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ELECTRON BEAM INSTABILITIES IN A MAGNETIZED PLASMA AND AURORAL PARTICLE ACCELERATION

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When the ambient magnetic field is significant, a rich variety of wave modes is possible. This can already be seen from the dispersion relation of a cold plasma which is often used to study ionospheric phenomena. Additional wave modes and kinetic instabilities occur in a warm plasma. The ratio of cyclotron frequency to plasma frequency Ω_e/ω_e is an important paramater characterizing the wave regime. In the **auroral zones** this ratio varies over a wide range, from small values in the dense low altitude ionospheric region to a maximum well exceeding unity and then back to small values characteristic of the interplanetary plasma at great distances from the Earth. In these zones one finds not only primary precipitating electrons (in the keV range) which ultimately produce auroras, but a whole variety of unusual features of the particle distribution functions [*Shelley,* 1995].

A particularly noteworthy feature are so called **ion conics**, named after the shape of the particle distribution function. It is thought that they are the result of low altitude heating perpendicular to the ambient magnetic field and subsequent upward acceleration by the magnetic mirror force. Such ions (Hydrogen, Oxygen, Helium) of ionospheric origin are observed at great distances from the Earth. *Chang and Coppi* [1981] proposed that the heating is due to lower hybrid waves, which propagate at large angles to the magnetic field. The basic idea is that the relevant phase velocity ω/k becomes small enough for a resonant interaction with (unmagnetized) ions, while the Cerenkov interaction with magnetized electrons occurs at much larger phase velocities $\omega/k_{\|}$. The waves could thus be destabilized by an electron beam.

The relation between precipitating electron and **auroral hiss** is indeed well established. The low frequency part of the hiss spectrum, near the cutoff at the lower hybrid frequency, thus may be a viable candidate for ion heating. Intense bursts of very short wavelength modes are indeed observed favors excitation of plasma waves at propagation angles close to the magnetic field. It has been pointed out that propagation effects in the inhomogeneous plasma may allow a possible solution of this problem. Plasma waves may propagate out of the finite instability region, thus allowing the lower hybrid waves to dominate [*Maggs and Lotko,* 1981]. Another solution has been proposed by *Omelchenko, Shapiro, and Shevchenko* [1994]. They pointed out that waves could be excited by virtue of the anomalous Doppler resonance

$$\omega - k_{\|}v_{\|} - n\Omega_e = 0, \quad n < 0 \tag{1}$$

even in the absence of a pronounced beam (positive slope of the distribution function) or after the beam has been transformed into an extended plateau by quasilinear flattening.

The rapid transformation of the beam by quasilinear effects due to the excitation of plasma waves and the subsequent much slower evolution of the wave spectrum towards very obliquely propagating lower hybrid waves can be observed in 2D computer simulations. Initialization of runs with a flat topped extended electron tail is also possible. The runs show also the simultaneous excitation of upper hybrid waves and nonlinear effects, such as the generation of waves propagating opposite to the beam drift direction, similar to the unmagnetized case.

While the wave particle interaction produces very interesting features in the electron distribution function, very little ion heating is observed in most simulations. Most waves apparently do not have sufficiently small phase velocities for an efficient interaction with the ions. A more thorough theoretical investigation also reveals that the common description of lower hybrid waves by invoking fully magnetized electrons and *unmagnetized* ions is not valid in describing the ion interaction. This interaction actually takes place by cyclotron resonance for frequencies near harmonics of the ion cyclotron frequency and could be located in space regions distinct from the instability region [*Dum,* 1996]. Obervation of auroral hiss with corresponding

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