Kodaikanal Observatory

BULLETIN No. CXLIV

INDIAN ECLIPSE EXPEDITION TO OBSERVE THE TOTAL SOLAR ECLIPSE OF JUNE 20, 1955

INTRODUCTION

The total eclipse of the sun which occurred on June 20, 1955 was one of exceptionally long duration and had long been looked forward to with great interest by astronomers all over the world. The track of totality passed over Ceylon, Andaman Islands, Burma, Thailand, Indo-China and the Philippines. From a general consideration of the climatic features of the regions along the path of totality it seemed that the so-called "dry zone" of Ceylon offered the most favourable weather conditions for observing the eclipse. This view was evidently shared also by many other nations, for there were in Ceylon expeditions from Britain, U.S.A., Germany, France, Switzerland, Holland and Japan To the Kodaikanal observers, Ceylon, which is very near, offered special advantages in as much as they could attempt a fairly long programme of eclipse studies at a relatively low cost. Construction of instruments and other preparations for observing the eclipse were commenced several months in advance in the expectation that our government would approve of the venture. We are thankful to Mr. S. Basu, Director-General of Observatories for encouragement and for obtaining Government's sanction of the funds required to finance the expedition.

The proximity of Ceylon also made it easy to make a preliminary exploratory visit to fix up a suitable site and to arrange for other essential facilities for the eclipse party so that much time and labour could be saved later in the actual establishment of the camp With this object in view I visited Ceylon in April 1955 and had general discussions with our High Commissioner in Ceylon and with some members of his staff regarding the scientific requirements which the observation site to be selected must satisfy, and also about the facilities that we would require for the transportation and installation of our equipment. I also met Prof. A. W. Mailvaghanam of the Ceylon University with whom I had already been in correspondence for sometime in connection with the arrangements for our expedition. I am grateful to him for much useful local information.

I visited a number of possible observation sites in the neighbourhood of Polonnaruwa and Hingurakgoda in the rain-shadow belt of eastern Ceylon over which the track of totality passed. From these exploratory visits it seemed to me that the Hingurakgoda aerodrome offered the best facilities both for observations and residential accommodation. Two observing parties one from Britain and another from Germany (whom the Ceylonese scientists were assisting) had already established themselves at Hingurakgoda aerodrome. I contacted Dr. Spencer Hatch, Director of the UNESCO Fundamental Education Project in Ceylon who had his hostels very near the aerodrome and whom I had known for many years. He kindly agreed to place at our disposal seven rooms of the Women's Hostel of the Education Project. Five of these rooms were reserved for our party and the other two were earmarked for the team from the U.P. Astronomical Observatory who had requested us to help them with accommodation for their party. I also made provisional arrangements with the Manager of the Rest House at Hingurakgoda about the supply of food to our team. Before returning to Kodaikanal I met the Dy. Surveyor-General and also the Chief Engineer, Electrical Undertakings, Ceylon at Colombo in order to ascertain whether tents could be borrowed and also whether it would be possible to have 24-hour electric supply for our observation purposes. (The hours during which electric supply is normally available in the Hingurakgoda area are from 1600 hrs. to midnight.) The Surveyor-General agreed that tents could be borrowed if we applied for them immediately. Accordingly I requested our High Commission to put in an application on our behalf. However, later it was found that tents suitable for our purpose could be borrowed more easily from the Ceylon Army; our High Commission finally obtained the tents from the Army. As regards electricity, the Chief Engineer promised to look into the matter. I was also advised that the most economical mode of transport of our scientific equipment would be to book it by railway from Talaimannar right up to Polonnaruwa and to take the help of the lorries of the Irrigation Department, Ceylon, stationed at Polonnaruwa to carry it to our observation site at Hingurakgoda aerodrome about 15 miles away.

After formal Government sanction for the expedition was received, an advance party consisting of myself, Mr. P. Madhavan Nayar, Professional Assistant, Mr. P. V. Sanker Narayan, Scientific Assistant and Mr. L. Peter, Chief Mechanic, left Kodaikanal on the afternoon of 17-5-1955 with nearly five tons of equipment It was arranged to have a separate van, attached to the train by which the party travelled from Kodaikanal Road Rly. Station to Dhanushkodi, to carry all the equipment packed in about 70 cases. The party reached Dhanushkodi in the afternoon of 18 May 1955. We left Dhanushkodi immediately by the Ferry and reached Talaimannar about 8 p.m. A representative of our High Commission met us at Talaimannar and rendered us all possible assistance in the booking of our equipment. The equipment was put in a separate van and was attached to the train by which we left for Polonnaruwa. We reached Polonnaruwa at about 9 a.m. on May 19. The lorries of the Irrigation Department helped us to transport the equipment from Polonnaruwa to Hingurakgoda; thus the advance party reached Hingurakgoda in the evening with all equipment intact.

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Our original plan was to have our observation site in the grounds of Hingurakgoda aerodrome which is a short distance away from the hostel where we were to camp On reaching the place, however, we found it more convenient to have the instruments installed in the courtyard at the back of the hostel, where we could have better facilities in regard to electric supply than at the aerodrome. Dr. Hatch who had already placed at our disposal the Women's Hostel readily agreed to our request to have the adjoining compound also for our use. The courtyard had an additional advantage in that it was sheltered from the strong winds which would have been very troublesome, had we installed our instruments in the aerodrome. The first few days after our arrival were spent in clearing the grounds adjoining our living quarters of bush and jungle and also in procuring materials for building the piers and platforms required for erecting the instruments. The grounds around the hostel were infested with poisonous snakes. One had to be always on the alert, and particularly so in the night when adjustments to the instruments had to be made with the help of the moon. Even at midday we found once a large cobra crawling across the platform of one of our instruments We saw dangerous snakes on several occasions crossing public thoroughfares in front of us.

Our programme of observations at Hingurakgoda during the eclipse was divided broadly into four parts :

(1) Optical,
(2) Geomagnetic,
(3) Ionospheric, and
(4) Radio-Astronomical.

In the course of the first two weeks all the instruments were installed in their proper places. The magnetic instruments were housed in three separate tents, borrowed from the Ceylon Army, with sufficient spacing so as to avoid interaction between the magnet systems; the optical instruments were installed in the open with a suitable plastic cover for each instrument to protect it from the weather; the receivers of ionospheric and radio-astronomical instruments were housed in the hostel rooms.

The second party of three members consisting of Dr. T. M. K. Nedungadi, Assistant Director, Mr. B. N. Bhargava, Meteorologist and Mr. C K. Ananthasubrahmanyam, Professional Assistant, reached the eclipse camp on 14 June 1955. Besides the seven members constituting the official party, four more persons with scientific training, *viz* Mr. B. G. Narayan, Retired Meteorologist, Dr. W. F. Kibble, Professor of Mathematics, Christian College, Madras, Professor K. R. Gunjikar, Retired Professor of Mathematics, Bombay and Dr. R. Ananthakrishnan, Director, Regional Meteorological Centre, Nagpur, came to Ceylon at their own expense a few days before the eclipse day and assisted the official party in their observational programme.

The observations planned, the instruments used and the persons in charge of each instrument during the eclipse are indicated below :—

I. *Optical.*

(*a*) Photographic photometry of the flash spectrum at different heights in the chromosphere using an autocollimating spectrograph with three-prism dispersion and 6 feet focal length, capable of rotation around its axis. This was arranged for photographing 12 spectra at different stages of the 'flash' at the second and third contacts on 12″ × 1″ plates covering the spectral range from K to a little beyond D. A two-pen tape chronograph of which one pen was coupled with a seconds pendulum was attached to the spectrograph in such a way that the other pen of the chronograph would be actuated by the opening and shutting of the spectrograph shutter and would automatically record the exact time and duration of the different exposures. The pendulum clock was also connected with an electric bell which gave a short but clearly audible ring at every seconds beat of the pendulum, so that all the observers could have a running check on the times of photographic exposures as well as on the durations of the operations.

The spectrograph was fed by a 12″ coelostat in conjunction with an 18″ parabolic reflector.

I was in charge of this instrument and was assisted by Mr. L. Peter.

(*b*) Photographic photometry of the coronal line-emission spectrum using a low-dispersion, two-prism spectrograph of 15″ focal length fed by a 12″ Foucault siderostat through an image-forming lens of 8″ aperture and $9\frac{1}{2}$ feet focal length. This spectrograph was intended to take one spectrum of the corona during the whole period of totality covering the spectral range from λ 3800 to λ 6000.

Messrs. P. Madhavan Nayar and P. V. Sanker Narayan were in charge of this instrument.

(*c*) Direct photography of the corona in red light using a camera of 10″ focal length with a specially designed circular plateholder carrying 12 plates ($4\frac{1}{4}$ in × $3\frac{1}{4}$ in.) which could be exposed in succession by rotating the rear half of the holder through 30 degrees each time. This camera was fed by a 7-inch coelostat and was also provided with an arrangement for measuring the polarisation in the corona at great distances from the sun's limb.

Mr. B. G. Narayan and Dr. R. Ananthakrishnan were in charge of this instrument.

(*d*) Direct photography of the corona in blue-violet light employing an equatorially mounted camera with an objective of 4" aperture (specially corrected for the blue-violet region) and 48" focal length. This instrument was meant to make in all 12 direct photographs of the corona on 8½ in × 6½ in. blue-sensitive plates, 6 of which were to be taken without a polaroid, but with varying exposures The other six photographs were to be taken with a polaroid and with varying exposures so as to obtain the polarisation in the corona at different distances from the limb.

Mr. C. K. Ananthasubrahmanyam assisted by Prof. Gunjikar was in charge of this instrument.

(*e*) Polarimetry of the corona with a photographic polarimeter using an object-glass of 24" focal length on an equatorial mount. This instrument was designed for measuring the polarisation of the corona in green light at various distances from the sun's limb.

Dr. T.M.K. Nedungadi assisted by a volunteer from the UNESCO Education Centre was in charge of this instrument.

All the above optical instruments were especially designed and constructed in the workshop and laboratories of the Kodaikanal Observatory.

Dr. Kibble was in charge of calling out the time, read from a Chronometer, at suitable pre-determined intervals from 5 minutes before totality till the end of totality. This was a very important help to all the persons operating the optical instruments.

II. *Geomagnetic.*

These observations were planned with the view of determining if the diminution in the horizontal and vertical forces, which one could anticipate from the reorientation of current systems resulting from the reduced conductivity in the ionosphere above 50 km. during the eclipse, could actually be observed and if the magnitudes of these changes were in accord with theoretically deduced values.

The instrumental equipment consisted of :

1. Two Eschenhagen Magnetographs, one for recording the horizontal force and the other for the vertical force—both recording photographically with a recording speed of 15 mm./hr. These instruments were lent to the expedition by the Colaba and Alibag Observatories, Bombay.
2. An Askania Magnetic Field Balance for horizontal force with a chopper-type recorder giving a directly visible ink record.
3. Quartz Horizontal Magnetometer (Q.H.M.) with three tubes for calibrating the H.F. instruments.
4. Zero Balance Magnetometer (B.M.Z.) for calibrating the V.F. instruments.

Calibration experiments were performed daily for fixing independently the base-line values for each day's record.

III. *Ionospheric.*

These observations consisted of continuous registration of field strength of signals received from a broadcast station. The equipment was a communication receiver with a recording milliammeter, D.C. amplifier and associated power supply. The problem was to study the effects of the eclipse, and consequently of the abrupt interruption of ionising radiation from the sun, on radio propagation in the broadcast band. Special transmissions for eclipse observations from the All India Radio Station, Trichinopoly, at 770 Kc/s. were received and registered.

IV. *Radio-Astronomical.*

A 200 Mc/s. radio-telescope for the observation of radio emission from the sun was installed at Hingurakgoda. The receiver was specially constructed at the Kodaikanal Observatory for this purpose and was used in conjunction with a Yagi type antenna with four directors and one reflector. The aerial gain was approximately 12. The registration was made on an Elliot Current-recorder of range 0-1 mA with a chart speed of 3 inches/hr. The purpose of the observation was to register the radio emission from discrete sources on the sun at a wavelength of 1·5 m

The variations of solar flux deduced from the records have been studied together with the distribution of activity on the disc. On the eclipse day there was a prominent sunspot group in the SW quadrant of the disc which was fairly active. For some time after the commencement of the eclipse (time of first contact—070810 hrs. I.S.T.) there was no reduction in the radio radiation received from the sun. However, a sharp decrease in the received noise was noticed 12 minutes afterwards when the active sunspot group was obscured by the moon. This decrease continued till 0745 hrs. I.S.T. and the level remained practically constant until 0830 hrs. I.S.T. when it began to recover. The recovery was almost complete at the time of the fourth contact.

The above observations were used for deducing the temperatures corresponding to the flux of radio radiation at 1·5 m. received from the whole disc of the sun, and from the region containing the spotgroup. As usual, these calculations were made on the assumption that the source of radio radiation was a black body radiating according to the Rayleigh-Jeans law. This gave a temperature of $1{\cdot}2 \times 10^6$ degrees K for the disc and $5{\cdot}3 \times 10^6$ degrees K for the spot region. Now, since the temperature of the photosphere is reliably known to be of the order of 6000° K and further since the chromosphere must be opaque to radiation of 1·5 m. wavelength, it follows that the radiation recorded by our radio telescope must have originated in the tenuous solar corona Accordingly, our observations mean that on 1955 June 20, the general solar corona had a temperature of the order of 1·2 million degrees while the corona above the sunspot group in the SW quadrant was much hotter, its temperature being higher than 5 million degrees.

Mr. B. N. Bhargava was in charge of all the magnetic, ionospheric and radio-astronomical instruments, which were all self-recording, and therefore only one person was necessary to keep a watch over them

Intensive rehearsals with all the optical instruments were carried out for a few days prior to the eclipse.

Although adequate arrangements had been made for electric supply to our camp for running our radio instruments we took with us as standbys two petrol-driven M G sets one of 2·5 KW. and the other of 400 watts capacity which were lent to the expedition by the Meteorological Office, Poona On the eclipse day the 2·5 KW. generator was kept running and ready to be put into service at a moment's notice in the event of failure of the local electric supply.

Because of cloudy skies over Hingurakgoda during the total phase of the eclipse we were unable to carry out the optical programme outlined above The magnetic, ionospheric and radio-astronomical observations were, however, successfully made In order to supplement the observations planned to be made in the belt of totality a programme of intensive ionospheric, magnetic and solar observations were also carried out at Kodaikanal for several days including the eclipse day. All magnetic and ionospheric observations made at Hingurakgoda and at Kodaikanal were pooled together; the results of the analysis of the data thus collected are incorporated in the three sections which follow this introduction

Immediately after the eclipse we began packing up our instruments which took us three days. Only the magnetic instruments were kept running till the last day. The party left Hingurakgoda in the afternoon of June 24 and returned to Kodaikanal on the 26th of June.

I would like to take this opportunity to thank the business community of Hingurakgoda, particularly the proprietors of Messrs. Central Trading Stores, for their cordiality and for much assistance in setting up our camp. The Ceylon Customs authorities at Talaimannar waived all official formalities and passed our scientific equipment as well as personal effects without even examining them both at the time of entry and of exit. Our special thanks are due to Dr Spencer Hatch, Director of UNESCO Fundamental Education Project for placing at our disposal an entire hostel and its adjoining grounds. We thank the Electrical Undertakings, Ceylon, for extending the hours of electric supply to suit our needs, the Ceylon Irrigation Department, Polonnaruwa, for transporting our equipment from Polonnaruwa to Hingurakgoda, the Ceylon Army for lending us tents and our High Commission in Ceylon for giving us every help that we asked for in the organisation of our eclipse camp and in the transportation of our personnel and equipment. Our thanks are also due to the Ceylon Railways for all the help they gave us in safely transporting our equipment and to the volunteers from the UNESCO Fundamental Education Project, Hingurakgoda, who helped us in carrying out our programme of observations on the day of the eclipse.

All the strenuous work of setting up the camp and of erecting the instruments and ensuring their satisfactory functioning fell naturally on the advance party. I am personally grateful to Messrs P. Madhavan Nayar, P V. Sanker Narayan and L. Peter for their unstinted and unfailing assistance under conditions of work often not easy or agreeable It is also a pleasure to acknowledge the assistance which the official eclipse team received from Mr. B. G. Narayan, Prof. W. F. Kibble, Prof. K. R. Gunjikar and Dr. R. Ananthakrishnan who joined us as volunteers

A K. DAS,
Deputy Director General of Observatories and Leader of the Expedition.

KODAIKANAL OBSERVATORY
KODAIKANAL, *June*, 1956.

SECTION I

IONOSPHERIC F2 LAYER BEHAVIOUR DURING THE ECLIPSE OF JUNE 20, 1955

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ABSTRACT

The effects of the partial solar eclipse (magnitude 0·91) of 1955 June 20, on the electronic density, height and layer shape of F2 region over Kodaikanal are described. Although the ionic density of the F2 layer was affected perceptibly before ground first contact, the overall effect was a delayed one, the maximum effect on the ionic density having been observed 18 mts. after the maximum phase of the eclipse. Recovery in ionic density was gradual and was attained about two hours after the end of the eclipse. These effects have been examined in relation to coronal and sunspot activities on the eclipse day. It is found that F2 layer ionizing radiation appears to originate in a slightly enhanced form from active regions associated with sunspots and possibly with active coronal regions.

An extraordinary phenomenon consisting in rapid upward drift of F2 layer after maximum phase of the eclipse has been described. A new stratification appeared intermediate between F1 and F2 layers also soon after the maximum phase of the eclipse and developed into a well defined layer. This layer registered an almost fourfold increase in ionic density and eventually replaced the F2 region that existed before the eclipse.

1. INTRODUCTION

During several eclipses in the past attempts have been made to investigate the ionospheric effects resulting from a reduction in or cessation of solar radiation. These investigations have positively confirmed the solar control of the E and F1 regions. However, the effects on the F2 region have been found to be erratic and often controversial. Large and irregular variations in the F2 layer are of common occurrence and the observations on days preceding and succeeding the eclipse day do not provide very satisfactory control data. Wells and Shapley (1946) examined the eclipse effects on the F2 layer during three eclipses and indicated that a form of solar control was operative. Savitt (1950) analysed the F region observations for the eclipse of 1947 May 20, and found good agreement between observations and theory by assuming an attachment process. Wells' (1952) observations during the eclipse of 1951 September 1, show agreement based on recombination process for a part of the time after which other factors such as ion transport take control. Again, while Wells and Shapley (1946), Ledig et-al (1946) from observations at Huancayo and Piggott (1955) from observations at Ibadan observed considerable changes in the magnitude and distribution of ionization in the F2 layer, Minnis (1955) found no significant eclipse effects on F2 layer ion density from his observations at Khartoum during the eclipse of 1952 February 25. During the same eclipse observations of Perers (1952) in Italy indicated that instead of decreasing, the critical frequency of the F2 layer increased during the initial phase and then dropped to a relatively constant value between the maximum phase and the last contact The solar eclipse of 1955 June 20, provided a good opportunity for the study of the eclipse effects on the F2 layer and with this view, intensive ionospheric soundings were made at Kodaikanal (latitude : 10°14'N; Longitude . 77° 28' E) for 15 days centred around the eclipse day.

2. ECLIPSE OBSERVATIONS

The observations were made with the C.R.P.L. type C-3 Ionosphere Recorder of this observatory which was set to cover the frequency range of 1 to 25 Mc/sec. in 30 seconds and to virtual height range of 1000 kms. h'f traces were photographed on 35 mm. film on control days and both on 35 mm. and 16 mm. films on the eclipse day using two oscilloscopes. The circumstances of the eclipse at Kodaikanal at ground level and at several levels in the ionosphere are given in table 1*.

[*Data kindly supplied by Mr Harold W. Richards of H.M. Nautical Almanac Office, Royal Greenwich Observatory, Herstmonceux Castle, Nr Hailsham, Sussex.]

TABLE I.—*Circumstances of the eclipse.*

Height	Circumstances (times in I S.T.)						
	First contact		Middle of eclipse		Last contact		Magnitude
	h	m	h	m	h	m	
Surface	07	08.4	08	11.9	09	25.2	0.914
100 kms.	07	06.8	08	10.2	09	23.6	0.912
200 kms.	07	05 1	08	08 5	09	22 0	0.910
300 kms.	07	03.5	08	06 7	09	20.3	0 908
400 kms.	07	01 8	08	05.0	09	18.6	0.905

Control data were obtained from mean values derived from observations of 14 days, seven of which were before and the other seven after the eclipse day. The observations were made at half-hour intervals throughout the twenty-four hours but during the four-hour interval centred around the eclipse, 5-minute observations were made. On the eclipse day, the observations were made every minute between 06 hrs 30 mts. and 1000 hrs. Thus about 137 ionograms were available for the duration of the eclipse.

3. DISCUSSION OF ECLIPSE EFFECTS

It will be seen from table I that the eclipse began at 0708 hrs. I S.T., that is, at a time when the ionization of the F2 layer normally increases rapidly. The time was, therefore, ideally suited for the observation of any discontinuities in the slope of the diurnal curve due to sudden masking of the ionizing radiation. The observed critical frequencies of the F2 layer on eclipse day and the mean critical frequency of the F2 layer for the control days have been plotted in Fig. 1.

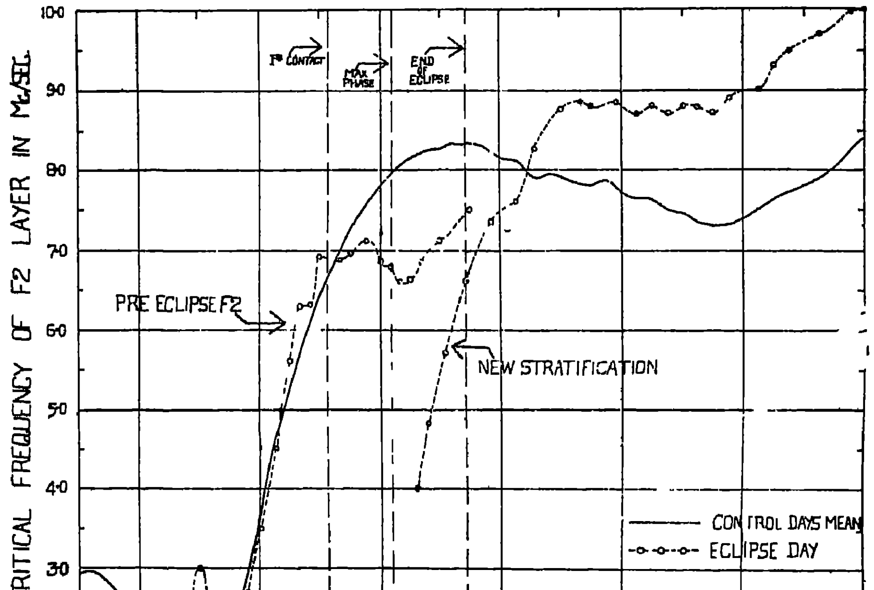

Fig. (1).—F2 Layer critical frequencies on eclipse day and mean control day.

(*a*) *Eclipse effects before first contact.*—The first discontinuity in the slope of the foF2 curve is seen at 0642 hrs., 22 mts. before the first contact at 250 kms. level. The effect is of short duration, but if it was due to the eclipse, it could be either due to the moon obstructing wave radiation originating some distance away from the solar limb or it could be due to the obstruction of corpuscular radiation from the sun. It can be seen that the nearest limbs of the sun and of the moon were about 11′ apart at the time of commencement of this discontinuity and the moon could be obstructing wave radiation originally in the solar corona about 500,000 kms. away from the sun's limb on the southwest quadrant.

In order to determine the distribution of coronal activity, a diagram was constructed with the help of the data [intensities of the green (5303 A°) line] of the coronagraph station at Climax, Colorado, published in the F series bulletins of the C.R.P.L Wells and Shapley (1946) have indicated that bright coronal regions or streamers have a lifetime up to several months and rotate with approximately the same period as the photosphere. Waldmeier (1947) has also shown that coronal structure does not undergo appreciable change in about 7 days. The positions of the active regions over the disc were, therefore, estimated from available observations on the limb by taking into account the period of solar rotation. The state of the corona as on June 20 together with the path of the centre of the moon are shown in Fig. (2). Most of the coronal activity was located in NW, SW and NE quadrants. It is also seen that there was no markedly bright coronal region on the SW limb at about 7° south heliographic latitude where the moon was nearest to the sun at the time of discontinuity. It is, therefore, unlikely that obstruction of wave radiation from the corona about 11′ away from the sun's limb was responsible for the abrupt discontinuity.

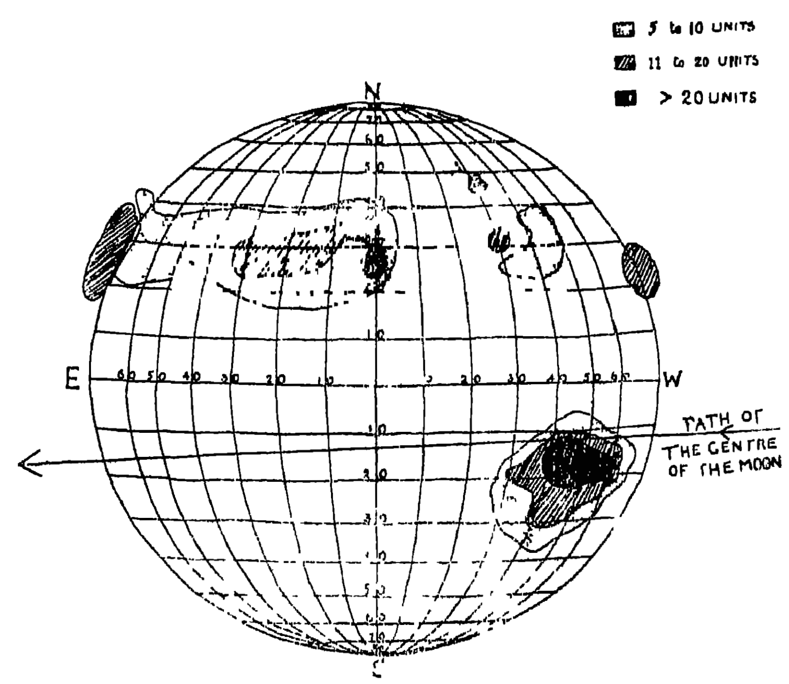

Fig. (2).—Coronal activity on eclipse day and path of moon's centre.

Again, if the obstruction of corpuscular radiation was responsible for the discontinuity, the speed of the particles would be about 8700 kms./sec., which is far in excess of the usually accepted value. There has been, so far, very little evidence of such fast corpuscular streams from the sun.

(*b*) *Ionic density during the eclipse.*—From control day curve in fig. (1) it is seen that the ion density begins to increase shortly after 0530 hrs. and continues to do so until 0930 hrs. when the midday decrease begins. The entire duration of the eclipse was, therefore, a period of normal increase in ionization. The two broad minima of critical frequency in Fig. (1) centred around 0720 and 0825 hrs. respectively are, therefore, significant. The first one of these began at 0700 hrs., a few minutes before the first contact at 300 kms. level. The period of low ionic density is practically the same as the period during which the bright coronal regions in the NW and SW quadrants were masked. It also coincides with the period during which a sunspot group in the SW quadrant (shown in fig 3) was obscured by the moon. That this sunspot group was moderately active is evident from the fact that 25 flares, mostly of minor importance, were recorded from its vicinity at McMath-Hulbert and Sacramento Peak observatories between June 13 and June 21. Further, the recovery in F2 ionization was noticed to start almost synchronously with the uncovering of this sunspot group between 0823 and 0833 hrs, There is, therefore, sufficient evidence of enhanced solar radiation emanating from the sunspot group on the SW quadrant.

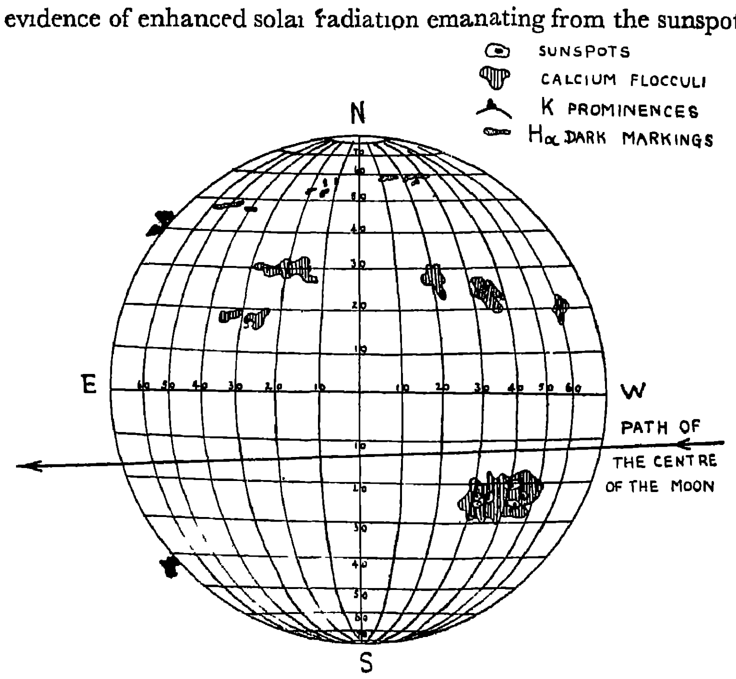

Fig. (3).—The state of Sun's activity on the morning of 20th June 1955 as observed Kodaikanal.

It will also be seen from fig (1) that the largest decrease in F2 ionization occurred 18 mts. after the maximum obscuration of the solar disc as viewed at 300 kms. and the decrease in ion density from the expected normal for the day was 33%. Subsequent recovery was gradual and was marked by rapid changes in the structure of the layer, vertical transport of ions and appearance of a new region.

Changes in Virtual Height and appearance of an unusual stratification.—The period after the maximum phase of the eclipse was marked by rapid and complex changes in the structure of the F2 layer About 15 mts. after the maximum phase of the eclipse, the F2 layer heights registered a rather abrupt upward rise. The ion-density started increasing rapidly at a height of about 300 kms. Soon after, a new stratification appeared intermediate between F1 and F2 layers. Half an hour after the maximum phase of the eclipse, the height and critical frequency of the new stratification were measured at 330 kms. and 4·0 Mc/sec. respectively It developed rapidly into a well defined layer and its ionic density increased nearly fourfold in the course of two hours. This increase in ionic density was almost identical with that normally observed for the F2 region during early morning hours. The average rate of increase as calculated from both the mean control day curve (0605 hrs.-0645 hrs.) and the new stratification curve (0835 hrs.-0925 hrs) was found to be 94 ions/C.C./sec. The development of this layer between 0835 and 0945 hrs. has been shown in fig. (4) where the ordinary components of the h'f traces have been reproduced.

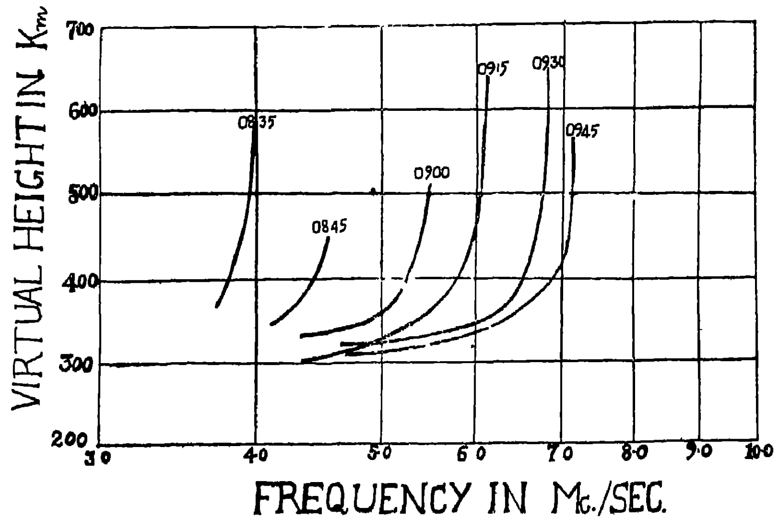

Fig. (4).—Ordinary component of the h'f curve showing development of the new F region.

The pre-eclipse F2 region continued to drift vertically upwards and in an hour and a quarter its virtual height exceeded 1000 kms., the upper limit of the recorder The layer probably continued to exist at greater heights. During this period the electronic density of the layer registered only a slight recovery. The ordinary component of the h'f curve for this layer between 0830 and 0937 hrs. has been shown in fig. (5) to indicate rapid upward drift of the layer.

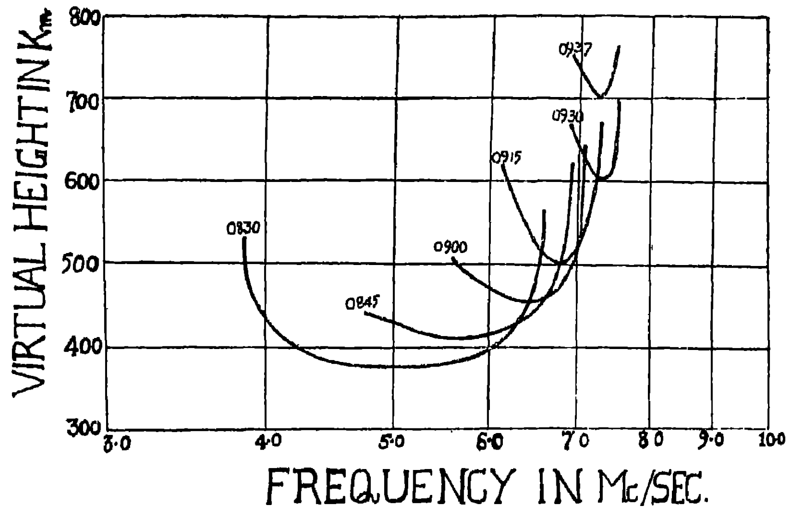

Fig. (5):—Ordinary component of h'f trace showing rapid upward drift of the pre-eclipse F2 layer.

Rapid changes of almost similar nature have been reported by Ledig et al (1946) and Wells and Shapley (1946) over Huancayo during the partial eclipse of January 25, 1944 and by Estrabaud (1952) from observations at Bangui. The new stratification over Huancayo, however, appeared at great apparent heights and descended rapidly. It may be mentioned here that the stratification of F layer into so-called lunar layer and subsequent upward drifts are of almost regular occurrence over Kodaikanal as indicated by one of the present writers (1955) and this occurrence is confined to certain solar hours and two distinct lunar times The stratification observed during the eclipse and those of lunar origin appear to have common features such as rapid upward drifts with velocities in excess of 250 kms/hr. and result in thick residual F2 layer. Observations suggest that once the F2 layer gets stratified, upward drifts necessarily take place due to a common mechanism.

The changes in virtual height of the new stratification were not so complex as the changes in ionic density. The variation of virtual height of F2 layer including that of the new layer has been shown in fig. (6). It will be seen that throughout the recovery period, the virtual height of the newly formed F2 region remained subnormal while the electronic density registered was higher than the normal for control days.

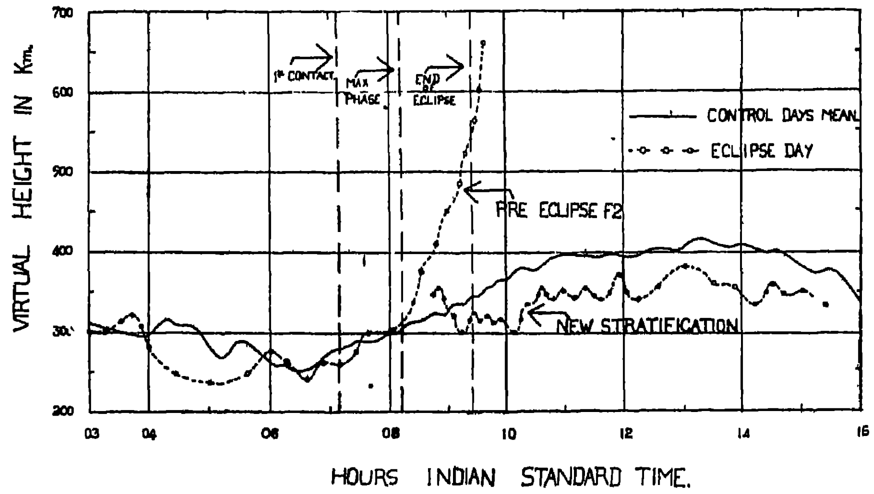

Fig. (6).—Virtual heights of F2 layer on eclipse day and mean control day.

Further analysis of observations regarding effective recombination characteristics in the F2 region is in progress.

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SECTION II

THE EFFECT OF THE SOLAR ECLIPSE OF 20TH JUNE 1955 ON THE LOWER IONOSPHERIC LAYERS.

By

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ABSTRACT

At Kodaikanal Observatory high speed soundings of the Ionosphere were made at one-minute intervals during the solar eclipse of 20th June 1955 The behaviour of the lower ionosphere comprising the F1, E and D layers during the eclipse is discussed in this paper By a detailed analysis of the variation of ion-density of the E layer throughout the progress of the eclipse it is shown that solar radiation responsible for the formation of this layer is not distributed uniformly over the sun's disc The vicinity of an active sunspot group situated on the south-west quadrant of the sun was found to be a discrete source of intense radiation The behaviour of the F1 and D layers suggests that the ionisation in these layers also is enhanced by the intense radiation from the vicinity of the active sunspot group.

INTRODUCTION

The solar eclipse of 20th June 1955 had a magnitude of over 0·9 at Kodaikanal where a regular ionospheric sounding station exists as a part of the Kodaikanal Observatory. The circumstances of the eclipse at Kodaikanal were as follows :

Height	Beginning of the eclipse		Time of maximum phase of the eclipse (I.S T.)		End of eclipse. I.S T		Magnitude
	h	m	h	m	h	m	
Surface	07	08.4	08	11.9	09	25.2	0 914
100 Km (E layer)	07	06.8	08	10.2	09	23.6	0 912
200 Km. (F1 layer)	07	05.1	08	08.5	09	22 0	0 910

An intensive programme of ionospheric observations was arranged here with a view to study the effects of the eclipse on the ionosphere Oblique incidence field-strength records were also made at Hingurakgoda, Ceylon, to supplement the vertical incidence data obtained at Kodaikanal. The behaviour of the lower ionospheric layers comprising the F1, E and D layers during the eclipse as shown by these data is discussed in this paper

Equipment used.—The Automatic Ionosphere Recorder, type C-3, designed by the National Bureau of Standards, Washington, which is in use at the Kodaikanal Observatory, covers the frequency range from 1·0 to 25·0 Mc/s in 30 seconds The pulse length chosen is 50μ sec. and the pulse repetition frequency is about 30 Terminated semi-rhombic antennae are used for both transmission and reception and the peak power of the transmitter is about 10 kilowatts.

Programme of observations.—During the entire month of June 1955 ionospheric records were obtained once every 5 minutes from 0700 to 1000 hrs I.S.T , so as to provide reliable normals for the morning hours. During a period covering one week on either side of the eclipse day, *i e.*, from 13th to 27th June, the Ionosphere Recorder was run continuously for all the 24 hrs. On the eclipse day records were obtained once every minute from 0630 hrs. I.S.T. to 1000 hrs. I.S.T. After an examination of all the records it was found that for studying the eclipse effects, a control period of 10 days (five days on either side of the eclipse day) would be the most suitable and accordingly this period was chosen for the present investigation. Throughout this period the performance of the recorder was quite satisfactory and there was no loss of records.

E LAYER

The detailed features of the normal E layer at Kodaikanal are not very clearly discernible due to the presence of the day-time sporadic E-layer as pointed out by one of the present writers [Rangarajan (1954)]. However, except on occasions when intense sporadic E is present the critical frequency of the normal E-layer can be read with a fair degree of accuracy The normal diurnal variation of foE at Kodaikanal has been found to be symmetrical about noon and to follow a $(\cos\psi)^n$ law, where (ψ) is the sun's zenith angle and the exponential *n* has a value ranging between 0·28 and 0·30. On the eclipse day n was found to have a value of about 0·28 In fig 1 the variation of quarter hourly median foE values for the 10-day control period is shown by the continuous line. On the same figure, foE values on the eclipse day are shown in small circles connected by a broken line During the eclipse period the day-time sporadic E-layer was either absent or observable only as a very thin layer and hence the foE values could be read with considerable accuracy

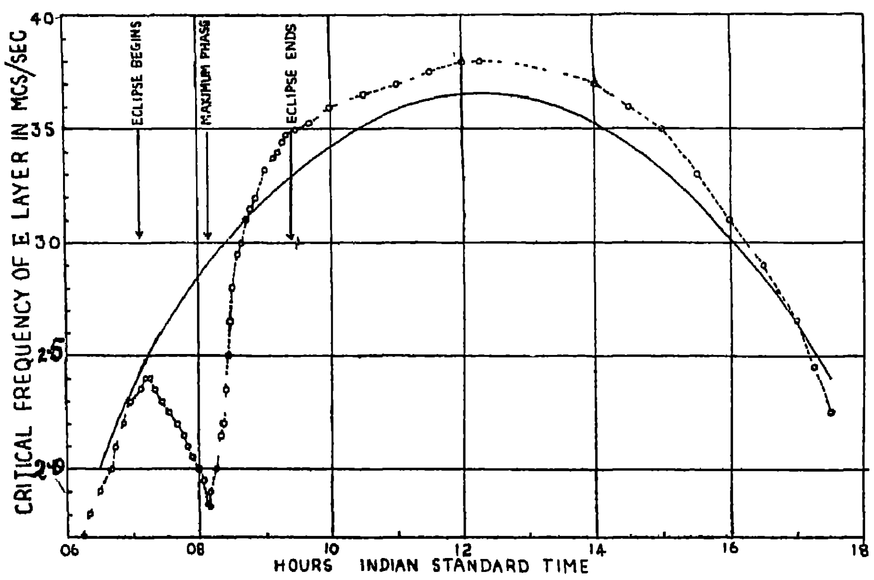

Fig. (1).—Variation of critical frequency of the E layer during the eclipse.— median of control period values. o-o-o-o-o values observed on eclipse day.

With the commencement of the eclipse in the E-layer at 0707 hrs. I.S T. a spontaneous change in the behaviour of foE could be seen. The normal upward rise of foE was arrested and it remained more or less constant at 2·4 Mcs/s. until 0716 hrs. I.S.T. Thereafter foE dropped steadily until at 0809 hrs it attained the lowest value of 1·82 Mcs/s This time is only one minute earlier than the time corresponding to the maximum phase of the eclipse in the E-layer. From 0809 hrs onwards foE rose rapidly till about 0830 hrs. and continued to rise with less rapidity until 0920 hrs.; thereafter the variation of foE was in accordance with the normal pattern. It will be seen from the figure that the foE values, after the eclipse, were higher than the corresponding median values of the control period

It will now be investigated how far the foE variations during the course of the eclipse are in accord with the calculated values on the assumption of a uniformly radiating solar disc. For the E-layer of the ionosphere the relation between the rate of electron production due to the sun's ultraviolet radiation, and decay due to recombination processes can be expressed by the simple relationship,

$$\frac{dN}{dt} = q_0 \cos\psi - \alpha' N^2 \qquad (1)$$

where

N = Electron density,

ψ = Solar zenith angle,

q_0 = Rate of electron production when $\psi = 0$,

α' = The effective recombination coefficient.

At noon time $\frac{dN}{dt}=O$ and hence we obtain

$$\frac{q_o}{\alpha'}=N^2 \ \mathrm{Sec}\ \psi \qquad (2)$$

where N is determined from the relation

$$N=1\cdot24\times10^4\times foE^2 \qquad (3)$$

The value of $\frac{q_o}{\alpha'}$ thus determined will be independent of the assumptions of the possible value of α' and is a measure of the ultraviolet radiation from the sun that is responsible for the ionisation of the normal E-layer. On the eclipse day the noon value of fo E was 3·8 Mcs/s. and from this $\frac{q_o}{\alpha'}$ is calculated to be $329\cdot4\times10^8$ cm $-^6$

When $\frac{dN}{dt}$ is not zero as is the case at other hours of the day

$$\frac{q_o}{\alpha'}=\left[N^2+\frac{1}{\alpha'}\ \frac{dN}{dt}\right] \mathrm{Sec}\ \psi \qquad (4)$$

During a solar eclipse the moon obscures the sun's disc progressively and cuts out a measurable fraction of the total radiation Assuming the solar disc to emit radiation uniformly, if A is the fraction of the disc unobscured we have the relation

$$\frac{Aq_0}{\alpha'}=\left[N^2+\frac{1}{\alpha'}\ \frac{dN}{dt}\right] \mathrm{Sec}\ \psi \qquad (5)$$

$$=J \quad \text{(say)}$$

If $\frac{q_0}{\alpha'}$ is assumed to be constant during the eclipse as was done by Minnis (1955) changes in J will be proportional only to the changes in intensity of the ultraviolet radiation which were caused by the eclipse and will not be influenced by the normal diurnal variation. Thus if the solar disc is radiating uniformly, the changes in J during the eclipse should be proportional to A only, and could be calculated theoretically from astronomical considerations. From the experimentally deduced values of N^2 and $\frac{dN}{dt}$ it is also possible to determine J from equation (5) and this can be compared with the theoretical values.

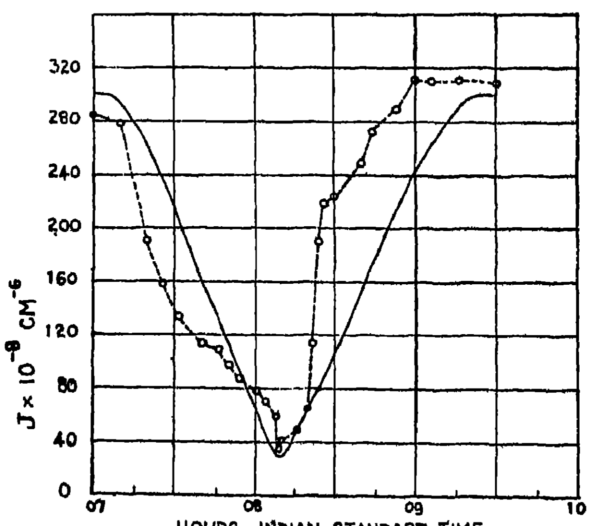

Fig. (2).—Changes in the E layer ionising radiation during the course of the eclipse.
— calculated assuming uniformly radiating solar disc. o-o-o-o observed values.

In figure 2 the experimentally determined values of J during the eclipse period are shown in small circles connected by dotted line. A value of $1 \cdot 0 \times 10^{-8}$ for α^1 was assumed, as this has been found to be the most probable value for the E-layer by earlier investigators In the same figure, the calculated variation of J during the eclipse, is also shown by the continuous curve, assuming J to be equal to $300 \times 10^{+8} \times cm^{-6}$ for the fully radiating solar disc The considerable deviation of the experimental curve from the calculated one seems to indicate the fact that the solar disc is not uniformly radiating. The following main features can be deduced from the figure

(1) At the beginning of the eclipse, between about 0720 and 0730 hrs. I.S T., the fall in J is much more rapid than what is indicated by the calculated curve

(2) At the maximum phase of the eclipse the calculated and observed values of J are nearly the same.

(3) Between 0820 hrs. and 0826 hrs., I.S.T., the rise in the observed values of J is much more rapid than what is indicated by the calculated curve

The discrepancies (1) and (3) above can be accounted for if we assume the sun's radiation responsible for the ionisation of the E-layer to consist of two components One distributed uniformly over the disc and the other due to a discrete source of intense radiation located on the SW quadrant of the sun's disc, which when obscured or uncovered by the moon produced a marked effect on the E layer ionisation It will now be seen how far the actually observed state of solar activity on the eclipse day fits in with the above deduction.

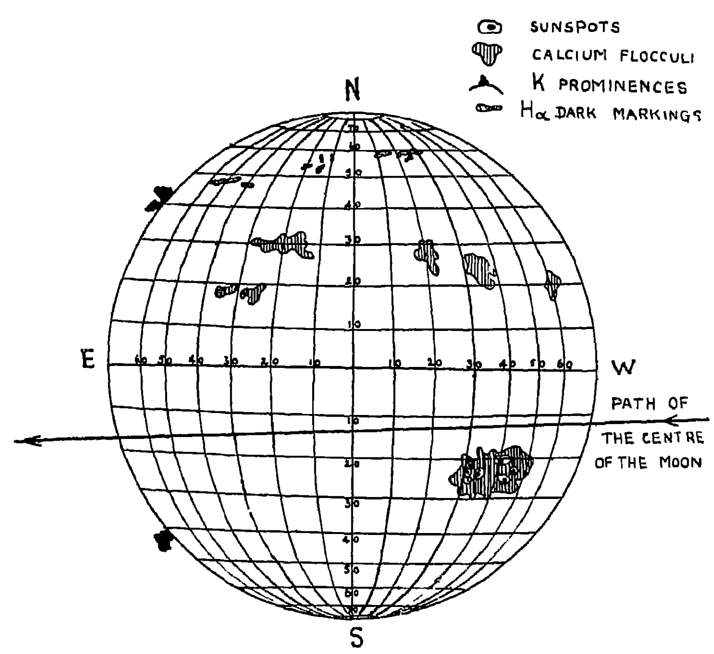

Fig. (3).—The state of Sun's activity on the morning of 20th June 1955 as observed at Kodaikanal.

Figure 3 shows a sketch of the sun showing the regions of activity as observed at Kodaikanal on the morning of the eclipse day. The spot group in the SW quadrant was very active as evidenced from the bright areas of calcium flocculi surrounding it. Its activity is further evidenced from the fact that on the eclipse day a sudden ionospheric disturbance (a partial radio fade-out) was observed at Kodaikanal between 1230 and 1400 hrs., I S T The time of obscuration of the area of the sunspot group by the moon's disc as calculated from astronomical considerations is 0715-0726 hrs., I S.T , and the time of uncovering of the same area is 0821-0831 hrs., I S.T These times are in reasonable agreement with the times when the observed J values fell and rose rapidly as mentioned earlier and thus the discrete source of intense radiation can be identified with the vicinity of the sunspot group. That individual sunspot groups can influence the conditions in the ionosphere has been concluded earlier by Allen (1948) from purely statistical studies on the variation of the ionospheric critical frquencies with sunspot activity. The present finding based on eclipse measurements lends support to this conclusion.

Besides the active sunspot group in the SW quadrant, there might have been other sources of less intense radiation over the sun's disc. However, with the accuracy with which foE measurement could be made, it is not possible to identify these, unambiguously.

In this connection, it may be mentioned that during the solar eclipse of 25th February 1952, also Minnis (1955), Piggot (1952), and Perers (1952) had found evidence that the ultraviolet radiation responsible for the ionisation of the E-layer is not emitted uniformly from all parts of the sun's disc On that eclipse day however, the sun's disc was free from sunspots but, the discrete sources of intense radiation were identified with regions of intense coronal emission.

F1 LAYER

At Kodaikanal the bifurcation of the F-layer into F1 and F2 layers starts within an hour after ground sunrise, but the cusp of the F1 layer becomes well marked with a measurable critical frequency only still later. Normally reliable values of foF1 are available only from about 09 to 16 hrs. I S T. During the control period, the values of foF1 could be read from 08 to 16 hrs. I.S.T. by measuring in some cases the frequency at which a well-marked retardation effect is seen between the F1 and F2 layers.

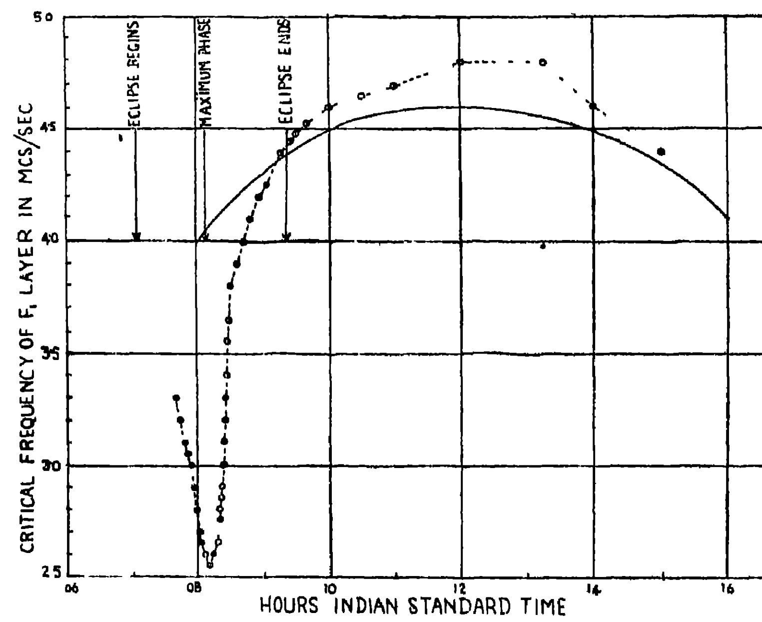

Fig. (4).—Variation of critical frequency of the F1 layer during the eclipse.
— median of control days. o-o-o-o values on eclipse day.

In figure 4 the variation of the quarter-hourly median foF1 values for the control period is shown by the continuous curve. On the same figure the values of foF1 observed on the eclipse day are plotted as small circles connected by broken line. On the eclipse day the F1 layer formed as a distinct layer much earlier than on other days and hence foF1 could be read accurately from 0740 hrs., I.S.T. onwards. The lowest value of foF1, *viz*, 2 5 Mcs/s. was reached at 0808 hrs, I.S.T —coincident with the time of maximum phase of the eclipse at the F1 level (200 km.); thereafter foF1 rose rapidly until 0821 hrs. I.S.T. and for the next 9 minutes the rise of foF1 was extremely rapid. During this 9 minute interval, foF1 rose at the rate of 0·1 Mc/s. per minute. From 0830 to the end of eclipse a steady increase of fo F1 was maintained. Quantitative analysis of the intensity of solar radiation responsible for the production of the F1 layer can be made with much less reliability than in the case of the E-layer owing to several uncertain factors and hence this has not been attempted at present. However, it is interesting to find that as in the case of the E layer, the maximum rate of rise of foF1 took place during the interval when the active sunspot group in the SW quadrant of the sun's disc was uncovered by the moon's disc. Thus it is possible that intense radiation from the spot region might have contributed to the ionisation of the F1 layer also.

From the minimum observed value of foF1 during the eclipse, *viz.*, 2·5 Mcs/s. it is found that the ion-density [α foF1^2] of the F1 layer dropped by 61·9% at the time of the maximum phase of the eclipse, when compared with the corresponding value of the control period. In the case of the E-layer the decrease in the ion-density at the time of the maximum phase of the eclipse is found to be 61·1%. This close agreement seems to suggest that the solar sources responsible for the ionisation of the E and F1 layers might be the same.

D LAYER

(a) The changes in the ionisation of the D-region of the ionosphere during the eclipse were studied only in an indirect manner from observations of the lowest frequency up to which reflections are observable from the E-layer (f min E). The f min E readings will be dependent to some extent on the power of the transmitter and the R F. gain setting of the receiver However, for comparative studies, the effects due to these instrumental factors can be neglected. The normal diurnal variation of f min E is known to follow a simple pattern with a maximum around noon and with decreasing values on either side. However, on occasions when sunspots with their bright active areas exist on the sun's disc significant and sporadic increases of f min E are known to occur.

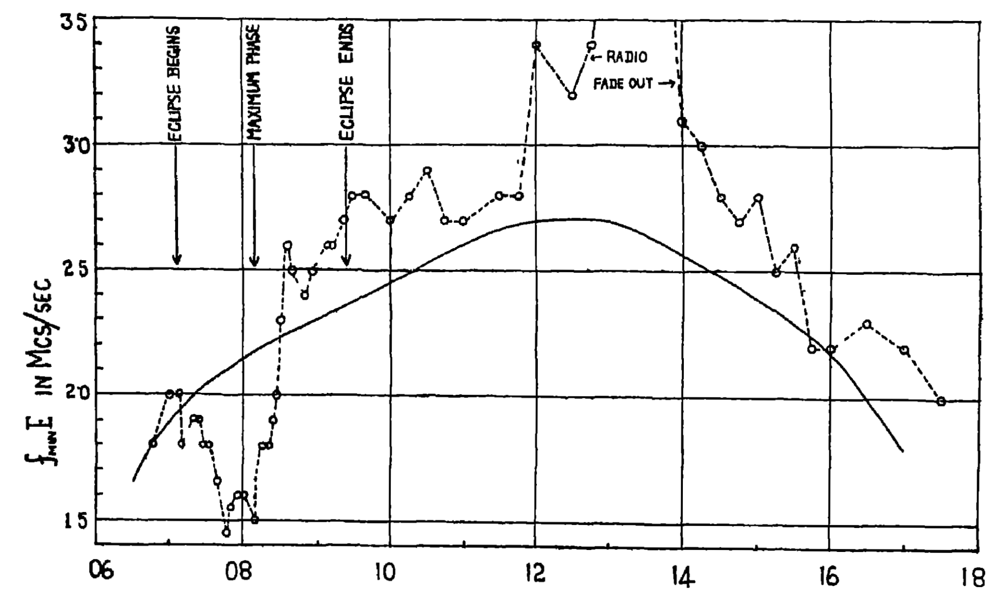

Fig. (5).—Variation of F min E during the eclipse.
—median of control period values. o-o-o-o-o observed values on eclipse day.

In figure 5 the variation of the quarter-hourly median values of f min E for the 10-day control period is shown by the continuous curve. The values of f min E on the eclipse day are shown in the same figure by small circles connected by dotted lines. It will be seen that f min E values were generally much higher on the eclipse day than the control-period values and this appears to be due to increased activity of the sunspot group. With the commencement of the eclipse f min E values decreased progressively, however, the fall was not steady and uniform The lowest f min E value of 1 45 Mcs/s. was reached at 0747 hrs I. S. T. and another minimum of 1 5 Mcs/s. at 0807 hrs. I.S.T. which is near about the time of maximum phase of eclipse in the D-layer.

As soon as the active sunspot group was uncovered by the moon's disc between 0820 and 0830 hrs. I.S.T. an abrupt rise of f min E occurred and even when half the sun's disc was still covered the f min E values were appreciably higher than the respective median values of the control period. This seems to indicate that at about the time of the eclipse some source near the vicinity of the sunspot group was emitting abnormal radiation to cause an enhanced ionisation of D-layer. The f min E values were thereafter much higher than usual and between 1245 and 1400 hrs. I.S.T. there was a sudden ionospheric disturbance (partial radio fade-out).

Assuming a value of about 2·3 Mcs/s. for f min E between 0800 and 0810 hrs. I.S.T on the eclipse day if there were no eclipse, it is seen that the decrease in the value of f min E at the time of maximum phase of eclipse was about 0 8 Mc/s. or about 35%. This is only a crude estimate of the decrease in the ionisation of the D-layer produced by the eclipse.

(b) At Hingurakgoda, Ceylon, ionospheric field—intensity measurements were made on the eclipse and surrounding days. The equipment consisted of a Hammarlund Communication Receiver Model SP-600-J the A.V.C. voltage from which was fed on to a D.C. amplifier and thence to a recording milliammeter. The receiver was tuned to broadcast signals at a frequency of 770 Kcs/s. radiated from the Trichinopoly Station of All India Radio. These transmissions during the morning hours were specially arranged by the A.I.R for the study of the strength of the received signals during the eclipse, An analysis of the field strength records made at Hingurakgoda indicates that on the eclipse day the signal strength at 770 Kcs/s. increased appreciably between about 0750 and 0830 hrs I.S.T. when compared with the corresponding values on the preceding and succeeding days. This increase in signal strength was apparently due to reduced absorption of the signal within the D-layer during the course of its transmission from Trichinopoly to the receiving end at Hingurakgoda *via* the E or sporadic E layer, the decreased D-layer absorption resulting from the low ion-density during the eclipse. The results of observations of D-layer by field strength measurement technique are consistent with those deduced indirectly from the vertical incidence observations of D layer at Kodaikanal.

Thus it is seen that the eclipse caused an appreciable decrease in the ion-density of all the three layers D, E and F1 indicating that the main source of ionisation in these layers is the ultraviolet radiation from the sun. It is also seen that the radiation is not distributed uniformly over the sun's disc A discrete source of intense radiation which affects the ionisation of the F1, E and D layers could be identified with the vicinity of an active sunspot group located on the southwest quadrant of the sun.

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3—2 D. D. G obs Kodaikanal/56.

SECTION III

A STUDY OF THE GEOMAGNETIC VARIATIONS DURING THE TOTAL SOLAR ECLIPSE OF 1955 JUNE 20

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ABSTRACT

Geomagnetic variations observed at Hingurakgoda, Ceylon, during the total Solar Eclipse of 1955 June 20 have been analysed for detection of possible effects in the horizontal and vertical components of the earth's magnetic field attributable to the eclipse. It has been found that in the horizontal component a decrease was registered during the eclipse, the departure commencing with the onset of the eclipse The maximum departure was found to be 18 gammas and its occurrence was simultaneous with the total phase of the eclipse This departure expressed as a fraction of the deviation between the normal value at eclipse time and the value obtainable a few hours before dawn works out to 0·29 which is very close to the value of 0·28 theoretically predicted by Prof S. Chapman.

In the case of the vertical component of the earth's field the eclipse-effect is not quite clear in the sense that Vertical Force registered a decrease until about the total phase and then increased far above the normally anticipated value. This increase continued till about the end of the eclipse after which it took up the usual diurnal course.

The geomagnetic observations here presented were made as part of the general eclipse programme of the Astrophysical Observatory, Kodaikanal. The observation site was at Hingurakgoda in Ceylon (latitude: 08° 03'N, longitude: 80° 59'E), a little over 5 miles to the north of the central line of totality. The location of the site and the eclipse track are shown in Figure 1.

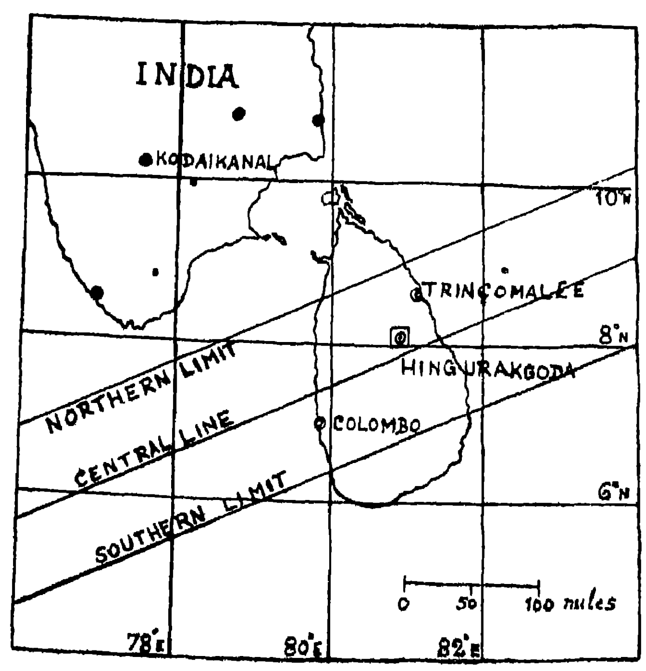

Fig. (1).—Map showing the observation site (marked by a circle inside a square) and eclipse track for the total solar eclipse of June 20th 1955.

Circumstances of the eclipse for Hingurakgoda were as follows :—

	H.	M	
Beginning of the eclipse	07	08	I S T.
Second contact	08	12	„
Third contact	08	17	„
End of the eclipse	09	32	„

All times referred to in the discussion are Indian Standard Time (also the Standard Time for Ceylon) which is 5 hrs. 30 mts. ahead of Greenwich Meridian Time.

The instrumental equipment for geomagnetic observations consisted of the following :—

1. Horizontal Force Variometer of the Eschenhagen type with a chart-speed of 15 mm. per hour.

2. Vertical Force Variometer of the Eschenhagen type with a chart-speed of 15mm. per hour.

3. 'Askania' Magnetic Field Balance for Horizontal Force employing a differential photocell and microammeter with chopper-type recorder and of chart-speed 20 mm. per hour

4. Quartz Horizontal Magnetometer (Q.H.M.) Nos 165, 166, 167.

5. Magnetometric Zero Balance (B.M.Z.) No 58.

The two Eschenhagen variometers were mounted in a tent and the 'Askania' Field Balance in a separate tent. The Q.H.M. and B.M Z. instruments were housed in a third tent not far away from the variometers. Care was taken to ensure that there was no interaction between the magnet-systems of the various instruments. The recording instruments were adjusted to give the following sensitivities :—

Eschenhagen H. F. instrument	3.05γ per mm.
Eschenhagen V F. instrument	1.7γ per mm.
'Askania' H. F. Balance	2 9γ per mm.

H. F. and V.F. magnetograms were available from the 11th to the 23rd June except for the loss of H.F. record on the 18th.

Observations for Variometer Calibration.

Q.H.M. and B.M.Z. observations were taken once a day from 11th to 16th and 21st to 23rd, and twice a day from 16th to 19th, one between 07 and 08 hours and the other between 15 and 16 hrs. On the eclipse day observations of H.F. and V.F. were made at 0630 (about 40 mts. before the first contact), at 1030 (about one hour after the last contact) and at 1530. These observations provided sufficient data for fixing the base-line values of H.F. and V.F. magnetograms every day independently. The scale co-efficients of the instruments were determined soon after they were set up and later checked on the 18th (2 days before the eclipse) and the 23rd (3 days after the eclipse) They were found to be quite consistent throughout the period.

Selection of Control Days.

The following were the magnetic characters of the days under study :—

June 11 : International Character Figure 0 3.

H. and V. records were smooth and almost free of any pulsations till 1100 hrs. after which they were slightly disturbed.

June 12 . International Character Figure 0·6

Slightly disturbed throughout the day. Diurnal drop of H much larger than usual.

June 13 : International Character Figure 0·5.

Records fairly smooth without any appreciable amount of pulsations. Diurnal drop still rather high.

June 14 : International character Figure 0·8.

A disturbed day. Records full of pulsations of large amplitude and duration till evening. A pronounced 'bay' disturbance between 2030 and 2200 hrs. Diurnal drop still rather large.

June 15 : International Character Figure 1·0.

A moderate disturbance in progress. Records very disturbed with pulses of short duration and fairly large amplitude. Diurnal drop still quite large.

June 16 : International Character Figure 0·9.

Disturbed conditions continue. Records full of short-duration pulses. Diurnal drop tends to become normal.

June 17 : International Character Figure 0·7.

Conditions returning to normal. Short-duration pulses distributed throughout day time and particularly prominent from 0900 to 1200 hrs. Diurnal drop practically normal.

June 18 : International Character Figure 0 4.

Conditions almost calm.

June 19 : International Character Figure 0·5.

Very slightly disturbed conditions. Between 0900 and 1030 hrs. there is a large isolated peak in the H.F. record.

June 20 : (*Eclipse day*). International Character Figure 0·3.

Calm conditions from dawn to 1030 hrs. Afterwards very slightly disturbed. After 0930 hrs. the average level of H.F. was far higher than on other comparatively quiet days. Diurnal drop normal.

June 21 : International Character Figure 0 1.

Almost calm. Diurnal drop normal.

June 22 . International Character Figure 0·5.

Fairly calm till 1610 hrs. At 1610 hrs. there is a 'sudden commencement' with an increase in H.F. by about 41γ in an interval of 2 minutes. The H.F. records of Kodaikanal Observatory (Latitude : 10° 14′ N, Longitude : 77° 28′E) also registered the S.C. at the same instant and of nearly the same amplitude.

June 23 : International Character Figure 0·9.

Disturbed conditions after the S.C. continue.

From the character of the magnetograms and from a scrutiny of the International Character Figures 11th, 13th and 21st were selected as control days for studying H.F. and 11th, 18th and 21st as control days for the study of V.F.

The mean values of H.F. and V.F. for 10-minute intervals were obtained from the magnetograms for the hours 0400 to 1400 hrs. for each day from 11th to 23rd. These are presented in Tables I and II respectively.

TABLE I

Values of Horizontal Force for 10-minute intervals.

40,000γ plus tabular quantities.

June 1955.

Date / Time interval (Indian Standard Time)	11	12	13	14	15	16	17	18	19	20	21	22	23
	γ	γ	γ	γ	γ	γ	γ		γ	γ	γ	γ	γ
0355–0405	241	267	246	265	253	243	265		245	250	243	245	245
0405–0415	241	270	247	265	254	244	265		245	249	243	246	244
0415–0425	242	269	247	264	255	245	265		245	247	244	246	245
0425–0435	243	271	246	266	255	244	266		246	246	245	245	246
0435–0445	244	270	244	268	256	243	267		245	245	245	244	245
0445–0455	244	266	243	271	258	244	266		245	244	244	245	244
0455–0505	245	268	242	271	258	243	265		245	244	245	244	243
0505–0515	244	268	244	273	259	241	266		244	243	245	245	246
0515–0525	246	267	247	274	261	246	266		245	245	247	245	251
0525–0535	248	268	250	275	263	250	266		247	246	249	244	250
0535–0545	250	268	252	279	267	250	264		249	249	252	248	249
0545–0555	255	269	252	284	268	250	270		254	253	255	255	263
0555–0605	260	276	258	290	276	254	276		258	255	256	257	261
0605–0615	262	278	260	291	281	256	277		264	257	258	263	260
0615–0625	263	279	262	292	285	264	275		267	257	259	266	258
0625–0635	265	284	266	295	290	270	278		270	261	261	270	259
0635–0645	268	285	268	295	295	276	284		273	266	264	272	258
0645–0655	270	287	270	296	298	278	286		276	266	263	274	258
0655–0705	269	285	274	296	304	279	286		277	270	263	277	256
0705–0715	270	286	274	298	306	276	286		275	270	267	282	258
0715–0725	271	282	273	301	300	271	288		280	267	268	282	258
0725–0735	272	280	272	296	298	267	293		282	266	270	288	256
0735–0745	270	276	274	296	298	266	293		281	262	271	293	256
0745–0755	270	278	275	296	291	260	291		283	260	272	295	260
0755–0805	274	277	274	301	281	261	296		285	261	274	299	262
0805–0815	276	273	276	304	279	263	299		285	259	278	302	267
0815–0825	278	274	275	304	290	271	296		279	263	281	305	267
0825–0835	280	275	275	304	296	278	289		279	268	282	307	267
0835–0845	282	274	278	302	300	284	288		283	275	286	309	261
0845–0855	282	273	278	304	298	288	291		285	284	288	312	264
0855–0905	284	277	274	306	289	286	292		285	286	286	314	270
0905–0915	286	280	272	308	280	289	294		282	289	285	317	276
0915–0925	289	278	275	309	276	293	288		295	295	283	318	277
0925–0935	289	286	277	314	278	298	301		302	298	280	319	275
0935–0945	290	304	279	319	281	303	308		290	300	276	317	290
0945–0955	292	297	276	325	290	316	312		322	302	274	319	286
0955–1005	291	293	279	327	299	305	316		309	305	276	321	268
1005–1015	291	277	268	323	301	298	319		299	308	278	326	290
1015–1025	289	275	266	316	302	301	323		291	310	282	331	296
1025–1035	292	271	265	309	296	309	327		284	304	285	327	296
1035–1045	290	270	268	308	299	301	332		281	307	290	324	295
1045–1055	291	272	269	299	299	293	338		281	314	293	325	293
1055–1105	289	271	268	307	295	286	334		273	314	295	325	289
1105–1115	289	266	270	293	307	291	338		268	311	295	323	290
1115–1125	292	263	268	274	295	295	334		267	312	294	322	294

TABLE I —*contd.*

Values of Horizontal Force for 10-minute intervals

40,000γ plus tabular quantities.

June 1955.

Date / Time interval (Indian Standard Time)	11	12	13	14	15	16	17	18	19	20	21	22	23
	γ	γ	γ	γ	γ	γ	γ		γ	γ	γ	γ	γ
1125–1135	288	261	258	.168	280	289	327		270	307	291	318	294
1135–1145	282	258	256	261	279	286	321		267	303	284	319	283
1145–1155	278	254	252	259	276	277	320		263	313	283	319	281
1155–1205	270	252	250	276	267	286	323		255	317	278	321	280
1205–1215	265	247	247	271	259	288	328		245	314	271	323	.
1215–1225	261	245	245	252	256	287	330		244	310	270	325	
1225–1235	257	246	244	246	255	273	335		247	309	273	325	.
1235–1245	253	245	243	253	252	265	338		244	304	274	324	
1245–1255	250	243	240	256	256	263	338		243	301	276	316	.
1255–1305	252	241	240	252	252	268	335		242	298	275	304	.
1305–1315	247	238	237	247	250	259	330		239	295	273	292	..
1315–1325	243	237	236	245	246	248	322		235	290	264	287	..
1325–1335	244	238	234	242	247	244	320		228	283	258	281	.
1335–1345	247	236	231	243	242	242	320		220	276	245	272	.
1345–1355	240	234	232	241	247	248	320		218	264	237	260	
1355–1405	231	234	232	240	246	256	315		213	253	233	255	.

TABLE II

Values of Vertical Force for 10-minute intervals.

June 1955.

1,800γ plus tabular quantities.

Date / Time interval (Indian Standard Time)	11	12	13	14	15	16	17	18	19	20	21	22	23
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
0355–0405	33	33	39	30	32	22	24	34	25	33	34	38	24
0405–0415	34	30	40	28	32	23	24	33	25	33	35	38	23
0415–0425	34	29	39	27	32	24	24	31	25	33	35	37	23
0425–0435	33	29	39	27	32	21	25	32	25	33	36	37	24
0435–0445	33	28	39	27	32	20	25	33	25	33	36	38	22
0445–0455	34	28	39	28	32	21	25	33	24	34	36	38	24
0455–0505	33	30	40	27	32	21	24	33	25	33	37	38	24
0505–0515	32	30	41	27	32	21	25	32	25	33	37	38	25
0515–0525	32	31	42	27	32	22	25	33	26	33	37	38	25
0525–0535	33	32	42	27	32	23	25	34	27	33	39	39	24

TABLE II—*contd.*

Values of Vertical Force for 10-minute intervals

1,800γ plus tabular quantities.

June 1955.

Date / Time interval (Indian Standard Time)	11	12	13	14	15	16	17	18	19	20	21	22	23
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
0535–0545	34	34	42	28	33	24	26	36	27	33	39	41	25
0545–0555	35	36	43	28	33	24	28	37	29	34	39	42	29
0555–0605	37	39	46	29	34	27	31	37	27	33	39	40	26
0605–0615	36	38	46	29	34	28	28	37	28	33	39	41	24
0615–0625	37	39	47	30	33	30	27	38	27	34	40	40	25
0625–0635	39	41	47	31	34	30	28	39	26	35	41	40	28
0635–0645	40	42	48	33	35	30	28	40	26	35	42	40	30
0645–0655	40	44	49	34	36	29	28	38	25	37	42	41	31
0655–0705	41	45	49	36	36	26	28	38	24	37	42	42	33
0705–0715	42	44	49	36	33	24	29	40	24	35	43	44	35
0715–0725	41	45	50	36	32	24	30	42	24	32	43	45	36
0725–0735	41	48	50	35	32	25	29	42	22	30	42	45	37
0735–0745	39	47	49	36	33	27	26	41	21	31	39	45	40
0745–0755	38	47	47	36	31	27	27	42	21	32	37	45	38
0755–0805	37	47	46	37	31	31	27	40	21	32	37	44	39
0805–0815	35	45	45	35	34	32	22	38	18	33	36	44	36
0815–0825	34	46	43	32	37	33	20	35	17	35	33	43	39
0825–0835	31	43	40	31	35	31	17	31	19	38	30	42	43
0835–0845	29	40	35	28	30	28	18	26	20	41	26	41	45
0845–0855	28	38	30	28	26	27	20	24	19	43	23	41	47
0855–0905	26	37	22	30	24	26	20	22	16	43	18	40	46
0905–0915	23	37	16	26	24	26	20	20	17	45	17	39	45
0915–0925	23	31	14	24	22	27	21	17	14	46	14	37	43
0925–0935	22	27	12	25	24	25	25	15	08	44	10	35	42
0935–0945	20	24	06	25	21	25	22	14	02	44	09	34	45
0945–0955	19	19	04	22	21	21	22	14	1790	42	07	33	41
0955–1005	17	16	05	16	18	13	21	16	1786	38	06	33	35
1005–1015	16	14	04	10	16	14	21	13	1786	36	04	33	35
1015–1025	15	18	06	05	14	14	23	05	1786	32	03	31	42
1025–1035	12	18	06	04	11	15		05	1787	30	02	29	37
1035–1045	08	20	07	04	10	08		06	1787	28	02	30	32

TABLE II—*contd.*

Values of Vertical Force for 10-minute intervals

1,800γ plus tabular quantities.

June 1955.

Date / Time interval (Indian Standard Time)	11	12	13	14	15	16	17	18	19	20	21	22	23
	γ	γ	γ	γ	γ	γ		γ	γ	γ	γ	γ	γ
1045–1055	05	21	09	02	09	25		08	1788	30	01	30	29
1055–1105	07	16	11	03	08	13		10	1789	27	02	30	27
1105–1115	07	15	13	04	14	11		11	1791	24	04	29	26
1115–1125	11	17	14	02	09	07		15	1794	25	06	28	25
1125–1135	13	20	16	02	08	11		18	1798	25	06	26	25
1135–1145	14	24	15	04	14	12		22	1800	23	08	27	21
1145–1155	16	23	16	07	12	13		25	03	28	10	29	20
1155–1205	18	25	17	10	08	16		29	07	29	12	28	16
1205–1215	21	28	16	01	11	19		32	11	30	13	29	16
1215–1225	23	28	16	00	13	21		34	14	31	14	31	12
1225–1235	25	27	18	09	13	23		36	18	34	16	29	12
1235–1245	26	27	20	12	12	25		38	22	36	18		
1245–1255	30	27	23	15	11	26		40	26	37	17		
1255–1305	31	29	25	12	12	31		42	27	38	20		
1305–1315	33	32	26	12	10	32		45	30	40	22		
1315–1325	35	35	31	16	08	34		48	34	42	26		
1325–1335	38	37	33	24	11	36		49	37	44	30		
1335–1345	39	38	38	33	16	38		50	43	45	33		
1345–1355	41	40	40	37	16	43		52	47	47	35		
1355–1405	43	44	42	48	26	46		56	47	48	40		

Variation of H.F.

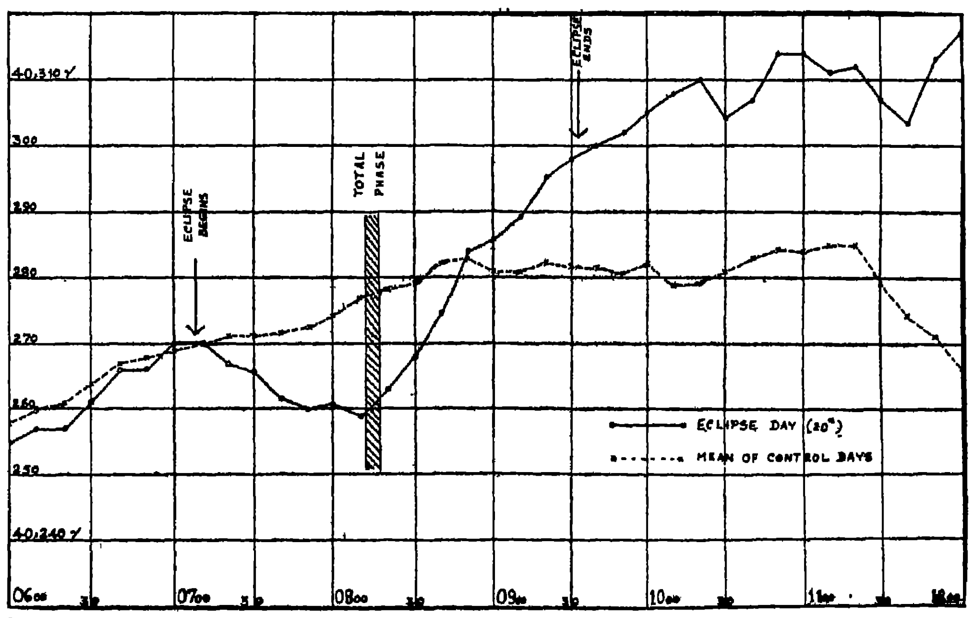

Fig. (2).—Variation of horizontal force.

X—axis—Hours in Indian Standard time. Y-axis—Absolute value of horizontal force in gammas.

With a view to identify qualitatively the eclipse-effect discussed by Chapman [1,2,3]. values of H F. at 10-minute intervals for the 20th June were plotted against time for the period 0600-1200 hrs. as also the mean of the corresponding values for the three control days 11th, 13th and 21st. This is given in Figure 2. Times of beginning and end of the eclipse are marked by arrows in the figure as also the period of totality by a block. The following qualitative observations can straight away be made from the diagram :—

1. Considering only the eclipse-day curve it is seen to change its normal course almost simultaneously with the commencement of the local eclipse
2. The departure appears to be a maximum at about the same time as the total phase of the eclipse.
3. The recovery to normal towards the end of the eclipse does not appear to be quite well defined.

Another significant feature observed, which may not be connected with any eclipse-effect is the higher value of H.F. on 20th (as compared with that of the control days) from about 0900 to the end of the day. This could probably be attributed to the increased conductivity of the ionosphere during the period caused by an enhancement of ultra-violet radiation from the sun as suggested by Allen[6]. It may be mentioned here that the ionic densities of the E, F1, F2 layers over Kodaikanal were also higher after 1000 hrs. on the 20th June than on the control days.

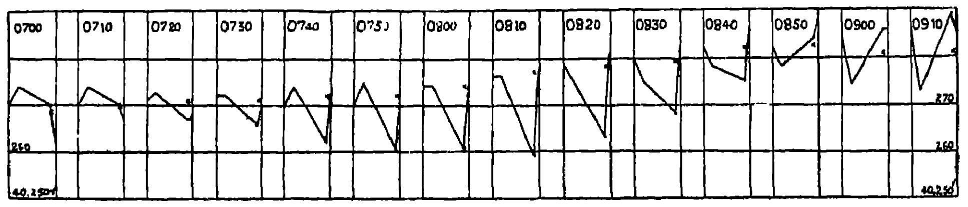

**Fig.(3).—Departure Diagram For H.F. Each Vertical block represents the synoptic situation of H.F. variation during the particular 10-minute interval indicated at the top. Eclipse day values of H.F. are marked by circles and the mean of control days by cross. All times are in Indian Standard Time.
Vertical axis — Absolute values of H.F. in gammas.**

To get a quantitative idea of the effect the 10-minute values of H.F. for the 20th and the corresponding values for the three control days 11th, 13th and 21st are plotted for each individual 10-minute interval from 0700-0910 hrs. (Fig. 3). Here each block gives the synoptic situation of variation during the particular 10-minute interval. In each block the eclipse-day value is marked by a circle and those of the three control days by three successive points from left to right. The mean of the three control values is indicated by a cross.

The following features will be noted from the diagram :—

1. On the eclipse day the value of H.F. centred at 0710 hrs. coincides with the mean of the control values.
2. By 0720 hrs. it has decreased to 4γ below the mean value. The value at 0810 hrs. gives the maximum departure from the average, namely 18γ. The departure gradually decreases and becomes positive at 0850 hrs. with a value of + 1·5γ.
3. After this the eclipse-day values of H.F. rise rapidly above the average of control days.

These departures are given in Table III below :—

TABLE III

Time (Indian Standard Time)	Departure of H F. from mean of control days
0700	+ 1·5γ
0710	0·0γ
0720	− 4·0γ
0730	− 5·0γ
0740	−10·0γ
0750	−12·0γ
0800	−13·0γ
0810	−18·0γ
0820	−15·0γ
0830	−11·0γ
0840	− 7·0γ
0850	+ 1·5γ
0900	+ 5·0γ

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According to Chapman's[1] theory during the eclipse H.F. can be expected to deviate towards the value obtainable a few hours before the dawn by about one-third the way. This fractional departure computed theoretically by Prof. Chapman comes to 0·22 to 0·28, depending upon the height at which the S-current flow is assumed. The night-time value chosen in this investigation was the one centred at 0100 hrs. and is equal to 40,215γ. The departure of the mean control value at 0810 hrs. (which is close to the maximum phase of the eclipse) from the night-time value works to 62γ. Using this value the fractional departure during the maximum phase of the eclipse is found to be 0·29, very close to the theoretically predicted value of 0·28. Chapman[3] had, in his original discussion on this subject, expressed the view that a fractional departure of H.F. by an amount of 0·28 could be expected on the assumption that the Solar Daily Magnetic Variation (S) has its origin in the E-layer. He has also indicated[3], from eclipse observations available at the time, that in all probability the seat of (S) may be in the F-region which would of course give only very small deviations in H. F. attributable to the eclipse. From the fractional deviation of 0·29 obtained in the present analysis it would seem likely that the region responsible for the Solar Daily Variation (S) may be the E-layer.

According to Chapman[3] the magnitude of eclipse-effect will be greater as one goes deeper into the eclipse track. Also the eclipse reduction can be expected to be greatest at the centre of the eclipsed area of the ionized layer[3]. Our observing site was practically on the central line of totality—just over 5 miles to the north (*see* Fig. 1). Considering the angular disposition of the shadow cone as it touches the ground our location appears to have a greater chance of being more or less vertically below the centre of the shadow area cast in the E-layer than, say, a point much farther to the north or south of the central line but still within the belt of totality. Also the theoretical value of 0·28 for fractional deviation obtained by Chapman[3] was based on the assumption that the observing location is not too near the S-current foci. From an examination of Bartels' diagram for June our observational site is seen to be quite remote from the two-S-current foci. These facts would probably explain the rather high value of fractional departure (0·29) obtained in the present investigation.

Phase of Diurnal Variation.

T. Nagata, Yokoyama and Fukushima[4] have observed for the eclipse of 1950 September 12, that the diurnal variation on the eclipse day was leading on the mean diurnal curve of the control days by about 30 minutes. The present investigation does not seem to reveal any phase difference.

Variation of V.F.

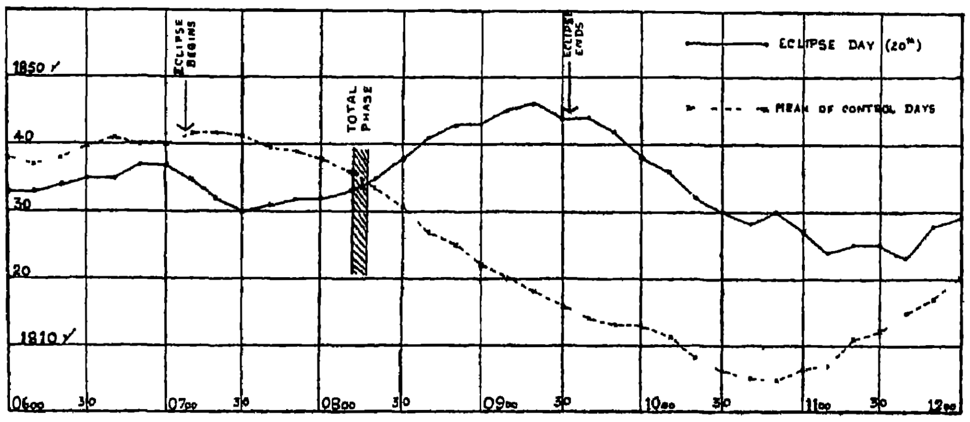

Fig. (4).—Variation of vertical Force.
X—axis Indian Standard Time in hours.
Y—axis Absolute value of Vertical Force in gammas.

As in the case of H.F. the 10-minute mean values of V.F. for June 20 were plotted for the period 0600 to 1200 hrs. together with the corresponding mean values of the control days (Fig. 4).

The following quantitative observations can be made from the diagram :—

1. The eclipse day values are in general lower than the control day mean values even from 0600 hrs.—well in advance of the optical eclipse.
2. At about the commencement of the eclipse the value of V.F. begins to depart from the mean curve.
3. At about the total phase V.F. actually reverses its trend and begins to increase and continues to remain higher.
4. This increase of V.F. continues till about 0930 hrs. after which the value begins to fall and takes up the normal diurnal trend, though the average level of the force is still higher than the mean of the control days.

Departures of the eclipse-day curve from the mean curve of control days for every 10-minute interval from 0700 to 0900 hrs. are given in Table IV. Even at the commencement of the eclipse the eclipse-day curve indicated a value of V.F. about 6γ below the mean control day value. Values centred at 0730 hrs. give the highest departure of 12γ. At 0810 hrs. which is just over a minute before totality the departure is 3γ, and by 0820 hrs. the eclipse-day curve goes above the mean curve by about 1·5γ. Thereafter the trend is a rapid increase in the positive direction.

The mechanism behind this behaviour is not quite clear. The V F. curves obtained by Hirano and Obayashi[5] for the eclipse of 1950 September 12 show the eclipse curve continuously above the control day curve with the largest departures during approximately the eclipse period.

Chapman's theory[3] would require that in the centre of the eclipsed area in the ionized layer where the deviation of H.F. is largest the vertical component will be practically normal.

TABLE IV

Time (Indian Standard Time)	Departure of V. F. from mean of control days.
0700	− 3·0γ
0710	− 7·0γ
0720	−10·0γ
0730	−12·0γ
0740	− 8·5γ
0750	− 7·0γ
0800	− 6·0γ
0810	− 3·0γ
0820	+ 1·5γ
0830	+ 7·0γ
0840	+14·0γ
0850	+18·0γ
0900	+21·0γ

In the present case the pattern of V.F. variation is quite different from the normal as can be seen from Fig. 4. The force appears to undergo a sine wave oscillation, the period from first contact to totality corresponding roughly to the trough of the wave and the period from totality to last contact corresponding roughly to the crest. After this the eclipse-day curve takes up the usual diurnal pattern, though of course still occupying a fairly higher average level with respect to the mean curve. The pattern of variation described above need not necessarily constitute a contradiction of Chapman's theory; the observed variation in V.F. may well be totally unconnected with the eclipse. At the same time it may be observed in passing that H.F. does not exhibit this behaviour to any noticeable extent.

Another significant feature noted is that the diurnal variation of V.F. on the eclipse day is considerably less than normal. It is felt that except for the above qualitative general picture of the behaviour of V.F. during the eclipse, no quantitative analysis can be made with any reasonable degree of certainty.

In conclusion, the author wishes to express his gratitude to Dr. A. K. Das, Deputy Director-General of Observatories, leader of the expedition for all the facilities given during the expedition and guidance on various technical matters connected with the observations and to Mr. B. N. Bhargava, Meteorologist-in-Charge, Magnetic and Ionospheric Section, Kodaikanal Observatory, for guiding him through this work.

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