High Frequency Geodesic Acoustic Modes in Electron Scale Turbulence

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There has been overwhelming evidence that coherent structures such as vortices, streamers and zonal flows ($m = n = 0$, where $m$ and $n$ are the poloidal and toroidal modenumbers respectively) play a critical role in determining the overall transport in magnetically confined plasmas [1]. The Geodesic Acoustic Mode (GAM) is the oscillatory counterpart of the zonal flow ($m = n = 0$ in the potential perturbation, $m = 1$, $n = 0$ in the perturbations in density, temperature and parallel velocity) and thus a much weaker effect on turbulence is expected. Nevertheless experimental studies suggest that GAMs ($n = 0$, $m = 1$) are related to the L-H transition and transport barriers. The electron-temperature-gradient (ETG) mode driven by a combination of electron temperature gradients and field line curvature effects is a likely candidate for driving electron heat transport. The ETG mode driven electron heat transport is determined by short scale fluctuations that do not influence ion heat transport and is largely unaffected by the large scale flows stabilizing ion-temperature-gradient (ITG) modes. We have utilized a fluid model for the ETG mode based on the Braghinskii equations with non-adiabatic ions including impurities and finite $\beta$ - effects. The ETG mode model consists of electron continuity, electron parallel momentum and energy equations in combination of an non-adiabatic ion response. The ion and electron counterparts are coupled using quasineutrality. We use the wave kinetic equation[1] to describe the background short scale ETG turbulence and derive an dispersion relation for the GAM. In describing the large scale plasma flow dynamics it is assumed that there is a sufficient spectral gap between the small scale fluctuations and the large scale flow. We note that the linear GAM is purely oscillatory and non-linearly the electron GAM is unstable with a growth rate depending on the saturation level $|\phi_k^2|$. To estimate the ETG turbulent fluctuation level and GAM growth, a predator-prey model was used to describe the coupling between the GAMs and small scale ETG turbulence. The stationary point of the coupled system implies that the ETG saturation level $\phi_k$ can be drastically enhanced by a new saturation mechanism, stemming from a balance between the Landau damping and the GAM growth rate.

References

[1] P. H. Diamond et al, 47 R35 (2005).