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Inner Magnetospheric Magnetic Dips: Pitch-Angle Filter of Energetic Particles and Propagating Hotspot for EMIC Wave Excitation

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Magnetospheric substorms are geomagnetic disturbance processes involving explosive energy release from the magnetotail into the near-Earth region. An important substorm-associated feature is the energetic particle injections into the inner magnetosphere. The diamagnetic motion of the injected ions could produce localized magnetic field depressions, referred to as magnetic dips, whose impact on energetic particle dynamics has been largely underestimated.

The magnetic dips, if deep enough, can produce a local minimum in the radial profile of the field strength, which can significantly alter the picture of westward ion drift motion and trap the equatorially-mirroring energetic ions within the propagating dip structure, as illustrated in Figure 1 [1]. This trapping mechanism applies to equatorially-mirroring ions across a wide energy range, leading to the nearly energy-dispersionless flux enhancements observed by spacecraft far from the injection boundary. The bouncing ions, on the other hand, are hardly affected by the trapping mechanism. Therefore, the magnetic dip can serve as a pitch-angle filter to trap the equatorially-mirroring ions and allow the bouncing ions to overtake, which leads to the observed reversed pitch-angle distributions of proton fluxes [2].

Furthermore, since these pitch-angle filters enable the accumulation of perpendicular-moving ions and leave the bouncing ions nearly unaffected, the resulting high proton anisotropy, together with the ring distribution of injected ions, facilitate the rapid generation of electromagnetic ion cyclotron (EMIC) waves therein [2,3]. Consequently, the magnetic dip becomes a propagating hotspot of EMIC wave activity and a drifting origin of precipitation for energetic ions and relativistic electrons [3]. These insights highlight the important role of magnetic dips in the inner magnetospheric dynamics.

References

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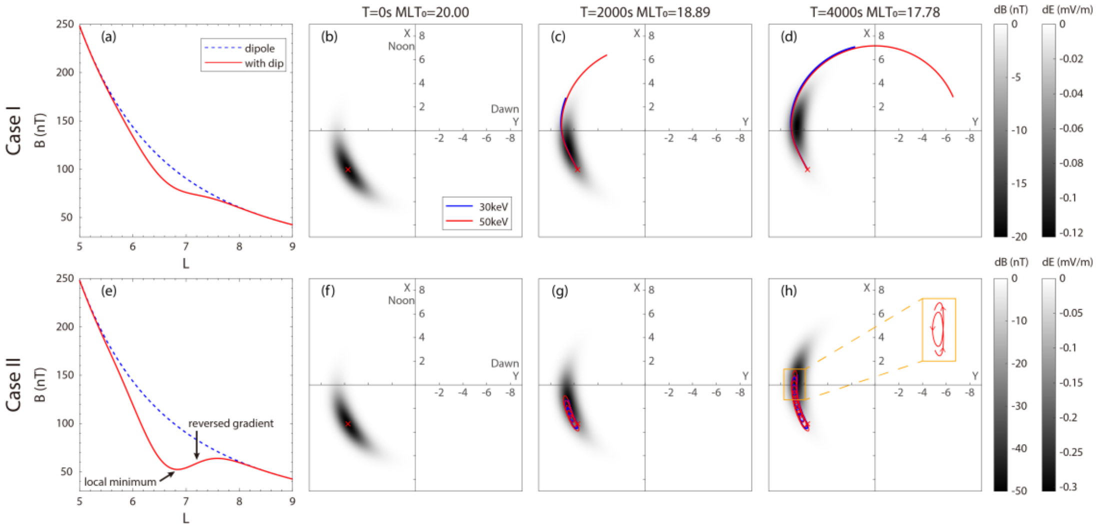

Figure 1. Guiding-center simulations for proton trajectories in the magnetic dip. The upper and bottom panels correspond to the two cases with different field depressions. (a), (e) The radial profiles of the dipole magnetic field (blue dashed) and the modeled field (red) along the magnetic dip's central meridian. (b-d, f-h) Simulated trajectories of equatorially mirroring 30-keV (blue) and 50-keV (red) protons under the effect of the field perturbations associated with the dip structure (grayscale background). The three columns correspond to the snapshots at 0s (initial state), 2000s, and 4000s, respectively.