Solar gamma ray events detected by the GEOTAIL plasma instrument

Yasuhiro Takei,[1] Toshio Terasawa,[1] Ichiro Yoshikawa,[2] Yoshifumi Saito,[2] Toshifumi Mukai,[2] Hiroyuki Takasaki,[3] and Kazunari Shibata[3]
(1) Department of Earth and Planetary Science, University of Tokyo, Tokyo, 113-0033, Japan
(2) Institute of Space and Astronautical Science, Sagamihara, Kanagawa 229-8510, Japan
(3) Kwasan Observatory, Kyoto University, Kyoto, 607-8471, Japan

Abstract

We have found the MCP (microchannel plate) of the LEP (low energy plasma) experiment aboard the GEOTAIL satellite was activated during large solar gamma ray events (such as the 6 Nov 1997 event). We have studied the statistical relationship between the MCP activations and solar events,@and found that significant activations occurred for X-class solar flares. Since the altitude of GEOTAIL is as high as 8-30 Re, our 'data coverage' for solar events could be nearly 100 percent, if we can separate the gamma ray 'signals' from the nominal counts by plasma particles. Therefore GEOTAIL may provide useful information of solar gamma ray events when the data from other satellites such as YOHKOH and RHESSI are not available.

1. Introduction

During solar flares photons in various wave lengths are emitted. We have found the particle sensors of LEP (Low Energy Particle Experiment, [1]) onboard GEOTAIL are sensitive to the solar gamma ray photons. LEP sensors consist of quadrispheric electrostatic analyzers to measure electrons and positive ions, and make the comprehensive observation of plasma with angular and energy sweeping that uses the spin of the satellite and voltage control of the electrostatic analyzers. For particle detection of LEP the microchannel plate (MCP) for energy ions and channeltrons for electrons are used. We report the event study for the solar flare on 6 November 1997 in this paper.

2. Observations

GEOTAIL was in the plasma sheet on 6 November 1997. The E-t diagrams (energy versus time plot of measured particles) for the electron sensor, the ion

pp. 3223–3226

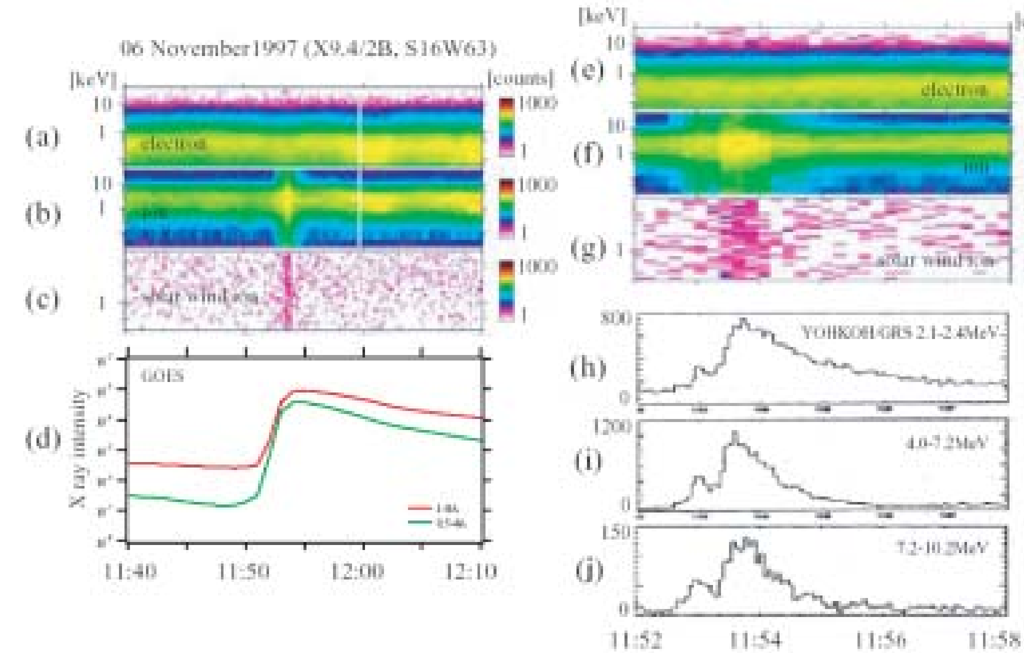

Fig. 1. (a), (b), and (c) are E-t plot for the electron sensor, the ion sensor, and the solar wind ion sensor of the LEP instrument, respectively. (d) shows the soft X-ray observation at two wavelengths (1-8 A and 0.5-4 A) observed by GOES. (e)-(g) are subinterval plot of (a)-(c) in same format. (h)-(j) show the gamma ray intensities at three energy bands, 2.1-2.4, 4.0-7.2, 7.2-10.2 MeV observed by the YOHKOH spacecraft.

sensor, and the solar wind ion sensor of the LEP instrument during the time interval between 11:40UT and 12:10UT on 6 November 1997 are plotted in Figure 1(a)-1(c). The LEP data showed typical particle counts in the plasma sheet during the interval. Around 11:53UT, however, there appeared energy-independent count increases in Figure 1(b) and (c), which were unlikely to be caused by the plasma sheet particles. Figure 1(d) shows simultaneous GOES soft X-ray observation, which shows the initial phase of the solar flare (X9.4/2B, S18W63). The intensity reached the maximum around 11:55UT. In Figure 1(e)-1(g) the subinterval E-t diagrams (11:52UT-11:58UT) of Figure 1(a)-1(c) are shown, and Figure 1(h)-1(j) shows the YOHKOH gamma ray spectrometer observation [2], which provides the evidence of a busty gamma ray emission around 11:53UT. By Comparison between the LEP observation and the solar gamma ray observation we found that the energy independent counts of ion and solar wind ion sensors were caused by solar gamma ray photons. Although the LEP instrument is installed inside the GEOTAIL spacecraft, high-energy solar photons above several hundred keV can penetrate through the GEOTAIL wall (the thickness $\sim$ several mm) and arrive

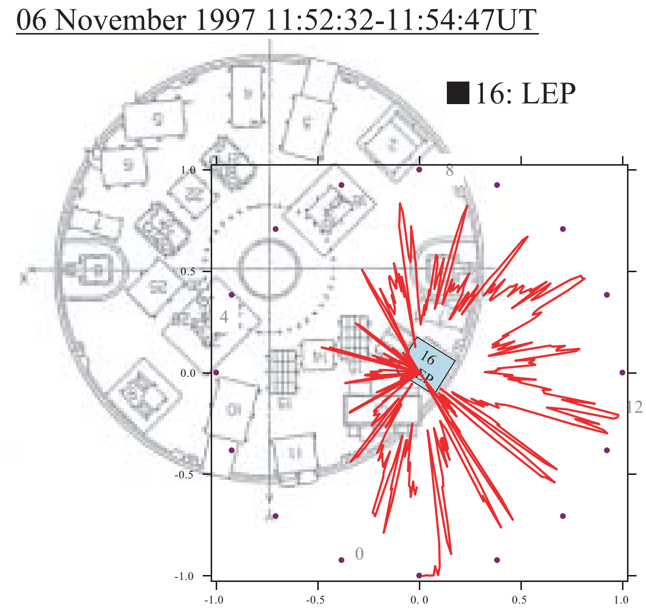

Fig. 2. Projected angular counts plot of LEP ion sensor data during the interval between 11:52:32 and 11:54:47 to the GEOTAIL cross section.

on the sensors of LEP. In the laboratory we have experimentally confirmed that the MCP is sensitive to the gamma ray photons with a quantum efficiency of several %. It is, therefore, natural to conclude that the solar gamma ray photons penetrated to LEP sensors in this event.

The projected angular counts plot of LEP ion sensor data during the interval between 11:52:32 and 11:54:47 to the GEOTAIL cross section is shown in Figure 2. This figure show relative counts for each incoming direction after subtraction of particle counts in the plasma sheet. Figure 2 thus shows how solar gamma ray photons arriving at the detector of LEP were attenuated by the many shielding material inside GEOTAIL (namely, the 'gamma-ray photograph' of GEOTAIL).

3. Discussion and Conclusion

The event study for the solar flare on 6 November 1997 is reported in this paper. We have studied the statistical relationship between the MCP activations and other solar flare events, and found 38 X-class solar flares encountered by GEOTAIL during 1997-2000, of which 15 (about 40%) flares gave the detectable effects on LEP. Most of events were observed by GEOTAIL in the solar wind and the magnetosheath. In the plasma sheet few solar gamma ray events were identified since the plasma counts were quite high (The 6 November 1997 event was an exceptional case). These studies give the following useful information: (1) For future mission coming closer the sun, like the Bepi-Colombo mission to the Mercury, eliminating solar-flare effects are important for plasma instrument. (2) Since the solar gamma ray detection by the LEP sensors or the other particle instruments is almost 100% data coverage, there is possibility to utilize these solar signals for scientific purpose. For example the solar flare gamma rays on 24 November 2000 were detected by GEOTAIL during the YOHKOH night, the GEOTAIL results are found useful in the study of this flare event.

4. References

1. Mukai T., Machida S., Saito Y., Hirahara M., Terasawa T., Kaya N., Obara T., Ejiri M., Nishida A. 1994, J. Geomag. Geoelectr. 46, 669
2. Yoshimori M., Shiozawa A., Kuga K. 1999, Proceedings of the 26th International Cosmic Ray Conf. 6, 5