

Rethinking Cosmic Distance: The Arcsecond, Parallax, and the Case Against the Light-Year in Modern Cosmological Frameworks

Introduction to the Crisis in Cosmological Measurement

The foundation of modern astrophysics rests heavily on the precision with which humanity can measure the unimaginably vast distances between celestial bodies. For over a century, the standard cosmological model, dominated by the Λ CDM (Lambda Cold Dark Matter) framework, has relied on a unified understanding of spacetime as a physical, expanding fabric.

Within this substantialist framework, the speed of light propagating in a vacuum (c) is treated as an absolute, immutable, and eternal constant of the universe.¹ This assumption of a constant velocity has deeply popularized the use of the "light-year"—the distance light travels in one Julian year—as a standard unit of cosmic measurement in both professional astronomy and public scientific discourse.²

However, recent observational anomalies have induced a severe crisis within standard cosmology, fracturing the foundational consensus. Most notably, the James Webb Space Telescope (JWST) has detected massive, highly evolved galaxies at extreme redshifts ($z > 10$) existing during the period known as the "cosmic dawn".¹ Under the strict standard Λ CDM timeline, which calculates the total age of the universe at roughly 13.8 billion years,

the universe at $z > 10$ would only be a few hundred million years old.¹ Standard mathematical models of hierarchical structure formation dictate that it is both physically and mathematically impossible for such mature, massive galactic structures to form in such a brief temporal window.¹ This anomaly is widely referred to in modern literature as the "impossible early galaxy" problem, and it has forced theoretical physicists to reevaluate fundamental cosmological constants, the nature of redshift, and the mechanisms by which distances are defined and measured across the cosmos.¹

Emerging alternative frameworks, specifically the modern systems-architecture cosmological paradigm, propose a radical departure from orthodox substantialist spacetime theories. By resurrecting and heavily modernizing the concepts of Tired Light (TL) cosmology and integrating Massive Electrodynamics via the Proca equations, this paradigm suggests that the

speed of light is not an immutable constant, but rather a variable, energy-dependent metric.¹ Consequently, if the velocity of light varies across time and space, the term "light-year" becomes fundamentally flawed. It can no longer be utilized as a reliable way to judge spatial distance based on a constant speed.¹ Under tired light theory, the light-year is deeply misleading and physically inaccurate. In a universe where light decelerates, disperses, and loses energy over immense relational distances, kinematic distance measurements must be entirely abandoned in favor of pure, invariant geometric measurements. This scientific paradigm shift necessitates a return to the foundational roots of astrometry: the arcsecond, the parsec, and the unyielding geometry of stellar parallax.

The Arcsecond: A Historical and Mathematical Foundation

To comprehend why geometric astrometry must supersede kinematic distance measurement in a variable-speed universe, it is necessary to thoroughly examine the arcsecond—its origins, its extreme precision, and its profound mathematical application in astronomical observation. The measurement of the cosmos begins not with linear rulers spanning the void, but with the highly precise division of observable angles.

The Definition and Origin of the Arcsecond

An arcsecond (denoted universally by the symbol $"$, which must not be confused with the symbol for inches) is a highly precise unit of angular measurement.³ To understand its scale, one must begin with a complete circle, which is geometrically divided into 360 individual degrees. Each of these degrees is further subdivided into 60 arcminutes, and each arcminute is subsequently divided into 60 arcseconds.³ Therefore, mathematically, an arcsecond is equivalent to 1/3600th of one degree, or exactly 1/1,296,000 of a full circle.⁴ The conceptual origins of using arcseconds to measure angles trace back to ancient Greece, where early astronomers required increasingly precise, minute units to catalog the localized details of the night sky.⁵ However, the modern formalization of the unit as a rigorous mathematical standard is attributed to the French astronomer Jean Picard in the year 1670.⁶ Picard developed and utilized the arcsecond in an ambitious scientific attempt to measure the size of the Earth with unprecedented accuracy by observing the precise angular elevation of celestial bodies from different latitudes.⁶ Since the 17th century, the arcsecond has remained the absolute cornerstone of modern astrometry. It allows researchers to measure distances between celestial objects, map their minute movements across the celestial sphere, and calculate the intrinsic brightness and structural composition of distant galaxies without any internationally recognized alternative.⁶

Angular Unit	Definition	Proportion of a Degree	Proportion of a Circle
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Degree (°)	Standard angular unit	1	1/360
Arcminute (')	1/60 of a degree	1/60	1/21,600
Arcsecond (")	1/60 of an arcminute	1/3,600	1/1,296,000
Milliarcsecond (mas)	1/1,000 of an arcsecond	1/3,600,000	1/1,296,000,000
Microarcsecond (μas)	1/1,000,000 of an arcsecond	1/3,600,000,000	1/1,296,000,000,000

Conceptualizing the Scale of an Arcsecond

Because the arcsecond represents such a microscopic sliver of the observable sky, it is often helpful to conceptualize its scale using terrestrial equivalents. One arcsecond is the exact angle subtended by a standard United States dime coin (which has a diameter of 0.705 inches, or 17.9 millimeters) when viewed from a distance of 3.7 kilometers (2.3 miles).⁷ In the metric system, it is mathematically equivalent to viewing an object measuring exactly 1 millimeter in diameter from a distance of 206.265 meters, or viewing an object measuring 0.485 millimeters from exactly 100 meters away.⁷ In the Imperial system, it represents the angle subtended by an object measuring 1/16 of an inch when viewed from a distance of 67 feet and 1 3/4 inches.⁷ When translated to immense astronomical scales, the precision of the arcsecond becomes even more apparent. If one were to observe the movement of stars across the sky as the Earth rotates, one arcsecond equates to roughly 66.48 milliseconds of stellar movement, given that the sky rotates at approximately 15.041 arcseconds per second.⁷ At the distance of one Astronomical Unit (AU)—the distance from the Earth to the Sun—one arcsecond subtends an object with a diameter of 725.27 kilometers.⁷ At the unfathomable distance of one standard light-year, an angle of one arcsecond subtends an object with a physical diameter of 45,866,916 kilometers.⁷ In radians, the standard mathematical unit of angular measure favored in pure physics, there are precisely 206,264.5 arcseconds in one single radian, yielding the critical conversion factor of $1'' = 4.848 \times 10^{-6}$ radians.³

Observational Limitations and Sub-Arcsecond Scales

While the mathematical abstraction of the arcsecond provides limitless precision, physically observing objects at this microscopic scale from the surface of the Earth presents severe engineering and optical challenges. The Earth's atmosphere is highly turbulent; it is filled with chaotic thermal currents, varying moisture levels, and differing air densities that constantly shift. As starlight passes through this turbulent medium, it is rapidly refracted in multiple directions—a phenomenon universally known in observational astronomy as "atmospheric seeing".³

This localized atmospheric turbulence actively smears out the light from distant point sources, such as stars, causing the optical illusion known as twinkling and artificially expanding their apparent angular diameter to the observer on the ground.³ Even under the absolute best atmospheric conditions, utilizing the world's premier terrestrial observatories situated at high altitudes, point sources of light will generally be smeared out to an angular diameter of about 0.5 arcseconds.³ Therefore, observing geometric shifts smaller than half an arcsecond requires overcoming the Earth's atmosphere entirely.

Because of these atmospheric limitations and the vastness of the universe, modern astrometric calculations frequently rely on extreme sub-arcsecond measurements. A

milliarcsecond is equal to 10^{-3} arcseconds, and a microarcsecond (μas) is equal to an astonishing 10^{-6} arcseconds.³ To achieve this level of precision, space-based observatories operating in the pure vacuum above the atmosphere, such as the Hipparcos satellite and the subsequent Gaia mission, have been deployed.⁸ These instruments have revolutionized galactic mapping, extending the distance at which reliable parallax angles can be measured into the microarcsecond regime and validating the arcsecond as the superior tool for structural cosmic measurement.⁸

The Mechanics of Stellar Parallax

The primary astrometric utility of the arcsecond is its direct application in observing and calculating stellar parallax, a geometric phenomenon that provides the most reliable and assumption-free method for determining the distance to relatively nearby celestial bodies.

The Geometry and Observation of Parallax

Stellar parallax is defined as the apparent, optical displacement or movement of a nearby star against the stationary background of much more distant, seemingly "fixed" stars and galaxies as the Earth revolves around the Sun in its annual orbit.⁸ To visualize this, one can hold a finger up close to their face and view it against a distant wall, closing first one eye and then the other. The finger appears to jump horizontally across the background. This optical shift is the essence of parallax.

In astronomical terms, the two "eyes" are the position of the Earth at opposite ends of its solar

orbit. As Earth moves from one side of its orbit to the opposite side over a six-month period, the optical vantage point from which astronomers observe a target nearby star shifts by a baseline of approximately 2 Astronomical Units (AU).⁸ For context, 1 AU is defined as the average physical distance from the Earth to the Sun, mathematically equal to

$$1.495978 \times 10^{11} \text{ meters.}^8$$

This shifting astronomical vantage point causes the nearby target star to trace a microscopic

ellipse in the sky relative to the distant background stars.⁹ The parallax angle ($\mathcal{P}$) is strictly defined not as the total angular shift observed over six months, but as half of this apparent angular shift.¹¹ Geometrically, it represents the exact angle subtended by a baseline of 1 AU at the physical distance of the star being observed.¹⁰

Due to the immense, sprawling distances between stars within our local galactic neighborhood, stellar parallax angles are exceedingly minute and notoriously difficult to detect. In fact, their existence and measurement remained a subject of intense astronomical debate and frustration for hundreds of years following the Copernican revolution.¹⁰ It was not until the period of 1832 to 1838 that optical technology advanced sufficiently for astronomers Thomas Henderson, Friedrich Georg Wilhelm von Struve, and Friedrich Bessel to successfully record the first verified parallax measurements for the stars Alpha Centauri, Vega, and 61 Cygni.¹⁰ These groundbreaking measurements provided the final, undeniable geometric proof of the Earth's orbit around the Sun and established the true scale of the local stellar neighborhood.¹⁰ It is also crucial to distinguish apparent annual parallax motion from a star's "proper motion." Proper motion refers to the permanent change in a star's position in the sky as a result of its true, genuine kinematic motion through physical space relative to the solar system.⁸ Parallax, on the other hand, is purely an optical consequence of the observer's movement on Earth, resulting in an annual closed loop or ellipse. Both proper motion and parallax must be carefully isolated and measured in arcseconds to build accurate models of stellar kinematics.⁸

Deriving Distance Using the Small-Angle Approximation

The calculation of cosmic distance via parallax relies entirely on the fundamental, indisputable laws of right-angle trigonometry. A vast right triangle is formed in space, with the vertices representing the Sun, the Earth, and the distant star.¹⁰ The leg of the triangle connecting the

Sun and the Earth has a fixed length of 1 AU, serving as the constant baseline ($\mathcal{B}$).¹⁰ The much longer leg connecting the Sun directly to the star represents the distance ($\mathcal{d}$) to the star.¹⁰ The

microscopic angle located at the vertex of the star is the parallax angle ($\mathcal{P}$).¹⁰

Because stellar distances are so vast and the baseline of 1 AU is comparatively infinitesimal, the resulting parallax angles are exceedingly small. Notably, there are no known stars beyond our own Solar System that present a parallax angle greater than 1 full arcsecond.³ Proxima

Centauri, definitively the nearest star to our solar system, exhibits the largest known parallax of just 0.7685 ± 0.0002 arcseconds.⁸

Because these observed angles are so incredibly small (measuring significantly less than 1 radian), astronomers confidently employ the mathematical principle known as the small-angle approximation.¹⁰ In standard radian measure, for extremely small angles, the trigonometric tangent of the angle is mathematically approximately equal to the angle itself ($\tan(p) \approx p$).¹⁰

When the parallax angle is converted from radians into arcseconds, the baseline (B) and distance (d) must be reconciled. The foundational formula dictating this geometric distance is expressed as:

$$p = \frac{206,265 \times B}{d}$$

Where p is the angle in arcseconds, B is the baseline, and d is the distance, with B and d expressed in identical units of length.¹¹ However, the formula simplifies dramatically when utilizing standard astronomical units. When the baseline (B) is expressed in astronomical units (AU), and the distance (d) is expressed in parsecs, the constant 206,265 is absorbed into the definition of the parsec itself. For observations originating from Earth's orbit, where the baseline B is exactly 1 AU, the relation becomes the elegant and highly functional equation:

$$d = \frac{1}{p}$$

Therefore, the distance to any star, measured in parsecs, is simply the mathematical reciprocal of its parallax angle measured in arcseconds.⁸ This simple relationship explains why geometric astronomy overwhelmingly prefers to measure distances in parsecs.⁹ For instance, if a star exhibits a parallax of exactly 0.5 arcseconds, its geometric distance is calculated as

$1/0.5 = 2$ parsecs.¹¹ If the parallax is 0.1 arcseconds, the distance is exactly 10 parsecs.¹¹

In the case of Proxima Centauri, the nearest star to Earth other than the Sun, its measured parallax of 0.7685 arcseconds yields a distance calculation of $1/0.7685 = 1.301$ parsecs.⁸ Another historical example is the star 61 Cygni, which exhibits a parallax of approximately 1/3 of an arcsecond, placing it at a distance of 3 parsecs.⁸ Barnard's Star, famous for exhibiting incredibly large proper motion across the sky, sits at a geometric distance of 1.8 parsecs, translating to an angular parallax of roughly 0.55 arcseconds.⁸ Further examples derived from this formula indicate that a parallax of 0.723 arcseconds results in a distance of 1.38 parsecs, while a star located 2.64 parsecs away would present an incredibly tight parallax of 0.34

arcseconds.⁹

To aid in the instruction and visualization of this complex geometry, numerous interactive modeling tools have been developed. For example, the University of Washington's introductory astronomy course provides a sophisticated java-based lab where researchers and students can manually adjust the inclination of a star relative to the planetary orbit, alter the distance to the star, change the physical size of the planet's orbit (the baseline), and seamlessly add in the effects of proper motion to see how these variables strictly dictate the resulting arcsecond measurements.¹¹

The Parsec: A Purely Geometric Distance Metric

The term "parsec" (abbreviated as pc) is a direct linguistic portmanteau derived from combining the words "parallax" and "second".¹² It is defined physically and precisely as the exact distance from the Sun to an astronomical object that presents a parallax angle of one single arcsecond.¹⁰ Furthermore, it can be visualized as the length of the leg of a right triangle adjacent to the angle of one arcsecond at one vertex, where the opposite, shorter leg is exactly 1 AU long.¹⁰

In standard physical terms, one parsec is equivalent to an astounding 3.085678×10^{16} meters, or precisely 206,265 Astronomical Units.⁸ For objects much further away, astronomers scale the unit up, utilizing the megaparsec (one million parsecs) or the gigaparsec (one billion parsecs) to chart the structure of the cosmos.¹³

Crucially, the parsec is a metric fundamentally rooted in pure geometry and rigid spatial relations. Its derivation depends entirely and exclusively on the physical spatial baseline distance between the Earth and the Sun, and the highly precise angular measurement of the arcsecond.¹⁰ The parsec does not factor in the speed of light. It does not rely on the passage of time. It does not assume that light propagates at a constant velocity. It is a rigid, mathematically pure triangulation of physical space.¹⁰ This critical distinction becomes paramount when evaluating competing cosmological models and understanding why the "light-year" is fundamentally incompatible with modernized physics.

The Kinematics of the Light-Year and its Inherent Vulnerabilities

In stark contrast to the geometric purity of the arcsecond and the parsec, standard substantivist cosmology and popular science media frequently employ the "light-year" (ly) as an alternative kinematic metric for vast distances.²

Defining the Light-Year

A light-year is explicitly and strictly defined as the distance that light travels in a vacuum during the time span of one Julian year, which is formally standardized as exactly 365.25 days.² Mathematically, standard accepted physics equates the light-year to approximately

9.46053×10^{15} meters.⁸ In round figures often utilized in public science communication, a light-year is nearly 9.461 trillion kilometers, or roughly 5.879 trillion miles.² Under the standard mathematical conversions based on current Λ CDM models, one parsec is equivalent to roughly 3.261633 light-years.²

Distance Metric	Definition	Value in Meters	Value in Alternative Units
Astronomical Unit (AU)	Average distance from Earth to Sun	1.495978×10^{11}	1 AU
Light-Year (ly)	Distance light travels in 1 Julian year	9.46053×10^{15}	6.324×10^4 AU
Parsec (pc)	Distance where 1 AU subtends 1 arcsecond	3.085678×10^{16}	3.2616 ly / 206,265 AU

Using these standard kinematic conversions, Proxima Centauri is often cited as being 4.24 light-years away (1.301 parsecs).² Barnard's Star is translated from 1.8 parsecs to roughly 5.9 light-years.⁸ While Astronomical Units (AU) are appropriately utilized for planetary distances localized within our solar system, the light-year and the parsec are heavily utilized for stellar, galactic, and intergalactic distances, such as measuring the distance to the Orion Nebula.¹³ The pervasive cultural reliance on these kinematic terms often leads to deep fundamental misunderstandings; for instance, the famous pop-culture reference of making the "Kessel Run in 39.12 light years" or "under twelve parsecs" famously confuses units of spatial distance with units of elapsed time, demonstrating the inherent cognitive vulnerability of linking distance to temporal light travel.¹⁴

The Core Assumption of the Constancy of c

The scientific validity of the light-year as a unit of spatial distance is entirely and inextricably predicated on a singular, foundational assumption derived from Einsteinian special and general relativity: that the speed of light propagating in a vacuum (c) is an eternal, absolute, and invariable constant for all observers in all reference frames, universally equal to exactly

299,792,458 meters per second.¹

Under standard Maxwellian electrodynamics, the photon is classified theoretically as a strictly massless gauge boson.¹ Because it entirely lacks rest mass, a photon propagating in a perfect vacuum cannot undergo physical deceleration, structural dispersion, or inherent energy dissipation.¹ It propagates infinitely and eternally at exactly c , preserving strict $U(1)$ gauge invariance.¹

Because the velocity is presumed to be perfectly constant, measuring spatial distance via the light-year is reduced to a simplistic kinematic exercise governed by the elementary equation:

Distance equals Rate multiplied by Time ($d = rt$). If the rate (c) is absolute and unyielding, the temporal delay of light perfectly and accurately maps to physical spatial distance. This theoretical assumption allows standard astronomers to observe distant galaxies and confidently infer the evolution and age of the universe based on the premise that looking deeper into space is mathematically and physically equivalent to looking backward in time.² However, this metric contains a fatal logical vulnerability. If the rate of electromagnetic propagation is not constant—if the speed of light varies depending on the specific age of the universe, the gravitational environment, or the internal energy frequency of the photon itself—

the entire mathematical concept of the light-year collapses instantly. A variable c permanently severs the fixed mathematical link between the time elapsed and the physical distance covered. Under conditions of a variable speed of light (VSL), a "light-year" ceases to be a reliable measure of distance, becoming instead a highly misleading, inaccurate abstraction.

The Crisis in Λ CDM Cosmology

The necessity to abandon the light-year and adopt the ArcSecs geometrical paradigm is not merely a philosophical exercise; it is driven by a severe observational crisis in standard cosmology.

For decades, the standard Einsteinian model has treated the phenomenon of galactic redshift as definitive proof of a metric expansion of a physical spacetime fabric.¹ As space physically stretches, it allegedly expands the wavelength of the light traveling through it. This model led directly to the Big Bang theory and the strict 13.8-billion-year timeline of the universe's existence.¹

However, the recent deployment of the James Webb Space Telescope (JWST) has shattered this timeline. The JWST has definitively observed massive, highly evolved, complex galaxies existing at extreme redshifts ($z > 10$) during the epoch known as the "cosmic dawn".¹ Under the Λ CDM timeline of 13.8 billion years, the universe at a redshift of $z > 10$ would only be a few hundred million years old.¹ Standard astrophysical models of hierarchical structure formation dictate that matter clumps together gradually over billions of years. It is mathematically, gravitationally, and physically impossible for such mature, massive galaxies to

coalesce and form in such a brief temporal window.¹ This "impossible early galaxy" anomaly has exposed the fundamental inadequacies of measuring the universe based on an expanding spacetime fabric and a constant speed of light.

The ArcSecs Paradigm: Tired Light and the Relational Void

To resolve the impossible early galaxy problem and correct the fundamental errors of standard measurement, the "ArcSecs" systems-architecture cosmological framework has been developed.¹ This advanced framework systematically responds to orthodox skepticism by shifting the debate from emotional dismissals of alternative physics to highly objective, test-driven engineering evaluations.¹

Rejecting Substantialist Spacetime

The first step in correcting cosmological measurement is the outright rejection of standard substantialist spacetime. In standard Λ CDM cosmology, space is treated as a physical fabric—a substantive continuum capable of expanding, bending, and mathematically warping.

Hubble's Law dictates that distant galaxies (specifically those where redshift $z \geq 1$) separate from Earth at recession velocities seemingly exceeding the speed of light.¹ To prevent a catastrophic violation of Einstein's special relativity, standard theory awkwardly asserts that the galaxies themselves are practically stationary, but "space itself" is undergoing a metric expansion between them, stretching the fabric of the universe.¹

The ArcSecs paradigm explicitly dismantles this substantialist concept. Following the strict relational philosophy originally outlined by Gottfried Wilhelm Leibniz, the framework posits that space is emphatically not an independent physical substance capable of physical manipulation.¹ Rather, space is an absolute "relational void"—it exists solely and entirely as the geometrically measured distance between physical objects, strictly defining the "order of co-existing things".¹ In the total and absolute absence of physical mass or matter, space does not independently exist.¹ Because space is a relational void utterly devoid of a physical medium, it cannot literally stretch, warp, or undergo metric expansion.¹ Consequently, the superluminal separation of high-redshift galaxies must be recognized as genuine, physical kinematic motion of celestial nodes through physical space, rather than a passive, illusory ride on expanding spacetime fabric.¹

Massive Electrodynamics and the Proca Lagrangian

If the universe is a relational void that is not undergoing metric expansion, alternative physical mechanisms must explain cosmological observations, most critically the redshift of distant starlight. Historically, early "tired light" theories proposed that photons simply lost energy as they traveled across the void, naturally shifting their frequency toward the red end of the

spectrum. However, these early theories struggled immensely to identify a viable physical mechanism for this energy loss without violating the standard laws of quantum electrodynamics and gauge invariance.¹

The ArcSecs framework resolves this historical hurdle through the rigorous implementation of Massive Electrodynamics, specifically governed by the Proca equations.¹ The Proca framework represents the simplest and most elegant relativistic generalization of standard Maxwell's equations. It fundamentally alters theoretical electrodynamics by introducing a crucial non-zero rest mass term (m_γ) directly into the electromagnetic Lagrangian.¹ The profoundly modified Proca Lagrangian is expressed mathematically as:

$$-\frac{1}{16\pi}F_{\mu\nu}F^{\mu\nu} + \frac{m_\gamma^2 c^2}{8\pi\hbar^2}A_\mu A^\mu$$

By consciously introducing this mass term, the Proca equations intentionally and explicitly break the standard $U(1)$ gauge invariance that protects the massless photon in standard models.¹ The vector potential (A_μ) is instantly transformed into a physically significant, massive quantity.¹ The Maxwell-Proca equations describe this new massive electromagnetic field mathematically as follows:

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0} - \mu^2 V$$

Where the term μ directly represents the Compton wavelength of the new massive photon.¹ While this newly defined rest mass is incredibly small, it is entirely non-zero. Astrophysical experiments utilizing highly sensitive galactic plasma constraints suggest a stringent upper mass limit of $10^{-18} \text{ eV}/c^2$.¹ Other advanced models involving massive photon interaction with the Higgs field vacuum postulate a photon condensation threshold energy incredibly close to 10^{-19} eV .¹ Regardless of the exact microscopic value, the endowment of the photon with invariant physical mass initiates a cascade of profound cosmological shifts that directly invalidate the concept of the "light-year."

The Variable Speed of Light (VSL) and the Mathematical Collapse of the Light-Year

The most critical consequence of Massive Electrodynamics is its devastating effect on the constancy of the speed of light. Because the photon possesses invariant physical mass, standard kinematic laws dictate that it requires infinite energy to travel exactly at the

fundamental speed limit of spacetime. Consequently, the literal speed of light (c) ceases to be the constant velocity of all propagating photons.¹

Instead, c must be strictly redefined. It is no longer a hardcoded, insurmountable structural barrier of the cosmos, but rather an unreachable asymptotic limit of localized spacetime kinematics, a localized propagation delay, and a structural bandwidth constraint of the electromagnetic interactions occurring within specific localized fields or media.¹

Energy-Dependent Dispersion

When electromagnetic waves propagate not as massless waves but as massive particles, they become subject to severe dispersion, even when traveling through a perfect, true vacuum.¹ The actual physical velocity of a massive photon becomes slightly energy-dependent. This critical relationship is defined by the physical equation:

$$v = c \sqrt{1 - \frac{m_\gamma^2 c^4}{E^2}}$$

In this equation, v represents the actual, physical velocity of the traveling photon, c is the asymptotic structural speed limit, m_γ represents the invariant rest mass of the photon, and E signifies the photon's internal energy.¹ Because quantum energy is directly and inextricably proportional to frequency, lower-frequency (lower energy) photons naturally travel slightly slower than high-frequency (higher energy) photons.¹

The Mathematical Invalidation of Kinematic Distance

This energy-dependent velocity presents a fatal, irreconcilable logical contradiction for the term "light-year." A light-year is intended mathematically to represent a fixed, constant spatial distance (9.46×10^{15} meters) strictly based on the absolute constancy of c .²

However, under the VSL constraints of massive electrodynamics, a high-energy gamma-ray photon travels faster than a low-energy radio-wave photon. Therefore, a "gamma-ray light-year" would represent a vastly different, much longer physical spatial distance than a "radio-wave light-year." The metric cannot be standardized.

Furthermore, as a single, massive photon travels across the galactic void and loses energy to redshift over billions of years, its intrinsic velocity continuously drops.¹ A "year" of travel for an early, highly energetic photon emitted during a supernova will physically cover more spatial distance than a "year" of travel for that exact same photon after it has lost energy, redshifted, and decelerated billions of years later.

Because the physical speed of light varies dramatically across the electromagnetic spectrum and changes continuously over a photon's lifespan as it loses energy, the fundamental conversion factor between spatial distance and light-travel time breaks down entirely.

Therefore, within the massive electrodynamics framework of the ArcSecs paradigm, the "light-year" is highly misleading, mathematically inaccurate, and entirely unusable.¹ It cannot be

utilized to judge distance based on a constant speed because the speed varies continuously.¹ To accurately map the structure of the cosmos without falling victim to kinematic illusions, astrometry must revert exclusively to invariant angular geometric relationships—the arcsecond and the parsec—which remain absolutely mathematically true regardless of the variable velocity of the light passing between the celestial nodes. This is the foundational scientific reasoning behind the naming and philosophy of the ArcSecs cosmological framework.

The Physical Mechanisms of Tired Light and Redshift

If the metric expansion of space is entirely rejected, the redshift observed in distant galaxies must be driven by purely physical interactions between massive photons and the intergalactic environment.

Cumulative Gravitational Drag

Because the photon in the ArcSecs framework possesses non-zero invariant mass, it interacts physically and gravitationally with the spatial void. The bending and magnification of light observed around massive bodies (such as gravitational lensing observed during solar eclipses) cannot be attributed to massless particles blindly following the curved geometric geodesics of a substantialist spacetime fabric.¹ Instead, massive photons are subject directly and unavoidably to classical Newtonian gravitational forces.¹ They deflect purely by gravitational attraction, governed by the identical mechanical principles that dictate the deflection of a massive comet as it passes by a star.¹

While the invariant mass of a single photon is minuscule, causing virtually invisible localized effects in isolated terrestrial laboratories, the cumulative gravitational drag becomes highly consequential and entirely dominant over massive astronomical distances.¹ As a massive photon propagates across millions of parsecs, interacting with the vast gravitational background or scalar fields present in extended higher-derivative gravity (HDG) or topological field theories, it experiences a relentless, physical dissipation of energy.¹ Because a photon's energy is proportional to its frequency, this physical energy dissipation naturally and predictably manifests as a shift toward the red end of the electromagnetic spectrum.¹ This mechanism provides the precise, mathematically rigorous, non-spacetime-dependent physical driver required to fully validate Tired Light cosmology.¹

Resolving the JWST Crisis: The CCC+TL Hybrid Model

To resolve the impossible early galaxy anomaly while simultaneously satisfying other highly sensitive modern cosmological constraints—such as the directional uniformity of the Cosmic Microwave Background (CMB) radiation discovered in 1965—researchers, notably Rajendra Gupta (2023, 2024), developed the Covarying Coupling Constants + Tired Light (CCC+TL) hybrid model.¹

Drawing deeply upon theoretical physicist Paul Dirac's famous 1937 Large Numbers

Hypothesis, the CCC approach posits that fundamental physical constants, explicitly including the asymptotic speed limit (c) and the universal gravitational constant (G), are not completely static. Instead, they covary dynamically as the universe itself evolves over massive epochs.¹ Integrating these relaxed, varying constants directly into the standard Friedmann equations naturally and elegantly generates mathematical terms that perfectly mimic the observed phenomenological effects traditionally and erroneously attributed to "dark energy" and "dark matter".¹ This mathematical breakthrough completely eliminates the theoretical necessity for a "dark sector" filled with arbitrary, invisible, unobservable entities like Weakly Interacting Massive Particles (WIMPs).¹

By successfully combining the physical tired light energy-loss effect with a component of covarying physical constants, the CCC+TL model organically extends the timeline of the universe from a constrained 13.8 billion years to a staggering and vast 26.7 billion years.¹ This vastly expanded timeline successfully passes all massive structural regression tests. It provides the mature early galaxies observed by the JWST with billions of additional years to naturally coalesce and mature, thus elegantly solving the impossible early galaxy anomaly.¹ Furthermore, the hybrid framework complies perfectly with the distribution of Baryon Acoustic Oscillation (BAO) features and fits the highly precise distance-modulus data generated by Type Ia supernovae just as accurately as the prevailing Einsteinian Λ CDM model.¹

Feature	Standard Model (Λ CDM)	ArcSecs Paradigm / Tired Light
Nature of Space	Substantivalist physical fabric	Relational void (measured geometric distance)
Speed of Light (c)	Absolute, invariant constant	Variable, energy-dependent limit (VSL)
Primary Astrometric Unit	Light-Year (Kinematic)	Parsec / Arcsecond (Pure Geometric)
Cause of Galactic Redshift	Metric expansion of physical space	Energy loss via gravitational drag/photon mass
Photon Mass	Strictly Massless (Gauge	Non-zero invariant rest

	boson)	mass (m_{γ}^{TTL})
Calculated Age of Universe	13.8 Billion Years	26.7 Billion Years (CCC+TL hybrid model)
The Dark Sector	Requires Dark Matter & Dark Energy	Eliminated entirely via Covarying Constants

Resolving Cosmological Skepticism: Time Dilation and Retardation

Historically, the primary weapon deployed by orthodox physicists against static, relational, or tired light cosmological models has been the observed phenomenon of high-redshift time dilation, often referred to in literature as "clock-rate broadening".¹

Standard metric expansion theory forcefully argues that as space stretches, it physically expands both the wavelengths of light (causing redshift) and the temporal arrival spacing between consecutive photons emitted by a source.¹ Therefore, high-redshift transient events, such as the brilliant explosions of Type Ia Supernovae, must appear to slow down or temporally broaden by a specific mathematical factor of $1 + z$.¹ The Dark Energy Survey's (DES) comprehensive 5-year data release on SNe Ia explicitly confirms this observed temporal broadening. For decades, standard skeptics argued that in a purely static tired light universe, a photon would lose energy without any physical alteration to its temporal spacing, meaning that supernovae at various extreme redshifts would appear to explode at identical perceived rates.¹ The successful observation of temporal broadening was frequently hailed as the definitive death blow to early tired light hypotheses.¹

The modernized ArcSecs paradigm responds to and entirely resolves this "clock-rate" skepticism through multiple robust, peer-reviewed pathways that completely dismantle the necessity for a physical spacetime continuum.

The Tipikin Diffusion-Scattering Model

Dmitriy S. Tipikin's profound 2024 modeling demonstrated conclusively that temporal dilation can be derived naturally and natively within a completely static universe void.¹ Tipikin's model asserts that tired light is heavily governed by a diffusion-like multiple scattering process as massive photons traverse the incredibly sparse intergalactic medium over distances spanning billions of parsecs.¹

As massive photons travel these immense distances, they interact probabilistically with the quantum vacuum or sparsely dispersed intergalactic particles. During these microscopic interactions, they experience both a distinct loss of energy (redshift) and physical scattering.¹ Because this is inherently a probabilistic quantum process, individual photons originating from the exact same celestial event (such as a supernova flash) take slightly different paths to the observer on Earth:

1. Photons that mathematically experience the fewest scattering events travel the most direct, linear path across the void, arriving first at the telescope.¹
2. Photons that undergo a much higher volume of scattering events are physically forced into a longer, erratic "random walk" diffusion path, taking longer to cross the void and arriving sequentially later.¹

This physical, probabilistic scattering process inherently and continuously disperses the arrival times of the photon stream across vast distances. This exact dispersion causes a noticeable temporal broadening of the supernova's light curve that perfectly, mathematically mimics the

$1 + z$ Doppler-like kinematic time dilation predicted by the Big Bang metric expansion theory.¹ Recent, highly detailed observations by the JWST of highly distant supernovae have actively validated and mathematically fit this diffusion model, proving definitively that an expanding spacetime fabric is absolutely not required to explain light curve broadening.¹

Deconstructing Relativistic Time Dilation as Atomic Retardation

Moving beyond intergalactic scattering, the ArcSecs framework systematically redefines the fundamental nature of localized time dilation itself, particularly in high-gravity or high-velocity environments where standard relativity typically invokes the literal, physical warping of a temporal dimension.

The strict relational paradigm dictates that time travel, temporal fabrics, and the physical malleability or warping of a dimension are mathematical fictions and philosophical misinterpretations.¹ What standard general relativity misinterprets as "time dilation" is structurally and physically redefined as the physical, mechanical retardation of atomic oscillators caused by the application of immense external physical forces.¹

Consider a standard atomic clock, such as a highly precise Cesium-133 frequency standard, frequently used to test relativity. This instrument does not measure an abstract, metaphysical "fabric of time." It functions strictly and entirely as a mechanical frequency counter, tallying the exact number of microwave oscillations required to induce a specific energy state change within the cesium atom's physical electron shell.¹

When this physical atomic clock is lowered deep into a dense gravitational well, it is subjected to a significantly increased Newtonian gravitational potential (Φ).¹ Because physical potential energy is defined structurally as the product of mass and potential, exposing the cesium atom to a deeper gravitational potential physically and materially increases the internal potential energy of the atom itself.¹ This immense mechanical increase in energy directly bogs down and

structurally reduces the physical oscillation frequency of the atom's electron shell.¹ The exact reduction in frequency is governed rigorously by the mathematical relation:

$$\nu_{\text{retarded}} = \nu_0 \sqrt{1 - \frac{2\Phi}{c^2}}$$

In this critical equation, ν_{retarded} represents the slowed, bogged-down oscillation rate, ν_0 is the standard baseline frequency, Φ is the Newtonian gravitational potential, and c acts as the asymptotic bandwidth constraint of the local field.¹

The atomic clock ticks slower strictly because its physical pendulum—the localized electron shell—is mechanically hindered by the dense gravitational potential, not because "time itself" has stretched, deformed, or dilated.¹ This purely physical, mechanical interpretation successfully and perfectly accounts for the highly publicized clock desynchronization observed daily in Global Positioning System (GPS) satellite networks, as well as classical relativistic tests like the famous Hafele-Keating experiment.¹ Crucially, it achieves this mathematical precision without ever resorting to substantialist, metaphysical spacetime warping.¹

The Rejection of Relativistic Mass and Superluminal Freedom

A further profound consequence of redefining c as a localized bandwidth constraint rather than an absolute, universal geometric speed limit is the total theoretical rejection of the classical concept of "relativistic mass".¹ Classical special relativity posits that as a physical object accelerates toward the speed of light, its physical mass continuously increases,

eventually requiring infinite energy to cross the c threshold.¹

The ArcSecs paradigm explicitly labels the concept of relativistic mass a dangerous "pedagogical virus" that has infected modern physics instruction.¹ It firmly asserts that the only

physically meaningful mass is an object's strict invariant mass (m_0), commonly known as rest mass. This invariant mass operates as a strict Lorentz scalar that remains absolutely and undeniably constant regardless of the object's velocity or the specific reference frame of a distant observer.¹

The immense physical resistance to acceleration experienced by highly energetic particles in modern particle accelerators (such as the Large Hadron Collider) is emphatically not caused by the object physically or structurally gaining mass. Instead, it is a localized property of the dynamic relationship between the object's massive momentum and the localized topological field of the specific interaction medium (representing the bandwidth constraint).¹ Because an accelerating object's actual structural, invariant mass does not physically increase, there is absolutely no intrinsic, object-level physical or structural barrier preventing superluminal (faster-than-light) velocity in a true void.¹

By completely discarding the continuous, shared spacetime manifold—a profound philosophical and mathematical problem in general relativity often critiqued by relational physicists as the "Borg Problem"—massive celestial objects and distant galaxies are properly modeled as entirely independent, autonomous physical nodes.¹ By removing this artificial, universal shared context window, massive objects and distant galaxies can dynamically achieve genuine faster-than-light (FTL) relative velocities without ever violating principles of local causality.¹ This mathematically aligns perfectly with the framework's core assertion that immense galactic recession is genuine kinematic motion of matter through a relational spatial void, rather than the impossible scenario of "space itself" physically expanding at superluminal speeds.¹

Conclusion

The persistence of the standard Λ CDM framework relies overwhelmingly on a series of theoretical assumptions established over a century ago, primarily the strict massless nature of the photon and the absolute invariance of the speed of light (c). These assumptions are uniquely necessary to mathematically justify the metric expansion of a physical spacetime fabric to explain galactic redshift, and they fundamentally validate the kinematic "light-year" as the standard yardstick of the cosmos.

However, under the crushing weight of modern observational evidence—most notably the impossible, massive, early galaxies detected routinely by the JWST—the mathematical and logical contradictions of this standard model have grown too severe to ignore. The rigorous modernization of Tired Light models, encapsulated holistically within the ArcSecs systems-architecture paradigm, offers a highly robust, purely physical, and mechanically sound alternative. By integrating Massive Electrodynamics via the Proca Lagrangian, permanently endowing the photon with invariant rest mass, and successfully recognizing physical space as an absolute relational void rather than a stretchable fabric, the paradigm resolves deep observational anomalies without ever requiring the invention of dark matter, dark energy, or a malleable, warping temporal dimension.

Crucially, the introduction of photon mass generates an undeniable, energy-dependent dispersion effect, proving that the physical speed of light (c) is inherently variable over vast cosmic distances and across different energy frequencies. Because the physical velocity of light changes continuously depending on its energy state and its degradation over time, standard kinematic distance formulas that rely on light travel time ($d = rt$) instantly collapse. The "light-year" becomes an unstable, highly misleading, and mathematically inaccurate abstraction that must be retired from rigorous scientific literature. It cannot be used to judge distance based on a constant speed because that speed actively varies.

In this new, variable kinematic universe, the only mathematically reliable method for charting the cosmos is pure, unadulterated geometry. The arcsecond—a highly precise angular measurement entirely independent of time, kinematics, or velocity—allows for the rigid

calculation of stellar parallax. This pure geometric triangulation yields the parsec, a rigid measure of physical distance that remains absolutely mathematically true regardless of how fast or slow a massive photon travels through the void. Therefore, astronomical astrometry must firmly and permanently pivot away from the kinematic distortions and variables of the light-year, returning exclusively to the unwavering, geometric precision of the arcsecond and the parsec.

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