Can quantum antiferromagnets reveal secrets of bosonic supersolids?

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"One of the fundamental issues in physics right now – and for the past many years – is whether or not bosons can form a supersolid phase," Frédéric Mila tells *PhysOrg.com*. Mila is a scientist at the Institute of Theoretical Physics at École Polytechnique Fédérale in Lausanne Switzerland. "We show how a supersolid phase may be achieved in a quantum antiferromagnet."

Mila worked with Schmidt and Dorier, also at EPFL, and with Läuchli at the IRRMA in Lausanne on this project. Their work, which relies on a model of bosons with correlated hopping, is described in *Physical Review Letters*: "Supersolid Phase Induced by Correlated Hopping in Spin-1/2 Frustrated Quantum Magnets."

"One of the issues has been whether or not a boson system can simultaneously form a superfluid and a crystal at the same place," Mila says. "Most of the work has been done with helium-4, but at this point it is still debated whether a supersolid phase can be realized. But," he continues, "for bosons already on a lattice, it may be easier to make a superlattice and realize a supersolid which may be seen in nature."

In and email, Mila explains that one difference from the main approach to inducing a supersolid state in actual bosons (like helium-4) is to "deal with effective spin 1 triplet excitations induced by a magnetic field in certain quantum antiferromagnets, such as dimer models realized for instance in several copper oxides."

Indeed, these excitations behave like bosons - those particles, such as photons or pions, with integral or zero spin. “The analogy between bosons and quantum magnets has proven to be very fruitful during the past ten years,” Mila says, “and there is a one-to-one correspondence between spin supersolid and bosonic supersolid.”

Additionally, Mila reports, the Lausanne team also made use of frustration in quantum magnets to induce correlated hopping between these bosons, whereby a boson can hop provided there is another boson nearby. This correlated hopping forms the basis of the model that Mila and his peers investigated: “Our paper shows that if bosonic triplets move through correlated hopping, the system will want to form a local solid order in order to gain kinetic energy,” Mila says, “thus realizing a spin supersolid”.

Mila admits that right now this work is still speculative: “So far compelling evidences have not been detected in the best copper oxide candidate [$SrCu_2(BO_3)_2$].” Mila points out that, “a supersolid is expected to undergo two phase transitions upon lowering the temperature where the two types of order develop, and only one has been reported in that compound. One cannot exclude that experiments were not performed at low enough temperature, but this could be due as well to anisotropy effects.”

There is potential for future uses of bosons that could display two orders in the same system. “First of all,” Mila says, “experimentally and fundamentally it would be interesting.” But there are also possible materials applications. “As far as the future goes, there is general agreement that materials that could have two different types of orders at once would be interesting.” He is quick to qualify: “Of course, we are very far from any such applications.”

For now, though, Mila is content to try and pursue the experimental route. “Our first interest is actually to convince experimentalists to look at quantum magnetism to see if there could be a supersolid phase.”