Scientists capture first direct images of theoretically predicted magnetic monopoles

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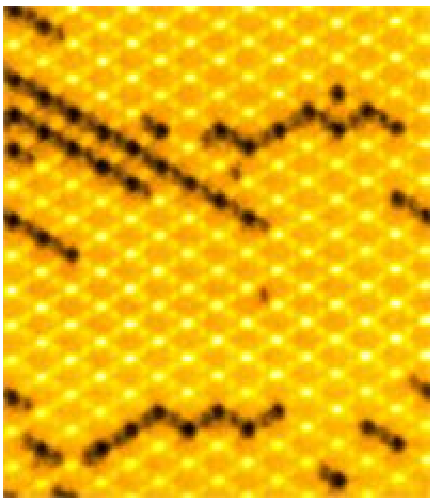


Image representing 12 micrometer x 12 micrometer of artificial magnetic metamaterial where monopoles can be seen at each end of the Dirac strings, visible as dark lines. The dark regions correspond to magnetic islands where the magnetization is reversed. (Image courtesy of Paul Scherrer Institute)

(PhysOrg.com) -- Scientists have captured the first direct images of magnetic monopoles which were theoretically conceived by the British-Swiss physicist Dirac in the early 1930s who showed that their existence is consistent with the ultimate theory of matter – quantum theory.

According to the findings published in the leading scientific journal Nature Physics on 17 Oct 2010, the scientists were able to directly image the monopoles by using the highly intense x-ray radiation from the Swiss

Light Source at the Paul Scherrer Institute.

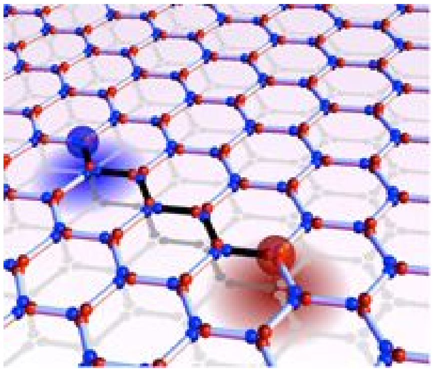
"A magnetic monopole is a 'hypothetical' particle that is a magnet with only one single magnetic pole," says UCD Theoretical Physicist, Professor Hans-Benjamin Braun from the UCD School of Physics, who co-led the study with Dr Laura Heyderman from the Paul Scherrer Institute in Switzerland.

"Some of the most important theories explaining how quantum matter behaves in the universe are based on their existence, but they have eluded direct imaging since they were first theoretically conceived in the 1930s."

"We have for the first time directly imaged emergent monopoles inside an artificially created magnetic nano-metamaterial consisting of tiny magnets with a size of a couple of hundred nanometers," explains Professor Braun.

As Dirac predicted, the monopoles observed by the researchers come with `strings attached' – the so called `Dirac strings' which feed magnetic flux into the magnetic monopole in very much the same way a garden hose feeds water into a sprinkler.

The scientific team were able to capture the first direct images of the elusive monopoles together with their attached Dirac strings at room temperature.



An illustration of the monopoles shown as large spheres residing at the ends of a Dirac string. The dipoles are represented as dumbbells of magnetic charges and the Dirac string corresponds to a string of overturned dumbbells shown in dark.

The experiments show directly how north- and south pole separate from each other in an external field, creating the Dirac string in their wake, “a fact that we were able to explain within a theoretical model” says SFI funded UCD postdoc Dr Remo Hügli who together with Professor Braun designed the theory behind the experiment.

When the researchers examined the way the monopoles moved, they realized that each time they increased the applied magnetic field they triggered an avalanche of magnetization reversal of adjacent islands, similar to a row of toppling dominoes. These types of avalanches are not simply restricted to magnetic systems, but apart from their snowy and icy counterparts, they also may manifest themselves in sand, in earthquakes, and in stockmarket crashes.

The research, funded by Science Foundation Ireland and the Swiss National Science Foundation, may ultimately assist scientists working to understand how monopoles might have interacted in the early universe.

But, the findings may also have far more immediate applications in data transfer and storage. So far, only electric charges have been used in information processing and the use of magnetic charges could provide significant advantage in power consumption and speed.

Current computer hard discs store data magnetically, and their next generation will most likely be built from tiny isolated magnets precisely of the type investigated in this research. Thus, with improved understanding of the behaviour of magnetic monopoles scientists would be able to develop hard discs with considerably higher density data storage and faster data transfer speeds.

Initially conceived by the British-Swiss theoretical physicist Dirac in 1931, monopoles were proposed to occur as emergent quasiparticles in so called pyrochlore spin-ice systems by Castelnovo, Moessner and Sondhi in 2008.

Initial evidence for such monopoles and associated Dirac strings in pyrochlore systems at sub-Kelvin temperatures was reported in October 2009 led by Japanese, German, French and British scientists. The present research provides the first direct space evidence for monopoles and the associated Dirac strings. The artificially produced system investigated allows the manipulation of monopoles at room temperature, a considerable progress that opens the door for applications in data storage.

The research reported was led by Hans-Benjamin Braun at University College Dublin (UCD) and Laura Heyderman at the Paul Scherrer Institute (PSI). Hans-Benjamin Braun and his postdoc Remo Hügli supported by Science Foundation Ireland developed the theory behind the experiments and performed the numerical simulations of the system. Elena Mengotti, a PhD student at the Paul Scherrer Institute, supported by the Swiss National Science Foundation, performed the experiments. Frithjof Nolting and Arantxa Fraile Rodriguez from PSI are experts in magnetic spectroscopy and microscopy. They led the experimental work at the Swiss Light Source SLS.

More information: Nature Physics www.nature.com/nphys/index.html

Provided by University College Dublin