Nonlinear dynamics of pedestal turbulence and ELMs

BOUT++
Boundary Plasma Turbulence Code

X. Q. Xu[1], B. Chen[1,2], T. F. Tang[1,3], T. Y. Xia[1,4], D. F. Kong[1,4], N. Yan[1,4], J. G. Chen[1,5], C. H. Ma[1,5], P. H. Diamond[6], P. B. Snyder[7], R. Groebner[7], T.H. M. Makowski[1], T. Leonard7,Osborne[2], A. Diallo[8], J. W. Hughes[9], B. Dudson[10]

1) Lawrence Livermore National Laboratory, Livermore, CA 94550 USA
2) University of Science and Technology of China, Hefei, China
3) Dalian University of Technology, Dalian, China
4) Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China
5) School of Physics, Peking University, Beijing, China
6) Center for Astrophysics and Space Sciences and Department of Physics, University of California San Diego, La Jolla, CA 92093-0429, USA
7) General Atomics, San Diego, CA 92186 USA
8) Princeton Plasma Physics Laboratory, Princeton, New Jersey 08543, USA
9) MIT Plasma Science and Fusion Center, Cambridge, Massachusetts 02139, USA
10) University of York, Heslington, York YO10 5DD, UK

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BOUT++ reproduces the magnitude and scaling of the divertor heat load width λ_q with ITPA multi-tokamak database

X.Q.Xu, *Lawrence Livermore National Laboratory, USA*

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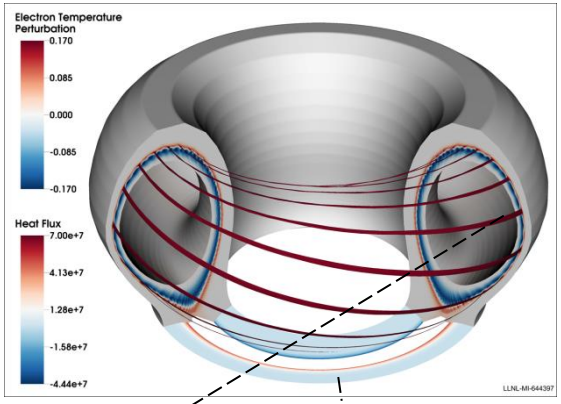
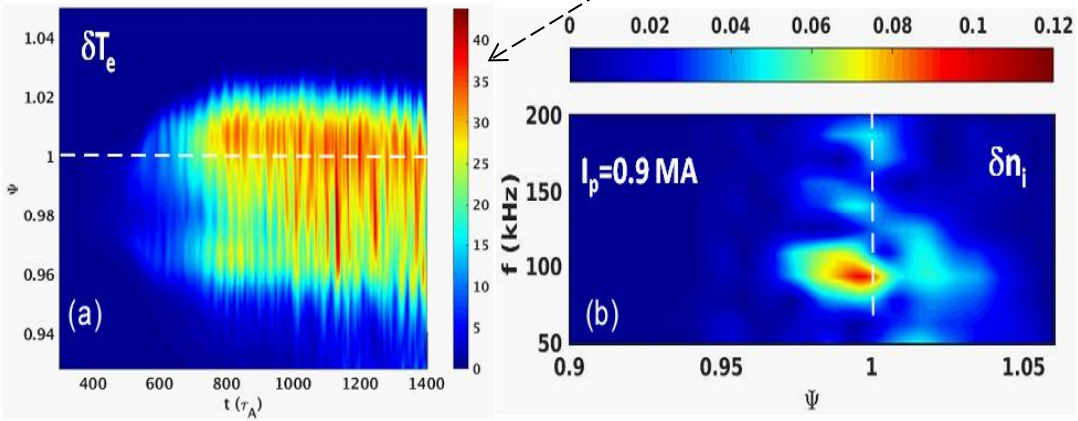
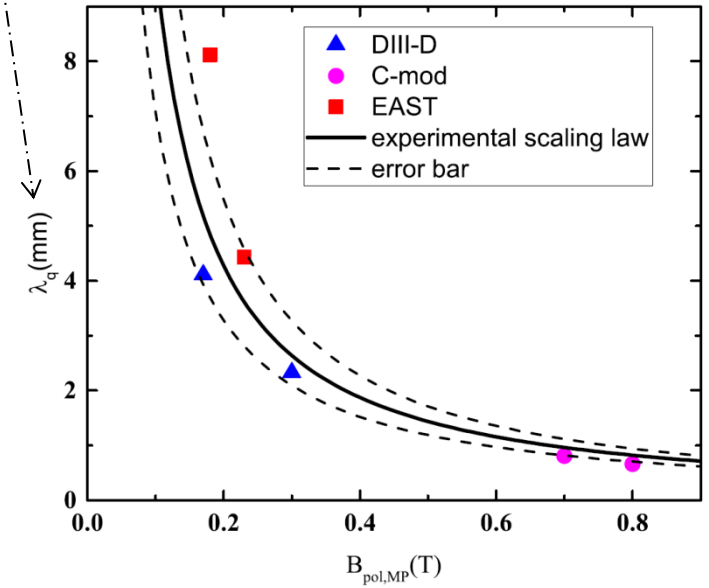
- **The BOUT++ simulations show that the electromagnetic fluctuations are localized inside the magnetic separatrix**
- **The fluctuations cause particle and heat to be turbulently transported down their gradients into the SOL, which then flow into the divertor with a rapid relaxation of parallel transport.**





Scaling law: $\lambda_q = 0.63 \pm 0.08 \times B_P^{-1.19\pm0.08}$



BOUT++ simulations show similar evolution of Quasi-Coherent Fluctuations in ELMy H-mode as C-Mod magnetic probe and reflectometer measurements

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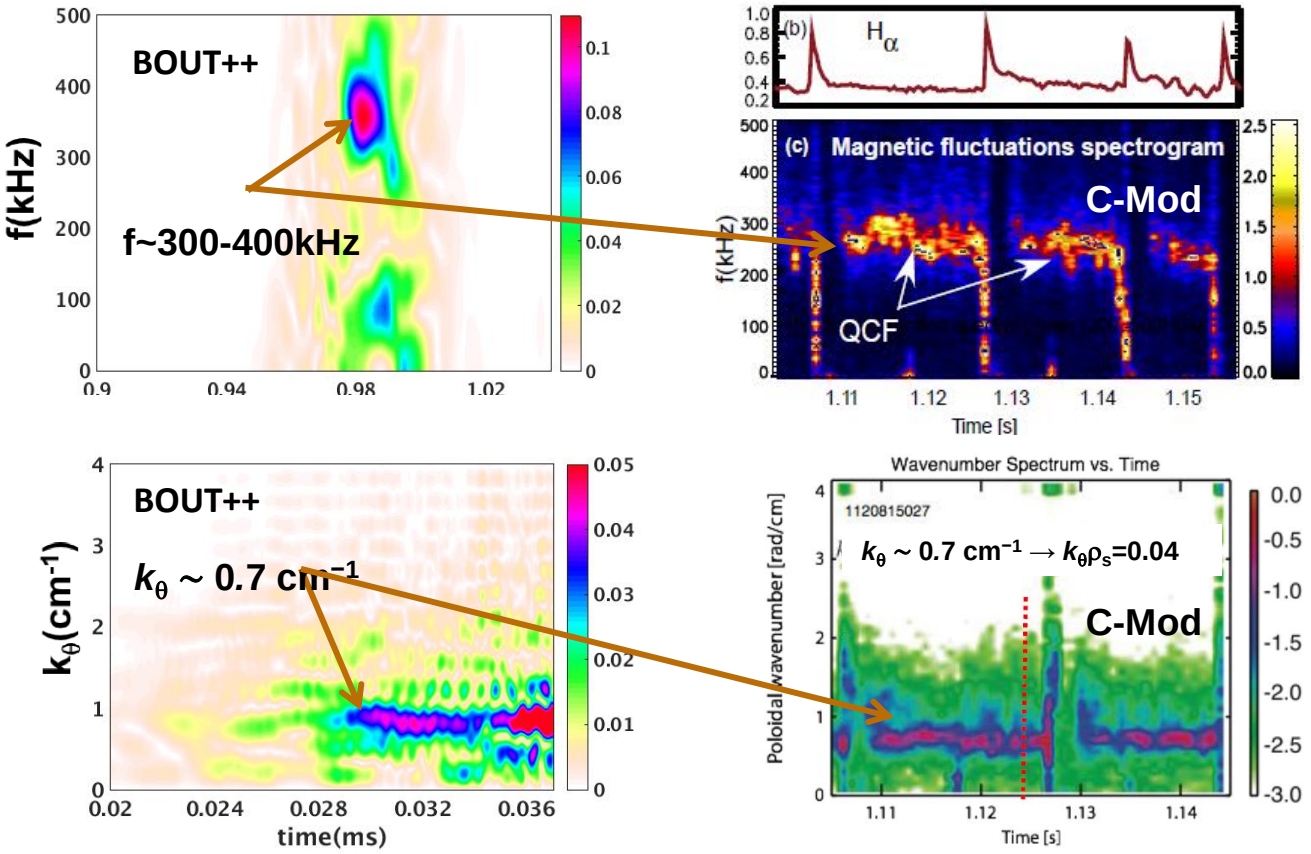
The quasi-coherent fluctuations (QCFs) are associated with the saturation of the pedestal between ELMs during ELMy H-mode discharges on C-Mod, DIII-D, Asdex-Upgrade, and JET.

The BOUT++ simulation results show that QCFs

- **are localized in the pedestal region with f≈300−400kHz & k_q≈0.7/cm,**
- **propagate in the electron diamagnetic direction in the laboratory frame**
- **GPI spectral analysis indicates that the QCF is radially localized in pedestal region as BOUT++**



For QH-mode plasmas without an ELM, Er shear modifies the PB stability boundary, leading to the transition from broadband turb. to EHO

X.Q.Xu, *Lawrence Livermore National Laboratory, USA*

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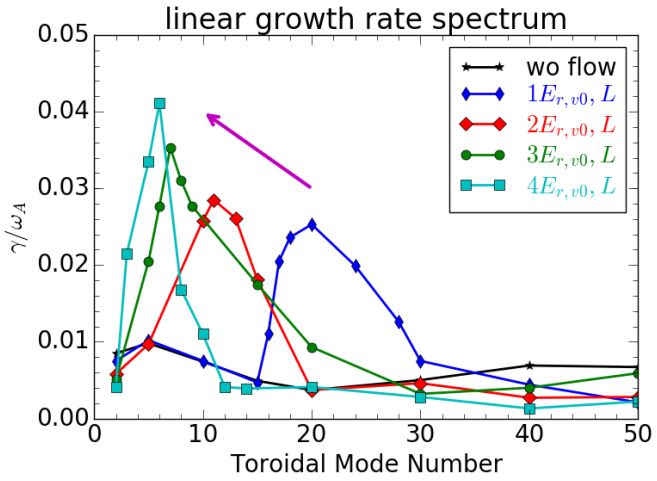

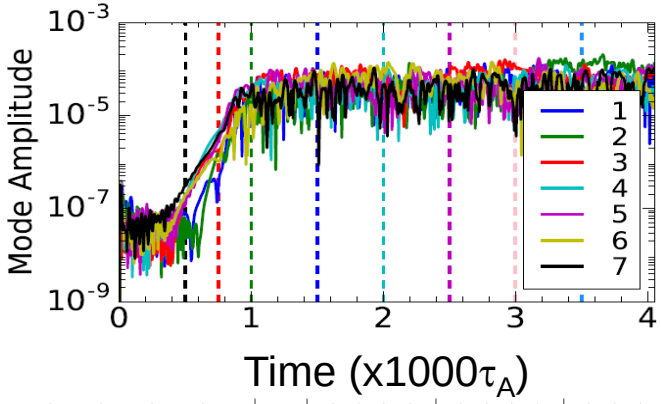

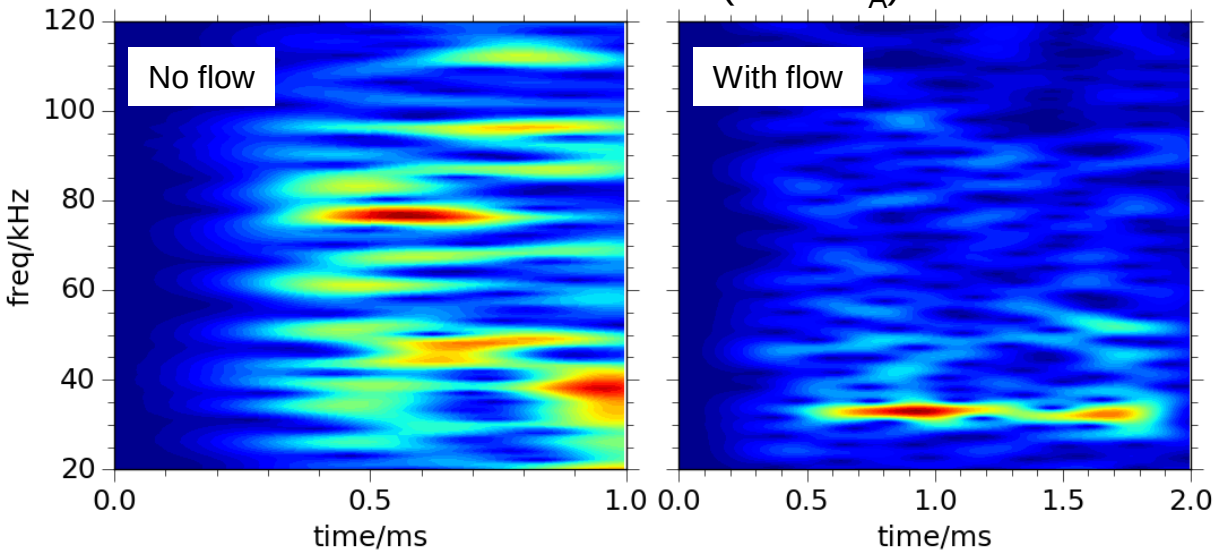

- **No flow → broadband turbulence**
- **Shear flow → narrower mode spectrum with dominant mode (n ~3)**

A reminiscent of the DIII-D ExB flow experiments, where a transition can be made from EHO to a regime with broadband turbulence, leading to a reduced pedestal pressure gradient, allowing the development of a broader and thus higher transport barrier in QH mode without ELMs.