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PHYSICS

Spooky Experiments Bring Quantum Weirdness to Nearly Macroscopic Scales

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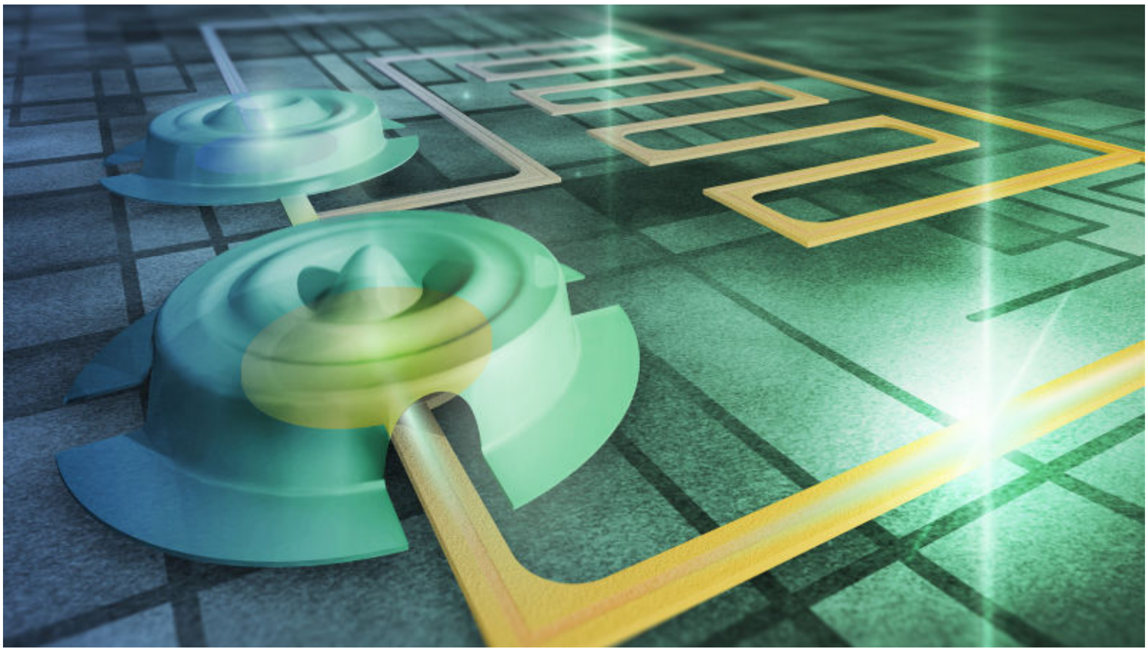

An illustration of one of the experiments, featuring two 15-micrometer vibrating drumheads. Illustration: Aalto University/Petja Hyttinen & Olli Hanhirova, ARKH Architects. (Phys.org)

Experimenters around the world are trying to harness perhaps the most perplexing property in physics: quantum entanglement, which Einstein called “spooky action at a distance.” A few teams of scientists have succeeded in bringing this eerie behavior, which normally only exists between pairs of particles, to much bigger systems.

Two of science's most prestigious journals have released a combined five articles in the past two days demonstrating entanglement's eccentricities in many-atom systems. The methods are different and have different applications: One set of papers took advantage of the weirdness of super-cold atomic clouds called Bose-Einstein condensates, while the other relied on vibrating components. But these are the kinds of advances that may bring some of quantum mechanics' quirkiest qualities into the mainstream.

"Seeing these phenomena on macroscopic scales in many-particle systems is an important step in this framework, in a field trying to control quantum behavior on larger scales and use them in technology and eventually everyday objects," Phillip Treutlein, one of the papers' authors from University of Basel in Switzerland, told Gizmodo.

Particles, according to quantum mechanics, must take on defined properties, like a ball at rest on one of many stairs, or a ball that can only be one of a few colors. But if these particles interact, they can become entangled, which means their inherent identity must be described together.

Think of it as a bucket full of purple balls. It drops two balls into two different black boxes but its color doesn't change at all—so these two balls must both be purple. You separate the balls hundreds of miles and open up your box, and suddenly, your ball is red. You call your friend with the other box—she tells you that hers is now blue.

"Easy," you think—the bucket must have been purple because it was mixed with red and blue balls all along. Nope! That would only work if this was classical mechanics. From what we can tell, in quantum mechanics, the balls were purple until you opened your box. You can tell whether you had all purple balls (entangled) or just red and blue balls (not entangled) by applying special kinds of measurements on your own box. Those measurements should immediately change the color of the other ball if they were entangled. Doing these kinds of measurements is called "Einstein-Podolsky-Rosen steering."

Three of the papers, those published in *Science,* do exactly this—except rather than purple balls, their bucket had tens of thousands of Rubidium atoms on a tabletop. Instead of red and blue, they were in one of two quantum states, and then split into two clouds instead into two black boxes. In every case, measurement of the two clouds revealed the spooky, entangled correlation.

"The three papers used systems of different sizes, demonstrated different types of entanglement, and used different entanglement-detection techniques," Daniel Cavalcanti at the Institute of Photonic Sciences in Barcelona, Spain told Gizmodo. "I believe that this could open up a variety of new experiments exploiting these systems for applications in quantum information and sensing, as well as more foundational questions," like where things stop behaving classical and start behaving quantum, for example.

Treutlein also saw potential applications in precision measurement devices—after all, they're not all that different in setup from atomic clocks currently in use.

The two papers published in *Nature* use a completely different method, with mechanical vibrating objects held near absolute zero, essentially trying to find a way to construct the purple state from the red and blue ones. In one, light was split and passed on a complex path through specially fabricated micrometer-length silicon beams, which vibrate as a result, and then into a detector—since you can't tell which beam it passed through, the beams are entangled. In the second experiment, teeny drum heads are connected in an electrical circuit. Microwaves are introduced into the circuit, which creates quantum-correlated vibrations in the drumheads.

Each of these two experimental setups have strengths—the former has the ability to exist in its entangled state over very long distances, study author Sungkun Hong of the University of Vienna told Gizmodo. A *Nature* comment calls the other "particularly striking," since it can remain in its entangled state for a seemingly arbitrarily long time, and doesn't require as precisely engineered parts. Each method may one day find use applying quantum entanglement to create super-secure communications links.

Just because these advances are exciting doesn't mean their applications are around the corner, though. Hong said engineers will still need to figure out a way to perfectly fabricate his team's objects in such a way that their quantum state isn't destroyed. But he's hopeful that engineering limitations can be overcome.

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There's clearly lots of interest in applying the weirdness of quantum mechanics to real-world problems that are interesting to more people than just theoretical physicists. But doing so will require more than just entangling a few atoms—it will require macroscopic systems that aren't so fragile that any nudge destroys the spooky entangled connection. With experiments like these, applications are inching ever closer.

[Science 1, 2, 3, Nature 1, 2]

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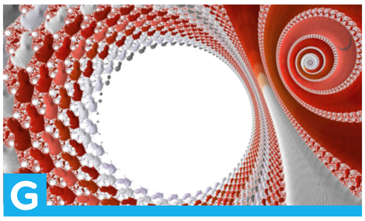

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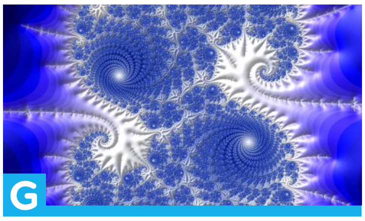

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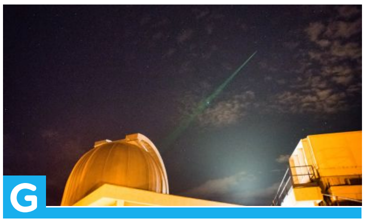

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