Mechanisms for onset of the whistler chorus in Earth's magnetosphere

G. Wang[1] and H.L.Berk[2]

[1] *CPTC, University of Wisconsin-Madison, Madison, WI, 53706, USA*
[2] *IFS, , University of Texas at Austin, Austin, TX, 78723, USA*

Abstract

We have extended the formalism that describes chirping phenomena in a fusion plasma [1] to model chirping of whistler waves in the magnetosphere, and developed a code that uses realistic physical scales and high phase space resolution near the particle resonance regions to study the onset of a whistler chorus. Pressure anisotropy in the magnetosphere excites convective whistler instability with the most unstable mode at a frequency ω_0 and then the excited wave packet moves away from the equator at the group velocity. The wave amplitude is spatially linearly amplified, until the nonlinearity of particles near the resonance region sets in. This nonlinearity arises from trapping of the resonance particles, so that the trapped distribution, f_T, will transport with a resonant velocity toward the equator (opposite to the propagation direction of the wave packet) in accord with the local resonance condition, while the ambient non-trapped distribution, f_0, is constrained to oscillate about the equilibrium particle orbit with the energy and magnetic moment conserved. This causes a hole to form in the trapped region, with a hole depth, $\Delta f = f_0 - f_T$, which steadily increases as the hole moves toward the equator with the field frequency still oscillating at the initial frequency ω_0, while transferring particle free energy to the waves. Thus a chain of holes move into an environment where the field amplitudes are spatially decreasing until the wave amplitude matches a nonlinear BGK condition[1, 2], which allows the BGK mode to form at a shifted frequency, that initiates a chirping signal as the the holes move in phase space. The chirping holes then serve as antennas that radiate new whistler frequencies amplified as the group velocities transmit the new frequencies toward a magnetic pole. The simulation is consistent with our conjecture that these mechanisms are what enable the emergence of the observed rising tone whistler chorus in the magnetosphere.

References

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