle. Also, they imply that the present interpretations of seemingly nonlocal phenomena like quantum teleportation and entanglement swapping are not correct.

A related issue is the so-called Complementarity Principle which is a basic foundational principle in the Copenhagen interpretation of quantum mechanics. It derives its roots from the uncertainty principle and has never been seen violated in interference experiments. Usual interpretation of the principle invokes the analogy with the Heisenberg microscope thought experiment where the physical origin of complementarity is traced to the position-momentum uncertainty principle. Loss of interference in atom interferometry experiments, where the "which-path" information can be obtained without disturbing the spatial wavefunction of the atoms, could not be explained within this picture and has been a subject of extended debate in the last decade. Recent work done in the Institute has shown that the physical origin of complementarity in this case is a discrete, but random phase change arising from the de-excitation of the atom, equivalent to the rotation of a spinor though 180 degree. This clarifies how complementarity can arise without Heisenberg back-action on momentum, and settles a recent debate on this issue.

5.3 Gravitation and Black Holes

A new way to test relativistic gravitation has been suggested. It is suggested that modern techniques of radio ranging, when applied to study the motion of the Moon, can improve the accuracy of tests of relativistic gravitation obtained with currently operating laser ranging techniques. Other auxiliary information relevant to the Solar system would also emerge from such a study.

An investigation into the empirical question of possible shielding of gravity by matter has been done. This question is at present outside the scope of the standard theory of gravitation. This is mainly due to the fundamental feature of gravity that there is only one type (sign) of gravitational charge. On the other hand, the question whether gravity could be shielded or absorbed by an intervening medium has been important from an empirical point of view. The issue has been addressed experimentally during the last century in several laboratory experiments and astronomical tests, and theoretically by several physicists. The experimental activity was brought to focus by Q. Majorana who conducted several high precision experiments with a weighing balance between 1920 and 1930 to see whether there was absorption of gravitational interaction by intervening matter. A tiny shielding effect was detected. The results of an experiment being conducted at the Physik-Institut, University of Zurich to measure the gravitational constant was recently analyzed by a scientist of the Institute in collaboration with another scientist from the University of Virginia, USA. This analysis has yielded a rather tight constraint on the Majorana gravitational shielding factor. The limit obtained in this analysis is two orders of magnitude lower than the positive results obtained by Majorana and a factor of about 5 better than the constraint obtained by Braginsky in a more modern laboratory experiment.

The long-term research project investigating Black Holes in non-flat backgrounds in General Relativity is continuing in the Institute. The research pertaining to black holes has so far been focused mainly on isolated stationary ones (Schwarzschild and Kerr). These two properties are equivalent to asymptotic flatness and time symmetry respectively. In a realistic situation, considering external influences such as local mass distribution or the expanding universe, neither of these properties may be valid. It is extremely important therefore to find out whether the known properties of black holes are modified, radically altered or retained unchanged. Towards this end the study of black holes in non-flat backgrounds has been undertaken. As a first step in this complicated investigation, the condition of asymptotic flatness has been relaxed retaining time symmetry. New results have been obtained regarding the geometry of the Kerr black hole embedded in the static Einstein universe and the properties of the energy-momentum tensor. Specializing to the non- rotating case, a composite model consisting of vacuum Schwarzschild black hole joined on to the Einstein Universe has been constructed. This enables the study of physical phenomena in the gravitational field of such a black hole in a non-flat background such as scattering of waves.

5.4 Non-Accelerator Particle Physics (NAPP)

Significant advances have been made in the Institute in the area of Non-Accelerator Particle Physics (NAPP) research.

On the theoretical side, work on Parity Non-Conservation (PNC) has continued. It has been recognized for about a decade now that PNC in atoms is an important non-accelerator probe of physics beyond the Standard Model. However, in order to make progress, it is necessary to improve the accuracy of the present atomic PNC theory. Relativistic and many-body effects play a crucial role in the theoretical determination of the PNC observable. Institute's scientists have been involved in the development of the relativistic version of an all-order many-body theory known as the coupled-cluster method for the last three years. Calculations based on this theory are highly computer-intensive. The major part of the work last year was the development and testing of parallel computer codes to carry out calculations of a number of different properties of Cs, Tl and Ba+ with an eye to determining the accuracies of the PNC calculations for those three atoms. These properties include ionization potential, magnetic hyperfine constants and transition amplitudes. Calculations were carried out successfully of the correlation energy of Tl+ with all the core electrons excited. The purpose of this work was to demonstrate the importance of core correlation for Tl PNC. The effects of nuclear structure on Cs PNC was also studied using the relativistic mean field theory. Studies of this kind are necessary for the analysis of atomic PNC as a probe of physics beyond the Standard Model.

On the experimental side, strong efforts are being made to equip the NAPP laboratory for pursuing several frontier experiments in Physics. A cylindrical ion trap has been designed and fabricated in collaboration with Indian Institute of Science, Bangalore. The necessary electron gun for ionizing the atoms has been fabricated. An air-core transformer has been designed and built to provide the necessary stepped-up RF voltage from a RF source. Initial experiments will be focused on trapping large number of ions. Necessary electronics for detecting the trapped ions is being developed. The vacuum system has been reconfigured into a differential pumping scheme to ensure better signal-to-noise ratio.

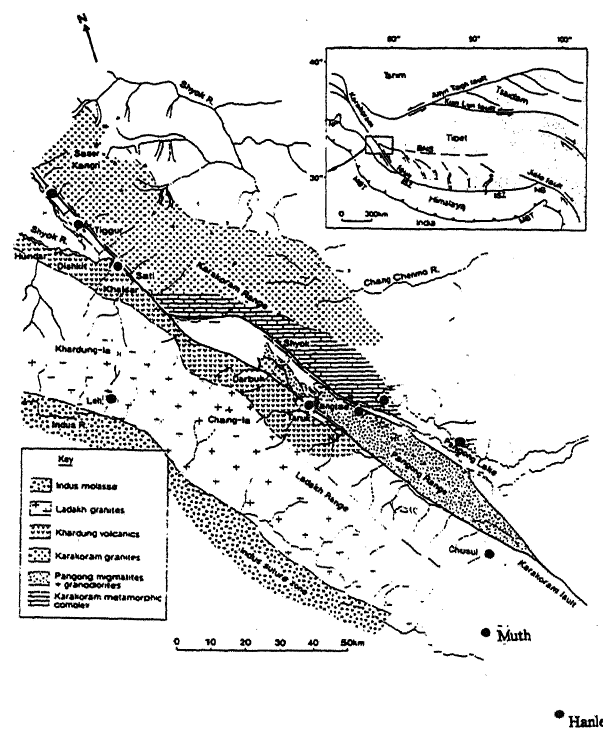
The "Casimir Balance" to measure the finite temperature correction to the short range Casimir force arising from confining the quantum vacuum modes of electromagnetic radiation is being tested. A new autocollimator using an array of high intensity LEDs as the source, spatially modulated by a high precision grid, and a CCD detector is fabricated and being assembled. This will be used for the measurement of the Casimir force at boundary separations ranging from 30 microns to 1 mm. A similar torsion balance designed to probe short range forces, hypothesized on the basis of results from scenarios motivated by string theory is also being fabricated. The goal is to search for possible new forces with a strength comparable to that of gravity, and a range as small as a millimeter.

Experiments on laser cooling of Helium metastable atoms are being done in collaboration with the laser cooling group at Ecole Normale Superieure, Paris (ENS), Paris. The cooled Helium atoms have been loaded into a magneto-optical trap and preliminary measurements on the trap life time have been done. The present goal is to load the cooled atoms into a magnetostatic trap in which the atoms are spin polarized. The collision loss rate due to ionizing Penning collisions are expected to be suppressed by a factor of about 105 for spin polarized atoms. After a measurement of the Penning loss rates, it is planned to proceed to experiments on evaporative cooling and Bose-Einstein condensation of metastable Helium.

5.5 Geodynamics of Continental Deformation

Experimental test of a hypothesis concerning the mechanism of continental deformation is being done by Institute's scientists using sub-centimeter precision Global Positioning System (GPS). Mathematical model of the process whereby continents deform in response to plate tectonic stresses is the major prerequisite for quantifying earthquake hazard and for refining our understanding of planetary dynamics generally. Global coordinates of marked points on earth with millimeter precision now make it possible to discriminate between contrasting hypotheses of this process by measurements of strain rate gradients across major faults in the deforming region. Ladakh Himalaya lying north of the Indo-Eurasian plate boundary, it being the fastest deforming region of the globe, is manifestly the most promising area for addressing this question. An experiment was accordingly designed in 1998 to determine strain rates along and south of the gigantic Karakoram fault which appears most prominently on satellite imageries as a deep 1000 km long gash in the earth stretching from the Pamirs to Mount Kailash in Tibet.

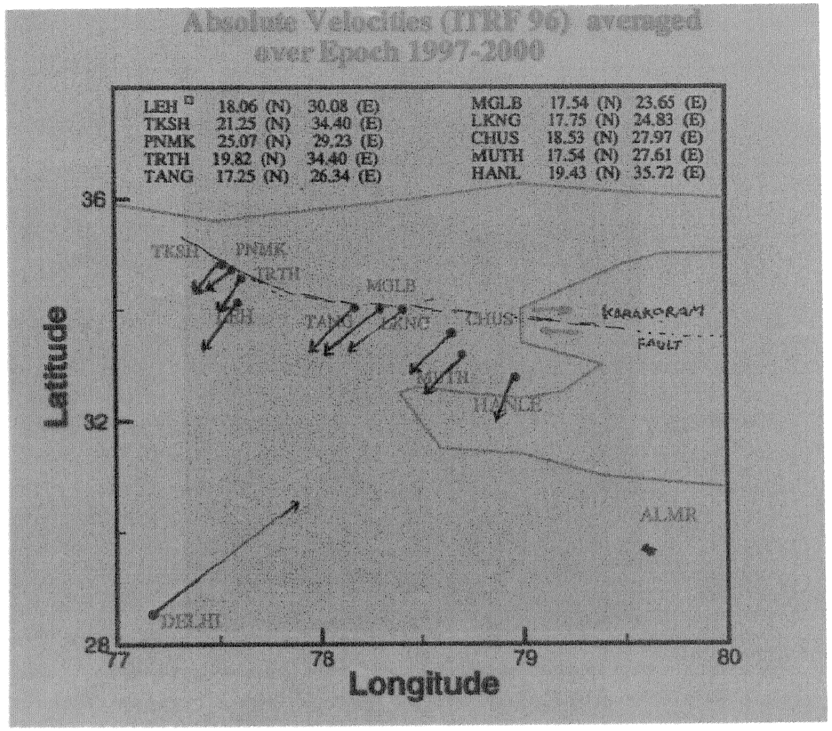
The Figure below shows the location of 10 points selected for repeat measurements of their coordinates to yield the desired strain rates. These were



Geological map of the Karakoram fault in northern Ladakh, India. Inset shows the area of approximately double thickness continental crust (shaded area), which, in the extrusion model, is moving eastward bounded by the dextral Karakoram fault in the southwest and the sinistral Altyn Tagh fault along the north.

the best sites available under the constraints of spatial coverage, accessibility, sky clearance, and logistic support. Two of these points, at Leh and Hanle, are marked on concrete monuments specially erected for the purpose, where measurements continued for 3 months each year since 1998. The other 8 points are marked by 2 mm diameter holes drilled into solid rock outcrops.

Preliminary determinations of annual site velocities in Ladakh marked by these points with respect to the Indian-plate velocity represented by a point in the IISc campus in Bangalore, are shown in the figure below. While a detailed analysis of the contemporary strain rate field in the region is in progress, preliminary studies clearly show that the intra-continental region in Ladakh bound by the Great Himalaya in the south and the Karakoram fault in the north does not deform as a nearly rigid plate, but as a viscous continental plate possessing a layered cake rheology.



The vector positioned at Delhi shows the annual velocity of a fixed point in Delhi marked on a quartzite outcrop in the campus of JNU (in the International Terrestrial Reference Frame (ITRF G6), while the vectors at other points in Ladakh and Almora show the relative annual velocity of these sites with respect to Delhi.

FACILITIES

Indian Astronomical Observatory, Hanle

The 2-m telescope fabrication was essentially complete at the Works of M/s EOST, Tucson, in February and Pre-shipment Acceptance Tests were conducted in March 2000. The year witnessed increased activity of infrastructure development, site characterisation, and other scientific activites at the site of Indian Astronomical Observatory, Hanle. The remote control, communication, data archiving and analysis facility will all be located in the CREST campus of IIA, near Hosakote where one wing of the main building is nearly ready for occupation.

1. 2-m Telescope

The 2-m telescope fabrication and assembly was complete by the end of February 2000 and the Pre-shipment Acceptance Tests were conducted in March 2000. The telescope specifications were set at the state of the art when the order was placed in 1997, together with stringent environmental specifications at the high-altitude cold desert conditions at Hanle. Subsequent design reviews have ensured that the telescope will continue to be the best at the current level of the state of art. Thus in many respects the telescope has exceeded the original specifications by a wide margin. For example, the zenith keyhole radius is only 1.8° against 3° specification; the encoder resolution is 0.002 arcsec in azimuth and 0.0225 arcsec in elevation as against 0.1 arcsec specification; the secondary motion resolution is 0.01 μm against the 0.2 μm specification; the primary and secondary mirrors have an rms surface smoothness of 8 and 10 Å against 20 Å specification. The pointing, tracking and Shack-Hartmann tests conducted at the Works indicated that the telescope will perform well in all specified aspects. Yet, some further improvements appeared possible with the primary mirror support system and the secondary focus mechanism. These improvements were scheduled to be completed before the telescope is shipped to India in May 2000.

The telescope is expected to reach the site by the end of July, and the first technical light at the site is scheduled for August. The scientific projects will be undertaken beginning September 2000.

Professor Yash Pal, Professor B.V. Sreekantan, Professor R. Cowsik, Dr. R. Srinivasan, Dr. A.K. Saxena and T.P. Prabhu made trips to the works of M/s EOST, Tucson to review the progress and also to witness the Pre-shipment Acceptance Tests. Shri Prakash Misar, Shri A.N. Raut, Dr. B.C. Bhatt, Dr. A. Subramanian, Shri B.N. Naidu, Shri F. Gabriel and Shri J.P.A. Samson made visits to EOST for training on different aspects.

2. 2-m Telescope: Enclosure

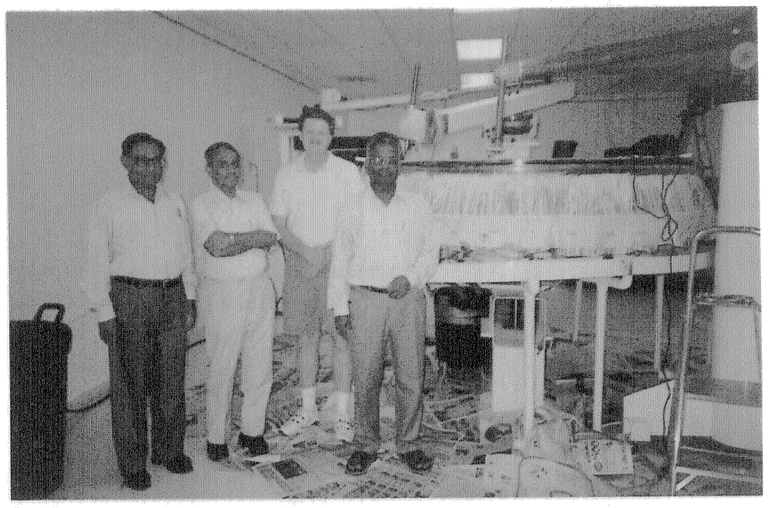
The main structure of the 2-m telescope enclosure was erected by M/s Mengi Construction Co., Jammu up to the observing floor level and the top ring beam of the dome by September 1999. Further work was discontinued due to reducing temperatures and is rescheduled for May 2000. The control room cladding was also completed and the electrical panels installed.

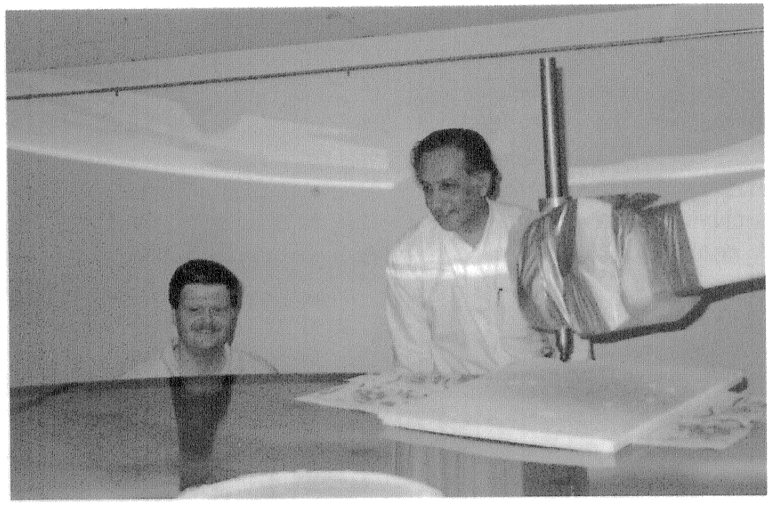
The dome is energised by a 4 x 1 hp Sumitomo ac induction motors. A 11 KW peak inverter has been procured and tested for its performance with the VBO 1-m telescope dome. A novel design power coupler was designed, fabricated and tested at the 1-m telescope dome. This coupler will avoid the complexity of bus-bars for electrical connectivity between the rotating dome and stationary enclosure. The dome was tested with a proportional controller for positioning accuracies. The trials proved a satisfactory performance of the power coupler in the operation of opening and closing the dome shutters. The final installation and tests at the 2-m enclosure are scheduled in June 2000 following the completion of the enclosure at the site. The dome control software being developed by IIA through a contract with Access Systems Ltd., Bangalore will also be tested during this period.

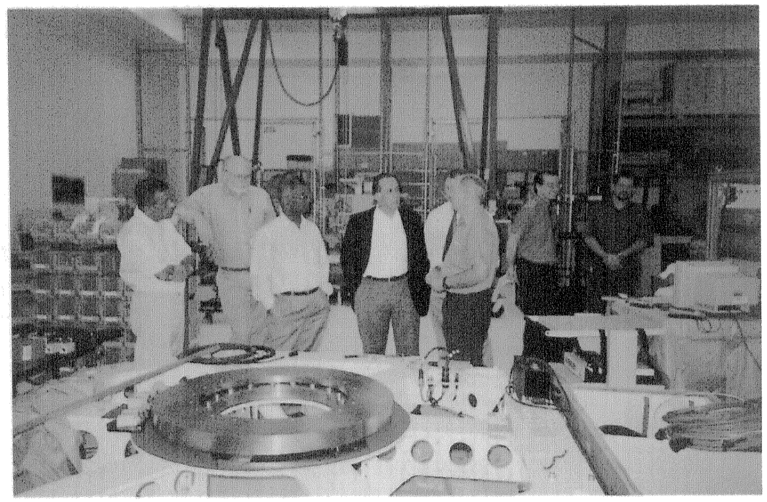
3. 2-m Telescope: Focal Plane Instruments

Three first generation instruments are in various stages of fabrication as described below :

CCD Imager : The first-light instrument will be a CCD imager being developed in-house. The instrument is built around a 2k x 4k, 15 μm pixel size thinned back-illuminated and VISAR coated CCD chip procured from M/s SITe. The







IIA Team testing the fabricated mirror of the 2-m telescope at Rayleigh Corporation, USA. (Top Left)

IIA team with engineers of the EOST, Arizona, USA, checking the mechanical fabrication of the 2-m telescope parts. (Bottom Left)

Reflecting on the mirror quality. (Top Right) dewar and controller are under fabrication. The filter-holder has been designed. The broadband UBVRIZ filters have been procured and some narrowband filters have been ordered.

HFOSC : The fabrication of mechanical components as well as electronic controls of the main instrument and its CCD detector are proceeding at Copenhagen University Observatory. The grism substrates have been procured and the gratings have been ordered. The optical design was finalized during the current year and order has been placed for its manufacture. The finished opitics is expected in July 2000; the instrument is expected to be assembled and tested at Copenhagen in September 2000 before it is transported to the site. The interface unit is being designed at IIA.

Near-IR Camera : An order has been placed with M/s Infrared Laboratories, Tucson, for a 512 x 512 pixel HgCdTe based IR camera with two choices of image scales, broad and narrowband filters in the JHK region. The instrument is expected to be available by March 2001.

4. 50-cm Antipodal Transient Observatory

The 50-cm telescope being provided by the Macdonell Center for Space Sciences, Washington University, St. Louis, is nearing completion. Professor R. Cowsik, Dr. A. Subramanian and Shri B.N. Naidu visited Washington University, ST. Louis and M/s Torus Precision Optics, Iowa to review the progress of the telescope.

The pier for the enclosure was cast during the summer of 1999. The main structure was fabricated in the workshops of IIA, transported to the site and erected in October. The cladding work will be undertaken during the summer of 2000.

5. Infrastructure Development

Power : The DG sets have been working satisfactorily. M/s CEL and M/s TATA BP Solar Ltd completed installations of their respective 30 KWP SPV power stations. These units also worked satisfactorily during the winter and supplied power required for the various activities at the peak. The smaller 1Kwp sytems installed at the office-cum-guest house at Leh and base camp at Hanle have also been performing well.

Road : The work on the unsurfaced link road between Hanle Monastery and observatory campus is nearly complete. Most of the area around the peak has also been levelled for future development.

Liquid Nitrogen Plant : The 5 lit/h capacity Liquid Nitrogen plant was transported to the site and installed in September 1999. It has been working satisfactorily through the winter.

Vehicles : Two Maruti Gypsy vehicles are already available at Leh/Hanle. A TATA 407 mini-truck was procured during the current year and transported to the site. It is used for transporting material between Leh and Hanle, as also for transporting water and personnel between base camp and Mt Saraswati peak.

Personnel : One Trainee Electrician has been employed at Hanle and is participating in the infrastructure development and maintenance activities.

6. Remote Operation

Control Room : One wing of the main building at CREST campus was nearly complete during the current year. The first floor of the building will house the remote control room for IAO, Hanle whereas the ground floor will house other laboraratories of interest. Guest rooms are available both at the ground and the first floor for visiting astronomers.

Satellite Communication Links : The communication dish antenna for use with INSAT 2C was shifted from its temporary location in the CREST campus to the roof of the main building. The NOCC tests for the corresponding dish at Hanle were concluded. A bandwidth of 450 kHz has been obtained on the transponder-17 of INSAT-2C to operate the 128 kbps link.

The dish antennae and electronics required for the 2 Mbps ISRO SPACENET point to point link between Hosakote and Hanle were procured and installed.

The NOCC tests for the antennae were concluded satisfactorily. The link was commissioned and tested for the voice and data communication.

Both the links were decommissioned to allow for the preparation of the communication room. The recommissioning is scheduled for May 2000.

7. Site Characterization

- Monitoring of Cloud Cover continued in its sixth year.
- Automated Weather Station monitored the meteorological parameters through the fourth year.
- A permanent enclosure for the Meade 12-inch telescope was erected during the year and the telescope installed in its enclosure in May 1999. The DIMM estimates of seeing were obtained through the year, often with participation of students from outside the Institute.
- The 220-GHz Radiometer built collaboratively with the Raman Research Institute and the University of Tokyo, was tested in the laboratories of RRI, transported to the site and installed near Meade enclosure with the control computer inside the enclosure. The instrument is measuring sky brightness and estimating sky opacity at this frequency continuously at an interval of 10 minutes since the end of December 1999. Early results indicate a median opacity of 0.1 during the months of December-January 2000.

8. Support for other Scientific Experiments

The infrastructure available at Hanle has induced other scientific institutions in the country to undertake scientific experiments in a variety of paradigms. IIA has been providing local support and logistics needed for such experiments. Some of the experiments are briefly described below.

Geodynamic Deformation Field : The Hanle GPS station has been upgraded to form a continuously monitoring GPS station as a part of the national GPS network established by the Department of Science & Technology, Govt. of India. This would provide a continous GPS reference in Ladakh and also enable real-time baseline determination between Hanle and the Kodaikanal, another field station of IIA where a similar system has been set up.

A continuously operating broadband seismograph will also be established at Hanle during the working season of 2000 under the aegis of the Department of Science & Technology. This will provide an important seismic station in a significant arena of Himalayan geodynamics.

Aerosol Content at Leh and Hanle : Measurements of atmospheric parameters at remote and high-altitude areas are scanty. As these areas are free from the influence of man-made sources, measurements at these locations will serve as background values of the parameters. As a part of the proposed aerosol and trace gases measurement programme, the Indian Institute of Tropical Meteorology carried out Aitken nuclei measurements at Leh (3312 m asl) and Hanle (4500 m asl) during October 1999. The study revealed the following:

The maximum concentration of Atiken nuclei at Leh (2200 /cm^3) occurred during daytime at 11 AM local time and thereafter the concentration slowly reduced reaching a minimum value of 400/cm^3 around midnight. At Hanle the peak of 385/cm^3 occurred at noon decreasing to 100/cm^3 in the evening and remaining steady thereafter during night hours. For comparison, the values at Hawaii are 1200/cm^3 at noon and 500/cm^3 at night.

Long-term aerosol monitoring has been continuing with the support of local staff of IAO.

Other Atmospheric Studies : The National Physical Laboratory, Delhi, has undertaken measurements of atmospheric ozone, water vapour, incident UV-B radiation, aerosol optical depth. Erythemal dose, etc. at Hanle. The initial experiments were conducted during the summer of 1999 and further experiments are planned during the summer of 2000.

INSTRUMENTATION

This year saw major achievements by the facilities and instrumentation development and support groups of the Institute. The major activities of the various groups are briefly described below.

Electronics and Electrical Engineering Division

- **Linear CCD Camera for Autocollimators** : A scheme to measure very small angular displacements (of the order of 10^{-9} radians) was developed using a Linear CCD camera. This instrument will be used in one of the major fundamental physics experiments (the "Casimir Balance" experiment) being done in the Institute.

- **A Mosaic CCD Camera System** has been developed using a set of Thomson-CSF 2K x 2K CCDs (THX7897M) in a 2 x 2 configuration for astronomical observation applications. The necessary data acquisition software to operate the mosaic camera system has also been developed, and after successfully testing the system in the lab, a few test runs were conducted with the 1-meter telescope at VBO, Kavalur.

- **Digital Spectrograph for Radio Observations:** A new digital spectrograph for observations of Solar radio burst emission in the frequency range 30—80 MHz was constructed and installed at the Gauribidanur Radio Observatory of the Institute. The instrument is in successful operation since November 1999. Observations of solar radio bursts with this instrument coupled with imaging observations carried out with the existing Gauribidanur radioheliograph are expected to provide a valuable data base containing information on the location of the burst sources.

- **TAXI Board :** A high speed general purpose data link PCB has been designed and is being fabricated. The data throughput rate can go up to 4 MBPS. The electronics is capable of transferring/receiving 32 bit parallel data over a serial link, and the board uses TAXI chip pair (Am7968 and Am7969) for transmitting/receiving parallel data.

- **Hardware Based Data Compression :** A hardware approach to data compression has been implemented in order to compress/de-compress on-line CCD data as well as stored data. A high performance adaptive loss-less data compression (ALDC) processor, ALDC1-20S-HA from IBM, is used to implement compression/de-compression.

- **Recabling and Rewiring Activity at the 1-m Telescope :** The vacuum tube version of the control electronics of the 1-m Carl Zeiss Telescope of the Institute installed in 1972 at VBO, Kavalur, was replaced with the state of the art telescope drive system, display system, dome drive system etc.. The cables and wires in the telescope at various locations were found to be weak in insulation properties and had turned brittle due to aging and environmental factors. To improve the reliability of the telescope, steps were taken to replace the cables and wires in a phased manner. High quality rubber cables and wires were used in the telescope rewiring. The entire recabling work of the telescope was completed in about three months and the telescope was released for observations from January 1, 2000. A detailed technical manual incorporating all relevant drawings, cabling details, modifications/changes has been prepared.

- **Optical Imager for the 2-m Telescope :** A CCD cryostat for the optical imager for the Hanle 2-meter telescope has been developed in house and tested for its performance in all respects.

- **A New High-Speed Link to Hanle :** A new communication system has been procured from TIW, U.S.A., for establishing high speed (up to 2 MBPS) link between Hanle and Hoskote. This point-point link is intended for the remote operation of the 2-meter telescope at Hanle. The system has been installed and tested at both Hosakote and Hanle.

- **Dome Automation Software for the 2-m Telescope :** In connection with the dome automation work, the various units like encoders, motors, inverter, converter and some i/o cards have been procured and tested in the lab. A 64 turn, 16 bit absolute position encoder from BEI Motion Control and System, USA, is used for dome position encoding. A circuit to test the encoder has been developed. Software routines have been developed to test the converter and all inverter functions from a PC. A test setup was made in the lab to carry out an integrated test on the inverter, motor and the encoder. The complete control algorithm was written in C language under DOS and tested.

- **Computer Centre — Installation of Sun Ultrasparc Systems :** A new set of eight Ultrasparc systems were installed in the computer centre to facilitate image data analysis. These Systems have 330 MHz Ultra sparc CPU with 128 MB RAM and 40 GB hard disk. These have been networked through a 12 port 3 COM switch. A directory structure with YP has been installed to facilitate simple management. Several IBM PC's have been added with LINUX software for general use.

Mechanical Engineering Division

In addition to regular maintenance work, the Mechanical Engineering Division of the Institute undertook major design, development, fabrication, and installation work mostly in connection with the development of various major facilities at IAO, Hanle. These include the work on the domes and buildings for the 50-cm and the 2-m telescopes, communications antannae at CREST, Hosakote and IAO, Hanle, the tower for monitoring microthermal variations in the atmosphere at Hanle, filter unit for the CCD imager for the 2-m telescope, etc.. In addition, design, development and fabrication works were undertaken for (i) an interface unit for the SILFID spectrograph for the VBO telescope, (ii) the mechanical mount for the antennae for the GPS at Kodaikanal, Hanle, Almorah, etc., (iii) the dewar for the CCD to be used in the Hanle telescopes, (iv) filter wheel assembly for the spectropolarimeter at the VBO, Kavalur, and so on.

Photonics Division

Major facilities development and instrumentation work done in the Photonics Division include (i) the completion of the grinding work of the primary mirror of the 40-inch telescope, (ii) completion of a new design concept of the optical head for the Long Trace Profilometer (LTP) in connection with the optics for the Synchrotron Radiation Beam Line (SRBL) project, (iii) fabrication and polishing (to a mirror finish) of a set of thin copper and aluminum plates for the Torsion Balance apparatus for measuring possible new millimeter range Yukawa type force — an experiment on fundamental physics being done in the Institute, and so on.

LIBRARY

The library added 503 books. A seed collection of 200 books was purchased for the new library at the Hoskote campus of the Institute. The Library subscribed to 155 journals. It continued to receive more than 100 observatory publications, newsletters and annual reports. More than 400 volumes of journals were stitched and bound, 296 inter library requests were honoured. The library established access to more than 40 electronic journals during the year.

Three new post graduate trainees were recruited for the library and they are undergoing training in various sections of the library.

An MOU was signed between IIA and C-DAC, Bangalore for digitizing archival material in the IIA library. With the help of C-DAC's new state of the art equipment for scanning and omni-scan software version 5.0, ten volumes including the oldest annual reports of the year 1792, Kepler's Astronomia Nova (1609), and Flamestead's Historia Coelestis (1725) (3 volumes) were digitized and they are all available on CD ROMS.

MISCELLANEOUS

STUDENT AFFAIRS

Four new students joined the Ph.D. Programme at IIA — three in August 1999, and one in January 2000. Six students were trained under the summer students' programme during May—July, 1999. Three students completed their doctoral work and submitted their thesis to Bangalore University: Gajendra Pandey worked on "Hydrogen Deficient Stars and Related Objects", Swara Ravindranath worked on "A Study of Star Formation in Nearby Star Forming Galaxies", and Arun Thampan worked on "Luminosities of Disk-Accreting Non-magnetic Neutron Stars."

COLLABORATIVE ACTIVITIES WITH OTHER INSTITUTIONS

Major collaborative activities were started with the following Institutes :

— **University of Calicut**, March 1999: Mutual cooperation in the common interests of teaching and research in Astronomy and related subjects.

— **Copenhagen University Astronomical Observatory, Denmark**, April 1999: Collaboration in the fields of galactic and extragalactic astronomy, and as a specific step towards building and utilization of a low dispersion spectrograph called "Hanle Faint Object Spectrograph & Camera" (HFOSC).

— **McDonnell Center for Space Sciences, Washington University, St. Louis, USA**, June 1999, to collaborate in the field of astronomical transient phenomena, as a specific step towards cooperation on the installation and utilization of two 50-cm aperture telescopes forming the Antipodal Transient Observatory.

— **Centre for Development of Advanced Computing (C-DAC), Bangalore**, November 1999, to collaborate in the field of storing rare archival documents, viz., printed astronomy books, written manuscripts, old correspondence and photographs in a specific digitized format towards the goal of establishing a digital library.

— **Wadia Institute of Himalayan Geology (WIHG), Dehra Dun**, December 1999, to foster cooperative researches in Geodynamics of Ladakh, Himalaya; a GPS receiver and a broad band seismograph provided by the WIHG will be installed at the Indian Astronomical Observatory, Hanle.

— **ISRO Satellite Center, Bangalore**, February 2000, for optical polishing at IIA of the sun-shield panels of the INSAT-3D spacecraft imager and sounder.

— **Steward Observatory, Univ. of Arizona, Tucson, USA**, March 2000, to develop astronomy from the high altitude site at Hanle, Ladakh. The principal goal of this collaboration is to build a large telescope, of order 6.5 to 8.4 meter aperture at Hanle.

OFFICIAL LANGUAGE IMPLEMENTATION

The institute has been carrying on the program of implementation of the official language in a systematic way. Administrative and other reports, official documents to be laid in the Houses of Parliament, have been prepared bilingually. These include the Institute's annual report, and other administrative reports. Official circulars have been brought out bilingually. This includes circulars relating to national and other holidays. A facility like "Learn a Hindi word everyday" has been continued, which is well received by the employees. The Hindi version of entries in the service books has been continuing as an essential part of the implementation. Hindi Divas is celebrated in the institute. Dictionaries, glossaries and other reference books have been bought and made available to the staff members. Latest Hindi software has been procured. Bilingual rubber stamps have been prepared for the institute and for the Hanle project.

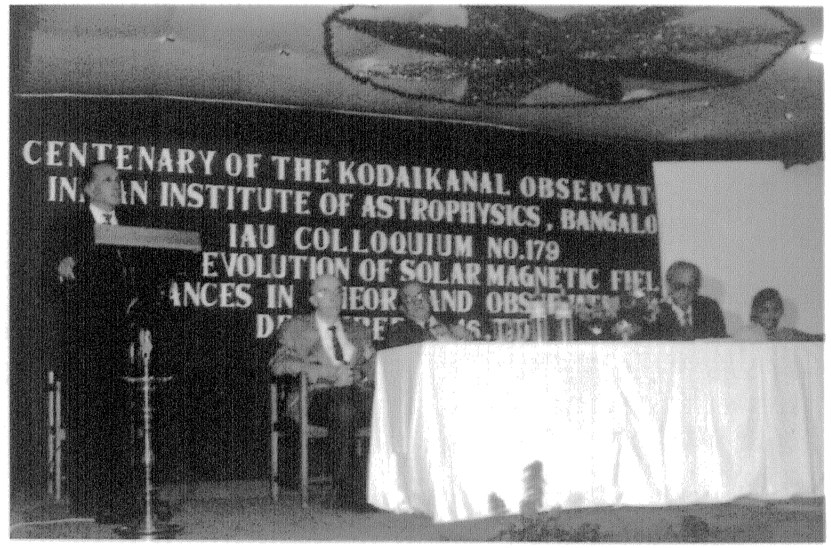
WELFARE ACTIVITIES FOR SC/ST

A senior officer of the Institute is functioning as the Liaison Officer to look after the welfare activities of the SC/ST staff members. Several members belonging to these communities were deputed for acquiring specialized training.

The total staff strength of the Institute as on 31-3-2000 was 365. As per the orders of the Government, 67 posts in scientific and technical categories were exempted from the reservations. Out of the 298 positions, 49 members belonged to SC and 10 members belonged to STs, forming 16.44% and 3.36% respectively. The shortfall was due to retirements/deaths. Necessary recruitment action is underway to fill these positions.

CONFERENCE REPORTS

Prof . R. Cowsik, Director, welcoming the participants to the IAU colloquium 179, (Dec. 13-16, 1999) on the occasion of the centenary of the Kodaikanal Observatory.



Scientific Highlights of the 'IAU' Colloquium 179 on "Cyclical evolution of solar magnetic fields : Advances in theory & observations" held at Kodaikanal during December 13-16,1999.

This important IAU Colloquium, on the occasion of the Kodaikanal Observatory centenary, organized by the Indian Institute of Astrophysics, can be viewed as a recognition by the international astronomical community, of the significant contributions to solar observations by the Kodaikanal Observatory, which commenced at the turn of the century, and of the growing contributions from Indian solar physicists to this specialised area of research.

I. In the Inaugural session, the historical perspective of Kodaikanal Observatory was brought in to focus. The importance of daily high quality observations of solar features to our understanding of origin of solar activity and also the new results on tilt angles of magnetic axes of active regions were presented.

II. The importance of synoptic observations and the objectives of the Synoptic Optical Long-Term Investigations of the Sun (SOLIS) were highlighted. The scientific goals associated with the measurement of accurate diameter of sun, and its total & UV luminosities (PICARD program), were overviewed.

III. Using sunspots as tracers of sub-surface processes, it was pointed out that the phase shifts in apparent torsional MHD oscillations are correlated to the amplitudes of subsequent cycles. The good complementarity of data obtained at Kodaikanal with those obtained at Mount Wilson was demonstrated and the utility of pooling such data in accurate measurement of sunspot rotation rates was discussed.

IV. A new paradigm was presented for the formation and evolution of filaments and filament channels. It was argued that the filaments trace the emerged toroidal fields.

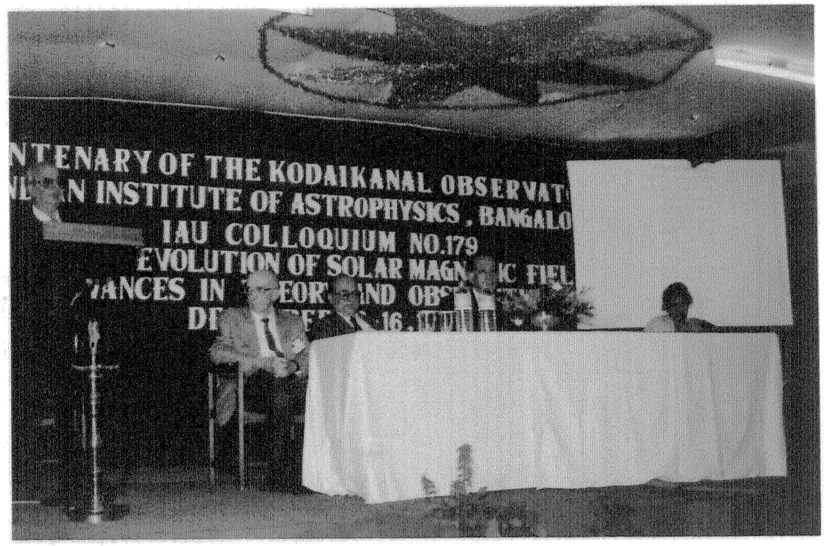
V. Full disk magnetograms were presented, which revealed interesting properties of magnetic helicity on global scales.

VI. Using helioseismology it is now possible to probe the sun's internal structure with high precision. It is becoming increasingly clear that the solution of solar neutrino problem lies in better understanding of the physics of neutrinos rather than in physics of the sun.

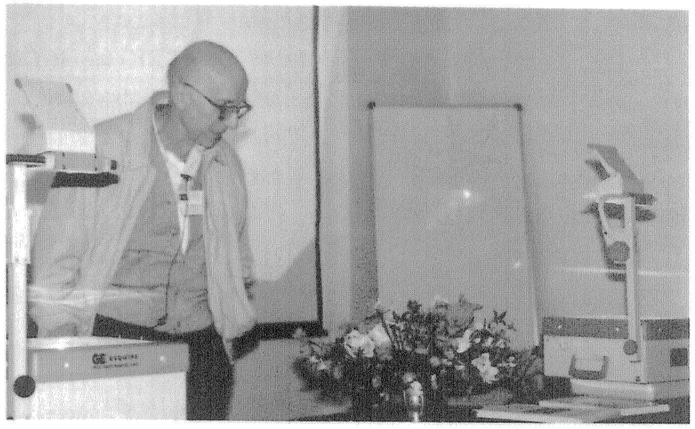
VII. The changes in galactic cosmic rays and energetic particles of solar and heliospheric origin over solar cycle periods and their relation to solar activity changes was examined.

VIII. In the concluding session the main achievements in solar physics during the century were highlighted as well as possible future directions were discussed. The contributions of several great solar physicists of the century, who changed the very landscape of our understanding of sun, were recalled.

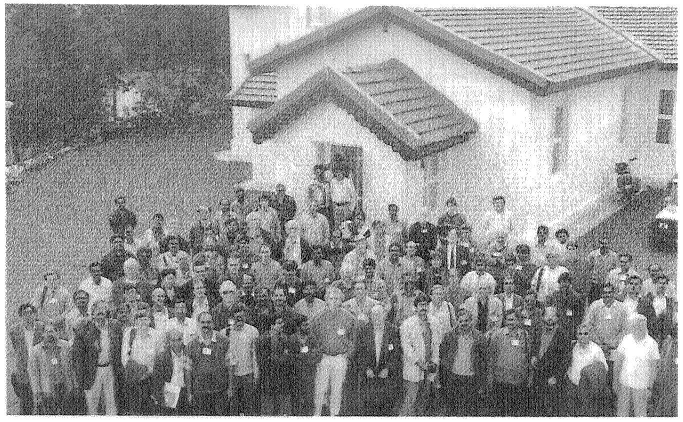
A total of 42 papers were presented during the 12 sessions. Further, 53 poster papers were presented in two poster sessions.



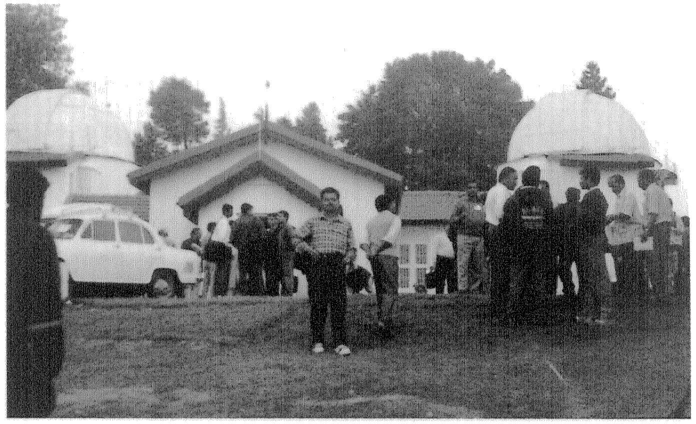
▲ Prof. B.V. Sreekantan, Chairman, Governing Council addressing the participants and inaugurating the centenary colloquium by lighting the lamp. ▼



Dr. Robert Howard, National Solar Observatory, Tucson, Arizona delivering the key note address.



Participants in front of the "Main Hall" where the scientific presentations were held.



Participants engaged in informal discussions in the front lawns of the "Main Hall". The "Main Hall" is flanked on either side by telescope domes - the dome on the left houses the 8 inch refractor used earlier for stellar work and presently used for astronomy education; the dome on the right houses the 6 inch refractor, one of the oldest telescopes, where the daily white light images of the sun are obtained since 1904.

Prof. B.V. Sreekantan and Mrs. K. Noorjahan IPS, Post Master General, Southern Region, Madurai, releasing the Special Cover with Special Postage cancellation on December 13, 1999, in commemoration of the Centenary of Kodaikanal Observatory.

Towards a National Science Programme around the unique site and the 2-m optical/IR telescope of the Indian Astronomical Observatory (IAO), at Hanle (GPS Reference : 32.7795051°N, 78.96423382°E, 4468.6047 M) (April 15 & 16, 1999)

A set of forward looking scientific programmes in Astronomical sciences as well as in other areas, notably upper atmosphere, aeronomy, geomagnetism, geodynamics and environmental sciences to be pursued at Hanle, were hammered out at a 2 day workshop held at the Indian Institute of Astrophysics (IIA), Bangalore on April 15 & 16, 1999. The objective of the exercise was to catalyze development of some seminal ideas for possible research endeavors around the Indian Astronomical Observatory, Hanle in Ladakh, which could be specially focussed on by taking advantage of the unique geophysical characteristics of the site: excellent astronomical seeing, low infra-red background, high UV transmission, the proximity of the 30° latitude of the Solar Quiet day magnetic variations field concentration and the descending Hadley Cell. All these conditions and the relatively clean environment- scape of Hanle, uncluttered by optical, chemical and electromagnetic noise, render the site potentially advantageous for studying a host of significant natural processes and phenomena.

Professor R. Cowsik, Director, IIA declared at the very outset that the Indian Astronomical Observatory at Hanle, Ladakh was a National facility whose utilization will be open to all scientists within and without the country, on the lines operated for such facilities elsewhere in the world. Allocation of time on this telescope will be accordingly made by a National Committee constituted for the purpose. He also said that there was considerable international interest in collaborating with Indian scientists to advance our endeavors at Hanle which would further enlarge the scope of work at IAO. Those currently underway are the establishment of a 50 cm antipodal transient telescope in collaboration with the Washington University, a 220 GHz radiometer jointly organized by the University of Tokyo, RRI and IIA and the development of a Faint Object Spectrograph Camera in collaboration with the Copenhagen University (CUO). A direct CCD imaging camera with filters is under development at IIA. An IR imaging camera system with a 512 x 512 pixel HgCdTe detector is on order.

Personnel

Academic / Scientific / Technical Staff as on 31-3-2000 includes the following

Director : Ramanath Cowsik

Senior Professor : J.H. Sastri, N. Kameswara Rao, Vinod Krishan

Engineer G : R. Srinivasan

Professor : R.K. Kochhar *(on lien to NISTADS, New Delhi)*, B.P. Das, S.S. Hasan, D.C.V. Mallik, M. Parthasarathy, P. Venkatakrishnan *(on lien to USO, Udaipur)* T.P. Prabhu, C. Sivaram, Ram Sagar *(on lien to UPSO, Udaipur)* B. Datta *(deceased on 3.12.1999)*.

Head Photonics : A.K. Saxena

Sr. Principle Scientific Officer : A.V. Ananth

Scientist E : A.K. Pati, R. Rajamohan, A.V. Raveendran, K.K. Ghosh, H.C. Bhatt, R.C. Kapoor, Jagdev Singh, G.S.D. Babu, S.P. Bagare.

Associate Professor II : Jayant Murthy

Scientist D : P.K. Das, S.G.V. Mallik, K.E. Rangarajan, K.N. Nagendra, S.S. Gupta, S. Chatterjee, S. Giridhar, R. Vasundhara, S. Mohin, P.M.S. Namboodiri, K.R. Subramanian, R. Surendiranath, S.K. Saha, P. Bhattacharjee, D. Mohan Rao *(resigned on 12-1-2000)*.

Scientist : K.M. Hiremath

Sr. Research Scientist : B. Raghavendra Prasad, Kaustuv Das.

Principle Scientific Officer : V. Chinnappan.

Engineer D : B.R. Madhava Rao, M.S. Sundararajan, G. Srinivasulu.

Librarian : A. Vagiswari.

Scientist C : Prajval Shastri, R.K. Chaudhuri, K.P. Raju, R. Kariyappa, A. Satyanarayanan, M.V. Mekkaden, G. C. Anupama, K. B. Ramesh.

Sr. Engineer (Civil Works & Estates) : N. Selvavinayagam

Scientific Officer SD : J.P.L.C. Thangadurai.

Engineer (Electrical) : A.N. Raut

Engineer (Electronics & Computer) : P. Misar

Engineer (Mechanical) : P.M.M. Kemkar

Engineer (Civil) : R. Ramachandra Reddy

Research Scientist : R.T. Gangadhara, P. Joarder, A.V. Mangalam.

Scientific Officer SC : P.S.M. Aleem, D. Karunakaran, B.A Varghese, L. Yeswanth, J. Javaraiah, M. Srinivasa Rao, J.V.S. Visheswara Rao.

Scientist B : B.S. Nagabhushana, K. Sundararaman, A. Subramanian *(w.e.f. 20.1.2000)*, S. Raizada.

Technical Officer : K.G. Unnikrishnan Nair, R. Muraleedharan Nair, N. Jayavel, J.P.A. Samson, S. Muthukrishnan, M. Mohd. Abbas, P.K. Mahesh, B. Nagaraja Naidu.

Engineer B : S.S. Chandramouli, K. Padmanabhan, A.T. Abdul Hameed, J.S. Nathan, F. Saleem, K.N. Kutty *(resigned on 30-9-1999)*, K.S. Ramamurthy *(V.R.S. w.e.f. 1-6-999)*.

Scientist C : B.C. Bhatt w.e.f. 1-10-1999

Engineer SC : M.P. Singh.

Asst. Librarian B : Christina Louis.

Research Associate : K. Jayakumar, K. Kuppuswamy, M.J. Rosario, S. Perumal *(on lien to Madras Planetarium)*.

Technical Associate : A.V. Velayuthan Kutty, A. Selvaraj, K. Rangaswamy, K.C. Thulasidharan, G.N. Rajasekhara, K.S. Subramanian, N. Sivaraj, F. Gabriel, G.S. Suryanarayana, E.E. Chellasamy, P.U. Kamath, R. Selvendran, P. Anbazhagan, A.M. Batcha *(retired on 31.1.2000)*.

Mechanical Associate : T. Johnson.

Documentation Associate : S. Rajiva.

Distinguished Professor : K.R. Sivaraman, Vinod K Gaur.

Adjunct Scientist : N. Krishnan, C.S. Unnikrishnan.

Visiting Sr. Professor : M.H. Gokhale, C.V. Vishveshwara.

Sr. Scientist (Honorary) : A. Krishnan.

UGC Emertus Fellow : N. Shankaran.

Visiting Fellow : H. Merlitz, R. Ramesh, S.K. Sengupta, A. Goswani, R. Srikant, S.K. Mathew, M. Das, A. Narayanan, M. K Samuel.

SRF : G. Pande, T. Sivarani, S. Banerjee, Charu Ratnam, S.P.K. Rajaguru, S.G. Bhargavi, S. Majumdar, D. Suresh, R. Sridharan, K.P. Geetha, V. Krishnakumar, K. Rajesh Nayak, K.S. Subramaniam, P. Chakraborty, Mangala Sharma, D.V. Lal, Rajalakshmi, B.S. Ramachandra.

JRF : B. Ravindra, P. Manoj, P. Kharb, Geetanjali, M. Gopinath, C. Kathiravan, Mahalakshmi (BRNS Project), Y. Lakshmi (BRNS Project), R.K. Banyal, P. Shamila, K. V. P. Lata, G.A.S. Sundaram, S. Ambika, P. Mazumdar, B.K. Shaoo.

JAP Students : S. Majumdar, S. Bhattacharyya.

APPENDIXES

APPENDIX A

PUBLICATIONS

In Journals

Anupama, G.C., *Dewangan, G.C. (2000) *AJ*, **119**, 1359.
The 1999 outburst of the recurrent nova U Scorpii.

Anupama, G.C., *Mikolajewska J. (1999) *A&A*,**344**, 177.
Recurrent novae at quiescence: Systems with giant secondaries.

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*Bobrowsky, M., *Sahu, K.C., Parthasarathy, M., *Garcia-Lario, P. (1999) *New Astr. Rev.*, **43**, 411.
The Stingray nebula : Watching the rapid evolution of a newly born planetary nebula.

*Bombaci, I., Datta, B. (2000) *ApJ. Lett.*, **530**, (in press).
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*indicates collaborating scientists from other institutions.

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*Fujii, T., *Nakada, Y., Parthasarathy, M. (2000) *A&A* (in press).
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Giridhar, S., *Lambert, D.L., *Gonzalez, G. (1999) *PASP* **111**, 1269.
The chemical compositions of the SRd variable stars: WY And , VW Eri and UW Lib.

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Subramaniam, A., Bhatt, H.C. (2000), Proc. XIX ASI Meeting, Bangalore, Ed. H.C.Bhatt, *BASI,* **28**, 255.
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Paper Presentations at Meetings

Cowsik, R.,
Cosmic ray bounds on violation of Lorentz Invariance
26th ICRC, Salt Lake City, Utah, USA, Aug 1999.

Gupta, S.S., Sivaraman, K.R., Howard, R.P.,
Rotation of the sun and cycle variation from the Kodaikanal photoheliograms for the period 1906 - 1987,
IAU Coll. 179 on Cyclical Evolution of Solar Magnetic Fields : Advances in Theory and Observations, Kodaikanal, 1999 December 13-16.

Kariyappa, R.,
CaII K imaging to understand UV irradiance variability,
IAU Coll. 179 on Cyclical Evolution of Solar Magnetic Fields : Advances in Theory and Observations, Kodaikanal, 1999 December 13-16.

Mallik, S.V.,
Lithium Abundance and Mass,
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Mangalam, A., Krishan, V.,
Models of solar flux tubes from plasma relaxation,
IAU Coll. 179 on Cyclical Evolution of Solar Magnetic Fields : Advances in Theory and Observations, Kodaikanal, 1999 December 13-16.

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The enhanced coronal green line intensity and the magnetic field gradients,
IAU Coll. 179 on Cyclical Evolution of Solar Magnetic Fields : Advances in Theory and Observations, Kodaikanal, 1999 December 13-16.

Raju, K.P., Sakurai, T., Ichimoto, K., Singh J.,
Distribution of emission line widths in a polar coronal hole from Norikura coronagraphic observations,
8th YOHKOH symp., ISAS, Tokyo, Japan, 1999 December 6-8.

Sankarasubramanian, K., Srinivasulu, G., Ananth A.V., Venkatakrishnan, V.,
Stokes Polarimetry at the Kodaikanal Solar Tower Telescope,
IAU Coll. 179 on Cyclical Evolution of Solar Magnetic Fields : Advances in Theory and Observations, Kodaikanal, 1999 December 13-16.

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Results from Kodaikanal synoptic observations,
IAU Coll. 179 on Cyclical Evolution of Solar Magnetic Fields : Advances in Theory and Observations, Kodaikanal, 1999 December 13-16.

Sridharan, R., Venkatakrishnan P.,
Simulations of High Resolution Imaging Technique,
IAU Coll. 179 on Cyclical Evolution of Solar Magnetic Fields : Advances in Theory and Observations, Kodaikanal, 1999 December 13-16.

Subramanian, K.R.,
Gauribidanur radio heliograph — present status and observations,
IAU Coll. 199 on The Universe at Low Frequencies, Pune, Nov. 30 - Dec. 4, 1999.

Subramanian, K.R.,
Multi baseline observations on the occultation of crab nebula by the solar corona at decameter wavelengths,
IAU Symp. on Solar Cycle Variation of Magnetic Field, Kodaikanal, December 7-11, 1999.

Sundara Raman, K.,
Emergence of twisted magnetic flux related sigmoidal brightening,
IAU Coll. 179 on Cyclical Evolution of Solar Magnetic Fields :
Advances in Theory and Observations, Kodaikanal, 1999 December 13-16.

Sundara Raman, K.,
Effects of spot and plage rotation in the triggering of flares and prominence evolution
International Conf. on Solar Eruptive Events, Catholic University,
Washington, D.C., USA, March 6-9, 2000.

Venkatakrishnan P.,
Is a sunspot in static or dynamic equilibrium ?
IAU Coll. 179 on Cyclical Evolution of Solar Magnetic Fields :
Advances in Theory and Observations, Kodaikanal, 1999 December 13-16.

Venkatakrishnan P., Kumar B., Tripathy S.C.,
Acoustic Frequency Map of the Solar Disk,
National Space Science Symposium-2K, Puri, March 1-4, 2000.

APPENDIX B

Invited Talks at Conferences, Workshops etc.

Anupama, G.C.,
Multiwavelength Astronomy,
Workshop on the Indian Astronomical Observatory, IIA, Bangalore, 1999 April 15-16.

Infrared astronomy programmes at IIA,
Workshop on Current trends in Infrared Astronomy, PRL, Ahmedabad, 1999 August 16-20.

Bhatt H.C., *Dust in molecular clouds,*
IUCAA workshop on "Interstellar Molecules", S.K. University, Anantapur, 31 October 1999.

Bhattacharjee, P.,
Cosmic Topological Defects, UHE Cosmic Rays, and Baryon Asymmetry of the Universe,
Parallel Session Talk at David N. Schramm Memorial Symposium: Inner Space/Outer Space II, Fermi National Accelerator Laboratory, Batavia, Illinois, USA, 26—29 May, 1999.

Ultrahigh Energy Cosmic Rays Above 10^{11} GeV: Hints to New Physics Beyond Standard Model?
Sixth biennial Workshop on High Energy Physics Phenomenology (WHEPP-6), Institute of Mathematical Sciences, Chennai, January 3—15, 2000.

High Energy Particles in Astronomy,
Discussion Meeting on High Energy Astrophysics (under the auspices of Indian Academy of Sciences), Orange County Resort, Coorg, 1—4 February 2000.

Cowsik, R.,
Invisible matter in the Universe,
Inaugural address at the Refresher Course in Physics for College Teachers, Bangalore University, Bangalore, May 24, 1999.

Invisible matter in the Universe,
Summer School in Astronomy and Astrophysics, Bangalore, May 27, 1999.

Brief history of Indian contributions to Cosmic Ray studies,
26th ICRC, Salt Lake City, Utah, USA, Aug 1999.

Future trends in space science & technology
Course on "Indian Space Enterprise: Foreseeing the Future", NIAS, Bangalore, October 4, 1999.

Astronomical Milestones and Vazhikattikal (Wegweiser),
Seminar on "Physics in 20th century and emerging trends for the new millenium", Indian Physics Association, Mumbai, Nov. 10—12, 1999.

Perspectives on gravitation and particle astrophysics,
Interaction meeting of the DHEP, TIFR, Mumbai, Nov. 25, 1999.

Rubies and diamonds from outer space,
Prof. K.R. Ramanathan memorial lecture, PRL, Ahmedabad, Feb. 2, 2000.

Kodaikanal observatory: History and achievements,
IAU Coll. 179 "Cyclical Evolution of Solar Magnetic Fields: Advances in Theory and Observations", Kodaikanal, Dec 11, 1999.

Das, B.P.,
New directions in parity nonconservation in atomic ions,
Intl. Workshop on Violations of Symmetries in Nuclei and Atoms, Seattle, USA, July 1999.

Application of laser cooling and trapping to symmetry violations in atoms,
Natl. Symp. on Physics of Cold Atoms, IACS, Calcutta, 2000.

Relativistic many-body theory of parity nonconservation in atoms,
Atomic Physics at the Frontiers, Univ. of Roorkee, Roorkee, 2000.

Giridhar, S.,
The application of stellar spectroscopy,
Workshop on Interstellar Molecules, Srikrishna Devaraya University, Ananthpur, Oct 29-31, 1999.

Krishan, V.,
Compton Scattering, Pair Annihilation and Pair Production in a plasma,
IAU symposium 195 on Highly Energetic Processes and Mechanisms for Emission from Astrophysical Processes, Montana State University, USA, 1999 July 6-10.

High Energy Universe — Satellite Missions,
14th National Symposium on Plasma Science and Technology, Guru Nanak Dev University, Amritsar, 1999 December 21-24.

Fast Plasma Processes in Active Galactic Nuclei,
Univ. of Delhi, Phys. Dept., 2000 Feb. 18.

Fast Plasma Processes in Active Galactic Nuclei,
Theoretical Physics Seminar circuit scheme of the DST, TIFR, 2000 Feb. 18.

Current Trends in Astrophysical Plasmas,
Meeting on "Current Trends in Plasma", PRL, Ahmedabad, 1999 March.

Solar Flares: Observations and Theory (2 lectures),
Plasma Processes in Active Galactic Nuclei (2 lectures),
DST school on High Energy Processes in Astrophysical Plasmas 1999 March.

Prabhu, T.P.,
Potential of Sites in Ladakh for Infrared Astronomy,
Workshop on the Current Trends in Infrared Astronomy, PRL, Ahmedabad, 1999 August 16—20.

Rao, N. Kameswara,
Some aspects of high resolution astronomical spectroscopy,
Dr Ranganadhama Rao centenary meeting on Spectroscopy, Andhra University, April 1999.

Sastri J.H.,
The equatorial ionosphere under disturbed geomagnetic conditions,
36th Annual Conf. of Indian Geophysical Union (IGU), Pondicherry Univ., 1999 December 21-23.

Saxena, A.K.,
Laser Beacons and Wavefront Sensing Through Atmosphere,
International conf. on "Laser Materials and Devices", Defence Science Centre, New Delhi, 1999 December 8-10.

Sivaram, C.,
Shock waves in astrophysics,
Workshop on Interstellar Matter, IUCAA, 1999 October.

Unnikrishnan, C.S.,
A unified view on Aharanov-Bohm like phases and applications,
Winter Institute of Foundations of Quantum Theory and Quantum Optics, Calcutta, January 1-13, 2000.

Venkatakrishnan, P.,
Acoustic frequency map of the Solar Disk,
National Space Science Symposium-2K, Puri, March 1-4, 2000.

Seminars given outside the institute

Bhattacharjee, P.,
The Origin of the Highest Energy Cosmic Rays: Bottom-Up or Top-Down?
Saha Institute of Nuclear Physics, Calcutta, 23 December 1999.

The Puzzle of the Highest Energy Cosmic Rays: Bottom-Up or Top-Down?
Mehta Research Institute for Mathemetics and Mathematical Sciences, Allahabad, 8 March 2000.

The Puzzle of the Highest Energy Cosmic Rays: Hints to New Physics Beyond Standard Model?
Physics Department, Delhi University, 10 March 2000.

The Puzzle of the Highest Energy Cosmic Rays: Bottom-Up or Top-Down?
Institute of Physics, Bhubaneswar, 13 March 2000.

Cowsik, R.,
Discovery, characterization and development of a new Himalayan site for astronomy,
Univ. of California, Berkeley, USA, 24 March 2000.

Das, B.P.,
Parity nonconservation in a single trapped and cooled ion,
Univ. of California, Berkeley, USA, July 1999.

New directions in Parity non-conservation,
Stanford Univ., USA, July 1999.

Parity nonconservation in a single trapped and cooled ion,
National Inst. of Standards and Technology, Boulder, USA, July 1999.

Parity nonconservation in atomic ions,
Vanderbilt Univ., Nashville, USA, July 1999.

Gangadhara, R.T.,
Orthogonal polarization modes from pulsars,
Max-Planck Institüt fün Radio Astronomie, Bonn, Germany, September 4-15, 1999.

Kariyappa, R.,
Solar Variability of Chromospheric Features and their Contribution to UV Irradiance Variability,
Pic du Midi Observatory, France, June 16-20, 1999.

Prabhu, T.P.,
Indian Astronomical Observatory,
Ravi Shankar University, Raipur, July 28-30, 1999.

Raju, K.P.,
Supergranulation : Lifetimes and sizes,
NAO, Japan, 1999 August 27.

Ramesh, R.,
Coronal radio observations with the Gauribidanur radioheliograph,
Meudon Observatory, Paris, June 18-20, 1999.

Rao N. Kameswara,
The high altitude astronomical site - Hanle,
Department of Astronomy, Univ. Texas at Austin, USA, July 1999.

Satyanarayanan A.,
Magneto acoustic - gravity surface waves with flows
Institute of Astronomy, Zurich, Switzerland, September 9-11, 1999.

MHD Waves with inclined magnetic fields,
Observatory of Torino, Turin, Italy, Sept 19 - 21, 1999.

MHD equilibria,
Department of Mathematical and Computational Sciences, Univ. of St. Andrews, Fife, Scotland, September 23 - October 29, 1999.

Saxena, A.K.,
A new trend in the Metrology of X-ray mirrors,
Brookhaven National Laborator, USA, June 25-30, 2000.

Sivaram, C.,
Some testable aspects of string theory,
Millenium meeting on String Theory, JNCASR, Bangalore, January 2000.

Subramaniam, A.,
Metal rich globular clusters of our Galaxy : NGC 6528 and NGC 6553,
Tokyo University, Japan, 1999 June 15.

Unnikrishnan C.S.,
Resolution of the EPR nonlocality puzzle,
Raman Research Institute, Bangalore, March 2000.

Unnikrishnan C.S.,
Quantum correlations from local amplitudes : Resolution of the EPR puzzle,
BARC, April 2000.

Vishveshwara C.V.,
Black holes in non-flat backgrounds,
Institute for Theoretical Physics, Santa Barbara, USA, April 1999.

Black holes in non-flat backgrounds,
Spanish Relativity Meeting, Bilbao, Spain, September 1999.

Inertial forces in General Relativity,
Spanish Relativity Meeting, Bilbao, Spain, September 1999.

Visits

Bhattacharjee visited the Saha Institute of Nuclear Physics, Calcutta, 23 December 1999; the Mehta Research Institute for Mathematics and Mathematical Sciences, Allahabad, as an invited speaker under the auspices of Theoretical Physics Seminar Circuit (TPSC), 8 March 2000; Physics Department, Delhi University, 10 March 2000; Institute of Physics, Bhubaneswar, as an invited speaker under the auspices of Theoretical Physics Seminar Circuit (TPSC), 13 March 2000.

R. Cowsik visited EOST, Kitt Peak National Observatory, Univ. of Arizona, Steward Observatory, during June 21 — 25, 1999, to coordinate the activities related to fabrication of the 2-m IR/Optical telescope.

R. Cowsik, Yash Pal, B. V. Sreekantan, R. Srinivasan and T. P. Prabhu visited the Steward Observatory and Mirror Laboratories, University of Arizona in March 2000 and held discussions on future projects at IAO, Hanle.

R.T. Gangadhara visited Max-Planck Institüt für Radio Astronomie, Bonn, Germany during September 4-15, 1999.

A. Goswami visited Institut D'Astrophysique de Paris, Paris, France from 14.10.1999—15.1.2000 to carry out collaborative research on Nucleosynthesis and Chemical Evolution of the Galaxy.

R. Kariyappa visited the Service d'Aeronomie du CNRS, France, for a period of six months, as a CNRS Research Associate, on collaborative research related to space research projects, PICARD and SOLARNET. He also visited Pic du Midi Observatory, France during June 16-20, 1999.

C. Louis attended the Focus Session on Physics, Astronomy, Mathematics & Computer Science, Asia Pacific Forum discussion at the 8th Asia/Pacific Specials - "Strait to the Future", Tasmania, Australia, August 1999.

K.N. Nagendra visited Observatoire de la Cote d'Azur, Nice, France, for two months during April - June, 1999 for continuation of ongoing collaboration on the 'Operator Perturbation Methods in Radiative Transfer Theory'. He continued the collaboration on several important problems of polarized line transfer theory with French, Spanish and Swiss collaborators during that visit.

T.P. Prabhu visited Ravi Shankar University, Raipur, during 28—30 1999. He also visited Carnegie Observatories, Pasadena, U.S.A. in March 2000 and also held discussions with scientists there and at Caltech on future programmes of the Institute.

K.P. Raju visited Kyoto University Astronomy Department on November 15, 1999.

J.H. Sastri visited the Department of Earth and Planetary science, Kyoto University, Kyoto, Japan at the invitation of the Japan Society for the Promotion of Science (JSPS) during January — March 2000. During his stay, he held extensive discussions with a number of research groups both at Universities and National Laboratories and initiated colloborative studies on the global-scale response of geomagnetic field to changes in solar wind dynamic pressure on various time scales at the dayside magnetopause.

A. Satyanarayanan visited the Institute of Astronomy Zurich, Switzerland, Sept. 9 - 11, 1999. He also attended the 9th European Meeting on Solar Physics, Firenze, Italy, Sept. 12 - 18, 1999. He visited the Observatory of Torino, Turin, Italy, Sept 19 - 21, 1999. He also visited the Department of Mathematical and Computational Sciences, Univ. of St. Andrews, Fife, Scotland, Sept. 23 - Oct. 29, 1999.

R. Ramesh visited Meudon Observatory, Paris during June 18-20, 1999.

A.K. Saxena visited Brookhaven National Laboratory in connection with the SRBL project.

R. Srinivasan visited EOS, Tucson, for conducting the pre-acceptance tests of the 2-meter telescope.

C.S. Unnikrishnan visited Kastler Brossel Laboratory, Ecole Normale Superieure, Paris, July 1999 — August 1999. He also visited University of Marseille, June 22-30, 1999.

C. Vishveshwara visited the University of California, Santa Barbara, USA April 7, 1999.

Talks given by Visitors at IIA

A Novel Method of Plasma Confinement Improvement
Sudip Sen, Univ. of St. Andrew, U.K.,
1 April 1999.

Cosmology in the Very Large Telescope Era
Yannick Mellier, Institute of Astrophysics, Paris, France
9 April 1999.

Pulsar Magnetospheric Emission Mapping : Images and Implications of Polar-cap Weather
Joanna M. Rankin, Univ. of Vermont, Burlington, USA
28 April 1999.

Far-UV Heating of Dense Clumps in Molecular Clouds
Uma Gorti, NASA-Ames Research Centre, California, USA
20 May 1999.

The 1995-96 Decline of R Coronae Borealis : High Resolution Spectroscopic Monitoring
David Lambert, Univ. of Texas, USA
1 June 1999.

X-ray Spectra from AGN Incorporating Relativistic Effects
Paul J. Wiita, Georgia State Univ., USA
11 June 1999.

The Stardust Mission
Premkumar R. Menon, Jet propulsion Laboratory, Pasadena, California
14 July 1999.

Brown Dwarfs and the Search for Extra-Solar Planets
Shrinivas Kulkarni, Caltech, USA
4 August 1999.

The Small-scale Magnetic Field Structure of the AGN 1803+784 from Space VLBI observations
Denise Gabuzda
11 August 1999.

Clumpy Mass Loss from Evolved Stars
Anita Richards, Nuffied Radio Astronomy Laboratories, Jodrell, UK
1 September 1999.

Circumstellar Environments of Symbiotic Stars
J.M. Mikolajewska, N. Copernicus Astronomical Center, Warsaw, Poland
27 September 1999.

Concepts of Universal Evolution
Tom Gehrels, University of Arizona, USA
28 September 1999.

Brown Dwarf Gliese 229B : Spectroscopic Diagnosis
Sujan K. Sengupta, Vanderbilt Univ. USA
9 November 1999.

Quantum Information, Computation and Entanglement
Ashish Thapliyal, Univ. of California at Santa Barbara, USA
12 November 1999.

Scattering Polarization in the Solar Spectrum
Dominique Fluri, Institute of Astronomy, ETH Zentrum, Zurich, Swizerland
16 November 1999.

Polar Activity on the Sun
V.I. Makarov, Pulkovo Astronomical Observatory, St. Petersbury, Russia
22 November 1999.

Very Steep Spectrum Radio Sources in Abell Clusters and in the UTR Catalogue
Heinz Andernach, Univ. of Guanajuato, Mexico
6 December 1999.

The Fast Project in China
Rendong Nan, Beijing Astronomical Observatory, China
7 December 1999.

Synchrotron Masers
G. Thejappa, Department of Astronomy, Univ. of Maryland, USA
8 December 1999.

Evolution of Radio Galaxies : Clues from Complete Samples
Katherine Blundell, Oxford University, UK
10 December 1999.

Radio-rich Solar Eruptive Events
N. Gopalswamy, Center for Solar Physics and Space Weather, The Catholic Univ. of America, Washington D.C., USA
20 December 1999.

Solarnet : A Very High Resolution Interferometric Space Mission to Reveal the Solar Fine Scale Structure
Luc Dame, Servie d'Aeronomic du CNRS, France
21 December 1999.

Astronomical Activities at the Institute of Radio astronomy
A.A. Konovalenko, Institute of Radioastronomy, Kharkov, Ukraine
22 December 1999.

Supernova Neutrinos : How Many ? For How Long ? And What We Might Learn ?
Sanjay Reddy, Institute for Nuclear Theory, Univ. of Washington, Seattle, USA
22 December 1999.

Precision Atomic Spectroscopy in Ion Traps
G. Werth, Institute fur Physik, Johannes Guttenberg Universitat, Mainz, Germany
12 January 2000.

Einstein's Days and Work in Prague
Jiri Bicak, Institute of Theoretical Physics, Charles University, Prague, Czech Republic
12 January 2000.

Relativistic Disks
Jiri Bicak, Institute of Theoretical Physics, Charles University, Prague, Czech Republic
13 January 2000.

The Shack-Hartmann Method for Testing Optical Systems : from the Telescope to the Human Eye
Rajiv Bhatia and Adriana Ciani, Spot s.r.l. and Osservatorio Astronomico di Padova, Italy
18 January 2000.

Evolutionary Constraints Imposed by Pulsations in Extreme Helium Stars
Simon Jeffery, Armagh Observatory, Northern Ireland
19 January 2000.

Subdwarf B Stars : Spectral Classification, Binarity, Chemical Peculiarities and Pulsations
Simon Jeffery, Armagh Observatory, Northern Ireland
20 January 2000.

The Influence of Indian Mathematics and Astronomy in Iran
Mohammad Bagheri, Encyclopedia Islamica Foundation, Teheran
21 January 2000.

Cepheids Radii from Intermediate-band Photometry
A. Arellano Ferro, Instituo de Astronomia, Universidad Nacional de Mexico
1 February 2000.

Stellar Physics and The High Predicion Photometry Space Mission Corot
Annic Baglin, Observatorie de Paris, France
8 February 2000.

Some Current Problems in Atomic and Optical Physics : Multiply Excited States, Intense lasers, Qubits
A. Ravi Prakash Rau, Dept. of Physics, Louisiana State Univ., USA
17 February 2000.

Are Chromospheres Always Hot or Mostly Cold ?
W. Kalkofen, Harvard-Smithsonian Center for Astrophysics, Cambridge, USA
21 February 2000.

APPENDIX C

Vainu Bappu Observatory

Time Allocation during 1999-2000

I. VBT		Total No. of Proposals received	50
	a.	No. of Spectroscopic Proposals	28
	b.	No. of Photometric Proposals	22
	c.	Total No. of Nights requested	346
	d.	No. of Nights requested for Spectroscopic work	180
	e.	No. of Nights requested for Photometric Work	166

The telescope was under maintenance during July – September 1999.

II. 102-cm		Total No. of Proposals received	17
	a.	No. of Spectroscopic Proposals	11
	b.	No. of Photometric Proposals	6
	c.	Total No. of Nights requested	147
	d.	No. of Nights requested for Spectroscopic work	85
	e.	No. of Nights requested for Photometric Work	62

The telescope was under maintenance during July – December 1999.

Sky conditions at Vainu Bappu Observatory

Year	Month	Spectroscopic Hours	Photometric Hours
1999	April	142	30
	May	79	12
	June	27	0
	July	No data	No data
	August	No data	No data
	September	39	0
	October	34	5
	November	103	36
	December	125	12
2000	January	235	47
	February	151	15
	March	211	43
	Total	1146	200

Kodaikanal Observatory

Spectro / Photoheliograms and Seeing Conditions at Kodaikanal

Year	Month	No. of photographs in				SEEING*				
		Hα	Kfl	HαPr	PHGM	5	4	3	2	1
1999	April	22	23	-	20	–	–	11	3	6
	May	17	24	2	16	–	1	9	4	2
	June	21	12	-	13	–	2	11	–	–
	July	12	10	-	13	–	2	6	4	1
	August	26	27	-	22	–	–	7	14	1
	September	20	17	1	19	–	–	10	7	2
	October	9	8	-	11	–	–	6	5	–
	November	22	18	-	16	–	1	12	3	–
	December	33	26	9	22	–	–	16	6	–
2000	January	23	20	15	19	–	–	17	2	–
	February	24	20	14	20	–	1	14	5	–
	March	44	35	22	31	–	4	22	3	2
	Total	273	240	63	222	–	11	141	56	14

Kfl = K–flocculus
HαPr = Hα Prominence
PHGM = Photoheliogram

*(1–Very poor, 2–Poor, 3–Fair, 4–Good, 5–Excellent)

Solar Tower Tunnel Observations

Year	Month	Total Number of days of observations	Seeing (in arc sec)						
			1 to 2	2	2 to 3	3	3 to 4	4	4 to 5
1999	April*	8	–	–	–	5	1	2	–
	May**	4	–	–	–	4	–	–	–
	Dec	20	–	–	5	14	–	1	–
2000	Jan	20	–	–	2	18	–	–	–
	Feb	20	–	1	6	13	–	–	–
	Mar	29	–	1	4	24	–	–	–
	Total	101	–	2	17	78	1	3	–

* 24-03-99 to 10-04-99All the three mirrors were sent for aluminizing to Kavalur.

** 15-04-99 to 07-12-99 CCD Camera was taken to Japan by Prof. Jagdev Singh.

APPENDIX D

AUDITORS' REPORT

We have audited the attached Balance Sheet of the "THE INDIAN INSTITUTE OF ASTROPHYSICS", BANGALORE, as at 31st March, 2000, and the Income and Expenditure Account for the year ended that date and report that.

We have obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purpose of our Audit.

In our opinion, proper Books of Accounts have been maintained by the Institute, so far as it appears from our examination of the Books of Accounts.

The Balance Sheet and Income and Expenditure Account dealt with by the report are in agreement with the books of account maintained by the Institute.

In our opinion and to the best of our information and according to explanations given to us, the accounts read with the notes thereon, give a true and fair view :-

i) In the case of the Balance Sheet, of the state of affairs of the Institute as at 31st March, 2000.

AND

ii) In the case of Income and Expenditure Account of the Surplus for the year ended 31st March, 2000.

Sd/-
for **B.R.V. GOUD & CO.,**
CHARTERED ACCOUNTS

September 20, 2000

PLAN

RECEIPTS AND PAYMENTS ACCOUNT UNDER PLAN AND OTHERS FOR THE YEAR 31 MARCH 2000

PREVIOUS YEAR Rs.	RECEIPTS	SCHEDULE	AMOUNT Rs.
20,05,252	Opening balance		1,31,18,807
21,94,44,715	Grants-in-aid	1 & 1A	20,27,23,531
41,84,887	Advances to Suppliers, Credits/Adjustments(net)	2	4,19,00,612
22,56,34,854	Total		25,77,42,950

PREVIOUS YEAR Rs.	PAYMENTS	SCHEDULE	AMOUNT Rs.
5,64,64,178	Recurring Expenditure	3	6,78,28,428
3,50,82,309	Non-Recurring Expenditure	4	3,05,94,839
10,38,191	Expenditure out of Grants/ Assistance from other Government Agencies	5	69,03,259
11,99,31,369	Deposit and other items	6	14,10,20,803
1,31,18,307	Closing balance		1,13,95,620
22,56,34,854	Total		25,77,42,950

(Closing balance 1,13,95,620/- represents the balance of external funds for the Projects (shown in Schedule 19)

NON-PLAN

RECEIPTS AND PAYMENTS ACCOUNT UNDER NON-PLAN AND OTHERS FOR THE YEAR ENDED 31 MARCH, 2000

PREVIOUS YEAR Rs.	RECEIPTS	SCHEDULE	AMOUNT Rs.
10,431	Opening balance		1,332
2,96,00,000	Grants-in-aid	7	2,87,00,000
3,048	Deposits and other items	8	25,868
21,40,526	Miscellaneous Receipts	9	32,52,479
3,17,54,005	Total		3,19,79,679

PREVIOUS YEAR Rs.	PAYMENTS	SCHEDULE	AMOUNT Rs.
3,17,09,323	Recurring Expenditure	10	3,19,27,023
43,350	Non-Recurring Expenditure	11	47,519
1,332	Closing balance		5,137
3,17,54,005	Total		3,19,79,679

Sd/-
SR. FINANCE & ACCOUNTS OFFICER

Sd/-
ADMINISTRATIVE OFFICER

Sd/-
DIRECTOR

Place : Bangalore
Date : 20-09-2000

Sd/-
B.R.V. GOUD & CO
CHARTERED ACCOUNTS

PLAN

INCOME AND EXPENDITURE ACCOUNT UNDER PLAN FOR THE YEAR ENDED 31 MARCH, 2000

PREVIOUS YEAR Rs.	INCOME	SCHEDULE	AMOUNT Rs.
21,00,00,000	Grants-in-aid	1	19,00,00,000
–	Interest on bank deposit		30,74,383
21,00,00,000	Total		19,30,74,383

PREVIOUS YEAR Rs.	EXPENDITURE	SCHEDULE	AMOUNT Rs.
2,93,03,069	Salaries and Allowances	15	3,47,93,161
2,79,14,035	Operational expenses	16	3,34,24,985
15,27,82,896	Excess of Income over Expenditure		12,48,56,237
21,00,00,000	Total		19,30,74,383

NON-PLAN

INCOME AND EXPENDITURE ACCOUNT UNDER NON-PLAN FOR THE YEAR ENDED 31 MARCH, 2000

PREVIOUS YEAR Rs.	INCOME	SCHEDULE	AMOUNT Rs.
2,96,00,000	Grants-in-aid	7	2,87,00,000
9,78,232	Miscellaneous Receipts	12	14,53,185
3,05,78,232	Total		3,01,53,185

PREVIOUS YEAR Rs.	EXPENDITURE	SCHEDULE	AMOUNT Rs.
2,53,64,892	Salaries & Allowances	13	2,54,02,735
43,54,032	Working expenses	14	37,83,884
8,59,308	Excess of Income over Expenditure		9,66,566
3,05,78,232	Total		3,01,53,185

Sd/-
SR. FINANCE & ACCOUNTS OFFICER

Sd/-
ADMINISTRATIVE OFFICER

Sd/-
DIRECTOR

Place : Bangalore
Date : 20-09-2000

Sd/-
B.R.V. GOUD & CO
CHARTERED ACCOUNTS

BALANCE SHEET AS AT 31 MARCH, 2000

PREVIOUS YEAR Rs.	SOURCES OF FUNDS	SCHEDULE	AMOUNT Rs.
56,90,79,318	Capital Funds	17	69,39,35,555
2,34,76,694	General Fund	18	2,44,43,260
1,29,27,111	External Funds for the Projects	19	1,57,69,157
40,36,134	Sundry Creditors	20	17,78,269
60,95,19,257	Total		73,59,26,241

PREVIOUS YEAR Rs.	APPLICATION OF FUNDS	SCHEDULE	AMOUNT Rs.
40,18,23,847	Fixed Assets (at cost)	21	42,92,77,129
19,45,75,271	Current Assets, Advances and Deposits	22	29,52,48,352
1,31,20,139	Cash and Bank Balances	23	1,14,00,760
60,95,19,257	Total		73,59,26,241

Sd/-
SR. FINANCE & ACCOUNTS OFFICER

Sd/-
DIRECTOR

Sd/-
ADMINISTRATIVE OFFICER

Sd/-
B.R.V. GOUD & CO
CHARTERED ACCOUNTS

Place : Bangalore
Date : 20-09-2000