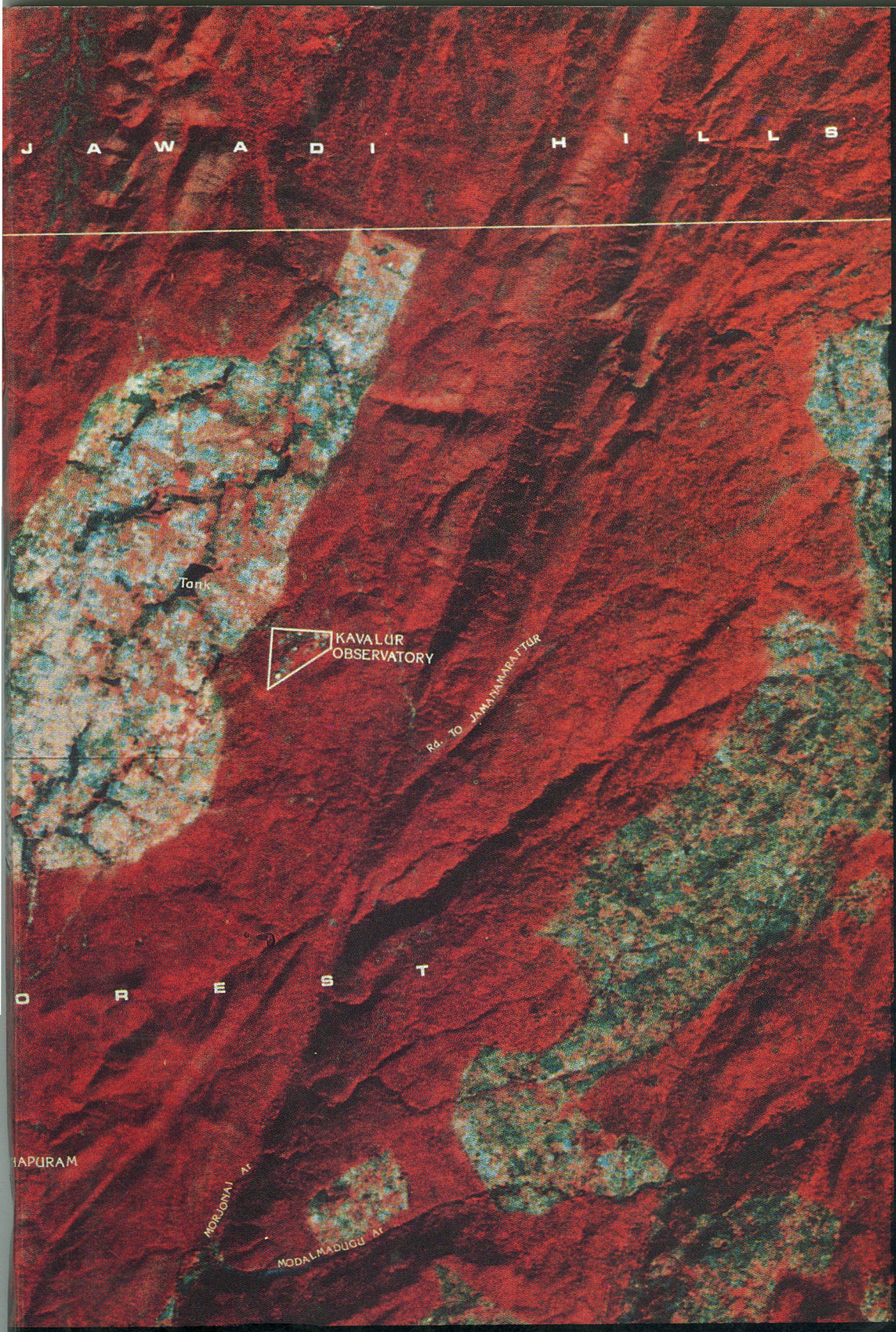

INDIAN INSTITUTE OF ASTROPHYSICS

ANNUAL REPORT
1991 - 92

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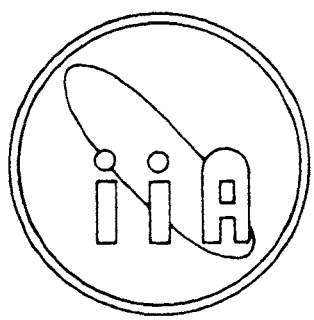

Annual Report 1991-92

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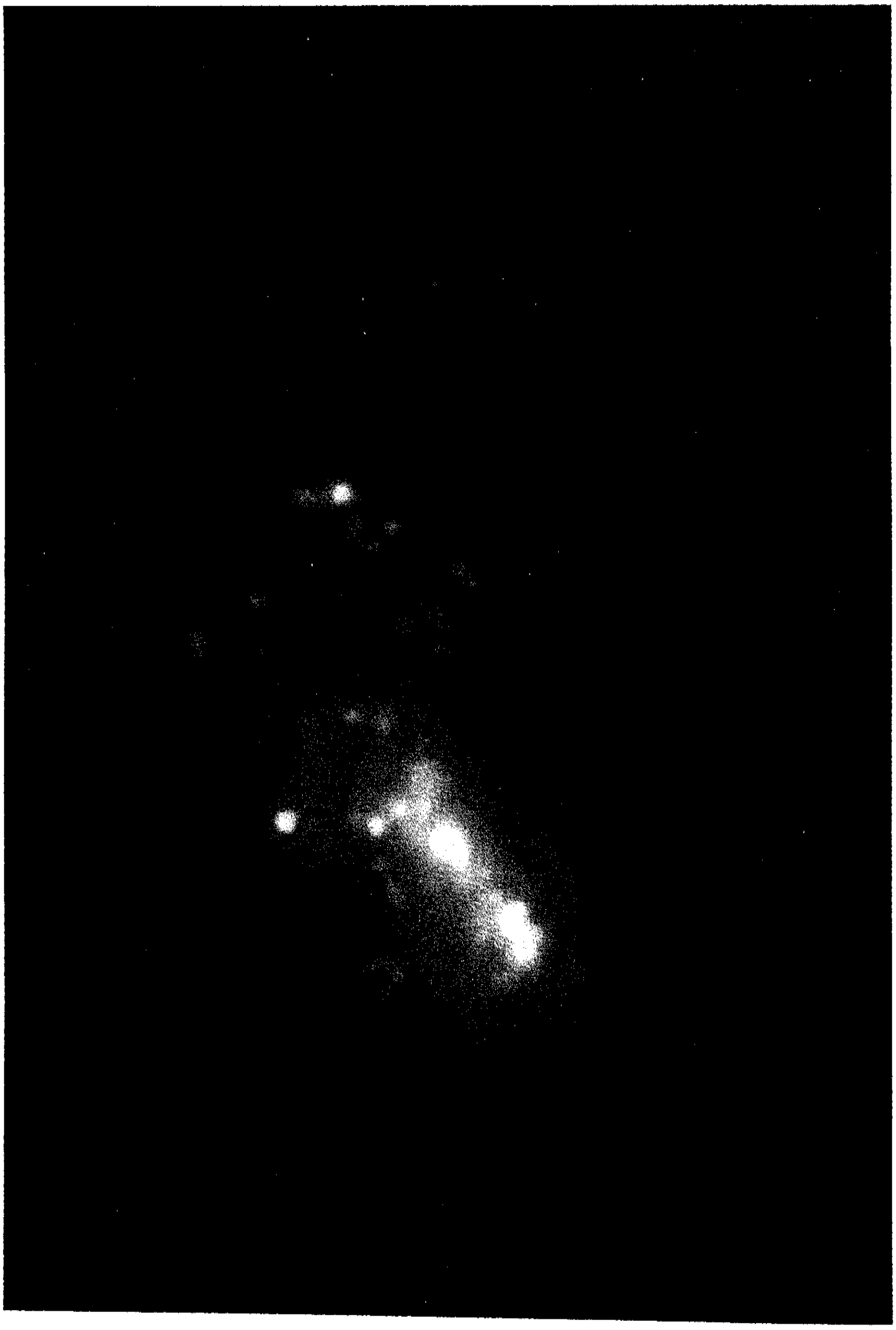


Irregular galaxy NGC 4449 imaged using the CCD detector at the prime focus of 2.3 m VBT. The composite colour picture is constructed using images obtained in B (blue), V (green) and Hα (red) bands. North is to the right and east at the top. The major sites of current star formation (red regions) lie at the north-eastern edge of the galaxy. (Y.D. Mayya)

The Year in Review

The year in review saw a good deal of progress in various areas of research as well as development in observational capabilities.

The primordial magnetic field of the Sun was estimated by the internal rotation determined helio-seismologically. The field was found to be dominated by the dipole and hexapole terms from the central source and a uniform field from an external source. The sunspot data of 1874-1976 was subjected to spherical-harmonic-Fourier analysis to study the solar long period global oscillations. Investigations into the latitudinal structure of the Sun's torsional oscillations showed that the eigenfunctions of the magnetic field in the MHD oscillations responsible for solar activity may be peaking deep below the photosphere. LTE radiative transfer was applied to the flux tubes in the Sun. It was found that at equal geometrical heights, the temperature on the tube axis is higher in the photosphere and lower in the convective zone. It now appears that the sunspot cycle 22 (see text) is the most active one after the 19th cycle observed since 1818 and the Sun appears to have reached its peak activity during 1990 August–1991 July. Observations of calcium K line profiles as a function of latitude were analyzed to study chromospheric rotation. The analysis of the time sequence spectra in the Ca II H line was completed. Theoretical modelling of x-ray charateristics of solar flares is being developed. The observed hard x-ray characteristics of solar flares can be inerpreted in terms of beamed thick target model in which electrons stream down to the loop footpoints and produce hard x-rays through electron-ion bremsstrahlung. The solar vector magnetograph was installed and is being utilized for polarization measurement. It was found that the radio brightness temperature of the ordinary radiation increased considerably in the presence of magnetic fields. The theory of ideal magnetohydrodynamic turbulence in cylindrical geometry was used to study the structure of coronal loops which gives interesting results that can be compared with observations. Considerable progress was achieved in the solar wind magnetosphere ionosphere studies. Work is in progress in several areas such as large amplitude oscillations in the F-regions, Doppler frequency shifts etc.

The polarimetric and photometric studies of dust in the circumstellar clouds reveals that the grains in these shells have larger sizes than those in the interstellar medium and that the dust in the circumstellar shells produce intrinsic polarization. Polarimetric, spectroscopic, photmetric studies of Herbig Ae/Be stars reveal several interesting physical features. Polarization measurements and IR Photometry of some of the T Tauri stars showed that those stars which have high polarization, have also large IR excesses. A programme to detect new bright Be x-ray binaries was taken up and three objects were identified. Work on speckle interferometry progressed well and is being utilized to estimate the separation of unresolved binaries. Spot modelling of the RS CVn binary DM UMa was successful in explaining the variation in B and V light curves of the star. Some of the unidentified IRAS sources were optically identified and CCD photometric observations of these objects were carried out. Stellar abundance analysis, Hα studies in supergiant chromospheres, Ca II triplet lines in cool stars, post AGB stars, hydrogen deficient stars, novae etc. were some of the major areas of work in stellar physics. The post AGB star SAO 244567 was studied extensively. Several new post AGB stars were identified. The evolutionary state of RCrB stars investigated by analyzing the high resolution CTIO spectra of these stars. Extensive theoretical stud-

ies of polarized line transfer reveal the fact that in resonance lines with large optical thickness, non-coherent electron scattering leads to appreciable changes of polarization in the far wings.

The effects of space-time curvature on the magnetic field of pulsars were investigated. Several complicated aspects of the equation of state of high density matter were under intense study. Studies on quark stars revealed that application of a realistic equation of state gives an important result that the fundamental mode radial oscillation can be as low as 0.06 milliseconds. Spin effects in black hole evaporation, blackhole wormhole transition were studied. Variable Mass Hypothesis is being extensively used in cosmological problems in relation to Hubble relation, "missing mass" etc.

A programme to map the diffuse interstellar bands by using Boller and Chivens spectrograph coupled with a CCD at the Cassegrain focus of the VBT, was started. Several star clusters have been studied photometrically and some spectroscopically. The study of the distribution of stars perpendicular to the plane of the Galaxy was continued. Distribution of planetary nebulae in the solar neighbourhood was derived. A photoionization model of WC11 group of planetary nebulae was developed that included the effects of dust.

Mass functions have been estimated for several star clusters and found to be in agreement with the established values. Studies of the LMC star cluster NGC 2214 reveal that there are two sequences of stars and that the older sequence is concentrated more toward the cluster centre while the younger one shows a more extended distribution. Studies of the giant extragalactic HII regions (in nearby galaxies) by synthetic aperture photmetry (carried on 2.3 m VBT) reveals that the gas and the associated dust form a patchy distribution and a large part of stellar radiation escapes unattenuated. x-ray spectra of 4 AGN's have been studied. Most of these objects appear to obey the power-law spectrum. Several attempts are being made to explain the continuum spectrum of quasars by invoking Compton, Raman scattering mechanisms.

Software for CCD data acquisition system has been improved to facilitate the data acquisition. A new DCS board for the Astromed CCD controller had been developed to obtain better S/N performance. The software aspects of the solar vector magnetograph have been improved. At the 1 m telescope, a digital display system is installed which shows the position coordinates RA, DEC, HA, the time ST, UT and parameters like airmass and zenith distance. Stepper motor controller for the 75 cm telescope was modified to improve the speed of response. Considerable amount of progress has been achieved in the wavefront sensing and evaluation for active optics experimentation. Specular polishing of a set of panels for the passive cooler for the very high resolution Radiometer for the INSAT-IIA satellite was successfully completed. Work on the EUV spectroheliometer is continuing. A memorandum of understanding between IIA and Space Physical Laboratory of VSSC was signed for design and fabrication of a 500 mm Cassegrain telescope optics. The construction of the aperture synthesis radio telescope operating at 150 MHz for galactic centre studies on the island of Mauritius is progressing. This is a joint project between RRI, IIA and the University of Mauritius. The pressure-scanned Fabry-Perot interferometer for high resolution spectroscopy of [OI] 630 nm night airglow emission was pressed into operation.

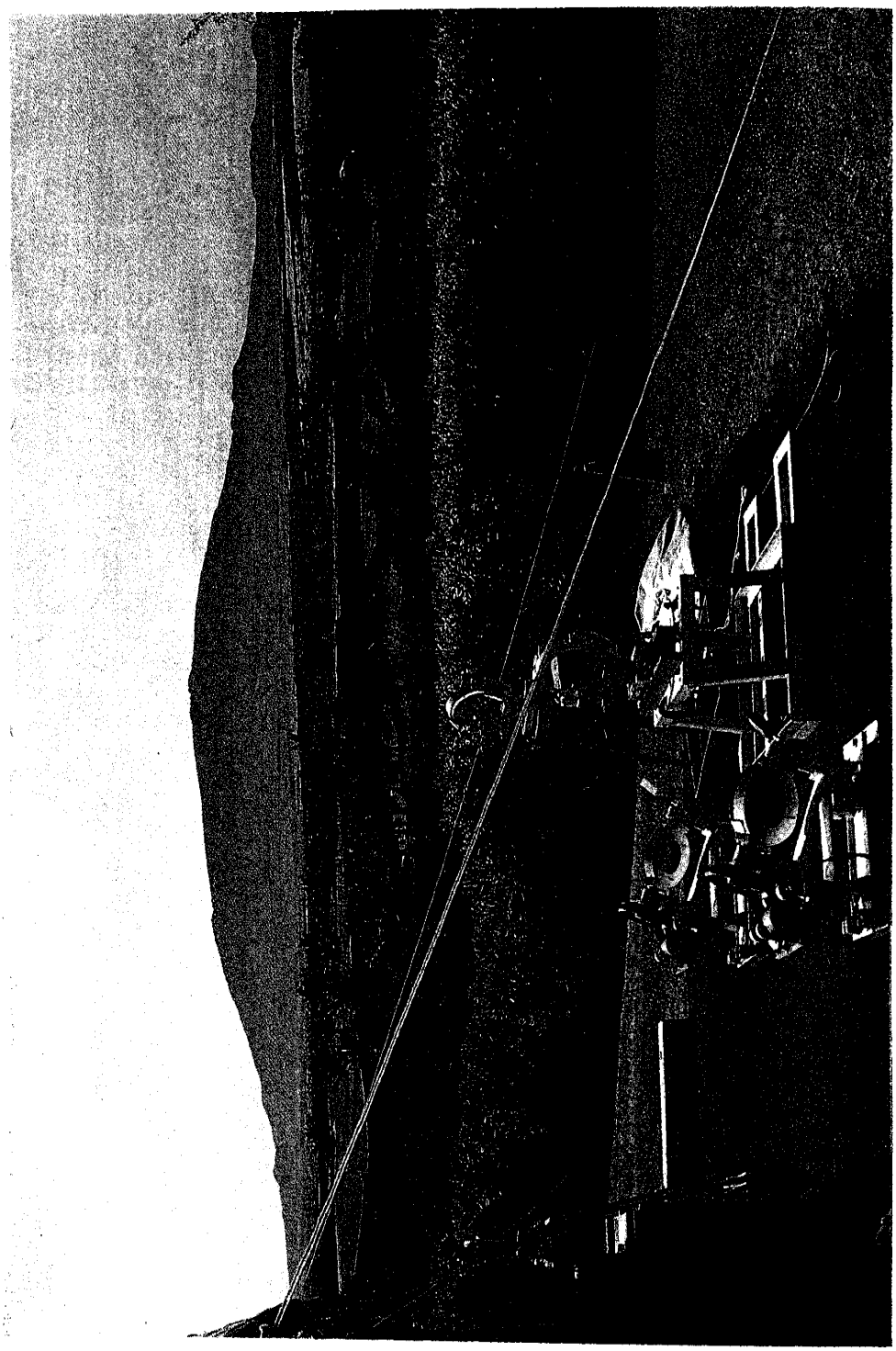
The capacity of the computer centre at Bangalore was augmented by the additon of a UNIX based Symphony 860 computer with an Intel 86064 bit RISC processor chip which uses supercomputer architecture and has 3-D graphics unit built in it. The computer speed

is 6.5 MFLOPS in double precision LINPACK. This is 40 times faster than VAX 11/780. This has 16 MB main memory. Further, SUN 4/280 server system with a discless SUN 3/50 client was acquired and installed. The server has 32 megabytes of main memory and 892 megabytes of disc storage, a 1600/6250 bpi half-inch tape drive and colour monitor with accelerated graphics interface attached to it.

The institute hosted a few national meetings and a miniworkshop on Plasma Astrophysics. Professor P.N. Tandon delivered the sixth Bicentennial Commemorative Public Lecture.

The **Year in Review** *was prepared by Professor A. Peraiah who was the Acting Director during part of the period of the report.*

R.Cowsik
Director



The eclipse camp of the Indian expedition at Waikoloa, Hawaii. Mauna Kea is seen in the background. (Jagdev Singh)

Modelling of Sun's primordial magnetic field using its helio-seismologically determined internal rotation

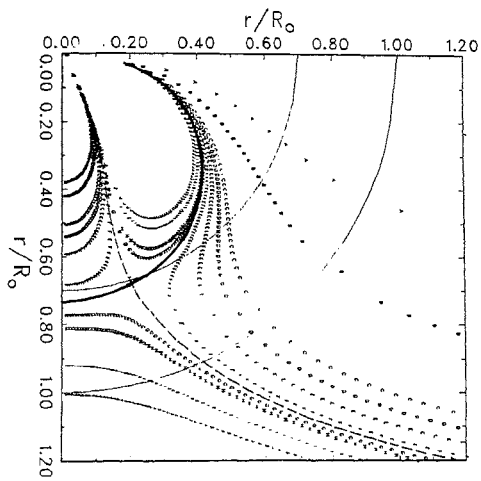


Fig. 1. Model of the 'steady' part of the Sun's poloidal magnetic field in one of the meridian planes. The field lines represented by A, B, ...J, correspond to flux values 0.5 to 2.1 in units of $B_o\ R_\odot^2$. The continuous and the dashed lines represent the separatrix S_* defined by flux value 1.84 units. In reality the field will be modified by presence of currents near the centre, convection and solar wind in the outer parts, and MHD waves everywhere.

A model of the Sun's primordial magnetic field is computed assuming the field to be current free in the outer radiative core and in the convective envelope and constraining it to be in isorotation with the helio-seismologically determined internal rotation of the Sun.

The field is found to be dominated by dipole ($l = 1$) and hexapole ($l = 3$) terms from the central source and a uniform field from an external source. The strengths of the dipole and the hexapole are :

$$(0.624 \pm 0.106) B_o R_\odot^3 \text{ and } (0.156 \pm 0.046) B_o R_\odot^5$$

respectively, where B_o is the strength of the external uniform field, estimated to be between 10^{-3} and 1 G, and $R_\odot$ is the radius of the Sun.

The field structure (see Fig.1) has a separatrix 'S_*' running close to the base of the convective envelope at low latitudes. The gradient of rotation velocity with respect to the magnetic flux function may have a discontinuity of a few nHz per $B_o\ R_\odot^2$ across S_*. This would correspond to non-isorotation which can provide a toroidal field ~ 2 MG in 10^{-9} - 10^{-6} yr. The best fit for rotation data in 0.4 $R_\odot$–0.7 $R_\odot$ requires inclusion of a term in $l = 5$ with a small, finite but presently uncertain strength. This indicates presence of MHD perturbations of latitudinal structure dominated by $l = 5$.

If confirmed, these conclusions may have important implications in studies of solar cycle, stellar magnetic fields and transport of energy and angular momentum in stars.
(M. H. Gokhale, K. M. Hiremath)

Study of Sun's long period global oscillations using spherical-harmonic-Fourier analysis of sunspot data 1874–1976

A. Kinematics of large scale fields :

The earlier SHF analysis of the solar magnetic field inferred from the data terms of odd degrees and frequency $\nu_o = 1/21.4\ \text{yr}^{-1}$, which define 4 independent 'geometrical modes' of

Sun's global oscillations, each covering a different range in the degree I , and in each of which all the SHF terms have the same phase as well as mutually well-correlated amplitude.

The same analysis of amplitudes and phases of terms in the SHF analysis of solar magnetic field is now extended to SHF terms in the lower power ridges at $\nu = 3\nu_o$ and at $\nu = 5\nu_o$. It is found that the SHF terms of these frquencies also define approximately the same four 'geometrical modes' as those defined by terms with frequency ν_o . Thus it is confirmed that the power in the harmonics $3\nu_o$ and $5\nu_o$ is not due to any independent modes other than those of frequency ν_o.

It is also found that the inclusion of these terms of higher harmonics do not lead to any substantial changes in the overall-latitude time variation of the magnetic field, but is certainly *necessary and sufficient* for explaining the *temporary asymmetry* of the sunspot cycle.
(M. H. Gokhale, J. Javaraiah)

B. Search for 154 day periodicity in the sunspot data :

Fourier analysis of the total sunspot occurrence probability as a function of time always yields power concentrations at a period of approximately 155 days. However, these concentrations are not stable from one sunspot cycle to another, indicating that they represent multiples of the rotation period of the 'average' latitude of sunspot occurrence rather than the period of any real oscillation of the Sun.
(M. H. Gokhale, J. Javaraiah)

C. Dynamics of the large scale field :

Attempts were made to fit the SHF spectrum of the inferred magnetic field for odd degree axisymmetric modes to Sen's generalized solution of Chandrasekhar equation for homogeneous isotropic turbulence. However it is not possible to obtain a satisfactory fit over the entire range $l = 1 - 29$. It may therefore be appropriate to consider the spectrum as a '4.5 dimensional chaos' (as indicated by Pavlos et al. 1992, preprint) rather than a turbulent spectrum. (M. H. Gokhale)

Latitudinal structure of the Sun's torsional oscillations

The least square fit of the latitudinal structure of the Sun's torsional oscillations of 22 year periodicity, observed at the photosphere (Labonte & Howard 1982, *Solar Phys.*,**75**,161) to the series of Legendre polynomials yields stronger amplitudes at $l = 2$ and 4 rather than at $l = 6$ as expected from the SHF analysis of the field inferred from sunspot data. This shows that the eigenfunction of the magnetic field in the MHD oscillation responsible for solar activity may be peaking deep below the photosphere.
(M. H. Gokhale, K. M. Hiremath)

Radiative transfer in intense flux tubes on the Sun

Spatially resolved observations combined with semi-empirical models have provided much information on the physical structure of intense magnetic elements or flux tubes in the solar photosphere. On the theoretical front, existing models are still not sophisticated enough to make meaningful comparison with observatons. In the present theoretical investigation, an attempt has been made to propose refinements which can bridge this gap. The main thrust of the work has been to improve the treatment of radiative transport, since this effect is very important in the energy balance of flux tubes, particularly in the surface layers.

The equilibrium structure of intense flux tubes on the Sun was determined for a cylindrical

flux tube by solving the magnetohydrostatic (MHS) equations in the thin flux tube approximation, allowing for both radiative and convective energy transport in the atmosphere. The radiative transfer equation was solved in the six-stream approximation, assuming grey opacity and local thermodynamic equilibrium, and the equation for convective energy transport was solved in the mixing length approach with an additional parameter $\alpha \leq 1$, which characterizes the efficiency of convection in the tube ($\alpha = 1$ in the external atmosphere). Since the equations are nonlinear in the temperature and the pressure, an iterative method was employed. First, the equations of hydrostatic and energy equilibrium for a plane-parallel atmosphere in the ambient medium for constant net vertical energy flux were solved. In this way a "quiet sun" model was constructed which was used as the external atmosphere in all self-consistent model calculations. Next, the atmosphere inside the flux tube that is embedded in the external atmosphere was constructed. This calculation assumed that the structure of the atmosphere inside the flux tube can be characterized by the values of the temperature, the pressure, and the intensity of the radiation field on the axis of the cylindrical flux tube. The calculation was based on the same multistream approximation as that employed in the external atmosphere, and it assumed a fixed value of β, defined as $\beta = 8\pi p/B^2$, where p and B are the gas pressure and magnetic field strength, respectively. For the initial guess, equality of internal and external temperatures at the same height was assumed. The linearized MHS and transfer equations were solved (in the thin flux tube approximation) to obtain corrections to the internal temperature, pressure and mean radiation intensity (Hasan 1988,*Ap.J.* **332**, 499). This procedure was repeated for the updated internal atmosphere until the corrections become sufficiently small.

In general, at equal geometric heights the temperature on the tube axis is higher in the photosphere, and lower in the convection zone than in the external medium. For tubes with radii less than 50 km, the internal temperature is higher also in the subphotospheric layers. However, at equal respective optical depths, the temperature inside the tube is higher than in the ambient medium, at least for the relatively thin tubes studied in this paper. At external optical depth unity, this difference is typically a few hundred degrees. Secondly, the thermodynamic structure of the flux tube atmosphere is influenced mainly by radiative transfer effects in the photosphere and by convection in the deeper layers. Thirdly, the temperature stratification inside the tube is insensitive to the value of α, i.e., the degree by which convection is inhibited in the flux tube by the magnetic field. (S. S. Hasan,*W. Kalkofen)

On the interchange instability of solar magnetic flux tubes

The interchange instability in photospheric magnetic flux tubes was examined using the thin tube approximation and satisfying both force and energy balance of the tubes with their surroundings. The stability of the tubes was found to be independent of the efficiency of internal convective energy transport and showed only a weak dependence on the plasma beta. The structures exhibited a tendency towards instability in a layer 200 – 300 km deep immediately below $\tau_{5000} = 1$. The presence of an internal atmosphere had the effect of reducing the magnetic field strength in comparison with that of an evacuated tube and hence had a stabilizing effect on the tube surface. In contrast, temperature differences between interior and exterior usually proved to be destabilizing. The two effects approximately cancelled each other for tubes with

radii below about 200 km for which the stability properties were very similar to those of completely evacuated structures. For larger tubes, the temperature contrast with respect to the surroundings ($T_i - T_e \leq -400$ K) began to dominate and destabilized the tubes. Thus, despite the inclusion of energy transport effects on the tube structure, the stability problem of small tubes (with magnetic fluxes $\Phi < 10^{19} - 10^{20}$ Mx) remained. (*M. Bünte, S.S. Hasan, *W. Kalkofen)

Solar rotation from sunspot measurements

Measurement of the daily positions and areas of sunspots from the Kodaikanal white light images has been in progress. Measurements of 40 years' of photoheliograms have been completed. Using a software programme developed for the purpose, rotation rates have been calculated. Results show the high precision with which rotation rates can be derived. Further there is good agreement with the Mt. Wilson results derived for the same period. It is seen that the Kodaikanal measurements have smaller error bars and have a precision and internal consistency superior to those of Mt. Wilson. Another significant fact is that the Kodaikanal images of the Sun are larger (being obtained with a long focus camera) and together with more number of observations in a year provide a substantial number of small spots in excess of those contained in the Mt Wilson measurements. The rotation values derived from Kodaikanal data with this larger numbers showed higher reliability in this range. (K.R. Sivaraman, S.S. Gupta, *R. Howard)

The solar cycle no. 22 : Is this the second most active cycle ?

The size of the solar cycle may be associated with the physics of the solar dynamo. The study of solar cycle becomes important because the solar activity has direct effect on communication systems, geomagnetic activity, upper atmospheric modeling and satellite orbital decay.

The daily sunspot numbers have been obtained from the 200 mm size photoheliograms taken at Kodaikanal using the 150 mm refractor telescope. The monthly mean sunspot numbers were computed from these observed daily RSS numbers. The 13-month running mean known as 'smooth sunspot number' was computed for the four solar cycles 19–22 using Kodaikanal data. The values of maximum smoothed sunspot number $R(M)$ for each cycle are given below. For comparison we have also listed the corresponding values derived by R.M. Wilson for the three cycles 19–21.

Solar cycle number	$R(M)$	
	From Kodaikanal data	Computed by R.M. Wilson
19	194.5	201.3
20	112.9	110.6
21	156.7	164.5
22	173.6	—

The small differences between these corresponding values may be due to non-availability of the data on a few days at Kodaikanal during cloudy sky, poor seeing conditions or the type of emulsion of the photographic plate. From the values of $R(M)$ listed above it appears that the sunspot cycle 22 is now the second most active cycle after the 19th cycle observed in modern times i.e., since 1818.

The data also show that Sun appears to have reached its peak activity during 1990 August–1991 July. (Jagdev Singh, P.S.M. Aleem, G.S. Suryanarayanan, R. Selvendran)

Mesogranulation

The morphological study of a large number of mesogranular cells reported earlier was continued and the work is nearing completion. The data show that these mesocell structures have a size distribution of 6 to 12 arcseconds on the Sun, in the quiet region studied. The mean size is around 8 to 9 arcsec corresponding to about 6,000 km. Exploding granules are found at the centres of many cells in areas of excellent seeing. Other morphological aspects such as cell shapes are also being studied. (S.P. Bagare)

Heating of the quiet solar chromosphere

The analysis of the time sequence spectra in the Ca II H line was completed. The number of samples studied was increased from 18 to 28 and in all, nearly 5000 line profiles were analyzed from the 177 frames of the 35 minute long sequence spectra with one frame every 12 seconds. Of these, 26 samples are bright points in the interior of the network and the remaining 2 are on the network boundaries. Although at first sight variations in the line profiles of the bright points seem amazingly diverse in their forms during evolution, they seem to fall into 3 classes : the most energetic ones with very large enhancement in brightness at the peak brightness phase constitute Class I and the lesser ones constitute Classes II and III.

The dynamical changes in the profiles accompanying the evolution of the bright points were studied using the following parameters – intensity of the emission peaks in violet $I_{H_{2V}}$ and in red $I_{H_{2R}}$; the ratio $I_{H_{2V}}/I_{H_{2R}}$; the intensity at the absorption core I_{H_3} and the Doppler shift of the H_3 core $\Delta\lambda_{H_3}$.

The light curves of $I_{H_{2V}}$ vs time show the quasi-sinusoidal oscillations and are characterized by a main impulse where the brightness rises 4 to 6 times the ambient level followed by a train of pulses whose amplitudes decay exponentially. Similar intensity oscillations are associated with the Class II and Class III bright points although the amplitudes of the main impulse as well as of the follower pulses are far less than that for Class I. The main impulse as well as the follower pulses in all classes have a period of 190 ± 10 sec and represent the 3 minute oscillations in the chromosphere. Results from earlier observations that the inner network bright points bear a one-to-one spatial correspondence with the magnetic points within the supergranular network at the photospheric level were used to interpret that the bright points act like magnetic flux tubes. The varying values of the magnetic fields associated with these flux tubes are presumably responsible for the differences among the three classes of bright points; the main impulses from the bright points located in regions of strong magnetic fields show the strongest intensity increase, and those associated with weaker fields have the main impulse itself much weaker (Class II and Class III).

The phase velocity of the pulses derived from the time delay in the appearance of the brightening at the H_{1V} and H_{2V} levels, turn out to be $\sim$ 24 km s^{-1}. With a sound velocity C_s of 9 km s^{-1}, the Alfvén velocity works out to 22 km s^{-1} which corresponds to a magnetic field of $\sim$ 80 gauss. Thus the propagation within the bright points associated with this magnetic field is through a combination of Alfvén and acoustic waves with a predominance of Alfvén waves, whereas the propagation is mainly by acoustic waves where the

fields are weak. The energy transported by the main impulses when summed over the entire Sun turns out to be $\sim 8.1 \times 10^6$ ergs cm^{-2} s^{-1}. It is known that the network boundary elements provide an energy of 7.5×10^6 ergs cm^{-2} s^{-1}. Thus in the quiet chromosphere, the energy carried by the bright points and the network boundaries together add up to 1.56×10^7 ergs cm^{-2} s^{-1} and can adequately meet the energy requirements of the chromosphere which is 1.4×10^7 ergs cm^{-2} s^{-1} from model calculations. The bright points are thus the sites where intense heating takes place and they supply about 50 % of the energy requirements for the support of the quiet chromosphere.
(R. Kariyappa, K. R. Sivaraman)

Calcium K emission

The programme of monitoring Ca II K line profiles in the integrated sunlight using the double pass spectrograph with high photometric accuracy was continued on a regular basis to look for the long and short term variation of chromospheric activity and to quantitatively assess the contribution of the emission from different features in the chromosphere to the total emission. This would enable us to construct a model of the chromosphere using the line profile parameters. This can be extended to infer the chromospheric variations from sunlike stars.

Nearly 4000 Ca II K line profiles of the integrated Sun have been acquired since 1988 December and reduction is in progress.
(K.R. Sivaraman, R. Kariyappa)

High resolution calcium K spectra as a function of latitude and integrated over visible longitudes are being obtained at Kodaikanal on a regular basis since 1987. During the 1991-92 period spectra on 122 days were obtained. Digitization of the spectra recorded during 1987 has been completed. The data are being analyzed using the computer facilities at Bangalore to study chromospheric rotation and variation in emission in polar regions on short as well as long timescales. (Jagdev Singh)

Chromosphere-corona transition region

In continuation of the investigation on the chromospheric-corona transition region ions Ne VI and Mg VI the theoretical emission line intensities have been analysed and compared with observed intensities for the quiet Sun conditions. The observed intensity values have been taken from the detailed paper by Vernazza & Reeves (1978, *Ap.J. Suppl.*,**37**, 485) on extreme ultraviolet composite spectra of representative solar features. The composite spectra, over the spectral range 280-1350 Å, were taken with ATM (Apolo Telescope Mount) ultraviolet spectrometer aboard the Skylab. Absolute intensities for Ne VI and Mg VI lines were computed using the available atomic data and an atmospheric model for the quiet Sun. The theoretical intensities and the observed values agree remarkably well when the neon and magnesium abundances are assumed to be 3.98×10^{-5} and 3.16×10^{-5} respectively. This amounts to a neon to magnesium ratio of 1.26. In literature one finds this ratio to range from 0.97 to 2.2. Several intensity ratios of Ne VI lines with respect to a resonance line of Mg VI have been found to be sensitive to electron density and temperature variations. Therefore, these ratios are useful for electron density and temperature diagnostics of the transition region. Results of the above investigation stress the need to observe the Ne VI and Mg VI lines around 558Å, 435Å, 401Å, 399Å, 349Å, and 314Åwith spectral resolution of the order of 0.1 Å or better. Equally important is the need to obtain reliable intensities to facilitate more detailed spectral diagnostics of the chromosphere - corona transition region. (P. K. Raju)

Flares

Sun as a star during flares

Observations have proved that the calcium K line profile of Sun as a star shows variations with solar rotation and phase of the solar cycle. Stellar observers wish to monitor the rotation and magnetic behaviour of stars by observing variation in the calcium K line. The occurrence of flare is also likely to change observed parameters of the line. With a view to detecting changes in the calcium K line during solar flares, spectra have been obtained on 8 days of the Sun as a star. The data are being analyzed to study the variation in the line parameters with the intensity and area of solar flares. (Jagdev Singh)

Evaluation of magnetic shear in flaring regions

Using the positions of sunspots and H-alpha filaments from the Kodaikanal data, the evolution of the shear angle during 2 days prior to and after the flare event was examined for ten events. It is seen that it is the change in the shear that occurs a day prior to the flare that can lead to the event and that this change can be in either direction i.e., it can be a large increase from a small value or a decrease from a large initial value. It is this change in the shear angle that seems to be a deciding criterion for a flare to occur and not a large value for the shear angle itself. It is quite possible that this change in shear angle occurs in a time interval much less than a day leading to the flare. Work is in progress with fresh material on flare events with good temporal resolution to examine this aspect. (K. R. Sivaraman, R. R. Rausaria, P. S. M. Aleem)

Time development of shear

Evolution of a double-ribbon flare in NOAA 6089 on 1990 June 11 and 12 has been studied using high resolution H-alpha data of Udaipur and Kodaikanal observatories. Using H-alpha filaments as the proxy for the neutral lines, and following the method described in Sivaraman, Rausaria & Aleem (1992, *Solar Phys.*,**138**, 353) we have studied the variation of the shear angle at different times on 1990 June 11 and 12. Analysis of the data shows that the change in the orientation of the H-alpha filament on June 11 between 0555 UT and 0955 UT was insignificant. However, the change in shear angle from 1990 June 11 at 0955 UT to 1990 June 12 at 0519 UT is approximately 60°. This change in shear angle over almost 12 hours is slow compared to the change in shear angle over a period of a few minutes when the flare was in progress on 1990 June 12 between 0519 UT and 0602 UT. Towards the end of the flare the shear tends to return to its normal configuration. This helps us to draw the conclusion that the change of shear from 1990 June 11 to 12 introduces the non-potential character in the field lines and after reaching a critical value this becomes untenable and results in the flare onset. Once the flare starts, magnetic reconnection takes over and there is a change in the value of the shear angle at a very short interval of half a minute. After the flare is over the field lines regain their original positions.(R. R. Rausaria, P. S. M. Aleem, K. Sundararaman)

On the triggering of a spotless double ribbon flare

We have studied the evolution of a double-ribbon spotless flare of 1992 February 21 using Kodaikanal H-alpha and Kf1 observations.

Analysis of the data shows that the H-alpha filament underwent large change in shear prior to the day of the onset of the flare. We find considerable rotation of the plage region before the emergence of a small magnetic pore. It is concluded that shear plays an important role on the triggering of spotless flares. (R. R. Rausaria, P.S.M. Aleem, K. Sundararaman)

Interpretation of observed hard x-ray characteristics of solar flares

The experimental results of x-ray bursts spectral characteristics, spatial distribution, fast time variations, polarization, and directivity measurements carried out with Intercosmos PVO/ISEE-3 spacecrafts, imaging instrument observations of hard x-rays (HXIS) and hard x-ray burst spectrometer (HXRBS) during Solar Maximum Mission have been studied. The observed results on the above charateristics are being investigated in detail in terms of thermal and non-thermal models. The variations of reverse current and potential taking multiple scattering into account as a function of the column density have been computed. It is found that reverse current decreases steeply with the increase in electron energy. However, it becomes significant for low energy electrons. The timelag between high- and low-energy photons has also been calculated. It is found that there is a small difference between timelags with observation angles. It is shown that the above observed results can be interpreted in terms of beamed thick target model in which electrons stream down to the loop footpoints and produce hard x-rays through electron-ion bremsstrahlung. (R. R Rausaria, *Ranjan Bakaya, *S. A. Chasti)

Microbursts at metre-decametre wavelengths

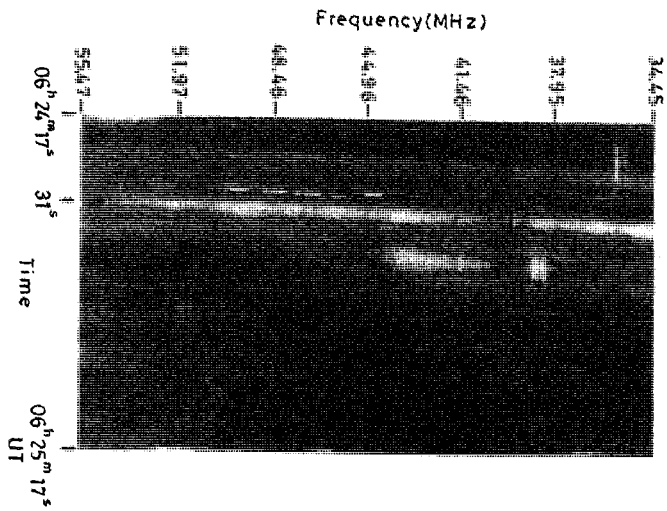
The broadband array of biconical dipoles at Gauribidanur was used to collect data on microbursts at metre-decametre wavelengths. New properties of microbursts such as time profile characteristics, flux density and energy spectra are investigated. The present study supports the idea that the microbursts and the normal Type III bursts are generated by electron beams of similar characteristics. The low brightness temperatures of microbursts are interpreted on the basis of isotropization of plasma waves generated by electron beams. (K. R. Subrahmanian, *N. Gopalswamy, Ch. V. Sastry)

Analysis of the radio burst data collected with the acousto-optic spectrograph and the broadband biconical dipole array is in progress. Particular attention is being paid to the study of various characteristics of absorption bursts we reported several years ago. (K. R. Subramanian, E. Ebenezer, Ch. V. Sastry)

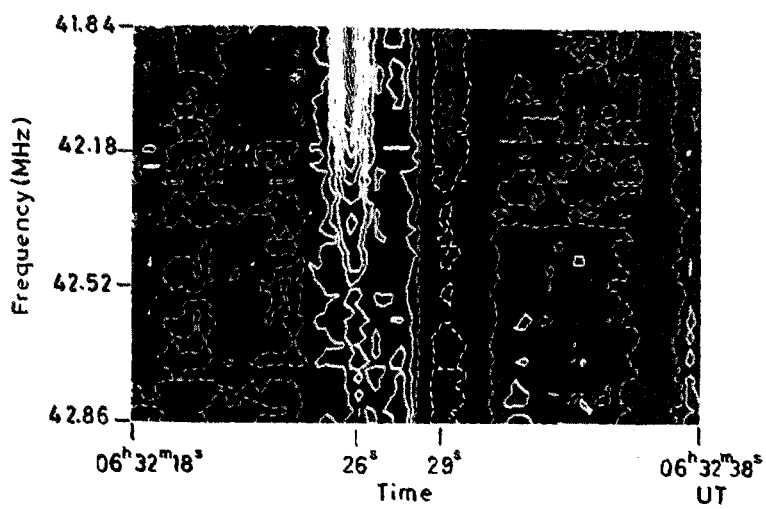
Solar corona

Radio brightness temperature

The radio brightness temperature of the quiet solar corona at a frequency of 35 MHz in the presence of a radial magnetic field is computed. It is found that the brightness temperature of the ordinary radiation increases significantly in the presence of a magnetic field. It is also found that in the presence of radial magnetic fields coronal holes appear as bright emission regions on the disc and as depressions on the limbs.
(*Kumar Golap, Ch. V. Sastry)



Solar radio burst observed 1990 February 1 using an Acousto-optic spectrograph and a broadband array. A type III radio burst is seen at 06 24 31 UT around 55 MHz drifting towards low frequency. After two seconds, another emission burst starts around 45 MHz and drifts towards low frequency. Blues and violets represent the background. Red, brown and yellow represent progressively increasing intensity.



Brightness contours of the emission absorption burst observed 1990 February 6 using an Acousto-optic spectrograph and a broadband array. The contours around 06 32 26 UT show the emission burst and the contours around 06 32 29 UT represent the absorption feature. Yellows and whites and blues represent the progressively increasing intensity in the case of the emission burst. The dotted violet contours represent the violet features.

Pressure structure of solar coronal loops

The theory of ideal magnetohydrodynamic turbulence in cylindrical geometry is used to study the steady-state structure of a coronal loop. The pressure profile is derived from MHD equations by representing the velocity and magnetic fields as the superposition of Chandrasekhar-Kendall functions. Such a representation brings out the three-dimensional structure of the pressure in the coronal loop. The radial, azimuthal and axial variations of the pressure for a constant density loop are discussed in detail. The pressure has an oscillatory behaviour for different azimuthal angles at some radial positions. This study predicts more features in pressure which can be compared with the presently available observations. (V. Krishan)

The solar vector magnetograph project

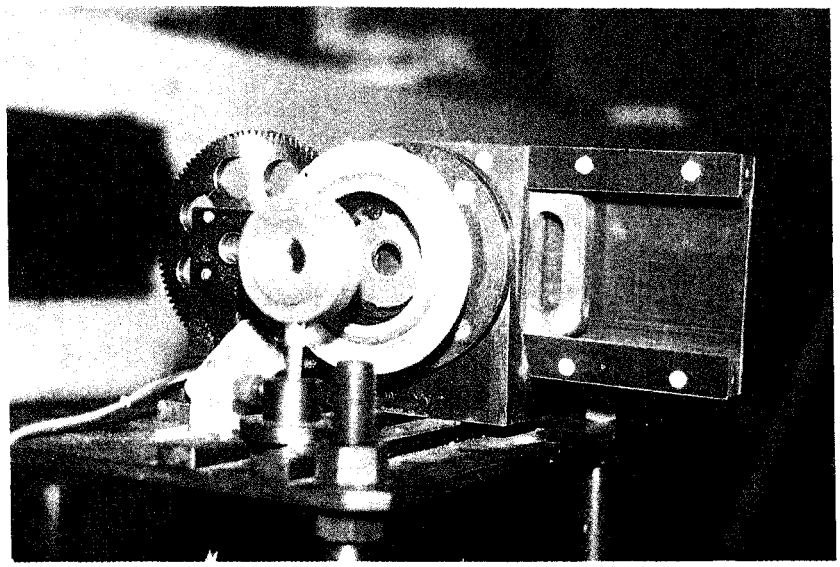
The solar vector magnetograph project has been completed with the installation and testing of all components of the polarimeter and camera at Kodaikanal in 1992 March. The software for the reduction of the raw data is also ready. The year 1991–92 was spent in making laboratory calibration and field trials of the instrument. For the laboratory calibration, a sodium vapour lamp was used as the course. The input beam was first polarized by passing it through a polaroid sheet. The degree of polarization as well as the position angle of the plane of polarization were initially determined using the analyzer alone. The half-wave retarder was then inserted and the modulation was measured. The degree and position angle of polarization were determined from the amplitude and phase of the modulation respectively. The results were correct to within 1 % and 1° respectively.

For the field trials, the defocussed sunlight was first analyzed to determine the instrumental polarization produced from unpolarized light. The method involved obtaining the frames at different positions of the halfwave retarder and then fitting a cos 4 θ and sin 4 θ curve to the data. The computer programme for reducing the data makes use of the special frame buffer cards and associated software to keep the computer memory requirements very low. A conventional programme would have either required 2.5 megabyte RAM or involved very large I/O operations that would increase the reduction time.

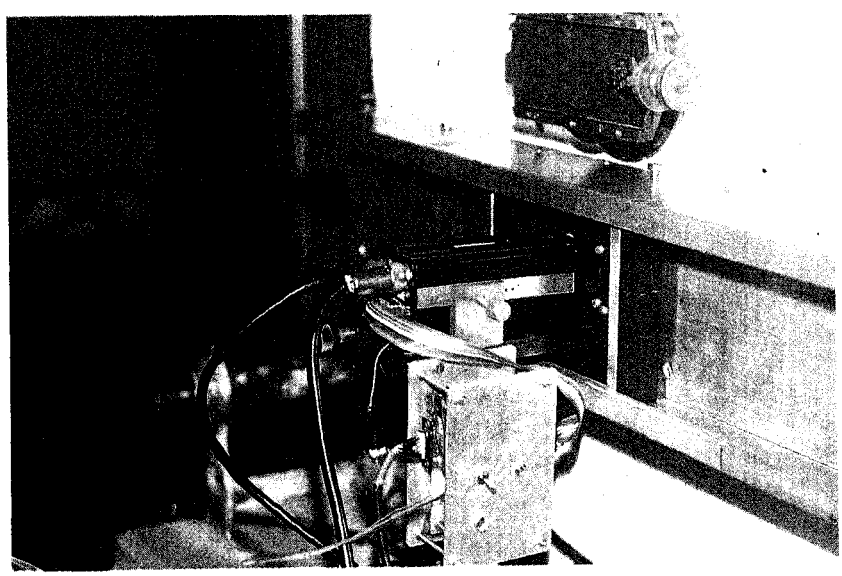
The results indicated a random intensity fluctuation of only 0.6 %, which is very good considering the fact that sequential nature of the exposures admits transparency fluctuations. The polarization measured was not significant, although one expected a measurable polarization of $\approx$ 3 %. Comparison of the observed equivalent width of the 6303 Å line with the true value as seen in the Liége atlas showed that scattered or parasitic light was present to the extent of a few hundred per cent. Replacing the 30-year old grating and spectrograph optics is expected to reduce the parasitic light. This will be taken up in 1992–93. With the reduction of stray light to manageable limits, a few good programmes using the vector magnetograph can be undertaken. (P. Venkatakrishnan, R.S. Narayanan, J.C. Bhattacharyya)

The solar-neutrino problem

The problem of solar neutrinos was studied in some detail for the large magnetic field in the innermost regions of the core ($R < 0.05\ R_\odot$) for neutrinos with magnetic moment. Some predictions were made as regards the expected SNU count rate of experiments using ^{71}Ga, ^{81}Br, D_2O, Borex as well as neutral current detectors of the Kamiokande type. (C. Sivaram, *V.de Sabbata)



Polarimetric assembly of the Kodaikanal vector magnetograph.



CCD camera at exit slit of the Kodaikanal tunnel spectrograph records the Zeeman broadened spectral line profiles.

Solar eclipse expedition

A five member team consisting of K.R. Sivaraman, Jagdev Singh, R. Srinivasan, K.K. Scaria and F. Gabriel went to Hawaii to observe the total solar eclipse of 1991 July 11. An eclipse camp was set up at Waikoloa on the northwest tip of Kohala-Kona coast of the big island of Hawaii. Three experiments were planned : (i) spectroscopy of the corona in the two emission lines [Fe XIV] 530.3 nm and [Fe X] 637.4 nm; (ii) imaging in five coronal emission lines, in Hα and in the electron-scattered continuum with narrow band filters using a Peltier cooled CCD as the prime detector and (iii) broadband photography. The telescope and the spectrograph were set up and aligned by July 2 at the camp site and in the following days, these and all the associated equipment were tested thoroughly. The tests were highly successful. The Peltier-cooled CCD system functioned satisfactorily. However by 4 AM local time on the day of the eclipse clouds started appearing all over the sky and viewing conditions deteriorated. A few images of the partially eclipsed Sun using the CCD system were obtained. But unfortunately by the time the totality occurred the sky was overcast and it was impossible to view the eclipse. This was unexpected since the site has a record of unusually large number of clear days in a year and even in 1991 July of the 25 days of stay of the team only 2 days were cloudy and one of them happened to be July 11.

Planets and Satellites

Mutual phenomena of Jovian satellites

Analysis of the mutual event data obtained from VBO during the 1991 apparition is nearing completion. The times of light minimum of the light curves were corrected for the phase defect arising due to the finite solar phase angle at the distance of the satellites. The corrected time corresponding to the time of closest approach can be directly used to correct the relative longitude between the centres of the two satellites predicted by the theory.

The model to generate the theoretical mutual event light curves for comparison with observations, which was used to fit the data of 1985 apparition was modified to include the difference in albedo between the equatorial and polar regions on the satellites. The new model also takes into account the variation in albedo with the longitude of the satellites. Most of the events observed during 1991 were eclipses and occultations of Io by Europa. A better fit was obtained using Lommel-Seeliger's law compared to Lambert's law to describe the scattering over the surface of Io. This confirms the trend noticed from the analysis of the data of 1985.
(R. Vasundhara)

Stars

Young stars and circumstellar matter

Herbig Ae/Be stars

Herbig Ae/Be stars are pre-main-sequence objects of intermediate masses ($\sim 2 - 5M_{\odot}$) still associated with their parent dust clouds. They are characterized by the presence of emission lines in their spectra, excess infrared emission and spectroscopic, photometric and polarimetric variability. Many aspects of their behaviour can be understood in terms of the presence of dusty circumstellar discs and shells around them. In order to understand the nature of the central objects and the structure and evolution of the circumstellar shells we have been making infrared photometric and optical polarimetric measurements and building physical models for the distribution of the circumstellar matter.

(a)*Infrared photometry* : The circumstellar dust absorbs light from the central star and reradiates in the infrared at $\lambda \geq 1\mu m$. Also in systems with accretion discs with large accretion rates the disc can radiate thermally in the infrared. Infrared photometric measurements in the J (1.2 μm), H (1.65 μm), K (2.2 μm) bands have been made for a number of these objects. All are found to have excess radiation in H and K bands. A detailed analysis of the spectral energy distributions is in progress. (H. C. Bhatt, Uma Gorti, *N. M. Ashok, *T. Chandrasekhar,*R. Sam)

(b) *Polarimetry* : Scattering of starlight by dust in the circumstellar shells that have a non-spherical geometry can cause polarization in these objects. We are monitoring their linear polarization by making frequent polarization measurements in order to study the temporal changes in the distribution of circumstellar matter. (S. K. Jain, H. C. Bhatt)

(c) *Anomalous dust in the circumstellar environs of Herbig Ae/Be stars* :
Circumstellar dust around Herbig Ae/Be stars can cause large amounts of reddening and extinction in their light. If this dust is anomalous (i.e. different in composition and /or grain size etc. as compared to the mean interstellar dust), then the wavelength dependence of the extinction will also be anomalous. We have analysed extensive photometric data available for these objects and evaluated the wavelength dependence of extinction. It is found that a majority of them show anomalous extinction requiring dust grains in their circumstellar shells that are larger in size than the mean interstellar grains. It is conjectured that grain growth in the cold high density parent dust clouds may have resulted in the larger grains. (H. C. Bhatt, Uma Gorti)

A type stars with circumstellar shells

The Infrared Astronomical Satellite (IRAS) has detected a number of A type stars in the far infrared indicating the presence of cold dust around them. Many of these stars also show shell spectra. Among these objects there could be proto-planetary systems in which the circumstellar matter is distributed in the form of flat discs. We have made polarization measurements for about 25 of these objects. Preliminary analysis of the measurements shows that circumstellar matter causes intrinsic polarization in some of them. (H. C. Bhatt, S. K. Jain)

HD 76534

Recently signature of non-radial pulsations

(NRP) has been detected in the spectra of the Herbig Ae star HR 5999. In order to search for NRP in other Herbig Ae/Be stars we have carried out time-resolved spectroscopic observations for two stars (HD 76534 and V 380 Ori) at the Cassegrain foci of VBT and 1 m reflector of VBO using respectively a Boller & Chivens and a UAG spectrograph both with CCD detectors. We have detected photospheric variability in HD 76534 on the timescale of a day which may be due to NRP. Detailed studies are under way. (K. V. K. Iyengar, K. K. Ghosh)

T Tauri stars

Strömgren photometry and Hα spectroscopy of a few T Tauri stars were carried out to study the nature of their surface activity. To investigate the circumstellar environment of these stars polarimetric observations and IR photometry were also done. Analysis of the photometry of the T Tauri stars TW Hya, V 4046 Sgr, HD 288313 and FK Ser showed that, due to the high level of activity in T Tauri stars, the periodic light variations normally do not continue for a long time; irregular light variations were noticed most of the time. Polarization measurements and IR photometry of the programme T Tauri stars showed that the stars that have high polarization also have large IR excess. High polarization of the order of 4% was detected in the T Tauri star S 33. (M. V. Mekkaden)

Be stars

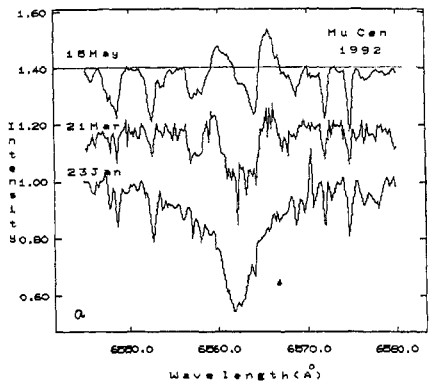
We have observed 16 Be stars, 5 Be-shell stars and 7 early type supergiants at the coudé focus of the 1 m reflector of VBO using an echelle spectrograph with a CCD detector. From each two-dimensional frame of the echelle spectrogram we obtained profiles of Hα, Si II ($\lambda\lambda$ 6347, 6371), He I ($\lambda\lambda$ 4471, 5876), Mg II (λ 4481) and of many Fe II lines. Dramatic activities were observed in many Be and Be-shell stars. We mention below in brief some information on two of these $-\mu$ Cen and 66 Oph. Detailed analysis of the observations is in progress.

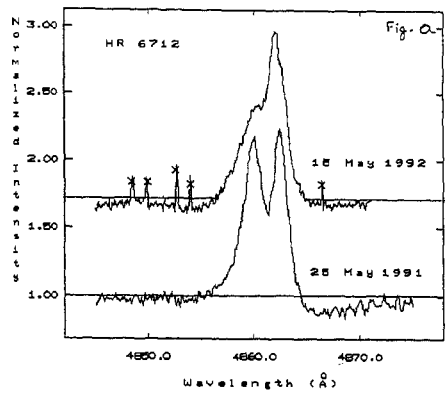
μ Cen (HR 5193)

After the major outburst of μ Cen in 1990 it continued to display weak emission features in Hα until the middle of 1991. The star entered the shell phase by the end of 1991. From a comparison of the Hα profiles of μ Cen, obtained in 1992, it is clear that another outburst of this star has taken place between 1992 January 23 and 1992 March 21 (Fig.2). Recent spectra of this star show strong emissions with $V/R < 1$ in Hα and $V/R > 1$ in He I(5876 Å) which suggest strong activity.

66 Oph (HR 6712)

During the last few years this star has displayed remarkable variability in the emission lines of Hα and He I 6678 Å. On the basis of the spectra of 66 Oph, obtained between 1991 May and 1992 May we find the following variations : (1) The inverse P cygni profile of $H\beta$ ($V/R < 1$ with emission intensity 2.2 $I_{\rm cont}$) seen in 1991 May has changed to a P-cygni profile with $V/R = 0.54$ and emission intensity = 2.3 $I_{\rm cont}$ in 1992 May. The blue absorption-edge velocity of Hβ was -600 ± 20 km s^{-1} on 1992 May 15. (2) He I 5876 Å was in absorption in 1991 May and in emission in 1992 May with an intensity equal to 1.08 $I_{\rm cont}$ with a blueshift of the line-centre by more than 6 Å. (3) The Hα emission intensity increased from 9.8 $I_{\rm cont}$ to 12.7 $I_{\rm cont}$ between 1991 May and 1992 May with remarkable changes in the structures of the profile. Also two emission lines at 5317 Å and 5732 Å, attributed to Fe II, are present in the 1992 May spectra of 66 Oph which were in absorption in 1991 May (Fig.3 a,b).(K. K. Ghosh, M. J. Rosario, G. Selvakumar, K. Kuppuswamy)





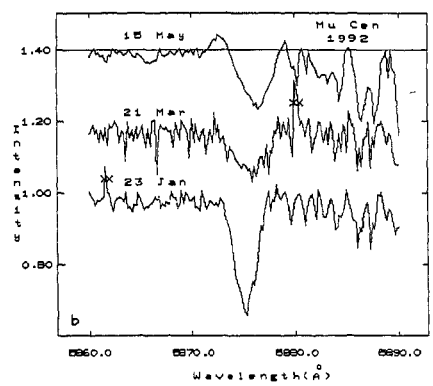


Fig. 2

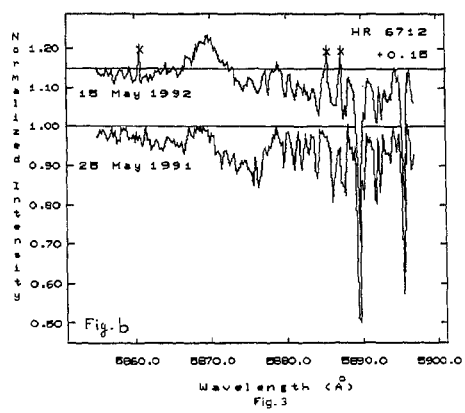


Fig. 3

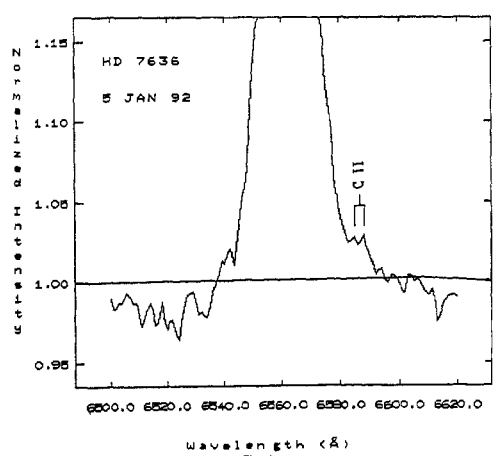


Fig. 4

Be x-ray binaries

Be x-ray binaries are an important group of stars which may provide clues to our understanding of binary stellar evolution. Only 30 such binaries are known today and the optical counterparts of most of them are too faint to allow detailed studies to be carried out. We have taken up a programme to detect new bright Be x-ray binaries. Our identification programme is as follows : we examine catalogues of bright stars to search for possible coincidences with x-ray error boxes which have been obtained from different x-ray sky surveys. Then we select candidates for follow-up optical spectroscopy to detect C II (6578 and 6583 Å) emission lines. Recently Ghosh, Apparao & Tarafdar (1989, *Ap. J.*, **344**, 447) have shown that the detection of C II emission lines along with the enhancement of other emission lines [Hα, Si II (6347 and 6371 Å), He I (5876 Å), $H\beta$, and Fe II lines] can be used as a good indicator of x-ray flares in Be x-ray binary systems. From the regular optical spectroscopic monitoring programme of 14 binaries, recently three such flares were detected in HD 7636 (Fig.4), HD 249179 and HD 72754 systems. (K. K. Ghosh, G. Selvakumar, M. J. Rosario)

Simultaneous infrared and H-alpha measurements of B[e] stars

The observed infrared excess in B[e] stars was usually interpreted as free-free and free-bound emission from a hot gas envelope around the B[e] stars. This hot gas should also emit H-alpha line radiation. Earlier observations of these two quantities (made at different times) showed their incompatibility. We have carried out simultaneous observations of infrared and Hα line radiations of four B[e] stars η Tau (HR 1165), ζ Tau (HR 1910), κ CMa (HR 2538) and β CMi (HR 2845). The ratios of infrared to H-alpha emission luminosities observed by us are much larger than the value of ~ 3 expected if both the infrared and H-alpha emission were to arise from the ionized gas. An examination of the different possibilities that may be responsible for the observed high ratios of $L_{IR}/L_{H\alpha}$ indicates that infrared radiation and Hα radiation cannot both arise from the same hot gas and that additional processes need to be invoked to account for the observed excess infrared radiation.(*K. M. V. Apparao, *S. P. Tarafdar, *R. P. Verma, K. V. K. Iyengar, K. K. Ghosh)

Optical identification and photometry of unidentified IRAS sources

Optical identification of 14 'unidentified' IRAS sources was carried out using the POSS, ESO and SERC sky survey prints. Twelve of these were found to have optical counterparts. These are sources with circumstellar dust shells emitting strongly in the IRAS survey bands. CCD photometric observations of the optical counterparts of these IRAS sources were carried out in the *BVRI* bands. A preliminary analysis of the data indicates that 3 of the sources viz., $12387-3717$, $17201-4613$ and $18599+2246$ are brighter than 6 magnitudes in the I band. These sources will also be observed in the near infrared (J, H and K bands) and their optical and near infrared colours will be used to obtain information on their evolutionary stage. (K. V. K. Iyengar)

Helium stars

Optical photometry of helium stars has been combined with their mid-ultraviolet photometric indices determined from the observations of TD1 satellite and analysed. It has been shown that segregating helium stars from normal B-type objects is possible using with some care the index $\Delta_3 = m_o(2740-2365) + m_o(2365-1965)$ and $(U-B)_o$ as well as

$(2365 - V)_o$, $(1965 - V)_o$ with c_o. A linear relation is obtained between $(1965 - V)_o$ index and the effective temperature derived from model atmosphere analysis. It is also shown that the effective temperatures estimated from $(1965-V)_o$ index are higher, especially for weak line stars compared to the effective temperature derived from spectral types. (*G.C. Kilambi, *P. Nagar, N.K. Rao)

Ap and Am stars

Physical parameters like effective temperatures, radii, bolometric corrections, etc. of about 30 Ap and Am stars were estimated from the spectrophotometric data obtained earlier. A new programme for studying the variation of the λ 5200 feature in Ap stars has been started. It is proposed to obtain the periodicities of these variations and then relate them to other variations in the respective programme stars. This study is expected to give some indications regarding the surface inhomogeneities of Ap stars. (G.S.D. Babu)

Speckle interferometry of close binaries

Speckle interferometry has made a major breakthrough in achieving angular resolutions of close binaries down to 20 milliarcsec at the largest available telescopes. The 50 milliarcsec resolving capacity of 2.3 m Vainu Bappu Telescope, has given us the opportunity of observing several close binaries using this technique. We have developed a 2-D auto-correlation programme to analyse these data. Several frames containing speckles of the 5.57 magnitude binary HR 5138 (HD 118889) were obtained on 1990 March 16-17 at VBT using a camera comprising a Barlow lens, ICCD and a filter in the Hα region (FWHM $\sim$ 50 Å). The spectral type of the star is F0 V. One such frame of this star was analysed by using our 2-D AC programme at VAX 11/780 in Kavalur. The point spread function of the atmosphere and the telescope was estimated from the specklegrams of an unresolved star. The separation between the two components in the binary system was found to be 0.12 arcsec. (S.K. Saha, K. Narayana Kutty)

The RS CVn binary DM Ursa Majoris

The B and V light curves of DM UMa available during 1979-90 have been analyzed by means of a spot model which assumes that large discrete spots are responsible for the observed light variation. The method of least squares using differential correction was employed to derive best-fit spot parameters. All spot parameters, including temperature, are optimized simultaneously.

Computations show that differential limb-darkening contributes a large fraction of the variation in $(U - B)$, $(B - V)$, $(V - R)$ and $(V - I)$ colours. The effects due to temperature in $(B - V)$ and $(V - R)$ colours are nearly the same, indicating that $(V - R)$ observations do not have any appreciable advantage over $(B-V)$ observations. But in $(V-I)$ colour, the effect due to temperature is larger, making it the more suitable for determination of the spot temperature.

The temperature determination relies on the fact that the mean light level changes appreciably with the spot temperature. B and V observations were directly and simultaneously used instead of using the amplitudes of V and $(B-V)$ modulations separately, and the spot temperature was treated as an unknown in the least-square solution along with the other spot parameters.

A mean spot temperature of 3400 ± 60 K was derived from the data obtained during ten ob-

serving seasons between 1979 and 1990. The value used for unspotted magnitude of the star would affect the derived temperature significantly. From 1984 onwards the brightness at light curve maximum has increased monotonically by around 0.20 mag and the value observed during 1989–90 was assumed to represent the unspotted magnitude. The computations show that an increase in unspotted brightness by around 0.1 mag would decrease the spot temperature by about 200 K.
(S. Mohin, A. V. Raveendran)

The semi-regular variable LR Sco

LR Sco has earlier been misclassified as a R CrB star, but its spectrum does not show the primary characteristics of R CrB stars. Bulk of the carbon lines, the He I 5876 Å feature etc that are normally seen in the spectra of R CrB stars are conspicuous by their absence. On the other hand the spectrum of LR Sco closely resembles that of a normal supergiant of spectral type G0. Atmospheric parameters and elemental abundances of LR Sco are determined using detailed depth-dependent model atmospheres and high resolution spectra. The line synthesis technique was used to derive abundances of the light elements C, N, O, Na, Al, Si, S, of the Fe-peak elements Ca, Sc, Ti, V, Cr, Fe, Mn, Ni and the s-process elements Y, Ba, Ce. Most of the elements show near-solar abundance with the exceptions of N which shows considerable enhancement, Si which shows marginal enhancement and Ca which is significantly deficient.

The strength of circumstellar components seen in Na D lines are used to derive the mass loss rate. The mass loss rate is also estimated independently using observed infrared flux from 1–100 μm. These two approaches lead to nearly the same value of the mass loss rate for an assumed $M_v = 4.5$. LR Sco shows many characteristics like semi-regular light variations, mass loss, incipient emission in the Hα line profile that makes it a likely member of the post AGB sequence. (S. Giridhar, N. K. Rao, *D. L. Lambert)

Hα in supergiant chromospheres

Radiative transfer calculations of Hα have been continued from the last year. The line profiles have been computed in spherically symmetric, expanding, non-LTE atmospheres for a wide range of parameters to simulate Hα profiles in 30 stars observed with the 1 m telescope of VBO with the oudé echelle spectrograph coupled with a CCD detector. Several density distributions have been tried to explore their effect on the shape and strength of the line profiles. It is found that a steeper density distribution results in a lower optical depth in Hα and a lower rate of mass outflow.
(S. V. Mallik)

Ca II triplet lines in cool stars

The Ca II triplet lines at $\lambda\lambda$ 8498, 8542, 8662 are potentially powerful tools for the study of stellar populations in galaxies because of their sensitivity to the stellar atmosphere parameters, in particular, luminosity and metallicity. They can, therefore, be used as a discriminant for the dwarf-giant ratio in stellar systems and also as indicators of metallicity of these systems. Last year we started a survey of the Ca II triplet lines in cool stars sampled from the Bright Star Catalogue and the [Fe/H] Catalogue of Cayrel de Strobel et al. (1985, *Astr. Astrophys. Suppl.* **59,** 145). A preliminary study of the dependence of the Ca II triplet strengths on luminosity and effective temperature was then made. The Ca II strengths were also found to be quite sensitive to metallicity. In a more extended survey in

progress both metal-poor and metal-rich stars and more dwarfs and subgiants have now been included . So far 90 stars have been observed spanning 4 orders of magnitude in g, a factor of 15 in metallicity i.e. [Fe/H] , and a range of spectral types F8 to M4. The observations were acquired using the coudé echelle spectrograph at the 1 m telescope of VBO with a CCD detector with pixel size 23 μm square. The configuration of the spectrograph gave a spectral resolution of 0.35 Å, far higher than in previous studies, thus ensuring an accurate determination of the equivalent widths of the Ca II triplet. A signal to noise ratio of 50–100 was achieved for most of the stars. The basic parameters like $\log g$, $(R-I)$ and [Fe/H] have been compiled from various sources. The detailed analysis shows that the Ca II equivalent widths are fairly insensitive to temperature over the range of luminosities covered. However, a very strong correlation exists between the equivalent widths and $\log g$ for any given spectral type, in the sense that the lower the surface gravity, the higher is the equivalent width of the Ca II triplet. A large scatter exists as a consequence of the chemical inhomogeneity of the sample. The relationship between $\log g$ and the equivalent width is much tighter in metal-rich stars than in metal-poor stars. The dependence of the Ca II equivalent widths on [Fe/H] has also been explored, the correlation is conspicuously stronger in supergiants than in dwarfs and giants. For a more complete analysis observations are in progress with the sample including stars with higher $(R-I)$, more dwarfs and subgiants and more metal poor stars with [Fe/H] ≤ -1.0. (S.V. Mallik)

Post AGB Stars

SAO 244567 (Hen 1357 = CPD-59°6926 = IRAS 17119-5926) is an IRAS source with far infrared colours and flux distribution similar to those of planetary nebulae. The IUE ultraviolet spectra obtained in 1988 July and 1992 April show nebular emission lines and also the changes in spectra suggest the formation of a planetary nebula and a rapid evolution of the central star. The optical spectrum of this star obtained by Henize around 1950 shows only the Hα line in emission, while the most recent one, obtained in 1990 shows strong forbidden emission lines corresponding to a low excitation and young planetary nebula. The IUE ultraviolet spectra show evidence for the presence of stellar wind and mass loss. The stellar lines show P-Cygni type profiles and the terminal velocity of the stellar wind is ~ -3000 km s^{-1}. The spectral type of the central star is ~O8 V. The presence of a detached cold dust shell (125 K), high galactic latitude and abundances suggest that SAO 244567 has recently evolved from a low or intermediate mass progenitor star which has ejected its outer envelope during the AGB stage of evolution and is rapidly evolving towards hotter spectral types. The nebula is carbon rich. The strong spectral changes and the drop in luminosity detected are not expected from theoretical evolutionary models. However, the low luminosity, abundances and the high galactic latitude indicate that the progenitor star is not massive. This star seems to be a part of the 'missing link' between post-AGB stars and PNe or proto-PNe. The evolutionary connection between this star and the other high-galactic latitude post-AGB stars needs further study. Monitoring programmes are necessary to evaluate these changes and confirm that we are observing for the first time the birth of a PN. (M. Parthasarthy, *P. Garcia Lario,*S. R. Pottasch, *A. Manchado, *J. Clavel, *D. de Martino, *G. v. d. Steene, *K. C. Sahu).

Post AGB candidates

From an analysis of the IRAS data a new class of stars has been detected. These stars have circumstellar dust with far infrared colours and flux distributions similar to the dust shells of planetary nebulae (Parthasarathy & Pottasch 1986, *Astr. Astrophys.* **154,** L16). Most of these objects show A, F, G and K supergiant-like spectra in the optical region (Parthasarathy & Pottasch, op.cit.). Parthasarathy & Pottasch interpreted these dust shells as the result of severe mass loss experienced by these objects during their AGB stage of evolution, being now in the post-AGB stage, evolving from the tip of the AGB to the left in the H–R diagram into the region of planetary nebulae. It is likely that these objects are a small part of a hitherto unseen phase of stellar evolution. From further analysis of IRAS data several new post AGB candidates have been detected. Several of these new post AGB candidates were observed with the CCD spectrographs on the 1 m and 2.3 m telescopes at VBO. Many of these new post AGB IRAS candidates were found to show F and G supergiant-like spectra. The new post AGB candidates detected are SAO 40039, SAO 112630, IRAS 05341+0852, SAO 173329, HD 114855, HD 145718, SAO 209008, HD 158616, HD 172324, HD 172481, HD 331319, IRAS 04296 + 3429, IRAS 05113 + 1347, IRAS 05238 – 0626, IRAS 05381+1012, IRAS 07227 – 1320, IRAS 07253 – 2001, IRAS 07430 + 1115, IRAS 08187 – 1905, IRAS 09032 – 3953, IRAS 20000 + 3239, IRAS 20572 + 4919, IRAS 22223 + 4327, IRAS 22574+6609 and IRAS 23304+6147. All these objects have detached cold circumstellar dust shells similar to the dust shells around planetary nebulae and high galactic A and F supergiants. (M. Parthasarathy, B. Eswar Reddy)

Chemical composition of post AGB stars

High resolution and high signal to noise ratio spectra of a few post AGB A and F supergiant-like stars were obtained with the facilities at ESO (Chile) and La Palma (Spain) to determine C, N, O, Fe and heavy element abundances. The abundance analysis of post AGB stars may enable us to understand nucleosynthesis, mixing and mass loss processes experienced by these stars. Some of the metal-poor post AGB stars show depletion of refractory elements and nearly normal abundance of volatile elements. Since most of these stars have circumstellar dust shells the depleted refractory elements appear to be locked up in the circumstellar dust grains. The chemical composition study of a few more post AGB stars is in progress. (M. Parthasarthy,*P. Garcia Lario, *S. R. Pottasch)

Hydrogen deficient stars

Analysis of high resolution CTIO spectra of R CrB stars was continued. The main interest was to study the elemental abundances and their distribution, which might give clues to the evolutionary state of these stars. For a few stars (V 3795 Sgr, Y Mus) the analysis was completed. Observations of the northern R CrB stars XX Cam, SU Tau, UV Cas and of α Per were obtained with the coudé spectrographs of 107- and 82-inch telescopes of McDonald Observatory, University of Texas in 1991 December . These observations are also being analysed. Other southern R CrB and cool Hdc stars, which were not observed on earlier occasions, are planned to be covered in the 1992 May run with the echelle spectrometer on the 4-m CTIO telescope. (N.K. Rao, S. Giridhar, *D.L. Lambert)

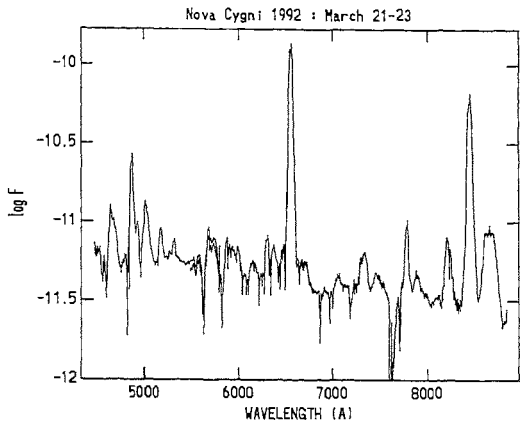
Polarimetric observations of several R CrB stars and some RV Tauri stars were obtained

at the Cassegrain focus of 2.3 m VBT using the PRL polarimeter. In particular, the star V 854 Cen (= NSV 6708) has been observed at maximum and a few times during the light minima in 1991 and in 1992. The polarization observations indicate consistency of the polarization angle of 66 ± 15° in these two minima implying that dust ejections might occur in the same plane. The *UBV* light curves of R CrB during deep minima obtained by us as well as by others are being studied in terms of the dust ejection model in the presence of a permanent chromosphere, proposed earlier by us. (N. K. Rao, A. V. Raveendran)

Spectroscopic monitoring of some of the hydrogen deficient stars (NSV 6708, R CrB etc) has been made along with the WC 11 stars CPD – 56° 8032, He 2–113, M 4–18 and a few others. The idea is to study the nebular and stellar features separately in these stars. These observations were made with the Boller & Chivens spectrograph with a CCD detector at the Cassegrain focus of VBT. In addition IUE observations in the low resolution mode have been obtained for He 2–113, CPD -56° 8032 and M 4–18 in both short and long wavelength ranges, with a view to monitoring the dust and continuum variations. A study of the nebular properties of the shells surrounding these objects using photoionization models is also in progress. (N. K. Rao)

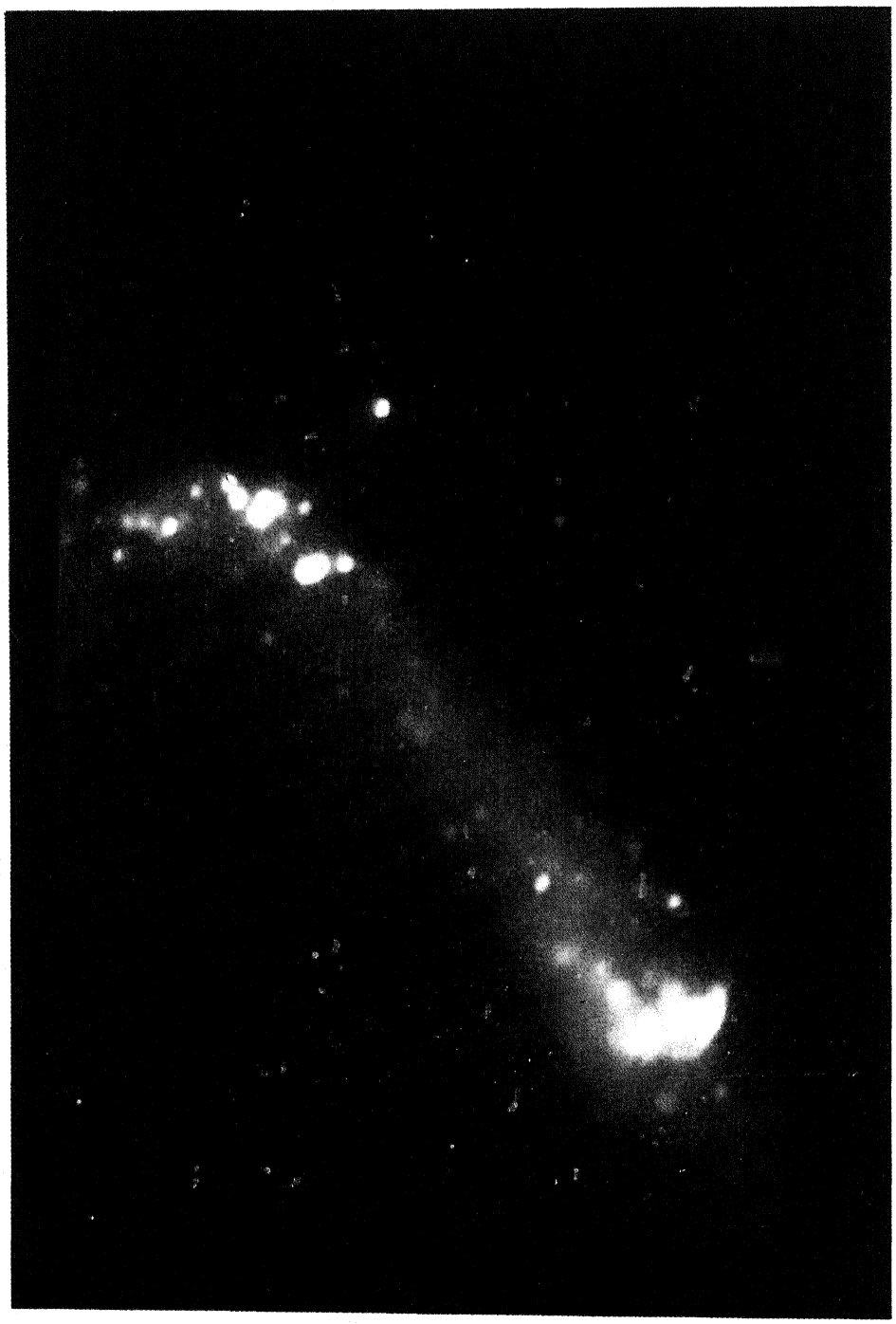
Spectra obtained with VBT of the RV Tauri star AR Pup show that in addition to Hα emission the star shows Na I D lines in emission at certain phases.
(N. K. Rao, A. V. Raveendran)

Novae



CCD images of the nebular shell of the old nova GK Per in [N II] obtained with the 1 m reflector in 1990 were compared with the published images obtained in 1984 to derive proper motions of 20 knots. The mean expansion rate was determined to be 0.31 ± 0.07 arcsec yr^{-1}. This value agrees with the models of ejecta into the ambient circumstellar medium. However, a correction for the projection effects indicates that the density in the circumstellar medium is 2–3 times higher than estimated earlier.

Several novae in outburst were monitored spectroscopically this year: Her 1991, Oph 1991, Pup 1991, Sgr 1992 and Cyg 1992. Both the 1 m and 2.3 m telescopes were used. The spectroscopic monitoring of recurrent novae T CrB, RS Oph, T Pyx and the classical nova GK Per was also continued using these telescopes.
(G. C. Anupama, T. P. Prabhu)



Irregular galaxy NGC 4656 imaged using the CCD detector at the prime focus of 2.3 m VBT. The composite colour picture is constructed using images obtained in B (blue), [O III] (green) and Hα (red) bands. North is to the right and east at the top. The bright emitting region at the southwest corner is the nucleus of the galaxy. (Y.D. Mayya)

Galaxy and the Interstellar Medium

Polarimetric observations of young stellar associations

To study the composition and distribution of dust in young stellar associations and clusters, a programme of measuring the degree of polarization and position angle of these objects as a function of wavelength was started. The observations of the members of, and stars foreground to, Pup III associations have been completed. Most of the stars were observed in *BVRI* bands. Detailed analysis of the results is in progress. (S. K. Jain)

Diffuse interstellar bands

A programme to map systematically the diffuse interstellar bands in various directions and locations with a view to studying their nature has been started. We use the Boller and Chivens spectrograph coupled with a CCD detector at the Cassegrain focus of the VBT. Using the 1200 line grating, the spectrum from 5620 Å to 6400 Å can be covered in one setting and several of the diffuse interstellar bands occur in this range. About 25 stars have been observed so far in this programme. (N. K. Rao, H. C. Bhatt, A. V. Raveendran)

Galactic H II regions

A collaborative programme has been started with the Physical Research Laboratory, Ahmedabad, to obtain velocity-field maps in Galactic H II regions using an Imaging Fabry-Perot Spectrometer at the Cassegrain focus of the 1 m telescope at VBO, Kavalur. Emission lines such as [NII] and [OIII] will be used to obtain Doppler profiles in selected regions of about 4 arcmin with spatial resolution of 1 or 2 arcsec and velocity resolutions of a few km s^{-1}. From the profile structure we propose to study various physical parameters in the regions including turbulence.
(*B. G. Anandarao, S. K. Saha, *D. P. K. Banerjee, *P. Seema)

Star Clusters

Fibre spectroscopy and *BV* CCD photometry of NGC 3114

New spectroscopic and photometric observations were presented for a sample of faint stars extending the colour-magnitude diagram of the southern open cluster NGC 3114 down to $V = 16$ mag. The distance to the cluster was estimated as 940 ± 60 pc. The spectroscopic observations indicated the presence of six Ca II emitters in a sample of 55 stars. Radial velocity measurements and spectral classification have been carried out for all the 55 stars. Both spectroscopic and photometric observations indicate the presence of a large number of field stars in the direction of the cluster. Isochrones fitted to the colour-magnitude diagram as well as the position of the red giant concentration yielded an age of about $1 - 2 \times 10^8$ yr for this cluster. (Ram Sagar, *R. M. Sharples)

CCD photometry of the distant young open cluster NGC 7510

CCD observations in B, V and I passbands were used to generate deep V, $(B - V)$ and V, $(V - I)$ colour-magnitude diagrams for the

open cluster NGC 7510. The sample consisted of 592 stars reaching down to $V = 21$ mag. The cluster appears to have non-uniform extinction over the face with the value of colour excess, $E(B-V)$, ranging from 1.0 to 1.3 mag. The law of interstellar extinction in the direction of the cluster was found to be normal. A broad main-sequence is clearly visible in both the colour-magnitude diagrams. From the bluest part of the colour-magnitude diagrams, the true distance modulus to the cluster was estimated as 12.5 ± 0.3 and an upper limit of 10 Myr was assigned for the cluster age. (Ram Sagar, *W.K. Griffiths)

CCD photometry of the open cluster NGC 2453

We completed the observations of this cluster in B, V and I passbands using the Photometrics CCD system at the 1 m telescope of VBO. Preliminary analysis of the data shows that we are able to see for the first time the unevolved main sequence of this distant cluster. We also obtained several CCD images of the planetary nebula NGC 2452 which lies in the close vicinity of this cluster. We hope to obtain an improved reddening-distance diagram in the direction of the nebula and determine a more accurate distance to it. (D.C.V. Mallik, Ram Sagar, A.K. Pati)

OCl 674 (Haffner 14) and OCl 692 (Haffner 20)

Preliminary results of the photometric work on the faint clusters OCl 674 (Haffner 14) and OCl 692 (Haffner 20) indicate their distances to be about 3.8 kpc and 5.2 kpc respectively. However both the clusters appear to have similar ages in the range of 10 to 70 million years. (G.S.D. Babu)

Kinematics and distribution

Distribution of stars perpendicular to the plane of the Galaxy

In the previous year we obtained rigorous analytical solutions of the Boltzmann-Poisson equations concerning the distribution of stars perpendicular to the Galactic plane. The velocity dispersion of the stars was assumed to arise from the stellar motion in a random force field and follow a power law in mass. We have modified this to $< v^2(m) >\sim$ constant for $m \leq m_*$, and $< v^2(m) >\sim \mathrm{m}^{-\theta}$ for $m > m_*$, where m_* is the stellar mass for which the stellar lifetime equals the age of the disc . New solutions have been obtained with the modified velocity law. It is seen that the height distribution of stars is very sensitive to the values of x and θ, the exponents of the mass spectrum and the velocity spectrum respectively, but in all cases the gravitational field scales as $K_z \sim z$ for $z \rightarrow$ o and $K_z \rightarrow$ constant for $z \rightarrow \infty$, in this one-dimensional solution to the problem. It is seen that the dispersion of the position of the stars follows the law $< z^2(m) >\sim$ constant for $m \leq m_*$, while $< z^2(m) >\sim m^{-\theta}$ for $m > m_*$. Finally, we have derived an expression connecting the surface density, volume density and the velocity dispersion of stars and have shown that this relation is a sensitive function of x and θ. Using the observational data due to Gilmore, we find that the velocity dispersion in thick disc is 30 km s^{-1}, while that in the thin disc is 15 km s^{-1}, so that the thick disc contributes about 8 % to the total disc mass. (S. Chatterjee)

Distribution of planetary nebulae in the solar neighbourhood

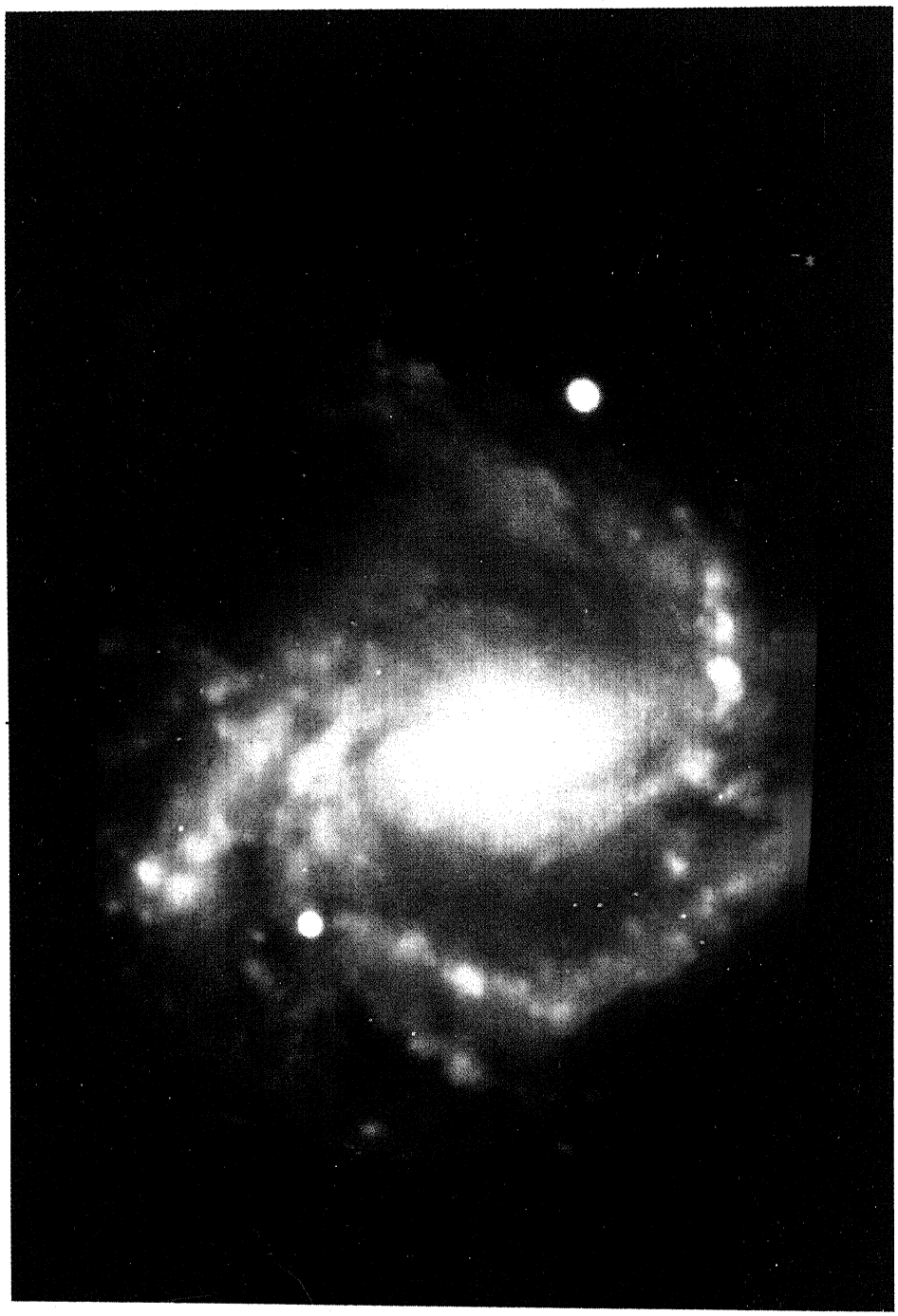
Using the analytical solutions of the Boltzmann-Poisson equations concerning the distribution of stars perpendicular to the Galactic

plane obtained by Chatterjee (1991, *J. Astrophys. Astr.*, **12**, 269), we have derived the distribution of planetary nebulae perpendicular to the plane. We have assumed that all stars between the Galactic turn-off mass and an upper mass given by $m_u \approx 6-8M_\odot$ become planetary nebulae at the end of their nuclear lifetime. The distribution differs significantly from the secant hyperbolic square law given by Spitzer (1942, *Astrophys. J.* **95**, 329) obtained on the assumption that all stars have the same mass. We assume a Salpeter-type power-law distribution of the stellar masses. The mean distances of planetary nebulae from the plane are found to be higher than previously thought. Comparison with observations is in progress. (D. C. V. Mallik, S. Chatterjee)

Photoionization modelling of WC 11 group PNe

A photoionization model code had earlier been developed with only gas present in the nebula. This code was upgraded to accept a filling factor and to include presence of dust mixed with gas.

M 4–18 was modelled in detail combining the results from new CCD spectroscopy done at VBO, Kavalur with both 1 m and 2.3 m telescopes, with IUE, J, H, K, L, IRAS and VLA observations taken from literature. The abundances of He, C, O, Ne and Ar were found to be solar while N and S were found to be underabundant. The mean T_e and N_e from the best matched models are 7200 K and 7400 cm $^{-3}$ respectively. The density distribution was found to be consistent with the observed radio continuum. Amorphous carbon grains in the size range 0.04 to 0.05 micron, with increased dust to gas ratio towards the edge of the density-bounded nebula, could account for the IRAS 12 and 25 micron band fluxes well, while failing to do so in the 1 to 10 micron region and in the 60 and 100 micron IRAS bands. In the light of these results, it appears that the central star may be a "born again AGB star". (R. Surendiranath, N. Kameswara Rao, *A .R. Hanumanthappa)



Spiral galaxy NGC 4303 imaged using the CCD detector at the Cassegrain focus of the 1 m reflector. The composite colour picture is constructed using images obtained in the B (blue), V (green) and I (red) bands. (Y.D.Mayya)

Galaxies

Dynamics

The stability of a spherical galaxy against tidal disruption when it is influenced by a heavy point-mass perturber has been investigated by numerical simulations. Tidal disruption is important in collisions of galaxies of unequal mass. For systems widely differing in mass, the rate of disruption of the less massive one is chiefly determined by the density ratio of the two galaxies. In the numerical simulations, the less massive satellite galaxy is modelled as a collection of stars following specific density law. The perturber is much more massive than the satellite and it is assumed to be a point-mass. The simulations use various values for the collision velocity and mass ratio keeping the pericentric distance constant. The stability of the satellite galaxy has been determined in terms of the ratio of the average density of the satellite to the Roche density of the perturber. It has been observed that tidal effects decrease more drastically in encounters where the initial relative orbit of the perturber is circular than in any other type of orbits. In the circular case, the transition from disruption to non-disruption occurs in a narrow region where the average satellite density is one half the Roche density. The survival of a satellite galaxy is ensured if its initial average density exceeds the critical density mentioned. If the average density is lower than the critical density, the satellite may suffer considerable disruption.
(P. M. S. Namboodiri, R. K. Kochhar)

The two important tidal effects observed in interacting galaxies are tidal stripping and tidal distension. A small galaxy influenced by a large companion is expected to undergo tidal stripping. Collisions of galaxies of comparable mass are likely to produce tidal distension. Numerical simulations have been performed to investigate these effects.
(P. M. S. Namboodiri)

The Large Magellanic Cloud

We obtained BV CCD data for the young star clusters NGC 1711, 2004, 2100, 2164 and 2214 and their nearby field regions in the LMC. The data were calibrated with a zero point accuracy of $\pm$ 0.04 mag in both B and V. The total sample consists of over 8960 stars reaching down to $V = 21$ mag. The data served as a base for the study of mass functions and for comparison with theoretical models. The CCD data compared very well with photoelectric observations of stars having a range in brightness ($11.8 \leq V \leq 18.1$) and in colour ($-0.17 \leq (B-V) \leq 2.17$). However, systematically varying differences were seen with the photographic data. In NGC 2004 and 2164, for example, the differences varied with brightness in both V and $(B-V)$, while in NGC 2100, photographic V data agreed very well with the CCD data up to $V \sim 15.5$ mag but the difference increased rapidly for fainter stars.
(R. Sagar,*T. Richtler, *K. S. de Boer)

We have analysed the data of the 5 young star clusters in order to determine their mass functions. The clusters span a range in age from $\sim$ 10–100 Myr. In the mass range $\sim 2 - 14 M_{\odot}$, x ,the slope of the mass function is approximately the same for the four well observed clusters the average value being $x = 1.1$. This is not too different from the Salpeter value of 1.35. For three clusters, the slopes in two annular rings located at $\sim$ 10 and 40 pc respectively from the cluster centre agree within the errors. In the case of NGC 2214, we do find a difference between the two slopes. (R. Sagar, *T. Richtler)

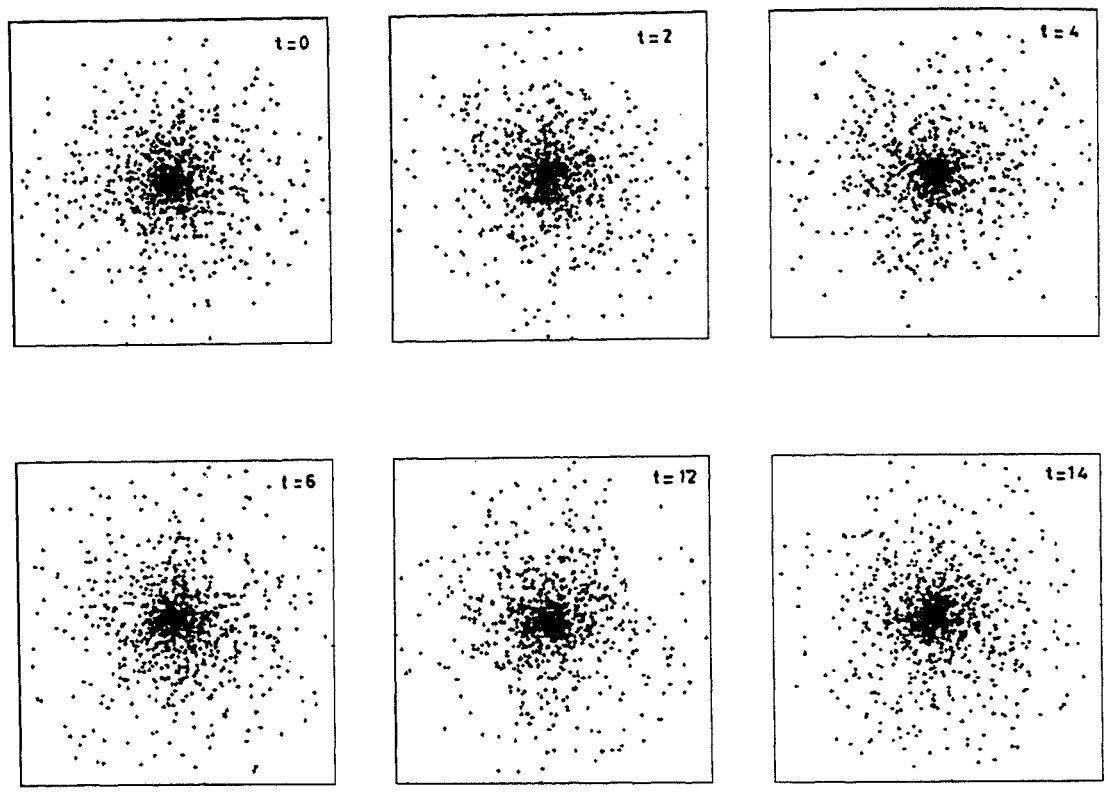


Fig.5. The evolution of an initially non-rotating spherical galaxy influenced by a massive (20 times) companion which undergoes a collision in a parabolic orbit. The galaxy is modelled as a cluster of 1000 equal mass points with moderate central concentration. Plots represent projection of particles on to the orbital plane. Mass of the galaxy $M = 10^{11} M_{\odot}$; Radius $R = 10$ kpc ; one time unit nearly corresponds to 10^8 yr. The figure shows the configurations at times t =0,2,4,6,12 and 14 respectively and $t = 4$ represents the instant of minimum separation. The galaxy is elongated in the orbital plane and shows signs of rotation.

Two distinct supergiant branches in the young LMC star cluster NGC 2214

We present compelling evidence that the LMC star cluster NGC 2214 actually consists of two stellar age groups, clearly visible in the form of two well-defined supergiant branches in the CCD V, $(B-V)$ colour-magnitude diagram. They are separated by ~ 2 mag in luminosity and have respective ages ~ 60 and 170 Myr. The spatial distribution of the stars of the two sequences indicate that the older population is more concentrated towards the cluster centre while the younger one shows a more extended distribution. (R. Sagar,*T. Richtler, *K.S. de Boer).

Galaxy population synthesis

With a view to deriving the distribution of stars of different spectral types, luminosity classes and metallicity in galaxies from spectra of their integrated light, the observations under this programme were continued using the Cassegrain CCD spectrograph at the 1 m telescope at VBO. The libraries of stellar spectra used for population synthesis are not adequately complete in wavelength coverage, spectral resolution and range of metallicities. In the present phase, observations have been aimed at separating metal-rich and metal-weak stars in the library, especially on the main sequence. Spectra of about 20 stars going down to a [Fe/H] of -2.6 were obtained over the wavelength range 5700–9500 Å with a spectral resolution of 10 Å. The data have been obtained with a view to deriving spectrophotometric fluxes. Spectrograms of three galaxies have also been obtained with the same setup. Most of the objects were observed more than once to obtain better average fluxes. The reduction of the data is in progress. (A.K. Pati)

Star-forming regions in nearby galaxies

Synthetic aperture photometry of a sample of giant extragalactic H II regions in nearby galaxies is carried out on the CCD images obtained over the last 2–3 years at the 1 m and 2.3 m telescopes of VBO. The photometric results are compared with the locally constructed theoretical evolutionary population synthesis model. The main results are the following:

If we allow the stellar continuum to suffer the same extinction as the gas (as estimated from the Balmer decrement), the resultant ratio of Hβ to blue continuum is too small compared to the model. A better agreement with the models is obtained by assuming that the stellar continuum undergoes only half the extinction compared to the gaseous component. This implies that the gas and the associated dust form a patchy distribution and a significant part of the stellar continuum escapes through 'holes' without suffering substantial extinction. The low values of extinction derived from the 220 nm feature can also be explained with this hypothesis. (Y.D. Mayya, T.P. Prabhu)

Supernovae

Three extragalactic supernovae were observed using the 1 m and 2.3 m telescopes. Of these, the peculiar SN 1991T in NGC 4527 was observed in greater detail from the maximum to 2 months thereafter. The supernova, though of Type I, did not have the characteristic strong absorption at 615 nm during the early phases. Its development since maximum is clearly seen in our spectra.

SN 1991AA in an anonymous galaxy and SN 1992A in NGC 1380, both Type I, were observed only close to maximum light.
(T.P. Prabhu, G.C. Anupama)

Active Galactic Nuclei, BL Lac objects, Quasars

X-ray ($0.1 - 10$ ke V) spectra of four AGNs which were observed with EXOSAT, were analysed using XSPEC (x-ray spectral fitting) software package. Results obtained from the analysis are as follows:

a) *NGC 3516*

X-ray spectra of this original Seyfert galaxy were well fitted by a power-law, uniform absorption and a Gaussian line model. Significant intrinsic absorption ($N_H \sim 10^{22}$ cm^{-2}) was detected in this flat spectrum galaxy. For the first time we have detected soft excess emission and a highly significant (99.9 %) emission line around 6.0 keV, in the spectra of NGC 3516. The detected emission line whose equivalent width ranges between 106 and 1240 eV, has displayed very broad line width which is the first observational result on the broadening of the Fe K-shell lines in an AGN and this result suggests the presence of a massive black hole at the centre of this galaxy.

b) *3C 390.3*

X-ray spectra of this double-lobed radio galaxy is best fitted with the two power-law, uniform absorption (fixed with the Galactic N_H value) and a Gaussian line model. The soft spectral component is steeper than the hard component. For the first time we have detected a highly significant ($> 99.9\%$) emission line around 6 keV which may be due to the fluorescence of cold iron from an optically thick accretion disc around the central nonthermal x-ray source.

c) *PKS 1217+023*

This radio-loud quasar has displayed steeper spectral index ($\alpha \sim 0.9$) than the canonical value of AGNs. No significant absorption was detected in this quasar. A thermal bremsstrahlung model also provides a good fit to the x-ray spectra of PKS 1217+023 (plasma temperature ~ 3 keV). We have shown that the spectral index values may not be a good indicator to distinguish between the radio-loud and radio-quiet quasars.

d) *1928+73*

We have published the first x-ray spectrum of this radio-loud superluminal quasar which can be explained by a power-law and a uniform absorption model. No significant low-energy absorption or soft excess was detected in the spectra of this quasar. However the uncorrelated variability of the soft ($0.1 - 2$ keV) and hard ($2 - 10$ keV) fluxes has indicated that they have different origins. A soft excess is apparent when the spectra are fitted with a canonical photon index ~ 1.7. A thermal bremsstrahlung model also fits well with the spectra of $1928 + 73$.
(K. K. Ghosh, S. Soundararajaperumal)

NGC 3783

As a part of an international campaign the Seyfert galaxy NGC 3783, is being monitored spectrophotometrically and photometrically since January 1992 using the 1 m reflector and the Photometrics CCD detector. The spectra cover a range of 4400–7000 Å at a resolution of 18 Å. The photometry has been carried out in Johnson-Cousins BVR bands.
(T. P. Prabhu, Ram Sagar, Annapurni Subramaniam, K.K. Ghosh, Y.D. Mayya, G.C. Anupama, A.K.Pati)

We have carried out the optical imaging polarimetry of seven x-ray selected BL Lac objects (0737+74, 0950+49, 1133+16, 1144+35, 1258+64, 1404+04 & 1458+22) at the prime focus of VBT using CCD system. We have observed these objects at three angles (0°, 60°, & 120°) of the polaroid through the V filter. Data analysis is in progress. (K.K. Ghosh, *K.P. Singh, *P.N. Bhat)

Role of Compton and Raman Scattering in the quasar continuum

There are three ways in which an electromagnetic wave can undergo scattering in a plasma: (i) when the scattering of radiation occurs by single electron, it is called Compton Scattering (CS); (ii) if it occurs by longitudinal electron plasma mode, it is called Stimulated Raman Scattering (SRS); and (iii) if it occurs by a highly damped electron plasma mode, it is called Stimulated Compton Scattering (SCS). The nonthermal continuum of quasars is believed to be produced through the combined action of synchrotron and inverse Compton processes, which are essentially single particle processes. Here, we investigate the role of SRS and SCS in the generation of continuum radiation from these compact objects. It is shown as an example that the complete spectrum of 3C 273 can be reproduced by suitably combining SCS and SRS. The differential contributions of SCS and SRS under different values of the plasma parameters are also calculated. (V. Krishan)

Statistical analysis of quasar galaxy angular separations

The inverse relation between quasar-galaxy angular separations and the galaxy redshifts $[\theta_{QG} \propto z_G^{-1}]$ in quasar-galaxy associations is well known. A statistical analysis to study the correlation between the median angular separations and quasar redshifts is in progress. (P.K. Das)

Effects of dynamical friction on the motion of a supermassive object

Based on the earlier work by Kapoor (1985, *Astrophys. Sp. Sci.*, **112**, 347) investigations are in progress to study the effects of dynamical friction on the motion of a supermassive object ($M \sim 10^9 M_\odot$) ejected from the centre of a galaxy ($M \sim 10^{11} M_\odot$) in the VMH scenario. (P.K. Das, R.C. Kapoor)

Clustering of galaxies by nonlinear α-effect

It was proposed (Krishan & Sivaram 1991, *MNRAS*, **250**, 157) that the clustering of galaxies up to the largest observable scales could be accounted for by applying the concepts of inverse cascade in a hydrodynamic turbulent medium. This was done in a phenomenological way, using Kolmogorovic arguments to derive the cascading characteristics of the invariants of the system. Formation of large-scale structures is also studied by investigating the effect of small scale flows on the large scale flows through Navier-Stokes equation, analogous to the generation of large scale magnetic field by the α-effect. The hope is that the stationary solutions of the Navier-Stokes equations will confirm and conform to the spectral predictions of the phenomenological view. Here, the role of the α-effect on the clustering of galaxies has been explored.
(V. Krishan)

Theoretical Astrophysics and Cosmology

Theoretical Astrophysics

Polarized resonance line transfer with non-coherent electron scattering

The importance of electron scattering in stellar line formation problems has been recognised for a long time. It has been already demonstrated that there is a need to consider the electron scattering correctly in order to derive the mass loss rates in O and B stars. In this work we have considered the combined effects of partial frequency redistribution by atoms (PRD) and non-coherent electron scattering (NCES) on the line formation taking account of the polarization state of the radiation field in resonance line scattering. For the purpose of comparison, a study is also made of the redistribution by other mechanisms, namely complete redistribution (CRD) and coherent scattering (CS) in the line, together with NCES. The static medium is stratified into plane parallel homogeneous layers. The conventional two-level atom approximation is employed as the basic model. The linear polarization in the emergent line profiles exhibits interesting characteristics in its variation across the line profile. The atomic redistribution plays an important role at line core and near wings of the resonance line. However electron scattering makes significant contributions only in the far wings ($x > 10$). For resonance lines with high optical thickness, NCES leads to measurable changes of polarization in the far wings irrespective of the atomic scattering mechanism employed. Since electron scattering is a dominant source of scattering of continuum and line photons in hot stars, and particularly in supernova atmospheres, it is important to include non-coherent electron scattering correctly, in computing emergent intensity and polarization profiles of these objects. (K.N. Nagendra, K.E. Rangarajan, D. Mohan Rao).

Pulsars

The spacetime curvature affects both the magnetic field configuration of a compact mass and the light propagation path in its vicinity. An estimate of these effects for the case of an aligned dipole in the Schwarzschild background of a neutron star has been made to study the variation of pulsar beam widths as a function of the altitude of the emission region. We consider emission points located at ≥ 6 km in the exterior of a neutron star of mass 1.2, 1.4 and 1.6 $M_{\odot}$. The theoretical framework is purely general relativistic and the extent of the beam width in the emitter's frame refers to emission from the last open magnetic field lines.

The main feature that these calculations reveal is that even though the spacetime curvature squeezes the particle trajectories moving along the magnetic lines of force thereby narrowing the pulsar beam width in the emitter's frame of reference, the photon trajectories are bent away from the original directions of their emission comparatively by a larger extent. Consequently the pulsar beams forming near the neutron stars are wider than their flat spacetime counterparts. These calculations enable us to assign an emission altitude of $\simeq$ 150 km to the 6.1 ms pulsar to explain its unusually large duty cycle and $\simeq$ 30 km in the case of the 3.1 ms pulsar. For the 1.56 ms pulsar, the calculations give a much wider beam than observed, for emission points within the light cylinder. An explaination may lie per-

haps in (1) the aberrational squeezing of the beam at a large emission altitutde (2) a large impact angle, or, a combination of both. Further work is in progress. (R. C. Kapoor)

Neutron Stars

Despite two decades of work, the equation of state of high density matter remains a focus of research interest, in part due to persistent unresolved aspects relating to (a) the nature of nucleon-nucleon interaction at very short separations (less than 0.5 fermi) and (b) the right many-body theory to be used, and, in part, motivated by experimental results using heavy-ion collisions. In the study of high density nuclear matter, the importance of chiral symmetry was emphasized by T.D. Lee and G.C. Wick in 1974. The non-linear terms of the chiral Langrangian can provide the three-body nuclear forces, now believed to be important at high densities ($\rho > 10^{14}$ g cm^{-3}). We have considered an SU(2) $\times$ SU(2) chiral sigma model description of nuclear and neutron matter, both at zero temperature and finite temperatures (up to 15 MeV). Our model includes isoscalar vector field generated dynamically via the Higgs mechanism. Application to neutron star structure and comparison with data inferred from heavy-ion collision experiments are discussed.
(B. Datta, * R. Basu, *P.K. Sahu)

If an oscillating neutron star is also rotating, then the rotation can provide a coupling between the radial and the nonradial oscillation modes, leading to rapid loss of radial vibrational energy. Since pulsars are rotating neutron stars, this constitutes an interesting astrophysical problem to investigate, and as such, has been a focus of theoretical attention for more than two decades. However, the problem in its detail, incorporating a microscopically realistic equation of state and a fully general relativistic framework with arbitrary rate of rotation, has not yet been worked out. Only Newtonian and post-Newtonian approximation approaches have been attempted so far, that too with a polytropic equation of state, which is an idealization to describe neutron star matter. We have applied the Chandrasekhar-Friedman formalism and a modern, realistic equation of state to estimate the rotationally shifted eigenfrequencies of radial oscillations of neutron stars. The formalism is fully general relativistic and to second order in the angular velocity of rotation. This formalism provides an exact formula to calculate the frequency of oscillation of a rotating stellar object, and it depends only on a knowledge of the Langrangian displacement associated with the radial mode oscillations of the nonrotating configurations and of the uniform spherical deformation caused by rotation. The major conclusion of our study is that the magnitude of the effect of the dynamical coupling of oscillation and rotation will differ substantially in a general relativistic treatment of the problem as compared to the Newtonian and post-Newtonian approximation approaches. (B. Datta, S.S. Hasan,*P.K. Sahu)

Quark stars

Nuclear matter at high densities is expected to undergo phase transition to its constituent quark matter of which so-called 'strange matter,' consisting of approximately equal numbers of u-, d- and s- quarks (together with electrons for charge neutrality) would be the lowest and the true ground state of matter. In principle, strange matter can exist in various forms ranging from 'strangelets' of size 5–200 fermi to huge 'strange quark stars' of mass equal to a solar mass and radius of the order 10 km. We have calculated the range of eigenfrequencies of radial pulsations of strange quark stars using the general relativistic pulsation equation given by S. Chandrasekhar and also investigated the sensitivity of the eigenfre-

quencies on the equation of state. The equation of state used by us incorporates the short-range quark-gluon interactions perturbatively to second order in the strong interaction coupling constant, and the long-range interactions are taken into account phenomenologically. We incorporate the density dependence of the coupling constant by solving the Gell-Mann-Low equation for the screened charge. The parameters involved are obtained by demanding that bulk strange quark matter be stable at zero temperature and pressure, with energy per baryon less than the lowest energy per baryon found in equilibrium nuclear matter.

The main conclusion of our study is that the use of a realistic equation of state is important in deciding the range of oscillation frequencies. We find that the fundamental mode radial oscillation periods can be as low as 0.06 milliseconds (which is much lower than the corresponding value for neutron stars), and that the fundamental mode case is the most sensitive to the equation of state compared to the higher harmonics. (B. Datta, *P. K. Sahu, *J. D. Anand,*A. Goyal)

Black holes

A microscopic basis for black hole entropy was proposed. Analogy was made with the exponentially rising level density spectra of massive strings. Several similarities between black hole and string thermodynamics were explored with possibilities of their unified understanding. Further spin effects in black hole evaporation and the black hole wormhole transition were studied. Consequences of space-time quantisation for black hole evaporation and entropy were explored. (C. Sivaram)

Modelling of stellar oscillations

A system of MHD equations has been developed in a form which can be used to compute the effects of rotation and magnetic field in the 'g' and 'p' modes of oscillations of a star. (M. H. Gokhale, *S. M. Chitre, *H. M. Antia).

Cosmology

Flat space-time cosmology and variable mass hypothesis

In the frame work of Hoyle-Narlikar conformal theory of gravity the standard Friedman cosmology with $k = 0$ can be equivalently described in a conformal frame in which the space-time is Minkowskian but the particle masses scale uniformly with epoch [Variable Mass Hypothesis (VMH)]. The observed cosmological redshift in this static, flat universe is a consequence of the systematic increase in particle masses with epoch.

In the previous work it was shown that in the VMH scenario quasars with 'anomalous' (discordant) redshifts can be interpreted as 'young' objects whose particle masses lag behind the universal mass function. The VMH model could adequately explain the various observed features of quasar-galaxy associations and in particular could provide an elegant interpretation of the phenomenon of luminous connections between objects of vastly dissimilar redshifts.

Recent work by Narlikar & Arp (1992, Preprint) shows that a variety of other extragalactic phenomena can also be understood in the framework of the VMH model. Some of these under investigation in detail are outlined below.

a) Hubble relation

The observed redshift-distance relation (Hubble Law) obtains naturally in VMH as an *age redshift effect.* The Hubble constant is

uniquely determined by the age of the galaxies which comprise the relation.

i) The predicted value of H_o in the neighbourhood of our Galaxy is $H_o \simeq 40 - 50$ km s^{-1} Mpc $^{-1}$ which agrees very well with the observed values of H_o (Sandage 1988, *Ap.J.* **331**, 583–604 , 605–619 ; 1991 Preprint).

ii) The apparent increase in observed H_o to values greater than 50 is due to the inclusion of increasing number of younger objects at higher redshifts.

iii) The dependence of the Hubble constant on redshift in VMH can also quantitatively explain the deviation from the Hubble line at higher z as reported by Spinrad & Djorgovski (1987,*IAU Symp.*124,D.Reidel, Dordrecht, p.29.)

(b) Quantization of redshifts

Quantization (periodicities) in redshift distributions has been observed from the lowest to the highest extragalactic redshifts (Tifft & Cocke 1984, *Ap.J.*, **287**,492 ; Guthrie & Napier 1991, *MNRAS*,in press ; Arp et al.1990,*Astr. Astrophys.*, **239**,33) which does not have an explanation in the expanding universe scenario. VMH could solve the quantization problem in a natural way where one could argue in terms of emergence of matter from zero mass, quantum-mechanical realm in discrete bursts spaced at discrete intervals.

(c) 'Missing mass' problem

The 'Missing mass' problem arises from the inferred peculiar velocities and velocity dispersion of galaxies. If redshifts contain a large intrinsic component the mass requirements of groups and clusters of galaxies is reduced and the 'Missing mass' problem may disappear.

(d) Excess redshifts of companion galaxies and stars

The systematically larger redshifts ($\sim$ 100 km s^{-1}) of companions of large, dominant galaxies (Arp 1987,*Quasars, Redshifts and Controversies,* Interstellar Media, Berkeley ; 1991, *Highlights of Astronomy,* in press, MPIA Preprint no. 614) and the excess redshifts ($\sim$ 35 km s^{-1}) of the youngest most luminous stars in LMC, SMC, NGC 1569, NGC 2777, NGC 4399 (Arp 1992, *MNRAS,* in press) can be quantitatively predicted by VMH models. (P.K. Das)

The Early Universe

(1) Quantum effects

The studies of the quantum effects of torsion in general relativity led to the elucidation of some theorems, interconnecting torsion, time and temperature which may have significant consequences for the early universe. In particular a new uncertainty relation between time and temperature was found and applied to the high energy phases of the early universe. These relations have been generalized to curved space-time. (*V. de Sabbata, C. Sivaram)

(2) Extended inflation

It was shown that extended inflation was possible in the framework of models invoking higher powers of the curvature scalar even in the general case of inhomogeneous and anisotropic space times. As a special case, some consequences of quadratic gravity were investigated. (C. Sivaram, *M. Campanelli)

(3) Minimal time

Linking torsion to defects in space-time topology through quantization of spin was shown to give rise to a minimum unit of time. This was found to lead to interesting effects for the earliest phases of the universe as well as physical implications for field theory, particle decay and information theory. The space-time defects induced by torsion were found to behave like a string so that the string tension could be calculated. (C. Sivaram, *V. de Sabbata)

(4) Some aspects of the electroweak unification with gravity for the early universe were studied especially in connection with baryogenesis. (C. Sivaram)

(5) The possibility of generating a primordial magnetic field through coupling between torsion and a gauge invariant massive electrodynamic field in the early universe was explored. (C. Sivaram, *V.de Sabbata, *G.de Andrade)

Astro-particle physics

We have investigated baryon number density inhomogeneity in the very early universe due to a first order preon-to-quark phase transition at or around the electro-weak symmetry breaking. Conformity with the standard model of primordial nucleosynthesis suggests that quark compositeness energy scale must be higher than 500 GeV. (B. Datta, *S. Chakravarthy, *B. Sinha)

Solar Wind – Magnetosphere – Ionosphere coupling

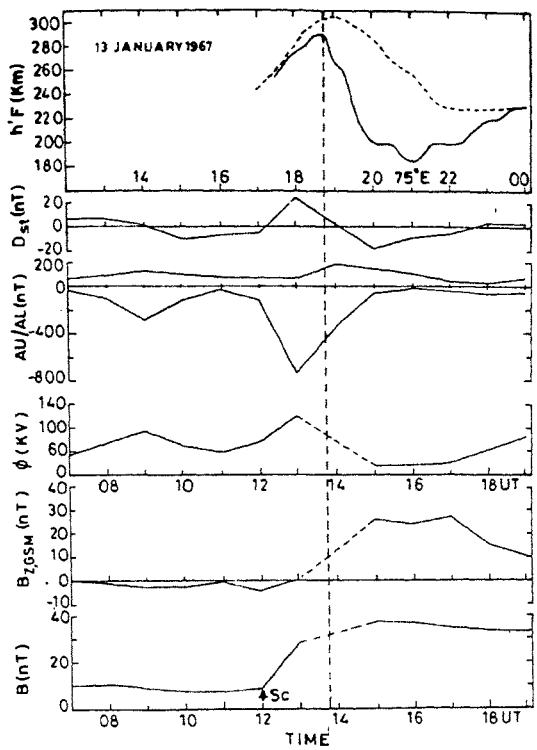


Fig. 6. Variation of IMF B, B_z, AU/AL indices, Dst index and polar cap potential drop (ϕ) on 13 January 1967 encompassing the initial phase of the SC geomagnetic storm induced by the passage of an interplanetary magnetic cloud. The top panel shows the variation of the height of bottomside F region (h'F) at Kodaikanal with the monthly median pattern (dashed line) superposed for reference. The anomalous and rapid decrease of h'F beginning at 1845 LT (1345 UT) concurrent with the northward swing of B_z and decrease in ϕ is the signature of a transient westward electric field disturbance near dip equator generated by the decrease in magnetospheric convection (decrease in ϕ) during the recovery phase of the auroral substorm.

Interplanetary magnetic clouds (bubbles) are structures in the solar wind wherein the magnetic field (B) is higher than the average ($\geq$ 10 nT) and undergoes a smooth change from a large southern (northern) direction to a large northern (southern) direction across the structure. The clouds typically last for about a day at Earth and are currently considered as interplanetary manifestations of solar coronal mass ejections (CME's). The characteristics of the Earth's magnetospheric – ionospheric environment can be expected to undergo perturbations at the time of passage of clouds, because the clouds possess a large southward IMF over a part of their $\sim$ 1 day duration at Earth which is highly conducive to the transfer of energy and momentum from the solar wind to the magnetosphere.

We found that the transit of a class 1 magnetic cloud (i.e.'negative cloud' with shock association) at Earth during 1967 January 13–15, did produce a transient disturbance in the equatorial ionospheric F region in the Indian sector. Analysis of Kodaikanal ionograms revealed the presence of a prominent, short-lived westward disturbance in the equatorial zonal electric field in the post-sunset period (18 45–20 30 LT) corresponding to the initial phase of the geomagnetic storm induced by the cloud's passage. The electric field disturbance which manifested as a perturbation in F region height occurred in excellent temporal association with a northward swing in IMF B_z and a decrease in polar cap potential drop (ϕ) estimated from IMF parameters. The maximum amplitude of the electric field disturbance is estimated to be ≈ 1.9 mV/m. The evidenced electric field perturbation finds a logical interpretation in terms of prompt penetration of convection-related high latitude electric fields to the geomagnetic equator as its polarity is consistent with the predictions of

global convection models. The duration and amplitude of the electric field disturbance do not, however, agree with the models. This discrepancy in the details of the observed and predicted characteristics of transient electric fields reaffirms the current view that though the basic mode of penetration of electric fields of magnetospheric origin into the sub-auroral ionosphere is well understood, comprehension of physical processes that control the magnitude and duration of the perturbations is only at a nascent stage.

Another unique feature of the response of equatorial ionosphere to the cloud passage is the remarkable increase in electron density (N_e) at and below the F-layer peak over Kodaikanal, that accompanied the post-sunset disturbance in the zonal electric field mentioned above. The response is considered unique because the fate of night time F layer near geomagnetic equator is governed by chemical loss and plasma transport and when the layer moves below 300 km (under the influence of the westward electric field disturbance), it has to decay as a rule bacause of enhanced chemical loss, while what is observed is exactly the opposite. For example, at 230 km where the changes in the electron density due to the electric field disturbance are seen for a major part of its manifestation, N_e increased by a factor of 30 between 19 15 and 20 30 LT. This type of rapid and prominent increases in N_e are quite uncommon. The increase in N_e has been explained as the outcome of ion convergence rate exceeding the chemical loss rate, when the layer as a whole experienced large downward drift because of the penetration of convection-related high-latitude electric fields into the equatorial ionosphere. (J. H. Sastri, H. N. Ranganath Rao, K. B. Ramesh)

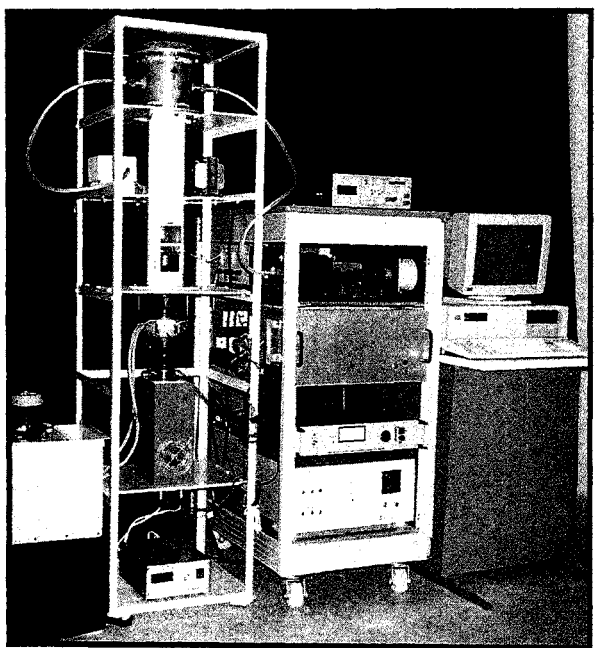
One of the rather intriguing observational results concerning the manifestation of auroral substorm-related transient electric field disturbances in the equatorial ionosphere is that they appear either with an increase in high latitude convection around the onset of substorm (due to southward turning of IMF B_z) or with a decrease in convection during the substorm recovery phase (due to northward turning of IMF B_z) but not both. This mutually exclusive nature of substorm-phase-related electric field disturbances near the dip equator is not consistent with the current theoretical models. In a case study based on the analysis of high time resolution ionograms of Kodaikanal in conjunction with high latitude magnetograms, we have obtained the first ever evidence for the occurrence of transient electric fields of composite polarity in the midnight-down sector near dip equator in association with isolated substorms. The polarity pattern of the composite electric field disturbance as evidenced in F region height is in good agreement with the currently available model results which predict westward electric fields at dip equator in response to an increase in the polar cap potential (or high latitude convection) and eastward fields with a decrease in the polar cap potential in the pre-dawn local time sector. In subsequent studies it was found that the occurrence of composite electric field disturbances is not very rare and that they occur at all local times and on a global scale i.e. both in the day and night hemispheres. The question as to why such composite electric field disturbances do not always manifest with storms is yet to be adequately answered. (J. H. Sastri, K. B. Ramesh, H. N. Ranganath Rao, D. Karunakaran)

Work is in progress to evaluate and interpret the large amplitude oscillations in the F region, (Doppler frequency shifts Δfs), that were observed at Kodaikanal 1991 March 24 concurrent with ground level geomagnetic pulsations in the Pc5 (150–600 sec) range.
(J. H. Sastri, K. B. Ramesh, D. R. K. Rao, *J. V. S. V. Rao)

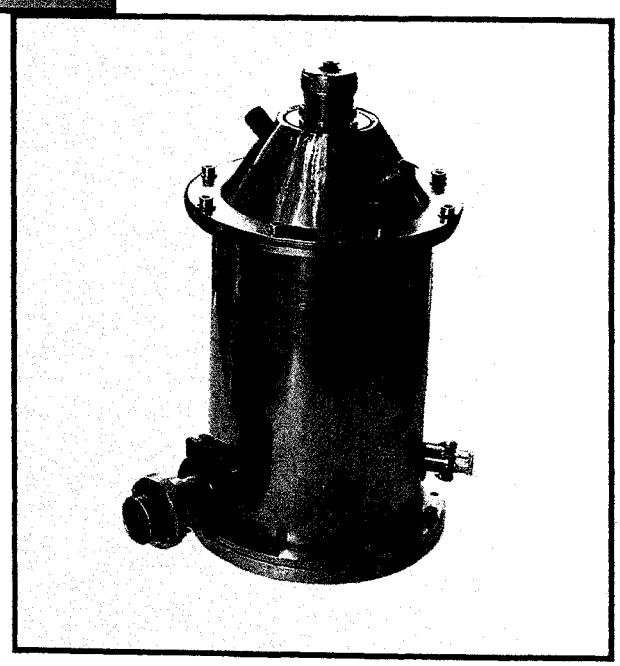
Dynamics of the ionospheric F-region

We have participated in the observational campaigns of 'Equatorial Ionosphere – Thermosphere System' (EITS) project of Solar–Terrestrial Energy Program (STEP) held in 1991 March–April and 1991 December – 1992 January. Analysis of the campaign data on night time vertical plasma drifts from the HF phase path (Doppler frequency) sounder at Kodaikanal is in progress.
(J. H.Sastri, K. B. Ramesh, J. V. S. V. Rao)

Reductions of line profiles of [OI] 630 nm night airglow emission obtained with Fabry–Perot Interferometer (FPI) at Kavalur are in progress to estimate thermospheric temperature (T_n). Our FPI data constitute the first systematic measurements of T_n close to the dip equator in India and will provide the much needed information on the latitudinal structure of thermospheric parameters.
(J. H. Sastri, H. N. Ranganath Rao)



Pressure-scanned Fabry-Perot interferometer at Kavalur.



CCD Dewar developed in collaboration with IISc, Cyrogenics Department.

Instrumentation

Solar Instrumentation

Seeing monitor at Kodaikanal

The limb monitor at the solar tower, Kavalur, had the problems of image wobble due to winds shaking the tower and also the lack of required precision in the coelostat and drive system. While efforts were on to improve these, the monitor was shifted to the solar tower telescope at Kodaikanal in 1992 January. After necessary improvements were made, the image motion and seeing measurements could be made during 1992 February/March. The image motion was calibrated and data obtained on a few days. The data are being studied and improvements are being planned for the measurement of image blurring, digitized data acquisition and automatic exposure control for optimal utilization of moments of good seeing. (S.P. Bagare)

Daytime sky condition at Kavalur

The data collection on daytime sky definition and cloud coverage at Kavalur is being continued. The final analysis will be taken up soon after 1992 May when three years of data collection would be complete. (S.P. Bagare)

Hardware/software aspects of the solar vector magnetograph

The vector magnetograph electronics comprises the following:

a) a polarimetric package, b) a CCD camera sensor, and c) an image data acquisition system.

The polarimetric package enables movement of a halfwave plate using an intelligent stepper motor controller sitting on PC/AT slot. The camera is a Peltier-cooled asynchronous CCD camera which can be used in : i) m.sec mode ii) 20 m.sec normal TV rate operation iii) asynchronous long integration mode where integrations up to 5 seconds can be achieved.

The camera uses a P 8603 scientific grade chip (with an organization of 385 $\times$ 576 pixels) and cooled to about -40 deg below the ambient temperature. The data acquisition system consists of a PC/AT with DT-2861 frame grabber/display. The frame grabber acquires integrated images from the CCD camera and stores into sixteen 512 $\times$ 512 $\times$ 8 bit images.

The software written in fortran and assembly language performs the following functions ; a) controls the stepper motor movements, b) operates the CCD camera in long integration mode, c) commands DT-2861 to grab images. The system has been installed at the solar tower tunnel telescope in Kodaikanal. This project has been funded by the Science and Engineering Research Council, DST.(A.V. Ananth, A.V. Kutty, N. Jayavel)

A new PC software for measurement and reduction of data from Kodaikanal images was developed. Extensive modifications were introduced in the original data reduction programme running on VAX 11/780 to make it suitable for handling the combined data from Kodaikanal and Mt Wilson while computing the solar rotation.
(K.R. Sivaraman, S.S. Gupta, A.V. Ananth, *R. Howard)

VBO telescopes

Digital display system for the 1 m telescope

The digital display system developed for the 1 m telescope has been released for regular use since 1991 November. The unit is housed in the control room and the PC at the observing floor. Differential line driver/receiver bins are wired for communications between the PC and the display unit. A change-over arrangement is made in the control room which enables one to select either the new digital display or the analogue dial display. The position co-ordinates RA, DEC, HA, the time ST, UT and other parameters like air mass and zenith distance are now displayed on the PC monitor.

Using this display system, the coordinates of about 75 stars in different regions of the sky were recorded for Cassegrain modelling. The collected data was fitted to a programme 'APCRD.EXE' which gives a pointing accuracy better than 10 arcsec. (R. Srinivasan, B. Nagaraja Naidu, A.V. Raveendran)

Faint object Cassegrain spectrograph

This spectrograph is planned for use at the Cassegrain focus of the 1 m telescope and is targeted at observations of faint, extended objects such as galaxies. The instrument could also be used at the VBT with some changes in the configuration and a reduced field. The design centres around concave, holographically ruled, aberration - corrected, flat field gratings to ensure a high throughput. A separate "blue" and "red" channel are planned at dispersions in the range 160 to 360 Å/mm. The dual channel facility also permits simultaneous shorter exposures covering similar wavelength ranges to avoid excessive cosmic ray events on the CCDs. At the 1 m telescope, the existing TH 7882 CCD could be used on one channel and a new CCD running off the same control computer is planned for the second channel. The gratings, mount, rotation stages and some components for the calibration system have been acquired. Some more components for the system have to be acquired and laboratory experiment is to be done before the optical system can be finalised. (A.K. Pati)

Modification to stepper motor controller for the 75 cm telescope

The original design of the stepper motor control and the co-ordinates display, was based on a single chip micro-controller. To improve the speed of response to the commands, a pulse generator card has been installed to generate all pre-determined frequencies, using IC 555 Timers, for different speeds of motion.

Another approach based on Intel 8085 processor has also been developed. This stand-alone card generates all the required frequencies which can be programmed in 'Speed mode'. A new feature has been added in the form of 'Index mode'. In the 'Index mode' the number of steps through which the motor needs to move and the direction of rotation, can be set with the thumb wheel switches. A single card controls the motion in both HA and DEC axes. (R. Srinivasan, B. Nagaraja Naidu, G. Srinivasulu)

Digital controller for MG set

A new digital controller has been designed and fabricated for the Motor Generator set at Kavalur. This replaces the original analogue control system which was not working satisfactorily. A shaft encoder giving 120 pulses/rev (3000 Hertz) is introduced in place of the tacho generator of the original system. A phase-lock loop compares the pulses from

the shaft encoder with a reference oscillator of 3000 Hz. The error signal from an up/down counter is fed to a 12 bit digital-to-analogue converter. The DAC output is used to control the triggering signal of a three-phase full-wave bridge SCR power circuit which drives the motor at the required speed.
(R. Srinivasan, S. Muraleedharan Nair, A. S. Babu)

CCD controller for fast photometry

A CCD controller has been developed for fast photometry applications. The unit comprises of the following cards :

i) PROM and address generation card. ii) Level shifter and thermal and shutter control card. iii) Bias and power supply card. iv) DCS module and a/d converter card.

A full frame read-out takes about 8 seconds. In the window acquisition mode, the programme star can be positioned in a 10 × 10 pixel window for continuous read out of its flux with a time resolution of 50 microseconds. The system has been assembled and initial trials are to commence in 1992 July.
(R. Srinivasan, S. Murali Shankar)

Novell net installation

A local area network has been installed, connecting the personal computers (PC/AT) at 2.3 m, 1 m and .75 m telescopes through an arcnet for high speed data transfers. The data gathered from a PC based instrument at any of these telescopes can be transferred to the PC/AT at 2.3 m and stored on a 9 track magnetic tape.

The local area network system operates at a rate of 2 M bits/second under Novell net version 2.01. Presently about 100 PC systems can be connected. It is possible to link other computers like VAX, SUN workstation, etc. to the network using gateways and suitable interfaces.(A. V. Ananth)

Optics

Wavefront sensing and evaluation for active optics experimentation

The theoretical basis for the two crossed Babinet compensator polarization interferometer for wideband wavelength has been completed. The phase shifting interferometric technique has been applied to this interferometer for accurate measurement of the phase. The wavefront errors are evaluated from these phase values. The data acquisition and reduction procedures are being worked out. A 27 inch spherical mirror is being fabricated to set up an active optics experiment. (A. K. Saxena, J. P. Lancelot, J. P. A. Samson)

Solid rotational shearing interferometer

In continuance of the earlier development we had a few runs of our observing schedule at VBT using RSI after overcoming the initial difficulties of mounting it and its alignment with the telescope. Successful observation was done on a few stars of interest. The first white light RSI fringe record at the Cassegrain focus of the VBT was obtained on 1991 May 1. The data for many other stars have also been collected with the improved performance of the interferometer. Due to limitations of the total light flux, detector efficiency and due to dome seeing effects interferometric records with narrow passband and fringes covering full pupil could not be obtained so far. Further steps are being planned taking into consideration these aspects. Records in similar situation in the laboratory have been obtained with an artificial point source. Results of these experiments show resolvable structure clearly. Suit-

able modifications in the software are being worked out for the reduction of RSI data obtained from stellar sources. (A. K. Saxena, *N. Uday Shankar, *N. Jayadev, *N. Selvamani, J. P. A. Samson).

VHRR passive cooler for INSAT-II (ISRO)

Specular polishing of a set of panels for the passive cooler for the Very High Resolution Radiometer for the INSAT-II A satellite was successfully completed. Panels integrated with the cooler under the ground test gave acceptable performance. The satellite is scheduled for launch during 1992 June. The fabrication of the second set of panels for INSAT-II B is under progress.
(A. K. Saxena, J. P. A. Samson, M. G. Mohan, S. Razack)

Vacuum coating plant and aluminizing

The secondary mirror and coudé mirrors of the 1 m telescope were aluminized at the 60 cm coating plant.

The 30 cm plant at Bangalore was used to aluminize various small optics from time to time. (K. Raman Kutty & aluminizing team)

Miscellaneous

Small optics fabricated during this period comprise the following:

1. Mirrors (8 inch size) for eclipse – 5 nos
2. Field lenses –2 nos
3. Lithium neobate crystals – 6 nos
4. Spherical balls of optical quality ($\lambda/4$ RMS) –2 nos

EUV spectroheliometer telescope optics

An 18 inch telescope optics for the EUV spectroheliometer to be placed on the NASA Black Brant sounding rocket is in its final stage of fabrication.
(A. K. Saxena & Optics team).

LIDAR telescope optics

To fulfil a requirement of Space Physical Laboratory, Vikram Sarabai Space Centre, Trivandrum a 500 mm Cassegrain telescope optics has been designed and is under fabrication. A memorandum of understanding between IIA and Space Physical Laboratory of VSSC was signed in 1992 January. The complete optics will be made ready before the end of this year.
(A. K. Saxena, J. P. Lancelot & Optics team).

Radioastronomy

Radioheliograph

The construction of a metre-decametre radioheliograph at Gauribidanur is progressing satisfactorily. Data obtained on various radio sources at four frequencies (55 MHz, 75 MHz, 120 MHz and 150 MHz) are analysed to study the phase and gain stabilities of the system. It is proposed to divide the EW array into 32 groups and the South array into 16 groups. Each one of the EW groups will be correlated with each one of the South group using a 1024 channel digital correlator. The design of the correlator is complete and a prototype system to correlate 8 EW outputs with 8 South outputs is being constructed to test the system.
(K. R. Subramanian, M. S. Sundara Rajan, Ch. V. Sastry)

India–Mauritius Radio Telescope

The construction of the aperture synthesis radio telescope operating at 150 MHz for Galactic Centre studies on the island of Mauritius is progressing satisfactorily. The entire EW arm consisting of 1024 helical antennas placed at intervals of 2 meters and the rail track in the south direction is completed. Tests are being conducted for determining the beam shapes and other characteristics of the various subgroups of the EW array. A 1024 channel digital correlator is also being installed. The project is a collaboration between Raman Research Institute, University of Mauritius and Indian Institute of Astrophysics.
(Ch. V. Sastry)

Auxiliary Instrumentation

Extreme ultraviolet spectrometer

The design of the telescope structure was completed. After a fresh finite element analysis, the design will be released for fabrication at the Bangalore-based HAL Aerospace Works. Fabrication of the optics is making steady progress.
(S. K. Jain, A. K. Saxena, J. C. Bhattacharyya)

Gain calibration of CCD systems

The system gains of the Photometrics CCD system at the 1 m telescope and the Astromed/IIA CCD system at the 2.3 m telescope were calibrated at different settings. For the Photometrics system where the gain is software-selectable through the parameter cgain (values between 0 and 4095), an empirical fit to the calibration between cgain = 0 and 500 is
$G = 0.0358 + 0.001111\text{cgain} + 2.2 \times 10^{-7}\text{cgain}^2$
in count per electron. The time taken for the transfer of full frame is
4.96 + 0.08901cgain seconds.

For the Astromed system we obtain G = 0.241 count per electron at the switch setting 9.2. Methods have been developed under RESPECT software package to derive the base-level noise and system gain easily using a few spectroscopic flats. (T. P. Prabhu, Y. D. Mayya, G. C. Anupama)

Photometric calibration of CCD camera

The CCD camera at the 1 m reflector with the Photometrics CCD system and Thomson CSF Th7882 chip was calibrated for BVR and Hα photometry. System efficiencies have been derived to be 2, 8, 10 and 10% in the four bands respectively. The first-order extinction coefficients on 8 nights of observations yield mean values of 0.41, 0.22 and 0.13 in B, V and R bands, respectively. Typical dark sky magnitudes were 21.4, 20.6 and 19.6 arcsec^{-2} in these bands. (Y. D. Mayya)

Speckle interferometer

The fabrication of the newly designed speckle camera system is in progress. This camera would be usable both at the primary and the Cassegrain foci of the 2.3 m Vainu Bappu Telescope at VBO, Kavalur. Significant progress has been achieved in making a focal plane optical flat of a low expansion glass with a precision-made hole of aperture 356 μm on its surface. This aperture is equivalent to a field of $\sim$ 9 arcsec at the prime focus and to a field of $\sim$ 2.25 arcsec at the Cassegrain focus of VBT. The rear side of the flat is shaped suitably to enable the microscope objective to be brought very close to the focal plane (to a distance of nearly the focal length of the microscope objective). The field covered by this aperture of the flat at prime focus of VBT would allow us to observe both the object and the reference star simultaneously, if the latter is located in the isoplanatic domain around the object. The image of the object will be allowed to pass on to the microscope

objective through this hole, which would slow down the image to $\sim f/120$ at prime focus and to $\sim f/480$ at Cassegrain focus of the same telescope. A collaborative programme to use the Image Photon Detector (IPD) of PRL, Ahmedabad, to record the specklegrams has been made. The surrounding star field of $\sim$ 10 arcmin at the prime focus and of $\sim$ 2.5 arcmin at the Cassegrain focus will be reimaged on an intensified CCD for monitoring. (S.K. Saha, A.P. Jayarajan)

Reconstruction of degraded images

The scheme of iterative blind deconvolution technique of the two convolved function is being implemented using a modified version of an earlier programme developed by P. Nisenson of the Centre for Astrophysics, Harvard, USA. The necessary software development is under way to run this programme at the SUN 4/280 workstation installed at IIA, Bangalore. It is to be noted that we have retrieved the phase of the two convolved functions by using the old version of the iterative deconvolution technique at VAX 11/780, Kavalur. A computer-simulated convolved image was used as an input. The residual noise level in the deconvolved image is less than 5 % after 100 iterations. (S.K. Saha, K. Narayan Kutty)

Liquid surface ripple based vibration analyzer

A vibrating system, when coupled to a liquid, generates ripple oscillations on the surface of the liquid. A narrow laser beam, reflected from this surface follows the gradient of this surface at the point of incidence. The fluctuation in the direction of incidence is converted into intensity fluctuations by passing the beam through an optical wedge and these intensity fluctuations are detected as fluctuations in the voltage output from a circuit. Analysis of these voltage fluctuations enables one to obtain the vibration spectrum of the mechanical system under study. In the accompanying figure we display a typical vibration spectrum, as obtained in the Electronics Laboratory of IIA. We are now in the process of developing a vibration isolation system as a part of the work to calibrate our sensor.
(S. Chatterjee, K.C. Thulasidharan, Nagaraj Naidu, R. Srinivasan).

Fabry–Perot interferometer

The pressure-scanned Fabry-Perot Interferometer (FPI) for high resolution spectroscopy of [OI] 630 nm night airglow emission was brought into operational mode 1991 December. Systematic observations were made for a fortnight centred on the new moon every month for studies on the equatorial thermosphere. This project was funded by ISRO/DOS under the RESPOND programme.
(H.N. Ranganath Rao, J.H. Sastri)

HF Doppler sounder

The HF phase path (Doppler) sounder augmented with a second probing frequency at 4.0 MHz has been effectively used to develop an extensive and good quality database on F-region vertical plasma drifts for the night time period.
(*J.V.S.V. Rao, K.B. Ramesh, J.H. Sastri)

Perkin-Elmer Digitizing System

The digitizing work covered 700 plates and 500 film rolls from the Solar Group of the Institute as well as from external agencies like PRL and HPF. The maintenance work during this period involved i) tension spring replacement for filter wheel assembly, ii) instrument bearing change for the X-carriage, iii) solution to stage

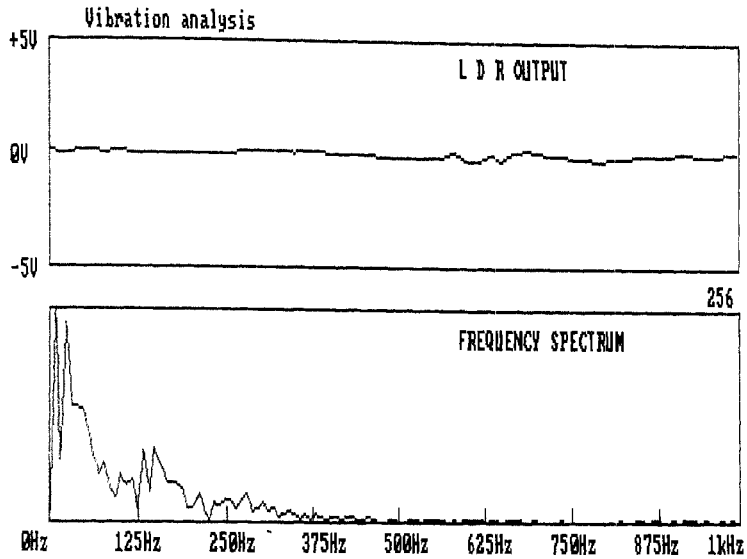


Fig.7

overtravel in X and Y directions by replacing DCRS module, iv) replacement of encoder illumination assembly which solved the residual stage offset.
(Ramaswamy, K.S. Ramamoorthy, S. Murali Shankar, A. P. Monappa, N. Jayavel, R. Srinivasan).

Computers

The latest addition to the Computer Centre of Bangalore campus is a Symphony 860 computer which is based on Intel 860, 64 bit RISC processor chip. This chip gives raw computing power to support applications such as modelling and simulation. On-chip instruction and data cache gives an aggregate data rate of 960 MB/sec which provides the necessary support for parallel vectorisation. This chip uses supercomputer architecture and has 3-D graphics unit built into it.

The computer which has been installed is made by Godrej & Boyce Company and its functions are laid out in a multi-layered single board. Therefore the system is highly reliable and sleek. It requires less than 200 watts of power and occupies only 0.5 ft x 1.5 ft floor space and works in room airconditioning environments. The computing speed is nearly 6.5 MFLOPS in double precision linpack which means that it is nearly 40 times faster than Vax 11/780. The configuration has 16 MB main memory, and contains 425 MB disc drive, 1.44 MB 3.5 inch floppy drive, 150 MB digital cassette drive and a VT 200 type console. This is a UNIX based machine and has Greenhills Fortran compiler. Vectoriser from Pacific Sierra is also available which makes most of the scientific programmes written in Fortran to be executed faster.

Symphony 860 has a unique power fail restart facility. This facility allows the programmes which are being executed to be stopped at any time (sometimes due to power failure) and they can be restarted without losing any CPU time. This useful facility will enable us to save several hundreds of computing hours.

We have networked the system through ether-

net with SUN 4/280, 80486 computer and E-mail 80386 systems. Therefore one can access this machine and its capabilities from any one of these systems by remote logging-in. One can print on any one of the printers available in the network. Networking this system to the Mighty Frame computer has been taken up and very soon the users may be able to access Symphony 860 from any one of the terminals of Mighty Frame. (B. A. Verghese, K. E. Rangarajan, D. Mohan Rao)

A Sun 4/280 server system with a discless SUN 3/50 client was acquired and installed at the Computer Centre at Bangalore. The server has 32 megabytes of main memory, 892 megabytes of disc storage, a 1600/6250 bpi half-inch tape drive and colour monitor with accelerated graphics interface attachment to it. The network configuration includes a Hewlett-Packard Laserjet III printer, a 132-column dot matrix printer, a Graphtec plotter and a 150 megabyte cartridge tape drive. The systems are connected on ethernet to the existing computers in the Computer Centre and are primarily meant for running data reduction/image processing software such as IRAF. (A. K. Pati, K. E. Rangarajan)

Working Group on National Large Optical Telescope

A. K. Pati and **A. K. Saxena** have been serving as members of the WG on National Large Optical Telescope (NLOT). **A. K. Saxena has** been working as the optics expert in the WG for both NLOT and NSVT projects. The NLOT Working Group has prepared a preliminary report giving conceptual design, preliminary assessment of the requirement of focal plane instrumentation etc. Further details are being worked out. Saxena has recently worked out the basic concept of the NSVT optical sytem also. The system requirement details will be finalized after clearcut inputs are available from the other members.

The main area of invovement of **A. K. Pati** was the evolution of a preliminary site selection methodology for the telescope, suitable for optical and infrared observations. As a first step, compilations of existing meteorological data were examined to identify the best "known" locations where detailed site survey activity can be taken up. The region around Dalhousie looks the most promising, with 180 to 200 fully clear mornings and evenings in a year. To a first approximation it was found that the estimates of clear days/nights from meteorological data seem to correlate fairly well with known observatory sites. Devasthal near Nainital also appears to be a promising site as per studies conducted by Uttar Pradesh State Observatory.

To determine whether better sites exist in more remote locations for which meteorological data are not available, the following strategy was adopted : topographical maps of the Himalayan regions were examined to shortlist locations which are promising, purely from topographical and general meteorological considerations. The next step is to explore the possibility of using satellite multi-band imagery to analyse the incidence of cloud cover (especially thin clouds not obvious on visual band images) over these locations. Sample INSAT 1B images in the visual and IR bands were obtained from the Indian Meteorological Department and software developed to read and display these images on the VAX system at VBO. A correlation, if any, needs to be established between the satellite image data and detailed cloud cover observations at existing observatories. To this end attempts are being made to acquire satellite images covering a period of one or two years. A site thus determined to be "good" would merit detailed site measurements on location.

National Facilities

Vainu Bappu Telescope

Servo-performance of VBT

Two preamplifiers for the power stage output failed and were replaced during February 1992. The DEC motor M2 developed a low resistance (14 Ohm) between motor winding to chassis. The motor was replaced with a new one. The 20-bit Baldwin Absolute Encoder at RA axis failed. The two lamps, one comparator and a clock generator were identified to be defective. A 17 bit Teledyne Gurley Encoder was spared by GMRT on loan basis to us and has been put into operation on the DEC axis. (R. Srinivasan, B. Nagaraja Naidu, K. Ravi, G. Srinivasulu)

Cassegrain acquisition and guiding unit for the VBT

This instrument is to be an accesory of the telescope and is meant to facilitate remote viewing of the Cassegrain field as well as remote offset guiding on stars as faint as m_v = 16 using cooled CCD cameras. The offset accuracy planned will permit a blind offset from reference stars to the programme object. Some of the precision translation stages, controllers and component mounts have been acquired. The optical system to be used in the guiding and viewing, which should preferably accomodate a range of Cassegrain focal plane positions, is in the design stage. The unit will also have a facility for accomodating filters, knife edge and cross wires. The design of the mechanical structure will be finalized once the internal components are all determined. (A.K. Pati)

Development work on CCD

The software for CCD data acquisition system has been substantially modified. User commands drive the CCD camera operation in lieu of the menu driven software and incorporates the following functions:

(1) System checkout (Controller, Shutter, Echo-test); (2) Data acquisition (Flat, Bias, Dark and Object); (3) Sample data analysis (Statistics, Row-cut, Column-cut, etc.); (4) Windowing features for focus adjustment (32 × 32 window, acquisition); (5) Instrument control for prime camera operation, guide scan, guide focus.

The programmes have been developed in MS Fortran and Assembly in PC/AT. They also utilize Fortran callable libraries for the image display using DT-2851 frame grabber card. (A.V. Ananth)

A new Double correlated sampling (DCS) board for Astromed CCD controller has been developed and tested. This card replaces the original board and gives a better S/N performance. (G. Srinivasulu, R. Srinivasan)

Under high humidity (>60 % RH) the Astromed CCD camera develops misting, spreading from the centre of the window towards the periphery. The camera controller also showed drop in various bias and clock levels affecting the image quality. A dry air plant has been procured from M/S Bry-Air to flush the window and the controller when the relative humidity exceeds 60 %. With this arrangement the working of the CCD camera system has been satisfactory up to 80 % RH. (R. Srinivasan, G. Srinivasulu, K. Ravi, F. Gabriel, N. Jayavel)

Utilization of the National Facility

Severe technical problems hampered observations with the VBT during significant parts of December 1991 and January 1992. Excluding these spells, a total of 161 nights were allotted to observational programmes between 1991 April – June and 1992 January – March. A total of 15 proposals were allotted time during 1991 and 18 during 1992. No proposal was rejected during 1991 whereas two were rejected during 1992. The telescope was used in the Cassegrain mode for 117 nights, the instruments used being the Boller & Chivens Spectrograph, IIA/RRI Rotational Shear Interferometer, ISRO two-star photometer, PRL polarimeter and PRL Imaging Fabry-Perot Interferometer. The telescope operated in the Prime Focus mode with the CCD camera for 44 nights.

Growth of Astronomy

Historical studies

In an attempt to trace the history of observational astronomy in India, some studies regarding archeo-astronomy were attempted.

It is suggested that the Buddhist Stupas of Sanchi including the Great Stupa built by Sunga kings around 2nd century BC are oriented towards the moonrise and sunset on the day of the Buddha Purnima. The arrangement of the inner and outer balustrades of both Stupa 1 and Stupa 2 might have been used as a luni-solar astronomical calendar. It is suggested that Sanchi Stupas is one of the oldest astronomical monuments presently known in India.

Astronomical orientation of sunrise , moon rise (full) at the time of solar and lunar solstice and equinoxes can be traced between the megalithic stone circles of Brahmagiri which have been dated to 900 BC. Such alignments might indicate the existence of a fair amount of astronomical knowledge among megalithic people. Further studies in this regard are desirable.

Investigations regarding the astronomical basis for the orientation of some ancient temples are also in progress. (N.K.Rao)

Awards

V. Krishan was awarded the Hari Om Ashram Prerit Vikram Sarabhai Research Award for the year 1991 in the field of Space Sciences.

S. S. Hasan was appointed an Associate of the Harvard College Observatory for one year from August 1991.

The paper titled *Torsion, Minimal Time, String Tension and its Physical Implications* by **C. Sivaram** received 'Honourable mention' at the 1991 competition of the Gravity Research Foundation, USA.

G. C. Anupama was awarded the Ph.D. degree by Bangalore University for her thesis *Studies of Classical and Recurrent Novae.* **M. F. Ingalgi** was declared qualified for the Ph.D. degree of Karnataka University Dharwad for his thesis *Dust in the Outer Layers of Stars.* R. Kariyappa submitted his thesis *Study of Inhomogeneities in the Solar Atmosphere* to the Bangalore University for the Ph.D. degree.

Science and Technology Exhibition during the Indian Science Congress at Vadodara

An exhibition sponsored by the DST, New Delhi, was organized during 1992 January 3–8 at Vadodara to concur with the Annual Meeting of the Indian Science Congress. The exhibits contained pictures of the Institutes's laboratories, a model of the Vainu Bappu Telescope as well as accounts of some recent achievements of the Institute in astronomy. These were greatly appreciated by the general public, students and scientists. (R.C. Kapoor)

National Science Day

An Open House was organized at the Institute on 1992 February 29 as part of the National Science Day programs. About 500 students of higher classes from the neighbouring schools visited the Institute during the day along with their teachers. (G.S.D. Babu, S.P. Bagare)

The Institute participated in the celebration of the National Science Day at Vidhana Soudha, Bangalore 1992 March 1–3 in collaboration with the Department of Science and Technology and Energy of the Government of Karnataka. Pictures of the Institute laboratories, some key astronomical discoveries and a model of the Vainu Bappu Telescope were displayed in the exhibition organized for the occasion. An arrangement was made for the public to see the sunspots in a 10cm image of the Sun produced on a screen using a 7.5 cm telescope. (R. C. Kapoor, S. P. Bagare)

VBO

August 10, 1991 was celebrated at Vainu Bappu Observatory, Kavalur to coincide with the 64th birthday of the late Professor M.K. Vainu Bappu. One hundred and fifty students from various colleges visited the Observatory and attended the celebrations. Professor Ch. V. Sastry gave a talk on General Astronomy.

The Vainu Bappu Observatory welcomed school, college and university students throughout the year and the night sky was shown through the visitor's telescope. Besides the Observatory remained open to the public during the day on Saturdays.

Meetings at IIA

The Institute hosted the following meetings during the year :

A Winter School on Stars and Stellar Systems was held at VBO, 1991 December 23–31 to generate interest in astronomy and astrophysics amongst students and teachers from colleges.

The Institute hosted the 13th meeting of the expert panel for Thermal and Optical Measurements of the National Coordination of Testing and Calibration Facilities 1991 January 10. The third group monitoring workshop of All India Coordinated Program for Ionospheric and Thermospheric Studies (AICPITS) was hosted by IIA 1992 February 26–28. J. H. Sastri was the Local coordinator. The IUCAA-IIA workshop on Plasma Astrophysics was hosted by IIA 1992 March 2–6. V. Krishan was the Chairperson.

Bicentennial Commemorative Public Lecture

The IIA bicentennial commemorative lecture was instituted in 1987. The **sixth** lecture in the series was delivered on 1992 January 24 by the distinguished neurosurgeon **Professor P.N. Tandon** of All India Institute of Medical Sciences, New Delhi and currently the President of the Indian National Science Academy. The theme of Professor Tandon's talk was *Brain and its Surgery.*

Professor P.N. Tandon delivering the sixth Bicentennial Commemorative Lecture.

Participants at the third group monitoring workshop of AICPITS.

Colloquia by visiting scientists

Accretion discs around compact stars
P. Bhaskaran, PRL, Ahmedabad, 1991 April 26

Plasma instabilities in the ionosphere
S. P. Gupta, PRL, Ahmedabad, 1991 May 8

Relativistic Rheology
L. Radhakrishnan, Shivaji University, Kolhapur, 1991 May 24

An empirical model of pulsar radiation mechanism
Joanna Rankin, University of Vermont, USA, 1991 June 4

Asteroseismology of DOV white dwarf PG 1159 – 035
S. Seetha, ISRO, Bangalore, 1991 June 25

Trends in workstation hardware and software
Patricia Monger, McMaster University, Canada, 1991 July 12

Hydromagnetic disc winds in young stellar objects and active galactic nuclei
R. E. Pudritz, McMaster University, Canada, 1991 July 15

Optical interferometry
M. Vivekanand, RRI, Bangalore, 1991 July 16

Properties of broad line profiles in active galactic nuclei
J. W. Sulentic, University of Alabama, USA, 1991 July 18

The amazing story of compact group of galaxies
J. W. Sulentic, University of Alabama, USA, 1991 July 19

Design and fabrication of the liquid-nitrogen-cooled cryostat
S. Jacob, IISc, Bangalore, 1991 July 30

The radio emissions from the magnetized planets
Yolande Leblanc, Observatoire de Paris, Meudon, France, 1991 August 6

High latitude Galactic cirrus clouds
P. Guhathakurta, Institute for Advanced Study, Princeton, USA 1991 August 20

Statistical analysis of star catalogues
K. U. Ratnatunga, Institute for Fundamental Studies, Kandy, Sri Lanka, 1991 September 2

Is there CN-cycled material in the atmospheres of early B-type stars ?
D. L. Lambert, University of Texas, USA, 1991 September 24

Boron in the early Galaxy — galactic or primordial?
D. L. Lambert, University of Texas, USA, 1991 September 27

Origins of p-process nuclei
D. L. Lambert, University of Texas, USA 1991 October 1

Models of voids in the expanding universe
Alberto Chamorro, University of Basque State, Spain, 1991 November 19

Facilities and research programs at the 6 m telescope of the Special Astrophysical Observatory, USSR.
I. Romanyuk, Special Astrophysical Observatory, USSR 1991 November 26

Deterministic chaos in time series
R. Pratap, Cochin University, 1991 December 12

LAGEOS : A satellite experiment to measure the Lense-Thirring effect
Salman Habib, Los Alamos National Laboratory, USA, 1992 January 8

Photon multiplicity detector
Y. P. Viyogi, Variable Energy Cyclotron Centre, Calcutta, 1992 January 22

Are coronal shocks piston-driven?
N. Gopalswamy, University of Maryland, USA, 1992 January 29

Variability in blazars
U. C. Joshi, PRL, Ahmedabad, 1992 February 10

A simple 3-D line-transfer in accretion disc modelling
Johannes Adam, CAM Computers Anwendung für Management Gmbtt, Heidelberg, Germany, 1992 February 28

From laser plasmas to astrophysical plasmas
H. C. Pant, BARC, Bombay, 1992 March 6

Dynamics of small galaxy groups and dark matter
Ludmila Kiseleva, Russian State Pedagogical Univ., St. Petersburg, 1992 March 10

Dynamical evolution of triple stars and galaxy systems
Joanna Anosova, St. Petersburg State University, 1992 March 11

Fabry-Perot spectroscopy in Astronomy
Ranjan Gupta, IUCAA, Pune, 1992 March 12

Publication pattern of physicists and astronomers in India
A. Ratnakar, RRI, Bangalore, 1992 March 17

Library

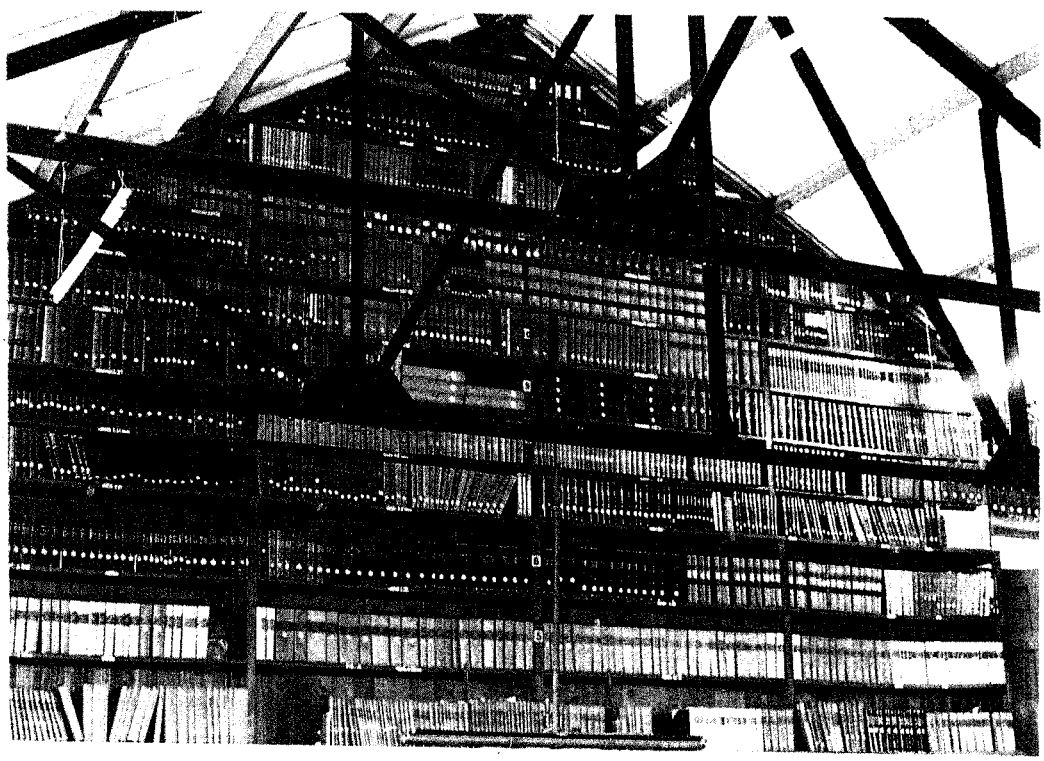
During the year the library added 200 books to its stock, bringing its total collection to 11247. The library subscribed to 142 journals and continued receiving 65 observatory publications. The inter-library exchange with other astronomical libraries in the city helped it to display an additional 20 journals. Scientific and technical information was disseminated through the IIA preprint list, and Recent Research in Astronomy and Astrophysics.

Library published a brochure highlighting the library activities. A database of books using CDS/ISIS software package is in progress and the entire database will be accessible online shortly.

The library used SIMBAD database extensively and thirty searches were made during the year for both scientists at IIA and on request from other astronomical institutes.

The librarian Ms A. Vagiswari participated in the Third International Conference on Informetrics in Bangalore 1991 August 9–12.

Ms. C. Louis attended a two-week Bibliometrics course conducted by INSDOC, New Delhi 1991 September 30–October 12.



Personnel

The academic and technical staff during the period 1991 April – 1992 March include the following :

Professor: M.H. Gokhale, N. Kameswara Rao, R.K. Kochhar, V. Krishan, A. Peraiah, J.H. Sastri, Ch.V. Sastry (Acting Director August1–March 31), G.A. Shah, K.R. Sivaraman (Acting Director till July 31)

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

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

Fellow : S. Chatterjee, S. Giridhar, D. Mohan Rao, K.N. Nagendra, K.E. Rangarajan, S.K. Saha, K.R. Subramanian, R. Surendiranath, G. Thejappa, R. Vasundhara

Research Associate : P.M.S. Aleem, S.S. Chandramouli, J. Javaraiah, R. Kariyappa, D. Karunakaran, S.V. Mallik, M.V. Mekkaden, B.S. Nagabhushana, R.S. Narayanan, K. Sasidharan, K. Sundara Raman, B.A. Varghese, L. Yeshwant

Senior Principal Scientific Officer : R. Srinivasan

Head, Optics Division : A.K. Saxena

Consultant, Optics Division : A.P. Jayarajan

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

Scientific Officer 'SD' : M.S. Sundara Rajan

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

Senior Computer Enginer : V. Chinnappan

Senior Civil Engineer : N. Selvavinayagam

Engineer (Elec.&Comp. Sci.) : G. Srinivasulu

Librarian : A. Vagiswari

Asst. Librarian : C. Louis

Mr A.P.Jayarajan (left) being presented a souvenir as he says goodbye to the Institute after an association lasting more than thirty years.

Professor G.A. Shah at a farewell party on his retirement.

Technical Officer : R. Muraleedharan Nair, K. Ramankutty, R. Sivashanmugam, K.G. Unnikrishnan Nair

Technical Associate : M.Md. Abbas, A.M. Ghouse, A.T.A. Hameed, H.N. Manjunath, S. Muthukrishnan, K.S. Ramamoorthy, J.P.A. Samson, K. Padmanabhan

Engineer Associate : Faseehana Saleem, K. Narayankutty

Emeritus Scientist : J.C. Bhattacharyya (CSIR), K.V.K. Iyengar (CSIR), K.R. Sivaraman (since August 1)

Visiting Scientist : P. Bhaskaran, A. Goswami (CSIR, SRF), R.R. Rausaria, A. Satya Narayanan

Graduate Students : S. Annapurni, G.C. Anupama, D. Banerjee, M. Dikpati, B. Eswar Reddy, R.T. Gangadhara, Y.D. Mayya, G. Pandey, R.D. Prabhu, R. Ramesh, H.N. Ranganath Rao, S.K. Sengupta, A.V. Thampan, G. Uma

Visiting Teachers(external candidates for Ph.D. Degree): C. Chowdappa, N.D.N. Prasad, T.D. Sreedharan, N. Sundara Rajan

G. A. Shah and **K. R. Sivaraman** retired as Professors 1991 July 31. **K. V. K. Iyengar** formerly of TIFR, Bombay joined IIA as a CSIR Emeritus Scientist. **J. C. Bhattacharyya** assumed the Emeritus Professorship of the Institute 1992 March 1. **G. C. Annupama** left IIA in 1991 October for IUCAA, Pune where she was appointed a post doctoral fellow. **Aruna Goswami** left IIA in 1992 August for IIT Kanpur. **P. Bhaskaran** joined as a Visiting Scientist in 1991 November. **M. S. Sundara Rajan** joined as Scientific Officer 'SD' in 1991 December. **A. P. Jayarajan's** term as a consultant ended in 1992 February 29 thus bringing to a close his long association with IIA and the erstwhile Kodaikanal Observatory spanning a period of well over three decades.

Involvement in the Scientific Community

J. C. Bhattacharyya has been elected President of IAU Comm. 9 on Instrumentation and Techniques. He has been nominated Chairman, SCOSTEP, INSA, New Delhi for a three-year term beginning 1991 July. **B. Datta** has been serving as a member of the National Programme Committee, International conf.on Non-accelerator Particle Physics scheduled 1993 January 3–9, TIFR, Bombay. Datta is also a member of the Scientific Organizing Committee, Second International Conference on Physics and Astrophysics of quark-gluon plasma scheduled 1993 January 19–23, Calcutta. S.S. Hasan was made Lecturer of Astronomy at Harvard 1992 February. **R. K. Kochhar** has been appointed a member of the Standing Advisory Committee of the Positional Astronomy Centre, Calcutta. He inaugurated the newly established school observatory at Sri Ramakrishna Vidyashala, Mysore 1992 January 11. **V. Krishan** has been elected Secretary, Plasma Science Society of India for the term beginning 1992. **D. C. V. Mallik** served as a member of the Scientific Organizing Committee of IAU Symp.155 : Planetary Nebulae

scheduled 1992 July 13–17, Innsbruck, Austria. **A. Peraiah** has been elected Vice-president of the Astronomical Society of India for the term beginning 1992. **N. K. Rao** has been made a member, Scientific Advisory Committee, IUCAA, Pune for the period 1992 January–1994 December. N. K. Rao is also a member of the Scientific Organizing Committee of VI Asian Pacific Regional IAU Meeting scheduled 1993 August 16–20, Pune, India. **J. H. Sastri** has been nominated Member-secretary, Indian National Committee for Solar-Terrestrial Physics (INSCOSTEP) of INSA, New Delhi for a three-year term beginning 1991 July.

Visitors

Paul J. Wiita, Georgia State University, Atlanta, USA
1991 July 6–July 12

Ralph Pudritz, McMaster University, Hamilton, Canada
1991 July 10–July 15

Patricia Monger, McMaster University, Hamilton, Canada
1991 July 10–July 15

K. M. Ghosh, University of Calcutta
1991 July 18–August 4

J. W. Sulentic, University of Alabama, Tuscaloosa, USA
1991 July 17–July 21

P. Bhaskaran, Physical Research Laboratory, Ahmedabad
1991 August 6–September 5

R. Pratap, Cochin University
1991 September 16–December 16

K. Ratnatunga, Institute for Fundamental Studies, Kandy, Sri Lanka
1991 August 27–September 11

David L. Lambert, University of Texas, Austin, USA
1991 September 6–October 2

W. Kalkofen, Harvard Smithsonian Center for Astrophysics, Cambridge, USA
1991 September 15–September 21

J. Gethyn Timothy, Stanford University, California, USA
1991 September 30–October 1

Thomas E. Berger, Stanford University, California, USA
1991 September 30–October 1

Martin C.E. Huber, ESTEC, The Netherlands
1991 September 30–October 1

T. Gehrels, University of Arizona, Tucson, Arizona, USA
1991 October 23–October 27

I. I. Romanyuk, Special Astrophysical Observatory, Russia
1991 November 18–November 27

R. Howard, National Solar Observatory, Tucson, Arizona, USA
1991 December 6–December 18

N. Gopal Swamy, University of Maryland, College Park, Maryland, USA
1992 January 28–January 31

P.K. Sahu, Institute of Physics, Bhubaneshwar
1992 March 12–June 17

J. Adam, CAM Computer Anwendung für Management Gmbtt, Heidelberg, Germany
1992 February 27–March 5

APPENDIXES

Appendix A

Publications

In Journals

Ananth, A.V., Srinivasan, R., Srinivasulu, G., Chandramouli, S.S. (1991) *Ind. J. Pure Appl. Phys.*, **29**, 529–534.
A PC/AT based image data acquisition/processing system for CCD cameras.

Anupama, G.C., Prabhu, T.P. (1991) *Mon. Not. R. astr. Soc.*, **253**, 605–609.
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Bhatt, H.C., Jain S.K. (1992) *Mon. Not. R. astr. Soc.*, **257**, 57–61.
Polarization measurements of stars in the region of the nearby molecular cloud MBM 12.

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Gangadhara, R.T., Krishan, V. (1992) *Mon. Not. R. astr. Soc.*, **256**, 111–120.
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Gokhale, M.H., Javaraiah, J. (1992) *Sol. Phys.*, **138**, 399–410.
Global modes constituting the solar magnetic cycle II : phases, geometrical eigenmodes and coupling of field behaviour in different latitudes.

Gokhale, M.H., Javaraiah, J., Kutty, K.N., Varghese, B.A. (1992) *Sol. Phys.*, **138**, 35–48.
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Invited talks at Conferences, Workshops and Seminars

Bhattacharyya, J.C.

Inaugural address
Indo-US Workshop on IPS and Propagating Solar Disturbances, Ahmedabad
1991 September 25–26

Inaugural address
Symposium on Solar Physics and Interplanetary Medium, PRL, Ahmedabad
1992 January 28

The role of observations in calendric astronomy
Symposium on Rectification and Astronomical Parameters
Indian Astronomical Society, Calcutta
1992 February 12

Minor planets
Symposium in honour of the sixtieth birthday of Prof. U.R. Rao
PRL, Ahmedabad
1992 March 10

Distances in the Universe
Punjabi University, Patiala
1992 March

Vainu Bappu Telescope
Thapar R & D Centre
1992 March

Datta, B.

QCD phase transitions in the early universe and primordial nucleosynthesis
Raman Research Institute, Bangalore
1991 May 16

Radial pulsations of rotating stellar objects in general relativity
International Conference on Gravitation and Cosmology, Ahmedabad
1991 December 13–18

Gokhale, M.H.

Third branch of helioseismology
Tata Institute of Fundamental Research, Bombay
1991 April.

Sun's internal and surface magnetic fields
Indo-US Workshop on IPS and Propagating Solar Disturbances, Ahmedabad
1991 September 25–26

Magnetic reconnection on the Sun
IUCAA Workshop on Plasma Astrophysics, Bangalore
1992 March 2–6

Jain, S. K.
High resolution extreme ultraviolet studies of the Sun
UN/ESA Workshop on Basic Space Sciences, Bangalore
1991 April 30–May 3

Krishan, V.
Modeling of structures on the solar atmosphere
Indo-US Workshop on IPS and Propagating Solar Disturbances, Ahmedabad
1991 September 25–26

Plasma processes in the universe
National Symposium on Plasma Science, Indore
1991 December 17–20

Fast plasma processes in quasars and generation of large scale flows
IUCAA Workshop on Plasma Astrophysics, Bangalore
1992 March 2–6

Mallik, D. C. V.
Origin and evolution of planetary nebulae
PRL, Ahmedabad
1991 September 12

Mayya, Y. D.
Star formation in H II complexes in nearby galaxies
Meudon Observatory, Paris
1991 December 17

Parthasarathy, M.
Spectral classification
Evolution of low and intermediate mass stars
Evolution of massive stars
Spectroscopic and eclipsing binary stars
Evolution of close binary stars
DST-sponsored Training Programme in Astronomy, Dept. of Astronomy, Osmania University, Hyderabad
1991 April 15–May 11

Peraiah, A.
Departure from sphericity in stellar atmospheres
XXI IAU General Assembly, Buenos Aires, Argentina
1991 July 23–August 1

Sagar, R.

Stellar photometry on CCD images
Young star clusters of our galaxy
Mass functions of the LMC star clusters
CASA, Dept. of Astronomy, Osmania University, Hyderabad
1991 October 9–11

Astronomical photometry–instrumentation, reduction procedures and applications to stellar photometry
Mini workshop on Automated Photoelectric Telescopes
IUCAA, Pune
1991 October 21–25

Non-uniform extinction in young open clusters
Spatial distribution of stellar mass in open clusters
Mass functions of star clusters in the LMC
CCD photometry in crowded regions
Uttar Pradesh State Observatory, Naini Tal
1991 October 29–November 8

Modern optical observational astronomy
Second All India Amateur Astronomer's Meet, Gandhi Ashram, Sevagram
1992 January 4

Sastri, J. H.

Magnetosphere–ionosphere coupling
National Space Science Symposium, Ahmedabad
1992 March 11–14

Saxena, A. K

Optical concepts in ophthalmology
Thin film coatings and their applications
Karnataka Optical Association Workshop, Bangalore
1991 November 10

New technology telescope –Indian context
Active and adaptive optics system for astronomical application
Osmania University, Hyderabad
1992 January 27–28

Sivaram, C.

The problem of the cosmological constant
International Symposium in honour of Peter Bergmann
Ettore Majorana Centre, Erice, Italy
1991 September 6

Constraints on the fundamental properties of gravity from solar system experiments and from SN 1987A
University of Pavia, Italy
1991 October 14

A critical discussion of observational evidence for the big bang and for competing models
University of Perugia, Italy
1991 October 16

Unification of gravity with other interactions
Indian Statistical Institute, Calcutta
1992 January 3

Paper presentations at Conferences

Babu, G. S. D.
Program for the restoration of the masonry instruments at Jai Singh's Delhi Observatory
First Indian astronomical observations in Antarctica
XXI IAU General Assembly, Buenos Aires, Argentina
1991 July 23–August 1

Hasan, S. S.
5 min oscillations in sunspots
NATO Advanced Research Workshop on the Theory of Sunspots, Cambridge, England
1991 September 23–28

Kapoor, R. C.
The effect of spacetime curvature on pulsar beam widths
International Conference on Gravitation and Cosmology, Ahmedabad
1991 December 13–18

Krishan, V.
Clustering of Galaxies by nonlinear α-effect
International Conference on Gravitation and Cosmology, Ahmedabad
1991 December 13–18.

Mallik, S. V.
The Hα line as a diagnostic of cool supergiant chromospheres
The Ca II triplet lines in cool stars
Women in astronomy : the Asian view
XXI IAU General Assembly, Buenos Aires, Argentina
1991 July 23–August 1

Rao, N.K.
Astronomy with Buddhist Stupas of Sanchi
Astronomical orientations of the megalithic stone circles of Brahmagiri
(Presented by K.D. Abhyankar)
International meeting on Indian and other Asiatic astronomies
Hyderabad, India
1991 December

Sivaram, C.
A basis for black hole entropy
International Conference on Gravitation and Cosmology, Ahmedabad
1991 December 13–18

Sivaraman, K.R.,*Makarov, V.
Green coronal emission and the global solar cycle
Twelfth NSO/Sacramento Peak Summer Workshop on the Solar Cycle
1991 October 15–18

Attendance in Conferences, Workshops and other Scientific Meetings

UN/ESA workshop on Basic Plasma Sciences
Bangalore
1991 April 30–May 3 — S. K. Jain, R. K. Kochhar

NATO Advanced Study Institute on Black hole physics
Erice, Italy
1991 May 10–24 — C. Sivaram

Spring College on Plasma Physics
ICTP, Trieste
1991 May 27–June 21 — R. T. Gangadhara

International conference on Asteroids, Comets, Meteors
Flagstaff, Arizona, USA
1991 June 24–28 — R. Rajamohan

NASA International Near-Earth Object Detection Workshop
San Juan Capistrano, California, USA
1991 June 30–July 3 — R. Rajamohan

29th International Subnuclear Physics Course of the Ettore Majorana Centre
Erice, Italy
1991 July 14–25 — C. Sivaram

Mini workshop on Image Processing
IUCAA, Pune
1991 July 21–26 — Ram Sagar

XXI IAU General Assembly
Buenos Aires, Argentina
1991 July 23–August 1 — G. S. D. Babu, J. C. Bhattacharyya, S. V. Mallik, A. Peraiah

12th International Meeting on Planetary Emergencies and Environmental Physics
Erice, Italy
1991 August 19–24 — C. Sivaram

International Conference on Fundamental Problems in Particle Physics and Astrophysics in honour of Daniel Chalone
Paris, France
1991 September 3–9 — C. Sivaram

International Conference on Particle Physics Phenomenology
Trieste, Italy
1991 September 22–25 — C. Sivaram

Indo-US Workshop on IPS and Propagating Solar Disturbances
PRL, Ahmedabad
1991 September 25–26 — J.C. Bhattacharyya, M.H. Gokhale, V. Krishan

DST–sponsored Meeting on Global Electrical Circuit
IIG, Bombay
1991 September 27–28 — J.H. Sastri

NATO Advanced Research Workshop on the Theory of Sunspots
Cambridge, England
1991 September 23–28 — S.S. Hasan

Twelfth NSO/Sacramento Peak Summer Workshop on the Solar Cycle
1991, October 15–18 — K.R. Sivaraman

Mini workshop on Automated Photoelectric Telescopes
IUCAA, Pune
1991 October 21–25 — Ram Sagar

III Canary Island Winter School on Star Formation in Stellar Systems
Tenerife, Spain 1991
December 2–13 — Y.D. Mayya

International Conference on Gravitation and Cosmology, Ahmedabad
1991 December 13–18 — B. Datta, V. Krishan, C. Sivaram

National Symposium on Plasma Science.
Indore
1991 December 17–20 — V. Krishan

Second All India Amateur Astronomer's Meet
Gandhi Ashram, Sevagram
1992 January 4 — Ram Sagar

National Symposium on Unified Field Theories
Calcutta
1992 January 1–5 — C. Sivaram

Symposium on Solar Physics and Interplanetary medium
PRL, Ahmedabad
1992 January 28 — J.C. Bhattacharyya

Symposium on Rectification and Astronomical Parameters
Birla Planetarium, Calcutta
1992 February 12–13 — J.C. Bhattacharyya

Third AICPITS Group Monitoring Workshop
IIA, Bangalore
1992 February 26–28 — J.H. Sastri

IUCAA–IIA Workshop on Plasma Astrophysics
IIA, Bangalore
1992 March 2–6 — S.S. Gupta, M.H. Gokhale, R. Kariyappa, V. Krishan

Symposium in honour of the sixtieth birthday of Prof. U.R. Rao
PRL, Ahmedabad
1992 March 10 — J.C. Bhattacharyya

National Space Science Symposium
PRL, Ahmedabad
1992 March 11–14 — J.H. Sastri

Visits to scientific institutions

A. V. Ananth visited the National Optical Astronomical Observatories, Tucson and the National Solar Observatory, Sunspot, U.S.A. in connection with software development for studies of sunspot measurements and for looking into electronic hardware and software aspects of the solar correlation tracker. **G. S. D. Babu** visited Instituto Argentina de Radioastronomia, Villa Elsa 1991 August 2–4. **M. H. Gokhale** visited TIFR, Bombay 1991 April 1–16 and the Udaipur Solar Observatory 1991 September 28–29. **S. S. Hasan** visited the Harvard-Smithsonian Center for Astrophysics, Cambridge, U.S.A. for one year from August 1991 during his sabbatical leave from the Institute. While at Harvard, he also visited Cambridge University, England; University of Arizona, Tucson; National Solar Observatory at Kitt Peak and Sacramento Peak; University of Chicago, Chicago; Cornell University, Ithaca and the Institute of Astronomy, National University of Mexico. **S. K. Jain** visited Stanford University and NASA Wallops Flight Facility, California, U.S.A. 1992 February 16–27 to participate in the critical design review meeting of the EUV spectrometer payload. **R. K. Kochhar** went to U.K. on a five-week study tour during 1991 August 16–September 26 for consulting source material on the history of modern astronomy in India. His visit was jointly sponsored by the British Council and the Institute. **Y. D. Mayya** visited Meudon Observatory, France 1991 December 16–20. **A. Peraiah** visited PRL, Ahmedabad 1991 August and gave several seminars. **T. P. Prabhu** visited IUCAA, Pune in 1991 December in connection with the collaborative work on surface photometry of galaxies. **N. K. Rao** was selected Visiting Scientist in the programme of Indo-US

Exchange of Scientists operated by CSIR, India and NSF, U.S.A. He spent about eight weeks at the Department of Astronomy, University of Texas at Austin, between 1991 November and 1992 January. He observed with the 107-inch and 82-inch telescopes at McDonald Observatory and had extremely fruitful interactions with the technical team that was installing a high resolution Cassegrain Echelle Spectrograph at the 82-inch telescope. N. K. Rao also visited the Lick observatory on Mt Hamilton and the University of California, Santa Cruz. He held discussions with Steve Vogt on high resolution spectroscopy and saw the Hamilton Spectrograph at Lick as also the new high resolution spectrograph being built for the 10-m Keck telescope. **Ram Sagar** visited the Centre of Advanced Study in Astronomy, Osmania University, Hyderabad 1991 October and delivered three extension lectures. He also visited the UP State Observatory, Naini Tal 1991 October 29–November 8 to carry out collaborative research work. **C. Sivaram** spent several months in Italy as Visiting Professor to various institutes. He was in the Institute of Physics and Astronomy, University of Bologna 1991 March–June, at the Ettore Majorana Centre, Erice 1991 July, in the Department of Mathematics, University of Perugia 1991 August and the Institute of Physics, University of Ferrara 1991 September. C. Sivaram also visited ICTP, Trieste 1991 October and the Department of Physics, University of Pavia and the World Laboratory, Lausanne, Switzerland 1991 December. **K.R. Sivaraman** visited the National Solar Observatory, Tucson for three weeks 1991 October.

Appendix B

Teaching of Astronomy

The Institute has continued its active participation in the Joint Astronomy Programme (JAP) of the Indian Institute of Science, Bangalore. In the first semester V.Krishan and A. V. Raveendran taught respectively the courses on Dynamical Processes in Astrophysics and Astronomical Techniques. In the second semester D. C. V. Mallik taught Stellar Physics, H. C. Bhatt Galactic and Extragalactic Astronomy and B. Datta shared the teaching of General Relativity and Cosmology with C. V. Vishveshwara of Raman Research Institute. At Bangalore University the Astrophysics Special Papers in the second year of M.Sc. were taught by M. H. Gokhale, R. K. Kochhar, A. Peraiah, T. P. Prabhu, A. V. Raveendran, J. H. Sastri and P. Venkatakrishnan. M. H. Gokhale continued as the coordinator of this programme.

B. Datta, R. K. Kochhar, D. C. V. Mallik, Ram Sagar and P. Venkatakrishnan gave talks at the Summer School in Astronomy and Astrophysics organized by JAP, IISc. The Summer School participants visited the Institute premises in Bangalore and Vainu Bappu Observatory, Kavalur.

S. S. Hasan taught a course on Solar Physics at the Center for Astrophysics, Harvard University, Cambridge, U.S.A. during 1992 March–April.

About 30 students and lecturers from various colleges and universities attended the Winter School on Stars and Stellar Systems held at VBO, Kavalur 1991 December 23–31. Several members of the staff gave lectures. K. K. Ghosh acted as the local coordinator. Fifteen M.Sc./B.Tech. students from different universities and IITs undertook summer projects at the Institute and its field stations at Kavalur and Kodaikanal during 1991 June–August. S.P. Bagare coordinated this Visiting Students Programme

Editing and Publishing

The editorial work of the Journal of Astrophysics and Astronomy (JA&A) published by the Indian Academy of Sciences, Bangalore and of the Bulletin of the Astronomical Society of India continued to be done in IIA. J. C. Bhattacharyya retired from the editorship of JA&A at the end of 1991. D. C. V. Mallik continued as the Associate Editor. S. Rajiva worked as the Editorial Secretary. N. K. Rao became a member of the Editorial Board, JA&A 1992 January replacing T. P. Prabhu who served on the Board till 1991 December. T. P. Prabhu continued to serve on the Editorial Board of the Bulletin of the Astronomical Society of India. J. H. Sastri has been made a member of the Editorial Board of the Indian Journal of Radio and Space Physics for a three-year term beginning 1992 January.

The IIA Newsletter entered its seventh year 1992 January. T. P. Prabhu and A.K.Pati continued to edit it on behalf of the Director, IIA.

Proceedings of the Eighteenth Optical Society of India Symposium on Optical Science and Engineering held 1990 March 21–23 was brought out as a special issue of the Kodaikanal Observatory Bulletin. A. K. Saxena was the Editor and A. Vagiswari, the Co-editor. J. P. Lancelot and C. Louis assisted in the publication.

Popular articles

Babu, G. S. D. (1991) *Wisdom,* September issue, p.49–53
The story of the telescope

Bhattacharyya, J. C.*Science Courier,* in press
Asteroids and planetary systems

Bhattacharyya, J. C.*Bona Mathematica,* in press
The system of minor planets

Bhattacharyya, J. C.*Festschrift in honour of U.R. Rao,* National Academy of Sciences, in press
Astronomical photometry in India

Kochhar, R.K. (1991) *Economic and Political Weekly,* **26,** 1927–1933
Science as a tool in British India

Krishan, V. (1991) *Current Sci.,* **60,** 662
The justice delayed...case of Lisa Meitner

Book reviews

Babu, G. S. D. (1991) *Sunday Herald,*Bangalore, June 23
Coming of age in the Milky Way. (Timothy Ferris, 1990, East West Press, New Delhi)

Bhatt, H. C. (1992) *Sp. Sci. Rev.,* in press
Chemistry in space. (J. M. Greenberg & V. Pirronello, 1991, Kluwer, Dordrecht)

Jain, S. K. (1991) *Bull. astr. Soc. India,* **19,** 172–174
Uranus (Ellis D. Miner, 1990, Ellis Horwood)

Kochhar, R. K. (1991) *Sunday Times of India, July 14.*
Scientist in exile – a review of
'Chandra : a biography of S. Chandrasekhar' (K.C. Wali, 1991, Penguin Books India, New Delhi)

Mallik, D. C. V. (1991) *Bull. astr. Soc. India,* **19,** 369–371.
Stellar structure and evolution. (R. Kippenhahn & A. Weigert, 1990, Springer Verlag, Berlin)

Mallik, D.C.V. (1991) *J. Indian Inst. Sci.*, **71**, 599.
Clusters of galaxies and extragalactic radiosources. (A.D. Kuzmin, Nova Science Publ. Inc.)

Popular Talks

Babu, G.S.D.
IX Indian Scientific Expedition to Antarctica– Experiences of an Astronomer
Master Control Facility, Dept of Space, Hassan. (1991 April 26).
Kendriya Vidyalaya, Hassan. (1991 April 26)
Sri Mahaveera College, Moodabidri. (1992 February 13)
Vijaya College, Mulki. (1992 February 14)
Visvesvaraya Industrial and Technological Museum, Bangalore. (1992 February 27)
Rotary Club of Bangalore Central, Bangalore. (1992 March 28)

Kapoor, R.C.
Black Holes
Kendriya Vidyalaya, Malleswaram, Bangalore. (1991 June 20)

Kochhar, R.K.
Science as tool in colonial India
Bangalore Science Forum. (1992 January 8)

Radio/TV and Film programmes

Babu, G.S.D.
Solar Systems
All India Radio, Bangalore. (1991 November 10)

Antarctica
All India Radio, Bangalore. (1992 February 9)

Bagare, S.P.
Assessing the age of the Universe
All India Radio, Bangalore. (1991 June)

S.P. Bagare served on various aspects of radio programme production such as (i) script translation and regional adaptation, (ii) preview of the production programmes, and (iii) answers to listeners questions, during 1991 June–September, for the AIR–NCSTC's co-produced year-long weekly educational serial on 'Human Evolution'.

Appendix C

Kodaikanal Observatory

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

Year	Month	Hα	KFL	HαPR	PHGM	Seeing*				
						5	4	3	2	1
1991	April	24	24	23	25	—	1	17	7	—
	May	20	21	19	25	—	1	15	9	—
	June	8	8	5	8	—	—	5	3	—
	July	4	4	4	6	—	—	3	2	1
	August	4	3	1	6	—	—	2	4	—
	September	9	9	1	15	—	—	10	5	—
	October	5	7	1	10	—	—	7	3	—
	November	9	11	6	14	—	—	13	1	—
	December	21	21	15	22	—	4	16	2	—
1992	January	28	28	21	28	—	2	24	2	—
	February	29	29	29	29	—	2	25	2	—
	March	30	30	30	30	—	—	28	2	—
	Total	191	195	155	218	—	10	165	42	1

KFL = K-Flocculus HαPR = Hα-Prominences PHGM = Photoheliograms
* (1 — Very poor, 2 — Poor, 3 — Fair, 4 — Good, 5 — Excellent)

Solar tower observations

Year	Month	Total number of days of observation	Seeing (in arcsec)				
			1	2	3	4	5
1991	April	14		1	12	1	
	May	12	1	5	5	1	
	June	4			3	1	
	July	2			1	1	
	August	1				1	
	September	7			3	3	1
	October	2			2		
	November	3		1	2		
	December	6			3	3	
1992	January	16		3	11	2	
	February	6			4	2	
	March	4			3	1	

Vainu Bappu Observatory

Sky condition at Kavalur

Year	Month	Spectroscopic hours	Photometric hours
1991	April	134.5	20.5
	May	128.5	20.5
	June	12.5	0.0
	July	18.0	1.5
	August	26.5	1.5
	September	22.5	0.0
	October	13.0	0.0
	November	47.0	4.0
	December	114.5	41.0
1992	January	179.5	30.0
	February	217.5	69.5
	March	287.5	134.5
	Total	1201.5	323.0

Satellite imagery by SPOT of Kavalur region with Vainu Bappu Observatory near the centre