Lorentz effects on photon travel time as a function of cosmic redshift

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ABSTRACT: When the Lorentz factor squared is multiplied by the ΛCDM calculated distance, a proposed proper distance and lookback time are found.

INTRODUCTION

Rajendra Gupta's interpretation of the 'impossible early Universe' problem (see [Gupta 2023] and references therein) led him to propose solutions involving an 'old' Universe which include the concept of 'tired light', where light energy is lost to some unknown energy 'sink'. In this paper, the author uses Einstein's theory of special relativity to demonstrate that such a 'sink' is unneccessary. The Universe is herein proposed as older than current estimates.

ASSUMPTIONS

In this communication, we will use the following assumptions:

1) Einstein's law of special relativity is accurate.
2) The Universe is 'flat' or Euclidean at large scale [Huterer 2023]. It is therefore unbound in *xyz*.
3) The Universe displays Hubble flow throughout.
4) Einstein's law of general relativity is accurate. Its effect on time dilation will be treated as negligible.
5) Mass density is sufficiently low that we can treat the speed of light *c* as its vacuum value.

Proper distance r gives photon travel time t_λ from source to detector, irrespective of their radial recession rate v:

$$t_\lambda = \frac{r}{c} \tag{1}$$

Hubble flow H is defined as:

$$H = \frac{v}{r} \tag{2}$$

In the distance-ladder method, r is (imperfectly) found *inter alia* via luminosity measurement of the light source, often as a connected series of different 'standard candles' [Reiss 2024].

Recession v of detector from source is more precisely found, from the cosmic redshift z:

$$v = \left(\frac{(z+1)^2-1}{(z+1)^2+1}\right)c \tag{3}$$

The present analytic best-fit for observed H_{obs} is the ΛCDM model, expressed here in its minimum flat-Universe form:

$$H_{obs} = H_0\sqrt{\Omega_{\lambda_0}a^{-4} + \Omega_{b_0}a^{-3} + \Omega_{c_0}a^{-3} + \Omega_\Lambda} \tag{4}$$

Where $a = 1/(z+1)$. The reader is referred to any one of several contemporary textbooks (e.g., [Ryden 2017] [Huterer 2023]) for the meaning of the other terms in Eq. (4). We will use the Ω values from Planck [Planck 2020] and Reiss et al.'s H_0 = 73.0 km/sec/Mpc [Reiss 2024].

Combining Eqs. (2)-(4) gives:

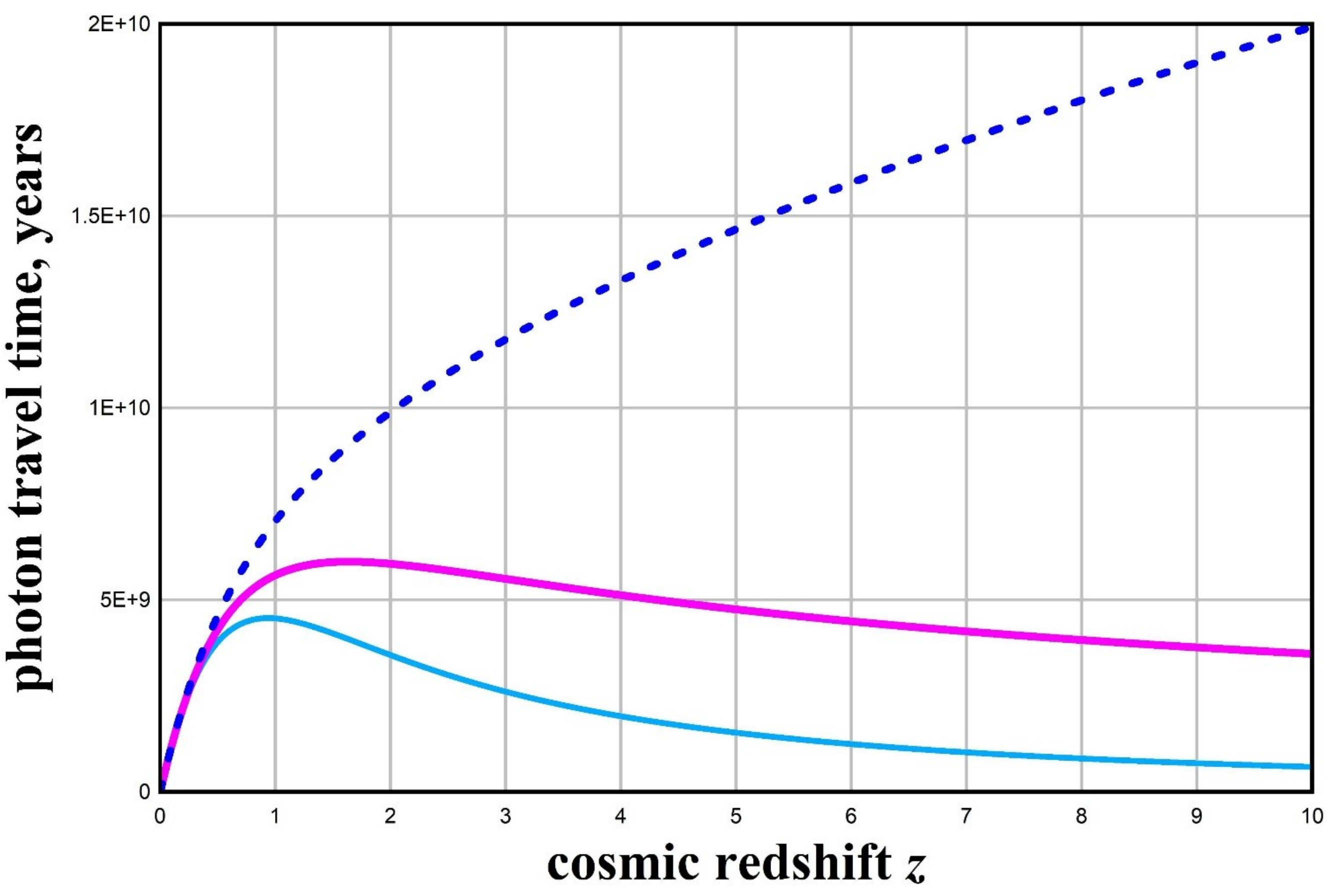
$$r_H = \left(\frac{(z+1)^2-1}{(z+1)^2+1}\right)\frac{c}{H_{obs}} \tag{5}$$

Where r_H is the ΛCDM calculated distance from source to detector using H_{obs}. Looking at Figure 1, when we plot r_H vs. z, we get the blue-green line. For $z < 0.5$ there is positive correlation. However, for $z > 1$, there is negative correlation, which is inconsistent with Eq. (2). Special relativistic effects must be considered:

$$r = r_H\gamma \tag{6}$$

Where γ is the Lorentz factor:

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \tag{7}$$



When we use Eq. (6), we get the pink line, which *still* gives negative correlation above $z = 1.5$. As Lorentz contraction operates in space and time, and we observe through both, the present author suggests that dilation in both of these must be taken into account, as the Lorentz factor squared:

$$r = r_H \gamma^2 \tag{8}$$

Equation (8) is shown in Figure 1 as a dotted line. It gives a monotonic increase. This is the proposed proper distance *r* as a function of *z*. The abscissa is given in light-years and is thus the photon travel time t_λ, and lookback $(t_0 - t)$. Its value at *z* = 10 is 20 Gyr. This exceeds *Planck*'s estimate (13.8 Gyr), at a much higher *z* (= 1089). Using Eq. (4), at z = 20, t_λ = 27.5 Gyr; at z = 30, t_λ = 33.4 Gyr.

REFERENCES

Gupta, R. P. JWST early Universe observations and ΛCDM cosmology. *Month. Notic. Roy. Astron. Sci*. 524, 3385-3395 (2023); https://doi.org/10.1093/mnras/stad2032

Huterer, D. *A course in cosmology.* Cambridge University Press (2023); https://doi.org/10.1017/9781009070232

Planck Collaboration. Planck 2018 results. *Astron. & Astrophys*. **641**, A1 (2020); https://doi.org/10.1051/0004-6361/201833880

Ryden, B. *Introduction to cosmology, second edition*. Oxford Press (2017); https://doi.org/10.1017/9781316651087