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ケルビン・ヘルムホルツ不安定の3次元MHDシミュレーション：密度差と磁場の影響

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Three-dimensional MHD simulation of the Kelvin-Helmholtz instability: effect of density difference and magnetic field direction

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The Kelvin-Helmholtz instability (KHI) is considered to be one of transport mechanisms of mass, momentum, and energy in the solar-terrestrial plasma environment. When the interplanetary magnetic field is northward, the KHI driven by the velocity shear between solar wind and magnetospheric plasmas plays a critical role in the solar wind plasma entry into magnetosphere. Large-scale vortex motion is observed in a solar prominence, which is induced by the nonlinear evolution of the Rayleigh-Taylor instability (RTI). It may affect the prominence dynamics, collapse and/or eruption. The KHI may relate to the nonlinear saturation of the magneto-rotational instability (MRI), which is a key mechanism for the angular momentum transport in accretion and protoplanetary disks.

Nonlinear numerical simulations have revealed that the KHI can contribute not only to the momentum transport but also to the mass transport through secondary instabilities. Using two-dimensional MHD simulations, Nykyri and Otto (2001) have shown that the vortex motion strongly twists in-plane magnetic fields, and then forms multiple current sheets. Magnetic reconnection occurs inside the vortex and transports plasma into an opposite region. Matsumoto and Hoshino (2006) have shown that the vortex motion induces the secondary RTI in the presence of large density difference across a velocity shear layer. The vortex collapses through the RTI and subsequent turbulence mixes plasma. Although these secondary instabilities enhance the mass transport efficiency, the competition between the reconnection and RTI is controversial. Three-dimensional effect on these instabilities is not clear.

To further study the nonlinear evolution of the KHI, we demonstrate a three-dimensional MHD simulation. This work is an extension of Matsumoto and Seki (2007), in which the stable vortex initiates a secondary instability along a transverse magnetic field. We additionally include the density difference across a velocity shear layer and the angle between an ambient magnetic field and a KH wave as free parameters. We examine the dependence of plasma beta, density difference, and the angle on the nonlinear evolution. When an ambient magnetic field is strictly perpendicular to a KH wave, the evolution is sensitive to the density difference. The vortex is stable against the RTI for small density difference, then can initiate the instability along the magnetic field. Therefore, the evolution is essentially 3D. For large density difference, on the other hand, the vortex collapses through the RTI, inhibiting the instability along the magnetic field. The transverse magnetic field suppresses the variation along the field. Therefore, the evolution is essentially 2D. In both cases, the vortex finally collapses through the secondary instability. In this talk, we will discuss in detail the wide variety of parameter dependence on the three-dimensional KH evolution.