低マッハ数無衝突垂直衝撃波における微視的不安定性

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Electron-scale microscopic instabilities at a low-mach-number perpendicular collisionless shock

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A full particle simulation study is carried out on the electron acceleration at a collisionless, relatively low Alfven Mach number (M_A = 5), perpendicular shock. Recent self-consistent hybrid shock simulations have demonstrated that the shock front of perpendicular shocks has a dynamic rippled character along the shock surface of low-Mach-number perpendicular shocks. In our simulation, the effect of the rippling of perpendicular shocks on the electron acceleration is examined. The simulation domain is taken to be larger than the ion inertial scale by using the shock-rest-frame model. We used 16 pairs of electrons and ions per cell in the upstream region and 64 pairs of electrons and ions in the downstream region, respectively, at the initial state.

The simulation result has been shown that a large-amplitude electric field is excited at the shock front in association with the ion-scale rippling, and that reflected ions are accelerated upstream at a localized region where the shock-normal electric field of the rippled structure is polarized upstream. The current-driven instability caused by the highly-accelerated reflected ions has a high growth rate to large-amplitude electrostatic waves. Energetic electrons are then generated by the large-amplitude electrostatic waves via electron surfing acceleration at the leading edge of the shock transition region.

It has been demonstrated that multi-dimensionality sometimes weakens the electron surfing acceleration in the 2D simulations of self-consistent shock models. The present result is an example showing the effect of ion kinetics to the electron surfing acceleration. It has been confirmed that the cross-scale coupling between an ion-scale mesoscopic instability and an electron-scale microscopic instability is important. Hence, a large-scale full particle simulation would be essential for studies of the electron acceleration at collisionless shocks.