Poloidal asymmetry of perpendicular velocity of the density fluctuations

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It is found that the perpendicular velocity, measured using Doppler backscattering technique in the core of limited L-mode plasmas of Tore Supra tokamak, is significantly assymetrical in the poloidal direction. Simultaneous measurements are performed at the low field side ($\theta \sim 0°$) and at the top of the plasma ($\theta \sim 90°$), in widely different plasma conditions and show that density fluctuations move faster in the equatorial plane.

A. Context

While turbulent transport is partly responsible for reducing tokamak performances, the shearing of radial electric field is known to play a key role in reducing the turbulent transport by shearing the turbulent structures elongated in the radial direction, such as streamers. However, what determines the radial electric field and its gradient at the edge is not *a priori* obvious. One view is that non ambipolar neoclassical fluxes generate the radial electric field in order that the resulting charge transport stay ambipolar. However since toroidal rotation is rarely neoclassical, one has to consider the alternative view, which is that the turbulence can generate toroidal and poloidal rotation which, together with the pressure gradient determine the radial electric field via the radial force balance. Interesting cases are plasmas without external input of momentum in which, intrinsic rotation is systematically present. For example, on Tore Supra plasmas, non-ambipolar particle flux induced by ripple loss have been shown to be the dominant mechanism that sets the radial electric field in the core [1] while the radial electric field at the edge (between $\rho = [0.9 - 1]$) is modified by changing the boundary conditions (ie. the contact point of the last closed flux surface) [2]. The existence of a poloidal asymmetry in parallel dynamics on several quantities in the SOL is well known [3]. However, in the confined plasma, the perpendicular velocity of density fluctuations (usually measured on the equatorial plane) is expected to be poloidally symmetric.

B. Experimental set-up

In the present study, we investigate the poloidal symmetry of the perpendicular velocity of density fluctuations by comparing its radial profiles at two poloidal locations. This study has been performed for a wide range of L-mode plasma parameters using two independent Doppler Backscattering (DBS) diagnostics simultaneously, one at the low field side (LFS), the other at the

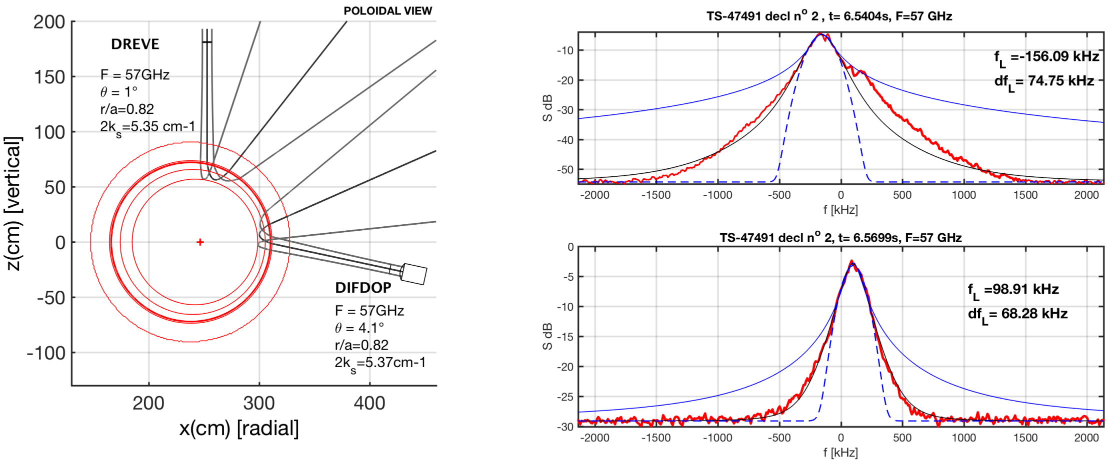

Figure 1: Example of beam tracing for DIFDOP (equatorial location) and DREVE (top location) systems and associated frequency spectra

top of the machine as illustatred in figure. Doppler backscattering (DBS) is a diagnostic technique, which can be used to probe density fluctuations at given scales. This sytem allows the determination of radial profiles of perpendicular velocity corresponding to the motion of density fluctuations. The system installed on Tore Supra provides an equatorial view with O- mode (V-band) and X-mode (W-band) channels on one hand, and vertical view with O-mode (V-band) channel on the other hand. The measured frequency spectra (see example presented in figure 1) are Doppler shifted due to the motion of density fluctuations perpendicular to the field lines, in the $\hat{\mathbf{b}} \times \hat{\mathbf{r}}$ direction [4]. This shift of the peak of the spectrum provides the mean Doppler shift frequency $\omega_{DBS} = \mathbf{k}_{sc}\mathbf{v}_{\perp}$ at a given radial location (an area of a few centimeters width) and at a given wavenumber, where $\mathbf{v}_{\perp} = \mathbf{v}_{\mathbf{E}\times\mathbf{B}} + \mathbf{v}_{ph}$ is the perpendicular velocity of density fluctuations in laboratory frame, mainly due to the $E \times B$ drift, written as : $\mathbf{v}_{\mathbf{E}\times\mathbf{B}} = \frac{\mathbf{E}\times\mathbf{B}}{B^2}$ plus fluctuation phase velocity $\mathbf{v}_{ph}$. Radial location and scattering wave vector of the measurements are computed using a ray tracing code [5] and the experimental density profiles measured using fast sweep reflectometers. In the confined plasma, measurements show that the density fluctuations move in the electron diamagnetic direction (upwards in the LFS) for both locations, as generally observed in Tore Supra [4, 6]. This picture is typical for Tore Supra plasmas in which, the radial electric field Er is negative (i.e. inwards) in the confined plasma and dominated by ripple effects[6], as long as the phase velocity of fluctuations are small compared to the drift velocity. For practical reasons, three representative discharges have been selected for deeper analysis and will be reported and discussed in the following (see table I).

Discharge	B_0	I_p	ICRH	n_l	q_{95}
TS-47224	3.87 T	1.12 MA	2 MW	$5.7\,10^{19} m^{-3}$	4
TS-47491	3.87 T	0.75 MA	4.3 MW	$6\,10^{19} m^{-3}$	6.5
TS-47177	3.41 T	1.29 MA	0	$6.9\,10^{19} m^{-3}$	3.2

Table I: Overview of the discharges considered

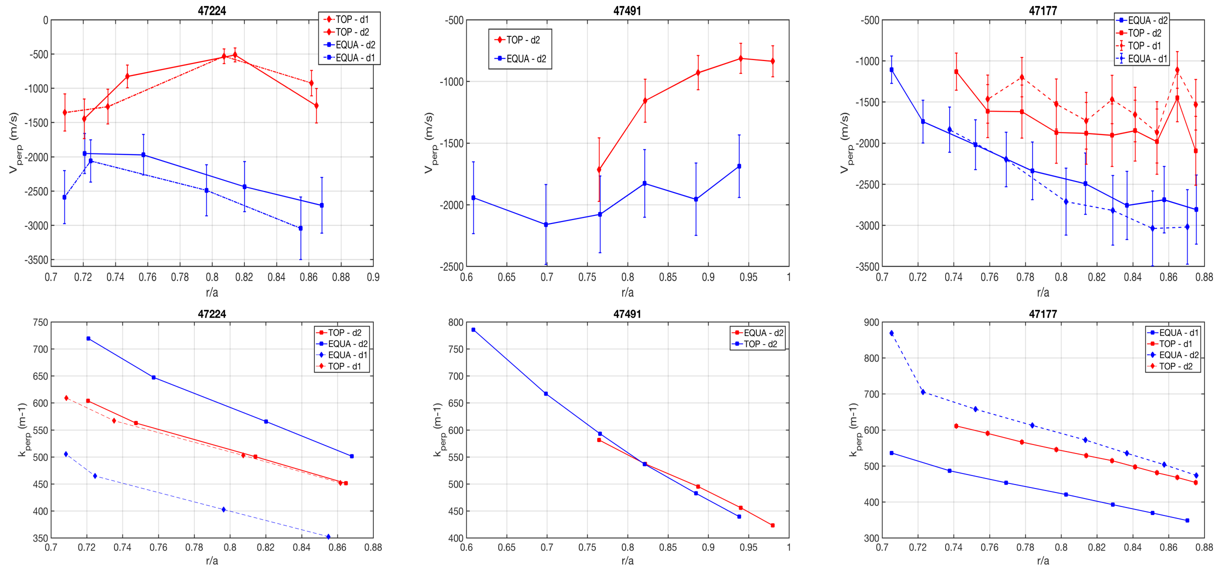

Figure 2: Radial profiles of the perpendicular velocity of density fluctuations measured using DBS at two poloidal locations (top) and radial profiles of the wavenumber of density fluctuations detected by DBS (bottom)

C. Observation of poloidal asymmetry of perpendicular flows

The comparison of the radial profiles of the perpendicular velocity of density fluctuations at different poloidal locations ($\theta \backsim 0°$ and $\theta \backsim 90°$) measured during three typical discharges are presented in figure 2. It is found that density fluctuations move clearly faster in the equatorial plane in all various plasma conditions (see table I). The measured perpendicular velocity can be up to three times higher in the equatorial plane than at the top, in the region $0.7 \leq \rho \leq 0.95$. Such asymmetry is systematically observed in all discharges in which data from top measurements are available and remains even applying corrections related to the $B \propto \frac{1}{R}$ dependence (and from the fact that the equatorial and the vertical measurements are done at different radius R) and related to the effect of Shafranov shift (which brings magnetic surfaces closer to each other at the LFS and makes E_r slighly higher at the LFS than at the top). Note that the perpendicular velocity of density fluctuations is usually assumed to be dominated by the $E \times B$ drift (i.e. $\mathbf{v}_{ph} \ll \mathbf{v}_{\mathbf{E}\times\mathbf{B}}$) however, on Tore Supra, it has been shown that the phase velocity of the density fluctuations can contribue up to 50% to the perpendicular velocity measured using DBS [7]. Therefore, a possible contribution to poloidal asymmetry due to the poloidal asymmetry of the phase velocity should be considered, in addition to that of $V_{E\times B}$.

D. Discussion

This observation of poloidal asymmetry of the velocity of fluctuations is actually comparable to the observations performed in TEXTOR in both auxiliary heated plasmas with neutral beam injectors (NBI) [8] and ohmic plasmas [9]. In the first reference, the poloidal asymmetry of the perpendicular velocity of density fluctuations measured by correlation reflectrometry is observed for both counter and co-NBI heating. For counter-NBI, density fluctuations flow faster in the equatorial plane than on the top of the machine, while for co-NBI, the situation is reversed in the core and the perpendicular velocity is faster in the equatorial plane. These results are however not trivial to compare with Tore Supra plasmas, in which no external momentum are applied. The second reference shows ohmic plasmas in TEXTOR where the density fluctuations flow faster in the equatorial plane than in the vertical one. However, in these experiments a correlation between the poloidal asymmetry and the plasma current (asymmetry decreases with decreasing the plasma current) is observed while measurements on Tore Supra do not show a similar behaviour when discharges at different plasma currents are compared . Nevertheless, since this present comparison is performed on wide range of plasma parameters (different density, heating power...), the effect of plasma current can not be properly extracted and no clear trend about the parameteric dependencies could be extracted from the limited set of discharges that were available. Considering the plasma velocity $V_{E\times B}$ contribution, turbulence is known to drive poloidal flows, such as zonal flows. In this spirit, one could imagine a poloidal mean flow generated by the turbulence, through Reynolds stress, which may be poloidally assymetrical due to the ballooning character of the turbulence.

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