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1. Gravity Prob B results

The summary of the final results has been presented of the NASA'S Gravity Prob B space experiment, which measured two relativistic gravitational effects: geodetic precession, and reference frame dragging by a rotating mass (the Lense–Thirring effect). The satellite was in a polar orbit around Earth, and its common axis of rotation was fixed by pointing at a single star, IM Pegasi. The measurement system was built around four ultra-precise gyroscopes — quartz balls with a superconducting niobium coating. The rotating balls created a magnetic field measured by SQUID magnetometers. This technique allowed conducting high-accuracy measurements of the angular displacements of gyroscope axes for almost a year. The results of the measurements are in agreement with the calculations within the framework of general relativity. The predictions have been confirmed at the level of the achieved accuracy: 0.28% for the geodetic precession, and at the level of 19% for the Lense–Thirring effect. These effects have already been measured at a comparable accuracy in laser ranging experiments. In this way, Gravity Prob B mission presented a reliable independent confirmation of earlier results. Numerous innovative solutions have been found and technologies have been developed (which have found important practical applications) in the process of designing and implementing the Gravity Pro B project — one of the longest running projects in NASA history started in 1963 for studying fundamental scientific issues.

Sources: http://www.nasa.gov/mission_pages/gpb/gpb.results.html
http://arxXv.org/abs/1105.3456vl

2. Neutrino oscillations in the MINOS experiment

In the MINOS experiment — a long-baseline neutrino experiment designed to observe the phenomena of neutrino oscillation using a facility at Fermilab — muon neutrinos ν_μ are recorded near the base of a neutrino beam produced by an injector accelerator and at a distance of 735 km along the beam. The deficiency (disappearance from the beam) of ν_μ in the second detector leads to the conclusion that ν_μ transformed (oscillated) into other types of neutrinos which are not directly recorded in this experiment. According to recent MINOS data, the difference of the masses squared of different neutrino mass states is $|\Delta m^2| = (2.32^{+0.12}_{-0.08} \times 10^{-3}$ eV^2, and the mixing angle is $\sin^2(2\theta) > 0.90$ at a 90% confidence level. Also, the ν_μ decay hypothesis and the quantum decoherence hypothesis were excluded at the 7σ and 9σ levels, respectively. The MINOS experiment also provided new data on the oscillations of $\bar{\nu}_\mu$ antineutrinos. The experiments with ν_μ and $\bar{\nu}_\mu$ give consistent results with an accuracy of 2.0% if the oscillation parameters in the two cases are identical. Furthermore, a constraint of $< 22\%$ was obtained for the fraction of ν_μ which could oscillate into the hypothetical sterile neutrino.

Sources: http://arXiv.org/abs/l 103.0340
http://arXiv.org/abs/l 104.0344
http://arXiv.org/abs/l 104.3922

3. Periodicity in the stripe phase of the quantum Hall effect

I V Kukushkin (Max Planck Institute for Solid State Physics Research, Stuttgart, Germany and the Institute of Solid State Physics, Chernogolovka, Russia) and his colleagues from Germany and Israel have investigated the state known as the quantum Hall stripe phase in the quasi-two-dimensional heterostructure GaAs/AlGaAs with a Landau-levels filling factor $v = 9/2$. This phase looks like an array of linear domains with alternating full and zero filling at the upper Landau level, thus forming charge density wave. The direction of the stripes corresponds to the [110] direction in the GaAs crystal lattice. The stripe phase wasalso observed in a number of other systems, including high-temperature superconductors. To measure the momentum of magnetophonon quasiparticles as a function of energy, the system was subjected to the combined action of surface acoustic waves, microwave radiation, and laser light which caused photoluminescence. When the impacts of the first two factors are in resonance with the dispersion relation, two-dimensional electron gas heats up and thereby affects the photoluminescence spectrum. Consequently, measuring this spectrum is a means of evaluation of dispersion properties. If the wave vector $\mathbf{k}_{\mathrm{SAW}}$ of the surface acoustic wave is parallel to the stripes, the dispersion characteristics have the theoretically predicted form; for instance, the curve reveals a roton minimum. The observation that the dispersion curve in the transverse direction is not flat but slowly rises as $\mathbf{k}_{\mathrm{SAW}}$ increases was an unexpected result. The exact mechanism of this behavior has not yet been identified. Also, as $\mathbf{k}_{\mathrm{SAW}}$ was increased, the authors observed a periodical (in wavelength) variation in the absorption coefficient of surface acoustic waves with period $3.6R_c$, where R_c is the cyclotron radius. The observed geometric resonance makes it possible to measure the period of the charge density wave in the quantum Hall stripe phase. According to calculations, the period would have to be $2.7R_c$; it has not been established yet what caused the discrepancy.

Source: *Phys. Rev. Lett.* **106** 206804 (2011)
http://dx.doi.org/10.1103/PhysRevLett.106.206804

4. Theoretical calculation of Hoyle energy level

In 1954, F Hoyle predicted the existence of the energy level of the ^{12}C nucleus near the threshold of the fusion reaction ^{8}Be + α-particle. The presence of this level, required for the

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occurrence of the nuclear cycle in stars, joins three α-particles and results in the formation of carbon. Soon after Hoyle's prediction, this energy level was discovered experimentally. However, it proved impossible until recently to calculate the Hoyle level by *ab inito* calculations, i.e., starting with the fundamental principles of quantum chromodynamics. E Epelbaum (Ruhr University, Bochum, Germany) and his colleagues were able to accomplish this for the first time in lattice computations in the framework of the effective field theory, which is based on expansion of quantities in a power series of the characteristic particle momentum Q; it is important that E Epelbaum et al. took into account all terms of third order big O of Q^3 and lower. The calculations faithfully reproduced the energy of the ground and an excited state with spin 2, and in addition revealed a resonance at -85 ± 3 MeV whose properties are fully consistent with the Hoyle level. The Hoyle level is an example of the fine-tuning of parameters: the synthesis of elements making organic life possible would have been impossible at the slightest shift of its energy, so that the Hoyle level is often discussed in the context of the anthropic principle.

Source: *Phys. Rev. Lett.* **106** 192501 (2011)
http://arXiv.org/abs/1101.2547v2

5. Rotational Doppler broadening in the photoelectron spectra of molecules

T D Thomas (University of Oregon, USA) and his colleagues have carried out the first experimental investigation of the effect of rotation of dimer molecules on the spectrum of the photoelectrons they emit. In the case of off-center emission, an electron may gain additional energy, and this explains the rotational Doppler effect. The contribution of this effect to the broadening of spectral lines may be comparable in magnitude to the contribution of the conventional Doppler effect caused by the movement of the centers of mass of molecules. High-resolution electron spectroscopy was used to record photoelectrons emitted by a gas mixture of N_2 and Kr irradiated by X-rays. Monatomic krypton gas was used for calibration: monitoring of Kr spectral lines made it possible to eliminate the contribution of the conventional Doppler effect. The measured dependence of line broadening on gas temperature and photoelectron energy is in good agreement with the theoretical model of Y-P Sun et al., which takes quantum effects into account but is also described rather well in terms of the simple classical model.

Source: *Phys. Rev. Lett.* **106** 193009 (2011)
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