Statistics of Anomalous Transport Events

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Abstract

Prediction of particle and heat transport is essential to obtaining a controlled magnetic fusion. In particular, large transport events of substantial amplitude, even if rare, can be dangerous for confinement, on account of their strength. There is mounting evidence, from simulations and experiments, that transport is intermittent and consists of an ensemble of events, with a non-Gaussian probability distribution function (PDF). These events are associated with coherent structures such as streamers or blobs and are often bursty in time, thus leading to non–Gaussian statistics in the PDF tails. Here, we present a novel statistical approach to the prediction of these rare, large transport events.

Based on the observation that intermittent transport is often associated with coherent structure, we relate PDF tails to a probability of creation of various coherent structures (or, the transition amplitude between the state with no fluid motion and that with coherent structures) in a long time limit. An instanton, with spatial form given by a coherent structure, captures this very process of the creation of a coherent structure, and thus can be associated with bursty and intermittent events which are thought to be responsible for PDF tails. With this ansatz, PDF tails can be computed by finding an instanton which is a saddle-point solution of an effective action expression for the PDF, which can, in general, be given by a path integral.

This idea is exploited for the prediction of the PDF tails of flux transport in a magnetically confined plasmas. We consider the momentum flux (R) in a forced Hasegawa-Mima turbulence, which is responsible for the generation/destruction of a large–scale shear flow. Under the assumption that the nonlinear structure is a modon in space (an exact solution of a nonlinear Hasegawa-Mima equation), we find PDF tail for R with the specific form $\exp[-cR^{3/2}]$, which is a stretched, non-Gaussian exponential. A similar result is also found for the PDF tail of heat transport in a simple toroidal ITG, when the nonlinear structure leading to the tail is a modon. Possible extensions of this approach to the prediction of the PDFs for transport events will be explored. In particular, PDFs of (large-scale) structure formation, such as streamers or zonal flows, will be discussed.