Current theories can't explain observed spin segregation

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(PhysOrg.com) -- Experiments with quantum systems sometimes yield surprising results. This is exactly what happened when John Thomas, a researcher at Duke University in Durham, North Carolina found out when he and his post doc, Du, and his students Luo and Clancy, attempted to study a trapped cloud of Fermi atoms all initially in the same quantum superposition of spin-up and spin-down states. They expected all of the atoms to move uniformly back and forth in the trap. Instead, the atoms moved in a way that not predicted using existing theory.

The results of their experiment can be found in *Physical Review Letters*: “Observation of Anomalous Spin Segregation in a Trapped Fermi Gas.”

“It was nuts,” Thomas tells *PhysOrg.com*. “The atoms in this prepared gas didn’t behave at all as one would expect. We thought we’d be doing something simple, and now we’re attempting to understand something we didn’t expect.”

Thomas explains that particles known as fermions (which make up the Fermi gas) act in a way that is very similar to electrons: When they are put in the same quantum spin state, or q-bit, they tend to avoid each other. This is useful in a variety of applications related to quantum computing because this prevents particles from colliding with each other, destroying information. As a result, fermions are being considered in the development of quantum memory, since they would (theoretically) avoid each other and remain coherent.

Thomas and his team wanted create a collection of fermions in identical quantum spin states by applying a radio frequency field. “We set up an experiment in which we used a very cold gas of lithium-6, all initially in the spin-up state,” he says. “We trapped these fermions in a laser beam, a sort of bowl made of light. We put about 100,000 atoms in this optical bowl and attempted to use a radiofrequency (rf) field to prepare them all in the same state of super position, which is 50 percent spin-up and 50 percent spin-down.”

At first, it looked as though all was as it should be. Thomas and his colleagues took images of the atoms just after applying the rf field, and found that immediately following the change, the fermions behaved as expected. “But, after tenths of a second,” Thomas continues, “we saw that things were different. The spin-downs were moving to the edges of the bowl, and the spin-ups were moving to the center, remaining in this pattern for several seconds.”

Thomas and his students began considering explanations for the phenomenon. “We know that this segregation does not arise from ordinary forces between the atoms, which are far too small to explain the observed effects. We believe that the segregation arises from the formation of a spin-wave, but the size of the effect that we observe is much larger and the timescale over which it occurs is much longer than predicted by existing spin-wave theory.”

On a practical level, it seems as though the idea of using a collection of fermions for quantum memory will have to be revisited. At the fundamental physics level, a lot more study is needed. “Ultimately we’ll do more on this,” Thomas says, “because it’s something that we want to understand. But we are waiting for help from theorists. We’d like to have theoretical feedback so that there are other facets to test.”