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Observation of a Critical Gradient Threshold for Electron Temperature Fluctuations in the DIII-D Tokamak[1]

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A critical gradient threshold for electron temperature fluctuations, directly correlated with an abrupt increase in the electron heat flux and reproduced in gyrofluid and gyrokinetic predictions, has been directly measured for the first time in the core of a confined high-temperature plasma. In an experiment in the DIII-D tokamak where $1/L_{Te} = -\nabla T_e/T_e$ and toroidal rotation were systematically varied in an L-mode target discharge, long wavelength ($k_\theta \rho_s < 0.4$) electron temperature fluctuations exhibit a threshold in $1/L_{Te}$: below they change little and above they abruptly increase, with the threshold at $1/L_{Te} = 2.8 \pm 0.4\,1/\mathrm{m}$. In contrast, long wavelength density fluctuations changed little. Concurrent with the increase in $\tilde{T}_e/T_e$, the electron heat flux increases rapidly with $1/L_{Te}$. A critical threshold for the electron thermal diffusivity was found at $1/L_{Te} = 3.0 \pm 0.21/m$, within uncertainties of the value for $\tilde{T}_e/T_e$. This implies the increase in $\tilde{T}_e/T_e$ plays a causal role for the increased electron heat flux. In linear gyrofluid calculations the critical gradient behavior is governed by the dimensionless parameter $\eta_e = L_{ne}/L_{Te}$, with an instability threshold of $\eta_e \approx 2$, which agrees well with the experimentally observed sharp increase in $\tilde{T}_e/T_e$ at $\eta_e \approx 1.9$. Both $\tilde{T}_e/T_e$ and the electron heat flux show little sensitivity to rotation. Above the critical $1/L_{Te}$, measurements are consistent with ∇T_e driven trapped electron mode turbulence. Below the threshold, measurements of the crossphase angle between electron density and temperature fluctuations indicate multiple instabilities may be active in the different rotation cases. The array of fluctuation measurements provides strong multifield constraints for turbulence model validation studies.

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