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Nonlinear equilibria and phase space transport in burning plasmas

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In this contribution, we introduce the formulation of a self-consistent transport theory, based on the evolution of the renormalized plasma equilibrium in the presence of a finite level of electromagnetic fluctuations, which we call the zonal state (ZS). This formulation involves the derivation of the nonlinear equations for 1) the PSZS that are phase space structures undamped by collisionless processes and provides a proper definition of nonlinear equilibrium distribution function; 2) its counterpart, zonal fields (ZFs) that corresponds to the long-lived components of electromagnetic fields, and 3) toroidal symmetry breaking perturbations. The study employs a comprehensive gyrokinetic transport theory formulation to derive governing equations for the ZS. By employing the Chew Goldberger Low (CGL) description, the study effectively separates microscale structures from macro-/meso-scale components of the equilibrium. This research builds upon the Phase Space Zonal Structure (PSZS) concept [1-6] and provides a general gyrokinetic phase space transport theory that characterizes nonlinear dynamics of weakly collisional plasmas. The study addresses the limitations of current numerical frameworks used for simulations of EP-driven instabilities and transport in fusion devices. We note that the PSZS transport theory employed here offers a phase space perspective, which further extends the understanding of plasma transport processes. In this talk, we will focus on the derivation of the governing equation for the ZS, which encompasses the evolving renormalized nonlinear equilibrium evolving in transport time scale in as well as toroidal symmetry-breaking fluctuation spectrum and transport time scale ordering. As an illustrative example, we explore the physics of Geodesic Acoustic Modes (GAMs) and Energetic particle driven Geodesic Acoustic Modes (EGAMs), including the linear dielectric response, generation of zero frequency zonal fields, and the modulation of GAMs by zonal fields themselves. The nonlinear dynamics of EGAMs are also investigated, considering the action of sources, collisions, and the emission and re-absorption of GAM/EGAM fluctuations. We finally summarize the findings and discuss future directions for research.

References:

[1] M.V. Falessi, L. Chen, Z. Qiu, and F. Zonca, "Nonlinear equilibria and transport processes in burning plasmas," New J.Phys. (submitted)

[2] M.V. Falessi, F. Zonca, "Transport theory of phase space zonal structures," Phys.Plasmas 26, 022305 (2019).

[3] L. Chen and F. Zonca, "Physics of Alfvén waves and energetic particles in burning plasmas," Rev.Mod.Phys. 88, 015008 (2016).

[4] F. Zonca et al., "Energetic particles and multi-scale dynamics in fusion plasmas," Plasma Phys.Control.Fusion 57, 014024 (2015).

[5] F. Zonca, L. Chen, M.V. Falessi, Z. Qiu, "Nonlinear radial envelope evolution equations and energetic particle transport in tokamak plasmas," J.Phys.Conf.Ser. 1785, 012005 (2021)

[6] F. Zonca et al., "Nonlinear dynamics of phase space zonal structures and energetic particle physics in fusion plasmas," New J.Phys. 17, 013052 (2015).

Author: FALESSI, Matteo Valerio

Co-authors: Prof. CHEN, Liu (Institute for Fusion Theory and Simulation, School of Physics, Zhejiang University, Hangzhou, China); Dr ZONCA, Fulvio (ENEA); Prof. QIU, Zhiyong (Institute for Fusion Theory and Simulation, School of Physics, Zhejiang University, Hangzhou, China)

Presenter: FALESSI, Matteo Valerio

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