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OBSERVATIONS AND INTERPRETATION OF ULTRAVIOLET EMISSION FROM THE GALAXY

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SUMMARY

Measurements carried out aboard AIS "VENERA-2" and "VENERA-3" have shown the presence of emission in the 1225 – 1340 A band and in the L_α-line in the direction toward the Milky Way. Measurements in the above band (flux: $3 \cdot 10^{-7}$ erg/cm^2·sec·sterad, $F_\lambda \sim 3 \cdot 10^{-9}$ erg/cm^2·sec·sterad·A) are explained by the aggregate emission of Galaxy stars and give for the luminosity ratio the value $F_\lambda(1300) / F_\lambda(5560) = 1.5 \cdot 10^{-2}$.

Taking into account the interstellar absorption it is shown that the ratio of volumetric luminosities of stars of plane component is $j_\lambda(1300)/j_\lambda(5560) = 4 \cdot 10^{-2}$ instead of the computed value 5.9 [1]. The upper limit is obtained of Galaxy luminosity in the ultraviolet band (1225 – 1340 A), which is $2 \cdot 10^{40}$ ergs sec. It is shown that the background of extragalactic nebulae in the ultraviolet does not exceed 10^{-24} erg·cm^2·sec·sterad·hz. The emission in L_α possibly is not of galactic origin for because of absorption on dust, the well known sources of L_α-emission in the Galaxy cannot assure the observed flux. An explanation of observations is offered by re-emission of solar L_α-quanta on hydrogen of the interplanetary medium. The necessary increase of plasma density to that of the Milky Way may be connected with the regular galactic magnetic field.

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* *

Measurements of the ultraviolet background were conducted in the experiment on "VENERA-2" and "VENERA-3" described in the works [2 – 5] with the aid of two photon counters with response in the spectral regions 1050 – 1340 A and 1225 – 1340 A. The first interval was hit by the line L_α (λ 1215.7 A), while the 2nd counter was insensitive to that radiation owing to CaF_2 filter, the transmission of which did not exceed 0.1 percent. In the first spectral channel the field of vision was 7°, in the second it was 20°; the geometrical factor was respectively $3 \cdot 10^{-4}$ and $3 \cdot 10^{-3}$ cm^2·sterad. Both devices were installed on the dark

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(*) NABLYUDENIYA I INTERPRETATSIYA ULTRAFIOLETOVOGO IZLUCHENIYA GALAKTIKI side of the stations and at rotation around an axis directed at the Sun, the field of vision of the devices described a cone with aperture angle of 140°. Two maxima were registered during rotation, the position of which coincided with the Milky Way band (the intensities of fluxes in both maxima coincide within the measurement precision. The photometer crossed the galactic equator at an angle of 40°.

Readings of the devices from distances of 164,000 and 820,000 km are shown in Fig.1 and Fig.2 represents the position of devices' field of vision in the celestial sphere. During one of the crossings of Milky Way band, the Earth hit the field of vision.

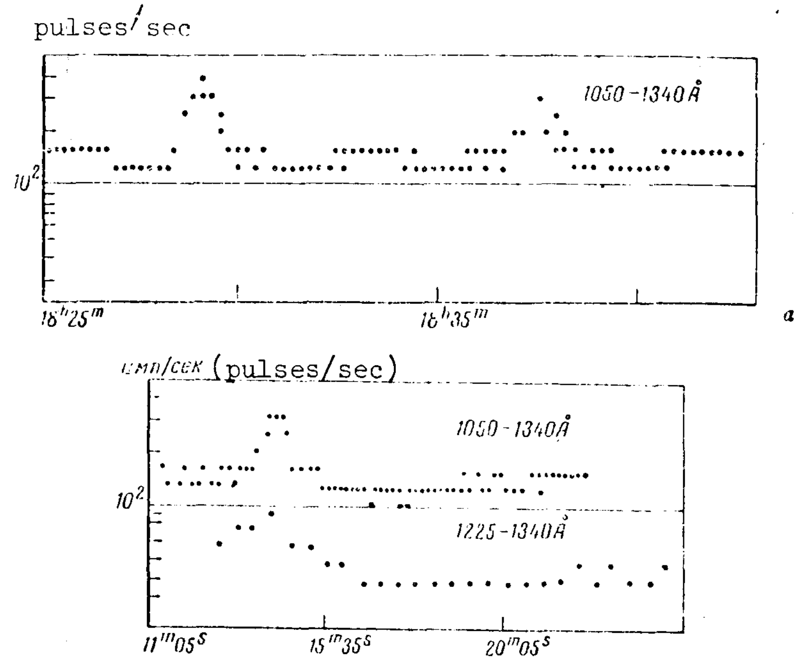

Fig.1. Readings of the devices on a) "VENERA-2", b) "VENERA-3"

The isotropic background in the channel 1050 − 1340 A was $5.5 \cdot 10^{-5}$ erg/cm^2 sec sterad. The excess above background, linked with the plane of the Milky Way, was $2.5 \cdot 10^{-5}$ erg/cm^2 · sec·sterad according to measurements on VENERA-2, which corresponds to 20 to 45 rayleighs after the measurement data of VENERA-3. In the 1225 − 1340 A channel the isotropic background did not exceed 10^{-7} erg/cm^2 · sec sterad [2], and the reading with respect to Milky Way was equal to $3 \cdot 10^{-6}$ erg/cm^2 · sec · sterad. The extent of the region of luminescence in the line L_α in a direction perpendicular to the galactic equator constituted 60°. Both maxima were shifted relative to the plane of the Galaxy by a quantity of the order of 10 to 20°

2. Measurements conducted in the band beyond the line L_α allow us to estimate the integral effect of the Milky Way band in the far ultraviolet. Assuming the region of sensitivity equal to 100 A, we shall obtain the intensity F_λ (1300 A) equal to $3 \cdot 10^{-9}$ erg/cm^2 sec sterad A, perpendicularly to the plane of the

Galaxy F_λ = (1300A) = 10^{-9} erg/cm^2/sec·sterad·A.

Theoretical estimates of the ratio F_λ(1300 A) / F_λ (5560 A) were made in the work [1] and for low galactic latitudes the value of 5.9 was obtained. However, rocket measurements of star emission fluxes in the region λ 1300 A [6, 7] have shown that the scale of effective temperatures in the ultraviolet is strongly overrated for stars of early spectral classes defining the brightness in the considered spectral region. Earlier it was noted in [3] that the estimate of [1] is strongly overrated. Measurements conducted on VENERA-3 allow us to obtain the value of this ratio. According to [6]. the brightness of the Milky Way near l = 50 and 200° is F_λ (5560 A) = 2 · 10^{-7} erg/cm^2·sec·sterad A, which corresponds to $4^m.3$ from the square degree. Then the observed value is

$$F_\lambda \text{ (1300 A) } / F_\lambda \text{ (5560 A) } = 1.5 \cdot 10^{-2},$$

For the radiation outgoing from the Galaxy this ratio will be different, for the observed ratio is strongly attenuated by the interstellar absorption on dust*). Rocket measurements show that the absorption on dust is $A_V \sim 2^m.0$ kps^{-1}; and A (λ · 1300) = $5^m.5$ kps^{-1} [8] for observations in the plane of the Galaxy, and for observations at high galactic latitudes the total absorption on the half-thickness of the galaxy is $0^m.3$ and $0^m.8$ respectively.

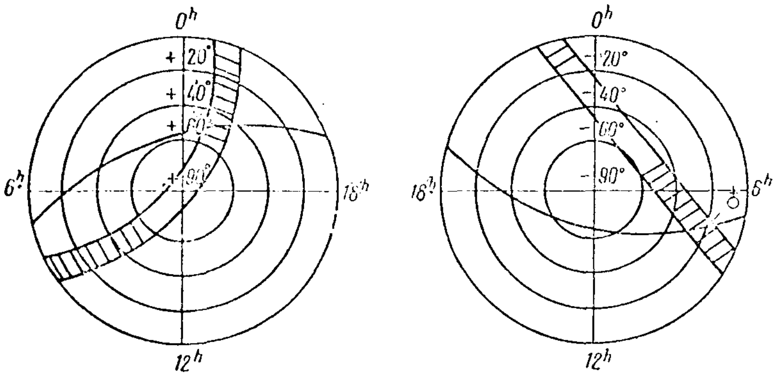

Fig.2. Position of the field of vision of devices in the celestial sphere

Absorption in the plane of the Galaxy weakens the emission several times over the distance of 540 ps (λ 5560 A) and 200 ps (λ 1300 A). It is obvious that for an "outside" observer

$$[F_\lambda(1300\text{Å})/F_\lambda(5560\text{Å})]_0 = 1.5 \times 10^{-2}\left(\frac{540}{200}\right) = 4.0 \times 10^{-2}\,.$$

Indeed

$$\frac{dF_\lambda}{dl} = -kF_\lambda + j_\lambda, \qquad (1)$$

where k is the absorption coefficient on dust; j_λ is the volumetric luminosity of the combination of stars of the Galaxy. Hence

$$F_\lambda = \frac{1}{k} j_\lambda, \qquad (2)$$

1/k is equal to 540 and 200 ps for λ 5560 and 1300 A. The obtained value of $4 \cdot 10^{-2}$ is precisely $j_\lambda(1300) / j_\lambda(5560)$. The ratio thus found is the upper limit, since for high galactic latitudes even the found upper limit of the flux gives a value of same order. This fact is sufficiently trivial, for the population of high galactic latitudes has a later spectral class **).

Pikel'ner was the one who pointed to a possible explanation of such a weak emission in the ultraviolet: the width of the absorption line L_α in spectra of stars may be quite significant ($\sim$ 100 A). The closeness of the utilized interval to the absorption line ($\Delta\lambda = 9$A) may have led to a substantial attenuation of the continuous spectrum of stars. As is shown in [3], the main contribution to the ultraviolet region (1225 – 1340 A) is made by stars of spectral classes from A0 to F0, where this effect must be manifest at maximum. For stars of earlier classes the absorption line L_α must be weaker. This explains that such stars are not noticeable during rocket observations [9], and the more so since the effective wavelength in [6] was 1370 A. Observations of stellar spectra in the constellation Orion [9] were completed for spectral classes earlier than A0. The one fact only of effective temperature decrease (for A0 8800°K) already allows us to diminish the theoretical estimate of the flux by about one order. Thus, the result obtained may be fully explained. Utilizing the ratio obtained we shall find the upper limit of the total luminosity Φ_λ (λ 1300) of the Galaxy in the ultraviolet region. According to the absolute stellar magnitude $M_V = - 20^m.3$, we shall obtain that the total flux in λ 5560 A, Φ_λ (5560 A) $=$ $= 5.6 \cdot 10^{39}$ ergs/sec·hz·A and $\Phi_\lambda(1300 \text{ A}) < 2.2 \cdot 10^{38}$ ergs/sec A or $\Phi_\lambda(\lambda 1300) <$ $< 10^{26}$ ergs/sec·hz. The total ultraviolet luminosity of the Galaxy in the wavelength range 1225 – 1340 A does not exceed $2 \cdot 10^{40}$ ergs/sec.

Thus the theoretical estimate of the background from extragalactic nebulae in the ultraviolet region, brought up in [3], obtained an experimental corroboration, and it results therefrom that the background from extragalactic nebulae must not exceed $10^{-23} - 10^{-24}$ erg/cm^{2}sec·sterad·hz.

3. Let us now pass to the interpretation of the results of measurements in the channel 1050 – 1340 A, where the reading was higher by two orders. It is clear that the emission in the line L_α was measured in the first channel. In connection with the coincidence of the emission maximum in this line with the direction toward the Milky Way let us consider the possible sources of emission in the Galaxy.

a) The stars of the Galaxy ought to give an emission in the line L_α as well as in the continuous spectrum. In this case the readings of both counters would have been commensurate, while their ratio is 10^2. Even for the Sun, the

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*) (from the preceding page). It was noted in [2, 3] that absorption on elements with low ionization potential is small by comparison with dust. Rocket investigations of ultraviolet spectra of stars (1600 – 1000 A) [9, 10] have shown the absence of absorption bands of molecules and of ionization thresholds in the interstellar medium.

**) The averaged value of $F_\lambda(1300) / F_\lambda(5560)$ may be obtained by way of rocket observations of Andromeda nebula.

the coincidence of the emission lines of heavy elements assures a ratio ~ 0.1, and for stars of earlier spectral classes this value must be 0.3. This is why the effect observed may be induced by stars in the Milky Way band.

b) Gas nebulae and the coincidence of zones HII around hot stars cannot assure the emission in L_α with the observed intensity either, for their glow is the result of reprocessing of star emission beyond the Layman threshold; this cannot significantly exceed the aggregate emission in the 1225 1340 A band.

c) The ionization losses of sub-cosmic rays in the interstellar medium [11] lead to the formation of a substantial number of L_α-quanta as a result of the excitation of the 2p-level, and also at recombination at that level. However, during the scattering of the formed L_α-quanta on neutral hydrogen,of the interstellar medium, they rapidly perish as a result of absorption on interstellar dust. It is true that there remains quite a hypothetical possibility of existence of hot regions practically free from dust. At further diffusion of L_α-quanta in cold medium ($T \sim 10^2$°K) the central part of the line will be absorbed while quanta, having "emerged" in the wings may be the cause of the observed effect. The observed angular dimension of the emitting region, which is $\sim 60°$, allows us to evaluate the length of the free path of quantum l, equal by order of magnitude to the thickness of the entire gas disk, i. e. ~ 400 ps. However, at hydrogen temperature of $\sim 10^2$°K, $l = 2 \cdot 10^{12}$ cm at the center of the line for a concentration of ~ 1 cm^{-3} *

Even the usual absorption on dust without taking into account the scattering leads to emission isotropy. It is possible to by-pass this difficulty only by assuming the presence of close objects, concentrating toward the plane with greater strength than the gas, and emitting a noticeably shifted line L_α. Omitting the discussion of the real possibility of existence of such objects and of the possibility of egress from them of L_α-quanta, we shall bring forth estimates of their emission in H_α. During the level excitation by electron impact the ratio of probabilities of level excitation with main quantum numbers $n_1 = 2$ and $n_1 = 3$ is equal to 5.

The ratio of recombination coefficients is less than $(n_2 / n_1) = 3.4$ (for $T_e \sim 10^4$°K it is equal to 1.32). Since at sub-cosmic ray interaction the number of ionization and recombination events is equal, the number of emitted H_α-quanta can not be less than one third of the number of L_α-quanta. If we take into account the different absorption on interstellar dust, we shall obtain that the number of H_α-quanta can not be less than the number of L_α-quanta. Observations of the averaged Milky Way background in H_α contradict the fixed flux by 200 rayleighs. Besides, separate objects with large emission in H_α would have been noticed earlier.

In the aggregate one may notice that the explanation of measurements by L_α emission in the Galaxy is of little probability.

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* If the line L_α forms in a widening shell of supernova remnants, the required velocity will exceed 10^3 km/sec [12].

d) There remains the possibility of explaining the observed effect by re-emission of the line L_α from the Sun by hydrogen atoms in interplanetary medium. (which determines the isotropic background). The concentration of the observed emission in the plane of the Galaxy points to the increased number of hydrogen atoms on the visual ray in that direction. The Galaxy may influence the interplanetary medium only owing to the presence of an ordered magnetic field and interstellar wind.

The presence of the galactic field leads to solar wind flow in a cylinder whose axis is parallel to the vector of field intensity, and this means that it lies in the plane of the Galaxy [13]. The grooved (channelled) plasma instability and the motion of the Sun relative to the interstellar medium may, for example, lead to cylinder transformation onto a disk lying in the galactic plane.

If $H \sim 3 \cdot 10^{-5}$ oe, the field and wind pressures equalize at the distance of 15 a.u. To explain this effect a neutral hydrogen pressure in the channel of the order of 10^{-2} cm^{-3} is required, which cannot be explained by recombination in the solar wind.

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**** THE END ****

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ANNOTATION FOLLOWS-.. /..

ANNOTATION DURING CORRECTION.

Measurements on AIS "VENERA-4" disclosed for Milky Way a flux in L_α nearly of 200 rayleighs. This flux cannot be linked either with gas outflow from hot stars, or with charge-exchange of subcosmic protons ($E \approx 10 - 100$ kev).

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