Simulation study to understand the behavior of highly energetic charged particles in the Jovian magnetosphere

Ayushi Srivastava*, Bharati Kakad, Amar Kakad

Indian Institute of Geomagnetism, Navi Mumbai, Maharashtra, India - 410218

e-mail (speaker): ayushisrivashtava@gmail.com

Jupiter has the largest magnetosphere in our solar system having magnetic field ~20 times stronger than Earth as shown in Figure 1. It hosts the strongest radiation belts. These belts derive their energy from the accumulation of high-energy charged particles, encompassing protons (~ 100 GeV), electrons (~ 100 MeV), and heavy ions like O^{+}, O^{++}, S^{+}, S^{++}, S^{+++} (~100 MeV) [1]. The origin of these particles can be attributed to the combined effects of solar wind and Io (one of Jupiter's moons), loading roughly 1000 kg of fresh material into Jupiter's magnetosphere every second. Predicting the trajectories of charged particles within Jupiter's magnetic field is crucial for ensuring space mission safety, protecting electronic equipment, and advancing our understanding of particle dynamics. Various theoretical models have been developed to predict particle trajectories, all of which are based on the gyro-center approximation [2]. This approximation neglects gyro motion and instead tracks the gyro center, assuming that particles gyrate near the magnetic field line. However, this approximation fails for highly energetic charged particles due to their larger gyro-radius. Therefore, a three-dimensional relativistic model has been developed including all particle motions i.e. gyro, bounce, and drift as illustrated in Figure 2 by incorporating Jupiter's magnetic field (intrinsic + current source) to study their behavior thoroughly. Simulations have been conducted for species present in Jupiter's radiation belt, considering different pitch angles and L-shells. The analysis has included both adiabatic and non-adiabatic behaviors of charged particles, leading to the identification of a threshold that distinguishes between adiabatic and non-adiabatic particle motion. This limit helps in predicting the nature of particle behavior within Jupiter's magnetosphere, contributing significantly to our understanding of this complex system

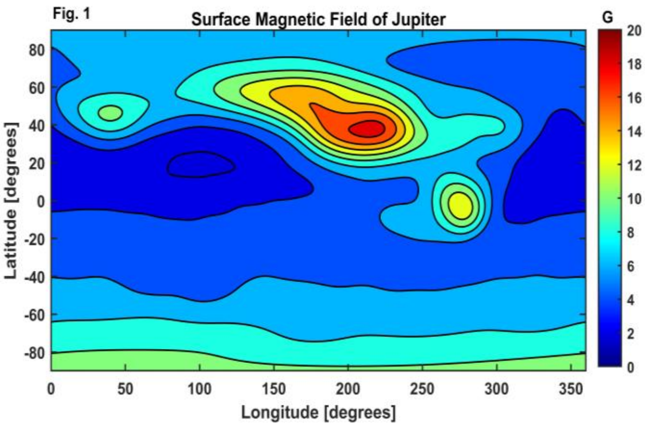

Figure 1: Surface magnetic field of Jupiter

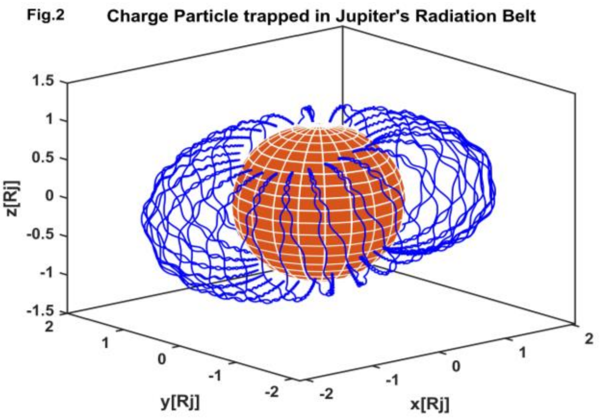

Figure 2: Trajectory of proton in Jupiter's magnetosphere

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

.

.