*34th EPS Conference on Plasma Phys. Warsaw, 2 - 6 July 2007 ECA Vol.**31F**, P-2.040 (2007)*

Comparison of L-mode and H-mode edge turbulence in NSTX with the GPI diagnostic

M.Agostini[12], S.J.Zweben[3], R.Cavazzana[1], P.Scarin[1], G.Serianni[1], R.J.Maqueda[4], D.P.Stotler[3]

[1]*Consorzio RFX, Associazione EURATOM-ENEA sulla fusione, Padova, Italy*
[2] *Dipartimento di fisica, Università di Padova, Padova, Italy*
[3]*Princeton Plasma Physics Laboratory, Princeton, New Jersey, USA*
[4]*Nova Photonics Inc., Princeton, New Jersey, USA*

Introduction. The edge turbulence in magnetically confined plasma is considered the main cause for anomalous transport in all the magnetic configurations [1], and plays also a significant role in the plasma-wall interaction. Edge turbulence probably also determines the H-mode threshold in tokamak experiments and so can affect the global plasma performance [2]. Experimental and theoretical investigation of these phenomena is progressing rapidly (see, e.g. [3]), and it has been pointed out that the edge particle transport, independently of magnetic or geometric configurations, is caused mainly by intense bursts that occur more often than predicted for a Gaussian distribution ([4] and references therein). These events are related to coherent structures ("blobs") moving in the plasma.

In this paper the difference in the edge turbulence of the spherical tokamak experiment NSTX [5] between the L-mode and the H-mode phases of the plasma discharges is studied, using the Gas Puff Imaging (GPI) diagnostic [6]. The GPI is an optical diagnostic that measures the D_α light emission emitted by the neutral deuterium puffed into the plasma edge, and views the radial and poloidal structure of the turbulence. All the analysis here reported are obtained using the poloidal array of lines of sight (LoS), which observes a radial position that is about *10-20 mm* outside the separatrix. The LoS centers are spaced by *20 mm.*

The edge turbulence during the L-H transition was already studied in NSTX with the GPI diagnostic. In [7] the decrease in the turbulence level in the H-mode respect to the L-mode was described, with no great difference in the poloidal and radial correlation lengths. In [8] the statistical bicoherence analysis was applied to the same data set, and there was no apparent increase in the bicoherence just prior to the L-H transition. Here different analysis is applied to the GPI data to characterize the edge turbulence in the two plasma regimes.

Edge structures. The time occurrence of the intermittent intense bursts in the GPI signal, caused by edge blobs crossing the diagnostic lines of sight, are detected using the statistical technique described in [9]. Then the linear density of bursts N_s is evaluated as:

$$N_s = \Delta N / (v_\theta \Delta t)$$

where Δt is the time-window used for the analysis (*10 ms*), ΔN the number of intermittent events detected in Δt and v_θ is the poloidal velocity of propagation of the fluctuations measured with the cross correlation technique using the poloidal array of PMTs. Here we assume that the radial velocity of fluctuations is negligible in the evaluation of the linear density of structures:

this assumption is based on estimates of the ratio between the two velocities; v_θ/v_r~5-3 both in L and H-mode [6].

The result of this analysis is given in figure 1. The linear density of structures N_s is plotted as a function of the poloidal velocity of the fluctuations (each point refers to one shot). The poloidal velocity assumes values from about *–4 km/s* to *–10 km/s,* both for the L-mode and for the H-mode phase, along the ion-diamagnetic drift direction (similar values are reported in [6-7]). Every discharge exhibits a sudden decrease of the linear density of intermittent events in the H-mode phase with respect to the L-mode one, with no significant change in the poloidal velocity between the two regimes. Therefore we can conclude the H-mode phase has a lower turbulent activity in the edge. This result confirms the difference detected in similar discharges of NSTX using the fast CCD cameras [7].

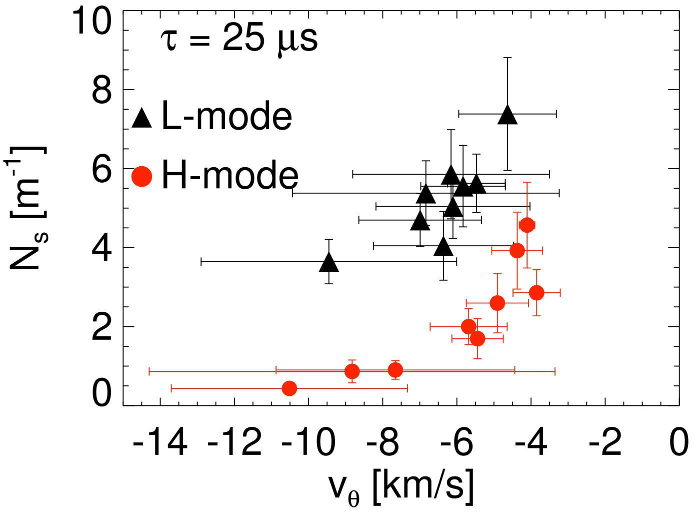

Fig1: *Linear spatial density of structures as a function of the poloidal velocity for L-mode (triangles) and H-mode (circles) measured with the poloidal array. Each point refers to a different shot*

Spectral analysis. In order to further characterize the differences of the edge turbulence in L-mode and H-mode phases, the $S(k_\theta,f)$ spectrum is evaluated. Two poloidal lines of sights spaced by *40 mm* are used, and the $S(k_\theta,f)$ spectrum is calculated from the two-point spectral analysis method described in [10]. In fig. 2 the result is shown for one L-mode and one H-mode discharge. It can be seen that the edge turbulence displays a broadband feature both in frequency and in the poloidal wavenumber, that is a common feature for the turbulence in different devices [11]. There is a quasi-linear dispersion relation between f and k_θ that indicates a propagation of the fluctuations in the poloidal direction. From these k_θ-f spectra, the k_θ-spectra of the GPI fluctuations can be evaluated for the two regimes. This quantity (together with k_r) is widely used in the edge turbulence theory. By integrating the spectrum in frequency, the normalized power spectra of fluctuations of the poloidal wavenumber k_θ are derived (see figure 3). In this graph the triangles refer to the L-mode, and the circles to the H-mode case. For each case the k_θ spectrum is normalized to its maximum and each point in the figure represents an average over the considered set of discharges; the error bars are the rms. The two spectra are quite different: both of them display two separated regions with different power law decay, but the "critical wavenumber" k_θ^* that separates the two regions is different. From the graph, in the L-mode case $k_\theta^* = 40m^{-1}$ and in the H-mode $k_\theta^* = 20m^{-1}$. The most evident difference between the two spectra is for the low wavenumbers, where the spectrum of the H-mode is quite flat, instead the L-mode one shows again a power law decay.

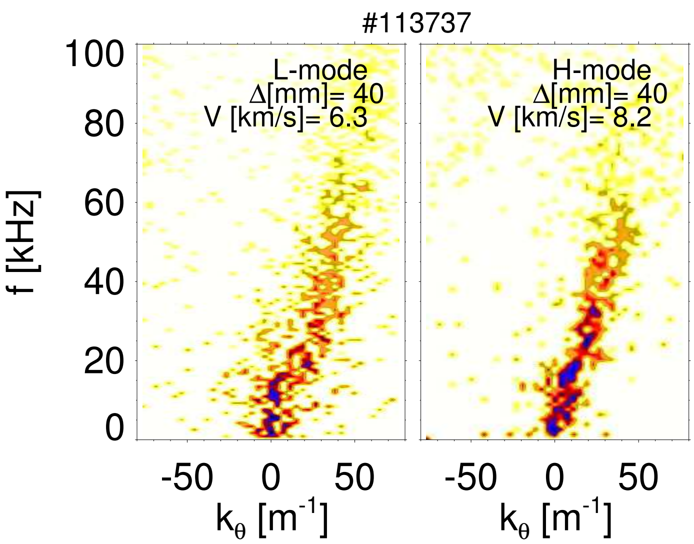

Fig2: *Poloidal $S(k_\theta,f)$ spectra measured with two poloidal GPI lines of sight spaced by 40 mm. The figure on the left refers to the L-mode part of discharge, the one on the right to the H-mode.*

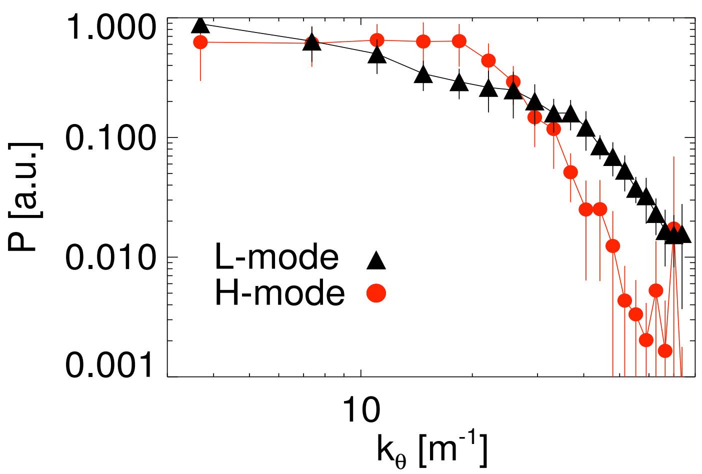

Fig.3: *Normalized poloidal wavenumber spectra for L-mode (triangles) and H-mode (circles) phase of the discharge. Each point is an average over similar shots and the error bars are the rms.*

In turbulence theory, the scale k_θ^* defining the change in the exponents of the power law-decay is related to the injection scale of energy in the system [12]. Since the two confinement regimes (L-H) show two different k_θ^*, we can suppose that there are two different energy injection scales. For the L-mode phase of the discharges, energy enters the system at $k_\theta^* = 40m^{-1}$; since the slopes of the power law are different from 0 for both $k_\theta < k_\theta^*$ and $k_\theta > k_\theta^*$, there may be two cascades with some structures breaking up toward small scales, and some others growing toward the largest scales. Instead, in the H-mode phase, the energy injection is at $k_\theta^* = 20m^{-1}$. Since for $k_\theta < k_\theta^*$ the k-spectrum does not exhibit a power-law decay, there is no cascade toward the lower wavenumbers. Therefore, only in the L-mode there is a build up mechanism toward larger structures; instead in the H-mode the energy injected in the turbulence flows toward higher wavenumber (and so toward smaller structures) [13].

Also in [14] the differences in the k-spectrum of the potential fluctuations between L and H-mode in plasma experiment is interpreted as due to different cascade processes.

Finally we observe that the average poloidal wavenumber assumes similar values both in the L-mode and in the H-mode, consistently with the similar correlation lengths found in [7]

Conclusions. In the NSTX experiment the H-mode is characterized by a more quiescent edge if compared with the L-mode plasmas: the linear density of intermittent bursts decreases, with no significant change in the poloidal velocity. The poloidal wavenumber spectrum in L-mode can be interpreted as the result of a double cascade process: the energy that enters the system is dissipated toward the smaller scale but it also flows to the small wavenumbers and feeds the larger turbulent structures. Instead in the H-mode case only the dissipation takes place.

Acknowledgments

This work was supported by the European Communities under the contract of Association between EURATOM and ENEA, and by USDOE Contract DE-AC02-76CHO3073. The views and opinions expressed herein do not necessarily reflect those of European Commission.

References

[1] A.J. Wootton *et al.*, Phys.Fluids B, **2**, 2879, (1990); E.Martines et al., Nucl.Fusion, **39**, 581, (1999)
[2] J.W. Connor and H.R. Wilson, Plasma Phys.Control.Fusion, **42**, 1408, (2000)
[3] S.J. Zweben *et al.*, Plasma Phys.Control.Fusion, **49**, S1, (2007); B.Scott, Plasma Phys.Control.Fusion, **49**, S25 (2007);
[4] F. Sattin, *et al.*, Plasma Phys.Control.Fusion, **48**, 1033, (2006)
[5] M. Ono *et al.*, Plasma Phys.Control.Fusion, **45**, A335, (2003)
[6]S.J.Zweben *et al.*,Nucl.Fusion,**44**,134,(2004); R.J.Maqueda *et al.*,Rev.Sci.Instrum.,**74**, 2020, (2003)
[7] S.J. Zweben *et al.*, Phys.Plasmas, **13**, 056114, (2006)
[8] A.E.White *et al.,* Phys.Plasmas, **13**, 072301, (2006)
[9] M. Onorato *et al.*, Phys.Rev.E, **61**, 1447, (2000); V. Antoni *et al.*, Europhys.Lett., **54**, 51, (2001)
[10] S.J. Levinson *et al.*, Nucl.Fusion, **24**, 527, (1984)
[11] R.Cavazzana *et al.*, Plasma Phys.Control.Fusion, **49**, 129, (2007); M.Endler *et al.*, Nucl.Fusion, **35**, 1307, (1995)
[12] M. Lesieur, *Turbulence in fluids*, Kluwer Academic Press, The Netherlands, 1997
[13] A.I. Dyachenko *et al.*, Phys.Lett.A, **165**, 330, (1992)
[14] M.G. Shats, *et al.*, Phys.Rev.E, **71**, 046409, (2005)