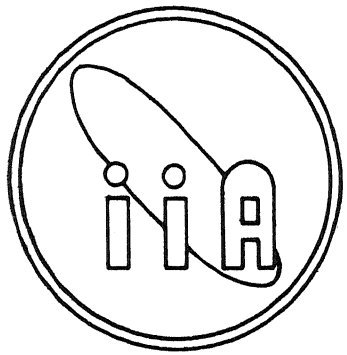
Indian Institute of Astrophysics

Academic Report 1995 - 96

INDIAN INSTITUTE OF ASTROPHYSICS



Academic Report
1995 — 96

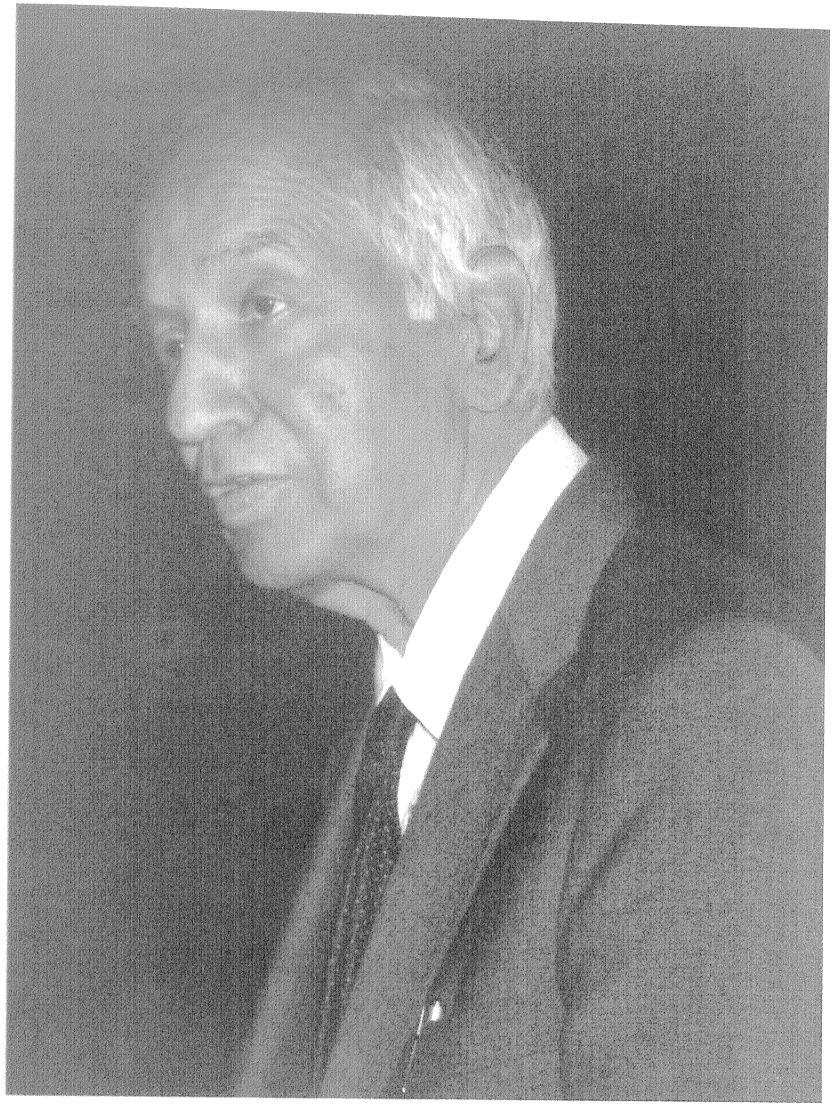
Editor :
P. Venkatakrishnan

Manuscript Editor :
Sandra Rajiva

Front Cover : View from the summit of Hoskote Campus
Back Cover : Approach to the Summit

Printed at : Vykat Prints, Airport Road Cross (Opp. ISRO), Bangalore - 560 017

CONTENTS



Professor Subrahmanyan Chandrasekhar
Nobel Laureate
Honorary Fellow, IIA
(b. 19 October 1910 – d. 21 August 1995)

GOVERNING COUNCIL

Prof. B.V. Sreekantan Radhakrishnan Professor National Institute of Advanced Studies Indian Institute of Science Campus, Bangalore	Chairman
Prof. P. Rama Rao Secretary (until 30 June 1995) Department of Science and Technology New Delhi	Member
Prof. V.S. Ramamurthy Secretary (from 1 July 1995) Department of Science and Technology New Delhi	Member
Mr. S.B. Krishnan Joint Secretary & Financial Advisor Department of Science & Technology New Delhi	Member
Dr. K. Kasturirangan Chairman, Space Commission and Secretary, Department of Space Bangalore	Member
Prof. I.B.S. Passi Professor, Department of Mathematics Punjab University, Chandigarh	Member
Prof. Yash Pal Chairman, Steering Committee Inter-University Consortium for Educational Communication, New Delhi	Member
Prof. S.K.Sikka Head, High Pressure Physics Division BARC, Trombay, Bombay	Member
Prof. G. Swarup Director, GMRT Project NCRA, Poona University Campus Ganeshkind, Pune	Member
Prof. Ramanath Cowsik Director Indian Institute of Astrophysics, Bangalore	Member
Mr. M. Ramani Controller Indian Institute of Astrophysics, Bangalore	Secretary to Council

HIGHLIGHTS

1. The total solar eclipse of 24 October 1995 was successfully observed, both from the ground and from aboard an aircraft of the Indian Air Force.

2. Uninterrupted monitoring of the sky conditions at Hanle was continued for the second consecutive year. A 1200 baud link was established between Bangalore campus and Hanle. A guest house for accomodating the observers was built.

3. As part of the Institute's goal towards building a bigger telescope, a 2 metre telescope project was initiated with T.P. Prabhu as the Project Manager.

4. Professor Sir Hermann Bondi visited the Institute and became the third Honorary Fellow of the Institute.

5. The Hoskote campus saw more development.

6. A 4 CPU Silicon Graphics Power Challenge computer was acquired to boost the number crunching capabilities. A reliable radiolink was established to the ERNET hub, thereby increasing the Institute's connectivity to the Internet.

7. A generous funding during the current year enabled all scientific groups of the Institute to make substantial improvements to their facilities.

8. The Institute contributed to the INSAT project in the task of polishing the last set of sun shield panels for the INSATII E.

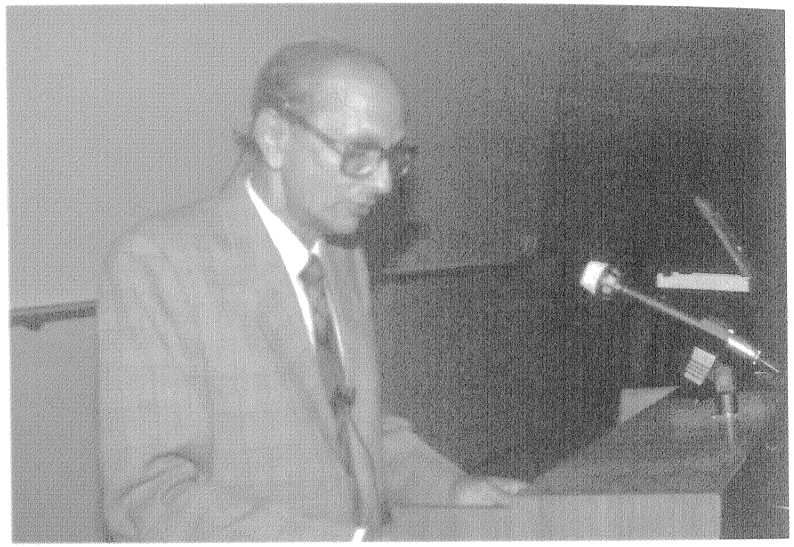
9. Two comets (Hale-Bopp and Hyakutake) appeared in the night sky and were thoroughly investigated. Preparations are afoot to observe Hale-Bopp in a big way in 1997.

10. The India-Japan cooperation in astronomy continued to flourish with important scientific findings and ideas for further work resulting from this cooperation.

11. A lot of scientific results accrued from the work done by the Institute's scientists as evidenced by more than 90 publications.

12. Some of the scientists received awards for their accomplishments. R. Cowsik received the Third World Academy Award for basic sciences in 1995. R.K. Kochhar was made a Jawaharlal Nehru Fellow, in 1996. C. Sivaram received an honorable mention at the May 1995 competition of the Gravity Research Foundation. R. Rajamohan, J.C. Bhattacharyya, A. Paranjpye, V. Moorthy, and R. Vasundhara received in January 1996 the Astronomical Society of India Medals for their earlier discovery of the asteroid "Ramanujam". J.C. Bhattacharyya received the Aryabhata medal awarded by the Astronomical Society of India in 1996. Sudeshna Sinha was awarded the associateship of ICTP, Italy for five years.

Professor Sir Hermann Bondi, Honorary Fellow of the Institute discussing with Professor Ramanath Cowsik.



Professor S. Ramaseshan delivering the tenth Bicentennial Commemorative lecture.

THE YEAR IN REVIEW

The Institute was the recipient of a high level of funding for the year under review. As a result, the various scientific groups could plan for significant improvements in their facilities. The absorption of these funds was done using the existing administrative infrastructure, thereby reaffirming the ability of this infrastructure to handle large projects.

The planning and execution of a large number of experiments to observe the total solar eclipse on 24 October 1995 demonstrated the ability of the Institute to operate in a coherent manner. Personnel from different disciplines were coopted to help the solar observers. The involvement of the Indian Air Force to conduct the nation's first set of airborne experiments was a unique event. The facilities of the National Remote Sensing Agency were utilised for the rapid dissemination of the eclipse pictures to the media and other agencies. The preliminary results were presented in a national symposium held in February, 1996. The meeting was very successful in promoting avenues for mutual sharing of the data obtained by various groups in the country, involving a broad spectrum of diverse areas from nuclear physics to radio astronomy.

The development of Hanle, near Leh, into a high altitude site for astronomical observations has seen steady progress. The site monitoring activity has continued unhindered for the second consecutive year and has shown stable conditions compared with the previous year. Crucial infrastructural facilities like accomodation for the observers and direct communication links with Bangalore were established.

The detailed project report for a high altitude infrared/optical telescope was completed and discussed in a meeting involving various national agencies. One of the recommendations that emerged was to deploy a 2-m class telescope at Hanle. A good beginning has been made during the year towards the realisation of this task.

The year ended on an optimistic note when Prof Sugimoto held a special session on possible Himalayan sites at the second India-Japan Seminar on Astronomy, held at Tokyo, and highly recommended the Hanle site as one of the best high altitude sites in Asia.

The stream of distinguished visitors to the Institute has remained unabated. Academic activity in the form of seminars and colloquia increased during the year, with a notable involvement of a larger number of younger people. The students programme has continued with great success.

The computer center received several additions, including a Silicon Graphics Power Challenge, that can provide major support to a host of theoretical problems. The connectivity to the outside world has also improved via a reliable radio link to the ERNET hub. A large number of individual scientists were also connected to the LAN by means of personal computers, which can improve productivity.

Professor Sivaraj Ramaseshan delivered the Tenth Bicentennial Commemorative Lecture on "Chandrasekhar - Some Remiscences". It was a powerfully emotional lecture, that served to remind us of our great loss when Professor Chandrasekhar breathed his last on August 21, 1995. We can offer no better homage than to re-dedicate ourselves to our commitment towards the highest standards in scientific research and ethics.

A brief description of the important scientific work done during the year follows.

SUN AND THE SOLAR SYSTEM

1.Solar Physics: The Institute has been regularly launching solar eclipse expeditions to various corners of the world. This time the eclipse was visible from India. The previous such occasion was on 16 February 1980. Fifteen years have brought on a virtual revolution in observing technology. A massive, Institute-wide effort was put up to observe the phenomenon. Keeping in view the weather pattern over the last 30 years and after the survey of the predicted path of totality, two places, Neem Ka Thana in Rajasthan and Kalpi in Uttar Pradesh were selected to set up camps. Since the camps were at remote places,

careful preparation had to be made to provide logisitc and other infrastructural support. Much before the eclipse, the workshops and laboratories of the Institute were busy fabricating the required instruments. After the eclipse, several people analysed the data and the preliminary results were presented at a special national meeting arranged at the Institute. There were 10 experiments conducted on the ground and video pictures of the event were even obtained from aboard an aeroplane of the Indian Air Force. A pleasant byproduct of the latter exercise is the offer of more help from the airforce for the next eclipse observable from India (in 1999). An interesting result from one of the ground based experiments is the detection of rapid oscillations in the corona. The analysis of the large amounts of the data from the several experiments is still in progress.

Several calculations of large scale processes on the sun have been made, e.g. relating the torsional oscillations seen in sunspot movements with the torques produced by solar system dynamics and models of large scale magnetic fields based on plasma flow like rotation and meridional flow in the interior of the Sun, even leading to observable patterns of the large scale coronal magnetic fields. Some definite changes were also seen in the average brightness of tiny points seen in the light of singly ionised Calcium, that varied in step with the eleven year sunspot cycle.

On more local scales, modern concepts of turbulence theory were used to predict some properties of the small bubbles called granulation seen on the sun's surface. The squeezing of small magnetic flux tubes by the solar oscillations was found to increase the internal energy of these tubes. A model for a coronal mass ejection was proposed based on upsetting of flow equilibrium within helmet streamers. Detailed studies of the predicted line intensity ratios based on atomic physics were prepared which can be used along with data from the recently launched SOHO satellite to obtain precise values of temperature and density of the solar corona. Analysis of oscillations of chromospheric bright points showed that the period of oscillations decreased with height. Analysis of the HeI 1083 nm line showed that HeI excitation must take place in tiny pockets of the solar atmosphere.

2. Solar Terrestrial Physics: The first direct experimental evidence for downward flow of ionospheric plasma produced by a disturbance in the Earth's magnetosphere was recorded at three stations, including Kodaikanal. The changes caused by the solar eclipse of October 24 1995 on the equatorial ionosphere were also studied. In another study, it was found that geomagnetic storms became more probable whenever a coronal hole on the sun grew in size, extending down towards the solar equator.

3. Solar System Studies: The analysis of several images of Comet Hale-Bopp, obtained in November 1995 using the Vainu Bappu Telescope at Kavalur, shows a maximum in the ejection of dust at the local noon of the comet, i.e. the place on the comet that is exactly facing the sun. Another comet, Hyakutake, showed interesting jet like features originating from its central portion called the coma. Spectroscopic analysis shows that the coma has a lot of dust, while the tail of the comet is lit up by emissions from molecules.

STARS AND STELLAR SYSTEMS

1. Stars: The spectrum of DY Cen, one of the only three known hot R CrB stars, showed changes in radial velocity, disappearance of emission components of CII lines, and change over to a P-Cygni profile shape in the high excitation HeI line. A study of chemical abundances of a few RV Tau variables has revealed that these are not metal poor, as thought of earlier, but that the metals are locked up in dust grains. Another star, FG Sge, was seen to be transforming into a R CrB star. The strength of the absorption line of singly ionised Calcium near 850 nm was found to be related to the fundamental properties of a star like its luminosity and metallicity, while the deviation from this general law was found to be related to the strength of stellar activity. Circumstellar material was also inferred to exist in a group of 30 A stars from the detection of anomalous polarisation in the light of these stars. The Murchison meteorite was analysed with different techniques to get some

clues about the formation of dust grains in the outer environments of stars. It seems likely that the grains were formed at high densities from a mixture of material in the inner shells of such stars with material in their carbon rich outer zones. The birth of a double star was studied theoretically to reveal a preferred separation of the binary components similar to what is actually observed in double star distributions.

2. Galaxies: Three compact groups of galaxies, which have been known to show evidence of hot gas that emits x-rays and cools by flowing out from the hot region, were imaged in the light of H-alpha , and were seen to have H-alpha emission (that comes from relatively cooler gas). A detailed study of the Sersic Pastoriza galaxy NGC 2903 has shown that there could have been more than one burst of star formation in small regions at the centre of the galaxy, while there is evidence for only one burst of star formation in an outer ring surrounding the nucleus. In a study of four star clusters, namely, NGC 1711, NGC 2004, NGC 2164 and NGC 2214, it was seen that the penetration of bubbles of convective gas into the stable regions above the convective core of the star, is an important process in the evolution of stars.

3. Active Galactic Nuclei: A study of the x-ray spectra of a sample of quasars with strong central radio emission supports the view that there is a single mechanism that produces both x-ray and radio emission, but an additional process seems necessary to explain the x-ray spectra properly. Imaging of such quasars in the light of ionised oxygen at the VBT, has shown the existence of regions of hot gas around these quasars, a result which also supports the view of a single mechanism for x-ray and radio emission. Strong polarisation in visible light was detected in a group of highly variable x-ray quasars (called blazars).

THEORETICAL ASTROPHYSICS

1. Early Universe: The recent observational results from the COBE experiment have been used to provide limits to some of the quantities that are used in the various theories of the early universe. At some stage in the evolution of the early universe, clumps of quarks (constituents of elementary particles) could have changed into large clumps of matter. The interaction of neutrinos with these clouds has been calculated. The results, when compared with the primordial abundances of the chemical elements, puts severe limits on the initial density of quark nuggets at the time of their formation.

2. Galaxies: Computer experiments on the interaction of two galaxies of nearly equal mass has shown that the brightness of the objects resulting from such encounters are related to their sizes. The experiments for galaxies of unequal mass were performed on the GRAPE supercomputer that was bought under the India-Japan cooperation on science and technology, and the results of these experiments are being analysed. The effect of a novel plasma process called Cerenkov-Raman radiation was used to explain the peculiar shapes of the infrared spectrum of active galactic nuclei. A new explanation for the extended rotation of galaxies has been proposed that uses modern theories of turbulence, and which does not require the presence of dark matter. On the other hand, the observed rotational behaviour of our own galaxy, viz., the Milky Way galaxy, has been modelled to provide information on the spread in velocities of dark matter particles, as well as on their density at the central regions of our galaxy.

3. Blackholes: A study of the natural modes of oscillation of blackholes subject to external influences shows that the fundamental mode is always related to the properties of the blackhole, while the higher harmonics show the effect of the external influence. The theory of strings was used to study the loss of information in an object when it collapses into a blackhole. It was seen that the time taken for information to diffuse out of the object is proportional to the cube of its mass.

4. Neutron Stars and Pulsars: The effect of rapid rotation of a neutron star on accretion of matter and on the resulting x-ray emission, was studied. It was found that this decay of the magnetic field on the surface of a neutron star depends very much on the composition of the matter which forms the outer crust of the neutron star. The bending of light in

the strong gravitational field near a pulsar was used to explain the detailed shape of the pulses emitted by the pulsar, while aberration of light was used to measure the angle of inclination of the pulsar's axis of rotation.

5. Radiative Transfer: Several calculations on the transfer of radiation were completed, for example, the transfer of high energy photons in the range of 1-125 KeV, the line profiles emerging from close binary stars, the asymmetric line profiles from active galactic nuclei models, etc. A new operator perturbation method for transfer of polarised light in spectral lines was tried out that can do calculations at great speed. The infrared spectra from the dust shells of the star called R CrB has been modelled. It was shown that correlated scattering is a better description for the transfer of radiation in resonance lines. A very efficient method was worked out for computing the effects of Compton reflection. The modifications produced in the polarisation of light as a function of wavelength in a spectral line, by sound waves travelling in the light emitting medium, were calculated.

PHYSICS

A detailed study of the origin of charge and mass of an elementary particle in terms of the geometrical properties of space-time gave new insights into the universal nature of particle charge, and the discrete nature of particle mass spectrum. Even neutral particles like neutrinos were shown to be capable of emitting radiation when they pass through matter. The expected results for experiments, that look for parity non-conservation in atoms, have been theoretically worked out for the element Ytterbium, both in its atomic and singly ionised state. Similar calculations have also been performed for singly ionised Barium. A new form of collective behaviour was seen in the non-linear dynamics of globally coupled systems. An experiment in quantum optics demonstrated the violation of some principles in quantum mechanics by showing the simultaneous presence of wave and particle properties, while another experiment to detect parity non-conservation in atoms is being organised.

INSTRUMENTATION AND FACILITIES

1. Electronics: Improvements made on the functioning of the VBT include, installations of safety devices to sound a warning buzzer whenever any part of the telescope comes within 1 metre of any obstacle, introduction of a cordless handset that can control the telescope remotely, from any place in the observing floor, and installation of a Photometrics CCD (1024 X 1024 picture elements) along with several useful software packages, for use at the VBT. The 1 metre telescope has an automatic guiding facility, and a capability for automatic positioning of the telescope to within a few degrees, merely by typing in the coordinates of the star. In the area of CCD instrumentation , new software was written for the various existing CCD cameras, while a Near Infrared Camera system is under construction for observation at the VBT as part of the India-Japan cooperation in science and technology. A linear CCD camera was tested at the tunnel telescope at Kodaikanal. Dewars for housing CCD chips were also developed. The electronics for controlling the CCD cameras was also designed and fabricated. Other projects undertaken by the electronics division include the fabrication of a 1024 channel digital correlator system for the radioheliograph at Gauribidanur, the development of a control system for the Schmidt telescope, and providing electronics and electrical support for the total solar eclipse experiments.

2. Computer Centre: A lot of additions were made to the computer centre at Bangalore. These include a supercomputer for theoretical computations, a number of small workstations for data analysis, a computer specially meant for connecting to the Internet, a large number of personal computers that allow individual scientists to connect to the main computer centre, and a high speed data link to the Ernet.

3. Electrical Section: Apart from providing support to the running of the telescopes at Kavalur, Kodaikanal, and Gauribidanur, the electrical section undertook a few new projects such as, wiring the newly constructed student hostel's wing and the administrative block extension, providing for UPS power in all offices of the Bangalore campus,

providing a water pumping system for the new campus at Hoskote, providing for standby power by generators at Evershed and Michie Smith Halls at Kodaikanal, and wiring of power line to the renovated INSA guest house at Kodaikanal.

4. Photonics: The photonics division has been involved in a project to fabricate optics for a synchrotron experiment. The mirrors are being shaped to the required precision. In another project of national importance, the polishing of the last set of sun shield panels for the INSAT II E satellite is being continued. Some special optics for obtaining perfect images at the Schmidt telescope was designed. A few experiments for using prisms in optical fractional fourier transformation, and in vibration measurements were tried. A cost saving device was fabricated for use in the aluminum coating plant. The primary and secondary mirrors of the VBT were realuminised and aligned.

5. Mechanical Engineering: The design and manufacture of several items were achieved. Examples are, a mount for a CCD camera for the Japal Rangapur observatory of the Osmania University, some precision flanges as well a precise mechanical device for moving some optics of the gravitational experiment at Gauribidanur, a large number of mechanical components for the various experiments for the total solar eclipse and a dewar for holding CCD chips. Apart from this, the workshops at Bangalore, Kavalur, and Kodaikanal supported various maintenance works. Recent efforts have led to the successful completion of a basic speckle camera for use at the VBT. The facilities at the Central Manufacturing Technology Institute, Bangalore were used for this.

NEW FACILITIES

1. Astronomical Site Survey at Hanle: The site survey at Hanle, Ladakh (longitude 78° 57.'5 E, latitude 32° 47' N, altitude of present camp 4300 m above msl), continued during the year. There is a continuous presence of astronomers of IIA at Hanle since December 1994. A guest house was established at Leh in hired accommodation during 1995 summer and a 1200 baud satellite communication link was established between Hanle and Bangalore during 1995 autumn. The main task undertaken during the first year was to monitor the cloud cover, temperature and humidity on an hourly basis. This data is complete to 90% level. Results for 1996 show that the conditions at Hanle are very stable.

2. The HIROT Project: The Department of Science and Technology, Government of India, commissioned a Detailed Project Report on the feasibility of a large telescope project named the High altitude Infra Red Optical Telescope (HIROT) project. The report was finalised. This effort by the members of IIA was conducted under the advice of a committee chaired by Dr. K. Kasturirangan, Secretary of the Department of Space, Government of India. The Committee recommended that the Planning Commission make necessary provisions under the IX and X Plan for this major facility for astronomy. The Committee also recommended that a 2-m class telescope be deployed before the Large Telescope Project is initiated. Eight vendors of telescopes of 2-m class have already been approached for budgetary estimates. Detailed discussions with them on specifications, time schedule, and aspects of design, deployment and training have been proceeding. Considerable progress has been made in the planning of infrastructure development at the site, including approach road and source of electrical power. Specifications of available generators using solar, wind and diesel power are being scrutinzed vis-a-vis conditions at the site. The communication link requirement as well as the philosophy of remote operation have been worked out in consultation of the Department of Space. Experiments are being conducted with the existing telescopes at Kavalur to gain experience in the field. The total time needed for the purchase and deployment of the telescope would be 2 1/2 years.

R. Cowsik
Director

Sun and the Solar System

1. SOLAR PHYSICS

1.1 SOLAR ECLIPSE OF OCTOBER 24, 1995

The Institute has been regularly launching expeditions to various corners of the world to observe and study total eclipses of the Sun. Most recently on 24 October 1995 such a total solar eclipse was visible from India. The previous such occasion was on 16 February 1980. Fifteen years have brought on a sea change in observing technology mainly through the development of cameras based on Charged Coupled Devices which have a high dynamic range and linearity. A massive, institute-wide effort was put up to observe the phenomenon. Keeping in view the weather pattern over the last 30 years and after the survey of the predicted path of totality, two places, Neem Ka Thana in Rajasthan and Kalpi in Uttar Pradesh were selected to setup camps. Following is a brief description of the camps and individual experiments. The contributions of the various engineering groups to this effort is described in chapter five of this report.

1.1.1 Camp Neem Ka Thana

A 30-member team from IIA lead by Jagdev Singh established a camp in Neem Ka Thana and conducted 5 experiments. The IIA supported the other teams e.g. Physical Research Laboratory, Ahmedabad; two teams from Russia; teams from The Slovak Republic, Japan, Germany, Brazil, USA and Georgia and other scientists from India. On the day of eclipse about 250 professionals and semi-professional scientists were present in the camp at Neem Ka Thana. The weather conditions before, during and after the eclipse were excellent. Almost all the experiments were successfully conducted. (Jagdev Singh)

1.1.2 Camp Kalpi

A 14 member team from the Institute headed by Dr.A.K.Saxena had setup a camp at Kalpi (a township about 78 kms from Kanpur) for the observation of the total solar eclipse on October 24, 1995. The camp was setup on a small hillock on the banks of river Yamuna. The campus of the Mandilya Gramodyog Prasikshan Kendra was used for this purpose. The cooperation of the Sub Divisional Magistrate Mr. S.K.Tripathi & their officials and zonal officer of the center Mr.Dhani Ram Verma & his colleagues is thankfully acknowledged. Five experiments were successfully conducted.

a. H-alpha emission in coronal region

b. Fast photometry for the study of short period oscillations

c. White light photography

d. Fast frame recording of the event using CCD

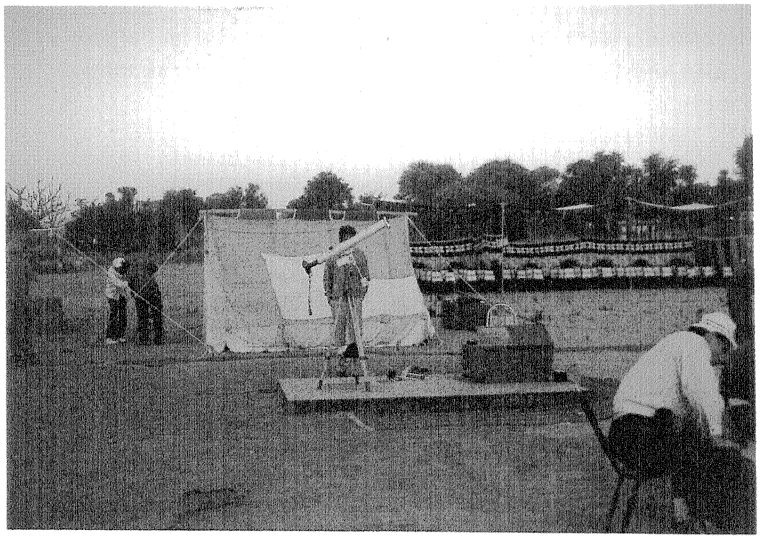
e. Video coverage of the event.

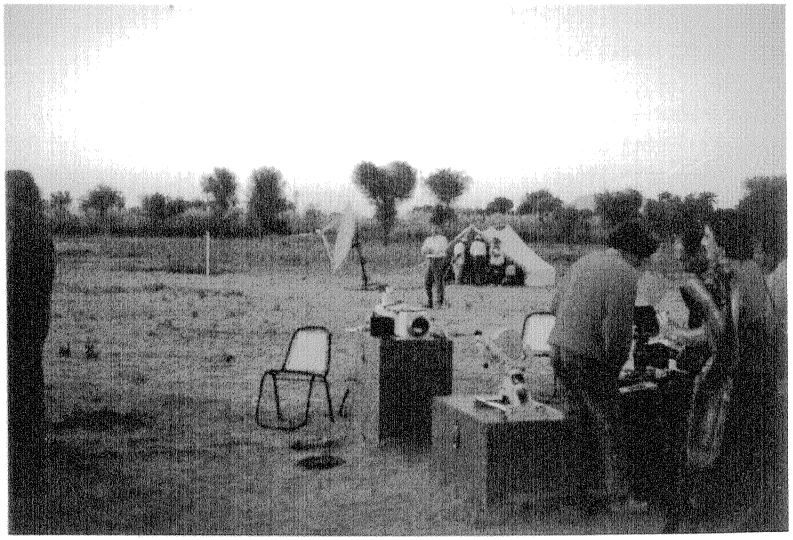
The sky was very clear during the entire period of this event and the totality lasted for about 49 seconds. The preliminary results of these experiments were presented in the national meeting on the total solar eclipse held during Feb.26-27 at Bangalore. (A.K.Saxena, expedition team)

1.1.3 Detection of Short-Period Coronal Oscillations

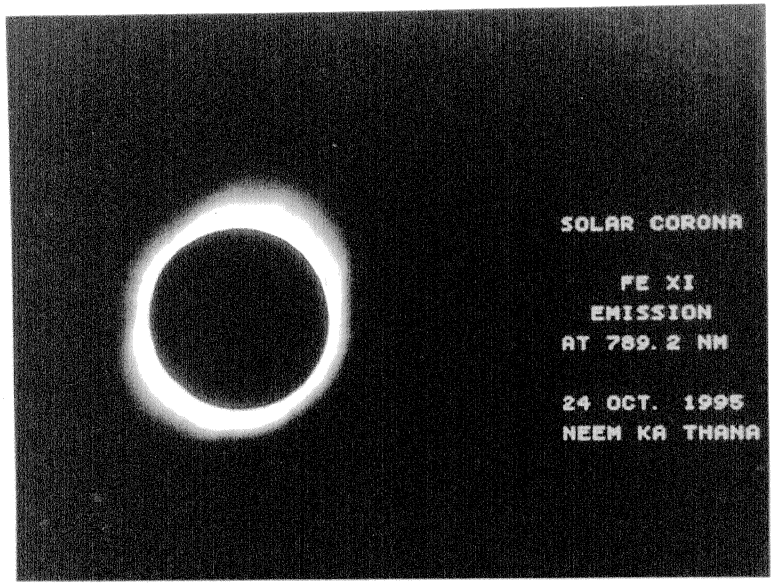
An experiment to search for short-period oscillations in the solar corona was conducted during the total solar eclipse of 1995 October 24 at Kalpi, India. A fixed telescope with f/10 objective of 10 cms aperture formed an image of the sun of 9.1 mm diameter. A circular aperture of 1.5 mm size isolated the coronal light at 1.25 solar radii. The intensity in the continuum, centred around 550 nm and with a passband having a half-width of 24 nm, was recorded at a counting rate of 20 Hz using a thermoelectric liquid cooled photomultiplier. The power spectrum analysis of the data reveals that most of the power is contained in 6 frequencies below 0.2 Hz. A least squares analysis gives the periods of

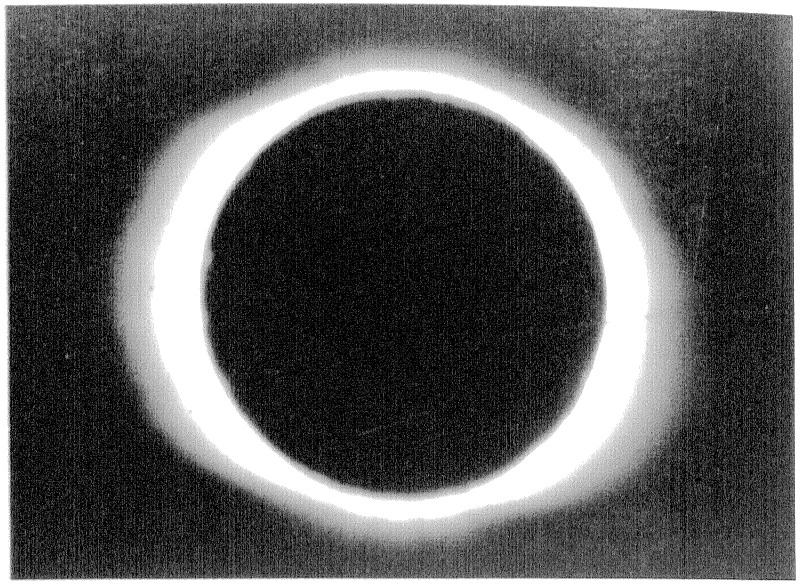

INDIAN INSTITUTE OF ASTROPHYSICS
NEEM KA THANA CAMP

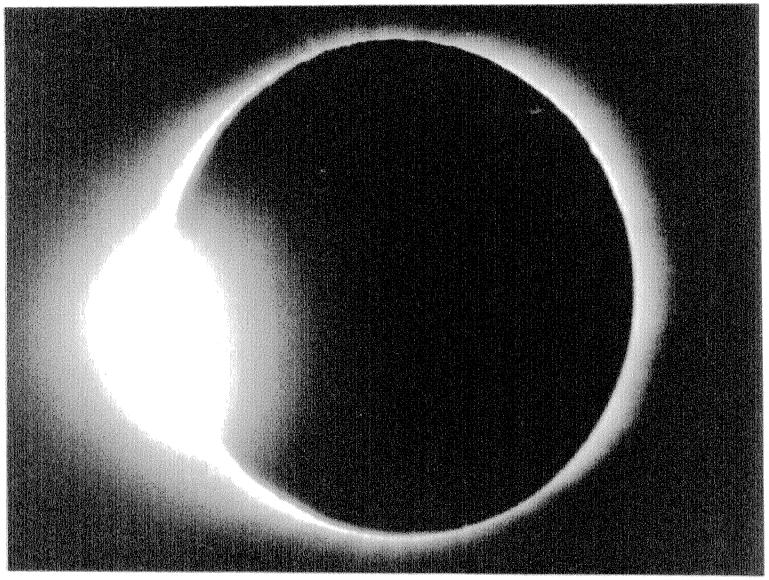





TOTAL SOLAR ECLIPSE 1995
KALPI CAMP
INDIAN INSTITUTE OF ASTROPHYSICS
BANGALORE-560034





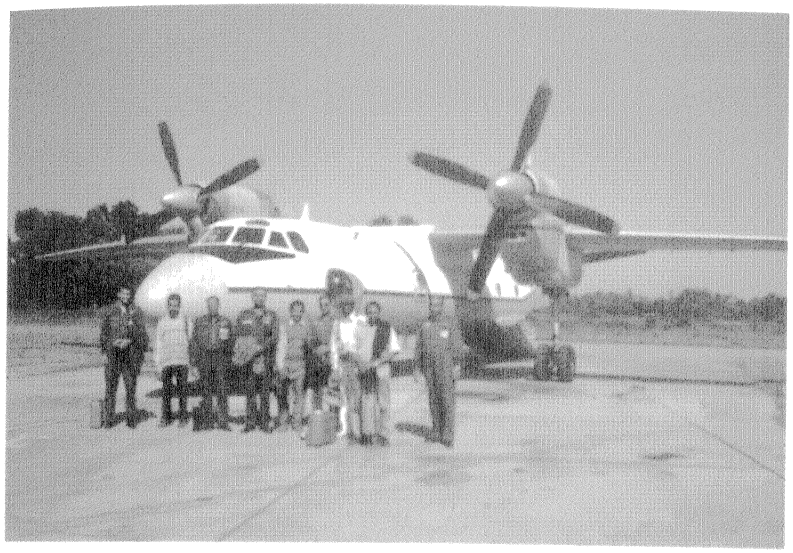


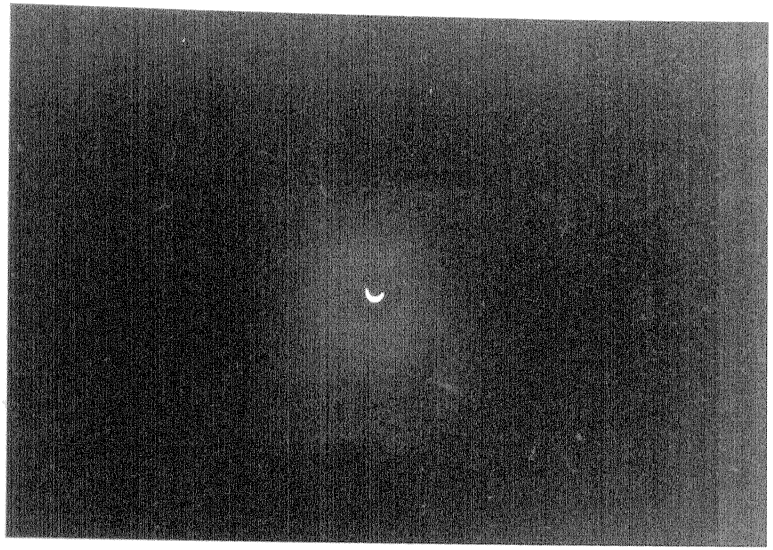
Top left : Solar corona in FeXI emission.

Top right : White light corona.

Left : Diamond ring.

IAF LENDS A HELPING HAND FOR THE TOTAL SOLAR ECLIPSE





the 6 frequency components to be 56.5, 19.5, 13.5, 8.0, 6.1 and 5.3 sec. These oscillations are found to be sinusoidal and their amplitudes are found to lie in the range 0.2% - 1.3% of the coronal brightness. Assuming these oscillations to be fast magnetosonic modes, the calculations indicate the availability of enough flux for the heating of the active regions in the solar corona.
(Jagdev Singh, R.Cowsik, A.V.Raveendran, S.P.Bagare, A.K.Saxena, K.Sundararaman, Vinod Krishan, Nagaraja Naidu, J.P.A.Samson, F.Gabriel)

1.1.4 Narrow Band Photometry in Emission Lines

To investigate the spatial variation of temperature and density within coronal structures, narrow band photometry in a number of coronal emission lines representing various temperatures was done.

The coronal emission lines which had been selected for narrow band photometry are: 637.4 nm (Fe X), 789.2 nm (Fe XI), and 530.3 nm (Fe XIV). The coronal ions corresponding to these lines are dominant emitters at temperatures of 1.0×10^6 K, 1.20×10^6 K and 2.0×10^6 K, respectively. Since the emission lines considered cover a temperature range, the various line-intensity ratios would enable us to determine temperature, electron densities and relative abundances of elements within the coronal structures. Estimates of electron densities and temperatures are essential for understanding the energy balance of the coronal plasma.

A two mirror coelostat was used to direct the coronal light to an objective of 3 inch aperture and 16 inch focal length. Narrow band filters of central pass band 637.4 nm, 789.2 nm, 530.3 nm and each of .5 nm band width were kept near the front of objective on a rotating wheel. The coronal pictures were recorded using peltier cooled CCD. A picture of solar corona in continuum at 700 nm was also obtained using 5 nm passband filter to subtract the continuum contribution from emission line pictures. Filters of .5 nm band pass are sufficient to isolate the coronal emission due to the lines from the background corona.
(Jagdev Singh, R. Cowsik, P.Venkatakrishnan, R.Srinivasan, V.Chinnappan)

1.1.5 Fabry-Perot Interferometric Observation of the Solar Corona in the Green Line

Imaging Fabry-Perot observation of the solar corona was made during the total solar eclipse of October 24, 1995, to obtain the two-dimensional distribution of coronal temperature and velocity. In the instrumentation scheme, a 12 inch coelostat mirror deflected the coronal light into the telescope objective of 100 mm aperture and 1000 mm focal length. The f/10 beam was collimated by a 102 mm focal length lens and then passed through an interference filter of 1 nm passband, which isolated the coronal green line. A dielectric coated Fabry-Perot etalon with 92% reflectivity and free spectral range of 0.4 nm, was used to obtain the interference fringes. A camera lens of 135 mm focal length was used to focus the interference fringes on a liquid nitrogen cooled CCD camera of 1024 x 1024 format with a pixel size of 24 microns. Green line emission was found to be weak and is restricted to the eastern and western limbs of the sun.
(K.P.Raju, Jagdev Singh, S.Muralishankar)

1.1.6 Photography of Solar Corona Using Indian Air Force Aeroplane

The teams of the Indian Air Force participated actively in the programme. They made several supersonic flights to follow the shadow zone of the moon on earth along the path of totality, thereby extending the duration of totality. Another aircraft AN32 was dedicated to acquire airborne images of the sun through filters attached to photographic cameras and video recording of the event using 8 mm video camera.
(M.Ramani, R.Cowsik, V.Krishnakumar, D.Bannerjee, Jagdev Singh)

1.1.7 Ultra Low Spatial Resolution Photometry in Near Infrared to Detect the Dust Ring

A telephoto objective of 210 mm focus collected the sun light through a coelostat and formed an image of 1.9 mm diameter. A near infrared filter with passband from 900 nm onwards was kept near the focal plane. The liquid nitrogen cooled CCD camera having 1024 x 1024 chip with pixel size of 21 microns enabled us to record the coronal images upto about 10 solar radii. The high dynamic range and low dark noise data is being analysed to detect the dust ring around the sun, if any. A dust ring at 4 solar radii has been predicted and there are conflicting views about its existence. A broad band coronal picture at 700 nm was also obtained by using an 8 inch coelostat an objective of 3 inch aperture and 16 inch focal length and a Peltier cooled 578 x 416 formal Astromed CCD with a 22 microns pixel size. Two colour photometry of the solar corona is being done by comparing the intensities in the two images. (Jagdev Singh, R. Cowsik, K.P. Raju, S.Mohin, K.Ravi)

1.1.8 High Resolution Multi-slit Spectroscopy of Solar Corona in Two Lines

On an examination of the list of corona emission lines in the visible, one finds that the two lines 530.3 nm (Fe XIV) and 637.4 (Fe X) are best suited for these observations. The ionization temperature of Fe X ion is about 1.0×10^6 K and about 2.0×10^6 K for Fe XIV ion.

The experimental set-up consisted of two mirror 8 inch coelostat and f/10 objective of 10-cm aperture to form the solar image of 9.1 mm diameter on the multislit of the spectrograph. The field lens behind the multislit focussed the objective onto the spectrograph lens. The Littrow spectrograph with a f/10 lens of 4-cm aperture and a 600 lines per mm grating provided a dispersion of 4.7 A/mm in the 2nd order red. Thus 2nd order 530.3 nm were separated by 228 mm. The 80 micron wide slit provided us a resolution of 11 arc secs. The spectrograph is capable of giving us a spectral resolution of 30 pm but the emulsion grain and image tube resolution of 15 micron restricts the resolution to 70 pm which corresponds to a velocity of 4 kms^{-1}. The 25 mm diameter of the image intensifier allowed us to obtain the coronal spectra upto 2 solar radii from the center of the sun. The spectrum was recorded on Kodak 2415 emulsion. These spectra have been scanned with PDS machine of the Institute to get the line profiles of emulsion lines using standard photometric technique. These line profiles will be used to derive "turbulence" and in the modelling of the solar corona. (Jagdev Singh, S.S.Gupta, R.Cowsik)

1.1.9 Search for H-alpha Emission from Corona

One of the experiments set up at Kalpi in Uttar Pradesh was to look for cool pockets of hydrogen alpha emission seen by Bappu and Bhattacharyya during the 1970 eclipse in Mexico. A 20 cm coelostat and a 15 cm objective were used to form an f/15 beam giving a 2 cm image of the Sun. A daystar filter of 750 pm pass band centred around H-alpha line was placed before the image plane. A 1024 x 1024 pixel liquid cooled Photometrics CCD camera was used to obtain two filtergrams of the North-Eastern portion of corona during totality.

No significant pockets of H-alpha emission are seen in the coronal region observed. A few pockets seen close to the limb are identified with prominences recorded in other broad band filtergrams. The details are being studied but it is concluded that the search should continue. (S.P.Bagare, R.Cowsik, Jagdev Singh, K.P.Raju, A.K.Saxena, J.P.A.Samson, B.Nagaraja Naidu)

1.1.10 High Resolution Photometry of Solar Corona

A 30 cm coelostat, a red broad band filter and a 15 cm objective providing an f/15 beam were used to obtain high spatial resolution images of the solar corona on 70mm Kodak 2415 film during totality at Kalpi. The sky was photometric and five exposures were obtained showing coronal structures upto 3.5 solar radii. The polar plume regions of this solar minimum activity corona are considerably extended.

Digital image processing of the frames show an interesting feature of a large loop around 2.5 to 3.5 solar radii at a heliocentric location of about 15 to 25 degrees from North. Such loop structures in polar regions have been seen earlier only in soft X-ray images from YOHKOH and it is significant to find them in the predominantly open field region. The possible associations of the loop with structures seen in X-ray and H-alpha filtergrams are being studied. (S.P.Bagare, P.S.M.Aleem, Jagdev Singh, A.K.Saxena)

1.1.11 Radio Observations

Radio observations of the 24th October 1995 solar eclipse were made at Neem Ka Thana using a 2 meter dish antenna and a receiver system operating at 3.8 and 4.2 GHz. Data from simultaneous radio observations made by ISRO at 2.2 GHz with 10 meter antennas were also used. Radio emission of the sun was recorded in total power mode from 1.39 UT to 5.00 UT. Our data indicates the presence of 2 active regions on the eastern part of the solar disc. The positions of these regions coincide with the sunspots seen in the optical data and active regions seen in the 17 GHz Nobeyama radio heliograph data and YOHKOH X-ray data. The size of the active regions at 3.8 GHz are estimated to be approximately 5.3 + 0.5 arc min. The brightness temperature derived is approximately 1.16×10^5 K.
(J.Bagchi, K.R.Subramanian, E.Ebenezer, Nanje Gowda, A.T.Abdul Hameed, & ISRO team (G.Viswanathan, S.Gandhi, L.Srinivasan, Periasamy & C.D.Sharma))

Radio observations of the solar eclipse were made at 77 MHz using a radio interferometer system at the Gauribidanur radio observatory. Sudden decreases in the intensity of the radio emission were detected at 2.06 UT and 3.24 UT, which recovered to the pre-eclipse level after 65 and 56 minutes respectively.
(R.Ramesh, K.R.Subramanian, M.S.Sundarajan & Ch.V.Sastry)

1.1.12 Solar Speckle Experiment

A solar speckle experiment was conducted for observing the solar eclipse of 24 Oct. 1995 visible as a partial eclipse from Bangalore. In this case, the lunar limb provides a sharp edge as a reference during the solar eclipses.

A Carl-Zeiss 15 cm Cassegrain-schmidt telescope was used for this experiment. To prevent heating of the optics, an aluminised glass plate was fixed in front of the telescope that reflected 80% of the sunlight and transmits the rest. A polaroid was placed in the converging beam ahead of the focal plane. A filter at 600 nm, FWHM = 3 nm, was placed after this, followed by another polaroid on a rotatable holder. The amount of light falling onto the camera can be adjusted by the second polaroid. A pin-hole of 1 mm diameter was placed at the focal plane for isolating a small field-of-view. A microscope objective (X5) reimages the pin-hole on to a CCD capable of acquiring images with 20 ms exposure, using Data Transmission frame grabber card DT-2861. No image of partially eclipsed sun could be acquired due to the unfavourable weather conditions at Bangalore on 24th Oct. 1995.
(S.K.Saha, B.S. Nagbhusana, A V Ananth, P Venkatakrishnan.)

1.1.13 Sharpening an Image of the Partially Eclipsed Sun

A technique called parametric deconvolution was developed to sharpen images that are degraded by "seeing". This technique was applied to an image of the partially eclipsed sun obtained at Kodaikanal on 24 October 1995. (V.Krishnakumar, P.Venkatakrishnan)

1.2 GLOBAL PROCESSES

1.2.1 Direct Evidence for Solar Spin Oscillations and Their Coupling to the Solar System Dynamics

The temporal variations in the spin torque T_{spin} on the Sun which were

BARYCENTRIC ANGULAR MOMENTUM OF THE SOLAR SYSTEM

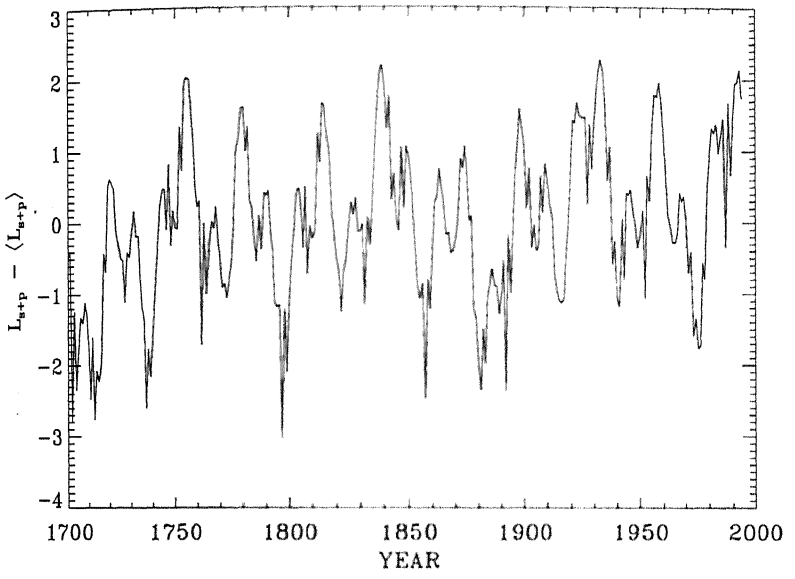


Fig. 1.2.1.1. Temporal variation of the sum, L_{s+p}, of the orbital angular momenta of the Sun and the planets about the barycentre of the solar system, about its temporal mean $(3.12028 \pm 0.000003).10^{50}$ gm $cm^2 s^{-1}$, during 1700-1994, as computed from the ephemeris programme of Bretagnon and Simon (1986). The unit of variation is 10^{46} gm cm^2 s^{-1}, and the maximum error is ± 0.5 unit. This variation implies equal and opposite variation in the Sun's spin angular momentum S_{sun}. The variations in the angular momenta of the smaller bodies, and those in the spins of the planets, are neglected.

FOURIER SPECTRUM OF SOLAR SPIN ANGULAR MOMENTUM

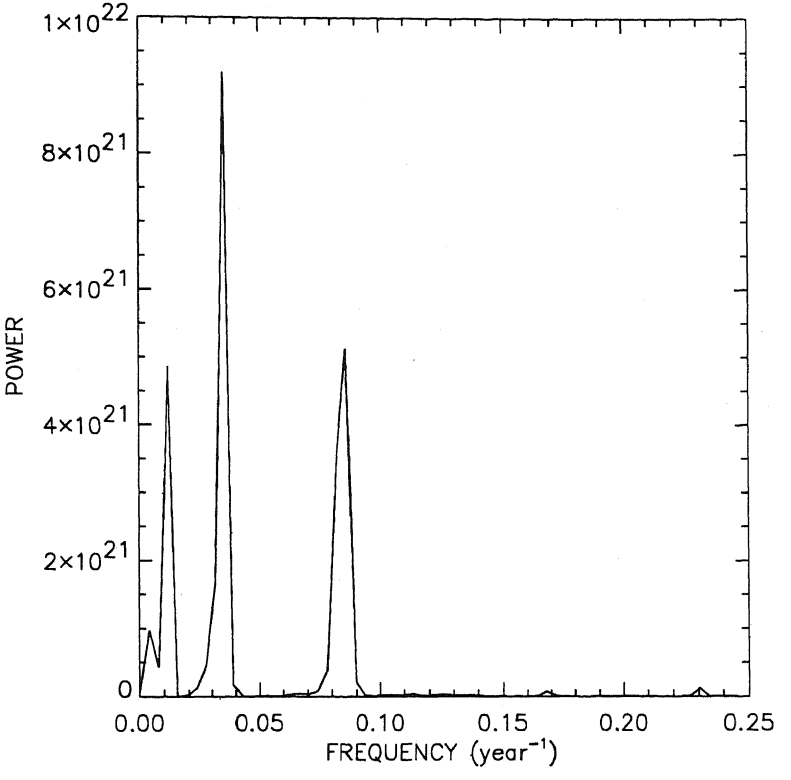


Fig. 1.2.1.2. Fourier spectrum of the variations of S_{sun} during 1700-1994 A.D.

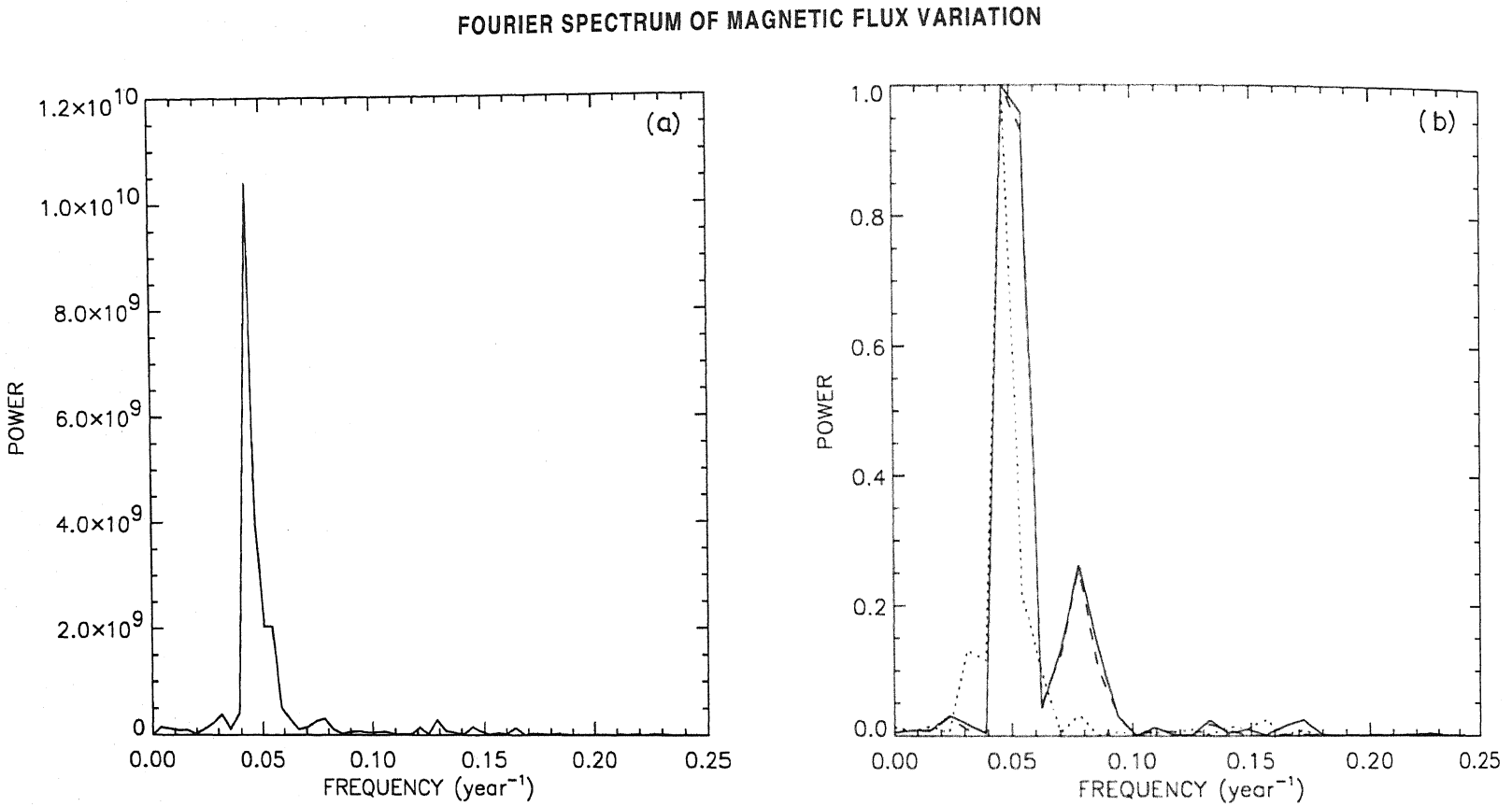


Fig. 1.2.1.3.(a) The Fourier spectrum of dϕ/dt during 1700-1994, and (b) The Fourier spectrum of dϕ/dt during 1874-1976 (dotted line) compared with the Fourier spectra of T_{spin} (continuous line) and T_{orb} (dashed line).

reported in the previous annual report, implied presence of variations in the Sun's spin angular momentum S_{sun}. The variations in the latter have now been evaluated directly in the following way. We computed the yearly mean values of the sum L_{s+p}, of the heliocentric z-components of the orbital angular momenta of the Sun and the planets about the barycentre of the solar system, during the years 1700-1994 (Fig. 1.2.1.1). Invoking the principle of conservation of angular momentum and neglecting the planetary spins and angular momenta of bodies other than the Sun and the planets, one concludes that the variations in Figure 1.2.1.1 represent, with negative sign, the variations in S_{sun}.

The Fourier spectrum of the variations in S_{sun} (Fig.1.2.1.2) shows that these variations constitute oscillations with frequencies in bands around the orbital frequencies of Saturn, Jupiter, Uranus and Neptune (in the decreasing order of the Fourier power). (M.H.Gokhale, J.Javaraiah, R.Vasundhara)

1.2.2 Orbital Angular Momentum Transfer

A computer simulation program has been developed to see whether significant amount of orbital angular momentum transfer occurs from the motion of Jupiter and Saturn to the internal spin of the Sun. Our results, however, show that the acquired spin during the first orbital period is negligible. Nevertheless the spin shows oscillations which is being further investigated. The accumulation of numerical error prevents us to follow the transfer of angular momentum during subsequent orbital periods. Tests are being performed to reduce the error in computation. (P.M.S. Namboodiri, M.H. Gokhale)

1.2.3 Resonance between the Solar Magnetic Cycle and Solar Spin Oscillations

The coupling between the solar magnetic cycle and the solar system dynamics, which was reported in the previous annual report in the form of the temporal variations of the spin and orbital torques (T_{spin}, T_{orb}) and those of the rate of emergence (d F/dt) of toroidal magnetic flux from the Sun, was established clearly by computing and comparing the Fourier spectra of these variations (Fig.1.2.1.3) (M.H.Gokhale, J. Javaraiah, R.Vasundhara)

1.2.4 Model of Rotation and Magnetic Field in the Sun's Convective Envelope

Our earlier model for the steady parts of magnetic field and rotation in the Sun's convective envelope, (which was based on Chandrasekhar's MHD equations for steady rotation and magnetic field in an incompressible fluid and on Nakagawa's boundary conditions), was modified allowing differential rotation at the base of the convective envelope. This modified model yields a better fit with the helio-seismically inferred iso-rotation than the earlier model which assumed rigid rotation at the base of the convective envelope.

Like the earlier model this mode also yields the toroidal field of a 'dipolar distribution' with strength of 1 gauss near the surface and a 'quadrupolar distribution' with strength of 10^4 gauss near the base of the convective envelope, with strongest fields at middle latitudes near the base. (K.M.Hiremath, M.H.Gokhale)

1.2.5 Periodicities in the North-South Asymmetry of the Solar Differential Rotation and Surface Magnetic Field

The temporal variations in the north-south asymmetries of the solar differential rotation parameters A and B were studied by determining them from Greenwich data on sunspot groups (1879-1976) during moving time intervals of lengths 3 yr and 5 yr, successively displaced by 1 year. The variation in the asymmetry of the mean rotation <A> is similar to the variation in the asymmetry of <B>, but has an opposite sign. This suggests that the torsional oscillations represented by the variations in <A> and <B> may be components of a single anti-symmetric oscillation which are in anti-phase with each other. The long

term variations of these asymmetries are approximately correlated (anticorrelated) to the long term variation of the asymmetry in the amount of solar activity. Since the amount of activity was more asymmetric during Maunder minimum (Sokoloff and Ribes, 1994, A & A 288, 293), it is suggested that the asymmetry in the magnitude of the differential rotation rate might have been unusually small during that period.

The FFT and MEM analyses of the temporal variations of the north-south asymmeries of <A> and <B> show existence of significant periodicities : 45.5 (+/- 11.5) yr, 21.3 (+/- 4.5) yr, 13.3 (+/- 1.5) yr and 10.5 (+/- 0.5) yr. These analyses also show other possible periodicities in the north-south asymmetry of <A> and in the asymmetry of sunspot activity, with similar relative magnitudes. (J.Javaraiah, M.H.Gokhale)

1.2.6 Periodicities in the Sun's Torsional Oscillations and Planetary Configuration

Each of the frequencies determined in the north-south asymmetry of the coefficient B (i.e., frequencies of the 'odd' parity torsional oscillations) are found to match with either a sum or a difference of the orbital frequencies of the major planets. Also, it is found that the amplitudes of the symmetric and anti-symmetric torsional oscillations of the Sun depend upon the contributions of the major planets to the 'symmetric' and 'asymmetric' parts of the angular momentum of the solar system with respect to the ecliptic plane. This supports our earlier suggestion that the perturbations needed for exciting the sun's torsional oscillations may come from the solar system dynamics. (J.Javaraiah)

1.2.7 Evolution of Coronal Magnetic Fields

The large scale solar magnetic fields originates in dynamo action deep within the sun. The large scale flows push this field from the equator to the polar regions of the sun on an eleven year time scale. This action of the large scale flow produces a coronal magnetic field that changes shape from the time of sunspot maximum to sunspot minimum. The observed changes in the shape of the corona can be explained by the process. (M.Dikpati, A.R.Choudheri*, P.Venkatakrishnan)

1.2.8 Variability of Total Solar and UV Irradiance Related to Bright Magnetic Features

The digitization of six years of CaII K spectroheliograms, observed at the National Solar Observatory at Sacramento Peak, covering the period of 1980 (maximum of SC21), 1985 (minimum of SC21), 1987 (beginning of the ascending phase of SC22), 1988 and 1989 (ascending phase and maximum of SC22), and 1992 (declining phase of SC22) has been completed. The software for image processing and a new method in an IDL programming language was developed and applied to the K-images for the time interval of 1980 and 1992. Using the "histogram method", the various chromospheric features like the plages, magnetic network and intranetwork elements have been segregated. The intensity and area of these features and the full-disk intensity (designated as spatial K index) have been measured. The full width at half maximum (FWHM) derived from the histograms has been introduced for the first time as a new index for measuring and describing the chromospheric activity in the K-line. The spatial K index has been compared to the spectral K index derived from the line profiles and to the CaII spectral irradiance. The spatial K index, FWHM, and the intensity of plages, the magnetic network and intranetwork elements have been compared to the UV irradiance measured in the MgII h & k lines by the Nimbus 7 and NOAA9 satellites. It has been found that the spatial K index, FWHM, and intensity of various chromspheric features are highly correlated with the MgII h & k c/w ratio. (R.Kariyappa, Judit M.Pap*)

It has been shown that besides the plages, a significant portion of the variations observed in UV irradiance is related to the changing emission of the network and intranetwork elements. This suggests that, in addition to network and plages, the intranetwork elements may also play a significant role in their contribution to the variation in UV irradiance. It has been shown that the intensity of the intranetwork

elements is not constant as assumed in the current irradiance models. On the contrary, it is changing in a fashion similar to the plages and the magnetic network. The results show an anticorrelation between the intensity and area of the network elements, and this means that during solar minimum the network is fainter but covers a larger area than during solar maximum. These results suggest that the variations in both the intensity and the area of the various spatial features have to be taken into account in irradiance models.

The power spectrum analysis of the time series data shows that besides the plages, the network and intranetwork elements exhibit a 27 and 16 day solar rotational modulations in their intensity variations. (R.Kariyappa)

1.2.9 Solar Cycle Variability of the Brightness of the CaII K Network Elements in Quiet Regions

The dependence of the brightness of chromospheric network elements on latitude was investigated for quiet solar regions. The calibrated photographic CaII K spectroheliograms of Kodaikanal Observatory for the period 1958-1983 have been used to compare the variation in the brightness at the center of the disk with higher latitude (40-45 degrees) of chromospheric network elements in a quiet region as a function of solar activity. It is found that there is no significant difference in brightness between the center of the solar disk and higher latitude. In other words, the brightness of the chromospheric network elements in a quiet region does not depend on the latitude but the variation in the intensity enhancement is highly related with solar activity. (R.Kariyappa)

1.3 LOCAL PROCESSES

1.3.1 Structure of Turbulence in the Solar Convection Zone

Based on the inverse cascade of energy in a turbulent medium, a model of the solar granulation. encompassing all spatial scales, has been proposed. The predicted spatial energy distribution agrees fairly well with that inferred from the observations of the photospheric motions. The model depends heavily on the presence of helicity fluctuations in the turbulent medium. Helicity is an invariant of a 3-D system. In case, the net helicity is zero, its second moment may be nonzero, then another invariant 'I' can be defined, the cascading properties of which in the inertial range give the spectral distribution of energy. The helicity is related to the mass density through a function analogous to the Bernoulli function. it is hoped that with the quality data obtained from GONG, we will be able to test some of these theoretical ideas. (V.Krishan)

1.3.2 Interaction of a Slender Magnetic Flux Tube With External p Modes

An earlier treatment by Hasan & Bogdan (1996, Bull. Astron.Soc. India, 24) and Hasan (1996, Ap.J., in press), on the study of the time asymptotic response of a vertical slender flux tube in the solar photosphere to the buffeting action by p-modes from the ambient atmosphere has now been extended to study this interaction as an initial value problem. The aims of the investigation are two fold: firstly, to compare the linear and nonlinear treatments to assess whether nonlinear effects become important at any stage of the interaction. A second aim is to see whether a significant buildup of energy in the form of flux tube oscillations can occur as a result of the driving action of the p-modes. The problem is analysed by solving the time dependent MHD equations for an isothermal tube, with the same temperature as the external atmosphere. Assuming that the upper boundary is closed, a comparison between the linear and nonlinear treatments is made. The calculations show almost perfect agreement between the two cases, thereby demonstrating that nonlinear effects do not appear to be important for this problem, since the velocity amplitudes of the oscillations are well below the tube speed. The calculations reveal that the buffeting action of the p-modes leads to a significant accumulation of energy in tube oscillations, particularly when the external frequency is close to one of the natural frequencies of the tube. In the latter case, beats are observed. The vertical velocity depicts an oscillatory

behaviour with a period of the incident p-mode, while wave envelope exhibits a modulation at the beat period. An interesting feature of the results is that the total wave energy density oscillates with the beat period, increasing from zero to a maximum value followed by a decrease to zero and thereafter a repetition of the previous sequence. This behaviour can be interpreted in terms of a coupled system of two oscillators in which there is a back and forth transfer of energy between the oscillators. These results have several important implications for the sun. (S.S.Hasan)

1.3.3 Radiation Damping of Kink Mode Oscillations

Previous work (for instance Choudhuri, Dikpati & Banerjee 1993, ApJ 413, 811) has demonstrated that kink modes in flux tubes can provide an efficient mechanism for channelling energy from the photosphere to the corona. However, due to the coupling of these modes with the external medium, it is of some interest to examine whether these kink modes lose energy through coupling with modes in the external medium. In the first part of this study, the coupled equations for a kink mode in the tube and a p-mode in the external medium are being solved. Damping rates will be calculated and their dependence on various parameters, such as the ratio of gas to magnetic pressure in the flux tube, will be examined. (S.S.Hasan, M.Dikpati)

1.3.4 Effect of Energy Leakage on Magnetoatmospheric Modes

Study of wave motions can reveal useful information on the structure of magnetic elements and thus serve as a powerful diagnostic tool to investigate the structure of magnetic elements. The present investigation is a continuation of work by Hasan & Christensen-Dalsgaard (1992, ApJ 396, 311) and Banerjee, Hasan & Christensen-Dalsgaard (1995, ApJ 451, 825), where the interaction of various elementary modes in a stratified atmosphere with a vertical magnetic field was studied. The present study concentrates on the behaviour of the normal modes for different boundary conditions, in which the vertical gradient of the displacement is zero at the upper and lower boundaries (instead of the displacements themselves). The main finding is that the eigen frequencies become complex in certain regions, known as avoided crossings, of the diagnostic diagram. However, away from the avoided crossings, the frequencies are real (in the adiabatic case) for these boundary conditions. Strong mode coupling in these regions permits energy leakage for zero-gradient boundary conditions.

As a continuation of the above study, the influence of non adiabatic effects on the modes of an isothermal stratified magnetised atmosphere has been examined. The inclusion of radiative dissipation in magnetoatmospheric wave problems is very important in the solar photosphere. An analytic expression is derived for the dispersion relation, which allows for the effect of a weak magnetic field on the normal modes to be studied. The frequency shift to the real part of the frequency and also the decay rate of the modes due to the inclusion of radiative dissipation is calculated. Furthermore, tha nature of the eigen frequency curves in the k - w diagram is examined. It is found that, similar to the previous analysis, the modes undergo avoided crossings, due to mode interaction, but this interaction is qualitatively different in the presence of dissipation. These results are being applied to waves in flux tubes on the sun. (Dipankar Banerjee, S.S.Hasan, J.Christensen-Dalsgaard*)

1.3.5 Solar Acoustic Overstability

The mechanism by which solar oscillations are excited is still not well understood. The present work attempts to examine whether solar oscillation can be excited by an acoustic overstability in the solar atmosphere. Acoustic overstability is a phenomenon where thermal energy is converted directly into acoustic energy. In certain special circumstances the thermal energy can drive acoustic waves overstable. An earlier investigation by Jones (1976) showed that acoustic overstability can occur in the solar atmosphere. However, in that analysis, rigid boundary conditions were considered, without allowing for energy loss at the boundaries. This effect may be important and is being considered in the present analysis. The fourth order differential equations with

radiative diffusion are being solved numerically, using an asymptotic expansion at the lower boundary, which allows the thermal mode to carry energy out of the atmosphere. The analysis is still in progress. (A.D.Jana, S.S.Hasan)

1.3.6 MHD Surface Waves

A simple two layer model to investigate surface waves arising due to the interaction between two fluids of different densities is studied. The interface separates the convection zone and the atmosphere of the Sun. The upper fluid is under the influence of a magnetic field which is inclined at an angle to the interface while the lower fluid is field free. The wave vector is in a direction different from the magnetic field. Making use of the continuity of the vertical velocity and the total pressure at the interface leads to a dispersion relation which is a polynomial of sixth degree. However, all the modes do not represent surface waves. The condition for the existence of surface waves and the variation of the normalized phase speed as a function of the different angles of propagation vector is studied.

Alfven surface waves along cylindrical flux tubes of uniform plasma density surrounded by a plasma of different density is studied. The effect of inclined magnetic fields on the properties of these waves is discussed in detail. It is found that both the symmetric and asymmetric modes are highly dispersive in nature. The condition for the existence of these modes is derived analytically. Limiting cases of the plasma parameters is discussed briefly. For a given set of plasma parameters, there exists a critical wavenumber wherein the modes change from backward to forward waves and vice versa. The normalized phase speed of these waves depend on the ratio of the densities, the magnetic fields in both the media and on the inclination angles. Thus we are forced to restrict the choice of the parametric values. Finally it is shown that this configuration is stable to small perturbations. (A.Satya Narayanan)

1.3.7 Electrodynamic Response of Solar Surface Magnetic Field to Coronal Changes

The sudden outburst of energy called solar flare requires the opening out of a closed magnetic field structure. When the field line is cut, the electric current flowing along the field is stopped. This interruption of current was modelled and was found to produce changes in the solar surface magnetic field. These changes mimic some recently observed changes in vector magnetic fields during major flares. (N.D.N.Prasad, P.Venkatakrishnan)

1.3.8 Transition in Flow Pattern within Helmet Streamers

The time varying flow within a helmet streamer, whose shape changes slowly in time was studied using hydrodynamic equations for a plasma of constant temperature. Sudden changes in the flow pattern were noticed when the shape changed gradually through a critical phase. This is suggested as one way of producing the observed eruptive phenomenon called a coronal mass ejection. (N.D.N.Prasad, P.Venkatakrishnan)

1.3.9 Temporal Behaviour of Pressure in Solar Coronal Loops

The temporal evolution of pressure in solar coronal loops is studied using the ideal theory of magnetohydrodynamic turbulence in cylindrical geometry. The velocity and the magnetic fields are expanded in terms of Chandrasekhar - Kendall (C.K) functions. The three mode representation of the velocity and the magnetic fields submit to the investigation of chaos. When the initial values of the velocity and the magnetic fields coefficients are very nearly equal, the system shows periodicities. For randomly chosen initial value of these parameters the evolution of the velocity and the magnetic fields is nonlinear and chaotic. The consequent plasma pressure is determined in the linear and nonlinear regimes. The evidence for the existence of chaos is established by evaluating the invariant correlation dimension of the attractor D_2, a

fractal value of which indicates the existence of deterministic chaos. (K.Sasidharan, T.D.Sreedharan, R.Pratap*, V.Krishan)

1.3.10 Electron Density and Temperature Diagnostics of Chromosphere-Corona Transition Region and the Corona

NeV/MgV and SiVII/MgVII theoretical line intensity ratios as function of electron density and temperature have been computed. The results are being analysed in the form of intensity ratio - ratio diagrams which, in principle, should allow simultaneous determination of electron density and temperature for the emitting region of the solar plasma. In addition, the utility of these line intensity ratio diagnostics is being examined to study the variation of the relative element abundances Ne/Mg and Si/Mg in different solar structures. The theoretical results are being compared with the available solar observations from space probes. The results of this diagnostic investigation is also being examined in the light of their application in the analysis and the interpretation of high resolution EUV observation obtainable shortly from the CDS (Coronal Diagnostic Spectrometer) and the SUMER (Solar Ultraviolet Measurements of Emitted Radiation) instruments flown aboard the SOHO satellite. (B.N.Dwivedi*, Anita Mohan*,P.K.Raju)

1.3.11 Solar Oscillations in Strong and Weak Fraunhofer Lines Over a Quiet Region

A 35-min-long time sequence of spectra in CaII H-line, NaI D1 and D2-lines, and in a large number of strong and weak FeI lines taken over a quiet region at the centre of the solar disc have been analyzed. The time series of these spectra have been observed simultaneously in these lines under high spatial, spectral, and temporal resolution at the Vacuum Tower Telescope (VTT) of the Sacramento Peak Observatory. The line profiles and their central intensity values at the sites of the chromospheric bright points, which are visible in H-line for easy identification have been derived. A power spectrum analysis for all the lines using their central intensity values has been done to determine the period of oscillations. It is shown that the 3 FeI lines, present 23 nm A away from the core of the H-line representing the pure photospheric lines, NaI D1 and D2 lines, 6 FeI lines at the wings of H-line, and CaII H-line exhibit 5 min, 3.96 min and 3.2 min periodicity in their intensity oscillations, respectively. Since all these lines form at different heights in the solar atmosphere from low photosphere to middle chromosphere and show different periodicities in their intensity oscillations, these studies may give an idea about the spatial and temporal relation between the photospheric and chromospheric intensities. Therefore these studies will help to better understand the physical mechanisms of solar oscillations. It is clearly seen that the period of intensity oscillations decreases outwardly from low photosphere to the middle chromosphere. (R. Kariyappa)

1.3.12 The Relation Between the Period of Oscillations and Brightness in Chromospheric Bright Points

The chromospheric bright points are the sites where an intense energy loss is discerned with a 3 min period. The bright points are grouped into three classes depending on the amount of intensity enhancement, and the pattern of their dynamical evolution. A 35-min time series of photographic spectra in the CaII H-line on a quiet region at the center of the solar disk taken at the Vacuum Tower Telescope (VTT) of the Sacramento Peak Observatory is used to show that the period of intensity oscillations seen at the sites of the bright points is independent of their intensity enhancements, and also it may not depend on the strength of the magnetic fields with which they are associated. (R.Kariyappa)

1.1.13 Evershed Flow in Sunspots

The analysis of sunspot spectra obtained to study the Evershed flow in the case of bipolar and other categories of sunspots was continued and the results are getting ready. (K.Sundara Raman).

1.3.14 HeI 1083 nm Line in Active Regions

The HeI spectral line at 1083 nm in the near infrared part of the solar spectrum is regularly observed from the Norikura mountain station of the National Astronomical Observatory in Japan. The line was found to be marginally deeper wherever it is broader in a solar active region. This behaviour has been now understood in terms of optical thickness. However, the apparent shallow nature of the line must be due to a low filling factor. Thus HeI excitation takes place in very small pockets of the solar atmosphere. (P.Venkatakrishnan, T.Sakurai*, Y.Suematsu*, K.Ichimoto*)

1.4 INSTRUMENTS AND TECHNIQUES

1.4.1 Gauribidanur Radio Heliograph

Considerable progress was made in the construction of the Gauribidanur radio heliograph and the 1024 channel digital correlator system. Delay shifters were installed in the southern arm of the heliograph to steer the beam of the array between + 45 degrees and -45 degrees in the NS direction. The modules of the 1024 channel digital correlator system were tested and will be installed by middle of 1996. Observations of the sun at 51 and 77 MHz were continued using the EW arm of the heliograph and a 64 channel digital correlator. (K.R.Subramanian, M.S.Sundarajan, R.Ramesh, Ch.V.Sastry)

1.4.2 Sharpening of Blurred Images

When long exposure images get blurred, there is also a decrease in the contrast of the various features. Often times, it is crucial to know the true contrast, but the amount of blurring may not be known. A parameter search based technique has been evolved to detect the parameters of a blurring function of known form, with the number of non-positive pixels as the estimator of the error in the deconvolution. This does not require prior knowledge of the source. This technique has enormous potential for practical application in a wide variety of problems, e.g. estimation of daytime seeing, obtaining true contrast of solar fine structure, etc. (V. Krishnakumar, P.Venkatakrishnan)

1.4.3 Preliminary Results From Kodaikanal Stokes Polarimeter

A PC based stokes polarimeter had been constructed in 1992 for use in Kodaikanal. A set of circular polarisation measurements of sunspots had been obtained by late Dr.R.S. Narayanan in Feburary 1994. These spectra were analysed. The line width and Zeeman splitting within different positions of a bipolar spot group were determined. The line width does not show a systematic behaviour with respect to the splitting, thereby ruling out magnetic broadening. (K.Sankarasubramanian, P.Venkatakrishnan)

1.4.4 Design of an Ellipsometer

An ellipsometer was designed for the measurement of the instrumental polarisation of the Kodaikanal solar tower telescope. The basis of this ellipsometric technique is the minimisation of a functional which contains information on the phase retardation introduced between orthogonal EM vibrations upon reflection at the mirror surface, as a function of the angle of incidence. The chief design consideration is maintaining the accuracy of the angle of incidence measurements. Since greater accuracy can be achieved for grazing angles of incidence, a folded beam design was adopted to launch the incident beam at very large angles of incidence. A facility has also been designed to move the patch of incident light over the entire mirror surface to detect variations, if any, in the effective refractive index of the aluminium coating. (K. Sankarasubramanian, J.P.A. Samson)

2. SOLAR TERRESTRIAL PHYSICS

2.1 MAGNETOSPHERE - IONOSPHERE COUPLING

The response of the equatorial-low latitude nightside ionosphere to the geomagnetic negative sudden impulse (si⁻) on March 15, 1993 is studied using recordings of Doppler velocity of ionospheric echoes at vertical incidence at Kodaikanal (10.2° and Doppler shift of standard HF signals on oblique paths at Lunping (25.0°) and Kure (34.25°). The si⁻ at 1541 UT is characterised by a simple decrease of H-field at low latitude stations widely distributed in longitude, and by a double-pulse structure at mid and high latitude stations on the dayside. The usual downward drift of F region plasma during the premidnight hours over Kodaikanal near the dip equator abruptly increased for about 2.5 min coincident with the first pulse of the si⁻ and immediately reversed direction to upward. Recordings at Lunping and Kure also showed short-lived Doppler frequency deviations simulataneous with those at Kodaikanal and of the same polarity and sequence. These observations constitute the first and direct experimental evidence for vertical plasma motions due to si⁻ associated electric fields in the nighttime equatorial-low latitude ionosphere. The case study supports the view that si⁻ can be explained by the physical model of sc/si⁺ with a reversal in the direction of the global current systems responsible for the ground level magnetic field variations. (J.H.Sastri, Y.N.Huang,* T.Shibata*, T.Okuzawa*)

2.2 EQUATORIAL IONOSPHERE

Simultaneous measurements of F-region vertical drift are made in the evening hours (1700-2100 IST) at Trivandrum (dip 0.6°N) and Kodaikanal (dip 4°N) on fifteen days during December 1993- January 1994 using the HF phase path technique on two different probing frequencies. The data are used to study the height dependence of vertical plasma drift in the bottomside F-region in the dusk sector after correcting the drifts (at Kodaikanal) for meridional wind effects and chemical loss. It is found that growth and decay of a positive height gradient in vertical drift occurs fairly regularly in the dusk period. On the average the vertical velocity gradient is positive in the interval 1815-1925 IST and is preceded by negative values. The positive height gradient of vertical plasma drift below the F layer peak is interpreted in terms of altitude dependence of the relative contributions of E and F region dynamos to the electric fields responsible for plasma drifts (vertical and zonal) of the dusktime equatorial F-region. These results are for winter solstice solar minimum conditions. (J.H.Sastri, V.K.Meena Varma*, S.R.Prabhakaran Nayar*)

A 15 day observational campaign was held with the ionosonde, magnetometer and HF Doppler Radar experiments at Kodaikanal Observatory to study the response of the equatorial ionosphere dynamics to the total solar eclipse of 24 October 1995. Reductions of the data are in progress (J.H.Sastri, D.Karunakaran, J.V.S.V.Rao).

STP group has participated in the STEP/EITS International Campaign held in March 1996. Reductions of the data are in progress (J.H.Sastri, J.V.S.V.Rao, D.Karunakaran)

2.3 GEOMAGNETIC STORMS

Daily geomagnetic index, Ap, covering the period 1966 through 1994 is studied for characterizing the solar sources of geomagnetic storms and their effectiveness in causing the storms. The occurrence of geomagnetic storms with AP > 30 is found to reach maximum during sunspot maximum or during the decending phase of the sunspot cycle. Non-recurrent storms showed their peak occurrence when the solar activity as represented by sunspots and flares, in general pertain to low heliographic latitudes (~ + 20°) within the main active zone. The occurrence of recurrent storms on the other hand are found to maximize when the polar coronal holes extend deep into the low latitudes beyond about + 20° latitude towards the equator. It has emphasized that the solar sources of geomagnetic storms are more effective in causing geomagnetic storms when they pertain mainly to heliographic latitude zone of +/- 20 ° namely, Geoeffective Solar Active Zone. (K.B.Ramesh)

3. SOLAR SYSTEM STUDIES

3.1 NEAR EARTH ASTEROIDS

Near Earth asteroids were imaged at the prime focus of VBT to carry out astrometry. The identification of the asteroids were carried out by 'blinking' the CCD frames on the image display at the SPARCLC workstation. The measurements of the positions of the asteroid and the HST guide stars (Russell et al.: 1990, Astron.J. 99, 2059-2081) were carried out interactively using the Image Reduction and Analysis Facility (IRAF)[1] at the Sparclc workstation at Bangalore. The positions derived using the computer codes developed to carry out astrometry with 4-5 independent triangulations were found to be of sub arcsecond accuracy. (R.Vasundhara, R.Rajamohan, K.Jayakumar, J.C.Bhattacharyya)

3.2 COMETS

3.2.1 Comet Hale-Bopp

Comet Hale - Bopp, C/1995 01 was discovered on July 23 by Alan Hale and Thomas Bopp when it was at 7 AU from the Sun. Dust jets from this comet were reported in late August 1995 (West, 1995, IAUC 6216; Fitzsimmons and Cartwright, 1995, IAUC 6220). Subsequent observations by several groups indicated rapidly evolving dust jets. The CO J(2-1) line was detected by Rauer et al. (1995, IAUC 6236) and Mathews et al. (1995, IAUC 6230) during Setpember 1995. The lines were blue shifted indicating outgassing from the day side of the nucleus. The derived production rate of 1.3 - 4.2 x 10^{28} molec.sec^{-1} are found to be insufficient to explain the huge dust coma around this comet. This comet thus appears to be exceptional and its observations have gained increased importance. An observational program was initiated to obtain the images and spectra of the comet using the facilities at the Vainu Bappu Observatory. The intensity variations in the radial direction at various azimuths in the images obtained during November 1995 were fitted to a theoretical profile given by the relation ϕ^{-k}. Preliminary analysis indicate a directional dependence with value of k of 0.88 + 0.05 along the north to 1.97 + 0.10 along the south, and intermediate values along the east-west direction. In the steady state coma, with a radial outflow of grains, the profiles are expected to be inversely proportional to the density. Preliminary results of determination of the position angles of the brighter extension of the coma towards the north and that of the compact region towards south are in accordance with the general scenario of a peak in the dust ejection following the onset of an outburst near local noon of the comet which is in a complex state of spin proposed by Sekanina (1995, IAUC 6248). (R. Vasundhara, K.Jayakumar, Pavan Chakraborty)

3.2.2 Comet Hyakutake

Comet C/1996 B2 (Hyakutake) discovered by Japanese amateur astronomer Yuji Hyakutake on January 31 1996, was a bright object with a spectacular tail extending to several degrees on the sky even much before the perihelion. The wide angle pictures (Fig.3.2.2.1) was obtained on 24 March at VBO, and shows condensed coma and interesting tail structures of both gas and dust extending to several degrees. Images of the comet obtained using a CCD camera at the 2.34 meter telescope show details of the inner coma at better resolutions. The left panel of Fig.(3.2.2.2) show images of the comet on March 23.79 UT (lower), March 24.84 UT (middle) and March 25.88 UT. The first image was through a B filter and the other two were through R filters. At the distance of the comet on these days the linear size corresponds to 18000 x 15750 square kms. The images shown in the right panel were processed using a median filtering technique to look for fine features embedded in the cometary background. Jets of matter coming out from the nucleus are readily seen.

A plot indicating the iso-intensity contours of the image of the comet taken on 25th March is shown in Fig.(3.2.2.3). The projected direction of the sun is indicated by the arrow. The jets are formed on the sunward side due to the directional out-flow of sublimed gas dragging along with it fine grains of dust from certain vents on the nucleus. Results of Giotto

COMET HYAKUTAKE

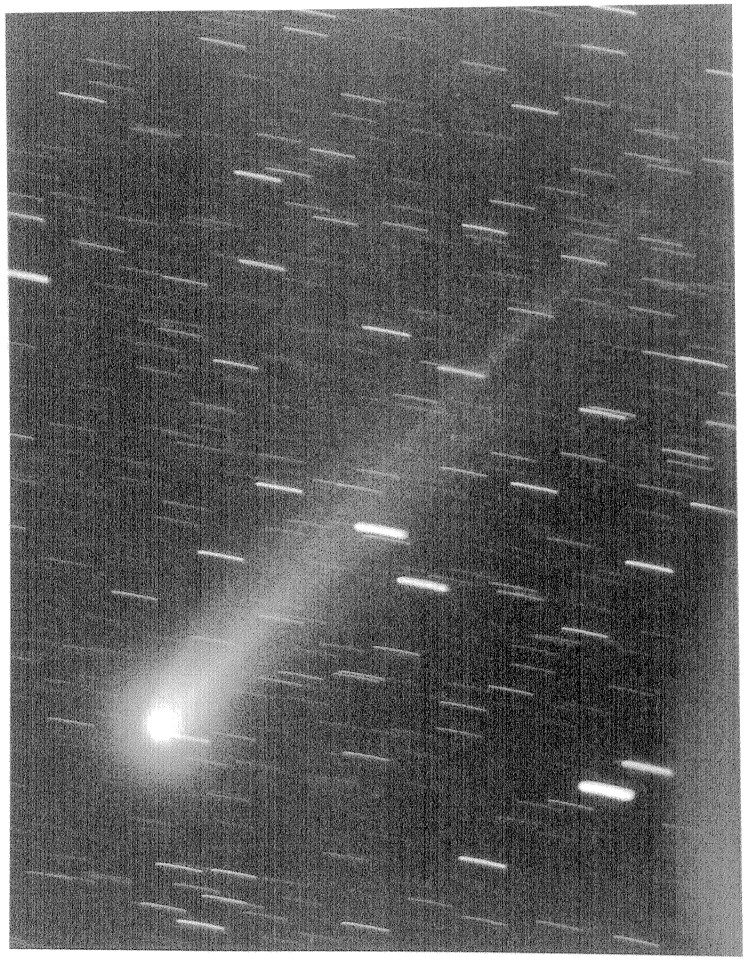


Fig. 3.2.2.1. Wide angle photograph of comet Hyakutake on 24th March, 1995 taken from the Vainu Bappu Observatory by K. Kuppuswamy and Pavan Chakraborty. The photograph spans 11 x 9 degrees. The tail extends to about 10 degrees along south west in this image.

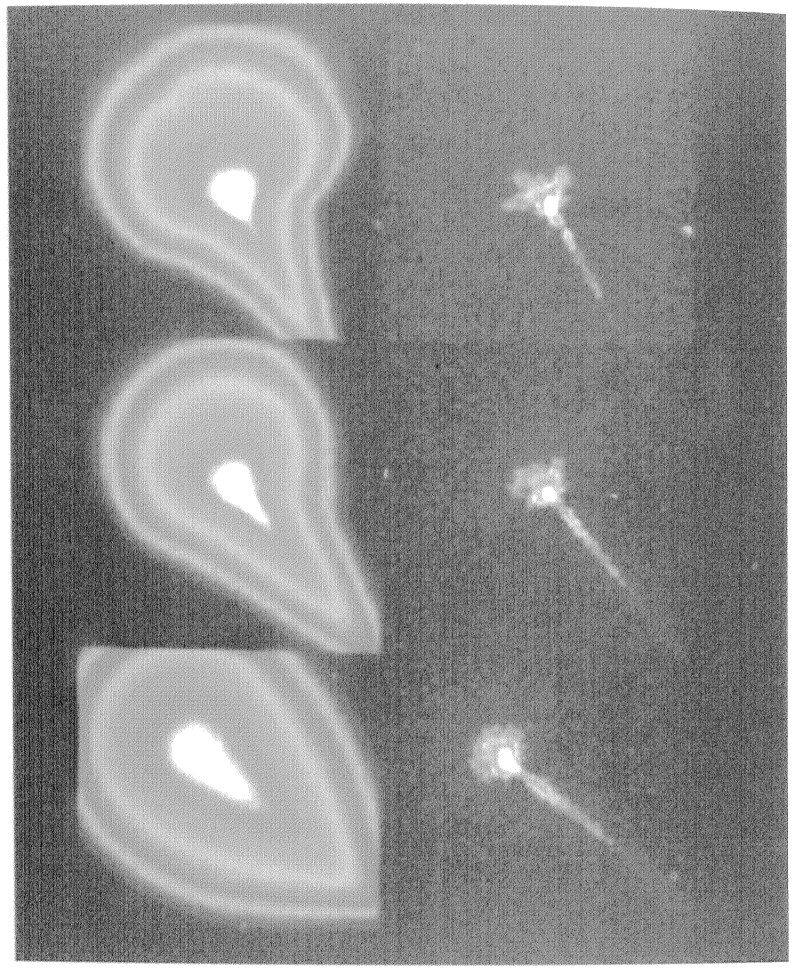


Fig. 3.2.2.2. The left panel : false color photographs of images of the comet obtained on March 23.69 UT (lower), March 24.84 UT (middle) and March 25.88 UT using the 1024 x 1024 pixels CCD Camera at the 2.34 meter telescope. The right panel : The corresponding median filtered images with the same scale. Jets of matter coming out from the nucleus are readily seen. Top is North and East to the left.

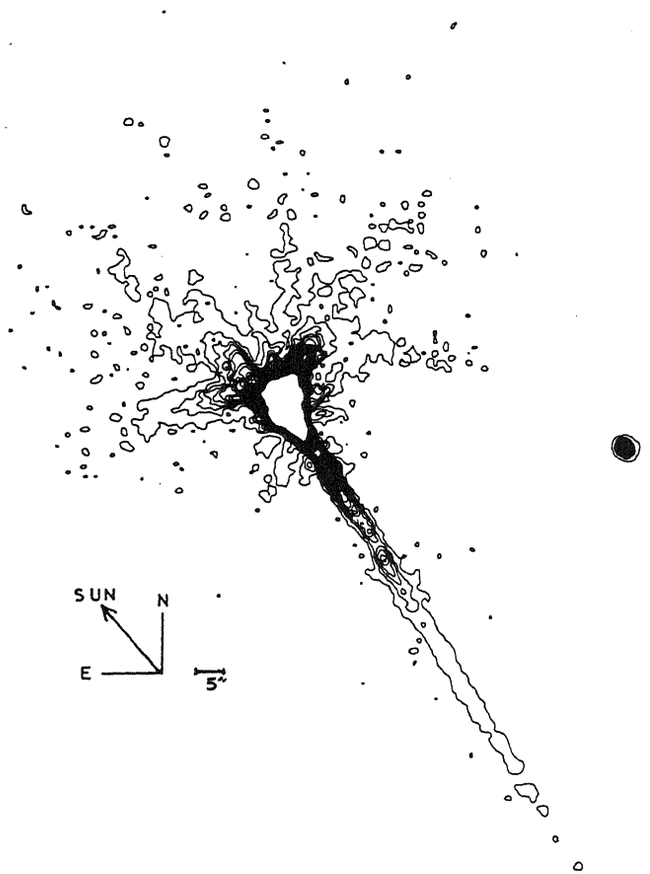


Fig. 3.2.2.3. Iso intensity map of the median filtered image of March 25.88 UT.

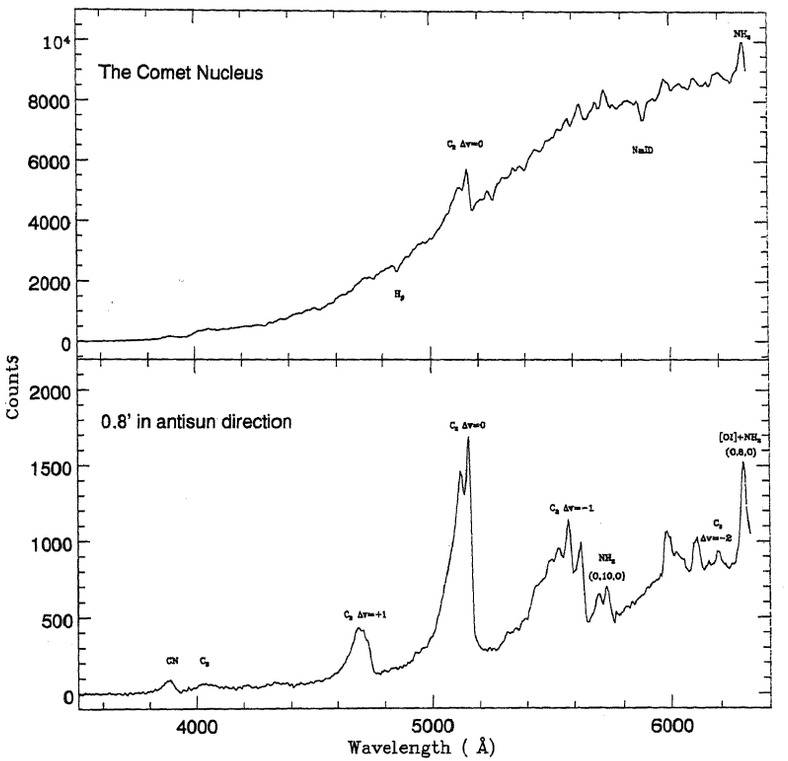


Fig. 3.2.2.4. Spectra of comet Hyakutake at the inner coma and at the tail at a distance of 0.8 arc min (7200 kms) obtained using the 102 cm telescope at VBO. The spectrum of the central region is mostly scattered sunlight. The molecular emissions of CPV2PV, CN and NH_2 dominate in the tail.

space-craft fly-by missions to comet Halley in 1986 indicated atleast for comet Halley that the sublimation from certain active vents were the primary sources of gas and dust. In the post Halley era studies of these jets have therefore gained increased importance. The series of images from VBO are being analyzed to investigate the time evolution of the jets.

Spectra of comet Hyakutake at the inner coma and at different locations along the tail were obtained using the 102 cm telescope at the Vainu Bappu Observatory. The spectrum at the nucleus and at the tail at a distance of 0.8 arc min (7200 Kms) are shown in Fig.3.2.2.4. The spectrum of the central region is mostly scattered sun light. The central region of comet Hyakutake therefore appears to be very dusty. The molecular emissions of C_2, CN and NH_2 dominate in the tail. A detailed analysis of the series of spectra is being carried out (Pavan Chakraborty, M.Appakutty, G.Ganeshan, Alok Gupta, K. Jayakumar, V.Moorthy, S.Perumal G.Selvakumar B.Shylaja* , R.Vasundhara).

Spectrophotometric observations of comet Hyakutake were obtained with VBO's 102-cm telescope during the months of February/March 1996 using the UAGS and 150 1/mm grating. In these observations, the emission features due to CN, the principal Swan band sequences of C2 and also the one due to Na are radily identified. The reduction and analysis work is in progress. (G.S.D.Babu, K.R.Sivaraman)

3.3 GALLILEAN SATELLITES

New constants for Sampson-Lieske theory of the Galilean Satellites have been derived using 6360 individual photographic positions (1891 - 1990) and 438 pseudo astrometric positions from mutual occulations during 1973, 1979, 1985 and 1991. Published values of accurate masses of the satellite and Jupiter related orbital parameters based on the Voyager data have been incorporated in the theory. Using these new sets of constants, significant improvement is noticed in the residuals of the sky plane coordinates and the residuals in longitudes for Io and Europa are found to improve. (R.Vasundhara, J.E.Arlot*, P.Descamps*)

3.4 TECHNIQUES

3.4.1 Image Processing of an Extended Object

Analysis is in progress, of the speckle images of Jupiter obtained in collaboration with the Department of Astronomy, Osmania University, Hyderabad, during the period 17-24th July 1994 of when the fragments of the comet Shoemaker Levy-9 slammed into it. In order to reconstruct the Fourier phase of this image, Blind Iterative deconvolution (BID) technique was applied. Flat field corrections were made for all the 550 images recorded during the aformentioned period. Several images have been processed. The individual spots, marked by the impact of the fragments of SL-9 on to Jupiter, can be identified. (S.K.Saha)

STARS AND STELLAR SYSTEMS

1. STARS

1.1 STELLAR VARIABILITY

1.1.1 Spectral Variations of DY Cen

A spectral atlas of DY Cen, one of the three known hot R CrB stars, is prepared, covering a spectral range 548 nm - 708 nm at a resolution of approximately 40,000. We compare the 1989 spectrum with the one taken in 1992 to comment on their spectral variability. The photospheric absorption lines show a radial velocity variation of 12 kms^{-1} between 1989 July and 1992 May. Emission components of some C II lines present in 1989 are almost entirely absent in 1992. However, HeI line at 587.6 nm that had two absorption components in 1989 shows P-Cygni profile with one absorption and two emission components in 1992. The singlet He I line at 667.8 nm is in absorption on both spectra but the 1992 spectrum shows emission in the absorption core. These lines are possibly formed in an outer region that is affected by wind outflow. Nebular forbidden lines of [O I], [N II] and [S II] appear unchanged. (Sunetra Giridhar, N.Kameswara Rao, D.L.Lambert*).

1.1.2 Abundance Analysis of the field RV Tau variables: EP Lyr,DY Ori, AR Pup and R Sge

The elemental abundances of the four field RV tau stars, EP Lyr, DY Ori, AR Pup and R Sge, indicate that to varying degrees they have experienced fractionation process that have preferentially depleted their atmosphere of elements with high condensation temperatures. In the order of increasing depletion they are R Sge, AR Pup, EP Lyr and DY Ori. The initial composition presumably indicated by the sulphur abundance, was nearly solar for AR Pup, R Sge and DY Ori, while it was about 0.6 dex less than solar for EP Lyr and DY Ori. This implies that the RV Tau stars as a group are not as metal-poor as they were earlier thought to be, but are instead metal-depleted and probably belong to the thick disk. Other stars showing such abundance trend in addition to the present sample of stars are IW Car and V1 w Cen (both RV Tau stars) and ST Pup a W Vir star.

The C^{12}/C^{13} ratio for Ep Lyr and DY Ori estimated using CN lines in 800 nm region are 9 +/- 1 and 6 +/- 3 respectively, indicating that CN-cycled material has been mixed with their surface layers. This is consistent with the general consensus view that RV Tau stars are in a post-AGB evolutionary stage. There is also evidence that EP Lyr has a stellar mass companion as indicated by the radial velocity perturbation. Additional observations are needed to calculate an orbit. But EP Lyr could be a link to the group of metal-depleted high altitude, A-F supergiants, all of which are binaries. (G.Gonzales*, D.L.Lambert*, Sunetra Giridhar).

1.1.3 Spectrum of S Aps at Deep Minimum

High resolution spectrum (30,000) of the cool RCrB stars S Aps has been obtained on 5 June 1992 (JD 2449143.500) with CTIO 4 metre cassegrain echelle spectrograph when the star was undergoing a deep light minimum.

The spectrum shows several emission lines superposed on the absorption spectrum. The spectrum has several interesting features, particularly interesting are the features of NaI D lines. There are two emission systems present (as is typical in R CrB type stars at minimum)

1. A very broad emission (FWHM = 340 Kms^{-1}) is blue shifted by 98kms^{-1} with respect to the stellar velocity of -78 kms^{-1} as reported by Herbig (1993).

2. A sharper component (FWHM = 49 Kms^{-1}) is located at the stellar velocity. (Na emission from the terrestrial airglow is seen but is clearly resolved from the two stellar components). The infrared triplet lines of CaII at 849.5 nm, and 854.7 nm have emissions corresponding to the second set of emissions seen at NaI D (at radial velocity -81Km/s).

The broad emission lines seen here are only in the Na D lines and are similar to those seen in the few other R CrB's observed in minimum (Rao and Lambert 1993, A.J. 105, 1915; Lambert et al. 1990, JAA, 11, 475; A.J.Kenneth and Gaposchkin 1963, Ap. J. 139, 813). The broad lines are clearly blue shifted with respect to the stellar velocity. It is possible that the broad emission from S Aps arises from an extended region which is asymmetrically arranged about the star such as a bipolar flow with the receding jet obscured by dust. The sharp emissions are quite likely in the 'chromospheric' lines seen in the decline of all R CrBs. (N.Kameswara Rao, Aruna Goswami, V.V. Smith*, David L. Lambert*)

1.1.4 Behaviour of OI 777.4 nm Feature in the Spectrum of 10 Day Period Cepheid Zeta Gem

The OI triplet at 777.4 nm is known to be a good luminosity indicator for yellow supergiants. We have therefore monitored OI triplet near 777.4 nm for classical cepheid zeta Gem, using 1 meter telescope of Vainu Bappu Observatory, Kavalur, India for using it for luminosity calibration of Cepheids. Although a well known P-L relation exists for classical cepheids, the advantage of this approach is that by observing once (even without knowing the period) one can get a fairly accurate absolute V magnitude. Secondly, OI triplet being a strong feature, can be measured even from medium resolution spectra. Considering the importance of the line variation during the pulsation cycle, we have carried out an extensive phase coverage with high resolution data. The spectra are obtained at 22 epochs enabling a good phase coverage. We have also monitored the strength of a few metallic lines in that spectral region to understand and account for variation of atmospheric parameters over the pulsation cycle. It is found that the OI line strength does vary with phase but does not follow the light curve pattern. Its strength attains maximum value between phase 0.7 to 0.9. The maximum value when used with a magnitude-equivalent width relation calibrated for F-G supergiants, gives M_v that agrees well with the other estimates of M_v within 0.6 magnitude. It is intended to study the behaviour of this feature for other classical cepheids. (Aruna Goswami, Sunetra Giridhar)

1.1.5 Novae

Two classical novae, N Aql 1995 and N Cas 1995 were observed spectroscopically during outburst. Spectra of N Aql 1995 were obtained before and during the dust formation phase, while N Cas 95 was observed during the pre-maximum, maximum and the immediate post-maximum phase.

Monitoring of the classical nova GK was continued. The nova was caught on its rise to a dwarf nova-like outburst on 1995 Feb 29. Spectra were obtained on Feb 29 and March 1.

Long term monitoring of the recurrent novae T CrB and RS Oph were continued. T CrB has entered the high state, showing strong emission lines. Completion of the analyses of the data on RS Oph obtained during the previous years indicated that more optical data were required to study in detail the spectra type variability of the secondary in this object. (G.C.Anupama, T.P.Prabhu, K.K.Ghosh, G. Pandey)

1.2 STELLAR ACTIVITY

1.2.1 Study of the RS CVn Eclipsing Binaries

The RS CVn eclipsing binaries have shown reddening of their colours as well as some forms of activity in all their spectral regions. Such effects are likely to be due to the circumstellar material which is probably causing the inhomogeneities in the density, temperature and pressure in the chromosphere and the corona of these stars. Since these physical parameters in the outer atmospheres of these stars are expected to be better understood through the study of the phase related variations in their respective energy distribution curves, we are in the process of obtaining the spectrophotometric observations of a few totally eclipsing binaries in the wavelength region of 400 nm to 750 nm at different phases with the facilities available at the 102 cm telescope in VBO. The observations as well as the reduction work are in progress. (G.S.D.Babu, I.E.Derman*, O.Demircan*)

1.2.2 Study of Peculiar A-type stars

The presence of certain peculiar spectral features seen in some A-type stars, place them in the special category of peculiar A-type stars. However, since the longer wavelength regions are generally found to be the peculiarity-free zones, the energy distribution curves of these stars are being obtained through spectrophotometric observations in the region of 400 nm to 800 nm. The data from IRAS observations also is being included for extending the energy curves into the IR regions. Using these curves, various physical parameters of these stars are estimated and based on the extent of normality, the specificities of these stars may be confidently accounted for. This is important for understanding the evolutionary stage of these stars. Spectrophotometric observations of a number of stars of this type have been commenced using the 102-cm telescope at VBO and the 120 cm telescope at Japal Rangapur Observatory.

Further, the variations in the 420 nm and the 520 nm features, seen in some of the Ap stars, indicate the inhomogeneities of the chemical composition on the surface of these stars, giving rise to the possibilities of large spots on the surfaces of these stars. For this purpose, a few selected stars are being monitored to respectively cover the complete periods of variation. The instrumentation and the observational techniques are the same as given above. (G.S.D.Babu, G.C.Kilambi*).

1.3 CIRCUMSTELLAR MATTER

1.3.1 Be Stars

Even though the first Be star (Gamma Cas) was detected in 1866 by A.Secchi, the physics of Be stars is not yet clearly understood. Several attempts have been made, in the past, to model the Be phenomenon. However not a single model is able to explain all the observed properties of Be stars. The most difficult part in modelling the Be stars, is to find out the correct rotational law of the envelope of Be stars.

From the high resolution H-alpha spectroscopy of a large (163) number of Be stars, at the coude focus of 1m reflector of VBO using echelle spectrograph with CCD camera, obtained between 1989 and 1995, we measured the ratio of emission shell rotation velocity to the stellar rotation velocity. We also measured the corresponding values of the equivalent widths of the H-alpha lines. The plot of log(velocity ratio) versus log(equivalent width) is shown in figure 1.3.1.1. The slope of this curve is .74 +/- .1, which is a new result. (K.K. Ghosh, K.C. Srinivasan*, K.R. Radhakrishnan*, R. Krishnamoorthy*)

Also we have found that at least 15 Be stars (out of 163 Be stars) have displayed the V/R variations of H-alpha and H-beta profiles on time scales of few years (figure 1.3.1.2). We are trying to model the periodic V/R variations in the frame work of global oscillations of the envelope or disk of Be stars (K.K. Ghosh, R. Krishnamoorthy*, K.R. Radhakrishnan*, V. Manivannan*, K.C. Srinivasan*)

1.3.2 Polarisation in A-type Stars with Circumstellar Shells

The infrared astronomical satellite found a large number of A-type stars to have infrared excesses. The star Vega is a famous example. The excess infrared emission arises in a shell of gas and dust that surrounds the star. We have made optical linear polarisation measurements of about 30 A-type stars that are known to be either Ae/A shell stars or have shown anomalous emission in the infrared. Compared with the general population of A type stars, stars of this group are found to have polarisation that is also anomalous and is suggested to be circumstellar in origin. (H.C.Bhatt)

1.3.3 Constraints on Stellar Grain Formation from Presolar Graphite in the Murchison Meteorite

We report the results of isotopic, chemical, structural and crystallographic microanalyses of graphite spherules (0.3 - 9 μm) extracted from the Murchison meteorite. The spherules have $^{12}C/^{13}C$ ratios ranging over 3

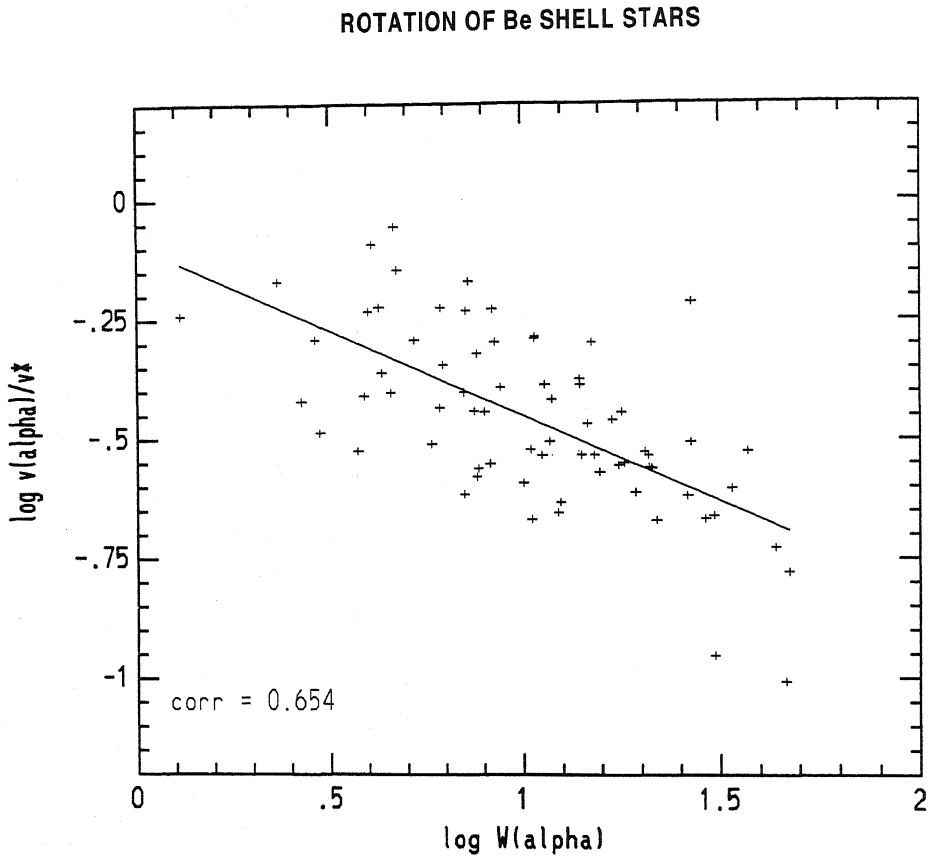


Fig. 1.3.1.1. A plot of log (velocity ratio) versus log (equivalent width). This plot relates the strength of the H-alpha line to the ratio of rotation velocities of shell to star.

H-ALPHA AND H-BETA PROFILES OF Be STARS

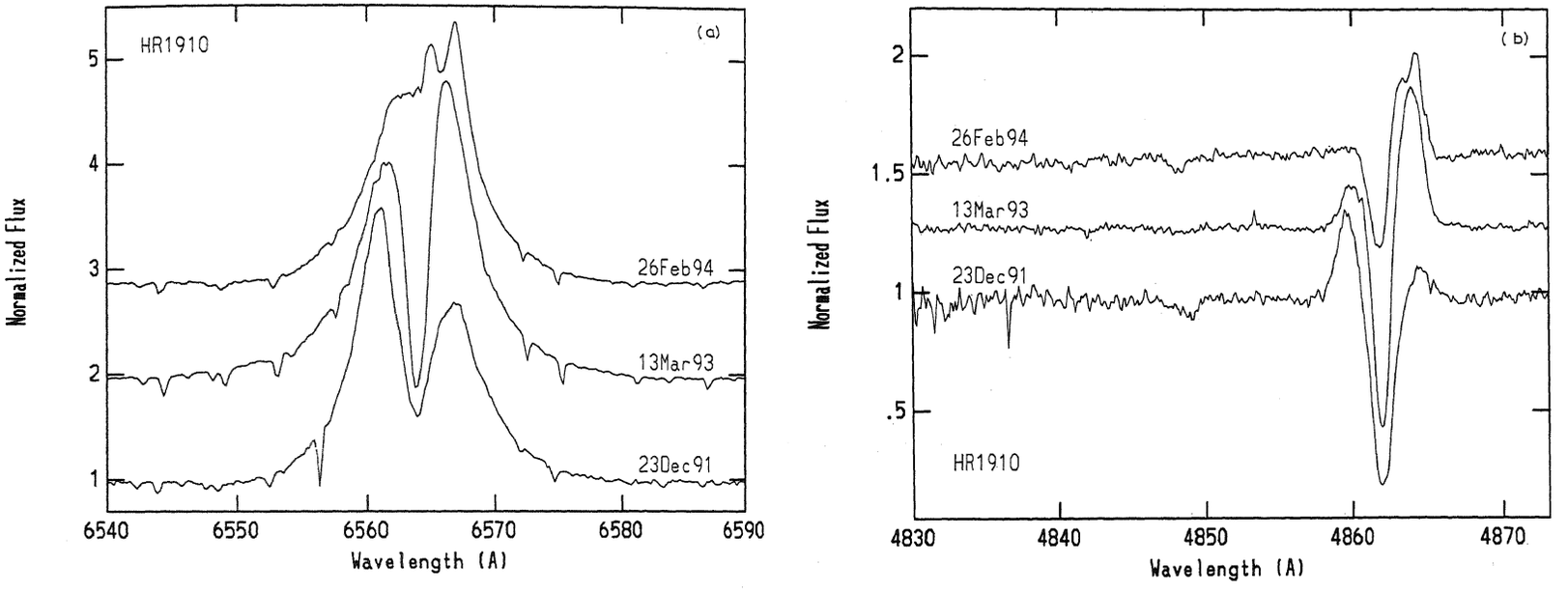


Fig. 1.3.1.2. The spectrum of HR 1910 is shown in the region of (a) H-alpha and (b) H-beta for three different epochs.

orders of magnitude (from 0.02 to 80 times solar), clearly establishing their presolar origin as stellar condensates. These and other isotopic constraints point to a variety of stellar types as sources of the carbon, including low mass AGB stars and supernovae. Transmission electron microscopy (TEM) of ultrathin sections of the spherules revealed that many have a composite structure consisting of a core of nanocrystalline carbon surrounded by a mantle of well-graphitized carbon. The nanocrystalline cores are compact masses consisting of randomly oriented graphene sheets, from PAH-sized units up to sheets 3-4 nanometers in diameter, with little graphitic layering order. These sheets probably condensed as isolated particles that subsequently coalesced to form the cores, after which the surrounding graphitic mantles were added by vapor deposition.

We also detected internal crystals of metal carbides in one-third of the spherules. These crystals (5 - 200 nm) have compositions ranging from nearly pure TiC, to nearly pure Zr-Mo carbide. Some of these carbides occur at the centers of the spherules and are surrounded by well-graphitized carbon, having evidently served as heterogeneous nucleation centers for condensation of carbon. Others were entrained by carbon as the spherules grew. The chemical and textural evidence indicates that these carbides formed prior to carbon condensation, which indicates that the C/O ratios in the stellar sources were very close to unity. Only one of the 67 spherules studied in the TEM contained SiC, from which we infer that carbon condensation nearly always preceded SiC formation. This observation places stringent limits on the possible delay of graphite formation and is consistent with the predictions of equilibrium thermodynamics in the inferred range of pressure and C/O ratios.

We model the formation of the observed refractory carbides under equilibrium conditions and show that the chemical variation among internal crystals is consistent with the predicted equilibrium condensation sequence. However, to account for crystals in which Mo is enriched relative to Zr, it is necessary to suppose that Zr is removed by separation of the earliest formed ZrC crystals from their parent gas. We also explore the formation constraints imposed by kinetics, equilibrium thermodynamics and the observation of clusters of carbide crystals in some spherules, and conclude that relatively high formation pressures (>0.1 dyne/cm^2) and/or condensible carbon number densities (>10^{-8} cm^{-3}) are required. The graphite spherules with $^{12}C/^{13}C$ ratios less than the solar value may have originated in AGB stellar winds. However, in the spherically symmetric AGB atmospheres customarily assumed in models of stellar grain formation, however, pressures are much too low (by factors of >10^2) to produce carbide crystals or graphite spherules of the sizes observed within plausible timescales. If some of the graphite spherules formed in the winds from such stars, it thus appears necessary to assume that the regions of grain formation are density concentrations with length scales less than a stellar radius. Some of the spherules with both $^{12}C/^{13}C$ ratios greater than the solar value and ^{28}Si excesses probably grew in the ejecta of supernovae. The isotopic compositions and growth constraints imply that they must have formed at high densities (e.g., with $\rho > 10^{-12}$ g/cm^3) from mixtures of inner shell material with material from the C-rich outer zones. (Thomas J. Bernatowicz*, Ramanath Cowsik, Patrick C. Gibbons*, Katharina Lodders*, Bruce Fegley, Jr*, Sachiko Amari*, Roy S. Lewis*)

1.4 HYDROGEN DEFICIENT STARS

1.4.1 Hydrogen Deficient Nature of Z UMi

Benson et al (A.J. 108, 247, 1994) classified Z UMi as a RCrB star based mainly on the light variations. Although their low resolution spectra show that Z UMi is a carbon star, the hydrogen deficiency, which is a characteric feature of all RCB type stars, is not established. To investigate this aspect and further explore the other spectroscopic features, we obtained high resolution (60000) spectra in both blue (420-463 nm) and red (505-795 nm) regions using the Sandiford echelle spectrometer at the Cassegrain focus of the McDonald observatory's 2.1m telescope on JD 2449471.829 and JD 2449826.900. The strong lines of the CH band (G band) at about 430 nm, which are prominently seen in normal carbon stars are conspicuous by their absence in the spectrum of Z UMi indicating the hydrogen deficient nature. The radial

velocity as measured from several relatively unblended atomic lines is -37.4 kms^{-1} for both epochs. We confirm the membership of Z UMi to the RCrB class of variables. Further analysis is in progress. (Aruna Goswami, N.Kameswara Rao, G.Gonzalez*, David L.Lambert*)

1.4.2 Abundances of RCrB Stars

The work on the surface chemical composition of RCrB stars has progressed well. The newly constructed model atmospheres of hydrogen deficient stars by Uppasala Group have been utilised in arriving at the abundances of the selected elements. The most interesting results are that the abundances of R Cr B star falls into two groups. For most RCBs a C/Hc value of 1% is found to be consistent with the abundance patterns and indicate the link with extreme helium stars. Most of the stars are generally metal (Fe) poor by a factor of 10 whereas a minority group shows deficiency of about 100. The surface hydrogen abundance is found to be correlated with abundance of s-processed elements Y and Ba. Thus the hydrogen ingestion into the helium burning region seems to be responsible for the neutron flux and $^{13}C\ (\alpha,n)^{16}O$ is probably the source of these neutrons. A mild exposure of neutrons is indicated from the overabundances of Y relative Ba. ON processed material also seems to have been brought to the surface. This work was presented as an invited review at the 2nd International Conference on "Hydrogen Deficient Stars" at Bamberg, Germany. (N. Kameswara Rao, D.L. Lambert*)

1.4.3 High Resolution Spectroscopy of RCrB

High resolution spectroscopic monitoring of RCrB during 1994-95 period with 2.1 and 2.7M telescopes of McDonald Observatory showed pulsation related spectral changes. The analysis of the spectrum with the help of the Uppasala model atmospheres show a change of 500° K in T_{eff} of the star between pulsation light maximum and minimum. The changes in the profile and appearance of absorption components in the Na I D lines suggests mass ejections even at maximum light. Velocity gradients in the atmosphere is found sometimess leading to shock heating. The detailed paper is being prepared and part of this work was presented at the 2nd International Conference on "Hydrogen Deficient Stars" at Bamberg, Germany. (N. Kameswara Rao, D.L. Lambert*)

1.4.4 Spectroscopic Changes in FG Sge

The spectroscopic changes in the famous born-again AGB star FG sge during the deep decline in 1994 have been studied along with other high resolution spectra obtained in 1992-93. The similarity with RCrB stars during the deep minimum are emphasised and shows that FG Sge is transforming into a RCrB star. A poster paper was presented at the 2nd International Conference on "Hydrogen Deficient Stars" at Bamberg, Germany. (V. V. Smith*, G.Gonzalez*, N. Kameswara Rao, D.L. Lambert*)

1.4.5 Spectroscopy of RCrB during 95-96 Minimum

High resolution spectroscopic monitoring of RCrB during the current 95-96 minimum is done with 2.1 and 2.7 meter telescopes of McDonald Observatory. Along with sharp emission lines, broad emissions of the [NII], [Ca II], HeI λλ 5876, 3889, 7065 along with NaI D, CaII and K, KI λλ 7665, 7698 have been detected. At some phase even the sharp absorption lines show red displaced emission components. The [N II] line profiles show double peaks. Analysis and observing is in progress. (N. Kameswara Rao, D.L. Lambert*)

1.4.6 CO in RCrB Atmospheres

In a collaborative project to detect and study the CO molecule in the atmosphere, RCrB star observations have been obtained with ESO 3.5 meter NTT at 2.3 microns. Several stars have been observed and analysis is in progress. (M.Asplaund*, B. Gustafsson*, D.L. Lambert*, N. Kameswara Rao)

Attempts to detect the CO molecular features at 2.3 microns in the RCrB stars SU Tau during a deep optical minimum with 3-m IRTF showed negative result i.e. no evidence for the presence of those features either in absorption or emission. (N. Kameswara Rao, Suchitra Balachandran*)

1.4.7 Polarimetry of RCrB Stars

Polarimetric observations of RCrB and other RCB stars and RV Tauri stars were obtained with 1.2 meter Gurushikhar telescopes of PRL. Analysis is in progress. (N. Kameswara Rao, M.R. Deshpande*)

1.5 POST - AGB STARS

1.5.1 The Chemical Composition of IRAS 05341 + 0852 : a Post-AGB F Supergiant with 21 μm Emission

An abundance analysis of the photosphere of the F-type Post-AGB candidate IRAS 05341+0852 is presented. It shows that the star is metal-poor ([Fe/H]=–1.0) and carbon-rich (C/O≈2.2). Carbon, nitrogen, oxygen, silicon, and possibly lithium and aluminum are found to be over abundant. Most importantly this star has large overabundance of s-process elements which are as follows: [Y/Fe]= 1.80, [Ba/Fe]= 2.58, [La/Fe]= 2.86, [Ce/Fe]= 2.95, [Pr/Fe]= 2.27, [Nd/Fe]= 1.97, and [Sm/Fe]= 0.86. The overabundances of s-process elements and carbon in IRAS 05341+0852 is direct evidence for the association of s-process enhancements with shell-flashes and dredge-up. These are likely responsible for the increase in C/O. The possible overabundance of Li ([Li/Fe]≤2.5) and Al ([Al/Fe]≤1.1) in IRAS 05341+0852 could indicate that there was Hot Bottom Burning (HBB), where the base of the convective envelope is hot enough for nucleosynthesis to occur (Lattanzio 1993). HBB has been suggested as the mechanism responsible for the production of Li in the Li-rich AGB stars discovered by Smith and Lambert (1989). In fact these are bright AGB stars which are oxygen-rich rather than carbon-rich. Recent calculations by Sackmann and Boothroyd (1992) showed that Li-rich and O-rich AGB stars are the result of HBB. In the HBB models temperatures of the order of 0.5 – 1 x 10^8 K are encountered at the base of the convective envelope. This is hot enough for the reaction $^{25}Mg(p,\gamma)\ ^{26}Al$ resulting in the production of Al.

The [S/Fe]=0.07 indicates that the low Fe abundance is intrinsic and is not due to fractionation. The low metallicity, heliocentric radial velocity (v_r = 25 km s^{-1}), and the high Galactic latitude (b = –12°) indicate that this star belongs to an old disc population. The presence of circumstellar carbon molecular lines and C/O≈2.2 suggest that the progenitor was a carbon star which has evolved to a carbon-rich post-AGB star.

Furthermore we have detected the C_2 Phillips and CN Red bands in absorption. We find rotational temperatures, column densities, and expansion velocities which show that these lines are formed in the detached circumstellar dust shell (the AGB ejecta) and we find an expansion velocity of the AGB ejecta of v_{exp} = 10.8±1.0 km s^{-1}.
(B.E. Reddy, M. Parthasarathy, G. Gonzalez*, E.J. Bakker*).

1.52 CCD Photometry and Spectroscopy of 14 IRAS Sources having Far-IR Colours Similar to Planetary Nebulae

CCD imaging and BVRI photometry of 14 IRAS sources with far-IR colours similar to planetary nebulae and post-AGB stars are presented. Also results of optical and near-IR spectroscopy of 10 of these candidates are given. Based on the spectral energy distribution from 0.4 μm to 100 μm, the sample of program stars are put into two groups. The sources IRAS 08187-1905, IRAS 05238-0626 and IRAS 17086-2403 present similar flux distributions. These three sources have detached cold dust components with dust radii $R_d \approx 1000\ R_*$. The low infrared variability of these sources suggests that the intense mass loss has been ceased. All three sources are at high galactic latitude (1>9°) suggesting that these are old low-mass evolved stars. In the IRAS colour-colour diagram these sources fall in the region where most of the stars are evolved stars and PNe but without CO detection. This is

consistent with at least one source IRAS 17086-2403, in which OH and CO molecular features are not detected. The far-IR excess, non-variablity and high latitude of these objects suggest that these are post-AGB supergiants, slowly evolving towards planetary nebulae phase.

The rest of the sources in the sample: IRAS 04296+3429, IRAS 05113+1347, IRAS 05341+0852, IRAS 06530-0213, IRAS 07253-2001, IRAS 08143-4406, IRAS 14429-4539, IRAS 17150-3224, IRAS 17291-2402, IRAS 17441-2411 and IRAS 23304+6147 present a double peak energy distribution. One peak represents the stellar emission, obscured by optically thin hot dust component and the other is produced by the reemission in the far-IR of the stellar radiation obscured by the dust envelope. The presence of hot and cold dust components suggest that there was a discontinuity in the mass loss history. A possible cause for such discontinuity may be periodic thermal pulsations predicted for the AGB model stars. Most of the sources in this second group are classified as carbon-rich based on the infrared properties of their dust envelopes. The carbon-rich dust envelopes imply the overabundance of carbon in the photospheres, which suggest that these stars have undergone third dredge-up which occurs in the advanced phase of AGB evolution of low and intermediate mass stars.

The analysis of low resolution optical spectra, BVRI photometry and the comparison of observed flux distribution with Kurucz models show that most of these sources are F and G post-AGB supergiants.
(B.E. Reddy, M. Parthasarathy)

1.5.3 BVRI Photometry of a Few 'unidentified' IRAS Sources

We selected 33 unidentified IRAS sources based on the following criteria: (i) galactic latitude more than 2°, (ii) have flux density higher than 1 Jy at 12 microns, (iii) have good fluxes at 12, 25, and 60 microns with flux quality factor=3, (iv) and are in the declination zone between +60° and -50°. We identified the optical counterparts of these sources on the POSS, ESO, and SERC sky survey prints. Out of the 33 sources studied by us, 30 have optical counterparts which are stellar in appearance. We have also made BVRI CCD photometry of the optical counterparts of these sources. The IRAS colours and optical photometry suggests that IRAS 00408+5933, 02408+5458, 04101+3103, 04278+2253, 06403-0138, 07430+1115, 08005-2356, 09032-3953, 09370-4826, and 14429-4539 are most likely late type post-AGB stars with cold detached circumstellar envelopes and the rest are most likely AGB stars with dust shells. (K.V.K. Iyengar, M. Parthasarathy)

1.5.4 Abundances of the He^3 star 3 Cen A (B5 IIIp) from the ultraviolet spectrum*

High resolution IUE ultraviolet spectra of the peculiar He^3 star 3 Cen A were analyzed in the whole 120-320 nm region. Abundances were derived from the comparison of the observed and computed spectra. For computing spectra a Kurucz ATLAS9 model with parameters T_{eff}=17500 °K, log g = 3.8, and microturbulent velocity ξ=0 km s^{-1} was adopted. A rotational velocity v sini=0 km s–1 was assumed. Colour indices, flux distribution, ultraviolet Si lines, and Balmer profiles were used to fix the model parameters. The observed spectra are reproduced at best with the following abundances : He [-0.55], B [-1.0], C [-0.75], N[-0.5], Mg [-0.5], Al [-1.5] underabundant, P [+1.6], Sc [+1.0], Mn [+1.5], Cu [+2.0] overabundant, Ga [+3.2], Kr [+3.3], Hg [+4.5] extremely overabundant.

The comparison of the ultraviolet spectrum and of the abundances of 3 Cen A with those of the normal B-type star ι Her and of the Pop II peculiar B-type star Feige 86 has shown that the same elements contribute to the line spectrum of ι Her and 3 Cen A even if with different abundances, so that the spectra can be compared. In the case of Feige 86, the overabundance of heavy elements which are not observed in 3 Cen A (i.e. Pt II, Pt III, Au II, Au III, probably Mo III), the lower over abundance of Ga [+1.0], and the larger underabundance of the light elements C [-2.5] and N [-2.0] make the ultraviolet line spectra of Feige 86 somewhat different from those of both ι Her and 3 Cen A. Also the He

* Based on observations by the International Ultraviolet Explorere (IUE)

I lines have different profiles in the two peculiar stars, although He is underabundant in both.

With the specific abundances of 3 Cen A we computed an opacity sampling ATLAS12 model having the same parameters as the ATLAS9 model. We found that the energy distribution from the ATLAS9 model and solar abundances is not very different from that derived from the ATLAS12 model, the synthetic spectrum approach, and the specific abundances of 3 Cen A. (F. Castelli*, M. Parthasarathy, M. Hack*)

1.5.5 Hot Post-AGB stars

Spectra of several hot post-AGB stars have been obtained to derive the spectral types and luminosity classes and to detect nebular and stellar emission lines. Spectra were obtained at CTIO (Cerro Tololo Interamerican Observatory, Chile) and at Kavalur. We detected nebular and stellar emission lines in several hot post-AGB stars. The spectra are being analysed to derive the Teff and log g (spectral type and luminosity class) and to study their location in the H-R diagram. From an analysis of these spectra we discovered two new planetary nebulae. All the stars considered in this program are IRAS sources with far infrared colours similar to planetary nebulae. Several of these stars are at high galactic latitudes, and detached cold circumstellar dust shells indicate that these are rapidly evolving to hotter spectral types and into early stages of planetary nebulae. (V. Jyotsna, M. Parthasarathy, J. Drilling*)

1.5.6 A and F Stars with Cold Detached Circumstellar Dust Shells

Several A and F stars with cold detached circumstellar dust shells have been detected from an analysis of IRAS point source catalogue far-infrared fluxes. Spectra of several of these stars were obtained using the spectrographs on the 1-m and 2.3-m telescopes at Kavalur. We detected H-alpha emission in several of these stars. In few stars we also found emission lines Na I. All these spectra are being analysed to study the circumstellar neutral envelopes, dust shells and the physical characteristics of these stars. Some of these stars are post-AGB stars and some of them are Vega and Beta Pictoris type of objects. (T. Sivarani, M. S. Parthasarathy)

1.6 STELLAR CHROMOSPHERES

1.6.1 The Ca II Infrared Triplet Lines in Cool Stars

A detailed study of the Ca II infrared triplet lines as diagnostics of stellar parameters in cool stars has now been completed. CCD spectra of the three Ca II lines at 849.8, 854.2, 866.2 nm have been obtained at a spectral resolution of 0.04 nm using the coudé echelle spectrograph at the 40-inch telescope at VBO in another 20 stars, the sample of program stars thus totalling now to 150. These stars are brighter than V = +7.0 spanning a range in spectral types from F7 to M4 of all luminosity classes which include several superluminous supergiants (of class Ia) and a range in metallicity [Fe/H] from -3.0 to +1.1. These have been analysed to investigate the dependence of the Ca II triplet strengths on stellar parameters like luminosity, temperature and metallicity. The data reduction has been carried out with the IRAF available at the SUN workstations. The analysis reveals a strong dependence on luminosity, much stronger for metal rich stars than for the poor ones and a milder dependence on metallicity, although much more conspicuous in supergiants than in dwarfs. All these correlations are found to be non-linear over the parameter space covered. This study has shown that the non-linear dependence is clearly apparent only over a sufficiently large parameter space. The present work also shows chromospheric activity to be an important phenomenon affecting the strength and the shape of the line profiles. A detailed systematic survey revealed that stars of similar luminosity and metallicity have varying Ca II line depths owing to varying chromospheric emission filling in the absorption in these stars. It appears from the search that the central depths of the Ca II triplet lines are excellent chromospheric activity indicators. The Ca II triplet strength/shape is thus observed to be a triparametric discriminant in cool stars. (Sushma V. Mallik)

1.6.2 H-alpha in Superluminous Supergiants

The earlier observations of the H-alpha line at 656.3 nm have shown it to be strong, deep and asymmetric in giants and supergiants in the sense that its core is shifted to the blue with respect to the line center, thus suggesting an outward moving chromosphere. Radiative transfer calculations were then done to compute H-alpha line profiles to simulate these observations assuming a positive velocity gradient across the chromosphere. CCD spectra of H-alpha have now been obtained in several superluminous supergiants at a resolution of 0.04 nm using the coudé echelle spectrograph at the 40-inch telescope at Kavalur. The H-alpha line is observed to be much wider and deeper than in supergiants, also revealing a more complex profile. In particular, small emission components are detected within the absorption and also lying on the red or blue end of the absorption above the level of the continuum. This indicates outflows in the atmosphere to be of a much more complicated nature than a simple outwardly increasing velocity flow. The future work would include an attempt to compute the H-alpha line profiles assuming a more realistic velocity distribution.

Two other chromospheric diagnostics, namely, the Na I D lines (589, 589.6 nm) and the K I lines (366.5, 369.9 nm) have also been observed in the above stars. The spectral regions in the vicinity of these lines are ridden with telluric lines. In order to remove this telluric contamination, for each program star, a hot star (B or A) with high rotational velocity has also been observed in the same direction (therefore through a similar air mass) so that only the telluric lines show up. The spectrum of the program star divided by that of the hot star would then be free of these contaminations. The data reduction is in progress. (Sushma V. Mallik)

2. THE GALAXY AND THE INTERSTELLAR MEDIUM

2.1 BINARY STAR FORMATION

Recent discoveries of larger numbers of pre-main-sequence (PMS) binary systems, in both high mass and low-mass star forming regions, indicate that binaries are formed very early in the star formation process. The evolution of a protostellar binary system is investigated while it is embedded in its parent molecular cloud core, and is acted upon by gas drag due to dynamical friction. Approximate analytical results are obtained for the energy and angular momentum evolution of the orbit in the limiting cases, where the velocity is much smaller than, and much larger than the velocity dispersion of the gas. The general case is solved numerically. It is found that dissipation due to drag causes a decay of the orbit to small separations in relatively short periods of time. For typical molecular cloud core parameters, with density 10^6 cm^{-3} and velocity dispersion 1.5 kms^{-1}, a one solar mass binary system with initial separation of 10^4 AU decays to 1500 AU in 10^6 years. It is suggested that decay of the orbit due to dynamical friction can circumvent the problem of forming close binaries, as long-period binaries get dragged and evolve to shorter periods.

Observations of MS and PMS binary systems show the presence of a distinct peak in the frequency distribution of periods. The dynamical friction timescale, being proportional to the velocity (and hence period) of the binary components, is different for binaries with different oribital periods. The initial frequency distribution of periods with which the binary systems are formed, is thus expected to change with time. Binary populations have therefore, been statistically generated and evolved, for comparison with observations of the frequency distributions with period of MS and PMS binaries. Two initial distributions (a) equal number of binaries per separation interval and (b) equal number of binaries per logarithmic separation interval, were considered. It is found that in both cases, drag due to dynamical friction causes a peak in frequency distribution, as found observationally. (H.C.Bhatt, U.Gorti).

2.2 STAR CLUSTERS

2.2.1 A Deep UBVRI CCD Photometric Study of the Moderately Young Southern Open Star Cluster NGC 4755

CCD observations in U, B, V, R and I pass bands have been used to generate (U-B), (B-V) colour-colour and deep V, (B-V); V, (U-B) and V, (V-I) colour-magnitude diagrams for the young open star cluster NGC 4755. The sample consists of 813 stars reaching down to 20 mag in V. There appears to be non-uniform extinction over the face of the cluster with a mean value of E(B-V) = 0.41 mag and a range of about 0.05 mag. The true distance modulus to the cluster has been estimated as 11.6+/- 0.2 mag. An age of 10 Myr has been assigned to the post-main sequence cluster members. Ages of the post-main sequence and pre-main sequence stars indicate that massive (>10 solar mass) and low mass (<2 solar mass) stars in the cluster are formed nearly at the same time from a molecular cloud which might have existed for a period of about 6-7 Myr. (Ram Sagar, R.D.Canon*)

2.2.2 Study of Young Open Clusters

Young open clusters have been found to be one of the very useful tracers of spiral structure of our Galaxy. The data of OCl 556-Haffner 3, (suspected to be a double cluster), obtained using the recently enhanced facilities of the 102 cm telescope of VBO, is being reduced and the analysis is in progress (G.S.D.Babu, M.N.Anandaram*)

2.3 PLANETARY NEBULAE

Our earlier photoionization modelling work on WC 11 type nebulae indicated that tiny dust grains of size approximately 1 nm may play a role in producing the observed excess radiation between .1 - 1 nm. Therefore the possibility of including them in the model code developed earlier was explored using an approach proposed by Siebenmorgen as applied to Poly Aromatic Hydrocarbons. CCD spectroscopy of select WC 11 type nebulae has also been continued at the VBT.

Furthermore, a programme for the detection of the forbidden line of Fe X at 637.4 nm in X-ray emitting planetary nebulae has been initiated in collaboration with Dr. B.G. Anandarao of the Physical Research Laboratory. Since the expected intensity of the emission is small, the Fabry-Perot technique needs some modification. Work on these lines is in progress. (R. Surendiranath)

2.4 INTERSTELLAR MEDIUM

2.4.1 Magnetic Fields in Interstellar Clouds

The programme to study the distribution of magnetic fields in interstellar clouds has been continued. Linear polarisation measurements are made of stars in the background of interstellar clouds. The observed polarisation position angles for the stars are used to map the geometry of the magnetic field in the cloud. Several cometary globules and high Galactic latitude molecular clouds have been observed. In a number of dense dark clouds, the ratio of polarisation to extinction in the outer regions of the clouds is found to be similar to that for normal interstellar polarisation, but much lower values for this ratio are found in the high density central regions. This may indicate that either the dust - grain alignment efficiency is lower in the central regions or the grains there are predominantly spherical in shape, perhaps due to rapid grain growth. (H.C. Bhatt)

3. GALAXIES AND ACTIVE GALACTIC NUCLEI

3.1 GALAXIES

3.1.1 Morphological Studies of Normal Luminous Ellipticals

A study of the detailed morphology of luminous elliptical galaxies was started this year with the aim of understanding why only a small fraction of them are associated with powerful radio galaxies (PRGs). From the

luminosity function of radio galaxies, it is known that the probability of radio emission increases with the optical luminosity of the host elliptical galaxy; the most powerful PRGs are all associated with optically luminous and optical morphological peculiarities indicative of mergers. To confirm this aspect as well as understand why all optically luminous ellipticals are not PRGs, a sample of radio quiet luminous ellipticals as well as a comparison sample of PRGs with luminous elliptical hosts is being imaged through broadband as well as narrow band filters, using the 2.3m VBT as well as 1m telescope at VBO. (A.K.Pati, L.Saripalli, S.G.Bhargavi).

3.1.2 Identification and Morphology of Core Dominated Radio Sources

A program to do optical identifications of a sample of core dominated radio sources has been initiated with the 2.3m VBT. The sample consists of approximately 700 sources selected from the Parkes survey and having a flat spectral index over a wide range of frequencies. These sources have been observed by one of the collaborators using the VLA at 8 GHz with a high resolution of 200 milliarcsec. Using the digitised POSS, a preliminary attempt was made to identify the sources; about 70% seem to be associated with point sources, 10% with galaxies, while 20% have no counterparts to the limit of the POSS. A large fraction of the cases with optical counterparts seen, are at the faint limit of the POSS and the nature of the objects is not clear.

With regard to the radio properties, about half of those identified with galaxies have extended radio structures in addition to compact, unresolved emission from the core. On the other hand, in the case of optical point objects and empty fields, a much smaller fraction (15% and 30% respectively) have extended structure. The frequent association of bent radio jets, superluminal motion at mill-arcsecond scales, the rapid radio flux variability and the overall complex radio structures of core dominated radio sources are thought to be indicative of beaming effects due to relativistic motion.

The current observational program is aimed at identifying the optical counterparts of the sources and whereever possible, obtaining structural information and morphology. With the strong possibility of AGN type activity indicated for this class of objects, in the long term, a program to study the variability characteristics of the objects in the optical is also planned. (A.K.Pati, L.Saripalli, A.R.Patnaik*)

3.1.3 Far Infrared Galaxy Counts

Far infrared galaxy counts were modelled using Monte Carlo simulation techniques. Emphasis was placed on separate behaviours of disc and spheroidal galaxies in the far infrared regime due to the very different dust geometries for the two systems. It was found that the deepest existing observed galaxy counts at 60 and 100 microns could be adequately modelled by passively evolving galaxy models. (Arati Choksi)

3.1.4 Compact Groups of Galaxies

Compact groups are dense concentrations of galaxies with overdensities comparable to those in the centers of rich clusters. They are of interest as their high galaxy densities and small crossing times make them ideal sites for the study of galaxy interactions and mergers and the products of these processes. In recent times the interest in these systems has been fuelled by the discovery of extended diffuse X-ray halos around these systems. In the last two years ROSAT observations of several groups have shown that compact groups are frequently associated with extended diffuse X-ray halos.

Three groups HCG44, HCG62 and HCG79 were observed in the BVRI bands, while HCG62 was also observed through an H-alpha +[N II] narrow band filter. HCG62, which is detected to have a cooling flow, based on ROSAT observations, shows H-alpha emission regions in the centres of three of the group galaxies, similar to those detected in the dominant galaxy in a cooling flow cluster. However, the total H-alpha luminosity is nearly two orders of magnitude lower than the cluster

galaxies. Also, the H-alpha to blue luminosity ratio is similar to that seen in individual X-ray loud ellipticals. These estimates are found to be consistent with the low rate of accretion of the cooling X-ray gas. (M.Valluri*, G.C.Anupama)

3.1.5 Central Regions of NGC 2903

A study of the central region of the Sersic Pastoriza galaxy NGC 2903 has been made based on new images in B, V, and R bands and published information on the velocity field. The oribital resonances have been identified. A new ring is identified at the Inner Lindblad Resonance region which is elliptical with major axis perpendicular to the bar. The nuclear ring is also elliptical with similar elongation, but oriented along the bar. The Lagrangian points and the outer ring seen in published H I maps are identified with corotation and outer Lindblad resonance. The photometry of knots in the rings in the central region and the nucleus is performed and compared with stellar evolutionary synthesis models. The nuclear knots present evidence for more than one burst of star formation during the last 10 Myr whereas the ILR ring photometry is consistent with a single burst of star formation. (T.P.Prabhu, G.C.Anupama, A.K.Kembhavi*).

3.1.6 Young LMC Star Clusters as a Test for Stellar Evolutionary Models

Study of the Magellanic Cloud star cluster is of extreme importance for understanding the processes of star formation and evolution. It is because they differ from the star clusters of our galaxy in a number of respects e.g. they occupy regions of the age and metallicity domain which are not populated in our galaxy. Therefore they extend the range of comparison between stellar evolutionary theory and observational data. A comparison of the observed colour-magnitude diagrams and the main sequence luminosity functions of four Large Magellanic Cloud star clusters namely, NGC 1711, NGC 2004, NGC 2164 and NGC 2214 with the synthetic ones derived from the theoretical stellar evolutionary models favours the convective core overshoot models. The synthetic integrated luminosity functions derived from the models can be matched with the observed ones by varying the value of mass function slopes within a reasonable range. In order to constrain the models from this comparison, reliable estimates of mass function slope and binary fraction are desired. (A.Subramaniam*, R. Sagar)

3.2 ACTIVE GALACTIC NUCLEI

3.2.1 Photometric Monitoring of Blazars

This program, aimed at studying the pattern of variability of this class of AGN, both in magnitude and colour, over different timescles, was continued. Approximately half a dozen objects have been observed with good temporal coverage in the timescales of hours and year to year. Due to the vagaries of weather, good temporal coverage in the timescales of days and weeks is not yet achieved. Preliminary photometric data reduction was done for some of the objects and it was found that due to primary flexure problems, it is necessary to fit separate point spread functions for image data taken at different positions, in order to reduce errors in the derived magnitudes. This reduction process needs a lot more time and is being carried out. (A.K.Pati, K.K.Ghosh).

3.2.2 X-ray Energy Distribution of Radio Loud Quasars

A sample of radio loud quasars with the PSPC on ROSAT were selected to study their X-ray spectra. The goal was to make a systematic study of the X-ray energy distribution of radio-loud quasars, and rigourously test predications of ubiquitous relativistic beaming and unified schemes. If the component of the X-ray emission from radio-quasars that is associated with the radio emission is also relativistically beamed, then unified schemes predict that the core-dominance of the quasar correlate with the X-ray energy index. The results strongly support this hypothesis. While no evidence for significant excess absorption at the

sight of the quasar was found, the results indicate that a parameter in addition to the core-dominance is required to characterize the slope. (P.Shastri, B.Wilkes*, M.Elvis* et al.).

3.2.3 Properties of the Host Galaxies of Quasars

It was earlier believed that core-dominated quasars did not have observable extended emission-line gas, and this is a severe challenge to unified schemes that postulate that core and lobe dominated quasars are intrinsically similar objects. To systematically test the result, the host galaxies of quasars have been imaged in the [OIII] emission line. Extended emission-line gas has been detected around several of them and interpretation of the systematics in the properties of this gas and the connection with radio morphology is being done. It turns out that the ionization of the extended gas is spatially correlated with the radio axis. The results indicate that the ionizing radiation must be axisymmetric, analogous to the case for nearby lower luminosity objects. The paucity of observable extended emissionline regions in core-dominated quasars is probably due to the fact that the gas has some bulk velocity in the direction of the jet, doppler-shifting the line emission out of the passband. The results suggest that there is in fact no inconsistency with unified schemes. (P.Shastri, L.Brown*, D.Wills*).

3.2.4 Imaging Polarimetry of AGNs

(i) X-ray selected BL Lac objects

Analysis of the imaging polarimetric observations (observed at the prime focus of VBT) of 6 X-ray selected BL Lac objects (XBLs) (MS0737+74, MS0950+49, MS1221+24, MS1402+04, MS1458+22 and MS1534+01) have been carried out. The term X-ray selected is used here to refer that these objects were first detected in Einstein Observatory Medium Sensitivity Survey. These blazars have been classified into two groups - XBLS and RBLs (radio selected BL Lac objects). Our present optical polarization measurements suggest that high polarization is not only restricted to RBLs but it also can be seen in XBLs. Multifrequency spectra and two-point spectral indices of these six sources indicate that these objects are highly polarized XBLs. New model will be required to explain this high polarization properties of XBLs. During these studies we have also detected several new unidentified sources with high polarization in the fields of these XBLs. (K.K.Ghosh, S.Soundararaja-perumal)

(ii) ROSAT A11 Sky Survey (RASS) sources

With the launch of ROSAT a new phase of AGN research was initiated. The unprecedented high sensitivity of the (PSPC) detector in the All Sky Survey, yielded about 60000 X-ray sources. The current estimates predict between 25000 and 30000 new, previously unknown AGN among them. The optical identification, the classification and cataloguing of these objects will require a substantial effort over the next years. Since the variable and high optical polarization is one of the defining properties of blazars we are currently performing imaging polarimetry of several RASS sources with VBT as a part of massive identification programme in collaboration with the AGN groups of MPE, Garching. (K.K.Ghosh, S.Soundararajaperumal, W.Brinkmann*, J.Siebert*).

3.2.5 Multi-Colour Deep Imaging of Three High Redshift Quasars

With the motivation to detect quasar clustering at high-redshifts, in order to constrain theories of structure formation at early stages in the history of the universe, we have carried out deep CCD imaging (total exposure times ranging from 90 minutes to 1425 minutes), at the prime focus of VBT, of the fields containing known $z > 4$ quasars at the centre.

The continuous monitoring of these objects also facilitate us to look for the pattern of variability, if any, in these objects. Observations are being continued and the processing of the images obtained is in progress. (K.K.Ghosh, S.Soundararajaperumal).

3.2.6 Imaging Photometry of Radio-Quiet Quasars

A large number (20) of radio-quiet quasars have been observed at the prime focus of VBT and at the cassegrain focus of the 1m telescope of VBO with an objective to study the pattern of variability over hours to nights to months to years and thus put constraints on the models of radio quasars. Data reduction is in progress. (K.K.Ghosh, S.Soundararaja-perumal).

3.2.7 Formation of Galaxies

Research was initiated on a project attempt to directly link AGN activity in galaxies to the overall, first large scale star burst within protogalactic environs. It was found that such a model could adequately explain the sizes and the current number densities of normal galaxies. (Arati Choksi)

3.2.8 Intra-night Monitoring of Optically Selected Bright Quasars

As part of an ongoing programme to search for intra-night optical variations, we report results for six radio-quiet and one radio-moderate, but all optically bright and luminous, quasi-stellar objects, using the 2.34m Vainu Bappu Telescope. Moderately strong evidence is found for the microvariability of the radio-quiet QSOs 0946+301 and 1444+408 and weaker evidence is found for 0117+213. We also find a few spikes (on time scales of < 10 minutes) seen in the optical output of the radio quiet QSOs 0117+213, 0946+301, and 11630+377. Additional observations of these and other QSOs could provide a powerful means of discriminating among various theoretical mechanisms proposed for the energy source and in particular, the origin of optical microvariability in active galactic nuelei. Finally, by comparing the present observations with those made by us 1 year earlier, long term variability (5% to 15%) is detected for 4 of the QSOs in our sample. (Ram Sagar, Gopal Krishna*, Paul J.Wiita*).

4. INSTRUMENTS AND TECHNIQUES

4.1 SPECKLE INTERFEROMETER

Recent efforts have led to the successful completion of a basic speckle camera for use at the 2.34 meter VBT, VBO, Kavalur. When supplemented by a modern PAPA (Precision Analogue Photon Address) detector, this camera will be an extremely sensitive instrument. The mechanical design and fabrication of this speckle interferometer was done at the Central Manufacturing Technology Institute (CMTI), Bangalore, using the computer aided design and analysis. Low expansion stainless steel (SS410) was used for fabricating the instrument. Blackening of stainless steel items was carried out for all the mechanical components and mounts etc. at the Material Science Division, National Aerospace Laboratory (NAL), Bangalore. A laboratory test using an artificial star and an artificial telescope with f/3.25 beam validated the design and fabrication of this sensitive interferometer. The system will be tested at the Cassegrain end of the 2.34 meter VBT very soon.

A mechanical spacer of 450 m has also been fabricated to keep the interferometer sufficiently away from the Cassegrain end of the telescope to obtain best focus. Care has been taken to ensure that the hot air is not getting trapped inside the interferometer during observations. (S.K.Saha)

4.2 COUDE ECHELLE SPECTROMETER

The design and fabrication of the collimeter system is being entrusted to Dr. Bingham of University College, London. The redesigning of the system is complete. The mechanical system to support the spectrometer is under design. (N. Kameswara Rao, Suresh, Mahesh)

THEORETICAL ASTROPHYSICS

1. EARLY UNIVERSE

1.1 QUANTISATION OF SPACE-TIME

The analogies between the twistor formalism and torsion in general relativity and unified theories was developed. The SL (2,c) group of transformations was used in particular to suggest a unified link. Commutation relations between conjugate twistor variable was developed. Incorporation of mass and charge as well as supersymmetry in the formalism was considered. Implications of such a quantized space time framework for the early universe are being examined. (C.Sivaram)

1.2. CONSTRAINTS ON ALTERNATE THEORIES OF GRAVITY

Recent theories such as those of extended inflation incorporate scalar-tensor theories, various low energy limits of superstring theories involving higher powers of curvature, theories with torsion, etc. Although these theories are severely constrained by solar system tests (as well as by binary pulsar limits), it is possible they could have played an important role in the very early universe. In that case they would have left some imprints in the COBE spectrum. The tilted COBE spectrum can be used to constrain some of the parameters of the theories in the early universe. Work along this direction is in progress. (C.Sivaram)

1.3 BARYON INHOMOGENIETIES

Large baryon inhomogeneities, which could be created by evaporating quark nuggets formed during a first-order phase transition from quark-gluon plasma to hadronic matter in the universe, would be damped by neutrinos which effectively transfer heat from the surroundings into the dense baryonic lumps causing the latter to heat up and expand. A detailed calculation of this πneutrino inflation' process has been done including all the relevant neutrino-lepton and neutrino-nucleon interaction processes and including the applicable degeneracy effects. Compatability with the results of primordial nucleosynthesis implies severe constraints on the initial number density of the quark nuggets at the time of their formation. (P.Bhattacharjee, J.Alam*, B.Sinha*, S.Raha*)

1.4 COSMIC RAYS

The "topological defect" (TD) scenario of origin of cosmic rays with energies above 10^{20} eV has been further explored.

It has been shown that persistence, at a quadrupled total exposure of the detector, of an apparent "gap" in the highest-energy cosmic ray spectrum as implied by the existing data, would rule out conventional shock acceleration mechanisms of origin of these particles at the 99 percent confidence level. The particles above 10^{20} eV might then be directly produced by decay from some higher energy scale (as in the TD scenario) in contrast to acceleration of charged particles from lower energies. Indeed, such a gap in the spectrum can be a potential signature of grand unification scale physics. (P.Bhattacharjee, S.Lee*, D.Schramm*, G.Sigi*)

The implications of "burst"-like nature of the sources in the TD scenario are being worked out. Also being studied are the implications of a possible non-power law injection spectrum of cosmic ray particles in the highest-energy regimes in the TD scenario. Other topics under study include constraints imposed on the parameters of the TD model by recent measurements of the low-energy cosmic ray antiproton flux, and the constraints on the particle injection rate in the TD model from various cosmological considerations and from the nature of evolution of specific kinds of TDs as revealed by recent numerical simulations of these TDs. (P.Bhattacharjee)

2. GALAXIES

2.1 DYNAMICS

The effect of varying the impact parameter on the structure of the remnant of a collision of two equal mass galaxies has been investigated by performing several numerical simulations. The simulations cover a wide range of values for the distance of closest approach and include both merging and non-merging types of collision. The galaxies are initially placed on parabolic or marginally bound orbits. It has been found that merging takes place when the distance of closest approach is less than 2.5 times the initial half mass radius of a typical galaxy. Tidal friction causes decay of companion orbit during the first close contact and merging occurs during subsequent close encounter. The simulations show that merging takes place in less than 50 crossing times if the angular momentum is less than a critical value. The fact that galaxies of comparable mass would merge in less than 80 crossing time has been earlier noted by other workers.

The merger remnants and the survivors tend to develop a single density profile which closely resembles that given by de Vaucouleurs. The surface brightness of the merger remnant decreases with the logarithm of the half mass radius with a slope of 1.3. Such a correlation was earlier observed by Kormendy for tidally disturbed galaxies. The survivors of the collision lie along a line in the plane of the `half-mass radius - brightess' parameter space as prescribed for normal ellipticals by Kormendy. The merger remnants lie slightly above this line with slope -2. They are fainter and larger than their progenitors. Merging does not take place in less than 100 crossing time for encounters with distance of closest approach greater than 3 times the half-radius. There is no significant change in the structure of the galaxies if the encounter is a distant one.

A series of computer simulations of collisons of galaxies of unequal mass and size has been performed using the GRAPE system computer recently procured under India-Japan collaboration. These simulations are to be used to investigate the process of merging of unequal mass galaxies which dld not receive much attention during the past. It is also expected to give some idea about the formation of multiple nuclei in the cores of remnants of collision. A huge amount of data has been generated and the analysis is progressing. (P.M.S. Namboodiri)

2.2 RADIATION PROCESSES

An electron moving with a superluminal velocity in a dielectric medium gives rise to spontaneous Cerenkov radiation. If, instead of a single electron, a high density superluminal electron beam is made to pass through a dielectric, the spontaneously generated radiation will grow exponential with distance and is known as stimulated Cerenkov radiation. If, in addition, an incident electromagnetic field interacts with a strong superluminal or subluminal electron beam, a frequency upconverted scattered radiation is produced, which by analogy to a similar process in vacuum with subluminal electron beams, is known as Cerenkov-Raman radiation. We explore and point out the role of these processes in the dust environs of Active Galactic Nuclei. Since the refractive index of the dust matter is a key factor in these processes, their inclusion links the properties of the dust grains with the characteristics of the nonthermal continuum especially in the infrared range, which the observations show to be particularly bumpy and therefore requires additional contributions over the thermal continuum. (V.Krishan)

2.3 TURBULENCE

We have proposed a model for the flat rotation curves of spiral galaxies in an earlier paper of ours (Prabhu and Krishan, Ap.J. 428, 483). We could resolve the galactic velocity field into a turbulent and a gravity component. Since the Tully-Fisher relationship highlights a tight correlation between the galactic velocity and its luminosity, we think that it is worthwhile to study the individual correlations between the luminosity of a galaxy and its turbulent and gravity components of velocity. This could give us an insight into the dynamics influencing the

overall correlations as observed. This, we believe, would lend a physical basis to the long accepted empirical relation, which is a powerful tool for distance determination. Towards this end, we have modelled the velocity fields of 76 galaxies and the individual correlations were studied in the U,B,V,I and $I_{23.5}$ bands. Despite the sample limitations our study reveals an interesting feature viz that the correlation between the luminosity and the average turbulent component of velocity is relatively better than that between luminosity and the average gravity component at short wavelengths. In the longer wavelength regions, the correlation between luminosity and the average gravity component is relatively better than that between luminosity and the average turbulent component of velocity. (R.D.Prabhu, V.Krishan)

2.4 ROTATION

The rotation curves of galaxies are modelled using very special properties of an hydrodynamically turbulent fluid processing helicity fluctuations. The development of correlations among these fluctuations leads to the formation of organized structures characterized by a new flat branch of the spatial energy spectrum in addition to the well known Kolgomogorov spectrum. It is proposed that the flat nature of the rotation curves of galaxies may be a result of the energy cascading processes occurring in turbulent galactic atmospheres. Thus, in this model, there is no need of invoking dark matter to account for the flat rotation curves of galaxies. (V.Krishan)

2.5 DARK MATTER

Several implications of the new result (obtained by the IIA group), that the velocity dispersion of dissipationless dark matter particles in the Galaxy is larger than or of the order of 600 km/s (a factor of two larger than the value usually assumed on the basis of some ad hoc assumptions), are being worked out. A new analysis of the data on the velocity distribution of stars perpendicular to the Galactic disk is being done in order to infer the amount of (dissipational) dark matter associated with the disk. Also being done is a rigorous two-parameter fit to the Galactic rotation curve data to obtain the best fit values of the velocity dispersion as well as the central density of the dark matter particles in the Galaxy. These studies have important bearings on the interpretation of the results of ongoing laboratory experiments in search of dark matter particles. (P.Bhattacharjee, R.Cowsik, C.Ratnam)

2.6 NON-STANDARD COSMOLOGY

2.6.1 The Narlikar-Das Model - Discordant Redshifts, Quasar-Galaxy Associations and Luminous Connections

A model developed by Narlikar & Das (ND) (1980, ApJ, 240, 401) in the VMH scenario was fairly successful in explaining the discordant (anomalous) redshifts and various other features of typical quasar-galaxy (Q-G) associations. The ND model has recently been used to obtain an elegant interpretation of the observed luminous connections between objects with vastly dissimilar redshifts. A preliminary analysis for the pair 3C 232/NGC 3067 [z = 0.534 and 0.005 respectively] was carried out. More detailed analysis for the same pair is nearing completion and some other well known objects such as the (in) famous MK 205/NGC 4319 are being studied along similar lines.

Also a detailed study of the effects of the redshift dependence of particle masses in a quasar in the ND model on its luminosity evolution is underway. (P.K. Das)

2.6.2 Hubble Relation

The Hubble relation in VMH has the simple form

$$z = H_o \Delta\tau \text{ (for small z)}$$

where $\Delta\tau$ is the look back time. Thus it is an 'age redshift' effect in the sense that the look back time to a distant galaxy shows it in an earlier era when its particle masses were smaller and its redshift therefore

larger. For higher z, the realtion

$$H = Ho\ (1+z)^{3/2}$$

can quanitatively account for the observed deviations from the Hubble line for Normal E galaxies.

2.6.3 Redshift Quantization

Quantization (periodicities) in the redshift dsitributions, which has been observed from the highest to the lowest redshifts, cannot be explained in the expanding universe scenario. However, VMH may provide a solution in the following manner. AT the zero mass surfaces, where the galaxies are created, the classical action is very small and quantum considerations are necessary. The emergence of matter from zero mass, quantum mechanical realm in discrete bursts spaced at discrete time intervals could then possibly lead to a quantized redshift distribution. An attempt is being made to further develop this interesting idea. (P.K. Das)

2.6.4 The 'Missing Mass' Problem and Rotation Curves

The 'missing mass' (dark matter) problem originates from the inferred peculiar velocities and velocity dispersions of galaxies. The failure in the detection of exotic dark matter inspite of strenuous searches, however, raises doubts as to whether the galaxy redshifts are indeed indicative of true velocities. Hence VMH, in principle, may have an answer to this problem. On a suggestion from J.V. Narlikar an interpretation is being sought for the flat rotation curves of the spirals in the VMH scenario using the equations of motion in the H N theory.

Preliminary calculations show that in VMH the particle orbits shrink and the orbital periods decreaase with time due to the increase in mass. If Δ is the logarithmic increment in mass the excess (or deficit) redshift z of matter in the spiral arm can then be expressed as

$$z = z_0 - \Delta\,[(1+z_{i0} - z_{d0}\,(1+2z_{d0})] + \Delta^2\,[1+z_{i0} + z^2_{d0}] + \ldots.$$

where $z = z_g + z_d + z_i$, z_g, z_d and z_i are respectively the gravitational, Doppler and intrinsic components of the redshift and the subscript denotes the initial values at $t = t_0$.

More detailed calculations are in progress. (P.K. Das)

2.6.5. Statistical Significance of Q-G Associations

The inverse correlation between the angular separations (o) and the galaxy redshifts (z_G) in Q-G associations has a theoretical explanation in the ND model. A search for a possible correlation between the angular separations and the quasar redshifts has not yet yielded conclusive results. Further work based on more recent data is being carried out. (P.K. Das)

2.6.6 Nucleosynthesis

The ejection of matter (quasars) from galactic nuclei in the ND model is an example of a white hole i.e. 'mini bang'. Mini bangs of larger dimensions giving rise to masses of cluster and super cluster size can be envisaged. It has been pointed out by Hoyle that a mini bang mass ~ $5x10^{15}$ M_0 can simulate the primordial nucleosynthesis exactly. This scenario is being further investigated. (P.K. Das)

2.6.7 The Cosmic Microwave Background Radiation (CMBR)

A qualitative interpretation for the CMBR in the static VMH scenario can be given. (Narlikar & Arp 1993, ApJ, 405, 51). The energy density generated by H→He conversion giving 4 He abundance of the order of 0.21 by mass in the mini bang nucleosynthesis entirely accounts for the observed CMBR energy density. Arp et al. (1990, Nature, 346, 807) have discussed the important problem of thermalization of this radiation with the help of graphite or iron whiskers, condensed from the metallic

vapours ejected by supernovae, which will produce a Planckian spectrum of 2.7 °K with $\Delta T/T < 10^{-6}$. Thus in this alternative scenario the CMBR is not of the relic type and its observed smoothnes can be understood despite the presence of discrete structures. It is planned to study this exciting scenario in further detail. (P.K. Das)

3. BLACK HOLES

3.1 KERR-NEWMAN BLACK HOLE

In order to study the interplay among gravitation, electromagnetism and spin dependent forces in general relativity, the equilibrium of a charged test particle with spin placed in the spacetime of a charged, rotating Kerr Newman black hole was studied in detail. This case differs considerably from that of a charged particle without spin. Spin dynamics of the particle was also analysed. (C.V.Vishveshwara)

3.2 QUASINORMAL MODES

Quasinormal modes of black holes have been considered to be a means of detecting both black holes and gravitational radiation. An important factor in this connection would be the sensitivity of the modes to external perturbing influences on the black hole. This would be reflected in small changes in the equivalent potential generated by the black hole spacetime which determines the modes. We have studied this problem by determining the modes for different potentials. Results indicate that the fundamental mode remains essentially unaltered exhibiting the signature of the black hole. Higher modes change considerably, probably revealing the nature of the perturbing influence. (C.V.Vishveshwara)

3.3 GYROSCOPIC PRECESSION

We have studied in detail the phenomenon of gyroscopic precession and the analogues of inertial forces within the framework of general theory of relativity. For this purpose we have focussed attention on the Ernst spacetime, an example of static metrics, and the Kerr-Newman spacetime, an example of stationary metrics, both containing black holes. We have shown how gyroscopic precession and centrifugal force reverse simultaneously at the photon orbits in the Ernst Spacetime. The more complicated situation in the Kerr-Newman Spacetime, in which this does not happen, has also been analysed.

3.4 STRINGS

In discussing the paradox of information loss in black holes connection is made with gravity of string theory. The nature of the microstates associated with the tremendous entropy when an object collapses to a black hole is obscure, unlike in other physical contexts where statistical mechanical entropy counts the number of accessible microstates. The striking similarity between the huge number of microstates implied by the black hole entropy on the one hand and the exponentially rising degeneracy of string modes (as in current superstring theories) rising with mass, is shown to indeed provide such microscopic basis. The information diffusion time for an outside observer is shown to be proportional to be cube of the hole mass, in this picture. The argument is extended to entropy of supermembranes in D dimensions. (C.Sivaram)

4. NEUTRON STARS AND PULSARS

4.1 DISC ACCRETION

Disc accretion on to a neutron star possessing a weak surface magnetic field (10^8 G) provides interesting x-ray emission scenarios, and is relevant for understanding x-ray bursters and low-mass x-ray binaries. Such weak-field neutron stars can rotate very rapidly and are also seen as millisecond pulsars and may be relevant for quasi-periodic oscillators. The equation of state of neutron stars and general relativity play essential roles in such a scenario. In a previous study, we have demonstrated that an incorporation of rotational effects always increases

the disc luminosity, usually decreases the boundary layer luminosity, and always reduces the rate at which the neutron star's momentum rises with accreted mass. The rotation was treated general relativstically, using the Hartle & Thorne approximation to obtain a first estimate. The effects found are large enough to merit their consideration in analyses of observations of low-mass x-ray binaries. In view of this, we have extended the calculations to include rotational effects beyond the Hartle & Thorne approximation by constructing rapidly rotating neutron star models, and using realistic equation of state models. (B.Datta, A.V.Thampan)

4.2 SPIN EVOLUTION

The spin evolution of pulsars may be an important factor for their magnetic field decay. A promising model in this category is suggested by G.Srinivasan et al. (Current Science, 59 (1990) 31). This involves the interpinning of the quantized flux tubes and the quantized vortices of superfluid neutron matter in the neutron star interior. The final field decay that can be achieved in this model is strongly dependent on the field diffusion time scales across the neutron star surface. We have investigated the Ohmic diffusion of the magnetic field that has just been expelled from the interior of a neutron star and deposited in the botton layers of the star's crust. Since, in our study, the currents supporting the field are located deep inside the stellar crust, we find that a major factor that influences the evolution is the impurity parameter of the crust lattice. We find that Ohmic decay time scales in the range $10^{7.5}$ 10^{9} years obtain for a wide range of crustal temperatures and impurity concentrations for various equation of state models of neutron star matter. This result is in agreement with the Ohmic time scale that appears to be required to explain observed magnetic field strengths of isolated and binary neutron stars in the spindown-induced magnetic flux expulsion scenario. (B.Datta, D.Bhattacharya*)

4.3 ABERRATION AND GRAVITATIONAL LIGHT BENDING

The work on the geometrical analysis of the magnetic field line structure of an oblique dipole has been continued to include the effects of aberration and gravitational light bending on photon propagation starting from a pulsar polar cap. As the open field lines actually divide into two branches, this has suggested an identification with the core and conal emissions from pulsars. In this picture, the core emission emanates from a high altitude contrary to what has been believed. This is a very satisfactory proposal for the following reason. Our work indicates that inclusion of the gravitational light bending effect raises serious doubts about the currently accepted proposal in which the core emission originates from the stellar surface. The reason is that a consideration of light bending effect on photon propagation precludes the fixing of the altitude of core emission at or near the surface of the neutron star based on simple dipole pictures.

Aberration effects have provided a potentially independent way to determine the inclination angle of a pulsar. Observations of a number of pulsars show a systematic shift of core centre with respect to the conal component in their pulses. In many the shift of the former is advanced in phase and if interpreted as due to aberration, it enables us to deduce the inclination angle by attributing a much larger altitude of emission to the core component than the conal one. (R.C.Kapoor, C.S.Shukre*).

4.4 GAMMA RAY BURSTS

Many models of gamma ray bursts involve simultaneous emission of gamma rays, neutrinos and gravitational waves. The relative amounts of neutrinos and gravitation waves emitted in various models such as those involving neutron star mergers, neutron star collapse, transition to quark or strange matter phase with or without giant glitches etc. are compared and other characteristic signatures such as intensity, duration of signals etc. are being studied. (C.Sivaram)

5. RADIATIVE TRANSFER

5.1 UNPOLARISED LIGHT

5.1.1 Transfer of High Energy Radiation

Radiative transfer is solved in the photon energy range 1-125 KeV. The equation of transfer is solved simultaneously with Kompaneets equation to find the enhancement of photon energy due to the presence of hot electron gas. Modified black body radiation is applied at one of the boundaries of a plane parallel slab and no radiation is given at the other boundary. Free-free emission and absorption are assumed to be present in the medium. The reflection of radiation at the boundaries and the emergent radiation are estimated. The internal radiation fluxes are estimated so that when radiation pressure or mean intensities are needed in the estimation of mass motions, these can be utilized. The solution in a spherically symmetric media is also obtained. (A. Peraiah, B.A. Verghese, M.S.Rao)

5.1.2 Line Profiles From Close Binaries

Spectral line profiles have been computed in expanding and extended and distorted atmospheres of the components of close binary systems. Reflection of light from the companion star is taken into account. The lines are computed with a two-level atom approach in Non-LTE approximation. The expansion of the atmosphere is treated in a comoving frame of the gas. Expansion velocities as large as 30 to 40 mean thermal units are included. Hydrogen Lyman alpha line is calculated in such a medium. A large atlas of line profiles have been calculated for different values of non-LTE parameter, ratio of continuum to line absorption, different line centre optical depths, different velocity laws, varying degrees of reflection from the companion component P cygni line profiles have been obtained. (A.Peraiah, B.A.Varghese, M.S.Rao)

5.1.3 Emission Lines from AGNs

Emission lines from the AGN's are being calculated. As the accretion discs are asymmetric in geometrical shape, no symmetric solution of radiative transfer - plane parallel spherical or cylindrical - would apply. Therefore we require to develop a solution which suits the particular geometrical shape which is done. Moreover the disc is rotating and this aspect should be taken into account within a given line of sight. We obtain asymmetric emission lines which look very similar to those observed. (A.Peraiah, B.A.Varghese, M.S.Rao)

5.1.4 Stellar Winds in O and B Stars

The work on stellar winds in O and B stars is continuing. More lines due to N, Ne, Mg, Sn are added. (A. Peraiah, B.A.Varghese, M.S.Rao)

5.2 POLARISED LINE TRANSFER

A new operator perturbation method for polarized line transfer is formulated. The work is in progress on further development of this method. (Faurobert-Scholl*, H.Frisch*, K.N.Nagendra)

The work on radiative transfer modelling of the IRAS observations on circumstellar dust shells of R CrB is complete. The modelling of observations of W Hya is in progress. (K.N.Nagendra, C.M.Leung*)

The work with Prof.V.V.Ivanov and his co-workers is in progress, under the ILTP program sponsored by DST. The area of research is analytical and numerical methods for polarized radiative transfer problems (K.N.Nagendra).

5.2.1 Line Polarization in Moving Stellar Atmospheres

The problem of polarized line formation in moving atmospheres is solved using the comoving frame technique. The completely non-

RESONANCE LINE POLARISATION IN MOVING ATMOSPHERES

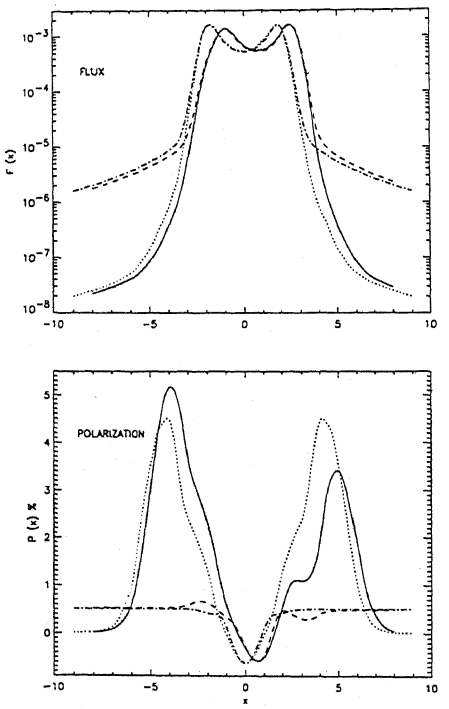


Fig. 5.2.1 Resonance line polarization in moving atmospheres : The emergent flux F(x) and the polarization P(x) profiles of an emission line formed in a planar model atmosphere are shown. The dimensionless frequency shift x represents the separation from the line centre (x = 0) in the units of Doppler width. Dotted and dash-dotted curves represent the PRD and CRD cases for a static slab : the solid and dashed curves, the corresponding cases for a moving slab with a velocity v = 1 Doppler unit. Notice the diminished blue-wing polarization peak, compared to the red-wing peak, and also the asymmetry about the line centre (x = 0).

COMPTON REFLECTION OF X-RAYS

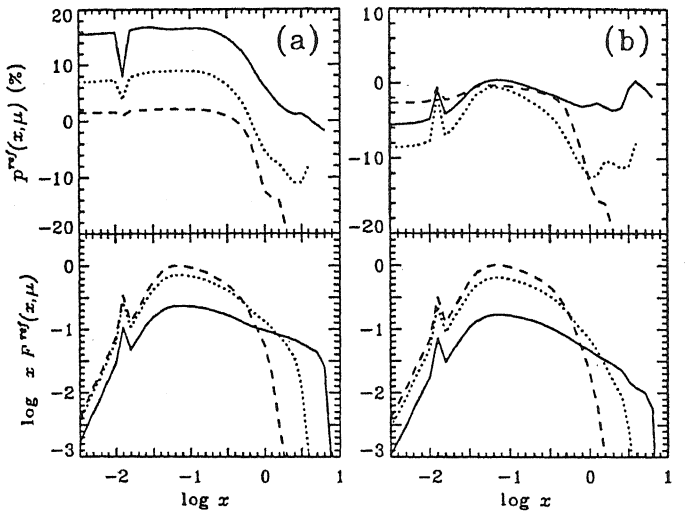


Fig. 5.2.2 Compton reflection of X-rays and gamma-rays by cold matter in accretion disks : The photon energies are expressed in units of the electron rest mass energy. The energy range is 1 kev to 4 Mev. The reflected flux x F^{ref} and polarization p^{ref} spectra are shown for viewing angles which are the inverse cosines of 0.11, 0.5, and 0.89 respectively. The hot corona above the disk is assumed to emit an isotropic spectrum (that is inversely proportional to the energy) which is incident on the top boundary of the cold accretion disk. Panels (a) show the results for this case. The panels (b) show the corresponding results for inverse square variation of the spectrum with energy. Notice the unusual angle dependence of the polarized spectra p^{ref} in this case. The sharp signals represent the unresolved Fe K-alpha, K-beta line doublets at 6.4 and 7.1 kev. The disk is modelled as a slab of density scaled total optical thickness T = 100.

coherent (CRD) and partially non-coherent (PRD) scattering mechanisms are compared. Through these highly accurate benchmark solutions, it is demonstrated that, PRD is a better approximation for resonance lines, even if the lines are weak, contrary to the widely used approximation of CRD. (K.N.Nagendra) .

5.2.2 Compton Reflection of Polarised Radiation in Accretion Discs

The problem of Compton reflection of high energy photons by cold matter in accretion disk models of Seyfert galaxies is studied. The relevant transfer of radiation is solved by an exact method. Fully relativistic polarized Compton scattering cross section, photoelectric aborption, and fluorescent Fe line frequency redistribution are considered. It is shown that the general problem of Compton reflection can be formulated as a Green's matrix approach, wherein highly accurate, temperature, frequency, angle and polarization dependent reflection coefficient matrix (a 4D Green's matrix) is computed by solving the exact radiative transfer problem once, and stored on a secondary memory. The problem of Compton reflection is thus reduced to a trivial 4D interpolation-convolution of the input spectrum with the Green's matrix. This technique is well suited for modelling the observations, in a computationally efficient manner. (K.N.Nagendra, C.M.Leung*)

5.2.3 Fluctuation of Line Polarization due to the Wave Motion

A systematic study of resonance line polarization in solar atmosphere has been undertaken. A computer code is written to incorporate the acoustic wave velocity into the calculation of resonance polarization. This program was tested and found to satisfy the known physical principles like flux conservation etc. Extensive checks were carried out to find the stability of the algorithm against the frequency and angular mesh sizes. The results show that the fluctuation in the linear polarization is of the order of 30% when acoustic waves are present in the atmosphere and the polarization profile may be characteristic of the type of wave present. We are extending the above mentioned code to include the partial redistribution mechanism. At present we are testing the subroutines. (K.E.Rengarajan)

PHYSICS

1. ELEMENTARY PARTICLES

1.1 CHARGE AND MASS

Analogy between torsion line defects in curved space time and vortex lines in a superconductor suggests that the electric charge and mass of elementary particles may have a geometrical origin. Just as the field vanishes everywhere in a superconductor except along the vortex line, where the flux is confined, we have the torsion being concentrated only along the topological defects giving rise to charge. The mass is related to the calculated defect tension while the charge is connected with the gravitational permeability induced by the defect in the space time. The tension is related to the integrated flux and vorticity. A detailed study of the equations implied by the model gives an insight of the universality of electric charge and the nature of the discrete particle mass spectrum. (C.Sivaram, de Sabbata*)

1.2 MATERIAL MEDIUM

The properties of elementary particles in a material medium were examined. One interesting result obtained is that the thermal green functions have a well-defined limit at zero momentum contrary to the traditional belief. This result was proved in a non-gauge theory, and is being extended to gauge theories. In another effort, we showed that neutrinos, which are uncharged particles, do nevertheless emit Cerenkov radiation when they pass through matter. (Palash B.Pal)

2. PHYSICS BEYOND THE STANDARD MODEL

2.1 PARITY NONCONSERVATION

Several experiments are under way to observe parity nonconservation (PNC) in atoms to a high degree of precision. One of the most promising of these experiments is on atomic Ytterbium, which is being carried out at the University of California, Berkeley. Our recent work on the theory of PNC in Ytterbium highlights the dramatic role played by many-body effects. We are presently developing non-perturbative methods to incorporate those effects in our theory. Indeed, the combined result of very accurate experiment and theory for PNC in atomic Ytterbium can provide a sensitive test of physics beyond the Standard Model. We have also performed theoretical studies of PNC in singly ionized Ytterbium in order to determine whether an experiment on that ion can be carried out in our institute. Our result suggests that such an experiment is probably feasible. We have made progress in our ongoing study of PNC in singly ionized Barium. We expect new results in the coming months. (K.P.Geetha, Angom Dilip Kumar Singh, B.P.Das)

2.2 ELECTRIC DIPOLE MOMENTS OF ATOMS

The observation of permanent electric dipole moments (EDM) of atoms arising from time-reversal (T) and parity (P) violation is an unambiguous signature of physics beyond the Standard Model. An important experiment to detect the EDM of atomic mercury is in progress at the University of Washington, Seattle. We have made significant advances in the computational aspects of our work on the theory of EDM in atomic mercury. We propose to apply our formulation of linearized coupled cluster theory to this problem after completing our present work which is based on the configuration interaction method. We have carried out a many-body calculation to determine the best limit to date on the CP violating scalar-pseudoscalar coupling constant.(Angom Dilip Kumar Singh, B.P.Das, E.P.Venugopal*, J.Andriessen*, D.Mukherjee*)

3. NONLINEAR DYNAMICS

3.1 GLOBALLY COUPLED SYSTEMS

We have constructed a prototype model of a globally coupled system on a lattice with space-time hierarchy. In our model fully chaotic dynamical elements at a certain level in the hierarchy are coupled to the levels

immediately above and below in the hierarchy through their mean fields. Remarkably we find, that even when the system is apparently "turbulent", the mean field of the finer scales develop pronounced peaks in their power spectra, signalling the emergence of a quasiperiodic "beating". Further, the fluctuation of the mean field does not decrease as 1/N, where N is the number of elements at a particular level in the hierarchy. Instead it displays marked non-statistical behaviour, with the mean square deviation of the mean field saturating (or even increasing) for high N (i.e. at finer scales). All these features indicate a subtle correlation among the different levels in the hierarchy resulting in a novel collective behaviour.
(Sudeshna Sinha, Gabriel Perez*, H.A.Cerderia*)

2.2 GLOBALLY COUPLED MAPS

We have studied the behaviour of globally coupled maps when the coupling mean field is either delayed or averaged over several time-steps. We find that introducing a delay does not reduce (infact in some cases it increases) the saturation values for the fluctuations of the mean field. The quasiperiodic behavior of the mean field changes, with the emergence of more frequencies in the spectrum and a linear reduction in the distance between the main frequencies. When the coupling mean field is averaged, on the other hand, we find that the saturation value for the fluctuations does decrease, but remarkably enough, averaging does not fully restore statistical behaviour, except in the limit of very large averages. As before, quasiperiodicity is changed by the introduction of more beating frequencies, and the distance between the most important among them decreases linearly. As an extra test, we have studied the effects of a small periodic driving on the dynamics, and find that there are no strong resonances to simple sinusoidal driving, that is, external driving does not enhance the subtle quasiperiodicities emerging in the collective dynamics of the system. (Gabriel Perez*, Sudeshna Sinha, H.A.Cerderia*)

4. PRECISION SPECTROSCOPY AND MODERN OPTICS

4.1 PARITY NON-CONSERVATION

We have looked at the potentiality of the different candidates (Ba, Sr, Ca and Yb ions), from both theoretical and experimental viewpoints and have decided that the Ytterbium ion is the most suitable candidate for experiments at IIA (the Ba ion is used by Fortson's group at Seattle). The predicted theoretical PNC signal decreases as one goes down the alkaline-earth ion sequence Ba, Sr and Ca. The predicted theretical signal for Yb ion is forty times larger than the signal predicted for Ba ion according to preliminary calculations performed by Bhanu Das of the theory group of NAPP. However, the experimental sensitivity for Yb is smaller (due to small lifetimes of the D states) than for Ba, resulting in an expected experimental signal of the same magnitude for both ions. There are more technical problems associated with Yb ion experiment due to extra levels between the states of interest (compared to Ba ion) and due to the wavelength of interest being much smaller than for Ba. These problems are overcome in our design by the use of an additional laser and a smaller rf trap to satisfy the Lamb-Dicke criterion.

Equipment acquired and fabrication of subsystems

A refurbished Argon ion laser, Diode lasers (five), monochromator, Lockin amplifiers, and several optical components have been purchased. Since diode lasers off the shelf are unsuitable for precision spectroscopy (due to inherent tuning gaps and broad linewidths), components required for the external cavities (which alleviate both problems), and electronic circuits (required for driving the diode lasers) were fabricated by A.S. Babu and Mahesh of IIA and Simon Perira of TIFR. Two Hamamatsu single photon detectors have been procured (by Dr. C.S. Unnikrishnan of TIFR) with the supporting electronics built there, and these systems have already been used by us in an experiment to test

the Bohr complementarity principle in refraction, to study some issues in wave particle duality of photons, and will also be used by us for future experiments at IIA, using entangled photon states.

For the Parity Nonconservation measurements using the Yb ion, the relevant frequencies have to be generated by doubling the frequency of diode lasers (or a homemade Ti:Sapphire laser) in nonlinear crystals, since available lasers do not generate the required wavelengths. We have initiated a collaboration with the Crystal growth center in Anna University at Madras, to grow the nonlinear crystals, Lithium Iodate for doubling the frequencies and Pottasium dihydrogen phosphate for down conversion to generate entangled single-photon states. (Sudha A. Murthy, C.S. Unnikrishnan*)

4.2 QUANTUM OPTICS

An experiment to study the wave-particle duality of single photons has been performed. Photons from a down-converted source (single photon states) propogate through a birefringent crystal, and the coincidence rate between the photons in the two refracted beams was measured and the results show that quantum complementarity is violated as simultaneous manifestation of wave and particle properties. (C.S. Unnikrishnan*, Partha Ghose*, G. Ravindrakumar*, Sudha A. Murthy)

INSTRUMENTATION AND FACILITIES

1. ELECTRONICS

1.1 VBT IMPROVEMENTS

1.1.1 Proximity Switches to Provide Additional Safety

Proximity switches have been installed as a safety device for the VBT providing buzzer annunciation. Whenever any part of the telescope comes in close contact with the platform or any other obstruction, annunciation is set in. Initially, seven locations covering cassegrain yoke and DEC tube have been identified on the telescope for mounting the proximity switches. These switches have a sensitivity to locate any obstruction within one meter distance from the telescope. (K.S.Ramamoorthy, R.Srinivasan, A.S.Babu, K.Ravi, A.Ramachandran)

1.1.2 Cordless Hand-set

A cordless hand-set has been designed and fabricated in the electronics laboratory to enable remote operation of the VBT. A pair of FM transmitter and receiver implements the various hand-set functions such as set, guide and fine guide operations of the telescope and also coarse and fine movements for the focus unit. The remote cordless hand-set is designed to operate in parallel with the existing manual hand-set. (K.S.Ramamoorthy, R.Srinivasan, A.S.Babu, P.Anbazhagan, Venkateswara Rao)

1.1.3 1K Photometrics CCD System

The Photometrics 1024 X 1024 CCD system has been installed at VBT and is working satisfactorily. The existing shutter caused 3-5% vignetting of the CCD images. This problem has been solved by selecting a 62.5 mm shutter with a suitable spacer plate between the CCD Dewar and the filter holder. A new version of CCD-tool was installed and a software routine which converts raw images into FITS format has been implemented. The Time Delay Integration (TDI) routine which finds use in scan-mode CCDs has been installed and images upto 10,000 rows were recorded during the testing. (S.Murali Shankar, R.Srinivasan, P.Anbazhagan, K. Ravi)

1.2 ONE METRE TELESCOPE

1.2.1 Auto-guider

An auto-guiding feature has been incorporated for the 1 metre telescope and is working satisfactorily since Nov 95. The star-tracker/imaging camera (Model ST-4) procured from SBIG has been installed in the cassegrain focus of the 10-inch guide telescope. The unit includes a thermoelectrically cooled CCD camera head, a processor with firmware and sufficient memory, a keyboard and digital display. The ST4 computes the centroid and generates control signals for guiding the telescope in both RA and DEC axis at pre-programmed intervals. The Star-Tracker's interval relays are connected in parallel with the hand-set relays, permitting manual override. A simplified command list covering the camera set-up under varying observing conditions has been provided for observer's ready reference. (B.Nagaraja Naidu, R.Srinivasan, N.Sivaraj, Ramamoorthy, Manoharan)

1.2.2 Auto-Positioning System

A few field trials have been carried out in auto-positioning the 1-metre telescope. The desired position coordinates are entered through a keyboard session into the computer while the present telescope position is obtained from the digital display system. The hardware of the system comprises of a parallel digital I/O card in a PC which drives the solid-state relays which in turn energises the corresponding main relays for the desired speeds of motion of the telescope. The position algorithm accommodates the acceleration and deceleration requirements of the

telescope to arrive at a desired target position. The software implements several procedures and remains in a loop until a match is obtained between the present and demanded positions. A position accuracy of 2.5"for RA and 5" for DEC has been obtained during the trials. (B.Nagaraja Naidu, R.Srinivasan)

1.3 CCD INSTRUMENTATION

1.3.1 WINDOWS-Based CCD Data Acquisition System

(a) Astromed Cameras

A WINDOWS-based CCD data acquisition has been designed and tested to replace the existing software for the Astromed controller operating at VBT. This software is implemented with a PC/AT-486 with multisync non-interlaced monitor with a display resolution 1024 X 768, a DT 3852 flexible Frame processor and MS windows software development kit using 'C' language. This software has all the features of the earlier system and in addition also converts the data to FITS format for portability and incorporates user friendly graphical interface. (Faseehana, A.V.Ananth)

(b)Thomson-CSF CCDs

A Data Acquisition Program compatible to Microsoft WINDOWS 3.1 is being developed to acquire, store and analyse the CCD images in a PC environment. The software is being developed using BORLAND PASCAL for WINDOWS and uses most of the familiar windows interface functions such as multiple windows, icon tools, scroll bars, menus and dialog boxes. The functions that have been implemented so far include Image Acquisition, Image Display, Image Analysis and Image Import/ Export to 16 bit FITS (Flexible Image Transport System) and BMP (Bit map) format. The methods in the Image Acquisition function will be implemented once the CCD controller gets ready. The Image display functions include Zoom, Squeeze, Different display scaling modes, Histogram equalization and user defined gray level and pseudo color lookup tables. Image analysis part consists of finding the minimum and maximum intensities in the image, average and standard deviation, Plotting across a row or column and histogram of the frame and measuring the point intensity. The Import/Export function provides for 'Read/Write' 16 bit FITS images with the corresponding header information and 'Read/Write' windows Device Independent Bit map files. The acquisition and analysis can cover a Region Of Interest (ROI) which can be defined either graphically or by the input parameters.

The software controls a number of independent windows which include the following types.

1. Main Window : Includes Create/Open Image and Global Options
2. Image Window: Facilitates Image Acquisition, display and Processing/ analysis functions for full image or ROI.
3. Plot Window: Provides a graphical representation of the Image data.
4. Status Window: Displays the statistics and results of measurement for full image or ROI.
5. Cursor Window: Provides the cursor position and pixel intensity.
6. Tool Box Window: Provides a quick way to access limited functions which are frequently called. (B.Nagaraja Naidu, R.Srinivasan)

1.3.2 Near Infrared CCD Camera System

As part of the Indo Japanese Science Exchange programme in Astronomy and Astrophysics, a Near Infrared Camera system is under construction for observation at the VBT. A cryogenic dewar operating at solid nitrogen temperature has been procured from the Infra-Red Laboratories, USA. The Analog to Digital Converter and the CCD Driver boards have been fabricated and tested in the University of Tokyo. The

IR CCD mount has also been designed and fabricated. The data-acquisition system is configured to work with a SUN workstation operating under UNIX environment. Observation is planned with VBT during early 1997. (M.Ueno*, R.Srinivasan, G.Srinivasulu)

1.3.3 Linear CCD Camera System for Tunnel Telescope

A linear-CCD data acquisition system has been installed and tested at the Tunnel Telescope, Kodaikanal during this year. An image of sun through H-alpha line has been obtained. To put the system to regular use calls for certain mechanical design changes in the camera mount and drive system. The software also requires modification to facilitate the initial setting-up of the camera system. These changes are being taken up for implementation. (G.Srinivasulu, R.Srinivasan, Jagdev Singh, F.Gabriel)

1.3.4 3 Litre LN2 Dewar

The fabrication of the three liter LN2 dewar has been completed at the Institute workshop. The dewar was evacuated and satisfactorily tested for vacuum integrity. The CCD mount has been fabricated. Since gold plating on the inside of the aluminium dewar body, as envisaged, was not possible, it was decided that it would be sufficient to buff the body to achieve a highly reflective surface. The LN2 can has been gold plated. The dewar is yet to be field tested. (S.Murali Shankar, R.Srinivasan, P.U Kamath, Sahaya Nathan)

1.3.5 Universal CCD Controller

A universal controller capable of operating any type of CCD has been designed. The controller has programmable DACs to set the bias and clock voltages. Instructions to the controller are sent from a PC-AT directly through I/O ports. The controller is fabricated from a single four layer board with outer two signal layers and inner two power planes. The Loral 2K X 2K CCD is planned to be mounted on the indigenously developed 3 liter liquid nitrogen Dewar and tested using this controller. (S.Murali Shankar, R.Srinivasan)

1.4 OTHER PROJECTS

1.4.1 1024 Channel Digital Correlator System for Radio Heliograph

Fabrication of a 1024 channel correlator system to correlate signals from EW antennas with signals from NS antennas continued. All the PCB's have been wired and tested. Chassis wiring is progressing. The completed system will be released for observations shortly. High speed data acquisition cards have been designed to acquire data for very long baseline interferometry system. (M.S.Sundararajan, D.Babu, Manoharan)

1.4.2 Control System for the Schmidt Telescope

The control system for the Schmidt Telescope is fully finalised. All the components like motors, encoders, amplifiers, power supplies, brakes and cables have been procured. Brushless D.C. motors of 7 Newton meter torque capacity and maximum speed of 4000 rpm have been tested with their power amplifier and brakes. Resolvers mounted integral to the motor give feedback for sinusoidal commutation. The motors and encoders are mounted in a test bed and an in house made PC compatible hardware generates drive signal for the amplifier. 220V, 3 phase AC power is supplied to the amplifiers through isolation transformers. Absolute encoders were coupled to the motors and the system was tested for position accuracy. Triangular velocity profiles were generated using absolute encoder feedback. It is found that the system is able to stop within the accuracy of the absolute encoders. All the tests at laboratory were carried out with no load coupled to the motor.

The tracking uses phase lock loop technique. The incremental encoder chosen gives 25000 pulse per rotation (ppr). It gives 90 deg. phase shifted output on two channels. Using electronics, the ppr is multiplied

by 4. After filtering, the pulses are given to counters. The difference between the reference counter and the encoder feedback counter is loaded to Digital to analog converters to generate voltage for tracking. The incremental encoder gives one pulse in 0.04 arc seconds and it is adequate for a smooth tracking. Actual trial with the telescope at Vainu Bappu Observatory is expected to be carried out shortly. (V.Chinnappan, A.S.Babu, N.Jayavel)

1.4.3 Power System for the Schmidt Telescope

The Schmidt telescope is going to be installed in the Leh area of Himalayan region. Restrictions in the availability of commercial electrical power in the region made us select renewable energy sources like solar and wind power to power the telescope and other support systems. In the first phase, solar panels of 10 KW continuous rating and Wind Turbines of 10 KW rating are to be installed at the site. Storage batteries of suitable capacity are chosen to store energy in day time and they will feed the systems during night through invertors. A 63 KVA Diesel Generator set will provide back up to the solar and wind power systems. (V.Chinnappan)

1.4.4 Electronics and Electrical support for Total Solar Eclipse

The total solar eclipse of October 1995 was very successful with very clear skies and all the instruments working very satisfactorily. Three new stepper motor drives were fabricated and used in the experiments. This is also the first time that very sensitive Liquid Nitrogen cooled Charge Coupled Devices (CCD) were used in the experiments at Nim Ka Thana, Rajasthan. These Sun work station based systems were transported from Japal Rangapur and Vainu Bappu observatories and installed and tested in site well in advance. Peltier cooled CCD cameras and Photon counting systems were also used. To power the entire experiments in Nim Ka Thane and Kalpi, two portable petrol generators and voltage stabilizers were procured. Good earthing was done at site for the instruments. Power was provided to all the Indian and foreign scientific teams present in the site. (S.Murali Shankar, B.Nagaraja Naidu, C.V.Sriharsha, K.Ravi, Venkateswara Rao, N.Jayavel, P.Janaki Ram, V.Chinnappan)

2. COMPUTER CENTRE AT BANGALORE

The computer centre has witnessed a substantial growth in the current financial year. The major expansion plans have been in the following areas:

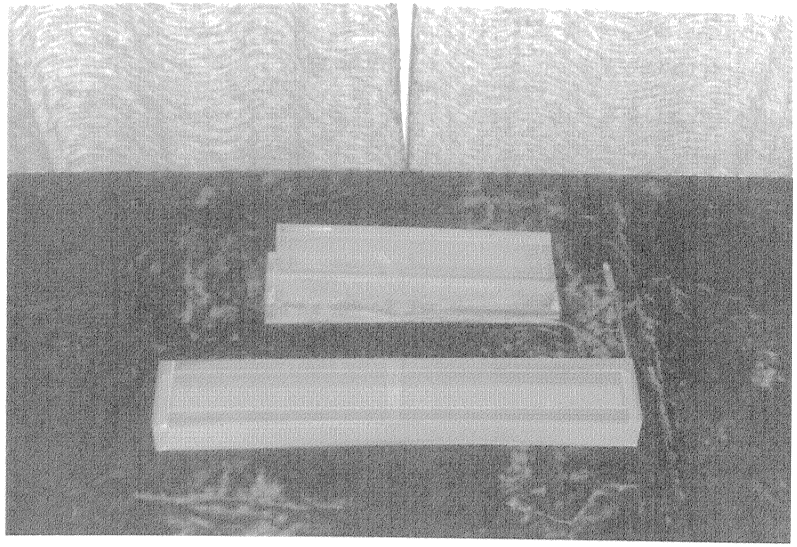
1) Super computer server for theoretical computations.
2) A number of low end workstations for observational data reductions.
3) A web server for internet connectivity.
4) A large number of personal computers for text processing and as front end systems for the workstations in the computer centre at the individual's desk top.
5) A high speed 64 K baud link to ernet HUB
6) A 60 KVA uninterrupted power supply.

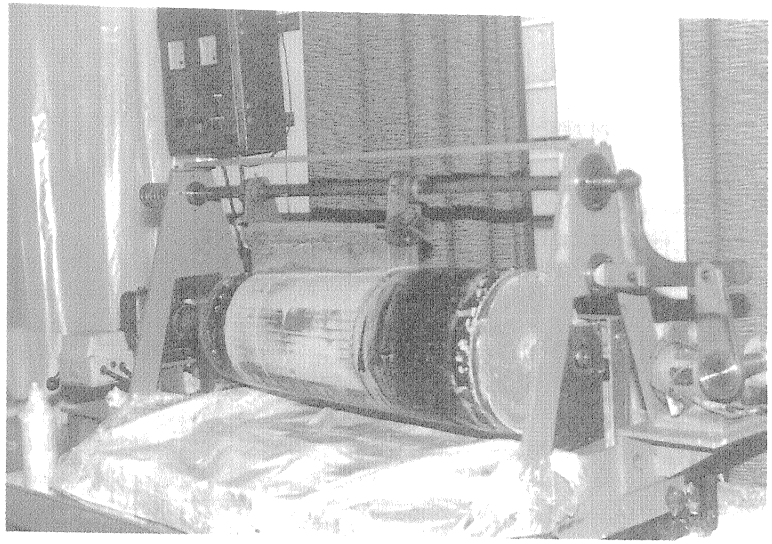
The super computer server is a 4 processor R 10000 CPU based Power-Challege L with 512 MB of RAM and 10 GB hard disk.

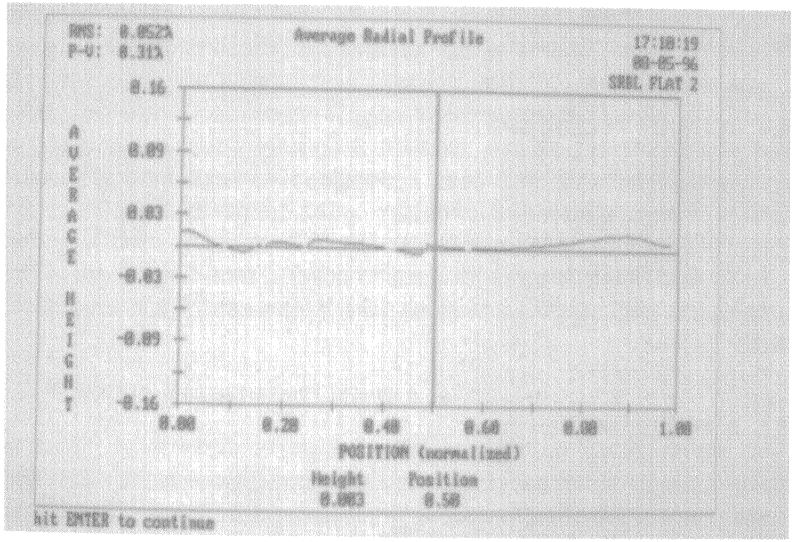
The Workstations for observational data reductions are the Sparc5 systems with 24 bit colour, 20 inch monitor, 2.1 GB hard disk and 64 MB RAM. An ultra Sparc system with substantial disk capacity is also proposed as a file server for astronomical data reductions. In order to obtain internet access using the World Wide Web an Indy system is being procured. It is also proposed to set up a web server site as well, so that users elsewhere can have access to IIA data base as well.

A high speed radio link is also proposed for connecting IIAP network to the ernet hub. This will facilitate file transfers across a more reliable and faster link than the leased line.

TECHNOLOGY DEVELOPMENT FOR THE FABRICATION OF SYNCHROTRON RADIATION BEAM LINE OPTICS







Top left : Synchrotron beam line optics spheroidal and flat mirrors.

Top right : Right-side view of the spheroidal mirror grinding and polishing machine.

Left : The average radial profile of the SRBL flat mirror.

A 60 KVA uninterrupted power supply is also being planned to cater to the increasing load from the new facilities. (A.V.Ananth, J.S.Nathan, S.S.Chandramouli)

3. ELECTRICAL SECTION

The newly constructed students hostel wiring was done in-house by the section. Administrative block extension also was wired. Both the jobs were completed in a very short time. Due to the modification done to the hostel rooms above stores, new wiring was done there also. UPS power distribution in the Bangalore campus to PCs was carried out. Provision is made in all the rooms to use UPS power.

The 11 K.V. / 440 V. indoor substation work has progressed well. All the material like H.T.Cables, L.T.Cables, Transformers etc. are received at site. Purchase of 200 KVA diesel generator is taken up. The work is being executed with the help of CPWD Engineers.

The Demand and Energy restrictions imposed by Govt. of Karnataka and KEB severely restricted our usage of electric power. Exemptions from Energy and demand cut was obtained.

The new campus at Hosakote was provided with water pumping system to water the new plants and trees. Regular K.E.B power is being obtained for the campus.

The Evershed and Michie Smith Halls at Kodaikanal were provided with stand-by power by Diesel generator set. New light fittings were installed surrounding the above halls.

Wiring of power line to the renovated guest house at Kodaikanal was carried out. New water sources were identified and new pumps are being installed.

Support to running of Vainu Bappu Observatory and Telescopes at VBO was carried out. (K.Padmanabhan, K. Rangasamy, Narasimhappa, M.A.Abbas, K.S.Subramaniam, V.Chinnappan)

4. PHOTONICS

4.1 VAINU BAPPU TELESCOPE

The primary and the secondary mirrors of the telescope were realuminized and aligned. (A.K.Saxena, K. Ramankutty, J.P.A.Samson)

4.2 SYNCHROTRON BEAM LINE OPTICS

The figuring of the spheroidal and flat mirrors are progressing well. A new test method has been evolved to test the spheroidal mirror using Zygo interferometer. Quantitative evaluation of the surface can be done using this method. The flat mirrors have achieved a surface roughness of about 10A°. The work is in progress to bring down the surface roughness to less than 5A°. (R.Cowsik, A.K.Saxena, Photonics team)

4.3 SUN SHEILD PANELS

The polishing of the last set of the sun shield panels is being continued for the INSAT II E satellite. (A.K. Saxena, Photonics team)

4.4 SCHMIDT TELESCOPE

A new field flattener has been redesigned for use in the Schmidt telescope which is intended for observing the optical counterparts of the gamma ray sources. In order to use the CCD detector effectively, the field flattenner has to be redesigned to cover a total field of 1.5°. The images are within 2 pixels of sizes 15 microns each. (J.P. Lancelot, A.K. Saxena)

4.5 ALUMINISING

Using a simple setup developed, the tungsten filaments for use in the coating plants are being prepared in the laboratory itself. This brings

reasonable savings in the recurring expenditure. Fresh coatings were provided to all the mirrors of the coelostats for the solar eclipse expedition. A parabolic mirror of 90 cm diameter of TIFR and a batch of 36 mirrors of ABAA were aluminized during this period. (Ramankutty)

4.6 HANLE PROJECT

To withstand high altitude conditions in Hanle, a prefabricated wooden modular type shelter having provision of quick and easy assembly at Hanle was proposed. The structure design has been completed. Building of a prototype in Bangalore is in progress. (R.Cowsik, J.P.A.Samson)

4.7 NOVEL APPLICATIONS OF PRISM

4.7.1 Prisms for Fractional Fourier Transformation

For monochromatic imaging, the intensity distribution in the back focal plane of the imaging lens is the fourier transform of the object intensity distribution in the front focal plane. Hence the object distribution evolves from the physical space into the fourier space. The evolution is continuous along the propagation direction, with the distribution in any intermediate plane following a Wigner distribution function (WDF). The free space propagation through a distance can be represented by a rotation and shearing of WDF. Hence, a fractional fourier transform can be studied by just doing a rotation and a shear. A prism was used to shear the diffracted image. The amount of shear can be controlled by changing the angle of incidence on the prism. Simple laboratory studies of this process is in progress. (V.Krishnakumar, K. Sankarasubramanian)

4.7.2 Vibration Measurement Using a Prism

The angle of emergence is a nonlinear function of the angle of incidence, with changes in the emergent ray direction being amplified for small changes in the incident ray direction. This property of a prism has been exploited for vibration measurements in a simple experimental setup. (V. Krishnakumar, K. Sankarasubramanian).

5. MECHANICAL ENGINEERING

5.1 DESIGN AND FABRICATION

5.1.1 CCD Mounting for the 1.2 Metre Telescope at the Japal-Rangapur Observatory

The design of a mounting arrangement for holding a 1K CCD and filters at the prime focus of the 1.2 Metre telescope which was done by M/s Teckons of Secunderabad was reviewed and the item was manufactured at an industry in Bangalore. It is ready for mounting on the telescope pending some Electronics works.

5.1.2 Aluminium Flanges for Gravitation Experiment

Two aluminium flanges of diameters approximately 4 metre and thickness 25 mm for vacuum sealing the gravitational experimental facility at Gauribidanur are being prepared. Selection of material and detail drawings have been done and the material procured. Machining work will commence shortly.

5.1.3 AUTOCAD Software

AUTOCAD drafting software has been purchased and installed in a PC kept for use in the section. Personnel in the section have also been trained in the software. About twenty drawings of sizes ranging from A2 to A4 have been generated using this software.

5.1.4 Microadvance Instrument for Autocollimator

An instrument for moving the autocollimator in the gravitational experiment facility at Gauribidanur has been designed and is being manufactured. This will allow a very precise and infinitesimally small movement for the autocollimator enabling the measurement of extremely weak signals expected in the experiment.

5.1.5 1995 Total Solar Eclipse

3 numbers of 10" coelostats and 2 numbers of 12" coelostats and mechanical fixtures for the following focal plane instrumentation were designed and manufactured:

a) Fabry Perot Experiment

b) Dust Ring Experiment

c) Polaroid Imaging Experiment

d) Shadow Band Photometry

e) White Light Imaging

f) Multislit

g) Narrow Band Imaging with CCD Camera

h) H-alpha Imaging

5.1.6 Dewar for a CCD

A Dewar for holding a 2K CCD chip has been designed and manufactured and is undergoing tests. A special aluminium alloy designated as B26S which is more superior than conventional aluminium in that it has a tensile strength almost equal to steel has been used in the manufacture of the main structure of the dewar. The dewar is to contain 3 litres of LN2 and is expected to hold a vacuum of 10E-05 Torr.

5.1.7 Coude Echelle spectrograph

The optical layout of the coude echelle spectrograph for the Vainu Bappu telescope has been prepared and the specifications of the mounts for the grating and the prism have been worked out like positioning accuracy, orientation details and amount of movement required.

5.2 MECHANICAL WORKSHOPS

5.2.1 Bangalore Campus

The following works were undertaken:

1) Machining of 2K CCD dewar components inclusive of CCD chip mount.

2) Machining of speckle camera interferometer components.

3) Fabrication and manufacture of 3 numbers of 10" and 2 numbers of 12" coelostat for 1995 Oct.total solar eclipse.

4) Machining of micro-advance instrument using SSGr.304 material.

5) Maintenance of air-conditioning plant cooling tower and pipeline.

5.2.2 Kavalur Campus

Maintenance of telescopes

a) 234 cm Vainu Bappu Telescope

During Sept 1995, in order to remove the primary and secondary mirror

for re-aluminising, the telescope was parked in safe position in R.A. and dec.axis.The 10 tonne dome crane was serviced for proper control of the hydraulic and thrust brake while inching.

Reference marks were established for correct location of the primary and secondary mirrors.

Reference marks were established for correct location of the primary and secondary mirrors.

Telescope was cleaned. Adjusted the mirror supports and obtained the correct mechanical alignment for the mirrors after the newly aluminised mirrors were loaded in the telescope. Painted the inner surface of tube assembly with dull black colour.

Proximity switches were installed for telescope safety when it is moving in R.A. and Dec.axis.

Carbon brushes for torque motor no:1 on R.A axis was replaced by new one.

Circumferential bus bar for power supply to dome was cleaned and rubber sheet covering were replaced.

Drive shaft of drive bogie no:2 was replaced.

Cable routing of 1024 CCD system from prime and cassegrain focal points to console room was completed.

Position locking arrangement was done for CCD to maintaining the pixel orientation in the east-west during observations.

Air-conditioning cooling tower control system was serviced.

Two adapters were made for the circular connectors of IIA CCD dewar.

Mechanical fixtures were designed and fabricated for using 1024 CCD and Boller and Chivens spectrograph.

Suitable exhaust duct and room air-conditioners were provided for the hydrostatic power pack room to control the temperature of the hydraulic oil within 30 deg C.

Instrument changeover at cassegrain and prime focus as per observer's schedule was carried out.

b) 102 cm Telescope

Mounting fixture was designed & fabricated to use ST4 CCD as auto guider at the guide telescope.

Arrangements and adapters were made for interchanging the Astromed CCD and Photometrics CCD at cassegrain focus imaging and coude' system.

One number new reduction gear box having gear ratio of was replaced for the dome drive system.

The 1 tonne chain hoist was re-conditioned

with the help of carpenters some of the broken plywood inner lining of the dome was replaced by new fire proof and water proof plywood of 4 mm thickness.

A coronagraph imaging camera was fabricated for imaging Saturn's rings.

c) 61 cm Schmidt Telescope

In continuation of the progress reported earlier, balancing on dec.axis has been completed. New lead counterweights for balancing on R.A. has been fabricated and mounted. Mounting arrangement for dec encoder completed. Two no:'s of tube assembly for use as guide telescope have been erected at north and south side of the Schmidt telescope tube.

d) 75 cm Telescope and 38 cm Telescope

One number guiding unit with filter unit was designed and fabricated for 30" cassegrain imaging with Astromed CCD.

Arrangements were made to mount the camera on 75 cm and 38 cm telescope to take photograph of the comet Hyakutake.

5.3 KODAIKANAL SOLAR OBSERVATORY

A grating mount with scanning arrangement was designed, fabricated and made operational for the H-alpha imaging at spectro building. The trailing mechanism of the mount was re-conditioned.

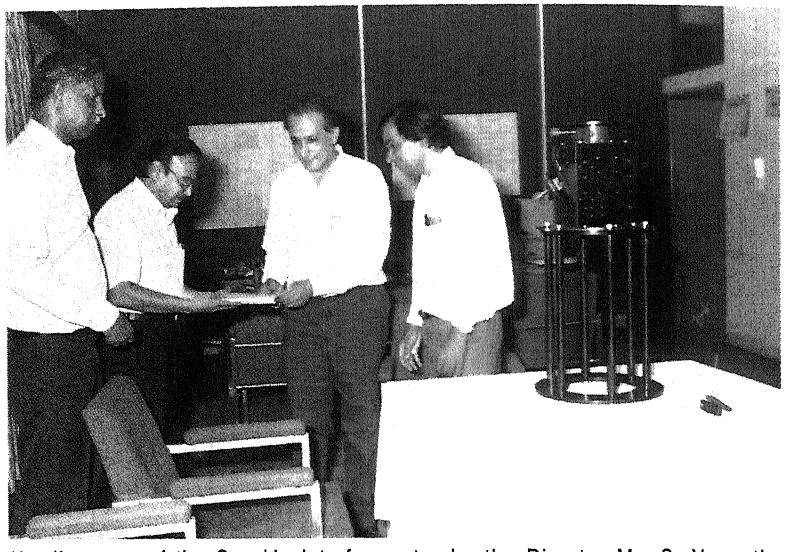
The H-alpha and calcium imaging telescope which was fabricated for the 1995 total Solar eclipse have been installed at Spectro-lab.

(Mechanical Engineering Staff)

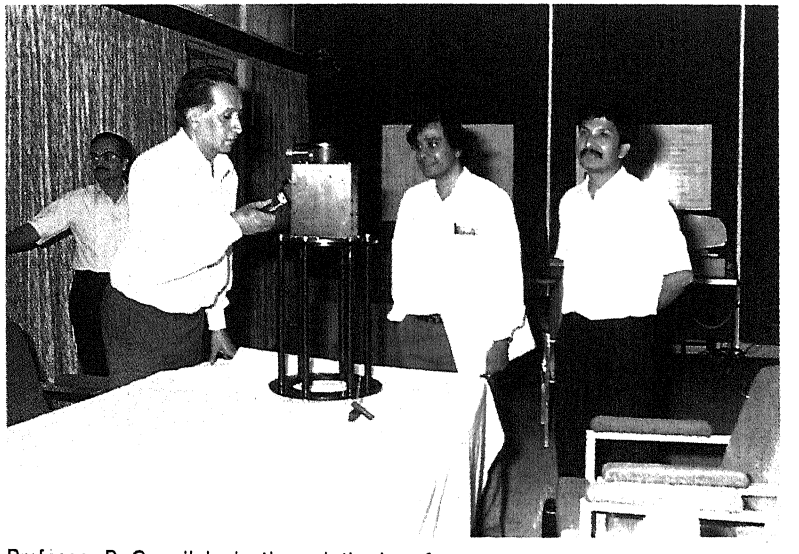
6. NATIONAL FACILITY (VBT)

During 1995-96, the 234cm Vainu Bappu Telescope (VBT) was the most over-subscribed telescope at the Vainu Bappu Observatory, Kavalur. In all 90 observing proposals, requiring 742 nights on the VBT, were received. Thus the average over-subscription was about a factor of 2. During the January-March trimester this factor was about 3.5. Seventeen observing proposals were received from astronomers working at institutions other than the indian Institute of Astrophysics. Three were from outside the country. Some of these were part of inter-institutional and international collaborations.

The number of nights allotted to CCD imaging/spectroscopic proposals were in the ratio 236/111. Nights were also allotted for testing new instruments under development (PtSi infrared CCD, fiber linked high resolution Echelle spectrograph, speckle camera). The VBT primary and secondary mirrors were realuminised in September, 1995.



Handing over of the Speckle Interferometer by the Director Mr. S. Vasantha Kumar, CMTI to Professor R. Cowsik.



Professor R. Cowsik looks through the Interferometer.

NEW FACILITIES

1. ASTRONOMICAL SITE SURVEY AT HANLE

The site survey at Hanle, Ladakh (longitude 78° 57.'5 E, latitude 32° 47' N, altitude of present camp 4300 m above msl), continued during the year. There is a continuous presence of astronomers of IIA at Hanle since December 1994. A guest house was established at Leh in hired accommodation during 1995 summer and a 1200 baud satellite communication link was established between Hanle and Bangalore during 1995 Autumn.

The main task undertaken during the first year was to monitor the cloud cover, temperature and humidity on an hourly basis. This data is complete to 90% level. The observations are made from a site near the edge of the plains due north of the hill, where logistic support was easily available. The cloud cover is not likely to be substantially different at the top of the hill compared to the current location. However, ground fog would certainly be higher at the current location which is situated in a crevice in the hills near the northern edge of Nilamkhul plain surrounding the hill (altitude 4517 m) identified as the observatory site. The humidity and temperature profile during the night will be more favourable at the top of the hill due to a laminar flow and reduced convection in air currents.

In addition to the meteorological parameters, the atmospheric extinction and sky brightness, precipitable water vapour, and seeing were estimated on a few occasions. In these cases also, the measurements will give a lower limit on what can best be achieved from the hill-top.

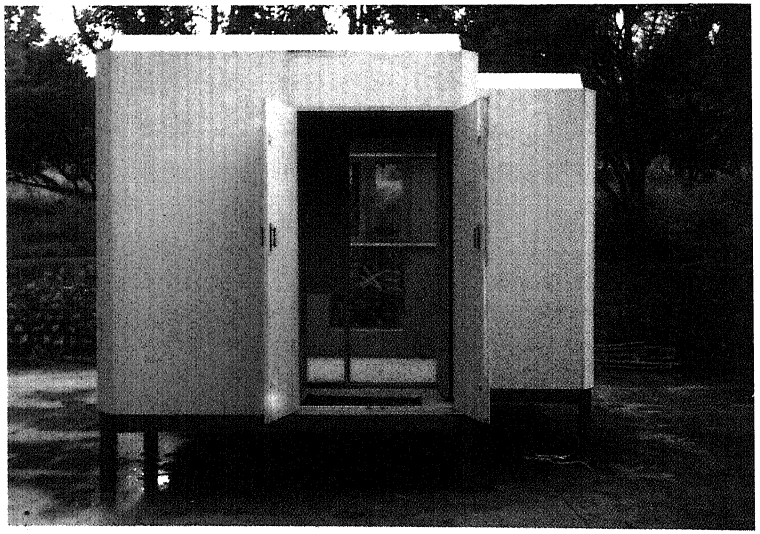
STATISTICS OF OBSERVING NIGHTS:

An analysis of cloud cover data for the year 1995 is given in Table 1.

Table 1. Monthly Distribution of Observing Nights/Hours at Hanle

Month 1995	Total nights	No.of hours	Photometric nights		Photometric hours		Spectroscopic Nights		Spectroscopic hours	
			no.	%	no.	%	no.	%	no.	%
Jan	31	310	20	64.5	176	56.8	23	74.2	209	67.4
Feb	28	270	7	25.0	57	21.1	13	46.4	95	35.2
Mar	31	250	8	25.8	56	22.4	18	58.1	115	46.0
Apr	30	216	7	23.3	44	20.4	15	50.0	97	44.9
May	31	186	14	45.2	90	48.4	18	58.1	114	61.3
Jun	30	150	23	76.7	130	86.7	25	83.3	148	98.7
July	31	175	12	38.7	69	39.4	16	51.6	97	55.4
Aug	31	204	2	6.5	16	7.8	5	16.1	34	16.7
Sep	30	233	16	53.3	129	55.4	22	73.3	174	74.7
Oct	31	279	26	83.9	221	79.2	29	93.6	258	92.5
Nov	30	270	23	76.7	200	74.1	24	80.0	227	84.1
Dec	31	305	10	32.3	85	27.9	13	41.9	108	35.4
Tot	365	2848	168	46.0	1273	44.7	221	60.6	1676	58.9

The astronomical twilight was excluded from the definition of an observing night from the point of view of observing faint objects in the optical region. Spectroscopy can be carried out during the twilight hours as well. Observations in the infrared bands can be made during and beyond the twilight hours. If one excludes only half an hour after sunset and before sunrise, the total number of useful hours increase by over



Top left : Visit of his Excellency the Governor of Jammu & Kashmir, Gen. M.V. Krishna Rao, to the Hanle Site Survey Camp on 1995 July 8. Dr. H.C. Bhatt is explaining the working of NGT-18 telescope.

Top right : Summit of Dikpa Raja Ree as seen from the western slope.

Left : Prototype solar-heated shelter fabricated and set up for testing at VBO, Kavalur.

200. Some useful data can be obtained even on nights which are partially clear for 3 hours. If we define these nights as useable, we obtain

Total number of useable nights: 250

Total number of useable hours: 2000

The lengths of continuous stretches of clear nights and of useless nights are also parameters useful in judging the probability of getting useful data from a given site. Table 2 lists the distributions of such spells in four categories: (i) spells of photometric nights; (ii) spells of spectroscopic nights; (iii) spells when photometry cannot be carried out for atleast 4 hours of night; (iv) spells when spectroscopy cannot be carried out for atleast 4 hours of night.

It can be seen from the table that there were 7 stretches of clear spells when photometry was possible for over a week at a stretch. The longest of these stretched for over two weeks in May/June. The longest spectroscopic stretch extended over three weeks in September. About half the photometric/spectroscopic nights are in stretches longer than a week and three-fourth in stretches longer than two days. Many good stretches are separated by only one or two useless nights as seen from the statistics of bad stretches which peak around one or two nights. The average lengths of photometrically useful and useless nights are 2.9 and 3.8 nights respectively. Similar numbers for spectroscopic nights are 3.8 and 2.5 nights respectively. Thus, if an observing length stretches for a week, there is a fair chance that one finds more than half the time useful.

Table 2. Spells of photometric and spectroscopic nights at Hanle

No.of nights in a spell	Number of useful spells		Number of useless spells	
	Photom.	Spectrosc.	Photom.	Spectrosc.
1	4	24	16	22
2	11	11	7	13
3	3	3	12	9
4	2	6	6	7
5	3	0	2	2
6	2	3	1	0
7	0	2	2	2
8	1	1	2	1
9	2	1	0	1
10	0	1	0	0
11	1	0	1	0
12	1	1	0	0
13	1	1	0	0
14	0	0	1	0
15	0	1	1	0
16	1	0	0	0
20	0	1	0	0
21	0	0	1	0
23	0	1	0	0
Average	2.9	3.9	3.8	2.5

PRECIPITATION

Hanle is an extremely dry site which facilitates maintenance of optical and other components, in addition to providing useful nights in all the months of the year and thus helping to observe objects at all right ascensions.

A small amount of snowfall occurs at Hanle during the winter months. During the first year, there was light snowfall (a few mm) roughly on one occasion in each of the months December - March. In addition, there was snowfall of about 2 cm in April. The rainfall occurred only during July/August. The onset of monsoon was heralded by light drizzle lasting for about 10 to 20 minutes on 3 occasions between July 20 and 22. There was intermittent light drizzle between August 1 - 13 and 18-28.

TEMPERATURE AND RELATIVE HUMIDITY

Information on temperature and relative humidity are vital in planning human endurance and equipment specifications. Listed in Tables 3 and 4 are the monthly extreme and average temperature and humidity values for the entire 24-hour day (Tmin, <T>, Tmax, Hmin, <H>, Hmax) as well as during the observing night (Tnmin, <Tn>, Tnmax, Hnmin, <Hn>, Hnmax).

It is clear from Table 3 that the extreme temperatures were 26.6 C in January and +34.3 C in June. The temperature minimum occurred during the morning twilight and not during the observing night. The high value of maximum and the continuous drop of temperature at night are characteristic of the topography of the current location. The maximum is expected to be lower and the night-time temperature would stabilize faster at the hill-top.

The low ambient temperature during a better part of the year implies reduced atmospheric and instrumental emission in the infrared and ease of operating the astronomical detectors which need to be cooled to reduce thermal emission.

Table 3. Monthly statistics of temperature at Hanle

Month	Tmin	<T>	Tmax	Tnmin	<Tn>	Tnmax
Jan	-26.7	-15.1	-0.8	-26.6	-17.5	-9.3
Feb	-24.0	-9.9	5.7	-21.1	-12.5	-3.2
Mar	-25.4	-5.4	9.6	-19.6	-8.4	4.7
Apr	-14.4	-0.3	15.2	-13.9	-3.5	3.9
May	-7.2	5.5	21.7	-7.0	1.5	9.0
Jun	-3.8	11.9	34.3	-1.7	8.2	5.8
Jul	6.8	15.4	31.8	7.6	12.0	21.2
Aug	3.2	12.4	26.0	5.0	9.9	15.6
Sep	-3.0	8.5	21.4	-1.8	5.7	11.5
Oct	-11.2	0.0	14.8	-11.0	-2.1	7.6
Nov	-18.8	-6.0	7.9	-17.5	-8.2	1.6
Dec	-26.1	-10.2	3.1	-25.5	-12.4	-3.6

The relative humidity is low on an average since Hanle is a high altitude desert. The low atmospheric water vapour and low precipitation make the relative humidity reach a value as low as 10% in May. The night-time minimum humidity was 18% in the same month. The average night-time humidity has exceeded 75% in December and August. It is expected to be higher at the current site than at hill-top due to settling of mist in the crevice. Even so, the observing hours lost to humidity above 85% are 2.9% of photometric hours and 3.2% of spectroscopic hours. This fraction is expected to be negligible at the hill-top.

Table 4. Monthly statistics of relative humidity at Hanle

Month	Hmin	<H>	Hmax	Hnmin	<Hm>	Hnmax
Jan	20	64	90	30	66	90
Feb	17	55	87	27	59	86
Mar	18	52	86	32	59	86
Apr	21	46	78	27	50	76
May	10	49	88	18	58	85
Jun	12	51	88	26	58	88
Jul	22	62	98	31	73	98
Aug	13	72	100	50	83	100
Sep	18	3	96	36	70	94
Oct	24	60	100	35	66	100
Nov	29	60	99	41	64	95
Dec	25	70	100	45	76	100

PRECIPITABLE WATER VAPOUR IN THE ATMOSPHERE

Measurements of precipitable water vapour at Hanle were made with the water vapour meter belonging to the Physical Research Laboratory (PRL), Ahmedabad. This instrument is identical to the one used at the Uttar Pradesh State Observatory (UPSO), Naini Tal, who also used it during their site survey at Devasthal. At Hanle, the measurements were made on 15 days during the period between 26 March and 27 April, 1995 with the Sun as the radiation source. The measured values were converted first to precipitable water vapour in millimeters using a calibration curve and then reduced to the zenith (ZPWV). The cumulative histograms of daily mean values are listed in Table 5.

Table 5. Cumulative percentage histograms of daily mean values of precipitable water vapour reduced to zenith (ZPWV)

ZPWV (mm)	All measure-ments %	upto 3 octa clouds %	clear sky %
< 1.5	40	44	50
< 2.0	47	55	86
< 2.5	87	89	100
< 3.0	93	100	-
< 3.5	100	-	-
Median (mm)	2.1	1.8	1.5

The measurements were made in the beginning of summer and mostly during the first half of the day. One expects the night time values to be still smaller. The values are expected to be even lower in winter. An estimate using recorded temperature, relative humidity, laboratory values of saturation water vapour pressure, and an emipirical scale factor depending on the scale height of atmospheric water vapour, shows that the Zenith Precipitable water vapour would be less than 1mm in January - March and December, 1-2 mm in April, May and October, and greater than 2 mm only during June - September.

EXTINCTION AND SKY BRIGHTNESS

Extinction and sky brightness were measured on a few occasions using the images of open cluster M67 which contains a large number of photometric standards. The images were obtained with a Peltier-cooled CCD (ST6 from Santa Barbara Instrumentation Group) and an 18-inch Newtonian telescope (NGT 18 from Jim's Mobile Inc.). The telescope is equipped with standard UBVRI filters. The average extinction measured on two days (1996 March 11 and June 29) in V aband is 0.10 +/- 0.04

mag. This value agrees with what is expected from a purely Rayleigh-scattering atmosphere at the altitude of Hanle and proves that there were essentially no aerosols in the atmosphere.

The values of sky brightnes in units of mag/sq. arcsec are listed in Table 6. Typical measurement errors are 0.15mag in BVRI bands and 0.3 mag in U band.

Table 6. The mesurements of night sky brightness

Band	1995 March 3 z = 20 deg	1995 June 29 z = 50 deg
U	24.2	23.2
B	23.2	23.1
V	21.5	21.4
R	19.8	19.6
I	18.5	18.0

ASTRONOMICAL SEEING

Preliminary estimates of seeing were obtained using the equatorial star trail method. The NGT 18 telescope was employed together with Kodak SO 2415 film. The resolution of the film is 5 microns which translates to 0.5 arcsec at the F/4.5 focus. The centroid measurements can be made to an accuracy of about 0.1 arcsec. A typical trail recorded in 1996 April yielded an rms image motion of 0.44 arcsec which corresponds to a value of Fried parameter 0.127m. This implies an image size of 1.15 arcsec for a large telescope. This is an upper estimate since the telescope vibrations are not filtered out, and the orography of the current location is not best-suited for achieving good seeing. It is planned to install a differential image motion monitor at the hill-top in near future.

RESULTS FOR 1996

Results for 1996 show that the conditions at Hanle are very stable. The results based on sky cover during the first quarters of 1995 and 1996 are compared below:

Jan to Mar	Photometric Nights %	Photometric Hours %	Spectroscopic Nights %	Spectroscopic Hours %
1995	38.8	34.8	60.0	50.5
1996	39.0	34.4	57.6	52.0

2. THE HIROT PROJECT

The Detailed Project Report for the High Altitude Infrared Optical Telescope has been finalised. This document is commissioned by the Department of Science and Technology to describe the modus operandi for the fabrication of a telescope of aperture larger than 4 m, operating at the infrared and optical wavelengths. It also describes the deployment of the telescope at a suitable high altitude site and the broad spectrum of astronomical problems that such a telescope can address. This effort by the members of IIA has been conducted under the advice of a committee chaired by Dr.K.Kasturirangan, Secretary of the Department of Space, Government of India.

The main purpose of the telescope is to provide the universities and research institutions in India with a facility to carry out research at an internationally competitive level in the fields of infrared and optical astronomy. This telescope will have a sensitivity of 100 times better than the largest telescopes operating in India today, i.e., comparable with the best in the world. The telescope is expected to be a useful instrument of research until well into the next century.

Even though IIA is enthusiastic about taking up the major part of the effort in setting up the Large Optical Telescope in India, yet equally enthusiastic participation by various research and educational institutions such as IUCAA, TIFR, NCRA, RRI, ISRO, PRL, UPSO, Osmania University, etc., is essential for the resounding success of the project and for the full utilization of its capabilities.

As a precursor to the project, several institutions, like IUCAA, IIA and TIFR might set up telescopes of smaller apertures, at several suitable locations.

IIA selected six prospective sites for reconnaisance and characterisation in search of a suitable site for setting up an astronomical observatory for studies in the infrared and optical wavelengths. The efforts of the members of IIA amounting to 30 man years have led to the identifications of a new site for astronomy, that has not been investigated earlier. This site is Hanle, South eastern Ladakh. Prof. S. Isobe, President of the IAU Commission on Astronomical Sites visited the site in February 1996 and opined that it is perhaps the finest site in South-east Asia. Site characterisation has been continuing at this site.

The telescope would be of modern design with an alt-azimuth mount and probably with f/1.7 honeycomb mirror, and capable of semirobotic operation. The detailed engineering design will be taken up soon after the approval of the project. The focal plane instruments planned initially are: (i) large format array camera in the infrared and (ii) a medium resolution spectrometer. The data from these instruments, the diagnostic and house keeping data from the telescope, and the real-time data on the telescope field and sky conditions will all be telemetered using a satellite MCPC link to the participating institutions. The band width required is initially 500 k baud in the first two years and will have to be increased to 1 Mbaud by the third year. Some voice channels for engineering maintenance and emergency operations will be needed. About 50% of the telescope, dome, etc. will be built in India and the other half will be imported.

The total power required will be about 200kW when the observatory is in operation. Almost all the available modes for power generation would be tried out at first during the next year or two and the most efficient pair of power sources such as 'diesel' and 'solar' will be adopted.

Logistic support at Leh will require about 9 persons, three of whom will at any one time be stationed at Hanle by rotation, if Hanle is chosen as the site. Transportation of the completed telescope (4m or 6m) will be done after the complete integration and testing in or near Bangalore. This will have to be carried out during the months of January (starting in Bangalore) and August (arriving in Hanle).

The project will take about 7 years from the date of funding. The site will have to be decided about 2 years into the project and the civil works will start at that time.

The cooperation of several departments of the Government of India, DST, DOS, DAE, Defence, Home, DOT, DHR etc., and the cooperation of several State Governments are essential to the success of this project. The infrastructure at the remote site would be utilized for other studies in areas like Geomagnetism, Geodesy, Meteorology, Ecology, etc.

The total cost of setting up of the telescope including the first generation focal plane instruments is estimated to Rs.110 crores over 5 years for a 4m telescope and Rs.140 crores over 7 years for a 6m telescope.

The Kastrurirangan Committee and representatives from the DST, and astronomers from various research and educational institutions in the country, met on March 13, 1996 to discuss the Report. The Committee recommended that the Planning Commission make necessary provisions under the IX and X Plan for this major facility for astronomy. While this facility is fully supported by all the Scientific Departments, it is recommended that the funds should be channelled through the Department of Science & Technology for the efficient execution of the project.

THE 2-M CLASS TELESCOPE PROJECT

The Advisory Committee for HIROT Project recommended that a 2-m class telescope be deployed before the Large Telescope Project is initiated. This will help in building up the infrastructure and expertise for installing and operating the large telescope. This will also augment the scientific potential of astronomers at IIA which will result in efficient utilization of the large telescope when it becomes available.

It is most economical if this telescope and the first light instruments are purchased outright and then deployed speedily at the location. Eight vendors of telescopes of 2-m class have already been approached for budgetary estimates. Detailed discussions with them on specifications, time schedule, and aspects of design, deployment and training have been proceeding. The design aspects of the dome in order to preserve the optimal conditions of seeing are also being studied. The first light instruments planned are 1K NICMOS array, medium resolution IR Spectrograph, optical CCD, medium resolution optical spectrograph and IR bolometer.

Considerable progress has been made in the planning of infrastructure development at the site, including approach road and source of electrical power. Specifications of available generators using solar, wind and diesel power are being scrutinzed vis-a-vis conditions at the site. The communication link requirement as well as the philosophy of remote operation have been worked out in consultation of the Department of Space. Discussions with the Department of Telecommunication have been initiated. Experiments are being conducted with the existing telescopes at Kavalur to gain experience in the field.

The detailed cost estimate of the project has been worked out to be Rs.30 crores over 3 years. The total time needed for the purchase and deployment of the telescope would be 2 1/2 years. The scientific benefits will follow immediately.

MISCELLANEOUS

Awards and Honours

A team of Astronomers from the Institute have been awarded the Astronomical Society of India medals for discovering the Asteroid "Ramanujan" from India. The team consists of **R.Rajamohan, J.C. Bhattacharyya, K.Kuppuswamy, A.Paranjpye, V.Moorthy and R.Vasundhara. J.C.Bhattacharyya** was also the recipient of the Aryabhata medal awarded by the Indian astronomical Society in March 1996. **R. Cowsik** received the Prof. A.C.Banerjee Memorial Award of the National Academy of Sciences and the Third World Academy of Sciences Award in Basic Sciences, in 1995. He delivered the Prof. S.D.Chatterjee Endowment Lecture of the Indian Physical Society, in the same year. **K.M.Hiremath** was awarded the Japanese Society for the Promotion of Science (JSPS) postdoctoral fellowship to conduct research in Tokyo University with H.Shibahashi, **R.K.Kochhar** has accepted, with effect from 1 January 1996, the Jawaharlal Nehru Fellowship to work on the project 'Modern science in India : A historical study in the national and global context', **Sudeshna Sinha** was awarded the Associateship of ICTP, Italy for a period of five years. The paper titled "String theory and a microscopic basis for black hole entropy" by **C.Sivaram** received 'Honorable Mention' at the May 1995 competition of the Gravity Research Foundation, Massachussetts, USA.

Summer School in Astronomy and Astrophysics

A summer school in Astronomy and Astrophysics was organised jointly by Raman Research Institute and IIA during May 29-June 24, 1995. About thirty students from across the country participated. Board and lodging were provided at the Indian Institute of Science and lectures were held in the Department of Physics Lecture Hall. Lectures covering a wide variety of topics were delivered. Those given by the IIA staff are:

Lecturer	Topic
R.Vasundhara	Solar system studies
H.C.Bhatt	Diffuse matter in space
S.Chatterjee	Distribution of stars in space
T.P.Prabhu	Galaxies
	Novae and supernovae
P.Venkatakrishnan	Coronae of sun and stars
A.K.Pati	Stellar populations
	Future telescopes
P.Bhattacharjee	Astroparticle physics
P.B.Pal	Neutrinos
	Dark matter

Participants were taken to VBO, Kavalur over a weekend. Several short term projects were also done by them under the guidance of the scientists in IIA. D.C.V.Mallik (IIA) and D.Bhattacharya (RRI) were the convenors of the summer school.

INSA Meeting in Kodaikanal

A one day symposium on *Interface of Astronomy with other Sciences* was hosted by IIA in Kodaikanal on May 4, 1995. About thirty participants including Fellows of INSA and special invitees attended the meeting. In Professor Cowsik's absence the organisation was done by Dr.R.Srinivasan, the Dean, Mr K.Thiyagarajan and Mr.S.S.Gupta, Resident Scientist in Kodaikanal. The INSA council met in Kodaikanal on May 5, 1995. There was an official banquet and a picnic outing to Berijam Lake was organised on May 6, 1995. The scientific proceedings of the symposium will be published by INSA under the editorship of Professor V.K.Gaur.

National Meeting on Total Solar Eclipse 24, Oct.1995

A National meeting to discuss the results obtained from the observations made during the total solar eclipse of October 24, 1995 was held at the Indian Institute of Astrophysics, Bangalore on February 26-27, 1996.

One hundred and forty scientists and amateur astronomers participated in this meeting. Fortyeight papers covering a number of subjects, e.g. Coronal physics, Modelling of solar corona, Changes in ionosphere, Change in earth's atmosphere, Animal behaviour during the eclipse, Radio measurements etc were presented and nine poster papers were displayed during the meeting. In the concluding session discussions were made to assimilate and collect the scientific data, co-ordinate the efforts to analyse the data for obtaining the detailed results and recommend the course of action for future eclipses. The Organising Committee consist of:

R.Cowsik	-	Chairman
Jagdev Singh	-	Secretary (Scientific Organising)
A.K.Saxena	-	Secretary (Local Organising)
B.D.Acharya	-	Member

Winter School Mar 7 - 9 1996 on Solar and Solar-Terrestrial Physics

A winter school on solar and solar-terrestrial physics was held at IIA, Kodaikanal during March 7-9, 1996. The school was conducted to educate the post-graduate students of Physics, about research openings in the field of Astronomy and Astrophysics. A very good response was noted from various colleges in Tamilnadu. One lecturer and two students from each college totally 45 participants attended the winter school. The topics selected for the winter school included: Introduction to Astronomy and Astrophysics - K.Sundararaman, Introduction to the Sun and Oscillations of the Sun - M.H.Gokhale, Solar Activity and Solar Differential Rotation - S.S.Gupta, Large convective cells and short period Oscillations in the corona - Jagdev Singh, Solar observational aspects - P.S.M.Aleem, Planetary atmospheres and Earth's atmosphere - J.V.S.V.Rao and Terrestial Ionosphere and Magnetosphere - D.Karunakaran. Popular lectures 1) Solar observations from Antarctica 2) Total Solar Eclipse 1995 - Jagdev Singh were arranged on March 7,8, 1996 and the respective documentaries were shown through video cassettes. An exposure was given to the partcipants by showing the scientific laboratories and historical telescopes. Through 8" telescope celestial objects on two nights were shown to the participants.

Vainu Bappu Observatory

August 10, 1995 was celebrated at VBO to coincide with the 68th birth anniversary of the late Professor M.K.Vainu Bappu. Around 350 B.Sc./ M.Sc. students from different colleges and Universities of Tamilnadu, attended the function. Professor Ramanath Cowsik gave a talk on "Invisible Universe". After the talk, the students were taken to different telescope buildings and the astronomical facilities available at VBO were explained to them. Also the night sky was shown to them through the 15cm telescopes.

Around 3000 amateur astronomers, students and visitors visited VBO on weekends during 1995-1996. They were mostly taken around the observatory and informal-popular talks were given to them about general astronomy and the availability of astronomical research facilities at VBO. Also, astronomical-slides and video-programs on astronomy were shown to them. In the evenings they were taken to the Bappu-Chandra telescope, in order to see the night sky. Experienced amateur astronomers and senior students were also permitted to use this telescope and the 15cm telescope of VBO, throughout the night for night sky observations.

Popularisation of Astronomy

K.K. Ghosh has given many lectures on general astronomy to the students and public who visited VBO. He has also guided many amateur astronomers for astronomical observations, data analysis and interpretations. S.S Gupta has also guided students on Solar Physics projects in local colleges of Madurai and Tiruchirapalli. K.Sundara Raman gave a series of lectures to the students of Zion matriculation Higher Secondary School, Kodaikanal covering the topics of optics and atomic physics and also to the staff and students of B.Sc. and M.Sc. levels of the Physics

Dept of Nehru Memorial College, Trichy. M. Thangaraj has been guiding students on solar terrestrial projects in the National College, Trichy.

Bicentennial Commemorative Public Lecture

The tenth Bicentennial Commemorative Public Lecture was delivered on March 14, 1996 by Professor S.Ramaseshan who spoke on 'Chandrasekhar - Some Reminiscences'. Professor Ramaseshan is one of the most distinguished students of Sri C.V. Raman and is well known internationally as a crystallographer of excellence. The bicentennial commemorative public lecture series was instituted in 1987.

LIBRARY

During the year the Library added 270 books to its stock and it subscribed to 140 journals. It also continued receiving 100 observatory publications, preprints, newsletters and annual reports. 750 volumes of journals were bound during the year, using both inhouse facility and private binders. The library borrowed and sent journals to Raman Research Institute for display and it also displayed a few journals received at Tata Institute of Fundamental Research, Bangalore. 200 Inter-Library Loan requests were handled during the year and 1,50,000 xerox copies were made for both institute staff and members of other astronomy institutes & universities. Two more consignments of Palomar Sky Survey charts were received.

The Library acquired a new Pentiumm PC and now it is able to browse the internet using Netscape. This has facilitated access to several libraries and information data bases and many reference queries were answered using this connection.

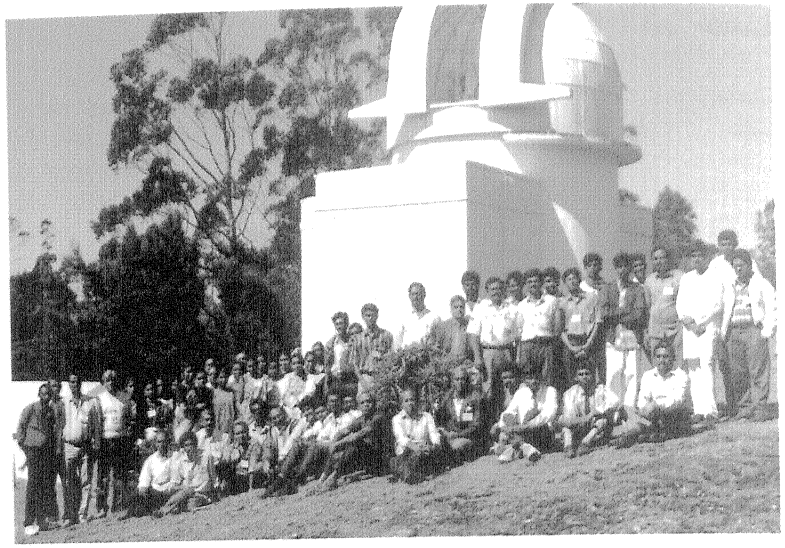
Ms. A. Vagiswari attended the Colloquim on Library and Information Services in Astronomy at Garching held in May 1995, and presented a paper titled 'Growing Importance of Conference Proceedings in Astronomy and Astrophysics and its Impact on Collection Development' Co-authored by Christina Louis. She also attended the seminar on 'Digital Libraries' held at Institute of Science, Bangalore.

A new data base of bound journals is being created and will be completed by the end of this year.

OFFICIAL LANGUAGE IMPLEMENTATION

The Annual Report and the Accounts Report of the Institute for 1994-95 were prepared and printed in Hindi. Description of the Total Solar Eclipse of 24 Oct 1995 was given in Hindi during the live coverage of the event by Doordarshan and All India Radio. Also reports in Hindi were prepared for Doordarshan, All India Radio, the print media as well as the general public in this connection.

The Institute worked further in the direction of the Official Langauge implementation. The directives of the Government regarding the implementation of Hindi were followed, such as cash and increment awards, books to staff members. Hindi Pragya classes were conducted and nine staff members qualified it. Many additions were made to the books and magazines of the Hindi Cell Library. Hindi Divas was celebrated with great enthusiasm and staff members were presented dictionaries and official works books.



Top : Participants of the Winter School on Solar and Solar-terrestrial physics, held at IIA, Kodaikanal during March 7-9, 1996.

Left : Gifting of the three inch refractor to the G.N. Modi Higher Secondary School, Neem Ka Thana.

PERSONNEL

The academic and technical staff during the period 1995 April - 1996 March include the following :

Director : R. Cowsik.

Senior Professor : A. Peraiah, C.V. Vishveshwara.

Professor : B.P. Das, M.H. Gokhale, S.S. Hasan, R.K. Kochhar, V. Krishan, N.K. Rao, J.H. Sastri.

Associate Professor : B. Datta, R.C. Kapoor, D.C.V. Mallik, P.B. Pal, M. Parthasarathy, T.P. Prabhu, R. Rajamohan, Ram Sagar, J. Singh, C. Sivaram, P. Venkatakrishnan.

Reader : S.P. Bagare, H.C. Bhatt, S. Chatterjee, A. Chokshi, P.K. Das, K.K. Ghosh, S. Giridhar, S. Mohin, P.M.S. Namboodiri, A.K. Pati, P.K. Raju, V. Raju, A.V. Raveendran, S. Sinha, K.R. Subramanian.

Fellow : G.C. Anupama, P. Bhattacharjee, R. Kariappa, S.V. Mallik, M.V. Mekkaden, B.S. Nagabhushana, K.N. Nagendra, K.P. Raju, K.E. Rangarajan, D.M. Rao, S.K. Saha, L. Saripalli, A. Satya Narayana, P. Shastri, K. Sundara Raman, R. Surendiranath.

Research Associate : K.M. Hiremath, K. Jayakumar, K. Kuppuswamy, J.V.S.V. Rao, M.S. Rao, M.J. Rosario, P. Singh, B.A. Varghese.

Head, Photonics Division : A.K. Saxena.

Senior Principal Scientific Officer : A.V. Ananth, R. Srinivasan.

Principal Scientific Officer : G.S.D. Babu, V. Chinnappan, B.R.M. Rao.

Scientific Officer SD : G. Srinivasulu, M.S. Sundara Rajan.

Scientific Officer SC : P.S.M. Aleem, S.S. Gupta, J. Javaraiah, D. Karunakaran, K.B. Ramesh, K. Sasidharan, J.P.L.C. Thangadurai, L. Yeshwanth.

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

Librarian : A. Vagiswari.

Assistant Librarian A : C. Louis.

Technical Officer : A.M. Abbas, S.S. Chandramouli, A.M. Ghouse, A.T.A. Hameed, S. Muthukrishnan, R.Muralidharan Nair, K.G.Unnikrishnan Nair, K. Narayanan Kutty, K. Padmanabhan, K.S. Ramamoorthy, K. Ramankutty, J.P.A. Samson.

Technical Associate : A. M. Batcha, P. Chockalingam, F. Gabriel, M. Irulappan, N. Jayavel, P.K. Mahesh, S. Muralishankar, J.S. Nathan, G.N. Rajasekhara, K. Rangaswamy, A. Selvaraj, R. Selvendran, N. Sivaraj, K.S. Subramanian, G.S. Suryanarayana, K.C. Thulasidharan, A.P. Velayuthan Kutty.

Documentation Associate : S. Rajiva.

Engineer Associate : F. Saleem.

Honorary Professor : J.C. Bhattacharyya, K.R. Sivaraman.

Professor (Radio astronomy Projects) : Ch. V. Sastry.

Visiting Scientist : S. Ananthamurthy, J. Bagchi, B.C. Bhatt, A. Goswami, A. Sharma, J. Vijapurkar.

Graduate Students : D. Banerjee, S. Banerjee, S.G. Bhargavi, P. Chakraborty, M. Dikpati, K.P. Geetha, U. Gorti, A.D. Jana, V. Krishnakumar, S. Majumdar, R. Nayak, G. Pandey, R.D. Prabhu, S. Rajagopal, Rajalakshmi, S.P.K. Rajaguru, B.S. Ramachandran, R. Ramesh, C. Ratnam, S. Ravindranath, E. Reddy, S.K. Sengupta, M. Sharma, A.D.K. Singh, T. Sivarani, R. Sridharan, A. Subramaniam, S. Subramaniam, Srikanth, D. Suresh, A.V. Thampan, D. Virlal.

Involvement in the Scientific Community

J.C. Bhattacharya is a member of the Indian National Committee on Solar Terrestrial Physics : Governing Council for the Jawaharlal Nehru Planetarium, Bangalore; Bangalore Association for Science Education. He inaugurated the new planetarium program on the Solar Eclipse; the Maths Lab by Bangalore Association for Science Education; and the workshop in Mathematics and Astronomy, National College, Bangalore. **G.S.D. Babu** is a member of the working group for the Worldwide Development of Astronomy. **B.P. Das** has refereed papers for the Journal of Physics B:Atomic, Molecular and Optical Physics. **T.P. Prabhu** served on the SOC of the XVII Annual meeting of ASI held at Guwahati 1996 January 17 - 20. **R. Kariappa** is a co-investigator on a research project belonging to the Solar Heliospheric Observatory (SOHO) - VIRGO and MDI experiments and also in the research project of High Resolution Local Helioseismology Imager at NASA/JPL. **Ram Sagar** has been made a member of the organizing committee of IAU commmission 37.

APPENDIXES

APPENDIX A

PUBLICATIONS

In Journals

*Aguirregabria, J.M., Vishveshwara, C.V. (1996) *Phys.Lett., A,* **210**, 251.
Scattering by black holes : a simulated potential approach.

Anupama, G.C., *Kembhavi, A.K., *Elvis, M., *Edelson, R. (1995) *MNRAS*, **276**, 125.
The interstellar medium in the Seyfert galaxy NGC 7172.

*Asoka, B.N., *Marar, T.M.K., *Seetha, S., *Kasturirangan,K., Bhattacharyya, J.C. (1995) *A&A*, **297**, L83.
Detection of optical pulsations from JO558 + 53.

*Asoka, B.N., *Seetha, S., *Marar, T.M.K., *Kasturirangan, K., *Rao, V.R., Bhattacharyya, J.C. (1994) *A&A*, **293**, 000.
High speed photometry of PG 1012-029.

Bagare, S.P. (1995) *BASI*, **23**, 57.
Day time seeing observations at Kodaikanal Tower Telescope.

*Balona, L.A. (Several authors including K.K.Ghosh) (1996) *MNRAS*, (in press).
Line profile variation in γ - Doradus.

*Barman, S.K., Sagar, R. (1996) *BASI*, **24**, 47.
Influence of a third body on the Luminosity of a compact binary system.

Bhatt, H.C. (1996) *A&A,* (in press).
Polarisation in A-type stars with circumstellar shells.

*Bhattacharya, D., Datta, B. (1996) *MNRAS*, (in press).
Ohmic decay of magnetic flux expelled from neutron star interiors.

*Bohme, T. (Several authors including K.K.Ghosh) (1996) *A&AS*, (in press).
Azimuthal structures in the wind and chromosphere of the Herbig Ae star AB Aur.

*Cameron, A.C. (Several authors including K.K.Ghosh) (1996) *MNRAS*, (in press).
Multi-site observations of surface structures on AB Doradus in 1994 November.

*Castelli, F., Parthsarathy, M., *Hack, M. (1996) *A&A*, in press.
Abundances of the He 3 star 3 Cen A (B5 IIIp) from the ultraviolet spectrum.

Cowsik, R., Ratnam, C., Bhattacharjee, P. (1996) *Phys.Rev.Lett.,* **76,** 3886.
Dispersion velocity of galactic dark matter particles.

Datta, B., Thampan, A.V., *Bhattacharya, D. (1995) *JAA,* **16,** 375.
A numerical survey of neutron star crustal density profiles.

Datta, B., Thampan, A.V., *Wiita, P.J. (1995) *JAA,* **16,** 357.
Disk luminosity and angular momentum for accreting, weak field neutron stars in the 'slow' rotation approximation.

*Faurobert-Scholl, M., *Frisch, H., Nagendra, K.N. (1996) *A&A*, in press
An operator perturbation method for polarized line transfer I Non-

---

• Names of collaborators from other institutions

magnetic regime in ID media.

Gangadhara, R.T., Hasan, S.S. (1996) *MNRAS*, in press.
Numerical simulation of sunspot equilibrium using dynamic relaxation.

Giridhar, S., Rao, N.K., *Lambert, D.L. (1996) *JAA*, in press.
Spectral atlas of the hot R Cr B star - Dy Cen.

Gorti, U., Bhatt, H.C. (1996) *MNRAS*, **278**, 611.
Dynamics of embedded protostar clusters in clouds.

Iyengar, K.V.K., Parthasarathy, M. (1996) *A&AS*, in press.
BVRI photometry of a few unidentified IRAS sources.

Kariyappa, R. (1994) *Solar Phys.*, **154**, 19.
Intensity oscillations in chromospheric bright points and network elements.

Kariyappa, R. (1996) *Solar Phys.*, **165**, 211.
Solar oscillations in strong and weak Fraunhofer lines over a quiet region.

Kariyappa, R., * Pap, J.M. (1996) *Solar Phys.*, in press.
Contributions of chromospheric features to UV irradiance variability from spatially resolved Ca II K spectroheliogram : A new method of analysis and preliminary results.

Kochhar, R.K., Namboodiri, P.M.S (1995) *Astrophys.Sp.Sci.*, **228**, 185.
Galaxy dynamics with small computers : some results on tidal interactions.

*Korchagin, V., *Kembhavi, A.K., *Mayya, Y.D., Prabhu, T.P. (1995) *ApJ*, **446**,. 574.
Are nuclear hotspots in galaxies sites of sequential star formation?

Krishan, V., (1995) *Pramana*, (in press).
Rotation curves of galaxies : Missing mass or missing physics in 'Fundamentals of Physics and Astrophysics'.

*Mahabal, A., *Kembhavi, A., *Singh, K.P., *Bhat, P.N., Prabhu, T.P. (1996) *ApJ*, **457**, 598.
A dust lane in the radio galaxy 3C 270.

Mahesh, P.K. (1996) *BASI*, **24**, 67.
Feasibility study for a polar disc mount.

Nagendra, K.N. (1994) *ApJ*, **432**, 274.
Resonance line polarisation in spherical atmospheres : Partial redistribution effects studied with Domke - Hubney redistribution matrix.

Nagendra, K.N. (1995) *MNRAS*, **274**, 523.
Collisional redistribution effects on line polarization in spherical atmospheres.

Nagendra, K.N. (1996) *Solar Phys.*, **164**, 67.
Partial redistribution effects on line polarization in the presence of velocity fields.

Nagendra, K.N., * Leung, C.M. (1996) *MNRAS*, in press.
Models of highly extended dust shells around R Coronae Borealis.

Pal, P.B., *D'Olivo, J.C., *Nieves, J.F. (1996) *Phys.Lett,B.*, **365**, 179.
Cerenkov radiation from massless neutrinos.

Pal, P.B., *Nieves, J.F. (1995) *Phys.Rev.D.*, **51**, 5300.
Thermal self-energies at zero momentum.

Pal, P.B., Sengupta S. (1996) *Phys.Lett,B.*, **365**, 175.
Constraints on cosmic electric charge asymmetry and neutrino charge from the microwave background.

Peraiah, A. (1996) *BASI*. **24**, 397.
Radiative transfer - Chandrasekhar and after.

*Poutanen, J., Nagendra, K.N., *Svensson, R. (1996) *MNRAS*, in press.
Green's matrix for Compton reflection of polarised radiation from cold matter.

Rao, N.K. (1996) *MNRAS*, in press.
The emission line spectrum of the hot R Coronae Borealis star - MvSgr.

Reddy, B.E., Parthasarathy, M. (1996) *AJ*, (in press).
CCD photometry and spectroscopy of IRAS sources having far IR-colors similar to planetary nebulae.

Reddy, B.E., Parthasarathy, M., *Gonzales, G., *Bakker, E.J. (1996) *ApJ Lett.* (in press).
The chemical composition of IRAS 05341 + 0852 : a post - AGB F supergiant with 21 micron emission.

Sagar, R., *Cannon, R.D. (1995) *A&AS* **111**, 75.
A deep UBVRI CCD photometric study of the moderately young southern open star cluster NGC 4755 ≡ κ Crucis.

Sagar, R., *Gopal - Krishna, *Wiita, P.J. (1996) *MNRAS*, in press.
Intra-night optical monitoring of optically selected bright quasars.

Sankarasubramanian, K., Venkatakrishnan, P. *Solar Phys.*, (in press).
Ellipsometry of coelostat coatings using a Babinet compensator.

Satya Narayanan, A. (1996) *Physica Scripta*, in press.
Axisymmetric MHD equilibrium of a self-gravitating incompressible fluid.

Shastri, J.H., *Huang, T., *Shibata, T., *Okuzawa, T. (1995) *Geophys.Res.Lett.*, **22**, *2649*.
Response of equatorial - low latitude ionosphere to sudden expansion of magnetosphere.

Shastri, J.H., *Meena Verma, V.K., *Nayar, S.R.P. (1995) *Geophys. Res.Lett.*, **22**, 2645.
Height gradient of F region vertical drift in the vening equatorial ionosphere.

Shastri, J.H. (1996) J.*Geophys. Res.*, **101**, 2445.
Longitudinal dependence of equatorial F region vertical plasma drifts in the dusk sector.

*Shukla, P.K., *Varma, R.K., Krishan, V. (1993) *Phys.Rev.E.*, **47**, 3612.
Electrostatic oscillations in the presence of grain charge perturbations in dusty plasmas.

*Sigl, G., *Lee, S., *Schramm, D., Bhattacharjee, P. (1995) *Science*, **270**, 1977.
A gap in the highest cosmic ray spectrum as a signature of unification scale physics.

*Simon, T. (Several authors including K.K.Ghosh) (1996) *A&A*, (in press).
MUSICOS observations of θ^2tau.

*Singh, K.P., *Bhat, P.N., Prabhu, T.P., *Kembhavi, A.K. (1995) *A&A*, **302**, 658.
Distribution of ionized gas in X-ray bright early-type galaxies.

Sinha, S. (1996) *Pramana* (in press).
Lattice dynamical models of adaptive spatiotemporal phenomena.

Sinha, S. (1996), *Phys.Rev.E*, **53**, 4509.
Transient 1/f noise.

Sivaram, C., * de Sabbata, V. (1995) *Found.Phys.Lett.*, **8**, 375.
Torsion, string tension and topological origin of charge and mass.

Sivaram, C., *de Sabbata, V. (1995) *Int.J.Mod.Phys.A.*, **10**, 000.
Twistors, torsion and the quantisation of space time.

Sivaram, C. (1996) J.Math.Phys. (in press).
Charge and mass through twistors.

Sivaraman, K.R., Gupta, S.S., Kariyappa, R., (1996) *Solar Phys.*, **163,** 93.
Ca II K line profile of the truly quiet Sun.

*Sridharan, T.K., Bhatt, H.C., *Rajagopal, J. (1996) *MNRAS*, (in press).
Magnetic fields in cometary globules I: CG 22.

Subramaniam, A., Sagar, R. (1995) *A&A*, **297,** 695.
Young LMC star clusters as a test for stellar evolutionary models.

*Unnikrishnan, C.S., Murthy, S.A. (1996) *Phys.Lett.A* (in press)
Some comments on the two-prism tunneling experiment.

Vasundhara, R., Pavan Chakraborty, Rajamohan, R. Bhattacharyya, J.C., *Som Sunder, G., *Vivekananda Rao, P., *Swaminathan, R., *Lokanadham, B. (1995) *Current Sci.*, **63,** 327.
Observation of Comet Shoemaker-Levy 9 from Japal Rangapur Observatory.

Venkatakrishnan, P. (1996) *Solar Phys.*, **166,** 195.
Onset of hydrodynamic non-equilibrium in helmet streamers.

Venkatakrishnan, P., *Sakurai, T., *Suematsu, Y. *Ichimoto, K. (1996) *PASJ*, **48,** L1.
Enhanced He I absorption at the feet of X-ray loops.

*Venugopal, E.P., Das, B.P., *Andriessen, J. (1996) *Phys.Rev.A.* in press.
Relativistic many-body calculation of the electric dipole moment of atomic Caesium arising from a scalar-pseudoscalar interaction.

In Proceedings

Anupama, G.C. (1995) in *Proceedings Cataclysmic Variables,* eds A.Bianchini et al., Kluwer, Netherlands, p.49.
The general trends of recurrent novae.

Bhattacharjee, P. (1996) in *Proceedings INSA Symposium on 'Interface of Astronomy with other Sciences'*, Kodaikanal in press.
The origin of the highest - energy cosmic rays.

Cowsik, R., *Friedlander, M.W. (1995) in *Proceedings 24th International Cosmic Ray Conference,* in press.
Implications of gamma-ray lines observed from the Orion complex-II.

Ghosh, K.K., Soundararajaperumal, S. (1996) in *Proceedings of 2nd Japan - India Seminar on Astronomy and Astrophysics,* in press.
Multifrequency spectra of AGNs.

Ghosh, K. K., Soundararajaperumal, S. (1996) in *Proceedings 3rd ASCA Symposium,* Japan in press.
Radio through X-ray spectra of EXOSAT Seyfert galaxies.

Gokhale, M.H. (1996) in *Proceedings International Conference on 'Windows on the Sun's Interior'*, eds H.M. Antia & S.M.Chitre, *BASI,* **24,** 121.
MHD Windows on the Sun.

Hasan, S.S., *Bogdan, T.J. (1996) in *Proceedings International Conference on 'Windows on the Sun's Interior'*, eds H.M.Antia & S.M.Chitra, *BASI,* **24,** 125.
The effect of p-modes on thin magnetic flux tubes.

*Iwasaki, K., *Akabane, T., Sagar, R., Ghosh, K.K., *Raharto, M., *Dirghantara, F. (1996) in *Proceedings 28th ISAS Lunar and Planetary Symposium*, in press.
Regression of martian north polar cap 1994-1995.

Kapoor, R.C., *Shukre, C.(1996) in *Proceedings IAU Coll.160*, in press.
A geometrical origin of the pulsar core and conal emissions.

Kariyappa, R. (1995) in *Proceedings 4th SOHO Workshop on Helioseismology*, ESA SP-376, Vol 2, p.437.
Pole-equator-difference and the variability of the brightness of the chromospheric Ca II K network elements in quiet region over solar cycle.

Kariyappa, R (1995) *in Proceedings 4th SOHO Workshop on Helioseismology*, ESA SP-376, Vol.2, p.525.
The relation between the period of oscillations and brightness in chromospheric bright points.

Kariyappa, R., *Pap, J.M. (1995) in *Proceedings 4th SOHO workshop on Helioseismology*, ESA SP-376, Vol.2, p.521.
Intensity oscillations in Na I DI and D2 lines.

Kariyappa, R., *Pap, J.M., *Balasubramaniam, K.S., *Kuhn, J.R. (1995) in *Proceedings 4th SOHO Workshop on Helioseismology*, ESA SP-376, Vol.2, p.429.

Krishan, V. (1996) in *Proceedings International Conference on 'Windows on the Sun's Interior'*, eds H.M. Antia & S.M. Chitre, *BASI*, **24**, 285.
Structure of turbulence in the solar convectione zone.

Mohin, S., Raveendran, A.V., Mekkaden, M.V. (1995) in Proceedings IAU Symp. 176.
Long term photometric variations of the active RSCVn binaries DM Uma and II Peg.

Parthasarathy, M. (1996) in *Proceedings IAU Symposium 177*, (in press).
Chemical composition and evolution of post-AGB stars.

Parthasarathy, M. (1996), in *Proceedings East Asian Meeting on Astronomy*, NOAO, Japan, in press.
Ground-based optdical astronomy in India.

Pandey, G., Rao, N.K.*Gonzalez, G. (1995) *ASP Conf.Ser.*, **96**, 167.
MV Sgr - the emission line spectrum.

Raju,P.K. (1995) in *Proceedings Tenth National Symposium on Plasma Science and Technology*
Election density and temperature diagnostics of solar plasma using emission lines of Mg^{+6} and Si^{+6}.

Ramesh, K.B. (1995) *ASP conference Series*, eds K.S.Balasubramaniam, S.L. Keil & R.N.Smartt, in press.
Solar cycle Variation of the occurrence of geomagnetic `storms.

Rao, N.K. (1995) in *Proceedings India - Japan Seminar on A&A*, eds.R.Cowsik and D.Sugimoto, *BASI*, **23**, 351.
Astronomy with Vainu Bappu Telescope.

Rao, N.K., *Lambert, D.L. (1996) in *Proceedings 2nd International Meeting on Hydrogen Deficient Stars*, PASP Conf.,Ser.96., eds C.S.Jeffrey and U.Heber, p.43.
The surface chemical composition of RCB stars.

Sagar, R., Gorti, U., Subramaniam, A., Bhatt, H.C. (1996) in *Proceedings IAU Symp.174*, in press.
Binary star clusters in galaxies : Our galaxy.

Sivaram, C. (1995) in *Proceedings ICGC*, IUCAA, Pune, in press.
Entropy, black holes and strings.

Sivaram, C. (1995) *in Proceedings 24th International Cosmic Ray Conference*, Rome, Vol.2., p.164.
Merger models of gamma ray bursts : A comparison.

Sivaram, C. (1995) in *Proceedings 24th International Cosmic Ray Conference,* Rome, Vol.OG 9-3.7, p.352.
Acceleration of the highest energy cosmic rays (>10^{20} ev) by superconducting cosmic strings.

Sivaram, C. (1995) in *Proceedings 24th Int.Cosmic Ray Conference, Rome*, Vol.1. H.E.5.1-2, p.642.
Interactions of UHE cosmic ray neutrino with the cosmological neutrinos background.

Vasundhara, R., *Arlot, J.E., *Descamps, P. (1996) in *Proceedings IAU Symposium 172 : Dynamics, Ephemerides and Astrometry in the Solar System*, in press.
New constants for Sampson - Lieske theory of the Galilean satellites of Jupiter from mutual occultation data.

In Books

Vishveshwara, C.V. (1995) in *Inhomogeneous Cosmologies*, ed.J.Senovilla & A.Molina, World Scientific.
Gyroscopic precession in general relativity.

Book Reviews/Conference & Technical Reports/Astronews

Krishan, V. (1995) *BASI*, **23,** 101.
A report on the 15th summer workshop of the National Solar Observatory at Sacramento Peak entitled `IR tools for Solar Astrophysics : What's next ?

Krishan, V. (1996) *BASI*, **24,** 77.
Book Review of Atlas of compact group of galaxies by Paul Hickson.

Pal, P.B. (1995) *BASI*, **23,** 279.
Theoretical implications of neutrino mass.

Sagar, R. (1996) *BASI*, **24,** 5.
Discovery of a planetary system around 51 Pegasus.

Attendance in Conferences, Workshops and other Scientific Meetings

UARS Science Meeting, Pasadena, CA,USA,1995 March 28-30, **R.Kariyappa**

4th SOHO Workshop on Helioseismology, Monterey, CA, USA, 1995 April 2-6, **K.M.Hiremath, R.Kariyappa**

First Sino-Indian Workshop on High Energy Astrophysics, Nanjing Normal University, Nanjing, China, 1995 April 11-19, **T.P. Prabhu**

INSA Symposium on Interface of Astronomy with other Sciences, Kodaikanal, 1995 May 4-5, **P.Bhattacharjee, S.S.Gupta, V.Krishan D.C.V.Mallik, J.V.S.V.Rao, Sushma V.Mallik**

1995 Spring AGU Meeting, Baltimore, MD, USA. 1995 May 30 - June 3/ December 11-15, **R.Kariyappa**

Coordinating Committee for Television Programming and Broadcasting for `The Total Solar Eclipse', DECV, Ahmedabad, 1995 June 23, **J.Singh**

National Seminar on Total Solar Eclipse, M.P.Birla Planetarium, Calcutta, 1995 July 23, **J.Singh**

IAU Symposium 172 on Dynamics, Ephemerides and Astrometry in the Solar System, Paris, 1995 July 3-8, **R.Vasundhara**

East Asian Meeting on 'Ground Based Astronomy in Asia', Tokyo, Japan, 1995 July 17-21, **A.Goswami**

Mid-year Meeting of the Indian Academy of Sciences, Bangalore, 1995 July 28, **B. Datta**

International Conference on Physics : Beyond the Standard Model at Low and Intermediate Energies, National Institute for Nuclear Theories, University of Washington, Seattle, USA, 1995 August, **B.P.Das**

24th International Cosmic Ray Conference, Roma, Italy,1995 August, **R.Cowsik**

Meeting of the Cosmic Ray Commission of the International Union of Pure and Applied Physics, 1995 August, **R.Cowsik**

Seminar on Total Solar Eclipse, Bhopal, 1995 August 26, **J.Singh**

2nd International Conference on Hydrogen Deficient Stars, Bamburg, Germany, 1995 August 28 - September 1, **N.K.Rao**

Spanish International Relativity Conference, Tenerife, Spain, 1995 September 5-10, **C.V.Vishveshwara**

XV Group Monitoring Workshop of DST Young Scientist Programme in the area of Physical Sciences, Madras, 1995 September 13-15, **A.Goswami**

NCSTC meeting held at Air Headquarters, 1995 September 22, **J.Singh**

Twentieth National Symposium on Instrumentation, Instrument Society of India, Hyderabad, 1995 September 25-28, **V.Krishnakumar, K.Subramaniam**

SAARC Workshop, Bal Bhavan Society of India, New Delhi, 1995 October 11, **J.Singh**

Tenth National Symposium on Plasma Science and Technology, Banaras Hindu University, 1995 October 16-19, **P.K.Raju**

16th NSO/SP Workshop on Solar Drivers of Interplanetary and Terrestrial Disturbances, Sacramento Peak, SUNSPOT, NM, USA, 1995 October 16-20, **R.Kariyappa, K.B.Ramesh**

International Workshop on Windows on the Sun's Interior, TIFR, Bombay, 1995 October 19-21, **S.S.Hasan, J.Javaraiah, V.Krishan, K.E.Rangarajan, A. Satya Narayanan**

65th Annual Session of the National Academy of Sciences, Tirupathi, 1995 November 2-3, **R.Cowsik**

Memorial meeting dedicated to Prof. S.Chandrasekhar, Bangalore, 1995 November 8 , **R.Cowsik, B. Datta, D.C.V. Mallik**

61st Annual Meeting of the Indian Academy of Sciences and Symposium on High Energy Physics in 21st Century, Madras,1995 November 10-12, **J.C.Bhattacharyya, R.Cowsik, B.Datta**

Indo-US workshop on Elliptical Galaxies : Structure and Dynamics, IUCAA, Pune, 1995 November 23 - December 7, **P.M.S.Namboodiri**

Review Panel Meeting on the project `Pierre Auger Observatory', UNESCO, Paris, France, 1995 November 23-24, **R.Cowsik**

International Symposium on M.N.Saha, S.N.Bose and N.R.Sen : Contributions to Astrophysics and Impact, Calcutta, 1995 November 28-30, **A.Satya Narayanan**

Meeting of the INSA Council, Amritsar, 1995 December, **R.Cowsik**

International Workshop on Quark-gluon Plasma and Phase Transitions in the Early Universe, Puri, 1995 December 4-12, **P.Bhattacharjee**

UGC National seminar on 'Pure and Applied Molecular Spectroscopy' Sri Krishnadevaraya University, Anantapur, 1995 December 8, **S.P.Bagare**

International Conference on Gravitation and Cosmology, IUCAA, Pune, P. Chakravarthy, 1995 December 14-20, **C.V.Vishveshwara**

IAU Coll.160 on Pulsars, Sydney, 1996 January, **R.C.Kapoor**

International Conference on Spectroscopy, Prospectives and Frontiers BARC, Bombay, 1996 January 2-6, **N.K.Rao**

Workshop on High Energy Physics Phenomenology (WHEPP), Calcutta 1996 January 2-15, **P.B.Pal**

National Laser Symposium, BARC, Bombay, 1996 January 17-19, **A.K.Saxena**

XVII ASI meeting, Guwahati, 1996 January 17-20, **G.C.Anupama, G.S.D. Babu, H.C.Bhatt, J.C.Bhattacharyya, R.Cowsik, K.K.Ghosh, K.Jayakumar, D.C.V.Mallik, P.B.Pal, T.P.Prabhu, Ram Sagar, N.K.Rao, J.Singh**

Space Science Symposium in Osmania University, Hyderabad, 1996 February, ***N.K.Rao***

National I- Step workshop Osmania University,1996 February 5, **M.H.Gokhale**

Golden Jubilee Celebrations of TIFR, Bombay,1996 February 9, **R.Cowsik**

XVIII Conference of the Indian Association for General Relativity and Gravitation, IMSC, Madras, 1996 February 15-17, **P.Bhattacharjee C.V.Vishveshwara**

National Meeting on Total Solar Eclipse of 1995 October 24, Bangalore, 1996 February 26-27, **P.S.M.Aleem, S.P.Bagare, P. Chakraborty, R.Cowsik, P.K. Das, E.Ebenzer, M.H.Gokhale, S.S.Gupta J.Javaraiah, R.C.Kapoor, V.Krishan, Ram Sagar, K.P.Raju, P.K.Raju, M.Ramani, R.Ramesh, J.V.S.V.Rao, N.K.Rao, S.K.Saha, J.H.Sastri, A.Satya Narayanan, A.K.Saxena,K.R.Subramanian, J.Singh, P.Venkatakrishnan V.Krishnakumar, K.Sankarasubramanian, Srikanth**

I - STEP National Workshop, Hyderabad, 1996 March 5, **R.Cowsik, J.H.Sastri**

9th National Space Science Symposium in Hyderabad, 1996 March 6, **R.Cowsik, J.C.Bhattacharyya**

Third ASCA Symposium Tokyo, Japan, 1996 March 11-14, **K.K.Ghosh**

Second Japan - India Seminar on Astronomy and Astrophysics, Tokyo, Japan, 1996 March 16 - 22, **R.Cowsik, K.K.Ghosh, J.Singh**

Colloquia and Invited talks at Conferences, Workshops and Seminars

Anupama, G.C.
Cataclysmic variables : inter - class relations
XVII ASI meeting, Guwahati
1996 January 17 - 20

Bagare, S.P.
Applications of Molecular Spectroscopy to Astrophysics
National Seminar on Pure and Applied Molecular Spectroscopy, Department of Physics, Sri Krishnadevaraya University, Anantapur
1995 December 8

Bhatt, H.C.
Astronomy at the Indian Institute of Astrophysics
IIT, Kanpur
1996 April 13

Bhattacharjee, P.
The origin of the highest-energy cosmic rays
INSA Symp. on 'Interface of Astronomy with other sciences', Kodaikanal Observatory, Kodaikanal
1995 May 4-6

Phase transitions in the early universe, topological defects, and the highest-energy cosmic rays
International workshop on Quark-Gluon Plasma and Phase Transitions in the Early Universe, Puri, Orissa.
1995 December 4-12

Topological defects in cosmology
XVIII-th conference of the Indian Association for General Relativity and Gravitation, IMSC, Madras
1996 February 15-17

Bhattacharyya, J.C.

Stellar sizes ; The eternal enigma
Indian Astronomical Society, Calcutta
1996 March

Some enigmatic circumplanetary features in the magnetosphere of Saturn
INSA Diamond Jubilee Lecture, PRL Colloquium Lecture
1995 August

Cowsik, R.

The implications of gamma-ray-line observations from the Orion complex
Possible identification of an unusual component of primary cosmic-ray electrons
24th International Cosmic Ray Conference, Roma, Italy,
1995 August 28 - September 8

Is the neutrino its own antiparticle ?
Jawaharlal Nehru Center for Advanced Scientific Research, Bangalore
1995 October

Study of gravitation and weeker forces using torsion balance
Is the neutrinos its own antiparticle ?
The Himalayan Infrared and Optical Telescope
Osservatorio Astronomico di Padova, Padova, Italy,
1995 August

Implications of gamma-ray lines observed from the Orion-complex II
24th International Cosmic Ray Conference, Rome, Italy,
1995 August

Subrahmanyan Chandrasekhar 1910 - 1995
Memorial Meeting dedicated to S.Chandrasekhar, Bangalore
1995 November

Hints of new physics from cosmology, astrophysics and non-accelerator experiments
Symposium on High Energy Physics in 21st Century, 61st Annual Meeting of the Indian Academy of Sciences, Madras
1995 November

1995 Nobel Prize in Physics : Martin L.Perl & Frederick Reines
Raman Research Institute, Bangalore
1995 November

Dark matter and its detection
Professor A.C.Banerjee Memorial Lecture
65th Annual Session of the National Academy of Sciences, Tirupathi
1995 November

Is the neutrino its own antiparticle?
Professor S.D.Chatterjee Endowment Lecture (1994-95)
Indian Physical Society, Calcutta
1996 February

The control system and communication network for a 2-m class telescope at Hanle
Annual Meeting of the Astronomical Society of India, Guwahati
1996 January

Indian initiatives in solar terrestrial phenomena
9th National Space Science Symposium, Hyderabad
1996 February

Dark matter and the problem related to its detection
The Himalayan Astronomical Observatory project
Japan-India Seminar on Astronomy & Astrophysics,
Tokyo, Japan
1996 March 16 - 22

Das, B.P.

Configuration interaction and coupled cluster approaches to parity and time - reversal violation in atoms.
University of Washington, Seattle, U.S.A.

Laser cooling, trapping and the creation of a new state of matter
IISc, Bangalore

Parity non-conservation in atomic ytterbium
RRI, Bangalore

Datta, B.

Matter at very high densities
Mid - year Meeting of the Indian Academy of Sciences, Bangalore
1995 July 28

Relativistic instabilities
Memorial meeting dedicated to S.Chandrasekhar, Bangalore
1995 November 8

The total solar eclipse of 1995
61st annual meeting of the Indian Academy of Sciences, Madras
1995 November 10 -12

Ghosh, K.K

Multifrequency spectra of AGN's
2nd Japan - India Seminar on Astronomy and Astrophysics,
Tokyo, Japan
1996 March 21

Gupta, S.S.

Astrophysics in relation to agriculture/horticulture crops
Horticultural Workshop, Dept of Horticulture, Tamil Nadu
1996 January 3

Hasan, S.S.

The interaction of magnetic flux tube with p-modes
High Altitude Observatory, NCAR, Boulder, USA
1995 June 12

The response of a magnetic flux tube to buffeting by p-modes in the solar atmosphere
National Solar Observatory, NOAO, Tucson
1995 June 19

Kochhar, R.K.

Science as a colonial tool : The Indian experience
Institute of Fundamental Studies, Kandy, Sri Lanka
1996 January 6

Astronomy with small telescopes : The Indian experience
UN/ESA Workshop on Basic Space Science : From small telescopes to space missions, Colombo, Sri Lanka
1996 January 11-14

Colonialism and science
Punjabi University, Patiala
1996 February 2

Krishan, V.

Is the Hubble flow, a result of an inverse cascade?
INSA Symposium on Interface of Astronomy and other Sciences, Kodaikanal
1995 May 4 - 7

Structure of turbulence in the solar convection zone
International meeting on Windows on the Sun's Interior,
1995 October 19-21

Thrust areas in astrophysical plasmas
Meeting on Vision - Plasma Physics, IPR, Gandhinagar
1996 January 1 - 2

Mallik D.C.V.

New measurements of the Hubble constant and its implications
INSA symposium on Interface of Astronomy and other Sciences, Kodaikanal
1995 May 4 - 7

On stars and their evolution
Memorial meeting dedicated to S.Chandrasekhar, Bangalore
1995 November 8

Astronomy with a 2-m telescope
XVII ASI meeting, Guwahati
1996 January 18

Namboodiri, P.M.S.

Remnants of closely interacting galaxies
Indo-US workshop on Elliptical Galaxies : Structure and Dynamics
1995 November 23 - December 7

Pal, P.B.

Do neutrinos have mass?
IUCAA, Pune
1995 April

Parthasarathy, M.

SAO 244567: A post-AGB star which has turned into planetary nebula within the last 20 years
Chemical composition of post-AGB stars
Early Chemical history of the Galaxy and abundances of heavy elements
Chemcial compostion of close-binary stars
PRL, Ahmedabad

Chemical compostion and evolution of post-AGB stars
IUCAA, Pune

Ground-based optical Astronomy in India
EAMA Meeting, Tokyo, Japan

Circumstellar dust shell characteristics of post-AGB stars and proto-planetary nebulae
Nobeyama Observatory, Japan

Post-AGB candidates from IRAS data
KISO Observatory, Japan

Evolution of post-AGB supergiants
NOAO, Mitaka, Japan

IUE and IRAS satellite observations of low mass stars in post-AGB stage of evolution
Trieste, Italy

Prabhu, T.P.

Starburst phenomenon
Astronomy in India
First Sino-Indian Workshop on High Energy Astrophysics, Nanjing Normal University, Nanjing, China
1995 April 11-19

Recent Astronomical Site Survey in the Himalayas
XVII ASI Meeting, Guwahati
1996 January 18

Ram Sagar

Latest trends in optical telescopes
BITS, Pilani
1995 April 6

Stellar mass distribution in young LMC star clusters
AAO, Epping, Australia
1995 November 2

Rao, D.M.

A study of finite - difference methods for radiative transfer problems
Department of Mathematics, University of Heidelberg
1996 February

Rao, N.K.

Ultraviolet Astronomy
Space Science Symposium, Osmania University, Hyderabad
1996 February

Saxena, A.K.

Laser based adaptive optics
National Laser symposium, BARC, Bombay
1996 January 17 - 19.

Singh, J.

Total solar eclipse of Oct. 24, 1995
Seminar on Total Solar Eclipse, Bhopal
1995 August 26
Observing programme of Indian Institute of Astrophysics during the Total Solar Eclipse of October 24, 1995
National Seminar on Total Solar Eclipse
MP Birla Planetarium, Calcutta

On the results of observations during Total Solar Eclipse of Oct 24, 1995
XVII ASI Meeting of
1996 January 18
Japan India Seminar at Tokyo, Japan
1996 March 21

Venkatakrishnan, P.

Search for flare related changes in Vector magnetic fields
Coronal mass ejections
HeI line in the solar atmosphere
Udaipur Solar Observatory
1995 April 12 - 14

Vishveshwara, C.V.

Gyroscopic precession and inertial forces: covariant connections
Spanish International Relativity Conference, Tenerife, Spain
1995 September 6

Gyroscopic precession and inertial forces in General Relativity
Queen Mary College, London, U.K.
1995 October 18

On the black hole trail – A personal journey
Vaidya - Raichaudhuri Endowment Lecture
Meeting of IAGRG, IMSc, Madras
1996 February 17

Paper presentations at Meetings

Bagare,S.P., Aleem,P.S.M., Singh,J., Saxena,A.K.
Broad band photometry of solar corona during the total solar eclipse of 1995 October 24
National meeting on Total Solar Eclipse 24 October 1995, IIA, Bangalore
1996 February 26-27

Bagare,S.P., Cowsik,R., Jagdev Singh, Raju,K.P., Saxena,A.K., Samson,J.P.A., Nagaraja Naidu,B.
Search for hydrogen-alpha cool pockets in Solar Corona during the total solar eclipse of 24 Oct 1995
National meeting on total solar eclipse of 1995 October 24, IIA, Bangalore
1996 February 26

Banerjee,D., Hasan,S.S., *Christensen-Dalsgaard,J.
Wave leakage in a magnetized isothermal atmosphere
International Conference on `Windows on the Sun's Interior' TIFR, Bombay
1995 October 19-21

*Bernatowicz,T., Cowsik,R., *Gibbons,P.C., *Lodders,K., *Fegley,B., Jr., *Mari,S., *Lewis,R.S.
Constraints on stellar grain formation from circumstellar graphite in the Murchison meteorite
Lunar Science Congress, Houston, USA
1996 March

Cowsik,R.
Problems related to the detection of dark matter in our Galaxy
The Himalayan Astronomical Observatory project
Japan-India Seminar on Astronomy and Astrophyhsics, Tokyo, Japan
1996 March 16-22

Dikpati,M., *Choudheri,A.R., Venkatakrishnan, P.
Solar cycle variation of the largescale coronal magnetic field
XV NSO Summer Workshop, Sunspot, New Mexico
1995 October

Gangadhara,R.T., Hasan,S.S.
Modelling sunspot equilibrium through a solution of the time dependent MHD equations
International Conference on `Windows on the Sun's Interior'
1995 October 19-21

Giridhar,S., Rao,N.K., *Lambert,D.L.
Spectral variations of DY Cen
ASP Conference, Bamburg, Germany
1995 October

Goswami,A.
Investigation of role of nucleosynthesis during explosive stage of stellar evolution
XV Group Monitoring Workshop of DST Young Scientists Programme in the area of Physical Sciences
1995 September 13-15

Goswami,A., Giridhar,S.
Behaviour of 017774 A feature in the spectrum of 10 days period ζ Gem
Third East Asian Meeting on `Ground Based Astronomy in Asia'.
1995 July 17-21

Goswami,A., Rao,N.K., *Gonzalez,G., *Lambert,D.L.
Hydrogen deficient nature of Z Umi
ASP Conference, Bamburg, Germany
1995 October

Gupta,S.S., Sivaraman,K.R., *Howard,R.
Measurement of solar rotation from Kodaikanal
International Conference on `Windows on the Sun's Interior', TIFR, Bombay
1995 October 19-21

Javaraiah,J.
Periodicities in the Sun's 'Torsional MHD oscillations' and planetary configurations
International Conference on `Windows on the Sun's Interior', TIFR, Bombay
1995 October 19-21

Krishan,V.
Modelling of solar coronal oscillations
National Meeting on Total Solar Eclipse, IIA, Bangalore
1996 February 26-27

Kariyappa,R., *Pap,J.M., *Vigouroux,A.
Variability of the solar chromospheric network and intranetwork regions and their contribution to irradiance variations
American Geophysical Union, 1995, Fall Meeting
1995 May 30-June 3

Karunakaran,D., Sastri,J.H.
Effect of the solar eclipse of 24 October 1995 on the ionospheric F region over Kodaikanal
National Meeting on Total Solar Eclipse, IIA, Bangalore
1996 February 26-27

Krishnakumar,V., Sankarasubramaniam,K.
Prism as a tool for fractional Fourier transform
Twentieth National Symposium on Instrumentation, Hyderabad
1995 September 25-28

Krishnakumar,V., Sankarasubramaniam,K.
Vibration measurement using prism
Twentieth National Symposium on Instrumentation, Hyderabad
1995 September 25-28

Murali Shankar,S., Srinivasan,R.
Design consideration for MOSAIC CCD controller development
National Symposium on Instrumentation
1995 September

Ramani,M., Cowsik,R. Singh,J., *Sehgal,N.K.,* Kamble,V.B.
Photography of solar corona using Indian Air Force aeroplane
National Meeting on total Solar eclipse of 1995 October 24, IIA, Bangalore
1996 February 26

Ramesh,K.B.
Solar cycle variation of the occurrence of geomagnetic storms
Sixteenth NSO/SP Workshop on Solar Drivers of Interplanetary and Terrestrial Disturbances, Sacramento Peak, SUNSPOT, NM, USA
1995 October 16-20

Rao,N.K.
R Cr B - pulsations and massloss
ASP Conference, Bamburg, Germany
1995 October

Rao,N.K., Goswami,A., *Smith,V.V., *Lambert,D.L.
Spectrum of S Aps at deep minimum
ASP Conference, Bamburg, Germany
1995 October

Saha,S.K., Nagabhusana,B., Venkatakrishnan,P.V.
A speckle experiment during partial eclipse
National Meeting on Total Solar Eclipse, IIA, Bangalore
1996 February 26-27

Satya Narayanan,A.
Surface waves in a two layered fluid model with an inclined magnetic field
International Conference on 'Windows on the Sun's Interior', TIFR Bombay
1995 October 19-21

Satya Narayanan,A.
Temperature distribution for self-organised coherent structures in three dimensions
International Symposium on M.N.Saha, S.N.Bose and N.R.Sen : Contributions to Astrophysics and Impact
1995 November 28-30

Saxena,A.K., Cowsik,R., Lancelot,J.P., Samson,J.P.A., Bagare,S.P., Ismail, R.
A study of inner solar corona during total solar eclipse of October 24, 1995
National Meeting on Total Solar Eclipse 24 October 1995, IIA, Bangalore
1996 February 26-27

Singh,J., Cowsik,R., Raju,K.P., Ravi
Ultra low spatial resolution photometry in near infrared to detect the dust ring
National Meeting on Total Solar Eclipse of 1995 October 24, IIA, Bangalore
1996 February 26

Singh,J., Cowsik,R., Raveendran,A.V., Bagare,S.P., Saxena,A.K., Sunderaraman,K., Krishan,V., Nagaraja Naidu,B., Samson,J.P.A., Gabriel,F.
Detectioon of short period oscillations during total solar eclipse of October 24, 1995
National Meeting on Total Solar Eclipse of 1995 October 24, IIA, Bangalore
1996 February 26-27

Singh,J., Cowsik,R., Venkatakrishnan,P., Srinivasan,R., Chinnappan,V.
Narrow band photometry in emission lines during the total solar eclipse of October 24, 1995
National Meeting on Total Solar Eclipse of 1995 October 24, IIA, Bangalore
1996 February 26

Singh,J., Gupta,S.S., Cowsik,R.
High resolution multi-slit spectroscopy of solar corona in two lines during the Total Solar Eclipse of October 24, 1995
National Meeting on Total Solar Eclipse, IIA, Bangalore
1996 February 26-27

*Smith,V.V., *Gonzalez,G., Rao,N.K.
High resolution spectra of FG Sge during the 1992 and 1994 minima
ASP Conference, Bamburg, Germany
1995, October

Vasundhara,R., Pavan Chakraborty, Jayakumar,K.
Intensity scans across the coma of comet Hale-Bopp
XVII ASI meeting, Guwahati
1996 January 17-20

Visits to Scientific Institutions

R.Cowsik visited the McDonnell Center for the Space Sciences and Department of Physics of the University of Washington at St Louis as Distinguished Visiting Professor for three months from mid March through mid June 1995 for carrying out teaching and research work. He visited the Osservatorio Astronomico di Padova, Padova and Asiago Observatory, Italy 1995 August. **B.P. Das** visited the University of Washington, Seattle, U.S.A. 1995 July-August to attend an International Conference and have discussions with E.N. Fortson and others in

connection with his experiments on atomic parity and time-reversal violation. He also visited the University of California, Berkeley, U.S.A. to discuss with E.D. Commins and co-workers their experimental work on atomic parity and time reversal violation. **K.K.Ghosh** visited ISAS, Tokyo, Japan; Department of Astronomy and Astrophysics, Tokyo University, Japan, Bisei Astronomical Observatory, Bisei, Japan during 1996 March 10-24. **A Goswami** visited Nobeyama Radio Observatory, Japan and National Astronomical Observatory, Osawa, Japan and held discussions with M.Hyashi. **S.S.Hasan** visited the High Altitude Observatory, NCRA, Boulder (U.S.A.) for four months during the period April to July 1995 under the visiting scientist program of the Observatory. During this period he made several visits to the Joint Institute for Laboratory Astrophysics, Boulder; the Space Environment Laboratory, NOAA, Boulder. During the month of June he visited the National Solar Observatory, NOAO, Tucson (U.S.A.) and in August he visited the Astronomical Observatory of Gottingen University, Germany. **D. Mohan Rao** visited the University of Heidelberg, and spent three months at the institut fur Theoretische Astronomy 1996 February - May, working on the modelling of radiation fields in Active galactic Nuclei. **K.N.Nagendra** visited Pulkova Observatory, St Petersburg, Russia, for discussing collaborative projects with scientists at the Observatory, and Leningrad University. He visited Observatoire de la Cote d'Azur, Nice, France for a period of three months in 1995. In the same year he also visited Stockholm Observatory, Sweden. **P.B.Pal** visited TIFR, Bombay, 1995 April and Mehta Institute, Allahabad, 1995 December. **M. Parthasarthy** visited the following observatories and Institutes PRL, IUCAA, Mitaka NOAO Japan, Kiso Observatory, Japan, Nobeyama Radio Observatory, Japan, ICTP, Trieste, Italy, Trieste Astronomical observatory and Department of Astronomy, Trieste, Italy. **T.P.Prabhu** visited Nanjing University, Xian Observatory and Xinlung station of Beijing Observatory following the Sino-Indian Workshop on High Energy Astrophysics, 1995 April 20 - 23. **Ram Sagar** visited the Anglo-Australian Observatory, Epping 1995 2 October -6 November as AAO visiting scientist. During this period he had one observing run at Siding Spring Observatory. He visited NCRA, Pune 1996 March 15-21. **S.Giridhar** visited the newly formed Department of Astronomy, University of Guanajutao, Mexico during 1995 May 1-June 4 to continue the study of high galactic latitude F-G supergiants in collaboration with Arellano Ferro and Laura E.Parrao. High resolution spectra of sample stars were obtained using the Cassegrain echelle spectrograph of the 2.1 m telescope of the San Pedro Martir observatory. She also visited the Department of Astronomy, University of Texas at Austin, USA during 1995 June -July, to work on RV Tauri stars in collaboration with D.L.Lambert and G.Gonzalez. A visit to McDonald Observatory was also made to obtain high resolution spectra of RV Tauri and post AGB stars. **S. Sinha** visited ICTP, Trieste, from 1995 October - December, in the capacity of an Associate Member. **P.Venkatakrishnan** visited Udaipur Solar Observatory 1995 April 10-15.

APPENDIX B

Teaching

Members of the staff continued to give full support to the teaching programmes in JAP, IISc and the M.Sc Astrophysics special papers of the Bangalore University. The list of JAP/IIA courses taught by IIA staff are listed below

Course	Lecturer
Survey of Astronomy	H.C.Bhatt
Astronomical Techniques	G.C Anupama (part of the course)
Radiative Processes in Astrophysics	P.Bhattacharjee
Physics I	B.P.Das, Sudeshna Sinha
Physics II (IIA)	B.P.Das, P.B.Pal

In Bangalore University courses of fifteen to thirty lectures were given by S.P.Bagare, J.H.Sastri,. K.B.Ramesh, T.P.Prabhu, R.Surendiranath and A.V.Raveendran. T.P.Prabhu guided K.P.Geetha in her project entitled "Site Survey -- A Study" towards partial fullfilment of her Ph.D.requirements at IIA. G.S.D.Babu is on the panel of examiners and question paper setters for the M.Sc, M.Phil and Pre-Ph.D examinations in Astronomy and Astrophysics of the Osmania University, Hyderabad. K.K.Ghosh has guided many M.Sc. Physics students for their projects on Astronomy and Astrophysics. S.K.Saha supervised two summer school students for their projects on a) Speckle interferometry of binary stars and b) Image processing. B.Datta has been the examiner for two Ph.D.thesis.

Ph.D.Thesis

M.Dikpati was awarded her Ph D degree for her thesis on 'Evolution of the poloidal magnetic fields and the heating of the quiet solar corona'. She was guided by A.R.Choudheri and P.Venkatakrishnan in this work. H.C.Bhatt has guided Uma Gorti for her Ph.D.thesis titled "Studies of protostars young stellar objects" which was submitted to the Bangalore University in 1996 March. K.M.Hiremath was also awarded the Ph.D. degree by the Bangalore University for his thesis work on Study of Sun's Long Period Oscillations and was guided by M.H.Gokhale. K.B.Ramesh was awarded the Ph.D degree for his thesis titled `Studies on Dynamics of the Equatorial Ionosphere' by the Bangalore University. H.N.Ranganatha Rao was also awarded the Ph.D.degree by the Bangalore University. Both of them worked under the guidance of J.H.Sastri. T.D.Sridharan has been awarded the Ph.D.degree from the Bangalore University, for his thesis titled MHD turbulence in solar coronal loops. This work was done under the guidance of Vinod Krishan.

Editing and publishing

J.C.Bhattacharyya is on the Editorial Board of the Journal of Pure and Applied Physics, New Delhi. R.Cowsik edited the proceedings of the International Conference on Non-accelerated Particle Physics, which was brought out by World Scientific, Singapore. K.N.Nagendra along with Prof.J.O.Stenflo, of ETH Zentrum, Zurich, Switzerland edited the Proceedings of the International Workshop on 'Solar Polarization', held at Pulkova Observatory, St Petersburg, Russia in 1995, and brought out by Kluwer Academic Publishers. H.C.Bhatt has become the Associate Editor of Bulletin of ASI. A.K.Saxena has been nominated to the Editorial Board of the Journal of Optics, a quarterly published by the Optical Society of India.

Popular Articles

Babu,G.S.D.
Vanishing rings of Saturn
Times of India, Bangalore
1995 May 21

Bhattacharyya,J.C.
Brihaspati grahe dhumketupat
(A comet falls on Jupiter)
Jnan-Vichitra, Agartala
1995 June

Ey Bachharer Suryagrahan
(This year's solar eclipse)
Jnan-Bijnan, Jignasa, Jhargam
1995 July

Puruliay Suryagrahan
(Solar eclipse in Purulia)
Ankur, Purulia
1995 August

Suryagrahan Sambandhe
Du-char Katha
(A few words about solar eclipse)
Kishore-Jnan Bijnan, Calcutta
1995 October

Bhartey Adhunik Jyotirbignan : Madras
Manmandir
(Modern Astronomy in India : Madras Observatory)
Jnan O Bijnan
1995 October

Purnagras Suryagrahan -
Nitya Athacha biral
(Total Solar eclipse, Regular yet rare)
Jnan-Vichitra, Agartala
1995 October

Mahavishwer Kendra
(Centre of the Universe, Part I)
Ankur, Purulia
1996 March

Singh,J.,
Total solar eclipses
Science Page, United Newspaper Network

Total solar eclipses on Deepawali Day
PTI Science Magazine, New Delhi

Studies during the total solar eclipse of Oct. 24, 1995
UNI-Varta Science Section

Thangadurai,P., Sundara Raman,K., Aleem,P.S.M.
Sun as a star
`Amudhasurabi'
1995 August

Radio/TV/Press

Babu,G.S.D.
Magic of the monsoon
AIR, Bangalore
1995 June 6

The family of the Sun
AIR, Bangalore
1996 January 14

Bagare,S.P.
Importance of eclipses for solar observations
AIR, Bangalore
1995 September 4

Panel discussion on 'Total solar eclipse 1995'
with B.S.Shylaja and N.Narasimhaiah
Doordarshan Kendra, Bangalore
1995 September 19

IIA's experiments at Kalpi during the total solar eclipse
An interview and report in Hindi and English
Doordarshan Kendra, Lucknow
1995 October 22

Cowsik,R.

The total solar eclipse
AIR, Bangalore
1995 October

Participation from Nim-Ka-Thana - live telecast of total solar eclipse
1995 October 25

What the total solar eclipse of 1995 has revealed
AIR, Bangalore
1995 November

Singh,J.

An interview regarding total solar eclipse of October 24, 1995 from Doordarshan, Jaipur, Rajasthan

A programme on total solar eclipse from Doordarshan, Bhopal, MP

Popular Talks

Aleem,P.S.M.

Total solar eclipse of October 24, 1995
Rotary club, Kodaikanal
1995 December 28

Babu,G.S.D.

The Indian scientific expedition to Antarctica
Cathedral Composite Pre-University College & High School
Bangalore
1995 June 30

Positional Astronomy
Zonal Workshop on 'Cosmic Voyage',
Bharath Gyan Vigyan Samithi, Karnataka
1995 May 26

Total solar eclipse
Council of the Karnataka Central Diocese, Bangalore
1995 October 22

Distance of stars
St Joseph's College, Bangalore
1996 February 9

Comet Hyakutake
St. Peter's Telugu Church, Bangalore
1996 March 3

Bagare,S.P.

Astronomical observations with a 3-inch telescope
Volunteers to 'Festival of Child', Palace Grounds, Bangalore
1995 May 12

Our celestial neighbourhood - New findings
Poornapragna Education Centre, Bangalore
1995 November 9

Understanding the Sun through eclipse observations
Technical Forum, BHEL
1995 December 1

Bhattacharyya,J.C.
Solar eclipse
Kalyanagar Welfare Association
Facts and myths of solar eclipse, Science Club, IISc
1995 September

Solar eclipses, regular yet rare
Defence Science Club, Delhi
1995 October

Solar eclipse and solar research
Rotary club, Bangalore
1995 December

Solar magnetic fields
Birla Planetarium, Calcutta
1996 March

Bhattacharyya,P.
Cosmic rays - the cosmic connection
Bangalore Science Forum
1995 June 7

Datta,B.
Pulsars : Cosmic radio clocks
MES Kishore Kendra, Malleswaram, Bangalore
1995 August 23

Ghosh,K.K.
Astronomy in India : Research and popularisation
Bisei Astronomical Observatory, Bisei, Japan
1996 March 24

Understanding the universe through quasars
VI All India Amateur Astronomers Meet, Madras
1996 January 26-28

Mallik,D.C.V.
The Challenge of Astronomy
Sri Kumaran's Children's School
1995, April 20

How stars die?
Bangalore Science Forum
1995 May 31

Singh,J.
The Sun and total solar eclipses
Key note address at M.P.Birla Planetarium, Calcutta
1995 July 3
SAARC Workshop, Bal Bhavan Society, New Delhi
District Level Karnataka Gian Vigyan Parishad
Janapada Loka, Bangalore
State Level Karnataka Bharath Gian Vigyan Samithi
at Tumkur

On the results of observations during total solar eclipse of October 24, 1995
Looking around, IISc, Bangalore
VI - All India Amateur Astronomers Meet, Periyar
Science and Technology Centre, Madras
Training programme of S & T communications
NCSTC, DST, Bangalore

Vishveshwara,C.

Age of the Universe
Bangalore Science Forum
1995 July 31

The cosmic picture book
Museo di la Ciencia yel Cosmos, Tenerife, Spain
1995 September 9

Bees, bubbles and minimal surfaces
Bangalore Association for Science Education
1995 November 18

Bees, bubbles and black holes
Bangalore Association for Science Education
1995 December 30

Space time and gravitation
Bangalore Association for Science Education
1996 January 27

Celestial colours
Bangalore Association for Science Education
1996 February 4

Life beyond earth
St Joseph's College
1996 February 9
Cosmology
Bangalore Association for Science Education
1996 February 11

APPENDIX C

Vainu Bappu Observatory

Sky conditions of VBO

Year	Month	Spectroscopic (hrs)	Photometric (hrs)
1995	April	205	57
	May	97	16
	June	80	07
	July	23	03
	August	16	01
	September	35	09
	October	37	00
	November	127	46
	December	243	115
1996	January	299	178
	February	255	108
	March	288	172
	Total	1725	712

Kodaikanal Observatory

Solar Tower Tunnel Observations

Year	Month	Total number of days of observations	Seeing (in arcsec) 1 to 2	2	2 to 3	3	3 to 4	4	4 to 5	5	>5(poor)
1995	April	4	—	2	—	2	—	—	—	—	—
	May	2	—	1	—	1	—	—	—	—	—
	June	—	—	—	—	—	—	—	—	—	—
	July	—	—	—	—	—	—	—	—	—	—
	August	3	—	—	—	3	—	—	—	—	—
	September	—	—	—	—	—	—	—	—	—	—
	October	—	—	—	—	—	—	—	—	—	—
	November	1	—	—	—	1	—	—	—	—	—
	December	7	—	—	—	6	—	—	—	—	—
1996	January	6	—	—	1	4	—	—	—	—	—
	February	3	—	—	1	2	—	—	—	—	—
	March	12	—	—	1	13	—	—	—	—	—
	Total	38	—	3	3	32	—	—	—	—	—

Spectroheliogram/Photoheliograms and seeing conditions (Kodaikanal Observatory)

Year	Months	No. of photographs in Hα	Kfl	HPr	PHGM	SEEING* 5	4	3	2	1
1995	April	24	25	18	23	–	1	22	–	–
	May	7	14	5	13	–	2	6	4	1
	June	13	10	10	10	–	2	8	–	–
	July	3	4	3	6	–	3	2	1	–
	August	11	12	9	14	–	4	8	2	–
	September	–	18	–	7	–	–	6	1	–
	October	18	20	5	17	–	1	15	1	–
	November	1	16	–	17	–	1	15	1	–
	December	1	6	–	10	–	1	4	4	1
1996	January	29	20	–	17	–	–	10	5	2
	February	7	7	–	16	–	2	6	6	2
	March	24	13	2	18	–	–	17	1	–
	Total	138	165	53	168	–	17	119	26	6

Kfl - K-floculus
HPr - Hα Prominence
PHGM - Photoheliogram

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