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1. EMC effect in light nuclei

In 1983, the European Muon Collaboration (EMC) discovered an effect which reflected how the maximum momentum of quarks in a nucleon depends on the characteristics of the nucleus in which the nucleon resides. J Seely and his colleagues at the DOE's Thomas Jefferson Laboratory carried out an experiment which revealed new features of the EMC effect. The conclusion was reached in a number of theoretical papers attempting to interpret the EMC effect that it is linked to the mean nuclear density or mass of the nucleus. The new experiment demonstrated, however, that these parameters give an ambiguous description of the effect and may be of only secondary importance. This experiment studied the scattering of 5.8-GeV electrons by targets of ^{2}H, ^{3}He, ^{4}He, ^{9}Be, and ^{12}C nuclei. It was found that the magnitude of the EMC effect for the ^{9}Be nucleus is close to that of ^{12}C even though the mean density of the ^{9}Be nucleus is considerably lower. The conclusion is that the mean nuclear density is not a decisive factor for the EMC effect. It was also established that the light nuclei ^{3}He and ^{4}He differ greatly in the magnitude of the EMC effect. The key to the explanation of the obtained results may lie in the cluster structure of nuclei. For example, the nucleus of beryllium-9 may be regarded as two bound nuclei of ^{4}He plus an additional neutron revolving around them, the average density of the ^{9}Be nucleus being considerably lower than the density of each of the ^{4}He nuclei. In view of this, the EMC effect in such nuclei may be a function not of average but of local density, so that the EMC effect in the ^{9}Be nucleus is analogous to the effect of individual ^{4}He nuclei. In other words, the properties of nucleons in nuclei are determined not by the mass or mean density of the nucleus as a whole but by the local environment of the nucleon, such as the characteristics of the clusters containing this nucleon.

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2. Emission cone of Vavilov–Cherenkov radiation in 'left-handed' metamaterials

Researchers at Zhejiang University, Hangzhou (China) and the Massachusetts Institute of Technology (USA) have observed for the first time the reversed Vavilov–Cherenkov radiation generated in a 'left-handed' medium (a medium whose permittivity and permeability are simultaneously negative). As V G Veselago predicted in 1967 (see *Usp. Fiz. Nauk* **92** 517 (1967) [*Sov. Phys. Usp.* **10** 509 (1968)]), the cone of Cherenkov radiation emission and the energy flux in left-handed media are directed backward relative to the motion of the charged particle. The experiment described here used microwave radiation propagating through a metamaterial — that is, an array of conductors. A charged particle was imitated by a sequence of dipoles with the phase changing in a certain manner; the dipoles were excited in a waveguide consisting of 14 open slots. The speed at which this 'particle' was moving equaled $v = 1.9c/n$, where n is the refractive index of the metamaterial. This set of dipoles is completely equivalent, from the standpoint of emission of radio waves, to a real charged particle; however, the imitation made it possible to achieve considerably higher (and measurable) intensity of Vavilov–Cherenkov radiation in the frequency range of 8.1–9.5 GHz. The Vavilov–Cherenkov radiation could not propagate in metamaterials studied earlier (owing to the nature of their anisotropy), so for observing Vavilov–Cherenkov radiation a metamaterial with a special configuration of unit cells was fabricated. Reversed Vavilov–Cherenkov radiation may prove useful in fast particle detectors and radiation generators, e.g., in accelerator experiments. For details on media with negative refractive index, see papers by V G Veselago in *Usp. Fiz. Nauk* **173** 790 (2003); **179** 689 (2009) [*Phys. Usp.* **46** 764 (2003); **52** 649 (2009)].

Source: *Phys. Rev. Lett.* **103** 194801 (2009)
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3. Bose–Einstein condensation of strontium atoms

Two independent groups of researchers from Rice University in the US and the Institute for Quantum Optics and Quantum Information (IQOQI) in Austria prepared the Bose–Einstein condensate of atoms of strontium isotope ^{84}Sr, whose natural abundance reaches only 0.56%. Even though the abundances of the isotopes ^{86}Sr and ^{88}Sr are much higher, they cannot be cooled evaporatively owing to the excessively large (in the case of ^{86}Sr) or small (^{88}Sr) atomic scattering length. Contrary to these two, the rare isotope ^{84}Sr has the scattering length of 123 Bohr radii, which suits cooling ideally; in the experiments of both groups, evaporative cooling was the concluding stage after laser cooling in a magneto-optical trap. The transition to the condensate state was identified by monitoring the optical profile of the gas cloud and from the value of the chemical potential calculated from the dynamics of expansion of the cloud. It is suggested that the condensate of ^{84}Sr atoms be used in ultraprecise experiments, in novel schemes for quantum computation, and as a buffer gas in cooling other isotopes, e.g., the fermion isotope ^{87}Sr, to the quantum-degenerate state.

Sources: *Phys. Rev. Lett.* **103** 200402 (2009)
Phys. Rev. Lett. **103** 200401 (2009)
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4. Laser acceleration of neutral atoms

U Eichmann and his colleagues at the Institute for Optics and Atomic Physics (Berlin) and the Max-Born-Institute (Berlin) have discovered the effect of acceleration of neutral atoms by

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a pondermotive force in the field of nonuniform laser radiation. Typically, one considers the effect of the pondermotive force on charged particles, but in fact a similar force may arise in the case of neutral atoms in view of the dynamic polarization of atoms after they are excited to Rydberg states. The electron on a distant orbit may then be accelerated as a free particle by the pondermotive force (the acceleration of the nucleus is much weaker because of its large mass). If the electron after acceleration remains bonded to the atomic nucleus, the momentum of the accelerated electron is transferred to the parent atom as a whole. In the experiment of the German scientists, a beam of neutral helium atoms was illuminated by short focused pulses of laser light, and roughly one per cent of the atoms underwent acceleration. In some cases, the acceleration of an atom was greater than the acceleration of free fall g by a factor of 10^{14}, a record high for observed accelerations of neutral atoms in external fields.

Source: *Nature* **461** 1261 (2009)
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5. Polarization of cosmic microwave background and cosmological parameters

The measurement of polarization of cosmic microwave background is one of the most efficient methods for studying physical processes in the early Universe and of improving the cosmological parameters. Measurements of polarization of cosmic microwave background became technically possible in 2002 and have been conducted since then with gradually better precision by a number of instruments. From 2005 to 2007 observations were conducted at the South Pole with a 2.6-m QUaD radio telescope equipped with 31 pairs of orthogonal bolometers sensitive to the polarization of electromagnetic waves and functioning at two frequencies: 100 and 150 GHz. To date, the data gathered during this period has been processed, and more accurate values of cosmological parameters have been computed. The accuracy of the results is at its highest when the data sets of several detectors are used simultaneously (WMAP, ACBAR, QUaD, etc.). For example, according to the latest data, the most probable value of the Hubble constant amounts to $H_0 = 70.6$ km s^{-1} Mpc^{-1}, the index of the density perturbation spectrum $n_s = 0.960$, and a scenario is possible in which the index depends on the scale (the running index). It was also possible to improve the constraint on the tensor mode of perturbations (gravitational waves) in comparison with scalar perturbations (density perturbations); now the ratio of these components is estimated as $r < 0.33$ at a confidence level of 95%.

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