Learning more about phase transitions in small systems

June 23 2011, By Miranda Marquit

(PhysOrg.com) -- "People want to understand phase transitions in a finite system by quantum simulation," Luming Duan tells *PhysOrg.com*. Duan is a professor at the University of Michigan, located in Ann Arbor. "Being able to see a sharp phase transition in a small finite system is unusual and would help us better understand the strength and limitation of quantum simulation. Quantum simulation is a useful tool to study the properties of new materials." So far, it has been difficult to observe sharp phase transitions in such small systems Duan, though, believes that it is possible to create a way to observe sharp transitions in small quantum systems associated with the trapped ion experiments.

Duan, along with G.-D. Lin, also at the University of Michigan, and C. Monroe, at the University of Maryland in College Park, has been working on a way to observe a sharp phase transition with just a few atomic spins. Their work is published in Physical Review Letters: “Sharp Phase Transitions in a Small Frustrated Network of Trapped Ion Spins.”

“Usually we only see sharp phase transitions in large systems,” Duan says. “In large systems, we see the sharp transition, such as from water to vapor, or water to ice.” However, in small systems it is harder to see such sharp transitions. Duan and his colleagues made a theoretical prediction about how it should be possible to observe sharp phase transitions with a small system of only a few atomic ions having long-range interaction with each other.

Understanding phase transitions in a finite system is important,

according to Duan. “We use quantum simulations from a finite system to try to understand new material in the bulk limit,” he points out. “The results can help us learn more about how the phenomenon in a small finite system simulates the physics in the many-body limit.”

In order to observe these phase transitions, Duan suggests that frustrated spins can be useful. “The unusual finite-size scaling laws in a frustrated spin network can be helpful in seeing phase transitions,” he says. An experiment meant to help scientists to see a sharp phase transition could be set up by controlling the parameter that determines spin. As the spin network becomes frustrated, a variety of spin orders would emerge, and certain couplings would allow for the expected sharp transitions between different types of ground states.

Right now, Duan believes that the technology exists to conduct an experiment to prove the theoretical prediction of an observable sharp phase transition in a small quantum system. “One major requirement to detect sharp phase transitions is the timescale of experiments,” Duan says. “You need a pretty long coherence time for this type of experiment.” However, Duan says that some experimental group can already meet the requirements.

“We need to understand the phase transition in a finite system,” Duan insists. “Phase transitions in a controllable finite quantum systems would allow us to find similar characteristics between different materials, and provide a way to look at new quantum materials.”

The use of frustrated spin networks in small systems to see sharp phase transitions might also be useful in understanding the importance of finite-size scaling. “We need to understand how the properties of a system changes as the system size varies,” Duan says. “If you can see sharp phase transitions in a smaller system, as well as a large system, this offers a significant implication for application of quantum simulation in

the future."

More information: G.-D. Lin, C. Monroe, and L.-M. Duan, "Sharp Phase Transitions in a Small Frustrated Network of Trapped Ion Spins," *Physical Review Letters* (2011). Available online: link.aps.org/doi/10.1103/PhysRevLett.106.230402