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Study on the coherent structure of drift wave turbulence by eigenmode method

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The achievement of controlled nuclear fusion is hindered by anomalous radial transport driven by drift-wave turbulence, where the spatiotemporal organization of multiscale coherent structures—critical for transport regulation—remains unresolved[1]. Key contradictions exist: (1) experiments show continuous wavenumber spectra but discrete frequency components; (2) traditional periodic boundary models fail to explain discrete spatial patterns.

This study integrates advanced diagnostics (probe arrays, fast imaging) and theory to address these gaps. Experiments reveal a dual spectral signature: density / potential fluctuations exhibit continuous wavevector distributions alongside quantized frequency peaks. A groundbreaking theoretical framework reformulates two-fluid equations as a cylindrical Schrödinger-type eigenvalue problem, incorporating (m,n) quantum numbers from toroidal symmetry. Radial dispersion effects [D(r,ω)] force mode collapse into temporal eigenstates, resolving the spectral decoupling paradox.

Nonlinear phase evolution is identified as a pivotal mechanism. Acting as a nonlinear term in the governing equations, progressive phase growth across potential barriers induces topological truncation of coherent modes. This process directly links phase singularities to the self-organization of band-like zonal flows—a critical step in turbulence regulation.

By bridging theory-experiment discrepancies in spatiotemporal quantization, this work establishes methods for characterizing and manipulating coherent structures, offering actionable strategies for turbulence control in tokamaks. The findings advance predictive models for plasma transport in fusion reactors.

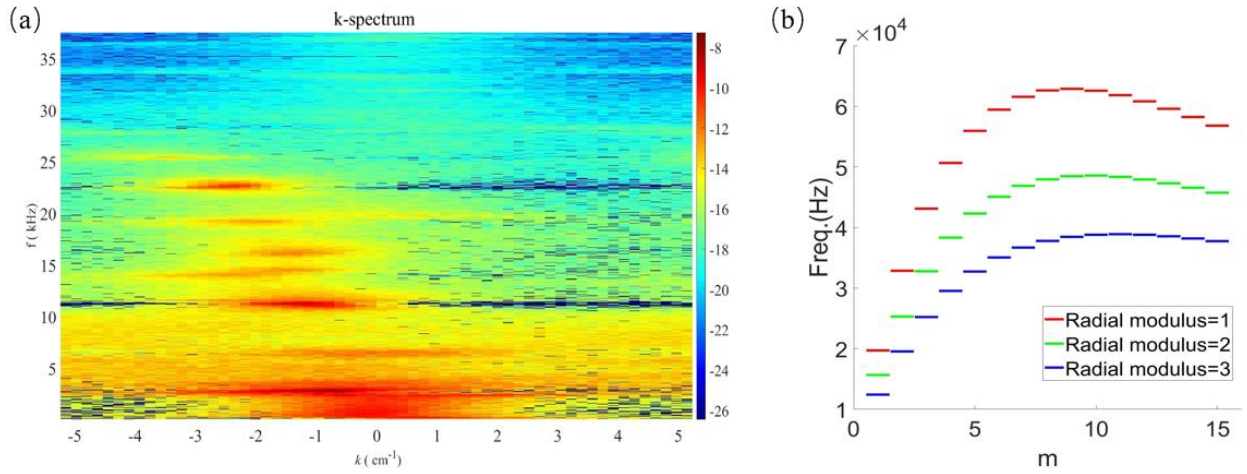

Figure1. (a) Turbulence K-spectrum of linear device. (b) Intrinsic frequency results under different radial modules