Nonlinear development of current-driven instabilities and selective acceleration of ^{3}He ions

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In some solar flares, the abundance of high-energy ^{3}He ions is extremely increased [1]. As a mechanism for these ^{3}He rich events, current-driven instabilities are believed to be important, and several theoretical models based on linear theories for the instabilities have been proposed. In those theories, the instabilities by weak currents such as $v_d < v_{Te}$ were mainly considered; here, v_d is the initial electron drift speed along the magnetic field, and v_{Te} is the initial electron thermal speed. However, according to the observations, there is good correlation between ^{3}He rich events and impulsive burst of energetic electrons with 1-100 keV [1]. Those electrons are considered to drift along magnetic field and to cause the strong current-driven (or beam) instabilities. We study nonlinear development of such instabilities and associated energy transfer to ^{3}He ions in a plasma containing H, ^{4}He, and ^{3}He ions with the abundance of ^{3}He being small [2, 3].

By means of a two-dimensional, electrostatic particle simulation code, we demonstrate that nonlinear evolution of the instabilities can cause selective acceleration of ^{3}He ions. After the development of the Buneman waves, H cyclotron waves are destabilized in a plasma with the electron temperature T_e higher than the ion temperature T_H; the electron temperature is of the order of the initial electron drift energy. The fundamental H cyclotron waves near the frequency $\omega = 2\Omega_{3He}$ (Ω_{3He} is the cyclotron frequency of ^{3}He ions) eventually grow to largest amplitudes. These waves transfer their energies preferentially to ^{3}He ions.

The condition under which the waves with $\omega = 2\Omega_{3He}$ eventually become dominant is also investigated. The frequencies and growth rates of H cyclotron waves in a plasma with $T_e > T_H$ are calculated theoretically and numerically. It is shown that the waves with $\omega = 2\Omega_{3He}$ have the greatest growth rates for a large region of the plasma parameters. The electron to ion temperature ratio must be $T_e > 10T_H$. The frequencies and growth rates are only weakly dependent on the values of the magnetic field or the plasma density. We can now predict that if the initial electron drift energy is higher than 1 keV, the waves with $\omega = 2\Omega_{3He}$ would grow to large amplitudes and selectively accelerate ^{3}He ions.

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