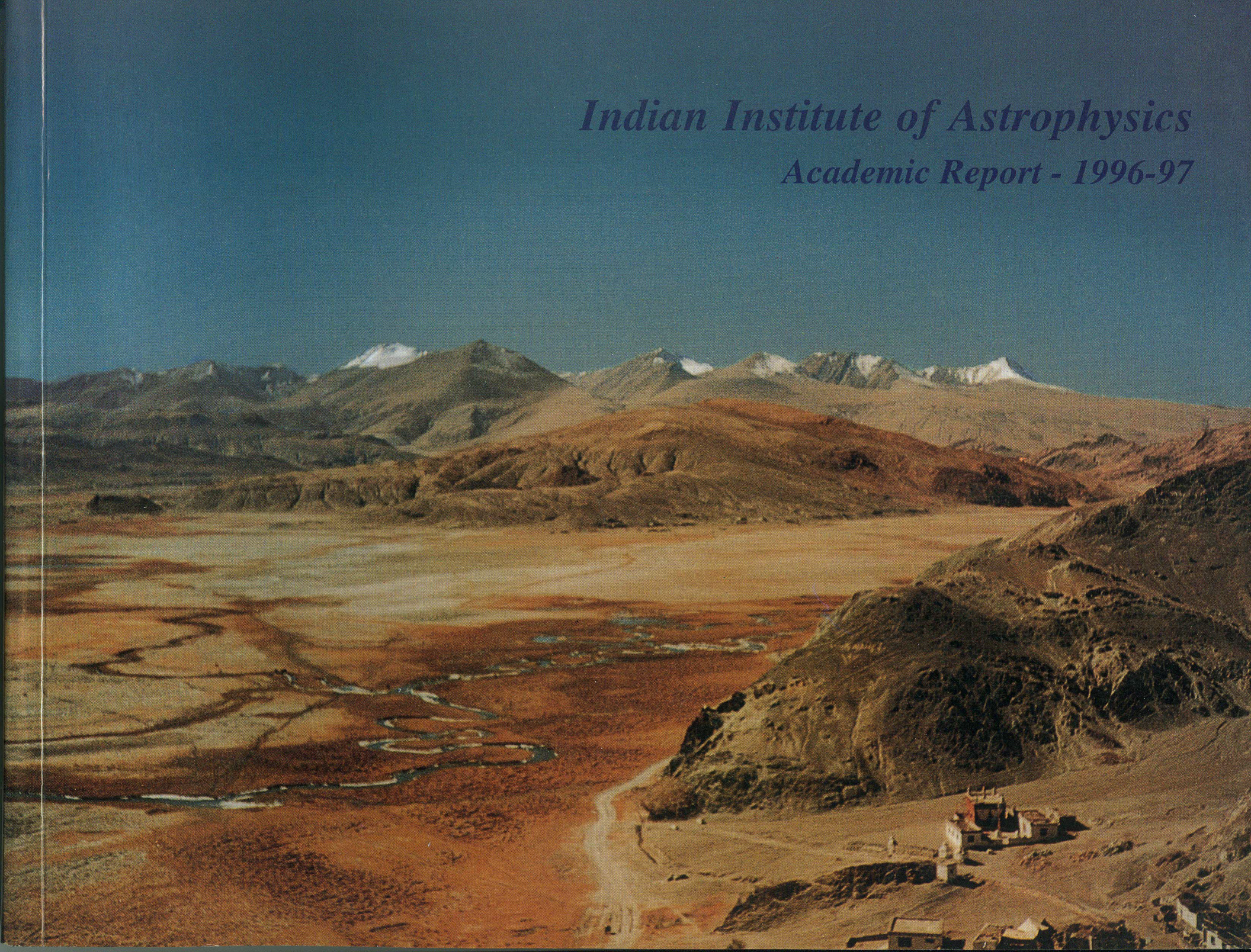
# *Indian Institute of Astrophysics*

## *Academic Report - 1996-97*



# INDIAN INSTITUTE OF ASTROPHYSICS


## Academic Report
## 1996 - 97

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Front Cover . The Site for Indian Astronomical Observatory, Mt. Saraswati, situated atop Digpa-ratsa Ri (4500m) at the centre of Nilamkhul Plain (4250m) in the Hanle region of south-east Ladakh.

Back Cover . Comet Hale Bopp during March, 1997

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## OVERVIEW OF ACTIVITIES DURING EIGTH PLAN

This year is the final year of the 8th Five Year Plan which is remarkable for the phenomenal growth and achievements of the Indian Institute of Astrophysics. It would be appropriate to provide an overview of these activities at the outset before describing in some detail on the specific activities and accomplishments of the current year:

A true measure of the accomplishments in the last five years is the fact that over 500 papers were written in subjects such as galactic and extra galactic astronomy, solar physics, magnetohydrodynamics, plasma physics, nonlinear dynamics, nuclear physics, particle physics and cosmology. Similar is the number of lectures and colloquia delivered by the members of the Institute both inhouse and at other institutions. The Institute also hosted a large number of scientific seminars and colloquia, some of which were by very distinguished personages like Professor Robert M. Walker, Professor Sir Herman Bondi and Professor Sir Arnold Wolfendale. The Institute also hosted several conferences, workshops and meetings. To enhance the prestige and profile of the Institute, the provision provided within the Bye-laws for the election of Honorary Fellows to the Institute, was undertaken for the first time at the beginning of this Plan period. These interconnections with the outside agencies resulted in creating awareness of the quality and the diversity of the academic programme that is being carried out in the Institute. Accordingly, during the last five years several members of the Institute were bestowed with major honours, awards and distinctions.

The Institute also provided distinguished service to the nation, lending its technological know-how to provide support to the national programs. In all these activities, the regular objectives of the Institute were not forgotten. The Vainu Bappu Observatory at Kavalur and the Solar Observatory at Kodaikanal worked with an increased efficiency, which led to major results in the fields of stellar, galactic and solar astronomy. Several expeditions to the sites where the total solar eclipse of occurred were also launched, again resulting in important findings pertaining to the behaviour of the high temperature solar corona. During the last five years, three major comet apparitions were studied in detail and important results of relevance to the astrophysics of the solar system were obtained.

One of the most important developments during the last five years is the discovery of a superlative high altitude site at Hanle for setting up of an observatory for optical and infrared astronomy. Of course, setting up of this and other national facilities entailed considerable amount of technical and administrative work, since they also involved the acquisition of a large tract of land for use by the Institute.

Several welfare measures were taken up in the Institute so as to stimulate the employees towards greater effort as demanded by all these programmes. Indeed, the favourable view taken by the Government of India at the time of the Mid-Term Appraisal of the 8th Plan resulted in the enhancement of the budget of the Institute and proved most helpful. The confidence placed in the Institute by the Government has been amply vindicated by the achievements during the last few years.

The increased activity in the Institute was supported by the Governing Council to strengthen and enhance the infrastructure available to its scientists Several new instruments and facilities were developed in the Institute during the Plan period. The enhanced budget also allowed the Library to be modernised.

One of the most remarkable successes of the Institute is its Students programme. Presently, the Institute can boast of about 40 students carrying out advanced research under the guidance of the Institute's Faculty. After obtaining their doctoral degrees, our students have found employment in several academic institutions both within India and abroad to pursue their research interests. Collaborative programs have been initiated with other institutions both within India and abroad. The interplay and interaction between these various institutions and IIA have been mutually very beneficial. All these activities have stimulated the large number of visits both by the scientists and senior dignitaries from across the world. International conferences and national conferences organized by the Institute have been well attended and have stimulated the research activity of the Institute. It is indeed heartening, that with the support of the Government of India and the active interest taken by the various members of the Governing Council, a qualitative change has occurred in the scientific output of the Institute. Attempts to popularise some of the major scientific achievements have gone on through a vari-

ety of channels such as participating in scientific exhibitions, popular lectures and through the Doordarshan/Akashvani programmes. In the rest of the report, some of the points made here would be highlighted and some of the details provided to bring out the fact that the Indian Institute of Astrophysics is emerging as one of the leading institutions in the field of Physics, Astronomy, Astrophysics and allied subjects.

### Awards and Distinctions

Citation by National Aeronautics & Space Administration for outstanding contribution to International Halley Watch, K.R.Sivaraman (1992)

Associate position at Harvard College Observatory, S.S.Hasan (1992)

Honourable Mention, Gravity Research Foundation Essay, C.Sivaram (1992)

Elected Fellow, Indian Geophysical Union, R.Cowsik (1993)

Best Ph.D. Thesis presentation at XV ASI Meeting, R.Kariyappa (1993)

Regents' Lecturership, University of California, R.Cowsik (1993)

M.N Saha Birth Centenary Lecture, Plasma Physics Society, R.Cowsik (1993)

NRDC Award, A.K.Saxena (with P.P.Gupta, S.C.Rastogi & Indira Rajagopal) (1994)

Senior Research Associateship of National Research Council, U.S. National Academy of Sciences, P. Venkatakrishnan (1994)

Resident Research Associateship of National Research Council, U.S. National Academy of Sciences, R. Kariyappa (1994)

A.C Banerjee Memorial Lecture, National Academy of Sciences, R.Cowsik (1995)

S.D.Chatterjee Endowment Lecture, Indian Physical Society, R.Cowsik (1995)

Third World Academy of Sciences Award in Basic Sciences (Physics), R.Cowsik (1995)

Honourable Mention, Gravity Research Foundation Essay, C.Sivaram (1995)

Astronomical Society of India Discovery Medal, R.Rajamohan, J.C.Bhattacharyya, A.Paranjpye, V.Moorthy & R.Vasundhara (1996)

Jawaharlal Nehru Fellow, R.K.Kochhar (1996)

Elected Fellow, Indian Academy of Sciences, B.Datta (1996)

International Center for Theoretical Physics, Sudeshna Sinha (1996)

Elected Fellow, National Academy of Sciences, Vinod Krishan (1996)

Elected Fellow, Third World Academy of Sciences, R.Cowsik (1996)

Alexander von Humboldt Fellow, R.T. Gangadhara (1996)

C.V.Raman Memorial Lecture Award, Indian Institute of Science, R.Cowsik (1996)

Greatest Papers of the Century, The Physical Review, American Physical Society, R.Cowsik (1996)

Senior Research Associateship of National Research Council, U.S. National Academy of Sciences, P. Bhattacharjee (1997)

Vainu Bappu Memorial Award, Indian National Science Academy, R.Cowsik (1997)

Vaidya-Raichaudhuri Endowment Lecture, Indian Association for General Relativity and Gravitation, R.Cowsik (1997)

### Service to the Nation

The technological skills and products developed by the Institute have to be put to the service of the nation in various ways. Some of the major contributions are listed below:

- 500 mm LIDAR optics for VSSC, Trivandrum
- Panels for passive cooling of VHRR for the INSAT series of satellites.
- Development of large aspherical optics for XUV beam line at the synchrotron facility at CAT, Indore.
- Controllers and servo systems for telescopes at UP State Observatory etc.

### Vainu Bappu Observatory

Ever since its commissioning in 1986, the 2.34 m aperture Vainu Bappu Telescope has been operated as a National Facility. The cluster of telescopes of various apertures have been maintained at the Observatory and the time available for astronomical observations have been allotted to various astronomers in India and from other countries purely on merit basis. The Observatory has also participated in several international studies such as the "The World Telescope Program" in which the intensity of certain stars which vary in time have been continuously monitored. By the time the star sets at an observatory to the east of India (such as the one at Siding Springs, Australia), it is picked up by our telescopes. The intensity is monitored until the star moves to a location too low in the western horizon when the telescopes in the countries to the west of us like in South Africa or Europe can pick them up. With such continuous monitoring, very precise determination of the frequencies of the variation of these stars has been made possible. During the last five years, more than 500 observing programs have been taken up. The sky conditions have been reasonable providing about 8500 hours spectroscopic skies of which about 3500 hours have been of photometric quality during the last five years. The observations made from the observatory facilities have resulted in more than 70 publications, including short term variability of the radiations from active galactic nuclei.

### Kodaikanal Observatory

The Solar Observatory at Kodaikanal is one of the oldest observatories of its kind in the world and has one of the longest records of the image of the Sun in specified wavelengths at which significant line emission takes place. This observatory boasts of several important instruments which record spectroheliograms as noted above as well as instruments that measure the solar magnetic fields. During the last five years, we have launched a program of upgradation and modernization of all the instruments - as far as possible charge-coupled devices have replaced the photographic plates as the recording medium thereby enhancing the dynamic range of the observations considerably and making the observations speedily available for careful analysis by computers. The long stretch of data on the sun showing various surface features like sunspots has been most useful in defining the solar rotation and the migration of spots through the solar cycle. These observations have resulted in more than a dozen publications. In some of these, the tidal torque exerted on the sun by planetary motion has been put forward as the possible cause of the 11 year solar cycle while in others it is noticed that the period of magnetic field reversal on the sun could be longer than 11-years, say up to 15 years. These findings would be of considerable importance in the understanding of the sun and its impact on the Earth. A 'digital ionosonde' has been installed in place of the outdated analog instrument. Very important results pertaining to the equatorial ionosphere and its interaction with the upper atmosphere have been obtained, leading to several publications in leading journals.

The Kodaikanal campus, along with the buffer zone on the periphery has now been fenced, thus safeguarding its integrity and preventing encroachments. The buildings have been renovated and a beautiful seminar complex has been created near the Summit, which was named "Vainu Bappu Hall" in an elegant ceremony by Professor B.V.Sreekantan, Chairman of the Governing Council of the Institute. The campus has been the venue for several academic meetings, workshops and seminars. One of the most stimulating of these meetings has been that hosted jointly with the Indian National Science Academy on

the interface of astronomy with various branches of physical and mathematical sciences

### Solar Eclipse Expeditions

The Institute has been regularly launching expeditions to various corners of the world to observe and study the total eclipses. Such expeditions allow us to observe the faint solar corona with the disturbing bright light of the photosphere blocked off by the moon. These studies aim at characterizing the corona more precisely with the aim of understanding its properties, especially how it is heated to temperatures exceeding a million degrees, even though the photosphere is at a mere 6000 degrees Kelvin. The total solar eclipse on 24 October 1995, with the band totality traversing India along a line approximately connecting Jaisalmer and Calcutta, provided an unprecedented opportunity to the Indian astronomers. At the time of the total solar eclipse on 16th February 1980 (with the band of totality falling in south India) charge-coupled devices were not the main recording medium, but only the photographic plates. The intervening 15 years saw tremendous development of CCDs which were therefore the main recording devices in the latter eclipse. Thus the 1995 eclipse was covered with great precision and accuracy.

A massive institute-wide effort was put up to observe the 1995 eclipse and also to facilitate the scientific groups from other institutions both from abroad and from within India. There were three main camps of the Institute - at Nim-ka-thana, Kalpi and Agra. The team at Agra coordinated with Vigyan Prasar and with the Indian Air Force to make observations of the eclipse from aboard an aeroplane (It is not out of place here, to reiterate our indebtedness to the Indian Air Force for their enthusiasm and help in making the observations). More than 10 different experiments were carried out. An important scientific finding was that the corona was observed to vary periodically in intensity with frequencies ranging from 0.01 - 1 Hz. We are now fabricating a more sophisticated instrument to confirm this result with observations of the total eclipse expected in February 1998.

### Cometary Studies

Comets are mud-balls of rock, solid carbon-dioxide and other gases, most probably the debris left behind after the formation of the solar system. Once in a long while they are perturbed from the Oort-cloud where they are thought to reside and come into the gravitational influence of the sun. They tend to have highly elliptical orbits with periods ranging from 100 years - 1000 years. Some of them may have parabolic or hyperbolic orbits and may never return again. As they approach the sun they produce a spectacular display in the sky heated by the sun spewing of dust and gases which scatter sunlight and emit fluorescent radiation. Cometary studies are an essential part of the activities of IIA. Thus when the disruption of a comet by the tidal field of Jupiter was reported by Shoemakers and Levy, the astronomical telescopes of IIA were deployed to study this beautiful event.

### Stellar Astronomy

i) The average luminosity of a star by and large remains constant over typical life span of any astronomer but can change over million or billions of years. However, with remarkably fortuitous circumstances the sudden brightening of the 'Sakurai Object' was recorded. In the 1950s the Palomar plates indicated that this object was fainter than 20 m, it increased in brightness to $\sim$ 15m in 1994 and dramatically to 11m by the beginning of 1996. This star is the central star of a planetary nebula with wispy circular veil of gas illuminated by the hot central star which was on its way to become a white-dwarf. The sudden increase in brightness is all likelihood caused by the final helium flash, a process of rapid energy generation by the nuclear burning of helium in a shell surrounding the core to Carbon. The detailed spectral observations indicated that the abundance of lithium, strontium, scandium, yittrium, titanium and zirconium increased (Astronomy & Astrophysics, 321, L31, 1997). Many of these elements were synthesised through the s-process and were dredged upto the surface. There was also a flaring up of the infrared flux showing that dust, most probably made up of carbon, condensed in the stellar atmosphere. This signifies the brief return of the star, back to the red giant stage, before it finally turns into a white dwarf.

ii) The astronomers at IIA have made use of the Hubble Space Telescope to observe the star SAO-244567. This star is in the Post Asympotic Giant Branch and is about to turn into a planetary nebula. This again is another example of a star which is in the final state of active energy generation; after this the star will essentially cool by radiation (Astronomy & Astrophysics 267, L19, 1993; ibid 300, L25, 1995).

iii) The mystery of the diffuse interstellar absorption bands is somewhat cleared up through the observation of the same bands in emission in the spectrum of hydrogen deficient stars like V854 Cen. This attributes the bands to Carbon chains rather than to hydrogenic compounds.

iv) Chandrsekhar's dynamical friction is shown to play an important role even in young star clusters in concentrating the more massive stars towards the centre. (Monthly Notices of the Royal Astronomical Society, 272, 61, 1995).

### Galactic and Extragalactic Astronomy

i) Stars with masses in excess of 10 solar masses explode as Supernovae and are responsible for the synthesis of heavy elements. The observation of SN 1993J in the galaxy M81 that the star that had exploded had passed through the cool Red Giant phase whose surface contained material synthesised through the CNO-process and dredged up prior to the explosion. The distance to the Supernova was estimated by the cooling and expansion rate to be 3.1 + 0.5 Mpc in agreement with the Cepheid-distance of 3.6 + 0.3 Mpc measured with the Hubble Space Telescope.

ii) The presence of H II regions in external galaxies is used as an indicator of the formation of new young and massive stars in external galaxies to show that there is an ongoing sequential star formation in the galaxies.

iii) The intense emission of radiation of quasars, quasi stellar objects and BL-Lac objects has been attributed to the presence of supermassive black holes at their centres accreting matter from the surrounding region. Such black holes will have horizons of about 1000 light seconds across, so that we may expect the intensity of the emitted radiation to vary over time scales of an hour to several hours. Such variations have been observed by the IIA astronomers evidencing the presence of black holes in them and also establishing a direct link between these different objects .

### Theoretical Astrophysics

i) The variability of the polarisation in intense emitters like active galactic nuclei has been attributed to stimulated Raman scattering. It is shown that the superposition of the incident and scattered radiations leads to highly complex and variable polarisation patterns.

ii) The density of pulsars reaches nuclear or even supernuclear densities, thus providing excellent opportunity to study the equations of state of nuclear matter and the nuclear forces. The 'glitch' process, which occurs when the pulsar crust readjusts to a more spherical configuration as the pulsar spins down, provides a unique opportunity to study the equation of state of neutron star matter. Our scientists have shown that the observations of glitches favour equations of state derived with certain amount of repulsive nuclear forces at such nucleon (very short) distances.

iii) The decay of the magnetic fields of pulsars has been showed to be slowed down because of General Relativistic effects in such a compact object.

iv) The spectrum of cosmic rays extends from $\sim 10^7$ ev to $10^{20}$ eV and even beyond. Whereas standard astrophysical conditions are adequate to accelerate bulk of these particles at low energies the acceleration of particles to energies beyond $10^{19}$ eV poses serious problems. An important suggestion has been made by the scientists of IIA that these could arise from the annihilation of topological defects such as magnetic monopoles, cosmic strings etc. This suggestion has been well received in the world scientific community and has stimulated much further work.

v) The Institute has a long standing interest in the study of 'Radiative Transfer'. Recently, a very elegant method to treat the transfer of polarised lines in spherical atmosphere and the formalism to study radiative transfer in the presence of propagating waves have been developed.

vi) Another long standing interest of the Institute's members is the study of "dark matter". In a pioneering effort to understand the phase space structure of galactic dark matter the self consistent distribution of the particles in their own gravitational potential and that of the visible

matter of the Galaxy has been derived. From this the expected speed of rotation of the Galaxy as a function of the distance from the centre was calculated. By comparing this with the observed rotational speeds it is shown that the typical speed of the dark matter particles is *sim* 6000 km $s^{-1}$, about twice as large as hitherto assumed. This shows that the dark matter halo of the galaxy may extend upto $\sim$ 300 kpc. It is expected that further work along this track will lead to a full understanding of the nature of the dark matter particles.

vii) During the last decade remarkable developments have allowed the isolation and study material dating back to times before the formation of the solar system: presolar carborendum, diamonds and rubies. Fine powders of these refractory materials remain behind when primitive meteorites are subjected to intense chemical processing like dissolving in hydrofluoric acid, potassium hydroxide etc. They exhibit huge "isotopic anomalies" (with, for example, $^{13}C/^{12}C$ ranging from 0.01 to 100.00 times the solar value). Such grains must form in the atmospheres of stars which started on the main sequence with metalicities lower than that of the solar system and which experienced appropriate nucleosynthetic and evolutionary history. Collaborative work with various members of the Washington University, explore in detail the conditions in stellar outflows where the different grains with differing isotopic anomalies are formed. A result of considerable general interest is that the studies of anomalies of the oxygen isotopes in presolar rubies ($^{203}Al$) yield an age for the universe of $\sim$ 14 Gyr.

The conclusion drawn from the study in the laboratory of presolar grains have been strengthened by the recent observations of the star FG-Sge which shows evidence of dredge up hydrogen deficient material rich in carbon to the surface This material is condensing into irregular clouds of dust and is being ejected to the surface. Cool Carbonmonoxide gas (CO at $\sim$ 1800° K) in the photosphere seems to have locked up bulk of the oxygen, as expected on the basis of the theory of equilibrium condensation. Similarly evidence that the surface composition of a post-AGB star is depleted in heavy elements by the formation of grains has come from the observations of RV Tauri star (IW-Car) which shows gaseous composition very similar to that in the general interstellar medium where such depletion has been noted earlier.

## Physics

i) Equivalence principle and the Fifth Force

In collaboration with the scientists of the Tata Institute of Fundamental Research, IIA operates a sensitive torsion balance at Gauribidanur. The current sensitivity of the balance is $\sim 10^{-13}$ cm $s^{-2}$ $day^{-1/2}$ and this balance is being improved for the testing of Einstein's Equivalence Principle at the $10^{-14}$ level. Studies with this balance have already ruled out the existence of any force coupling to isospin with a strength greater than 3 x $10^{-5}$ gravity/amu. Currently apparatus is also being built to study the Casimir Force and its dependence on temperature.

ii) In collaboration with the Washington University, IIA has successfully made precise measurements of the life times of double beta decays of $^{128}Te$ and $^{130}Te$. These turned out to be $(7.7 + 0.4) \times 10^{24}$ year and $(2.7 + 0.1) \times 10^{21}$ year, respectively the longest two radioactive decays ever to be established. Furthermore these measurements constrain the Majorana mass of the neutrino to be less than 1eV and place strict bounds on other parameters describing weak interactions.

iii) Various atomic physics and molecular calculations have been carried out with an intention of designing experiments to study discrete symmetry violations in atomic systems. Parity violation and T-reversal violation leading to finite electric dipole moment of electron are examples of such violations. In this study the ions RaII, YbII and SrII have been found to be particularly suitable for the study of parity non conversation in atoms.

## National Facility - Vainu Bappu Telescope

The 2.3 m Vainu Bappu Telescope at VBO, Kavalur, has emerged during the last five years as the premier National Facility in the country for optical astronomy. This achievement was made possible due to rigorous schedules of preventive maintenance and periodic in-house coating of aluminium on reflecting surfaces, efforts invested in automation of various components by the development group at the Institute, and improvements made in the focal plane instrumentation.

Significant gain was achieved in the tracking accuracy of the telescope. The implementation of the pointing model assured pointing accuracies

of 15 arcsec (rms). Automation of the focusing module, filter positioner in the Prime Focus Imager, and intensified-CCD based guiding systems improved the efficiency of observing. The CCD camera used in the earlier five years was replaced by a more efficient, large-format (1024 x 1024 pixels) CCD. This system has 50 per cent higher efficiency compared to the earlier system and covers 5 times larger area on the sky.

The Cassegrain focus was equipped with a Boller & Chivens spectrograph that had served earlier as the Image Dissector Scanner at the Anglo-Australian Observatory. Modifications were made to improve its efficiency and it was later converted into a spectropolarimeter. A new, efficient, computer-controlled spectrograph has been acquired for spectroscopy and spectrophotometry and put in operation during 1996-97.

All these improvements have altogether resulted in a ten-fold increase in the efficiency of observations. Even so, the telescope time is currently over-subscribed by a factor of 4 during the clear season. The regular users include, about 20 astronomers from IIA and ten astronomers from other national centres such as the Tata Institute of Fundamental Research, Bombay, National Centre for Radio Astronomy, Pune, Inter-University Centre for Astronomy & Astrophysics, Pune, Ravi Shankar Unviersity, Raipur and U.P. State Observatory, Naini Tal. There have been occasional requests for telescope time from astronomers based in Japan, Korea and Russia as well. Some of the programmes involved international cooperation utilizing the longitudinal advantage of India.

Four Ph.D. theses have appeared during this period incorporating results based on observations carried out using the VBT, and several students are currently using the facility. More than 50 research articles have been published during the last five years. The topics cover a wide range of fields: variability of quasi-stellar objects, groups of galaxies, star-forming regions in galaxies, dust and gas in elliptical galaxies, extragalactic supernovae, galactic novae, chemically peculiar stars, late stages of stellar evolution and planetary phenomena.

### India-Japan Collaborative Research Programme

Under the India-Japan Cooperative Research Programme, three major programs were undertaken: (i) Studying the N-body problems with GRAPE, (ii) Development of solid Nitrogen cooled PtSi Infrared CCD Camera, and (iii) Fabrication and installation of a 1024 channel correlator for Gauribidanur radio telescope and observations of the sun at decameter wavelengths. Professor D.Sugimoto of the University of Tokyo, who is the inventor of the GRAPE computer board architecture and Co-chairman of the Area for Astronomy and Astrophysics visited the Institute in 1994, 1995 and 1997, and donated a 4.8 GFlop GRAPE computer board. With the installation of these super-fast computers of 12 GFLOPS with GRAPE architecture, the scientists have taken up detailed calculations of angular momentum and energy exchange in galaxy-galaxy collisions for a variety of Plummer-models and impact parameters. The criteria for tidal break-up and merger of galaxies have been extended to these systems. The Institute hosted the first India-Japan Seminar on Astronomy and Astrophysics in Bangalore. The CCD camera system has been developed, installation of the PtSi chip on to the dewar, hardware and software integration were completed. Trial runs of astronomical observations with this instrument are expected soon. After studying the chips deployed in Nobeyama Radio Observatory, the design was finalised for 1024 correlator system for meterwave observations. The system has been successfully built and the observations with the Gauribidanur Radio heliograph were commenced in 1995. The joint observations yielded important data for analysing the vertical structure of the solar upper atmosphere. The millimeter observation data from NRO and the meterwave (55 MHz and 75MHz) data from Gauribidanur have opened up exciting possibilities in understanding the structure and activity of the solar corona by comparing the radio data with the X-ray data from YOHKOH, and the EUV data from SOHO.

### The Indian Astronomical Observatory

By the year 1989, it was clear that the Vainu Bappu Observatory was inadequate to fulfill the growing aspirations of the Indian astronomical community - for one, the time available on each of the telescope at Kavalur was over-subscribed by a factor of three. Secondly, the precipitable water vapour in the atmosphere above the observatory was typically more than 10 mm which absorbed the infrared radiations coming

from any astronomical source and made matters worse by emitting its own radiations. Finally, most of the Indian sub-continent is subjected to two monsoons in a year which bring in clouds making high quality astronomical observations well nigh impossible in several months in the year, so that some part of the astronomical sky was not accessible to observations. On the other hand, fascinating astronomical discoveries were being made from observatories like Mauna Kea and La Silla. It was at this time that the Planning Commission took active steps. Under its auspices in several meetings of astronomers with the eminent scientist Professor B.V.Sreekantan in Chair deliberated the right course of further action. They concluded that a modern astronomical telescope working at optical and infrared wavelengths must be speedily installed at a good site. They noted that such an observatory would carry out observations which would complement the observations carried out with other national facilities like the Giant Meter wave Radio Telescope, the high energy Gamma-ray telescopes and the X-ray telescope aboard the Indian satellite, it would also carry out independent astronomical observations that may lead to new astronomical insights and discoveries. Sreekantan Committee opined that it would be most appropriate if the Indian Institute of Astrophysics, with its extensive experience in fabricating the 2.34 m telescope and running the national facility at Kavalur would act as the nodal agency for creating this modern facility.

In the year 1992, the Institute deliberated on these recommendations and felt that the essential requirement for creating such a facility was a superlative site which would compare favourably with the best observatory sites in the world. From the very beginning it was clear that we have to search for a site which was not affected by the monsoons and was located at high enough altitude to reduce the amount of water vapour in the overlying atmosphere down to acceptable levels. The place has to be accessible and at the same time sufficiently remote from man-made disturbances and light pollution. The contours of the terrain surrounding the site should not obscure the sky too much near the horizon, nor should there by nearby hills which will cause turbulence in the prevailing winds. Such a site could only be found in the Himalayas where the first series of mountain ranges could effectively block the monsoon winds.

After an extensive study of toposheets to assess the terrain and satellite imagery to assess the cloud cover six prospective sites were selected for study. An expedition consisting of six teams was launched for the first reconnaissance. Photographs of some of these sites are reproduced here. Upon their return, the teams submitted their detailed reports about the sites, their accessibility, weather conditions, suitability of the terrain for setting up the Observatory and so on. All these reports were thoroughly discussed by a large group of astronomers, drawn from various academic institutions, and it was decided that a detailed site survey be conducted at Hanle, Ladakh which showed the best promise amongst the six places reconnointed by the expedition. Another thought provided the Indian Institute of Astrophysics further motivation to carry out the arduous site survey in south-eastern Ladakh – in the hemisphere spanning longitudes from 20 degrees west to 160 degrees east the facilities for optical and infrared astronomy are very limited; this makes it crucial to set up one in India (longitude 78 degrees East) plumb in the middle of this lacuna in the facilities. Such an Observatory will be an essential partner in any international effort that is needed to study time-varying astronomical phenomena. This longitude advantage can be reaped fully only when the coverage in right ascension is uniform, i.e. the site should have good observing conditions year-round.

With this background a proposal for a project was submitted to the Science & Engineering Research Council of the DST to carry out the site survey and to study the engineering aspects of setting up an observatory with an appropriate telescope in the Himalayas. The approval of SERC in April 1994 was a shot in the arm and immediately an advisory committee was constituted under the Chairmanship of Professor K.Kasturirangan, Secretary, Department of Space. On the basis of the advice by this committee, several working groups with national representation for 'Science and Astronomy', 'Engineering' and for 'Logistics and Operations' were set up. The 'Science & Astronomy' group suggested that in order to carry out good astronomy, we have to search for an observatory site with the following specifications and that we should not compromise in this essential feature of the observatory.

**Table 1: The National Working Group's site criteria:**

1. Number of clear nights (spectroscopic) more than 200/year
2. Extinction in V band better than 0.2 mag/airmass
3. Sky brightness in blue lower than 22 mag/sq.arc.sec.
4. Seeing typically better than 1 arc second
5. Mean precipitable water vapour less than 3 mm
6. Annual precipitation of rain and snow less than 100 mm
7. Low level of seismic disturbances
8. Preferably above the tree line, by at least 200 m.

The Indian Institute of Astrophysics expended more than 50 man years' effort over the last five years and established the suitability of Hanle as a world-class astronomical site with site characteristics as indicated in Table 2.

**Table 2: Hanle, Site Characteristics**

i) Good accessibility round the year

ii) Elevation above mean sea level ~4517 m – much above the tree line

iii) Number of spectroscopic nights ~250 per year

iv) Number of photometric nights ~170 per year

v) Precipitable water vapour in the atmosphere $< 2$ mm

vi) Annual precipitation of rain and snow $< 9$ mm

vii) Extinction in V band $0.1 + 0.04$ m/air mass

viii) Sky brightness B-band $= 23^m.2$ arcsec$^{-2}$, V-band $= 21^m.5$ arcsec$^{-2}$

ix) Seeing: typically $> 1$ arcsec

x) The 250 useful nights are distributed uniformly through the year, providing uniform access to objects of all right ascension

xi) The longitude of Hanle ~79° E locates it plumb in the middle of a large lacuna in astronomical facilities between Canary Islands (~20° W) and Eastern Australia (157° E).

xii) Low ambient temperature and very low humidity

xiii) Low seismicity

xiv) Wind speed $< 20$ km s$^{-1}$

xv) No man-made disturbances like pollution, aerosols, smoke etc.

xvi) Leh-Hanle road open throughout the year.

After studying the preliminary reports on the engineering and site aspects, the Kasturirangan Committee suggested that it would be most convenient to set up a 2-m aperture telescope at Hanle. Accordingly, this stepwise development of the observatory at Hanle was emphasised in the Detailed Project Report submitted to the SERC in early 1996. This report was favourably received by the SERC paving the way to the issue of a memo of the Expenditure Finance Committee, DST, in April 1997. The proposal received favourable notings from the Planning Commission, Finance Ministry, Defence Ministry, Department of Space, Department of Atomic Energy and so on. On the basis of all these favourable notings from Professor Y.K.Alagh, Hon'ble Minister for Science and Technology and subsequently, Shree P.Chidambaram, Hon'ble Finance Minister approved the project which will be completed in the next five years.

Anticipating this approval much preparatory work, for the transfer of land of ~ 800 acres at Hanle, communication and other facilities was taken up even at the beginning of 1996. With the gracious cooperation of the Government of Jammu and Kashmir and with the perspicacious advice of His Excellency General K.V.Krishna Rao, PVSM (Retd), Governor of J & K, the transfer of the requisite amount of land at

Hanle is imminent. The Government of Karnataka, had already made a munificent grant of 40 acres of prime land at Hoskote, near Bangalore, for setting up the communication centre for the remote control of the telescope and for the development of a Centre for Research and Education in Science and Technology.

It would now be appropriate to reproduce the national and international opinion of eminent astronomers; some of these astronomers and their teams had actually visited the site and carried out several technical measurements before these opinions were expressed:

"*In order to provide matching facility to GMRT, it will be important to build over the next 5 years a 3.5 to 4 m class optical telescope using the modern active and adaptive optics, at a suitable site in the Himalayas. This will allow Indian scientists to exploit fully some of the discoveries expected to be made using GMRT. Hanle site may be approved as a field station.*"

– Professor Govind Swarup, FRS, Professor of Eminence, NCRA, Pune

"*. . . it may well become a great asset to astronomy in India, and even beyond its borders. The successful large, 'remote', observatories (ESO, Tololo, Las Campanas) are carried by broad astronomical communities from which highly competitive observing proposals emerge. I therefore suggest that the project aim at the broadest possible rooting in the Indian astronomical/astrophysical community.*"

– Professor A.Blauuw, formerly Director-General of European Southern Observatory, past President of the International Astronomical Union and past President of the IAU Commission 50.

" *Hanle is perhaps the finest site in south-east Asia*"

– Professor S.Isobe, Chairman, IAU Commission 50

" *Hanle is one of the best sites in the world.* "

– Professor S.Yamamoto, University of Tokyo

The scientific returns that we might expect in the years to come from this effort are succinctly presented below:

- Observational cosmology and large scale structure of the universe
  - Short exposure limit of 25 B mag
  - 75000 galaxies per sq.deg over the limit of VBT
- Quasars and Active Galactic Nuclei & High Redshift Radio Galaxies
  - K-band limit of 19.5
  - 2000 galxaxies per sq.deg or median z = 2 among 3CR sources
  - Spectroscopy at R = 1000: 19 mag in B
  - Spectroscopy at R = 100: 21.5 mag in B
  - Emission lines at R = 100: 23 mag in B
- Structure and Evolution of Galaxies
- Extra Galactic Supernovae
  - Photometry of Type I: upto z = 4
  - Photometry of Type II: upto z = 2
  - Spectroscopy: upto z = 2
- Stellar Evolution
- Time Varying Phenomena in Stellar Astronomy
- Star-forming Regions
- Complementarity to GMRT, X-ray & $\gamma$-ray Observations
- Training students in astronomy
- Infrastructure for other paradigms of science
- Logistics for new initiatives

Even though we have not covered all the scientific activities extensively, the overview presented above brings out the multifaceted character of the work carried out at the Institute.

Ramanath Cowsik
Director

# SUN AND THE SOLAR SYSTEM

# 1. SOLAR PHYSICS

## 1.1 GLOBAL PROCESSES

### 1.1.1 Modeling of The Steady Parts of Rotation and Toroidal Magnetic Field in the Sun's Interior

Using reasonable assumptions and approximations, the steady parts of rotation and toroidal magnetic field in the Sun's convection zone (CE) and radiative core (RC) are modeled as analytical solutions of the diffusion equation in an incompressible medium of constant diffusivity. By satisfying corotation with the helioseismically determined rotation in the RC, the strength of the first diffusion eigen mode of the poloidal magnetic field in RC is estimated. The solutions in CE and RC both give rotational contours similar to those given by helioseismology. The two models are subjected to continuity of rotation frequency at the RC-CE boundary. Using this condition it is estimated that (i) the rotation frequency increases from 440 nHz at the base of the convection zone to about 462 nHz at the center. (ii) the toroidal part of the magnetic field is $\sim 10^3$ G near the center, to $\sim 10^5$ G near the base of the convection zone, and $\sim$ 1 G near the surface. Assuming that the steady parts of rotation and poloidal and toroidal components of the magnetic field have same evolutionary history, the characteristic diffusion time scale of first eigenmode is estimated to be $\sim 10^{12}$ yrs.
(K.M.Hiremath and M.H.Gokhale)

### 1.1.2 Variation of the Rotation of Sunspot Group with its Age and Life-span

Using the compilation of Greenwich data on sunspot groups during 1874-1939, the following results were obtained. For each spot group born on disc, and having life span $\tau$, the 'initial' rotation frequency, $\omega_{ini}$ was defined and determined as value of rotation frequency ($\omega$) between the first and second day of its life. For spot groups in latitudes $10^o - 20^o$ which live for 2-12 days, the mean variation $\omega_{ini}(\tau)$, is found to have a trend similar to the radial variation of the rotation frequency of the solar plasma, $\Omega(r)$, across the convective envelope at $15^o$ latitude, as given by helioseismology ( fig 1.1.2.1). From this similarity it is concluded that the magnetic structures of spot groups with successively longer life spans, are initially anchored at successively deeper layers of the Sun. For spot groups in latitude interval $10^o - 20^o$ and living 10-12 days, it was found that the mean variation of rotational frequency, $\omega(t)$, with respect to the age '$t$', also has a trend similar to $\Omega(r)$ at latitude $15^o$. This similarity of trends of $\omega(t)$ and $\Omega(r)$ was interpreted as caused by the rate of rise of the magnetic structures of spot groups across the convective envelope as the spot groups grow older.
(J. Javaraiah and M. H. Gokhale)

### 1.1.3 Estimation of the Depths of Initial Anchoring and the Rising Rates of Sunspot Magnetic Structures

Magnetic structures of sunspot groups of life spans $\leq$ 2 day are anchored at $r \sim$ 650 Mm , i.e., near the Sun's surface and those of spot groups with successively longer life spans between 3 and 9 day are anchored at successively increasing depths at the rate $\sim$ 21 Mm/day. The magnetic structures of the spot groups with $\tau > 9$ days are initially anchored at $r_o \leq$ 500000 km (i.e. inside the base of the convective envelope). From the expression for $r(t)$ we infer that for spot groups of life spans 10-12 days in latitudes $10^o - 20^o$, the magnetic structures are initially anchored at $r_o \sim$ 500000 km (i.e. near the base of the convective envelope) and these structures rise across the envelope at the rate of $\sim$ 21 Mm/day (i.e., $\sim$ 240 m/s).
(J. Javaraiah and M. H. Gokhale)

### 1.1.4 Torsional MHD Oscillations of the Sun

The aim of the study was to determine whether the axisymmetric terms of long period global oscillations with nearly the same periodicity are admitted by the Sun's steady field, assuming Sun has such a field. For the steady field to admit such oscillations, the Alfven wave travel time along different field lines of the steady part of the field should be independent of the latitudes of the photospheric intersections. In order to get an idea as to what type of the steady field structure can satisfy this condition, we have computed the Alfven wave travel time along the field lines in the following five models of magnetic field. The first three of these models are adhoc. In the first model, the field is taken to be uniform and in the second it is assumed to be a dipole field. In the third model, the field is taken to be a combination of a uniform field and a dipole field. The fourth and the fifth models are the models of 'steady' part of the magnetic field satisfying the law of isorotation with the helioseismologically inferred internal rotation. For all these models,

we compute standard deviation and its ratio to mean Alfven wave travel time. The last two models yield the smallest relative bandwidth for the frequencies of the MHD oscillations. However, the last model is the only admissible one which can sustain global Alfvenic oscillations with well defined frequency for the fundamental mode. In order that the solar cycle period be $\sim$ 22 yr, we get the intensity of the steady part of the solar magnetic field to be $\sim$ 1 G.
(K.M.Hiremath and M.H.Gokhale)

### 1.1.5 Solar Seismic Model

The aim of the present study is to deduce density, pressure, temperature and hydrogen abundance profiles in the solar interior by solving basic stellar structure equations with the constraint that sound speed profile is that determined from the helioseismology (Vorontsov, S. and Shibahashi, H. 1991, PASJ, **43**, 739). In order to solve the stellar structure equations, the knowledge of the equation of state, opacity of matter and nuclear reaction rates in the solar interior are required. If perfect gas law is assumed , equations of hydrostatic equilibrium (which govern the equations of mass and pressure ) and thermal equilibrium (which govern the equations of luminosity and temperature) are decoupled and hence solved separately (Shibahashi, H and Takata, M. 1995, PASJ, **48**, 377). In the present work, we consider MHD equation of state and hence stellar structure equations are solved simultaneously. The numerical tables of MHD equation of state are kindly provided by Däppen. In this model, the metal abundance is assumed to be constant in the solar interior and is considered to be the same as that observed spectroscopically near the surface. We adopt OPAL opacity library (Rogers, F.J. and Iglesias, C.A. 1992, ApJS, **79**, 507) for the opacity and Bahcall's subroutine for the nuclear reaction rates. We treat the $^3$He distribution as the equilibrium distribution in the deep interior and assume the distribution in the outside follows the accumulation of $^3$He due to D(p,$\gamma$) $^3$He reaction without destruction. Since, there is an uncertainty in the theory of convection, we set the base of the convection zone as the outer boundary rather than $r = R_\odot$. This work is still in progress.
( K.M.Hiremath and H.Shibahashi*)

### 1.1.6 Quiet Sun Variability

In evaluating the contribution of various chromospheric features to total CaII K-emission and UV irradiance variability, the Quiet Sun is also an essential and important component. We made an attempt to segregate the disc center intensity in a very quiet region, considered to be as a Quiet Sun component, from the CaII K spectroheliograms of 1992 and 1980, observed at the National Solar Observatory at Sacramento Peak. It is seen that the Quiet Sun will vary with the solar activity/cycle. Our results suggest that the variations in Quiet Sun will contribute in the UV irradiance variability and hence its contribution should be taken into account in UV irradiance models. Using a standard FFT time series analysis, our results show, for the first time, the 51-day periodicity in the Quiet Sun variability. The work is in progress.
(R. Kariyappa)

### 1.1.7 Coronal Green Line Variability

Lomnicky Slit data of 5303 A coronal green line index (CI) is analysed for the years 1965 through 1994. The yearly quiet sun component ($Q_{ci}$) of CI estimated through the linear regression analysis of CI with sunspot numbers (SS) and CI with Ca plage index (CA) are found to vary with the 11-year solar activity cycle. Comparison of $Q_{ci}$ with quiet sun component of 10.7cm flux ($Q_{10\,7}$) revealed that the $Q_{ci}$ contributes principally to the entire CI while $Q_{10\,7}$ assumes much smaller values compared to it's yearly averages. The slowly varying component of 5303 A emission associated with sunspots and plages seems to be nearly absent in CI. This aspect is also confirmed through the multiple-linear regression analysis of CI with sunspots and plages. The delayed response of green corona to both sunspots and plages also revealed similar results. This may be because the line observations of 5303 A emission is made once a day and such snapshots may not always include the short lived events. On the other hand, the enhancements in coronal 5303 A emission are not restricted only to low latitude belts like those of sunspots and plages. Enhancements in 5303 A are seen even at higher latitudes which are obviously not associated with sunspots or Ca plage activity. CI, therefore, effectively might represent the background green coronal in- tensity. Need for a more refined index for the green corona which includes the component associated with photospheric/chromospheric active regions is suggested. A more detailed analysis of the latitudinally spaced limb observations of green coronal

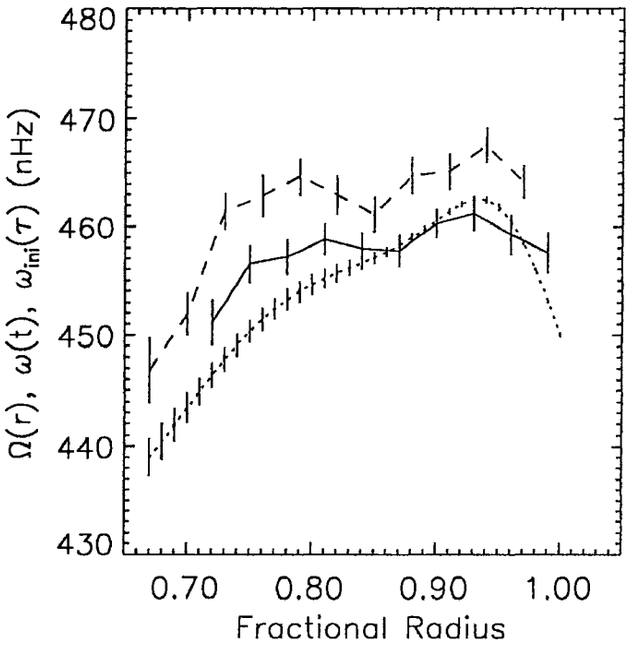



**Fig. 1.1.2.1** Curves $\omega_{ini}(\tau)$ (dashed curve) in the entire sunspot latitude belt and $\omega(t)$ (continuous curve) in latitude interval $10^o - 20^o$, plotted using values of $r_1$, $k_1$, $r_2$ and $k_2$ which yield *maximum correlations* with $\Omega(r)$ at latitude 15°, (dotted curve). From left to right the values of $t$ are 1.5, 2.5,...,10.5 days, and those of $\tau$ are 11.5,10.5,...,1.5 days respectively. (The values of $\Omega(r)$ were provided to us by Dr. H. M. Antia, determined from BBSO helioseismic data by using the inversion method of Antia and Chitre (1986, *Bull. ASI* 24, 321).)

intensity in association with the photospheric activity is in progress.
(K. B. Ramesh)

## 1.2 LOCAL PROCESSES

### 1.2.1 Modeling of Solar Coronal Loops

Montgomery et al. (1978) have developed a frame work to describe the steady state of a turbulent magnetofluid, without the usual recourse to linearization. Thus, the magnetic and velocity fields emerge in their fully nonlinear form as a consequence of the selective decays of the invariants of the system. Using this statistical theory of magnetohydrodynamic turbulence, the pressure, magnetic and flow fields of a solar coronal loop have been determined. The spatial and time profiles of the loop pressure are derived. A comparison with the observed properties of the loop is made, whenever possible.
(Vinod Krishan)

### 1.2.2 Nonlinear Interaction of Fast Magnetosonic Modes with Sausage Modes in Coronal Structures

The observed low-frequency pulsations in the Sun are often associated with MHD oscillations. Their periods vary typically from several seconds to minutes. It is also known that these oscillations are connected with the problem of coronal heating. The most important and efficient mechanism by which the heating takes place is by resonant absorption when the exciting frequency coincides with the global Alfven mode frequency in the loops. It is also possible that the fast magnetosonic kink mode with a selected frequency interacts (nonlinearly) with sausage and kink modes which are at a higher frequency, resulting in the transfer of energy from the high frequency part of the spectrum to the low, selected frequency. The nonlinear interaction of the fast magnetosonic modes of coronal loops with sausage modes has been studied for a simple slab geometry with uniform fluid motion. The normalized frequency of the resulting dispersion relation changes quite significantly compared to the case of slab geometry without fluid motion.
(A. Satya Narayanan)

### 1.2.3 Wilson Depression in Sunspots

We examined the possible relation between Wilson Effect (WE) and the longitudinal magnetic field strength (B ) in sunspots using our observational data of spot magnetic fields obtained at the Solar Tower Telescope and the synoptic white light images taken at the Kodaikanal Observatory. Out of the hundreds of spots observed, twenty four individual isolated spots suitable for the study were selected. It was found that WE, a measure of the width of limbward side of the penumbra to that of the discward side, does not bear a direct relation with the magnetic field strength of the spot, B . WE is neither related directly to the maximum field strength attained by the spot during its disc passage. During the above study, however, it was noticed that a significant number of spots do not exhibit WE. In fact, a large number of them show either no WE or reverse WE ! A depression in the spot umbra is supposed to cause WE and, so far, the effect is taken as more or less a standard phenomenon in sunspots eventhough exceptions are reported occasionally. We therefore carefully examined the sunspots observed at Kodaikanal during the Solar maximum of the cycle 21 and selected over a thousand spots for detailed study. Our preliminary results indicate that most of the 'individual' spots exhibit WE ; a selection effect which explains the understanding so far. It appears from the study of a variety of sunspots that the effect probably depends on the overall magnetic field configuration of the region. A further detailed study is in progress.
( S.P.Bagare and S.S.Gupta )

### 1.2.4 Excitation of Longitudinal Modes in a Slender Magnetic Flux-tube by External p-modes

This work deals with the excitation of longitudinal or sausage waves in a slender flux tube by p-modes in the ambient medium. In a previous calculation by Hasan (1996, ApJ, **480**, in press) the time-asymptotic response of a vertical tube in the solar photosphere due to the buffeting action by external p-modes was examined using linear theory. For mathematical tractability an isothermal atmosphere was assumed, which allowed the problem to be solved exactly. This study provided insight into the behavior of the tube response and its dependence on various parameters. The previous analysis has now been enlarged to examine the interaction of p-modes with a flux tube as an initial value problem. In order to apply the calculations to the Sun, a realistic stratification has been used for the flux tube and external atmospheres, based upon the models of Hasan and Kalkofen (1994, ApJ **436**, 355). The

time-dependent MHD equations for a thin flux tube have been solved and the gradual buildup of energy in flux tube oscillations examined. Non-adiabatic effects involving radiative transport have been taken into account. These calculations confirm the linear prediction that the interaction is *non-resonant*. It is found that the response does not exhibit a monotonic variation with the p-mode degree $l$ (for a fixed order), but increases to a maximum and then falls off sharply as $l$ increases. For the $f-$ mode, $l_{max} \sim 700$. The amplitude of the oscillations tend to become stationary (i.e. constant in time) implying a balance between energy input from p-modes and losses through radiative damping and leakage from boundaries. The dominant contribution to the energy flux in the upper photosphere comes from the enthalpy flux. This flux by itself appears to be insufficient for chromospheric heating, but may contribute partially to the required flux. P-modes of low order and degree appear to be most efficient for exciting longitudinal oscillations in flux tubes.
(S.S. Hasan)

### 1.2.5 Multidimensional Radiative Transfer in Flux-tubes

This study is a continuation of the earlier work by Hasan & Kalkofen (1994, ApJ **436**, 365, hereafter **HK**) on models of magnetic flux tubes, extending vertically through the photosphere and convection zone of the sun. In the calculations of HK, the equilibrium structure of intense magnetic flux tubes was determined by solving the magnetostatic equations in the thin flux tube approximation, allowing for energy transport by radiation and convection. The most significant aspect of this work was the inclusion of multistream radiative transfer in cylindrical geometry and the continuous transition between radiative and convective energy transport. Model flux tube atmospheres were constructed for various values of $\beta$ (the ratio of the gas to magnetic pressure) and radius at the base of the photosphere. These calculations were sufficiently realistic to yield model atmosphere for flux tubes that could be compared with observations. However, a limitation of this work was that the influence of the flux tube on the ambient medium was not taken into account. This effect is important for examining the horizontal temperature variation, especially at the interface between the flux tube and the external medium. In the new calculations, magnetostatic models of flux tubes have been constructed in which the flux tube and the ambient medium are treated self-consistently. Radiative transport has been included by solving the multidimensional transfer equation in cylindrical geometry. These models satisfy the condition of radiative equilibrium. The structure of the thermal boundary layer at the interface of the flux tube and the ambient medium has been determined. It is found that the temperature does not abruptly change from its value on the flux tube axis to the ambient value far away from the tube. Rather, there is a transition layer at the periphery of the tube, where there is a significant horizontal temperature gradient. Detailed calculations are underway to examine physical conditions in this layer as well as its horizontal extension for different values of $\beta$ and tube radius. The results of this investigation will be compared with observations for the HK models. The results may cast light on the question whether the inclusion of the boundary layer at the interface of the flux tube and the ambient medium could lead to a better agreement with observations of Stokes parameters and intensity contrast. The calculations are also likely to provide clues as to whether additional physics through the inclusion of dynamical effects, is necessary to reproduce the observations.
(S.S. Hasan and W. Kalkofen *)

### 1.2.6 The Influence of Radiative Damping on the Modes of a Magnetized Isothermal Atmosphere

Magnetic fields dominate the structure of the solar surface layers, and the existence of magnetic field in other stars has been confirmed by several observations. A study of wave motions is useful for probing the atmosphere within magnetic elements. Indeed oscillations in a fairly broad range of frequencies occur in solar magnetic flux tubes. Recently Hasan & Christensen-Dalsgaard (1992, ApJ **396**, 311) and Banerjee, Hasan & Christensen-Dalsgaard (1995, ApJ **451**, 825), examined the effects of a vertical magnetic field on the normal modes of an isothermal stratified atmosphere by combining a semi-analytic approach, based on asymptotic dispersion relations, with numerical solutions. The nature of interaction between various modes was investigated and it was shown that this interaction becomes particularly important in the regions of *avoided crossings*, which are the locations in the $k-\omega$ diagram where the frequencies of different elementary modes coincide. Physically this oc-

curs due to a strong coupling between the two modes and consequently the character of the solution is a mixture of these two modes. In the present study the previous analysis has been generalized to include radiative dissipation using Newton's law of cooling. Radiative heat exchange gives rise to a temporal decay of the oscillations, on a time scale which can be as short as two oscillation periods. The existence of mode damping in the presence of radiative exchange is hardly surprising; however, a new feature of the analysis is that the damping is significantly altered by mode coupling in the regions of avoided crossings. In the weak magnetic field limit, the damping is maximum for horizontal wave numbers $k \sim 0.65$ Mm $^{-1}$ assuming a temperature of 6500 K. This roughly corresponds to a magnetic element having a width of a few Mm. For stronger fields, such as those found in pores or faculae, the cell width decreases as the field strength increases. Thus, radiation damping may be important for efficiently damping waves in flux tubes with typical horizontal dimensions of a few thousand kilometers. These new calculations have demonstrated the importance of enhanced radiative damping for coupled Lamb and magnetic modes. These results are likely to be relevant in the investigation of energy transport in active regions, particularly in small-scale magnetic elements.
(D. Banerjee, S.S. Hasan and J.C. Dalsgaard*)

### 1.2.7 Non-adiabaticity and Convective Collapse of Solar Magnetic Flux-tubes

The thermal effects due to radiative energy exchange, which introduce a size(flux)-strength dependence for solar magnetic flux tubes, on the 'convective collapse' process operating in the super-adiabatic photospheric layers have been examined; inclusion of both the vertical and the lateral energy exchange self-consistently is the new aspect of this calculation;the radiation is treated in the diffusion approximation; we also studied the overstable behaviour of the oscillatory motions in the tubes;thus we have improved over the previous studies (Hasan, 1984, 1986; Venkatakrishnan, 1986) of this kind, establishing a clear relation between the size(flux) and the strength for the solar magnetic flux tubes which are formed by convective collapse. Also the periods and growth rates of the overstable oscillations have been found. In the next study we are improving on the treatment of radiative transfer by employing the generalized Eddington approximation and also include convective flux in the equilibrium energy balance.
(A. Rajguru and S.S. Hasan)

### 1.2.8 Calculation of Line Radiation Cooling in Solar Chromosphere with shocks

Acoustic and MHD-shock waves are accepted as one of the main sources for the heating of solar chromosphere. Energy is deposited by the dissipation of waves and is lost by radiation in the strong resonance lines of Ca II, MG II and H I. To model the time-dependent behaviour of the chromosphere, one has to calculate accurately the radiation losses in these lines. The assumption of complete redistribution (CRD) for the line scattering in the treatment of radiation transport yields energy losses which are often wrong by more than orders of magnitude. This leads to excessive mechanical heating requirements for empirically derived chromospheric temperature distributions as well as for the time-dependent chromospheric modeling. Several workers developed numerical techniques (Ulmschneider, 1994, A & A, **288**, 1021; Hunerth and Ulmschneider, 1995, A & A, **293**, 166) for solving the transfer equation in an atmosphere where shocks are present and assumed more realistic line scattering described by angle-averaged partial redistribution (PRD) function. They calculated the MGII k cooling rates for two solar acoustic wave calculations with initial energy fluxes $F_{Af}$=2.0.10$^8$ ergs/cm$^2$ s and periods P=45 and 30s. They found that the use of PRD significantly changes the physics of radiation cooling. Though they have assumed more realistic line scattering mechanism, the calculations are confined to single-scattering approximation (i.e., the radiation is traveling in only one direction). So we modified their code for the multi-stream approximation and found a difference of 10 to 20 % in the cooling rates compared to their estimates. We also found that MG II and Ca II k line profiles are identical for VAL model with both two and multi-stream approximations. But for the shock model there are large differences in the profiles between multi and two-stream approximations. At present, we are using full angle-dependent PRD function for line scattering to improve the previous calculation of radiation losses due to the lines.
(D.Mohan Rao)

### 1.2.9 Resonance Line Polarization in the Presence of Travelling Wave and Standing Wave - A Comparative Study

Waves and oscillations in the atmosphere of the sun provide a field of lively and intense research. They are the means to transport energy from photospheric and sub-photospheric layers to heat the chromosphere and corona. The study of phase relations of line shifts and brightness fluctuations has been exploited to derive the type of waves present in the atmosphere of sun by several workers in this field. *For the first time from this institute we propose that the study of the temporal behaviour of the resonance line polarization will provide useful, additional information on the dynamical structure of the atmosphere.* A systematic study of Resonance line polarization in the presence of wave motion in solar atmosphere has been undertaken. Line center intensity as well as the polarization vary with a period which is half of that of the wave. The variation amplitude for polarization is much higher compared to the intensity towards the limb. Hence polarization in the limb may serve as an additional information to characterize the wave. Standing wave gives different type of polarization fluctuation compared to travelling wave even though their intensity fluctuations are similar. At $t = T/4$ and $t = 3T/4$ (T being the period of the wave), we find a decrease in polarization for the standing wave at the line center. For travelling wave this does not happen. At these time points the velocity of the standing wave is zero and the Doppler shift is zero for all angles. The angular dependence reduces and the radiation field becomes less anisotropic. Since polarization is a measure of anisotropy, we find it to be reduced for the standing wave compared to the travelling wave. (K.E. Rangarajan)

### 1.2.10 The Correlation Lifetimes and Scales of Chromospheric Ca II K Network Cells

The lifetimes and spatial scales of emission network cells in the solar chromosphere were studied from a nearly continuous sequence of Ca II K filtergrams, obtained from Antarctica. The temporal and spatial autocorrelation functions (ACF) were calculated for spatially aligned windows from the time-sequence of filtergrams. The lifetimes of network cells were found to be dependent on the activity of the region. The correlation lifetimes were obtained in the range 24-34 hours for quiet region and 58-61 hours for active region windows. The temporal ACF shows a prominent modulation in some of the quiet region windows. (K.P. Raju, R. Srikanth and Jagdev Singh)

### 1.2.11 The dependence of chromospehric Ca II K network cell sizes on solar latitude

Calcium K line spectroheliograms obtained during the solar minimum phases between 1913-1974 at Kodaikanal have been used to study the network cell sizes. The autocorrelation is calculated for two dimensional strips at $5^o$ interval upto $\pm 50^o$ latitude. The average size of the network cells was found to have a dependence on solar latitude with a maximum variation of about 7%. The pattern shows an apparent north-south symmetry with two minima at about $20^o$ N and S.
(K.P.Raju, R.Srikant, Jagdev Singh)

### 1.2.12 Multibaseline Observations of the Angular Broadening of Crab Nebula by the Solar Corona

Multibaseline observations of the angular broadening of crab nebula by the solar corona at 34.5 MHz obtained during 1986.87 and at 55 and 77 MHz during 1995 were analysed to study the variation of structure function with baseline. Asuuming a power law spectrum of electron density fluctuations , the fitted spectral component beta have the value of 2 to 3.8 for scale sizes between 0.5 to 5 Km. The value of beta remained constant at distance of 10 - 30 solar radii. The radial variation of scattering showed no enhanced scattering in the range 10 - 30 solar radii.
( K.R.Subramanian )

## 1.3 SOLAR ECLIPSE RESULTS

### 1.3.1 Detection of Short-period Coronal Oscillation During the Total Solar Eclipse of 24 October 1995

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. The intensity in the continuum, centred around 550 nm and with a passband having a half-width of 240°, was recorded at a counting rate of 20Hz 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 0.2Hz. A least square analysis gives the periods of 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, V. Krishan, B. Nagaraja Naidu, J. P. A. Samson and F. Gabriel)

### 1.3.2 Lunar Occultation Observations of the Microwave Sun During the October 25, 1995 Solar Eclipse

The analysis and interpretation of the lunar occultation data recorded at several microwave frequencies from two observing stations during the October 25, 1995 solar eclipse were completed. Radio observations were made at Neem Ka Thana (Rajasthan) using a 2 meter parabolic dish antenna and a receiver system operating at 3.8 and 4.2 GHz in total power mode. Simultaneous, circularly polarized radio data obtained at Shriharikota station (Andhra Pradesh, ISRO Station) using a 10 meter diameter antenna operating at 2.5 GHz frequency were also used. The solar eclipse event was used to advantage in obtaining high resoluition information on the solar activity even with these moderate sized radio dishes. A 2-station triangulation analysis has enabled us to identify and locate unambiguously, an intense radio emitting active region about 10 arcminutes to the south-east of the sun centre, to within 30 arcseconds positional error. We obtained an angular size of 5.0 arcminutes and a brightness temperature $T_b$ of $1.2 \times 10^5$ K for this radio source. Towards understanding the nature of this radio emission, several other solar data at other wavelengths, recorded on the day of the eclipse, were also studied. The Nobeyama Radio Observatory 17 GHz solar radio image was used to obtain an angular size of 3.0 arcminutes and a brightness temperature of $1.5 \times 10^4$ K , implying a fall of brightness temperature by at least a factor of 10 and a considerably smaller angular size for this active region (between 2.25 and 17 GHz frequencies). We also compared the radio data with the YOHKOH soft x-ray telescope data in the 4 to 60 Angstrom band and with the Solar Magnetogram obtained at the Mt. Wilson Obeservatory. We found intense, arch-shaped x-ray emitting stuctures connecting magnetic zones of opposite polarities, to be present at the site of the radio source. The major axis of the x-ray emission was found to lie along the same direction as the major axis of the radio stucture at 17 GHz and the angular sizes were also comparable. These data indicated that the component plasmas radiating the radio and the soft x-rays are probably closely associated and the morphology of the radiating gas largly governed by the structure of the magnetic field lines over the identified active region.
(J. Bagchi, K. R. Subramanian, E. Ebenezer, N. Gowda, A. T. Abdul Hameed and ISRO Team: G. Viswanathan*, S. Gandhi*, L. Srinavasan*, Periasamy* and C. D. Sharma*)

## 1.4 INSTRUMENTATION

### 1.4.1 HIRES Project

A continued collaborative program on "Small Scale Structures in the Solar Atmosphere and Their Effects on the Terrestrial Environment" has been signed with Prof.Gethyn Timothy of University of New Brunswick, Canada, principal Investigator of the program. This proposal has been submitted to Canadian Space Agency.
(A.K.Saxena and J.C.Bhattacharyya and other collaborators)

### 1.4.2 Filtergrams at Kodaikanal

A horizontal telescope with an objective of 15 cm aperture and 225 cm focal length was built to obtain filtergrams in calcium K-line. BG7 filter of 9cm aperture is used to cut of Infra-red part of the spectrum. A narrow band 1.2A passband filter kept near the focal plan isolates the calcium K line. The picture of the sun is calcium K-line is being recorded on daily using 1K x 1K pettier cooled CCD camera from Photometrics.
(Jagdev Singh, S.P.Bagare, S.S.Gupta, F.Gabriel, P.S.M.Aleem, R.Selvendran, G.Suryanarayanam, P.Kumaravel and K.P.Raju).

### 1.4.3 Stepper motor driven siderostat

The siderostat at spectro building at Kodaikanal was being driven using a gravity clock. This always created a problem in proper guiding of the solar image especially in winter when grease in the gear system caused extra friction due to drop in temperature during night. The gravity clock has been replaced by a stepper motor whose frequency can be adjusted by digital means to track the sun accurately and which can

overcome the extra friction during winter. The new drive is working very well.
(Jagdev Singh, F.Gabriel, P.S.M.Aleem)

### 1.4.4 CCD Camera at Solar Tower Telescope at Kodaikanal

A pettier cooled 1K x 1K CCD camera system has been installed at the spectrograph to obtain the observations at regular basis. An arrangement is also made to view and centre the required wavelength region onto the CCD camera. The grating is blazed at 2.2 micron in the first order and hence permits recording of the spectra in blue, green and red in 6th, 5th and 4th order respectively. But the use of glass filters and sensitivity of CCD camera to infra-red wavelengths do not permit the observation in higher orders. We need to procure interference filters of about 10 nm pass band with the blocking of Infrared wavelengths to make observations in the higher orders. At present we can observe upto 3rd order. The spectrum quality is very good.
(Jagdev Singh and F.Gabriel)

### 1.4.5 Solar Telescope at Hanle

A 20 cm coelostat system fabricated at Kavalur was shifted to Hanle and installed for observations of the sun. A 15 cm objective formed the solar image of about 20 mm diameter. A thermo-electrically controlled 1-2A pass band filter centred around calcium K line at 3933.7 A was mounted just before the focus. The trial pictures of the sun in this line were obtained using 35 mm Kodak 2415 film and ST6 CCD camera. These pictures show the chromospheric features such as plages, calcium - K bright points which will be used to estimate the daytime seeing conditions.
(Jagdev Singh)

### 1.4.6 The Gauribidanar Radioheliograph

The radio astronomy group is primarily responsible for the setting up of a Radioheliograph for imaging the outer solar corona in the frequency range of 40 to 150 MHz. In order to map the sun in two dimensions, a 1024 channel digital correlator was designed, constructed and successfully installed. To steer the beam of the South array in the North - South direction, delay shifters were installed at appropriate places in the South array. The major problem with regard to imaging the sun at long wavelengths is to remove the effects of random phase fluctations imposed on the radiation by the ionosphere and the transmission lines. A redundancy calibration method using the appropriate correlations obtained by the digital correlator and specialed algorithm was evolved. The testing of both the hardware and software for the redundancy calibration was carried by imaging several point sources like Cas A, Cyg A etc. Maps of the sun at 51 and 75 MHz are being made using the redundancy calibration method.
(K. R. Subramanian, R. Ramesh, M. S. Sundarajan, Ch. V. Sastry, E. Ebenezer, C. Nanje Gowda and A. T. Abdul Hameed)

# 2. SOLAR TERRESTRIAL PHYSICS

## 2.1 EQUATORIAL IONOSPHERE - THERMOSPHERE SYSTEM (EITS)

The STP group of the institute has been participating in the campaigns of EITS project of the International Solar-Terrestrial Energy Program (STEP) since March 1991, with the experimental facilities at Kodaikanal and Kavalur. A major line of activity from of the group is analysis and interpretation of the campaign data by collating with those of other groups (within and outside the country), with reference to specific scientific problems of EITS which demand such an approach. A begining has been made in this direction with the initiation of collaborative work with the Aeronomy group at the Brazilian National Institute for Space Research (INPE). The following is a brief summary of the first results of the joint efforts.

### 2.1.1 Disturbances in Equatorial Zonal Electric Fields and Related Effects

Geomagnetic substorms/storms are known to lead to perturbations in ionospheric electric fields/currents in the dip equatorial regions on different time scales. Comprehensive characterisation and understanding of the electric field disturbances and their effects on related phenomena is one of the major objectives of the EITS project. On 16 December 1991, corresponding to the EITS-2 campaign period, intensifications of asymmetric ring current occurred in quick succession over a 12-hour period preceded by quiet conditions for an extended period. This unique event is utilised to evaluate the response characteristics of equatorial zonal electric field and F region plasma density to asymmetric ring current activity. Simultaneous ionospheric data of Indian (75 E) and Brazil (45 W) sectors are analysed in relation to high time resolution (1-min) data of asymmetric ring current indices, ASY for the purpose. It is shown for the first time that short-lived (duration about 2 hrs) perturbations in F layer vertical drift and height, indicative of westward and eastward electric fields prevailed simultaneously in the dusk and predawn sectors, respectively, in association with the decay phase of asymmetric ring current activity. Electric fields of opposite polarity do also seem to manifest at these times, particularly in the early morning sector in conjunction with intensifications of asymmetric ring current. This finding substantiates the view that, at a given location, electric fields associated with individual asymmetric ring current events are primarily of bipolar character, with fields of opposite polarity during the development and decay phases. The nature and polarity structure of the observed electric field disturbances are in agreement with the theoretical/model predictions of prompt penetration of transient high latitude electric fields associated with rapid changes in the magnetospheric convection into the equatorial region, to rapid changes in magnetospheric convection. Prominent and uncommon changes in ionospheric plasma density distribution with increase in electron density at and below the F layer peak near the dip equator and in electron content at a location farther from the equator are noticed in the Brazil sector during the time span of the westward electric field disturbance associated with one of the asymmetric ring current events. This behavior is explained in terms of plasma redistribution due to the combined effects of the equatorward retreat of the ionization anomaly because of the transient westward electric field, and the dominance of plasma convergence due to the abnormal downdraft of the layer over chemical loss in the bottomside F region. The study showed that the characteristics of the equatorial ionosphere in the dusk and predawn sectors respond very sensitively to asymmetric ring current activity, a fact that must reflect in the predective models of ionospheric variability.
(J. H. Sastri, M. A. Abdu* and J. H. A. Sobral*)

Disturbances in equatorial electric fields of slowly varying and persistent nature are seen long after (delay > 9 hrs) the onset of some geomagnetic storms. These are considered as electric fields due to the disturbance dynamo (DD) mechanism. The limited evidence available to-date for DD fields is based on single site data, leaving the longitudinal structure of DD fields as unexplored. So also is the situation of the effect of DD fields on the equatorial spread-F (ESF) processes. These issues of the storm-time ionospheric electrodynamics are addressed with the multi-site data obtained simultaneously in India and Brazil during the GUARA/EITS campaign of September-October 1994. The study showed the presence of a longitudinal structure in the manifestation of DD electric fields. This suggests that DD electric fields involve themospheric disturbance circulation cells of limited restricted longitudinal

extension that predominate, atleast intitially,in preferred longitudinal sectors of the low latitude region. With increasing time (within about 17 hrs of the onset of magnetic storm) the longitudinal extension becomes > 120 degrees, and the DD fields are then seen simultaneously at different longitudes as predicted by the theoretical model, which assumes a uniform high latitude energy input. The campaign results also provided clear examples of the interplay between DD fields and short-lived perturbations due to substorm activity. The DD electric fields are shown to lead to inhibition of the normal onset of ESF in the post-sunset period but do not necessarily result in the generation of ESF in the predawn period, inspite of creating the favourable condition of an elevated F layer. The latter feature is ascertained to be the result of the stabilising effect of transequatorial neutral winds associated with storm-time circulation on the growth rate of Rayleigh-Taylor (RT) plasma instability responsible for ESF.
(M. A. Abdu*, J. H. Sastri, J. MacDougall*, I. S. Batista* and J. H. A. Sobral*)

### 2.1.2 Effect of Equatorial Midnight Temperature Maximum (MTM) on Low Latitude Meridional Winds

An energetically significant and semi-permanent feature of equatorial upper atmosphere is the midnight temperature maximum (MTM) and the associated pressure bulge. The current knowledge of MTM and its effects on neutral and plasma dynamics is limited to that derived from AE-E satellite data and sparse groundbased measurements at a few widely separated sites including Kavalur. There is now a resurgence of interest in equatorial MTM motivated by the need to charaterise the phenomenon for the different longitude zones to spur and guide parallel theroretical modelling effort. As a first step in the direction of ascertaining the characteristics of MTM in the East Brazil sector, the average seasonal patterns of nighttime thermospheric magnetic meridional winds over the low latitude station, Cachoeira Paulista (CP) are examined for the effects of MTM. The winds are derived from hmax data for quiet conditions of high solar activity, using a modified form of the servo model wherein plasma transport due to electric field is taken into account. It is found that the neutral wind pattern over CP due to solar forcing is effectively modulated by the winds due to the MTM, especially during the December solstice (local summer). The MTM modulation is seen as a rapid abatement and reversal of the equatorward winds around midnight.In contrast, the MTM modulation of meridional winds is best seen over SHAR, India during the equinoxes. This difference between the Indian and East Brazil sectors in the visibilty of MTM effects on neutral dynamics may well be due to the differences in the local tidal forcings as well as the difference in the location of CP and SHAR relative to the magnetic equator.
(I. S. Batista*, J. H. Sastri, R. T. de Medeiros* and M. A. Abdu*)

# 3. SOLAR SYSTEM STUDIES

## 3.1 COMETS

### 3.1.1 Spectrophotometric Observations of Comet Hale-Bopp

Spectrophotometric Observations of Comet Hale-Bopp were obtained with the VBO's 102-cm telescope during the months of October 1996 and February/March 1997 using the UAGS and the 150 l/mm grating. In these observations, the emission features due to the principal Swan band sequences of C2 and also the one due to Na are readily identified. The reduction and analysis work is in progress.
(G.S.D. Babu and K.R.Sivaraman)

### 3.1.2 Imaging and Spectroscopy of Comet Hale-Bopp

The observational program of imaging and spectroscopy from the Vainu Bappu Observatory were continued. Figure 3.1.2.1 shows the development of asymmetric coma due to jet activity from several active regions. For comparison the top left image shows the image obtained when the comet was 6.8 AU from the Sun.
(R.Vasundhara and Pavan Chakraborty)

### 3.1.3 Modeling of Jets

The shape, length and orientation of the jets from comet Hale Bopp in the images obtained using the Vainu Bappu Telescope during October and November 1996, are modeled. Following Sekanina and Bahnhardt ( IAUC 6542, Jan 21, 1997 ) we assume that dust is emitted continuously from the active spots from local sunrise to local sunset and that a pair of jets correspond to the edges of the cone as seen from the earth. The observed jets were compared with the images simulated using our model. Although a variety of combinations of the coordinates of the visible pole ( $\alpha_p, \delta_p$) of the comet yield same orientation for the jets in the North-East direction, simultaneous modeling of the shape and length of the jets extended in other directions while taking into account the effects of solar radiation pressure on the grains helps in constraining the pole positions to $35^\circ \pm 5^\circ$ for $\alpha_p$ and $+50^\circ \pm 5^\circ$ for $\delta_p$ (equinox 2000.0) during October 6 and $30^\circ \pm 5^\circ$ for $\alpha_p$ and $+50^\circ \pm 5^\circ$ for $\delta_p$ during November 4 –6. . The location of major active spots from our model are at $20^\circ$, $60^\circ$, $90^\circ$ and $120^\circ$ from the visible pole in the North – East quadrant. Fig. 3.1.3.1 shows the image obtained on 6 October 1996 which has been contrast stretched using median filtering to enhance the jet features. The dotted lines are the simulated jets using the model.
(R. Vasundhara and Pavan Chakraborty)

### 3.1.4 Stellar Occultation by Dust around Fragments of the Comet Shoemaker–Levy 9

Images of comet S-L 9 taken on 8 April 1994 at the prime focus of the $2.34m$ telescope at the Vainu Bappu Observatory showed occultation of a star by the dust around fragments $Q_1$ and $Q_2$. A photometric technique using standard packages like DAOPHOT and aperture photometry was developed for reliable estimation of the changes in stellar flux during the occultation. Due to non symmetric variation of the coma standard photometric techniques can not be directly applied. Field stars which were sufficiently away from the comet tail were used for differential photometry. One expects the starlight to undergo extinction during occultation. Surprisingly, our results show an enhancement of the star light at the central coma around the fragments $Q_1$ and $Q_2$ and extinction as the star emerged away from the central condensation. We propose that both extinction and forward scattering by cometary grain compete with each other. Very close to the fragments where the column density of grains is large, multiple scattering reduces forward scattering and extinction starts dominating. From the suggestion by Olson and Mumma (1994,*Bull. Am. Astron. Soc.*, **4**, 1574) and Rettig et al (1996,*J. Geophys. Res. Planets*, **101**, 9271) that the S-l 9 fragments were self gravitating swarms of cometesimals, Hahn et al (1996,*Icarus*, **121**, 291) suggested that the dust production might have been due to the ejection of dust due to collisions of cometesimals. The solar radiation pressure sorts the grains according to their sizes. If the continuous production model is applicable we expect that the centroid of distribution of lighter grains (1 - 10 $\mu$) would be offset along the sun-comet vector. Since most of the light is scattered by grains of this size range, we may expect the photo center to be offset from the actual centroid of the cometesimals. The more heavier or larger grains which will be detected through occultation fall behind. This may explain the observed offset of $2.34arcsec$ seen along the occultation path which is very close to the sun-comet vector. The present technique is general

enough to be applied to stellar occultations by any comet.
(Pavan Chakraborty and R.Vasundhara)

### 3.1.5 Observations of comet Hale-Bopp at Kodaikanal

Pictures of comet Hale-Bopp were obtained on daily basis from February 10, 1997 to March 17, 1997 using objective of 210 mm focus and Kodak Multispeed film. The film with an exposure time of 30-40 minutes yielded a very good picture of the comet. The pictures of comet were also obtained using Astro-graph of 50 cm focus and Kodak 4415 film. The exposure time of about 30 minutes provided high spatial resolution pictures of the comet. Low spatial resolution pictures of the comet were obtained using pettier cooled 1K x 1K CCD camera from Photometries and Coelostat of Solar Tower Telescope at Kodaikanal. The pictures of comet were obtained in red and near infrared light using broad band glass filters.
(P.S.M.Aleem, Jagdev SIngh, P.Devendran)

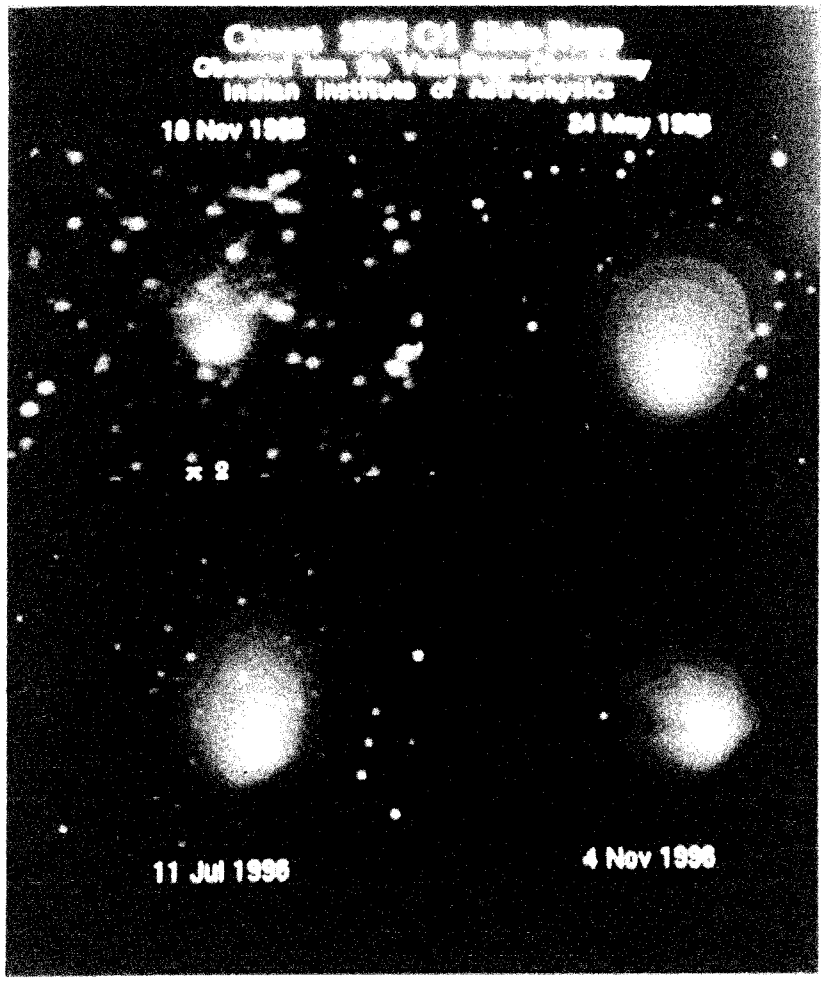
## 3.2 INSTRUMENTS AND TECHNIQUES

### 3.2.1 Design of add-on polarimetric optics to the B & C Spectrograph at the VBT

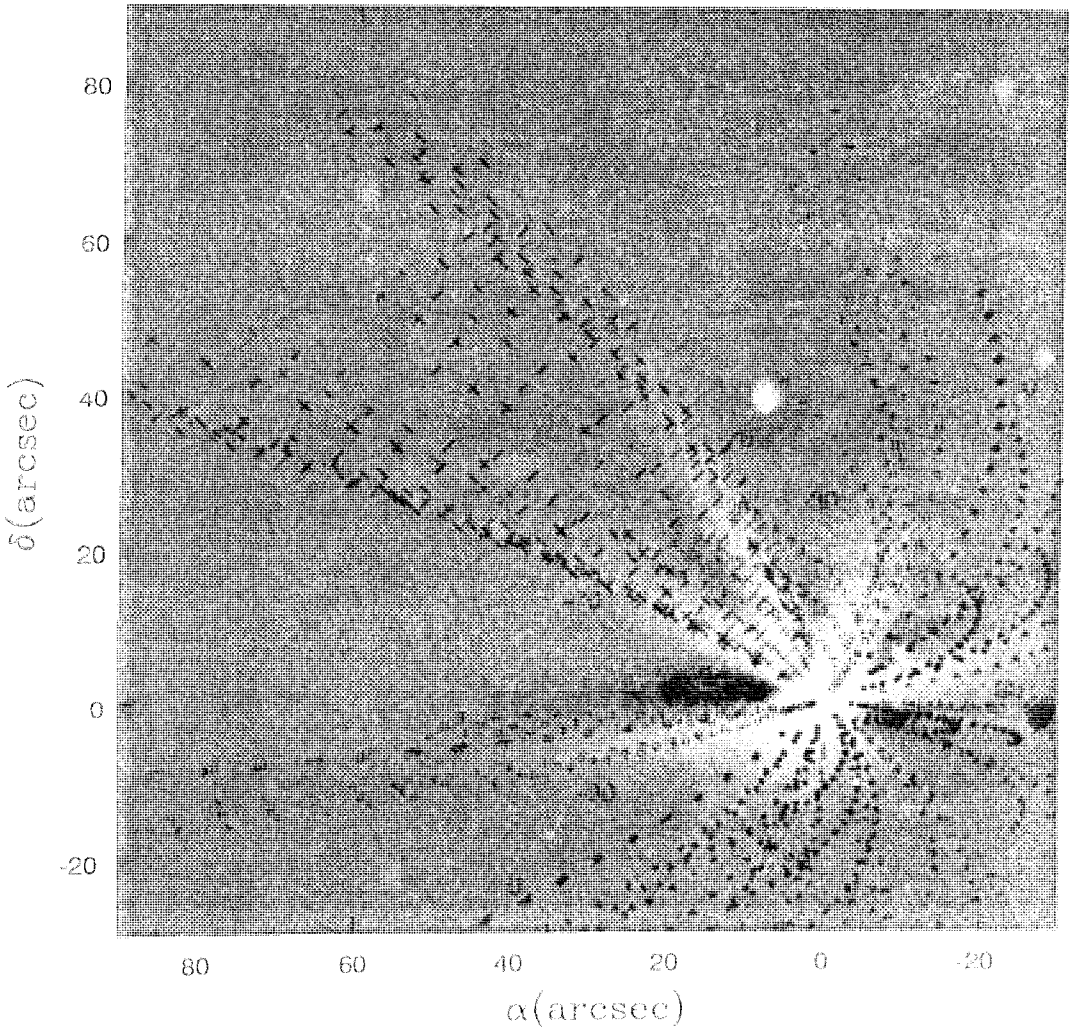
A spectropolarimetric optics consisting of a Pancharatnam design half wave plate and a modified Glan Taylor prism was designed for use with the B & C spectrograph at the Cassegrain focus of the VBT. The design is an adaptation of the spectro polarimetric unit designed by R.Goodrich ( PASP **103**,1314). The Glan Taylor calcite prism of 10 mm clear aperture yields two beams ( ordinary and extraordinary ) running parallel to each other. The six plate Pancharatnam design half-wave plate is optimized for 3500 $\AA$ to 10000 $\AA$. The optical components have been assembled with the help of the mechanical division of the Institute at Bangalore and Kavalur. Test runs have been obtained on the VBT of standard stars. The data analysis to check the performance of the unit for further modifications is being carried out.
(Pavan Chakraborty and R.Vasundhara)

### 3.2.2 Image Processing of an Extended Object

Surface photometry is being done on the deconvolved images of the Jupiter obtained at 1.2 meter telescope of Japal-Rangapur Observatory, Osmania University, Hyderabad, during 17-24th. July'94, using speckle interferometric technique, when the fragments of comet Shoemaker-Levy 9 had slammed into the former. The Blind Iterative Deconvolution (BID) technique was used to remove the atmospherically induced Point Spread Function (PSF) from these images and were able to identify the individual spots produced by the fragments of comet Shoemaker-Levy 9 on Jupiter.
(S.K. Saha)


Indian Institute of Astrophysics
18 Nov 1995
24 May 1996
11 Jul 1996
4 Nov 1996

Main jets from Comet Hale-Bopp on October 6, 1996



# STARS AND STELLAR SYSTEMS

# 1. STARS

## 1.1 EVOLVED STARS

### 1.1.1 Spectral Characterstics of RV Tau Stars

Spectroscopic properties of RV Tau variables as a class and the distinctive features of various subgroups are summarized. We find that the RV Tau variable SS Gem which was earlier classified as RV A type (implying carbon-poor group), shows numerous lines of CI and CH, normally seen in RV B type star. Another field RV Tau variable V360 Cyg shows very high radial velocity and indeed is a metal-poor star as indicated by low sulphur abundance. Many RV Tau stars show selective depletion of condensable elements whereas elements sulphur and zinc that are not easily condensable show near solar abundance. Though the abundance pattern of V360 Cyg indicate that dust-gas separation has taken place, the star appear to be metal-poor in addition of being metal-depleted.

(Sunetra Giridhar)

### 1.1.2 Abundances and Atmospheric Parameters of Selected F-G Supergiants

Spectroscopic abundance determinations for a sample of seven F-G stars have been carried out. The majority of them have large galactic latitudes. One objective in deriving spectroscopic abundances is to differentiate evolved objects seen at high galactic latitudes from the young population I supergiant stars that happened to have large galactic latitudes but actually belong to the galactic disk. Secondly, it is important to get good calibrators for photometric metallicity indices. It has been suggested in the past that many high galactic latitude F-G stars that are classified as supergiants are in reality subgiants or dwarfs. Our spectroscopically derived gravities show that two of the stars studied in this paper, HR 5165 and HD 114520, are not supergiants as classified in Bright Star Catalogue but are subgiants belonging to the solar neighbourhood. In our sample, HR 3229 and HR 8470 display solar abundances and the derived gravities support the bright giant luminosity class ascribed to them. HR 4114, HR 4912 and HR 7671 have abundances significantly different from those of young supergiants of galactic disk. The evolutionary status of these objects is discussed.

(Sunetra Giridhar, A.Arellano Ferro*, L.Parrao*)

### 1.1.3 Chemical compositions of field RV Tau variables

A study of the cool members of RV Tau stars, DY Aql and CE Vir led to the detection of LiI features in these two stars. However, the derived lithium abundances are similar to those found in less evolved giants. A chemical composition study of the relatively cooler sample containing DY Aql, SS Gem, CT Ori,CE Vir shows that the fractionation process (that makes the atmospheres of these objects preferentially depleted in easily condensable elements) seems to operate even for the coolest members. A comparison with RV Taur stars studied earlier shows that there are two distinct groups in field RV Tau stars. One belonging to thin disk is represented by SS Gem and R Sge, with moderate mass and members situated relatively nearer to the galactic plane. The other group has low-mass members belonging to the thick disk. This group is represented by DY Aql, IW Car, EP Lyr, CT Ori and DY Ori.

(G. Gonzalez*, D.L.Lambert*, Sunetra Giridhar)

### 1.1.4 Studies of post-AGB stars and Proto-planetary Nebulae

We selected a sample of IRAS sources whose colours are similar to PNe and post-AGB stars. We studied their spectral energy distribution (SED) using optical, IR photometry and low-resolution optical spectra. We derived spectral types and luminosity classes for all the stars. We found all stars are in the A-F-G spectral types with luminosity class I or II. The stellar parameters like gravity and $T_{eff}$ and dust envelope parameters like dust temperature, dust mass, dynamical life time of the dust envelope and high galactic latitude coupled with molecular observations of CO, OH, HCN, 3.3 $\mu$m and 21 $\mu$m features suggest that all the stars considered here are associated with post-AGB evolutionary phase.

One of the important results obtained in this study, comes from the chemical composition analysis based on high resolution spectra of IRAS 05341+0852. This is one of the few stars in which 21 $\mu$m emission has been detected. We found from the chemical composition analysis that the star is metal-poor ([Fe/H] = -1.0), carbon-rich (C/O$\geq$1) and large overabundance of s-process elements Y ([Y/Fe] = 1.80), Ba ([Ba/Fe] = 2.58), La ([La/Fe] = 2.86), Ce ([Ce/Fe] = 2.95), Pr ([Pr/Fe] = 2.27), Nd ([Nd/Fe] = 1.97 and Sm ([Sm/Fe] = 0.86). With low metallicity, large

C/O and overabundance of s-process elements, IRAS 05341+0852 is a third post-AGB star which shows clear cut evidence for nucleosynthesis and third dredge-up during helium shell flashes on the AGB phase. The other two post-AGB stars are HD 56126 and HD 187885 both are metal-poor, carbon-rich and overabundant in s-process elements. However, for the first time in post-AGB stars, we found overabundance of Li and Al which are not enhanced in the other two post-AGB stars. Presence of large contents of Li and Al indicate that IRAS 05341+0852 has developed Hot Bottom Burning during its AGB evolution. Low metallicity, radial velocity, large displacement from the galactic plane indicate that it is a low-mass star belonging to an old thick disc or halo. The observed overabundance of Li and post-AGB nature of IRAS 05341+0852 suggest that Li can be produced in the low-mass post-AGB stars also.

We studied the chemical composition of three post-AGB stars: HD 179821, HD 70379 and IRAS 18095+2704, based on high resolution spectra. The chemical analysis study of HD 179821, made it possible to understand the nature of this coldest IRAS source. From the analysis of high resolution spectra we found that the star is metal-poor ([Fe/H] $\approx$ 1.0) and overabundant in C and s-process elements. The abundance of Zn found to be deficient, similar to Fe. These results suggest that the observed metallicity of HD 179821 is intrinsic and the overabundances of C and s-process elements are the result of nucleosynthesis and deep mixing during the AGB phase. Its large radial velocity, low-metallicity and overabundances of C and heavy elements indicate that HD 179821 is a low-mass post-AGB star in transition between AGB and PNe and not a massive yellow supergiant. HD 70379 is another bright IRAS source which has been suggested as a good candidate for low-mass post-AGB supergiant. The chemical composition analysis results show that it is slightly metal-poor ([Fe/H]=-0.3) and overabundant in C,N and s-process elements. It is also found to be overabundant in sulphur, similar to C. Overabundance of S as a result of nucleosynthesis in low-mass stars is difficult to understand. Thus the normal abundance (solar) of S indicates that the observed low metallicity is not intrinsic but it is due to depletion of iron-peak elements. Taking S abundance as the metallicity indicator, we discussed the chemical composition of HD 70379. We found slight overabundance of C and s-process elements which indicate that the star has undergone AGB nucleosynthesis and third dredge-up mixing. We conclude from its optical, IR properties, galactic position and chemical composition that HD 70379 is a new post-AGB star. In our study of chemical composition, we found IRAS 18095+2704 as an oxygen-rich post-AGB star. Evidence for third dredge-up is seen with CNO overabundances. The photospheric oxygen nature of this candidate confirms the chemical classification of oxygen-type based on dust envelope properties. However, we found deficiency in s-process elements Y and Ba.

We studied in detail the medium and high resolution optical spectra of HD 105262. This is a high C1-index (C1=1.4), high galactic latitude (+72°) and high proper motion (0.057 arcsec) star. Comparison of spectral features of HD 105262 with that of FHB star and supergiant of same spectral types show that it is an A-type supergiant with an extended atmosphere. The atmospheric parameters: $T_{eff}$=9000 K and log g=2.0 have determined from the fittings of observed Balmer profiles with that of calculated profiles, from Strömgren photometry and from UBVR photometry. Using LTE model atmospheres we derived elemental abundances. We found that the star is extremely metal-poor ([Fe/H] = -2.4). The abundances of CNO and $\alpha$-process elements Mg, Si are found to be overabundant relative to Fe. We also discussed in detail the kinematics of HD 105262. From the derived radial velocity and absolute magnitude ($M_v$=−4 to −5) we found its space motion to be around 700 km $s^{-1}$ which is much larger than the escape velocity from the Galaxy of 290 km $s^{-1}$ near the Sun. From the galactic positional components (X,Y,Z) and space velocity components (U,V, W) we conclude that HD 105262 is a member of halo group of stars. We argued in detail the results of both chemical composition analysis and kinematics and concluded that it is most probably a low-mass post-AGB star.
(E. Reddy and M. Parthasarathy)

### 1.1.5 Ca II Triplet Lines in Cool Stars and Chromospheric Activity - The Lithium Connection

A detailed study of the behaviour of the Ca II triplet lines 8498A, 8542A, 8662A with respect to stellar atmosphere parameters in a large sample of cool stars of all luminosities and a large range in metallicity

has revealed that the central depth of these line profiles is a good discriminant of chromospheric activity. When stars of similar luminosity, temperature and metallicity were grouped together, about 13 stars were found to have a higher central depth than their counterparts suggesting that chromospheric emission fills in the absorption cores of the Ca II triplet profiles. The shallower the lines are in the spectrum of a star, the more active the chromosphere of this star is. Based on the assumption that such activity is related to the age of the star and that the lithium content of a star depletes with age, one would expect a link between chromospheric activity and lithium abundance. In order to explore how far this interpretation holds true, a study of the Li I line at 6707.8A has been undertaken in these 13 chromospherically active stars and their counterparts and also in an unbiased sample of stars selected from the 150 stars observed for the Ca II triplet survey. CCD spectra in the Li region were obtained with the coude echelle spectrograph at the 102cm telescope at Kavalur at a spectral resolution of about 0.45A. Sneden's spectrum synthesis code LINES was used to calculate lithium abundances with the measured Li EQW and the appropriate choice of a model atmosphere as the inputs. The analysis shows that only 3 of the chromospherically active stars are Li rich. There does not exist one-to-one correlation between Li abundance and chromospheric activity. In fact a large range in Li abundance is obtained (over 2 orders of magnitude) for the active stars of similar types and is not dissimilar from what is observed in the sample of cool giants not specifically selected on the basis of activity. The simplest interpretation is that the star's mass may be the dominant factor since Li depletion on the main sequence is a strong function of mass. The range in abundances observed in giants is perhaps a consequence of range in masses of the progenitor stars and in the depths of their convective envelopes and hence in Li depletion. We are extending our analysis to a larger sample of stars to look further into the lithium problem.
(S.V. Mallik)

### 1.1.6 Study of peculiar A-type stars

The energy distribution curves in the wavelength region of 3900 $\AA$ to 7800 $\AA$ for more than 150 chemically peculiar stars have so far been obtained over the past few years, using the spectrophotometric scanners available with the 0.5-meter and 1-meter telescopes at the U.P.State Observatory, Nainital and at the Vainu Bappu Observatory (of IIA), Kavalur. About 50 more stars of this type have been further observed using the Universal Astro-Grating Spectrograph (UAGS) and the CCD facility with the 1-meter telescope at VBO of IIA. The UAGS in combination with a 150 lines per mm grating provides a low dispersion spectrum of the stars, which essentially shows the continuum with only the Balmer lines superimposed on it. These energy curves, were utilised for determining the stellar physical parameters namely, the effective temperatures, radii and bolometric magnitudes. An extended analysis of these parameters, with reference to the evolutionary aspects, indicates that these chemically peculiar stars are probably transiting towards the yellow giant region and are presently in the hydrogen shell burning phase.
(G.S.D. Babu)

## 1.2 VARIABLE STARS

### 1.2.1 Variability of Spectral Features in Peculiar Stars

The energy distribution curves of peculiar A-stars have been analysed to study the periodic variations in the broad spectral features around 4200 $\AA$ and 5200 $\AA$, which are readily noticed in some of the observed stars. The respective equivalent widths of these features are found to be varying with the same periodicities as those of the light variations, magnetic field variations, etc. of the given chemically peculiar star. Such variations observed in the above mentioned broad spectral features have been interpreted as due to the surface inhomogeneities of these stars having large sized patches of certain predominant chemical compositions. Study of the chemically peculiar stars is being continued as one of the on-going programmes with the 1-meter telescope at VBO.
(G.S.D. Babu)

### 1.2.2 Rotation of Be Stars

Between April 1996 and March 1997, we have obtained the Coude and the Cassegrain spectra of more than 175 Be stars. Preliminary results obtained from these spectra, suggest that the Be stars may be, intrinsically, both slow and fast rotators. This is contrary to the earlier suggestion that all Be stars are rotating at a critical velocity (450 km $s^{-1}$) at the equator. We shall continue our observations to increase the

database and also to check the validity of the present result. If our results are confirmed, then it will greatly help us to underswtand the physics of these objects.
(K.K. Ghosh, R. Krishnamoorthy*, V. Manivannan, C. Velu, and M.J. Rosario)

### 1.2.3 Discovery of Nine New Be Stars

It can be seen from the Bright Star Catalogue (D. Hoffleit & C. Jaschek, 1982) that a large number of early type stars have been classified as Bn and An stars. From the literature we have been able to obtain only one information that 'n' stands for nebulous meaning diffuse and broad lines (Adams & Joy, 1922, ApJ, 56, 242) and no other information is available for these objects. We have taken up a spectroscopic program to study these objects. During 24-26 January 1997 - 02 February 1997, we have obtained spectra of more than 80 Bn/An stars. These spectra were obtained using the Echelle spectrograph at the Coude focus and the Universal Astronomical Grating spectrograph at the Cassegrain focus of 102 cm reflector of VBO, with CCD-system. From a close inspection of these spectra, it was found that nine stars were in emission at $H_\alpha$ during our observations. These nine stars (HR1037, HR1056, HR1544, HR2191, HR2244, HR2300, HR3134, HR3878, HR4552) are not know as Be stars or emission line stars. Figs 1.2.3a, b shows the $H_\alpha$ profiles of these newly discovered Be stars. Detail spectral analysis of the Bn/An stars is in progress.
(K.K. Ghosh, K.M.V. Apparao*, C. Velu and S. Pukalenthi)

### 1.2.4 Dust Formation in Novae Shells

The spectra of nova Aquila 1995 obtained using the 2.3m VBT between 1995 March - May and the IR data obtained from the Gurushikhar IR Observatory between 1995 February - May, during the dust formation phase were analysed. The nova belongs to the FeII class and the development of its spectrum and the infrared colours closely follow those of other novae belonging to the same class. Comparing the spectral development with that of V443 Scuti 1989, the date of outburst maximum, the maximum magnitude and the rate of decay have been estimated for Nova Aql 1995. Interstellar extinction towards the nova was estimated using the HeI line ratios. The temporal evolution of the neutral and ionized zones of the nova shell were studied in detail. The infrared magnitudes were used to study the evolution of the dust formed in the nova and also its properties. The dust is optically thin accounting for the lack of a significant change in the optical light curve during dust formation. This nova is unique in having formed dust as well as developing coronal lines in the infrared.
(U.S. Kamath*, G.C. Anupama, N.M. Ashok*, and T. Chandrashekar*)

### 1.2.5 Long Period Variability of T Cr B

Spectroscopic data on the recurrent nova T CrB obtained for over ten years under the long-term monitoring of recurrent novae with giant secondaries were analysed. A slow, long-term variation of the emission line strengths was detected, superposed over which are several short-term variations, including an orbital-phase dependent variation. The most significant periods detected are the ones corresponding to 3640 days, 906 days and 113.76 days.
(G.C. Anupama)

### 1.2.6 Spectroscopy of Supernovae

Spectra of two Type Ia supernovae SN1995AL in NGC 3021 and SN1997Y in NGC 4675 were analysed. Spectra of SN1995AL were obtained on 1995 December 14 using the B&C Spectrograph on the VBT in the wavelength range 3600–8100 Å. The spectrum closely resembles that of the well studied supernova SN1981B about 56 days past maximum. SN1997Y was observed using the OMR spectrograph on the VBT in the wavelength range 4000–8000 Å on 1997 February 25. The spectrum is quite similar to that of SN1981B 17 days past maximum The mean expansion velocity measured from the absorption minima of the P-Cygni profiles is 9600 km/s for SN1995AL and 9100 km/s for SN1997Y.
(G.C. Anupama)

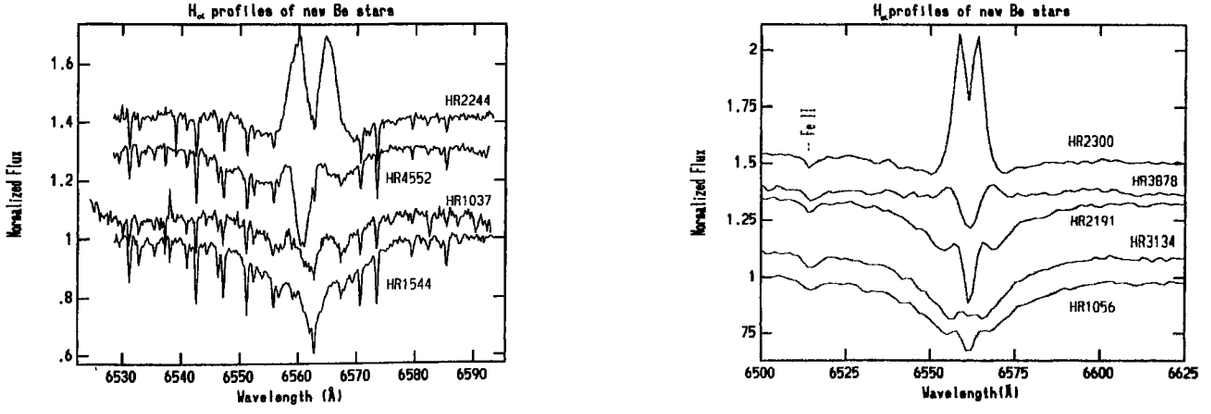



**Fig. 1.2.3a** H$\alpha$ profiles of four newly discovered Be stars. These profiles were obtained using Coude Echelle spectrograph.

**Fig. 1.2.3b** H$\alpha$ profiles of five newly discovered Be stars obtained using the Cassegrain spectrograph (UAGS).

# 2. THE INTERSTELLAR MEDIUM

## 2.1 COMETARY GLOBULES

The Gum Nebula in Vela contains the largest number of cometary globules (dark clouds with cometary tails and bright rims), shaped and excited by the central luminous star Zeta Pup. In an earlier polarimetric study we had found that the magnetic field in the cometary globule CG 22 is parallel to the cometary tail pointing away from the central star. Polarisation measurements have been made for stars in the region of another cometary globule CG 30 in Gum Nebula. Preliminary analysis of these observations shows that for this globule too the magnetic field is parallel to the cometary tail, now with a different position angle. This indicates that stellar radiation, gas dynamics and the magnetic field in this complex are closely interacting.
(H. C. Bhatt)

## 2.2 GALACTIC AGE ESTIMATES FROM STARDUST

The $^{16}O/^{17}O$ and $^{16}O/^{18}O$ ratios of refractory oxide grains extracted from primitive meteorites suggest that they originated in low-mass red giant stars prior to the formation of the Solar System $4.6\times10^9$ years ago. Detailed comparison of the isotopic compositions of the grains with models of stellar evolution and galactic chemical evolution imply that the age of the Galaxy is 14.4 Gyr with a statistical error of $\pm$ Gyr. Systematic uncertainties are of order several Gyr, however, and are primarily due to inadequacies in present theoretical modeling.
(L.R. Nittler* and R. Cowsik)

# 3. STELLAR SYSTEMS

## 3.1 OUR GALAXY

### 3.1.1 Study of Young Open Clusters as Tracers of Spiral Features in our Galaxy

Open clusters having stars of O type or early B type are considered to be rather young (less than $10^7$ years) and may be expected to be found physically near the places of their origin, which are generally in the region of the spiral arms. This happens to be so because the random velocities in the Galaxy tend to smear out these clusters over the plane within about $10^8$ years. Further, the distance determination of open clusters is fairly straight forward with the reliability being expected to be quite good. Based on these two factors, several hitherto not-well-studied open clusters were chosen to be used mainly as tools for tracing the spiral features in our Galaxy. This also leads to the fact that if such young clusters contain very faint stars of O type or early B type, then the respective distance modulii of the faint young open clusters would yield very far away and yet reliable distances. Thus, by finding the location of such young clusters in the map of the Galaxy, we would be able to trace the spiral features and thereby get a better understanding of the structure of our Galaxy. In the on-going programme of photometric observations, several such clusters located in the anticenter direction of the Galaxy, were selected in order to reach as far away distances as possible. This is basically due to the fact that in these parts of the Galaxy, the problems of interstellar extinction are minimal. The reduction and analysis of the observational data of two clusters (OCl 556 and OCl 689), obtained with the CCD imaging techniques at the 102-cm telescope of VBO, are presently in progress.
(G.S.D. Babu)

## 3.2 GALAXIES

### 3.2.1 The Central Region of NGC 2903

A continuing study of the central region of the Sersic-Pastoriza galaxy NGC 2903 has revealed a nested bar-within-bar structure with the inner bar counter-rotating with respect to the galaxy. This may have resulted from mild accretion of a retrograde satellite. This bar has induced

current burst of star-formation in the inner Lindblad resonance region, as also induced gas flow to the nuclear regions inducing star-formation in the nuclear and circumnuclear regions.
(T.P. Prabhu, G.C. Anupama, and A.K. Kembhavi*)

### 3.2.2 Massive Black Hole Formation in Protogalaxies

Within the framework of a two phase model for protogalaxies, we study the dynamical evolution of protoglobular cluster-like clumps of baryonic matter in the gravitational field of a smoothly distributed dark matter component. The motion of the clumps is resisted by drag due to dynamical friction caused by the dark matter. The result is that the clumps lose energy and angular momentum and gradually spiral in towards the center of the protogalaxy. As the clumps accumulate at the center of the protogalaxy, a massive central core of baryonic matter is built up there. For the values of the parameters typical of a protogalaxy, as much as $10^8 M_\odot$ of baryonic matter can be accumulated in the central region on a time scale of $< 10^8$ yrs for clumps of mass $\sim 10^6$ $M_\odot$. This mass concentration then leads to the formation of a massive black hole fuelling of which ignites quasar activity. Numerical simulations have also been performed that support the analytic arguments.
(Arati Chokshi, Uma Gorti and H. C. Bhatt)

### 3.2.3 A Cocoon Model for Galaxy Formation

A model of galaxy formation was developed with the primary episode of star formation being induced in high pressured cocoons around AGNs. This cocoon model succesfully explains the sizes, shapes, environments and statistics of the present day galaxy population. Thus the epoch of galaxy formation is coincident with the observed epoch of maximum AGN activity between redshifts of 2-3.
(Arati Chokshi)

### 3.2.4 Radio and Optical Investigation of Radio Galaxies with Precessing Jets

We have initiated a programme to obtain detailed radio and optical data for a selected sample of radio galaxies showing unambiguous signatures of precession of radio beams in the form of "S" or "Z" shaped inversion symmetric radio morphology. It is believed that cause of such precession involves either binary black holes or a precessing accretion disk surrounding a supermassive black hole. The general features of these models are mergers and close gravitational interaction between pairs or groups of galaxies. We intend to search for observational evidences for such processes in the nuclear and extranuclear regions of the selected radio galaxies. Towards this end, under an ongoing programme, optical photometry data using the 2.3 meter VBT at Kavalur and multiband radio data using the Very Large Array (VLA) at New Mexico, USA, has been obtained for a few objects in the sample. The analysis and interpretation of these data are in progress.

Interesting new results have been obtained for the cD galaxy at the center of galaxy cluster Abell 2626. In optical red band, the galaxy shows peculiar morphology consisting of a pronounced (13 kpc) shift of the galaxy nucleus towards the north-east and significant isophotal distortions, suggestive of a possible merger in the recent past. In radio band, remarkable inversion symmetry of the radio emission over the angular scales ranging from arcseconds to arcminutes was discovered. The VLA 1.4 GHz data has revealed a compact flat spectrum radio core coincident with the optical nucleus and a pair of emerging radio jets showing the morphology of helically twisted precessing beams. The large scale morphology mapped with VLA at 327 MHz confirms to the precession geometry and suggests that the axis of the radio jets started precessing sometime in the recent past (possibly due to a merger) as the outermost regions of the radio stucture, at a projected distance of 160 kpc from nucleus, show linear instead of helical precession geometry. An estimate of the precession period P= $3.5 \times 10^8$ year was obtained from morphological and the spectral index data. Another order of magnitude estimate of the precession period, P = few $10^8$ year was obtained assuming an accreting super massive black hole of mass M = few $10^8$ $M_\odot$, generating a limiting 'Eddington Luminosity' of $L_{Edd}$ = few $10^{46}$ erg/second and having a mass to energy conversion efficiency of 10 percent. The close agreement between the two periods and the radio/optical morphology are consistent with the precessing beam hypothesis. A higher resolution (< 1 arcsecond) radio and optical study of the nuclear region is underway to understand this interesting object better.
(J. Bagchi and A.K. Pati)

### 3.2.5 Optical variability of Blazars

Blazars show dramatic variations on all time scales, but few objects have been studied well enough to determine the power density spectra or structure functions over more than two decades in time. Variations on time scales of about one day or less is commonly described as Intra-day variability (IDV). Irrespective of the detailed mechanism, IDV in blazars provides an important tool for studying variations on very small spatial scales. There is currently no other means at hand to achieve similar resolution, so increasing our reliance on this tool depends solely on improving our understanding of the phenomena involved. IDV will not only enable us studies at high resolution, but also about the photon densities, spectral energy distributions, polarization properties, flares, etc. Result obtained from such studies will provide clues for deeper understanding of the radiation processes, origins of jets, jet acceleration mechanisms and in general the physics of AGNs.

We have regularly monitored two blazars, OJ287 and 3C66A, during December 1995 and April 1966, using the CCD systems at the Cassegrain focus of 77 cm reflector of VBO. White light differential photometric observations were carried out for these two blazars. IRAF and DAOPHOT software packages were used to obtain relative variations of these objects. Both the blazars have displayed dramatic variations on different time scales (within the night, night-to-night and major outburst on the times cale of a month or so). Long-term variations of OJ287 and 3C66A are shown in Fig. 3.2.5.1a,b. We shall use different models to explain these results and to undestand the physics of these objects.

(K.K. Ghosh, S. Soundararajaperumal, S. Pukalenthi, M. Gopal, and M.J. Rosario)

### 3.2.6 Radio through $\gamma$ - ray Observations of AGNs

Active Galactic Nuclei (AGNs) emit radiation over the entire electromagnetic spectrum and the energy output varies with time, on different time scales for different frequencies and more rapidly at higher energies. Gravitational energy release is usually invoked to explain both short time-scale variations at higher frequencies and large overall luminosity of AGNs. However, the details of physical processes involved remain obscure. In order to find out the various physical mechanisms responsible for the origin of their entire electromagnetic spectrum, it is important to observe these objects from radio to $\gamma$ - ray frequencies. Also it is important to monitor their variations in each waveband. From an observational point of view it is an extremely difficult job. However, we have been successful in organizing international campaigns to observe a Seyfert galaxy, Fairall-9, a radio galaxy, 3C390.3, and a blazar.

(K.K Ghosh, Soundararajaperumal)

### 3.2.7 Environmental Effects on Properties and Evolution of Galaxies

Deep optical images using the VBT, in B, V, R and I bands have been obtained for the first time for several nearby and intermediate-redshift clusters of galaxies discovered serendipitously by the Einstein x-ray satellite. Identification of cluster members, their photometry and analysis of their surface-brightness profiles are in progress. The clusters imaged this year are : MS0735.7+7421, MS0849.7-0521, MS0904.5+1615 MS1125.3+4324 and MS1306.7-0121. A Hickson Compact Groups of galaxies (HCG 42), 2 poor clusters of galaxies from the AWM Catalog (AWM 5, AWM 7) and field elliptical galaxies have also been imaged with the same filters. Aperture photometry is being performed on these as well.

(Mangala Sharma and T.P. Prabhu)

### 3.2.8 Optical Surface Photometry of Radio Galaxies

Several radio-galaxies in the optical B,V,R bands using the VBT were observed. Surface photometry of these radio-elliptical galaxies was performed. The preliminary results show that there are no optical features like dust lanes, embedded nuclear disks etc in these elliptical galaxies.

(P.N.Bhat*, K.P.Singh*, T.P. Prabhu and Mangala Sharma)

## 3.3 CLUSTERS OF GALAXIES

### 3.3.1 Simulation of Deep Galaxy Fields

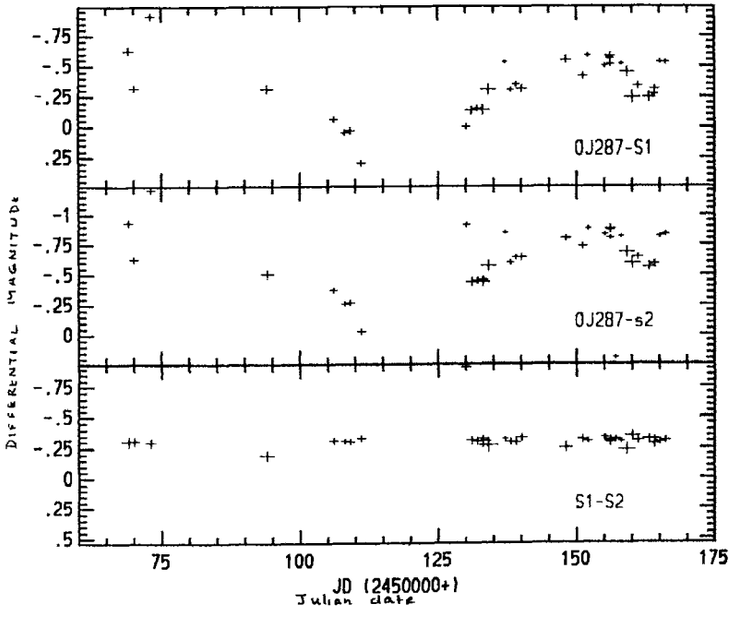
Simulation work of deep galaxy fields was continued at the FIR and submm wavelengths to assess the role of passive galaxy evolution in systems at high redshifts.

(Arati Chokshi, Paola Mazzei* and Carol Lonsdale*)

### 3.3.2 Estimation of Cluster-Scale Magnetic Fields Derived from Inverse Compton X-rays

The estimation of the magnetic fields permeating the large scale cosmic structures such as the clusters and the superclusters of galaxies and the study of origin and evolution of these fields is one of the challenging problems of Cosmology. Very little or incomplete data on the above topic exists at present owing mainly to the difficulties involved in the estimation of such fields with sufficient accuracy. A new project, with an aim to estimate the magnetic field strengths in clusters has been initiated recently. We focus on clusters where diffuse, synchrotron emitting , ultra-steep-spectrum radio sources were detected in our previous studies using the Ooty Synthesis Radio Telescope (OSRT) and the Very Large Array (VLA). We search for the diffuse, X-ray 'glow' generated by the amplification of the energy of cosmic microwave background photons through the inverse Compton scattering on the relativistic synchrotron electrons/positrons residing in the intra-cluster medium. An umambiguous detection of this X-ray flux would lead to an estimate of the average magnetic field pervading the volume of the diffuse radio plasma. In this method no a-priori assumptions such as the equipartition or the minimum energy condition need be invoked. A search employing the new or archival data from EINSTEIN, EXOSAT and ROSAT X-ray telescopes is in progress. A diffuse, very steep spectrum radio source (VSSS), 0038-096 in the field of cluster Abell 85 was detected by us in an earlier survey with OSRT and the VLA. At 327 MHz frequency the source was found to be extremely large in linear size (major axis size about 500 Kpc) and to possess an unusually steep spectrum at centimetric wavelengths. No optical galaxy, visible to the limits of the Palomar Sky Survey plates could be associated with the radio source, suggesting that 0038-096 is possibly a 'relic' radio plasma of unknown origin. The spectral shape strongly suggests that the emission mechanism is synchrotron radiation and thus, the presence of an internal magnetic field is virtually certain. The search for inverse Compton scattered X-rays has resulted in the first of its kind detection of an X-ray source co-spatial with 0038-096. The X-ray emission was detected both in EINSTEIN observatory data (in 0.2 to 4.0 Kev band ) and in the ROSAT data (in 0.5 to 2.0 Kev band). An excess X-ray emission (over the normal cluster thermal X-rays) of 1.35 X $10^{43}$ erg/s (in 0.2 to 4 Kev band) was detected with about 4 sigma significance. The average magnetic field in the cluster volume co-spatial with the radio and the X-ray emission was derived to be 1.23 (+0.42,-0.31) $\times$ $10^{-6}$ Gauss. Interestingly, this field value is remarkably close to the magnetic field strength of 1.55 $\times$ $10^{-6}$ Gauss derived assuming the standard minimum energy condition. It is thus possible that the minimum energy condition actually holds in the case of 0038-096. Further work, towards understanding the origin and evolution of the 'relic' 0038-096 and its magnetic field is being carried out.

(J. Bagchi)



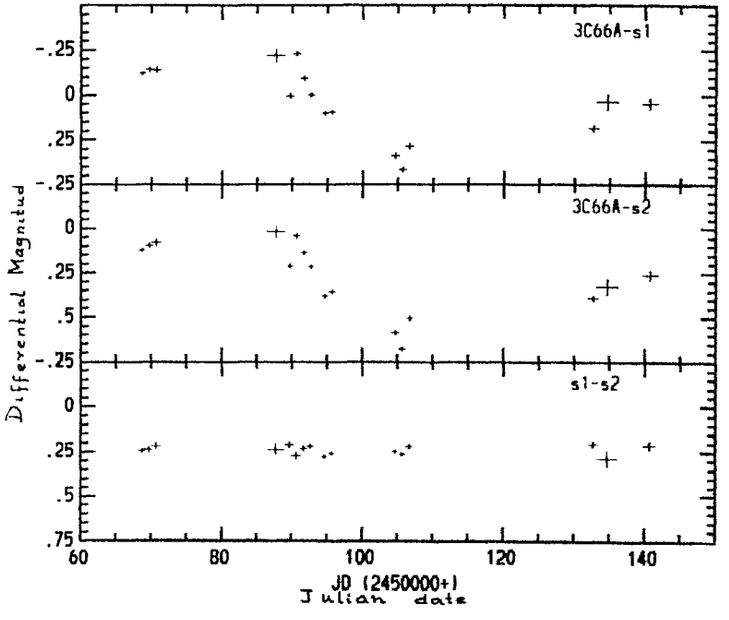




**Fig. 3.2.5.1a** The upper panel shows the differential magnitude between OJ287 and a field star (S1) versus Julian date. The middle panel is the same as that of the upper panel, but for another field star (S2). The lower panel shows the differential magnitude betwen S1 and S2 versus the Julian date. Both the upper and the middle panels show the dramatic variations of OJ287 between night-to-night and major outburst on months time-scale.

**Fig. 3.2.5.1b** Same as Fig. 3.2.5.1a, but for 3C66A.

# 4. INSTRUMENTS AND TECHNIQUES

## 4.1 SPECKLE INTERFEROMETRY

### 4.1.1 Testing of Speckle Interferometer

I. The newly developed speckle interferometer for the 2.34 meter Vainu Bappu Telescope (VBT), at Vainu Bappu Observatory (VBO), Kavalur, has been tested at the Laboratory as well as at the Cassegrain end of the said telescope, using an uncooled EEV intensified CCD as detector. Based on these tests, we have corrected a few attachments which got disturbed during black chromium plating treatment of the mechanical adapters and house, made of low expansion Martensitic variety of stainless steel material (SS 410), at the Central Manufacturing Technology Institute (CMTI), Bangalore. The performance of this interferometer is excellent. The details of the performance of the interferometer is reported in a journal.
(S.K. Saha)

### 4.1.2 Reducing Internal "Seeing"

The flat wavefront enters the telescope warped significantly by virtue of its passage through a turbulent atmosphere containing a distribution of cells of differing in size and refractive index. These cells move rapidly across the path of the light, which could be due to the winds at various heights, convection in and around the dome, off the surface of the telescope structure etc. In this respact, we found a significant improvement of the seeing at VBT, during the observations of speckles of close binary stars (separation $<$ 1 arc second), by introducing an interface (spacer) between the mounting flange on the telescope and the afore-mentioned interferometer. This spacer is designed with two plates separated by six pillars of equal heights (450 mm), so as to prevent the formation of eddies that may be produced due to hot air entrapment, and allows the free movement of air.
(S.K. Saha)

## 4.2 SPECKLE IMAGING OF CLOSE BINARY STARS

### 4.2.1 Observations of Close Binary Stars

The new speckle interferometer was used to record a few thousand specklegrams of 8 close binary stars (separation $<$ 1 arc second) using 2.34 meter Vainu Bappu Telescope (VBT), at VBO, Kavalur, through the narrow band filters, using an EEV uncooled intensified CCD (ICCD) camera which provides a standard CCIR video output. The images were acquired with exposure times of 20 millisecond using a Data Translation$^{TM}$ frame-grabber card DT-2861 and subsequently stored on to the hard disk of a PC486 computer. This system allowed us to record 64 frames continously in a few seconds time. Data are being analysed. Conversions of these data from DT-IRIS to Fits, to suit IRAF compatable has been completed. It is to be noted here that, the afore-mentioned ICCD is capable of attaining a limit of 7th. magnitude. If an intensified photon counting system can be made available, this interferometer can reach the faintest limiting magnitude ($\sim$ 16th. magnitude). Though the newly acquired Peltier-cooled intensified CCD was also used to record a few speckle-grams of stars, it is essential to use photon counting system for the faint object beyond 10th magnitude.
(S.K. Saha)

### 4.2.2 Blind Iterative Deconvolution of Binary Stars

The technique of Blind Iterative Deconvolution (BID) is being used to remove the atmospherically induced point spread function (PSF) from short exposure images of 17 binary stars, obtained at the Cassegrain focus of the VBT, Kavalur, using earlier version of the speckle interferometer. Though the earlier analysis of 2 binary stars, viz , HR5138, HR5747 showed the similarity of the magnitude diferences for the reconstructed objects (Saha and Venkatakrishnan, 1997) with those published in the bright star catalogue, the present analysis would help us to characterise the photometric quality of the reconstructions
(S.K. Saha)

# THEORETICAL ASTROPHYSICS

# 1. EARLY UNIVERSE

### 1.1 COBE Spectrum and Space-Time of String Theories

The geometric structure of superstring theories goes beyond the usual Riemannian one of general relativity. They also contain antisymmetric tensor fields and dilation scalar fields. The distinctive effects associated with these entities should have manifested themselves under the conditions prevailing in the early universe. This could have left a detectable imprint on the cosmic microwave background as the measured anisotropies give direct information about the way the amplitude of the inhomogeneities vary with wavelength i.e. they tell us about the variations in the space-time metric and the relative contributions of the different entities producing such variations. This in turn can be related to the additional geometric structure present in the gravity of superstrings. Thus we obtain constraints on the couplings and magnitude of these additional geometric features in these theories. These constraints are more stringent than those from other considerations such as primordial nucleosynthesis.
(C. Sivaram)

### 1.2 Topological Defect Scenario of Origin of the Highest-Energy Cosmic Rays (HECR)

The observed cosmic ray events at energies above $\sim 10^{20}$eV are difficult to explain in terms of the standard diffusive shock acceleration mechanism of origin of cosmic rays. An alternative possibility is to invoke the so-called "Topological Defect" (TD) mechanism, in which particles can be directly created with energies up to $\sim 10^{25}$eV from collapse and/or annihilation of topological defects such as magnetic monopoles and cosmic strings which could possibly have been produced in symmetry breaking phase transitions in the early universe as envisaged in grand unified theories.

A major uncertainty in the TD scenario is the injection spectra of various kinds of particles. The injection spectra are determined by the hadronic jet fragmentation spectra of quarks and gluons coming from the decays of massive "X" particles released from collapsing and/or annihilating TDs. The jet fragmentation of these quarks and gluons should be similar to those of the quarks and gluons produced in $e^+e^-$ collider experiments. We perform a detailed study of the recent LEP data on $e^+e^-$ experiments to extract a suitable fragmentation function and extrapolate it to energies of our interest. This is done by parametrizing the fragmentation function in a suitable manner within the framework of Modified Leading Logarithm Approximation (MLLA) in QCD together with the hypothesis of Local Parton-Hadron Duality (LPHD) which have recently been found to explain the collider data very well.
(P. Bhattacharjee and *G. Sigl)

The fragmentation function so obtained is being used to calculate the injection and the predicted processed spectra of nucleons, photons and neutrinos in the ultrahigh energy region ($E \geq 10^{18}$eV). These predictions will be testable by the up-coming Auger extensive air-shower detector and the proposed future MASS/OWL detector.
(P. Bhattacharjee, G. Sigl* and S. Yoshida*)

# 2. BLACK HOLES

### 2.1 Inertial Forces in General Relativity

Extensive study of gyroscopic precession (GP) has been undertaken earlier using the Frenet-Serret formalism in a completely covariant and geometric manner. Recently there has been considerable interest in the general relativistic analogues of inertial forces (IF). We have studied GP and IF together in static and stationary spacetimes in great depth. A major development in this area is our results leading to covariant connections between GP and IF. In the case of static spacetimes GP is directly related to centrifugal force. In the stationary case centrifugal force is replaced by a combination of centrifugal and Coriolis forces. These studies are expected to be significant for the physics of compact objects and black holes.
( K. Rajesh Nayak and C. V. Vishveshwara)

### 2.2 Balance between Gravitational and Electromagnetic forces

In a previous work, we investigated the equilibrium of a charged test particle placed in the combined gravitational and electromagnetic fields of a Kerr-Newman black hole. We have followed this up by analysing

both general relativistic analogues of inertial forces and the electromagnetic forces acting on the test particle. This has led to an understanding of the behaviour of these forces as well as the mechanism of equilibrium. (*J M. Aguirregabiria, *A Chamorro, K. Rajesh Nayak *J. Suinaga and C. V. Vishveshwara)

### 2.3 Kerr Metric

The role of the parameter 'a' associated with the Kerr metric which represents the angular momentum per unit mass of a rotating massive object has been converted into determining the rotationally induced quadrapole electric field outside a rotating massive object with external dipole magnetic field. A comparison of the result with that of the Newtonian case implies that the parameter 'a' represents the angular momentum per unit mass of a rotating hollow object.
(Sujan Sengupta)

### 2.4 Charge Particle Dynamics

Trajectories of charged particle in combined poloidal, toroidal magnetic field and rotation-induced unipolar electric field superposed in Schwarzschild background geometry have been investigated extensively in the context of accreting black holes. The main purpose of the investigation is to obtain a reasonably well insight on the effect of spacetime curvature to the electromagnetic field surrounding black holes. The coupled equations of motion have been solved numerically and the results have been compared with that for flat spacetime. It is found that the toroidal magnetic field dominates the induced electric field in determining the motion of charged particles in curved spacetime. It is shown that the toroidal magnetic field repels a charged particle from the vicinity of a compact massive object in a jet like feature and deconfines the particle from its orbit. The inclusion of electric field doesn't affect the trajectory significantly . In the absence of toroidal magnetic field the particle is trapped in a closed orbit. The major role of gravitation is to reduce the radius of gyration significantly while the electric field provides an additional force perpendicular to the circular orbit. Although the effect of inertial frame dragging and the effect of magnetospheric plasma have been neglected, the results (fig 2.4a,b) provide a reasonably well qualitative picture of the important role played by gravitation in modifying the electromagnetic field near accreting black holes and hence the results have potentially important implications on the dynamics of the fluid and the radiation spectrum associated with accreting black holes.
(Sujan Sengupta)

## 3. NEUTRON STARS AND PULSARS

### 3.1 Evolution of Crustal Magnetic Field

The ohmic decay of magnetic fields confined within the crust of neutron stars is considered by incorporating the effect of space-time curvature produced by the intense gravitational field of the star. It is shown that general relativistic effect reduces the magnetic field decay rate substantially and that especially at the late time of the evolution the decay rate decreases by several orders of magnitude when compared with the case without the relativistic effect. The message which is conveyed by the calculations is that whatever be the electrical conductivity of the crustal material, high or low, irrespective of the question whether the magnetic field vanishes at the core or not and whatever be the impurity content of the neutron star crust, the decay time of the magnetic field is lengthened by the intense gravitational field that certainly exists inside the star (fig 3.1.1). Although the effect of neutron star cooling – another factor that reduces the rate of field decay – is not taken into account for the sake of simplicity, the result is important in the sense that it establishes concrete restrictions on the possible ways of obtaining short ohmic decay times for magnetic fields in neutron star models. An interesting feature of these results is the fact that the decay time depends on the compactness of the neutron star. Therefore, the general relativistic effects on the decay of magnetic field could be a possible tool for restricting the equation of state of matter inside the star which determines the compactness of the neutron star.
(Sujan Sengupta)

### 3.2 Pulsar Magnetosphere

Considering stationary and axisymmetric electromagnetic vector potential in Schwarzschild background geometry the components of the induced electric field that arises due to the rotation of the magnetic dipole of a spinning neutron star, have been derived and compared with

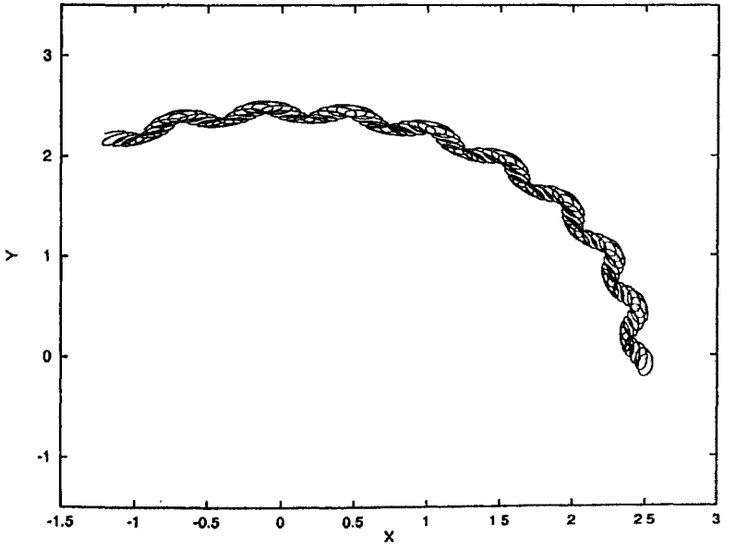



Fig 2.4a. Projection (in XY plane) of the trajectory of a charged particle in poloidal magnetic field and rotation-induced unipolar electric field around a Schwarzschild black hole.

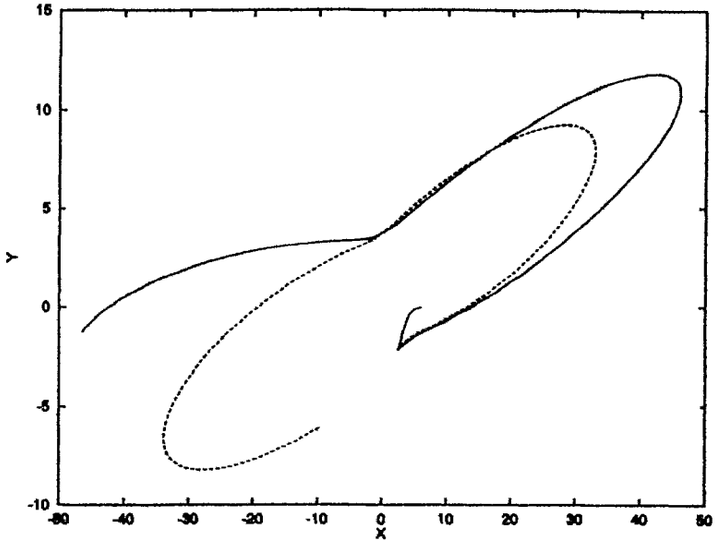



Fig 2.4b. Projection of the trajectory of a charged particle in XY plane. Solid line represents the trajectory in combined poloidal and toroidal magnetic field and rotation-induced unipolar electric field around a Schwarzschild black hole while broken line represents that without the electric field

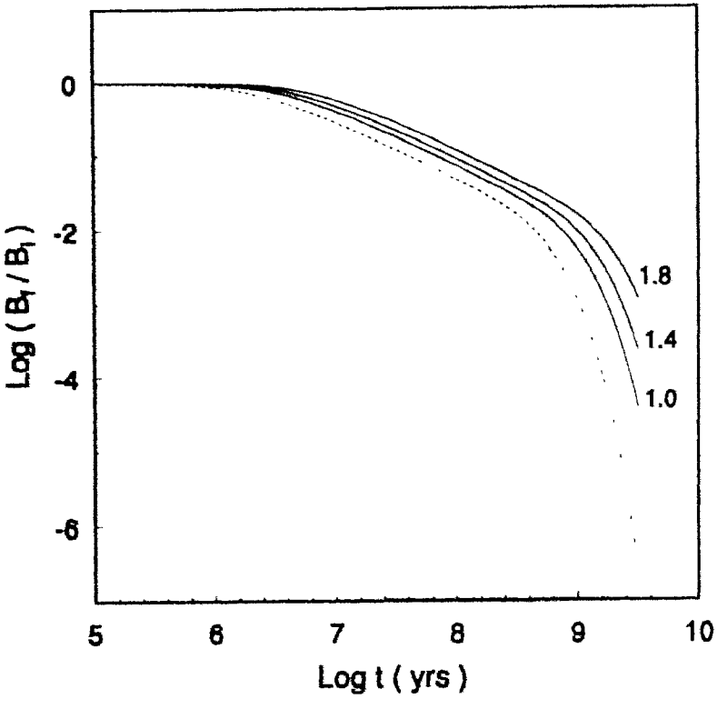
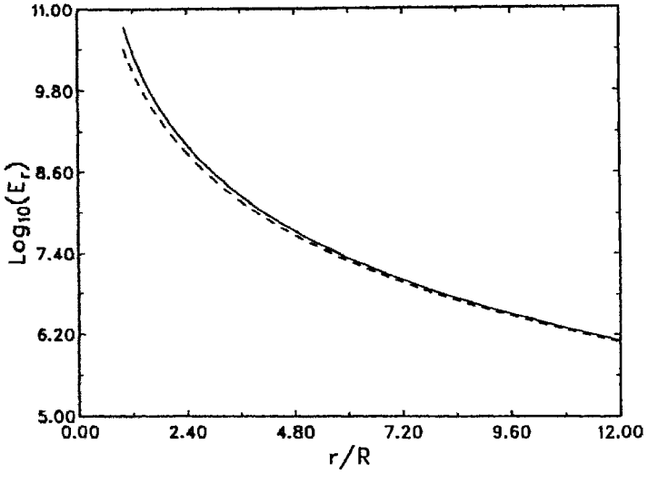



Fig 3.1 1 The evolution of surface magnetic field normalized to its initial value for flat and curved space-times. Solid lines represent the results for curved space-time while broken lines represent that for flat space-time. The numbers near the curves indicate mass in 1 $M_{\odot}$. For all the cases the radius of the star is taken as R=10.6 km and the electrical conductivity is calculated for a 1.4 $M_{\odot}$ neutron star crust.



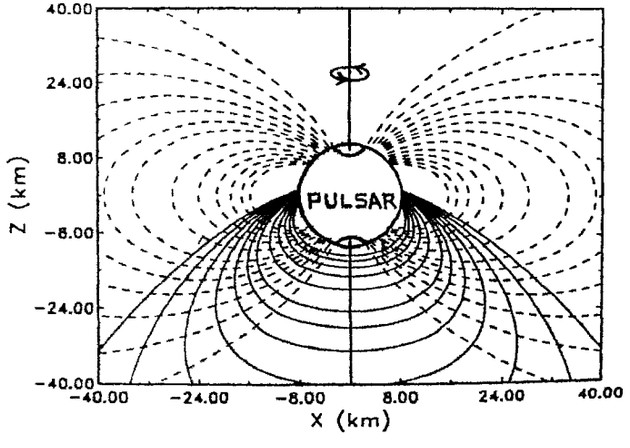




Fig 3.2a. The r component of the quadrapole electric field at an angle theta=0° to the axis of rotation for Crab pulsar as a function of distance from the stellar surface. Solid curve represents the field intensity for curved spacetime while dashed curve for flat spacetime.

Fig 3.2b. The combined dipole magnetic and induced electric field lines in curved spacetime for the Crab pulsar with $\mu$=2 x $10^{30}$ G $cm^3$ by considering plasma filled magnetosphere. Solid curves represent the induced electric field lines while dashed curves for the dipole magnetic

that in flat spacetime. It is found that spacetime curvature increases the electric field intensity significantly near the surface of the star. As a consequence, in vacuum magnetosphere the acceleration of charged particles along the direction of the magnetic field increases significantly near the surface. Also the increase in the electric field intensity near the surface results in increasing the surface charge density significantly. The quadrapole electric field lines have been presented for Crab pulsar, as an example, in both curved and flat spacetime and it is found that the difference in the field lines for the curved and the flat spcetimes is well distinguishable upto 40 stellar radii (fig 3.2a,b). In a plasma filled pulsar magnetosphere the electric field lines are independent of distance in flat spacetime but in curved spacetime they depend on $r$ near the surface. However, the field lines in curved spacetime asymptotically become independent of $r$ at large distance. The induced electric field lines in curved spacetime have been presented by taking Crab pulsar, as an example and the combined dipole magnetic field lines and the induced electric field lines near the surface of the star have been presented as well. Due to the increase in the electric field intensity near the surface the space charge density of a plasma filled magnetosphere increases significantly from that in flat spacetime. All the quantities measured in curved spacetime, however asymptotically reach their respective values in flat spacetime as a result of the usual boundary condition. Since the ratio of the components of the electric field in curved spacetime to that in flat spacetime is the same, therefore the effects of gravitation on various electromagnetic mechanisms remain the same for all types of magnetospheric models which assume stationary and axisymmetric vector potentials. Hence the results are very important in the context of radiation mechanisms in pulsars. Though the most idealized models of the pulsar magnetosphere have been considered, the effects of spacetime curvature to the induced electric field would remain the same provided there is no dipole or gravitational radiation. The effect of inertial frame dragging is negligible even for millisecond pulsars but the depurture from spherical symmetry due to rapid rotation of the star could alter the scenario significantly. Nevertheless, the results would provide reasonably well insight on the effect of spacetime curvature to the induced electric field outside a rotating neutron star with its magnetic axis aligned to the rotational axis.
(Sujan Sengupta)

### 3.3 Disk Accretion onto Rapidly Rotating Neutron Stars

General relativistic effects, most notably the rotation induced inertial frame dragging effect, have been studied for disk accretion onto rapidly rotating, low magnetic field neutron stars. In particular, we have investigated these effects for the X-ray emission, and have computed the disk and boundary layer luminosities for realistic neutron star models. Along with these, we have obtained the sequences of rotating neutron star models and the Keplerian termination point of these models, using a rapidly rotating neutron star equation of state has also been investigated.
(B.Datta and A.V.Thampan)

### 3.4 Radial Pulsations of Rotating Neutron Stars

Eigenfrequencies of radial pulsations of slowly rotating neutron stars were calculated in a general relativistic formalism given by Chandrasekhar and Friedman. The main result obtained was that the squares of the frequencies are always a decreasing function of the central density of the neutron star. The decrease of the squared frequency is sensitive to the equation of state of neutron star matter, and was illustrated using realistic equation of state models.
(B.Datta, S.S.Hasan, P.K.Sahu* and A.R.Prasanna*)

### 3.5 Accretion onto Quark Stars

The possibility that the central object in low-mass compact binaries is a quark star has been explored, and the accretion luminosities incorporating general relativity and rapid rotation of the quark star (assuming it to be non-magnetic) have been calculated. For this, two classes of evolutionary sequences of the rotating quark star were considered : normal and supramassive of fixed baryon rest mass. Because quark star sequences allow for very low mass stable configurations, several interesting accretion luminosity scenarios are possible - in contrast to the usual low-mass X-ray binaries with neutron star as the central compact object.
(B.Datta and A.V.Thampan)

# 4. TURBULENCE

### 4.1 Evolution of a Turbulent Fluid

We have developed a code for studying the effect of compressibility and anisotropic forcing in the evolution of a turbulent fluid. We had adopted the spectral method to evaluate the various spatial derivatives and used Runge-Kutta Fourth order explict time marching scheme to study the evolution in time . We could confirm the onset of the instability which was also studied by Frisch et.al.(Physica 28D (1987) 382) and is known as the Anisotropic Kinetic Alpha effect (AKA). The key feature of such a phenomena is the lack of parity on small scales. This condition can be brought about either by a specific type of forcing or by other mechanisms like compressibility or rotation. In our work we have concentrated on the role of compressibility and different types of forcing in producing such an effect. We note that in our simulations apart from an inverse cascade of energy (which is evident from a look at the energy spectrum at different intervals, and studying the temporal evolution of different wave modes..) the medium acquires a strong polarity in terms of developed regions of helicity of either a positive or negative sign. The flow appears to be 'Re-laminarised'. (as seen by the 3D vector field pictures). We have also studied the evolution of vorticity, and found that persistent vortex structures evolve during the evolution. This work lends an additional support to the idea that it is possible that coherent stuctures and thus structure - formation as such involve the concept of inverse energy cascade, and that helicity and helicity related quantities (like helicity fluctuations) play an important role. The code was executed on the SP2 Convoy at the Supercomputer Education and Research Centre ,I.I.Sc as well as on the Power Challenge at I.I.A.
( R. D. Prabhu, V. Krishan, and *A. Basu)

### 4.2 Flat Rotation Curves Including Keplerian Motions

A model of the flat rotation curves of galaxies was given in an earlier work. This model attempts to explain the rotation curves without invoking dark matter. Instead it depends on certain properties of a turbulent medium. By going into the local Keplerian frame, the equations for turbulent motions were re-derived. It is found that the contributions of Keplerian and turbulent motions are required to account for the flat rotation curves of galaxies.
(R. D. Prabhu and V. Krishan)

# 5. RADIATIVE TRANSFER

### 5.1 Line Profiles from Stars with Circumstellar Shells

The observations of KI emission line profiles by Gustafsson and his colleagues of the star R Scl are simulated theoretically. The star has circumstellar shell which is expanding at an approximate velocity of 15 Km $s^{-1}$. The observations of the line at different points in the shell are computed. The star with a radius of 3.5 x $10^{13}$ cm (with $T_{eff} = 2550K$) has its shell extended upto $\approx 8 \times 10^{16}$ cm. The observed lines are at $2.5 \times 10^{16}, 3 \times 10^{16}$ cm etc. The radial optical depth at the centre of the ine 7699 $\AA$ of KI between the radii $r_n$ and $r_{n+1}$ is

$$\tau(r_n, r_{n+1}) = K\Delta r(v r_n r_{n+1})^{-1}$$

where $\Delta r = (r_{n+1} - r_n)$, $\bar{v}$ is the average velcoity of the matter between the radii $r_n$ and $r_n + 1$ and K is the physical constant corresponding the line 7699 $\AA$ of Kl and equal to $5.1 \times 10^{18}$. The optical depth along the line of sight is

$$\tau(p) = 2KL(\tau p^2 \bar{v})^{-1}$$

where p is the impact parameter and $L^2 = R^2 - p^2$, $R$ being the outer radius of the shell. The euqation of line transfer has been solved in comoving frame using the radial optical depth and the line profiles are obtained by using the optical depths along the line of sight. The impact parameter p at $\tau = 1$, is $4.4 \times 10^{16}$ cm. The radial otical depth is 6.67 and the line of sight optical depths change from maximum (p = 1.07 x $10^{16} cm$) of 194.2 to a minimum of (p = 8.69 x $10^{16}$ cm) 0.1. The computed profiles are shown in figures. The quantities $V_a$ and $V_b$ are the inner and outer velocities in mean thermal units. $\epsilon$ is the Non-LTE parameter and $\beta$ is the ratio of absorption in the continuum to that in the line centre. F is the flux in the line in ergs $cm^{-2} s^{-1} hz^{-1}$. x is the normalised frequency measured in Doppler units.
(A.Peraiah, B.A.Varghese and M.Srinivasa Rao)

**5.2 Radiative Transfer in 2- and 3- Dimensions**

The interaction principle for these two geometries have been developed. For example for a two dimensional case ( X - Y geometry), the principle is written for the configuration given in figure 5.2.1. Here the output intensities $U^-(A), U^-(B), U^-(C), U^-(D)$ are written in terms of the reflected fractions of the input intensities $U^+(A), U^+(B), U^+(C)$ and $U^+(D)$ and the transmitted fractions of the intensities $U^-(A0), U^-(B0), U^-(C0)$ and $U^-(D0)$ together with the internal sources $\Sigma(A), \Sigma(B), \Sigma(C)$ and $\Sigma(D)$. The principle is written as

$$\begin{bmatrix} U^-(A) \\ U^-(B) \\ U^-(C) \\ U^-(D) \end{bmatrix} = \begin{bmatrix} R_A U^+(A) \\ R_B U^+(B) \\ R_C U^+(C) \\ R_D U^+(D) \end{bmatrix} + \begin{bmatrix} T_{AA} & T_{BA} & T_{CA} \\ T_{AB} & T_{BB} & T_{CB} \\ T_{AC} & T_{BC} & T_{CC} \\ T_{AD} & T_{BD} & T_{CD} \end{bmatrix} \begin{bmatrix} T_{DA} \\ T_{DB} \\ T_{DC} \\ T_{DD} \end{bmatrix} + \begin{bmatrix} U^-(A0) \\ U^-(B0) \\ U^-(C0) \\ U^-(D0) \end{bmatrix} + \begin{bmatrix} \Sigma(A) \\ \Sigma(B) \\ \Sigma(C) \\ \Sigma(D) \end{bmatrix}$$

Similarly for a three dimensional cuboid the interaction principle can be written. Next step is to obtain a star algorithm in the two-dimensional X-Y geometry.

(A.Peraiah)

**5.3 Line Polarization In Expanding Stellar Atmospheres**

The effect of differential radial velocity on the distribution of line intensities and line polarization in a stellar atmosphere stratified in parallel planes has been presented in detail. The medium is assumed to be homogeneous and isothermal. Two different types of velocity rules have been adopted in this case with zero velocity at the innermost layer. The results have been compared with that of the static case. The line intensity profile and the polarization profile in the comoving frame as well as in the observer's frame are discussed in detail. It is found that in a purely scattering homogeneous and isothermal atmosphere, the amount of emergent and backscattered intensities of the radiation field is the same at each point along the geometrical depth, i.e., there is no change in photon energy at any layer of the atmosphere. This situation is altered significantly with the inclusion of a non-zero velocity field. With the inclusion of even a small velocity gradient, the intensity of the emergent radiation falls slowly from the innermost layer to the outermost layer. As the velocity gradient increases, the fall in the intensity towards the outer region is more rapid. The emergent intensity in the comoving frame decreases as the velocity increases with substantial asymmetry in the profile at the wing. Except for large velocity gradient the degree of polarization in comoving frame remains almost the same for any velocity gradient. In a purely scattering medium the flux profile along the line of sight becomes more and more asymmetric with absorption feature when a high velocity gradient is included. The amount of total flux in this case decreases with the increase in velocity gradient. The degree of polarization in the observer's frame is maximum for small velocity gradient and it decreases with the increase in velocity. In a partially scattering medium, the degree of polarization in comoving frame as well as in the observer's frame is substantially less compared to that in the purely scattering medium implying that a non-zero thermalization parameter decreases the anisotropy of the atmosphere. Unlike the case for a purely scattering medium, in a partially scattering medium the flux profile in the observer's fraime is symmetric even with the inclusion of large velocity gradient. The results could be useful in obtaining a general idea about the resonance line polarization in a radially expanding plane-parallel stellar atmosphere. As the stellar radius increases the curvature effect plays a dominant role and a spherically symmetric geometry becomes more relevant in that case. In the present thesis the effect of differential radial velocity in the distribution of line intensities and line polarization for a spherically symmetric, inhomogeneous and isothermal medium is also presented in detail. The atmospheric models could represent the photospheric layers of early type stars, giant and supergiant stars as well as luminous late type stars. In the case of a spherically symmetric stellar atmosphere, a fixed value of the thermalization parameter is taken in all models and the effect of differential radial expansion to line polarization under different optical depth as well as sphericity of the medium has been discussed in detail. Two different types of velocity laws have been adopted with zero velocity at the innermost shell. The velocity at the

outermost shell has been taken to be 5, 10, and 20 mean thermal units to study the effect of small, medium and large velocity gradients. The results have been compared with that of the static case. The emergent intensity in comoving frame increases significantly with the inclusion of velocity field. The change in the emergent intensity in comoving frame is maximum when a small velocity gradient is included. The emergent total intensity profile in comoving frame remains almost symmetric at the line but significant asymmetry is found at the wing. The asymmetry increases with the increase in the velocity gradient. The degree of polarization in comoving frame decreases with the increase in velocity gradient. The frequency independent l and the r components of the source function increases towards the inner region for all velocity gradients. The total flux profile along the line of sight for static case is symmetric but with the inclusion of velocity field it becomes highly asymmetric with the greatest change in the profile when small velocity gradient is considered. As the velocity gradient increases, the amount of emergent flux decreases at the line. The important role of velocity profile is revealed when large velocity gradient is included. The degree of polarization in the observer's frame is negligible at the line where it is almost zero. It is found that the effect of different velocity rules is more important than that of the velocity gradient in the formation of the polarization profile along the line of sight. Significant changes in both the intensity profile and the polarization profile in comoving frame are found when the total optical depth is increased. With the increase in total optical depth, the effect of velocity field on the emergent total intensity and the degree of polarization in comoving frame reduces. Although the increase in total optical depth reduces the effect of velocity field on the source function, the emergent total flux and the degree of polarization along the line of sight are not affected significantly. The emergent intensity in the comoving frame increases with the increase in sphericity. However the polarization profile remains unaltered. With the increase in sphericity, the total flux along the line of sight increases in great extent and the profile becomes more symmetric. The anisotropy of the medium remains almost unaffected and hence the degree of polarization remains the same with the increase in sphericity.

The net polarization of light emitted by a spherical star, however, is identically zero. Therefore a comparison with observational results are not possible at this stage. For that purpose one has to consider a distorted medium and to calculate the disc integrated flux and polarization profiles. This aspect is a topic which needs further study since it represents the closest situation to the feasibility of observations. Nevertheless, the present study can provide a reasonably good understanding of the basic features of the polarized line formation problem in a radially expanding and extended spherical stellar atmosphere.
(Sujan Sengupta)

### 5.4 An Operator Perturbation Method for Polarized Line Transfer: Hanle effect in weak magnetic field regime in 1D media

A Polarized Approximate Lambda Iteration (PALI) method (Faurobert-Scholl et al. 1996, ) was developed to treat the resonance scattering in lines formed under the influence of a weak magnetic field. It is well known that the presence of a magnetic field in general, makes the radiation field non-axisymmetric. We restrict our attention to lines formed with complete frequency redistribution (CRD) in 1D media. We employ the Fourier azimuthal decomposition technique of Faurobert-Scholl (1991) as a theoretical framework to include the azimuthal angle dependence of the radiation field, in the presence of a magnetic field. In this technique, the polarized transfer equation for the Stokes vector $(I\ Q\ U)^T$ is Fourier decomposed to an equivalent transfer equation for a vector with 6 components which represent the irreducible tensorial components of the non-axisymmetric radiation field. The transfer equation is basically solved in the Fourier space, and finally, the Stokes vector $(I\ Q\ U)^T$ is obtained by a Fourier composition of these azimuthal components. This procedure turns out to be very efficient.

The Hanle redistribution problem is formulated as an integral equation for a 6-component source vector (see Faurobert-Scholl 1991). This integral equation is solved using our PALI method. The approximate Lambda operator is now a $(6 \times 6)$ matrix, with the first $(2 \times 2)$ block being identically same as the approximate operator of the PALI method. Thus, the equations of our PALI method can be recovered from the more general Hanle redistribution method (which we refer to as PALI-H) presented here, by setting the magnetic field intensity $B$ to

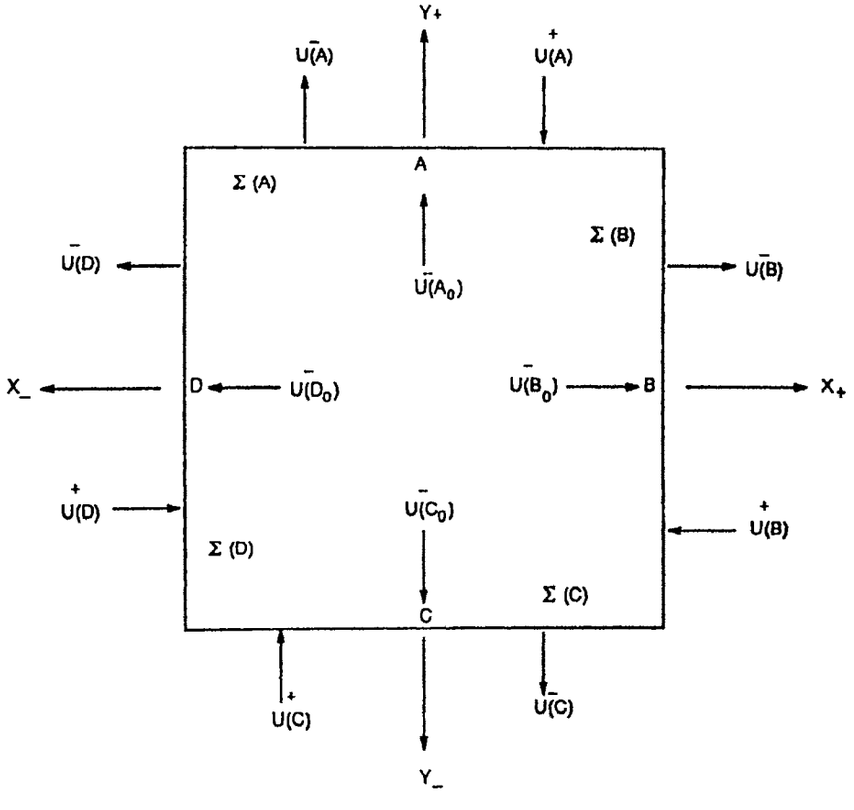



Fig 5.2.1. Schematic diagram for the rays undergoing radiative transfer in 2 dimensions.

zero.

The natural way in which the source vector in Fourier space can be factorized into a product of angle dependent matrix $\hat{B}(\mu)$, magnetic field dependent matrix $\hat{M}_B$, and optical depth plus frequency dependent source vector $\mathbf{P}(\tau, x)$, allows us to deal with the more general case of an arbitrary depth variation of vector magnetic field, in a straightforward manner. In this paper, we extend to the case of polarized line transfer, the scalar grid doubling strategy of Auer et al. (1994). We show that such a strategy, which automatically estimates the true error of an iterative solution, apart from accelerating the iterative convergence, is very useful to the polarized transfer problems, because it avoids the arbitrary imposition of an iterative stopping criterion by the user. As in the case of PALI method, the convergence rate is basically controlled by the 'propagator for the intensity', although the contributions to the maximum relative correction comes mainly from the 'polarization coupling components'.

(*M.Faurobert-Scholl, K. N. Nagendra, and *H. Frisch)

# PHYSICS

# 1. GRAVITATION EXPERIMENTS

## 1.1 Equivalence Principle Test

The primary focus of work in this area has been towards a Test of the Principle of Equivalence at a precision exceeding 1 part in $10^{13}$. Our previous runs of data acquisition have shown large correlations between drift in the torsion balance and the ambient pressure in the underground laboratory. Atmospheric pressure in the tropics varies dominantly with diurnal and semi-diurnal time periods; the resultant drift in the torsion balance, being at very low frequencies, constitutes background noise in the signal band (diurnal frequency), and needs to be suppressed in order to reach the precision levels that are targetted. Much engineering effort in the past year has been directed towards shielding the sensitive apparatus from variations in atmospheric pressure. This effort has two prongs, the first of which is that the entire ultra-high-vacuum (u.h.v.) chamber that contains the torsion balance, together with the optical lever that interrogates the balance, has been enclosed within a very large (6.5 metre tall, 1.6 metre diameter, 3 tonne mass) high vacuum (h.v.) chamber that was brought into operation during the past year. The h.v. chamber with its large thermal mass will damp thermal variations, and will also directly shield away the pressure wave from the primary apparatus.

(R.Cowsik, N. Krishnan*, D.B. Mane*, P.K.S. Murthy*, S.M. Pereira*, C. Rajanna*, P.G. Rodrigues*, C.S. Unnikrishnan*, A. Vaidyanathan* S.K. Guram* and P.U. Kamath)

The second prong of this engineering activity has been to generate a hermetic seal for the entire underground laboratory, so that the sealed-off portion does not experience the atmospheric pressure wave - this involves the manufacture of large ( 4.2 metre diameter) aluminium flanges, to seal against an epoxy flange cast on the concrete wall of the laboratory. The flanges, being of such large size, have to be constructed in a segmented (angular sectors) form, and involve precision machining in order for the segments to match sufficiently accurately to allow hermetic sealing. This has been a multi-institution effort, with procurement and rough cutting largely handled at IIA (Mechanical Design Section and Workshop), heat treatment for hardening at the BARC Central Workshop, CNC milling at the TIFR Central Workshop, and final turning of the assembled flange at the BGML Workshop at KGF. The final stage of work on the flanges at the BGML Workshop is now almost over, and it is envisaged that this apparatus will be tested in situ in July 1997.

(R.Cowsik, P.U. Kamath, B.R. Madhava Rao, J. Krishnan*, N. Krishnan*, and D.B. Mane*)

New apparatus for the damping of the torsion balance has been developed in the past year: pendular oscillations are damped by a passive eddy-current scheme, which has the feature that it efficiently damps simple-pendular motion alone, while still permitting very high torsional Q ($> 10^6$) for the oscillator. A separate, active, mechanism for torsional damping is also designed, and this can be turned on whenever required. Work is currently underway to computerise the drive scheme for the active torsion-mode damping. A new suspension scheme has been developed for the balance, and this is anticipated to lead to lesser intrinsic dissipation in the suspension itself.

(N. Krishnan* and S.M Pereira*)

The ion pumps that maintain vacuum in the u.h.v. chamber operate on high voltage. With the installing of the u.h.v. chamber inside the h.v. chamber, coronal discharge is expected to arise, and some development activity was conducted in order to overcome this problem. New high-voltage feedthroughs were designed and tested; while these have not been perfect, a way has been found that overcomes the problem. Further design activity is continuing. Power and signal feedthroughs have been developed for carrying cables into the protected space of the experiment.

(N. Krishnan*, S.M. Pereira* and C.S. Unnikrishnan*)

## 1.2 Casimir Effect at Finite Temperature

Subsequent to our realization that the torsion balance constitutes a very sensitive measuring device for characterisation of the Casimir Force, some measurements elsewhere have been made that utilize this instrument for the purpose. However, there remains a very interesting aspect not yet probed, and that is the nature and magnitude of the Casimir Force at finite temperature. With our torsion balance we can precisely determine the Casimir force for a cavity size (wall separations) upto 300 microns, where the expected finite temperature force dominates over the zero- temperature value. Preliminary design is now underway.

(R. Cowsik, N. Krishnan*, C.S. Unnikrishnan*, B.P.Das, G. Rajalakshmi and D. Suresh)

## 2. ATOMIC PHYSICS

### 2.1 Comparison of the High Order Perturbative Convergence with Effective Valence Shell Hamiltonian Theory and Intermediate Hamiltonian Method

Convergence problem of Many-Body perturbation theory is known for a long time. Several techniques have been put forward to overcome this difficulties. We have analyzed the origin of the numerical instability of perturbative equations for both techniques as well as of the standard perturbative scheme. We have shown how to avoid this undesirable situation and obtain rapid perturbative convergence through proper choice of zeroth order energy.

(Rajat K Chaudhuri and K. F. Freed*)

### 2.2 Application of Effective Valence Shell Hamiltonian Method to Accurate Estimation of Oscillator Strengths and Excitation Energies for Mg-like Ions

Excitation energies and oscillator strengths are important parameters in astrophysics. We have computed these quantities for Mg-sequence using effective valence shell Hamiltonian method and obtained encouraging results.

(Rajat K Chaudhuri, B. P. Das and K.F. Freed*)

# INSTRUMENTATION AND FACILITIES

## 1. COMPUTER CENTRE

a) The Multiprocessor Power Challenge Computer from Silicon Graphics U.S.A has been installed. The system is used for high end numerical computing involved in theoretical astrophysics and physics problems.

The System configuration is
- four R 10000 processors
- 512 MB RAM
- 10 GB hard disk
- 2 GB DAT
- CD-ROM drive
- VT-100

Software packages include Multi processor Fortran, Mathematical libraries and a large number of utilities.

b) Hardware and Software installation of several workstations including the Ultra sparc for image data reductions. Systems are used for analysing data acquired from observational facilities at various field stations. The system configuration includes :Ultra Sparc model 170 /E with 128 MB RAM ,36GB Harddisk,24 Bit colour graphics monitor. Each of the Sparc 5 systems has 64 MB RAM and 2.1 GB harddisk.

c) A Domain Name Server on a INDY workstation has been setup as a prelude to developing a IIA web site. The content creation for the web server is to be initiated shortly.

d) A Number of personal computers were also installed on the desk top of the individual scientists which would allow them to have facilities like Graphics/Image display ,Text processing ,E-Mail and Internet access.

e) Planned, procured and installed a 60 KVA uninterrupted power supply to provide backup and conditioned power to computational and communication equipment currently available and planned in the near future.

f) In order to accommodate the newly acquired computing and communication equipment a new centre has been established on the fifth floor of the main building.

g) A Special purpose 8 processor CARD (GRAPE) for high speed computing of N-BODY problems obtained under the INDO-JAPANESE collaborative program has been installed and is operational.
(A.V.Ananth, J.S.Nathan and S.S.ChandraMouli)

## 2. ELECTRONICS

### 2 .1 DSP Based CCD Data Acquisition Board

A CCD Data acquisition board based on a high speed Digital Signal Processor (DSP-M56002), has been developed to acquire data from the CCD controller. The board interfaces with an ISA bus host computer. The heart of the interface board is the DSP56002 whose host port (Port B) provides much of the logic necessary for interfacing the device with the ISA bus of a host processor. The 8 registers which comprises the DSP's host interface are mapped into the ISA bus I/O space. The implementation of this interface is accomplished by using a Programmable Logic Device (PLD) and an octal data transceiver. The PLD generates all the control signals required by the host interface of the DSP and mode selection during the reset. The Octal buffer is used to buffer the data lines between the host interface of the DSP and ISA bus. The communications with DSP including the bootstrapping are obtained via I/O operations on the appropriate registers. In addition to the built in memory of the DSP, an option for external memory is provided A delay counter is incorporated to force the DSP to generate required number of wait states. On-Chip Emulator port (for full speed debugging) and general purpose 24 bit digital I/O ports are also provided. The incoming CCD data transfers into the host memory via a set of FIFOs. A simple program has been developed using Borland Pascal for Windows to generate a test pattern from DSP- Host.
(B. Nagaraja Naidu and R. Srinivasan)

### 2.2 Data Acquisition Software for General purpose CCD Controller

Laboratory tests have been performed on the general purpose CCD controller using the data acquisition software in Turbo Pascal developed under MS-Windows. The general acquisition package has been blended with several routines that are unique to the general purpose CCD controller. These routines include various dialog boxes to set bias and clock levels, enabling bias supplies, pre flush, reset the camera etc. Initial tests in the laboratory with the EEV-385*578 chip shows stable performance with readout noise of 12-15 electrons. An Optimal Non-Linear Method is added which uses image histogram to determine a non-linear function which optimizes the image contrast. Basically, all the input pixel intensities are mapped to output intensities to produce an output intensity histogram that is as flat as possible. A 'Focus' procedure is also added which defines a region of interest (ROI) to perform a quick focus operation. This procedure checks for the validity of the ROI and if it is active, it repeatedly collects the data for the region specified and displays until the user interrupts the process. A general routine to evaluate the system gain (Electrons / ADU) has been developed and integrated into acquisition package. This routine requires a set of bias frames and a few pairs of uniformly exposed flats.
(B Nagaraja Naidu, S. Murali Shankar, R. Srinivasan and K. Ravi)

### 2.3 CCD Data Acquisition System Under LINUX

Image data acquisition software for CCD camera under linux environment is under development. The software uses X-Window calls for graphical user interface. Presently the software has been tested for the Astromed camera which controls the operation of a 385*578 EEV sensor. This system is to be field tested shortly. The software could be extended to 1K*1K and larger CCD arrays for which the hardware is currently under development. The main motivation for the development under LINUX Operating system are:
a) It is Public domain software and hence O.S.upgradations are not a problem.
b) It has required software libraries.
c) Being a UNIX variant, has good networking facilities built in and it lends itself well to client/server situations.
d) Availability of analysis packages like IRAF,MIDAS etc.,under the same environment so that users have the advantage of accessing these packages directly when required.
(A.V.Ananth)

### 2.4 Dome Automation for the 1-Metre Telescope

In order to implement automation in the dome of the 1-metre telescope, a 48.5:1 reduction gear has been procured and installed with the dome motor. A Siemens inverter has also been installed to provide smooth speed control of the two 5 HP ac motors. The absolute encoder fitted to the dome motor reads digitally the position of the dome. The software running in a PC reads the RA, DEC & ST values from the Digital Display System and transforms the equatorial coordinates into alt-azimuth coordinates. The dome motors are driven till the dome azimuth reading matches the telescope azimuth value. The installation and testing of the system is to commence shortly.
(R.Srinivasan, K.S.Ramamoorthy, B. Nagaraja Naidu and N.Sivaraj)

### 2.5 High Speed Control System Development for Adaptive Optics

We have taken up a project to implement adaptive optics system for existing telescopes at VBO. Adaptive optics has four primary components. They are wave front sensing, phase error computation, reconstruction of the required phase and control of adaptive mirrors such as tip tilt and rubber mirrors to correct the phase errors. Experiments are being conducted in wave front sensing area in optics division. For high speed control system design and analysis, MATLAB package with control system tool box was obtained. Observations are conducted with VBT to measure the Fried parameter $r_0$ that gives seeing value from Speckle experiments. Analysis of the data is being taken up now.
(V.Chinnappan, A.K.Saxena, J.P. Lancelot and S.K.Saha)

### 2.6 Microthermal Data-Acquisition System

A microthermal measurement system has been developed to characterise the turbulence of air as a function of height above the ground. The microthermal probes are based on thin-film Platinum Resistance Thermometer with a nominal value of 100 ohm at zero degree Celsius. A

Wheatstone bridge has been configured to measure the differential air temperature in a given spatial separation. The bridge is excited by an AC voltage and the imbalance in voltage across the bridge is amplified and synchronously demodulated. A low-pass filter removes the high-frequency components at the demodulated stage and gives a dc output representing the differential air temperature. Four such stages have been built to measure the differential temperatures at four different heights. The average air temperatures at the four heights are measured using the Analog Devices temperature sensors (AD-590s). A program has been written in C language in a PC for the calculation of the seeing parameter $C_T{}^2$ from the data obtained from the microthermal probes.
(R.Srinivasan, G.Rajalaksmi and T.P.Prabhu)

### 2.7 Installation of 1024 Channel Correlator System at Gauribidanur

The 1024 channel correlator system configured to correlate 32 EW signals with 32 NS signals of the LPD array was installed at Gauribidanur. This system will be used to make radio maps of the sun at 55 MHz and 75 MHz . Preliminary observations of point sources like CAS-A and CYGNUS have been conducted to calibrate the system.
(M.S.Sundararajan and Ebenezer)

## 3. PHOTONICS

### 3.1 Aluminising Work

The primary and the secondary mirrors of the 40 inch telescope were aluminised during August 96.
(Optics Team)

### 3.2 Stereoscope Imaging

A laboratory model for obtaining a stereoscope image of an extended object has been tried out. The fabrication of a prototype is in progress.
(R. Cowsik, R. Srinivasan, J.P. Lancelot, G. Srinivasulu and J.P.A. Samson)

### 3.3 UVIRT for Astrosat

A proposal is being prepared for the UVIT telescope payload Astrosat to be launched by the ISRO for UV surveying and related astronomical studies. Different configurations of the proposed telescope have been worked out and the final configuration will be frozen in consultation with other participating institutions. (N. Kameshwara Rao, A.K. Pati and A.K. Saxena)

### 3.4 HiRES Project

The launch of the HiRES pay load for EUV observations of the Sun has been scheduled in the month of April. All the subsystems have been tested thoroughly in the laboratory and all the work connected with the launch formalities have been completed. A continued collaborative program on "Small Scale Structures in the Solar Atmosphere and Their Effects on the Terrestrial Environment" has been signed with Prof.Gethyn Timothy of the University of New Brunswick, Canada, who is the principal Investigator of the program. This proposal has been submitted to the Canadian Space Agency.
(A.K. Saxena, J.C. Bhattacharyya and other collaborators)

### 3.5 SRBL Project

The fabrication of the Synchrotron Radiation Beam Line Optics for BARC is progressing well. The figuring work on the spheroidal mirrors are being continued. A new testing procedure has been evolved to test spheroidal mirror at grazing incidence using Zygo interferometer. The figure of one of the spheroidal mirror has reached an accuracy of about 0.5 waves. The figuring of the two flat mirrors have been completed. A figure less than 0.05 waves rms has been achieved for both the mirrors. The mirrors were tested at grazing incidence and with a reflection flat along with the Zygo interferometer. Specular reflectance measurements are being conducted using recently acquired fiber optics spectrophotometer. In collaboration with Prof.Thareja of IIT, Kanpur and Dr.Ratna Sarkar of Feroze Gandhi college, Rae Bareli, a study of thin film coating suitable for synchrotron beam line optics using thermal evaporation method and laser ablation method on Zerodur substrate has been taken up. The Zerodur substrate samples had been coated with Cr, Al, Cu, & Zr at IIT, Kanpur, using Laser ablation technique. Efforts are on to coat the sample substrate with Au & Ir. Process for the base Cr coating has already been settled. Reflectance and absorbance

measurements are being done in our laboratory. The study is of an academic nature and could well be utilised for specific need of the SRBL Optics.
(A.K. Saxena, R. Cowsik and Optics Team)

### 3.6 VHRR Sun Shield Panels

A set of six sun shield panels have been ground and delivered to ISRO for profilometer measurements and electroless plating. The polishing of the same will be taken up after the coating.
(A.K. Saxena and Optics Team)

### 3.7 48 Inch Telescope Primary Mirror (Japal Rangapur Observatory)

The 48 inch concave hyperbolic mirror of the Japal Rangapur Obeervatory telescope primary mirror, was tested for its optical quality. Polarisation interferometric testing technique was employed for the evaluation of its surface figure. The primary mirror and other optics of the telescope were realuminised during November 1996.
(A.K. Saxena and Optics Team)

### 3.8 40 Inch Telescope

As proposed earlier, to replace the 40inch telescope primary mirror, a new Zerodur blank was procured. The primary mirror has to be fabricated to the exact specification of the existing primary mirror. The 40 inch blank has been loaded onto the 90inch polishing machine. Back surface grinding of the blank is in progress.
(J.P. Lancelot, J.P.A. Samson and Optics Team)

## 4. ELECTRICAL SECTION

Considerable progress was made in the installation of 11KV/440V indoor sub-station. Major items like 250 KVA transformer, HT breaker, 200KVA Diesel Generator set, Automatic mains failure detection and change over panel, low tension (440 V) panels for distribution to all buildings are in place. HT cable was laid from the road to CPWD GOS panel. Underground cables to different load points are laid. A 250 KVA stabilizer is being ordered. After installing this stabilizer, the power from the indoor sub-station can be fed to all the places. This work is being carried out with the cooperation of CPWD, Kendriya Sadan, Koramangala.
KEB power to Hoskote campus was obtained. A 11KV/440V Transformer was installed by KEB very near to the load distribution points. LT power for the existing building was obtained. Maintenance of the power lines was carried out in collaboration with KEB authorities.
Several buildings in Kodaikanal campus are very old and the electrical wirings in these buildings are being rewired. Some improvement in the electrical distribution system is also being done.
Routine support was given for regular observations at VBO. Regular maintenance was done at Bangalore, Kodaikanal and Kavalur. New electrical power connections were provided for 60 KVA uninterrupted power supply (UPS) and the 64 KB communication tower. Good earthing system was provided to the new telephone exchange, UPS system and communication tower.
(K.Padmanabhan, K. Rangaswamy, Narasimappa, M. Balakrishnan, K.S. Subramaniam, M. Abbas, V.Chinnappan and the Electrical Staff)

## 5. MECHANICAL ENGINEERING

### 5.1 Mechanical Design Section

a. Design and fabrication of a tower (for measurement of microthermal variations in the atmosphere for a height of 50 feet at Hanle) was carried out. The tower is made of aluminium angles,channels etc. and are joined using dowel pins,bolts and nuts.The testing of the microthermal sensors is to be carried out at the Hoskote campus.
(R. Cowsik, P.K. Mahesh, P.U. Kamath and B.R. Madhava Rao)
b. Design,fabrication and testing of spectropolarimeter : This is a add on facility to the existing Boller and Chivens spectrograph of V.B.T. It consists of antibacklash spur gear driven by stepper motor for rotation and positioning of Pancharatnam plate. Accurate positioning is achieved by employing an IR sensor and limit switch.
(P.U. Kamath, Pavan Chakraborty and B.R. Madhava Rao)

c.Design and manufacture of pillar bases for material handling at Gauribidanur has been completed.
(R. Cowsik, P.U. Kamath and B.R. Madhava Rao)
d. Design modification following testing of micro-advance instrument used in the Gravitational facility at Gauribidanur was carried out.
(R. Cowsik, P.U. Kamath and B.R. Madhava Rao)
e. Mechanical stiffeners for the UHV chamber at the Gravitational facility at Gauribidanur were designed, manufactured and installed.
(R. Cowsik, P.U. Kamath and B.R. Madhava Rao)
f. The fabrication of two large flanges for seating the dome used for vacuum sealing the Gravitaional facility at Gauribidanur is being carried out. The material was procured and cutting was carried out in Bangalore. Further to this it was sent to Bombay where the heat treatment was carried out at BARC and machining was carried out at TIFR. The components of the flanges are presently at Kolar where it will undergo the final machining in assembly at the factory of M/s. Bharat Gold Mines Ltd.
(R. Cowsik, P.U. Kamath and B.R. Madhava Rao)
g. A new and modified mount for a spectrograph involving a concave grating is being designed.
(N.Kameswara Rao, P.K. Mahesh and B.R. Madhava Rao)
h. A design for a linear motion mechanism for achieving motions of the order of a micron was completed and the item was fabricated. Further to tests conducted on the same, a design for a modified version is ready for fabrication. This unit is for use in the experiments conducted at the Zero lab. in the field of Non-accelerator Particle Physics.
(D. Suresh, P.K. Mahesh, P.U. Kamath and B.R. Madhava Rao)
i. Design modification of speckle camera for VBT prime focus observation was carried out.
(R.M. Paulraj, K. Sagayanathan and B.R. Madhava Rao)
j. Further to the above works, support for other sections of the division was given in the form of involvement in maintenance activities.
(P.K. Mahesh, P.U. Kamath and B.R. Madhava Rao)

### 5.2 Scientific Drawing Office

About 175 drawings for the work titled "Twenty five years of Astronomy and Astrophysics" of Dr. Peraiah were done. About 50 drawings for the concept report titled "Total Solar Eclipse" of Dr. Jagdev Singh was also done. Most of the scientific drawings in connection with publications of the Scientific staff in national and international journals were also done. Drawings required by Research Scholars Mr.Gupta, Mr.Dipankar Banerjee, Mr. Hiremath, Mr. K.B. Ramesh, Ms. Uma Gorti, Mr. Mekkaden, Mr. Krishna Kumar and Ms. Annapurni were also done.
(S. Muthukrishnan)

### 5.3 Mechanical Laboratory, Bangalore

The following fabrication works were carried out:
a. Components for the CCD focussing assembly of the Schmidt telescope.
b. Polarimeter attachment to the Boller & Chivens spectrograph.
c. Fabrication and assembly of the tower to conduct studies of the microthermal variation of temperature at Hanle.
d. Surface grinding,welding,sheet metal cutting,blackening & painting of instruments,mechanisms and accessories.
The following maintenance works were carried out·
a. Maintenance work on the mount of the 6" Carl Zeiss telescope.
b. Maintenance work of CCD focussing assembly of the 1.2m telescope for the Japal-Rangapur observatory and fixing of limit switches for the same.
(B.R. Madhava Rao, A. Selvaraj, T. Johnson, Mallappa, K. Sagayanathan, N. Thimmaiah and Periyanayagam)

### 5.4 Mechanical Laboratory, Kavalur

The following maintenance and fabrication works were carried out:

VAINU BAPPU TELESCOPE
Arrangement was done to mount the larger shutter for the prime camera and B & C spectrograph.
The 17 bit absolute encoder was replaced for the DEC axis.
Arrangement was done to replace the pressure gauge for the hydrostatic power pack line.
Arrangement was done to test the LVDT on the focus assembly.
Focus display system problem was rectified.

Arrangement was done for machining the modified wheel axis for the dome wheels.
Arrangement was done for dome painting.
Arrangement was done to mount the window air-conditioner for the hydrostatic power pack room.
Associated with Dr. T.P. Prabhu to set right the problem and to commission the OMR spectrograph. Necessary arrangement was done to mount the new OMR spectrograph onto the telescope,mounting arrangement for the CCD controller and cable routing from the cassegrain end to the console room.
Interface with guiding assembly was made to mount the IR imaging CCD at prime focus.
Prime camera's filter wheel was altered to accomodate 3 inch dia filters.

102 CM TELESCOPE
Arrangement was made to eliminate water leakage on the dome and to do the painting.
One motor was replaced for the dome shutter drives.
An adapter was designed and fabricated for dome automation.
Arrangement was made to mount 2 Nos of window air-conditioners for the console room.
Telescope drive mechanism was overhauled.
Ball bearings of 8 nos were replaced in the RA worm shaft assembly.
Primary mirror support system was serviced.
The prime,secondary (cassegrain), and coude III, IV and V and the spectrograph mirrors were removed for aluminising and after the process were put back and aligned.
An adapter was fabricated for the seeing measurement by using 10 inch telescope and ST4 CCD.
A camera (10 inch focal length) with focusing arrangement was designed and fabricated for the coude echelle spectrograph.

75 CM TELESCOPE
Arrangement was done for painting the dome.
Arrangement was done to mount the 17 bit encoder for the R.A. and DEC axes.

WORK DONE FOR KODAIKANAL OBSERVATORY
The sliding roof mechanism of the Spectro building was converted to motor drive from manual drive. This job was done without any change to the 100 year old civil structure.
Mechanical arrangement was designed and fabricated to mount the linear CCD array onto the Spectroheliograph at the tunnel building.
An interface with viewing arrangement was designed and fabricated to mount the Peltier cooled CCD on the main spectrograph of the tunnel building.
The north dome shutter mechanism was repaired.

OTHER WORKS
Necessary arrangements were done to obtain the photograph and observation of comet Hale-Bopp through the VBT and the 6 inch telescope.
Necessary help was rendered to Mr.Samson to complete the fabrication of a shelter for use at Hanle.
15 inch telescope mirrors were removed for aluminising and aligned after reloading.
(F. Gabriel, A. Mani, C.V. Rajappan, K. Chinnappayyan, R. Annamalai, V. Loganathan, Annadurai, V. Murugesan, V. Vinayagam, D. Karthigeyan, G. Nandan and V. Armugam)

### 5.5 Air conditioning plant and refrigeration system
Preventive and periodical maintenance of central air conditioning system, window air conditioners,refrigerators were carried out. The details of the plants are: Annual maintenance service contract which was continued until last year was discontinued and now the plants are being maintained by IIA staff. This has resulted in a saving of Rs.2.5 lakh.
(V. Loganathan, F. Gabriel and B.R. Madhava Rao)

### 5.6 Carpentry section, Bangalore
In addition to the regular maintenance activities of the Bangalore campus and fabrication of small furniture, the purchase of material for fabrication of a shelter at Hanle was also carried out. Some of the important carpentry works that were fabricated are:
1. Teakwood file racks with sliding shutters.

2. Teakwood book shelves with sliding shutters.
3. Plywood boxes for transportation of instruments tools etc. to observation site.
4. Fitting of glazed partition under the handrail of the staircase at the main lab building.
5. Accesories for the Photonics, Electronics, Telecommunication divisions.
6. Glazed partitions for clean room and computer room facilities.
(Alphonse, Jerald, Sebastian, Nagaraj, Muthukrishnan and B.R. Madhava Rao)

## 6. SCHMIDT TELESCOPE PROJECT

The west bearing housing of the mount structure of the 61cm Schmidt telescope was redesigned and manufactured to improve the balancing of the telescope. Steps are also being taken to conduct a vibration measurement of the telescope structure in order to ascertain the vibration parameters.
(P.U. Kamath, F. Gabriel, P.K. Mahesh and B.R. Madhava Rao)

The Schmidt telescope is presently installed at VBO, Kavalur. The telescope was fitted with Brushless DC motors and runs by PWM DC power amplifiers. 17 Bit, single turn absolute, optical, binary encoder was fitted in the Declination axis of the telescope. The absolute encoder feedback was used to position the telescope, based on encoder data. Triangular waveform was generated for position control. It is found that the positioning in the Declination axis is satisfactory. Similar test in the polar axis will be carried out soon.
(V.Chinnappan and A.S.Babu)

Arrangements were done to mount the DEC gear box on the modified west bearing housing of the telescope mount. Arrangement was done to mount the focusing arrangement and the CCD mounting assembly on the tube. The declination and right ascension axis were balanced.
(F. Gabriel, A. Mani, C.V. Rajappan, K. Chinnappayyan, R. Annamalai, V. Loganathan, Annadurai, V. Murugesan, V. Vinayagam, D. Karthigeyan, G. Nandan and V. Armugam)

The location for the Schmidt Telescope was decided at the top of the Hanle hill and preparations for the foundation work was done.
(R. Cowsik, J.P.A. Samson and T.P. Prabhu)

## 7. THE HANLE 2 M TELESCOPE PROJECT

The site survey and development at the High-altitude astronomical station at Hanle, Chhangthang Ladakh (longitude 78 deg 57', latitude 32 deg 47', altitude 4500 m) continued more vigorously. The various activities related to this project are given below:

### 7.1 Installation of Weather Station at Hanle

An automatic weather recording station procured from M/S Campbell Scientific Inc. (CSI), (model CR10) has been installed. Presently, the data logger records hourly data of air temperature, soil temperature, relative humidity, wind velocity, wind direction, the solar radiation and total rainfall. The minimum, average, standard deviation and maximum values of wind velocity and direction are also recorded. The CR10 has 64K RAM which is used for storing the results of the measurements, the intermediate results to do certain processing, computed data and program for compiling the programming instructions. The execution interval and the output storage interval can be separately programmed. The output storage module has 192 KB battery backed-up RAM. A portable keyboard with display is used to communicate/program the CR10 over a serial link. Programming the CR10 involves entering sequence of instructions in EDLOG, supplied by CSI. The compiled code can be down loaded to a storage module (SM) and passed on to CR10 using the keyboard interface. Whenever the SM is connected to CR10, the recorded data is automatically transferred to SM from which the data can be transferred to PC over a serial link.
(B. Nagaraja Naidu, B. C. Bhatt, R. Srinivasan and T.P. Prabhu)

### 7.2 Modular Wooden Shelter for Hanle

A proto-type Modular Wooden Shelter of floor area 8ft x 12ft (with attached bath) to withstand the high altitude conditions was fabricated. This shelter collects and conserves the sunlight during the day and maintains the room temperature inside when the atmospheric temperature falls down during the night. The fabrication and the trial assembling were done at VBO and shelter was installed at Hanle dur-

ing October 1996 in the base camp site. A temperature difference of + 150C between inside room and outside during the nights without any direct heating source like bukari is observed and the living was comfortable.
(R. Cowsik, J.P.A. Samson and VBO Carpentry section)

### 7.3 Microthermal Tower Foundation

The foundation for the Microthermal Tower was successfully completed at the top of the Hanle hill. This cement concrete work was done during the winter hence special arrangements to heat up the foundation pit and cement mortar have been improvised and the work was done very satisfactorily.
(R. Cowsik, J.P.A. Samson and T.P. Prabhu)

### 7.4 Summary of Other Activities

1. A differential image motion monitor (DIMM) was assembled and tested at VBO, Kavalur in June 1996 and used at the base station, Hanle, during July 1996. The typical seeing values were 1.0 to 1.5 arcsec. The DIMM will be installed at the summit for routine observations as soon as the infrastructrual facilities become available.
2. Design and fabrication of a micro-thermal tower is in the final stages. It will be tested at CREST campus of IIA and installed at Hanle summit during the summer of 1997.
3. A team of 5 Japanese scientists visited Leh and Hanle in November 1996 to carry out measurements of 220-GHZ opacities. The measured values indicated that the atmospheric water vapour is only about 1 mm. The team concluded that the site is one of the best in the world for infrared, sub-mm and mm-wave astronomy.
4. Work is progressing on the construction of road between Hanle monastery and Dikpa Raja Ree summit. It is expected that it would be possible for light vehicles to drive upto the peak during the summer of 1997.
5. An MOU has been signed between IIA and Central Electronics Limited, for installing a 30-kVA (peak) solar powered electrical power station on the Hanle summit. The installation is expected to be carried out in August 1997.
6. An MOU has been signed between IIA and India Satcom Limited, for the installation of a 128-kbps satellite based link between Bangalore and Hanle to facilitate remote operations of telescopes to be installed at Hanle.
7. The area including the Dikpa Raje Ree summit at Hanle and its surroundings have been surveyed by the District authorities with a view to transfer it for the high-altitude observatory. The identification of suitable land for establishing transit and coordination centres at Leh and Nyoma have been progressing.
(T. P. Prabhu)

## 8. NATIONAL FACILITY ( VBT )

At the Vainu Bappu Observatory, Kavalur, the 2.34m Vainu Bappu Telescope ( VBT ) continued to be the most over-subscribed telescope during the year 1996-97. There were 85 observing proposals requiring about 700 nights of observing time. The number of nights allotted to CCD imaging/spectroscopic proposals were in the ratio 210/126. Nights were also allotted for speckle interferometry and testing of the PtSi infrared camera.
A new spectrograph acquired from the Optomechanics Research Inc., Arizona was commisioned at the Cassegrain focus of the VBT. This spectrograph is now available for use by the general astronomical community.

## LIBRARY

Library added 346 books to its collection and subscribed to 144 journals. It continued receiving 100 observatory publications, preprints, news letters and annual reports. Nearly 300 inter-library loan requests were handled during this year. Since the library database is available on the network, individuals can access the database from their terminals to know the availability of a particular document in the library. Journal database is being built up continuously. Information on 9000 bound volumes have been entered in this data base. In addition to the journal data base it has built a " IIA publications data base" where 1400 papers of IIA scientists from 1971 to 1996 have been input. Users can search for papers by IIA scientists through, Author, Title, and Key word. During the year, the library acquired a new copier,Xerox 3441 which has many new additional features and can handle large volumes of work. A set of Palomar sky survey on CDs was added to the reference collection. The abstract volume for the national meeting on total solar eclipsed organised by the Institute was prepared by the library. Ms. Ellen Bouton, Librarian from NRAO, Charlottesville was a special invitee to the IIA library and during her visit a joint discussion was held between, her, Librarian of Raman Research Institute and IIA library staff for improving inter-library activities. Ms. A. Vagiswari attended a meeting organised by the Indian Institute of Science Library in connection with the visit of few librarians from Australia during february 1997. Several searches were done on Internet, using Netscape. The Melvyl catalog, Uncover database and Astronomical Data Services, were frequently used for reference work.

## OFFICIAL LANGUAGE IMPLEMENTATION

The Institute's Annual Report, Audited Accounts Report, a few circulars and new forms have been produced in bilingual form during the year. In order to have a smooth Hindi training programme, Hindi roster has been prepared on the basis of which employees can be nominated for Hindi Prabodh classes. Winscript Hindi software has been acquired and installed in the Administrative Section. A large number of Hindi books have been purchased for the Hindi Cell library. Hindi Divas was celebrated and on this occassion Hindi-English dictionaries were distributed among new students in the Prabodh class. Some helpful literature was given to trained students and some administrative section employees were given cash awards after passing their Pragya exams.

# BULLETIN BOARD

### Honourary Fellow

The Institute is proud to welcome Professor R. M. Walker of the McDonnell Center for the Space Sciences, Washington University, St. Louis, as an Honourary Fellow this year. Professor Walker has the unique distinction of being a pioneer in the analysis of stardust in the laboratory! His visit was marked by a high quality one day seminar on Dust In The Universe.

### Bicentennial Commemorative Public Lecture

The Eleventh Bicentennial Commemorative Public Lecture on *Inside and Outside Venus* was delivered by Professor Dan McKenzie, FRS, Department of Earth Sciences, Cambridge University, U. K. and Raman Professor of the Indian Academy of Sciences, on March 5, 1997. The lecture highlighted the power of intelligent planning, execution, and data analysis in remote experiments.

### India - Japan Collaboration in Astronomy

Indo-Japanese collaboration maintained its vitality. A team of 5 Japanese scientists conducted measurements of opacities in the 220 GHz band at Hanle, and concluded that the site is one of the best in the world for infrared, millimetre, and sub-millimetre wave astronomy. Professor Sugimoto visited the Institute, bringing an updated version of the GRAPE supercomputer and his visit was also marked by an intensive one day seminar on Numerical Techniques in Computational Astrophysics.

### VIP Visits

Mr R.Sudarshan (Asst Resident Rep, UNDP), Mr Michael White (First Secretary-Science, British High Commission), Dr Tomasz Geriach (Counsellor, Embassy of Poland), Mr Meir Eshet (Counsellor-Economic Affairs, Embassy of Israel), Dr Givsto Sciarabba (Scientific Counsellor, Italian Embassy), Dr S.F. von Welck (Counsellor for Science, Technology & Environment, German Embassy), and Dr Ronald M.Roberts (American Embassy, Delhi) visited the Institute. They discussed matters of mutual interest in areas of science and technology with scientists of the Institute.

### Awards and Honours

**R.Cowsik** received the 9th Sir C.V.Raman Memorial Lecture Award, 1996. The paper titled 'An upper limit on the neutrino rest mass' by **R.Cowsik & J.McClelland**(Physical Review: The First Hundred Years, Ed: Henry Stroke, AIP Press 1996) has been included as *One of the thousand Greatest (Hits) Papers.* **V.Krishan** has been elected Fellow of the National Academy of Sciences. The paper entitled 'Tilt of cobe can constrain aspects of superstring geometry by **C. Sivaram** received "Honourable Mention" at the May 1996 Competition of Gravity Research Foundation, USA.

### Involvement in the Scientific Community

**R. Kariyappa** is the Principal Investigator for an accepted research proposal entitled "Local Helioseismology and Heating of the Chromosphere and Corona" under NASA/ESA/SOHO/SOI/MDI/SUMER Science Programme. **V. Krishan** has been invited to be a member of the Physics Panel constituted by UGC, for a period of 3 years. **Jagdev Singh** and **P. Venkatakrishnan** became members of the Indian Solar Terrestrial Energy Programme's (ISTEP) Working Group I on Solar Radiation. **G.S.D. Babu**, in his capacity as Secretary, Astronomical Society of India, was successful in fund-raising efforts.

### Winter School on Solar and Solar - Terrestrial Physics

A winter school on Solar and Solar - Terrestrial Physics was held at IIA, Kodaikanal, during Feb. 26-28, 1997. Lecturers and students from colleges and Physics departments (PG) of various Universities, totalling 50 participants attended the school. The school was meant to give an introduction and insight into the research areas of Solar and Solar - Terrestrial Physics fields. There was a very good response from the participants. The organising committee consisted of S.S.Gupta & Jagdev Singh The topics covered were : *Physics of the Sun, Solar Rotation* (S.S.Gupta); *Sun and its Atmosphere, Future programs of IIA - 1) Antarctic expedition 2) Site survey at high altitudes* (Jagdev Singh); *Physics of sunspots I & II, New frontiers in Astro-*

*nomy* (S.P.Bagare); *Basics of Astrophysics* (K.Sundara Raman); *Solar Instrumentation* (P.S.M.Aleem); *The living planet* (J.V.S.V.Rao) and *Solar terrestrial relations* (D.Karunakaran).
The participants were shown the observational facilities at Kodaikanal. A video cassette on Kodaikanal and Kavalur observatories, 1980 and 1995 Solar Eclipses, Antarctic expedition was also shown. On two nights, the participants were shown the celestial objects through the 8 - inch refractor telescope.

**National Science Day**

The National Science Day was organised in the Institute by P. Venkatakrishnan on 28 February 1997 by inviting neighbourhood schools to participate in a "Cosmic Awareness Quiz" competition. Dr. Madhusudhana of the Bangalore Association for Science Education (BASE) conducted the quiz with the help of several PhD students of the Institute. Professor J.C. Bhattacharyya gave away the prizes. There was also a slide show on Solar System objects conducted by Pawan Chakraborty and a few science exhibits, which were set up and manned by the PhD students as well as by the Photonics Division.

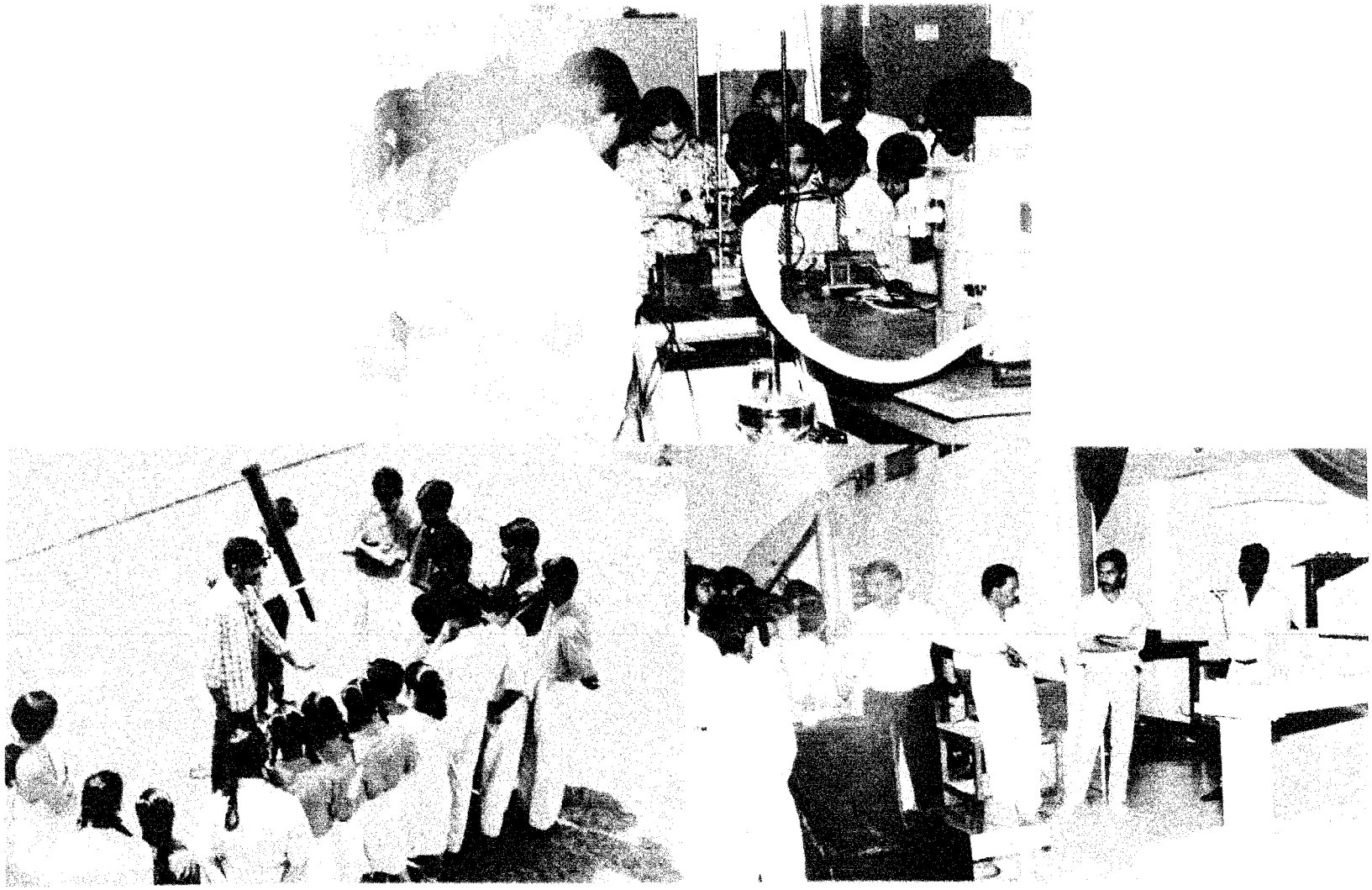
**Farewell**

Drs Laksmi Saripalli and Sudeshna Sinha left the Institute's service during the year. It is hoped that they will continue their academic pursuits with undiminished vigour.
Professor P. K. Raju retired on 30 September 1996, after more than two decades of dedicated service. His uncompromising attitude towards quality and ethics will be an example for years to come.
Sri K. Sasidharan died in harness on 14 April 1996. His death is particularly poignant because he had recently published an interesting paper with T.D. Sreedharan, R. Pratap and V. Krishan based on the application of chaos in solar atmospheric dynamics and was poised for path-breaking accomplishments.

*Professor Robert M Walker Honorary Fellow, being welcomed*

Cosmic Awareness Quiz conducted on National Science Day

Exhibition Organised on National Science Day



## PERSONNEL

The academic and technical staff as of 31 March 1997 include the following:

**Director**: R. Cowsik.

**Senior Professor**: M.H. Gokhale, A. Peraiah, C.V. Vishveshwara.

**Professor**: B.P. Das, B. Datta, S.S. Hasan, R.K. Kochhar, V. Krishan, D.C.V. Mallik, M. Parthasarathy, N.K. Rao, J.H. Sastri.

**Associate Professor**: H.C. Bhatt, K.K. Ghosh, R.C. Kapoor, P.B. Pal, T.P. Prabhu, R. Rajamohan, J. Singh, C. Sivaram, P. Venkatakrishnan.

**Reader**: S.P. Bagare, P. Bhattacharjee, S. Chatterjee, A. Chokshi, P.K. Das, S.S. Gupta, S. Giridhar, S. Mohin, P.M.S. Namboodiri, A.K. Pati, V. Raju, A.V. Raveendran, K.R. Subramaniam.

**Fellow**: G.C. Anupama, R.K. Chaudhuri, R. Kariyappa, S.V. Mallik, M.V. Mekkaden, B.S. Nagabhushana, K.N. Nagendra, A. Satya Narayanan, K.P. Raju, K.E. Rangarajan, D.M. Rao, S.K. Saha, P. Shastri, K. Sundara Raman, R. Surendiranath.

**Research Associate**: K.M. Hiremath, K. Jayakumar, K. Kuppuswamy, Prabhjot Singh, J.V.S.V. Rao, M.S. Rao, M.J. Rosario.

**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. Madhava Rao.

**Scientifc Officer SD** : G. Srinivasulu, M.S. Soundararajan, J.P.L.C. Thangadurai.

**Scientific Officer SC**: P.S.M. Aleem, J. Javaraiah, D.Karunakaran, K.B. Ramesh, B.A. Varghese, L. Yeshwanth.

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

**Librarian** : A. Vagiswari .

**Assistant Librarian B** : C. Louis

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

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

**Electronics Engineer** : F Saleem

**Documentation Associate** . S. Rajiva

**Mechanical Associate** : T. Johnson

**Project Officer** : B.C. Bhatt

**Distinguished Professor** : V.K. Gaur.

**Emeritus Professor** : J.C. Bhattacharyya, K.R Sivaraman.

**Professor (Radio Astronomy Projects)** . Ch.V Sastry.

**Visiting Scientist** : J. Bagchi, A. Goswami, J Vijapurkar.

**Visiting Fellow** : P. Joarder.

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

# APPENDIXES

# APPENDIX A

## PUBLICATIONS
### In Journals

*Abdu M.A., Sastri J.H., *MacDougall J., *Batista I.S., *Sobral J.H.A. (1997) *Geophys. Res. Lett.*, **24**, 1707.
Equatorial disturbance dynamo electric field, longitudinal structure and spread-F: a case study from GUARA/EITS campaign.

*Aguirregabiria J.M., *Chamorro A, Rajesh Nayak K., *Suinaga J., Vishveshwara C.V. (1996) *Class.Quantum Grav.*, **13**, 2179.
Equilibrium of a charged test particle in the Kerr-Newman spacetime: force analysis.

Anju Sharma, *Raja Ramanna,(1996) *Mod. Phys. Letts.*, **A11**, 2335.
Particle symmetries in $\Gamma/M$ ratios and the life-time of proton.

Banerjee D., Hasan S.S., *Christensen-Dalsgaard J. (1997) *Solar Phys.*,(in press).
Effects of Newtonian cooling on waves in a magnetized isothermal atmosphere.

*Batista I.S., Sastri J.H., *de Medeiros R.T., *Abdu M.A. (1997) *J. Geophys. Res.*, **102**, 20059.
Night-time thermospheric meridional winds over Cahoeira Paulista: Evidence for effects of midnight pressure bulge.

*Bernatowicz T.J., Cowsik R., *Gibbons P.C., *Lodders K., *Fegley B.,Jr, * Amari S., *Lewis R.S. (1996) *ApJ*, **472**, 760.
Constraints on stellar grain formation from presolar graphite in the Murchison meteorite.

Bhattacharjee P. (1996) *Current Sci.*, **71**, 532.
Origin of the highest energy cosmic rays.

Chaudhuri R.K., * Finley J.P., *Freed K.F. (1997) *J. Chem. Phys.*, **106**, 4067.
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Cowsik, R., Ratnam, C., Bhattacharjee, P. (1997) *Phys. Rev. Lett.*, **78**, 2262.
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Method of intermediate Hamiltonians via eigenvalue-independent partitioning : application to theoretical spectroscopy.

Datta B , Hasan S.S., *Sahu P.K., *Prasanna A.R. (1997) *Int.J Mod Phys.*, in press.
Radial modes of rotating neutron stars in the Chandrasekhar-Friedman formalism

*Dietrich M ,Ghosh K.K , Soundararajaperumal S , (1997) *ApJS*, in press.
Steps towards determination of the size and structure of the broad-line region in Active Galactic Nuclei. XI. Variability of 3C390.3 from optical data.

*Dwivedi B.N ,*Anita Mohan, Raju P.K. (1977) *Adv. Space Res.*,in press
On the line ratio diagnostics for Ne V, Mg V, Si VII and Mg VII.

*Faurobert-Scholl M., Nagendra K.N., *Frisch H. (1997) *A&A*, 1.
An operator perturbation method for polarized line transfer. II. Hanle effect in weak magnetic field regime in 1D media.

*Finley J.P., Chaudhuri R.K., *Freed K.F. (1996) *Phys. Rev. A.*, **54**, 343.
Convergence behavior of multireference perturbation theory: Forced degeneracy and optimization partitioning applied to the beryllium atom.

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*Mitra A.N., Anju Sharma (1996) Int. J. Mod. Phys. **A11**, 3787.
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*Nittler L.R., Cowsik R. (1997) *Phys. Rev. Lett.* **78**, 000.
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Charged particle trajectories in the presence of a toroidal magnetic field on Schwarzschild background.

Rajesh Nayak K., Vishveshwara C.V. (1996) *Class.Quantum Grav.*, **13**, 1783.
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A correlative study of Green coronal intensity with other solar indices.

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Resonance line polarization in the presence of wave motion

Saha S.K.,*Jayarajan A.P., *Sudheendra G., *Umesh Chandra A. (1997) *BASI*,25,000.
Performance of a speckle interferometer.

Saha S.K., Venkatakrishnan P. (1997) *BASI*, 25, 000.
Blind iterative deconvolution of binary stars images.

*Santos-LIeo M.,Ghosh K.K., Soundararajaperumal S. (1997) *ApJS*, in press.
Steps towards determination of the size and structure of the broad-line region in Active Galactic Nuclei. X. Variability of Fairall 9 from optical data.

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General relativistic effects on the ohmic decay of crustal magnetic fields in neutron stars.

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Detection of short period coronal oscillations during the total solar eclipse of Oct. 24, 1995.

Sivaram C., *Borzeszkowski H., *de Sabbata V., *Treder H. (1996) *Found. Phys. Lett.*, **9**, 157.
On the quantisation of general relativity in anholonomic variables.

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A new digital display system for 1-meter telescope at Vainu Bappu observatory.

*Stevens J.E., Chaudhuri R.K. *Freed K F. (1996) *J Chem.Phys.*, **105**, 8754
Global three-dimensional potential energy surfaces of $H_2S$ from the *ab – initio* effective valence shell Hamiltonian method.

*Valluri M., Anupama G.C. (1996) *AJ*, **112**, 1390
H$\alpha$ imaging of Hickson compact group HCG62.

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On the correlation between line width and line depth of the solar HeI 1083 nm line.

Vijapurkar J., *Drilling J.S., Parthasarathy M. (1997) *AJ* in press.
IRAS 17395-0841 : A new young low-excitation planetary nebula.

**In Proceedings**

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Anupama G.C. (1997) in *Physical Processes in Symbiotic Binaries and Related Systems*, ed. J. Mikolajewska (in press).
The optical emission line variability in TCrB. Based on ten years data from the Vainu Bappu Observatory.

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Broad band photometry of solar corona during the total solar eclipse of 24 October 1995.

Bagare S.P.,Cowsik R.,Singh J.,Raju K.P.,Saxena A.K.,Samson J.P.A., Nagaraja Naidu B. (1997) in *Proc. Nat. Meeting on the Total Solar Eclipse October of 24,1995, KOB*, **13**, 53.
Search for hydrogen-alpha cool pockets in solar corona during the total solar eclipse of 24 October 1995.

Banerjee D., Hasan S.S., Christensen-Dalsgaard J. (1997) in *Proc. SCORE'96 Workshop on Convection*, eds J. C. Dalsgaard & F. P. Pijpers, Kluwer, Holland (in press).
The influence of radiative damping on the modes of a magnetized isothermal atmosphere.

*Bernatowicz T., Cowsik R. (1997)in *Proc. meeting of the American Institute of Physics*, in press.
Physical conditions in stellar outflows: Inferences from presolar grains

Bhattacharjee P. (1996) in *Proc. IAGRG Meeting, Madras, 1996. IMSc Technical Report*, (eds G. Date and B. Iyer).
Topological defects in cosmology.

Bhattacharjee, P. (1997) in *Extremely high energy cosmic rays: Astrophysics and Future Observatories*, ed. M. Nagano (ICRR, Univ. of Tokyo).

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Disk luminosity for accreting weak magnetic field neutron stars in the 'slow rotation approximation'.

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Quark Stars in Compact Binaries.

Dikpati, M., Choudhuri, A.R., Venkatakrishnan, P. (1996) in *Solar Drivers of Interplanetary and Terrestrial Disturbances, ASP Conf. Ser.*, Vol. 95, p. 309, eds. K.S. Balasubramaniam, S.L. Keil, R.N. Smartt
The Evolution of the Magnetic Structure of the Solar Corona with the Solar Cycle.

Giridhar S. (1997)in *Proc. I.A.U. Symp. 177 on Carbon Star Phenomenon* Anthalaya, Turkey, ed. R.F. Wing, in press.
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Behaviour Of OI7774A Feature In The Spectrum Of The 10 Day Period Zeta Gem.

Hiremath K.M.(1997) in *Proc. of the 7th Asian-Pacific Regional Meeting of the IAU*, 1996,in press.
Torsional MHD oscillations of the sun.

Hiremath K.M.(1997) in *Proc. of the Sounding of Solar and Stellar Interiors, IAU Symp 181*, 1996, in press.
Steady parts of rotation and magnetic field in the solar interior.

Hiremath K.M.(1997)in *Proc. PRL Golden Jubilee Workshop on "Solar Physics in India during the next solar maximum and beyond ", Udaipur, Oct,* 1996, in press.
Steady part of the Sun's internal rotation.

Hiremath K.M., Gokhale M.H. (1996) in *Proc. Int. Conf.on 'Windows on the Sun's Interior'*, eds H.M. Antia and S.M. Chitre, BASI, 24, 345.
Steady parts of rotation and magnetic field in the Sun's convective envelope.

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Model of steady parts of rotation and magnetic field in the Sun's convection zone.

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Recent astronomical site survey at Hanle, Ladakh.

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Nagaraja Naidu B., Srinivasan R., (1997) in *Proc. Int. Conf. on Instrumentation*, IISc, Bangalore, 1996, in press.
A DSP Based Digital Pattern Generator for Charge Coupled Devices.

Rajaguru S. et al. (1997) in *Proc. Nat. Meeting on the Total Solar Eclipse of October 24,1995, KOB*, **13**, 000.
Determination of the Linear Polarization of the Solar Corona During the total solar eclipse of October 24, 1995.

Saha S.K,. Nagabhushana B., Ananth A.V., Venkatakrishnan V. (1997) *Proc. Nat. Meeting on the Total Solar Eclipse of October 24,1995, KOB*, **13**, 00.
A speckle experiment during partial eclipse.

Satyanarayanan A. (1996) in *Proc. Int. Conf.on 'Windows on the Sun's Interior'*, eds H.M. Antia and S.M. Chitre, BASI, 24, 371.
Surface waves in a two layered fluid model with an inclined magnetic field.

Saxena,A.K.,Cowsik,R.,Lancelot,J.P.,Samson,J.P.A.,Bagare,S.P., Ismail,R. (1997) *Proc. Nat. Meeting on the Total Solar Eclipse of October 24,1995, KOB*, **13**, 11.
A study of inner corona during the total solar eclipse of October 24, 1995.

Singh J., Cowsik R., Raveendran A V., Bagare S.P., Saxena A.K., Sundararaman K., Krishan V , Nagaraja Naidu B., Samson J.P.A., Gabriel,F. (1997)*Proc. Nat Meeting on the Total Solar Eclipse, KOB*, **13**, 5
Observation of intensity oscillations in corona during the total solar eclipse of 24 Oct 1995.

Vasundhara R., (1996) in *Proc. PHESAT95, Bucharest, Romania, Annales de Physique***21**, 91.
Modelling mutual event light curves in the post Voyager era. Effects of prominent surface features.

## Book Review, Technical Report, Conference Report

Giridhar S. (1996) *BASI*, **24**, 561.
Conference Report : IAU Symp 177. Carbon star phenomenon.

Krishan V. (1997) *BASI*, **25**, 141.
Book review of elements of cosmology, by J.V. Narlikar

Saxena A.K. (1997) Book Review of optical communications, Orient Longman.

Vasundhara R. (1996) *Curr. Sci.*, **70**,1047.
Comet Hyakutake.

Venkatakrishnan P. (1996) *Curr. Sci.*,**71**, 175
Optical imaging using radio techniques (Research News).

**Attendence in Conferences, Workshops and other Scientific Meetings**

SUSY 96: Conference on Supersymmetry, University of Maryland, College Park, MD, USA, 1996 May 29 – June 1 **P.Pal**

International Conference on Physical Processes in Symbiotic Binaries and Related Systems, Koninki, Poland, 1996 June 14–20,**G.C. Anupama**

17th National Solar Observatory/Sacramento Peak - SOLERS22 International Workshop, NSO/Sacramento Peak, Sunspot, NM, USA, 1996 June 17-21. **K.B. Ramesh, R. Kariyappa**

31st COSPAR Scientific Assembly, Birmingham, U.K., 1996 July 14-21, **P.K. Raju**

National Meeting on Science in the Medieval Age, New Delhi, 1996 August, **S.S. Hasan**

International Conference on Perspectives in High Energy Astronomy and Astrophysics, Mumbai, 1996 August 12 - 17 **Ghosh K.K.**

7th Asian-Pacific Regional Astronomy Meeting of the IAU, Pusan, South Korea, 1996 August 19-23, **K.K. Ghosh, K.M. Hiremath, T.P. Prabhu**

IAU Symposium 180 on Planetary Nebulae, 1996 August 26-30, Groningen, The Netherlands, **E. Reddy**

International Symposium on Extremely High Energy Cosmic Rays: Astrophysics and Future Observatories, Tokyo, Japan, 1996 September, **P. Bhattacharjee**

CMMACS - IIA one day workshop on Astrophyical Fluid dynamics and Computer Simulations held on 1996 September 9 **R.D. Prabhu**

European Summer School on Stellar Atmosphere: Theory and Observations during 1996 September 10-20, Vrije University, Brussels, Belgium, **E.Reddy**

Royal Netherlands Academy of sciences Coll. on Pulsar Timing, General Relativity and the Internal Structure of Neutron Stars, 1996 September 24-27, **B.Datta**

Sounding of Solar and Stellar Interiors, IAU Symposium, 181, Nice, France, 1996 October, **K.M. Hiremath**

National Plasma Physics Symposium, Bhopal, 1996 October, **V. Krishan**

PRL Golden Jubilee Workshop on Solar Physics in India and during the next Solar Maximum and Beyond, Udaipur, 1996 October 7–10. **S.P. Bagare, J.C. Bhattacharyya, R. Cowsik, S.S. Gupta ,S.S. Hasan, K.M. Hiremath, V. Krishan, P.Pal, Rajguru, K.B. Ramesh, K. Sundara Raman, P. Venkatakrishnan**

Star Dust Meeting, St Louis, USA, 1996 October 31-Nov 2 **R. Cowsik**

Annual Meeting of the Indian Academy of Sciences, Jodhpur, 1996 November 1-3,**B. Datta**

8th General Meeting of the Third World Academy of Sciences in Trieste, Italy during 1996 November 25 - 28, **R. Cowsik**

Golden Jubilee Symposium on Gravitation and Particle Physics, 1996 December, **C.V. Vishveswara**

Second Zel'dovich Meet on Large Scale Structure, IUCAA, Pune, 1996 December, **Mangala Sharma**

The Golden Jubilee Celebration of the Physical Research Laboratory, PRL, Ahmedabad, during 1996 December 11–14,**P. Pal**

Instrumentation Workshop, Jyoti Nivas College,Bangalore, 1996 20 December, **A.K. Saxena**

National High Power Laser Symposium, Defence Science Centre, Delhi, 1996 December 23, **A.K. Saxena**

National Seminar on Dust in the Universe, IIA, 1996 December 31, **H.C. Bhatt, R. Cowsik, Mangala Sharma, P.Pal, S.K. Saha**

National Seminar on Numerical Computation IIA, 1997 January 9 **R. Cowsik, R.D. Prabhu, S.K. Saha**

IUCAA-JNC discussion meeting on Big Bang and Alternative Cosmologies: A Critical Appraisal, Bangalore, 1997 January 6-8, **P. Bhattacharjee, R. Cowsik, T.P. Prabhu.**

IUCAA sponsored workshop on Astrophysical Spectroscopy, S.K. University, Anantapur 1997 February 12-14, **S.P. Bagare, S. Giridhar**

Third International Conf. on Physics and Astrophysics of Quark-Glon Plasmas, Jaipur, 1997 March **B. Datta**

## Colloquia, Technical Talks, Invited Talks at Conferences, Workshops and Seminars

Bhatt H.C.
Protostar clusters in molecular clouds
*PRL, Ahmedabad*
1997 February 28

Chokshi A.
Formation of QSOs *UPSO, Naini Tal* 1996 October 25

Cowsik R.
My meanderings in search of neutrino mass
*Sir C.V.Raman Memorial Award Lecture, IISc, Bangalore*
1996 September

Perspectives on Dark Matter in the Universe
*TWAS Basic Sciences (Physics) Award Lecture, Trieste, Italy*
1996 November

Datta B.
Spin 2 interaction in high density matter
*Variable energy cyclotron centre, Calcutta*
1996 June 28

Disk luminosity for accreting weak magnetic field neutron stars
*Royal Netherlands Academy of Sciences, Amsterdam*
1996 September 26

Disk luminosity of accreting old neutron stars
*Laboratorio de Astrofisica Espacial y Fisica Fundmental, Madrid, Spain*
1996 October 4

Equation of state of neutron star
*Institute for Astronomy 'Anton Pannekoek', Amsterdam, The Netherlands*
1996 October 28

Disk luminosity of accreting old neutron stars
*JNU, School of Physical Sciences, Delhi*
1996 November 6

Quark Matter
*RRI, Bangalore*
1997 March 6

Neutron Stars
*Bangalore University, Bangalore*
1997 April 2

Hiremath K.M.
Steady parts of rotation and magnetic field in the solar interior
*Dept Astronomy, Univ.Tokyo*
1996 October

Mangala Sharma
Review of 'A 3.5 Gyr galaxy at z = 1.5' by Dunlop et al., (Nature, 381,581, 1996) ; Candidate primeval galaxies in the Hubble deep

field by Clements and Couch, (MNRAS,280,L43);
Near-IR observations of the Hubble deep field with the Keck telescope, (AJ, 1997)
*Extra-galactic Journal Club ,IIA*

Nagendra K.N.
Resonance line polarization – old and new methods of solving the radiative transfer problem
*Institute fur Astronomie, Zurich, Switzerland* 1996 July 5

Prabhu R.D.
Review of 'Turbulence and magnetic fields in elliptical galaxies', by D. Moss and A. Shukurov (MNRAS, 279,229,1996)
*Extra-galactic Journal Club ,IIA*

Rajguru
Review of 'Accounting for the solar luminosity variability from the deep convection zone' by J.R. Kuhn et al. ApJ Lett.; Discussion of 'Dynamical and thermal effects and the strengths and sizes of solar magnetic elements' based on the papers by P. Venkatakrishnan Nature(1986), S.K. Solanki et al AA Letters (1996), E.N. Parker (1978) Ap.J.,etc.
*Solar Physics Journal Club*

Ramesh K.B.
A correlative study of green coronal intensity with other solar indices
*NASA, GSFC, Greenbelt, USA*
1996 June 14

Reddy E.
Chemical composition of post-AGB stars
*Katholieke University, Leuevn, Belgium*
1996 September 6

Saha S.K.
Seeing at VBT
*Group Committee II, IIA*
1996 April 25

Speckle interferometry at VBO
*Group Committee II, IIA*
1996 December 30

Vishveshwara C.
Gyroscopic precession and inertial forces in general relativity
*University of Padua, Padua, Italy*
1996 June

Inertial forces in general relativity
*PRL, Ahmedabad*
1996 December

## Paper Presentations in Scientific Meetings

Aleem P.S.M., Sundararaman K.
Broad band photometry of solar corona – 1995
*PRL Golden Jubilee Workshop on Solar Physics in India during the next Solar Maximum and Beyond*
1996 October 7-10

Bagare S.P., Gupta S.S.
On the relation between magnetic field strength and Wilson depression in sunspots
*PRL Golden Jubilee Workshop on Solar Physics in India during the next Solar Maximum and Beyond*
1996 October 7-10

Bhatt H.C.
Dust in molecular clouds and star-forming regions
*National Seminar on Dust in the Universe IIA Bangalore*
1996 December 31

Bhattacharjee P.
Cosmic topological defects as possible sources of EHECR: The cur-

rent status
*International Symposium on Extremely High Energy Cosmic Rays: Astrophysics and Future Observatories, Tokyo, Japan*
1996 September

Astro-particle physics related evidence for the standard model of cosmology (discussion session talk)
*Discussion meeting on Big Bang and Alternative Cosmologies: A Critical Appraisal,IISc, Bangalore*
1997 January 6-8

Chokshi A.
Epoch of galaxy formation
*Discussion meeting on Big Bang and Alternative Cosmologies: A Critical Appraisal, IISc, Bangalore*
1997 January 6-8

Cowsik R.
Dark matter in our Galaxy
The elusive Hubble constant
*International School of Cosmic-Ray Astrophysics 'Towards the Millenium in Astrophysics: Problems and Prospects' Erice, Italy*
1996 June 16 - 23

The hard x-ray background: Its nature, sources and cosmological implications
*International Coll. 'Perspectives in High Energy Astronomy and Astrophysics', TIFR Golden Jubilee Event, Mumbai*
1996 August 12-17

Neutrinos, dark matter and all that (Summary)
*International Coll. Theoretical Physics' (SUJAYATA), TIFR Golden Jubilee Event, Mumbai*
1996 September 3-7

Star dust in my hands
*PRL Golden Jubilee Workshop on Solar Physics in India during the next Solar Maximum and Beyond*
1996 October 7-10

Star Dust
*Discussion Meeting on Big Bang and Alternative Cosmology: A Critical Appraisal IISc, Bangalore*
1997 January 6-8

Giridhar S.
Abundance determination technique in stellar spectroscopy
*Workshop on Astronomical Spectroscopy Sri Krishnadevaraya Univ., Ananthpur, A.P.*
1997 February 12 -14

Gokhale M.H.
Facilities for solar optical observations at IIA (invited review)
Mechanism of solar cycle : Recent results and new ideas
*PRL Golden Jubilee workshop on 'Solar Physics in India during the Next Solar Maximum and Beyond', Udaipur Solar Observatory*
1996 October 7-10

Gupta S.S., Jagdev Singh
Reconnection of field lines in the upper solar atmosphere
*PRL Golden Jubilee Workshop on Solar Physics in India during the next Solar Maximum and Beyond*

Gupta S.S., Sivaraman K.R., *Howard R.F.
Solar rotation studies from Kodaikanal photoheliograms (Poster paper)
*PRL Golden Jubilee Workshop on Solar Physics in India during the next Solar Maximum and Beyond*
1996 October 7–10

Hiremath K.M.
Torsional MHD oscillations of the sun
*7th Asian-Pacific Regional Meeting of the IAU, Pusan, Korea*
1996 August

Steady part of the sun's internal rotation
*PRL Golden Jubilee Workshop on Solar Physics in India during the next Solar Maximum and Beyond*
1996 October 7–10

Kariyappa R.
Contribution of chromospheric features to UV irradiance variability from spatially resolved CaII K spectroheliograms, II. Variation in intensity and area of the chromospheric features
*17th National Solar Observatory/Sacramento Peak - SOLERS22 International Workshop, NSO/Sac Peak, Sunspot, NM, USA*
1996 June 17-21

Krishan V.
On a theoretical basis for force free magnetic fields and beltrami flows in the solar corona
*Solar Phys. Meeting, USO, Udaipur*
October 1996

On radiation mechanisms in AGN
*National Plasma Physics Symposium, Bhopal*
October 27, 1996

Nagendra K.N.
Resonance line polarization – new methods of solving the radiative transfer problem
*Symp. on Numerical Techniques in Computational Astrophysics*
1997 January 9

Pal P.B.
Problems with the interpretation of quantum mechanics
*Looking Around, a group of interdisciplinary interactions, IISc, Bangalore*
1996 November 20

Calendars and astronomy
*Young Astronomers Meet, Bangalore*
1996 September

The solar neutrino problem: update and outlook
*Solar Physics in India during the next solar cycle and beyond*
1996 October 7

How good is the standard model of particle interactions ?
*The Golden Jubilee Celebration of PRL, Ahmedabad*
1996 December 13

Prabhu R.D.
The inverse cascade model in the light of Tully - Fisher Relation, (Poster)
*In-house Symposium of Physics Department, IISc*
1996 April 30 - May 1

Turbulence in astrophysics
*CMMACS-IIA Workshop on Astrophysical Fluid dynamics and Computer Simulations*
1996 September 9

Turbulence, why is it so elusive ?
*Young Astronomers Meet, IIA*
1996 September 3 - 5

Prabhu, T.P.
Indian 4-m telescope
*Future Large-Scale Facilities in the Asia-Pacific Region: VII Asian-Pacific Regional Astronomy Meeting, Pusan, Korea*
1996 August 22

Ramesh K.B.
A correlative study of green coronal intensity with other solar indices
*17th NSO/SP Workshop on Solar Electromagnetic Radiation Study for cycle 22, Sacramento Peak, SUNSPOT, NM, USA*
1996 June 17-21

5303 A coronal irradiance variations
*PRL Golden Jubilee Workshop on Solar Physics in India During the next Solar Maximum and Beyond Udaipur Solar Observatory*
1996 October 7-10

Rao D.M.
Stability analyis of finite-diffrences methods of radiative transfer
*Symposium on Numerical Techniques in Computational Astrophysics, IIA, Bangalore*
1997 January 9

Saxena A.K.
Laser propagation and adaptive optics
National High Power Laser Symposium, Defence Science Centre, Delhi
1996 December 23

### Visits to Scientific Institutions

**P.Bhattacharjee** is currently on sabbatical leave (January - December 1997) and visiting the Laboratory for High Energy Astrophysics, NASA/Goddard Space Flight Center, Greenbelt, Maryland, USA as a NAS/NRC Senior Resident Research Associate. **A.Chokshi** visited USA(IPAC/Caltech and Princeton University) April-May 1996. **R. Cowsik** represented India and attended the function of the official inauguration of the Telescopio Nazionale Galielo telescope at the Observatorio del Roque de los Muchachos on the island of La Palma, Spain and Themis solar telescope at Teide Observatory in Tenerife, Spain in June 96. The telescopes were inaugurated in the presence of His Excellency King of Spain and His Excellency President of Italy. He visited the Laboratory for Astrophysics at LAEFF, Madrid , Spain during June 1996. **R.Cowsik** visited the McDonnell Center for the Space Sciences and Physics Department of the Washington University, St Louis, USA as a Distinguished Visiting Professor during April and May and July 1996, and carried out teaching and research activities. Visited the Laboratory for Astrophysics at LAEFF, Madrid, Spain during June 1996 for scientific discussions and gave a seminar. **B. Datta** visited Laboratorio de Astrofisica Espacial y Fisica Fundmental, Madrid, Spain 1996 28 September-8 October; NASA Goddard Institute for Space Studies, New York, U.S.A. 1996 9-22 October; Institute for Astronomy 'Anton Pannekoek' Amsterdam, the Netherlands, 1996 23-30 October. **k.K. Ghosh** visited the Department of Earth Sciences, Pusan National University, Korea during 1996 August 19-23, for collaborative work on Be stars with Hyung Mok Lee. He also visited Korea Astronomy Observatory on 1996 August 21 for discussions with Woo- Baik Lee; Chonbuk National University, 1996 August 23-25 and had discussions with Chulhee Kim. **S.Giridhar** visited Dept. of Astronomy, Univ. of Texas at Austin, USA during May 1 -24, 1996 to work on spectra of cooler members of RV Tau group in collaboration with Prof.D.L.Lambert and Dr.G.Gonzalez. **S.S. Hasan** is spending his sabbatical leave during 1996-97 at the Harvard-Smithsonian Center for Astrophysics, Cambridge, U.S.A. and carrying out joint collaborative research with W. Kalkofen on "Radiative transfer in intense flux tubes on the Sun". **K.N.Nagendra** visited Observatoire de la Cote d'Azur, Nice, France, during May-June, 1996 for continuation of ongoing collaboration in the field of polarized line formation theory. He visited the Institut fur Astronomy, Zurich, Switzerland, for one week during July, 1996 to start a fresh collaboration, and gave a colloquium talk. **K.B.Ramesh** visited NASA, GSFC, MD, USA ; University of Maryland, MD, USA; Sacramento Peak Solar Observatory, NM, USA ; Jet Propelsion Laboratory, Caltech, CA, USA during 14-24 June 1996. **E. Reddy** visited Katholieke University, Leuven, Belgium, during September 1-8, 1996. **J. H. Sastri** visited the Brazilian National Institute for Space Research (INPE) for one year under the Visiting Professor Fellowship Program of the Brazilian National Research Council (CNPq). He did colloborative work with the Aeronomy Group at INPE, Sao Jose dos campos, Brazil, during the visit on sabbatical leave from the institute. **C.V. Vishveshwara** visited Universidad del Pais Vasco, Bilbao, Spain (March-April 1996); Boston University, Boston, USA (April-May 1996); University of Padua, Padua, Italy (June 1996) as Visiting Professor.

# APPENDIX B

## Teaching

Fifteen to twenty lectures each were given by IIA staff members during 1996-97 for Bangalore University's M.Sc. Astrophysics specialization program. The program, with lectures held partly at the Physics Department of BU and partly at IIA, was coordinated by M.H. Gokhale with the assistance of S.P.Bagare. The following courses were given (names of lecturers in parantheses) : *Planetary Physics* (Ramesh, K.B.), *Solar Physics* (Bagare, S.P.), *Interstellar Matter* (Surendiranath, R.), and *Galactic Structure* (Anupama, G.C.).

Visit to VBO, Kavalur for practical course work by the students was organized by Ravindran, A.V.

R. Cowsik was a staff lecturer at the 10th Course of the International School of Cosmic Ray Astrophysics entitled "Towards the Millenium in Astrophysics: Problems and Prospects", at 'Ettore Majorna' Centre for Scientific Culture, June 16-23, 1996.

P. Venkatakrishnan and Arati Chokshi taught the JAP course on Stellar Astrophysics.

M. H. Gokhale gave an 'Advanced Course' in Solar Physics.

P B. Pal taught a course on Neutrino Physics at the SERC school on Particle Physics and Field Theory held at CTS, IISc, Bangalore. He also taught the course on Quantum Field Theory'to the 1st year students of IIA from January – April 1997

P Bhattacharjee taught the one-semester JAP core course Radiative Processes in Astrophysics, August – December, 1996.

A course of ten lectures on Processes involved in Galaxy Formation was given to graduate students by C. Sivaram.

T.P. Prabhu delivered lectures on Optical Astronomy and Galaxies at the IUCAA-NCRA Summer School in Astronomy and Astrophysics, Pune, May 1996.

Bagare,S.P. served as a member of the Board for PG examinations in Physics of the Bangalore University during 1996.

P.S.M. Aleem guided the work of the ten XII Std students of Bhavan's Gandhi Vidyashram, Kodaikanal, for their 1996-1997 CBSE examination. He was also their external examiner.

A.K. Saxena and J.P. Lancelot provided extensive training on Optical Workshop Practices to the undergraduate students of the Instrumentation Department of Jyoti Nivas College.

## PhD Degrees

Dr. S.S. Gupta has been awarded the Ph.D., degree by Pandit Ravishankar Shukla University, Raipur,for his thesis on 'Studies on the variation of rotation on the surface and in depth on the Sun in relation to the photospheric magnetic fields', under the guidance of Prof.K.R. Sivaraman. Mausumi Dikpati obtained her PhD degree from IISc on 'Evolution of Polar Fields and the Heating of the Quiet Solar Corona' in May, 1996, under the guidance of Dr A. R. Chaudhuri and Prof. P. Venkatakrishnan N. D. Narasimha Prasad (a student of Prof. P. Venkatakrishnan) submitted his thesis to Bangalore University in September 1996, while D Banerjee (a student of Prof. S. S Hasan) submitted his thesis to the Bangalore University in December 1996.

## Popular Articles

Aleem P S M
The approaching Hale-Bopp
Thinakaran (Tamil Daily)
1997 March 3

Babu G.S.D.
Fixing of Easter and Christmas in the calendar
Newsletter of All Saints' Church, Bangalore,
1997 March

Pal P.B.
Sutrapat : Bengali translation of Isaac Asimov's Beginnings,
Anustup Prakashani, Calcutta.
Translation done in collaboration with Shekhar Guha.

Vishveshwara C.V.
On the black hole trail... : A personal journey

Current Science, 71, 824 (1996)

## Radio/TV

Babu G.S.D.
Finding the last continent
AIR, Bangalore
1996 July 21

Are we alone in the Universe?
AIR, Bangalore
1996 September 15

Can atoms be split ?
AIR, Bangalore
1997 February 16

Bagare,S.P.
New findings from total solar eclipse observations
AIR, Bangalore
1996 April

Measurement of time - past, present, and future
AIR, Bangalore
1996 November

The celestial rendezvous - A talk on comet Hale-Bopp
AIR, Bangalore
1997 March

Sivaram C.
Top quark discovery and its significance
AIR, Bangalore
1996 April 16

The quantum universe - Some new developments
AIR, Bangalore
1996 September 3

Current space probes to Mars :What they hope to achieve
AIR, Bangalore
1997 January 3

Vasundhara R.
Discovery and its significance of extra solar planets
AIR, Bangalore
1996 June 2

## Popular Talks

Babu G.S.D.
Gravity and the solar system
Chief Guest, Investiture Day,
Bishop Cotton Girls' High School, Bangalore,
1996 June 14

Stars, nebulae and galaxies
Science Village, IIA, Bangalore
1996 June 17

Our beautiful Universe
Eureka Forbes Limited, Bangalore
1996 July 27

The shining stars
IGL Primary School, Bangalore
1996 August 15

The universe and its beauty
R.T.Nagar Public School, Bangalore
1996, September 6

The enchanting universe
Chinmaya Vidyalaya, Bangalore
1996, September 19

Principles of physics in astronomy
Bishop Cotton Boys' School, Bangalore
1996 November 14

Solar system and our galaxy
R.B.A.N.M's (Bifurcated) High School, Bangalore
1997 December 19

Life cycle of stars
Annual Science Seminar
Sri Aurobindo Memorial School, Bangalore
1996 December 21

Ninth Indian Scientific Expedition to Antarctica
Bowring Institute, Bangalore
1997 February 22

General astronomy
ISRO Satellite Centre, Bangalore
1997 February 28

Chokshi A.
Big Bang and Alternate Cosmologies
IISc, Bangalore
1997 Jan 5-9

High Redshift Universe
Orange County, Coorg

Cowsik R.
The expanding universe
Physics Society, M.E.S. College
Bangalore
1996 August 26

Ghosh K.K.
Quasar – the most luminous objects in the Universe
Thiruvannamallai Govt Arts College, Tamil Nadu
1996 October

Expanding universe
Astronomy Club, Gudiyatam Govt arts College, Tamil Nadu
1996 November

Role of astronomy to remove superstition and blind faith in Astrology
Tamil Nadu Science Forum, Ambur
1996 December

Hiremath K.M.
Indian people, history and culture
International School of Language, Tokyo
1996 December

Nagendra K.N.
The evolution of stars
Vijaya High School, Bangalore
1996 September

Saxena A.K.
Photonics technology - Past, present and future
Instrumentation Workshop, Jyoti Nivas College
1996 December 20

Sundara Raman K.
Universe
Adarsh Senior Secondary School, Madras
1996 July 15

Principles of astrophysics with special emphasis on solar physics

Physics Dept, Seethalakshmi Ramaswamy college, Trichy
1996 March 7

Basics of astrophysics and in particular solar physics
Physics Dept, Jamal Mohamed College, Trichy
1996 March 10

Vishweshwara C.V.
Black holes: Looking around for the invisible
IISc, Bangalore
1996 November

The cosmic picture book
PRL, Ahmedabad
1996 December

# APPENDIX C

## Vainu Bappu Observatory

### Sky Conditions at VBO

| Year | Month | Spectroscopic (hrs) | Photometric (hrs) |
|---|---|---|---|
| 1996 | April | 104 | 20 |
| | May | 137 | 27 |
| | June | 77 | 9 |
| | July | 39 | 3 |
| | August | 20 | 0 |
| | September | 10 | 0 |
| | October | 51 | 8 |
| | November | 114 | 27 |
| | December | 138 | 30 |
| 1997 | January | 198 | 83 |
| | February | 245 | 100 |
| | March | 237 | 87 |
| | Total | 1370 | 394 |

## Kodaikanal Observatory

### Spectro/photoheliograms and seeing conditions at Kodaikanal

| Year | Month | No. of photographs in | | | | SEEING* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Hα | Kfl | Hpr | PHGM | 5 | 4 | 3 | 2 | 1 |
| 1996 | April† | - | - | - | 7 | - | - | 3 | 4 | - |
| | May† | - | - | - | 5 | - | - | 2 | 2 | 1 |
| | June† | - | - | - | 5 | - | - | 1 | 2 | 2 |
| | July† | - | - | - | 6 | - | - | 5 | 1 | - |
| | August† | - | - | - | 9 | - | - | 1 | 8 | - |
| | September† | - | - | - | 11 | - | - | 7 | 3 | 1 |
| | October† | - | - | - | 13 | - | 1 | 7 | 3 | 2 |
| | November† | - | - | - | 9 | - | - | 5 | 4 | - |
| | December | 26 | 7 | - | 19 | 2 | 6 | 7 | 4 | - |
| 1997 | January | 24 | 17 | - | 21 | 1 | 2 | 10 | 7 | 1 |
| | February | 27 | 17 | - | 21 | - | 7 | 9 | 2 | 3 |
| | March | 35 | 26 | - | 28 | 2 | 7 | 15 | 4 | - |
| | Total | 112 | 67 | - | 154 | 5 | 23 | 72 | 44 | 10 |

Kfl = K-floculus
Kpr = Hx Prominence
PHGM = Photoheliogram

*( 1- Very poor, 2- Poor, 3- Fair, 4-Good, 5- Excellent )
†No observations for many reasons including civil works, Kfl slit repair, and overhauling of spectroheliographs.

**Solar Tower Tunnel Observations**

| Year | Month | Total number of days of observations | Seeing (in arcsec) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 2 to 3 | 3 | 3 to 4 | 4 | 4 to 5 | 5 |
| 1996 | April | 4 | 1 | - | 3 | - | - | - | - |
| | May | - | - | - | - | - | - | - | - |
| | June | - | - | - | - | - | - | - | - |
| | July | 1 | - | 1 | - | - | - | - | - |
| | August | - | - | - | - | - | - | - | - |
| | September | 3 | - | - | 3 | - | - | - | - |
| | October | 2 | - | - | 2 | - | - | - | - |
| | November | 3 | - | - | 2 | - | 1 | - | - |
| | December | 3 | - | - | 2 | - | - | - | - |
| 1997 | January | 7 | - | - | 7 | - | - | 1 | - |
| | February | 8 | - | - | 6 | 1 | 1 | - | - |
| | March | 12 | - | - | 12 | - | - | - | - |
| | Total | 43 | 1 | 1 | 37 | 1 | 2 | 1 | - |