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Non-linear interaction between ions and ion cyclotron waves in the solar wind: a hybrid simulation

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Resonant interaction between ions (oxygen ions O^{+5} and protons) and ion cyclotron waves is investigated using a one dimensional hybrid code. Ion cyclotron waves are self-consistently generated by an ion cyclotron anisotropy instability. We focus on the detailed acceleration process of ions. The non-linear interaction between oxygen ions and ion cyclotron waves is found to have two stages. During the first stage, oxygen ions are accelerated and heated in the direction perpendicular to background magnetic field and can develop extreme high temperature anisotropies with $T_{O\perp}/T_{O\parallel} \approx 22$ in an initially low beta plasma (beta value at 0.01) with very little parallel heating. During this stage, oxygen ions do not show an appreciable bulk acceleration along background magnetic field. In the second stage, a large bulk acceleration of oxygen ions (as large as 0.3 Alfvén speed) is observed. Ion cyclotron waves are not able to maintain the high temperature anisotropy as resonant heating continues. The non-linear nature of wave particle interaction makes oxygen ions have highly complex velocity distributions. In contrast, the heating and acceleration behavior of the major species, protons, is quite different. The velocity distributions of protons are less complex than the oxygen velocity distributions. Protons can also develop an large temperature anisotropy with preferential heating in the perpendicular direction. A bulk acceleration of protons (much smaller than the acceleration of oxygen ions) along background magnetic field is observed to develop simultaneously with the development of proton temperature anisotropy.