INDIAN INSTITUTE OF ASTROPHYSICS

Annual Report

Koramangala - Bangalore-34
INDIA

INDIAN INSTITUTE OF ASTROPHYSICS

Facilities and research

Annual report 1985-6

CONTENTS

Vainu Bappu telescope and Vainu Bappu Observatory

The prime minister, Shri Rajiv Gandhi visited the Kavalur Observatory on 6 January 1986 and at a brief ceremony named both the 2.3m telescope and the observatory after M.K. Vainu Bappu (1927-1982), the late director of the Institute, whose vision, power of persuation, and qualities of leadership brought about a revolution in optical astronomy in India.

At the ceremony held on the observing floor of the 2.3m telescope, Professor M.G.K. Menon paid tributes to the versatility of Vainu Bappu's interests and abilities, multiplicity of his achievements, and his human qualities of dignity and kindness. Professor Menon appreciated the able assistance of Mr. S.C. Tapde, the project manager, and Mr. A.P. Jayarajan, the optician, in Bappu's endeavour of building 2.3m telescope in the country. Professor Menon requested the prime minister on behalf of the governing council and the staff of the Institute to name the Kavalur observatory and the 2.3m telescope after Vainu Bappu.

The prime minister unveiled a plaque at the south pier of the telescope, naming it Vainu Bappu telescope. Paying rich tributes to Bappu, the prime minister said 'Today, we hope that his example will show the way to many more scientists to come back to India; to scientists who are already in India to give the type of lead and direction that Vainu Bappu gave'. After unveiling the plaque, the prime minister released a brochure on the Institute.

Apart from Professor Menon, chairman of the Institute's governing council, many council members attended the naming ceremony: Professors V. Radhakrishnan (Raman Research Institute), S.K. Trehan (Panjab University), N.A. Narasimham (INSA senior professor), and George Joseph (Space Applications Centre). Other distinguished scientists and technologists present included Professors U.R. Rao (Space Commission), G. Swarup (TIFR Radio Astronomy Centre), Anna Mani (Indian Institute of Tropical Meteorology), the late S.N. Seshadri (Bhabha Atomic Research Centre), and N.V.G. Sarma (Raman Research Institute), Walchandnagar Industries who fabricated the mechanical parts of the telescope was represented by Shri V.L. Doshi. The Tamil Nadu government was represented by its finance minister, Shri Nedunchezhiyan. Mrs. Yemuna Bappu also attended the function.

After the naming ceremony, the prime minister visited the Institute computer centre. Through the 1m telescope he observed comet Halley. He also looked at the Orion nebula, Crab nebula, Jupiter, many double stars, and star clusters. He spent a considerable time discussing with the technicians of the optical and mechanical aspects of the telescopes.

At a buffet dinner, the prime minister discussed with the scientists topics such as the nature of the comets, astronomical education at the universities, and the proposed giant metre-wave radio telescope. He also showed interest in the history of the Institute and how astronomers prepare their observing programs.

He also visited the satellite tracking and ranging station of the department of space, situated in the observatory campus.

Facilities

The research and supporting facilities of the Institute are spread over four centres Bangalore, Kavalur, Kodaikanal and Gauribidanur. The optics and electronics laboratories, mechanical workshop and the administrative offices are at Bangalore. Solar research facilities are at Kodaikanal, and the decametre wave radio telescope (run jointly with Raman Research Institute) is located at Gauribidanur. The Institute's main research facility is the Vainu Bappu Observatory at Kavalur.

VAINU BAPPU OBSERVATORY, KAVALUR

Situated in the Javadi hills in the North Arcot district of Tamil Nadu, Vainu Bappu Observatory houses a number of optical telescopes, of apertures 2.3m, 1.0m, 0.75m, 0.45m (Schmidt), and 0.38m. Kavalur has a VAX 11/780 computer system for the eventual control of the 2.3m telescope and for data acquisition.

Supporting facilities at Kavalur include electronics and mechanical workshops, and two aluminizing chambers which can handle mirrors of upto 2.4m aperture. There is also a small library which provides reference material when the skies are clear and reading material when they are not. Two 144 KW diesel generators, and a few smaller ones, keep the vital installations in operation in the event of power failure.

A few small-aperture telescopes and a small museum cater to an ever-increasing number of school and college students and visitors to the observatory.

1. The 2.3m Vainu Bappu telescope

The F/3.25 paraboloid primary of the 2.3m telescope saw its first light of the night sky in the autumn of 1985.

The equatorially mounted horse-shoe-yoke structure of the 2.3m telescope is ideally suited for low latitudes and permits easy observation near the north celestial pole. The prime focus with an image scale of 29 arcsec mm^{-1} is now available for direct photography. A photoelectric photometer and a CCD camera are under construction.

The Cassegrain secondary has been ground in the Institute laboratories and is being figured. At an F-ratio of 13 and a consequent image scale of 6.6 arcsec mm^{-1}, the focus is well-suited for medium and high-resolution spectroscopy, spectrophotometry, and photometry.

The 10m diameter observing platform is divided into three sectors which can be independently moved up and down hydraulically, during observations at the Cassegrain focus.

1.1. Photography

The prime focus of the 2.3m telescope has two alternative cages: the manual and the automated. The manual cage is optimised between the constraints of easy positioning and movement of the observer on the one hand, and the upper limit of 15% on the obstruction of the incoming beam, on the other. Consequently, it is not possible to mount large sized instruments.

The 3 element Wynne corrector system provides an aberration-free field of diameter 40 arcmin. The plate holder has been designed to capture the entire field using a 10cm x 10cm filter and 8cm x 8cm photographic plate. The guiding is achieved by acquiring a star near the edge of the field, with the help of a mirror attached to a movable arm. The arm can move in only one direction, but the plate-holder can be rotated to access any star in an annular area located at the periphery of the field. The star image is guided through a fibre optic bundle of 10mm x 8mm cross-section and 1-m length, to a convenient position, thus enabling an easy access by the observer.

2. The 1m telescope

The 1m telescope by Carl Zeiss, Jena, was installed in 1972 and has been in continuous use since then. The equatorial 2-pier (German mount) of the telescope obstructs the north celestial pole only slightly. In fact, the star Polaris itself can be observed for several hours when it transits at midnight.

The telescope is of Ritchey-Chretien design with a coma-free field of 40 arcmin diameter at the F/13 Cassegrain focus. Thus the Cassegrain focus is versatile and can be used for photography and photometry as also for low and medium resolution spectroscopy and spectrophotometry. The F/30 Coude focus contains an instrumentation platform which extends from the observing floor, to the ground 12m below. One may place here larger sized and heavier high-resolution spectrographs which cannot be mounted at the Cassegrain focus.

Some photographic equipment came with the telescope. Other instruments of interest were developed at the Institute. To these has now been added a spectrograph by Carl-Zeiss.

2.1. Photography and objective-prism/grating spectroscopy.

The entire 40 arcmin diameter coma-free field of the Cassegrain focus can be covered by the Zeiss plate-holder at the F/13 focus, using a 16cm x 16cm photographic plate and a same size filter. Guiding is achieved by directing a star from the edge of the field to the guide eye-piece. The mirror which selects the star can move in only one dimension, but the entire plate-holder can be rotated to access any star situated in an annular region around the periphery of the field. Attachments are available for employing smaller-sized plates if entire field is not required to be photographed.

Two focal-reducers are available at the Cassegrain focus to collimate the beam to a smaller beam diameter. A faster camera of smaller aperture may then be employed to photograph the field. These Zeiss focal-reducers are coupled respectively to an F/6 and an F/2 camera. with resultant image scales of 38 and 100 arcsec mm^{-1}, respectively. Experiments have successfully beem made to attach a Zeiss F/3.5 camera coupled to an image intensifier. Though the system is not in regular use, it can easily be assembled when required.

Excepting the F/13 plate-holder, other cameras have provisions for mounting interference filters, for narrowband photography, and prisms/transmission gratings for low-resolution and ultra-low resolution spectroscopy. An objective grating attachment has been developed for employment at the converging F/13 focus. The set-up has proved useful in crowded fields such as galactic open clusters.

2.2. Photoelectric photometry

Two dry-ice-cooled and one thermoelectrically-cooled photoelectric photometers are in regular use. These may either be used with a chart recorder in dc mode or coupled to one of the three microprocessor-controlled photon counting units designed, fabricated and programmed in the Institute laboratories. Two of these are versatile photon counting systems, and are described later. The third one, developed earlier, provides just continuous count-and-print facility over preassigned integration times ranging between 1 s and 99 s(in integral numbers).

Various filters, apertures and photomultipliers are available for UBVRI photometry observations. Interference filters may be fitted into the filter-holders if narrow-band photometry is desired.

2.3. Infrared photometry

An InSb infrared detector system is available for infrared photometry. The basic system was acquired from the Infrared Laboratories, Inc., Tucson. The image acquisition and focal-plane sky-chopping unit was fabricated in the Institute laboratories. The liquid-nitrogen-cooled system consists of a set of JHKLM filters and two circular variable filters (1.2 - 1.6 micron, 1.5-3.9 micron) driven by a stepper motor.

At present, only a chart recorder is available for recording the data.

2.4. Universal astronomical grating spectrograph (UAGS)

A spectrograph manufactured by Carl-Zeiss is available for spectroscopic observations at the F/13 Cassegrain focus. The catadioptric collimator system and the folding of collimated beam before the grating is illuminated makes the spectrograph fairly compact. only one grating is available at present, with 651 grooves mm^{-1} at a blaze angle of 8° and an efficiency of over 40% between 3000 and 4000 Å peaking at 4000 Å (85%). Two Schmidt-type cameras of focal length 110mm and 175mm respectively may be used interchangeably for photographic observations. The resultant reciprocal dispersions are 136 and 86 Å mm^{-1} respectively, in the first order.

For observations with a single-stage image intensifier, a Schmidt-Cassegrain camera of 150mm focal length is available (dispersion : 100 Å mm^{-1}). The Varo 8605 electrostatically-focused single-stage image intensifier may be coupled to the camera. The intensifier has input and output fibre-optic windows of 40mm diameter. The fibre-optics cuts off the wave-lengths shorter than 4000 Å. The advantage lies, however, in the S-20 photocathode which helps extending observations till 8600 Å, and with some difficulty, till 8900 Å. However, note that the present grating is inefficient in the near-IR region. The P-20 green output phosphor and the resolution of 64 line pairs per mm are ideally suited for the employment of Kodak IIa-D emulsion.

The spectrograph as a field-viewing arrangement which helps in acquiring visually objects as faint as 15 mag on the 1-m reflector. The diameter of this field is 8 arcmin. The slit-jaws are made up of hardened chromium-nickal steel with vapour-deposited aluminium coating. The slit-viewing microscope allows a 15 mag object to be seen off the slit by a fully dark-adapted eye. A star as faint as 13 mag can be centred easily on the slit and guided using the light reflected from the slit jaws. The maximum unvignetted slit length is 10mm, corresponding to 160 arcsec at the F/13 focus of the 1-m reflector.

Point objects can be trailed along the slit for upto 3mm using a rocker prism. The period for one cycle is 30s. The comparison spectrum can be recorded on either side of the spectrum of the object at any separation between 0.2 and 10mm. An intensity calibration spectrum can be obtained on a separate plate. To affect this, the wavelength calibration source is replaced by the continuum source and a neutral density stepwedge of transmissivities 0.10, 0.16, 0.25, 0.40, 0.63, and 1.00 inserted in the light path.

A filter wheel following the slit allows a choice of filters for order separation and also for matching the colour of intensity calibration source with the spectral type of object. A neutral density filter can be inserted while observing bright stars.

2.5. The Cassegrain image-tube spectrograph

A Cassegrain-image-tube spectrograph made at the Institute has been in regular use for the past several years. The spectrograph is of conventional design and can be mounted on an offset guide device. The offset guide and the mirror slit together have the capability of acquiring and guiding a star as faint as 15 mag, though the slit-viewing microscope and the available wavelength comparison sources are not fully optimized for faint object spectroscopy. A number of gratings of ruled area 76mm x 65mm and cameras of various focal lengths are available yielding dispersions ranging from 22 Å mm^{-1} to 1000 Å mm^{-1} in the visible and image-tube IR parts of the spectrum. Varo 8605 image intensifier is fixed at the output of the camera. The most efficient use of the spectrograph is with objects of intermediate brightness, at medium-low resolution, in green-near IR region of the spectrum.

2.6. Photoelectric spectrophotometry

The single-channel photoelectric spectrum scanner has undergone continuous upgrading since its installation in 1972. It can be mounted on the Cassegrain offset guide, is provided with a set of entrance apertures and order-separation filters, and can be used in conjunction with a range of photomultipliers in the available cooled housings. The basic spectrograph is conforms to the Ebert-Fastie design, however, using two separate identical mirrors for collimator and camera. A grating with 600 grooves mm^{-1} blazed for 7600 Å in the first order yields a reciprocal dispersion of 25 Å mm^{-1} in the first order.

The grating is driven by a stepper motor coupled through a wormwheel and a gear. One step of the motor corresponds to a step of 10 Å in wavelength in the first order and 5 Å in the second order. The data acquisition as also the control of the stepper motor is through a microprocessor-controlled photon counting unit, with a spare unit standing by.

It is possible to replace the grating with one of 1800 grooves mm^{-1} and achieve a better resolution of 3 Å in the first order.

2.7. Microprocessor-controlled photon counting system.

A microprocessor-based photon-counting system is available for the following tasks: (i) Control of the photoelectric spectrum scanner, and data acquisition. (ii) Data acquisition in filter photometry. (iii) Data acquisition during continuous photometric monitoring of an object. (iv) Data acquisition in fast photometric mode(such as lunar occultation records). (v) On-line folding and co-adding fast photometric data, useful for period-search of optical pulsars.

The system is based on the Intel 8085 8-bit microprocessor board and includes a 16-bit timer; 16K of read only memory); 4K of random access memory; a 24-bit counter; 24 input/output lines; an interrupt controller; an I/O expander with control circuits; two digital-to-analog converters; display units to display the minimum and maximum of the counts stored in the memory as well as the number of scans; and a printer with key board, an optional oscilloscope for display of spectrum scans. The system was developed in the Institute laboratories; a spare unit has also been subsequently assembled.

2.8. Coude B spectrograph

The highest available spectral resolution with the 1m reflector is with the Coude B spectrograph. The spectrograph has a collimator of focal length of 6m and a camera of focal length 3m, resulting in a reduction factor of only 2 from the slit to the detector. A grating of 400 grooves mm^{-1}, blazed at 1.2 μm in the first order, and of ruled area 206mm x 154mm yields a dispersion of 2.8 Å mm^{-1} in the third order blue. The F/30 beam at coude focus has an image scale of 6 arcsec mm^{-1}. This, coupled with the small reduction factor of the spectrograph implies that only a small fraction of the stellar image goes through the slit. Hence the typical exposure for a fourth magnitude star runs into several hours on Kodak IIaO emulsion. It requires an equally long exposure to hit the circumstellar cores of Ca II H and K lines in a star of about first magnitude.

2.9. Coude echelle spectrograph

In the echelle spectrograph higher resolution is achieved by going to a high order of diffraction and hence a short focus camera may be employed resulting in a larger reduction factor from the slit to the detector. The echelle spectrograph at the coude focus of the 1m reflector has a collimator of 1.4m focal length. Several cameras are available (focal lengths 150mm, 175mm, 250mm, 500mm). The 250mm camera results in a reduction factor of 5.6. Thus the slit can be widened to let in most of the star-light in good seeing. An echelle grating of 79 grooves mm^{-1} blazed at 5461 Å of 42nd order, and ruled area of 128mm x 56mm yields a dispersion of 7 Å mm^{-1} with the 250mm cameras in the 34th order of the spectrum. Gratings of 80, 150, or 300 grooves mm^{-1} may be used as cross dispersors to separate orders. Typical exposure times in the red region using Kodak 098-02 are several hours for a fourth magnitude star. There is a provision to use Varo 8605 single stage image intensifiers which help in reducing the exposure times by a factor of about 10.

2.10. Calibration spectrographs

There are two instruments that can help in registration of calibration steps for the photographic emulsion. One is to use the UAGS in the calibration mode. The other one is to use the auxiliary calibration spectrograph, whose basic unit is a quartz prism spectrograph by Adams Hilger. The slit is widened and illuminated by a uniform diffuse source. A sector rotating in front of the slit obstructs light (in steps) for different durations as a function of slit height. The sector is cut such that the logarithmic exposure time difference from one step to the next is close to 0.1. The width of each step is 0.1 mm and 13 steps are accommodated by the slit. The reduction factor of the spectrograph is unity.

3. The 0.75m telescope

The 0.75m telescope is a Cassegrain reflector designed and built at the Institute. The mounting ring is similar to the Cassegrain mounting ring of the 1m reflector. Hence, in principle, any of the spectrographs or photometers used with the 1m reflector can be used with the 0.75m reflector. However, in practice, only the photoelectric photometer is transported. A spectrograph is permanently available with the telescope.

3.1. Bhavnagar spectrograph

The first stellar spectrograph to be built in the Institute, the Bhavnagar spectrograph is named after the 0.5m reflector with which it was first used. This reflector had been purchased from a grant by Maharaja of Bhavnagar for Poone and was sent to Kodaikanal in 1912.

The spectrograph was later attached to the 1-m telescope, and then finally to the 0.75 reflector. The spectrograph has a collimator lens of 4cm aperture and 36.5cm focal length. The camera is mounted at an angle of 45° to the slit-collimator line. Two cameras are available with focal lengths of 125mm and 50mm. A range of gratings from 80 grooves mm^{-1} to 1800 grooves mm^{-1}, of ruled area of 76mm x 65mm, allows a range of dispersions, the best resolution possible being 17 Å mm^{-1} in the red and 30 Å mm^{-1} in the blue.

4. The 0.38m telescope

The home made 0.38m Cassegrain reflector was installed in Kavalur in 1968 when the site survey was in progress. Though some spectroscopic observations have been secured with it in the early days, the telescope is now dedicated to photoelectric photometry. A UBVRI photometer is available for observations.

5. The 0.45m Schmidt telescope

The 0.45m Schmidt telescope was fabricated in the Institute to coincide with the return of the Comet Halley. The telescope consists of 60cm F/2.245 primary and a 45cm corrector plate. A field flattener of 100mm x 125mm is placed in front of the focal plane so that a flat photographic plate can be employed. The entire corrected field of the telescope is 6° in diameter. The unvignetted field has a diameter of little over 3°. The field flattener yields a flat field of 4° x 5°. The image scale is about 2.5 arcmin mm^{-1}.

6. Photography laboratory

All the telescope buildings, excluding the 0.38m telescope one are equipped with independent photography laboratories for processing the photographic plates. The 1m telescope building is equipped also with facilities for obtaining enlarged and contact prints. An oven with thermostat control and air-tight containers, and dry nitrogen cylinders are available for nitrogen-baking hypersensitization of emulsions.

7. Vacuum-coating facilities

The 2.8m vacuum coating plant commissioned in 1984 and 1.5m vacuum coating plant commissioned in 1978 form an in-house facility for periodic aluminizing of the telescope mirrors and other optics. High quality surfaces upto 2.4m diameter can be coated using these plants, which were designed, fabricated and commissioned with the help of Bhabha Atomic Research Centre (BARC), Bombay.

The 2.8 m vacuum coating plant was used for the first aluminizing of the primary mirror of the Vainu Bappu telescope in August 1985. It has been used for other applications requiring metal coatings by the vacuum evaporation technique.

The 1.5m plant has been used to periodically aluminize many astronomical mirrors including the 1.2m primary mirror of Japal Rangapur observatory and the 1.02m primary mirror of the 1m telescope.

A 30cm coating plant at Bangalore is used for experiments on different types of coating and coating materials, and for aluminizing small mirrors.

8. VAX 11/780 system

VAX 11/780 computing system is installed in the Vainu Bappu telescope building for eventual telescope control, and data acquisition and processing.

8.1. Hardware

Word length	32 bits
Main memory	3 Mbytes
Disc drive	RM80 : 1 x 124 Mbytes RM05 : 2 x 300 Mbytes
9 track tape drives	TU77 : 800/1800 bpi TU78 : 1600/6250 bpi
Card reader	200 cards per min.
Printer/plotter	Printronix 600
Terminals	2xVT 100 1xVT 125 2xVT 240
Graphics terminal	Tektronix 4115B
Colour copier	Tektronix 4691
Image processor	COMTAL Vision One/20
Interface	CAMAC LPA 11K
Operating system	VMS Version 3.5

8.2. Software

Languages	Macro assembler Digital command VMS Fortran (superset of Fortran 77)

Graphic packages	PLXY (on Printronix) IGL (Tektronix) ReGis (VT125, 240)
Mathematical package	Scientific subroutine package (SSP)

9. Mechanical workshop

The mechanical workshop at Kavalur is equipped for the maintenance and fabrication of light-duty instrumentation. The equipment includes two milling machines, two lathes, a shaping machine, a plate-bending machine, a band saw machine and a bench drilling machine. Though these equipments cannot handle all the precision work needed in astronomical instrumentation, instruments have been fabricated in the past using them. Cranes are available at various locations for assembling instruments/parts of telescopes.

10. Library

Though there is no full-fledged library at Kavalur, the copies of essential books, catalogues and atlases are available in the 1m reflector building. Recent volumes of main journals in the field are also available.

11. Telescopes for the visitors

Two small telescopes of apertures 0.15 and 0.20m are available for visitors and students to look. The

0.15m telescope is of Maksutov type fabricated by the Carl Zeiss, Jena. The 0.20m telescope was gifted to Kavalur by Mrs. Yemuna Bappu, whose husband Dr. M.K. Vainu Bappu had got it from Mr. R.G. Chandra of Jessore who in turn had received it from the American association of variable star observers.

KODAIKANAL OBSERVATORY

Located in the Palani Hills, Kodaikanal Observatory has been devoted to solar research since the beginning of the century. The principal facility - in regular use since 1962 - is the solar tunnel telescope which provides high image resolution and high spectrographic dispersion.

1. The tunnel telescope

The 11m high tower houses a two-mirror, fused quartz Coelostat of 61cm diameter, which reflects light onto a third quarts flat. The flat mirror directs the horizontal beam into a 60m long underground tunnel, where an achromatic objective of 38cm aperture and 36m focus forms a solar image, 34cm in diameter, and on a scale of 5.5 arc-sec mm^{-1}. The telescope has been made by Grubb Parsons. The solar image feeds light to a Littrow type spectroheliograph which utilizes a 20cm aperture, 18.3m focus Hilger achromat in conjunction with a 600 lines per mm Babcock grating of ruled area 200mm x 135mm and blazed in the fifth order at 5000 Å.

2. Spectroheliographs

Kodaikanal has three spectroheliographs. A Foucault siderostat with a 46cm diameter mirror reflects sunlight onto a 30cm Cooke photovisual triplet lens which forms a 60mm solar image. This image then feeds light to the two spectroheliographs. The K-spectroheliograph, is a two-prism instrument with a dispersion of 7 Å/mm near 3930 Å. Its exit slit admits 0.5 Å about K_{232}. In use since 1904, the K-spectroheliograph produces daily spectroheliograms of the solar disc and prominences. The other, hydrogen-alpha spectroheliograph uses a Littrow grating. Its exit slit isolates 0.35 Å about hydrogen alpha. This instrument has been taking daily pictures of the sun since 1911.

The third spectroheliograph, made by K.C.A. Raheem in the 1960s is used with the tunnel telescope. Meant for specialized work, it is a Littrow arrangement of 4.3m focus with a 1200 lines per mm grating blazed at 7500 Å.

3. Spectrohelioscope

The Foucoult siderostat also feeds light to the Hale spectrohelioscope. Obtained in 1934 as a gift from Mount Wilson Observatory, the spectrohelioscope daily monitors the solar chromospheric activity.

4. Photoheliograph

The photoheliograph made out of a 15cm aperture telescope by Lerebours and Secretan of 1850 vintage produces white-light photographs 20cm in diameter.

Kodaikanal has also a 20cm equatorial by Troughton and Simms which was acquired in 1866 at Madras.

5. Solar-terrestrial relationship

Kodaikanal's proximity to the magnetic equator makes it an ideal field station for solar-terrestrial relationships. A C3 ionosphere recorder has been in use at Kodaikanal since 1952. A Lacour magnetometer and a Watson magnetometer are available for geomagnetic recordings. Since 1983 a high frequency phase path sounder set up is in operation for monitoring small scale dynamics of the equatorial ionosphere.

DECAMETRE-WAVE RADIO TELESCOPE, GAURIBIDANUR

Operated jointly with Raman Research Institute, the Gauribidanur telescope is a T-shaped array of 1000 broad-band dipoles, 640 in the east-west arm and 360 in the south arm. All dipoles accept east-west polarizatio A fully reflecting screen, 60000 m^2 in area, is mounted 1.5m below the dipoles. The entire structure is support on a grid of 3500 wooden poles of varying heights. The east-west arm is 1.4 km long, and the south arm 0.45 km.

In the east-west arm, the elements are arranged in four rows, placed 5m apart. Each row has ten groups of 16 broad-band dipoles; each group has its own feeder system to permit phasing in the north-south direction. To preserve the bandwidth of the system a binary branching feeder network is used through out.

The south arm of the T consists of 90 rows placed 5m apart, each with four broadband dipoles. The four dipoles are coupled together in a branched feeder system and each row is connected into the main north-south feeder system. The outputs of the east, west and south arms are carried by coaxial cables to the centre of each arm and from there to the main observatory building. The signals are amplified and the sum of the east and west signals is correlated with that of the south arm. In this way a beam of about 26arcmin x 40 arcmin at the zenith is produced at a frequency of 34.5 MHz.

The beam of the south arm can be pointed anywhere within $\pm$ 60° of the zenith on the meridian. This is accomplished by adjusting the phase gradient across the aperture using remotely-controlled diode phase shifters. The phase shifters are designed to introduce phase variation in binary steps of 22°.5 from 0° to 360°. The phase variations are achieved by switching calibrated lengths of coaxial cables in the circuit path with the aid of diodes. A special purpose digital control system supplies the switching voltages to set the beam to the required position. The digital control system also cycles the beam through several declinations sequentially. The time required to change the beam from one position to another is of the order of a few milliseconds. The number of declinations through which the beam is cycled can be varied from one to 16. The beam of the east-west array can be tilted in hour angle to $\pm$ 5° of the meridian. This tilting is also accomplished by remotely-operated diode phase shifters, controlled by another special purpose digital system. It is thus possible to track a source for about 45 minutes around meridian transit.

The receiving system extracts the in-phase (come) and the quadrature (sine) correlations between the two arms for each one of the beam positions. Predetection band-widths of 30 and 200 KHz, and postdetection time constants ranging from 1 to 30 s are available. The output of the receiving system is recorded in both analog and digital forms.

The effective area of this instrument is, about 25,000 m^2. At 34.5 MHz, the mean sky brightness is of the order of 10,000 K. So the collecting area is sufficient for the detection of sources whose flux densities are in the range of 10 to 15 Jy (1 Jy = 20^{-26}/W/m^2/Hz).

Research Highlights

THE SUN

Asymmetries in line profiles: Line profiles of several absorption lines in the range 4000-7000 Å were obtained during 1983 fall with the Fourier transform spectrometer at the McMath telescope with a view to studying the asymmetries in the line profiles caused by the solar granulation. These spectra are for different positions along the equatorial and polar diameters (μ = 1.0, 0.5, 0.25, 0.125, 0.0635, and 0.0313).

A preliminary study of the line asymmetries and centre limb variation of 17 Fe I lines chosen from the large number of lines from the FTS spectra has been completed. The differences between the polar and equatorial line shifts show a red shift. This redshift in the polar direction has been interpreted as a manifestation of a poleward meridional motion. The main finding of this study is that lines with central depths 70% - 90% show a weak meridional flow polewards around μ = 0.5 which increases to larger values (about 40 ms^{-1} beyond μ = 0.3. Out of the 17 lines, some are Zeeman sensitive and a few are non-Zeeman lines with Lande factor g = 0. It is found that the poleward flow does not depend upon the Lande' factor of the lines (K.R. Sivaraman, R. Kariappa, W.C. Livingston* and G. Ladd*).

- -

* Denotes authors not from the Institute.

<u>Magnetic structure</u>: Several high quality filtergrams were obtained in the Mg b_1 line at the core as well as at four $\Delta\lambda$ positions within the line and in the continuum, using the vacuum tower telescope and the universal birefringent filter at Sacramento Peak Observatory. These filtergrams along with those obtained on either wing of the magnetically sensitive line Fe I 6302.5 Å are being studied with a view to establishing the location, with respect to the photospheric granulation, of the foot points of the sub-arcsec intense magnetic structures within the supergranular network (K.R. Sivaraman, L. November* & R.B. Dunn*).

<u>Global magnetic field</u>: It has been found that the global magnetic field of the sun is not related to the disc averaged Ca II K emission although on the surface of the sun K emission is everywhere known to be correlated to the magnetic field. The absence of correlation is explained by the fact that the global value is the algebraic sum of the fields, whereas the K emission is additive, irrespective of the polarity. It has been suggested that this fact could be used with advantage in the case of stars for determining their fields with proper calibration. The work on this calibration procedure is in progress (K.R. Sivaraman & R. Kariyappa).

<u>He I 10830 Å line:</u> A preliminary analysis of the time sequence of 10830 Å spectra obtained at the vacuum tower telescope of National Solar Observatory, Tucson, has indicated that the line depth varies with periods of about 2-3, 6, and 12-13 minutes (J. Singh, P. Venkatakrishnan, S.K. Jain, W.C. Livingston* & F. Recely*).

<u>Active loop prominence:</u> The sequence of spectroheliograms of this loop of 1984 February 2 show that the individual loops in the archade underwent a sequence of activity starting with the brightening of kernel followed by brightening of portions of the loop, appearance of a zig-zag shaped brightening and the diffuse appearance of the loop at the end phase. The observations provide convincing evidence for free fall of calcium emitting material under gravity along the loop legs in the preflare activity of the loop system. (S.P. Bagare, B.S. Nagabhushana & P.S.M. Aleem).

<u>Type II solar radio bursts:</u> In an attempt to construct a self-consistent model for solar type II radio bursts, it is proposed that the ring type distribution of the reflected ions in the downstream drives the low frequency oblique magnetosonic waves unstable. Due to the anisotropy in the phase velocities of these waves along and perpendicular to magnetic field, the electrons will be accelerated to very high velocities parallel to the magnetic field. It is also proposed that the frequency

splitting in the observed radiation both at fundamental and at second harmonic is due to the nonlinear scattering of electron-beam excited Langmuir and upper-hybrid waves. The frequency splitting is approximately equal to electron cyclotron frequency (G. Tejappa).

Radio sun at VLA: A solar plage was observed at 6cm and 20cm wavelengths using the VLA. The high frequency 6cm emission correlates well with the associated sunspots, whereas the 20cm emission shows good correlation with the hydrogen-alpha plage. Large variations over a period of one day were observed in the plage-associated component without any significant change in the sunspots. The dominant emission mechanism at 6 and 20cm are found to be gyro-resonance and bremsstrahlung respectively. It is concluded that the coronal condensation above the chromospheric hydrogen-alpha plage has an electron density of about 5×10^9 cm^{-3} and extends to a height of about 5×10^4 km (R.K. Shevgaonkar & M.R. Kundu*).

Simultaneous solar burst observation at 6 and 20cm wavelengths was carried out with the VLA. Structural changes and preheating have been observed in the flaring regions on time scales of a few minutes before the onset of the impulsive phase. The 6cm burst sources are located close to the magnetic neutral line, or near the legs of a flaring loop. The observations are interpreted in terms of a two-component model (bulk heating as well as acceleration of particles) and the physical parameters derived (M. Melozzi*, M.R. Kundu* & R.K. Shevgaonkar).

Vector magnetic fields:

An ellipsometer has been designed for monitoring the complex refractive indices of the aluminized coelostat mirrors of the tunnel telescope in order to know the amount of instrumental polarization, a precise knowledgement of which is necessary for estimating the vector magnetic fields.

The analyser optics is located in front of the entrance slit of the spectrograph. The error due to the uncertainity in the positioning of the quarter-wave plate and polaroid has been estimated to produce a maximum error of 2% in each of the Q, U and V signals.

Observations of Stokes profiles in Fe I 6301.5 A, 6302.5 A spectral lines across a sunspot group having a common penumbra were made in 1986 March.

To compare observations with the numerically generated profiles, the polarized radiative transfer codes sent by A.D. Wittmann of Goettingen University have been adapted for use on the VAX 11/780 computer (K.S. Balasubramaniam, P. Venkatakrishnan & J.C. Bhattacharyya).

<u>Coronal loops:</u> The dynamical evolution of the coronal loop in the minimum energy Chandrasekhar-Kendall representation, as it moves outwards in the external medium has been studied. It has been found that the coronal loop must lose energy in order to maintain its minimal energy configuration, and that the non-axisymmetric state becomes more favourable when the external pressure falls below a critical value (V. Krishan).

The interaction between the velocity field and the magnetic field fluctuations in the case of a coronal loop has been studied using nonlinear MHD equations and the statistical description of MHD turbulence. It has been found that these fluctuations are of Alfvenic type (V. Krishan).

<u>Flux tubes:</u> A study of the stability of slender radiating optically thick flux tubes, has revealed that the size of a photospheric magnetic flux tube must depend on its field strength. The distribution should consist of kilogauss tubes with large dispersion in sizes as well as a family of thin tubes of fairly small dispersion in sizes but with field strength ranging from kilogauss intensity to the equipartition value of a few hundred gauss (P. Venkatakrishnan).

<u>Solar activity:</u> Monthly distribution of the maximum areas of sunspot groups with respect to the 'initial' heliographic longitudes of their sources was determined

for spot groups during 1933-43 and 1944-54 using different choices of the initial epoch and the differential rotation amplitude b to determine how the distribution of the peaks in the longitude time diagram depends upon the choice of the initial epoch t_* and b. It was found that for any choice of t_* and b the peaks remain concentrated (with χ^2 - confidence $\gtrsim$ 99%) along five to seven sinusoidal curves in the longitude diagram plane. It was concluded that the sources might be associated with some global solar oscillations and that a Fourier analysis will be needed to identify the frequencies of these waves (M.H. Gokhale & J. Javaraiah).

The time series representing peaks in the monthly distribution of sunspot activity with respect to the heliographic longitudes was Fourier analysed and significant peaks were identified. For activity during 1933-1943, there exists one statistically significant (6 sigma) peak at 66 month periodicity. For activity during the cycle 1944-54 there is a statistically significant peak at about 22 month periodicity. Several other peaks with lesser statistical significance were also found to exist. It was concluded that the sunspot activity may be originating in many modes of global oscillations of the sun and that a spherical harmonic Fourier analysis of the sunspot data may be needed to identify such modes (M.H. Gokhale & J. Javaraiah).

The maximum area of sunspot group, as a measure of solar activity, was subjected to a spherical-harmonic-Fourier analysis with respect to heliographic co-ordinates and the time of occurrence. Fourier amplitudes and Fourier power were determined for 55 spherical harmonics ($\ell = 0$ to 9, m = 0 to ℓ) and for frequencies 0 to 9 in units of 1/11 or 1/22 yr^{-1} using the Greenwich data for solar cycles 1933-43 and 1944-54 first separately and then in combination. Several peaks were found in the Fourier amplitudes and Fourier power for many harmonic modes at different frequencies. Many, if not all, peaks seem statistically significant. A preliminary conclusion was that the sunspot activity might be originating in global solar oscillations and that if it really does, then axisymmetric even parity modes were dominent during 1933-43 and odd parity modes were dominent during 1944-54 (M.H. Gokhale & J. Javaraiah).

The 1980 solar corona: Theoretical investigation aimed at understanding the mode of excitation of Fe X and Fe XIV forbidden lines has been completed. In this study electron density profile, as derived from brightness and polarization measurements of the solar corona during eclipse of 1980, was adopted to compute line of sight emission fluxes for Fe X 6374 and Fe XIV 5303 lines (P.K. Raju & J. Singh).

The quiet sun: A comparative study of emission line fluxes from the quiet sun and coronal hole regions has been carried out. The semi-empirical model by Kopp & Orrall for the quiet sun and coronal hole regions was used in computing line fluxes. The emission lines considered belong to Mg VIII, Si X (boron-like); Mg VII, SI IX (carbon-like); and Si VII, S IX (oxygen-like ions (B.N. Dwivedi* & P.K. Raju).

THE SOLAR SYSTEM

Comet Halley:- A systematic, well thought out program to observe comet Halley was carried out. The results are described under various heads: (i) Astrometry; (ii) near-nucleus studies; (iii) large scale phenomena; (iv) photometry and polarimetry; (v) spectroscopy; (vi) infrared studies; and (vii) occultation studies.

(i) Astrometry: Astrometric work done entirely on the images of the comet obtained at the F/13 Cassegrain focus of the 1m telescope at Kavalur. The sky photographs were obtained on 16cm x 16cm photographic plates with an image scale of about 15 arcsec mm^{-1} and covering a field of 40 $arcmin^2$. The first photograph of the comet obtained on 1985 August 29 was folled by another on September 2. Earlier attempts made in April and May had been unsuccessful as the brightness of the comet was beyond the reach of the 1m telescope. The positions of the comet were measured from the photographs obtained every month till December 1985 with reference to many standard stars in the same field named in Donald Yeoman's IHW catalogue. These positions have an accuracy of ± 1 arcsec for the September and October data and ± 12 arcsec for the rest of the data. These results were communicated to the astrometry net of IHW as well as to USSR who have used these along with similar data from many other centres as input data for correcting the positions of the spacecrafts to Halley (K.K. Scaria, S.P. Bagare & M. Rozario).

(ii) Near-nucleus studies: The many photographs obtained of the nucleus at the F/13 Cassegrain focus show fine structural details in the outer coma. These would be used to study the brightness profiles and their evolution within the coma.

(iii) Large scale phenomena: Direct images obtained with the 0.45m, F/3 Schmidt telescope at Kavalur form a very good material for the study of the changes in the ionic tail of the comet. The Schmidt telescope has a corrected field of 6 degree square and a scale of 3 arcmin mm^{-1}. The Schmidt pictures along with those obtained with an F/15 system installed at Kodaikanal provide a well connected record of the ionic tail behaviour during the present apparition. They show changes in the structures in the plasma tail within hours, which can be traced from plate to plate (R. Rajamohan, K. Kuppuswamy; P.S.M. Aleem & J.S. Nathan).

Profiles of H-alpha (OI) 6300 A, and Na I 5890 A at high resolution were obtained on three nights in April, at the 1m reflector using the Physical Research Laboratory piezo-electric scanning Fabry-Perot interferometer (K.R. Sivaraman, J.N. Desai*, T. Chandrasekhar & Deviprasad*).

(iv) Photometry and polarimetry: Photometry using the 8 narrow band filters recommended by IHW was done regularly at the 0.40m telescope. The polarization of the continuum and in the emission bands were measured in 1985 November and 1986 March using the Physical Research Laboratory polarimeter (K.R. Sivaraman, U.C. Joshi* & A.K. Kulshreshtha*).

(v) Spectroscopy: The observations with the spectrum scanner at the 1m telescope which started in 1985 mid-October were continued through the post perihelion period. These spectra covering a range from 3650 A - 7000 A are with 40 Å and 20 Å resolution, and show the evolution of the emission from the cometary atmosphere. Starting with the continuum, in early October, the spectra show up several emission features due to CN(0,0), CH(0,0); C_3 group, CN(0-1), C_2(1-0); C_2(0-0); C_2(0-1); C_2(0-2), bands of H_2O^+, as the comet approached the sun. The subtle changes in the intensity level of the continuum and the emission bands are seen well in the series of spectra (K.R. Sivaraman, G.S.D. Babu & B.S. Shylaja).

(vi) Infrared studies: The infrared photometer of the Tata Institute of Fundamental Research, Bombay, was used on the comet in 1985 November and the J, K, L magnitudes measured were all equal with a value of 7.5 ± 0.5. In April the comet was observed with an infrared photometer made at the Institute (K.R. Sivaraman).

(vii) Occultation studies: The large number of cometary photographs obtained through telescope the 1m and the 0.45m Schmidt telescope show occultation of many stars by the comet's coma and tail almost every night. These calibrated photographs would be used to infer the properties of the dust with the help of those stars which possess well determined magnitude estimates (K.R. Sivaraman).

Comets Hartley-good and Giocobinni-Zinner were observed in 1985 October (B.S. Shylaja).

Dust in comets: Numerical calculations on the angular distribution of the scattered intensity and polarization have been made for spherical and nonspherical (oblates and prolates) particles for various size distributions. These results would help interpreting the observed photometric and polarimetric data on comets in terms of size, shape and composition of dust particles (D.B. Vaidya).

Galilean satellites: Five eclipses of Galilean satellites involving Io were recorded at the 1m telescope: Eclipses of Europa by Io on 1985 September 24 and October 12 and eclipses of Io by Ganymede on 1985 October 17, 24 and November 15. Precisely timed eclipse and occultation events involving Io are by far the best means of evaluating the tidally induced deceleration of Io's mean motion, which is a major aim of this experiment (J.C. Bhattacharyya & R. Vasundhara).

Pluto-Charon mutual event: The orbit of Pluto's satellite Charon is approaching an edge on configuration as seen from the earth. Occultation of Charon by Pluto and transits of Pluto by Charon can be observed for the next few years and will then cease for another 120 years. Two of the mutual events, one on 1986 January 21 and the other on February 6 have been partially recorded at the 1m telescope (R. Vasundhara & J.C. Bhattacharyya).

Lunar occultations: Lunar occultations of SAO 80674, SAO 78483 and SAO 78531 were recorded at the 1m telescope at Kavalur. Several occultations have been timed on the 0.40m telescope (J.C. Bhattacharyya, R. Vasundhara & M. Appakutti).

Magnetic monopole flux: Owing to the data available mainly from interplanetary spacecraft, there have been recent improvements in the quantitative estimates of the observed heat flow from the various planetary objects of the solar system. This has been used to put rather stringent limits on the background magnetic monopole flux in the solar system as the captured monopoles can catalyse nucleon decay and accelerate the decay process via the Callan - Rubakov effect according to which the monopoles gravitate to the cores of the planets and the resulting energy release from the nucleon decays is converted to heat. In the case of the earth, known amounts of radioactive heat generated lowers the limits even further. The limits are several orders more stringent than the Parker bound and the IBM data (C. Sivaram).

THE STARS

R Cr B: The radial velocity and photometric observations of R Cr B obtained with 1m and 0.75m telescopes at Kavalur combined with published observations were analysed. Photometry shows the presence of a long period of 1170 days with V about 0.1, similar to the one seen in 3.5 micron (L band) data. This period has been attributed to circumstellar dust. Data prior to 1972 did not show any unique period of the order of days. Later data, particularly the radial velocity data, show a period of 47.1 days, which should probably be ascribed to stellar pulsations (A.V. Raveendran, B.N. Ashoka & N. Kameswara Rao).

Spectrophotometric observations of the 1972 and the 1974 minima of R Cr B were analysed with a view to studying the properties of the circumstellar dust formed during the minima. The differential energy distribution (with respect to the maximum light) corrected for the presence of emission lines suggests that the observations fit power law distribution of graphite particle sizes, with the mean size decreases as the star comes out of the minimum (N. Kameswara Rao, R. Vasundhara & B.N. Ashoka).

Broad line profiles of Ca II H and K, and He I 3889 Å seen during the light minimum of R Cr B have been studied to understand the physical conditions of the gas being ejected from the star. On the basis of non-LTE analysis, where velocity fields have not been taken into account, Te of 10^4K and n_e of 10^{11} to 10^{12} cm^{-3} are inferred (R. Surendranath, K.E. Rangarajan & N. Kameswara Rao).

Circumstellar dust: Polarimetric observations of several hydrogen deficient stars have been made, using the 1m telescope at Kavalur, to study the nature of the circumstellar dust. Stars like HD 30353 show dramatic variations in a day or so in H-alpha polarization. In addition AR Pup, a carbon RV Tauri star, showed a flare in its polarization, registering an increase to 14% in U band in a few days (A.V. Raveendran, N. Kameswara Rao & M.R. Deshpande*).

Hydrogen deficient stars: Spectra of hydrogen deficient stars V348 Sgr and R Cr B in the 3.0-3.5 micron range were obtained using UK1RT. A weak 3.3 micron emission feature in dust was seen in V348 Sgr but not in R Cr B. The light curves of HV 12842 and the R Cr B stars in LMS were studied using the plates taken at the UK Schmidt telescope (N. Kameswara Rao, K. Nandy* & D. Morgan*).

VLA observations: Additional VLA observations at 2cm and 6cm of the hydrogen deficient stars and nebulae A58, V348, and Upsilon Sgr, were obtained. Contrary to what is expected from the IR excess - radio flux relation for planetary nebulae, A58 showed no radio flux (N. Kameswar Rao & V.R. Venugopal*).

Spectroscopic observations at H-alpha of A58 have been obtained using the 3m Shane telescope of the Lick observatory and the CCD spectrograph. The nebular patch in A58 shows an expansion velocity of less than 40 km s^{-1} (N. Kameswara Rao & G.H. Herbig*).

R Cr B star UW Cen: The southern R Cr B star UW Cen has been reported to exhibit a metal deficiency by a factor of 660 relative to the sun. The metal deficiency of this order is unusual in R Cr B stars. Also the observed radial velocity (34 kms^{-1}) of this object and its galactic location do not support such an extreme metal deficiency. A reanalysis of existing line data using up-to-date gf values and model atmospheres appropriate to R Cr B type atmosphere shows that the earlier study (using very uncertain gf values, particularly for Fe I) gave excitation temperatures that are systematically lower by 1500 K. The use of more precise line data leads to temperatures that are in good agreement with photometric estimates. The resultant abundances of Fe-peak elements are very close to the solar value (Sunetra Giridhar & N. Kameswara Rao).

Epsilon Aurigae: High resolution, high signal-to-noise ratio spectra of Epsilon Aurigae obtained with the 82-inch Coude Reticon spectrograph of the McDonald observatory during 1981-83 show a systematic increase in the strength of the KI 7699 Å and 7664 Å resonance lines.

In the pre-eclipse spectrum of Aur (Fo Ia) only interstellar K I lines are seen; the photospheric K I lines from the Fo Ia primary are extremely weak or absent. The neutral gas confined in and around the disc-shaped secondary is directly and clearly traced for the first time by the K I resonance lines during the eclipse. From the radial velocity variation of K I 7699 A resonance lines during the eclipse and from the known mass function of the system the masses of the components have been determined. Epsilon Aurigae is found to be a low or intermediate mass system. The mass of the primary (Fo Ia) is about 2 M_0 and the mass of the disc-shaped secondary is about 4 M_0. The primary component is likely an asymptotic giant branch (AGB) or post AGB star.

The K I line strength variation shows that the eclipse by the gaseous component of the disc had started a few months earlier than the photometric eclipse. The geometric extent of the disc with its gaseous component is larger than anticipated from earlier investigations. It turns out that the neutral gas is mostly confined to the outer edges of the opaque disc. It appears that either the eclipsing disc is tilted with respect to the equatorial plane of the primary, or there is a ring around the primary which is at an angle with respect to the eclipsing disc (M. Parthasarathy).

<u>High galactic latitude F supergiants:</u> HD 161796 (F3 Ib), HD 101584 (Fo Ia), 89 Her (F2 Ibe), HR 4912, and HD 46703 are high galactic latitude luminous F supergiants. These stars are also called UU Her type stars, because of some similarities in their long period Cephied like pulsational properties with UU Her. These stars are near the blue edge of the Cepheid instability strip and show switching of pulsation modes which is uncommon in Cepheids of long period. Strong far-infrared (IRAS) excesses due to large amounts of dust around HD 161796, HD 101584 and 89 Her and related stars have been discovered. If the ratio of gas to dust mass is about 100, as it is in the interstellar medium, the total shell masses are between 0.3 and 1 M_{O}. These shells are similar to those found in planetary nebulae and suggest a possible connection between these objects and nebulae. There are differences, however, the most striking being the higher luminosity of the F supergiants by about an order of magnitude compared to nebulae. It is concluded that these stars originated from low mass population II stars and are in the AGB or post-AGB phase of evolution.

SAO 163075 has been joined to have a far-infrared flux very similar to HD 161796. It is an event more extreme case, since the visual brightness is only 9 magnitude. It is likely that these objects are a small part of hitherto unseen phase of stellar evolution (M. Parthasarathy & S.R. Pottasch*).

<u>Nucleosynthesis in Beta Lyrae:</u> High signal-to-noise ratio Reticon observations of visible and near-infrared lines of He, C, N, O Ne, and Fe have been used to determine the abundances of these elements in the B8 primary of the eclipsing binary β Lyr. Analysis of weak He I lines shows a definite He enrichment N (H) = 0.4, N (He) = 0.6. Nitrogen in extremely overabundant - 20 times more abundant than in the sun. Carbon and oxygen are very underabundant relative to N : C/N $\lesssim$ 0.011 and O/N = 0.025. These ratios are close to the equilibrium ratios of the C N O cycle and show that the material has been fully processed by the C N O cycle. The processed core of the primary is exposed to view as a result of close binary evolution and subsequent mass transfer/mass loss. From a comparison of the observed H, He, C, N and O abundances with the calculated interior abundances of evolved stellar models it is concluded that 2 $M_{\odot}$ primary is the remnant of a 12 $M_{\odot}$ star that has lost 10 $M_{\odot}$ by Roche lobe overflow (M. Parthasarathy).

<u>IUE observations of Upsilon Sagittarii:</u> The analysis of several high resolution UV spectra of the hydrogen-poor binary Upsilon Sgr obtained with IUE at different orbital phases during different cycles indicates that the companion is a hot star (late O or early B-type) probably showing excess of N and C, like the primary. The far-UV spectrum is characterized by the presence of strong

shortward-shifted absorptions of the resonance lines of N V, C IV, Si IV, Si III, Al III, and C II with typical wind profiles at all phases. The near-UV spectrum is characterized by the presence of several lines of once-ionized metals. The masses of the two members of the system satisfying the mass function are 5 M_0 and 2 M_0 (M. Parthasarathy, M. Cornachin* & M. Hack*).

Wolf-Rayet stars: In the program of study of Wolf-Rayet binaries, the spectrophotometric results on the shortest period eclipsing binary, CQ Cep, were analyzed, supplementing it with the spectroscopic data from the collection of plates of Prof. Bappu. The various radial velocity curves yield different orbital solutions, with a general positive shift of the gamma axis. Excepting the N V line at 4603 Å, the fluxes of all other lines show enhancement at minima. They can be explained by Roche surfaces which take into account the strong wind of the WN7 component. An approximate size of the N V emitting region may be arrived at, by its eclipse measures, although there is no signature of the companion.

Similar analysis of spectrophotometric data of another WN5 star HD 50896 reveals long term variability in visual magnitude as well as in emission line measures. Only the N V line at 4603 Å shows a periodic variation, of 3.763 days. The lines of N IV at 4058 Å and C IV at 5808 Å also suggest this type of behaviour but not very significantly (B.S. Shylaja).

RS CVn binary II Peg: A single-lined spectroscopic binary with a period of about 6.72 d, II Peg is one of the most active members of the RS Canum Venaticorum group of binaries. As part of a photometric programme on RS CVn systems and related objects, II Peg was observed on a total of 39 nights during 1980-81, 1981-82 and 1984-85 observing seasons through B and V filters with the 0.34m telescope at Kavalur. An analysis of the data thus obtained when combined with that available in the literature shows that the light curves change drastically from season to season. Phases of the light minima observed during the interval from 1979.83 to 1980.97 are found to lie on two distinct lines with different slopes, the respective photometric periods are $6^{d}.672 \pm 0^{d}.010$ and $6^{d}.694 \pm 0^{d}.002$. On the basis of the spot model it implies the simultaneous existence of two centres of activities located at different latitudes and longitudes on a differentially rotating star during this period. The life time of an 'activity centre' is found to be about 5-6 yr, similar to that seen in DM UMa, another active member of this group. The observed (B-V) though shows a large scatter with a total range of 0.1 mag has apparently no correlation with the visual magnitude of the object (S. Mohin, A.V. Raveendran & M.V. Mekkaden).

Recurrent novae: The recurrent nova RS Ophiuchi registered its fifth recorded outburst in 1985 January. Two of its past outbursts (1933, 1958) have been well-observed spectroscopically and show a remarkable similarity of development. The spectroscopic observations obtained at Kavalur (using Cassegrain image-tube spectrograph at the 1m reflector) between 1985 February 28 and May 18 (days 31 - 110 after outburst) show that the present outburst is no exception. Different combinations of grating and camera gave different dispersions: 46 Å mm^{-1} (7200-8700 Å); 124 Å mm^{-1} (4000-5800 Å); and 204 Å mm^{-1} (4800-8900 Å). Prominent among the permitted lines are H-alpha to H-delta; P_{11-15}; He I 5016, 5876, 6678, 7065 Å; He II 4686 Å; and N III 4640 Å. The strong coronal lines, characteristic of this system, include AX 5535 Å; AXI 6919 Å; FeX 6374 Å; FeXI 7892 Å; and FeXIV 5303 Å. The unidentified feature at 6827 Å also seen during the previous outbursts of this system but not in other novae, is also clearly seen. There has been some denate in literature whether to attribute this line to K III 6826.9 Å.

All the photographic spectra were digitized using a Carl Zeiss microdensitometer, automated at the Institute. The reductions incorporating Fourier filtering, bringing to uniform wavelength scale, and correction for instrumental response, were carried out using a specially-developed interactive code on the VAX 11/780 computer at Kavalur.

The recurrent nova T Coronae Borealis, which is currently in its minimum state following the outburst of 1946, is being spectroscopically monitored (204 Å mm^{-1} 5000–8900 Å) (G.C. Anupama & T.P. Prabhu).

<u>Cataclysmic variables:</u> The photometric data of the nova-like variable BD −7° 3007 obtained in 1980–81 in B and V filters have been analyzed. The light curves show irregular variations, except at one epoch, where they show a sinusoidal variation of about an hour. Rapid flickering appears to be present at all phases, implying an unfavourable angle of inclination for seeing eclipse effects (B.S. Shylaja).

<u>Peculiar and metallic line stars:</u> Many Ap and Am stars have been observed with a view to obtaining not only their physical parameters like the effective temperature, radius etc., but also to understanding the broad 5200 Å feature, which is characteristic of the Ap stars. Fast photometry of a few stars, which are likely to show rapid fluctuations and variability of the 5200 Å feature, has also been done (B.S. Shylaja & G.S.D. Babu).

<u>Stellar rotation:</u> Effect of stellar rotation on colours and line indices of stars is being studied. The narrow band colours uvby and H-beta line indices of member star clusters available in the literature have been utilised to derive the changes produced in these indices due to stellar rotation. Such effects, though expected to be

present, have not so far been quantitatively determined and taken into account in calibration of these indices with effective temperature and absolute magnitude. Since these colours and indices are also affected by spectral peculiarity, binary nature and evolution, only well observed rich open clusters are utilised to derive the rotation effects. Preliminary results for alpha-Persei cluster and Scorpio-Centaurus association indicate that the C_0 index of the early type member stars of these clusters is considerably affected by stellar rotation (R. Rajamohan & K.K. Ghosh).

Infrared excess in Alpha Lyrae: Recent measurements in far-infrared (12-200 μ micron) by IRAS and KAO have shown evidence of infrared excess in the A0 star Alpha Lyrae. A model has been presented to explain the infrared fluxes observed on Alpha Lyr in terms of multiple dust shells of different temperatures. It is shown that dust grains of about 10 micron size seem to explain the excess emission in the entire region 12 - 200 micron with temperatures of 130 ± 15K and 40 ± 5K. This work lends further support to the interpretation of far-infrared excess in Alpha Lyrae as emission from circumstellar shell with large (about 10 micron) size grains (D.B. Vaidya & B.G. Anandarao*).

Polarization: A program of studying the wavelength dependence of polarization and position angle in very young (about 10^5 - 10^6 yr) associations and clusters was started, with a view to studying the distribution of dust in these systems. The observations of a few members of Pup III association show that (i) the degree of polarization is higher in the red region, and (ii) the degree of polarization is reasonably well correlated with the reddening of these members (S.K. Jain).

High angular-resolution interferometry: A working group on high angular resolution interferometry was formed to examine the possibility of starting stellar optical interferometry at Kavalur. While considering the distortions produced by atmospheric turbulence, it was seen that conventional theory erroneously assumed the unbounded growth of relative phase fluctuations between two points as their separation is increased. By introducing the concept of saturation of atmospheric fluctuations at large separations, it was theoretically shown that vanishingly small bandwidth is not required for arbitrarily large baselines in optical interferometry. Other tasks undertaken by members of this group are the experimental verification of the new theory on phase fluctuation the computer simulation of the atmospherically induced image distortions as well as the implementation of fast-Fourier transforms and image reconstruction algorithms (J.C. Bhattacharyya, P. Venkatakrishnan, S. Chatterjee, S.K. Saha, K.N. Kutty, K.E. Rangarajan, J. Vijapurkar, S.C. Tapde, R. Srinivasan & A.P. Jayarajan).

Late type dwarf stars: Two late type dwarf stars UV Ceti and YZ CMi were observed with the VLA at 6 and 20cm wavelengths. It is concluded that the microwave emission is due to gyrosynchrotron radiation of nonthermal electrons having a power law energy distribution. The emission originates from a source whose size is 2-3 R_* for UV Cet and 4-6 R_* for YZ CMi. From life time of 1 hr of the nonthermal particles against radiation and collisional losses, a magnetic field of few thousand gauss has been estimated on the photosphere of the stars. Observations suggest that the ambient density in the corona of YZ CMi is an order of magnitude higher than that of UV Cet. It also suggests that the flaring rate on the star YZ CMi is higher than that on UV Cet. (R.K. Shevgaonkar & M.R. Kundu*).

Fast pulsars: A study has been made of the effect of large spacetime curvature and rotation on the arrival time of pulses from fast pulsars. It is the rotationally induced effect of inertial frame drag on arrival time of pulsar signals, recalling the frequency to radius mapping inherent in polar cap models, that leads to an arrival time advancement of pulses. For the fast pulsar PSR 1937 + 214, this advancement is found to be 20-50 microseconds for a reasonable choice of the emission region thickness. These calculations suggest that the emission region thickness is less than that suggested by present observations. Alternatively, either the polar cap model for pulsar emission should be abandoned in the case of fast pulsars, or if it is to be retained should be without its radius-to-frequency mapping feature (R.C. Kapoor & B. Datta).

Quarks in neutron star cores: Neutrino transport properties in quark matter are investigated by calculating the neutrino emissivities taking into account quark-quark interactions and the effects of finite rest mass of the quarks. Neutrino emissivity of quark matter is significantly larger than that of ordinary neutron matter, and the possibility of the existence of quark matter in neutron star cores has been investigated by comparing the theoretical emissivity results with the recent data obtained by the Einstein x-ray observatory (B. Datta, B.C. Sinha* & S. Raha*).

INTERSTELLAR MEDIUM

Interstellar clouds: Interstellar clouds exhibit a large range in masses. The largest clouds are the giant molecular clouds with mass $M \sim 10^6\ M_0$ and globules as small as about 1 M_0 are found. In a previous study we had found the mass spectrum for clouds in our galaxy to be a power law of the form $dN/dM \propto M^{-s}$ with the index s about 1.5. Analysis of the observed distribution of clouds in the Andromeda galaxy and the Large Magellanic Cloud shows that the cloud mass spectrum in these galaxies is also a power law with s about 1.5. Thus the cloud mass spectrum is a universal law. The Oort model for interstellar cloud formation and destruction is consistent with the observed mass spectrum (H.C. Bhatt & I.P. Williams*).

Dust grains in Bok globules: Polarization observations of the stellar background to the interstellar clouds can give important information about the dust grains in the clouds and the geometry of the magnetic field that permeates the cloud. Polarization measurements of stars in the region of the dust globule B5 indicate that the average dust grain size in the cloud is much larger than the mean interstellar grain size. Within the cloud the average grain size is found to increase with decreasing distance from the cloud core where IRAS detected a newly born star IRS1. It is concluded that the dust grains in B5 grew in size by the accretion of condensable heavy elements from the gas on a time scale of about 10^6 yr and gravitational segregation of the larger grains on a longer time scale (about 3×10^7 yr) caused the observed radial variation in grain size. The gravitational settling of dust towards the cloud center might have triggered star formation in this globule. The cloud is found to have a rather disturbed magnetic field geometry (H.C. Bhatt).

Dust in planetary nebulae: The characteristics of the dust in planetary nebulae are still rather poorly known. By making use of the new far-infrared measurements made by IRAS and the 6cm radio observations of planetary nebulae, a correlation has been found between the dust temperature T_d, the angular radius of the nebula θ and the radio flux density S_ν all distance independent quantities. Comparison with a theoretical relation derived on the basis of the heating of the dust by the Lyman alpha radiation trapped in the nebula yields some constraints on the average properties of the dust grains in planetary nebulae. The dust in planetary nebulae on an average might be characterized by an infrared emissivity law $Q \propto \nu^\alpha$ with $\alpha \simeq 2$ and $\log (Q_{uv}/Q_{25\mu m}) \simeq 2.4$ which makes the dust likely to be dominated by graphite (H.C. Bhatt & S.R. Pottasch*).

Cn 1-1: Cn 1-1 is a high density planetary nebula that shows an emission line spectrum superposed on the stellar spectrum of an F5III-IV star. Using the IRAS far-infrarec measurements the absolute luminosity of the hot star in Cn 1-1 has been estimated to be L_* $63L_0$. On the basis of IRAS and IUE data, the temperature of the central star has been estimated at 25000K it is one of the hottest central stars of planetary nebulae. The position of the star on the HR diagram is discrepant with the young age of the nebula deduced from the high nebular density. On the assumption that the gas and dust are coextensive in Cn 1-1, the dust to gas mass ratio is anomalously large if the grains have properties similar to interstellar graphite; or else the grains are much larger (larger than 1 micron). In addition to the cool dust at about 215K there is a second distinct hot dust component at about 850K that is probably heated by the radiation from the F type star in its neighbourhood, the star being embedded in the cool nebular dust. Cn 1-1 may be a type I protoplanetary nebula with a massive star of mass greater than 1.2 M_0 evolving in a binary system. (H.C. Bhatt & D.C.V. Mallik).

Cosmic dust: It has been shown that maximum microwave radiation that could possibly be produced by all the graphite needles in space is considerably less than the observed total energy of the cosmic microwave background. This is true even if one considers all the carbon atoms in the universe to be locked up in the elongated graphite grains. The question of relevant optical depth of the cloud containing the graphite needles has been examined. It has been found that the optical depth is not sufficiently large. The intergalactic optical depth under the steady state cosmological model has also been derived and it is found to be much less than unity. Such a situation will not permit the cloud of grains to radiate like a blackbody contrary to the assumption made by Hoyle, Narlikar & Wickramsinghe (C. Sivaram & G.A. Shah).

Interstellar medium: Measurement of the expansion velocity of planetary nebulae is an important observational aspect of studies of planetary nebulae. A program of observation of the internal kinematics of these nebulae was initiated sometime ago in collaboration with Prof. J.N. Desai and his colleagues at Physical Research Laboratory (PRL), Ahmedabad. A pressure scanned Fabry-Perot spectrometer, fabricated by PRL group was used for these observations. Monochromatic scans of the nebulae in the lines of [OIII] $\lambda 5007$ and H_α $\lambda 6563$ are obtained.

Recent [OIII] scans of the planetary nebula NGC 2440 indicate that the nebular shell is expanding with a velocity of 15 kms^{-1}. This is substantially lower than the only previous measurement available of NGC 2440, namely the one by Robinson et al (1982, MNRAS, 199, 549) who quote V_{exp} = 22 kms^{-1}. The lower velocity is more in conformity with what is expected from theory (S.K.Jain, D.C.V. Mallik, J.N. Desai*, B.G. Anandrao* & D. Bannerjee

RADIATIVE TRANSFER

Effects of aberration and advection: It is widely believed that velocities much smaller than the velocity of light do not affect the radiation field in a moving gaseous medium. It has been shown that aberration and advection terms become important when terms of the order of v/c are retained. They do not produce any noticeable change in the radiation field when the optical depth is small. However, when the optical depth is large these effects become significant. For an atmosphere of optical thickness 40 and geometrical thickness five times the stellar radius, there is a 45% change in the emergent mean intensity if v/c = 0.0033 (that is v = 1000 kms^{-1}). For v/c = 0.0167 the corresponding change is 90% (A. Peraiah).

Line profiles: Integral operator techniques have been used to solve the line transfer equation, after a small amount of line emission has been added, assuming that the expansion velocity is proportional to the radius. It is found that the line shift is not exactly proportional to the real velocity of expansion. This is an important factor one should take note of while measuring radial velocities (A. Peraiah, E. Varghese & M.S. Rao).

Dusty shells around stars: Several lines in an expanding spherically symmetric dusty shells have been computed incorporating scattering due to dust, and line and continuum emission due to gas. It is found that for small values of dust optical depths, (<2), photons are removed from the core of the line. However, for larger values of the optical depth photons are added to the line core and the lines disappear altogether in a few cases. Thus from the strengths of the line cores one can obtain the amount of dust present in stellar atmospheres (A. Peraiah, M.S. Rao & B.A. Varghese).

Neutrino transfer: With a view to studying the problem of transfer of neutrinos from the dense core of a neutron star, a formal solution has been obtained by taking asymmetric scattering functions. Also the energy per free partice has been calculated for different temperatures and densities (A. Peraiah & B.A. Varghese).

Compton scattering: A formal solution has been obtained for the transfer of photons by Compton scattering (A. Peraiah).

Polarized radiation: A simplified version of the earlier general method for solving the radiative transfer equations in the case of polarized radiation has been worked out. First the relationship between the formal matrix solution of the vector transfer equation and the general solution was established. Then the simplified solution was tested for accuracy using the symmetry properties of the vector transfer equation. It has been shown that the simplified approach is very useful in practical computatic of stellar fluxes and polarization in the continuum as well as in spectral lines (K.N. Nagendra).

Spectral line formation: The effects of optical depth, the redistribution mechanisms, thermal sources, the ratio of continuum to line optical depth, and the boundary conditions on spectral line formation were studied. For an optically thick medium, the non-coherent redistribution gives high intensity in the wings. Continuous opacity sources make the spectral lines appear weak even if the scattering partially redistributes the photons. The effect of thermal sources was found to be less dominant compared to the effect of continuous opacity (K.E. Rangarajan).

A comparitive study of discrete space theory (DST) method with Auer's Hermitian method (HM) for solving radiative transfer equation was made. It was found that DST gives more accurate solutions than HM. DST also gives stable solutions even when complex physical processes are included in the transfer equation. One can reduce the computing time for high optical depth cases in DST by incorporating logarithmic optical depth scale. One can cut down the computing time by a factor of three for every decade of optical depth when optical depth is greater than 10^3 (D. Mohan Rao & K.E. Rangarajan).

A numerical solution to the monochromatic radiative transfer equation in spherical geometry has been obtained.

Three different schemes have been tried. A comparative study has been made of the above schemes for various boundary conditions and for various types of media including the extreme case of a pure absorbing medium and of a pure scattering medium (D. Mohan Rao).

Time-dependent behaviour of the emergent and reflected radiation from a medium has been studied by incorporating the effects due to the time spent by photon in the absorbed state (case 1) and the time spent by photon between two consecutive acts of scatterings (case 2). It is found that in case 1 the behaviour of the radiative field is determined by distribution of photons over the number of scatterings whereas for the case 2, it is determined by finding the distribution of path lengths in the medium (D. Mohan Rao).

THE GALAXY

<u>Young open clusters:</u> Twelve open clusters have been photometrically studied, using the telescopes at Mount Stromlo and Siding Spring Observatories. The number of stars studied in each ranges from 12 to 55; and the faintest magnitude reaches is 15 to 16, sometimes even 17.

The cluster ages are in the range 6.0×10^6 to 5.9×10^8 yr, supporting the earlier suggestions that star formation in clusters is not coeval, but is prolonged.

Out of these twelve clusters, four (OCl 585, 674, 692, 715) are located along the Cygnus-Orion arm and one (OCl 798) is a definite member of the Sagittarius-Carina arm. The existence of the outer Perseus spiral feature is substantiated by four clusters (OCl 427, 493, 501, 556) at distances of about 4 to 5.5 kpc, in the direction of the galactic longitude 170° to 220°, some evidence for which was found by earlier authors. There is a clear indication that this outer feature probably extends into the Puppis group of clusters which seems to be the junction for the merging of the local arm with the outer Perseus arm. This is supported by one of the currently studied clusters (OCl 694) which is located at a distance of about 6.5 kpc in the galactic longitude of about 245°.

There is an indication of a feature which originates from the Orion-Cygnus arm at a distance of about 4.5 kpc and extends upto a distance of about 8 kpc towards the galactic longitude of 280°. This inference is based on the location of one of the program clusters (OCl 762) at a distance of about 7 kpc in the direction of galactic longitude 270° along with two other already known clusters in the same area. Even though there is some suggestion of this branching off feature from the radio observations, this is perhaps its first optical indication (G.S.D. Babu).

GALAXIES AND COSMOLOGY

Galaxy dynamics: Macroscopic equations for collisionless stellar systems have been set up, starting from the equation of continuity in phase space. The tensor virial equations are recovered, and the tensor equivalent of the energy equation has been obtained for the first time. These equations have been used to study the dynamical evolution of homogeneous (or heterogenous) spheroidal stellar systems where the velocity distribution is not assumed to be isotropic.

It is shown that in the case of nonzero pressure and negative total energy, the cluster executes finite amplitude oscillations both in size and eccentricity. However, unlike in the isotropic case, the amplitude of the oscillations depends upon the initial eccentricity. If the total energy is positive, the system expands and eventually disperses (G. Som Sunder & R.K. Kochhar).

Active galactic nuclei: Stimulated Raman scattering processes offer an attractive and efficient method for producing both essentially the entire nonthermal continuum as well as fast electrons in the active galactic nuclei. The spatial density profiles of the emission regions have been derived. The radiation spectral index is shown to be a function of the density variation law. Time variability is dominated by density fluctuations in the magnetohydrodynamic flows present in this picture (V. Krishan).

<u>Relativistic star clusters:</u> Analysis of dynamical stability of core-envelope type high redshift star clusters has been completed. The earlier conjecture, that central redshifts as high as $z \simeq 1.5$ can be obtained from stable physical clusters, has been confirmed. This value of redshift is significantly higher than the usually quoted value of about 0.7 for star cluster models of Ipser, Fackerell, Bisnovatyi-Kogan, and others (P.K. Das).

<u>Companions of bright spiral galaxies:</u> Detailed observations by Arp show that the companions of bright spirals have systematically higher redshifts. An attempt was made to account for this excess redshift within the framework of Hoyle-Narlikar's theory of conformal gravity, as had been successfully done previously for the quasars associated with these spirals. But it was found that the formalism developed for the earlier work could not be used due to the smaller differences in the redshifts. Alternative approaches are being investigated (J.V. Narlikar* & P.K. Das).

<u>Hubble plot for quasars:</u> A possible reason for the scatter in the redshift magnitude plots (Hubble diagram) of quasars could be that a major portion of the redshifts is noncosmological. A χ^2_{min} analysis of the angular diameter and redshift ($\theta - z$) data of the 3CR QSOs is being done (P.K. Das).

<u>Distant radio galaxies:</u> Detailed infrared observations of 83 3CR galaxies with redshifts $0 < z < 1.6$ by Longair & Lilly show that the high redshift galaxies are systematically brighter than those nearby, the effect amounting to a change of more than a magnitude at $z = 1$. The conventional explanation is being attempted within the frame-work of Hoyle & Narlikar's theory of conformal gravitation with creation of matter and a variable gravitational constant G. Preliminary analysis of the data shows that the theoretical predictions are not inconsistent with the observations (C. Sivaram & P.K. Das).

<u>Decollimation of radio jets:</u> The central cores of compact radio sources are understood to produce fast moving plasma in the form of dirdcted beams (jets). The contribution of gravitational effects to the collimation process of the jets has been investigated. The foremost effect of spacetime curvature is to widen the beam (decollimation). The effect is larger if the acceleration takes place closer to the central black hole and if particle velocities are smaller. As a result of decollimation, the particle density and effective luminosity inside the beam decrease by an order of magnitude. The collimation mechanisms involving magnetic fields, radiative pressure would prevail over gravitational effects in rdgions away from the black hole where decollimation in the beam due to gravity serves as an input to the collimation process (R.C. Kapoor).

Black hole through a galaxy: The impulsive approximation has been used to numerically estimate the effect of dynamical friction on the motion through a 10^{11} $M_{\odot}$ galaxy of a black hole assumed to be a polytrope with a massive particle at its centre. It is found that a velocity of 1.1 times the escape velocity at the centre of the galaxy is needed for the object to escape from the galaxy. The energy exchange of the object with the galaxy is not large enough to cause any appreciable damage to the galaxy. For velocities of ejection less than 1.1 times the central escape velocity, damped oscillatory motion through the centre of the galaxy ensues. The star system around the black hole, however, does not suffer any pruning due to tidal effects (R.C. Kapoor).

Einstein gravity: An attempt has been made to construct a theory for the behaviour of the gravitational interaction at very high energies by comparison with weak and strong interactions. Just as an effective theory of pions, describing low energy strong interactions, emerges from the high energy quantum chromodynamics (QCD) at low energies, Einstein's theory would be the low energy effective counterpart of the gauge invariant high energy gravity theory (described by a dimensionless coupling constant and quadratic scale invariant action) arising from scale invariance being broken by quantum fluctuations at the Planck length (C. Sivaram).

<u>GUTS:</u> The energy at which gravity unites with the grand unified theories has been considered in the context of a scale invariant high energy theory unifying all the interactions with a single coupling constant. (C. Sivaram).

<u>Cosmological constant:</u> Uncertainty principle limits on the cosmological constant were put and it was shown that any reasonable time variational decay of a large initial cosmological constant produced as a result of GUT phase transition would not result in any helium or other elements produced at the nucleosynthetic stage of the big bang (C. Sivaram).

<u>Pop III objects:</u> The possibility has been considered that clusters of supermassive population III objects could have existed prior to quasars, producing the solar system abundance of heavy elements seen in quasars and then collapsing to form central black holes. It is shown that such population III objects could not have formed before $z = 5$ (C. Sivaram).

<u>Density of the universe:</u> A cosmological model with clustering of quasar redshifts at different z has been used to predict the average density of the universe at the present epoch. It has been shown that such clustering of redshifts if it occurs at any z, is inconsistent with the prediction of closure density by the inflationary model (C. Sivaram).

<u>Dark matter:</u> General upper limits on the density of dark matter in the universe and lower limits on the rest mass of axion (assuming dark matter to be made up of axions) have been derived on the basis of general properties of the large scale structure of spacetime. The most important feature of this derivation is a relationship between the age of the universe and the minimum value of the axion rest mass. If current experimental attempts to determine the axion rest mass succeed, then this theory will provide a new way of putting useful limits on the age of the Universe (B. Datta & P.S. Joshi*)

SOLAR-TERRESTRIAL RELATIONSHIPS

Solar filaments and geomagnetic activity: The origin of the recently reported link between the 'disparition brusque' (DB) of quiescent solar filaments and geomagnetic activity has been examined through a study of the composite data base on interplanetary plasma and magnetic field parameters, in relation to DBs over the period 1967 January - 1978 March. The investigation has revealed that the geomagnetic disturbances noticed after DBs were almost invariably associated (in 28 out of the 30 events) with the passage of high-speed solar wind streams at the earth, and a majority of the streams (about 68%) were found to exhibit the 27 d recurrence pattern, and so also the geomagnetic disturbances caused by them. Besides, the time delay in the onset of the geomagnetic disturbances with respect to DBs is found to depend not on the characteristics of the disappearing filament (e.g. size), but on the data of transit of the stream at the earth. Further more no systematic spatial relationship in the solar atmosphere between the potential sources of the streams (coronal holes and flares) and DB sites was found. It is concluded that the transit at the earth of corotating and transient high-speed streams in the solar wind is the basic cause of geomagnetic storms that are found to occasionally accompany DBs (by chance temporal coincidences). This principal conclusion does <u>not</u> lend credence to the view that DBs are a unique source of geomagnetic activity (besides coronal holes and flares) and can be used for forecasting geomagnetic storms (J.H. Sastri, K.B. Ramesh & J.V.S.V. Rao).

Motivated by the above results, the cause of the geomagnetic disturbances that sometimes follow eruptive prominences, EPLs (filament disappearances as seen on the limb) with long delays (about 10d) has been investigated. The study showed that, as in the case of DBs, the relationship between EPLs and long-delay geomagnetic storms arises primarily due to chance temporal correlations between EPLs and the transits near the earth of high-speed streams in the solar wind. That there is no valid physical basis for directly associating EPLs with geomagnetic storms that follow them with delays in the range of 8-12 d (as recently reported in the literature) has thus been emphasised (J.H. Sastri & K.B. Ramesh).

<u>Ionospheric irregularities</u>: Evidence has been obtained to show that, during epochs of high sunspot activity, the duration of manifestation of equatorial spread-F(ESP) irregularities in the earth's equatorial ionosphere undergoes a systematic modulation around the times of crossing of the heliospheric current sheet by the earth (sector boundary transits at earth). The modulation which is assessed to be an indirect and 'geomagnetic

activity - associated effect', is characterized by an enhancement in the duration of ESF prior to the current sheet crossing and a reduction thereafter. This response of the equatorial ionosphere to heliospheric current passage has been interpreted as primarily a modifications in the equatorial zonal electronic field in the post-sunset period, and consequent changes in the physical conditions conducive to the growth of field-aligned irregularities responsible for ESF (J.H. Sastri).

An investigation is made of the characteristics of the solar wind plasma near 1AU around the times of transit of Hale and anti-Hale sector boundaries (SB) of the interplanetary magnetic field at the earth. It has been found that the prominent increase in proton number density at the SB and the minimum in the flow speed at SB are not dependent on the type of SB, and so also the speed profile prior to SB. The flow speed 1-2d after the passage of anti-Hale SB, in contrast, is found to be significantly higher compared to that after Hale SB. The results strongly indicate that differences in the characteristics (spatial extent/field strength/geometrical divergence) of solar wind stream sources in the inner corona are responsible for the difference in the profiles of solar wind flow speed after the passage of Hale and anti-Hale SBs (J.H. Sastri).

Regular recordings of the phase path variations of ionosphere reflections at normal incidence, using the high frequency phase path sounder in Kodaikanal observatory were continued. Analysis of a major chunk of the data so far obtained (since 1983) is nearing completion, and is expected to give important information on the small scale dynamics of the equatorial ionosphere (J.H. Sastri, K.B. Ramesh & J.V.S.V. Rao).

Magnetic sub-storm: A moderate enhancement has been observed in equatorial peak atomic oxygen density following a magnetic substorm, The observed absence of OI (6300 Å) peak intensity may be due to the time lag of about 6 hours between the peak of the disturbances and the associated effect on the atmosphere at the equatorial station (S.K. Saha).

2.3m TELESCOPE PROJECT

The 2.3m telescope was installed and the first light seen in October 1985. On 6 January 1986, it was named Vainu Bappu telescope by the prime minister.

Optics: The Cassegrain secondary mirror and the coude third mirror are being figured. The 1.27m F/1.5 sphere for testing the Cassegrain secondary has been figured and is ready for aluminizing.

Automatic control and display: The Servo system was commissioned in association with Bhabha Atomic Research Centre. The Tachogenerator feedback, current and counter torque fadeout system, and incremental encoder feedback were adjusted at site to give optimum performance. The display system using a 16 bit microcomputer was developed. About 50 bright stars evenly distributed in the sky were observed to find out the difference between almanac position and the actual display position. The positional correction required due to refraction, nutation, precession, flexture of the telescope structure etc are being worked out. Photographs of selected open clusters and star trailings showed that the telescope is able to point and track within one arcsecond.

VAX 11/780 system software: Demonstrative programs have been developed to introduce the VAX 11/780 users to various plotting facilities available at Kavalur.

The RGL interactive programs RGLSCAN, RGLGRY use ReGis commands and enable visual inspection of data on VT125 and VT240 graphic terminals and demonstrate the use of gray scale for a given picture. Another interactive program PLXPLOT enables a plot of one or several arrays with chosen symbols and markers on Printronics 300 printer The graph parameters like length of the two axes, their legends and figure captions could be fed interactively and a hard copy made. High resolution plotting is accomplished with Tektronics 4511 B terminal using IGL routines and hard copies in colour obtained using colour copier. In addition to these graphic routines, utility programs like the precession of coordinates and reduction of observed radial velocities to sun have been developed (Sunetra Giridhar).

Instrumentation and techniques

Photoelectric photometric system: was installed using Lecroy amplifier discriminator and level converter with RCA 31034 photomultiplier tube.

Vainu Bappu telescope: Devices such as dome, wind screen, shutter, RA and dec counterweights, mirror flap, and hydraulic platform were energized through Hall effect switches from the console. Handset for the operation of telescope from the console, from the prime focus cage, or from the Cassegrain cage has been installed. Work is in progress on a stand-alone CCD camera system with a magnetic tape interface for logging the CCD image data.

A 64-channel data acquisition system with magnetic tape interface is under fabrication for use at Gauribidanur.

Monochromator: The double pass monochromator which K.C.A. Raheem had developed and assembled has now been put into regular operation and is being used to monitor the Ca II K line during the present solar minimum. (K.R. Sivaraman & R. Kariyappa).

Photographic spectra reduction: Interactive software has been developed at the VAX 11/780 system for the reduction of photographic spectra, digitized using the automated Zeiss microdensitometer. The software consists of a set of FORTRAN programmes linked by DCL command procedure. The ReGis Graphic Library (RGL) is utilized for the display of intermediate results on the terminal, the PLXY software for printing the graphs on the Printronix printer/plotter, and the Interactive Graphic Library (IGL) to prepare the final figures on the Tektronix colour copier. The following options are available for the reductions of programme spectra: (i) Fourier smoothing using optimal filter or low-pass filter; (ii) conversion to intensities and background subtraction; (iii) automatic identification of emission and absorption lines; (iv) reduction to continuum; and (v) binning the spectrum into uniform wavelength intervals.

If a spectrophotometric standard star is observed, it is also possible to determine the wavelength response of the instrument and to correct the observed spectrum for it.

The IGL routine helps in examining the final spectrum, choosing the region for the display, preparing the final figure with both the axes labelled, and automatically labelling lines from the line-list (T.P. Prabhu, G.C. Anupama & S. Giridhar).

Minimum relative entropy: In aperture synthesis radio astronomy, generally the sampled spatial coverage (uv - coverage) is not compact. As a result the extended brightness distributions are rather poorly reconstructed. A method called minimum relative entropy method has been worked out to improve the images for extended distributions. The method has been further generalized for partially polarized images. The strength of the method has been demonstrated by simulated examples (R.K. Shevgaonkar).

Atmospheric extinction at Kavalur: The variation of the atmospheric extinction at Kavalur during the years 1980-85 have been studied. In general, the extinction appears to follow a λ^{-4} law. There is a general increase in the aerosol absorption during these years. An attempt to compare with the meteorological measures on ozone and water vapour content showed that the marginal increase in absorption due to ozone was reflected in the extinction measures during 1980-81. The band at 7100 Å, considered to represent the absorption due to water vapour showed varying strengths during the night, implying the necessity of simultaneous meteorological measurements at Kavalur for determining meaningful relationships (B.S. Shylaja & J.C. Bhattacharyya).

Prime focus photometer: Design of a prime focus photometdr to be used at the 2.3m telescope has been completed.

Ultra-light weight mirror casting: Technology for the casting of the ultra-light weight mirror blank is being developed at the Institute. An attempt is being made to cast a 63cm mirror blank as a first step in this direction.

Vacuum coating: A high quality coating was produced on the 2.3m primary mirror, using the 2.8m vacuum coating plant. Its sixteen runs were used for the nickel coating of the 400 neutron guider plates for BARC Bombay. Realuminizing of the 1m telescope optics was done during this year.

More than fifty mirrors (15cm-20cm apertures) were aluminized. These belonged to the participants of the 'Workshop on telescope making' organised by Visvesvaraya Industrial and Technological Museum under the guidance of the Institute.

1.22m infrared telescope (PRL): The 1.22m primary mirror is in the final stages of figuring. Fabrication and aluminizing of the other optics of the telescope have been completed except for the 90mm vibrating secondary which is being figured and will be ready shortly.

Several small optics like field lenses, prisms, flats, spherical and aspheric optics were fabricated for internal use and for users at Indian Space Research Organization, Raman Research Institute, and Osmania University.

Library

The library subscribed to 134 journals and received 65 publications on exchange basis. A record number of 500 books was added during the year. Cataloguing and classification of all these books is complete. A comprehensive catalogue for all the journal holdings is ready and will be stored in the computer. A start has been made on the list of observatory publications and of astronomical catalogues in the library. Library continues to circulate the current awareness bulletin 'Recent Research in Astronomy and Astrophysics' and the IIA preprint lists. A new microfiche reader printer Minolta RP 505 was acquired. Two members of the library staff attended the annual seminar of Indian Association for Special Libraries and Information Centres and presented a paper on 'Current information on astronomy and astrophysics'.

Miscellany

Ph.D.

G. Som Sunder: Applications of tensor viral equations to stellar dynamics, Osmania University (Guides: R.K. Kochhar & S.M. Alladin*).

Pre-Ph.D. courses

D.C.V. Mallik taught survey of astronomy; and

T.P. Prabhu gave lectures on observational astronomy, and galaxies to the students of joint astronomy program at the Indian Institute of Science.

Awards

B. Datta & R.C. Kapoor: Received honourable mention at the 1985 Gravity Research Foundation essay competition.

C. Sivaram: Received honourable mention at the 1985 Gravity Research Foundation essay competition.

Scientific meetings and visits

R.C. Kapoor attended the conference on active galactic nuclei at International Centre for Theoretical Physics, Trieste 1985 April 10-13, and spent a month at the Centre, after which he visited University College Cardiff, U.K for three weeks.

C. Sivaram attended a course on 'Topological structure and global properties of spacetime' at Erice 1985 May.

B.S. Shylaja visited Vrije Institute, Brussels, ETH Zentrum, Zurich, and Institute for Astronomy, Vienna 1985 April. She attended ESA workshop on 'Recent results on cataclysmic variables' Bamberg, FRG, 1985 June 16-19.

V. Krishan spent two months at ICTP, Trieste, 1985 May 25-July 25, and attended the college on radiation in plasmas May 25-June 19.

B. Datta attended IAU Symposium No.117 'Dark matter in the universe' Princeton 1985 June 24-28, and 'Summer workshop on high energy physics and cosmology' at ICTP Trieste 1985 June-July. He attended topical meeting on quark-gluon plasma, VEC Centre, Calcutta 1985 December 2-3.

N. Kameswara Rao visited VLA, Lick Observatory, and Royal Observatory, Edinburgh, to make observations and for collaborative work (1985 July-September).

Comet Halley for school

A 30cm, F/3.5 reflector tube at Kodaikanal International School was provided with a mount and commissioned for white light photography of comet Halley. The staff and students were instructed in the use of the facility (J. Singh & R.K. Kochhar).

National workshop on astronomical instrumentation, Bangalore, 1985 September 25-27: The workshop was organized by the Institute and attended by a large number of active workers in the field.

National workshop on solar physics, Kodaikanal, 1985 September: The Institute organized the workshop which was attended by a large number of scientists from the Institute and outside. The proceedings edited by Ch.V. Sastry and V. Krishan have appeared as Volume 6 of Kodaikanal Observatory Bulletins.

IAU Colloquium No.87 'Hydrogen deficient stars and related topics', Mysore, 1985 November 10-15: The colloquium was organized by the Institute and attended by a large number of scientists. The proceedings edited by K. Hunger, D. Schoenberner & N. Kameswara Rao are being published by Reidel.

Scientific meetings and visits

R.C. Kapoor attended the conference on active galactic nuclei at International Centre for Theoretical Physics, Trieste 1985 April 10-13, and spent a month at the Centre, after which he visited University College Cardiff, U.K for three weeks.

C. Sivaram attended a course on 'Topological structure and global properties of spacetime' at Erice 1985 May.

B.S. Shylaja visited Vrije Institute, Brussels, ETH Zentrum, Zurich, and Institute for Astronomy, Vienna 1985 April. She attended ESA workshop on 'Recent results on cataclysmic variables' Bamberg, FRG, 1985 June 16-19.

V. Krishan spent two months at ICTP, Trieste, 1985 May 25-July 25, and attended the college on radiation in plasmas May 25-June 19.

B. Datta attended IAU Symposium No.117 'Dark matter in the universe' Princeton 1985 June 24-28, and 'Summer workshop on high energy physics and cosmology' at ICTP Trieste 1985 June-July. He attended topical meeting on quark-gluon plasma, VEC Centre, Calcutta 1985 December 2-3.

N. Kameswara Rao visited VLA, Lick Observatory, and Royal Observatory, Edinburgh, to make observations and for collaborative work (1985 July-September).

A. Peraiah, G. Tejappa, D. Mohan Rao and K.E. Rangarajan attended a UGC-sponsered national seminar on transport problems at North Bengal University, Rajaram mohanpur, 1985 October 7-11.

S. Giridhar attended IAU Symposium No.115 'Star forming regions' Tokyo 1985 November 11-15.

P.M.S. Namboodiri attended 'International workshop on Space dynamics and celestial mechanics' Delhi 1985 November 14-16.

IAU general assembly, New Delhi, 1985 November 19-28.

The 19th general assembly was attended by practically all the scientific and technical staff. Many scientists presented papers at the various commission meetings. J.C. Bhattacharyya served on the national organizing committee, while R.K. Kochhar served on the local organizing committee.

A.K. Saxena and S. Mohin attended IAU Symposium No.118 'Instrumentation and research programs for small telescopes', Christchurch, New Zealand, 1985 December 2-6. A.K. Saxena visited Anglo-Australian observatory and CSIRO, Sydney. S. Mohin visited Mt. John University observatory and Mt. Stromlo and Siding Spring observatories.

IAU Symposium No.119 'Quasars' Bangalore 1985 December 2-6 was attended by P.K. Das, R.C. Kapoor, R.K. Kochhar, T.P. Prabhu, V. Krishan and C. Sivaram.

J.C. Bhattacharyya, K.R. Sivaraman and J.H. Sastri attended the National space sciences symposium, Guwahati 1986 February 19-22.

J.C. Bhattacharyya, K.R. Sivaraman and G.S.D. Babu attended the national workshop on comet Halley, Nehru Planetarium, Bombay 1985 November; and Q_a seminar on comet Halley at B.M. Birla Planetarium, Hyderabad, 1986 March.

K.R. Sivaraman attended seminars on comet Halley at Trivandrum and Calicut, 1985 November, organized by the Kerala government's department of science and technology.

G.S.D. Babu attended a seminar on comet Halley at Ramakrishna Mission Vivekananda College, Madras, 1986 March.

Lectures by visiting scientists

P.C. Vaidya (Gujarat University, Ahmedabad) Geometry and nature (4-6-85).

A.K. Ray Chaudhari (Presidency College, Calcutta) A new approach to cosmological homogeneity (7-6-85).

H.C. Bhatt (PRL, Ahmedabad) Interstellar dust, dark nebulae and globules (3-7-85).

W.M. Goss (Kapteyn Astronomical Institute, Netherlands) Radio spectroscopy in the direction of Cas A : H_2CO. Zeeman, HI observations (23-7-85).

D.B. Vaidya (PRL, Ahmedabad) Light scattering : Interstellar dust and cometary dust (25-7-85).

K. Sivanandan (Naval Research Laboratory, Washington, USA) Strategy for planning infrared program (2-9-85)

K. Sivanandan (Naval Research Laboratory, Washington, USA) Scientific objects of near-IR astronomy - Highlights of recent observational results (9-9-85).

IRAS - Scientific results and future IR missions (11-9-85; 12-9-85).

V.V. Dixit (University of the West Indies, Kingston, Jamaica) Hadronic phase transition in the early universe (30-9-85).

Y. Amagishi (Nagoya University, Japan) Experiments on mode conversion of compressional Alfven waves (11-10-85).

A.E. Piskunov (Astronomical Council of USSR) Activities of the Soviet astronomical data centre (24-10-85).

____ Star formation rate, time variations and chemical evolution of the galactic disc (25-10-85).

S.R. Pottasch (Kapteyn Astronomical Laboratory, Netherlands) Hot central stars of planetary nebulae 7-11-85).

Smithsonian Inst. Camb. Mass. USA
W. Kalkofen (~~Kapteyn Astronomical Laboratory, Netherlands~~) A modern approach to radiative transfer (2-12-85).

J.E. Solheim, Nordic telescopes (3-12-85).

A.O. Benz (Institute of Astronomy, Zurich, Switzerland) Acceleration processes in solar flares and observations (4-12-85).

M.J. Smyth (University of Edinburgh, UK) Astronomical infrared spectroscopy (5-12-85; 6-12-85).

Yu Fadeyev (Astronomical Council of the USSR) Theory of dust formation in R Cr B stars (5-12-85).

Judith Perry (Institute of Astronomy, Cambridge, UK) Cloud dynamics (9-12-85).

J.E. Baldwin (Cavendish Laboratory, Cambridge, UK) Imaging from the ground (10-12-85).

W.B. McAdam (University of Sydney) Astronomical programs at Molenglo observatory (3-1-86).

M.R. Kundu (University of Maryland, USA) Stellar radio astronomy (27-1-86).

Swadesh Mahajan (University of Texas, Austin) Alfven wave heating (19-2-86)

Sibaji Raha (Saha Institute of Nuclear Physics, Calcutta) Stable vortices in physics and astrophysics (17-3-86).

Lectures given outside the Institute

S.P. Bagare: The earth, moon and the sun, School teachers association, Bangalore (1985 September).

J.C. Bhattacharyya: Halley's comet, National Institute of Mental Health and Neuro-sciences (1985 May).

_____ 2.3m telescope, Central Scientific Instruments Organization (1985 june).

J.C. Bhattacharyya: Some puzzles in present day solar research, Bhabha Atomic Research Centre, Bombay (1985 August).

____: Minor bodies in the solarsystem (P.A. Pandya memorial lecture) Indian Physics Association, Bombay (1985 August).

____: Apparition of comet Halley 1985-6, Indian Institute of Science (1985 August).

____: Apparition of comet Halley, National Workshop on comet Halley, Bombay (1985 October).

____: Kavalur's large optical telescope and new dimensions in astronomy (Vikram Sarabhai memorial lecture) Institution of Engineers, Bombay (1985 October).

____: Evolution of different astronomies in India, S.K. Mitra commemoration seminar on the Evolution of radio and space research in India, Calcutta (1985 November).

____: Some astronomical experiments for schools, IAU meeting on teaching of astronomy, New Delhi (1985 November).

____: Comet Halley, Central College, Bangalore (1986 January).

____: Modern optical astronomy - perspectives and challenges, 2nd ADCOS lecture, Udaipur University (1986 February).

J.C. Bhattacharyya: New optical and infrared telescope facilities (invited review), National Space Sciences Symposium, Guwahati (1986 February).

J.C. Bhattacharyya & B.S. Shylaja: Atmospheric extinction at Kavalur observatory, IAU Commission No.50, New Delhi (1985 November).

B. Datta: Recent developments in neutron star physics, Institute of Mathematical Sciences, Madras (1985 October).

___: Quarks and superdense matter, VEC Centre, BARC, Calcutta (1985 December).

___: General relativistic effects in fast pulsars, Saha Institute of Nuclear Physics, Calcutta (1986 January).

R.K. Kochhar: Romance of astronomy, Kodaikanal International School, Kodaikanal (1986 February).

M. Parthasarathy: Reticon observations of close binary systems (invited review), IAU Commission New Delhi (1985 November).

A. Peraiah: Difference schemes by flux vector splitting (invited review), IAU Coll. No.89, Copenhagen, (1985 June).

___: Radiative transfer on discrete spaces and its applications, North Bengal University, Rajarammohunpur (1985 October).

___: Integral operator techniques, IAU Commission 36, New Delhi (1985 November).

A. Peraiah: Discrete space theory on radiative transfer, 6th National Symposium on Radiation Physics, Kalpakkam (1986 March).

___: Comet Halley, Mythic Society, Bangalore (1986 Janaary 3).

A.K. Saxena: How to make your own telescope ? Future of the optical telescope making, Visvesvaraya Industrial and Technological Museums, Bangalore.

B.S. Shylaja: The eclipsing system CQ Cep, Vrije Institute Brussels (1985 April).

___: The observations of eclipsing WR binaries, ETH Zentrum, Zurich (1985 April).

___: Birth and death of stars, Visvesvaraya Industrial and Technological Museum (1986 January).

___: Stellar evolution (Kannada), Bangalore Science Forum (1986 January).

___: Popularising science (Kannada), Seminar of Karnataka Sahitya Academy, Kanakapura (1986 March).

C. Sivaram: Energy generation in quasars, Visvesvaraya Industrial and Technological Meseum, Bangalore (1985 August).

___: The creation and evolution of the universe according to modern cosmology, Karnataka Sanskrit Academy and Mysore University, Mysore (1986 January).

K.R. Sivaraman: Solar line bisector as a function of disc radiation (invited review), IAU Commission No.12, New Delhi (1985 November).

P. Venkatakrishnan: Interaction of flux tubes with their environment, Indian Institute of Science, Bangalore.

Popular articles

J.C. Bhattacharyya: Kavalur road to the cosmis, Science Age, 1985 Aug.

____: Kodaikanal and Kavalur observation towers, Mandakini (IAU general assembly Newsletter, New Delhi), 1985 Nov.

____: Stories of comets in the context of Halley (Bengali) Desh, 1985 May.

____: Stellar evolution (Bengali) Kishore Jnan Bigyan, 1985 Oct.

____: Mystery of solar cosmogony (Bengali), Jnan O Bigyan, 1985 Oct.

J.C. Bhattacharyya, & R.K. Kochhar (1985) Indian Institute of Astrophysics Instruments over the (1786-1985) CZ Instrument Rev. 3 & 4, 7.

B. Datta & J.C. Bhattacharyya (1985) King Comet, Science Age, Sep.

R.K. Kochhar: Halley's comet in Babylon's time, The Week, 1985 Jan. 23-29.

R.K. Kochhar: From Hyderabad to Harvard (M.K.V. Bappu) The Week, 1986 Feb. 9-15.

____: Ancient Star gazers, The Week, 1986 Feb. 9-15.

B.S. Shylaja: Comet Halley (Kannada), Sudha, 1985 Oct.

____: Viewing Halley (Kannada), Balavijnan, 1985 Oct.

____: IIA - an introduction (Kannada), Balavijnana, 1985 Dec.

____: History of IIA (Kannada), Kasturi, 1985 Dec.

C. Sivaram: A quantum jump (1985 physics Nobel prize) The Week, 1985 Nov. 16-23.

K.R. Sivaraman: Now that comet Halley is out of hiding, Science Age, 1985 Nov.-Dec.

<u>Radio and television programs</u>

S.P. Bagare: Comet Halley (Kannada)

____: The sun (Kannada)

____: Telescopes in space (Kannada) AIR Bangalore (1985 May-June).

J.C. Bhattacharyya: Interview - Meet the scientists series, AIR, Bangalore (1985 August).

____: Interview with IAU president and general secretary, AIR, New Delhi (1985 November).

J.C. Bhattacharyya: Indian astronomy today, Doordarshan, New Delhi (1985 November)

____: Yeh hai dhoomketu Halley (Hindi), AIR, Hyderabad (1986 February).

B.S. Shylaja: Small bodies in the solar system (Kannada).

____: Stars and their evolution (Kannada).

____: The galaxy and galaxies (Kannada) (1985 May-June).

____: Comet Halley (Kannada) AIR Bangalore (1985 December)

____: Viewing Halley (Kannada) AIR Bangalore (1986 March).

T.P. Prabhu, B.S. Shylaja & S.P. Bagare: A series of six programs on astronomy (Kannada), Bangalore Doordarshan (1985 April-July).

List of academic and technical staff

J.C. Bhattacharyya, D. Phil.	Director
Ch.V. Sastry, Ph.D.	Professor
K.R. Sivaraman, Ph.D.	"
M.H. Gokhale, Ph.D.	Associate Professor
J. Hanumath Sastri, Ph.D.	"
A. Peraiah, D. Phil.	"
G.A. Shah, Ph.D.	"
P.K. Das, Ph.D.	Reader
S.S. Hasan, Ph.D.	"
N. Kameswara Rao, Ph.D.	"
R.C. Kapoor, Ph.D.	"
R.K. Kochhar, Ph.D.	"
V. Krishan, Ph.D.	"
D.C.V. Mallik, Ph.D.	"
M. Parthasarathy*, Ph.D.	"
R. Rajamohan, Ph.D.	"
P.K. Raju, Ph.D.	"
R. Sagar*, Ph.D.	"
A.K. Saxena, Ph.D.	"
G.S.D. Babu, M.Sc.	Fellow
S.P. Bagare, Ph.D.	"
S. Chatterjee, Ph.D.	"
V. Chinnappan, B.E.	"
B. Datta, Ph.D.	"
K.K. Ghosh, Ph.D.	"
N. Gopalswamy, Ph.D.	"
S.K. Jain, Ph.D.	"
A.K. Pati, M.Sc.	"
T.P. Prabhu, Ph.D.	"
~~P. Santhanam, M.Sc~~.	"
B.S. Shylaja, M.Sc.	"
K.K. Scaria, Ph.D.	"
J. Singh, Ph.D.	"

---

* Asterisk denotes appointment in the current report period.

C. Sivaram, Ph.D.	Fellow
P. Venkatakrishnan, Ph.D.	Fellow
S. Giridhar, Ph.D.	Research Associate
S.S. Gupta,* M.Sc.	"
S.V. Mallik,* Ph.D.	"
S. Mohin, M.Sc.	"
~~K.N. Nagendra*, M.Sc.~~	"
P.M.S. Namboodri, M.Sc.	"
K.N. Nagendra,* M.Sc.	"
R.S. Narayanan,* Ph.D.	"
A.V. Raveendran, M.Sc.	"
K.R. Subramanian, M.Sc.	"
R. Surendiranath, M.Sc.	"
C. Thejappa, M.Sc.	"
R. Vasundhara, M.Sc.	"
~~Parag Seal, Ph.D.~~ S.K. Saha	CSIR Scientists Pool Officer
C.G. Anupama, M.Sc.	Research Scholar
K.S. Balasubramaniam, M.Sc.	" (Joint Astronomy Program)
D. Mohan Rao, M.Sc.	"
~~Parthasarathy Joarder, M.Sc.~~	" (Joint Astronomy Program)
K.E. Rangarajan, M.Sc.	"
~~G. Som Sunder, M.Sc.~~	"
~~J. Vijapurkar, M.Sc.~~	"

18 theory

Technical staff

A.P. Jayarajan, M.A.	Consultant
S.C. Tapde, B.Sc. (Engg.)	Project Manager, 2.3m telescope project
R. Srinivasan, Ph.D.	Principal Scientific Officer (Electronics)
A.V. Ananth, M. Tech.	Sr. Electronics Engr.

---

* Asterisk denotes appointment in the current report period.

T.S. Raghu, M.E.	Sr. Electronics Engineer
B.R. Madhava Rao, B.E.	Sr. Mechanical Engineer
R.K. Shevgaonkar, M.Tech.	Electronics Engineer
N. Selvavinayagam, B.E.	Civil Engineer
R. Sivashanmugam	Technical Associate
R. Muraleedharan Nair,B.Sc.	"
K. Raman Kutty	"
K.G.Unnikrishnan Nair,B.Sc.	"
A. Vagiswari, M.A.	Librarian

Dr. N.A. Narasimham took up at the Institute a project on High resolution spectroscopic studies as an Indian National Science Academy senior scientist.

Governing Council meeting

The council met only once, on 25 November 1985 at New Delhi.

LIST OF PUBLICATIONS

A. In journals.

Anandrao*, B.G. & D.B. Vaidya (1986) On the infrared excess of Alpha Lyrae, Astr. Ap. (in the press).

Ananth, A.V. (1985) A computer controlled microdensitometer, Kodaikanal Obs. Bull. 5, 37.

Babu, G.S.D., Shylaja, B.S. & Sivaraman, K.R. (1986) Spectrophotometry of comet Crommelyn 1986, IHW Newsletter No.8, 25.

Bagare, S.P. (1985) Solar flare of 1982 April 14, Bull. Astr. Soc. India 13, 394.

Balachandran*, B., Lambert*, D.L., Tomkin*, J. & Parthasarathy, M (1986) The chemical composition of Algol systems. III-Beta Lyrae Nucleosynthesis revealed, M.N.R.A.S. 219, 479.

Balasubramaniam, K.S., Venkatakrishnan, P. & Bhattacharyya, J.C. (1985) Measurement of Vector magnetic fields. I. Theoretical approach to the Instrumental polarisation of the Kodaikanal Solar Tower, Solar Phys. 99, 333.

Bappu, M.K.V., Parthasarathy, M. & Scaria, K.K. (1985) A survey of red stars in the direction of the large magellanic cloud. 3. Some regions north of bar, Kodaikanal Obs. Bull. 5, 1.

Chinnappan, V. & Bhattacharyya, J.C. (1985) The microprocessor control of the Kavalur 234-cm optical telescope, Bull. Astr. Soc. India 13, 153.

Datta, B. & Kapoor, R.C. (1985) Space time curvature, rotation and pulse profiles of a fast pulsar, Bull. Astr. Soc. India 13, 217.

Ghosh, K.K. & Bhattacharyya, J.C. (1985) Gravitational instability of interstellar magnetic clouds, Ap. Sp. Sci. 117, 89.

Asterisk denotes authers not from the Institute.

Gopalswamy, N. & Thejappa, G. (1985) Ion-sound turbulence due to shock gradients in collisionless plasmas, Pramana, 25, 575.

Gopalswamy, N., Thejappa, G., Sastry, Ch.V. & Tlamicha*, A. (1986) Estimation of coronal magnetic fields using type I emission, Bull. Astr. Inst. Czech. 37, 115.

Hasan, S.S. (1986) Oscillatory motions in intense flux tubes, M.N.R.A.S. 219, 357.

Jain, S.K. & Bhattacharyya, J.C. (1986) A single-cell photo-polarimeter, Kodaikanal Obs. Bull. (in the press).

Kameswara Rao, N. (1986) AR Puppis, IAU Circ. No.488.

Kameswara Rao, N. & Nandy*, K. (1986) IRAS observations of R Cr B stars, M.N.R.A.S. (in the press).

Kapoor, R.C. (1986) Central engine or locomotive ? Bull. Astr. Soc. India, 14 (in the press).

Kapoor, R.C. (1986) General relativistic decollimation of a jet, Ap. Lett. (in the press).

Kochhar, R.K. (1985) Madras Observatory:Buildings and Instruments, Bull. Astr. Soc. India 13, 287.

Krishan, V. (1986) A probable initial configuration of a flaring loop, Plasma Phys. & Controlled Fusion 28, 510.

Kundu*, M.R. & Shevgaonkar, R.K. (1985) Microwave emission from late type dwarf stars UV Ceti and YZ Canis Mineris, Ap.J. 297, 644.

Mallik, S.V. (1986) Expanding chromospheres of late G and K Supergiants, M.N.R.A.S. (in the press).

Melozzi, M., Kundu*, M.R. & Shevgaonkar, R.K. (1985) Simultaneous observations of solar flares at 6 and 20cm wavelengths using the VLA, Solar Phys. 97, 345.

Mohin, S., Raveendran, A.V., Mekkaden, M.V., Hall*, D.S., Henry*, G.W., Lines*, R.D., Fried*, R.E., Louth*, H, & Stelzer*, H.J. (1985) Evolution of starspot regions in DM UM, Ap. Sp. Sci. 115, 353.

Nagendra, K.N. & Peraiah, A. (1985) Some aspects of the solution of vector transfer equation in a magnetized medium, Ap. Sp. Sci. 117, 121.

Namboodiri, P.M.S. & Kochhar, R.K. (1985) On the formation of tails and bridges in interacting galaxies, Bull. Astr. Soc. India 13, 363.

Narasimham, N.A. (1985) A search for organic molecules in space : High resolution infrared laser diode and radio frequency spectroscopic studies (K. Rangadhama Rao memorial lecture 1983). Proc. Ind. Nat. Sci. Acad. 51, 769.

Parthasarathy, M. & Frueh*, M.L. (1986) Epsilon Aurigae in eclipse : The light and colour variations, Ap. Sci. 123, 31.

Parthasarathy, M.P. & Pottasch*, S.R. (1983) The far infrared (IRAS) Excess in HD 161769 and related stars, Astr. Ap. 154, L15.

Peraiah, A. (1985) Discretization of the equation of radiative transfer with Compton scattering, Kodaikanal Obs. Bull. 5, 61.

Peraiah, A. (1986) Integral operator techniques of line transfer, Kodaikanal Obs. Bull. 5, 113.

Peraiah, A. (1986) Relativistic effects of radiative transfer equation : Order of magnitude study, Kodaikanal Obs. Bull. 5, 141.

Sagar, R., Piskunov*, A.E., Myakutin*, V.I. & Joshi*, U.C. (1986) Mass and age distributions of stars in young open clusters, M.N.R.A.S., 220, 383.

Saikia*, D.J., Subrahmanya*, C.R., Patnaik*, A.R., Unger*, S.W., Cornwell*, T.J., Graham*, D.A. & Prabhu, T.P. (1986) Radio observations of the SO galaxy NGC 1218 (3C 78) M.N.R.A.S., 219, 547.

Santhanam, P. & Bhattacharyya, J.C. (1985) A fast optical pulse counting system for crab pulsar, Kodaikanal Obs. Bull. 5, 27.

Sastri, J.H. (1985) Patchy occurrence of equatorial spread, Ann. Geophys. 3, 589.

Sastri, J.H. (1986) Earth's equatorial ionosphere and the heliospheric current sheet, Earth, Moon, Planets (in the press).

Sastri, J.H. (1986) Characteristics of the solar wind of IAU in relation to Hale sector boundaries, Planet Sp. Sci. (in the press).

Sastri, J.H. (1986) Disappearing solar filaments and geomagnetic activity, Solar Phys. 105, 191.

Sastri, J.H. & Ramesh, K.B. (1985) Eruptive prominences and long-delay geomagnetic disturbances, Bull. Astr. Soc. India 13, 231.

Sastri, J.H., Ramesh, K.B. & Ramamoorthy, K.S. (1985) A system for recording phase path variations of ionospheric reflections, Kodaikanal Obs. Bull.5, 15.

Sastri, J.H., Ramesh, K.B. & Rao, J.V.S.V. (1985) Geomagnetic disturbances associated with disappearing solar filaments.

Saxena, A.K. & Lancelot, J.P. (1985) An empirical relation for the optical quality and the image size, J. Opt. 14, 150.

Seal, P. (1985) Identification of infrared sources in IRAS circulars, Ap. Sp. Sci. 113, 391.

Shevgaonkar, R.K. and Kundu, M.R. (1985) VLA observations of a radio plage at centimeter wavelengths, Solar Phys. 97, 119.

Shylaja, B.S. & Bhattacharyya, J.C. (1986) Atmospheric extinction at Kavalur Observatory during 1980-1985, Kodaikanal Obs. Bull. (in the press).

Sivaram, C. (1985) Einstein gravity as a low energy effective theory : Comparison with weak and strong interactions, Bull. Astr. Soc. India 13, 339.

Sivaram, C. (1985) The inconsistency of a model for internal structure of black holes, Pramana 25, 221.

Sivaram, C. (1986) Remarks on binding energy of fermions in Newtonian gravity, Pramana, 26, 561.

Sivaram, C. (1986) Uncertainty principle limits on the cosmological constant, Int. Theor. Phys. 25, 825.

Sivaram, C. (1986) A cosmological prediction from the coupling constants of fundamental interactions, Ap. Sp. Sci. 124, 195.

Sivaram, C. & Shah, G.A. (1985) A feasibility study of cosmic microwave radiation via graphite needles, Ap. Sp. Sci. 117, 199.

Sivaraman, K.R., Singh, J., Kapoor, R.C. & Kariyappa, R. (1985) Broad band photometry of the solar corona of 1983 June 11, Kodaikanal Obs. Bull.5, 31.

Saleem, S.S. & Srinivasan* T.K.K. (1985) Laser Raman and far-infrared spectra of rare earth molybdate single crystals in the external mode region, Spectrochimica Acta 41A, 1419.

Som Sunder, G. & Kochhar, R.K. (1986) On the dynamical evolution of a spheroidal cluster. II Anisotropic velocity distribution, M.N.R.A.S. 221, 553.

Vaidya, D.B. & Desai*, J.N. (1986) Detection of sub-millimetre size particles in the inner coma of a comet their forward scattering, Earth, Moon, Planets (in the press).

Venkatakrishnan, P. (1986) Nonlinear response of slender magnetic flux tubes to external pressure fluctuations, Solar Phys. 104, 347.

B. In proceedings

Anupama, G.C. & Prabhu, T.P. (1986) The optical spectrum of RS Ophiuchi, RS Ophiuchi and the Recurrent Nova Phenomenon (ed. : M.F. Bode) VNU Science Press (in the press).

Bhattacharyya, J.C. (1984) Minor planets and planetary rings, Proc. Platinum Jubilee Symp. Nizamiah Obs. on 'Binary and Multiple Systems', p. 95.

Bhattacharyya, J.C. & Balasubramaniam, K.S. (1986) Measurement of solar magnetic fields, Kodaikanal Obs. Bull. 6, 30.

Ghosh, K.K. (1986) Probability of the formation of complex ring molecules in interstellar medium and their detection technique, IUE Symp. No.120 (in the press).

Ghosh, K.K., Jayakumar, K. & Rosario, M. (1986) Spectrophotometric studies of emission nebulae in the spectral region 3700-6800 Å, IAU Symp. No.118 (in the press).

Ghosh, K.K., Saleem, S.S. & Kutty, K.N. Interstellar shocked region chemistry-certain reactions between interstellar molecules and O and N atoms, IAU Symp. No.120 (in the press).

Giridhar, S. (1984) Abundance gradients in interstellar medium, Proc. Platinum Jubilee Symp. Nizamiah Obs. on 'Binary and Multiple Systems', p. 157.

Giridhar, S. (1986) Abundances of classical cepheids and evidence for secondary star formation, IAU Symp. No.115 (in the press).

Giridhar, S. & Kamesvara Rao, N. (1986) Abundance analysis of R Cr B variable, IAU Coll. No.87 (in the press).

Gokhale, M.H. (1986) Solar cycle : Observations and theory, Proc. 2nd Indo-US Workshop on Solar-Terrestrial Physics, p. 399.

Gokhale, M.H. (1986) Search for mechanisms of solar magnetism, Kodaikanal Obs. Bull. 6, 113.

Gokhale, M.H. & Hiremath, K.M. (1986) Longitudinal flows in solar magnetic flux tubes' Proc. COSPAR Symp. on 'Solar and Stellar Activity' (in the press).

Gopalswamy, N. (1986) Type-I solar radio bursts, Kodaikanal Obs. Bull. 6, 77.

Gopalswamy, N., Thejappa, G. & Sastry, Ch.V. (1986) An interpretation of decametric absorption bursts, Proc. 2nd Indo-US Workshop on Solar-Terrestrial Physics, p. 197.

Jain, S.K. (1986) Astronomical fourier transform and spectroscopy, Proc. Workshop on 'Emerging Trends in Astronomical Instrumentation' Bangalore, 1985 (in the press).

Jain, S.K. & Bhattacharyya, J.C. (1986) A single-channel polarimeter, IAU Symp. No.118 (in the press).

Kameswara Rao, N. (1986) Peculiar R Cr B stars (Invited Review) IAU Coll. No.87 (in the press).

Kameswara Rao, N. & Nandy*, K. (1986) Dust distribution around the hydrogen deficient irregular variable V348 Sgr, Proc. Workshop in V348 Sgr Liege 1985 (ed.: L. Houziaux) (in the press).

Kameswara Rao, N., Vasundhara, R. & Ashoka, B.N. (1986) Spectrophotometric observations of R Cr B during 1972-74, IAU Coll. No.87 (in the press).

Kapoor, R.C. (1986) Decollimation of a jet due to space-time curvature, IAU Symp. No.119, p. 413.

Krishan, V. (1985) Equilibrium configuration of coronal loops, Proc. Solar Optical Telescope Workshop, Garching, p. 323.

Krishan, V. (1986) Coronal loops, Kodaikanal Obs. Bull. 6, 64.

Krishan, V. & Wiita*, P.J. (1986) Stimulated Raman scattering active galactic nuclei, IAU Symp. No.119, p. 419.

Kundu*, M.R. & Shevgaonkar, R.K. (1985) Microwave emission from late type dwarf stars UV Ceti and Yz CM, Radio Stars (eds. : R.M. Hjellming and D.M. Gilson) Reidel, p. 229.

Mallik, S.V. (1986) High resolution spectroscopy in Astronomy, Proc. Workshop on 'Emerging Trends in Astronomical Instrumentation' Bangalore 1985 (in the press).

Mohin, S., Raveendran, A.V. & Mekkaden, M.V. Photometry of the RS CVn binary II Peg, IAU Symp. No.118 (in the press).

Morgan*, D.H., Nandy*, K. & Kameswara Rao, N. (1986) Light variations of LMC R Cr B Star HV 12842, IAU Coll. No.87 (in the press).

Namboodiri, P.M.S. & Kochhar, R.K. (1986) Numerical experiments on the formation of bridges and tails in galaxies, Proc. Int. Workshop on 'Space Dynamics and Celestial Mechanics', Delhi 1985.

Nandy*, K., Kameswara Rao, N. & Morgan*, D.H. (1986) 3.0 to 3.5 micron spectrum of V348 Sgr and R Cr B, IAU Coll. No.87 (in the press).

Narayanan Kutty*, K.R., Marar*, T.M.K., Padmini*, V.N., Seetha*, S. Kasturirangan*, K., Rao*, U.R., Bhattacharyya, J.C., Mohin, S., Jayakumar, K. (1986) Detection of an extremely active state of AM Canum Venaticorum, IAU Col. No.87 (in the press).

Pati, A.K. (1986) Astronomical acquisition and storage, Proc. Workshop on 'Emerging Trends in Astronomical Instrumentation', Bangalore 1985 (in the press).

Prabhu, T.P. (1986) Faint-object spectroscopy, Proc. Workshop on 'Emerging Trends in Astronomical Instrumentation', Bangalore 1985 (in the press).

Rajamohan, R. (1986) Photographic imaging, Proc. Workshop on 'Emerging Trends in Astronomical Instrumentation', Bangalore 1985 (in the press).

Raveendran, A.V., Kameswara Rao, N., Deshpande*, M.R. & Joshi, U.C., Polarimetric observations of hydrogen deficient stars, IAU Col. No.87 (in the press).

Raveendran, A.V., Ashoka, B.N. & Kameswara Rao, N. (1986) Photometric and radial velocity variations of R Cr B near maximum light, IAU Coll. No.87 (in the press).

Sastry, Ch.V. (1986) Radio emission from the quiet sun and the active regions at decametric wavelengths, Kodaikanal Obs. Bull. 6, 72.

Sastry, Ch.V. (1986) Observations of the quiet sun at decameter wavelengths, Proc. STIP Symp. on Retrospective Analysis and Future Coordinated Intervals, Switzerland 1985 (in the press).

Saxena, A.K. (1986) A new polarimeter for stellar polarisation measurement, IAU Symp. No.118 (in the press).

Saxena, A.K. (1986) New technology telescopes, Proc. Workshop on 'Emerging Trends in Astronomical Instrumentation, Bangalore 1985 (in the press).

Shevgaonkar, R.K. & Kundu*, M.R. (1985) Simultaneous dual wavelength observations of an impulsive burst using the VLA, Adv. Sp. Res. (Proc. 25th COSPAR meeting).

Shylaja, B.S. (1985) Spectrophotometry of nova Vul 1984, Recent Results on Cataclysmic Variables (ESA-SP 236), p. 183.

Singh, J. (1986) Solar optical observations from Kodaikanal and from eclipses, Kodaikanal Observatory Bull. 6, 19.

Sivaram, C. (1986) Some constraints on quasar progenitors and quasar evolution, IAU Symp. No.119, p. 417.

Sivaram, C. (1986) Inflationary universe models and clustering of quasar redshifts, IAU Symp. No.119, p. 509.

Sivaraman, K.R. (1986) Ca II K emission from the solar chromosphere, Kodaikanal Obs. Bull. 6, 11.

Sivaraman, K.R. (1986) Fine structures in the interior of the chromospheric network, Proc. 2nd Indo-US Workshop on Solar-Terrestrial Physics, p. 459.

Surendranath, R., K.E. Rangarajan & Kameswara Rao, N (1986) A preliminary analysis of broad He I emission lines in R Cr B, IAU Col. No.87 (in the press).

Thejappa, G. (1986) A model of the generation mechanism of type II solar radio bursts, Kodaikanal Obs. Bull. 6, 97.

Vagiswari, A. & Louis, C. (1986) Current information in astronomy and astrophysics with special reference to IAU Telegrams, Proc. IASLIC Seminar.

C. Notes for the Observer

Anupama, G.E. (1985) Bull. Astr. Soc. India, 13, 212; 409.

Prabhu, T.P. (1985) Bull. Astr. Soc. India, 13, 107; 206; 334; 406.

Singh, J. & Venkatakrishnan, P. (1985) Bull. Astr. Soc. India 13, 412.

Vasundhara, R. (1985) Bull. Astr. Soc. India 13, 420.

Compiled and edited by R.K. Kochhar

Appendix: Observing conditions at Kodaikanal

1. Spectroheliograph: No. of days of observation

		White light	H-alpha	K_{fl}	K_{pr}
1985	APR	25	22	22	17
	MAY	17	16	14	12
	JUN	7	6	6	5
	JUL	8	7	6	5
	AUG	13	9	5	6
	SEP	16	11	10	7
	OCT	21	18	18	16
	NOV	16	16	16	15
	DEC	18	17	17	16
1986	JAN	21	21	21	18
	FEB	23	21	21	20
	MAR	23	20	21	20

2. Solar tunnel telescope observations

		No. of days of obser-vation	Seeing (in arcsec)						
			2	2-3	3	3-4	4	4-5	5
1985	APR	13	-	-	3	1	4	4	1
	MAY	10	-	-	3	3	4	-	-
	JUN	1	-	-	-	1	-	-	-
	JUL	7	-	-	-	1	5	-	1
	AUG	7	-	-	-	1	4	2	-
	SEP	11	-	-	1	2	5	1	2
	OCT	10	-	-	3	3	3	1	-
	NOV	8	-	-	3	-	5	-	-
	DEC	15	-	-	4	6	5	-	-
1986	JAN	14	1	1	7	1	3	-	1
	FEB	6	-	-	3	1	1	-	1
	MAR	7	-	-	7	-	-	-	-
		109	1	1	34	20	39	8	6

Appendix: Hours of observation and seeing condition at Kavalur

	Spectroscopic hours	Photometric hours
1985 Apr	150.5	7
May	162.9	27
Jun	41	8
Jul	10	0
Aug	18	0
Sep	61.7	4
Oct	125.5	36
Nov	112	56
Dec	88.5	31
1986 Jan	70	29
Feb	191.5	54.5
Mar	246.5	76.5
1985-86	1278.1	329

Lectures given outside the Institute (Addendum)

K.R.Sivaraman: Halley's comet, National Workshop on Comet Halley, Nehru Planetarium, Bombay (1985 November).

____: Comet Halley, Seminar on Comet Halley, organised by the Department of Science & Technology, Government of Kerala, Trivandrum (1985 November).

____: Comet Halley, Seminar on Comet Halley, during the Science Week organised by the Department of Science & Technology, Government of Kerala at Calicut, (1985 November)

____: Comet Halley - Observations in India & abroad, National Science Symposium, Guwahati (1986 Febrauary).

____: Comet Halley - Review of Indian Observation Programme, Seminar on Comet Halley at the Birla Planetarium, Hyderabad (1986 March).

____: Comet Halley, Physics Faculty, Mangalore University, (1986 March)

LIST OF PUBLICATIONS (Addendum)

Sivaraman, K.R. (1986) "Sun as a star"
Preprint series No: 2154, Centre for Astrophysics, Harvard - Smithsonian Astrophysical Observatory, Cambridge, Massachusetts.

Sivaraman, K.R. & Kariyappa, R. (1986) II K-line emission and the Integrated Surface Magnetic Fields on the Sun - Presented at the 4th Cambridge Workshop on "Cool Stars, Stellar Systems and the Sun" (1985 October)