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1. Ultracold gas of polar molecules

D Jin and her colleagues at the NIST/JILA Laboratory in Boulder, Colorado, USA obtained a stable ultracold gas of molecules possessing large electric dipole moments. Earlier attempts to create such a gas had failed because of difficulties with its cooling. The new experiment began with forming a mixture of potassium and rubidium atoms in an optical trap. A magnetic field triggered attraction between atoms of different types through the Feshbach resonance mechanism [see, e.g., *Phys. Usp*. **49** 333 (2006)], and polar diatomic $^{40}K^{87}Rb$ molecules were formed in an excited state. The difficulty in cooling stemmed from the fact that the energy of rotational and vibrational states of molecules converted to kinetic energy of molecules and the gas heated up. The researchers from NIST/JILA developed a new technique of radiative cooling: the gas was irradiated by laser light of a specially selected frequency in the near-IR range. As molecules dropped back to lower energy levels, released energy did not go into heating the gas but was carried away by the emitted photons. The success with the method of cooling is based on progress in theoretical calculations of the structure of molecular energy levels, which made it possible to choose the radiation frequency correctly. In this way, it was possible to cool the gas to a temperature of 350 nK and achieve a transition to a nearly degenerate state at a number density of 10^{12} molecules per cm^3. Ultracold gas consisting of polar molecules which interact with each other over relatively large distances may find applications in a wide range of quantum phenomena including quantum computing.

Source: *Science* **322** 231 (2008)
http://dx.doi.org/10.1126/science.1163861

2. Superconducting films

A team of research workers led by I Božović at the US Department of Energy's Brookhaven National Laboratory along with researchers at Cornell University and the FEI Company in Oregon created and studied two-layer films in which each of the layers is nonsuperconducting on its own but the thin zone (1 to 2 nm in thickness) close to the common interface proves to be superconducting. Layers of lanthanum cuprate doped with strontium (LSCO) were deposited using molecular epitaxy, which created an almost ideal interface between the layers. Depending on the amount of admixture, the cuprates constitute insulators, superconductors, or ordinary conductors. The layer of La_2CuO_4 in the specimen obtained was insulating, while the layer of $La_{1.55}Sr_{0.45}CuO_4$ was a conductor. However, the boundary layer, which was only several atoms thick, was superconducting with a critical temperature exceeding 50 K, which is by 10 K higher than the critical temperature of one thick layer in which the impurity concentration corresponds to the superconducting state. It was shown using atomic-resolution transmission electron microscopy that the interface between the layers is sharp — that is, there is no transition 3D region in a specimen with an intermediate impurity concentration. Therefore, the two-dimensional superconductivity of the specimen is essentially an effect induced by the boundary between two physically and chemically different layers. The researchers hope that thin superconducting films like this may constitute a basis for creating superconductive field-effect transistors and other nanometer-scale devices. For superconductivity of cuprate thin films, see *Phys. Usp*. **51** 170 (2008).

Sources: *Nature* **455** 782 (2008)
http://dx.doi.org/10.1038/10.1038/nature07293

3. Anomalous spin-state segregation

J Thomas and his colleagues at Duke University in Durham, North Carolina discovered an effect which continues to resist attempts to give a theoretical explanation. Cold gas of lithium-6 atoms with an identical spin orientation was put into an optical trap. Then the researchers tried to apply radiofrequency radiation to transfer the atoms to the state of superposition at a probability of 50% for each of the two directions of spin. However, several tenths of a second later the atoms unexpectedly separated spatially, with atoms with one spin direction (spin-ups) rushing towards the center of the trap, while atoms with the opposite spin (spin-downs) moved to the periphery; the gas remained in this state for several seconds. Interaction forces between individual atoms are far too small for explaining the observed effect. The researchers believe that segregation in spin states occurred through the formation of a spin wave; however, according to the reigning theoretical models, the spin waves mechanism is also insufficiently efficient and the timescale over which it occurs is much longer for producing such a strong segregation.

Source: *Phys. Rev. Lett*. **101** 150401 (2008)
http://dx.doi.org/10.1103/PhysRevLett.101.150401

4. Magnetic field in a remote galaxy

Observations made with the world's largest Green Bank radio telescope in Green Bank, West Virginia by the astronomers from the University of California led by A Wolfe were used to measure the magnetic field in the DLA-3C286 protogalaxy, which we can see at the epoch when the Universe was 6.5 billion years younger. The field was found to be approximately 10 times stronger than the average magnetic field in our Galaxy. This result came as very unexpected since it was assumed that the magnetic field in galaxies increases gradually over billions of years through the dynamo mechanism. Another interesting fact is that the rate

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of new star formation in DLA-3C286 is relatively low, which may be related to an unusually high magnetic field. It is possible that the mean-field-dynamo theory needs modification to suit the DLA-3C286 galaxy. Another hypothesis suggests that the high magnetic field is a result of shock waves in the gas produced by a collision of two galaxies.

Source: http://www.eurekalert.org/pub_releases/2008-10/uoc-fdo092908.php

5. Massive dwarf galaxy

Using the Keck telescope in Hawaii, M Geha of Yale University and her colleagues discovered the least luminous dwarf galaxy — a satellite of our Galaxy — populated by only several dozen or perhaps hundreds of stars; however, the mass of this galaxy is almost 1000 times larger than is deduced from its luminosity. This galaxy, now known as Segue 1, is one of roughly two dozen dwarf galaxies orbiting our Galaxy but not ranked among globular clusters. The latter evidence was derived from the large virial velocities of its stars and the corresponding large mass of the galaxy. Furthermore, the metal content in the stars of Segue 1 is considerably lower than in stars of globular clusters of our Galaxy. The large invisible mass of Segue 1 rests most likely in dark matter, whose nature is so far unknown. The mass-to-luminosity ratio for Segue 1 is a record high among all known galaxies.

Source: http://arXiv.org/abs/0809.2781

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