

PACS number: **01.90. + g**

Physics news on the Internet (based on electronic preprints)

DOI: https://doi.org/10.3367/UFNe.2019.04.038552

1. Measurement of zero quantum electromagnetic-field fluctuations

Fluctuations of an electromagnetic field in the ground (vacuum) state have only been observed by indirect methods, for instance, by the Casimir effect. J Faist (High Technical School of Zurich, Switzerland) and his colleagues have taken direct measurements of zero fluctuations in a nonlinear crystal for the first time. The optical properties of the crystal were affected by the electric field fluctuations (electrooptical effect), which had an effect on light passage through the crystal. To register this effect, the light intensity was measured at two points of the crystal through which laser pulses passed with a time delay. The measured correlation functions contained a contribution of zero quantum fluctuations. Thus, quantum fluctuations were registered and their spectrum was found in the terahertz frequency range.

Source: *Nature* **568** 202 (2019)
https://doi.org/10.1038/s41586-019-1083-9

2. Quantum optomechanical effect in liquid helium

A B Shkarin (Yale University, USA) and his colleagues have become the first to measure quantum fluctuations in an optomechanical cavity with superfluid helium between two mirrors which are terminations of optical fibers. Laser pulses transmitted through the optical fibers in helium excited coupled electromagnetic and mechanical vibrations, and the spectrum of outgoing light was observed. The vibrations were related by varying the refractive index of the medium under its compression and by the force exerted on the medium by the electromagnetic field. In the system vibrations, the contribution of quantum fluctuations was singled out, which differed in the form of the spectrum from the contribution of thermal fluctuations.

Source: *Phys. Rev. Lett.* **122** 153601 (2019)
https://doi.org/10.1103/PhysRevLett.122.153601

3. Potential difference in thunderclouds

A record value of the potential difference in thunderclouds has been obtained in the GRAPES-3 experiment carried out in India under the guidance of S Gupa. The possibility of reaching $\Delta U \sim 1$ GV during a thunderstorm was predicted by C Wilson in 1929, but the values observed up to the present day have been an order of magnitude lower, which is insufficient to explain the 100-MeV gamma-ray bursts noticed during some thunderstorms. This emission is presumably generated by accelerated electrons through the braking mechanism. GRAPES-3 includes the G3MT muon telescope with a wide field of vision and additional strength sensors separated by several kilometers. Muons (more precisely μ^+) produced in the atmosphere by cosmic rays lose energy while flying through the region with ΔU, which affects their flux near Earth's surface. During the thunderstorm of December 1, 2014, the ΔU value found by the muon flux variation was equal to 1.3 GV. This confirmed C Wilson's theoretical prediction and solved the problem of Earth's gamma-ray burst generation. The charge configuration might be represented to high accuracy by a flat capacitor with a capacity of $\geqslant 0.85$ μF formed by cloud layers at altitudes of 8 to 10 km. Charging up to 1.3 GV lasted 6 min, which corresponds (for comparison) to the power of a large nuclear reactor. Measurement of the muon flux variations immediately gives the total ΔU value in clouds as distinct from a local airplane or balloon strength measurements. For the physics of lightning, see the review by A V Gurevich and K P Zybin in *Usp. Fiz. Nauk* **171** 1177 (2001) (*Phys. Usp.* **44** 1119 (2001)), the paper by D I Iudin et al. in *Usp. Fiz. Nauk* **188** 850 (2018) (*Phys. Usp.* **61** 766 (2018)), and the paper by L P Babich, "Thunderstorm neutrons" accepted for publication in *Usp. Fiz. Nauk* **189** (10) (2019) (*Phys. Usp.* **62** (10) (2019)) (DOI: 10.3367/UFNe.2018.12.038501).

Source: *Phys. Rev. Lett.* **122** 105101 (2019)
https://doi.org/10.1103.PhysRevLett.122.105101

4. Diffraction of atoms by a quasicrystal

Quasicrystals are structures that have a long-range order and no exact periodicity. U Schneider (Cavendish Laboratory of Cambridge University, Great Britain) and his colleagues have investigated for the first time the diffraction of ultracold atoms by a two-dimensional quasicrystalline optical lattice. A Bose–Einstein condensate of ^{39}K atoms was used. Involved immediately after the release of atoms from the trap was the quasicrystal potential formed by four laser beams. The atoms underwent two-photon scatterings (the Kapitza–Dirac effect, see *Usp. Fiz. Nauk* **88** 396 (1966) (*Sov. Phys. Usp.* **9** 178 (1966)) and gained recoil momenta. The diffraction of atomic waves resembled the diffraction of electrons by quasicrystals observed in previous experiments. The diffraction pattern for small wavevectors had a fractal structure, and its dynamics on short time scales were a random quantum roaming in a four-dimensional momentum space.

Source: *Phys. Rev. Lett.* **122** 110404 (2019)
https://doi.org/10.1103/PhysRevLett.122.110404

Uspekhi Fizicheskikh Nauk **189** (5) 518 (2019)
DOI: https://doi.org/10.3367/UFNr.2019.04.038552
Translated by M V Tsaplina

5. Shadow of a black hole in galaxy M 87

Light cannot come out of a black hole (BH); therefore, against a light background, a BH must look like a dark spot casting a 'shadow'. This prediction of General Relativity has been verified for the first time with the help of eight radio telescopes located on different continents and assembled to constitute the Event Horizon Telescope with a very long base. Synchronous observations on all the telescopes allowed reaching the angular resolution of 20 mas at a wavelength of 1.3 mm. In the center of galaxy M 87, a bright ring is observed around a dark spot. The ring is due to the emission of an accretion disk that underwent gravitational lensing on the central supermassive BH. The ring size corresponds to the BH mass $M = (6.5 \pm 0.7) \times 10^9 M_\odot$. An analysis of alternative models (without a BH) showed that they could not explain the observed picture. Thus, there is more direct evidence of the existence of a BH in the Universe, along with the recent recordings of gravitational waves from BH collisions in pairs. The image of a BH shadow in the center of our Galaxy is expected to be presented soon. For the prospects of BH shadow observations, including those on the Millimetron space observatory to be launched, see the review by P B Ivanov et al. in *Usp. Fiz. Nauk* **189** 449 (2019) (*Phys. Usp.* **62** 420 (2019)).

Source: *The Astrophysical Journal Letters* **875** L1 (2019)
https://doi.org/10.3847/2041-8213/ab0ec7

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