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1. Running mass of the t-quark

The Standard Model predicts that the constants of the interactions and masses of elementary particles can be 'running', i.e., can depend on the energy at which the measurements are carried out. This effect, which is explained by vacuum polarization and other processes, was actually observed in experiments, in particular, the running of b- and c-quark masses, as well the running of strong interaction constant, were measured. A decrease in the t-quark mass with increasing energy has been demonstrated for the first time by the CMS collaboration in an LHC experiment. The reaction products distribution in pp collisions at a center-of-mass energy of 13 TeV was analyzed. The running of the t-quark mass obtained from these data up to the energy of 1 TeV agrees well with the predictions of the renormalization group equation in quantum chromodynamics calculations, while the statistical hypothesis about the absence of mass running is ruled out with 95% reliability.

Source: https://arxiv.org/abs/1909.09193

2. Direct measurement of nonlocal quantum entanglement

In 2011, J S Lundeen and colleagues measured directly the complex wave function of a single photon (both the amplitude and the phase) using so-called weak measurements, in which the perturbation of the system is small due to obtaining only limited information on the quantum state. This method is, however, inapplicable for measuring the total wave function of two spaced systems. Such a measurement is of great interest, since it would allow tracking the relation between the total wave function and nonlocal quantum entanglement. W-W Pan (University of Science and Technology of China) and co-authors have performed such a measurement for the first time using a new method developed by them. Instead of the weak values obtained in weak measurements, modular values were used. This allowed in measuring the wave function of two spaced hyperentangled photons. The photon trajectories were used as a measurer. For large systems, the new method of measurement may turn out to be simpler than quantum tomography, as it does not require numerous copies of the system.

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3. Quantum dependence on an observer

In 1961, Wigner considered the gedanken experiment, the 'Wigner's friend paradox' (a modified 'Schrodinger's cat' experiment) in which for different observers the results of quantum measurements in the laboratory are different: one particular state is chosen or a superposition of states remains. Later, an extended version of Wigner's experiment with two laboratories was proposed and analogues of Bell's inequalities were formulated that may serve to verify the dependence on the observer. A Fedrizzi (Heriot-Watt University, United Kingdom) and colleagues have verified experimentally the extended version of the 'Wigner's friend paradox'. Using an interferometer, they measured the polarization of photons in an entangled state and recorded the results of measurements in photon memory cells that played the role of observers. They showed the violation of the above inequalities at a confidence level of 5σ, which confirmed the dependence on the observer in this particular statement of the problem. It is not yet clear what result would be obtained in the case of classical (not quantum) observers more complicated than the photon memory cell. For the concept of consciousness in the context of quantum mechanics, see the review by M B Menskii in *Usp. Fiz. Nauk* **175** 413 (2005) [*Phys. Usp.* **48** 389 (2005)]. Fundamental questions of quantum mechanics were also elucidated in the book by B B Kadomtsev, *Dynamics and Information*, and in his review in *Usp. Fiz. Nauk* **164** 449 (1994) [*Phys. Usp.* **37** 425 (1994)].

Source: *Science Advances* **5** eaaw9832 (2019)
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4. Non-Abelian gauge fields in real space

Synthetic Abelian (commutative) gauge fields modeling real fields have already been implemented in a number of systems, including cold atoms and photons. It is more difficult to generate non-Abelian fields. Their noncommutativity implies the importance of the sequence in which the field is affected. Such fields have so far been only obtained in momentum space or in auxiliary synthetic space. M Soljacic (Massachusetts Institute of Technology, USA) and colleagues have demonstrated for the first time synthetic non-Abelian gauge fields in ordinary space generated by classical light waves with the use of the non-Abelian Aharonov–Bohm effect. Two types of non-Abelian gauge fields were obtained with the help of the Faraday effect and light modulation, and these fields were shown to produce interference patterns depending on the light propagation direction in a Sagnac interferometer. This means that the fields are actually non-Abelian. The application of non-Abelian gauge fields is expected to allow observation of topological insulators in lattices, non-Abelian monopoles in superfluid liquids, and other interesting phenomena.

Source: *Science* **365** 1021 (2019)
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5. New population of gamma-ray sources

Observations using the high-sensitivity gamma-ray telescope HAWC with a wide field of view have revealed a new population of unidentified cosmic gamma-ray sources. Nine discovered sources have fractions of a degree as angular dimensions and are observed at energies above 56 TeV, and the spectrum of three of them extends to energies exceeding 100 TeV. Eight sources are projected onto the Galactic disc, and therefore are probably Galactic in origin. At an angular distance of less than 0.5° from each source, young pulsars exist, and this coincidence may not be accidental. Models of gamma-ray halos around pulsars have been discussed, but the sizes of these halos must be much smaller than the observed distances between the sources and pulsars. It cannot be ruled out that the gamma-ray emission from the new sources is generated in extended remnants that remained after supernova explosions in which the pulsars had been born.

Source: https://arxiv.org/abs/1909.08609

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