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Physics news on the Internet (based on electronic preprints)

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1. Anomalous CP violation

The D0 collaboration at the Tevatron accelerator at the Fermi National Accelerator Laboratory (Batavia, Illinois) detected asymmetry of semilepton decays of B_q^0 and $\bar{B}_q^0$ mesons ($q = d, s$), which may point to new physics beyond the Standard Model of elementary particles. Pairs of $B_q^0\bar{B}_q^0$ mesons were created in $p\bar{p}$ collisions. Among the products of B_q^0 and $\bar{B}_q^0$ decays were antimuons μ^+ and muons μ^-, respectively. The particles B_q^0 and $\bar{B}_q^0$ may transmute into one another (oscillate) in processes involving two $W^{\pm}$ bosons. The emergence of lepton pairs with an identical sign of charge, $\mu^-\mu^-$ or $\mu^+\mu^+$, among the decay products was an indication that such an oscillation has taken place, and the excess of the number of $\mu^+\mu^+$ over that of $\mu^-\mu^-$ detected in the D0 experiment pointed to asymmetry in the direction of oscillations. The asymmetry due to violation of CP invariance is indeed predicted by the Standard Model, but the measured size of oscillation asymmetry effect was found to be greater than the predicted one, the difference being 3.2 standard deviations. An additional CP violation above the Standard Model level has been expected by theorists for some time now, as it is required for explaining the dominance of matter over antimatter in the Universe.

Source: *Phys. Rev. Lett.* **105** 081801 (2010)
http://dx.doi.org/10.1103/PhysRevLett.105.081801

2. Three-slit quantum interference

G Weihs (Innsbruck and Waterloo Universities) and his colleagues from Canada and France performed an experiment which studied the interference of photons flying through three slits. Unlike the case of two slits, the fundamental predictions of quantum mechanics for three-slit interference have not been tested in the past. Within the framework of the standard approach, the probability density of a photon appearance at a given point on a screen behind slits is defined by the quadratic formula (Born rule) $P_{ABC} = |\psi_A + \psi_B + \psi_C|^2$ and is given through the probabilities of two-slit ($P_{AB} = |\psi_A + \psi_B|^2$, etc.) and one-slit ($P_A = |\psi_A|^2$, etc.) measurements. Deviations from this expression, such as higher-order terms, could be expected in generalizations of quantum mechanics. The researchers studied the transmission of single photons emitted by a source of very low luminosity through three slits, each 30 μm wide, separated by gaps of 100 μm each. A series of measurements were performed for all possible combinations with one and two closed slits, and with three open slits. The above expression for P_{ABC} containing the probabilities for one- and two-slit measurements has been confirmed at the achieved experimental error of 1%, i.e., no deviations from the Born rule have been found within the scatter of the measurement.

Source: *Science* **329** 418 (2010)
http://dx.doi.org/10.1126/science.1190545

3. Turbulence in superfluid helium-4

Heat from a heating source is transferred in superfluid liquids by a thermal counterflow of the normal-fluid component of the liquid (in terms of the two-fluid model). A number of experiments have demonstrated that the flow of the superfluid component becomes turbulent at a sufficiently high heat flux, and that the motion of quantized vortex filaments is also turbulent. Similar studies on the normal-fluid component have not been carried out in view of the absence of suitable tracer particles that would allow monitoring its speed. W Guo (Yale University) and his colleagues from the US and UK have established, using the new technique, that the flow of the normal-fluid component of ^{4}He in a glass tube also changes to the turbulent mode when the liquid at one of the ends of the tube is heated at a sufficiently high power level. Metastable He_2 molecules in the triplet state were formed in the tube by the electric field, and their fluorescent light emission was observed after excitation by laser pulses. He_2 molecules moved together with the normal-fluid component of the liquid; owing to their small size they were not trapped on the quantized vortex filaments and were practically unscattered by them, unlike what took place in experiments with macroscopic tracers. The lines of molecules oriented transversely to the heat flow remained straight at a sufficiently high heat flux and grew broader. This pointed to a flat velocity profile in the tube and the presence of additional disordered molecular velocities, which is typical of turbulent flow. The parabolic profile of velocities at low heat fluxes was revealed by studying compact clusters of molecules at various distances from the flow axis. In this last case, both the superfluid and the normal-fluid components of the liquid were in a laminar mode of flow.

Source: *Phys. Rev. Lett.* **105** 045301 (2010)
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4. Active metamaterial

Metamaterials possessing a refractive index $n < 0$, which were first investigated theoretically by V G Veselago (see *Usp. Fiz. Nauk* **92** 517 (1967) [*Sov. Phys. Usp.* **10** 509 (1968)]), may in the future find numerous useful technical applications. At the moment their utilization is thwarted by the high dissipation of electromagnetic waves by metallic components of the metamaterial. V M Shalaev (Purdue University) and his colleagues in the USA designed a metamaterial incorporating in its structure molecules of a fluorescent dye, Rh800. Rh800 molecules are excited by laser pulses (pumping pulses) so that the second light pulse can for some time stimulate light emission in reverse transitions to the lower states. The optimum time between pumping pulse and probe pulse was

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54 ps. As a result, the metamaterial acquired the properties of an optical amplifier in the visible wavelength range between 722 and 738 nm, and it compensated for the losses in the reflected and transmitted signals, plus it increased the magnitude of the negative refractive index. This method of creating active optical negative-index metamaterials (NIMs) was discussed some time ago in a number of theoretical papers, but its practical implementation in the near future was considered very problematic.

Source: *Nature* **466** 735 (2010)
http://dx.doi.org/10.1038/nature09278

5. Stars — the progenitors of magnetars

As a rule, a stellar cluster is formed after a single cloud of gas has fragmented. As a result, all stars of the cluster are nearly the same age. The character of evolution of individual stars in a cluster is dictated most of all by their masses — the more massive a star, the faster its evolution, and if the mass is sufficiently large, the star would explode as a supernova. An open cluster of young massive stars Westerlund 1 has been observed in the Ara constellation, and the same cluster contains a magnetar CXOU J164710.2-455216 — a neutron star possessing a giant magnetic field. Theoretical models and the data of indirect observations indicate that magnetars are born in explosions of very massive stars. This conclusion received additional support in new observations using the VLT telescope of the European Southern Observatory (ESO) in Chile. To determine the lower limit of stellar mass whose explosion gave rise to the magnetar, the masses were determined of two other stars in the same cluster forming the W13 binary system. The characteristics of their orbital motion and photometric data established that the masses of these stars are close to 23 and 35 solar masses. A star — the progenitor of a magnetar — cannot have a smaller mass because it was born simultaneously with the stars of the pair W13 but had exploded before them. Taking into account the mass loss by the stars of the W13 binary system during its evolution, it was concluded that the mass of the progenitor star of the magnetar CXOU J164710.2-455216 was 40 to 45 times greater than the solar mass.

Source: http://www.eso.org/public/news/eso1034/

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