Heavy Ion Telescope onboard the "TSUBASA" Satellite

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Abstract

Japanese Satellite "TSUBASA" has been operating well in the orbit of geostationary transfer orbit since February in 2002 for more than one year. It carries Heavy Ion Telescope (HIT). HIT measures fluxes of heavy ions from helium to iron-nuclei in the energy range from 20 MeV/n for He to 179 MeV/n for Fe. The HIT instrument, based on the $\Delta E \times E$ particle identification method, consists of two position-sensitive-silicon-detectors and 16 PIN-typed Si-detectors with 420μm thickness. The geometric factor is 18–24 cm^{2}sr depending on energies of ions. Energetic ion population relating to solar energetic ion events was observed. Excellent separation of nuclear charge of energetic ions has been obtained for quiet and active periods of geomagnetic activity. Details of the HIT instrument and its recent results of observation in orbit are presented.

1. Introduction

Recent missions of CRESS [1,3], SAMPEX [2,4] and AKEBONO [5, 6] revealed successful results of radiation belts and led a new understanding of the structure and its variation of radiation belt particles, which has revived the study of radiation belts closely coupling to the Earth's middle atmosphere. The sources, redistribution processes and loss mechanisms of particles in radiation belt are primary issues in magnetospheric physics. Energetic electrons hold special interest because of their ubiquity in the Earth's magnetosphere as well as general astrophysical objects. It suggests that the radiation belts are a cosmic accelerator with high efficiency. The measurement of particles in space, moreover, is essential from the point of space dosimetry and bulk charging effects of space vehicles. Measurements of electrons and protons have played an important role in the progress. Only a few missions such as CRESS and SAMPEX , however, carried heavy ions spectrometer so far, though they are a good indicator of various high-energy phenomena in space.

The Mission Demonstration test Satellite-1 (MDS-1), "TSUBASA", was

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launched on February, 2002. TSUBASA has been operating well in the orbit of the geostationary transfer orbit for more than one year. TSUBASA provides a good opportunity to study important issues in radiation belts. It carries the Space Environment Data Acquisition equipment, SEDA, for measurement of the space environment which consists of four instruments. Heavy Ion Telescope, HIT, in SEDA, measures energetic ions in space.

2. Heavy Ion Telescope (HIT)

The Heavy Ion Telescope (HIT), one of four instruments in SEDA package on TSUBASA, measures heavy ions with an energy range between 20 MeV/n He and 179 MeV/n Fe in the Earth magnetosphere. The detector arrangement of HIT is schematically shown in Fig. 1. It consists of 18 Si PIN typed detectors. In order to shield low energy ions and electrons, a particle window made of 2.1 mm thick aluminum is placed in front of the Si stack. The top two detectors are two dimensional position-sensitive detectors, PSD1 and PSD2, to determine the trajectory of energetic ions, and the following 16 detectors are PIN detectors to measure energy loss or residual energy of stopping ions. HIT has a geometric factor of 18–24 cm^{2}sr depending on the species and their energies. The last detector operates as a veto counter.

The electronics includes a pulse height analyzer (PHA) and a data processing unit. Signals from Si detectors are read out by charge-sensitive preamplifiers and fed to shaping amplifiers. The information to determine the trajectories and energy losses or residual energy is processed by 16bit ADC in PHA analysis. Data bits for an ion event and the analysis time are 87 words and 133 μs, respectively.

HIT and its electronics is packaged in the aluminum box of 574 mm $\times$ 414 mm $\times$ 230 mm. The total weight and power dissipation are 27.7 kg and 38.8 W, respectively. The HIT instrument is located on the -X panel of the spacecraft. The characteristics of HIT is listed in Table 1.

3. Preflight Calibration

In the observation of energetic ions in space, the position resolution and its linearity of PSDs and the linearity of energy deposition of Si detectors used in HIT have a great importance for the particle identification. Careful check and precise calibration are required for each Si detector and integrated HIT system. The characteristics of the HIT instrument were obtained using heavy ion beams from the RIKEN Ring Cyclotron accelerator. Firstly, monochromatic Ar beam was irradiated to check the position response and the detector uniformity of Si detectors used in HIT. Then fragmented beam produced by Ar ions with energy of 90 MeV/n was used for the particle identification of ions by HIT. Fig. 2(a) shows the scatter plot of energy loss ΔE in detectors D1-D5 vs. total energy E for the

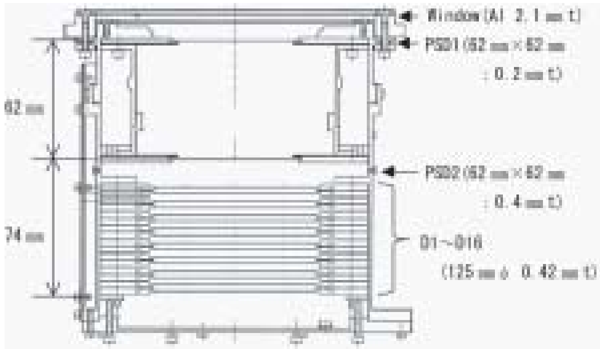

Fig. 1. Schematic drawing of the Heavy Ion Telescope (HIT) in the SEDA instrumental package carried on the "TSUBASA" satellite.

Energy Range (MeV/n)	He:	20	–	43
	C:	39	–	80
	O:	45	–	98
	Si:	63	–	132
	Fe:	86	–	179
Dynamic Range	PSD1 High-Gain			100MeV
	PSD1 Low-Gain			1400MeV
	PSD2 High-Gain			100MeV
	PSD2 Low-Gain			2100MeV
	D1 – D16:			2100MeV
Energy Resolution	16bit			
Geometric Factor (cm2sr)		18	–	24

Table 1. Characteristics of the Heavy Ion Telescope (HIT) on the TSUBASA satellite.

fragmented ions stopped in the detectors D1–D15. Charge histogram from He to N is shown in Fig. 2(b). We confirmed that elements from He to N are clearly separated. Charge resolutions for He and N are 0.49 and 0.36 amu in fwhm. In addition to nuclear charge separation, the mass separation of light elements like Be, B and C can be seen in Fig. 2(a) and Fig. 2(b).

4. Initial Flight Data

TSUBASA was launched on February, 2002. It has been operating well since February 14, 2002 for more than one year in the geostationary transfer orbit of 500 km × 36,000 km with an inclination of 28.5°. While it's in this orbit, TSUBASA will be exposed to 10 times the radiation more than in the geostationary orbit. HIT observes energetic ions from He to Fe-nuclei in the period from the declining phase to the minimum of solar activity. Fig. 3(a) shows the counting rates of He(20–40 MeV/n) for the period for March in 2002 to March in 2003. Several peaks relating to solar energetic particle (SEP) events are seen in the figure. In general, these ion events have so steep spectra that the fluxes of heavy ions with energies greater than 40 MeV/n are small. The statistics of He counts are enough but counts of ions heavier than CNO are small. Fig. 3(b) shows the results of charge histogram ($2 \geqq Z \geqq 26$) observed for one year starting from March in 2002 by HIT. As can be seen from the figure, nuclear charges of energetic ions stopping in the telescope are highly resolved.

HIT on TSUBASA have been measuring heavy ion composition and its variation in the radiation belt and those data obtained contribute to the modeling of radiation belt and the transport mechanism of ions from interplanetary space to inner magnetosphere of the Earth.

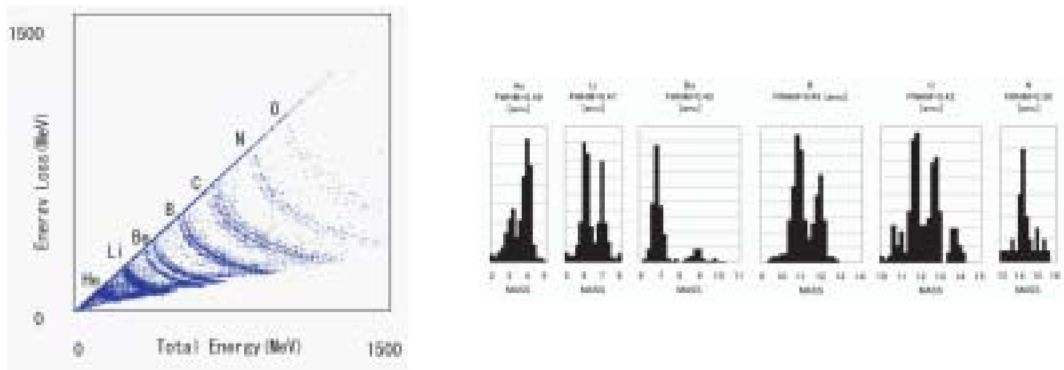

Fig. 2. **(a)** The $\Delta E \times E$ scatter plot for the HIT instruments boarded on the "TSUBASA" satellite obtained from fragmented beam produced by 90 MeV/n Ar with an Acrylics target. The ordinate (ΔE) and abscissa(E) represent the energy loss in detectors from D1 through D5, and the total energy of particles stopping between D1 and D15, respectively. **(b)** Charge histogram of fragments in the Z = 2 − 7 produced by Ar beam obtained by HIT for the data plotted in Fig. 2(a).

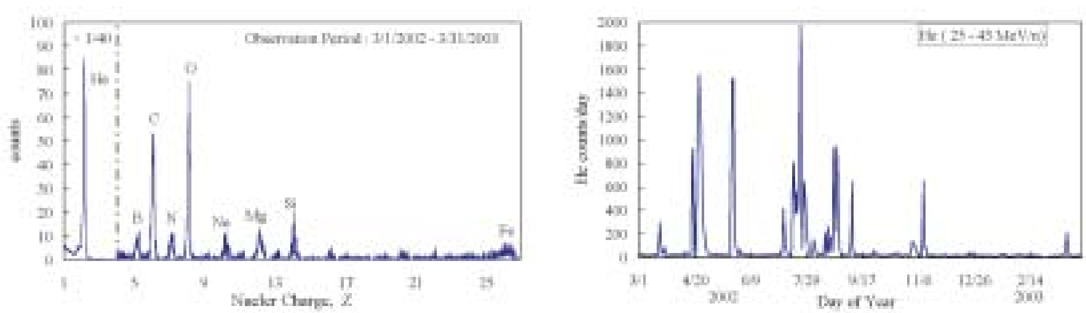

Fig. 3. **(a)** Time profile of He counts for the period from March in 2002 to March in 2003. The energy interval is 25–43 MeV/n for He. **(b)** The histogram of energetic ions in the Z = 2 − 26 charge range observed by HIT orbiting in the geomagnetosphere. Ion data for the period from March in 2002 to March in 2003 are taken in the analysis. Clear separation of elements in the energetic ions can be seen.

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