Observation of a Critical Gradient Threshold for Electron Temperature Fluctuations in the DIII-D Tokamak*

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Gyroradius-scale, temperature and density gradient driven instabilities are widely thought to result in the turbulent transport of particles, momentum, and heat in fusion plasmas. Many of these modes have been predicted to possess a critical gradient threshold, above which instability occurs [1]. For the first time in a systematic, controlled experiment, a critical gradient threshold has been observed in a measured fluctuating quantity in the core of a tokamak. The local inverse electron temperature gradient scale length and toroidal rotation at $r/a = 0.6$ are systematically varied using electron cyclotron heating and neutral beam injection heating in DIII-D L-mode plasmas. A coupled correlation electron cyclotron emission radiometer-reflectometer diagnostic is used to simultaneously measure electron temperature fluctuations and the crossphase between electron temperature and density fluctuations, α_{nT}. The local temperature fluctuation level, $\delta T_e/T_e$, exhibits a threshold at $1/L_{Te} = -\nabla T_e/T_e \approx 3\,\mathrm{m}^{-1}$, increasing from $\sim 1.2 \pm 0.2\%$ for $1\,\mathrm{m}^{-1} < 1/L_{Te} < 3\,\mathrm{m}^{-1}$ to $\sim 2.1 \pm 0.2\%$ at $1/L_{Te} \approx 4\,\mathrm{m}^{-1}$. This increase in temperature fluctuation level is concurrent with increased electron heat flux and thermal transport stiffness; initial gyrokinetic and gyrofluid predictions also exhibit a critical gradient. Little rotation dependence for either electron thermal transport or temperature fluctuations is observed; however, the crossphase measurements are observed to depend on both $1/L_{Te}$ and rotation, implying variation in the dominant instability at low $1/L_{Te}$. Above the critical gradient, measurements are consistent with ∇T_e-driven trapped electron mode turbulence.

References

[1] W. Horton, Rev. Mod. Phys. **71**, 725 (1999)

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