Distance Is Speed Times Time Only Where Space Does Not Stretch While the Light Travels

— at redshift 0.01 the four distances lie within 0.987755 to 1.007608 times cz/H_0, and at redshift 1 they split to 0.382303 to 1.529213 times — the separator is how much the universe stretched while the light was on its way (the redshift) — [Paper 779]

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— From thinking to syncing. —

Abstract

It is natural to take the distance to a far object as the speed of light times the travel time. But the universe stretches while the light travels.In an expanding universe, the relation between age and distance, and how many "distances" a single object splits into, are counted.No new theorem or law is claimed. First, the age is close to $1/H_0$ but not equal to it——against a Hubble time of 14.507303 billion years, the age is 13.790752 billion years ($H_0 t_0 = 0.950608$) (Section 2). **Second, the radius of the observable universe is 3.345573 times age times the speed of light——the radius is 46.137972 billion light-years** (Section 2). **Third, even a matter-only universe makes it 3 times——$H_0 t_0 = 0.666666667$ and radius over age times light speed $= 3.000000000$** (Section 2). **Fourth, and this is the core. Nearby the four distances coincide; far away they split——0.987755 to 1.007608 times cz/H_0 at redshift 0.01, 0.382303 to 1.529213 times at redshift 1** (Section 3). **Fifth, the distance of apparent size has a maximum——the angular diameter distance peaks at 5.851408 billion light-years at redshift 1.587641, and beyond it objects of the same size look larger the farther they are** (Section 3). **Sixth, the separator is how much the universe stretched while the light was on its way (the redshift)——"distance equals speed times time" has no truth value until one says which distance and how much stretching** (Section 4). **Keywords**: age of the universe, observable universe, redshift, comoving distance, angular diameter distance, Friedmann equation.

Scope of this paper (scope note): **No new theorem or law is claimed——the Friedmann equation, the age and observable radius of a flat universe, the definitions of light-travel, comoving, luminosity and angular diameter distances, and the maximum of the angular diameter distance are all known (Ryden 2017, Hogg 1999).Values are representative——$H_0 = 67.4$ km/s/Mpc, matter fraction 0.315 and radiation fraction 9.1×10^{-5} are for comparison, and which values are right is not treated. The H_0 tension counted in Paper 297 is not entered.No cosmology is built——only a flat model with constant dark energy is used.Distance measurement is not treated——the rungs of the ladder and the calibration of standard candles are left to Paper 297.Four names of distance only——other names (such as one equal to the comoving distance in a flat universe) are not treated.Relation to earlier papers**: **Paper 297 showed that cosmic distance is a ladder of seven rungs and only the first is measured directly——its scope note built no cosmology and stated that only one division and one root of a sum of squares were used. There the same distance had seven rungs of measurement. Here, integrating the expansion, the word "distance" itself is counted as splitting into four before any measurement. The number of methods, and the number of words.**What is added is **checking the integral against the closed values of a matter-only universe ($2/3$ and 3)**, **deriving by the same integral an age of 13.790752 billion years and a radius of 46.137972 billion light-years**, **tabulating four distances at five redshifts and counting where they coincide and split**, and **placing the separator on how much stretching**.

1. Notation and the Question

Setting: **let a be the scale factor of the universe (now 1), and write the expansion rate $H(a)$ with the fractions of radiation, matter and dark energy. From the time light of redshift z was emitted, four distances follow.**

$$H(a) = H_0\sqrt{\Omega_r a^{-4} + \Omega_m a^{-3} + \Omega_\Lambda}, \qquad t(z) = \int_0^{1/(1+z)} \frac{da}{a\,H(a)}, \qquad D_C(z) = c\int_{1/(1+z)}^{1} \frac{da}{a^2 H(a)}$$

$$D_{\mathrm{lt}} = c\,\big(t_0 - t(z)\big), \qquad D_L = (1+z)\,D_C, \qquad D_A = \frac{D_C}{1+z}$$

D_{lt} is light-travel time times the speed of light, D_C the present distance (comoving distance), D_L the luminosity distance set by brightness, and D_A the angular diameter distance set by apparent size. Take $\Omega_m = 0.315$, $\Omega_r = 9.1 \times 10^{-5}$ and $\Omega_\Lambda = 0.684909$.

Question: **does the light's travel time multiplied by the speed of light give the distance to the object?**

2. The Age and the Observable Universe

Computation 2.1: **the age and the radius of the observable universe (the comoving distance as $z \to \infty$) were derived by integration, and the same integral applied to a matter-only universe ($\Omega_m = 1$).**

quantity	value
Hubble time $1/H_0$	**14.507303** billion years
age t_0	**13.790752** billion years
$H_0 t_0$	**0.950608**
radius of the observable universe	**46.137972** billion light-years
radius / (ct_0)	**3.345573**
$H_0 t_0$, matter only	**0.666666667**
radius / (ct_0), matter only	**3.000000000**

> **Observation 2.2**
>
> **the age is close to $1/H_0$ but not equal to it.$H_0 t_0 = 0.950608$——with matter only it falls to $2/3$; being near 1 comes from the combination of deceleration and acceleration.**

> **Observation 2.3**
>
> **the radius of the observable universe is $\mathbf{3.345573}$ times age times the speed of light.Light has travelled only 13.790752 billion years, yet the place that emitted the farthest light is now 46.137972 billion light-years away. Even in a matter-only universe the ratio is exactly 3.000000000, agreeing with the formula's 3 to 1.332×10^{-14}——while the light travels, the path it has covered itself stretches.**

3. Four Distances

Computation 3.1: **four distances were derived at five redshifts and set beside the naive cz/H_0 (in billions of light-years).**

redshift	light-travel	comoving	luminosity	angular diameter	cz/H_0
0.01	0.144011	0.144730	0.146177	0.143297	0.145073
0.1	1.349997	1.415867	1.557454	1.287152	1.450730
1	7.949953	11.092381	22.184762	5.546191	14.507303
3	11.652285	21.215181	84.860722	5.303795	43.521909
1100	13.790386	45.227948	49795.970982	0.041079	15958.033289

ratio to cz/H_0	light-travel	comoving	luminosity	angular diameter
redshift 0.01	0.992681	0.997632	1.007608	0.987755
redshift 1	0.547997	0.764607	1.529213	0.382303

Observation 3.2

this is the core: nearby the four distances coincide, far away they split.At redshift 0.01 all four lie within 0.987755 to 1.007608 times cz/H_0, but at redshift 1 they split to 0.382303 to 1.529213 times——one word suffices for “distance” nearby because the universe barely stretches while the light travels.

Observation 3.3

light-travel distance falls further and further short of the present distance.Light-travel over comoving is **0.995037** at redshift 0.01 and **0.716704** at redshift 1. Luminosity over angular diameter is fixed by definition at $(1+z)^2$ (1.020100 and 4.000000) and is not a finding——the size of the split is measured not by a ratio fixed by definition but by the gap between light-travel and comoving.

Observation 3.4

the distance of apparent size has a maximum.The angular diameter distance peaks at 5.851408 billion light-years at redshift 1.587641, returning to 5.303795 at redshift 3 and 0.041079 at 1100——beyond redshift 1.587641, objects of the same size look larger the farther they are.

Observation 3.5

the place that emitted light of redshift 1100 lies near the edge of the observable universe.Its comoving distance of 45.227948 billion light-years is 0.980276 of the radius.

4. The Separator

Observation 4.1

the separator is how much the universe stretched while the light was on its way (the redshift).With almost no stretching the four distances coincide as speed times time; with stretching they split into four, and the observable radius becomes 3.345573 times age times the speed of light——"distance equals speed times time" has no truth value until one says which distance and how much stretching.

Observation 4.2

beside Paper 297.Paper 297 showed, with one division and one root of a sum of squares, that cosmic distance is measured on a ladder of seven rungs and only the first is measured directly——here the expansion is integrated, and the word "distance" itself is counted as splitting into four before any measurement.

Observation 4.3

what is not said.The values are representative, and neither the H_0 tension, nor the nature of dark energy, nor distance measurement is entered——what is shown is that the word for distance is one nearby and four far away.

5. Roll Call and Closing

1. **age 13.790752 billion years** (Computation 2.1): **close to $1/H_0$ but not equal.**
2. $H_0 t_0 = 0.950608$ (Observation 2.2): **$2/3$ with matter only.**
3. **radius 46.137972 billion light-years** (Computation 2.1): **the observable universe.**
4. **3.345573 times age times light speed** (Observation 2.3): **the path stretches.**

5. **3.000000000 with matter only** (Observation 2.3): **checking the integral.**
6. **0.987755 to 1.007608 at redshift 0.01** (Observation 3.2): **coinciding.**
7. **0.382303 to 1.529213 at redshift 1** (Observation 3.2): **the core.**
8. **light-travel over comoving 0.716704** (Observation 3.3): **the size of the split.**
9. **angular diameter maximum at redshift 1.587641** (Observation 3.4): **farther looks larger.**
10. **how much stretching** (Observation 4.1): **the separator; Paper 297.**

Closing: **Distance is speed times time only where space does not stretch while the light travels.In a flat universe with $H_0 = 67.4$ km/s/Mpc and matter fraction 0.315, the age is 13.790752 billion years ($H_0 t_0 = 0.950608$) and the observable radius is 46.137972 billion light-years, 3.345573 times age times the speed of light——even with matter only the ratio is exactly 3: the path covered by the light stretches while it travels.Light-travel, comoving, luminosity and angular diameter distances coincide within 0.987755 to 1.007608 times cz/H_0 at redshift 0.01 and split to 0.382303 to 1.529213 times at redshift 1; the angular diameter distance peaks at redshift 1.587641, beyond which objects of the same size look larger the farther they are——one word for distance suffices nearby because the universe barely stretches.The separator is how much the universe stretched while the light was on its way (the redshift).Placed among the earlier papers——Paper 297 showed seven rungs of measuring distance; this counts the word for distance splitting into four before any measurement.To be honest——the values are representative, and neither the H_0 tension nor the nature of dark energy is entered.**

References

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