Physics – Uspekhi **64** (4) 425 – 426 (2021)

PACS number: **01.10. – m**, **01.30. – y**, **01.90. + g**

Physics news on the Internet (based on electronic preprints)

Yu N Eroshenko

DOI: https://doi.org/10.3367/UFNe.2021.02.038938

1. Resonant event using IceCube

The resonant interaction of an electron antineutrino $\bar{\nu}_e$ with an electron via a W^--boson was first registered using the IceCube neutrino telescope [1]. This process is called Glashow resonance, after Glashow, who suggested recording muons born in the $\bar{\nu}_e + e^- \to W^- \to \bar{\nu}_\mu + \mu^-$ reaction, assuming the mass of a boson — the interaction carrier — to be ~ 1 GeV [2]. Later, on the basis of the Weinberg–Salam model, which had not yet been experimentally confirmed, V S Berezinskii and A Z Gazizov formulated a theory of 30- to 100-GeV W^- decay in the hadron channel. This process is an analog of Glashow resonance, but differs from it in the end product. Decays into quark-antiquark pairs with allowance for color were considered. It was shown in [3, 4] that the resonance width and, therefore, the expected number of cascades is much larger than it had been believed before. The resonance peak must be distinguished against the background of nonresonant processes of neutrino scattering by nucleons. V S Berezinskii and A Z Gazizov proposed seeking a resonant W^--boson in a DUMAND type underwater experiment. At the present time, the IceCube telescope is scanning a cubic kilometer of Antarctic ice at depths of 1.45–2.45 km. Photomultipliers register Vavilov–Cherenkov radiation generated by secondary charged particles, and machine learning algorithms are used in the search for neutrino events. The particle $\bar{\nu}_e$ induced a cascade of particles with a total measured energy of 6.05 ± 0.72 PeV, which is consistent with the predicted value of 6.32 PeV and is classified with 5σ significance as an astrophysical antineutrino. The event registered with IceCube with allowance for the currently known W^--boson mass agrees with the calculations [3, 4]. High- and superhigh-energy neutrinos might be born in active galactic nuclei [5] or in pregalactic stars [6], or be cosmogeneous [7]. Observation of $\bar{\nu}_e$ limits the models of possible cosmic sources of these particles, since in some models the birth of antineutrinos, unlike that of neutrinos, is hardly probable. PeV-scale (10^{15} eV) astrophysical neutrino observation makes it possible to investigate particle interaction at energies now inaccessible on accelerators. For experiments in neutrino astrophysics, see [8–10].

2. Quantum entanglement in a double waveguide

E Borselli (Vienna Center for Quantum Science and Technology, Austria) and their co-authors have realized experimentally a new type of quantum entanglement, namely, quantum entanglement of atoms in the state of their motion in double beams [11]. In the transverse direction of a quasi-one-dimensional atomic trap, a potential appeared in the form of two potential wells separated by a barrier. A Bose–Einstein condensate of 600 to 2000 atoms was immersed in this double waveguide. In a pair collision, two excited atoms could acquire oppositely directed momenta along the waveguides and get into one of them. Thus, alternative four atomic states occurred with possible interference among them. In the experiment, atoms were observed using fluorescence, and their momentum distribution was measured after the trap potential was off. The second-order correlation functions showed the presence of the expected interference pattern.

3. Maxwell's demon strategy

G Manzano (International Center for Theoretical Physics (ICTP), Italy, and Institute for Quantum Optics and Quantum Information, Austria) and his co-authors have designed an apparatus, which is functionally close to 'Maxwell's demon', but follows a given gambling strategy without knowing the particle velocities [12]. The strategy is aimed at obtaining the maximum energy gain while working with a stochastic system during a fixed time interval. The system stops operating either at the instant of time when a defined gain is reached or goes on operating to the end of the time interval. This conception was experimentally demonstrated in a single-electron quantum well. The mathematical fluctuation relations derived by the authors and characterizing the apparatus's operation were confirmed in experiment to an accuracy of $\sim 99.5\%$. It has been shown that such a system can operate in a quantum regime, too. This study may turn out to be important for constructing microscopic heat engines.

4. A turbulent dynamo in experiment

A F A Bott (University of Oxford, United Kingdom and Princeton University, USA) and his co-authors have obtained and experimentally studied turbulent plasma with magnetic Prandtle number $P_m \geqslant 1$ and confirmed the magnetic field growth with the help of a 'fluctuation dynamo' [13]. With a fluctuation dynamo, plasma stochastic motions induce extension and summation of magnetic lines of force, which leads to a magnetic field amplification exponential in time. Earlier, laboratory investigations were limited by the regime $P_m < 1$, where the amplification follows another law. Investigation of the case $P_m \geqslant 1$ is important for understanding magnetic field evolution in cosmic objects [14]. High-power laser pulses at the Omega Laser Facility at the University of Rochester evaporated a hydrocarbon foil, and the two plasma beams thus formed collided. Seed magnetic

Yu N Eroshenko Institute for Nuclear Research,
Russian Academy of Sciences,
prosp. 60-letiya Oktyabrya 7a, 117312 Moscow, Russian Federation
E-mail: erosh@ufn.ru

Uspekhi Fizicheskikh Nauk **191** (4) 444 (2021)
Translated by M V Tsaplina

fields were generated by the 'Biermann-battery' mechanism and were then amplified by a turbulent dynamo. The plasma's magnetic field, temperature, density, and velocity were measured with a high time resolution. The magnetic field was increased by three orders of magnitude, the field growth rate exceeding substantially the anticipated one.

5. Search for a neutron star in the SN 1987A supernova remnant

Upon the SN 1987A supernova explosion, which happened in the Large Magellanic Cloud and was observed on Earth on 23 February 1987, a neutrino flux was observed. This testified to a neutron star birth in the explosion [15]. However, this neutron star has not yet been reliably found hitherto; only some ambiguous ALMA data on the existence of a compact object were obtained earlier. E Greco (University of Palermo and Astronomical Laboratory of Palermo, Italy) and his co-authors have presented new convincing evidence of the presence of a neutron star in the supernova remnant [16]. Analysis of the data from the Chandra and NuSTAR X-ray telescopes revealed a nonthermal component at 10 to 20 keV corresponding to synchrotron radiation, and magnetohydrodynamic modeling has shown that this component is most likely associated with radiation from the pulsar wind nebula (plerion) surrounding the neutron star, although the model of radiation generation in a shock wave cannot currently be completely ruled out. For the pulsar magnetosphere and accretion to neutron stars, see [17, 18].

References

1. Aartsen M G et al. *Nature* **591** 220 (2021); https://doi.org/10.1038/s41586-021-03256-1
2. Glashow S L *Phys. Rev.* **118** 316 (1960)
3. Berezinskii V S, Gazizov A Z *JETP Lett.* **25** 254 (1977); *Pis'ma Zh. Eksp. Teor. Fiz.* **25** 276 (1977)
4. Berezinskii V S, Gazizov A Z *Sov. J. Nucl. Phys.* **29** 816 (1979); *Yad. Fiz.* **29** 1589 (1979); *Sov. J. Nucl. Phys.* **33** 120 (1981); *Yad. Fiz.* **33** 230 (1981)
5. Berezinskii V S, Zatsepin G T *Sov. Phys. Usp.* **20** 361 (1977); *Usp. Fiz. Nauk* **122** 3 (1977)
6. Berezinsky V, P. Blasi P *Phys. Rev.* D **85** 123003 (2012)
7. Beresinsky V S, Zatsepin G T *Phys. Lett. B* **28** 423 (1969)
8. Spiering Ch *Phys. Usp.* **57** 470 (2014); *Usp. Fiz. Nauk* **184** 510 (2014)
9. Petrukhin A A *Phys. Usp.* **58** 486 (2015); *Usp. Fiz. Nauk* **185** 521 (2015)
10. Dzhilkibaev Ja-A M, Domogatsky G V, Suvorova O V *Phys. Usp.* **58** 495 (2015); *Usp. Fiz. Nauk* **185** 531 (2015)
11. Borselli E et al. *Phys. Rev. Lett.* **126** 083603 (2021); https://doi.org/10.1103/PhysRevLett.126.083603
12. Manzano G *Phys. Rev. Lett.* **126** 080603 (2021); https://doi.org/10.1103/PhysRevLett.126.080603
13. Bott A F A et al. *PNAS* **118** e2015729118 (2021); https://doi.org/10.1073/pnas.2015729118
14. Sokoloff D D, Stepanov R A, Frick P G *Phys. Usp.* **57** 292 (2014); *Usp. Fiz. Nauk* **184** 313 (2014)
15. Imshennik V S *Phys. Usp.* **53** 1081 (2010); *Usp. Fiz. Nauk* **180** 1121 (2010)
16. Greco E et al., https://arxiv.org/abs/2101.09029
17. Beskin V S *Phys. Usp.* **61** 353 (2018); *Usp. Fiz. Nauk* **188** 377 (2018)
18. Shakura N I et al. *Phys. Usp.* **62** 1126 (2019); *Usp. Fiz. Nauk* **189** 1202 (2019)