Kodaikanal Observatory (1901-1950)

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1. Introduction

The Solar Physics Observatory at Kodaikanal is located on the crest of the Upper Palni Hills at an elevation of 7700 ft above sea level. This institution which is the only one of its kind in India has just completed fifty years. A brief account of the nature of the work carried on at this observatory and a rapid survey of its achievements during the half century of its existence is attempted in this article.

2. Historical

The establishment of the Solar Physics Observatory at Kodaikanal is closely associated with the Madras Observatory which was started in 1792 by the East India Company. Mr. Pogson who was the last astronomer of the Madras observatory conceived the idea of establishing a branch of that observatory at a suitable site in the Palni or Nilgiri Hills " for certain classes of astronomical work, more especially photographic and spectroscopic observations of the Sun and the Stars ". Although no action was taken to implement this idea during Mr. Pogson's life time, it was given effect to during the time of his successor Prof. C. Michie Smith. Kodaikanal in the Upper Palni Hills was chosen for the location of the proposed high-level observatory, and the constructional works were commenced in 1898 under the supervision of Prof. Michie Smith, who became the first Director of the Kodaikanal Observatory. The completion of the Observatory buildings and organisation of regular observational work took about two years. Systematic solar observations commenced at Kodaikanal from early 1901. A photographic view of the Observatory is shown in Fig. 1.

3. Present Instrumental Equipment and Observational Work

Apart from the study of the Sun to which the Observatory is primarily devoted, magnetic, meteorological and seismological observations have been in progress at Kodaikanal from the very beginning. The magnetic observatory which was originally under the Survey of India was closed down in 1923, but after the second world war, it has been restarted with the old instruments. An ionospheric laboratory is under construction and very soon regular ionospheric soundings will be started with the automatic ionosphere recorder which has been acquired for the observatory. A 20-inch Grubb reflector is being installed, and in the near future stellar work will form a regular feature of the activities of the Kodaikanal Observatory.

The present equipment of the Observatory consists of the following principal instruments —

1. *The Lerebours and Secretan Equatorial (Photoheliograph)*
2. *The six-inch Cooke Equatorial and Grating Spectroscope (Prominence Spectroscope)*
3. 18-*inch Foucault Siderostat*
4. *The K and H-alpha Spectroheliographs (Fig.* 2)
5. *The Hale Spectrohelioscope*
6. *Six-inch Cooke Telescope*

7. *Six-inch Transit Telescope*
8. 12-*inch Cooke Siderostat*
9. 12-*inch Coelostat*
10. 10-*inch Polar Siderostat*
11. 20-*inch Reflecting Telescope by Grubb* (*Fig*. 3)
12. *Spectrographs* —
    - (*a*) 14-*foot Littrow Prism Spectrograph*
    - (*b*) 10-*foot Concave Grating Spectrograph in Rowland Mount.*
    - (*c*) 20-*foot Combined Plane Grating and Prism Spectrograph in Littrow Mount*
    - (*d*) 21-*foot Concave Grating Spectrograph in Eagle Mount*
    - (*e*) 14-*foot Angular Plane Grating Spectrograph*
13. *Cambridge Recording Microphotometer*
14. *Magnetic Observatory Instruments*—
    - (*a*) *Watson H-F, V-F and D Magnetographs*
    - (*b*) *Kew Magnetometer*
    - (*c*) *Earth Inductor* (*Wild Pattern*)
    - (*d*) *Dip Circle*
15. *Automatic Multi-frequency Ionosphere Recorder* (*Fig*. 5)
16. *Milne-Shaw Horizontal Seismograph*
17. *Complete set of Visual and Self Recording Meteorological Instruments.*

The daily solar observations commence soon after sunrise. Visual and photographic observations of the Sun are made with the prominence spectroscope, the photoheliograph, the spectrohelioscope and the spectroheliographs. Spectroheliograms of the disc and limb are taken in the K and H-alpha lines [Figs. 4 (a), (b) and (c)]. The positions of sunspots and faculae are sketched on special charts on which the prominences and H-alpha dark markings as recorded on the spectroheliograms are subsequently sketched. These charts are used for the compilation of statistical data relating to prominences and H-alpha dark markings which are published in the Bulletins of the Observatory.

4. Brief survey of the work of the Observatory during the past 50 years

(1) *Early days* — During the first few years, the work of the Director was naturally concerned mostly with lay-out, planning and organisation. Prof. C. Michie Smith, the first Director of the observatory did much pioneering work in this direction. The constructional works were done under his personal supervision. The grounds of the Observatory were quite barren at the beginning; Michie Smith had a large number of trees and shrubs planted so as to serve as windbreakers and also to improve the definition of the solar image by reducing ground heating. He installed the instruments for routine observational work and formulated a scheme for daily observations. During a short period when Michie Smith was absent on leave, the Observatory was under the direction of Mr. C. P. Butler.

In 1907 Mr. J. Evershed joined the Observatory as Assistant Director. With the retirement of Michie Smith in 1911, Mr. Evershed became the Director of the Observatory and Dr. T. Royds joined as Assistant Director. The period of 16 years that Evershed spent at Kodaikanal was marked by great activity and his and Royds' researches during this period brought the Kodaikanal Observatory to the front rank among astrophysical observatories. Evershed was elected a Fellow of the Royal Society of London in 1915 and was also awarded the Gold Medal of the Royal Astronomical Society, London, for his original contributions to astrophysics.

(2) *Discovery of Radial motion in Sunspots*— Evershed had had considerable experience of astronomical work before he joined Kodaikanal Observatory. Soon after his arrival here he took up a systematic study of the spectra of sunspots using two high-dispersion grating spectrographs. On 7 January 1909 he made an outstanding discovery relating to sunspots, now known as "*Evershed Effect*". A few months earlier Prof. G. E. Hale of Mt. Wilson had discovered the presence of magnetic fields in sunspots. This apparently implied a circular motion of matter around an axis more or less perpendicular to the Sun's surface in the sunspot area. Evershed's discovery, on the other hand, revealed a radial motion of matter in the penumbral region of sunspots—a result which was totally unexpected. Also there was little evidence of circular motion, and Evershed concluded that even if such a motion is present it is

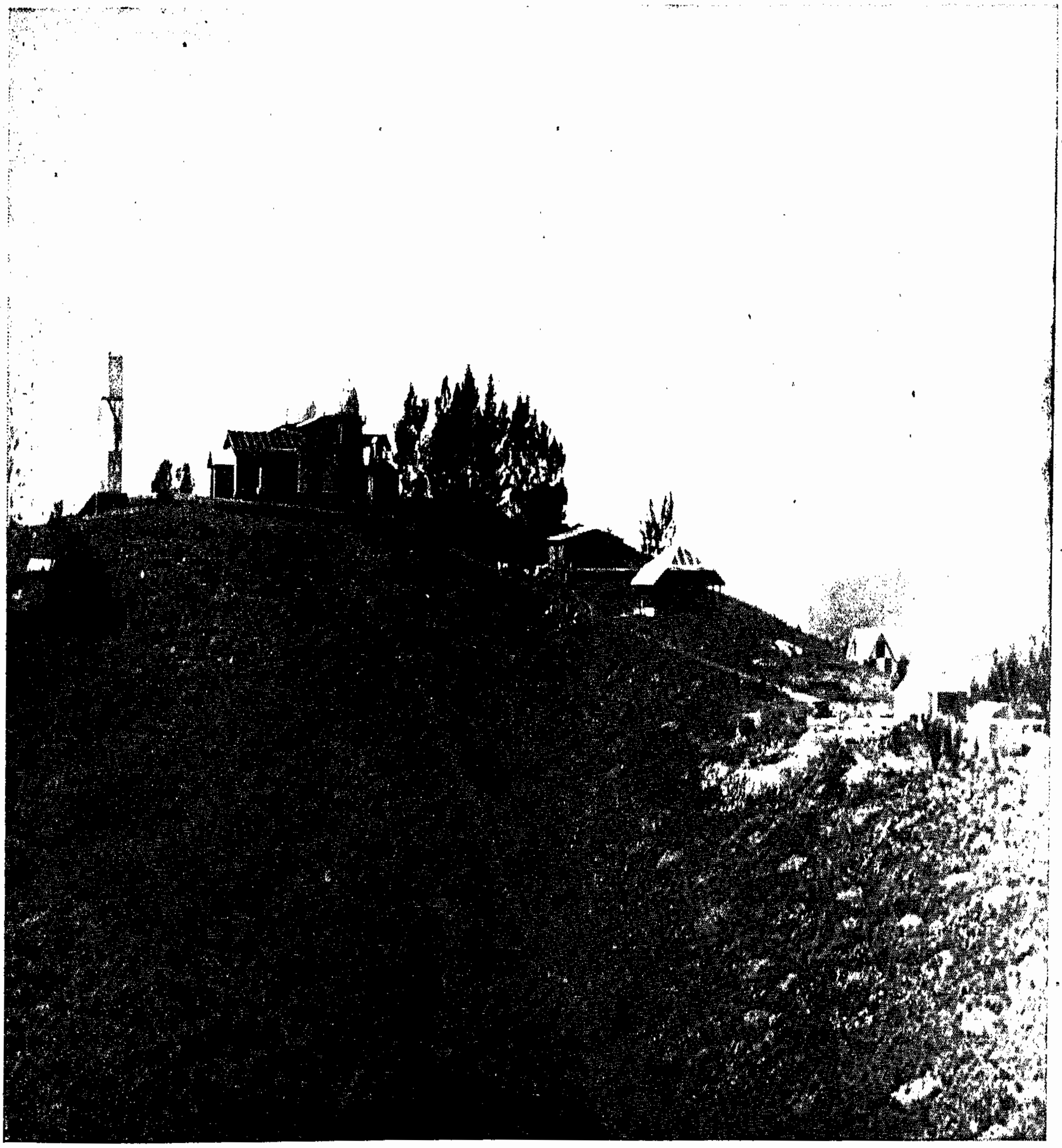

Fig. 1 General View of the Kodaikanal Observatory

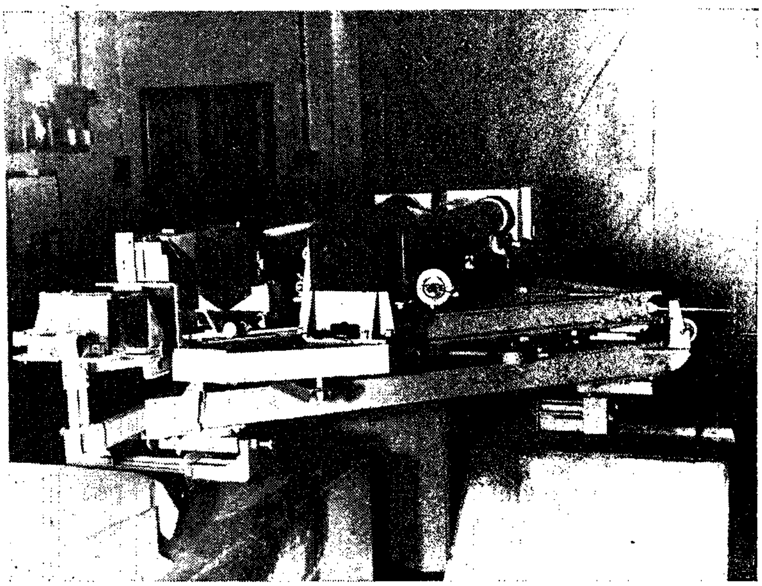

Fig. 2 K and H-alpha Spectroheliographs

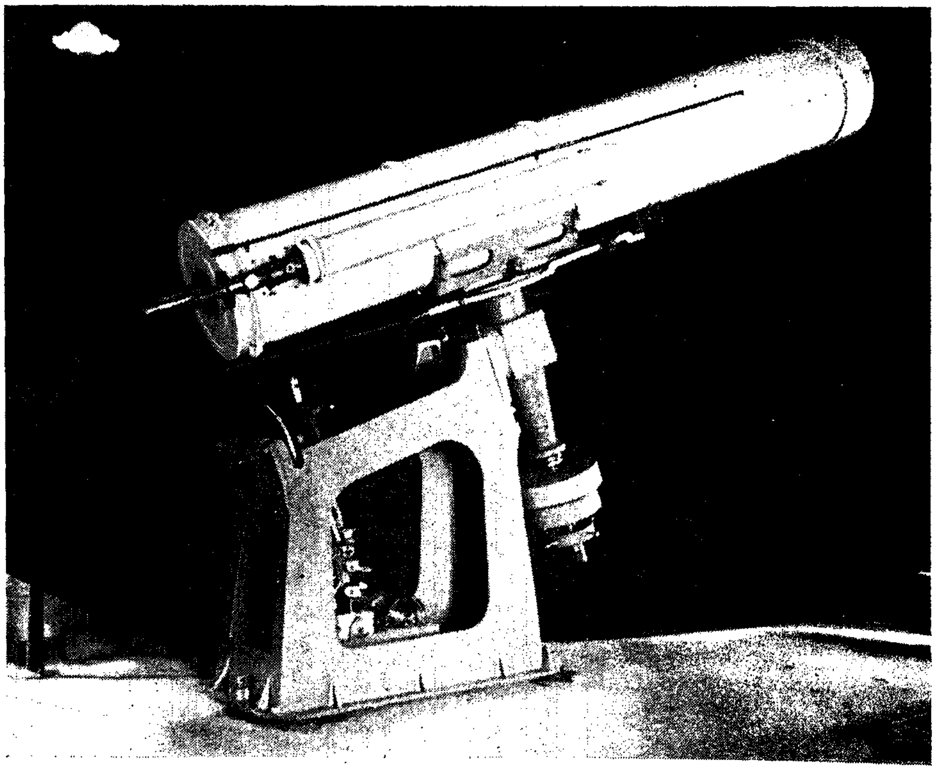

Fig. 3 20-inch Grubb Reflector

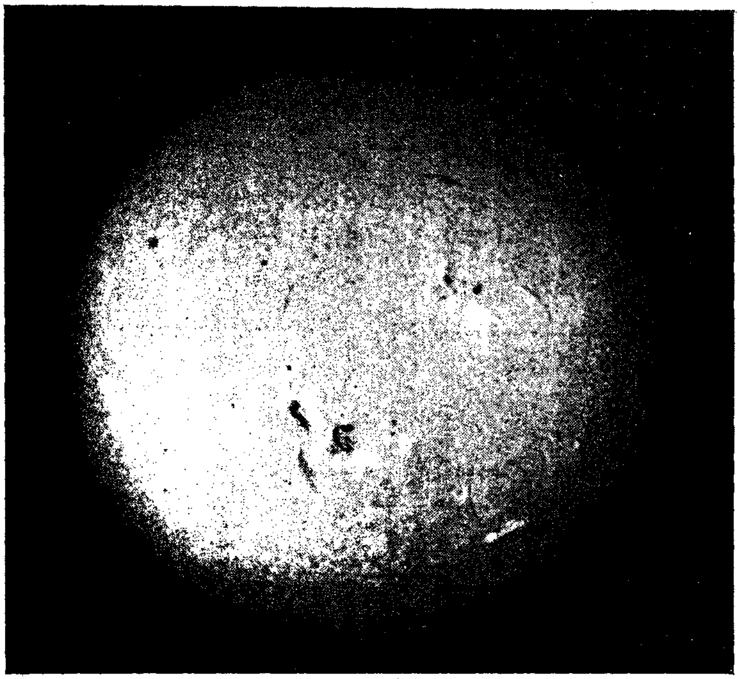

Fig. 4 (a) H-alpha Disc Spectroheliogram (10-3-1947)

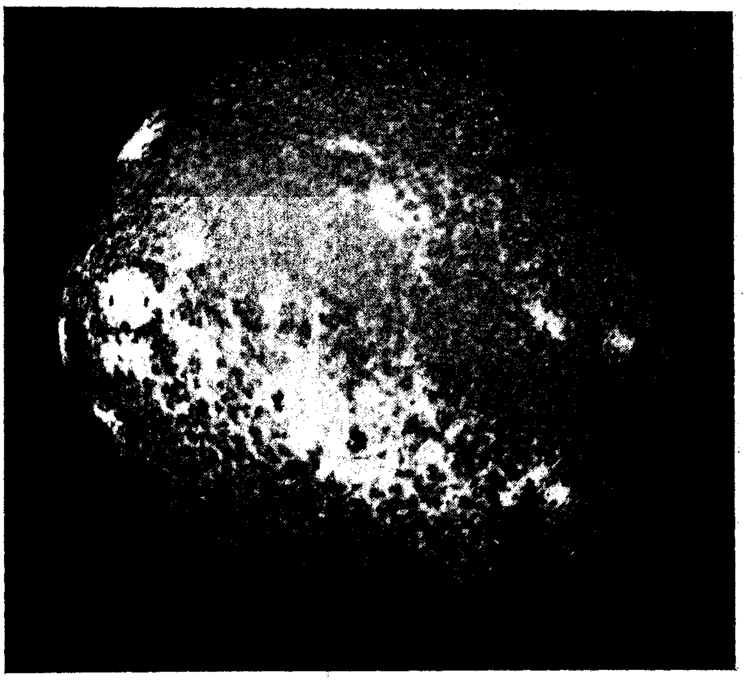

Fig 4 (b) K Disc Spectroheliogram (7-4-1947)

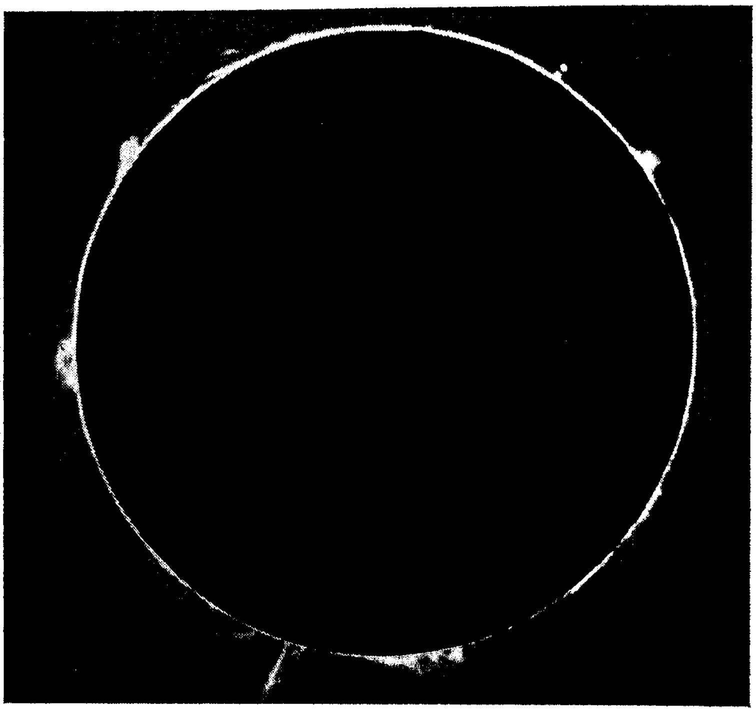

Fig. 4(c) K Limb Spectroheliogram (1-6-1937)

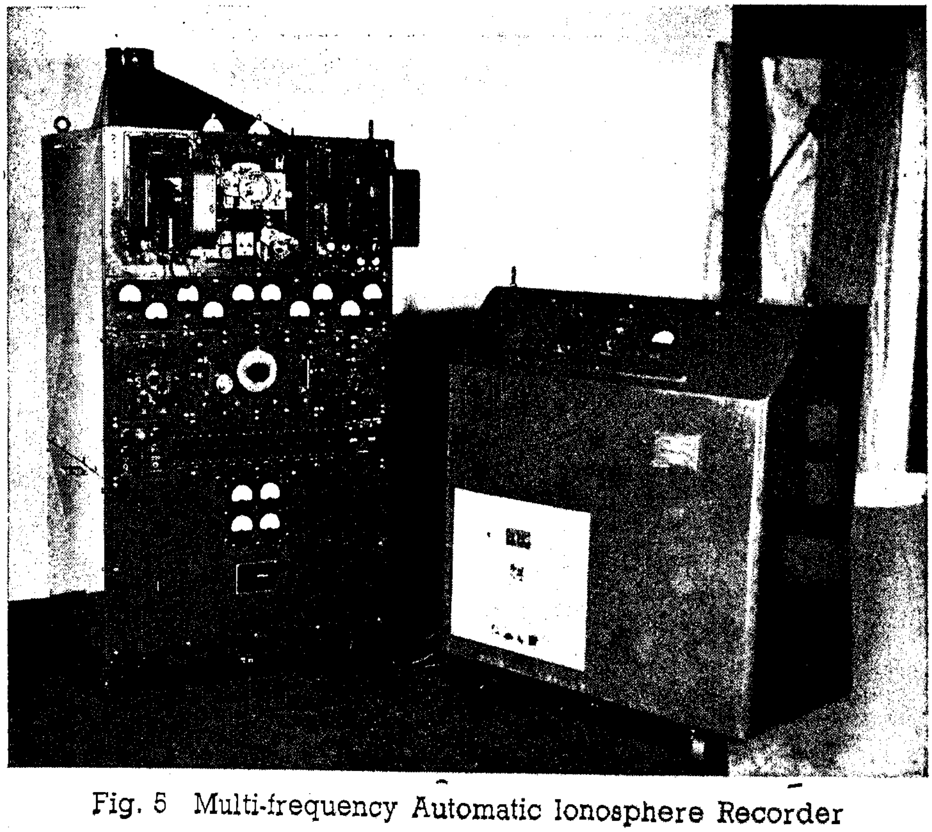

Fig. 5 Multi-frequency Automatic Ionosphere Recorder

of a much smaller order of magnitude compared with the radial motion. Detailed studies of the "*Evershed Effect*" were soon taken up by St. John at the Mt. Wilson Observatory. The investigations of Evershed and St. John revealed a consistent picture of the circulation of matter in a sunspot; but it was not the picture of a circular vortex with a vertical axis. It was found that over the sunspot zone matter in the lower levels near the photosphere moves outwards from the centre of the spot; the velocity of this radial motion decreases with height and reaches zero value at a certain level above which the direction of motion is reversed and is directed from the periphery towards the centre of the spot. Also it was found that in the lower levels the radial motion increases from the centre outwards, but comes to an abrupt stop near the periphery of the sunspot. Thus the flow of matter in the supraphotospheric regions of a sunspot is the reverse of that in a common smoke-stack, so that the flow in the subphotospheric levels of the spot is presumably similar to what is observed in ordinary chimney stacks.

(3) *Memoirs on Sunspot Spectra and Prominences*—An important memoir on "The Spectrum of Sunspots" was published by Evershed in 1909 in which several aspects of sunspot spectra were discussed at great length based on the results of his observations at Kodaikanal. A few years later, another memoir on "Results of Prominence Observations" was published by Mr. and Mrs. Evershed which embodied the results of his observations made at Kenley, England, supplemented by those made at Kodaikanal. In this memoir the distribution and frequency of prominences in different years and in different solar regions, the gases of which they are composed, their movements in the line of sight, their form and changes and their connection with sunspots and other phenomena are set forth in detail.

(4) *Sun-Arc displacements—Pressure in the reversing layer*—Another line of work to which Evershed and also Royds devoted considerable time and attention was the accurate measurement of the minute displacements of the solar absorption lines and the corresponding lines in the laboratory arc spectra. Interpreting these displacements as due to a pressure effect, Jewell, Humphreys, Mohler and Mm. Fabry & Buisson had deduced a value of about 5 atmospheres for the pressure in the reversing layer. Evershed attacked the problem in a novel way. Instead of considering the displacements of individual lines which can arise from a variety of causes such as motion in the line of sight etc., he considered the relative displacements of the different lines of an element, thus eliminating any cause which gives an equal displacement to all the lines. He thus deduced that the pressure in the reversing layer of the sun cannot be more than 0.13 atmosphere and is probably much less than this. It is of interest to note that recent estimates based on theory and experiment give a value of 10^{-4} to 10^{-6} atmosphere for the pressure in the reversing layer.

(5) *Venus Spectra*—Having disproved the notion prevalent at the time that the observed sun-arc displacements were due to pressure, Evershed first explained these as due to motion in the line of sight, perhaps due to a repulsion of solar gases by the earth. He also considered the alternative hypothesis that the sun's gravitational field influenced the wavelengths of the solar lines in accordance with Einstein's theory of Relativity. In order to decide between these two alternative hypotheses he conceived the ingenious idea of observing the spectrum of sunlight from a face of the sun turned 90° or more from the earth. For this purpose he made a systematic study of the spectrum of Venus over a period of 6 years. Spectrograms of Venus were taken for various values of the angle Venus-Sun-Earth ranging from 45° to 135°. Although from the earlier spectra taken with a grating spectrograph Evershed was led to conclude in favour of an "earth-effect" on the solar gases, his measurements in 1922 with a prism spectrograph revealed a systematic error in his earlier observations. His final conclusion was that "the lines are shifted towards red in light from all parts of the Sun, there being no difference between the visible and the invisible hemisphere. The general shift of the iron lines increasing from the centre towards the limb cannot, therefore, be explained by motion alone and our researches on the whole seem to support the Einstein Gravitational Effect combined with radial outflow of the iron vapour varying according to level and possibly varying with sunspot period". It may be mentioned here that no satis-

factory explanation of the observed red shift of the solar lines has yet been found.

For measuring the minute shifts of the spectral lines in the above researches, Evershed devised his so-called "positive on negative" method of spectrum plate measurement and constructed a special measuring microscope for the purpose.

(6) *Other investigations*—Among other investigations carried out at Kodaikanal Observatory, may be mentioned Evershed's observation of a large temporary increase in the magnetic field of the sunspot of 28 September 1909 in association with an intense solar flare, the field strength attaining about 3 times its normal value. Evershed's observations on *Halley's Comet* (*1910*) and his studies of the spectrum of *Nova Aquilae* (*1918*) during its different phases are also noteworthy.

Mr. Evershed retired in 1922 and Dr. T. Royds became the Director of the Observatory. Dr. A. L. Narayan joined as Assistant Director in 1928.

(7) *Spectroscopic Studies*—The earlier work of Royds related mainly to laboratory studies of the arc spectra of certain elements under different conditions with a view to investigating the cause of the observed displacements of solar lines with reference to lines in the spectra of terrestrial sources. Working with an iron-arc he found that while lines which were symmetrical in the arc spectrum showed normal displacements to the red in the sun, unsymmetrical lines behaved abnormally. Lines widened unsymmetrically towards red in the arc were found to be displaced to the violet (of the arc line) in the sun, while lines unsymmetrically widened to violet in the arc were displaced to red in the sun. He also found that when the spectrum of the region of the iron and calcium arcs near the negative poles was compared with that of the centre of the arcs, the unsymmetrical lines were displaced in the direction of their greater widening, *i.e.*, lines widened more towards red were displaced to the red at the negative pole and those more widened to the violet were displaced to the violet. Symmetrical lines showed only negligible displacement. He attributed the cause of these displacements to the increase of vapour density of the material producing the spectrum near the poles and concluded that the vapour density in the sun's reversing layer was lower than that at the centre of the arc under the conditions of his experiment. He studied the displacements of Ni and Ti lines in the sun and arc and found that the results were generally consistent with the conclusions drawn from the investigations of iron lines. He also examined the effect of introducing various substances into the arc on the wavelength of spectral lines.

(8) *Studies on Sunspots and Prominences* — Royds made a statistical study of prominence and sunspot periodicities using the periodogram method of Schuster. The apparent effect of planets on the distribution of prominences was also examined by him.

(9) *Study of H-alpha dark markings*— A special study of various aspects of the dark markings seen in H-alpha spectroheliograms was made by Royds and his co-workers and a number of papers were published on this subject. It was found that the average inclination of dark markings changes from a direction along the meridian in the equatorial region until in latitudes higher than about 35° the markings lie nearly along a parallel of latitude. The dark markings near the limb have almost invariably a bright margin on the side nearest to the sun's centre. Near the solar equator, the sidereal rotation period of the markings is nearly the same as for spots, but the polar retardation, although evident, is less than for spots. The inclination of the markings to the solar meridians increases during successive rotations, the magnitude of the increase corresponding roughly with the amount to be expected from the polar retardation of the sun's rotation. The areas of longitudinal dark markings are least near the central meridian and progressively increase towards the limb. The ratio of the height to the breadth of the markings is about 1.8 on the average.

(10) *Prominences and Radiation Pressure* — Royds made a comparative study of prominences taken in H-alpha and K lines during the period 1928-1931 and came to the conclusion that prominences are of essentially the same height and form in both these lines. He pointed out that this

result is opposed to Milne's theory of selective radiation pressure as the force supporting the prominences, since this pressure is considerable in the case of calcium atoms only.

(11) *Oxygen in the Chromosphere* —Royds succeeded in photographing outside an eclipse, the infra-red triplet of oxygen $\lambda\lambda$ 7771, 7774 and 7775 as emission lines in the chromosphere. These lines are normally observed as absorption lines in the Fraunhofer spectrum.

(12) *Contours of Fraunhofer Lines*—The contours of several strong lines in the solar spectrum at various points of the sun's disc were studied by Royds and Narayan by photographic photometry. It was found that the residual intensities of all the lines increase from the centre towards the limb. The concentration of atoms at different levels in the sun's reversing layer was calculated from the measures of the line-contours.

In 1937 Dr. Royds retired and was succeeded by Dr. A. L. Narayan as Director. Dr. A. K. Das joined as Assistant Director.

(13) *Studies in Atomic Spectra*—Narayan's earlier work at Kodaikanal was in the field of atomic spectra and a number of papers on this subject were published by him and his co-workers. Among these are the spectra of doubly and trebly ionised Lead, the hyperfine structure of Indium and Thallium, arc spectrum of Arsenic, the first spark spectrum of Bromine, the resonance lines of Thallium and their probable absence in the sun etc.

(14) *Direct Reading Photoelectric Photometer*—A photoelectric recording photometer for the direct measurement of the intensities of Fraunhofer lines was constructed by Narayan and the profiles of a few Fraunhofer lines near the centre and the limb of the sun were studied by him and his co-workers.

(15) *Band Spectra*—Among other investigations carried out under the direction of Narayan may be mentioned the studies on the band spectrum of phosphorus which led to the conclusion that the P2 molecule exists in the sun. From a study of λ3883 band of CN at the centre and the limb of the sun, temperatures of 5000° K and 4500° K were computed for the disc and the limb of the sun.

In 1946 Dr. A. L. Narayan retired and Dr. A. K. Das became the Director. Dr. R. Ananthakrishnan joined as Assistant Director.

(16) *The Motion of Gases in the Sun's Atmosphere*—During the period 1937 to 1942 Das made detailed studies of the motion of gases in the sun's atmosphere and published a series of papers. He was able to explain a large number of observed features relating to H-alpha dark markings, prominences, the reversing layer, the chromosphere and the corona on the basis of his theory. Some of these were the tendency of dark markings to orient themselves parallel to the meridians near the solar equator and in a perpendicular direction at higher latitudes, the westward tilt of prominences, the heights of reversing layer, the chromosphere and quiescent prominences, the increase of rotation speed with altitude in prominences, the occurrence of highly stripped atoms in the solar corona etc.

Among other studies made by Das and his co-workers may be mentioned the following—

(17) *Earth-effect on Prominences*—The apparent influence of the earth on solar prominences was examined by making a statistical study of Kodaikanal observations of solar prominences during the period 1913-1937. Evidence was found of the existence of a terrestrial influence on solar prominences, perhaps associated with a tide-raising force varying inversely as the cube of the distance between the earth and the sun.

(18) *Cosmic ray studies*—The results of cosmic ray intensity measurements at Agra (June-July 1936) and Kodaikanal (February 1938) with a Kolhoerster apparatus were analysed and the absolute intensity of cosmic rays for these two places was worked out. No relationship was found to exist between mean daily cosmic ray intensity and solar activity represented by sunspot numbers and flocculi figures.

(19) *Some observations of H and K lines*—More recently, experimental studies of the

variation in the width and structure of the H and K lines of calcium at various points of the sun's disc have been carried out using a high-dispersion spectrograph. The measurements reveal that the absorbing vapour producing the H_3 and K_3 lines has a descending motion of 1.5 km/sec while the vapour responsible for the emission lines H_2 and K_2 has a very slight ascending motion of the order of 0.3 km/sec. Although the absolute widths of the H_2, K_2 and H_3 and K_3 lines increase progressively from the centre towards the limb, their relative width remains constant over the entire disc.

(20) *Relation between base and height of Prominences*—A statistical study of the H-alpha dark markings over a whole solar cycle has shown that the length to height ratio is most frequently 2 : 1. The same result has been obtained for arch-type prominences at the limb. These results are in agreement with the theory of formation of prominences proposed by Das.

5. International Co-operation—Scientific Expeditions—Post-war Developments

(1) *International Co-operation*—Almost from the very beginning Kodaikanal Observatory has been participating in the scheme formulated by the International Astronomical Union for co-operation in solar research. Supply of photoheliograms to the Astronomer Royal, England, and exchange of spectroheliograms with the Solar Physics Observatory, Cambridge, have been in vogue from 1906. In accordance with the resolution of the International Astronomical Union meeting held at Rome in 1922, the Kodaikanal Observatory was made responsible for the work of compilation and discussion of statistics derived from photographs of prominences and H-alpha absorption markings on the sun. The observatories at Mt. Wilson (U.S.A.) and Meudon (France) co-operate with the Kodaikanal Observatory by supplying copies of their photographs for those days for which Kodaikanal record is imperfect or wanting. The statistics are published half-yearly in the Bulletins of the Observatory commencing from 1 January 1923. Since the installation of the spectrohelioscope, the Kodaikanal Observatory has been communicating quarterly lists of solar flares observed with the instrument to the International Astronomical Union for inclusion in their Quarterly Bulletin on solar activity. Cablegrams relating to intense solar flares are sent to the Meudon Observatory, France, which collects such information from solar observatories all over the world and broadcasts the same for the benefit of geophysicists all over the world. Beginning from 1 May 1949 daily broadcasts of coded messages (URSIGRAMMES) giving information about solar activity based on observations made at Kodaikanal are being made from the Transmitting Station of the India Meteorological Department at New Delhi for the benefit of geophysicists and radio specialists all over the world.

(2) *Eclipse and other Expeditions*—The Kodaikanal Observatory has participated in three eclipse expeditions. In 1922, Evershed undertook an expedition to Wallal, Western Australia, to observe the total solar eclipse of September 21. In 1929, Royds went on deputation to Pattani in Siam to observe the total solar eclipse of May 9. Again in 1936, Royds went to Japan in order to observe the total solar eclipse of June 19.

Apart from eclipse expeditions, officers of the Kodaikanal Observatory have taken part in expeditions for the exploration of sites suitable for the location of astronomical observatories in India. Evershed made two expeditions to Kashmir Valley in 1914 and 1915-16. As a result of his observations he came to the conclusion that whereas at Kodaikanal the hours most favourable for solar observations are confined to the first two or three hours after sunrise, remarkably good conditions prevailed in the Kashmir Valley throughout the day.

Very recently, in connection with a scheme sponsored by the India Meteorological Department for the establishment of a multi-purpose high altitude research station in the Himalayas for the study of cosmic rays, astronomy, meteorology, geophysics etc., a party of scientists representing various branches of science visited a number of places in the high Himalayas. In all these expeditions, which took place in the summer months of 1948 and 1949, Dr. R. Ananthakrishnan of Kodaikanal Observatory took part as a representative for astronomy. A few sites have been provisionally chosen, but observations of sky and seeing conditions have to be undertaken in order to examine the suitability of these sites from the astronomical standpoint.

(3) *Future Developments*—Although outstanding contributions on the theoretical side of astronomy and astrophysics have been made by Indian workers the corresponding contributions in practical and observational work have not been so significant, largely due to inadequate instrumental equipment available in Indian Observatories. During the last few years a number of instruments of basic value in solar research have been built at Kodaikanal largely through improvisation and local ingenuity at a negligible financial cost. These can be and are being utilised for dealing with a variety of problems within their reach. But improvisation, however ingenious, cannot produce the very complex and expensive apparatus of modern astrophysical research which the enormous strides in technological development in the western world have made possible. To mention only the most immediate needs, Kodaikanal Observatory requires a really large solar spectrograph with an adequately powerful coelostat and other accessories and a Lyot Coronagraph for modernising its activities in solar physics. These requirements can be met only if adequate funds become available.

A Committee for the planning of post-war development of Astronomy and Astrophysics in India was appointed by the Government in 1945 with Prof. M. N. Saha, F.R.S. as Chairman. The Committee in their report made several recommendations towards the expansion of the activities of the Kodaikanal Observatory. They made a forceful plea for modernising the instrumental equipment at Kodaikanal for solar work so that the Observatory can be on a par with the best equipped solar observatories in other parts of the world. They also recommended that steps should be taken for starting Planetary and Stellar Spectroscopic work as well as Magnetic and Ionospheric work at Kodaikanal.

Some progress has been made towards implementing the recommendations of the Committee, but much more remains to be done, the chief impediment in the way being, of course, finance. As already mentioned, the magnetic observatory has been restarted and ionospheric work is expected to begin before long. Preliminary work in the field of stellar and planetary spectra is also expected to begin within the next few months.

In 1948 the Government of India appointed a Standing Advisory Board for Astronomy and Astrophysics. The first meeting of the Board was held at Kodaikanal in April 1949, when matters relating to the development of astronomy and astrophysics in India with special reference to the expansion of work at Kodaikanal were discussed and several recommendations made to Government; their implementation, however, will depend upon the availability of the necessary large funds.

NOTE:—The above article was contributed by the officers of the Kodaikanal observatory
—EDITOR.