Institute for Space Weather Sciences Colloquium

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Generation of Quasi-Parallel Whistler Waves in the Solar Wind

Whistler waves (right-hand polarized electromagnetic waves with frequencies above local proton cyclotron frequency, but below local electron cyclotron frequency) in the solar wind have drawn a lot of attention due to their potential role in the heat flux regulation and electron scattering that results in formation of typical solar wind electron velocity distribution functions (eVDFs). Modern satellite measurements provided conclusive evidence that whistler waves are generated locally via the so-called whistler heat flux instability (WHFI). Such experimental successes have driven theoretical and modelling efforts to understand the influence of the locally generated whistler waves on the particles. Simulations of the nonlinear evolution of WHFI demonstrated that parallel whistler waves are incapable of suppressing the electron heat flux. At the same time, eVDF observations show that hot electrons have temperature anisotropy that might drive generation of anti-parallel whistler waves. Anti-parallel waves generated due to temperature anisotropy would interact with a substantial fraction of halo electrons carrying the heat flux. Therefore, they could influence the heat flux more significantly than parallel waves.

We performed Particle-In-Cell simulations of the combined whistler heat flux + anisotropy instability and studied how the wave properties depend on the electron distribution parameters. In particular, the calculations revealed a scaling relation between the saturated wave amplitudes and the linear growth rates. Our calculations also demonstrate that anti-parallel whistler waves generated via the combined instability decrease the heat flux. From the observational point of view, though, it is more difficult to directly observe the anti-parallel whistler waves than the parallel ones. But particle measurements might provide a good insight on the occurrence rate of these waves in the solar wind. We performed a linear stability analysis of a large dataset of eVDFs observed by the Wind spacecraft. Our results demonstrate that plasma is quite often unstable with respect to anti-parallel whistler wave generation, but the occurrence rate and saturated amplitudes are lower than for the parallel waves.

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