The Role of the Kelvin-Helmholtz Instability for Mass Exchange at the Magnetopause: Mercury versus Earth

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Effects of ion mass-loading on the development of the Kelvin-Helmholtz (K-H) instability and the resulting mass exchange at the planetary magnetopause have been investigated using both linear theory and numerical simulations. Linear theory predicts that a planetary dayside magnetopause becomes absolutely unstable against the K-H instability, when the magnetospheric plasma adjacent to it has a mass density about an order of magnitude greater than that of the magnetosheath. The K-H instability evolves approximately in the center of mass frame between two plasmas flowing in opposite directions to each other. Because of the sunward convection of the magnetospheric plasma on the dayside, the center of mass frame between the magnetosphere and the magnetosheath plasmas can be in the rest frame at some locations of the magnetopause, leading to an absolute evolution of the K-H mode. Global multi-ion-species MHD simulations as well as multi-fluid simulations are then invoked to examine its nonlinear evolution. For southward IMF cases, we find that magnetic reconnection takes place both at subsolar region and inside vortices as a result of the evolution of the K-H mode in an anti-parallel field lines condition. Simulation results for northward IMF cases are compared with the observational findings of the MESSENGER 1st flyby. This process may take place not only at the Mercury's magnetopause but also at that of Earth during the events of drainage plume from the plasmasphere, and also at those of other magnetized planets with extended atmosphere such as close-in exoplanets (hot Jupiters).