Category: TH-D

Edge Sheared Flows and Blob Dynamics*

J. R. Myra,† D. A. D'Ippolito, and D. A. Russell, *Lodestar Research Corporation, Boulder CO, USA*, S. J. Zweben and W. M. Davis, *Princeton Plasma Physics Lab, Princeton, NJ, USA*, J. L. Terry, *Massachusetts Institute of Technology, Cambridge MA, USA*

It is well known that sheared flows play an important role in regulating turbulence in fusion plasmas. [1] Here, we consider the interaction of sheared flows with blob-filaments, [2,3] focusing on their generation and dynamics. The work is motivated by several considerations. Edge sheared flows are believed to be important for the L-H, and H-L transitions, and improved understanding of their role will be required for first-principles scalings of these transitions for ITER and future devices. Blob generation and dynamics impacts both the (near-separatrix) scrape-off-layer (SOL) width critical for ITER power handling in the divertor, and far SOL interaction with plasma-facing components, which is also an important concern. A fluid-based 2D curvature-interchange model embedded in the SOLT (SOL turbulence) code [4] has been employed to study these issues. Combined with ongoing analysis of experimental data from NSTX and Alcator C-Mod, a picture of the interaction of blobs and sheared flows is emerging.

Diffusive-convective transition for SOL turbulence – Simulations with the SOLT code in various regimes have demonstrated the dramatic effect of sheared binormal (approximately poloidal) flows on edge turbulence, and the generation of mesoscale structures. Simulations [5] with sheared flows completely suppressed led to the generation of radial streamers emanating from the resistive curvature-driven instability growth zone and extending far into the SOL. Normally, sheared zonal flows develop by self-consistent Reynolds stress interactions. In such simulations using L-mode-like parameters, radial streamers were converted to discrete blob structures when the shearing rate was strong enough to dominate the linear growth rate [4], i.e. at the same location in parameter space where zonal flows significantly mitigate the nonlinear transport flux. Furthermore, in simulations [4,6] using NSTX L-mode parameters, zonal flow relaxation oscillations, coherently coupled to the transport flux, were observed in a frequency range similar to that seen in analysis of gas-puff imaging (GPI) data which examined the quiet period preceding the L-H transition [6,7]. Finally, when even stronger binormal flows were applied artificially to simulate H-mode discharges on NSTX, [8] blobs were suppressed, qualitatively in accord with other NSTX experimental data. [9] In this case, the SOLT particle and heat transport across the separatrix was concentrated in the near SOL and was mediated by intermittent convective cells. [8]

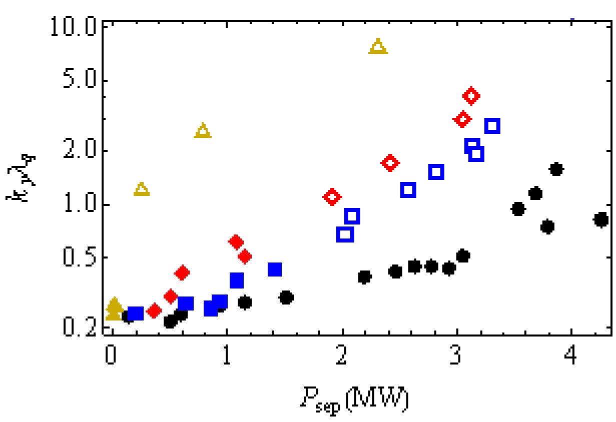

Fig. 1. Power scaling of the simulated heat-flux width, normalized to the mean turbulent poloidal wavenumber. Open symbols represent cases where convection dominates.

A recent study of the parameter space relevant to low power Lithium-walled H-mode discharges in NSTX, revealed a transition in SOL turbulence from a diffusively-dominated to a convectively-dominated transport regime (see Fig. 1). Sheared binormal flows play the dual role of regulating the turbulence level (and hence the power flux crossing the separatrix) and controlling the character of emitted turbulence structures such as blob-filaments. At a critical power level (depending on parameters) the laminar flows containing intermittent, but bound, structures give way to full-blown blob emission.

At lower power levels the turbulence is quasi-diffusive in character; at higher power levels it is mostly convective. Critical parameters for the transition include the power flux into the SOL, the field line pitch, the connection length and the plasma collisionality. As shown in Fig. 1, the transition occurs when $k_y\lambda_q > 1$ where k_y is the mean turbulent poloidal wavenumber for each case and λ_q is the heat flux width. At larger λ_q, gradient driven diffusion is ineffective and gives way to convective transport.

Blob tracking in sheared flows – In order to both diagnose sheared flows in experiments and assess their interaction with blobs, a blob-tracking algorithm has been developed and applied to both NSTX and Alcator C-Mod data. The algorithm is based on 2D time-resolved GPI images, and is able to track both the blob motion and changes in blob structure, such as ellipticity and tilt angle, that can be affected by sheared flows. In addition to providing statistical data on the blob speed, the tracking data shows interesting cases, such as in Fig. 2, where the poloidal motion can reverse. Results of seeded blob simulations for these shots will be compared with the data to determine the role of blob initial conditions and parameters (blob size, amplitude and vorticity) on the blob tracks and elliptical deformations, and to evaluate the exchange of momentum between the blobs and flows. Significant exchange would be important for understanding edge flow dynamics, while negligible interactions could validate the usefulness of blobs as a passive tracer diagnostic of the background shear layer.

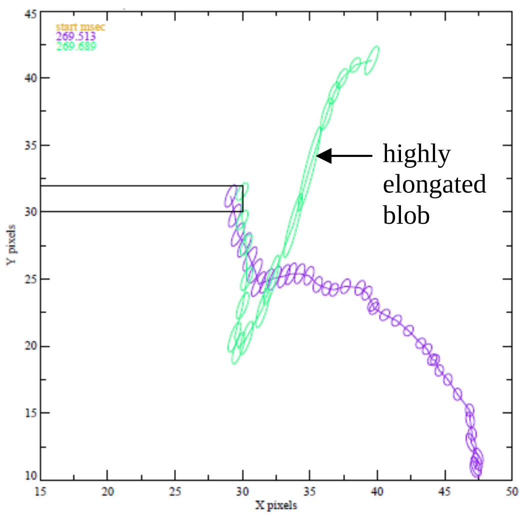

Fig. 2 Sample blob tracks in edge region from processed GPI data on NSTX showing elliptical deformation and poloidal (Y) flow reversal. The elliptical deformation is shown as the symbol shape on the blob track. Positive X is radially outwards.

Summary – Recent advances in the theory and simulation of edge turbulence, combined with ever-improving capabilities for edge diagnostics and their analysis, have enabled new insights into SOL dynamics that are impacting both the basic edge physics of flows and confinement transitions, and practical issues relevant to ITER such as the heat flux exhaust channel and PFC damage.

† email: jrmyra@lodestar.com

*Supported by the USDOE under grants DE-FG02-97ER54392, DE-FG02-02ER54678, DE-AC02-09-CH11466, DE-FC02-99ER54512, DE-AC02-09CH11466, and PPPL Subcontract S009625-F.

[1] P. H. Diamond, et al., Plasma Phys. Control. Fusion **47**, R35 (2005).
[2] S. I. Krasheninnikov, et al. J. Plasma Phys. **74**, 679 (2008).
[3] D.A. D'Ippolito, et al., Phys. Plasmas 18, 060501 (2011)
[4] D. A. Russell, et al, Phys. Plasmas **16**, 122304 (2009)
[5] D. A. Russell, et al., Phys. Plasmas **14**, 102307 (2007).
[6] Y. Sechrest, et al., Phys. Plasmas **18**, 012502 (2011).
[7] S. J. Zweben, et al., Phys. Plasmas **17**, 102502 (2010).
[8] J. R. Myra, et al., Phys. Plasmas **18**, 012305 (2011).
[9] M. Agostini, et al., Phys. Plasmas **14**, 102305 (2007).