The ALTEA experiment onboard the International Space Station

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Abstract. The knowledge of the composition of the radiation environment is an important information for all the radiation safety issues needed for the planning of future long manned space missions. The ALTEA detector is on board the International Space Station since July 2006 and during this period it has performed a detailed measurement of the radiation environment. In this paper we present a summary of past measures and results.

1. Introduction
The detailed knowledge of the radiation environment in the International Space Station (ISS) is a mandatory step toward a successful radiation risk assessment, needed for the planning of future long manned space missions. ALTEA (Anomalous Long Term Effects on Astronauts) is a multidisciplinary program also devoted at monitoring the International Space Station radiation environment. The ALTEA active particle telescopes feature real time monitoring capability and nuclear discrimination [1, 2, 3]. The ALTEA-space detector was placed on board the ISS on July 2006 and it has been operative since August 2006 in different configurations and different positions and orientations inside the UsLab and the Columbus module of the International Space Station (ISS). In this paper we will provide a summary of the results and findings of these years of measurements.

2. The ALTEA-space detector
The ALTEA cosmic ray detector is composed by six Silicon Detector Units (SDUs). Each SDU consists of a particle telescope made of six planes divided in strips to measure energy loss and direction of detected particles. Each SDU has a geometric factor of 230 $cm^2 sr$. The LET (in silicon) range of the detector goes from a threshold of $2.9 \pm 0.2 keV/mm$ up to about $800 keV/mm$, which corresponds to ions between $Li$ and $Fe$ with a small energy windows on Helium and protons. The modularity of ALTEA permits to work with different configurations. The SDUs were arranged on a helmet-shaped structure until September 2010. In this configuration the whole detector sports a geometric factor of $1190 cm^2 sr$. For further details the reader is addressed to [1].

In this configuration ALTEA can operates in two different modes, named Dosimetry (DOSI) and Central Nervous System Monitoring (CNSM), which are, respectively, unmanned and manned operative modes. DOSI is a continuous measure, while the CNSM sessions lasts 90 minutes. During DOSI mode ALTEA measures radiation fluxes on board ISS. Only Silicon
Detector System (SDS) is switched on and telemetry data, both engineering and scientific, are downloaded in real-time. Seven 90–min CNSM sessions on three different astronaut subjects were performed between 2006 and 2007. During each session the astronaut signal perceptions of Light Flashes with a pushbutton while SDS will measure cosmic rays flux, so that it is possible to study concurrently the passage of cosmic radiation through the brain, the functional status of the visual system and the electrophysiological dynamics of the cortical activity.

In September 2010 ALTEA SDUs were rearranged in a different configuration on a different support structure for Survey, the first part of the ESA experiment ALTEA-Shield. Each SDU couple forms a silicon telescope of twelve planes, and each telescope aims at a different direction in space. In this configuration ALTEA measured the cosmic ray particle flux until June 8, 2012, when ALTEA was moved to the Columbus module of the ISS to start the second part of the ALTEA-Shield experiment, named Shield.

3. Measurements
The typical particle rate measured by the ALTEA SDS shows the typical periodic modulations due to the passage between high and low latitude regions (see Fig.1)[2]. The highest peaks correspond to passes through the South Atlantic Anomaly (SAA), where there is a large increase of the particle flux due to the contribution of the protons trapped in the inner radiation belt. The lower curve shows the particle count rate of the $Z > 5$ component which, excluding protons, does not show SAA increase. There is another visible modulation within a 24–h period called the longitude effect [2].

![Figure 1](image)

**Figure 1.** Particle rate for 1 day of ALTEA data, the typical oscillations due to the passage between high and low latitude regions and the SAA high peaks are visible. The 24–h modulation is the longitude effect [2].

Correlating ALTEA data with ISS orbital information, we grouped these events with respect to the value of their geomagnetic coordinates [3], $B$ and $L$, $B$ being the magnetic field value...
and $L$ the McIlwain coordinate. Three regions were considered: the polar region or region of Galactic Cosmic Rays (GCR), the South Atlantic Anomaly and the equatorial region. In Fig. 2 the three time normalized spectra are plotted. Relative nuclear abundances, calculated with the method described in [2] starting from a Landau fit to reconstruct the full energy released spectra, are presented in the three different regions and compared with the abundances found for the total data (see Fig. 3). ALTEA was able to measure the particle rate and energy spectrum during the December 2006 SPEs [4]. The December 2006 SPEs, occurred between 6th and 14th, originated from the active region NOAA 10930. The comparison with the ($>50$ MeV) proton

![Figure 2](image1.png)

**Figure 2.** Energy spectra of data acquired in three different geomagnetic regions: in the inbox, the zoomed plot at the lower energies [3].

![Figure 3](image2.png)

**Figure 3.** Relative nuclear abundances ($Si = 1$) for the different geomagnetic regions and for the total data [3].
flux measured by the GOES-11 satellite shows the correlation of the events recorded with the two instruments. The SPE effects can finally be identified in the unusually high rate peaks of Fig. 4. A study on ion abundances was performed using a novel algorithm that permits to estimate nuclear composition even from spectrum that lacks enough statistics to apply the standard fitting method [5]. Comparing these measurements with analogous measurements during quiet Sun conditions we observed an increase of the light ion \((Z < 5)\) rate with respect to the values recorded during the quiescent times. In our limited acceptance window for proton the mean measured rate over the whole SPE week is 1.5 times greater than the rate during the quiescent condition, but the ratio rises to about 10 (lower limit) when averaged over the solar most active period (three ISS orbits). By contrast, the abundance of heavier nuclei results unchanged within the errors with respect to quiet Sun conditions. Measurements carried on during 2009

![Diagram](image.png)

**Figure 4.** SDU1 rate for fast particles during the SPE week in comparison with the GOES-11 \((> 50\ MeV)\) proton flux during the same period of time. Each day starts from 00 : 00 am UT. In the figure the longitude effect, the passages of the ISS over the SAA and the SPE effects are well visible [4].

show that the radiation fluences in the USLab-ISS feature quite different constituents along the three axes: the radiation coming from different directions has significantly different quality. This anisotropy for high-LET particles (LET \(> 50\ keV/mm\)) is a factor of 3 in LET and consequently in dose and is minimum along the USLab longitudinal axis and maximum normal to it.

To analyze flux anisotropies, we calculated the LET spectra in three orthogonal directions corresponding to the main axis of ISS, where the Y and Z directions correspond to the transverse sections of the USLab while X is along the ISS longitudinal axis. All the spectra are then normalized with the proper geometric factor. We notice that high-LET particle flux is very attenuated along the X direction (Fig. 5), while at low LET \((< 13\ keV/mm)\) the X spectrum is the highest (Fig. 5, inset). Integrating these LET spectra for all particles (LET \(> 3\ keV/mm\))
and for high-LET particles, defined here as those with energy release more than 50 keV/mm in Silicon (corresponding to ions that deposit more energy than a Mg ion at 2 GeV/nucleon), we can compare the particle fluxes and total LET rates in the three directions defined above and in the different geomagnetic regions (see Fig. 6). High-LET particles in the X direction are a factor between 1.6 and 2.3 lower than in the Y and Z directions in all regions. This anisotropy for high-LET particles becomes a factor between 2.3 and 3.2 in terms of LET rates.

Figure 5. LET spectra in three orthogonal directions. The Y and Z directions correspond to transverse sections of ISS while X is along the ISS longitudinal axis. The X spectrum is lower than those for Y and Z for high-LET particles and higher at low LET (see inset)[6].

Figure 6. Particle Fluxes and LET Rates for Particle with LET Greater than 3 and 50 keV/mm. All fluxes are presented for the X, Y and Z directions and for all geomagnetic regions.

4. Conclusions
The ALTEA detector is on board the International Space Station since July 2006; it was operative non continuously within the USLab since August 2006 and it was recently moved
in the Columbus module.
In this period ALTEA, exploiting its large energy window acceptance, performed a detailed measurement of the radiation environment on board a space vessel, studying for example the different components of the cosmic rays depending on the measurement position and on the incidence direction, and it was capable to evaluate the enhancement of the flux during the SPEs.
ALTEA is now operative in the Columbus module, where it will evaluate the effects of different shielding materials on the incidence particle flux.
All the ALTEA measures will provide a hint to assess the radiation risks for the human permanence in the space.

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