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Galactic Cosmic Rays impact on Saturn innermost radiation belt formation

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Abstract

Rely on Cassini observations of ENAs during the orbital insertion in 2004, Krimigis et al. pointed out possible existence of the innermost radiation belt between Saturn ‘s atmosphere and D-ring (1). In the end of mission in 2017, Cassini is going to come again to this enigmatic and various region and pass directly through this narrow gap between planet and its rings.

In our study we would like to simulate possible sources and losses for energetic particles population there and model the environment, which Cassini will meet during these last orbits.

As a main possible sources for the innermost radiation belt we assume the interaction of the Galactic Cosmic Rays (GCR) with the Saturn’s atmosphere and rings, which due to CRAND process can produce the keV-MeV ions or electrons in the region and the double charge exchange of the ENAs, coming from the middle magnetosphere, what can bring the keV ions to the region of our interest. Both of these possible sources are possible to evaluate using the charged particle tracer, which we developed in our group. It works in different modes (Newton-Lorentz full equation of motion, guiding centre or bounce averaged approximations), and allows use of different magnetic field models (from simple dipole magnetic field till complex realistic magnetic field model like Khurana model of Saturn’s magnetosphere) for both forward and backward tracing simulations. This charged particle tracer was validated using the comparison of the simulation results and observations during several flybys of Cassini by icy moons of Saturn.

Through the backward-tracing of GCRs around the planet we evaluate how the ring shadow filters the GCR spectrum that hits the Saturn’s atmosphere and how non-dipolar effects change the Strömer cutoff rigidities of GCRs, especially for the high-latitude atmosphere that maps magnetically in the outer magnetosphere. Also we estimate the production of secondaries (and from the multiple impacts of these secondaries on the rings or atmosphere as well) and evaluate the energy spectrum of neutrons, the decay of which leads to the production of final CRAND elements in the inner Saturnian radiation belts.

Thereby the theoretical analysis of innermost radiation belt properties will help us to prepare instruments for so-called “proximal” orbits. It will also provide speculative prediction for future MIMI\LEMMS in-situ measurements, what can be useful for proper data analysis.

References

[1] S. M. Krimigis et al., “Dynamics of Saturn's Magnetosphere from MIMI During Cassini's Orbital Insertion”, Science 25 February 2005: 307 (5713), 1270-1273.