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EXTRA-ATMOSPHERIC MEASUREMENTS OF THE ULTRAVIOLET AND X-RAY BACKGROUNDS AND THEIR ROLE IN THE STUDY OF INTERGALACTIC GAS

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SUMMARY

Results are given of background measurements in the ultraviolet (UV) wavelength range. It is shown that combined UV and X-ray measurements make it possible to determine the density and "thermal history" of the intergalactic medium and, consequently, to estimate the density of matter in the Universe. It is concluded that the background in the UV spectral region from extra galactic nebulae, stars and interplanetary medium does not exceed 10^{-26} to 10^{-27} w/m$^2\cdot$ster$\cdot$htz.

INTRODUCTION

Inspite of the widespread opinion [1-6] that the bulk of the matter of the Universe consists of intergalactic gas more or less uniformly distributed in space, not a single experimental study is available to date, either demonstrating or refuting the validity of this hypothesis. The possibility of an experimental study of density and temperature of this medium is examined in this article, alongside with a concrete analysis of the results of measurements. The importance of such experiments for cosmology and cosmogony is clear, since the average density of metagalactic matter (and, therefore, also the model of the Universe) are still unknown. In principle, such measurements may lead to the quantity $\Omega = \rho/\rho_{cr} > 1$ and, therefore, to the conclusion about a closed model of the Universe (see Note 1). At the same time, the result $\Omega < 1$ leaves the possi-

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1. Here ρ is the density of intergalactic gas, $\rho_{cr} = 3H^2/8\pi G = 2.10^{-29}$ g/cm^3 $\cdot$ 10^{-5} cm^{-3} is the critical density, H is Hubble's constant, and G is the gravitation constant. If $\rho > \rho_{cr}$, then the world is closed and the expansion observed now will later be replaced by contraction; $\rho < \rho_{cr}$ corresponds to an open model of the Universe.

bility (although rather improbable) that optically nonobserved objects (such as collapsed stars, neutrinos (see Note 2), etc.,) are present, which could contain the bulk of matter present in the Metagalaxy. The average density of matter present in galaxies is about 3.10^{-9} ρcr.

Simultaneously with the determination of the average density of matter, these measurements will permit to reproduce the "thermal history" of the Universe at a late stage of evolution. We will use this term to describe the relation between the change of temperature and the expansion. The hot model of the Universe (see, for example, the review article [1]) predicts the cooling of matter and the recombination of hydrogen at a density which is 10^9 times greater than the present density. The assumption of the presence of a hot intergalactic gas requires a subsequent heating up of the medium. The course of the temperature change after this heating up period (thermal history) will help to reproduce the experiments discussed here. The methods used for studying intergalactic gas and examined in this article are based on the possibilities afforded by the extra-atmospheric astronomy, which makes it possible to conduct observations in the X-ray and UV spectral regions.

1. MEASUREMENTS OF THE UV BACKGROUND ON THE AIS "VENERA-3"

The automatic interplanetary station "Venera-3" was equipped with an instrument for the registration of ultraviolet radiation in the two spectral bands: 1050-1340 Å and 1225-1340 Å. Photon Geiger counters filled with gas (nitrogen oxide) and provided with a lithium fluoride window were used as radiation receivers. An additional 1 mm. thick filter (calcium fluoride), cutting off radiation of wavelength λ < 1225 Å, was mounted in front of one of the Geiger counters. The field of vision in the first spectral channel was equal to 7°, and the second channel to about 20°. The efficiency of the counters in the second channel was 15-20%, and the geometric factor for UV radiation was respectively 3.10^{-4} and 3.10^{-3} cm^{-2}.sterad. The apparatus, consisting of pickup element

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2. The maximum possible density of neutrinos and gravitons in the Universe can be estimated in the same way as in [6], from the age of the Earth, which, according to present data, exceeds $T_0 = 5.10^9$ years. Since the Hubble's constant is H_0 = 100 km/sec. Mpc. = 10^{-10} years^{-1}, and the age of the world filled with radiation is $\tau = H_0^{-1}(\sqrt{\Omega}+1)^{-1}$, we obtain from the condition $\tau > \tau_0$, $\Omega < 1$. The condition $\rho rad/\rho cr < 1$ will not change, even if the main contribution to the density of the Universe is made by other types of matter.

unit with two counters and the first amplifier stages, an electronic unit containing the onboard voltage stabilizer, and two identical logarithmic intensity-meters with a range of 2 - $2 \cdot 10^3$ pulses/sec, was described in detail in a previous article [7]. The method of absolute calibration of the photon counters with the aid of a vacuum monochromator and a thermocouple is described in [8], where the spectral sensitivity curves of the counters are also given. The photometer was placed on the shady side of the AIS and its optical axis was pointed at an angle of 110° in the direction of the Sun. Around this axis, the field of vision of the instrument could describe a cone with an aperture angle of 140°, whereby the rotation angle was not controlled. Data were transmitted from the station to the ground during communication sessions of approximately 5 min. duration. For the second counter, the system for measuring the voltage at the output of the logarithmic intensity meter with a time constant of 3 sec. made it possible to record specific values of the quantum counting rate for one of the following levels: 13-17, 17-22, 22-28, 28-36, 36-47 and 47-60 pulses/sec. As a rule, the measured values were recorded in 2-3 adjacent channels and the total number of measurements was approximately 30-50 during one communication session. Most of the measurement points were then located in the range of 28-36 pulses/sec. (Figure 1).

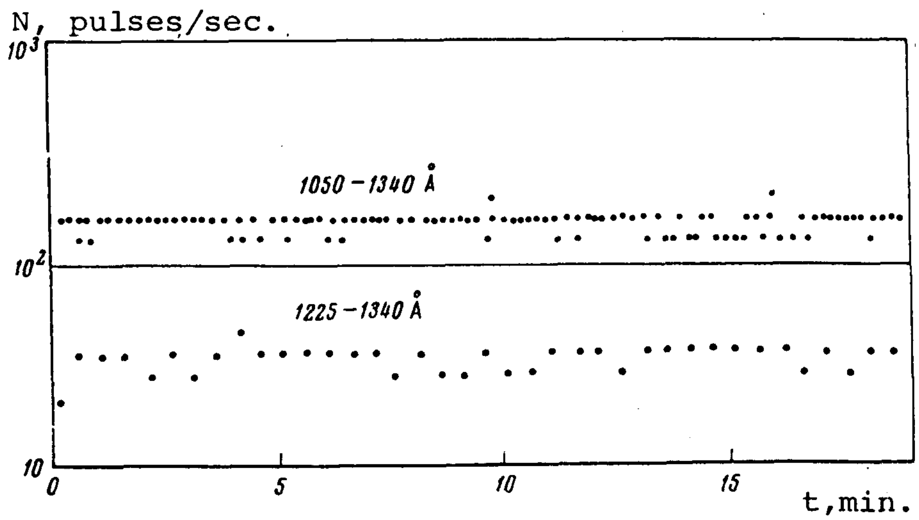

Fig.1.

Readings of the Device installed aboard the AIS "Venera-3" during one of the communication sessions.

In the 1050-1340 Å spectral region, hit by the solar line L_α (1216 Å), scattered on interplanetary neutral hydrogen was located, the count corresponded to $\sim$200 pulses/sec. In the range (interval) of interest to us, outside the L_α-line, the main and probably the total contribution was made by the cosmic ray background. In order to study the effect of this background, we used the data of S. N. Vernov and G. P. Lyubimov [9] on the measurement of cosmic ray intensity on the same AIS with the STS-5 Geiger counter. The shielding of both counters was close to 3 g/cm^2. and the measurement precision [9] was very high in view of the long information storage time, equal to 4 hours. However, even measurements during a communication session yielded a precision quite sufficient for our purposes.

For a final processing of data, we selected the five longest communication sessions yielding a total of 133 values (one of these is illustrated in Fig.1.). All data refer to the period from 16 November to 9 December 1965. The readings of the two counters were compared by taking into account the ratio of geometric factors, calculated according to the formula

$$\frac{\Gamma_1}{\Gamma_2}=\frac{R_1(R_1+l_1)}{R_2(R_2+l_2)}, \quad (1)$$

where Γ_1 is the geometric factor of the UV radiation counter, R_1 is the radius and l_1 is the length of the counter, and Γ_2, R_2 and l_2 are the corresponding symbols for the STS-5 counter. From the data on the dimensions of the counters it was found that the ratio $\Gamma_1/\Gamma_2 = 1{,}14 \pm 0{,}04$. At the same time, the results obtained with the STS-5 counter correspond to a counting rate of N = (31.2 $\pm$ 1.4) pulses/sec. The error, equal to 1.4 pulses/sec, also includes the measurement error with the STS-5 counter.

Summing up the data obtained in all sessions, we obtain the distribution of counting rate measurements shown in Fig.2.

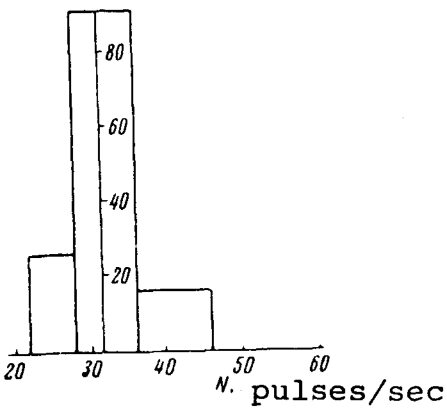

Fig.2. Histogram of counting rates plotted from the aggregate of data obtained in five communication sessions with "Venera-3"

The mean value of this distribution is 31.4 pulses/sec. and its standard deviation is 4 pulses/sec.; however. the mean value can be obtained with a greater precision but the wide range of measurements associated with the discrete nature of telemetry do not allow us to achieve a precision much greater than the standard deviation value. Therefore, we shall assume further in this paper, that the signal associated with the UV radiation in the 1225-1340 Å band does not exceed 4 pulses/sec. Taking into account that the counter used had an efficiency of about 0.17, averaged from the spectral sensitivity curve, account being taken of the transmissivity of calcium fluoride, a value of 10^{-7} erg/cm^2.sec.sterad, we obtain for the upper limit of the radiation flux which, for a plane spectrum, corresponds to an intensity (see Note) $I_\nu < 5.10^{-25}$ w/m^2.hz.sterad in a frequency scale.

The presence of an UV background in this spectral region can be due to the following: a) to the metagalactic background; b) to the background of the aggregate stellar radiation; c) to radiation scattered on interplanetary gas and dust; and d) to L_α-radiation, partially arriving through the CaF_2 filter.

The metagalactic UV radiation is partly absorbed in our Galaxy by interstellar dust (this problem will be examined in greater detail in Section 4 below). This absorption attenuates the radiation flux arriving from the Metagalaxy by no more than two times. Thus, the upper limit of the metagalactic background is equal to 10^{-24} w/m^2.hz.sterad. Obviously, the background will consist of the sum of the emission of intergalactic gas and of the background of extra galactic nebulae.

2. RADIATION OF INTERGALACTIC GAS

At present it is assumed that the space between galaxy clusters contains a hot, almost completely ionized gas [1-4, 10] consisting of 70% hydrogen and 30% helium (by weight) [11-13]. The radiation of this gas in the UV spectral region is determined by free-free transitions and emission in the resonance lines by hydrogen (λ 1216 Å) and helium ion (λ 304 Å). The radiation of the resonance line of neutral helium (λ 584 Å) can be disregarded, since it is material at temperatures of the order of $(3\text{-}5) \cdot 10^4$ degrees K, when it is completely absorbed by weakly ionized hydrogen. Radiation in

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Note. The recalculation of the background level, performed by us for measurements of the emission of stars near λ 1314 Å [39] gives for the upper limit of UV radiation an estimate which is in agreement with the above figure.

resonance lines of hydrogen and the ions is caused by the excitation of the 2p level by electronic impact and by recombination at the excited levels, Since these processes are strongly dependent on temperature (Fig.3) and density ($\sim n_e^2$), the presence of an upper limit of radiation makes it possible to establish an upper limit of the gas density for each value of the temperature.

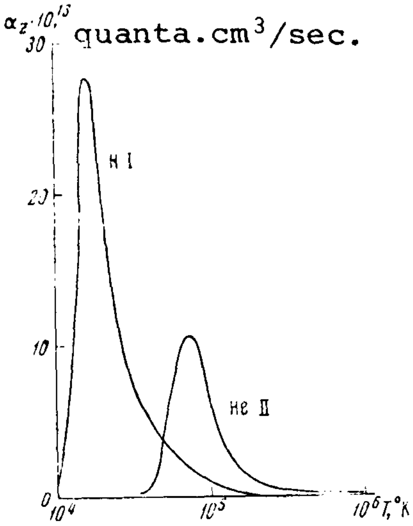

Fig.3
Number of quanta emitted in the lines L_α H I and λ 304 Å He II, calculated per one electron in the temperature function. A 10% He content is taken into account.

During the course of Universe expansion the wavelengths vary according to the law $\lambda = \lambda_0/(1 + z)$, and the density according to the law

$$n = n_0 \ (1 + 2)^3 \qquad (2)$$

where λ_0 and n_0 are wavelengths of the received radiation and the contemporary density of the gas, _z_ is the red shift. The emission in the L_α line will hit the considered 1225-1340 Å spectral range from the region where $0.01 < z < 0.1$, and that in the line λ 304 Å from the region where $3 < z < 3.4$. Assuming that within the limits of these regions, the temperature of the gas varies insignificantly we may, using formula [10] (see Appendix), find the upper limits of the density as a function of the temperature when $z \sim 0.1$ and $z \sim 3$. The corresponding curves are shown in Fig.4, a and b. When $z \sim 0.1$ it is important to examine also the case of nonstationary hydrogen ionization: upon rapid cooling, the plasma does not have time to recombine. In this case, the emission in the L_α line is determined exclusively by recombination. Fig.4, besides showing the curve of nonstationary recombination, shows the experimental data relative to the Fig.4 also observation of absorption in the 21-cm line in spectra of extra galactic radio sources [14-15]. These experiments provide information on the ratio n_H/Ts in the region $z \sim 0.1$ (n_H is the density of neutral hydrogen, Ts is the spin (temperature). According to data of Kohler and Robinson [15] $n_H/Ts = 1.1.10^{-7}$ cm^{-3}, since $Ts_{min} = 3$°K (temperature of residual radiation [13] and $n_{H\ min} = 3.10^{-7}$ cm^{-3}.

It is interesting to compare the results of background measurements in the UV spectral region with the available information on the intergalactic medium. It shows, first of all the absence of absorption in L_α in the spectrum of quasar 3C-9 [4], pointing to the low density of neutral hydrogen and by way of consequence to the high temperature of the gas when $z \sim 2$. Gunn and Peterson [4]

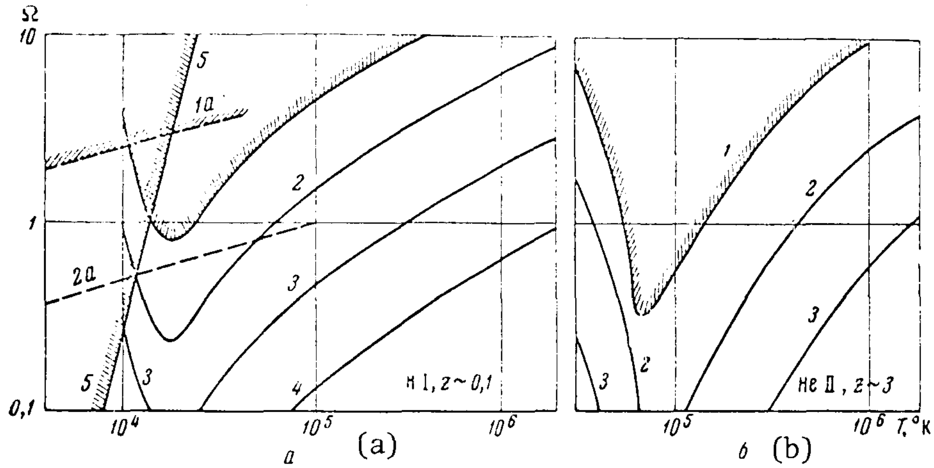

Fig.4.
Upper limit of the density of intergalactic gas a function of its temperature.

The area of densities above curve 1 is forbidden by the results of measurements [10]. The area to the left of curve 5 is forbidden by measurements in λ 21 cm, and curve 1-a gives the upper limit of Ω in the case of nonstationary gas ionization. Curves 2 and 2a, 3, 4 are plotted with the assumption that the upper limit of the UV radiation flux will be respectively reduced 10, 100, and 1000 times. a) H-I emission in the L_α-line (provides information on the region where $0.01 < z < 0.1$); b) He II emission in the line λ 304 Å (provides information on the region where $3.1 < z < 3.4$)

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have shown that $n_H < 6.10^{-11}$ cm^{-3}, which in the case when $\Omega = 1$ ($\rho = \rho cr$) corresponds to T (z = 2) > $1.2.10^6$ degrees K. Linds, Oke and Burbidgees consider that $n_H < 10^{-11}$ cm^{-3} and T (z = 2) > > 6.10^6 degrees [1,16] (precisely this value is given in Fig.5) Second, by measurements of the isotropic X-ray background in the 3-8 Å wavelengths by Field and Henry [3] have shown that this background (7 quanta/cm^2.sec.sterad) is the upper limit of the radiation of intergalactic gas and have found the upper temperature limit. Since the flow in the case of free-free transitions is equal to:

$$I_\nu \sim \Omega^2 \int_0^{z_{\max}} \frac{1}{T^{1/2}(z)} \frac{(1+z)}{\sqrt{1+\Omega z}} \exp\left[-\frac{h\nu(1+z)}{kT(z)}\right] dz, \qquad (3)$$

it is possible, knowing I_ν^{max}, to calculate the upper temperature limit for each region z. All the available experimental data are shown in Fig.5, a, b for Ω = 1 and Ω = 3. The shaded areas are prohibited by observations.

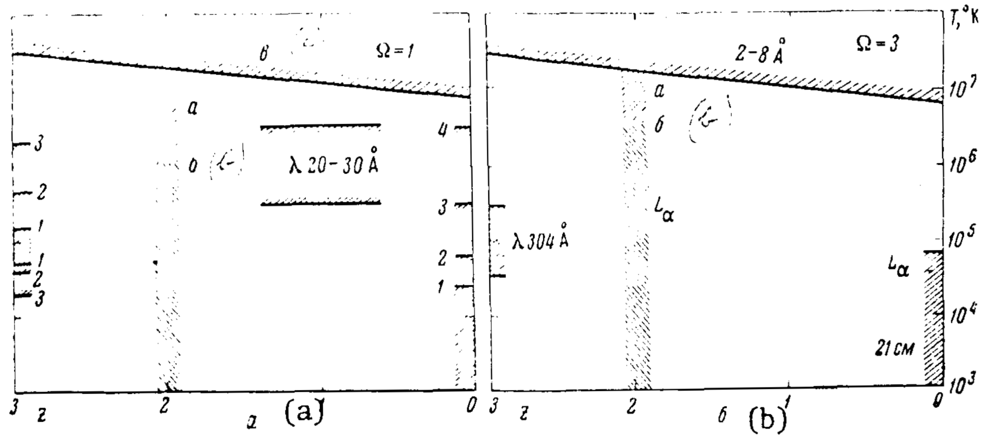

Fig.5.
Temperature areas forbidden, when Ω = 1 (a) and Ω = 3 (b), by measurements in the UV band and in the 21-cm line (region 1), in the 2-8 Å band (region c) according to line absorption in spectra of quasars with z ∿ 2 (Gunn and Peterson's estimate - region b; Burbigees, Linds and Oke's estimate - region a).

Regions 2, 3, 4 correspond to the assumptions used for plotting curves 2, 3, 4 in Fig.4. Also shown is the temperature region in which maximum information may be provided by the background measurements in the λλ 20-30 Å interval.

There is no resolved temperature region on the curve where Ω = 3 when z = 2, which excludes any density exceeding 6.10^{-29} g/cm^3. This limit is obtained with the assumption that, at z = 2, the degree of ionization of the gas is determined by the electron temperature. No known UV radiation sources of any kind (quasars, quasi-galaxies, radiogalaxies, etc.) can ensure such a high degree of ionization, even if their evolution is taken into account according to Longair [17].

3. PROSPECTS OF FURTHER OBSERVATIONS OF THE RADIATION OF INTERGALACTIC GAS.

The examination of Fig.5 shows that experiments yielding information on high-temperature plasma ($3.10^4 < T < 7.10^6$ degrees K) are of fundamental importance. Under these conditions, free-free transitions represent the principal mechanism of radiation. This radiation can be observed both in the UV and in the X-ray regions of the spectrum.

In addition to this mechanism, a certain contribution is made in the UV region by emission in the lines L_α (z ∿ 0.1) and He II (λ 304 Å) (z ∿ 3). L_α-quanta can be excluded in observations with λ < 1216 Å. The He II radiation cannot be separated in this manner. Let us note, by the way, that our galaxy becomes totally opaque for wavelengths shorter than 912 Å (a table showing the optical thickness in the X-ray region will be given later in this article). Observations in the UV spectral region make it possible to narrow down considerably the interval of permissible temperatures when z ∿ 0.1 and z ∿ 3, and these conclusions are practically independent of the mode of function T(z). The permissible temperature range, obtained at a fixed value of Ω for three values (see Note 1) of z, allows us to judge, although rather approximately, about the nature of T(z) variation. By drawing upon additional theoretical considerations in regard to the course of cooling with expansion [18,2] it is possible to define more precisely the mode of the function in the interval where z < 3, T(z). Study of the emission in a continuous spectrum, both in the X-ray and UV spectral regions, allows us to determine Ω, and also the value of $z = z_{max}$ at which heating of the gas took place [19] (see Note 2). At the same time, an additional control will be realized of the correctness of the selection of T(z).

Let us demonstrate this by a simple example: let the temperature vary according to the law $T = T_0(1 + z)$. Then, formula (2) will take the form:

$$I_\nu = 7\cdot 10^{-21}\frac{\Omega^2}{T_0^{1/2}}\exp\left(-\frac{h\nu_0}{kT_0}\right)\int_0^{z_{max}}\sqrt{\frac{1+z}{1+\Omega z}}\,dz \quad \text{erg/cm}^2\text{.sec.sterad.hz.} \qquad (4)$$

Knowledge of the flux in three different spectral intervals is necessary to determine the three parameters defininf I_ν. In fact, it is experimentably possible to measure the flux in the following four wavelenght ranges: 1050-1340 Å, 44-60 Å, 15-20 Å and 2-8 Å, and also in the radio frequency range (in the optical region of the spectrum, the background is determined by the aggregate stellar radiation). The availability of data in two additional spectral intervals offers the hope of a possible unambiquous determination of Ω, z_{max} and of the mode of T(z).

The results of measurements in any one of the above-mentioned

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Note 1. This range can be significantly reduced as a result of observations of the L_α absorption line in the spectrum of quasar 3C-237 (z ∿ 0.16) (see below)

Note 2. Additional information on z_{max} and T(z) is provided by observations of the isotropic radio background on 100-1000 Mc. In [A] it is shown that z_{max} < 300.

spectral intervals bear a significant information: obviously (see formula (3) and (4)), in the region where $h_\nu > kT$, I_ν is not sensitive to Ω variation and it greatly depends on the mode of $T(z)$, whereas for $h_\nu < kT$ (UV and radio frequency range) the dependence on Ω and z_{max} is great.

Consideration of experimental possibilities shows that even the present state of the available instrumentation is fully adequate to cope with the problems formulated.

a). X-ray region. In the 2-8 Å region it is necessary to separate the background associated with unresolved, weak, extra galactic sources of X-ray radiation. Unfortunately, no measurements are available in the 15-20 Å region. It would be extremely important to know the upper limit of radiation in this range. Of interest also are fluxes ranging from $6 \cdot 10^{-2}$ to 60 quanta/cm^2 sec. sterad. In the 44-60 Å region, absorption in the Galaxy and in the local group becomes important. An estimate of the absorption based on the knowledge of the number of atoms in the column and the chemical composition [20,21] allows us to compute the optical thickness, τ, for various wavelengths, equal to $\sigma n l$, where $nl = 6 \cdot 10^{-26}$ cm^{-2} hydrogen atoms (see Table 1).

Table 1.

λ, Å	15	20	30	40	50	60
τ	0,20	0,40	0,70	1,85	2,80	5,40
I/I_0	0,82	0,68	0,48	0,15	0,06	0,005

The integral radiation flux with a plane spectrum in the 44-60 Å region will be weakened 20 times. Measurements in this range with the threshold response of $1\text{-}10^2$ quanta/cm^2.sec.sterad are of interest, but this requires some improvement of the instrumentation.

b). Radio Frequency Band. In order to determine the plane component it is necessary to perform in this band a careful analysis of the background emission in the frequencies of 600-1000 Mc. As is well known, the mean spectral index of radiogalaxies is $L_\alpha = 0.80$ ($I_\nu \sim \nu^{-\alpha}$). A realistic method is the separation of the metagalctic component analogous with the work done by Briddle [17,22] and the deduction there from the total contribution made by radio sources and the relict radiation [22,19].

c). The UV Portion of the Spectrum. In the λλ1000-1500 Å range the sensitivity may be substantially increased. It is shown in Section 5 of this paper that the isotropic background, not associated with radiation from the intergalactic medium, does not exceed 10^{-10} erg/cm^2.sec.sterad. The stellar background can be eli-

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Note. Measurements by S. L. Mandel'shtam and I. P. Tindo (Doklady AN SSSR - in print) have shown that the background in the 8-14 Å region does not exceed 5 quanta/cm^2.sec.sterad).

minated in observations with instruments having a small field of vision ($\sim$ 0°.1) (see Section 4). Thus, the limit of background measurements in the UV region is defined only by instrumental possibilities.

A small field of vision, while retaining the significance of the geometric factor, can be easily obtained with the aid of optics. Naturally, it is necessary in this case to realize a constant orientation of the instrument on the time during which sufficient information will be obtained. The background of charged particles can be substantially lowered by using anticoincidence schemes between the photon counter and the scintillation detector of charged particles.

The background of scattered L_α-emission can be reduced to the desired extent by increasing the thickness of the calcium fluoride filter. The filter 1 mm thick, used in the λ 1216 Å, had a transmission of less than 0.1 %. The available photon counters allow the overlapping of the following spectral regions: 1225-1340, 1225-1550, 1450-1550 Å. In principle, it is possible to design a counter responding in the 1050-1200 Å region. By using such counters together with a medium-sized telescope ($\sim$ 10 cm), it is possible to obtain information from regions with different z values, and also to separate the emissions in the L_α and He II λ 304 Å lines.

d). <u>Spectrophotometry of Quasar 3C-237 in the UV Spectral Region</u>. It was already mentioned previously that it is possible, in principle, to determine the content of neutral hydrogen by the absorption in the L_α-line of the spectrum of the nearest quasar 3C-237($z = 0.159$, $m = 13^m$). For z=2(quasar 3C-9) this method was proposed by Gunn and Peterson [4]. Observations were performed by methods of ground astronomy, for in this quasar the L_α-line is shifted into the optical region. The spectrum of quasars 3C-273 can be obtained only with the aid of a telescope transported beyond the limits of the Earth's atmosphere.

The UV spectra of stars [23,25] brighter than $3^m.5$, obtained at the present time, make it possible to determine the approximate parameters of the telescope capable of solving this extremely difficult (from an experimental standpoint) problem. Of course, the use of a slit photoelectric spectrometer is obviously preferable. The flux of $\sim$ 0.03 quanta/cm^2.sec. Å will require in this case a telescope with a mirror of $\sim$ 20 cm diameter. Such a high magnitude of the flux in the OV region of the spectrum for an object of 13^m is associated with an almost plane spectrum (in frequency scale) for quasars. This fact is confirmed with sufficient reliability by observations of the optical spectra of weaker quasars with z $\sim$ 2 [26,27].

When $\Delta\lambda \sim 200$ Å, a spectral resolution of ~ 10 Å would be quite acceptable. If the spectral resolution were made equal to about 1 Å, the observations of the absorption line profile ine quasar 3C-273 would have provided the possibility of determining the neutral hydrogen content in the Coma Virgo Galaxy clusters located at a distance of 12 Mpc from us, which corresponds to a Doppler shift of 5 Å. A resolution of ~ 10 Å will not require a guidance of the telescope on the object with $m = 13^m$ during a period of time of about 200 sec. It would be quite satisfactory if a slitless photographic spectrogram could be obtained during the same time period, with a stabilization of the telescope in an approximately given direction, as was done in the experiments described in[24,25]. It can be expected that in the UV spectral region quasar 3C-273 is an abnormally bright object for high galactic latitudes. The plane spectrum of quasars, yielding a powerful flux in the UV spectral region, allows us to use relatively modest optical means for narrow-band photometry ($\Delta\lambda \sim 100$ Å). Even such a resolution is quite sufficient provided the content of neutral hydrogen exceeds 10^{-10} atoms/cm^3. In this case, quasar radiation in the $\lambda\lambda$1225-1340 Å region will simply be absent. Such observations can be effected by means of a telescope with a diameter of ~ 20 cm and a time constant of ~ 100 sec. Apparently, the results obtained by Kohler [15] can be checked in such a manner.

The upper limit of neutral hydrogen concentration that can be detected is found from the relation

$$\tau_\alpha = \frac{n_H(1+z)^2}{\sqrt{1+\Omega z}}\left(\frac{\pi e^2 f}{m\nu_\alpha}\right)\frac{1}{H_0} = \frac{5\cdot 10^{10}(1+z)^2 n_H}{\sqrt{1+\Omega z}}, \tag{5}$$

where H_0 is Hubble's constant and e, m, f are the charge, the mass of the electron and the oscillator strenght for the transition 1S - 2P. For the minimum detectable concentration we shall obtain a value of $\sim 6.10^{-12}$ cm^{-3}.

Absroption in the spectrum of quasar 3C-273 can be estimated by using two counters in the range $1050 < \lambda < 1200$ Å and $1225 < \lambda < 1400$ Å. Radiation in the first spectral range is not absorbed either by intergalactic or interstellar gas, and in the second spectral range the flow will be 150 times smaller than the expected flow of $n_H = 10^{-10}$ ($\tau \sim 5$). This experiment requires that the telescope be aimed (pointed) at quasar 3C-273. The neutral hydrogen concentration found in this manner makes it possible to calculate the temperature of the gas for any value of the density. The study of the UV spectrum of a quasar offers greater advantages in comparison with the method of studying absorption on the 21-cm wave (sensitivity threshold $\sim 10^{-7}$ atoms/cm^3 [14,15]). In addition, here it is not necessary to make use of the extremely poorly known value of the spin temperature.

Such observations will make it possible to detect density and temperature inhomogeneities and also to establish the depencence T(z) when $z < 0.16$. When compared with data on 3C-9, the absence of absorption in the spectrum of quasar 3C-273, will point to the absence of neutral hydrogen when $z < 2$, and this opens up possibilities for studying spectra of quasars with $z \sim 2$ in the UV region ($\lambda = \lambda_0/(1 + 2) \sim 400$ Å). This radiation can be absorbed only in the λ584 Å line of neutral helium.

e). Observations of Gas in Galaxy Clusters. The gas present in such clusters can contribute significantly to the average density of matter in the Metagalaxy. It is generally accepted [28] that the mass of galaxies making up the cluster is not sufficient for its equilibrium at a certain distribution of velocities of individual galaxies. Calculations show that the presence of gas with an average density of $10^{-2} - 10^{-4}$ atoms/cm^3 is sufficient to stabilize the cluster. At the same time, this gas can make a significant contribution to the average density of matter in the Universe,

Bahcall and Salpeter [29,30] have called attention to the fact that the gas in galaxy can lead to the formation of absorption lines in the spectra of remote quasars. Such lines have been found for quasars 3C-9, PKS 1116 + 12, and 1021 [31,38]. Observations of lines of elements present in a high stage of ionization simultaneously with the L_α-line point to high temperature of the gas ($\sim 5.10^5$ deg. K) at a density of $\sim 10^{-3}$ cm^{-3}. However, since heavy elements must be absent [1] in "primary" matter not having undergone a "reprocessing" in stars, this method cannot be effective (Note). At the same time, the hot model of the Universe predicts a 10% helium content (based on the number of atoms). Unfortunately, the He spectrum does not show resonance lines in the visible and near-UV spectral regions. The presence of the metastable level 2^3S (lifetime $\sim$ 105 sec) affords the hope that it will be possible to observe the lines $\lambda\lambda$10830 and 3880 Å in the absorption. Also of interest are observations of the lines $\lambda\lambda$3889, 7086 and 5876 Å in the emission of galactic clusters gas [11]. Calculations of the thermal balance of gas in clusters [18] show that the following 3 temperature ranges are the most likely ones: $T < 10^4$ deg.K; $2.5.10^4 < T < 5.5.10^4$ deg.K and $T > 3.10^5$ deg. K. Observations in the 21-cm line afford the only possibility for the

Note. A certain number of heavy-element atoms could have been formed during explosions of parent (ancestor) stars and as a result of ejection from galaxies.

first temperature range, in the same way as was shown in [15]. The maximum luminescence of the helium line lies precisely in the second temperature range, whereas for remote clusters absorption lines of heavy-element ions can be observed in the third temperature range. But if the temperature is greater than 10^6 deg. K, the observations of X-ray radiation appear to be most promising. Thus, for example, X-ray radiation from a cluster in the Coma Berenica constellation was detected in the region $E \approx 25$ kev [34,35]. Friedman's observations [36] in the 1-10 Å region failed to disclose a source with an upper flux limit of 0.4 quanta/cm^2.sec. It seems to us that these observations can be matched when $T > 3.10^8$ deg. K, $n \sim 10^{-3}$ cm^{-3}, and cluster dimensions $l \sim 3$ Mpc [26]. For the case of an extended cluster, the flux is calculated by using the formula:

$$I_\nu = \frac{6{,}4 \cdot 10^{-39}}{T^{1/2}} n_e^2 l \exp\left(-\frac{h\nu}{kT}\right) \text{ erg/cm}^2\text{.sec.ster.hz} \tag{6}$$

From 10^4 to 10^5 deg. K, there are some prospects for observations of gas in galactic clusters in the L_α-line, displaced by the cosmological red shift if only by 10 Å. This shift is sufficient to eliminate the background of scattered L_α-emission in the interplanetary medium. Such a shift is exhibited by clusters located at a distance greater than R = 25 Mpc:

$$R = \left(\frac{c}{H}\right)\left(\frac{\Delta\lambda}{\lambda}\right). \tag{7}$$

The flow recorded by an instrument with a field of vision substantially smaller than the dimensions of the clusters is found by the formula

$$F = \frac{1}{4\pi} \varphi(T) n_e^2 l h\nu \text{ erg/cm}^2\text{.sec.ster.} \tag{8}$$

where $\phi(T)$ is the volume luminosity divided by the square of the density, shown in Fig.3. In the 10^4 - 10^5 deg. K range, the instrumentation available makes it possible to record such a radiation with a field of vision of 1°. (Note). By narrowing down the spectral range it is possible to increase the sensitivity of the recording instruments.

Note. The dimensions of numerous clusturs constitute $\sim 0.5°$.

4. STELLAR COMPONENT OF THE BACKGROUND IN THE UV REGION. ABSORPTION IN THE INTERSTELLAR MEDIUM.

To calculate the background associated with the aggregate radiation, 18 Captine (kapteyn) squares (areas, sections) were selected at high galactic latitudes with b > 60° and 18 squares (areas, sections) with b < 10° [37].

Each square had a size of 12.5 square degrees and contained all stars up to $12^m.0$. Apparently, the count up to $12^m.5$ was already incomplete. All stars of spectral classes from BO to G9 were divided into 8 groups. For each group of stars, within the interval of stellar magnitudes from (m + 1/2) to (m - 1/2), the emission flux at the boundary of the Earth's atmosphere was calculated near 5400 Å

$$\lg f_\lambda(pg) = -0{,}4 m_{pg} - 8{,}40, \qquad (9)$$

where $f\lambda$ is expressed in $erg/cm^2.sec.Å$. This relation is valid for a wide range of spectral classes. Then, using the scale of effective temperatures, a correction was introduced allowing the calculation of $f\lambda$ (λ = 5560 Å). References [38,39] give data on the UV radiation of bright stars of early spectral classes. These data were obtained with the aid of rocket photometric measurements with photon counters, analogous to those used in our experiment for the effective wavelenghts λ1314 Å and λ1370 Å. The above references give the relationship of $f(\lambda_{eff})$ as a function of spectral class for stars from O5 to A0. By adding to these data the value for the sun, we shall obtain a curve from which the flux near λ1300 can be found from the stellar magnitude and the spectral class (Figure 6). To calculate the flux of solar UV radiation in the 1225-1340 Å band we used the data given in [40]. The following emission lines lie in this region: N V $\lambda\lambda$1238.8; 1242.8 Å; Si II $\lambda\lambda$1260.7 and 1265.0 Å, the triplet O I $\lambda\lambda$1302.2; 1304.7 and 1306.0 Å; C II $\lambda\lambda$1334.5 and 1335.7 Å. The total intensity of the lines is 0.2 $erg/cm^2.sec$, which amounts to 2.10^{-3} $erg/cm^2.sec.Å$, while the ratio of $f\lambda$ (1300 Å) to $f\lambda$ (5460 Å) is equal to 10^{-5}. It is true that there remains the purely hypothetical pssibility of anomalous UV emission from stars of late spectral classes; however, the absence in the list [39] of stars of spectral classes later than A0 apparently excludes this possibility. Indeed, for a star with $m_{pg} = 0^m$, $f\lambda$ (5400) = 4.10^{-9} $erg/cm^2.sec.$ Å. According to data of [39] the limit detectable flux, is equal to 10^{-10} $erg/cm^2.sec.$ Å, which makes it possible to exclude the region where $f\lambda$ (1370) $f\lambda$ (5560) > $2.5.10^{-2}$ for all spectral classes later than F0. We shall return once more to this problem later in this article.

The intensity of the stellar background can be obtained by adding up the radiation for all ranges of stellar magnitudes and spectral classes. Let us now consider the role of interstellar absorption.

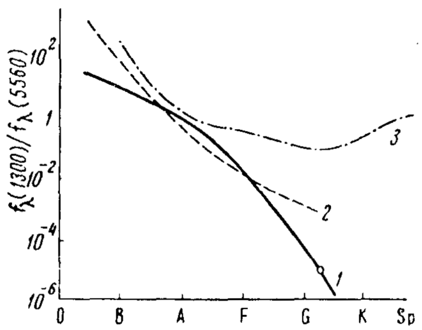

Fig.6.

Ratio of emission fluxes as a function of spectral class for λ1300 Å and λ5560 Å.

1. According to data in [38] for stars O, B, and A.
⊙. Value of f_λ (1300)/f_λ (5560) calculated for the Sun from data given in [40].
2. Absolutely black body at a temperature equal to T_{eff}
3. Upper limit of the ration f_λ (1300)/f_λ (5560) from measurements taken by AIS "Venera-3" for high galactic (b > 60°) latitude.

Absorption on neutral hydrogen in the wings of the L_α-line is determined at T = 100° K by attenuation for $\Delta\lambda > 3\ \Delta\lambda_D$, where $\Delta\lambda_D$ is the width of the Doppler line. In this case the optical mass is found by the formula

$$\tau = \frac{\pi e^2}{4\pi m_e c^3 (\lambda - \lambda_\alpha)^2} f_{2p1S} A_{2p1S} \lambda^4 n_H l. \tag{10}$$

For a ray of vision perpendicular to the plane of the Galaxy, τ = 0.1 for Δλ = 3 Å, which corresponds to λ1219 Å. For the threshold response of the counter described in Section 1 of this article, τ = 0.01.

Absorption by elements with an ionization potential lower than 10.2 ev is insignificant for the abundance of such elements is small [41]. For an ionization cross-section of 6.10^{-18} cm² in the direction of the pole of the Galaxy τ ∿ 0.4 and a total abundance of 10^{-4}, τ ∿ 0.4 in the direction of the pole of the galaxy. The interstellar dust plays a basic role in the absorption. For the absorption on dust in the visible spectral region we shall assume that the absorption in the galactic plane for b < 10°, is $A_{pg} = 2^m.0$ per kpc. and during observation at the pole of the Galaxy the absorption in the photographic spectral region is $\Delta m_{pg} = 0^m.30$.

For the transition to the λ1300 Å wavelength region, we shall assume, according to [42], that the absorption is equal to $5^m.5$ kpc^{-1} in the galactic plane and $0^m.80$ during observations at the pole of the Galaxy. The latter value gives a two-fold attenuation of the flux, fact that was taken into consideration when calculating the upper boundary of background intensity.

As a result of absorption in the galactic plane, stars with high values of m_{pg} in the UV region become invisible starting at distances of approximately 1-2 kpc. The data used for the accounting of the absorption are compiled in Table 2.

TABLE 2

m_{pg}	Spectral class											
	O5			B0			A0			F0		
	r,	Δm	lg I_0/I	r, пс	Δm	lg I_0/I	r, пс	Δm	lg I_0/I	r, пс	Δm	lg I_0/I
6	$1,6 \cdot 10^3$	8,8	3,53	$0,7 \cdot 10^3$	3,8	1,52	$1,2 \cdot 10^2$	0,66	0,26	40	0,22	0,09
7	2,5	13,8	5,53	1,1	6,0	2,40	1,9	1,04	0,42	63	0,35	0,14
8	4,0	22	8,80	1,7	9,4	3,76	3,0	1,65	0,66	10^2	0,55	0,22
9	6,3	35	14	2,8	15,4	6,16	4,8	2,63	1,05	$1,6 \cdot 10^2$	0,88	0,35
10	10	55	22	4,4	24,2	9,70	7,6	4,17	1,68	$2,5 \cdot 10^2$	1,38	0,55
11	16	88	35	6,9	38,0	15,20	12	6,60	2,64	$4,0 \cdot 10^2$	2,20	0,88

Since stars of earlier spectral classes have a smaller absolute stellar magnitude, they are observed from greater distances at a fixed visible stellar magnitude. An examination of the data given in Table 2 shows that the radiation of stars of spectral classes O5, B0, A0 and F0 is, on the average, attenuated 100 times for visible stellar magnitudes of respectively 5^m, $6^m.7$, $10^m.5$ and $13^m.5$. Since we observe stars only from distances closer than 1 kpc, this fact determines the contribution to the sky background made by stars of different spectral classes. Figure 7 shows the integral dependence of sky brightness in orbitrary units as a function of visible stellar magnitude for the UV and the visible region of the spectrum. The fact that the sky background is determined by stars brighter than $7-8^m$ causes strong background fluctuations when the field of vision is sufficiently small.

Table 3 lists the number of stars of early spectral classes per square degree for high galactic latitudes.

For regions close to the plane of the Galaxy the number of stars per square degree is, naturally, greater, especially for early spectral classes; however, this number is greatly compensated by the effect of interstellar absorption. On the average, for the squares (areas) selected, the stellar background is equal to 10^{-24} $w/m^2.hz.sterad$. At the same time, for high galac-

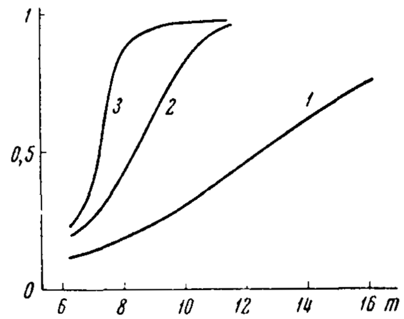

Fig.7.

Brightness of the sky in arbitrary units as a function of visible stellar magnitude.

1). In the visible region of the spectrum.
2). For λ1300 Å without consideration of absorption by interstellar dust;
3). Taking into account the absorption.

tic latitudes, 99% of the background is determined by ∿ 10^3 stars per steradian of spectral classes earlier than F5 and of visible stellar magnitudes brighter than 9^m. By selecting a field of vision of the instruments smaller than 1 square degree, the background can be lowered to 3.10^{-27} w/m^2.hz.sterad. At the same time, the time constant of the instrument and the scanning rate must ensure the recording of a solitary star brighter than 9^m. One star of spectral class A0, and 10^m stellar magnitudes which happens to be within the field of vision of the instrument, corresponds to a background of $1.3.10^{-25}$ w/m^2.hz.sterad (precisely such a situation can be expected to occur during the overwhelming time of operation of instruments with a 1 sq. degree visual field). If, on the other hand, the field of vision is reduced to 0°.3 X 0°.3, then the probability of the presence of a star of spectral class earlier than F5 becomes ∿ 1/2 up to $13\text{-}14^m$. At high galactic latitudes, the number of stars of early spectral classes and weaker than $13\text{-}14^m$ is extremely small.

Table 3.

m	Spectral Class		
	A0	F0	G0
0—8,5	0,08	0,13	0,14
9	0,05	0,11	0,41
10	0,06	0,30	1,09
11	0,11	0,22	2,93
12	0,15	0,28	7,20

The above-mentioned value of the background of $\sim 10^{-27} - 10^{-26}$ w/m^2.hz.sterad is a very optimistic one and permits to hope that substantial progress will be made in improving the instrumentation. Integral measurements make it possible to estimate the maximum possible contribution on the part of classes later than A0, which were not recorded in [38,39]. Figure 6 shows the upper limit of the ratio f_λ (1300 Å)/f_λ (5560 Å), starting from the results of the estimate of the upper boundary of the UV background made in Section 1 of this article.

5. ISOTROPIC UV BACKGROUND.

a). Background from Extragalactic Nebulae. Data on the background of the sky in the visible region of the spectrum from extragalactic nebulae, given in [43], show that this background is lesser by two orders than the stellar background of our Galaxy and is equal to 0.5 of a 10^m star from a square degree. Let us estimate the contribution made by extragalactic nebulae to the UV region (λ1300 Å) of the spectrum. All of the radiation of wavelength $\lambda < 912$ Å is reprocessed on interstellar hydrogen and converted into quanta of the L_α-line, which in their turn "perish" when absorbed by interstellar dust. For a great optical thickness the attenuation is approximately determined by the factor $\exp - \{\sqrt{3(1 - \Lambda)}\tau\}$ where $(1 - \Lambda)$ is the albedo of a single scattering act τ is the optical thickness of resonance scattering of hydrogen; for the Galaxy we have $(1 - \Lambda) \sim 10^{-8}$ and the radiation is greatly attenuated when $\tau > 10^4$, which corresponds at the center of the line to a distance $r < 0.1$ nc.

The optical thickness of our Galaxy in a direction perpendicular to its plane is greater than 4.10^8. It is obvious that the line will be attenuated hundreds of times At the same time, the stellar radiation in the region $\lambda < 912$ Å does not exceed the radiation in the λ1225-1340 Å band (Note). This is why, further in this article we shall not take into account the emission in the L_α-line, to which, by the way, only galaxies with $z < 0.1$ contribute. The radiation of stars in the wavelength range of 1100 to 912 Å is absorbed by interstellar carbon of which the ionization potential is equal to 11.264 ev while its abundance is $3.7.10^{-4}$ as compared to hydrogen. The optical thickness for carbon atoms in our Galaxy is about 2.5 in the direction of the galactic pole. Since, as a rule, hot stars are found in regions where interstellar gas accumulates, we can assume that radiation for $\lambda < 1100$ Å is attenuated by at least 10 times. (In those galaxies where little gas is found there are, as a rule, no hot stars either; in addition,

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Note. This fact is confirmed by observations of emission in the H_α-line from other galaxies.

hot stars are concentrated in the plane of galaxies, in spiral arms). Absorption on interstellar dust further reduces the flux two-fold.

The averaged stellar radiation is sharply reduced for wavelengths shorter than λ1100 Å, and this fact, combined with what has been said above, makes it possible to also disregard this spectral range (which corresponds to the band $0.14 < z < 0.47$ in case of emission registration in the 1225-1340 Å band.

Let us now pass to the examination of the wavelength λλ1100-1340 Å. A repetition of the calculations of the total stellar radiation, performed by Lambrecht and Zimmerman in 1954 [44], while taking into account experimental data on the radiation flux of stars of different spectral classes at λλ1314 Å (see Fig.6), has shown that it does not exceed 2.4 instead of 5.9 in [44] even for low galactic latitudes f_λ (1300)/f_λ (5560). This is linked with the fact that the flux from hot stars of spectral classes O and B, measured in the UV region, is considerably lesser than that obtained by calculations using the adopted effective temperatures. A ratio of f_λ (1300)/f_λ (5560) ∿ 0.5 was adopted in [44] for high galactic latitudes. Since the integral spectra of galaxies have been studied up to λλ3300 Å, the upper limit of the unknown quantity f_λ (1300) can be obtained on the basis of the measured values of f_λ (3300) for galaxies of different types and on the basis of the maximum possible ratio f_λ (1300)/f_λ (3300) taken for low galactic latitudes. The scale of color temperatures for stars in the region λλ3300-5560 Å agrees sufficiently welly well with the spectra, and f_λ (3300)/f_λ (5560) can be easily calculated. To summarize, the maximum possible ratio f_λ (1300)/f_λ (3300) is equal to 1.35; f_ν (1300)/f_ν (3300) = 1.35 $(1300/3300)^2$ = 0.2. In these calculations we used the luminosity function of stars in the vicinity of the Sun; this function is clearly overrated in the region of stars of early spectral classes as a result of the position of the Sun in the galactic plane.

To calculate the magnitude of f_ν (1300) the following data given in Table 4 were used: the percentage of the total number of

Table 4

Type of Galaxy	E	S0	Sa	½Sb	½ Sb	Sc	Sd	Sm	Im
%	22	18	12	7	8	19	8	3	3
Sp	K0				G5	F5	A5		
M_{pg}	−14	−16	−18	−19	−19	−17	−16	−16	−15
T_s, °K	5400				6000	7600	11000		
$\frac{f_\nu (3300)}{f_\nu (5560)}$	0,27				0,33	0,50	0,85		

galaxies, the integral spectral class, the mean absolute stellar magnitude, the color temperature, and the ratio f_ν (3300)/f_ν (5560). We finally obtain for the maximum possible ratio f_ν (1300)/f_ν (5560) = $6.6.10^{-2}$. For λ < 1300 Å, the ratio of the flux in the UV region to that at λ5560 Å drops sharply as a result of both the reduced number of hotter stars and the relative lowering in the UV region of the effective temperature of stars of spectral classes O and B (see Fig.6). Even if we assume tha f_ν (1100 < λ < 1300) = = const, the background from galaxies in the UV region $\lambda\lambda$1225-1340 Å will be less than $6.6.10^{2}.10^{-23}$ abw/m^2.hz.sterad, where F_ν (5560) = = 10^{-23} w/m^2.hz.sterad [43], a = 1/4 and characterizes the absorption on dust in our Galaxy and in radiating galaxy, b < 1/3 is a coefficient which takes into account that at 5560 Å galaxies radiate at least up to z = 0.46, whereas in the range 1225-1340 Å a full contribution is made only by galaxies with z < 0.13 and a partial contribution by galaxies with z < 0.22. Hence, in the range examined here we shall obtain for f_ν an overrated estimate of 5.10^{-26} w/m^2.hz. sterad. Obviously, a more careful analysis, taking into account the avalanche in the integral spectra of galaxies when λ <1300 and the fact that the value of f_ν (1300)/f_ν (3300) for the galaxies is much smaller than the one assumed by us, will make it possible to considerably lower the estimate obtained above (at least down to 10^{27} w/m^2.hz.sterad).

b). <u>Luminescence of the Interplanetary Medium.</u> Solar radiation in the UV spectral region may be the cause of formation of a practically isotropic background as a result of resonance scattering on the ions and atoms of the interplanetary medium. Table 5 lists the strongest lines in the spectral region of interest to us.

Table 5.

λ, Å	Ион ion	1.10 ^{3} erg/cm^2 sec	λ, Å	Ион ion	1.10 ^{3} erg/cm^2.s
1238,8	N V	4	1302,2	O I	13
1242,8		3	1304,7		20
			1306,0		25
1260,7	Si II	10	1334,5	C II	50
1265,0		20	1335,7		50

The continuous background in this spectral range is ∿ 3.10^{-4} erg/cm^2.sec.Å. All the lines shown in the table are formed in the chromosphere or in the transition region. Since the interplanetary medium consists of matter ejected from the solar corona, their chemical and ionization compositions must be identical. For a temperature of the solar corona of (1 - 2).10^6deg. K, Si II, C II, and O I ions will be completely absent. Even the concentration of the N V ion does not exceed 10^{-6} of the total nitrogen concentration [45]. The recombination in the solar wind when moving from the

Sun towards the Earth cannot substantially increase this estimate. Indeed

$$\frac{\Delta n_i}{n_{i+1}} = \alpha_t n_e \frac{R_0}{v}, \qquad (11)$$

where n_i is the concentration of the i-th ion, α_t is the recombination coefficient, R_0 is the astronomical unit, and v is the solar wind velocity.

Assuming that $\alpha_t \sim 3.10^{-13}$cm^3/sec, $n_e \sim 10$ cm^{-3}, and $v \sim 4.10^7$ cm/sec, we find that the role of recombination is negligibly small. Let us find the flux of quanta reradiated in the N V lines,

$$I = \frac{1}{4\pi} \int\limits_{R_0}^{\infty} F(R) n_i(R) \sigma_0 k_\lambda \, dR, \qquad (12)$$

where F(R) is the flux in lines at the distance R; n_i is the density of N V ions in the solar wind; σ_0 is the cross-section of resonant scattering; k_λ is a factor taking into account the drift of the line into the wing caused by the motion of ions in the solar wind. Formula (12) will then take the form:

$$I = \frac{1}{12\pi} F(R_0) n_i(R_0) \sigma R_0 k_\lambda. \qquad (13)$$

The width of the chromospheric lines $\Delta\lambda_{chr}$ does not exceed 0.1 Å, and the shift is $\Delta\lambda \sim 1.5$ Å. Hence it is clear that the factor $k_\lambda \sim 10^{-3}$. For the N V lines $I < 10^{-17}$ erg/cm^2.sec.sterad.

Since the ions absorb the radiation only in the distant wings of lines ($\Delta\lambda > 15\Delta\lambda_D$), it is necessary to take into account the reradiation in the continuous spectrum, the intensity of which is $\Phi = 3.10^{4}$ erg/cm^2.sec.Å.

$$I = \frac{1}{12\pi} \Phi_\lambda(R_0) n_i(R_0) \sigma R_0 \Delta\lambda_D. \qquad (14)$$

For the nitrogen line $\Delta\lambda_D \sim 2$ Å and $I \sim 4.10^{-15}$ erg/cm^2.sec. sterad. The available reserve of $\sim 10^7$ times show that a background of interplanetary origin does not limit the experimentl possibilites (Note)

Note. It is obvious that the intensity of zodiacal light in the λ1300 Å region does not exceed 10^{-27} w/m^2.hz.sterad.

c). Radiation of the Intergalactic Medium in the Lines of Heavy Elements. The hot model predicts the absence of heavy ($z \sim 2$) elements in primary, prestellar matter. These elements could have appeared as a result of ejection from galaxies. The quantity of heavy elements can be estimated on the basis of data on the explosion in galaxy M 82 (NGC 3034), where the ejection mass is $\sim 10^{-5}$ to 10^{-4} of the galaxy mass and the ejection velocity is $\sim$ 1000 km/sec [46]. At the critical density of the intergalactic medium, 1/30 of all matter is concentrated in the glaxies. Assuming that each galaxy ejects the same mass as does M 82 we arrive at the conclusion that the content of heavy elements in the intergalactic medium will be $\sim 10^6$ times less than in the galaxies, that is, $\sim 2.10^{-8}$ (according to the number of atoms). Obviously, in order to obtain an equal content in heavy elements it is necessary to ensure explosions in galaxies every 10^4 years, which clearly contradicts the data obtained from observations.

It is possible to assume that the enrichment of the intergalactic medium with heavy elements took place during explosions (bursts) of parent (ancestor) stars [47]; however, observations of absorption in quasar spectra [31-33] show that the abundance of heavy elements in the intergalactic medium does not exceed 10^{-1} to 10^{-2} of their content in our own Galaxy. Such an abundance of heavy elements cannot ensure the upper limit of the UV radiation background at all permissible temperature values. A further increase in the sinsitivity of the instruments will allow the lowering of this estimate also.

6. METAGALACTIC COSMIC RAYS.

The discovery of Planck's relict radiation has made it possible to obtain a considerable amount of information on metagalactic cosmic rays [48], but this concerns mainly the election component on which the inverse Compton effect is responsible for the X-ray background. As a result of Compton losses, the electrons rapidly lose their energy.

The emission of energetic quanta by cosmic rays (by the proton component) takes place only during interaction with intergalactic gas. But if the temperature of the gas is high, its proper radiation is considerably greater than the X-ray radiation during scattering of cosmic protons on electrons of the intergalactic medium and also greater than the UV radiation arising as a result of ionization losses.

A study of the properties of intergalactic gas will make it possible to also learn a great deal about cosmic rays. By knowing the thermal history of the gas we can determine the upper limit of the energy density of nonrelativistic cosmic rays (the heating by relativistic cosmic rays is negligibly small). In addition, there is a basic possibility (knowing the thermal history of the gas and, therefore, also the variation in the energy liberation of relict cosmic rays during the expansion of the Universe) of clarifying the problem concerning the time at which metagalactic cosmic rays originated and obtaining some information on their spectrum.

CONCLUSION

The above analysis shows that the prospects of an experimental investigation of the intergalactic medium are quite encouraging. All the methods examined are based on an analysis of observations of the isotropic metagalactic background. Combined UV, X-ray and radioastronomical measurements will make it possible to obtain the basic parameters of the intergalactic medium, and consequently, to make an estimate of the average density of matter in the Universe. Very important also are theoretical calculations of the cooling process of the intergalactic medium, estimates of the heating by various sources and the evolution of this heating process. Some information can be obtained from the analysis of statistical counts of radio sources.

A successful solution of such a difficult problem can be obtained only as a result of a complex study of the background in different ranges extending from the X-ray to the radio frequency bands. Also important are stellar and astronomical calculations carried out up to $12\text{-}15^m$ at high galactic latitudes, and investigations of light-blue galaxies from a statistical standpoint. As a result of the progress achieved in the field of extraatmospheric astronomy, we may hope that telescopes with a diameter of about 1 m, placed beyond the limits of the Earth's atmosphere, will make their appearance in the next few years. Observations carried out with such telescopes may completely clarify the problem of the gas present in the intergalactic medium.

The authors are grateful to Ya. B. Zel'dovich for his constant interest in their work and for a number of valuable remarks, and also to the members of the Fourth Winter Course on Cosmogony in Bakuriani in 1967 for their useful discussion.

* * *

A P P E N D I X

RADIATION OF INTERGALACTIC GAS

Let us denote by j_ν the spectral luminosity of a unit of volume. Then $dF = 4\pi j_\nu dt d\nu$ is the density of the energy radiated during the time dt in the frequency band $d\nu$. During the expansion of the Universe the density of radiation energy varies proportionally to $(1 + z)^4$ (the number of quanta in a unit of volume varies as $(1 + z)^3$ and the energy of the quantum as $(1 + z)$, i.e. $dF_0 = dF/(1+z)^4$, dF_0 being the density of the energy radiated at z and registered at z = 0. Since $d\nu = d\nu_0(1+z)$ nd

$$\frac{dt}{dz} = -\frac{1}{H_0}\frac{1}{(1+z)^2(1+\Omega z)^{1/2}},$$

we obtain

$$dI(\nu) = \frac{c}{4\pi}\frac{dF}{d\nu} = dI(\nu_0)(1+z)^3,$$

$$dI(\nu_0) = \frac{dI(\nu)}{(1+z)^3} = \frac{cj_\nu dt}{(1+z)^3} = -\frac{c}{H_0}\frac{j_\nu(z)dz}{(1+z)^5(1+\Omega z)^{1/2}},$$

whence

$$I(\nu_0) = \int dI(\nu_0) = \frac{c}{H_0}\int_0^{z_{max}}\frac{j_\nu(z)dz}{(1+z)^5(1+\Omega z)^{1/2}} = \frac{c}{H_0}\int_0^{z_{max}}\frac{j(\nu', z)dz}{(1+z)^5(1+\Omega z)^{1/2}} \quad (\Pi.1)$$

where $\nu' = \nu_0(1+z)$.

a.- Emission in the Continuous Spectrum in the Case of Free-Free Transitions. The spectral luminosity during free-free transitions in the case of Maxwellian distribution of electrons with temperature T (*) and ions with a charge Z and density n_e and n_Z respectively, is given by the formula

$$j_\nu = n_e n_Z \frac{2^5\pi}{3^{3/2}}\frac{e^6Z^2}{m_e{}^2c^3}\left(\frac{2\pi m_e}{kT}\right)^{1/2} g(\nu, T)\exp(-h\nu/kT),$$

where $g(\nu,T)$ is the Gaunt's factor [49, 50]

$$g(\nu, T) = \frac{\sqrt{3}}{\pi}\left(\ln\frac{4kT}{h\nu} - 0{,}577\right), \quad \frac{h\nu}{kT} \ll 1, \qquad g(\nu, T) = 1, \quad \frac{h\nu}{kT} \gg 1.$$

(*) Despite the low density of intergalactic gas, a Maxwellian distribution of electrons takes place in it. Indeed: the average time between collisions $\tau_c \sim 1/\sigma n_e V \sim 2\cdot10^{12}$sec (where $\sigma \sim 10^{-16}$ cm^2 is the interaction cross-

.../next page..

For helium-hydrogen plasma n_{He}/n_H + 0.1, we obtain

$$j_\nu = 6{,}4 \cdot 10^{-39} g(\nu, T) T^{-1/2} \exp(-h\nu / kT) n_e^2 \quad \text{erg/cm}^3 \text{ sec} \cdot \text{ster.hz} \qquad (\Pi.2)$$

When T < 8 · 10⁴ °K, helium is singly ionized and

$$j_\nu = 5{,}44 \cdot 10^{-39} g(\nu, T) T^{-1/2} \exp(-h\nu / kT) n_e^2 \quad \text{erg/cm}^3 \text{ sec ster hz}$$

(the g(ν,T)-factor was taken equal to the unity in all estimates). Since

$$n(z) = n(0)(1+z)^3, \qquad \nu = \nu_0(1+z), \qquad T = T(z),$$

$$I(\nu_0) = 6{,}4 \cdot 10^{-39} \frac{c}{H_0} n_0^2 \int_0^{max} [T(z)]^{-1/2} \exp\left[-\frac{h\nu_0(1+z)}{kT(z)}\right] \frac{(1+z)dz}{(1+\Omega z)^{1/2}} =$$

$$= 6{,}4 \cdot 10^{-21} \Omega^2 \int_0^{z_{max}} [T(z)]^{-1/2} \exp\left[-\frac{h\nu_0(1+z)}{kT(z)}\right] \frac{(1+z)dz}{(1+\Omega z)^{1/2}} \quad \text{erg/cm sec ster hz} \qquad (\Pi.3)$$

b.- <u>Emission in the Continuous Spectrum during Recombinations</u>

The energy of a photon emitted during recombination at the n-th level is $h\nu = E_e + \chi_n$, where E_e is the energy of the recombining electron and χ_n is the ionization potential from this level. Since we are interested only in energy quanta, we shall consider only the emission during recombination at the main level (χ_n is maximum). For a Maxwellian distribution of electrons we have

$$j_\nu = 1{,}7 \cdot 10^{-33} g n_e n_Z Z^4 T^{-3/2} \exp\left(\frac{\chi_n - h\nu}{kT}\right) \quad \text{erg/cm sec} \cdot \text{ster} \cdot \text{hz}. \qquad (\Pi.4)$$

Here g ∿ 1.

For T > 4 · 10⁵ °K, hydrogen emission during recombinations is insignificant, while helium emission plays an important role up to T ∿ 10⁶ °K.

The recombination radiation of helium-hydrogen plasma is

$$I(\nu_0) = 1{,}7 \cdot 10^{-15} \Omega^2 \int_0^{z_{max}} [T(z)]^{-3/2} \left[1{,}6 \exp\left(\frac{4\chi_H - h\nu_0(1+z)}{kT(z)}\right) + \right.$$

$$\left. + \exp\left(\frac{\chi_H - h\nu(1+z)}{kT(z)}\right)\right] \frac{(1+z)dz}{(1+\Omega z)^{1/2}} \quad \text{erg/cm} \cdot \text{sec} \cdot \text{ster} \cdot \text{hz} \qquad (\Pi.5)$$

where χ_H is hydrogen's ionization potential.

(continued from the preceding page) .. section between electrons $n_e \sim 10^{-5}$ cm⁻³, $V \sim \sqrt{3kT/m_e} \sim 6 \cdot 10^8$ cm/sec for T ∿ 10⁶ °K) is much smaller than the hydrodynamic $\tau_r \sim 10^3/\sqrt{\rho} \sim 3 \cdot 10^{17}$ sec $\sim 1/H_0$

c.- Emission in Lines. In the intergalactic medium the lines are formed as a result of recombinations at levels with n ≠ 1 and during excitation of levels by electron impact. The number of quanta emitted in a unit of volume per unit of time is

$$N_{nm} = \frac{(\alpha_n n_e n_Z + q_{1n} n_e n_{Z-1}) A_{nm}}{\sum_{k=1}^{n-1} A_{nk}}, \qquad (II.6)$$

where α_n is the probability of recombination when successive transitions to the given level are taken into account, q_{in} is the probability of excitation by electron impact, and A_{nk} are Einstein coefficients.

We are interested in the emission in the L_α-resonance lines of hydrogen and λ 304 A of He II. For any of these lines (*)

$$N_{2P\to 1S} = \alpha_{2P} n_e n_Z + q_{1S\to 2P} n_e n_{Z-1} = \alpha_{2P} n_e n_Z + q_{1S\to 2P} n_e n_Z \frac{\alpha_t - \alpha_{1S}}{q_{1i}},$$

since $\alpha_{2P} \approx {}^3/_4(\alpha_t - \alpha_{1S})$,

$$N_{2P\to 1S} = (\alpha_t - \alpha_1)\left(\frac{3}{4} + \frac{q_{1S\to 2P}}{q_{1i}}\right) n_e n_Z = \alpha_Z n_e^2.$$

Figure 3 gives the values of α_Z for the L_α-lines of hydrogen and HeII as a function of temperature (a 10% helium content, based on the number of atoms, is taken into account). The values

$$q_{1S\to 2P} = 4\pi\left(\frac{m}{2\pi kT}\right)^{3/2} \int_{\sqrt{2\chi_{2P}/m}}^{\infty} \sigma_{1S\to 2P}(v)\, v^3 e^{-(mv^2/2kT)}\, dv$$

and

$$q_{1i} = 4\pi\left(\frac{m}{2\pi kT}\right)^{3/2} \int_{\sqrt{2\chi_i/m}}^{\infty} \sigma_i(v)\, v^3 e^{-(mv^2/2kT)}\, dv,$$

where q_{1i} for hydrogen and helium, $q_{1S\to 2P}$ for H I, was computed according to experimental cross-sections [51] and $q_{1S\to 2P}$ for He II -- by the cross-section obtained in the Born approximation [52]. Since the local line widening (due to thermal and turbulent motion, etc.) is much smaller than the cosmological expansion, we shall assume that the local profile of the line is given by the δ-function. Then

$$j_\nu = \frac{1}{4\pi} h\nu \alpha_Z n_e^2 \delta(\nu - \nu_\alpha), \qquad (II.7)$$

where ν_α is the frequency corresponding to the transition

$$j(\nu', z) = \frac{1}{4\pi} h\nu_0 \alpha_Z n_0^2 \delta(\nu' - \nu_\alpha)(1+z)^7,$$

(*) The existence is assumed of ionization equilibrium $q_{1i} n_{Z-1} n_e = (\alpha_t - \alpha_1) n_Z n_e$, where $\alpha_t - \alpha_1$ is the recombination coefficients at all levels, except the main one, and q_{1i} is the probability of ionization by electron impact.

where

$$\nu' = \nu_\alpha(1+z),$$

$$I(\nu_0) = \frac{1}{4\pi}\,\frac{c}{H_0}\,h\alpha_z n_0^2 \int_0^{z_{max}} \frac{(1+z)^2}{(1+\Omega z)^{1/2}}\,\delta\left[\nu_0(1+z)-\nu_\alpha\right]\nu_0\,dz =$$

$$= \frac{1}{4\pi}\,\frac{c}{H_0}\,h\alpha_z n_0^2 \frac{(1+z_\alpha)^2}{(1+\Omega z_\alpha)^{1/2}} = 5.2\cdot 10^{-10}\alpha_z\Omega^2\frac{(1+z_\alpha)^2}{(1+\Omega z_\alpha)^{1/2}} \qquad (\Pi.8)$$

$$(1+z_\alpha = \nu_\alpha/\nu_0).$$

The emission during the dielectrònic recombination of He II may be neglected, for it is much smaller than the emission in the line He II λ 304 A.

**** ~~THE END~~ ****

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