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Comparing Turbulence in L and H-mode plasmas in the Scrape-off Layer of the ASDEX-Upgrade Tokamak

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Abstract: We present results showing that the statistical properties of turbulence in the scrape-off layer (SOL) are not modified in a high-confinement mode (H-mode), in-between edge-localized modes (ELMs), with respect to a low confinement mode (L-mode) at lower heating power. The probability distribution functions of the turbulent fluctuations are found similar in L and H-mode reflecting that the transport processes, mainly of diffusive and convective types, are not affected by the transition. Moreover, the power spectra are also observed to be similar in L and inter-ELM H-mode indicating that there is no modification in the energy distribution among the turbulence scales. The probe results are cross-checked with mid-plane profiles from the lithium beam and the Thomson scattering diagnostics.

Introduction

Even after almost three decades of discovering the high confinement mode (H-mode) on the ASDEX tokamak [1], the role of turbulent transport in this transition is still ambiguous. It was postulated but not firmly confirmed that H-mode might be caused by the radial electric shear [2]. Recently, a series of investigations were made in low confinement (L-mode) plasmas where it was shown that intermittency in the scrape-off layer (SOL) is caused by convective large-scale structures that are called avaloids [3] or blobs [4] with a universal character [5].

The experimental setup

The experiment is performed on the ASDEX Upgrade tokamak. In shots 21284 and 21285 the average density of the H-mode is low leading to large time lapses in-between ELMs. The H-mode heating power is about twice that of L-mode. Discharges 20356 and 20357 are used mainly because the plasma parameters are about the same. One difference is the 5 MW of neutral beam heating in 20357 whereas for 20356 it is cut off 300 ms before the X-point probe plunge. The plasma is in the upper-single null (USN) magnetic configuration allowing the X-point Demokritos probe to perform its reciprocations in the SOL without having to cross the separatrix. The motion of the probe on the low-field side is mapped to a distance of 2-3 cm from the separatrix at the mid-plane.

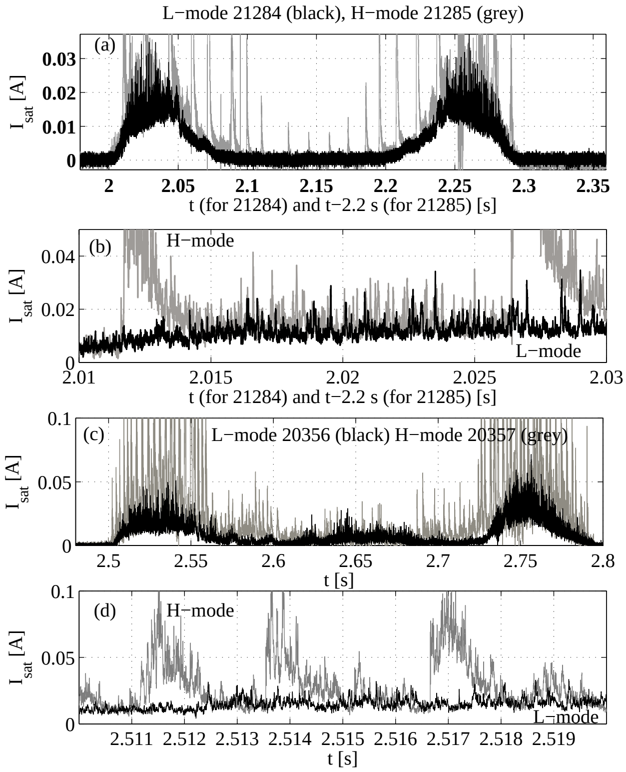

Figure 1: (a) illustrates I_{sat} for the two discharges 21284 and 21285; for the latter the time is shifted by −2.2 s. (b) is a zoom on (a) where the probe is on the low-field SOL. In (c), we represent the same plot as in (a) but for the shots 20356 and 20357. In (d) is shown a zoom on the signals of (c).

Comparing the ion saturation current in L and H-mode

In Fig. 1(a) the ion saturation current (I_{sat}) is shown as a function of time for the two discharges 21284 and 21285 where the plasma is respectively in L and H-mode during the probe plunge. A zoom on the time in-between ELMs is done in (b). In Fig. 1(c) and (d) the same traces as in (a) and (b) are plotted but for the discharges 20356 and 20357. One can visually deduce that, not only the absolute values of I_{sat} in-between ELMs in H-mode and L-mode are close, but also the level of turbulence and the nature of the fluctuations. The normalized level of fluctuations as well as the skewness and flatness factors of I_{sat} are found similar in L-mode and in-between ELMs in H-mode.

The statistical properties of turbulence in L and H-mode

We use the same number of points (10,000) in L and H-mode and I is calculated after subtracting the average value from I_{sat} and then normalizing by the standard deviation. In Fig. 2(a), the PDF of I is shown in L-mode and in-between ELMs in H-mode. The two curves are similar and agree well with the PDFs that were published in L-mode plasmas on various fusion devices [5]. The fact that the two PDF's agree so well reflects that the relative amplitude of the fluctuations and their probability of occurrence are, within the experimental precision, the same in the two confinement modes. Hence, the diffusive transport, mainly reflected by values smaller than the average, and the convective transport, by values greater than the average, are not modified by the L to H-transition.

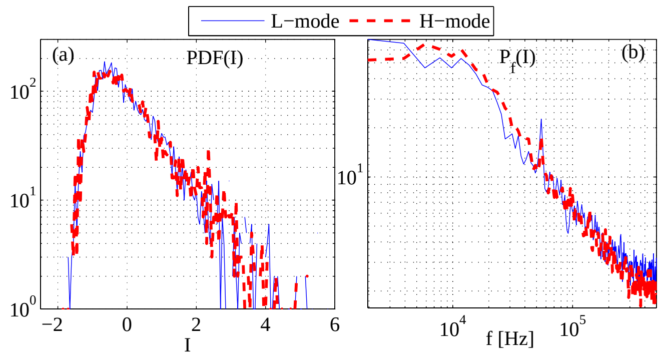

Figure 2: (a) and (b) represents respectively the PDF and the power spectrum (P_f) of I in L (solid) and H-mode (dashed) from shots 21284 and 21285. The spatial average is about 1 cm when mapped at the mid-plane.

In Fig. 2(b), we illustrate the power spectra of I in L and H-mode. Here again the agreement is good as the two curves have the same frequency dependence. Accordingly, the power distribution among the turbulent scales is unchanged in H (in-between ELMs) when compared to L-mode. One can deduce that if turbulence at the edge was suppressed or reduced, then the underlying processes should affect all the turbulent fluctuations at the same time and not some particular scales.

Mid-plane density profiles

The average density profiles of the shots 20356 and 20357 are plotted in Fig. 3(a). Within the experimental precision degraded by the high frequency of the ELMs, they have similar radial profiles. For shots 21284 and 21285, the profiles are plotted in Fig. 3(b) where the statistical variations are significantly reduced due to the large lapse between ELMs. As the two profiles are normalized to the density at the separatrix, illustrated in Fig. 3(c), they end up having similar radial profiles despite the difference in the heating power. The lithium beam profiles offer an independent and additional argument that the processes underlying radial transport into the SOL, namely turbulent diffusion and convection, are not modified by the L to H transition.

Profiles at the mid-plane are also determined using the Thomson scattering. Fig. 3(d) shows that the level of fluctuations is very similar in L and in H-mode at the mid-plane. This is, not only in agreement with the probe data, but also extends the results to distances close to the separatrix ($r/a = 1$) where electrical probes do not usually venture.

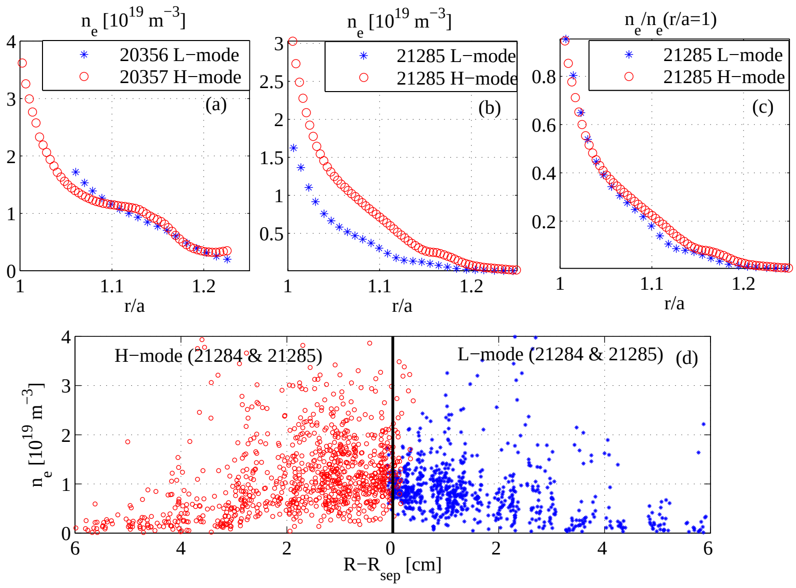

Figure 3: In (a) and (b) we plot the average density profile in the SOL as a function of r/a. In (c) is shown the profiles of (b) but normalized by the density at $r/a = 1$. In (d) we plot the density profile by the Thomson scattering.

Conclusion

Discharges with an upper single null magnetic configuration are analyzed and the properties of turbulence in the SOL in L and H-mode are compared. It was shown in a rather straightforward fashion that the statistical properties of turbulence in the SOL are not modified in H-mode (in-between ELMs) when compared to L-mode at much lower heating power. The underlying mechanisms of transport, that are turbulent diffusion by incoherent eddies and convective transport by avaloids (or blobs), are thus not modified. Furthermore, since the power spectra are unchanged, one can rather safely deduce that the distribution of fluctuations among the turbulence scales is also not modified.

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