Mathematician makes breakthrough in understanding of turbulence

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(Phys.org)—A mathematician at the University of Glasgow is helping to find an answer to one of the last unsolved problems in classical mechanics.

Dr Andrew Baggaley, of the University's School of Mathematics and Statistics, has published a paper in the journal Physical Review Letters, which extends our understanding of the chaotic motion of fluids, commonly known as turbulence. The incredibly complex ways in which liquids and gases move and interact has proven very difficult for scientists to understand and predict.

A better understanding of turbulence in fluids would be tremendously helpful to a wide range of fields including weather forecasting, aerospace engineering and astronomy.

Dr Baggaley has developed a mathematical model of how liquid helium behaves on the quantum scale when cooled to just a few degrees above absolute zero (-273°C). At such extremely low temperature, liquid helium contains a both a normal fluid with an element of viscosity or friction but also what is known as a 'superfluid' – a rare state of liquid matter which is entirely frictionless.

Detailed computer simulations of this mathematical model help to understand the link between the apparently very different behaviours of superfluids on the quantum scale and more familiar classical, viscous, fluids all around us.

Dr Baggaley said: "We all have some basic understanding of turbulence from experiences in our everyday lives. For example, when we swim, the friction between our arms and the water excites complex motion at a lengthscale of a meter or so.

"When we get out of the pool, the motion of the water will eventually become still as the energy from the eddies we created cascades into a series of smaller and smaller eddies. Ultimately, the kinetic energy from the motions of our arms is released through the rotation of the water at very small scales, and converted to heat.

"Nearly every fluid in the universe is affected by turbulence, just like the water in the pool. Although our understanding of the nature of turbulence is improving, the random, chaotic motion of those liquids and gases can't currently be entirely predicted."

At the quantum scale the behaviour of superfluids becomes a great deal more unfamiliar. Instead of creating random eddies of varying strength, rotational motion in frictionless superfluid helium spontaneously creates atomic-size holes of uniform size, around which the fluid circulates at uniform rate. In superfluid helium the holes, known as quantised vortices, are around 10 nanometres in width or about 10,000 times narrower than a human hair.

Dr Baggaley added: "We commonly think of turbulence as a collection of interacting eddies at different sizes. At very low temperatures, the weirdness of quantum mechanics becomes apparent and initially the fluid motion seems very different. The fluid loses its friction, rotational motion in the fluid is very limited, and these quantum vortices, which are like mini tornadoes, thread through the fluid.

"However, this work shows these small tornadoes have a tendency to bundle together and cause the quantum turbulence to have the same statistical properties as turbulence in a viscous fluid such as water. What initially seemed so strange becomes much more familiar.

"These similarities, combined with the simpler nature of these quantum fluids, provides the opportunity to cast an old problem in a new light and hopefully advance our understanding of fluid dynamics and turbulence.

"I'd hope that further research over the next 10 years or so will greatly deepen our understanding of both quantum and classical turbulence which could revolutionise the world we live in."

Dr Baggaley's paper, titled 'Vortex-Density Fluctuations, Energy Spectra, and Vortical Regions in Superfluid Turbulence', is published in *Physical Review Letters* and is available from bit.ly/UFu9o6 .

Provided by University of Glasgow