INVESTIGATION OF THE DENSITY TURBULENCE IN OHMIC ASDEX PLASMAS.

G. Dodel and E. Holzhauer, Institut für Plasmaforschung, Universität Stuttgart, FRG.

L. Giannone, H. Niedermeyer and ASDEX-Team, MPI für Plasmaphysik, EURATOM Association, Garching, FRG.

A 119 μm homodyne laser scattering experiment is used on ASDEX to investigate wavenumber and frequency spectra of the density fluctuations occurring in the different operational conditions of the machine. Details of the scattering system are described in [1]. It allows shot-to-shot spatial scans in three horizontal and two vertical channels which traverse the plasma at distances of 0, 10.5, 25, 30 and 39.5 cm from the plasma centre (minor plasma radius = 40 cm). The wavenumber range accessible is $2.5\ cm^{-1} < k_\perp < 25\ cm^{-1}$ and can be scanned within one shot. For $k_\perp < 10\ cm^{-1}$, where the dominant part of the fluctuation spectrum is found, the measurements are chord-averaged.

The changes of the density turbulence caused by additional heating are of primary interest with regard to a possible correlation to anomalous transport. Therefore, in the current experiment particular emphasis is placed on these investigations. On the other hand it is the ohmic phase which constitutes the least complicated physical situation in a tokamak and is therefore best suited to reveal the basic physical nature of the density turbulence. In the following we present a summary of our findings in the ohmic phase and make an attempt to compare these findings with what would be expected from the simplest model of density-gradient-driven driftwave turbulence saturated at the mixing-length level.

1. Density scaling of the density turbulence.

The rms value of the frequency integrated scattered power scales linearly with the mean electron density, as illustrated in Fig. 1 for a density ramp with two plateaus. This was established for $\bar{n}_e < 5\times10^{13} cm^{-3}$ in the important $k_\perp$ range and in different spatial chords. Since the shape of the density profiles (and hence the gradient length L_n) during density ramping remained fairly similar, our result suggests that $\tilde{n}_e/n_e$ is constant. This scaling is consistent with a fluctuation level determined by the mixing length criterion $\tilde{n}_e/n_e \propto (k_\perp L_n)^{-1}$. The linear dependence of the fluctuation level on line density was observed both in the SOC (standard ohmic confinement) and IOC (improved ohmic confinement) regimes. Note that the homodyne system presently used does not allow to determine the propagation direction of the fluctuations. This leaves open the possibility of the existence of the η_i-mode travelling in the ion diamagnetic drift direction.

2. Isotope scaling of the density turbulence.

The maximum of the frequency integrated $k_\perp$ spectrum shifts towards lower $k_\perp$ and its value increases when the gas filling is changed from pure hydrogen to an approximately 1:1 mixture of hydrogen and deuterium at constant electron density (Fig. 2). Both the shift of the maximum and the increase of the fluctuation level are consistent with $k_\perp^{max} \cdot \rho_s$ = const. and $\tilde{n}_e/n_e \propto (k_\perp^{max} \cdot L_n)^{-1}$ as suggested by driftwave turbulence theory. The quantity ρ_s constitutes a characteristic length scale and is given by $\rho_s = (k_B T_e/m_i)^{1/2}/\omega_{ci}$, where $\omega_{ci} = ZeB/m_i$ (m_i - ion mass; Ze - ion charge). Note that the global confinement time increases with atomic mass in ASDEX [2]. Hence the increase of the fluctuation level is in contrast to what would be expected if the confinement were determined predominantly by the density fluctuation level.

3. Scaling of the density turbulence with toroidal magnetic field.

In a series of discharges in deuterium the toroidal magnetic field was varied from 1.9 T to 2.8 T while keeping the line electron density and the safety factor constant ($q(a)=3$). The shape of the density and temperature profiles remained practically unchanged. The electron temperature on the axis increased from $T_e(0)$ = 1.1 keV at B_T = 1.9 T to $T_e(0)$ = 1.7 keV at B_T = 2.8 T. The frequency integrated $k_\perp$ spectra are shown in Fig. 3. The clear decrease of the fluctuation level with increasing field is consistent with the mixing length model. No definite statement can be made about a possible ρ_s scaling of the $k_\perp$ spectra expected from the relation $k_\perp{}^{max} \propto \rho_s{}^{-1}$, since no maximum is observed in deuterium at these temperatures even at the highest achievable toroidal field.

4. Scaling of the density turbulence with electron temperature.

In "cold" hydrogen discharges a maximum of the frequency integrated $k_\perp$ spectra is observed as can be seen in Fig. 4 for $T_e(0)$ = 650 eV. The maximum shifts towards lower wavenumbers with increasing electron temperature. This is consistent with the T_e dependence of the ρ_s-scaling. A value $k_\perp^{max} \cdot \rho_s \approx 0.3$ is inferred from the "cold" shot under the assumption that the main contribution of the scattered radiation originates from the gradient region.

5. Frequency spectra.

In the central chord which sees primarily poloidally propagating fluctuations a maximum of the scattered power is observed around ~ 100 kHz in the dominant $k_\perp$ range. This is on the order of the diamagnetic drift frequency evaluated in the gradient region of the discharge. In the outer vertical chord which sees predominantly radially propagating fluctuations the frequency spectra are significantly narrower [1].

In a preliminary heterodyne experiment a frequency shift of 45 kHz for the local oscillator was achieved with a rotating diffraction grating. This was sufficient to observe both the positive and negative frequency components of the narrow spectrum in the outer vertical channel close to the separatrix. The spectra were found to be symmetric. Similar results have been reported for the radial components of the fluctuations close to the limiter in TEXT [3].

A clear correlation was observed between the Mirnow coil signals at frequencies of a few kHz. This indicates a principal complication for the interpretation of frequency and wavenumber spectra, because it becomes difficult to distinguish between microturbulence and macroscopic MHD phenomena.

Conclusions

The aim of the investigation in the ohmic phase was the determination of the effect of a systematic variation in plasma parameters on the density turbulence, with the view to identifying the nature of the fluctuations. The interpretation of the results is complicated by the fact that one-parameter-scans are inherently impossible. Nevertheless, there is strong evidence for a drift wave origin of the fluctuations observed under ohmic conditions.

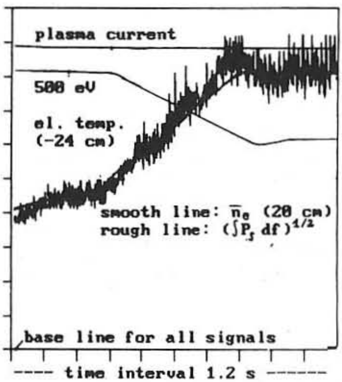


Fig.1: Density scaling of the rms scattering signal $(P_s)^{1/2}$ illustrated in a shot with a density ramp and two plateaus ($k_\perp = 3\ cm^{-1}$, $r = 0$ cm).

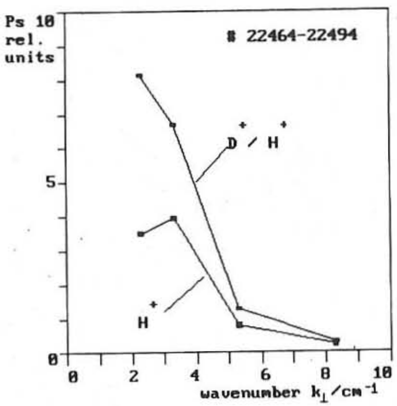
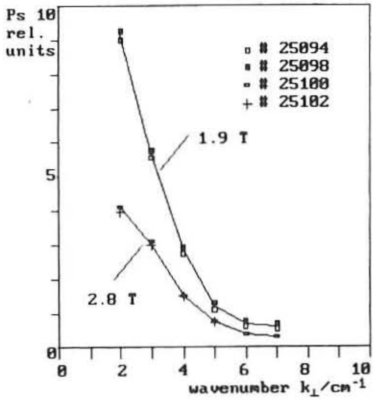


Fig.2: Change of the wavenumber spectra with gas filling. Note: Same vertical scale for both curves.



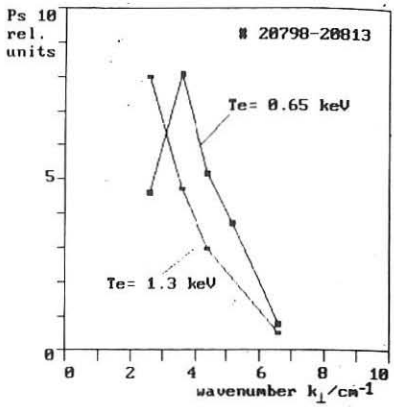


Fig.3: Wavenumber spectra in ohmic discharges with low and high toroidal magnetic field ($n_e(0)$ = $4x10^{13} cm^{-3}$, D^+). Note: Same vertical scale for both curves.

Fig.4: Wavenumber spectra in "hot" and "cold" ohmic hydrogen plasmas. The densities in the center are $1.75x10^{13}$ cm^{-3} and $4.8x10^{13}$, respectively. Signals are normalized to maximum value.

References

[1] G. Dodel, E. Holzhauer, H. Niedermeyer, K. McCormick, ASDEX-, ICRH-, NI-, and Pellet-Teams, Proc. 15th European Conf. on Controlled Fusion and Plasma Heating, Dubrovnik, 1988, Part I. p. 43.

[2] F. Wagner, M. Bessenrodt-Weberpals, G. Dodel, O. Gehre, L. Giannone, O. Gruber, E. Holzhauer, V. Mertens, H.D. Murmann, H. Niedermeyer (this conference).

[3] C.P. Ritz, D.L. Brower, T.L. Rhodes, R.D. Bengtson, S.J. Levinson, N.C. Luhmann, Jr., W.A. Peebles, E.J. Powers, Nuclear Fusion, vol. 27, p. 1125 (1987).