

# ANNUAL REPORT\* OF THE KODAIKANAL OBSERVATORY FOR THE YEAR 1968

## Solar Physics

The solar magnetometer was used extensively in the velocity mode for studies covering a long time interval of the quasi-periodic oscillatory velocity fields. These were carried out at the centre of the disc in the lines FeI 5072, NiI 5094, MgI 5172 and the H  $\beta$  line for durations ranging from 1½ to 4 hours. A tilted glass plate ahead of the entrance slit served to compensate for the rotation of the sun. These records are being subjected to power spectra analysis.

The oscillatory fields beneath an H-alpha dark filament have also been examined in FeI 5250. Maps of the longitudinal magnetic fields were drawn over regions covered by a dark marking.

Several spectra were obtained under very good seeing conditions, covering a large number of Fraunhofer lines of varying Rowland intensities and excitation potentials in order to study the spatial variation of small scale velocity fields and intensity fluctuations on the sun. These observations cover different positions on the solar disc. A time sequence of spectra around the Mg-b (5172Å) region was taken to study the quasi-periodic oscillations in photospheric and lower chromospheric layers.

A study is in progress of spectra of the K-line of ionized calcium of the sun, to locate the agencies responsible for the emission line width absolute magnitude relationship of Wilson and Bappu. For this the best frame out of a K-spectra time sequence was chosen. About 200 line profile traces were obtained at discrete close intervals for measuring widths. Also scans along the line at the K<sub>3</sub> core, K<sub>2v</sub>, K<sub>2Rv</sub>, K<sub>iv</sub> and K<sub>IR</sub> and on a neighbouring Fe line were obtained to assess the correlation of intensity fluctuations in each of the layers in which these wings are formed and also to obtain the sizes of the elements. The analysis shows that the mottles of average size 2000 km seen on K-spectroheliograms have the characteristic values of line width of a G2 V star.

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\*The 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.

A study of the relation between sunspot area changes and occurrences of solar flares showed that changes if any in the sunspot area noticed after a major solar flare, cannot really be ascribed to flare stimulation but are only features associated with normal sunspot evolution.

A doppler comparator to measure velocities from Fraunhofer lines of solar spectra was constructed. In this comparator the light flux from both the wings of a Fraunhofer line are directed to two light dependent resistances through a system of two slits located at  $\pm \Delta\lambda$  on the line profile. The Doppler displacement at any location on the line is obtained by setting the two slits, so as to equalize the D.C. output signals of the two L.D.R.'s. The displacement of the slits is measured by a precision Hilger screw. The spectral line is scanned manually along its length and Doppler displacements are obtained at discrete points at the choice of the observer.

The 18-metre spectrograph has been provided with an image guiding facility that ensures an accuracy of guiding to better than a second of arc. For the programmes on time sequence spectra a 35 mm film magazine with a storage of 100 feet has been built during the year.

Several modifications have been incorporated in the 4.2 metre spectroheliograph that have yielded improved performance. A cylindrical lens curvature corrector, a beam splitter ahead of the entrance slit, and a split line shifter near the exit slit capable of equal offsets on either side of a Fraunhofer line core, are new additions that have increased the versatility of the instrument.

On the occasion of the total solar eclipse of February 15, 1961 two spectrograms were obtained by A. Kubicela at the moments of second and third contact of the eclipse. The spectrograms contain a smooth transition of the photospheric spectrum into the chromospheric one and vice versa. Continual registration has been achieved by means of a moving plate combined with a slit spectrograph. The 1961 eclipse data have been used to find the intensity of solar continuum radiation dependence on heliocentric heights within the last second of apparent solar radius.

The velocity field structure in a supergranule is under study using the 4554 Ba+ line and a weaker Fraunhofer line. Near

simultaneous K-line spectra provide a picture of the chromospheric network and hence the supergranular boundary. Comparison spectra from the same region of the solar disc provide the reference system for zero velocities.

The sun was photographed in white light on 300 days. H-alpha disc, K-disc and K-Prominence spectroheliograms were obtained on 272, 277 and 250 days respectively. H-alpha filtergrams of the disc and prominences with the Lyot monochromatic heliograph were obtained on 220 days. The total number of exposures of each kind was as follows:—

|  |     |     |
|--|-----|-----|
| (1) Photoheliograms                    | ... | 302 |
| (2) H-alpha spectroheliograms          | ... | 735 |
| (3) K <sub>232</sub> Spectroheliograms | ... | 658 |
| (4) K-Prominences                      | ... | 478 |
| (5) K <sub>1</sub> Spectroheliograms   | ... | 236 |

Observations of the solar chromosphere were made on 298 days covering a total duration of 1289 hours of patrol. 70 flares were observed during the year of which 26 were sub-flares, 35 were classified as belonging to types 1<sup>+</sup>, 1n and 1b, 8 of importance 2f, 2n and 2b and one of importance 3b. The data provided by routine solar observations have been sent regularly to the World Data Centres.

Observing conditions were more or less as in the previous year. The average definition of the sun's image was 3 on a scale of 5. The north dome recorded 8 days of seeing 5, 74 days of seeing 4 and 147 days of seeing 3.

The mean equatorial distance of northern hemisphere spot groups was 15°.9 and of the southern hemisphere spot groups 17°.5 as against 18°.3 and 21°.1 respectively in 1967. Details of the spot observations are given in the following table.

### Solar Data 1968

|   | Jan.  | Feb.  | Mar.  | Apr. | May   | Jun.  | Jul. | Aug.  | Sep.  | Oct.  | Nov. | Dec.  | Total<br>mean |
|---|-------|-------|-------|------|-------|-------|------|-------|-------|-------|------|-------|---------------|
| No. of spot<br>groups N                           | 15    | 18    | 16    | 20   | 25    | 12    | 12   | 15    | 18    | 15    | 12   | 10    | 188           |
| S   | 15    | 21    | 17    | 11   | 19    | 10    | 7    | 19    | 14    | 12    | 10   | 18    | 173           |
| Mean daily<br>No. of spot<br>groups               | 6.1   | 7.8   | 6.2   | 5.2  | 8.6   | 6.9   | 4.8  | 6.4   | 6.6   | 5.4   | 3.6  | 6.2   | 6.2           |
| Kodajkanal<br>daily relative<br>sunspot<br>number | 125.6 | 143.8 | 117.2 | 87.0 | 174.3 | 128.4 | 87.1 | 115.5 | 113.2 | 107.4 | 84.3 | 135.4 | 118.3         |

The following table gives the mean daily areas and numbers of calcium prominences at the limb, derived from Spectroheliograms obtained at Kodaikanal during 1968.

| 1968                                | Area (Sq. minutes) |      |      |      |       | Numbers |      |      |      |       |
|-------------------------------------|--------------------|------|------|------|-------|---------|------|------|------|-------|
|                                     | N                  | S    | E    | W    | Total | N       | S    | E    | W    | Total |
| Jan.—<br>June                       | 4.30               | 3.26 | 3.79 | 3.77 | 7.56  | 6.65    | 5.11 | 5.86 | 5.90 | 11.76 |
| July—<br>Dec.                       | 3.93               | 2.90 | 3.18 | 3.65 | 6.83  | 6.51    | 5.38 | 5.91 | 5.98 | 11.89 |
| Whole<br>year<br>(Weighted<br>mean) | 4.15               | 3.12 | 3.55 | 3.72 | 7.27  | 6.59    | 5.22 | 5.88 | 5.93 | 11.81 |

Compared to the last year, there is no variation in activity of areas, whereas the numbers show an increase of 14.4%. The distribution of areas in five degree ranges in latitude in the northern hemisphere shows two peaks of activity extending from 35°—40° and 70°—75°. In the southern hemisphere, the maximum is between 55°—60°.

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

| 1968                                     | H-alpha dark marking area<br>(in millionths of the Sun's<br>visible hemisphere uncor-<br>rected for foreshortening) |      |      |      |       | Numbers |       |       |       |       |
|--|---|------|------|------|-------|---------|-------|-------|-------|-------|
|  | N   | S    | E    | W    | Total | N       | S     | E     | W     | Total |
| Jan.—<br>June                            | 3266  | 3022 | 3171 | 3117 | 6288  | 26.05   | 24.11 | 25.08 | 25.08 | 50.16 |
| July—<br>Dec.                            | 2998  | 2665 | 2904 | 2759 | 5663  | 27.94   | 23.01 | 26.02 | 24.93 | 50.95 |
| Whole<br>year<br>(Weigh-<br>ted<br>mean) | 3155  | 2874 | 3060 | 2969 | 6029  | 26.83   | 23.65 | 25.47 | 25.01 | 50.48 |

Compared to the previous year, there is no appreciable variation in activity of areas, whereas the numbers show an increase of 11.4%. In both the hemispheres there was a predominance of activity in the latitude belt  $15^{\circ}$ — $25^{\circ}$ .

The exchange of Spectroheliograms with foreign Observatories was continued. For the period July 1967 to June 1968, 74 H-alpha disc, 54 K-disc and 72 K-Prominence spectroheliograms were received from the Meudon Observatory. 54 H-alpha disc and 126 K-disc spectroheliograms for certain days for the period 1967-68 were sent to the Meudon Observatory.

### Stellar Physics

A major event in the progress of the observatory has been the regular commencement of observations at its field station in Kavalur. A 38cm aperture reflector built in the observatory's optical and mechanical shops has been commissioned in a roll-off shelter. The telescope is equipped for photoelectric photometry. It also has a 4-inch aperture quartz prism of small angle for obtaining very low dispersion spectra of  $3000 \text{ \AA}/\text{mm}$  in the blue. Programmes commenced with this telescope are observations of eclipsing variables, photoelectric H-gamma photometry and low dispersion spectroscopy of selected fields in the southern Milky Way.

High dispersion spectra of the cepheid variable RT Aurigae have been used for an analysis of the parameters of the stellar atmosphere over a cycle of pulsation. Eighteen of these spectra were utilized for a study of the radial velocities. The displacement curve derived from the velocities was utilized with the light and colour curves of Eggen, Gascoigne and Burr to furnish by the application of Wesselink's method, a value of  $R/R_{\odot} = 33.7$ . A differential curve of growth analysis relative to the Sun has been carried out at eleven phases to evaluate the variation of the atmospheric parameters. The range in  $\theta_{\text{exc}}$  is from 0.94 to 1.07. The variation of  $\beta_{\text{k}}$  is by a factor of ten over the cycle. A second hump in this curve at phase 0.68P is perhaps a result of the sudden onset of a pulse of compression. Mean abundances relative to (Fe) have been derived for 21 elements. A general deficiency in s-process elements is seen in comparison with those formed by the e-process.

Spectroscopic observations of Nova Delphini 1967 have been continued. Radial velocities of different ejected shells have

been measured. Line profiles of different elements identified have been obtained and their equivalent widths computed. Spectra obtained during September and October show that the Nova has reached the nebular stage with the characteristic forbidden lines of doubly ionized oxygen of appreciable intensity.

Spectra of Nova Vulpeculae 1968 have been obtained at  $45\text{\AA}/\text{mm}$  dispersion in blue and  $90\text{\AA}/\text{mm}$  dispersion in red. The radial velocities of two absorption systems were found to be  $1150\text{ km/sec.}$  and  $2180\text{ km/sec.}$

Scanner observations have been made of the spectra of the two bright novae in May. Scans were obtained on four nights with an exit slot of  $30\text{\AA}$  with the new scanner on the 38cm reflector. The scanner has a twin-Newtonian optical system that functions along with an 1800 lines/mm grating and a refrigerated photomultiplier. The scanner has also been used with slot widths of  $9\text{\AA}$  to obtain Balmer line intensities in B and A stars.

Monochromatic flux values of the dwarf Cepheid Rho Puppis have been evaluated over the cycle from observations made in the 1967 season through four narrow band filters centered at  $3859\text{\AA}$ ,  $4720\text{\AA}$ ,  $4310\text{\AA}$  and  $5875\text{\AA}$ . A variation of  $320^\circ\text{K}$  in effective temperature has been found.

Light curves of the eclipsing binary V Puppis in blue and yellow colours have been obtained from the 1967 observations. The depths of primary and secondary minima are 0.6 mag. and 0.5 mag. respectively. Further observations are in progress for an interpretation of the light curve. Photoelectric observations of R Canis Majoris and FT Orionis were also obtained during the year.

Spectra of the members of the Scorpio-Centaurus association are being obtained at  $45\text{\AA}/\text{mm}$  for the study of rotational velocities.

### **Radio Astronomy**

The designing and construction of electronics and antenna systems for a phase switching interferometer operating at 25 MHz was commenced. The half power beam width of the antenna arrays used for the interferometer is about one hour in R.A., and about  $30^\circ$  in Declination. The instrument is mainly meant for studies of ionospheric scintillation of discrete radio sources. The radio sources Cyg A, Tau A and Virgo A, are being used for this purpose. In addition, radio bursts

from the sun were recorded on several occasions. The instrument will also be used for monitoring radio emission from the planet Jupiter.

A new total power interferometer operating at 220 MHz was constructed. This consists of a low noise receiver with a band width of 2 MHz connected to an interferometric aerial with a separation of  $6\lambda$ . This forms an addition to the existing battery of radiometers utilized for solar patrol.

An investigation into the radio emission associated with solar bright microwave regions was completed. The results indicate that the directivity of the region varies with the brightness, the directivity being asymmetrical for weak regions and symmetrical for strong regions.

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 MHz has been continued whenever possible. Regular recordings of solar noise flux on a frequency of 100 MHz were continued.

Two new dual input RC null networks have been evolved which utilize RC Ladders with an auxiliary input derived from the main input. The null frequency of these networks can be varied simply and widely by varying the ratio of the two inputs.

Another use of the null networks is in picking up of the incremental component of an impedance that varies in response to some change in the physical quantity. Here the difficulty is that (i) they have to be externally balanced before each measurement, (ii) the null point is subject to drift etc., (iii) they may not have a terminal common to the input and output, and (iv) there may be ambiguity of output wave form if the network is not properly balanced. A study shows that a simple potentiometer circuit can replace the bridge or other type network in many, though not all, applications and can eliminate the difficulties mentioned above, without any loss in sensitivity and linearity.

### **Solar Terrestrial Relationships**

A semi-automatic airglow photoelectric photometer was built for the study of Red airglow line (6300 and 6364 Å) intensity variations and its correlation with the ionospheric electron



content variations. Two narrow band filters were used in this equipment, one centred about  $6330\text{\AA}$  and the other around  $5300\text{\AA}$ . Arrangements to check the dark level and Radium source calibration signal was also incorporated in the equipment. The photomultiplier signals were amplified by a GR DC Electrometer amplifier and recorded on a Brown Potentiometric Recorder. The equipment was used for recording observations on seven nights during January-February, 1968.

Three nights' airglow intensity variations was correlated with computed electron density variations of the ionosphere at different levels in the 250-320 km interval. All these show that the correlation coefficient is highest in the 260-270 km height irrespective of the height of the F layer.

Work on the experimental set-up for recording 20 Mc/s signals from satellite Explorer 22 together with existing 40 Mc/s signals was continued. The regular observations on two frequencies harmonically related, which is essential for giving second order corrections, are expected to begin shortly.

Work on sizes of ionospheric irregularities from Faraday fading records was continued.

A correlation between H-alpha plage brightness and several ionospheric parameters were sought with a view to find out possible solar control of short time ionospheric variations. The standard parameters do not show good correlation with H-alpha brightness, except during flares. N-h profiles do show variations at different levels, but the process of reduction being time-consuming, a direct easily derivable parameter was being sought after. It was seen that a derived parameter based on the virtual heights of reflection of ordinary and extra-ordinary waves at corresponding frequencies gives a good correlation with H-alpha brightness variation. For further investigation it is planned to correlate the ionospheric variations with direct photoelectric estimation of K-line intensity for which the experimental set up is nearing completion.

The two geomagnetic storms that followed the two proton events of 7th July 1966 and 2nd September, 1966 were analysed. For this analysis data from a number of stations around the geomagnetic equator were collected and separated from the total field, the Ring current part, Disturbance Solar part etc. Current vectors are computed for each of these station for both these storms for about 60 hours from the commencement of storm.

Continuous recordings of H, D and Z elements of the Earth's magnetic field with La Cour and Watson 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 26 geomagnetic storms including 7 of the sudden commencement type have been recorded at Kodaikanal with ranges in Horizontal Force between  $190\gamma$  and  $480\gamma$ .

Regular vertical incidence soundings of the ionosphere and registration of shortwave field strength 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 test sphere 50 cm aperture and focal ratio F/1.268 designed for the testing and figuring of the cassegrain secondaries of the 61 cm Ritchey Chretien reflector and the 76 cm reflector was completed. The optics of a 14 cm F/1.2 Maksutov camera for use as a Cassegrain spectrograph camera were also completed. A 12.5 cm F/15 achromatic objective was designed and construction completed. This is to be used as a guide telescope for the 76 cm reflector. The 76 cm paraboloid is now in the final stages of figuring. A quartz objective prism of 10 cm aperture and vertical angle  $15'$  was completed for very low dispersion spectroscopy.

### **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**

Shri K. S. Ganesh, a former research scholar of this Observatory, was awarded the Ph.D. degree of the Karnatak University for a thesis entitled 'Spectrographic studies of Wolf-Rayet Stars'.

Dr. M. K. V. Bappu attended the I.A.U. Executive Committee meeting held at Hamburg.

Dr. M. K. V. Bappu, Sri J. C. Bhattacharyya and Dr. Ch. V. Sastry attended the T.I.F.R. Colloquium on "High Energy Astrophysics". Dr. Bappu gave an invited talk on "Quasi-stellar sources."

Dr. Bappu and Sri J. C. Bhattacharyya attended the second meeting of the Indian National Committee for Solar Terrestrial Physics.

### Visitors

Dr. W. A. Baum, Director, Planetary Research Centre, Lowell Observatory, U.S.A. visited the Observatory. He delivered two lectures entitled "Image Intensities" and "Techniques in faint star photoelectric photometry."

### Publications

1. Bappu, M. K. V.  
Grigorjev, V.M.  
Stepanov, V. E.                      On the Development of Magnetic fields in active regions—Solar Physics—Vol. 4, 409—421.
2. Bappu, M. K. V.  
Raghavan, N.                              An analysis of the Cepheid variable RT Aurigae—Mon. Not. R. astr. Soc., 142, 295—316.
3. Bhatnagar, A., and  
Doss, A. T.                                On Nova Delphini 1967—Proc. Tenth Symposium on Cosmic Rays, Elementary Particle Physics and Astrophysics 1967 Organized by the Cosmic Ray Committee, Department of Atomic Energy, Government of India, 353—355.
4. Gopala Rao, U. V.                      Directivity of Solar Microwave regions—Solar Physics—Vol. 4, 428—431.
5. Kubicela, A.                              Solar limb gradient from eclipse spectra of February 15, 1961—Kodaikanal Obs. Bull. 188.

6. Raghavan, N.                      Line Profile Analysis of Carbon Molecules in the Sun—Kodaikanal Obs. Bull, 186.
7. Sastry, Ch. V.                     Decameter Radio Emission from Jupiter and Solar activity—Planet. Space Sc. Vol. 16, 1147—1153.
8. Sen Roy, N.                        Dual input Null Networks utilizing R. C. Ladders—Ind. J. Pure and Applied Phys., Vol. 6, 647—648.
9. Sen Roy, N.                        Potentiometer as a substitute for Bridge Circuit in Transducer application—Symposium on Electronics in Industry, New Delhi.
10. Sivaraman, K. R.                On the relation between Sunspot area change and flare occurrence—Solar Physics, Vol. 6, 152—153.
11. Sivaraman, K. R.,  
    Kubicela, A.                     A Doppler comparator for Solar Spectra—Kodaikanal Obs. Bull. 189.
12. Thulasidoss, A                    Photoelectric studies of Rho Puppis—Kodaikanal Obs. Bull. No. 191.

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