"Nonthermally Dominated Electron Acceleration during Magnetic Reconnection in a Low-β Plasma"

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The primary question addressed in this work was the mechanism by which electrons are accelerated to nonthermal energies during magnetic reconnection in a nonrelativistic plasma. The conversion from magnetic energy to plasma kinetic energy that generally occurs during reconnection is well understood, but how the electrons are accelerated to the point where their energies are represented by a power-law, rather than a Maxwell distribution, is not. Two possible mechanisms thought to drive these accelerations were the *Fermi* mechanism, which is known to drive energy gain in other events, such as shocks, and direct acceleration in the diffusion region. These high accelerations are seen on the sun during solar flares, and investigating the cause can lead to a better understanding of these types of events.

This question was investigated by running kinetic simulations with the 'VPIC' code. Initial conditions included equal values of β for both electrons and ions (protons), and Maxwellian speed distributions characteristic of (initially) thermal particles. Other variables included the mass ratio of electrons to ions, electron drift velocity, and several plasma parameters, such as gyrofrequency, plasma frequency, and electron/ion inertial length. Magnetic reconnection was induced by adding a wavelength perturbation. Previous work focused on β values greater than $\sim$0.1 (lower values were unexplored due to lack of computational abilities). Here, the authors were able to investigate β values of 0.007, 0.02, 0.06, and 0.2. The output of these simulations included the rate of energy conversion, the change in current density, and the overall increase in energy for each β.

After running the simulations, the *Fermi* mechanism was found to be the dominant accelerator, and that lower values of β resulted in higher energy gain. Figure 1(d) provides a good illustration of the increase in energy for the four different values of β. The lowest, 0.007, produced an energy increase greater than ten times the original energy. The authors concluded with two constraints that were required to produce a power-law electron energy distribution. First, the reconnection process itself required a timescale long enough for the electrons to aquire the appropriate energy distribution. Second, the β parameter had to be sufficiently low. As β is expressed by

$$\beta = \frac{P_{th}}{P_{mag}} = \frac{nk_BT}{B^2/8\pi} \propto \frac{nT}{B^2}$$

its value could be lowered either by decreasing the particle number density n, decreasing the temperature T (which was found to have a negligible effect), or increasing the strength of the magnetic field B. Possible future investigations included ion acceleration in addition to electron acceleration, the addition of an external guide field in the simulations (which could result in three-dimensional instabilities), and particle loss mechanisms.