§35. Simulation Study of Current-Driven Instability in a Multi-Ion-Species Plasma

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The presence of multiple ion species provides many interesting issues.[1-4] We have studied its effects in magnetosonic waves and current-driven instabilities. We here describe the work on current-driven instabilities.

The properties of current-driven instabilities in a multi-ion-species plasma can be different from those in a single-ion-species plasma. For example, in a plasma with the same elemental composition as the solar corona, for some plasma parameters, ion-cyclotron waves or oblique ion-acoustic waves can have positive growth rates near the cyclotron frequency of ^{3}He, $\omega \simeq \Omega_{3\mathrm{He}}$.[5] At the same time they can have negative growth rates near ^{4}He cyclotron frequency, $\omega \simeq \Omega_{4\mathrm{He}}$. These waves could play an essential role in ^{3}He-rich events where the abundance ratio ^{3}He/^{4}He becomes quite high, up to order unity, in the energetic particles produced in solar flares.

We have started the simulation study of the current-driven instability in a multi-ion-species plasma using a three-dimensional electrostatic particle code with full ion and electron dynamics. We will investigate effects of the presence of multiple ion species on the growing and saturation of ion cyclotron waves and ion acoustic waves, giving great attention to the energy transport in association with these instabilities. Firstly, we simulate the two-ion-species plasma, where the main component is hydrogen and the minority component is helium; the aboundace ratio is $n_{\mathrm{He}}/n_{\mathrm{H}} = 0.1$ as in space plasmas. The temperature ratios are $T_e/T_{\mathrm{H}} = 5.0$, $T_{\mathrm{He}}/T_{\mathrm{H}} = 1.0$. The electron current along the magnetic field is $v_{de}/v_{Te} = 1.0$, where v_{de} is the electron drift velocity parallel to the ambient magnetic field and v_{Te} is the electron thermal velocity. For these parameters, ion acoustic waves are unstable and ion cyclotron waves are stable.

Figure 1 shows the time variation of electron current, light-ion and heavy-ion energies. The dotted lines are energy components parallel to the magnetic field and solid lines are perpendicular components. The heavy ions as well as light ions are heated, unlike the prediction of the linear theory. In both H and He, perpendicular energy $E_\perp$ mainly increases. Interestingly, $E_\perp$ in He keeps increasing, even though the increasing rate of hydrogen energy quickly goes down. This result indicates that the heavy ions play a significant role in energy transport as well as in the growing of waves.

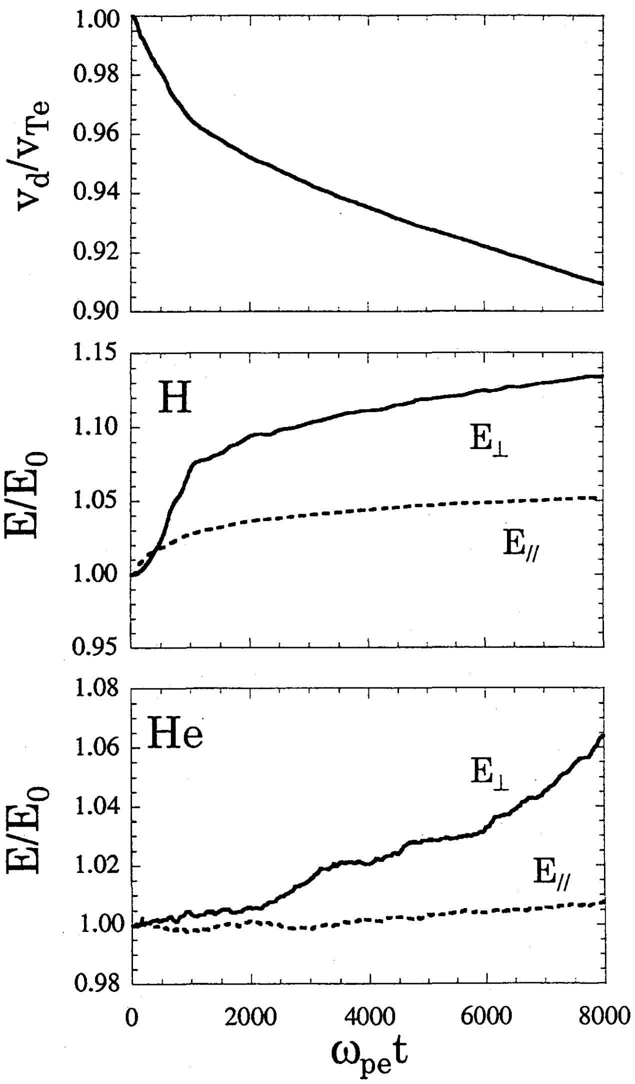

Fig. 1. Time variation of electron current, light ion and heavy ion energies.

Reference

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