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1. Quantum model of 'Zitterbewegung'

C Roos and his group at the Institute for Quantum Optics and Quantum Information and the Institute of Experimental Physics (The University of Innsbruck, Austria) and the University of the Basque Country (Bilbao, Spain) carried out an experiment with $^{40}Ca^+$ ions in which they recorded the 'quivering motion' effect (Zitterbewegung) predicted for electrons by E Schrödinger in 1930 using the Dirac equation. Rapid spatial oscillations of a particle arise owing to a superposition of states with positive and negative energies. The experiment with ions is a quantum model of the Zitterbewegung of free relativistic electrons: in other words, the joint evolution of the vibrational degrees of freedom and the internal spin state of the ion is described by the same equations as the spatial trajectory of free electrons. Laser pulses transferred ions into a prescribed initial state and a short time later their fluorescent radiation was observed. The properties of this radiation yielded the characteristics of the Zitterbewegung. The Zitterbewegung can be experimentally examined with a quantum model only in which it is linked to the spin state of the ion. At the moment it is quite infeasible to detect this effect with real electrons since its amplitude amounts to only $\sim 10^{-10}$ cm and proceeds at a frequency of $\sim 10^{21}$ Hz. The idea of quantum models was suggested by R Feynman in 1982 for those cases in which the complex behavior of real systems is beyond any hope of direct or numerical computer experiments.

Source: *Nature* **463** 68 (2010)
http://dx.doi.org/10.1038/nature08688

2. The E_8 group in crystals

R Coldea (Clarendon Laboratory, Oxford University) and his colleagues in Germany and the United Kingdom discovered in neutron scattering experiments that the distribution of spins in the quasi-one-dimensional ferromagnetic crystal of cobalt niobate ($CoNb_2O_6$) at low temperature and in a strong magnetic field obeys the symmetry group E_8. In 1989, A B Zamolodchikov (The L D Landau Institute of Theoretical Physics, Chernogolovka, Russia) showed that in certain cases this Lie group describes the spectrum of spin excitations in the 1D Ising model. In recent years, the E_8 group has also been discussed in elementary particles theory but has never been observed in real physical systems. The phase transition in the quasi-one-dimensional Ising model occurs when the magnetic field directed along the atomic chains increases above a certain critical value which separates the magnetically ordered and the paramagnetic phases. The experiment studied the spin excitations in the two phases above and also investigated the properties of a crystal in the immediate vicinity of the phase transition point. The measured ratio of the two lower resonance frequencies (two meson states) of atomic chains close to the critical magnetic field of $\simeq 5$ T was found to lie close to the golden mean 1.618, in agreement with the prediction of A B Zamolodchikov's theory.

Source: *Science* **327** 177 (2010)
http://dx.doi.org/10.1126/science.1180085

3. Goos–Hänchen effect for neutrons

Researchers at the Delft University of Technology (The Netherlands) and the Rutherford Appleton Laboratory (United Kingdom) were able for the first time to detect the Goos–Hänchen effect in matter in the reflection of spin-polarized neutrons by a potential barrier. This effect, which was already predicted by Isaac Newton for a beam of light reflected at a glass–vacuum surface, produces a lateral shift between the points of incidence and reflection of a beam. In a manner of speaking, we can say that the beam penetrates into the sample and is reflected at a certain depth under the reflecting surface. The effect was first measured for light by the German physicists F Goos and H Hänchen in 1947. In the case of neutrons, reflection imparts a certain phase shift to the wave function of a particle, which may be represented by a spatial translation along the reflecting surface. The experiment above made it possible to measure the Goos–Hänchen effect owing to the fact that the height of the reflecting potential barrier in a magnetic field depends on neutron spin direction (and on the orientation of the neutron magnetic moment), so that neutrons of different spin polarization are reflected at different efficiencies. The neutron beam was reflected by a layer 3 μm thick of permalloy $Fe_{0.2}Ni_{0.8}$. The choice of this material with high permeability was predicated on the need to create a magnetic field under the reflecting surface, thus producing a phase-shifted wave function. Reflected neutrons were recorded with the Offspec neutron reflectometer installed at the ISIS Neutron Source in Oxfordshire. A small change in the polarization of the reflected beam was an indication of the nonzero Goos–Hänchen effect. The Goos–Hänchen effect may be used for practical applications, such as generation of coherent neutron beams and for creating improved neutron 'waveguides'.

Source: *Phys. Rev. Lett.* **104** 010401 (2010)
http://dx.doi.org/10.1103/PhysRevLett.104.010401

4. Electron 'liquid crystal' in an iron-based superconductor

J C Davis (Brookhaven National Laboratory), P C Canfield (Ames Laboratory), and co-workers of a team of US and Chinese physicists conducted a scanning tunneling spectroscopy study of the compound $Ca(Fe_{1-x}Co_x)_2As_2$ (x is the fraction of dopant atoms) and discovered a static spatially ordered state of electron wave functions whose structure resembles that of liquid crystals. This compound is a parent

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of one class of high-temperature superconductors – layered iron-based superconductors (see review papers in *Usp. Fiz. Nauk* **178** 1243, 1273, 1307 (2008) [*Phys. Usp.* **51** 1201, 1229, 1261 (2008)]). Electron wave functions with an elongated shape were observed on the specimen surface, stretching along one of the crystal axes. Their longitudinal size was approximately eight times as great as the distance between two neighboring iron atoms, and they were in spatial correlation with the dopant atoms. It was conjectured that the 'liquid crystal' state of electrons is critically important for high-temperature superconductivity to emerge. Similar ordered electron states have already been reported in cuprate superconductors. This may be an indication that the superconductivity mechanism in iron-based superconductors is closer to the currently unknown superconductivity mechanism in cuprates than to the Bardeen–Cooper–Schrieffer mechanism in low-temperature superconductors.

Source: *Science* **327** 181 (2010)

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5. Gamma-radiation background at intermediate galactic latitudes

The results have been published concerning the observation of cosmic gamma radiation at intermediate galactic latitudes $10^\circ \leqslant |b| \leqslant 20^\circ$ in the energy range from 100 MeV to 10 GeV, obtained by the Large Area Telescope (LAT) aboard the cosmic Fermi gamma observatory during the first five months after its launching. New background measurements do not confirm some earlier observations conducted by the EGRET gamma telescope aboard the orbital Compton Observatory in 1991–2000. According to the standard model of the origin of the diffuse galactic gamma radiation, it is generated when charged particles of cosmic rays interact with interstellar gas and radiation. This model is calibrated using cosmic ray data and provides sufficiently specific predictions for the gamma radiation background. EGRET had earlier detected an excess of gamma radiation flux in comparison with the standard model outlined above. This information gave rise to conjectures on additional contributions to gamma background from annihilation of dark matter particles and other hypothetical sources. LAT is more sensitive than EGRET by approximately an order of magnitude, but the LAT data reveal no excess in the gamma background and thus the measured spectrum supports with high accuracy the predictions of the standard model of background generation.

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