Evaluation of Radiation Dose in Space Environment

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Introduction

For the purpose of the radiation protection from damage of semiconductors installed in a satellite or astronauts in manned space vehicles, there is a great need of a knowledge of the fluences, energies and charges of the radiation particles in space. The space radiation consists of three main categories according to their source; (1) trapped particles, (2) galactic cosmic rays (GCR) and (3) solar particle events (SPE). Among of these radiations, geomagnetically trapped particles which are known as Van Allen Belt have a large contribution to absorbed dose due to its large amounts and high energy.

On February 20th, 1989, the Institute of Space and Astronautical Science launched an aurora observation satellite EXOS-D (AKEBONO). Since this satellite has a trajectory through the Van Allen Belt having high intensities of electrons and protons, the RaDiation Monitor (RDM) including High Energy Particle Monitor (HPM) was installed in it to measure these particles. We have analyzed the measured data, and compared with the models of the National Aeronautics and Space Administration (NASA) which is commonly used.

HPM detector

The High energy Particle Monitor (HPM) uses four silicon semiconductor detectors (0.2 mm-thick, 10 mm-diameter) with absorbers of Al (100 μm-thick), Cu (0.7 mm-thick), and Ta (2 mm-thick) put among these SSDs as shown in Figure 1. These SSDs can measure the protons, electrons and alpha particles separated by energies shown in Table 1. The HPM detector is covered with a conical collimator, and its geometric factor is about 0.024 cm^2 sr for electrons and protons, and 0.22 cm^2 sr for alpha particles.

Flux on satellite trajectory

Figure 2 shows an example of the particle intensity data with the passage of Universal Time on March 10th, 1989. The top graph is the proton intensity of 6.4 MeV – 15 MeV in particles per cm^2 per second, the second is the electron intensity of 0.25 MeV – 0.7 MeV in the same unit. The third and fourth graphs are the satellite orbit parameters, geomagnetic latitude and altitude respectively. This figure indicates that the satellite perigee was near North Pole, and the apogee in about middle latitude on the southern hemisphere.

Figures 3 and 4 are the results of electron and proton fluxes averaged from the data collected for a week, compared with the calculation by the NASA models for trapped particles, AP8MIN[1)] for proton and AE8MAX[2)] for electron. The calculated flux is averaged from the intensities calculated over the trajectory for 56 weeks obtained from the orbit calculation code ORB.

With considering the difference of averaged time intervals, a week for observation and 56 weeks for calculation, the measured electron flux roughly agrees with the calculation, especially in the spectral shape, but the disagreement can be clearly seen for protons. This discrepancy may partly come from the inaccurate response function of detectors for protons.

Dose calculation

Using the flux calculated from the trapped particles models, AE8MAX and AP8MIN, we calculated the absorbed dose in a 70 cm radius sphere of homogeneous aluminium of 0.3 g/cm^3 density which approximated the EXOS-D. The codes to calculate the dose are HERMES[3)] and SHIELDOSE[4)] for protons, EGS4[5)] and SHEILDOSE for electrons. The results are shown in Figures 5 and 6. The SHIELDOSE code can calculate only for 2.7 g/cm^3 density aluminium, so we converted the result to that of 0.3 g/cm^3 density to compare with the results of EGS4 and HERMES.

The SHELDOSE results agree well with the EGS4 and HERMES results, excluding near the surface of the sphere. From these comparison, the easy-handling SHIELDOSE code is possible to use with sufficient accuracy for calculation of a simple geometry like sphere.

We can find from these results that primary particles stop within about 8 cm thick aluminium, so that this thickness needs to shield radiations on the EXOS-D orbit. Since the present evaluation is based on a very simplified model, we intend to calculate the absorbed dose in the satellite in more detailed geometry.

References

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Table 1. Particles and energy ranges to measure

ch	particle	energy range [MeV]		
eE1	proton	30	-	38
eE2	proton	15	-	30
eE3	proton	6.4	-	15
pE1	electron		>	2.0
pE2	electron	0.70	-	2.0
pE3	electron	0.25	-	0.70
A	alpha particle	15	-	45

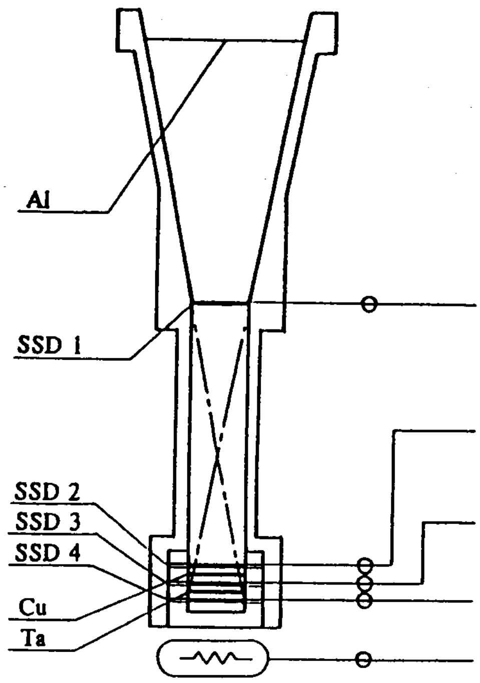

Fig. 1. Schematic view of HPM detector on EXOS-D

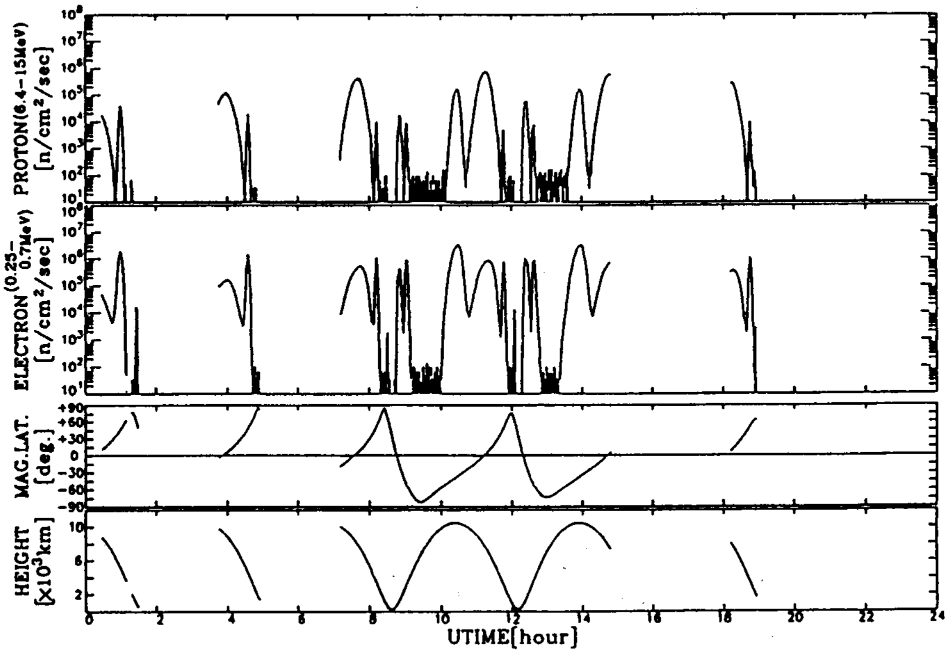

Fig. 2. Particles intensity on 1990.3.8

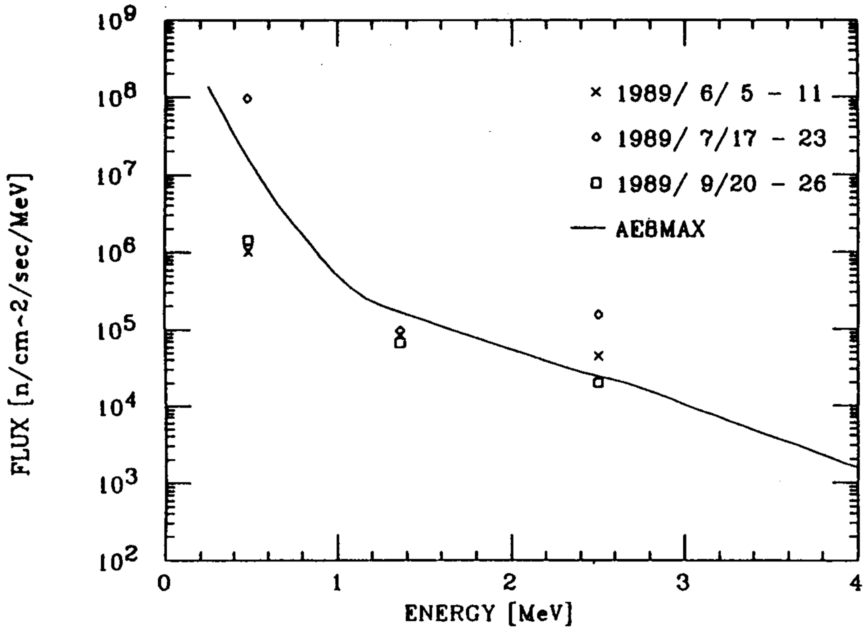

Fig. 3. Electron flux on the trajectory of EXOS-D

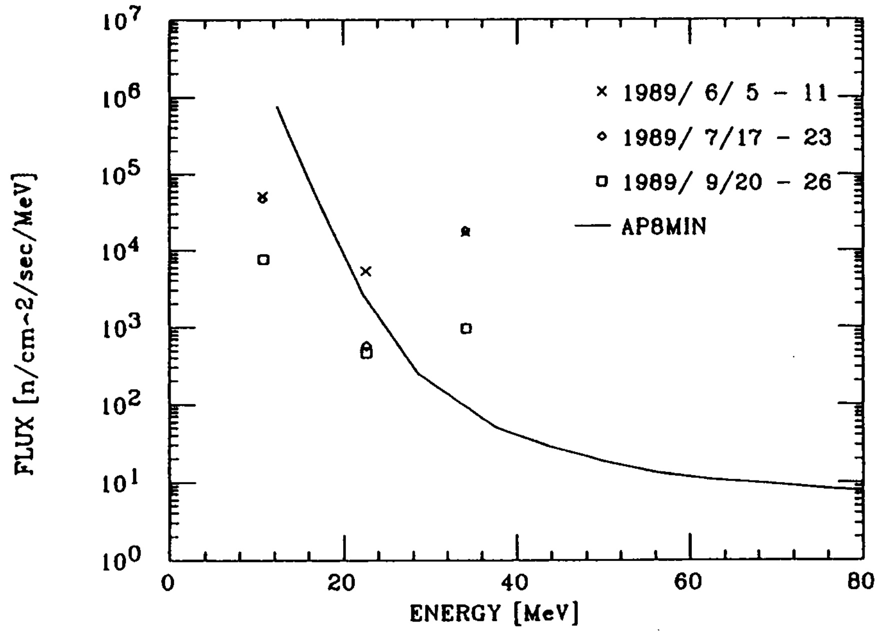

Fig. 4. Proton flux on the trajectory of EXOS-D

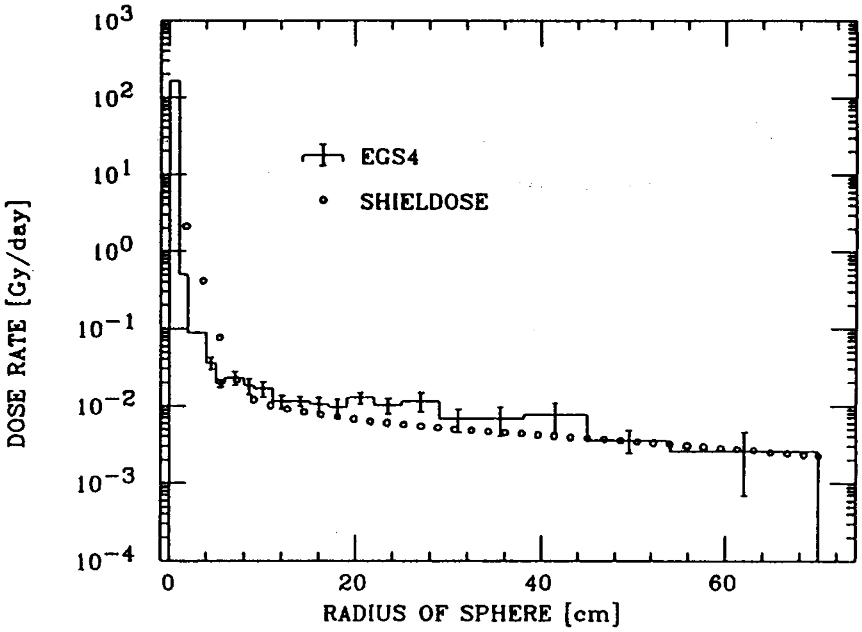

Fig. 5. Dose distribution in 70cm-radius Al sphere by electron

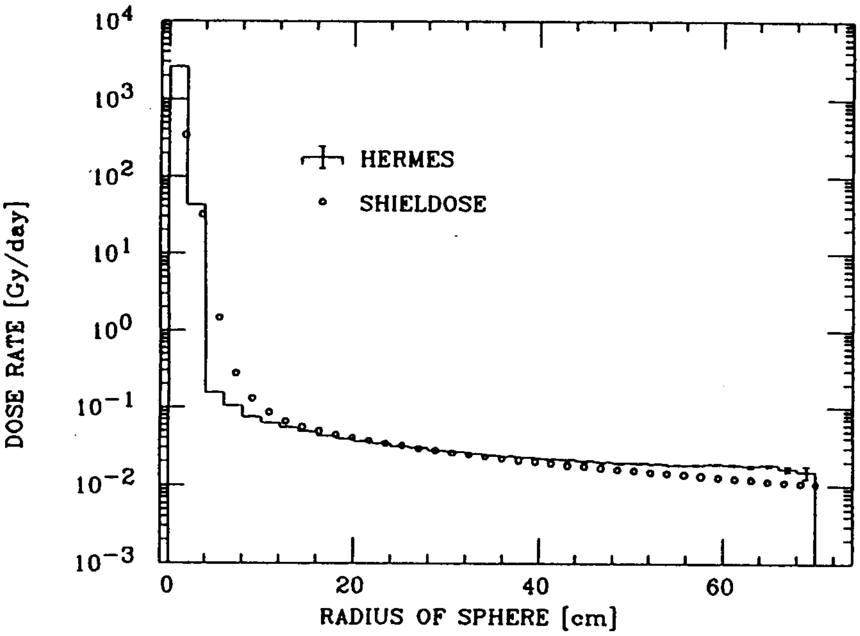

Fig. 6. Dose distribution in 70cm-radius Al sphere by proton