ABSTRACT

- We introduce a theoretical framework to describe transport in the phase space based on the theory of Phase Space Zonal Structures (PSZS) [1-5].
- We extend the usual definition of plasma equilibrium in the presence of a residual level of electromagnetic fluctuations, i.e., the Zonal State (ZS).
- Governing equations are derived by means of gyrokinetic transport theory as a simple application, we describe ZS evolution in the absence of symmetry breaking fluctuations.
- We show the evolution of PSZS during an EPM simulation by means of HMGC [6].

BACKGROUND

- Predicting the dynamics of a burning plasma over long timescales, i.e., comparable with the energy confinement time or even longer, is essential to understand next generation fusion experiments.
- Most of the works for the study of core plasma transport are based on a systematic separation of scales between the reference equilibrium and fluctuations.
- Energetic particle (EP) transport in fusion devices is a spatiotemporal multi-scale process.
- Spatio-temporal mesoscales can be observed even in drift wave plasma turbulence simulations.
- In a recent work [2] we have emphasized the fundamental importance of the self-consistency of the adopted description, including the determination of the characteristic spatiotemporal scales of the reference state.

PHASE SPACES ZONAL STRUCTURES (PSZS)

- PSZS equation is connected with the macro-meso-scopic component unperturbed orbit-averaged distribution function:

\[ \frac{d}{dt} F_{ZS} + \frac{1}{\tau_b} \left( \frac{\partial}{\partial \phi} \left( r_b \delta \phi F_{ZS} \right) \right) + \frac{\partial}{\partial \phi} \left( r_b \delta \phi F_{ZS} \right) = \left( \sum_b G_b \left[ F_b + \delta F_b \right] \right) s_{ZS} \]

- We can decompose the toroidally symmetric distribution function:

\[ F_{ZS} = F_{ZS} - \delta F_{ZS} + \delta F_{ZS} \]

- Micro-scales are accounted by \( \delta F_{ZS} \) while macro- and meso-scales are described by PSZS.

CONCLUSION

- We have introduced the concept of zonal state to describe the evolution of the plasma between neighboring nonlinear equilibria;
- Governing equations for all the components of the ZS have been derived;
- The system is closed by the governing equations for em potentials.

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