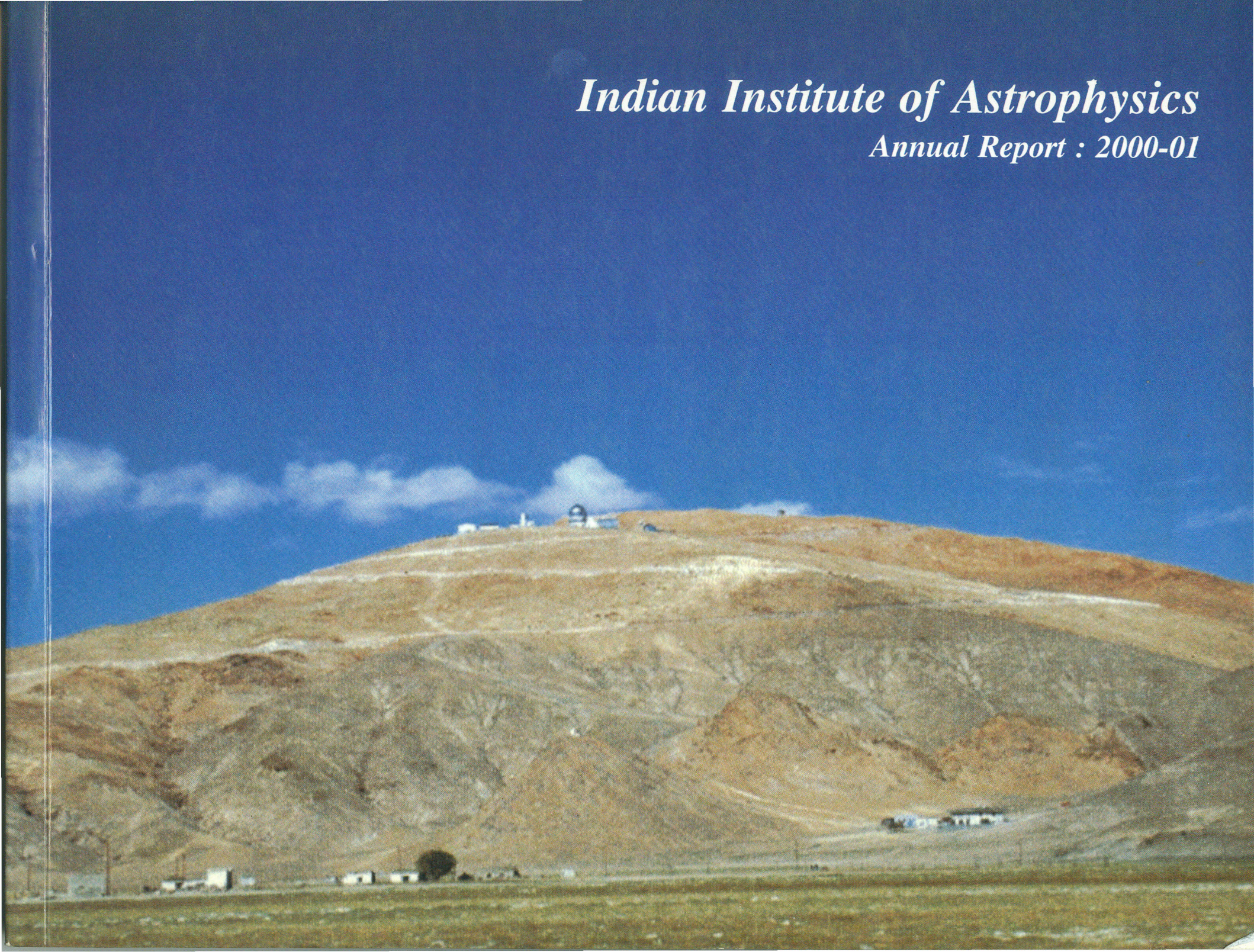
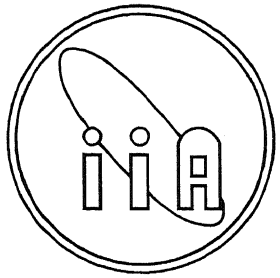
Indian Institute of Astrophysics

Annual Report : 2000-01



INDIAN INSTITUTE OF ASTROPHYSICS



ANNUAL REPORT
2000-01

Edited by : R.C. Kapoor

Editorial Assistance : Sandra Rajiva

Front Cover : Indian Astronomical Observatory (IAO) atop Mt. Saraswati, Hanle - a panoramic view.

Back Cover : The 2-m Telescope and building, IAO, Hanle.

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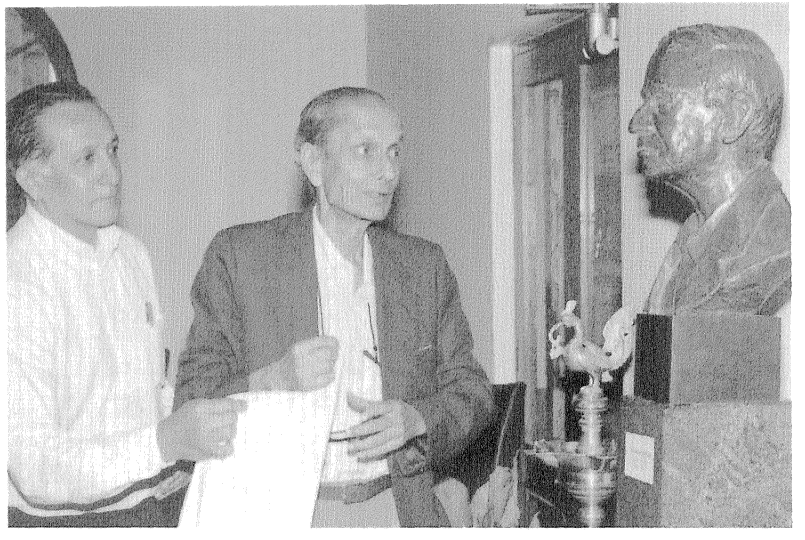
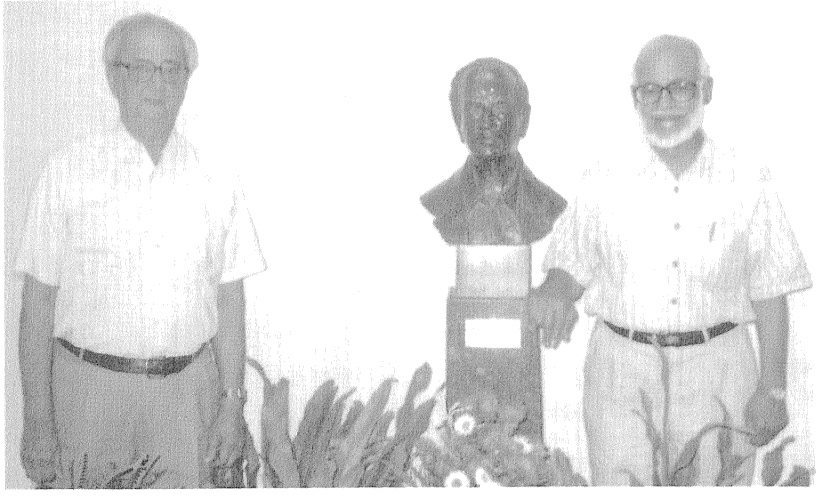


▲ On the occasion of 90th birthday on 19 October 2000 of late Prof. S. Chandrasekhar, his bust, sculpted in bronze by the well known sculptor Paul Granlund (Minneapolis, USA), was installed at the CREST, Hosakote and unveiled by Prof. S. Ramaseshan



▲ Prof. M.G.K. Menon, Honorary Fellow, and Founder Chairman of the Institute's Governing Council, visits CREST, Hosakote; seen here with Prof. B.V. Sreekantan near the bust of Prof. S. Chandrasekhar

▲ Prof. V.S. Ramamurthy visits Hosakote on January 28, 2001

GOVERNING COUNCIL

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Old Madras Road,
Bangalore 560 093.

Professor Ramanath Cowsik, — Member
Director,
Indian Institute of Astrophysics,
Bangalore 560 034.

The Administrative Officer, — Non-member
Indian Institute of Astrophysics, secretary to Council.
Bangalore 560 034.

Prof. Yash Pal with Prof. R. Cowsik, after the inauguration of the Megh Nad Saha Archives building at Hanle.

Honorary Fellows:

Professor M.G.K. Menon, FRS
C-63, Tarang Apartments,
19, IP Extension, Mother Dairy Road,
Patparganj,
Delhi 110 092.

Professor S. Chandrasekhar, Nobel Laureate (deceased)

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Professor P. Buford Price
Physics Department,
University of California,
Berkeley, CA 94720. USA.

Professor V. Radhakrishnan,
Raman Research Institute,
Bangalore 560 080.

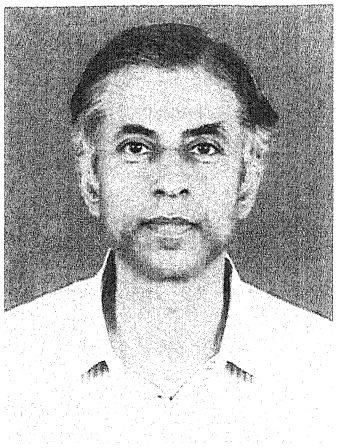
Honours & Awards :

R. Cowsik : S.N. Bose Birth Centenary Award for the year 2000-01 for his outstanding contribution to the advancement of Science by Indian Science Congress.

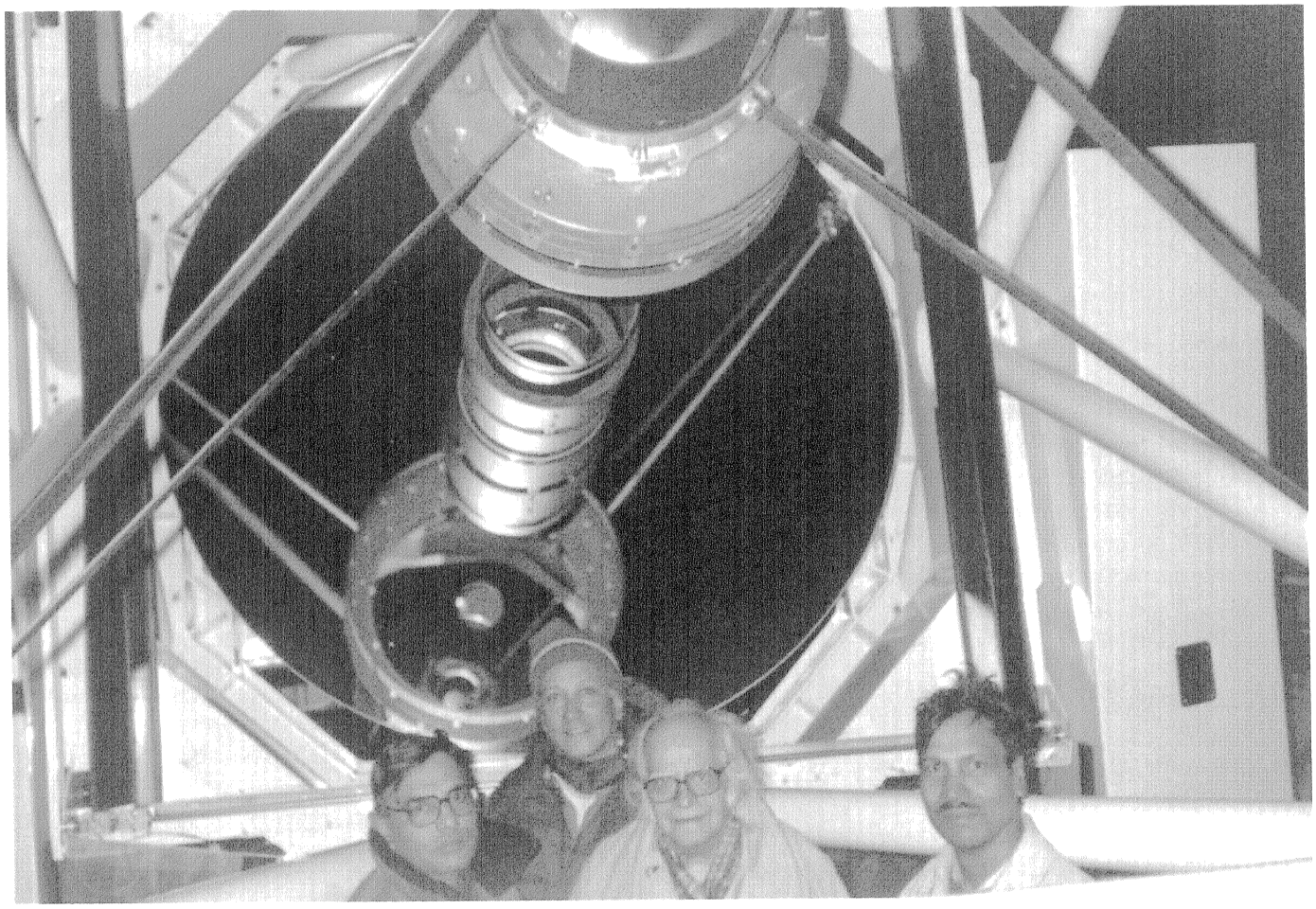
V.K. Gaur : 2001 Edward A. Feinn III award for his unselfish co-operation in research by the American Geophysical Union, Washington, D.C., USA.

Ram Sagar : Elected Fellow, Indian Academy of Sciences, India.

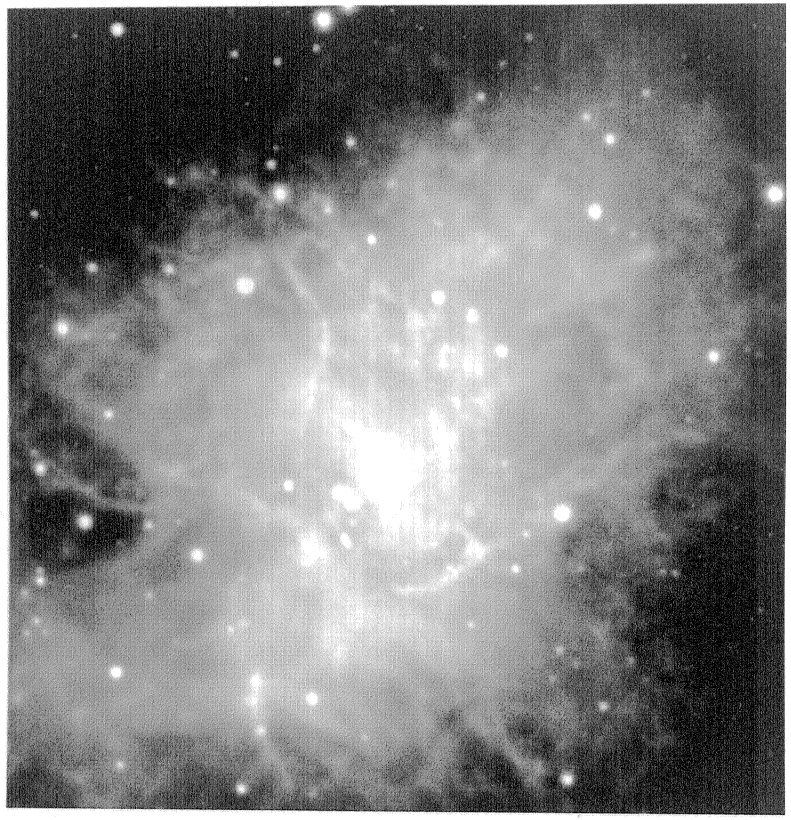
C. Sivaram : Received Fourth Award for his paper "Black Hole Hawking Radiation may never be observed" from the Gravity Research Foundation, Massachussetts, USA.



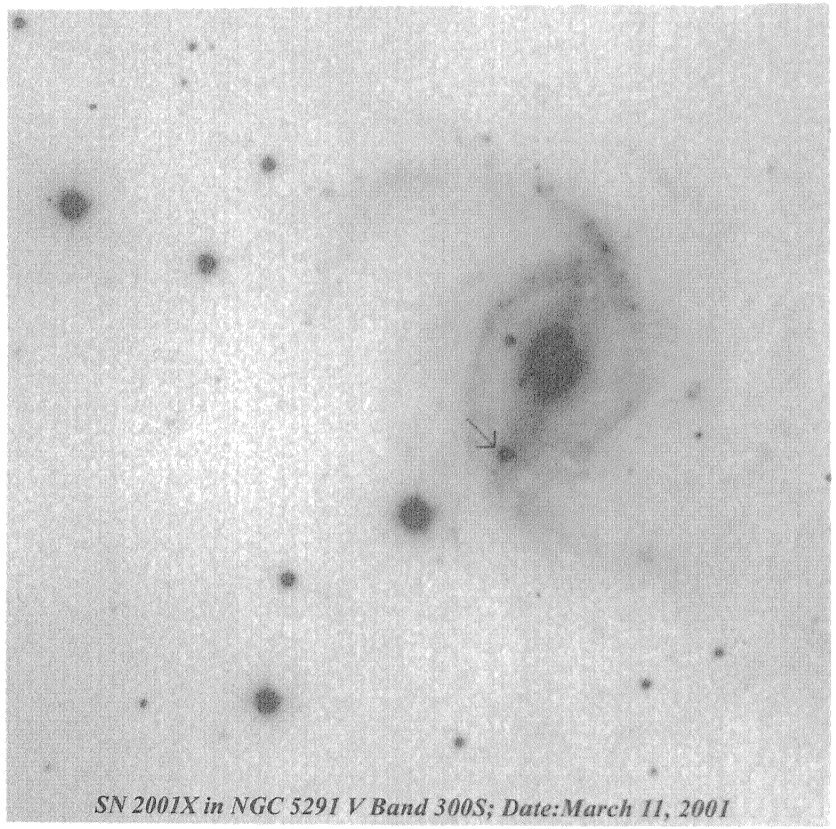
Prof. N. Mukunda who delivered the 15th IIA Bicentennial Commemorative Public Lecture on 'Pancharatnam, Bargmann and Berry Phases', on 27th March, 2001.



Profs. Yash Pal, Ramanath Cowsik, R. Srinivasan and T.P. Prabhu with the 2m telescope.



Crab Nebula, taken with the 2m telescope at IAO, Hanle.



A supernova in a distant galaxy as indicated above, taken with the 2m telescope at IAO, Hanle.

The year in Review

The most remarkable achievement of the Institute this year has been the installation of a new technology optical/infrared telescope of 2-meter aperture at Hanle. At the mid night hour intervening 26/27 September 2000, this telescope imaged the first astronomical light, thus heralding the birth of the Indian Astronomical Observatory, the highest in the world, situated in the thin trans-Himalayan air at an altitude exceeding 4500 m above the mean sea level. In last year's review, I had noted that 'the Indian Institute of Astrophysics was in full readiness for the final phase of this exciting project' which began in July 1997 with the formal approval by the Department of Science and Technology of the Government of India. The preparedness of the team from the Institute and the planning of the final phase of the operations were thorough. Every aspect of the shipping and transportation had been looked into carefully and action plan for every eventuality was worked out. The hazardous mountain road from Leh to Hanle had been surveyed and all the bridges on the way had been strengthened to carry the 20 ton load of the telescope and the related components. In one location, the over hanging rocks were too low and in several locations the road was too narrow. The Border Roads Organization was informed of this and upon our request they enthusiastically took up the task of improving the road conditions at these locations. Late in March 2000, after careful inspection by the IIA team, the telescope at the factory was dismantled and packed carefully for shipping. The Customs Department and the Directorate General of Shipping were informed of the arrival of the sensitive equipment and it is gratifying to note here their excellent cooperation in clearing the shipment at the Bombay-docks upon its arrival in mid-July. The caravan of trucks with the containers and the flat-bed loads left the docks of Bombay within about a week of the arrival of the ship! They moved on a pre-planned route, piloted by IIA personnel.

Arrangements had been made in Chandigarh to receive the truck loads, unpack them and load them on to IL-76 air-craft operated by the Indian Air Force. In making these arrangements, the DRDO officials were of great help. Because of some of the heavy oversize items, the loading of the aircraft posed serious problems. However, these were overcome by the grit of the loading crew who operated the 'telfers' and by the tactical decisions taken by the Institute. By working round the clock, the loading operations were successfully completed to meet the flight schedules on August 2 and the shipment was successfully airlifted to Leh. The unloading crew at Leh were in readiness to complete the operations within the two hour maximum halt available at the high altitude station. It is a pleasure to acknowledge here the help provided by the Army, Air Force, Field Research Laboratory, Border Roads Organization and the Kutch shipping agency.

Because of an unusually hot summer, the snow on the high Himalayan peaks was melting and the Indus was in floods. Thus the unloaded shipment had to be stored for nearly two weeks until the floods subsided and the caravan of trucks loaded with the less critical parts of the shipment left Leh on August 16 and the major part of the shipment with all the critical parts left Leh on August 19, accompanied in each case by a few members of the IIA team, of course. The journey on the mountain roads was difficult and the pace was kept low, so as not to jeopardize the shipment in any way, especially during the last 60 km of the journey when we traversed the Hanle valley. Finally, the shipment reached Mt Saraswati on the evening of August 22, in perfectly safe condition. All of us heaved a sigh of relief and began the installation process in right earnest, starting with the grouting of the massive base to the pier. Through out the installation process at least two members of the telescope manufacturing firm viz. EOS/EOST team were present, along with a large team from IIA, and there was an excellent rapport amongst all of them. The installation work proceeded so smoothly that we felt confident enough to invite Professor Yash Pal, the Chairman of the Project Management Board, to Hanle to witness the imaging of the first astronomical light. To the great satisfaction of one and all the 2-m telescope was installed and at the midnight hour intervening the 26th and 27th September 2000, a star Beta Cassiopeiae was imaged through the

telescope, heralding the birth of the Indian Astronomical Observatory. The first images are shown in the figure 1.

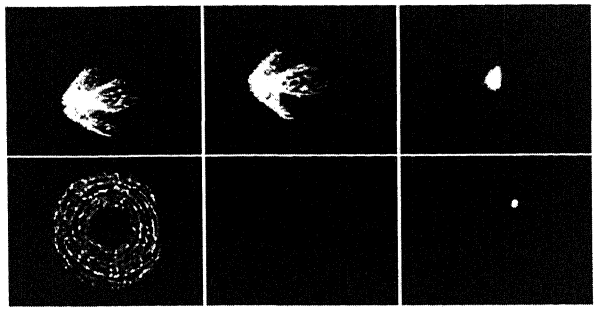


Figure 1. The first-light comatic image of B.Cassiopeiae, observed with the Himalayan Chandra Telescope, was brought to good focus by aligning the secondary and examining extra focal images.

The dome that houses the telescope was designed by IIA to ensure that it does not degrade the excellent "seeing" (i.e. quality and sharpness of the images) possible at the high altitude site. The design also had to take into account several other aspects such as dew formation on the inner surface of the dome. A particularly innovative aspect of the design was that the conventional bus-bar, which goes around the dome to supply power to it, was done away with. Instead IIA-team devised 'docking-connectors' thereby saving considerable expenditure and ensuring trouble-free performance. A paper written on this device was submitted to IEEE-EIT conference and will appear in its proceedings. The STUP consulting engineers helped in detailing the design and the Menghi Engineering Co. undertook the job of fabrication of the dome, shipping it to Hanle and the arduous job of erection at the site.

A noteworthy feature of this telescope and the dome is that they can be operated through a satellite communication link from Hosakote, near Bangalore set up with the cooperation of Dept of Telecommunications, Department of Space and TIW Systems. In the main body of the report, we will see many astronomical images thus obtained through remote operations. Amongst these, I would like to highlight the observations of the afterglow of the Gamma Ray Burst GRB-010222. This event generated a luminosity of ~ 10^{52} ergs all in gamma rays of mean energy ~ 250 keV emitted within a few seconds! This energy is so enormous that comparison is virtually impossible even with other astronomical events. The slow fading of the optical afterglow of this event (which occurred in a distant galaxy near the edge of the visible universe) is shown in the figure 2.

Theory of the sharp steepening of the rate of decrease in the optical emission after about half a day indicates that the gamma rays were beamed like a search light with an opening angle of about 10°.

It would be appropriate here to include some of the technical information about the telescope; this is provided in the form of the table below:

Basic specifications of the 2m telescope

Aperture	2.01 metres
Mirror material	Ultra Low Expansion
Optics	Ritchey-Chretien
Mount	Altitude over azimuth
Focus	Cassegrain; provision for Nasmyth
F-ratio	f/1.75 primary; f/9 Cassegrain
Image scale	11/5 arcsec/mm
Field of view	7 arcmin; 30min with corrector
Image quality (zenith)	80% power < 0.33 arcsec dia
Jitter & periodic errors	< 0.25 arcsec on each axis
Pointing accuracy	< 0.45 arcsec over 17 arcsec move < 1.5 arcsec for > 10° move
Tracking accuracy	< 0.55 arcsec rms over 10 min < 0.3 arcsec with autoguider
No. of instrument ports*	5
Can be operated locally and through the satellite link from Bangalore†	Yes

* The light collected by the telescope may be cued with a tertiary mirror to any one of the instruments; option for setting up Nazmyth foci is available

† Remote operation is preferred mode, keeping in mind the high altitude of Hanle and time to be spent by the astronomer in acclimatizing.

The first generation instruments will consist of a Faint Object Camera & Spectrograph built in collaboration with the Copenhagen University, a Near Infrared Imager, operating up to ~ 3ìm fabricated by M/s Infrared Laboratories and an Optical Imager cover 5.9 arcmin x 11.8 arcmin fabricated by our Institute and a large format optical imager built in the Institute. It is thus clear that the Indian Astronomical Observatory at Hanle will provide unprecedented opportunities to the Indian academic community in general and to the astronomers in particular.

Research was carried out in the Institute on subjects ranging from non-accelerator particle physics to cosmology resulting in many new findings, facilitated by proactive library staff, administrators and engineers. For example, in the paper 'Information metamorphosis in physics and astronomy libraries' shows how to match the needs of an academic institution with the prerogatives of the economy measures by using the rapidly developing tools of information technology. Here I would like to highlight a few among the several important findings. Before I do this, I would like to recall that we have a strength of about 25 Ph.D. students and about 12 engineers trainees, and in the last 10 years 20 Ph.D. degrees have been awarded to the students of the Institute. It is this group of young men and women who will constitute our human resource in the future.

Starting with the fields of non-accelerator particle physics and theoretical astrophysics, I would like to mention here the theoretical calculation of the electric dipole moment of atomic Ytterbium which may be induced by simultaneous violation of parity and time-reversal symmetries; such a calculation would be needed in the assessment of experiments which are being planned in several laboratories across the world. In order to explain the width of the pulse cores of radio pulsars, delving into the subtleties of the sub-atomic world, our scientists have speculated that pulsars may be condensates of strange particles, instead of neutrons. Building up a pulsar with strange quarks gives it the correct radius and mass as indicated by the pulse profiles. Turning their attention to even more esoteric particles, namely dark matter, by theoretically modeling the dynamics of the dwarf spheroidal galaxies in the gravitational field of our Galaxy including its dark matter halo, it has been concluded that these dark matter particles must have high root mean square velocity of ~ 600 kms^{-1} and that the halo extends at lest up to ~ 150 kpc. Even more exotic is the black hole: Combining the essential concepts of quantum physics and of the relativistic theory of gravitation Hawking has shown that they will emit thermal black body radiation at a temperature inversely proportional to their mass. This process of radiation leads to a decrease in the mass of the black hole and the radiation temperature increases rapidly – inversely as the mass of the black hole -and finally the black holes 'evaporates' away emitting gamma rays. Is it possible to observe such a process of evaporation? Many scientists have argued that black holes created in the big bang with a mass of a 10^{14} g would most likely be observable because such a black hole will have a life time similar to that of our universe and would be radiating easily observable gamma rays in the present epoch. Work at the Institute has shown that unfortunately such a scenario is unlikely – the black holes will tend to accrete the surrounding radiation during the hot phase of the universe and increase in mass rather than evaporate. Thus it appears that the Hawking radiation will not be observable at all.

Sun is our nearest star and acquires importance not only as the essential source of all energy on this earth and as being creating and supporting life, but also, because of its proximity, as the primary stimulus for the growth of astronomy, mathematics and physics from time immemorial. During the last hundred years, our Institute has pioneered in the astronomical study of the sun by recording its images every day both in visible light and in some chosen spectral lines. This extensive data is shared with the observatories in Meudon, France and in Tucson, USA which also have similar data, of similar vintage. The analysis of these data has resulted in an understanding of several aspects of the sun, its 11 year cycle, its magnetic fields, flaring activity on its surface and so on. This large body of work has been published extensively. Work carried out during the year 2000 – 2001 has added importantly to these finds: By studying the tilt-angle and size variations of sunspot groups the scientists of

the Institute have noted that growing and therefore arguably younger sunspot groups rotate their magnetic axes more rapidly than the decaying and older groups do.

Based on the magnitude and direction of the correction between the changes in the tilt angle and those in the polarity angle in sunspot groups, they have concluded the Corriolis force is largely responsible for their dynamics. Studying the physical conditions in a polar coronal hole and the surrounding regions using the data obtained with the Norikura Coronograph and Spectrograph, as well as with the SOHO satellite they have found evidence to support the view that the sources of the fast solar wind are located in the interplume regions. It is well recognized that Coronal Mass Ejections (CMEs) have a great impact on the 'Space Weather'. The Gauribidanur Radioheliograph built and maintained by the Institute was operated to recorded in detail the halo CME-event of 23 October 1997 and the pre-event corona. Prior to the event an enhancement in the low frequency radio intensity close to the disc center was observed where a sigmoid structure had also been recorded in soft x-ray pictures of the solar corona. From such a study it has been concluded that such enhancement in the radio band at meter wavelengths can be used as precursors to predict the CME events and that the material ejected in the event is from the prevent structure.

Now, I would like to exemplify the work being carried out at our Vainu Bappu Observatory, Kavalur, by quoting a few recent results. Spectroscopic observations of selected sources obtained with the survey by Infrared Space Observatory Galactique (ISOGAL) were conducted with the OMR-spectrograph attached to the 2.3 m Vainu Bappu Telescope at Kavalur. This has led to the identification of a set of K and M giants in state of mass-loss. In order to probe the chemical evolution and star formation history of our Galaxy, four K-giants, with [Fe/H] in the range –2.4 to –3.1, were chosen for detailed study with the Cassegrain spectrograph at the Vainu Bappu Telescope. Apart from yielding detailed elemental composition of these stars, the study supports the conclusion that metal poor stars with [Fe/H] < -2.5 exhibit considerable star-to-star variations in the abundances of several elements.

Moving on to the work on extragalactic astronomy from Kavalur, the early time optical spectroscopy of the supernova SN 1998S is noteworthy. Several spectroscopic observations carried out over a time span of more than a month were analysed to show that SN 1998S belongs to type-IIn where the supernova ejecta cools rapidly as it expands and dynamically interacts with the presupernova circumstellar material. The study of the active nucleus in the post-starburst galaxy: KUG 1259+280 at optical and x-ray bands shows the power of multicolour astronomy; detailed understanding of the characteristics this galaxy and its identification as an active, narrow line Seyfert type1 galaxy has been reported.

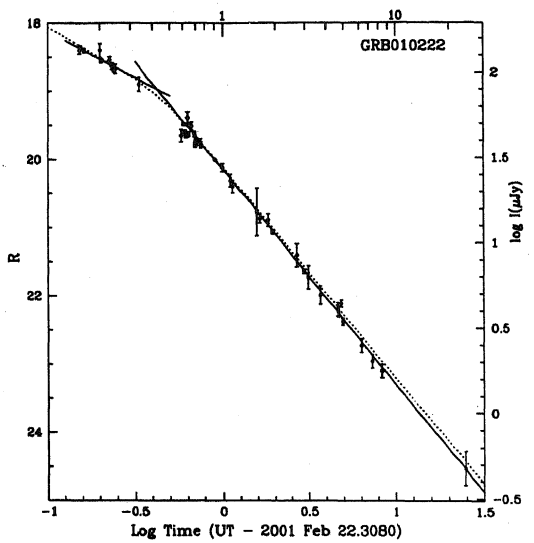


Figure 2. The power law fits to the early and late phases of the GRB 010222 optical transient in the *R* band.

Finally we turn to the most energetic and dramatic of all astronomical events – Gamma Ray Bursts – where n an enormous amount of energy ~ 10^{52} ergs, all in gamma rays, is emitted within a short interval of ~ 10 seconds. Making full use of the favourable georgraphic location of India, we were able to conduct

early photometry of the afterglow of this event in several bands and show that there was no discernible evolution of (B-V) colour in the first 12 days that followed the gamma ray emission.

The Institute has made some major development plans for the period 2002-2007 consisting of two major projects:

(a) the Himalayan Binocular Telescope and

(b) Ultra Violet Imaging Telescope

to be launched into the orbit by the Department of Space, Government of India.

Apart from these, there are major ongoing programmes of the activity with the profile similar to the current plan.

A number of the lectures by various Distinguished Professors both from within India and abroad have been organised by the Institute. It is specially noteworthy that Professor N. Mukunda of the Centre for Theoretical Studies, IISc. and Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, gave the 15th Bicentennial Lecture of the Institute on the topic ''Pancharatnam, Bargmann and Berry Phases". A special scheduled programme for human resources development has been taken up in the Institute: Regular Summer/ Winter Schools on advanced topics in physics and astrophysics have been conducted at Kodaikanal Observatory, Kodaikanal and young brilliant students from all over India were invited to attend these lectures delivered by the Distinguished Professors from leading academic Institutions in India.

Major welfare measures were taken for the welfare of the staff of the Institute in various ways, particularly by giving them the opportunity to improve their skills in computers and other allied fields. The SC/ST communities were specially taken care of in this regard and the standard recommendations of the SC/ST Commission have been kept in mind in the implementation of various programmes.

In this yearly review, I have touched on various studies and research activity in the Institute. We should refer to to the later parts of the Annual Report and the list of publications for further details. Such concerted activity as that reported here has also resulted in awards and other recognition in national and international fora; some of these are also listed below. I would like to end this review by noting that at the beginning of the 21st century, the Indian Institute of Astrophysics is poised in a very strong position and by expressing the fond hope that this Institute will grow further to support the aspirations of the astronomers and scientists of India and indeed of all mankind.

Ramanath Cowsik
Director

1. Sun and the solar system

1.1 Solar Physics

The Institute has been actively pursuing research work in the area of solar physics, both observational and theoretical. The scientists have interests in the solar interior as much as they explore the surface phenomena, or, the Sun's surroundings and its planetary system.

There has been a collaborative programme with the Pulkovo Astronomical Observatory , Russia during the past two decades to study the dynamics of the large-scale unipolar magnetic regions on the sun. The H-alpha synoptic maps were constructed starting from the H-alpha images of the sun from the Kodaikanal and Kislovodsk collections and these were used to study the evolution of the large -scale unipolar magnetic regions on the sun and the dynamics of the polar field reversals (an important feature of the solar cycle) covering a period of nearly 8 solar cycles (1910 - 1990). The H-alpha filaments on the sun represent the magnetic neutral lines and by tracing their movements, the migration of the magnetic fluxes on the solar surface can be inferred. In a recent study the polar reversal phenomenon was extended to the solar cycles 22 and 23 (1985 - 2000) and the rate of the poleward migration of the equatorial fluxes was worked out in relation to the total flux contained in the sunspot latitudes using the H-alpha synoptic maps constructed for this purpose. The striking features of this study are : i) the polemost filament bands in the north and south hemispheres migrate towards their respective poles and ultimately cause the polar reversal ; ii) the filament bands just below the polemost ones also migrate and reach latitudes 35 - 45 deg by the time of the polar reversal and become the polemost once the reversal is over. The migration to the poles starts (at a low speed of 3 m s^{-1}) only when the spot activity has risen to a significant level and then suddenly accelerates to 30 m s^{-1} at the peak of activity. This possible cause and effect phenomena has been quantified by introducing the concept of the "strength of the solar cycle". "The speed of poleward migration of the filament bands (and hence the magnetic flux) is found to be a linear function of the strength of the solar cycle".

What consequences could be there of the effects of perturbations due to Jupiter's motion on the Sun's internal gravity modes? It has been found that the post-Newtonian resonances for primary excitation of g mode perturbations which define sizes and lifespans of supergranulation cells are provided more efficiently by finite travel time of 'tidal' forces due to the asymmetries of g modes of *odd* azimuthal orders. Sun's internal g-modes of *odd* azimuthal orders m (referred to rotation axis) are coupled to unobservably small variations in Sun-Jupiter distance, $r_{\odot J}$ and therefore in Jupiter's tidal feedback to the mode. This feedback will be resonant at a particular frequency. As Jupiter orbits the Sun, this resonance will lead to maintenance of a quasi-steady spectrum of about 5000 solar 'granular' g modes in the frequency range 366-405 μHz, against their absorption in the convective envelope. The absorption itself will provide solar luminosity variations of magnitudes comparable to those of observed variations, for reasonable amplitudes of modes in the quasi-steady spectrum. This result may have important implications for theories of convection, rotation, activity and luminosity variations in sun and stars.

Solar rotation : Solar rotation has been looked at from various angles, giving several important results. The Sun does not rotate as a solid body. From the helioseismic observed rotational splittings, one can infer internal rotation of the Sun. Though most of the inferred results in the convective envelope yield almost similar rotational isocontours, in the radiative core the rotational rates and isorotational contours are widely different. Knowing of magnitude of internal rotation near the central part of the radiative core is also a vital information for explanation of the orbital perihelion precession of the Mercury.

A study has been made to solve hydrodynamic equations to estimate magnitude of core rotation and obtain and compare isorotational contours with isorotational contours inferred by the helioseismology. Important findings are (i) in order to match the rotational isocontours obtained by solution with the rotational isocontours as inferred by helioseismology, the magnitude of

SCIENTIFIC RESEARCH

central part of core rotation is found to be nearly same as magnitude of the rotation near base of the convective envelope. (ii) the characteristic time scales of the first two diffusion eigen modes are estimated to be $\simeq$, 10^{14} yrs, and, 10^{11} yrs respectively. In either case these results indicate that the local dynamics of the solar plasma in the radiative core may be different than the earlier expectations.

Sunspots : It is believed that sunspots are formed near base of the convection zone where seat of dynamo is supposed to be situated and brought to the surface by buoyancy forces. While rising towards the surface in the convection zone, structure and dynamics of sunspots are influenced by external forces such as the Coriolis force, the drag force, the convective and turbulent forces, etc. Thus sunspots are reliable tracers which may represent the structure and dynamics of the plasma beneath the surface. It is not clear whether all the spot groups of different sizes originate at a particular place, say near base of the convection zone as expected by dynamo theories, or sizes of different spot groups originate at different places in the convective envelope.

From 103 years (1874-1976) data of non-recurrent sunspot groups and for the two sets (area < 100 millionths of hemisphere and > 100 millionths of hemisphere), irrespective of their life span, rotation rates and rate of change of rotation rates during their life time have been computed. It is clear from this study that *irrespective of their size, spot groups which have life times of* $\geq$ *12 days may be originating near base of the convection zone and, spot groups which have life times* $\leq$ *3 days may be originating near the surface*. However, realistic MHD calculations and complimentary studies from the local helioseismology are necessary in order to understand these observed results.

Short-term periodicities have been studied in the north-south asymmetry of the Sun's surface rotation. From the values of the rotation coefficients *A*, *B* and *C* determined from the Mt. Wilson velocity data during 1967—1994, temporal variations of the N—S asymmetries of the coefficients $\bar{A}$, $\bar{B}$ and $\bar{C}$, viz., the coefficients in the differential rotation representation were determined.

The 7°.17 inclination of the Sun's equator to the ecliptic may be responsible for the 374 day periodicity in the N—S asymmetries of the solar rotation and the differential rotation.

When some sunspots are observed near the solar limb, their umbrae appear displaced towards the disk centre. This phenomenon, known as the Wilson Effect, is generally accepted to be due to a depression in umbra and has been taken to be a common property of all sunspots. A detailed study of the Wilson Effect was taken up and over 2000 sunspot groups were examined. It turns out that the penumbral ratio representing the Wilson Effect is dynamically related to the magnetic configuration of the sunspot group. Any change in the magnetic configuration is reflected in the penumbral ratio.

One derives physical limits on stellar surface magnetic field strengths based on the convective stability behaviour and the opacity dependent Wilson effect that determines the maximum observable field strengths in thick structures like starspots. The Wilson depression, well observed in sunspots, caused by the magnetic field induced coolness of the spot and the attendant reduction in the opacity of the magnetised gas, is found to be sensitive to the surface gravity and the effective temperature of a star and thus the maximum observable field strengths.

It has been believed for long that the flux inhibited by the sunspot from emerging in the photosphere must be radiated away in enhancements of the emission from neighbouring regions. Multi-wavelength observations of bright rings around sunspots have been reported in the recent times. The scientists however find that the bright rings seem to occur only in certain phases of evolution of sunspots and that ring-like structures are present around certain sunspots when observed in the D3 line of Helium. This line is formed in the upper layers of the chromosphere above sunspots.

The archival data from Kodaikanal Solar Observatory which covers a time span of about 100 years have been used to study the synoptic changes in the Sun. This would give insights on solar variability, rotation and convection. The first step in such a study is the determination of a 'quiet background' Sun. Presence of non-uniform brightness variations in the solar disk makes this task quite complex. The IIA scientists have obtained a temporal correlation function from the time sequences of Ca II K filtergrams and Dopplergrams

from Antarctica, Taiwan Oscillation Network (TON)and Solar and Heliospheric Observatory (SOHO). It gives the time evolution of the pattern under examination, supergranulation in this case, and in fact it shows oscillatory signals of both five minute and long-term periods. The causes of these oscillations are not fully known at present, but the instrumental and atmospheric factors can be ruled out, pointing to their solar origin. Some of the observed periodicities may be considered as probable candidates for long-term oscillations in the Sun, such as the elusive gravity modes.

Chromosphere : The hot atmosphere of the Sun has mysteries of its own. Studies on the chromospheric activity have been made to find out temporal and spatial variations of the quiet upper chromosphere from SOHO / SUMER observations of hydrogen Lyman lines. The scientists have analyzed a time series of spectra in the hydrogen Lyman lines and the Lyman continuum obtained by the Solar Ultraviolet Measurements of Emitted Radiation (SUMER) spectrometer on the Solar Heliospheric Observatory (SOHO). Phase difference analysis shows that there is a preponderance of upward-propagating waves in the upper chromosphere. A fast Fourier analysis has been performed in the spatial domain, all along the slit length used, for all the spectra and for the total duration of the observations. This provides evidence for the existence of a meso-scale in the upper chromosphere, of the same size as observed in the photosphere and lower chromosphere by earlier studies.

The variations in the solar UV flux may cause significant changes in the Earth's climate. An understanding of the physical origin of UV irradiance changes is an extremely important issue in solar physics. In order to better understand the variations in UV irradiance related to various bright - magnetic chromospheric features as a function of the solar cycle, the scientists have analyzed over 900 National Solar Observatory CaII K spectroheliograms for the years 1980, 1985, 1987, and 1992. This time period includes the maximum, minimum, and intermediate phases of the solar cycle. The power spectrum analysis on the time series of intensity of plages, network, and intranetwork features show a strong 27 and 13-day rotation modulation. It is also important to note that the network and intranetwork elements behave similar to the plages in their rotation modulation, and they contribute to the 27 and 13-day rotation modulation of the CaII K irradiance.

Corona : Observations of solar coronal oscillations provide valuable insights to the unresolved problems in coronal physics such as coronal heating, acceleration of solar wind and the origin of CMEs. The observations of waves and oscillations in coronal structures may lead to coronal seismology, from which coronal physical parameters can be obtained through oscillation properties. Time-sequences of spectra in the coronal green line [FeXIV] 5303 Å and red line [FeX] 6374 Å have been obtained at Norikura Solar Observatory. Power spectral analysis of the data shows coronal oscillations at localized regions with periodicities in the range of a few minutes to a few tens of minutes. Oscillations have been found to be prominent in Doppler velocities, while weak oscillatory signals are sometimes observed in line widths and intensities. The oscillation periods tend to increase with coronal height. The diverse range of oscillation periods could be due to different kinds of oscillation mechanisms in the corona.

Spectroscopic observations of coronal active regions were performed with coronagraphs at the Norikura Solar Observatory, and time variations of intensity and Doppler shift of coronal emission lines were investigated to study the coronal oscillations and waves. Recent filter-based observations give a hint of transient disturbances of Doppler signal propagating upward in the corona.

Coronal Mass Ejections (CME) : It is well known that eruptive events in the solar atmosphere like flares, CMEs, etc. lead to expulsion of material from the corona. The possible manifestations of the resultant voids are coronal depletions, transient coronal holes and coronal dimming. These regions are shortlived and their lifetime varies from less than a day to more than 3 days. Observations of these regions are of interest since transient increases in the solar wind speed are considered to be closely linked to them. In this respect, low frequency radio observations play an important role since they provide information on the density and temperature structure in the outer solar corona. Our Scientists estimated the mass loss associated with one such depletion, and the value is $\sim 10^{14}$ gm. This is approximately same as the mass of the material released during a CME.The radio brightness temperature at the location of the depletion compared to the ambient was less by a factor of ≈ 7. The angular extent over which the decrease in brightness took place was $\leq 3'$. The electron density variation was found to be proportional to r^{-10}. Since observations at

different wavelength bands have different physical origins, the radio method might be useful in independantly estimating the characteristics of CME induced coronal depletions.

What makes and keeps the Sun's corona so extremely hot ? Can kink waves contribute to coronal heating? The Institute's scientists earlier demonstrated that the excitation of kink oscillations flux tubes in the magnetic network of the Sun through their footpoint motions can provide sufficient energy for chromospheric heating. Using a specified form of the footpoint motions, which is compatible with observations, they have calculated the energy fluxes in vertically propagating kink waves and show that there is in principle adequate energy in the waves to heat the corona.

It is well known that the radio waves from a distant cosmic source passing through the solar corona get scattered because of the refractive index variations from point to point. Consequently there is an apparent increase in the angular size of the source. Such studies can be used to yield valuable data concerning the structure of the solar corona.The amount of coronal scattering depends to a large extent on the relative location of Sun and the radio source. One generally observes a gradual increase/decrease in the angular size of the latter during its ingress/egress. But there are instances where short term changes in the observed pattern have been noticed,particularly in the case of Crab nebula which lies close to the plane of the ecliptic and passes as near as about 5 $R_\odot$ from the Sun around June 15-16, every year. The scientists found that such transient changes are due to the passage of a CME between the observer and the source, in the interplanetary medium. In one such case, they estimated the characteristics of a CME at a distance of about 40 $R_\odot$, from their occultation data. The estimated electron density in the CME was about 50 times greater than that of the ambient at that location.

One of the primary goals of the Gauribidanur radioheliograph is to try and detect weak, pre-event signatures of the onset of a CME. The data from the Japanese X-ray satellite YOHKOH is used by NASA scientists to show that transient structures in the shape of letter 'S' (sigmoid) often indicate the onset of a CME. The Institute's scientists have used the Gauribidanur radioheliograph data to show that it is possible to observe a faint pre-event thermal structure (at meter-decameter wavelengths) at the would be site of a CME under favourable conditions, and using high dynamic range mapping. This is a significant advancement in the prediction of CMEs since one uses ground based data.

Miscellaneous : In another work, photospheric flow fields and properties of embedded small-scale magnetic flux concentrations have been the focus of attention. The association between the different scales of convection on the solar photosphere and the field strengths/flux content of discrete magnetic flux concentrations is analysed using simultaneously recorded SOHO/MDI high resolution filtergrams and magnetograms.

Pairs of temporally simultaneous Ca II K-line spectroheliograms and magnetic area scans have been used to search for spatial correlation between Ca II K_{2V} bright points in the interior of the network and corresponding magnetic elements. When magnetic fields of opposite polarity merge and form bipoles, the associated K_rm_{2V} bright points show excess emission. It appears that these cases of excess emission at the sites of the bipoles, as well as at the sites of fields > 4 Mx cm^{-2} are both instances of magnetic field related emissions.

The dynamical consequences of radiative energy transport on the evolution of gas confined to small-scale magnetic structures on the Sun have been studied. Convective collapse, which transforms weak field structures into intense structures of field strengths in the 1-2 kG range on the photosphere, is strongly influenced by radiative heating from the surroundings. The results provide a physical explanation for the observed flux dependent (equivalently size dependent) field strengths of the solar small-scale magnetic structures in the form of weak intranetwork and strong network components.

1.2 Solar System Studies

Comets : Investigations of the dust environment of comet Hale-Bopp have continued to give important information.

During the last four years since the perihelion passage of comet Hale-Bopp, a vast amount of data on polarimetry and imagery in visible and JHK bands at a range of phase angle were published by different groups. Using the photometric-dynamic model developed in the previous years, a detailed investigation was carried out by deriving the size distribution law, porosity and organic fraction

of the grains in the coma and shells which attempted to explain all the multi-colour polarimetric observations. A narrow size distribution between 0.08 μm - 0.6 μm is inferred for 70% of the grains in the coma and shell which may represent statistically the size range of individual sub units of larger highly porous aggregates of fractal dimension close to two. From the fits to polarization data at different epochs, the scientists propose a dichotomy in the surface composition of comet Hale-Bopp, with the northern region being relatively more Mg poor.

The spectro-polarimetric data of comet Hale-Bopp and Wild 2 obtained from VBO in April, 1997 were modeled assuming porous grains of astronomical silicate with organic inclusions. For comet Wild 2, the polarimetric fits indicate presence of grains of micron size and of higher absorptivity. Spectro-polarimetric studies of comet Wild 2 are valuable because this comet is the target of NASA's STARDUST mission.

Asteroid occultation : Asteroids may be very small members of the solar system, they have proved very useful to the astronomers through their occultations of the star light. The occultation of the star HIP 66446 by one such asteroid 423 Diotima on 15 March, 2001 was recorded at the 102 cm telescope at VBO using fast photometry.From the two stage occultation dip, the star has been found to be a binary with a projected separation along the path of the asteroid of ≈ 0.060 *arcsec*. Earlier, this star was listed as a single star in the SAO and Hipparcos - Tycho II catalogues.

1.3 Solar Terrestrial Physics

Case studies are done to investigate the nature of transient disturbances (duration ~ 2 hr) in the equatorial electrojet current during the different phases of isolated substorms triggered by directional changes in the interplantary magnetic field, IMF. Data from the Indian magnetometer network spanning the dipole latitude range 1.2 S-13.5N are used. A positive bay-like perturbation is found to prevail during the growth phase of the substorm, followed by a conspicuous negative-bay perturbation precisely with the onset of the expansion phase. The amplitude of both the postive bay and the subsequent negative bay is markedly enhanced in the equatorial electrojet region compared to stations outside the electrojet. This repeatable response pattern is strongly indicative of the occurrence of short-lived disturbances in the ionospheric zonal electric field with both the growth phase and expansion phase onset of isolated substorms, a feature that has never been reported before. The evidenced electric field perturbations are suggested as signatures of prompt penetration electric fields associated with rapid changes in magnetospheric convection brought about by swift transitions in IMF Bz/By componets during substorms.

2. Stars and stellar systems

2.1 Stars

The study of stars, be it their composition, structure, evolution or their environment, forms an important part of the Institute's research activities.

Abundances : A spectroscopic survey is being carried out for a sample of high proper-motion stars using OMR spectrograph of the 2.3m VBT at Kavalur. The objective of the survey is to find metal-poor stars among them. A large number of candidate stars are taken from Lee's high proper motion and high tangetial velocity stars list and prismatic HK surveys. These stars showed weak or nearly absent metallic lines when compared to the normal stars of similar hydrogen line strengths. Comprehensive abundance analysis using high resolution spectroscopy confirmed their being significantly metal-poor with [Fe/H] less than –2.5. The large spread in aluminum abundances and also in α elements for stars with [Fe/H] < –2.5 indicates that before this metallicity level was attained, the early Galaxy experienced very unusual chemical enrichment. Galactic chemical enrichment models including the effect of incomplete ISM mixing are required to explain the observed abundance peculiarities.

There is an ongoing programme focussing on the high-galactic latitude supergiants with IR fluxes with a view to look for candidates for post-AGB stars. Several such stars have been identified.

SRd stars are the ones showing high radial velocity, are metal-poor and show strong emission components in hydrogen line profiles. Photometric criteria used in GCVB have resulted in a mixed bag of rather unrelated objects being called SRds. Our scientists studies of 8 real SRd objects show them to have [Fe/H] in range -1.1 to -1.8. Their compositions are identical to (within measurement errors) the compositions of subdwarfs, subgiants or less evolved giants of the same [Fe/H]. The observed abundance pattern also shows that SRd variables are at the tip of the first giant branch or in the early stages of evolution along the asymptotic giant branch (AGB). There is no conclusive evidence that these SRds have experienced thermal pulses and the third dredge-up on the AGB. The SRd variables appear to be at the cool limits of the sequence of RV Tauri variables.

A study of Li abundance in stars believed to have just evolved off the main sequence to explore the long standing problem of precisely how much depletion takes place in the MS phase itself is being done. In continuation of this work, high resolution CCD spectra of another 75 stars have now been obtained with the coude echelle spectrograph at the 102cm telescope at Kavalur. As a result, the preliminary analysis shows an unexpected trend between lithium abundance and rotation.

One learns so much more from clusters than from field stars : the samples within the cluster allow one to examine differences in Li between stars of the same mass, age and composition. The cluster alpha Per (50-70 Myr old) is an open cluster accessible to large telescopes at high spectroscopic resolution. It is unusual in having a high proportion of low Li stars - the essential problem remains of how such stars have come to deplete so much Li in so little time when other stars of the same age appear to have depleted no Li at all. The G and K stars of α Per show a large v sin range, so their observations would shed light on how the rotational history of these stars has influenced their Li abundance.

Abundances of cool extreme helium stars : Extreme helium stars (EHe) with effective temperatures from 8000K to 13000K are among the coolest EHe stars and overlap the hotter R CrB stars in effective temperature. The cool EHes may represent an evolutionary link between the hot EHes and the R CrBs. Abundance analyses of four cool EHes, FQ Aqr, LS IV -14o 109, NO Ser, and V2244 Oph are presented. All these stars show evidence of H and He-burning at earlier stages of their evolution.

To test for an evolutionary connection, the chemical compositions of cool EHes were compared with those of hot EHes and R CrBs. Relative to Fe,the N

abundance of these stars is intermediate between those of hot EHes and R CrBs. For the R CrBs the metallicity M derived from the mean of Si and S appears to be more consistent with the kinematics than that derived from Fe. When metallicity M derived from Si and S replaces Fe, the observed N abundances of EHes and R CrBs fall at or below the upper limit corresponding to thorough conversion of initial C and O to N. There is an apparent difference between the composition of R CrBs and EHes; the former having systematically higher [N/M] ratios. The material present in the atmospheres of many R Cr Bs is heavily CN and ON-cycled. Most of the EHes have only C N-cycled material in their atmospheres. There is an indication that the CN- and ON-cycled N in EHes was partially converted to Ne by alpha-captures. Hence, the inferered [N/M], C/He, [Ne/M], and the H-abundances of these two groups indicate that the EHes and the R Cr Bs may not be on the same evolutionary path.

The atmospheres of H-deficient stars most likely consist of three ingredients: a residue of normal H-rich material, substantial amounts of H-poor CN(O)-cycled material, and C-(and O-) rich material from gas exposed to He-burning.

Herbig Ae/Be stars : Herbig Ae/Be stars are pre-main sequence stars of intermediate mass. They show large infrared excess emission due to dust in their circumstellar environment. Many of them exhibit the phenomenon of bipolar outflows and a large fraction of them are in binary systems. Polarization measurements of a number of these objects and the relationship between polarization, outflows and binary orbital planes indicate optically thick or thin circumstellar disks around these stars that drive outflows perpendicular to the disk plane and the binary orbits that are coplanar with the disks.

Hot post-AGB stars : From the study of IRAS sources with far-IR colors similar to planetary nebulae (PNe), several proto-planetary nebulae with hot (OB) post-AGB central stars have been detected. These stars form an evolutionary link between the cooler G, F, A supergiant stars that have evolved off the Asymptotic Giant Branch (AGB) and the hot (OB) central stars of PNe. The UV(IUE) spectra of some of these objects revealed violet shifted stellar wind P-Cygni profiles of CIV, SiIV and NV, indicating hot and fast stellar wind and post-AGB mass loss. These objects appear to be rapildy evolving into the early stages of PNe similar to that observed in the case of Hen1357 (Stingray Nebula) and SAO85766.

There are very few cases where observations allow to check models of isotopic abundance evolution in the Galaxy, especially concerning the early (i.e. halo) phase of that evolution. One of these rare cases concerns the Mg isotopes ^{25}Mg and ^{26}Mg. In a study the scientists have simulated and predicted the evolution of the isotopic abundance ratios of Mg, Ca and Ti in the Milky Way halo and in the local disk. The predicted isotopic abundance ratios ^{25}Mg/^{24}Mg and ^{26}Mg/^{24}Mg are found to decrease sharply with decreasing metallicity [Fe/H] well in agreement with observations.

Emission line spectra of XXOph : The star XX Oph has been known to exhibit peculiar spectral variabilities since the work of Merrill in 1924. A high resolution spectroscopic study of the XX Oph spectra taken in July 1996 and later in June 1997 also exhibit distinctly different line profiles in several spectral regions. The scientists have estimated the displacement velocities of the strong emission line profiles and their absorption components whenever possible. They have traced the available spectroscopic history of XX Oph and attempted to examine possible physical scenarios that can account for its peculiar variability. However, to understand the nature of this unusual object high dispersion spectra particularly during episodes showing strong absorption components would be extremly useful.

Star clusters: The colour-magnitude diagram (CMD) of a star cluster is an important tool to obtain the information on distance and age of the cluster and interstellar extinction in the direction of cluster. Accurate deep photometric observations down to V > 20 mag are necessary for such studies.

CCD photometry of the northern open star cluster NGC 7790 has been carried out in *BVI* photometric passbands down to *V* 21 mag for 1150 stars of which for 700 stars, the data is obtained for the first time. The theoretical isochrone fittings to the Cepheid variables as well as the evolved part of the main sequence near turn-off point indicate that the cluster is 120 pm 20 Myr old. Both the distance and age determined using period luminosity/age relations for the Cepheid variables are consistent with their membership of the cluster. This unique opportunity has therefore been used to refine the zero-point of the

period-luminosity relation for the Galactic Cepheids.

Similarly, a new CCD photometry of the distant old open star cluster Berkeley 32 was done in Johnson *V* and Cousins *I* passbands.

Theoretical isochrones have been used to convert the observed cluster luminosity function into a mass function in the mass range 0.6 – 1.1 $M_{\odot}$. The scientists find a much flatter mass function than what has been found for young clusters. If the mass function is a power law $dN\, m^{\alpha}$, then $\alpha = -0.5 \pm 0.3$. This may be seen as a signature of the highly evolved dynamical state of the cluster.

2.2 Novae

V1494 Aql: Novae represent a more violent form of variability among stars. The classical nova V1494 Aql, which had an outburst in 1999 November was observed, spectroscopically using the telescopes at VBO. A few spectra were also obtained from the GHO, Mexico. Preliminary analysis of the spectra indicates the nova belongs to the fast, Fe II class of novae. The emission line profiles show rapid variability over a timescale of 2-3 days during the initial phases. The emission lines have a saddle-shaped profile indicating non-spherical symmetry in the ejected shell with small scale clumpiness.

The Large Magellanic Cloud (LMC) is one of the very few external galaxies where a number of novae have been detected and studied in detail over the years. This is also a galaxy where the stellar population is well understood. A study of the immediate environment of novae in the LMC will help in our understanding of the the progenitors of different classes of novae and explain the differences observed during the outburst.

A study shows that 60% of the novae in LMC belong to the very fast/fast category and are all located inside and south of the bar, with the exception of the single recurrent nova detected in the LMC. The slow-very slow novae all lie in the outer regions. Two potential SN type Ia progenitors have been identified. The scientists conclude the bar in LMC consists of an intermediate — older population; ONeMg novae occur in regions of relatively high metallicity.

2.3 Supernovae

SN2001X: The recent supernova SN2001X has been observed from both VBO and IAO. Spectra have been obtained using the VBT, while photometry was done with the Hanle 2-m telescope. The supernova belongs to type II. Figure shows the image of SN2001X in the *V* band obtained from IAO on 2001 March 11.

2.4 Gamma ray bursts

The optical afterglow of GRB 010222 was observed using the recently installed 2-m telescope at the Indian Astronomical Observatory, Hanle, and the telescopes at the Vainu Bappu Observatory, Kavalur, beginning $\simeq 0.6$ day after the detection of the event. The *R* band light curve shows an initial decline of intensities proportional to $t^{-0.542}$ which steepens, after 10.3 hours, to $t^{-1.263}$. Following the model of collimated outflow, the early break in the light curve implies a very narrow beam angle ($\sim 2° - 3°$). The two decay rates are consistent with the standard jet model in a uniform density ambient medium, but require a hard spectrum of electron power density with $p \sim 1.5$. The early spectral energy distribution derived using published fluxes in different bands and our *R* band light curve suggests that the ambient density is low: $n \sim 0.1\text{–}1\,\mathrm{cm}^{-3}$. GRB 010222 is thus an example of a highly collimated outflow with a hard spectrum of electron energy distribution in a low density environment.

Optical follow-up observations of GRB afterglows: The study of Gamma-ray bursts, electromagnetically the most luminous events in the Universe though only for a few seconds, was revolutionized in 1997 when the Italian-Dutch X-ray satellite BeppoSAX started providing the positions of some events with an accuracy of a few arcminutes within a few hours after the burst. The optical observations of 5 GRB afterglows namely GRB 991208, GRB 991216, GRB 000301C, GRB 000926 and GRB 010222 were carried out. The light curves, spectral energy distributions and energetics of these were studied in the light of recent fireball plus blast wave theoretical models of GRBs.

3. Theoretical astrophysics and cosmology

3.1 Radio pulsars

A knowledge of the altitude of radio emission in pulsars is very crucial as it can shed light on the emission mechanism. The scientists here have analyzed high-quality single pulse data of PSR B0329+54 at 325 MHz and 606 MHz from GMRT to study the structure of the emission beam and find the PSR B0329+54 to have 9 emission components — the highest among all known pulsars. The distribution of the pulse components around the central core component indicates that the emission beam consists of four nested cones. The inferred emission heights range from ~ 160 km to ~ 1150 km.

Radio pulsars are believed to be the most common manifestations of neutron stars. By including general relativistic effects of the stellar mass on pulsar beam shapes, which makes the stellar mass and radius relevant parameters in determining the pulse widths, it has been shown that core component widths provide tight constraints on equations of state (EOS) of neutron stars. Our scientists have extensively examined earlier works for neutron star M - R relations. About 40 EOSs M - R plots were examined. Very conservatively dropping some among them which are now replaced by modern versions, and imposing an additional condition that their mass range allow the value 1.4 $M_{\odot}$, it is found that no neutron star EOS can satisfy the constraints implying that pulsars are not neutron stars but strange quark stars, i.e., ones composed of quarks of flavours u, d, and s. Pulsars being strange stars fits well with the constraints. Whether pulsars are bare strange stars, strange stars with normal crusts or the newly proposed third family of ultra-compact stars is difficult to decide at present. It has been proposed that pulsars showing the phenomenon of drifting sub-pulses are bare strange stars. The constraints apply to pulsars showing core emission. However, the core emission and drifting of subpulses which is a property of the conal emission are not mutually exclusive. Therefore the proposal that pulsars are bare strange stars can be extended to all pulsars. The core width constraints are now one more independent indication that pulsars are strange stars.

3.2 Magnetohydrodynamics

In an important study, attention has been focussed on the relaxation of a compressible plasma to an equilibrium with flow. The constraints of conservation of mass, energy, angular momentum, cross-helicity and relative magnetic helicity are imposed. Equilibria corresponding to the energy extrema while conserving these invariants for parallel flows yield three classes of solutions and one of them with an increasing radial density profile, is relevant to solar flux tubes.

3.3 Black holes

Formation of quasar black holes : There seems to exist tantalizing clues from demographics of supermassive black holes that they are relics of a violent earlier universe and that it is a consequence of the galaxy formation process. Cosmological simulations predict the formation of potential quasar sites at redshifts as high as $z = 8$. The corresponding density peaks involve massive self-gravitating clouds of cold gas that have collapsed to a scale below the spatial resolution (~ 1 kpc) of the simulations. A model has been developed for formation of quasar black holes from a magnetized accretion of a collapsed disk. This work has implications for dwarf galaxy formation and a residual large scale seed field.

Black holes in non-flat backgrounds : For more than three decades now, black holes have been investigated in great depth and detail. However, most of these studies have focussed on isolated black holes which are time independent and asymptotically flat. In a totally realistic situation however, the black hole would be surrounded by local mass distributions and may be embedded in a cosmological spacetime. In such cases one or both of the two basic properties may have to be given up. Black holes in non-flat backgrounds form, therefore, an important topic.

Recently, the Institute scientists have studied the Schwarzschild black hole in the background of the Einstein Universe. They have given a composite model

comprising a vacuum Schwarzschild black hole matched on to a mass distribution represented by a solution due to Vaidya which itself is joined to the Einstein Universe. They have been studying some characteristic physical effects in this composite spacetime. These include the three classical tests of General Relativity and geodesics in detail.

Hawking radiation : It was shown from the dynamics of the radiation dominated early universe, that at the epochs when primordial low mass black holes form, the ambient radiation temperature considerably exceeds their corresponding Hawking temperature. This results in rapid continual accretion (absorption) of ambient radiation by these holes. Consequently by the end of the radiation era, their masses grow much greater so that their lifetimes (Scaling as M^3) would now be enormously greater than the Hubble age implying undetectably small emission of Hawking radiation. Again (several times) solar mass black holes which are the only ones to form in the present epoch, have Hawking temperatures millions of times smaller than the CMBR. Thus Hawking radiation from blackholes is very unlikely to be ever observed in any cosmic epoch !

3.4 Plasma astrophysics

General relativistic effects especially with the inclusion of the torsion of space time is shown to result in a modification of plasma screening around compact (dense) objects. The torsion-modified general relativistic Maxwell-Proca equations applied to describe a plasma are shown to give rise to corrections to the Debye screening length etc. For ultrahot new born neutron stars the corrections are shown to be significant and can give rise to observable effects.

3.5 Galaxies

Dynamics : The outcome of a galactic collision depends on the masses, the density and the sizes of the galaxies involved in the collision. An attempt has been made to study the tidal effects of close collisions of galaxies of different masses, forms and sizes. Several N-body simulations have been performed using the GRAPE computer system. The results show that the tidal effects are quite sensitive to mass ratio and mass distribution of the galaxies. The centrally concentrated less massive galaxy undergoes greater expansion while the more massive but less centrally concentrated one is hardly affected. The phenomena of tidal capture and tidal disruption are dependent on the choice of the model and mass ratio of the galaxies. A scheme of classification for colliding galaxies has also been proposed.

3.6 Cosmology

The machian theory of conformal gravitation of Hoyle & Narlikar (HN) provides an alternative and more versatile description of the Universe than that given by the standard Friedmann cosmology. In HN cosmology in a static,flat,Minkowskian space-time the systematic increase of particle masses with epoch [Variable Mass Hypothesis (VMH)] gives rise to the cosmological redshift. Thus the expanding universe scenario is replaced by the notion of variable particle masses. A model originally developed in 1980 in the VMH scenario was fairly successful in explaining the anomalous redshifts of quasars and various other features of typical quasar-galaxy associations such as alignments & redshift bunchings. The model was suitably modified to analyse the latest data on X-Ray quasars. The model correctly predicts the observed inverse correlation between the quasar-galaxy angular separation and the galaxy redshifts.

4. Physics

4.1 Foundations of quantum mechanics and quantum information

A fledgeling field growing rapidly and of considerable interest both for its relevance to the foundations of quantum mechanics and its future powerful applications in information processing is quantum information. Of added interest is the fact some of these applications can be implemented at IIA in the Zerolab and at CREST, Hoskote once the laser facility is fully operational.

Information flow in entangled systems : An important unresolved issue about quantum nonlocal systems is whether their correlations represent merely a local inaccessibility of information or an actual nonlocal transfer of quantum information. In a recent work it has been pointed out that quantum communication protocols like quantum teleportation and remote state preparation imply a causal transfer of classical information about the state, that far exceeds the classical communication cost (≤ 2 bits) needed to implement the protocol. They consider extreme manifestations of this phenomenon whereby in certain operations the transferred information is noncausal. The important question is whether there are grounds that render the operation responsible for the information transmission unimplementable thereby ensuring conformance to relativistic causality.

It had been earlier 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. This implied that the measurements in one spacial region do not affect the state of an entangled particle that is space-like separated from the first, and this resolves the celebrated Einstein-Podolsky-Rosen (EPR) nonlocality puzzle in quantum mechanics. Now the empirical proof against state reduction at a distance in an experiment proposed by Karl Popper in 1933 has been found. The experiment measures the dispersion in the momentum of the second particle after a measurement of the position of the first particle when they are space-like separated. The standard interpretation of quantum mechanics that the first measurement reduces the position state of the second particle to a definite value also imply that the momentum of the second particle should disperse according to the uncertainty principle. This does not happen, and the simplest interpretation is that there is no state reduction for the second particle as a result of the measurement on the first particle. This observation entirely changes the current interpretation of all experiments that involves entangled particles and Bell type measurements.

4.2 Non-Accelerator Particle Physics

An alternative route has been developed to compute the parity non-conserving transition moments along with parity-conserving properties like, transition energies, oscillator strengths, dipole and hyperfine transition matrix elements. The approach is based on open-shell coupled cluster (CC) method, a method which is now considered to be one of the state-of-art approaches.

The relevant CC codes have been developed to compute the above mentioned atomic properties and have been applied to a wide variety of atomic systems (lithium to thallium). Relativistic second order MBPT and CC code (linear response version as well as open-shell version) to compute the ionization potentials and electron affinities of atomic systems ranging from small to large Z values has also been developed. The linearized version of relativistic CC method (CCLRT) not only provides accurate ionization potentials for the principal states but also for 2h-1p satellite states. It may be pertinent to mention here that this is the first application of relativistic CCLRT for the computation of satellite ionization potentials. The scientists have interfaced Multireference Many-Body Perturbative Methods (MR-MBPT) in widely used Quantum Chemistry code called GAMESS (General Atomic and Molecular Electronic Structure System). This code is capable of computing a wide variety of atomic and molecular properties (Non-relativistic). So far as perturbative calculations were concerned, it was limited to single-reference MBPT method and now it can be used for computing atomic and molecular properties using MR-MBPT.

Casimir force and quantum vacuum : The scientists have been preparing to measure the Casimir force - the attractive force arising from restricting the

quantum vacuum of the electromagnetic field - between parallel plates at separations between 30 microns to about 300 microns to detect and study the finite temperature corrections. The final assembly is being tested.

Laser Cooling and Trapping : Our scientists have been collaborating with the Helium laser cooling group at the Kastler Brossel laboratory, ENS, Paris. Recently the Bose-Einstein condensation (BEC) of metastable Helium, a new species in the family of atomic BECs, was achieved. The transition temperature was measured to be about 4.7 micro-Kelvin, and the condensate contains about 105 to 106 atoms. The route to BEC involved implementation of a high intensity discharge source of low velocity metastable Helium atoms, an efficient Zeeman slower to reduce the velocity from about 1000 m/s to 50 m/s, a high density magneto-optical trap and finally, an efficient high density magnetostatic trap in which polarized Helium atoms were cooled to few microKelvins by evaporative cooling.

Detecting TeV Gamma rays from Gamma ray burst sources by ground based muon detectors : Gamma ray bursts are among the most powerful astrophysical phenomena in the universe. GRBs have so far been detected mostly in the sub-MeV region, emission extending to 10 TeV is known. For power law spectra falling with energy, the photon number flux at TeV energies may be too low, ground based detectors can in principle detect TeV photons from GRBs by detecting the secondary particles (electrons, muons) of the atmospheric showers generated by these in the Earth's atmosphere. Motivated by the importance of the possible TeV photon emission from GRBs a project has been undertaken to detail out the possibility of detecting muons, reconstructing the energy and direction of the shower initiating parent photons to a directional accuracy of typically a degree, by using the relatively shallow underground muon detectors such as AMANDA, Lake BAIKAL detector and the proposed ICECUBE, and surface muon detector such as MILAGRO. For reasonable range of values of various parameters, the scientists predict about 1 event in 20 years in AMANDA (and a similar number for BAIKAL) while the event rate may be larger by factors of 10 depending on area of the detector, in the proposed next generation detectors such as ICECUBE. Detection of TeV photons from the GRBs will shed light on the nature of these exotic sources.

4.3 Atomic probes of Physics beyond the Standard Model

Parity Nonconservation (PNC) in atoms due to neutral weak currents and electric dipole moments(EDMs)arising from violations of parity and time-reversal symmetries are two important non-accelerator probes of the Standard Model of elementary particle physics.

PNC in atoms : The scientists have made significant progress in their many-body formulation and calculation of a PNC observable and related properties in singly ionized barium(Ba^+).Several ionization potentials and excitation energies for low-lying states were calculated to better than one per cent using an all-order many-body theory known as the Coupled-Cluster Method (CCM).Allowed transition amplitudes and hyperfine constants for states of relevance to PNC in Ba+ have also been calculated by the same approach.The formulation of the PNC observable(parity non-conserving electric dipole transition amplitude)by CCM is not unique. Their present formalism is rather straightforward as it involves directly summing over intermediate states with parities opposite to those of the initial and final states for the PNC transition. They have obtained new results for this PNC observable corresponding to the $6s \rightarrow 5d(3/2)$ transition. An experiment to observe this effect using a single trapped and laser cooled ion is currently in progress at the University of Washington, Seattle,USA.The result of this experiment when available can be combined with our theoretical work to provide important information about the validity of certain classes of theories that unify the different fundamental forces.

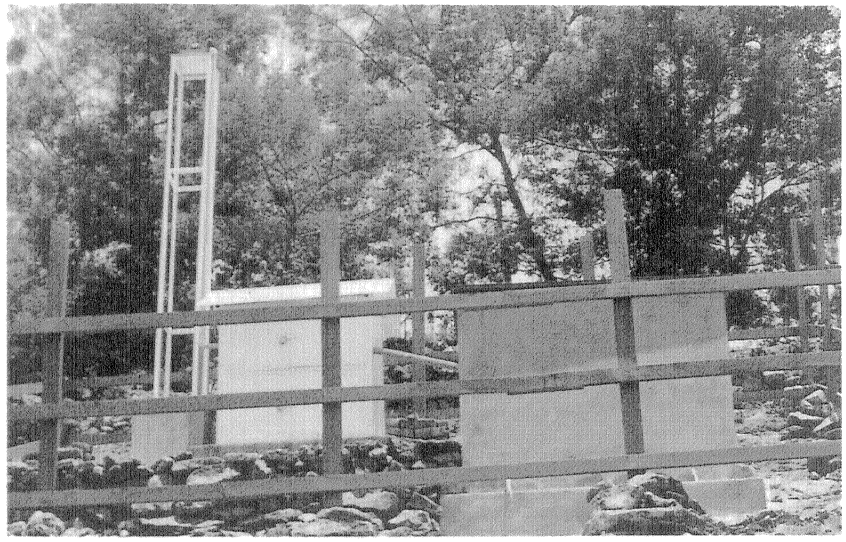
They have also carried out coupled-cluster calculations of the ionization potentials of several low-lying states of atomic thallium.This is a necessary step towards a full-fledged many-body calculation of the PNC observables.

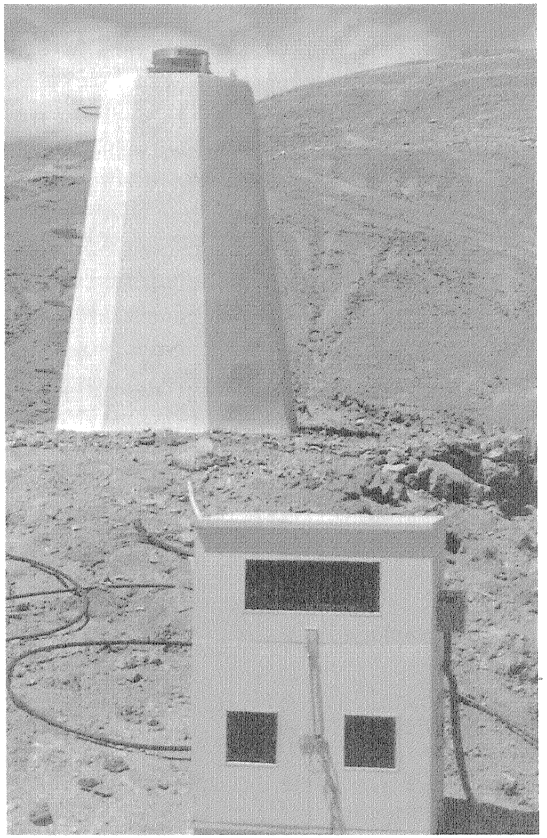
They have recently initiated a rigorous theoretical study of PNC in atomic caesium with the objective of testing the possible existence of new physics beyond the Standard Model.

EDMs of atoms : Atomic EDMs can in principle yield unique information about time-reversal/CP violating interactions in the hadron and lepton sectors. An experiment to search for EDM in atomic ytterbium based on the techniques

▲ GPS installed at the Kodaikanal Observatory

Broad band Seismometer at the Kodaikanal Observatory ▼





▲ GPS installed atop Mt. Parvati, Hanle.

of laser cooling and trapping is currently underway at University of Kyoto,Japan. The scientists have performed theoretical studies of the EDM of ytterbium arising from a specific type of parity and time-reversal violating electron-nucleus interaction. The calculations have been carried out by three different methods — configuration interaction,perturbed configuration interaction and the Epstein-Nesbet perturbation theory and the three results are in very good agreement. They have very recently started work on the theory of mercury and thallium EDMs.Experiments on these atoms are underway at the University of Washington,Seattle and University of California, Berkeley.

4.4 Atomic Astrophysics

Excitation energies and oscillator strengths : 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.

Our scientists have performed relativistic coupled-cluster calculations to determine the oscillator strengths of the 3s→3p and the rather weak 3s→4p transitions in singly ionized magnesium(Mg^+).The result of the *ab initio* and semi-empirical calculations for the latter transition were in disagreement. The first-principle calculation incorporating a large class of many-body effects to all orders has yielded results in favour of the semi-empirical calculations. Mg^+ is important from the point of view of astrophysical studies.

Atoms in strong magnetic fields : Intercombination or spin-forbidden electric dipole transitions are of great astrophysical importance.There are situations in astrophysics where a knowledge of their strengths under the influence of strong magnetic fields is necessary. They have very recently started work to determine the quantum mechanical atomic wavefunctions incorporating the effects of the magnetic field.These wave functions will be used to calculate the intercombination transition probabilities.

4.5 Geodynamics of the Indian continent

The Karakoram: Repeat GPS measurements at the 10 sites in Ladakh (vide figure on p-31 of IIA Annual Report, 1999-2000) during the summer of 2000 confirmed the arc normal convergence of Tibet with the Indian continent. The nearly equal value of these vectors to those in Kumaon Himalaya and their normality to the Himalayan plate boundary indicates that the continental collision zone north of the Himalaya deforms more like a viscons material. This is additionally corroborated by the Leh GPS data which shows extension of the baseline between Lhasa and Leh. Finally, these measurements refute the hypothesis that Tibet slips eastwards along the Karakoram fault at a rate of 30 mm/year.

Precipitable water vapour in the Hanle atmosphere and the Hanle - Kodaikanal base line: Permanent GPS stations were established at the IIA observatories of Hanle and Kodaikanal. These stations, maintained and operated by IIA form a part of the national GPS station network being established by DST, Govt. of India. Collocated with meteorological observatories, the GPS data from these sites are aimed at providing near real time information on the geodynamic strain between Hanle and Kodaikanal as well as estimates of precipitable water vapour for atmospheric modelling.

A broad band station was also installed in a specially constructed rock vault at the Indian Astronomical Observatory (IAO), Hanle and has already generated over 8 months of data, currently being analyzed.

5. Instrumentation

5.1 NITSI: Near Infrared Testbed Stellar Interferometer

Scientists at the Institute have been developing a fiber based prototype stellar interferometer in the infrared using existing optical telescopes at Kavalur. Presently, the emphasis is mainly on building a phase-I instrument, namely NITSI-I, which is a reduced version without delaylines and fringe tracker. This version will be tested in the laboratory with simulated stellar beams in order to evaluate instrumental capabilities and make necessary instrumental calibrations. NITSI-I will be then tested on the sky at a radio/millimeter dish or at the 2.3m telescope at Kavalur. NITSI-II will have delaylines and will be tested by combining stellar beams from the 102 cm and 234 cm telescopes at Kavalur. A fringe tracker will be added to NITSI-I at a later stage in order to reach fainter magnitude limits. The objectives are (a) developing know-how in the area of stellar interferometry in order to go for a multiple aperture stellar interferometer in the future at a good observing site(b) carrying out scientific investigations on several issues related to topics such as late stages of stellar evolution and star forming regions.

NITSI with its milliarcsecond spatial resolution capability could provide valuable observational data in most of the areas of stellar astronomy. We restrict scientific objectives to two broad research areas, namely, stellar evolution and star formation. High spatial resolution observations of evolved stars with sufficient angular resolution to resolve the stellar surface and its immediate circumstellar environment have the potential to address various issues related to topics such as stellar pulsation, mass loss, shock wave propagation, dust formation, dust properties and effective temperature. Bright YSOs are the other class of interesting objects, observable with NITSI when equipped with a fringe tracker. Our objective here is to detect and study circumstellar disks, young companions and jets around relatively bright young stellar objects. Speckle and lunar occultation observations of nearby star forming regions have shown definite excess of binarity over what is expected on the basis of main sequence stars. However, these techniques are restricted to an incomplete range of angular separations and stellar interferometry could extend the angular separation coverage.

A laboratory workbench is being set up to simulate a two-telescope interferometer and characterize the interferometric performance of various sub-systems involved. The various components required to assemble the phase-1 instrument, NITSI-I are being acquired. Mounting this instrument at the telescope involves developing tip/tilt units. Light beams from independent telescopes will be combined once delaylines become available.

5.2 Speckle interferometer

The new speckle interferometer has been in operation since 1996, at the Cassegrain end of the 2.34 meter Vainu Bappu Telescope (VBT) to record speckle-grams of various objects, viz., close binary stars ($\rho < 1''$), active galactic nuclei etc. Studies involving the optimization of speckle imaging are part of the important ground work for addressing these basic astrophysical problems. A new microscope objective holder has been developed and fabricated facilitating its movement with an accuracy of a few nanometer. This component has replaced the old one which was an integral part of the afore-mentioned speckle interferometer. The performance of the interferometer is found to be excellent. Recent development of the solid state based non-intensified CCD which effectively reduces readout noise to less than one electron rms has enabled substantial internal gain within the CCD before the signal reaches the output amplifier. Such a detector brings a ray of hope for the quantitive measurement of diffraction-limited stellar images by using 'selective image reconstruction' technique. Efforts have been made to procure such detector (–90° cooled) for these programmes that are in progress at the Institute.

Close binary stars : Thousands of speckle-grams of several close binary stars and of reference stars (unresolved) were successfully recorded with the speckle interferometer at VBT through the narrow band filters, using the Peltier

cooled ICCD camera system as detector. A few binary systems have been reconstructed with a triple correlation technique.

Active galactic nuclei : An important field of observational astronomy is the study of the physical processes, viz., temperature, density and velocity of gas in the active region of the active galactic nuclei (AGN). High resolution optical imaging in the light of emission lines on sub-arcseconds scales can reveal the structure of the narrow-line gas. Another important phenomenon – the time variability of AGNs, ranging from minutes to days can also be studied. The specklegrams of the AGN, NGC4151, obtained at 2.34 meter VBT, are being processed.

Measurement of r_0 : The night time variations of Fried's parameter at the 2.34 meter VBT site were computed using the speckle interferometric technique.

5.3 IR photometry

An IR photometer has been assembled using existing liquid nitrogen cooled InSb detectors. The instrument has also been modified with necessary mechanical parts fabricated in order to mount this dewar at the telescope and have chopping facility. It will have a data acquisition card, capable of controlling this instrument in addition to acquiring data. Recently, this photometer has been mounted at the 102cm telescope and optical alignment has been done through passing clouds. Further fine-tuning of this instrument during clear night is essential. This instrument will be subsequently used for observational studies of evolved stars, novae and pre-main sequence stars by lunar occultation and infrared photometric observations at the VBO telescopes.

5.4 Holographic data storage

Optical storage of data has been one of the bright spots in science and technology over the past 15 years. Due to the rapid advancement in laser technology over the last few years, holographic data storage has generated lot of interest in research activities all over the world. Some of the distinct features like, very high storage density, extremely fast retrieval time and parallel data processing, make it a more useful and deserving candidate for information storage. Holographic memories, it is now believed, could conceivably store hundreds of billions of bytes of data per cubic centimeter, transfer them at a rate of a billion or more bits per second and select a randomly chosen data element in 100 microseconds or less. The main advantages of holographic storage - high density and speed - come from three-dimensional recording and from the simultaneous readout of an entire page of data at one time. A rather unique feature of holographic data storage is associative retrieval i.e. imprinting a partial or search pattern on the object beam and illuminating the stored holograms to reconstruct all of the reference beams that were used to store data. Holographic memories store each bit as an interference pattern throughout the entire volume of the medium.

Photo refractive crystals - materials whose refractive index changes when a beam of light passes through them (this phenomenon of changing the optical properties of the media by the very light that passes through them is known as nonlinear optical phenomenon) - have several advantages over the conventional photographic plates. Scientists at the Institute have been working on holographic data storage in photorefracive crystals like pure and doped LiNbO3 and BaTiO3. A practical implementation of the system would require an in-depth study of all aspects of the systems. First and foremost is characterization of storage medium. For example, (a) the response time of the crystal determines the speed of data storage and retrieval, (b) diffraction efficiency of the grating puts the ultimate limit on the number of holograms that can be stored inside the crystal, (c) energy transfer efficiency in two-beam coupling (TBC) can be used to amplify the weak signal and (d) study of the phase conjugate properties of the crystals are extremely useful in aberration correction and lens less imaging, which in turn is helpful in reducing bit error rate (BER). At present the study of above-mentioned properties of the storage medium is going on.

5.5 Radio astronomy

A new digital radio spectrograph for obtaining a dynamic spectrum of the transient burst emission from the solar corona in the frequency range 80-30 MHz i.e., in the altitude range rm 1.3-1.6 $R_\odot$ from the center of the Sun, has been recently constructed and commissioned at the Gauribidanur radio

observatory. The two main advantages of the present system over the existing conventional solar radio spectrographs are: (i) it allows the user to select the frequency bands which are completely free of inteference, and (ii) the desired spectral accuracy can be achieved by just changing the delay resolution in the digital receiver. This instrument is expected to play an useful role particularly during the maximum of the present solar cycle (Cycle 23) since we have the unique opportunity of also locating the position of the burst sources using the two dimensional images obtained with the Gauribidanur radioheliograph (GRH).

The GRH receiver unit is now fitted with a highly accurate astronomical clock facility using rubidium oscillator standard. This aids in timing the onset and duration of the transient energy releases from the Sun in a more accurate manner.

5.6 Photonics Division

Adaptive Optics :

As an effort towards developing a low cost adaptive optics system for dynamic image correction, experiments are being performed using CMOS imager and micro machined deformable membrane mirror (MMDM). A 37 channel MMDM was tested and evaluated using Zygo interferometer. To understand more the behavior of the mirror, finite element analysis of the mirror has been taken up. A laboratory AO system would be ready shortly.

Wavefront Sensing :

Experiments are being performed in the laboratory using Shack Hartmann wavefront sensor. It is planned to compare the results from Shack Hartmann Sensor and Polarization Shearing Interferometer method.

Metrology Facility :

An Advanced Optical Metrology Facility is getting ready at Photonics Division. Veeco make profilometer, capable of microscopic profiling and roughness measurement ~1Å, Long Trace Profilometer (LTP), Zygo Interferometer, Fiber Spectro Photometer are the main instruments as part of this facility. The major funding for this facility has been received from ISRO, Department of Space and BRNS, Department of Atomic Energy under two separate projects.

Long Trace Profilometer :

Design and development of Long Trace Profilometer (LTP) has been completed. A new design of optical head for Long Trace Profilometer (LTP) was conceived and finalized. Using this head a set up for measurement of the profile has been made ready. A robust computer controlled optical translational stage for the same has been made at CMTI, Bangalore. The software for the reduction of the data has been completed and the same has been integrated with the system for on line evaluation of the data. The test profile of 10M radius calibration sphere matches well with the test profiles obtained from Brookhaven National Laboratory. Integration of LTP translational stage and optical head is in progress. LTP in its final form will be ready shortly. The total system will be tested and evaluated for its final performance during the coming year. The instrument will be capable of measuring profiles of 1metre long synchrotron optics with an accuracy of tangent error <0.25 arc sec.

Synchrotron Radiation Beam Line (SRBL) Optics :

Work on the optical polishing and figuring of the flat and ellipsoidal mirrors was continued. The optical surface quality of the ellipsoidal mirrors has improved significantly and a set of plane and parallel mirrors are ready for delivery to BARC. For gold coating of these mirrors a new setup has been built which can be accommodated in the existing 1.5-M vacuum coating plant at Kavalur. Al, Cr, & Au coating on strip mirrors upto 500x50 mm can be suitably done.

Imager & Sounder Sunshield Panels of INSAT-3D :

Two new optical polishing machines for mirrors upto 63cm diameter have been added to the existing facility to facilitate the polishing of the INSAT 3D Imager and Sounder Sunshield panels. These were specially designed and manufactured and supplied by LENSEL Optics, Pune. These machines are more versatile and have added features to accommodate INSAT 3D imager and sounder cooler sunshield fabrication and specular polishing. A new profilometer of Veeco make has already been procured and installed in

Metrology lab. of Photonics Division. The new facility will be used for the evaluation of the sun shield panels of the INSAT 3D program and Astrosat UVIT Optics. These require highly specular finish and roughness of the order of 15-20 Å.

102cm Telescope :

The figuring of the 102 cm telescope primary mirror is almost complete. The rms value has already reached 0.1 waves. Efforts are on to bring the rms value to 0.05 waves. In the mean time efforts is on to test the present 102cm telescope primary mirror using Shack Hartmann sensor in order to compare the performance of this mirror.

5.7 Computer Centre, Bangalore

The computer centre at Bangalore campus was equipped with an additional HP laserprinter to cater to the increased printing needs. A networked version of mathematica package was installed on the sun server for the benefit of scientific users. This could be used under LINUX,IRIX,and SOLARIS platforms. To provide a faster internet access and also to have redundancy, a high speed link has been proposed.It is expected to be available in the coming months. A 64K VSAT link is also proposed for Kavalur to replace the existing RABMN link.This new facility can provide internet access to Kavalur.

FACILITIES

6. Facilities

6.1 CREST

Experimental Facilities : A laboratory with clean-room environment has been developed at CREST, Hosakote, to do various laser-based experiments. Following lasers have been installed so far. BeamLokTM 2085 argon-ion laser from Spectra Physics (USA) is a high power (15W) cw laser. It can be operated in both multi-line (350-540nm) and single frequency mode. BeamLok is an active beam positioning system which when engaged, the output beam of the laser is locked on to a fixed reference point outside the cavity. If the beam drifts, active mirror actuators respond to restore the position. Optional Z-Lok accessory eliminates mode hoping and provides active cavity stabilization for single frequency operation. Single frequency operation is achieved by an etalon inserted in the cavity. Thus, if laser line width is changed from $\Delta \nu = 6$GHz to $\Delta \nu < 3$MHz, the coherence length increases from 50mm to 20m. High coherence length is very important feature for all the experiments involving the principle of interference. J-Lok option helps in reducing the low frequency jitter caused by water flow around the plasma tube.

Millennia TM V from Spectra Physics is a solid-state diode-pumped Nd:YVO4) cw laser. It offers high beam quality, beam pointing, and amplitude stability. Its closed cycle cooling system virtually eliminates low frequency optical noise (jitter). A simple menu driven control module provides an easy method of controlling and monitoring the system. This can be used as an ideal pump laser. Titanium doped sapphire (Ti: Sapphire) is a solid-state cw laser from Spectra Physics. Tunable laser action over a broad range at near infrared (750-950 nm) makes it an excellent substitute for the dye lasers. Ti:sapphire has broad absorption band in blue and green region. So the output of available argon-ion laser or Millennia solid-state laser can be used to pump this laser.

All the three lasers are mounted on a 1.5 x 3m, vibration isolation (Micro-g from TMC) table. Special design of the table prevents coupling of all the ground-based vibrations into the vibration sensitive experiments. Further work is in progress to develop various electronics and interface them with a computer for data acquisition and analysis.

6.2 Vainu Bappu Observatory

The design of the various subsystems like grating mount, prism mount, camera/ collimator mount of the echelle spectrograph for the Coude focus of the Vainu Bappu telescope was completed and the assembly and testing of the same was conducted at Bangalore as also at site. Fine tuning of the systems are going on.

A prism mounting arrangement, an add on facility to the existing spectro-polarimeter at the VBT was designed and fabricated.

Regular maintenance of the telescopes, instruments and other mechanical sub-systems were carried out at the observatory.

The axial support system of the primary mirror of the Vainu Bappu telescope was redesigned and the same was fabricated and installed in the telescope during period when the mirror was moved for the aluminising process. The new system has been found to be working satisfactorily and some of the problems faced in the earlier system like poor image quality at some orientations of the telescope has been overcome. A prototype load cell for measuring the load on the axial support was tested and studies conducted. Some changes in the design of the same has been noted and it is expected to be installed in the telescope axial supports during the next maintenance season.

6.3 Ultra-Violet Imaging Telescope (UVIT)

An Ultra-Violet Imaging Telescope which is expected to be launched by ISRO as part of the ASTROSAT, in about 5 years is being designed. The optical layout of the same has been finalised and the mechanical details are being worked out. This will be a twin telescope, each of 40 cm aperture and a cassegrain (Ritchey-Chrieten) system. The detectors are being designed and developed by Canadian collaborators.

Miscellaneous

A mount for the Global positioning system (GPS) for installation at IIA, Kodaikanal and a modified system for an already existing system at Hanle were designed and fabricated. Coordination was also done for the setting up of the GPS and seismograph facilities at Hanle and Kodaikanal.

7. Indian Astronomical Observatory

7.1 The 2-m telescope project

The development of Indian Astronomical Observatory, Hanle reached a critical phase during the year with the installation of the 2-m telescope, completion of all the necessary infrastructure, and completion of the enclosure for the 50-cm telescope of the Antipodal Transient Observatory. It is expected that the 2-m telescope, dome and first generation instruments will all be fully ready for user trials by the winter of 2001.

The Telescope : The 2-m telescope was shipped by M/s EOST, Tucson in 2000 June and reached the shores of Mumbai in the month of July. It cleared the customs in a week and was transported to Chandigarh by road escorted by IIA astronomers. The containers were destuffed at Chandigarh and loaded into IL-76 aircrafts provided by the Department of Defence under the supervision of astronomers of IIA. By this time, the Indus was in floods and the equipment had to wait for a week in Leh until the road was safe for its transport to Hanle. The telescope reached Hanle escorted by a team led by Prof. Cowsik in mid-August and the uncrating and installation work began immediately.

The telescope saw its first technical light on the night of 2000 September 26/ 27, and was witnessed by Prof. Yash Pal, Chairman of the Project Management Board. The first stage of commissioning activity concluded by mid-October. The telescope has been undergoing further commissioning tests thereafter. Some observations of targets of opportunity such as photometry of GRB 010222 and Mrk 421 were also undertaken in between tests of telescope, dome, instruments and remote operation.

The telescope is currently functioning without the autoguider and observatory server. These are expected to be delivered by the manufacturers and installed during the summer of 2001. Further finetuning of the telescope optics and electronic controls is also scheduled during that time.

The Enclosure and Dome : The erection of dome and enclosure was completed in time for the installaton of the telescope, together with all electrification. A power coupler designed and built by the Institute was installed to provide power to the dome shutters. This design avoids use of bus bars which are expensive, risky, and add to the total weight of the structure.

The software for automation of the dome was developed by the engineers of the Institute and was implemented with the help of an external agency. The dome drive is scheduled to undergo a modification to its wheel assembly during the summer of 2001 after which the dome automation software will be finetuned and integrated with the observatory software.

Focal Plane Instrumentation : Three first generation instruments are planned to be available on the instrument mounting cube:

- *Large Format CCD Imager*

A CCD imager was developed as the first light instrument in the laboratories of IIA. The imager uses a 2k X 4k SITe ST002AB thinned, back-illuminated and VISAR coated CCD device of 15 μm square pixels. The instrument underwent user trials in the month of October 2000 following which further finetuning is taken up in the laboratories of IIA. The next stage of user trials is scheduled during the summer of 2001. A 1k X 1k CCD unit by M/s Photometrics, Inc, has been lent by the VBO for use at the telescope in the interim period. The imager has been calibrated and used for observations of targets of opportunity as also tests on telescope pointing, tracking and image quality.

- *Hanle Faint Object Spectrograph Imager*

The HFOSC instrument was completed and tested at the Copenhagen University Observatory during December 2000. The CCD detector system for this instrument was integrated and tested during the following months. The filter wheel and calibration unit is currently under fabrication. The complete

instrument is expected to be shipped in July 2001 and installed at the telescope in September 2001.

• *NIR Camera*

The order for an NIR camera was placed with M/s IR Laboratories, Tucson, at the beginning of the year. The instrument was undergoing integration by the end of the year. It is expected to be shipped during the summer of 2001. Additional application software will be developed at IIA and integrated before the system is taken to Hanle and installed.

Remote Operation and Data Centre : The high-speed satellite link between IAO, Hanle and CREST, Hosakote worked reliably during this period at the current bandwidth of 1 MHz. The data from the telescope is routinely downloaded and copied periodically on tapes. The remote operation of the dome and the backup CCD imager was successfully tested in January 2001 and of the telescope in March 2001. Efforts to further finetune all related software and integrate the telescope, dome and instrument software, will continue into the next year.

Software has been developed for automatically archiving the raw CCD data and also preprocessed data from the telescope. Further tests of the software will be carried out when the user tests begin on the telescope and instruments during the winter of 2001.

Infrastructure : The SPV and diesel generators worked satisfactorily during the year. An additional 62.5 kVA diesel generator set was installed as a backup to the existing one at the base station. The electrical connections are complete to all the existing facilities at the peak as well as the base station.

LAN and telephone cables were laid to connect all the facilities at the peak as well as the base station. Computer network was energised and a telephone exchange was established interconnecting all facilities.

The liquid nitrogen plant functioned well with technical support from M/s Phillips India Ltd. Liquid was continuously available except for a brief period in November/December. Additional spares have been acquired to reduce the down-time of the plant even further. A turbomolecular pump was set up at the site to facilitate evacuation of the CCD dewars. Some facilities were developed for mechanical workshop support which include a mechanical lathe. Electrical, electronics and mechanical maintenance of routine nature can now be undertaken at the site itself.

The ground floor of the permanent laboratory at the base station was completed during the year and was inaugurated on 2000 September 25 by Prof. Yash Pal who named it Megh Nad Saha Astronomical Archives. The first floor is scheduled to be completed in the working season of 2001.

Manpower and Training : Minimal manpower was provided to the observatory through recruitment of 14 positions which included engineers, technical and non-technical maintenance staff. These positions were recruited through a special drive for ST candidates so as to provide opportunities for the local tribal candidates. One astronomer and one engineer posted at the site by IIA earlier continued to coordinate all the activities.

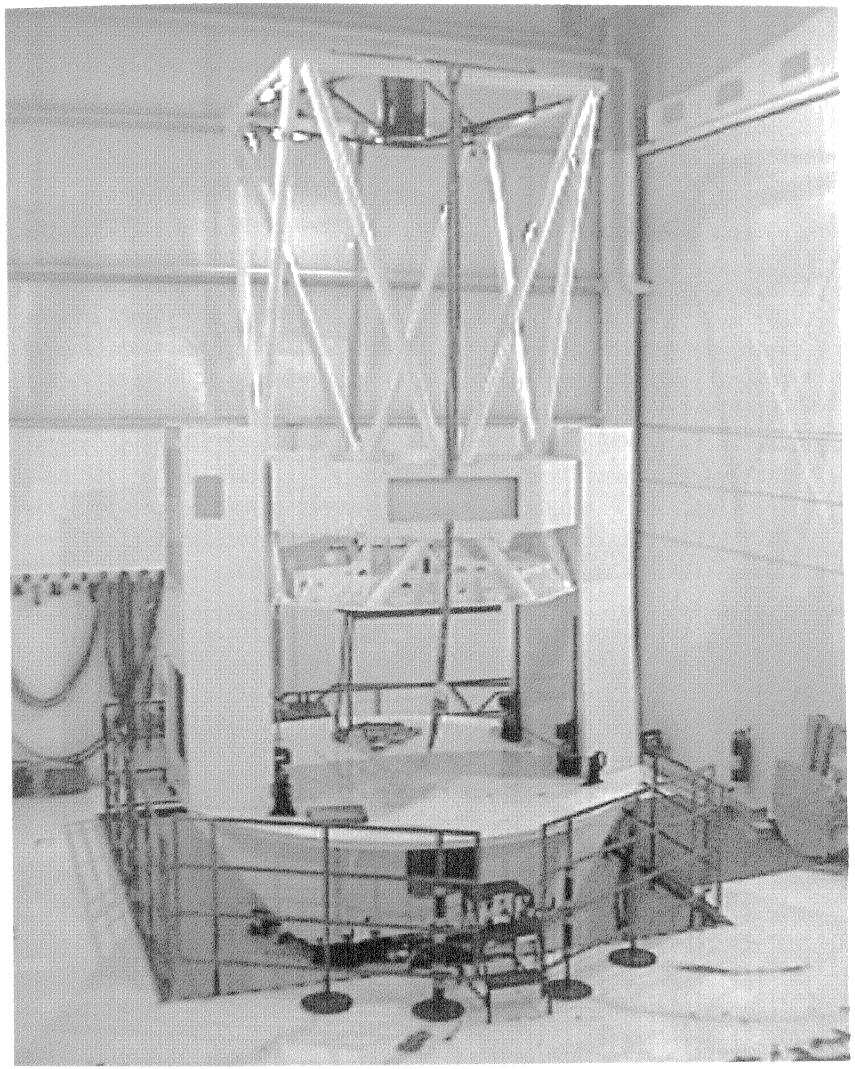
One student from Delhi visited IAO Hanle to undertake seeing and microthermal measurements. One engineer trainee worked at Bangalore to develop software for data archiving.

7.2 Other Activities

IAO has provided support to other scientific endeavours at the site initiated independently or jointly with IIA by other institutions. The major ones are described below.

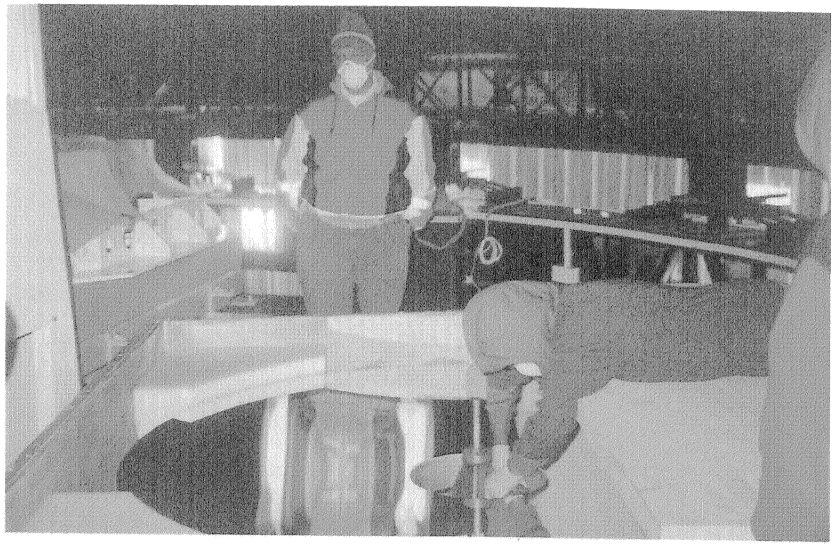
The enclosure for the 50-cm telescope of Antipodal Transient Observatory, which was designed, fabricated and erected by the engineers and technicians of IIA, was completed during this year. The two telescopes to be installed at Hanle and Arizona were also ready and are undergoing tests in Arizona.

The geodynamic deformation studies continued with a permanent GPS station and a broadband seismograph installed under the aegis of the DST. The Indian Institute of Tropical Meteorolgy conducted experiments to determine aerosol content at the site to provide background values for their measurements across the country. Experiments to measure the CO_2 content of the atmosphere and its seasonal variation at Hanle was initiated as an Indo-French collaborative project.

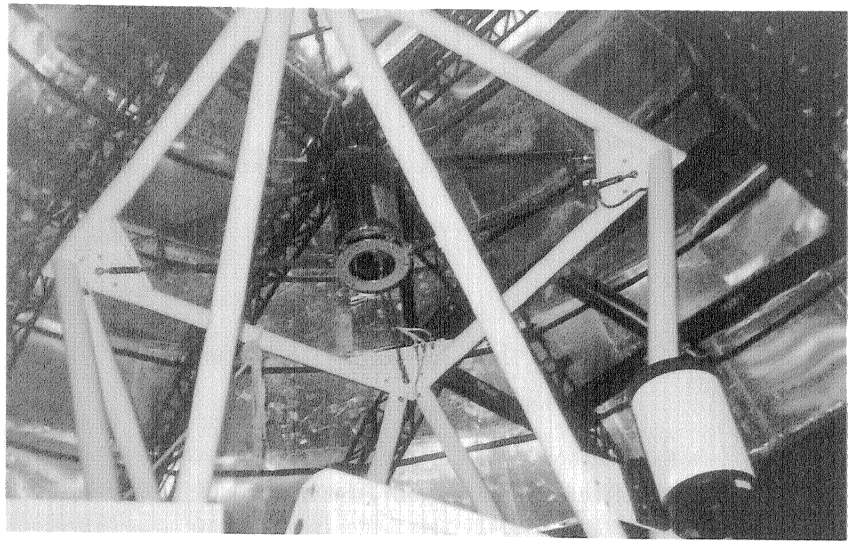


The 2m telescope before its shipment from Tuscon to India.

The 2m telescope in transit from Mumbai to Hanle, July - August 2000.



The 2m telescope in the process of its installation at Hanle, August 2000.



The automated 220-GHz radiometer operated jointly by the RRI, University of Tokyo and IIA, began to monitor the skies reliably providing information on atmospheric opacity at this frequency at an interval of 10 minutes round the clock. The winter observations showed that the opacity is less than 0.1 most of the time between December and March. This shows that the site has excellent potential for infrared and sub-mm wavelengths. The automated weather station continued to operate into its fifth year. The seeing monitor was operated occasionally to obtain estimates of atmospheric seeing at the site and also through the 2-m enclosure.

Hosakote Computer Centre : The computer centre has been equipped with a number of computer systems for facilitating control of 2 m. telescope,dome and optical imager.Image data archival facility for 2 m. data has also been provided.Systems have also been provided with packages like IRAF,STSDAS and Super Mongo for facilitating image data reduction. Systems have also been configured for E-mail,DNS service and internet access. To facilitate exchange of information between Hanle and Hoskote ,Video and audio conferencing facilities have also been set up. A 64 K Microwave link to STPI, Bangalore provides internet connection to Hosakote.E-mail facility is also available to Hanle through the high speed link.

Wide area network between Hanle and Hosakote : The LAN at Hosakote and Hanle were set up. The LAN comprises of 3 COM switches providing switched 100 MBPS ethernet connectivity between nodes.The LAN connects 2 m. proposed 50 cm. and Mead telescope buildings through CAT5 UTP cables at both Hanle and Hosakote. Routing to the WAN link is provided by CISCO 2501 routers.Presently about 36 nodes are provided at Hanle end and 24 Nodes at Hosakote end. All the nodes are provided with 100 MBPS ethernet cards for network connectivity. The WAN connectivity is through a satellite link with a 2 MBPS Transponder provided by ISRO and is a part of ISRO SPACENET. The communication equipment procured from TIW (U.S.A) incorporates 2 voice and 2 data channels. The connectivity provides Data,Video,Audio and Fax communication between Hanle and Hosakote.

Remote operation of the 2 m. telescope from Hosakote : A preliminary version of the telescope control software has been used to control the 2 m. telescope for positioning and focussing.The software for 2m. dome operation and the optical imager including filterwheel motion has been tried out for remote observation using VNC.(Virtual network Computing from AT&T).There is also a provision to monitor the guiding from Hosakote. The computer systems at both Hosakote and Hanle have also been tuned to optimize for bulk data transfer (ftp).The download speeds are approximately 80% of the maximum available speeds.Currently it takes about 25 seconds to download a 1k x 1k ccd image (2 Mb) and 200 seconds for 2k x 4k image from Hanle to Hosakote.These speeds are from a LINUX system to a Solaris Sun system. Better speeds have been obtained from Solaris to solaris (about 92%) on the SUN platform. A portion of the bandwidth is also used to monitor the movements of telescope and dome visually during observations or maintenance through video equipment at Hanle for the benefit of observers and technical persons at Hosakote.

MISCELLANEOUS

8. Miscellaneous

8.1 Library

The Library added 555 books during the year and subscribed to 157 journals. 46 of these journals can be accessed electronically. A few of the important journals are also available electronically at Hoskote Campus. 143 journals were bound during the year. The Library responded to 175 Inter library requests.

The Librarian served as a Consultant to the Committee for promotion of a network of Science Libraries in Chennai titled Science city which was organised by CLRI. The Library also organised a Bangalore science libraries group meeting, marked by the presentation of the paper 'Consortia Formation in India' at the meeting. Another representative from the Library was selected as a resource person in the workshop on the knowledge management network held at IIT Delhi during Dec. 2000. This was organised by Ministry of HRD. She was also invited by International Relations Committee of the Physics Astronomy and Mathematics division of SLA USA to be the chairperson of IRC for 2 years.

8.2 Student Affairs

Five new students joined the Ph.D. Programme at IIA - two in August 2000, and three in Junuary 2001. Eight students were trained under the 'Summer Students' programme during May - July, 2000.

Three students completed their doctoral work and submitted their thesis to Bangalore University : T. Sivarani worked on "A & F stars with circumstellar dust", under the guidance of Prof. M. Parthasarathy, and Pavan Chakraborty worked on "Investigations of dust from selected comets" under the supervision of Dr. R. Vasundhara.

S.P. Rajaguru was awarded the Ph.D. degree by IISc in 2000, for his thesis titled 'Radiative transfer and the dynamics of small-scale magnetic structures on the Sun'. It was done under the supervision of Prof. S.N. Hasan.

8.3 Collaborative activities with other institutions

Major collaborative activities were started with the following Institutes :

University of Calicut, Since March 1999 : mutual cooperation in the common interests of teaching and research in Astronomy and related subjects.

Copenhagen University Astronomical Observatory, Denmark, Since 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).

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

ISRO-Satellite Centre, Bangalore : Optical polishing of the sun shield panels of the INSAT-3D space imager and sounder has been continuing at the Photonics Division laboratory.

Observational Programmes with I-step : The STP group participated in the Sporadic-E (Es) Campaign held in Summer 2000 under I-STEP. Regular data acquisition in the monitoring mode continued with the experimental facilities in Kodaikanal Observatory (IPS42 ionosonde, HF Doppler Radar and magnetometer.

Centre for Mathematical Modelling and Computer Simulation (C-MMACS), Bangalore: 'Inverse modeling of broadband seismograms to determine the shear velocity structure beneath some geodynamically significant parts of the Indian continent'.

Laboratoire des Science du Climat et de L'Environment (LSCE), CEA, Saclay - Orme des Merisiers - France: 'Monitoring of carbon and green house gases concentration at Hanle, and inverse modelling of global fluxes'.

8.4 Official Language Implementation

All round efforts have been made to ensure successful implementation of the official language. Section 3/3 of the Official Language Act has been complied with, and administrative and other reports have been prepared bilingually. These include the Institute's Annual Report. Official circulars are brought out in Hindi. Letters received in Hindi are replied to in Hindi. Bilingual rubber stamps have been prepared for the Institute, including the new campus, the Iadian Astronomical Observatory, Hanle.

A program like 'Learn a Hindi word every day!' has been continued which is well received by the employees. Hindi divas is celebrated in the Institute.

Hindi Reference books have been made available to the staff members. Hindi software also is procured and it is in use.

8.5 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.

Housing facilities have been extended to many SC/ST and general category members. Assessments and promotions have been conducted for all categories at regular intervals as per norms.

The total staff strength of the Institute as on 31.3.2001 was 375. As per the orders of the Government, 65 posts in scientific and technical categories were exempted from the reservations. Out of the 298 positions, 46 members belonged to SC and 23 members belonged to ST, forming 14.84% and 7.42% respectively. The shortfall was due to retirements/deaths. Necessary recruitment action is underway to fill these positions.

A grievences committee is functional in the Institute to address grievances.

CONFERENCE REPORTS

The Third India Japan Seminar in Astronomy and Astrophysics :

The third Indian Japan Seminar in Astronomy and Astrophysics was organized by the DST between September 27-30 2000, and hosted by IIA at Leh. The seminar is an annual event and hosted in India and Japan in alternate years. Some of the collaborators in various individual proposals under the DST-JSPS collaborative programme meet and present seminars on their individual projects. The teams from individual countries are led by their respective coordinators in the field of Astronomy and Astrophysics. During the current year, the Japanese team was led by Prof. H. Shibai and the Indian team by Prof. R. Cowsik.

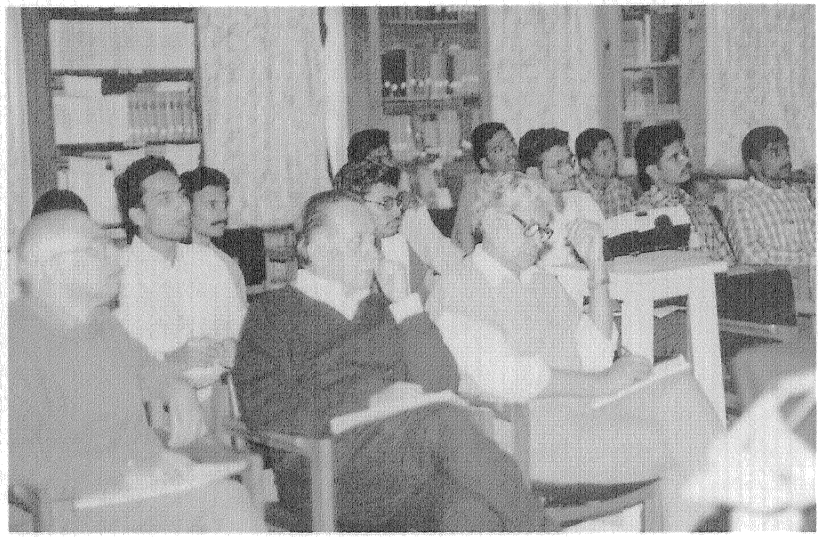
The seminar was inaugurated by Prof. Yash Pal, Chairman, Project Management Board of the 2-m telescope, Hanle, on 27 September 2000. There was a full day session on ongoing collaborations as well as future potential in the characterisation and utilisation of IAO site at Hanle, and also on the balloon-borne X-ray and infrared astronomy.

The participants visited the facilities at IAO, Hanle on 29 September and watched the night sky.

Summer School on Classical Mechanics :

A summer school on classical mechanics was conducted at Indian Institute of Astrophysics, Kodaikanal during June 05-21, 2000. Sixteen final M.Sc., and B.Sc., Physics students on an all-India basis were selected to attend the course. The course comprised of lectures and tutorials. The courses were on 1) Classical Dynamics, 2) Nonlinear dynamics and Deterministic Chaos, 3) Classical Electrodynamics, and 4) Special relativity. Lectures and tutorials were taken

by Professors N. Mukunda, I.I.Sc., Bangalore; V. Balakrishnan, I.I.T.M, Chennai; S. Govindarajan, I.I.T.M., Chennai; and T. Padmanabhan, IUCAA, Pune.



Personnel

Academic / Scientific / Technical Staff as on 31.3.2001 includes the following

Director: Ramanath Cowsik

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

Professor: B.P.Das, S.S.Hasan, D.C.V.Mallik, M.Parthasarathy, T.P.Prabhu, C.Sivaram, Ram Sagar *(on lien to SO, NainiTal)*, Jagdev Singh.

Head Photonics: A.K.Saxena

Sr.Principal Scientific Officer: A.V.Ananth

Scientist E: A.K.Pati, R.Rajamohan, A.V.Raveendran, K.K.Ghosh *(on lien to NASA, Marshel Space Flight Center, US)*, H.C.Bhatt, R.C.Kapoor, 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.

Sr.Research Scientist: B.Raghavendra Prasad

Principal Scientific Officer: V.Chinnappan

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

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 (Mechanical): P.M.M.Kemkar

Engineer (Civil): R.Ramachandra Reddy

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

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

Scientist B: B.S.Nagabhushana, K.Sundararaman, A.Subramanian.

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.

Scientist C: B.C.Bhatt

Engineer SC: M.P.Singh

Engineer B : Dorje Angchuk

Scientist : K.M.Hiremath

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, Tsewang Dorjai.

Librarian: A.Vagiswari

Asst.Librarian B: Christina Louis

Documentation Officer: 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

UGC Emeritus Fellow: N.Sankaran

Visiting Fellow: R.Ramesh, S.K.Sengupta, A.Goswami, R.Srikanth, M.Das, U.S.Kamath, P.S.Parihar.

SRF: S.P.K.Rajaguru, S.G.Bhargavi, S.Majundar, D.Suresh, R.Sridharan, K.P.Geetha, P.Chakraborty, Mangala Sharma, D.V.Lal, Rajalakshmi, B.S.Ramachandra, P.Manoj, P.Kharb, Geetanjali, M.Gopinath, C.Kathiravan.

JRF: R.K.Banyal, P.Shamila, K.V.P.Lata, G.A.S.Sundaram, S.Ambika, P,Mazumdar, B.K.Sahoo, M.Mukherjee, P.Ahmadi, R.M.C.Thomas, M.S.Rahaman, D.K.Jana, V.P.Kowshik.

JAP Students: S.Majumdar, S.Bhattacharyya, M.K.Nayak

APPENDIXES

APPENDIX A

Publications

In Journals

Angom Dilip Singh, Das B.P., (2001) J.Phys.B:At.Mol.Opt. Phys, **34**, 30891.
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Anupama G.C., Sivarani T., Pandey G. (2000), A&A, **367**, 506
Early time optical spectroscopy of supernova SN1998S.

*Arellano Ferro A., Giridhar S., *Mathias P. (2001), A&A , **368**, 250
Atmospheric abundances in post-AGB candidates of intermediate temperature

Aruna Goswami, Rao N.K., *Lambert D.L. (2001), The Observatory, (in press)
Emission-line spectra of XX Ophiuchi in 1996 and 1997

*Ashoka B.N., *Kumar Babu V.C., *Seetha S., *Girsh V., *Gupta S.K., Ram Sagar, *Joshi S., *Narang P., (2001), JAA, 22, 131.
Development of a three channel photometer for UPSO, Naini Tal

*Balaji K.R.S., Bhattacharjee P., *Mohanty S., *Nayak S.N. (2000) Pramana, **55**, 323
Signature of Dirac vs Majorana nature of neutrinos from HECR observations

*Bendick R.,*Bilham R.,Gaur V.K., et al.,(2001), Seismological Lett., 72, No.3.
The 26 January 2001 "Republic Day" Earthquake, India

Bhargavi, S.G., Cowsik, R. (2000), Ap. J. Letts., **545**, L77
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Origin of the highest energy cosmic rays : Hints to New Physics ?

Bhattacharya, J., *Pereda, E., Kariyappa, R., *Kanjilal, P.P. (2001), Solar Phys.,(in press)
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*Dewangan G.C., *Singh K.P., *Mayya Y.D., Anupama G.C. (2000), MNRAS, **318**, 309
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APPENDIX B

Miscellaneous

Invited Talks

R. Cowsik, 'Astronomy and Astrophysics Programme at Hanle' DST's Workshop on "Physical & Biomedical Studies at High Altitude", Darjeeling, June 20 - 22, 2000

R. Cowsik, 'Perspectives - Physics, Astronomy and Astrophysics' Symposium on Harnessing Science and Technology for the New Era' 70th Annual Session of the National Academy of Sciences, India, Allahabad, November 3 - 6, 2000

R. Cowsik, 'Direct Neutrino Mass Measurements' Neutrino 2001 & Rajaji Symposium, Chennai February 22, 2001

R. Cowsik, 'Measurement of G', SERC School on "Precision Physical Measurement & Measurement Science", National Physical Laboratory, New Delhi, December 7, 2000.

B.P. Das, "Table-Top Particle Physics",DAE Symposiuon on High Energy Physics",Hyderabad,Dec 2000.

B.P. Das, "Atomic Probes of Physics Beyond the Standard Model", International Conference on Perspectives in Theoretical Physics", Ahmedabad, Jan 2001.

B.P. Das, "The Nuclear Anapole Moment",National Conference on Atomic and Molecular Physics,Kolkata,Jan 2001.

Seminars

B.P. Das, "Parity Nonconservation in a Single Trapped and Cooled Ion" University of Mainz,Germany,Oct 2000.

B.P. Das, "Parity Nonconservation in a Single Trapped and Cooled Ion" University of Innsbruck,Austria,Oct 2000.

B.P. Das, "Parity and Time-Reversal Violation in Atoms",Calcutta University, Kolkata,Jan 2001.

B.P. Das, "The Nuclear Anapole Moment",Institute of Physics, Bhubaneswar, Jan 2001.

B.P. Das, "The Nuclear Anapole Moment",Utkal University, Bhubaneswar, Jan 2001.

Attendance / Participation

R. Cowsik, Neutrino 2001 and Rajaji Symposium, Chennai, Feb 21, 2001

R. Cowsik, Kodai School 'Classical Dynamics', June 2 - 7 2000

R. Cowsik, 9th Marcel Grossman Meeting, Rome, Italy, 2 - July 2000

S.S. Hasan, Solar Physics Division of the American Astronomical Society, Tahoe, (U.S.A.), June 16-19, 2001
National Workshop on Solar Physics, IUCAA, Pune, Dec. 6-10, 2000

K.P. Raju, IAU symp. 203, Manchester, UK, August 2000
Recent insights into the physics of the Sun and Heliosphere

J. H. Sastri, Tenth International Symposium on Equatorial Aeronomy (ISEA-10), Antalya, Turkey during May 17-23, 2000

J.H. Shastri, AGU Chapman Conference on 'Storm-substorm Relationship' held in Lonavala during March 12-16, 2001

A.K.Saxena attended Instrument Society of India Symposium and gave an invited talk on "Technology of Astronomical Telescope-Present and Future" at Bangalore on November 6th and 7th 2000.

A.K.Saxena attended the National Laser Symposium NLS 2000 at LASTEC New Delhi during December 213 to 15, 2000 and delivered an invited talk on "Adaptive Optics and Laser Beam Control for Missile Defense Systems.

Papers presentations in meetings

Anupama G.C.,
Automated Data Analysis in Astronomy held at IUCAA, 2000 October
IAO 2-m Telescope : Remote observations and pipeline data

Raju K.P., *Sakurai T., *Ichimot K.,
Recent Insights into the physics of the Sun and Heliosphere - Highlights from SOHO and other Space Missions, eds P. Brekke et al.
A spectroscopic study of the solar corona from Norikura and SOHO data

Vasundhara R., Chakraborty P.,
IAU Colloquium 181 - COSPAR Coll. II, Dust in the solar system and other planetary systems.
Investigations of colour of dust shells in the post perihelion CCD images of Comet Hole-Bopp (C/1995 01)

Awards

Kariappa R., Received the (Outstanding Scientist of the 21st Century Medal/Award), International Biographical Center, Cambridge, England (2000)

Positions/Fellowships

Hasan S.S., Smithsonian Fellowship of the Smithsonian Institution (Washington D.C., U.S.A.) for research at the Harvard Smithsonian Centre during 2000

Memberships

Bhatt H.C.
Served as Editor, Bulletin of Astronomical Society of India
Served as a member GMRT Time Allocation Committee
Served as a member SOC XX ASI Meeting at Gorakhpur

Krishan V., Member of the Indian National Committee for Scientific Committee on Solar - Terrestial Physics 2000.

Member of the Scientific Review Committee of the Centre for Plasma Physics, Guwahati.

Visits

G.C. Anupama, T.P. Prabhu and R. Srinivasan visited the Astronomical Observatory, Copenhagen University, in December 2000 for the integration and testing of the Hanle Faint Object Spectrograph Camera and its CCD detector system.

R. Cowsik, visited Institute of Astrophysics, Paris, Jan 18, 2001, and gave a talk on 'Dark Matter Halo of our Galaxy.

R.T. Gangadhara visited Dept. of Physics, Univ. of Varanasi, September 4-8, 2000 and gave a couple of lectures on 'Parametric Instabilities' during the refresher course on Space Plasmas.

K.N. Nagendra visited Observatoire de la Cote d'Azur, Nice, France, for three months during June-August 2000, to continue ongoing collaboration. Several important problems of polarized line transfer theory with French, Spanish, Swiss and Italian Scientists were discussed.

N.K. Rao visited the Department of Astronomy, University of Texas at Austin, USA in connection with collaborative programmes.

R.Ramesh visited Meudon Observatory, Paris for 3 months from December 2000 for joint work using the data obtained with the Nancay radioheliograph, Gaurbidanur radioheliograph and space based instruments like SOHO, WIND, etc.

V. Vishveshwara visited the Inter University Center for Astronomy and Astrophysics (IUCAA), April 2000

Teaching/Guidance

S.P. Bagare was a resource speaker at 'Workshop on Astronomical Photometry & Spectroscopy' organised by IUCAA and Bangalore University, Bangalore (BUB), in Jan 2001.

B.P. Das, Quantum Physics I (Aug-Dec 2000)

B.P. Das, Quantum Physics II (Jan-May 2001)

R.T. Gangadhara Gave a set of lectures on Polarization of Synchrotron Radiation and Pulsars for first year graduate school students April 2000. He also taught a course on "Data analysis in Experimental Physics", a mini course held at IIA for students on Measurements, Data and Interpretation, June 1-10 2000, and a full course of Radiative Processes in Astrophysics, for Graduate School students at IIA/JAP, August-December 2000.

S. Giridhar guided a summer school student Preethi Nair with her dessertation on 'Spectroscopic survey of large proper motion stars; A search for metal-poor stars' that was part of her M.Sc. final year requirment at IIT, New Delhi. Giridhar also gave an extended lecture course consisting of 14 lectures on 'Stellar atmospheres, chemical composition and other related topics' for JAP and IIA graduate students.

M.H. Gokhale gave a "Lecture Course in Solar Physics" (9 lectures) in Dept of Space Science, University of Poona, Pune, (March 2001).

A. Mangalam taught the Stellar Structure and Evolution aspects of the Stellar Astronomy core JAP course for the Fall semester, 2000 and guided a visiting student, Vikas Agarwal from Allahabad university on an 8 week project (May-June 2000) entitled "Field external to a rotating magnet".

K.N. Nagendra taught as 'Guest Faculty' at the newly founded "Birla Institute of Fundamental Research (BIFR)", Bangalore. Advanced Level Course work was given to the PhD students at IIA, apart from occasional lectures, and seminars.

P.M.S. Namboodiri was an examiner for M.Sc. Astronomy examination of Osmania University, Hyderabad.

Vishveshwara C.V. gave two tutorial lectures for the students at Birla Institute of Fundamental Research, Bangalore, titled 'Physics of the Sun.

Involvement with Scientific Community

R. Cowsik, continued to be the Secretary of the Commission 4 of the IUPAP, Area Coordinator for Astronomy, Astrophysics and allied topics & Member of the Council of the India Japan Science Council, Chairman of the Planning & Program Committee and Member of the Executive Committee of VITM, organized a parallel session on 'Sensitive Tests of Equivalence Principle' in 9th Marcel Grossmann Meeting, Rome, Italy 2 - 8 July 2000, organized the III India-Japan Seminar in Astronomy & Astrophysics, Leh/Hanle, Sep 27 - Oct 1, 2000

J. H. Sastri served as a Co-convener of a session at the Tenth International Symposium on Equatorial Aeronomy (ISEA-10) held in Antalya, Turkey during May 17-23, 2000. He also served as a Member of the National Science Steering Committee of I-STEP and Working Groups II and III.

J. H. Sastri served as Member of the Scientific Advisory Committee of Space Physics Laboratory (SPL) of VSSC (ISRO), Trivandrum.

Involment in educational programmes

C.V. Vishveshwara, In the capacity of the Vice Chairman of the Bangalore Association for Science Education (BASE) and Honarary Director of the Jawaharlal Nehru Planetarium, has arranged a number of science workshops for students at all levels, for teachers and for disabled children. He has also supervised the setting up of exhibitions called 'Science in Action'. He has written and directed a planetarium programme entitled, 'Time : The eternal stream'

S.S. Gupta, as the Course Director of a summer school in classical mechanics at Kodaikanal, Jun 5-21, 2000.

A.K. Saxena, A month's training was given to the 2nd year B.Sc. (Instrumentation) students of Jyoti Nivas College, Bangalore, as part of their course curricula

Non-technical Talks

Vishveshwara C.V., IUCAA, April 2000
S. Chandrasekhar: Leaves from an unwritten Diary

ASI Meeting, November 2000
The Masks of Space and Time

Indian Institute of Science, Bangalore, February 2000
Black Holes

Bangalore Science Forum, National College, Bangalore. July 2000
Accidental Astronomers.

Gokhale M.H., Walchand College of Engineering Sangli, December 31, 2000.
Mathematics in Solar Physics

M.H. Gokhale Shivaji University, Kolhapur, January 1, 2001
Mathematics in Solar System Dynamics

Popular Talks

Bagare S.P., Open House Day IIA, National Science Day, 28 Feb 2001
Solar corona

A.K. Saxena gave a talk on "Optical Telescopes- Concept and New Developments" at M.P.Birla Institute of Fundamental Research, Bangalore on January 20 2001.

Popular Article

Krishan V., Deccan Herald, May 2000
Zoom into Chandra

Colloquia and talks given by visitors

Imaging Fabry-Perot Spectroscopy
Abhijit Chakraborty
Tata Institute of Fundamental Research
Mumbai
18 April 00

Role of Multiple-Scattering in Probing the Lower Crust and Upper Mantle using Seismic Waves
Kabir Roy-Chowdhury, Utrecht University, Netherland
25 April 00

Study of High Mass Star Formation using Balloon-Borne Telescope
T.N. Rengarajan
Tata Institute of Fundamental Research
Mumbai
26 April 00

Aspects of Bi-Dimensional Spectroscopy with Optical Fibres
C. Vanderriest
Observatoire de Paris-Meudon
27 April 00

Energy Spectra and Transfers in Magneto- Hydrodynamic Turbulence
Gaurav Dhar
IIT, Kanpur
19 May 00

X-Ray Multilayer Optics for Astronomy Applications, G.Lodha
Centre for Advanced Technology, Indore
29 May 00

Astronomical Activities at INPE, Brazil,
Hanumant Sawant
INPE, Brazil
30 May 00

Neutrinos and Cosmology
Urjit Yajnik
IIT, Mumbai
26 June 00

The Magnitude Distribution of First-ranked Cluster Galaxies
Suketu Bhavsar
Univesity of Kentucky, USA
20.6.00

Early Science Results from Fuse
John Hutchings
Dominion Astrophysical Observatory
Victoria, Canada
21 June 00

Relics of the Microsecond Universe-Quark , Hadron Phase Transition
Bikash Sinha
Saha Institute of Nuclear Physics, Calcutta
25 Aug 00

Issues in Statistical Mechanics of Gravitating Systems
T.Padmanabhan
Inter-University Center for Astronomy & Astrophysics
Pune
13 Oct 00

Electron Attachment to Excited Molecules
V.S.Ashoka
Tata Institute of Fundamental Research
Colaba, Mumbai
17 Oct 00

GRS1915+105 : A Strange Microquasar in our Galaxy
Sandip K. Chakrabarti
S.N. Bose National Centre for Basic Sciences, Calcutta
12 Dec 00

Cosmic Ultra-High Energy Neutrinos
Raj Gandhi
Harish-Chandra Research Institute, Allahabad
15 Dec 00

TeV Emission from Gamma Ray Bursts ?
Results from the Milagro Gamma Ray Telescope
Gaurang B. Yodh
Univ. of California Irvine, USA
19 Dec 00

Understanding Pulsars
Wolfgang Kundt
Univ. of Bonn, Germany
26 Dec 00

Radio Observations of High Energy Solar Flares
M.R.Kundu
Univ. of Maryland, USA
5 Jan 2001

Status of G-Mode Detections on Ulysses, Voyager, and ACE
David J.Thomson
Bell Labs, USA
12 Jan 2001

The Physics of the Solar Chromosphere :
Deductions from Empirical Models
Wolfgang Kalkofen
Harvard-Smithsonian Center for Astrophysics
USA
13 Feb 2001

Diagnostics with Scattering Polarization
Dominique M. Fluri
Institute of Astronomy
Switzerland
27 Feb 2001

Current Status of Subaru Telescope
Yoichi Itoh
Kobe Univ., Japan
16 Mar 2001

Beyond the GeV Domain : Gamma-ray Astrophysics
using Ground-based Instruments
Reshmi Mukherjee
Columbia Univ., USA
20 Mar 2001

Spectroscopy - A Bridge Between Sky and the Earth
S. Civis
J. Herjrosky Instut of Physical Chemistry
Czech Republic
22 Mar 2001

Importance of Observation of X-ray Polarization
from Cosmic X-ray sources
H.Sakurai
Yamagata Univ., Japan
27 Mar 2001

Pancharatnam, Bargmann and Berry Phases
N.Mukunda
Centre for Theoretical Studies
Indian Institute of Science, Bangalore
27 Mar 2001

Cosmic Evolution of QSOs
John Hutchings
Dominion Astrophysical Observatory
Victoria, Canada
28 Mar 2001

APPENDIX C

Vainu Bappu Observatory

Time Allocation during 2000-2001

I. VBT		Total No. of Proposals received for 236 cm Telescope	48
	a.	Total No. of Spectroscopic Proposals received for 236 cm Telescope	25
	b.	Total No. of Photometric Proposals received for 236 cm Telescope	23
	c.	Total No. of Nights requested for 236 cm Telescope	337
	d.	Total No. of Nights requested for Spectroscopic work	175
	e.	Total No. of Nights requested for Photometric Work	162
II. Zeiss		Total No. of Proposals recieved for 102 cm Telescope	32
	a.	Total No. of Spectroscopic Proposals received for 102 cm Telescope	13
	b.	Total No. of Photometric Proposals received for 102 cm Telescope	19
	c.	Total No. of Nights requested for 102 cm Telescope	258
	d.	Total No. of Nights requested for Spectroscopic work	120
	e.	Total No. of Nights requested for Photometric Work	138

Sky conditions at Vainu Bappu Observatory

Year	Month	Spectroscopic Hours	Photometric Hours
2000	April	170	11
	May	118	9
	June	57	3
	July	36	0
	August	23	0
	September	40	0
	October	95	32
	November	100	14
	December	151	66
2001	January	156	32
	February	273	93
	March	271	76
	Total	1436	336

Sky conditions at IAO, Hanle

Year	Month	Photometric (night hrs)	Spectroscopic (night hrs)	Useless (night hrs)	Total (night hrs)
2000	April	158	168	72	240
	May	116	140	77	217
	June	70	110	100	210
	July	26	64	153	217
	August	171	205	43	248
	September	157	231	39	270
	October	306	310	–	310
	November	144	252	78	330
	December	249	288	533	341
2001	January	185	252	89	341
	February	202	239	41	280
	March	132	213	66	279
	Total	1916	2472	811	3283

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
2000	April	26	26	21	28	–	7	13	8	–
	May	27	27	22	27	–	2	18	6	–
	June	11	11	6	13	–	1	11	1	–
	July	11	10	4	14	–	1	12	1	–
	August	7	7	1	7	–	–	4	2	1
	September	13	14	–	15	–	2	6	6	1
	October	13	13	3	19	–	1	15	3	–
	November	13	12	–	16	–	3	10	3	–
	December	20	20	16	23	–	8	15	–	–
2001	January	17	17	12	20	–	5	9	5	1
	February	24	26	24	26	–	7	18	1	–
	March	29	29	25	29	2	6	19	2	–
	Total	211	212	134	237	2	43	150	38	3

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	5	> 5 Poor
2000	April	26	–	–	–	26	–	–	–	–	–
	May	18	–	–	3	15	–	–	–	–	–
	June	13	–	–	1	12	–	–	–	–	–
	July	13	–	–	1	12	–	–	–	–	–
	Aug	4	–	–	–	4	–	–	–	–	–
	Sep	13	–	–	–	13	–	–	–	–	–
	Oct	15	–	1	–	13	1	–	–	–	–
	Nov	12	–	1	–	10	1	–	–	–	–
	Dec	21	–	2	6	9	2	2	–	–	–
2001	Jan	13	–	–	–	12	–	1	–	–	–
	Feb	23	–	–	–	20	–	1	–	2	–
	Mar	29	–	1	–	26	–	2	–	–	–
	Total	200	–	5	11	172	4	6	–	2	–

APPENDIX D

AUDITORS' REPORT

We have audited the attached Balance Sheet of the "THE INDIAN INSTITUTE OF ASTROPHYSICS", BANGALORE, as at 31st March, 2001, 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, 2001.

AND

ii) In the case of Income and Expenditure Account of the Surplus for the year ended 31st March, 2001.

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

September 12, 2001

PLAN

RECEIPTS AND PAYMENTS ACCOUNT UNDER PLAN AND OTHERS FOR THE YEAR 31 MARCH 2001

PREVIOUS YEAR Rs.	RECEIPTS	SCHEDULE	AMOUNT Rs.
1,31,18,807	Opening balance		1,13,95,620
20,27,23,531	Grants-in-aid	1, 1A & 1B	21,20,53,173
4,19,00,612	Advances to Suppliers, Credits/Adjustments(net)	2	4,73,71,151
25,77,42,950	Total		27,08,19,944

PREVIOUS YEAR Rs.	PAYMENTS	SCHEDULE	AMOUNT Rs.
6,78,28,428	Recurring Expenditure	3	6,63,05,252
3,05,94,839	Non-Recurring Expenditure	4	4,24,18,655
69,03,259	Expenditure out of Grants/ Assistance from other Government Agencies	5	1,22,12,521
14,10,20,803	Deposit and other items	6	13,11,58,827
1,13,95,620	Closing balance	23	1,87,24,688
25,77,42,950	Total		27,08,19,944

(Closing balance 1,87,24,688/- 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, 2001

PREVIOUS YEAR Rs.	RECEIPTS	SCHEDULE	AMOUNT Rs.
1,332	Opening balance		5,137
2,87,00,000	Grants-in-aid	7	3,16,00,000
25,868	Salary Recoveries (Net)	8	21,191
32,52,479	Miscellaneous Receipts	9	28,01,922
3,19,79,679	Total		3,44,28,250

PREVIOUS YEAR Rs.	PAYMENTS	SCHEDULE	AMOUNT Rs.
3,19,27,023	Recurring Expenditure	10	3,43,74,710
47,519	Non-Recurring Expenditure	11	43,879
5,137	Closing balance	23	9,661
3,19,79,679	Total		3,44,28,250

Sd/-
SR. FINANCE & ACCOUNTS OFFICER

Sd/-
ADMINISTRATIVE OFFICER

Sd/-
DIRECTOR

Place : Bangalore
Date : 12-09-2001

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

PLAN

INCOME AND EXPENDITURE ACCOUNT UNDER PLAN FOR THE YEAR ENDED 31 MARCH, 2001

PREVIOUS YEAR Rs.	INCOME	SCHEDULE	AMOUNT Rs.
19,00,00,000	Grants-in-aid	1	19,00,00,000
30,74,383	Interest on bank deposit	1A	40,00,608
19,30,74,383	Total		19,40,00,608

PREVIOUS YEAR Rs.	EXPENDITURE	SCHEDULE	AMOUNT Rs.
3,47,93,161	Salaries and Allowances	15	3,28,96,124
3,34,24,985	Operational expenses	16	3,33,23,775
12,48,56,237	Excess of Income over Expenditure		12,77,80,709
19,30,74,383	Total		19,40,00,608

NON-PLAN

INCOME AND EXPENDITURE ACCOUNT UNDER NON-PLAN FOR THE YEAR ENDED 31 MARCH, 2001

PREVIOUS YEAR Rs.	INCOME	SCHEDULE	AMOUNT Rs.
2,87,00,000	Grants-in-aid	7	3,16,00,000
14,53,185	Miscellaneous Receipts	12	7,85,787
3,01,53,185	Total		3,23,85,787

PREVIOUS YEAR Rs.	EXPENDITURE	SCHEDULE	AMOUNT Rs.
2,54,02,735	Salaries & Allowances	13	2,83,24,778
37,83,884	Working expenses	14	38,98,950
9,66,566	Excess of Income over Expenditure		1,62,059
3,01,53,185	Total		3,23,85,787

Sd/-
SR. FINANCE & ACCOUNTS OFFICER

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ADMINISTRATIVE OFFICER

Sd/-
DIRECTOR

Place : Bangalore
Date : 12-09-2001

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

BALANCE SHEET AS AT 31 MARCH, 2001

PREVIOUS YEAR Rs.	SOURCES OF FUNDS	SCHEDULE	AMOUNT Rs.
69,39,35,555	Capital Funds	17	82,17,16,264
2,44,43,260	General Fund	18	2,46,05,319
1,57,69,157	External Funds for the Projects	19	2,14,76,723
17,78,269	Sundry Creditors	20	25,23,510
73,59,26,241	Total		87,03,21,816

PREVIOUS YEAR Rs.	APPLICATION OF FUNDS	SCHEDULE	AMOUNT Rs.
42,92,77,129	Fixed Assets (at cost)	21	47,37,44,510
29,52,48,352	Current Assets, Advances and Deposits	22	37,78,42,957
1,14,00,760	Cash and Bank Balances	23	1,87,34,349
73,59,26,241	Total		87,03,21,816

Sd/-
SR. FINANCE & ACCOUNTS OFFICER

Sd/-
DIRECTOR

Sd/-
ADMINISTRATIVE OFFICER

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

Place : Bangalore
Date : 12-09-2001