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

The primary physical phenomenon addressed by the authors is the acceleration of particles, specifically the mechanism by which electrons and protons with nonthermal energies are accelerated in regions of magnetic reconnection. Emission from solar flares has indicated that these energies, are considerably higher than thermal energies, and it is unclear exactly how they are obtaining such high energies. Two mechanisms had been previously explored: the *Fermi* mechanism (need source) and direct acceleration (another source). In the past, low-β simulations were difficult to produce (presumably because of a lack of compuational ability) so the authors investigated β values between 0.007 and 0.2. The particles were modeled in a "fully relativistic manner", whatever that means.

Hoping to obtain a power-law model to match observations, this problems was investigated using kinetic simulations in a code that solved Maxwell's equations, namely, Ampere's law. Starting with certain initial conditions: equal values of β for both electrons and protons, a mass ratio of ions (protons) to electrons of 25, and Maxwellian speed distributions all around, magnetic reconnection was induced by adding a wavelength perturbation, and changing β as a function of the electron plasma frequency (source) and the electron gyrofrequency (source). This was done for four different values of β, which were determined somehow. The results from these simulations included the rate at which energy was transformed from magnetic energy before reconnection to nonthermal energy after reconnection.

After plotting all the plots that they plotted, the authors concluded with two main constraints on the production of "power-law electron distribution" (need to word this better). The first is that the reconnection process itself requires a timescale of around something in order for the electrons to aquire the resulting distribution. Second, the β parameter has to be sufficiently low, qualitatively meaning that the magnetic pressure dominates the thermal pressure by a factor of something. As β is expressed by

$$\beta = \frac{P_{th}}{P_{mag}} = \frac{n k_B T}{B/8\pi} \propto \frac{n}{B}$$

its value could be lowered either by decreasing the particle number density (n) or increasing the strength of the magnetic field (B). The temperature was also an adjustable parameter, but was not found to have much of an effect on β, nor did the size of the system used during the simulations. This makes sense, as we learned in class that the low power of T compared to B means that B dominates. (source: class notes? look this up!). As shown in figure 1(d), the lower β values result in a greater energy increase: a difference of more than ten times the original kinetic energy for the lowest value of 0.007. The *Fermi* mechanism was found to be the dominant accelerator. The low values of β produced the power-law energy distribution, where said energy came from the conversion of the magnetic energy that was present before reconnection to the nonthermal energy possessed by the electrons after reconnection. These findings may help to expain the electron acceleration present in major events such as solar flares and the magnetosphere of the Earth.

In section 2., the authors mention that they carried out their simulations using a code that solves Maxwell's equations. Using what you know about Maxwell's equations, which one(s) do you think they needed to solve, and why?

In section 4, the authors mention that the results may be influenced by three-dimensional instabilities, such as the kink instability. What is the kink instability? Why might it have an effect on the science being done here?