URSI-RCRS 2024, ARIES/GEHU, Bhimtal, India, 22 - 25 October, 2024

Probing Jupiter's Radiation Belt: Insights from Test Particle Simulations of Charged Particle Dynamics

Ayushi Srivastava*, Bharati Kakad, and Amar Kakad
Indian Institute of Geomagnetism, Navi Mumbai, Maharashtra, India - 410218
ayushisrivashtava@gmail.com, bkakad9@gmail.com, amar.kakad@gmail.com

Jupiter possesses the largest magnetosphere in the solar system, which contains the strongest radiation belts. Its strong magnetic field is responsible for trapping the energetic ions and electrons, including ultra-relativistic GeV protons. Jupiter's radiation belts are unique due to the presence of the most volcanically active moon Io, which ejects 1000 kg of material (sulfur dioxide) every second into the Jupiter's magnetosphere. Its radiation belts consist of negatively charged electrons and positively charged ions (H^+,O^+,O^{++},O^{+++}, S^+, S^{++}, S^{+++})[1]. These belts are powerful enough to generate significant radio noise.

Predicting the trajectories of these charged particles within Jupiter's magnetic field is essential for any space mission safety, protecting electronic payloads, and enhancing our understanding of particle dynamics. Conventionally, theoretical models predicting particle trajectories rely on the gyro-center approximation, which neglects gyro motion and instead tracks the gyro center, assuming particles gyrate near the magnetic field line [2]. However, this approach is inadequate for highly energetic charged particles due to their larger gyro-radius.

To overcome this issue, we develop a three-dimensional relativistic test particle simulation model, incorporating all particle motions—gyro, bounce, and drift—within Jupiter's magnetic field (including intrinsic and current sources) to comprehensively study particle behavior. Simulations for charged species present in Jupiter's radiation belt have been conducted considering various pitch angles and L-shells. This analysis includes both adiabatic and non-adiabatic behaviors, leading to the identification of a threshold distinguishing between these motion types. This threshold is crucial for predicting particle behavior in Jupiter's magnetosphere, which will significantly advance our understanding of this complex system.

References

[1] Roussos, E., Cohen, C., Kollmann, P., Pinto, M., Krupp, N., Gonçalves, P., & Dialynas, K. (2022). A source of very energetic oxygen located in Jupiter's inner radiation belts. Science Advances, 8(2), eabm4234.

[2] Baumjohann, W. and Treumann, R. A. (2012). Basic space plasma physics.World Scientific