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Electron anisotropies in the inner heliosphere

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Ulysses observations have indicated the presence of low-energy electron 'jets' with extraordinary anisotropies off the equatorial plane as far as 2.2 AU from Jupiter. Jovian electron 'jets' were also observed during Ulysses' first encounter with Jupiter in 1992 and still needs a satisfactory explanation. These 'jets' are a very interesting feature of the jovian electron profiles, and are important in evaluating and testing propagation and modulation models. This work revisits the basic modulation theory of what processes may cause anisotropies from a global modulation point of view and to what extent they contribute in understanding these kind of observations. Emphasis is placed on the role of polar perpendicular diffusion which contributes significantly to modulation off the equatorial plane.

It was discovered by the Pioneer 10 spacecraft and firmly established by the Voyager spacecraft and the recent Jupiter fly-bys of the Ulysses spacecraft that the jovian magnetosphere, located at ~5.2 AU in the ecliptic plane, is a relatively strong local source of electrons with energies up to ~30 MeV. Ulysses has sampled the inner heliosphere up to 80° off the ecliptic plane since its launch in Oct. 1990. During this time the jovian electron population varied significantly with varying heliomagnetic distance to Jupiter and with changing solar activity. In 1992 and 2004, Ulysses had encounters with Jupiter allowing the study of the propagation of jovian electrons originating from a 'point' source in the heliosphere. The closest approach to Jupiter was 0.003AU (6RJ) in 1992 and 0.803AU (1682RJ) in 2004. Jovian electron 'jets' were observed during both encounters in the 3–10 MeV range as events with sharp increases and decreases, a strong field-aligned anisotropy, and durations of up to a few hours, as far out as 2.2 AU from the planet in 2004. After the 1992 flyby 'jets' were observed at distances of 0.6 AU from Jupiter, and at north-south displacements of almost 0.5 AU, implying direct magnetic connection to Jupiter over these distances. See Heber et al. [this issue].

The physical process producing electrons within the jovian magnetosphere and how jets are produced is not well understood, and requires a further in-depth study, in particular on the physics of the production and the distribution of electrons in the magnetosphere of Jupiter, and how the interplanetary magnetic field connects to the huge jovian magnetosphere. During Ulysses' recent distant flyby its trajectory was such that direct magnetic connection to Jupiter was unlikely for a standard interplanetary spiral magnetic field, implying that extreme deviations from a Parker-type spiral connecting to Jupiter, extending over many degrees of latitude, are not uncommon. Confinement of the particles (with a large anisotropy vector) to individual flux tubes implies that diffusion out of the tubes is weak. This is important information for how polar transport of low-energy particles may happen and how large it may be.

These aspects will be studied and discussed. Results of a three-dimensional numerical modulation model will be used to illustrate the theory.