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Slow avalanches oscillate in new experiment

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A microcrystal array for which extremely small forces and motions are tracked with atomic-scale precision to probe and model the avalanche response at slow driving rates. Within the image, a view of the San Andreas fault, where such effects can be seen in the world. Credit: Stefanos Papanikolaou

"Avalanches"—the crackling behavior of materials under slowly increasing stress, like crumpling paper or earthquakes—may have a novel facet previously unknown, say Cornell researchers.

A study led by former postdoctoral associate Stefanos Papanikolaou employs both theory and experiment to describe never-before-seen oscillatory behavior of microcrystal plastic bursts at very small scales, under highly controlled conditions.

The study, co-authored by James Sethna, professor of physics, is featured on the cover of the journal *Nature*, Oct. 25.

The experiments were done by co-author Dennis M. Dimiduk of the Air

Force Research Laboratory, using microfabricated nickel microcrystals. They recorded individual microcrystals' behavior as they were slowly crushed, causing microscale avalanches. What emerged was a new power law that determined the probability of crackles of different sizes.

Analyzing the data, Papanikolaou and collaborators found that slowing the crushing of microcrystals led to an oscillation of avalanches themselves—large then small, in a repeating pattern, and with time periods between the large events roughly periodic. This was different from previous experiments and theories of crackling noise and avalanches.

Avalanches have previously been known to happen at random times following a power law behavior, in that the number of avalanches is given by a power of the avalanches' size. The new experiments not only display oscillations, but also give a markedly different power law—a "new route to criticality, with a perpetual cycle leading to the emergence of self-similarity," Sethna said.

They explain and model the oscillations and this new law by including other smooth "oozing" processes that compete with the avalanches; oozing becomes important when the crystals are crushed nearly as slowly as they ooze.

It's a theory the scientists think could apply to many intermittent phenomena that become oscillatory as "relaxation" increases—earthquakes deep in the earth crust, for one, but even less conventional ones—like the low-frequency oscillations of brain waves during sleep.

"We could maybe open a window to actually starting to model accurately the emergence of such phenomena in large collections of neurons," Papanikolaou said.

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