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1. Search for quantum gravity effects in neutrino observations

The theory of quantum gravity, aimed at unifying the gravitational field with other fundamental interactions, has not yet been completely formulated [1, 2], but a search for its possible experimental manifestations has already begun. One of the promising areas is the search for cosmological neutrinos coming from far galaxies. The space-time fluctuations described by quantum operators of different dimensions could induce noticeable anomalies in neutrino oscillations as they pass. Thus, neutrinos are a giant interferometer on a cosmological scale. The IceCube telescope has recently reached, for the first time in its gathering of statistics, the range of parameters making obvious the contribution of dimension-6 operators in cosmological neutrino oscillations [3]. IceCube contains an array of photomultipliers at depths of 1450–2450 m in Antarctic ice that scan a volume of 1 km^3. The interaction between neutrinos of different flavors (electronic, muon, and tau-neutrino) and atoms generate fluxes of secondary particles whose properties are indicative of neutrino flavor. Numerous events have been detected with neutrino energies over 60 TeV with different flavors. These observations were compared with the results of numerical simulation of neutrino spectra that appeared in astrophysical sources and experienced oscillations. Quantum gravity effects in neutrino oscillations have not been revealed to date, but the negative result allowed obtaining new limits on the theory's parameters.

2. Tripartite quantum correlations

Verification of basic elements of quantum mechanics remains a topical subject of research, especially in connection with new directions in quantum technologies. In quantum mechanics, along with entangled quantum states of two particles (bipartite-entangled states), also possible are quantum correlations of three particles (tripartite-entangled states) that have no classical counterpart. A theoretical analysis has shown that tripartite correlations cannot be reduced to several bipartite ones. H Cao (University of Science and Technology of China) and their authors have obtained a new, more rigorous criterion for verification of this statement [4]. The criterion resembling Bell inequalities can be applied to different modifications of quantum mechanics. H Cao with colleagues performed an experiment in which such a verification was successfully realized. The experiment involved laser radiation photons in Greenberger–Horne–Zeilinger states. Tripartite correlations were shown with 26.3σ confidence not to be reduced to hidden variables or to a combination of so-called 'exotic bipartite correlations' but are a fundamental form of quantum correlations. Laser technologies similar to those used in this experiment find wide application in quantum communication devices and in quantum calculations (see, e.g., [5–7]).

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3. Electron optics in graphene

The linear form of the dispersion relation for electrons in a graphene monolayer allows control of the electron motion by methods similar to those of classical optics. In particular, it was demonstrated earlier that electron fluxes passing through a p–n junction in graphene can be collimated with the Klein tunneling effect and can undergo refraction in the course of Veselago lensing in a substance with negative dielectric permittivity and magnetic permeability [8]. However, the collimation and focusing efficiency remained low. The latter, in particular, obstructed realization of controlled quantum interference of electrons. X Zhang (University of Minnesota, USA) and their co-authors have designed a new architecture of a bipolar graphene microcavity, in which one can solve the above-mentioned problems through graphene deformation and certain electrostatic potentials [9]. A combination of these effects creates several consecutive Veselago lensing processes. Thus, electrons were localized, and the general collimation efficiency heightened. This method may prove to be useful in designing new optical devices for carrying out controlled quantum interference. For graphene electronics, see [10, 11].

4. Unusual ring-like radio source

Machine learning algorithms allow discovering astronomical objects with extraordinary properties, which remained unnoticed in giant catalogues in the course of their customary processing. In particular, the set of Astronomaly algorithms demonstrated the best advantage in the search for optical transients and galaxies with unique morphology. M Lochner (University of the Western Cape and South African Astronomical Observatory) and her co-authors applied Astronomaly to process the MeerKAT Galaxy Cluster Legacy Survey (MGCLS), including $\sim 720,000$

radio sources [12]. The survey was drawn up mainly with the help of the MeerKAT radio telescope located in South Africa — the prototype of SKA class telescopes 1 km^2 in area. A unique ring-like radio source 75 kpc in size with a luminosity of 10^{25} W Hz^{-1} comparable to the luminosity of powerful radio galaxies was discovered by Astronomaly in the Abell 209 galactic cluster. The source is located near the galaxy at redshift $z = 0.55$, surrounded by a diffuse envelope. Close to it are structures resembling radio jets and radio blades. The ring-like object may have resulted from the action of a shock wave after termination of the active star formation in the galaxy. It could also have been formed by matter ejected from a powerful radio galaxy or from a pair of merging supermassive black holes. However, the existing models cannot provide an exhaustive explanation for the observed source structure. This source remotely resembles the radio circles discovered recently by the ASKAP radio interferometer, whose origin now remains unclear.

References

1. Gorelik G E *Phys. Usp.* **48** 1039 (2005); *Usp. Fiz. Nauk* **175** 1093 (2005)
2. Kazakov D I *Phys. Usp.* **62** 364 (2019); *Usp. Fiz. Nauk* **189** 387 (2019)
3. Abbasi R et al. (The IceCube Collab.) *Nat. Phys.* **18** 1287 (2022)
4. Cao H et al. *Phys. Rev. Lett.* **129** 150402 (2022)
5. Khabarova K Yu, Zalivako I V, Kolachevsky N N *Phys. Usp.* **65** 1217 (2022) https://doi.org/10.3367/UFNe.2022.10.039270; *Usp. Fiz. Nauk* **192** 1305 (2002)
6. Sukachev D D *Phys. Usp.* **64** 1021 (2021); *Usp. Fiz. Nauk* **191** 1077 (2021)
7. Zheltikov A M, Scully M O *Phys. Usp.* **63** 698 (2020); *Usp. Fiz. Nauk* **190** 749 (2020)
8. Veselago V G *Sov. Phys. Usp.* **10** 509 (1968); *Usp. Fiz. Nauk* **92** 517 (1967)
9. Zhang X et al. *Nat. Commun.* **13** 6711 (2022)
10. Ratnikov P V, Silin A P *Phys. Usp.* **61** 1139 (2018); *Usp. Fiz. Nauk* **188** 1249 (2018)
11. Antonova I V *Phys. Usp.* **65** 567 (2022); *Usp. Fiz. Nauk* **192** 609 (2022)
12. Lochner M et al. *Mon. Not. R. Astron. Soc.* stad074 (2023) https://doi.org/10.1093/mnras/stad074; arXiv:2211.02062