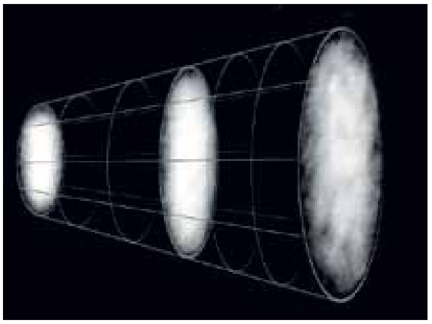
The effects of quantum turbulence

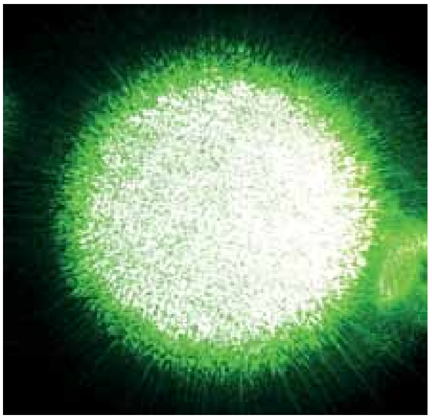
Disturbing a cloud of cold rubidium atoms produces a wave phenomenon similar to light

Victória Flório

PUBLISHED IN JANUARY 2018



1



2

Three-dimensional speckles that are generated by quantum turbulence in a Bose-Einstein (*above*) condensate resemble the effect of a laser on a screen

When subjected to the conditions of quantum systems, the same atoms that form everything, from stars to living beings to a piece of paper, cease to behave as particles and begin to manifest as waves. In this state, matter can exhibit effects that contradict traditional assumptions, and atoms can cross barriers that were previously thought to be impassable. In recent experiments, a team coordinated by researchers from the São Carlos Institute of Physics at the University of São Paulo (IFSC-USP) found that the aspects of the undulatory behavior of a supercooled and confined rubidium atom cloud are preserved even after being disturbed by the generation of vortices and progressing into a state of quantum turbulence. Atoms have already been well studied under these conditions; however, the effects of introducing a major disturbance into this type of system were previously unknown.

In an article that was published in the journal PNAS in October, researchers report that a speckle pattern emerges as the cloud expands, which is characteristic of wave interference, such as when laser light is projected onto a screen, which creates a two-dimensional speckle; in the cooled rubidium atom cloud, the speckles were three-dimensional. "This is the first observation of three-dimensional speckles," explains physicist Vanderlei Bagnato from IFSC-USP, who is one of the authors of the article and coordinator of the Optics and Photonics Research Center (CEPOF), which is one of the FAPESP Research, Innovation, and Dissemination Centers (RIDC).

The USP group studied a trapped superfluid, namely, a Bose-Einstein condensate, that was formed by a cloud of hundreds of thousands of rubidium atoms that were enclosed in a magnetic trap. Quantum phenomena begin to manifest when the matter is cooled to temperatures of approximately 1 millionth of a degree above absolute zero – the absolute zero is equivalent to zero Kelvin and -273.15 degrees Celsius. Under this condition, the grouped atoms lose all viscosity and become a superfluid, which is another state of matter. To introduce quantum turbulence into the cloud, the physicists used a magnetic field to induce the formation of vortices. Then, they turned off the trap and observed the condensate as it expanded. It was during this moment of instability that the speckle was generated.

The São Carlos team has pioneered the introduction of turbulence into a Bose-Einstein condensate. In partnership with colleagues from the University of Florence, Italy, the researchers from São Paulo showed in 2009 that a condensate offers a simpler means of studying turbulence in superfluids than the traditionally used liquid helium. The new study provides opportunities for further investigation into the behavior of speckles and quantum turbulence. "This is a new situation in physics, which could reveal as yet unknown effects," says Pedro Ernesto Tavares, the lead author of the PNAS article. The two-dimensional granular pattern that is generated by lasers is widely used for studying material surfaces. ■

Project

CEPOF – Optics and Photonics Research Center (No. 13/07276-1); **Grant Mechanism** Research, Innovation, and Dissemination Centers (RIDC); **Principal Investigator** Vanderlei Salvador Bagnato (USP); **Investment** R$ 28,014,802.21 (for the entire project).

Scientific article

TAVARES, P. E. S. *et al.* Matter wave speckle observed in an out-of-equilibrium quantum fluid. **Proceedings of the National Academy of Sciences (PNAS)**. v. 114, i. 8, p. 12691-95. 28 Nov. 2017.

PHOTOS 1 PEDRO ERNESTO TAVARES 2 WIKIMEDIA COMMONS