SCIENCE FLASH NEWS

No. 3/2025
March

The first comprehensive characterization of unconventional superconductivity arising from multipolar moments

Superconductivity is a quantum phenomenon, observed in some materials, that entails the ability to conduct electricity with no resistance below a critical temperature. Over the past few years, physicists and material scientists have been trying to identify materials exhibiting this property (i.e., superconductors), while also gathering new insights about its underlying physical processes.

Superconductors can be broadly divided into two categories: conventional and unconventional superconductors. In conventional superconductors, electron pairs (i.e., Cooper pairs) form due to phonon-mediated interactions, resulting in a superconducting gap that follows an isotropic s-wave symmetry. On the other hand, in unconventional superconductors, this gap can present nodes (i.e., points at which the superconducting gap vanishes), producing a d-wave or multi-gap symmetry.

Researchers at the University of Tokyo recently carried out a study aimed at better understanding the unconventional superconductivity previously observed in a rare-earth intermetallic compound, called $PrTi_2Al_{20}$, which is known to arise from a multipolar-ordered state. Their findings, published in *Nature Communications*, suggest that there is a connection between quadrupolar interactions and superconductivity in this material.

https://phys.org/news/2025-03-comprehensive-characterization-unconventional-superconductivity-multipolar.html

Quantum imaging method developed for enhanced image clarity

For decades, quantum imaging has promised sharper images and greater light sensitivity than classical methods by exploiting the unique properties of quantum light, such as photon entanglement. But the approaches to do so rely on delicate, specially engineered light sources that are easily overwhelmed by real-world noise, and it is difficult to generate quantum light bright enough for practical use.

Fatemeh Mostafavi's team developed a quantum imaging scheme that uses advanced photon-counting sensors to extract quantum features from natural light sources and produce extraordinarily clear images. Their work is published in the journal *Applied Physics Reviews*.

"Our technique isolates the 'quantum features' hidden in ordinary light, allowing us to see what's invisible to conventional cameras," said author Mostafavi. "By carefully selecting and counting photons in the image field, we can reconstruct images with exceptional clarity, even in noisy environments where conventional imaging fails."

The researchers used a single-pixel camera with photon-number-resolving capabilities which employs a technique known as conditional photon detection that isolates specific photon interactions to filter out unwanted noise.

https://phys.org/news/2025-03-quantum-imaging-method-image-clarity.html

Might the proton decay in other places or at other times?

Does the proton decay? While this was a famous prediction of Grand Unified Theories (GUTS) developed in the 1970s and 1980s, experimentalists have ruled it out—or rather, put lower limits on its mean lifetime of about 10^{34} years. That's 24 orders of magnitude greater than the age of the universe.

But two physicists have been wondering: Could the lifetime be different in other places and at other times? Could the proton have decayed faster in the past? Could it decay faster somewhere else in the universe? They have reimagined some physics processes assuming the proton does decay and calculated possible lifetimes of around 10^{18} years. That's only eight orders of magnitude beyond the universe's lifetime. Their work was recently published in *Physical Review D*.

"People had previously asked various questions of the type, 'Are the fundamental physics parameters measured on the Earth the same elsewhere in the universe?'" said Peter Denton, a co-author at Brookhaven National Laboratory on Long Island, New York in the U.S. "One case that hadn't been investigated was the stability of the proton. Earth experiments show that the proton is incredibly stable, but those only apply here, in our part of the galaxy, and now, over the last several decades. What if proton decay depended on time or space?„

https://phys.org/news/2025-03-proton-decay.html

Scientists measure the spin-parity of charm baryons for the first time

In a new development at CERN, researchers at the LHCb collaboration have determined the spin-parity of singly heavy charm baryons for the first time, addressing a long-standing mystery in baryon research.

Singly heavy baryons are particles containing one heavy quark—which in this case is a charm quark—and two light quarks. While the existence of these particles is not new, the exact nature of their excitation modes has remained elusive.

The study, published in *Physical Review Letters*, determined the nature by measuring the spin-parity of these charm baryons. Phys.org spoke to co-author Guanyue Wan, a Ph.D. Candidate at Peking University, China.

"Our study focuses on measuring a fundamental property of the $\Xi_c(3{,}055)^+$ and $\Xi_c(3{,}055)^0$ i.e., $\Xi_c(3{,}055)^{+,0}$ baryons—its spin-parity, which describes how these particles behave under certain symmetry transformations," explained Wan.

"The study of charm baryons like $\Xi_c(3{,}055)$ is particularly intriguing because it helps us test theoretical models of quantum chromodynamics (QCD), the theory that describes the strong interaction."

Scientists have long discussed the configuration and interactions of constituent quarks, exploring multiple theoretical models with spin-parity assignments spanning from $1/2^{\pm}$ to $7/2^{+}$. Without knowing the spin-parity measurements, the excitation modes of the particles cannot be determined.

https://phys.org/news/2025-03-scientists-parity-charm-baryons.html

A possible way to generate electricity using Earth's rotational energy

A trio of physicists from Princeton University, CIT's Jet Propulsion Laboratory and Spectral Sensor Solutions, all in the U.S., is proposing the possibility of generating electricity using energy from the rotation of the Earth. In their study, published in the journal *Physical Review Research*, Christopher Chyba, Kevin Hand and Thomas Chyba tested a theory that electricity could be generated from the Earth's rotation using a special device that interacts with the Earth's magnetic field.

Over the past decade, members of the team have been toying with the idea of generating electricity using the Earth's rotation and its magnetic field, and they even published a paper describing the possibility back in 2016. That paper was met with criticism because prior theories have suggested that doing so would be impossible because any voltage created by such a device would be canceled as the electrons rearrange themselves during the generation of an electric field.

The researchers wondered what would happen if this cancelation was prevented and the voltage was instead captured. To find out, they built a special device consisting of a cylinder made of manganese-zinc ferrite, a weak conductor, which served as a magnetic shield. They then oriented the cylinder in a north-south direction set at a 57° angle. That made it perpendicular to both the Earth's rotational motion and the Earth's magnetic field.

https://phys.org/news/2025-03-generate-electricity-earth-rotational-energy.html

Thermomajorization theory provides new framework for quantifying mysterious Mpemba effect

The Mpemba effect is an intriguing physical phenomenon that causes some systems to cool faster when they are hot than when they are warm or colder. This effect was observed in various systems, including water, which sometimes freezes faster when it is hot than when it is cold.

While it is now well-documented, the Mpemba effect remains poorly understood from a theoretical standpoint. This is partly due to the methods that conventional physics theories offer for quantifying the speed with which a system relaxes (i.e., its relaxation speed).

Researchers at Kyoto University recently devised a new rigorous and unified approach for quantifying the Mpemba effect. The criterion they devised, presented in *Physical Review Letters*, is rooted in thermomajorization theory, a mathematical framework for comparing the disorder (i.e., entropy) between different thermodynamic states.

"The Mpemba effect—the counterintuitive phenomenon where a hotter system cools faster than a colder one—has fascinated scientists for decades," Tan Van Vu, co-author of the paper, told Phys.org.

"Despite recent extensive theoretical and experimental studies, a fundamental challenge remained: the detection of this effect depends on the choice of a specific distance measure used to evaluate relaxation speed. This led to inconsistencies, as the effect observed with one measure might not appear within finite time when assessed with another."

https://phys.org/news/2025-03-thermomajorization-theory-framework-quantifying-mysterious.html

Key decay mechanism behind superior biological effects of heavy-ion cancer therapy uncovered

Heavy-ion therapy, one of the most advanced radiotherapy techniques, has proven to be more effective than conventional X-rays and proton radiation in cancer treatment. However, the mechanisms behind this superior biological effectiveness remain unclear.

Published in *Physical Review X* on March 11, a new study has uncovered a key mechanism involving intermolecular Coulombic decay (ICD) in aqueous environments initiated by heavy-ion irradiation, providing insights about the effectiveness of such irradiation.

The study was conducted by researchers from the Institute of Modern Physics (IMP) of the Chinese Academy of Sciences (CAS), in collaboration with researchers from Russia's Irkutsk State University, Germany's Heidelberg University, the University of Science and Technology of China, Xi'an Jiaotong University, and Lanzhou University.

This study examined the effects of heavy-ion radiation on biomolecules at the molecular level. The researchers developed an advanced supersonic gas jet technology to produce clusters of biomolecules attached to water molecules. Pyrimidine, a fundamental structural unit of DNA bases, was selected to simulate DNA in the tissue environment and to investigate its decay mechanism after heavy-ion irradiation.

https://phys.org/news/2025-03-key-decay-mechanism-superior-biological.html

Thank you

Edited by

Adrian-Sorin Gruia, Ph.D