THE UNIVERSE MAY BE MORE THAN A TRILLION YEARS OLD

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Abstract: When Lorentz contraction is included into travel time, the Universe is found to be much older than present estimates suggest.

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 much older than current estimates, including Gupta's.

With the 'flat universe' assumption [Huterer 2023] and the Cosmological Principle [Ryden 2017], we can construct a sparsely populated model 'universe' which behaves similarly to our actual Universe. This 'universe' consists of an infinite Cartesian grid of hydrogen atoms, spaced at an arbitrarily large distance, e.g. one trillion light-years on a side. These atoms' mutual gravitational attraction is so low that they can be held stationary. The remainder of this 'universe' is empty, having no other energy density ε from photons, neutrinos, or any other form of equivalent rest mass. 'Vacuum energy' density is held at zero.

We occupy some sort of life-sustaining vessel within this 'universe', and add a light-emitting source, e.g. a star, at some large proper distance r. This star can be either at fixed r, or can be moving away from us at a radial speed v_r.

If the star isn't moving away from us, the elapsed time t_m or *lookback* upon our reception of its light is simply given:

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

Where t_λ is photon travel time, and c is the speed of light. According to Einstein, the speed of light doesn't change, so light's travel time t_λ upon emission doesn't change for any one r, regardless of how fast the star is moving away.

In our reference frame, if the star is moving away from us, elapsed time t_m in *its* reference frame *does* change, by the Lorentz factor γ:

$$\gamma = 1/\sqrt{1 - v_r^2/c^2} = 1/\sqrt{1 - \beta^2} \tag{2}$$

Where $\beta = v_r/c$. This gives:

$$t_m = \gamma t_\lambda = \frac{r}{c\sqrt{1-\beta^2}} \tag{3}$$

Time dilation γ in such a model 'universe' is independent of the proper distance *r* at the time of emission, and only depends on the recession rate v_r. This concept applies to the actual Universe in which we live. In our Universe, however, γ is distance-dependent, due to Hubble flow. The light source's recession rate v_r is connected to the cosmic redshift *z* by the Doppler shift $z' = z + 1$:

$$z' = z + 1 = \sqrt{\frac{1+\frac{v_r^2}{c^2}}{1-\frac{v_r^2}{c^2}}} = \sqrt{\frac{1+\beta_{z'}}{1-\beta_{z'}}} \tag{4}$$

The function $\beta_{z'}$ vs. z' isn't readily found by this author at least, so instead we solve Eq. (4) for z' by numeric convergence of $\beta_{z'}$. We can then connect γ with the z' domain by inserting $\beta_{z'} = \beta$ into Eq. (2).

For $z > 10$, γ vs. z' approaches linearity:

$$\gamma = \frac{z'}{2} \tag{5}$$

For $z \leq 10$, the author found an adequate analytic approximation for γ as a third-order ln-ln polynomial. We will nonetheless use Eqs. (2) and (4), as they give better precision. Some relevant values of γ are given in Table 1.

Table 1. Lorentz factor γ vs. cosmic redshift z.

Cosmic redshift z	Lorentz factor γ	$\gamma/(z+1)$
0.1	1.0045	0.913
0.5	1.083	0.722
1	1.250	0.625
2	1.667	0.555
3	2.125	0.531
4	2.600	0.520
5	3.083	0.514
6	3.571	0.510
7	4.062	0.508
8	4.556	0.506
9	5.050	0.505
10	5.546	0.504
11	6.042	0.503
12	6.540	0.503
13	7.036	0.503
14	7.533	0.502
15	8.031	0.502

The Lorentz factor γ is a special effect. This means that $\gamma t_\lambda = t_m$ is the same if source and observer switch places. Lorentz-adjusted lookback thus constitutes elapsed cosmic time since emission. For example, the recently found galaxy JADES-GS-z13-0 [Curtis-Lake 2023] has a cosmic redshift $z = 13.2$, so from Table 1 it's older than its photon travel time by a factor of seven. At the epoch of last scattering, $z = 1089$ [Bennett 2003], so from Eq. (5) the Universe was older by a factor of 545. One current estimate [Planck 2020] of Universal age at last scatter is around 13.3 billion years ago. If this age is based solely on photon travel time, then Lorentz contraction indicates that the last-scatter Universe was actually much older: 7.25 trillion years ago. Gupta's estimate is somewhat lower: 0.026 trillion years ago.

Equations (2) – (5) suggest that $v_r < c$ for all $r \to \infty$. In other words, there may not be any place in the Universe where rest mass is moving away from us faster than the speed of light. Indeed, solution of Eq. (3) for $v_r > c$ gives an imaginary γ. This would then require an imaginary t_λ and negative t_m to give a real result. The present author is unsettled by such interpretation, as it appears to be inconsistent with both the Cosmological Principle, and the second law of thermodynamics.

The author would also like to touch upon the subject of time dilation due to general relativity. It arises from increased ε as $z^{-1} \to 0$. Such an effect was undoubtedly significant in the very early Universe. Its effect on the observable Universe, to my knowledge, has yet to be numerically expressed.

References:

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