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1. Radiative β-decay of free neutrons

Besides protons, electrons, and antineutrinos, photons can be emitted in rare cases under β-decay of the free neutron. The main mechanism of their production is the electron bremsstrahlung, while the contribution from the other processes does not exceed 1%. The radiative decay $n \to p + e^- + \bar{\nu}_e + \gamma$ was first registered reliably in the 2006 RDK I experiment. At the National Institute of Standards and Technology (NIST) (USA), a new experiment, RDK II, was performed in which the branching ratio of neutron radiative decays was measured to the highest accuracy, and the energy spectrum of newly born photons was also measured for the first time. Progress was achieved through an increase in the statistical data volume and refinement of the measurement methods. A neutron beam from the nuclear reactor was transmitted through superconducting electromagnets, where p and e^- particles produced in the decays declined to charge-sensitive detectors, while the photons flew straight and were registered by two photon detectors using the method of temporal coincidence with charged particles. One array of avalanche photodiodes registered photons directly (in the energy range of 0.4 to 14 keV), and the other one by scintillator luminescence (14.1–782 keV) triggered by these photons. In both cases, the measured shape of the photon spectrum and the probability of their emission agree well with the predictions of the Standard Model. The results of this experiment are important for verification of the Standard Model and the search for effects beyond it.

Source: *Phys. Rev. Lett.* **116** 242501 (2016)
http://arXiv.org/abs/1603.00243

2. Squeezed quantum states in an atomic clock

The precision of atomic interferometers is restricted by noises associated with the quantum-mechanical uncertainty principle. I Kruse (Institute of Quantum Optics, Leibniz University, Germany) and colleagues have proposed and demonstrated experimentally a new configuration of atomic interferometer in which the standard vacuum limit is overcome by vacuum squeezing in the empty interferometer input channel. The interferometer operates by the Ramsey principle in the regime of an atomic clock. First, 10^4 ^{87}Rb atoms in the state of a Bose–Einstein condensate in an optical dipole trap were transferred to certain electronic states through exposure to a sequence of microwave pulses. Given this, one of the interferometer channels was cleaned, so that on average 0.75 atoms remained in it. The microwave pulses squeezed the vacuum in this channel — that is, contracted the corresponding rms value of the quadrature below the standard quantum limit. This improved the quantum state purity of 10^4 atoms located in other channels and heightened the interferometer sensitivity by 2 dB. This method of quantum state squeezing may help in creating the next generation of atomic clocks.

Source: http://arXiv.org/abs/1605.07754

3. ‘Schrödinger’s cat’ in two boxes

C Wang (Yale University, USA) and colleagues have performed an experiment in which an electromagnetic analogue of ‘Schrödinger’s cat’ was simultaneously located in two boxes in a superposition of ‘alive-cat’ and ‘dead-cat’ states. This kind of experiment was proposed theoretically in 1993. It had already been shown before that the role of Schrödinger’s cat can be played by a harmonic oscillator residing in superposition of two vibrational states with large occupation numbers. The experiment described was carried out with coherent microwave photons in quasiclassical states excited in two superconducting cavities joined by a tunneling contact. Several dozen such photons were simultaneously present in the cavities. The ‘alive-cat’ states corresponded to identical directions of electromagnetic oscillations simultaneously in the two cavities. The states were measured and the Wigner function reconstructed by the quantum tomography method. It was shown that in the experiment was actually Schrödinger’s cat which simultaneously lived in two boxes (in two cavities in this case).

Source: *Science* **352** 1087 (2016)
http://dx.doi.org/10.1126/science.aaf2941

4. Tunneling time in strong field ionization

It is a known fact that quantum tunneling is not instantaneous but takes some time. However, the time delay involves the problem of definition of quantities and their relation with the observed characteristics. The tunneling time can only be well determined in the Bohm approach, where it is simply the time during which the particle trajectory lies inside the potential barrier. T Zimmermann (Swiss Federal Institute of Technology, Zürich) and colleagues have calculated the tunneling time for hydrogen and helium ionization in a strong field. The ionization theory formulated by L V Keldysh in 1964 [see, e.g., the reviews in *Phys. Usp.* **47** 855 (2004) and *Phys. Usp.* **58** 3 (2015)] was applied in various tunneling models, and the results obtained were compared with the available experimental data. The best agreement of time delay measurements taken on attosecond time scales was achieved with Larmor determination of the tunneling time, whereas the Bohm approach showed poor agreement with experiment. The authors of the research believe that the Bohm time does not correspond to the tunneling time but rather to the lifetime of the bound state.

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5. Supermassive black holes in the early Universe

F Pacucci and his colleagues from Italy and Japan have discovered two remote objects which may be supermassive black holes (BHs) produced as a result of a direct collapse of gas clouds, i.e., due to gas cooling and compression without its fragmentation and star formation. The mechanism of supermassive BH origination on red shifts $z \sim 6$, where they are sources of quasar radiation, has not yet been completely clarified. Help in this regard can come through a search for BHs at the stage of their formation and early growth through matter accretion. Young BHs are very likely to reside in gas–dust clouds, so that IR radiation is prevalent in their spectra. The authors of the research constructed the accretion model and predicted the spectrum shape and X-ray luminosity of such objects. The joint review CANDELS/GOODS-S containing Hubble, Spitzer, and Chandra data reported on two such objects–candidates with $z > 6$. If their spectra are assumed to be formed by young stars, the star formation time seems to be unrealistic ($> 2000 M_{\odot}$ year^{-1}). Therefore, the most probable model for these objects is that of accreting BHs with masses of $\sim 10^5 M_{\odot}$ produced in the course of direct collapse.

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