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1. Complex numbers in quantum mechanics

The mathematical formalism in quantum mechanics, based on the state vector in a complex Hilbert space, successfully describes experimental data. However, attempts have been made to reformulate quantum mechanics in a real Hilbert space using real numbers only. In the recent paper by M-O Renou and his co-authors, it has been shown that the theory thus formulated is not fully equivalent to the theory in a complex Hilbert space, and the discrepancy can be revealed in experiment. The difference between the results can be written as relations resembling the Bell inequalities. The idea of the experiment suggests the use of a 'quantum net,' where observers A and C each send one particle from a quantum entangled pair to observer B, who performs their common quantum measurement, thus entangling in a certain way the states remaining with A and C. Then, a correlation analysis in the spirit of the Bell test is carried out. This scheme was realized in two experiments. In [1], quantum entangled photon pairs were used, while, in [2], they were superconducting qubits controlled by microwave pulses. In both cases, it has been shown with high fidelity that the formalism of quantum mechanics in a complex Hilbert space is valid, whereas the real-number formulation is ruled out at a high level of statistical confidence. It was 43σ in [2] and 4.5σ in [1].

2. Dissipation-time uncertainty relation

In 2020, G Falasco and M Esposito (University of Luxemburg) used mathematical methods of statistical mechanics to show that the dissipation-dependent entropy production rate bounds the evolution pace of physical processes and to derive the corresponding 'dissipation-time' relation. Its limiting case is an infinite time of evolution in the absence of dissipation, i.e., the process is reversible. L-L Yan (Zhengzhou University, China) and his co-authors have performed an experiment [3], in which this relation was verified for a nonequilibrium system on the basis of laser-induced electronic transitions in a unit $^{40}Ca^{+}$ ion. Investigated was energy transfer between two dedicated levels, which were two heat baths, and the role of dissipative processes was played by transitions to other levels. Each individual transition in an ion is random, but these transitions are on average determined by the character of the dissipation. The existence of restriction on the energy transfer rate corresponding to entropy production (dissipation) and described by the dissipation-time relation was shown for the first time. These results are of importance for investigating the relation between quantum mechanics and thermodynamics and appear to be useful for quantum information facilities, because quantum operations can be sped up through dissipation control. For the limiting speed of quantum dynamics, see [4].

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3. Quantum boomerang

The Anderson localization effect was predicted as far back as 1958, but its interesting feature, the counterintuitive quantum effect called a 'quantum boomerang,' was theoretically discovered only recently, in 2019. The effect is as follows: the Anderson localization in a disordered medium in combination with time reversal symmetry results in the fact that the quantum wave packet of a particle starts propagating in the reverse direction and returns to its starting point. R Sajjad (University of California, Santa Barbara, USA) and his co-authors have become the first to experimentally observe the predicted quantum boomerang effect [5], but instead of the return of the particles themselves, they considered the return of their momenta to the initial values. A Bose–Einstein condensate of 10^7 ^7Li atoms was placed into an optical lattice, and the interatomic interaction was switched off via Feshbach resonance. The second pulsating phase-shifted lattice had a pulsed action on the atoms. Measurements have shown that the pulses received by the atoms returned to zero values with time, which is an analog of wave packet return in the quantum boomerang effect.

4. SiC-based qubit

Solid-state quantum logic cells based on spin defects are promising for use in quantum information and communication devices owing to a long coherence time and the possibility of creating optical interfaces. Of particular interest are cells in the form of neutral divacancies in silicon carbide SiC, since they are highly compatible with other semiconducting devices. However, the defect spin state readout, typically realized by observing spin-dependent fluorescence after laser excitation, is difficult. In this method, the average number of photons registered per readout cycle is $\ll 1$. In a new experimental approach developed by C P Anderson (University of Chicago, USA) and his co-authors [6], both readout within a cycle and a long-lived coherent state of nearly 5 s were achieved. This time is about two orders of magnitude longer than was reached previously for SiC-based qubits. The method of spin-charge conversion in combination with spin-selective ionization by laser pulses was used. The readout process only comes down to recording the presence or absence of an electron at the electron level after ionization. The photon signal in this case is 10^4 times stronger than in ordinary fluorescence, and the readout is much more efficient. For quantum nets, see [7].

5. Unusual radio transient

N Hurley-Walker (International Center for Radio Astronomy Research, Australia) and her colleagues have revealed an unusual variable radio source with a periodicity of 18.2 min [8], which has never been observed before. According to the archive data of low-frequency observations with the Murchison Widefield Array (MWA) radio telescopes, 71 pulses from this source were registered from January to March 2018. The pulses persisted from 30 to 60 s and contained shorter (< 0.5 s) peaks as well. The emission dispersion measure in combination with models of electron density in the Galaxy testifies to source localization within our Galaxy at a distance of 1.3 ± 0.5 kpc. It has a nonthermal spectrum with index $\alpha = -1.16$, and the brightness temperature of 10^{16} K is indicative of a coherent emission mechanism. The emission is linearly polarized at a level of $88 \pm 1\%$, which may show the presence of a strong magnetic field in the source. The origin of this unusual radio transient remains unknown. This may be a very long-period magnetar (a strongly magnetized neutron star), a white dwarf, or even a new type of cosmic object.

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