New study shows unique magnetic transitions in quasicrystal-like structures

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A breakthrough study unravels the presence of unique magnetic transitions in peculiar structures similar to Quasicrystals. Credit: Tokyo University of Science

In the world of materials science, many have heard of crystals—highly ordered structures in which atoms are arranged in a tight and periodic manner (in which the atomic arrangement is repeated). But, not many people know about quasicrystals, which are unique structures with strange atomic arrangements. Like crystals, quasicrystals are also tightly arranged, but what's different about them is the fact that they possess an unprecedented pentagonal symmetry, such that the atomic arrangement is highly ordered but not periodic.

This distinctive feature gives them unique properties, like high stability, resistance to heat, and low friction. Since their discovery only about 30 years ago, scientists globally have been trying to understand the properties of quasicrystals, in an effort to make more advancements in materials research. But, this is not easy, as quasicrystals are not prevalent in nature. Luckily, they have been able to make use of structures similar to quasicrystals, called "Tsai-type approximants." Understanding these structures in detail could give insights into the many properties of quasicrystals. One such property is antiferromagnetism, in which magnetic moments are aligned in a quasiperiodic order, strikingly distinguished from conventional antiferromagnets. This property has never been observed in quasicrystals so far, but the possibility was exciting for materials scientists, as it could be a gateway to a plethora of new applications.

In a new study published in *Physical Review B: Rapid Communications*, a team of scientists at Tokyo University of Science, led by Prof Ryuji Tamura, found for the first time that a type of Tsai-type approximant exhibits an antiferromagnetic transition. This was an exciting finding, as it suggested that even quasicrystals could show such a transition. The scientists already knew that Tsai-type approximants have two different variants: 1/1 and 2/1 approximants.

The main difference between the two is that 2/1 approximants contain an additional rhombohedral unit in their structure, which is absent in the 1/1 type, making them even more highly ordered and closer to the structure of quasicrystals. And this is why the scientists wanted to see the conditions in which 2/1 approximants could show antiferromagnetism; it created a possibility of seeing this new property even in quasicrystals. Prof Tamura says, "Antiferromagnetic transitions have been observed in 1/1 approximants, but we observed it in a 2/1 approximant for the first time. This is interesting because unlike the 1/1 approximant, the 2/1 approximant contains all the components necessary to construct a quasicrystal."

To take a closer look at the magnetic properties of 2/1 approximants, the scientists synthesized metallic alloys with a crystalline structure, which contained both 1/1 and 2/1 approximants. By using a device called the superconducting quantum interference device (SQUID), they studied the conditions under which the approximants showed different magnetic properties. Interestingly, they found that a single parameter dictates the presence of antiferromagnetism in both types of approximants. This was the ratio of electron per atom, which slightly differed in the two types. By manipulating the electron-per-atom ratio, Prof Tamura and his team saw a "transition" to an antiferromagnetic state in both types of approximants. This property had been seen in the 1/1 type before but never in the 2/1 approximant. This was an exciting development, as the highly ordered structure of the 2/1 approximant meant that it could be used to generate quasicrystals, making this the very first study to show the possibility of antiferromagnetic quasicrystals.

Elaborating on their findings, Prof Tamura says, "We succeeded in observing, for the first time, antiferromagnetic transitions in the 1/1 and 2/1 AFM approximants in the *same* alloy system." He adds, "Our finding clearly shows that the antiferromagnetic order survives in the 2/1 higher-order approximant, which has all the building blocks for creating a quasicrystal."

The significance of quasicrystals—such as in routine applications like making frying pans and needles for acupuncture and surgery—is well known. But, given their very recent discovery, not much has been understood about what makes them so unique. By showing the existence of antiferromagnetism in a quasicrystal-like structure, Prof Tamura and his team have potentially paved the way for greater developments in quasicrystal research. Prof Tamura concludes by saying, "Antiferromagnetic quasicrystals had never been seen before, and this discovery has a great academic impact." He adds, "The possibility of the existence of antiferromagnetic quasicrystals is a big step towards deciphering the mystery of quasicrystals."

More information: S. Yoshida et al, Antiferromagnetic order survives in the higher-order quasicrystal approximant, *Physical Review B* (2019). DOI: 10.1103/PhysRevB.100.180409

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