Irreversible transport from time reversible dissipative chaotic dynamics

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Abstract

I will present a rather general outline of a theory that aims at understanding the emergence of irreversible macroscopic transport starting from reversible microscopic dynamics. No pre-knowledge apart from basic dynamical systems theory and statistical physics is required, and I hope my talk will to some extent be entertaining. I may also remark that Prof. David Ruelle, who received the Max Planck Medal 2014, spent quite some time working out the rigorous mathematical foundations of this approach, but here I will focus on the physics side of it.

At the heart of this approach is to suitably model the interaction of a subsystem with a thermal reservoir. A simple example is a tracer particle in a fluid exhibiting Brownian motion for which there is the well-known description in terms of stochastic Langevin dynamics. Three decades ago scientists proposed a fully deterministic, time reversible modeling of thermalized motion by deriving a generalized Hamiltonian formalism yielding generalized friction coefficients in terms what is called Gaussian and Nosé-Hoover thermostats. Surprisingly, in nonequilibrium situations such as, e.g., under an external electric field, this time reversible dissipative dynamics generates fractal attractors, exhibits an identity between phase space contraction and entropy production, and furnishes formulas that express transport coefficients in terms of Lyapunov exponents. In my talk I will show how this class of dynamical systems is constructed, will review its basic dynamical systems properties, and will critically discuss a conjectured universality of these properties.

[1] R.Klages, Microscopic Chaos, Fractals and Transport in Nonequilibrium Statistical Mechanics (World Scientific, Singapore, 2007)