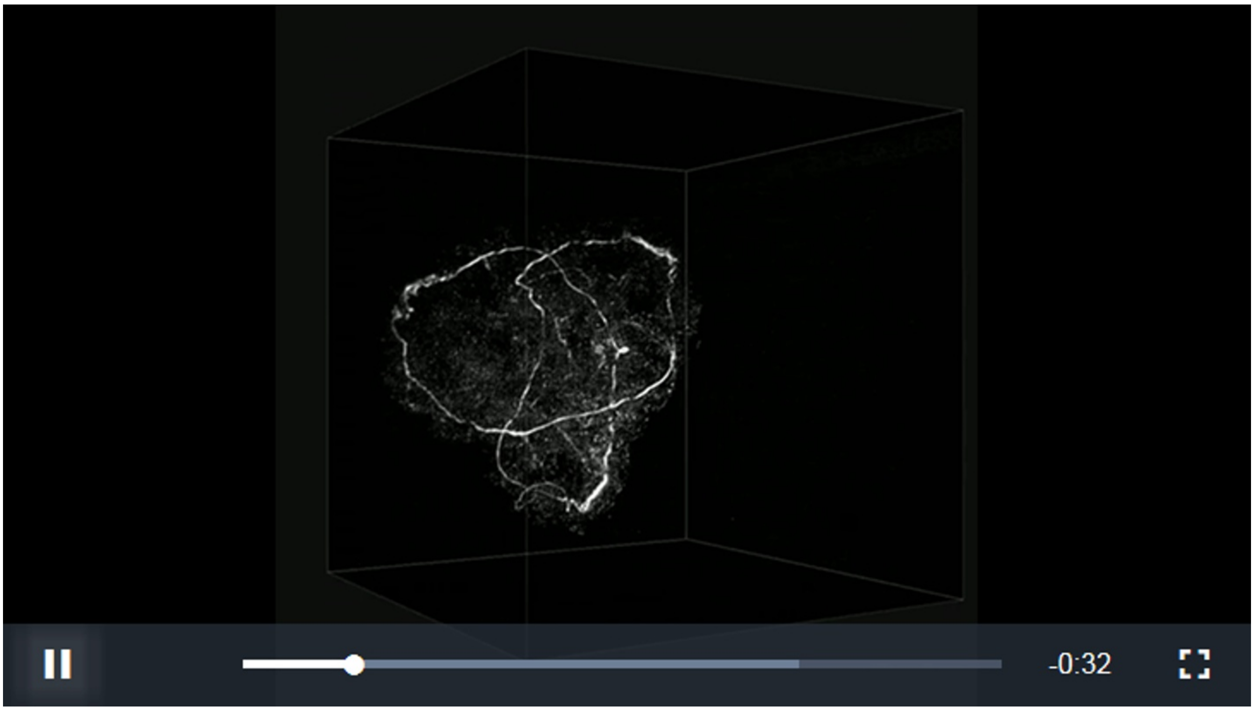
# Physicists twist water into knots

**3-D-printed vortex maker may improve understanding of braided fluids in nature.**

Ron Cowen

03 March 2013




More than a century after the idea was first floated, physicists have finally figured out how to tie water in knots in the laboratory. The gnarly feat, described today in *Nature Physics*[1], paves the way for scientists to experimentally study twists and turns in a range of phenomena — ionized gases like that of the Sun's outer atmosphere, superconductive materials, liquid crystals and quantum fields that describe elementary particles.

Lord Kelvin proposed that atoms were knotted "vortex rings" — which are essentially like tornado bent into closed loops and knotted around themselves, as Daniel Lathrop and Barbara Brawn-Cinani write in an accompanying commentary. In Kelvin's vision, the fluid was the theoretical 'aether' then thought to pervade all of space. Each type of atom would be represented by a different knot.

Kelvin's interpretation of the periodic table never went anywhere, but his ideas led to the blossoming of the mathematical theory of knots, part of the field of topology. Meanwhile, scientists also have come to realize that knots have a key role in a host of physical processes.

Creating a knot in a fluid bears little resemblance to tying a knot in a shoelace, say Dustin Kleckner and William Irvine, physicists at the University of Chicago in Illinois. The entire three-dimensional (3D) volume of a fluid within a confined region, such as a vortex, must be twisted. Kleckner and Irvine have now created a knotted vortex using a miniature version of an aeroplane wing built with a 3D printer.

During an aeroplane's flight, a wing induces a rotational or vortex-like motion of air currents that gives lift to an aeroplane. When a wing at rest suddenly accelerates, it creates two vortices of air circulating in opposite directions. The researchers submerged their tiny wings in a tank of water and gave it a sudden acceleration to create a knotted structure (videos below and at top).

Capturing images of the knot was another technical tour-de-force. Fluid dynamicists often use coloured dye to trace the motion of fluids, but Kleckner and Irvine injected tiny gas bubbles into the water that were drawn to the centre of the knotted vortex by buoyancy forces. A high-speed laser scanner capable of producing CT-scan views of the fluid at 76,000 frames per second enabled the researchers to reconstruct the 3D arrangement of the bubbles, thus revealing the knots.

"The authors have managed a remarkable achievement to be able to images these vortex knots," says Mark Dennis, an optical physicist at the University of Bristol, UK, who has made knotted vortices from light beams[2]. The new study, he adds, transforms abstract notions about physical processes involving knots into testable ideas in the laboratory.

"Knotted vortices are an ideal model system for allowing us to study the precise way in which knots untie themselves in a real physical field," says Irvine.

Knotted vortices show up in several branches of physics. Particle physicists, for example, have proposed that 'glueballs', hypothetical agglomerations of gluons — the elementary particles that bind quarks to form protons and neutrons — are tightly knotted quantum fields[3].

And in January, scientists reported evidence of 'unbraiding' or relaxation of knotted magnetic fields that may help to transfer heat to the Sun's corona, or outer atmosphere[4], explaining why the plasma in this region is much hotter than the Sun's surface.

*Nature* | doi:10.1038/nature.2013.12534

## References

1. Kleckner, D. & Irvine, W. T. M. *Nature Phys.* http://dx.doi.org/10.1038/nphys2560 (2013).
2. Dennis, M. R., King, R. P., Jack, B., O'Holleran, K. & Padgett, M. J. *Nature Phys.* **6**, 118–121 (2010).
3. Buniy, R. V. & Kephart, T. W. *Int. J. Mod. Phys. A* **20**, 1252–1259 (2005).
4. Cirtain, J. W. *et al*. *Nature* **493**, 501–503 (2013).