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Research suggests how turbulence can be used to generate patterns

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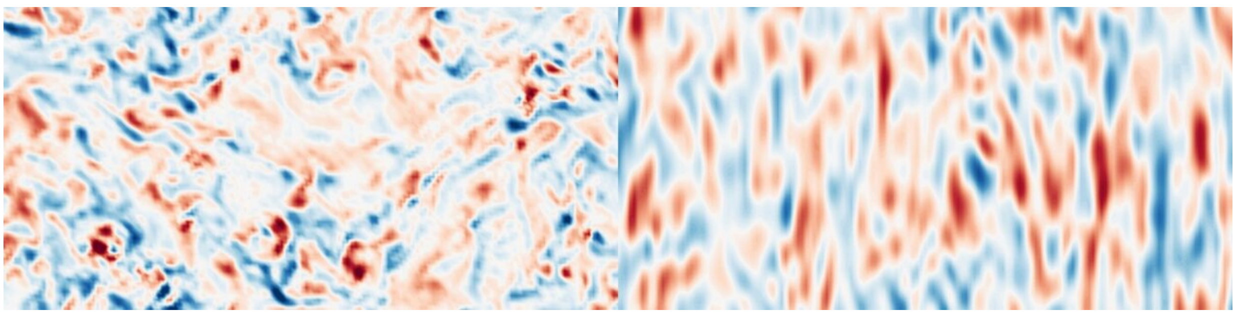

Left image: Normal turbulence is a random mix of eddies. Right image: Patterns with a particular characteristic size form when each of the particles spin like tops. Credit: de Wit and Fruchart et al.

The turbulent motion of a tumbling river or the outflow from a jet engine is chaotic: that is, it contains no obvious pattern.

But according to a new study, regular patterns can emerge from the turbulent motion of fluids. What you need is an intriguing property called "odd viscosity" that arises under certain conditions, such as when the particles in the fluid all spin in the same direction. Though it's a specialized circumstance, there are many contexts in nature where a version of this effect may exist, such as in the corona of the sun and the solar wind.

"This surprising effect may add to the growing toolbox to control and shape turbulence," said Michel Fruchart, formerly a postdoctoral researcher at UChicago, now faculty at the French Centre National de la Recherche Scientifique (CNRS) and co-first author of the paper describing the findings.

The study, a collaboration among the University of Chicago, Eindhoven University of Technology in the Netherlands, and CNRS, is published in *Nature.*

A chaotic nature

Despite how much we've learned about classical physics in the past centuries, there's one problem that still resists full explanation: the phenomenon known as turbulence. Though turbulence appears every day around us—from the clouds churning in the atmosphere overhead to the very blood flowing through our vessels—it is still not as well understood as other common physical phenomena.

"Turbulence might be commonplace in nature, but it is still only partially understood," said Xander de Wit, co-first author of the publication and a Ph.D student with Eindhoven University of Technology.

This is despite the fact that if we could understand and control turbulence, we might be able to achieve many breakthroughs; perhaps we could design more efficient airplane wings, engines, and wind turbines, for example.

However, there are things scientists do know about turbulence. If you shake a bottle of water, you'll see eddies forming. They start out at roughly the size of the length of the bottle; then the eddies split into smaller eddies, and then again into smaller eddies, and so on until the eddies dissipate. This is known as a cascade. But if you do the same thing but confine the water to a thin layer, the eddies will instead merge to form one big vortex—the Great Red Spot on Jupiter's surface is an example of this phenomenon, said Fruchart.

The group of scientists wondered whether it was possible to make and hold medium-size eddies—neither one big eddy, nor smaller and smaller ones.

The answer is yes—if your fluid has is displaying a property known by the term "odd viscosity."

Viscosity usually means a measurement of how hard it is to stir—for example, it's harder to stir a jar of honey versus a jar of water. In normal viscosity, the movement dissipates the energy you've injected to it by stirring with your spoon. But "odd viscosity" changes the way objects move but doesn't dissipate energy. It's been seen in certain rare conditions in the laboratory.

The researchers built a simulation where the particles displayed odd viscosity—in this case, by making all of the particles of the fluid spin like tops. Then, by tweaking the parameters, such as how fast the particles would spin, the researchers found a surprise. At a particular point, they began to see patterns instead of random eddies.

"The trick, we found, is to create a mixed cascade, where large eddies tend to split and small eddies tend to merge," said Fruchart. "If you get the balance just right, you see patterns form."

"When we first saw these effects, we didn't fully understand what we were looking at, but you could tell there was something different even to the unaided eye," said study co-author and UChicago Ph.D student Tali Khain. "We had to develop a theory to explain it, and that was really exciting."

Though not all particles in fluids spin like tops, there are examples in nature. For example, electrons or polyatomic gases in a magnetic field do behave this way.

"In addition to the sun and solar wind, there are diverse contexts where a version of this effect may exist, including atmospheric flows, plasmas and active matter," said UChicago Prof. Vincenzo Vitelli, one of the senior authors on the paper.

As the scientists work to develop a fuller understanding of their findings, they hope it will lead to a better understanding of the interplay between eddies and waves in turbulent flows.

"We are only at the beginning," Vitelli said, "but I am fascinated by the idea that you can take a turbulent state that is the epitome of chaos, and use it to make patterns—that is a profound change made by just a twist on the smallest scale."

More information: Xander M. de Wit et al, Pattern formation by turbulent cascades, *Nature* (2024). DOI: 10.1038/s41586-024-07074-z

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