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Stochastic electron acceleration during turbulent reconnection in strong shock waves

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Acceleration of charged particles is a fundamental topic in astrophysical, space and laboratory plasmas. Very high energy particles are commonly found in the astrophysical and planetary shocks, and in the energy releases of solar flares and terrestrial substorms. Evidence for relativistic particle production during such phenomena has attracted much attention concerning collisionless shock waves and magnetic reconnection, respectively, as ultimate plasma energization mechanisms. While the energy conversion proceeds macroscopically, and therefore the energy mostly flows to ions, plasma kinetic instabilities excited in a localized region have been considered to be the main electron heating and acceleration mechanisms.

We present that efficient electron energization can occur in a much larger area during turbulent magnetic reconnection from the intrinsic nature of a strong collisionless shock wave. Supercomputer simulations have revealed a multiscale shock structure comprising current sheets created via an ion-scale Weibel instability and resulting energy dissipation through magnetic reconnection. A part of the upstream electrons undergoes first-order Fermi acceleration by colliding with reconnection jets and magnetic islands, giving rise to a nonthermal relativistic population downstream. The dynamics has shed new light on magnetic reconnection as an agent of energy dissipation and particle acceleration in strong shock waves.