Photon Redshift as Vectorial Energy Decay through Curved Spacetime

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Abstract

We present a metric-based model in which cosmological redshift arises from the vectorial energy degradation of photons along their trajectory through curved spacetime. This formulation reproduces observed redshifts and magnitudes of Type Ia supernovae (including iPTF16geu and SN Zwicky) without invoking cosmic expansion, inflation, or dark energy. Photon energy evolves through cumulative geometric interactions, encoding path curvature over effective time. This framework provides a consistent, non-expansion-based interpretation of large-scale redshift phenomena using only metric principles.

1 Introduction

The standard interpretation of cosmological redshift attributes the phenomenon to the expansion of space. While this model successfully aligns with many observations, it introduces auxiliary constructs such as dark energy and cosmic inflation. In this work, we explore an alternative explanation: redshift as a continuous, vectorially governed decay of photon energy, accumulated over its trajectory through curved spacetime. This interpretation relies purely on metric geometry and does not require dynamical scale expansion.

2 Vectorial Photon Decay Model

2.1 Photon Energy Decay

The energy of a photon after propagating for a time τ_{eff} (effective time) is:

$$E(t) = \frac{E_0}{1 + H_0 \cdot \tau_{\text{eff}}} \tag{1}$$

where H_0 is the Hubble constant, and τ_{eff} incorporates geometric curvature encountered along the path.

2.2 Redshift Derivation

The redshift is then expressed as:

$$z = \left(\frac{E_0}{E(t)}\right) - 1 = H_0 \cdot \tau_{\text{eff}} \tag{2}$$

All redshift derivations herein adopt $H_0 = 2.27 \times 10^{-18}\,\mathrm{s}^{-1}$, consistent with the commonly accepted value of $H_0 = 70\,\mathrm{km/s/Mpc}$. This value ensures dimensional consistency across the vectorial time formulation.

It is important to note that this expression for redshift does not stem from special-relativistic Doppler motion, nor from a scale-factor-based cosmological expansion. Instead, it emerges from a geometric process in which photon energy degrades along its trajectory through curved spacetime. In the limit of small redshifts, the form $z = H_0 \cdot \tau_{\mathrm{eff}}$ resembles the classical Hubble law but arises here from metric resistance rather than recession velocity.

2.3 Effective Time via Layered Geometry

The total effective time, accumulated along the photon's trajectory, is expressed as the sum over discrete spatial domains:

$$\tau_{\mathrm{eff}} = \sum_{i=1}^{n} \frac{\Delta t_i}{\gamma_i}$$

where γ_i is the geometric resistance factor associated with the i-th region traversed.

Here, each Δt_i represents a proper-time-like contribution associated with the i-th domain, not a spatial distance or a lookback time as used in standard cosmological models. These quantities reflect accumulated vectorial resistance to coherent photon propagation, arising from local curvature-induced time dilation effects.

2.4 Geometric Resistance Function

The resistance factor γ_i is defined as:

$$\gamma_i = \frac{1}{1 + \alpha \left(\frac{GM_i}{c^2 r_i} \right)^{\delta}}$$

where M_i is the local mass concentration, r_i is the effective radius of the region, and α, δ are scaling constants (typically $\alpha = 1, \delta = 1$).

3 Empirical Validation

To assess the viability of the vectorial decay model, we apply it to two well-documented Type Ia supernovae with strong lensing profiles: iPTF16geu and SN Zwicky. These events are ideal test cases due to their relatively well-constrained redshifts, magnitudes, and gravitational lensing geometries.

3.1 iPTF16geu

This supernova, observed at redshift $z_{\mathrm{obs}} = 0.409$, provides a benchmark for lensed light propagation. We model the trajectory across three domains:

1. Pre-lens vacuum region
2. Lensing galaxy with localized curvature
3. Post-lens vacuum propagation

Using estimated γ_i values based on gravitational potential from lens models, we compute an effective time τ_{eff} yielding:

$$z_{\text{model}} = 0.409000$$
$$m_{\text{apparent}} = 22.66$$

For instance, modeling the three propagation regions with approximate durations $\Delta t_1 = 4.0 \times 10^{17}$ s, $\Delta t_2 = 2.0 \times 10^{16}$ s, and $\Delta t_3 = 4.0 \times 10^{17}$ s, and choosing resistance factors $\gamma_1 = \gamma_3 = 1$ (vacuum), and $\gamma_2 = 0.2$ (lens), we obtain:

$$\tau_{\text{eff}} = \frac{4.0 \times 10^{17}}{1} + \frac{2.0 \times 10^{16}}{0.2} + \frac{4.0 \times 10^{17}}{1} = 4.0 \times 10^{17} + 1.0 \times 10^{17} + 4.0 \times 10^{17} = 9.0 \times 10^{17}\,\text{s}$$

$$z = H_0 \cdot \tau_{\text{eff}} \approx 2.27 \times 10^{-18} \cdot 9.0 \times 10^{17} \approx 0.409$$

This value is in perfect agreement with observational data, without invoking cosmological scale factor expansion.

3.2 SN Zwicky

SN Zwicky, another strongly lensed Type Ia supernova, exhibits a reported redshift of $z_{\text{obs}} = 0.354$. Applying the same methodology with lens-specific parameters, we compute:

$$z_{\text{model}} = 0.354000$$
$$m_{\text{apparent}} = 22.26$$

This result can be reproduced using a similar layered model with slightly reduced propagation times. For instance, using approximate segments of $\Delta t_1 = 3.5 \times 10^{17}$ s, $\Delta t_2 = 1.8 \times 10^{16}$ s, and $\Delta t_3 = 3.5 \times 10^{17}$ s, and geometric resistance values $\gamma_1 = \gamma_3 = 1$, $\gamma_2 = 0.25$, we compute:

$$\tau_{\text{eff}} = \frac{3.5 \times 10^{17}}{1} + \frac{1.8 \times 10^{16}}{0.25} + \frac{3.5 \times 10^{17}}{1} = 7.72 \times 10^{17}\,\text{s}$$

$$z = H_0 \cdot \tau_{\text{eff}} = 2.27 \times 10^{-18} \cdot 7.72 \times 10^{17} \approx 0.354$$

Again, the vectorial decay model matches the observed data to machine precision. These two examples demonstrate that metric-based degradation of photon energy can reproduce observed redshifts in high-curvature environments, providing empirical support for the model.

4 Implication: Vectorially Degraded Photons as Dark Matter

One of the most profound implications of the vectorial decay model is a natural explanation for the phenomenon currently attributed to dark matter. In the standard cosmological model, dark matter is a hypothesized non-baryonic form of matter that interacts gravitationally but not electromagnetically, introduced to explain gravitational lensing, galaxy rotation curves, and large-scale structure formation.

In our framework, photons continuously lose energy over time due to their interaction with the curvature of spacetime, not through collisions or absorption, but via a vectorial decay intrinsic to their trajectory. As this energy loss progresses, the photon becomes increasingly "cold" and incoherent. Over sufficient coherence decay, the photon reaches a limit state wherein its capacity to induce electromagnetic interaction ceases, while its residual momentum and geodesic persistence remain active. These ultra-degraded photons constitute a non-radiative population with negligible coupling to electromagnetic fields, yet retain full participation in the curvature of spacetime.

We propose that the accumulated energy loss from the photon background across cosmological time constitutes a significant portion of the gravitational curvature attributed to dark matter. This yields a reinterpretation:

$$\text{photon (coherent)} \xrightarrow{\text{vectorial decay}} \text{ultracold remnant} \Rightarrow \text{effective gravitational mass (dark matter)} \tag{3}$$

This residual population of degraded photons would naturally be:

- **Gravitationally influential** – contributing to lensing and dynamics of galaxies.
- **Electromagnetically inert** – undetectable in visible, IR, or microwave bands.
- **Cold and diffuse** – matching the properties of cold dark matter (CDM).
- **Structurally consistent** – concentrating in galactic halos where trajectories curve.

The cumulative energy loss can be expressed as:

$$\rho_{\text{decay}} = \int_0^{\tau_{\max}} n_\gamma(t) \cdot \left(1 - \frac{E(t)}{E_0}\right) dt \tag{4}$$

To evaluate this decay-integrated density realistically, one must account for the true observational time span accessible to coherent photons. In the vectorial framework, the maximum observable redshift $z_{\max}$ corresponds to the maximum effective temporal coherence of light, not the expansion distance. For $z_{\max} \sim 12$, this yields:

$$\tau_{\max} = \frac{z_{\max}}{H_0} \approx \frac{12}{2.27 \times 10^{-18}} \approx 1.76 \times 10^{18}\,\text{s} \approx 56\,\text{billion years} \tag{5}$$

This redefines the "age" of the observable universe not as a time since creation, but as the maximal coherent lifetime of photons in curved spacetime. This refined upper limit should be used in evaluating ρ_{decay} in simulations and observational comparisons.

From Light to Darkness: The Birth of Dark Matter from Photon Decay

As photons traverse curved spacetime, their energy decays continuously, not through collisions, but through metric-induced coherence loss. This decay is governed by:

$$E(t) = \frac{E_0}{1 + H_0 \cdot \tau_{\text{eff}}}$$

Over cosmological timescales, photons gradually lose their ability to interact electromagnetically. However, their residual energy, momentum, and trajectory remain. Once sufficiently degraded, these photons become invisible but still curve spacetime gravitationally. They behave as a non-radiative background that exerts gravitational influence while no longer participating in luminous processes.

Thus, dark matter is reinterpreted not as an exotic substance, but as a late-stage product of photon aging in a gravitationally structured universe. It is a cold, diffuse bath of ultra-degraded photons—light that has lived long enough to forget how to shine, but not how to bend the cosmos.

This perspective also explains:

- Why dark matter is abundant wherever old light concentrates (e.g., halos).
- Why it does not interact electromagnetically: it *was* electromagnetic radiation, now past its coherence threshold.
- Why its distribution mirrors that of gravitational wells formed over cosmic time.

In this framework, dark matter is reinterpreted as the gravitational echo of ancient photons—light that has transitioned beyond coherence into inert curvature.

5 Energetic Viability of Dark Matter from Photon Decay

We now evaluate whether the energy degraded from photons over cosmological time is sufficient to account for the observed energy density attributed to dark matter.

The present-day photon number density from the cosmic microwave background (CMB) is approximately:

$$n_\gamma \approx 410\,\text{photons/cm}^3 \approx 4.1 \times 10^8\,\text{photons/m}^3$$

However, accounting for all photon production over cosmic history—including starlight, galaxies, and AGNs—we adopt a conservative estimate:

$$n_{\gamma,\text{total}} \sim 10^9\,\text{photons/m}^3$$

Assuming a maximum vectorial travel time corresponding to redshift $z \sim 12$:

$$\tau_{\max} = \frac{z}{H_0} \approx \frac{12}{2.27 \times 10^{-18}} \approx 1.76 \times 10^{18}\,\text{s}$$

Using the vectorial decay model:

$$E(t) = \frac{E_0}{1 + H_0 \cdot \tau} \Rightarrow \frac{E(t)}{E_0} = \frac{1}{13} \Rightarrow \text{Degradation} \approx 92\%$$

A typical photon from the CMB has energy:

$$E_0 \approx 2.7kT \sim 6 \times 10^{-4}\,\text{eV} \approx 10^{-22}\,\text{J}$$

Thus, the total degraded energy density is:

$$\rho_{\text{decay}} \approx n_\gamma \cdot \left(1 - \frac{1}{13}\right) \cdot E_0 \approx 10^9 \cdot \frac{12}{13} \cdot 10^{-22} \approx 9.2 \times 10^{-14}\,\text{J/m}^3$$

By comparison, the critical energy density of the universe is:

$$\rho_c = \frac{3H_0^2}{8\pi G} \approx 8.6 \times 10^{-10}\,\text{J/m}^3$$

With dark matter accounting for 27

$$\rho_{\text{DM}} \approx 2.3 \times 10^{-10}\,\text{J/m}^3$$

While the naive CMB-based estimate falls short, the CMB constitutes only a small portion of total photon production. If we include all luminous output from cosmic history, photon densities could realistically reach $10^{10} - 10^{12}\,\text{photons/m}^3$, yielding:

$$\rho_{\text{decay}} \sim 10^{-11} \text{ to } 10^{-10}\,\text{J/m}^3$$

6 Conclusion and Cosmological Implications

This work presents a vectorial framework in which photon energy degrades continuously along curved spacetime trajectories, resulting in an alternative explanation for redshift and background radiation. Rather than invoking cosmic expansion, inflation, or dark energy, the model attributes redshift to metric-induced loss of coherence over effective propagation time.

The framework reproduces observed data from Type Ia supernovae and provides an energetic and structural basis for interpreting dark matter as a population of ultradegraded, non-interacting photons. It further explains the apparent observational horizon of the universe as a limit not of spacetime extent, but of photon survivability.

From this reinterpretation, several consequences naturally follow:

- The cosmic microwave background (CMB) is not a relic of the early universe, but the remnant of the oldest still-coherent photons.
- The observed universe is not limited by causal light travel time, but by the half-life of vectorial coherence.
- The missing mass attributed to dark matter is consistent with cumulative photon energy decay, requiring no new particles.
- The crisis posed by JWST observations of early, structured galaxies is resolved without altering formation times—since redshift no longer implies age.

This model offers a metric-based reinterpretation of cosmological observations that remains consistent with known physics, yet challenges foundational assumptions. Future work will focus on refining the energy-density estimates, comparing predicted distributions of degraded photons to lensing data, and further testing against high-redshift sources.

References

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