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1. $D^*_{sJ}(2860)^-$ particle

The states of the $D^*_{sJ}(2860)^-$ particle with spins 1 and 3 have been identified by the LHCb collaboration at the Large Hadron Collider. These states were revealed at the 10σ confidence level as intermediate resonances in the $B^0_s \to \bar{D}^0 K^- \pi^+$ reaction. Although the presence of $D^*_{sJ}(2860)^-$ resonance at an energy of ≈ 2.85 GeV had been noticed before, its structure was first elucidated in the LHCb experiment. The $D^*_{sJ}(2860)^-$ particle consists of $\bar{c}$ and s quarks which, depending on the spin and the orbital angular momentum, can represent a family of different resonant states, and such a state with spin 3 was observed for the first time. The creation of a spin-3 particle in B-meson decays was also revealed for the first time.

Source: http://lhcb-public.web.cern.ch/lhcb-public/

2. Quantum paradoxes

'Quantum Cheshire Cat'. T Denkmayr (Vienna University of Technology, Austria) and his colleagues have become the first to demonstrate in experiment the quantum-mechanical effect referred to as the 'quantum Cheshire Cat', where the object and its quantum property are spatially separated. The experiment designed around a neutron interferometer was implemented at the Institute Laue-Langevin (Grenoble, France). On passing through a silicon crystal, a neutron beam split into two beams in which neutron spins underwent some flips, and at the interferometer outlet neutrons in certain spin states were selected. Thus, the spin states were pre-selected and post-selected, and a quantum Cheshire Cat was created, which was shown with the aid of weak quantum measurements. The neutron absorber had an effect on the neutron flux only if it was located in the first interferometer arm, and a weak magnetic field displaced the interference pattern only upon an impact on the second arm. This proved the fact that neutrons passed along one interferometer arm, while their spin states (magnetic moments) passed along the other arm. This effect can be applied in high-precision measurements.

Source: *Nature Communications* **5** 4492 (2014)
http://dx.doi.org/10.1038/ncomms5492

'Pigeonhole paradox'. The quantum-mechanical 'pigeonhole paradox' takes its name from the classical assertion that if three pigeons reside in two holes, then at least two pigeons will necessarily find themselves in one of the holes. Y Aharonov (Tel Aviv University, Israel; Chapman University, USA) and his co-authors have shown in their theoretical examination that such an assertion may appear to be incorrect in quantum mechanics. Namely, three particles can be placed in two quantum boxes in such a manner that none of the boxes will contain two particles at a time. As an example, the authors pointed out concrete linear combinations of wave functions corresponding to the initial and final states in which at no intermediate instant of a quantum system evolution does a state occur in which two or three particles could reside in one box, because the corresponding probability amplitude is equal to zero. The authors suggested the idea of an experiment with three electrons in two interferometer arms. When flying along one path electrons repulse by their charges, and therefore their measured position will differ from the case where two electrons never pass simultaneously along one path.

Source: http://arXiv.org/abs/1407.3194

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3. Soliton vortices in an ultracold gas

The existence of long-lived soliton vortices, i.e., phase defects of the order parameter, in a degenerate ultracold gas has been confirmed for the first time in two experiments. An elongated cloud of superfluid Fermi gas of ^{6}Li atoms in an optical dipole trap was studied by 3D-tomography in the experiment performed at the Massachusetts Institute of Technology. Soliton vortices were created by the phase shift of the order parameter with the aid of laser radiation, and their precession near the phase transition point was observed. In the experiment carried out by researchers from the University of Trento (Italy) and the Kapitza Institute of Physical Problems (Russia), an elongated cloud of Bose–Einstein condensate of sodium atoms was observed by the absorption technique at the stage of their free expansion. The twisted regions of lowered atomic density around the vortex filaments testified to the presence of soliton vortices. In previous experiments by the same research teams, soliton vortices had also been born, but the structures then observed were interpreted differently, namely, as other types of solitons. Having established in the new experiments that the correct explanation points to the soliton vortices, the researchers arrived at an agreement between the experimental data and theoretical calculations for the lifetime and other characteristics of the solitons.

Sources: *Phys. Rev. Lett.* **113** 065301, 065302 (2014)
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http://dx.doi.org/10.1103/PhysRevLett.113.065302

4. Time asymmetry in a turbulent flow

The turbulence is a time-asymmetric (time-irreversible) process, because the energy of motion is pumped over from larger- to smaller-scale turbulent pulsations. At the Max Planck Institute for Dynamics and Self-Organization (Germany), an experiment has been performed which traced the kinematics of this asymmetry for individual elements of the liquid. Turbulent motion in a vessel was generated by rotating blades, and the positions of polystyrene microspheres in water, which served as markers of motion, were traced with the aid of high-speed video cameras. The theoretical prediction was confirmed whereby the difference in mean squares of distances between particles of time-reversed and time-forward turbulent flows is positive in short time intervals (i.e., this difference raises faster under time reversal) and increases as $\langle R^2(-t)\rangle - \langle R^2(t)\rangle \propto t^3$. The data on the asymmetry are still more clear for an ensemble of four particles which, at the initial instant of time, form a regular tetrahedron. The difference between intermediate eigenvalues of the tetrahedron strain tensor increases linearly in time: $\langle g_2(t) - g_2(-t)\rangle \propto t$. The third and first degrees of t in the indicated dependences reflect the existence of turbulent flow asymmetry under time reversal, viz. $t \to -t$.

Source: *Phys. Rev. Lett.* **113** 054501 (2014)
http://dx.doi.org/10.1103/PhysRevLett.113.054501

5. Intermediate-mass black hole in galaxy M82

Analyzing Rossi X-ray telescope data, D R Pasham, T E Strohmayer, and R F Mushotzky (University of Maryland and the Goddard Space Flight Center, USA) showed that the ultrabright X-ray source X-1 in galaxy M82 is most likely to be a black hole (BH) of mass $\sim 400 M_{\odot}$. Two modes of quasi-periodic pulsations with frequencies of 5.1 Hz and 3.3 Hz were revealed at the 4.7σ confidence level. The modes remained stable over the entire observational period. Similar double modes with the 3:2 frequency ratio are already known for $(3-50 M_{\odot})$ stellar-mass BHs. Although the nature of double pulsations has not been exactly clarified, their frequencies correlate with BH masses. If this correlation also holds true for X-1, the BH mass appears to be equal to $(428 \pm 105) M_{\odot}$. X-1 has already been supposed to contain a BH of mass $(10^2-10^4) M_{\odot}$, but the possibility of a stellar-mass BH with super-Eddington luminosity has also been hypothesized. Since double pulsations have been discovered, the latter hypothesis turned out to be hardly probable. The result obtained is one of the strongest pieces of evidence for the existence of intermediate-mass BHs: between stellar-mass BHs and supermassive BHs in galactic nuclei.

Source: *Nature* **513** 74 (2014)
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