A bit of prehistory

Phys. Rev. Lett. (in the press); preprint at http://arxiv.org/abs/1009.2475 (2010)

By definition, the behaviour of a thermodynamic system alters dramatically at a phase transition. In some systems, however, more subtle changes precede the transition. Shih-Kuang Tung and colleagues have gathered information about what happens to a two-dimensional gas of bosonic rubidium-87 atoms before it becomes superfluid.

Unlike their three-dimensional counterparts, two-dimensional Bose gases do not undergo Bose–Einstein condensation on cooling: in lower-dimensional systems, long-range order is destroyed by thermal fluctuations. Instead, a phase transition known as Berezinskii–Kosterlitz–Thouless crossover takes place, which is associated with the pairing of vortices with opposite circulations and results, like Bose–Einstein condensation, in superfluid behaviour.

In comparing their experimental data with a 'bare-atom' model that omits the relevant many-body effects, Tung *et al.* have identified properties that go beyond mean-field behaviour. They see a steep increase in coherence as the gas is cooled towards the transition temperature. But well before that, the compressibility of the gas diverges from the predictions of the bare-atom model. Tung *et al.* associate this slow divergence with a gradual change in the interaction energy between the constituent bosons, but a full understanding of these observations is yet to be developed.

Pick the odd one out

Nature **467,** 1084–1087 (2010)

Replacing a single atom in a crystal lattice with a magnetic substitute creates an ideal system for developing spintronic devices. The difficult part is accessing and manipulating just this one lone atom. Alexander Khajetoorians and colleagues have now demonstrated a magnetically sensitive technique with atomic-scale resolution that can both excite and read out the spin state of an iron atom in an indium antimonide matrix.

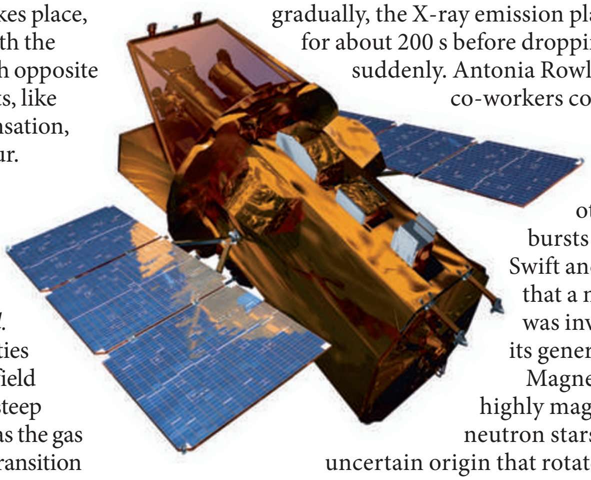
The team used the sharp metal tip of a scanning tunnelling microscope: when the tip is brought close to the sample surface, a current flows between the two that can be used to either manipulate the spin of the iron atom or probe the magnetic ground state. The approach enables an investigation of the influence of the local atomic environment on the properties of the substitute atom, and the researchers hope that the idea can soon be extended to related systems such as nitrogen-vacancy defects in diamond or manganese dopants in gallium arsenide, for example.

Birth of a magnetar

Mon. Not. R. Astron. Soc. **409,** 531–540 (2010)

The merger of two neutron stars (or a neutron star and a black hole) is the most popular candidate source for the short γ-ray burst GRB 090515. It is one of the shortest-lived γ-ray bursts, with a low γ-ray fluence, but its X-ray 'afterglow' is the brightest so far observed by NASA's Swift satellite (pictured). Moreover, instead of fading gradually, the X-ray emission plateaued for about 200 s before dropping suddenly. Antonia Rowlinson and co-workers compare GRB 090515 with other γ-ray bursts studied by Swift and suggest that a magnetar was involved in its generation.

Magnetars are highly magnetic neutron stars of uncertain origin that rotate rapidly enough to counterbalance the force of gravitation that would otherwise cause them to collapse to black holes. But a magnetar loses magnetic energy by emitting high-energy radiation such as X-rays and γ-rays. Rowlinson *et al.* suggest that the plateau in X-ray emission corresponds with the formation of a magnetar with a spin period of 10 ms and a magnetic field of 2.5×10^{12} T or a period of 66 ms and a field of 4×10^{11} T, depending on the redshift.



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A light BEC

Nature doi:10.1038/nature09567 (2010)

Bosons, unlike fermions, can occupy the same quantum energy level. The forcing of all bosons in a system into the ground state, creating a Bose–Einstein condensate (BEC), has been achieved with a number of different types of boson, but not with the most ubiquitous of all: the photon. Jan Klaers and co-workers have now managed this by devising an optical cavity in which the number of photons remains constant.

A prerequisite for creating a BEC is that the number of bosons remains constant as the system is brought into thermal equilibrium. This is not an easy task when working with photons, because light is absorbed by the cavity walls. To circumvent this problem, Klaers *et al.* constructed a cavity lined with a dye that scatters back incident photons (*Nature Phys.* **6,** 512–515; 2010).

As the system is pumped with progressively more optical power, the researchers observe the spectral distribution of photons in the cavity evolve from that of a black body to one with a noticeable peak near the cavity cut-off wavelength — a clear signature of a BEC.

Correction

In the version of the Research Highlight 'All mixed up' originally published (*Nature Phys.* **6,** 836; 2010), the surname of the author Len Pismen was spelt incorrectly. This has now been corrected in the HTML and PDF versions 10 November 2010.

Caught in a trap

Nature doi:10.1038/nature09610 (2010)

Antihydrogen — an antiproton and positron in a bound state — was first produced at CERN in 2002. The latest round of experiments at the lab has now proved that it is possible to trap these anti-atoms.

Using the ALPHA apparatus at CERN's Antiproton Decelerator, a worldwide collaboration of physicists has succeeded in cooling and mixing charged plasmas of antiprotons and positrons to form trapped antihydrogen. Chief among the confining components of ALPHA is a novel superconducting magnetic trap, comprising a transverse octupole magnet and two solenoidal coils, designed to reduce the perturbation of the charged plasmas.

From the interactions of 10^7 antiprotons and 7×10^8 positrons in the apparatus, a total of 38 trapped antihydrogen atoms has been recorded — the anti-atoms are detected through their annihilation after controlled release from the trap. Although not huge, this sample compares favourably with the measured background (from, for example, cosmic rays crossing the apparatus), of only 1.4 ± 1.4 events. The collaboration is optimistic that the trapping rate can be improved, eventually enabling precise tests of the properties of antihydrogen for comparison with those of its matter counterpart, hydrogen.