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Data on Radiation Belt and Solar Energetic Particles deduced from Dosimetry in Low Earth Orbits

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Abstract

A small particle telescope based on two silicon detectors was flown on three NASA Shuttle-to-MIR missions and on the Russian orbital station MIR behind a shielding of about 10-20 g/cm² in low Earth orbits at 51.6 degree inclination during 1996/98. The instrument was designed to measure count rates and dose rates as well as energy deposit spectra (in silicon) of the radiation inside the spacecraft. The count rate dependence on the L-parameter for crossings of the inner and outer radiation belts as well as preliminary results from the Nov 6, 1997 SEP event are presented.

1 Introduction

Radiation is a primary concern for manned spaceflight and is a potentially limiting factor for long-term orbital and interplanetary missions. Since the beginning of manned spaceflight, the problem of radiation protection from the multiple sources of ionising radiation of the space environment has been a permanent topic of experimental biomedical research in nearly all spaceflight missions. Dosemeters were therefore part of each manned mission.

Dosimetry packages may use passive (integrating) and/or active devices. Active dosimetry provides information on temporal changes of the dose rate in orbit and can separate the contribution of galactic cosmic rays, radiation belt particles and sporadic SEP events. Mission averaged dose rates in silicon, recently measured with our instrument DOSTEL in LEO, are in the range 98-108 $\mu Gy.d^{-1}$ and 137-178 $\mu Gy.d^{-1}$ for the GCR and SAA contributions respectively (Beaujean, Kopp & Reitz, 1999). These values indicate the weight of the SAA contribution. Actual measurements are required to improve the radiation belt models which are used to calculate the radiation risk for future LEO missions.

2 Instrumentation and Mission Description

The instrument DOSTEL is based on two identical passivated implanted planar silicon detectors and designed to measure the energy deposit of charged particles. Both detectors have a thickness of 315 μm and a sensitive area of 693 mm². They are mounted at a distance of 15 mm forming a telescope with a geometric factor of 824 mm².sr for particles arriving from the front. The same geometric factor is valid for particles coming from the rear, which have to pass through PC boards. The instrument can be operated in a single detector mode (no coincidence required) for count and dose rate measurements in the individual detectors or in the telescope mode in order to limit the pathlength for energy deposit distribution measurements. Additional hardware and operation description is given elsewhere (Beaujean, Kopp & Reitz, 1999).

The instrument was flown as part of the Dosimetric Mapping experiment (PI: G. Reitz) inside Biorack on Shuttle-to MIR missions STS76 (Mar 22-31, 96), STS81 (Jan 12-22, 97) and STS84 (May 15-24, 97) and as part of the ADCP experiment (PI: J.U. Schott) during the NASA6 mission in the Kristall module on MIR (Oct 9, 97 - Jan 28, 98). The orbit inclination for all missions was 51.6 deg at an altitude of about 390 km which is similar to the orbit parameters of the future International Space Station. The shielding around the instrument depends on the viewing direction, the average is estimated to about

10-20 g/cm². Shuttle mission data in this paper were measured with the telescope axis pointing vertically out of the shuttle cargo bay; STS76 data and STS84 data from a second DOSTEL unit are not discussed.

3 Results and Discussion

Prime objectives of the DOSTEL measurements were count and dose rates. Fig. 1 (top panel) shows the measured DOSTEL count rate on Nov 6, 1997 during the NASA6 mission inside MIR. The low peaks occur at high latitude orbit segments, whereas the first three major peaks are due to ascending crossings of the SAA. All minima indicate crossings of the cosmic ray equator. The first phase of the SEP event, as measured by the EPHIN instrument on SOHO (Bothmer, 1999), is well detected inside the MIR station. Unfortunately we lost DOSTEL data during this event after the fifth half orbit segment for a long period (and data of the Nov 4 event as well). At the time being detailed information on the actual shielding and pointing of our instrument and the MIR orbital position are not available to us.

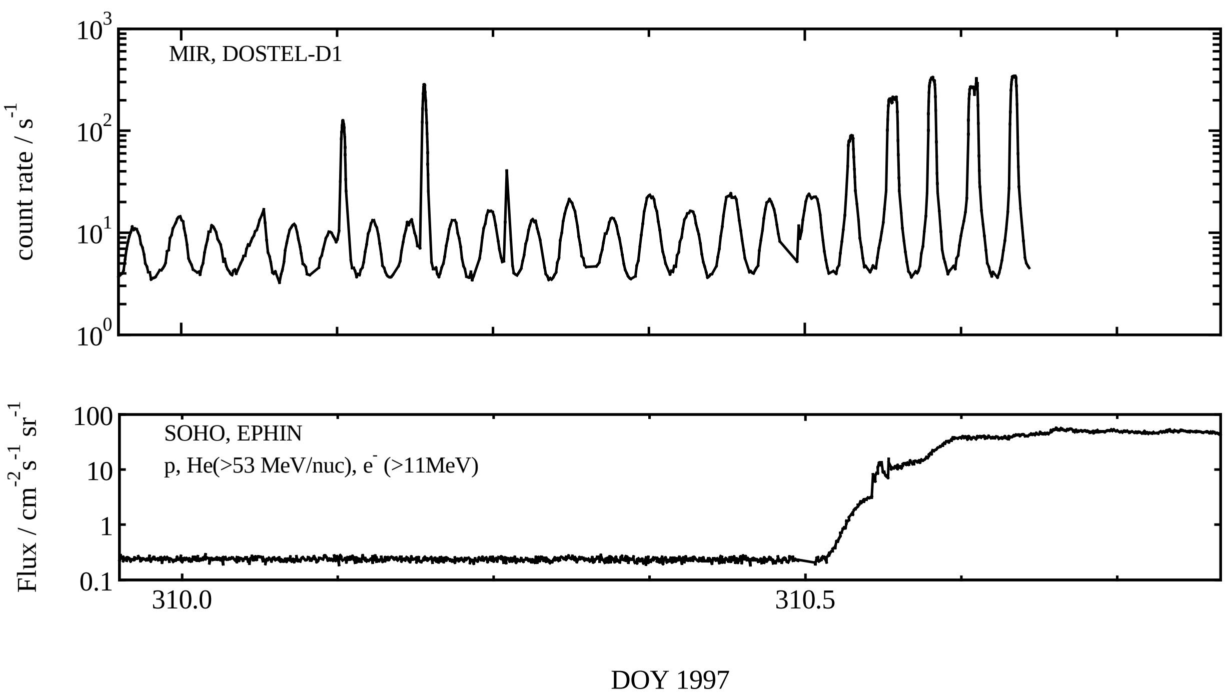

Figure 1: DOSTEL count rate inside MIR (top) and EPHIN data on SOHO (bottom) during Nov 6, 1997.

In order to demonstrate the dosimetric characteristics of the three main radiation contributions including secondary particles, Fig. 2 shows the energy deposit distribution of GCR and SAA particles averaged during five quiet days and of the SEP event averaged over the available SEP data for orbit segments above 45 deg latitude on both hemispheres. The peak in the GCR distribution belongs to high energy particles with charge Z=1. Obviously the SAA and SEP contributions show a different slope compared to GCR due to the different energy spectra of the detected particles. It can be deduced that the SEP event contains more high energy particles than the proton radiation belt (harder energy spectrum).

During STS84, significant small peaks were detected in excess of the normal count rate maxima at specific high latitude positions. Fig. 3 shows an example from the beginning of the mission when these excess peaks occur very clearly. The highest peak at about 12.6 h belongs to a descending crossing of the SAA. In order to study the count rate in dependence of the geomagnetic position, the shuttle orbit position data files were used to correlate the measured count rate with L-parameters (NSSDC 1999). The result is depicted in Fig. 4 for STS81 and STS84.

Three contributions can be separated:
a) the narrow band of GCR particles stretches from L=1 to L=6;
b) particles from the inner belt were detected at L=1.2-1.8 with count rates increasing by two orders of magnitude. The analysis of our STS84 measurement verified the strong anisotropy of this contribution (Kopp et al., 1998);
c) a small contribution of the outer belt is detected at L=3-5.

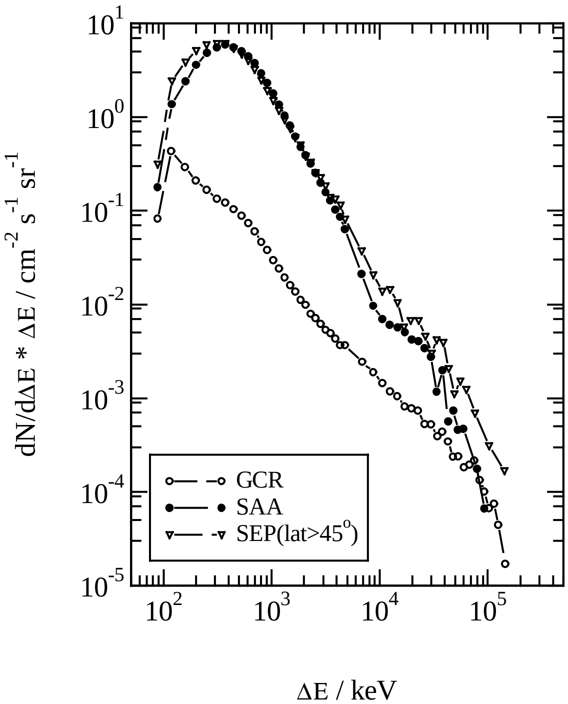

Figure 2: Energy deposit distribution in the top 315 µm Si-detector (coincidence mode, inside MIR).

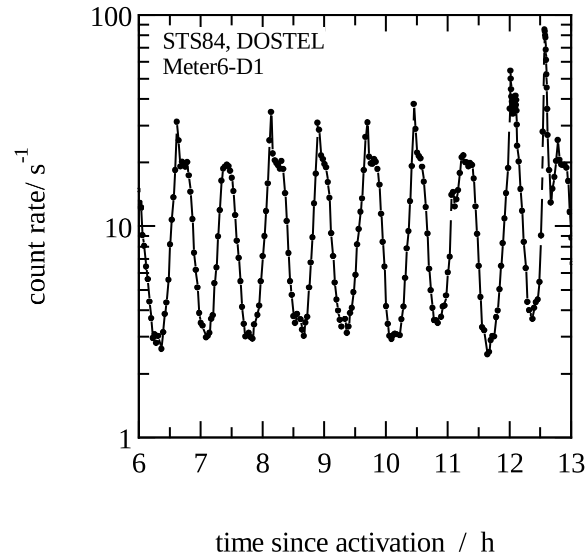

Figure 3: Count rate on STS84 versus elapsed time.

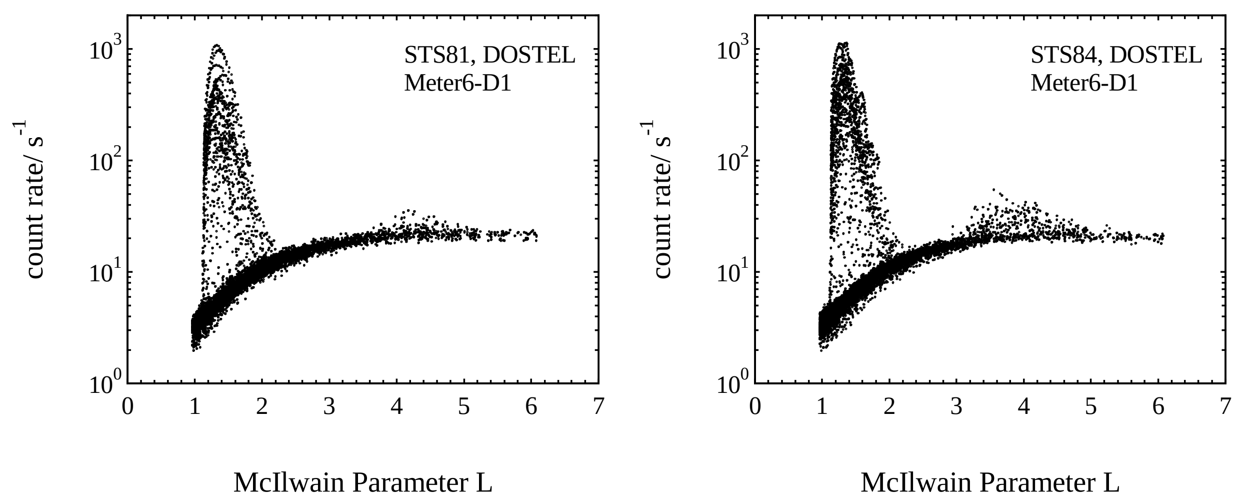

Figure 4: Count rate on STS81 (left) and STS84 (right) versus L-parameter in 390 km altitude.

The GCR and SAA results are very similar in both missions whereas the outer belt contribution above L=3 shows a difference. In this region, the excess of counts above the band of GCR counts is attributed to interaction of secondary photons (γ) which are produced by electrons from the outer belt in the region of the horns by interaction with the spacecraft. The contribution of the electron belt in count rate is higher on STS84 compared to STS81 and the location of the highest contribution has shifted from L=4.2-4.5 in STS81 to about L= 3.6 in STS84. Similar dynamics were observed before by the REM instrument on MIR (e.g. Buehler et al., 1996). The contribution of the electron belt to the measured dose rate inside the spacecraft is negligible.

Fig. 5 shows the geographical positions with count rates exceeding the band of GCR count rates versus L of Fig. 4. It displays the location of the SAA and the region where the electron belt contributes to the count rate in LEO. Contour lines for the SAA protons are in progress taking into account detailed Shuttle attitude and altitude information.

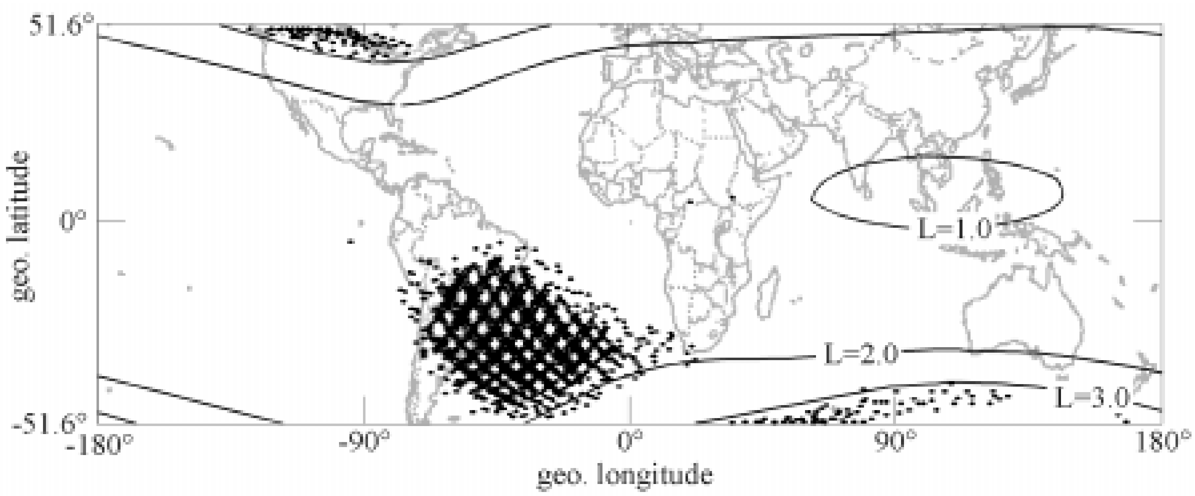

Figure 5: Geographical positions of inner and outer belt contributions to the count rate on STS 84.

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References

Beaujean, R., Kopp, J. & Reitz, G. 1999, Active dosimetry on recent space flights, accepted for publication in Rad. Prot. Dosimetry

Bothmer, V. 1999, Solar corona, solar wind and solar particle events, Conference Proceedings, ESA Workshop on Space Weather, Nov. 98, publ. by ESA

Buehler, P., et al. 1996, Radiation environment monitor, Nucl. Instr. Meth. A368, 825

Kopp, J., Beaujean, R., Reitz, G. & Schott, J.U. 1998, Radiation measurement on manned space flights, COSPAR 1998 General Assy., Paper F2.1-0010, to appear in Adv. Space Res.

National Space Science Data Center 1999, http://nssdc.gsfc.nasa.gov