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1. Triangular singularity

Quark interaction becomes stronger with decreasing energy, which hampers calculation of quark bound states. Several states unpredicted theoretically and referred to as exotic have been observed in experiments [1, 2]. These states are worth studying, for it may clarify the properties of strong interaction. A resonance-like peak, called $a_1(1420)$, has recently been found in the COMPASS experiment performed at an energy of 1.4 GeV at CERN in the study of collisions of π^--mesons with a proton target. This peak cannot be qualified as an ordinary meson resonance, since it has a small width and is close to the ground state. It was assumed to be a new particle — a tetraquark or a diquark-antiquark molecule. M Mikhasenko, B Ketzer, and A Sarantsev (University of Bonn, Germany and Kurchatov Institute) have hypothesized that the peak $a_1(1420)$ can be explained by the so-called triangular singularity (a triangle in a diagram), when the ground state decays into K^* and $\bar{K}$ with subsequent decays $K^* \to K\pi$, $K\bar{K} \to f_0(980)$. But before the decay, kaons exchange quarks, which imitates the occurrence of new particles. G D Alekseev (JINR) and his co-authors have performed new detailed calculations [3] taking into account spin effects and higher-order scattering processes. The calculations have shown that the triangular-singularity model describes well experimental data requiring no new particles. Thus, the triangular singularity, predicted by L D Landau in 1959 [4], has been revealed in the low-energy meson sector perhaps for the first time.

2. Ghost hyperbolic polaritons

W Ma (Huagune University of Science and Technology, China) and their co-authors have predicted theoretically and demonstrated experimentally a new type of hyperbolic polariton (with a hyperbolic dispersion law) [5]. Polaritons are quasiparticles resulting from interactions between photons and excitations of the medium [6, 7]. Known earlier were bulk and surface hyperbolic (Dyakonov) polaritons only. The new polaritons, called 'ghost polaritons', propagate across the surface, but have nonvanishing wave fronts in the bulk. They are a solution of the Maxwell equation in the case when the optical axis is slanted with respect to the surface and result from the interaction of IR photons with phonons in anisotropic media. The mineral calcite was employed in the experiment, in which elements of the permittivity tensor along and across the surface have different signs. Near-field scattering scanning optical microscopy was used. Directional (ray-like) diffractionless propagation of ghost hyperbolic polaritons was observed at a distance of over 20 μm — a record distance for room-temperature polaritons. Polaritons may find practical application in subdiffraction microscopy.

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3. Quantized vortices with violated symmetry

In continuous phase transitions, a random local choice of a symmetry-breaking order parameter may be responsible for the formation of topological defects, such as quantized vortices. This process is known as the Kibble–Zurek mechanism. Researchers from Aalto University (Finland), Lancaster University (Great Britain), and the L D Landau Institute of Theoretical Physics (Russia) have examined experimentally [8] the vortex formation process with an integral and half-integral flux value in the ^{3}He transition to the polar phase in the presence of a symmetry-breaking magnetic field. As a result of symmetry violation, the choice of the order parameter in different regions is no longer quite random. It has been established that, when the length scale associated with the bias field becomes smaller than the Kibble–Zurek length, the Kibble–Zurek mechanism is replaced by the adiabatic regime, and vortex formation is exponentially suppressed. (For ITP studies, see [9]).

4. Quantum complementarity of wave-particle duality

The quantum complementarity principle is of special interest in application to corpuscular-wave duality, since it concerns the fundamental aspects of quantum mechanics. T H Yoon and M Cho (Institute of Fundamental Research and University of the Korean Republic) have experimentally verified in [10] the new complementarity relations derived by X-F Qian and G S Agarwal in 2020. These relations characterize moving from a wave to a corpuscular description. They used an interferometer with two nonlinear crystals, in which quantum-entangled photons were born. Input signals in the arms were generated by synchronized optical lasers, and the degree of corpuscularity could be changed by changing the intensity of one of the beams. In the experiment, the complementarity relations were verified and the relation between the quantum source purity and entanglement obtained by the authors was confirmed. It has also been demonstrated that the experimental scheme with two down-conversion processes is the best one for investigating the complementarity principle in the case of corpuscular-wave dualism.

5. Global structure of the Universe

The investigation of relic radiation anisotropy provides important information on processes in the early Universe and allows drawing certain conclusions regarding its global structure. Still unclear is the question of the Universe's topology — of how space goes to infinity or closes up to itself on large scales. In ordinary cosmological models with an infinite three-dimensional Euclidean space, two-point correlations of relic radiation fluctuations must be present on all scales. However, observations from the WMAP and Planck satellites have shown that these correlations are suppressed on scales separated by angles above 60°. To explain these facts, models of the Universe with finite spatial scales, for example, a three-dimensional torus topology model, have been considered. R Aurich (Ulm University, Germany) and his co-authors [11] have proposed a new observational criterion based on statistics of the relic radiation temperature gradient, sensitive enough to reveal scales of the spatial cross sections of the Universe. The application of this criterion has shown that the torus model with a circumference of about three Hubble scales is well consistent with the available observational data and solves the question of two-point correlation suppression. However, further research is needed to draw a reliable conclusion concerning the global structure of our Universe. For observation of relic radiation, see [12].

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