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Physicists repair flaw of established quantum resource theorem

Quantum information theory is a field of study that examines how quantum technologies store and process information. Over the past decades, researchers have introduced several new quantum information frameworks and theories that are informing the development of quantum computers and other devices that operate leveraging quantum mechanical effects.

These include so-called resource theories, which outline the transformations that can take place in quantum systems when only a limited number of operations are allowed.

In 2008, two scientists at Imperial College London introduced what they termed the generalized quantum Stein's lemma, a mathematical theorem that describes how well quantum states can be distinguished from one another. In this generalized setting, one typically considers multiple identical copies of a specific state (the null hypothesis) and tests them against a composite alternative hypothesis, i.e., a set of states (e.g., resource-free states).

Researchers at the Chinese University of Hong Kong, Shenzhen (CUHK-Shenzhen) and the University of Tokyo re-examined this mathematical theorem and tried to fix a flaw of the theorem that was first identified a few years ago.

Their paper, published in *Nature Physics*, introduces new rules that repair the gap in the quantum Stein's lemma, restoring confidence in the theorem and improving the current understanding of quantum information systems.

https://phys.org/news/2025-12-physicists-flaw-quantum-resource-theorem.html

Dual-cation strategy boosts upconversion efficiency in stable oxide perovskites

Researchers at the Hefei Institutes of Physical Science of the Chinese Academy of Sciences have developed a new way to significantly enhance upconversion luminescence in oxide perovskites, a class of materials known for their thermal and chemical stability but limited optical efficiency.

Led by Professor Jiang Changlong, the team introduced a dual-cation substitution strategy in titanate perovskites by precisely adjusting the sodium-to-lithium ratio at the crystal's A-site. This controlled substitution triggers a structural transition that improves energy transfer between rare-earth ions, resulting in a marked increase in luminescence intensity and quantum yield.

The findings are published in *Journal of Alloys and Compounds*.

Efficient and stable luminescent materials are in growing demand for applications such as solid-state lighting, full-color displays and secure anti-counterfeiting. While fluoride-based upconversion materials can deliver high efficiency, they often suffer from poor long-term stability. Oxide perovskites offer greater robustness, but their use has been restricted by low efficiency and thermal quenching.

In this study, the researchers synthesized a series of dual-cation titanate perovskites with the formula $Li(1-x)NaxLaTi_2O_6$, doped with Yb^{3+}/Er^{3+} or Yb^{3+}/Tm^{3+} ion pairs. Replacing Li^+ with Na^+ induces a phase transition from a tetragonal to a rhombohedral structure, which alters the local crystal field around the luminescent ions and enables more efficient energy transfer.

https://phys.org/news/2025-12-dual-cation-strategy-boosts-upconversion.html

Ultracold atoms observed climbing a quantum staircase

For the first time, scientists have observed the iconic Shapiro steps, a staircase-like quantum effect, in ultracold atoms.

In a recent experiment, an alternating current was applied to a Josephson junction formed by atoms cooled to near absolute zero and separated by an extremely thin barrier of laser light. Remarkably, the atoms were able to cross this barrier collectively and without energy loss, behaving as if the barrier were transparent, thanks to quantum tunneling.

As the oscillating current flowed through the junction, the difference in chemical potential between the two sides did not change smoothly, but instead increased in discrete, evenly spaced steps, like climbing a quantum staircase. The height of each step is directly determined by the frequency of the applied current, and these step-like chemical potential differences are the atomic analog of Shapiro steps in conventional Josephson junctions.

The findings are published in the journal *Science*.

The experimental team at the European Laboratory for Non-Linear Spectroscopy (LENS) in Sesto Fiorentino, Italy, carried out the study in collaboration with researchers from the National Institute of Optics (CNR-INO), the University of Florence, the University of Catania, the Technology Innovation Institute (TII) in Abu Dhabi, and the National Autonomous University of Mexico (UNAM).

A complementary study carried out at RPTU University of Kaiserslautern-Landau was also published in the same issue of *Science* in a back-to-back format.

https://phys.org/news/2025-12-ultracold-atoms-climbing-quantum-staircase.html

Why a chiral magnet is a direction-dependent street for electrons

RIKEN physicists have discovered for the first time why the magnitude of the electron flow depends on direction in a special kind of magnet. This finding could help to realize future low-energy devices.

The work is published in the journal *Science Advances*.

In a normal magnet, all the spins of electrons point in the same direction. In a special class of magnets known as chiral magnets, the electron spins resemble a spiral staircase, having a helical organization.

This structure imparts chiral magnets with special magnetic and electronic properties. For example, electrons can preferably flow along them in one direction but not another. This effect is akin to what occurs in diodes, except it occurs within a single material rather than in a junction between two semiconductors.

Chiral magnets and electron flow

Chiral magnetics could have practical applications since they can host tiny magnetic whirlpools known as skyrmions, which are promising for realizing memory devices that have low energy consumption.

Several mechanisms have been proposed for the direction-dependent flow of electrons in chiral magnets, but no previous study had successfully separated and assigned multiple mechanisms in a single material.

Understanding what causes the effect has been important, as it would help physicists to exploit it better.

https://phys.org/news/2025-12-chiral-magnet-street-electrons.html

Anything-goes 'anyons' may be at the root of surprising quantum experiments

In the past year, two separate experiments in two different materials captured the same confounding scenario: the coexistence of superconductivity and magnetism. Scientists had assumed that these two quantum states are mutually exclusive; the presence of one should inherently destroy the other.

Now, theoretical physicists at MIT have an explanation for how this Jekyll-and-Hyde duality could emerge. In a paper published in the *Proceedings of the National Academy of Sciences*, the team proposes that under certain conditions, a magnetic material's electrons could splinter into fractions of themselves to form quasiparticles known as "anyons." In certain fractions, the quasiparticles should flow together without friction, similar to how regular electrons can pair up to flow in conventional superconductors.

If the team's scenario is correct, it would introduce an entirely new form of superconductivity—one that persists in the presence of magnetism and involves a supercurrent of exotic anyons rather than everyday electrons.

"Many more experiments are needed before one can declare victory," says study lead author Senthil Todadri, the William and Emma Rogers Professor of Physics at MIT. "But this theory is very promising and shows that there can be new ways in which the phenomenon of superconductivity can arise."

What's more, if the idea of superconducting anyons can be confirmed and controlled in other materials, it could provide a new way to design stable qubits—atomic-scale "bits" that interact quantum mechanically to process information and carry out complex computations far more efficiently than conventional computer bits.

https://phys.org/news/2025-12-anyons-root-quantum.html

Bazinga! Physicists crack a 'Big Bang Theory' problem that could help explain dark matter

A professor at the University of Cincinnati and his colleagues have figured out something two of America's most famous fictional physicists couldn't: how to theoretically produce subatomic particles called axions in fusion reactors.

Particle physicists Sheldon Cooper and Leonard Hofstadter, roommates in the sitcom "The Big Bang Theory," worked on the problem in three episodes of Season 5, but couldn't crack it.

Now UC physics Professor Jure Zupan and his theoretical physicist co-authors at the Fermi National Laboratory, MIT and Technion–Israel Institute of Technology think they have one solution in a study published in the *Journal of High Energy Physics*.

Axions are hypothetical particles that physicists suspect could help explain dark matter. Researchers are interested in dark matter because it helps explain the evolution of the universe after its creation in the Big Bang nearly 14 billion years ago.

Dark matter has never been observed directly, but physicists believe it represents a majority of the mass in the universe that is attributed to matter, while only a fraction is due to normal, visible matter. Dark matter is called dark because unlike normal matter, it does not absorb or reflect light.

Nevertheless, physicists have identified its existence through its gravitational effects, modifying the motion of galaxies in the universe and stars in the galaxies. One of the main theoretical possibilities for dark matter is that it is a very light particle, the so-called axion.

https://phys.org/news/2025-12-bazinga-physicists-big-theory-problem.html

Laser light and the quantum nature of gravity: Proposed experiment could measure graviton energy exchange

When two black holes merge or two neutron stars collide, gravitational waves can be generated. They spread at the speed of light and cause tiny distortions in space-time. Albert Einstein predicted their existence, and the first direct experimental observation dates from 2015.

Now, Prof. Ralf Schützhold, theoretical physicist at the Helmholtz-Zentrum Dresden-Rossendorf (HZDR), is going one step further. He has conceived an experiment through which gravitational waves can not only be observed but even manipulated. Published in the journal *Physical Review Letters*, the idea could also deliver new insights into the hitherto only conjectured quantum nature of gravity.

"Gravity affects everything, including light," says Schützhold. And this interaction also occurs when gravitational waves and light waves meet.

Schützhold's idea is to transfer tiny packets of energy from a light wave to a gravitational wave. By doing so, the energy of the light wave is reduced slightly, and the energy of the gravitational wave is increased by the same amount. This energy is equal to that of one or several gravitons, the exchange particles of gravity that have been postulated in theoretical models, but not yet proven.

"It would make the gravitational wave a tiny bit more intense," explains the physicist. The light wave, on the other hand, loses exactly the same amount of energy, which leads to a minute change in the light wave's frequency.

"The process can work the other way around, too," Schützhold continues. In this case, the gravitational wave dispenses an energy package to the light wave. It should be possible to measure both effects, that is, the stimulated emission and absorption of gravitons, albeit with considerable experimental effort.

https://phys.org/news/2025-12-laser-quantum-nature-gravity-graviton.html

Thank you!

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