Enhanced ion acoustic lines due to strong ion cyclotron wave fields

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The incoherent scatter radars (ISR) are designed to detect tiny thermal electron density fluctuations, and, therefore, they would be very sensitive to any ion wave enhancements that are energized by a strong field-aligned plasma turbulence. In the literature, these ISR enhancements are called as NEIALs, naturally enhanced ion acoustic lines.

The Fast Auroral Snapshot Explorer (FAST) satellite detected such strong electrostatic turbulence, which has the form of intense, 40 mV/m peak-to-peak, and coherent decameter-scale electric field structures, in the high-latitude topside auroral ionosphere between the altitudes of 350 km and 650 km (This altitude region coincides with where NEIALs have been observed.) The electric fields appear to belong to saturated electrostatic ion cyclotron (EIC) waves in terms of their amplitude, frequency and wavelengths. For a decameter-scale EIC waves aligned nearly with the magnetic field the parallel wavelength and therefore the parallel phase velocity could be significantly greater than the ion thermal velocity, and could be comparable to the electron thermal velocity. Numerical simulations of the response of an electron plasma to the parallel components of these fields show that the waves are likely to excite a wave-driven parallel ion acoustic (IA) instability, through the creation of a highly non-Maxwellian electron distribution function (EDF), which when combined with the (assumed) Maxwellian ion distribution function provides inverse Landau damping.

In this paper, we present the EDF results by solving a kinetic equation with the BGK collision term. The kinetic equation is solved continuously (as opposed to via a particle-in-cell code) and the resulting EDFs are sufficiently smooth for the Nyquist instability analysis for the IA waves. We find that that the phase-space plots of the EDF response to a periodic ion density perturbation along the field lines show fine structures near the zero-velocity axis. The Nyquist analysis confirms that these fine structures are unstable to IA waves.

Because the counter-streaming threshold for excitation of EIC waves is well below that for excitation of IA waves (assuming Maxwellian statistics) our results suggest a possible two step mechanism for destabilization of IA waves. Combining this simulation result with the observational fact that these EIC waves share a common phenomenology with the naturally enhanced IA lines (NEIALS) observed by incoherent scatter radars, especially that they both occur near field-aligned currents, leads to the proposition that this two-step mechanism is an alternative path to NEIALS.