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Physics news on the Internet (based on electronic preprints)

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1. Role of phonons in the mechanism of high-temperature superconductivity

J C Davis of Cornell University, New York and his colleagues from the US and Japan have presented new experimental evidence of the key role of phonons (quantized vibrations of the crystal lattice) in the mechanism of high-temperature superconductivity, namely, in the process where electrons form Cooper pairs as they interact with phonons. While this effect has been observed previously in conventional (low-temperature) superconductors using tunneling spectroscopy, no definitive results have been obtained in similar studies on high-temperature superconductors. One possible explanation for this fact is that electron pairing in a high-temperature superconductor occurs only in small-sized regions that are distributed chaotically throughout the material — necessitating measurements on many atomic-scale regions along the surface of the semiconductor. Davis and his colleagues used a scanning tunneling microscope to perform new measurements of tunneling current on a nanometer scale in the superconducting compound $Bi_2Sr_2CaCu_2O_{8+\delta}$. The interaction of electrons with phonons was identified by peaks in the second derivative plot of current I vs voltage, d^2I/dV^2. Additional studies showed that this interaction has nothing to do with magnetic-structure peculiarities of the sample and that on substituting the isotope ^{18}O for ^{16}O the phonon mode is displaced in energy by 6%, consistent with what theory predicts. Also, the phonon mode energy and the magnitude of the superconducting pairing-gap energy anticorrelate with each other at each point of the sample surface — again pointing to the interplay between superconductivity and phonons.

Source: *Nature* **442** 546 (2006); www.nature.com

2. Bloch oscillations in the field of a light wave

A new technique to study the force of gravity on a micrometer scale has been developed at the University of Florence, Italy, which determines the force by measuring the Bloch oscillation frequency of atoms in an optical trap consisting of a vertical standing light wave (with a periodicity in the vertical direction). The quantum-mechanical phenomenon of Bloch oscillations arises when, in addition to a periodic potential, a particle also experiences a static force (as exemplified by electron oscillations in a crystal in an external electric field). In the experiment by G Ferrari and his colleagues, the role of the potential was played by the dipole interaction of atoms with the periodic field of the light wave, and the role of the external force by the force of gravity. Because the ultracold bosonic ^{88}Sr atoms that were used in the experiment had spin and nuclear magnetic moment zero in their ground state, they interacted weakly with one another and with external electromagnetic fields, allowing coherent Bloch oscillations to be observed for a record time longer than 7 seconds. The plans for using this technique in the near future include superaccurate measurements of the force of gravity on the micrometer scale and the verification of the Newton gravitational law at small scales.

Source: *Phys. Rev. Lett.* **97** 060402 (2006); prl.aps.org

3. Direct evidence for dark matter

Direct weak lensing observations of the merging galaxy cluster 1E0657-558 have been made using NASA's Chandra X-ray Observatory and the Hubble telescope, the cluster consisting in fact of two separate clusters just starting to fly apart after their collision. The hot gas present in the clusters was observed via its X-ray radiation, whereas the mass distribution was inferred from the way the optical images of galaxies far beyond the cluster were distorted. Because the gravitational lensing of light makes galaxies oblong in shape, it proves possible statistically to derive the distribution of mass in the lens. In this way it was found that the gas cores of the clusters are not located at the centers of mass of the galaxies flying apart, giving the impression that the gas lags, as it were, behind invisible mass concentrations and the galaxies flying apart, and thus proving in fact the existence of dark matter. The finding is given the following interpretation. In an isolated galaxy cluster, the gas core is located at approximately the center of the more extended dark matter halo. As the clusters collided and flew through each other, their gas clouds experienced mutual friction and so slowed down, whereas the collisionless dark matter and the galaxies continued to move by inertia — leading to a spatial separation of the clusters' baryonic component and dark matter. This separation, although not complete, was established conclusively to exist by comparing the X-ray image and the dark matter distribution as obtained from the optical observations of gravitational lensing. While until now various modifications of the law of gravity have been suggested to explain galaxy rotation curves and the high temperature of gas in galaxy clusters, the reported findings make them unnecessary and indeed most of them fail to account for the cluster collisions observed. It is not yet clear exactly what dark matter is made of. According to the most likely hypothesis, it is made of elementary particles that have not yet been discovered experimentally. A quite definitive solution to the dark matter problem would be the detection of such particles by a terrestrial detector — which is where most laboratory efforts are currently being concentrated and plans for future experimental work focused on.

Source: http://arxiv.org/abs/astro-ph/astro-ph/0608407

4. Lithium in the Universe

The exact primordial nucleosynthesis calculation of the initial (prestellar) chemical composition of the Universe has now become possible due to the latest cosmic microwave aniso-

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tropy data from the WMAP satellite. However, the theory is found to overestimate by a factor of 2 to 3 the abundance of lithium as obtained from the astronomical data on the chemical composition of stars. A J Korn and his colleagues may have removed this discrepancy by spectroscopically studying 18 stars in the globular star cluster NGC 6397, using the 8.2-m VLT telescope in Chile. The oldest stellar population in the galaxy, globular-cluster stars differ in their mass and temperature but are all of the same age and initial chemical composition, thus allowing a comparison of the observational data with what the theory of stellar evolution predicts. The amount of lithium near the visible surface of a star first remains nearly constant with increasing temperature (which is seen as a plateau in the plot) and then sharply drops. This dependence is described by a theory which assumes that, subject to a diffusion process with the participation of turbulent mixing, lithium nuclei move down to the center of a (sufficiently hot) star and are destroyed there in nuclear reactions under high-temperature conditions. As a result, the near-surface region of a star is lithium-depleted by about 78% during the star's lifetime, whereas the initial amount of lithium is within one standard deviation from the prediction of primordial nucleosynthesis theory.

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