INDIAN INSTITUTE OF ASTROPHYSICS

Annual Report

Kormangala - Bangalore-34
INDIA

INDIAN INSTITUTE OF ASTROPHYSICS

Annual report 1986-87

Contents

BICENTENNIAL CELEBRATIONS

Indian Institute of Astrophysics traces its origin back to an observatory set up at Madras in 1786 by William Petrie, an officer of the East India Company. The Observatory was taken over by the company in 1789. The astronomical activity shifted to Kodaikanal Observatory in 1899, which was made into Indian Institute of Astrophysics in 1971.

To mark its bicentennial, a symposium on 'Two hundred years of astronomy' was held at Bangalore on 5 December 1986. The date was chosen to coincide with the date of the oldest observation recorded in a manuscript at the Institute. Taken on 1786 December 5 by Michael Topping, the observation pertains to the longitude and latitude of Masulipatam fort.

The symposium held at Guru Nanak Bhavan, Karnataka government auditorium, was attended by about 300 delegates: professional astronomers and astrophysicists from all over the country; a few visiting astrophysicists from abroad; students and teachers from universities; and informed laypersons. Conspicuous by his presence in mufti was Air Chief Marshal Dennis A. La Fontaine.

Following were the speakers and the topics of their talk:

R.K. Kochhar : Advent and growth of modern astronomy in India

J.C. Bhattacharyya: Astrophysics in India over the years

A.K. Raychaudhuri : Evolution of ideas in theoretical cosmology

G. Swarup : Radio astronomy at metre wavelengths - new challenges

P.C. Agrawal : Space astronomy in India - Past and present.

An exhibition of old instruments, old books, and old and new photographs on the history of the Institute was also set up at Guru Nanak Bhavan.

The three field stations at Kavalur, Kodaikanal and Gauribidanur observed 1986 December 5 as Open House Day. The observatories were kept open for visitors, and a public lecture on Astronomy, the old ever-young science was delivered. The speakers were S. Mohin (Tamil, Kavalur), G.S.D. Babu (English, Kodaikanal), and G.N. Rajasekhara (Kannada, Gauribidanur).

Simultaneous special postal cancellation at the four Institute centres was a special feature of the day.

A plaque to mark the bicentennial was installed on the south pier of the 2.3m Vainu Bappu Telescope at Kavalur.

The Institute had organized - jointly with the Visvesvaraya Industrial and Technological Museum, Bangalore - an astronomy quiz on Bangalore television for college students in and around Bangalore, and an all India Essay competition. The winners were given astronomy books as prizes. The quiz winners won 7.5 cm telescopes for their colleges.

About 200 delegates visited Vainu Bappu Observatory Kavalur on December 6. The bicentennial programme was followed by the eleventh meeting of the Astronomical Society of India hosted by the Institute, that is, December 7-9.

On 1987 January 6, Professor M.G.K. Menon, Scientific Advisor to the Prime Minister, and member, Planning Commission, delivered the first IIA bicentennial commemorative lecture on International Co-operation in Science, at the Indian Institute of Science faculty hall. Before delivering the lecture, Professor Menon unveiled a plaque at IIA, Bangalore, commemorating the bicentennial. He also planted a sapling of Brachychiton Acerifolia on the occasion.

Research Highlights

THE SUN

Solar calibration for stellar magnetic fields: From a large number of Ca II K-line profiles over plages on the sun obtained at the Kodaikanal solar tower telescope, the 1A emission flux centred at the K_3 minimum have been computed. These 1A flux measures that cover large variety of plages of varying brightness and age have large values for intense bright plages and smaller values for plages of lesser brightness. A relation between the 1A fluxes and the local values of the longitudinal component of the magnetic field from the Kitt Peak magnetograms has been derived. This relation provides a calibration for detecting and estimating the surface magnetic fields of sun-like stars for which the 1A flux measures are available from their Ca II K-line profiles. This work is in the final stages of completion (K.R. Sivaraman, S.P. Bagare, S.S. Gupta & R. Kariyappa).

Two toroidal components of solar activity: The butterfly diagram of sunspots shows the shift of the latitude zone of sunspot emergence on the sun. The solar activity is interpreted in terms of a poloidal component seen at latitudes higher than 40° and a sub-photospheric toroidal component which migrates towards the equator at middle latitudes. Recently the role of polar faculae, an indicator hitherto unused, was studied in the solar activity cycle using the Ca II K_{232} spectroheliograms of the data archives of Kodaikanal. The study has brought out the new fact that the activity consists of two toroidal components. The first wave of activity of the toroidal component appears in the latitude belt 40°-70° in the form of polar faculae soon after the polar field has reversed. This component migrating

polewards is in antiphase with the conventional solar activity and shows up all over the sun in general unlike the latter which is confined to low latitudes. Close to the maximum of this wave, the second and more powerful toroidal component appears at lower latitudes in the form of sunspots that migrate towards the equator giving rise to the butterfly diagram. Thus the new picture of the global process of activity is that of an extended cycle of duration 17-18 years instead of the canonical value of 11-years (V.I. Makarov*, V.V. Makarova* & K.R. Sivaraman).

H-alpha synoptic charts: The H-alpha synoptic charts constructed earlier by us for the period 1940-1982 were extended back in time to 1870. The present study, besides confirming the earlier findings on the poleward migration of large-scale magnetic fields on the sun and the mechanism of reversal of the polarity of the magnetic fields at the poles for the period 1940-1982, provides a clear picture of the solar cycle with the longest time base. The poleward migration charts show a latitudinal zonal structure. The boundaries of the latitude zones of magnetic field either oscillate about a mean latitude or show a poleward migration. Three types of quasi-periodical oscillations are noticed, the periods being different in the north and south hemispheres. The most probable period for these oscillations seen in the southern hemisphere is about 20 solar rotations. The work on the publication of these H-alpha synoptic charts that have been constructed from the spectroheliograms and solar prominence data of Kodaikanal, Kislovodsk solar station and Meudon data is in progress (V.I. Makarov* & K.R. Sivaraman).

Solar rotation rate: The data of daily measurements by W.C. Livingston at Tucson of Ca II K-index of integrated

sun have been analysed to derive the solar rotation rate. Power spectral analysis shows that one can obtain a well-defined value of solar (or stellar) rotation rate in a six-month period, provided the data is fairly continuous. It is hence possible to study the variation of solar rotation rate with time, a variation arising from a combination of differential rotation and shift in the active latitude. A comparison between observed rates and prevailing dominant activity zones does not show any correlation, atleast for the interval studied. Rather, our rates seem to depend on the birth and decay of active regions (Jagdev Singh & W.C. Livingston*).

The earlier work on variation of solar rotation rate with time in 10°-20° latitude belts is being extended to other latitude belts. Also to study the correlation of the variation of solar rotation rate in various latitude belts, the back data for the year 1930 to 1950 has to be sketched and measured. With this in view the plage areas for 1947-50 have already been sketched (Jagdev Singh).

He I 10830A time sequence spectra: Further analysis of time sequence spectra of He I 10830A line obtained on 1985 January 20 reveals large amplitude variations of equivalent width at places of high intensity. The places with low intensity seem to have smaller period variations of small amplitude. Two more time sequence spectra of 10830A each of about 80 minute duration and higher time resolution (interval 30s) were obtained by Jagdev Singh in 1986 June at KPNO. The data are being analysed to study the temporal and spatial variation of 10830A equivalent width (Jagdev Singh, P.Venkatakrishnan, S.K. Jain, W.C. Livingston* & F. Recely*).

Low-frequency observations: The measurements of the total flux from the undisturbed sun were continued at four low frequencies (36.25 MHz, 47.50 MHz, 55.50 MHz, and 64.25 MHz) using the broadband antenna system. The data obtained with high time and frequency resolution on several types of radio bursts from the sun are being analysed (A.R. Subramaniam).

The compound grating interferometer was used to obtain the one-dimensional brightness distribution of the sun with three arcmin resolution in the east-west direction on many days during the period 1986 May-September. These observations are being used to derive the characteristics of coronal holes at heights of about 2 solar radii.

Speckle reconstruction of solar features: The technique of speckle reconstruction of solar features using the Knox-Thompson algorithm has been developed by the solar speckle group at Harvard over the past ten years. A recent data set acquired at Sacramento Peak consisting of a sequence of short-exposure CCD images of an evolving pore yielded reconstructions with curious fringe-like features. The origin of these features was shown using simulations, to be not due to a paucity of grey levels in the acquired data. Removal of large-scale trends in the images somewhat reduced the artefacts, but not completely. Other sources of such artefacts like non-isoplanatism or rapid evolution of solar features within the observation period are being investigated (P.Nisenson*, R.W. Noyes*, R.V. Stachnik* & P. Venkatakrishnan).

Coronal emission lines: In order to understand the mode of excitation of Fe X (6374A) and Fe XIV (5303A) forbidden lines, theoretical fluxes for these two lines have been computed as a function of solar radii and at various

coronal temperatures. Fluxes at adjacent continua have also been computed. The computed ratios of line flux to the square of continuum flux at a coronal temperature of 1.6×10^6 K shows a good fit with the observed values for Fe X (6374A) line. Further, radiative excitation seems to dominate over collisional excitation beyond 1.3 solar radii (P.K. Raju & Jagdev Singh).

Line-intensity ratios which are sensitive to a particular physical parameter such as electron density or temperature, but are insensitive to the detailed structure of the emission regions, provide us with a powerful method for the determination of these physical parameters. In this connection several emission line intensity ratios as a function of electron density and temperature have been obtained from the published emission rates, at optical wavelengths, for the ions: Fe X, Fe XI, Fe XIV, Ca XII, Ca III and Ca XV. The usefulness of these ratios for diagnostic purposes is being examined (P.K. Raju).

Studies of long period global oscillations of the sun:
The preliminary spherical harmonic Fourier (SHF) analysis of sunspot occurrence probability using only 2600 first day's data for sunspot groups during two sunspot cycles (1933-1954) had indicated earlier that sunspot activity might be originating in long-period global oscillations of the sun. A more detailed and extensive analysis of 54000 daily values for sunspot groups during 1902-1954 has now been completed using a magnetic tape of sunspot data acquired from Dr. H. Balthassar of Goettingen University. In each separate cycle only ($l = 6$, $m = 0$) mode and sequences of 3 or 5 cycles taken as single time series, all even parity axisymmetric (l = even $m = 0$) modes show 11-year peaks. The ($l = 6$, $m = 0$) mode has phase significance in that its 11-year peak cannot be reproduced by a simulated data

with random values for heliographic latitudes even if the 'epochs' are assigned the real values. The power distribution with respect to 'l' is stationary and stable from one cycle to another or from one sequence to another. Most of the SHF power lies in even modes with $0 \lesssim l \lesssim 24$ and with maximum power at $l = 10 \sim 12$. If the data in the two hemispheres is attached signs (+/-) simulating Hale's laws of magnetic polarity, the analysis yields odd parity 22-yr modes as obtained by Stenflo & Vogel from magnetogram data. However, these modes do not have the phase-significance which the ($l = 6$, $m = 0$, 11-yr) mode has (M.H. Gokhale & J. Javaraiah).

Non-adiabatic effects in hydromagnetic surface waves: Effects of radiative losses and thermal conductivity on hydromagnetic surface waves have been studied analytically as well as numerically in the context of magnetic discontinuities in the solar corona. It is shown that the effects of radiative losses are appreciable only when the plasma pressures on the two sides of the discontinuity are substantially different. The overstability of a surface mode requires that the Fields' criterion of thermal instability be satisfied on the side where the mode produces larger compression. This requires that the temperature of the corresponding region be in a narrow range $10^{5.4}$ - $10^{5.75}$K (P.S. Joarder, M.H. Gokhale & P. Venkatakrishnan).

Cause of Evershed flow and other longitudinal flows in stellar magnetic flux tubes: The conventional equations for equilibrium of a thin magnetic flux tube in a stratified atmosphere admit longitudinal non-equilibrium in the inner and outer parts of the tube. By considering a mode of a thin, isolated, untwisted tube with a current free core and a thin current sheath satisfying similarity

condition, it is demonstrated that an overall equilibrium of such a tube implies unbalanced longitudinal forces on the core and the current sheath. Under suitable conditions the force in the current sheath is upwards and of the right order to simulate the Evershed flow in sunspots (M.H. Gokhale & K.M. Hiremath).

Catastrophe in the equilibrium of thin force-free magnetic flux tube in a stratified atmosphere: The equations for equilibrium of a thin axisymmetric force-free magnetic flux tube in a stratified atmosphere obtained by Browning & Priest require an auxiliary assumption about the temperature of the plasma in the tube. The reason is that Browning & Priest write only one equation for the radial equilibrium of plasma in the tube, neglecting inhomogeneities of plasma pressure and density in the non-horizontal cross-sections of the tube. These inhomogeneities cannot be neglected even if the tube is thin. The set of equations and constraints are rederived to the second order in the parameter representing the thinness of the tube. The set of equations and constraints is mathematically closed, leaving no necessity or scope for any auxiliary assumption. It is shown that starting from a given point in the atmosphere as top point of the tube, one obtains either two or no possible solutions and a mathematical catastrophe similar to that in the numerical results of Browning & Priest (M.H. Gokhale & Prasanna Laxmi).

Mode classification and oscillation in magnetic flux tubes on the sun: An understanding of the nature of wave modes in a magnetically structured atmosphere is of considerable interest for a number of reasons: Flux tubes most likely play an important role in chromospheric and coronal heating. Furthermore, the study of waves provides a diagnostic for probing different layers of

the atmosphere in a flux tube. The aims of our study are (a) to classify the modes of a flux tube, (b) to determine the oscillation spectrum, and (c) to calculate the height dependence of the perturbation amplitudes.

As a first step in this direction, we treat the case of a vertical magnetic flux tube with rectangular cross-section, assuming a polytropic stratification in the vertical direction. We use a gauged version of Helmholtz's Theorem, to decompose the perturbations into irrotational and solenoidal components. The latter is further split into the sum of poloidal and toroidal components. These modes are identified with p, g and t (Alfvén) modes of a fluid. The normal modes are determined using a Rayleigh-Ritz variational technique. Our method efficiently isolates the modes to high orders. Our results can be summarized as follows: (a) There exists typically one unstable mode (g_1) with a growth rate of a few hundred seconds. (b) Higher order g modes are stable with frequencies increasing with k. For large k, g modes are essentially slow modes. (c) g modes have significant amplitudes over the entire tube; they can be used for probing the deeper layers. (d) p modes have periods of the order of seconds. They are essentially gravity modified fast modes. (e) p modes suffer appreciable amplitude attenuation with depth; they are potentially useful for probing the surface layers of a tube. (f) t modes can always be identified with Alfven waves. For lower k, the frequencies of t and g modes are almost identical. (g) For low k, the modes are well-separated in the frequency domain (S.S. Hasan & Y. Sobouti*).

Model atmosphere and energy transport in flux tubes: Observations suggest that the surface magnetic field on the sun occurs in the form of intense flux tubes.

Physical conditions within flux tubes are not well known observationally. The aim of our study is to provide theoretical calculations which determine the structure of a flux tube. Assuming that dynamical effects can be neglected for determining time-averaged quantities, the stratification within the tube is intimately related to the energy transport mechanisms. We consider energy transport only through radiation and convection. We allow for heat exchange with the ambient medium and also for the efficiency of convective energy transport being reduced by the magnetic field.

We assume a thin flux tube (i.e. neglect horizontal variations), hydrostatic equilibrium, a grey atmosphere and radiative transfer in the Eddington approximation. We solve the equations using Mihalas'. method of complete linearisation.

Model atmospheres are calculated for various magnetic field strengths (parametrized by β, the ratio of gas and magnetic pressures at the top boundary) and for various α (the degree of convective inhibition). The results indicate that (a) the temperature on the tube axis is generally higher than the ambient medium at equal optical depths; (b) the final stratification is not very sensitive to β or α; (c) in the final state β is not constant, but varies with depth, although this variation is rather weak; (d) horizontal heat exchange plays an important role in determining the final thermodynamic state of the gas in the flux tube (S.S. Hasan).

Escape of magnetic flux from solar surface: The escape of magnetic flux from the surface of the sun is important in its own right as well as in providing a boundary condition for dynamo in the solar interior and affecting

the corona and solar wind models. Magnetic buoyancy brings the azimuthal component of the magnetic field up to the surface of the sun from whence it can leave the sun only if it can disengage itself from the plasma. The plasma and the magnetic field can part their ways through the process of magnetic reconnection. The escape of magnetic flux is considered taking three different geometrical configurations of magnetic dipoles, viz. (i) two dipoles, (ii) a one-dimensional infinite chain of equidistant dipoles, and (iii) a three-dimensional arrangement where the dipoles are situated at the corners of a square. The variation of fractional flux escape with the ratio of dipole separation to their size is calculated for the three cases. It is found that only a small amount of magnetic flux can actually leave the sun since magnetic reconnection cannot occur very efficiently when the relative separation of the dipole is large (V. Krishan & E.R. Priest*).

Pressure in coronal loops: Spatial variations of pressure in coronal loops has been studied by using the statistical theory of MHD turbulence. Attempts are now being made to study the time variations of pressure. This is done by studying the nonlinear wave-wave interaction processes which govern the dynamics of the velocity and magnetic fields in the coronal loops. The invariance of the total energy and the magnetic helicity is actually shown by numerically solving the MHD equations (V. Krishan & E.R. Priest*).

THE SOLAR SYSTEM

Spectrophotometry of comet Halley: Extensive observations of comet Halley which were done using the telescopes at Kavalur and Kodaikanal were under analysis. The comet was observed on 6 nights in 1985 November and December and on 11 nights in 1986 March, April and May, with the automated scanner at the f/13 Cassegrain focus of the 1-m reflector. The scans cover either the range from 3900-6200A or 4500-7200A. The spectrum scans obtained with the 26 arcsec entrance diaphragm at the nucleus show the emission bands of C_3(4050), CH + CN (0,1), C_2(1,0), NH_2(0,13,0), C_2(0,0) C_2(0,1) and C_2(2,4) and also their changes with the heliocentric distance r. One interesting feature of the spectrum is the presence of NH_2 emission. Emission from NH_2(0, 7, 0) was seen in the scans of November and extended till 7200A. NH_2 (0, 13, 0) emission at 4900A seen only marginally in the November and December scans, became unusually intense after perihelion and was seen to extend to more than 1.5 arcmin from the nucleus within the coma. NH_2 (0,10,0) was also present close to the NaI emission on all the scans of March 1986. On 6 nights, besides the scans at the nucleus, the entrance diaphragm was systematically displaced to locations in the antisunward direction, thus sampling newer regions within the coma as far as 2 arcmin from the nucleus. On 3 other nights, scans were obtained with the same diaphragm at locations approximately normal to the sun-comet radius vector. The fluxes in all the emission bands and in the continuum, and also the total number of molecules of each species have been computed from these scans for the nucleus and for other regions sampled within the coma. The high spatial resolution provided by the f/13 set up, made it possible for the first time in the cometary observations to

derive the spatial gradients and the spatial asymmetries in the distribution of the molecules and dust within the coma (K.R. Sivaraman, G.S.D. Babu, B.S. Shylaja & R. Rajamohan).

Spectra of comet Halley were also recorded in 1986 April at the 1.5 m telescope at ESO, using the Boller & Chivens spectrograph equipped with a Reticon detector. The spectra cover the wavelength region 8000 to 10350A with a resolution of about 2A (K.R. Sivaraman & A.K. Pati).

Near-nucleus studies: A number of images of the coma of comet Halley have been digitised and employing image processing software developed at the Institute, the structural features within the coma have been brought out. Detailed studies concerning the velocities, recurrence of jets, etc. are in progress (K.R. Sivaraman & A. Bhatnagar).

Photometry of comet Halley: The photometric fluxes of the comet measured through the narrow-band filters recommended by the International Halley Watch have been computed from raw observations. These fluxes show most unexpected kind of sinusoidal brightness variations. Detailed study on this phenomenon is in progress (K.R. Sivaraman, G.S.D. Babu, J.S. Nathan & R. Rajamohan).

Astrometry of comet Halley: Astrometric measurements of comet Halley, on six different dates during the 1985-86 apparition, have been completed (S.P. Bagare & K.K. Scaria).

Occultation by comet Halley: A seventh magnitude star was spectrophotometrically monitored as it was occulted by the coma of comet Halley on 1986 April 11. Nine scans were obtained through different regions of the coma (R. Vasundhara).

Cometary dust environments: Photographic plates of comet Halley and comet West have been analyzed, using a PDS microdensitometer and image-processing techniques. For each plate isodensity contours are obtained. Comparison of these results with calculated synchrones and syndynes, using Finson-Probstein theory for comet dust tails would give size distributions and composition of dust particles. Angular distribution of the scattered intensity and polarization has been calculated using power-law size distributions for spherical and non-spherical, absorbing and nonabsorbing particles. These results are used to infer size, shape and composition of cometary dust particles (D.B. Vaidya).

The dust grains in the coma of comet West: The observed variation of reddening as a function of the heliocentric distance and the spatial variation of reddening within the coma of comet West in the visual wavelength range have been considered to infer the properties of the cometary dust grains. The relevant model incorporates the variation in the size distribution function as well as the composition of the spherical grains. The real part of the complex index of refraction ($m = m' - i\,m''$) is chosen such that $m' = 1.6$. The imaginary part is required to vary from $m'' = 0.2$ to 0.05 over the wavelength range 0.4 to 0.7 μm. This choice of refractive index corresponds to dirty silicate grains. As a by-product, the model also satisfies the observed polarization and albedo of comet West (G.A. Shah & K.S. Krishna Swamy*).

Comet Wilson: A photograph of comet Wilson was taken on 1987 March 28, using the 1-m telescope at Kavalur. More observations are underway (K.R. Sivaraman & G.S.D. Babu).

19R occultation of Saturn: Reduction and interpretation of the data on Saturn occultation at 19R, obtained on 1984 May 12, was completed. Comparison of the Naini Tal and Kavalur light curves suggests that the extinction signatures are possibly caused by irregular density enhancement of ions, charged dust grains or gas.

A possible explanation of the asymmetry in the immersion and emersion light curves at 12.5 Saturn radii was suggested : The asymmetry possibly arises due to different density gradients of absorbing matter on either side of equatorial plane. An upper limit of 1500 km has been set on the vertical thickness of the possible ring system, which is in conformity with the Voyager results for the E ring of Saturn (J.C. Bhattacharyya & R. Vasundhara).

Pluto-Charon mutual events: Photometric observations of the mutual event of Pluto and Charon are being continued on the 1-m telescope at Kavalur. Eclipse events were recorded 1986 May 16, 1987 January 5, 1987 March 9, and 1987 March 25 (R. Vasundhara).

Asteroid occultations: Occultation of AGK3 + 23° 1108 by Ceres was recorded on 1987 April 26 using the 1-m telescope at VBO (R. Vasundhara).

Occultation of SAO 185428 by the asteroid 336 Lacadiera was recorded with the 50-cm telescope at the high altitude site survey observatory of DST in Leh on 1986 May 12. The lower limit on its size along the direction of the track is estimated to be 119 $\pm$ 5 km (Arvind Paranjpye & G.S.D. Babu).

Schmidt surveys: A regular schmidt survey to discover fast-moving objects like comets and asteroids was started in 1987 February. Regular photography of

regions of sky in opposition were done during the period February 19 - March 9 and are continuing. In the February observing run eleven asteroids were detected out of which seven asteroids had already been numbered. In one hour exposure, the limiting magnitude of the telescope is 18.0 on 098-02 plates without any filter. The project is expected to yield atleast two or three new asteroids per year on an average. The amateur astronomers of the Bangalore amateur astronomy association are planning to take active part in this survey project (J.C. Bhattacharyya & R. Rajamohan).

THE STARS

Supernova 1987A in the Large Magellanic Cloud: The most exciting astronomical event of the year was the supernova (SN 1987A) outburst in the Large Magellanic Cloud. The supernova was discovered by Shelton, Duhalde and Jones on 1987 February 24 at naked-eye brightness. The information reached the Institute the next day, and the 1-m, 0.75-m and 0.40-m reflectors were pressed into service for continuous monitoring of the supernova beginning 1987 February 26. Several spectrograms and photoelectric spectrum scans were obtained; some polarization measures were taken in collaboration with the scientists at the Physical Research Laboratory, Ahmedabad; photoelectric photometry was also attempted though the altitude of the supernova above horizon was very low. A large number of scientists of the Institute participated in the observational program. The analysis of the data is in progress, whereas some preliminary results have been communicated to IAU Circulars.

The spectrum showed considerable change during the month following the outburst. The P Cygni profile had an absorption minimum at $\sim$-16400 km s^{-1} on February 26 which continuously decreased in magnitude, reaching -7700 km s^{-1} on March 22. The lines of Fe II yielded much lower expansion velocities. In addition to the lines of H and Fe II, also lines of He I, Na I, Sc II, and Ca II could be clearly identified. The NI 8680A line continuously brightened with time. The lines of Ca I, OI and Mg I were also possibly present. By the end of March, the Hα profile became narrow, and double-peaked with peak-to-peak separation of $\sim$1400 km s^{-1}. This is suggestive of an expanding shell or

ring of gas. The anomalous brightness of NI 8680A line suggests enhancement of nitrogen abundance in the ejected shell.

Neutrinos from SN 1987A: The neutrino detection from SN 1987A claimed by several groups has been used to put limits on neutrino properties such as rest mass, decay time, oscillations etc. It is shown that the energy range and flux of the detected neutrinos is consistent with the collapse of an O-Ne-Mg stellar core and formation of a neutron star at the distance of LMC. It strongly supports the idea of neutrino diffusion in the dense core with large optical depth ($>10^4$) prior to their escape from the star rather than prompt release.

The observed neutrino flux is also shown to put rather severe constraints on emission of exotic particle species such as axions and photinos in the supernova producing processes (C. Sivaram).

High angular resolution interferometry: Preliminary attempts to record 30 ms exposures of bright stars on commercial 16mm film by mounting a Bolex-Polliard movie camera at the Cassegrain focus of the 1-m reflector proved encouraging. In order to resolve the speckles, the f/13 beam was magnified using a Barlow lens, with different enlargements depending on the distance of the camera focal plane from the lens. Speckles of various stars were recorded: α LeO, αCMi, αGem etc. using typically a f/90 beam. The 2.99 mag companion of α Gem was also registered on the film even for 6 ms exposure. A more sophisticated version of this camera is being developed for use at the Cassegrain focus of the 2.3-m VBT (S.K. Saha, P. Venkatakrishnan, A.P. Jayarajan & N. Jayavel).

The Fried's parameter r_0 was identified as a physical scale in the wavefront over which there is typically π radians of rms phase difference. Computer simulations of phase screens following a power law with Lorentzian tail in power spectral density distribution showed a residual non-blurred core of the point-spread function whenever the telescope size was larger than the largest eddies in the turbulence (P. Venkatakrishnan & R.A. Shevgaonkar).

A method has been developed to determine the probability of arrival of a ray of light in a particular direction for propagation of light through the turbulent atmosphere of the earth, taking into account the random fluctuations in the refractive index due to turbulence. Steps are indicated for the final intensity calculation (S. Chatterjee).

The intensity distribution in an overexposed photograph of a star was qualitatively studied, where the exposure time was varied from 10 to a few minutes, i.e. time scales much larger than the speckle-boiling time. The blurring of the image is sought to be interpreted in terms of atmospheric turbulence (S.K. Saha, S. Chatterjee, K.E. Rangarajan & D. Mohan Rao).

Some experiments on digital filtering and convolution and deconvolution of images have been performed. The practical difficulties were noted and overcome. Various programs and subroutines were added to the library of VAX-11/780 at Kavalur. The important among them are programs for (a) magnification, (b) shearing, (c) rotation, (d) 3-D plot, (e) print and (f) clipping of images (K. Narayankutty).

Transfer of Hα in supergiant chromospheres: The expanding chromospheres of late G and K supergiants produce strong Hα absorptions with blue displaced cores and small emissions flanking the absorption either on the blue side or the red side or both. In earlier work (Sushma V. Mallik 1986 M.N.R.A.S. 222, 307) the chromosphere was modelled as a non-LTE, spherically symmetric, expanding, isothermal atmosphere with an increasing velocity gradient. This work has now been extended by including appropriate temperature structure in the chromosphere. Extensive computations have been performed for a variety of temperature structures, chromospheric extents and optical depths. With a linear gradient in velocity, the density law is implicitly fixed for an assumed mass conservative flow. An important consequence of the temperature and density structures is the depth dependence of the n = 2 population which controls the structure of the Hα profile. The n = 2 population does not follow the outward fall in the total H density, instead goes up steadily because of the temperature rise until a high enough temperature (depending upon density) is reached when ionization from n = 2 becomes important. As a result, the n = 2 population stars declining.

A direct outcome of inclusion of temperature gradient and ionization is that the Hα optical depths are consistently much higher than for iso-thermal calculations for the same density. In the pure scattering case for a static medium using a temperature distribution where the plateau exists only towards the very outer layers, symmetric blue and red emissions appear flanking the absorption. With increasing velocities, the absorption core moves blueward reducing the blue emission while the red emission increases. Higher extent and larger optical depth also yield enhanced

red emission and darker absorption. Comparison of the observed profiles with the computed ones give initial densities in the range 10^9 - 10^{11} cm^{-3} and line-centre optical depths of Hα in the range 10-2000. The mass outflow rates are substantially lowered - they now lie in the range 10^{-7} - 10^{-9} $M_\odot$ yr^{-1} (Sushma V. Mallik & D.C.V. Mallik).

Spectroscopy of G and K supergiants in the yellow-red region: Observations of cool supergiants in the yellow-red region are being continued. Spectra of HD 62576, BS 5171, HD 137709, β Arae, θ Sco, α Ori, λ Vel, 84 UMa, ϵ Gem, η Per, σ CMa, o^1 CMa were obtained at the 1-m telescope with the UAGS employing the 1800 l mm^{-1} grating and the 175 mm camera giving a dispersion of $\sim$ 28A mm^{-1}. Apart from Hα, the Na I D lines at 5890-5896A and K I line at 7699A are also found to have asymmetric cores. Blue spectra covering Hβ - Ca II H and K have also been obtained for a few bright stars. Analysis of these data is in progress (Sushma V. Mallik).

Alpha Cygni as a radial velocity variable: One hundred and twenty three radial velocities for α Cyg are derived between December 1977 and October 1982. These photospheric velocities are derived from N I lines near 8700A. Semiregular variations in radial velocities are present with periods of 7 to 20 days. The range of variation of 14.3 km s^{-1} observed in the present radial velocities of α Cyg is close to the sum of the amplitudes (10.44 km s^{-1}) of all the pulsation periods from 7 to 101 days and is also approximately equal to micro- and macro-turbulent velocities (M. Parthasarathy & D.L. Lambert*).

Spectroscopy of southern Cepheid β Dor: Atmospheric abundances have been derived for high galactic latitude Cepheid β Dor at various phases of its pulsation cycle

using detailed model atmospheres and spectrum synthesis technique. It is found that for its high galactic latitude, the s-process elements are only mildly deficient. The Fe group elements are almost solar in abundance (S. Giridhar).

UU Her stars: A project has been commenced on the study of the atmospheric properties of UU Her stars. Strömgren photometry for a sample of 30 stars has been carried out with the 1.5-m telescope at San Pedro Martir observatory and high resolution spectra of bright members of the group have been obtained using echelle spectrograph at the Cassegrain focus of the 2.1m telescope at San Pedro Martir. Analysis of the data is in progress (S. Giridhar & A.A. Ferro*).

Hydrogen-deficient stars: Reticon spectra obtained with ESO 1.5mtelescope of the hydrogen deficient (WC 10) stars, He 2-113 and CPD -56°8032 have been analysed. Particularly the nebular spectrum of the two objects was studied with a view to obtaining the abundances. Earlier studies by Dahari & Osterbrock, and Goodrich & Dahari, of the other two members of WC 10 group, V348 Sgr and M4-18, indicated high abundance of oxygen in M4-18 and low abundance of sulphur (compared to the solar abundance) in V348 Sgr. Our study is based on the 78A mm^{-1} and 228A mm^{-1} reticon spectra in the region of 5535-11000A. The electron density and temperature have been estimated from the line ratio of 5755A and 6548A of [NII] and 8727A and 9850A of [CI]. We also used the radio flux densities for estimating the physical parameters. The results show that in CPD -56°8032, sulphur, nitrogen and oxygen seem to have solar abundances whereas carbon and neon are enhanced. The sulphur abundance in He 2-113 also appears to be solar.

There appears to be a systematic behaviour in the nebular properties of these four objects of WC 10 group. He 2-113 which has a hotter central star (30000 K) has a compact nebulosity and high electron density $\sim 10^5$ cm^{-3}; CPD -56°8032 with a central star at 23000-26000 K has a nebula of 1.3 arcsec extent with electron density of 2×10^4 cm^{-3}; V348 Sgr with a central star at 20000 K and optical nebulosity of 18 arcsec extent has an electron density of 10^3 cm^{-3}; M4-18 is more like CPD -56°8032. All the four stars appear to have roughly the same luminosity. In the H-R diagram they scatter around the theoretical evolutionary track for a post-asymptotic giant branch star of 0.56 $M_\odot$ as computed by Schönberner. This trend of hot star surrounded by high density compact nebula and the cool star with low density extended nebula indicate that the stellar evolution might be from left to right towards asymptotic giant branch stars for a second time and might form a link with R CrB type stars.

The reticon spectra of DY Cen, a hot R CrB star, shows the presence of Paschen lines of hydrogen in absorption and H-alpha in emission indicating that there is some hydrogen in the star (N. Kameswara Rao).

Radio observations of hydrogen deficient stars and nebula obtained with Very Large Array (VLA), in the B/C hybrid configuration have been analysed. The observation at 6 cm have been obtained of υ Sgr, V348 Sgr and Abell 58. Abell 58 was also observed at 2 cm. Only upper limits to the flux density could be set for these sources. A new radio source at 6 cm was found in the field of υ Sgr. The upper limit for 6 cm flux density of V348 Sgr sets an upper limit to its reddening as $E(B-V) \leq 0.65$. The hydrogen deficient planetary nebula A58 shows much lower radio flux than expected

from the infrared-radio flux density relationship of planetary nebulae. This property seems to be common for other hydrogen deficient nebulae also (A30, A78) (N. Kameswara Rao, V.R. Venugopal*, A.R. Patnaik*).

High resolution IUE spectra by R CrB and γ Cyg obtained by us are being analysed using the starlink package with our VAX 11/780 system at Kavalur. The absorption spectrum of both stars match well except for the few resonance lines of Mg II, Fe II, Mn II, Mg I etc. These lines in R CrB show P-Cygni type profiles with two absorptions at -53 km s^{-1}, -171 km s^{-1} indicating mass loss. The profiles are being studied to estimate mass loss (N. Kameswara Rao & S. Giridhar).

A program of survey of hydrogen-deficient stars in LMC has been started with the UK Schmidt objective prism plates (R. Vasundhara, N. Kameswara Rao & D.H. Morgan*).

Study of peculiar and metallic line stars: The observations of 5200A feature in many Ap stars have shown periodic variation in some cases. Many more Am stars in the southern region and others reclassified as Ap and Am stars in the latest edition of the Bright Star Catalog were observed in order to derive the physical parameters like effective temperatures, radii and bolometric corrections (G.S.D. Babu & B.S. Shylaja).

RS CVn systems and related objects: As part of an ongoing programme on RS CVn systems and related objects, photometric observations of V711 Tau, UX Ari, II Peg, DM UMa and HD 116204 were obtained in B and V on several nights during 1987 January-March. The 34-cm telescope at Kavalur was used for this purpose. Reduction of the data is in progress (S. Mohin & A.V. Raveendran).

Study of WR binaries: Among the members of the galactic cluster NGC 6231, the WR members HD 151932 and HD 152270 were studied for understanding the flux variation. In the case of HD 152270, which is an established spectroscopic binary, the flux variation of various emission lines show a scatter over the orbital phase. However, the highest excitation line flux, e.g. C IV, shows a decrease near phase 0.4 which implies that its origin is closer to the photosphere. In the case of HD 151932 there is an irregular variation of flux and the monochromatic magnitudes at the continua, free of emission line effects, give an approximate period of about 6 days, which value can be improved only by continuous monitoring.

The behaviour of the 4686A line of He II was studied for flux variation in many WN binaries. The radial velocity variations also show a marked difference relative to the nitrogen lines. This may be explained in terms of the asymmetric distribution of line-emitting material, since the proximity of the companion seems to have an effect on this behaviour (B.S. Shylaja).

Proto-planetary nebulae - II : Luminous F-G stars: The far-infrared (IRAS) excess are found in ten luminous F-G stars. The far-infrared fluxes from these stars are due to large amounts of dust around them. The temperatures, luminosities, and masses of the dust envelopes are derived. The far-IR luminosities and dust masses are similar to those observed in planetary nebulae. The mass of the dust around HD 187885 (F5Ia) and HD 179821 (G5Ia) is of the order of $10^{-2} M_{\odot}$. If the ratio of gas to dust mass is about 100, as it is in the interstellar medium, the total shell masses are between 0.3 and 1 $M_{\odot}$. These stars appear to be similar to HD 161796 (M. Parthasarathy and S.R. Pottasch 1986, Astr. Astrophys.,

154, L 16). The results suggest that these stars suffered extensive mass loss on AGB post-AGB stage and are now in protoplanetary stage of evolution (S.R. Pottasch* & M. Parthasarathy).

The proto-planetary nebulae - III : BQ[ ] and related stars: The emission line B stars showing abnormal spectra and strong forbidden emission lines were designated as BQ[ ]stars by Wackerling (1970). In addition to emission lines the spectrum of these stars shows P-Cygni type profiles and also shell component. The far-infrared IRAS flux distribution and colours of fifteen peculiar emission-line stars (BQ[ ]) are found to be similar to that observed in young compact planetary nebulae. From the far-infrared fluxes the temperatures, luminosities and masses of the dust envelopes are estimated. The observed circumstellar dust shells around these stars are a result of severe mass-loss on the AGB post-AGB stage of evolution; these are in transition stage and are proto-planetary nebulae and the central stars are rapidly evolving towards hotter spectral types (M. Parthasarathy & S.R. Pottasch*).

The far-infrared (IRAS) excess of steep - Balmer decrement objects: From the low-dispersion objective prism survey, Sanduleak & Stephension (1973) found 50 stars with very strong Hα emission and very weak or absent emission in Hβ and higher order Balmer lines; also the continuum in the blue-green region is very weak. They have described these stars as unknown type (X) with very steep Balmer decrements. We have analysed the far-infrared IRAS data of these objects. Out of the 50 stars with steep Balmer decrement, 34 were found to be IRAS sources. The dust temperature of these objects is found to be in the range of 140 - 300 K. The IR fluxes of these objects are in the range of 1.25×10^{-11}

to 1.8×10^{-13} w m^{-2}. The large ratio of total IR flux to visual region flux suggests that the hot stars are embedded in dust envelopes similar to that observed in the bipolar planetary nebulae. The IRAS data suggests that these objects are young compact planetary nebulae. The central stars are late O - early B type emission line stars and are obscured by the circumstellar dust envelopes (M. Parthasarathy, S.R. Pottasch* & R. Olling*).

Polarimetry of AR Puppis and R Aquarii: Polarization observations of the remarkable RV Tauri star AR Pup have been obtained. The light variations and IR excess alongwith linear polarization have been studied. The energy distribution from V to 100 μm show three components - (a) a variable F-G super-giant, (b) hot dust characterised by 1000-800 K blackbody, and (c) a cool dust component characterised by a blackbody of 250 K. The polarization as well as the light minima seem to follow a period of 75.3 days (the recent light curves shows a longer period indicating the presence of other oscillations) and there is an increase in the linear polarization around the time of light minima, the amount of polarization being high in the U band. The position angle is roughly constant for U to I bands at $120 \pm 7^{\circ}$ at the time of light maximum. However, during the minimum the position angle changes from 87° in U to 110 degrees at R filter. A model of the star surrounded by a dust torus and bipolar scattering lobes is being proposed (A.V. Raveendran, N. Kameswara Rao, M.R. Deshpande*, U.C. Joshi*, & A.K. Kulshrestha*).

Linear polarization measurements of the R Aqr system shows strong wavelength dependence in both the amount and position angle which is also strongly time dependent. There is a large variation in percentage polarization in the ultraviolet whereas the variation

decreases towards the red region. Contrary to the variation of percentage polarization, the variation in position angle is small in U band and large in the other bands towards the red region. These observations support a binary model in which a hot white subdwarf accretes material from a Mira variable forming dust around the subdwarf. When the accreting mass exceeds a critical limit a jet-like structure at the polar regions of the subdwarf is formed. The U-band position angle variations are suggestive of precession of the jet-like structure (M.R. Deshpande*, U.C. Joshi*, A.K. Kulshrestha*, A.K. Sen*, N.K. Rao & A.V. Raveendran).

Novae: The recurrent novae RS Ophiuchi and T Coronae Borealis were monitored spectroscopically during their quiescent phase. Recent classical novae - Nova Cygni 1986, Nova Andromedae 1986, Nova Centauri 1986, and Nova Herculis 1987 were observed spectroscopically during their outburst. Spectra of old nova GK Persei were also recorded during one of its minor outbursts. The spectra cover a range of 4000-7000A at a reciprocal dispersion of $\sim$100A mm^{-1}, and were recorded photographically with or without employing an image intensifer (G.C. Anupama & T.P. Prabhu).

The spectra of Nova LW Serpentis, obtained during its outburst in 1978, have been analyzed. The spectra cover a range of $\lambda\lambda$4000-8000A with reciprocal dispersions ranging between 30A mm^{-1} (only H α line) and 600A mm^{-1}. The nova was characterized by a lack of prominent principal absorption, and a fast evolution of lines of CNO. The emission line of H α showed considerable structure. A kinematical model of the shell of LW Ser is proposed based on the structure of H α profile. The model consists of equatorial rings and polar caps embedded in a prolate ellipsoidal shell whose major axis lies close to the line of sight (T.P. Prabhu & G.C. Anupama).

Shock accelerated particles in type II supernovae: The anomalous calcium enhancement in the cosmic ray spectrum in the energy range 10^{14} - 10^{16} eV per nucleus is shown to be associated with SN-II involving 8-15 $M_\odot$ producing overabundance of Ca/Fe which can be as high as ten. The cumulative effect of acceleration from the neutron star as well as the shock acceleration in the supernova remnant in the pre-Sedov and Sedov phases is shown to lead to a limiting energy for calcium nuclei in the range 10^{15} - 10^{16} eV per nucleus. This strengthens the belief that SN-II are sources of these cosmic ray particles (C. Sivaram).

Pulsars: A work on some general relativistic effects (of large spacetime curvature and rotation) on radiation from a fast rotating neutron star, relevant in the context of fast pulsars with periods in the millisecond range has been in progress. A hitherto unknown effect, namely, a variation in redshift over the cone of emission from a fast pulsar has been noticed which leads to an intrinsic dispersion in a pulse (B. Datta & R.C. Kapoor).

Deshpande devised a scheme to enable high-time resolution observations of highly dispersed pulsar signals, involving a basic swept frequency dedispersion procedure. A new method was used to avoid the need for gain calibration of individual frequency channels, as well as the need for absolute synchronization of the sweep. It is shown that with this method higher resolution can be obtained for strong pulsar signals. Suitable observational procedures along with software algorithms, were developed for this purpose. Use of this scheme has successfully demonstrated its ability to observe pulsars having dispersion measures as high as 35 cm^{-3} pc, with high sensitivity and high resolution. The highlights of the results obtained using this system

include (1) measurements of average profiles for four pulsars at 34.5 MHz (PSRs 0628-28, 0834+06, 0943+10, 1919+21) with high time resolution and sensitivity; (2) a marginal detection of interpulse emission in the case of PSR 0628-28; (3) absence of significant interpulse or off-pulse emission in those cases where significant interpulse emission has been reported at 25 MHz by the Soviet observers; (4) the scaling law for intrinsic pulse width as a function of frequency was shown to break down and in one case, (PSR 0628-28), the intrinsic width at 34.5 MHz appears to be smaller than at high frequencies; and (4) it is clearly demonstrated that estimation of interstellar scattering from the observed pulse profiles at low frequencies can be unreliable and misleading.

Rotation induced quadrupole deformation effects on the structure of fast pulsars were investigated, and the eccentricity and the quadrupole moment of a fast pulsar like PSR 1937+21 were calculated for an exhaustive set of presently available realistic equation of state models of neutron star matter (B. Datta & J. Thomas).

Theoretical work on the possibility that period derivatives of pulsars are affected by kinematics was continued. The preliminary result that such a possibility strongly exists was found from the correlation of the observed transverse velocities of seventy pulsars and their period derivatives. It is argued that a proper understanding of the concept of time would indeed produce such a result. The results are controversial and if real, has far reaching consequences in the interpretation of the observed period derivatives of pulsars (R. Rajamohan).

Monopole flux limits: For a magnetic field of 10^{12} gauss, the usual bounds on the monopole flux from neutron star nucleon catalysis apply only for monopoles with energy $>10^{15}$GeV, or $> 10^{12}$GeV for millisecond pulsars. Otherwise no catalysis occurs. Even for monopoles of larger masses, their being trapped inside the neutron star depends sensitively on the internal structure of the star, especially if it has a superconducting core. For pion superconductivity, the magnetic field can accelerate the monopoles out of the star (C. Sivaram).

THE INTERSTELLAR MEDIUM

Planetary nebulae: In continuation of the work started a couple of years back in collaboration with PRL, Ahmedabad, a pressure-scanned Fabry-Perot spectrometer was used to obtain [O III] line profiles in several planetary nebulae. The bipolar planetaries NGC 650/1, 2346, 2440 were scanned in many positions. In several of these, the profile shows clear split as evidence of expansion. In NGC 650/1 the profile shows complex triple structure in the north-eastern lobe but no structure in the centre and south-eastern lobes. In NGC 2440 we find a central expansion of 15 km s^{-1} while in the two outer lobes 30 arcsec apart the splits yield expansion velocities of 22 km s^{-1} (north) and 18 km s^{-1} (south). In the centre of NGC 2346 (15 arcsec aperture) the [O III] line also shows a split indicating a low expansion velocity of 6 km s^{-1}.

In addition, a piezo-electrically scanned Fabry-Perot spectrometer has been used to obtain Hα, [S II] and [N II] profiles in NGC 1535, 2346, 2440, 2818, 4361, 6302, and IC 4593. Both NGC 2440 and 6302 show strong [N II] signals with clear splits. Reductions are in progress (D.C.V. Mallik, S.K. Jain, B.G. Anandarao*, D. Banerjee* & J.N. Desai*).

Reticon spectra of planetary nebulae NGC 2440, 3132 and 6572 were obtained using ESO 1.5m telescope and the Boller & Chivens spectrograph, with a view to studying the [C I] lines 8727, 9823, 9850A. Some of the spectra have a resolution of 6A in the range 5500-10300A, whereas others 2A in the range 8000-10300A (N. Kameswara Rao & A.K. Pati).

Multiple-shell planetary nebulae: It has recently been realised that as many as 50% of the planetary nebulae have multiple shells. The role of dust in the evolution of such nebulae (MSPN) has been studied. Shells that are ejected later absorb radiation from the central star and make the outer shell invisible optically for $\sim 10^3$ yr, during which time the MSPN is a strong infrared source. These considerations lead to the conclusion that all planetaries may in fact be MSPN and many cool infrared objects might have faint hydrogen line emission surrounding them for which a search should be made (H.C. Bhat).

Models of interstellar dust: Precise calculations of interstellar extinction and polarization have been performed, using the scattering efficiencies of spheroidal (oblate and prolate) particles. In particular, for an Oort-Hulst-Greenberg size distribution we have computed the ratio R of total to selective extinction and the wavelength of maximum polarization λ_{max} for various shapes and orientations. By matching the predicted and the observed values we are able to put constraints on various grain models. A quantity of interest from the chemical abundance point of view is V_c, the volume extinction factor, defined as the ratio of total volume of the grains to the total extinction cross-section. We have evaluated V_c for each model that reproduces the average observed value of $R \sim 3.1$. It is planned to extend our calculations to other size distributions (e.g. the Mathis-Rumpl-Nordsieck size distribution) and complex indices of refraction (D.B. Vaidya).

RADIATIVE TRANSFER

Effects of aberration and advection in fast moving fluids: The investigation is continued on the effects generated on the radiation field by fluids moving with velocities to the first order of c, in a medium which scatters and absorbs radiation in plane-parallel stratification. The differences between moving and non-moving media are not as spectacular as those produced in a purely scattering medium. It is being investigated whether or not sphericity has any effect on changing the radiation field. Photon frequency redistribution is also studied with aberration and advection terms included (A. Peraiah & M.S. Rao).

Compton scattering: The radiative transfer equation is solved incorporating the Compton and inverse Compton scattering. The constraint of conservation of total energy integrated over all frequencies is maintained. This will explain the spectrum from γ-rays to soft X-rays. This is being applied to γ-ray, X-ray sources and AGN (A. Peraiah & B.A. Varghese).

Cosmic masers: Radiative transfer effect on the maser lines is studied. Sphericity and geometrical extendedness are considered in evaluating these effects. The masing effect is produced more efficiently in plane-parallel geometry than in spherical geometry. Dust plays an important role in reducing the masing effect (A. Peraiah & G. Murthy).

Infrared emission from dust: Temperature of dust is determined from emission of infrared radiation by considering the radiative equilibrium in a mixture of gas and dust. Temperature correction procedures are employed in a plane parallel and spherical medium with

different composition of dust and gas. Changes in temperatures due to expanding medium in the presence of dust is being investigated (A. Peraiah & M.F. Ingalgi).

THE GALAXY

Capture of field stars by molecular clouds: The giant molecular clouds (GMC) in the Galaxy, during their lifetime ($\sim 10^8$ yr), can capture a significant number of field stars. The life of a GMC is terminated by new star formation giving rise to a star-cluster. Such young star-clusters will, therefore, contain two distinct populations of stars: a young population of stars from the recent star formation, and an old population of field stars. This mechanism naturally explains the existence of a number of anomalous objects in open clusters (H.C. Bhat).

Associations and clusters: The program of studying the wavelength dependence of polarization and position angle in very young associations and clusters was continued. Apart from observing some more members of Pup III Association, some members of the cluster NGC 2244 were also observed (S.K. Jain).

Further, to help interpret the polarimetric observations, spectroscopic observations of the members of these systems are also being obtained (S.K. Jain & Ram Sagar).

Mass and age distribution of stars in young open clusters: Due to the small ages of young open clusters in comparison to their dynamical evolution times ($\sim 10^8$ yr), the mass and age distribution in these clusters can provide answers to some crucial questions concerning the initial mass function (IMF), ages of young stars, and ultimately, help in understanding the star formation processes. Mass and age distributions of stars, based on homogeneous photoelectric UBV data and reliable cluster membership, are studied in 11 young open clusters. Stellar

masses and ages are determined by fittings the theoretical stellar models to each star's position in the HR diagram by means of an interpolation procedure. Analysis of the probable errors in mass determination and comparison with masses of binary stars has shown that the error in mass is of the order of or less than 15 per cent. The age can be found with considerably less accuracy. The error in the age estimates strongly depends on a star's position in the HR diagram as well as on a number of systematic effects such as rotation and unresolved binaries. The main conclusions drawn from the present analysis are:

i) The slope of the mass spectrum of stars, x, in five young and well-populated clusters is approximately the same, the average value being $x = 1.4$.

ii) The slope of the mass spectra of cluster stars will be overestimated ($\sim$15%) if the effect of mass loss in massive stars is not taken into account.

iii) Contrary to some results on the IMF of field stars, we have not found any substantial increase in slope for massive stars (say, $M > 5\ M_{\odot}$).

iv) In general, the clusters under discussion do not show significant variations of mass function slope x with galacto-centric distance, although two inner ones have a flat mass function ($x = 0.85$) and also clusters are located in a circular area with a diameter = 4 kpc with respect to sun.

v) In two clusters (NGC 6611 and NGC 6823) some contracting pre-main sequence stars have masses of the order of $10M_{\odot}$. In the classical theory

of non-homologous collapse some additional assumptions about the initial conditions of star formation are required to explain their presence.

vi) Age distribution of cluster members indicates non-coeval star formation in these young open clusters.

(R. Sagar, A.E. Piskunov*, V.I. Myakutin*, & U.C. Joshi*).

UBV photometry of NGC 2539: Photoelectric UBV magnitudes have been determined for 88 stars in the region of the cluster NGC 2539 with an aim to establish the cluster sequence towards the fainter side, the cluster membership of the stars, and to determine the cluster parameters. The cluster membership of the stars is decided on the basis of its position in the cluster field and in the UBV photometric diagrams. The average value of reddening is E (B-V) = 0.08 $\pm$ 0.02 mag and the cluster distance is estimated at 1050 $\pm$ 150 pc. From the H-R diagram the following inferences can be drawn:

i) A well defined cluster main sequence which extends from M_V = 0.6 mag to M_V = 3.8 mag is clearly visible.

ii) An evolutionary effect is clearly visible in the upper part of the cluster MS. Some stars have reached to the giant phase of their stellar evolution.

iii) Based on the fittings of isochrones, age estimate of the cluster comes out to be 5×10^8 yr.
(U.C. Joshi* & R. Sagar).

Young open clusters: Continuing the work on faint young open clusters in order to use them as tools in the study of the structure of our Galaxy, the following clusters have been observed with the 102-cm telescope at Kavalur employing UBV photometric techniques.

OCl 483 681 781 670 684

The reductions are in progress (G.S.D. Babu, J.C. Bhattacharyya & M.N. Anandaram*).

Dark matter: The recent recommendation of IAU commission 33 on Galactic structure to reduce the solar distance to our galactic centre from 10 kpc to 8.5 kpc (a 15% reduction) and solar rotation speed around it to 220 km s^{-1} from 250 km s^{-1} (a 10% slower speed) can be shown to accentuate the galactic dark matter problem. In particular this would imply an increase in the ratio of dark to luminous matter in the local group by as much as 20% but if neutrinos were the dark matter this would not much alter the constraint on neutrino rest mass (C. Sivaram).

GALAXIES AND COSMOLOGY

Population synthesis of galaxies: A project on population synthesis of galaxies has been going on with a view to deriving parameters such as the initial mass function, the time of the last major star formation event, and the distribution of metallicity in the various stellar components. Spectroscopic observations required are being obtained at VBO using the 1-m telescope. To extend the observations to fainter objects, and beyond the wavelength range possible at VBO, spectroscopic data of good signal-to-noise were obtained for three galaxies and several late-type standard stars using the 1.5-m telescope at ESO, Chile. The Boller & Chivens spectrograph equipped with the Reticon detector system, was used in the spectral region 5500-10350A with a resolution of about 6A. The preliminary reduction of the data was done at ESO, Munich and further reductions and analysis on the VAX system at VBO.

Apart from standard spectral features normally used, many additional atomic and molecular features have been identified for use in population synthesis. The Wing-Ford band due to FeH, has been detected in at least one galaxy, despite the severe difficulties of observing in the 1μm region of the spectrum. This enables placing more stringent limits on the relative numbers of late-type giant and dwarf stars in the galaxy observed. Further, more realistic values of the mass-to-light ratios can be derived.

Software has been written to perform detailed population synthesis using a nonlinear optimization technique subject to constraints. The astrophysical

constraints to the problem are derived from stellar evolution tracks. Trials of these synthesis programs are presently under way. Programs are also being written for the models of the evolution of galaxies, incorporating the latest stellar evolution tracks computed by workers elsewhere (A.K. Pati & J.C. Bhattacharyya).

String models of galaxy formation: The cosmic string parameters required for galaxy formation are compared with corresponding parameters in various particle physics models such as the heterotic super string, GUT strings, etc. Effects associated with gravitational lensing of distant objects by strings enables constraints to be put on string parameters. The angular momentum-mass relation for celestial objects is discussed in the context of string models. Formation of galactic halos with flat rotation curves is shown to be possible by accretion onto cosmic strings (C. Sivaram).

Binary galaxies: The energy radiated by binary galaxies in the process of merger was estimated. The energy loss by gravitational radiation was compared with that due to the transfer of energy from orbital motion of the galaxies to their internal motions by tidal interactions in galaxy mergers. A simple relationship connecting the two energy loss mechanisms was obtained. An interesting result was that the amount of energy loss due to gravitational radiation from merging galaxies is comparable with that for massive close binary stars. Merger due to gravitational radiation loss may be relevant in earlier epochs of galaxy formation when the protogalaxies were denser and closer (C. Sivaram & S.M. Alladin*).

Interacting galaxies: Numerical experiments on the tidal model of interacting galaxies were performed with various values for the mass ratios and the distances of closest approach, with a view to study whether similar structures could be produced by simple scaling of the mass ratios and the distances. It was shown that one could identify a parameter (ν) for collision of galaxies which is the ratio of the magnitude of the typical velocity increment of a star at the periphery of the test galaxy to the circular velocity at that point. The formation of bridges and tails in interacting galaxies depends on this parameter (ν) in a narrow range (0.1 - 0.7) in the case of parabolic coplanar encounters. When $\nu < 0.1$, the collision produced very little change in the test galaxy and when $\nu < 0.7$, appreciable disruption in the test galaxy is observed (P.M.S. Namboodiri, R.K. Kochhar & S.M. Alladin*).

Active galactic nuclei: It is shown that the nonthermal radio radiation from a quasar is intense enough to drive parametric instabilities in the fully ionized emission line regions. These instabilities cause significant enhancement of the plasma resistivity around the normal modes of the plasma and thus lead to an anomalous heating effect. The maximum plasma temperature is a function of the luminosity of the nonthermal radio radiation and the plasma parameters of the emission line regions (V. Krishan).

Inverse bremstrahlung or the free-free absorption is believed to be the main mechanism of absorption of the nonthermal quasar radiation in the emission line regions (ELR). The absorption rate is found to change significantly when the inhomogeneous nature of the plasma (in ELR), and the nonlinear effects associated

with the high intensity of the electromagnetic radiation are taken into account. A new process of resonance absorption comes into play when the electromagnetic radiation obliquely incident on a plasma density gradient excites plasma oscillations at the critical density surface (V. Krishan).

It appears possible to explain both the typical continuum electromagnetic spectrum and the relativistic velocities of electrons in the region of an active galactic nucleus (AGN) around a supermassive black hole (SMBH) by invoking stimulated Raman scattering processes. The gist of our proposal is that seed photons beat through Raman forward scattering (RFS), thereby creating Langmuir plasma waves which can very rapidly accelerate electrons to Lorentz factors $\sim$ 1000. These electrons preferentially lose their energy through Raman back scattering (RBS) off spatially quasi-periodic magnetic fields. Such fields are naturally produced via magnetic modulational instabilities acting on the Langmuir waves. Reasonable density distributions that satisfy various physical constraints seem to be capable of yielding the high luminosities and broken power-law continua typically found in quasars and Seyfert Type 1 galaxies. Additional bremsstrahlung emission in the optical and UV bands could possibly explain the "big blue bump" (P.J. Wiita* & V. Krishan).

Alternative energy mechanisms for quasars: Some of the difficulties associated with the conventional black hole models of quasars can possibly be solved by a scaling down of the energy requirements. This can be achieved by assuming that quasar distances are smaller than that implied by the Hubble law. Alternative energy mechanisms for such noncosmological redshift quasars are being investigated (C. Sivaram & P.K. Das).

Escape of black holes: The astrophysical aspects of proposals of escape of supermassive black holes from active galactic nuclei and their implications in relation to quasars were investigated. It was concluded that high velocity recoil of the central engine can at best be considered an exception rather than a rule since it requires a violent release of mass energy in a asymmetrical manner, which would be spectacular in nature. However, scope for the concept of low velocity motion of a central engine in the inner regions of the host galaxy exists in view of some observations of galaxies with displaced centres of activity (R.C. Kapoor).

Jets: The investigation of general relativistic effects influencing collimation processes in the jets of AGNs was continued. An interesting effect which might be important is twisting of the beam caused by dragging of inertial frames in case the black hole possesses substantial rotational energy. The dragging modifies particle trajectories as it will exert a torque on particles at a given location from the centre of the black hole which, therefore, tend to acquire an angular velocity same as that of cumulative dragging of inertial frames, in the direction of rotation of the black hole. Calculations indicate that for large opening angles and large angular momentum of the black hole and for the low gamma component of the jet, this twisting effect will be appreciable. Thus a jet consisting of multi-gamma components will suffer differential decollimation and twisting due to spacetime curvature and inertial frame drag respectively (R.C. Kapoor).

Periodicity in the redshift distribution of quasars: Quantum conformal fluctuations of space-time in HN theory gives rise to quantization of particle masses

and consequently of the redshifts. A preliminary analysis has shown that this may provide a natural theoretical interpretation of the observed periodicities in the redshift distribution of quasars. More detailed analysis based on the most recent QSO catalogues is being carried out (P.K. Das).

Luminosity evolution of distant galaxies in HN cosmology: In order to provide an alternative interpretation than that given by standard cosmological models, of the recent observations of distant galaxies ($z \lesssim 1.6$), luminosity evolution of distant radio galaxies in the framework of varying G HN cosmology was studied. With a time dependent gravitational 'constant' $G(t) \propto t^{-g} \propto (1 + z)^{2g}$ and galactic luminosity $L(t) \propto t^{-e} \propto (1 + z)^{2e}$ variations of magnitudes as a function of evolutionary parameters g, e and redshift z were investigated for both power law and blackbody sources. The main results are as follows:

(a) HN theory predicts systematic brightening in the past.

(b) The galactic temperature T is time dependent and varies as $T \propto \frac{1}{t} \propto (1 + z)^2$. This would make the distant galaxies appear systematically bluer as observed by Lilly et al. (1983).

(c) For thermal blackbody sources the increase in infrared K band luminosity is about 1.5 magnitudes out to a redshift $z \simeq 1$. Similar results were obtained by Lilly & Longair (1984) from their observations of 3CR galaxies (P.K. Das & C. Sivaram).

Varying G cosmologies: In varying G cosmologies, stellar evolution proceeds at a faster rate at higher z. The effect of the accelerated rate of evolution on the

main sequence turn-off mass is being investigated (P.K. Das & C. Sivaram).

The early universe: The evolution of the universe through the Planck epoch and the problem of its emergence from that epoch was considered in the context of a unified theory of gravity with other interactions. It was shown that owing to the breaking of scale invariance at the Planck energy scale, in such a theory, an early exponential expansion phase of the universe can occur. This approach leads to interesting constraints on the cosmological constant in terms of the coupling constants of various interactions (C. Sivaram).

From the cosmological requirement that gravitating zero point energy or vacuum energy in curved space time does not overdominate the dynamics of the universe, a quantum gravitational cutoff length is arrived at which is of the same magnitude as the Planck length. This suggests that the Planck length may arise as a cosmological constraint on curved space zero point energy. The possibility that the horizon problem in cosmology may be connected with non-local aspects of quantum reality in the sense of the EPR paradox has been considered in some details (C. Sivaram).

The flatness problem (i.e. the average density of the universe being very close to the closure density at all epochs) is explained in this approach as a quantum gravity constraint on vacuum energy (C. Sivaram).

Various observational and theoretical limits on the cosmological constant were obtained and discussed in some detail (C. Sivaram).

Conducting cosmic strings: Significant electromagnetic interactions of conducting cosmic strings with the ambient cosmic plasma are shown to lead to the production of high energy particles and gamma rays. The relativistic shock front connected with the relativistic motion of current carrying cosmic strings would accelerate ions and electrons to typical energies of well over a 100 MeV and plasma instabilities in the string wake can accelerate them to energies of several hundred GeV. Such strings can be an intense source of MeV gamma rays at cosmological distances and also produce synchrotron radiation at typical radio wavelengths. They can act as energy sources for powering quasars as well as contribute to the cosmic ray background (C. Sivaram).

Particle energies in pregalactic processes: Pregalactic processes like explosions or collapse of supermassive objects as well as other violent events like fragmentation of primordial objects would be expected to produce extremely energetic particles and photons whose energies would, however, be subject to cut-offs owing to their interaction with the more intense microwave background at larger z. The manner in which the cut-off cosmic ray energy of both protons and photons behaves with epoch has been studied and limits are placed for a background of such particles (C. Sivaram).

SOLAR-TERRESTRIAL RELATIONSHIPS

A HF pulsed phase path sounder is operated at Kodaikanal to investigate the small-scale dynamics (in time and space) of the ionospheric plasma near the geomagnetic dip equator. Preliminary analysis of data acquired over the period 1983 July through 1985 October revealed the regular presence of small amplitude (~ 20 m s^{-1}) quasi-sinusoidal fluctuations of 45-180 s periods in the time rate of change of phase path, P (Doppler frequency) of reflections from blanketing sporadic-E (sheetlike ionization structures with steep vertical plasma gradients that form rather irregularly around 100 km). Hydromagnetic waves do not seem to be the primary cause of the evidenced P pulsations, because ground-level geomagnetic micropulsation activity in the Pc4 (45-150 s) range was not seen at Trivandrum on all the numerous occasions, when simultaneous phase path and geomagnetic data were available. Besides, the short-period, small-amplitude quasi-periodic fluctuations were also consistently seen with the ubiquitous equatorial sporadic-E (E_{sq}) reflections. The $\dot{P}$ pulsations are interpreted as representative basically of those in the vertical electron drift in the equatorial electrojet medium, associated with the longitudinal electrostatic drift waves generated there by the gradient drift plasma instability mechanism (J.H. Sastri, K.B. Ramesh, J.V.S.V. Rao & D.R.K. Rao*).

Reflections from lower ionospheric F-region (~ 200 km) during day time ($08^h\ 16^m$ LT) also showed similar quasi-periodic fluctuations in $\dot{P}$, but over a slightly extended period range from 45 to 600 s. These fluctuations were found to manifest during normal equatorial electrojet conditions as well as partial counter-electrojet conditions. The spectral content of the

fluctuations, however, seems to depend on the ambient electrojet strength in that, while the longer-periods ($T \gtrsim 300$ s) persist almost all the time, the shorter-periods ($T < 240$ s) show a preference for normal electrojet conditions and almost disappear during the absence of E_{sq} in bottom side ionograms. Correlative studies with simultaneous geomagnetic micropulsations data from Trivandrum showed the absence of distinct P_{c4}/P_{c5} micropulsation activity at ground level, indicating that hydromagnetic waves are not the principal cause of the pulsations in $\dot{P}$. The longer-period pulsations in $\dot{P}$ ($T \gtrsim 300$ s) are interpreted as manifestations of perturbations in the F-region vertical electron drift, due to electric field fluctuations associated with internal gravity wave activity at E-region altitudes (at the magnetic link latitudes of F-region over Kodaikanal) and communicated along field lines to F-region levels over Kodaikanal (J.H. Sastri, K.B. Ramesh, D.R.K. Rao* & J.V.S.V. Rao).

Motivated by the above results, which are the first ones of their kind obtained with the HF Doppler technique on small-scale plasma motions in the equatorial ionosphere, a comprehensive program of further phase path observations is implemented to investigate in depth the interpretative aspects of the first results. The phase path sounder is to be augmented with multi-height and multi-frequency probing facilities for the purpose. Efforts are being made to achieve this objective, and a multi-height observational facility (on a single probing frequency) has been added in 1987 March (J.H. Sastri, K.B. Ramesh & J.V.S.V. Rao).

The signal strength of VHF transmissions from MARISAT are recorded at Bangalore, with a view to assess the onset and sustenance characteristics of ionospheric irregularities (through the study of scintillations

they produce in VHF transmissions from satellite) at locations from near dip equator to lower midlatitudes in the Indian equatorial region. This is a collaborative project with IIG, Bombay and the equipment was loaned by IIG (S.K. Saha, K.B. Ramesh & J.H. Sastri).

2.3m TELESCOPE PROJECT

The alignment of the 2.3m prime focus optical arrangement for photography was improved by using a laser beam. Optical set-up for testing the 2.3m secondary mirror using 50" Hindle sphere was made ready. The figuring work was taken up in 1986 November. The surface accuracy close to $\lambda/4$ has been achieved. A wire test for quantitative evaluation of hyperbolic surface in Hindle sphere test set-up has been developed and used for periodic evaluation of the secondary surface.

A camera for direct photography at the prime focus of the Vainu Bappu Telescope was put into operation and many long exposure photographs of celestial objects were obtained. A camera for colour photography using 35mm film roles is being fabricated.

Prime focus photometer: Design, fabrication, installation and testing of prime focus photometer for the VBT has been completed. First observations with this instrument were made between 1987 February 21 and 1987 March 4, as a part of the international watch programme of AMCVn (Hz 29), in collaboration with Indian Space Research Organisation. The performance of the system has been satisfactory.

Control systems: The VBT control system improvements and trimming the fine tuning were carried out. The oscillations in the star image noticed earlier was traced to a faulty tacho-generator which was then replaced. Minor errors in tracking left after proper balancing of the telescope was traced to improper seating of incremental encoder in the bull gear face and it was rectified by adjusting the tension in the mount. The remote

sensing of power supplies powering the encoders was picking noise enroute, and hence a local regulation was devised which eliminates the drift in the least significant digit in the declination and reduced it in hour angle. About 120 stars were observed at different hour angles to find out the flexure, refraction and non-orthogonality errors. The reductions are in progress (V. Chinnappan).

A safety interlock circuit has been incorporated to prevent the runaway condition occurring due to the failure in feedback pulses from the RA/DEC incremental encoders (R. Srinivasan).

Software has been developed to display the counterweight positions, and to scan the switch inputs from console for operation of counterweights, telescope dome, shutter, and hydraulic platforms (P. Santhanam).

The design of the Cassegrain control panels has been completed and the panels are taken up for fabrication (A.K. Pati).

The CAMAC interface system between future instruments on the VBT and the VAX 11/780 system has come to its final operational stages. CAMAC system software is being made to function under the VAX VMS operating system. CAMAC module and register addressing and data transfers to and from the VAX computer, have been working well. Direct memory access (DMA) transfers of large blocks of data are being tried out. Routines accomplishing these functions can easily be called from user-written FORTRAN programs. Documentation is also being written to explain the use of this software. The DMA routines will be especially useful for fast data acquisition from CCD detectors and/or TV-type camera

tubes when used in conjunction with the high-speed video digitiser module in the CAMAC system (A.K. Pati).

VAX 11/780 Installation, VBO: To aid astronomers in data reductions, the STARLINK software package (from the UK) was implemented on the system. Modifications were made, as required, for the package to work on the VAX hardware configuration at VBO. The various sub-packages within STARLINK are being tried out before the software is released for general use (A.K. Pati).

Data reduction packages IUE, IUEDR and DIPSO that are contained in STARLINK software were tested. The user's manual contained in STARLINK has been supplemented with explanatory notes. These notes caution users against unwanted, undesirably large output file created by certain commands, and extravagent data formatting caused by a few commands. Certain commands that are inoperable due to the difference in system configuration at Royal Observatory, Edinburgh from where the STARLINK was brought, and VBO Kavalur are listed separately. These supplementary notes titled 'User's Aid at Vainu Bappu observatory' are available at VBO Kavalur as well as at IIA Library, Bangalore (S. Giridhar).

INSTRUMENTATION AND TECHNIQUES

PDS microdensitometer: A Perkin-Elmer PDS (Photometer Data System) model 1010 MS micro-densitometer system has been installed during 1986 August-September. The system combines an accurate high-speed photometer with a precision x-y co-ordinate scanning system to allow acquisition of density and position information from transparent films/plates of size upto 25cm x 25cm. The digitized data can be stored on standard 9-track magnetic tapes at 800/1600 bpi, plotted on a strip-chart recorder or printed out at the console terminal. The model D 1010A photographic play-back system provides the facility to generate photographic images from digital images stored on the magnetic tape.

Infrared photometer: An infrared photometer has been assembled. This system was calibrated from observations of standard stars at the 1-m telescope at Kavalur. The system is designed for optimum performance with a f/13 beam (K.R. Sivaraman, K. Sivanandan, K.K. Scaria & R. Muraleedharan Nair).

Universal astronomical grating spectrograph: To make efficient use of the new Zeiss spectrograph various mounting plates which can take cameras other than those supplied by Zeiss were made. This enables the use of Varo image tubes with 10-inch and 6-inch cameras possible. Further, the spectrograph was equipped with the 1800 line mm^{-1} Baush and Lomb grating. A new cell for this grating was made such that it can easily replace the original Zeiss grating. It is planned to have cells for 600 line mm^{-1} and 300 line mm^{-1} gratings also.

Hypersensitization: A hypersensitization unit for photographic plates to considerably increase their sensitivity has been designed and given to HINDVAC

company at Bangalore for manufacture. The basic design features include a stainless steel chamber which can hold upto four 16cm x 16cm photographic plates, a vacuum pump to evacuate the chamber from 10^{-2} to 10^{-4} torr, a heating coil which can preheat dry nitrogen before it is used to flush the plates, and other auxillary measuring devices for reading pressure, temperature etc. The unit is expected to be ready by August 1987 (R. Rajamohan, A. Paranjpye, B.R. Madhava Rao & A. Charles).

CCD imaging: A TV display system has been developed to display CCD image data. This card supports 256 x 256 pixel elements with 256 gray levels (8 bits). The display memory can be read or written by any computer system which has parallel I/O ports.

A stand-alone CCD imaging system is being developed, based on a 16-bit Intel 8086 processor. This integrated system comprises of one single-board microcomputer with 32K RAM, 24 I/O lines, and one timer and interrupt controller, one I/O expander with 96 I/O line, six timers and two RS 232 ports, one 256 k bytes of RAM memory, and a tape controller and formatter with a standard 9-track tape drive unit, a TV monitor for display of CCD image data, drive electronics for CCD, cryogenic dewar, and a CRT terminal for interaction with the system. An interactive CCD image acquisition software is also being developed, which includes provision for selecting integration time, selection of charge transfer format to CCD (like adding pixels in column and row), provision to display the image on the TV monitor and to write the data on the magnetic tape in FITS format (P. Santhanam).

Independently, a commercial CCD system has also been configured, for use with 1m and 2.3m telescopes, and an order has been placed.

Photon-counting system: A microcomputer-based photon-counting was commissioned at the prime focus of VBT, and another similar system was assembled for the 38cm telescope (V. Chinnappan).

75cm telescope: A digital position display system for 75cm telescope was designed and checked based on Intel 8052, 8 bit microcontroller (V. Chinnappan).

Digital lock-in amplifier: A digital lock-in amplifier has been designed which provides advantages like high S/N ratio, and insensitivity to intensity drifts. The system is built around Intel 8085 micro-processor and provides programmable features for choosing reference waveform frequency, pulse delays, pulse width and the number of scans (K. Srinivasan).

Instrumentation link: An instrumentation link has been established between 75cm and 1m telescopes, and VAX 11/780 minicomputer in the VBT building. The interface adapted conforms to RS-422 standard (R. Srinivasan).

Kodaikanal spectroheliographs: Two spectroheliographs are used to take daily pictures of the sun in Ca K and H-alpha. Over the years the image quality had become rather poor. Efforts were hence made to improve the image quality.

i) Line shifters: The line shifters in front of the second slit of the spectroheliographs were found to be full of dust and fungus. These were washed with acetone and soap solution. Most of the dust and fungus

have been removed. Two small stains of fungus have gone into the glass surface of Ca K line shifter and hence cannot be removed by washing.

ii) Gravity weights: The gravity weights meant to move the spectroheliographs with uniform speed were touching one concrete wall of the housing at a number of points. The varying friction between the wall and weights produced non-uniform motion. The gravity weights were readjusted to ensure uniform motion.

iii) Photographic plate housing: There was a large amount of friction between the faces of the photographic plate housing and the moving part of the spectroheliograph, again causing non-uniformity in motion. The housing was removed and machined to minimize friction.

iv) Guiding bar: The movement of the spectroheliograph should be along the guiding bar. This, however, was not the case; in the last one mm of winding, the spectroheliograph moved in a different direction. As a result, on releasing the spectroheliograph, a sudden motion and jerk was produced which disturbed the centring of the line and image quality. A washer was put in the winding unit, removing the defect to a large degree.

v) Image position: The top 3 mm portion of the (60 mm) image was fainter than the rest because of defects in the top portion of the second slit. Pending replacement of the second slit, the image was lowered to avoid the top portion of the second slit. The image now is more uniform (Jagdev Singh, P.M.S. Aleem & B.S. Nagabhushana).

Low-frequency radio astronomy: Hardware to obtain maps with a zenith angle coverage of $\pm$ 50° was installed.

Test observations carried out gave encouraging results. Detailed observations to survey the continuum radiation at 34.5 MHz were carried out during 1987 January. Raw maps showing the brightness distribution of the sky in the declination range -35° to +65° and spanning 24 hours in R.A were made. Software for "cleaning" and other operations of such large size maps are being developed.

A VAX 11/730 computer was installed at Gauribidanur. Fabrication of the interface hardware between the existing digital correlation receiver and Fourier transform system and the VAX computer is under construction.

A microcomputer-based 32-channel data logger has been developed for the Gauribidanur radio telescope, including a standard 9-track magnetic tape transport. Interactive software required has also been developed.

Fourier transform spectrometer: A collaboration with the Royal Observatory, Edinburgh, has commenced on IR spectroscopy using Fourier transform spectrometer. First observations after the installation of the spectrometer are expected in 1987 May (S.K. Jain & M.J. Smyth*).

Optics: The following small optics were fabricated: (1) Prime focus photometer optics, (2) FTS optics, (3) Beam attenuator for Zygo interferometer, (4) Field lenses and flats for ISRO.

1.22m telescope optics (PRL): The figuring of the 1.22m primary mirror and the vibrating secondary were completed (A.P. Jayarajan, J.S. Chauhan* and Optics Team).

Unconventional techniques for acquisition of object information: The work on the above project has been recently started. In first approach, amplitude correlation is used for spatial intensity distribution of the object under study. The second approach makes use of multiple intensity correlation. A coherence interferometer for a 40mm beam size is being fabricated. Efforts are on to build the optics for the four identical telescopes to form an array for multiple correlation studies (A.K. Saxena & A.S. Marathey).

Vacuum coating: Vacuum coating plants were used for the following aluminizing jobs during the year: (1) 50" Hindle sphere; (2) 48" telescope optics of Japal Rangapur Observatory, Hyderabad; (3) 48" IR telescope primary mirror and other optics (PRL - Ahmedabad); (4) 36" parabolic dishes of CRL - Ooty; (5) 15" telescope optics; (6) About Twenty mirrors of 6"-8" sizes belonging to ABAA.

Vacuum plant facilities were also used for periodic evacuation of IR dewar and CCD Chambers for PRL, TIFR.

VHRR - passive cooler fabrication: The developmental work has been undertaken on the highly specularly reflecting polishing of the VHRR Passive Cooler plates for ISRO, at the optics workshop (A.A. Saxena).

Ultra-light weight mirror blank casting: A furnace fabricating ultra-light weight mirror blank upto a size of 25 inches is being built at the optics workshop.

History of Optical Glass Industry and Optical Technology in India - Project sponsored by Indian National Science Academy: The work on this project was started in 1987 January. Presently, literature survey and data collection is being done on the subject. To collect detailed information, a questionnaire has been sent to different organisations in the country and also to individuals in the field (A.A. Saxena & A. Vagiswari).

Software for spectroscopic reductions: A software package was developed for interactive reduction of photographic and other spectrophotometric data. The package, named RESPECT, consists of a large number of basic commands which execute simple operations on 1-dimensional images. Some higher-order commands are also available, and are generated as command procedures. The basic commands are defined using Digital Command Language Definition Utility. The display, plotting and interactive graphic commands use Tektronix Interactive Graphic Library, Digital ReGis Graphic Library and Digital PLXY software. The graphic input/output is possible on Digital VT240 and Tektronix 4100 series terminals. Graphic output is possible also on the Printronix printer/plotter. Detailed HELP library and reference manual are also made available (T.P. Prabhu, G.C. Anupama & S. Giridhar).

A FORTRAN program applying Marquardt algorithm was developed. The program is particularly useful to deblend the lines in a blend and to extract their fluxes and central wavelengths. The program achieves this by fitting a theoretical spectrum to the observed spectrum by assuming the line profile to be a linear combination of Gaussian and Lorentzian and the continuum as a first order polynomial (R. Surendiranath).

TDC-316 computer: Software has been developed for conversion from VAX 11/780 to TDC-316 in labelled tape as well as back-up tape formats. Software has also been developed for reading data from PDS tapes into TDC-316 (A.V. Ananth).

Automation for administration and accounting: Software has been developed for preparing pay-slips and administrative file management on TDC-316. A new personal computer has been acquired for developing software needed in administration and accounting, in library management, and in instrumentation on PCBs (A.V. Ananth & S.Chandramouli).

Site survey at Leh: The observations with 20-inch telescope at Leh for determining the extinction curve are being continued. The data is being analysed to study the variation of extinction with season to monitor the sky conditions, e.g. number of hours available per night for photometric/spectroscopic observations.

LIBRARY

The library subscribed to 136 journals with the addition of 2 new journals, Comments on Plasma Physics, and Nuclear Fusion. It continued to receive some 65 publications on exchange basis. A total of 344 books were added to the collection during the year. The current awareness service is being continued by the library through Recent Research in Astronomy & Astrophysics and the IIA preprint lists.

Some additional journals were procured as second copies for Kavalur library. All efforts are being made to update the Kavalur library which will be housed in the 2.3 m VBT building.

A collaborative project of compiling a thesaurus on astronomy & astrophysics has been undertaken by the library staff under the auspices of IAU commission 5, with the librarian of Anglo-Australian Observatory as the coordinator.

Miscellany

Ph.D theses

G.S.D. Babu : The study of faint galactic open clusters, Bangalore University (Guides : J.C. Bhattacharyya & M.N. Ananda Ram).

B.S. Shylaja : Emission line studies of Wolf-Rayet binary systems, Bangalore University (Guides : J.C. Bhattacharyya & M.N. Ananda Ram).

K.N. Nagendra: Radiative transfer with Strokes vectors, Bangalore University (Guides : A. Peraiah & B.C. Chandrasekhara).

M. Phil thesis

T. Mangayarkarasi : Cyclotron radiation in an inhomogeneous magnetic field, Bharathidasan University (Guide : V. Krishan).

Awards

B. Datta & P.S. Joshi* : The essay titled 'Lower bounds on axion rest mass in a general cosmological scenario' received honourable mention at the 1986 Gravity Research Foundation essay competition.

R.C. Kapoor : The essay titled 'Central engine or locomotive ?' received honourable mention at the 1986 Gravity Research Foundation essay competition.

Ram Sagar : Received the Young Astronomers award of ASI for 1983-84 for the paper 'Integrated photometric parameters of open and globular clusters' by Ram Sagar, U.C. Joshi & S.D. Sinvhal.

J.C. Bhattacharyya: Elected fellow of the institution of electronics and telecommunication engineers.

Pre-Ph.D courses

T.P. Prabhu gave lectures on observational and extra-galactic astronomy;

Vinod Krishan gave a course on 'Radiation processes and plasma astrophysics'; and

H.C. Bhatt taught the course on interstellar medium to the students of joint astronomy program at the Indian Institute of Science.

Teaching of astronomy

C. Sivaram gave a three weak lecture course on 'Modern aspects of stellar evolution especially in relation to the sun', to the scientific staff at IIA, Kodaikanal during 1986 May-Jun.

He also gave a ten lecture course on 'Current Aspects of Relativistic Astrophysics and Cosmology' to post graduate teachers at the South Zone Winter School on Relativity and Cosmology held at Mysore University 1986-87 Dec.-Jan.

Laboratory projects

Three students from MCP, Gondia, and four students from Bangalore Institute of Technology took up projects in the electronics laboratories of the Institute.

Popularization of astronomy

Wooden models of the 2.3m Vainu Bappu telescope were gifted to the Department of space and technology, New Delhi and to Periyar science and technology centre, Madras.

A public astronomical exhibition was set up to celebrate the national science day 1987 Feb. 28. Video films on the Institute were also shown.

R.C. Kapoor participated in the science and technology exhibition organized by D.S.T (Ministry of Science and Technology) at the Parliament Annexe during 1986 April 23-27.

Publication channels

IIA Newsletter continued its publication into Volume 2 in January 1987. Kodaikanal Observatory Bulletins Volume 7 was published. The editorial work of the Journal of Astrophysics and Astronomy and of the Bulletin of the Astronomical Society of India continued to be done at the Institute.

Scientific meetings and visits

N. Kameswara Rao attended the Kashi Nandy symposium on 'Hot stars and interstellar matter' held at Royal Observatory, Edinburgh from 1986 Sep. 29-30, and spent over a week there. He visited the Observatory and the Astronomy Department of St. Andrews University in the beginning of 1986 Oct. He also visited University College, London to discuss collaboration projects related to Hydrogen deficient stars.

T.P. Prabhu attended the school on advanced techniques in computational physics, 1986 Sep. 29-Oct. 28, and the Conference on 'Perspectives in computational physics', Oct. 29-31, International Centre for Theoretical Physics, Trieste. He also visited Astronomical Institute, Muenster, F.R. Germany, 1986 Nov. 1-6.

K.R. Sivaraman attended the IHW steering group committee meeting at Heidelberg in 1986 Oct. Following this, he attended the 20th ESLAB symposium on the Exploration of Halley's comet held at Heidelberg.

R.C. Kapoor participated in the conference on Neutron stars, active galactic nuclei and jets held at the NATO-Advanced Study Institute, Erice, Italy during 1986 Sep. 17-25, and spent a month at International School for Advanced Studies, Trieste, 1986 Sep.-Oct.

Jagdev Singh went to National Solar Observatory, KPNO, Tucson, USA to take observations at the Vaccum tower telescope.

V. Krishan visited NOAA, HAO in Boulder, Colorado and attended a meeting on 'High resolution solar physics'; she also visited University of California in San Diego; SAC Peak in New Mexico; University of Maryland; and University of St. Andrews (U.K) between 1986 Sep.-Dec.

S. Giridhar attended the 5th Latin American Regional Meeting conducted at Merida, Yucatan in Mexico during 1986 Oct. 4-10. She visited National University of Mexico during 1986 Oct.-Dec. She also visited Dominion Astrophysical Observatory, Canada to work on a data reduction project during 1987 Jan. 6-10.

A.K. Pati made a trip to the European Southern Observatory at Chile for observations. He also visited Kitt Peak National Observatory, Tucson, the University College, London, and the European Southern Observatory headquarters at Munich to study astronomical instrumentation. He carried out at Munich preliminary reductions of the data obtained in Chile. The duration of the entire trip was 1986 Apr.8-Jun.1.

P. Venkatakrishnan visited the Centre d'Etudes et de Recherches Geodynamiques et Astronomiques in France from 1986 Aug.29-31. He also visited the Harvard-Smithsonian Centre for Astrophysics from 1986 Sep.2-Dec. 2.

R. Vasundhara attended the symposium 'The origin and evolution of planetary and satellite systems' held at Potsdam, GDR during 1986 Oct. 14-18.

B.S. Shylaja attended the IAU Colloquium no.93 on Cataclysmic Variables at Bamberg, FRG between 1986 Jun. 15-19 and the IAU symposium no.122 on Circumstellar matter at Heidelberg, FRG between 1986 Jun.22-26. She also visited the Observatorium Hoher List, Bonn.

J.H. Sastri attended the 6th international symposium on Solar-Terrestrial Physics held in Toulouse, France during 1986 Jun.30 - Jul.5. He also attended the symposium on 'New trends in geomagnetism' held at University of Rajasthan, Jaipur on 1986 Oct. 27., and participated in the national workshop on 'World ionosphere - thermosphere study' (WITS) held at NPL, New Delhi during 1987 Mar. 18-19.

S.S. Hassan attended the COSPAR meeting on solar and stellar activity (1986) held at Tolouse, France and the 5th European meeting on Solar Physics (1987) held at Germany. Hassan also visited the following institutions : Dept. of Applied Mathematics and Theoretical Physics, Cambridge in March 1986; Paris Observatory, Meudon, France in 1986 June; International Centre for Theoretical Physics, Trieste in June 1986; Observatory Göttingen, West Germany in May 1987; University of St. Andrews, Scotland in May 1987.

M.H. Gokhale attended the COSPAR symposium no.11: 'Solar and stellar activity' in France from 1986 Jun.30 - Jul.2. He also attended the IAU symposium no.123: 'Advances in helio and astro seismology', held at Aarhus, Denmark between 1986 Jul. 6-11. He visited the Kiepenheuer

Institute, Freiburg, W. Germany 1986 Jul.3-5 and the Astronomical Institute, Utrecht, Holland 1986 Jul.12-15.

R.K. Kochhar attended IAU symposium no.127 'Structure and Dynamics of Elliptical Galaxies' at Princeton 1987 May 27-29; and a workshop on 'The use of super computers in stellar dynamics', at Princeton June 1-3. He spent a fortnight at RGO and India Office, London researching into IIA's history.

J.C. Bhattacharyya attended the annual meeting of the Indian Academy of Sciences, Varanasi during 1986 Nov.; and National symposium on physical and chemical basis of life and non-life, Calcutta, 1986 Nov.; Professor J.N. Bhar commemoration symposium on advances in radio sciences in India, Calcutta, 1986 Dec.

J.C. Bhattacharyya & S.K. Jain attended the workshop on recent developments in astronomical detection techniques for infrared, optical, and X-ray bands, Srinagar, 1986 Jul.14-24.

D.C.V. Mallik visited the Department of Astronomy, Osmania University, Hyderabad during 1986 Jul.

P.K. Raju attended the 6th national workshop on atomic and molecular physics, Banaras Hindu University, Varanasi, 1986 Dec. 8-13.

J.C. Bhattacharyya, R. Ismail, J.P. Lancelot, J.P.A. Samson & A.K. Saxena attended the workshop on optical and opto-electronic instrumentation held at CSIO, Chandigarh, 1986 Sep.4-5.

IIA Bicentennial workshop on 'Two hundred years of astronomy' and the eleventh annual meeting of the Astronomical Society of India, Bangalore, 1986 Dec.5-10 : Both were well attended.

A.K. Saxena attended the workshop on modern optics, laser and laser spectroscopy, Kanpur, 1987 Jan.23-29.

J.C. Bhattacharyya, S. Chatterjee, V. Krishan & S.K. Saha attended the national seminar on frontiers of astronomy and astrophysics, Calcutta, 1987 Feb. 17-19.

G.C. Anupama, J.C. Bhattacharyya, S. Giridhar, K.N. Kutty, T.P. Prabhu, Ram Sagar, S.K. Saha, R.K. Shevgaonkar & P. Venkatakrishnan attended the national workshop on image processing in astronomy, Udhagamandalam, 1987 Mar. 23-27.

Lectures by visiting scientists

Valentine, I. Makarov (Pulkovo Observatory, USSR): Recent studies on the global processes of the solar activity (1-4-1986).

M.R.S. Hawkins (Royal Observatory, Edinburgh, U.K): Missing mass from low luminosity stars (14-4-1986).

N. Mukunda (Indian Institute of Science, Bangalore): Group theory and paraxial optics (15-4-1986).

V.E. Zuev (Academecian, USSR); Laser sounding of the atmosphere (9-4-1986).

Rajaram Nityananda (Raman Research Institute, Bangalore): Caustics in optics and dynamics (10-6-1986).

Paul Wiita (Georgia State University, USA): Neutrino Emission in post main sequence stars (17-7-1986).

B.C. Chandrasekhara (Bangalore University, Bangalore): Heat transfer problems in fluid mechanics (5-8-1986).

R.S. Iyengar (Mt. Allison University, Canada): Spectrophotometric observations of the solar radiation (26-8-1986).

S.M. Alladin (Osmania University, Hyderabad): Tidal models of interacting galaxies (2-9-1986).

Ajit Kembhavi (TIFR, Bombay): CCD observations; Prospects and frontiers (9-9-1986).

K.D. Abhyankar (Osmania University, Hyderabad): Elements of Astrophysics - informal talk on his book (19-9-1986).

K.V.K. Iyengar (TIFR, Bombay): IRAS observations of unidentified equatorial infrared catalogue 1 sources (28-10-1986).

John Leibacher (National Solar Observatory, USA): Helioseismology (5-11-1986).

Tom Gehrels (Lunar and Planetary Centre, University of Arizona, USA): A proposal survey of comets, asteroids and the tenth planet (10-12-1986).

Tom Gehrels (Lunar and Planetary Centre, University of Arizona, USA): CCD scanning (10-12-1986).

Tom Gehrels (Lunar and Planetary Centre, University of Arizona, USA): A few forgotten problems in polarimetry (11-12-1986).

Jayant Murthy (John Hopkins University, Baltimore, USA): Observations of hydrogen and deuterium in the local interstellar medium (30-12-1986).

George W. Wetherill (Carnegie Institution of Washington, USA): Formation of the terrestrial planets (23-2-1987).

K.V. Barve (Nehru Planetarium, Bombay): Popularization of astronomy at Nehru Planetarium (25-2-1987).

Technical/Popular
Lectures given outside the Institute

J.C. Bhattacharyya: How large are stars ? Nehru Planetarium, New Delhi (1986 Apr.).

_____:Frontiers of astronomy, Inaugural lecture, Birla Industrial & Tech. Museum, Calcutta (1986 May).

_____:Seminar on Planetarium, Bangalore (1986 May).

_____:Measurement of stellar diameters, Prof. S.V.C. Aiya lecture at the Inst. of Electronics & Telecom. Engrs. Bangalore (1986 Jun.).

_____:Observational Optical astronomy in India, Facilities and challenges, Joint Astronomy Program, Physics Department, IISc, Bangalore (1986 Oct.).

J.C. Bhattacharyya: 200 years of astronomy in India, Indian Inst. of World Culture, National College, Bangalore (1986 Nov.).

_____:Recent advances in the Indian astronomy, Inaugural address, Silver Jubilee function of the Physics Department, Burdwan University, Burdwan (1986 Nov.).

_____:Reminicenses of Professor J.N. Bhar, Professor J.N. Bhar commemoration symposium on advances in radio sciences in India, Calcutta (1986 Dec.).

_____:Indian contributions in present day astronomy, Administrative Research Institute, Bangalore (1986 Dec.).

_____:Inaugural address on exhibition of 25 years of space photography, Visveshwaraiah Industrial & Technological Museum, Bangalore (1987 Mar.).

_____:Valedictory address at Mathematics olympiad, Central College, Bangalore (1987 Mar.).

_____:*Astrophysics in India over the years (invited review), IIA Bicentennial Symp., Bangalore (1986 Dec. 5).

_____:*Focal plane instrumentation for large optical telescopes (invited review), Workshop in recent development in astronomical detection techniques for infrared, optical and X-ray bands, Srinagar (1986 Jul.).

_____:*New experiments on the frontiers of astronomy (invited review), National workshop on optical and opto-electronic instrumentation, Chandigarh (1987 Feb.)

B. Datta: *Effects of general relativity on the arrival times of signals from fast pulsars, TIFR, Bombay,(1987 Jan.).

M.H. Gokhale: *Advances in helioseismology (invited review), XI ASI mtg. (1986 Dec.).

R.K. Kochhar: *Advent and growth of modern astronomy in India (invited review), IIA Bicentennial Symp., Bangalore (1986 Dec.5).

V. Krishan: *On pressure structure of coronal loops, NOAA, Boulder (1986 Sep. 18).

_____:*On radio emission from the sun, University of Colorado (1986 Sep. 19).

_____:*On pressure structure of coronal loops, SAC Peak Solar Observatory (1986 Oct. 3).

_____:*On pressure structure of coronal loops, University of Maryland (1986 Oct. 7).

_____:*On pressure structure of coronal loops, University of St. Andrews, Scotland (1986 Nov. 18).

_____:*On nonthermal radiation in active galactic nuclei, National seminar on frontiers in astronomy, Calcutta (1986 Feb. 19).

A. Peraiah: How far are the stars ?, Maharani's college for women (1987 Feb. 4).

T.P. Prabhu: *Optical spectrum of nova LW Serpentis, Astronomical Institute, Meuenster (1986 Nov. 4).

P.K. Raju: *'Importance of atomic and molecular research for astronomical interpretations', 6th national workshop on atomic and molecular physics, Banaras Hindu University, Varanasi (1986 Dec.8-13).

B.S. Shylaja: Glimpse of the Universe, VITM, Bangalore (1987 Feb.).

C. Sivaram: Anthropic principle in Astronomy, VITM, Bangalore (1987 Mar.).

_____:*Physics of stars and galaxies (2 lectures), Physics department, Central College, Bangalore (1987 Mar.).

_____:*Eötvös experiment and equivalence principles, RRI Journal club (review talk).

K.R. Sivaraman: *Physics of the sun, (2 lectures), Summer institute on 'Physics in Astronomy', Astronomy Department, Osmania University, Hyderabad, (1986 Jun.).

_____:Comet Halley - new results, Science Forum, National College, Bangalore.

_____:*Results of the Comet Halley (invited review), IX ASI mtg. (1987 Dec.).

P. Venkatakrishnan: *Speckle interferometry, National workshop on image processing in Astronomy, Udhagamandalam (1987 Mar.).

Popular articles

S.P. Bagare: 'The solar atmosphere', Science Reporter (1987 Mar.).

S.K. Jain: Cosmic rays, Anvesha (1987 Jan.-Feb.).

N. Kameswara Rao & S. Giridhar: IUE data reduction, IIA Newsletter (1986 Oct.).

R.K. Kochhar: Transits of Venus 1761 and 1769, IIA Newsletter (1986 Apr.).

_____:Advent of modern astronomy in India, IIA Newsletter (1986 Oct.).

D.C.V. Mallik: Robert Oppenheimer: Letters and recollections, Bull. of Sciences, Vol.3, No.2 (1987).

_____: SN 1987a, Bull. of Sciences, Vol.3, No.2 (1987).

B.S. Shylaja: On the history of IIA (Kannada), Sudha (1986).

_____: On the Supernovae (Kannada), Sudha (1986).

C. Sivaram: (1986) Bull. Astr. Soc. India 14, 64. Review of the book 'The big bang and Georges Lemaitre', 1984, ed. A. Berger, Reidel.

K.R. Sivaraman: A new look at Comet Halley, Science Age (1987 Feb.).

Radio and Television Programs

K.R. Sivaraman: A.I.R. Madras (English) Live transmission from Kavalur on the viewing conditions of Comet Halley (1986 Apr. 11).

_____: A.I.R. interview, Bangalore (English) (1986 May).

_____: Comet Halley, Doordarshan, Madras (1986 May).

_____: The TV program titled 'Window of the World - Secrets of the Sun' recorded at Kodaikanal in 1984 won the National Award announced in 1986 Nov.

List of academic and technical staff

1.	J.C. Bhattacharyya	Director
2.	A. Peraiah	Professor
3.	Ch.V. Sastry	"
4.	K.R. Sivaraman	"
5.	M.H. Gokhale	Associate Professor
6.	N. Kameswara Rao	"
7.	R.K. Kochhar	"
8.	J.H. Sastri	"
9.	G.A. Shah	"
10.	Vinod Krishan	"
11.	Bhaskar Datta	Reader
12.	P.K. Das	"
13.	R.C. Kapoor	"
14.	D.C.V. Mallik	"
15.	M. Parthasarathy	"
16.	T.P. Prabhu	"
17.	K. Rajamohan	"
18.	P.K. Raju	"
19.	Ram Sagar	"
20.	A.K. Saxena	"
21.	K.K. Scaria	"
22.	R.K. Shevgaonkar	"
23.	S. Sirajul Hasan	"
24.	C. Sivaram	"
25.	P. Venkatakrishnan	"
26.	G.S.D. Babu	Fellow
27.	S.P. Bagare	"
28.	H.C. Bhat*	"
29.	S. Chatterjee	"
30.	V. Chinnappan	"

*Asterisk denotes appointment in the current report period.

31.	K.K. Ghosh	Fellow
32.	N. Gopalaswamy	"
33.	Jagdev Singh	"
34.	S.K. Jain	"
35.	A.K. Pati	"
36.	A.V. Raveendran	"
37.	P. Santhanam	"
38.	B.S. Shylaja	"
39.	G. Thejappa	"
40.	R. Kariyappa*	Research Associate
41.	D. Mohan Rao*	"
42.	S. Mohin	"
43.	K.N. Nagendra	"
44.	P.M.S. Namboodiri	"
45.	R.S. Narayanan	"
46.	K.B. Ramesh*	"
47.	K.E. Rangarajan*	"
48.	J.P.L.C. Thangadurai	"
49.	S.K. Saha	"
50.	K.R. Subramaniam	"
51.	Sunetra Giridhar	"
52.	R. Surendiranath	"
53.	S. Surendra Gupta	"
54.	Sushma G.V. Mallik	"
55.	Vasundhara Raju	"
56.	Parag Seal	CSIR Scientist's Pool Officer
57.	G.C. Anupama	Research Scholar
58.	K.S. Balasubramaniam	" Joint Astronomy Program
59.	Parthasarathy Joarder	"
60.	Jacob Thomas*	"

*Asterisk denotes appointment in the current report period.

Technical staff

1.	A.P. Jayarajan	Consultant
2.	S.C. Tapde	Project Manager 2.3m Telescope Project
3.	R. Srinivasan	Head, Electronics Laboratories & Computer Centres
4.	A.V. Ananth	Sr. Electronics Engineer
5.	B.R. Madhava Rao	Sr. Mechanical Engineer
6.	N. Selvavinayagam	Civil Engineer
7.	G. Srinivasalu*	Engr. (Electronics & Computer Sciences)
8.	A.S. Joseph*	Engineer Associate
9.	K. Narayanan Kutty*	"
10.	R. Muraleedharan Nair	Technical Associate
11.	K. Ramankutty	"
12.	R. Sivashanmugam	"
13.	K.G.Unnikrishnan Nair	"
14.	A. Vagiswari	Librarian

*Asterisk denotes appointment in the current report period.

Governing Council meeting

The council met once, on 1986 Sep. 27, at Bangalore.

List of publications

A. In Journals

Ashoka, B.N., Anupama, G.C., Ghosh, K.K., Jain, S.K., Pati., A.K., Prabhu, T.P., & Rao, N.K.(1987) IAU Circ. 4339, 4340. Supernova 1987A in Large Magellanic Cloud.

Ashoka, B.N., Ghosh, K.K., Giridhar, S., Mallik, S.G.V. & Rao, N.K. (1987) : IAU Circ. 4359. Supernova 1987A in Large Magellanic Cloud.

Bhatt, H.C. & Mallik, D.C.V. (1986) Astr. Ap. 168, 248. Cn 1-1: a peculiar compact planetary nebula.

Boischot, A*., Sastri, J.H. & Zarka, P*. (1987) Astr. Ap. 175, 287. Localization of Io and non-Io sources of Jovian decameter emission.

Chandola, H.C*., Rajput, B.S*., Sagar, R. & Verma, R.C*. (1986) Indian J. Pure & Appl. Phys. 24, 51, Tachyons in gravitational field.

Datta, B. & Joshi, P.S.* (1986) Bull. Astr. Soc. India 14, 156. Lower bounds on axion rest mass in a general cosmological scenario.

Deshpande, M.R*., Joshi, U.C*., Kulshrestha, A.K*., Sen, A.K*., Rameswara Rao, N. & Raveendran, A.V. (1987) Publ. Astr. Soc. Pacific 99, 62. Variation of linear polarization in the R Aquarius system.

Gokhale, M.H. (1986) J. Ap. Astr. 7, 241. Does sunspot activity originate in slow global oscillations of the sun ?

Hassan, S.S. (1986) M.N.R.A.S. 219, 359. Oscillatory motions in intense flux tubes.

Hassan, S.S. & Keer* (1986) Astr. Ap. 158, 288. Stability of cool flux tubes in the solar chromosphere.

Hassan, S.S. & Sobouti, Y*. (1987) M.N.R.A.S. (in the press). Mode classifications and wave propagation in a magnetically structured medium.

Joarder, P.S., Gokhale, M.H. & Venkatakrishna, P. (1987) Solar Phys. (in the press). Thermal over-stability of hydromagnetic surface waves.

Joshi, U.C*., & Sagar, R. (1986) Bull. Astr. Soc. India 14, 95. UBV photoelectric photometry of the open cluster NGC 2539.

Kameswara Rao, N., Venugopal, V.K*. & Patnaik, A.R*. (1987) J. Ap. Astr. (in the press). Further VLA observations of hydrogen deficient stars.

Kapoor, R.C. & Datta, B. (1986) Ap.J. 311, 680. Effects of spacetime curvature and rotation on arrival times of pulse from fast pulsars.

Krishan, V. (1987) M.N.R.A.S. 226, 629. Anomalous heating of quasar emission line regions.

Krishna Swamy, K.S*. & Shah, G.A. (1987) Earth, Moon & Planets, 39 (in the press). The dust grain in the coma of comet west.

Makarov, V.I*., Makarova, V.V.* & Sivaraman, K.R. (1986) Soln. Donn. No.10, 96 (in Russian). Butterfly diagram for polar faculae and sunspots for the period 1940-1985.

Makarov, V.I*., Tavastsherna, K.S* & Sivaraman, K.R. (1986) Russian Astr. J (in Russian) 63, 534. Magnetic neutral lines of the large scale magnetic field and the solar activity.

Makarov, V.I*. & Sivaraman, K.R. (1986) Kodaikanal Obs. Bull. 7, 2. Atlas of H-alpha synoptic charts for solar cycle 19 (1955-1964).

Makarov, V.I* & Sivaraman, K.R. (1986) Bull. Astr. Soc. India 14, 163. On the epochs of polarity reversals of the polar magnetic field of the sun, period 1870-1982.

Nagendra, K.N. (1987) Astr. Nachr. (in the press). Polarization line radiative transfer in the atmospheres of magnetic white dwarfs.

Nagendra, K.N. & Peraiah, A. (1987) Astr. Ap. (in the press). Some physical processes influencing the polarization of continuum and line radiation.

Paranjpye, A. & Babu, G.S.D. (1986) Curr. Sci. 55, 1020. Occultation of SAO 185428 by 336 Lacadiera.

Parthasarathy, M., Cornachin, M*. & Hack, M*. (1986) Astr. Ap. 166, 237. The ultraviolet spectrum of Upsilon Sagittarii.

Parthasarathy, M. & Lambert, D.L*. (1987) J. Ap. Astr. 8, 51. Alpha Cygni as a radial velocity variable.

Peraiah, A. (1987) Ap.J. 317, 271. Abberation and advection effects in a plane parallel medium in motion.

Peraiah, A. (1987) Bull. Astr. Soc. India 15, 1. Transmission and reflection operators of radiative transfer equation with abberation and advection terms. I. Monochromatic radiation field with spherical symmetry.

Peraiah, A., Rao, M.S. & Varghese, B.A. (1986) Kodaikanal Obs. Bull.5, 155. Line profiles in an expanding spherical medium.

Peraiah, A., Varghese, B.A. & Rao, M.S. (1987) Astr. Ap. Suppl. (in the press). Effects of dust on the formation of lines in an expanding spherical medium.

Pottasch, S.R*. & Parthasarathy, M. (1987) Astr. Ap. (in the press). Proto-planetary nebulae-II : Luminous FG stars.

Prabhu, T.P & Anupama, G.C. (1987) Ap. Space Sci. 131, 479. The optical spectrum of nova LW Serpentis 1978.

Raju, P.K & Singh, J. (1987) Solar Phys. (in the press). Comparison of computed fluxes for Fe X and Fe XIV lines with observed values at 1980 eclipses.

Raveendran, A.V., Joshi, U.C.*., Vadher, N.M*. & Rao, N.K. (1987) IAU Circ. No.4339. LMC supernova 1987A.

Raveendran, A.G. & Kameswara Rao, N. (1987) Astr. Ap. (in the press). Polarimetric observations of AR Pup.

Sastri, J.H., Ramesh, K.B., Rao, D.R.K*. & Rao, J.V.S.V. (1987) Phys. Scr. (in the press). Manifestations of short-period electric field fluctuations in the equatorial lower thermosphere.

Saxena, A.V. & Lancelot, J.P. 1986. Kodaikanal Obs. Bull. (in the press). A program for testing aspheric Schmidt corrector plate.

Shylaja, B.S. (1986) J. Ap. Astr. 7, 171. Spectrophotometric studies of CQ Cep.

Shylaja, B.S. (1986) J. Ap. Astr. 7, 305. A spectrophotometric study of WN 5 star HD 50896.

Shylaja, B.S. (1987) J. Ap. Astr. 8, 183. The He II line 4686 in WN binaries.

Shylaja, B.S. (1987) Ap. Space Sci. 130, 181. Photometry of BD-7°3007.

Shylaja, B.S. & Babu, G.S.D. (1986) M.N.R.A.S. 222, 683. The variation of the λ5200 feature in HD 34452.

Sivaram, C. (1986) Ap. Sp. Sci. 127, 133. The Planck length as a cosmological constraint.

Sivaram, C. & Alladin, S.M. (1986). Bull. Astr. Soc. India. 14, 229. Energy loss due to gravitational radiation in galaxy mergers.

Sivaram, C. (1986) Gurutva (Bull. Ind. Assoc. Gen. Rel. Grav). p. 38. The cosmological constant - To be or not to be ?

Sivaram, C. (1987) Earth, Moon & Planets. 37, 155. Planetary heat flow limits on monopole and axion fluxes.

Sivaram, C. (1987) Nature 327, 108. Cosmic strings and the angular momentum-mass relation for celestial objects.

Sivaram, C. (1987). Ap. Sp. Sci. (in the press). Gravitational radiation constraint on string tension.

Sivaraman, K.R., Babu, G.S.D., Shylaja, B.S. & Rajamohan, R. (1987) Astr. Ap. (in the press). Spectrophotometry of comet Halley. 1. Flux, column density and emission gradients within the coma in the emission bands and the continuum.

Sivaraman, K.R., Singh, J., Bagare, S.P. & Gupta, S.S. (1987) Ap.J. 313, 456. Chromospheric Ca II K-line variations in the sun as a star over a solar cycle.

Subramanian, K.R., Nanje Gowda, C., Abdul Hameed, A.T. & Sastry, Ch.V. (1986) Bull. Astr. Soc. India 14, 236. A broadband radio telescope at Gauribidanur.

Vasundhara, R., Bhattacharyya, J.C. & Rozario, M. (1986). Bull. Astr. Soc. India 14, 232. Plume-like structures of extinction clouds at 19 Saturn radii.

Vasundhara, R. & Kuppuswamy, K. (1986) IAU Circ. No.4207.

Vaidya, D.B. & Desai, J.N*. (1987) Ap. Sp. Sci. 129, 335. Interstellar extinction by spheroidal absorbing dust grains.

Venkatakrishnan, P. & Chatterjee, S. (1987) M.N.R.A.S. 224, 265. On the saturation of the refractive index structure function. I. Enhanced hopes for long base-line optical interferometry.

B. In Proceedings

Anupama, G.C. Prabhu, T.P. & Giridhar, S. (1987) Proc. Image processing in Astronomy (ed. : T. Veluswamy) Radio Astr. Centre, Udhagamandalam, RESPECT-Software for reduction of spectroscopic data.

Balasubramaniam, K.S. (1987) Proc. Conf. 'The role of fine-scale magnetic fields in the structure of the solar atmosphere, Cambridge University Press (in the press). Asymmetry of Stokes profiles across a Sunspot-measurement.

Bhattacharyya, J.C. (1986) Proc. Dr. D.M. Bose Commemorative symp., Calcutta. Life in the Universe: Astronomer's point of view.

Bhattacharyya, J.C. (1986) Proc. Nat. seminar on frontiers of Astr. Calcutta. Frontiers of Astronomy - key note address.

Cayrel de Strobel, G* & Parthasarathy, M. (eds.) (1987) Proc. Nucleosynthesis in the galaxy from the study of low mass stars: J. Ap. Astr. 8, pp 79-167.

Datta, B. & Joshi, P.S. (1987). IAU Symp. No.117, p. 491 Constraints on dark matter density and axion mass from the large scale structure of spacetime.

Gokhale, M.H. (1986) IAU Symp. No.123. Study of long period global oscillation of sun through spheroidal harmony Fourier analysis of sunspots.

Giridhar, S. (1986) Proc. 5th Latin Am. regional mtg (ed. : S. Torres-Peimbert). Spectroscopic studies of southern Cepheid β Dor.

Giridhar, S. & Bhattacharyya, J.C., & Kutty, N. (1987) Proc. Nat. workshop on image processing (ed. : T. Veluswamy) Radio Astr. Centre, Udhagamandalam. Image processing facilities at Vainu Bappu Observatory.

Hassan, S.S. (1987) Proc. 5th European mtg. on Solar Phys. (in the press). Model atmospheres in intense flux tubes.

Hassan, S.S. & Sobouti, Y*. (1987) Proc. 5th European mtg on Solar Phys. (in the press). Oscillations in magnetic flux tubes.

Kameswara Rao, N. (1987). Quart. J. R.A.S. 28 (in the press). The nebular spectrum of CPD - 56° 8032 and He 2-113 (Invited paper: Kashi Nandy symp. on Hot Stars and Interstellar matter).

Kapoor, R.C. (1986) Proc. NATO - ASI Conf. Astrophysical jets and their engines (ed. : W. Kundt) Reidel, (in the press). General relativistic effects on collimation of a jet.

Krishan, V. (1986) Proc. Conf. 'High Resolution Solar Phys.' (ed. : D.S. Spicer) Boulder. Pressure structure of coronal loops.

Krishan, V. (1986) Proc. conf. 'Supermassive Black Holes (ed. : M. Kafatos) Cambridge Univ. Press. Absorption of radiation in the emission line regions.

Mallik, D.C.V. (1987) Proc. Nat. Seminar on Frontiers of Astr. Astrophys. Calcutta. Planetary nebulae and the galactic interstellar medium.

Peraiah, A. (1987) 'Numerical Methods in Radiative Transfer' (ed. : W. Kalkofen) Cambridge Univ. Press. An integral operator technique of radiative transfer in spherical symmetry.

Raju, P.K. (1986) Proc. 6th Nat. workshop on Atomic and Molecular Phys., Banaras Hindu University. Importance of atomic and molecular research for astronomical interpretations.

Sastry, Ch.V. (1987) Proc. STIP Symp. Observations of the brightness distribution of the quiet solar corona at decametric wavelengths.

Saxena, A.K., Bhattacharyya, J.C., Samson, J.P.A., Ismail, K. & Lancelot, J.P. (1986) Proc. Nat. Symp. on optical and opto-electronic instrumentation.

Shylaja, B.S. (1987) Proc. IAU Symp. 122 (in the press) The behaviour of λ4686 line of He II in WN binaries.

Sivaram, C. (1987) Proc. 20th Int. Cosmic Ray Conf. Upper limit to particle and photon energies in pre-galactic process (in the press).

Sivaram, C. (1987) Proc. Foundations of Modern Phys. (in the press) Quantum constraints on cosmological parameters.

Sivaram, C. (1987) Proc. 20th Int. Cosmic Ray Conf. (in the press). Relativistic acceleration of monopoles in neutron stars.

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Sivaram, C. (1986) Proc. South Zone Winter School on General Relativity and Cosmology: Mysore Univ. p.279. Relativistic astrophysics I.

Sivaram, C. (1986) Proc. South Zone Winter School on General Relativity and Cosmology, Mysore Univ. p.340. Aspects of early universe.

Sivaram, C. (1987) Proc. 20th Int. Cosmic Ray Conf. High Energy Particle Production from conducting Cosmic Strings.

Sivaraman, K.R., Babu, G.S.D., Shylaja, B.S., Rajamohan,R. (1986). Proc. 20th ESLAB Symp. p.479. Exploration of Halley's Comet', Heidelberg. Spatial distribution of molecules and dust within the coma of comet Halley.

Sivaraman, K.R. & Kariyappa, R. (1986) Proc. 4th Cambridge Workshop on Cool Stars, Stellar systems and the Sun. New Mexico. K-line emission and the integrated surface magnetic field on the sun.

Sivaraman, K.R., Kariyappa, R. & Livingston, W.C*. Reports on Astronomy, XIX IAU Mtg. 1985, p. 137. Solar line bisector as a function of disk position.

Som Sunder, G. & Kochhar, K.K. (1987) IAU Symp. No.127 (in the press). The dynamical evolution of a star.

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C. Notes for the Observer

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Appendix

1. No. of days of observation for the period 1986 Apr to 1987 Mar

Photoheliograms	225
H-alpha	151
K-flocculus	194
K-Prominence	160

2. Solar tunnel telescope observations

	No. of days of observation	Seeing(in arc sec)							
		2	2-3	3	3-4	4	4-5	5	>5
1986 Apr	18	1	2	12	-	3	-	-	-
May	5	1	-	4	-	-	-	-	-
Jun	5	-	-	2	-	3	-	-	-
Jul	7	-	-	1	-	5	-	1	-
Aug	8	-	-	-	-	5	1	1	1
Sep	5	-	-	2	-	2	1	-	-
Oct	5	1	1	3	-	-	-	-	-
Nov	12	-	-	4	2	5	1	-	-
Dec	10	-	-	3	-	5	-	2	-
1987 Jan	19	1	1	7	1	6	1	1	1
Feb	13	1	-	3	4	4	1	-	-
Mar	17	-	-	8	4	4	-	-	1
	124	5	4	49	11	42	5	5	3

3. Hours of observation and seeing conditions at Kavalur

		Spectroscopic hours	Photometric hours
1986	Apr	189.5	52.5
	May	121	25
	Jun	58.5	7
	Jul	65.5	1
	Aug	16.5	1
	Sep	65	9
	Oct	86.5	12
	Nov	138.5	52
	Dec	132.5	39.5
1987	Jan	241	90
	Feb	246.5	93
	Mar	212	100
1986-87		1573	482
(1985-86		1278	329)