Physics – Uspekhi **64** (6) 638 – 639 (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.2021.04.038970

1. Searching for axions

Axions were initially proposed to solve the problem of strong CP violation (see, e.g., [1]). These hypothetical particles have not yet been discovered, but are being actively searched for. Axions and axionlike particles are among the probable candidates for dark matter particles. For several years, T S Roussy (University of Colorado, USA) and her co-authors have carried out an experiment on measuring the electric dipole moment of $^{180}\mathrm{Hf}^{19}\mathrm{F}^{+}$ ions, which can be contributed by effects beyond the Standard Model. Although they have not yet been found, the experiment provided a new constraint on axions [2]. The oscillating axion field, which constitutes dark matter, would provoke a shift of Stark sublevels in $^{180}\mathrm{Hf}^{19}\mathrm{F}^{+}$. Because of the absence of such a shift, a constraint on the axion–gluon coupling constant in the axion mass range of $10^{-22}-10^{-15}$ eV was found at today's precision level, this constraint having been reached for the first time for $10^{-17}-10^{-15}$ eV. The stochasticity of axion field distribution was also taken into account for the first time. Another group of researchers, A Basu (Karl Schwarzschild Observatory and Bielefeld University, Germany) and their co-authors have devised a new prospective axion searching method from observations of strong gravitational quasar lensing [3]. Waves with different polarizations can propagate at different velocities because of parity violation in the course of photon–axion field interaction. The observation of several lensed quasar images with a time delay could reveal axion field oscillations from the difference in the radiation polarization plane rotation angle. The new method was applied to a quasar at the red shift $z = 1.019$ lensed by a galaxy with $z = 0.439$. New constraints on the axion–photon coupling constant $g_{a\gamma}$ were obtained in the axion mass range of $3.6 \times 10^{-21} - 4.6 \times 10^{-18}$ eV. The new constraints are 1–2 orders of magnitude stronger than those obtained previously.

2. Landau damping in accelerator beams

The perturbation damping in collisionless plasma caused by collective particle interaction (Landau damping) was predicted by L D Landau and A A Vlasov in 1945 and first confirmed experimentally in 1964 [4, 5]. Landau damping plays the key role, in particular, in beam stabilization in accelerators, where active stabilization methods are also applied, namely, beam deformation is recorded and the beam is effected in the reverse direction. For the design and exploitation of accelerators, it is of importance to know the so-called stability diagram (SD) characterizing the beam stability limits. An SD was earlier found using indirect approximate methods. In a test experiment at the Large Hadron Collider, S A Antipov (CERN, Switzerland) and his co-authors proposed and demonstrated a new direct SD measurement method [6]. To this end, a regular transverse feedback system was used with opposite polarity to amplify occurring transverse beam deviations. The low-intensity proton beam behavior was traced for different magnitudes and phases of the action, which made it possible to design an SD and, thus, measure the Landau damping.

3. Thermal conductivity oscillations in α-RuCl$_3$

Quantum spin liquids have quantum spin coherence but no long-range magnetic ordering. These states attract great attention owing to their unusual properties. Experiments have shown that the quantum spin-liquid state is probably realized in a layered insulator α-RuCl$_3$ in the range of magnetic fields $H = 7.3-11$ T. The indicated interval H is located between the paramagnetic and zig-zag states. P Czajka (Pakistan University, USA) and his co-authors have performed a new investigation of α-RuCl$_3$ to reveal an unexpected effect of periodic thermal conductivity oscillations with increasing $1/H$, and it is only the component H along the layer plane that plays the role [7]. These oscillations resemble Shubnikov–de Haas oscillations in metals, but here, they occur in an insulator and must be excited by another mechanism. The oscillations are strongest in the rage $H = 7.3-11$ T and are suppressed otherwise. Therefore, they can be associated with the state of a quantum spin liquid. The authors of the paper suggest that the oscillations can be due to spin Fermi surface quantization. For some topical issues of solid-state physics, see [8–10].

4. Quantum entanglement of macroscopic membranes

S Kotler (National Institute of Science and Technology and University of Colorado, USA) and his co-authors have demonstrated quantum entanglement of two 70-pg aluminum membranes [11]. Quantum states of the membranes have been measured efficiently, which could not be done in previous experiments. The space between the membranes formed a microwave cavity with the resonance frequency dependent on the membrane position. In this hybrid system, entanglement occurs in mechanical degrees of freedom and control is realized in electric ones, which makes the requirement of the system's isolation from the environment not so

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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

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Translated by M V Tsaplina

strict. The membranes were cooled to lower vibrational levels with the help of microwave pulses. Then, pulses at side frequency bands transferred the membranes into quantum entangled states. And, finally, quantum tomography, namely, a quantum-state measurement, was implemented through recording signals reflected from the cavity. The Simon–Duan criterion has shown that the membranes were in a quantum entangled state even without noise filtration. Observing quantum entanglement of macroscopic bodies is of importance for the investigation of the fundamental basis of quantum mechanics. For the state-of-the-art of quantum technology, see [12, 13].

5. Neutron star radius

Measurement of neutron star (NS) radii is of importance for the investigation of the properties of nuclear matter at extreme densities. The X-ray telescope NICER aboard the International Space Station (ISS) is intended for NS observation and testing new pulsar-based space navigation technologies. With the help of NICER, the radius of a comparatively light ($\approx 1.4M_{\odot}$) NS has already been determined. More massive NSs must have a higher central density, and therefore their study is of great interest. The radius of NS PSR J0740 + 6620 entering in a binary system with an ordinary star and having a mass of $2.08 \pm 0.07M_{\odot}$ is measured though a combination of the new NICER and XMM-Newton telescope data [14]. NS pulses modulate companion-star radiation with a modulation depth depending on NS compactness. This effect suggests that the NS equatorial radius is $13.7^{+2.6}_{-1.5}$ km. Making use of the information on other NSs and the LIGO/Virgo data on the absence of observed tidal NS deformation in gravitational wave effects, one can fix the radius of PSR J0740 + 6620 in the interval of 12.35 ± 0.75 km and specify the nuclear matter equation of state [15]. For NSs, see [16–18].

References

1. Kazakov D I *Phys. Usp.* **62** 364 (2019); *Usp. Fiz. Nauk* **189** 387 (2019)
2. Roussy T S et al. *Phys. Rev. Lett.* **126** 171301 (2021); https://doi.org/10.1103/PhysRevLett.126.171301
3. Basu A et al. *Phys. Rev. Lett.* **126** 191102 (2021); https://doi.org/10.1103/PhysRevLett.126.191102
4. Kadomtsev B B *Sov. Phys. Usp.* **11** 328 (1968); *Usp. Fiz. Nauk* **95** 111 (1968)
5. Rukhadze A A, Silin V P *Phys. Usp.* **62** 691 (2019); *Usp. Fiz. Nauk* **189** 739 (2019)
6. Antipov S A et al. *Phys. Rev. Lett.* **126** 164801 (2021); https://doi.org/10.1103/PhysRevLett.126.164801
7. Czajka P *Nat. Physics*, online publication of May 13, 2021; https://arxiv.org/abs/2102.11410
8. Lider V V *Phys. Usp.* **63** 907 (2020); *Usp. Fiz. Nauk* **190** 971 (2020)
9. Kvon Z D et al. *Phys. Usp.* **63** 629 (2020); *Usp. Fiz. Nauk* **190** 673 (2020)
10. Dolgopolov V T *Phys. Usp.* **62** 633 (2019); *Usp. Fiz. Nauk* **189** 673 (2019)
11. Kotler S et al. *Science* **372** 622 (2021); https://doi.org/10.1126/science.abf2998
12. Trushechkin A S et al. *Phys. Usp.* **64** 88 (2021); *Usp. Fiz. Nauk* **191** 93 (2021)
13. Arbekov I M, Molotkov S N *Phys. Usp.* **64** (6) (2021); *Usp. Fiz. Nauk* **191** 651 (2021)
14. Miller M C et al., https://arxiv.org/abs/2105.06979
15. Raaijmakers G et al., https://arxiv.org/abs/2105.06981
16. Beskin V S *Phys. Usp.* **61** 353 (2018); *Usp. Fiz. Nauk* **188** 377 (2018)
17. Shakura N I et al. *Phys. Usp.* **62** 1126 (2019); *Usp. Fiz. Nauk* **189** 1202 (2019)
18. Tutukov A V, Cherepashchuk A V *Phys. Usp.* **63** 209 (2020); *Usp. Fiz. Nauk* **190** 225 (2020)