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A Fermi mechanism for the production of energetic electrons during magnetic reconnection

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The production of energetic electrons has been documented in observations of solar flares, magnetic reconnection in the Earth's magnetosphere and in laboratory tokamak experiments yet the understanding of these widespread observations remains poor. Simulations reveal that magnetic reconnection with a guide field leads to the growth and dynamics of multiple magnetic islands rather than a single large x-line. Above a critical energy electron acceleration is dominated by the Fermi-like reflection of electrons within the resulting magnetic islands rather than by the parallel electric fields associated with the x-line. Particles trapped within islands gain energy as they reflect from ends of contracting magnetic islands, slowly drift outwards and scatter as they undergo non-adiabatic motion near the magnetic separatrices. A Fokker-Planck equation for the distribution of energetic particles similar to that developed in shock acceleration theory is obtained by averaging over the particle interaction with many islands. Steady state solutions in reconnection geometry result from convective losses balancing the Fermi drive. Distribution functions take the form of a powerlaw whose spectral index depends on the mean aspect-ratio of the islands. In large systems the spectral index is the same as that obtained for high mach number shocks – namely the conversion efficiency of magnetic energy into energetic electrons is high. The energy content of these particles is a consequence of their high mobility – they can rapidly interact with many islands to reach high energy. The model is consistent with several key solar and magnetospheric observations: the production of large numbers of energetic electrons; the isotropy of the particle distributions at high energy and powerlaw distributions.

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