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A double-pass spectrograph for solar research

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Abstract. We have described the double-pass spectrograph built at the Indian Institute of Astrophysics. Measurements of the scattered light within the spectrograph using the photoelectric scans of the NaI D-lines show that this is a good near-scatter-free system. This instrument is used to monitor the disk integrated CaII K line profile of the sun on a regular basis.

Key words : double-pass spectrograph—Ca II K-line profiles

1. Introduction

It is customary in laboratory spectroscopy to employ a double-pass arrangement in spectrographs for the purpose of increasing dispersion and resolution. Another advantage exploited mainly by astronomers is the reduced scattered light within the spectrograph when used in the double pass mode. The necessity of reducing the scattered light to a minimum possible level becomes all the more important when studies concerning the profiles of Fraunhofer lines and the subtle changes in them are attempted photoelectrically. Among the early attempts of employing a double pass system with solar telescopes are those by Evans & Waddell (1962) and Mitchell & Mohler (1964). In this paper we describe the double-pass spectrograph built by us at the Indian Institute of Astrophysics and discuss the performance of the system. This instrument was built at the Bangalore campus in the year 1988 to serve as a dedicated instrument to monitor the CaII K line profiles in the integrated light of the sun with high photometric accuracy as an extension of the ongoing programme at the Kodaikanal solar tower. The main purpose is to procure disc integrated profiles in the K line and look for the contributions for the various chromospheric features to the K line emission in quantitative terms.

2. Optical layout of the double-pass system

The optical set up uses the Czerny-Turner system in the double-pass mode. The schematic representation of the system and the optical path are shown in figure 1. M_1 and M_2 are two identical off-axis paraboloids of aperture 20 cm and focal length 570 cm; the former serves

as the collimator and the latter as the camera mirror. G is a Bausch and Lomb plane grating of size 10.8 cm × 13.0 cm with 1200 grooves mm^{-1}. For the K-line programme the grating is used in the third order where the dispersion is 5.2 mm A^{-1} in the double-pass mode. A two mirror coelostat of 30 cm aperture directs a beam of sunlight on the entrance slit S_1 of width 120μ and this beam continues and strikes the collimator mirror M_1 forming the patch CO_1. Since the purpose is to acquire K-line profiles in the integrated sunlit, we do not use the image forming optics before S_1 although the sun could be imaged on S_1 at the choice of the observer. The spectrum of the first pass falls on M_2 at CA_1 and this spectrum is now passed through the intermediate slit S_2 using the flat mirror F_1. While using the instrument for scanning the K-line region, we place a Schott filter (BG 25) in front of the intermediate slit S_2 to cut off the overlapping orders. The light traversing S_2 contains a narrow band of the spectrum centered at wavelength λ_0 (~ 3934 Å which is the centre wavelength of the K-line) besides the ghosts as well as the scattered light of other wavelengths. We have set S_2 with a width of 120 μ and this cuts off the ghosts on either side of the solar K-line (3934 Å). CO_2 (figure 1) represents this spectrum falling on the mirror M_1 which collimates it on

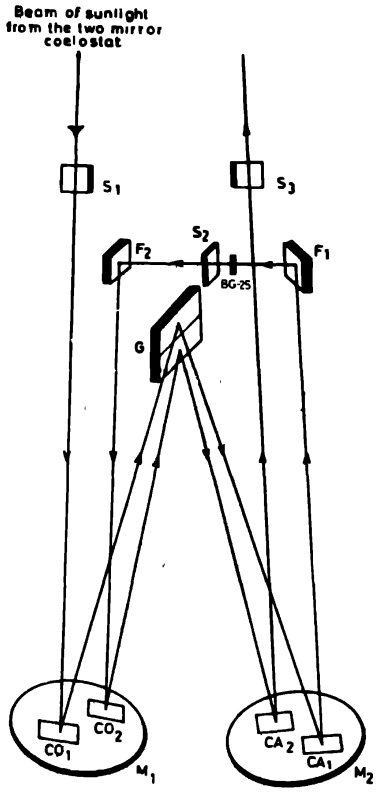

Figure 1. The optical layout of the Czerny-Turner type double-pass spectrograph with low level of scattered light for solar research.

S_1, entrance slit, width 120μ; S_2, intermediate slit, width 120μ; S_3, exit slit, width 240μ; M_1, collimator mirror 20 cm aperture and 570 cm focus; M_2, camera mirror identical to M_1; BG-25, broad band Schott filter with a half width of 1200Å and peak transmission efficiency of 94% at λ 4000Å; G-Bausch and Lomb grating, 1200 grooves mm^{-1}; Dispersion, third order K-region is 5.2 mmA^{-1}; F_1 and F_2 are the two flat mirrors that fold the spectrum of the single pass; CO_1 is the patch of incident sunlight on the collimator mirror M_1; CA_1 is the spectrum after single pass falling on the camera mirror M_2; CO_2 is the spectrum before the double pass; and CA_2 is the spectrum after the double pass.

the grating. The grating separates the scattered light from the λ_0 band in the second pass and the spectrum CA_2 free of the scattered light is focussed on the exit slit S_3 by M_2. A 1P21 photomultiplier tube in a light proof housing is mounted behind the slit S_3 and the out put of the photomultiplier is fed to a Lecroy D. C. amplifier and a chart recorder. The most attractive feature of this system is that the mirrors M_1 and M_2 are tipped in the vertical plane so that light is sent to the flat mirrors F_1 and F_2 off the plane of the system and the beams belonging to the first and second passes fall on the upper and lower half of the grating. With a system of baffles we have segregated the first and second pass optical paths from each other completely and this eliminates any cross talk between them. This feature makes this instrument superior to other double-pass spectrographs associated with the solar telescopes elsewhere.

The grating is mounted on a base plate which can be rotated smoothly by operating a synchronous motor. The base plate is coupled to the motor through a system of gears which permits four different speeds for the grating rotation. These are 0.004, 0.01, 0.02 and 0.04 Å/sec. Of these, we use the scan speed of 0.01Å/sec which combined with a width of 240μ for the exit slit S_3 enables a satisfactory scanning of the K-line in the third order with good spectral resolution. One scan covering a span of 6Å around the K line takes about 10 minutes. The grating can be rotated to any other position for obtaining the line profile of any other line at the will of the observer.

3. Measurement of scattered light

The narrow band pass of the intermediate slit S_2 (~ 0.024Å corresponding to a width of 120μ) eliminates most of the diffuse scattered light and the effects of the Rowland ghosts in the final spectrum. We have measured the scattered light within the spectrograph by measuring the central intensities of NaI D lines. The central intensities of the D_1 and D_2 lines have been measured by earlier workers (see table 1) for double-pass spectrographs and these permit comparison of our values with all of them. A sample profile of the D_1 and D_2 lines from our collection of scans is shown in figure 2. We have done the photometric reduction of the profiles and computed the central intensities of D_1 and D_2 lines from line profiles obtained on different days with reference to the continuum at λ5894Å. We have adopted the intensity at this wavelength as 98.07% of the continuum from Del Bouille *et al.* (1973). We present in table 1 the mean central intensity value for D_1 and D_2 lines from our measurements along with similar values obtained by other workers. The performance of our double-pass system seems quite satisfactory. We have collected a few thousands of K-line profiles in the integrated sunlight during the last three years with this instrument. The reduction of this data is in progress.

Table 1. Central intensities of NaI D lines expressed in percentage of the continuum at λ 5894Å.

Line	Our measurements (1989)	Evans & Waddell (1962)	Mitchel & Mohler (1964)	Brault *et al.* (1971)	Del Bouille *et al.* (1973)
NaD_1	4.86	5.00	5.4	5.04	5.23
NaD_2	4.28	4.40	4.6	4.38	4.40

4. The Instrumental profile

We have determined the instrumental profile using the telluric lines as this would be a valid one being obtained under the same conditions as in the regular observations. We have used the 3 narrow water vapour lines red ward and the two lines violet ward of D_2 for this purpose (figure 2). We have computed the full width at half maximum for these 5 telluric lines from our scan records. We have also measured the full width at half maximum for these telluric lines from the Photometric Atlas of Minnaert *et al.* (1940) and that of Del Bouille *et al.* (1973) to serve as comparison. These values are presented in table 2. The agreement appears satisfactory.

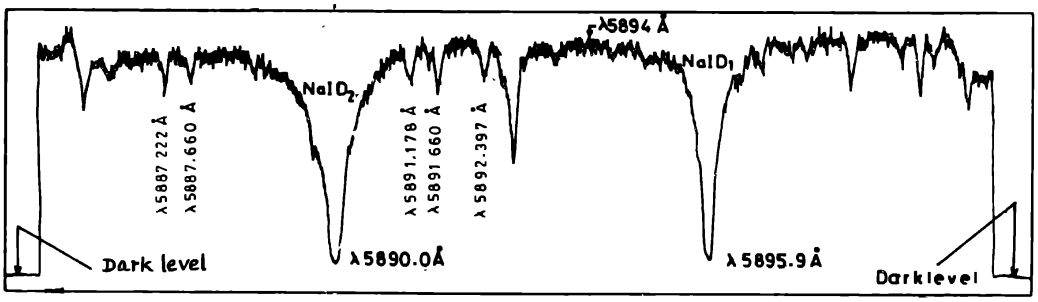

Figure 2. Sample photoelectric scan of NaI D_1 and D_2 line profiles obtained with the double-pass system. The 3 sharp absorption lines red ward and 2 lines violet ward of NaI D_2 line are the atmospheric H_2O lines used for the instrumental profile.

Table 2. Full width at half maximum in mÅ for five atmospheric H_2O lines in the D_1 and D_2 wavelength region

Atm. H_2O line λ (Å)	Our measurements (1989)	Minnaert *et al.* (1940)	Del Bouille *et al.* (1973)
5887.222	9.53	9.40	9.60
5887.660	5.90	5.94	5.80
5891.178	9.52	9.86	9.72
5891.660	7.50	7.40	7.45
5892.397	9.52	9.86	9.75

Acknowledgement

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Reports from astronomical centres

National Centre for Radio Astrophysics
Tata Institute of Fundamental Research

REPORT FOR THE PERIOD 1991 APRIL 1-1992 MARCH 31

Solar wind

The Ooty Radio Telescope (ORT) has been used extensively for observing interplanetary scintillation (IPS) properties at 327 MHz of about 200 radio sources with line of sight heliocentric distances in the range of 0.15–0.75 AU. The recently installed new feed with low-noise RF amplifiers behind each dipole has increased the sensitivity of the ORT by a factor of ~ 4, making it possible to obtain power spectra of compact sources with scintillating flux densities as low as ~ 250 mJy in less than about 3 minutes of observing time. In addition to monitoring scintillation indices (g-maps), the high signal-to-noise ratio of the Ooty data permits the estimation of the solar wind velocities (v-maps). Concurrently, a survey of scintillating sources which can be used for daily mapping of the solar wind throughout the year, is also being carried out. During April-May 1992, IPS observations at Ooty will be done in coordination with the Cambridge IPS array and the Nagoya 3-station IPS observatory. As Ooty observations yield both g values and velocities, intercomparison of the results from Cambridge (only g values) and Nagoya (only velocities) with Ooty results will be possible for the first time (P. K. Manoharan, S. Ananthakrishnan & V. Balasubramanian).

A careful analysis IPS g-maps produced by the Cambridge IPS array, during the past two years, shows that the ambiguities in the present maps, arising due to the mixing of IPS scintillation with ionospheric contribution, need to be resolved before the maps can be routinely used for geomagnetic weather forecasting (H. Leinbach and S. Ananthakrishnan). Colour stack plots of g-maps (T. Detman, S. Ananthakrishnan and H. Leinbach) show interesting stream and transient structures in the solar wind. These are being analysed to produce an archetypal disturbance for simulation purposes. The Cambridge array is being refitted with hardware designed to eliminate ionospheric scintillation and to measure power spectra (G. Woan, H. Leinbach and S. Ananthakrishnan). Simulation of interplanetary disturbances by developing 3D MHD models are in the advanced stage (T. Detman, S. Ananthakrishnan & M. Dryer).

The project to study the short time scale variability of the solar wind for which about a thousand hours of Inter Planetary Scintillatin (IPS) data were acquired using the Ooty Radio Telescope in 1990-91, has made considerable progress. The analysis of all the data has been completed. This involved development of new software to model the effects of various kinds of disturbances in the solar wind on the observed scintillation properties. About a dozen short time scale events have been detected, with time scales ranging from minutes to hours. Detailed modelling of the observed events, along with classification and association with solar and terrestrial effects, is in progress (P. Gothoskar & A. Pramesh Rao).

Galactic radio sources

As part of the ongoing efforts to identify new supernova remnants with active pulsars, further X-ray observations have been made of SNR G 33.6 + 0.1, which has a bright inner ring as well as an outer shell in the radio, with the ROSAT Observatory using (i) the PSPC to map the internal X-ray emission with resolution ~ 1 arcmin and to measure spectra accurately in different regions, and (ii) the HRI to distinguish arcsec structures (T. Velusamy, F. D. Seward & R. H. Becker).

The data taken with the Ooty Synthesis Radio Telescope in selected regions along the galactic plane are being analysed to look for interesting small diameter radio sources (T. Velusamy & V. Venkatasubramani).

Further analysis of pulsar scintillation data taken at the Fallbrook radio telescope has shown that the inner-scale model for the spectrum of electron density fluctuations in the interstellar medium provides a good explanation for the enhanced refractive scintillation indices for several pulsars. There is weak evidence for smaller inner-scale values to be associated with an enhanced level of plasma turbulence. (Y. Gupta, B. J. Rickett & W. A. Coles).

A detailed study was carried out to explore the possibilities of pulsar polarisation observations to be carried out with the phased array mode of the Giant Metrewave Radio Telescope under construction. Special calibration requirements were also investigated. A new scheme for instrumental polarisation calibration for GMRT has been proposed (Y. Gupta & S. Upreti).

The prospect of searching for millisecond pulsars using the refurbished Ooty Radio Telescope has been investigated and found to be very promising. Considerable progress was made in developing search software for parallel processing machines (Y. Gupta, G. Swarup & S. Upreti).

Nearby Galaxies

Detailed, multifrequency observations have been made with the VLA at 1.49 and 4.86 GHz of the edge-on spiral galaxies NGC 4388 and NGC 4438. They are both members of the Virgo cluster of galaxies and have linear elongated radio features emerging from the nucleus perpendicular to the plane of the galaxy. From these observations it has been possible to identify the nucleus of NGC 4388 which has been reported to have a hidden Seyfert 1 nucleus. The larger scale structure of NGC 4388 consists of an elongated collimated structure to the south and a diffuse extended bubble to the north. The ridge of the radio emission is bent, possibly by density gradients perpendicular to the plane of the galaxy. The observations of NGC 4438 show a shell-like structure near the nucleus with a significant enhancement of

the radio emission near the centre of the shell. Possible explanations for the radio structures have been explored (E. Hummel & D. J. Saikia).

A radio survey of nearby 'Starburst' nuclei shows that compact radio components similar to those found in M82 are common place. In some cases (e.g. NGC 1808) the compact components are substantially more luminous than even the brightest of the M 82 sources. While there appears to be no detailed spatial association with the optically visible giant HII regions in any of the galaxies studied, the radio sources are generally located in dense circumnuclear molecular rings. The immediate aim of this work is to determine the size of the radio components in order to get some limit on their age. In the case of NGC 4321, new 8 GHz observations have clearly resolved out all but 2 of the objects that were detected with the B-array at 5 GHz, suggesting that we are seeing objects in a range of ages. These and other nuclei turned up by our VLA survey are being monitored both by the VLA and with MERLIN with a view to measuring the supernova rate in the starburst region of a number of galaxies. The observations will be equally important to our understanding of the evolution of Supernovae in external galaxies in general (D. J. Axon, P. Collison, A. Pedlar & D. J. Saikia).

Clusters of Galaxies

An extensive radio survey at 1.4 GHz of a sample of about 50 distant Abell clusters ($0.1 < z < 0.2$) dominated by cD galaxies was completed. About 35 of these were mapped both at 1.4 GHz and 330 MHz, using the VLA. The radio luminosity function (RLF) of the cD galaxies was found to agree with the known RLF of giant elliptical galaxies (located in less richer galactic environments) whose 1.4 GHz radio luminosity $< 10^{24.5}$ WHz^{-2}. But beyond this limit, the cD galaxies are found to be more probable radio sources than ellipticals. This behaviour of the RLF was explained by considering the radio luminosity versus optical luminosity correlation known in case of the giant elliptical systems. No significantly large population of steep spectrum radio sources with 330-1400 MHz spectral index $\alpha > 1.2$ was found in these clusters. A re-examination of the radio and X-ray data on the nearby ($0.03 < z < 0.15$) Abell clusters with cD galaxies revealed a significant negative correlation between the radio luminosity of the cD galaxy and the cooling time of the hot intra-cluster medium. As many as 70% of the radio emitting cD galaxies with 1.4 GHz radio luminosity $> 10^{22.6}$ WHz^{-1} were found to be located at the focus of 'cooling-flows', suggesting that the majority of the radio-loud cDs detected by us in distant Abell clusters should be associated with massive 'cooling-flows'. Physical models of the confinement of the radio plasma and the fuelling of central energy sources of cDs were examined to understand the effect. It was also found that while the radio-emitting cD galaxies are located practically on the geometric centres of their host clusters, the radio quiet cDs do not show this behaviour. The possibility of dynamical evolution of clusters causing this effect was considered (J. Bagchi & V. K. Kapahi).

Radio galaxies and quasars

Work has been continued on deep optical and infrared imaging and spectroscopy of faint galaxies identified with complete samples of Molonglo 1 Jy radio sources, using the 2.5 m telescope at Las Campanas and the 4 m telescope at Cerro Tololo in Chile in collaboration with P. J. McCarthy of the Carnegie Institution, Pasadena and W. van Breugel of IGPP,

Livermore, U.S.A. The project has already led to the detection of a large number of galaxies at high redshifts ($z > 1$), resulting in a substantial increase in the number of known galaxies at high redshifts. The scope of the project has also been enlarged considerably to include all the remaining sources in the Molongly 1 Jy sample irrespective of the optical identification. Radio imaging observations of an additional sample of 200 sources have been made using the Very Large Array in U.S.A. towards this end (V. K. Kapahi, C. R. Subrahmanya & R. Athreya).

The ongoing optical follow up of the Ooty sample of ultra-steep-spectrum radio sources at the European Southern Observatory, La Silla (Chile) has led to several new results, including the discovery of 3 rich clusters of galaxies at redshifts of $z \doteq 0.56$, 0.75 and 0.84. Only a handful of such distant clusters are presently known and the Ooty sample is expected to yield ~ 10 clusters at $z > 0.5$. Such clusters are currently the most effective way of discovering 'normal' galaxies at high redshifts and studying their cosmological evolution. Furthermore, the detection of blue 'arcs' believed to be produced by gravitational lensing effect of distant clusters can provide powerful constraints on the distance of the population of faint blue galaxies that show up in deep imaging. The sample has already led to the discovery of a bright ($m_R = 19.4$) and nearly straight blue 'arc' in the direction of the rich cluster at $z = 0.56$. This is one of the most distant lensing clusters known so far. Another important outcome of this programme is the discovery of a few examples of powerful radio galaxies with extremely low-ionization emission-line spectrum with a line ratio [OII]/[OIII] >> 1. These weakly ionized, powerful extragalactic radio sources (WIPERS) are exceptionally interesting objects since such ultra-soft emission line spectrum has hitherto been found to be associated almost exclusively with LINER type AGNs, which are, at best, weak radio emitters (Gopal-Krishna, J. Melnick, B. Altieri & E. Giraud).

Several sources in the optically deep Molonglo samples of quasars have been mapped with high angular resolution (< 0.5 arcsec) at 8 GHz using VLA data. Work on analysing the optical spectroscope data on many quasars in the sample taken with the Anglo Australian Telescope has been carried out in collaboration with R. W. Hunstead and J. Baker at Sydney University (V. K. Kapahi & C. R. Subrahmanya).

Using large samples of radio galaxies and quasars, covering a wide range in redshift ($z = 0.1$ to 2.0), it has been shown that the cosmological evolutions of the linear sizes of large radio galaxies and quasars are indistinguishable. This constitutes further evidence in favour of the orientation-based scheme to unify radio-loud quasars and radio galaxies (Gopal-Krishna & V. K. Kulkarni).

A kinematic model has been proposed to explain the ultra-rapid variability of AGNs, which emphasizes the changes in relativistic aberration resulting from minute non-linearities in the jet's flow direction. The model explains some intriguing correlations and time offsets observed between the variable, total and polarized intensities and makes predictions that could be verified using dedicated VLBI arrays, such as VLBA (Gopal-Krishna & P. J. Wiita).

A first search for intra-night variability in radio-quiet but optically luminous quasars has been carried out using two southern QSOs. No evidence for such micro-variability was found. A more intensive series of observations has been launched using the Vainu Bappu Telescope at Kavalur, which could discriminate between the different mechanisms for the optical microvariability that invoke either relativistic jets or flaring accretion disks (Gopal-Krishna, P. J. Wiita & B. Altieri).

VLA and MERLIN observations have been made of the quasar 1222 + 216 (z = 0.435) at 1465, 1666, 4885 and 4995 MHz. The radio structure is reminiscent of a wide-angle-tailed source with an angular size of 16.8 arcsec (corresponding to ~ 113 kpc). While such radio structures are common among radio galaxies, they are rare among quasars. The location of the quasar in a region of high galaxy density suggests that its structure could well be due to interaction of the radio emitting plasma with the external cluster environment. The implications of this and other possible explanations of the observed structure have been discussed (D. J. Saikia, P. J. Wiita & T. W. B. Muxlow).

Cosmology—Galaxy formation

The Zeldovich aproximation and the spherical model, used to follow the non-linear evolution of density fluctuations, was extended so that it can be applied right from the radiation dominated era. This generalised Zeldovich approximation was used to study nonlinear evolution in Cold dark matter and texture seeded models of galaxy formation (T. Padmanabhan & K. Subramanian).

The question of how to calculate the probability distribution for the excess density contrast, $P(\delta, t)$ which is valid even in the nonlinear regime, when the mean $\delta \sim 1$, was examined. The Zeldovich approximation was used to show that as nonlinearities develop on any scale, P becomes distinctly non gaussian : it becomes more sharply peaked with the maximum of P shifting to negative values of $\delta > -1$ and a long tail develops for positive δ (T. Padmanabhan & K. Subramanian).

The implications of the detection by Uson *et al.*, of a large mass of neutral hydrogen at a redshift z = 3.4, was studied. Uson *et al.* interpreted their observations as the first example of a Zeldovich pancake. However pancake theories of galaxy formation have well known difficulties. As an alternative, it was proposed that the HI emission could be arising from collection of gas rich protogalaxies of the kind needed to explain the damped Ly α systems seen in quasar spectra (K. Subramanian & G. Swarup).

An extensive invited review on galaxy formation was written. It covers the linear theory of perturbations, applications of linear theory to the microwave background anisotropy and peculiar velocity fields, non linear evolution using spherical model, Zeldovich approximation and adhesion models, the origin of characteristic masses, mass functions and angular momentum of galaxies, the formation of disk and elliptical galaxies, the implications of the high redshift universe to galaxy formation and finally the origin of perturabations (T. Padmanabhan & K. Subramanian).

Instrumentation and techniques

Ooty radio telescope (ORT)

Installation of the new feed system on the Ooty radio telescope with low noise GaAs FET amplifiers and four bit microstripline phase shifters behind each of the 1056 dioles has been completed. Tests carried out on the individual modules (consisting of 48 dipoles) as well as the entire new feed array show an excellent performance in its gain and phase stability. The declination pointing is achieved by suitably phasing the dipoles along the feed. The phase shifters are controlled by a digital communication system. The synchronous Data Link Control is based on 8273 programmable protocol controllers used for controlling and monitoring the

1056 phase shifters and the RF amplifiers. The new feed has an overall system temperature of 150 K (compared to 350 K of the old feed) and the measured sensitivity is 26 (i.e. signal to noise ratio for a 1 Jy source for 1 sec integration over a 4 MHz bandwidth) which is a factor of ~ 4 times higher than the earlier feed. This has made ORT much more powerful. In addition to the increased sensitivity, the new feed provides a high degree of stability and the digital control system provides quick and easy monitoring of the telescope performance (A. J. Selvanayagam, R. Balasubramanian, D. Nandagopal, K. Kalyanasundaram, S. M. Louis, S. K. Venkataraman, T. Venugopal, T. Velusamy & V. Balasubramanian).

A new digital/analog backend for the existing 512 channel correlator is being built at Ooty for simultaneously observing the four recombination lines of Hydrogen, Helium and Carbon (270α, 271α, 272α, 273α), within the 12.0 MHz frequency band of ORT centered at 326.5 MHz. These lines can be observed with a frequency resolution of 1 KHz, which is achieved by recycling the sampled and digitized signals through the correlator, and hence measuring the correlations for larger delays. Since the four lines are due to adjacent electron transitions, the four final spectra can be averaged to improve the signal to noise ratio by a factor of two, thus reducing the duration of observations by four times. The new digital back end will allow simultaneous observations at 2 positions in the sky. The increased sensitivity of ORT achieved by the new feed and the capability to observe 4 transitions simultaneously reduces the integration time required for line observations drastically by a factor ~ 40. It is therefore, proposed to carry out a survey of recombination lines in the Galaxy during the next year (D. Anish Roshi, K. R. Anantharamiah (RRI) & T. Velusamy).

Giant metrewave radio telescope

Work has progressed on the erection of six of the 30 antennas at Khodad site. Due to high inflationary trends in the country, both the major contractors for the antennas had to slow down the work on the first two antennas. These problems have been sorted out and 'first light' from the first two antennas is expected in late August 1992. Electrical lines of 33 KV have been energized and the power position in the central array has improved greatly. Work on energizing of 11 KV lines to the Y-arm sites is progressing. The laying of fibre optic cables in the central array has been completed. The central laboratory building and the guest house at Khodad site have been completed and occupied (G. Swarup, S. C. Tapde, M. K. Bhaskaran, B. S. Dalawat, B. S. Mathakari, N. V. Nagarathnam, H. L. Nagendra, R. V. Swami & the C&S Group of DAE).

The prototype and the first mass production unit of Servo Control Racks for GMRT antennas has been completed at BARC incorporating counter torque antiback lash drive facility (S. Ananthakrishnan, B. M. Barapatre, V. G. Hotkar, N. V. Nagarathnam, V. A. Vaidya and BARC Group of G. Govindarajan, G. P. Srivastava, Y. S. Mayya & R. Gopalakrishnan).

Antenna feeds for the frequency bands of 150 MHz and 50 MHz were developed and the performance of the feeds at 150, 233/610 and 327 MHz were optimized for low spill over and good E&H match. The 150 MHz and 50 MHz feeds are basically thick dipoles made out of a number of thin wires spaced appropriately in the form of a cylinder and have wide band characteristics (VSWR < 2 for nearly an octave range of frequencies). The structures are light weight with low wind loading. Theoretical analysis and experimentation with a model at a higher frequency (400 MHz) was used in designing and fabricating these

feeds. One set of the above feeds was installed in the first GMRT dish (M. R. Sankararaman, G. Sankarasubramanian, S. M. Izhak & G. Swarup).

A versatile state-of-the-art Electronics system for the GMRT receiver has been successfully prototyped and debugged. This includes :

(a) Units for frequency-agile phase-coherent local oscillator generation over spatially distributed locations to convert the RF signals into a common IF signal;

(b) Low-noise broad-band RF front ends at various radio frequencies of interest to GMRT and IF units with good dynamic range;

(c) An analog broad-band optical fibre link using single-mode fibre at 1300 nm with good signal to noise ratio for linking the various antenna locations to the Main Receiver;

(d) A base-band converter with Doppler tracking capability to make the IF signals thus brought to the Main Receiver compatible to the Correlator; and

(e) A digital Control for automatic set up of the various parameters of the receiver and a comprehensive monitor for a feedback on the health of the sub-assemblies.

Considerable progress has been made in integrating the overall electronics system for the first GMRT antenna (S. Ananthakrishnan, T. L. Venkatasubramani, A. Praveen Kumar, G. Chattopadhyay, R. Somashekhar, B. Ajith Kumar & A. Ramakrishna).

The design of individual cards of the GMRT correlator has been finalised and most of the components required for the system have been procured. The work on the prototypes of the sampler, delay and control cards is in progress. It is planned to have a subsystem built and connected to the Ooty Radio Telescope to enable an observing programme for pulsar search to begin in October 1992. For this purpose, it is planned to have an initial system consisting of sampler, FFT and the associated control circuitry for up to four channels integrated with Raman Research Institute. The correlator for interferometry with the first few dishes of GMRT is expected to be completed towards the end of 1992 (C. R. Subrahmanya, A. K. Dutta, R. Malik, P. Chopra, S. V. Shukla & V. M. Tatke).

A prototype of the software for the Control and Monitor System for the GMRT antennas has been developed and is working in the laboratory. With this system, an operator typing commands on a Sun workstation can control (move, set frequencies etc.) all the antennas of the GMRT and also get back information from the various monitor points at the antennas. Apart from the Sun workstation and its operating system, the rest of the hardware and software have been locally developed. (A. Pramesh Rao, A. Ramakrishna, M. Anturkar, M. Gadgil, B. N. Usha, V. Balasubramanian & B. K. Ravi).

Considerable progress has been made in the design and fabrication of the pulsar machine for GMRT. This dedicated back-end being designed in collaboration with RRI, Bangalore will cater to recording and analysis of GMRT signals for pulsar observations such as pulsar search, pulsar timing, polarimetry, microstructure studies. The basic design has been finalised and construction of prototype cards has begun at RRI, Bangalore. A version for the 4 dish GMRT system will be ready by end of 1992 (Y. Gupta, S. Upreti, G. Swarup and the RRI team).

Further progress has been made on the design of the pulsar timing machine for GMRT. This hardware is being designed at NCRA. It will interface with the rest of the GMRT pulsar machine and will be used for high time resolution studies of pulsars. For this, details of the coherent dedispersion system have been worked out and the hardware design has begun. Development of basic algorithms for software analysis of timing data was also started (Y. Gupta, S. Upreti, G. Swarup and C. R. Subrahmanya).

Parallel processing project

The collaboration with C-DoT, Bangalore to develop a parallel processing system for radio astronomy image processing has been continued. A 16-processor system is now working well at Pune. A 64-processor system is working at C-DoT, Bangalore. Work is in progress to further improve the performance of these system (V. K. Kulkarni, C. R. Subrahmanya and S. Khobragade).

Radioastron project

The engineering model for the 324 MHz low-noise space qualified front-end for the Radioastron VLBI Satellite was successfully completed and delivered to the Astrospace Centre, Moscow. The flight model is under development (S. Ananthakrishnan, A. Praveen Kumar, N. G. Sreedharan & the SAC Group, Ahmedabad).

Conferences organized by the group

GMRT Winter School (January 10-18, 1992)

A Winter School on 'Solar Radio Astronomy and Interplanetary Medium' was successfully organised at the Institute of Radio Physics and Electronics (IRPE), Calcutta, between January 10-18, 1992. There were about 40 participants from various Universities and Institutions in India including Madurai Kamaraj University, Kerala University, Saurashtra University, Aligarh Muslim University, I.I.T. Kharagpur, Gorakhpur University, Physical Research Laboratory, Raman Research Institute, Indian Institute of Astrophysics, National Physical Laboratory, Tata Institute of Fundamental Research and from universities in Calcutta. About 32 students from IRPE also attended the lectures. The list of the speakers of the Winter School included visitors from abroad : Dr Tim Bastian from National Radio Astronomy Observatory, Socorro, USA, Dr C. J. Gibbins from Rutherford Appleton Laboratory, U. K., Prof. M. R. Kundu and Dr N. Gopalaswamy from University of Maryland and Dr C. Mercier from Observatoire de Paris, Meudon. Dr S. Alurkar, Dr V. Balasubramanian, Prof. Arvind Bhatnagar, Prof. S. M. Chitre, Mr P. Gothoskar, Mr R. Malik, Dr P. K. Manoharan, Dr A. P. Rao, Dr A. K. Sen, Prof. R. K. Shevagaonkar, Dr R. P. Sinha, Prof. G. Swarup, Prof. P. V. Venkatakrishnan, and Prof. V. R. Venugopal were the other invited speakers from different institutions and universities in India. The Winter School was inaugurated by Dr A. P. Mitra, Bhatnagar Fellow, on January 9, 1992. Funding for the School was kindly provided by the Department of Science and Technology and effective logistics support was provided by the local host, The Institute for Radio Physics and Electronics, Calcutta University.

Considerable interest has been developed among the Universities in the Calcutta region for starting a programme for providing research facilities in Solar Radio Astronomy and for training staff and students from Universities in the general field of Radio Academy.

Young Astronomers' Meet (YAM) (February 10-13, 1992)

The first Young Astronomers' Meet (YAM), 1992 was held at the National Centre for Radio Astrophysics and the Inter University Centre for Astronomy & Astrophysics, Poona University Campus, Pune from February 10-13, 1992. It was funded by the Department of Science &

Technology and organized by the research students of NCRA and IUCAA. YAM was organized to provide a forum to research students in Astronomy and Astrophysics from all over the country to interact with each other and get to know the work being done in other universities and research institutes. Such meetings could foster collaborative work at the level of research students and improve their skill in presenting their work to fellow researchers.

Nineteen outstation participants took part in this meet in addition to ten students from the two host institutes. The programme consisted of presentations by students of their work, special talks by invited speakers from various institutes and a visit to the GMRT site at Khodad. Students of Raman Research Institute, Bangalore and Indian Institute of Science, Bangalore have agreed to organize YAM 1993.

Participation in Conferences, Workshops, Schools, Symposia and Meetings

International

STScI workshop on 'Active Galactic Nuclei at High Redshifts', Baltimore, August 21-23, 1991. V. K. Kapathi

World Administrative Radio Conference (WARC) 1992 for allocation of frequencies, Malaga-Torremolinos, Spain, February 3-March 2, 1992. R. P. Sinha, G. Swarup.

XXI General Assembly of the International Astronomical Union, Beunos Aires, July 23-August 1, 1991. G. Swarup.

National

GMRT Winter School on Radio Astronomy and Interplanetary Medium, Calcutta, January 10-18, 1992. V. Balasubramanian, P. Gothoskar, R. Malik, P. K. Manoharan, A. P. Rao, R. P. Sinha, G. Swarup.

Invited talks

V. K. Kapahi

The most distant radio galaxies, 57th Annual Meeting of the Indian Academy of Sciences, Pune, November 9, 1991.

D. J. Saikia

(1) Spectra and structure of quasars, (2) BL Lacs and highly polarized quasars, (3) Variability of active nuclei, (4) Unification schemes, IUCAA miniworkshop on quasars : continuum and line radiation, Ravishankar University, Raipur, December 1991.

Splendours of the radio universe : Galactic sources, School on Introductory Astronomy, IIT, Madras, March 1992.

Splendours of the radio universe : Extragalactic sources, School on Introductory Astronomy, IIT, Madras, March 1992.

Visits abroad

S. Ananthakrishnan took up a senior NRC Research Associateship at the Space Environmental Laboratory (SEL) of NOAA at Boulder, Colorado, USA, from August 1991 on sabbatical.

Gopal Krishna visited the European Southern Observatory (ESO), Chile from October to December, 1991.

V. K. Kapahi spent two weeks at the Space Telescope Science Institute, Baltimore, U.S.A. in August-September 1991.

A. K. Singal was a visiting scientist at the Max-Planck Institute fuer Radioastronomie till July 1991 and took up a visiting position at the Netherlands Foundation for Research in Astronomy, Dwingeloo, Netherlands.

R. P. Sinha attended the meeting on the formation of AIPS^{++} Consortium at National Radio Astronomy Observatory, Socorro, USA from July 4-7, 1991.

R. Subrahmanyan has been a visiting Postdoctoral Fellow at the Australia Telescope National Facility (CSIRO), Australia.

G. Swarup visited U. K. in July 1991 to attend the Formal Ceremony of Admission to the Royal Society on July 11, 1991; he also visited the Institute of Astronomy, Cambridge, the Nuffield Radio Astronomy Laboratories, Jodrell Bank, the Netherlands Foundation for Research in Astronomy, Dwingeloo and the Kapteyn Laboratorium, Groningen in the Netherlands.

Lectures by visitors

Verun Sahni (Inter University Centre for Astronomy & Astrophysics, Pune) : *The adhesion model and the large-scale structure of the Universe.* (5.4.1991)

N. Shapirovaskaya (Lebedev Physical Institute, USSR) : *Intraday variations of extragalactic sources : Diffractive interstellar scintillations ?* (6.4.1991)

Y. Kovalev (Lebedev Physical Institute, USSR) : *Multi-frequency monitoring programme for extragalactic variable sources : some results of a ten-year study.* (6.4.1991)

P. K. Saha (Institute of Radio Physics & Electronics, Calcutta) : *A review of horn antennas as feed for microwave reflectors.* (20.4.1991)

P. K. Saha (Institute of Radio Physics & Electronics, Calcutta) : *Corrugated waveguides as low noise feed.* (22.4.1991)

Sanjay Wagh (Inter University Centre for Astronomy & Astrophysics) : *How does a black hole lose its energy?* (26.4.1991)

G. Buvana (Student Trainee from Madura College, Madurai) : *The galactic population of pulsars.* (15.6.1991)

K. Rajmohan (Student Trainee from Andhra University, Waltair) : *Lobes of radio galaxies.* (18.6.1991)

G. Ganesh (Student Trainee from Anna University, Madras) : *Design of logarithmic amplifier.* (28.6.1991)

Avijit Bhattacharya (Student Trainee from IIT Kanpur) : *Data transmission on VHF link.* (1.7.1991)

Malay Ganai (Student Trainee from IIT Kanpur) : *Data transmission on VHF link.* (1.7.1991)

Dhiraj Goswami (Student Trainee from IIT Kanpur) : *QPSK (theoretical aspects).* (1.7.1991)

Divas Sanwal (Student Trainee from IIT Kanpur) : *QPSK (ckt design).* (1.7.1991)

Niranjan Thatte (Univ. of California, USA) : *Novel cryogenic receiver for the Berkeley Illinois Maryland Array* (19.7.1991)

Paul Wiita (Georgia State University, Atlanta, USA) : *Extremely rapid variability in blazars : observations and models* (2.8.1991)

V. Balasubramanian (RAC, Ooty) : *Stretched membrane solar energy concentrators.* (5.8.1991)

P. K. Manoharan (RAC, Ooty) : *Solar-wind studies using single station interplanetary scintillations.* (9.8.1991)

Puragra Guhathakurta (Institute of Advanced Study, Princeton, USA) : *Imaging of faint galaxies and lensing.* (12.8.1991)

Puragra Guhathakurta (Institute of Advanced Study, Princeton, USA) : *Infrared, optical, radio 21 cm and CO studies of Galactic cirrus.* (14.8.1991)

Nimesh Patel (Raman Research Institute, Bangalore) : *Circumstellar SiO MASERS.* (20.8.1991).

M. P. Mathur (Regional Engineering College, Kurukshetra) : *Computer aided antenna design.* (22.8.1991)

S. V. Damle (TIFR, Bombay) : *Natalya-II gamma ray astronomy experiment on PHOTON satellite.* (23.8.1991)

Debiprosad Duari (Inter University Centre for Astronomy & Astrophysics, Pune) : *Are quasar redshifts periodic?* (4.10.1991)

Prasenjit Saha (CITA, Canada) : *New and not-so-new methods in dynamical astronomy.* (1.11.1991)

A. D. Gangal (Poona University, Pune) : *Wavelet transform : Time frequency methods and phase space.* (15.11.1991)

Anil Degwekar (Centre for Development of Advanced Computing, Pune) : *PARAM Computer System.* (22.11.1991)

Kenneth Lang (Tufts University, USA) : *(i) Radio emission from single stars the Sun.* (5.12.1991) *(ii) Radio emission from single stars. flare stars.* (5.12.1991) (iii) *Wanderers in Space.* (11.12.1991) (iv) *Radio emission from Interacting Binary Stellar Systems.* (12.12.1991)

Ratan Bisht (Inter University Centre for Astronomy & Astrophysics, Pune) : *Star formation : A study through the Far Infrared (FIR) window.* (27.12.1991)

M. Vivekanand (Raman Research Institute, Bangalore) : *Optical Interferometry.* (23.1.1992)

Michael Bietenholz (Univ. of Toronto, Canada) : *Activity near the Crab and Vela pulsars.* (21.2. 1992)

A. A. Deshpande (Raman Research Institute, Bangalore) : *Pulsar observations at the University of Tansmania* (13.3.1992).

Ch. V. Sastry (Indian Institute of Astrophysics, Bangalore) : *The Mauritius Radio Telescope.* (17.3.1992)

Ch. V. Sastry (Indian Institute of Astrophysics, Bangalore) : *Solar radio observations with the Gauribidanur telescope.* (18.3.1992)

Colloquia and seminars

Y. Gupta : Refractive interstellar scintillation of pulsar signals. (12.4.1991)

Gopal Krishna : High-redshift galaxies : what about them? (19.4.1991)

Rakesh Malik : Solar radio bursts. (22.4.1991)

A. P. Rao : The Giant metrewave radio telescope. (14.6.1991)

G. Swarup : Highlights from the IAU General Assembly in Buenos Aires. (16.8.1991)

Sanjay Upreti : Digital pulsar search techniques. (17.8.1991)

Pradeep Gothoskar : Modelling the solar wind. (21.8.1991)

Sanjay Bhatnagar : Focal plane coherence function. (27.81991)

V. K. Kulkarni : Compact steep spectrum radio sources.

Ramana Athreya : Unification schemes. (25.9.1991)

Joydeep Bagchi : Radio properties of clusters of galaxies. (29.11.1991)

Abhijit Dutta : The GMRT correlator system. (29.1.1992)

Graduate courses

Graduate School at Pune

The IUCAA-NCRA Astronomy Programme was started in 1991 with twelve students in the first batch. Of these twelve, nine students were from NCRA (TIFR). The graduate school programme consists of eight core courses, one optional course, one reading project and an advanced minor research project during the third semester. The core courses and their teachers were as follows :

1. Mathematical Methods (Sanjeev Dhurandhar, IUCAA).
2. Electrodynamic Theory and Radiative Processes (K. Subramanian, NCRA).
3. Quantum and Statistical Mechanics (Patrick Dasgupta, IUCAA).
4. Astronomy and Astrophysics (Ajit Kembhavi, IUCAA).
5. Astronomical Techniques (S. N. Tandon, IUCAA).
6. The Galaxy and the Interstellar Medium (Y. Gupta & K. Subramanian, NCRA, N. C. Rana, IUCAA).
7. Computer Oriented Numerical Methods (V. K. Kulkarni, NCRA).
8. General Theory of Relativity, Cosmology and Extragalactic Astronomy (N. Dadhich & V. Sahni, IUCAA, D. J. Saikia, NCRA).

The optional course 'Signal Processing' was given by C. R. Subrahmanya.

Lecture courses delivered outside the institute

D. J. SAIKIA

Introductory Astronomy (8 lectures), Jyotir Vidya Parisanstha, Pune.

Extragalactic Astronomy (17 lectures). Second year M.Sc. students, Poona University, Pune.

C. R. SUBRAHMANYA

Signal processing (43 lectures). Second year M.Sc. students, Poona University, Pune.

S. ANANTHAKRISHNAN

Solar wind velocity measurement from a single station using interplanetary scintillation. Space Environmental Laboratory, Boulder, USA, November 1991.

V. BALASUBRAMANIAN

The Giant metrewave radio telescope. VLB Janaki Ammal College of Engineering and Technology, Coimbatore, July 1991.

Cultivation of experimental skills. Science Talent Exhibition at Sri Ramakrishna Mission Vidyalaya Arts College, Coimbatore, September 1991.

Pulsars—Recent advances. Seminar on 'Recent Trends in Cosmology and Astrophysics', held at N.G.M. College, Pollachi, Tamil Nadu, February 1992.

GOPAL KRISHNA

A radio test of the quasar-radio galaxy unification scheme. European Southern Observatory, Chile, November 1991.

V. K. KAPAHI

High Redshift Radio Galaxies. Raman Research Institute, Bangalore, April 1991.

D. J. SAIKIA

The sky at different wavelengths. Spicer Memorial College, Pune, February 1992.

A glimpse of astronomical objects. Slide show and talk as part of Science Day celebrations, IUCAA, Pune, February 1992.

G. SWARUP

Neutral hydrogen at high redshifts and Giant metrewave radio telescope (GMRT). National Radio Astronomy Laboratories, Jodrell Bank, UK, July 15, 1991. Westerbork Radio Observatory, Netherlands, July 18, 1991. Kapteyn Laboratory, Netherlands, July 19, 1991.

Giant Metrewave Radio telescope (GMRT). IAU General Assembly, Buenos Aires, Argentina, July 25, 1991.

Protection of radio Astronomy services from radio frequency interference in India. IAU General Assembly, Buenos Aires, Argentina, July 31, 1991.

Splendour of the radio universe. INSA Scientific Forum, Fergusson College, Pune, October 16, 1991.

Search for neutral hydrogen clouds and Giant metrewave radio telescope. Indian Academy of Sciences, Annual Meeting, NCL, Pune, November 9, 1991.

Giant metrewave radio telescope and solar radio astronomy. GMRT Winter School, Calcutta, January 11, 1991.

Exploration of the radio universe. Santhanu Ghosh Memorial Lecture, Indian Physical Society, Calcutta, January, 13, 1992.

Giant metrewave radio telescope (GMRT)—India's thrust towards excellence. Homi Bhabha Anniversary Lecture, Institution of Engineers, Bombay, January 24, 1992.

Splendour of the radio universe. Science Day Lecture, Defence Scientific Information & Documentation Centre, New Delhi, February 28, 1992.

T. VELUSAMY

Physical Processes in interstellar medium. Seminar on 'Recent Trends in Cosmology and Astrophysics', held at N.G.M. College, Pollachi, Tamil Nadu, February 1992.

National and international involvements

S. Ananthakrishnan : Member, Radioastron International Scientific Council.

V. Balasubramanian : Member, Solar Energy Sectional Committee HMD-04 Bureau of Indian Standards, for preparing standards for Solar thermal devices.

V. K. Kapahi : Member, Editorial Board, Indian Journal of Radio and Space Physics, CSIR, New Delhi. Member, Editorial Board, Journal of Astrophysics & Astronomy, Indian Academy of Sciences, Bangalore. Member, Programme Advisory Committee, Department of Science and Technology, New Delhi. Co-convenor, National Organizing Committee and Co-chairman, Local Organizing Committee, 6th Asian Pacific Regional Meeting on Astronomy, Pune, 1993.

G. Swarup : Co-Chairman, Scientific Organizing Committee of the 6th IAU Asia-Pacific Regional Meeting, Pune, 1993. Member, Editorial Board, National Academy of Science Letters and Proceedings of the National Academy of Sciences, Allahabad, India.

Awards and distinctions

V. K. Kapahi was Awarded the Henri Chretien International Research Grant Prize for 1991 by the American Astronomical Socety.

Ph.D. Theses

D. K. Mohanty : *A search for pulsating radio sources in the neighbourhoods of supernova renmants* (Guide : G. Swarup).

P. K. Manoharan : *Study of solar wind using single-station interplanetary scintillation* (Guide : G. Swarup).

Publications

In Journals

V. Balasubramanian & G. Sankarasubramanian : The stretched membrane design of a compound parabolic through collector, *SESI J.*, **1**, 35 (1991)

Gopal-Krishna & P. J. Wiita : Gaseous halos of elliptical galaxies, the cosmic evolution of their radio sizes and the phenomenon of compact steep spectrum sources, *Astrophys. J.*, **373,** 325 (1991).

Gopal-Krishna : Cosmic evolution of linear sizes and luminosity function of powerful radio galaxies : Is there a common cause ? *Astron. Astrophys.*, **248,** 415 (1991).

Gopal-Krishna, E. Giraud, J. Melnick & H. Steppe-: An ultra-steep spectrum double radio sources associated with an extremely low excitation emission-line galaxy, *Astron. Astrophys.*, **254**, 42 (1992),.

Gopal-Krishna & V. K. Kulkarni : The unification of radio galaxies and quasars and their linear size evolution, *Astron. Astrophys.*, **257,** 11 (1992).

P. J. McCarthy, W. van Breugel & V. K. Kapahi : Correlated radio and optical asymmetries in powerful sources, *Astrophys. J.*, **371,** 478 (1991).

P. J. McCarthy, W. van Breugel, V. K. Kapahi & C. R. Subrahmanya : High redshift radio galaxies from the Molonglo catalogue—II, *Astron. J.*, **102,** 522 (1991).

D. L. Jauncey, *et al.* : An unusually strong Einstein ring in the radio source PKS 1830-211, *Nature*, **352,** 132 (1991).

D. J. Saikia, C. J. Salter, D. G. Banhatti, T. Ghosh, P. Gothoskar & P. K. Manoharan : The Ooty summer training programme, *Bull. Astr. Soc. India,* **19,** 109 (1991).

E. Hummel & D. J. Saikia : The anomalous radio features in NGC 4388 and NGC 4438, *Astron.. Astrophys.*, **249,** 337 (1991).

A. K. Singal : On the charge invariance and relativistic electric fields from a steady conduction current, *Phys. Lett. A.*, **162,** 91 (1992).

A. K. Singal : Energy-momentum of the self-fields of a moving charge in classical electromagnetism, *J. Phys. A*, **25,** 1606 (1992).

R. Subrahmanyan : 330 MHz radio continuum observations of the HII regions M42 and M43, *MNRAS*, **254,** 291 (1992).

R. Subrahmanyan : Radio jet in HII region Orion B, *MNRAS*, **254,** 719 (1992).

J. H. Zhao, D. A. Roberts, W. M. Goss, D. A. Frail, K. Y. Lo, R. Subrahmanyan, M. J. Kestervan, R. D. Ekers, D. A. Allen, M. G. Burton & J. Spyromilio: A transient radio source near the centre of the Milky Way Galaxy, *Science,* **255,** 1538 (1992).

S. Djorgovski, G. Meylan, A. Klemola, D. J. Thompson, W. N. Weir, G. Swarup, A. P. Rao, R. Subrahmanyan & A. Smette : A search for the opticl/IR counterpart of the probable Einstein ring source 1830-211, *MNRAS*, **257,** 240 (1992).

K. Subramanian & Gopal-Krishna : Enhanced probability of intensity outbursts via superluminal microlensing of quasars, *Astron. Astrophys.*, **248,** 55 (1991).

T. Velusamy & Anish Roshi : High resolution radio images of the Crab Nebula, *Curr. Sci.*, **60,** 120 (1991).

T. Velusamy, R. H. Becker & F. D. Seward : G 33.6 + 0.1 : A shell type supernova remnant with unusual structure, *Astron, J* , **102,** 676 (1991).

T. Velusamy, Anish Roshi & V. R. Venugopal : Crab Nebula filaments : Expansion and radio spectra, *MNRAS*, **255,** 210 (1992).

In Proceedings

V. Balasubramanian, S. Jayaraman, K. Perumal & G. Sankarasubramanian : In situ solar steam generation with CPC modules, *ISES Solar World Congress,* Denver, USA, 1991.

V. Balasubramanian : Important aspects of configuring stand-alone solar photovoltaic water pumping installations to achieve high reliability and system efficiency, *Proc. Sixth Intrnational Photovoltaic Science and Engineering Conference,* New Delhi, 1992.

Gopal-Krishna & P. J. Wiita : AGN variability and polarization via swinging jets, *Bull. Amer. Astr. Soc.*, **23,** 1431, 1991.

A. P. Rao : GMRT Mapping Strategies, in 'Radio Interferometry—Theory, Techniques and Applications, eds: T. J. Cornwell and R. A. Perley, *ASP Conf. Ser.*, **19,** 212 (1991).

D. J. Axon, P. Collison, A. Pedlar & D. J. Saikia : Young Supernovae in starburst nuclei—Hot gas in the Galaxy, ed. : P. M. Gondhalekar, *SERC Rutherford Appleton Laboratory*, 106 (1991).

D. J. Saikia, P. J. Wiita & T.W.B. Muxlow : The peculiar radio quasar 122 + 216, *Bull. Amer Astr Soc.*, **23,** 1426 (1991).

C. R. Subrahmanya : Low frequency imaging and the non-isoplanatic atmosphere, in 'Radio Interferometry—Theory Techniques and Applications, eds.: T. J. Cornwell and R. A. Perley, *ASP Conf. Ser.*, **19,** 218 (1991).

G. Swarup : Giant Metrewavelength Radio Telescope (GMRT), in 'Radio Interferometry—Theory, Techniques and Applications (eds.: T. J. Cornwell and R. A. Perley), *ASP Conf. Ser.*, **19,** 376 (1991).

T. Velusamy : Supernovae, Supernova Remnants and Pulsars—Report on Working Group IV, *Proc Workshop on Supernovae and Stellar Evolution*, eds. : A. Ray and T. Velusamy, World Scientific, Singapore, 1991.

Books

Alak Ray and T. Velusamy : editors, 'Super novae and Stellar Evolution', *Proc of the School/Workshop held at Goa, March 8-17, 1989*, World Scientific, Singapore, 1991.

Internal Reports, Patents and Technical Reports

S. Bhatnagar : Software environment for parallel processing.
S. Bhatnagar : Time analysis for the C-DoT PPS.
G. Chattopadhyay : Round trip phase correction for GMRT LO and IF Systems.
Y. Gupta : A technique for instrumental polarization calibration.
Y. Gupta and S. Upreti : GMRT polarization calibration and pulsars.
V. K. Kapahi : Surface errors and aperture efficiency of GMRT dishes.
V. K. Kulkarni : Simulation of GMRT observing fields.
R. K. Malik : Dynamic spectrograph : Design details.
A. Ramakrishna : Fibre optic video signal transmission.
A. P. Rao : Overview of GMRT online computer system (software).
A. P. Rao and C. R. Subrahmanya : Walsh switching—Required accuracy and possible schemes.
C. R. Subrahmanya : Maximum data rate from GMRT correlator.
C. R. Subrahmanya : Operating modes of GMRT correlator.

Bull Astr. Soc. India (1993) **21,** 159-164

Uttar Pradesh State Observatory, Naini Tal

REPORT FOR THE PERIOD 1990 JANUARY 1-1991 DECEMBER 31

Solar physics

Spectroscopy of the sun

Identification of the $A^1\Pi - X^1\Sigma$ transitions of the CH^+ molecules in the solar spectrum was reinvestigated by Sinha & Tripathi (1990) using new laboratory data on molecules, standard photospheric models, the KPNO and the Liege solar atlases. They believe that CH^+ lines may not be detectible in the solar spectrum, though the predicted upper limits of equivalent widths exceed the observed upper limit by a factor of 6. A possible explanation for the absence of CH^+ lines is also suggested.

The partial pressures of 20 ionic molecular species are studied by Sinha & Tripathi (1990) for standard facular, photospheric and sunspot model atmospheres with a view to picking up ionised molecules for a possible identification in the solar spectrum. Comparing the partial pressures with those of the molecules SiH^+, which is already detected in the solar spectrum, it appears probable that additional ionic species can be identified in the same spectrum. To predict the line intensities of such species, accurate values of oscillator strengths and dissociation energies are needed.

With a view to assess the role of changing magnetic field strengths on line intensities, the results of equivalent width calculations of some lines of C_2, MgH and TiO molecules are studied by Sinha & Tripathi (1991) for standard photospheric and sunspot model atmospheres. Such an approach is expected to throw some light on evolution of sunspots and on a better structuring of semi-empirical sunspot models by way of correct evaluation of scattered photospheric light.

Utilizing the model atmospheres proposed by Sobotka for umbrae of different sizes and those proposed by Maltby *et al.* for well developed umbare, at different phases of solar activity, Sinha & Tripathi (1991) had examined the molecules C_2, MgH and TiO for a study of sunspot evolution.

In view of the already available reviews on the subject, the progress after 1972 is summarised by Sinha (1991). Newly identified species and molecular transitions are listed. How the studies of solar molecules can be helpful in understanding the solar atmosphere, in structuring better models and in deriving molecular parameters with some degree of confidence, is stated.

The partition functions of the H_3^+ molecular ion have been calculated by Chandra *et al.* (1990) for temperatures from 500 to 8000 K. They have accounted for the rotational levels in seven vibrational bands in the ground electronic state of H_3^+.

Solar activity

On the basis of Kippenhahn and Schluter's magnetohydrostatic model of a quiescent prominence, an attempt has been made to study the effect of irrotational motion existing in the prominences on the magnetic field pattern in it, introducing an irrotational velocity field. It is found that, under such a condition, the magnetic field geometry in the model does not change (Pande & Bondal 1990).

On the basis of Kippenhahn and Schluter's magnetohydrostatic model of a quiescent prominence Pande & Bondal (1991) have attempted to study the effect of a rotational velocity field in it. They find that a physically plausible solution is not possible in the vertical plane. A possibility, however, is shown in the horizontal plane, with certain assumptions to get equal velocity contours.

It is shown that for certain definite conditions of symmetry imposed on the permitting magnetic field geometry for an isothermal case in Kippenhahn and Schluter's (1957) model of a quiescent prominence, any irrotational velocity field would quickly get converted to rotational (Bondal & Pande 1991).

Verma (1990) studied the relationship between coronal mass ejection (CME) events with solar flares and coronal holes. Out of 79 CME events whose locations and spans are known, 10 CME event circles contain solar flares. On the other hand out of 71 CME events (selected for the study with coronal holes) 40 CME event circles contain coronal holes. Verma (1990) examined the above associations by calculating Yule coefficients of association and found that the CME events and solar flares are statistically not associated while CME events and coronal holes are statistically associated. This does not necessarily indicate that CMEs come from coronal holes as claimed by Hewish & Bravo (1986).

Uddin *et al.* (1990) have studied the relation between solar proton flares and associated optical radio and X-ray events. It was found that proton flares are usually associated with large optical flares in H-alpha ($\geq$ 2 B) and long duration type II and IV, microwave and hard X-ray bursts. The summation curve analysis shows that a sharp rise in the cummulative flares index seems to be a prerequisite for the occurrence of proton flares. The correlation studies between proton flares and microwave and proton flares and hard X-ray have also been carried out. The results obtained in the present analysis may be used to predict solar proton flares.

A team of astronomers from the Indian Institute of Astrophysics, Bangalore and the Uttar Pradesh State Observatory, Naini Tal set up a solar telescope at Maitri, India's permanent base on Antarctica. Three of the scientists, who were part of the ninth Indian Antartic expedition, use the telescope between December 1989 and March 1990—the Antarctic summer to study convection process in the solar photosphere (Singh *et al.* 1990).

The distribution of the sunspots for the period 1967-1987 (solar cycles 20 and 21) is presented here. Uddin *et al.* (1991) find that the $\pm$ 11 – 20° latitude belt is most prolific for the occurence of various spot types irrespective of magnetic field ranges. Furthermore, longitudinally sunspots occur most prolifically at six or more places on the Sun. Spatially 7-9 zones are present in each hemisphere (north and south) of the Sun where about 50% sunspots occur and occupy only about 40% area of the Sun. During the above cycles at least

5 flare zones were regularly present in each hemisphere. The existing models cannot explain these active zones on the Sun. Thus, the present analysis emphasizes the need for a new magnetic model of the Sun.

Verma (1991) find that gamma-ray line (GRL) emissions start later than the hard X-ray (HXR) emissions during impulsive and extended solar flares. Starting delay is more in the case of extended solar flares suggesting a slow acceleration of electrons and ions, in comparison to impulsive solar flares which indicate different acceleration mechanisms for impulsive and extended solar flares. Verma (1991) further infer that during solar flares, electrons and ions are accelerated simultaneously and the delay between HXR and GRL emissions results mainly due to differences in acceleration times of electrons and ions to attain energies required for producing HXR emissions for electrons and GRL emissions for ions. Verma (1991) is of the view that a single step acceleration mechanism may work in solar flares.

Verma *et al.* (1991) have carried out a power spectrum analysis of the daily number of solar flares producing type I, II, III, IV and V radio bursts for the period 1980-1984. The analysis shows that type II and IV radio bursts confirm the existence of a 152-158 days periodicity in the rate of occurence, while type I, III and V radio bursts do not show that periodicity. They conclude that only type II and IV radio bursts should be used as a parameter which indicates the solar activity.

Miscellaneous papers

Research papers published in the Bulletin of the Astronomical Society of India during the 17 year period since its inception in 1973 to 1989 have been examined with a view to discern the publication trends. It is pointed out that 73% of the published papers were accepted within 100 days of their receipt at the editorial office. Some comments are made on the declining popularity of the Bulletin (Gupta & Sinha 1991).

Stellar and cometary physics

Physical study of comets

Spectrophotometric scans in the visible region have been obtained for comet Bradfield (1987s), P/Halley and comet Okazaki-Levy-Rudenko (1989r). Abundances and production rates of CN, C_2 and C_3 have been determined for those comets using Haser model. It is found that the production rates of molecular species decrease with increasing heliocentric distance while the dust production rate is almost constant at different heliocentric distances.

Stellar studies

Photometric and period studies have been done for a number of eclipsing binary stars TX Ceti, IT per, SZ Ari, AL Cam, DF Hya, V450 Her, ER Vul and RS CVn. UBV photometry of RS CVn shows wave like distortion in the light curve. Spectrophotometry of AR Lac has been done in the visible region during total eclipse and outside eclipse. The continuum energy distribution of the primary component of AR Lac yielded $T_e = 6000$ and $\log g = 4.0$. Spectrophotometric observations of the RS CVn binary UX Arietis show that the temperature does not vary significantly. These observations also reveal a brightness variation of $0^m.23$

but the effective temperature obtained with the help of model stellar atmospheres shows no significant variation. Therefore, this brightness variation may be due to change in the surface emitting region.

A number of binary systems have been investigated to study their power output by gravitational radiation and spiralling time relation.

Temperature estimates and certain peculiarities in the energy distribution curves of high rotational velocity B type stars HR 1207 and HR 1776 have been discussed.

The radial velocity for hydrogen Balmer and HeI 3888 Å shell lines of spectroscopic binary Be star ϕ Per have been obtained. There is a synchronous variation of V/R ratio with radial velocity. Mass and density of the gases in the envelope are estimated but it is difficult to explain the envelope size of the primary component which extend the Roche lobe.

A total number of 103 nearby main sequence stars of spectral types F and G have been searched for infrared excess in order to find 'Vega like' characteristics. Only four F type stars are found to be Vega like. Equilibrium distances of dust shells in these stars are within the planet forming region.

Clusters

It is found that in open clusters the differential extinction decreases with the age of the cluster. Consequently, the gas removal time must be 10^8 yr. The study supports the existence of a corona around open clusters which remains dynamically stable in the tidal forces of the Galaxy. It has been found that the star formation efficiency in clouds of various masses depends on IMF.

It is found that the slope of mass function is steeper in the outer part of young open clusters and mass segregation might have taken place at the time of cluster formation. Integrated luminosity distribution of galactic open clusters has been studied.

Study of the data on open clusters, WR stars and supernova remnants (SNRs) suggests that the planes of symmetry defined by them are inclined with respect to the formal galactic plane. The location of the Sun with respect to these planes of symmetry has been obtained. Ages of clusters in LMC have been obtained. The age distribution supports the conclusion of a burst in the cluster formation rate about 3 Gyr ago.

Galaxies

The investigation of a few Markarian galaxies shows that Markarian and other active galaxies are more blue than those for normal NGC galaxies. The comparison of stellar colours suggest the presence of excess of early type stars in the active galaxies and the presence of nonthermal component of radiation. The higher infrared luminosity (L_{80}) Markarian and other active galaxies in the sample may be due to reradiation in the infrared by the excess gas and dust in the nuclear regions of the galaxies.

Instrumentation

Practical method to increase coating uniformity and reduce pin holes in a vacuum coating unit has been suggested. The design of evaporation source assembly for small units has been simplified.

A star tracker/imaging camera has been installed in the 20 cm guiding refractor of the 104-cm telescope for automatic tracking.

An optical multichannel analyser system has been acquired for use at the Cassegrain focus of the 104-cm telescope. The system consists of a 1024 element reticon array, a spectrograph, an interface for remote operation, a 14 bit ADC and a system processor for data acquisition and analysis. There are two gratings, one gives dispersion of 0.25 nm/element and the other gives a dispersion of 0.215 nm/element. The data can be stored on a 5".25 floppy disk. For image processing, a Sun Sparc I Workstation has been acquired. IRAF and VISTA software packages have been installed.

Doctoral Theses

K. R. Bondal, B. B. Sanwal, U. S. Chaubey, A. K. Pandey and M. Singh have received their Ph.D. degree.

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Indian Institute of Astrophysics

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THE SUN

Modelling of Sun's primordial magnetic field using its helioseismologically determined internal rotation

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 : $(0.624 \pm 0.106)\ B_0 R_\odot^3$ and $(0.156 \pm 0.046)\ B_0 R_\odot^5$ respectively, where B_0 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 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 $B_0\ R_\odot^2$ 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. Gokhala, 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 $\nu_0 = 1/21.4\ \text{yr}^{-1}$, which define 4 independent 'geometrical modes' of Sun's global oscillations, each covering a different range in the degree l, 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 $\nu = 3\nu_0$ and at $\nu = 5\nu_0$. It is found that the SHF terms of these frequencies also define approximately the same four 'geometrical modes' as those defined by terms with frequency ν_0. Thus it is confirmed that the power in the harmonics $3\nu_0$ and $5\nu_0$ is not due to any independent modes other than those of frequency ν_0.

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 observations. 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 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 $\Phi < 10^{18}$-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_{H2V} and in red I_{H2R}; the ratio I_{H2R}; the intensity at the absorption core I_{H3} and the Doppler shift of the H_3 core $\Delta\lambda_{H3}$.

The light curves of I_{H2V} 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 ~ 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 ~ 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 ~ 8.1×10^6 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 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 314Å with spectral resolution of the order of 0.1Å 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 sunpots and H-alpha filaments from the Kodaikanal data, the evolution of the shear angle during 2 days prior to and after the 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 characteristics 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 mirobursts 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).

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 magnetograh 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 frames at different positions of the halfwave retarder and then fitting a cos 4θ and sin 4θ 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).

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 north-west 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 acount 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 (~ 2-5$M_\odot$) 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 (λλ 6347, 6371), He I (λλ 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 –μ 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. 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. 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*β ($V/R < 1$ with emission intensity 2.21_{cont}) seen in 1991 May has changed to a P-cygni profile with $V/R = 0.54$ and emission intensity $= 2.3\ I_{cont}$ 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_{cont} with a blueshift of the line-centre by more than 6 Å. (3) The Hα emission intensity increased from 9.8 I_{cont} to 12.7I_{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 (K. K. Ghosh, M. J. Rosario, G. Selvakumar, K. Kuppuswamy).

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 CII (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*β, 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, 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 of 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. Iyenger).

Helium stars

Optical photometry of helium stars has been combined with their mid-ultraviolet photometric indices determined from the observations of TDI satellite and analysed. It has been shown that segregating helium stars from normal B-type objects is possible using with some care the index $\Delta_3 = m_0$ (2740 – 2365) + m_0 (2365 – 1965) and $(U - B)_0$ as well as $(2365 - V)_0$, $(1965 - V)_0$ with c_0. A linear relation is obtained between $(1965 - V)_0$ and the effective temperature derived from model atmosphere analysis. It is also shown that the effective temperatures estimated from $(1965 - V)_0$ 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 ~ 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 observing 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 coudé 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 λλ 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 spaning 4 orders of magnitude in g, a factor of 15 in metallicity i.e. [Fe/H], and a range of spectral type 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 widthof 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. Parthasarathy, *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 + 115, 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 4-128 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. Anupam, T. P. Prabhu).

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 and 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).

OCI 674 (Haffner 14) and OCI 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 $< v^2 (m) > \sim m^{-\theta}$ 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 $z \to 0$ and $K_z \to$ constant for $z \to \infty$, 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 $m_u \approx 6\text{-}8 M_\odot$ 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).

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 ± 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 ~ 10–100 Myr. In the mass range ~ 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 ~ 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).

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 18Å. 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 and 1458 + 22) at the prime focus of VBT using CCD system. We have observed these objects at three angles (0°, 60° and 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 scenatio. (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 $\geq$ 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 perhaps in (1) the aberrational squeezing of the beam at a large emission altitude and (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 eigenfrequencies 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. (H. M. 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 Friend man 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 $H_0 \simeq 40\text{-}50$ km s^{-1} Mpc^{-1} which agrees very well with the observed values of H_0 (Sandage 1988, *Ap. J.*, **331**, 583-604, 605-619; 1991 Preprint).

(ii) The apparent increase in observed H_0 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 (~ 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 (~ 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. 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 TERRESTRIAL PHYSICS

Solar wind-magnetosphere-ionosphere coupling

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 ~ 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 $\approx$ 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 because 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).

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 integration up to 5 sec can be achieved.

The camera uses a P 8603 scientific grade chip (with an organization of 385 × 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 × 512 × 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 motor.

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-lack 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 2M 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. Suitable 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. Jaydev, *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 :

(i) Mirrors (8 inch size) for eclipse, 5 nos.
(ii) Field lenses, 2 nos.
(iii) Lithium neobate crystals, 6 nos.
(iv) 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).

Radio astronomy

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 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 sub-groups 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. Battacharyya).

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 $G = 0.0358 + 0.001111$ cgain $+ 2.2 \times 10^{-7}$ cgain^2 in count per electron. The time taken for the transfer of full frame is 4.96 + 0.08901 cgain 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 ~ 9 arcsec at the prime focus and to a field of ~ 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 ~ f / 120 at prime focus and to ~ f / 480 at Cassegrain focus of the same telescope. A collaborative programme to use the Image Photon Detector (IPD) of PRL, Ahmedabad, to record specklegrams has been made. The surrounding star field of ~ 10 arcmin at the prime focus and of ~ 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 interative 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. 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 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 vactorisation. 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 × 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 cassettee drive and a VT 200 type console. This is a UNIX based machine and has Green hills 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 ethernet 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. Thenetwork 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 system 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 day/nights from meteorological data seem to correlate fairly well with known observatory sites. Devasthal near Naini Tal 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 satsifactory 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. 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 10 cm image of the Sun produced on a screen using a 7.5 cm telescope. (R. C. Kapoor, S. P. Bagare).

Vainu Bappu Observatory

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*.

Colloquia by visiting scientists

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

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

L. Radhakrishnan, Shivaji University, Kolhapur, *Relativistic rheology*. 1991 May 24

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

A. Ratnakar, RRI, Bangalore, *Publication pattern of physicists and astronomers in India*. 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 on-line 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 institute.

The librarian Ms A. Vagiswari participated in the Third International Conferene 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.

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 Conference 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 6-12

Ralph Pudritz, McMaster University, Hamilton, Canada. 1991. July 10-15

Patricia Monger, McMaster University, hamilton, Canada. 1991 July 10-15

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

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

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 17-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 15-21

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 23-27

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

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

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

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

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

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. Hα variability in the quiescent spectrum of the recurrent nova T Coronae Borealis.

Anupama, G. C., *Duerbeck, H. W., Prabhu, T. P., Jain, S. K. (1992) *Astr. Astrophys* , **263,** 87-96. Spectroscopic evolution of nova V443 Scuti 1989.

*Arellano, A., Giridhar, S., Goswami, A. (1991) *Mon. Not. R. astr. Soc.*, **250**, 1-6. A new discussion on the M_V – W_λ (OI 7774) relationship for F-G stars in the light of high resolution data.

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*Bertotti, B., Sivaram, C. (1991) *Nuovo Cimento,* **106B**, 1299-1305. Radiation of the "fifth-force" field.

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.

Bhatt, H. C., Sagar, R. (1992) *Astr. Astrophys. Supl.*, **92,** 473-480. Optical CCD imaging of some Herbig Ae/Be stars.

Chatterjee, S. (1991) *J. Astrophys. Astr.*, **12,** 269-280. Distribution of stars perpendicular to the plane of the Galaxy.

Datta, B., *Sahu, P. K., *Anand J. D., *Goyal, A. (1992) *Phys. Lett. B.*, **283,** 313-318. Eigen frequencies of radial pulsations of strange quark stars.

*de Sabbata, V., Sivaram, C. (1992) *Foundations of Physics Letters,* in press. A new uncertainty relation between time and temperature.

*de Sabbata, V., Sivaram, C. (1992) *Astrophys. Space Sci.*, **187**, 149-154. Torsion, minimum time, string tension and its physical implications in cosmology.

*de Sabbata, V., Sivaram, C. (1991) *Nuovo Cimento,* **104 A,** 1577-1580. The solar neutrino problem.

*de Sabbata, V., Sivaram, C. (1991) *Comm. Theoret Math. Phys.*, **11,** 121-138. Theorems on torsion, time and temperature.

D'Souza, J., Mathew, A., Rajmohan, R. (1992) *J Astrophys. Astr* , **13,** 109-128. Effects of rotation on the colours and line indices of stars. 6. The reality of the blue straggler phenomenon.

Gangadhara, R. T., Krishan, V. (1992) *Mon Not. R. astr. Soc* , **256,** 111-120. The role of Compton and Raman scattering in the quasar continuum.

Gokhale, M. H., Javaraiah, J. (1992) *Sol. Phys.*, **18,** 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. Global modes constituting solar magnetic cycle I : search for dispersion relations.

*Names of collaborators from other institutions.

*Ghosh, S. K., *Bisht, R. S., Iyengar, K. V. K., *Rangarajan, T. N., *Tandon, S. N., *Verma, R. P. (1992) *Astrophys. J.*, **391**, 111-120. Far infrared observations of NGC 4945 and the Circinus galaxy.

Ghosh, K. K., Kuppuswamy, K., Pukalenthi, S., Selvakumar, G. (1991) *Astr. J.*, **102,** 1191-1196. Detection in additional absorption in the post-outburst spectra of μ Centauri.

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Krishan, V. (1991) *Ind. J. Phys.*, in press. Self organization processes in astrophysics.

*Malagnini, M. L., *Morossi, C., *Buser, R. K. , Parthasarathy, M. (1992) *Astr. Astrophys.*, **261,** 558-564. Cool star flux spectra for population studies in galaxies.

Mallik, S. V. (1993) *Astrophys. J.*, **402,** 303. CCD observations of the Hα line in late G and K supergiants and their interpretation.

Mathew, A., Rajamohan, R. (1990) *Bull astr. Soc India,* **18,** 329-339. Effect of rotation on the colours and line indices of stars. 4. The effect on broad band *UVB* colours.

Mathew, A., Rajamohan, R. (1992) *J Astrophys Astr* , **13,** 61-107. Effects of rotation on the colours and line indices of stars. 5. The ZRMS and the ZRZAMS.

Mayya, Y. D. (1991) *J. Astrophys.*, **12,** 319-331. Photometric calibration of the CCD camera of 1-m telescope at VBO.

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Namboodiri, P. M. S., Kochhar, R. K. (1991) *Mon. Not R. astr. Soc.*, **253,** 683-685. On the tidal disruption of a spherical galaxy.

Parthasarathy, M., *Garcia Lario, P., *Pottasch, S. R. (1992) *Astr. Astrophys* , **264,** 159. The chemical composition of the high velocity post AGB star HD 56126 (F5 I).

Parthasarathy, M., Jain, S. K., Bhatt, H. C. (1992) *Astr. Astrophys* , **266,** 202. Possible young stellar objects in the region of Cygnus OB2 (VI Cygni) association from IRAS observations.

Prabhu, T. P., Anupama, G. C. (1991) *Bull. astr. Soc India,* **19,** 97-104. Spectroscopic reductions using RESPECT software.

Prabhu, T. P., Mayya, Y. D., Anupama, G. C. (1992) *J Astrophys. Astr.*, **13,** 129-144. Gain calibrations of CCD systems at VBO.

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Notes/Technical Reports/Newsletters/Circulars

Ananth, A. V., Kutty, A. V. V. (1991) *IETE Technical Review,* **8,** 354-360. A PC based data acquisition system using MODULA-2.

Anupama, G. C., Prabhu, T. P. (1991) *IIA Newsletter,* **6,** 23. Hα variability in the quiescent spectrum of the recurrent nova T Coronae Borealis.

Anupama, G. C., Prabhu, T. P. (1991) *VBT News,* **6 & 7,** 5-7. Gain calibration of the Astromed CCD system at the VBT.

*Kembhavi, A. K., Prabhu, T. P., *Bhat, P. N., *Singh, K. P. (1991) *VBT News,* **8 & 9,** 8-9. Surface photometry of galaxies.

Krishan, V. (1991) *Current Science,* **61,** 433-435. Solar Plasma Physics.

Prabhu, T. P. (1991) *IIA Newsletter,* **6,** 15-17. Calibration of the Photometrics CCD system at the 1-m reflector.

Prabhu, T. P. (1991) *VBT News,* **8 & 9,** 1-5. Evaluation of the CCD system at VBT for astronomical applications.

Prabhu, T. P., Anupama, G. C. (1991) *IAUC* 5255. Supernova 1991 T in NGC 4527.

Prabhu, T. P., Anupama, G. C. (1991) *IIA Newsletter,* **6,** 17-18. Supernova spectroscopy from VBO.

Prabhu, T. P. Anupama, G. C., Mayya, Y. D. (1991) *VBT News,* **6 & 7,** 3-5. Faint object spectroscopy with the VBT.

Prabhu, T. P., Ghosh, K. K., Anupama, G. C., Selvakumar, G. (1991) *IIA Newsletter,* **6,** 12. Nova Herculis 1991.

Prabhu, T. P., Ghosh K. K. Anupama, G. C., Selvakumar, G. (1991) *IAUC* 5236. Nova Herculis 1991.

*Richtler, T., *de Boer, K. S., Sagar, R. (1991) *The Messenger,* **64,** 50-53. Saltpeter mass functions of young populous clusters in the LMC?

Saha, S. K. (1991) *VBT News,* **8 & 9,** 9-10. Speckle imaging.

Sastri, J. H. (1991) *IIA Newsletter,* **6,** 21-23. Ionospheric electric field disturbances associated with changes in magnetospheric convection.

*Singh, K. P., *Bhat, P. N., Prabhu, T. P. *Kembhavi, A. K. (1991) *VBT News,* **8 & 9,** 6. CCD surface photometry of the standard elliptical galaxy NGC 3379.

Surendiranath, R., Rao, N. K. (1991) *VBT News,* **8 & 9,** 11-12. M 4-18 : A low excitation PN around a WC 11 star.

Invited talks at Conferences, Workshops and Seminars

J. C. Bhattacharyya

Inaugural address, Indo-US Workshop on IPS and Propagating Solar Disturbances, Ahmedabad, 1991 September 25-16.

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.

B. Datta

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.

M. H. GOKHALE

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 Progagating Solar Disturbances, Ahmedabad, 1991 September 25-26.

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

K. S. JAIN

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

V. KRISHAN

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.

D. C V. MALLIK

Origin and evolution of planetary nebulae, PRL, Ahmedabad, 1991 September 12.

Y. D. MAYYA

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

M. PARTHASARATHY

(i) *Spectral classification,* (ii) *Evolution of low and intermediate mass stars,* (iii) *Evolution of massive stars,* (iv) *Spectroscopic and eclipsing binary stars,* (v) *Evolution of close binary stars,* DST-sponsored Training Programme in Astronomy, Department of Astronomy, Osmania University, Hyderabad, 1991 April 15-May 11.

A. PERAIAH

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

R. SAGAR

(i) *Stellar photometry on CCD images,* (ii) *Young star clusters of our galaxy,* (iii) *Mass functions of the LMC star clusters,* CASA, Department 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.

(i) *Non-uniform extinction in young open clusters,* (ii) *Spatial distribution of stellar mass in open clusters,* (iii) *Mass functions of star clusters in the LMC,* (iv) *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.

J. H. SASTRI

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

A. K. SAXENA

(i) *Optical concepts in ophthalmology,* (ii) *Thin film coatings and their applications,* Karnataka Optical Association Workshop, Bangalore, 1991 November 10.

(i) *New technology telescope Indian context,* (ii) *Active and adaptive optics system for astronomical application,* Osmania University, Hyderabad, 1992 January 27-28.

C. SIVARAM

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

G. S. D. Babu

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.

S. S. Hasan

5 Min oscillations in sunspots, NATO Advanced Research Workshop on the Theory of Sunspots, Cambridge, England, 1991 September 23-28.

R. C. Kapoor

The effect of specetime curvature on pulsar beam widths, International Conference on Gravitation and Cosmology, Ahmedabad, 1991 December 13-18.

V. Krishan

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

S. V. Mallik

(i) *The Hα line as a diagnostic of cool supergiant chromospheres,* (ii) *The Ca II triplet lines in cool stars,* (iii) *Women in astronomy . the Asian view,* XXI IAU General Assembly, Buenos Aires, Argentina, 1991 July 23-August 1.

N. K. Rao

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

C. Sivaram

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

K. R. Sivaraman, *V. Makarov

Green coronal emission and the global solar cycle, Twelfth NSO/Sacremento 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.

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. Sivaram.*

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, 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 Udipur 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 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 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 Centre 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

G. S. D. Babu (1991) *Wisdom,* September issue, pp. 49-53. The story of the telescope.
J. C. Bhattacharyya, *Science Courier,* in press. Asteroids and planetary systems.
J. C. Bhattacharyya, *Bona Mathematica,* in press. The system of minor planets.
J. C. Bhattacharyya, *Festschrift in honour of U R. Rao,* National Academy of Sciences, in press. Astronomical photometry in India.
R. K. Kochhar (1991) *Economic and Political Weekly,* **26**, 1927-1933. Science as a tool in British India.
V. Krishan (1991) *Current Sci.,* **60**, 662. The justice delayed...case of Lisa Meitner.

Book reviews

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

H. C. Bhatt (1992) *Sp. Sci Rev.*, in press. *Chemistry in space* (J. M. Greenberg & V. Pirronello, 1991, Kluwer, Dordrecht).
S K Jain (1991) *Bull astr. Soc India*, **19,** 172-174. *Uranus* (Ellis D. Miner, 1990, Ellis Horwood).
R. K. Kochhar (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).
D C. V. Mallik (1991) *Bull. astr Soc. India*, **19,** 369-371. Stellar structure and evolution (R. Kippenhahn & A. Weigert, 1990, Springer Verlag, Berlin).
D C. V. Mallik (1991) *Indian Inst. Sci.*, **71,** 599. Clusters of galaxies and extragalactic radiosources (A. D. Kuzmin, Nova Science Publ. Inc.).

Popular Talks

G S. D. Babu
IX Indian Scientific Expedition to Antarctica—Experiences of an Astronomer Master Control Facility, Department 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).

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

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

Radio/TV and Film programmes

G. S. D. Babu
Solar Systems, All India Radio, Bangalore. (1991 November 10)
Antarctica, All India Radio, Bangalore. (1992 February 9)

S P. Bagare
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'.