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J.A. BOEDO,[*] R.J. MAQUEDA,[†] N. CROCKER,[‡] D.L. RUDAKOV,[*] A.E. WHITE,[‡] S.J. ZWEBEN,[¶] D.A. D'IPPOLITO,[§] E.M. HOLLMAN,[*] R. MAINGI,[#] G.R. McKEE,[◊] R.A. MOYER,[*] J.R. MYRA,[‡] D.V. SOUKHANOVSKII,[◆] J.G. WATKINS,[∞] N.H. BROOKS, C.E. BUSH,[#] M.J. BURIN,[¶] T.A. CARTER,[‡] T.E. EVANS, M.E. FENNSTERMACHER,[◆] M. GROTH,[◆] T.S. HAHM,[¶] S.I. KRASHENINNIKOV,[*] J.A. KROMMES,[¶] C.J. LASNIER,[◆] M.A. MAHDAVI, A.G. McLEAN,[α] L.A. ROQUEMORE,[¶] D.P. STOTLER,[¶] W.P. WEST, D.G. WHYTE,[◊] K.M. WILLIAMS,[¶] C.P.C. WONG, and L. ZENG[‡]

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[*]University of California-San Diego, La Jolla, California.
[†]Nova Photonics, Princeton, New Jersey.
[‡]University of California-Los Angeles, Los Angeles, California.
[¶]Princeton University, Princeton, New Jersey.
[§]Lodestar Research Corp., Boulder, Colorado.
[#]Oak Ridge National Laboratory, Oak Ridge, Tennessee.
[◊]University of Wisconsin-Madison, Madison, Wisconsin.
[◆]Lawrence Livermore National Laboratory, Livermore, California.
[∞]Sandia National Laboratories, Albuquerque, New Mexico.
[†]University of Toronto Institute for Aerospace Studies, Toronto, Canada.

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Particle and Energy Transport in the SOL of DIII-D and NSTX EX-D

J.A. Boedo,[1] R.J. Maqueda,[2] N. Crocker,[3] D.L. Rudakov,[1] A.E. White,[3] S.J. Zweben,[4] D.A. D'Ippolito,[5] E.M. Hollmann,[1] R. Maingi,[6] G.R. McKee,[7] R.A. Moyer,[1] J.R. Myra,[3] D.V. Soukhanovskii,[8] J.G. Watkins,[9] N.H. Brooks,[10] C.E. Bush,[6] M.J. Burin,[4] T.A. Carter,[3] T.E. Evans,[10] M.E. Fenstermacher,[8] M. Groth,[8] T.S. Hahm,[4] S.I. Krasheninnikov,[1] J.A. Krommes,[4] C.J. Lasnier,[8] M.A. Mahdavi,[10] A.G. McLean,[11] L.A. Roquemore,[4] D.P. Stotler,[4] W.P. West,[10] D.G. Whyte,[7] K.M. Williams,[4] C.P.C. Wong,[10] and L. Zeng[3]

[1]University of California-San Diego, La Jolla, California, USA
email: boedo@fusion.gat.com
[2]Nova Photonics, Princeton, New Jersey, USA
[3]University of California-Los Angeles, Los Angeles, California, USA
[4]Princeton University, Princeton, New Jersey, USA
[5]Lodestar Research Corp, Boulder, Colorado 80301, USA
[6]Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA
[7]University of Wisconsin-Madison, Madison, Wisconsin 53706, USA
[8]Lawremce Livermore National Laboratory, Livermore, California, USA
[9]Sandia National Laboratories, Albuquerque, New Mexico, USA
[10]General Atomics, San Diego, California 92186-5608, USA
[11]University of Toronto Institute for Aerospace Studies, Toronto, Canada

Intermittent transport is known to determine most of the radial transport in the edge/scrape-off layer (SOL) plasma [1] in L-mode and, as recently demonstrated [2], in high density H-mode plasmas. Inter-edge localized mode (ELM) intermittent particle transport can exceed ELM radial transport in H-mode operation above ~60% of the Greenwald density limit. Thus, understanding the source of intermittent transport and its dependence on plasma parameters is crucial for the International Thermonuclear Experi-mental Reactor (ITER). Scrape-off layer measurements in NSTX and DIII-D [1-4] indicate the presence of intense intermittent transport and that both intermittent transport and ELMs are comprised of filaments of hot, dense plasma (n_e ~1x10^{13} cm^{-3}, T_e ~ 50-100 eV) originating at the pedestal, convective in nature and capable of transporting both particles and heat into the SOL [1-4]. Intermittent filaments and ELMs are 2-5 cm in poloidal/radial size and leave the pedestal region at ~0.5-1 km/s, losing heat and particles by parallel transport as they travel through the SOL.

Both NSTX and DIII-D data show that the intermittency is comprised of positive density excursions in the SOL and depressions or "holes" at or near the LCFS, consistent with an interchange instability being the source of the filaments. I_{sat} profile data from NSTX is shown in Fig. 1. Inspection of the data reveals that: 1) the fluctuations in the SOL, [Fig 1(a-c)] feature positive spikes while those in the core/edge Fig. 1(d)] feature negative "holes", 2)

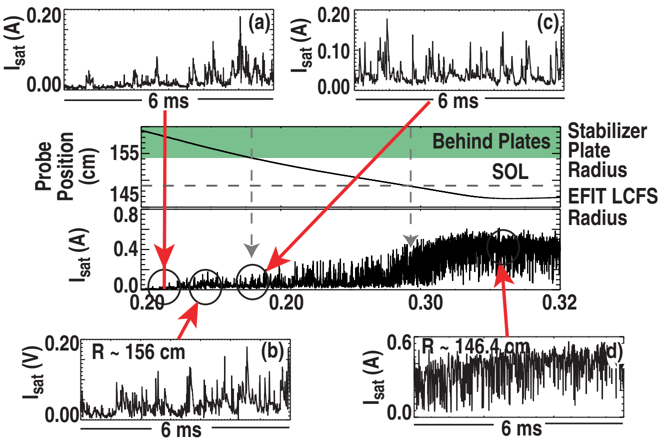

Fig. 1. NSTX probe data showing the time evolution of the probe position (top) and I_{sat} (bottom) in the edge shows the character of intermittency changing from positive spikes in the SOL to dips "holes" inside the LCFS, marked as a dashed line. Vertical arrows indicate when the probe crosses the position of the stabilizer plates and the LCFS. Insets magnify the signal at various times/locations.

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the amplitude of the signal (i.e J_{sat} or N_e) decays rapidly away from the LCFS, and 3) objects appear with a frequency of ~4-8 kHz and last ~20-40 µs in the probe signal.

Intermittency changes character in H-mode; while in DIII-D the intensity and frequency of the filaments decrease compared to L-mode, in NSTX only the frequency is reduced. NSTX gas puff imaging (GPI) data features images from a radial-poloidal cut near the midplane. Images of the filaments in L-mode [Fig. 2(a)] show formation at the LCFS, limited poloidal and radial extent (~4 cm), radial motion, and radial decay. In H-mode, turbulence [can be absent for a period [Fig. 2(b)] followed by activity practically indistinguishable from that of L-mode [Fig. 2(c)].

ELMs, which consist ~1-2 ms long sequence of ~20 -40 fast bursts of hot, dense plasma, show similar characteristics. Whereas the energy is quickly reduced in the ELMs at all collisionalities, featuring a short (1-2 cm) decay length, the density decay length is highly dependent on collisionality. For low collisionality (0.5) the ELM density decay length is (~13 cm) indicating that the ELM particle flux impacts the walls directly whereas at high collisionality the particle flux decays in ~3.5 cm.

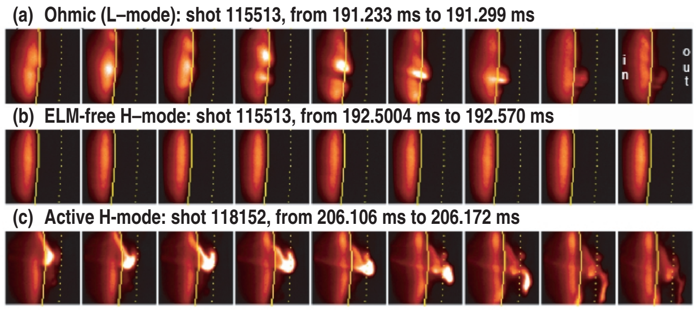

Fig. 2. Sequence of ~23 cm x 23 cm images obtained at 120000 frames/s with each image exposed for 3 µs at NSTX. A deuterium puff is injected from the right (solid line: separatrix, dotted line: antenna limiter shadow).

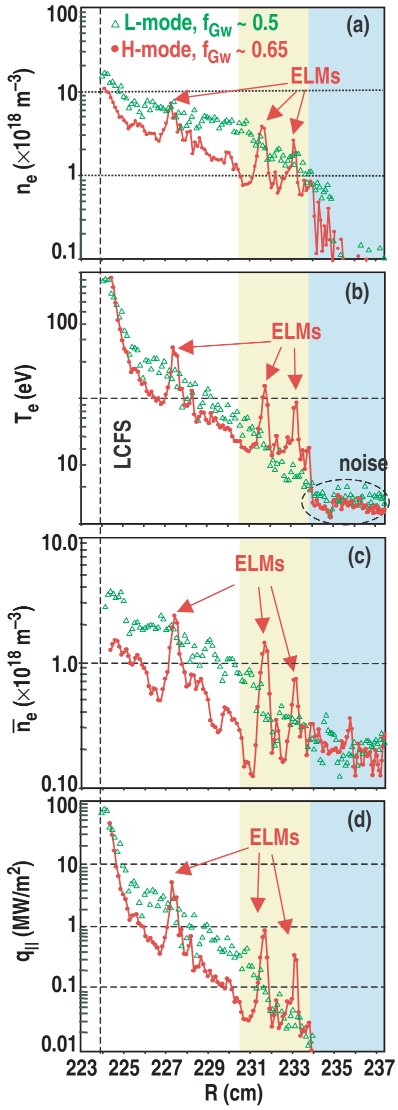

Fig. 3. Radial profile of n_e (a), T_e (b), N_e fluctuations (c) and parallel heat flux (d) for DIII-D, LSN, 1.1 MA, otherwise similar L- and H-mode discharge.

Data in Fig. 3 compares the ELM heat and particle flux to L-mode flux and to the inter-ELM flux. Type I ELM density, temperature and fluctuations can be momentarily comparable or higher than L-mode transport in most conditions but is dependent on the ELM duty cycle and discharge density. DIII-D [2] work using collisionality scans revealed that the ELMs account for ~90% of the wall particle flux at low collisionality (~0.3), decreasing to ~30% at ~1.0. Wall/divertor damage by plasma contact is a crucial issue for the success of ITER. The SOL radial transport and plasma-wall contact is determined by two main SOL transport vehicles: intermittent transport and ELMs. While intermittent transport is the main vehicle in L-mode, the relative importance of inter-ELM and ELM particle flux at the wall in H-mode varies, among other parameters, with density. The understanding of the physics and role of radial intermittent plasma transport is quite important and recent nonlinear simulations of the plasma edge are successfully reproducing the observed features [5].

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