

PACS number: 01.90.+g

Physics news on the Internet (based on electronic preprints)

DOI: 10.3367/UFNe.0180.201003c.0264

1. Gravitational redshift

In an experiment with ultracold caesium atoms, researchers H Müller, A Peters, and S Chu from the USA and Germany measured the effect of gravitational redshift (the slowing down of time in a gravitational field) at an accuracy of 7×10^{-9}, which is the current record. The authors used the data of an earlier experiment on measuring the freefall acceleration. Caesium atoms kicked upwards were placed by a laser pulse into a superposition of two states that corresponded to trajectories which differed in maximum heights by 0.12 mm. The next pulse corrected the trajectories in such a way that they intersected at the lower point, while a third laser pulse was used for interference measurement of the phase difference between atomic wave functions on different trajectories. The data obtained in this experiment made it possible to improve the previous result (obtained in 1980 by comparing the readings of the atomic clocks on the surface of Earth and in a rocket) by four orders of magnitude. Super-accurate measurements of the gravitational redshift are important, among other things, for testing the metric theories of gravity. Also, the improved accuracy of such measurements may have practical significance for global positioning systems.

Source: *Nature* **463** 926 (2010)
http://dx.doi.org/10.1038/nature08776

2. Chemical transformations of ultracold molecules

A group of researchers led by R Grimm (University of Insbruck and Institute of Quantum Optics and Quantum Information in Austria) observed elementary exchange processes in an ultracold (quantum) gas of caesium atoms in a magnetic field (at a temperature of 50–100 nK) in an optical trap. Some atoms were transferred to different states (A and B) of hyperfine splitting by applying microwave pulses. A change in magnetic field (and hence in the molecular binding energy) in the vicinity of the Feshbach resonance caused proceeding of controllable exchange processes in an ultracold atom–dimer mixture: replacement of caesium atoms A in a weakly bound dimer A_2 by caesium atoms B in a different quantum state, viz. $A_2 + B \rightarrow A + AB$. The second research team from the Joint Institute of Laboratory Astrophysics (JILA) and Kansas State University Department of Physics studied chemical reactions involving ultracold molecules formed of atoms of potassium and rubidium. This experiment also studied how the spin state of molecules affected the rate of chemical reactions.

Sources: *Phys. Rev. Lett.* **104** 053201 (2010)
http://arXiv.org/abs/0911.1999
http://www.sciencedaily.com/releases/2010/02/100211141130.htm

Uspekhi Fizicheskikh Nauk **180** (3) 264 (2010)
DOI: 10.3367/UFNr.0180.201003c.0264
Translated by V I Kisin

3. Phonon 'lasers'

Two independent groups of researchers have created phonon analogs of the optical laser, which emit coherent beams of phonons (acoustic oscillations of the crystal lattice). I S Grudinin and his coworkers at the California Institute of Technology used two quartz ring microresonators (microtoroids) whose mechanical resonance frequency fell in the radio frequency range. The energy pumping of the system was created by an optical laser beam through an optical fiber. The microresonators were coupled by means of an evanescent field of the beam, which resulted in a splitting of the energy levels (oscillation modes) of the electromagnetic field. The difference between the energies of sublevels equaled the energy of phonons (at a frequency of about 21 MHz) emitted as a coherent beam at photon transitions between sublevels. Stimulated emission of phonons had already been observed in earlier experiments, but a stimulated emission intensity greater than that of spontaneous emission had not yet been achieved. In the present study this result was obtained owing to the high quality of the resonators. R P Beardsley and his colleagues at the University of Nottingham, UK created a device that resembles a quantum-cascade laser. Phonons at a frequency of approximately 441 GHz were generated through electron–phonon interaction, when electrons tunnel through potential barriers of a semiconductor superlattice which is formed of alternating layers of GaAs and AlAs. The acoustic wave was generated by a powerful femtosecond laser pulse; new phonons are then generated coherently and amplify the wave. Phonon 'lasers' may find useful applications both for observing microscopic objects and for their targeted modification.

Sources: *Phys. Rev. Lett.* **104** 083901, 085501 (2010)
http://dx.doi.org/10.1103/PhysRevLett.104.083901
http://dx.doi.org/10.1103/PhysRevLett.104.085501

4. Studies of supernovae

Mildly relativistic ejecta. Z Paragi and his coworkers used EVN (European VLBI Network), GBT, and WSRT radio telescopes to observe the SN 2007gr supernova which exploded in the NGC 1058 galaxy at a distance of about 10.6 Mpc from Earth, and discovered a mildly relativistic expansion of matter in the shell shed during the explosion. According to the data of optical observations, the SN 2007gr is a typical type Ic supernova and the expansion velocity of its shell is a mere ~ 6000 km s^{-1}. Four Ic supernovae have been recently identified as sources of cosmic gamma-ray bursts, which from the theoretical point of view requires that much faster collimated relativistic ejecta (jets) should have been produced; however, no jets have been directly observed. Z Paragi et al. carried out two radio (interferometric) measurements separated by 60 days and obtained a conservative estimate for the ejecta velocities of $v \geqslant 0.6c$. A comparison with optical observations implies that only a very small part of the matter of the shed shell reached relativistic velocities. An independent team of researchers

(A M Soderberg et al.) has recently discovered a relativistic jet in another supernova, SN 2009bb.

Source: *Nature* **463** 516 (2010)

http://arXiv.org/abs/1001.5060

Mechanism of explosion of type Ia supernovae. M Gilfanov and A Bogdan (the RAS Space Research Institute, Russia, and the Max Planck Institute for Astrophysics, Germany) have established by analyzing the data of observations using the Chandra, Spitzer, and 2MASS space telescopes that nearly 95% of explosions of type Ia supernovae should have been caused by collisions between two white dwarfs. An earlier most probable candidate for the cause of thermonuclear explosions of white dwarfs was the increase in dwarf mass above the Chandrasekhar limit due to the accretion of matter from the companion star in a binary system. M Gilfanov and A Bogdan analyzed the available statistics of X-ray sources in several nearby galaxies. The number of such sources was found to be 30–50 times lower than was predicted by the above model of slow accretion in which X-rays are generated for about 10^7 years before the explosion. By contrast, the X-ray emission before the explosion in the model of binary merger is very low, which agrees with the absence of X-ray sources. The scenario of the merger of two white dwarfs was suggested theoretically by A V Tutukov and the dominance of this mechanism was established in theoretical calculations by the method of 'population synthesis' (V M Lipunov et al., 1997). It should be mentioned, however, that the observation of the type Ia supernova SN 2006X in the M100 galaxy carried out in 2007 favors the alternative accretion scenario of its origin. The SN 2006X supernova may thus belong to the remaining 5% of cases. Since type Ia supernovae serve as 'standard candles' for cosmology to measure distances, a clarification of the mechanism of their explosions is necessary for evaluating the accuracy of determining cosmological parameters.

Source: *Nature* **463** 924 (2010)

http://arXiv.org/abs/1002.3359

Compiled by *Yu N Eroshenko*