The Ledger of the Way: Cumulative Redshift as a Potential Difference

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Abstract. Take a photon born on the surface of a neutron star, deep in its own gravitational well, inside a galaxy's well, inside a cluster's well, riding the background curvature a gigaparsec to our telescope — itself sitting inside the Milky Way's well. What total redshift arrives? This note derives the answer in one equation and shows that in a static cosmology the whole journey collapses into a *ledger*: a sum of entries, one per well, plus one for the background — and only the endpoints matter. The worked example: twelve kilometres of neutron-star surface are worth 905 megaparsecs of universe. Out of the same equation falls the cleanest falsifier this series owns: the redshift of every source must never drift with time — while the standard model demands it must. Every symbol is introduced before use.

1. The Question

Light climbing out of a gravitational well loses energy and arrives redder — measured on Earth to exquisite precision, and enormous on a neutron star's surface. Light crossing the cosmos arrives redder too. When one journey involves both — wells within wells, then the long way home — how do the redshifts combine? Multiply or add? Does the path matter? Is there one equation for the whole way?

2. The Master Equation

Recall two definitions, walked slowly. The *redshift* z measures stretching: 1 + z is the factor by which each received wave is longer than when it was sent. The *lapse* N(x) is the local rate of clocks: at a location x deep in a well, or deep in the cosmic curvature, clocks run slow compared to a reference clock, and N(x) — a pure number, close to 1 in shallow places, smaller in deep ones — is that rate.

Because the geometry of this series is static (Postulate 3: the stage never changes), a photon carries one conserved quantity along its entire way: the product of its locally measured energy E(x) and the local clock rate,

$\tilde{E} = N(x) \cdot E(x)$ = the same number all along the ray.

Nothing en route can change $\tilde{E}$; only the *exchange rate* N between local clocks and universal time varies from place to place. Divide two readings of this conservation law — one at the emitter, one at the observer — and the whole journey collapses:

$1 + z = N(\text{observer}) / N(\text{emitter})$

The total redshift is a ratio of two local clock rates. Nothing else. To make it a ledger, take the logarithm (the natural bookkeeping of multiplied factors) and define the *potential of the way*, $\Phi(x) = -\ln N(x)$ — a pure number that grows with depth. Then:

$\ln(1 + z) = \Phi(\text{emitter}) - \Phi(\text{observer})$

And the lapse of a many-welled universe factorizes — the background times each well:

$N(x) = e^{(-k \cdot r)} \times \prod$ over wells i of $\sqrt{(1 - r_{s,i} / \rho_i(x))}$

where $k = H/c$ is the background curvature per metre (H the Hubble rate, c the speed of light); r is proper distance from the observer; $r_{s,i} = 2GM_i/c^2$ is the Schwarzschild radius of well number i (G Newton's constant, M_i the well's mass — r_s is the size the well's mass would have as a black hole); and $\rho_i(x)$ is the distance from the point x to that well's center. The logarithm turns the product into a sum: **wells within wells become entries in a ledger**, each shallow well contributing simply its depth, $GM/(\rho c^2)$. Redshift in this cosmology is not stretching en route; it is *climbing out*, and the books are kept in $\ln(1+z)$.

3. The Ledger, Executed: a Neutron Star at One Gigaparsec

entry on the way
neutron-star surface (1.4 solar masses, 12 km radius)
host galaxy's well (rotation speed ≈ 220 km/s)
host cluster's well
Milky Way's well (we climb *down* into our own: blueshift)
the background, 1 gigaparsec of way
total

Read the first and last lines together: the twelve kilometres of a neutron star's surface contribute as much to the ledger as **905 megaparsecs of universe**. This is why the local-well correction to supernova cosmology died (a white dwarf's light leaves from millions of kilometres out — its entry is a millionth of a millionth) and why it lives at compact objects. Note also the honest minus sign: the observer's own well partially refunds the climb. The ledger balances at both ends, as a ledger must.

4. What the Equation Buys: Two Theorems and a Falsifier

Path independence. The ledger depends only on endpoints — mathematically, because a difference of potentials doesn't care about the route. Physical consequence: gravitational lensing can bend a ray around any detour whatsoever and cannot change its redshift by one part in anything.

4.1 The Fork: Does the Distance Grow? The objection arrives naturally: "surely the object gets more distant over time, so tomorrow's redshift is greater." That is the expanding picture, and the model must choose. Branch one, *strictly static*: redshift is position in the potential, not history; the drift is exactly zero. Branch two, *the slow spiral*: if proper distances really grow, consistency already caps the rate — today's redshift is fully paid by the potential, so any true recession stacks its own Doppler shift on top, and the supernova fit (good to ±0.1 magnitudes) tolerates only a few percent of the naive rate. The three contenders then separate cleanly, per decade of watching:

z
1
2
4

(The units: a drift in redshift is expressed as an apparent velocity change, centimetres per second, over ten years of observation.) Note the standard model's signature: its drift *changes sign* near $z \approx 2$ — positive nearby, −5 cm/s at $z = 4$ — because in an expanding universe redshift is accumulated history, and history accumulates differently at different depths. This model, in either branch, can never produce that sign flip.

4.2 The Yardstick: Why the Distance Does Not Grow. The deeper form of the objection: "tomorrow's distance is measured with tomorrow's yardstick — it has to increase." A yardstick is atoms; its length is set by the Bohr radius, $\hbar/(m_e \cdot c \cdot \alpha)$. For the yardstick to shrink, the electron's mass or the fine-structure constant must drift with time — local physics evolving from day to day. Postulate 3 forbids exactly this, and not as decoration: the same time symmetry that conserves $\tilde{E}$ along the ray (Section 2) and makes the temperature law of the cosmology hold is what freezes the yardstick. The dimensionless statement: a redshift measurement is a ratio, $\lambda_{photon}/\lambda_{lab}$ — fossil light against a laboratory atom. For z to grow overnight, either the climb changes (static potential: it doesn't) or the lab atom shrinks (eternity: it doesn't). Both frozen, ratio frozen, drift zero. The shrinking-yardstick alternative is an honest, known theory — Wetterich (2013), a static geometry with growing particle masses — but it is *constructed* to be observationally identical to the expanding model: adopting it would surrender this falsifier and reopen every settled contest in different units. The distinctness of metric D lives in the frozen yardstick: **redshift is where you are in the potential, not what date it is.**

The falsifier, named. The Extremely Large Telescope's high-resolution spectrograph programme (ANDES) is being built to measure precisely these few centimetres per second per decade, against quasar absorption forests, over roughly twenty years. No candles, no calibration ladders, no dust corrections — the same object against the same atomic clock, years apart; everything systematic cancels. One confirmed sign-flipping drift and metric D is dead, no appeal. A persistent null while the standard model demands −5 cm/s at $z = 4$, and the standard model has a crisis. Few predictions in cosmology are this clean, and this series stakes its background metric on it.

5. Remarks

Moving emitters add an ordinary Doppler factor multiplying the static ledger — peculiar velocities are entries of order $v/c \approx 10^{-3}$, kept in the same logarithmic books. And the ledger's structure is the Bookkeeping paper's thesis in miniature: between the drains and the horizons, every account balances, and the way home is a sum of honest entries.

References

R. C. Tolman and P. Ehrenfest, Phys. Rev. 36, 1791 (1930); I. M. H. Etherington (1933); A. Sandage (1962) and A. Loeb (1998) on redshift drift; C. Wetterich, Phys. Dark Univ. 2, 184 (2013); the ELT/ANDES instrument programme; and the papers and notes of this series (Paper 2 and the Four Calculations note; the Postulates). *(Citations from memory; the literature-verification pass applies.)*