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The Altcriss project on board the International Space Station

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Abstract: The Altcriss project aims to perform a long term survey of the radiation environment on board the International Space Station. Measurements are being performed with active and passive devices in different locations and orientations of the Russian segment of the station. The goal is to perform a detailed evaluation of the differences in particle fluence and nuclear composition due to different shielding material and attitude of the station. The Sileye-3/Alteino detector is used to identify nuclei up to Iron in the energy range above $\simeq 60$ MeV/n. Several passive dosimeters (TLDs, CR39) are also placed in the same location of Sileye-3 detector. Polyethylene shielding is periodically interposed in front of the detectors to evaluate the effectiveness of shielding on the nuclear component of the cosmic radiation. The project was submitted to ESA in reply to the AO in the Life and Physical Science of 2004 and data taking began in December 2005. Dosimeters and data cards are rotated every six months: up to now four launches of dosimeters and data cards have been performed and have been returned with the end of expedition 12, 13 and 14.

Introduction

The Altcriss (Alteino Long Term Monitoring of Cosmic Rays on the International Space Station) project aims to perform a long term survey of the radiation and cosmic ray environment on board the ISS. It was submitted to ESA in response to the AO in Life and Physical Science of 2004 with observations beginning at the end of 2005 (increment 12) and expected to continue for three years. This experiment follows previous ones on Mir where relative nuclear abundances and Light Flash perception[1, 2, 3] measurements have been performed with similar silicon detector based devices (Sileye-1 and Sileye-2). Previous measurements on ISS with Sileye-3/Alteino have been performed in 2002 and 2005 in the framework of the first and second Italian-Soyuz Missions. In those missions measurements were limited to the taxi flight duration (< 10 days each) and to the Pirs

module. The main goals of this project are:
1) *Monitoring of long and short term solar modulation of cosmic rays.* The active nature of the device allows to identify particles of galactic, trapped and solar origin according to their position and temporal profile. Observations are currently being carried at solar minimum, going toward solar maximum.
2) *Observations of Solar Particle Events.* We expect in three years about 10 events with an energy and fluence high enough to reach the interior of the station and trigger our detector. For these events we plan to observe the temporal profile and the nuclear abundances.
3) *Survey of different locations of the ISS modules.* By relocating and rotating the instrument it is possible to study the differences in flux and nature of cosmic rays due to the different shielding of the station material (hull, racks, instruments etc.). Flux is also dependent on station attitude and orientation: currently several locations in the Pirs (Russian docking) and in the Service Modules (Central area, crew cabins) have been studied. In the future it is planned to make measurements in the Columbus module and in the US section of the station.
4) *Study of the effectiveness of shielding materials.* Different materials are being considered to reduce the dose to the astronauts: the current approach in weight effective shielding in space is to use low Z materials for their higher stopping power and fragmentation cross-section of the projectile. In this way it is possible to reduce the LET (Linear Energy Transfer) and the quality factor of the radiation, thus reducing the equivalent dose to the astronauts. Although several steps are being taken in this direction (such as putting water reserves in the crew quarters) the best materials from this standpoint are often not practical. For instance, liquid hydrogen would be the best shielding material but cannot be used for the dangers involved in handling such a material. In the Altcriss project we are currently employing two set of tiles to study the effect of shielding on the nuclear radiation field:
a) Polyethylene tiles. These are similar to what currently is used in the crew cabin of the US section of the ISS. These tiles are located on top and bottom of the bidirectional acceptance window of the detector to evaluate the effect of this material (for a thickness of $\simeq 5g/cm^2$) on the radiation and the nuclear abundances. Passive dosimeters are interposed between the detector and the shielding tile to compare the dose measured with TLD and CR-39 with active data coming from Sileye-3/Alteino.
b) Multimaterial tiles. These tiles are divided into four sections, each composed of a different material: Polyethylene, Kevlar, Nextel/Capton Composite and one section left empty as a reference. These tiles were used in 2005 in the framework of the second Italian Soyuz Mission. In the Altcriss project they have until now been used with passive dosimeters interposed between the shielding tiles to measure the radiation dose.
c) *Comparison with other detectors.* Given the complexity of the radiation field in space, in order to build a comprehensive picture of the cosmic ray environment on board the ISS it is necessary to correlate the measurements obtained with Sileye-3/Alteino with other detectors on board the station. To this purpose the device was located in the starboard cabin close to the Matroska-R spherical phantom. Furthermore a cross-comparison measurement campaign with the ESA Matroska[4] facility is planned to be carried forth during expedition 15: in this case Sileye-3 will be placed at the same locations as the human phantom (but not at the same time) to have the exact comparison of the cosmic ray flux. Comparison of the nuclear abundances measured with NASA IV-CPDS will also be performed. To study the propagation of cosmic rays in the Earths magnetosphere and from the exterior to the interior of the station the data coming from the Pamela experiment[5], a satellite borne cosmic ray detector placed in a 350*650 km, 70^o inclination will be used.

Sileye-3/Alteino characteristics

Sileye-3 is a cosmic-ray detector composed of 8 silicon strip detector planes, each divided in 32 strips, with 2.5 mm pitch[6, 7, 8, 9]. The device has a dynamic range capable of detecting particles from He to above Iron. Also non-relativistic protons releasing a signal above 1 mip can trigger the apparatus. Geometrical factor is 23.78 cm^2sr, considering that particles from both sides can trigger the detector. Data are stored on standard PCMCIA cards. Their contents can be downloaded to the ground via telemetry, although usually only data samples relating to one day of acquisition are transferred using this procedure. The used cards are sent to the ground with the Soyuz and the ISS crew at the end of each increment. New cards are uploaded with Soyuz or Progress.

Passive Dosimeters

A number of passive dosimeters is used to measure the dose absorbed in space in the shielded and unshielded configuration and complement the active data coming from Sileye-3. These dosimeters come from JAXA, DLR and Napoli Federico II University and consist of different types of TLD and CR39 detectors. They are placed in four pouches:

1) two pouches with all dosimeters are interposed between the two polyethylene shielding tiles and the acceptance windows of Sileye-3 when performing measurements in the shielded configuration (and thus are shielded by roughly 2π polyethylene). When the Silicon detector is performing unshielded measurements the tiles and pouches are packed close one to the other and placed near the device (and the dosimeters are behind 4π polyethylene shielding).

2) one pouch with four Federico II dosimeters is placed behind the multimaterial tile. Four samples of TLDs and CR39 are present in the unpackaged configuration and are located behind each material to facilitate the alignment between different materials and maximize the shielding geometrical factor.

3) a control pouch with all dosimeters. This pouch is kept with data cards close to the detectors and moves to the different locations of the station.

4) a ground control pouch follows the others in all phases up to launch in Baikonur.

The pouches are rotated every 6 months, with each taxi flight; except for the first set of material that was launched at the end of December and returned in April the duration was shorter.

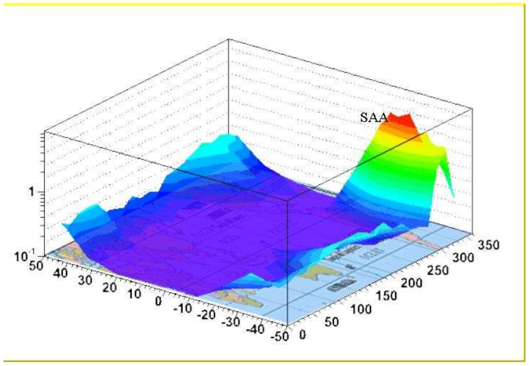

Figure 1: All particle rate (arb. units) vs position measured with Sileye-3. It is possible to see the trapped proton peak in the South Atlantic Anomaly and the increase in the high latitude regions due to galactic nuclei.

Survey of the radiation environment in the ISS

Data cards, dosimeters and polyethylene shielding necessary for the experiment were first sent on board ISS on 21-12-05 with a Progress craft. The detector was switched on 24-12-05 in the Pirs module in the unshielded configuration. A first data sample of 40 hours was downlinked to the ground to verify the correct functioning of the device. Subsequently two long term sessions with and without shielding material (respectively 11 and 15 days) in the Pirs module were performed. In January 2006 the measurement campaign in the Russian Service module started: up to now the device has been located in both cabins and in several locations of the main area. For each position it has been tried (keeping into account all constraints of logistics and observational time) to have a shielded and an unshielded measurement; acquisitions with different orientations at the same location have also been performed to assess the differences in flux and nuclear abundances due to different shielding material.

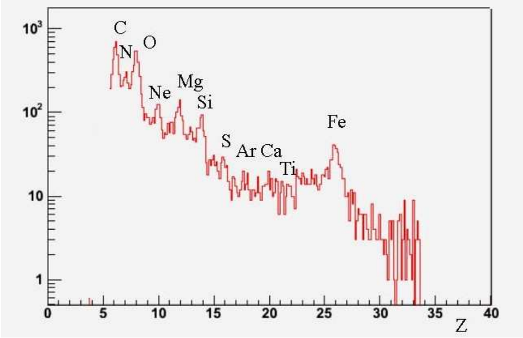

Figure 2: Histogram of particle counts showing the nuclear identification capabilities of Sileye-3 from C to Fe in the Pirs module. Note how even numbered nuclei are more abundant than odd numbered ones.

Flight data and nuclear identification capabilities

Flux modulation is due to the geomagnetic shielding, with higher rate at the poles, where the cutoff is lower and lower rate at the equator where the shielding is higher. The highest peaks occur during passage in the South Atlantic Anomaly (SAA), where particle rate increases due to the trapped proton component. It is possible to build an all particle map (see Figure 1) which shows the latitude increase at high latitude due to galactic particles and the SAA peak due to trapped protons.

To derive the spectrum for nuclei up to and above Iron, shown in Figure 2 (referring to 11 days in the unshielded configuration in the Pirs Module) relativistic particles in the detector were selected. It is possible to distinguish peaks from C to Fe, with the even Z nuclei more abundant and evident than the odd, as found in cosmic rays. Nuclear abundances and trigger efficiency in the different configurations is currently being evaluated. The active nature of the device allows for charge determination to be performed in different points of the orbit and different geomagnetic cutoff regions. Also abundance comparison spectra with/without shielding will contribute to the determination of effectiveness of shielding materials in space.

Conclusions

In this work we have outlined the primary goals and presented preliminary results of the Altcriss project on board the International Space Station. The data gathered up to now are under analysis and will be useful for determining of the radiation environment on board the station and the validation of Montecarlo transport codes. These measurements will be compared with those obtained with a large area detector, the Altea facility[10], sent to the ISS on July 2006. Altea will also continue to investigate the LF phenomenon and the cosmic ray radiation in space.

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References

[1] Avdeev S., et al, Acta Astronautica, 50(8), 511-25 (2002).

[2] Bidoli V., Casolino M., De Grandis E. et. al, J. Phys. G, 27, 2051-64 (2001)

[3] M. Casolino, Bidoli V., Morselli A. et al, Nature, 422, 680 (2003).

[4] Reitz G., Berger T., The MATROSHKA Facility Dose determination during an EVA. Radiat Prot Dosimetry, 120: 442 - 445 (2006).

[5] P. Picozza et al., Astrop. Physics, 27, 4, 2007, 296.

[6] Casolino M., et al., T Nuc. Phys. B, 113B, 71-8 (2002).

[7] Bidoli V., Casolino M., et al., J. Radiat. Res., 43, S47-S52 (2002).

[8] Casolino M., et al., Adv. Sp. Res., 37, 9, 1691-1696 (2006).

[9] Casolino M. et al, The ALTCRISS project on board the International Space Station, In press on Adv. Sp. Res.

[10] Zaconte V., et al, Adv. in Sp. Res. 37, 9, 1704-1709 (2006).