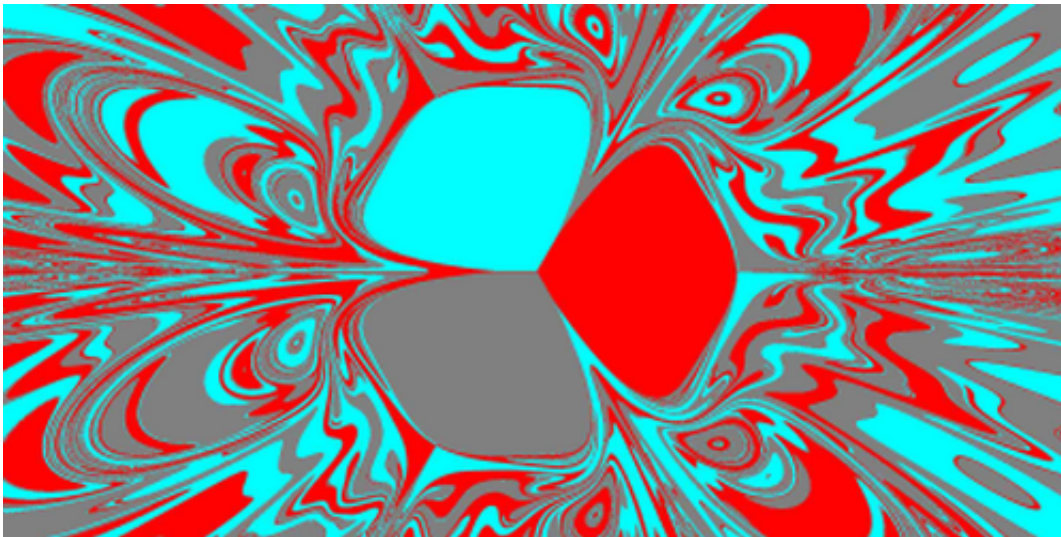


Physicists find doubly transient chaos can emerge due to dissipation

November 22 2013, by Bob Yirka



Credit: A. E. Motter et al., *Phys. Rev. Lett.* (2013)

(Phys.org) —A team of researchers, one from the U.S. and the others from Hungary, has found that a condition they've dubbed doubly transient chaos can emerge from a system due to dissipation. In their paper they've had published in the journal *Physical Review Letters*, the team describes how their experiments with a triple-magnet pendulum showed that even systems that come to stop eventually can have chaos attributes.

At first blush, most people recognize chaos when they see it—a crowd of people, each behaving unpredictably, for example. In physics, chaos can

be seen with examples such as the constantly changing images that result from [fractal geometry](#). One property that all chaotic systems have in common is that changes continue occurring (due either to an external force or lack of one such as gravity or friction), aka, transient chaos, as long as the system is in existence—otherwise, the system would dissipate to a non-changing state. But, is that system that results chaotic as well? The researchers in this new effort say yes, but not in the same way as other chaotic systems. For that reason, they have called it doubly transient chaos.

Chaos can exist in even the simplest of systems, such as a pendulum, for example. If it's started and left to swing till it stops, it will follow a routine that can be accurately described mathematically—but not if it is disturbed periodically by an external energy source—say a person reaching over and pushing it a little bit to keep it going. If that extra push can't be described in an orderly way, then the motion and duration of the pendulum's swing can be described as chaotic. The researchers used just such an example to prove their idea about transient chaos. They used a pendulum with three magnets attached to a triangle—suggesting three final states for the pendulum when it finally stops moving. In such a setup, the pendulum was subject to magnetic forces, gravity, and air drag.

In studying the ways in which the [pendulum](#) swung and eventually stopped, the researchers found that it conformed to doubly transient chaos—one of whose hallmarks is that parameters describing its rate of change to a final state are not constant as they are with transient chaos, but are instead exponential.

The researchers believe that doubly transient [chaos](#) may be at play in many other systems (chemical reactions, binary star behavior, etc.) and because of that are likely far less predictable than has been previously thought.

More information: Doubly Transient Chaos: Generic Form of Chaos in Autonomous Dissipative Systems, *Phys. Rev. Lett.* 111, 194101 (2013) prl.aps.org/abstract/PRL/v111/i19/e194101

Abstract

Chaos is an inherently dynamical phenomenon traditionally studied for trajectories that are either permanently erratic or transiently influenced by permanently erratic ones lying on a set of measure zero. The latter gives rise to the final state sensitivity observed in connection with fractal basin boundaries in conservative scattering systems and driven dissipative systems. Here we focus on the most prevalent case of undriven dissipative systems, whose transient dynamics fall outside the scope of previous studies since no time-dependent solutions can exist for asymptotically long times. We show that such systems can exhibit positive finite-time Lyapunov exponents and fractal-like basin boundaries which nevertheless have codimension one. In sharp contrast to its driven and conservative counterparts, the settling rate to the (fixed-point) attractors grows exponentially in time, meaning that the fraction of trajectories away from the attractors decays superexponentially. While no invariant chaotic sets exist in such cases, the irregular behavior is governed by transient interactions with transient chaotic saddles, which act as effective, time-varying chaotic sets.

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