

Cosmic Distance Is a Ladder of Seven Rungs, and Only the First Is Measured Directly

— Parallax Reaches **10%** Precision Only to **5000** pc, While the Observable Universe Is **2.8×10^6** Times Farther — At the Top Rung Two Routes Disagree by **4.85σ** — [Paper 297]

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August 2026

— *From thinking to syncing.* —

Abstract

When one says “that galaxy is a billion light-years away,” it is a measured quantity. This paper asks how it was measured—the answer is by stacking a ladder of seven rungs. No new mathematical theorem and no new law is claimed. First, how far does direct measurement reach? At Gaia’s parallax precision of $20\mu\text{as}$, 10% precision reaches only to **5000** pc (Section 2). Second, this is the core of the paper. The observable universe is 1.4×10^{10} pc, so we are **6.4** orders short—all the rest is ladder (Section 2). Third, there are seven rungs. Parallax → spectroscopic parallax → main-sequence fitting → Cepheids → TRGB → type Ia supernovae → Hubble’s law (Section 3). Fourth, the errors stack. If each rung adds only 5%, the top rung reaches **12.41%** (Section 3). Fifth, at the top rung two routes disagree. 73.04 ± 1.04 against 67.36 ± 0.54 , that is **4.8471σ** —once in 798,192 by chance (Section 4). Sixth, the separator is ladder or ruler. One stacks upward from the local; the other assumes an acoustic horizon (Section 5).

Scope of this paper (scope note): No new mathematical theorem and no new law is claimed——trigonometric parallax, the rungs of the distance ladder, the period--luminosity relation, and the two measured values of H_0 are all standard. We do not build cosmology——all we use is one division and one root of a sum of squares. We assert no cause for the disagreement——whether it is new physics, a systematic error, or neither is not treated at all. We only count how many σ the difference is. We do not say which is right——this paper endorses neither value. We do not enter calibration detail——the metallicity dependence of Cepheids, the calibration of the TRGB, and supernova standardisation are not treated. The parallax reach depends on premises——the 5000 pc follows from two conventions: $\sigma_\pi = 20\mu\text{as}$ and “10% relative error”. Change σ_π and it moves in proportion. The error stacking is illustrative——the “5% per rung” of Section 3 is an assumption chosen to show the structure, not the actual error of each rung. If systematics correlate across rungs, a sum of squares is not enough. We do not call 4.85σ a discovery——it is merely a division of two published values, resting on the premise that the systematics have been correctly estimated. Relation to earlier papers: Paper 250 showed that measuring one question with two instruments can reverse the sign——that concerned the coding of the corpus’s own text; this concerns a physical constant, the same figure with a different object. Paper 255 separated two things called “accuracy,” only one removed by calibration——the ladder here has each rung calibrated against the one below, which is the side where systematic error does not vanish. Paper 169 showed that Sciamia’s famous coincidence is an identity, using the Hubble constant——this paper treats the measurement of that constant itself. Paper 190 measured “rare” on a logarithmic scale——the “once in 798,192” here is likewise read logarithmically. What is added is computing the parallax reach at 10% as 5000 pc and measuring the gap to the observable universe as 6.4 orders, tabulating the seven rungs, showing that 5% per rung stacks to 12.41%, and computing the H_0 disagreement as 4.8471σ , once in 798,192.

1. Notation and the Question

Setting: There is in effect only one way to measure a distance to a star directly——trigonometric parallax. Measure the apparent shift π produced by the Earth’s orbit and the distance is $d[\text{pc}] = 1/\pi[\text{arcsec}]$.

Question: How far does that reach? And how is everything beyond it measured?

Observation 1.1

Parallax alone is geometry. It measures a triangle and assumes nothing about the star——every other rung uses an assumption about the nature of the object.

2. The Core: We Are 6.4 Orders Short

Setting: Take Gaia’s parallax precision as $\sigma_\pi = 20\mu\text{as}$. The relative error is $\sigma_\pi/\pi = \sigma_\pi d$.

Check 2.1:

Distance [pc]	Parallax [mas]	Relative error
10	100.0000	0.02%
100	10.0000	0.20%
1000	1.0000	2.00%
5000	0.2000	10.00%
10000	0.1000	20.00%
100000	0.0100	200.00%

Observation 2.2

A relative error of 10% reaches to 5000 pc; 1% reaches to 500 pc. At 10^5 pc the error is 200%——larger than the distance itself.

Check 2.3: We compare with the observable universe.

Quantity	Value
Parallax reach at 10% precision	5.0×10^3 pc
Radius of the observable universe	1.4×10^{10} pc
Ratio	2.8×10^6
In orders	6.4

Observation 2.4

This is the core of the paper. Direct measurement covers a mere 3.6×10^{-7} of the universe——the remaining 99.99996% is all measured by ladder.

Observation 2.5

A point to write honestly—the figure 5000 pc follows from two conventions, $\sigma_\pi = 20\mu\text{as}$ and “10%”. Halve σ_π and the distance doubles—what does not change is the structure, that the orders do not suffice.

3. Seven Rungs, and the Errors Stack

Check 3.1:

Rung	What is assumed	Reach
1. Trigonometric parallax	geometry only (direct)	$\sim 10^3$ pc
2. Spectroscopic parallax	absolute magnitude from spectral type	$\sim 10^4$ pc
3. Main-sequence fitting	cluster HR diagrams overlay	$\sim 10^5$ pc
4. Cepheids	the period--luminosity relation	$\sim 10^7$ pc
5. TRGB	the red-giant branch tip is constant	$\sim 10^7$ pc
6. Type Ia supernovae	peak luminosity is nearly constant	$\sim 10^9$ pc
7. Hubble's law	redshift is proportional to distance	beyond

Observation 3.2

Only rung 1 assumes nothing. Every rung from the second is calibrated against the one below—move the first and all seven move.

Check 3.3: Taking each rung to add 5% independently (the first 2%), we watch the accumulation.

Rung	Accumulated relative error
1. Trigonometric parallax	2.00%
2. Spectroscopic parallax	5.39%
3. Main-sequence fitting	7.35%
4. Cepheids	8.89%
5. TRGB	10.20%
6. Type Ia supernovae	11.36%
7. Hubble's law	12.41%

Observation 3.4

If independent, the sum of squares gives **12.41%**. Six additions of 5% do not reach 30% because variances add—the same single line stands here too: summing independent contributions grows the standard deviation only as a square root.

Observation 3.5

A point to write honestly—“5% per rung” is an assumption to display the structure, not the actual error of each rung. And if systematics correlate across rungs, a sum of squares is not enough—correlated errors add at first order.

Observation 3.6

Paper 255 separated two things called “accuracy,” noting that calibration removes only one. Each rung of the ladder is calibrated against the one below—so a systematic error in the first rung vanishes at no rung at all.

4. At the Top Rung, Two Routes Disagree by 4.85σ

Setting: The Hubble constant H_0 is measured by two entirely different routes.

Check 4.1:

Route	H_0 [km/s/Mpc]	What it rests on
Ladder (SH0ES)	73.04 ± 1.04	stacking from the local
Ruler (Planck)	67.36 ± 0.54	the acoustic horizon of the CMB

Check 4.2:

Quantity	Value
Difference	5.6800
Combined $\sigma = \sqrt{1.04^2 + 0.54^2}$	1.1718
Discrepancy	4.8471σ
Two-sided p	1.2528×10^{-6}
By chance	once in 798,192

Observation 4.3

It is **4.85σ** . Particle physics conventionally calls 5σ a “discovery,” so this is one step short——awkward to explain by chance, insufficient to call settled.

Check 4.4: We recast the difference into something felt.

Quantity	Value
Relative difference	8.09%
$1/H_0$ (SH0ES)	13.3872 Gyr
$1/H_0$ (Planck)	14.5160 Gyr
Difference	1.1288 Gyr

Observation 4.5

Recast as an estimate of the age of the universe, the disagreement is **1.1 billion years**.In percentage it is only 8%, but both sides claim 1--2% precision—it is because the precision rose that the disagreement became visible.

Observation 4.6

A point to write honestly——this paper says neither which is right nor what the cause is.The number 4.85σ rests on the premise that the systematics have been correctly estimated——break that premise and the number loses its meaning.

5. Separator: Ladder or Ruler

Observation 5.1

Separator——how do the two measurements differ?

	Ladder side	Ruler side
Starting point	nearby stars (geometry)	the CMB acoustic horizon (model)
Direction	stacked from near to far	extrapolated from far to near
Governing assumption	calibration of each rung	the cosmological model (Λ CDM)

Observation 5.2

The two share not a single rung.The ladder’s errors and the ruler’s errors are independent——which is why the combined σ may be taken as a sum of squares.

Observation 5.3

And they measure the same quantity. This is what makes the disagreement serious——had they measured different quantities, disagreement would be expected.

Observation 5.4

Paper 250 treated a case where measuring one question with two instruments reverses the sign. That concerned the coding of the corpus's own text; this concerns a physical constant——the same figure with a different object. Both ask what is at stake when two instruments fail to agree.

Observation 5.5

Finally we join Sections 2 and 4. The ladder has seven rungs because direct measurement falls 6.4 orders short——and at the tip of those seven rungs it disagrees with the ruler side by 4.85σ . That there are many rungs and that there is a disagreement cannot be unrelated——though this paper does not assert that it is the cause either.

6. Roll Call and Closing

1. Parallax at 10% reaches 5000 pc (Check 2.1): 500 pc at 1%.
2. 200% error at 10^5 pc (Check 2.1): Larger than the distance.
3. Ratio 2.8×10^6 (Check 2.3): 6.4 orders short.
4. Direct covers 3.6×10^{-7} (Observation 2.4): The rest is ladder.
5. Seven rungs (Check 3.1): Only the first is geometry.
6. Accumulated 12.41% (Check 3.3): A sum of squares if independent.
7. 73.04 against 67.36 (Check 4.1): Ladder and ruler.
8. 4.8471σ (Check 4.2): Once in 798,192.
9. Relative difference 8.09% (Check 4.4): 1.1288 Gyr.
10. Not one shared rung (Observation 5.2): Hence independent.

Closing: Cosmic distance is measured by a ladder of seven rungs, and only the first is measured directly. Trigonometric parallax reaches 10% precision only to 5000 pc, while the observable universe is 1.4×10^{10}

pc——**6.4** orders short, so direct measurement covers a mere 3.6×10^{-7} of the whole. The rest is stacked by spectroscopic parallax, main-sequence fitting, Cepheids, TRGB, type Ia supernovae and Hubble’s law, and 5% per rung already brings the top rung to **12.41%**. And at that top rung, a value measured by an entirely different route disagrees by **4.8471σ** —— 73.04 ± 1.04 against 67.36 ± 0.54 , once in **798,192** by chance, a difference of **1.1** billion years in the age of the universe. One thing separates them——whether one stacked up from nearby or extrapolated in from afar. The two share not a single rung, which is why their errors are independent, and why the difference means something. And both are measuring one and the same quantity.

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