HELMHOLTZ ZENTRUM BERLIN für Materialien und Energie

# Press Release

**Embargo time: 3. September 2:00 p.m. US Eastern Time**

## Magnetic monopoles detected in a real magnet

**Researchers from the Helmholtz-Zentrum Berlin für Materialien und Energie (HZB) have, in cooperation with colleagues from Dresden (Germany), St. Andrews (UK), La Plata (Argentina) and Oxford (UK), for the first time observed magnetic monopoles and how they emerge in a real material. They publish this result in the journal Science within the Science Express web site on 3. September.**

Magnetic monopoles are hypothetical particles proposed by physicists that carry a single magnetic pole, either a magnetic North pole or South pole. In the material world this is quite exceptional because magnetic particles are usually observed as dipoles, north and south combined. However there are several theories that predict the existence of monopoles. Among others, in 1931 the physicist Paul Dirac was led by his calculations to the conclusion that magnetic monopoles can exist at the end of tubes – called Dirac strings – that carry magnetic field. Until now they have remained undetected.

Jonathan Morris, Alan Tennant and colleagues (HZB) undertook a neutron scattering experiment at the Berlin research reactor. The material under investigation was a single crystal of Dysprosium Titanate. This material crystallises in a quite remarkable geometry, the so called pyrochlore-lattice. With the help of neutron scattering Morris and Tennant show that the magnetic moments inside the material had reorganised into so-called „Spin-Spaghetti". This name comes from the ordering of the dipoles themselves, such that a network of contorted tubes (Strings) develops, through which magnetic flux is transported. These can be made visible by their interaction with the neutrons which themselves carry a magnetic moment. Thus the neutrons scatter as a reciprocal representation of the Strings.

During the neutron scattering measurements a magnetic field was applied to the crystal by the researchers. With this field they could influence the symmetry and orientation of the strings. Thereby it was possible to reduce the density of the string networks and promote the monopole dissociation. As a result, at temperatures from 0.6 to 2 Kelvin, the strings are visible and have magnetic monopoles at their ends.

The signature of a gas made up by these monopoles has also been observed in heat capacity measured by Bastian Klemke (HZB). Providing further confirmation of the existence of monopoles and showing that they interact in the same way as electric charges.

In this work the researchers, for the first time, attest that monopoles exist as emergent states of matter, i.e. they emerge from special arrangements of dipoles and are completely different from the constituents of the material. However, alongside this fundamental knowledge, Jonathan Morris explains the further meaning of the results: „We are writing about new, fundamental properties of matter. These properties are generally valid for materials with the same topology, that is for magnetic moments on the pyrochlore lattice. For the development of new technologies this can have big implications. Above all it signifies the first time fractionalisation in three dimensions is observed."

Article in Science Express 3-Sep-2009:

**Dirac Strings and Magnetic Monopoles in Spin Ice $Dy_2Ti_2O_7$**

D.J.P. Morris, D.A. Tennant, S.A. Grigera, B. Klemke, C. Castelnovo, R. Moessner, C. Czternasty, M. Meissner, K.C. Rule, J.-U. Hoffmann, K. Kiefer, S. Gerischer, D. Slobinsky, and R.S. Perry

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**Further informations:**

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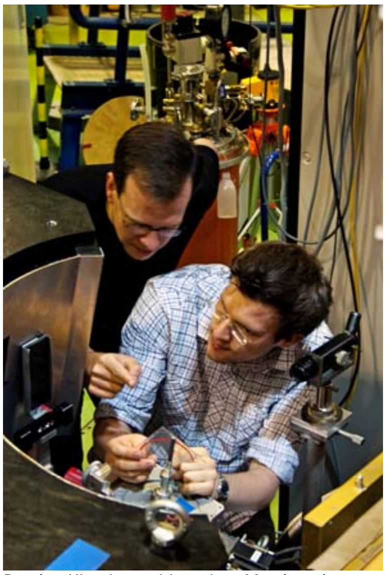

Bastian Klemke and Jonathan Morris at instrument E2 of the Research-Reactor at HZB in Berlin (Flat-Cone Single Crystal Diffractometer).

Bastian Klemke measuring the heat capacity at HZB.

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The **Helmholtz-Zentrum Berlin für Materialien und Energie (HZB)** operates and develops large scale devices for research with photons (synchrotron radiation) and neutrons. Every year, the partially unique experimental possibilities are utilised by more than 2.500 guests from universities and other research organisations around the world. Above all the HZB is known because of the unique sample environments that can be realised (high magnetic fields, low temperatures). The HZB undertakes materials research on those themes that especially benefit from and match with the large scale facilities. Research themes are magnetic materials and functional materials.

Main focus of the solar energy research is the development of thin film solar cells, while developing chemical fuels from sunlight is a vital research theme too. HZB has around 1.100 employees with around 800 on the Lise-Meitner-Campus in Wannsee, and 300 on the Campus Wilhelm-Conrad-Röntgen in Adlershof.

The HZB is a member of the Helmholtz Association of German research centres, the largest scientific organisation in Germany.

Part of the team at instrument E2 of the Research-Reactor at HZB in Berlin (Kirrily Rule, Jonathan Morris und Bastian Klemke).

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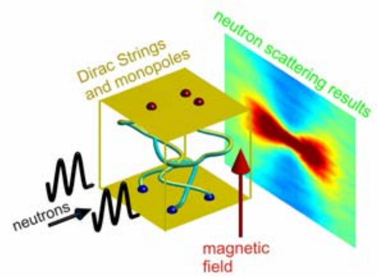
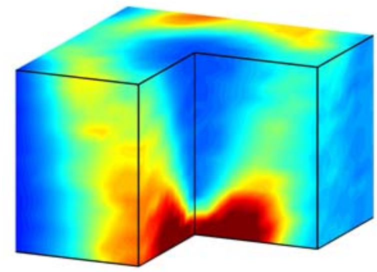
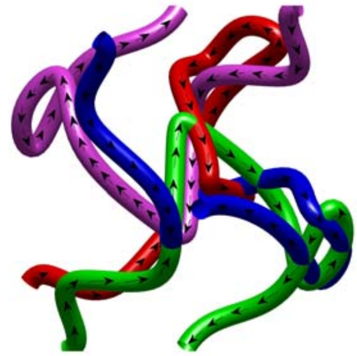
HZB / D.J.P. Morris & A. Tennant




Schematic diagram of the neutron scattering experiment: Neutrons are fired towards the sample, and when a magnetic field is applied the Dirac strings align against the field with magnetic monopoles at their ends. The neutrons scatter from the strings providing data which show us the strings properties.



3D calculation of a cone of scattering due to Dirac strings.



Impression of a ‘spin spaghetti’ of Dirac strings.