Study of intermittent turbulence in the edge of RFX-mod by optical diagnostic

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The turbulent fluctuations of the edge plasma in fusion experiments are characterised by large-amplitude events in the plasma potential and pressure. These electrostatic events are considered the main cause of anomalous particle transport both in RFP [1] and tokamak [2] experiments and so a great effort is concentrated on their investigation. To this purpose the Gas Puffing Imaging Diagnostic (GPID) system [3] has been installed on RFX-mod device. The system consists of a gas-puffing nozzle and 32 optical channels divided into 3 fans to measure the local HeI (667.8 nm) emission from the puffed neutral gas. The optical lines are 5 mm spaced and cover an area of 70 mm along the toroidal direction and 50 mm in the radial one; so the plane normal to the local magnetic field (that is poloidal in the edge of the RFPs) is observed. Signals are sampled at 10 Msample/s and the effective bandwidth of electronics is 2 MHz. Being a non-invasive diagnostic, the GPID is used to study plasma edge also for high plasma current pulses when the Langmuir probes cannot be inserted.

In this paper results obtained in RFX-mod device (R=2m, a=0.5m) [4] are described for discharges at 500-600 kA plasma current and "Virtual Shell" operation. In particular the connection between edge plasma fluctuations and core MHD phenomena is analysed. This MHD activity is mirrored in the periodic fluctuations of the reversal parameter $F = B_\phi(a)/\langle B_\phi \rangle$, where B_ϕ is the toroidal magnetic field. Such fluctuations of F, particularly enhanced in virtual shell discharges, are a signature of the cyclical process of diffusion-relaxation taking place in RFP plasmas [5] (Dynamo Relaxation Event - DRE). In a previous work [6] a relation between F dynamic and floating potential measured by Langmuir probes in RFX has been reported.

Using the 16 Lines of Sight (LoS) of the central fan of the GPID it is possible to evaluate by the cross-correlation technique the toroidal velocity of fluctuations (Fig 1(b)) which varies from –20 to -40 km/s and its direction is along the ExB flow. As the GPID provides a high time resolution, the velocity is evaluated every 0.2 ms, and so it is possible to follow its variation inside the F crash that has a typical time duration of few milliseconds (2-3 ms). Moreover, using the continuous wavelet transform it is possible to extract from the optical signals the fluctuations of characteristic time-scale τ. By applying the same algorithm based on the cross-correlation between the LoS to the wavelet coefficients the toroidal velocity of fluctuations is evaluated as a function of the time-scale.

The correlation between the edge toroidal velocity of fluctuations and the core MHD activity can be seen clearly comparing the panels (a) and (b) of Fig.1, for a discharge with F crashes in the range from –0.20 to -0.28. For every F crash velocity varies from –20 to –40 km/s. In panel (c) velocity is shown for fluctuations with characteristic time-scale τ = 1.3 and 3.6 μs. The smallest scale has a higher toroidal velocity and no clear link with the reversal parameter; on the other hand, the fluctuations with τ = 3.6 and higher assume values of about –20 km/s to -40 km/s and reflect the F time behaviour. As the velocity of Fig.1 (b) can be argued to be the ExB edge plasma velocity (measurements made by insertable Langmuir probes give comparable results [7]), fluctuations with τ >1.3 μs move with the flow. In order to better characterise such behaviour, in Fig.2 the correlation between F and fluctuations velocity of different time scale τ is shown. Except for the smallest time scales, there is a great correlation (up to 47%) with F; the absolute value of velocity increases about 1 ms before the decrease of F (high correlation) and then reaches the "standard" value of about -20 km/s 0.5 ms after F assumes its minimum value (anti-correlation up to 67%). These time lags could be due to the penetration time of the toroidal magnetic field through

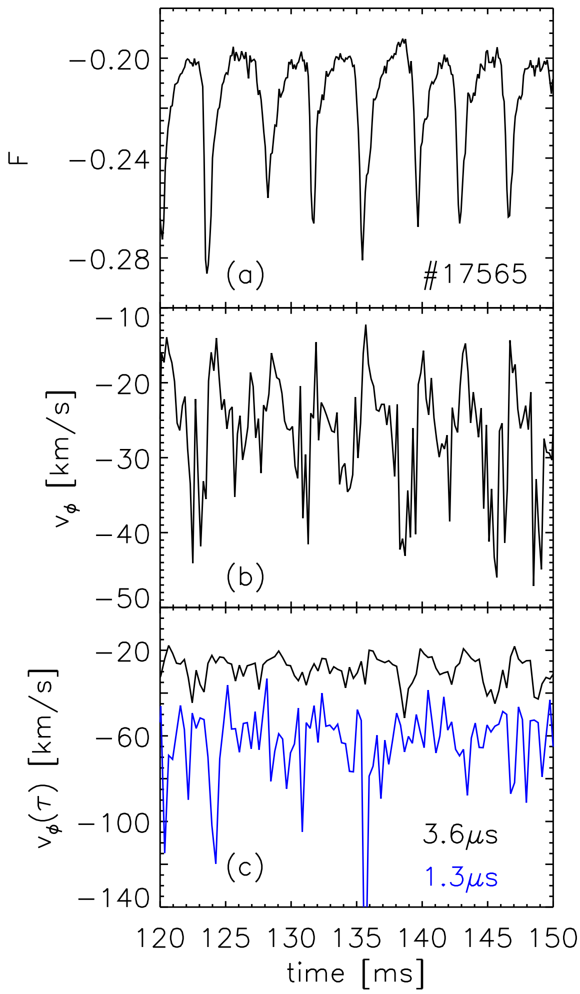

Fig.1. (a) time behaviour of reversal parameter F; (b) toroidal velocity of fluctuations; (c) toroidal velocity of fluctuations for 2 different characteristic time scales.

the vacuum vessel and not to a real time shift: as a matter of fact, the magnetic field used to evaluate the F parameter is measured beyond the vacuum vessel.

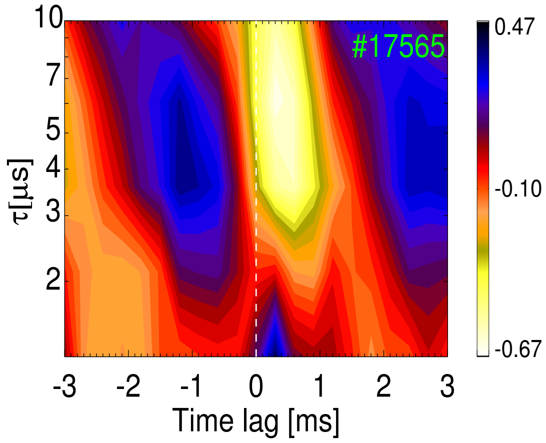

Fig.2: correlation between the reversal parameter F and toroidal velocity of different time-scale fluctuations.

Then it is possible to analyse the influence of the DRE on the electrostatic structures in the edge plasma detected by the GPID. Using the method described in [6], with the wavelet transform we can extract from the time series of the GPID signal large intermittent events that can be associated to the electrostatic vortices and density blobs [8-9]. For time intervals of 0.4 ms, the space density N_s of these intermittent events is evaluated as function of time and scale. The result is shown in figure 3 (left) with the time behaviour of F. The graph shows the contour plot of the intermittent structures density as function of time and time-scale τ. In the upper plot the time behaviour of N_s for τ=3.6 μs is shown. It is evident that the electrostatic structures tend to cluster during the DRE, and that their number decreases on increasing their characteristic time length. Between two crashes the number of intermittent events reduces for all time scales. In the same figure, on the right, the correlation between the reversal parameter and N_s is shown, and it is well anticorrelated with F, with a periodicity of about 4 ms (250 Hz): this is the frequency of the relaxation

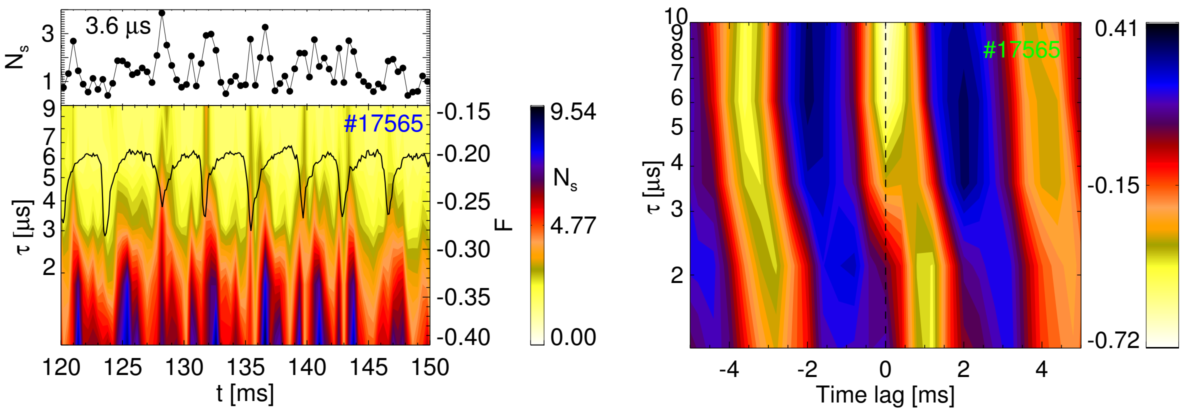

Fig. 3: (left) time behaviour of density of structures N_s for different characteristic time-scale τ and reversal parameter F; on the top, the time behaviour of N_s for τ=3.6 μs; (right) correlation between F and number of structures

events in this shot. The analysis of the intermittent events is carried out up to 10 μs, as they are not detected for higher time scales. In order to highlight the difference of the fluctuations between and during the DREs, a Fourier analysis is carried out for the optical signal of the GPID. In Fig. 4 the spectrogram of a central LoS of the central fan is shown compared again with F cyclical oscillations. During the DRE there is an increase of edge fluctuations for frequency of about 50 kHz that decreases between the F crashes. Therefore, the core MHD dynamic is correlated both with the high frequency (>100 kHz) and the low frequency (~50 kHz) electrostatic fluctuations of the edge plasma.

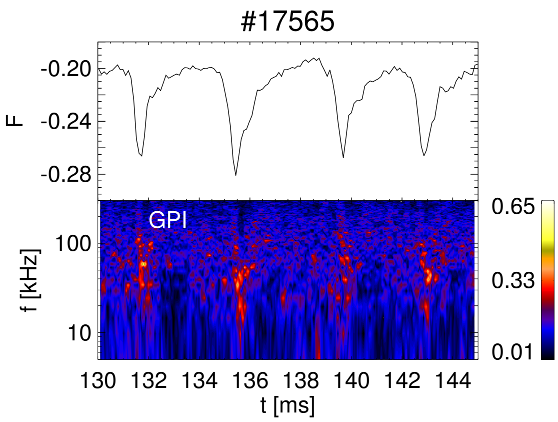

Fig.4: reversal parameter and spectrogram of a GPID signal.

In this paper we pointed out that there is link between the low-frequency MHD fluctuations (hundreds Hz) in the core and the edge electrostatic turbulence. As suggested in [6], this can be explained with a non-linear coupling between MHD and electrostatic fluctuations; a consequence is that the particle transport at the edge and the transport process in the plasma core are correlated. Further analysis is necessary to better understand this phenomenon.

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