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MEASUREMENTS OF THE ULTRAVIOLET RADIATION OF THE METAGALACTIC GAS, MADE OUTSIDE THE ATMOSPHERE

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A radiation receiver mounted on the automatic interplanetary station (AIS) "Venera-3" [Venus-3] was used to observe the upper limit of the uv flux in the wavelength interval 1225 - 1340 Å. The main source of such radiation is the line L_α ($\lambda = 1216$ Å) of intergalactic hydrogen, shifted in the red direction by the cosmological expansion. The experimentally obtained upper limit of the flux yields information on the density and temperature of the intergalactic medium, where present-day notions presume the bulk of the matter of the Universe to be located.

The AIS Venera-3, which was launched on 16 November 1965, was equipped with an instrument to measure the radiation in two spectral intervals, 1050 - 1340 and 1225 - 1340 Å. The uv reciver was a photon Geiger counter with a window of lithium fluoride, filled with NO. An additional filter of calcium fluoride, approximately 1 mm thick, was used for the measurements in the second band. The fields of view for the indicated spectral intervals were 7 and 20° respectively, and the corresponding geometric factors were 3×10^{-4} and 3×10^{-3} cm^{2}sr. The counter efficiencies at the investigated wavelengths were approximately 10 - 20%, as determined by laboratory measurements. The field of view of the photometer subtended a cone with apex angle 140° around the antisolar point in a time of approximately 10 minutes. Both counters, with the exception of the window (7 mm diameter) were shielded with 3.5 mm of lead, which cut off completely the soft component of the cosmic radiation.

The flux measured far from the earth in the first spectral interval was 5.5×10^{-5} erg/cm^{2}sec-sr. It can be naturally attributed to the solar L_α emission resonantly scattered by the interplanetary neutral hydrogen [1]. In the 1225 - 1340 Å band outside the L_α line the rate was 31.6 ± 4 counts/sec. Comparison with measurements made on the same AIS with an STS-5 Geiger counter with approximately the same shielding has made it possible to estimate the counting rate due to cosmic rays in our instrument. This counter read 31.4 ± 1.4 counts/sec.[*] (These measurement data were graciously furnished by G. P. Lyubimov.) Figure 1 shows the counter readings in both spectral intervals during one of the transmissions. At a rate of about 31 counts/sec, it can be stated that the radiation in the 1225 - 1340 Å band did not produce more than 4 counts/sec, corresponding to an upper flux limit of 10^{-7} erg/cm^{2}sec-sr.

If we now take into account the absorption in the Galaxy, then we can obtain an upper limit for the flux from the Metagalaxy. Absorption by elements with a low ionization potential (< 10 eV) is obviously negligible. Assuming that for wavelengths ~4000 Å the absorption by the dust along the perpendicular to the Galactic plane is 0.18 and that the absorption is proportional to λ^{-1} [2], we find that in the wavelength interval of interest to us the absorption by the dust decreases the flux, averaged over the sky, by a factor 2.5 and consequently the flux from the Metagalaxy does not exceed 2.5 x 10^{-7} erg/cm^{2}sec-sr.

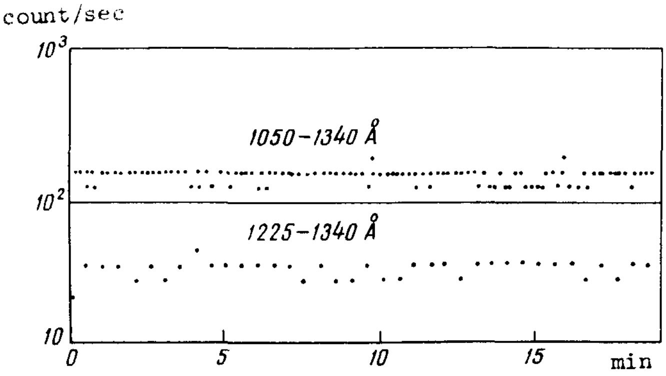

Fig. 1. Transmission from the AIS "Venera-3" on 7 January 1966.

We proceed now to an interpretation of the experimental results. It is assumed at present that the space between the galactic clusters contains hot almost fully ionized gas [3] consisting of 70% hydrogen and 30% helium (by weight). During the course of the expansion, the wavelengths vary like $\lambda = \lambda_0(1 + z)$, where z is the red shift, and the density varies like $n = n_0(1 + z)^3$; we assume for simplicity that the temperature is constant. Under these assumptions we can find the radiation flux in the measured frequency interval:

$$I = \frac{c}{H}\int_0^\infty j_{\nu_1}\frac{dz}{(1+z)^5\sqrt{1+\Omega z}}\,\Delta\nu_0,$$

where $\nu_1 = \nu_0(1 + z)$, $\Omega = 2q = \rho/\rho_{cr}$, $\rho_{cr} = 2 \times 10^{-29}$ g/cm^3, q is the acceleration parameter, H is Hubble's constant, $\Delta\nu_0$ is the received frequency interval, and j_ν the volume luminosity; for a line of frequency ν_α we have

$$j_{\nu_1} = \frac{1}{4\pi}n_1^2\,h\nu_1 f(T)\,\delta(\nu_1 - \nu_\alpha) = \frac{1}{4\pi}n_0^2\,h\nu_0(1+z)^7 f(T)\,\delta[\nu_0(1+z) - \nu_\alpha].$$

The functions f(T) for the emission in the H I L_α line and in the resonance λ = 340 Å He II line are shown in Fig. 2. We obtain ultimately $I = \Omega^2\psi(T)$.

Inasmuch as only the upper limit was measured for the flux, we can indicate for each value of T an upper density limit. The corresponding curve is shown in Fig. 3. In different temperature regions, the main contribution is due to the following processes:

1. When $10^4 < T < 6 \times 10^4$°K the radiation is due to atomic hydrogen excited by electron impact, and to a lesser degree to recombination radiation of the hydrogen in the L_α line. In this case the layer with z < 0.1 is effective. What was essentially measured was the upper limit of the measure of emission, which equals 0.03 at the most favorable temperature. This demonstrates directly the efficacy of the measurement method: objects having such an emission

measure are not observable in the optical band, owing to the background of the night sky, and in outer space owing to the background of the stars.

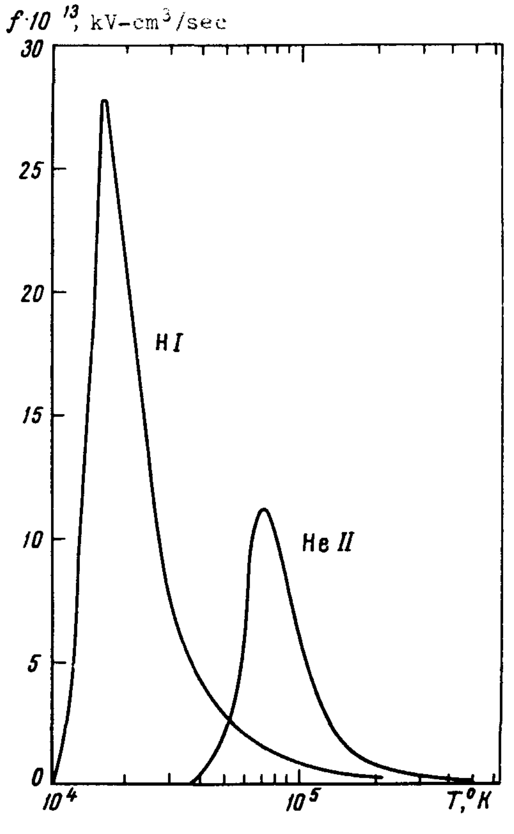

Fig. 2. Dependence of the emissivity of hydrogen and helium in the lines L_α and λ = 304 Å as a function of the temperature.

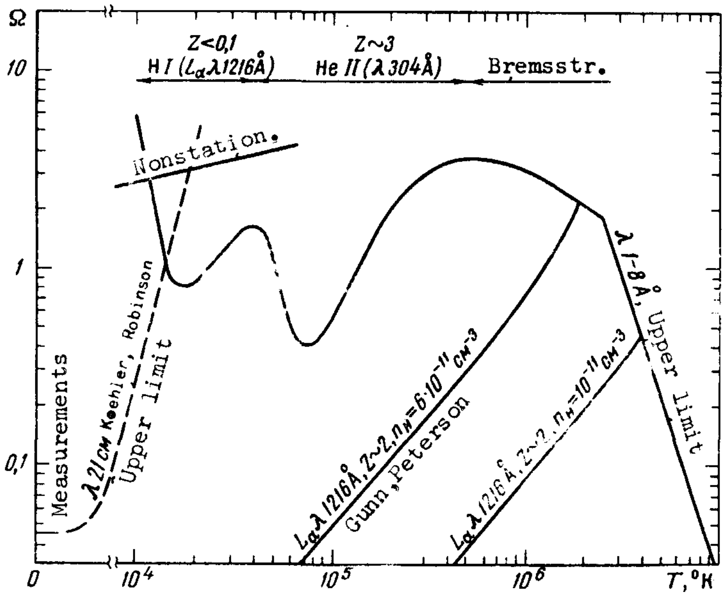

Fig. 3. Upper limit of density of the intergalactic gas as a function of the temperature.

2. At higher temperatures, $6 \times 10^4 < T < 5 \times 10^5$°K, the main contribution is made by the resonance line of ionized helium, which emits in the interval $3 < z < 3.4$.

3. When $T > 5 \times 10^5$°K the main contribution is made by free-free transitions. In this case the effective regions are those with large $z \sim 10^{-5}T$, i.e., $z > 5$ in this case.

Since radiation from regions with large z plays an important role in the second and third cases, the function $\psi(T)$ also depends on Ω, and the recalculation of the flux becomes somewhat more complicated.

Figure 3 shows also data obtained by other methods. Gunn and Peterson [4] observed neutral hydrogen of density 6×10^{-11} cm^{-3} at $z \sim 2$, as revealed by the absorption in the spectrum of the 3C-9 quasar. The Burbidges and others prove that Gunn's estimate is too high by at least 3 - 4 times, and that $n_H < 10^{-11}$ cm^{-3}. So low a density of the neutral hydrogen is attributed to the high gas temperature. Plots, at each point of which the neutral-hydrogen density is 6×10^{-11} and 10^{-11} cm^{-3} respectively, were prepared with allowance for the dependence of the degree of ionization on the temperature.

Field and Henry [5] interpreted the x-ray background in the 1 - 8 Å region as being due to bremsstrahlung of the gas. The presented curve delineates that region of the ρ-T plane in which there is no contradiction of the observations of the background in the x-ray region of the spectrum.

In a recent paper, Koehler and Robinson [6] determined the density of neutral hydrogen in the intergalactic medium at small values of z, by measuring the absorption in the 21 cm line. Assuming the spin temperature to be 4°K, Koehler gives $n_H = 4.5 \times 10^{-7}$ cm^{-3}. The corresponding values of ρ and T, for which such values of n_H are attained in the stationary state, are also shown in Fig. 3. At such a neutral-hydrogen density, the medium is opaque to the L_α line, and the optical thickness, allowing for the Lyman continuum,is $\tau = 10^4$, while the thickness for the Lyman continuum is $\tau \sim 10^3 - 10^4$. Absorption in L_α is accompanied by reradiation, and therefore does not change the conclusions for the temperature region $T < 5 \times 10^4$°K, while radiation in the free-free transitions and in the helium line is completely absorbed.

Comparison with the small n_H at $z \sim 2$ [4] shows, if Koehler's interpretation is correct, that the neutral hydrogen appeared somewhere near $z < 2$. The region of this appearance can be determined by extending the investigated spectral interval to the low-frequency side.

A check on the results of Koehler and Robinson would be to compare the fluxes in two spectral intervals with $\lambda < 1216$ Å and $\lambda > 1216$ Å. This would make it possible to distinguish the emission hydrogen (near region) from emission in free-free transitions and in the $\lambda = 304$ Å helium line. If the degree of ionization at $z \sim 2$ corresponds to the electron temperature of the gas, then the hydrogen cannot recombine within the cosmological time. The curve corresponding to radiation under nonstationary recombination is also shown in Fig. 3.

The authors intend to analyze in the nearest future the mutual compatibility of the available experimental data under different assumptions concerning the time variation of the temperature.

The sensitivity of the apparatus can be greatly improved. The sensitivity limit is apparently determined by the stellar component of the background. The summary emission of the stars in the investigated spectral region, for sections of the sky far from the galactic plane, does not exceed 3×10^{-9} erg/cm^{2}sec-sr, which is much lower than the value presented here. The importance of further measurements is evident, for observations of the course of expansion give a value $\rho \sim 2\rho_{cr}$, with very low accuracy [7].

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* With due allowance for the ratio of the geometric factors.

ELECTRON PARAMAGNETIC RESONANCE PRODUCED BY THE SURFACE OF DIAMOND

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A number of recent papers are devoted to electron paramagnetic resonance (EPR) studies of the surfaces of semiconductor compounds with diamond-type lattices [1-8]. Diamond itself is dealt with in only one paper [4], which contains very sketchy information in the EPR spectrum connected with the surface of diamond (single line with $g = 2.0027 \pm 0.0002$ and $\Delta H = 5.5$ Oe).

We have undertaken a more detailed study of the surface centers in diamond by the EPR method, using a radiospectrometer (RE-1301) operating in the 3 cm band at a high modulation frequency. The spectra were recorded at room temperature. The samples were crushed natural diamonds of type 1 (nitrogen). The mean particle dimensions in the various samples are listed in the table.

Table

Number of electrons with unpaired spins (EPR data), and calculated number of carbon atoms on the surface, as functions of the sample particle dimensions

Sample	Grain size (μ)	Calculated number of carbon atoms on surface of a sample weighing 1 gram	Measured number of spins (EPR data) per gram of sample
1	57 ± 7	5×10^{17}	0.8×10^{17}
2	34 ± 6	8×10^{17}	1.4×10^{17}
3	8.5 ± 2	3×10^{18}	0.7×10^{18}
4	~1	2.5×10^{19}	0.6×10^{19}

Since the initial material of our samples was diamond containing nitrogen as an impurity, it was natural to expect the EPR spectra to include lines due to the donor nitrogen (Fig. 1, lines (a)).* The measured concentration of the unpaired spins causing this type of spectrum is $\sim 10^{15}$ cm^{-3}. The intensity of another spectrum obtained by us, consisting of a line (b) whose characteristics coincide with those obtained in [4] and which is ascribed to surface centers, depends on the dimensions of the diamond crystallites. The smaller these dimensions (and consequently the larger the surface of the sample), the more intense the line (b). Measurements of the number of paramagnetic centers corresponding to the line (b) have shown that, in order of magnitude, the number of unpaired spins is close to the number of carbon atoms on the surface of each diamond sample (see the table). Line (b) has a Lorentz shape, which does not change from sample to sample. The diamond samples with crystallite dimension close to 1 μ revealed a new type of spectrum (Fig. 2, lines (c)). This spectrum has a g-factor equal to that of line (b). The form of the separate spectral components that are symmetrically disposed relative to the line (b) is analogous to the form of the hyperfine structure (hfs) of the EPR spectrum of donor nitrogen in small-crystal samples [9,10]. This is evidence that in the spin-Hamiltonian term describing the hfs

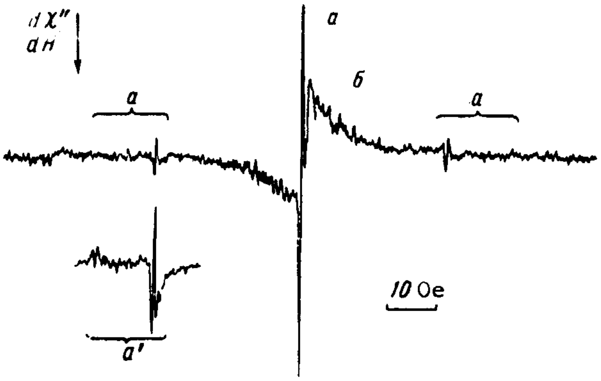

Fig. 1. EPR spectrum of fine crystalline powder (particle dimension ~34 μ) of natural diamond. The system of lines a is due to the nitrogen donor centers; the spectrum detail a' was obtained with a better signal/noise ratio. Line b is due to paramagnetic centers connected with the surface of the sample.

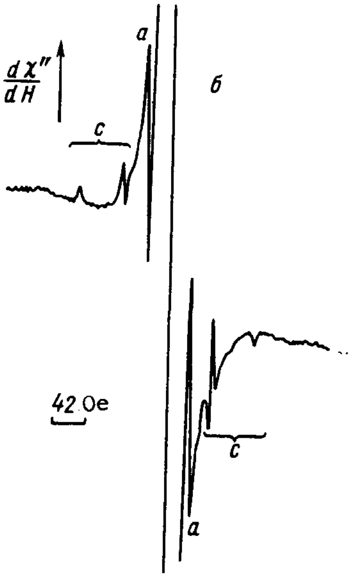

Fig. 2. EPR spectrum of powdered (~1 μ) natural diamond. Lines a - spectrum of donor nitrogen (the central peak goes off the chart), line b - same as in Fig. 1, but much more intense; lines c - new type of spectrum (see text).

$$AS_zI_z + B(S_xI_x + S_yI_y) \tag{1}$$

we have $A \neq B$. Here S is the electron spin operator, I the nuclear spin operator, and A and B the hfs constants. The method used in [1] to determine $g_{\parallel}$ and $g_{\perp}$ in polycrystalline samples yielded A = 238 Oe and B = 120 Oe. Calculations have shown that the number of spins causing the lines (c) amounts to 1.7% of the number of spins as determined from line (b). The obtained ratio is close to the natural content of C^{13} in natural diamond (1.1%). This allows us to advance the hypothesis that the paramagnetic centers connected with the surface include an electron with unpaired spin, localized on a carbon atom, and that the observed spectrum consisting of the lines (c) is the hfs of the interaction between the unpaired electron with the magnetic moment of the C^{13} nucleus.

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* The EPR spectra of donor nitrogen in small-crystal samples are considered in [9,10].

SEARCH FOR RESONANCES IN A SYSTEM OF TWO BARYONS WITH s = -1 AND s = 0

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At present the existence of resonances in systems of elementary particles with baryon number greater than unity is not known to be forbidden. This paper is devoted to an investigation of the mass spectrum of dibaryon states of the systems Λp and pp, obtained by reducing the photographic data from the 55-cm propane bubble chamber of the JINR High-energy Laboratory [1], irradiated with neutrons having kinetic energies up to 10 GeV [2]. The neutrons were obtained by interaction of maximum-energy protons with a beryllium target measuring 5 x 5 x 2 cm placed in the vacuum chamber of the accelerator. The neutron beam axis was tangent to the proton trajectory at the point of target location. Steel collimators 1.5 and 2.2 m long produced on the front wall of the chamber a sharp image of the

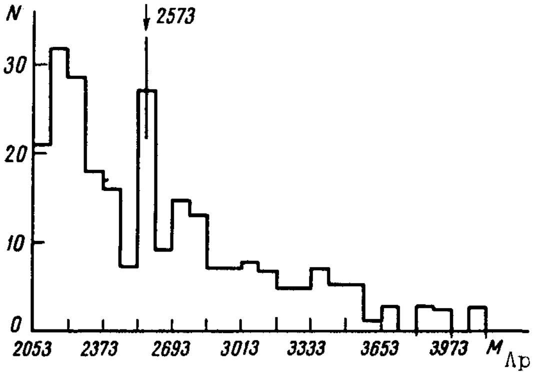

Fig. 1. Effective-mass spectrum of the Λp system, from single- and three-prong events produced on free protons.