New insight into superfluids reveals a storm at the surface

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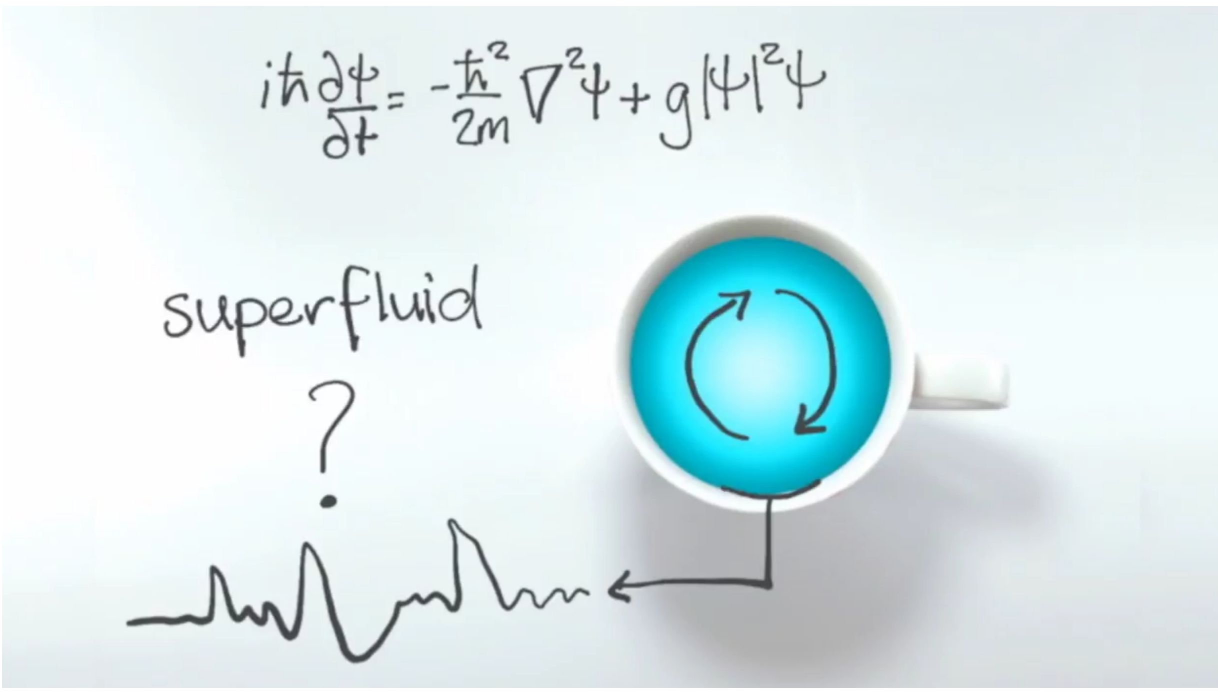

The discovery of a 'storm' layer created when superfluid helium flows across a rough surface has turned a century of understanding about one of the most important discoveries in quantum physics on its head.

Mathematicians from Newcastle University, UK, have shown for the first time that superfluid Helium has a boundary layer that 'sticks' to surfaces in the same way as an ordinary fluid.

However, unlike normal fluids that are pulled back by friction, in superfluid Helium the resistance is caused by the creation of mini tornadoes, which tangle together like spaghetti, slowing the flow.

Published today in the academic journal *Physical Review Letters*, this first evidence of a 'storm' layer changes all past assumptions about how superfluids move and could be used to better understand their use as coolants and in precision measurement devices such as gyroscopes.

Storm in a teacup

Lead author on the paper Dr George Stagg, from the School of Mathematics & Statistics at Newcastle University, says that to visualise the research findings you only need to think of your morning cuppa.

"Imagine you stir a cup of tea and then remove the spoon," he explains.

"It looks like the whole of the tea is swirling, but actually at the wall of the cup the tea stands still since it gets stuck there. Due to friction, adjacent layers of fluid get held back as they try to swirl around the cup. This "boundary layer" soon causes the flow to grind to a halt.

"But if we were to repeat with a cup of superfluid helium, the fluid would keep swirling forever since there is no friction, and no boundary layer, to hold it back.

"Or at least this is what has always been believed.

"What our research has shown is that this phenomenon is only true for perfectly smooth surfaces. If the surface is 'rough' down to the scale of nanometres, as all surfaces are, then mini tornadoes are created as the superfluid flows past the surface.

"These swirling vortices tangle together like spaghetti and - just like when you drain your spaghetti and leave it for too long in a pan - they stick together, creating a slow-moving boundary layer between the free-moving fluid and the surface.

"So in our teacup, what we would actually see around the edge is a 'storm' - a layer of whirling tornadoes sticking together and bringing the flow of fluid closest to the boundary almost to a halt.

"This means that, contrary to our past understanding, superfluid helium actually behaves in much the same way as an ordinary fluid."

One of the most important discoveries of the 20th century

Helium is one of the few known elements that will never become a solid but remains a liquid even at extremely low temperatures.

In 1908, Dutch physicist Kamerlingh Onnes became the first person to liquefy helium and two years later he discovered the when it was cooled to just a couple of degrees above absolute zero, it would abruptly stop boiling.

It would be several decades later, however, before scientists were able to explain the strange properties of the super-cold helium - its lack of viscosity and its constraint to swirl only through tiny tornadoes of fixed size and strength.

Along with other properties, these became the 'hallmarks of superfluidity'.

"This unimpeded flow was one of the most exciting properties of a superfluid," explains Dr Nick Parker, Senior Lecturer in Applied Mathematics and co-author on the paper.

"It changed everything we thought we knew about the laws of friction. For example, if we stir a cup of tea and create a 'tornado', as soon as we remove the spoon the tornado starts to slow down and eventually stops. But if we stir a superfluid, the tornado will continue forever even once the spoon has been removed.

"This lack of viscosity is one of the key features that defines a superfluid ."

Importance of boundary layers

Boundary layers arise when everyday fluids, flowing past surfaces, are slowed down by viscous forces and understanding what is happening at the boundary layer is particularly important in engineering.

"Seeing this close connection between superfluids and classical fluids helps us to piece together the links between these apparently distinct types of fluid, possibly to even form a universal understanding of how fluids flow across surfaces," says Dr Parker.

"Boundary layers are crucial in normal fluids for many applications, such as improving the flow of liquids through pipes or the run-off of rainwater on building materials.

Now, in superfluids, we can use this understanding to improve their applications as coolants and in precision measurement devices such as gyroscopes."

More information: A superfluid boundary layer, arXiv:1603.01165v2 [cond-mat.other] 14 Feb 2017, arxiv.org/abs/1603.01165

Provided by Newcastle University