On the Nature of Some Cosmic Radiations

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Frequency distributions of the spectrum of hydrogen and hydrogen-like elements help to determine the most probable excited elements spectral radio lines in outer space. Based on the geometrodynamic concept of J. Wheeler, the reason for the appearance of recombination radio lines is explained, and the background cosmic radiation maximum nature is established. The hydrogen atom limiting quantum number is calculated. It has been established that the wavelength during proton-electron recombination at the limiting quantum level coincides with the known 21 cm cold atomic hydrogen wavelength.

1 Introduction

Space is filled with various types of radiation, and some of them, such as the background cosmic (relic) radiation, recombination radio lines (RRL) and atomic hydrogen radiation at a wavelength of 21.1 centimeters, are of particular interest to researchers. The study of radio lines of excited atoms is the most effective method of astrophysical research to obtain the important information about various galactic and extragalactic objects. The spectrum of the relic radiation filling the Universe corresponds to the completely black body radiation spectrum with a temperature of 2.73 K. Its maximum falls at a wavelength of 1.9 mm.

The conditions for the occurrence of this kind of radiation exist in a cold rarefied interstellar medium. Under such conditions, in the process of electrons and ions recombination, some highly excited stable hydrogen atoms and other light elements can be formed with a quantum number theoretically possible up to $n = 1000$, where the electronic levels are still distinguishable; the atom limiting size is limited by the background nonthermal radio emission of the Galaxy and $n_{lim} = 1600$ [1].

High electronic levels are inhabited mainly due to recombinations, and radio lines most often manifest themselves during electron transitions between neighboring electronic levels. The spectral RRLs emitted during the transitions fall in the radio range. To date, the recombination radio lines of hydrogen have been registered in the scale from the infrared to the metre scale at $n = 10\ldots300$. At higher excitation levels, radio lines were observed in the process of absorption only [2–4].

Atomic hydrogen in the interstellar medium is observed due to emission and absorption in the 21 cm line. The hydrogen radio line is an effective means of studying the Universe, because there is about half the mass of galactic interstellar matter in the atomic hydrogen ground state form. It is assumed this spectral line to be the result of transitions between sublevels of the hyperfine structure of the hydrogen atom ground energy level. The reason for hyperfine splitting is the interaction of the nucleus spin and the electron spin, since these spins can be parallel or antiparallel. When the electron spin orientation is reversed, emission (or absorption) of quanta with the frequency of 1420 MHz occurs [5, 6].

2 On the shape of the spectra of frequency distributions

The presence and spectral lines intensity of specific sources depend on various factors, and usually a small part of the spectrum is realized. However, the averaging with respect to many sources in large space and time scales (infinite scales as an ultimate case) of all possible hydrogen atom electron transitions and the spectral lines corresponding to these transitions gives characteristic *frequency distributions* in accordance with the Balmer-Rydberg formula

$$W = \frac{m^2 n^2}{m^2 - n^2}\,, \tag{1}$$

where $m, n = 1, 2, 3\ldots$ Moreover, in the range of $n, m = 10\ldots300$ (in radiation), the characteristic frequency distribution will correspond to the completely black body radiation spectrum with a temperature of about 3 K, and the characteristic frequency distribution over all remaining levels at $n, m = 300\ldots500$ will take a similar shape with a maximum of about 21 cm, see Fig. 1. Such a result to some extent explains the nature of these radiations. For example, the shape of the background radiation curve could be explained

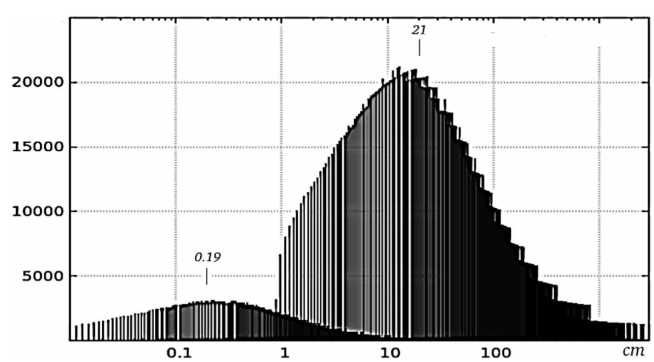

Fig. 1: Frequency distribution of the Balmer-Rydberg formula for $n, m = 10\ldots300$ (left) and for $n, m = 300\ldots1500$ (right).

by natural factors currently taking place. Details about frequency distributions and methods for their construction are given in [7, 8].

The radio lines of excited atoms provide information about the electron temperature, density, composition of the interstellar medium, and about other important parameters. However, finding useful RRL is a laborious task, because building even one spectrum for a single observed point at decameter waves requires many days of observations. Frequency distributions help solve this problem.

Fig. 2 shows the characteristic frequency distribution of the Balmer-Rydberg formula in the decameter range. The currently recorded radio links according to the data of [1] and [3] are also shown there. Although these lines belong to carbon, its atoms under these conditions are hydrogen-like. Designations, for example, $427\,\alpha$ means transition $428 \to 427$. At $n = 1530$ (this value, as will be shown below, is equal to the limiting value of n), good agreement with the experimental data is achieved.

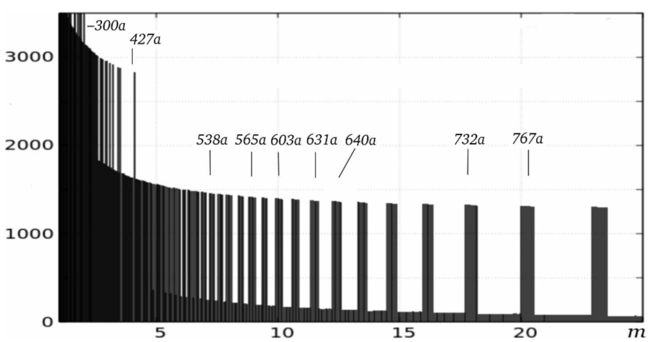

Fig. 2: Frequency distribution for hydrogen-like atoms at $n, m = 300 \ldots 1530$. The designated a-lines belong to carbon.

Not all lines are observable in practice, and not only and not so much for external reasons. As follows from the analysis of the characteristic frequency distributions, the most active radio lines are in fact a superposition (combination) of closely spaced spectral lines, when the electrons make a variety of transitions. Of course, the spectrograms constructed under the condition of the equiprobability of all possible electron transitions cannot completely coincide with the real radiation spectrum, but where the combinatorial factor is significant, the important spectral lines should be sought in the areas of concentration of spectral lines of the frequency distribution. The strong *widening* of radio links at large n [3] can also be explained by the summation, superposition, and combination of close frequencies.

3 Proton-electron contour and the nature of RRL

Recombination radio lines were recorded starting from $n \approx 10$, moreover, at $n \approx 100$ and more, only RRLs are observed. These features, as well as the recombination phenomenon itself, can be explained by considering the atom from the point of view of *J. Wheeler's geometrodynamic concept* [9].

According to Wheeler's concept, charged microparticles are singular points on a topologically non-unitary coherent and fractalized two-dimensional surface of our world, connected by a "wormhole", a vortex tube or a force current line of the drain-source type in an additional dimension, forming a closed *contour*. According to the adopted model [10], the vortex tube (contour) has mass M, radius r_e, and it is helically filled with some medium in the triple vortex thread form with radius r, circulating along the contour at a velocity υ.

The parameters of an arbitrary proton-electron contour are defined in dimensionless units of the electron mass m_e, its classical radius r_e, and the speed of light c:

$$M = (an)^2\,, \tag{2}$$

$$\upsilon = \frac{c_0^{1/3}}{(an)^2}\,, \tag{3}$$

$$r = \frac{c_0^{2/3}}{(an)^4}\,, \tag{4}$$

where a and c_0 are the reciprocal fine structure constant and the dimensionless speed of light c divided by [m/sec].

It is assumed the contour to be structured into ordered units (let's call them photons for short), and their number z is determined by the contour total length to the wavelength ratio. As a result, the formula is obtained:

$$z = \frac{n^6}{k\,W}\,, \tag{5}$$

where $k = 1.7 \ldots 1$ depending on the parameter n, and for large n can be accepted $k \approx 1$. The contour unit mass corresponding to one photon is equal to

$$m = \frac{M}{z}\,. \tag{6}$$

It is clear, a unit mass kinetic energy's changing during an electron transition from n_i to n_k orbit is:

$$E_k = \left(m_i \upsilon_i^2 - m_k \upsilon_k^2\right) \tag{7}$$

or, bearing in mind (2), (3), (5), and (6) and setting $n = n_i$ and $m = n_k$ in the Balmer formula, we obtain in units of $m_e c^2$:

$$E_k = k\,W\,c_0^{2/3}\left(\frac{1}{n_i^8} - \frac{1}{n_k^8}\right)\frac{1}{a^2}\,. \tag{8}$$

At the same time, the energy of the corresponding photon is:

$$E_h = \frac{hc}{\lambda}\,, \tag{9}$$

where Planck's constant is:

$$h = 2\pi\alpha m_e c r_e\,, \tag{10}$$

wavelength is:

$$\lambda = \frac{W}{R_\infty}\,, \tag{11}$$

and the Rydberg constant is:

$$R_\infty = \frac{1}{4\pi\alpha^3 r_e}\,. \tag{12}$$

Then the photon energy, taking into account (10), (11) and (12), in units of $m_e c^2$ is:

$$E_h = \frac{1}{2Wa^2}\,. \tag{13}$$

The ratio of a unit mass energy and a photon energy, bearing in mind (8) and (13), in units of $m_e c^2$ takes the form:

$$\frac{E_k}{E_h} = 2kW^2 c_0^{2/3}\left(\frac{1}{n_i^8} - \frac{1}{n_k^8}\right), \tag{14}$$

and for large n and for neighboring levels, when $W \approx n^3/2$

$$\frac{E_k}{E_h} = \frac{1}{2}\,kn^6 c_0^{2/3}\left(\frac{1}{n_i^8} - \frac{1}{n_k^8}\right), \tag{15}$$

where $n \approx \frac{1}{2}\,(n_i + n_k)$.

As the quantum number n grows, i.e. as the contour increases when an electron passes from the n_k level to the n_i level, there comes a moment when the increment of kinetic energy of a unit mass per photon is not enough to form the corresponding photon, and additional energy is required through external influence. In these cases the emission is preceded by an act of *recombination* – the capture of a free electron by an ion to one of the high levels, for example, photorecombination. Free electrons recombine with a proton or ions. An excess of energy equal to the difference between the electron energy and its binding energy in the atom is carried away with the quantum. During subsequent downward cascade transitions, RRL radiation occurs with frequencies $\nu \sim \Delta n/n^3$. Thus, from (15) it follows that for $n > 110$ the ratio E_k/E_h is always less than 1, and *all radio lines will already be recombination*. Moreover, the electron-proton recombination according to the type $\infty \to n$ at n close to 110 just forms quanta, with a frequency equal to the frequency of the relic radiation maximum.

At $n < 110$, in the millimeter range, there are possible transition where electrons can spontaneously move to lower levels, forming the corresponding spectral lines. These lines in the hydrogen spectrum are observed experimentally [1], and they are well revealed when the restriction $E_k/E_h > 1$ is introduced into the program for calculating the characteristic frequency distributions, Fig. 3. Without this condition, it is difficult to isolate them in the full spectrum. If one builds a frequency distribution with an inverse constraint $E_k/E_h < 1$, then one can make sure that RRLs can occur starting from $\lambda = 0.1$ mm, i.e. at $n \approx 10$.

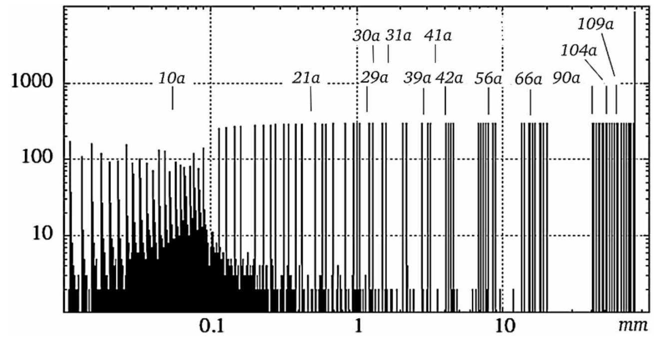

Fig. 3: Frequency distribution for hydrogen in the millimeter range at $n, m = 1 \ldots 130$ under the condition $E_k/E_h > 1$.

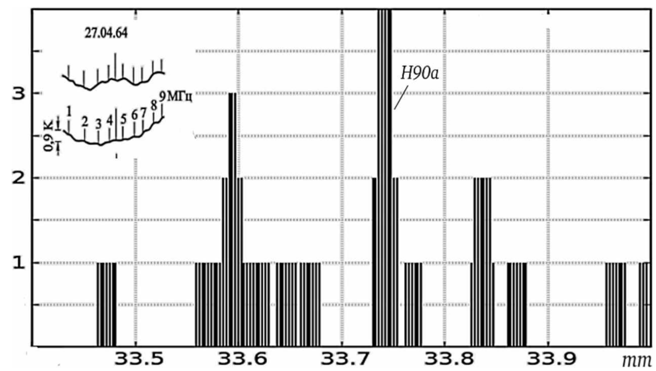

Fig. 4: Frequency distribution of the H90a line at $n, m = 50 \ldots 250$; 207 intervals per range. Top left – the line of hydrogen according to observations in Pushchino in the direction of the Omega Nebula compared with the control spectrogram with the antenna retracted from the source.

It is obvious that the detected radio lines in the range $n = 10 \ldots 110$ can be the result of the superposition of close spectral lines, both recombination and non-recombination ones, for example, the 33.76 mm radio line [11]. This line was one of the first to be discovered in space, perhaps because it is the combination of several very close lines, Fig. 4, and the central peak in the figure is not RRL. That is, the peak does not disappear when the restriction $E_k/E_h > 1$ is imposed. If there are other known restrictions or conditions, they can also be entered into the program for calculating the characteristic frequency distributions.

These distributions explain the features of some spectra noted by some authors. Thus, in [1], the profiles of the H29a, H30a, and H31a lines are given, which turned out to be two-humped, which the authors have given an exotic explanation to. However, the analysis of the spectrum in Fig. 5 narrow part shows that the two-humped profile of the mentioned lines is due to the presence of two closely spaced spectral lines.

In another case, the reason for the unusually low intensity of the H41a line, namely, more than 50 times lower than the intensity of the above lines, is clear from Fig. 3. Indeed, the H41a line height is 60 times lower than the neighboring lines height (in arbitrary units).

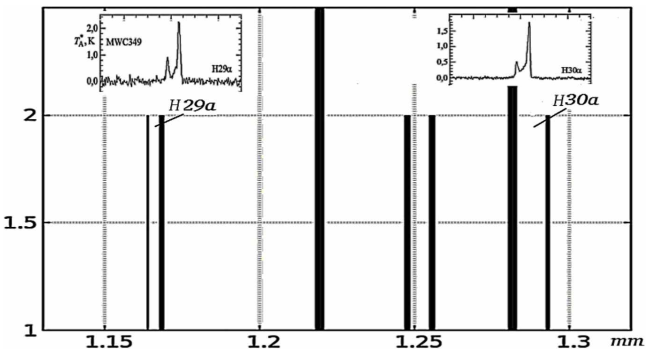

Fig. 5: Frequency distribution in the millimeter range of the H29a and H30a lines at $n, m = 30 \ldots 70$, provided $E_k/E_h > 1$; 341 intervals per range. Above: RRL spectra obtained from the MWC349 source.

4 The hydrogen atom limiting size and the 21 centimeters line

It is believed the atom limiting size to be limited by the background non-thermal Galaxy radio emission and n cannot be more than 1500–1600. But the background radiation is not a constant, and more fundamental parameters are needed to accurately determine the limiting level.

In the adopted model based on Wheeler's geometrodynamics, the vortex thread radius r, which fills the proton-electron contour like a spiral, decreases as the contour increases according to (4). On the whole, the thread consists of three unit threads, and each of them can in the limit have the Planck size r_h [12]. Then, under the condition of their dense packing and based on geometric considerations, the vortex thread size (circumferential diameter) will be:

$$r_0 = \left(1 + 2/\sqrt{3}\right) r_h = 2.1547\, r_h\,, \tag{16}$$

where the Planck size is:

$$r_h = \left(\frac{\hbar\,\gamma}{c^3}\right)^{1/2} = 1.616 \times 10^{-35}\ \text{m} \ \text{ or } \ 5.735 \times 10^{-21}\, r_e\,, \tag{17}$$

where $\hbar = h/2\pi$, and γ is the gravitational constant.

Let us assume that in the limit the thread fills the contour in the spiral form, having turns being twisted into the last (tertiary) spiral structure, then the thread (by the Bohr atom general analogy) has the size:

$$r = a^2 r_0\,. \tag{18}$$

Then, when taking into account (4), (16), (17), and (18), one obtains the limiting quantum number value:

$$n_{lim} = \frac{c_0^{1/6}}{\left(1 + 2/\sqrt{3}\right)^{1/4} r_h^{1/4} a^{3/2}}\,. \tag{19}$$

Further, substituting the dimensionless value r_h in units of r_e, one obtains the limiting quantum number $n_{lim} = 1530$ and the proton-electron recombination wavelength for the transition $\infty \rightarrow n_{lim}$:

$$\lambda = \frac{n_{lim}^2}{R_\infty} = 21.3\ \text{cm}\,. \tag{20}$$

Thus, the recombination wavelength for the $\infty \rightarrow n_{lim}$ transition turned out to be actually equal to the hydrogen radio line 21.1 cm.

It is assumed some mechanism for the atomic hydrogen radiation appearance to exist in which when the atoms are impacting, there is their electron with different directions of spins exchanging [5, 6]. The very same transitions between the hyperfine structure sublevels of the hydrogen atom main energy level, as quantum calculations show, occur with a negligible probability of $2.85 \times 10^{-15}\ \text{sec}^{-1}$. Moreover, although there are analogs of the 21 cm line for atoms of hydrogen isotopes as well as for some other atoms whose nuclei have a nonzero spin moment, such lines are not found in astrophysical sources [5]. Therefore, the low probability and the absence of analogues of this radiation in other atoms make it possible to doubt the main reason for the radiation at 21 cm. It is logical to assume the recombination radiation to be the main reason. Its energy coincides with the spin reorientation energy, that in general creates radiation in a relatively narrow range of about 21 cm.

Thus, the situation with recombination at $n = 10$, where the photon energy is compared with the energy of a unit mass, which forms the background radiation maximum, is reproduced symmetrically at a higher level at $n = 1530$, where the photon energy is compared with the spin reorientation energy, which forms the recombination radiation maximum. This situation seems to be harmonious and logical.

5 Conclusion

It is shown that the frequency distributions make it possible to use the combinatorics factor to identify spectral regions with the most intense spectral lines of excited elements in outer space. In general, the range of cosmic radiation can be divided into two subranges: at $n = 1 \ldots 300$ (mainly in radiation), which has a total maximum coinciding with the background (relic) radiation maximum and at $n = 300 \ldots 1530$ (in mainly in absorption), which has a total maximum coinciding with the atomic hydrogen wavelength.

It has been established that the transition to recombination radiation is due to the equality of the recombination photon energy and the energy of a unit mass of the contour per one photon at $n \approx 110$, which corresponds to the background radiation maximum during the transition $\infty \rightarrow n$.

The limiting quantum level for hydrogen has been determined and it has been found that the photon recombination energy is at this level equal to the electron spin reorientation energy with respect to the atomic hydrogen nuclear spin.

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