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内部磁気圏における運動論的不安定性の高エネルギー粒子ハイブリッドシミュレーション

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Energetic Particle Hybrid Simulations for Kinetic Instabilities in the Inner Magnetosphere

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The energetic ring current particles dominate the plasma pressure in the inner magnetosphere. Therefore, it is essential to take into account the ring current dynamics in understanding the various inner magnetospheric phenomena. It has been known that the Magnetohydrodynamics (MHD) approximation is not adequate in numerical modeling of the ring current dynamics and the kinetic effect associated with the ring current ions must be taken into account for modeling the global magnetic-field reconfiguration in the inner magnetosphere. In addition, local kinetic instabilities excited by the ring current population may also play important roles. For instance, the so-called drift-bounce resonance has been considered to be a plausible mechanism for internal excitation of Pc5 ULF waves. Also, Electro-Magnetic Ion-Cyclotron (EMIC) waves responsible for pitch-angle scattering for relativistic radiation belt electrons are thought to be excited by the temperature anisotropy of energetic protons.

We have developed a new three-dimensional numerical simulation code that incorporates the self-consistent coupling between the fully kinetic ring current particle dynamics and the cold background plasma. In other words, it is essentially a hybrid code that solves the ring current ions by using the particle-in-cell method, whereas the two-fluid approximation is adopted for the background electron and proton fluids. The coupling between the two populations has been introduced in a systematic manner. By performing kinetic temperature-anisotropy driven instabilities in a homogeneous plasma, we show that the code is indeed capable of describing the kinetic effect associated with the ring current ions. The code is applied for studying the ring-current driven kinetic instabilities with the effect of background magnetic-field inhomogeneity. An initial equilibrium obtained by iteratively solving a Grad-Shafranov-like equation for an anisotropic bounce-averaged ring current pressure distribution is used. We investigate the dependence of the instability on the plasma beta, temperature anisotropy, and the ratio between the Larmor radius and the gradient scale length of the background magnetic field.