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Effects of Stochastic Noises on Limit-Cycle Oscillations and Power Losses in Magnetically confined Plasmas and information theory

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Magnetically confined plasmas are far from equilibrium and turbulent and pose considerable challenges for confinement and ultimately for accessing/maintaining an optimal sustainable confinement state. For example, edge localised modes (ELMs) are sudden, quasi-periodic oscillations/bursts caused by instabilities of pressure and/or current gradient in the transport barrier for a sufficiently high input power in the H-mode; rare, bursty, large-amplitude (Type I) ELMs impose a large heat load, or even damage to the fusion container walls, and should be mitigated/suppressed for sustainable fusion operation.

In this talk, I report the effects of different stochastic noises on the dynamics of ELMs by using a time-dependent PDF method, path-dependent information geometry (information rate, information length), and entropy-related measures (entropy production, mutual information). A key effect of stochastic noise is a phase mixing which can mix different phases of quasi-periodic (explosive) oscillations, altering the amplitude and frequency of those oscillations.

Specifically, the oscillation quenching occurs due to either stochastic particle or magnetic perturbations, although particle perturbation is more effective in this amplitude diminishment compared with magnetic perturbations. On the other hand, magnetic perturbations are more effective at altering the oscillation period; the stochastic noise acts to increase the frequency of explosive oscillations (large ELMs) while decreasing the frequency of more regular oscillations (small ELMs) [1-2].

These stochastic noises are also shown to significantly reduce power and energy losses caused by ELMs and play a key role in reproducing the observed experimental scaling relation of the ELM power loss with the input power. Furthermore, the maximum power loss is closely linked to the maximum entropy production rate, involving irreversible energy dissipation in non-equilibrium. Notably, over one ELM cycle, the information rate appears to keep almost a constant value, indicative of a geodesic. The information rate is also shown to be useful for characterizing the statistical properties of ELMs, such as distinguishing between explosive and regular oscillations and the regulation between the pressure gradient and magnetic fluctuations [3].

Overall, our results highlight the limited utility of mean value and variance while indicating the possibility that stochastic noise may be an important factor that should be considered in understanding experimental data.

References

[1] E. Kim and R. Hollerbach, Philosophical Transactions of Royal Society A: Mathematical, Physical and Engineering Sciences, vol. 381, 20210226:1-16

[2] E. Kim and R. Hollerbach, Phys. Plasmas 29, 112302:1-24 (2021).

[3] E. Kim, Entropy 23, 1393 (2021)