

Kelvin-Helmholtz turbulence in space and astrophysical plasmas

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Solar wind interactions with magnetized or un-magnetized planets destabilize planetary boundaries such as the magnetopause of the Earth magnetosphere and the ionopause of Mars and Venus. The Kelvin-Helmholtz (K-H) instability arising at a velocity shear layer has been considered to be important for momentum transport of the solar wind across the boundary layers, and been a universal nature of the planetary interactions. Linear and nonlinear growths of the instability depend on background plasma and magnetic field configurations. At the Martian ionopause, where the ionospheric ion escape is expected by the K-H instability, a fast (~ 400 km/s), dilute (~ 1 /cc) plasma flow directly interacts with a high density (10^4 - 10^5 /cc), low temperature (a few thousand K) plasma. The situation can be found similarly at the terrestrial magnetopause, where in-situ observations have often indicated growth of the instability and resultant transport of the solar wind plasma into the magnetosphere, in the sense that the K-H instability grows in a strongly inhomogeneous plasma.

In this presentation, we review nonlinear evolutions of the K-H instability in strongly inhomogeneous plasmas. The evolutions are characterized by the secondary instabilities such as the Rayleigh-Taylor instability and the magnetic reconnection, by which a coherent eddy structure are destroyed and the energy is transported to smaller scales. Recent kinetic plasma simulations have shown that electron-scale structures are spontaneously generated as a consequence of the secondary instabilities (Karimabadi et al., 2013). The micro-scale structure accompanied with the MHD-scale evolution enhanced mixing of collisionless plasmas. It was also found that the spatial size of the turbulent area was quickly broaden when coupled with a coalescence of large scale K-H modes, that is, the inverse energy cascade (Matsumoto & Seki, 2010). When nonlinear mode coupling was considered the time scale of the inverse energy cascade can be even faster than the fastest growing mode of the K-H instability. These nonlinear features in micro and macro scales have large impact on plasma transport process in the solar wind - planetary interactions as well as in astrophysical plasmas.

Keywords: Kelvin-Helmholtz instability, turbulence, Earth's magnetosphere, Planetary atmosphere