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1. Testing Lorentz invariance in decays of K^0_S mesons

A de Angelis (Physics Institute of the Max Planck Society, Germany) and his colleagues from Italy have obtained new constraints on the hypothetical effect of Lorentz invariance violation in $K^0_S \to \pi^+\pi^-$ decays. They analyzed 62.3 million decay events recorded by the KLOE detector at the DAFNE synchrotron accelerator of the National Laboratory in Frascati (Italy) and permitting reliable reconstruction. Researchers measured the K^0_S meson lifetime as a function of the direction of motion of the Earth relative to the reference frame fixed to the microwave background radiation, i.e., the frame in which the microwave background radiation has a zero dipole component. The measured degree of asymmetry, $A = (-0.13 \pm 0.40) \times 10^{-3}$, is compatible with the zero value of $A = 0$, i.e., no dependence of the lifetime of K^0_S mesons on their direction of motion was found at a confidence level of 95%. This result improves previously calculated upper limits by about an order of magnitude.

Source: http://arXiv.org/abs/1011.3720vl

2. Heat production in nuclear fuel

Of the energy generated in nuclear reactors, approximately 8% is contributed by natural decays of radionuclides, i.e., products of the main reactions. Uncertainties still survive in the characteristics of these fission processes and their removal may significantly improve the safety of storing and processing nuclear materials, plus this may generate an appreciable economic gain. The new experiment carried out by an international team of scientists at the IGISOL isotope separator of the University of Jyväskylä (Finland) studied heat release in decays of nuclides $^{102,104-107}$Tc, ^{105}Mo and ^{101}Nb. The total-absorption gamma spectrometer designed at the B P Konstantinov Petersburg Nuclear Physics Institute was directly coupled to a Penning trap, into which all nuclides generated in the cyclotron were sent, and which recorded the total-absorption γ-cascades that followed β-decays. For the nuclei $^{104-107}$Tc and ^{105}Mo, the amount of decay heat removed by gamma radiation was found to be greater than that yielded by earlier measurements with germanium detectors. The new measurements removed much of the uncertainty in energy release in decays of ^{239}Pu and daughter nuclei in the time interval from 4 to 3000 s after the termination of fission in the reactor. The results are also useful for improving the accuracy of the spectrum of the antineutrino signal from nuclear reactors, which is important for studying neutrino oscillations.

Source: *Phys. Rev. Lett.* **105** 202501 (2010)
http://dx.doi.org/10.1103/PhysRevLett.105.202501

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Translated by V I Kisin

3. Magnetic excitations in cuprate superconductors

M Greven (University of Minnesota, USA) and his colleagues, using the method of inelastic scattering of spin-polarized neutrons, found a new type of magnetic waves (magnetic excitations) characterized by low dispersion in high-temperature superconducting $HgBa_2CuO_{4+\delta}$. The energy of these excitations ranges from 52 to 56 meV, and they are observed at temperatures below the characteristic temperature T^* at which a pseudogap is formed in the electron spectrum of the material. The study of the pseudogap state is an ever important problem because the mechanism of its generation may hold a clue to the mechanism of high-temperature superconductivity. The discovered collective mode of magnetic excitations is likely to be directly connected with the pseudogap as the mode's intensity begins to increase as the material is cooled to temperatures below T^*. Electron–phonon excitation may prove to be the mechanism responsible for these excitations. The energy of excitations is close to the energy of one of the resonances of the compound $HgBa_2CuO_{4+\delta}$, which explains why they were not observed in earlier experiments.

Source: *Nature* **468** 283 (2010)
http://dx.doi.org/10.1038/nature09477

4. Information is used to increase free energy

M Sano (University of Tokyo, Japan) and his colleagues have demonstrated that the free energy of a Brownian particle can be increased by using information on the direction of its velocity. A dimer particle — a pair of polystyrene beads 287 nm in diameter — was fixed to the wall of a chamber filled with buffer solution and could rotate around its axis. A rotating ellipsoidal electric field was created in the chamber, which applied torque moment to the particle. Molecules of the buffer solution caused the particle to execute rotational Brownian motion which was monitored through a microscope and high-speed video camera. The particle was allowed to rotate in the direction of increasing the potential energy (against the torque moment), while in the opposite direction its motion was artificially blocked by changing the phase of the electric field. This created a feedback loop that controlled the motion of the particle by using the information on its direction. As a result, the particle was raised to a state with greater and greater potential energy. This process resembles the thought experiment with 'Maxwell's demon', which sorts out molecules according to their energy. In terms of L Szillárd's interpretation, information is consumed to create a temperature difference, which results in the growth of entropy in the compound larger system that includes the demon itself. Thus, the second law of thermodynamics is not violated here. Quantitative measurements conducted by M Sano et al. confirmed the theoretical relations derived by C Jarzynski (University of Maryland, USA) that characterize the efficiency of obtaining the free energy from information.

In this experiment, the demon is a cumbersome system involving a video camera, computers, and other pieces of equipment. Moving the whole experiment to the nanoscale could be the next step, e.g., by creating a microscopic control system for 'molecular motors'.

Source: *Nature Physics* **6** 988 (2010);
http://dx.doi.org/10.1038/nphysl821

5. Massive neutron star

Using the Green Bank radio telescope, P Demorest (National Radio Astronomy Observatory, USA) and his colleagues have discovered a neutron star with a record large mass of 1.97 ± 0.04 solar masses. The astronomers studied the PSR J1614-2230 millisecond pulsar in a binary system at a distance of about 3000 light years from Earth. A new technique of coherent filtering of signal fading caused by dispersion in interstellar gas was utilized. Owing to a favorable orientation of the plane of orbit (seen from Earth almost perfectly edge-on), it proved possible to use the timing technique (measurement of pulse rate) for high-precision measurements of the Shapiro effect, i.e., the delay of signals propagating in a gravitational field. Taking this effect and the expected characteristics of the orbital motion into account, the mass of the neutron star was inferred. Measuring the masses and radii of neutron stars makes it possible to determine constraints on the equation of state of matter at the nuclear densities they consist of. Hypotheses have been advanced on the presence in neutron stars of an exotic hadron matter — hyperons or kaon condensate. The fact that a neutron star with a mass of $\approx 1.97 M_{\odot}$ does exist rules out these models and imposes severe constraints on models with quark matter, without as yet ruling them out completely.

Source: *Nature* **467** 1081 (2010)
http://arXiv.org/abs/1010.5788vl

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