Solar Energetic Particles Events Observed with EIS Onboard NOZOMI Spacecraft

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Abstract

The satellite NOZOMI is a first Japanese mission to the Mars. The electron and ion spectrometer was onboard NOZOMI for measuring the fluxes of electrons, protons and heavy ions. During the cruising phase of NOZOMI toward the Mars, solar activity was maximum and EIS has observed several solar energetic particles events around 1AU associated by Coronal Mass Ejections (CMEs) and interplanetary shocks. In this paper, we report temporal variation of the solar energetic particles events fluxes which were associated to the flares occurred at October 14th, 1999, March 24th, 2000, and July 12th, 2000 observed with EIS. From this observation, different temporal fluxes variation profiles have seen related to the NOZOMI and the flare point angle.

1. Introduction

Proton event associated with LDE flare often accompanies the CMEs. Thus this kind of solar energetic particle (SEP) thought be originated from the solar wind plasma and accelerated from the interplanetary CME shocks. From a composition ratio of those SEP also support these ideas which are similar to the solar wind composition [e.g. 4].

The interplanetary shock associated with CMEs distribute with very large field so that the temporal variation of the SEP fluxes should be different according to the IMF which can simple define as a relative location between flare point and observer point. Cane has illustrated this feature as following [1]. When observer looks toward the sun, temporal variation of SEP flux from the west side of flare steeply increase and decrease slowly and from the east side of flare shows the slow increase until interplanetary shock reached to the observer.

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In this paper, we report the temporal variation of the fluxes which observed by EIS (described at the next section) from different point around $\sim$ 1AU.

2. Observation

2.1. EIS onboard NOZOMI spacecraft

NOZOMI was launched on July 4, 1998 as a Japanese first mission to the planet Mars. After for the first five month in a near Earth orbit, NOZOMI leave the Earth toward the Mars. Even during the cruising phase of NOZOMI before reach to the Mars (this has planned at the time between December 2003 and January 2004), some scientific instruments including EIS (The Electron and Ion Spectrometer) are working and thus NOZOMI will provide the interplanetary data during the solar maximum period.

The EIS is one of the plasma detectors on NOZOMI which consist with two kinds of telescope (TOF-E and DE-E telescope) for measuring the fluxes of electrons, protons and heavy ions (He, CNO-group, NeMgSi-group, and Fe-group) in the energy range from $\sim$40 keV to a few MeV around the Mars and interplanetary space. Details about the EIS detector has described by Ihara et al. [2, 3].

During the cruising phase, EIS expect to observe the Coronal Mass Ejections (CMEs) in interplanetary space, particles from Corotating Interaction Region (CIR) and other event related to the interplanetary space physics.

2.2. Solar Energetic Particles Events Observed with EIS

Figure 1 shows temporal variation of the proton fluxes (particles/(cm^2 s sr MeV/nucleon)) observed by EIS with the energy of $>$ 140keV during the SEP event. The fluxes shown in the figures were observed by ΔE-E detector of EIS. Each of the figures corresponds to (a) October 14th, 1999, (b) March 24th, 2000, and (c) July 12, 2000 solar flares. Horizontal axis represent the day of year (DOY).

Table 1. List of solar flares corresponds to the Fig 1. The relative location of NOZOMI (NOZOMI to Flare point angle and Earth to NOZOMI angle) are also shown.

Fig 1	Date (Day of Year)	Flare type	NOZOMI - Flare Point angle	Earth - NOZOMI angle
a)	1999/10/14 (287)	X1.8, N11E32	W39.1	E71.1
b)	2003/03/22 (82)	X1.1, N14W57	E178.8	124.2
b)	2000/03/24 (84)	X1.8, N16W82	E153.8	E124.2
c)	2000/07/12 (194)	X1.9, N17E27	W87.9	E114.9
c)	2000/07/14 (196)	X5.7, N22W07	W122.1	E115.1

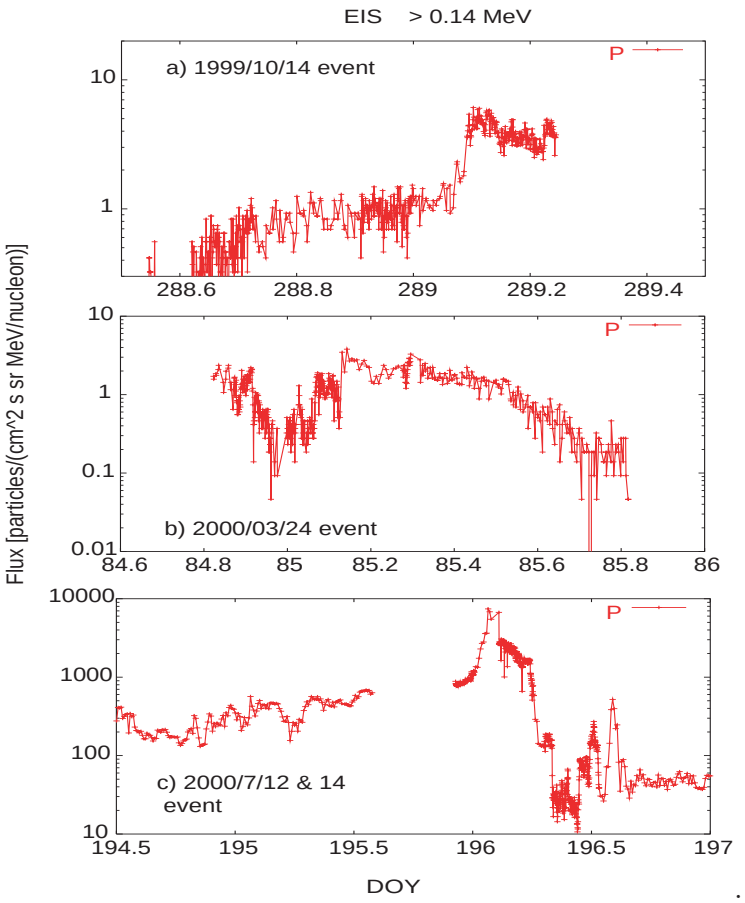

Fig. 1. The temporal variation of proton fluxes with the energy of >140keV during the SEP event. Each figure corresponds to a) October 14, 1999, b) March 24, 2000, and c) July 12, 2000 solar flares. Flares of a) and c) has occurred at the west side looking from NOZOMI toward sun and flare of b) has occurred at the east side.

Flare types and the relative locations of NOZOMI (NOZOMI to Flare point angle and Earth to NOZOMI angle) are summarized at Table 1.

a) October 14th, 1999

The flare size was X1.8 and the NOZOMI to flare point angle was 39.1 degree west. From this event steep increase and the slow decrease of flux has observed at October 16th (DOY=289). Note that EIS did not observe the data for a part after 289.3 day (DOY) which is in the flux decreasing phase.

b) March 24th, 2000

The flare size was X1.8 and the NOZOMI to Flare point angle was 178.8 degree east. From this event relatively slow increase of flux has observed at March

26 (DOY=85) compare to Fig1 (a). The X class flare has been occurred at same active region two day before this flare (see Table 1), figure also shows this decreasing phase.

c) July 12, 2000

The flare size was X1.9 and the NOZOMI to Flare point angle was 87.94 degree west. From this event, steep increase has observed at July 14 (DOY=194) which are similar profile with Fig 1 (a).

3. Discussion and Conclusion

As Fig 1 (a) and (c) shows, when the solar flare occur at the west side looking from NOZOMI toward the sun, we have observed the steeply increasing the fluxes while flare occur at the east side, gradually increasing the flux has been seen. These results indicate the good agreement with the feature described previously which taking account for the IMF spiral structure.

Hence EIS onboard NOZOMI has observed the particles fluxes during the solar maximum phase at the near Earth region and also interplanetary region of 1 $\sim$ 2 AU around the sun. This will make possible to combining with others spacecraft data such as ACE and/or SOHO. This kind of multi spacecraft observations allow us to study the features of large scale interplanetary event related to CME, CIR and etc.

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