Bull. Astr. Soc. India (1998) **26**, 311-315

Solar proton events in relation to H-alpha flares

T.K. Das, T.K. Nag and A.K. Dutta

Eastern Centre for Research in Astrophysics, Institute of Radio Physics and Electronics, 92, A.P.C. Road, Calcutta 700009, India

Abstract. A study has been made about the solar proton events observed by NOAA satellite during the period 1976-1993 by considering their association with H_α-flares. The proton flux has been found to depend linearly upon the estimated flare energy output per day. The proton flux varies with the rise time also in a linear way. Study about the visual features of the proton - associated H_α-flares reveals that the proton events are connected with those kinds of flares which have multiple instabilities in the associated active regions.

1. Introduction

Solar proton events have become a subject of great interest in recent times. From the history of solar proton event observations Shea and Smart (1995) inferred that prompt, large magnitude, peak flux solar proton events are associated with solar activity on the western side of the solar disk, however, the long duration high fluence solar proton events are associated with major solar activity near the central meridian of the sun. Our previous studies (Chakravorti et al. 1991; Das et al. 1987) were made about the proton - associated active regions which revealed that the active region characteristics, such as, Ca-plage index, radio emission flux, etc. attain their peak value on the day of occurrence of proton onset. Moreover, energy flux distribution of proton events were examined to follow a power law and the rate of rise of proton flux were found to vary with the energy flux. In a recent paper we have observed that the power spectral analysis of the time series of the daily proton fluences shows a periodicity of 73 days which conforms to that of the solar flare index as reported by earlier authors (Ozguc and Atac 1994), indicating, as a consequence, the intimate relationship of proton flux with that of solar flare. This has prompted us to make a study on the solar proton events in relation to H_α-flares, especially on the basis of their energy consideration.

2. Data collection

Altogether 120 proton data which had been observed by the satellite of NOAA Space Environment Services Centre under U.S. Department of commerce during the period from 1976 to 1993 were considered for the present analysis. Each of these proton events were associated with the Hα-flares and the respective active region Mcmath number was noted. The Mcmath region was searched for the last consecutive fifteen days before the day of onset of a particular proton event. The daily values of the various parameters of the H_α-flares that had evolved in the same active region during the last fifteen days or less were collected from the Solar Geophysical Data bulletins issued by NOAA, U.S. Department of commerce.

3. Analysis and results

As there is no direct method for measuring the energy output of a solar flare, different indirect techniques are adopted for estimating the energy evolved in a flare. The term "flare importance sum" signifying the estimated energy output of a flare has been introduced in the following way. Each flare has been weighted according to both the area of the flaring region at the time of maximum brightness and the maximum luminosity. The weighting factors as adopted by Lemmon (1972) and used here are shown in Table 1.

Table 1. Weighting factors for estimating flare energy.

Importance	Intensity	Weighting factor
Subsub	Faint	1
Sub.	Normal	2
1	Bright	3
2		4
3		5

The product of luminosity factor and area is computed for each of the flares and the results of the products are added together for all the flares occurring in an active region for all the days considered.

The flare index F_I has been calculated from the following relationship (Dasgupta et al. 1981).

$$F_I = 0.82\, F_s^{1.08}$$

where F_I indicates flare index and F_s the flare importance sum. The value of F_I thus found out has been divided by the total number of days D for which the Mcmath region remains flare-active. Thus we get

$$I = \frac{F_I}{D} = \frac{0.82\, F_s^{1.08}}{D}$$

The plot of I against the proton flux is shown in Fig. 1 and the correlation coefficient between these two data has been found to be 81.7%. In order to plot I against the proton flux, the values of proton flux have been grouped into convenient classes and the frequency distribution of I in those adopted ranges has been found out. From the frequency distribution the mean values of I have been determined and plotted against the mid values of the respective proton flux classes. The plot reveals that the proton flux is linearly dependent upon the flare index per day, i.e. the average rate of energy output by way of flaring.

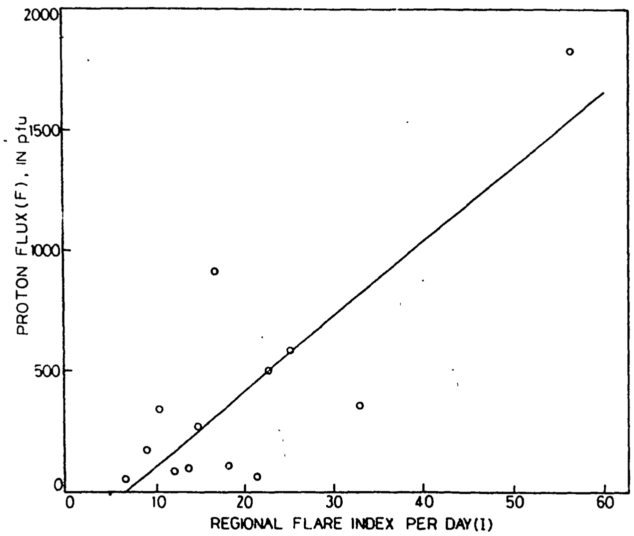

Figure 1. Straight line shows the variation of proton flux with the flare index per day (I).

In order to confirm it the integrated intensity which also gives the energy estimate of a flare has been calculated by means of the following expression (Sawyer 1967)

$$I_{(i)} = 7.6\ A_s^2$$

where A_s is the apparent area of a flare in millionth of solar disk. The average energy output per day has been found out after evaluating the integrated intensities of all the flares that occurred in the active region during its life-time before the day of proton onset. Thus

$$I' = \frac{0.76\ \Sigma A_s^2}{\Sigma^T}$$

where T is the time in min. The plot of I' against the proton flux also shows that these two variables bear a linear dependence with each other giving rise to a correlation coefficient 79.6%.

The rate of energy flow during proton events has been found out by plotting the proton flux against the rise time which is the time interval between the starting and the respective maximum phase of the event. The result has been displayed in Fig. 2 which shows that the proton flux varies linearly with the rise time.

Lastly, the visual features of the proton - associated H_α-flares have been studied. Histograms shown in Fig. 3 give the occurrence frequency distribution of the proton events in different types of flares as designated by the various alphabets which represent different kinds of visual indications. The nomenclatures of all types are given in the descriptive text of Solar Geophysical Data bulletins, but here only those types are explained in which the percentage occurrences are relatively high. D: Brilliant point; E: Two or more brilliant points; F: Several eruptive centres; K: Several intensity maxima.

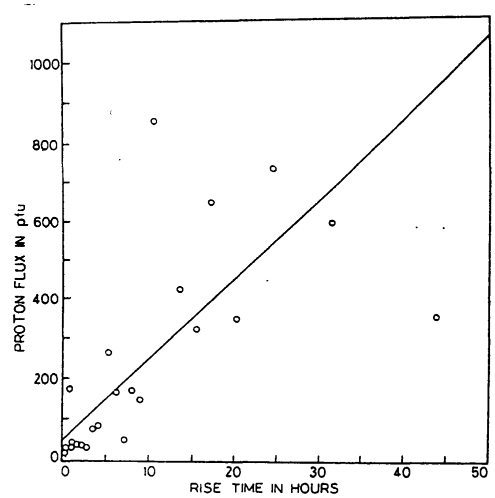

Figure 2. The plot gives the linear variation of proton flux with the rise time.

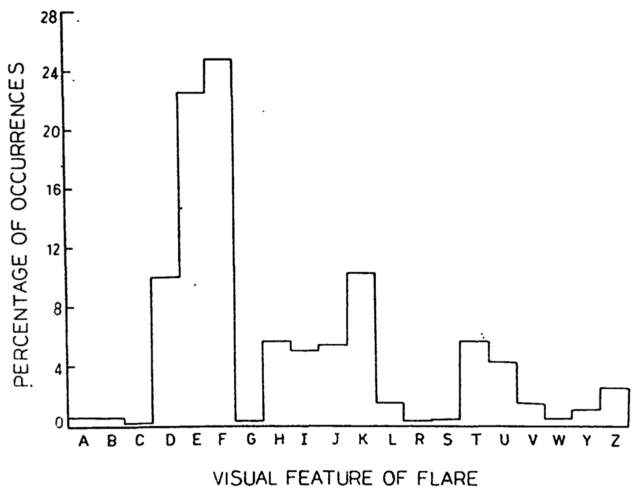

Figure 3. Histograms showing the percentage of relative occurrences of proton events with different kinds of flares classified according to their visual features.

From Fig. 3 it appears that the proton events are mostly associated with D,E,F, and K types of flares which have more brilliant points as well as several centres of eruption.

4. Discussions

It appears from the foregoing analysis that the proton flux bears a linear relationship with the regional flare index per day. So if the energy output of a flare increases, the associated protons become more energetic. The relationship between the flux of proton events and the estimated energy output of H_α-flares indicates that the acceleration of very high energy protons might be linked with the shock acceleration which was proposed as a 'second-stage' acceleration process in a solar flare (Tandberg -Hanssen and Emslie, 1988). Moreover, if the rise time increases, more energetic protons are generated, as it is evident that the proton flux has a good bearing with the rise time. So far as the visual features of the associated flares are concerned, it may be inferred that the flares which possess a large number of erupting points, giving rise to multiple instabilities in the active region are correlated with the proton events.

References

Chakravorti T.B., Das T.K., Sen A.K., Das Gupta M.K., 1991, Bull Astr. Inst. Czechhosl., 42, 165.

Das Gupta M.K., Das T.K., Sarkar S.K., 1981, Sol. Phys., 69, 131.

Das T.K., Chakravorti T.B., Das Gupta M.K., 1987, Bull Astr. Inst. Czechosl., 38, 206.

Lemmon J.J., 1972, Solar activity observations and predictions, MIT press, Mass, U.S.A.

Ozguc A., Atac T., 1994, Sol. Phys., 150, no. 1-2, 339.

Sawyer C.B., 1967, J. Geophys. Res., 72, 385.

Shea M.A., Smart D.F., 1995, Nucl. Phys. B. Proc. Suppl. (Netherlands) Vol. 39, No. A, b. 16.

Tandberg-Hanssen E., Emslie A.G., 1988, The Physics of Solar flares, Cambridge University Press, Cambridge.