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Effects of plasma kinetic parameters on broad mixing layer formation by the Kelvin-Helmholtz instability

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We have recently shown by 2D MHD simulations of the Kelvin-Helmholtz instability (KHI) in a highly asymmetric density layer in a large simulation domain that rapid formation of a plasma mixing layer can be achieved by forward and inverse energy cascades of the KHI. The forward cascade is triggered by the growth of the secondary Rayleigh-Taylor instability (RTI) [Matsumoto and Hoshino, 2004, 2006] excited during the nonlinear evolution. The inverse cascade is accomplished by a nonlinear coupling of the fastest growing mode of the KHI and other unstable modes. We suggested that the proposed mechanism well explained the observational requirements and is therefore responsible for the LLBL formation, although some issues are remained to be understood. One major issue, which is not treated accurately in the MHD simulation, is the mixing process itself; the mixing of plasmas is due to the numerical dissipation implicitly or explicitly added in the simulation.

To understand all the mechanisms ranging from the dissipating scale to the scale of the largest vortex in a self-consistent manner, we have carried out 2D fully kinetic particle-in-cell (PIC) simulations of the KHI in a large simulation domain which allows growth of multiple KH unstable modes. As a result, we found the inverse energy cascade among the KH unstable modes as have been shown by the 2D MHD simulation. It is also found that the direct energy cascade results in plasma mixing by exciting strong electric fields embedded in the ion scale with amplitudes comparable to the initial convective electric field. The locally excited electric field is the key agent for the mixing. We have also found two-component distribution functions in the mixed region for the ion and the electron which have been reported by in-situ observations. In this presentation, we show that both direct and inverse energy cascades of the KHI contribute to formation of a large scale plasma mixing layer in a time scale much faster than we expect from the linear theory. Also, dependence of the mixing efficiency on the mass ratio and the ratio of plasma to gyro frequencies are discussed by simulation runs with various kinetic parameters.

Keywords: Kelvin-Helmholtz instability, turbulence, boundary layer, mixing, plasma kinetics