Category: EX-S

Electron Gyro-Scale Turbulence in the National Spherical Torus Experiment

E. Mazzucato[1], D. R. Smith[1], R. E. Bell[1], C. W. Domier[2], J. C. Hosea[1], S. M. Kaye[1], B. P. Leblanc[1], N. C. Luhmann[2], Jr., W. Lee[3], H. K. Park[3], J. R. Wilson[1], H. Yuh[4] and the NSTX Group

[1]Princeton Plasma Physics Laboratory, Princeton University, Princeton, NJ 08543, USA
[2]University of California at Davis, Davis, CA 95616, USA
[3]POSTECH, Pohang, Korea
[4]Nova Photonics Inc., Princeton, NJ 08540, USA

E-mail: mazzucato@pppl.gov

After more than fifty years of research, the cause of anomalous electron transport in tokamaks is still an outstanding issue. This is particularly worrisome since in a burning plasma, such as that of ITER, a large fraction of the energy of charged fusion products will be released directly to the electrons.

The National Spherical Torus Experiment (NSTX) is uniquely suited to the study of this phenomenon since, while the transport of ions is very often at or near neoclassical levels, that of electrons is anomalous in all operational regimes [1].

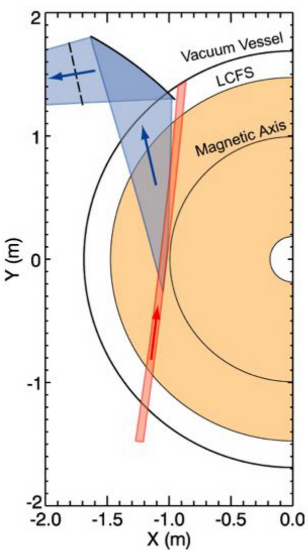

FIG.1. Schematic view of scattering geometry showing the probing beam (red) and scattered waves (blue).

Various theories and numerical simulations support the conjecture that the ubiquitous problem of anomalous electron transport in tokamaks may arise from an electron gyro-scale turbulence driven by the ETG instability [2,3]. To check whether such a turbulence is present in NSTX plasmas, density fluctuations were measured with a five-channel coherent scattering system using a probing beam with frequency of 280 GHz. The system employs a novel scattering geometry [4] that takes advantage of the curvature of magnetic field lines for achieving a good radial resolution of ±3 cm (Fig. 1). The wave vectors of measured fluctuations (5-20 cm^{-1}) are mainly perpendicular to the magnetic surfaces, with small components along the diamagnetic velocity and the toroidal plasma current from which one can infer the wave phase velocity.

Measurements were performed in helium plasmas with high harmonic fast wave (HHFW) heating, a technique that provides the largest increase in core electron temperature in NSTX [5]. Figure 2 shows the time evolution of the electron temperature (T_e) with 2 MW of RF power in a plasma with minor radius 0.65 m, major radius 0.85 m, magnetic field 0.55 T and plasma current 700 kA.

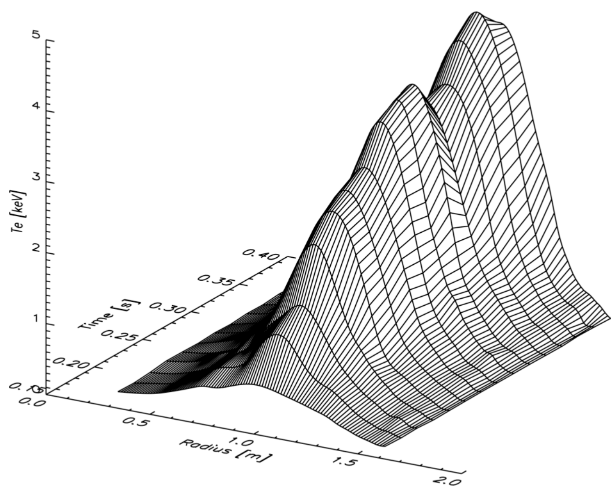

Fig. 2. Time evolution of T_e during HHFW heating (2 MW, Δt=0.15-0.4 s).

Scattering measurements confirmed the existence of turbulent fluctuations with an electron gyro-scale, as illustrated by Fig. 3 showing the time evolution of the spectrum of fluctuations at R=1.2 m with wave numbers in the range $k_\perp \rho_e$=0.2-0.4 (with ρ_e the electron gyroradius at the location of measurement), corresponding to values of $k_\perp \rho_s$= 8-16 (with ρ_s the ion gyroradius for $T_i = T_e$).

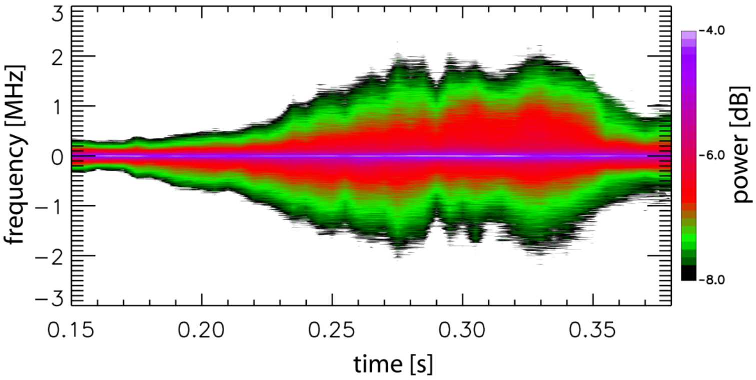

FIG. 3. Spectrogram of measured fluctuations at R=1.2 m with wave numbers in the range $k_\perp \rho_e$= 0.2-0.35 during HHFW heating (2 MW, Δt=0.15-0.4 s).

These fluctuations appear to be driven by the gradient of T_e, as illustrated in Fig. 4 showing the time evolution of the measured value of R/L_{Te} (with L_{Te} the radial scale of T_e) together with an empirical fit to numerical results of the linear gyrokinetic GS2 code for the threshold of the ETG instability [1]. Note that plasma fluctuations begin to rise at the beginning of the RF pulse when the measured value of R/L_{Te} becomes larger than the empirical critical gradient, and drop towards the end of the pulse when the opposite occurs. Similar results were obtained in plasmas with NBI heating. Finally, from the frequency asymmetries of measured spectra we conclude that fluctuations propagate in the electron diamagnetic direction.

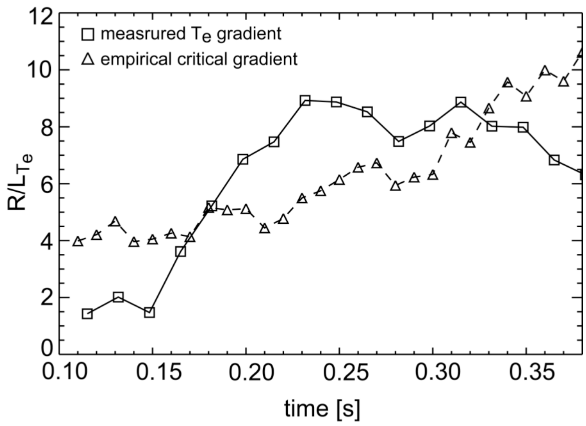

FIG. 4. Time evolution of measured R/L_{Te} and numerical threshold of ETG mode.

In conclusion, we have measured turbulent fluctuations with the electron gyro-scale in NSTX plasmas. Large values of $k_\perp \rho_s$ seem to suggest that neither the Ion Temperature Gradient mode nor the Trapped Electron Mode is the source of turbulence. Agreement with numerical results of the linear gyrokinetic GS2 code supports the conjecture that the observed fluctuations are caused by the ETG mode.

This work was supported by U. S. DOE Contract No. DE-AC02-76CH03073GTC-NEO

[1] S. M. Kaye *et al*., Phys. Rev. Lett. **98**, 175002 (2007).
[2] F. Jenko, W. Dorland, and G. W. Hammett, Phys. Plasmas **8**, 4096 (2001)
[3] W. Horton, G. T. Hoang, C. Bourdelle *et al.*, Phys. Plasmas **11**, 2600 (2004).
[4] E. Mazzucato, Phys. Plasmas, **10**, 753 (2003), Plasma Phys. Control. Fusion **49**, 559 (2007).
[5] J. Hosea *et al*., to be published in Phys. Plasmas