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1. Testing relativity theory

Gravitational influence of the Sun on radio waves. Bruno Bertotti (University of Pavia, Italy) and his colleagues from Rome and Bologna achieved an accuracy 50 times higher than previous experiments when studying the effect of the solar gravitational field on electromagnetic waves passing by the Sun. What the physicists measured was the time it takes a radio wave to make a round trip between the Earth and the 4-meter antenna onboard the *Cassini* spacecraft, when the Earth and (Saturn-bound) *Cassini* were on different sides of the Sun. The accuracy of previous experiments was limited by the noise produced by the solar corona. A new data processing method made it possible to overcome this problem. Another novelty was that instead of taking one measurement, the time history of the effect in the course of the spacecraft's motion was studied. As a result, the parameter γ was measured, whose GRT value is exactly 1 — unlike in many alternative theories. Within the relative accuracy of 2×10^{-5}, no deviations from GRT predictions were found.

Source: *Nature* **425** 374 (2003); http://www.nature.com

Time dilation. The relativistic time dilation has been studied in many experiments for decades. The most accurate measurement of this effect to date has been carried out at the Max Planck Institute for Nuclear Physics in Heidelberg, Germany, by comparing the radiation from laser-excited lithium ions in motion and at rest. Apart from being affected by the ordinary Doppler effect, the radiation frequency changes due to the time dilation effect. The mobile ions in the beam had a velocity of 19,000 km s^{-1} (6.3% of the speed of light in vacuum). The time dilation corresponds within 2.2×10^{-7} (four times the accuracy of previous experiments) to the value obtained from the Lorentz transformations.

Source: *Physics News Update*, Number 655; http://www.aip.org/physnews/update/

2. 'Hardening' K-mesons

When two high-energy heavy ions collide, a so-called 'fireball' appears in the collision region in which various types of elementary particles are intensely created and then annihilate. As the ball expands and cools down, the number of particles levels off (they are said to harden) and from then on can only decrease due to their decays. Similar processes also occurred in the early universe. If the properties of particles and antiparticles were identical (except for the sign of the charges), so would the hardening processes they undergo. However, the KaoS collaboration in Germany has now found that 'hardened' K^+- and K^--mesons differ in their angular distributions and energy spectra — in a way, specifically, which suggests that the hardening of K^+-mesons precedes that of their K^- counterparts. Mesons were produced in Ni + Ni and Au + Au ion collisions at about 1.5 GeV at the GSI accelerator. Verification of this important result is clearly needed.

Source: *Phys. Rev. Lett.* **91** 152301 (2003); http://www.prl.aps.org

3. Superfluidity and superconductivity at nanometer scales

In recent years, the microscopic analogs of É L Andronikashvili's experiment have been repeated a number of times to study the rotation of OCS molecules in microscopic droplets of liquid helium cooled below 2.2 K — the temperature at which macroscopic volumes of helium become superfluid. In 2002, R McKellar and his colleagues in Canada discovered that droplets consisting of about eight helium molecules do not possess superfluidity. Now, in a new experiment by the same researchers — but with rotating N_2O molecules to study — it proved possible for the first time to trace the superfluid transition with increasing droplet size (miniclusters) in the range from 3 to 12 helium molecules. Droplets of helium with N_2O molecules inside were created by passing the mixture of the gases through a cold nozzle. Spectroscopic methods allowed droplets of different sizes to be distinguished in the experiment. Exposure to infrared light and microwave radiation excited the vibrational and rotational degrees of freedom of N_2O molecules in the droplets. From the level of radiation absorption, the moment of inertia of N_2O molecules was determined. If helium is not superfluid, helium molecules are dragged into rotation with N_2O molecules, thus increasing their moment of inertia. It turned out that as the number of helium molecules in the droplets increases from 3 to 6, the moment of inertia builds up, but as this number is further increased from 7 to 12, the moment of inertia goes down, signaling the helium transition to the supefluidity regime.

Source: *Phys. Rev. Lett.* **91** 163401 (2003); http://www.prl.aps.org

R Reich and his colleagues in Israel have studied the magnetic susceptibility of lead grains 4 to 1000 nm in size and cooled to a temperature of about 5 K. An abrupt disappearance of the Meissner effect upon transition to grain size of less than 30 nm has been discovered. This critical size of superconducting grains is consistent with the Anderson criterion. Although the absence of superconductivity in small grains had been observed earlier, the experiment discussed is the first to investigate a superconducting transition with increasing grain size.

Source: *Phys. Rev. Lett.* **91** 147001 (2003); http://www.prl.aps.org

Uspekhi Fizicheskikh Nauk **173** (11) 1246 (2003)
Translated by E G Strel'chenko

4. Ordinary crystals with a negative index of refraction

A theoretical study of materials possessing both a negative electric permittivity and a negative magnetic permeability was carried out in the 1960s by V Veselago of the P N Lebedev Physics Institute, RAS in Moscow. In 2000, such materials, with an index of refraction $n < 0$ in the microwave range, were created at the University of California in the form of an assembly of microscopic rings and wires (see *Usp. Fiz. Nauk* **170** 552 (2000) [*Phys. Usp.* **43** 520 (2000)]). Now, Y Zhang and his colleagues in the USA have for the first time found that not only composite materials but also ordinary crystals can have a negative index of refraction. Two samples of a crystalline alloy containing yttrium, vanadium, and oxygen were brought into contact along a flat surface, with the samples' optical axes differently oriented. This double crystal has $n < 0$ for light of any frequency passing through the interface, and even for a coherent beam of electrons (quantum electron waves). At the same time, at certain angles of incidence the same crystal exhibits $n > 0$ or transmits light completely, without reflection. The discovered property of the crystal may find advantageous practical applications, in particular, in the manufacture of nonreflective lenses.

Source: *Phys. Rev. Lett.* **91** 157404 (2003);
http://www.prl.aps.org

5. Pentagonal crystal symmetry

Unit cells of ideal solid crystals do not possess a pentagonal symmetry because such a symmetry cannot be translated along a crystal. The exception is made for quasi-crystals in which translation is not exact and pentagonal symmetry is observed. It has long been predicted, however, that pentagonal symmetry can arise in liquid crystals which, as is known, are not completely chaotic and form crystalline structures at small scales. Earlier, pentagonal symmetry had been observed only in thin films of liquid metals. Now, pentagonal symmetry in a volume of liquid copper has been found for the first time by A Di Cicco and his colleagues in Italy. The team studied the diffraction of X rays obtained from an accelerating source. Unlike liquid film experiments, not only scattered X-ray photons but also electrons knocked out of atoms were observed, enabling the geometry of the crystal lattice cells to be determined with a considerably greater accuracy. From these data, about 10% of the atomic clusters in the melt have a pentagonal crystal structure. Theory predicts that pentagonal symmetry can be found not only in copper but also in some other (liquid) metals — specifically, in silver, lead, and gold — which do not possess this symmetry in the solid state.

Source: *Phys. Rev. Lett.* **91** 135505 (2003);
http://www.prl.aps.org

Compiled by *Yu N Eroshenko*