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1. Search for dark matter (DM) particles

Dark-matter particle scattering by scintillation NaI(Tl) crystals with a total mass of ≈ 250 kg is being searched for in the DAMA/LIBRA experiment (Gran Sasso National Laboratory, Italy), which has been reporting for 20 years the observation of seasonal signal variations corresponding to variations in DM flux through a detector as Earth moves in its orbit [1, 2]. However, such seasonal variations have not been confirmed in other experiments with fewer statistics and using other detection methods. The same NaI(Tl) crystals with a total mass of ≈ 112.5 kg are being used in the ANAIS-112 experiment (Canfranc Underground Laboratory, Spain), and, in six years, the amount of statistical data obtained is sufficient to verify the DAMA/LIBRA results on seasonal variations [3]. However, at a 4σ confidence level, seasonal variations were not detected either. Thus, it is highly probable that the DAMA/LIBRA experiment data also contain an unaccounted for error simulating seasonal variations in the DM flux. The nature of DM constituting about 27% of the Universe's mass remains unclear to date. DM, if it consists, for example, of axions [4], may be undetectable in this type of experiment.

2. Spin-triplet exciton insulator

An exciton insulator is a condensate of excitons, which are bound states of electrons and holes [5]. The exciton insulator phase has previously been observed in some materials, but only in the singlet state with identically directed electron and hole spins. J. Liu (University of California, Irvine, USA) et al. have become the first to obtain evidence for a spin-triplet state in an experiment with $HfTe_5$ compound in a magnetic field [6]. With increasing magnetic field B, a topological Lifshitz transition [7] to a one-dimensional Weyl phase and a transition of the semimetal to an insulator occurred. The preservation of the insulator state up to $B = 72$ T suggests the formation of a correlated phase corresponding to the spin-triplet state of an exciton insulator, and a numerical simulation confirms this interpretation. The spin-triplet phase is interesting, in particular, because it can exhibit unusual magnetic properties, such as spin superfluidity.

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3. Transverse Thomson effect

A Takahagi (Nagoya University, Japan) and his co-authors are the first to observe experimentally a transverse version of the well-known thermoelectric Thomson effect [8]. In the usual Thomson effect, discovered as far back as the 19th century, the rate of heat release per unit volume $\dot{q}$ is proportional to the vector of the electric current density and the temperature gradient T in the same direction. It is shown in [8] that, in the transverse Thomson effect, $\dot{q}$ depends on mutually perpendicular current density, gradient T, and the magnetic field direction. The experiment was carried out with $Bi_{88}Sb_{12}$ polycrystals synthesized by spark plasma sintering. The applied electric field was modulated to reveal the thermoelectric effect. Thermography using an IR camera in a magnetic field confirmed the variable heat release corresponding to the transverse Thomson effect.

4. Imaginary part of time delay

In many physical processes, the transition from the initial to final state proceeds with a time delay. Its mathematical expression in terms of the scattering matrix has a complex form in the general case. The real part is interpreted directly as the time the signal spends inside the scattering system, but the meaning of the imaginary additive remained unclear. In 2016, M. Asano et al. theoretically showed that the complex part should describe the shift of the central frequency of the wave packet in the Fourier expansion of the signal. I.L. Giovannelli and S.M. Anlage (University of Maryland, College Park, USA) have confirmed this interpretation in their experiment [9]. Using an oscillograph and a network analyzer, they observed the passage of Gaussian microwave pulses through a loop consisting of two unequally long coaxial cables. Registered was a shift by 0.48 MHz of the central frequency of packets in the Fourier expansion, expressed in terms of the imaginary part of the time delay in accordance with the theory of M. Asano et al.

5. Gravitational-wave burst GW231123

Among black hole (BH) merger events, registered until recently by the gravitational-wave detectors LIGO/Virgo/KAGRA, the record high mass of a BH formed by a merger was $\sim 140 M_{\odot}$. Paper [10] has presented the results of observations by two LIGO detectors of event GW231123, in which the final BH mass is already $(190-265) M_{\odot}$, the merged BH masses are estimated as $137^{+22}_{-17} M_{\odot}$ and $103^{+20}_{-52} M_{\odot}$, and their dimensionless spins are ~ 0.9 and ~ 0.8. An unusual property of GW231123 is that one or both of the merged BHs had masses falling within the so-called mass gap of $(60-130) M_{\odot}$. Within this interval, BHs cannot be formed because of the formation of e^+e^- pairs in the star core and its mass loss. However, the gap boundaries are not known exactly because of theoretical uncertainties. The presence of BHs within the forbidden gap can be explained by a star merger before a gravitational collapse or the merging of already formed BHs in a dense cluster. Previous BH mergers can explain the large value of their angular momenta, but the problem with this mechanism is the ejection of BHs from the cluster after the merger due to the recoil rate. Also considered was the model with primordial BHs having masses inside the mass gap and increased spin in the course of accretion [11]. The hypothesis concerning the existence of primordial BHs was proposed in 1966 by Ya.B. Zel'dovich and I.D. Novikov [12].

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