The effect of solar eruption promulgation on the propagation of solar energetic particles

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Abstract. Solar eruption events investigated for the period from 2000 to 2014. These events associated with solar energetic particles (SEPs) that composed of halo-type coronal mass ejections (CMEs) and accompanying with intense flares. The incline of the time intensity profile are computing by analysing the eastern and western events through the CMEs source regions. This study shows that the incline angle for west events is smaller than Eastern Events. The western events are seem to be sharper in the acceleration phase than the eastern event. Considerate these phenomena is important to relate the space weather environment near Earth and other destinations in the solar system.

1. Introduction

Expressive the source of the solar proton event is very important where the protons can be accelerated to more than 10 MeV during the propagation of the CMEs and near the front of the shock or solar flare growth. The solar energetic particles (SEPs) acceleration could be due to flaring processes, acceleration in coronal mass ejections (CMEs) and/or interplanetary shocks, or it could be a combination of all [1]. These two sources and their location at the Sun, make the time intensity profile to be different depending on the position of the observation point. In addition, the spiral pattern of the interplanetary magnetic field (IMF) gives rise to the longitude dependent solar proton profiles. It can be interpreted as proton acceleration by an expanding shock in the IMF [2-3].

The heliographic coordinates of the CMEs have been identified as the location of the associated flare, or coronal darkening from various observations [4]. Numerous physical relationships have been studied to show the behaviour of the time intensity profile for the SEPs such as CME angular width, CME location and speed. There is no differences found for the probability effect of the background solar wind speed on the SEP event timescales which studied by Kahler and Vourlidas [5].

Our study is concentrated on the location of the source region of SEPs events and its effect on the behaviour of the time intensity profile. There were about 259 Halo CMEs and intense flares, which originated towards the western and eastern side of the Sun, which compiled in order to infer properties that benefit to study the change and compute the incline’s angle in the time intensity profile of the produced SEPs.

2. Data Analyses

The purpose of this study is to compute the incline’s angle of the time intensity profile, and how solar energetic particles can propagate, which had to be observed with the CMEs, and were well-connected to the field-lines near L1, where the Energetic and Relativistic Nuclei and Electron (ERNE: [6]) instrument on board the Solar and Heliospheric Observatory (SOHO) is located. For finding the characteristics of CMEs (speed, angular width, and lift-off time) we used The SOHO/Large Angle and Spectrometric Coronagraph (LASCO) CME catalog at (http://cdaw.gsfc.nasa.gov/). The NOAA National Geophysical Data Center (NGDC) are listings at http://www.ngdc.noaa.gov/stp/spaceweather.html was used for flares and its locations. The X-ray data
were checked from the Geostationary Operational Environmental Satellite (GOES). To study the time intensity profile for associated SEP events, we used the SOHO/ERNE proton data at http://www.srl.utu.erne data/main english.html.

These CMEs with angular widths of 60° and up, and have speed with more than 850 kms⁻¹. Their associated flares are having M and X classification. On the other hand we exclude the backside and ambiguous events to reduce uncertainties in predicting the eruption source properly. After that, we have examined the time intensity profiles of all the 259 SEPs for protons particles with intensities larger than 10⁻³cm⁻²sr⁻¹s⁻¹MeV⁻¹.

3. Results and Discussion

The solar events which selected are associated with halo and fast CME with angular widths of 60° and up, and intense flares that occurs for areas within ±80° heliographic longitude and ±40° heliographic latitude from all the examined events. These indicated the occurrence of the variation in protons flux from one event to another during the rising phase for low and high-energy channels.

We sort numerical analysis to give a description of the fits in with the issue of the study to reduce the errors as much as possible. The results sorted according to the longitudinal lines with incline’s angle and coronal mass ejections velocity, as shown in Figures (1) and (2) respectively.

Figure 1. The variation of incline’s angle with longitude.
Figure 2. The coronal mass ejection velocity variations with longitude.

Figure (1) shows gradual increase in the intensity with the solar source located in the eastern hemisphere of region with angle (21° to 90°), fast increase with eastern hemisphere of region within (20° to -20°), and have swift increase with western hemisphere of region within (-21° to -90°). While figure (2) shows the SEPs associated with fast CMEs that have velocity from about (900 - 2400) km s⁻¹ within western events which were well-connected to the field lines near L1, were the ERNE instrument on board SOHO is located.

Figure 3. The longitude variation with SEPs intensities time scales (squares) for high energy and (circles) for low energy.
Figure (3) displays the variations of SEPs intensities with high and low energies which increase within the center of the Sun at hemisphere of region within (-9˚ to -54 °) western events.

Figure 4. Shows the latitude variation with SEPs intensities time scales (squares) for high energy and (circles) for low energy.

On the other hand the eastern events in figure (4) shows increasing in intensities of SEPs at hemisphere of region within (11˚-12°) which indicate the solar cycle’s maximum. Figure (5) represents the variation of incline’s angle of (50 °) and up at eastern latitude while its increasing of 45˚and up for western latitude events. While the figure (6) shows variation of CMEs velocity with latitude which increase from (850 -2000) kms^{-1} with distinction of latitude of (9˚ to 31˚).
The results show the western events are seem to be sharper in the acceleration phase than the eastern event. The rising phase of the high energies take shorter time than the low energies. This marks that the bulk of acceleration take place near the Sun where the shock wave efficiency is higher due to the perpendicular propagation to the Sun magnetic field lines. Geomagnetic storms are
associated with CMEs which is a major disturbance of Earth’s magnetosphere and they also can disrupt navigation systems so Consider these phenomena is important to relate the space weather environment near Earth and other destinations in the solar system.

4. Conclusions

From this study we can conclude that:

1- Solar eruption events were investigated for the period from the maximum of solar cycle 23 to the maximum of solar cycle 24 observing by SOHO, and GOES satellites.
2- These events were chosen with solar energetic particles (SEPs) that accelerated by both (X and M) X-ray flare and high speed coronal mass ejections (CMEs).
3- The incline of the time intensity profile determined by analyzing the eastern and western events through the CMEs source region shows that the incline for west events is smaller than Eastern Events.
4- The solar energetic particle events are fewer regular for solar cycle 24 than those of solar cycle 23.
5- The western events are seem to be sharper in the acceleration phase than the eastern event.

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References

[1] Trottet G, Samwel S, Klein K-L, Dudok de Wit T, Miteva R 2015 Solar Phys. 290 819.
[2] Cane H V, Reames D V, Rosenvinge T. T. von J. 1988 Geophys. Res. 93 9555–9567.
[3] Reams D V 1999 Space Sci.Rev. 90 413.
[4] Gopalswamy Akiyama and Yashiro 2007 JGR 112 A06112.
[5] Kahler S W, Vourlidas A 2014b Astrophys. J. 791 4.
[6] Torsti J , Valtonen E , Lumme M , Peltonen M P , Eronen T , et al. 1995 Solar physics 162 505- 531.