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Physics news on the Internet (based on electronic preprints)

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1. Replication of states in a quantum dot

A M Burke and his colleagues at Arizona State University found that magnetoresistance in an open quantum dot is distributed in the form of diamond-shaped periodic structures. A quantum dot of lateral dimensions 1.1×1.1 μm was prepared by etching and electron-beam lithography in a thin InAs layer. The scanning atomic-force microscope used in these experiments fixed the variations of magnetoresistance in the quantum dot (which were produced in response to perturbations introduced by the field of the microscope tip) as a function of the magnetic field strength. The repeated periodic structures identified in a quantum dot can be described by the so-called scar wave function of electrons. The data obtained agree well with the concept of 'Quantum Darwinism' proposed by W Zurek (Los Alamos National Laboratory) in 2003. In this model, which describes the transition from the quantum state to the classical one, the decoherence of the most stable quantum state (pointer state) is accompanied by its replication in the classical environment. Repetitive structures in the quantum dot are interpreted by the authors as classical copies of the same pointer state that went through decoherence.

Source: *Phys. Rev. Lett.* **104** 176801 (2010)
http://dx.doi.org/10.1103/PhysRevLett.104.176801

2. Dipolar intermolecular interactions in ultracold gases

Researchers at the University of Colorado and the National Institute of Standards and Technology (NIST) studied for the first time the properties of ultracold gas consisting of polar $^{40}K^{87}Rb$ fermionic molecules characterized by a long-range potential of dipole–dipole pair interaction. Molecules in one of the states of hyperfine splitting of electron energy levels were obtained by sending laser light onto a mixture of potassium and rubidium atoms cooled in a nonuniform magnetic field. The induced electric dipole moment of $^{40}K^{87}Rb$ molecules with a magnitude of up to 0.22 D is dictated by the intensity of the external electric field, and this relationship creates possibilities for controlling the properties of the gas. The $^{40}K^{87}Rb$ molecules placed in the electric field interact with each other anisotropically. If a collision occurs with the relative velocity directed along the field, the interactions between molecules become attractive, as these are collisions between opposite charges of dipoles oriented along the field. In collisions in the transverse direction, molecules are more often repelled, and the rate of inelastic processes (chemical reactions) is lower. The anisotropy of pairwise interactions of molecules manifested itself, in particular, in anisotropic thermalization of the gas, i.e., in different relaxation rates of the components of the molecular velocity directed longitudinally and transverse to the electric field.

Source: *Nature* **464** 1324 (2010)
http://dx.doi.org/10.1038/nature08953

3. Melting mechanism in plasma-dust crystals

L Couedel and his colleagues at the Max Planck Institute for Extraterrestrial Physics (Germany) found that the melting of two-dimensional plasma-dust crystals takes place in view of the crossing and the resonance coupling of the two branches of dusty-plasma oscillations. The mechanism of melting was theoretically predicted by A V Ivlev and G Morfill in 2000 for the one-dimensional case. Plasma-dust crystals are spoken of as an ordered state of dust particles in dusty plasmas [for details see V E Fortov et al. *Usp. Fiz. Nauk* **174** 495 (2004) (*Phys. Usp.* **47** 447 (2004))]. In this experiment dusty plasmas were created in a chamber above a planar electrode generating high-frequency discharge at a frequency of 13.56 MHz. The discharge-ionized argon was kept at a pressure of 0.4–1 Pa; it had an admixture of dust, namely, melamine formaldehyde particles of size ≈ 9 μm. The structure of the produced plasma-dust crystals was studied using high-speed video recording in reflected laser light. The development of instability accompanied by an increase in the kinetic energy of the dust particles and the melting of plasma-dust crystals were caused by a decrease in the discharge power or by a lowering of the gas pressure. Three branches of dusty-plasma oscillations were observed in these experiments. The crossing and the resonance coupling of the transverse (relative to the plane of the electrode) mode and one of the two longitudinal modes of oscillations were observed near the melting point, which corresponds exactly to the theoretical model.

Source: *Phys. Rev. Lett.* **104** 195001 (2010)
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4. Intergalactic magnetic field

S Ando (California Institute of Technology) and A Kusenko (University of California and University of Tokyo) determined for the first time the strength and characteristic scale of intergalactic magnetic fields. The magnetic field was found from the effect of diffuse emission (halo) of gamma radiation around the active galactic nuclei, which themselves are pointlike gamma sources. The halo is due to deflections in the magnetic field of charged particles of an electromagnetic cascade produced by high-energy gamma-ray photons interacting with background radiation. The observed angular size and brightness of the halo correspond to the magnetic field $B \approx 10^{-15}(\lambda_B/1\ \text{kpc})^{1/2}$ G, where $\lambda_B < 10$–100 kpc is the correlation length of magnetic fields; in fact, larger scales are not excluded. It is rather difficult to measure reliably the profile of the gamma halo around an individual active galactic nucleus, and the decisive factor proved to be that the statistical study used a set of 170 bright active nuclei

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observed by the Fermi-LAT Space Telescope. It was established that the gamma-ray halo is not produced by observation errors or by the emission of extended objects around galactic nuclei since the scale of such objects would be about 5–15 Mpc. Knowledge of intergalactic magnetic fields is important for cosmic-ray physics and gamma-ray astronomy. It is not inconceivable that these fields are remnants of a very early universe (of an inflationary stage or cosmological phase transitions), and that primary magnetic fields in galaxies and stars have been strengthened by the dynamo mechanism.

Source: http://arXiv.org/abs/1005.1924

5. Black hole shifted along the jet in M87

Observations using the Hubble Space Telescope revealed that the supermassive black hole in M87 is shifted from its galactic center by 6.8 ± 0.8 pc. Isophotes of the central bulge of the galaxy were plotted and their geometric center was determined. The black hole which is a pointlike source of radiation is displaced from the above center along the line of the relativistic jet towards the less bright counterjet. Several possible causes of the displacement of the black hole are discussed. It is possible that the black hole gets a recoil in response to jet emission (this mechanism of acceleration of black holes was suggested by I S Shklovsky in 1982), while the depth of the gravitational potential well in the nucleus of the galaxy M87 is insufficiently large for retaining the black hole at its center. The black hole can form a binary system with another black hole or experience the gravitational attraction of a massive star cluster, which would also have led to its displacement away from the center of the galaxy. A black hole could have formed by a merger of two black holes and get recoil momentum via the anisotropic emission of gravitational waves. The last scenario and Shklovsky's mechanism yield a correct order of magnitude for the displacement and are regarded as the most likely, but the exact cause of the black hole displacement remains unclear.

Source: http://arXiv.org/abs/1005.2173

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