HALL MAGNETOHYDRODYNAMICS: NUMERICAL METHODS AND RESULTS

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Over the past fifteen years it has become increasingly clear that Hall magnetohydrodynamics plays a crucial role in many space and laboratory plasma processes: magnetic reconnection, sub-Alfénic plasma expansions, and plasma opening switches to name a few. Hall magnetohydrodynamics is important for plasma dynamics on length scales less than the ion inertial scale length but greater than the electron inertial length. On these scales the ion and electron motions are decoupled; the electrons remain frozen to the magnetic field but the ions are not. In this paper we provide a basic overview of Hall magnetohydrodynamics with an emphasis on numerical methods. We also provide several concrete examples of Hall dynamics: whistler waves, Hall drift waves, and three dimensional magnetic reconnection. For the 3D reconnection simulation study we initialize the system with a magnetic field perturbation localized along the current channel in a reversed field plasma configuration. The perturbation induces a magnetic wave structure that propagates opposite to the current, and leads to the asymmetric thinning of the plasma layer, strong plasma flows in the direction of the current, and rapid magnetic reconnection. The propagating wave structure is a Hall phenomenon associated with magnetic field curvature. We also present results of the reconnection rate as a function of a guide field. It is found that the reconnection rate and plasma energization are reduced for increasing guide field strength. This is caused by a $\mathbf{J} \times \mathbf{B}$ force associated with Hall currents and the guide field that reduce the inflow and outflow velocities. However, the reconnection rate and plasma energization are only reduced by a factor of 2 for $B_{\rm gf} = 5\,B_0$. Applications to magnetospheric plasmas are discussed.

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