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1. Excess of events in XENON1T

In the XENON1T experiment being carried out at the Gran Sasso National Laboratory (Italy) [1], an excess of recoil electrons has been observed [2], which can be explained by the scattering of new particles by electrons not described by the Standard Model. The XENON1T detector contains 2 tons of liquid xenon visible through photomultipliers. The low background at the laboratory allows searching for rare particles and interactions. The electron scatterings registered at an energy of 1 to 7 keV exceeded the expected value of 232 ± 15 background events by 53. The excess is considered to be possibly due to β-decays of tritium nuclei in the xenon composition present as an impurity. This explanation does not imply going beyond the limits of the Standard Model, but the tritium content in the detector has not yet been measured. The observed excess is best explained (with a statistical significance of 3.5σ) by the scattering of axions, i.e., hypothetical particles born inside the Sun in various processes. The axions proposed initially to solve the problem of CP invariance in strong interactions are regarded as one of the main candidates for the role of dark matter particles in the Universe. With a lower significance of 3.2σ, the excess can be explained by the scattering of neutrinos from the Sun under the condition that neutrinos have magnetic moment $\mu_{\nu} = (1.4 - 2.9) \times 10^{-11}$ of Bohr magnetons. This value is close to the upper limit obtained by the direct method in the Borexino experiment but contradicts the indirect astrophysical restrictions. It has not been ruled out that the event excess is due to other particles, for instance, 'dark photons'. More reliable conclusions will require a further collection of statistics.

2. Branched flow of light

In a disordered scattering medium, waves may propagate along individual channels divergent and branching like tree branches due to diffraction and caustic formation. In optics, a branched flow was discovered and investigated in 2002 at the P N Lebedev Physical Institute of the Russian Academy of Sciences (FIAN) and reported by A V Startsev and Yu Yu Stoilov [3, 4] (for a more detailed description of this phenomenon, see [5]). A thin soap film where laser radiation in the optical and IR ranges was introduced was observed through a microscope (see [3–6]). The film showed natural thickness fluctuations that caused fluctuations of the effective refractive index. Transverse light scattering allowed the observation of light intensity distribution in the film. Contrary to expectations, some light threads did not spread chaotically, but remained collimated along large paths, then branched into smaller fibers. In a similar new experiment, A Patsyk (Israel Institute of Technology — Technion) and co-authors have observed branched laser light in a soap film [7]. The film thickness was equal to 1–2 light wavelengths and the light was directed to it through an optical fiber. A branched propagation similar to that reported earlier by A V Startsev and Yu Yu Stoilov was observed, and its statistical characteristics were found. They are of a universal form and only depend on the correlation length of inhomogeneities and on the average variation of the refractive index. The distance at which the flow begins branching is also described by a simple universal dependence. A branched flow was observed earlier for electron waves in semiconductors. It is predicted that in a three-dimensional case waves can propagate along branched two-dimensional surfaces.

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3. Cascade of phase transitions in graphene

The study of bilayer graphene whose layers are turned with respect to each other by the so-called 'magic angle' of $\approx 1.1°$ testified to the fact that cooling must induce phase transitions due to electron band occupation. U Zondiner (Weizmann Institute, Israel) and colleagues have revealed [8] a cascade of such phase transitions. Graphene on a substrate was investigated at a temperature above the superconducting transition temperature. The band occupation was examined by measuring electron compressibility using a nanotube-based one-electron transistor. Characteristic jumps due to band occupation were revealed, after which a Dirac-type dispersion relation occurred. Some quantum degrees of freedom disappear under cooling, but new collective degrees of freedom appear. The results of measurements are interpreted as retraction of electrons from partially occupied former bands by the new band. The properties of high-temperature graphene may inherit a number of low-temperature effects, which may provide insight into the mechanisms of superconductivity. For graphene and its properties, see [9–11].

4. Superradiation in acoustics

Ya B Zel'dovich, A V Rozhanskii, and A A Starobinskii [12–14] predicted theoretically the possibility of electromagnetic wave amplification by scattering the waves with a rapidly rotating metallic cylinder, as well as wave amplification and the production of particles from a rotating black hole. This process was called 'superradiation'. On this basis, Stephen Hawking predicted the effect of black hole quantum evaporation. The condition of amplification has the form $\omega < l\Omega$, where ω is the incident wave frequency, Ω is the rotation frequency, and l is the order of the angular mode. Electromagnetic wave superradiation has not been observed in experiments because of the need for very fast rotation. The condition for amplification is more simply attained for sound waves, and M Cromb (University of Glasgow, Great Britain) and co-authors have observed it for the first time in their acoustic experiment [15]. Instead of scattering by cylinders, the sound was transmitted between two discs through an absorbing medium. Sixteen loudspeakers were placed along the circumference of a motionless disc. Each of them sounded with a phase shift so that the sound front had a spiral structure with different l. Two microphones were placed on a rotating disc. Between the two discs was a thin layer of absorbing foam, and the sound could only reach the microphones after passing through the foam. The Zel'dovich condition was met beginning at the rotation frequency of 15 Hz. A 30% amplification was observed above 25 Hz, which confirmed the prediction of Ya B Zel'dovich and his colleagues.

5. Gravitational-wave burst GW190814

The LOGO/Virgo gravitational wave detectors have registered event GW190814, corresponding to the merging of compact objects with a record large mass ratio [16]. The more massive object of the pair, with a mass of $23.2^{+1.1}_{-1.0} M_{\odot}$, is obviously a black hole, while the origin of the other object of mass $2.59^{+0.08}_{-0.09} M_{\odot}$ is not yet clear. It may be either the most massive neutron star or the lightest black hole of those observed in binary systems. The above-mentioned mass of the light object is near the upper boundary of admissible neutron star masses or even exceeds it. At the same time, the known astrophysical black holes have masses of $\geqslant 5 M_{\odot}$. Thus, the mass of the light object is typical neither of neutron stars nor of black holes. This may be a black hole formed by the merging of two neutron stars. Such a binary system could have been formed dynamically in a young star cluster. The burst source is at a distance of $\simeq 240$ Mpc, and no associated electromagnetic radiation from it has been registered. Owing to the large mass ratio, this event made it possible to confirm the predictions of General Relativity (GR) in the earlier unexplored region where high multipoles are excited upon object merging. For the discovery of gravitational waves, see [17], and for GR effects, see [18].

References

1. Bettini A *Phys. Usp.* **44** 931 (2001); *Usp. Fiz. Nauk* **171** 977 (2001)
2. Aprile E et al., https://arxiv.org/abs/2006.09721
3. Startsev A V, Stoilov Yu Yu, *Quantum Electron.* **33** 380 (2003); *Kvantovaya Elektron.* **33** 380 (2003)
4. Startsev A V, Stoilov Yu Yu *Quantum Electron.* **34** 569 (2004); *Kvantovaya Elektron.* **34** 569 (2004)
5. Stoilov Yu Yu *Phys. Usp.* **47** 1261 (2004); *Usp. Fiz. Nauk* **174** 1359 (2004); *Usp. Fiz. Nauk* **174** 1359 (2004)
6. Startsev A V, Stoilov Yu Yu *Quantum Electron.* **42** 750 (2012); *Kvantovaya Elektron.* **42** 750 (2012)
7. Patsyk A et al. *Nature* **583** 60 (2020), https://doi.org/10.1038/s41586-020-2376-8
8. Zondiner U et al. *Nature* **582** 203 (2020), https://doi.org/10.1038/s41586-020-2373-y
9. Morozov S V, Novoselov K S, Geim A K *Phys. Usp.* **51** 744 (2008); *Usp. Fiz. Nauk* **178** 776 (2008)
10. Lozovik Yu E, Merkulova S P, Sokolik A A *Phys. Usp.* **51** 727 (2008); *Usp. Fiz. Nauk* **178** 757 (2008)
11. Ratnikov P V, Silin A P *Phys. Usp.* **61** 1139 (2018); *Usp. Fiz. Nauk* **188** 1249 (2018)
12. Zel'dovich Ya B *Pis'ma Zh. Eksp. Teor. Fiz.* **14** 270 (1971)
13. Zel'dovich Ya B *Zh. Eksp. Teor. Fiz.* **62** 2076 (1972)
14. Zel'dovich Ya B, Pozhanskii L V, Starobinskii A A *Izv. Vyssh. Ucheb. Zaved. Radiofiz.* **29** 1008 (1986)
15. Cromb M et al. *Nature Physics*, онлайн-публикация от 22 июня 2020 г., https://doi.org/10.1038/s41567-020-0944-3
16. Abbott R et al. *Astrophys. J. Lett.* **896** L44 (2020), https://arxiv.org/abs/2006.12611
17. Reitze D H *Phys. Usp.* **60** 823 (2017); *Usp. Fiz. Nauk* **187** 884 (2017)
18. Sheel M A, Thorne K S *Phys. Usp.* **57** 342 (2014); *Usp. Fiz. Nauk* **184** 367 (2014)