Scaling of Particle Heating in Shocks and Magnetic Reconnection

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Abstract

Particles are heated efficiently through energy conversion processes such as shocks and magnetic reconnection in collisionless plasma environments. While empirical scaling laws for the temperature increase have been obtained, the precise mechanism of energy partition between ions and electrons remains unclear. Here we show, based on coupled theoretical and observational scaling analyses, that the temperature increase, ΔT, depends linearly on three factors: the available magnetic energy per particle, the Alfvén Mach number (or reconnection rate), and the characteristic spatial scale L. Based on statistical datasets obtained from Earth's plasma environment, we find that L is on the order of (1) the ion gyro-radius for ion heating at shocks, (2) the ion inertial length for ion heating in magnetic reconnection, and (3) the hybrid inertial length for electron heating in both shocks and magnetic reconnection. With these scales, we derive the ion-to-electron ratios of temperature increase as $\Delta Ti/\Delta Te$=*(3βi/2)^(1/2) (mi/me)^(1/4)* for shocks and $\Delta Ti/\Delta Te$=*(mi/me)^(1/4)* for magnetic reconnection, where βi is the ion plasma beta, and mi and me are the ion and electron particle masses, respectively. We anticipate that this study will serve as a starting point for a better understanding of particle heating in space plasmas, enabling more sophisticated modeling of its scaling and universality.

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