Beta dependence of electron heating by whistler turbulence

Shinji Saito[1]
[1] NICT

Solar wind magnetic turbulence is observed to have power law energy spectra in frequency. The spectral indices in the MHD regime, at frequencies are less than 0.1Hz, are frequently close to -5/3. At higher frequencies, the magnetic spectra usually show steeper spectral indices. The spectral breakpoint around 0.1Hz corresponds to wavelengths close to the ion inertial or Larmor scale , assuming the Taylor frozen-in-flow hypothesis is valid in the solar wind at 1 AU. This first spectral breakpoint suggests that kinetic properties of the plasma become effective at shorter scale turbulence. Recent solar wind observations found that magnetic spectra have a second breakpoint around the electron inertial or Larmor scale (Sahraoui et al. (2009)).

Whistler fluctuations are likely to make an important contribution to electron scale turbulence. Several studies have done computer simulations of whistler turbulence and found steeper magnetic energy spectra (=<-7/3) and anisotropic wavenumber spectra that are broader in wavenumber perpendicular to the background magnetic field than parallel (e.g. Cho et al. (2004)). Saito et al. (2008) used particle-in-cell simulations to show that the anisotropic whistler turbulence heats the electrons in the parallel direction as predicted by linear theory. Further, Saito et al. (2010) show that in low beta plasmas the magnetic wavenumber spectrum becomes even more strongly anisotropic. A spectral index in the perpendicular direction is close to -4 which corresponds to recent solar wind observations (Sahraoui et al. (2009)) and a phenomenological turbulence scaling model.

Here two-dimensional particle-in-cell simulations of whistler turbulence are carried out in a collisionless, homogeneous, magnetized plasma at several plasma betas. Our simulation results show that at higher plasma betas magnetic energy cascade in the perpendicular direction becomes weaker and leads to more isotropic wavenumber spectra. The electron energy ratio between parallel and perpendicular component becomes closer to unity at higher betas. Since oblique-propagating whistler fluctuations tend to heat electrons in the parallel direction through Landau damping as predicted by linear theory, our simulation results suggest that the forward energy cascade of whistler turbulence in higher beta plasmas is also more isotropic. Thus both the wavenumber spectrum of whistler turbulence and electron heating tend toward isotropy in high beta plasma.