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1. Local parity violation in nuclear collisions

The 'chiral magnetic effect', predicted in 1998 by D Kharzeev, R D Pisarski, and M H G Tytgat, was first detected by the STAR Collaboration at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory in the US using the STAR detector. The effect consists in parity violation (violation of the mirror reflection symmetry) which manifests itself in a partial spatial separation of positively and negatively charged quarks along the direction of the orbital angular momentum of the colliding nuclei. The separation of charges is caused by the difference between the numbers of quarks of different chiralities in the newly formed metastable domains and by the strong magnetic field with an intensity up to 10^{15} T, which is created in nonzero impact parameter (noncentral) collisions of nuclei. The experiment collided nuclei of Au + Au and Cu + Cu with a center-of-mass energy up to 200 GeV per nucleon pair. The distribution of charges on the two sides of the reaction plane (i.e., along the direction of the angular momentum) was measured using correlation analysis. Possible sources of background noise and experimental uncertainties, such as the contribution from scatterings of three or more particles and from resonance decays, were studied and eliminated. This resulted in identification of statistically significant correlations which could correspond to parity violation. As predicted by theoretical calculations, the measured effect was found to be stronger in the case of copper nuclei than with gold nuclei.

Source: *Phys. Rev. Lett.* **103** 251601 (2009)
http://arXiv.org/abs/0909.1739

2. Measurement of extreme low temperatures

D M Weld and coworkers at the Massachusetts Institute of Technology developed a new sufficiently universal technique of measuring the temperature of ultracold atoms in optical lattices. The method of spin-gradient thermometry was tested successfully in a nonuniform magnetic field on the gas of ^{87}Rb atoms trapped in a three-dimensional laser beam lattice. The gas was maintained in the Mott insulator regime in which conductivity vanishes due to strong repulsion between particles. The width of the transition zone between atom clouds in different spin states (and having different magnetic moments) depends on temperature; these clouds are separated under the action of a gradient of the external magnetic field. As temperature decreases, the transition becomes sharper; incomplete separation at finite temperatures is caused by the presence of spin excitations. Therefore, the temperature of the gas can be found from observations of the transition zone. In this particular experiment, it was possible to measure temperatures down to 1 nK and the researchers predict that the new technique will allow measuring temperatures down to $\sim$ 50 pK. The study of atoms trapped in optical lattices at extreme low temperatures is important for implementing quantum spin Hamiltonians which model materials with unique properties, such as high-temperature superconductors.

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3. Relativistic plasma 'mirror'

M Kando and coworkers at the Advanced Photon Research Center (Kyoto, Japan) and the P N Lebedev Physical Institute of the RAS (Moscow, Russia) studied the reflection of laser pulses from a relativistically moving 'mirror'. The mirror was a plasma wave (modulation of electron density) generated by a high-power laser pulse. When laser light propagates toward the mirror, the double Doppler effect increases the frequency of the reflected light by a factor of 37 to 66. A frequency jump of this magnitude may prove useful in a number of practical applications, for instance, for laser acceleration of ions or for the generation of ultrashort pulses. The flying mirror reflectivity in this experiment ranged from 1.3×10^{-4} to 0.6×10^{-3} for the pulse energy, which is close to the quantity predicted by the theory for this experiment. The experiment with laser beam reflection by a relativistic plasma mirror was first carried out in 2007. In this new experiment, it proved possible to achieve considerably higher reflectivity and to investigate in detail the characteristics of the reflected light.

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4. A close pair of compact stars

C Badenes and his coworkers in the US and Israel discovered a binary system at a distance of about 50 pc from Earth, in which one object is a white dwarf with a mass of about $0.9M_{\odot}$, and the second object is a neutron star or a black hole with a mass higher than $1.6M_{\odot}$. This system therefore contains the compact remnant of supernova explosions, which is known as nearest to the Earth. The binary system SDSS 1257+5428 with an orbital period of 4.6 hours was found by studying the spectral features of objects in the Sloan Digital Sky Survey catalog and was then additionally investigated by a DIS spectrograph using the 3.5-meter ARC telescope in New Mexico. The components of the pair gradually move closer because of the emission of gravitational waves. Estimates of the orbital parameters make it possible to conclude that these compact stars will collide within about 500 million years. T A Thompson and his colleagues at Ohio State University used these data to evaluate the total number and rate of mergers of binary systems of this type. By their calculations, the Galaxy contains about 10^6 such systems and the rate of mergers in the Galaxy is estimated as 5×10^{-4} year^{-1}. It cannot be excluded that a collision of a white dwarf and a compact object generate gamma bursts, powerful neutrino flashes, and ultrahigh-energy cosmic rays. Binary systems with white dwarfs might constitute the principal source of the background gravitational wave signal in the currently planned laser space interferometer LISA.

Sources: http://arXiv.org/abs/0910.2709
http://arXiv.org/abs/0912.0009

5. Waves on a cell membrane

The propagation of wave excitations along the outer shell of live cells depends on a variety of physical and chemical factors, some of them nonlinear, so that the observation and theoretical explanation of the properties of waves on cell membranes is an interesting and complex issue of biophysics. Surface waves are directly linked to the ability of many cells to move. Researchers at the Institute of Biophotonics Engineering and Research Center for Applied Sciences (Taipei, Taiwan) were able to clarify how waves propagate on the surface of fibroblasts, i.e., cells of connective tissue. The method of observation they used is known as noninterference wide-field optical profilometry (NIWOP). It is based on using the interval of the linear dependence of light intensity on the amount of spatial shifting out of the focal point of a microscope. This technique made it possible to achieve the required resolution in the three-dimensional picture of wave propagation. The experimentalists measured profiles of waves, their speed (~ 100 nm s^{-1}), their dispersion, and other characteristics. Observations confirm the detailed theory of wave propagation suggested by R Shlomovitz and N S Gov in 2007. Their model was based on the interaction between the repulsion force that arises when the protein actin polymerizes and the compressive force produced by the protein myosin which forms links between actin fibers. The researchers discovered that waves disappeared when they added reactants blocking myosin and the polymerization of actin, which confirms the decisive role of these proteins in the wave process. The outlined results may lead to important applications in medical sciences and biotechnologies.

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