# Cosmological Redshift

In the Expanding Universe

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## ABSTRACT

Based on observations, it is clear that universe expands faster than the speed of light. Traveling photons for distances more than several mega parsecs become redshifted, so that photon loses some of its energy. To explain this event, we will try to create a logic in which photons have quasi-expansion-potential to carry the wave by redshift process.

We will start with studying the energy density functions and modeling the vacuum as a standing wave. Later on, we will be studying about the functions of distribution of photons produced from the black body box to compare the energy densities of vacuum and photons with the logic of heat transfer as radiation. After we have shown all the cases about black body radiation, we will try to build up a conserved function dependent to the energy density of vacuum that results Planck's distribution. We will see that there is an expansion energy that carries the thermodynamic energy. Contrary to popular belief, this new energy has no relation with the heat or thermodynamic energy but it only gives a motion to it. We will see a logarithmic energy that forces photons to move at the speed of light. This quasi-potential must be responsible for the cosmological redshift of light because it forces photon to move at the speed of light as it changes its medium.

# INDEX

# INFORMATION

We can start with the black body radiation because; it is the initial point for quantum mechanics. It is independent from chemical interactions and potentials, for this reason, we can start with black body box to understand the energy content of the black body radiation. The first important equation of the quantum mechanics is the ***Planck Law***, which gives the spectral radiance per angular frequency per unit area with respect to the temperature.

$$B_\omega(\omega, T) = \frac{\hbar\omega^3}{4\pi^3c^2}\frac{1}{exp(\frac{\hbar\,\omega}{k_B\,T})-1}$$

Then by integrating the Planck law at every wavelength and every direction, there is the ***Stefan-Boltzmann law***, which gives the total power of a surface area $A$ at temperature $T$.

$$P = A\frac{\pi^2{k_B}^4T^4}{60\hbar^3c^2}$$

Afterwards, to find the ***radiation constant*** which is the total internal energy of a volume $V$ at temperature $T$, we can multiply Stefan-Boltzmann law with $4/c$.

$$U = V\frac{\pi^2{k_B}^4T^4}{15\,\hbar^3c^3}$$

Because we will compare the energy density of black body box and photons created from the box, we need to find the total radiated light from the box until temperature drops to zero. If we ask how temperature decreases with time;

$$U(t) = U_0\,exp(-x\,t) \;\rightarrow\; \frac{d}{dt}(U) = Power = \sigma T^4 = (-A\,\frac{\pi^2\;{k_B}^4\,T^4}{60\,\hbar^3\,c^2}) = \frac{d}{dt}(\frac{\pi^2\;{k_B}^4\,T^4}{15\,\hbar^3\,c^3}V)$$

Therefore, we should write temperature's time dependency as;

$$\frac{dT}{dt} = -\frac{A\,\sigma\,T}{4\,V\,a} = -\frac{A\,\sigma\,T}{4\,V\,\sigma\frac{4}{c}} = -\frac{A\,c\,T}{V\,16} \quad and \quad T = T_0 * exp(-\frac{c\,A\,t}{16\,V})$$

Than what will we do is simply use temperature in the Planck's law because we need total radiated light until our box temperature becomes zero.

Function of the ***total radiated energy per frequency*** of the black body box;

$$\int_0^\infty A\frac{\hbar\omega^3}{4\pi^2c^2}\frac{dt}{exp(\frac{\hbar\omega}{k_BT}exp(\frac{cAt}{16\,V}))-1}$$

As we can see integral is only time dependent so, we can write it easily like;

$$\int_0^\infty \frac{dx}{exp(\beta\exp(\gamma x))-1} \quad most\ simplest\ form \rightarrow \quad \int_\alpha^\infty \frac{dx}{exp(\exp(x))-1}$$

Because this integral has no known solution, we need to write it as an empirical function;

$$= V\frac{4\hbar\omega^3}{\pi^2c^3} * \frac{1}{exp(\frac{\hbar\omega}{k_BT})-1} * \frac{1}{1+\frac{\hbar\omega}{k_BT}} \quad more\ precisely \quad = V\frac{4\hbar\omega^3}{\pi^2c^3} * \frac{1}{exp(\frac{\hbar\omega}{k_BT})-1} * \frac{1,025}{1,04+\frac{\hbar\omega}{k_BT}}$$

For the energy density equivalence we need to write the function of photon's energy density dependent to angular frequency $\omega$;

$$energy\ of\ the\ photon\ is\ \hbar\omega \quad and\ volume\ of\ photon\ is\ \lambda^3 = {c^3}/{\nu^3} = {8c^3\pi^3}/{\omega^3}$$

Finally, thermodynamic energy density of the photon is;

$$\frac{\hbar\omega}{\lambda^3} = \frac{\hbar\omega}{8\pi^3c^3/\omega^3} = \frac{\hbar\omega^4}{8c^3\pi^3}$$

So, the energy density equivalence function;

$$V\frac{\hbar\omega_0^4}{8c^3\pi^3} = V\frac{\pi^2\;{k_B}^4T^4}{15\,\hbar^3c^3} \quad and\ from\ this\ relation \rightarrow\ \hbar\omega_0 = \sqrt[4]{\frac{8\pi^5}{15}}\;k_BT \quad (k_BT\ \approx 0.279777\,\hbar\omega_0)$$

Even if we have written an empirical function, we should have to use numerical analysis for the integrals to get better results.

## METHODOLOGY

Unlike the current theories we are assuming heat is standing and it is not simple as distributed photons. Because, the energy density of photons is too low when we compared with the box. The black body box has no chemical energy or interaction except the heat inside it and it is dark enough to stop the light even if it is infinitely thin or small. Moreover, the real reason for the assumption comes from the particle or density property of light, we will assume that the heat inside the box gains kinetic energy with the expansion or simply decreasing the photon's energy density. So, we are modeling the internal thermodynamic energy or simply heat in the box repels itself and gains kinetic energy until its speed reaches to the speed of light. Therefore, we have to split the energy terms into two; all of us know first one as thermodynamic energy and the second one is quasi-energy that carries the first.

Before the radiation starts, the internal energy inside the box is equal to energy of radiated light from the box, so, all functions have same amount of thermodynamic energy.

$$V\frac{\hbar\omega^4}{8c^3\pi^3} = V\frac{\pi^2 {k_B}^4 T^4}{15\,\hbar^3 c^3} = \int_0^\infty \left( \int_0^\infty A\frac{\hbar\omega^3}{4\pi^2c^2} * \frac{dt}{exp\left(\frac{\hbar\omega}{k_BT} exp\left(\frac{cAt}{16\,V}\right)\right)-1} \right) d\omega$$

$$\approx \int_0^\infty V\frac{4\hbar\omega^3}{\pi^2c^3} * \frac{1}{exp\left(\frac{\hbar\omega}{\hbar\omega_0 * 0,28}\right)-1} * \frac{1.025}{\frac{\hbar\omega}{\hbar\omega_0 * 0,28}+1.04} d\omega$$

Because we just stuck energy term as thermodynamic energy in all physics, all of our functions are all based on heat exchange process and we do not think the process of carrying the energy. We know amount of energy or heat in universe is conserved, however, we do not know what kind of energy carries the thermodynamic energy as light or wave (*and we call it **dark energy** because its source is unknown*). For this reason, we will create quasi-energy to radiate the heat as light. Our new energy term the quasi-energy must be a massless energy because, it also carries thermodynamic energy and it must be dependent to energy density that can be written as a standing wave with angular frequency $\boldsymbol{\omega}$.

We are not driving a function in this part; we are just trying to understand relation between the first and final conditions. To understand the process, we have to look at the initial and final conditions;

We have initially one-wavelength photons; and finally distributed photons; which have kinetic energy of;

$$V\frac{\hbar{\omega_0}^4}{8c^3\pi^3} \rightarrow V\frac{4\hbar\omega^3}{\pi^2c^3} * \frac{1}{exp\left(\frac{\hbar\omega}{\hbar\omega_0 * 0,28}\right)-1} * \frac{1,025}{1,04+\frac{\hbar\omega}{\hbar\omega_0 * 0,28}} + V\frac{\hbar{\omega_0}^4}{16c^3\pi^3}$$

$$Kinetic\ energy\ of\ photon\ {}^1/_2\, mv^2 = {}^1/_2\, \hbar\omega_0\ \ is\ half\ of\ the\ thermodynamic\ energy\ \hbar\omega_0 = mc^2$$

As we know, heat always becomes light no matter what the initial energy density. Therefore, we need to find a conserved function that can always create kinetic energy by decreasing the density of thermodynamic energy. If we want to normalize the thermodynamic energy;

We have initially one-wavelength photon; and finally distributed photons; which have kinetic energy of;

$$\hbar\omega_0 \rightarrow \frac{32\pi\hbar\omega^3}{{\omega_0}^3} * \frac{1}{exp(\frac{\omega}{\omega_0 * 0.28})-1} * \frac{1.025}{\frac{\omega}{\omega_0 * 0.28}+1.04} + \frac{\hbar\omega_0}{2}$$

If we want to get a constant kinetic energy per constant thermodynamic energy:

We have constant energy density; distributed constant density photons; constant kinetic energy;

$$\frac{\hbar\omega_0}{\hbar\omega_0} \rightarrow \frac{32\pi\omega^3}{{\omega_0}^4} * \frac{1}{exp(\frac{\omega}{\omega_0 * 0.28})-1} * \frac{1.025}{\frac{\omega}{\omega_0 * 0.28}+1.04} + \frac{\hbar\omega_0}{2\hbar\omega_0}$$

When we normalize the energies we can see that there is always a produced kinetic energy to move the light and we can see the distribution is always the same around the point $\frac{\hbar\omega}{k_BT}$.

If everything is started around the initial temperature or angular frequency as $\omega_0$, we should see the logarithmic energy function gives that relation. We can see the exponential decrease of temperature and at the same time exponential energy density decrease. For one photon, it's mass and kinetic energy must be proportional, however, energy density change with initial $\omega_0$ and distributed $\omega$ part must be logarithmic because distributed frequency is dependent to initial frequency so, it is dependent to itself and its integral is logarithmic.

Let's assume expansion energy of photons is just a function that is only dependent to $\omega$. ($f(\omega)$)

Photon number times expansion energy; distributed photons number times energy; which have kinetic energy of;

$$V\frac{{\omega_0}^3}{8c^3\pi^3} * f(\omega_0) = \int_0^\infty V\frac{4\omega^2}{\pi^2c^3} * \frac{f(\omega)}{exp(\frac{\omega}{\omega_0 * 0.28}) - 1} * \frac{1.025}{\frac{\omega}{\omega_0 * 0.28} + 1.04} d\omega + V\frac{\hbar{\omega_0}^4}{16c^3\pi^3}$$

If we normalize the thermodynamic and kinetic energy, we can write the function as:

$$\frac{f(\omega_0)}{\omega_0} = \int_0^\infty \frac{32\pi\omega^2}{{\omega_0}^4} * \frac{f(\omega)}{exp(\frac{\omega}{\omega_0 * 0.28}) - 1} * \frac{1.025}{\frac{\omega}{\omega_0 * 0.28} + 1.04} d\omega + \frac{1}{2}$$

If we divide all parts into frequency of photon, our energy function becomes logarithmically dependent to frequency. Therefore, there must be a linear multiplier of the thermodynamic energy inside the expansion energy of photon. Now we can understand that the function of the expansion energy has linear and logarithmic parts and we need to write energy function.

$$f(\omega) = (c_1 * \hbar\omega) * (log_b(c_2 * \hbar\omega))$$

As we can understand, logarithmic quasi-energy gives an infinite value in both ends. Therefore, we have to write the energy function by changing the angular frequency.

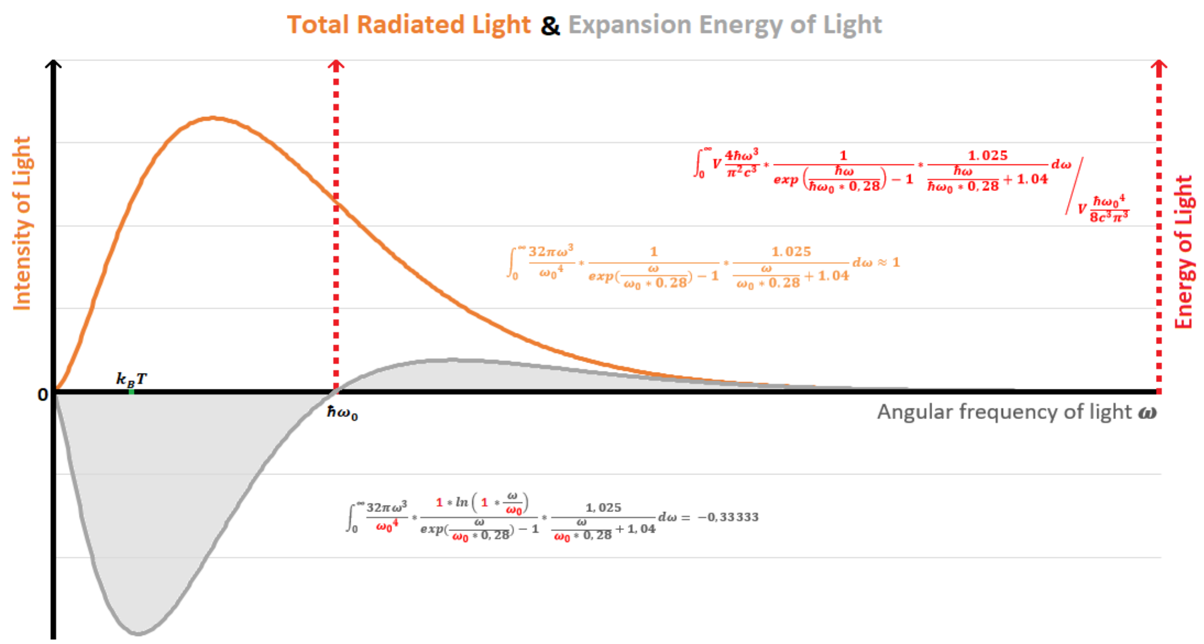
The energy of one photon; and finally distributed photons times the energy of photons; kinetic energy;

$$f(\omega) \to (c_1 * \hbar\omega_0) * (log_b(c_2 * \hbar\omega_0)) = \int_0^\infty \frac{32\pi\omega^2}{{\omega_0}^3} * \frac{(c_1 * \hbar\omega) * (log_b(c_2 * \hbar\omega))}{exp(\frac{\omega}{\omega_0 * 0.28}) - 1} * \frac{1.025}{\frac{\omega}{\omega_0 * 0.28} + 1.04} d\omega + \frac{\hbar\omega_0}{2}$$

We can easily say that logarithm's base can easily be equal to $e$ which is a natural logarithm $ln$ and with it we should calculate the constants $c_1$ and $c_2$. Moreover, we can make some simplifications because of the $\hbar\omega_0$ dependency. We should start with a normalized function that is division of energy densities of heat and produced light. Whatever we take the initial temperature or the frequency $\omega_0$ it becomes always $1$.

$$\int_0^\infty \frac{32\pi\omega^3}{{\omega_0}^4} * \frac{1}{exp(\frac{\omega}{\omega_0 * 0.28}) - 1} * \frac{1.025}{\frac{\omega}{\omega_0 * 0.28} + 1.04} d\omega \approx 1$$

Because we have empirical function we need to calculate the integral numerically. When we calculate logarithm of produced light frequency $\omega$ with respect to initial heat frequency $\omega_0$:



Now, we will compare all the radiated lights angular frequency with initial frequency $\omega_0$. Therefore, our graph shows the function of;

$$\int_0^{\infty} \frac{32\pi\omega^3}{{\omega_0}^4} * \frac{c_1 * ln\left(\frac{\omega}{\omega_0}\right)}{e^{\frac{\omega}{\omega_0 * 0.28}} - 1} * \frac{1.025}{\frac{\omega}{\omega_0 * 0.28} + 1.04} d\omega = -\frac{1}{3}$$

Now we can speak about the $c_1$ and $c_2$. If we can create energy in every case as we did in functions, we do not need to have a constant inside the logarithmic part.

$$c_1 * ln\left(c_2 * \frac{\omega}{\omega_0}\right) \quad is\ equal\ to \quad c_1 * \left( ln(c_2) + ln\left(\frac{\omega}{\omega_0}\right)\right)$$

We do not need to have linear energy difference inside function. We can see that we do not need $c_2$, because we do not have any constant linear energy difference inside the equations, so we can take $c_2$ as $1$ and $ln(1) = 0$.

$$Expansion\ energy\ of\ photon = c_1 * ln\left(\frac{\omega}{\omega_0}\right) = \quad c_1 * (\ ln(\omega) - ln(\omega_0))$$

We must transform this function to real energy density function or just one photon's energy transformation function. We can create energy by changing the wavelengths of the photons, while the thermodynamic energy in box is constant. If we have only one photon we should find its energy change with distribution or if we have a volume, we should find its expansion energy function.By taking an average expansion energy of all distributed photons we have find a constant which is equal to $-1/3$. It must be equal to $-1/2$, because it is the difference between the thermodynamic energy and the kinetic energy of the particles. Therefore, $c_1$ is just $1.5$ and the function becomes like;

$$1.5 * \hbar\omega * \ ln\left(\frac{\omega}{\omega_0}\right)$$

Because we have energy function which is logarithmically dependent to wavelength change, there must be a function with respect to speed of light to give that photon to kinetic energy. For normalized function which has constant thermodynamic and quasi-expansion energy;

$$\int_0^{\infty} \frac{32\pi\omega^3}{{\omega_0}^4} * \frac{1.5 * ln\left(\frac{\omega}{\omega_0}\right)}{e^{\frac{\omega}{\omega_0 * 0.28}} - 1} * \frac{1.025}{\frac{\omega}{\omega_0 * 0.28} + 1.04} d\omega = -0.5 \qquad (normalized\ function)$$

And for black body box, total kinetic energy produced from box;

$$-V\frac{{\omega_0}^3}{8c^3\pi^3} * 1.5 * \hbar\omega_0 * ln(\omega_0) \ + \ \int_0^{\infty} V\frac{4\omega^2}{\pi^2 c^3} * \frac{1.5 * \hbar\omega * ln(\omega)}{e^{\frac{\hbar\omega}{\hbar\omega_0 * 0.28}} - 1} * \frac{1.025}{\frac{\hbar\omega}{\hbar\omega_0 * 0.28} + 1.04} d\omega$$

We can give simple example about expansion energy exchange of heat and light, if we take an average of quasi-expansion energy;

$$1.5 * \hbar\omega_0 * ln(^{\omega}/_{\omega_0}) = -\hbar\omega_0/2 \quad so;\ ln(^{\omega}/_{\omega_0}) = -1/3 \quad and\ (^{\omega}/_{\omega_0}) = 0.716531311$$

This number $0.716531311$ is the frequency of average quasi-energy of photons. This means that, if we have initially one photon that has frequency as $\omega_0 = 1$ then it can decrease its energy and frequency by $\%28,34$ to gain the speed of light. We are using the potential energy for heat to become light and this potential energy must work for the case when the ***speed of light changes*** with respect to our first reference point. So, wavelength of photon increases as $\lambda/\lambda_0 = 1.39561242$ and volume expands as; $V/V_0 = \lambda^3/\lambda_0^3 = 2.7182818$ at every gained speed of speed of light. So, we can say that one photons redshift formula is;

$$1 + z = e^{(v/3c)} \quad or\ simply \quad z = e^{(v/3c)} - 1$$

As we can understand, for black body box all the internal energy must be radiated as photons so, there is no lose for thermodynamic energy. However, for cosmological redshift, we have initially created photons at source and only logic becomes logarithmically losing of mass, kinetic and quasi-potential energy at the same time by changing the medium of light. As we can see, the quasi-expansion-potential forces photon to move at the speed of light.

## MY COMMENTS

As we can understand this new quasi-energy must play a very important role for the expansion of the universe. Even if I have written this article only about cosmological redshift and its formulation, I did not want to write everything about it. I'm also trying to work about its particle property in a different mechanical way. However, due to the lack of mathematics I'm suffering from the series functions of infinitely many particle systems and explaining this potential in a particular way.

The problem is not the mathematics that we used in this article but, the assumptions. I am thinking that the mechanics of the physics must be very different than our expectations because, our current mechanics cannot explain all the physics. If you interested in my ideas, you can look for my another article and I am also searching for help about its mathematics. Maybe you can help me about its mathematical derivation.

http://vixra.org/author/kadir_aydogdu
http://vixra.org/abs/1809.0455 Dark Heat

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