§11. Identification of Micro-Turbulence in LHD from 2d Phase Contrast Imaging

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It is well known that particle and energy transport are strongly influenced by fluctuation-driven processes. Here we focus the relationship between parameter profiles and fluctuation profiles. The purpose of such an investigation is twofold, since fluctuation profiles have ramifications for the transport and may regulate the profiles, and also to provide evidence for particular theoretical descriptions of the turbulence behaviour. Drift-wave like fluctuations are driven by gradients in density and ion/electron temperature profiles, and are affected by magnetic properties. Linear growth rates for ITG have been performed in LHD [1].

Fluctuation measurements presented here were made using a novel 2-d CO_2 laser phase contrast imaging (PCI) system, which was recently upgraded in the 9^{th} cycle [2]. This diagnostic has the capability to simultaneously resolve line-integrated fluctuations both along the line of sight, which we label by flux coordinate ρ (with +/- denoting above/below the midplane), and in k. The system uses a (6x8) 2d detector array to measure to determine the position of fluctuations. The phase velocity of the fluctuations conveys information about the underlying nature of the instability, depending on whether it is in the ion or electron diamagnetic direction. It is necessary to compare fluctuation velocities with the ion/electron drift velocities in the plasma frame of reference: $v_{ph} = v_{ExB} \pm v_{dr}$. The ExB rotation is measured directly from the Doppler shift of C VI CX radiation driven by perpendicularly injected positive NBI, recently installed in the last experimental campaign, providing detailed information near the edge of the plasma. A comparison of PCI phase velocity and diamagnetic velocities is shown in Fig. 1. The measurements are consistent in that the shape of the ExB profile closely corresponds with the fluctuation velocity. In the edge, there is a significant ExB shear. This may play a role in regulating the transport in certain scenarios. The fluctuation velocities are approximately offset from the ExB velocity by the electron drift velocity, which would be expected of primary TEM-driven modes.

We consider the change of the profile from peaked to hollow, after pellet injection, to elucidate the role of density gradient. The fluctuation profiles are shown in Fig. 2. In the peaked density profile, fluctuations are strongest in the edge, while when the profile hollows, a new branch is excited towards the core, in the hollow part of the profile. The temporal dynamics at ρ=0.7 are shown explicitly in Fig. 3. After pellet ablation, the density profile is transiently hollow. When the profile switches to peaked, fluctuations are reduced. At around t=1.8s, the heating power is increased and the profile returns to hollow. Again, when and the sign of η changes, fluctuations increase again. Because the temperature gradient is non-zero, and density gradient is a regulating parameter, this is evidence of a slab-like ITG mode. However, ITG dominated modes propagate in the ion-diamagnetic direction, contrary to the observed phase velocity described in the previous section. This feature is also inconsistent with the theoretical expectations [1], which show that fluctuations should be reduced in the hollow part of the density profile, for a peaked temperature profile. The presence of a fluctuation peak in the hollow region of the density profile is universal in that it occurs in a variety of discharges, though exceptions can be found with no peak in the hollow region. The direction and magnitude of the fluctuation-induced flux may have ramifications for the causality of the hollow density profile.

[1] O. Yamagishi et al., *submitted to PoP*
[2] C. Michael et al., *RSI. (proc. HTPD),accepted (2006)*

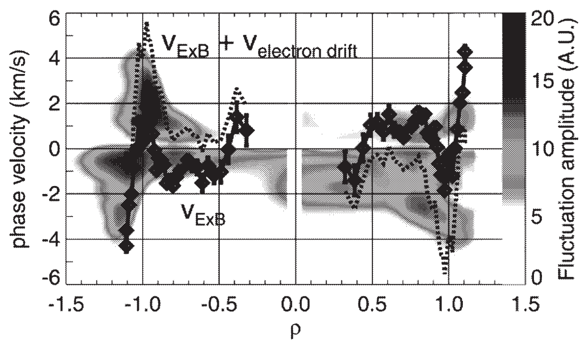

Fig 1: Fluctuation phase velocity compared with ExB and drift velocities

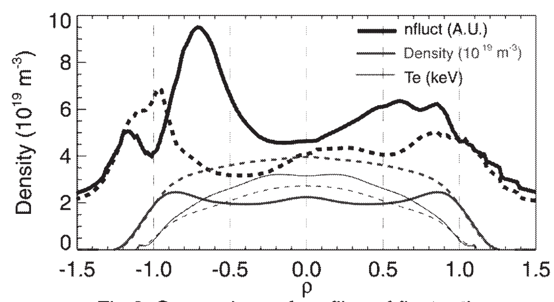

Fig 2: Comparison of profiles of fluctuation amplitude, density and temperature at t=1.9s (dashed lines) and t=2.2s (solid lines)

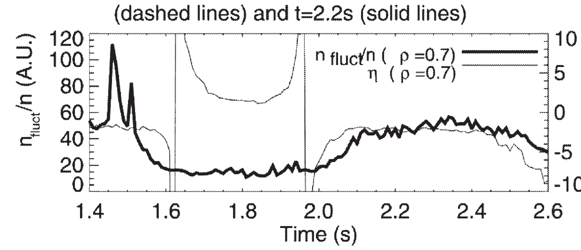

Fig 3: Time evolution of relative fluctuation level and η=(∇T/T) / (∇n/n) at ρ=0.7