Distinguishing decoherence in quantum systems

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"Over the years, work on Bose-Einstein condensates, known as BEC, have led to more and more interesting phenomena," Artur Widera tells *PhysOrg.com*. "This is because they behave according to quantum mechanics, and are fairly large objects. The goal is to use them to explore opportunities in the quantum regime."

Widera, a scientist at the Johannes Gutenberg University in Mainz, Germany, believes that he and his colleagues have found a technique that can help understand the spin dynamics of one-dimensional quantum systems.

Widera worked with Stefan Trotzky, Patrick Cheinet, Simon Fölling, Fabrice Gerbier and Immanuel Bloch at Johannes Gutenberg, as well as with Vladimir Gritsev, Mikhail D. Lukin and Eugene Demler at Harvard University. The group's efforts can be seen in *Physical Review Letters*: "Quantum Spin Dynamics of Mode-Squeezed Luttinger Liquids in Two-Component Atomic Gases."

Because Bose-Einstein condensates are so large (they are comprised of hundreds of thousands of atoms), while still adhering to the rules of quantum physics, many experimentalists use them to test the properties of quantum mechanics. It is thought that such study can advance technology for use in more precise atomic clocks and sensors.

Widera, though, points out some of the difficulties encountered by scientists who use BEC to study quantum mechanics. "In experiments, we see that quantum properties somehow decay. We call this decoherence," he explains. "They do so for two main reasons. The first is technical. It usually means that we have done something wrong. The second reason is due to the interactions between atoms that go on at that level and make our signals look like decoherence. At the same time these interactions can lead to probably the most intriguing phenomena in quantum physics, namely quantum correlations."

The problem, Widera continues, is that "using the decoherence signals, so far we did not have the tools to distinguish between a technical problem and these interactions that might signal something interesting."

In order to solve this problem, Widera and his colleagues introduced a new way to try and distinguish between the different reasons for decoherence in quantum systems. The team took a BEC in its three-dimensional state and then squeezed it down into a one-dimensional trap in order to encourage more interactions.

"In solid state physics, we find that there are interesting phenomena in the lower dimensions that are not possible in three dimensions," Widera explains. "Experimentally, we used, not a single system, but an array of one-dimensional systems."

Widera says that they were able to distinguish between the decoherence caused by interactions in the BEC and by more technical issues. "Additionally, we even saw that quantum fluctuations play a big role, and that they dominate the behavior. This is a fundamental property of one-dimensional quantum systems, which in our experiment could be understood thanks to our colleagues from Harvard."

The next step, though, is to actually try and create and control the interesting interactions and correlations in the BEC. "Now, we've been able to see and understand what effects are going on," Widera points out.

“But no one’s been able to control these interactions. This would be the key to reliably create these novel quantum states.” Widera admits that they tried to do so in the experiment, but the attempt was unsuccessful. “There was too much novel physics going on which we had to understand first.”

“Right now this work deals with fundamental quantum physics,” Widera says. “Think how it will be when we know how to control these issues.”