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# Crackling noise during growth

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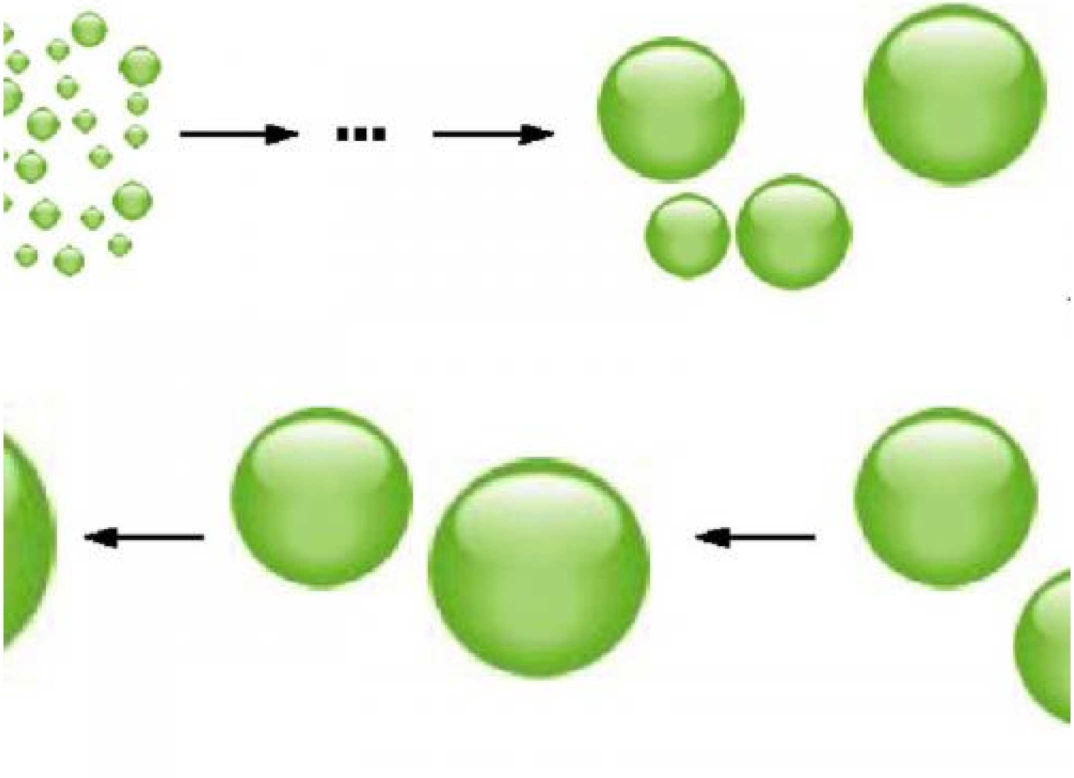


Birds of a feather: In many cases where small units, such as drops, form a whole, these units are all of similar size. Credit: Dynamics & Self-Organization

Globules of fat in homogenised milk, dust particles in the early solar system and small magnetic domains in ferromagnets are all examples of small parts coming together to form one whole, like "birds of a feather"; or, in this case: particles of the same size flock together. Scientists from the Max Planck Institute for Dynamics & Self-Organization, the

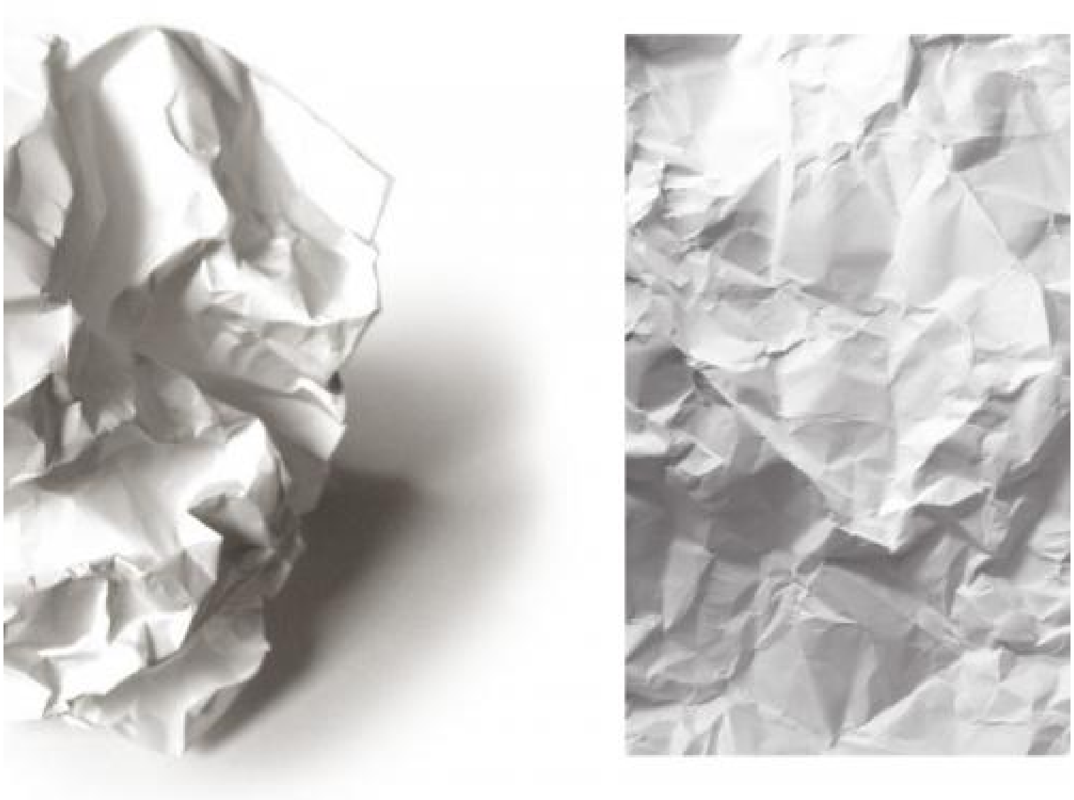
University of Göttingen and Azarbaijan Shahid Madani University in Iran have demonstrated that such growth processes "crackle". What this means is that during growth, the individual parts perform jumps that are randomly distributed in terms of size. This random distribution is subject to the same statistical laws as the intensity of the sound made by a sheet of paper being crumpled. The new models help scientists understand, among other things, the jerky magnetisation of ferromagnets.

When a glass falls from a table and shatters on the floor, a physicist will be intrigued rather than annoyed. The pieces that are formed are all of similar size. Some large pieces can be picked up by hand; others are collected with a sponge cloth or the vacuum cleaner. However, microscopic shivers are hardly ever found. "In many naturally occurring growth processes, the sequence of events is the reverse, so to speak", Jan Nagler, a researcher at the Max Planck Institute for Dynamics & Self-Organization, explains. "Primarily, subsystems of similar size coalesce to form a new, larger unit."

However, how exactly do these systems grow? "Our models have shown that these growth processes 'crackle'", Nagler says, describing the findings of the new study. He suggests a mental exercise: "Let's assume that similarly sized droplets fuse step by step and that the droplets emit a noise for every step; a quiet noise when the largest drop that is formed only grows slightly, a loud noise when the largest drop experiences a significant growth spurt."

## A kind of symphony of growth

The growth of the drops is thus accompanied by sounds of varying intensity – a symphony of growth, as it were. "The noise that is produced is a crackle, similar to the one made by paper being crumpled in the hand", according to Nagler.



Left: A paper being crumpled crackles: a broad range of both loud and quiet sounds emerges. Right: The length of creases on an unfolded crumpled paper also follows the “crackling distribution”. Credit: www.sxc.hu

"We have all crumpled up paper a thousand times – because we were angry, frustrated or bored", Malte Schröder, a Masters student at the University of Göttingen, says. However, it pays listen more carefully when we do it, he adds. The paper being crumpled makes both loud and quiet noises, just like a crackling fire. Quiet crackling is sometimes interrupted by a very loud crack. In both cases, the sounds cover a wide range of intensity.

This distribution is what physicists refer to as "crackling noise" – something which occurs in many other contexts, far from sounds and volume. "If you unfolded the crumpled paper again, you would see a complex pattern of long and short creases", Nagler says. The distribution of these crease lengths also follows the "law of crackling noise". So does that of earthquake magnitudes or solar flares – as well as the growth spurts when subsystems coalesce.

The range of potential, randomly distributed growth spurts increases with the size of the overall system. This makes larger systems much more difficult to predict than small systems, which is relevant for materials that consist of a very large number of subsystems, such as the atoms of a magnet or the nodes and links in a network.

## Jumpy magnetic domains

The scientists simulated different growth processes on the computer. Instead of focusing on globules of fat or dust particles, they looked at a general description of such a growth process. The only condition: the subsystems merging had to be of similar size. "Such growth processes can be described mathematically in a new network theory", says Schröder. The smallest possible subsystem is represented by a node. When two subsystems connect, a link is created - and gradually a network is formed.

In the second stage, the scientists studied a particular system: ferromagnetic substances, such as iron, nickel and cobalt. When these substances come in contact with a magnet, they become magnetised. Within these substances are microscopic areas – so-called Weiss domains – that are magnetised due to the external influence. This process causes increasingly larger homogeneous magnetic areas to form and leads to randomly distributed discontinuous jumps in the total magnetisation.

"Since Weiss domains are all of similar size, our model is useful for describing this process too", Nagler says. "The sudden jumps in magnetisation and, above all, the distribution of these jumps can be accurately reproduced using our calculations."

In the next stage of the project, the scientists want to identify more systems that display the necessary conditions for crackling growth. There are many possibilities – from oil globules on a slowly evaporating water surface to fusions of large companies in economics.

**More information:** Schroder, M. et al. Crackling Noise in Fractional Percolation, *Nature Communications*, 26 July 2013; DOI: 10.1038/ncomms3222

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