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GOVERNMENT OF INDIA
DIRECTOR GENERAL OF OBSERVATORIES

ANNUAL REPORT
OF THE
KODAIKANAL OBSERVATORY
FOR THE YEAR
1963

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ANNUAL REPORT* OF THE KODAIKANAL OBSERVATORY
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Solar Physics

Several spot spectra were obtained with the tower telescope and 18 metre spectrograph for a detailed study of the spatial velocity field distribution in sunspots. The influence of the spot magnetic fields in the velocity measures was eliminated by using the three Zeeman insensitive lines 4912.027 Å, 5576.101 Å and 5691.101 Å. The radial, tangential and vertical velocities in the spots were determined with the aid of an IBM 1620 computer. Besides the major contributing factor of radial motion, tangential velocities were also detected in sunspot penumbrae. However, these velocities exhibited no systematic trend of variation with distance from the spot centre.

A photometric study of the phenomenon of line-asymmetry in the spot penumbral region, first discovered by Evershed in 1916, has been completed. The asymmetry is seen to be a function of the disk-position of the spot as well as the line intensity.

Spot spectra, obtained under very good conditions of seeing, show variations in continuum intensity in the penumbral region. A correlation study shows that a significant negative correlation exists in the penumbral region between the continuum brightness and the equivalent widths of lines.

Calcium spectroheliograms covering the period 1913-1919 have been utilized in a study of the life history of calcium plages. Changes of form, area and inclination are being correlated with the development phases of the underlying spot group.

Centre-limb spectra at six values of $\cos\theta$ on the solar disk have been obtained for a study of rotational temperatures from equivalent widths of selected lines of CN, C₂ and CH. An analysis of these plates indicated an agreement in rotational temperature of 4500°K for the three molecules.

All cases of prominences with high activity were collected from the I.G.Y. solar activity reports in order to find out their possible association with terrestrial effects similar to those observed in the case of solar flares.

The study revealed that about 90 per cent of the cases of active prominences were followed by bursts of solar radio radiation, about 60 per cent by partial or complete short wave radio fadeouts and about 7 to 20 per cent by other SID's like S.E.A. and S.C.N.A. Thus it is seen, that prominences of high activity are also sources of enhanced solar radio radiation and X-rays, and are probably next in importance to that of solar flares.

An expedition to Athens, Maine, U.S.A. successfully photographed the solar corona at the total eclipse of July 20, 1963. The films are currently being utilized in a photometric study of the outer corona.

*This report deals chiefly with the astronomical and allied geophysical work of the Kodaikanal Observatory. The Meteorological data will be published in the India Weather Review, the Seismological data in the Seismological Bulletin and the administrative details in the Administrative Report of the India Meteorological Department.

An analysis of Greenwich sunspot data for the period 1930-1944 has been made in an effort to study some of the finer details of characteristic features exhibited by spot activity within a cycle. The longitudes of the individual groups corrected for differential rotation have been obtained in order to study the pattern of activity in narrow longitudinal belts. The investigation makes use of the assumption that the regions of sunspot formation experience differential rotation.

Regular observations with the Lyot Monochromatic Heliograph was continued after rearranging the system into one of greater efficiency than available before. The resolution and speed of the instrument have considerably increased as a result of this arrangement. Filtergrams have been obtained of the disc and prominences on 206 days against 224 days in 1962. Photoheliograms were taken on 327 days compared to 332 days in 1962. H—alpha disc, K—disc and K—prominence spectroheliograms were secured on 184, 300 and 253 days as against 229, 299 and 256 days respectively during 1962. The total number of exposures of each kind was as follows :—

| | | |
|---|-----------|-----|
| (1) Photoheliograms | | 350 |
| (2) H—alpha spectroheliograms | | 358 |
| (3) K ₂₃₂ spectroheliograms | | 694 |
| (4) K—prominences | | 499 |
| (5) K ₂₃₂ disc and prominence composites | | 81 |

Observations with the spectrohelioscope were made on 295 days covering a total duration of 1137 hours of solar patrol. Sixtyone solar flares were observed during the year, one of importance 3⁺, one of importance 3, three of importance 2⁺, eleven of importance 2, one of importance 1⁺, twelve of importance 1 and thirtytwo of importance 1⁻.

Observing conditions were better than in the previous year. The average definition of the Sun's image was 3 on a scale of 5. There were 51 days of seeing 4 and 180 days of seeing 3. The total rainfall recorded was 1965 mm. which was about 22.2% more than the annual normal. The total number of hours of sunshine was 1710.

Sunspot activity continued to be on the decline during the year. The mean equatorial distance of the northern hemisphere spot groups was 10°.5 and of the southern hemisphere spot groups 10°.1 as against 10°.3 and 10°.5 in 1962. Details of sunspot observations are given in the following table.

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Total |
|--|------|------|------|------|------|------|------|------|------|------|------|------|-------|
| | | | | | | | | | | | | | Mean |
| No. of new spot N | 7 | 6 | 3 | 4 | 11 | 11 | 7 | 6 | 5 | 9 | 4 | 3 | 76 |
| groups | S 1 | 1 | 3 | 2 | 3 | 3 | 0 | 3 | 2 | 2 | 0 | 2 | 22 |
| Mean daily No. of spot groups | 1.0 | 1.7 | 1.1 | 1.5 | 2.5 | 2.3 | 1.3 | 1.8 | 2.0 | 2.1 | 1.2 | 0.8 | 1.6 |
| Kodaikanal daily relative sunspot Nos. | 18.6 | 25.7 | 15.3 | 28.6 | 41.6 | 38.3 | 18.2 | 29.6 | 38.2 | 35.2 | 17.3 | 9.6 | 263 |

The following table gives the mean daily areas and numbers of calcium prominences at the limb as derived from spectroheliograms obtained at Kodaikanal during 1963.

| 1963 | Area (in Square minutes) | | | | | Numbers | | | | |
|-------------------------------|--------------------------|------|------|------|-------|---------|------|------|------|-------|
| | N | S | E | W | Total | N | S | E | W | Total |
| January- June. | 1'91 | 0'71 | 1'08 | 1'54 | 2'62 | 4'19 | 2'65 | 3'22 | 3'62 | 6'84 |
| July- December. | 1'57 | 1'27 | 1'49 | 1'55 | 2'84 | 4'20 | 3'60 | 3'40 | 4'40 | 7'80 |
| Whole year (weighted mean) | 1'78 | 0'93 | 1'17 | 1'54 | 2'71 | 4'20 | 3'00 | 3'30 | 3'90 | 7'20 |

The figures show a slight increase in the prominence activity judged by areas, and a slight decrease judged by numbers, from the previous year, the increase in area being 8.8 per cent and the decrease in number being 3.1 per cent. The distribution of areas in the northern hemisphere in five degree ranges of latitude shows a peak of activity extending from 30-35° with a secondary maximum in the zone 20-25°. In the southern hemisphere the maximum activity is in the zone 40-45° with a secondary maximum in the zone 20-25°. Three sudden disappearances of dark absorption markings were observed at Kodaikanal during the period.

The mean daily areas and numbers of hydrogen absorption markings on the disc as obtained from Kodaikanal records are as follows :-

| 1963 | H-alpha dark marking area (in millionths of the Sun's visible hemisphere uncorrected for foreshortening.) | | | | | Numbers | | | | |
|-------------------------------|---|-----|------|------|-------|---------|------|------|------|-------|
| | N | S | E | W | Total | N | S | E | W | Total |
| January- June. | 1439 | 519 | 879 | 1079 | 1958 | 10'33 | 4'01 | 6'78 | 7'56 | 14'34 |
| July- December. | 2527 | 741 | 1483 | 1785 | 3268 | 16'20 | 6'60 | 9'90 | 2'90 | 22'80 |
| Whole year (Weighted mean) | 1787 | 590 | 1072 | 1305 | 2377 | 12'20 | 4'80 | 7'80 | 9'20 | 17'00 |

Compared to the previous year there is an increase of activity of the absorption markings judged both by areas and numbers. The increase in area amounted to 21.3 per cent while the numbers showed an increase of 18.6 per cent. In the northern hemisphere the peak of activity is in the latitude belt 20°-30° with a secondary maximum activity in the zone 10°-20°, and another secondary maximum in the zone 45°-50°.

The exchange of spectroheliograms with foreign observatories was continued. For the period July 1962 to June 1963, 98 H-alpha disc, and 46 K-disc and 58 K-Prominence spectroheliograms were received from the Meudon Observatory. 39 H-alpha disc, 5 H-alpha filtergrams and 134 K-disc spectroheliograms for certain days for the period 1962-63 were sent to the Meudon Observatory.

Stellar Physics

Photoelectric observations of the short-period variable SX Phoenicis were obtained with the photometer on the 20 cm. refractor. The observations have been reduced for a study of the changes in light and colour curves. Observations on UW Canis Majoris and Zeta Aurigae are in progress.

Equivalent widths of 100 selected FeI, FeII, Ti I and Ti II lines have been measured from direct intensity traces at 11 phases for the 3.7 day Cepheid RT Aurigae. Excitation temperatures derived from these measures vary from $0^\circ \text{exc} = 0.88$ to $0^\circ \text{exc} = 1.08$ in the first approximation. Suitable lines of all other elements have been measured on 4 selected high dispersion plates for a determination of element.

Research in Ionospheric Physics and Geomagnetism

All flares accompanied by magnetic crochets in the horizontal force records of the earth's field at Kodaikanal during the six-year period 1956—1961 have been examined with the purpose of detecting crochet differences between relativistic and non-relativistic flares. The amplitude, durations and impulsive nature of the geomagnetic effects associated with relativistic flares are found to be different in nature from those of the non-relativistic type. These can be explained in terms of strong hardening of X-ray bursts of solar origin in the spectral range 1-8 \AA , associated with the high energy part of the electron spectrum responsible for intense microwave bursts during relativistic flares.

Diurnal ranges in the horizontal and vertical intensities of the earth's field at Kodaikanal, have been evaluated for quiet and disturbed days during periods of low as well as high solar activity. The maintenance of the diurnal range during disturbed days at the same level as observed on quiet days at equatorial stations has been attributed to strengthening of equatorial electrojet by the polar electrojet, thus masking the effect of decrease in the field due to westward ring currents during storms.

A study of the characteristics of the blanketing type sporadic E layer observed at Kodaikanal indicates that this type of sporadic E occurs in the Indian equatorial region 3 to 5 times more frequently than at stations of similar magnetic latitudes in the American zone. Changes of large magnitudes in the F_2 layer as well as in the horizontal intensity of the earth's magnetic field occur simultaneously with the appearance of blanketing E_s . Lunar tidal effects have also been found to exist both in the time of appearance of blanketing E_s and in its strength. Some evidence exists to show that this type of E_s as well as the blanketing frequency, $f_b E_s$, have a biennial maximum. These characteristics are examined as part of the Far-East Anomaly.

A study of the diurnal control of solar flare effects in the ionospheric F_2 region over Kodaikanal reveals that the discontinuity in the pre-flare and

post-flare trends in the F₂ layer ionic densities are more markedly seen in the morning and afternoon hours when the F₂ layer peak is closer to the level of maximum electron production. No noticeable effects are seen around local noon when the F₂ layer is displaced by electrodynamic drifts considerably from the maximum production level.

A study has been commenced of the tidal effects of lunar origin in the maximum electron densities of the F₂ layer over Kodaikanal. Preliminary results suggest that the amplitude of the semi-diurnal lunar variation increases considerably during the afternoon and evening hours and that the phase also undergoes a change subsequent to local noon.

Continuous photographic recordings of the earth's magnetic elements H, D and Z using La Cour and Watson magnetographs and visible recordings of H and Z with Askania field Balances have been continued. Absolute values of H, D and Z have been determined with a set of Q.H.M. and B.M.Z. instruments. Absolute measurements of H with a Kew Magnetometer have also been made once every month. Scale value determinations of these magnetographs have been made twice a month. During the year 24 magnetic storms, which include 7 storms of sudden commencement type, have been recorded with ranges in the horizontal intensity between 119γ and 332γ.

Routine ionospheric soundings have been made at 15 minute intervals. Shortwave field intensity recordings have also been made during day light hours on all days of the year. Shortwave radio fadeouts of the Dellinger type have been recorded on 24 occasions. Round-the-clock recordings of cosmic noise at 30 Mc/s. have been made daily.

Monthly median values of foF₂ and (M₃₀₀₀) F₂ have been supplied to the Central Radio Propagation Laboratory, Boulder, U.S.A. Quarterly statements of monthly median values of all ionospheric parameters have been sent as in previous years to the Radio Research Station, U.S.A. Periodical statements of observational data concerning ionospheric characteristics, geomagnetic storms and ionospheric disturbances have been supplied to several interested institutions. Daily messages in I.G.Y. codes relating to solar, magnetic and ionospheric observations at Kodaikanal have been sent to New Delhi for inclusion in the AIMBC broadcasts.

Radio Astronomy

Regular recordings of solar noise flux at a frequency of 100 Mc/s. have been continued. Radio star scintillation observations of Cygnus A and Cassiopeia have been made at 100 Mc/s. whenever possible. Construction of an interferometric aerial for use with 200 Mc/s. radiometers was in progress.

Under the joint Kodaikanal-Yale Project, recordings of radio radiation from Jupiter at a frequency of 22.2 Mc/s. have been made using a phase switching interferometer.

Instrumentation

A 4.3 metre spectroheliograph in a Littrow form, constructed in the machine shop, went into operation towards the end of the year. A 1200 grooves/mm grating blazed at 7500 Å serves as the dispersing element.

A focal plane photoelectric scanner has been constructed for use with the 18 metre spectrograph for single-pass recording of solar line profiles.

A design has been worked out in detail for a grinding machine that can handle mirrors up to 1.3 metres in diameter. Detailed designs are also complete for the fabrication of an aluminizing tank that can accommodate mirrors upto 75 cms. in diameter.

A quartz oscillator controlled electric clock was designed and built in the electronics laboratory.

A new image forming mirror of focal length 18 metres was ground and figured in the optical shop. The optics for a 20 cm. aperture cassegrain telescope have also been completed during the year.

Miscellaneous Observations

Meteorological observations with the visual and self recording instruments have been carried out as usual. The Milne-Shaw Seismograph recorded 72 earthquakes during the year. Regular observations of ozone with the Dobson Ozone Spectrophotometer have been made on 259 days. Earthshine observations have been recorded on 12 days.

General

The Director was on foreign service ex-India as a Visiting Professor for the spring semester at the University of Arizona and the Kitt-Peak National Observatory, U.S.A.

The Director continued to serve as a member of the Indian National Committee for Space Research and the Indian National Committee for the IQSY.

Visitors

Visitors who gave colloquia at the observatory included Dr. N. V. Mednikova and V. J. Pochtazev of the U.S.S.R.

Publications

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|---|---|--|
| (1) Bhargava B. N. and Subrahmanyam R. V. | { | Spatial, Seasonal and Solar cycle characteristics in the Ionospheric F-region. The Indian Journal of Meteorology and Geophysics. |
| (2) Bhargava B. N. | { | Lunar Tidal Effects in Equatorial Es—Journal of Atmospheric and Terrestrial Physics. |
| (3) Bhargava B. N. | { | A note on the equatorial Electrojet—Indian Journal of Meteorology and Geophysics. |
| (4) Nirupama Subramanyam | { | An analysis of Eruptive Prominence motions—Kodaikanal Observatory Bulletin No. 163 (1963) |
| (5) Sankaran K. S. | { | Cusps and Distortions in Ionospheric F Layer over Kodaikanal—Indian Journal of Meteorology and Geophysics. |
| (6) Subrahmanyam R. V. | | See Bhargava B. N. |

Quarterly synopses of results of solar, magnetic, ionospheric and ozone observations made at Kodaikanal appeared in the Indian Journal of Meteorology and Geophysics. The monthly Notices of the Royal Astronomical Society published a report of the work done at Kodaikanal Observatory during 1962 as well as on the prominence activity during the same year.

Kodaikanal Observatory,
November, 1964.

M. K. VAINU BAPPU,
Director.