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1. Anomalous muon magnetic moment

The problem of the anomalous magnetic moment of the muon $a_{\mu} = (g - 2)/2$, a radiative correction to the gyromagnetic ratio $g = 2$ and associated with the production of virtual particles, has been known since the 1990s [1]. A discrepancy was noted between the a_{μ} value calculated within the Standard Model and measured in experiments. In particular, the effects of 'new physics' beyond the Standard Model have been used to explain it. The Muon $g - 2$ collaboration presented the results of new measurements of a_{μ} based on the precession of spins of muons decaying in a storage ring [2]. The measured value $a_{\mu} = 1165920705(148) \times 10^{-12}$ is four times more accurate than the previous value. Previously, the method based on experimental data on hadron production (the data-driven method) and the lattice QCD method were used to calculate a_{μ}. However, some inconsistencies have recently been discovered in the first approach, which casts doubt on it. In the new theoretical paper [3], the way to calculate a_{μ} was revised, and the lattice method was shown to give $a_{\mu} = 116592033(62) \times 10^{-11}$, which is consistent with the measured value at the level of $26(66) \times 10^{-11}$. This possibly solves the problem of the anomalous muon magnetic moment. Although excellent agreement between the Standard Model predictions and experiment has been achieved, the final conclusions require independent confirmations of experimental and theoretical results.

2. Muon puzzle

The problem called the 'muon puzzle' is known in cosmic ray physics. It consists in the fact that more muons than predicted by the theory are registered from extensive air showers (EASs), particle cascades in the atmosphere initiated by cosmic rays. Attempts were made to explain the observed excess by nonstandard processes, for example, by Lorentz invariance violation [4]. The ALICE detector at the Large Hadron Collider can also register muons produced in EASs. The ALICE collaboration presented data of the second run of observations (Run 2) in 2015–2018 [5]. Muons were registered when the proton beam of the accelerator was off. The results obtained were compared with the predictions of three models of hadron interactions. It was only the QGSJET-II-04 model that agreed with the data on muons on the assumption of a heavy composition of cosmic rays (iron nuclei), whereas, for a proton composition, it gives a smaller number of muons than is observed. The EPOS-LHC and SIBYLL 2.3d models predict an understated muon recording rate for any composition, although for a heavy composition their predictions are not so far from the results of measurements. The mutual disagreement of the hadron interaction models and the above-mentioned discrepancy between their predictions and the measured values may testify to a connection between the muon puzzle and the imperfection of the theoretical models.

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3. Bell test in $\Lambda\bar{\Lambda}$ system

The violation of Bell inequalities (rejection of the principle of local realism in quantum mechanics) was successfully verified at low energies, for example, in experiments with photons, while at high energies it was only quantum entanglement of quark states that was checked earlier. The Bell test with pairs of Λ hyperons (the class of baryons) in spin entangled states was performed for the first time by the BESIII collaboration at the electron–positron collider BEPCII (Institute of High Energy Physics IHEP, Beijing, China) [6]. $\Lambda\bar{\Lambda}$ pairs are produced with zero total spin, and the Λ and $\bar{\Lambda}$ spins correlate with the direction of ejection of protons appearing upon their decays. The angular distribution of proton escape corresponds to Bell inequality violation with a reliability of 5.2σ. Two of the three loopholes in the Bell test, namely, locality and free will, were excluded. Thus, the experiment with hyperons confirmed that the strong and weak interactions responsible for $\Lambda\bar{\Lambda}$ decays also obey the fundamental principles of quantum mechanics [7].

4. Postperovskite properties and the D$''$ layer

Seismic wave recording made it possible to determine with high accuracy the depth-dependent sound velocity inside Earth. In particular, the so-called D$''$ layer, in which a jump of velocity occurs, was discovered in the lower part of the mantle. The cause of the jump was not completely clear, but this phenomenon was assumed to be associated with the transformation of the texture of perovskite $MgSiO_3$, which makes up the lower mantle, to the postperovskite phase. In 2004, T. Iitaka et al. and A. Oganov and S. Ono pointed out that the jump of velocity in $MgSiO_3$ can be explained by an anisotropic transformation of the substance, when the velocity of sound begins depending on the crystal orientation. M. Murakami (Swiss Federal Institute of Technology, Zurich, Switzerland and Tohoku University, Japan) et al. were the first to obtain an experimental confirmation of this assumption for the perovskite $MgGeO_3$, whose properties are similar to $MgSiO_3$ [8]. The experiment was performed in a diamond anvil at a pressure up to 115 GPa, and the substance structure was studied by synchrotron X-ray diffraction. An anisotropic transformation and a jump of the velocity of sound, which explained the properties of the D$''$ layer, were found. In the Earth, an alignment of crystals probably results from the flow of rock along the interface between the core and the mantle.

5. A distant galaxy

Observations by the James Webb Space Telescope have shown that galaxies at redshifts $z > 10$ are brighter and more numerous than predicted by the Standard ΛCDM Cosmological Model [9]. This excess of galaxies has not yet been reliably explained. The Webb Space Telescope conducted a new survey, Mirage or Miracle (MoM), to provide spectroscopic confirmations and to study early galaxies. The galaxy MoM-z14, whose spectrum shows a bend in Ly_{α} and several emission lines, is now the most distant galaxy with a spectroscopically confirmed redshift $z = 14.4 \pm 0.2$ (the age of the Universe is 280 million years) [10]. The MoM-z14 observations confirm the conclusion that such galaxies at $z > 10$ are more numerous than expected. MoM-z14 is rather compact and probably has a mass of $\approx 10^8 M_{\odot}$. The absence of 'absorption wings' suggests that the gas near the galaxy is partially ionized. This may indicate an earlier onset of Universe reionization than previously thought.

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