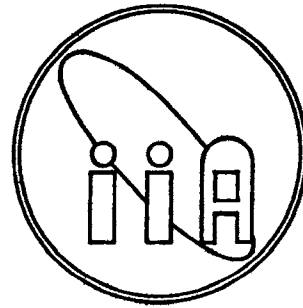




Annual Report 1993-94
Indian Institute of Astrophysics

INDIAN INSTITUTE OF ASTROPHYSICS



Annual Report
1993-94

Editor :
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Front Cover : Hanle region against the
backdrop of Southern Karakoram Ranges

Back Cover : En route Hanle

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Contents

	Page		Page
Governing Council	v	Instrumentation	49
The Year in Review	1	Computing Facilities	51
The Sun	7	Vainu Bappu Observatory	53
Solar System Studies	15	National Facilities	57
Stars	17	Miscellaneous	63
Galaxy and the Interstellar Medium	25	Library	71
Galaxies and Active Galactic Nuclei	27	Personnel	73
Theoretical Astrophysics and Cosmology	33	Appendixes	
Solar Terrestrial Physics	41	A. Publications, Notes, Conferønces, Invited talks, Lectures, Paper presentations, Visits	79
Atomic and Molecular Physics	43	B. Teaching, Editing, Popular articles and talks	95
Gravitation	45	C. Sky conditions in Kodaikanal, Kavalur	98
Optics	47		

Governing Council

(for the triennium 1992 October - 1995 October)

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The monastery at Hondo

The Year in Review

The year 1993-94 was a year full of activities and excitement. The Institute hosted an international meeting, the *International Conference on Nonaccelerator Particle Physics (ICNAPP)*, at the Bangalore campus in 1994 January. A large tract of land (measuring about 36 acres) was acquired, from the Government of Karnataka, near the eastern fringe of Bangalore City, for future expansion. The Institute was also identified by the Department of Science and Technology, Government of India, as the nodal agency for carrying out a detailed project study of the proposed *Himalayan Infrared and Optical Telescope (HIROT)*. It sent teams to various high-altitude locations (above 4000 m msl) in U.P., H.P. and the Ladakh region of Jammu & Kashmir to explore possible sites for the location of the telescope. Serious efforts were started to re-engineer the existing 24/18 inch Schmidt telescope with a view to deploying it on a hilltop at Hanle in south eastern Ladakh. Detailed scientific planning of the observations of the forthcoming encounter between Jupiter and *Comet Shoemaker-Levy 9* in July 1994 also began. New directions of research started in IIA with the induction of new members of staff. Some of the new areas are relativistic atomic structure calculations, problems at the atomic/particle physics interface, particle physics aspects of dark matter in the universe, topological defects, cosmic strings, origin of ultrahigh-energy cosmic rays. An *SERC School on Astronomy and Astrophysics* was organised at VBO, Kavalur. In 1993 November *Kavalur Observatory*, renamed *Vainu Bappu Observatory* in 1986, completed twenty five years of its scientific existence.

The Institute geared itself up admirably for hosting ICNAPP. Infrastructural facilities were vastly improved. A new dining hall and lounge area was constructed on the ground floor of the Annexe to the Main Laboratory. The Library Hall was reorganised, its acoustics improved and electrical wiring completely redone for holding the plenary sessions of the conference. It had a seating capacity of over 250. The gardens were relaid and a Japanese-style garden was architected near the Optics Laboratory. At

the Kavalur campus, a new dining hall replaced the old workshop. The civil works were completed in a near record time.

ICNAPP was attended by nearly two hundred people from India and across the world. The scientific programme consisted of invited talks and contributed poster papers. Care was taken to present a programme that was a good blend of papers on theoretical advances in nuclear and particle physics and related subjects and those on related experimental and observational work. There was intense discussion and debate. In the opening ceremony *Prof. B. V. Sreekantan, Chairman, IIA Council* was the Chief Guest and the inaugural address was delivered by *Prof. B. Barish of Caltech, USA*. Among the various themes covered extensively during the conference, neutrino physics and astrophysics had the most complete coverage, and all the latest results from the experiments on the mass of the neutrinos, their mixing and fluxes of solar neutrinos were reported. *Prof. Roger Penrose* of the University of Oxford, UK delighted the audience with an evening public lecture *Noncomputability and the mind* on January 7, 1994. The valedictory session of *ICNAPP* was held in Kavalur on the floor of the 234 cm Vainu Bappu Telescope. It was addressed by *Prof. A. Wolfendale, Astronomer Royal, Britain*.

Following *ICNAPP* serious discussions started between the scientists at IIA and astronomers observing with GRO, notably *Prof. J. Ryan of the University of New Hampshire, USA*, on possible directions of work in the area of gamma-ray sources. IIA has offered to set up a facility for optical follow-up work on gamma-ray bursters. This has led to the Hanle project.

Prof. D. Sugimoto of the University of Tokyo, Japan visited IIA in 1994 January in connection with the *Indo-Japanese collaborative scientific programmes*. He described the development of terraflop computing ma-

chines in his laboratory that have the facility to handle gravitational many-body simulations in record time. A team of scientists from IIA, in turn, visited Japan and procured the hardware for this machine which has to be interfaced with the Sun SPARC LC station already installed at IIA. Once in operation, these simulations will further aid the understanding of the distribution of dark matter. As a result of further discussions, the Japanese have also offered to build a IR CCD camera for VBO. The required manpower will be provided by IIA. Dr.M.Ueno of the University of Tokyo who heads the Japanese project of building IR CCD cameras visited IIA, Bangalore and VBO, Kavalur and held extensive discussions with the astronomers and the technical personnel.

The *Vainu Bappu Telescope* operated satisfactorily during the year. During the lean monsoon months several maintenance jobs were taken up. These have improved the performance of the telescope. During the peak season, December-March, the telescope was oversubscribed by a factor of three and a half. The Boller and Chivens spectrograph also underwent several technical changes with the result that there has been a gain of a factor of two in the power of the spectrograph.

Towards the end of the period of this report IIA was gearing itself up for observing in all aspects the crashing of the fragments of Comet Shoemaker-Levy 9 on Jupiter. The planned observations include CCD imaging at the prime focus of the 234 cm VBT in V,R and I bands, polarimetry using an imaging polarimeter, IR photometry in the K band with the 75 cm telescope, wide angle imaging and radio observations at very low frequencies (18-28 MHz).

The Ph D programme for training competent scientists of the future was continued with renewed vigour. After the recruitment in 1993 July, the student strength in IIA went up to twenty nine. Of these six belong to the Joint Astronomy Programme (JAP) of IISc, Bangalore. The Faculty of IIA continued to teach in JAP, IISc as well as in the Post graduate classes of Bangalore University. Several new physics and mathematics courses were

offered at IIA. Students from all the research institutions in the Bangalore area have been welcome to attend these courses.

In its efforts to popularise science, IIA participated in the *Science Exhibition* organised by 'Karnataka Rajya Vijnana Parishat' at Belgaum in 1993 October and in the *National Science Day Exhibitions* organised by the Department of Science and Technology, Govt. of India and the Govt. of Karnataka at the Jawaharlal Nehru Planetarium in 1994 February.

It is perhaps appropriate at this juncture to review briefly the major scientific results obtained during the year. These are compiled according to their respective areas.

1. The Solar System and Solar Terrestrial Physics :

Many new observational and theoretical results were obtained during the year pertaining mainly to the dynamics on the solar photosphere and the chromosphere. A radioheliograph working at 75 MHz was commissioned at Gauribidanur based on indigenously fabricated log-periodic antennas. Scientists obtained data on the Sun with the facilities at Kodaikanal, and supplemented these with those obtained from Greenwich, Sacramento Peak etc. The key point that seems to emerge from these studies is the importance of the magnetic fields in controlling the phenomena such as, granulations, bright points, mottles, global solar oscillations and solar flares. Detailed theoretical investigations were carried out using magnetohydrodynamical techniques in studying these diverse solar phenomena. Also, possible existence of torsional oscillations of the Sun was indicated through a study of sunspots recorded from 1874 until 1976.

Astrometric observations were carried out on the Comet Shoemaker-Levy 9 which had been tidally disrupted into fragments by Jupiter, perhaps during a close encounter in 1992. These observations provided part of the

requisite data for predicting the orbits of the cometary fragments and for the evaluation of the date, time and location of their impact on to Jupiter in July 1994.

Studies of the Equatorial Upper Atmosphere and the Ionosphere have been carried out with a Fabry-Perot spectrometer, a HF-Doppler radar and a Digital Ionosonde which give information about the state of the neutral plasma, the F-region of the ionosphere etc. One of the key findings is that the midnight temperature maximum of the F-layer is closely related to the poleward reversal of the meridional winds and the descent of the F-layer at low latitudes. It should be mentioned that the Digital Ionosonde IPS 42/DBD 43 was commissioned in September 1993 and is already yielding very useful information on the time variability of the ionosphere.

II. Stellar and Galactic Astronomy :

Extensive work has been carried out in this field with observations conducted from Kavalur and other observatories. The topics of interest extend from pre-main sequence stars to the final stages of stellar evolution such as supernovae, neutron stars and black holes on the one hand and to the formation and cosmological evolution of galaxies and clusters of galaxies on the other. Some of the results obtained are listed below:

1. **Be Stars:** Pre-main sequence Herbig Ae/Be stars, classical Be stars and Be stars in x-ray binary systems were observed polarimetrically and spectroscopically. Herbig Ae/Be stars show polarimetric variations on time scales as short as 1 month, implying the existence of dusty clumps orbiting the young star within 10 stellar radii.
2. **RV Tauri Stars:** Abundance analysis of the carbon rich ($C/O \geq 1$) RV Tauri star IW Car shows a remarkable pattern. The photo-

spheric abundances in this star are very similar to the depleted abundances seen in the interstellar medium.

3. **Hydrogen deficient Stars:** The first phase of the major study on the elemental abundances of 18 R Cr B stars is complete. The major result is that the majority of the stars show solar metallicity (i.e. $[Fe/H] \sim 0$) but with odd patterns of Si, S, and a mild excess of lighter s-processed material. However 4 stars show deficiency of Fe peak elements i.e. $[Si/Fe] \sim -2$, but not of Na, Si, S and some other elements. One of the stars V854 Cen shows elemental depletions similar to that of the interstellar medium. For the first time such diversity in the abundance pattern is seen.
4. **Lunar occultations of Infrared Stars:** 10 objects from the 2- μ m survey catalogue that are thought to have infrared emitting circumstellar dust were observed. One object (IRC + 30094) was resolved and found to have a size ~ 10 milliarc sec.
5. **Star clusters:** (a) The cluster NGC 1976 in Orion nebula has been observed in the infrared JHK bands. The intracluster reddening law is found to be anomalous suggesting the existence of dust grains larger in size than that attributed to the general interstellar medium. (b) Spatial distribution of stellar mass in 5 young LMC star clusters has been studied. Mass segregation is indicated in NGC 1711.
6. **Evolution of protostellar discs in molecular clouds.** Stars are born in molecular clouds with circumstellar discs. The young star-disc systems move around within the parent cloud and experience gas drag. This drag deforms, limits the disc radius and even disrupts the disc depending on circumstances. The process is being numerically studied.

III. Galaxies :

1. Monte Carlo simulations were carried out for galaxy clusters in open and flat cosmological models. It is found that at low fluxes ($m_B \geq 22$) the angular correlation amplitude decreased by orders of magnitude over that input, due to high density of galaxies. The low observed correlation in faint blue galaxy samples therefore does not require a new population of smoothly distributed galaxies and is consistent with little evolution in clustering amplitude to $z \sim 0.5$.
2. A collaborative programme to observe the integrated photometric properties of the Magellanic Clouds in the near infrared using the Pt Si IR CSD array has been initiated. The data will be compared against various galaxy population synthesis models and predictions will be made for high z galaxy population studies.
3. Active Galactic Nuclei (AGN): EXOSAT x-ray spectra of several AGN have been analysed. Evidence is found for the presence of the redshifted 6.4 KeV fluorescent Fe K-line.
4. SN 1993J in M81 was monitored in the optical region from VBO. The expanding photosphere method gave a distance of 3.1 ± 0.5 Mpc for M81 which compares well with the HST estimate 3.6 ± 0.3 Mpc based on cepheids.

IV. Theoretical Physics and Astrophysics :

Several scientists working in the areas of atomic physics, particle physics and modern dynamics have joined the Institute during the year, adding new facets to its scientific enterprise. These scientists are expected to interact symbiotically with the existing group which is well known for its contributions to Magnetohydrodynamics, Radiative Transfer, Equation of State of Neutron Star Matter and Astro-Particle Physics. Some of the contributions of this group are listed below:

1. Radiative transfer studies for a central source embedded in a thick disc show the polarization structure suitable for modelling quasars.
2. A comparative study of various numerical techniques for solving radiative transfer equations conducted shows the advantages of using first-order differential equation for the specific intensities.
3. A careful calculation of the electrical conductivity of the crust of a neutron star was performed in an attempt to understand the Ohmic dissipation of the crustal magnetic fields.
4. The possible origins of cosmic rays of energy higher than 10^{18} eV in the annihilations of strings and other topological defects, surviving from phase transitions in the early universe, were studied in detail. The flux of the isotropic background of high energy gamma rays was used to constrain the parameters describing the cosmic strings.
5. Violation of parity and time reversal invariance in atoms provides a unique probe into the nature of fundamental interactions at very low momentum transfers. As a tool to study this and devise experiments a sophisticated computer code is being developed to carry out atomic structure calculations.

V. Instrumentation :

Several new instruments such as the digital ionosonde, the CCD imaging system for the spectroheliograph, the solar vector magnetograph were developed and commissioned during the year. Contributions to other institutions such as ISRO and DAE continued through the fabrication of VHR-panel for passive cooling and through the development of ellipsoidal mirrors for the extreme ultraviolet to operate at the Synchrotron Facility being set up at Indore.

In the following pages of the report the main areas of scientific activity are enumerated and the research done in each of these areas is described in detail. Developments in optics, electronics and instrumentation are also included. The upgradation of the library and computing facilities is also described. The lists of publications, invited talks, attendance at conferences by IIA scientists and the sky conditions in Kavalur and Kodaikanal are appended.

In closing, I would like to express my appreciation of the fine cooperation that exists between different wings of the Institute, as also between the different campuses. The Institute is now poised and ready to take up major new challenges and the enhanced level of activity can begin the moment the fillip is given for it.

R. Cowsik
Director



At ICNAPP

The Sun

Internal magnetic field

Admissibility of global torsional MHD oscillations in a model of the 'steady' part of the sun's magnetic field

The travel times of Alfvén waves along different field lines between their photospheric intersections have been computed in our improved model of the 'steady' part of the sun's internal poloidal magnetic field. The travel times along all the field lines which pass through the radiative core are nearly the same. This shows that the model of the 'steady' field admits global torsional MHD oscillations. The frequency of the fundamental torsional MHD mode lies within the range of the frequency band of the solar magnetic cycle if B_0 is on the order of 0.01 G which is well within the limit set by the magnetogram observations (K M Hiremath, M H Gokhale)

'Initial' configuration of the sun's primordial magnetic field

The 'improved' model of the 'steady' part of the sun's internal magnetic field was used to infer that the initial (zero age main sequence) ratio of the two leading diffusion eigenmodes in the sun's primordial poloidal magnetic field must have been 4:1. Assuming the mean diffusivity in the radiative core to be the same as the one calculated using kinetic theory, it was estimated that the time scales of the diffusion of these two terms must be 10.6 and 2.7 billion yr respectively. (K.M. Hiremath, M.H.Gokhale)

Magnetic field and solar oscillations

The effect of a uniform vertical magnetic field on the modes of an isothermal stratified atmosphere is studied. The present investigation is a continuation of earlier work by Hasan and Christensen-Dalsgaard (1992, ApJ 396, 311)

in which this problem was studied for rigid boundary conditions. In this work, we extend the earlier results for a more general set of boundary conditions. We explicitly demonstrate how these boundary conditions affect the various elementary wave modes present in the atmosphere. In the weak field limit, an analytic expression for the dispersion relation is derived, which allows the effect of a weak magnetic field on the modes to be studied. We show that, to lowest order in our perturbation expansion, the oscillation spectrum can be analysed in terms of (a) p- and g- like modes, (b) magnetic Lamb modes, (c) magnetic or slow modes and (d) gravity-Lamb modes. The first three of these were present in the previous analysis. However, the last one is a new mode, not seen earlier. A simple model solar atmosphere is used to find that these four types of modes avoid intersections of the eigen curves in the $K-\Omega$ diagram. We explicitly demonstrate that the choice of boundary conditions govern the nature of avoided crossings. We focus on the properties of the gravity-Lamb mode. It is conjectured that conditions for the existence of this mode may be satisfied in the subphotospheric layers of the sun where $C_S \gg v_A$. However, more realistic calculations are clearly called for before these results can be applied to sunspots and other magnetic flux tubes. (D.Banerjee, S.S.Hasan, *J.Christensen-Dalsgaard)

Exact solution

A solution of the axisymmetric MHD equilibrium of a self-gravitating incompressible fluid has been obtained neglecting the contribution due to meridional motion. Under special conditions this solution reduces to those given by Prendergast (1956, ApJ 123, 498) and by Nakagawa and Trehan (1968, ApJ 151, 1111). (A. Satya Narayanan)

Global solar cycle

Periodicities in the sun's differential rotation (sun's torsional oscillations)

Using Greenwich data on sunspot groups of the period 1874-1976, the temporal variations of the coefficients 'a' and 'b' in the sun's differential rotation were studied by determining their values during time intervals of given length (1-5 years) successively displaced by 1 year. The FFT analysis of the temporal variations of b/a shows several periodicities from 18.1 yr to 2.6 yr at levels $\geq 2\sigma$. The maximum entropy method gives the estimates of the periods as : 18.9 \pm 1.1 yr, 8.3 \pm 0.8 yr, 3.9 \pm 0.1 yr, 3.1 \pm 0.1 yr and 2.6 \pm 0.1 yr. This analysis also shows a few more periodicities at levels 1 - 2 σ . Reality of the existence of all the periodicities except the one at 2.8 yr is confirmed by analyzing simulated time series of b/a with values of 'a' and 'b' randomly chosen within the limits of their respective uncertainties.

The existence of these periodicities is further confirmed by analyzing the variation of the residual rotation of each of the four latitude zones of widths 7.5° between 0° and 30° on either side of the solar equator.

(J.Javaraiah, M.H. Gokhale)

Solar magnetic cycle as a manifestation of torsional MHD oscillations

It has been found that among the above reported periodicities of torsional oscillations, those at 18.3, 8.5, 3.9 and 2.6 yr in 'b/a' (or in 'b') agree, within their uncertainties, with the dominant periodicities in the distribution of the photospheric magnetic field, detected from the magnetogram data of the period 1960-1985 (Stenflo and Vogel 1986, Nature 319, 285, Csada 1974, Sol. Phys. 35, 325), and also in the large scale magnetic field inferred from the sunspot data during 1874-1976 (Gokhale et al. 1992, Sol. Phys. 138, 35). This suggests that the solar magnetic cycle may be a manifestation of torsional MHD oscillations of the sun. (J. Javaraiah, M.H. Gokhale)

Relationship of the torsional MHD oscillations and sun's revolution about the centre of mass of the solar system

The above mentioned common periodicities between the differential rotation and the magnetic field of the sun are found to be same as the periodicities of positional configurations of two or more planets which control the rates of change of the sun's orbital angular momentum about the centre of mass of the solar system. This strongly suggests that the inertial torques due to the sun's orbital motion about the centre of mass of the solar system may be providing the perpetual excitation of the sun's torsional MHD waves required to maintain the spectrum of such waves against the loss of energy in the form of solar activity. (M.H. Gokhale, J. Javaraiah)

Flux tubes and acoustic waves

The interaction of an intense flux tube, extending vertically through the photosphere, with p-modes in the ambient medium is studied. The tube is assumed to be initially in hydrostatic and energy equilibrium. Equilibrium flux tube models based upon the solar stratification have recently been constructed by Hasan and Kalkofen (1994, Ap. J., in press) for various values of the field strength and radius at the surface. These models use a realistic energy equation, based upon a multistream treatment of radiative transfer in cylindrical geometry, and also include convective transport, assuming the mixing length theory. It is of interest to investigate the interaction of such model tubes with p- or acoustic modes in the external atmosphere. The effect of the tube being buffeted by external waves is modelled by solving the nonlinear time-dependent MHD equations in the thin tube approximation (S.S.Hasan)

Rotation measurements from sunspots

Daily positions and areas of sunspots and solar diameter have been measured from the photoheliograms for the years 1904 to 1987. (K.R.Sivaraman, S.S.Gupta, *R.F.Howard)

Ca II K line profiles as a function of latitude and phase of the solar cycle

To investigate the change in background chromospheric flux, if any, a new technique was developed to obtain high resolution Ca II K line profiles as a function of the latitude with integration over the visible 180 degree range of the longitude. Observations have been freshly started using 35 mm 4415 Kodak film. To record the data the width of the entrance slit has been increased to 250 micron from 120 micron and the exposure time to about 100 seconds. The data are being digitised using the PDS machine at Bangalore. A programme has been developed to compute various parameters of the K line profile with a resolution of 5° in latitude. (J.Singh)

Network cycle

Variability of the solar chromospheric network over a solar cycle

From a large sample of the Kodaikanal spectroheliograms in the K line we have studied the variations in the intensity of the network elements over two solar cycles for the period 1958-1983 and have estimated their contribution to the overall variability seen in the disc-averaged K line profiles. The relative contribution of the network elements and the bright points to the K-emission are of the order of 25% and 15% respectively. We have shown that the area of the emission wall of the chromospheric network is anti-correlated with the solar activity and it increases by about 24% during the solar minimum compared to the period of the solar maximum.

(R. Kariyappa, K.R.Sivaraman)

Coronal diagnostics

Line intensity ratios of Ne V emission lines with respect to a resonance line of Mg V have been computed assuming constant electron pressure, for electron density and temperature determinations within the chromosphere-

corona transition region (CCTR). These intensity ratios would enable us to estimate the relative abundance of neon to magnesium. Theoretical line intensities for the ions Ne V and Mg V have been computed using a model solar atmosphere and the reliable relevant atomic data currently available. The theoretical intensities have been compared with the values as observed by the ATM (Apollo Telescope Mount) ultraviolet spectrometer aboard the Skylab. The observed intensities correspond to the average quiet sun conditions. Some of the computed Ne V intensities agree well with the observed values. Other Ne V lines are blended. Mg V lines have observable intensity values but they have not been identified in the observed line list due to blending with other lines. (P.K.Raju)

Coronal heating

Scudder's approach to coronal heating via velocity filtration is being investigated. The feasibility of producing non-Maxwellian particle velocity distributions was examined and Landau damping of ion-acoustic waves was identified as a suitable mechanism.

In another investigation, the presence of turbulent heating of the corona was shown to produce large scale velocity flows in coronal structures. (P.Venkatakrishnan)

Coronal loops

The temporal evolution of pressure in solar coronal loops was studied in detail using the ergodic theory of chaos and strange attractors and the ideal theory of magnetohydrodynamic turbulence in cylindrical geometry. The three-mode representation of the velocity and magnetic fields in the expansion in terms of the Chandrasekhar-Kendall (C-K) functions submits to the investigation of chaos. It was found that when the system is perturbed from a state where the magnetic energy $B^2/4\pi$ and the kinetic energy $(1/2)mv^2$ are nearly equal, it exhibited marginal stability. On the other hand, when there were large deviations from the equilibrium, the system was nonlinear

and so was the corresponding time evolution of pressure. The existence of chaos in the temporal evolution of pressure was established by evaluating the invariant correlation dimension of the attractor D_2 and the fractal value of it indicated the existence of deterministic chaos. The calculated values of D_2 at axial and surface points of the loop showed that as one proceeded from the axis of the loop towards the surface, the dynamics showed the development of strange attractors ending up in complete randomness. The transition from the strange attractor state to randomness requires a much finer analysis such as the evaluation of the Lyapunov constants and this will be investigated in future. By specifying the Lyapunov constants one can possibly evaluate the class of initial states which can give the observed lifetime of the loops. (K.Sasidharan, V.Krishan, *T.D.Sreedharan, *R.Pratap)

Continuum radio emission

The continuum emission from the undisturbed sun was mapped at a wavelength of 8.7 meters during 1981-85 using the large decameter wave radiotelescope at Gauribidanur with a resolution of $26' \times 38'$. During the period August 6-30, 1983 the sun was exceptionally quiet at meter and decameter wavelengths and it was possible to make maps on several consecutive days. On these days the position of the centroid of the radio sun agreed quite closely with the centre of the optical sun indicating that there is very little or no contribution from active regions. But the observed peak brightness temperature varied from 100,000 K to 700,000 K. The half power widths of the brightness distribution were in the range of 3 to 4 R_{\odot} . The variations of the brightness temperature and the half power widths are not correlated. It is therefore suggested that the variations of the brightness temperature are not caused by uniform density variations or due to scattering by an irregular corona. (Ch.V. Sastry)

Spot magnetic field and the Wilson depression

Independent spots suitable for this study have been selected out of the spots and groups for which Zeeman line splitting observations were ob-

tained during 1979-83 at the Kodaikanal Observatory. It is interesting to note that a large number of spots do not show the Wilson effect. Further, a significant number of spots show the opposite of Wilson effect. Measurements have been started on the photoheliograms for the depressions in penumbrae and the evaluation of magnetic field strengths using the spectra of selected spots. (S.P.Bagare, S.S.Gupta, P Venkatakrisnan)

Small scale magnetic structures

Intensity oscillations in chromospheric bright points and network elements

From a 35 minute time series of photographic spectra in the Ca II H line obtained at the Vacuum Tower Telescope (VTT) of the Sacramento Peak Observatory, New Mexico, USA under high spatial, spectral and temporal resolution, a large number of H line profiles at the sites of the bright points in the interior of the supergranulation cells, and at the network elements, on a quiet region at the centre of the solar disc have been derived. It is shown that the bright points are associated with a 3 minute periodicity in their intensity oscillations whereas the network elements exhibit a 7 minute periodicity. It is surmised that the large difference in periods of the intensity oscillations, the strength of the magnetic fields, and the intensity enhancements at the sites of the bright points and the network elements themselves may probably be taken as evidence to argue that the mechanism of heating in the two cases are dissimilar, irrespective of the sizes of these structures. (R.Kariyappa)

The Ca II K bright points and H α bright-dark mottles

Very high quality spectroheliograms have been obtained simultaneously in Ca II K line, in the core and wing of H α and in the continuum using the spectroheliograph of the Sacramento Peak Observatory during the first week of July, 1993. The aim is to determine whether K_{2V} bright points, H α bright-mottles, off-band H α dark grains and granular-intergranular fea-

tures are different aspects of the same feature. Analysis of the data is in progress. (R.Kariyappa)

Flares

From the circular flare of 14 March, 1984 observed at Kodaikanal, it is concluded that the relative motion between the emerging spot field and its neighbouring field is responsible for the field line reconnection which triggered the flare. It is believed that the reconnection is indicated by the dynamic activity of the H α filament at the chromospheric level, where it attained a severe twist before erupting as a 4B flare. (K. Sundara Raman, P.S.M.Aleem, Jagdev Singh, R.Selvendran, *R.Thiagarajan)

Solar seeing and atmospheric turbulence

Study of the data on daytime seeing measurements obtained at Kodaikanal in Feb-March 1992, has been completed. Durations of image stability and rms Fried-parameters have been evaluated. A phenomenon of clustering of good moments is observed; these good spells occur apparently between successive turbulent cells in the atmosphere. Using the seeing data and the local wind velocity measurements during observations, the dimension range of dominant cells is estimated to be 100-700 meters. It is suspected that this dominant scale is perhaps the range for the controversial upper scale of atmospheric turbulence in the Kolmogorov spectrum, for the day skies. (S.P.Bagare)

Solar Instrumentation

Vector Magnetograph

The solar vector magnetograph has been operational at the solar tunnel, Kodaikanal since last year. On the basis of the experience gained, several mechanical fixtures were fabricated for the second unit of the polarimeter

These include a Roche prism holder, a half-wave plate holder and a filter holder. (N.Jayavel, A.V.Ananth, P.Venkatakrisnan)

The validation of the vector magnetograph was completed in 1993 May/June. Initial observations, made in 1994 January/February used the magnetograph in the line-of-sight mode. The results obtained from these runs will be used to establish the relationship, if any, between magnetic fields and mechanical energy generation in the photosphere (P.Venkatakrisnan, R.S.Narayanan)

Velocity structure inside the supergranular cells

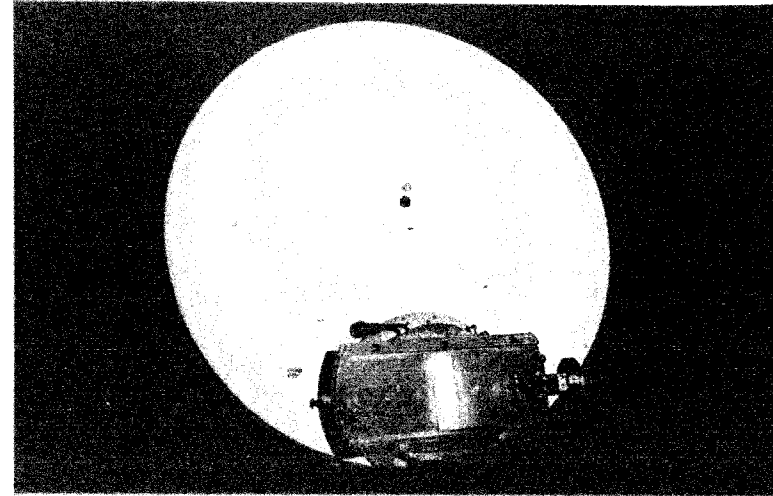
Work has started on a new method of obtaining velocity grams using an image subtraction technique. Using the 13-inch solar image from the Solar Tower Telescope, the high resolution spectroheliograph, a beam splitter and a linear diode array, two images of the same region will be obtained in the two wings of an absorption line simultaneously. Intensity fluctuations on the sun will be removed from the data by subtracting one image from the other. The remaining intensity fluctuations will yield the velocity pattern on the sun. The use of a diode array is expected to provide reasonable accuracy for measurement of velocity structures inside the large convective cells. (J.Singh, R.Srinivasan, G.Srinivasulu)

Solar Tower Telescope at Kodalkanal

For improving the spectral quality a new lens of 60 feet focus and a reflecting grating have been installed at the Solar Tower Telescope in Kodaikanal in 1994 January. A single pulse to the motor rotates the grating through an angle of 32.4 arc sec and shifts the spectrum by 2.8 mm at the focal plane. The grating can be rotated at a maximum speed of 1.8 degree per second and a minimum speed of 2.7 arc min per second. The spectral quality has become much better and according to eye-estimates the scattered light has come down to 3-7 percent from the earlier 20-50 percent. (J.Singh, F.Gabriel)



Picture of the telescope at the entrance of the high resolution spectrograph of the Solar Tower Telescope (July 1990).



Picture of the Sun in white light as seen at the entrance of the high resolution spectrograph of the Solar Tower Telescope.

An imaging system for the spectroheliograph

A linear CCD based imaging system is being developed for the spectroheliograph, operating at Kodaikanal. The objectives of developing the CCD system are as follows:

1. To eliminate the need for the photographic plates.
2. Achieving higher dynamic range and resolutions.
3. Direct recording of the information in the digital format.

A linear CCD camera has been procured from M/S Fairchild keeping in view the following points:

1. Compatibility to the existing mechanical scanning facility.
2. A single two-dimensional CCD array of the required size (60 mm x 60 mm) is not available commercially.

The proposed linear CCD camera will cover the 2D solar image giving a 6000 x 6000 pixel resolution. Due to the memory limitations of the acquisition system, the resolution is reduced to 2000 x 2000 pixels.

The camera is mounted in the location where the photographic plates were fixed earlier. The present mechanical arrangement scans the camera across the solar image at a fixed rate. As the camera sweeps the solar image, it provides digital data corresponding to the image. The data are acquired and stored in the computer via the interface electronics. The interface electronics generates the clock under software control and synchronises data flow from the camera electronics. The computer stores the data in expanded memory during acquisition and later transfers it to the disk. The acquired image is displayed on the monitor at super VGA resolution. (G.Srinivasulu, R. Srinivasan, M.R.Somashekar)

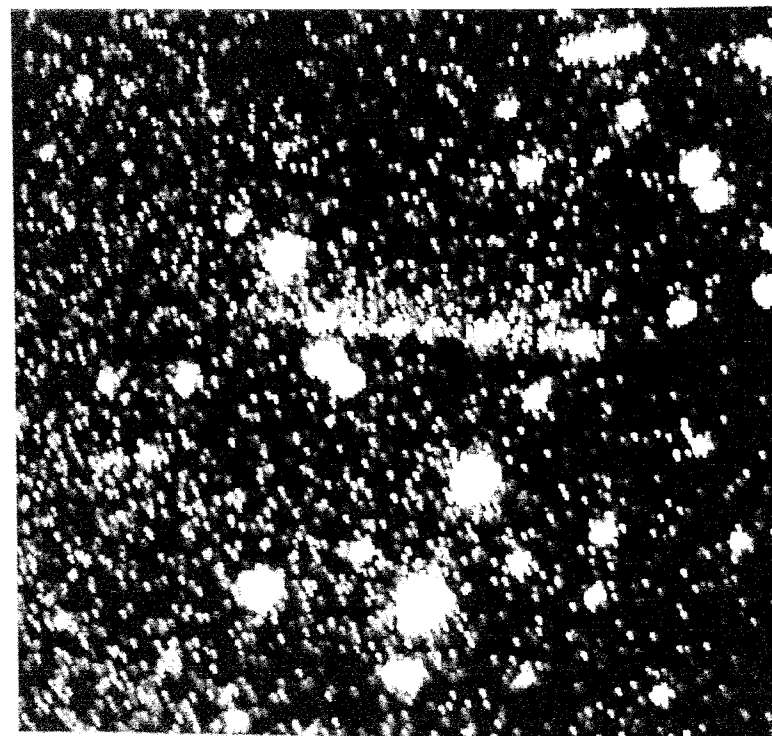
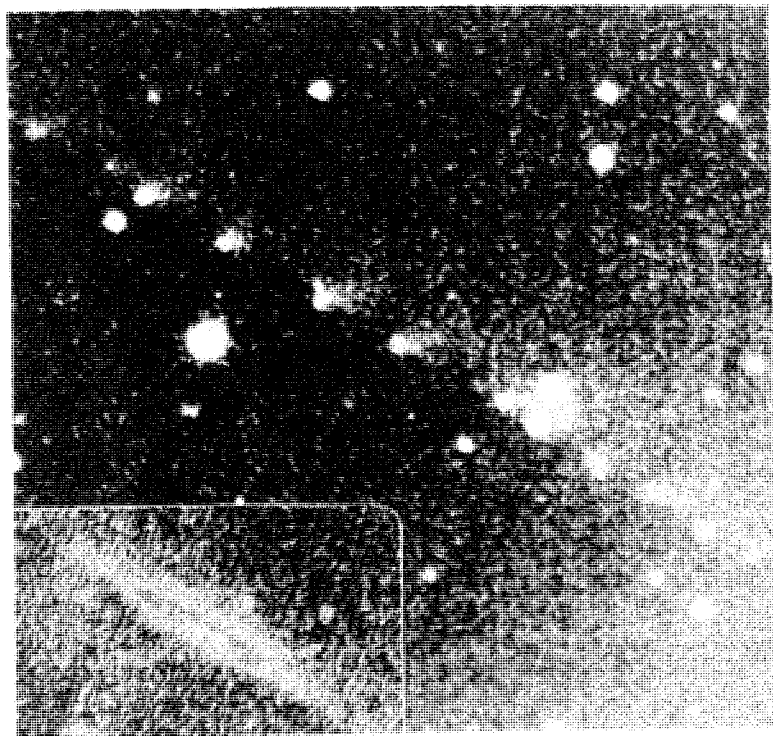
Solar scanner

In order to scan the solar image through the slit, the existing Coelostat Drive system required certain modifications. The frequency of the drive system is made selectable through a PC port in the 'remote mode' and through the thumb wheel switches in the 'local mode'. A user-friendly software has been developed for the solar scanner. The programme takes the parameters like the drive frequency, time period and the number of programming steps from an input ASCII file and executes one step at a time upon user's command. The 'Skip' facility allows branching capability from one programmed step to another. The system is under development and is expected to go into operation in early 1995.

(R.Srinivasan, B.Nagaraja Naidu, K.S.Ramamoorthy, C.V.S.Harsha)

Site survey for the eclipse of 1995

The shadow of the total solar eclipse of October 24, 1995 touches India at about 8.31 IST in Rajasthan and the path of totality passes through parts of Rajasthan, Uttar Pradesh, Bihar and West Bengal. The duration of totality will be about 60 seconds in Rajasthan and about 90 seconds in West Bengal. The altitude of the sun at the time of the total eclipse will be about 20 degrees in Rajasthan and U.P. and 30 degrees in West Bengal. Weather data indicate that the chances of having a clear sky are more in Rajasthan and U.P. as compared to Bihar and West Bengal. After visiting a number of villages close to the central line of the path of totality and taking into account the logistics available, Nim Ka Thana and Praggpura have been found to be good locations for setting up camps for observations of the eclipse. Nim Ka Thana is located at a distance of 100 km from Jaipur and 200 km from Delhi. It is accessible from Delhi by both road and rail transport. The survey will be continued. (J.Singh)



Solar System Studies

Near Earth asteroids

CCD imaging at the prime focus of the 120 cm telescope of the Japal Rangapur Observatory (JRO) was started this year jointly by the Department of Astronomy, Osmania University and the Indian Institute of Astrophysics. The 512 x 512 CCD of JRO had no facility for scan mode observations earlier. This has now been done. Although initial efforts consisted mainly in setting up the system, some efforts were also spent in obtaining images of Comet Shoemaker-Levy 9. Test runs of selected regions for moving objects were conducted and necessary PC-based software was developed for this work.

A 1024x1024 CCD and a SUN SPARC station for data acquisition have been procured by IIA for studies of solar system objects. The design of the mechanical assembly for holding this large format CCD at the prime focus of the 120 cm telescope of JRO with provisions for tilt, rotation, focussing and filter unit is now ready. This assembly together with the large CCD and the SUN SPARC station is expected to be available for observations from next year onwards. (R.Rajamohan)

Observations of Comet Shoemaker-Levy 9

Tidal disruption of comets under the intense gravitational field of Jupiter have been discussed, predicted and inferred in the past by several investigators, but never witnessed until March 24, 1993 when a squashed comet was first spotted by Eugene and Carolyn Shoemaker and David Levy. Subsequent observations indicated that the progenitor comet was fragmented due to tidal forces during its close encounter with Jupiter on 1992 July 7-8. The train of fragments is now in a joviocentric orbit. The broken up chunks which are of size 2.5 - 4.3 kms will make another close approach to Jupiter and are predicted almost certainly to crash on Jupiter one after the other over a 6-day period centered on 1994 July 20. The comet was

being monitored at the Vainu Bappu Telescope since its discovery. Fig 1 shows two of the images taken using a CCD camera at VBT. Image in the inset was taken on JD 2449136.23, two months after the discovery of the comet. The bigger image was taken on JD 2449448.30. Significant changes can be noticed in the two images over the ten-month period. The total length of the chain has increased four times between May 1993 and end March 1994. Images were also obtained at the prime focus of the 120 cm telescope of JRO. A large corrected field of 13' x 13' permitted imaging of several field stars of magnitude down to 15.5 in a single CCD frame which could be identified from the Guide Star Catalogue (see Fig 2). Accurate astrometry was therefore possible using these images (R Vasundhara, R.Rajamohan, Pavan Chakraborty, *P. Vivekananda Rao, *R.Swaminathan, *G. Som Sunder, N. Kameswara Rao, Y.D. Mayya, B.Eswar Reddy, T.P.Prabhu)

Radio bursts from Jupiter

A sixteen-element array operating in the frequency range of 18 to 28 MHz was constructed to observe radio bursts from Jupiter. This array is being used in conjunction with an acousto-optic spectrometer. The equipment is being set up especially to observe the activity of Jupiter in radio wavelengths during the 1994 July encounter of Comet Shoemaker-Levy with the planet. (K.R. Subramanian, E.Ebenezer, Ch.V Sastry)

Predictions of stellar occultations by Comet Shoemaker-Levy 9

The dusty envelope created at the time of tidal disruption and absence of emissions make this comet a favourable object of study using the technique of stellar occultations. A search for candidates in the Guide Star Catalogue was carried out to predict the appulses by 9 of the 21 individual fragments. Geocentric circumstances of about 300 events were computed for the period starting 1993 January 28, till the time of the impact in 1994 July. Since cometary positions are continually updated based on new observations, the predictions can be updated by using simple expressions using the corrections to the ephemerides. (R.Vasundhara)

Stars

Herbig Ae/Be stars

During 1993-94, short (hours to days) to long (months to years) time scale spectroscopic observations have been carried out in the interval 5950 - 6700 Å, of fifteen Herbig Ae/Be stars ranging in V magnitude from 7 to 13. A Boller and Chivens spectrograph with a CCD detector has been used at the Cassegrain focus of the Vainu Bappu Telescope. From these observations it has been found that in six of these stars (AB Aur, HK Ori, KK Oph, BD +40°4124, HD 200775, BD +46°3471) forbidden [O I] emission at 6303.3 Å with a P Cygni profile or a double-peak H α profile is present while in the rest of the stars only single-peak H α emission profiles are present. We suggest that stars with a P-Cygni or double-peak H α profile have strong stellar winds and the forbidden lines originate from the outer parts of the stellar winds, whereas stars with single-peak emission profiles do not have sufficiently large winds to produce forbidden line emission. Detail modeling is in progress. (K.K.Ghosh, S.Pukalenti)

Polarimetric monitoring of Herbig Ae/Be stars was continued. About 50% of the objects show variability in the degree of polarization as well as in the position angles on time scales of months to years. These stars are also being observed in the infrared. Photometric variability in the infrared has been recorded in a number of them. (S.K.Jain, H.C.Bhatt)

AB Aur

As part of MUSICOS 1992 (Multi-site continuous spectroscopy), the Herbig Ae star AB Aur was observed at moderately high resolution. The aim of the spectroscopic investigation was to study the azimuthal structures in the wind and the chromosphere of this pre-main sequence star.

The He I 5876 Å line, supposed to be originating in the expanding chromosphere of AB Aur, in the innermost parts of its wind, was monitored at a

resolution of 30000 nearly continuously for about 4 days. A spectacular variability of this line was discovered, the profile changing from pure emission to a composite profile including a deep absorption component in the course of a few hours. This variability can be the signature of azimuthal structures in the wind of AB Aur.

The rotational modulation of the Mg II and Ca II resonance lines has been interpreted by a model involving streams in the wind of AB Aur. If these streams originate from the stellar surface, as would be the case if they are controlled by a surface magnetic field, then we expect that the chromospheric He I 5876 Å line, formed near the base of the wind, is also modulated by the rotation of the stream structure. The observations reported here are in agreement with this model, which suggests that the structure of the wind of AB Aur indeed originates from the stellar surface. We propose that the He I 5876 Å line of AB Aur is the superposition of 2 components:

- (a) a quiet-chromosphere component; this component has (i) an absorption centered at zero velocity, formed at the base of the wind and chromosphere, where the wind velocity is small and the chromospheric temperature is not far above the effective temperature, and (ii) a blue-shifted emission component formed further out in the wind and chromosphere, at higher velocity and temperature;
- (b) a stream component; this component, formed in the streams originating from the stellar surface, is in emission, and its position in wavelength is modulated by the rotation of the star; there may be one or several of these streams.

Further studies are in progress. (K.K.Ghosh, *C.Catala)

T Tauri stars

Spectroscopic observations of the weak and moderate emission T Tauri stars have been continued. Spectra in the region of H α were obtained for the programme stars so as to cover a few rotation periods to monitor the short-term as well as the periodic variations in the emission strengths. It is found that the H α emission strengths of weak emission T Tauri stars behave more or less as in the active main sequence G-K stars while in moderate emission T Tauri stars the emission strength varies rapidly. The weak emission T Tauri stars HD 288313 and HD 283572 do not have H α emission.

Broad band photometry of the weak emission T Tauri star HD 288313 obtained during 1993 was analysed. It is found that the light variations show a periodicity of 1.8 days. Simultaneous H α spectroscopy and photometry are carried out during the current season to check the correlation between the H α strength and the light variation.

The Strömgren photometry of the active chromospheric stars HD 84140 and HD 127535, obtained at ESO, Chile between 1985 and 1990 as a part of the observing programme of long-period variables, is also being analysed. The stars were observed continuously over a few photometric periods during several seasons to study the short and long term variations in activity.

A comparison between the photometric behaviour of weak to moderate emission T Tauri stars and active chromosphere stars yields several interesting results. Though the light variations in moderate emission T Tauri stars at times show periodicity, most of the time we see irregular light variations due to the extreme activity. But in the case of weak emission T Tauri stars and active chromosphere stars the light variations are generally periodic, though the shape and the amplitude of the light curves vary from one period to another.

We have obtained polarimetric observations of T Tauri stars TW Hya and V 410 Tau for a period of 10 nights. Further, simultaneous photometry of these stars has been done to study the correlation between variability in polarization and light variability. The analysis of the data is in progress. (M.V.Mekkaden)

Be stars

Sixty seven bright Be stars, at different epochs, have been observed during 1993-94 using the 102 cm reflector with a coudé-echelle spectrograph and a CCD detector system. From the high resolution (0.17 Å per pixel at H α) and high signal-to-noise ratio spectra of these Be stars, it has been found that a few of them have changed from Be to Be-shell phase. Before entering into the shell phase, violent outbursts have been observed in the spectra of these stars. These stars have displayed inverse-P-Cygni profiles in He I and higher-order Balmer lines before the outburst. Detail modeling of these observations is in progress.

During 1993 November-December nearly simultaneous polarimetric (U, B, V, R, I) and spectroscopic (H α and He I) observations of 43 Be stars were carried out. It is hoped that the multiband polarimetric data will allow us to find out the presence or absence of shocks in the disks of Be stars. (K.K.Ghosh, *R.Radhakrishnan, *R.Krishnamurthy, *C.Srinivasan, G.Selvakumar, M.J.Rosario)

RS Canum Venaticorum Stars

DM UMa

The differential BV photometry of DM UMa obtained over 19 nights and near-simultaneous H α spectroscopy obtained over 7 nights during the 1990-91 observing season were analysed. From an analysis of the available data it was found that the light curve shows both periods of small and large amplitudes with remarkable changes in its mean light level. Apparently, the amplitude of light variation does not depend either on the mean brightness of the system, or on its ΔV_{\max} or ΔV_{\min} .

It is found that the light minima phases fall on four well separated lines. The minimum, first observed in 1979, could be traced until 1982. A second minimum, which first appeared some time in 1981, could be traced until 1985. During 1986-87 there was a short-lived minimum. The minimum which originated some time in 1988 still existed in 1991. Earlier a lower limit

of about four years was assigned to the lifetime of a centre of activity (spot or spot group). But the present analysis indicates that the lifetime of a spot or spot group can be as short as two years. It is interesting to see that all the minima show migrations towards decreasing orbital phases. If the equator is synchronized with the orbital rotation, this implies that higher latitude regions are rotating faster than the equatorial region. The modelling indicates the presence of spots at high latitudes. The H α emission equivalent width in DM UMa shows a modulation with the photometric phase so that the maximum emission equivalent width is close to the minimum of the light curve. The spectrum of DM UMa obtained on 1991 Jan 7 shows strong evidence of a flare (S Mohin, A.V.Raveendran)

Totally eclipsing RS CVn binaries

These systems have been found to show interesting forms of activity in almost all portions of the spectral regions ranging from x-rays to radio region. In order to understand the atmospheric properties of these RS CVn components of the eclipsing binary systems, a programme of spectrophotometric observations has been initiated. The energy distribution curves of some of these stars at different phases have been obtained in the wavelength range of 4000 Å to 7000 Å at the Vainu Bappu Observatory. Detailed analysis will be carried out at the Ankara University Observatory, Turkey. (G.S.D.Babu, *E.Derman, *O Demircan)

Eclipsing binary HU Tauri (HR 1471)

The photometric elements of HU Tauri are derived from an analysis of its blue and visual light curves using the Wilson and Devinney light curve synthesis method. The photometric elements suggest that HU Tauri is a semidetached system and the primary minimum in its light curve is due to an occultation eclipse. Combining the photometric elements and the spectroscopic orbital elements the absolute dimensions of the system are derived. The masses and radii of the B8 V primary and F8-G2 III-IV type secondary are found to be $4.68 M_{\odot}$, $2.9 R_{\odot}$ and $1.26 M_{\odot}$, $3.34 R_{\odot}$ respectively. The cool and less massive secondary appears to have filled its Roche lobe. (M.Parthasarathy, *M.B.K.Sarma, *P.Vivekananda Rao)

A critical compilation of oscillator strengths of Fe II lines

A compilation is made of oscillator strengths for 841 Fe II lines of astrophysical interest. Oscillator strengths from various sources e.g. laboratory measurements, semi-empirical estimates and those derived from solar Fe II lines are critically examined for random and systematic errors. The errors of experimental and solar oscillator strengths are found to be lower than those of semi-empirical estimates.

After omitting the measurements with large errors (more than 25%), oscillator strengths from experimental and solar data have been brought to one scale by applying necessary corrections and hence we had a compilation of gf values with an accuracy within 10-25%. Next the list of semi-empirical gf values from Kurucz (1989, private communication) which is overwhelmingly extensive was examined. But for heavier elements like iron, quantum mechanical formulations required to calculate gf values need many simplifying assumptions and hence it is noticed that theoretical and semi-empirical gf values suffer from large systematic errors. Systematic corrections have been calculated that should be applied to gf values of Kurucz (1989) using our compilation of experimental data. It is found that the systematic errors are dependent upon excitation potentials of the lines. The correction is very small for 0. eV lines but grows as 4-5 eV lines are approached. (S. Giridhar, *A.Arellano Ferro)

Hydrogen deficient stars

Abundances

A comprehensive analysis of the surface abundances in R Cr B stars was done based on the high resolution spectroscopic observations obtained at CTIO 4-m and McDonald 2.7- and 2.1-m telescopes. The analysis of the observations was carried out using the computing facilities at both VBO, Kavalur and IIA, Bangalore. In a review based on the above data the authors present a selection of recent highlights of observations of R Cr B variables. Emphasis is placed on an abundance analysis of a complete sample (18 stars) of the warm Galactic R Cr B variables. It is shown that 14

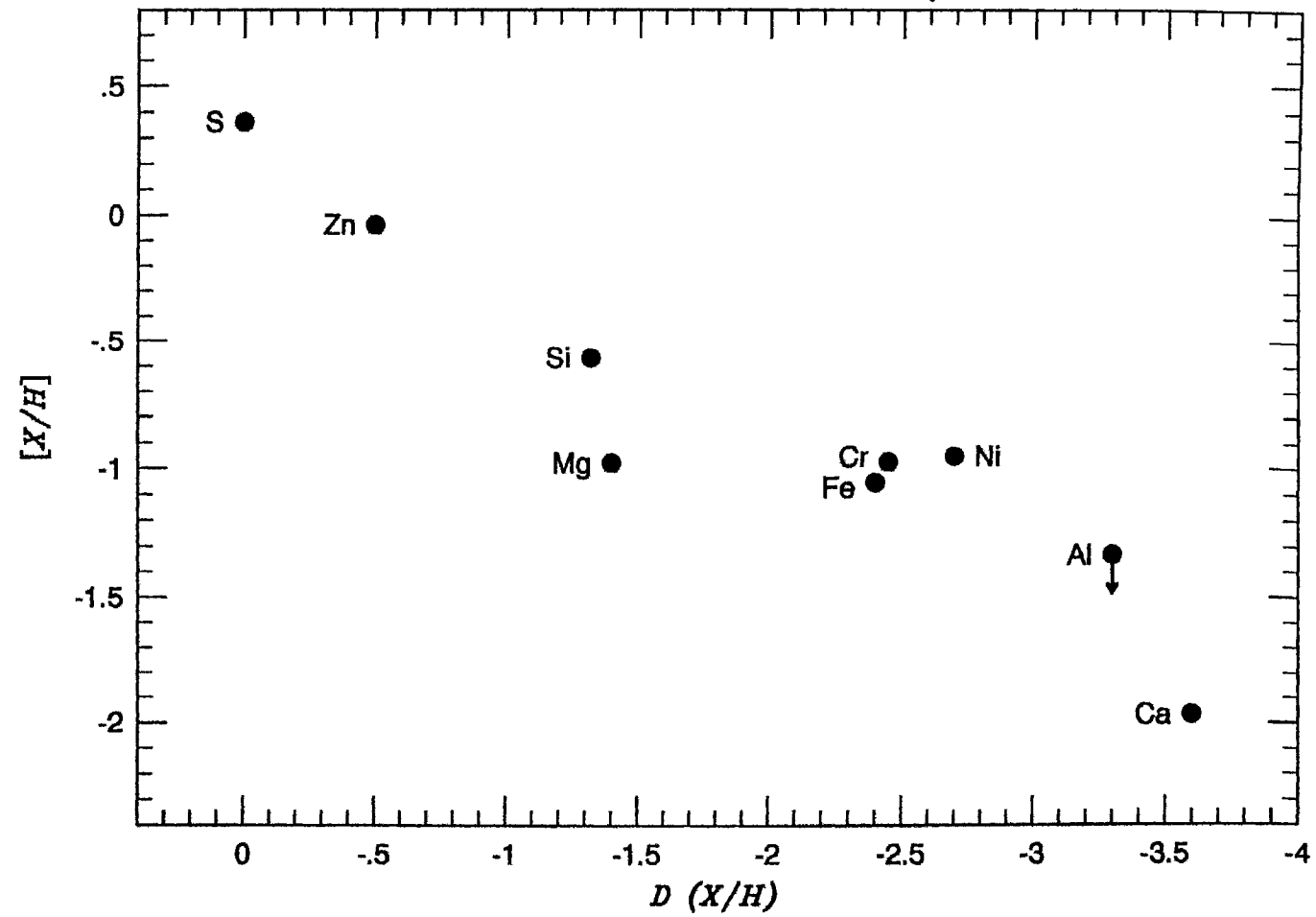


Fig.3. Differential abundance $[X/H]$ of IW Car versus the depletion $D(X/H)$ observed in the diffuse cloud at -15 km s^{-1} in the line of sight to ζ Oph.

out of the 18 stars have very similar compositions: the iron mass fraction varies by about a factor of 3 around the solar value (assuming C/He = 3%) but abundance ratios X/Fe for elements from Na to Ba show little variation. By contrast, the other 4 stars are deficient in iron but not in Na, Si, S and some other elements. With a value of $[\text{Si}/\text{Fe}] \sim 2$, the quartet is indeed 'peculiar'. One of the quartet, V 854 Cen shows depletions of elements (other than CNO) similar to the depletions seen in interstellar medium corresponding to an average $\log N(\text{H})_{\text{tot}} = -1.5$. Scenarios for creating R Cr B variables from normal single and double stars have also been summarised in this review. (N.Kameswara Rao, *D.L.Lambert)

The detailed analysis of the observations of R Cr B stars using Schönberner's atmospheric models is in progress. Not only the atomic lines but also the strengths of the molecular bands are being studied to be consistent with the values of T_{eff} , $\log g$ of the models and the abundances. A study including the kinematical properties obtained from the radial velocity observations of these stars is also being done. (N.K.Kameswara Rao, S.Giridhar, *D.L.Lambert, G.Pandey)

MV Sgr

A preliminary study of the emission line spectrum of the hot R Cr B star MV Sgr is complete. The high resolution spectra obtained with CTIO 4-m telescope are being analysed. These show the presence of [O I], [N II] and other forbidden lines. The emission lines of Fe II dominate the spectrum and are also double. The appearance of double lines of [O I] indicates a bipolar or disk-like geometry of the surrounding gas rather than an optical thickness effect in the lines as thought earlier by other observers. The [O I] and [N II] line ratios give respectively $N_e \sim 3 \times 10^6 \text{ cm}^{-3}$ and $T_e \sim 1.6 \times 10^4 \text{ K}$. The presence of low-density nebulae around R Cr B stars is of importance in the context of stellar evolution. (G. Pandey, N.Kameswara Rao, *D.L.Lambert)

IW Car

The carbon rich RV Tau star IW Car has been analysed in detail. The spectrum of IW Car shows many interesting features. The observed

hydrogen alpha line is very complex with weak blue and red emission components, a sharp deep absorption feature and a shallow broad blue-shifted absorption feature. The sharp deep absorption is close to the position of the expected photospheric absorption line but the shallow absorption feature is blue shifted by about 82 km s^{-1} with respect to the photospheric lines. The gas giving rise to this absorption appears to be escaping from the star. The weak emission lines may come from a shell or a disk near the star. A high resolution spectroscopic analysis of IW Car has been carried out for abundance studies. The star shows a photospheric composition unlike that reported previously for any other RV Tau star but resembles the pattern seen in certain post-AGB stars. IW Car is carbon-rich: several lines of C I are detected and suggest C/O ~ 1 . The star is generally metal poor. The derived composition of $[\text{Fe}/\text{H}] \sim -1.0$, $[\text{Ca}/\text{H}] \sim -1.9$ but $[\text{Zn}/\text{H}] \sim 0.0$ reflects gas of solar metallicity from which easily condensable elements have condensed into dust grains and been removed from the star's photosphere. Figure 3 displays a plot of the differential abundance $[X/\text{H}]$ of IW Car against the depletion observed in the $\sim 15 \text{ km s}^{-1}$ cloud component of ISM in the line of sight to ζ Oph. Separation of gas and dust may have occurred in the present or the recent stellar wind of IW Car. These characteristics also suggest that RV Tau stars are post-AGB objects. (S.Giridhar, N.Kameswara Rao, *D.L.Lambert)

V Cr A and UW Cen

Analysis of the spectra at minimum light of the two R Cr B stars V Cr A and UW Cen has begun. V Cr A shows strong Na I D lines in emission, both broad and sharp, very typical of the R Cr B's. In addition the differential spectra, compared to that of maximum light, show emission of the molecular bands of C_2 and of other sharper metallic lines. UW Cen only displays shifted absorption components of Na I D lines with velocities of ejection ranging from 105 km s^{-1} to 5 km s^{-1} . (N.Kameswara Rao, S.Giridhar, G.Pandey, *D.L.Lambert)

SU Tau

The programme of CCD imaging of the fields of R Cr B variables and other related stars, particularly, when they are at minimum light, is being contin-

ued with the 1-m and 2.3-m telescopes at VBO. The star SU Tau has been imaged in BVRI filters. Its field reveals heavy reddening and the presence of a field galaxy close to the object particularly prominent in the R,I bands. It is possible that this galaxy might contribute to the flux excess seen in the IRAS measurements of SU Tau at 60 μm and 100 μm .

The spectroscopic monitoring of some of these stars is being done with a view to studying their pulsation and related phenomena.
(N. Kameswara Rao, S.Giridhar, G.Pandey)

Lunar occultations of infrared sources

Stars with circumstellar dust are generally bright in the infrared. However, the angular sizes of the circumstellar shells are often in the sub-arc second range. Lunar occultations provide a unique opportunity to resolve these structures. In this technique the diffraction pattern of the source occulted by the moon is observed and a detailed deconvolution process yields the source structure. Angular resolution at the level of milli arc seconds can be obtained. About 10 objects from the 2 μm survey catalogue have been observed with the various telescopes at VBO, Kavalur. Analysis of the data is in progress. (H.C.Bhatt, *T.Chandrasekhar, *N.M Ashok, *Sam Ragland)

Ca II triplet lines in cool stars

Survey

The analysis of the Ca II triplet near-infrared lines $\lambda 8498$, $\lambda 8542$, $\lambda 8662$ as sensitive indicators of luminosity, temperature and metallicity of cool stars has been continued. High dispersion CCD spectra have been obtained of several more metal-poor stars with the coudé echelle spectrograph at the 102 cm telescope. Observations of $\lambda 8498$ and $\lambda 8542$ now exist for 130 stars of all luminosity types, spanning a spectral type range of F8 to M3 and $[\text{Fe}/\text{H}]$ from -3.0 to $+1.1$. The third line of the triplet at $\lambda 8662$ has a particularly clean profile free from blends. Because of high spectral resolution, all three lines could not be observed simultaneously. The earlier data set has now been supplemented with observations of this line in 80 stars observed this year.

Triplet lines as indicators of chromospheric activity

From the existing Ca II triplet data, stars of the same luminosity, temperature and roughly the same metallicity have been grouped together. It is found that within a given group, there is a star or two with Ca II triplet line profiles not as deep as those of the other stars in that group. This is most likely due to the presence of emission filling in the absorption profile suggesting a higher chromospheric activity in these stars. A detailed study of the Ca II triplet line profiles in the 130 stars observed has shown that at least nine stars, namely 56 Peg (G8 Ib), HR 2269 (K3 Ib), ϵ Eri (K2 V), χ^1 Ori (G0 V), ϕ Vir (G2 IV), ν Hya (K2 III), ϵ Hya (G5 III), δ Vir (M3 III), θ CMa (K4 III) have higher central depth than the respective stars of the same luminosity, temperature and metallicity. These observations have been compared with the existing data on the Ca II H and K lines for these stars. There is a striking correspondence in the sense that the stars with higher central depth have a higher intensity index assigned to the H_2/K_2 emission. In the present observations, the spectrum of each star with higher central depth has been divided by that of one of lower central depth of the same spectral type and luminosity with the idea that the divided spectrum would indicate the amount of emission due to chromospheric activity. The divided spectra yield for both 8498 Å and 8542 Å larger full widths at half maximum for supergiants than for giants and is still lesser for dwarfs, roughly in analogy with the well-known width-luminosity relation described by the Ca II H and K lines.

Relationship between the Ca II triplet lines and the Li I $\lambda 6707$ line

The central depths of the Ca II triplet lines are excellent chromospheric activity indicators; the shallower the lines are in the spectrum of a star, the more active is the chromosphere of this star. Such activity is tightly connected to the age of a star. The more active the chromosphere, the younger is the star. Both chromospherically active and quiet stars were observed in the Li I line at 6707.83 Å. More than half of the active stars have been found to have a strong Li I line whereas it is very weak in the quiet stars. This finding is consistent with the idea that the more active star is much younger, hence a strong Li I line. On the other hand, Li is most likely already

depleted in chromospherically quiet stars which are older. Further investigations are in progress to elucidate the lithium problem.
(Sushma V. Mallik)

Post-AGB Stars

IRAS 10215-5916

From low and high resolution spectroscopic observations of IRAS 10215-5916 we have discovered the presence of nebular emission lines in this G-type supergiant star in post-AGB stage. From its high resolution spectrum we derive an expansion velocity of 17 km sec^{-1} for the shell, similar to the values usually observed in planetary and proto-planetary nebulae. The images taken in the near infrared show that IRAS 10215-5916 is slightly extended and asymmetric. Although we cannot rule out a possible binary nature for the central star of this IRAS source, in which a hot component could be responsible for the observed nebular emission, no indications of binarity have been found so far. We suggest that the observed spectrum and morphology could be produced by the asymmetric mass loss of a single star in the post-AGB phase. Post-AGB mass loss can play a fundamental role in shortening the transition time towards the planetary nebula stage and favour the formation of the bipolar structures commonly observed in evolved planetary nebulae. In this sense, it is shown that this mass loss is more intense and frequent for massive progenitors of PNe.
(*P Garcia-Lario,* A.Manchado, M.Parthasarathy, *S.R.Pottasch)

LS II + 34° 26

LS II + 34° 26 is a high velocity, low gravity B1.5 Ia-labe supergiant star. It is an IRAS source with far-infrared colours similar to post-AGB stars and planetary nebulae. We showed that LS II +34° 26 is a low mass post-AGB B supergiant and not a massive Population I B star located near the outer edge of the Galaxy. LS II +34° 26 was observed with the IUE. Low dispersion ultraviolet spectra from 1150Å to 3200Å have been obtained. From an analysis of the 2200Å feature the E(B-V) colour excess is found to be 0.25. Radial velocities of Si IV and C IV absorption features yield

respectively stellar wind velocities of $-2780 \text{ km sec}^{-1}$ and $-2200 \text{ km sec}^{-1}$ and show evidence for post-AGB mass loss.

High resolution optical spectra of LS II +34° 26 were obtained with the Isaac Newton Telescope at La Palma. Forbidden emission lines from N⁺, O⁺, S⁺ and permitted lines due to C II, NII, Si II, Fe III have been found. Several He I lines were found to show emission and/or P Cygni profiles. The spectrum of LS II +34° 26 in 1977 (Turner & Drilling 1984) shows only H α in emission. The recent spectra show nebular emission lines in addition to emission lines of H and He indicating variation in the spectrum within the last 10-15 years. Absorption lines show night-to-night variations in profile shapes and radial velocities. Emission lines show a constant radial velocity. The presence of circumstellar dust shell with characteristics similar to planetary nebulae, the presence of nebular lines in the optical region and the high velocity of the star suggest that LS II + 34° 26 is a low mass post-AGB star and it is rapidly evolving into a planetary nebula
(M.Parthasarathy, *P.Garcia-Lario, *D.de Martino, *S.R.Pottasch.)

Hot post-AGB stars

From an analysis of IRAS data, several hot post-AGB stars have been detected. To study their spectra, flux distribution and circumstellar matter, low resolution spectra in the optical region and CCD BVRI images have been obtained with the 102 cm and 234 cm telescopes at Kavalur. Analysis of the data is in progress.(M.Parthasarathy, B Eswar Reddy)

Post-AGB A-F supergiants

High resolution optical spectra of post-AGB A-F supergiants HD 101584 and IRAS 10215-5916 were obtained with the ESO CAT to study the chemical composition. Analysis of the spectra is in progress.
(M.Parthasarathy, *P Garcia-Lario, B.Eswar Reddy, *S.R.Pottasch)

Low resolution spectra in the optical region and CCD BVRI images of several post-AGB supergiants and IRAS sources with far-infrared colours

similar to planetary nebulae have been obtained with the 102 cm and 234 cm telescopes at Kavalur. The data are being analysed to derive their spectral types, luminosities and flux distribution.
(B.Eswar Reddy, M.Parthasarathy)

On the depletion of refractory elements in post-AGB A-F stars and Lambda Bootis stars

The abundance patterns in λ Boo stars and post-AGB A-F type stars were studied. They are found to show large depletions of refractory elements (Fe, Ti, Ca, Mg, Si, Al) and nearly normal abundances of volatile elements (C, N, O, S, Zn). Most of the post-AGB A-F stars have circumstellar dust shells. Some of the λ Boo stars also have circumstellar dust. The presence of circumstellar dust shells lends strong support to the idea that the depleted refractory elements are locked up in dust grains.

It is thought that the processes that produce photospheres with depleted refractory elements in λ Boo stars and post-AGB A-F stars may be the same. Mass loss, cold outflows and extended atmospheres are understood to be common during the pre-main sequence stage of evolution and also during the AGB and post-AGB stages of evolution.

The formation of dust close to the star during the pre-main sequence stage of λ Boo stars and during the AGB and/or post-AGB mass loss phase in the case of post-AGB A-F stars can deplete the refractory elements from the surface. The subsequent gas and dust separation and dust-driven mass loss (driving out mostly the dust) can explain the photospheric abundances of λ Boo stars and post-AGB A-F stars. To quote Yorke (1979) "the separation of dust and gas during "advanced" evolutionary stages (i.e. some time after the formation of the main sequence star) is a common phenomenon". Thus λ Boo stars may be the result of separation of circumstellar gas and dust during or immediately after their pre-main sequence stage and the dust is swept outwards by the processes described by Yorke

(1979). Similar processes during the AGB and/or post-AGB mass loss phases may also take place resulting in dust and gas separation and driving out mostly the dust. The signature of the depleted refractory element abundances in the photospheres of λ Boo stars and post-AGB A-F stars may be relatively long lasting, in spite of the rapid rotation and variability (in the case of λ Boo stars) and mass loss and pulsation (in the case of post-AGB A-F stars). It is possible that a considerable depth of the atmosphere is made up of material with depleted refractory elements. (M Parthasarathy)

Interferometric binaries

The Blind Iterative Deconvolution technique (BID) is being used to obtain phases of seventeen close binaries whose specklegrams were obtained earlier using the Vainu Bappu Telescope. A second method of reconstructing the object intensity is to develop a bispectrum. This venture has been now taken up. This powerful algorithm will enable one to reconstruct the phase and the modulus of the object spectrum. If the object is known to be a double star a model is available to fit to the bispectrum phase the parameters of a binary star system, i.e., relative brightness, distance and orientation. (S. K. Saha)

Novae

The programme on spectroscopic monitoring of novae was continued during the year. Intermediate resolution spectra were recorded of novae T Coronae Borealis, RS Ophiuchi and GK Persei during quiescence, of novae Puppis 1991, Cygni 1992 during the late nebular stage and of novae Aquilae 1993, Ophiuchi 1993 and Cassiopeiae 1993 in the immediate post-outburst stage. The last of these is a DQ Her class of slow nova as seen from the light and spectral evolution. The excitation conditions in the ejecta of novae in 1991 and 1992 increased beyond the values noted last year. (*G C Anupama, T P. Prabhu)

Galaxy and the Interstellar Medium

Evolution of protostellar discs in molecular clouds

Stars are born in molecular clouds together with circumstellar discs around them. The young star-disc systems then move around within the parent molecular cloud and encounter drag due to the ambient gas. This drag can detach the circumstellar disc from the young star. The discs can also be disrupted due to close encounters with other star-disc systems. These processes are being studied numerically. (H C Bhatt, Uma Gorti)

A near infrared photometric study of the young Orion nebula star cluster NGC 1976

The JHK magnitudes of 47 stars in the region of the extremely young Orion nebula star cluster NGC 1976 have been measured. These, in combination with the existing near-infrared and optical data, are used to study the intracluster reddening law. This indicates an anomalous distribution of intracluster grains in the vicinity of many stars causing less extinction in the V, B, R and I passbands than that obtained from the colour excess $E(V-J)$ using a normal interstellar reddening law. This implies a small shift in the grain size distribution towards larger than normal sized particles in these regions. (R.Sagar, *Z.Y Qian)

Cygnus OB2 (VI Cygni) association

From an ultra-low dispersion spectroscopic survey of the Cyg OB2 association several red and reddened stars are detected. Since the Cyg OB2 association stars show heavy reddening it is concluded that most of the red stars found in our survey are most likely reddened OB stars. Some of the fainter red stars may be low luminosity and lower main sequence members of the Cyg OB2 association. (M.Parthasarathy, S.K Jain)

Distribution of stars perpendicular to the Galactic plane

Coupled Boltzmann-Poisson equations were earlier solved with the assumption that the velocity dispersion of stars perpendicular to the plane goes as $V^2(m) \propto m^{-\theta}$. These exact solutions have been fitted with various sets of data and it is found that a surface density of matter $\Sigma \sim 46 M_{\odot}/pc^2$ and a volume density $\rho \sim 0.1 M_{\odot}/pc^3$ give the most acceptable fit to the data. (S. Chatterjee)

Distribution of planetary nebulae

Observed samples of planetary nebulae suffer from incompleteness due to various selection effects. While the smallest nebulae are missed because their sizes are not resolvable, the largest ones are undetectable due to their low surface brightness. The variation of interstellar extinction with galactic latitude and longitude causes further problems in the detection of these objects. On POSS plates the limiting surface brightness in V is 25 mag per arcsec², which translates to a limiting emission measure of about 25 cm⁻⁶ pc. The discovery of low surface brightness nebulae on Kiso-Schmidt plates suggests that a sizeable fraction of them is yet to be discovered.

The nebular parameters are being modelled and using a simple extinction law in the solar neighbourhood the fraction of missing nebulae as a function of distance from the plane of the Galaxy is being estimated. The correction due to selection effects will be applied to the height distribution of planetary nebulae. (D.C.V.Mallik)

BVI photometry of planetary nebula fields

Determination of accurate distances to planetary nebulae is of crucial importance for any further discussion of these objects. Of the many indirect methods, the extinction-distance method is a very promising one. To apply

this method effectively a large number of stars lying in the direction of planetary nebulae in the sky are observed for their spectral types and colours so that a $E(B-V)$ vs $m-M$ diagram for the region in the sky can be determined. In a new version of this method the spectral class and the luminosity of stars can be accurately determined from their BVI photometry alone and the method works better for stars later than F5. Accurate spectral type calibration has thus been obtained by using $(B-V) - (V-I)$ vs $(V-I)$ diagrams (see Pollacco and Ramsay 1992, MNRAS 254, 228). The rich PN fields where this method can be exploited to its maximum advantage are generally located in the Southern Hemisphere in the Galactic plane. Many of these fields are accessible from VBO, Kavalur although the vast majority of them are available only in the months May-August. A programme has been initiated to observe the rich PN fields using the Vainu Bappu Telescope in the prime mode with a CCD photometer. Half a dozen PN fields have been imaged during 1993 November-1994 February along with appropriate Landolt-Cousins standards in all three filters. Data analysis is in progress. (D.C.V.Mallik, A.K.Pati, *D.Pollacco, *K.Exter)

WC11 type nebulae

a) Observations:

Spectroscopic observations of WC11 type nebulae in the wavelength range of 4000-10000 Å were continued at a higher resolution than attempted earlier with the B and C spectrograph at VBT.

b) Modelling:

The dust modelling incorporated in the photoionization code developed here and reported last year, has been revised in an attempt to fully explain the observed IR characteristics of WC11 type nebulae. A new feature is the introduction of dust in the halo region surrounding the photoionized nebula besides the nebular region. M4-18 has been remodelled using this new code. (R.Surendranath)

The IUE ultraviolet spectrum of PC 11

PC 11 (HD 149427, PK 331 - 5°1) is classified as a young planetary nebula with strong [O III] 4363 Å emission and a Zanstra temperature of $T_z = 27000^\circ\text{K}$. It is also classified as a D - type yellow symbiotic star with an A-F type companion. It is an IRAS source with detached cold dust shell with far infrared (IRAS) colours similar to planetary nebulae. The IUE short wavelength (SWP) spectra show emission lines due to O III] (1661/1666 Å), N III] (1746/1754 Å), C III] (1907/1909 Å). The O III] and N III] emission lines show significant variation. Variation in the strength of C III] is not very significant. The strength of O III] has decreased and that of N III] has increased. The long wavelength (LWP) spectrum shows stellar continuum (A-F) and absorption lines due to Mg II 2800 Å feature. It also shows emission lines at 2772 Å (?), 3133 Å - 3140 Å (very strong) (O III, [Fe V]), 3209 Å (He II?, [Fe II]). The variation in the strengths of the emission lines due to O III] and N III] and the presence of stellar continuum (A-F) suggest that the central star of PC 11 may be a binary. Further IUE ultraviolet spectra are being obtained to understand the causes for the variations in the spectrum. (M.Parthasarathy, *D.de Martino, *S.R.Pottasch, *J Clavel)

Galaxies and Active Galactic Nuclei

Dynamics

The merging phenomenon of a pair of identical galaxies undergoing head-on collision has been further investigated by N-body simulations. The simulations cover a large range in the initial velocities of the galaxies. The merging of the galaxies takes place when the relative velocity of collision V is less than about four times the internal velocity dispersion i.e., $V < 4.1\sigma$. The quantities like the energy change, the mass loss, the halfmass radius, the central concentration etc reach a maximum value when $V = 4.1\sigma$. Mass transfer dominates when the collision velocity is small and consequently the merger remnants show negligible mass loss. The velocity distribution is broadened and slightly asymmetric with respect to the collision axis. The comparison of the numerical results with analytical estimates, obtained using impulse approximation, shows large discrepancy in the merging cases. In the non-merging cases the analytical formula overestimates the energy change by more than a factor of two. (P.M.S.Namboodiri)

MOND and galaxy formation

Modification of Newtonian Dynamics or MOND was initially proposed by Milgrom and studied by several people as an alternative hypothesis to account for the flat rotation curves of spiral galaxies without the need to invoke halo dark matter.

The consequences of MOND for galaxy formation have been studied. It is found that standard parameters like the Jeans length, Silk mass etc get modified. The growth of density fluctuations in an expanding universe has been studied with the MOND force law. It is found that there is not much improvement in the rate of growth of fluctuations as in the standard CDM scenario. So although MOND may explain flat rotation curves and cluster dynamics, it does not seem to improve the situation as far as formation of large scale structures is concerned. (C.Sivaram)

Modelling rotation curves - the turbulent way

Helical hydrodynamic turbulence can magnify perturbation seed eddies and this can lead to the appearance of large scale structure. The evolution of the instability is accompanied by a transfer of energy from small scale to large scale fluid motions. Rotation curves of several galaxies have been modelled by combining the effects of rigid rotation, gravity and turbulence. The model has yielded very good estimates of parameters like the mass of the galaxy, its turbulent velocity and the angular velocity. This encourages one to study the velocity fields on large scales such as those of clusters and superclusters to vindicate the model's predicted spectrum (R.D.Prabhu, V.Krishan)

Clusters in the Large Magellanic Cloud

The stellar mass distributions has been studied in halo regions (radius ranging from 19 to 94 arcsec) of five young Large Magellanic Cloud star clusters. Effects of the mass segregation have been observed in only NGC 1711. A comparison of cluster age with its relaxation time indicates that the observed mass segregation could have taken place at the time of star formation. Absence of mass segregation in most of the clusters may indicate that there is generally no spatial preference for the formation of massive stars. Most of the clusters have similar spatial density profiles which follow a power-law with indices around 3.5. This may indicate a slow but efficient process of star formation in the young star clusters of the Large Magellanic Cloud. (A.Subramaniam, R.Sagar, H.C.Bhatt)

CCD photometry of early type galaxies

VRH α imaging of several, primarily x-ray selected, early type galaxies was used to detect and measure the H α + [N II] emission from the central regions

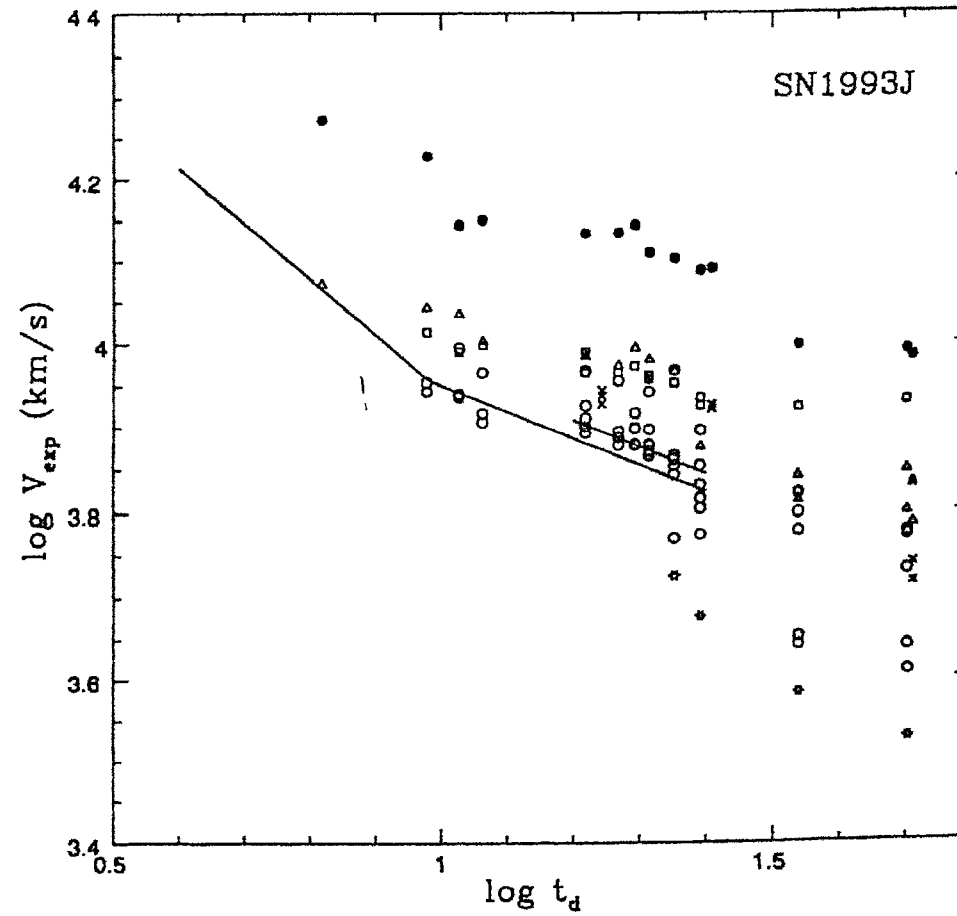


Fig 4 Variation of velocities of different absorption lines observed in the spectra of SN 1993 J as a function of time since outburst. Filled circles : H α , open squares : H β , H γ ; open triangles : He I lines; open circles : Fe II lines; crosses : Ca II and O I lines; stars : Ba II and Sr II lines. The long line implies a density exponent ($\rho \propto r^{-n}$) of $n=4.0$ for the first segment and $n=7.4$ for the second segment and an implied distance of 3.0 Mpc. The shorter line is the second segment shifted such that the implied distance is 3.14 Mpc

of seven of them, viz., NGC 1399, 1600, 2563, 4203, 4636, 4753 and 5044. The observed emission-line luminosities imply a mass of $10^5 M_{\odot}$ in ionized gas. The presence of ionized gas is associated with the presence of dust rings and lanes. In some cases, shell-like enhancements are noticed in the background stellar population as well. All of these appear to be manifestations of accretion and merger events. Star formation consequent to merger appears to be a viable mechanism for ionizing the gas. (T.P.Prabhu, *K.P.Singh, *P.N.Bhat, *A.K.Kembhavi)

Extragalactic Supernovae

Coordinated photometric and spectrophotometric monitoring of SN 1993J in M 81 (NGC 3034) was carried out during 1993 April/May. Evolution of the photospheric velocities was determined from the spectra (see Figure 4). Blackbody fits to published BVRIJHK photometry after effecting corrections for interstellar absorption and line emission from the extended photosphere, yielded estimates of temperature and radii of the photosphere. The evolution of the photospheric radius implies a density variation in the progenitor $\rho \propto r^{-7/4}$ for layers that became transparent around the second maximum. The distance to the supernova is estimated using the expanding photosphere method as 3.1 ± 0.5 Mpc. This value is slightly lower than the current estimate of distance to M81 (3.6 ± 0.3 Mpc), but the difference is within the quoted errors.

The monitoring of SN 1994D in NGC 4526 has begun during 1994 March. (T.P.Prabhu, Y.D. Mayya, *K.P.Singh, N.K.Rao, K.K.Ghosh, M.V.Mekkaden, A.K.Pati, A.V.Raveendran, B.E.Reddy, R.Sagar, A.Subramaniam, R.Surendiranath)

AGN

CCD photometry of x-ray selected quasars

BVR photometry was carried out for a few of the quasars in the Einstein Medium Sensitivity Survey. Standard magnitudes and colours were obtained for MS 0914.7-2348 ($V=18.54$) and MS1030.2-2757 ($V = 15.85$). (T.P.Prabhu, *K.P.Singh, *P.N.Bhat)

X-ray spectroscopy and multifrequency studies of blazars

X-ray emission is an extremely common property of active galaxies and a large fraction of their total luminosity appears in the x-ray domain. Detailed x-ray spectroscopy will continue to have a crucial role in understanding the active galaxy phenomenon because of its apparent association with the innermost regions of AGN. Low-(0.1-2 keV) and medium-energy (2-10 keV) spectra of several blazars, Highly Polarised Quasars (HPQs), Optically Violent Variables (OVVs) and a Seyfert galaxy (NGC 4593), which were observed with EXOSAT, were analysed and different emission models were used to fit the x-ray (0.1 - 10 keV) spectra of these objects. Further, multifrequency spectra (radio through x-ray) of thirty four EXOSAT blazars were analysed. Results of the x-ray spectral analysis suggest that BL Lacs are steep spectrum and soft x-ray sources and HPQs/OVVs are, relatively, flat spectrum and hard x-ray sources. Even though the HPQs/OVVs are, in general, higher redshift objects than BL Lacs, they are slightly more luminous (by a factor of 4 to 7) in x-rays than BL Lacs. But in radio the HPQs/OVVs are much more luminous (by 2 to 3 orders of magnitude) than the BL Lac objects. The multifrequency spectra can be well represented with a single parabolic curve for BL Lacs and such smooth change of the continuum spectra indicates that they are produced via synchrotron radiation. However, for the HPQs/OVVs two parabolic curves are needed with spectral discontinuity in the uv to x-ray region to fit the multifrequency spectra. It has been suggested that the emission mechanism in the radio through uv from HPQs/OVVs is synchrotron in origin while the x-ray emissions are from the inverse Compton mechanism. Luminosities in different bands have been computed for all the blazars and a bimodal nature of the distribution has been found in the radio and x-ray luminosity plane. The above results can be explained in the framework of a 'wide jet' model in which the flow velocity of the jet is constant but the degree of beaming increases with decreasing frequency, that is the opening angle of the x-ray emitting region in the inner part of the jet is much wider than that of the radio emitting region in the outer part. (K.K.Ghosh, S.Soundararajaperumal)

Photometric monitoring of blazars

Photometric monitoring of blazar candidates was continued, with the aim of obtaining the pattern of variability over different timescales, this information

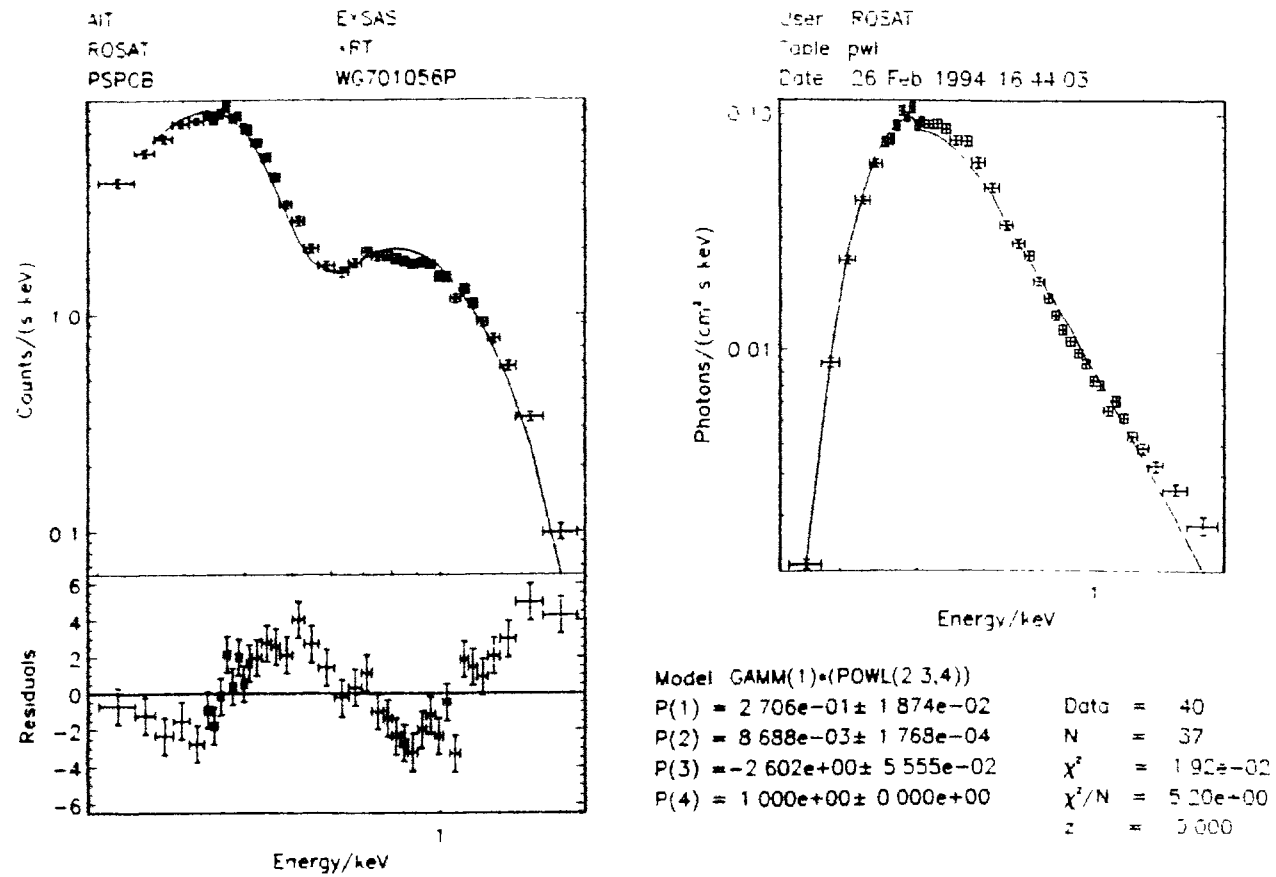


Fig. 5. ROSAT spectrum of MKN 766

will be used to constrain models of these objects. We have fairly good coverage for two blazars over the last two years. Four other objects have been observed with incomplete coverage. (A.K.Pati, K.K.Ghosh)

X-ray spectroscopy of the Seyfert galaxy NGC 4593

X-ray (0.1 - 10 KeV) spectra of NGC 4593 were obtained with EXOSAT on seven epochs between 1984 and 1986 using the low- and medium-energy detectors. Single power-law, two power-laws, thermal bremsstrahlung and broken power-law models with fixed absorption (fixed with respect to the Galactic hydrogen column density value) were used to fit the data. A model having a broken power-law and a fixed absorption describes a better fit to the spectra than those obtained from the others. However, this model cannot completely fit the soft excess emission present in the spectra of NGC 4593, which leads to the suggestion that, most probably, two soft emission components are present in this galaxy. A highly significant emission line feature was detected which could be the redshifted 6.4 KeV fluorescent iron K line. (K.K.Ghosh, S Soundararajaperumal)

Soft x-ray spectroscopy of Seyfert galaxies with ROSAT

One of the important problems in AGN research is to understand the origin and nature of the soft x-ray excess. The main problem has been the non-availability of high resolution soft x-ray spectra of AGN. ROSAT observations having a better spectral resolution than the previous payloads reveal an absorption edge around 0.7 KeV in the spectra of a few AGN. This had led to the suggestion of a warm absorbing medium around the central part of the AGN. However, this alone cannot explain the observed soft x-ray excess. From recent ROSAT observations of certain Seyfert galaxies we have obtained very high signal-to-noise ratio spectra ($S/N \geq 30$) and from these spectra we have detected an emission line around 0.4 KeV along with an absorption line around 0.8 KeV (see Fig.5). Based on the present results we suggest that the x-ray emission from AGN may be due to the emission, absorption and reflection from the photoionized gases present around their central engines. (K.K Ghosh,*R.Staubert)

Spectroscopy of AGN with Hubble Space Telescope

In 1966, before the discovery of any absorption features in the spectra of quasi-stellar objects, it was suggested that intergalactic gas in clusters of galaxies would produce ultraviolet quasar absorption lines. Recently observations with the Hubble Space Telescope, of a larger than expected number of Ly α absorption lines in the spectra of a few quasars suggest that probably, the excess absorption lines are associated with the clusters. However, it is not clear whether or not these observations confirm the above suggestion since these lines could arise from individual clouds in large halos of galaxies within the clusters. One possible way of distinguishing between gas in halos of galaxies and gas between galaxies is the widths of the lines. Broad absorption lines may be produced in the intergalactic medium and the width of the lines will reflect the velocity dispersion within the cluster potential, but there may also be localized clumps of gas between galaxies in the cluster which will produce relatively narrow lines. However, a reliable determination of AGN absorption line systems will enable us to understand the cosmic evolution of these systems. HST spectra of 103 AGN have been collected and they will be used for the above studies. Also different emission lines (See Fig 6) present in the spectra of these AGN will be analysed and used, along with simultaneous or quasi-simultaneous optical and x-ray spectra, to study the interactions between the warm absorbing medium and the broad-line emitting region of AGN. (K.K.Ghosh, S.Soundararajaperumal)

UV studies of AGN

AGN are generally known to vary in radio, infrared, optical, uv and x-ray wavelengths. BL Lac objects and HPQs/OVVs show the strongest variations, whereas Seyfert galaxies and quasars do not vary strongly in radio and far infrared wavelengths, but their variability increases with frequency from the near infrared and optical region to the ultraviolet and x-ray wavelengths. It is especially useful to study the ultraviolet variability of Seyfert 1 galaxies and quasars because the large amplitude continuum variation can be compared with variations in the emission lines. Study of the ultraviolet continuum will help in solving many important issues in AGN research, like relating continuum variations to possible variations in

the spectral index and emission-line equivalent widths. If variations in the continuum can be related to those in the emission lines, then it is possible, in principle, to constrain the distribution of the line-emitting gas. Ultraviolet variability is also important for understanding the well-known inverse correlation between the C IV (1549Å) equivalent width and the continuum luminosity – the 'Baldwin effect'.

From the IUE database installed in VAX 11/780 computer at VBO we have extracted SWP (1200 - 1975 Å) and LWP and LWR (1975 - 3200Å) spectra of AGN. There are 2383 spectra of Seyfert galaxies, 1135 spectra of quasars, 177 spectra of radio galaxies, 660 spectra of blazars and 315 spectra of emission-line galaxies (non-Seyferts). Analysis of the data is in progress with a view to elucidating the above.
(K.K.Ghosh, S.Soundararajaperumal)

Gravitationally lensed quasars

From the first K band images of Q 2345+007, taken with the 3.8-m UKIRT and also B,V,R images measured afresh on earlier data, it is shown that the two components of the QSO differ in apparent magnitude by 1.2 ± 0.1 over the wavelength range 0.4 to $2.2 \mu\text{m}$. There appears to be a hint of a smaller separation in the K-band images as compared to the other wavelengths. An important new result of these measurements is the evidence for intensity variations of the individual components in the blue and visual bands.
(A.K.Pati, *Gopal Krishna)

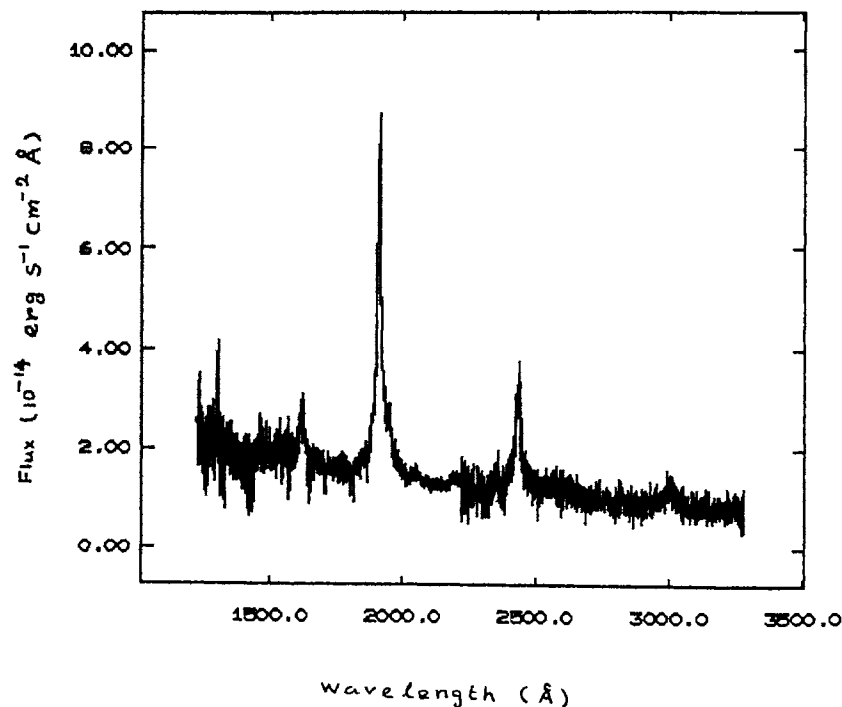


Fig 6 HST spectrum of the radio-loud quasar PKS 0405-12

Theoretical Astrophysics and Cosmology

Radiative Transfer

Winds in O and B stars

In continuation of the work on radiatively driven winds in O and B stars reported last year, the equations of continuity and momentum conservation were solved simultaneously with the transfer equation for an atmosphere containing hydrogen, helium and carbon. The population density in different levels was estimated from the statistical equilibrium equations involving collisional and radiative rates.

$$\begin{aligned}
 & - \sum_{j < i} n_j C_{ji} + n_i \left[\left(\sum_{j < i} (n_j/n_i)^* C_{ji} + \sum_{j > i} (C_{ij} + C_{ik}) \right) \right. \\
 & \quad \left. \sum_{j > i} n_j (n_i/n_j)^* C_{ij} - n_k (n_i/n_k)^* C_{ik} - \sum_{j < i} n_j R_{ji} \right. \\
 & \quad \left. + n_i \left[\left(\sum_{j < i} R_{ij} + \sum_{j > i} R_{ij} + R_{ik} \right) \right] - \sum_{j > i} n_j R_{ji} - n_k R_{ki} \right] = 0
 \end{aligned}$$

where the starred ratios are the equilibrium numbers.

This leads to the equation

$$\mathbf{A} \mathbf{n} = \mathbf{b}$$

where we have,

$$\begin{aligned}
 \mathbf{A} &= [a_{ij}] \\
 a_{kk} (k = 1, I) &= \sum_{p=1}^I C_{k,p}, p = 1, I; k \neq p \\
 C_{kk} &= R_{kk} = 0
 \end{aligned}$$

or

$$\begin{aligned}
 a_{kk} &= \sum_{p=1}^I (C_{k,p} + R_{k,p}), \quad k = 1, I \\
 a_{ij} &= - \left(\frac{n_i}{n_j} \right) C_{ij} - R_{ij}, \quad i \neq j \\
 a_{k,p=1,I} &= 1 \\
 \mathbf{n} &= [n_1, n_2, \dots]^T \\
 \mathbf{b} &= [0, 0, \dots, \rho/A_m]^T
 \end{aligned}$$

The solutions lead to a derivation of the temperature profile in the wind. As expected the number densities in different stages of excitation and ionization derived from the statistical equilibrium equation are different from those derived from Saha-Boltzmann formalism. The new population densities would change the line radiation pressures and would give different terminal velocities in the wind. Further calculations are in progress. (A.Peraiah, B.A. Varghese, M.Srinivasa Rao)

Finite-difference methods for radiative transfer problems

A comparative study has been done of the numerical results of two widely used difference methods for the radiative transfer equation in plane-parallel medium. Peraiah and Grant's technique (PG) (1973, J Inst.Math Applics 12, 75) is based on the direct first-order differential equation for the specific intensity whereas Auer's Hermitian method (AH) (1976, JQSRT 16, 931) uses the second-order form of Feautrier (1964, C R.Acad Sci. Paris 258, 3189) for the mean intensity and flux-like variables.

The numerical results are compared with analytical solutions under the two-stream approximation in a semi-infinite atmosphere. For the many-stream case, the numerical errors are estimated using the value of Chandrasekhar's discrete ordinate method (1944, ApJ 76, 100). It is found that the PG method is stable with respect to the logarithmic optical depth scale and gives the less surface relative error (SRE) for the specific intensity than that of the AH method. The maximum relative error (MRE) for the mean intensity variable is less for the AH method.

The Table below shows SRE and MRE for difference equation methods in a semi-infinite atmosphere under the two-stream approximation. B is the Planck function, the parameter ϵ is the probability for collisional de-excitation and τ is the optical depth variable. B is varied as 1, τ and τ^2 .

Table 1

B(τ)	1			τ			τ^2		
ϵ	1	10^{-2}	10^{-4}	1	10^{-2}	10^{-4}	1	10^{-2}	10^{-4}
PG Method									
SRE	0.0	0.0	0.0	0.0	0.0	0.0	3.8E-05	7.1E-05	7.5E-05
MRE	4.0E-03	7.5E-03	8.3E-03	1.5E-03	2.7E-04	3.2E-04	1.5E-03	2.6E-03	2.9E-03
AH Method									
SRE	3.4E-04	6.1E-04	6.6E-04	5.4E-04	2.6E-04	2.0E-04	4.2E-05	3.0E-04	3.6E-04
MRE	9.2E-04	1.7E-03	1.9E-03	1.9E-03	2.6E-04	2.4E-04	4.4E-04	4.0E-04	4.0E-04

(D Mohan Rao, B.A.Varghese, M Srinivasa Rao)

The redistribution function R_{∞} in expanding spherically symmetric stellar atmospheres

Most often the limiting case of complete redistribution (CRD) is taken to be an adequate representation of the partial frequency redistribution function R_{III} in radiative transfer problems to study spectral line formation in stellar atmospheres. Earlier works have shown that for plane-parallel (static and moving) stellar atmospheres the differences between the emergent intensities due to R_{III} and CRD are below 20%. But, with the advent of very high

resolution stellar spectroscopy ($\lambda/\Delta\lambda \sim 10^5$ to 2×10^5), highly accurate line profiles are available. Therefore, even small differences between CRD and PRD profiles could be important in a quantitative analysis of stellar spectra. Also, the combined effect of sphericity and macroscopic velocity on these differences cannot be estimated a priori.

We have considered a parametrised spherically symmetric and differentially expanding stellar envelope to study the effects of angle-averaged R_{III} on spectral line formation. The line transfer equation has been solved in the rest frame of the star assuming a two-level atom model within the framework of the Peraiah-Grant formalism using the discrete space theory of radiative transfer. As a part of this work we have also examined the behaviour of emergent mean intensity profiles J_x , the source function S and the emergent flux profiles F_x as a function of atmospheric extension ($b/a = \text{outer/inner stellar radius}$), maximum velocity of expansion (V_b) and the thermalization parameter (ϵ). The behaviour of these parameters is in agreement with the earlier results of Kunasz and Hummer (1974, MNRAS 166, 19).

The emergent mean intensity profiles due to angle-averaged R_{III} and CRD have been compared. The differences between the profiles are found to be much smaller in expanding spherically symmetric atmospheres than reported for plane-parallel atmospheres in earlier investigations (Prabjhot Singh, A Peraiah).

Polarization in the telluric bands

The transfer equation is solved to study the behaviour of linear polarization in the earth's atmosphere of O_2 and H_2O bands. It is found that when the sun is near the horizon, O_2 lines at 6900 Å, 7600 Å, and 12000 Å show maximum linear polarization of about 80% at zenith in the line centre. But it reduces in the wings of the lines by more than 15%. Percentage of linear polarization across the 7600 Å line shows a steeper variation compared to the 6900 Å and 12000 Å lines. When the sun is near zenith the maximum linear polarization is near the horizon and the variation of polarization across the lines is the same as above. H_2O lines near 13500 Å show a steeper variation of polarization across the line profile compared to the 9000 Å and 11000 Å lines (D.Mohan Rao, K.E.Rangarajan, *K.D.Abhyankar).

Nonconservative Rayleigh scattering in a finite atmosphere –polarization of skylight

The main mechanism for producing polarization in the earth's atmosphere is Rayleigh scattering. The extinction of the radiation field consists of absorption and scattering. There are always some small particles present in the atmosphere which absorb the light. We can define the albedo for single scattering, ω as the ratio of scattering and extinction coefficients. In the realistic case of nonconservative scattering, $\omega \neq 1$. The value of ω gives some clues to the distribution of the particles. The present study pertains to this situation. Polarimetric observations of the skylight in the visual continuum show a shift of Babinet and Brewster points (points of zero polarization) towards the sun. By invoking the nonconservative Rayleigh scattering mechanism in our calculations, we could account for this observational fact. A typical result of the calculations is shown below.

Table 2
Neutral points for the transmitted light.

Optical depth τ	sun's position $\phi - \phi_0$	θ_0	$\omega = 1.0$ (Conservative) scattering)	$\omega = 0.8$	$\omega = 0.5$	$\omega = 0.2$	Remarks
0.2	0	60	43.47 80.5	45.4 77.5	48.6 73.5	52.7 68.0	Babinet Brewster

The numbers in columns 3-7 are the zenith angles in degrees. The clear sky observations are in close agreement with a value of $\omega \approx 0.9$.

(K.E.Rangarajan, D.Mohan Rao, *K.D.Abhyankar)

Resonance-line polarization

The effect of differential radial velocity on the distribution of line intensities and line polarization along the line of sight of an extended stellar atmosphere stratified in parallel planes has been studied. Complete redistribution of frequency is considered with two different velocity laws. First a homogeneous and isothermal medium has been considered and the effect of radial velocity is studied extensively by taking the velocities of expansion

of the medium as 5, 20 and 50 mean thermal units. The results are compared with those of the static case.

As the stellar radius increases the curvature effect plays a dominant role. Therefore we next consider the medium to be inhomogeneous, isothermal and spherically symmetric. The results with spherically symmetric geometry are compared with those of plane parallel geometry to investigate the effect of curvature as well.

For this purpose the scalar radiative transfer equation in comoving frame is modified in its vector form to include linear polarization and it is solved numerically by using the discrete space theory. It is found that significant effects are generated in the polarized radiation field when differential radial expansion is taken into account. The atmospheric models may represent the photospheric layers of early type stars, giant and supergiant stars, symbiotic stars as well as of luminous late type stars (S.Sengupta)

Plasma Physics

Plasma mechanisms for variability in active galactic nuclei

Several physical processes, dominated by plasma effects, that might be important in producing variability in AGN have been considered. One class of processes involves oscillations in the plasma itself. If accretion disks around supermassive black holes have coronae not too different from that of the sun, then magneto-acoustic oscillations of coronal loops can yield fluctuations on time scales from days to years. Such coronal loops could also produce flares with substantial emission variations over the short times comparable to those associated with the recently observed broad-band microvariability. A second class of processes depends upon electromagnetic fields acting to modulate themselves, these modulational instabilities can produce filamentation, hence rapid variability. The question how a shift in emission and scattering mechanisms (e.g., from Compton scattering to Raman scattering) can yield variability in the observed emission was also considered. (V.Krishan, *P.J.Witta)

Clustering of galaxies by the α -effect

The development of large-scale flows from the stresses generated by small-scale flows in a Navier-Stokes system is studied in order to model the large-scale structure of the Universe. This process is an analogue of the α -effect by which a large-scale magnetic field can be generated beginning with small-scale fields. It is shown that, under similar conditions of anisotropy and non-zero mean helicity large-scale flows can be generated. The clustering of galaxies on all possible scales is then suggested to be a result of the hydrodynamic hierarchy (V.Krishan)

Hydrodynamics

A variational equation connecting the invariants of a three-dimensional hydrodynamic turbulence was derived and an exact solution of the equation for the special case of quasi two-dimensional flows was obtained. Using the stability criteria that any flow with a hyperbolic stagnation point is unstable, it was shown that the variational equation does admit solutions that are unstable to small perturbations

The variational equation for the case of constant helicity reduces to the equation governing Beltrami flows. However, when the helicity is assumed to be a slowly varying function of space variables, the variational equation retains its nonlinear nature. We have obtained a simple, exact solution of the (reduced) variational equation. (A.Satya Narayanan)

Compact objects

Pulsars

We have completed the conventional geometrical analysis of a pulsar polar cap for the case of an oblique rotator. A new result of the analysis is the existence of a second solution to the open magnetic field lines. This solution appears to be naturally relevant for the explanation of core emission in the pulses from a pulsar. The role of general relativistic effects is

confined to only within two stellar radii. At higher emission altitudes, aberration becomes more significant. It is found to twist the pulsar beam, a result of direct significance in the pulse polarization characteristics. Calculations are in progress to quantitatively assess the contribution of aberration. (R.C.Kapoor, *C.S.Shukre)

Neutron Stars

Crusts

Neutron stars possess crusts that are made up of neutron-rich nuclei, a relativistic and degenerate electron gas and small concentrations of superfluid neutrons. The crust extends to about ten to fifteen per cent of the radius from the surface, and is important for understanding a variety of observable features associated with neutron stars such as surface temperatures, glitches in the rotational periods and possible decay of crustal magnetic field. An important quantity in this context is the density distribution of the crustal matter. A detailed and accurate numerical survey of the density distribution has been made for several neutron star configurations corresponding to a wide catalogue of representative equation of state models available in the literature. This is also used to obtain an accurate determination of the electrical conductivity profiles in neutron star crusts (B.Datta, A.V.Thampan)

Interiors

A new relativistic theory of neutron-rich matter incorporating the possible effects of short range spin 2 interaction between nucleons has been derived. Also included in the model are the interactions due to the exchange of vector mesons (omega and rho) and of scalar meson. For the latter we adopt a hybrid derivative scalar coupling nuclear field theory. The equilibrium thermodynamic properties of the system are calculated using the mean-field approximation for the meson fields. An equation of state is derived for asymmetric nuclear matter (neutrons, protons and electrons) in beta equilibrium, and applied to calculate the structure of stable neutron stars. We also make a sensitivity study of the neutron star maximum gravitational mass with respect to the value of spin 2 meson coupling

constant, and derive an upper bound on the magnitude of this coupling constant using binary pulsar mass data (B Datta, *V Canuto, *G Kalman)

Magnetic field decay

The investigation of the decay of neutron star crustal magnetic field was continued. A numerical programme has been set up to solve the Ohmic decay equation for the magnetic field, using the Crank-Nicolson difference scheme. The preliminary results obtained suggest that the magnetic field decay depends markedly on the impurity parameter in the crustal lattice. (B Datta *D. Battacharyya)

Disk accretion onto a rapidly rotating neutron star

The effects of rotation on the disk-type accretion onto a rapidly rotating neutron star with a weak magnetic field was investigated. The sensitivity of the results with respect to the neutron star equation of state was also examined (B.Datta, A.V.Thampan)

Neutrino astrophysics

Neutrino dominated supermassive objects

Some typical physical characteristics of supermassive objects ($M > 10^6 M_{\odot}$) dominantly composed of degenerate massive neutrinos (or Majorons) but also containing some baryonic matter are discussed. General relativistic effects are included in considering the stability of such objects and it is shown that they can become unstable at several times their Schwarzschild radius, leading to their collapse. These may be the possible progenitors of massive black holes powering quasars, AGN at large red shifts. (C.Sivaram)

Neutrino mixing in gravitational fields

Stringent constraints on CP-violating gravitational interactions are put while considering mixing of neutrinos and antineutrinos in strong gravitational fields. (C.Sivaram)

Neutrino magnetic moment

Some additional constraints on the neutrino magnetic moment (NMM) from stellar evolution and Type Ia Supernovae were stipulated. The effects of NMM in preventing carbon-oxygen deflagration that causes SN Type Ia were used to give a limit $\mu_{\nu} < 10^{-13} \mu_B$ (μ_B is the Bohr magneton). Constraints on CP-violating weak interactions were also put. (C.Sivaram)

Astroparticle Physics

Origin of ultrahigh-energy cosmic rays

There is no known mechanism to accelerate cosmic rays observed in the ultrahigh energy range 10^{19} - 10^{20} eV and beyond. Non-acceleration mechanisms have been considered. The fluxes of such particles from terminal stages of primordial black hole evaporation have been estimated and constraints put. Some characteristics of the expected composition at these energies have been obtained and a comparison made with some other mechanisms e.g. decay of topological defects formed in the early universe (C.Sivaram)

Work has been continued on the Topological Defect (TD)-models of origin of ultrahigh-energy (UHE) ($E \geq 10^{18}$ eV) cosmic rays (CR). In TD models UHE CR originate from the decay of massive gauge and Higgs bosons released from collapsing and/or annihilating cosmic topological defects such as closed loops of cosmic strings, metastable monopole-antimonopole bound states, etc., and not from any astrophysical acceleration mechanisms. The latter encounter severe problems in explaining the observed highest energy CR events. In TD models, particles can be produced with energies as high as $\sim 10^{24}$ eV without any acceleration mechanism. The TDs are envisaged to have formed at a symmetry-breaking phase transition in the early universe at the Grand Unified Theory (GUT) energy scale 10^{16} GeV. The predicted spectra of UHE protons, gamma rays as well as neutrinos were calculated earlier. (P.Bhattacharjee)

Analysis of the highest energy CR events

The Fly's Eye detector of the University of Utah, USA, has recently reported the detection of a CR event at energy 3×10^{20} eV. This is the highest energy CR event recorded so far. Interestingly enough, the second highest energy CR event, having an energy $\sim 2.3 \times 10^{20}$ eV and recorded by the Yakutsk group, is located in sky within $\sim 7.8^\circ$ from the Fly's Eye event. In the work reported here, it is shown that the conventional and widely favoured diffusive shock acceleration mechanism associated with relativistic shocks in active galactic nuclei (AGN) has severe difficulties in explaining the energetics of these highest energy CR events. Protons above around 2×10^{20} eV could have marginally been produced by this mechanism in an AGN or a rich galaxy cluster not farther than about 1000 Mpc. This limit on the possible source distance comes from consideration of energy loss during propagation through the extragalactic medium. However, for the highest energy Fly's Eye and Yakutsk events mentioned above, this is shown to be inconsistent with the observed arrival directions associated with the events because no known AGN or galaxy clusters are found to lie within 1000 Mpc and within a reasonable "error box" in the sky corresponding to the events. The galactic and intergalactic magnetic fields are also shown to be unable to alter the direction of such energetic particles by more than a few degrees. The conclusion is that, some hitherto unknown mechanism is needed to explain the highest energy events.

As one possible way out of the 'puzzles' discussed above, the possibility of TDs being the source of these highest energy CR events has been suggested and investigated. (TDs need not be associated with any particular astrophysical object such as AGN or galaxy clusters). Specifically, it is shown that the above events could very well be due to TD-produced *primary photons* (possible only in TD-like scenarios) rather than protons accelerated by any conventional diffusive shock acceleration mechanism. (P.Bhattacharjee, *D.N.Schramm, *G.Sigl)

"Low" energy gamma rays from TD-induced processes

The UHE protons as well as gamma rays produced by TD-induced processes generate lower energy gamma rays by $\gamma-\gamma_b$ and $p-\gamma_b$ collisions

with the photons γ_b of the background radiation fields in the universe. The electromagnetic component of the energy lost by the photons and protons in these collisions cascades down to lower energies by electromagnetic cascading in the universal radio background (URB), the cosmic microwave background (CMBR) and the cosmic infrared background (CIRB) (in order of decreasing energy of the propagating photon). The measured flux of extragalactic gamma rays in the 100 MeV region provides an upper limit to the total energy density of the cascade-initiating electromagnetic radiation that can possibly be released in the universe due to $\gamma-\gamma_b$ and $p-\gamma_b$ interactions. This, in turn, restricts the shapes of proton as well as primary photon spectra in the highest energy regions.

A numerical calculation of the cascading process mentioned above has been done. It is found that the predicted level of 100 MeV gamma ray flux depends strongly on the level of the CIRB as well as on its cosmological evolutionary history, both of which are rather uncertain at this moment. If for example it is possible, in future, to reliably extract the CIRB from the COBE satellite data the results of the numerical calculations reported here can be used to constrain the shapes of the injection spectra of UHE protons and gamma rays in the TD model and for that matter, in any other model of the origin of UHE CR. (P.Bhattacharjee, *F.Aharonian, *P.Coppi, *D.N.Schramm)

UHE CR from collapsing monopolonium

A monopolonium is a bound state of a magnetic monopole and an antimonopole. As is well-known, monopoles are one kind of TDs predicted in essentially all models of Grand Unified Theories (GUT). Monopolonia of binding energy E_b could form in the early universe when the universe cooled through a temperature at which the thermal energy $kT \sim E_b$. These monopolonia would, however, be highly metastable, and would undergo series of transitions to tighter and tighter bound states by emitting various particles such as photons, gluons, Z-bosons and so on. Ultimately, however, the monopole and the antimonopole constituting the monopolonium would overlap and annihilate each other releasing a large amount of energy in the form of massive particles (the "X" particles) with mass of the order of GUT energy scales $\sim 10^{15}$ GeV. The subsequent decay of these massive

X particles could produce UHE CR.

The contribution of these collapsing monopoles to the UHE CR flux has been estimated. It is found that this contribution is proportional to the square of the (constant) ratio of monopole-to-photon number density in the universe. But more importantly, the contribution depends exponentially on η , ratio of the binding energy to the thermal energy in the universe at the time of formation of any given monopole. It is found that even for a relatively small abundance of monopoles compared to the stringent Parker bound on the relic monopole abundance, a significant contribution to the UHE CR flux can result if, for example, $\eta \geq 10$. Thus monopoles, if they exist in the universe, could also give rise to UHE CR. (P.Bhattacharjee)

Phase-space structure of dark matter in the Galaxy

A project on studying in detail the phase-space structure of dark matter in the Galaxy is in progress. A numerical code has been developed for solving in an iterative manner the dark matter potential self-consistently coupled to the visible matter potential in a two-dimensional (i.e. axisymmetric) model of the Galaxy. The final aim of the study is to reliably estimate the velocity dispersion of the dark matter particles (assuming that they are some kind of weakly interacting massive particles or WIMPs) from fits to the measured rotation curve of our Galaxy. This information on the velocity dispersion is then to be used to estimate realistic values of signal-to-noise ratio for some of the ongoing laboratory experiments that have been set up to detect the WIMPs. The results at hand indicate a WIMP velocity dispersion of about 500 km/sec, a value somewhat higher than the usually assumed value of 250-300 km/sec. The implication of this result for the laboratory experiments is being worked out. (P. Bhattacharjee, R.Cowsik, C.Ratnam)

Baryon density enhancement around quark nuggets

The work on "quark nuggets" (QNs), possibly formed during a first-order quark-hadron phase transition in the early universe, has been continued. The QNs could survive as relics in the present universe if their initial baryon numbers were $\sim 10^{44}$ or higher. These QNs are well known to be a good

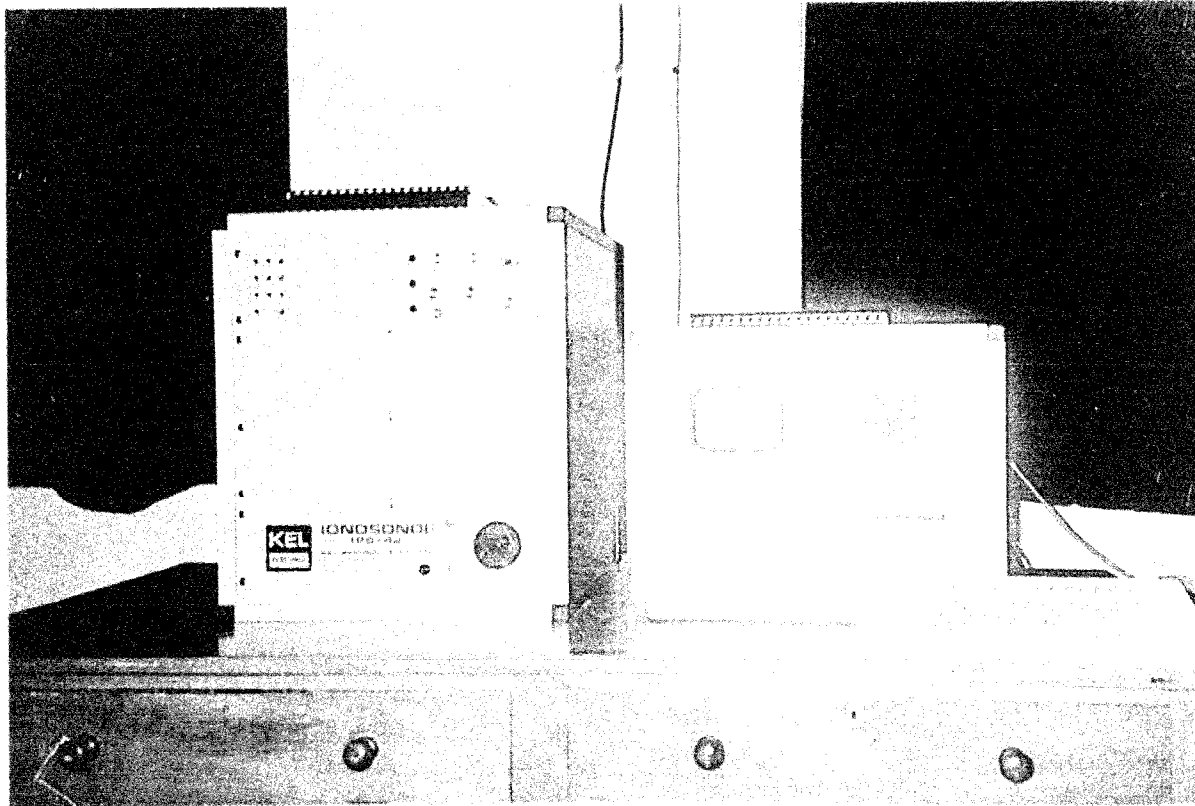
candidate for baryonic dark matter in the universe. A new aspect of the possible existence of QNs is being investigated. This pertains to a possible large enhancement of the baryonic density around individual QNs. This arises because the nucleons emitted by QNs through the process of baryon evaporation tend to accumulate, due to slow diffusion speed, forming a kind of "baryon halo" around individual QNs. This large baryon enhancement, if it survives up to the time of nucleosynthesis, can significantly affect the latter. The full baryon diffusion equation in the expanding universe is being solved numerically to calculate the size and magnitude of the baryon halo around QNs of various different sizes. The preliminary results do in fact indicate enhancement factors of as large as $\sim 10^6$, which puts strong constraints on the nature of the quark-hadron phase transition in the early universe. (P.Bhattacharjee, *J.Alam, *B.Sinha)

Fundamental interactions in the early universe

The energy dependence of the coupling constants in various unified approaches to fundamental interactions was explored and its consequences for the early universe were studied. (C.Sivaram)

Problem of a primordial black hole hydrogen-like atom

It was shown that a system composed of an electron and a primordial Hawking black hole forming a hydrogen-like atom, as proposed recently by many authors, cannot be stable. On the contrary, if the hole has zero Hawking temperature either due to extremal values of its charge or spin, the required values of these parameters are too large for the electron to be stably bound. However, if the hole has a magnetic moment due to its spin, electrons scattered from the hole could have spin-flip transitions producing high energy gamma rays. (C.Sivaram, *V.de Sabbata)



Two units on the desktop (HPN1, HPN2) installed at Kowloon in September 1993

Solar Terrestrial Physics

Structure and dynamics of the equatorial upper atmosphere

Neutral plasma coupling in the equatorial upper atmosphere is investigated from coordinated measurements made on two nights in December 1992 of the thermospheric temperature over Kavalur (78.5° E ; 9.5° N) with the Fabry-Perot interferometer (FPI), and of F-layer height with ionosonde at Trivandrum (dip 0.6° N), Kodaikanal (dip 3° N), Sriharikota (SHAR, dip 9.5° N) and Ahmedabad (dip 34° N). On both the nights which were geomagnetically quiet ($A_p \leq 9$), the FPI measurements revealed a distinct enhancement in thermospheric temperature around midnight over Kavalur. Thermospheric neutral winds estimated from F-layer height data of Trivandrum and SHAR showed significant poleward winds in association with the temperature increase over Kavalur. At Ahmedabad, an impressive descent of the F-layer followed the temperature enhancement over Kavalur. This pattern, which is consistently seen on both the nights, confirms the view that the equatorial midnight temperature maximum (MTM) is responsible for the midnight poleward reversal of meridional winds there, and which, in turn, leads to the 'post midnight collapse' of F-layer at low latitude locations on the same meridian. The simultaneous thermospheric and ionospheric measurements constitute the first ever demonstration of the relationship, *in totality*, between the equatorial MTM, poleward reversal of nighttime meridional winds and post-midnight collapse of the F-layer at low latitudes. (J.H.Sastri, H.N.R.Rao, *V Somayajulu, *H.Chandra)

Measurements of the Doppler width of 630 nm night airglow emission were made at Kavalur (12.5° N , dip $\sim 9.5^\circ \text{ N}$) on 62 nights during 1992 March-April and 1992 November - 1993 April for determination of the thermospheric temperature (T_n). The data are used to derive, *for the first time*, the characteristics of the equatorial midnight temperature maximum (MTM) in

the Indian sector. MTM is found to manifest on ~ 30 per cent of the nights over Kavalur. It occurs on the average, one hour after midnight in local winter and just before midnight in vernal equinox. The frequency of occurrence of the MTM and the seasonal change in the time of its occurrence over Kavalur are in broad agreement with the behaviour of MTM at the equatorial station, Jicamarca in the American sector. The amplitude of the MTM at Kavalur (100-400 K) is, however, larger than at Jicamarca (40-200 K). A significant difference in the MTM amplitude thus seems to exist between the Indian and American equatorial regions. This noteworthy feature of the global manifestation of MTM is attributed to the difference in the *in situ* neutral ion drag interaction between the Indian and American sectors. (H.N.R. Rao, J.H.Sastri)

Information on the seasonal and solar cycle variations in the vertical drift (V_z) of the F-region plasma over Kodaikanal is derived from measurements of the Doppler velocity, V_d of F-region reflections on 410 days from February 1991 through February 1993. The data, which correspond to moderate to high solar activity conditions ($94 \leq F_{10.7} \leq 297$) cover the evening/night time period (1600-0600 IST). It is found that the evening prereversal enhancement in V_z (V_{zp}) is higher in equinoxes and winter than in summer. The ubiquitous day-to-day variability in V_{zp} , on the other hand, is highest in summer and lowest in winter. This seasonal pattern is found to persist more or less independently of the level of geomagnetic activity. V_{zp} is found to bear a positive relationship to 10.7 solar flux in all the three seasons but with a trend for saturation for large fluxes (≥ 230 units) during local summer and winter months. V_{zp} decreases with the increase of geomagnetic activity but only during equinoctial months of the moderate solar activity epochs. Comparison of the results of the present study with the published work showed that there are distinct differences in the details in the way V_{zp} varies with season and solar and geomagnetic activity at the dip equatorial stations, Kodaikanal and Jicamarca in the Indian and American sectors respectively. (K.B.Ramesh, J.H.Sastri)

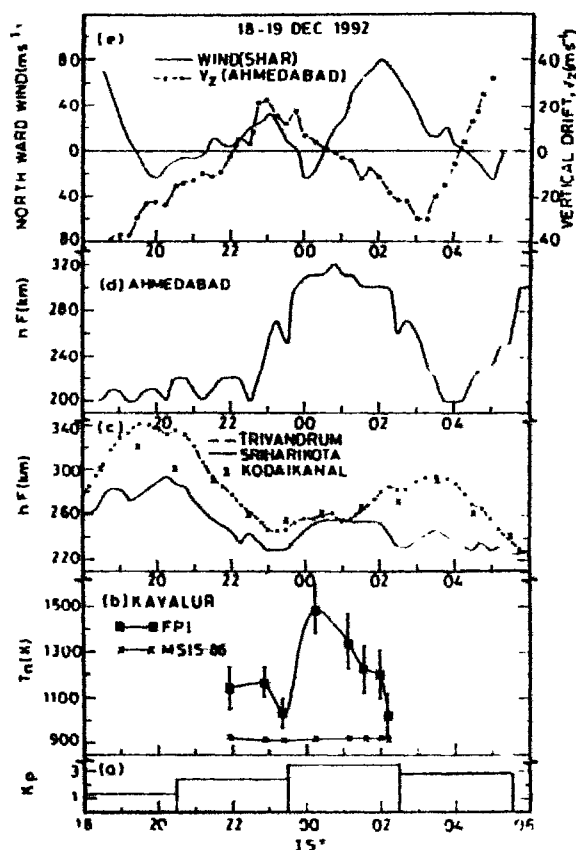


Fig. 7 Temporal pattern of thermospheric and ionospheric parameters at selected stations in India on the night of 18/19 December 1992, illustrating the neutral-plasma coupling in the equatorial upper atmosphere. Parameters shown are the F-region neutral temperature over Kavalur (panel b), height of bottomside F-layer at Trivandrum, Kodaikanal, Sriharikota and Ahmedabad (panels c-d) and the F-region meridional neutral winds (derived from height data of Trivandrum and Sriharikota) and F-region vertical plasma drift, V_z over Ahmedabad (panel e). The measurements confirm the effect of the equatorial midnight temperature maximum (MTM) on neutral and plasma dynamics, i.e. the association of the increase in temperature over Kavalur around midnight with the poleward reversal of neutral winds and the precipitous 'post-midnight descent or collapse' of F-layer over Ahmedabad.

Instrumentation

Fabry-Perot Interferometer

Line profiles of 630 nm night airglow emission were acquired at Kavalur over the fortnight centered on the new moon every month from November 1993 through March 1994, for studies of the structure and dynamics of the equatorial thermosphere. (K.B.Ramesh, H.N.R.Rao, J.H.Sastri)

Digital Ionosonde

Digital ionosonde model IPS 42/DBD 43 was commissioned at Kodaikanal in September 1993 as a part of the modernisation of the experimental facilities at the observatory. The digital unit replaces the analogue NBS model C-3 ionosonde which has been in continuous operation since 1955. Quarter-hourly soundings were made round the clock as in the past for synoptic information on the state of the ionosphere. 5-min interval soundings were made with the IPS42/DBD43 during the evening-night time periods for the national campaigns held from December 1993 through March 1994. (J.H.Sastri, D.Karunakaran, J.V.S.V.Rao, I and M Staff)

HF Doppler radar

The HF Doppler radar at Kodaikanal was effectively operated with the long-term objective of developing a large and good quality database on F-region vertical drifts (during the evening - nighttime period) near the dip equator for the Indian sector. Observations were made on 135 nights from April 1993 through March 1994, including the national and global campaign periods of international programmes such as STEP and IEEY. (J.V.S.V. Rao, J.H.Sastri)

Atomic and Molecular Physics

Atomic probes of physics beyond the Standard Model

The Standard Model (SM) of particle physics is a theory of strong, electromagnetic and weak interactions, with the latter two unified

Atomic parity non-conservation (PNC) arising from neutral weak currents and electric dipole moments (EDMs) are two important non-accelerator probes of new physics beyond SM.

The results of searches for PNC in several atoms during the last decade were in agreement with the predictions of SM. A new generation of ingenious PNC experiments based on developments in modern optics are just getting off the ground in laboratories in different parts of the world. Fortson from the University of Washington, Seattle, USA, has proposed to do a novel high-precision experiment by trapping singly ionized barium (Ba^+) We have recently carried out a theoretical analysis of the different mechanisms that can give rise to PNC in Ba^+ . Our result suggests that the many-body theory of Ba^+ PNC has several subtleties. We have also made progress in explaining some of the peculiar features of PNC in atomic bismuth

We have developed a formalism based on relativistic many-body theory to calculate the EDM of heavy atoms arising from CP violation in either the electron or the nuclear sector. Using that formalism, we have obtained results for rubidium and cesium. We are presently carrying out theoretical studies on the EDM of atomic mercury, which is sensitive to CP violation in the semi-leptonic as well as the hadronic sectors. Our work on atomic EDM using a powerful many-body theory known as the coupled-cluster approach is presently under way. An improvement in our theory along with the results of the latest mercury and thallium EDM experiments can indeed provide useful insights into a variety of CP violating interactions. (S.Malhotra, A D K Singh, B P Das, A Shukla, *P G.H.Sandars, *D.Mukherjee.)

Interaction of atoms with radiation

The interaction of atoms with radiation is important in different physical situations. Our interest is in the theory of high precision atomic clocks and forbidden radiative transitions in astrophysical processes. We have recently studied the interplay of relativistic and correlation effects in the intercombination transitions in Mg-like ions. (B.P.Das)

Problems in the atomic / nuclear interface

We have made considerable progress in our work on the theoretical aspects of nuclear anapole moments, which arise from parity violating interactions in the nucleus. The observation of such a rare electromagnetic moment will have profound implications for nuclear physics

We also plan to undertake the study of a variety of subtle effects that arise from the hyperfine interaction. (S.Malhotra, A D K Singh, B P.Das, *S.Bhagwat, *P.G.H.Sandars, *A.Banerjee)

Computational methods for relativistic structure calculations

In order to calculate various atomic and molecular properties, a reasonably good description of the corresponding ground (or excited) state many-electron wave function is needed. Since the exact solution to the quantum many-body problem is unknown, one needs to explore various approximation schemes which are computationally feasible. Computational efficiency becomes even more important for the relativistic case because the electronic orbitals here are represented by Dirac spinors which in general, have four components (as against two components for the nonrelativistic case), thus leading to a tremendous proliferation in the number of degrees of

freedom and consequently computational effort. There are many approximation schemes in vogue, the simplest of which is the so-called Dirac-Fock method, which is the relativistic generalization of the nonrelativistic Hartree-Fock approach where the electron-electron interaction (correlation) is treated in an average manner. The next in the order of complexity are the schemes that take explicit account of the electron correlation namely, many-body perturbation theory configuration-interaction (CI) approach, multi-configuration Dirac-Fock (MCDF) approach etc. Currently a computer programme to implement the Dirac-Fock method for both the closed and the open-shell atoms, employing a finite basis set expansion using Gaussian type functions, is being written. A relativistic CI programme to perform correlated calculations on atoms is ready and has been used successfully to evaluate the ground state energy of the He atom. In future, we plan to test it on heavier atoms. Various algorithms to implement the basis set based MCDF method are being explored and its computer implementation will be undertaken in future. Additionally, a relativistic effective core potential programme is ready and has been tested on atoms as big as sulphur. Its applications to study heavier atoms are also planned (A Shukla, *A.Banerjee)

Gravitation

Experimental Gravitation

The torsion balance operating at Gauribidanur is being upgraded to improve its sensitivity to any composition dependent forces weaker than gravitation. The torsion fibre was changed from a circular section to a rectangular one. The natural period of the balance was measured after this change and was found to be 2000s. This alone improves the sensitivity by a factor of 4 besides reducing by 4-5 times the noise and drift. The autocollimator was fitted with a more powerful light source, an LED, whose output is about 5 times larger than the tungsten filament-lamp used earlier. The autocollimator is capable of measuring $\sim 3 \cdot 10^{-10}$ rad. Hz $^{-1/2}$. Arrangements are under way to enclose the whole set-up inside a large high-vacuum chamber which will shield the UHV-chamber and the Optics from diurnal and semidiurnal variations in the atmospheric pressure. The balance will be used to test the Principle of Equivalence at the 10^{-14} level. (R. Cowsik, *N. Krishnan, *S.N. Tandon, *C.S. Unnikrishnan).

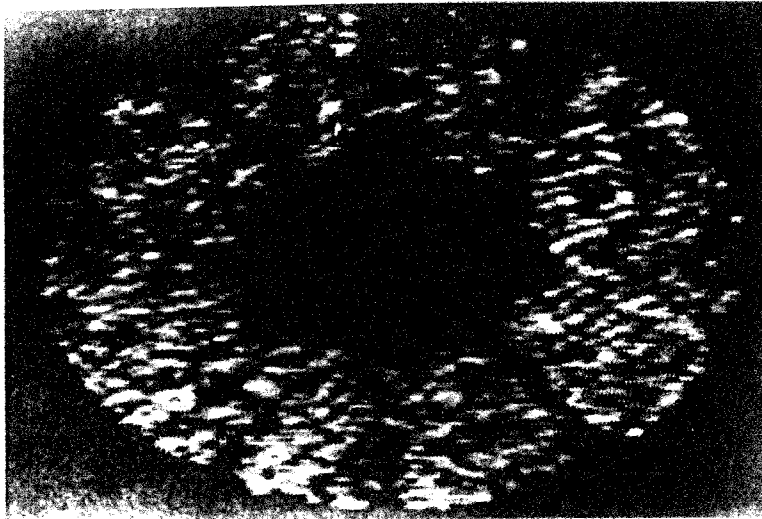
Quantum Gravity

Some finer aspects of problems arising in quantum gravity were studied. It was shown that Einstein's general relativity rather leads to a quantum mechanics than to a quantum field theory of gravity. This is chiefly due to the resistance of this theory to a canonical formulation which is caused due to the fact that in Riemann geometry one has either non-vanishing curvature of R^i_{jkl} (holonomic representation) or non-vanishing torsion (anholonomic representation). It was demonstrated that in the purely affine Einstein-Schrödinger theory, considered as a purely gravitational model with Riemannian and non-Riemannian parts, the homothetic curvature and the torsion vector behave like canonically conjugate variables. (C.Sivaram, *H.Borzeszkowski, *V.de Sabbata, *H.Treder)

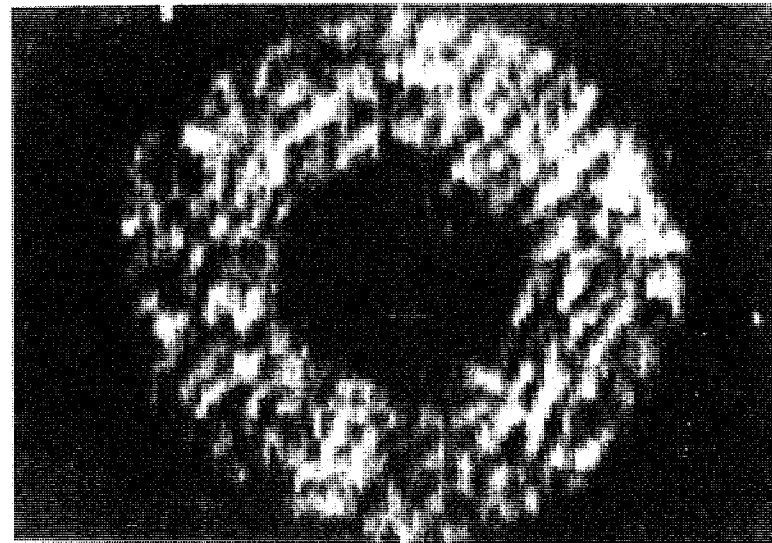
The notion of the existence of maximal and minimal field strengths in gravitation was explored. Interesting consequences for gravitational collapse, for explaining rotation curves of galaxies and other situations were found. (C.Sivaram, *V. de Sabbata)

Torsion-related defects in space-time topology were shown to have a universal charge. This raises the possibility of understanding electric charge as a topological concept. (C.Sivaram, *V.de Sabbata)





Rotational Shear Interferometric Record of interference fringes of the star Alpha Bootis on VBT using 60 nm filter and exposure time of 20 ms. As the fringes are narrow a careful observation is necessary. The elliptical shape of the record is due to the different aspect ratio of the laser printer in X-Y directions, otherwise the pupil is circular.



Rotational Shear Interferometric Record of interference fringes of the star Alpha Canis Majoris on 40" telescope using 50 nm filter and exposure time of 20 ms. As the fringes are narrow a careful observation is necessary.

Optics

High resolution astronomical imaging using rotational shearing interferometer

There has been continued efforts at IIA and RRI in the area of optical interferometry. We had two runs of RSI observation at VBT. Good quality data on α Ori the programme star and α Boo, the calibration star have been obtained. Digital data so obtained is being reduced to derive the image intensity distribution information. The appropriate theoretical simulation is being worked out. It is also planned to improve the instrument in terms of polarization compensations and on-line corrections of the atmospheric fluctuations. Also a suitable algorithm for reduction of the data is being developed that will identify particular kinds of objects and their intensity distribution from the fringe data. (A.K.Saxena, *N.Udayshankar, *N.R.Jayadev, *M.Selvamani, J.P.A.Samson)

Sun shield panels for Very High Resolution Radiometer cooler

Another set of panels was fabricated and supplied to ISRO for INSAT 2B satellites. Performance of the VHRR cooler as tested by the experts from ISRO has been confirmed as excellent. (A.K.Saxena, M.G.Mohan and Optics team)

Development of an active optics system

We have completed the development of a Babinet compensator polarization interferometer for the evaluation of a wavefront received at the focal plane of a telescope. Results of the evaluation of a mirror in the laboratory were presented at the SPIE meeting at San Diego in July 1993. A prototype

active optics support system is also being developed incorporating micro-processor control and a load cell. (A.K.Saxena, J.P.Lancelot, J.P.A.Samson)

Synchrotron radiation beam line optics

Proposal on the project "Development of Technology for Vacuum Ultra Violet Optics and supply of components for use on XUV Synchrotron source INDUS - I" was pursued and its sanction with a project budget of about 25 lakhs was received in the last week of June 1993. Initial preparatory work had started even before receiving the grants. The actual fabrication work could start in the first week of July. The strategy of fabrication and testing has been worked out. Fabrication of a prototype plane mirror (500 mm x 50 mm x 50 mm) and a spheroidal focussing mirror (300 mm x 50 mm x 50 mm) using float glass substrate is under progress.

Various equipment required for fabrication and testing of these optics are under procurement and development. A machine for grinding and polishing of the spheroidal mirror has been designed and fabricated for the purpose. Zerodur/fused silica substrate material for both mirrors have been ordered. (R.Cowski, A.K.Saxena)

EUV telescope optics

The optics of the EUV telescope was completed and sent to Stanford University. Evaluation of the optics at Stanford before flow polishing showed a diffraction-limited performance in the visible and the MTF is almost indistinguishable from the ideal. Flow polishing and system integration are in progress. It is expected that a EUV image below 0.5 arc sec and with high specular quality shall be achievable. The first launch of EUV payload is scheduled for 1994 August. (A.K.Saxena, J.P.Lancelot, V.Gopinath)

Aluminising

The 15 inch telescope optics and the 18 inch Schmidt telescope optics were aluminised at the 1.02 m vacuum coating plant, VBO, Kavalur. A number of small optics of sizes less than 8 inch were aluminised at the 12 inch coating plant at Bangalore. About twenty four 6 inch mirrors were aluminised for the amateur astronomers. Using the digital thickness monitoring unit, experiments were carried out for perfecting the aluminium coating with required thickness. (K.Ramankutty)

Speckle Interferometer

A prototype mechanical mount and adapter for the optical components of the speckle camera were fabricated in the mechanical workshop and the performance tested in the laboratory. Based on these tests the mechanical design of the mounts and house for the speckle camera has been made. Due to nonavailability of Invar, we have procured the necessary materials made of special stainless steel 410, whose thermal expansion is less than that of crown glass. Some of the mounts, particularly for the microscope objective, the flat, and the lens will be machined out of a solid piece so as to maintain high precision. Computer Numerical Controlled (CNC) machine will be used to fabricate these sensitive mounts. (S.K.Saha)

Instrumentation

A seeing meter

A seeing monitor is under development for site survey application. This involves the use of a two sector LDR detector which measures the fluctuations in centroid motion of the image as produced by a telescope. The detector fabricated at present can give an output of 10V for every 10 μ deflection of the image. At this stage, using a 15 cm diameter telescope with a focal length of 15 cm one can measure up to 1 arc second deflection. Further calibration of the system is under way. An ADSP 2101 micro computer has been designed to handle image processing functions.

The board specifications are as follows.

- | | | |
|---------------------|---|------------------------------------|
| 1. Processor | : | ADSP 2101 DSP microprocessor |
| 2. Data memory | : | 256K on board data memory |
| 3. Programme memory | : | 64K on board programme memory |
| 4. Boot memory | : | 16K on board boot memory |
| 5. ADC | : | 800 ns analog devices chip -12 bit |
| 6. PC interface | : | By using bus sharing technique |

Since the address bit of the processor is 14 bits, memory banking concept is used for memory enhancement
(S Chatterjee, K C Thulasidharan, R.Srinivasan)

Modifications on the vibration analyser

The earlier version of the vibration analyser is being upgraded to incorporate a DSP for implementing the FFT routines. This will speed up the analysis of the FFT thereby providing real-time information on the various Fourier components of the vibrations.
(K.C.Thulasidharan, R.Srinivasan, S Chatterjee)

Status of the single board controller for EEV CCDs

A single board controller for the P8603 device has been completed during this year. Suitable noise reduction techniques enabled the noise to be brought down from 200 to 30 electrons. The observations made at 30" telescope with this controller indicate satisfactory imaging performance.
(S Muralishankar, R.Srinivasan, K.Ravi)

CCD cryostat fabrication

The first prototype of the CCD cryostat, was extensively tested for the vacuum performance and was loaded with the EEV P8603C chip. Imaging in the prime focus of VBT showed small elongation at the edges. This was traced to the nonplanarity of the CCD surface with that of the mounting flange. Using a travelling microscope, the CCD was adjusted. A scientific grade CCD chip has been loaded into the dewar and the field trials are to commence soon.

The second prototype made up of stainless steel has been checked for the vacuum performance and is found to be satisfactory. Work on the third model using aluminium has progressed well. The liquid nitrogen inner vessel, copper base and the neck tube have been fabricated and tested. The outer vessel is under fabrication. (V.Chinnappan, R Srinivasan, G Srinivasulu, *S.Jacob, *S Kasturirangan, *R Karunanidhi)

DSP based DC motor controller

A joint project has been taken up with the Centre for Electronics Design and Technology (CEDT), Indian Institute of Science to develop controllers for DC servo motors using high speed Digital Signal Processors (DSPs). Study phase of the project is complete and the detailed design is being taken up now. Stand-alone DSP based cards will be fabricated for motor controllers
(V.Chinnappan, *K.Muthukumar)

New drive systems for stepper motor and DC motors

Pulse width modulated (PWM) amplifiers using power MOSFETs are efficient and consume less power for high power drives. Experiments are conducted in the laboratory for driving stepper motors using PWM drives. This modified drive is currently employed in the position angle device at VBT. PWM amplifiers meant for DC motors are also being developed in the laboratory. Initially low power and low voltage controllers have been developed. High power amplifiers are under development. (V.Chinnappan)

Digital display system for the 1-metre telescope at UP State Observatory, Naini Tal

A digital display system for the one metre telescope at UPSO, Naini Tal is being built at our Electronics Laboratory. The following cards have been developed for the system

1. Synchro to digital converter cards for HA and DEC axes
2. Data multiplexing card for data multiplexing from sidereal clock.
3. Line driver/receiver cards for both the display unit side and the PC side
4. A 16 bit digital I/O interface card.

The complete assembled system is undergoing tests at our 1-metre telescope, Kavalur. It is planned to install the unit at UPSO, Naini Tal in 1994 July. (R.Srinivasan, B Nagaraja Naidu)

Photo Digitizing System (PDS)

The Photo Digitizing System (PDS) continues to be used for digitizing mostly solar plates and films. The major projects where this facility was utilized are the following:

1. Digitization of Ca II K spectroheliograms for study of global magnetic oscillations.

2. Digitization of Antarctic data.
3. Digitization of data for time sequence spectroscopy in the Ca II H line
4. Digitization of photographic plates for JAP
5. Trial scans for coating plant.
(Ramaswamy, R.Srinivasan)

Radio astronomy

Gauribidanur radioheliograph

The East West arm of the Gauribidanur radioheliograph was split up into 8 groups, each consisting of 16 log periodic dipole elements. A 64 channel digital correlator was used to correlate the signals from the 8 East-West groups. Drift scans on the sun were taken at 75 MHz during periods of minimum solar activity (K.R Subramanian, M S Sundara Rajan, R Ramesh, Ch.V.Sastry)

Digital correlator system

A 64 channel digital system was installed at Gauribidanur. This system is currently used for making solar observations. Work is progressing on a 1024 channel correlator system to correlate the 32 signals from EW antennas with the signals from NS antennas for the Gauribidanur radioheliograph. This system will be constructed using the correlator chips designed by the Nobeyama Radio Observatory. (M.S. Sundara Rajan)

India-Mauritius radio telescope

This Radio Telescope was constructed in collaboration with the University of Mauritius and RRI.

One dimensional synthesis observations of discrete sources are being made with the East-West array. We are also developing special purpose algorithms using the available limited redundancy in baselines for phase and gain calibration (Ch V Sastry)

Computing Facilities

Bangalore Centre

The following systems were installed enhancing the facilities at the Computer Centre:

1. A DEC-ALPHA 3000 model 400 working under OPEN VMS with the following configuration:
 - a) A DEC-ALPHA AXP 21064 operating at 133 MHz with 512 Kb cache
 - b) 32 Mb RAM
 - c) 1 Gb Winchester
 - d) CD-ROM 640 Mb capacity
 - e) 16" colour monitor (1280 × 1024 resolution)

The system is connected through ethernet to other systems.

2. A SPARC-LC and a SPARC-10/30 from SUN Microsystems have been procured. The installation is nearing completion. The SPARC - 10/30 has the following configuration :

- a) Super scalar SPARC Viking processor
- b) 64 Mb RAM
- c) 1.05 Gb Winchester drive
- d) 424 Mb Winchester drive
- e) 3 1/2" floppy drive
- f) CD-ROM 644 Mb capacity
- g) 19" colour monitor (1152 × 900 resolution)

The system works under SUN OS4.1.3

The above system is also connected through a thin ethernet to the other machines in the Computer Centre. A new 486 PC-AT has been installed and the existing one expanded to run packages like IDL.

The graphics software IDL has been installed on the SUN 4/280.
(A.V.Ananth, J.S Nathan)

Software development

A set of Fortran programmes for reading images acquired on the PC platform under DT-IRIS environment to IRAF has been developed. These programmes allow two-dimensional images to be displayed on the SUN system under IRAF. (A.V Ananth, S.K Saha)

Local area network for the Bangalore campus:

A local area network comprising about 90 nodes has been planned for connecting the terminals/PCs in various offices to the computer systems in the Computer Centre. This work has commenced. (A.V Ananth)

Kavalur Computer Centre

The VAX-11/780 computer continues to be used for image analysis functions for the data acquired from the various telescopes at Kavalur. However this system is to be replaced with two SUN SPARC-LC systems in the near future. (A.V Ananth, K.Narayanan kutty).

The IUE ULDA/USSP on the Vax 11/780 at VBO

The International Ultraviolet Explorer (IUE) spacecraft and instruments have been operated since 1978 January. It has carried out ultraviolet

spectrophotometry of different types of astronomical objects at two resolutions (at the low resolution mode $R = 300$ and at the high resolution mode $R = 10,000$) in the wavelength range from 1150 Å to 3200 Å. European Space Agency (ESA) has developed the IUE spectral archive and a subset of this archive is the IUE Uniform Low Dispersion Archive acronymed ULDA. Also ESA has developed the ULDA support software package ULDA/USSPF. The latest ULDA version contains more than 54,000 low dispersion spectra complete to the end of 1991.

ULDA/USSP has been installed on VAX-11/780 computer of VBO. IUE spectra can be searched from the archive by one or more of the following:

- i) a list of cameras and/or image numbers and/or apertures,
- ii) a list of RA and Declination ranges,
- iii) a list of IUE object classes,
- iv) a list of homogeneous object IDs.

Then the spectra can be selected and downloaded from the archive in FITB, ASCII, LOCAL (optional) or PMIDAS (optional) formats.
(K.K.Ghosh, S.Soundararajaperumal)

Vainu Bappu Observatory

Vainu Bappu Telescope

Mechanical maintenance and improvement

Based on the study of the fluctuation and drift of the stellar image on the TV monitor and the feedback from the observers and control system personnel, the servicing of carbon brushes of the tachogenerators and torque motors was carried out. The friction track of the bull gear was observed to be slightly worn out because of higher hardness of the friction roller. Unevenness of the contact between the friction roller and the worn out surface was affecting the control system while tracking. To solve this the bull gear friction surface was cleaned, and a new friction roller with less hardness than that of the bull gear was designed to roll on a fresh adjacent surface to avoid error on the control system while tracking. The system performance has improved.

Recently a failure of the telescope dome axles adjacent to the bearing shoulder was noticed. This appears to be a fatigue failure and was from the bogies located under the base of the dome shutter and between the main arches. The unbalanced weight due to the windscreen drive system and the dome shutter could also be the cause of a failure of this nature. To solve the problem without going into major changes some of the off-axis loads have been removed. These are functionally not required at present. Efforts are on to design a modified axle to avoid the weaker zone of the axle. To meet the immediate need five forged spare dome wheels and two axles were fabricated in Bangalore. The wheel and axle assembly was carried out by hydraulic pressing. Two sets of spare wheel and axle assembly are kept ready at VBT to meet any emergency.

The linear focussing system of the VBT is supported by four steel spiders 6 mm thick and about 600 mm wide. These are held radially 90° apart. These steel spiders are pre-tensioned by fork assembly to keep the focus

drum assembly at a firm position. The fork assembly was modified by introducing on one an M42 hexagonal nut in place of a circular nut to facilitate rotation through box spinners. By using specially designed forged adaptor which can lock on to the hexagonal M42 nut at one end and provide a square socket at the other to accommodate a torque wrench it is feasible to pre-tension the spider assembly of the linear focussing drum to about 80 kg m. This method of calibrated tensioning which was not available earlier helps while undertaking major maintenance work of the telescope. (B.R.Madhava Rao, Mechanical Division staff)

Proximity switch mount for VBT

The proximity switch is a light sensitive switching gadget used as a safety device which will stop the telescope in case of any obstruction to telescope movement. The mount is a mechanical fixture to house the proximity switch and orient its light sensing device in the direction of likely collision. This is obtained by having a pair of finely machined ball and socket joint for each fixture. At present 3 fixtures are mounted and they are under electronic trials. (B.R Madhava Rao, Mechanical workshop staff)

Auto-dome rotation

To improve the performance of the auto dome programme, the encoder which was originally mounted outside has been shifted inside the dome thereby preventing malfunctions. A dummy wheel spring-loaded bogie has been designed, fabricated and mounted in the dome for this purpose. The dummy wheel makes 128 turns for one rotation of the dome. The rotation of the wheel is connected to the 256 turn absolute encoder in the console room through a selsyn transmitter-receiver pair.

The system is a compactly designed one consisting of a smooth rolling encoder wheel coupled to the transmitter and a spring-loaded guide. This

mechanism ensures uniformly reliable rolling contact of the wheel during the rotation of the 250 ton dome at 1/7 rpm.

(F.Gabriel, B.R Madhava Rao, V.Chinnappan)

Performance of the geared encoder systems

Keeping in view the cost and the difficulties in procurement of 20 bit absolute encoders, an alternate high resolution encoding system employing two medium resolution encoders was tried at VBT, Kavalur. Two approaches are listed below:

i) A 1 : 16 gear train assembly was mounted directly on the HA axis of VBT. One 17 bit absolute encoder was mounted on the HA axis and the other on the shaft with a gear of coupling ratio 1 : 16. The position data from these two encoders were synchronized in the software and the resultant 21 bit position data was compared with the existing 20 bit absolute encoder. It is found that this system was not accurate to even 18 bits due to the inaccuracies in the gears.

ii) The second approach involves mounting one encoder directly on the motor shaft and the other encoder on the HA axis with the existing gear ratio of 711.1. The data from these two encoders were synchronized and the resultant 23 bit position information was found to be accurate at least to the existing 20 bit Baldwin absolute encoder.

(R.Srinivasan, B Nagaraja Naidu, A.Anbazagan, K.Ravi)

Electronics

Electronics related to the servo system in VBT is continuously being upgraded for better reliability. Periodic checking of the telescope's tracking performance is carried out during daytime, so as to correlate the chart output to any image movements noticed during the night observations. The performance of the tachogenerators, encoders and DC motor brushes are periodically checked. The CCD camera system is also periodically tested for its specified performance. In order to eliminate the noise pick-up from the Mains wiring, the signal cables are segregated and properly shielded.

(V.Chinnappan, K.Anbazagan, K.Ravi, A.Ramachandran, S.V.Rao)

A digital interlock safety system

A new solid state, digital interlock safety system has been designed to replace the present electro-mechanical relays. The existing system requires large power supplies, large space and also contributes to the heating of the observing floor. The new design incorporates logic gates and PCB mountable DIP reed relays. All the components can be accommodated in a single card and the power supply requirements are minimal. The prototype is ready for tests at the VBT. (R.M.Nair, A.S.Babu)

New CCD's for VBT

The Tek 1024x1024 CCD and associated hardware were received towards the end of the period 1993-94. The CCD system is being integrated with a Sun Sparc Classic workstation in the laboratory. (A.K.Pati)

Enhancement of the PC based CCD image data acquisition system software

The CCD image acquisition system presently operating at the VBT is being modified and rewritten under MS-windows with a view to bringing about the following improvements: to accommodate larger CCD array sizes, an integrated image and PC monitor, larger display resolution of 1024x768 pixels, a more user friendly graphical interface.

(Faseehana Saleem, A.V Ananth)

Experiments with fiberlink spectrograph

Some experimentation with fibers to link the prime focus to a stationary spectrograph on the floor of VBT continued. A new smaller echelle spectrograph was built as a prototype to be used with the 102 cm and 234 cm telescopes, using an echelle grating with 70 l/mm and a 120 mm Zeiss camera already available. This spectrograph will later be shifted to the 75 cm telescope and be put in regular use.

(N.Kameswara Rao, F.Gabriel, A.K.Saxena)

Boller & Chivens Spectrograph

Since the small format of the grating employed in the Boller & Chivens spectrograph was known to result in a severe loss of light within the spectrograph, modifications were carried out to accommodate larger format gratings. Further, improvements have also been done in the guiding by providing a special shutter arrangement that can be controlled from the console panel. The working of the spectrograph has thus been automated nearly fully.

Tests conducted subsequently have shown a factor of two improvement in the efficiency of the spectrograph. Gratings with rulings 300 l mm^{-1} and 600 l mm^{-1} are currently available. (T.P. Prabhu, F. Gabriel, P.U. Kamat, B.R. Madhava Rao, Mechanical Workshop staff)

102 cm telescope***Mechanical maintenance***

The telescope declination fine motion clutch system was serviced. The dome shutter drive worm reduction gear box and spur gears were replaced and the complete drive system was serviced. The dome bearings and bearing housing had been damaged very badly due to long usage resulting in uneven and noisy motion. It needed major changes, since the original design did not provide the accessibility to remove the wheel bearing assembly for servicing. During the maintenance work in August 1993, the dome structure was carefully cut open, to remove the worn-out wheel bearing assembly. New bearing housing with fresh ball bearings were assembled and the entire assembly was individually bolted on to the base of the dome structure. With this there is adequate provision for preventive and breakdown maintenance of the dome wheel assembly without weakening the dome structure. (B.R. Madhava Rao, Mechanical Division staff)

Infrared photometer

The mechanical mount for the In Sb infrared photometer was modified. The

photometer was tested on the 102 cm telescope at VBO, Kavalur. Its performance was found to be satisfactory. The limiting magnitude in the K band with one second integration on the 102 cm telescope is now 9.0. (H.C. Bhatt, R. Sagar)

75 cm telescope

Twenty six dome wheels made of steel were replaced by rubberised wheel assembly to reduce the noise during dome rotation. These rubberised wheels are readily available and comparatively cheap. They can be replaced as and when rubber wheels wear off. One of the dome drive motors was replaced by a new one. Parts of the dome sheet metal were rusted; these were replaced by new sheets which were welded, then blended by rough grinding and painted to the finish. (B.R. Madhava Rao, Mechanical Division staff)

Site Survey



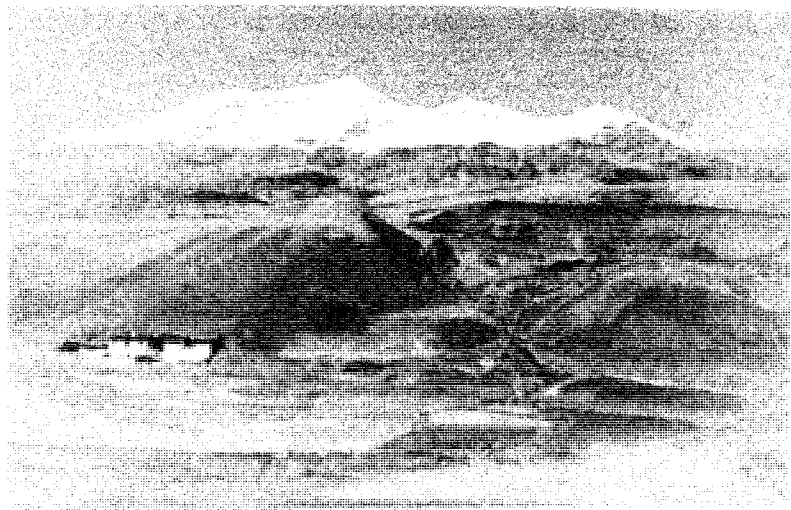
Delta plain near Seston, 25 km west of Haidu



Lanzhi H.P.



View from the top of the hill of Nohankin plain (1994 January)



Northern Lanzhi H.P.

National Facilities

Himalayan infrared and optical telescope project (HIROT)

In the foreword to the Astronomy and Astrophysics Facilities proposed for the Eighth Five-year plan, Professor B.V.Sreekantan wrote : "As desired by the Planning Commission of the Government of India, a national meeting was organised by the Department of Science and Technology on the 24th and 25th Aug '89 at the Indian Institute of Astrophysics, Bangalore to discuss various issues relating to the setting up of national facilities in Astronomy and Astrophysics." In July 1992, soon after taking charge as Director, IIA, Professor R.Cowsik made a detailed presentation to the Planning Commission, Government of India on the proposed National Large Optical Telescope (NLOT) and apprised them of the financial requirements as also of the positive impact of this project on science, industry and human resources of the country. During 1993 efforts have been on to generate a Detailed Project Report (DPR) for NLOT with approval and sanction of DST. IIA was identified as the nodal agency for carrying out the project study. NLOT has since been rechristened HIROT.

Site survey

In continuation of the work initiated earlier towards the selection of possible sites, a study of the general meteorological and topographical information on likely sites was made, supplemented with satellite imagery wherever available. Keeping in view the need for a telescope that may be used for both optical and near infrared observations, special emphasis was placed on dry high-altitude sites (heights above 4000 metres) in the Himalayan region. The states of Uttar Pradesh, Himachal Pradesh and the Ladhak region of Jammu & Kashmir were scanned in detail and six sites were shortlisted for reconnaissance survey. These are: (i) Vasuki Tal region (latitude 30° 43'.5 N, longitude 79° 2'.15 E) near Kedarnath, U.P., (ii) Lamdal area in H.P., (iii) Kalpa area, Kinnaur dt., H P., (iv) Kaza in Spiti

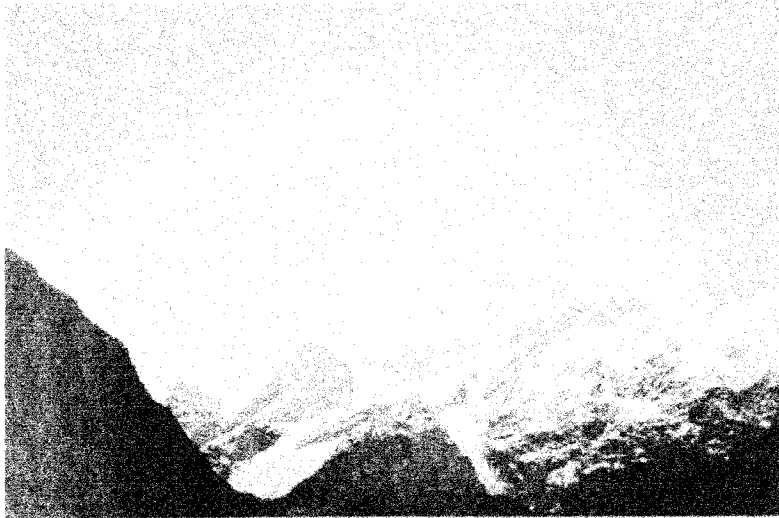
Valley, H.P., (v) Hanle region (latitude 32° 47'N, longitude 78° 57'.5 E), south-east Ladakh and (vi) Tso Morari region (latitude 32° 52' N, longitude 78° 26' E) also in Ladakh. Six teams from IIA each consisting of six members, visited these locations in 1993 September and made preliminary surveys for about a week. The accessibility of the sites, general weather conditions, wind pattern and a variety of related aspects were studied. The teams presented detailed reports of their survey on return. Some of the sites were assigned lower priority because of the inclement weather conditions or poor accessibility during the better part of a year. Of the remaining sites, the Hanle region in south-east Ladakh was chosen for further study at this preliminary stage.

The Hanle Project

Location

The Hanle region includes mainly a large, more or less flat, high altitude plain in south-east Ladakh. The plain, bearing the name 'Nilamkhul Plain', is roughly elliptically shaped, with a major axis of 13 to 14 km running in the direction ENE to WSW, and a minor axis of 5 to 6 km in the direction NNW to SSE. Somewhat off centre, towards the ENE end of the plain, is a hill with a fairly flat top affording an area of about half a square kilometre. The altitude of the top is 4517 metres above msl; the average altitude of the plain immediately surrounding the hill is 4240 metres above msl. The coordinates of the top of the hill are, approximately: Latitude 32° 47' N; Longitude: 78° 57'.5' E.

Hanle can be accessed the year round by road from Leh. There is a metalled road running due south east, connecting Leh to the sub-divisional town of Nyoma about 180 km away; this is normally a full day's drive. From Nyoma, an unmetalled road runs roughly 22 km eastward to a location called Loma, from where a dirt road runs about 45 km southward to the plain at Hanle. Though at places the dirt road is little more than a track made by



View of Mt. Dhaulagiri



Parvati Kailash from Kalpa, H.P.



At Kalpa with Nani



Mountaineers at Chiro Village, H.P.

repeated passage of vehicles, it can be easily negotiated by jeeps and trucks. The roads are maintained by the Border Roads Organisation. Within the Nilamkhul Plain itself, there are dirt roads, again created by repeated passage of vehicles, going right to the base of the hill. Most of these roads and tracks will take the load of a standard lorry with about 4 to 5 tons of material. The most difficult part of the access is to the top of the hill from the plain.

Weather

Teams from IIA have visited Hanle in 1993 September and 1994 January; it has been observed that sometimes there is local formation of patches of cloud, starting around mid morning, which however tend to dissipate by early evening. During these two visits, each lasting a few days, a fraction of the time (about 30%) has shown incidence of cloudiness during the day with the tendency of clearing up in the night. The information from the paramilitary forces indicates that in the winter months there may be two or three spells of snowfall, each lasting a few days, during which the sky is fully cloudy.

Sample photographic data from the low scale INSAT images and the high resolution IRS images have been examined for the Hanle and the adjacent (about 40 km away) Tso Moriri region. In particular, the IRS images from the LISS II camera have a resolution on the ground of about 36 metres, with a field of view of 85 km by 74 km. Visual analysis of the data for a sample of 69 days covering 1988 to 1992 shows 57% of the days to be fully clear; if one adds days where only isolated cloud patches are seen, then 78% of the days are clear. This preliminary analysis indicates that one may expect between 210 to 290 clear nights in a year (the latter from the assumption that isolated cloud patches dissipate by evening).

Meteorological data recorded by the paramilitary units in Hanle for most of the year 1992 have been available to us. These are recorded at the camp in a hollow between the hills on the NE edge of the plain. The maximum temperature recorded is 20°C in August and the minimum is -26°C in February. The wind speeds are generally well below 20 kmph, with two days in May showing 45 kmph and three days in September showing 25 kmph.

The IIA team in 1994 January recorded a minimum temperature of -28.5°C at the camp of the paramilitary forces. The local information is that in some years, the temperature can dip substantially lower, perhaps going down to below -35°C.

Plans for Astronomy at Hanle

Given the fact that the Hanle region is the most accessible of the sites initially listed for site survey and considering the indications of a large fraction of clear nights in a year, the issues of on-site astronomical measurements have been taken up. Conducting a round the year site survey in a remote high altitude location is a daunting task and calls for a substantial amount of effort and funds. The challenge has, however been taken up and the various difficulties are being tackled in a deliberate approach.

Telescopes are not immediately available, that will work at high altitude in temperatures going down to -40°C. The first step therefore is one that gives experience in dealing with the critical technologies of operation at the same time it is an advantage to be able to show some scientific results for the money spent. With these aims, the initial plan is to deploy the existing 24/18 inch Schmidt telescope, appropriately re-engineered for the purpose for doing astronomy from the hilltop at Hanle. The existing optics of this telescope is to be installed in a newly designed mount with drive electronics and data acquisition systems to suit the harsh environmental conditions. The following aims are to be achieved with this project.

- (a) Carrying out of research programmes such as the optical follow up of Gamma ray burst sources and other programmes requiring wide field imaging.
- (b) Gaining experience with the critical engineering methodology required to build and operate telescopes at a remote high altitude location. This includes facilities for remote operation of and data acquisition from the telescope.
- (c) Evolving logistical facilities and support for the planned scientific and engineering activity.
- (d) Assessing the requirements for the HIROT project, from both the engineering as well as the logistical point of view.



Palaia (a) palaia (a) K. a. H.P.



Telescope at ERP station, Haulle

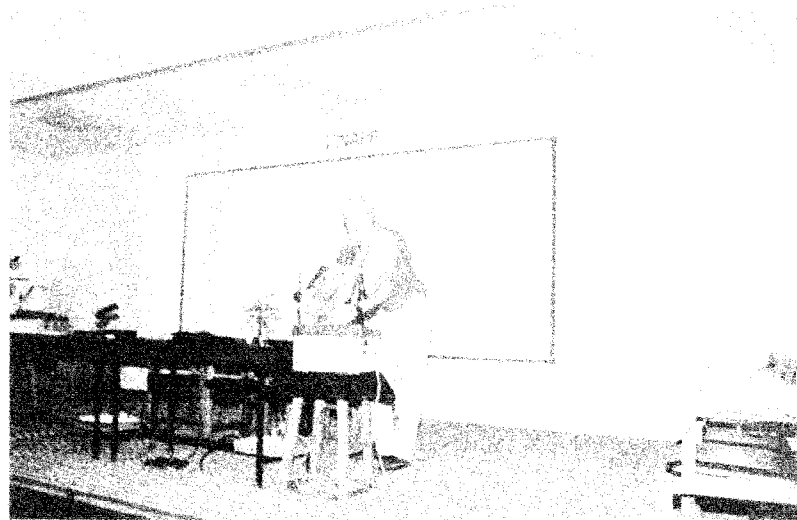
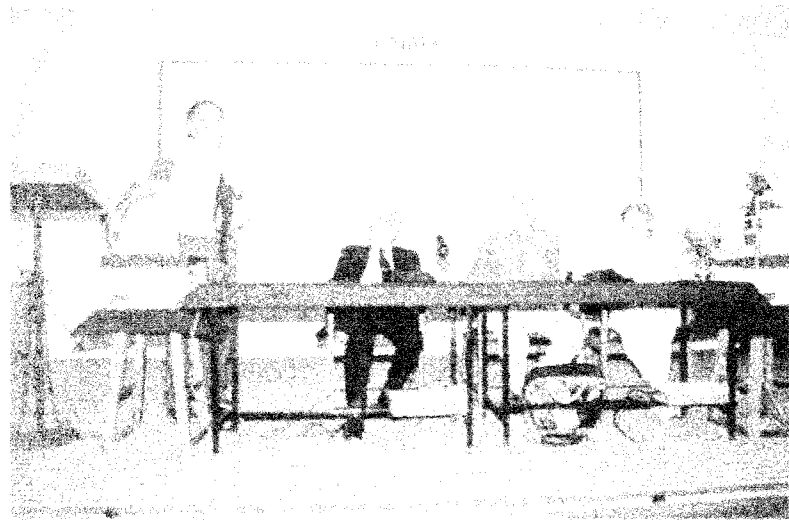
Efforts are also to be made to acquire or build a smaller telescope suited to measurements of astronomical 'seeing' and to install it at the site once the methodology of operating in the area has been worked out and the necessary infrastructural facilities set up.

During 1994 January a team of IIA scientists carried sensitive equipment such as CCD cameras and computers and tested their operation successfully in extreme winter conditions. Clearances for remote operations using communication equipment have also been obtained from relevant Government Departments. The engineering design of the Schmidt telescope structure is nearing completion and fabrication of components has commenced. Methods have been identified to provide continued support to teams at Hanle during the phases of deployment of the Schmidt telescope as well as during observations thereafter.

Utilization of VBT during 1993-1994

The Vainu Bappu Telescope was nearly fully operational during 1993 April - 1994 March. During 1993 April-June and 1994 January-March, time on the telescope was oversubscribed by a factor of three and a half. A total of thirty five scientific proposals were allotted observing time. The telescope operated in the prime mode on 165 nights and in the Cassegrain mode 145 nights. The remaining nights during the year were utilized for maintenance and change overs of the modes. In the prime mode CCD imaging was done using broad band and narrow band filters for a variety of programmes by the scientists of IIA, IUCAA, TIFR and Ravi Shankar University, Raipur. In the Cassegrain mode spectroscopy was done on 95 nights using the Boller and Chivens spectrograph. PRL astronomers did Fabry-Perot spectrometry on eight nights and used the IR photometer on another four nights. The two-star photometer of ISRO was used on three nights and the rotational shearing interferometer on four nights.

11/11/93



Miscellaneous

International Conference on Nonaccelerator Particle Physics (ICNAPP)

The International Conference on Nonaccelerator Particle Physics was held at IIA, Bangalore 1994 January 2-9. The conference was sponsored by the International Astronomical Union (Commissions 47, 48 & 9), Department of Science and Technology, Govt. of India, and major Indian scientific institutions and academies. This was the first ever international conference held on the campus of IIA. Before the conference the infrastructural facilities at the Bangalore and Kavalur campuses were vastly improved. The conference was held in the Library Hall in Bangalore. An audiovisual room with close circuit TV connections was also provided to accommodate extra people. Lunch and dinner were also provided in the refectory specially set up for the conference. The valedictory session of the conference was held at Vainu Bappu Observatory, Kavalur. Professor A. Wolfendale, the Royal Astronomer of UK addressed the session.

More than 200 participants from all over the world attended the conference which was spread over twenty one sessions from Monday January 3 through Saturday January 8. Apart from oral presentations consisting of invited talks, several poster papers were also presented. Two cultural programmes were organised. A Veena-Sitar Jugalbandhi was presented by R.K. Suryanarayana and Jayantilal Das on January 4. On January 5 Shreemati Protima Gauri and her troupe from Nrtyagram presented a collage of Indian classical dances. Proceedings of the conference are being edited and will be published by World Scientific, Singapore.

Lecture by R. Penrose

On the occasion of ICNAPP, Roger Penrose, Rouse Ball Professor of Mathematics, University of Oxford, UK gave a public lecture *Non-comput-*

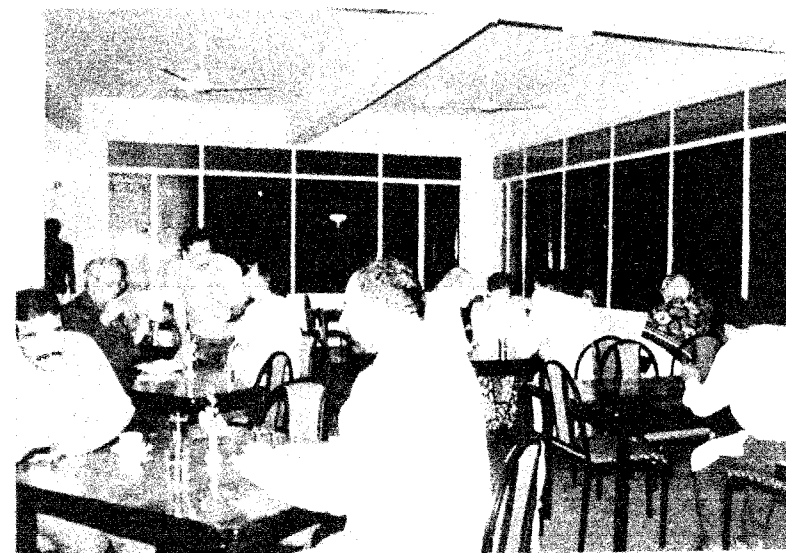
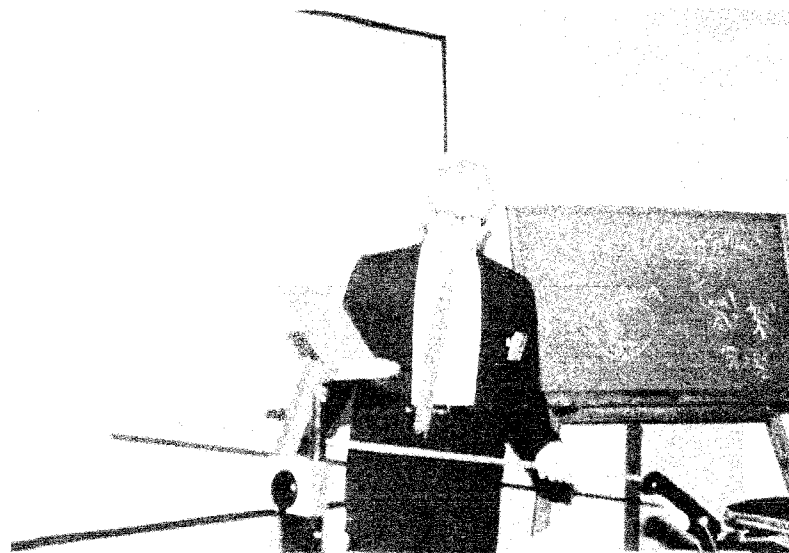
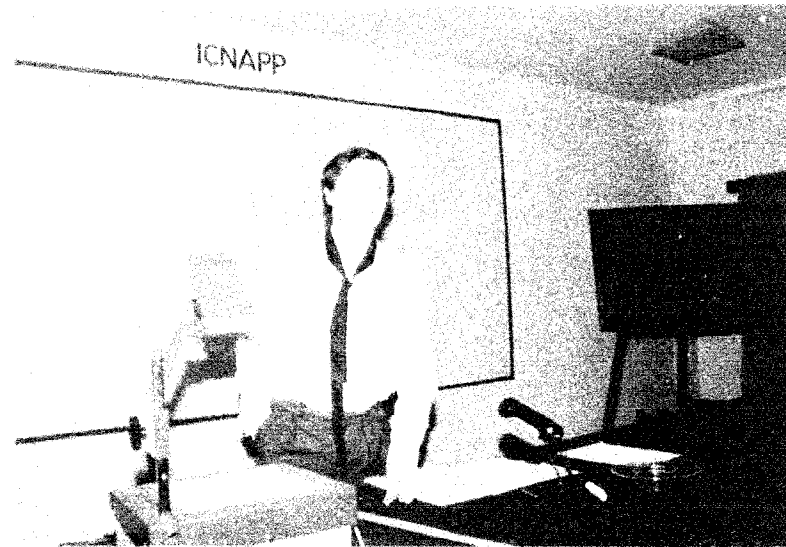
ability and the Mind in the evening of January 7, 1994. The lecture was attended by well over two hundred people.

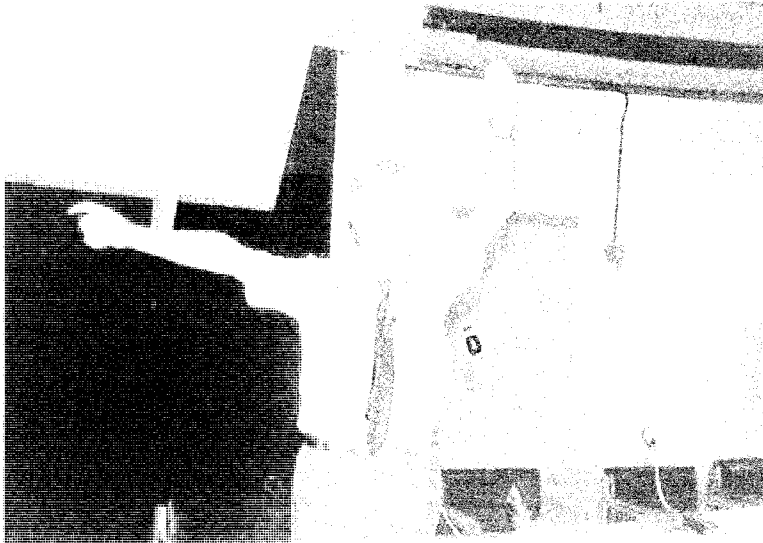
Awards and distinctions

Professor Ramanath Cowsik had been a Distinguished Visiting Professor at the McDonnell Center for the Space Sciences, Department of Physics, Washington University, St. Louis, USA since 1994 February 14 for a period of four months. Dr. A.K. Saxena along with Mr. P.P. Gupta and Mr. S.C. Rastogi of ISRO and Dr. Indra Rajagopal of NAL, share the NRDC award for the development of passive radiant cooler for high resolution radiometer of INSAT II Satellites. The passive radiant cooler houses the infrared detector and the infrared channel's optical elements. The cooler maintains a temperature 105° K utilizing deep space as the heat sink. The development of this technology has resulted in considerable foreign exchange savings. Professor C. Sivaram was a Visiting Professor to the Department of Physics and Astronomy, University of Bologna, Italy during 1993 March-June and a Visiting Scientist to the Department of Physics, University of Edmonton, Canada during 1993 July-August.

Doctoral dissertations

R. Vasundhara was awarded the Ph.D. degree of Bangalore University for her thesis titled *Physical studies of solar system objects*. Prof. J.C. Bhattacharyya was the thesis supervisor. Y.D. Mayya was awarded the Ph.D. degree of the Indian Institute of Science, Bangalore for the thesis titled *Star formation in giant extragalactic H II regions*. He worked under the supervision of Prof. T.P. Prabhu. R.T. Gangadhara was awarded the Ph.D. degree of the Indian Institute of Science for his thesis *Nonlinear propagation of intense electromagnetic waves in quasar and pulsar plasmas*. He worked under the supervision of Prof. V. Krishan. R. Surendranath was awarded the Ph.D. degree of Bangalore University for his thesis *A study of*





Dr. S. K. Somasundaram
during the lecture



Students during the lecture

planetary nebulae. He worked under the guidance of Prof.N.Kameswara Rao.

SERC School on Astronomy and Astrophysics

An SERC school on the theme *Advanced stages of stellar evolution* was held at the Vainu Bappu Observatory, Kavalur during February 1-6, 1994. The school was supported by the Department of Science and Technology. There were about 45 student participants from all over the country and 15 speakers. The topics discussed at the school included: Stellar structure, Evolution of intermediate mass stars and massive stars, End products of stellar evolution, Star clusters and stellar evolution, Pulsations and mass loss, Circumstellar matter, AGB stars and Planetary nebulae, Nucleosynthesis, Chemical evolution of the Galaxy, Neutrinos and stellar evolution and the Stellar-solar connection. Special tutorial classes were held for the student participants in the evenings. They were also exposed to the basic techniques of astronomical observations.

Seminar on MACHO

The possible detection of dark matter in the form of *Massive Compact Halo Objects* in the Galactic halo through gravitational microlensing evoked great interest in the astronomical community in 1993 September/October. A seminar was organised at IIA with a programme of talks that touched upon the discovery and its various implications in astrophysical terms. The meeting was attended by a large gathering of astronomers and students.

Historical studies

Studies related to the astronomical orientations of ancient monuments have been pursued for some years. During 1993-94 the Sun temple at Modhera, Gujerat built in 1026 AD was studied. The rising Sun's rays in equinoxes are supposed to illuminate the deity — the Sun god (the statue is presently missing). Further studies on the architectural plan of the temple and the accuracies involved in these alignments are on. (N.K.Rao)

Data service

Ionospheric data and magnetograms are supplied from the Kodaikanal station to NPL, Delhi and IIG, Bombay and are published annually. The geomagnetic storm data for every month is also sent to IIG, Bombay. The annual mean values computed from the monthly means are regularly sent to the British Geological Survey in Scotland. All the data till end 1992 have already been communicated.

Exhibitions

The Institute took part in the Science Exhibition conducted by 'Karnataka Rajya Vijnana Parishat' at Belgaum during 27-29 October 1993. Popular Astronomy topics, Astronomy in India, and the achievements of IIA were highlighted using pictures, posters, telescope models and video shows. The exhibition coincided with a conference of active science writers and science popularization enthusiasts from all over the state.

During ICNAPP exhibitions were organised at IIA campus. In addition to an exhibition on scientific books by local booksellers, there was an exhibition on computers and instruments and computer software. The audiovisual room exhibited original paintings of several well known artists of Karnataka.

National Science Day was celebrated by actively participating in the Science Exhibition held jointly by the Departments of Science and Technology, Government of India and Government of Karnataka, at the Jawaharlal Nehru Planetarium, Bangalore, during 26-28 February 1994.

The exhibitions were well received by thousands of inquisitive school and college students as well as the general public.

At IIA National Science Day was celebrated on February 28, 1994 by organizing popular lectures and video shows on astronomy for school children. More than two hundred children visited the Institute on that day.



Famagarty at IITR, 1964



Graduate school, 1964



U.S. staff at the Exhibition, Bangalore, 1964



Film on Sir J.C. Ghosh

R C.Kapoor organised and filmed the IISc campus sequences of a video film on Sir J.C.Ghosh (Director, IISc 1939-1945) produced in 1993 by the J.C.Ghosh Memorial Centenary Committee.

Visitors' day at VBO

Every Saturday students from schools, colleges and universities, amateur astronomers and other visitors have been taken around the observatory and in the evening they have been shown the night sky through the visitor's telescope. Short lectures on astronomy and VBO have also been organised often

Colloquia by visiting scientists

Large-scale structure of the universe and the adhesion model
Varun Sahni, IUCAA, Pune
1993 April 28

Signatures of CP violation in astrophysics and cosmology
S.N. Nayak, Institute of Physics, Bhubaneswar
1993 May 18

Infrared emission from early-type stars
B.S.Shylaja, PRL, Ahmedabad
1993 May 25

Beyond stars and galaxies - do we live in a false vacuum?
C W. Misner, Univ. of Maryland, USA
1993 June 4

The thermodynamics of black holes and radiation
The horizons of two black holes
Nigel Bishop, Univ. South Africa, Pretoria, S.A.
1993 July 8

The development of torsion balances for gravitational research
R.D. Newman, Univ. California, Irvine, USA
1993 July 9

Testing the inverse square law of gravity : a new class of torsion pendulum null experiments
Paul Boynton, Univ. Washington, Seattle, USA
1993 July 12

Gravitational effects on superconductors
The meaning of wave function
J.S. Anandan, Univ. South Carolina, USA
1993 July 16

Creativity in science and arts
R L. Kapur, National Institute of Advanced Studies, Bangalore
1993 July 27

Measurements of global Hubble constant
N. Visvanathan, Mt. Stromlo & Siding Spring Obs., Australia
1993 July 30

The chemical evolution of the Galactic disk
D.L. Lambert, Univ. Texas, Austin, USA
1993 August 4

The recurrent nova RS Ophiuchi
G.C. Anupama, IUCAA, Pune
1993 August 10

Coronal mass ejections and metric radio emission
N. Gopalswamy, Univ. Maryland, USA
1993 August 13

From quarks to baryons
S Sahu, Inst. of Physics, Bhubaneswar
1993 August 19

- Instrumentation for solar research
Li Ting, Nanjing Astronomical Instruments Research Centre, China
1993 August 23
- Galactic bulge planetary nebulae
M A. Ratag, Indonesian National Institute of Aeronautics and Space, Bandung, Indonesia
1993 August 23
- Squeezing of vacuum fluctuations and its applications to experiments
C V Sukumar, Oxford Univ , U.K
1993 August 26
- Martian polar caps
Kyosuke Iwasaki, Kyoto Univ. Japan
1993 August 27
- The real value of Ω_0 and the biasing
E Regos, Inst of Astronomy, Cambridge, England
1993 August 30
- The formation of cataclysmic variables and algols
C A Tout, Inst of Astronomy, Cambridge, England
1993 September 1
- A statistical model for the radiation field of non-interacting stars
H Parthasarathy, Electrical Engineering Dept , IIT, Delhi
1993 September 1
- Infrared spectroscopy of discs around young stars
John Carr, Ohio State Univ , USA
1993 September 2
- Activity in galaxies - New theoretical insights
Judith Perry, Inst of Astronomy, Cambridge, England
1993 September 6
- Some unconventional electric machines (Linear and rotational motors)
K.C Tripathy, BARC, Bombay
1993 September 10
- Globally coupled chaos
Sudeshna Sinha, TIFR, Bombay
1993 September 23
- Evolution of solar active regions
K S Balasubramaniam, NSO Sacramento Peak, USA
1993 October 14
- Statistical mechanics of strings and an application to cosmology
Nivedita Deo, Indian Institute of Science, Bangalore
1993 November 9
- Some low-energy consequences of the unification of electromagnetic and weak interactions
Subhendra Mohanty, Institute of Physics Bhubaneswar
1993 November 16
- Ritual art of the west coast
Balan Nambiar, Bangalore
1993 December 7
- Changes in the concepts of space and time brought about by relativity
John Stachel, Boston Univ , USA
1994 January 11
- Torsion in general relativity - Quantum effects and some consequences
V de Sabbata, Univ Bologna & Ferrara Italy
1994 January 14
- Dedicated terraflop machine - application to many-body problems
D Sugimoto, Univ Tokyo Japan
1994 January 25

Scattering and black holes

Nils Andersson, Univ. Wales, Cardiff, UK
1994 February 21

Integrated photometric parameters of star clusters

B.C.Bhatt, UPSO, Naini Tal
1994 February 22

Recent results from IR camera

M.Ueno, Univ. Tokyo, Japan
1994 February 28

Centrifugal force reversal in general relativity

A.R. Prasanna, PRL, Ahmedabad
1994 March 3

Raman ripple lasers

R.V. Pratap, Cochin Univ., Cochin
1994 March 4

Many-body theory and its applications to molecular systems

D.Mukherjee, Indian Association for the Cultivation of Science,
Calcutta
1994 March 15

T.G. Cowling and the early days of stellar structure theory

L.Mestel, Univ. Sussex, UK
1994 March 18

Soft gamma ray repeaters

S.R. Kulkarni, Caltech, USA
1994 March 29

Library

IIA Library acquired 380 books during the year and 5 new journals were added two of which are from India. Twenty five SIMBAD searches and four searches using the Easynet were made during the year. The library staff was actively involved in the organisation of ICNAPP. The whole library was reorganised for holding the meeting.

The Kodaikanal Observatory Bulletins continued to be published by the Library

The Library was able to get 250 journal references and more than 20 documents for scientists on inter-library loan from various libraries both locally and from outside Bangalore. The Library continued to borrow 20 journals from Raman Research Institute and 4 journals from TIFR Centre, IISc campus, Bangalore for display. It also lent 15 journals to RRI Library for display

Special xerox work was undertaken by the Library during ICNAPP in addition to the 200,000 copies of xeroxing from various journals and books for the scientists. 350 volumes of journals and reports were bound during the year

Ms.A.Vagiswari, the Librarian attended 3 Bangalore Science Libraries Group meetings. She was also on the Local Organising Committee of ICNAPP

Personnel

The academic and technical staff during the period 1993 April - 1994 March include the following :

Director : Ramanath Cowsik

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

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

Associate Professor : B.Datta, S.S.Hasan, R.C.Kapoor, D.C.V.Mallik, M. Parthasarathy, T.P.Prabhu, R.Rajamohan, Ram Sagar, C.Sivaram, P.Venkatakrisnan

Reader : G.S.D.Babu, S.P.Bagare, H.C Bhatt, A.Chokshi, P.K.Das, K.K.Ghosh, S.K.Jain, A.K.Pati, P.K.Raju, A.V.Raveendran, J.Singh

Fellow : Alok Shukla, P Bhattacharjee, S Chatterjee, S.Giridhar, R.Kariyappa, S.G.V.Mallik, M.V.Mekkadon, D.Mohan Rao, B.S.Nagabhushana, K.N.Nagendra, R S.Narayanan, K.E.Rangarajan, S.K.Saha, A Satya Narayanan, K R Subramanian, K Sundara Raman, R.Surendiranath, G.Thejappa, R Vasundhara

Research Associate: J.Javaraiah, D.Karunakaran, Prabhjot Singh, K.Sasidharan, B.A.Varghese, L.Yeshwant

Senior Principal Scientific Officer : R.Srinivasan (Dean)

Head, Photonics Division : A.K.Saxena

Principal Scientific Officer :A.V. Ananth, B R Madhava Rao,

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

Scientific Officer 'SC' : P S.M.Aleem, S.S.Gupta, J.P Lancelot, S.Mohin, P.M.S.Namboodiri, K.B.Ramesh

Senior Computer Engineer : V Chinnappan

Senior Civil Engineer : N Selvavinayagam

Senior Technical Officer : R Sivashanmugam

Librarian : A.Vagiswari

Assistant Librarian 'A': C Louis

Assistant Librarian 'B' : H N.Manjunath

Technical Officer : J.P.Abraham Samson, S S Chandramouli, M.Mohd Abbas, A.Mohd.Ghouse, R Muraleedharan Nair, K.Narayanan kutty, K Padmanabhan, K.S.Ramamoorthy, K.Ramankutty, K.G Unnikrishnan Nair

Technical Associate: A.M.Batchu, P.Chockalingam, F Gabriel, A.T A.Hameed, N.Jayavel, P K.Mahesh, S.Muralishankar, S Muthukrishnan, J.S.Nathan, A.Selvaraj, N.Selvaraj, K.S Subramanian, K C Thulasidharan

Engineer Associate : Faseehana Saleem

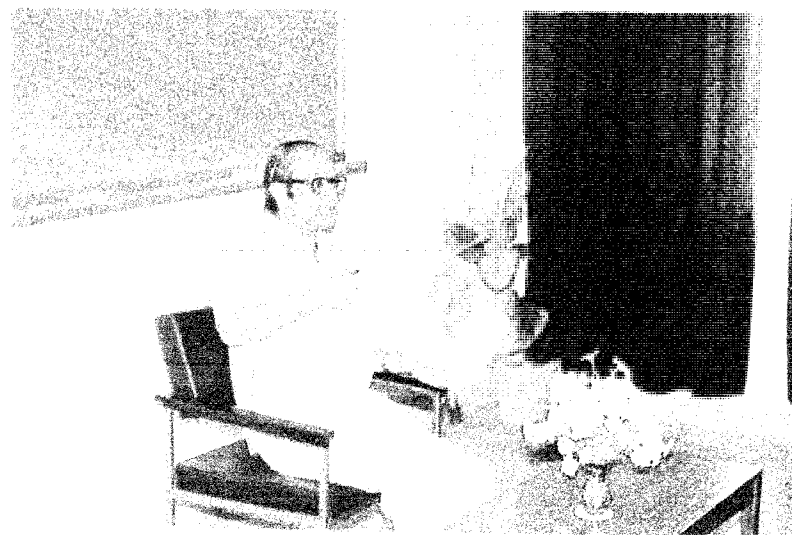
Documentation Associate : Sandra Rajiva

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

Emeritus Scientist (CSIR): K.V K.Iyengar

Post Doctoral Fellow (CSIR): P.Bhaskaran

Visitors



Visiting Fellow. R.T.Gangadhara, H.Parthasarathy, P.Saraswat

Graduate Students : Angom Dilip Kumar Singh, S.Annapurni, Atish Dipankar Jana, D.Banerjee, S Banerjee, S.G.Bhargavi, Charu Ratnam, Chitra Rangan, M.Dikpati (CSIR), B.Eswar Reddy, V.Krishnakumar, Mangala Sharma, Y D.Mayya (up to 1993 Nov.30), G.Pandey, S.Paul Kasper Rajaguru, Pavan Chakraborty, R.D Prabhu, K.Rajesh Nayak, R.Ramesh, H.N Ranganath Rao, K.Sankara Subramaniam, S.K.Sengupta (CSIR), T.Sivarani, Sonjoy Majumder, Srikanth, Swara Ravindranath, A.V.Thampan, G.Uma, R.T. Gangadhara (up to 1993 Dec 31)

G.S.D.Babu resigned from the directorship of Jawaharlal Nehru Planetarium, Bangalore and returned to his position in IIA 1993 August 1. **B.P.Das** joined IIA as Professor 1993 July 15 **Arati Chokshi** joined IIA as Reader 1994 January 20 and **Alok Shukla** as Fellow 1993 October 7. **H.Parthasarathy** and **R.T.Gangadhara** were appointed Visiting Fellows effective 1993 October 5 and 1994 January 1 respectively **Y.D.Mayya** left IIA 1993 December to take up a post doctoral assignment in TIFR, Bombay

Involvement in the scientific community

B.P.Das has been appointed an Affiliate of the National Institute for Nuclear Theory, Seattle, USA. **N.K.Rao** along with B Hidayat chaired and organized the Stellar Physics session of the Sixth Asian-Pacific Regional IAU Meeting, which was held in Pune 1993 August 16-20. N.K.Rao was an SOC member for the same meeting. N.K.Rao is also a member of the Science Advisory Committee of IUCAA **J.H.Sastri** served as member-secretary, Indian National Committee for SCOSTEP of INSA, New Delhi. **A.K.Saxena** was invited to serve as a member of the Standing Committee of UGC for formulating undergraduate and graduate courses on Photonics **C.Sivaram** was a co-director of Projects of the World Laboratory, Geneva. He also acted as a referee and consultant for approval of funds for international projects of the NSF, USA.

Visitors

Varun Sahni, IUCAA, Pune
1993 April 28

Virendra Singh TIFR, Bombay
1993 May 18

S N.Nayak, Institute of Physics, Bhubaneswar
1993 May 18

S Sreedhara Rao, Astronomy Department, Osmania University, Hyderabad
1993 June 1-20

N Bishop, University of South Africa, Pretoria
1993 July 7-9

R.D Newman, University of California, Irvine, USA
1993 July 8-9

P Boynton, University of Washington, Seattle, USA
1993 July 8-12

J S Anandan, University of South Carolina, USA
1993 July 15-17

R M Godbole, Dept of Physics, University of Bombay
1993 July 24-26

D L Lambert, University of Texas, Austin, USA
1993 July 10 - August 4

N.Visvanathan, Mt Stromlo and Siding Spring Observatories,
Australian National University, Australia
1993 July 29-31

G C Anupama, IUCAA, Pune
1993 August 2-11

N.Gopalswamy, Department of Astronomy, University of Maryland,
College Park, USA
1993 August 13-16

M A.Ratag, Indonesian National Institute of Aeronautics and Space,
Bandung, Indonesia
1993 August 18-23

S.Sahu, Institute of Physics, Bhubaneswar
1993 August 19

D.Enard, ESO, Garching, Germany
1993 August 22-23

Li Ting, Nanjing Astronomical Instruments Centre, Nanjing, China
1993 August 23-24

P.Guhathakurta, Princeton University, USA
1993 August 24

J.L.Osborne, Physics Department, Durham University, Durham, USA
1993 August 23-24

K.Iwasaki, Kyoto University, Japan
1993 August 24-28

Judith Perry, Institute of Astronomy, Cambridge, England
1993 August 27 - September 7

E.Regös Institute of Astronomy, Cambridge, England
C.A.Tout, Institute of Astronomy, Cambridge, England
1993 August 27 - September 1

J Carr
Suchitra Balchandran
Department of Astronomy, Ohio State University, USA
1993 September 1-2

K.C.Tripathy, BARC, Bombay
1993 September 10

K.S.Balasubramaniam, NSO, Sacramento Peak Observatory,
New Mexico, USA
1993 October 14

Sisir Roy, Physics and Applied Maths Unit, ISI, Calcutta
1993 October 15 - November 12

A.R.Prasanna, PRL, Ahmedabad
1993 November 1-5

Osman Shinaishin, NSF, Washington D.C , USA
1993 November 14

S.Mohanty, Institute of Physics, Bhubaneswar
1993 November 16-19

Martin A Lee, University of New Hampshire, Durham, USA
1993 December 22 - 1994 January 17

Sudha Murthy, KAI Science and Technology Inc, Lancaster, USA
1994 January 1 - March 15

V. de Sabbata, Ettore Majorana International School of Cosmology and
Gravitation
1994 January 8-9

J.Stachel, Department of Physics, Boston University, Boston, USA
1994 January 11

J Ryan, Space Science Center, University of New Hampshire,
Durham, USA
1994 January 2-12

D.Sugimoto, University of Tokyo, Japan
1994 January 22-26

Nil Andersson, University of Wales, Cardiff, UK
1994 February 18-25

B C.Bhatt, UPSO, Nainital
1994 February 22

M Ueno, Department of Earth Sciences and Astronomy
College of Arts and Sciences, University of Tokyo, Japan
1994 February 25 - March 4

A R Prasanna, PRL, Ahmedabad
1994 March 1-10

R V Pratap, Department of Physics,
Cochin University of Science and Technology, Cochin
1994 February 27 - March 5

D Mukherjee, Indian Association for the Cultivation of Science,
Calcutta
1994 March 15

L Mestel, University of Sussex, UK
1994 March 18

S R Kulkarni, California Institute of Technology, USA
1994 March 29

Appendixes

Appendix - A

Publications

In Journals

- Ananth,A.V., Venkatakrishnan,P , Bhattacharyya,J C , Narayanan,R.S. (1994) *Sol Phys* , in press.
A PC based Stokes polarimeter for solar observations.
- *Apparao, K M V., *Tarañdar, S P , *Verma, R P., Iyengar, K.V.K , Ghosh, K.K (1993) *JAA* 14, 131
Simultaneous infrared and H α measurements of Be stars.
- *Ashok, N.M , *Chandrasekhar, T., *Ragland, S , Bhatt,H.C , (1994) *Experimental Astronomy*, in press.
A high speed near-infrared photometer for lunar occultation studies.
- Bagare,S P (1994) *Bull ASI*, in press
Daytime seeing observations at Kodaikanal Tower Telescope
- Bhatt,H C (1993) *Curr.Sci.* 65, 145
Oort and the comets
- Bhatt, H.C., Sagar, R., Subramaniam, A , Gorti, U., *Chandrasekhar, T ,*Ashok, N.M ,* Ragland, S. (1994) *A&A*, in press
SAO 75669 a late type giant behind the molecular cloud MBM 12.
- Bhattacharjee, P. (1994) *Curr.Sci.* 66, 268.
Detection of dark matter in the Galactic halo.
- *Borzesszkowski, H.,*de Sabbata, V., Sivaram, C.,*Treder, H J., (1994) *Foundations of Physics*, in press.
Torsion and curvature in quantum gravity.
- *Catala, C. (25 authors including K.K.Ghosh) (1994) *Sol. Phys.*, in press.
Azimuthal structures in the wind and chromosphere of the Herbig Ae star AB Aur - preliminary results from the MUSICOS 1992 campaign.
- Datta, B , *Sahu, P.K. (1993) *Phys. Lett B* 318, 277.
Nuclear matter in the derivative scalar coupling model: energy per nucleon and a finite temperature equation of state.
- *de Sabbata, V , Sivaram, C. (1993) *Foundations of Physics Lett.* 6, 201.
On the universality of charge arising from torsion.
- *de Sabbata V., Sivaram, C. (1994) *Foundations of Physics Lett* . in press.
On limiting field strengths in gravitation
- *Fohing, B et al.(46 authors including K K.Ghosh) (1994) *A&A*, in press.
RS CVn system HR 1099 - MUSICOS results of 1990 campaign
- *Garcia-Lario, P ,*Manchado, A., Parthasarathy, M . *Pottasch, S R (1993) *A&A* 285, 179
Nebular emission lines in IRAS 10215-5916
- Ghosh,K.K., Soundararajaperumal,S (1993) *A&A* 273, 397
X-ray spectral variability of the Seyfert galaxy NGC 4593
- *Gilliland, R.L et al (14 authors including M.Parthasarathy) (1993) *AJ* 106, 2441
Search for solar-like oscillations in the stars of M67 with CCD ensemble photometry on a network of 4-m telescopes.

- Giridhar, S., Rao, N.K., *Lambert, D L. 1994, *ApJ*, in press.
The chemical composition of the carbon rich RV Tauri star IW Car
- Gokhale, M H., Javaraiah, J. (1994) *Sol. Phys.*, in press,
Global modes constituting the solar magnetic cycle III.
Shapes and sizes of sunspot cycles and maintenance of MHD spectrum by energy cascade.
- *Gopal Krishna,*Yates, M.,*Wiita, P J.,*Smette, A , Pati, A.K.,*Altieri, B. (1993) *A&A* 280, 360.
Near-infrared and optical imaging of Q 2345 + 007 : the largest gravitationally lensed QSO system?
- Gorti, U., Bhatt, H.C. (1994) *MNRAS*, in press
Effect of gas drag on the dynamics of clumps in molecular clouds.
- Hasan,S S , *Kalkofen,W. (1994) *ApJ*, in press
Equilibrium of solar magnetic flux tubes. energy transport with multistream radiative transfer.
- *Iyer,B.R., Vishveshwara, C.V. (1993) *Phys. Rev. D* 48, 5706.
Frenet Serret description of gyroscopic precession.
- Kariyappa, R., Sivaraman, K.R. (1994) *Sol.Phys.*, in press
Variability of the solar chromospheric network over a solar cycle
- Kariyappa, R , Sivaraman, K R., *Anandaram, M N (1994) *Sol Phys.* , in press.
Heating of the quiet solar chromosphere I. Role of the inner network bright points.
- Krishan, V. (1994) *Physica Scripta* 49, in press.
Role of plasma processes in astrophysics.
- Krishan, V., *Wiita, P.J. (1994) *ApJ* 423, 172.
Plasma mechanisms for variability in active galactic nuclei.
- Krishan, V. (1993) *MNRAS* 264, 257.
Clustering of galaxies by the α - effect.
- *Kumar Golap, Sastry, Ch V (1994) *Sol. Phys.* 150, 295.
The radio brightness of the undisturbed outer solar corona in the presence of a radial magnetic field.
- *Lambert, D.L., Rao, N.K (1994) *JAA* 15, 47
The R Coronae Borealis stars - a few mere facts
- Mallik, D.C.V. (1993) *Curr.Sci.* 65, 42.
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Attendance in Conferences, Workshops and other scientific Meetings

Conference on Highlights of Particle and Condensed Matter Physics
ICTP, Trieste
1993 April 8-14

C Sivaram

Erice International Seminar on Planetary Emergencies 17th Workshop Erice, Italy 1993 April 29-May 3	R.Rajamohan	SPIE International Symposium on Optics, Imaging and Instrumentation San Diego, USA 1993 July 11-15	A.K.Saxena
NATO Advanced Institute Meeting on 'Interface between Particle Physics and Cosmology' Erice, Italy 1993 May 12-27	C Sivaram	23rd International Cosmic Ray Conference Calgary, Canada 1993 July 19-31	C.Sivaram
Workshop on Gravitational Waves and their Detection in honour of Prof. J.Weber Rome, Italy 1993 May 19-21	C.Sivaram	Sixth Asian-Pacific Regional IAU IUCAA, Pune 1993 August 16-20	G.S.D.Babu, S.Giridhar, K.K.Ghosh, R.Kariyappa, T.P.Prabhu, Ram Sagar, N K.Rao, Ch.V. Sastry, K.R.Subramanian,R.Swara
Workshop on High Energy Physics and Cosmology ICTP, Trieste, 1993 June 5-20	C. Sivaram	Tenth National Symposium on Radiation Physics Indira Gandhi Centre for Atomic Research, Kalpakkam 1993 August 17-20	A.Peraiah
Solar Magnetic Fields Freiburg, Germany 1993 June 29-July 2	S S.Hasan	Symposium on Astronomy and Astrophysics SINP, Calcutta 1993 August 23-25	P Bhattacharjee, M.H.Gokhale, N.K.Rao
IAU Colloquium 143 : The Sun as a Variable Star : Solar and Stellar Irradiance Variations Boulder, Colorado, USA 1993 June 20-25	R.Kariyappa	Mini-Workshop on Cataclysmic Variables IUCAA, Pune 1993 August 23-25	T P Prabhu
International Conference on Non-accelerator Particle Physics and Astrophysics ICTP, Trieste, Italy 1993 June 25-July 9	C.Sivaram	XIV Summer Workshop on Active Region Evolution National Solar Observatory, USA 1993 August 30-September 3	M.H.Gokhale P.Venkatakrishnan
National Conference of Planetarium Directors, Educators and Engineers Birla Planetarium, Calcutta 1993 July 2-4	G.S.D.Babu	IAU Symposium 159 · Active Galactic Nuclei across the Electromagnetic Spectrum Geneva, Switzerland 1993 August 30-September 3	K K.Ghosh

Conference on Acceleration and Radiation Processes in Space and Laboratory Plasmas Kardamyli, Greece 1993 August 30-September 4	V.Krishan	International Conference on Non-accelerator Particle Physics IIA, Bangalore 1994 January 2-9	P Bhattacharjee, R Cowsik, B P Das, B Datta K K Ghosh, M H Gokhale, D C V Mallik T P.Prabhu, C Sivaram, P Venkata- Krishnan, C V Vishveshwara
International Workshop on The MK process at fifty years · A powerful tool for astrophysical insight Tucson, USA 1993 September 22-26	M Parthasarathy	Workshop on Nuclear Equation of State Puri 1994 January 4-14	B Datta
IAU Symposium 162 · Pulsation, Rotation and Mass Loss in Early Type Stars Juan-les Pins, France 1993 October 5-8	K K Ghosh	American Astronomical Society Washington, D C . USA 1994 January 12-16	V Krishan
24th General Assembly of URSI Kyoto, Japan 1993 September 25-October 2	K R Subramanian	SERC School on Astronomy and Astrophysics IIA, VBO, Kavalur 1994 February 1-6	H C Bhatt P Bhattacharjee B Datta M H Gokhale, D C V Mallik S Giridhar, M Parthasarathy T P Prabhu Ram Sagar A K Saxena P Venkatakrishnan
M.N Saha Birth Centenary Symposium National Academy of Sciences Allahabad 1993 October	N K Rao	Workshop on Astroparticle Physics IUCAA Pune 1994 February 20-25	P Bhattacharjee
Indo-US Workshop on Active Galactic Nuclei IUCAA, Pune 1993 December 6-18	T P Prabhu, R Swara	Indian Association of General Relativity and Gravitation 1994 March	C V Vishveshwara
International Conference on Astrophysics and Cosmology SINP, Calcutta 1993 December 20-23	P Bhattacharjee, S Chatterjee B Datta, N K Rao, P Singh	Discussion Meeting on Pulsars RRI, Bangalore 1994 March 14-18	B Datta V Krishan

Colloquia and Invited talks at Conferences, Workshops and Seminars

Babu G S.D.

An astronomer in the Indian Expedition to Antarctica
*National Conference of Planetarium Directors, Educators, Engineers,
 Birla Planetarium, Calcutta*
 1993 July

Bhattacharjee.P

Cosmic relics from the microsecond epoch
M N Saha Birth Centenary Symposium, SINP, Calcutta
 1993 August

Cosmic strings and the origin of ultrahigh-energy cosmic rays
RRI, Bangalore
 1993 November 8

Cosmic topological defects and the ultrahigh-energy cosmic rays
*International Conference on Astrophysics and Cosmology, SINP,
 Calcutta*
 1993 December

Cosmic rays from cosmic strings and other topological defects
ICNAPP, IIA, Bangalore
 1994 January

Topological defects
Workshop on Astroparticle physics, IUCAA, Pune
 1994 February

Cowsik, R.

Experimental studies of gravitation and feebler forces
Spring meeting of the American Physical Society, Washington, D.C
 1993 April

Neutrino mass bounds from the studies of double beta decay of
 Tellurium isotopes
University of New Hampshire, Durham, USA
 1993 April

Neutrino mass bounds from the studies of double beta decay of
 Tellurium isotopes
University of Chicago, Chicago, USA
 1993 June

Perspectives on dark matter
 Neutrino mass bounds from the studies of double beta decay of
 Tellurium isotopes
University of the Phillipines, Quezon City, The Phillipines
 1993 June

Is the neutrino its own antiparticle?
TIFR, Bombay
 1993 July 28
Astronomy Dept , Osmania Univ., Hyderabad
 1993 August 25
Dept. of Physics, IISc, Bangalore
 1993 September 2

Acceleration of relativistic particles in astrophysical shocks
*Saha Centenary Memorial Lecture, Plasma Physics Society Meeting,
 Allahabad University*
 1993 October 11

Torsion balances and their application to the study of gravitation at
 Gauribidanur
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 1993 November 26

Is the neutrino its own antiparticle?
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 1993 December

- Das, B.P
 Present status of electric dipole moments of atoms due to time reversal and parity violation
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 Extended hadronic matter at high densities
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 1993 December
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ICNAPP, IIA, Bangalore
 1994 January
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 1994 January 4-14
- Neutron stars
Department of Physics, Utkal University, Bhubaneswar
 1994 January 19
- Ghosh, K K
 Radio through X-ray emission from blazars
Astronomisches Institut, Tübingen, Germany
 1993 September, 7
- Anisotropic emission from AGN
Institut d'Astrophysique, Paris
 1993 September 17
- Gokhale, M H
 Ins and outs of solar magnetic field
M N Saha Birth Centenary Symposium, SINP, Calcutta
 1993 August
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 New developments in the theory of magnetic fields on the surface of the sun
Physics Colloquium, TIFR, Bombay
 1994 March
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 Plasma processes in quasars
Lawrence Berkeley Laboratory, Berkeley, California
 1993 October & 1994 January
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Astronomy Dept. Univ of California Berkeley California
 1993 December 8
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 1994 January 14
- Parthasarathy, M
 The chemical composition and evolution of post AGB stars
Department of Astronomy, Indiana University Bloomington
 1993 October
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- Peraiyah, A
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 1993 August

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 Nova photospheres
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 1993 August 23-25

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 1993 December 11

Spectra of supernovae
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 1994 March 23

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The collision of an asteroid or comet with the Earth
International Seminar on Planetary Emergencies, Erice, Italy
 1993 April

Rao, N.K.

UV astronomy and stellar chromospheres
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 1993 August

Optical astronomy in Saha's time and beyond
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 1993 October

Chemical composition of peculiar supergiants
International Conference on Astrophysics and Cosmology, SINP, Calcutta
 1993 December

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CCP 7 Meeting on 'Hydrogen deficient systems', St. Andrews, Scotland
 1994 March

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 1993 August

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Recent optical technology development
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 1993 August

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Gravity and the uncertainty principle
Dept. of Physics, University of Bologna, Italy
 1993 April 6

Aspects of dark matter and its detection
 MOND and other alternatives to dark matter - a critical discussion
 Models of inflation in the early Universe and their consequences
NATO Advanced Institute meeting on Particle Physics and Cosmology, Erice, Italy
 1993 May

Gravitational waves generated in the early Universe and their present detectability
Workshop on Gravitational Waves, Majorana Centre, Italy,
 1993 May 17

On the non-acceleration origin of the highest energy cosmic rays
 Constraints on the neutrino magnetic moment from stellar evolution and supernovae Type Ia
 Cosmic upper limits on the electric charges of the photon and the neutrino
23rd International Cosmic Ray Conference, Univ. of Calgary, Canada
 1993 July

Problems of black hole entropy
Dept. of Physics, University of Alberta, Canada
 1993 August 4

Cosmological consequences of black hole entropy
Dept. of Physics, University of Edmonton, Canada
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Curvature from spin and curvature confinement
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Optical activity of biomolecules
ICTP, Trieste
 1993 October 29

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 1993 May 26

Higher dimensional generalisation of the Vaidya metric
IAGRG Meeting, IUCAA, Pune
 1994 February 17

Lectures

Bhatt, H.C.
 Circumstellar dust (2)
 SERC School on Astronomy and Astrophysics
 VBO, Kavalur
 1994 February 4,5

Bhattacharj e, P.
 Neutrino and stellar evolution
 SERC School on Astronomy and Astrophysics
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Das, B.P.
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 Utkal University, Bhubaneswar
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Giridhar, S.
 Abundances in stars
 SERC School on Astronomy and Astrophysics
 VBO, Kavalur
 1994 February 2

Gokhale, M.H.
 Physics of the sun and stars
 Sun's magnetic field
 UGC Winter School
 Karnatak University, Dharwad
 1993 December 3

Sun in the context of stellar structure
and evolution
SERC School on Astronomy and Astrophysics
VBO, Kavalur
1994 February 1

Hasan,S.S

Solar activity and its impact on astrophysics
S.V.College, New Delhi
1993 April

Physics of the solar atmosphere (2)
Physics Department, Jamia Millia University,
New Delhi
1993 April

Solar magnetohydrodynamics (3)
AMU, Aligarh
1994 January

Mallik,D.C.V.

Stellar structure and evolution(2)
Planetary nebulae
SERC School on Advanced Stages of Stellar Evolution
VBO, Kavalur
1994 February 1,6

Parthasarathy,M

Evolution of intermediate mass stars (2)
SERC School on Astronomy and Astrophysics
VBO, Kavalur
1994 February 1,2

Prabhu,T.P.

Telescopes
Galaxies
Workshop for urban/rural children, Jawaharlal Nehru Planetarium,
Bangalore
1993 April 27

Supernovae

Young Astronomers Meeting, IIA, Bangalore
1993 July 19

Chemical evolution of the galaxy and stellar evolution
SERC School on Astronomy and Astrophysics
VBO, Kavalur
1994 February 6

Classical and Recurrent Novae
Star-forming Regions in Galaxies
Physical Research Laboratory, Ahmedabad
1994 March 24-25

Rao,N.K.

Anatomy of an AGB star
SERC School on Astronomy and Astrophysics
VBO, Kavalur
1994 February 6

Ram Sagar

Introduction to astrophysics
Modern optical telescopes
Modern astronomical detectors
Binary pulsars
Devi Ahilya University, Indore
1993 November 30-December 3

Star clusters as tools for the study of
stellar evolution (2)
SERC School on Astronomy and Astrophysics, VBO, Kavalur
1994 February 3,4

Saxena,A.K.

New technology and large optical telescopes
SERC School on Astronomy and Astrophysics
VBO, Kavalur
1994 February 5

Venkatakrishnan,P
Pulsations (2)
SERC School on Astronomy and Astrophysics
VBO, Kavalur
1994 February 3,4

Vishveshwara,C.V.
Spacetime symmetries
IUCAA, Pune
1993 April 6-7

Paper presentations at Meetings

Chatterjee,S.
Distribution of stars above the Galactic plane
International Conference on Astrophysics
and Cosmology, SINP, Calcutta
1993 December 20-23

Ghosh,K.K , Soundararajaperumal,S.
Multifrequency spectra of AGNs
Sixth Asian-Pacific Regional IAU, IUCAA Pune
1993 August 16-20

Ghosh,K.K.
Physics of Be phenomena
Sixth Asian-Pacific Regional IAU, IUCAA, Pune
1993 August 16-20

Ghosh,K K , Soundararajaperumal,S.
Multifrequency spectra of EXOSAT blazars
IAU Symposium 159, Geneva, Switzerland
1993 August 30-September 3

Ghosh,K.K
Physics of the phase changes of Be stars
IAU Symposium 162, Nice, France
1993 October 5 - 8

Prabhu,T.P.
SN 1993J in M81 : Photometry and Spectrophotometry
Sixth Asian-Pacific Regional IAU, IUCAA, Pune
1993 August 16 - 20

Rao,N.K., (with Giridhar,S., *Lambert,D.L.)
The chemical composition of the carbon-rich
RV Tauri star IW Car
Sixth Asian-Pacific Regional IAU, IUCAA, Pune
1993 August 16 - 20

(with Raveendran,A.V.)
The polarization observations of the RV Tauri star AR Pup
Sixth Asian-Pacific Regional IAU, IUCAA
Pune
1993 August 16 - 20

(with Giridhar,S., Pandey,G., *Lambert,D.L.)
Spectrum of V Cr A and UW Cen during a light minimum
CCP7 Meeting on Hydrogen deficient systems
St. Andrews, Scotland
1994 March

Saha,S.K. (with Venkatakrishnan,P.)
Image restoration by blind iterative
deconvolution : results obtained from VBT
Sixth Asian-Pacific Regional IAU,
IUCAA, Pune
1993 August 16-20

Singh,P.
Effects of partial frequency redistribution function R_{ff} on spectral line
formation in expanding spherically symmetric stellar atmospheres
International Conference on Astrophysics and Cosmology, SINP,
Calcutta
1993 December 20 - 23

Subramanian, K.R.

The Gauribidanur radioheliograph
Sixth Asian-Pacific Regional IAU, IUCAA, Pune
1993 August 16 - 20

The Gauribidanur radioheliograph
24th General Assembly of URSI, Kyoto, Japan
1993 September 25 - October 2

Visits to scientific institutions

S.Chatterjee visited the Institute of Physics, Bhubaneswar. *B.P.Das* visited Utkal University as UGC lecturer and taught a refresher course on Atomic Physics. *K.K.Ghosh* visited Observatoire de G eneve during 1993 August 31 - September 3, and Astronomisches Institut, T ubingen in 1993 September 4-7 and again in 1994 February 17 - March 16. He also visited ESO and Max Planck Institut f ur Extraterrestrische Physik, Garching 1993 September 8 - 15, Institut d'Astrophysique de Paris 1993 September 16-19, Observatoire de Paris - Meudon 1993 September 20 - October 4. During his visit in France he also went to the observatory at Pic du Midi for observations. During 1993 October 4 - 9 he visited Observatoire de Nice, France. *M.H.Gokhale* visited TIFR, Bombay in 1993 August 19-21 and again in 1994 January 27 -31 in connection with his collaborative programme with TIFR scientists and to attend the INCA meeting. He also visited the National Optical Astronomical Observatories, Tucson (USA) 1993 September 9 - 11 and held discussions with J.Leibacher and R.Howard. *S.S.Hasan* visited Sri Venkateswara College, New Delhi 1993 April, Aarhus University, Denmark 1993 June, G ttingen University Observatory, Germany 1993 July, Jamia Milia University, New Delhi 1993 October. He spent a month at the Center for Astrophysics, Cambridge, USA in 1993 November. He also visited Aligarh Muslim University 1994 January and TIFR, Bombay 1994 March. *R.Kariyappa* visited the Sacramento Peak Observatory, New Mexico 1993 June - July and observed with the Spectroheliograph. *V.Krishan* visited ICTP, Trieste, Italy 1993 July 13 - August 29 as an Associate member. She also visited the Lawrence Berkeley Laboratory, Berkeley, California 1993 October 14 - 1994 January 10, the Department of

Astronomy, University of California at Berkeley 1993 December 8, the Department of Electrical Engineering, University of California, Los Angeles, 1993 December 15 and the Goddard Space Flight Center, NASA, Maryland 1994 January 15. *S.Muralishankar* visited the Institute for Astronomy, University of Hawaii to get exposure on the CCD mosaic and dewar development, its characterization of performance as a detector. He also went to the Astronomy Department of the San Diego State University to get exposure on CCD controller development for mosaic and its performance for best noise figures achievable. During the same trip he visited NOAO and met various scientists working in the controller development field. *M.Parthasarathy* visited KPNO and Mount Graham Vatican Observatory, in Tucson, Arizona, Department of Astronomy, University of Bloomington, Indiana and the Space Telescope Science Institute, Baltimore 1993 October. He also visited the Department of Astronomy, University of Trieste, Italy. *T.P.Prabhu* visited TIFR, Bombay for collaborative research programmes 1993 October 25-28. He also visited PRL, Ahmedabad on invitation for lectures, 1994 March 22-25. *Ram Sagar* visited the Devi Ahilya University, Indore for a week from 1993 November 28 to December 4. *N.K.Rao* visited PRL, Ahmedabad in connection with the site survey trip to Lamdal. He also visited the Osmania University, Hyderabad, during its Golden Jubilee Celebrations. *A.K.Saxena* visited the Brookhaven National Laboratory, New York 1993 July 7-11 and had meetings with Prof.Peter Tackas regarding the testing of SRBL Optics and the details on Long Trace Profilometer. During 1993 July 16-20 *A.K.Saxena* attended the Review meeting of the EUV Telescope Project. *P.Singh* visited the Institute of Physics, Bhubaneswar 1993 December 26-28. *R.Srinivasan* visited the University of Tokyo, Japan to discuss the joint programme of developing a IR CCD array for observations with VBT. *Harish Parthasarathy* also visited the University of Tokyo, Japan to familiarise with the GRAPE computer useful in N-body studies. *M.S.Sundara Rajan* visited Japan under the Indo-Japanese Scientific research in Astronomy and Astrophysics. During the visit, he stayed for a week at Nobeyama Radio Observatory for discussions with Japanese scientists on the development of correlator chips.

Appendix B

Teaching

The academic staff members continued assisting with the teaching programmes in JAP, IISc and the M.Sc. Astrophysics special papers of Bangalore University. In addition, IIA introduced a couple of new courses open to all Ph D students. The JAP/IIA courses were semester-long. A list of these is given below.

Subject	Lecturer
Astroparticle physics (IIA)	P.Bhattacharjee
Fluid mechanics & plasma physics (JAP)	S S Hasan S Chatterjee
Quantum mechanics (IIA)	B P Das
Astronomical techniques (JAP)	Ram Sagar
Stellar astronomy (JAP)	M Parthasarathy
Interstellar matter (JAP)	D C V Mallik
Galactic and extragalactic astronomy (JAP)	R K.Kochhar

In Bangalore University fifteen to thirty hours of lectures were given by M H Gokhale, J H Sastri, D C V Mallik, T P Prabhu and A.V.Raveendran. M.H.Gokhale continued to coordinate this programme. At the Summer School 1993 organised by JAP, IISc G S D Babu spoke on the celestial sphere. D.C.V.Mallik delivered lectures on stellar evolution and gaseous nebulae and T.P.Prabhu on galaxies. Two MSc students of American

College, Madurai and one MSc student of Voorhees College, Vellore worked on summer projects on Spectroscopy of Be stars during 1993 May - July under the guidance of K.K.Ghosh. Two MSc students from National College, Thiruchirappalli did their projects under the guidance of S.S.Gupta.

Editing and Publishing

D C.V.Mallik continued to serve as the Associate Editor of the Journal of Astrophysics and Astronomy (JAA) and Ram Sagar as the Associate Editor of the Bulletin of the Astronomical society of India (BASI). D C.V.Mallik and T P Prabhu edited the Annual Report (1992-1993) on behalf of the Director with the assistance of S.Rajiva. N K.Rao continued to serve on the Editorial Board of JAA and T.P.Prabhu on that of BASI. T P Prabhu and A K Pati continued to edit, on behalf of the Director, the IIA Newsletter which has entered its eighth year in 1993. J H Sastri served on the Editorial Board of the Indian Journal of Radio and Space Physics.

Popular articles

Babu,G S D
The transit of Mercury
Deccan Herald, Bangalore, 1993 November 1

Vishveshwara,C.V.

From cadavers to computers
The apple and the fall
Food for thought
1993. Bulletin of Sciences, Vol IV

Book Reviews

Babu,G.S.D.

Our Solar System
A.W.Joshi & N C.Rana
1994, Journal of the Indian Institute of Science, Bangalore

Mallik,D.C.V.

Astrophysics : Stars and Galaxies
K.D Abhyankar
1994, Current Science 66, 171.

Radio/TV

Babu,G.S.D.

The transit of Mercury
AIR, Bangalore
1993 November 5.

Stephen Hawking - Man and ideas
AIR, Bangalore
1994 February 6.

G.S D.Babu gave an interview on the not-so-common celestial event of the transit of Mercury across the disc of the Sun that occurred on 6th November 1993 which was included in the National Network News of Doordarshan on 4 November 1993.

Popular talks

Babu,G.S.D.

Introduction to Astronomy
Summer Science Camp for school students, Jawaharlal Nehru Planetarium, Bangalore
1993 April 28
Course for Trained Graduate Teachers in Social Studies, Kendriya Vidyalaya, NAL Campus, Bangalore
1993 June 16
The Valley School, Bangalore
1993 October 15

Nebulae and Stars
Space Colony Welfare Association, Bangalore
1993 December 18

IX Indian Scientific Expedition to Antarctica-Experiences of an Astronomer
Rotary Club of Bangalore East, Bangalore
1993 April 6
Lions Club of Bangalore North, Bangalore
1993 May 19
Course for Trained Graduate Teachers in Social Studies, Kendriya Vidyalaya, NAL Campus, Bangalore
1993 June 16
The Valley School, Bangalore
1993 September 8

Bagare,S P

Telescopes for observing the Sun
St Peters Public School, Kodaikanal
1993 August 19

Understanding the solar atmosphere
Bangalore Science Forum
1994 January 19

Science and scientific temper in human evolution
(Radio serial titled 'Human Evolution')
AIR-NCSTC
1994 February 28

Vishveshwara, C V

On the black hole trail
Young Astronomer's Meet
Indian Institute of Science, Bangalore
1993 July 19

The Cosmic design
The masks of spacetime
Life beyond earth
National Institute of Design, Ahmedabad
1993 July 25-30

Life and work of Copernicus
Bangalore Science Forum
1993 July 6

Many channels of science communication
Indian Institute of Science,
1994 January 29

Appendix C

Kodaikanal Observatory

Spectroheliograms/Photoheliograms (No. of Plates and Seeing conditlons)

Year	Month	H α	KFL	H α PR	PHGM	Seeing *					
						5	4	3	2	1	
1993	April	26	28	25	28	-	3	21	4	-	
	May	18	17	15	21	-	-	16	5	-	
	June	9	10	7	15	-	1	8	5	1	
	July	4	4	4	4	-	-	4	-	-	
	August	5	5	4	13	-	-	10	3	-	
	September	11	17	7	16	-	-	10	3	3	
	October	8	7	6	8	-	-	6	2	-	
	November	10	10	10	11	-	-	11	-	-	
	December	10	9	11	14	-	-	12	2	-	
	1994	January	25	25	25	25	2	2	17	4	-
		February	18	21	17	22	-	1	17	3	1
		March	26	26	23	26	-	-	14	10	2
Total		170	179	154	203	2	7	146	41	7	

KFL = K-Flocculus H α PR = H α -Prominences PGHM = Photoheliograms
 * (1-Very poor, 2-Poor, 3-Fair, 4-Good, 5-Excellent)

Vainu Bappu Observatory

Sky condition at Kavalur

Year	Month	Sky condition at Kavalur		
		Spectroscopic hours	Photometric hours	
1993	April	200.0	74.0	
	May	121.0	8.0	
	June	88.0	19.0	
	July	22.0	0.0	
	August	20.0	5.0	
	September	18.0	1.5	
	October	12.5	0.0	
	November	68.5	36.5	
	December	68.0	17.0	
	1994	January	180.5	28.0
		February	137.0	28.5
		March	256.5	120.0
Total		1192.5	337.5	

