Spatial Distribution of Energetic Heavy Ions and Its Time Structure in the Radiation Belt

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Abstract

Energetic heavy ions with the energies from 20 MeV/n to 179 MeV/n in the radiation belts were measured by Heavy Ion Telescope (HIT) instrument onboard the "TSUBASA" satellite launched on Feb 2002. We observed four energetic ion events for a period from March 1 to May 30 in 2002. The spatial and temporal features of heavy ions were studied during the period. L-shell distribution of He seems to have a similar structure to that of relativistic electrons in the quiet time. However, the L-shell distribution of heavy ions ($\geqq$ CNO) are different from that of He in L<3. The rapid increase and then short drop of heavy ion($\geqq$ CNO) flux are observed during the short-term geomagnetic disturbance.

1. INTRODUCTION

There was a revival of interest in observing radiation belts, mainly triggered by the measurements of energetic particles. The CRRES spacecraft observed the creation of a new and short radiation belt which was formed by an intense shock in the interplanetary medium, and consisted of protons and relativistic electrons[2,4]. New radiation belts formed by shock-injection events were also observed by SAMPEX[1,5,7]. These unexpected observations created intense interest in both experimental and theoretical/numerical study. SAMPEX found a different radiation belt to be composed of anomalous cosmic rays[3,5]. It is found that the fluxes of electrons and protons in radiation belts are far from static but they undergo a strong change in structure. Recent measurements with high sensitivity and time resolution have given new insights into the behavior of relativistic electrons in the Earth's radiation belts. They provide important and unique information of long-term observations, dynamic processes of sources, redistribution processes, and loss mechanisms of radiation belt particles. Relativistic electrons and energetic protons have played so far an important role in the progress of radiation belt physics, though energetic heavy ions are a good indicator of vari-

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ous high-energy phenomena in space. In addition, space dosimetry, especially of heavy ions, is quite important for protection of electronic devices and astronauts.

We have measured energetic heavy ions in the radiation belts using Heavy Ion Telescope (HIT) instrument[6] onboard Japanese satellite, "TSUBASA," launched on February in 2002. The spatial and temporal features of heavy ion compositions were studied in both the active and quite time of radiation belts.

2. SATELLITE ORBITS AND INSTRUMENT

The Japanese Mission Demonstration test Satellite-1 (MDS-1), "TSUBASA," carries the Space Environment Data Acquisition equipment, SEDA, for measurement of space environment which consists of four instruments. The Heavy Ion Telescope (HIT), one of four instruments in SEDA package, consists of all PIN-typed Si-detectors with the use of an energy loss vs residual energy loss for particle identification [6]. It measures heavy ions with an energy range between 20 MeV/n He and 179 MeV/n Fe in the Earth magnetosphere. HIT has an excellent charge resolution (See ref. [6]). It has a geometric factor of 18–24 cm^2sr depending on the species and their energies. The HIT instrument is located on the X-panel of the spacecraft.

3. OBSERVATIONS

TSUBASA was launched on February, 2002. HIT has been observing since February in 2002 for more than one year in the geostationary transfer orbit of 500 km $\times$ $36,000$ km with an inclination of 28.5°. TSUBASA has been exposed to about 10 times more the radiation than in the geostationary orbit, while it's in this orbit. The solar activity, from the point of energetic ion events, is relatively quiet, because it is in the period from the declining phase to the minimum one. Clear separation of heavy ions from He to Fe was obtained by HIT. Four ion events enhanced in intensity were observed and some of them are periodically coincident with solar rotation. These ion events are dominantly observed for He. The temporal variation of He ion flux with energies of 20–43 MeV/n in the period from March to May in 2002 is shown in Fig. 1. Flux increase of He in the outer radiation belt are closely correlated with the flux increase of electrons (ACE/EPAM) in the interplanetary space during the period from April 17 to April 27. Those flux-increases accompanying major storms are seen from the figure. Major substorm injections of energetic ions accompany Dst depression. In this period, a magnetic storm seems to have caused big changes in the Earth radiation belts, greatly increasing the flux of He ions, probably together with relativistic electrons and protons in some radiation belts.

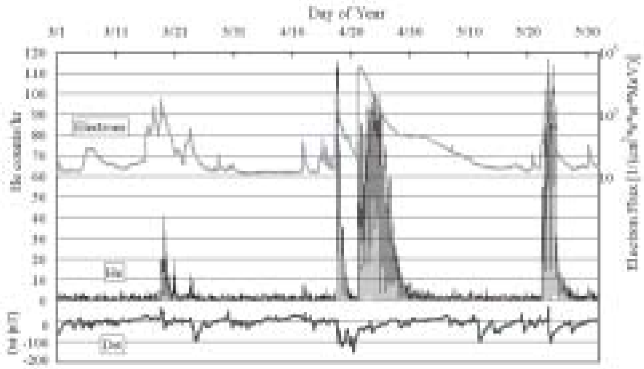

Fig. 1. Time profiles of He counts and electron fluxes in the period from March 1 to May 31 in 2002. He counts (25–43 MeV/n) measured by HIT on TSUBASA in the geostationary transfer orbit and electron flux (0.175–0.315 MeV) measured by ACE/EPAM. Dst is also presented in the bottom panel.

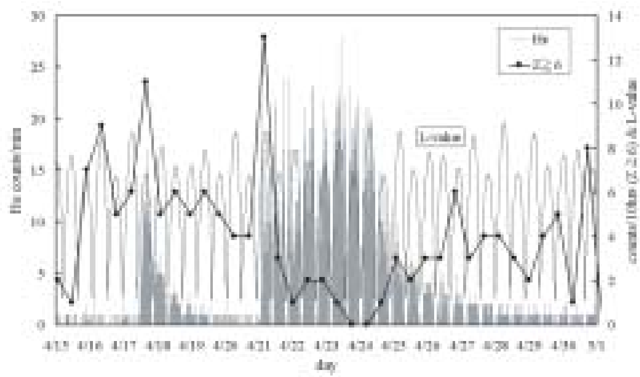

Fig. 2. Time profile of energetic He (25–43 MeV/n) and heavy ion (≧CNO; 50 MeV/n C–179 MeV/n Fe) counts during April 15–April 30 in 2002. Counting rate of heavy ions(≧CNO) was accumulated over one rotation of spacecraft. The heavy ion count rate has just increased for one day or less on April 17 and April 21. Orbit expressed by L-value is also shown.

4. DISCUSSION

Counts of He and heavy ions (Z≧6) in the period from April 15 to April 30 in 2002 are shown in Fig. 2. During this period we observed two ion events, April-17-event and April-21-event. The enhancement of He counts for April-17-event continued for about two days, while Aril-21-event showed about one week enhancement of He counts. The count enhancement of newly injected heavy ions (Z≧6) was just observed for a day or shorter than a day for the two events, and dropped quickly down to a lower level before April-17-event, then recovered after April 26.

L-shell distributions of fluxes of 25–43 MeV/n He ions are shown for the

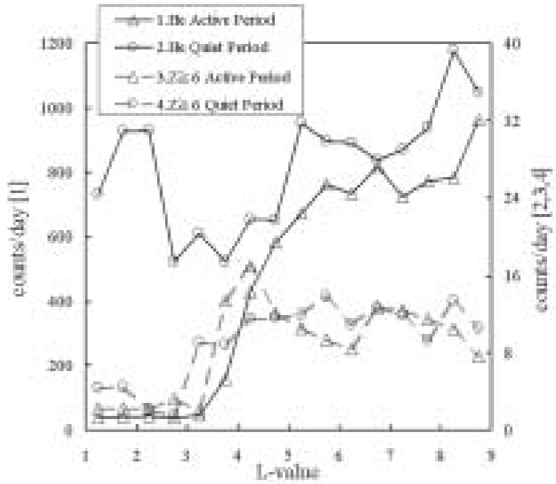

Fig. 3. Count rates of He and heavy ions (≧CNO) as a function of L-value observed by HIT in the quiet and active periods of ion events during March 1–May 31 in 2002. The energy ranges for He and heavy ions (≧CNO) are 25–43 MeV/n and 50 MeV/n C–179 MeV/n Fe. Data in active period are accumulated four ion events.

quiet period and the active ones during ion events in Fig. 3. The quiet-time distribution of He counts has a minimum about L=3, while heavy ion (Z≧6) distribution does not show the increase in the low L-values for both the quiet and active periods. During the active period when energetic ion events are observed, the L-structure of He and heavy ions (Z≧6) are similar each other. Energetic ions relating to the solar event propagate through interplanetary space and impact the magnetosphere. Then energetic ions are injected into the outer radiation belt, and they could have their orbits modified and become trapped.

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