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Persistent Stability of a Chaotic System

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Abstract

We report that trajectories of a one-dimensional model for inertial particles in a random velocity field can remain stable for a surprisingly long time, despite the fact that the system is chaotic. We provide a detailed quantitative description of this effect by developing the large-deviation theory for fluctuations of the finite-time Lyapunov exponent of this system. Specifically, the determination of the entropy function for the distribution reduces to the analysis of a Schrödinger equation, which is tackled by semi-classical methods. The system has 'generic' instability properties, and we consider the broader implications of our observation of long-term stability in chaotic systems.

Keywords: Stochastic analysis methods. nonlinear dynamics and chaos, fluctuation phenomena, random processes, noise, Brownian motion, butterfly effect.

1. Introduction

This Letter concerns a phenomenon illustrated by the peculiar nature of the trajectories $x(t)$ of inertial particles (Fig. 1) in a one-dimensional model, which is described in detail later (Eq. (2)). The plot shows a very large number of trajectories, which start with a uniform initial density. The trajectories clearly show a strong tendency to cluster, and the plot is color-coded (online version) using a logarithmic density scale to illustrate the very intense accumulation of