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High-energy particle acceleration processes in a current sheet of pair plasmas

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There are many electron-positron plasmas in high-energy astronomical locations. For example, there is a fast plasma outflow of electron-positron plasmas, called 'pulsar wind', around the Crab pulsar. In order to satisfy both theories and observations, the electro-magnetic field energy has to be converted into the particle kinetic energy in the wind. Recently, Coroniti (1990 ApJ) and Lyubarsky et al. (2001 ApJ) discussed magnetic reconnection processes in the striped plasma sheet structure in the pulsar wind, but the problem still remains unclear. We study particle acceleration processes in a current sheet structure of electron-positron plasmas, which may be essential to solve problems like that.

First, we will review particle acceleration in relativistic magnetic reconnection. We have carried out a 2D full particle simulation of magnetic reconnection on condition that its outflow jet speed (which is known to be a typical Alfven velocity of the system) is nearly as fast as the light speed. In this case, corresponding reconnection electric fields become so strong that the electric fields become much dominant than the magnetic field in a relatively large space around the X-type region. This region is main location of acceleration and we call it AR below here. Particles are accelerated and gain energy very effectively in the AR traveling through relativistic-modified Speiser-like orbit. As a result, a noticeable number of non-thermal particles are observed in their energy spectrum.

Second, we will introduce another new acceleration process corresponding to a cross-field instability of a plasma sheet. We study an instability of a thin plasma sheet of e+ - e- plasmas using 2D particle simulation in a cross field plain and we have observed a typical growth of a drift kink instability (DKI). In the non-linear stage of DKI, the current sheet is transformed into a folded curve structure, and spacial regions inside the folded curves become acceleration regions(ARs). High-energy particles, whose larmor radii are large enough to skip across the scale length of DKI, are successively accelerated through multiple ARs, in a timescale of several tens of ion(positron) gyration. A considerable number of non-thermal particles are also observed in their energy spectrum.

The above two acceleration processes have a very important feature: high-energy particles are more likely to be accelerated. In a relativistic case, accelerated particles become heavier by relativistic effect, and so their Larmor radii become longer and longer. This means that they are likely to stay in the ARs, or tend to be trapped in the ARs in our field configurations. Thus high energy particles are much more accelerated and they form non-thermal components of the energy spectra.

These acceleration processes are important basic processes in energetics in an electron-positron plasma sheet. They are also important to study the origins of non-thermal particles in the universe.