PURE AND APPLIED MATHEMATICS

Turbulence and magnetic instabilities in plasmas

Funded By	Dipartimento DENERG Dipartimento DISMA FONDAZIONE CRT CASSA DI RISPARMIO DI TORINO [P.iva/CF:06655250014]

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Context of the research activity	An interdisciplinary study among statistical mechanics, fluid dynamics and plasma physics is proposed concerning the future energetic scenarios related to the controlled thermonuclear fusion and the space activities, such as the space weather. In particular, the problem of the mutual interaction between fluid and magnetic instabilities in hot and rarefied plasmas, such as the solar wind and the tokamak plasmas, will be addressed.

	An interdisciplinary study among statistical mechanics, fluid dynamics and plasma physics is proposed concerning the future energetic scenarios related to the controlled thermonuclear fusion and the space activities, such as the space weather. In particular, the problem of the mutual interaction between fluid and magnetic instabilities in hot and rarefied plasmas, such as the solar wind and the tokamak plasmas, will be addressed. Understanding the transport mechanisms due to the coexistence of structures associated with magnetic instabilities and fluid turbulence is crucial for controlling the stability of the fusion plasmas [1] as well as the penetration of the solar wind into the Earth's magnetosphere, which is responsible for magnetic storms that can damage satellites and communication systems. Although the importance of this research topic is demonstrated by a large body of literature [2-4], recent observational and experimental measurements have highlighted the need for different investigation techniques. Our project will adopt a new methodological approach combining kinetic and perturbation-response theory [5] with models of fluids able to retain kinetic scales, with the purpose of identifying the specific fluid [6] and magnetic [7] instabilities involved and their nonlinear interactions [8]. Objectives: New low-collision plasma regimes including kinetic scale effects, related to the electron skin depth and the ion sound Larmor radius, will be analyzed assuming a fluid plasma modelling. In this fluid context these regimes can be described in terms of Hamiltonian systems to which the theory of response to

Objectives	perturbations can be applied. The stability of the intense current and vorticity sheets characteristic of the plasma dynamics will be investigated by mathematical and numerical tools. Advanced numerical simulations that efficiently exploit parallel computing resources will be performed. The research activity will be carried out in collaboration with the Istituto dei Sistemi Complessi -CNR and internationally recognized research and training institutions, such as Columbia University (NYC) and the Centre National de la Recherche Scientifique (CNRS, Nice), where the PhD student is expected to spend part of his time. Bibliography. 1. Choi, M. J. et al., Effects of plasma turbulence on the nonlinear evolution of magnetic island in tokamak, Nat. Commun. 12, 375 (2021). 2. Zhao, K. J. et al., Plasma flows and fluctuations with magnetic islands in the edge plasmas of J-TEXT tokamak, Nucl. Fusion 55, 073022 (2015). 3. Agullo, O., Muraglia, M., Benkadda, S., Poyé, A., Dubuit, N., Garbet, X., & Sen, A., Nonlinear dynamics of turbulence driven magnetic islands. II. Numerical simulations, Phys. Plasmas 24, 042309 (2017). 4. Biskamp, D., Schwarz, E., On 2D magnetohydrodynamic turbulence, Phys. Plasmas, 8, 3282 (2001). 5. L., Rondoni, Introduction to Nonequilibrium Statistical Physics and Its Foundations, In Xiang-Yang Liu, Singapore, Springer Nature, 1-82 (2021). 6. Loureiro, N. F., Schekochihin, A. A., Cowley, S.C., Instability of current sheets and formation of plasmoid chains, Phys. Plasmas, 14, 100703 (2007). 7. Grasso, D., Borgogno, D., Pegoraro, F., & Tassi, E., Coupling between reconnection and Kelvin-Helmholtz instabilities in collisionless, Nonlinear Process. Geophys., 16, 241 (2009). 8. Borgogno, D., Grasso, D., Achilli, B., Romé, M., Comisso, L., Coexistence of Plasmoid and Kelvin-Helmholtz Instabilities in Collisionless Plasma Turbulence, ApJ, 929, 62 (2022)

Skills and competencies for the development of the activity	Knowledge of kinetic theory and statistical mechanics, fluid mechanics, plasma physics and numerical techniques.