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Particle Acceleration at Reconnecting X points in Solar Flares by Electrostatic Waves

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Abstract. In the impulsive phase of solar flares, the electrostatic waves can be excited during magnetic reconnection. The proton and electron at reconnecting X points can be accelerated by perpendicular propagating electrostatic waves.

Keywords. sun:flares, magnetic reconnection, acceleration of particles, waves

As well known from radio and HXR burst observations that solar flares may be divided into a rise phase, an impulsive phase and a decay phase. Anomalous resistivity during the magnetic reconnection has been widely invoked to explain the fast energy release in the impulsive phase of solar flares. The plasma instabilities are often taken as the responsibility for anomalous resistivity. These instabilities, however, also amplify various waves during magnetic reconnection. In fact, the plasma waves have been observed at magnetic reconnection sites in the magnetotail and magnetopause (Bale *et al.*, 2002), as well as found in three dimensional particle simulation of magnetic reconnection (Drake *et al.*, 2003). On the other hand, the electron may be accelerated continuously by electrostatic waves, which has been studied in laser plasma, if an uniform transverse magnetic field is superposed.(Dawson *et al.*, 1983).

We apply this mechanism to study electron and proton acceleration in the impulsive phase of solar flares. It is found from the calculation results of analytical solution and test particle simulation, they may be divided into two categories for solar flares.

(a) Both parameters $G_e = \omega_{\|e}^2 - \frac{v_p}{d}\omega_{0e} > 0$ and $G_p = \omega_{\|p}^2 - \frac{v_p}{d}\omega_{0p} > 0$ are satisfied, where v_p is phase velocity of electrostatic wave, d is the half thickness of current sheet, $\omega_{\|e}$ and ω_{0e} are electron cyclotron frequency of longitudinal and reconnection magnetic field, respectively. Protons and electrons are accelerated simultaneously and their acceleration velocity are along outflow direction x in reconnection sheet. v_{ze} and v_{zp} are much smaller than v_{xe} and v_{zp} separately, as shown in Fig. 1.

(b) Only condition $G_e > 0$ is satisfied, but $G_p < 0$. The protons escape rapidly from the boundary of reconnection sheet and the protons acceleration processes will discontinue. In this case, only electrons can be accelerated effectively, as shown in Fig. 2(a) and 2(b).

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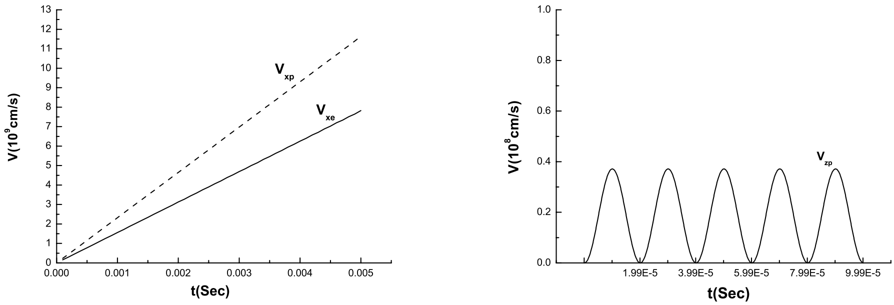

Figure 1. The time evolution of proton and electron velocity trajectory for $B_0 = 200G, B_y = -40G, B_z = 1G, v_p = -5 \times 10^8 cm/s, d = 2 \times 10^4 cm$, and $G_e > 0, G_p > 0$ (a) v_{xe} and v_{xp}, (b) v_{zp}.

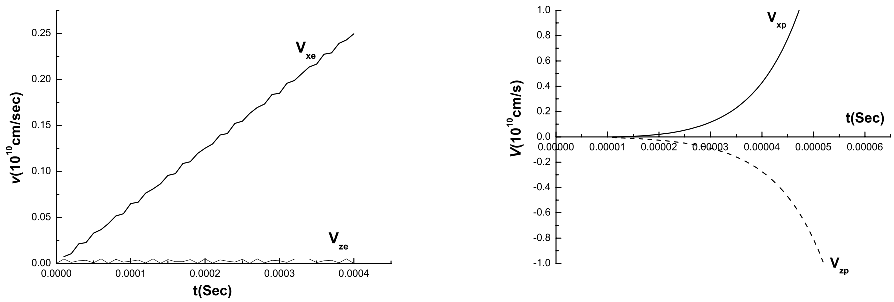

Figure 2. The time evolution of proton and electron velocity trajectory for $B_0 = 200G, B_y = -20G, B_z = 1G, v_p = -5 \times 10^8 cm/s, d = 2 \times 10^4 cm$, and $G_e > 0, G_p < 0$ (a) v_{xe} and v_{ze}, (b) v_{xp} and v_{zp}.

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