stellarator news

Published by Fusion Energy Division, Oak Ridge National Laboratory
Building CR 5600 P.O. Box 2008 Oak Ridge, TN 37831-6169, USA

Editor: James A. Rome Issue 136 April 2012

E-Mail: jamesrome@gmail.com Phone (865) 482-5643

On the Web at http://www.ornl.gov/sci/fed/stelnews

Dynamical coupling between gradients and transport in tokamaks and stellarators

Understanding the relation between free energy sources and transport in systems far from thermal equilibrium is a fundamental issue that has been debated for years. Instabilities governed by a gradient will typically produce transport events at all scales, thus connecting different regions of plasma. In the case of a critical gradient mechanism, the functional dependence between the transport flux and the gradient is expected to show a sharp increase as the system crosses the instability threshold and finite background transport below the threshold, implying a nonlinear relation between gradients and turbulent transport [1].

Edge turbulent transport is strongly bursty and a significant part is caused by a few large transport events within a small fraction of time [2]; this possibly reflects the fact that systems out of thermal equilibrium are dynamically exploring different accessible states, i.e., regimes with different plasma gradients and correspondingly different transport levels. Then, the physics of transport and plasma gradients should be discussed and characterized in terms of probability distribution functions instead of just average values. The dynamical coupling between gradients and transport has been investigated in the plasma boundary of different tokamak (JET, ISTTOK) and stellarator (TJ-II) devices, revealing that the size of turbulent events is minimum near the most probable gradient [3]. These experimental results are compared with results from two simple and very different models of plasma turbulence and transport.

Experiments were carried out in the TJ-II stellarator ($P_{ECRH} \leq 600$ kW, $B_T = 1$ T, $R = 1.5$ m, $a \leq 0.22$ m) [4], the ISTTOK tokamak ($R = 0.46$ m, $a = 0.085$ m, $I_p =$ 5–7 kA, $B = 0.5$ T), and the JET tokamak [5]. Edge fluctuations have been characterized using multiple Langmuir probes arrays. We measured the ion saturation current (I_{sat}) as a proxy for the edge plasma density (n), the plasma floating potential, and the turbulent radial **E**×**B** turbulent transport $\Gamma_{\mathbf{E}\times\mathbf{B}}$ ignoring temperature fluctuations.

The coupling of the probability density function (PDF) of the turbulent transport with the PDF of the density gradient is studied by computing the conditional expected value of the **E**×**B** turbulent flux for a given density radial gradient. The investigation of the dynamical interplay between edge fluctuations in density gradients and **E**×**B** turbulent transport has shown that these parameters are strongly coupled in tokamak and stellarator plasmas. Observations suggest that fluctuations are self-regulated in such a way that the most probable density gradient minimizes the size of the radial turbulent transport events; thus, as the density gradient deviates from the most probable gradient, the **E**×**B** turbulent driven transport increases, and the system performs a relaxation that tends to drive the plasma back to the marginally stable situation that minimizes the size of transport events (Figs. 1 and 2). The local system relaxes to the most probable state in a time comparable to the autocorrelation time of turbulence.

Experimental results were found to be consistent with results from two very different models [6, 7] of plasma turbulence and transport, where nonlocal effects play an important role. These nonlocal effects result from a series

In this issue . . .

of feedback mechanisms at different radial locations where at a given point in the plasma the local gradients drive the turbulence and turbulence controls the transport.

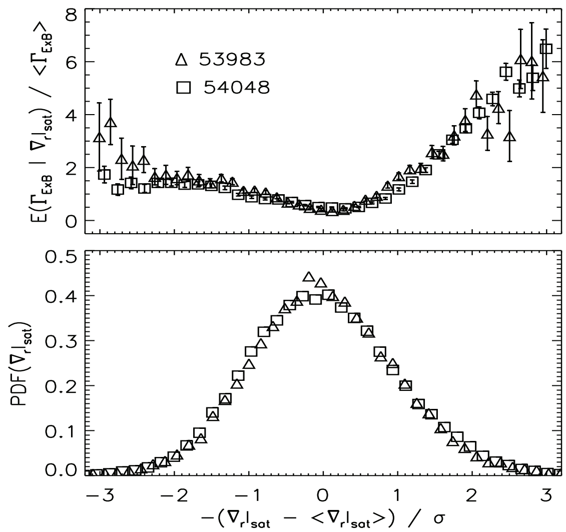

Fig. 1. Probability density function (PDF) of fluctuations in radial I_{sat} gradients and expected value of turbulent flux for a given value of fluctuating density gradient as a function of $(\nabla_r I_{sat} - \langle \nabla_r I_{sat} \rangle)/\sigma$, where σ is the $\nabla_r I_{sat}$ standard deviation, in the plasma edge in the JET tokamak.

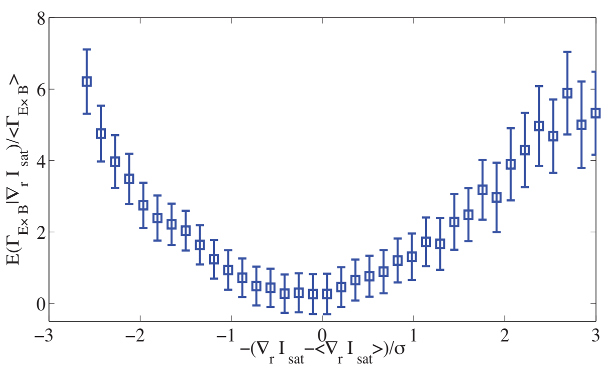

Fig. 2. Flux-gradient relation in the TJ-II stellarator.

These observations [3] provide a guideline for further developments in plasma diagnostics, transport modeling, and data processing to characterize transport and gradients in terms of joint PDFs. In particular, the influence of plasma conditions in the sharpness of the flux-gradient dynamical relation when the plasma deviates from its average value above the most probable gradient should be investigated systematically.

References

[1] F. Ryter, F. Leuterer, G. Pereverzev, et al., Phys. Rev. Lett. **86** (2001) 2325

[2] M. Endler, H. Niedermeyer, L. Giannone, et al., Nucl.Fusion **35** (1995) 1307.

[3] C. Hidalgo, C. Silva, B. A. Carreras, et al., Phys. Rev. Lett. **108** (2012) 065001.

[4] J. Sánchez et al., Nucl. Fusion **49** (2009) 104018.

[5] C. Hidalgo, B. Gonçalves, M.A. Pedrosa, et al., J. Nucl. Mater. **313** (2003) 863.

[6] L. Garcia, B. A. Carreras, and D. E. Newman, Phys. Plasmas **9** (2002) 841.

[7] L. Garcia, B. A. Carreras, V.E. Lynch, et al., Phys. Plasmas **8** (2001) 4111.

C. Hidalgo,[1] C. Silva,[2] B.A. Carreras,[3] B. van Milligen,[1] H. Figueiredo,[2] L. García,[4] M. A. Pedrosa,[1] B. Gonçalves,[2] A. Alonso[1]

1) EURATOM-CIEMAT, Madrid, Spain
2) EURATOM-IST, Lisbon, Portugal
3) University of Alaska, Fairbanks, AK USA
4) Universidad Carlos III, Madrid, Spain
E-mail: carlos.hidalgo@ciemat.es