DIMENSIONALITY OF FLUCTUATIONS IN ASDEX

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INTRODUCTION

Dimensionality analysis of experimental series of data has revealed a new powerfull tool for a deeper understanding of turbulent physical systems. The analysis of the so-called strange attractors provides a tool to identify the fractal dimension ν of a time series. This fractal dimension is associated with the number of indipendent processes which characterize the system, and if it exists, it provides a distinction between deterministic chaos and noise /1/. Here it is used the well known definition of ν as the lim $R \to 0$ of the ratio (d log C(R))/(d log R); $C(R) = 2/((N-1)N) \cdot \sum_{ij}^{N} H(R - |\overline{x}_i - \overline{x}_j|)$ where H is the heaviside function and $R_{ij} = |\overline{x}_i - \overline{x}_j|$ is the Euclidean norm between all pairs of $\overline{x}_i$ whose components are the values of the single time series signal at D different delayed times: $\overline{x}_i = \{x_i, x_{i+M}, x_{i+2M}, \cdot\cdot x_{i+(D-1)M}\}$ D is the so-called embedding dimension and M is the delay time factor. In the context of fusion research this method has been applied previously to the study of fluctuations on DITE, RFP, TOSCA and JET /2/, /3/, /4/. The present analysis exploits the poloidal divertor configurations of ASDEX and its strong additional heating power which give it access to the new favourable H-confinement regime and allow it to approach MHD Beta limits /5/. As a consequence a wider variety of fluctuation phenomena are observed by Mirnov coils and soft X-Rays diagnostics /6/.

CHOICE OF DIAGNOSTICS AND DISCHARGE PHASES

Different phases of a typical high power NI-heated discharge are analyzed. The important time traces of this discharge are shown in fig. 1. (Actually four shots are used of the same series because of the high time-resolution diagnostics (250 kHz) recovered over different shots, #18041, #18040, #18026, #18039.) The analysis is concentrated on the characteristic phases indicated in the same fig. 1. For comparison also an L-discharge is analyzed (#18024). Diagnostics used for characterization of the MHD fluctuations were soft X-Rays and Mirnov coils. For present analysis 5 signals are considered: SXF and SXJ which are central X-Rays signal ($q < 1$); SXL and SXA which are peripheral X-Rays signals ($q > 1$) and A8SSW which is a Mirnov signal from a coil located externally in the equatorial plane of the ASDEX torus.

In general 10 windows of 8 ms each corresponding to 2000 data are taken and analyzed for each shot in order to give account of different physical phases and to have enough data (at least if the dimensionality is low). For some specific situations, the windows could be taken different, for a better definition or much longer in order to have a better establishment of dimensionality or to distinguish between noise and chaos.

If the dimensionality is low it is found indipendent of the number of data from 1000 to 10000. Also for the delay time it is found a range of independence of results with $5 \leq M \lesssim 10$, for $N = 2000$ (e.g.), but in general $M = 5$ is taken.

ASDEX RESULTS

According to the preceding definitions results are presented phase by phase. During an H-shot one can distinguish approximately four phases: They are shown in fig. 1 on the bottom border.

Phase 1: Deep L-phase, after additional NI heating and before $L \rightarrow H$ transition. Combined results from #18041 and #18040.

SXF: $\nu \sim 1$ at the beginning and then increases to $\nu \sim 2$ through splitting of dimensionality: $\nu \sim \left\{ \begin{matrix} 1.22 \\ 0.8 \end{matrix} \right\}$

SXJ: $\nu \sim 1$ at the beginning and then increases to $\nu \sim 2.25$ through splitting of dimensionality: $\nu \sim \left\{ \begin{matrix} 2.25 \\ 0.75 \end{matrix} \right\}$

SXL and SXA: $\nu \sim 1$

A8SSW: value of dimensionality $2.25 < \nu < 3.5$

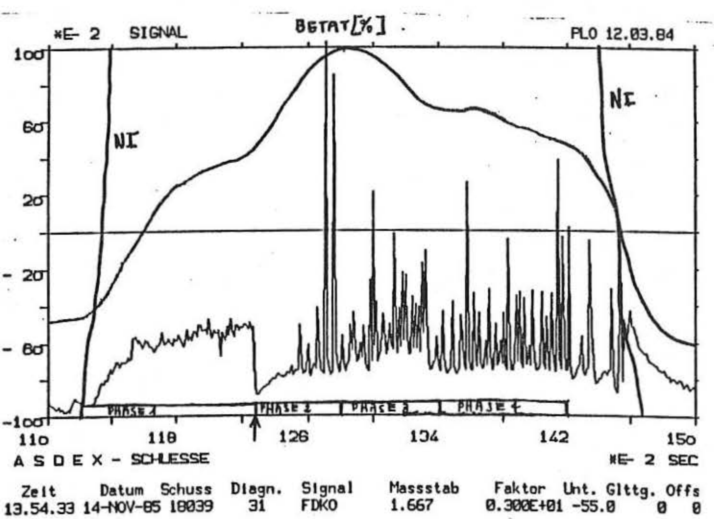

Fig. 1 shows some important parameters during a typical H-shot: NI is the neutral injection interval, FDKO is the signal connected with H_α activity which points the $L \rightarrow H$ transition (indicated with an arrow) and BETAT behaviour. In the bottom side the four phases of the analysis are reported.

<u>Phase 2:</u> After L → H transition, toward maximum BETAT. #18040. H-phase begins with sawtooth in edge region and fishbone like signal in central region.

SXF: $\gamma \sim 3.3$

SXJ: $\gamma \sim 0.75$

SXL and SXA: $\gamma \sim 1$

A8SSW: $\gamma \sim 3.5$

<u>Phase 3:</u> From BETAT maximum toward stationary phase with constant BETAT. #18026.

SXF: γ begins with value ~ 1 and then increases up to $\gamma \sim 3.6$

SXJ: $\gamma \sim 3$

SXL, SXA: $\gamma \sim 1$ in presence of well pronounced sawteeth

A8WNW: $2.6 < \gamma < 3.5$

<u>Phase 4:</u> Stationary H-phase at reduced but constant BETAT.#18039.

SXF: $\gamma \sim 1$ and after $2.5 < \gamma < 3.5$. Presence of a splitting of dimensionality at the beginning $\gamma \sim \begin{Bmatrix} 2.5 \\ 0.75 \end{Bmatrix}$

SXJ: noise

SXL: $\gamma \sim 0.85$, SXA: $\gamma \sim 1.2$ with well pronounced sawteeth (fig. 2 and 3)

A8SSW: $\gamma \sim 3.75$

In comparison an L-shot was considered (BETAT max ~ const.) #18024. In general the signals are very noisy and no definite values of dimensionality can be given.

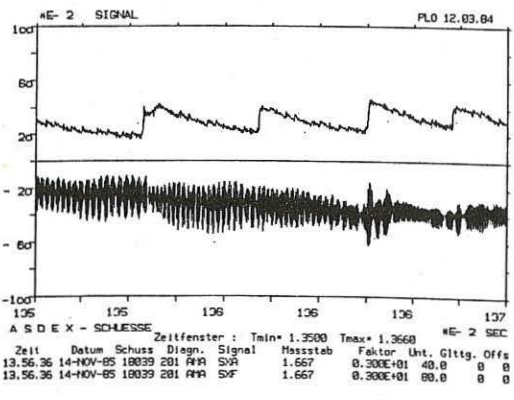

Fig. 2: Signals traces of two X-Rays chords during a time-window of 16 ms. SXA, the edge chord, shows definite sawteeth, while SXF, the core chord, exibits a fishbone-like structure. There seem to be no correlation between the two signals. #18039

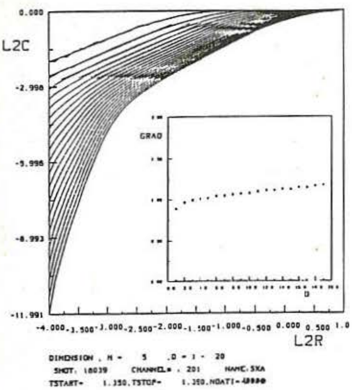

Fig. 3:
Dimensionality analysis for chord SXA signal. Same shot as in fig. 2 but for a longer period of 40 ms corresponding to 10000 data points. The result is identical for 1000 data point due to the very low dimensionality. M=5 is the delay time factor chosen. The embedding curves are simply connecting 50 calculated points (10 per decade). Logarithms in base 2 are used. The straight lines which show the D-depending slope are constructed with the least mean square method, starting from the same calculated points. In the square window the slopes, that is the gradients of the embedding curves as functions of embedding dimensions D are reported. The asymptotic saturation value of the slope is the dimension. $\nu \sim 1.2$ in this case.

CONCLUSIONS

The MHD activity present in ASDEX NI heated divertor plasma configurations, has in general a low dimensionality: $\nu < 3.75$. Signals with a non-strictly convergent saturation slope are ascribed to noise.
The edge soft X-Rays signals show a very low dimensionality: $\nu \sim 1$ during all phases.
The central soft X-Rays signals, in general, develope a higher dimensionality passing from L to H-phase and $1 < \nu < 3.5$.
The Mirnov coil signal seems to have an higher dimensionality in respect to other signals during all phases with $3 < \nu < 3.75$.
In comparison the L-shot shows no information from edge signals and central signals because of their noisy-like structure.
Thus in general the MHD activity is characterized by fractal dimensionality associated with strange attractors.
The system seems to be characterized by two subsystems: a core region where at the end of the evolution a minimum of four indipendent processes is necessary, and an edge region where for the most of time a unique variable could be enough to characterize the system evolution reminding the theoretical example of the non-linear logistic map.
In some cases the central soft X-Rays signal splits into two different value of ν. An X-Ray signal is an integrated information that is it takes into account both central and edge X-Ray emission. Two different values of dimensionality should indicate that the two subsystems are physically indipendent /7/.
It is to be noted that a $\nu = 1$ dimensionality value is obtained also in JET /3/, when soft X-Rays diagnostics exibits sawtooth activity.

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