

Edited by Alison Wright

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Bose–Einstein condensate goes molecular

Researchers in Texas, US, have reported the first observation of molecules formed in a Bose–Einstein condensate of rubidium atoms.

Confined in a magnetic trap, the atoms were cooled first by lasers, then using evaporation, until the condensate formed. Using laser-absorption imaging, the team measured the gas temperature to be below 130 nK and it determined that 80% of the atoms had settled into the condensate.

The team then fired lasers into the gas, which, at the right frequency, stimulated Raman transitions, and a dip in the measured number of atoms was seen as molecules were formed.

The linewidth for the transition in the condensate was less than a 10 000th the width of previous experiments using laser-cooled gases, because Doppler broadening and the kinetic energy spread of the colliding atoms are negligible in the condensate.

The precise shape and position of the resonance depended on the density of the condensate, indicating that there was sensitivity to the interactions between the molecules and the condensate atoms.

The researchers predict that this technique will allow molecular binding energies to be determined with unprecedented accuracy and that it will provide extremely precise information on long-range atomic interactions.

SQUIDs give support to symmetry with d-waves

In low-temperature superconductors, Cooper pairs of electrons (or holes) are essentially spherical and are said to have "s-wave" symmetry. However, in high-temperature superconductors the symmetry is believed to be a "d-wave", resembling a four-leaved clover, and with a π phase change between neighbouring leaves of the clover in the quantum wave function of the Cooper pair.

Evidence to support this has now been revealed by a group of German physicists with its fabrication of a " π -SQUID". A SQUID (superconducting quantum interference device) is a superconducting loop, interrupted by two thin insulating junctions, through which Cooper pairs tunnel. The researchers produced a SQUID in a 100 nm thick film of $\text{YBa}_2\text{Cu}_3\text{O}_7$ grown on a SrTiO_3 tetracrystal.

The SQUID was designed to exploit the expected "d-wave" symmetry and to introduce a π phase change over one of the two 9 μm diameter junctions. Exactly this behaviour was seen in tests up to 77 K, supporting the theory of "d-wave" symmetry in high-temperature superconductors. These devices could also find application as superconducting "qubits" in a quantum computer.

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Silicon particles make great balls of fire

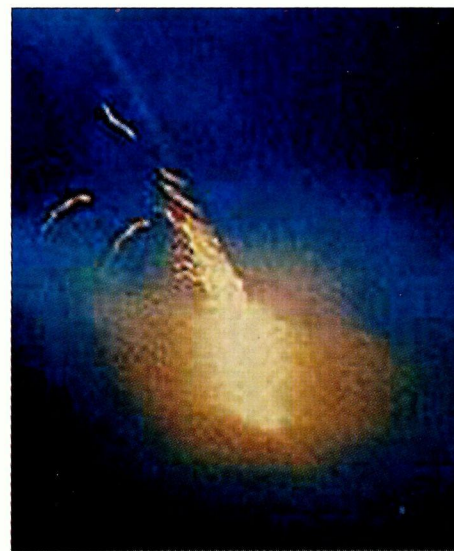
Since the Middle Ages, eyewitnesses have reported ball lightning during thunderstorms. This extraordinary natural phenomenon of a football-sized sphere of light, floating just above the ground for anything from 2 to 50 s, has defied explanation.

Now, two New Zealand researchers have proposed a model that offers the most comprehensive explanation yet. They realized that in soil with a carbon to silica ($\text{C}:\text{SiO}_2$) ratio of 1:2, a lightning strike creates a sufficiently high temperature (approximately 3000 K) to extract pure silicon – exactly the chemistry exploited by the integrated-circuit industry.

Fast cooling following the strike causes the silicon to clump into chains of nanometre-sized particles. Then tangled chains of silicon could float through the air, as gradual oxidation releases thermal energy as heat and light.

The scientists exposed soil to a lightning-like 10–20 kV DC discharge, transferring up to 3.4 C of charge. Under an electron microscope, deposits from the air close to the discharge revealed chains of nanoparticles, 5–70 nm in diameter, exactly as predicted, but no ball lightning.

However, such is the attractiveness of this model in getting right so many features of ball



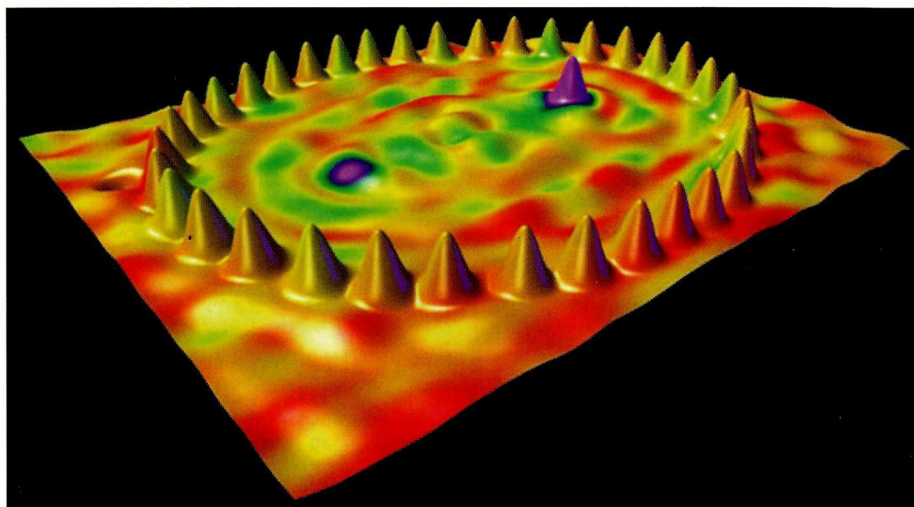
The spectacular phenomenon of ball lightning, seen here in a photograph taken in Austria in 1978, might be due to the oxidation of silicon particles released from the ground by a lightning strike.

lightning (size, motion, duration, luminosity and extinction), that the researchers are confident that more work on the lightning–soil interaction will allow them to home in on exactly the right ingredients to make ball lightning in the laboratory.

Cobalt magnetic resonance forms quantum mirage

Classical image projection by lenses or resonant cavities is familiar in the bending of light in the atmosphere to form mirages, and the focusing of sound in whispering galleries. Researchers at IBM, California, have now uncovered an analogous phenomenon in condensed matter systems that they call a "quantum mirage".

The researchers arranged cobalt atoms in an ellipse of a few angstroms' breadth on the surface of a copper crystal and an extra cobalt atom was placed at the focus of the ellipse. Cobalt has a magnetic moment and, at low temperatures, exhibits a "Kondo resonance": the conduction electrons in the copper surface around the cobalt atom align their spins to screen the magnetic moment of the atom. The resonance is seen as a rise in resistance as the magnetic atom, surrounded by the spin-aligned electron cloud, becomes a more effective scatterer of conduction electrons.



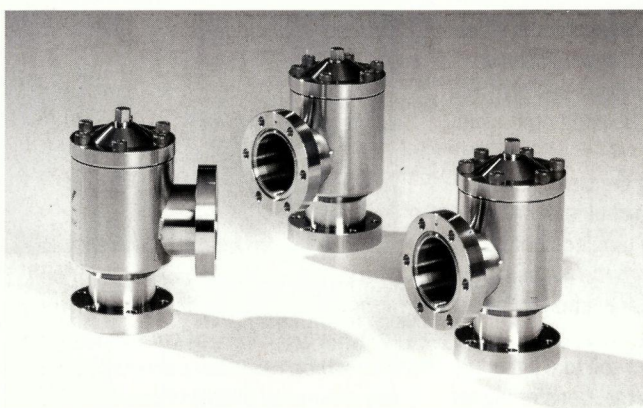
Cobalt atoms, positioned on a copper surface, form an elliptical "quantum corral". When an additional cobalt atom is placed at one of the foci of the ellipse, a "mirage" of another cobalt atom appears at the other focus.

To measure the Kondo resonance, the researchers bombarded the cobalt atom at one focus of the ellipse with electrons from the tip of a scanning tunnelling microscope and saw a "ghost" cobalt atom appear at the other focus of the ellipse. Electron partial waves in the copper surface had been scat-

tered by the cobalt atom and reflected (though not 100%) by the surrounding ellipse of atoms, to add coherently at the second focus. This quantum mirage is a surprisingly faithful spectroscopic replica of the real atom and opens the way for many "spectroscopy-at-a-distance" experiments.

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VAT Germany

Tel (089) 46 50 15
Fax (089) 46 37 65
Email deutschland@vatvalve.com

VAT U.K.

Tel 020 8346 1999
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Email uk@vatvalve.com

VAT Japan

Tel (045) 333 1144
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