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RELICT RADIATION OF THE UNIVERSE AND POPULATION OF ROTATIONAL LEVELS OF INTERSTELLAR MOLECULES

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SUMMARY

The author establishes that there is a foundation for the assertion that relict radiation of the Universe was discovered as early as a quarter of a century ago, but remained unintelligible till recently. In the current note the author discusses the influence of that radiation on the rotational temperature of interstellar molecules.

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The recently revealed isotropic radiation of the sky in centimeter waves [1] much rather has a relict character, i. e., it is connected with an earlier evolution of the initially hot Universe [2]. This radiation is apparently Planck with temperature $T_r \sim 3°$. Its intensity maximum corresponds to the spectral region near 1 mm, and the energy density of this radiation in the Universe is ~ 1 ev/cm^3, which is substantially greater than the density of all other forms of energy (besides $\bar{\rho}c$, where $\bar{\rho}$ is the mean density of matter in the Metagalaxy).

A radiation of such a high density must, generally speaking, exert a certain influence upon the physical state of the matter in the intergalactic and interstellar space. We shall consider in the present note the influence of this radiation on the rotational temperature of interstellar molecules.

As is well known, diatomic molecules CH, CH^+ and CN were discovered in the interstellar space by optical astronomy methods. Recently the OH molecule was discovered by radiostronomical method. If these molecules are in the field of "relict" radiation, it may be easily ascertained that the excitation of their rotational levels must be realized exclusively by way of radiation absorption. In reality, the probability of such an absorption, computed for one molecule will be

$$B_{12}u_{21} = A_{21}(e^{h\nu/kT_p} - 1)^{-1}$$

* RELIKTOVOYE IZLUCHENIYE VSELENNOY I NASELENNOST' VRASHCHATEL'NYKH UROVNEY MEZHZVEZDNYKH MOLEKUL.

where B_{12} and A_{21} are Einstein factors, u_{21} is the spectral density of the relict radiation corresponding to the temperature $T_r \sim 3°$. We may consider in the first approximation that A_{21} is determined by the classical expression

$$A_{21} = 8\pi^2/3 \cdot e^2/Mc \cdot 1/\lambda_o^2$$

where M is the reduced mass of the molecule, λ_o is the wavelength of the rotational spectrum line. In the most interesting case of molecule CN we have $\lambda_o = 0.26$ cm, which is rather near the wavelength to which corresponds the relict radiation maximum. In other interstellar molecules, such as hydrides, λ_o is about 5 times smaller and is located in the vinous region of relict radiation.

Assuming $M \sim 10^{-23}$g, we find that

$$A_{21} \sim 3 \cdot 10^{-4} \text{ sec}^{-1},$$
$$B_{21}U_{21} \sim 5 \cdot 10^{-5} \text{sec}^{-1},$$

while the probability of excitation by collision with hydrogen atoms is

$$n_H \bar{\sigma} \cdot \bar{v}\, e^{-h\nu/kT},$$

where $\bar{\sigma} \sim 10^{-16}$cm^2 is the effective cross section, $\bar{v} \sim 10^5$ cm/sec is the thermal velocity of hydrogen atoms, $n_H \sim 10$ cm^{-3} is the concentration of hydrogen atoms in the interstellar gas clouds. Having completed the calculations, we find that the probability of excitation by collision is $\sim 10^{-11}$ sec^{-1}.

Since the population of the lower rotational levels of interstellar molecules is regulated by the relict Planck radiation with temperature T_r, it will be described by the Boltzmann formula for the same temperature. Because of comparative smallness of the rotational constant B_V only at the CN molecule, the population of the second rotational level, at $T_r = 3°$, will be comparable with the population of the first level. In other interstellar molecules -- the hydrides – the population of rotational excited levels are negligibly small.

Let us now estimate the optical thickness of the interstellar medium for radiation in the frequency of the CN rotational line, $\lambda_o = 0.26$ cm. The absorption coefficient k_ν is determined by the Doppler velocities of interstellar medium's clouds, whereupon the role of negative absorption at $T_r \sim 3°$K is negligibly small :

$$k_{\nu_o} = \frac{\pi}{mc^2} \cdot e^2 \frac{\lambda_o^2}{\Delta\lambda_D} n_{CN} \sim 3.5 \cdot 10^{-13} \cdot n_{CN} \text{ cm}^{-1}$$

Assuming the concentration of molecules as being $CN \sim 3 \cdot 10^{-9}$cm^{-3} (see [3]), and the extension of the interstellar medium layer in a direction perpendicular to the plane of the Galaxy, $l \sim 3 \cdot 10^{20}$ cm, we shall find that the optical thickness at the center of the line in that direction will be

$$\tau_\nu = k_\nu l \sim 0.3,$$

that is, the metagalactic radiation in these frequencies will freely penetrate the interstellar medium and excite the molecules CN. V. I. Slysh called our attention to the fact that Adams revealed the interstellar rotational line of CN absorption, in which the initial level is excited [4]. This question was considered at length in 1947 by McKellar [5]. According to Adams' estimate, the relative intensity of the lines R(0) λ 3874.00 and R(1) λ 3874.61 is 5 : 1. Hence McKellar found that the excitation temperature of 2.3°, in perfect agreement with the temperature of relict radiation discovered in the course of the past year. McKellar stressed the fact that the integral radiation of stars of our Galaxy cannot explain the excitation of the rotational levels of interstellar molecules CN. Therefore, we have a basis to assert that experimentally, the relict radiation of the Universe was discovered a quarter of a century back; however, the required theoretical conclusions of that discovery were not then made, and it was unintelligible.

This work was reported to the Astrophysical Colloquium of the State Astronomical Institute in the name of Shternberg on 7 October 1965. We recently were made aware of the fact that, independently and practically simultaneously, an analogous investigation was conducted by Field, who presented his work at the cosmological conference held in Miami, Florida in the middle of December 1965.

*** T H E E N D ***

G.A.I.Sh. March 1966

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