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Saturn Neutron Exosphere as Source for Inner and Innermost Radiation Belts

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Energetic proton and electron measurements by the ongoing Cassini orbiter mission are expanding our knowledge of the highest energy components of the Saturn magnetosphere in the inner radiation belt region after the initial discoveries of these belts by the Pioneer 11 and Voyager 2 missions. Saturn has a neutron exosphere that extends throughout the magnetosphere from the cosmic ray albedo neutron source at the planetary main rings and atmosphere. The neutrons emitted from these sources at energies respectively above 4 and 8 eV escape the Saturn system, while those at lower energies are gravitationally bound. The neutrons undergo beta decay in average times of about 1000 seconds to provide distributed sources of protons and electrons throughout Saturn's magnetosphere with highest injection rates close to the Saturn and ring sources. The competing radiation belt source for energetic electrons is rapid inward diffusion and acceleration of electrons from the middle magnetosphere and beyond. Minimal losses during diffusive transport across the moon orbits, e.g. of Mimas and Enceladus, and local time asymmetries in electron intensity, suggest that drift resonance effects preferentially boost the diffusion rates of electrons from both sources. Energy dependences of longitudinal gradient-curvature drift speeds relative to the icy moons are likely responsible for hemispheric differences (e.g., Mimas, Tethys) in composition and thermal properties as at least partly produced by radiolytic processes. A continuing mystery is the similar radial profiles of lower energy (< 10 MeV) protons in the inner belt region. Either the source of these lower energy protons is also neutron decay, but perhaps alternatively from atmospheric albedo, or else all protons from diverse distributed sources are similarly affected by losses at the moon orbits, e.g. because the proton diffusion rates are extremely low. Enceladus cryovolcanism, and radiolytic processing elsewhere on the icy moon and ring surfaces, are additional sources of protons via ionization and charge exchange from breakup of water molecules. But one must then account somehow for local acceleration to the observed keV-MeV energies, since moon sweeping and E-ring absorption would remove protons diffusing inward from the middle magnetosphere. Although the main rings block further inward diffusion from the inner radiation belts, the exospheric neutron-decay source, combined with much slower diffusion of protons relative to electrons, may produce an innermost radiation belt in the gap between the upper atmosphere and the D-ring. This innermost belt will first be explored in-situ during the final proximal orbits of the Cassini mission.