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Numerical Modelling of Particle Energization during Dipolarization Substorm Events by Test Particle Simulations

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During certain dipolarization substorm events, particles originating from the magnetotail can undergo significant acceleration, leading to their transport into the inner magnetosphere. This phenomenon, observed by various spacecraft such as THEMIS, is marked by a substantial increase in particle flux. The energy enhancement during these events is believed to be driven by an intensified magnetic field, coupled with induced and polarized electric fields, which together energize and transport particles earthward.

To better understand the particle energization mechanisms from the magnetotail to the inner magnetosphere, we developed a hybrid test particle simulation code. This code was used to study the dynamics of particles during specific dipolarization events observed by the THEMIS mission during substorm periods in 2008 and 2009. Our simulations calculated the trajectories of electrons, protons, and oxygen ions across an energy range from 0.1 keV to 1 MeV, considering a variety of initial pitch angles and L-shells. The code integrates two particle tracing methods: the Tao-Chan-Brizard guiding center model and full Lorentz particle motion, with transitions between the two governed by the evaluation of the adiabaticity condition.

To replicate the time-dependent magnetic field, we utilized the Tsyganenko TS05 and IGRF models, which also account for computing the associated inductive and polarized electric fields. Preliminary results indicate significant energy enhancement levels, and a comparison of these numerical findings with observational data supports their consistency.