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Turbulent transport in fusion magnetised plasmas/Transport turbulent dans les plasmas magnétisés de fusion

Scaling laws of density fluctuations in tokamak plasmas

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Abstract

Fluctuation measurements provide key elements for turbulent transport analysis. In scaling experiments, they bring complementary *local* information for validating confinement dependence on nondimensional parameters. The scaling of spatial and temporal characteristics of the fluctuations allows a more detailed comparison with transport models. This article will review the fluctuation observations of the scaling experiments in different tokamaks. They concern mainly scaling laws with the normalised gyroradius ρ^*. This article also presents another aspect of fluctuations dependence, the scaling with the wavenumber, which provides information on the nonlinear turbulence mechanisms. ***To cite this article: P. Hennequin, C. R. Physique 7 (2006).***

Résumé

Des lois d'échelle de fluctuation de densité dans les plasmas de tokamak. Les mesures de fluctuations apportent des éléments clés pour l'analyse du transport turbulent dans les plasmas de tokamak. Elles complètent les expériences d'analyse de dépendance du confinement avec les paramètres sans dimension par des informations locales et détaillées. Les caractéristiques spatiales et temporelles fournissent notamment des contraintes supplémentaires pour la validation des modèles. Cet article présente les principales observations réalisées sur les tokamaks, principalement en lien avec le rayon de Larmor normalisé ρ^*. L'analyse de la dépendance de la structure spatiale est complétée par l'étude des lois d'échelle en nombre d'onde, caractéristique des mécanismes non linéaires de saturation et de dissipation. ***Pour citer cet article : P. Hennequin, C. R. Physique 7 (2006).***

Keywords: Tokamak plasma; Fluctuation measurements; Turbulent transport

Mots-clés : Plasma de tokamak ; Mesures de fluctuations ; Transport turbulent

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1. Introduction

Turbulent transport limits the quality of confinement in tokamak plasmas. Its prediction for the next step machines remains challenging for transport models, and relies on extrapolations of scaling laws based on multi-machine data base [1]. The dimensionless form of these scaling laws should reveal the underlying mechanisms of turbulent transport, each of the dimensionless parameters involved being linked with a particular aspect of turbulent transport. Understanding these parametric dependences is thus a central point for validating and improving transport

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models, and has drawn a large experimental and simulation effort. Fluctuation measurements provide key elements for this analysis. When they are associated to confinement scaling experiments, they bring local information on turbulence magnitude scaling which provides further insight on the possibly different global and local transport dependence.

In addition, the scaling of their spatial and temporal characteristics is also crucial for testing and discriminating the transport models. For the spatial structure, the normalised Larmor radius ρ_i/a is the nondimensional parameter whose impact is the most sensitive, and a key parameter for next step extrapolation. As has been seen in previous papers, a large variety of modes can become unstable in a tokamak plasma, depending on the species considered (ion, electron, trapped or not) the collisionality regime, the geometry. They differ in particular by their typical length scale [2]: the ion temperature gradient mode (ITG) has a typical scale longer than the ion Larmor radius ρ_i ($k_\perp \rho_i < \sim 1$), the trapped electron mode (TEM), also of the order of ρ_i, and the electron temperature gradient mode (ETG) occurs at smaller scale with $k_\perp \rho_i \gg 1$. There is growing experimental evidence that turbulence at the largest scale (ITG, TEM) is responsible for the most part of transport. However, fluctuations at high k linked with ETG modes could play a role in electron thermal transport and account for some different behaviour of ion and electron transport channel in high confinement regimes [3]. Their role should be central when electron heating is dominant [4,5], and this will be the case in burning plasmas since alpha particles will heat mainly the electrons.

Beyond the driving mechanisms, analysing fluctuations on a wide range of scales yields information on saturation and dissipation mechanisms. We will thus examine the scaling of fluctuation magnitude with the wavenumber. The k-spectrum characterises the nonlinear dynamics and the energy transfer process between scales. In tokamak plasmas, this energy transfer is believed to be similar to the two-dimensional fluid turbulence, where an inverse cascade takes place leading to fluctuations energy concentrated at wavenumbers lower than the most unstable ones, consistent with observations at low k. However, from medium to high k, measurements have shown a departure from usual power laws, which indicates a dependence on scale.

In this article, we will present some of the experimental studies of fluctuation scaling laws. These studies remain difficult and thus scarce, because they add the intrinsic difficulty of complete turbulence measurements in the core to that of scaling experiments, where one parameter is explored while the others must be kept constant. The dependence of turbulence magnitude will first be examined, especially its correlation with confinement, the scaling with the gyroradius and other dimensionless parameters. Then the spatial and temporal structure of fluctuations is reviewed, from long to small scales, and their dependence on the gyroradius. Finally, the form of the k spectra scaling law in the medium and high k range is discussed.

2. Scaling of turbulence level and confinement

2.1. Global and local transport correlate with the turbulence level

Conversely to the edge region, the direct evaluation of the turbulent fluxes in the core has not been possible. It requires the measurement of $\tilde{n}, \tilde{\phi}, \widetilde{T}_e$, that are not accessible simultaneously in the tokamak plasma core. However, there is strong experimental evidence of the direct correlation between confinement and fluctuation level, which was obtained from the early turbulence measurements in tokamaks [6–8]. For larger machines, the global confinement time is observed to be correlated with turbulence level in the plasma *core* in standard confinement regimes (e.g. L-mode) [9–11]. This correlation is also a local property: an example is the scaling of the relative fluctuation level, both electrostatic $\tilde{n}/n$ and magnetic $\tilde{b}/B$, with transport coefficient in Tore Supra [12,13]. In high confinement regimes, the formation of the transport barrier is accompanied by the local reduction of fluctuations [14]. The stabilisation mechanisms, especially via $E \times B$ shear flow have been studied in detail at the L–H transition for edge transport barrier [15,16]. For the Internal Transport Barrier, it has been shown that the decrease in the ion thermal conductivity within the barrier is correlated with suppression of long wavelength turbulence ($k_\perp \rho_L \ll 1$) [17–19]. Suppression of shorter wavelength turbulence is associated with a localised drop in the electron thermal conductivity in JET [20]. In addition to $E \times B$ shear flow stabilisation, magnetic shear has been identified as a generic stabilisation mechanism for ITG turbulence: whether underlying instabilities are controlled, or reduced correlation length dominate in the turbulence transport reduction, is still not elucidated.

2.2. *The expectation for the fluctuation level versus nondimensional parameters*

Analysing energy and particle transport in terms of dimensionless parameters is a powerful technique for comparing tokamak experiments with theory and for providing predictions for next step machines [21,22]. The principle of similarity assumes that physics is independent of the size scale. Accordingly, it has been demonstrated that tokamaks of different physical size but similar nondimensional parameters will have the same energy transport [23–25].

If energy transport is dominated by plasma physics, transport coefficients, normalised to the Bohm value $\chi_B \equiv T/eB$, can be expressed as functions of three dimensionless parameters $\chi \equiv \chi_B F(\rho^*, \nu^*, \beta)$ at fixed safety factor q, plasma geometry, and ratio T_e/T_i [21,22,25]; $\rho^*(\equiv \rho_i/a)$ is the normalized gyroradius, ν^* the collisionality and β the ratio of kinetic to magnetic pressure. The confinement scaling with these parameters provide the basis for predicting the performance of the next step machines. The value of the parameter ρ^* expected on these next step machines is not achievable in the present experiments. The large extrapolation for their design requires the determination of χ scaling with ρ^* with the highest accuracy. The electron transport channel shows an explicit dependence $\chi \equiv \chi_B \rho^*$ (gyro-Bohm scaling), which is favourable. The situation is less favourable for the ion transport channel, except in high confinement regime [24,26].

Numerical simulations usually predict a gyro-Bohm behaviour for small ρ^* [27–29]. Most of turbulent transport theories are intrinsically gyro-Bohm since they predict that the typical scale length of turbulence is the Larmor gyroradius, and the correlation time of the order of the transit time a/c_s. Thus a crude estimate of the diffusion coefficient obtained from analogy with random walk, $\chi \sim \rho^2 c_s/a \equiv \rho^* T/eB$ leads to a gyro-Bohm scaling of the turbulent transport.

Furthermore, the mixing length rule [30,31] predicts the turbulence level from the balance between linear drive and nonlinear saturation term: the relative level of fluctuations thus scales as $\tilde{n}/n \sim 1/(\langle k_\perp \rangle L_n)$, where L_n is the density gradient length, that is $\tilde{n}/n \equiv \rho_i/L_n$ with a correlation length scaling with ρ_i (gyro-Bohm).

2.3. *Fluctuation level scaling with the ion gyroradius ρ_i*

The mixing length rule was mostly satisfied in early fluctuation observations [6,8,32]. A better agreement is found when the relative fluctuation level is compared with the inverse of the mean wavenumber $\langle k_\perp \rangle$ or the mean correlation length [33,34] rather than ρ_i. However, the detailed comparison sometimes fails, for instance, in the radial distribution and in some parametric studies [35], especially in improved confinement regimes [36] possibly due to intricate dependences.

To clarify the dependence of the turbulence on ρ_i, dedicated scaling experiments were performed on several tokamaks. On DIIID, in L-mode [37], ρ_i is changed by 1.6 by varying the magnetic field ($B = 1$ and 2 T). The other dimensionless parameters ($\nu^*, \beta, q, T_e/T_i$, and their profile, plasma geometry) were kept constant [24] by adjusting gas feeding and heating power. Fluctuation level was obtained from beam emission spectroscopy (BES), which measures the local long wavelength ($k < 2.5\ \mathrm{cm}^{-1}$) density fluctuations from the light emitted from the injected neutral beam, over a substantial part of the plasma ($0.6 < r/a < 1$). The fluctuation profiles for both low and high ρ_i and their ratio, shown in Fig. 1, indicate a scaling $\tilde{n}/n \sim \rho_i^\alpha$, with $\alpha > \sim 1$. The radial variation of the $\tilde{n}/n$ ratio shows significant variance and, given the experimental uncertainty, is consistent with the gyro-Bohm predictions. However, the global confinement time in these discharges shows a Bohm behaviour, as well as ion thermal diffusivity, while electron diffusivity has rather a gyro-Bohm scaling. This discrepancy in the turbulence level behaviour and confinement could be due to a mismatch in rotation profiles between the two discharges, resulting in different growth rates of instabilities due to an change in the $E \times B$ shearing rate.

In Tore Supra, scaling experiments, also performed using magnetic field B scan [38], show that the fluctuation level change is consistent with expectations from a gyro-Bohm scaling, in L-mode and ohmic discharges. Fluctuation measurements from CO_2 laser scattering diagnostic [39], show that this agreement is valid over the whole wavenumber k range (5 to 26 cm^{-1}) [40].

2.4. *Fluctuation level scaling with β, $T_e/T_i, \ldots$*

The dependence with the other parameters is less well established, and an effort is being made on different machines to clarify this, and correlate them with fluctuation measurements. Indeed, discrepancies have been found between the

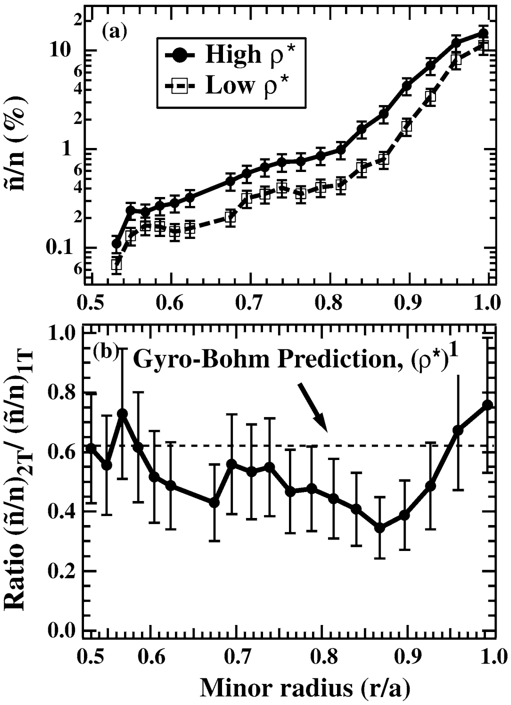

Fig. 1. Profile of the normalised density fluctuation amplitude $\tilde{n}/n$ at low and high ρ_i (a) and their ratio (b) in DIIID, from [37].

ITER H-mode scaling law, which predicts a degradation of the energy confinement with β, and dedicated similarity experiments on JET and DIIID or JT-60. One part of the controversy is the influence of the edge in H-mode where the ELMs show a strong MHD activity. L-mode discharges in Tore Supra are thus particularly suitable for studying the β dependence of turbulent transport without edge and pedestal physics to interfere. The fluctuation level profile measured in the β scan experiment (with similar ion Larmor radius, collisionality, q profile) shows no or little dependence over $0.3 < r/a < 0.8$ [41], consistent with the weak dependence of the global confinement time, observed similarly to JET and DIIID. Unfortunately on DIIID, fluctuations measurements were not possible during the β scan, performed in H-mode, due to the too low level of fluctuations in these discharges. This result implies that electromagnetic effects should not play a major role, and models based on electrostatic turbulence codes would already give the principal trends. The dependence of fluctuations and transport on the electron to ion temperature ratio has been studied in DIIID [42]. BES and reflectometry measurements show no or little dependence while thermal diffusivity does. This could be due to profile or other parameter mismatch, or more basically, to the possibility that the increase of transport is due to increase of other fluctuating quantities (not only density).

3. Correlation length scaling with the gyroradius

3.1. Long radial and poloidal correlation lengths

The spatial characteristics of fluctuations can be measured in the plasma core by different techniques that are mainly of two types: (i) in real space from the correlation functions of two-points measurements – localised measurements are obtained for example by BES, reflectometry, phase contrast imaging, heavy ion beam probe; (ii) in the wavenumber space from scattering of electromagnetic waves using laser or microwave beams. The latter is a powerful technique for the purpose of fine scale analysis, because it provides directly the space Fourier transform of the fluctuating density at a specified wavenumber, and has been used since the early fluctuation measurements in small machines. It was found that the most energetic part of the wavenumber spectrum (i.e. the spectral density of fluctuations $S(\vec{k}) \equiv |n(\vec{k})^2|$ at the wavenumber $\vec{k}$) lay below $k_\perp \rho_i < 1$ [43]. The wavenumber at maximum is found around: $k_\perp \rho_i \ll 1$, ~0.1–0.5 [44,9,34,45]. An asymmetry is observed at small $k_\perp$ between the poloidal and radial wavenumber spectra [46]: the

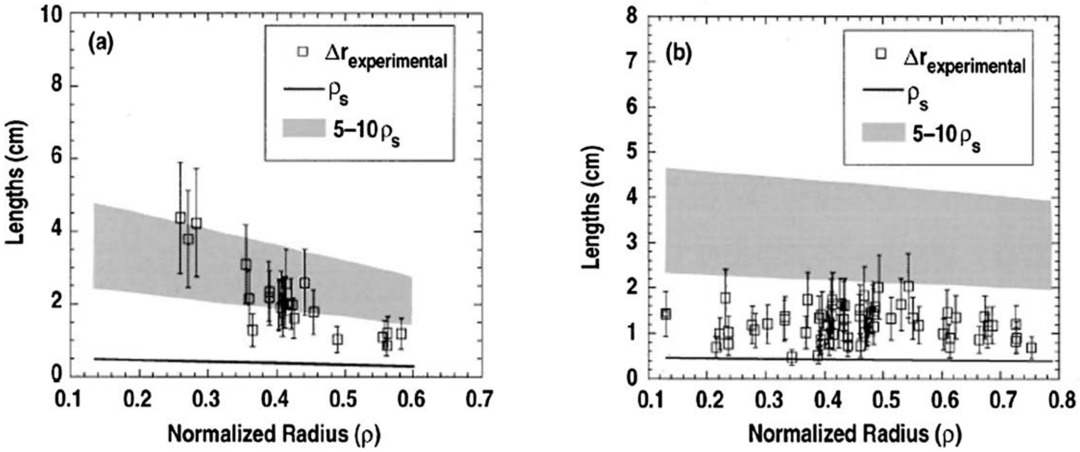

Fig. 2. Correlation lengths in the DIIID tokamak, determined with correlation reflectometry, in (a) L-mode plasmas and (b) the quiescent double barrier regime from [52].

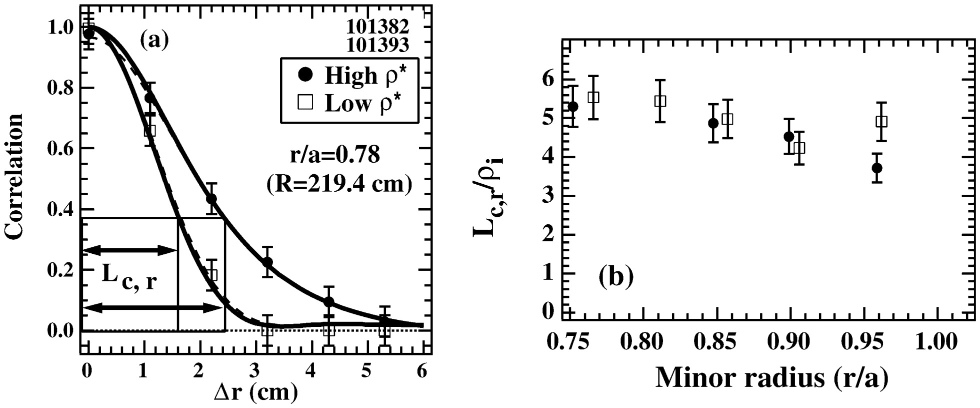

Fig. 3. Radial correlation function of density fluctuations measured by BES at low and high ρ_i in the DIIID tokamak (a) and the ratio of the inferred radial correlation length to the ion Larmor radius (b), from [37].

k_θ-spectrum saturates around $k_\theta \rho_i \sim 0.3$ [47] and decreases towards small k [34]. The radial wavenumber spectrum saturates at lower k. Since the maximum of the spectrum lay in the range of the lowest measurable wavenumbers with scattering systems ($k \sim 2$–$4\ \mathrm{cm}^{-1}$), localised measurements joined to correlation techniques have been used to assess the role of long scales: beam emission spectroscopy [9,48,37] and correlation reflectometry [49,36,50,51] confirm that very long scales dominate in the radial direction with typical values from 2–4 cm are in the core, decreasing towards the edge to less than 1 cm. The scaling of the correlation length is observed to be around 5 to 10 ρ_i on a large outer part of the plasma [51] (see Fig. 2(a)). These values also correspond to $\rho_{i,\theta}$ (the ion Larmor radius for the poloidal magnetic field) but very little change is seen when changing the current (and the safety factor q) which invalidates this possible scaling [52]. The observed values are thus generally larger than those predicted from analytical ITG theories.

In scaling experiments on DIIID mentioned in Section 2.3 [37] the correlation lengths have also been measured thus confirming the scaling of the radial correlation length around 5 to 6 ρ_i.

The measured values of radial correlation lengths are consistent between BES and reflectometry. They show also a good agreement with predicted values from gyrofluid and gyrokinetic codes [53,54]; competition between the inverse cascade process leading to the formation of large structures and Landau resonance or shear flows for limiting their size [30] seems to result in structures with typical radial size larger than ρ_i but scaling with it.

The poloidal correlation length measured by BES is also shown to scale with the ion Larmor radius (Fig. 3). BES measurements confirm the asymmetric structure of the fluctuations at low k, since the poloidal spectrum is shown to be peaked in the region $k\rho_L < \sim 0.1$–0.3 [48,37]. This feature shows also a good agreement with predicted values from gyrofluid code [53,55]. Asymmetry (i.e. wave-like structure in the poloidal direction, long correlation length in the radial direction) has also been observed on small size machine, though the scaling with ρ_i is different ($\rho_i^{1/3}$) [56].

Radial correlation lengths are observed to be shorter in high confinement regimes associated with the formation of the internal transport barrier: the reduction of correlation lengths inside the Internal Transport Barrier region [57,58, 20,59] is consistent with the reduction mechanism through the $E \times B$ shear: the resulting velocity shear tears apart the structure and reduces its size and the associated transport. Simulation including $E \times B$ shearing, obtains correlation lengths values consistent with those measured.

3.2. The k-spectrum in the medium k range

Analysing the fluctuation distribution among a wide range of scales permits the characterisation of the nonlinear dynamics and the energy transfer process between scales. A classical example is the Kolmogorov law in 3D isotropic fluid turbulence [60], where energy injected at large scale is redistributed by nonlinear interactions down to the dissipative length. This characteristic decay of large vortices breaking into smaller ones has been described by Kolmogorov in terms of an energy cascade $E(k) \equiv k^{-5/3}$ in the inertial range, where $E(k)$ is the kinetic energy at the scale $1/k$ ($\int E(k)\,\mathrm{d}k = 1/2\langle v^2\rangle$). It assumes that far from production and dissipation ranges, the energy transfer is local and independent of the scale. The situation is different in 2D fluid turbulence because in addition to energy, enstrophy is also an invariant, and a dual cascade takes place on either side of the length scale at which energy is injected [61]: the energy cascade is in that case directed towards larger scales, with the same spectral index $E(k) \equiv k^{-5/3}$, leading to the formation of large structures. The direct enstrophy cascade follows a power law $E(k) \equiv k^{-3}$ for smaller scales down to the dissipation length-scale [62]. Because of the strong anisotropy induced by the large magnetic field, turbulence perpendicular and parallel wavenumbers are very different $k_\parallel \ll k_\perp$; magnetised plasma turbulence is then expected to follow this 2D picture [63,64] implying a mode condensation (formation of large scale structures) below the wavenumber k_f of the driving instability. The wavenumber k_f delimiting (at the transition between) the direct and inverse cascade spectral zones varies with the different models ($k\rho_i < 1$) [2,64,65]). Nevertheless tokamak plasma turbulence may depart from this simplified description [2,65] for different reasons: 3D effects, a larger complexity involving multi-field dynamics with different invariants, the possibility to inject energy at different scales.

The fluctuation wavenumber spectrum $S(k_\perp)$, measured mainly by scattering diagnostic for their high k resolution, is observed to fall off monotonically above its maximum [43], following a power law $S(k) \propto k^{-a}$. The power exponent is $a \sim 3.5 \pm 0.5$ for most experiments [46,45,47]. This is close to the exponent expected in the direct cascade range. Indeed the quantity measured is the tri-dimensional wavenumber spectrum, i.e. for $\vec{k}$ fixed in modulus and direction; it is related to the omni-directional k-spectrum $E(k) \equiv \int_{|\vec{k}_\perp|=k} S(\vec{k}_\perp)\,\mathrm{d}\vec{k}_\perp = kS(|\vec{k}_\perp| = k)$. Assuming isotropy in the perpendicular plane, a 3D spectrum with a scaling exponent of -4 yields $E(k)$ with a spectral index of -3. This exponent is generally used for a practical transport coefficient estimate from the fluctuation level. For comparison, in 3D fluid turbulence, light scattering has also permitted to measure the k-spectrum [66] indicating a very good agreement between the measured spectral index of -3.6, and that expected from the Kolmogorov law $E(k) \equiv k^{-5/3} \equiv k^2 E_{\mathrm{3D}}(\vec{k})$, yielding $E_{\mathrm{3D}}(\vec{k}) \equiv k^{-11/3}$.

3.3. Transition in the k-spectrum at high k

Higher k domain $k\rho_i \gg 1$ has raised new interest recently because of its possible implication in the electron thermal transport. Several theoretical and numerical studies have recently shown that ETG modes have a typical scale length larger than the electron Larmor radius due to the formation of long scale structures in the radial direction [67,68], and thus could account for a significant part of electron transport [69]. Fluctuations at high k linked with ETG modes could explain why the ion thermal transport can be reduced down to neoclassical values in high confinement regimes associated with an Internal Transport Barrier, while the electron transport channel remains at a high level. Experiments with dominant electron heating have exhibited a critical electron temperature threshold which also pointed toward the potential role of ETG modes [4,5]. These regimes deserve attention since the alpha particles will heat mainly electrons in burning plasmas. Experimental observations in the high k range are still sparse because of the very low level of fluctuations in this range requiring sensitive techniques to be developed [40,71,73].

The high k range ($k\rho_i > 1$) has been investigated on the Tore Supra tokamak with a CO_2 laser scattering experiment [39] which modular configuration permits access to high $k_\perp$ values, up to $26\ \mathrm{cm}^{-1}$. Observations have been made

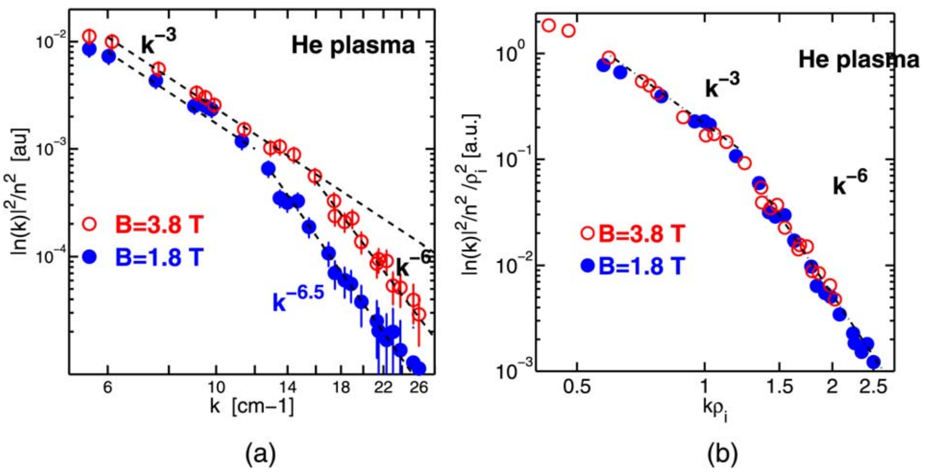

Fig. 4. (a) k-spectrum of the density fluctuations $|n(\vec{k})|^2$ (normalised to the squared density) as a function of k (logarithmic scales), for Tore Supra Ohmic discharges in He are compared with $B = 3.8$ T (open circles) and $B = 1.8$ T (closed circles). The power laws are obtained by fitting the data on either side of the transition (dashed lines), and prolonged on the whole k range. (b) $|n(\vec{k})|^2$ (normalised to the squared density) divided by (ρ_i^2) as a function of $k\rho_i$ for the same series [40].

in ohmic and L-mode discharges where the gyroradius was changed (by around 30%, $B = 1.8$, and 3.8 T). The wavenumber spectrum $S(k) \equiv |n(\vec{k})|^2$ (normalised to the squared density) is shown on Fig. 4(a) for He series. Fig. 4(b) presents the same data, divided by (ρ_i^2), as a function of $k\rho_i$, to test the gyro-Bohm prediction. The good overlapping of the two cases (low and high ρ_i) shows that the gyro-Bohm dependence of the turbulence scale holds throughout the k range [40].

The second observation is that the wavenumber departs substantially from the usual power law, showing a transition around $k_c = 15\ \text{cm}^{-1}$ [74]. The lower k part of the spectrum is similar to former results on Tore Supra [45,47] and other observations (Section 3.2), with a spectral index of -3.5 ± 0.5. Above the transition, the power spectrum falls off much faster, typically with a power law, $S(k) \sim k^{-6.\pm.5}$. This transition and the spectral index are not those characteristic of the 2D turbulence. This can be the sign of dissipation. Finite Larmor radius effects also yield a transition around $k\rho_i \sim 1$ [76,2], however different spectral shape are expected by these theories. Moreover, the experimental spectral indexes depend on plasma conditions. This is not consistent with the fundamental assumption yielding these spectral power laws: the existence of an inertial range, where no energy is injected nor dissipated, and the energy transfer rate between scales does not depend on k nor on the system characteristics. However, the observation of a transition between two different ranges with different spectral exponents indicates that a characteristic length must be taken into account, breaking in this range the assumption of self-similarity. Another way to represent the k-spectrum clearly exhibits this characteristic length: an exponential law of the form $e^{-\alpha k\rho_i}$, with $\alpha = 4$ is observed to better fit the data, on the whole k range [40]. The exponential shape could be the signature of a more continuous length effect, for example due to other damping processes.

In these experiments, there is no signature of specific modes at high k associated with ETG modes, which should be detected by an increase of the fluctuation amplitude in the range of unstable modes wavenumbers. However, small k fluctuations are detected in even higher k range [70,75]. Preliminary measurements show an increase of the turbulence level in this range when electron cyclotron heating is applied. However, the level of fluctuations remains small, and makes it difficult to account for anomalous electron transport [72]. These observations should be confirmed by experiments performed in optimised conditions having a high predicted level of ETG turbulence.

3.4. Correlation time scaling with the transit time L/c_s

The fluctuation correlation time is related to the lifetime of the turbulent structure. Linked to the eddy turn-over time, it should be of the order of the typical transit time $\tau_T \equiv L/c_s$. The inverse width of the fluctuation temporal spectrum is usually observed as being of the order of a few μs, and scales like a diamagnetic time [6]. Correlation times, in ρ_i scan experiments [37,40], are shown to be independent of ρ_i. Together with the scaling of turbulence scale length with ρ_i, it supports the picture of turbulence characteristics leading to a gyro-Bohm scaling of confinement.

4. Conclusions

Scaling of density fluctuations characteristics observed in tokamak plasmas, especially during ρ_i scan experiments, are consistent with a nearly gyro-Bohm-like confinement scaling: the typical scale length of turbulence scales with the ion Larmor radius, the typical time scales with a/c_s; the turbulence level also scales with ρ_i, according to the mixing length rule. These observations are favorable and corroborate the predictions from simulations. Experimental scaling studies of turbulence are developing now on several tokamaks to re-examine or extend these studies to the other dimensionless parameters ν^* and β. Indeed, recent results show, for example, a weak β dependence [77], which is also favorable for the next step machine, and suggests an electrostatic nature of the turbulence.

Fluctuations at high k show a departure from classical k-spectrum power law, with a typical spectral index larger than usual observations and predictions, which is still unresolved. The resulting very low level of fluctuations in this range does not indicate a strong effect of ETG modes. However, further investigation of high k turbulence and especially its link with electron transport is required and in preparation on several tokamaks.

Fluctuation measurement develops towards correlated multi-field measurements, especially through the measurement of the turbulent velocity; together with density and temperature fluctuation measurements, it could provide decisive information from the direct evaluation of turbulent transport in the plasma core. It should also permit the investigation of stabilisation/regulation mechanisms by correlating the fluctuation level, the eddy size, the phase between the fluctuating parameters and the confinement.

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