Collisionless turbulent heating and inter-species energy transfer in CTEM turbulence

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We reconsider the classic problems of calculating "turbulent heating"and collisionless inter-species transfer of energy in drift wave turbulence. This issue is of interest for low collisionality, electron heated plasmas, such as ITER. Having observed that net heating is necessarily volumetric, we note that the net heating in a finite annular region of width Δr is given by $\int d^3r\langle \tilde{E}\cdot\tilde{J}\rangle = -\left(\tilde{\varphi}\tilde{J}_r\right)S\rrbracket_{r_1}^{r_2} \neq 0$. Here S is the surface area of the annular contained within $r_1 < r < r_2$. Note net heating is determined by the differential in mesoscale radial current (i.e. $\tilde{J}_r$) across the region of interest. In addition to *heating*, there is inter-species heat *transfer*. For CTEM, the total collisionless heat transfer is due to quasilinear cooling of precession resonant trapped electrons and nonlinear electron cooling by electron Compton scattering. Ion heating occurs by quasilinear and nonlinear channels, where the first accounts for ion Landau damping and the second for nonlinear ion Landau damping. In addition, perpendicular heating via ion polarization and diamagnetic effects, accounts for the net Reynolds work of the turbulence on the zonal flow. Since at steady state, work on zonal flow must balance zonal flow friction , it is no surprise that zonal flow friction($\sim \nu_{ii}\langle V_{ZF}\rangle^2 \sim \left|{e\tilde{\varphi}}/{T}\right|^4$) gives an important channel for ion heating. This process of energy transfer via zonal flows has not previously been accounted for in analyses of energy transfer. As an application, we compare the rate of turbulent energy transfer in a collisionless plasma with the rate of the energy transfer by collisions. The collisionality ν_* for crossover is 10^{-2}. *For ITER plasma, with a collisionality of the order of* 10^{-3}, *the collisionless turbulent energy transfer is thus anticipated to be the dominant coupling process.* Furthermore, we compare the volume integral of electron cooling to the surface integrated of the electron heat flux in CTEM. The ratio of transfer to transport loss is given by $\frac{2a}{R} \approx \frac{2}{3}$ which suggests that the electron turbulent energy transfer to ions in a collisionless plasma can be of the same order as electron heat diffusion loss.