Non-diffusive transport in fusion plasmas: theory and applications

Raul Sanchez

Fusion Energy Division

Oak Ridge National Laboratory, Tennessee, U.S.A

Understanding the nature of radial transport in tokamak plasmas is not only rewarding to the never-ending curiosity of scientists, but also essential for the success of the fusion energy program. The traditional way to model radial transport is by means of effective transport coefficients such as diffusivities or conductivities. This approach has been extensively and successfully used in both modeling and predictive activities. However, there are quite a few experimental observations, mostly in L-mode, that suggest that this "diffusive" description may not be the most adequate in some situations. Ultimately, the appropriateness of such models relies on the existence of well-defined characteristic transport scales in both space and time. Observations like radial avalanches, super-diffusive radial propagation of pulses or long-term temporal correlations in fluctuations suggest that these characteristic scales might be absent, at least in certain regimes.

In this talk, I will discuss the physics of several possible mechanisms that could cause the onset of this type of behavior. In order to illustrate these ideas, both fluid and numerical simulations of magnetically confined turbulent plasmas will be used. The analysis of the simulations must however be done with tools that lie beyond the usual diffusive framework. In particular, one needs to embrace several mathematical frameworks borrowed from the theory of stochastic processes, such as continuous-time random walks, fractional Brownian/Levy motion and fractional transport equations. A brief overview will be given on the significance and fundamentals of these tools, together with examples of their application to the problem of elucidating the mechanisms responsible for the appearance of non-diffusive dynamics. Finally, some hints on how these frameworks can also be used to construct effective transport models in real plasma discharges will be given.