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1. Rydberg levels of a hydrogen atom in an electric field

The proton charge radius r_p, measured in the muon hydrogen atom on the basis of the Lamb shift effect, where the electron is replaced by a muon, is smaller than the one measured in ordinary hydrogen. This divergence is known as the 'proton radius puzzle'. r_p is found in an indirect way from measurements of the Rydberg constant R_∞, the electron wave function being partially found in the proton volume, and r_p and R_∞ must correlate. In this connection, experiments with highly excited Rydberg states sensitive to R_∞ but almost indifferent to r_p are of importance for resolving the r_p problem. However, such measurements would require a very high frequency resolution. S Scheidegger and F Merkt (ETH Zurich) have overcome this difficulty by studying hydrogen in an electric field [1]. Transitions to Rydberg states (with the known correction due to the Stark effect) with quantum numbers $n = 20$ and $n = 24$ were measured. The ionization energy was found with record precision for a two-body system, and the Rydberg frequency cR_∞ was obtained by a method insensitive to r_p. The result indirectly confirms the r_p value obtained in the experiment with muon hydrogen. New data will possibly help resolve the r_p problem. It is preliminarily concluded that it is not related to effects beyond the Standard Model, which may be responsible for the difference in the properties between ordinary and muon hydrogen.

2. Miassite superconductivity

The rare mineral miassite $Rh_{17}S_{15}$ was first found in a deposit in the upper reaches of the Miass river (Southern Urals, Russia). It is one of the few compounds in nature which can be superconducting. As a matter of fact, superconductivity was revealed in pure miassite synthesized in the laboratory, because the natural compounds include many impurities and do not form large crystals. Miassite superconductivity has several remarkable features, namely, an anomalously high upper critical field of H_{c2}, a large jump of thermal conductivity, etc. R Prozorov (University of Iowa, USA) and his colleagues have proved the existence of a unconventional type of $Rh_{17}S_{15}$ superconductivity, which is not described by the Bardeen–Cooper–Schrieffer theory [2]. A synthesized miassite single crystal showed a linear temperature dependence of the London penetration depth $\Delta\lambda(T)$ (in ordinary superconductors, $\Delta\lambda(T) = \text{const}$ at low T). T_c and H_{c2} were found to be suppressed by nonmagnetic defects induced by an electron beam. The results of measurements agree with the presence of nodes in the energy gap, which are a distinctive feature of unconventional superconductivity. An unconventional type of superconductivity has been shown by a number of substances, for instance, high-temperature superconductors, cuprates, but these materials are products of synthetic chemistry and, as distinct from miassites, do not exist in nature.

3. Fundamental limit for radiation absorption in a medium

The radiative and absorbing properties of media are important for many practical applications in information transmission, energetics, etc. A fundamental constraint on the absorbing layer thickness and the wavelength range width for absorption in a medium of radiation reflected from a metal surface was obtained earlier in the theoretical work of the Russian physicist K N Rozanov (Institute of Theoretical and Applied Electrodynamics of RAS) [3]. K N Rozanov's approach was used further to investigate some other configurations. Also largely based on K N Rozanov's calculations, a group of researchers from Duke University (USA) has obtained a new limit relating the width of the absorption band to the thickness of homogeneous layers of the absorbing medium without a reflective surface [4]. To this end, the analytical properties of reflection and transmission coefficients were considered using the Kramers–Kronig relations. The obtained result was confirmed in particular cases by the transmission matrix method and numerical simulations of wave passage through dielectric metamaterials.

4. Dark matter density spikes around supermassive black holes

According to theoretical models, supermassive black holes (SMBHs) in galactic centers must be surrounded by dark-matter density spikes. Researchers M N Chan and C M Lee (Educational University of Hong Kong, China) have possibly become the first to discover such a spike for a binary SMBH in the system OJ 287 [5]. The measured rate of decrease in the orbital period of this system is higher than it should be due to gravitational wave radiation only. If an additional decrease is assumed to be explained by the dynamic SMBH friction in the dark matter, then it follows that the spike profile has the exponent $\gamma_{sp} = 2.351^{+0.032}_{-0.045}$, very much in agreement with the theoretical value $\gamma_{sp} = 2.333$. More exact information about the density spikes will be possible to obtain from observations of stars in the vicinity of SMBHs and from further measure-

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ments of low-frequency gravitational waves emitted by pairs of SMBHs.

5. Constraints on epoch of reionization using the kinematic Sunyaev–Zeldovich effect

The kinematic Sunyaev–Zeldovich (kSZ) effect is related to the scattering of cosmic microwave background (CMB) radiation photons by moving electron clouds. After the reionization of the Universe was over, the kSZ effect was revealed from mutual CMB correlation and galaxy distribution maps. In the reionization epoch, the kSZ signal must be modulated by the velocity field and create nongaussian corrections in CMB maps. S Raghunathan (Center for AstroPhysical Surveys, National Center for Supercomputing Applications, Urbana-Champaign, Illinois, USA) and his co-authors have presented the results of an analysis of the kSZ trispectrum using the CMB temperature maps obtained by the South Pole Telescope and Herschel-SPIRE [6]. The main contribution to the trispectrum is made by CMB lensing signals and the astrophysical foreground. No kSZ heightening above the level of this background has been revealed, which, together with the data obtained using the Gunn–Peterson effect, allowed setting the upper limit on the reionization duration $\Delta z < 4.5$. The result obtained agrees with data from the Planck Space Telescope. For the Sunyaev–Zeldovich effect and other work by Ya B Zeldovich, see [7].

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