Emergent magnetic monopoles controlled at room temperature

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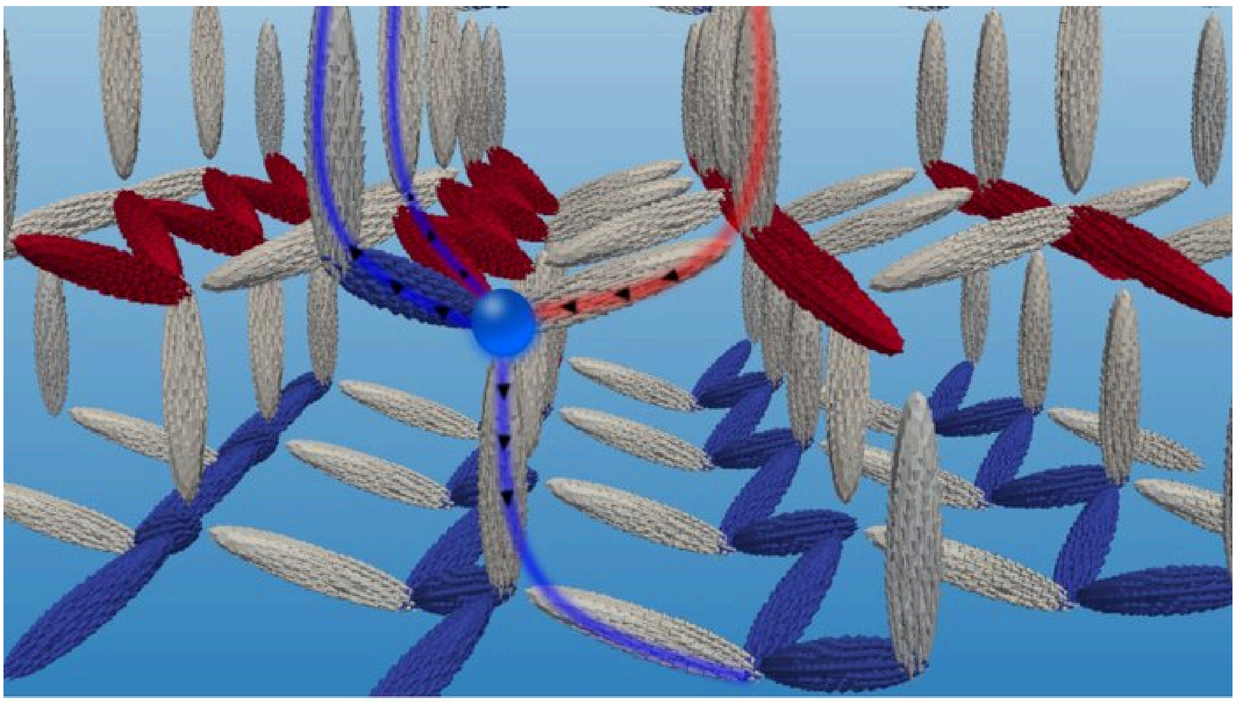

Researchers at the University of Vienna have designed a new 3D magnetic nanonetwork, where magnetic monopoles emerge due to rising magnetic frustration among the nanoelements, and are stable at room temperature. Credit: © Sabri Koraltan University of Vienna

Three dimensional (3D) nano-networks promise a new era in modern solid state physics with numerous applications in photonics, bio-medicine, and spintronics. The realization of 3D magnetic nanoarchitectures could enable ultra-fast and low-energy data storage devices. Due to competing magnetic interactions in these systems, magnetic charges or magnetic monopoles can emerge, which can be utilized as mobile, binary information carriers. Researchers at University of Vienna have now designed the first 3D artificial spin ice lattice hosting unbound magnetic charges. The results published in the journal *npj Computational Materials* present a first theoretical demonstration that, in the new lattice, the magnetic monopoles are stable at room temperature and can be steered on-demand by external magnetic fields.

Emergent magnetic monopoles are observed in a class of magnetic materials called spin ices. However, the atomic scales and required low temperatures for their stability limit their controllability. This led to the development of 2D artificial spin ice, where the single atomic moments are replaced by magnetic nano-islands arranged on different lattices. The up-scaling allowed the study of emergent magnetic monopoles on more accessible platforms. Reversing the magnetic orientation of specific nano-islands propagates the monopoles one vertex further, leaving a trace behind. This trace, known as Dirac Strings, necessarily stores energy and bind the monopoles, limiting their mobility.

Researchers around Sabri Koraltan and Florian Slanovc, and led by Dieter Suess at the University of Vienna, have now designed a first 3D artificial spin ice lattice that combines the advantages of both atomic- and 2D artificial spin ices.

In a cooperation with Nanomagnetism and Magnonics group from University of Vienna, and Theoretical Division of Los Alamos Laboratory, USA, the benefits of the new lattice are studied employing micromagnetic simulations. Here, flat 2D nano-islands are replaced by magnetic rotational ellipsoids, and a high symmetry three-dimensional lattice is used. "Due to the degeneracy of the ground state the tension of the Dirac strings vanish unbinding the magnetic monopoles," remarks

Sabri Koraltan, one of the first-authors of the study. The researchers took the study further to the next step, where in their simulations one magnetic monopole was propagated through the lattice by applying external magnetic fields, demonstrating its application as information carriers in a 3D magnetic nano-network.

Sabri Koraltan adds "We make use of the third dimension and high symmetry in the new lattice to unbind the magnetic monopoles, and move them in desired directions, almost like true electrons." The other first-author Florian Slanovc concludes, "The thermal stability of the monopoles around room temperature and above could lay the foundation for ground breaking new generation of 3D storage techonologies."

The study was published in *npj Computational Materials*.

More information: Sabri Koraltan et al, Tension-free Dirac strings and steered magnetic charges in 3D artificial spin ice, *npj Computational Materials* (2021). DOI: 10.1038/s41524-021-00593-7

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