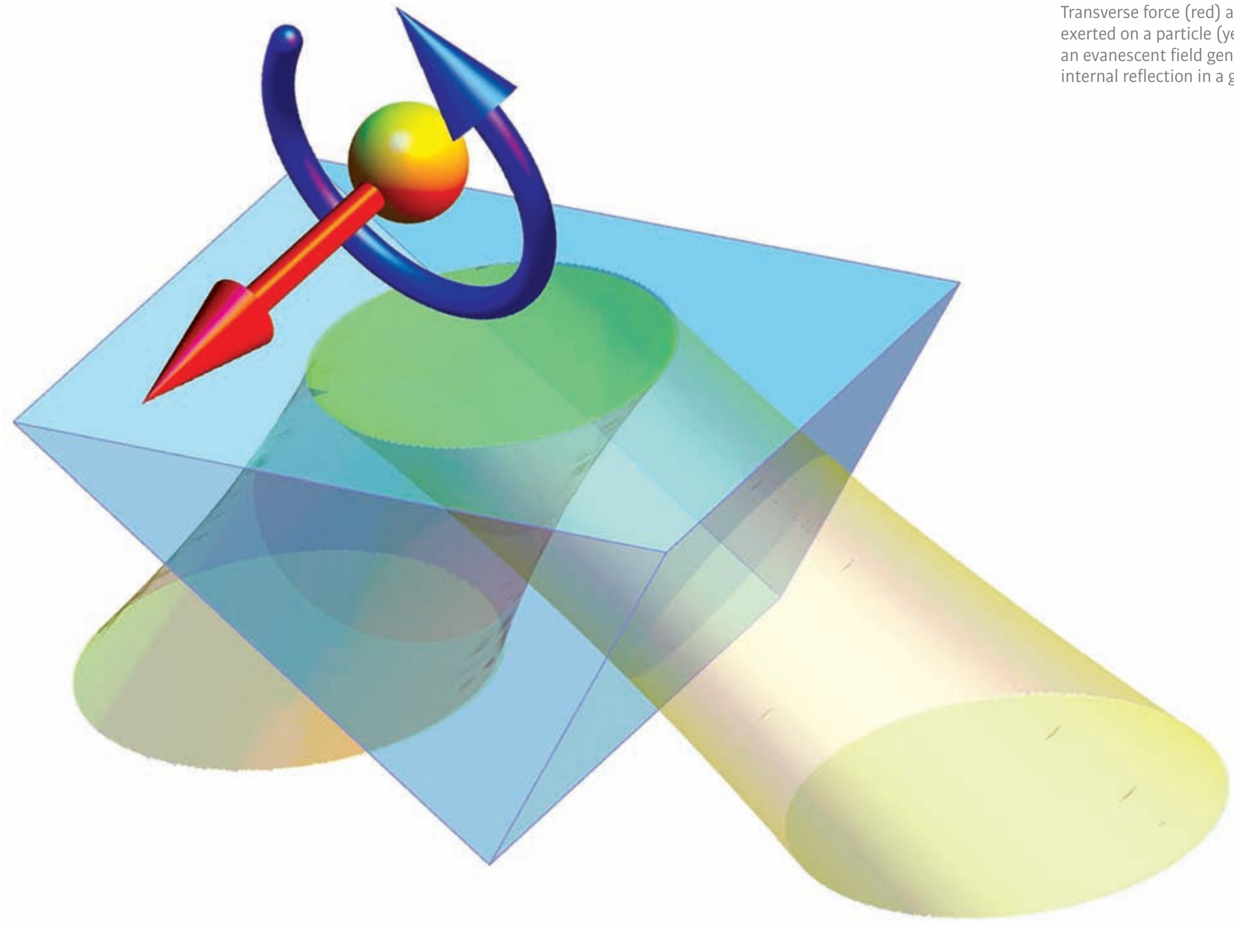


Transverse force (red) and torque (blue) exerted on a particle (yellow sphere) in an evanescent field generated by total internal reflection in a glass prism.

A new twist in the properties of light

Evanescent electromagnetic waves are found to have very different fundamental dynamical properties to those of normal light

Light has some well-established dynamical properties that have defined our understanding of electromagnetic radiation for over a century. Two of the most fundamental of these properties are that photons of light carry momentum in the direction of propagation, and a 'spin' about the propagation axis defined by the electromagnetic wave's circular polarization. These properties play critical roles in a range of everyday phenomena and experimental interactions between light and matter.

Konstantin Bliokh from the RIKEN Interdisciplinary Theoretical Science Research Group (iTHES) and Aleksandr Bekshaev and Franco Nori from the RIKEN Center for Emergent Matter Science have now made the remarkable discovery that a particular type of light known as evanescent waves possesses unexpected dynamical properties that are in sharp contrast with previous knowledge about light and photons[1].

Evanescent waves are produced, for example, when light undergoes total internal reflection at a boundary with another medium. In such situations, the main electromagnetic wave is reflected back into the originating medium and an evanescent wave is produced in the second medium. The evanescent wave decays rapidly away from the boundary but can propagate along the interface.

By investigating the dynamic characteristics of evanescent waves, Nori's team discovered that the momentum and spin of these waves have transverse components that are oriented at right angles to the plane of propagation. Equally surprising, they also found that the transverse momentum, and not the transverse spin, is determined by the wave's circular polarization—precisely the opposite to the dependence seen in normal light.

"Although these extraordinary properties seem to be in contradiction with what is known about photons," explains Bliokh, "we have shown that they reveal what is known as 'spin momentum'—an enigmatic quantity that was introduced more than 70 years ago to explain the spin of quantum particles."

The research team's analysis suggests that these extraordinary properties of evanescent waves do in fact manifest in light–matter interactions, potentially leading to effects that are impossible to achieve and observe using normal light. For example, evanescent waves exert a transverse force and a transverse torque on small particles, where the force is dependent on the circular polarization but the torque is not (see image).

"Such remarkable properties, revealed in very basic objects, offer a unique opportunity to investigate and observe fundamental physical features that were previously hidden in usual propagating light and were considered impossible," concludes Bliokh. ■

Reference

1. Bliokh, K. Y., Bekshaev, A. Y. & Nori, F. Extraordinary momentum and spin in evanescent waves. *Nature Communications* **5,** 3300 (2014).

A quick chill releases magnetic frustration

The delicate interplay between electronic properties and crystal structure explains how 'frustrated' magnets escape magnetic deadlock at low temperatures

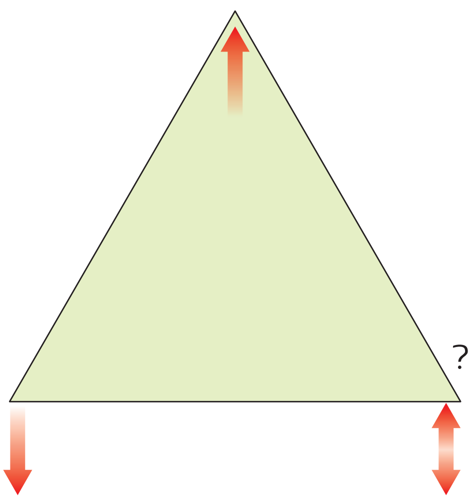
Magnetism in a material arises from how its electrons behave, which is influenced by the material's structure and the way that atoms and magnetic 'spins' of electrons are ordered within it. Frustrated magnets are a special type of magnet in which the crystal structure prevents the most energetically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

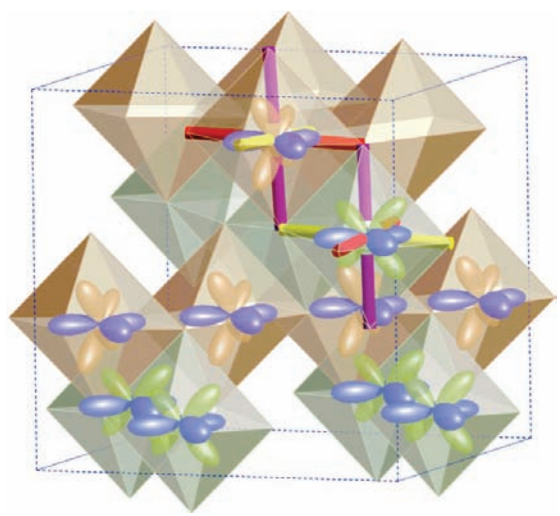
Seiji Niitaka from the RIKEN Low Temperature Physics Laboratory, Hidenori Takagi from the RIKEN Magnetic Materials Laboratory and colleagues from other RIKEN centers and Japanese institutions have now discovered how small changes in crystal structure can help such magnets release their frustration[1].

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 (see image). 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





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).