Researcher studies unsolved problem of interacting objects

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Daniel Sheehy is an assistant professor of physics at Louisiana State University. Credit: Daniel Sheehy, Louisiana State University

(Phys.org) —One of science's biggest puzzles is figuring out how interacting objects behave collectively. Take water, for example. "It's a molecule, but it's also a liquid with specific properties," says Daniel Sheehy, an assistant professor of physics at Louisiana State University. "How does the liquid come from the microscopic action of these water molecules?"

Sheehy doesn't study water, but he likes to use it to describe what he does study, which is many-particle quantum mechanics, that is, how atoms organize themselves at very low temperatures when they become trapped in beams of laser light, and whether they reach a superfluid state, a phenomenon that occurs only when it is extremely cold.

In a superconductor, the electrons form a superfluid which "is like a liquid, but better," Sheehy says. "It never slows down and the electrical resistance is zero, meaning none of the energy is lost."

The down side, however, is that this requires very cold temperatures to achieve, on the order of 10 kelvins (minus 263 C, minus 442 F), for conventional superconductors, which is why they generally only are used in special applications, such as in MRI machines, where they are kept cold with liquid helium.

"This is why they are not used in power lines," he says. "You would need refrigerators, which isn't very practical."

Sheehy's goal is to gain further insights that could enable more widespread uses for superconducting materials. "Might it be possible to make material that is a superconductor at ambient temperatures?" he asks. "No one knows. It is a very difficult goal, a very big goal. But we would like to use superconductors in places where they are not used now."

He is performing theoretical calculations regarding clouds of extremely cold atoms—imagine very dilute particles of gases trapped in a laser field—to see how they behave and whether they show superconducting properties. "All I want to know is if I put a million atoms in a small region and watch them interact, what can they do?" he says.

He is examining the activities of different alkali gases—those in the first column of the Periodic Table—because "they have only one outermost electron, making them easier to control," he says. "First, let's understand the simplest system we can think of so we can develop the theory. Let's fundamentally understand nature and this unsolved problem of interacting objects."

He does not conduct actual physical experiments, but is a theorist "who uses a computer, as well as paper and pencil calculations," to determine the properties of these clouds of atoms. "I am interested in the superfluid states of these atoms, which is where the particles don't have any viscosity; they flow without resistance," he says.

Sheehy is conducting his research under a National Science Foundation (NSF) Faculty Early Career Development (CAREER) award, which he received in 2012. The award supports junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education, and the integration of education and research within the context of the mission of their organization. NSF is funding his work with $428,200 over five years.

The grant's educational component includes developing more interactive materials in large-size physics classes so that they go beyond the "lecture" format, "with more hands-on activities that get them thinking," he says. "We will be trying to use Internet applications with certain computer programs that demonstrate the principles of quantum mechanics. This, hopefully, will get them to better learn physics, and get them excited about a future in science."

He also plans an outreach project to the public, and to high school and middle school students, including an in-school demonstration program aimed at inspiring the interest of minority students in science, and in pursuing science careers.

"The field of cold atoms is growing rapidly, fueled by numerous recent experimental breakthroughs, making it an ideal area for students to work in," he says. "We're working on fundamental problems that are conceptually simple but yet still intellectually stimulating and experimentally relevant."

More information: "Density profiles and collective modes of a Bose-Einstein condensate with light-induced spin-orbit coupling." Qin-Qin Lü, Daniel E. Sheehy. *Phys. Rev. A* 88, 043645 (2013) arXiv:1306.5717 [cond-mat.quant-gas] arxiv.org/abs/1306.5717

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