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Article

# Time Density: A Theoretical Framework for Variability in Light Speed and Local Space-Time Behavior

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**Abstract:** This paper introduces the concept of **time density** ( $\rho_t$ ) as a fundamental scalar field influencing the apparent behavior of light, gravitation, and matter. We propose that local variations in  $\rho_t$  affect the effective speed of light, introduce refractive-like effects in spacetime, and may account for phenomena currently attributed to dark matter, dark energy, and cosmic inflation. The theory is explored through dimensional analysis, derived equations, testable predictions, and a philosophical interpretation of time as a physical medium.

**Keywords:** time density; scalar field theory; redshift interpretation; variable speed of light; temporal refractive index; cosmology; toroidal fields; analog gravity

## 1. Introduction

A number of foundational works in cosmology have modeled redshift and acceleration through metric expansion [1], while others interpret these through Type Ia supernovae observations [2]. The standard model of cosmology relies heavily on assumptions about a constant speed of light, metric expansion of space, and the existence of non-baryonic dark matter and dark energy. This paper proposes that these assumptions can be revisited through a new quantity: time density  $\rho_t$ , which quantifies the local density of temporal flow per unit volume. We consider the possibility that  $\rho_t$  variations explain redshift observations, affect gravitational coupling, and provide an avenue to unify relativity and quantum behavior through a common temporal substrate.

## 2. Defining Time Density

This concept draws from dimensional foundations laid by early quantum theory [3]. Time density is defined as a local accumulation of proper time across a spatial region:

$$\rho_t(x, t) = \lim_{\Delta V \rightarrow 0} \frac{1}{\Delta V} \int_{\Delta V} d\tau$$

where  $d\tau$  is the proper time measured along the worldlines of a congruence of observers passing through volume  $\Delta V$ . This formulation treats time as a physical field with variable density, enabling gradients and flow-like behavior across space.

It is postulated that  $\rho_t$  varies smoothly across regions and acts as a local refractive index for light propagation. The quantity has dimensions of  $[T][L^{-3}]$  (e.g., seconds per cubic meter).

While we refrain from defining a fundamental unit, we note that should experimental calibration emerge, a new vibrational unit of time-per-volume—tentatively referred to as a “rik”—may serve as a base unit for  $\rho_t$ .

## 3. Implications for the Speed of Light

If the speed of light is not a universal constant but instead an emergent property dependent on local time density, then:

$$c'(x) = \frac{c_0}{\sqrt{1 + \kappa \cdot \frac{\rho_t(x)}{\rho_0}}}$$

where  $\kappa$  is a dimensionless coupling constant and  $\rho_0$  is a background reference time density. This leads to an apparent variation in light speed in regions of differing  $\rho_t$ , producing effective refraction and redshift.

#### 4. Redefining Redshift

Rather than attributing redshift solely to Doppler motion or metric expansion, we model it as a consequence of cumulative refractive delay across temporal gradients:

$$z(d) = \int_0^d \nabla \rho_t(x) \cdot dx$$

This naturally explains why more distant light appears redshifted—because it traverses more  $\rho_t$  structure.

#### 5. Gravitational and Quantum Coupling

In general relativity, spacetime curvature is governed by the Einstein field equations [4]. Gravitational coupling may vary with  $\rho_t$ . Let the effective metric be:

$$g'_{\mu\nu}(x) = f(\rho_t(x)) \cdot g_{\mu\nu}(x)$$

Additionally, quantum decoherence rates may relate to local fluctuations in time density:

$$\langle \Delta \rho_t^2 \rangle \propto \Gamma_{\text{decoherence}}$$

This opens the possibility of connecting macroscopic spacetime behavior with fundamental quantum noise.

#### 6. Phenomena Reinterpreted

Other alternative gravity theories have proposed similar reinterpretations of mass and curvature without exotic particles [5]. Several phenomena can be reanalyzed under the time density model:

- **Dark Matter:** Effective mass increase due to local  $\rho_t$  gradients:

$$m_{\text{eff}} = m + \delta m(\rho_t)$$

- **Dark Energy:** Apparent acceleration as a result of spatial variation in  $\rho_t$ .
- **CMB Uniformity:** Homogenization due to early universe resonant  $\rho_t$  equilibrium.
- **Inflation Alternative:** Rapid early-time field relaxation in  $\rho_t$ .

#### 7. Model Example: Simplified Galactic Shell

Let:

$$\rho_t(r) = \rho_0 e^{-\lambda r}$$

Then the local effective speed of light becomes:

$$c'(r) = \frac{c_0}{\sqrt{1 + \kappa \cdot e^{-\lambda r}}}$$

Redshift follows as:

$$z(r) = \int_0^r \nabla \rho_t(x) \cdot dx \approx \rho_0(1 - e^{-\lambda r})$$

This offers a predictive profile of redshift without invoking expansion.

## 8. Experimental Proposals

This approach is inspired by research into analogue gravity systems which demonstrate how emergent spacetime behavior can arise from fluid-like systems [6].

- **Differential Redshift Mapping:** Correlating redshift gradients with known galaxy cluster density variations.
- **Metuzelah Lens Test:** Using the Methuselah star's position as a natural  $\rho_t$  lens. If background light passes through the  $\rho_t$  envelope surrounding an ancient stellar system, a temporary shift in redshift may occur along specific lines of sight.
- **Rotating Shell Experiment:** Simulating time density gradients via high-permittivity copper shells, rotating around a central axis to mimic temporal drag fields.
- **CMB Refraction Signatures:** Testing for anisotropy patterns consistent with refractive distortions from early-time  $\rho_t$  fluctuations.
- **Temporal Echo Trails:** Observing time-delayed photon pairs in gravitational wells to detect subtle deviations linked to  $\rho_t$  shifts.
- **Temporal Field Sensors:** Hypothetical instruments designed to infer  $\nabla \rho_t$  via:
  - Clock drift in spatially distributed atomic clocks
  - Asymmetry in photon echo timing
  - Interferometric instability in fiber-loop setups

Though speculative, such tools could form the core of future experiments targeting  $\rho_t$  structure directly, in analogy to how gravitational wave detectors measure spacetime strain.

## 9. Appendix B: Field Equation for $\rho_t$

We follow curvature notation as detailed in modern GR treatments [7]. We postulate that  $\rho_t$  satisfies a scalar field equation:

$$\square \rho_t - \mu^2 \rho_t + V'(\rho_t) = J(x)$$

with Lagrangian:

$$\mathcal{L} = \frac{1}{2} \partial^\mu \rho_t \partial_\mu \rho_t - \frac{1}{2} \mu^2 \rho_t^2 - V(\rho_t) + \rho_t J(x)$$

The source term  $J(x)$  may relate to entropy gradients or spacetime shear. While we postulate this Lagrangian form, the observable consequences — such as variation in  $c'$ , redshift behavior, and effective metric coupling — follow from treating  $\rho_t$  as a field mediating temporal refractive effects. Its gradient  $\nabla \rho_t$  accumulates delay across null geodesics, leading to integral-based redshift. Likewise, local  $\rho_t$  variation can modulate the effective metric tensor via scalar scaling, enabling gravitational reinterpretations without requiring new particles.

To relate this to observational redshift  $z(d)$ , we adopt the optical analogy where light rays propagate through a temporally varying medium. In such a scenario, variations in  $\rho_t$  induce differential delays analogous to Fermat's principle, and redshift arises from the integrated delay experienced over the light path.

## 10. Model-Observation Link

The link between the variation in the speed of light  $c'(x)$  and the redshift formula  $z(d)$  is conceptually modeled through the refractive behavior of  $\rho_t$ . As light traverses regions of higher  $\rho_t$ , it slows down and accumulates delay. While  $c'(x)$  gives a local variation,  $z(d)$  captures the cumulative effect.

In this view,  $z(d)$  arises as a phenomenological summary of  $\int dx/c'(x)$ , approximated by gradients in  $\rho_t$  under small-angle and weak-field assumptions.

## 11. Challenges and Objections

Key challenges include:

- Distinguishing from tired light (this model maintains coherence and supports lensing).
- Stability of constants: ensuring  $\kappa$  does not introduce pathologies.
- Lorentz invariance: preserved locally due to slow spatial variation in  $\rho_t$ .
- Experimental verifiability: requires high-precision redshift-distance mapping.

## 12. Philosophical Implications

These ideas echo notions of implicate order and the primacy of holistic fields [8]. This model repositions time as a dynamic field, not a passive dimension. It supports:

- Time as a vibrational fabric with spatial topology.
- New interpretations of simultaneity, consciousness, and causality.
- Reconceptualizing entanglement as mediated via  $\rho_t$  turbulence.

## 13. Conclusion

Time density presents a unified lens through which cosmological and quantum-scale observations may be reframed. Its refractive effect on light provides a compelling reinterpretation of redshift and cosmic structure without invoking new matter forms. Further theoretical refinement and observational validation are necessary.

## Nota iz Etera

*Ako prostor titra poput napetih žica violine, onda je vrijeme rezonantna koža bubnja iz kojeg izvire bitak. Svaka vibracija koju zabilježimo — svjetlost, misao, zrak — prolazi kroz mrežu gustoće vremena, zamućena slojevima prošlosti i budućnosti koje tek trebamo otkriti. A ako smo sjena fotona koji je krenuo bez da zna kamo ide — možda je istina da svaka teorija, poput svake zrake svjetlosti, traži vlastito prelamanje prije nego zasja u svom punom spektru.*

## Disclosures

The authors declare there are no financial interests, commercial affiliations, or other potential conflicts of interest that have influenced the objectivity of this research or the writing of this paper.

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## Appendix N Time Density Function Candidates

- Gaussian shells
- Inverse-square distributions
- Toroidal or vortex-centric fields

## Appendix O Units and Scaling

- $[\rho_t] = T/L^3$  (e.g., seconds per cubic meter)
- $\kappa$  is a dimensionless coupling constant

- $\rho_0$  is a reference background time density used for normalization
- Sample scaling: voids  $\sim 10^{-6} \rho_0$ , galactic cores  $\sim 10^4 \rho_0$

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