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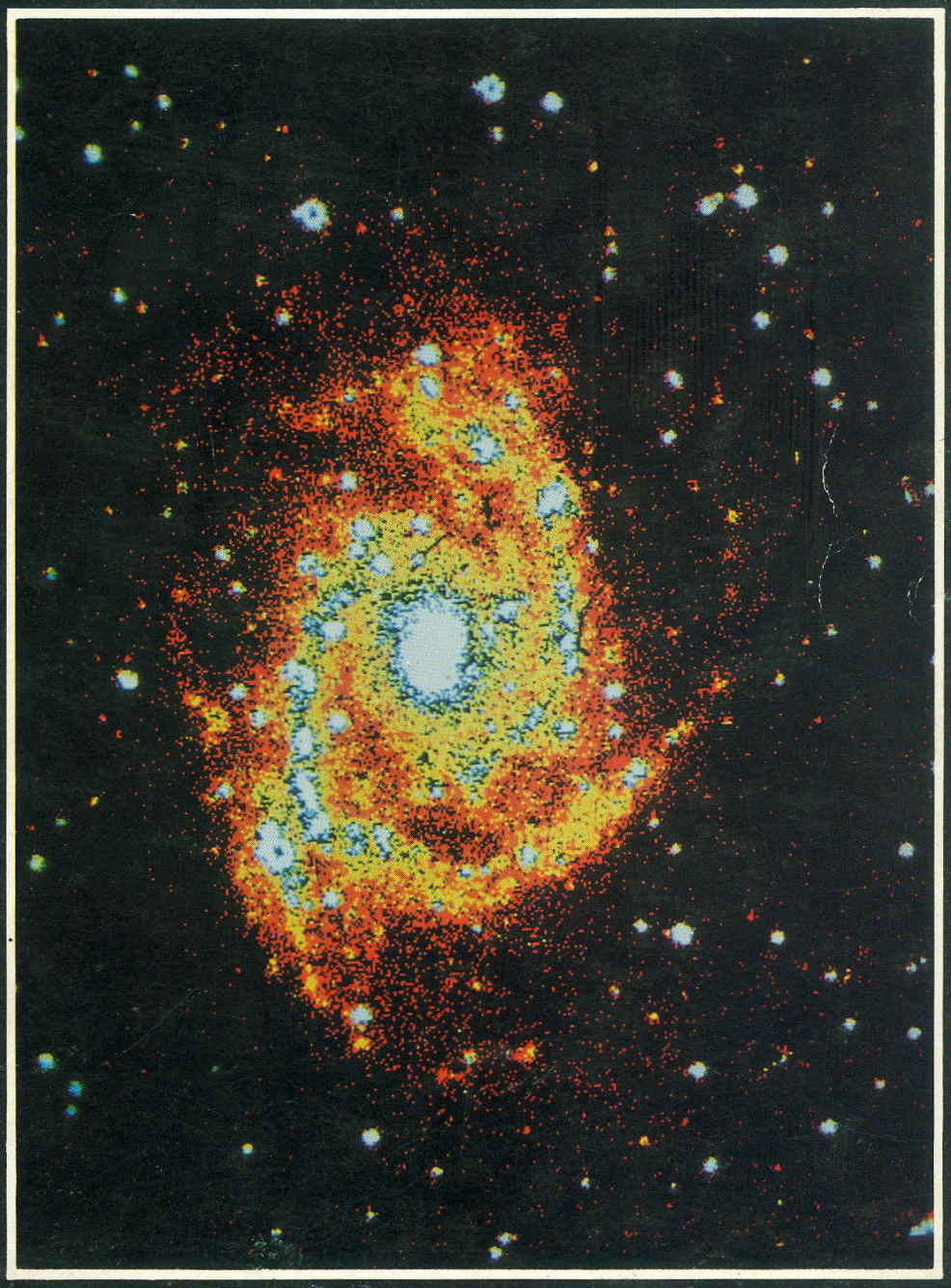
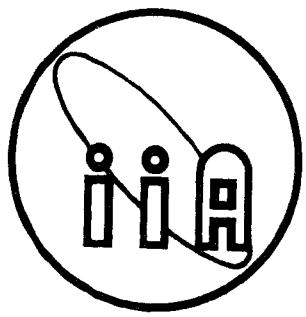


Annual Report 1987-88

INDIAN INSTITUTE OF ASTROPHYSICS



Annual Report

1987-88

Front Cover: Pseudo-colour image of NGC 2997 taken with the 2.3 m telescope at VBO, Kavalur

Photo: K.K.Scaria & M J.Rosario

Image Processing: K.E.Rangarajan

Cover Design. Sultana Hasan

Edited by S.S.Hasan

Typeset by Artintel, Bangalore

Printed at Vykat Prints, Bangalore

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Governing Council

(for the triennial term 1985 June to 1988 June)

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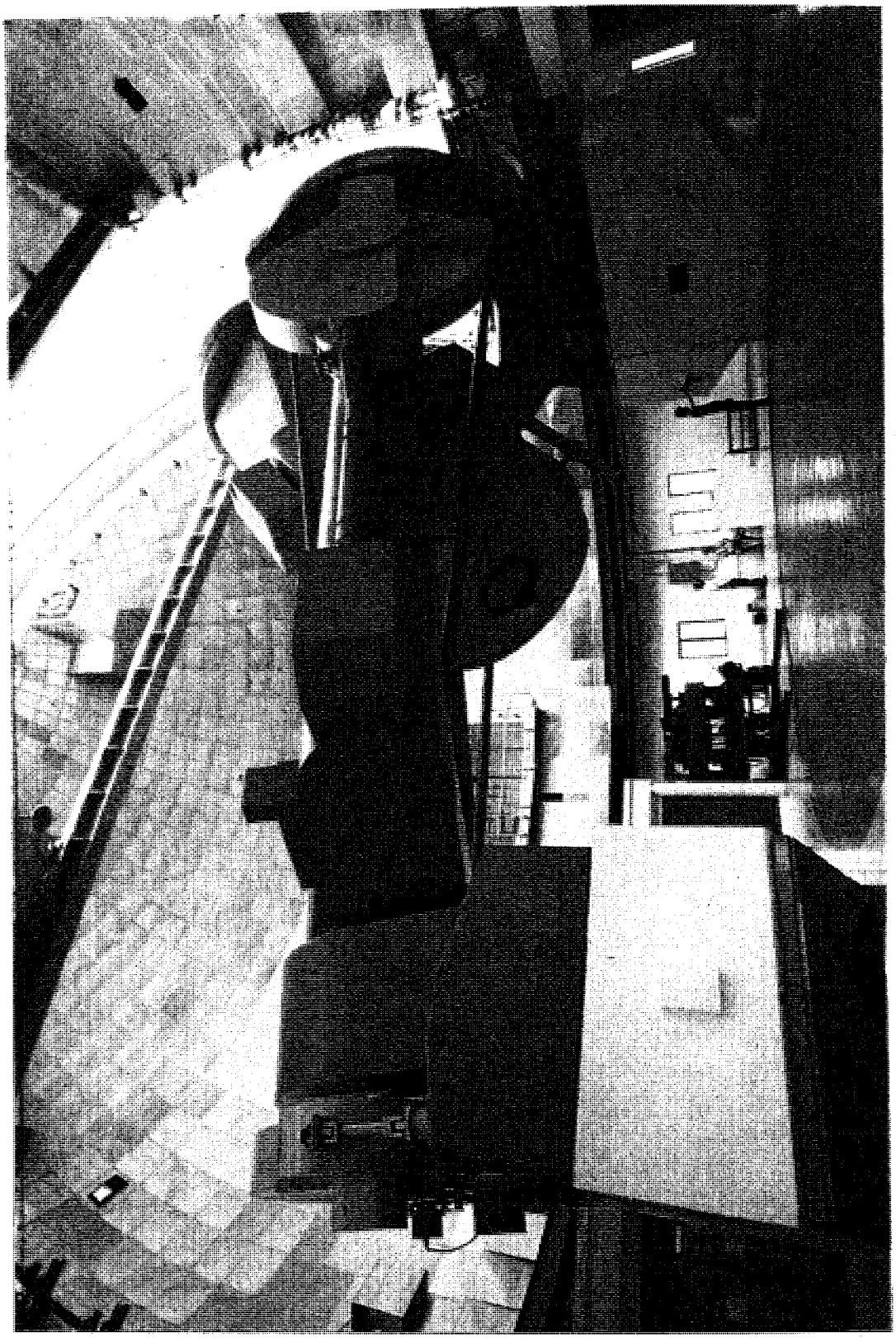


2.3 m Vainu Bappu Telescope, viewed from the east.

The Year in Review

The year 1987-88 witnessed the commencement of several new programmes as well as the fruition of old ones. In brief, the year could perhaps be remembered as one marking the start of many experiments. With the completion of the first phase of the large telescope project in 1985-86, another year was needed to rectify the initial teething problems and make the functioning of the telescope almost trouble free. During the present year, planned observations got under way by scientists from institutes, both within and outside the country. A large number of new experiments were carried out using the Vainu Bappu National Facility.

As many as six scientific proposals for use of the Vainu Bappu Telescope were received and observation time accordingly allotted. Among the groups which came to Kavalur, three were from scientific institutions, including one from the University of Cambridge, England. Another group from the Tata Institute of Fundamental Research, Bombay brought a CCD camera system and installed it at the prime focus; still heavier instruments are awaiting completion of the second phase, when the Cassegrain focus will be made operational. Several such instruments progressed to different stages of development, from the drawing office to laboratories and finally to fabrication shops.

In recognition of the pioneering work carried out in the design and construction of the 2.3 m optical telescope indigenously, A.P. Jayrajan and S.C. Tapde were awarded the prestigious VASWIK award.

The newly installed Perkin Elmer data digitising system came under considerable demand from groups at several institutes and universities in the country. Detailed analysis of comet Halley pictures contributed partly to the rush.

Two more CCD camera systems were introduced in observational work, while several pieces of observational equipment were modernized by incorporating on-line computers. In the optics workshop, a furnace for casting medium sized mirrors was completed.

On the observational front, the new supernova generated much excitement and debate among the astronomers. In stellar physics, the main areas to be investigated were novae, supergiants, variable stars and binary systems. Theoretical aspects related to radiative transfer in atmospheres were also pursued.

The year also saw the start of an ambitious programme for measuring the enigma of solar rotation, by combining the collections of photoheliograms at Kodaikanal and Mount Wilson, U.S.A.. Special equipment for this work was installed and measurements recently began at Kodaikanal. Research into solar activity, quantitative aspects of magnetic field structures and radio bursts continued. Evidence was found linking the solar activity cycle with global oscillations.

The study of the solar system concentrated mainly on comets, particularly comet Halley, and the search for new asteroids. As part of the latter programme, named 'Kalki', several hitherto unfamiliar objects were spotted and taken up for detailed observation.

Investigations into the field of the interstellar medium, focused broadly on aspects of star clusters and planetary nebulae. In solar terrestrial physics, ionospheric studies associated with equatorial electric fields and spread-F ir-

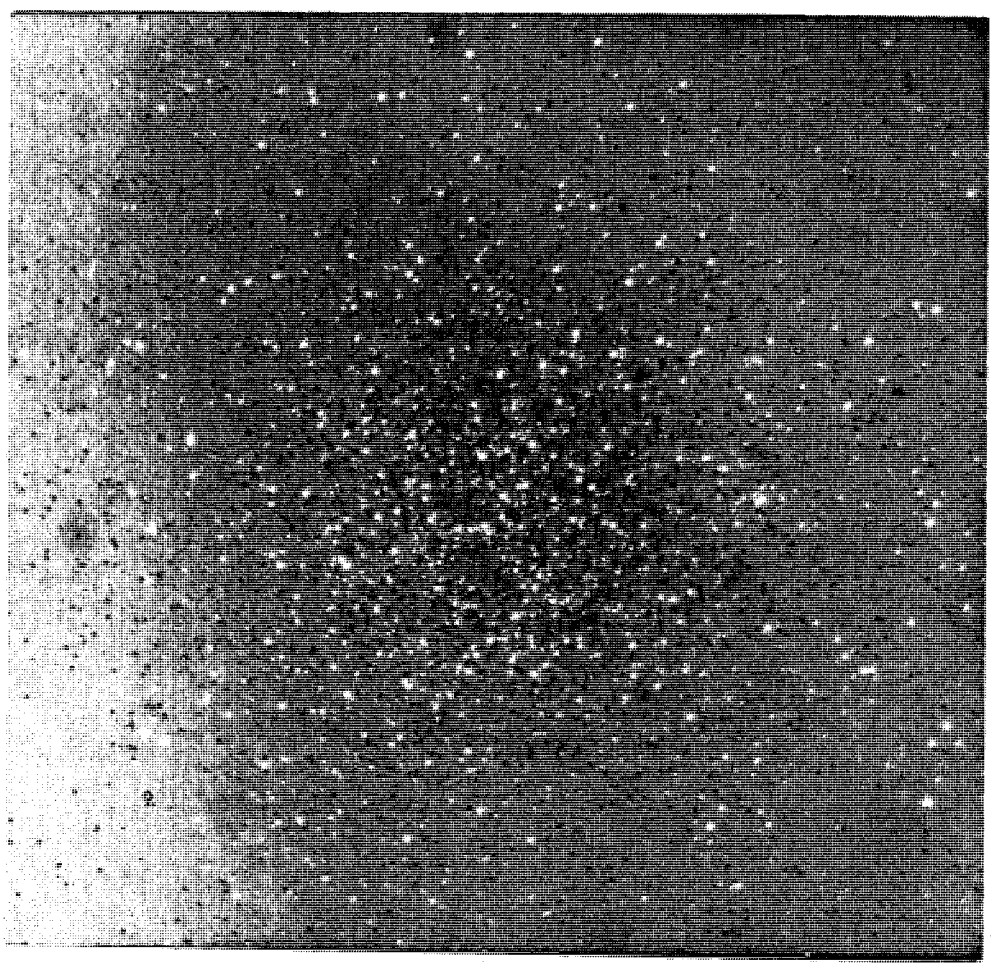
regularities were made.

In theoretical high energy physics, cosmological models, high density matter and quasars received considerable attention. Some interesting results were found in connection with radiation from neutron stars and possible energy sources in quasars. Radio observations were used to map select regions in the galactic plane.

Four important workshops were organized by the Institute during the year. Two were at Kodaikanal on astronomical instrumentation and solar physics respectively, and two in Bangalore on comet Halley and supernova 1987A. Furthermore, the Institute sponsored two major international meetings on quark- gluon plasma and gravitation and cosmology at Bombay and Goa respectively, as well as several national meetings.

A major thrust towards development of multi-institutional involvement programmes, was an important feature of the year. Several universities expressed their keenness to actively support the growth of astrophysics in the country. In addition, some CSIR and Defence science laboratories proposed collaborative ventures with the Institute. Some new instrument components, which can take observational astronomy beyond our present limits, were fabricated after ingenious design efforts, through these ventures.

J.C.Bhattacharyya
Director



The distribution of blue horizontal stars (black dots) and red giant branch stars (white dots) in the inner regions of the metal poor globular cluster ω Centauri. The picture a superimposition of two photographs through different filters was taken by K.K.Scaria with the 2.3 m telescope.

Research Highlights

The sunspot measurement programme at Kodaikanal using a Calcomp digitiser (extreme right) and an LSI-II Computer.

Activity and the Solar Cycle

Origin of sunspot activity

A spherical harmonic Fourier (SHF) analysis of the distribution of sunspot activity on the surface of the Sun during the five sunspot cycles (1902-54) was completed. In addition to the stability of the relative amplitudes of the various axisymmetric modes from cycle to cycle (Fig. 1), it was found that even the relative phases of the even degree modes up to $l=22$ are stable and 'remembered' throughout the five cycles (Table 1).

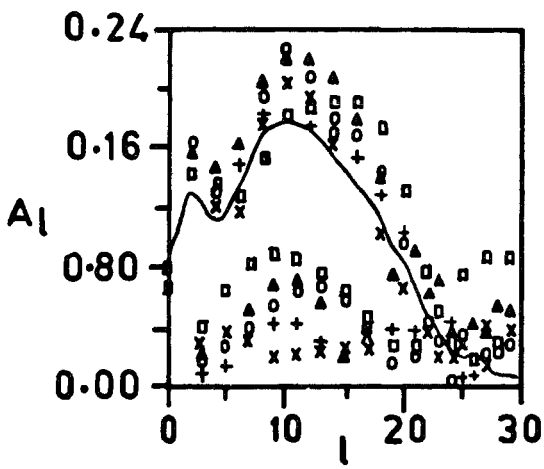


Fig 1. Amplitude Al as a function of l during the sunspot cycles 14 to 18 represented by symbols □ ,o, ▲, and + respectively. The continuous curve corresponds to Al as function of l during the whole sequence 1902-1954

A new feature of the study is the discovery that sunspot activity, during these five cycles, originated as a superposition of the Sun's global axisymmetric oscillations of even degree up to $l=22$, with periods of about 10.5 years and with relative amplitude and phases as shown in Fig.1 and Table 1 respectively. The data also show that the lifetime of these oscillations must be more than 53 years.

In the aforementioned analysis, the sunspot occurrence probability at the location and epochs of each sunspot group was weighted proportional to the number of days it was observed. Thus, the weighted occurrence probability is a rough measure of the magnetic flux concentrated at that location and epoch. By attaching plus and minus signs to this data, in the two hemispheres, and by interchanging the signs at the ends of each sunspot cycle, a rough measure of the toroidal magnetic flux distribution on the Sun and its variation with time was obtained. An analysis of this estimated toroidal magnetic field revealed that most of the SHF power goes into axisymmetric odd degree modes of 22 year periodicity, as expected. Furthermore, what is important is, that the relative amplitudes of these modes was similar to those obtained by Stenflo and Vogel[1] from the observed (poloidal) magnetic fields during 1960-85 (Fig.2). Thus, the magnetic nature of the oscillations becomes clear. The periods of about 22 or 11 years (for odd or even modes) indicates that the oscillations must resemble slow hydromagnetic waves.

An interesting by-product of this analysis is that it also provides a method for studying hydromagnetic oscillations of the Sun during many

[1]Stenflo, J O & Vogel,M (1986) Nature 319, 285

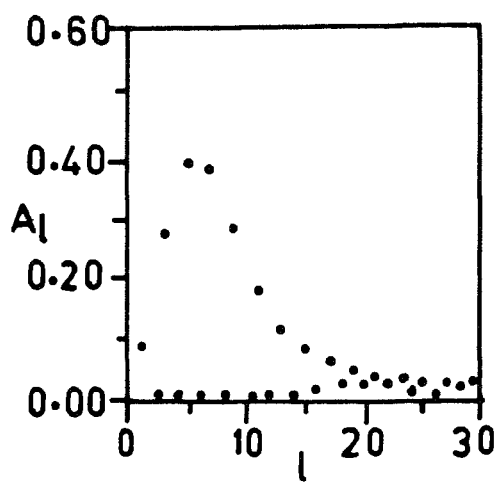


Fig.2: Amplitude Al as a function of l obtained from the whole sequence 1902-1954 with signs (+, -) attached according to Hale's laws of magnetic polarity.

decades, prior to the development of magnetograms. (M.H. Gokhale & J. Javaraiah).

Polar faculae as a means to forecast a sunspot cycle

Data from Kodaikanal and Kislovodsk (Pulkova Observatory) on polar faculae and sunspot areas for five solar cycles (1940-86) were analysed. It was noticed that the monthly numbers of polar faculae of any particular cycle and the monthly values of sunspot areas of the following cycle had a high correlation with each other. This correlation was found to hold true for all the five cycles, that were examined.

The technique, hence, could profitably be used to forecast a sunspot cycle, if the behaviour of polar faculae in the preceding cycle is known.(V.I.Makarov*,V.V.Makarova*,K.R.Sivaraman).

Solar cycle variation of coronal neutral lines

Observations of the corona, prominences and polar faculae reveal that solar activity is present at all latitudes, in contrast to sunspot activity, which shows up only at low latitudes, as the 11 year cycle. It was demonstrated, from an analysis of Hα spectroheliograms, that the large scale magnetic field regions show a zonal structure in latitude. The dominant modes are $l=3$ and $l=5$, while the $l=1$ (dipole) mode is almost absent. An analysis, using several years of emission data at 5303Å from Sacramento Peak, showed that these dominant modes can be identified in the coronal data too. This leads to the new result, that these modes are present in the large scale structure of the corona. It was further found, that these coronal zonal structures relate well with the eclipse photographs of the corona and the agreement holds for the different phases of the solar cycle. (V.I.Makarov*, V.V.Makarova*, S.Koutchmy* & K.R. Sivaraman).

Solar rotation rate from spot measures

A collaborative programme between the Indian Institute of Astrophysics, The National Solar Observatory, Tucson and the High Altitude Observatory, Boulder was started this year. The aim is to measure solar rotation and its variation with the solar cycle, using sunspots as tracers. The collection of white light solar images, dating back from 1905 at the Kodaikanal Observatory, would be used for this investigation. Sunspot position, rotation rate and latitude drift would be measured for several thousands of spots. These measurements would be combined with similar ones from Mount Wilson. The Mount Wilson data, which are of a shorter duration, show that smaller spots rotate faster than larger ones. One interpretation for this rate difference is due to the unequal rotation rates at various depths, at which spots of several sizes are anchored. But is has not yet been possible to detect certain important dynamical features, like torsional oscillations, since these are swamped by noise. Increasing the number of spots, through

*Names of coworkers from outside institution.

the use of the Kodaikanal data, is likely to provide the sensitivity needed to detect this effect. (K.R.Sivaraman, S.S. Gupta. S.M. Aleem, R.Howard[k], P.Gilman*).

22 year modulation of the absolute phases

In the analysis of the sunspot occurence probability it was found that the absolute phases of all the even degree modes moved forward by amplitudes $\approx 35°$ from odd number cycles and backward by similar amounts from even number cycles to odd number cycles. This can not be accounted for by the uncertainities in the onsets of the sunspot cycles, since removal of shifts by choice of onset dates requires alternately short and long cycles (which again amounts to forward and backward phase shifts). (M.H. Gokhale & J.Javariah).

Table 1

(a) Relative phases $Q_l - Q_o$, averaged over sunspot cycles 14 to 18, and the small r m s deviations, of modes with even degrees upto l = 22 showing 'phase stability'

l.	2	4	6	8	10	12
Q_l-Q_o	170 ± 2	-41 ± 8	86° ± 12	-132 ± 11	21° ± 10	174 ± 9

l	14	16	18	20	22
Q_l-Q_o	-33 ± 9	125° ± 9	-71 ± 11	93° ± 14	-90° ± 16

(b)Relative phases of the above modes during the whole sequence 1902-1954 showing that the phases are 'remembered'

l	2	4	6	8	10	12
Q_l-Q_o	170°	-42°	84°	-134°	19	172°

l:	14	16	18	20	22
Q_l-Q_o	-34°	125	-71	92	-86

Calcium K emission

Calibration on the Sun for stellar magnetic fields

The well known association between the surface magnetic fields and the Ca II K line emission on the Sun can be used for detecting the presence of global magnetic fields in solar type stars. A large number of K-line profiles were obtained over a variety of plages and related to the 1Å emission flux centred at the K_3 minimum, for these profiles, with the corresponding values of the longitudinal component of the photospheric magnetic fields. This method provides a calibration for detecting and estimating the surface magnetic fields on stars that show Ca K emission.(K.R. Sivaraman, S.P. Bagare,S.S. Gupta & R. Kariyappa).

Contribution to Ca emission from the chromospheric network

From the Kodaikanal plate vault, over 200 Ca II K spectroheliograms, covering the period 1958-87, were selected on the basis of being well exposed and recorded under good seeing conditions. The chromospheric network regions at disc centre were singled out on each plate and scanned using the PDS microphotometer of the Institute and the relative and residual intensities were derived.

The identifiable contributors to the Ca II K emission are the quiet network, the active network, the bright points and plages. It would be worthwhile to find out whether the components of K-emission, viz. the quiet network and the bright points, have any solar cycle related contribution at all. Once these contributions are known, it would be possible to construct synthetic profiles, simulating variability in the Ca II K line profiles. (K.R. Sivaraman & R. Kariyappa).

Solar Variability

The Sun as a star has been monitored by a number of observers since 1969 in the Ca K line, in order to study solar variability. A three component model of solar cycle variability of the Ca emission, using extant contrast and fractional area parameters cells, the network and the plage component, is not entirely satisfactory.

A better technique was developed to study solar variability and chromospheric rotation. Observations made at the Kodaikanal solar tower telescope provided high resolution spectra in the ionized Ca K line at different latitudes. These were integrated over 180° of visible longitude. Six days of data were analysed to study the variability of the line profile, as a function of latitude. Daily measurements over the next few years will be used to investigate solar variability, chromospheric and differential rotation, activity and the variability of K line parameters, in polar regions as well as in other latitudes, with the phase of the solar cycle.

A major advantage of this technique is that it is likely to yield very important information about polar regions. (J. Singh).

Coronal lines

Diagnostic studies

Under this long term project, several line intensities from nitrogen like ions, NeIV, MgVI, AlVII, SiVIII, PIX and SX, were computed as a function of electron density and temperature. Intensity ratios of some of these lines were found to be sensitive to variations in the electron density. This technique provides us with a powerful tool to probe the solar atmosphere. The method is independent of the specific model atmosphere. In addition, absolute line fluxes were computed using a model atmosphere for the chromosphere-corona transition region and the solar corona. The computed fluxes were compared with available observed line fluxes. Several lines, not detected thus far, were suggested for observation. (P.K. Raju & B.N. Diwedi*).

Several emission line intensity ratios for the ions: FeX, FeXI, FeXIV, CaXII, CaXIII and CaXV, were found to be sensitive to variations in the electron density and temperature. This provides a powerful diagnostic probe of the solar atmosphere. (P.K. Raju).

Solar coronal emission lines

Theoretical models were simulated to explain the observed full widths at half maximum (FWHM) of the emission lines at 5303Å and 6374Å, due to the ions FeXIV and FeX respectively, observed during a total solar eclipse. Turbulence was not included in the modelling, but a small radial expansion of the corona was assumed. The model broadly explains the full width at half maximum. However, inhomogeneities in the densities of the corona should also be taken into account to explain the radial variation of FWHM. (A. Peraiah & B.A. Varghese).

Magnetic fields

Classification of magneto-atmospheric modes in sunspot umbrae

An extensive programme has been started to classify and determine the oscillation spectrum of modes, corresponding to various magnetic field configurations on the Sun. In an earlier paper, the mathematical formalism was developed. Essentially, the method is based on using a modified form of Helmholtz' theorem, to decompose an arbitrary linear displacement as a sum of irrotational *(p)* and solenoidal components. The latter is further split into poloidal *(g)* and toroidal *(t)* components. The *t* component corresponds to an Alfven wave, whereas the other two can often be identified with the usual hydromagnetic fast and slow modes. The effectiveness of the technique was demonstrated

by calculating the axisymmetric normal modes of a thin flux tube. Reasonable agreement was found between the fundamental frequency, obtained from this calculation, and that from an independent calculation.

In the next part of the study, umbral oscillations are being considered. The aim is to delineate the various types of modes that occur in sunspot umbrae, compare the results with observations and make predictions on modes to observe. As a preliminary step in this direction, the sunspot atmosphere was approximated as isothermal, and the diagnostic diagram, i.e. the variation of frequency with horizontal wave number *(k)*, for different orders obtained. An important result of this investigation is that, although, the frequency does not depend, strongly on k, the nature of the mode is sensitive to it. Another important result is the existence of 'avoided crossings', or the step-wise change in the frequency when two different order branches come close to intersecting. A comparison of the results from the present calculation with results from previous studies has been made and some observational implications pointed out. (S.S. Hasan & T.E. Abdelatif*).

Potential field calculations

A technique was developed for calculating the potential field corresponding to the distribution of magnetic flux normal to the photosphere from vector magnetograms of regions observed far away from the disc centre. The major advantage of this technique was that it avoided the need for interpolation (normally required when changing from observed to heliographic coordinates) by redefining the heliographics derivatives of the field in terms of the derivatives with respect to the image plane coordinates. This method was successfully tested on a simulated magnetogram which included the effects of measurements errors. The transverse potential field could be recovered with an accuracy ≈ 20 G in strength and $\approx 5°$ in azimuth, in regions of strong magnetic fields, thus establishing the utility of this method for evaluating magnetic shear along polarity inversion lines from vector magnetograms obtained far away from disc centre. (P.Venkatakrishnan & G.A.Gary.*)

Preflare evolution of magnetic fields

A comparison of two vector magnetograms of NOAA region AR4474 obtained prior to two flares (one on 24 April and the other on 28 April, 1984) showed that a significant increase in magnetic shear occurred on a time scale of a day or so prior to each flare. This indicates the importance of the dynamical evolution of shear for the onset of solar flares. (P.Venkatakrishnan.)

Structure of coronal loops

The structure of the velocity and magnetic fields *(V,B)* plays a pivotal role in determining the heating, stability and evolution of the plasma in coronal loops. In earlier studies, the steady state pressure structure of the loop plasma was examined using a Chandrashekhar-Kendall function. Now, the dynamics of these fields, described by a set of infinite coupled nonlinear differential equations, is being studied. For mathematical tractability, a superposition of the three lowest order Chandrashekhar-Kendall functions is considered. The temporal evolution of *(V,B)* in each of these modes is determined using the ideal MHD equations, for firstly, small departures from the equilibrium and secondly, in the pump approximation. In the former case, the system exhibits sinusoidal oscillations with a period that depends upon the equilibrium values of the fields. The latter case shows the development of large gradients and reversals in the fields. (V.Krishan).

Time dependent energy transport in intense flux tubes

Energy transport in intense magnetic field structures in the photosphere and convection zone of the sun is being studied. The aim of the investigation is to examine the role of flux tube

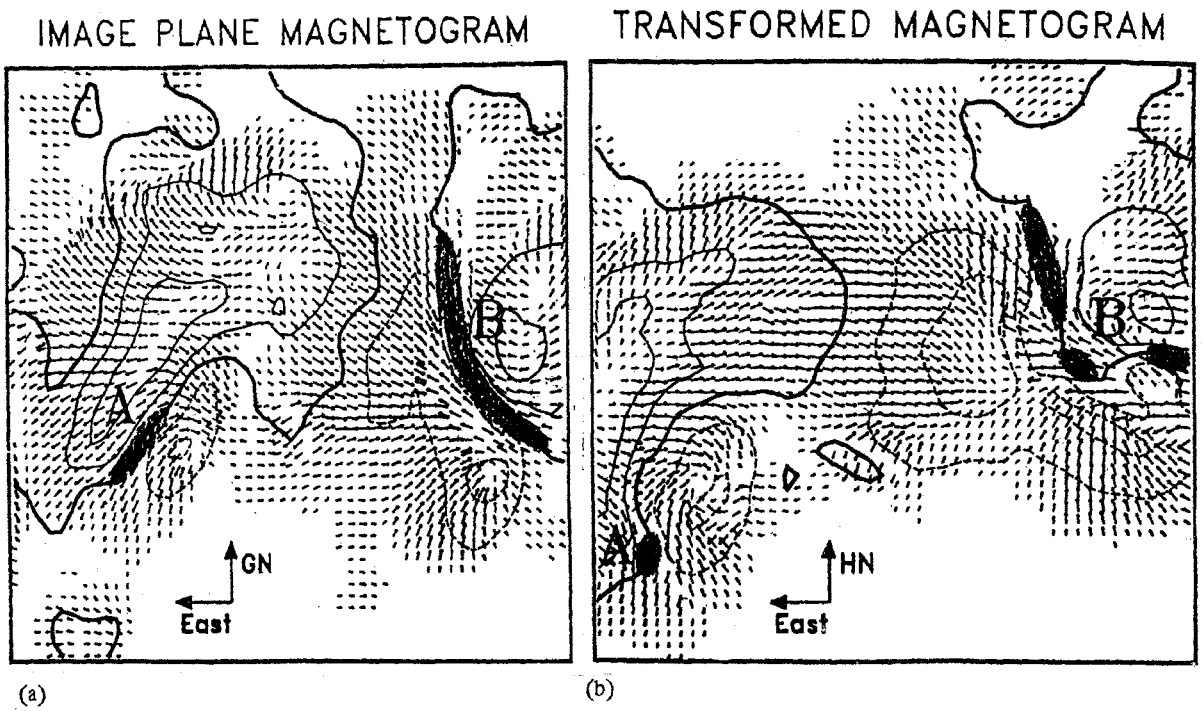


Fig.3: Comparison of the magnetic shear (shaded region) of AR4474 in (a) image plane coordinates and (b) heliographic coordinates. The contours are of the longitudinal magnetic field strength, while the arrows represent the transverse components.

oscillations in energy transport, to delineate the contributions of various energy transport mechanisms and to study dynamical effects and their influence on the themodynamics of tubes.

The energy budget consists of contributions from radiation, convection and wave heating. A new feature of the analysis is the use of the generalized Eddington approximation in three dimensions in modelling radiative transport in flux tubes. Convective transport is treated using a mixing length theory, with an additional parameter α, where α is a crude measure of the magnetic inhibition of convection. An equilibrium atmosphere is first constructed using the linearization method of Auer and Mihalas along with the Feautrier technique. The equilibrium is perturbed by introducing a small downflow and the time evolution of the flux tube is followed numerically, by integrating the hydromagnetic equations in the thin flux tube approximation.(S.S. Hasan).

Transformation of vector magnetograms

A technique for transforming vector magnetograms to the heliographics coordinates was developed and applied to AR 4474 observed at 45° E longitude with the MSFC vector magnetograph. This example [figures 3 (a) and (b)] showed that 70% of the extent of magneric shear seen at the follower group in the observed magnetogram disappears when transformed to heliographic coordinates. (P.Venkatakrishnan, M.J.Hagyard* & D.H.Hathaway*.)

Wave Propagation in a weakly tapered magnetic flux tube

The calculations of Hasan and Sobouti (1987)[2] were extended to examine the effect of a non-

[2]Hasan,S.S. & Sobouti,Y. (1987) M.N.R.A.S. 228, 427.

uniform magnetic field on the modes in a flux tube. The main result is that the Alfven *(t)* modes get coupled to the other two MAG (*p* and *g*) modes. This coupling is, however, weak and of the order of ß, where ß characterizes the degree of inhomogeneity of the field. The oscillation spectrum for the modes was obtained and compared with the uniform field case, to estimate the change in the wave frequencies. (S. Nasiri*, S.S. Hasan & Y.Sobouti*).

Radio Emission

Theory of type II bursts

The "backbone" emission of shock initiated coronal (metric) type II solar radio bursts was considered. The source had extremely narrow bandwidth and appeared to be stationary in relation to the shock. A clue to the particles responsible for radio emission was provided by the Earth's bow shock, which is much better understood. It was proposed, that the radiation originates from electrons and ions of a few KeV energy, which constitute the dominant population of accelerated particles, upstream of the shock. These particles may locally form velocity distributions that are unstable to growing electrostatic waves (*Z* mode, ion acoustic and/or lower hybrid waves). The "backbone" source seems to require an exciter that is different from the classical type III producing beam. A shifted ring distribution (the result of fast Fermi acceleration) was suggested. Ion beams may excite ion-acoustic and lower hybrid waves and provide low frequency turbulence. A model was developed, which can explain the major observed features by wave-wave coupling between electron plasma waves with themselves and with ion waves. Observational tests for interplanetary and bow shock waves were proposed.

The role of electrons accelerated by wave-particle interaction and by a fast Fermi mechanism was studied. Low frequency waves, excited by the ion beams, accelerate electrons along the magnetic field and in most cases, these electrons are scattered by the whistlers and fill a small gap in the downstream and upstream of the shock forming the gap distributions. The resultant radio emission gives rise to frequency splitting in the backbone emission. Electrons accelerated by the fast Fermi process escape both in the upstream and downstream directions, giving rise to fast drifting herring bones at the fundamental and higher harmonics with positive as well as negative drift rates.

Data on type II bursts were analysed in order to study the high time resolution and polarization. It was found that the fine structures are present in some events, whereas they are completely absent in few other cases. The fine structures generally appear at the beginning of an event. The polarization remains constant during the entire event. Fine structures are polarized up to 15% more than the continuum (backbone) and the sense is the same for both. Sometimes, the continuum can also be highly polarized. Experimental data are in good agreement with the proposed theory. (G.Thejappa).

Low frequency emission

The total flux from the Sun at four frequencies in the range 30-70 MHz is being measured using the broadband antenna array and a four channel receiver system. These observations will be used to derive the spectrum and its variations in the low frequency radio emission from the Sun. High time and frequency resolution studies of transient radio bursts from the Sun are also being carried out. (K.R. Subramanian & Ch.V. Sastry).

The compound grating interferometer is being used to obtain one dimensional scans of 3 arc minutes resolution of the Sun at 34.5 MHz. An analysis of some of the observations is in progress. (Ch.V. Sastry).

Ray Tracing

Electromagnetic waves in an anisotropic medium do not travel in the direction of the wave normal, but in a different direction. In an inhomogeneous anisotropic medium, the rays follow a curved path, called the *ray path*. Tracing the trajectories of rays in the solar corona at a given wavelength is an important problem.

Hamilton's method provides the differential equations in a form which is suitable for integration by standard numerical methods. Magnetic fields can also be incorporated in the analysis. The equations were solved using the Runge-Kutta method. Ray paths were evaluated for a spherically symmetric corona. (D. Mohan Rao & C.h.V. Sastry).

Supergranulation

In a two dimensional incompressible fluid, the total energy as well as the total squared vorticity, called enstrophy are conserved. The energy spectrum cascades to smaller wave-numbers, and, therefore, the energy is expected to accumulate at the longest wave lengths that the system permits. The observed two dimensional nature of the velocity fields in supergranulation permits us to make use of the characteristics of 2D hydrodynamic turbulence. On this basis, it was proposed, that supergranulation is produced from granulation by the selective decay process in which the energy tends to accumulate at the largest scales. The latter are determined from the ratio of energy to enstrophy. This ratio presumably determines the scale of the solar supergranulation. (V. Krishan).

Solar System

Asteriods

Sky survey

A sky survey with the 45 cm Schmidt telescope was continued. Between November 1987 and March 1988, a total of 150 plates were taken of 38 regions. In order to expedite the search for new asteroids, it was decided to measure only those asteroids, which are likely to be new. A microcomputer along with special software made this possible.

Newly discovered objects were taken up for observation and their progress monitored. Out of eight new objects, only two (1988 DR and 1988 DQ1) could be followed up and a precise orbit determined. Further work on orbit determination and improvement of orbital elements, from measured coordinates, is being carried out. (J.C. Bhattacharyya & R. Rajamohan).

Monitoring of Pluto-Charon mutual events is being continued on the 1 m reflector at the VBO.

A computer code was developed for computing the orbital elements of newly discovered asteroids, using Gauss's method. This code can be used to predict the position of asteroids at any future date. (R.Vasundhara).

Comets

Cometary comae

A study of dust grains in cometary comae was undertaken. Several aspects were considered. Firstly, the observed spectral charactersitics of cometary grains were examined. Secondly, an analysis of the size distribution function of the grains, obtained from the VEGA and GIOTTO space probe missions to comet Halley, was made. Thirdly, the scattered radiation in the continuum and infrared wave bands was investigated. Finally, the albedo of the dust grains and the polarization of the scattered continuum radiation was calculated. (G.A. Shah).

The spatial variation of the light scattered by the dust grains in the coma of comet Halley was investigated. From the spectral scanner observations at VBO, the fluxes in the continuum radiation at wavelengths 3950Å, 4250Å, 4450Å, 4850Å, 5250Å, 5850Å and 6100Å were evaluated. The continuum shows progressive reddening as one goes towards longer wavelengths. In addition, an increasing reddening, as the line of sight moves away from the nucleus towards the coma boundary, was found. A theoretical model and a computer code were developed to explain these and other features, such as polarization. The model incorporates the size distribution of the grains derived from the VEGA space mission. The attenuation of light along ray paths was also taken into account. Modelling the dust atmospheres of comets is a novel feature of the analysis. (G.A.Shah, K.R.Sivaraman, G.S.D.Babu, B.S.Shylaja & R.Rajmohan).

Cometary tails

The Kelvin-Helmholtz instability of a plasma cometary tail, characterized by helical velocity and magnetic fields, was studied. It was shown that helicity stabilizes the long wavelength modes. At a given wavelength, an increase in helicity decreases the growth rate of the instability. The

growth rate and phase velocity are inversely and directly proportional, respectively to the wavelength. (R.Kochhar & S.K. Trehan*).

Lifetimes of molecules

The spectro-photometric data on comet Halley were used to compute the lifetimes of parent and daughter molecules. This is the first time that lifetimes have been derived from observations without resorting to any model for the coma. (K.R. Sivaraman, G.S.D. Babu & B.S. Shylaja).

Photometry of comet Halley

The photometric fluxes of comet Halley, measured through narrow band filters, were derived from Kavalur observations. These fluxes show sinusoidal brightness variations. A detailed examination of the data was made. (K.R. Sivaraman, G.S.D. Babu & R.Rajmohan).

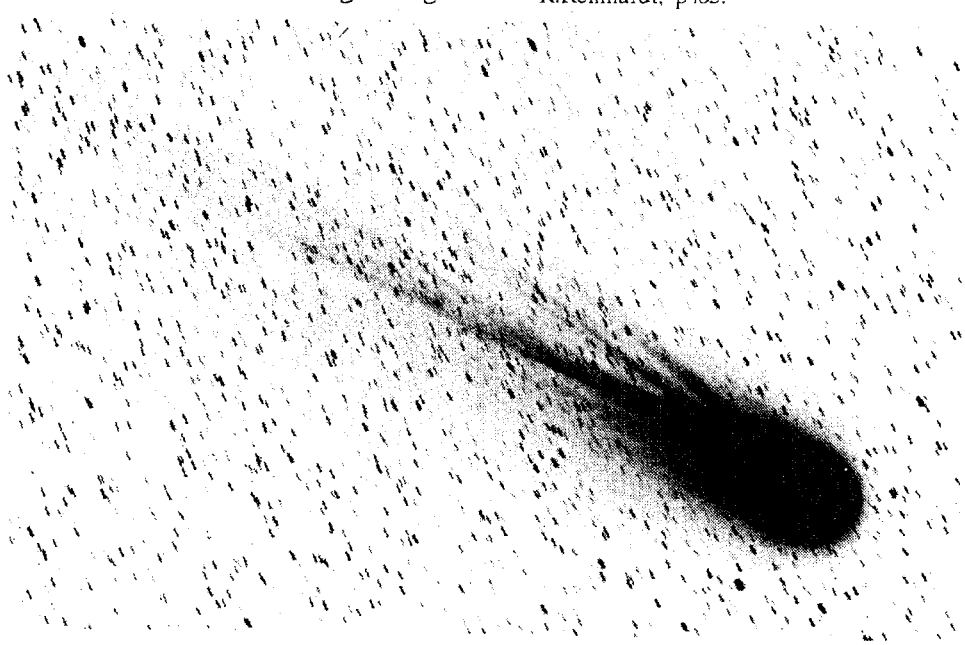
Molecules

Comet Halley was observed on April 1986, using the ESO 1.5 m telescope with the Boller and Chivens spectrograph and a reticon detector. The spectra covered the wavelength range 8100-10200 Å. Reduced to absolute fluxes, the spectra clearly showed the molecular bands CN(1,0), CN(2,1), CN(4,2), CN(5,3), C_2(2,0), and C_2(3,1). There is very little data for comets available in this region and there is a wealth of unidentifiable features in the spectra. The Phillips bands of C_2(2,0) are striking in comparison to the only other observation available (Fink *et al.*)[1]. The C_2(3,1) band is very strong compared to C_2(2,0), which is contrary to what is expected. (A.Pati & K.R.Sivaraman).

Planetary occultation

A search was made in the SAO (Smithsonian Astrophysical Objects) catalogue for occultation of stars by Saturn's magnetosphere at 12.5 and 19 Saturn radii. Five events were predicted to occur in 1988. (R.Vasundhara)

[1] Fink,V., DiSanti,M. & Shultz,A. (1986) Proc. 20th ESLAB Symp., eds. B.Bartrick, E.J.Rolfe & R.Reinhardt, p485.



Comet Halley photographed with the 45 cm Schmidt telescope at VBO Kavalur in March 1986. The details in the tail were brought out using techniques of Unsharp Masking and Contrast Enhancement.

Stellar Physics

Binaries

Wolf Rayet stars

The study of Wolf Rayet binary stars is being continued to understand the variation of emission line fluxes in terms of the extended atmospheric structure. (B.S. Shylaja).

Hydrogen deficient stars

Helium stars

In response to a call by P.W. Hill and C.S. Jeffery, for simultaneous IUE and ground based observations, the hot extreme star BD -9°4395 was observed with the 1 m reflector at the VBO (Vainu Bappu Observatory) on April 16 and 17, 1987. The starlight in v,b and y bands showed irregular variation by as much as 0.1^m during a run of six hours. (R. Vasundhara and N.K.Rao)

Large Magellanic Cloud

The survey programme to search for hydrogen deficient stars in the Large Magellanic Cloud (LMC) is being continued, with the help of the UK Schmidt Objective prism plate. As a by-product of this search, over 80 stars in the magnitude range 14-16.5^m, have so far been classified. The spectra of the progenitor star of SN 1987A, which was available on the same film, was analysed. The progenitor Sanduleak -69° 202 exhibited stronger lines of HeI and NII than the normal supergiants. (R. Vasundhara, N. K. Rao and D.H.Morgan*)

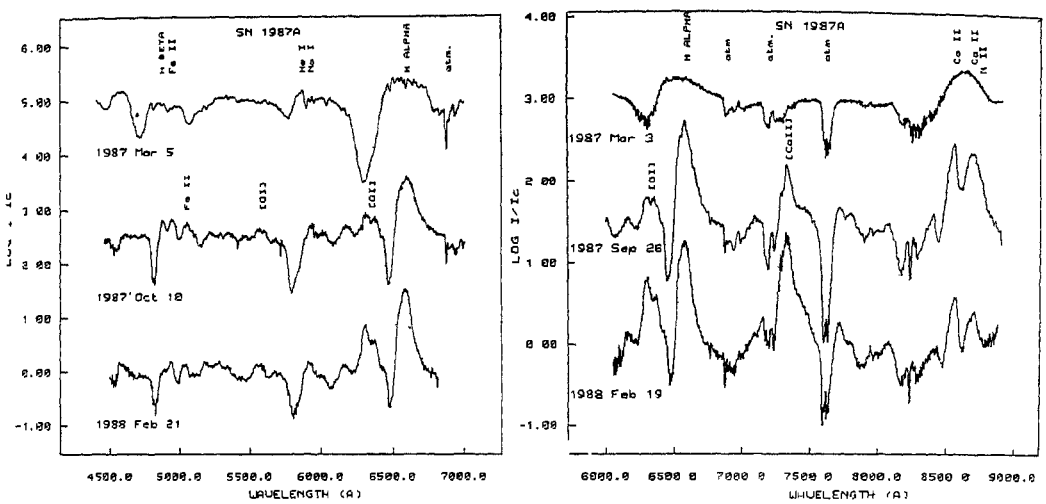
The ultraviolet spectra SWP 31335 and LWP 11302 of CPD -56° 8032 were analysed, using Starlink software.. The aim was to derive an effective temperature of the star by comparing the observed ultraviolet continuum fluxes with the model atmosphere fluxes. This star is known to possess a circumstellar shell and does not follow the normal reddening law, in the ultraviolet wave length range, applicable to the diffuse interstellar medium. Using both the emission line ratios and continuum fluxes, the observed anomalous reddening is being studied. Amorphous carbon grains in the circumstellar shell are being considered as the likely agents for anomalous extinction. A temperature of 24000 K, estimated by comparing these fluxes with the model atmosphere fluxes for helium stars, agrees with the Zanstra temperature, derived by Aitken *et al.* (1980).[1] (N.K.Rao, S.Giridhar & K.Nandy*)

Novae and Supernovae

Classical Novae

Spectroscopic observations of classical novae provide information on the temperature, density, mass, abundances and geometric structure of the envelopes ejected during outburst. It is of interest to correlate this information with the nature of the overall light curve, and when possible, with the model of the prenova system. Novae in outburst are spectroscopically monitored from the VBO. During the current year, Nova Andromeda 1986, Nova Herculis 1987 and Nova Sagittarius 1987 were spectroscopically

[1]Aitken,D.K., Barlow,M.J., Roch,P F. & Spencer,P.M. (1980) M.N.R.A.S. 192, 679.



(a) (b)

Fig.4 : The evolution of the spectrum of SN 1987A in (a) the visual and (b) the infrared regions. Note the shift of Hα and Hβ absorption towards the red and the emergence of [OI] 6300, 6363 Å in October 1987. The narrowing of emission and absorpion features, and the emergence of [CaII] lines at 7300 Å also occur.

monitored on the 1 m telescope. The wavelength range of 4000-8800 Å was covered at dispersions $\approx$ 100 Å mm^{-1} and $\approx$200 Å mm^{-1}. A few observations of the Hα profile in Nova Her 1987 were also secured at a better dispersion $\approx$ 30 Å mm^{-1} (G.C. Anupama & T.P. Prabhu).

Recurrent Novae

A few novae are known to have outbursts, recurring over time scales of decades. It is important to understand how they differ from classical novae, whose estimated recurrence times are ~ 10^4 - 10^5 y. The observations made at quiescent times show that the recurrent novae have longer orbital periods than classical novae, and have a giant rather than a dwarf secondary. Spectroscopic observations, made during the quiescent phase, throw light on the nature of the primary, secondary, and the accretion disc. Such observations can also help in identifying changes in the spectrum that could take place in phase with orbital motion, or just prior to outburst. A programme was initiated at the VBO to monitor the recurrent novae T Coronae Borealis and RS Ophiuchi, spectroscopically, during quiescence. The 1 m telescope is currently being employed. The wavelength range of 4000-8000 Å is covered at dispersions $\approx$ 100 Å mm^{-1} and 200 Å mm^{-1}. Striking variations are seen in the strength of emission lines in T CrB. (G.C. Anupama & T.P. Prabhu).

Supernova 1987A -a report

Spectroscopic observations of SN1987A commenced at the VBO, two days after the discovery of the supernova on February 24, 1987. A large number of astronomers took active part in recording the spectra and reducing them. The 75

mm reflector telescope was in continuous service during this period.

The Bhavnagar spectrograph, a 75 mm camera and gratings with 300 and 400 groves per mm were used on the 75 cm reflector. The 1 m reflector was also used for spectroscopy and occasionally (during March 1987) for polarimetry and photoelectric spectrophotmetric observations. Spectrograms were recorded using the Zeiss spectrograph along with gratings of 300, 651 and 1800 groves per mm and 110 mm,150 mm cameras. The wavelength range covered was 4400-8800 Å at intermediate dispersions.

The spectra exhibited p-cygni type emission and absorption features of H, He, N, O, Na, Ca, Mg and Fe. A close resemblence of the spectrum to that of a typical type II supernova was found. However, the velocities of absorption systems were very high in magnitude, though declining rapidly with time. The absorption velocity of Hα evolved from -16400 km s^{-1} on February 26, 1987 to -7700 km s^{-1} on March 23; that of Fe II varied from -8600 km s^{-1} on February 26 to about -3000 km s^{-1} on March 30. In the higher Balmer lines of hydrogen, and the lines of helium and sodium, intermediate velocities were measured. At later epochs, the evolution of velocities slowed down.

The anomalous strength of NI at 8700Å, during March 1987, gave the first hint that nitrogen was overabundant in SN 1987A. This fact, together with the precursor type being a blue supergiant, provides severe constraints on theoretical models. The flux of OI 7774 Å could be used to estimate the abundance of oxygen, which also appeared high. A double structure was observed in the Hα profile, towards the end of March. The feature at longer wavelengths faded and disappeared in April. It should be noted that speckle interferometric observations, from Australia and Chile, showed the appearance and fading of a new source close to the supernova, at about the same time. This source was bright in Hα and hence the new emission feature observed in Hα may correspond to this source.

A comparison between the VBO spectra of March-April with those in October 1987, is not compatible with the presence of barium lines in the supernova, as claimed by some groups.

The spectra recorded between August 1987 and March 1988 were dominated by forbidden lines such as [OI] and [Ca II]. A comparison between the fluxes observed 310 days from outburst with the model of Fransson and Chevalier (1987)[2], leads to the conclusion that the precursor mass was about 18$M_\odot$ (while on the main sequence). (N.K. Rao *et al.*).

Supergiants

High galactic latitude F supergiants.

High galactic latitude F supergiants show large far infrared excess and dust shells, but show no reddening in the blue visual region. They show small amplitude long period pulsations, with more than one period. This suggests that such stars have low masses (~1$M_\odot$). They are also called population II supergiants, as well as UU Her stars. These stars may be in the protoplanetary nebulae stage of stellar evolution; the far infrared emission then comes from material very recently ejected by them. Two of these stars have been recently observed in the ultraviolet with the IUE satellite.

Low resolution (6 Å) IUE ultraviolet spectra of high galactic F supergiants HD 161796 (F3Ib) and HD 187885(F2I) were analysed. The UV spectrum (1250 Å to 3250 Å) of HD 161796 showed no excess UV flux attributable to a hot degenerate companion. From the UV spectrum, the temperature was found to be 6300 K. There is no evidence for significant metal deficiency.

[2]Fransson,C. & Chevalier,R.A. (1987) Ap.J. 332, 145.

Except for the NIV line at 1487 Å, the rest of the transition region emission lines are weak. In spite of the large infrared excess, the 2200 Å region shows no evidence for circumstellar reddening.

The UV spectrum (1250-1900 Å) of HD 187885 is peculiar. A broad emission feature with emission peak centred around 1580 Å is present, which may be due to SiI lines. There is a crowding of SiI lines in this wavelength region. These lines can be in emission if for some reason, the temperature at the surface would not drop as steeply as in normal A and F supergiants, or there is an outward increase of temperature. A broad absorption feature, nearly 100 Å wide, centred around 1657 Å, may be due to CI or due to quasi-molecular absorption of H_2.

The size and mass of the dust shells and overabundance of N clearly suggests that HD 161796 and related stars are evolved population II stars, which are now in the luminous post AGB stage of evolution. The latter is most likely a stage of evolution, just preceding the planetary nebula stage. (M. Parthasarathy, S.R. Pottasch* & W.Wamsteker*)

Phi Cassopeia

The radial velocity as well as light variations in the UBVRI as well as in the u v b y photometric system were monitored for ϕ Cas. A Fourier analysis was performed on the data to derive the period. In addition, the temperature was derived from the photometric indices and the mass and radius were estimated from evolutionary considerations.(A.A.Ferro* L.E. Parao* & S.Giridhar)

Variable stars

Ap and Am stars

The spectrophotometric observations of several new Ap and Am stars, which were obtained during 1987, are in the process of reduction. The aim is to determine their physical parameters, like effective temperatures and radii, in addition to the study of the variation of the characteristic radiation at 5200 Å. (G.S.D. Babu & B.S. Shylaja).

Be Stars

Variability of Be stars with time scale of years, months and days is well known. However, the emission line variability of Be stars on the time scales of hours, minutes or less is not fully understood. In order to study the rapid spectral variability of Be stars, high time resolution and high signal to noise ratio Hα profiles (approximately 300 profiles) of 13 bright Be stars were obtained on several nights between 1985 and 1986 using the automated spectrum scanner at the 1 m reflector of VBO. Results of the observed Hα profiles suggested that rapid (on the time scale of minutes) and irregular variability of emission strength were present in nine Be stars (HR 496, HR 1772, HR 1789, HR 8539 and HR 8628). However four Be stars (28 Ori, χ Oph, 66 Oph and π Aqr) did not display any rapid variability during the interval of observations. It appears that the observed variations of emission strength may be due to the material in circulation in the envelope of these stars. No rapid variations of continuum level flux were observed in the above Be stars. (K.K. Ghosh).

Cepheids

Four small amplitude Cepheids HR 8034, HR 8157, HR 7165 and HR 690 were observed in Stromgren's u v b y photometric system using the 1.5 m reflector telescope at the San Pedro Martir observatory. Atmospheric parameters were derived by comparing the observed dereddened indices $(b-y)_0$, $m1_0$ and $c1_0$ with the model atmosphere fluxes of Kurucz (1979)[3]. (S.Giridhar, A.A. Ferro*, & L.E.Parrao*).

[3]Kurucz,R.L. (1979) Ap.J. Suppl. 40, 1.

RS CVn type

B and V photometry obtained during 1983-84 and 1986-87 indicated a mean photometric period of 21.9 days and a mean (B-V) of 1.196, for HD 116204. The observed changes in the mean light level and amplitude of light variation were very similar to the photometric characteristics of RS Canum Venaticorum (RS CVn) systems, where the photometric variations are attributed to the presence of large scale starspots on the giant/subgiant component, which rotationally modulate the observed flux. If HD 116204 behaves similarly to the active component of of RS CVn systems, then its photometric period is the same as the rotation period of the star. The rotation period of 22 days, with the already known orbital period of 21 days, suggests that the system is a member of an almost synchronous binary, with a mass ratio close to unity. The low amplitudes of light variation and the change in the mean light level of HD 116204, imply that the distribution of the spots is such that a major fraction of them is always presented on the star's hemisphere, facing the observer. This suggests a low inclination of the rotation axis. (S. Mohin & A.V. Ravendran).

RV Tau type

B and V photometry of AR Pup obtained during January-April 1987, indicated a period of 751 days. The total amplitudes in V and (B-V) were found to be $0.^{m}52$ and $0.^{m}32$ respectively. Like other RV Tauri stars, AR Pup showed a phase lag between the V and (B-V) light curves, the phase shift being slightly larger at the secondary minimum ($\approx 0.^{P}08$) than at the minimum ($\approx 0.^{P}05$). (A.V. Raveendran).

Search for variable stars

A search for variables amongst late type stars in galactic clusters was taken up, to study the relationship between chromospheric activity of single and binary stars with age and rotation, in the presence of magnetic fields. The photographic technique is being used to make a short list of most probable variables in clusters. The Sabattier technique was attempted to get over the problems of the nonlinear response of the photographic plate. In this technique, the sabatteured images give equidensity contours, which can be chosen such that the density falls on the linear portion of the characteristics curve of the photographic plate. This is likely to improve the accuracies of magnitude determination.

The 45 cm Schmidt telescope was used to photograph the old open galactic cluster M67 on twelve nights to find the most probable variables, using the technique just outlined. About twelve objects, out of seventy five, for which the diameters of the sabatteured images were measured, were found as the most likely candidates for variables. (R.Rajamohan & J.C.Bhattacharyya)

Symbiotic stars

The far infrared (IRAS)observations of all the known symbiotic stars were analysed. Of the 129 symbiotic stars in Allen's catalogue (1984), 42 were found to be IRAS sources; in this 22 are D type (warm-dust,symbiotic Miras), 4 are D′ type (cool-dust) and 16 are S type (stellar). Apart from the D′ type symbiotic stars, the D and S types symbiotics show decreasing IR flux with increasing wavelength. He2-106, Ap 1-8,He2-390 show significant flux at 100μ;these are close to the galactic plane. The increased emission at 100μ may not be real, it may be due to IR cirrus. In the H-K versus flux ratio log $\{F_{\lambda}(25\mu)/F_{\lambda}(12\mu)\}$ plot, the S type, D type and D′ type symbiotic stars were well separated. The H-K colour and the flux ratio of SS 122 suggests that it is a D type symbiotic star, similar to He2-176 and He2-147. Ap1-8, H2-5 and AS 245 may also be D type symbiotics. The D type appear to divide into two groups; those with and without the 10μ silicate feature. All of the D type sym-

biotics show broad energy distributions, indicative of dust covering a range of temperatures. The S type symbiotics show a far infrared flux distribution, similar to normal M giants. However, BI Cru, AS 210, He2-104 and He2-390 show a featureless spectrum, with no silicate component. The far infrared energy distribution of He2-104 and He2-390, suggests the presence of large dust particles. From the far infrared fluxes and from the known periods of symbiotic Miras (D type) stars, the masses of the dust shells were derived to be ~0.3 $10^{-6}M_{\odot}$. From the IRAS data, dust temperatures ~ 250 K were found for M 1-2, Wray 157 and HD 149427 and ~160 K for AS 201. The dust masses were determined to be ~ 10^{-6} $M_{\odot}$. The far infrared colours are similar to those observed in planetary nebulae. (M. Parthasarthy & H.C. Bhatt).

The symbiotic variable star UV Aurigae was observed on the 1 m telescope in the wavelength regions 4200-5000Å and 6000-7000Å. Spectrophotometry was also carried out. From the relative intensities of important lines, the temperature of the hot component and the electron density of the nebular component were derived. Bolometric luminosity and effective temperature were calculated using the infrared data of Kenyon (1983)[4]. Several spectra of a few other symbiotic and symbiotic like stars were also taken. (P.Seal).

T Tau stars

High resolution S/N spectra of active stars in CaII H and K lines were analysed, to check the effect of rotation on emission strength. Broad band photometry of chromospherically active stars was carried out to study the nature of long term activity and temperatures and areas of spot coverage. It was found that short lived spot groups are the main cause for sudden changes in activity. An analysis of the photometry of isolated T Tau stars showed periodic modulation of the photospheric light level. (M. Mekedden).

UU Her type stars

A detailed spectroscopic investigation of UU Her type stars 89 Her and HD 161796 was conducted. Its aim was to derive atmospheric abundances of different elements. The atmospheric parameters were derived using model atmospheres and the spectrum synthesis technique. The effective temperatures derived were systematically cooler by some 1000 K, compared to the photometric estimates found earlier. The resonance line of LiI was identified and studied. A value of 2.3 was derived for the lithium abundance. This is much larger than the solar value, although the atmospheric abundances of elements like Ti, Cr and Fe are close to the solar value. The Hα line for these stars contains an emission component of varying intensity. The Hα profile with sharp absorption superposed on a broad absorption feature, suggests the presence of an extended atmosphere or circumstellar shell. (S.Giridhar,A.A. Ferro* & L.E. Parrao*)

Pulsars

Work on the concept of time was continued in order to understand the observed correlation between transverse velocities of pulsars and their period derivatives. It was found that the observed correlation can be understood if the assumption, that time flow exists, is dropped. Flow of time cannot be related to an observed event unless the event itself is in some physical way related to this flow. If an event can be described by known physical laws, then there is no way of measuring a time flow. In that case, the role of t variables or the role of clocks is to strictly conform to the set of equations chosen, in which the t variable occurs. This hypothesis, when followed

[4]Kenyon,S.J. & Gallogher,J.S. (1983) Ap.J. 88, 666.

strictly, leads to the interesting result that the average observed period derivatives of pulsars is basically due to galactic rotation effects.

The results that follow from this simple concept are in conformity with all the observational evidence, accumulated over the years in support of special and general relativity. Also, for uniform density of matter in the universe, the observed redshifts of galaxies can be interpreted as the gravitational redshift in a static or rotating universe. (R.Rajamohan).

Clusters

Proper motion and membership probability

Kinematical criteria, based on accurate data, have the advantage over other methods, that they segregate, more effectively, cluster members from the field stars. However, the extent of separation in proper motion, depends upon the relative differences in their motions. The relative proper motion and data of membership probability *(p)* for nine open clusters was examined. The proper motion data come from two or more independent sources, but have the homogeneous membership probability assignment for the stars in each cluster region. An attempt was made to examine the effects of measurement errors on the estimation of cluster membership and to analyse the difference in the components of proper motion vectors of the stars, obtained by different investigators. The main conclusions are two fold: firstly, a difference in the observational errors and the procedure of pruning the vector point diagram in two proper motion studies of a cluster, may give different values of the parameters describing the frequency distribution of cluster and field stars. This can strongly affect the middle range membership probabilities (p in the range 0.25-0.75), in contrast to higher membership probability ($p \approx 0.8$). Secondly, the proper motion data, in agreement with various other investigators, can be combined. Stars, present in more than one study, will have relatively accurate proper motion estimates in the combined data. Hence, such data will improve the segregation of cluster members from field stars. As the problem of incompleteness will be reduced in the combined data, it will ultimately help in tackling the cluster studies, like initial mass function and cluster dynamics, which require information about all cluster members up to a certain brightness. (R.Sagar).

Distances

An accurate estimate of distances to open star clusters is required for many astrophysical investigations. One application is in tracing the spiral arms of the galaxy, because these clusters can be detected to large distances. The current photometric distances of open clusters are correct to within 20-30%. Even then, it would be clearly useful to check them with a totally independent technique. Such an exercise was carried out. A method of open star cluster distance estimation, that is based on the observable kinematical parameters, *viz.* proper motions and radial velocities of open cluster members, was used. The method is, therefore, independent of interstellar extinction and metallicity corrections, as well as of photometric calibration. It can also be used for calibrating cosmic distances. The basic assumption of the method is, that the distribution of the stellar velocities in a cluster is isotropic.

A comparison of the kinematical distances, estimated for six open clusters, with the photometric distances showed a good agreement. At present, the kinematical distances cannot generally be estimated with accuracies better than the photometric distances. However, it is

unlikely, that the accuracy of photometric distances will improve significantly with the current methods. On the other hand, it is expected that the accuracy of kinematical distances will improve considerably when more accurate proper motion measurements from the HIPPARCOS space mission, or from the Hubble Space Telescope or from ground- based observations become available in future. As the distances, based on present methods, are independent of any calibrations, corrections and standard candles, they can be used to calibrate the cosmic distance scale in future. (R.Sagar & H.C. Bhatt).

Stellar rotation

The effects of rotation on colours and line indices of stars is a subject of some controversy. Empirical calibrations of these indices, in terms of intrinsic colour and absolute magnitude found in the literature, were all carried out on the assumption, that the rotational velocities of stars does not substantially affect their colours. In order to check this assumption, the analysis of all the available observational data, especially for galactic clusters, was taken up. An analysis of the Alpha Persei cluster data, shows that rotation effects are considerable on the intermediate band indices C_1 and (u-b). In C_1, rotation produced a reddening of 0.040 magnitude per 100km s^{-1}. In (u-b), the effect for B stars was found to be 0.06 magnitude per 100km s^{-1} of *Vsini*. The binaries and peculiar stars were found to behave differently in the colour excess (due to rotation) versus *Vsini* diagrams. These empirical effects will be determined for different clusters, so that the effects of rotation can be taken into account to recalibrate these colour indices and also to separate members that are likely to be chemically peculiar or to be in binary systems. (R.Rajamohan & A.Mathew).

Lunar occultations

Lunar occultations of Alpha Vir on August 1,1987 and Beta Tauri on January 29,1985 were recorded through a narrow band Hα filter, using the 1 m reflector telescope at the VBO.

The programme of timing lunar occultations is being continued from VBO. (J.C. Bhattacharyya, M.Appakutti and R. Vasundhara).

Radiative Transfer

Aberration and advection in a spherically symmetric medium

The effect of photon redistribution on line formation was studied, taking into account aberration and advection, due to large velocities. There are substantial differences in the radiation field due to moving and non-moving media. In a gas in which radiation is scattered isotropically and coherently, the effect is even more spectacular, for velocities as small as $v/c \sim 0.01$. If still larger velocities are to be treated, the method of solution would have to be completely altered. This is currently under examination (A. Peraiah & M.S. Rao).

Hα formation in late type supergiants

Fresh computations of the Hα line profiles were performed in a non LTE differentially expanding chromosphere, with a temperature rise, to simulate the characteristics in a sample of G and K supergiants. The comoving frame radiative transfer code was modified to explicitly incorporate the effects of ionization. A source function appropriate for a low level atom with continuum was used. The sensitivity of the Hα line profiles was explored for a wide variety of schematic temperature structures, velocity gradients, chromospheric extent and densities. The inclusion of the temperature structure changes the appearance of the profiles fairly drastically.

A comparison between the observed characteristics of the Hα profile and the computed one, restricts the range of variation of the other physical parameters too. Reasonably good fits yield total hydrogen densities in the range 10^9-10^{11} cm^{-3} at the base of the line forming region, integrated chromospheric optical depths in Hα in the range 50-5000 and expansion velocities in the range 0.25-2 times the maximum random (microturbulent and thermal) velocity. The inferred mass loss rates turn out to be in the range 10^{-7}-10^{-9} $M_\odot$ y^{-1}. The model is able to reproduce the line profiles with deep asymmetric absorption cores and emission in the red wing with non-zero velocities. However, the present calculations do not reproduce blue emission for outflow velocities larger than some 10 km s^{-1}, contrary to what is observed in several stars. (S.V. Mallik & D.C.V. Mallik).

Infrared emission from dusty stellar envelopes

Procedures based on temperature correction were developed to treat both dust and a mixture of dust, hydrogen and helium, assuming the existence of radiative equilibrium. The method works in both physical situations in which the dust density is constant or when it increases outwards. The method was tested for plane parallel and spherically symmetric media. (A. Peraiah & M.F. Ingalgi).

Radiative transfer in the atmosphere of magnetic stars

The polarized continuum and Zeeman line transfer equation was solved, using model atmospheres of magnetic white dwarfs and Ap stars. Several processes, which are well known in the laboratory plasma, were individually considered, and their effects explored. These processes include: the Stark-Zeeman effect, the plasma polarization shift of spectral lines, the atomic orientation effect caused by a strong magnetic field or anisotropic collisions, ray refraction, quadratic Stark effect and the Lorentz effect. (K.N. Nagendra)

Scattering in an optically thick medium

A photon undergoes a large number of scattering in an optically thick medium. Therefore, the number of scatterings encountered by a photon and the escape probability of a photon from a medium are important quantities in spectral line formation problems. The amount of dust and the scattering mechanism determine the mean number of scatterings and the mean escape probability. To obtain these quantities, the radiative transfer equation, including dust and scattering, was solved. When the optical depth and number of frequency points were increased in the spectral line calculations, incorrect solutions were obtained. This problem was circumvented by using spline interpolation to evaluate the scattering integral accurately. The method was tested for optical depths as large as 10^6. The main result is that a coherent mechanism scatters less photons, in the line wing, compared to a non-coherent type of scattering process. (K.R. Rangarajan & D.M. Rao).

Interstellar Medium

Star Clusters

Dust segregation in protoclouds

Segregation of dust in globular cluster protoclouds was proposed as a new mechanism for producing inhomogeneities in the observed heavy element abundances within globular clusters. Heavy elements in the protocloud are locked up in dust grains. Under the influence of gravitational and radiative forces, dust grains move relative to gas. Segregation of dust towards the protocloud centre produces a radial gradient in the dust to gas mass ratio within the cloud. Stars that form from material with different dust to gas mass ratio, consequently have different heavy element abundances. A radial abundance gradient is thus naturally produced. If the globular cluster has a long relaxation time, the radial gradient may survive up to the present time, otherwise only star to star variations in abundances are observed. For any significant abundance variations to be produced, it is required, that the dust segregation time scale be of the order of or less than the protocloud lifetime. The segregation time scales were estimated to be $\sim 10^7 - 10^8$y, so that the primordial abundance inhomogeneities could be established by dust segregation processes, provided the globular cluster protoclouds had lifetimes $\sim 10^8$ y, similar to the mean lifetime of the present day interstellar clouds. (H.C. Bhatt).

Interstellar extinction

As the interstellar matter plays an important role in the evolution and formation of stars and of the galaxy, study of interstellar matter, which is present between members of a young star cluster, helps in understanding the star formation process. Studies of nonuniform extinction in young open clusters are generally based either on accurate observational data without reliable cluster members or vice versa. Consequently, contradictory results about the nonuniform interstellar extinction across the cluster regions have been reported in the literature. The use of both accurate observational data and reliable cluster members in this type of study is unavoidable. Recently, the required data became available for 15 young open clusters and were used in studying their nonuniform interstellar extinction.

Cluster members were selected on the basis of proper motion analysis. Spectroscopic spectral classification and photoelectric photometric data were used to estimate the interstellar extinction. Nonuniform extinction was present in 10 out of the 15 analysed young open clusters. A study of the variation of reddening across the cluster face, with spatial position, luminosity and spectral class (Fig. 5 and Table 2), indicated that the observed variation of reddening in young open clusters may not have a simple explanation, as it depends upon a number of factors. However, a number of conclusions may be drawn. The observed systematic spatial variation of E(B-V) (abbreviated hereafter as E) in NGC 6530 and 6611 may be because of the presence of systematically varying amount of gas and dust. No dependence of E either on luminosity or spectral class is observed. Secondly, the scatter in E, does not depend upon spectral class, at least in the range O-K. Thirdly, random variation of E over a cluster face may be due to either patchy

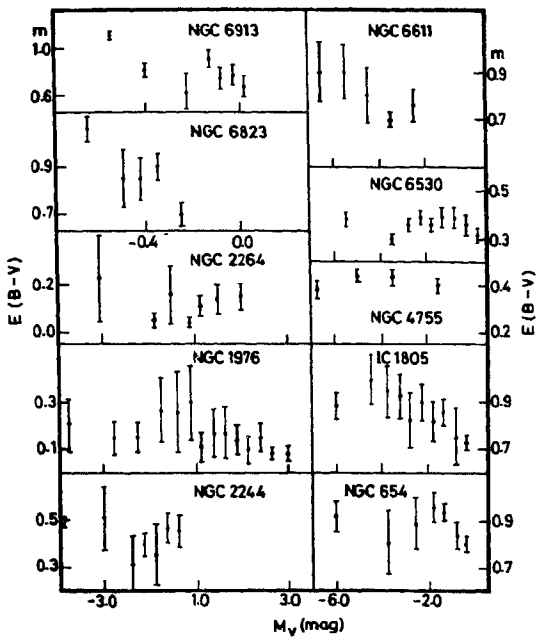


Fig.5: Plot of E (B-V) and it's standard deviation with M_V The length of each bar denotes the standard deviation.

distribution of interstellar matter across the cluster region or due to the presence of circumstellar shells around young massive stars or possibly a combination of both. Finally, the variation of E with either luminosity or spectral type is not observed in all the clusters younger than 5 10^6 y and having massive stars. It may indicate that the factors responsible for this variation are not present in all the clusters under discussion.

It, therefore, appears that the reddening variation in one cluster is distinctly different from the others and ,furthermore, there is no uniformity in the relationship of spatial extinction, spectral type, luminosity or age among these clusters. A complicated physical scenario is thus required to explain the nonuniform extinction in all young open clusters. (R.Sagar).

Planetary Nebulae

Filling factors

Most planetary nebulae show density inhomogeneities and structures on all scales. The simplest way of describing these is through the filling factor f, which is defined as the fractional volume occupied by radiating matter within the ionized nebula. This factor can be determined from the total $H\beta$ flux, the distance and the measured forbidden line electron density. Since all three observational quantities are difficult to determine, the effect of f was often ignored in earlier work. The situation has changed drastically over the last few years, as large samples of planetary nebulae have been observed in radio and optical wavelengths, to give accurate fluxes and densities. Recent work on distance determination has also provided moderately accurate values of this important parameter for a few tens of nebulae. Three samples of planetary nebulae were chosen. The first consisted of a set of 36, for which distances have been independently measured by various methods (such as using 21 cm absorption, interstellar extinction, angular expansion and spectroscopic analysis of central stars). The second and third sets were based on the statistical distance scales of Daub and Cudworth respectively, who determined f, using the latest electron density data. It was found that the f values were often small (0.05-0.2) and that there was an inverse correlation with the size of the nebula. The ionized masses of the sample nebula were calculated. It was found that mass increased with size.

All nebulae in the sample were thus optically thick. A power law fit to the scale-independent sample showed mass proportional to radius,

which is in agreement with the predictions of theoretical models by Kwok (1983)[1]. It was also found that M_{dust}/M_{gas} in planetary nebulae does not vary over three orders of magnitude and that the average value for 18 nebulae is close to the interstellar medium value. Based on a scale-independent sample and also on a correlation between forbidden line densities and radii, two new ways were suggested for measuring distances. The new distances are larger by a factor 1.5 compared to Cahn and Kaler distances. This has far reaching implications for birthrate and total number of nebulae in the galaxy. (D.C.V. Mallik & M. Peimbert*).

Kinematics

The programme, started earlier in collaboration with the Physical Research Laboratory (PRL) at Ahmedabad, was continued further. A piezo-electrically scanned Fabry-Perot spectrometer of the PRL was used to obtain [OIII], Hα and [NI] profiles at several positions in the bipolar nebulae NGC 2346 and NGC 2440. The central region of NGC 2346 showed an expansion velocity of 8 km s^{-1} in the [OIII] line, of 10 km s^{-1} in Hα and 11 km s^{-1} in [NII] lines. (D.C.V. Mallik, S.K. Jain, B.G. Anandrao*, D.P.K. Banerjee* & J.N. Desai *).

Nuclei of planetary nebulae

Until recently, it was believed that all low mass stars ($M/M_\odot < 2$) evolve through a planetary nebula phase to white dwarfs. The intermediate mass stars ($2 \leq M/M_\odot \leq 8$) also evolve in much the same fashion. However, the problem of relating the final remnant masses to the initial masses on the main sequence is ridden with difficulties, owing to our poor knowledge of the mass loss processes during the first and second red giant phases of the evolution of these stars. The observational data on planetary nebulae in the solar neighbourhood are reasonably complete. An analysis of the information on kinematics and height distribution, the theoretical as well as the

TABLE 2.

Results of variation of E (B-V) with spatial position, luminosity and spectral class of members of clusters under discussion.

Cluster		Variation of E (B-V) with: Spatial position (Behaviour)	Luminosity (Correlation)	Spectral Type (Correlation)	Group
NGC	654	Random	Weak	No	B
IC	1805	Systematic	Yes	Yes	A
NGC	1976	Random	No	No	C
NGC	2244	Random	No	No	C
NGC	2264	Random	No	No	C
NGC	4755	Random	No	No	C
NGC	6530	Systematic	No	No	C
NGC	6611	Systematic	No	Weak	B
NGC	6823	Random	Yes	Yes	A
NGC	6913	Random	Yes	Yes	A

[1]Kwok,S. (1983) IAU Symp. 103. ed. D.R.Flower, p. 293.

empirical initial-final mass relations, and the birth rate of planetary nebulae indicate that there are few nebulae, which could have originated from stars less than about 1.5 $M_\odot$ in the solar neighbourhood. Similarly, the data on chemical composition, occurrences of planetary nebulae in binary systems and the presence of white dwarfs in young open clusters support the view that the upper initial mass limit of planetary nebula/white dwarf formation may be as large as 7-9 $M_\odot$. (D.C.V.Mallik).

Spherically symmetric nebulae

A photoionization model of a spherically symmetric nebula around a central star is being constructed. The model assumes no time dependence. A number of physical processes were considered and relevant atomic data collected. A numerical scheme for solving the equations was developed and coded. The method computes the variation of the electron temperature and electron density. Fluxes of lines, observed in the spectrum of a planetary nebula, can also be calculated in the model. A comparison between calculated and observed fluxes will be used to improve model parameters. (R. Surendiranath).

Young planetary nebulae

Hen 401,Hen 591 and Hen 1428 are emission line stars found to show far infrared flux distributions and colours similar to those observed in young planetary nebulae. Hen 401 appears to be a bipolar planetary nebula. The [OI],FeII and [Fe II] lines are strong in emission. There are also emission lines due to [OII], [SII] and [NII]. Hen 591 also shows a number of FeII lines in its spectrum. IUE ultraviolet observations of these four objects is proposed to be carried out. (M. Parthasarathy & S.R.Pottasch*).

Galaxies, High Energy Astrophysics & Cosmology

Galaxies

Dynamics

Numerical simulations, using a restricted three-body approach, were continued. The sizes and shapes of bridges and tails in interacting galaxies were studied. It was shown that the structure of a tidally interacting galaxy is determined by the dimensionless parameter ν, which is a function of firstly, the ratio of the distance of closest approach to the size of the galaxy, secondly, of the mass ration and finally, of the eccentricity of the perturber's orbit. The impulse approximation suggests that similar structures would be produced in the outer parts of a galaxy for identical values of ν. Numerical experiments showed that, in interacting galaxies, identical structures could be produced by suitably choosing the mass ratios, eccentricities and distances. (P.M.S. Namboodri, R.K.Kochhar & S.M.Alladin*).

Population synthesis

The main aim of the project was to determine the relative proportions of stars of different spectral types and luminosity classes in galaxies, from observations of their integrated spectra. Input observational data consisted of photographically recorded spectra from the 1 m reflector telescope at the VBO and digital spectra from the 1.5 m telescope at ESO, Chile, using the reticon detector. The latter data, of high quality, covered the wavelength region 5500-10300 Å, with a resolution of 6 Å.

The reticon data were obtained for three galaxies and several population synthesis standard stars. They were then reduced to absolute fluxes. Using the spectra of these stars, other compilations of standard spectra were augmented, especially for stars of late spectral type, in the near infrared region of the spectrum. These augmented spectra were in turn used for synthesising the population of observed galaxies.

Apart from standard line indices, generally used in this kind of work, several indices, covering the molecular bands of TiO, CN and FeH (Wing-Ford bands) in the near infrared region of the spectrum, were calculated. The behaviour of the strengths of these indices are consistent with spectral type and luminosity and hence can be profitably used in population synthesis of galaxies.

A population synthesis of the galaxy N5128 (Cen A), yields interesting results. A large fraction (about 40%) of the light at visual wavelengths comes from massive O-type stars on the main sequence and/or from B-type giant stars and horizontal branch stars. It was, however, not possible to distinguish between these types with the available observations. But the occurrence of massive main sequence stars, given the large fraction of dust and gas in N5128, seems to be consistent with recent analysis of star formation activity from IR observations. It was found that the main sequence turn-off for N5128 occurs at spectral type K2 to K3, implying an age of 17-20 10^9 y (assuming helium and heavy element abundances $Y=0.3$ and $Z=0.01$ respectively) or greater ($Y=0.2$ and $Z=0.01$). Despite

this large age, star formation in N5128 appears to be widespread.

Contrary to earlier work, the light at wavelengths near 1 micron is not dominated by late M-giant stars; the contribution from late spectral type dwarf stars and giant stars seems to be comparable. Further synthesis runs are currently underway using different sets of constraints. (A.K. Pati).

High Energy Astrophysics

Black Hole Evaporation

The last stages in the evaporation of a black hole cannot be adequately dealt with in the framework of the current semi-classical approaches to quantum theory. The problem of the eventual remnant, if any, of a decaying black hole is thus still an open question. In this connection, recent suggestions that a black hole may transform into a massive superstring as a final state were examined. The role of higher dimensional spaces in suppressing black hole evaporation at near Planck energies were discussed and the thermodynamic properties of these higher dimentional black holes compared with those of strings. Quantum corrections to event horizons of classical metrics were also studied. (C.Sivaram).

Neutrino Charge

The detection of about a dozen neutrinos of over 7 MeV, within 10 s from the supernova 1987A, was used by many workers to constrain the electron neutrino rest mass to less than 10 eV. It was also possible to place a limit on their electric charge q, to be about 10^{-17} times the electron charge, otherwise trajectory lengths for neutrinos of different energy (and therefore their arrival time) would be different due to the galactic magnetic field. Calculations were made to obtain constraints on q from other considertions, *viz.* by assuming that the neutrinos, with small rest mass ($\approx$10eV), constituted the bulk of the dark matter in galactic halos and clusters

It was also shown, that the SN 1987A limit on q would also limit the neutrino magnetic moment to around 10^{-12} times that of the electron (μ_B) for 10 eV neutrinos; this is smaller than the $\mu_\nu \sim 10^{-10}\mu_B$ limit required by the Voloshin - Vysotski - Okun mechanism to explain the anticorrelation between the solar neutrino capture rate and the sunspot number (C.Sivaram).

Radiation from neutron stars

A numerical study of the frequency shifts in radiation from the surface of rapidly rotating neutron stars and rotation induced spectral line broadening has been made as a function of their mass. It has been found that despite large rotation rates, gravitational effects dominate over the Doppler contribution to the frequency shifts, over the allowed mass range of a stable neutron star. The results indicate a substantial line broadening and a largy asymmetry in the line profile, when rotation rates are large, say corresponding to millisecond periods. In view of this, the concept of detection of line emission as a line from rapidly rotating neutron stars (and the associated interpretation for the mass to radius ratio of the star) will no longer hold good. An important conclusion that follows is that the detection of line emission from neutron stars in high energy radiation sources (such as X-ray or gamma ray sources), where large rotation rates of the star are otherwise inferred, would then imply that the emission region is located far away from the neutron star surface. This in turn would suggest a non accretion scenario for the gamma ray line emission. (B.Datta & R.C. Kapoor).

High density matter

Recent experimental results, reported to be consistent with the creation of a quark-gluon plasma in heavy-ion collisions, give support to the theoretical conjecture that a more fundamental description of matter at very high densities should be in terms of a quark-gluon plasma. This raises the possiblility of firstly, the existence of quark matter cores in heavy neutron stars and/or degenerate stars, made up entirely of strange quark matter. Secondly, it suggests a rich early universe cosmological scenario. Two important issues in this context, are the critical density at which quarks will make their appearance and the question of what constitute 'good' signals, indicative of such a phase transition.

A chiral sigma model description of dense neutron and nuclear matter has been considered and the results applied to examine a first order phase transition to quark matter. A marginal case can be made for quarks to exist in heavy neutron star cores (Basu* & Datta).

Non-perturbative QCD interactions in high density matter and its relevance for a maximum mass of stable neutron stars was earlier investigated.

In the context of quark signals, diphotons and dimuons, escaping the interaction regions in ultra-relativistic heavy ion collisions, were studied in a thermodynamic framework. The application of such an analysis in quark plasma diagnostics was highlighted. (B.Datta, S.Raha* & B.Sinha*).

Cosmological models

Early universe

There are severe theoretical problems with the standard big bang theory, especially at the earliest epoch, such as the so called "flatness" and "horizon" problems, which have been explained to some extent by inflationary models. However, by examining the balance between the different forms of the energy and velocities of expansion in the early stages of the big bang, it was possible to find the solution to the horizon and flatness problems, by using the correct relativistic equation of motion (C. Sivaram).

Grand unified theory

Most of the grand unified theories (GUT) involve the unification of weak, electromagnetic and strong interactions at energies around 10^{-3} to 10^{-4} times the Planck energy ($\sim 10^{19}$ GeV), when the three coupling constants, characterizing these interactions, must become equal. Above this energy, the three interactions can be parameterised by a single dimensionless constant, $\alpha_{GUT} \approx 10^{-2}$. If gravity gets unified with the three other interactions at the Planck energy, the interactions must all be characterized by a single dimensionless coupling constant. However, in a totally contrasting behaviour, the gravitational coupling constant, α_{grav}, continues to rise with increasing energy. At the GUT unification energy, it attains a value $10^{-6}\,\alpha_{GUT}$ and at the Planck energy, its value ~ 1, thus far exceeding α_{GUT}. A scale-invariant unified theory of gravity and GUTS was constructed which attempts to avoid these discrepancies. The consequences of such a unification for the early universe were explored.(C.Sivaram).

Hoyle-Narlikar cosmology

Hoyle-Narlikar(HN) cosmological models, with a gravitational 'constant' G, decreasing with time, predict higher luminosities and temperatures for galaxies at earlier epochs. The luminosity enhancement is of $\sim 1^m$-3^m for redshifts upto $z \geq 1$, and the increase in temperature more than compensates the cosmological reddening, thus making the galaxies bluer in the past. There is a fair degree of agreement of these

theoretical predictions with recent observations of Lilly & Longair (1984)[1], Djorgovski *et al.* (1984)[2] and others. Unlike in standard Friedmann cosmologies, this agreement is obtained in the HN cosmology as a natural consequence of the G variation, without the need to invoke ad hoc evolution. Other consequences of the HN theory, such as its effects on the main sequence turn off are being investigated. (P.K. Das).

Olber's paradox and universe size

Olber's paradox would have strongly suggested to nineteenth century astronomers that a dark night sky implied that a static infinite universe was inconsistent with observations and, therefore, untenable. Even if it were static, it had to be finite in extent. However, it is not so apparent that with their existing knowledge and concepts, early nineteenth century astronomers could have proceeded to estimate the size of such a static universe, consistent with a dark night sky. They would have been able to arrive at a value, remarkably close to the presently known Hubble radius of the universe. Calculations were made to show that this estimate could have been possible by invoking the well known argument of Laplace, proposed in 1798, that radiation, from a luminous body of mass M, would not be able to escape if its radius were smaller than $2GM/c^2$, along with the observed parameters, derived from a measure of the solar constant, and the total flux from all the stars illuminating the night sky. (C.Sivaram).

String models

Cosmic strings, produced in the early universe, have topological line defects in a phase transition. It is believed that they are able to provide the requisite density fluctuations needed to initiate galaxy formation. These strings can be extremely massive and their gravitational interactions are characterized by a dimensionless parameter $\mu G/c^2$, where μ is the string tension. To be relevant from the point of view of the formation of astrophysical structures, constraints on the value of μ were considered in different particle physics models. (C.Sivaram).

Time variation of G

It was pointed out that there is no conclusive evidence for a nonzero $\dot{G}$ (Canuto, private communication). This, however, does not conflict with HN models, for which the empirical evidence for $\dot{G}$ is superfluous. The evidence is, anyway, inconclusive to rule out HN cosmology. Nevertheless, this aspect is being examined.(P.K. Das & C. Sivaram).

Quasars

Energy mechanisms

The difficulties associated with the standard massive black hole (MBH) models for quasars could possibly be resolved by adopting one of two approaches. In the first, the energy requirements are scaled down. This can be achieved by assuming that quasar distances are smaller than that implied by the Hubble law. The second approach consists of using alternative cosmological models (such as HN cosmology). Both these approaches are under study. (P.K. Das)

Nonthermal continuum

The quasar nonthermal continuum in the radio band can undergo Raman scattering in the accretion disc plasma around the central black hole, provided the frequency and the wave vector match and, furthermore, if the threshold con-

[1]Lilly,S.J. & Longair,M.S. (1984) M.N.R.A S. 211, 833..
[2]Djorgovski,S., Spinrad, H & Marr,J. (1984) Lecture Notes in Phys. 232, 193

ditions are satisfied. The scattered radiation has a frequency $\omega_o/2 \sim \omega_p$ where ω_o is the frequency of the incident radiation and ω_p is the electron plasma frequency. The spectral shape of the scattered radiation is significantly different from that of the incident radiation. It is proposed that the observed spectral shape of the radio radiation may be accounted for by including the effects of Raman scattering (V.Krishan).

21cm line

The 21cm absorption line has been observed from several quasi-stellar object (QSO) systems. This line is believed to occur in the neutral hydrogen clouds close to the QSO. It is suggested that absorption at 21cm can also originate in the highly ionized emission line region, where the electron plasma frequency is close to 1420 MHz (21cm), through a parametric decay instability. This absorption process has a line character in principle, since it occurs only when a frequency matching condition is satisfied. The width of the absorption feature results from the width of the electron density distribution function of the emission line region. The absorption coefficient for the parametric decay process is much larger that that for the spin flip transition. A part of the radio continuum, therefore, is depressed, because this absorption process occurs over a range of frequencies. (V.Krishan)

Radio observations

Galactic and extragalactic sources

Observations obtained with the Compound Grating interferometer, on some galactic and extragalactic sources, were used to study one dimensional structure at 34.5MHz, with a resolution of 3 arc min. During a preliminary analysis of the data, using specially developed software techniques, problems of phase calibration were encountered. The origin of the variations in phase were traced to both ionospheric propagation effects and the system configuration. A new observational technique is currently being used and a fresh analysis of the data is in progress. (Ch.V.Sastry).

Galactic plane

Observations of some select regions of the galactic plane are being made using the north extension array in conjunction with the east-west and south arms of the T antenna. This should improve the resolution in declination of radio maps by a factor of 2.(Ch.V Sastry & A.A.Deshpande)

Scintillation observations

Scintillation observations of some select sources using the T antenna in the tracking mode were continued. A power spectral analysis of the obtained, to detect interplanetary scintillations is in progress. A data base of about a year will be needed for this purpose. (Ch.V Sastry)

Solar Terrestrial Physics

Ionosphere

Solar wind-magnetosphere-ionosphere coupling

It was argued, as well as demonstrated from experimental data, that a high level of variance of the interplanetary magnetic field (IMF) is a necessary condition for the occurrence of anomalous reversals in the diurnal pattern of ionospheric electric fields at equatorial latitudes, in association with the sudden northward turning of the B_z component of the IMF. A highly time varying IMF at the time of northward swing in B_z enhances the efficiency of momentum exchange between the solar wind and the magnetosphere. This triggers a rapid and effective decrease of the convection electric field, by affecting the reconnection process. The polarization charges in the inner magnetosphere, which normally shield out the convection electric field from the low latitude ionosphere, are, as a consequence, thrown out of balance. They, in turn, become the source of a dusk to dawn electric field perturbation, that penetrates in to the low latitude ionosphere. This finding, emphasizes the importance of shielding charges in the magnetospheric boundary layer in the solar wind-magnetosphere-ionosphere coupling. Furthermore, it explains the absence of a one to one correspondence between the sudden northward turnings of the B_z and perturbations in the equatorial electric fields, reported in the literature. (J.H. Sastri).

A specific search was made for equatorial electric fields of the ionospheric disturbance dynamo mechanism (i.e. electric fields generated by geomagnetic activity induce modifications in the global thermospheric circulation) using a ground based magnetometer and ionosonde data. Only those storm time intervals were examined in which a prominent ionospheric storm (insignia of a modified thermosphheric circulation) prevailed in the longitude zone of interest. The analysis showed that such electric field patterns can be detected under favourable conditions, even in magnetometer and ionosonde data, which give only indirect information on electric fields. This result demonstrated that the extensive data, from the global networks of ionosondes and magnetometers, can be used to derive the characteristics of disturbance dynamo electric fields and compare them with model predictions. The study revealed the absence of discernible patterns of equatorial disturbance dynamo electric fields after some geomagnetic storms, even through they did result in conspicuous negative ionospheric storms at mid-latitudes in the same longitude sector. This finding indicates the importance of localized heat sources in the low latitude thermosphere (e.g. midnight temperature bulge) and the associated neutral winds in the generation and manifestation of disturbance dynamo electric fields in the equatorial regions (J.H. Sastri)

Dynamics of the F region

The origin of the conspicuous vertical uplift of the equatorial ionospheric F region in the pre-sunrise period was investigated, through a detailed analysis of a large number of such events observed at Kodaikanal over the period 1966-82. It was found that the pre-sunrise height rises were preceded by magnetospheric sub-storms of

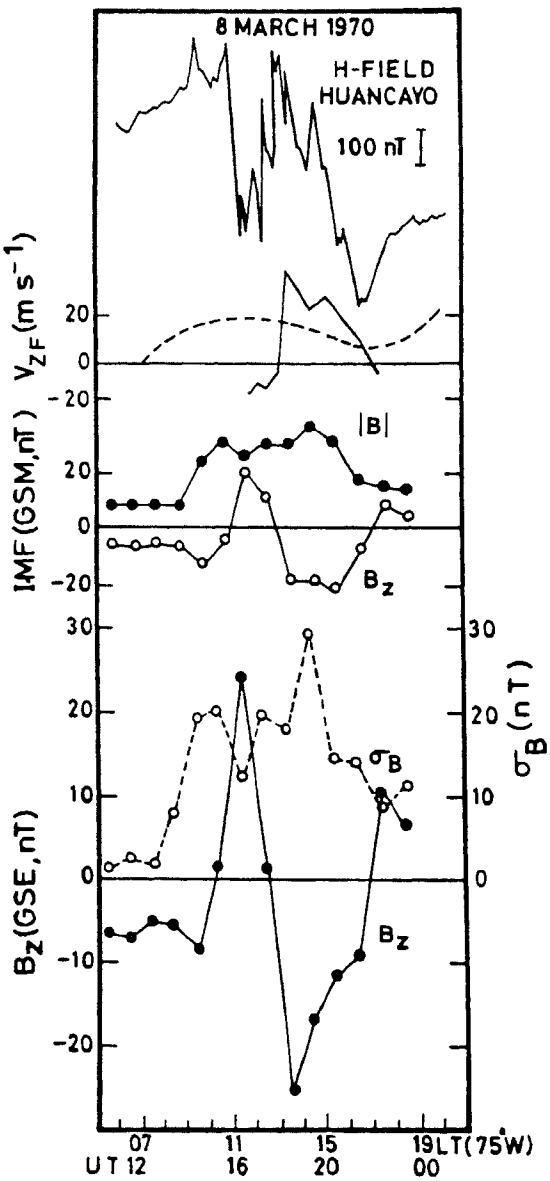


Fig.6 A daytime reversal in the equatorial zonal electric field associated with a sudden northward turning of the B_Z componenent of the interplanetary magnetic field around 16 UT on March 8, 1970 near Earth. The dashed curve in the V_Z plot corresponds to the quiet diurnal pattern of V_Z.

moderate to severe intensity and occurred in their recovery phases. The recovery phase-related height rises were also consistently noticed to exhibit a close temporal association with sudden south to north transitions of the Bz component of the IMF, wherever such data became available. No convincing evidence for equatorward propagating Travelling Ionospheric Disturbances (TID), was found from a comparative height study of variations in the same longitude sector. It was concluded from these results, that anomalous reversals of the equatorial electric fields , due to the sudden decrease of magnetospheric convection in the recovery phase of substorms, is the mechanism that is predominantly responsible for the prominent vertical uplift of the equatorial F region in the pre-sunrise period (J.H. Sastri & D. Karunakaran).

Spread-F (ESF) irregularities

The contribution of various physical factors to the post sunset onset of spread-F irregularities (ESF) near the dip equator was investigated, using simultaneous data from HF Doppler and ionosonde experiments at Trivandrum and Kodaikanal respectively. The analysis showed that the onset of ESF occurred whenever the height of the bottom-side F region and vertical plasma drift exceeded 400 km s^{-1} and 30 m s^{-1} respectively. ESF did not manifest itself when these values were 300 km s^{-1} and 15 m s^{-1}. The onset of ESF was found to be insensitive to the electron density gradient, on the bottom-side, once the height and velocity parameters attained the above mentioned limits. It was only when the height and velocity values fell below the limits mentioned, that the electron density gradient was found to control the onset of ESF. The ion-neutral collision frequency and the chemical recombination rate, which operate through the height factor, thus seem to govern the plasma instability growth rate and the onset of ESF. (B. Jaychandran*, J.H. Sastri, N. Balan* & P.B. Rao*)

Latitude structure of electron density

The latitude structure of the electron density distribution in the equatorial ionospheric F region, with reference to the post-sunset onset of ESF irregularities, was investigated with (N-n) profile data from the national ionosonde network. It was found that, on days with ESF, the ratio of electron density in the altitude range 270-300 km, between Ahmedabad and Waltair, showed a sudden enhancement, starting at 1700 hrs LT, by a factor 8 to 30, from a near constant value of 2 during daytime. Such an increase in the density ratio was not seen on days without ESF. The increase of the electron density ratio, prior to the onset of ESF, can be interpreted as an intensification of the northern crest of the equatorial ionization anomaly. Ionization, in the bottom-side F region as far north as 9° from the equator, participated in the crest intensification process. The rapid intensification of the ionization anomaly engenders a similar augmentation of the neutral anomaly around sunset. This in turns creates a localized cell of altitude dependent equator-ward neutral winds. An intensification is thus further aided of the crests of both the anomalies and preferential mass loading of the flux tubes, passing through the height of maximum electron density in the F region, over the dip equator. The net result of these coupling processes is a weakening of the trans-equatorial wind and reduction of the north-south asymmetry of the ionization anomaly crests; a condition favourable for the onset of ESF. A new feature of the study is that it indicates the role of the anomaly intensification, in the bottom-side F region and associated neutral dynamics in the post-sunset onset of ESF. (R.R. Rao*, N.N. Rao, J.H. Sastri, G.D. Vyas * & M.S.Rao*).

Imaging

CCD system

The CCD system was received in December 1987. Designs of the mechanical interfaces for initial trials of the system in the imaging and spectroscopic modes at the 1 m telescope had been worked out in advance.

The first trials of the imaging capabilities of the system in January 1988, were extremely successful. White light images of stars, down to apparent magnitude 18 could be obtained in some minutes. The CCD chip (from Thompson CSF), being used for the first time in astronomical observations, performs well, with almost zero pixel defects and no geometric distortion. The noise level is also very low, thus allowing long exposures. Further trials in the imaging mode using the Fernie U,B,V,R,I filters, available at the IIA, were carried out in February 1988. An exposure of 400s through the V filter records stars of apparent visual magnitude 17, with a good signal to noise ratio. The CCD chip is coated for sensitivity in the ultraviolet wave band, and this was borne out by exposures with the U filter: exposures of some 30 min, record stars with apparent visual magnitude 16. White light imaging experiments of fields of faint clusters of galaxies and stars, not present in the Palomar charts, show up these in exposures of about 500s. Figure 7 shows a photograph of a field, which includes Abell 754, the brightest member of the cluster of galaxies.

Filter CCD observations of faint galaxies were carried out by Lynden Bell's group from Cambridge during six nights in March 1988.

Trials of the system for spectroscopic work were carried out in March 1988, using the Zeiss-UAGS (Universal Astronomical Grating Spectrograph) at the 1 m telescope. Despite the elaborate arrangements made to reduce flexure, the system could not be used for regular spectroscopy. Further modifications are needed to achieve this aim. (A. Pati)

CCD imaging

A CCD 2000 imaging system belonging to the Tata Institute of Fundamental Research was tested at the prime focus of the 2.3 m VBT. A visual magnitude of about 18 was achieved in an integration time of 60s The data acquisition software is being continuously updated (A.Kembhavi*,P.N. Bhatt*,A.Patnaik* & T.P. Prabhu).

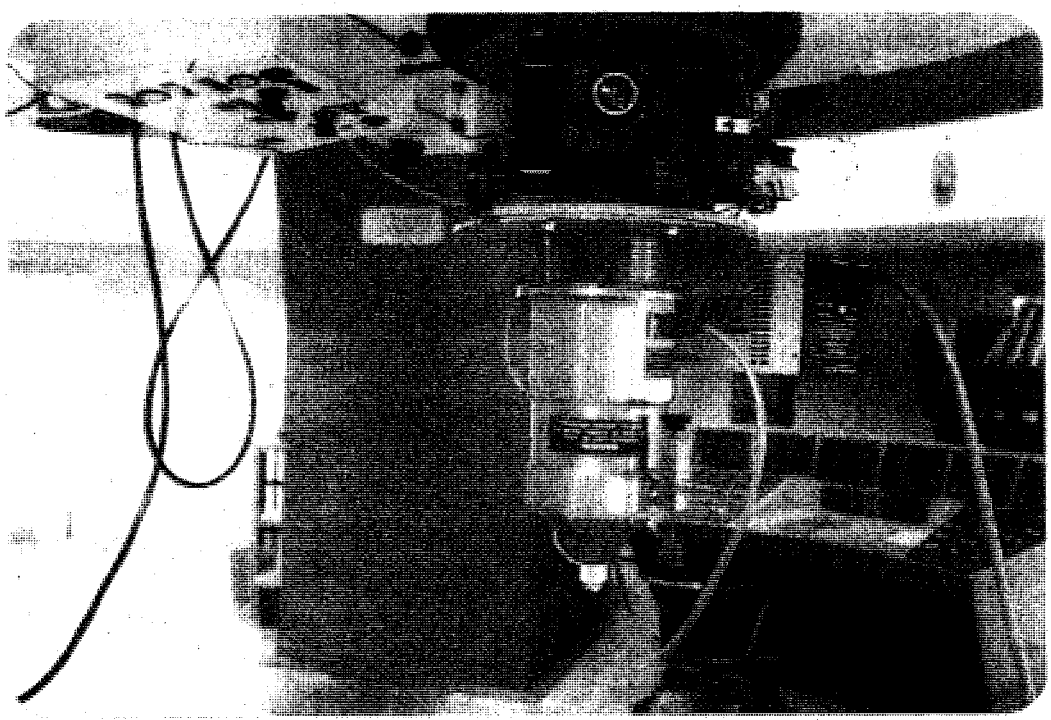
Image correction

The quality of stellar images is degraded due to the passage of light through the Earth's atmosphere. An attempt is being made to correct the images.

Atmospheric turbulence creates random fluctuations in the refractive index of the intevening medium. This results in fluctuations in the angle at which light rays arrive and also in the phase. The consequences of these fluctuations on stellar images was investigated. An expression for the probability of the arrival angle was derived. (S. Chatterjee).

Intensity simulation in multiple beam interferometry

Multiple beam interferometric methods have recently been recognized to be important for the determination of stellar diameters. A computa-



CCD System mounted on the 1 m telesope at Kavalur.

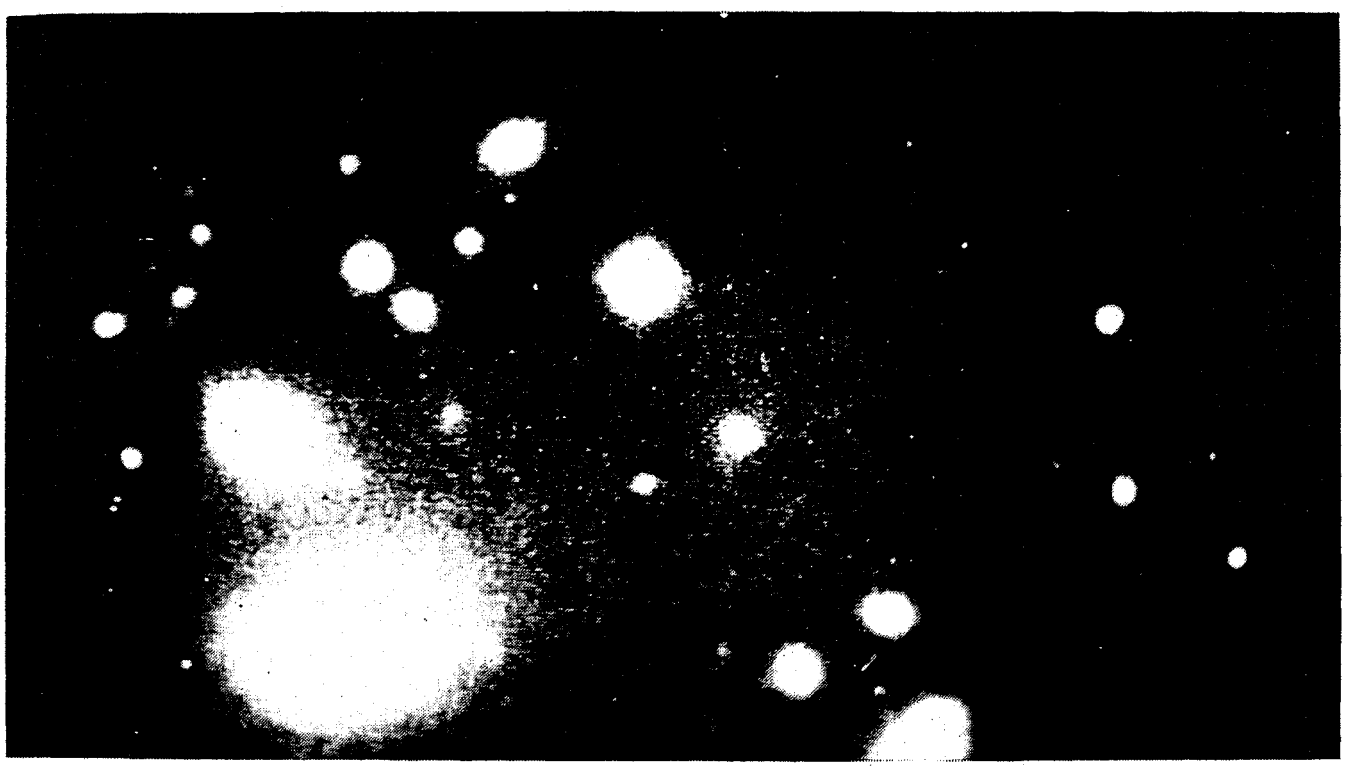


Fig.7: CCD picture of a field around the brightest galaxy in the cluster of galaxies Abell 754, taken at the Cassegrain focus of the 1 m telescope.

tional technique was recently developed to obtain the intensity pattern in the focal plane of several interfering apertures. The effects of diffraction, due to the finite size of the apertures, were incorporated. Random phases were also introduced. (S. Chatteree).

Proposal for a multiple application system for faint objects

A proposal for a versatile instrument (modelled after the ESO faint object spectrograph camera) for the VBT was drawn up. Such an instrument will exploit the fullest capability, at the faint limit, of the VBT, and provide the means to do low resolution spectroscopy, two dimensional photometry and polarimetry, multiple object spectroscopy and medium resolution echelle spectroscopy. The proposal has been submitted for funding. (A. Pati).

Star and sky chopping polarimeter

Polarimetric measurements are particularly sensitive to variations in the sky transparency. If adequate measures are not taken in a polarimeter, large errors can result in the observations, particularly when the sky is not very stable. To reduce the errors due to the slow variations in the sky transparency, a polarimeter was designed, in which the programme star and the neighbouring sky are observed alternately every 20 milliseconds. The analysing optics consists of an HNP'B polaroid sheet, which is mounted on a stepper motor controlled rotator. The entire instrument is under the control of a microprocessor cum BBC microcomputer based control unit, which also acts as the data acquisition unit. Testing of the various sub-assemblies in the laboratory is currently in progress, and the integrated instrument is expected to be used on the telescope in the coming observing season. (S.K. Jain)

Infrared group

Infrared Fourier transform spectrometer (FTS)

The infrared FTS, in collaboration with the Royal Edinburgh Observatory, Edinburgh, was successfully tested at the Cassegrain focus of the 1 m telescope at Kavalur. Some high quality infrared spectra of the moon were recorded with this spectrometer. Stellar spectra, however, could not be recorded owing to technical problems. This problem will shortly be rectified, after which the spectrometer will be used at the Cassegrain focus of the 2.3 m VBT. (S.K. Jain & M.J. Smyth*).

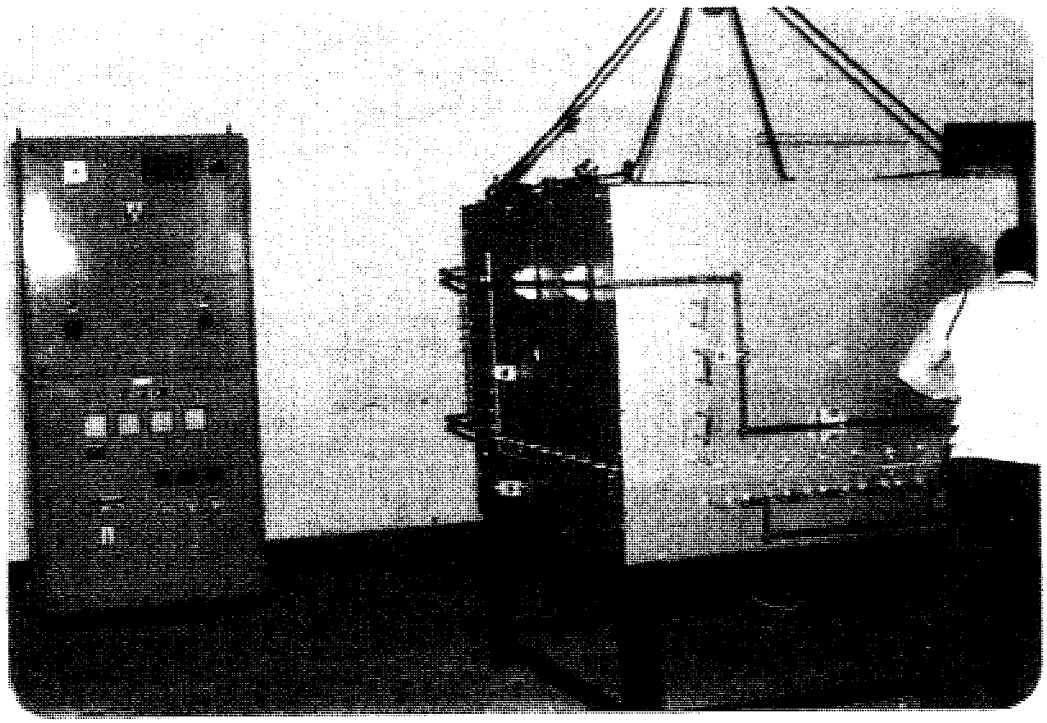
Infrared photometer

A microprocessor based lock-in amplifier model 510, which is remotely programmable via the RS 232 and GPIB interfaces, was added to the data acquisition system of the infrared (IR) photometer, developed at the IIA. Details regarding the IR photometer and its calibration are available. (K. Shivanandan*, R.M. Nair & K.R. Sivaraman).

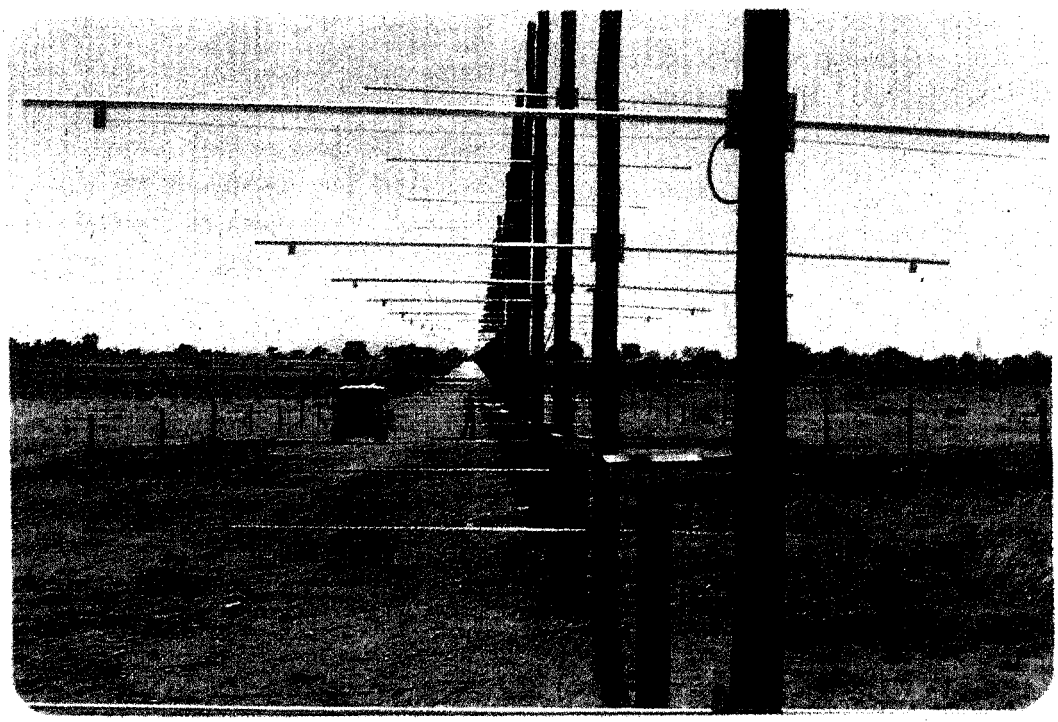
Ionospheric Group

Fabry-Perot spectrometer

Work on the development of a Fabry-Perot(FP) spectrometer, for high resolution spectroscopy of the 630nm night airglow emissions, was initiated with financial support from ISRO. The FP spectrometer will be used for measurements of neutral temperature and neutral wind field in the thermosphere over Kodaikanal/Kavalur during the WITS/STEP programme periods and the SROSS mission by ISRO (J.H. Sastri, A.K.Saxena, R.Sridharan*, K.B. Ramesh & J.P. Thangadurai).



The furnace and the electrical control.



The northern arm of the Decametre Wave Radio Telescope atGauribidanur

HF phase path (Doppler) sounder

To enhance the sensitivity and temporal resolution of the measurements of the phase path of ionospheric reflections and also to facilitate their speedy reductions, an IBM PC/XT based data acquisition system (DAS) was acquired and configured. Software for on line data acquisition was developed and tested. Application software is currently under development. The phase path sounder is equipped with multi-height/multi-aerial recording facilities. (J.H. Sastri, A.V. Ananth & K.B. Ramesh)

Optics Division

Casting of lightweight mirror blanks (CLIMB)

The project "CLIMB" made good progress. The furnace for casting the mirror upto 25" was completed. A first successful trial run of melting glass was carried out in early 1988. Preparations are now under way for casting a ribbed core mirror. (A.K.Saxena, J.C. Bhattacharyya, J.P.A. Samson, J.P. Lancelot & R.I. Jabilullah).

RC telescope

Fabrication of 27" RC telescope optics has been started. This telescope is being built jointly by the Bhabha Atomic Research Centre and IIA. A new mount and unconventional building concept is being tried. It will provide a feedback for the future 4 m telescope of the Uttar Pradesh State Observatory. A location for similar three telescopes has been finalised with a view to use them for intensity correlation studies (a collaboration with A.S. Marathay, OSC, Arizona) and speckle interferometry, for high resolution imaging (A.K. Saxena).

Small optics fabrication

Several small optical instruments (Table 3), were fabricated for the IIA as well as for the Indian Space Research Organization, the Udaipur Solar Observatory and Hindustan Photo Films. In addition, the polishing of Lithium Neobate crystals and the refiguring of an echelle collimator was also undertaken. (Optics team).

Table 3

Small optical instruments fabricated in the I.I.A. optics workshop.

Description	Quantity
Field lenses	4
Prisms	1
Optical windows	5
Flat mirrors	4

Solid coherence interferometer

A solid coherence interferometer is being fabricated using an alternative approach, by first fabricating a dove prism and then later cutting it into two halves, to give two arms of the interferometer. The right angle prism for the two arms can conveniently be made on the two cut sections. In the earlier approach from a parallel slab, the desired high accuracy could not be achieved. This instrument will be used for studying high resolution astronomical imaging. (A.K. Saxena, A.S. Marathay, J.P. Lancelot & L.Yeswanth).

Vacuum coating plants

Twenty mirrors in sizes ranging from 3" to 10", belonging to the IIA and other organizations, were aluminized. (A.K. Saxena, K.R.Kutty & J.P.A.Samson).

VHRR - Passive cooler fabrication

Satisfactory polishing of the VHRR passive cooler (sun shield panel) for the development model of the INSAT II satellite was recently

completed. A special glass blanking plate was made for polishing purposes. This yielded better results than the metal plate, used earlier. The work is continuing for models ETM-1 and ETM-2. (A.K. Saxena,M.G. Mohan and S. Razack).

Radio Group

Antenna array

The construction and testing of an array of 64 Yagi antennae, located at a distance of 450 m from the centre of the east west array in the northerly direction, is complete. (Ch.V Sastry & K.R. Subramanian)

Detector system

A data logging system, capable of recording 12-bit data at a rate of 30 s per sample, was built and tested. This unit will be used with the existing analog and digital receiver systems.

An 8 channel receiver, suitable for a variety of observations, was also built and tested. (Ch.V Sastry & K.R. Subramanian).

Solar Group

Digitiser

A microprocessor controlled digitiser for measuring solar rotation and its variation with the solar cycle, using the Kodaikanal data from 1905 onwards, was installed in April 1988. Measurements will commence soon. (K.R. Sivaraman, S.S. Gupta, S.M. Aleem, R. Howard* & P.Gilman*)

Solar variability

An experimental setup to form slit images of the Sun was developed. The study of solar variability involves the collection of a large amount of data, as well as uncertainty in flux measurements. To circumvent these constraints, an optical arrangement was designed, which makes use of the unidirectional focusing properties of a cylindrical lens. The optical setup will greatly aid in obtaining Ca K spectra, at all latitudes on the Sun. It is expected that this method will be more reliable than previous ones (J. Singh)

National Solar Vacuum Telescope

A concept report for the construction of a solar vacuum telescope in India was prepared. The proposed telescope will make use of adaptive optics and active mirror systems, to achieve theoretical resolution limits. Other salient features of this telescope are that is would be polarization free and would have a polarization measurement package in addition to a large echelle spectrograph. (K.R. Sivaraman & J.C. Bhattacharyya)

VBT - 2.34m Project

Documentation

Complete documentation for the VBT is now available. The manual was prepared in collaboration with the engineers of the Bhabha Atomic Research Centre. The 120 schematic and wiring diagrams, that appear in the manual, were fully tested. These have also been documented. (V. Chinappan)

Fibre linked coudé-echelle spectrograph

A proposal to construct an efficient coudé spectrograph, giving a resolution of 10^5 was made for the 2.34m VBT. The spectrograph would be kept at the coudé floor for stability and temperature control. It will be linked to the prime focus of the VBT, with the aid of optical fibres. Using the present design for the

spectrograph, good photometric accuracy with a clean instrumental profile, is likely to be achieved. Some flexibility in the choice of resolution and spectral range will accrue, by the use of two different cameras and detectors. This instrument could meet the requirements of many astrophysical problems, such as chromospheric activity, isotropic ratios, surface brightness distribution in spotted stars and a very high precision in line strength measurements. The estimated magnitude limit for a 1 hr exposure is about 10th magnitude, with the CCD detector. The operations of the spectrograph, like grating, rotation and so on would by handled by a microprocessor.(N.K.Rao, A.K.Saxena & S. Giridhar).

Optics

The 2.34 m mirror of the VBT was realuminised. The support system was improved, by replacing the bush bearing. An optical realignment was performed using the Wynne corrector system.

The secondary mirror figuring was also completed. The surface errors are within an accuracy of $\lambda/10$. These corrections were limited by the integrated surface errors of the Hindle sphere and bending flat used for testing the system. Any further corrections can be made only after seeing its performance on the telescope in conjunction with the primary mirror (A.K. Saxena & optics team).

Two 8" aperture and 3000 mm focal length achromats were purchased from Carl Zeiss for the two guide telescopes of the VBT. Work on the focussing units is continuing (K.K. Scaria & A.Gabriel).

Secondary mirror

Work on the secondary mirror and counterweight assembly control for the VBT has been started. A closed loop D.C. servo-motor control is being designed for this purpose. (V. Chinappan & R. Srinivasan)

Telescope control

An intel 8052 micro-controller based telescope control was installed and commissioned in the 0.76 m telescope at the VBT. Different speeds, such as set, guide, fine guide were produced by the micro-controller to move the stepper motor. The slow speed is achieved through the existing induction motor. Absolute encoders were mounted on right ascension and declination axes of the telescope. An accurate gear set manufactured locally was designed. The gear sets were ground to an accuracy greater than 5. To eliminate backlash, split gears with spring tension were designed. The 8052 micro-controller computes the hour angle, declination and right ascension.

Pointing and tracking

Further improvements in the pointing accuracy was achieved on the VBT. About 120 star positions were noted using the CCD camera at the prime focus. Though the pointing errors appeared large at first instance, a major fraction could be attributed to zero point errors of encoders, misalignment in altitude and azimuth, telescope flexure. The encoder zero points were corrected in the software, and the polar axis was readjusted. Better models of refraction correction, nutation and so on were used. Based on the data collected, the position of the telescope was corrected in both altitude and azimuth directions. (N.K.Rao, T.P. Prabhu, K.K.Scaria, V.Chinappan, A.V. Raveendran & R.Surendiranath)

Telescope flexure

A model for telescope flexure was developed. Corrections, based on this model, are currently being incorporated into the control micropro cessor. (N.K. Rao, T.P.Prabhu, K.K.Scaria, V.Chinappan, A.V.Raveendran & R.Surendiranath)

National Facilities

2.3 m VBT, data digitising equipment & computer system

To make the large optical telescope facility built up at the Vainu Bappu Observatory, Kavalur available to scientists of various Indian institutions, a programme was initiated. A national committee was formed to advise the Director regarding the suitability of various proposals received for observational time on the 2.3 m VBT. Besides this, a Perkin Elmer data digitising system (at Bangalore), a VAX 11/780 computer system are also offered to the entire astronomical community. The net result of these efforts has come in the form of CCD cameras being deployed for astronomical research in the country as well as towards the fabrication of a multi-channel photometer, which will enable the use of the telescope, even on partially cloudy nights.

Arrangements for several faint image detection systems have been worked out. These are expected to be utilized during the coming season, bringing out hitherto unavailable information in astronomy.

The scientists of the Institute have also designed a new instrument system for this national facility, which was discussed at length in the national workshop on astronomical instrumentation at Kodaikanal. Proposals for additional funds are presently under consideration by the Department of Science and Technology. It is expected to utilize this national facility by many more groups in the country in the forthcoming observing run.

The programme of making the Cassegrain focus available for general use did not progress as quickly as originally anticipated. This was mainly due to the design and fabrication difficulties of the secondary spider system. Fortunately, these problems have now been overcome and the mechanical part is ready for delivery by a manufacturing firm in Hyderabad. Efforts will be made, during the lean time in the coming observing season, to have the system mounted on the VBT.

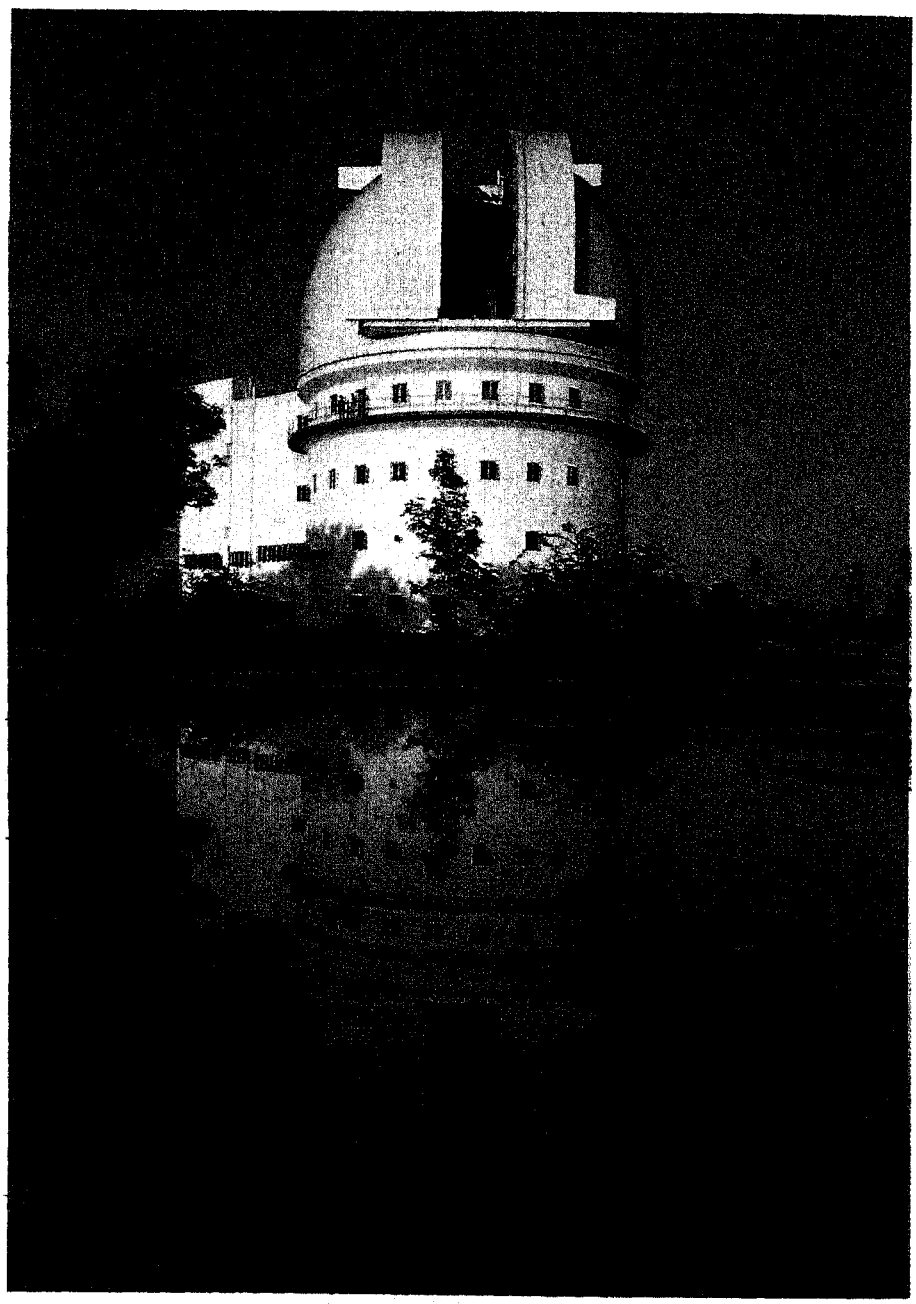
Instrumentation cell

The present phase of developments in observational astronomy is heavily dependent upon availability of new techniques and instruments. Hitherto, there was no established national facility by means of which new instruments for advanced astronomical observations could be designed and constructed. It was with precisely this in mind, that an instrument cell was created at the Institute. The cell offers a centrally located team which can take up such projects.

The programme functions as follows. A team of scientists, nominated from several institutions in India, supervise and offer technical advise on the suitability of specific designs. Individual scientists interested in building a new instrument can submit a proposal, accompanied with available details and rough sketches. Proper engineering drawings are then made by the core engineering group (CEG). The CEG will give due consideration to the engineering aspects of the design as well as to the possibilities of fabricating different parts and components, either indigenously or through imports of specific parts. After the preparation of these details, the principal investigator will be called to this unit for discussions and the designs and working drawings finalized. Instrumentation projects to be

funded from the budgets of individual institutes will also considered.

Funds for running the intrumentation cell will come initially from the allotted funds of the Institute. If the volume of work connected with this unit increases considerably, the Institute will examine the possibilities of expanding this unit to accommodate such demands.

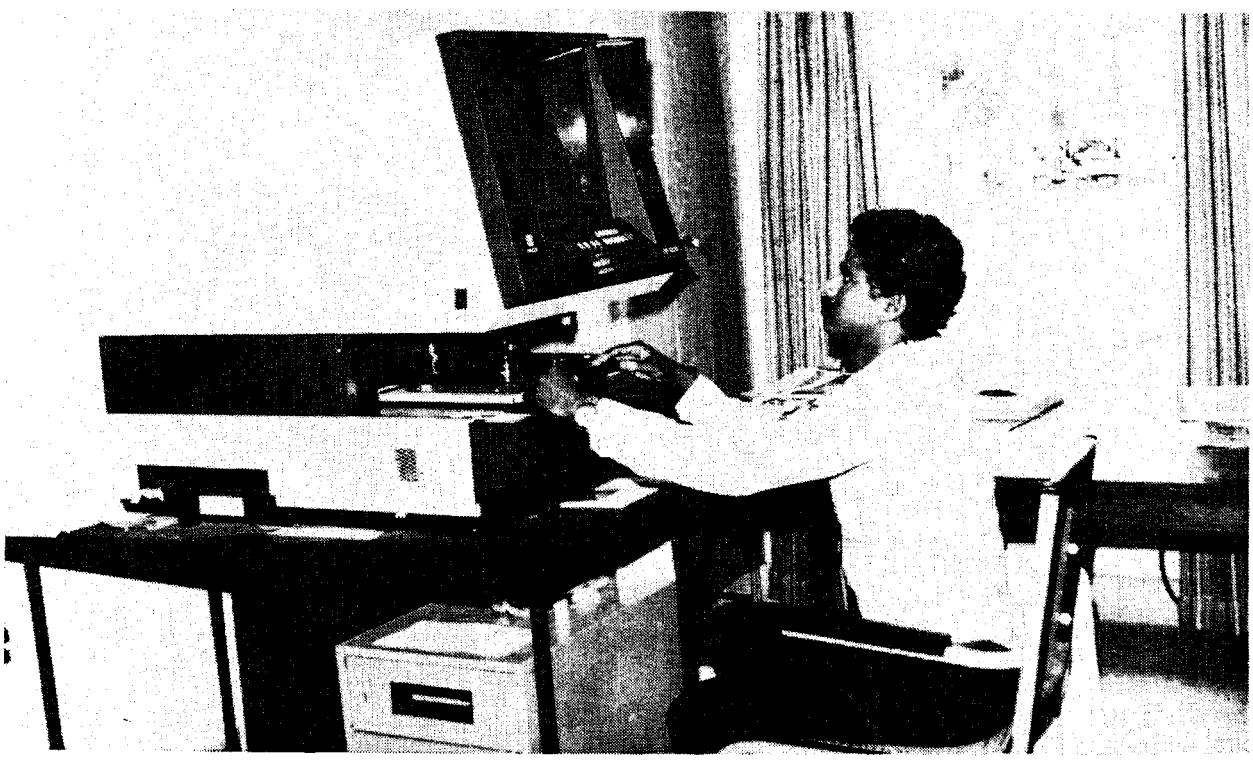


2.3 m telescope building at VBO, Kavalur.

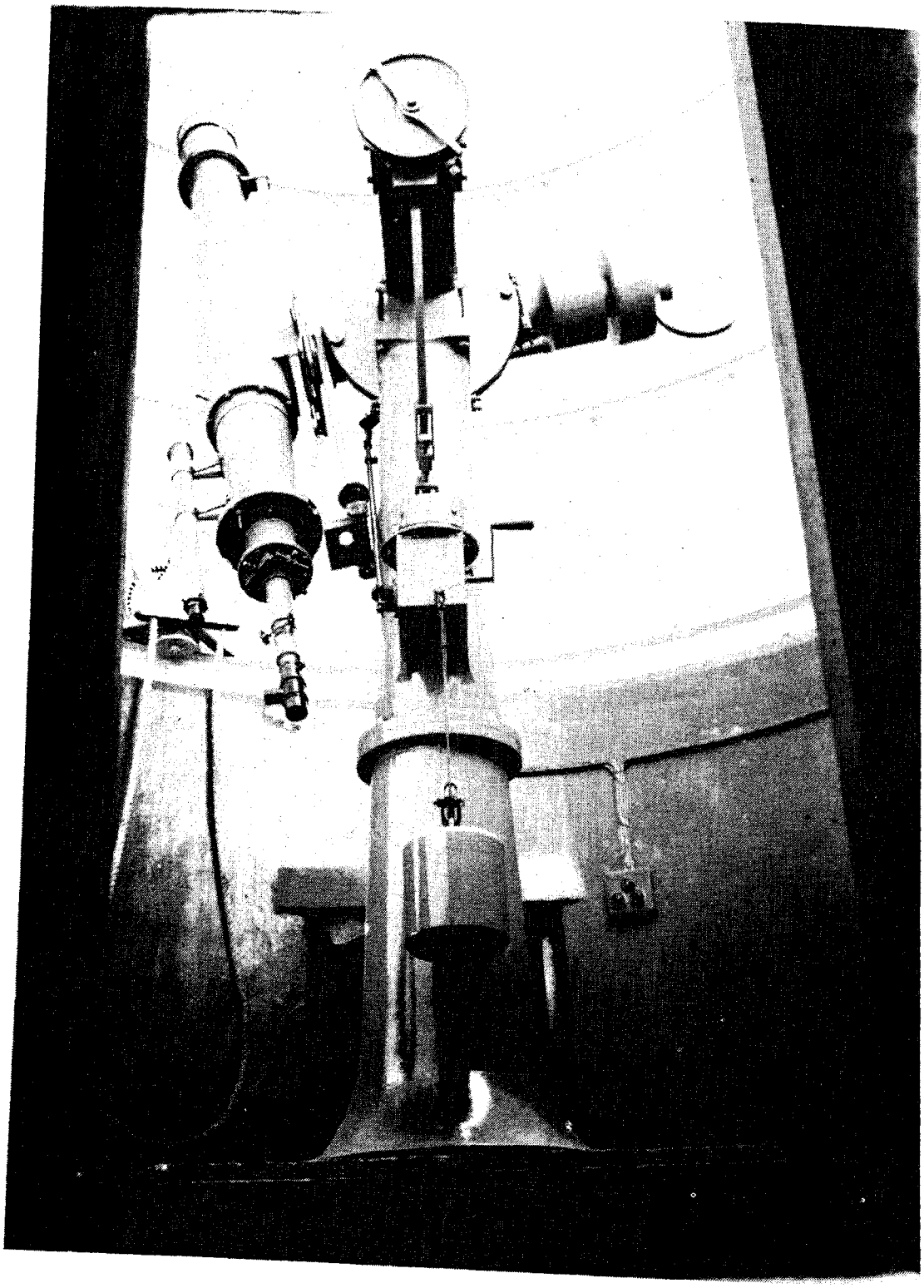
Library

The library subscribed to 139 journals with the addition of 2 new journals, Infrared Physics and Journal of Geomagnetism and Aeronomy. It continued to receive some 65 pubications on an exchange basis. An inter-library exchange with other astronomical libraries in the city helps it to display an additional 20 journals. During the year, 257 books were acquired for the library. The library extends a current awareness service through Recent Research in Astronomy and Astrophysics and the IIA preprint lists.

Some additional books and journals were procured as second copies for the Kavalur and Kodaikanal Libraries. The Library has acquired a Minolta RP 505 microfiche reader-printer. Computerisation of library routines is underway. Reference facilities are extended to outside research workers and scientists. Xerox copies of articles from the collection at the Institute were also supplied to other libraries.



The new Minolta RP 505 microfiche reader printer.



Equatorial 8 inch refractor telescope at the Kodaikanal Observatory.

Growth of Astronomy

Historical Landmarks

A bicentenary is an unique event in the lifetime of any institution. The Institute recently commemorated this occasion, by organizing symposia, exhibitions and popular talks. This is, perhaps, an appropriate moment to take stock of some of the notable events which occurred in its calendar.

1786

The Institute began as a private observatory in Egmore, Madras at the residence of William Petrie (died 1816), an officer of the East India Company. It was subsequently taken over by the Company and moved to a new campus in 1792.

1830

A five feet focus transit instrument and a four feet diameter mural circle, both made especially for the Observatory by Dolland, were acquired. With these instruments, Glanville Taylor (1804-1848) prepared the Madras catalogue, containing the position of 11015 stars.

1850

The Observatory obtained its first major telescope. Made by Lerebours and Secretan of Paris, it had an aperture of 6 inches and an equatorial mounting.

1866

An 8 inches aperture equatorial telescope was installed. This instrument along with the 6 inches telescope played an important part in the discovery from Madras of minor planets and variable stars by Norman Robert Pogson (1829-1891).

1868-1872

Madras observatory teams observed solar eclipses in 1868,1871 and 1872, the first two being total and the third annular. At the latter, the chromospheric or flash spectrum was taken by Pogson. This is the first record of such an observation at an annular eclipse.

1900-1905

After the Observatory moved to Kodaikanal in 1900, systematic visual observations of prominences commenced thereafter, using the 6 inches telescope and a grating spectroscope. In 1904 a two prism spectroheliograph, made by Cambridge scientific instruments, was installed and daily photographs of the solar limb and disc were taken.

1909

John Evershed discovered the presence of radial mass outflow in sunspots. This phenomenon is known as the Evershed effect.

1934-35

A Hale spectrohelioscope was acquired and from then on visual examination of prominences and solar flare patrol observations began. The presence of oxygen in the solar chromosphere was discovered by T. Royds.

1957-58

The Observatory became a part of the IGY (international geophysical year) network. An H-alpha Lyot filter was installed.

1960-1970

A solar tower telescope was commissioned in 1960 and a new era began in solar observations at high spatial and spectral resolution. Using molecular lines, a model for the chromosphere near the temperature minimum was developed. In 1966 a magnetograph was constructed for measuring weak magnetic and velocity fields on the solar surface. Detailed studies of 5 min oscillations and the monitoring of the sun as a star, as well as its time variability, were carried out.

1968

Stellar work was resumed with the completion of a new observatory at Kavalur. Regular observations commenced, using an indigenously built 38 cm telescope. Subsequently, a 1 m telescope, from Carl Zeiss Jena, was installed.

1970

A two-man expedition observed the total solar eclipse in Mexico. An analysis of the data indicated the presence of neutral hydrogen and helium in the solar corona.

1971

The Observatory was restructured as an autonomous research institute and renamed Indian Institute of Astrophysics. In 1972, an atmosphere was detected around Jupiter's satellite Ganymede.

1974

A project for indigenously building a 2.3 metre optical telescope at Kavalur was officially sanctioned. A blank of Zerodur glass, bought from West Germany arrived and shortly afterwards work on the telescope began under the guidance of M.K.V.Bappu (1927-1982).

1976

The main campus was shifted from Kodaikanal to Bangalore.

1977

Rings around Uranus were discovered utilizing the technique of lunar occulation.

1979

A decameter wave radio telescope, built jointly with the Raman Research Institute, started functioning at Gauribidanur, near Bangalore.

1980 & 1983

Expeditions were sent to Raichur and Indonesia in 1980 and 1983 respectively, to observe total solar eclipses. These enabled two dimensional maps of the temperature structure in the solar corona to be made. A solar cycle dependence of the random turbulent velocities was found.

1984

A ring structure was detected around Saturn at a distance of 12.5 radii.

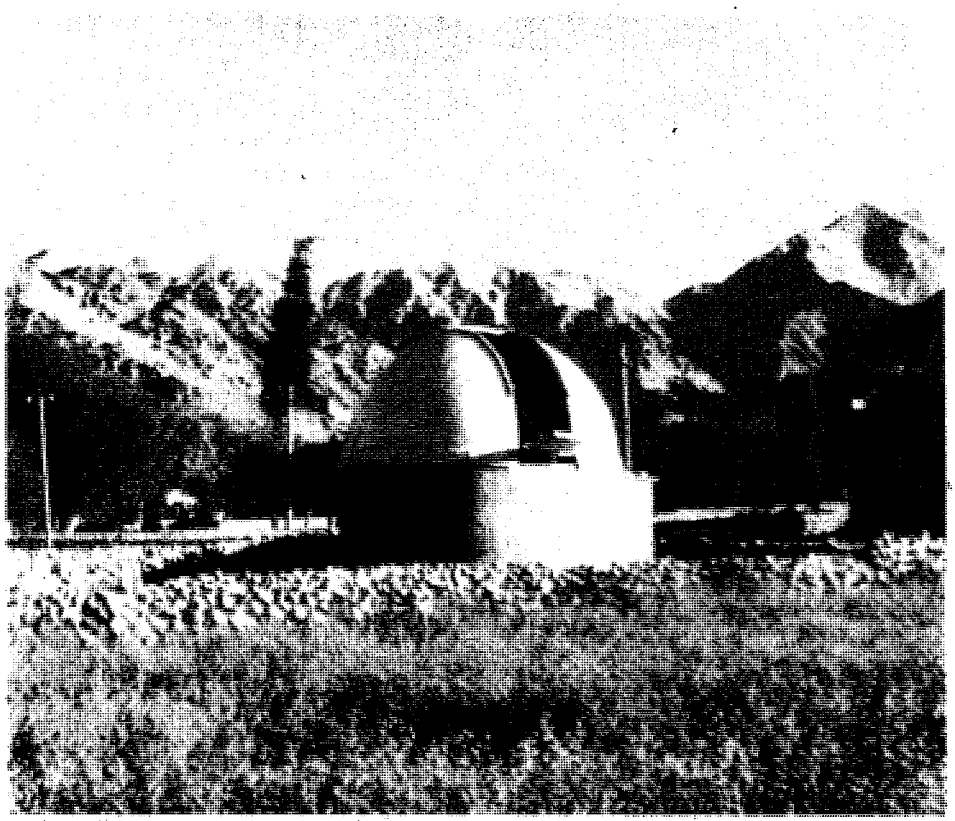
1986

The 2.3 metre telescope was officially inaugurated by the Prime Minister Rajiv Gandhi, although the earliest observations were obtained the year before. Both the telescope and observatory were named after Vainu Bappu, in recognition of his pioneering achievements.

Astronomy museum at Kodaikanal

As part of its programme to disseminate astronomy, the Institute set up an Institute Museum in the Mitchie Smith Hall at the Observatory in Kodaikanal. This was possible through the efforts of two of the staff members, R.C. Kapoor and K.K.Scaria.

The museum has photographic displays, a spectrograph, a photohelioscope, a model (in metal) of the 2.3 m VBT and a few instruments of historical interest. Themes are developed



20 inch telescope building at Leh (village Scara), Ladakh.

through photographs and charts to introduce the Sun, the stars, the galaxies and astronomical techniques. Also on display are the accounts of the Institute's history and contributions to astronomy by former directors. A touch of realism is injected through the live display of a spectrograph, which shows the visible solar spectrum, and a photohelioscope, which depicts various features on the solar disc, like sunspots. A Foucault siderostat is used to shine sunlight on both these instruments.

The Foucault siderostat is one of the oldest instruments the Observatory possesses. It was received from the Takhtasinghji Observatory, Poona in 1912 by John Evershed, the director at that time. The 12" flat mirror of the instrument, made by Grubb, has been used in many research projects of the Observatory. It was used by K.K.Scaria in 1980 to obtain 5 high quality photographs of the solar corona in white light. At present this instrument along with the spectrograph and photohelioscope are located in the north end of the Museum.

High Altitude Site Survey Observatory - Leh project

Situated in the Ladakh region at an altitude of 3300 m above sea level, the High Altitude observatory at Leh functions under the auspices of the Department of Science and Technology. The site was favoured because it is a high altitude desert, where the low level of atmospheric moisture prevents a significant absorption of infrared radiation. Furthermore, since the monsoons never reaches this area, the skies are usually clear. There are several peaks, with heights over 4000 m, in the region, from which

the final site for the future observatory may be chosen.

A 50 cm optical reflector telescope, equipped with a photoelectric photometer, was installed by the Institute. Regular site survey and serious scientific observations are being carried out. Photoelectric observations initially faced a major problem due to the electronic components malfunctioning when the ambient temperature dropped far below freezing. However, it is now possible to observe at ambient temperatures up to -10°C, by incorporating heater elements in the system.

A final assessment regarding the suitability of this site for astronomical observations is likely to be made in early 1989.

Pachmarhi project

The Madhya Pradesh Council of Science and Technology plans to set up an optical observatory in Pachmarhi (altitude 1300 m), located 240 km from Bhopal. A 8" reflector telescope, with an equatorial mount and electrically operated diurnal drive, was acquired for this purpose. The telescope was modified in the workshop of the Institute for direct photography and photoelectric photometry at its Cassegrain focus. Two scientist, sent from Bhopal, were trained in the use of telescopes and photometry. K.K.Scaria and co-workers are assisting the Madhya Pradesh Government in the realization of this project.

Expedition to Mauritius

Since the extreme southerly position of supernova 1987A was inconvenient for observations from Kavalur, a southern hemisphere site on the island of Mauritius was selected for observing this astronomical object. A two-man expedition, consisting of G.S.D.Babu from the Institute and A.K.Bhatnagar of the Positional Astronomy Centre (PAC), Calcutta, were sent for this purpose. Their aim was to carry out photometry of the supernova in B,V,R,Hα and 6300Å, using a Celestron-14 telescope, belonging to the PAC.

During their stay of a month in February 1988, the number of cloudless nights was very low. Nevertheless, they were able to get reasonably good observations of the supernova on one night. These observations revealed that the counts in B and V filters were comparable to each other, while those in the R filter were twice as large as those in the V filter. The counts in the Hα and 6300Å filter were well above the sky background. The visual magnitude of the the supernova was around +7 magnitude during this period.

History of optical technology in India

Investigations into the history of the optical glass industry in India had been previously compiled and presented in the form of a paper to the Journal of History of Science. Work is currently being carried out on optical technology in India, by A.K.Saxena, A.Vagiswari and M.Manjula. This project has been sponsored by the Department of Science of Technology.

Conferences/lectures organized by the Institute

National workshop on 'Astronomical instrumentation in India: past, present & future',Kodaikanal, 1987 August 10-12.

Second national workshop on 'Solar physics',Kodaikanal, 1987 September 24-29.

National workshop on 'Comet Halley', Ban-

galore, 1987 October 27-29.

Workshop on 'Supernova 1987A', Bangalore, 1988 February 24-25.

Bicentennial commemorative public lecture 2 by A.P.Mitra (Director General CSIR) on 'Aeronomy research in India: problems and prospects', Bangalore, 1988 January 29.

Awards/Honours

A.P.Jayrajan and S.C.Tapde were awarded the VASWIK award in recognition of their services towards the design and construction of the 2.3 m optical telescope. The paper entitled 'Vertical uplift of equatorial F region during post mid-night period' and by J.H.Sastri and D.Karunakaran was awarded the second prize for the best contributed paper in the poster session of the National Space Science Symposium, PRL, Ahmedabad in December 1987. Another paper 'Simultaneous HF Doppler and ionosonde observations on the onset conditions of equatorial spread-F' by Sastri *et al.* was awarded the prize for the best contributed paper in the session on 'Upper atmosphere and ionospheric dynamics' at the same meeting.

J.C.Bhattacharyya was nominated as a member of the editorial board of Astrophysics and Space Science. B.Datta and V.Krishan were selected as panel speakers in the Theoretical Physics seminar circuit of the Department of Science and Technology. V.Krishan was elected as a council member of the Plasma Science Society of India in December 1987. A.K.Saxena was elected as an executive council member of the Optical Society of India for 1988-89.

Staff at the Bangalore Campus, June 1988.

Seated (from left): S.K.Jain, K.R.Sivaraman, J.H.Sastri, G.A.Shah, R.Rajamohan, M.Parthasarathy, J.C.Battacharyya (Director), V.Krishan, R.C.Kapoor, R.Sagar, B.R.Madhava Rao, S.S.Hasan, G.S.D.Babu.

Standing, First Row: K.S.Balasubramaniam, R.K.Kochhar, P.K.Raju, Ch.V.Sastry, D.C.V.Mallik, P.K.Das, A.K.Saxena, J.Singh, S.V.G.Mallik, S.P.Bagare, P.M.S.Namboodiri, R.Vasundhara, G.C.Anupama, K.Ramankutty, A.T.A.Hameed, R.Surindranath, S.Mohin.

Second Row: A.K.Pati, M.H.Gokhale, A.Peraiah, R.Muraleedharan Nair, H.C.Bhatt, R.Kariyappa, K.B.Ramesh, J.P.L.C.Thangadurai, J.P.A.Samson, K.S.Ramamoorthy, K.R.Subramanian, K.E.Rangarajan, A.V.Raveendran, D.Mohan Rao.

Third Row: V.Chinnappan, G.Thejappa, K.N.Nagendra, R.S.Narayanan, G.Srinivasulu, K.K.Scaria, K.G.Unnikrishnan Nair, T.P.Prabhu.

Staff List

(in June 1988)

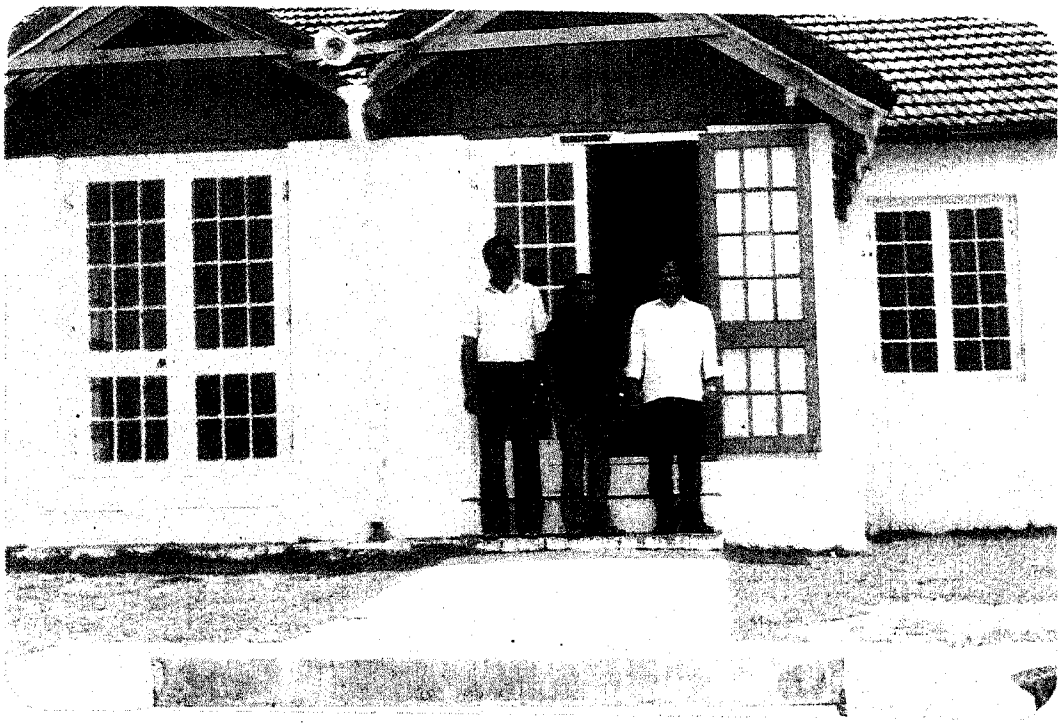
Academic Staff

J.C.Bhattacharyya	Director
M.H.Gokhale	Professor
A.Peraiah	Professor
Ch.V.Sastry	Professor
G.A.Shah	Professor
K.R.Sivaraman	Professor
S.S.Hasan	Associate Professor
R.K.Kochhar	Associate Professor
V.Krishan	Associate Professor
N.K.Rao	Associate Professor
J.H.Sastri	Associate Professor
P.K.Das	Reader
B.Datta	Reader
R.C.Kapoor	Reader
D.C.V.Mallik	Reader
M.Parthasarathy	Reader
T.P.Prabhu	Reader
R.Rajamohan	Reader
P.K.Raju	Reader
R.Sagar	Reader
A.K.Saxena	Reader
K.K.Scaria	Reader
J.Singh	Reader
C.Sivaram	Reader
P.Venkatakrishnan	Reader
G.S.D.Babu	Fellow
S.P.Bagare	Fellow
H.C.Bhatt	Fellow
S.Chatterjee	Fellow
V.Chinnappan	Fellow
K.K.Ghosh	Fellow
S.K.Jain	Fellow
A.K.Pati	Fellow
A.V.Raveendran	Fellow

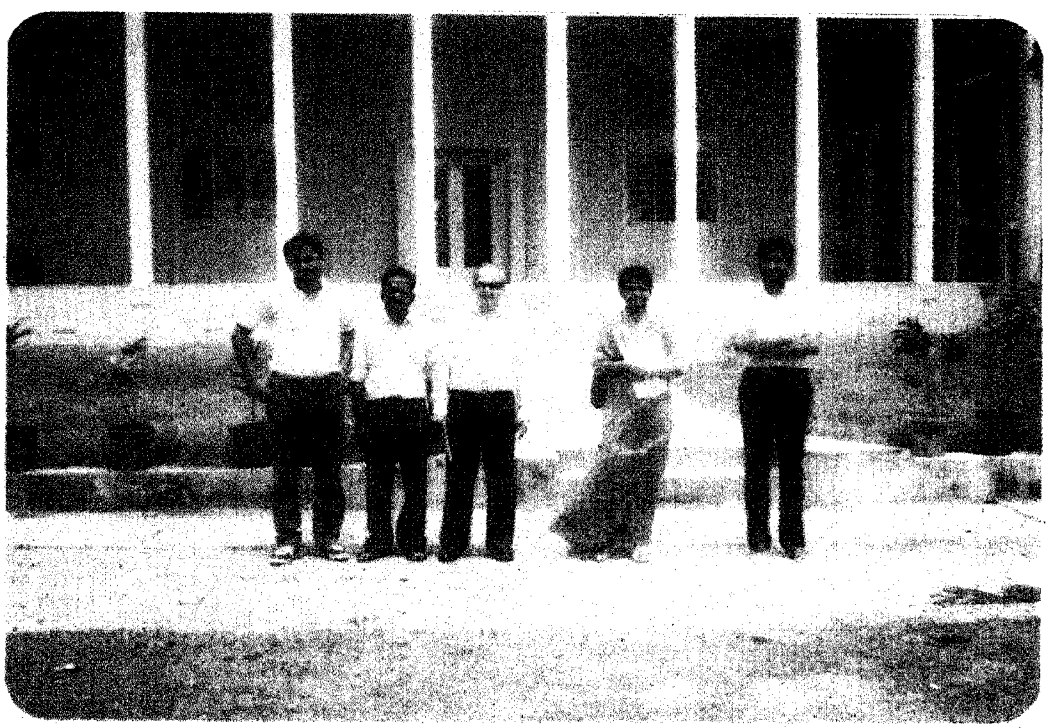
B.S.Shylaja	Fellow
K.R.Subramanian	Fellow
G.Thejappa	Fellow
P.S.M.Aleem	Research Associate
S.Giridhar	Research Associate
S.S.Gupta	Research Associate
R.Kariyappa	Research Associate
S.V.G.Mallik	Research Associate
D.M.Rao	Research Associate
S.Mohin	Research Associate
B.S.Nagabhushana	Research Associate
K.N.Nagendra	Research Associate
P.M.S.Namboodiri	Research Associate
R.S.Narayanan	Research Associate
K.B.Ramesh	Research Associate
K.E.Rangarajan	Research Associate
S.K.Saha	Research Associate
K.Sasidharan	Research Associate
K.Sundar Raman	Research Associate
R.Surindranath	Research Associate
J.P.L.C.Thangadurai	Research Associate
R.Vasundhara	Research Associate

Technical Staff

A.P.Jayarajan	Consultant
R.Srinivasan	Head, Electronics Labs. & Computer centres
A.V.Ananth	Senior Electronics Engineer
B.R.M.Rao	Senior Mechanical Engineer
N.Selvavinayagam	Civil Engineer
R.Sivashanmugam	Technical Officer
G.Srinivasulu	Computer Engineer
S.S.Chandramouli	Technical Associate
A.M.Ghouse	Technical Associate
A.T.A.Hameed	Technical Associate
R.Muraleedharan Nair	Technical Associate
K.Narayanankutty	Engineer Associate
K.Ramankutty	Technical Associate
K.S.Ramamoorthy	Technical Associate
J.P.A.Samson	Technical Associate
K.G.Unnikrishnan Nair	Technical Associate
A.Vagiswari	Librarian



Staff at the Kodaikanal Observatory, June 1988.
(from left) : K. Sunderaraman, S.S.Gupta & B.S.Nagabhushana



Staff at the Vainu Bappu Observatory, Kavalur, June 1988
(from left) : K.K.Ghosh, R.Sivashanmugham, J.C.Bhattacharyya, Sunetra Giridhar & K. Narayanan Kutty.

APPENDIXES

Appendix A

Publications

In Journals

Ashoka,B.N., Anupama,G C., Prabhu,T.P., Giridhar,S., Ghosh,K K., Jain,S.K., Pati,A.K., Rao,N.K.(1987) J. Ap. Astr. 8,195 . Evolution of the optical spectrum of SN 1987A in the Large Magellanic Cloud .

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Datta,B. & Kapoor,R.C.:International conference on

'Gravitation & Cosmology', Goa, 14-19 Dec. 1987 Effect of large rotation on the spectral characteristics of radiation from neutron stars as a function of their masses.

Despande, A.A. & *Radhakrishnan, V.:12th Astronomical Society of India meeting, Raipur, 2-5 Dec. 1987. Pulsar observations at 34.5 Mhz with the Gauribidanur radio telescope.

Giridhar,S :12th Astronomical Society of India meeting. Raipur, 2-5 Dec. 1987. The ultraviolet observations of WCll hydrogen deficient star CPD -56° 8032.

Krishan,V.:Plasma Science Society of India meeting, Ahmedabad, Dec. 1987. Parametric instabilities in astrophysical plasmas

—: Indo-US workshop on 'Solar Activity', Udaipur, Feb. 1988. Theories of solar flares.

—: Workshop on 'Supernova 1987A', Bangalore, 24-25 Feb. 1988. Introduction to the supernova phenomenon.

Lancelot,J.P. & Saxena,A.:16th Optical Society of India Symp., Calcutta, 16-18 Jan. 1988. Coherence interferometer for astronomical seeing.

Pati, A.K.:National Workshop on 'Astronomical instrumentation in India - past, present and future', Kodaikanal, 10-12 August,1987. A multiple application system for faint objects for the 2.3 metre VBT.

Prabhu,T.P.:National Workshop on 'Astronomical instrumentation in India - past, present and future', Kodaikanal, 10-12 August,1987. Current astronomical instrumentation - a global view

—: Workshop on 'Supernova 1987A', Bangalore, 24-25 Feb. 1988. Supernova statistics.

Sastri,J.H. & Karunakaran,D.:National Space Sci.Symp., Physical Research Lab., Ahmedabad, 21-24 Dec 1987. Vertical uplift of equatorial F region during post midnight period.

Saxena,A.K. & Bhattacharyya,J.C.:12th Astronomical Society of India meeting, Raipur, 2-5 Dec. 1987. A step towards new technology telescope - CLIMB.

Scaria,K.K..Jagdish Bose Science Talent Search Silver Jubilee Seminar, Calcutta, 3-5 July 1987. Astro-photography.

Seal,P.:IAU Coll. 103 on 'The Symbiotic Phenomenon',Torun, Poland, 18-21 Aug. 1987. The Symbiotic star UV AUR.

*Sinha,B.,*Raha,S. & Datta,B.:International conference on 'Ultra-relativistic nucleus-nucleus collisions', Schloss Nordkirchen, West Germany, 24-28 Aug. 1987. Dileptons and photons in the transverse mass momentum window.

Sivaram,C.:International conference on 'Gravitation & Cosmology', Goa, 14-19 Dec. 1987. Some astrophysical consequences of an intermediate-range force modification of gravity.

—: The final state of an evaporating black hole.

—: Workshop on 'Supernova 1987A', Bangalore, 24-25 Feb. 1988. Gravitational waves from collapsing stars.

—: Neutrinos from supernova 1987A.

Sivaraman,K.R.:2nd National Workshop on 'Solar physics',Kodaikanal, 24-29 September 1987. National Solar Vacuum Telescope.

Thejappa,G.:Spring College on 'Plasma Physics',Trieste, Italy, May-June 1987. Solar type II bursts.

Vasundhara,R.&Bhattacharyya,J.C.B.:Symposium on 'Advances in planetary physics', Banaras, 14-19 Dec. 1987. Outer rings of Saturn.

Venkatakrishnan,P.,*Haygard,M.J. & *Hathaway, D.:American Geophys. Union Meeting, Baltimore, 16-20 May, 1988. Quantitative estimation of magnetic shear in off-disk center magnetograms.

Venkatakrishnan,P.:American Astronomical Society Meeting, Kansas City, 5-9 June 1988. The magnetic configuration of AR 4474 before the flares of April 24 & 28 1984: a comparison.

Lectures by visiting scientists

B.Sinha (VECC, Calcutta) : Quark-gluon plasma: some astrophysical applications (5-6-87).

P.Witta (Georgia State University, Georgia, USA) : The cosmological evaluation of the size of the extended radio sources (28-7-87).

R.Pratap (Cochin University, Cochin) : Invariant representations in dissipative systems (13-10-87).

S.Ramadurai (JAP, IISc., Bangalore) : Supernova 1987A - role of rotation (20-10-1987).

C.Jog (JAP, IISc., Bangalore) : The velocity dispersion of the giant molecular clouds: a viscous origin (17-11-1987).

W.Kundt (University of Bonn, Bonn, West Germany)· Supernovae and supernovae shells.

Martin,A.Lee (University of New Hampshire, USA) : Shock acceleration of energetic particles in the heliosphere (4-12-1987).

Yasuo Fukui (Nagoya University, Japan) . Where stars are born? (10-12-1987).

N.Vishwanathan (Mt.Stromlo and Siding Spring Observatories, Australia) : Global values of the Hubble constant (21-12-1987).

C.Iwaniszevska (Nicolous University, Torun, Poland) : Polish Astronomy-Copernicus Havelines and Contemporary Astronomy (29-12-1987).

V.V Krasnosel'skikh (IZMIRAN, Troitsk, USSR) : Quasiperpendicular collisionless shocks with high Mach numbers (18-01-1988).

C.T.Vanajakshi (NASA/AMES Research center, USA): Angular momentum problem in star formation-models of possible mechanisms (19-01-1988).

A.Arellano Ferro (University of Mexico Mexico) · F-supergiants off the galactic disc (25-01-88).

—: Modern Astronomy in Mexico (17-2-1988).

K.Shivanandan (NRL, Washington, USA,) : Arrays for infrared astronomy (27-01-1988).

R.Howard (NSO, Tucson, Arizona, USA) : National solar Observatory (2-2-1988).

M C E Huber (E.S.A. The Netherlands) : Deformable grating for an EUV spectrometer (2-2-1988).

J.Rankin (University of Vermont, Burlington) : The Crab Nebula: dispersion, scattering and Faraday rotation variations to the pulsar 1969-1977 (8-3-1988).

R.Ramanna (Former Chairman, Atomic Energy Commission) : 50 years of Nuclear Fission (22-3-1988).

J.E.Solheim (University of Tromso, Norway): Oscillations on white-dwarfs single and binary systems (18-4-1988).

—: Nordic Telescope Project (20-4-1988).

—: History of physics of northerm lights (Aurora) (15-5-88).

M.A.Gopinath (I.S.I., D.R.T.C. Bangalore): Applications of Thesaurus in informational retrieval (19-4-1988).

C.L.Bhat (B.A R.C. Srinagar) : γ-ray Astronomy with conventional optical telescopes (20-4-1988).

A.R Prasanna (P.R L. Ahmedabad) : Gravitation as a gauge theory (28-4-1988)h.

S.K.Trehan (Punjab University, Chandigarh) . Perturbation methods (27-4-1988).

R.Sinha (Space Science & Engineering System Corporation, USA) : The 3K microwave background (20-5-1988).

B.Chakraborty (Dept. of Mathematics, Jadavpur University, Calcutta) : Physics of Rotating Frames I.Electrodynamics (17-5-88).

—: Physics of Rotating Frames II Some geometry, transformation and mechanics (19-5-1988).

—: On non-linear rotation of polarization ellipse of waves in plasmas and other media (24-5-1988).

—: Non-linear Alfvén waves in plasmas (31-5-1988).

Lectures given outside the Institute

J.C Bhattacharyya: Optical and infrared astronomy, Summer school on astronomy and astrophysics, Bangalore (1987 June).

—:Observational astronomy in India, Bhopal University, Bhopal (1987 September).

Hasan,S.S.:Oscillations in magnetic flux tubes on the Sun, Kiepenheuer Institut fur Sonnenphysik, Freiburg, F R.G. (1987 September).

S K.Jain:Photoelectric measurements in astrononomy, in the short-term course on 'Opto-electronic systems', Indian Institute of Science, Bangalore, (1987 September).

—: Some applications of optical modulators in astronomy.

Mallik,D.C.V.:Mass loss from late-type supergiants, IA-UNAM, Mexico (1987 November).

—: The filling factor, IA-UNAM, Mexico (1988 January).

—: Progenitors of planetary nebulae, Washburn Observatory, University of Wisconsin, Madison, U.S.A. (1987 January).

K.N.Nagendra:Resonance line polarization in spherical atmospheres, Observatoire de Nice, Nice, France (1987 September).

—: A theoretical study of linear polarization in the lines formed in extended atmospheres, Institute fur Theoretische Astrophysik der Universitat Heidelberg, Heidelberg, F.R.G. (1987 October).

R.Sagar:Observational techniques in astrophysics, Schrodinger Birth Centenary refresher course in theoretical physics, D.A.University, Indore (1987 November).

C.Sivaram: Inflation and quantum gravity Moscow Univ. (1987 August).

—: The early universe and problems of big bang cosmology, Summer school on astronomy and astrophysics, Bangalore(1987 June).

—: Cosmic strings and galaxy formation, Institute of Nuclear

Physics, Bologna University (1988 April).

Meetings attended

Annual Meeting of the Indian Academy of Sciences, Hyderabad 7-9 Nov. 1987.
J.C. Bhattacharyya

Asiatic Society Seminar on 'Astronomy & mathematics in ancient India', Calcutta, 17-19 May 1987.
R.K. Kochhar.

5th Cambridge Workshop on 'Cool stars, stellar systems and the Sun', Boulder, U.S.A., 8-11 Aug. 1987.
S.P.Bagare.

Indo-US Workshop on 'Solar activity', Udaipur, Feb. 1988
V. Krishan, Ch.V.Sastry & G.Thejappa.

International Conference on 'Physics and astrophysics of quark-gluon plasma', Bombay, 8-13 Feb. 1988.
J.C.Bhattacharya, V.Krishan & G.Thejappa.

International conference on 'Gravitation & Cosmology'.Goa 14-19 Dec. 1988.
J.C.Bhattacharya.

NATO Advanced Study Institute on 'Hot thin plasmas in astrophysics', Cargese, Corsica, France, 7-19 Sept. 1987.
K.N.Nagendra.

171st Meeting of the American Astronomical Society, Austin, U.S.A., 10-14 Jan. 1988.
D.C.V.Mallik.

Symp. on 'Advances in planetary physics', Banaras, 14-19 Dec. 1987.
P.K.Raju & R.Sagar.

12th Meeting of the Astronomical Society of India. Raipur, 2-5 Dec. 1987.
R.Sagar.

Visits to scientific institutions

S.P Bagare visited the National Solar Observatory at Sacramento Peak,Sunspot and Kitt Peak, Tucson, U.S.A. during July-August 1987 for observational work. S.S. Hasan returned in December 1987 after a long term visit to the School for Mathematical Sciences, Queen Mary College, London, England. S.K. Jain and D.C.V. Mallik visited the Physical Research Laboratory, Ahmedabad in August 1987. Mallik also visited the Instituto de Astronomia of Mexico University. Mexico between October 1987 and January 1988 followed by a fortnight's stay at Washburn Observatory, University of Wisconsin, Madison, U.S A. K.N.Nagendgra visited the Institut d' Etudes Scientifiques de Cargese, Cargese, France in September 1987. He also spent a month at the Institut fur Theoretische Astrophysik der Universitat Heidelberg, Heidelberg, F.R G. in October 1987. B.S.Shylaja visited the Physical Research Laboratory, Ahmedabad during April-June and September 1987. C.Sivaram visited the Academy of Sciences, Moscow, U.S.S.R. during July-August,1987 under an exchange programme with the Indian National Science Academy. G.Thejappa spent May-August 1987 at the Astronomical Observatory, Trieste, Italy P.Venkatakrishnan spent a year from July 1987 as an NRC-NAS resident research associate at NASA/MFSC, Huntsville, U.S.A..He was also a short term consultant at the Harvard Smithsonian Center for Astrophysics in May 1988

Appendix B

Teaching of astronomy

The Institute has continued its active participation in the Joint Astronomy Programme (JAP) with the Department of Physics, Indian Institute of Science, Bangalore. H.C. Bhatt and T.P.Prabhu gave courses on 'The interstellar medium' and 'Techniques in optical astronomy' respectively. The Institute also played a prominent role in the 1987 summer school in Astronomy and Astrophysics, organized by JAP. D.C.V.Mallik gave two lectures on 'Gaseous nebulae'. T.P.Prabhu also lectured at the summer school and guided one of the students on a short project.

M.Parthasarathy gave four extension lectures at the Centre of Advanced Study in Astrononmy, Osmania University, Hyderabad on 'High galactic latitude F supergiants', 'Symbiotic stars', 'Nucleosynthesis' and' Early chemical history of the Galaxy'. A. Peraiah gave 20 lectures on 'Stellar atmospheres' in the Department of Astrononmy and Space Sciences of Punjabi University, Patiala in October 1987.

The Birla Institute of Technology and Science, Pilani deputed a batch of students as part of their Practice School I to the Institute. T.P.Prabhu is guiding G.C.Anupama and D.Mayya towards their Ph.D theses.

Editing and publishing

The Journal of Astrophysics and Astrononmy (JAA) and the Bulletin of the Astronomical Society of India (BASI) continue to be edited in the IIA. JAA has entered its ninth volume. J.C.Bhattacharyya assumed the chairmanship of its editorial board since December 1987. T.P.Prabhu and R.K.Kochhar continue as associate editors of JAA and BASI respectively.

The IIA newsletter entered its third year in January 1988. T.P.Prabhu and A.K.Pati edit the newsletter on behalf of the Director of the Institute.

Proceedings of the 2nd National Workshop on Solar Physics, organized by the Institute, were edited by Ch.V.Sastry and V.Krishan.

Book reviews

S.K.Jain reviewed 'Polarized light in Nature' by G.P.Konnen. Cambridge University Press (1986) for the Bull. Astron. Soc. India. V.Krishan reviewed 'Wave interactions and fluid flows' by A.D.D Craik, Cambridge University Press (1987) and 'Interstellar magnetic fields'.ed. R.Beck & R.Grave, Springer Verlag (1987) also for the Bull. Astron. Soc. India (vols. 15 & 16 respectively).

Popular Articles

Bhattacharyya,J.C.(1987) Asia-Pacific Physics news..Vol 2,No. 1. Facilities for optical astronomy in India.

Bhattacharyya,J.C.(1987) Science Age, May. Supernova 1987A.

Bhattacharyya,J.C.(1987) Science & Culture (in press). Saha Equation: A giant step in Astrophysics.

Bhattacharyya,J.C.(1987).Desh (Bengali), April. Grahanu.

Bhattacharyya,J.C.(1987).Desh (Bengali) April. Supernova.

Bhattacharyya,J.C.(1987).Kishore Jnan Bigyan (Bengali). Bahu Puratan Bhav. Nava Aviskar.

Bhattacharyya,J.C.(1988).Jnan O Bigyan (Bengali). Doppler-Fizeau-Prabhav.

Babu, G.S.D. (1987). Jantar Mantar Science Today, June.

Datta, B. & Kapoor, R.C. (1987) Science Today, July. Fast Pulsars.

Datta, B. & Kapoor, R.C. (1988) L'Astronomia (Italian, in press). Fast Pulsars.

Gokhale,M.H. (1987) Science Age, August. The Active Sun

Jain,S.K. (1987) Science Express, Sept 1. Big Bang in the sky

Jain,S.K.(1988) Science Express, March 22. The hot n' cold of weather.

Shylaja,B.S.1987, Manvantara (Kannada). Comet Wilson.

Sivaraman.K.R. (1987) Science Age, July. The Inconstant Sun.

Popular reviews

B.Datta reviewed 'Asimov's new guide to Science' by Isaac Asimov, Penguin (1987) for The Sunday Telegraph, Calcutta (13.12.87).

Radio/TV and film programmes

G.S.D.Babu coordinated and participated in a UG television programme on the facilities at the Kavalur Observatory. The script was written by him and N.K.Rao J.C.Bhattacharyya gave two interviews on All India Radio (AIR), on 'Astronomy for the common man' and 'New supernova' (in Bengali). M H.Gokhale wrote the script and coordinated the production of an educational film 'In-

troduction to the physics of the Sun', presently being edited at the E.M.R.C Gujarat University, Ahmedabad.

Popular talks

J.C.Bhattacharyya gave talks on 'The present astronomical observations in India' at the Bangalore Science Forum, Bangalore (1987 July) and two talks in Gulbarga at the Science Gallery of the District Science Centre and Science Club. G.S.D.Babu spoke on popular themes at St. Joseph's College and the Rotary Club, Bangalore, the Nehru Planeterium and the Airforce Officer's Mess, New Delhi, the Rotary Club and Meteorological Services Headquarters, Mauritius and the Vijaya College, Mulki, South Canara. K.R.Sivaraman gave talks at St. Joseph's College and National College in Bangalore. He was the guest speaker at the Satellite launching Centre, Sriharikota on Sir Raman's Day (1988 February), where he spoke on '200 years of Astronomy in India'.

Appendix C

Kodaikanal Observatory

Number of Days of Observation

Year	Month	Photoheliograms	Spectroheliograms		
			Hα	K-Flocculus	K-Prominences
1987	April	24	20	20	19
	May	26	23	22	19
	June	15	12	12	11
	July	20	14	15	12
	August	11	6	6	3
	September	17	5	12	10
	October	9	7	6	6
	November	13	10	10	9
	December	12	10	11	10
1988	January	29	29	29	25
	February	28	27	27	24
	March	22	20	19	20
	Total	226	183	189	168

Seeing Conditions

Year	Month	Seeing (in arc seconds)				
		5	4	3	2	<2
1987	April			15	9	24
	May			16	10	26
	June			3	12	15
	July			11	9	20
	August			6	5	11
	September			11	6	17
	October			6	3	9
	November			13	-	13
	December			2	10	12
1988	January			20	9	29
	February			21	7	28
	March			19	3	22
	Total			143	83	226

Number of days of observation at the Solar Tunnel Telescope-Spectrograph

Year	Month	No.of days of Obser-vation	Seeing (in arc seconds) 2	2 to 3	3	3 to 4	4	4 to 5	5	>5
1987	April	8	-	-	1	3	2	1	-	1
	May	22	2	7	3	5	5	-	-	-
	June	2	-	-	-	-	-	-	2	-
	July**	4	-	-	-	-	1	1	2	-
	Aug.**	6	1	1	2	2	-	-	-	-
	Sept.	11	2	1	6	2	-	-	-	-
	Oct.	4	-	1	1	1	-	-		-
	Nov.	5	-	1	2	-	1	-	-	-
	Dec.	7	2	1	1	-	2	1	-	-
1988	Jan.	9	-	1	6	1	-	-	1	-
	Feb	13	-	-	6	5	-	2	-	-
	March	6	1	5	-	-	-	-	-	-
	Total	97	8	18	28	19	13	5	5	1

*1 = v poor, 2 = poor, 3 = fair, 4 = good, 5 = v.good
**Repair work was carried out during 22.7.87 - 7.8.87

Vainu Bappu Observatory Kavalur

Year	Month	Spectroscopic hours	Photometric hours
1987	April	159	35
	May	157	46
	June	58	1
	July	76	3
	August	47	3
	September	70	2
	October	53	5
	November	77	33
	December	73	25
1988	January	195	57
	February	181	58
	March	159	42
	Total	1305	310