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SOME GEOMAGNETIC DISTURBANCES AT ALIBAG OBSERVATORY (INDIA) & ALLIED RADIO AND SOLAR EFFECTS (1937-1946).

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ABSTRACT. The paper presents an account of some magnetic disturbances associated with solar flares and radio fade out during the period 1937—1946. The ionospheric irregularities associated with four great magnetic storms recorded at the Magnetic Observatory, Alibag (Bombay) are discussed. On some occasions an intense solar flare is followed about a day later by a great magnetic storm. This occurs far more often than by chance. The presence of a "Crochet" in the magnetic records occuring simultaneously with a radio fade out and the appearance of a solar eruption of flare has been interpreted as showing that radiation from the flare travelling with the speed of light causes the "Crochet", while the magnetic storm which appears between 18 and 30 hours later is attributed to corpuscular radiation travelling at a speed of 1,000 to 2,000 miles/sec.

A list of sudden ionospheric disturbances of the Dellinger type from observations made in India during the period 1937—1946 has been collected and the principal features of the observations discussed.

1. *Introduction.*

Data on intense solar flares from spectroscopic records followed by brilliant aurorae and wide-spread magnetic storms between 1892 and 1930 were discussed by Hale.[1] Since then the data of nearly one 11 year cycle of observations of solar flares have been co-ordinated and a statistical discussion of all the available data on intense flares upto 28th February 1942 has been made by H. W. Newton. Newton has concluded that, far more often than could occur by chance, an intense flare is followed about a day later by a great magnetic storm, provided that the flare is not farther than about 45° from the centre of the disk.[2]

The general synchronization of flare, radio-fade-out and geomagnetic "Crochet" (ultra-violet solar radiation effect) has also been studied over 11 years.[3] For a complete geomagnetic study of "Crochets" and magnetic storms, data are required from a number of widely separate stations. The purpose of the present paper is to give all available data from 1937 to 1946 from observations made in India and to make a correlated study of terrestrial magnetic, solar and radio disturbances from the data collected from the Colaba and Alibag Observatories, the Solar Physics Observatory, Kodaikanal and the All India Radio (A.I.R.), Delhi. The results are in general agreement with Newton's conclusions.

Out of a number of storms which occurred during the period 1937—1946 four typical magnetic storms are considered in detail, viz. the severe magnetic storm of 24th March, 1940, the magnetic storm of 1st March, 1941, the magnetic storm of 18th September, 1941 and the magnetic storm of 1st March, 1942. Each of the above storms show certain irregularities regarding the passage of the sun spot over the central meridian and certain ionospheric irregularities. In the case of the storm of the 24th March, 1940, *a spot group crossed the central meridian two days after the commencement of the magnetic storm. The big group of sun spots* which is possibly associated with the causation of the magnetic storm of 18th to 19th

September, 1941, *had crossed the central meridian one day before the actual commencement of the storm on 18th September, 1941. The great magnetic storm of 1st March, 1941 was not associated with bright chromospheric eruptions or great sun spot activity.*

The results are given below.

2. Magnetic storm of 24th March, 1940.

Magnetic Data. A very severe storm commenced at 13 hours 50 min. G. M. T. on 24th March with a sudden rise of 1.3 minutes in westerly D and 62 gammas in H and a fall of 10 gammas in Z at Bombay. The most disturbed period during the storm was between 1545 hrs. and 1903 hrs. G. M. T. March 24th, when telegraphic transmission throughout the world was disturbed. The storm ended at about 1805 hrs. on 25th March.

Solar Data. On 24th March, i.e. on the day of the commencement of the severe magnetic storm, a large sun-spot group was lying about 20° east of the central meridian. It was a fairly large group covering an area of 1450 millionths of the sun's visible hemisphere. On the 23rd March, a bright chromospheric eruption was observed at Kodaikanal with its maximum brightness at 0802 hrs. I. S. T. having an intensity " one " according to area. Eruptions were photographed on 24th and 25th March also. This was a large bi-polar group of spots at lat. 12°N. *which crossed the central meridian* of the sun on the 26th March, 1940.

Radio Data. On 23rd March, 1940, the Research Engineer, A. I. R., reported complete radio fade out between 1130 hrs. and 1245 hrs. G. M. T. On 24th March 1940 at 0645 hrs. G. M. T. a partial fade-out was observed and the lower frequencies were affected more. At 2000 hrs. all stations were found to be suffering from flutter fading.

At Watheroo and Huancayo magnetic observatories where an almost continuous radio watch is maintained, seven radio-fade-outs preceding and during the magnetic storm were recorded.[4] Of these, three were observed to coincide with bright solar chromospheric eruptions. The fade-out which occurred near about 1145 hrs. G. M. T. on 23rd March and agreed with the time of fade-out given by A. I. R. in India was the most intense. The bright eruption producing this effect preceded the beginning of the major magnetic activity by about 28 hours.

Ionospheric Effects. Radio reception in India was not markedly affected during the most intense period of the very severe magnetic storm of 24th March, 1950.[5]

At Huancayo, the ionospheric disturbance began about 40 minutes before the first really large magnetic change. During the first great magnetic changes, the F2 layer swept upward and disappeared in about 30 minutes. At the same time, the ion density of the E layer rose by about 40 per cent.

At Watheroo Magnetic Observatory, ionospheric changes followed the general pattern usually experienced during magnetic disturbances in temperate zones.[4]

3. Magnetic Storm of 1st March, 1941.

Magnetic Data. A severe storm commenced at 0358 hrs. G. M. T. on 1st March with a sudden rise of 1·4′ in westerly D and 42 gammas in H and a fall of 15 gammas in Z. At 1339 hrs. the H trace went off the photogram for about 96 minutes. The storm practically ended at 2305 hrs. March 1st. Ranges D 16′ H 785 gammas, Z 130 gammas.

Solar Data. No chromospheric eruption appears to have been recorded at Kodaikanal on 1st March, 1941 or on the preceding day. Detailed knowledge of chromospheric activity shortly preceding the above storm from other stations is not available, but there was a fairly large sun-spot not far from the central meridian. Mount Wilson Observatory had recorded a complex sun-spot group which crossed the central meridian on February 27 in Lat. 16°.[6]

Radio Data. On 1st March 1941, partial radio-fade-out was observed by A. I. R. at 1400 hrs. G. M. T. At 1430 hrs. G. M. T. conditions improved and again at 1448 hrs. G. M. T. partial fade-out appeared. At 1450 hrs. G. M. T. reception conditions improved.

Ionospheric effects. There was close correspondence (as observed at Delhi and other A. I. R. stations) between the most intense period of the magnetic storm and the period of greatest disturbance of the ionosphere as far as observations from Indian stations indicate.[7]

4. Magnetic Storm of 17th to 19th September, 1941.

Magnetic Data. A rather severe storm began at 0114 hrs. G. M. T., September 18, with a sudden rise of 26 gammas in H, a westerly movement of 1′·3 in D and a fall of 9 gammas in Z. H attained its maximum value at 0522 hrs. and the minimum was reached at 1750 hrs. The storm practically ended at 11 hours 5 minutes on September 19. Ranges D, 12′·0, H greater than 650 gammas, Z 87 gammas.

Solar Data. On 17th September, 1941, Kodaikanal reports a big spot-group situated at 12° N crossing central meridian on the same day. Chromospheric eruptions are recorded on 17th, 18th and 19th September, 1941.

Radio Data. (*a*) On 17th September, 1941, sudden fade-out was observed between 0830 hrs. G. M. T. and 0855 hrs. G. M. T. After 0855 hrs. G. M. T., the high frequency European stations came up, but there was no trace of Indian short-wave stations till 0915 hrs. G. M. T.

(*b*) On 18th September, 1941, sudden fade-out of a partial Dellinger type was noted between 0220 hrs. G. M. T. and 0249 hrs. G. M. T. There was no trace of Indian stations during that time. Between 1430 hrs. and 1500 hrs. G. M. T., a partial fade-out of doubtful nature was observed.

(*c*) On 19th September, 1941, practically the whole day and night and up to 0430 hrs. G. M. T. on the morning of the 20th September, 1941 there was the magnetic storm effect.

Ionospheric Conditions. The magnetic storm, as shown by the Alibag magnetograms had its maximum intensity on September 18th between 0550 hrs. G. M. T. and 1452 hrs. G. M T., whereas ionospheric conditions were seriously disturbed during the whole of 19th September up to 1730 hrs. G. M. T. There appears to be no coincidence between the most intense period of greatest disturbance of the ionospheric and the most intense period of magnetic storm.

5. Magnetic Storm of 1st March, 1942.

Magnetic Data. A storm of great intensity commenced suddenly at 0726 hrs. G. M. T. on 1st March. H magnet was unsteady with rapid fluctuations till 0905 hrs. on 1st March, after which the oscillations became less intense. H attained the maximum value at 0729 hrs. on 1st March and the minimum at about 1414 hrs. on 1st March. The disturbance practically ended at about 0300 hrs. on 2nd March, though minor fluctuations continued thereafter for a few hours. Ranges D, 12′0; H, 2?7 gammas; Z, 70 gammas.

Solar Data. A big spot group was seen showing slight activity between 28th February, 1942 and 1st March, 1942.

Radio Data. No radio fade-outs were recorded by the A. I. R. during the storm of 1st March, 1942. But on 28th February, 1942 there was a complete fade-out of all stations between 1200 hrs. and 1245 hrs. G. M. T. Even medium wave stations became poor.

6. Time travel of solar corpuscles.

The storm taken here for study provides data for determining the time of travel of the solar stream of particles from the sun to the earth assuming that the ejection of the stream occurs at or near the time of peak intensity of the bright eruption which is also closely indicated by the beginning of the radio fade-out and the small crochet movement of the magnetic traces. The characteristic solar phenomena associated with these storms suggest that they are of the "Nascent" type of Bartels classification of magnetic storms.

For "Nascent" storms, the travel time according to Bartels is $T=t_e - t_s$ where t_s is the time of eruption and t_e the time of the out-break of the magnetic storm.[9]

A list of intense solar flares with radio fade-out and sudden pulses in Alibag (Bombay) magnetic traces as counterpart and the associated magnetic storm the next day for the period 1937 to 1946 is given in Table I. The mean of these time intervals 21 hours 41 minutes is some hours shorter than the value of 1·0 to 1·5 days derived from available records of earlier bright eruptions from 1892 to 1938. The statistical time interval given by H. W. Newton is $2{\cdot}^{h}\ 5^{m} \pm 2^{h}\ 1$.[2]

Accumulating evidence points to the brilliant chromospheric eruptions (with these radio-fade-outs as counter part) as being a vital factor for occurrence of intense magnetic storms.

The prediction of a great magnetic storm is made by considering the following phenomena :—

(1) Proximity in time to one of the two maxima in the annual frequency of storms near the equinoxes.

(2) The appearance of a great spot near the central meridian.

(3) An associated brilliant chromospheric eruption with radio fade-out as counter part.

Sudden Ionospheric disturbances of the Dellinger type.

During the period in question, the A. I. R. had reported about 99 cases of radio-fade-outs and bad reception of which 18 cases are distinctly of the Dellinger type which are accompanied by distinct magnetic pulses in horizontal intensity, vertical force, and declination records of the Alibag Magnetic Observatory.

7. Discussion of results.

A few reproductions of the Alibag Magnetic Observatory magnetograms are given in figures 1, 3, 4 and 5.

Small abrupt pulses are seen in horizontal intensity, vertical force and declination records of the Alibag Magnetic Observatory at the time of radio-fade-outs of the Dellinger type. The magnetic effects accompanying radio-fade-outs are strikingly different from the perturbations occurring in so called magnetic storms. A magnetic storm lasts many hours or sometimes even more than a day in contrast to the brief period of the disturbance here studied; the magnetic storm is simultaneous over the whole earth but these sudden ionospheric effects occur only on the sun-illuminated side of the earth.

For example, Cables and Wireless Ltd., had reported[11] ionospheric eruptions giving rise to wireless fade-out as follows :—

1941. February 27—1545 hrs. to 1610 hrs. (G. M. T.)
February 28—1527 hrs. to 1540 hrs. (G. M. T.)

No fade-out corresponding to the above two times were noticed by the A. I. R. in India. The Alibag magnetograms also do not show any sudden disturbance characteristic of radio fade-out at the times of fade-outs given by Cables and Wireless Ltd.

On 6th February, 1946, brilliant solar flares of intensity[3] were photographed throughout the great sun spot group from 1628 hrs. to 1838 hrs. G. M. T. at Mount Wilson Observatory[12]. Reports of fade-outs from Cables and Wireless Ltd., indicate with a high degree of probability that two intense solar flares occurred on 6th February, 1946[8]. The G. M. T. of these fade-outs 03 hours 30 minutes, 06 hours 20 minutes, 16 hours 15 minutes to 18 hours 30 minutes show the coincidence of the third radio fade-out with the intense flare seen at Mount Wilson[13]. No fade-out is reported in India by A. I. R. at the time of the solar flare seen at Mount Wilson nor any sudden pulses seen at the Alibag magnetograms (Fig. 6).

Again on 25th July, 1946 brilliant solar flares were seen at 1600 hrs. G. M. T. both at Sherborne and at Solar Physics Observatory, Cambridge. Concurrent with this great flare, there was a radio fade-out on short wave transmission beginning at 1610 hrs. G. M. T[14]. No fade-out is reported in India at that time nor any perturbations seen in the Alibag magnetograms.

But on February 28, 1941 at "0930 hrs. to 1030 hrs. G. M. T." the time given by Cable and Wireless Ltd. of another fade-out[11], the Alibag magnetograms show sudden pulses in H, V and D traces quite characteristic of radio fade-out (Fig. 2). The A. I. R. however did not notice any fade-out on that day.

The above facts clearly show that the sudden ionospheric disturbances occur only on the sunlit side of the Earth.

On 28th February, 1942 at the time of fade-out in India, Alibag magnetograms showed a slight decrease in H with corresponding increase in V and decrease in D westerly. This is rather unusual for this latitude (Figs. 7 and 8) but the time of the occurrence was near 17 hrs. local time and a feeble corpuscular disturbance was also on (Figs. 7 and 8). The magnetic effect on D is more than that on H. On the same date at 1200 hrs. G. M. T. a sudden fade-out occurred and continued on some circuits according to Cable and Wireless Ltd, until 2000 hours—an abnormal duration for a fade-out of this type. The Abinger magnetograms show a sudden movement, especially marked in horizontal force beginning at 1201 hrs. G. M. T. with partial recovery in the case of H and V about an hour later. The extent of the twitch or crochet in H was -70 gammas and that in V -20 gammas. In D there was a small crochet of range 4' westwards beginning at 1159 hrs. G. M. T.[15]. Solar noise was detected for the first time from February 26 to 28.

On 4th February, 1946 the Alibag magnetograms (Fig. 5) showed distinct crochets in all the traces between 0600 and 0630 hrs. G M.T. agreeing in time with the A.I.R. fade-out. The Watheroo Magnetic Observatory (Latitude 30° 19'·1 S Longitude 115° 52'·6E) also reports 16 sudden pulses in all the three elements, a decided effect on the earth current recorder, and departures of gradient of earth potential from their normal values at about 0600 hrs. G.M.T. concomitant with a brief but an intense fade-out. No magnetic storm occurred the next day.

The simultaneity of the solar effect with the other effects is not usually as exact as the simultaneity of the other two effects. This is in part because of considerable uncertainty as to the times of many of the solar eruptions; they are sometimes seen with difficulty and the observer cannot be sure when the disturbance begins or ends; reports of times of occurrence of given eruptions as observed at different observatories sometimes give considerable difference.

On 23rd March, 1942 A. I. R. reports a partial radio-fade-out at 0240 hrs. G. M. T. Kodaikanal on the same day reports a chromospheric eruption of intensity 2 according to area having its maximum intensity at 0245 hrs. and ending at 0315 hrs. G. M. T. But no marked concomitant disturbance is noticed in the Alibag magnetograms.

On 28th February, 1941 before the big storm of 1st March, 1941, no radio-fade-outs or chromospheric eruptions are reported in India. But the Alibag magnetograms show a slight increase in H with corresponding decrease in V and increase in westerly D between 0930 hrs. and 1030 hrs. G. M. T. Cables and Wireless Ltd. however reports an intense fade-out on 28th February, 1941 between 0930 hrs. and 1030 hrs. G. M. T. (Fig. 2).

An explanation of these facts is desirable. The occurrence of fade-outs accompanied by no reported solar eruption is due in part to the absence of solar observations at the time of occurrence. As Mcnish has pointed out, the most intense and the largest eruptions produce both fade-outs and magnetic effects, smaller and less intense eruptions cause only fade-outs while the least intense but more numerous eruptions produce no noticeable effects on the earth.

8. Conclusions.

1. Individual magnetic storms differ considerably in their detailed morphology. The magnetic storm of 24th March, 1940, the storm of 1st March, 1941, of 18th September, 1941 and of 1st March, 1942 all had different characteristics.

2. There are however common features in magnetic storms. Many storms for instance start from quiet conditions with a sudden jerk, simultaneous within a minute of time all over the earth.

3. Storms do not prefer a definite time of day but may occur at any hour (See the times of commencement of the storms taken for study).

4. A great magnetic storm can be predicted by considering the combination of the following phenomena :—

(*a*) proximity in time to one of the two peaks in the annual frequency of storms at about the equinoxes,

(*b*) the occurrence of a great spot group near the central meridian with associated brilliant chromospheric eruption and radio fade-out as counterpart.

The time of travel of the solar streams of corpuscles from the sun to the earth is given by the difference in time between the commencement of the bright eruption and the beginning of the associated magnetic storm.

5. Magnetic changes occurring at a large number of stations simultaneously with bright chromospheric eruptions reveal that the magnetic effect is an augmentation of the normal diurnal variation. This is presumably due to increased atmospheric ionisation by ultra-violet rays from the eruption.

6. The cause of "magnetic storm disturbances" is different, being due to solar corpuscles.

7. Studies of the ionosphere by means of wireless waves support the view that the Sun, sends us ionising radiation to be classed as wave radiation and particles. The wave radiation ionises the day side of the ionosphere and is geomagnetically effective in producing the solar and lunar daily variation. The corpuscular radiation mainly reaches the earth's night side and produces auroral and magnetic disturbances.

9. *Acknowledgments.*

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TABLE

Intense Solar Flares with radio-fade-out and sudden pulses in magnetic traces

	Solar Flare.					Radio Fade-out.	
Ref. No.	Date	Time.	Mean. Lat.	Mean. Long.	Intensity.	Date.	Time.
		G. M. T.					G. M. T.
1	27-1-37	02h. 23m (Kodai)	+19°	+13°W	Moderate	26-1-37	0800—0820
2	15-4-38	02h 45m. (Kodai) 08h. 30m. (Greenwich).	+26° +27°	+85°E +12°W	Slight Great }	15-4-38	0830
3	23-3-40	02h. 32m. (Kodai) 11h. 45m. (Huancayo).	.. ..	.. ..	Slight Great }	23-3-40	1130—1245 A. I. R.
4	28-2-41	No eruptions recorded at Kodai.	..	..	..	28-2-41	No fade-out reported by A. I. R. Cable and Wireless Ltd. reports fade-out between 0930 and 1030 G. M. T.
5	17-9-41	03h. 06m. (Kodai) 08h. 30m. (Greenwich).	+10° 11°N	4°W 9°W	Great Great }	17-9-41	0830—0855 A. I. R.
6	28-2-42	02h. 35m. (Kodai) 12h. 42m. (Sherborne).	+5° 7°N	10°E 3°E	Moderate Great }	28-2-42	1200—1245 A. I. R.
	6-2-46	16h. 28m. (Mt. Wilson).	..	..	Great	6-2-46	1615—1830 (Cable and Wireless) 0630—0730 A. I. R.
8	25-7-46	16h. 21m. to 18h. 30m. (Mt. Wilson).	..	..	Great	25-7-16	0315—0500 A. I. R. 1610—1930 (Sherborne).

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as counter part and the associated Magnetic Storms the next day (1937—1946).

Magnetic crochets or sudden pulses.					Magnetic storms within ± two days.					
		Ranges.					Magnitude (ranges).			
Date.	Time.	H. F. γ	V. F. γ	D. ′	Date.	Magnetic storm (time).	H. F. γ	V. F. γ	D. ′	Time interval.
	G. M. T.					G. M. T.				
26-1-37	0758—0850	25	—2·4	—0·87W	27-1-37	0839	125	42 (Moderate).	3·7W	24h. 39m.
15-4-38	0830	+37·9	—11·2	—2 6W	16-4-38	0548	532	.. (Great).	133W	21h. 18m.
23-3-40	1130	No crochets in Alibag magnetograms.			24-3-40	1350	785	100 (Great).	17·1	26h. 05m.
28-2-41	0930	+13·17	—3·73	—0·93W	1-3-41	0358	785	130 (Great).	16·0	18h 28m.
9-41	0830	+24·31	—15·27	—3·39W	18-9-41	0414	650	87 (Great).	12·0W	19h. 44m.
28-2-42	1200	—10·68	+6·29	0·93W decreases	1-3-42	0726	227	70 (Great).	12·0	19h. 26m.
6-2-46	No crochet in Alibag magnetograms				7-2-46	1018	241	57 (Great).	10 7	17h. 50m.
25-7-46	No crochet in Alibag magnetograms				26-7-46	1845	499	103	12·5	26h. 00m.

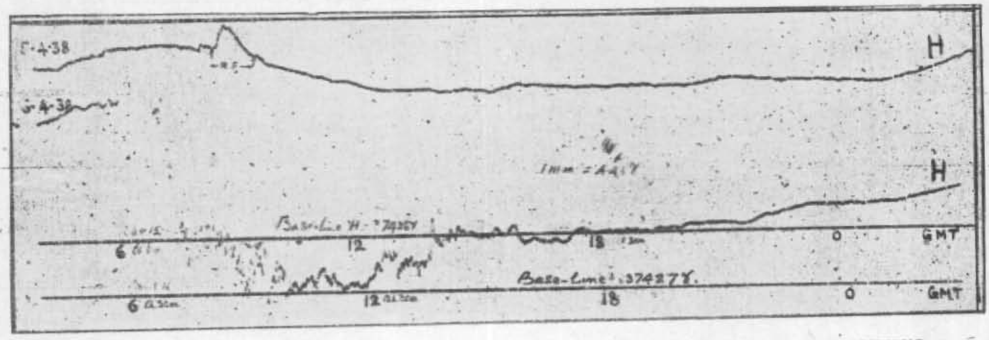

Fig. 1.

Alibag (Bombay) Magnetogram of Horizontal Force showing the sudden commencement of the great magnetic storm of 16-4-38 at 0548 hrs. G.M.T. following the outbreak of a brilliant solar eruption the previous day at 0830 hrs. G.M.T. at Greenwich, agreeing in time with a distinct "Crochet" in the H trace giving the approximate time travel of solar corpuscles as 21 h. 18 m.

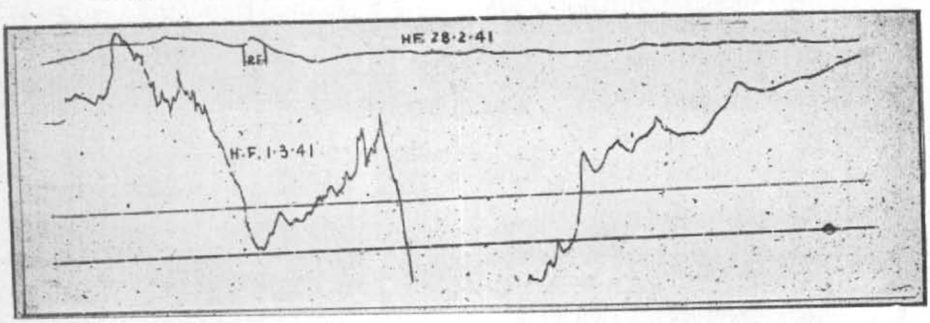

Fig. 2.

Alibag (Bombay) Magnetogram of Horizontal Force showing the sudden commencement of the great magnetic storm of 1-3-41 at 0358 hrs. G.M.T. following the radio fade-out the preceding day at 0930 hrs. recorded by Cable and Wireless Ltd., coincident in time with the perturbations in the Alibag H trace giving the approximate time travel of solar corpuscles as 18 h. 28 m.

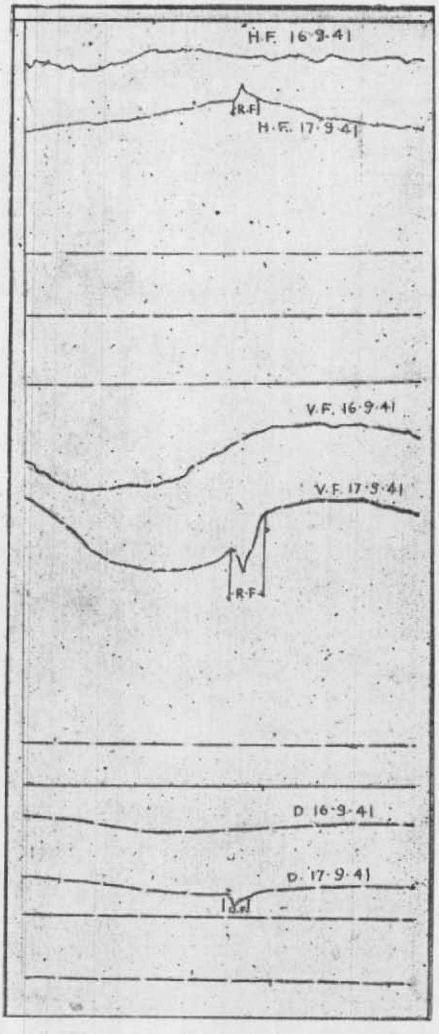

Fig. 3.

Alibag (Bombay) Magnetograms showing sudden pulses in all the elements on 17-9-41 preceding the great storm of 18-9-41 coincident in time of the brilliant solar eruption recorded at the Greenwich Observatory at 0830 hrs.

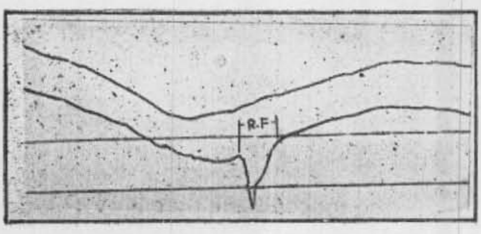

Fig. 4.

Alibag (Bombay) Magnetogram of 17-9-41 showing Declination Crochet by the rapid running La Cour Instrument.

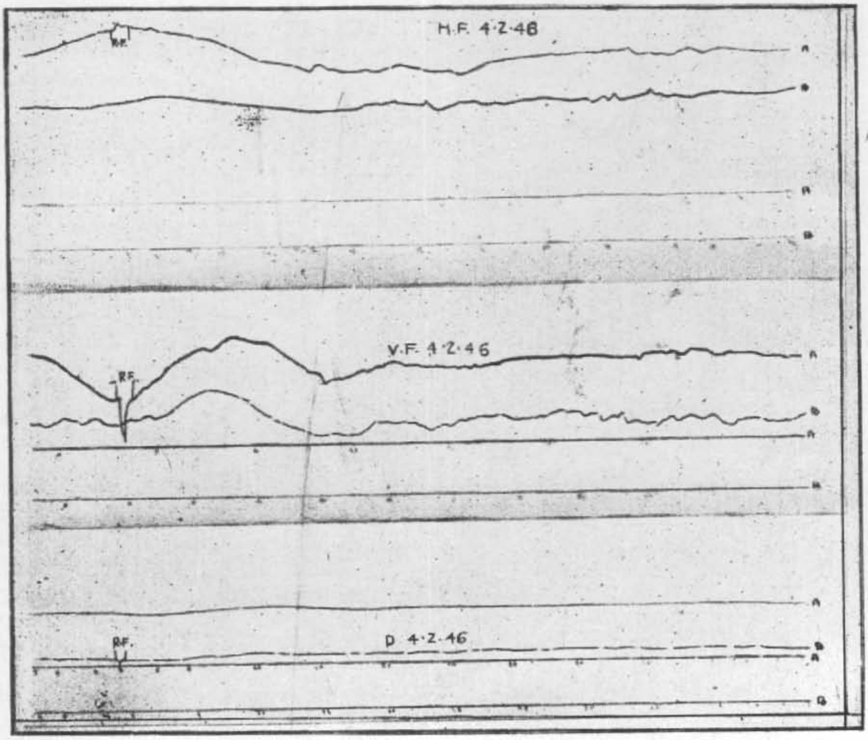

Fig. 5.

Alibag (Bombay) Magnetograms of 4-2-46 showing distinct Crochet in all the elements between 0600 to 0730 hrs. G.M.T. coincident in time with the A.I.R. radio fade-out. No magnetic storm occurred the next day.

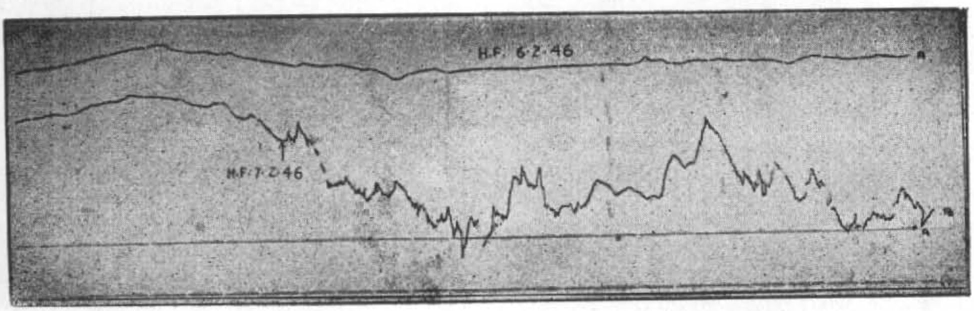

Fig. 6.

Alibag (Bombay) Magnetogram of Horizontal Force showing the sudden commencement of the great magnetic storm of 7-2-46 at 1018 hrs. G.M.T. following the outbreak of a brilliant solar eruption the previous day from 1628 to 1838 hrs. G.M.T. at Mount Wilson Observatory giving the approximate time travel of solar corpuscles as 17 h. 50 m.

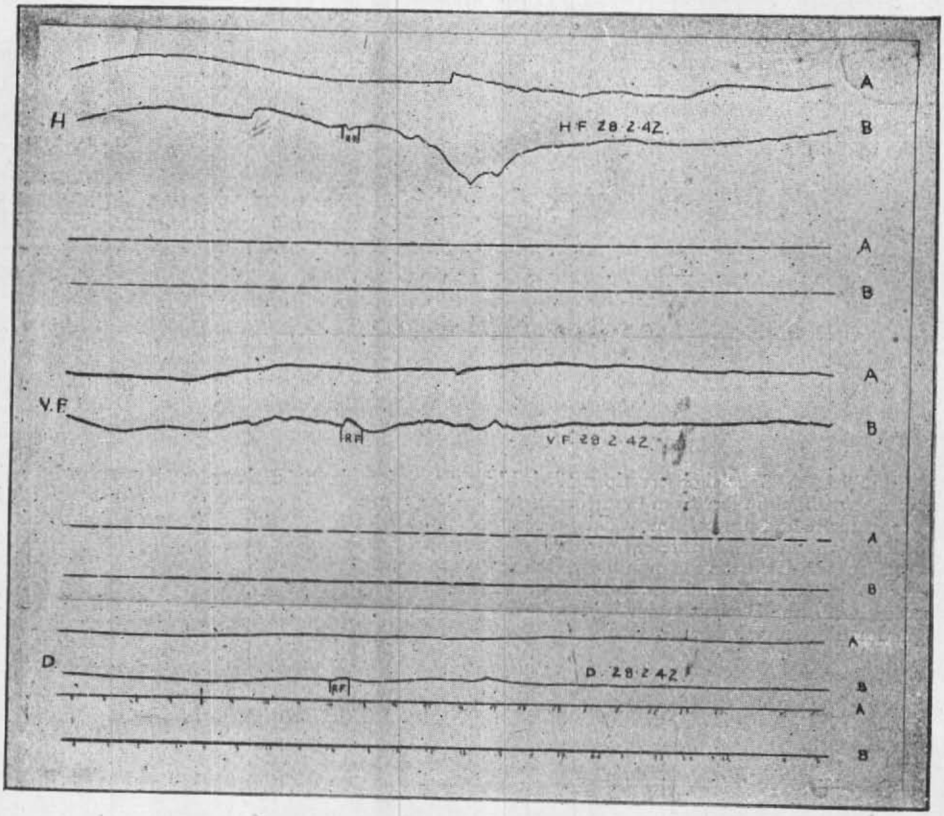

Fig. 7.

Alibag (Bombay) Magnetograms of 28-2-42 showing distinct Crochet in all elements between 1730-1815 I.S.T., coincident in time with the A.I.R. fade-out.

Fig. 8.

Alibag (Bombay) D. Magnetogram of 28-2-42 showing distinct Crochet between 1730-1815 I.S.T. by the rapid running La Cour Instrument.