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INDIAN INSTITUTE OF ASTROPHYSICS

(Director, Dr M.K.V.Bappu)

(Report for the year 1971 April 1 to 1972 March 31)

This first year of functioning as an autonomous research Institute under the control of a Governing Council set up by the Government of India, has witnessed a considerable enlargement of the horizons of activity. The Institute has a long history of astronomical endeavour, for it had its origin at Madras in 1972 sponsored by the East India Company for promoting the knowledge of astronomy, geography and navigation in India. A hundred years of observational effort at this site witnessed much useful activity in the form of meridian circle observations and the well-known sequence of Madras catalogues of star positions, as well as the discovery and measures of brightness of variable stars and asteroids. There was also the participation in discovery associated with the famous total solar eclipses of the sixties and seventies of the nineteenth century that created solar physics and set the foundations of observational astrophysics.

Towards the end of the nineteenth century an observatory was established at Kodaikanal for the photographic and spectroscopic studies of the Sun and stars, and all research activity of the Madras Observatory transferred to Kodaikanal. The observatory was brought under the control of the India Meteorological Department, an association that has lasted from 1899 April 1 to 1971 March 31. The contributions to astrophysics from this observatory by men like John Evershed form part of recent scientific history.

The new Institute now functions with its solar facilities at Kodaikanal and its resources for stellar research at Kavalur.

SOLAR PHYSICS

The detailed study of the spatial and temporal properties of the quasi-periodic oscillations in the solar atmosphere has been completed by Sivaraman. Time-sequence spectra obtained under excellent 'seeing' conditions around 6356 Å, 6590 Å and 4280 Å regions with the 36-m solar telescope and 18-m spectrograph formed the source of study. A measure of the spatial resolution attained during the observations was derived from the autocorrelation function of the granulation field as seen in the continuum. The full width at half maximum of the autocorrelation 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 the study from the three sequences. These lines cover a good range of heights in the solar atmosphere. The time power spectrum of the velocity field which is the cosine Fourier transform of the autocorrelation function of the fluctuating component of velocities were obtained for all the 14 lines included in the study. The period of oscillation in the velocity field for the deep-lying C I line is 304 s, for weak lines, 300 s and for medium and strong lines 295 s.

From areas of the power spectra curves in the three domains defined as, the low frequency range ($\nu = 0$ to $1{\cdot}5 \times 10^{-3}$ Hz), the oscillation range ($\nu = 2{\cdot}75$ to $4{\cdot}25 \times 10^{-3}$ Hz), and the high frequency range ($\nu = 5{\cdot}5$ to $8{\cdot}0 \times 10^{-3}$ Hz) one finds the following characteristics.

(i) In the oscillatory range the percentage of power increases as one goes up in 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 C I 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 stable layers of the photosphere, caused by the convective motions below.

For 11 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 coherence in the 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 C I line and the high level Fe I 6593·884 line is 5 s. 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 s. Thus there exists a large phase velocity in this range compared to the sonic velocity. This may mean that either these are standing acoustic 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 Fe I 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 $\nu = 3{\cdot}0 \times 10^{-3}$ Hz, while that of the line core has a distinct peak in the resonance range around $\nu = 3{\cdot}3 \times 10^{-3}$ 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°.

The coronal single spectrogram obtained at the 1970 March 7 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 D3 line and the H and K lines of ionized calcium, in addition to forbidden Fe XIV and Fe X lines at 5303 Å and 6374 Å of known coronal origin. The Balmer series are seen until Hη, and weak emission at 3820 Å is tentatively identified with neutral helium. The exceptionally clear sky at Miahuatlan on the 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.

The solar telescopes at Kodaikanal continue to gather basic solar data which are utilized in numerous research projects both at the Institute and at many other solar observatories of the world. For the year ending 1972 March 31, white light photoheliograms were obtained on 304 days; H-alpha spectroheliograms on 271 days, K_{232} disk spectroheliograms on 259 days and K prominence spectroheliograms on 244 days.

The spectrohelioscope was used for 1161 hr of observation and 78 flares were observed. Twenty-nine were of Class I, six 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.

THE SOLAR SYSTEM

A 24-in. 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 1971 June 28, and has been used exclusively for photography of Mars and Jupiter at a scale in the focal plane of 4·4 sec of arc per millimetre. The photographs taken during the close approach of Mars have been of much use in evaluating especially the dust cloud formation seen strikingly during the recent opposition.

The emergence of β Scorpii from behind the Jovian disk at the occultation of 1971 May 13 was observed photoelectrically with the 38-cm reflector and oscillographic recording of the photoelectric output. Bhattacharyya has analysed the record following Pannekoek's formulation of star light refraction in a planetary atmosphere. A scale height in the outer layers of the Jovian atmosphere of 3 km 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 2–4 s. These presumably arise from stratification in the atmosphere causing the observed refraction anomalies.

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

STELLAR PHYSICS

Rotational velocities of over 40 members of the Scorpio–Centaurus association have been derived by Rajamohan from spectra obtained at 45 Å mm^{-1} with the 51-cm reflector. These spectra are also being utilized for a measure of the hydrogen and helium line intensities. Extension to fainter limits of both rotational velocities and line spectrophotometry will be carried out with the same spectrograph on the 1 m reflector.

Observations of the Wolf–Rayet binary Gamma Velorum at 45 Å mm^{-1} have been continued in order to establish the value of period of the system derived earlier. Bappu and Rajamohan are currently measuring the spectra for radial velocities. The 3888 Å 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.

Rajamohan has derived a distance modulus of 7·4 mag for the γ^2 Velorum system using Petrie's calibration for $H\gamma$ and absolute magnitudes and a Kodaikanal determination of the equivalent width of $H\gamma$ in γ^1 Velorum. With the aid of absorption line intensities at 4101 Å, 3970 Å, 3835 Å and 3797 Å, he derives a difference in brightness between the O star and Wolf–Rayet star of 0·6 mag. Corroboration of the difference is obtained by a comparison of emission lines of γ^2 Velorum and HD 192103 in the near infra-red. The value derived from the emission lines is 1·4 mag. Both determinations thus show the O star to be brighter than the Wolf–Rayet star by 1 mag.

Bappu has completed a detailed study of line identifications and profiles on Wolf–Rayet spectra of high dispersion. Bappu and Scaria have made much progress in the preparation of an Atlas of Wolf–Rayet intensity tracings that will be published shortly.

The analysis of spectra of Nova Delphini (1967) obtained at 45 Å mm^{-1} is now complete. Doss, Bhatnagar and Natarajan have studied 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 22 000 °K from a spectrum obtained in 1968 May.

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.

Optical observations of Sco X-1, in conjunction with X-ray measurements by the balloon and rocket groups of the Tata Institute of Fundamental Research, have been made with the 38-cm reflector and single channel pulse counting photometer on several nights in 1972 February and March. Photometric measures on the *UBV* system have also been made of the Quasar 3C 273.

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.

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.

RADIO ASTRONOMY

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 was also obtained. These observations are made with a four-channel dynamic spectrum analyser of central frequency 25 MHz a time constant of 10 ms and with channel separations of 80–200 KHz. The simultaneous polarization information comes from a polarization analyser capable of yielding the right and left circular components with a time resolution of 10 ms. The central frequency of this instrument can be varied between 24 and 26 MHz. The east–west position information is obtained from a multiphase 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 and 1·0 s. 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 200–300 ms. The majority of the storm bursts do not show any regular frequency drift. For these bursts which exhibit frequency drift, the rate of drift lies between $\pm 1 \cdot 0$ MHz s^{-1}. 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 1–2 s. 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 200–300 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. At the 25 MHz plasma level, the field strength turns out to be about 1 Gauss.

INSTRUMENTATION

A new mounting for a 61-cm 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 has been operational since 1971 June. A 7-m steel dome for it has been fabricated in the machine shop for subsequent erection at Kavalur.

Jayarajan has progressed satisfactorily on the fabrication of the Cassegrain and coudé spectrographs for the 1-m 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 coudé camera is in the final stages of figuring. It is 87 cm in aperture and has a radius of curvature of 4·8 m. An off-axis parabolic collimator of 8·1-m focus has also been completed.

A new spectrum scanner in an Ebert–Fastie arrangement has been built for the 1-m reflector. It has an offset system ahead of the monochromator and facilitates continuous scans to be obtained simultaneously in the blue and infra-red.

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 ionizing flux at *XUV* and spectral regions. The ionizing 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 has been the subject of study by Balakrishnan and his collaborators. Data from the magnetograms recorded by 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.

Professor 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 an electrostatic field associated with the electrojet.

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