§24. Further Acceleration of Energetic Ions by Nonlinear Magnetosonic Waves

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The propagation of nonlinear magnetosonic waves and associated particle acceleration are under exploration in our group for several years. Recently we have been studying effects of the presence of multiple ion species,[1,2] relativistic effects in strong magnetic fields,[3,4] production of ultrarelativistic electrons,[5] etc. We here briefly describe the further acceleration of energetic ions.[6]

In a plasma containing hydrogen and (minority) heavy ions, a large-amplitude magnetosonic wave can accelerate some of the H ions by the longitudinal electric field and all the heavy ions by the transverse electric field. Hence, after the passage of a large-amplitude magnetosonic pulse, there must be energetic ions. In a plasma with strong magnetohydrodynamic disturbance, such as in solar flares, there would be a number of large-amplitude magnetosonic pulses (Alfvén waves would also be present). Each pulse will produce some energetic ions, and they will encounter many other pulses. We studied how the energetic ions interact with those pulses. We were especially interested in whether or not there is a mechanism further accelerating energetic ions.

We considered a plasma consisting of electrons, bulk (thermal) ions, and a small number of nonthermal energetic ions. The velocities of these energetic ions were assumed to be much greater than the Alfvén speed v_A. First, we analytically obtained the amount of energy that an energetic ion can gain from a magnetosonic pulse. Then, to study the interaction between the particles and a nonlinear magnetosonic wave in a self-consistent manner, we used a one-dimensional, fully relativistic, fully electromagnetic, particle code with full ion and electron dynamics. The code contained H and (minority) He ions. It is found that some energetic ions can be further accelerated by a magnetosonic wave.

We carried out several simulations with different values of initial momenta of energetic ions, keeping the other parameters unchanged, and observed the dependence of the increase in p^2 (p is the momentum of an energetic ion) on the initial momenta, which is shown in Fig. 1. The solid and dotted lines represent theoretical values for H and He, respectively. The dots and white circles show simulation results for H and He, respectively. We see that ions with greater energies can gain greater energies.

Some of the energetic ions can be further accelerated by a shock wave. This suggests that some ions can be accelerated many times by many different magnetosonic pulses.

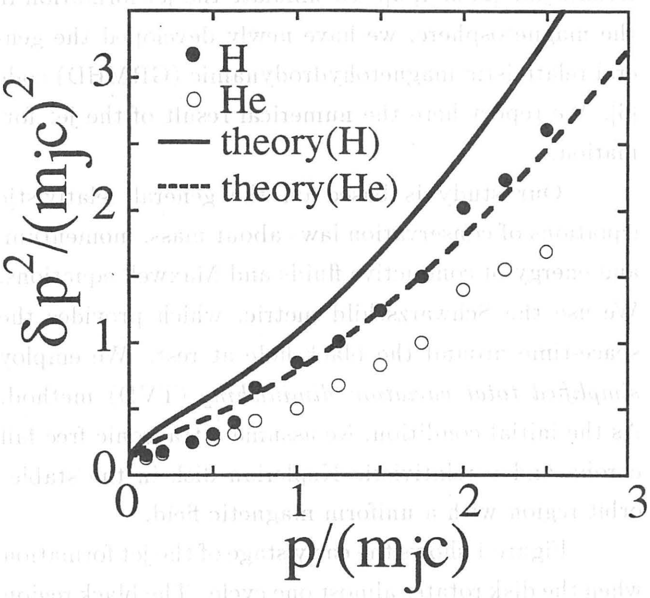

Fig. 1. Increase in p^2 as a function of the initial momentum p.

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