ANNUAL REPORT OF THE DIRECTOR

INDIAN INSTITUTE OF ASTROPHYSICS

1971-1972

CONTENTS

INTRODUCTION

This first annual report of the Indian Institute of Astrophysics reviews the activities at Kodaikanal and Kavalur for the year ending March 31, 1972.

Many aspects of astrophysics have come during this period within the scope of study by the research staff of the Institute. These range from the solar system and the sun to the brightest of the quasi-stellar galaxies. The sun is a typical star and forms the testing ground of several conjectures on phenomena in the Universe. The Institute's studies of solar phenomena and extension to the stellar situation have been in accordance with this theme. The developments made in faint light photometry have been substantial and have enabled the research staff embark on programmes hitherto impossible at Kodaikanal. The light curves of faint long period cepheids and the intensity variations of quasi-stellar sources are new programmes launched that will escalate into major projects of endeavour as telescope resources improve year by year. As we stand on the threshold of availability of a new facility in the form of the 102 cm reflector by Carl Zeiss getting ready for operation in May 1972, we have the heartening prospect of a much larger facility becoming available by the mid-seventies. This possibility stems from the capabilities developed at the Institute over the last decade and holds the prospect of enabling a major Indian participation in widening the horizons of Man's knowledge of the Universe.

PHYSICS OF THE SUN

The solar telescopes at Kodaikanal continue to gather basic solar data which is utilized in numerous research projects both at the Institute and at many other solar observatories of the world. White light photoheliograms were obtained on 304 days. For the year ending March 31, 1972, the following systematic observations were obtained: (April 1, 1971 - March 31, 1972)

White light photoheliograms	..	304
H-alpha spectroheliograms	..	271
K_{232} disk spectroheliograms	..	259
K prominence spectroheliograms	..	244

The spectrohelioscope was used for 1161 hours of observation and 78 flares were observed. 29 were of Class I, 6 of Class II and one of Class III.

Systematic total flux measures at 100 MHz and 3000 MHz have been obtained on 249 days. There were 34 events having good data coverage.

The flare data are published in the Solar Geophysical data and in the International Astronomical Union publication, Quarterly Bulletin on solar activity.

Small scale velocity fields

Sivaraman has completed a detailed study of the spatial and temporal properties of the quasi-periodic oscillations in the solar atmosphere. Time sequence spectra obtained under excellent conditions of "seeing" around 6350A, 6590A and 4280A regions with the 36 meter solar telescope and

18 meter spectrograph formed the source of the study. The solar image was guided photoelectrically and solar rotation during the exposure interval of the sequence compensated by a plane parallel guide plate. Sequences of 6350A and 6590A contain 120 and 62 spectrograms respectively, each obtained every 20 seconds on high contrast Eastman IV-E emulsion. The sequence at 4280A has 160 spectra taken at 15 second intervals on Ansco Hypan X film. A measure of the spatial resolution attained during the observations was derived from the auto-correlation function of the granulation field as seen in the continuum. The full width at half maximum (FWHM) of the auto-correlation curve gave a value of 825 km for the size of the granulation pattern for two of the best frames and an overall average value of 1100 km for the entire observations.

Fourteen Fraunhofer lines were chosen for study from the three sequences. These lines cover a good range of heights in the solar atmosphere as shown by the contribution curves calculated for them. The neutral Carbon line 6387.622A of Rowland intensity (-1) and high excitation potential (8.53eV) has a mean depth of formation almost near the granulation layer. The other lines studied are mostly of neutral iron and nickel that have mean depths of formation ranging from $\log \tau = -0.4$ to -1.2.

The time power spectrum of the velocity field which is the cosine Fourier transform of the auto-correlation function of the fluctuating component of velocities, were obtained for all fourteen lines included in the study. The spectra show for all the lines dominant power around a period of 300 seconds. To obtain a good resolution in the frequency domain, the power spectra for each line were

obtained with six different lags for the auto-correlation function. The period of oscillation in the velocity field for the deep lying CI line is 304 seconds, for weak lines 300 seconds, and for medium and strong lines 295 seconds. The power spectrum of the CI line shows in addition considerable power in the low frequency range ($\nu < 1 \times 10^{-3}$ Hz). This component decreases fast in the photospheric lines and becomes insignificant in the low chromospheric line of FeI 6358.695A.

From areas of the power spectra curves in the three domains defined as the low frequency range (ν = 0 to 1.5×10^{-3} Hz), the oscillation range (ν = 2.75 to 4.25×10^{-3} Hz) and the high frequency range (ν = 5.5 to 8.0×10^{-3} Hz) one finds the following characteristics:

i) in the oscillatory range the percentage of power increases as one goes up the solar atmosphere starting from the deep lying lines to the lines in the low chromosphere.

ii) the low frequency component shows a fast decrease with height that is specially significant in the low level lines.

iii) the high frequency tail remains substantially constant. The CI line alone has also substantial power in the high frequency regions. This is due to the proximity of the region of formation of the line to the source of mechanical flux, which has a broad frequency spectrum at the place of generation.

The significant low frequency power seen in the low level lines, represents the convective component in the macroscopic velocity field in the low photosphere and is in conformity with the theoretical prediction of the "convective overshoot" into the stable layers of the photosphere, caused by the convective motions below.

For eleven pairs of lines, coherence and phase spectra calculated as a function of frequency have been used to compare the velocity fields in the different lines with each other. In many cases a high value of 0.98 for the coherence in velocity fields in different lines is obtained. As a rule the high level lines lag behind the low level lines. In the resonance range the phase difference between the low level CI line and the high level FeI 6593.884 line is 5 seconds. The difference in the mean depth of formation between the two lines is about 120 km. If sound waves are propagated vertically the phase lag should have been about 17 seconds. Thus there exists a large phase velocity in this range compared to the sonic velocity. This may mean that either these are standing accoustic waves or internal gravity waves which do not have a vertical phase velocity. In the low frequency range the phase difference is insignificantly small which is to be expected for convective motions penetrating from below. In the high frequency range the phase difference is about 20° which is a reasonable value for the propagation of sound waves.

The intensity fluctuations perpendicular to the direction of dispersion were measured for FeI 6358.695 in the line core, the line wings and in the adjacent continuum. The power spectrum of the continuum intensity and line wings showed weak oscillatory component at $\nu = 3.0 \times 10^{-3}$ Hz, while that

of the line core has a distinct peak in the resonance range around $\nu = 3.3 \times 10^{-3}$ Hz.

There is good coherence between upward velocity in the line and brightening in the continuum with a lag of the velocity behind the continuum brightening by 38°. The line wing brightness lags behind the continuum brightness by 13° in the resonance range. The velocity lags behind the line wing brightness by 21° and the core brightness by 93°. This phase difference of about 93° is typical of standing waves in a gas behaving adiabatically, since for a standing wave the oscillations of temperature and density lead the velocity oscillations by 90°.

Eclipse data

The coronal single spectrogram obtained at the March 7, 1970 eclipse in Mexico has been examined for emission and absorption lines in the inner and outer corona. Bappu, Bhattacharyya and Sivaraman have identified on this spectrogram emission lines of the Balmer series, the helium D_3 line and the H and K lines of ionized calcium, in addition to forbidden Fe XIV and FeX lines at 5303A and 6374A of known coronal origin. The Balmer series are seen until H_η , and weak emission at 3820A is tentatively identified with neutral helium. The exceptionally clear sky at Miahuatlan on eclipse day rules out the possibility of scattering of prominence radiation by the terrestrial atmosphere. Also, if scattered prominence radiation is the source, the spectrum should show many of the finer details normally characteristic of prominences such as the emission lines of sodium or neutral magnesium, which are not seen. A coronal source for

these emission lines seems most probable. A cooler columnar component in the outer corona is not unlikely. Further studies substantiating these observations would be necessary at forthcoming eclipses before one can conjecture on the likely source.

Much progress has been made in the analysis of high resolution photographs of the solar corona of the same eclipse. Sabattier techniques have been utilized for the isophotometry as has been done for Kodaikanal observations of the 1963 eclipse. Absolute intensity calibration is made possible from small scale photographs obtained during totality and the partial phases.

Decameter radio bursts

Extensive observations with high resolution were made by Sastry on the time, frequency and polarization structure of solar decameter radio bursts during several noise storms. A set of limited data on the East-West positions of the radio bursts are also obtained. These observations are made with a four-channel dynamic spectrum analyser of central frequency 25 MHz, a time constant of 10 milliseconds and with channel separations of 80 to 200 KHz. The simultaneous polarization information comes from a polarization analyzer capable of yielding the right and left circular components with a time resolution of 10 milliseconds. The central frequency of this instrument can be varied between 24 and 26 MHz. The East-West position information is obtained from a multi-phase interferometer.

In addition to detecting several new types of short period and narrow band bursts these observations gave important information on the generation and propagation of storm bursts in the solar corona. The average half power duration of singly occurring storm bursts lies between 0.5 to 1.0 sec. The time profile of the storm bursts at decameter wavelengths is significantly different from that found at short wavelengths. Several bursts with very sharp rise and fall and extremely short durations, known as spike bursts have been detected for the first time at decameter wavelengths. The half power duration of the spike bursts were in the range 200 to 300 milli-seconds. The majority of the storm bursts do not show any regular frequency drift. For those bursts which exhibit frequency drift, the rate of drift lies between $\pm$ 1.0 MHz/sec. Two types of unusual bursts with frequency drift were seen. Several bursts with double structure in time (time splitting) were detected. The average delay between the two components of a double burst is of the order of 1 to 2 sec. The two components are also found to be polarized in the same sense. This probably means that the double structure in time is neither an echo effect nor is it due to magneto-ionic splitting. A large number of bursts with frequency splitting of the order of 200 to 300 KHz were also detected.

In a particular event the duration of either element can be larger and the high frequency element is generally more intense. In a majority of split pairs the low frequency element appears earlier than the high frequency element. A study of the time profiles of both the high and low frequency elements showed that the decay times tend to be larger in the case of the high frequency elements. If the frequency splitting is due to the emission at the plasma frequency and the upper hybrid resonance frequency then the magnetic field

at the source can be derived and in the present case at the 25 MHz plasma level the field strength turns out to be about 1 Gauss.

PLANETS AND THE MOON

A 24-inch planetary telescope with focal ratio of f/75 has been installed at Kavalur. The fused quartz optics and planetary camera are on loan from the Lowell Observatory. The mounting of the telescope was fabricated at Kodaikanal. The telescope functioned on 125 nights since June 28, 1971 and has been used by U.K. Nair and Ganesh exclusively for photography of Mars and Jupiter at a scale in the focal plane of 4.4 seconds of arc per millimetre. The photographs taken during the close approach of Mars have been of much use in evaluating specially the dust cloud formations seen strikingly during the recent opposition.

The emergence of β Scorpii from behind the Jovian disk at the occultation of May 13, 1971 was observed by Bhattacharyya photoelectrically with the 38cm reflector and oscillographic recording of the photoelectric output. Bhattacharyya has analyzed the record following Pannekock's formulation of star light refraction in a planetary atmosphere. A scale height in the outer layers of the Jovian atmosphere of 3 kms fits the data best. A mean molecular weight of 5 is obtained if the temperature parameter of the region is assumed to be 150°K. On the other hand, if a predominantly hydrogen atmosphere is assumed, the temperatures of the refracting layers must be around 500°K to explain the observed light curve.

Superposed over the normal light curve are some flash type increases in intensity that last for 2 to 4 seconds. These presumably arise from stratification in the atmosphere causing the observed refraction anomalies.

The colour and magnitude changes at Hadley Rille on the moon were observed by Bhattacharyya and Nair with the 38cm reflector during the total lunar eclipse on the night of 6-7 August 1971. The observations have been obtained on the UBV system.

STELLAR SPECTROSCOPY AND PHOTOMETRY

Scorpio-Centaurus association

Rotational velocities of over 40 members of the association have been derived by Rajamohan from spectra obtained at 45A/mm with the 51cm reflector. These spectra are also being utilized for a measure of the hydrogen and helium line intensities in the spectra. Extension to fainter limits of both rotational velocities and line spectrophotometry will be carried out with the same spectrograph on the one metre reflector.

Genetic differences as a source of rotational velocity differences perhaps controls the result that the distribution of rotational velocities of main sequence B and A stars shows a predominance of slowly rotating stars in the direction $l^{II} = 270$. Rajamohan interprets this as due to differences in the characteristics of the older inter-spiral galactic members when compared to their younger counterparts in the spiral features.

Wolf Rayet stars

Observations at 45A/mm have been continued by Rajamohan of the Wolf-Rayet binary Gamma Velorum in order to establish the value of period of the system derived earlier. The spectra are currently being measured by Bappu for radial velocities. The 3888A violet shifts have shown a remarkable periodicity in exhibiting sharpness around zero phase and a splitting around phase 0.25. A survey of all available spectra of this object at Kodaikanal shows the zero phase sharpening to be confined to about a day around the precise phase, and was found to occur at the predicted time during the cycle observed last winter. Apart from the intrinsic interest caused by such a phenomenon, the regularity of repetition coincident with predicted zero phase indicates also the accuracy of the period derived earlier.

Rajamohan has derived a distance modulus of 7.4 magnitudes to the γ_2 Velorum system using Petrie's calibration for H_γ and absolute magnitudes and a Kodaikanal determination of the equivalent width of H_γ in γ_1 Velorum. With the aid of absorption line intensities at 4101A, 3970A, 3835A and 3797A, he derives a difference in brightness between the O star and Wolf-Rayet star of 0.6 magnitudes. Corroboration of the difference is obtained by a comparison of emission lines of γ_2 Velorum and HD 192103 in the near infrared. The value derived from the emission lines is 1.4 magnitudes. Both determinations thus show the O star to be brighter than the Wolf-Rayet star by one magnitude.

Bappu has completed a detailed study of line identifications and profiles on Wolf-Rayet spectra of high dispersion. These results were reported in detail in a review

lecture at the Buenos Aires IAU Symposium on Wolf-Rayet and High Temperature Stars. Bappu and Scaria have made much progress in the preparation of an Atlas of Wolf-Rayet intensity tracings that will be published shortly.

Novae

The measurement and analysis of spectra of Nova Delphini (1967) obtained at 45A/mm with the Bhavnagar telescope is now complete. Doss, Bhatnagar and Natarajan describe in detail the changes in velocity and profile of several of the emission and absorption lines at different epochs after the first maximum. They derive a value of ionization temperature of 22000°K from a spectrum obtained in May 1968.

Stellar Chromospheres

Bappu and Sivaraman have extended their earlier efforts at identification of the agency on the solar surface that gives rise to the width of the K emission - absolute magnitude relationship in the stars. Since the fine mottling in calcium is seen to be the agency a comparison of the average profile of several mottles and the profile in integrated light has been made. The integrated spectrum of the entire sun as a star has been obtained on several occasions with the same experimental arrangement and dispersion that provided the fine mottle spectra. The integrated profile shows the contribution by solar rotation to the overall profile, thus causing an increased width of K_2 emission over that of the average mottle profile. It will, therefore, be necessary to incorporate this new value for the solar chromosphere in the absolute magnitude - K line width relationship of Wilson and Bappu.

X-ray and radio sources

A programme of optical observations of Sco X-1, in conjunction with X-ray measurements by the balloon and rocket groups of the TIFR, have been made with the 38cm reflector and single channel pulse counting photometer on several nights in February and March 1972. Sixty second integrations separated every thirty seconds provide a good monitoring efficiency with data points at close intervals in time. Sco X-1 showed little flaring on the nights when it was observed.

Photometric measures on the UBV system were also made of the quasi-stellar source 3C273.

Long period cepheids

The cepheids of period greater than 13 days have been recognized as good tracers for the study of spiral structure of the galaxy. A programme of observation of several of these in the Puppis and Vela regions has been commenced.

INSTRUMENTATION

A new mounting for a 61cm aperture cassegrain system operating at a focal ratio of f/75 has been fabricated in the machine shop and installed at Kavalur under a roll-off roof. The optics are on loan from the Lowell Observatory. The telescope was operational since June 1971. A 7 meter steel dome for it has been fabricated in the machine shop for subsequent erection at Kavalur.

Work has progressed satisfactorily on the cassegrain and coude spectrographs of the one metre reflector. The optics for the cassegrain spectrograph have been completed in the optics laboratory. These include a 7.5 cm aperture Maksutov of focus 9 cm, and an off axis paraboloid for the collimator. The long focus coude camera is in the final stages of figuring. It is 87cms in aperture and has a radius of curvature of 4.8 metres. An off axis parabolic collimator of 8.1 metres focus has also been completed.

A new spectrum scanner in an Ebert-Fastie arrangement has been built for the one meter reflector. It has an off set system ahead of the monochromator and facilitates continuous scans to be obtained simultaneously in the blue and infrared.

SOLAR TERRESTRIAL RELATIONSHIPS

The effect on the ionospheric layers of an isolated solar flare during the last International Quiet Sun Year was a subject of study by Joseph. The event was so chosen that clear ionograms with simultaneous Lyot filtergrams of the sun were available for comparative study. The quiet period enabled better estimation of the recombination and drift coefficients in the various heights of the ionosphere, and ultimate estimates of the solar ionising flux at XUV and spectral regions. The ionising flux densities were seen to have close relation with the H-alpha plage intensities during the flare, the increases mostly being in the X-ray region.

The morphology of long period geomagnetic pulsations was the subject of study by Balakrishnan and his

collaborators. Data from the magnetograms recorded in a chain of equatorial and low latitude stations during a large magnetic storm, were examined by the methods of cross spectral analysis to study the spectral densities of the geomagnetic oscillation during and following the storm. It was found that characteristic oscillations with periods of a few minutes persisted during the initial and main phases of the storm, but died down during the recovery phase. The oscillations were highly coherent and no phase lags were noticed between stations separated geographically thus indicating the source to be quite distant. Indications of slow drift of the characteristic periods during the storm were also noticed.

In a co-ordinated study of the total electron content of the low latitude ionosphere with the Institute of Radio Physics and Electronics, Calcutta, Scaria computed the total electron contents over Kodaikanal and near about, for a number of days, from the Faraday fading records of the BE-B satellite. Together with similar results worked out by the Calcutta group, these are expected to give a picture of the latitudinal variation of the total electron content on some selected days.

GUEST INVESTIGATORS

Prof. R.G. Rastogi from the Physical Research Laboratory, Ahmedabad, spent about a month in the Solar Terrestrial Physics laboratory, examining the ionospheric and magnetic records obtained at Kodaikanal for studying solar cycle variations. An interesting feature of the behaviour of equatorial Es with geomagnetic activity was noticed during

the investigations. An abnormal large increase in the horizontal force during day time almost always resulted in the disappearance of the equatorial Es. The phenomena were also seen to be accompanied by a reversal of the direction of electron drift from westward to eastward. The observation offers a possible explanation of the occurrence of equatorial Es as due to electrostatic field associated with the electrojet.

Dr. M.N. Joshi of the Tata Institute of Fundamental Research used the facilities at Kodaikanal for optical identifications of the radio sources picked out by the Ooty radio telescope.

BIBLIOGRAPHY

Balakrishnan, T.K. - A preliminary analysis of the Geomagnetic storm of March 8, 1970 - Indian Journal of Radio and Space Physics (In press)

Bappu, M.K.V - The spectra of Wolf-Rayet stars at high dispersion, "Wolf-Rayet and High temperature stars", International Astronomical Symposium No.49, M.K.V. Bappu and J. Sahade Eds. D. Reidel Publishing Co., Dordrecht-Holland.

Bappu, M.K.V, J.C. Bhattacharyya and K.R. Sivaraman - On emission lines of hydrogen, helium and ionized calcium seen on a coronal spectrogram of the March 7, 1970 eclipse. Solar Physics (In press)

Bhattacharyya, J.C - On the occultation of Beta Scorpii by Jupiter on May 13, 1971 - Nature (In press).

Bhattacharyya, J.C - Velocity oscillations in the solar atmosphere - Solar Physics (In press).

Doss A.T., A. Bhatnagar, and V. Natarajan - Photoelectric and Spectrographic studies of Nova Delphini (1967) Kodaikanal Observatory Bulletin Number 217.

Douglas, J.N., F.A. Bozyan and U.V. Gopala Rao, Decameter radio emission from Jupiter : Astronomical Journal (in Press).

Rajamohan, R - The absolute magnitude of Gamma Velorum - The Observatory.

Sastry, Ch.V - The frequency drift and time splitting of solar decameter radio bursts - Astrophysical Letters (In press).

Sastry, Ch.V - Observations on the time and frequency structure of solar radio bursts - Solar Physics (In press).

Sivaraman, K.R., see Bappu, M.K.V.

STAFF

Academic staff in position during the year are as follows:-

1. M.K.V.Rappu, A.M., M.Sc., Ph.D., F.A.Sc., F.N.A.	Director.
2. J.C.Bhattacharyya, M.Sc., D.Phil.	Associate Professor.
3. K.R.Sivaraman, M.Sc. Ph.D.,	Reader.
4. Ch.V.Sastry, M.Sc., Ph.D.	-do-
5. A.P.Jayarajan, M.A.	-do-
6. K.C.Abdur Raheem, B.Sc.	Research Associate.
7. V.Natarajan,B.Sc.(Hons)	-do-
8. T.K.Balakrishnan, M.Sc.	-do-
9. Julius Joseph, M.Sc.	-do-

The Technical, Administrative and Non-Technical maintenance staff numbered 81.

Five members of the Technical and Administrative category were transferred to the India Meteorological Department.

One Mazdoor died during the year and in his place a new mazdoor was appointed.

BUILDINGS AND GROUNDS

The Central Public Works Department who were entrusted in 1968 with the task of fabricating the Tower

...19

and construction of the Dome to house the 40" telescope completed the building in the beginning of 1972.

An amount of Rs.2.6 lakhs was deposited with the C.P.W.D. for road, storm water drains, water supply and sanitary installations at Kavalur and airconditioning of the dark room and switch cabinet room of the tower housing the 40" telescope.

The fire lines at Kodaikanal and Kavalur have been kept in good condition.

COUNCIL MEETINGS

The Governing Council of the Institute met four times during the year at New Delhi. The Finance Committee met once.

PARTICIPATION IN SCIENTIFIC MEETINGS & SYMPOSIA

Dr.M.K.V. Bappu attended Symposium No.49 on "Wolf-Rayet and High Temperature Stars" at Buenos Aires. Dr.Bappu was Chairman of the Symposium. He visited the European Southern Observatory at La Silla and the Cerro Tololo Observatory of AURA at Cerro Tololo in Chile. He later attended the meetings of the Executive Committee of the International Astronomical Union held at the Ille de Yen in France, visiting enroute the Observatories at Pic du Midi and Haute Provence.

...20..

Dr.Ch.V.Sastry visited the Radio Observatory of the University of Sydney and the C.S.I.R.O.Laboratories in Australia to see several aspects of Antenna design that would be of use in his subsequent work at the Institute.

LIBRARY

166 Books were added to the Library bringing the total collection to 4346 books. The bound volumes of journals numbered 11197. The Institute subscribed to 96 journals. Publications from 2200 Observatories and Institutions all over the world were received in exchange for our publications.

VISITORS

Visiting Scientists have included Dr.Robert Lowell Millis of the Lowell Observatory and Dr.C.O.Alley, Department of Physics and Astronomy of the University of Maryland.
