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Physics news on the Internet (based on electronic preprints)

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1. Spin echo method for neutron studies

P Schmidt-Wellenburg (Paul Scherrer Institute, Switzerland) and his colleagues have developed a new method of neutron spectroscopy based on the measurement of spin echo in magnetic and gravitational fields. The method resembles magnetic resonance tomography typically applied to atomic nuclei. Cold neutrons were placed in a chamber and underwent reflections from its walls, showing a certain kinetic energy distribution and, correspondingly, the distribution in the maximum trajectory height relative to the chamber bottom. The magnetic field in the chamber had a vertical gradient, and therefore neutrons with different energies were, on the average, in fields of different strengths and experienced spin precession at different rates, which led to dephasing. The experiment began with an electromagnetic pulse that made spins co-directed, and, several dozen seconds after the exposition to another two auxiliary pulses, the neutron polarization was measured. This method made it possible to reconstruct the neutron energy spectrum with record accuracy and determine the magnetic field gradient with an error of only 1.1 pT cm^{-1}, which is one eighth that in previous experiments. The new method is planned to be used, in particular, to measure the neutron electric dipole moment, which is predicted to be associated with a CP invariance violation, but has not yet been revealed with the accuracy now attained.

Source: *Phys. Rev. Lett.* **115** 162502 (2015)
http://dx.doi.org/10.1103/PhysRevLett.115.162502

2. Thermodynamic time arrow in quantum systems

T B Batalhao (Federal University of ABC, Brazil) and colleagues have experimentally examined the entropy production in a microscopic quantum system. The investigated nuclei of ^{13}C atoms entering into the composition of $CHCl_3$ chloroform molecules were placed in an oscillating magnetic field. When the oscillation frequency was low, the nuclear spins had time enough to change direction, but upon frequency heightening a 'breakdown' occurred and the spin flip became chaotic, which introduced disorder and, accordingly, raised the entropy. The entropy measurements were based on the effect of interaction between ^{13}C and H nuclei in the same molecules, which were quantum q-bits to which the quantum tomography method was applied. Although the experiment was performed with a macroscopic liquid chloroform sample, the ensemble of carbon nuclei could be regarded as different realizations of states of single nuclei. The magnetic pulses had an asymmetric time profile, and chloroform was exposed first to direct and then to time-reversed pulses. The experimental results confirmed the Kullback–Leibler relationship describing the difference in the change in the system's entropy upon direct and reverse variation of its properties. Before, the Kullback–Leibler relationship had been checked for classical systems only, and the quantum regime was examined for the first time in the work described here. The results of the experiment can provide insight into time irreversibility from the point of view of quantum phenomena.

Source: *Phys. Rev. Lett.* **115** 190601 (2015)
http://dx.doi.org/10.1103/PhysRevLett.115.190601

3. Phase transition with a change in the symmetry and topology

Most phase transitions are explained by a change in the symmetry in the framework of the Landau theory. However, topological phase transitions exist that cannot be described by the order parameter but are characterized by topological invariants. E H Rezayi and F D M Haldane theoretically predicted in 2000 that a hybrid phase transition is possible in some cases when a change in the topology is accompanied by a symmetry breaking, but no unambiguous evidence of such processes had ever been observed. A group of researchers from the USA and Netherlands has revealed such a rare transition in a two-dimensional electron gas in a superpure GaAs/AlGaAs crystal. The measurements were carried out at a temperature near 0.012 K and a pressure of 10^4 atm. The original goal was observation of a topological transition associated with a fractional (the occupation factor $\nu = 5/2$) quantum Hall effect with rising pressure. But it turned out that the topological transition was preceded by a transition with a change in symmetry according to the Landau theory. This effect is possibly explained by a non-Coulomb electron interaction and mixing of the Landau levels. Topological phase transitions are a promising subject of research and can find useful applications in nanoelectronics.

Source: *Nature Physics*, online publication of October 26, 2015.
http://dx.doi.org/10.1038/nphys3523

4. Microscopic heat engine

I A Martinez (The Barcelona Institute of Science and Technology, Spain) and colleagues have realized the Carnot cycle with a single optically trapped Brownian microparticle as the working substance of a heat engine. A 1-μm in diameter polystyrene microsphere immersed in water was held by laser radiation and was observed under a microscope. Just as in large heat engines, the microscopic engine operation was supported by the temperature difference. The electric field fluctuating with the white noise spectrum induced jitter and Brownian motion of the particle and thus imitated the working conditions from room temperature to thousands of kelvins, and the displacement of the particle from the trap center corresponded to a change in the working substance

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volume. By changing two parameters (intensity of electric field fluctuations and trap rigidity), the Carnot cycle was realized by passing through two isothermal regions joined by two adiabatic ones. The engine efficiency amounted to $\eta = 0.25 \pm 0.05$. The experiment illustrates thermodynamics on small scales and characterizes the sources of irreversibility. Its results may turn out to be useful in nanomotor designing.

Source: *Nature Physics*, online publication of 26 October 2015.
http://dx.doi.org/10.1038/nphys3518

5. Hidden baryons around central galaxies

An analysis of data from the Planck cosmic telescope carried out by C Herandez-Monteagudo (Centro de Estudios de Fisica del Cosmos de Aragon) (CEFCA), (Center of Cosmos Physics Research of Aragon, Spain) and colleagues has evidenced the fact that a considerable portion of baryons in the Universe reside not inside galaxies but in the gas clouds around the central galaxies in the galactic groups and clusters observed by the Sloan Digital Sky Survey. The kinematic Sunyaev–Zeldovich effect was investigated, which consists in a Doppler frequency shift of the CMB radiation upon its scattering by moving gas clouds. This leads to the additional temperature fluctuations in relic radiation observed by Planck. On the basis of this effect, the specificities of gas motion around central galaxies were disclosed, and it was suggested that about half of all the baryons should reside around central galaxies. Baryons from the galaxies could have been ejected in various processes, such as the radiation pressure delivered by active galactic nuclei.

Source: *Phys. Rev. Lett.* **115** 191301 (2015)
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