Dynamics of blobs: Statistical analysis based on the international edge turbulence data base

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Introduction: One of the main challenges of fusion research is a better understanding of energy and particle transport. The dominant transport losses are due to turbulence caused by micro instabilities. Plasma edge turbulence has been investigated for over 30 years in various devices and many similarities have been found in the turbulent behavior of tokamaks and stellarators with high- and low-temperature plasmas. Progress has been achieved by combination of experimental results and comparison with simulations. The *international edge turbulence data base* within the International Stellarator/Heliotron Profile Database (ISHPDB, http://www.ipp.mpg.de/ISS and http://ishpdb.nifs.ac.jp) was initiated to concentrate these efforts. It provides a platform to access and analyze data from various experiments under the aspect of inter-machine comparison and code validation.

Turbulence takes place on a broad range of different scales, differs locally from the plasma core to the scrape off layer (SOL) and can be investigated with a vast number of diagnostics. In a first step, the data base is limited to fluctuation data from Langmuir probes in the edge and SOL region. Probes are available on almost all plasma devices and provide local density, potential and temperature measurements, which are considered to be the key players in edge turbulence. It is possible to measure with Langmuir probes in the SOL and across the separatrix even in high-temperature plasmas. Furthermore, Langmuir probes enable the investigation of small-scale turbulence because of their high spatial and temporal resolution. In this paper, the data base is introduced and its content is described. Main objectives are defined. The current

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device	AUG	U-3M	HSX	WEGA a)	MAST	WEGA b)	TJ-K
R (m)	1.65	1.0	1.2	0.72	0.85	0.72	0.6
a (m)	0.50	0.12	0.12	0.19	0.65	0.19	0.10
M_i (m_p)	2	1	1	4	2	4	4
B (mT)	1540	640	880	390	350	45	44
T_e (eV)	40	40	60	10	20	10	8
n_e ($10^{18}\,m^{-3}$)	13.	0.35	1.0	2.0	4.0	0.2	0.2
ρ_s (mm)	0.6	1.0	0.9	1.7	1.8	14.	13.
$L_\perp$ (mm)	9	5	12	14	18	26	80
references	[1]	[2]		[3]		[3]	

Table 1: Plasma and device parameters corresponding to the signals available in the edge turublence data base: major R and minor radii a, ion mass M_i, local magnetic field B, electron temperature T_e, density n_e, drift scale ρ_s and ion-saturation current decay length $L_\perp$ at the separatrix.

status and first results are presented.

Edge turbulence data base: One goal is to identify universal features and specific differences of plasma turbulence under various confinement concepts and plasma conditions. The scaling of characteristic features with plasma parameters can be accessed over a large range and used for comparison with simulation results. Issues to be addressed with the data base are the experimental conditions and mechanisms for blob and hole generation. Different regimes are examined for blob propagation and transport to the wall.

The data base contains Langmuir probe measurements in the SOL and across the separatrix of magnetically confined plasmas in different configurations. The probes are radially movable to capture profiles of the background plasma and the electrostatic fluctuations. Ideally, a few probes are aligned poloidally on a flux surface and measure alternating floating potential and ion-saturation current. This enables investigations of poloidal propagation, cross-phases and radial transport. Long time traces at all positions are preferred for good statistics. The measurement time, however, is often limited by short-pulse operation or the speed of reciprocating probes. The probe data is stored in ASCII files together with some meta information (device, configuration, probe setup and plasma parameters). For each signal there is one separate file per probe and position. The continuous data from reciprocating probes is cut into appropriate sub windows. Such windows are choosen as long as possible (for statistical analysis) and as short as necessary to reduce the radial uncertainty. Meta information and probe data are stored on a web server together with routines to save and access data from 'IDL' and 'MatLab' environments. The edge turbulence data base contains at present data from two tokamaks (ASDEX Upgrade and MAST) and four stellarators (Uragan-3M, HSX, WEGA, TJ-K). The main machine and local plasma parameters are shown in Tab. 1. Technically, the data base has proven to be operable. First results are presented in the next paragraph, showing similarities of turbulence characteristics over the present range of devices.

First results: The Langmuir probe data of all devices have been analyzed with respect to the statistical properties and frequency power spectra. For inter-machine comparison, length scales are normalized by the perpendicular gradient scale length $L_\perp$ and time scales by $L_\perp/c_s$, where c_s is the speed of sound. The fluctuation levels σ (rms of $\tilde{I}/\bar{I}$) of the ion-saturation currents were found to increase substantially across the separatrix, which indicates the increasing importance of turbulent fluctuations in the edge. In almost all machines, this feature goes along with a transition from negatively to positively skewed probability density functions within one decay length of the ion-saturation current around the separatrix (Fig. 1). This indicates, that blobs and holes appear close to the separatrix under various confinement and plasma conditions, as it has first been reported from DIII-D [4] and recently confirmed in ASDEX Upgrade [1]. While blobs are observed to be a universal feature, further studies should include conditions where holes are absent as in the case of HSX (Fig. 1, bottom).

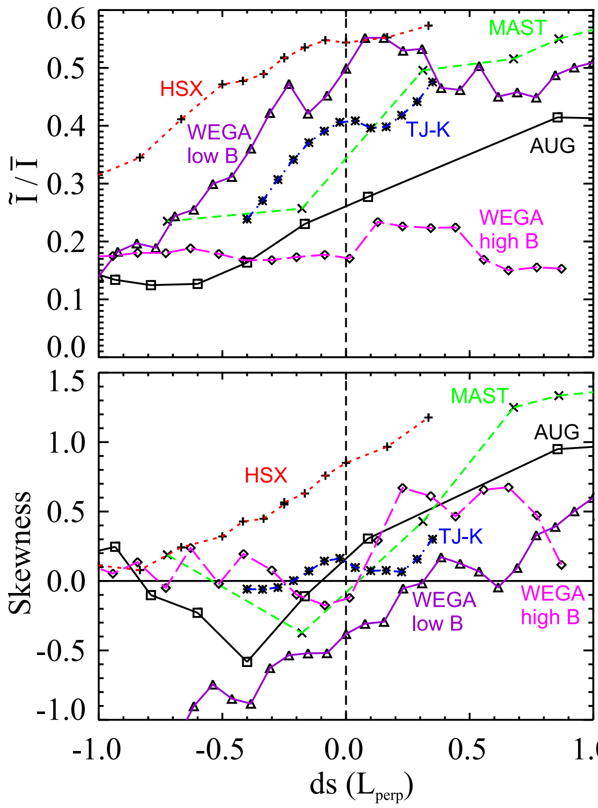

Figure 1: Fluctuation level and skewness profiles of the ion-saturation current data available in the edge turbulence data base. The radial distances to the separatrix d_s are normalized to the corresponding decay lengths.

The universal character of the parabolic relation between kurtosis K and skewness S of ion-saturation current fluctuations in magnetically confined plasmas was confirmed for the data of all machines with the following fit parameters: $K = 1.54S^2 + 2.68$.

Power spectra of ion-saturation current fluctuations in magnetized plasmas have been observed to decay exponentially in the low frequency range. This can be an indication for the presence of Lorenzian pulses with a narrow time-width distribution [5]. Figure 2 shows the lin-log plot of power spectra measured close to the separatrix of six devices with toroidal plasma confinement. A linear trend shows up in the low frequency part of most signals. This indicates an exponential decay, but normalization of the frequency to $L_\perp/c_s$ did not lead to an overlap of the different spectra. The significant deviation of the HSX data is attributed to the non-negligible influence of $E\times B$ flows. Additional information about radial electric fields needs to be included in the data base for direct comparison of frequency spectra.

Conclusions: The international edge turbulence data base currently combines Langmuir probe data from two tokamaks and four stellarators. Statistical analysis revealed similarities of the statistical properties on scales of the decay length in all devices.

The parabolic relation between kurtosis and skewness of ion-saturation fluctuations was confirmed and a close to exponential decay was found in the low frequency range of most devices in the SOL. Future investigations aim at the scaling properties of turbulent features and a comparison with results from turbulence simulations. Having overcome the very initial phase, the assessment of universal features in edge transport is now open to the magnetic confinement community.

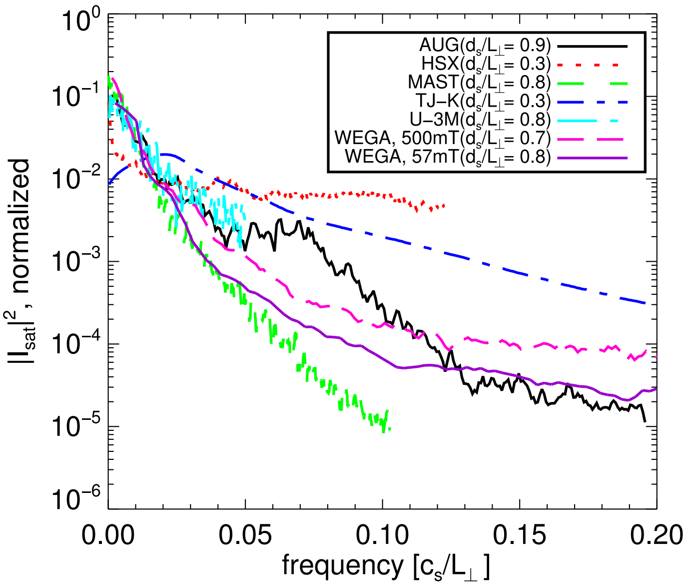

Figure 2: Power spectra of $I_{i,sat}$ fluctuations in the SOL of different devices. The frequencies are normalized to the corresponding sound speed devided by the decay lengths.

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