Chaos-on-a-chip model shows market bubbles may be predictable, controllable

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(Phys.org) —It's an idea financial regulators have dreamed of. Experiments on a simple model of chaos have found that it may be possible not only to predict an extreme event, like a stock market collapse, but to intervene and prevent it from happening.

In a paper appearing October 21 in the journal *Physical Review Letters*, an international team of chaos researchers say that these extreme events, which they call "dragon kings," are less random than had been thought and that, in a simple experiment at least, they can be anticipated and controlled.

"These dragon kings are predictable, if we knew what to measure," said co-author Dan Gauthier, the Robert C. Richardson professor of physics at Duke University.

The latest finding is an outgrowth of experimental work Gauthier has been doing since the 1990s with simple electrical circuits he calls "chaos generators." Two identical circuits consisting of two capacitors, an inductor, a nonlinear diode and a power source, are each set to generate chaotic oscillations in their voltages and currents. Being identical, the credit-card sized circuit boards are supposed to oscillate in synch with each other when they are coupled - called "synchronized chaos." But in practice, they experience subtle variations in behavior so that the voltages and currents in one circuit do not match their twin.

Because the behavior of each circuit is chaotic, the voltages and current change in an erratic manner over time, but both circuits are synchronized, so that they both change together and show the same behavior most of the time, Gauthier said.

During a long run of the experiment, the data reveal that the chaotic behavior visits "hot spots" in which an extreme event, "a bubble," might occur. This is an event in which the circuits suddenly and temporarily loose synch. Sometimes the size of the event is small, like a small change in a financial market, and other times it is gigantic, like a market crash. And the size of most of these disturbances follows a power law distribution, in which one variable changes as a power of the other. The most extreme events, the "dragon kings," are responsible for significant deviations from the curve of the power law.

Extreme events that may be governed by these laws would include sudden population crashes in species or freak waves in the ocean, Gauthier said. Other examples might be epileptic storms of activity in the brain and rolling power outages caused by an initial small disturbance, like a squirrel shorting out one substation on a large grid.

Other examples could be found in the occurrence of incipient failure of materials and of engineering structures, in the synchronized behavior of kidney and heart cells in the body, in meteorological front dynamics and in climate change, among many others.

In a series of experiments performed with the coupled chaos circuits by Gauthier's colleague and former post-doctoral research associate, Hugo Cavalcante, who is now at the Federal University of Paraiba in Brazil, it was found that the introduction of a tiny amount of current injected into one of the circuits at just the right time prevented a predicted dragon king from happening. "Maybe tiny nudges can make a big difference," Gauthier said.

Gauthier and Cavalcante co-authored the paper with Edward Ott of the University of Maryland, College Park; Marcos Oria from the Federal University of Paraiba; and Didier Sornette of the Swiss Federal Institute of Technology, who is director of a group called the Financial Crisis Observatory. The Observatory has applied similar principles to predict several market disturbances in recent years.

Sornette coined the term "dragon king," which he explained in a TED-Global lecture in Edinburgh, Scotland in June 2013.

"The limitation of our paper is that we haven't shown that our circuit has relevance to the stock market," which has many more variables, Gauthier said. "We aren't yet sure where to look, but for this one simple system, we figured out how to find it."

Gauthier said the five-page paper faced a difficult gauntlet of reviewers before being accepted in PRL. "We're trying to open up people's thinking to the possibility that systems that change are constantly evolving in time," he said. "We're trying to show that there's a wider, richer set of systems that express extreme events," Gauthier said, "and that they might be controlled."

More information: "Predictability and Suppression of Extreme Events in a Chaotic System," Hugo L.D. de S. Cavalcante, Marcos Oriá, Didier Sornette, Edwart Ott, Daniel J. Gauthier. *Physical Review Letters*, Oct. 21, 2013. On Arxiv: arxiv.org/pdf/1301.0244v3.pdf

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