Capturing the transition from laminar to turbulent flow on a macroscopic level by a predator–prey model now establishes another fascinating example of this theme.

Nevertheless, many puzzles about turbulence and fluid flow in general still remain. Although the Navier–Stokes equation provides a fully accepted mathematical description for fluid dynamics on an enormously broad range of length and time scales, the understanding of physical principles underlying particular phenomena, such as transitional turbulence, requires coarse-grained descriptions. It seems that we need 'reduced' descriptions at some special points in the parameter space of the Navier–Stokes equation to fathom these principles. Why is this so? A physicist trained in the age of renormalization group theory might reply that it is because there are 'critical points' at which universal models are an appropriate way of approaching the problem. But why are there those critical points in the first place, and are there really critical points in fluid turbulence? At present we lack a deeper understanding of mathematical models, such as the Navier–Stokes equation and its cousins for more complex fluids, to answer this question. Further research is certainly needed to unravel the secrets of turbulence and the hidden surprises of tap water. ❒

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QUANTUM FERROFLUIDS

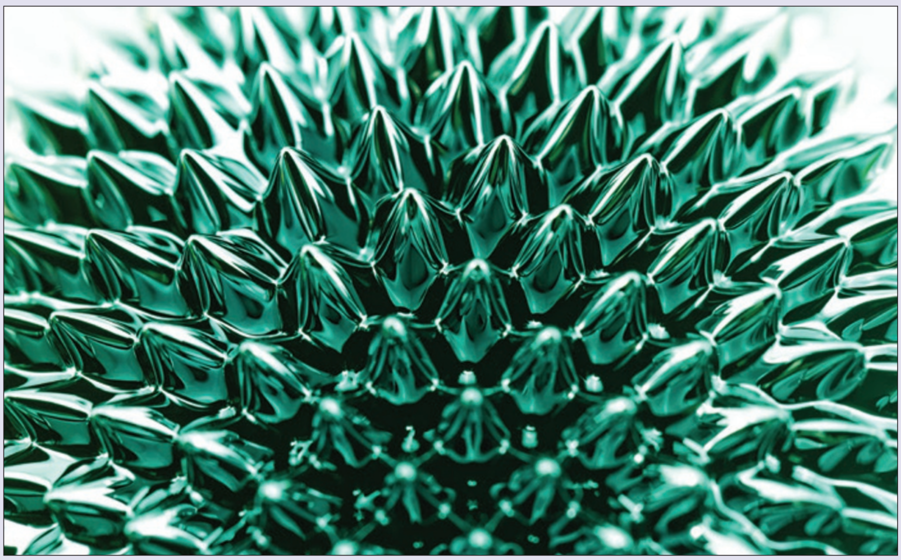
Made to order

Hydrodynamics and magnetism meet spectacularly in ferrofluids — liquids containing magnetic nanoparticles. The ferrohydrodynamic magic happens when an amount of ferrofluid is put on a superhydrophobic surface and exposed to a magnetic field. The forces at play, notably the liquid's surface tension and the tendency of the magnetic particles to align with the field, result in a hedgehog-like droplet crystal (pictured). Holger Kadau and colleagues have now observed this phenomenon, known as the Rosensweig instability, for a quantum ferrofluid (*Nature* http://doi.org/bcf4; 2016) — a Bose–Einstein condensate (BEC) with strong magnetic dipolar interactions.

The authors cooled down a gas of ^{164}Dy atoms and created a BEC of about 15,000 atoms at a temperature of 70 nK. The atoms were held in a pancake-shaped trap and subjected to an external magnetic field of approximately 0.7 mT, which aligned their magnetic moments perpendicularly to the 'pancake' containing the atomic ensemble.

The quantum Rosensweig instability resulted from the interplay between the trapping, the dipolar interactions and the contact interactions in the BEC. The latter can be tuned through Feshbach resonances, which occur when the kinetic energy of a scattering pair of atoms coincides with a bound-state energy of the atomic interaction potential. In turn, Feshbach resonances can be adjusted by varying the external magnetic field.

By using a Feshbach resonance to control interparticle interactions, Kadau *et al.* succeeded in triggering the Rosensweig instability in their dipolar dysprosium BEC. Through *in situ* imaging of the atomic density, they recorded the formation of ordered, triangular arrangements of up to ten droplets. An analysis of various realizations of such ordered structures revealed a linear increase in the number of droplets with the number of atoms, with an average of 1,750 atoms per droplet — showing that the 'droplet crystal' grew when more atoms were added.



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Fourier analysis of a 2D atomic-density image provided a measure (a single number called the spectral weight) for the periodicity, or crystallinity, present in the pattern. Repeating the analysis for each image in a time sequence allowed the formation and decay times of a droplet crystal to be deduced. Kadau and colleagues found that the droplet patterns were fully developed after 7 ms, and then decayed exponentially with a mean lifetime of 300 ms. They also monitored the spectral weight when ramping the magnetic field down, and up again, and noticed differing values — hysteretic behaviour, indicative of a crystallization process.

The BEC is not only a quantum ferrofluid, but also a superfluid — at least, in the unordered phase. Whether the individual droplets display superfluidity — and hence whether the ordered system represents a supersolid state — remains an open question.

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