The Origin of Jupiter's Outer Radiation Belt

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Abstract

The intense inner radiation belt at Jupiter (>50 MeV at 1.5 R_J [1]) is generally accepted to be created by radial diffusion of electrons from further away from the planet [2]. However, this requires a source with energies that exceed 1 MeV outside the orbit of the moon Io at 5.9 R_J, which has never been explained satisfactorily. Here we test the hypothesis that this source population could be formed from a very soft energy spectrum, by particle injection processes and resonant electron acceleration via whistler mode chorus waves.

Using the first simulations at Jupiter combining wave particle interactions and radial diffusion, we calculate the change in the electron flux between 6.5 and 15 R_J with the BAS Radiation Belt Model starting from a very soft spectrum. The electron flux after 30 days at 100 keV and 1 MeV lies very close to the Galileo Interim Radiation Electron (GIRE) model spectrum [3] after 1 and 10 days respectively. The primary driver for the increase in the flux is cyclotron resonant acceleration by chorus waves, which causes an increase in the flux by a factor of 10^6 from the soft spectrum. The radial diffusion does not affect the magnitude of this increase to any great extent, but acts to smooth out variations in the phase space density with L. The variation of chorus wave power with radial distance from Jupiter results in a peak in phase space density such that inside L≈9 radial diffusion transports electrons towards Jupiter, but outside L≈9 radial diffusion acts away from the planet.

The results are insensitive to the softness of the initial energy spectrum but do depend on the value of the flux at the minimum energy boundary. The overall shape of the flux after 30 days remains very similar but the magnitude of the flux at all energies is dependent on the flux at the minimum energy boundary. We show that individual injections of particles at a few tens of keV would have a cumulative effect on the increases in flux at energies of a few MeV by varying the flux at the minimum energy boundary in a time dependent manner based on the injections reported in [4].

We conclude by suggesting that the source population for the inner radiation belt at Jupiter could indeed by formed by wave-particle interactions.

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