

ANNUAL REPORT* OF THE KODAIKANAL OBSERVATORY FOR THE YEAR 1964

Solar Physics

Line profiles of selected molecular lines of C_2 , CH and CN have been photoelectrically scanned at six positions on the solar disc using the solar tower telescope and 18 metre spectrograph. Synthetic line profiles of six molecular lines of CN, C_2 and CH were constructed using the Pierce-Waddell and HAO models for each of the observed disc positions.

A study of the centre-limb variation of rotational temperatures using the Swan system of C_2 with band head at 5165Å representing the variation in temperature over an optical depth range $T=0.04$ to 0.06 has been made. The observations show no departures from LTE and hence suggest that the postulate of deviations from the mechanism of pure absorption in line formation, to explain centre-limb variation of equivalent widths, is unnecessary.

The analysis of spectra obtained in 1963 for Evershed effect measures has been completed. The spectra cover two successive passages of the same spot group and velocity configurations have been derived on the different days from measures of the Zeeman insensitive lines 4912.027Å of NiI, 5576.101Å of FeI and 5691.508Å of FeI. The mean depths of formation of the lines have been computed with the aid of Makita's penumbra model and have been used in obtaining the gradient of maximum radial velocity with depth.

Spectra of the H-alpha line observed in the fourth order of the 18 metre spectrograph with a dispersion of 7 mm/Å have been used for the study of some of the characteristics of chromospheric mottling on the solar disc. The fluctuations in intensity, indicated by the r.m.s. values have been determined for $\Delta\lambda = 0.6\text{Å} \pm 0.2\text{Å}$ as well as the line centre. The fine mottles are found to have sizes less than 1800 km. Values of the total number of mottles visible on the disk have been estimated from mottle counts made at slit positions on the solar disk at $\mu=1.00$ and $\mu = 0.45$.

Monthly mean values of the projected areas of Ca-plage have been compared with those of the sunspots and faculae and $\lambda 10.7$ cm. solar flux. Their mutual phase relationship and their changes during the maximum and minimum periods of solar activity have been obtained.

The nature of the Ca-plage activity drift pattern through the solar latitudes with the advancement of the solar cycle have been studied using the latitude distribution of the monthly values of the projected areas of Ca-plage in 5° latitude belts.

For the period 1938—54, the monthly mean values of the two Minnis-Bazzard (1959) indices, IE and IF₃₀₀₀, of the ionospheric solar cycle variations, have been compared with the following solar activity indices *viz.*,

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

the sunspot, faculae, Ca-plage projected areas and λ 10.7 cm solar flux. It is found that the ionospheric E and F layer variations are delayed with respect to the above four solar activity indices variations by +0.5, -0.45, 0.0., +0.2 and +0.8, +0.1, 0.3, +0.5 month respectively.

From a study of the relationships between the ionospheric and the solar activity indices it is observed that the Ca-plage index based on emissivity, given by the product of area and intensity, would prove to be useful for ionospheric studies.

A solar magnetometer for the detection of very weak magnetic fields on the solar surface is under construction. Preliminary test measures made have indicated a satisfactory performance of the instrument in measuring the weak longitudinal fields in the polar regions of the sun as well as in the regions of enhanced activity.

A new double monochromator is under construction for the precise photoelectric determination of solar line profiles. Built on the principle of the conventional laboratory model of double monochromator, it promises to be an arrangement with an absolute minimum of scattered light and ghost intensity contribution. The monochromator utilizes two 600 line/mm gratings blazed in the fourth order green and the two individual 6.4 metre spectrographs operate in tandem. Both gratings are mounted on the same grating-scan assembly, thus ensuring an 'identical' rate of rotation during the scan.

Filtergrams have been obtained of the disc and prominences on 256 days against 206 days in 1963. Photoheliograms were taken on 332 days compared to 327 days in 1963. H-alpha disc, K-disc and K-Prominence spectroheliograms were secured on 282, 290 and 268 days as against 184, 300 and 253 days respectively during 1963. The total number of exposures of each kind was as follows:—

(1) Photoheliograms	...	337
(2) H-alpha spectroheliograms	...	801
(3) K ₂₃₂ Spectroheliograms	...	858
(4) K-Prominences	...	523
(5) K ₂₃₂ disc-prominence composites	...	44

Observations with the spectrohelioscope were made on 295 days covering a total duration of 1348 hours of solar patrol. Twelve Solar flares were observed during the year, ten of importance 1-, one of importance 1 and one of importance 2.

Observing conditions were more or less the same as in the previous year. The average definition of the Sun's image was 3 on a scale of 5. There were 45 days of seeing 4 and 194 days of seeing 3. The total rainfall recorded was 1829 mm which was 8.3% more than the annual normal. The total number of hours of sunshine was 1996.

There has been a further decline in sunspot activity. The mean equatorial distance of the northern hemisphere spot groups was 16°.2 and of the southern hemisphere spot groups 7°.4 as against 10°.5 and

10°.1 in 1963. Details of the sunspot observations are given in the following table.

1964	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total mean
No. of new spot groups	N 5 S 3	4 3	5 3	5 1	6 0	3 1	3 0	4 0	3 0	3 1	2 1	8 2	51 15
Mean daily No. of spot groups	1.0	1.1	1.1	0.6	0.7	0.7	0.3	0.3	0.8	0.3	0.4	1.5	0.7
Kodaikanal daily relative sunspot Number	13.9	18.8	14.6	7.5	9.4	10.6	4.0	11.7	4.8	6.4	6.8	18.4	10.6

The following table gives the mean daily areas and numbers of calcium prominences at the limb as derived from spectroheliograms obtained at Kodaikanal during 1964.

1964	Area (in Square mts.)					Numbers				
	N	S	E	W	Total	N	S	E	W	Total
January— June	1.69	0.87	1.21	1.35	2.56	4.75	3.09	3.85	3.99	7.84
July— December	1.28	0.36	0.72	0.92	1.64	2.81	1.52	1.82	2.51	4.33
Whole year (Weighted mean)	1.54	0.68	1.03	1.19	2.22	4.02	2.49	3.08	3.43	6.51

The figures show a slight decrease in activity from the previous year judged both by areas and numbers, the decrease in area being 14% and the decrease in number being 9.6%. The distribution of areas in the northern hemisphere in five degree ranges of latitude shows a peak of activity extending from 45°—55°. In the southern hemisphere the peak of activity is in the latitude belt 45°—50° with a secondary maximum in the zone 20°—25°.

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

1964	H-alpha dark marking area (in millionths of the Sun's visible hemisphere un- corrected for foreshortening)					Numbers				
	N	S	E	W	Total	N	S	E	W	Total
January— June	1760	435	1195	1000	2195	12.82	4.38	8.67	8.53	17.20
July— December	1221	171	688	704	1392	8.20	1.75	4.25	5.70	9.95
Whole year (Weighted mean)	1548	331	995	884	1879	11.00	3.34	6.92	7.42	14.34

Compared to the previous year there is a decrease of activity of the absorption markings judged both by areas and numbers. The decrease

in area amounted to 20.9% while the decrease in numbers was 15.7%. In the northern hemisphere the peak activity is in the latitude belt 45° — 55° and in the southern hemisphere it is in the zone 10° — 15° .

The exchange of spectroheliograms with foreign observatories was continued. For the period July 1963 to June 1964, 86 H-alpha disc, 54 K-disc and 60 K-Prominence spectroheliograms were received from the Meudon Observatory. 18 H-alpha disc and 147 K-disc spectroheliograms for certain days for the period 1963-64 were sent to the Meudon observatory.

Stellar Physics

All preliminary formalities for the purchase of a 1 metre reflecting telescope from VEB Carl Zeiss, Jena, have been completed.

A considerable amount of effort in the machine shop has been spent in renovating the mounting of the 20-inch Bhavnagar telescope. The telescope is now in a form where it can be used with reasonable efficiency as a light collector on spectroscopic and photoelectric programmes. Several important accessories have been built for it and are in use with the instrument. A low dispersion spectrograph with good light efficiency has been built and is utilized in obtaining the spectra of stars brighter than magnitude 8.0. A two channel photoelectric photometer for simultaneous measurement of two spectral regions isolated by interference filters is under construction for operation with a pulse counting unit.

A study of physical parameters and abundances of elements in four F-type stars has also been completed, using Mount Wilson high dispersion spectra.

A study is in progress of line profiles of the Balmer and Paschen series of hydrogen in a B9 supergiant star. A similar study of two helium series in the spectrum of an Of star has progressed satisfactorily with the aid of high dispersion spectrograms obtained with the Mount Stromlo 74-inch telescope.

The low dispersion spectrograph has been used for a study of the radial velocity variation of the Wolf-Rayet spectroscopic binary γ -Velorum. On many nights spectrograms of the MK standards have also been obtained.

Photoelectric photometry of variable stars with the 8-inch Cooke refractor has been continued during the year. An investigation of the light and colour changes of the ultra short period variable SX-Phoenicis has been completed. Observations made during early 1963 of the eclipse of Zeta Aurigae have been analysed for a determination of the luminosity of the secondary component and of the extent of interstellar reddening experienced by the system. New observations have also been made of the eclipsing system 29 Canis Majoris.

Ionospheric Physics and Geomagnetism

Radio star scintillation observations made during the period 1960 through 1963 under local summer conditions at Kodaikanal, situated about 170 km. from the dip equator, have been analysed and the study

reveals that (a) the scintillation rates were the highest between 2000 and 2200 hrs. local time (b) that the rates decreased in general, with decrease in solar activity (c) the scintillation occurrence was maximum when the virtual height of the F region was about 300 km. (d) that the average rate of scintillation increased with spread index and (e) that the day-time scintillations reported by the other workers to occur in the African Equatorial region are not present in the Indian Equatorial region.

The temporal variations of foF_2 at Kodaikanal and Huancayo under identical conditions of solar activity for June and December solstices have been examined for the study of seasonal and longitudinal anomalies in the ionospheric F_2 region. It has been found that while significant difference exists at Huancayo in the temporal variations of foF_2 for June and December solstices, such difference is practically absent in the daily variations of foF_2 at Kodaikanal, in spite of the fact that both the stations are identically situated with respect to dip equator. This difference in the temporal variations has been ascribed to the mechanism responsible for the greater frequency of occurrence of blanketing type sporadic E layer at Kodaikanal than at Huancayo.

Representative electron density true height profiles have been obtained from Kodaikanal ionograms covering a period of about a solar cycle for the study of the effects of solar activity on the ionic densities at different levels of the equatorial ionosphere. The study indicates that the effect of increase of solar activity is more significantly observed at the higher levels of the F region with little or no change in the vicinity of E and F_1 regions. The seasonal variations at different levels indicate that winter electron density at any particular level is larger than that in summer. From the (N,h) profiles, the total electron content has been calculated for different solar hours and it has been observed that the temporal variation of nT exhibits a diurnal asymmetry similar to NmF_2 . The longitudinal effects in the seasonal anomaly of low winter to summer F_2 layer peak electron density ratio observed at Kodaikanal, compared to that observed at Huancayo is explained in terms of the Far East Anomaly.

An examination of the data on spatial, seasonal and solar cycle variations in the lunar semidiurnal oscillations in the ionospheric F region suggests that these variations are quite complex. Preliminary results indicate that some of the factors which profoundly influence the dynamical processes in the F region all over the world may be responsible for the anomalous behaviour of the semidiurnal lunar tidal effects in the F region at stations which are otherwise identically located in so far as geographic latitude and geomagnetic conjugacy are concerned. These are (a) magnetic declination effects (b) wind shears around 100 km. level responsible for the meridional current (North-South component) system in middle latitudes (c) Influx of electrons from the magnetosphere into the F region in the higher temperate and high latitudes, responsible for the "Winter" anomaly and (d) longitudinal effect in the F_2 region associated with the occurrence of blanketing sporadic E in the equatorial zone, peculiar to locations situated in Asia and the Far East.

A simple method of finding the characteristics of the intense tropical current known as 'Electrojet' from horizontal force obtained from Magnetic survey, when applied to the existing data from the American, African and Indian equatorial regions has been found to yield reasonable

values of the width and height of the equatorial electrojet. These agree fairly closely with the values obtained by other authors using different methods.

Continuous recordings of H, D and Z elements of the Earth's magnetic field with Watson and La Cour magnetographs and Askania Field Balances have been continued. Absolute values of H, D and Z have been determined weekly with a set of QHM and BMZ instruments. During the year 22 magnetic storms including 8 storms of sudden commencement type have been recorded with ranges in horizontal force between 103 γ and 258 γ .

Regular vertical incidence soundings of the ionosphere and registration of shortwave signal strength have been continued. Instrumentation for Faraday rotation observations at two frequencies, 40 and 41 Mc/s. from NASA S-66 polar beacon satellite has been completed and regular observations of Faraday fading were commenced from the middle of October, 1964.

A proton precession magnetometer has been designed and constructed and trial observations of the total magnetic intensity of the earth's field have been made.

A self recording Air-glow equipment for automatic observations in pre-selected wavelength bands has been designed and constructed. The equipment was found to be working quite satisfactorily.

Monthly median values of foF₂ and (M3,000)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 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 on a frequency of 100 Mc/s were obtained. Scintillation observations of Cygnus A and Cassiopeia were made whenever possible. Jupiter radio radiation recordings, at a frequency of 22.2 Mc/s, were resumed in May, 1964 when night observations of Jupiter became possible.

Instrumentation

Considerable progress has been achieved during the year in the preparation of optical surfaces at Kodaikanal. The optical figuring of two twelve inch mirrors has been completed and these are in regular use in the solar tower. Three of the 6.4 metre focal length mirrors used in the new double monochromator of the solar tower have been ground, polished and figured in the optical shop. The optics of a 5-inch aperture f/1.1 Schmidt camera have been constructed successfully and the instrument is in use attached to the 8-inch refractor for the photography

of bright extended surfaces. Several small aperture paraboloids for use in numerous monochromators and spectrographs have been constructed in the optical shop.

A new optical grinding machine has been under construction, for handling mirrors up to 52 inches in diameter. Much progress has also been made in the fabrication of an aluminizing chamber that can aluminize mirrors up to 28 inches in diameter.

Miscellaneous Observations

Routine ozone, earthshine, meteorological, seismological and radiation observations have been carried out as in previous years. Three long period and three short period seismographs installed under a co-operative arrangement with U.S. Coast and Geodetic Survey, are in continuous operation.

General

The Director went on deputation to Germany to attend the XII General Assembly of the International Astronomical Union. He also attended the 23rd session of the ANZAAS at the invitation of the Australian Academy of Sciences.

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 Prof. Bart J. Bok, Director of Mount Stromlo Observatory, Australia.

Publications

Bappu, V. M. K.	{ Intensity Fluctuations in the H-alpha line intensity caused by chromospheric mottling—Journal of the Institution of Telecommunication Engineers. Vol. 10, No. 8 (1964)
Bhargava B. N. and Subrahmanyan R. V.	{ Geomagnetic disturbances associated with Equatorial Electrojet. Journal of Atmospheric and Terrestrial physics. Vol. 26 (1964)
Bhargava B. N.	{ Radio Star Scintillation in Equatorial Region. Journal of the Institution of Telecommunication Engineers. Vol. 10, No. 8 (1964)
Bhargava B. N. and Subrahmanyan R. V.	{ A study of Blanketing Sporadic E in the Indian Equatorial Region—Proceedings of Indian Academy of Sciences. Vol. LX, (1964)
Subrahmanyan R. V.	{ Geomagnetic effects associated with Relativistic flares—Journal of Atmospheric and Terrestrial Physics Vol. 26 (1964)

Quarterly synopsis 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 1963 as well as on the prominence activity during the same year.

Kodaikanal Observatory,
December, 1965.

M. K. VAINU BAPPU,
Director.