

How 'frustrated' magnets escape magnetic deadlock at low temperatures

April 11 2014

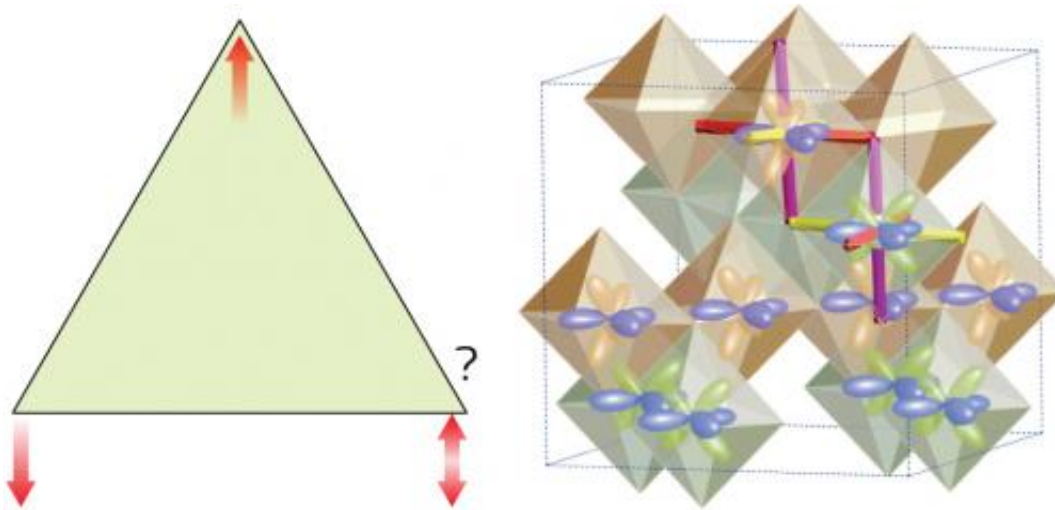


Figure 1: Geometric frustration in the triangular structural unit of the magnesium vanadium oxide compound MgV_2O_4 (left). Crystal structure of MgV_2O_4 , showing the variation in electron states between adjacent layers (right). Credit: American Physical Society

Magnetism in a material arises from how its electrons behave, which is influenced by the material's structure and the way that atoms and magnetic 'spins' of electrons are ordered within it. Frustrated magnets are a special type of magnet in which the crystal structure prevents the most energetically favorable arrangement of magnetic spins from being achieved, resulting in a magnet that is deadlocked in an unfavorable state.

Seiji Niitaka from the RIKEN Low Temperature Physics Laboratory, Hidenori Takagi from the RIKEN Magnetic Materials Laboratory and colleagues from other RIKEN centers and Japanese institutions have now discovered how small changes in [crystal structure](#) can help such magnets release their frustration.

The research team investigated the magnesium vanadium oxide compound MgV_2O_4 . The magnetic vanadium ions in this material form a three-dimensional network consisting of a regular triangular unit with intrinsic geometrical spin frustration (Fig. 1). However, at very low temperatures, this compound shows strikingly simple magnetic ordering with significantly less frustration. The ordering of magnetic spins follows the temperature-related structural phase transition of the atoms, suggesting that the crystal structure and magnetic properties of MgV_2O_4 are linked.

Studying the material's atomic arrangement with high precision required a combination of careful sample preparation and highly precise measurement techniques, explains Niitaka. "We were able to study the crystal structure only at the RIKEN SPring-8 Center, which has x-rays of high brightness and a high-performance camera." Importantly, Niitaka, Takagi and their colleagues also succeeded for the first time in growing single crystals of MgV_2O_4 at sufficiently high quality for such experiments.

The team's x-ray investigation revealed that the atomic bonds between vanadium and oxygen atoms on the crystallographic plane are of different lengths, and that in the low-frustration state the orientation of these long and short bonds alternates between adjacent layers. This distortion is attributed to variations in the electron state between layers, which influences spin interactions. As a consequence, the deadlock of magnetic spins is lifted and the material can escape frustration.

The discovery of the role of electron orbitals in this process could be important to understand not only frustrated magnetic materials, but also other materials characterized by strong interactions between electronic and structural properties. "This interplay between the different degrees of freedom of electrons in a material is one of the intriguing behaviors leading to rich physics in [materials](#)," says Niitaka.

More information: Niitaka, S., Ohsumi, H., Sugimoto, K., Lee, S., Oshima, Y., Kato, K., Hashizume, D., Arima, T., Takata, M. & Takagi, H. "A-type antiferro-orbital ordering with I41/a symmetry and geometrical frustration in the spinel vanadate MgV₂O₄." *Physical Review Letters* 111, 267201 (2013). [DOI: 10.1103/PhysRevLett.112.068103](#)

Provided by RIKEN

Citation: How 'frustrated' magnets escape magnetic deadlock at low temperatures (2014, April 11) retrieved 10 April 2024 from <https://phys.org/news/2014-04-frustrated-magnets-magnetic-deadlock-temperatures.html>

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