ORIGINAL ARTICLE

Possible experimental verification of Bellert's cosmological red shift law using the Cosmic Microwave Background Radiation

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Abstract The author presents a loose proposal of an experiment of measurements of the spectrum of the local black body thermal radiation of the quantum vacuum. The experiment may verify the Bellert's and other theories about the nature of the cosmological red shift of electromagnetic waves and give a new interpretation of measurements of Cosmic Blackbody Radiation delivered by the satellite missions COBE and WMAP. Differently to the Big Bang theory, it is assumed that the quantum vacuum continuously generates thermal noise with the spectrum given by Planck's law.

Keywords Cosmic background radiation · Red shift law · Bellert's theory

1 Introduction

The Cosmic Background Radiation (CBR) has been discovered already in the early stage of the development of radioastronomy (Hey 1973; Sullivan 1984). The measurements of the spectrum of CBR delivered by satellite Cosmic Backgroung Explorer (COBE) and later by the Wilkinson Microwave Anisotropy Probe (WMAP) and also by Boomerang (Balloon Observations of Millimetric Extragallactic Radiation and Geophysics) have shown that the spectrum of CBR is perfectly described by the Planck's law of

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thermal black body radiation with a temperature of 2.725 Kelvins. The measured anisotropy of CBR is negligible. Recently, the observation of the red shift of a large group of supernovae located at various distances has been interpreted as the evidence that the expansion of the Universe is accelerating (Perlmutter et al. 1988, 2011; Riess et al. 1988). In this paper, we recall the Bellert's law of the cosmological red shift and describe a loose proposal of an experiment which could verify the Bellert's law and the hypothesis that the quantum vacuum is a source of black body thermal radiation with the Planck's spectrum of temperature of about 3.55 K.

2 Bellert's geometrical hypothesis about the nature of the red shift

In a series of papers (Bellert 1969; Bellert 1970; Bellert 1977) Bellert derived a formulae describing the cosmological red shift. The derivation starts with two geometrical postulates.

2.1 Postulate of equivalence

Bellert assumed that two stationary reference frames are equivalent with respect to radial elongation. Consider a path r_{AC} from a point A to C and a path r_{BD} from a point B to D. Bellert postulated that if r_{AC} and r_{BD} have the same length, the red shifts of electromagnetic waves propagating from A to C and from B to D are equal, i.e., $\Delta\lambda_{AC} = \Delta\lambda_{BD}$.

2.2 Postulate of uniqueness

Consider a path from point A to C, which is a union of a path from A to B and a path from B to C. The red shift by

direct transmission from A to C is denoted with $\Delta\lambda_{AC}$. Let us assume that the electromagnetic radiation emitted from a source at A is received at B and retransmitted to C. The postulate of uniqueness has the form: $\Delta\lambda_{AC} = \Delta\lambda_{AB} + \Delta\lambda_{BC}$.

Using the above geometrical postulates, Bellert derived the following formulae describing the cosmological red shift

$$\frac{\Delta\lambda(x)}{\lambda_0} = \frac{k_H x}{1 - k_H x} \tag{1}$$

where λ_0 is the wavelength of a monochromatic wave radiated by a stationary (immobile) source located at the distance $D = x$ from a stationary observer and $\Delta\lambda$ is the elongation of the wavelength due to red shift (elongation of the wavelength or lowering the frequency) induced during the travel of the wave from the source to the observer. The constant

$$k_H = \frac{1}{cT_H} \ [\text{m}^{-1}] \tag{2}$$

where c is the speed of light in vacuum and T_H is the Hubble time (name of the American astronomer who discovered the phenomenon of red shift) given by

$$T_H = \frac{1}{H} \times 10^{12} \ [\text{years}] \tag{3}$$

where, as measured by WMAP, the actually accepted value of the Hubble constant is $H = 71.0 \pm 0.5$ [km/s/Mpc]. This yields $T_H \approx 1.4 \times 10^{10}$ [years] $= 4.44 \times 10^{17}$ [s]. Therefore, we have

$$\begin{aligned} k_H &= \frac{1}{cT_H} = \frac{1}{2.997 \times 10^8 \times 4.441 \times 10^{17}} \\ &\approx 7.5 \times 10^{-27} \ [\text{m}^{-1}]. \end{aligned} \tag{4}$$

The Bellert's law can be rewritten in the frequency domain. Since $\lambda f = c$, we get

$$f(x) = f_0 (1 - k_H x). \tag{5}$$

The equation $k_H x = 1$ defines the *Bellert's cosmological horizon* given by

$$D_{\text{Hor}} = \frac{1}{k_H} = 1.332 \times 10^{26} \ [\text{m}]. \tag{6}$$

The time of travel of electromagnetic waves over the distance D_{Hor} equals $T_h \approx 4.33 \times 10^{17}$ [s] corresponding to $T_H \approx 1.375 \times 10^{10}$ [years] and *equals the actually accepted value of the age of the Universe*. Actually, we have no information about the Universe at overhorizontal distances.

3 Grzegorz Hahn's theory of the Bellert's red shift

My recently died son, Grzegorz Hahn (1949–2012), derived the Bellert's red shift adding to the Maxwell equations a small nonlinear term representing *viscosity of the vacuum*

(Hahn 1981). However, differently to the Bellert's derivation which is based on geometrical arguments, G. Hahn's derivation shows the physical properties of the vacuum responsible for the existence of the red shift. Actually, our knowledge of the properties of the quantum vacuum is far to be complete. Nevertheless, many authors accept the idea that the vacuum has the property corresponding to the *viscosity of fluids* (see recent papers (Meng and Ma 2012; Davies 2005). G. Hahn's derivation strongly supports the Bellert's law given by (1) and (5).

The anonymous reviewer suggested that the reference of Hahn (1981) is hard to get. In response, we decided to rewrite the paper of Hahn (1981) using Word editor and make it accessible at: http://www.ire.pw.edu.pl/~ksnopek/GHahn2012.pdf.

Note that G. Hahn argued that the viscosity of space or vacuum (the name quantum vacuum has not been applied) is responsible not only to explain the red shift but also to explain the nature of gravitation. However, this paper is not devoted to describe all ideas presented in Hahn (1981).

4 Planck's radiation law

The famous German physicist derived in the year 1900 the following formulae for the spectrum of a blackbody radiation in thermal equilibrium

$$B_f(f) = \frac{2hf^3}{c^2} \frac{1}{e^{\frac{hf}{kT}} - 1} \ [\text{J/m}^2] \tag{7}$$

where $h = 6.62617 \times 10^{-34}$ [J s] is the Planck's constant, $c = 2.997024 \times 10^8$ [m/s] is the speed of light in vacuum and $k_B = 1.380662 \times 10^{-23}$ [J/K] is the Boltzmann constant.

5 Hypothesis about the origin of CBR

In cosmology we have the notion of the Observable Universe (OU). The WMAP mission gave the evidence that for an observer located in the center of OU, the CBR is isotropic, i.e., the intensity of radiation is equal for all directions. In consequence, we accept that the OU has the shape of a sphere (a ball) with a radius equal to R_{horizont}. This sphere can be regarded as a union of many elementary spherical shells. Let us formulate a hypothesis that the quantum vacuum in any small part of the Universe is a source of a thermal black body radiation with the Planck's spectrum given by (7) with temperature T_{local}. We propose to verify the hypothesis by an experiment described in the next section.

Note that the observer located at the center of OU receives the radiation generated by successive shells. Assuming the validity of Bellert's red shift law, the observed radiation from a given shell is red shifted. Since the red shift is a
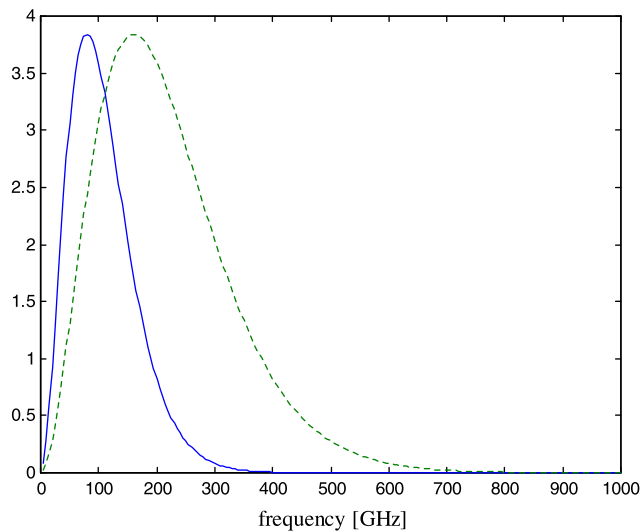
Fig. 1 *Dotted line*: The spectrum of CBR given by the Planck's law for $T = 2.725$ [K] experimentally confirmed with great accuracy by COBE and WMAP (maximum 160 GHz). *Solid line*: The same *red* shifted spectrum emitted from a shell located half the way to the cosmologic horizon
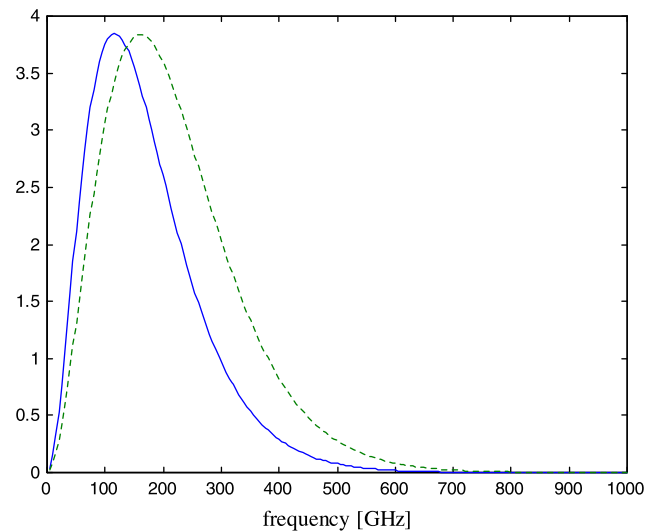
Fig. 3 *Solid line*: The computed global spectrum obtained by summation of 49 *red* shifted spectra emitted from successive shells beginning from the observer to near the cosmologic horizon and assuming $T_{local} = 2.725$ [K]. It differs from the Planck's law of Fig. 1 (*dotted line*) considerably
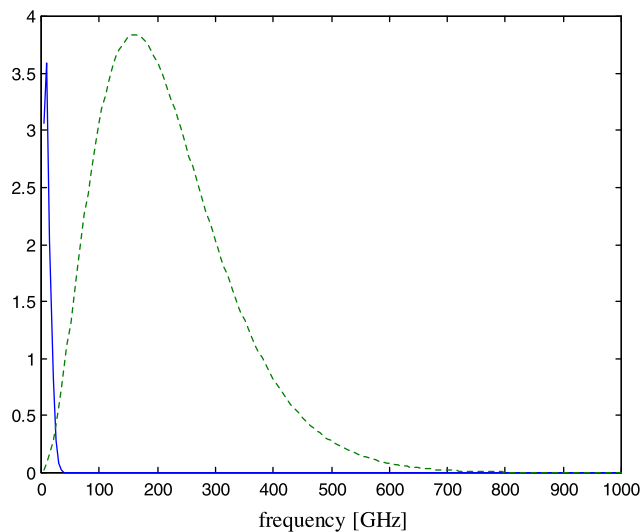
Fig. 2 *Dotted line*: Again, as in Fig. 1, the spectrum of CBR given by the Planck's law for $T = 2.725$ [K] experimentally confirmed with great accuracy by COBE and WMAP. *Solid line*: The same description as in Fig. 1 for the shell located 0.95 the way to the cosmologic horizon
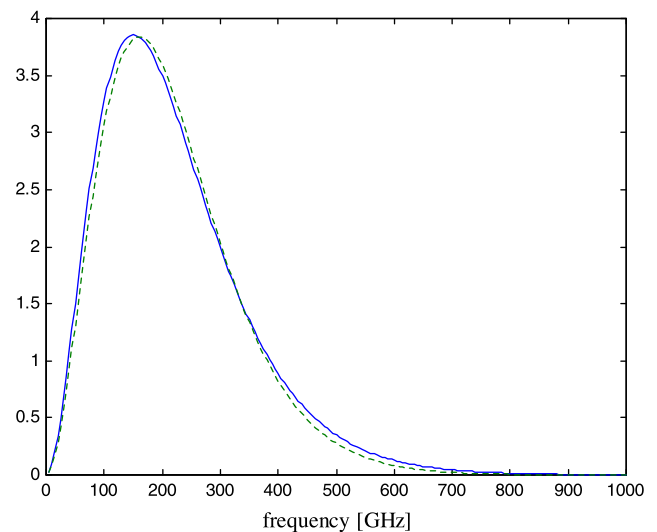
Fig. 4 *Solid line*: The same description as in Fig. 3 assuming $T_{local} = 3.45$ [K]. The coincidence with the Planck law of Fig. 1 is not perfect but fully acceptable from the point of view of confirmation of Bellert's law and the hypothesis that $T_{local} = 3.45$ [K]

function of distance, the observer sees the effect of summation of radiations with different red shifts. Figure 1 compares the red shifted spectrum radiated by the shell located at the half of the radius of OU with the Planck's spectrum measured by COBE and WMAP, $T = 2.725$ [K]. Figure 2 shows the same for a shell located near the horizon (0.95 $R_{horizunt}$). In next calculations, we divided the OU into 49 shells. Figure 3 shows the summation of these 49 spectra calculated using the local temperature $T_{local} = 2.725$ [K] again compared with the Planck's law for the same temperature. Evidently,

the two functions differ considerably. To get coincidence, as shown in Fig. 4, we calculated the sum using a local temperature $T_{local} = 3.55$ [K]. Evidently, assuming the validity of Bellert's red shift theory, the temperature $T = 2.725$ is not the local temperature of the vacuum. Let us denote it T_{global}. The eventual experimental verification of the value of T_{local} (in our calculations 3.55 [K]) will validate Bellert's red shift theory. Let us mention that the coincidence of the two functions in Fig. 4 is not perfect, but fully satisfactory from the point of view of the experimental verification.

All solid line functions in Figs. 1–4 are calculated by insertion into the Planck's law (7) the red shift defined by (5). The vertical scales are corrected to get equal maxima of both functions.

6 Possible experimental verification of the above hypothesis

Let us propose the following experiment. We have to construct a vessel (a kind of a resonator) with walls cooled to nearly zero Kelvin (probably mK). The vessel should be efficiently screened against any outside electromagnetic radiation. The vacuum inside the vessel should be as perfect as the actual vacuum technology is able to deliver. The thermal radiation inside the vessel should be measured by appropriate sensors. The unavoidable noise of the sensors could be eliminated using statistical signal processing methods, as for example have been used in the Boomerang experiment. It should be reminded that Planck derived his formulae using modes of a hypothetical resonator. In free space, the number of modes is infinite. In the proposed experiment, we should have in mind the finite number of modes and eventually calculate corrections.

7 Conclusion

Actually, the Bellert's law given by the Eqs. (1) and (5) has not been tested experimentally. The chance to measure the redshift using a monochromatic source of extremely stable frequency offered by modern atomic clocks is small or unrealistic due to the need to measure the phase difference between the emitted and received monochromatic waves propagating over large distances, for example thousands of kilometers. The Bellert's red shift could be eventually detected using laser interferometers like LIGO (Laser Interferometry Gravitational-Wave Observatory). Actually, no detection of the red shift is reported.

The proposed experiment opens a realistic chance of verification of Bellert's red shift law. We do not need any atomic clock since the source according to the presented hypothesis is offered by the nature in the form of a noise generated by the quantum vacuum. The experiment will check the hypothesis that the quantum vacuum generates thermal noise. Long time ago, I have had the opportunity to discuss with Bellert the problem of experimental verification of his theory. Bellert believed that the observation by Rust (1974) a

supernovae could be interpreted as confirmation of his theory. Nowadays, the observation of 40 various supernovae are interpreted as experimental confirmation, that the Universe is expanding and the observed red shift is the result of the Doppler effect. The goal of this paper is to show that it would be possible to check experimentally the validity of Bellert"s red shift theory. It is not our intention to open here a discussion about eventual consequences. Let us mention the paper (Sant'Anna and Freitas 1998) which introduces to the theory of quantum vacuum the notion of temperature.

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