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Time-dependent geomagnetic cutoff estimation along the ISS orbit

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Summary. — In this contribution we present the calculation of a realistic time-dependent geomagnetic cutoff along the International Space Station orbit, at about 400 km above the Earth's surface. For this work the Tsyganenko05 and IGRF models have been employed, including the temporal variation of the external component of the geomagnetic field due to the solar activity. The technique and its results will be discussed, as well as the relevance of this study to distinguish galactic cosmic rays from trapped secondary components in the geomagnetic field.

1. – Introduction

The charged galactic Cosmic Rays (CR) arrive at the top of atmosphere with an isotropic distribution. The presence of the geomagnetic field breaks the isotropy at low energies ($O(10\,\mathrm{GeV})$), since it deviates the particles trajectories, such that only particles with magnetic rigidity, $R = p/Ze$, greater than a minimum value, called cutoff rigidity, can reach from infinity a given position from a given direction [1, 2]. In this work the cutoff rigidity was evaluated with a back-tracing tecnique in the geomagnetic field by integrating backward the particle motion [3].

2. – Transition function and geomagnetic cutoff

The back-tracing tecnique used here is based on a 4th-order Runge-Kutta integration with the turning angles method to optimize the integration step. The magnetic field models used were IGRF10, for the internal component, and Tsyganenko05 [4, 5] for the external component. The external field parameters were updated every 300 sec. The particle trajectories are traced back from a given position until one of the following conditions occurs:

(a) path length reaches 1500 Earth radii, R_e.

(b) trajectory intercepts the atmosphere at 20 km above sea level.

(c) distance of 12 R_e from the field center is reached.

(d) trajectory intercepts the magnetopause (a boundary surface of influence of the geomagnetic field).

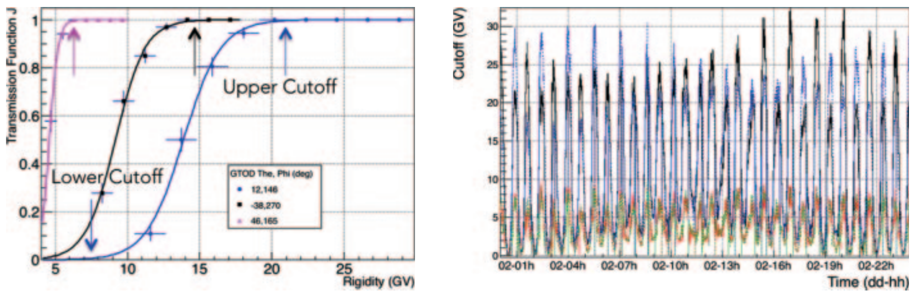

Fig. 1. – Left: Transition function averaged over the arrival directions as a function of rigidity for three different locations within the geomagnetic field, at the altitude of ISS. Right: Upper and lower cutoff for positive particles (blue and black curves, respectively) and for negative particles (red and green curves, respectively) as a function of time for July 2nd 2011.

At each position of the ISS, 1500 trajectories are generated:

1. choosing random directories in a cone with aperture 40° with respect to AMS-02 apparatus [6], and rigidities in a range around the expected cutoff.
2. for each trajectory, the transmission function J is defined by using the back-tracing. If condition b) is verificated, $J = 0$ (trapped), else $J = 1$ (primary).
3. for each rigidity, J is averaged over the arrival directions.

It is possible to define two rigidities that characterize trapped and primary trajectories: an *upper cutoff*, as the minimum rigidity such that all the trajectories are primary and a *lower cutoff*, as the maximum rigidity such that all the trajectories are trapped (fig. 1, left). An accurate knowledge of the upper and lower cutoff allow to distinguish galactic cosmic rays from trapped secondary components in the geomagnetic field. In this work we calculated the upper and lower cutoff along the ISS orbit over a period of one year, from July 1st 2011, every 30 seconds for positively and negatively charged particle trajectories. The upper cutoff shows remarkable differences between positive and negative particles (fig. 1, right). By comparing the cutoffs obtained wih and without external field, the IGRF alone underestimates the cutoff at high latitudes and overestimate it at low ones, with a discrepancy up to 80% in polar regions [7].

3. – Conclusions

In this work a method to calculate realistic time-dependent geomagnetic cutoffs along the ISS orbit has been presented. The results show that even for low earth orbits the inclusion of the external field contribution is crucial for a proper description of the cutoffs.

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