Geomagnetic Crochets Associated with Proton Flares

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Magnetogram data of Kodaikanal for a 13-yr period from 1957 to 1969 have been examined for sfes (Crochets) associated with proton flares (PCA events). A study of these indicated that they are characterized by longer rise time and total duration, compared to those associated with normal flares. It is inferred from the range of values of αN that the region of enhanced conductivity is in the D region, below the normal electrojet.

THE EFFECT of solar flares on geomagnetic variation designated as sfe (also known as Crochet) has been studied by several workers using observations over a range of latitudes. It is established that the occurrence of sfe is maximum around local noon and the amplitude of sfe has a local time variation similar to that of Sq. field[1-4]. As for the physical mechanism responsible for sfe, the prevailing consensus is that the region of enhanced conductivity lies below the normal dynamo region and the ionizing agency responsible for the increase in conductivity is the soft X-ray spectrum below 20 Å (Ref. 4-8).

The eruption of a solar flare is usually accompanied by emission of electromagnetic radiation over a wide spectral range and occasionally by particle emission. The particle emission is inferred, especially during earlier times, from ground-based techniques, viz. PCA event (polar cap absorption, the corresponding flare is referred to as proton flare) and GLE (ground level effect, the corresponding flare is referred to as relativistic flare). With the advent of space vehicles, the detailed characteristics of particle emission during normal and flare times are being monitored by satellite-borne equipment. Evidence exists to indicate that the characteristics of microwave and X-ray bursts that follow a solar flare with particle emission differ from those of normal flares. Aarons *et al.*[9] observed that the microwave bursts associated with proton flares exhibit characteristics which, from the form of the radio spectrogram, are known to have a 'U' type spectrum. This indicates that the observation of such a feature may be used to forecast the probable occurrence of a proton flare, which hinders communications around the polar region. Sen Gupta[10] reported that Type III X-ray bursts (for which the spectral hardening factor is $> 6\%$) are accompanied by microwave bursts with a 'U' type spectrum. Based on the work of Aarons *et al.*[9],

Table 1 – List of PCA Flares and Details of the Associated Sfe Events

No	Date	Time of optical flare maximum hrs UT	Flare position		Crochet Time Characteristics			Crochet amplitude	
					Rise time T1 min	Decay time T2 min	Total duration T3 min		
1	31.8.1957	0536	25°N	2°W	22	22	44	48	1·48
2	18.9.1957	0310	31°N	8°E	8	14	22	−37	2·5
3	29.3.1960	0658	12°N	31°E	29	23	52	75	1·02
4	14.8.1960	0510	24°N	15°W	19	16	35	76	2·28
5	18.7.1961	1118	7°S	59°W	4	8	12	21	5·7
6	26.9.1963	0711	15°N	76°W	17	57	74	91	1·36
7	24.3.1966	0235	20°N	32°W	5	30	35	32	0·90
8	2.9.1966	0545	22°N	58°W	14	57	71	64	1·4
9	28.5.1967	0608	28°N	33°W	4	13	17	29	1·25
10	6.6.1967	0700			10	20	30	10	2·5
11	9.6.1968	0848	18°S	8°W	4	4	8	− 7	1·5
12	6.7.1968	0937	12°N	90°E	10	43	53	−38	2·1
13	4.11.1968	0510	15°S	90°W	20	20	40	− 9	2·8, 1·0
14	25.2.1969	0906	13°N	36°W	14	28	42	33	1·35
15	5.6.1969	0958	11°N	64°E	6	28	34	− 4	3·7

Sengupta[10] inferred that Type III X-ray bursts follow flares with particle emission. It follows, therefore, that for proton flares, considerable hardening of the X-ray spectrum occurs. Since it is known that enhancement of X-ray flux below 20 Å produces excess ionization mainly below 100 km, any changes in the X-ray energy spectrum should, in principle, reflect in the characteristics of the corresponding sudden ionospheric disturbances (SIDs). Some evidence exists in support of this understanding. Using Kodaikanal data, Subrahmanyam[4] reported that the characteristics of sfe associated with relativistic flares (GLE events) differ from those of normal flares, while Pinter[11], using Huybanovo data, reported that the sfe characteristics associated with proton flares differ from those of normal ones.

The present study is an attempt to see whether there are any prominent differences in the characteristics of sfe associated with proton and non-proton flares, using Kodaikanal (geogr. lat., 10°14'N dip., 3·5°) magnetograms. The sfe events observed over a 13-yr period (1957-1969) have been used. Data on proton flares which occurred during this period have been taken from various sources[11-15]. A total of 15 sfes associated with proton flares became available for study, a list of which together with their characteristics are given in Table 1. A total of 92 sfes associated with normal flares have also been studied for the purpose of comparison. The characteristics describing the sfe are rise time, decay time, total duration, amplitude and the nature of decay. In Fig. 1 are presented the statistical features of the characteristics of sfe associated with proton flares and normal flares. It may be noted that there are no striking differences in their characteristics except for the fact that the rise time and total duration of sfe associated with proton flares are relatively larger compared to the corresponding values for the normal flares. The local time variation of sfe occurrence associated with PCA flare is relatively more scattered compared to that of sfes associated with normal flares, although a maximum around local noon is evident. It may be seen from Table 1 that the decay time is more than the rise time in a majority of the events. However, a study of the distribution of the ratio of the decay time to rise time showed that it is similar to that for sfes associated with normal flares. A rather striking feature noticed is the positional asymmetry (east-west) on the disc of proton flares which produced sfe, as can be seen from Table 1. Out of the 15 proton flares, 10 occurred on the western side of the solar disc. The decay portion of the sfes (i.e. from maximum to the normal diurnal level) has been analyzed on the assumption that after the excess ionization is produced, the enhanced conductivity decays to the normal level as a consequence of recombination alone. This procedure gives the values of αN. It is noticed that the range of values of αN for sfes associated with proton flares is $1{\cdot}0\text{-}6{\cdot}0\times10^{-4}$ sec^{-1} while that of the normal flares is $(0{\cdot}5\text{-}13)\times10^{-4}$ sec^{-1}. These values suggest an altitude range of 60-90 km below the electrojet for the region of enhanced conductivity responsible for sfes associated with proton and normal flares.

To sum up, the present study showed that the sfes associated with proton flares are characterized by

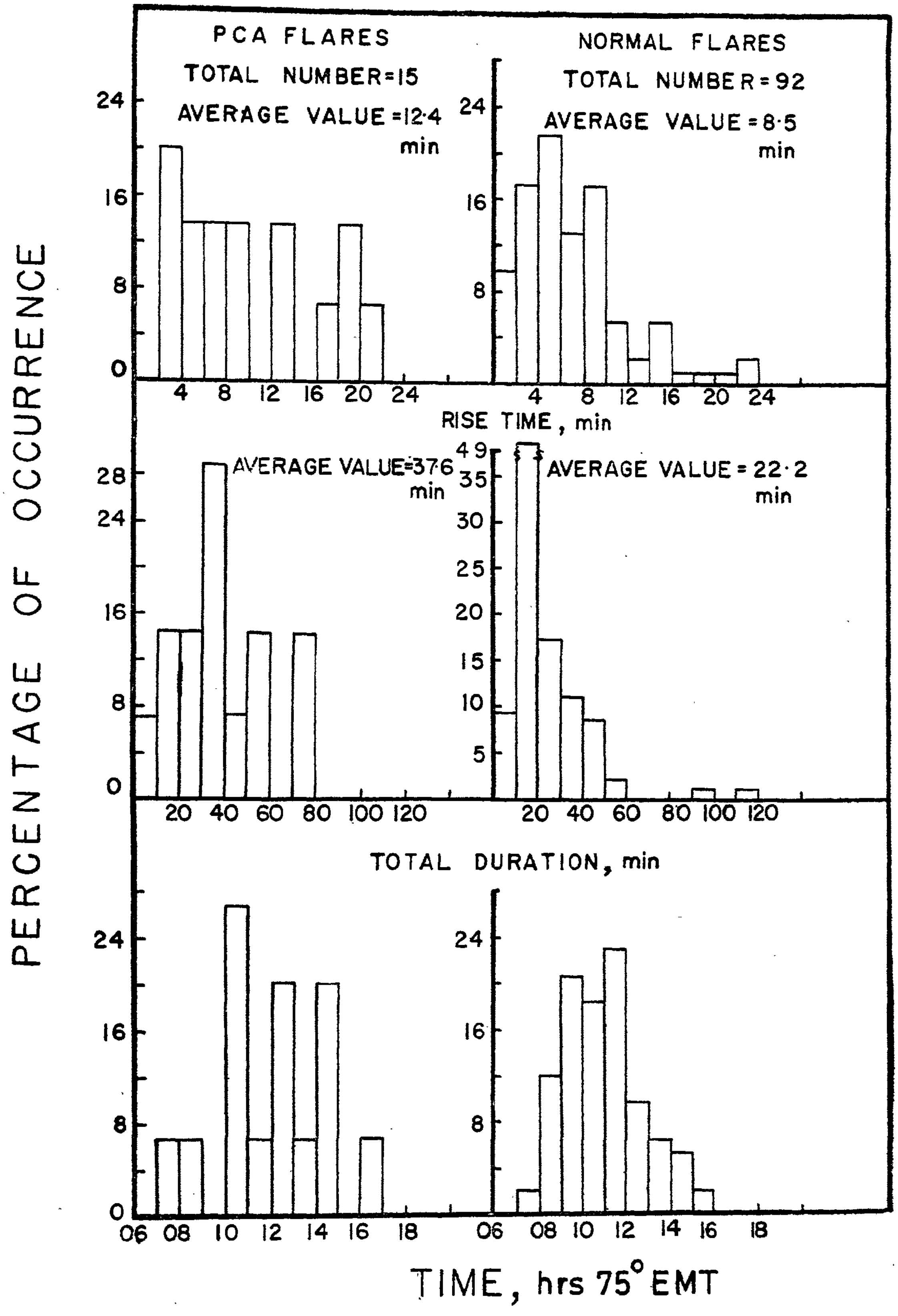

Fig. 1—Histograms of the characteristics of sfes associated with proton and normal flares

longer rise time and total duration compared to those of normal flares and the proton flares which produced sfes exhibit east-west asymmetry as regards their position on the solar disc. Similar observations were reported by Pinter[8,11] using Hurbanov magnetogram data. The range of values of αN suggest that the region of excess ionization is about 60-90 km.

The observation of relatively longer rise times for sfes associated with proton flares suggests that sfe is insensitive to changes in X-ray energy spectrum. In fact, Deshpande *et al*[16] noticed that the time profile of sfe follows that of the integrated X-ray flux level rather than the spectral hardening factor. This is understandable at least on a quantitative basis, in terms of the fact that the sfe is an integrated effect of enhanced conductivity over a region of the ionosphere from about 60 km upto and including the electrojet region, although the relative contribution to the observed variation on ground from different heights, is not known. More work is, therefore, necessary using time profiles of sfe X-ray bursts in different wavelength bands and microwave bursts; and also in the direction of estimating the relative contribution to sfe from enhanced ionization at different levels.

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References

1. McNish, A. G., *Terr. Magn. atmos. Elect.*, **42** (1937), 109.
2. Newton, H. W., *Mon. Not. R. astr. Soc., geophys. suppl.* No., 5 (1948), 200.
3. Nagata, T., *J. géophys. Res.*, **57** (1952), 1.
4. Subrahmanyam, R. V., *J. atmos. terr. Phys.*, **26** (1964), 1119.
5. Veldekamp, J. & Van Salbeen, D., *J. atmos. terr. Phys.*, **18** (1960), 192.
5. Volland, H. & Taubenpeim, J., *J. atmos. terr. Phys.*, **12** (1958), 258.
7. Ohshio, M, *J. Rad. Res. Labs. Japan*, **11** (1964), 377.
8. Pinter, S., *Bull. astr. Insts Csl.*, **18** (1967), 274.
9. Aarons, J., Castelli, J. P. & Michael, G. A., *J. géophys. Res.*, **72** (1967), 5491.
10. Sengupta, P. R., *Proceedings of the symposium on solar radiation and the earth*, edited by J. N. Tandon (Hindustan Publicity House, India) 1973, 77.
11. Pinter, S., *Bull. astr. Insts Csl.*, **18** (1967), 282.
12. Krivsky, L., *Bull. astr. Insts Csl.*, **16** (1965), 27.
13. Krivsky, L., *Bull. astr. Insts Csl.*, **17** (1966), 141.
14. Hustquist, B., *Solar flares and space research* (North-Holland Publishing Co. Ltd, Amsterdam), 1969, 215.
15. *Annals of the IQSY*, Vol. 2 edited by A. C. Stickland (The M. I. T. Press, Cambridge, Mass).
16. Deshpande, S. D., Subrahmanyan, C. V. & Mitra, A. P., *J. atmos. terr. Phys.*, **34** (1972), 211.