Communications

Geomagnetic Solar Flare Effect in the Dark Hemisphere

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Received 4 *April* 1975; *revised received* 31 *May* 1975

Evidence is presented from normal run magnetogram data of Huancayo, Kodaikanal and Kakioka to show that geomagnetic solar flare effect (SFE or Crochet) occurs not only in the sunlit hemisphere but also in dark hemisphere. Using a selected sample of five events observed over the period 1969-71, it is noticed that discrepancy exists between the observed characteristics of nighttime geomagnetic SFE and those expected from the interpretation that the nighttime geomagnetic SFE is due to induced currents that are forced to flow into the dark hemisphere owing to the sudden increase in electrical conductivity of the sunlit hemisphere. This discrepancy may be due to some of the inherent assumptions of the theoretical model used for calculating the characteristics of induced currents in the dark hemisphere.

SOLAR FLARES are usually accompanied by bursts of electromagnetic radiation over a wide spectral range and occasionally by particle emission. One of the immediate consequences of the interaction of flare emitted electromagnetic radiation with the earth's upper atmosphere is the occurrence of sudden ionospheric disturbances (SIDs). One of these SIDs is the geomagnetic solar flare effect (SFE or Crochet) which manifests as a sudden short-lived perturbation in the geomagnetic elements as monitored in the sunlit hemisphere. Most of the earlier work on SFE is mainly devoted to the sunlit hemisphere as it is generally considered that SFE occurs only in the sunlit hemisphere. However, Ohshio[1] from an analysis of 15 crochets observed during IGY reported for the first time that geomagnetic solar flare effect occurs not only in the sunlit hemisphere but also in the dark hemisphere. He noticed the amplitude of the nighttime geomagnetic SFE to be small and its shape to be not distinct even at the maximum stage. Later observations of Pinter[2] and Srivastava and Abbas[3] lend further support to this observation. Ohshio[1] advanced the interpretation that the nighttime geomagnetic effect of solar flare is due to electric currents induced in the dark hemisphere due to enhanced electrical conductivity in the sunlit hemisphere. Using the earlier work of Rikitake and Yukutake[4] who treated the geomagnetic solar flare effect as a world wide transient phenomenon, Ohshio[1] calculated the time lag and intensity of geomagnetic SFE due to electromagnetic induction. He found that a weak current flows in the dark hemisphere and its intensity (near midnight area) is about 20% of that in the sunlit hemisphere (near the subsolar area) and reaches a maximum over the globe in about 0·5 to 1·0 min after sudden increase in conductivity in the sunlit hemisphere.

An examination of normal run magnetogram data of Kodaikanal, a station in the electrojet, showed several instances during nighttime when there are conspicuous short-lived perturbations in geomagnetic elements (usually in H component) which are noticed to occur in concurrence with both solar X-ray flares (1-8 Å) (monitored by SOLRAD-9 and published in *Solar Geophysical Data, ESSA/NOAA*) and SIDs in the sunlit hemisphere (*Solar Geophysical Data*). This observation lends further support to the possibility that SFE on geomagnetic variation occurs not only in the sunlit hemisphere but also in the dark hemisphere reported by earlier workers. Hereafter, for the sake of convenience the nighttime geomagnetic effect of solar flares will be referred to as NTSFE, while the daytime effects will be referred to as SFE throughout this communication. A preliminary study of NTSFEs observed at Kodaikanal showed that they exhibited a well defined shape and sufficient amplitude in H-component ($> 4\gamma$ at the maximum) and are characterised by slower rise and decay compared to SFEs observed at the same location[5]. The purpose of this communication is to show that NTSFE occurs both at equatorial and low latitude stations in the dark hemisphere using normal run magnetogram data of Huancayo (geogr. lat., 12°03'S; geogr. long., 75°20'W), Kodaikanal (geogr. lat., 10°14'N; geogr. long., 77°28'E) and Kakioka (geogr. lat., 36°14'N; geogr. long., 140°11'E); and to study the characteristics of SFE and NTSFE in the light of the existing theory on the origin of NTSFE by Ohshio[1] mentioned earlier. This is done with a selected sample of 5 events observed over a period of three years, viz. 1969-71. The flare events are so selected such that at the time of their occurrence, Huancayo lies in the sunlit hemisphere, and Kodaikanal and Kakioka lie at various distances in the dark hemisphere. All the 5 events studied are accompanied by solar X-ray flares (1-8 Å) and SIDs. In Fig. 1 is

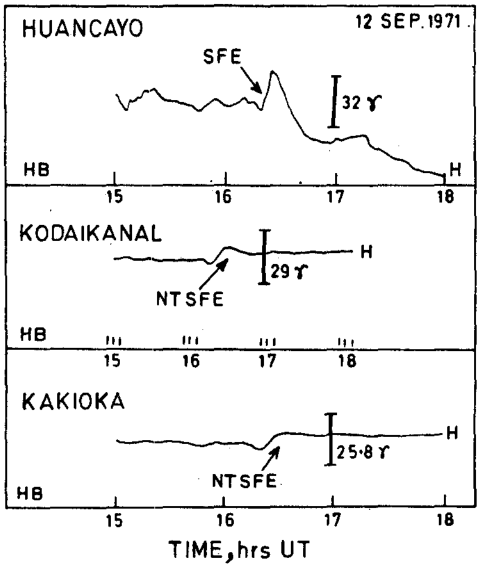

Fig. 1—A typical example of simultaneous SFE and NTSFEs observed at Huancayo, Kodaikanal and Kakioka on 12 Sep. 1971 as a consequence of solar X-ray flare (1-8 Å) *at* 1619-1624-1634 hrs UT

shown a typical example of the geomagnetic solar flare effect observed simultaneously at Huancayo, Kodaikanal and Kakioka on 12 Sept. 1971. In Fig. 2 is presented the time correlation of the occurrence of SFE at Huancayo and NTSFEs at Kodaikanal and Kakioka for the 5 events studied, with the solar X-ray flare (1-8 Å). The convincing association in time between the occurrence of solar X-ray flare, SFE and NTSFEs may be noticed. None of the 5 events studied occurred during the course of a magnetic storm and hence could not be magnetic bays, which occur usually during the main phase of the storm. Further, the possibility that the effects noticed in the dark hemisphere at Kodaikanal and Kakioka could be sudden impulses (SIs) is eliminated after checking with the data on sudden impulses (*Solar Geophysical Data ESSA/NOAA*). These observations clearly indicate that the effects observed at Kodaikanal and Kakioka are genuine effects that occur simultaneously with SFE at Huancayo and the corresponding solar X-ray flare (1-8 Å).

To study the characteristics of the simultaneous SFE and NTSFE, their times of start, maximum and end have been read from the original magnetograms with an accuracy of ± 2 min. The amplitude $|m|_\gamma$ of both SFE and NTSFE has been calculated following accepted practice using the expression;

$$|m|_\gamma = h_3 - (h_1+h_2)/2 \qquad ...(1)$$

where h_1, h_2 and h_3 are the values of the horizontal component of magnetic field at the start, end and maximum of the event. In Table 1 is presented the data concerning the characteristics of SFE and NTSFE for these 5 events. The following features may be noticed. Firstly, the occurrence of the maximum of SFE and NTSFE is not nearly simultaneous in all the cases considered as the time delay between the maximum of SFE and NTSFE is too high to be

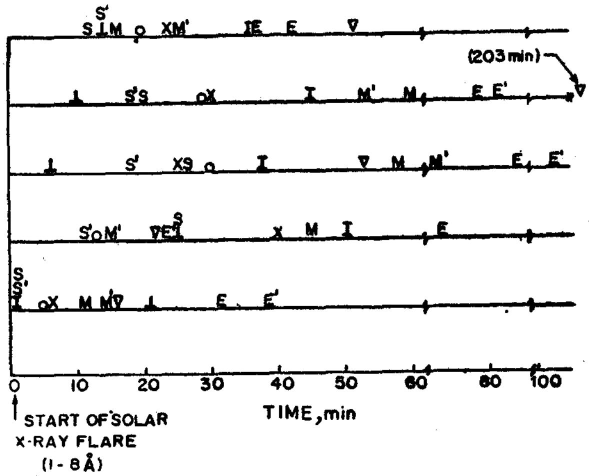

Fig. 2—Time correlation of SFE, NTSFE with solar X-ray flare (1-8 Å)

[(Solar X-ray Flare (1-8 Å)) O—Maximum, ▽—End
SFE (Huancayo) ⊥—Start, X—Maximum, ⊤—End
NTSFE (Kodaikanal) S—Start, M—Maximum, E—End
NTSFE (Kakioka) S′—Start, M′—Maximum, E′—End]

Table 1—Characteristics of Simultaneous SFE (at Huancayo) and NTSFE [at Kodaikanal (KDK) and Kakioka (KA)]

Date	Solar X-ray flare (1-8 Å) Start	Max	End	Ratio of amplitude of SFE to NTSFE at KDK	KA	Time delay in minutes between the maximum of SFE and NTSFE at KDK	KA
	hrs	UT					
28 Feb. 1969	1936	1956	2028	0·13	0·10	— 8·0	+ 1·0
18 Jan. 1970	1444	1514	1537	0·45	0·47	+ 33·0	+ 47·0
18 Feb. 1970	1805	1818	1827	0·32	0·07	+ 5·0	— 25·0
12 Sep. 1971	1619	1624	1634	0·21	0·13	+ 5·0	+ 8·0
3 Oct. 1971	1330	1359	1653	0·15	0·11	+ 30·0	+ 23·0

ascribed to any artificial errors involved in scaling of the magnetograms. Secondly, the ratio of amplitude of NTSFE to SFE lies in the range 0·10 to 0·50. A consideration of the above results in the light of those expected on Ohshio's work shows only partial agreement as the maximum of SFE and NTSFE do not occur simultaneously within 1 min and the ratio of the amplitude of NTSFE to SFE is not always less than 0·2 as expected. These discrepancies and the inadequacy of the Ohshio's interpretation, in its present form, could be due to the fact that Ohshio's work is based on the simple model of Rikitake and Yukutake[4] which assumes the electric conductivity of the sunlit hemisphere to increase suddenly without duration and the ionospheric conductivity is assumed to be isotropic.

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Nighttime Pi2 Micropulsations at Kodaikanal

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Received 2 *January* 1975; *revised received* 6 *July* 1975

The occurrence characteristic of nighttime Pi2 micropulsations at Kodaikanal (geogr. lat: 10° 14′ N; dip: 3·5° N) is studied from normal run magnetogram data for a 1-yr period from January to December 1973. It is noticed that the occurrence of Pi2 pulsations is a broad maximum around local midnight. The dependence of the occurrence of Pi2 pulsations on magnetic activity is of composite nature in that the occurrence is positively correlated with K_p index in the range 0^+ to 2, and negatively correlated with K_p index in the range 2 to 5.

Irregular Pulsations in geomagnetic field have been studied for more than half-a-century under various names ever since it was noticed as a characteristic pulsation at the start of a geomagnetic bay by Angenheister[1]. The nomenclature for geomagnetic micropulsations is now standardized[2] and irregular damped oscillations in geomagnetic field with periods in the range 40-150 sec are designated as Pi2 (Pi2 corresponds to P_t adopted by the 10th committee of IAGA in 1957). Earlier work on Pi2 pulsations has been reviewed by Jacobs and Westphal[3] and Troitskaya[4] and on micropulsations in general by Campbell[5] (for the period 1969-71). It is now more or less established that Pi2 micropulsations occur more frequently during nighttime with a maximum just before local midnight and its amplitude is dependent on latitude with a maximum at the auroral latitudes. The dominant period of Pi2 micropulsations is, however, independent of latitude according to most investigators.

Continuous photographic recording of the *H*, *Z* and *D* of the geomagnetic field is being done at this institute with the La Cour and Watson variometers calibrated with quartz horizontal magnetometer (QHM) and magnetic zero balance (BMZ) and supplemented with a proton precession magnetometer. In this communication we present the results of our study on nighttime (1800-0600 hrs) Pi2 micropulsations (in *H* component) over a period of 1 yr (Jan.-Dec. 1973) at Kodaikanal (geogr. lat: 10°14′) using normal run magnetogram data (from Watson variometer: sensitivity 6·4 γ-11·4 γ/cm, chart speed 15 mm/hr). It is to be emphasized that our recording system is not ideally suited for the study of micropulsations in view of its low sensitivity and low time resolution. However, we have noticed from careful visual examination of the magnetograms that they are adequate for the study of Pi2 micropulsations, especially their occurrence. With this understanding our analysis mainly consisted in noting down the time of occurrence of the Pi2 pulsations from careful visual examination of the magnetograms. From this data the occurrence of Pi2 micropulsations in relation to local time during night and level of magnetic activity is studied and the results are presented in the following. In view of the low

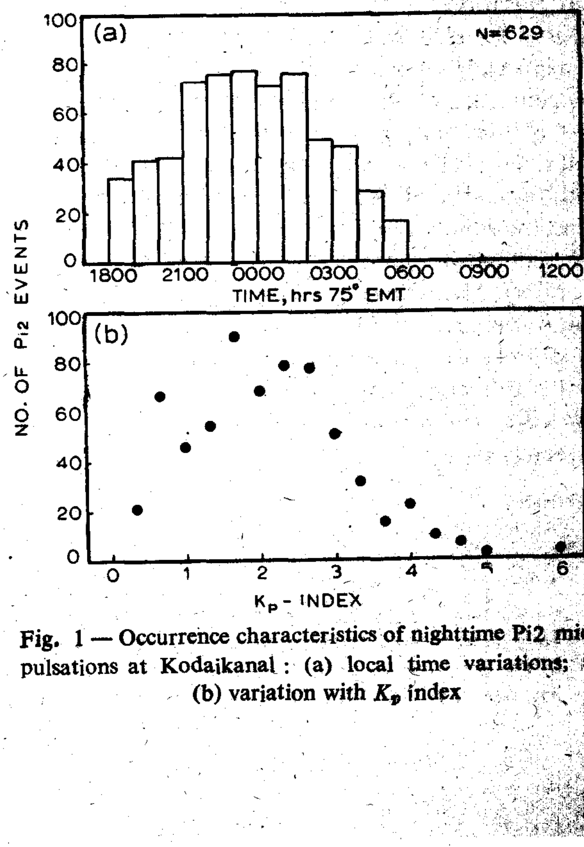

Fig. 1 — Occurrence characteristics of nighttime Pi2 micropulsations at Kodaikanal: (a) local time variations; and (b) variation with K_p index