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# Researchers crack an enduring physics enigma

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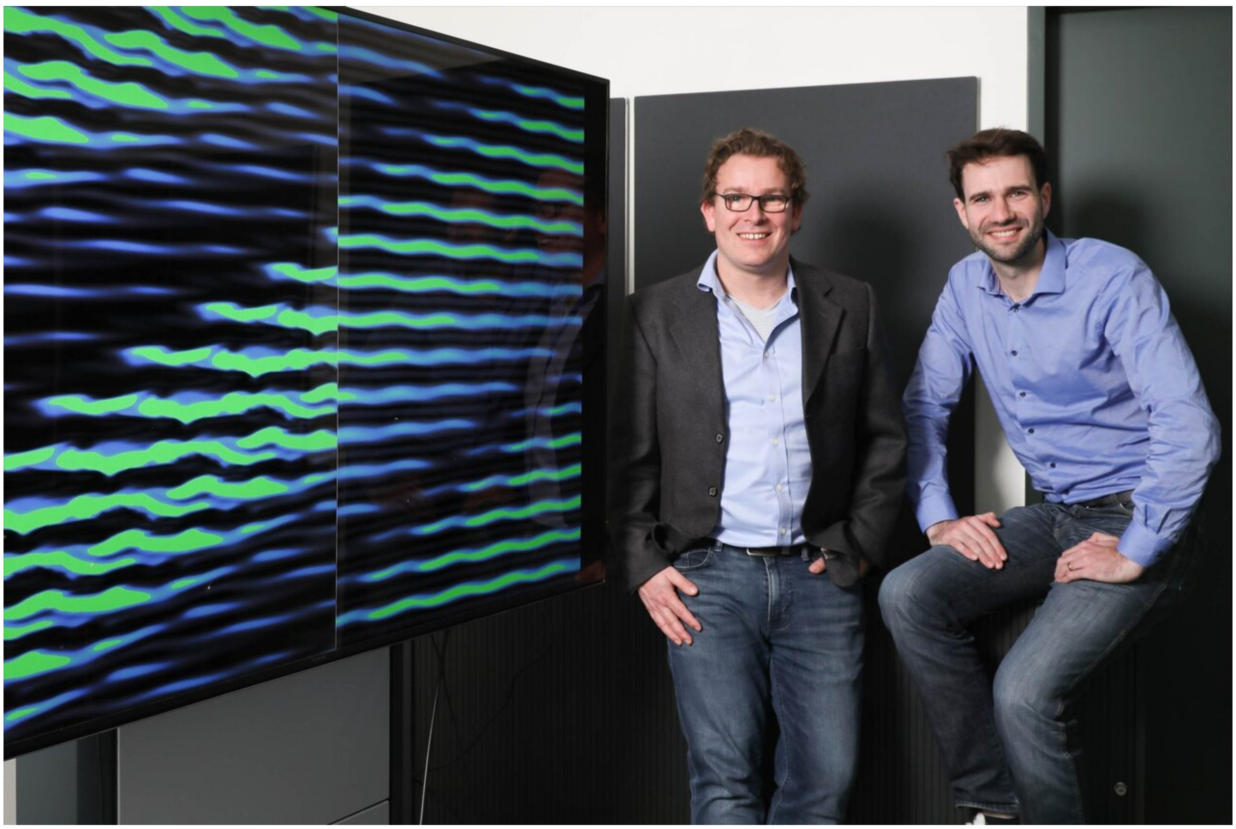

Tobias Schneider and Florian Reetz. Credit: Ecole Polytechnique Federale de Lausanne (EPFL)

For decades, physicists, engineers and mathematicians have failed to explain a remarkable phenomenon in fluid mechanics: the natural tendency of turbulence in fluids to move from disordered chaos to perfectly parallel patterns of oblique turbulent bands. This transition from a state of chaotic turbulence to a highly structured pattern was observed by many scientists, but never understood.

At EPFL's Emerging Complexity in Physical Systems Laboratory, Tobias Schneider and his team have identified the mechanism that explains this phenomenon. Their findings have been published in *Nature Communications*.

## From chaos to order

The equations used to describe the large variety of phenomena occurring in fluid flows are well known. These equations capture the fundamental laws of physics that govern fluid dynamics, a subject taught to all physics and engineering students from undergraduate level onwards.

But when turbulence comes into play, the solutions to the equations become non-linear, complex and chaotic. This makes it impossible, for example, to predict weather over an extended time horizon. Yet turbulence has a surprising tendency to move from chaos to a highly structured pattern of turbulent and laminar bands. This is a remarkable phenomenon, yet the underlying mechanism remained hidden in the equations until now.

Here's what happens: when a fluid is placed between two parallel plates, each moving in an opposite direction, turbulence is created. At first, the turbulence is chaotic, then it self-organizes to form regular oblique bands, separated by zones of calm (or laminar flows). No obvious mechanism selects the oblique orientation of the bands or determines the wavelength of the periodic pattern.

### Concealed in simple equations

Schneider and his team solved the mystery. "As the physicist Richard Feynman predicted, the solution was not to be found in new equations, but rather within the equation that was already available to us," explains Schneider. "Until now, researchers didn't have powerful enough mathematical tools to verify this."

The researchers combined one such tool, known as dynamical systems theory, with existing theories on pattern formation in fluids and advanced numerical simulations. They calculated specific equilibrium solutions for each step of the process, enabling them to explain the transition from the chaotic to the structured state.

"We can now describe the initial instability mechanism that creates the oblique pattern," explains Florian Reetz, the study's lead author. "We have thus solved one of the most fundamental problems in our field. The methods we developed will help clarify the chaotic dynamics of turbulent-laminar patterns in many flow problems. They may one day allow us to better control flows."

## An important phenomenon

In fluid mechanics, stripe pattern formation is important because it shows how turbulent and laminar flows are in constant competition with each other to determine the final state of the fluid, i.e., turbulent or laminar. This competition arises whenever turbulence forms, such as when air flows over a car. The turbulence starts in a small area on the car's roof, but then it spreads—because turbulence is stronger than laminar flow in this particular case. The final state is therefore turbulent.

When the stripe pattern forms, it means that the laminar and turbulent flows are equal in strength. However, this is very difficult to observe in nature, outside of the controlled conditions of a laboratory. This fact points to the significance of the EPFL researchers' success in explaining a fundamental property of turbulence. Not only do their findings account for a phenomenon that can be observed in a laboratory, but they could help to better understand and control flow-related phenomena occurring in nature as well.

**More information:** Florian Reetz et al. Exact invariant solution reveals the origin of self-organized oblique turbulent-laminar stripes, *Nature Communications* (2019). DOI: 10.1038/s41467-019-10208-x

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