

ANNUAL REPORT* OF THE KODAIKANAL OBSERVATORY FOR THE YEAR 1967

Solar Physics

The new photoelectric detector head of the solar magnetograph was completed and put into operation. Several modifications have been incorporated in the new unit thus providing facility for more accurate measurements of solar longitudinal magnetic fields and velocity fields of the sun, with compensating arrangements for intensity variations and Doppler shifts. Observations with the new unit have been started in the velocity mode, and the quasi-periodic oscillatory fields have been recorded on lines having mean depths of formation at different heights in the solar atmosphere.

A series of K and H-alpha spectra of a sunspot close to the limb obtained with the Kitt Peak Solar telescope have been used to determine the Chromospheric heights in an active region. These spectra have been measured, using equidensity contours obtained by the Sabattier effect. The displacements with wavelength of the level of unit optical depth in the chromosphere over the active region have been obtained. The level in H-alpha is found to be very much lower than in the K-line of Ca⁺. At the K-line centre, unit tangential optical depth in the Umbra, Umbra-Penumbra interface and Penumbra are 1310, 1610 and 2330 km respectively. The corresponding value for the Umbra in the H-alpha line centre is 1080 km.

Spectra of a few more spots near the limb, in the lines of the Balmer series and metallic lines of lower chromospheric origin have been obtained for study of opacities of the chromosphere over the spots.

In a joint programme with the Sayan Observatory, U.S.S.R., Bappu, Stepanov and Grigorjev obtained transverse and longitudinal magnetic field scans together with K₂₃₂ Spectroheliograms covering the early phases of active region formation. Noticeable changes in the background magnetic field are recorded three days prior to the appearance of the sunspot.

*The report deals chiefly with the astronomical and allied geophysical work of the Kodai-kanal 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.

Magnetic hills of the longitudinal component appear along with bright localized K_{232} emission. The K_{232} emission subsequently spreads along the boundary of one or two adjacent supergranules and at the time of spot formation occupies the whole super-granular cell. Transverse field of 100-150 gauss form closed regions in the area of the longitudinal component hills, in the very early phases of the region. These fields stretch and link up the two areas later, at which time the peak transverse fields with values near 250 gauss coincide with the zero line of the longitudinal field. When subsequently the spots appear in the new region, the transverse fields are located about the hills of the longitudinal field. The total field vectors just prior to sunspot formation are pressed to the surface. These are inclined about 45° to the surface after the spot appears. These indicate that the magnetic field of a new region emerges from the sub-photospheric layers and the super-granule is only instrumental in bringing out these magnetic fields into the outer layers of the solar atmosphere.

Magnetic field measures were obtained on selected sunspots photographically on 20 occasions during the year.

The sun was photographed in white light on 310 days compared to 293 days in 1966. H-alpha disc, K-disc and K-Prominence spectroheliograms were secured on 259, 282 and 252 days against 274, 270, 243, days respectively in 1966. H-alpha filtergrams of the disc and prominence with the Lyot heliograph were obtained on 148 days against 278 days in 1966. The total number of exposures of each kind was as follows:—

(1) Photoheliograms	. . .	316
(2) H-alpha spectroheliograms	. . .	755
(3) K_{232} Spectroheliograms	. . .	758
(4) K-Prominences	. . .	507
(5) K_1 spectroheliograms	. . .	263

Observations of the solar chromosphere with the spectrohelioscope were made on 290 days covering a total duration of 1169 hours of patrol. 59 flares were observed during the year of which 16 were sub-flares, 34 were classified as belonging to types 1f, 1n and 1b, 7 of importance 2f, 2n and 2b and

2 of importance 3n and 3b. The data provided by routine solar observations have been sent regularly to the World Data Centres.

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. The North dome recorded 5 days of seeing 5, 94 days of seeing 4 and 139 days of seeing 3. The total rainfall recorded was 1349 mm which was 20.1% less than the annual normal. The total number of hours of sunshine was 1868.

There has been a considerable increase in sunspot activity during the year. The mean equatorial distance of northern hemisphere spot groups was $18^{\circ}.3$ and of the southern hemisphere spot groups $21^{\circ}.1$ as against $22^{\circ}.5$ and $18^{\circ}.6$ respectively in 1966. Details of the spot observations are given in the following table.

Solar Data 1967

	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
													mean
No. of spot groups	20	14	17	20	10	11	15	17	17	19	15	17	192
	N												
	8	9	8	11	13	7	10	10	10	9	9	18	122
	S												
Mean daily No of spot groups	5.6	5.7	4.9	5.6	5.0	4.2	5.6	5.9	5.5	6.9	6.2	7.4	5.7
Kodaikanal daily relative sunspot number	116.9	107.6	137.0	106.7	122.3	82.6	108.8	122.0	96.9	117.4	113.5	150.5	115.2

The mean daily areas and numbers of calcium Prominences at the limb as obtained from Kodaikanal records are as follows:

1967	Area (Sq. minutes)					Numbers				
	N	S	E	W	Total	N	S	E	W	Total
January— June	4.60	4.08	4.71	3.97	8.68	6.3	4.9	5.8	5.4	11.2
July— December	3.17	1.99	2.15	3.01	5.16	5.1	3.9	4.1	4.9	9.0
Whole year (weighted mean)	4.03	3.25	3.69	3.59	7.28	5.8	4.5	5.1	5.2	10.3

Compared to the last year, the figures show an increase in activity of both areas and numbers, the increase being 26.6% in areas and 21.1% in numbers. The distribution of areas in five degree ranges in latitude in the northern hemisphere shows two peaks of activity extending from 30°-35° and between 60° and 65° with a secondary peak between 25° and 30°. In the southern hemisphere the maximum is between 45° and 55°.

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

1967	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	3750	2704	3262	3192	6454	25.7	18.2	22.0	21.9	43.9
July— December	3273	1967	2653	2587	5240	28.7	18.8	24.4	23.1	47.5
Whole year (weighted mean)	3598	2440	3054	2984	6038	26.9	18.4	23.0	22.3	45.3

Compared to the previous year, there is a great increase of both areas and numbers of the absorption markings. The increase in area amounted to 77.9% whereas it is 76.6% in the case of numbers. In both the hemispheres there was a predominance in the latitude belt 20° — 35° .

The exchange of Spectroheliograms with foreign Observatories was continued. For the period July 1966 to June 1967, 51 H-alpha disc, 50 K-disc and 62 K-Prominence spectroheliograms were received from the Meudon Observatory. 96 H-alpha disc and 100 K-disc spectro-heliograms for certain days for the period 1966-67 were sent to the Meudon Observatory.

Stellar Physics

Photographic, photoelectric and spectroscopic observations were made of Nova Delphini 1967 from September 1967 onwards. The spectra were obtained with the Bhavnagar cassegrain spectrograph with dispersions of $46 \text{ \AA} / \text{mm}$ in the blue and $92 \text{ \AA} / \text{mm}$ in the red. During September, 1967, the mean velocity of expansion of ejected shells was 255 km/sec. After the December 14, 1967 outburst the spectrum of the Nova had dominant emission lines with violet shifted double absorption lines. The secondary absorption system of FeII lines gave a mean velocity of 736 km/sec. Considerable changes were seen from day to day in the line profiles of the emission and absorption lines.

Independent photoelectric observations made at Kodai-kanal confirmed the second out-burst around August 26, 1967 and the magnitude of Nova Delphini continued to be around 4.7 until 18th November, 1967. A brightening of 0.3 magnitude was recorded on 23rd November, 1967.

Photoelectric observations of ρ Puppis, were obtained with B, V and narrow band filters centered around 3890, 4290, 4737 and 5890 \AA for the study of colour temperature variations with phase.

Photoelectric observations of the eclipsing binary V Pup were obtained with B, V filters for the study of its light curve. Observations were also made on several nights of the eclipsing systems RCMa, FT Ori and β Aur.

A series of 127 spectrograms of the Wolf-Rayet binary HD 68273 obtained at Kodaikanal during 1965 and 1966 have been used for a study of radial velocities of the emission and absorption lines. The period is found to be 78.5 days. The spectral type of the O component is O7.5 as determined from a single high dispersion Mount Stromlo coude spectrogram. The velocity curves of the Wolf-Rayet component are determined for HeII 4686, the CIII complex at 4652 Å and CIV 4441. The velocity curve for the O component is from measures of the absorption line H5. Arguments are presented to show that the velocity curve of CIII 4652 is the best suited for the study of masses of the components. The eccentricity of the orbit is 0.17. The gamma-axis for HeII 4686 is red-shifted with respect to that of H5 by 82 km/sec. The values of $m_o \sin^3 i$ and $m_w \sin^3 i$ are 46.3 and 13.0 solar masses respectively. The inclination of the orbit is likely to be such that the system exhibits eclipses. The W component seems to be the most massive yet known among the very small group of Wolf-Rayet stars.

Low dispersion spectra ($75\text{Å}/\text{mm}$ at 4300Å) of HD 193576 have been utilised for radial velocity measures as well as line profile determinations of some of the emission lines. Using such measures for HeII 4686, the elements derived are γ -axis = +16.2 km/sec, $K = 282.8$ km/sec., $e = 0.11$, $\omega = 163^\circ$. The velocity measures of NIV 4058 are combined with earlier measures of Munch to yield the following values: γ -axis (NIV 4068) = -41.5 km/sec., $K = 302.6$ km/sec., $e = 0.09$, $\omega = 130^\circ$, $T^\circ = 0.26$, $T = 0.62$. The velocity measures of the absorption lines 4340Å and 4100Å that originate from the O component show much scatter. A combination of the K values of NIV 4058 and H δ yield masses of the O and W stars as 23.3 and 8.2 solar masses respectively. If 4058Å is used with the K value derived by Munch from measures of the higher members of the Balmer series, these are 25.0 and 9.9 solar masses respectively. A few Mount Wilson Coude spectrograms ($10\text{Å}/\text{mm}$) of this star were obtained at primary and secondary minima and outside eclipse. The emission line NIV 3483 shows a violet absorption edge at primary minimum. Profiles of H9, H11 and H13 show clearly the increase in width at primary minimum caused by electron scattering. The intensities of the hydrogen lines are also found to increase slightly at this phase.

Radial velocities and line profiles have been studied of the three Wolf-Rayet binaries HD 193928, HD 186943 and HD 211853.

A new orbit for HD 193928 has been determined from radial velocity measures of HeII 4686. The orbital elements are as follows: γ -axis = +60 km/sec., $K = 147$ km/sec., $e = 0.12$, $\omega = 51^\circ$, $f(m) = 4.62$ solar masses. The NIV 4058 velocities can be represented by the HeII 4686 velocity curve displaced in phase by 0.1P. A displacement of 185 km/sec., in the gamma-axis suffices to fit the 4686Å curve onto the NV 4603 velocities. Line profile variations with phase of the emission lines are described. This system is likely to have an orbital inclination that will enable the detection of eclipses.

A revised period of 9.5594 days is derived for HD 186943. Orbital elements are derived using velocity curves HeII 4686, NV 4603 and NIV 4058. The orbital elements derived from HeII 4686 are as follows:

γ -axis	= +107 km/sec.
K	= 212 km/sec.
e	= 0.40
ω	= 151°
γ (NIV 4058)	= +70 km/sec.
γ (NV 4603)	= +30 km/sec.

Preliminary elements have been derived for HD 211853 from velocity curves of HeII 4686, NV 4603 and NIV 4058. These are as follows: (HeII 4686) = +15 km/sec., (NV 4603) = +35.0 km/sec., (NIV 4058) = -120 km/sec., e (HeII 4686) = 0.12., K (HeII 4686) = 220 km/sec., $f(m)$ (HeII 4686) = 7.25.

Radio Astronomy

Stanford Radio spectroheliograms (9.1 cm) were analysed to study the directivity of solar microwave bright regions near sunspot minimum period. The 3000 MHz radiometer has been in regular operation for solar patrol on a tracking 2 metre paraboloid. The recording of sporadic radio emission from Jupiter at 22.2 Mc/s has been continued whenever possible. Regular recordings of solar noise flux on a frequency of 100 Mc/s were continued.

Solar-Terrestrial relationship

Ionospheric F-region vertical drift velocity over Kodai-kanal just after sudden commencement of magnetic storms have been studied with particular reference to the storms

that followed proton flare events of July 7, 1966 and September 2, 1966. A 60-hour period following the storm commencement has been taken for the analysis. Assuming the conductivity from the standard model atmosphere, the electromagnetic drift velocities are calculated using Poynting's Vector. It is found that during the main phase of the storm, the velocity is of the order of a few meters per second and is directed downwards. This value is used in the calculation of the variation of electron density due to Dst.

From the variation of the rate of Faraday fading of Explorer 22 signals recorded at Kodaikanal, estimates of the size distribution of ionospheric irregularities near the magnetic equator have been made.

Continuous recordings of H, D and Z elements of the Earth's magnetic field with Watson and Lacour magnetographs and Askania field balances have been continued. Absolute values of H, D and Z have been determined every week with a set of QHM and BMZ instruments. During the year 20 geomagnetic storms including 16 of the sudden commencement type have been recorded at Kodaikanal with ranges in Horizontal force between 159 γ and 599 γ .

Regular vertical incidence soundings of the ionosphere and registration of shortwave field strengths have been continued. Observations of Faraday fading of 40 and 41 Mc/s transmission from the beacon satellite Explorer 22 have been made regularly.

Optical Shop

A 61 cm aperture wide angle reflector telescope based on the Ritchey Chretien principle was designed. The construction of the primary mirror of 61 cms aperture (F/3.5) for this telescope was completed. The secondary of 25 cms aperture is under construction. Grinding and polishing of a 50 cm aperture spherical mirror (F/1.3) has been completed. The figuring of this mirror is under progress.

Grinding, polishing and figuring of a 30 cm F/3.5 primary mirror for a Cassegrain photometric telescope have been completed.

Miscellaneous Observations

Routine ozone, meteorological, seismological and radiation observations have been carried out as in previous year.

Three long period and three short period seismographs installed under a cooperative arrangement with U.S. Coast and Geodetic Survey are in continuous operation.

General

The Director visited the works of VEB Carl Zeiss, Jena, for finalising the details of the design of the 40-inch telescope for Kavalur.

The Director attended the meeting of INCOSPAR at Bombay on April 27, 1967.

Shri J. C. Bhattacharyya, Assistant Director went on deputation to London to attend the COSPAR meeting and IQSY Symposium held from 17th to 29th July, 1967.

Dr. M. K. V. Bappu attended the XIII General Assembly of the IAU held at Prague from 22-31 August, 1967. He has been elected Vice-President of the International Astronomical Union. Dr. Bappu also attended the symposium on "Solar Active Regions" held at Budapest from September 1-8, 1967.

Visitors

Dr. D. W. Peat of the Cambridge University visited the Observatory under the scheme of the Indo-British Exchange of Young Scientists.

The Prime Minister, Mrs. Indira Gandhi visited the Observatory on 26th August, 1967. Dr. Karan Singh, Minister for Tourism and Civil Aviation visited the Observatory on 28-12-1967.

Publications

1. Bappu, M. K. V. Solar Physics at Kodaikanal,
Solar Physics, Vol. 1, Jan.,
1967.
2. Bappu, M. K. V., Emission Band Photometry of
Sivaraman, K. R. Comet Ikeya Seki (1965f),
Monthly Notices of the Royal
Astronomical Society, Vol.
137, 1967.

3. Bappu, M. K. V.,
Sivaraman, K. R. Comet Ikeya Seki (1965f) and the nature of Interplanetary medium during the apparition. IQSY symposium 1967.
4. Bappu, M. K. V.,
Sivaraman, K. R. Size of the Ca⁺ coarse network in the solar chromosphere at sunspot minimum. IQSY symposium 1967.
5. Bappu, M. K. V.,
Sivaraman, K. R.,
Bhatnagar, A.,
Natarajan, V. Monochromatic Polarization Measures of Comet Ikeya-Seki (1965f). Monthly Notices of the Royal Astronomical Society, Vol. 136, 1967.
6. Balakrishnan, T. K.,
Thanikachalam, K.,
Subramaniam, T. H. Vertical drift in the middle equatorial ionosphere. IQSY symposium 1967.
7. Bhatnagar, A. The Evershed Effect and line asymmetry in sunspot penumbrae, Kodaikanal Observatory Bulletin No. 180.
8. Bhattacharyya, J. C.,
Balakrishnan, T. K. Spectral Characteristics of a solar flare from Ionospheric data. Journal of Atmospheric and Terrestrial Physics, Vol. 29, 1967.
9. Bhattacharyya, J. C.,
Balakrishnan, T. K.,
Thanikachalam, K.,
Subramanian, V. A comparison between the ionizing radiation from the sun during sunspot maximum and minimum periods. IQSY symposium 1967.
10. Bhattacharyya, J. C.,
Rajagopalan, K. Variation of total electron content in equatorial Ionosphere, IQSY symposium 1967.
11. Ganesh, K. S.,
Bappu, M. K. V.,
Natarajan, V. The Wolf-Rayet eclipsing Binary 193576. Kodaikanal Observatory Bulletin No. 184.

12. Ganesh, K. S.,
Bappu, M. K. V. The Wolf-Rayet Binary HD
68273. Kodaikanal Observa-
tory Bulletin No. 183.
13. Gopala Rao, U. V. Influence of Satellite Io on
Jupiter's decametric radio
emission—Proceedings of the
Indian Academy of Sciences,
Vol. 66, 1967.
14. Kuriyan, P. P. Calcium Flocculi as an index
of Solar Activity, Kodai-
kanal Observatory Bulletin
No. 172.

KODAIKANAL OBSERVATORY

M. K. VAINU BAPPU,
Director