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ANALYSIS OF SOLAR PROTON EVENT

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Abstract:

The solar proton flares affecting the solar terrestrial environment were recorded during the period January 1995 to May 2012. The statistical analysis of 94 solar proton events was carried out in this work, and data were compared with the solar flares observed during the period from January 1976 to January 1990. Proton fluxes were integral 5-minute averages for energies >10 MeV, given in particle flux units (pfu). The proton fluxes were classified into 7 classes ranging from 11 to > 31,700 pfu. Both events were measured by GOES Space craft at Geosynchronous orbits.

Keywords: *Sun: Solar Flares, Proton Flux, Solar Proton Events (SPE), Solar Energetic Particles (SEP).*

Introduction

The solar proton events during the period January 1995 to May 2012 were studied, and the important results can be reported as follows:

1. The data of proton events occurring consists of 94 events in which the integrated flux of the events exceeded 10^2 proton cm^{-2} for protons with energies above 10 MeV.
2. The analysis of the data during the period January 1995 to May 2012. gave a periodicity of almost 106 days.

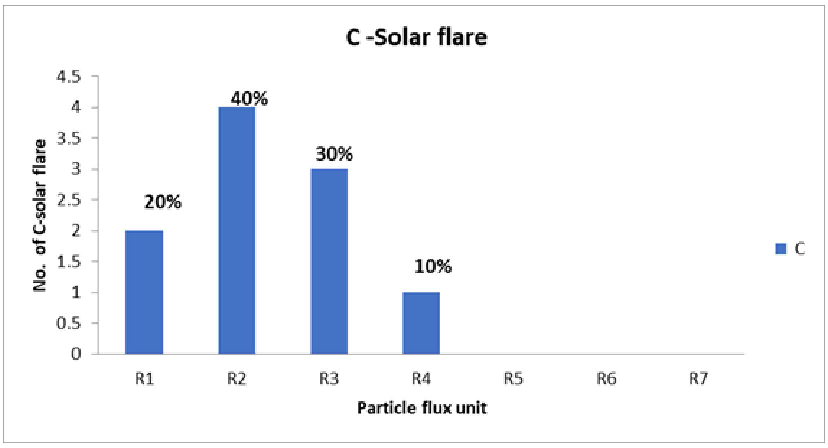
The geomagnetic storm strength depends largely on the energy of the plasma cloud, and since this depends on the energy released during the flare occurrence, the strength of the geomagnetic storm will subsequently depend on the energy of the associated flare. With this assumption, occurrence of geomagnetic storms is possible when the proton flare energy reaches a certain level. Below this energy level geomagnetic storm will not occur / 4/.

Using data on the solar X- ray bursts in the two spectral bands 0.5 – 4 A^0 and 1- 8 A^0. It is found from /4/ reasonable linear correlations between the peak flux of solar X– ray bursts (associated with solar proton flares) and velocity of the associated interplanetary shock wave. The analysis showed also weak correlation between the peak flux bursts and Kp magnetic index of the associated geomagnetic storms.

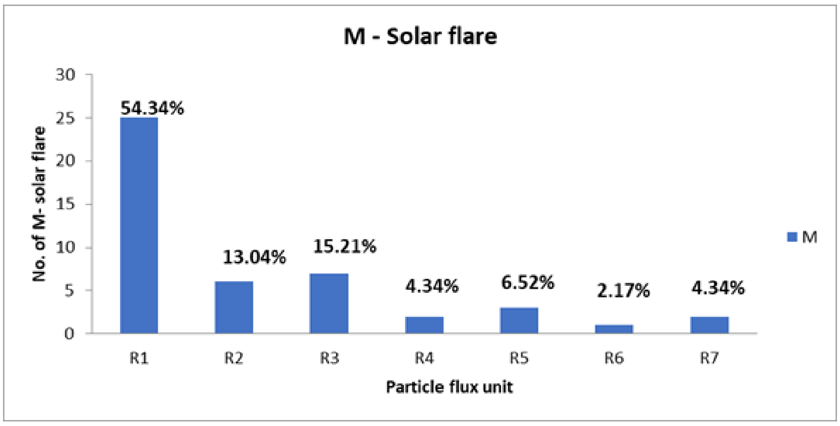
According to the National Oceanic and Atmospheric Administration of the Solar Environment Center (NOAA/SEC) definition, a "solar proton event" (SPE) is the solar energetic particles' enhancement in which proton flux with energy Ep>10 MeV is greater or equal to 10 part/cm^2.s.sr (10 pfu) up to the background level near 1AU. The onset time of a proton event is defined by the first three consecutive 5 min average data points with fluxes greater than or equal to 10 pfu. The end of the event is the last time when the flux was greater than or equal to 10 pfu. This definition allows for multiple proton enhancements to be considered as one proton event.

Analysis of flares

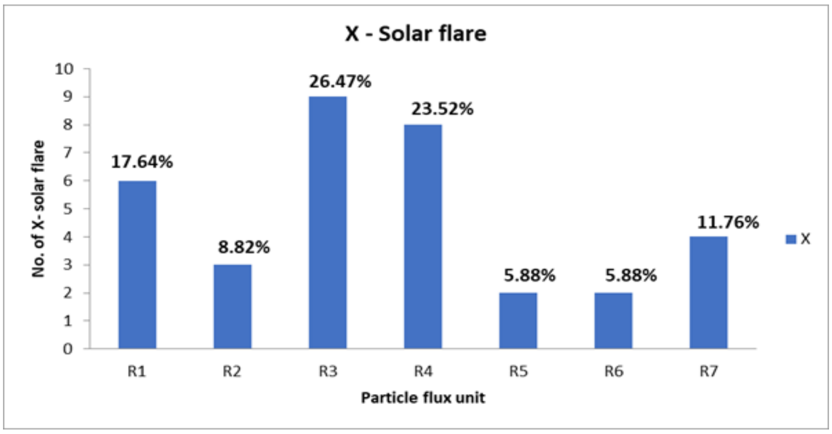
The solar proton events during the period January 1995 to May 2012 were studied the solar flares were classified into three classes such as C, M and X type. These flares are graphically analyzed as shown below.



Classification of C - type solar flare in the particle flux unit



Classification of M - type solar flare in the particle flux unit



Classification of X - type solar flare in the particle flux unit

Table 1: The grouping of proton flux units

Class	Grouping of proton flux (pfu)
R_1	50 > Ø > = 10
R_2	100 > Ø > = 50
R_3	500 > Ø > = 100
R_4	2000 > Ø > = 500
R_5	5000 > Ø > = 2000
R_6	10000 > Ø > = 5000
R_7	Ø > = 10000

Table 2: The maximum and minimum particle flux units

Sr. No.	Type of solar flare	Maximum	Minimum
1	C- type solar flare	R_2	R_4
2	M- type solar flare	R_1	R_6
3	X- type solar flare	R_3	R_5 and R_6

Data

We consider all the 94 solar proton events observed by NOAA SPACE ENVIRONMENT SERVICE CENTER (http://www.swpc.noaa.gov)

All data used in this work represent optical and X – ray observations, Using the NOAA SPACE ENVIRONMENT DATA CENTER (http://www.swpc.noaa.gov) During period from January 1995 to May 2012 there were 94 significant solar proton flares affecting the solar terrestrial environment, the events measured by GOES spacecraft at geosynchronous orbit.

Proton flares are integral 5- minute averages for energies >10 MeV, given in particle flux unit (PFU) Where 1pfu = 1 $p/cm^2 s^{-1} sr^{-1}$.

Analysis and Results

Statistical analysis was carried out for 94 solar proton events and their associated solar flares and active region. Table (1) contains the classification of the fluxes of proton flares occurring during the period under investigation. This classification proved to be useful in the detailed study of proton flares.

Associated with Hα flares

The result of association study between the number of proton flare occurrences for each class of proton flux and different classes of Hα solar flare classification is investigated.

Examination of table (2) indicating the following:

1. Most of proton flares occurred in sub- class 2B, and 3B, and class SF, 2F & 1B proton flares are rather rare phenomena.
2. The proton flares in class B are more associated (58%) than that in class N (31%) and class F (11%).
3. There are 29 events with unknown class.

Association with X – ray bursts

The proton flares in our period were analyzed for each class of proton flux with each sub class of SESC X- ray classification /5/. The results are presented in table (3). From this analysis we can clearly notice that:

1. Proton flares in the M – class are more associated (49 %) than that in X- class (36 %) and C – class (11%).

2. There are four proton flares with unknown X- ray class (8^{th} Nov. 1998; 24^{th} Apr. 1999; 10^{th} Aug. 2001; 16^{th} Aug. 2001;).

Conclusions

The solar proton flares are mostly associated with the brilliant type (58) more than that with the normal type N (31), or faint type F (11) in the Hα flare luminosity classification. On the other hand, the proton flares are more associated with the type M (49) than that with the type X (36) and type C (11) in SESC X – ray classification.

The association of the class B in Hα flare classification with the number of proton flare occurrences is acceptable since that class B is always produced from active regions of magnetically complex type i.e. of mixed magnetic particles /6/. And this complexity of magnetic field configuration is the basic cause of the proton flares productivity. On the other hand, the association of number of occurrences of proton flares with the X – class in the SESC classification can be understood as follows, The X- class can be produced only at higher energy and accompanied by a higher X- ray peak flux. From table (3) We notice that, the X- class (peak energy 10^{-1} erg.cm^{-2}.s^{-1} and X-ray peak flux greater than 10^{-4} Watt.m^{-2}). This level of energy and peak flux are most suitable for proton flare productivity.

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