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Inverse and Exponential Dependences of Energy on The Earth-Galaxy Distance.

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In one of our previous communications [1], we emphasized that there are two general possibilities for the loss of energy of photons traveling through intergalactic space. According to the first, the photon energy would decrease inversely proportional to the photon traveling distance in the intergalactic space distance or mathematically expressed

$$E \propto 1/d.$$

The second is that this energy would decay exponentially or mathematically speaking

$$E = E_0 e^{-\alpha d}$$

where E_0 is the initial photon energy, E is the photon's energy after traveling a distance d and α is the rate of energy loss. In both of these cases, it is assumed that the photons lose energy owing to some known or unknown process. Let us consider the first possibility, then the second one.
We found that only one possible equation in which appears $E \propto 1/d$ and that is

$$E = \kappa E_0/(d + \kappa) \quad \ldots (1).$$

where κ is a temporary, arbitrary constant expressed in Gly. If $d \rightarrow 0$ then $E \rightarrow E_0$ and if $d \rightarrow \infty$ then $E \rightarrow E_0$.

Eqn. (1) after a bit of algebra can be written as

$$E/E_0 = 1/[(d/\kappa) + 1] \quad \ldots (2).$$

Denote with λ_0 and λ the corresponding wavelength of the photon. Substituting into this equation E/E_0 with λ_0/λ[1] and after a bit of algebra, we find

$$(\lambda/\lambda_0) - 1 = d/\kappa.$$

The cosmological redshift of the photon light $z = (\lambda/\lambda_0) - 1$, we then write the above equation as

[1] From elementary physics, we know that $E/E_0 = h\nu_0/h\nu$. Multiplying the denominator and numerator of the right side of this formula with the inverse of the speed of light c we get $E/E_0 = (h\nu_0/c)/(h\nu/c)$. This physics also shows that $(\nu_0/c)/(\nu/c) = \lambda/\lambda_0$.

$$z = d/\kappa.$$

If we substitute d with a distance between the Earth and galaxy D, that equation takes the following form

$$z = D/\kappa \quad \ldots (3).$$

This formula is equivalent to Hubble's linear redshift-distance relation (z = constant × D) and it is only valid is valid for small redshifts or z << 1. Therefore, eqns. (1 - 3) are valid for this z-limit. This Hubble's relation is usually expressed as

$$cz = H_0 D \quad \ldots (4)$$

where H_0 [say about 72 km $sec^{-1} \times (Mpc)^{-1}$] is the Hubble constant and D is the distance between the Earth and a nearby galaxy.[2] Combining this equation and eqn. (3), we get

$$\kappa = c/H_0.$$

In Hubble terminology, c/H_0 represents the Hubble distance $D_H \approx 14$ Gly. Therefore, we have

$$\kappa = D_H \approx 14 \text{ Gly}.$$

The distance D_H represents, roughly speaking, the radius of the observable Universe. For $H_0 = 72$ km sec^{-1} $(Mpc)^{-1}$, we find that $D_H \approx 14$ Gly. This is the limit of the observable Universe or our observable cosmic horizon.

We now write eqn. (2) as

$$E/E_0 = 1/[(D/D_H) + 1] \quad \ldots (5).$$

The direct distance measurement method, the "megamaser" method, has demonstrated its capability for precise distance measurement of nearby galaxies. It appears this method is suitable for very few of these galaxies - "megamaser" galaxies. For the present case, we select five of these galaxies whose redshift z and distance D from the Earth (determined by this method) are known (Table 1) and their peculiar motion is negligible.

[2] We define nearby galaxies as those whose redshift z is from 0.001 to 0.1 (or $0.001 \leq z \leq 0.1$) [1,2].

Table 1. "Megamaser" galaxies with their z, D {for details see [5]} and E/E_0 values.

Name of galaxy	Redshift z	D (Gly)][1]	E/E_0*
NGC 1052	0.004930	0.065	0.995
UGC 3789	0.010679	0.162	0.99
NGC 6323	0.02592	0.349	0.975
NGC 5765B	0.02754	0.411	0.97
NGC 6264	0.03384	0.447	0.97

*Calculated using eqn. (5).

Plugging into eqn. (5) given the above values of D and D_H, we calculated E/E_0 corresponding to these galaxies, Table 1. Their arithmetic mean is $E/E_0 = 0.97\ (Gly)^{-1}$. In other words, on average their final energy is only about 3 percent of their initial photon energy.

An example of the second case is the tired-light energy loss of photons traveling through intergalactic space. In this type of energy loss,

$$E = E_0 e^{-\beta d} \quad \dots (6)$$

where β is the energy attenuation coefficient or the rate of energy attenuation [3, and references therein].

Within the Hubble law

$$\beta = H_0/c = 1/D_H = 1/\kappa.$$

As $E/E_0 = \lambda_0/\lambda$ then substituting d with D (a distance between the Earth and galaxy), and after a bit of algebra eqn. (6) becomes

$$\lambda/\lambda_0 = e^{\beta D}.$$

Subtracting 1 from both sides of this expression and since $z = (\lambda/\lambda_0) - 1$, we arrive after some rearrangement at

$$1 + z = e^{\beta D}.$$

Applying the natural logarithm to both sides of this equation we get

$$\ln(1 + z) = \beta D \quad ... (7).$$

Having in mind that $1/\beta = \kappa$, eqn. (3) can be written, after a bit of algebra, as follows

$$z = \beta D \quad \dots (8).$$

It follows from these two last equations that

$$\ln(1 + z) = z.$$

In mathematics and cosmology, it makes no sense or it is nonsense.

Of course, eqn. (8) is equivalent to Hubble's redshift-distance relation.
In conclusion, we propose that Hubble's linear redshift-distance relationship, given by eqn. (4), is a result of the inverse relation between a redshift and the Earth-nearby galaxy distance given by eqn. (1) or eqn. (2).

References

[1] P. I. Premović, *The cosmology redshift and the loss of energy*. The General Science Journal, November 2022.
[2] P. I. Premović, *Distant galaxies in the non-expanding (Euclidean) Universe: the light speed redshift.* The General Science Journal, December 2021.
[3] P. I. Premović, *The tired-light hypothesis: Derivations of Basic Relations*.
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[4] P. I. Premović, *The expanding Universe vs. tired-light Universe: the rate of energy attenuation and the cosmological distance*. The General Science Journal, December 2022.
[5] P. I. Premović, *The age of the "megamaser" galaxies in the Big Bang Universe*. The General Science Journal, December 2021.