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Efficient electron and ion acceleration and heating at oblique magnetised mildly relativistic shocks

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Mildly relativistic collisionless plasma shocks allow for a broader range of oblique subluminal mean magnetic field configurations, in contrast to inherently superluminal ultra-relativistic shocks. This enables particle acceleration and heating mechanisms, as well as the generation of electromagnetic waves, driven by particle reflection off the shock. Here, we present our recent results from large-scale particle-in-cell (PIC) simulations of mildly relativistic magnetised shock waves in ion-electron plasmas. Our study examines two configurations: an oblique shock with an obliquity angle just below the critical angle and a quasi-parallel shock. We show that in the oblique configuration a shock transition is characterised by a train of magnetosonic waves with very strong longitudinal electrostatic gradients. The resulting electrostatic potential efficiently traps electrons and ions, enabling their acceleration via the E×B drift. Particles repeatedly bounce within the wave, gaining very high energies over multiple cycles. In the quasi-parallel shock configuration large-amplitude coherent waves form in the upstream region and are further amplified in the reflected hot ion beam region. Interactions of ions and electrons with these waves lead to their efficient heating to relativistic temperatures. These results are applicable to jets of Active Galactic Nuclei and microquasars, where sites of intense non-thermal X-ray and gamma-ray emission are often associated with mildly relativistic shocks. Our findings also highlight previously unexplored mechanisms for the generation of high-energy cosmic rays in relativistic astrophysical jets.

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