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1. Tetraquark X(5568)

In processing the 2002–2011 data of the D0 experiment carried out at the Fermilab Tevatron accelerator (Batavia, IL, USA), a new particle X(5568) has been discovered, which is most likely to be a tetraquark, i.e., the bound state of four different types of $\mathrm{ub\bar{d}\bar{s}}$ or $\mathrm{db\bar{u}\bar{s}}$ quarks. It can also be represented as a combination of the light and heavy mesons $\mathrm{B_s^0}$ and $\pi^{\pm}$, respectively. Other types of tetraquarks and a pentaquark always containing pairs of $\mathrm{c\bar{c}}$ quarks of the same flavor that possibly make up a solitary structure (core) have already been found in the earlier Belle and LHCb experiments. By contrast, all four valence quarks in X(5568) possess different flavors. One cannot now predict exactly all the characteristics of such multiquark systems because of the complexity of the calculations. The X(5568) particle is identified through the characteristic chain of its decay: $\mathrm{X(5568)} \to \mathrm{B_s^0}\pi^{\pm}$, $\mathrm{B_s^0} \to \mathrm{J}/\psi\phi$, $\mathrm{J}/\psi \to \mu^+\mu^-$, $\phi \to \mathrm{K^+K^-}$. The rate of X(5568) birth in $\mathrm{p\bar{p}}$ collisions is several orders of magnitude higher than expected theoretically, and this discrepancy has not yet been explained. The measured mass and width of X(5568) decay are $m = 5567.8 \pm 2.9(\mathrm{stat.})^{+0.9}_{-1.9}(\mathrm{syst.})\,\mathrm{MeV}$ and $\Gamma = 21.9 \pm 6.4(\mathrm{stat.})^{+5.0}_{-2.5}(\mathrm{syst.})\,\mathrm{MeV}$, respectively, and X(5568) identification significance is estimated to be 5.1σ.

Source: http://arXiv.org/abs/1602.07588

2. Study of the mechanism of high-temperature superconductivity

Since the discovery in 1987 of high-temperature superconducting cuprates not described by the Bardeen–Cooper–Schrieffer theory, a variety of new theoretical approaches have been proposed to explain their properties. In 2003, C M Varma (University of California, Riverside, USA) developed a theory in which the interaction of electrons with fluctuations near the quantum critical point accounts for the symmetry observed in superconductors. A new experimental study of high-temperature superconductors was performed at the Institute of Physics, Chinese Academy of Sciences (Beijing, China) using a highly stable laser in angle-resolved photoemission measurements. The $\mathrm{Bi_2Sr_2CaCu_2O_{8+}}$ crystals with different degrees of doping were examined in the normal and superconducting states. The fluctuation spectrum and the binding energy of Cooper pairs were measured. The new experiment confirmed Varma's predictions concerning the role of fluctuations. It has turned out that in the attractive d-wave channel no interaction of fermions with excitations is observed, while it is present in the s-wave channel. This is the reason why frequency-independent fluctuations are scattered predominantly at angles of $\pm\pi/2$ in the attractive channel, and are angle-independent in the case of repulsive interactions.

Source: *Science Advances* **2** e1501329 (2016)
http://arXiv.org/abs/1601.02493

3. Mid-IR laser

Ordinary silica glass cannot be utilized to fabricate fiber-optic lasers operating in the mid-IR range because of its poor transparency at wavelengths $\lambda > 2.8$ μm. Whereas quantum-cascade lasers are only effective beginning from $\lambda > 3.5$ μm. Thus, no laser generation methods convenient for practical applications existed within the wavelength range from 2.8 to 3.5 μm. M R A Hassan and colleagues (University of Bath, United Kingdom) have created a new mid-IR laser based on a silica hollow-core fiber filled with gaseous acetylene as the active medium. The emission of mid-IR gas photons by acetylene was earlier investigated in the single-pulse regime only. In the new experiment, continuous lasing was achieved for the first time. Part of the radiation from the main optical fiber passed through the second optical fiber (a feedback loop) and was again fed to the input of the first fiber. The loop was rather long — nearly 100 m — in order to provide the necessary signal delay for stable lasing. Pumping at a frequency of 1530 nm was performed using a conventional diode laser. Lasing in the range between 3.1 and 3.2 μm with a pulse repetition rate of about 2.6 MHz was demonstrated.

Source: *Optica* **3** 218 (2016)
http://dx.doi.org/10.1364/OPTICA.3.000218

4. Ring laser gyroscopes in geophysics

At the Gran Sasso underground laboratory (Italy), the large ring laser gyroscope GINGERino located in an underground tunnel was used to register rotational signals generated in Earth's crust by a seismic wave from an earthquake at teleseismic distance. Along with linear perturbations, weaker, rotational perturbations are also present in the wave. Conventional seismographs can register them only when assembled in a curved chain, but the sensitivity of this method is low. Rotational perturbations have already been registered by ring laser gyroscopes on the surface, but the location of GINGERino in the underground laboratory made it possible to avoid noise sources and to perform measurements with an accuracy much higher than before. The gyroscope operation principle rests on the Sagnac effect. Two light pulses from a helium–neon laser run towards each other along a 3.6-m ring mounted on a granite block in a tunnel under a 1400-meter rock layer. Rotations of the ground results in a frequency shift and the occurrence in the resultant signal of beats with the frequency proportional to the angular velocity of rotation. The sensitivity of the device constructed by G Saccorotti (Instituto Nazionale di Geofisica e Vulcanologia) and his colleagues was 10^{-11} rad s^{-1} over the frequency band of seismological interest (0.01–1 Hz). The rotational perturbations were registered in a wave from an

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earthquake of magnitude 7 that took place in the Atlantic Ocean. Registration of rotational motions in Earth's crust may prove to be useful for earthquake forecasting. The GINGERino experiment is a precursor of the GINGER experiment planned for the study of General Relativity effects.

Source: http://arXiv.org/abs/1601.05960

5. Galaxy as a source of the fast radio burst

E F Keane (Jodrell Bank Observatory, United Kingdom) and colleagues have become the first to discover a galaxy from which a fast radio burst come. The FRB 150418 burst was initially registered by the Parkes radio telescope. Then, a transient radio signal coming from the same point and fading over six days was registered by the Australia Telescope Compact Array (ATCA). Such signals are rare, and therefore the probability of accidental coincidence is very low. Finally, the redshifted galaxy ($z \approx 0.5$) was discovered by the optical Subaru telescope in the region of the radio burst localisation. The mechanism of generation of millisecond bursts has not yet been ascertained. The sustained signal looks like an afterglow in the radio frequency range of short gamma-ray bursts (mergers of neutron star pairs are most likely to be their sources), and the model of giant bursts from pulsars fails to reproduce such a signal. It is quite probable that there exist several classes of fast radio bursts having different origins. This is consistent with observations of repeated bursts from the source of the other fast radio burst, FRB 121102. The Arecibo radio telescope registered repeated millisecond radio bursts with sky position and dispersion being almost the same as those of the first FRB 121102 burst. The observations began 2.3 years after the detection of the first burst, and within three hours of observation ten additional bursts were registered with different spectra and a lack of periodicity in their arrival times. The observation of repeated bursts supports the model of bursts originated from neutron stars, because repeated bursts are impossible upon the merging of neutron star pairs.

Sources: *Nature* **530** 453 (2016); *Nature* **531** 202 (2016)
http://arXiv.org/abs/1602.07477
http://arXiv.org/abs/1603.00581

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