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1. Soliton collision in Bose–Einstein condensate

J H V Nguyen (Rice University, USA) and colleagues have shown that solitons moving in a Bose–Einstein condensate can pass through each other, preserving their size and shape. The ^{7}Li atom condensate obtained through evaporative cooling was kept in a cylindrical potential trap. Laser radiation directed across the trap generated an additional potential barrier, and the cloud was divided into two. By varying the magnetic field, the elastic scattering length was decreased by passing through the magnetic Feshbach resonance. Then, solitons consisting of $\approx 28{,}000$ atoms each appeared at a distance of 26 μm from each other in the two parts of the trap. The barrier having been switched off, the solitons began moving towards one another, passing through the trap back and forth several times. The real-time observation of the solitons was conducted using radiation scattering. As was predicted theoretically from the solution of the Gross–Pitaevskii equation, for the zero phase difference $\Delta\phi = 0$ of the soliton wave functions, the solitons strengthened each other at the collision point, and in the counterphase $\Delta\phi = \pi$ the gas density lowered because of destructive interference. In some cases, a spatial gap was left between colliding solitons. However, it has been proved that solitons do not spring back elastically but pass through the gap and through each other. To this end, solitons of unequal size were created, for example, with 2:1 ratio of the number of atoms, which could be distinguished both before and after passage. When colliding, sufficiently dense solitons which could not already be thought of as one-dimensional objects collapsed, i.e., were destroyed. Similar soliton collapses had already been observed before in nonlinear optics.

Source: *Nature Physics* **10** 918 (2014)
http://arXiv.org/abs/1407.5087

2. FFLO phase in a superconductor

V F Mitrovic (Brown University, USA) and her colleagues have confirmed experimentally the theoretical prediction made by P Fulde, R Ferrell, A I Larkin, and Y N Ovchinnikov in 1964. According to their calculations, near the upper critical magnetic field, a superconductor can be divided into discrete layers between which normal-conductivity layers reside at the order-parameter nodes. This state is called the FFLO phase after the names of the authors. This effect is possible provided that a superconductor contains unequal numbers of electrons with opposite spin directions. Unpaired electrons then induce the formation of quasiparticles in Andreev bound states accompanied by the occurrence of nonsuperconducting layers. The experiment was performed at the National High Magnetic Field Laboratory (LNCMI, Grenoble, France). The organic superconductor κ-(BEDT-TTF)$_2$Cu(NCS)$_2$ was examined by nuclear magnetic resonance method on ^{13}C atoms, and the superconductor had been specially fabricated using this isotope. The sample was exposed to a sequence of pulses, and the spin relaxation time was found from the spin echo. The maxima of the magnetic-field dependence of the relaxation time testified to the presence of Andreev states and the FFLO phase. Earlier, the latter phase was only observed by an indirect method from the phase diagram of the superconductor. The FFLO phase possibly occurs in the substance of neutron stars in which superconductivity and strong magnetic fields supposedly exist. Moreover, the FFLO phase can find practical application in spintronics.

Source: *Nature Physics* **10** 928 (2014)
http://arXiv.org/abs/1409.0786

3. Gas of dipolar molecules

T Takekoshi (University of Innsbruck, Austria) and colleagues have obtained and studied the ultracold gas of ^{87}Rb^{133}Cs molecules in the lower state of hyperfine splitting of their energy levels. The ^{87}Rb^{133}Cs molecules were obtained through magnetic association in an ultracold mixture of ^{87}Rb and ^{133}Cs gases in the magnetic field. Molecular transitions between levels were induced by lasing at specially selected frequencies with the use of stimulated adiabatic Raman passage. The gas was set to the lowest of the hyperfine splitting states with an efficiency of 90%, the state being controlled using the magnetic field. The dipolar nature of ^{87}Rb^{133}Cs molecules was shown by the characteristic quadratic shift of transition frequencies depending on the electric field. Also investigated and confirmed in the experiment was the good stability of dipolar ^{87}Rb^{133}Cs molecules in the lowest energy state under pairwise collisions in a gas.

Source: *Phys. Rev. Lett.* **113** 205301 (2014)
http://dx.doi.org/10.1103/PhysRevLett.113.205301

4. Magnetic mirror for the IR range

Radiation reflection from a mirror proceeds, as a rule, due to the interaction between the vector of the electric field of an incident electromagnetic wave and the electric charges in the substance. S Liu (Sandia National Laboratories, USA) and colleagues designed a nonmetallic mirror for the IR range in which the magnetic rather than the electric field of the wave underwent interaction with the mirror substance. In the latter case, the reflection induces phase reversal, while in the magnetic interaction the phase of the reflected wave coincides with the phase of the incident wave, which was demonstrated in an experiment for the first time. Magnetic mirrors on the base of metamaterials had already been made of metallic and silicon elements, but they showed great reflection loss, and the phase variation was not directly verified in experiments. S Liu and colleagues fabricated a new metamaterial consisting of a two-dimensional array of

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approximately cubic subwave microcavities made of a low-loss insulator (tellurium) on a BaF_2 substrate. The measurements were taken using time-domain spectroscopy based on laser radiation reflection from a sample and a comparison of the reflected light with the reference beam upon their mixing in a GaSe crystal. A part of the surface of the same sample was covered with a layer of gold, which allowed a direct comparison of the reflectivities of a magnetic and a usual mirror and finding the distinction in the reflected wave phases. The phase remained unchanged under wave reflection from the metamaterial, which testified to the magnetic character of the reflection. Such magnetic mirrors are promising for the creation of sensitive chemical sensors and temperature-sensitive elements.

Source: *Optica* **1** 250 (2014)
http://arXiv.org/abs/1403.1308

5. Stellar-mass black hole in an ultraluminous X-ray source

A probable explanation for the nature of ultraluminous X-ray sources observed in galaxies is thought to be matter accretion onto intermediate-mass ($\geqslant 10^2 M_\odot$) black holes or super-Eddington accretion onto stellar-mass black holes. A part of ultraluminous sources emit according to the first mechanism (e.g., source X-1 in galaxy M82), and some according to the second mechanism, as was shown in a new analysis of source P13 in galaxy NGC 779311 carried out by C Motch (University of Strasbourg, France) and colleagues. They used the data from X-ray and optical telescopes obtained over several years. Object P13 is a binary system with an orbital period of 64 days, consisting of a supergiant star with a mass of $(18-23)M_\odot$ and a black hole. The high luminosity and the shape of the P13 spectrum are typical of ultraluminous X-ray sources. By modeling optical and UV emission modulations due to X-ray star heating, the black hole mass was found not to exceed $15M_\odot$. Thus, this ultraluminous X-ray source belongs to the class of sources with a stellar-mass black hole, although its X-ray luminosity is about two times higher than the Eddington luminosity.

Source: *Nature* **514** 198 (2014)
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