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Sandpile Dynamics as a Paradigm for Turbulent Transport

D. E. Newman and B. A. Carreras
Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-8071
P. H. Diamond
University of California at San Diego, La Jolla, California 92093-0319

Abstract

To shed some light on the apparent discrepancies between most theoretical models of turbulent transport and experimental observations of the transport in magnetically confined plasmas, a model for transport[1] has been developed based on the concept of self-organized criticality (SOC).[2] This model seeks to describe the dynamics of the transport without relying on the underlying local fluctuation mechanisms. Computations based on a cellular automata model have found that SOC systems maintain average profiles that are linearly stable (submarginal) and yet are able to sustain active transport dynamics in contrast to naive marginal stability arguments. It is also found that the dominant scales in the transport dynamics in the absence of sheared flow are system scales rather than the underlying local fluctuation scales. However, the addition of sheared flow into the dynamics leads to a large reduction of the system-scale transport events and a commensurate increase in the fluctuation-scale transport events needed to maintain the constant flux. The dynamics of these models and the potential ramifications for transport studies are discussed.

I. Introduction

A new paradigm for turbulent transport[1] has been suggested to shed some light on the discrepancies between predictions based on local turbulent transport theory and experimental observations. This new paradigm is based on the concept of self-organized criticality (SOC).[2,3,4] This concept seeks to describe the general properties of the dynamics of the transport without relying on the underlying local transport/fluctuation mechanisms. The simplest example of such a system is a sandpile model. It has been found that such SOC systems maintain average profiles that are linearly stable (submarginal) and yet are able to sustain active transport dynamics in contrast to standard marginal stability arguments. It is also found that the dominant scales in the transport dynamics are system scales rather than the underlying local fluctuation scales. In addition to allowing the paradigmatic investigation of turbulent transport, the introduction of sheared flow (wind), which arises in the context of magnetically confined plasmas, acts as a novel and important extension to their chaotic dynamics.

The dynamics of such systems can be computationally investigated with a cellular automata model of "running sandpile" dynamics. This model allows us to investigate the major dynamical scales and the effect of an applied sheared flow on these dominant scales.

The importance of this model lies in investigating two of the difficulties standing in the way of understanding anomalous transport in magnetically confined plasmas, the stability problem and the scale problem. It has long been thought that some linear instability is driving turbulent fluctuations, which are causing the anomalous transport.[5] A number of modes have been put forward as candidates for dominating transport in magnetic confinement devices. In many of these modes a linear marginal stability condition has been assumed for the profile. This is based on the assumption that the turbulent system would relax its driving gradient back to the linearly least unstable profile (the marginal profile) just allowing for the drive to continue. Ballooning modes