衝撃波における電子加熱のマッハ数依存性

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Mach number dependence of electron heating in collisionless shocks

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Mach number dependence of electron heating rate through microinstabilities in transition regions of supercritical quasi-perpendicular shocks are investigated by performing one-dimensional PIC (Particle-In-Cell) simulations and model analyses.

It is known from observations that electron heating is quite efficient in supernova remnant (SNR) shocks, while it is often not so evident in shocks near 1AU. The heating mechanism is one of the outstanding issues in space and astrophysical plasmas, because types of microinstabilities generated in the foot are inherently dependent on upstream plasma parameters. Recent PIC simulations reveal that modified two-stream instability (MTSI) becomes dominant for relatively small Mach numbers (less than 10), while Buneman instability (BI) is dominant for extremely high Mach numbers (a few tens). However, the saturation levels of those instabilities have never been compared in a systematic manner. In this study shock waves are reproduced by performing one-dimensional PIC simulations with various Mach numbers and effective electron temperatures just behind the shocks are measured. While the effective electron temperature in BI dominant cases is an increasing function of Mach number, MTSI dominant cases indicate less dependent on Mach number. Details of the above heating processes are discussed by utilizing two different models. A trapping model gives a good estimate of electron temperature for the BI dominant cases, while electron temperature is appropriately estimated from a quasilinear analysis for the MTSI dominant cases. As a result, it is concluded that a dominant heating process in low (high) Mach number shocks is MTSI (BI) and may switch at Mach number ~20.