

Waves and particle acceleration around the separatrices of magnetic reconnection

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Understanding the properties of waves in magnetic reconnection is very important in collisionless plasmas. The waves can transport the momentum and energy between the different species in plasmas, which results in the anomalous magnetic dissipation, particle heating, and formation of non-thermal particles. Therefore, the wave activities relevant to the kinetic interactions can have a significant impact on the dynamical behaviour of magnetic reconnection. Theoretical modeling of waves in the reconnection region is also beneficial to reveal the reconnection dynamics using in-situ satellite observations where wave properties are obtained in much higher time resolution than plasma distribution functions.

Recent satellite observations in the Earth's magnetotail have shown that the wave activities are significantly enhanced in a broad range of frequency around the separatrices of anti-parallel magnetic reconnection. The waves were recognized as lower hybrid waves, Langmuir waves, electrostatic solitary waves (ESWs), and whistler waves. In most cases, they were associated with cold electron beams and density cavity. However, because of the limited space-time resolutions of the observations, it has been difficult to identify the generation mechanisms of the waves and their roles in magnetic reconnection.

In this study, large-scale 2D particle-in-cell simulations with adaptive mesh refinement have been performed under an open boundary condition. The simulations use a set of more realistic parameters than those in most other simulations, achieving lower plasma beta in the upstream region that leads to stronger electron beams in the reconnection region. The wave activities are dominant in the inflow side of the separatrices. The waves are generated mainly due to the electron beams that constitute the Hall current. The relatively weak beams before strong acceleration trigger the Buneman instability which results in the waves with a frequency of the lower hybrid range. The strong acceleration occurs along the field line due to a localized potential hump and causes the density cavity. The intense electron beams excite the electron two-stream instability and the beam driven whistler instability. The former mode gives the Langmuir waves and the flat-top electron distributions in the parallel direction, both of which have been observed frequently in the Earth's magnetotail. The latter mode, on the other hand, scatters the electrons in the perpendicular direction, forming isotropic distribution with non-thermal high-energy tail. Both the Buneman and electron two-stream instabilities evolve the ESWs in the nonlinear phases.

In this talk, we present the generation mechanisms of the waves around the separatrices and their roles in magnetic reconnection. The mechanism of the intense electron acceleration along the field line will be discussed.

Keywords: magnetic reconnection, plasma waves, particle acceleration, particle-in-cell simulations