Active Dosimetry of Charged Particles (ADCP)

Experiment ID: 681

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Preliminary Research Report

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Introduction

With the advent of manned space flight, radiation risk assessment entered new dimensions. It encountered the energetic heavy particle component of the space radiation field, a radiation quality being absent on earth and hence without established risk estimates. The lack of adequate radiobiological data for risk assessments enforced experiments on radiobiological effects of single heavy ions, ground based and in space.

Measurements of the spectra of charged particles and their linear energy transfer yield basic physical parameters for the assessment of the radiation risk to men in space on the base of the specific radiobiological efficiency of particles of different charge number and energy deposition.

Previous experience with the measurement of the physical parameters of heavy ions in space was obtained with integrating passive solid state nuclear track detectors, mainly. With the use of time resolving active detectors, these measurements can be correlated to orbital parameters and thus to radiation components of different origin.

Hypothesis

Radiation doses deposited in orbital spaceflight by charged energetic particles mainly depend on orbital parameters, solar activity and mass shielding of the spacecraft. All these quantities are subject to changes within a dedicated space mission as well as from mission to mission. The experiment measures particle spectra and spectra of their Linear Energy Transfer (LET) for mean quality factor calculations inside the Mir module with temporal and spatial resolution. These data contribute to radiation risk estimates and to improvements of radiation transport codes.

Objectives of Experiment

Based on two passivated implanted silicon detectors (PIPS) of 300 microns thickness and 6 cm^2 sensitive area each (stacked on top of each other), the time profile of dose and particle rate is measured with an integration time of 100 sec and 20 sec outside and inside the south-atlantic anomaly (SAA) region respectively. Separate linear energy transfer (LET)-spectra in the range from 0.1 to 200 keV/µm water are available for each crossing of the radiation belts in the SAA and for each orbit. The system is capable to manage fluxes of 10^3 particles/cm^2 s with full LET-analysis, which is sufficient for measurements inside the SAA.

The time resolved angular distribution of heavy charged particles will be obtained from particle effects in the pixels of Charge Coupled Devices (CCDs). Three of them in telescopic arrangement measure the coordinates of the impinging point of a particle with a local resolution of 15 µm. The analysis of coinciding signals results in the determination of the direction of a single particle or the angular distribution of all particles detected, respectively. The sensitivity of the CCDs is 2 keV/µm, which corresponds to the detection of protons up to 60 MeV, He-ions up to 400 MeV and heavier particles at any energy.

Together with shielding data at the site of the detector sets, calculated from three dimensional mass models of the Mir station, tranport code models will be tested for the radiation environment inside and outside the SAA. The final results of the experiment are expected to contribute to predictable

quantities of the radiation load from the particle radiation field depending on orbital parameters and the mass shielding environment.

Previous Mission Experience

The PIPS device has measured LET spectra inside Biorack on US-Space-Shuttle missions STS76, STS81 and STS84 (DOSTEL-Experiments). The CCD telescope was used in the EUROMIR'95 program.

Research Operations

Discussion of Method/Protocol

The aim of the experiment is to gather radiation data of charged particles througout the mission in order to obtain the variation of its spectra with orbital parameters as well as with temporal fluctuations. The evaluation of those data sets permit to discriminate them from the origin of the radiation, the cosmic component and contributions from the radiation belt at the site of the South Atlantic Anomaly (SAA) as well as solar particles from unpredictable flare events.

The PIPS detector set is based on the DOSTEL equipment proven sucessfully in earlier spaceflight experiments. Power and data transfer have been adapted to the experiment computer (CEC). Once in 5 or 10 days, the data stored in the internal memory of DOSTEL has been transfered to the harddisk of the CEC.

For the angular resolved detection of particles a telescopic set of Charge Coupled Devices (CCDs). Together with the DOSTEL device they are housed in the Particle Telescope Head (PTH). For the reading of particle events in the CCDs, three chanell TV image analysis hardware has been used. Due to the limited data storage capability and downlink restrictions, the data have been reduced onboard to frames showing coincident particle events in two or three CCDs. Online digitizing and threshold checking for every pixel have been used for particle event recognition and triggering for data storage. In order to avoid wrong triggering caused by the potential occurance of a hard error in a single pixel by the passage of a single heavy ion, the threshold for triggering has been set on the difference image of the live frame and the previous frame.

The experiment is operated on a menue base. With switching ON the experiment starts automatically with a default program and default parameters for trigger conditions and trigger threshold. On request, the crew may choose different programs for radiation measurements and change the parameters.

Internal routines control the data management system of the CEC. Data blocs of 360 Mbyte are transfered from the harddisk to a magnetic tape. Actual status of the experiment and necessary exchanges of tape cartridges are displayed to the crew. Some operational data and samples of scientific data have been transfered to a floppy disk for data downlinking.

List and Desciption of All Functional Objectives

FO1. Installation of CEC and PTH:
FO2. Activate ADCP
FO3. Read status of experiment
FO4. Set program and parameter
FO5. Exchange tape
FO6. Downlinking data samples
FO7. Rebooting of CEC
FO8. Backup and software reset

FO9. Deactivation of ADCP
FO10. Deinstallation

List and Desciption of All Hardware Items Used

All HW items are PI provided.

HW1. CHAPAT Experiment Computer (CEC)
HW2. Particle Telescope Head (PTH)
HW3. Cable POWER
HW4. Cable DATA
HW5. Magnetic Tape Cartridges
HW6. Storage Bags for all HW items

Sessions Table

FO3 and FO6 was not performed periodically, as requested, but whenever crewtime was available.

For sessions and functional objectives see Table 1.

Results

List of Pre-, In-, Postflight Anomalies

Preflight Anomalies

None to report

Inflight Anomalies

Communication problems occured, which caused delays for the exchange of the cartridge of the tape recorder, two of the tapes have been damaged. Due to the reduced transfer of status data and scientific data samples and delays in the availability of these data, about 20% of measuring time was lost for trouble shooting.

Postflight Anomalies

None to report

Completeness/Quality of Data

The hardware and the data tapes were completely sent back to the PI's lab. 13 tapes have been used during the mission. Two tapes are damaged, the other tapes are readable.

Preliminary Research Findings

All investigations reported are based on the evaluation of data obtained from the magnetic tapes returned to ground.

Fig. 1 shows the dose rate measurement with DOSTEL for 24 hours on October 25, 1997. Three features can be seen: a) small maxima of the cosmic ray flux every 45 minutes during hight latitude positions with minima at the cosmic ray equator crossings, b) long time variations of the cosmic ray flux at the high latitude maxima values during 24 hours according to the longitude/latitude dependence of the magnetic shielding (cutoff) for the Galactic Cosmic Rays (GCR) inside the earth magnetic field, c) high fuxes along the path through the South Atlantic Anomaly (SAA) due to the large proton population in the inner radiation belt. For a detailed analysis of these SAA crossings the attitude information for the DOSTEL telescope is needed in order to correct the measurement of the highly anisotropic radiation of the radiation belt.

A dosimetry highlight during the NASA6 mission were the solar energetic particle (SEP) events on Nov 4 and Nov 6, 1997. Fig. 2 shows the DOSTEL data in correlation to GOES data. Unfortunately the DOSTEL data during the high flux phase of the Nov 4 event were completely lost and for the Nov 6 event only data during the initial phase of the event are available. However, during the onset of the Nov 6 event the MIR station was in the most favourable orbital position (i.e. lowest cutoff portions of the orbit) and therefore the DOSTEL measurement reflects the onset and the period of the highest SEP dose contribution. The obvious feature of the SEP event is the presence of high dose maxima at high north and south latitudes, which are comparable to the date experienced during SAA crossings.

Fig. 3 shows preliminary differential LET spectra for the three main constituents of the radiation field. GCR includes the radiation during quiet times outside the South Atlantic Anomaly, SAA contains mainly trapped protons (with minor GCR background) measured during crossings of the radiation belt over the South Atlantic, SEP were measured at latitudes >45 degree during the peak fluxes of the Nov 6 event. All these measurements reflect the radiation environment inside the Krystall module.

Table 2 summarizes preliminary mean values for the measured dose, the quality factors and the dose equivalents for a 5 day period not affected by solar particles.

The data of the CCD telescope have been investigated first for the temporal distribution of stored frames. Fig. 4 shows the trigger rate during Oktober 17, 1997 together with the dose rate measured by DOSTEL. The increased trigger rate during the passage of the SAA shows that the CCD telescope is sensitive to protons. The lower sensitivity of the CCD telescope does not permit to resolve the periodical fluctuations of the cosmic ray proton fluxes due to the magnetic shielding (cut-off).

Trajectories of single heavy particles have been detected based on the analysis of coincident particle events in all CCD sensors. As a quick lock, the coindidence frequency has been investigated in dependance of the signal of the event in any of the CCDs. Fig. 5 shows the differential spectrum. The event size is related to the LET of the particle. Event size and geometry of these coincident events clearly correlates them to the passage of a single heavy particle.

For radiation tranport calculations, the shielding function at the site of the PTH has been derived from the mass distribution of the Kristall module.

Conclusion

The data obtained from both sensor systems are in good aggreement with each other. DOSTEL measured the doses of GCR, protons of the SAA and SEP contributions during the initial phase of the Nov. 6 solar flare event and determined the mean quality factors for the GCR and the SAA protons in the Kristall module of Mir. The CCD telescope is capable to detect single heavy particles spatially resolved.

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Fig. 1 Measured time profile of the dose rate in a single Si-detector.

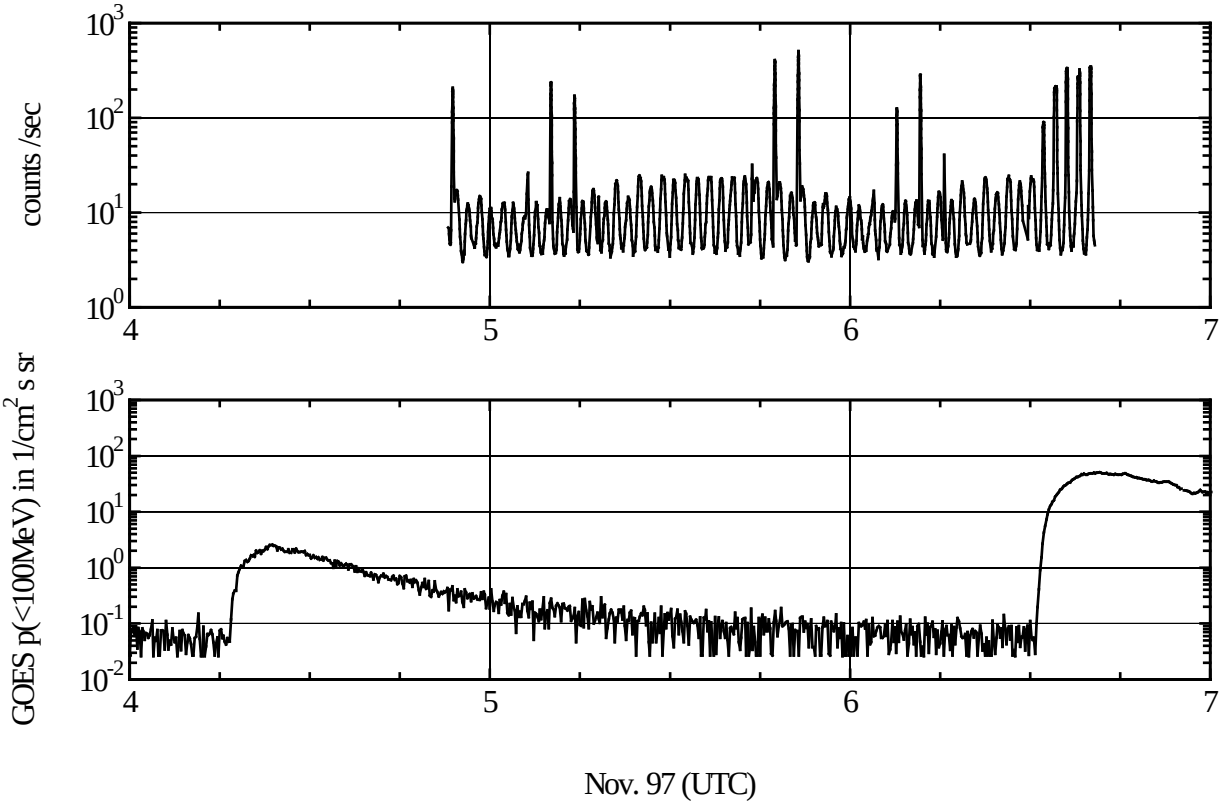

Fig. 2. Time profile of the count rate measured onboard the MIR station during the November 06 1997 solar particle event (top panel) and of protons measured on the GOES-satellite (NOAA, 1997) (bottom panel).

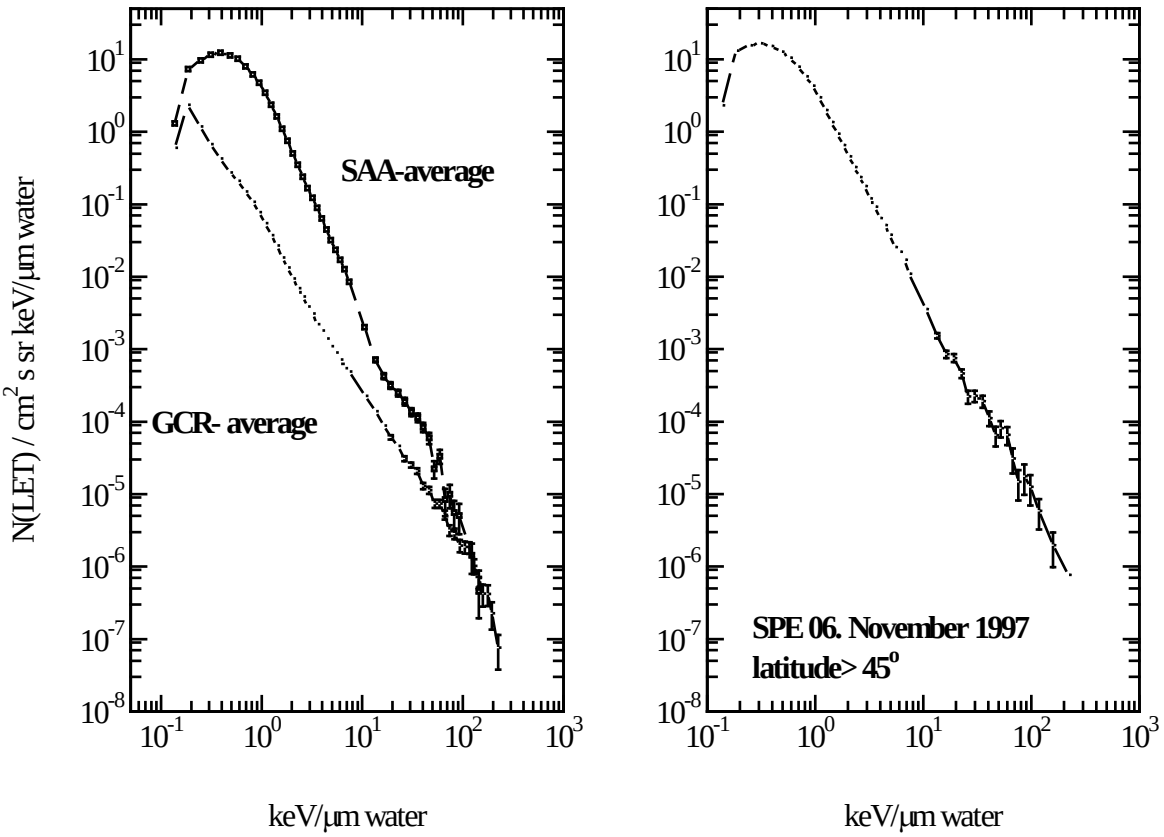

Fig. 3 Measured LET spectra for the different components of the radiation field.

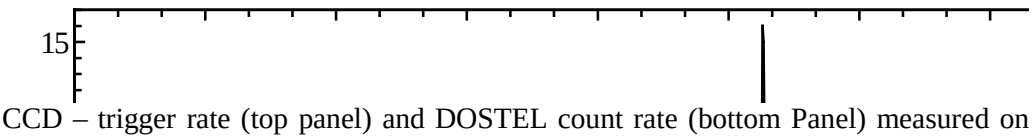

Fig. 4 CCD – trigger rate (top panel) and DOSTEL count rate (bottom Panel) measured on Oct.17,1997

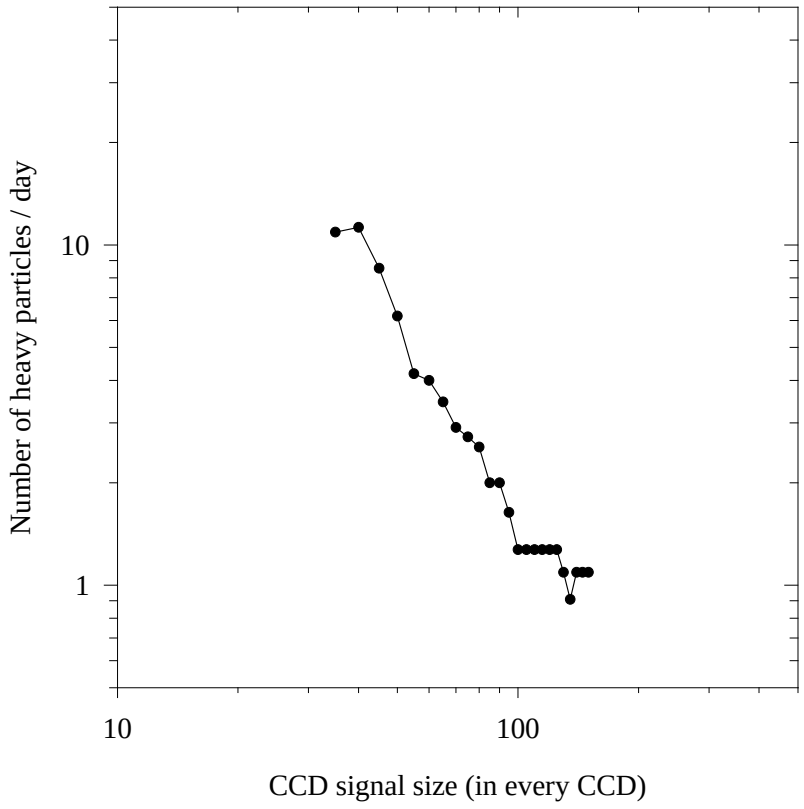

Fig. 5 Differential spectrum of heavy particles (arb. units)

TABLE 1. DATA COLLECTION SESSIONS / FUNCTIONAL OBJECTIVES

DATE	TIME	FUNCTIONAL OBJECTIVES	HARDWARE	ACTION	PARAMETER Threshold / Trigger-Mode
09.10.97	16:05	FO 1 FO 2, 4, 3	HW 1-6	Installation of HW and activation	35 / R-G-B [7]
14.10.97	16:20	FO 5	HW 1+5	Tape Exchange ->2	
16.10.97	23:46	FO 5	HW 1+5	Tape Exchange ->3	
20.10.97	06:56	FO 9	HW 1	Powered OFF	
21.10.97	23:32	FO 2, 4	HW 1	Powered ON	
23.10.97	22:52	FO 7	HW 1	REBOOT	
23.10.97		FO 5	HW 1+5	Tape Exchange ->4	
26.10.97	22:02	FO 7	HW 1	REBOOT	
29.10.97	21:17	FO 7	HW 1	REBOOT	
13.11.97	10:26	FO 5, 8, 5, 4	HW 1+5	BACKUP MANUAL + SOFT RESET + Tape Exchange ->6	32 / R-G [2]
14.11.97	12:03	FO 7	HW 1	REBOOT	
14.11.97	ca.23:50			POWER DROP	
18.11.97	10:49	FO 2, 4	HW 1	Powered ON	
19.11.97	09:27	FO 5	HW 1+5	Tape Exchange ->7	
20.11.97	10:54	FO 5	HW 1+5	Tape Exchange ->8	
21.11.97	02:20	FO 4		START AGAIN	
22.11.97	01:06	FO 1		Powered OFF	
23.11.97	11:19	FO 2, 4		Powered ON	
23.11.97	11:52	FO 1, 4		ESC PRESSED + START AGAIN	
24.11.97	15:50	FO 5	HW 1+5	Tape Exchange ->9	
24.11.97	22:16	FO 1		Powered OFF	
25.11.97	11:01	FO 2, 4		Powered ON	
27.11.97	21:16	FO 5	HW 1+5	Tape Exchange ->10	
27.11.97	21:16	FO 8		MANUAL BACKUP OF DOSTEL DATA	
01.12.97	00:20	FO 5	HW 1+5	Tape Exchange ->11	
02.12.97	23:55	FO 7		REBOOT	
03.12.97	10:02	FO 5	HW 1+5	Tape Exchange ->12	
06.12.97	09:57	FO 7		REBOOT	
14.12.97	11:50	FO 5	HW 1+5	Tape Exchange ->13	
16.12.97	20:00	FO 1	HW 1	Parameter Setting	35 / R-G-B(7)
20.12.97	00:35	FO 1	HW 1	Parameter Setting	250 / R-G-B(7)
10.01.98	21:29	FO 4	HW 1	START AGAIN	
21.01.98	11:57	FO 9 FO 10	HW 1-6	Deactivation + Deinstallation	

TABLE 2. PRELIMINARY MEAN VALUES FOR THE MEASURED DOSE AND THE QUALITY FACTORS FOR A 5 DAY PERIOD (WITHOUT SOLAR PARTICLES).

	Mission average			GCR average			SAA average		
Period	µG/d (Si)	Q	µSv/d	µG/d (Si)	Q	µSv/d	µG/d (Si)	Q	µSv/d
25.10.25 - 30.10.97	201	2.1	546	115	2.7	403	86	1.3	143