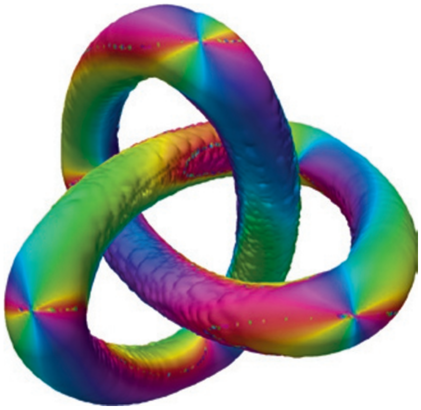
Knotty business

Nature Mater. http://doi.org/q2m (2014)



In one of the pre-quantum models of the atom, developed by Lord Kelvin, atoms were imagined to be knotted objects ('vortices') in the ether. Although subsequent advances in physics made the idea obsolete, it did spark mathematical developments in knot theory. In turn, many of the discoveries about mathematical knots have now resurfaced in various branches of physics such as cosmology, quantum chromodynamics and materials science.

The field of soft matter, in particular, has become a playground for the exploration of knot theory. Indeed, increasingly complicated micrometre-sized fibre structures — knots — can nowadays be spun from monomer solutions by means of laser-induced polymerization. Angel Martinez and colleagues now report how various knot-shaped particles interact with a nematic liquid-crystal field.

The nematic phase of a liquid crystal has high orientational but low translational order; its director field — giving the preferential direction of a particle — is constant. Martinez *et al.* found that the presence of knotty particles introduces topologically non-trivial defects in the director field. In this image of a trefoil knot, the colours are a measure of the director field's angular deviation at the knot's surface. *BV*

In the mix

Phys. Rev. Lett. (in the press); preprint at http://arxiv.org/abs/1310.6732 (2013)

The three flavours of neutrino have mass and their mass eigenstates mix, the mixing being defined by a set of 'mixing angles'. The trickiest of these to pin down was the so-called θ_{13} mixing angle, but in 2012 the Daya Bay collaboration, based at a nuclear reactor complex in China, achieved the first measurement of this parameter, which has since been backed up by other experiments including T2K in Japan and MINOS in the USA.

Now, with the addition of more data and a refreshed analysis that exploits the three 'near' and three 'far' antineutrino detectors positioned around the reactor complex, the Daya Bay collaboration has a refined measurement of θ_{13}, the most precise yet. Moreover, their study of the oscillation patterns of the electron antineutrinos emitted by the reactors has made possible the first direct measurement of a quantity known as the 'mass-squared difference'. Its consistency with a similar quantity measured for muon neutrinos (by MINOS) supports the three-flavour mixing model for neutrino oscillations. *AW*

Trap and conquer

Nature Commun. **5,** 3089 (2014)

The standard model of particle physics predicts a CPT–symmetric Universe in which matter and antimatter are mirror images of each other: even the tiniest difference between the two would have dramatic consequences, but so far no violation of CPT symmetry has been found.

There are already high-precision measurements of the spectroscopic properties of matter atoms — such as the ground-state hyperfine splitting of hydrogen — so performing the same tests on hydrogen's antimatter twin would provide a very sensitive test of CPT symmetry. That's easier said than done, however, as it's not straightforward to produce or manipulate antihydrogen, and for spectroscopic studies large numbers of antiatoms are needed. But, in experiments at CERN's Antiproton Decelerator, Naofumi Kuroda and colleagues have taken a step forward in developing the tools needed for precision spectroscopy of antihydrogen.

Using a magnetic cusp trap, Kuroda *et al.* have succeeded in confining and guiding a reasonably sized sample of antihydrogen atoms (about 80, most of which are in a relatively low Rydberg state) over a distance of more than 2.5 metres towards an apparatus in which the ground-state hyperfine transition can be investigated. *IG*

A flare to remember

Astrophys. J **781,** 59 (2014);
Mon. Not. R. Astron. Soc **435,** 1904–1927 (2013)

Abell 1795 was an unremarkable star cluster in the northern constellation Boötes (the ploughman) until two teams of astrophysicists — led by Davide Donato and by Peter Maksym, respectively — independently found evidence for the aftermath of a star being ripped apart by a massive black hole. Such a 'tidal disrupture event' leads to stellar debris falling into the black hole. This in turn causes shock-heating and accretion onto the black hole, giving rise to a luminous X-ray or ultraviolet flare, believed to be brighter than a supernova. But as with many astrophysical phenomena, telescopes have to be looking at the right place at the right time.

Fortunately, the two teams were able to use archival data from many telescopes, in particular ESA's XMM-Newton and NASA's Chandra and the Extreme Ultraviolet Explorer (EUVE). By painstakingly corroborating data taken over 6–12 years from various telescopes, the teams managed to piece together what happened: about three months before the first EUVE observations, a standard star was sheared apart by an intermediate-mass black hole (10^5 solar masses) in a dwarf galaxy. Given that scant evidence exists for intermediate-mass black holes, theorized to be 'seeds' for supermassive black holes, this was a remarkable find indeed. *MC*

A mathematical metamaterial

Science **343,** 160–163 (2014)

Light can process information at a much higher rate than electrons. But electronics has the advantage of being more compact, which makes it the technology of choice for computation. Alexandre Silva and colleagues now show, however, that engineered materials can perform mathematical functions on a scale much smaller than bulky optical components, down to the wavelength of light itself.

Metamaterials are arrays of sub-wavelength structures that can interact with the electric and magnetic components of light in a way that atoms do not. Thus, scientists can design metamaterials with far more complex optical properties than those of natural materials.

Silva *et al.* consider a burst of light in which information is encoded in the pulse shape, and show theoretically that a metamaterial thin film can alter this shape as the light passes through so that the output pulse gives the correct response to a mathematical function. From this, they simulate a metamaterial that can perform basic image-manipulation processes, such as spatial differentiation, integration and convolution. *DG*

Written by May Chiao, Iulia Georgescu, David Gevaux, Bart Verberck and Alison Wright.