Non-local models of non-diffusive transport

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There is increasing experimental, numerical, and theoretical evidence that transport processes in fusion plasmas can, under certain circumstances, depart from the standard local, diffusive transport description. Some experimental examples include fast pulse propagation phenomena in perturbative experiments, non-diffusive scaling in L-mode plasmas, and non-Gaussian statistics of fluctuations. Non-diffusive transport has also been documented in numerical studies of turbulent transport in fluid and gyrokinetic simulations. From the theoretical perspective, non-diffusive transport descriptions naturally arise from the relaxation of the restrictive assumptions (e.g., locality, scale separation, and Gaussian/Markovian statistics) that lay at the foundation of diffusive models.

In this presentation we discuss an alternative class of models able to capture some of the experimentally and numerically observed non-diffusive transport phenomenology. The models are based on the use of a type of non-local integro-differential operators known as fractional derivatives. These operators provide a unifying framework to describe non- Fickian scale-free transport, non-Markovian (memory) effects, and non-diffusive scaling. We present a review of the theoretical foundations of this description based on generalized random walks and generalized effective turbulent transport operators. Following this, we present a non-local model for radial transport and discuss numerical results illustrating anomalous confinement time scaling, profile peaking, and fast propagation phenomena. We discuss the application of the model to perturbative experiments in JET involving fast cold pulse propagation and ICRH power modulation. Local transport models have found problematic to reconcile the fast propagation of the cold pulses with the comparatively slower propagation of the heat waves generated by power modulation. Here we show that the proposed non-local models can successfully describe both types of perturbations. To conclude, we present results on the dynamics of non-local transport in the presence of internal transport barriers.

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