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POSSIBILITY OF IDENTIFYING THE LINES OF THE QUARK-ATOM Mg q II AND Hq IN THE SPECTRUM OF THE SUN

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The possible existence of quarks, stable particles with fractional electric charges ±1/3 or ±2/3, has been recently under discussion. It was shown earlier [1] that 10^{-9} - 10^{-10} quarks per nucleon 1) from the initial period of the expansion of the hot Universe could still be extant. The quarks could subsequently become annihilated at a temperature sufficient to overcome the Coulomb barrier, but the negatively-charged quarks could stick to nuclei whose charge protected them against annihilation. At $T \sim 10^{6}$°K the quarks with charge -1/3 break away from protons and go over to He, and at $T \sim 10^{7}$°K they go over from He to heavier elements. The same paper raised the question of the possible observation of quark-atom lines in spectra of celestial objects. We now consider this question in greater detail.

Hydrogen emission lines are produced by recombination and by impact excitation. It can be shown that the L_α emissions of hydrogen H and of quark-hydrogen Hq (λ = 2733 Å) upon recombination are related like $10N_H/N_{Hq}$ (with allowance for the difference in charge). Impact excitation increases somewhat the Hq radiation - by a factor 7 - 10 at $T \sim 15,000°$, but at higher temperatures the Hq is practically fully ionized. Since $N_q/N_H \sim 10^{-10}$, we can state that in none of the emitting objects (planetary and diffuse nebulae, shells of supernovae and quasars, the solar chromosphere, etc.) can the $L_{q\alpha}$ be observed. The same holds for the emission lines of other quark-atoms, even if the quarks are joined only to elements heavier than C.

Observation of the λ = 2733 Å line in interstellar gas is hindered not only by the small number, but also by the high degree of ionization ($\sim 10^{7}$) of Hq. Conditions are more favorable for the observation of the absorption lines in the atmosphere of the Sun and of the stars, where the number of atoms in the column is larger than in the interstellar gas. If the quarks remain bound to the H, then the Hq 2733.3 ± 0.1 Å line (the uncertainty is due to the unknown mass of the quark) in the Sun's spectrum should have an equivalent width $W \sim 0.03$ Å at a quark abundance of 10^{-10} relative to H. The solar spectrum [2] has absorption-line overlaps in this region, but it can be stated that $W < 0.001$ Å. Consequently the abundance of Hq does not exceed 3×10^{-12}. It must be borne in mind that in the base of the Sun's convective zone the temperature exceeds 10^{6}°K, and the matter is sufficiently thoroughly mixed. Therefore the quarks are probably separated from the H and are joined to He and heavier elements, and possibly only to the latter.

In this connection, interest attaches to the resonant lines Mg q II and the somewhat less abundant Ca q II. Mg constitutes 2% of the heavy elements. The optical thickness in the Mg II lines is approximately 10^6. If the quark abundance is 10^{-10} of H, then the thickness in the Mg q line should be of the order of 0.1 or 0.001 (if the quarks are attached to the heavy elements or to He, respectively). In the Ca q II line the thickness should be smaller by almost two orders of magnitude - by a factor 18 due to the abundance and by 4 times due to the second ionization.

The position of the center of gravity of the doublet (Λ) for the resonant line Mg q II (3s - 3p) was determined by extrapolating to $Z = 5/3$ the experimental data for Na I, Mg II, and Al III. It is obvious that to ensure maximum accuracy it is necessary to interpolate the quantity ω, which is uniquely related to λ, but which possibly depends less on Z. If we assume $\omega = Z\lambda$, then $\lambda = 3399$ Å, with a probable error ~ 30 Å. A much more accurate result can be obtained by inverting the semi-empirical method proposed by Vainshtein [3]. Here ω is a scale factor in the potential of the single-electron Schrodinger equation. For Na I, Mg II, and Al III the value of ω was defined so that the eigenvalue ϵ of the equation coincided with the experimental value. ω is then interpolated to $Z = 5/3$ and the values of ϵ_{3s}, ϵ_{3p}, and λ are determined for Mg q II. The accuracy of the method can be judged by using the error in the calculation of λ for Mg II from data for Na I and Al III. After averaging (with suitable weight) the results obtained with and without allowance for exchange and polarization, it was found that the wavelength (in air) is $\lambda = 3381 \pm 2.5$ Å.

The situation is much simpler when it comes to calculation of the doublet splitting $\Delta\lambda$, which depends very little on Z. The interpolation yields $\Delta\lambda = 6.87 \pm 0.05$ Å, from which we get for the strong (short-wave) component $\lambda_{3/2} = 3378.5 \pm 2.5$ Å.

Similar calculations yield fro Ca q II (from the data for K I, Ca II, and Sc III) $\lambda_{3/2} = 4688 \pm 6$ Å and $\Delta\lambda = 34.62 \pm 0.05$ Å.

To search for possible lines of quark-atoms we used Rowland's tables [4], checking them against Minnaert's tables [5] and the high-resolution spectrograms obtained by M. A. Livshitz. As a result we selected two pairs of unidentified lines, for which λ, $\Delta\lambda$, and the 2:1 intensity ratio satisfy the foregoing estimate (the parentheses contain the rough values of the equivalent widths):

3378.07 (6) - 3384.93 (3);
3375.73 (20) - 3382.59 (6).

Seven pairs of lines were chosen for Ca q II in accord with [4]. The situation is even more uncertain here than for Mg q II, and furthermore the expected line intensity is too low. We therefore omit the wavelengths to save space. Thus, the observations do not contradict the presence of 10^{-10} quarks in the solar atmosphere. At the same time, it remains desirable to reduce the uncertainties in the determination of the line parameters.

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1) If the Universe was cold at the initial instant, the number of quarks should be appreciably smaller. However, the recently observed relict radio emission is evidence in favor of the hot model.

CHARACTER OF CONDUCTION-ELECTRON REFLECTION FROM THE SURFACE OF COPPER WHISKERS

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It has been assumed until recently, on the basis of experimental data on both the conductivity of thin polycrystalline samples (foils, wires, films) and the anomalous skin effect, that practically all the electrons that participate in charge transport in real samples are scattered diffusely by the surface [1-4].

It has been observed lately, however, that specular reflection of the electrons from the surface plays an important role in the conductivity of a number of objects [5-10]. The conditions under which this phenomenon takes place have not yet been thoroughly studied.

The objects used in the present work to study the character of reflection of conduction electrons were single-crystal copper whiskers having small dimensions and a natural crystallographic faceting. This obviously should contribute to specular reflection or to regular diffraction of the electrons on the surface, the possibility of which should be taken into account for electrons with wavelengths smaller than the period of the distribution of the atoms on the crystal face.

The single-crystal whiskers were obtained by reducing spectrally-pure copper iodide in a hydrogen stream at 610 - 620°C [11]. They were produced with three crystallographic orientations ([100] with square cross section, [110] with rectangular section, and [111] with hexagonal section).

We selected for the investigations, using a microscope, straight, elastic single-crystal whiskers of uniform thickness, having different diameters and optically smooth surfaces with cross sections that were either hexagonal or differed little from square. Each investigated