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The Photon Quantum of Energy of the Observable Universe

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According to the Big Bang theory, cosmological redshift (or more commonly just redshift), denoted here as z_G, is the result of the Universe expansion during the flight of the light from nearby/distant galaxies[1] to Earth. In contrast, Lerner [1, and references therein] reported that the ultraviolet surface brightness data of nearby/distant galaxies, over a very wide redshift range, are in agreement with the hypothesis of the non-expanding (Euclidean) Universe (NEEU). Moreover, a detailed analysis of the gamma ray-burst sources performed by Sanejouand [2] suggests that the observable Universe has been Euclidean and static over the last 12 Gy. To explain the redshift, Premović [3] entertained a possibility that the speed of light emitted by nearby/distant galaxies in NEEU is superluminal. However, if a photon loses part of its energy in transit to Earth, there is a possibility to explain this redshift only by that.

Redshift for nearby galaxies is defined as

$$z_G = (\lambda_G - \lambda)/\lambda \quad \dots (1)$$

where λ_G is the wavelength of light emitted by nearby galaxies and measured by the Earthlings, and λ is the wavelength of light generated by the corresponding source on Earth.

According to elementary physics $\lambda_G = c/\nu_G$ and $\lambda = c/\nu$ where c (= 2.99792×10^5 km sec^{-1}) is the speed of light. Multiplying these formulas with Planck's constant h (= 6.63×10^{-34} J sec) and then the products hc/ν_G and hc/ν plugging into eqn. (1) we get

$$\Delta E = = h\nu - h\nu_G = (z_G hc/\lambda_G) = z_G(h\nu_G) \quad \dots (2)$$

where ΔE is the difference of energy. There are two opposing views about this difference. According to one view, a photon emitted by nearby or distant galaxies traveling through intergalactic space loses energy due to the expansion of Universe or due to other possible causes. In contrast, another view is that there is no energy loss. In this case, the energy difference arises from the fact that observers in the Earth's and galaxy's frames of reference measure different energies of a photon emitted by nearby or distant galaxies. In the following part of this communication, we will only deal with nearby galaxies.

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[1] We define nearby galaxies as those whose redshift z_G is from 0.001 to 0.1 (or $0.001 \leq z_G \leq 0.1$) and distant galaxies with $z_G > 0.1$ [3]. Of course, there is no sharp line between nearby and distant galaxies.

Hubble's law states that there is a linear relationship between the distance D_G of nearby galaxies to Earth and the redshift of light coming from them. It is usually written as follows:

$$D_G = z_G c/H_0 \quad \ldots (3)$$[2]

where H_0 is the Hubble constant which ranges from 50 km sec^{-1} $(Mpc)^{-1}$ to 100 km sec^{-1} $(Mpc)^{-1}$. We are going to use H_0 = 72 km sec^{-1} $(Mpc)^{-1}$ = 2.21×10^{-18} sec^{-1}. (When considering distant galaxies, the Hubble linear relationship (3) cannot be used, and we have to consider a non-linearity option, which is beyond the scope of this communication).

Combining equations (2) and (3) we arrive at

$$\Delta E = z_G h\nu_G = (D_G/\lambda_G)hH_0 \quad \ldots (4).$$

Of course, this equation is only valid for nearby galaxies. To estimate their energy change ΔE using eqn. (4) we have to know their distance to Earth – D_G, provided that λ_G is known. This distance is unknown for most of the nearby galaxies except for a few whose distance is directly measured by the megamaser method. The distance of these "megamaser galaxies" ranges from 62 Mly to 447 Mly [3, and references therein].[3] A graph of their distance *vs.* redshift shows a linear relationship between them with a slope c/H_0 of about 13.65 Gly [3]. This slope corresponds to the above value of H_0 = 72 km sec^{-1} $(Mpc)^{-1}$.

For convenience, we can write eqn. (3) as

$$\Delta E/hH_0 = (D_G/\lambda_G).$$

The wavelength of electromagnetic radiation ranges from about 1.2×10^{-14} nm (the hard-gamma photon wavelength) to about 1.2 m (the far-infrared photon wavelength). Taking into account this wavelength range, a simple analysis shows that for nearby galaxies

$$\Delta E/hH_0 = (D_G/\lambda_G) >> 1.$$

The ratio D_G/λ_G for nearby galaxies must be either a very large rational number or even (likely?) a natural number $\mathcal{N}_G$. So, we write eqn. (4) as

$$\Delta E = \mathcal{N}_G(hH_0) \quad \ldots (5).$$

Hence, $\varepsilon = hH_0$ (= 6.63×10^{-34} J sec × 2.21×10^{-18} sec^{-1}) = 1.5×10^{-51} J is the photon quantum of energy of the observable Universe with a frequency $\nu_\varepsilon = H_0 = 2.21 \times 10^{-18}$ sec^{-1}. Of course, if $\mathcal{N}_G$ is a natural number then the change of the photon energy ΔE is quantized with the photon quantum of energy $\varepsilon = hH_0$ (= 1.5×10^{-51} J).[4]

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[2] The graph of this equation is a straight line with a slope c/H_0 that passes through the origin and it applies to the "megamaser galaxies" (see below) in the Big Bang Universe and also in NEEU[3]

[3] The contribution of the peculiar motion to their redshift is negligible [3].

[4] We will discuss this issue in one of our next communications.

To the photon quantum of energy ε corresponds a momentum $p_\varepsilon = \varepsilon/c = hH_0/c$ (= 1.5×10^{-51} J/3 × 10^8 m) = 5×10^{-60} kg m sec^{-1} and a rest mass $m_\varepsilon = \varepsilon/c^2$ (= 1.5×10^{-51} J/9 × 10^{16} m^2 sec^{-2}) = 1.7×10^{-68} kg. These values are given in Table 1.

Eqn. (5) can also be expressed as follows

$$\Delta E = \mathcal{N}_G(hH_0) = \mathcal{N}_G\varepsilon \ (= \mathcal{N}_G h\nu_\varepsilon).$$

Using the above value for H_0 and after a bit of elementary physics, we find that the wavelength of photon quantum of energy ε is $\lambda_\varepsilon = c/H_0$ = 13.65 Gly which is the Hubble length and $\lambda_\varepsilon/c = 1/H_0$ = 14.4 Gy which is the Hubble time.
For comparison, we also give the values of related Planck units: energy = 1.96×10^9 J, frequency = 1.86×10^{43} sec^{-1}, momentum = 6.53 kg m sec-1 and mass = 2.18×10^{-8} kg.

Table 1. The photon quantum of energy ε and related physical quantities calculated using H_0 = 72 km sec^{-1} $(Mpc)^{-1}$.

Physical quantity	Expression	Value/unit
Quantum of energy	$\varepsilon = hH_0$	1.5×10^{-51} J
Frequency	$\nu_\varepsilon = H_0$	2.21×10^{-18} sec^{-1}
Momentum	$p_\varepsilon = \varepsilon/c$	5×10^{-60} kg m sec^{-1}
Rest mass	$m_\varepsilon = \varepsilon/c^2$	1.7×10^{-68} kg

Previously, Alfonso-Faus [4, and references therein] had reported in another context that a minimum quantum energy (self-gravitational energy of the visible Universe) $E_G \approx kT \approx \hbar H_0$ where $\hbar = h/2\pi$ (= 1.05×10^{-34} J sec and k (= 1.38×10^{-23} J K^{-1}) is Boltzmann constant. This energy is about 10^{-52} J with an equivalent mass of about 10^{-69} kg corresponds to a temperature of about 10^{-29} K. Plugging $h/2\pi$ instead $\hbar$ into $E_G \approx \hbar H_0$ after a calculation we obtain that $2\pi E_G \approx hH_0 \approx 10^{-51}$ J and associated mass of about 10^{-68} kg at 10^{-29} K. At the average temperature of the Universe today approximately of 2.73 K this minimum quantum energy would be about 10^{-23} J.

References

[1] E. J. Lerner, *Observations contradict galaxy size and surface brightness predictions that are based on the expanding universe hypothesis*. Monthly notices the Royal Astron. Soc. (MNRAS) 477, 3185-3196 (2018).
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[3]. P. I. Premović, *Distant galaxies in the non-expanding (Euclidean) Universe: the light speed redshift.* The General Science Journal, May 2020.
[4]. A. Alfonso-Faus, *Fundamental principle of information/to-energy conversion*. Recent Advances in Information Science, Proc. 7th European Computing Conference (EEC'13), June 2013.