# Cross-Dressing Rubidium May Reveal Clues for Exotic Computing

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(PhysOrg.com) -- Neutral atoms--having no net electric charge--usually don't act very dramatically around a magnetic field. But by “dressing them up” with light, researchers at the Joint Quantum Institute, a collaborative venture of the National Institute of Standards and Technology and the University of Maryland at College Park, have caused ultracold rubidium atoms to undergo a startling transformation.

They force neutral atoms to act like pointlike charged particles that can undergo merry-go-round-like “cyclotron” motions just as electrons do when subjected to a suitable magnetic field. This extreme makeover for ultracold atoms promises to give physicists clues on how to achieve an exotic form of computation that would rely upon special “fractionally charged” particles dancing around on a surface.

Just as good theatrical plays provide teachable insights about complex human situations, ultracold atomic gases are ideal proxies for studying complex phenomena in physics. Since it is relatively easy to manipulate the energy levels of ultracold atoms in gases and to control the interactions between them, scientists can learn important clues about physical phenomena that occur in more complicated and less controllable liquid or solid systems.

Among such complex phenomena are the quantum Hall and fractional quantum Hall effects, the subjects of the 1985 and 1998 Nobel Prizes in physics. In the latter effect, low-temperature electrons, confined to a plane and placed in high magnetic fields, can act as if they form "quasiparticles" carrying a fraction of an electric charge as well as several bundles of magnetism known as "magnetic flux quanta." Physicists believe an as-yet-unseen configuration of such quasiparticles might provide a practical system for achieving "topological quantum computing," in which quasiparticles on a two-dimensional surface would be able to perform powerful logic operations that obey the particular rules of quantum mechanics.

With this goal in mind, postdoc Yu-Ju Lin, physicist Ian Spielman and the rest of the JQI team have set out to make a gas of neutral atoms behave like electrically charged particles. They couldn't simply add electric charges to the atoms, or play around with electrons themselves because their mutual electrical repulsion would cause the cloud to fly apart.

In their experiment, they cause a gas of rubidium-87 to form an ultracold state of matter known as a Bose-Einstein condensate. Then, laser light from two opposite directions bathes or "dresses" the rubidium atoms in the gas. The laser light interacts with the atoms, shifting their energy levels in a peculiar momentum-dependent manner. One nifty consequence of this is that the atoms now react to a magnetic field gradient in a way mathematically identical to the reaction of charged particles like electrons to a uniform magnetic field. "We can make our neutral atoms have the same equations of motion as charged particles do in a magnetic field," says Spielman.

In this first experiment, Spielman and colleagues have effectively "put an electric charge" on atoms, but haven't "turned on the field." In subsequent experiments, they plan to introduce an effective magnetic field and watch "electrified" rubidium atoms go on their merry cyclotron ways, with the goal of revealing new insights about the fractional quantum Hall effect and topological computing. Stay tuned!

*More information: Y.-J. Lin, R.L. Compton, A.R. Perry, W.D. Phillips, J.V. Porto and I.B. Spielman, A Bose-Einstein condensate in a uniform light-induced vector potential. *Physical Review Letters* (forthcoming).

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