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1. Search for spin-gravitational interaction

As distinct from other fundamental interactions, the gravitational force is known from experiment not to depend directly on the spin of elementary particles. However, it can not be ruled out that, although small, the coupling constant of the spin and gravitational force is not exactly zero. Such a coupling would cause a spin-dependent local gravitational acceleration violating the equivalence principle. S-B Zhang (University of Science and Technology of China) et al. have performed a new experiment searching for spin-gravitational interactions [1]. A comagnetometer was used to compare the ratios of spin precession frequencies in ^{129}Xe and ^{131}Xe nuclei, depending on the orientation relative to the gravitational field direction. It was necessary to use two types of nuclei to exclude the contribution of the magnetic field. An additional nonmagnetic precession would testify to a spin-gravitational interaction. This interaction has not been revealed with available precision, but the restrictions on the corresponding coupling constant and on the magnitude of interactions mediated by axion-like bosons were improved 17-fold.

2. Einstein–Podolsky–Rosen paradox for two Bose–Einstein condensates

The Einstein–Podolsky–Rosen (EPR) paradox is the possibility of a simultaneous measurement of two non-commuting quantum quantities characterizing a remote system more precisely than allowed by the Heisenberg uncertainty principle in local measurements. This paradox is now known to lie completely within standard quantum mechanics, and for small systems it has been shown in several experiments. For large atomic ensembles, such as mechanical oscillators, quantum entanglement has already been demonstrated, but the precision of previous measurements was insufficient to verify the Heisenberg inequalities. P Colciaghi (University of Basel, Switzerland) and his co-authors have become the first to demonstrate the EPR paradox for two macroscopic Bose–Einstein condensates [2]. They managed to do this by using a new technique of condensate splitting into two parts and a new method of high-precision coherent spin state rotations. Microwave pulses generated entanglement between spins of 1400 ^{87}Rb atoms in a magnetic trap. Then, the condensate cloud escaped the trap, and some of the atoms were transferred to states with a zero magnetic moment, which allowed the condensate to be divided into two parts separated by ≈ 100 μm with the help of the magnetic field gradient. Spin state measurements have shown quantum entanglement of the two parts and a violation of Heisenberg relations (the EPR paradox).

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3. Dissipation in superfluid vortex rings

In the two-component model, a superfluid liquid is represented by the normal and superfluid components. In the superfluid component, quantized vortices may appear [3], by which, according to K W Schwarz's theoretical prediction of 1977, quasiparticles of the normal component scatter, which must cause vortex energy dissipation. However, direct experimental observations of the predicted effect have been absent up to now, and theoretical calculations of different groups have given different prognoses concerning the exact mechanism and the magnitude of dissipation. Y Tang (National High Magnetic Field Laboratory and Florida State University, USA) and her co-authors have performed a new experiment, where the dissipation effect in vortices was observed for the first time [4]. To this end, solid deuterium particles were added to liquid helium-4 as markers. Their motion together with vortices was observed by laser light scattering. The dissipation coefficient was calculated from the measured vortex ring compression rate. Of all the proposed theories, the model developed by L Galantucci et al. in 2020 gives the best description of the experimental results. The vortex overturn had been observed in experiment for the first time. The authors explain this phenomenon by the mutual action of gravity and dissipation.

4. Magnetic skyrmion transistor

Topologically stable field configurations, which were proposed by T Skyrme in 1961 as a model of nucleons, were discovered in 2009 as quasiparticles — skyrmions [5]. These vortex structures of atomic spins were considered promising elements for spintronics, and, in 2019, I Hong and K Lee suggested the idea of a skyrmion field transistor [6]. S Yang (Korea Research Institute of Standards and Science) et al. have demonstrated for the first time the prototype of a magnetic skyrmion transistor operating at room temperature [7]. In the multilayer $MgO/CoFeB/W/TaO_x$ system, magnetic skyrmions with a fixed spin chirality were excited. Magnetic anisotropy was controlled by an electric field, and the transistor effect was obtained, when skyrmions passed through a controlled region or were blocked.

5. Cosmological time dilation in quasar emission

The effect of cosmological time dilation has only been reliably recorded for supernovae, while for other objects the data remained ambiguous. Furthermore, some papers reported the lack of such an effect for variable quasar radiation. This effect would have been shown as redshift (z)-dependent time dilation of all variations by the law $1 + z$. A fast quasar emission variability is typically associated with processes in accretion discs near central black holes. The absence of this effect would mean that the emission becomes variable not in the sources themselves but on the way towards the observer, for example, due to gravitational lensing on black holes. A special form of quasar population evolution in time, which would compensate the law $1 + z$, was not ruled out either, but such a coincidence hardly seems probable. G F Lewis (University of Sydney, Australia) and B J Brewer (University of Auckland, New Zealand) undertook a new search for cosmological time dilation in quasar emission to register this effect reliably for the first time and to show that the negative result of the previous studies was explained by insufficient statistics [8]. Investigated in the new study were 190 quasars from the Sloan Digital Sky Survey monitored photometrically from 1998 to 2020. The hypothesis of time dilation by the law $1 + z$ turned out to be much more probable than the assumption of its lack. If the dilation law is represented as $(1 + z)^n$, then the statistical analysis gives the quantity $n = 1.28^{+0.28}_{-0.29}$, consistent with $1 + z$, although a contribution of the cosmological evolution of quasars can not be ruled out.

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