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1. t-Quark electric charge

The heavy quarks discovered in 1995 at the Fermilab Tevatron proton – antiproton collider were widely recognized as the t-quarks of the Standard Model of elementary particles, according to which their electric charge is $+2e/3$. In fact, the charge as such was not measured in these experiments, which left possible an alternative theoretical scenario of the new quark having the charge $-4e/3$ and forming a doublet with another unknown quark having the charge $-1e/3$. In this case, the t-quark predicted by the Standard Model may have remained unobserved until now. The D0 Collaboration ran a new experiment in the Tevatron collider, which excludes this hypothetical scenario at the 92% confidence level. The subject of study was the decay of particles, discovered in 1995, to W-bosons and b-quarks. Their charge was established to be $+2e/3$ and, hence, they are indeed the t-quarks of the Standard Model.

Sources: *Phys. Rev. Lett.* **98** 041801 (2007); prl.aps.org

2. John Wheeler's 'delayed decision' experiment

The result of the famous two-slit experiment (formation or absence of an interference pattern) depends on whether measurements are carried out that are capable of determining through which of the slits the photon has passed. In order to clarify the conceptual foundations of quantum mechanics, John Wheeler proposed in 1984 an experiment with a 'delayed decision' in which the decision on measuring or not measuring is taken after the photon has passed through a slit but still prior to the moment by which the information on the decision, traveling at the speed of light, could have reached the photon. In this case, the behavior of the photon (traversing through both slits at the same time as a wave or through a single slit as a particle) and the act of making a decision on conducting the measurements are not causally connected: these events are separated by a spacelike relativistic interval and therefore no 'hidden parameters' could have been passed on to the photon in advance. Speaking metaphorically, the photon 'is unaware' of whether its trajectory is to be measured. V Jacques and co-workers in France and China carried out an experiment with a delayed decision using the arrangement that is closest to the original proposal by John Wheeler. Having passed through the splitter at the entrance to a 48-m-long Mach – Zehnder interferometer, photons could travel along two different paths. Impurity atoms in a diamond nanocrystal excited by laser pulses were utilized as sources of single photons. An electro-optical modulator installed at the other end of the interferometer was controlled by a quantum random-number generator. If a signal was sent, the modulator rotated the photon polarization plane. Depending on the state of the modulator, a photon that travelled along any of the two paths in the interferometer either had the same polarization in both and then underwent interference when traveling through a prism, or acquired different polarizations and reached the detectors on emerging from the two paths without undergoing interference. In the latter case it is possible to establish which path the photon followed — that is, the measurement was carried out. The photon source and the modulator were synchronized with a time delay in such a way that passage of the photon through the splitter at the entrance to the interferometer and the random selection of the state of the modulator were causally unrelated. Therefore, in contrast to earlier 'delayed decision' experiments, all conditions of the John Wheeler thought experiment were fully met. In those cases where no trajectory measurement was carried out, the interference pattern with 94% sharpness was recorded (this deviation from 100% was caused by experimental errors), but if the trajectory was measured, interference was absent with a 1% accuracy. The experiment thus confirmed once again the predictions of quantum mechanics and demonstrated that the wave – particle dualism is the profound fundamental property of the theory and cannot be reduced to 'hidden parameters'.

Sources: *Science* **315** 966 (2007); www.sciencemag.org

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Translated by V I Kisin

3. The Casimir – Polder force as a function of temperature

The force of interaction between atoms and a surface due to electromagnetic quantum fluctuations is known as the Casimir – Polder force. This phenomenon is one of the manifestations of the Casimir effect — that is, the attraction between two surfaces. In 1955, E M Lifshitz predicted the temperature would affect the Casimir force, resulting from the influence of temperature on thermal fluctuations and on the spectrum of electromagnetic oscillations in the space between the bodies. J M Obrecht and co-workers at JILA (Colorado) were the first to study experimentally the temperature effect on the Casimir – Polder force. They measured the frequency of mechanical vibrations of a Bose – Einstein condensate cloud of ^{87}Rb atoms at a distance of several microns from a dielectric plate and calculated the attraction force from the measured frequency. The thermal background temperature outside the plate on the side of the condensate was kept constant (at 310 K), while the plate temperature and, correspondingly, that of the thermal radiation inside the plate can be varied by laser-heating the side of the plate opposite to the condensate. The theoretical foundation of this method was given by P Antezza, L P Pitaevskii and S Stringari in 2004 – 2005; the results of measurements are in good agreement with these calculations. Thus, heating a plate from 310 to 605 K increased the Casimir – Polder force by a factor of three. This temperature effect should be taken into account when designing nanoscale devices.

Sources: *Phys. Rev. Lett.* **98** 063201 (2007); prl.aps.org

4. The Hanbury Brown – Twiss effect for bosons and fermions

The Hanbury Brown – Twiss effect, initially discovered with photons, manifested itself in the tendency of photons to reach a detector bunched into groups; this is a consequence of the Bose – Einstein statistics, which dictates the correlated behavior of photons. Contrary to this, fermions in a similar experiment should produce anticorrelation. T Jeltes and coworkers in the Netherlands and France were able for the first time to study the Hanbury Brown – Twiss effect for bosons and fermions in one and the same experimental setup, which made it possible to directly compare the results. Ultracold ^{4}He atoms (bosons) and ^{3}He atoms (fermions) fell due to gravitational force from an atomic trap onto a detector. The temperature and cloud size in the trap were identical for both types of particles. The experiment measured spatial and temporal correlations of the detected atoms. In agreement with expectations, two-particle correlation (bunching) was observed with bosons and anticorrelation (antibunching) was registered with fermions. The measured ratio of correlation lengths, determined by the ratio of particle masses, was found to be 1.3 ± 0.2, in agreement with the theoretically predicted value of $4/3$.

Sources: *Nature* **445** 402 (2007); www.nature.com

5. Nanopolymers

Researchers at the Massachusetts Institute of Technology (Cambridge, USA) created a new class of material called 'nanopolymers'. Ligands, such as thiol molecules incorporating a sulfohydrilic group SH, were bonded to the poles of spherical metallic nanoparticles. These groups are capable of bonding to one another and thus building chains of nanoparticles, as well as creating films by chain-to-chain bonding. The film structure resembled that of ordinary polymers formed from filament-shaped organic molecules. The process of formation of a nanopolymer is also very similar to ordinary polymerization reactions. Up to 50,000 nanoparticles could be bound into a single chain, and film area reached up to 1 cm^2. Nanopolymers may lead to useful practical applications, for instance, to designing materials with controlled porosity on the nanoscale.

Sources: *Science* **315** 358 (2007); www.sciencemag.org

Compiled by *Yu N Eroshenko*