Relational Cosmology and Kinematics: A Parsec-Centric Framework for Astronomical Measurement

The Ontological Substrate: Deconstructing the Spacetime Continuum

The standard model of cosmology and astrophysics has historically relied upon the constancy of electromagnetic propagation to define macroscopic distances, effectively scaling the universe through the metric of the "lightyear." However, contemporary computational physics frameworks and post-relativistic spacetime models mandate a severe ontological paradigm shift. The substantialist reification of spacetime—specifically the continuous differential manifold proposed by Albert Einstein in General Relativity—introduces coordinate singularities and constraint violations when attempting to simulate or map the cosmos with absolute digital precision.[1] Furthermore, reliance on distance metrics derived from the time-of-flight of electromagnetic radiation is fundamentally flawed due to the variable speed of causality and the decay of light speed over scalar distances.[1]

The foundational premise of this framework asserts that the propagation velocity of electromagnetic radiation is not an absolute constant, but rather a variable subject to exponential deceleration. Under this post-relativistic model, empty space is not modeled as a geometric void, but as a physical, discrete relational state space—a fundamental Hilbert space.[1] Inspired by Konrad Zuse's cellular automaton models and Edward Fredkin's digital physics, the universe is mapped utilizing tensor products to compose large state spaces from localized, discrete subsystems.[1] Spatial coordinates are treated as "logical qubits" derived from underlying "physical qubits" differentiated strictly by their intrinsic angular momentum and internal energetic states rather than absolute grid points.[1]

Empty space itself acts as a massive physical substrate of ambient magnetic vector potential governed by modified Proca equations, which grant vector bosons mass-energy equivalence.[1] As electromagnetic waves traverse this massive Proca substrate, their instantaneous velocity, $v_{EM}(d)$, decays exponentially as a function of the traversed scalar distance d. This decay is governed by a universal deceleration constant α [1]:

$$v_{EM}(d) = c_0 e^{-\alpha d}$$

Simultaneously, the energy of these photons undergoes a degeneration commonly referred to as "tired light" mechanics, initially proposed by Fritz Zwicky, wherein photon energy diminishes exponentially over an attenuation coefficient μ [1]:

$$E(d) = E_0 e^{-\mu d}$$

By coupling these attenuation constants such that $\alpha = \mu$, cosmological time dilation emerges natively as an observer-dependent arrival effect without invoking the continuous metric expansion of space or altering the localized clock of the emitter.[1] This formulation perfectly reproduces supernova time dilation profiles.[1] Because electromagnetic velocity decays over vast distances and is subject to density-dependent line-of-sight integrals—where traveling through dense intergalactic mediums alters the refractive index—any unit of spatial measurement based on the distance light travels over a localized temporal cycle is inherently unstable, mathematically inconsistent, and epistemologically invalid.[1] Consequently, the "lightyear" and all time-dependent distance metrics based on electromagnetic propagation are entirely discarded from this framework.

The Parsec: Pure Geometric and Relational Metrology

To replace unstable electromagnetic metrics, cosmological metrology must be anchored in pure geometry and relational dynamics. The parsec (parallax second) serves as this absolute geometric standard, defined completely independently of the speed of light or any propagation variables.[1]

The parsec is derived from trigonometric parallax, utilizing a gridless angular coordinate system. It is strictly defined as the distance at which one astronomical unit subtends an angle of one arcsecond.[1] In this discrete relational state space, the physical universe is mapped as an interconnected network of nodes defined by mutual angular coordinates rather than absolute Cartesian grid points.[1] The calculation relies on the small-angle trigonometric approximation, where the distance d in parsecs is the reciprocal of the parallax angle θ measured in arcseconds [1]:

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

One arcsecond is strictly defined as $1/3600$ of a degree, allowing for immense precision in spatial relations.[1] By utilizing this small-angle approximation ($\theta \approx \frac{s}{r}$), absolute spatial positioning is completely bypassed, and the structural integrity of a coordinate-free Hilbert space is maintained.[1] Spatial arrangements are therefore computed solely using dimensionless ratios of side lengths, perfectly aligning with Julian Barbour's Shape Dynamics and Machian relationalism.[1] Within advanced computational frameworks like the World programming language, researchers leverage unique datatypes, such as the KWATZ! datatype, to load distinct SI values into the simulation system. Through precise lexical analysis, fundamental constants (Planck's constant h, Boltzmann's constant kB) are integrated alongside pure geometric spatial units to process complex cosmological metrics directly without relying on continuum mechanics.[6]

Establishing Relational Chronology: Clockless Time

Velocity and kinematics require a temporal denominator. However, localized physical clocks—such as highly precise cesium atomic systems—are subject to mechanical distortions, kinematic dilation, and intense gravitational gradients.[1] In a universe defined by discrete relational mechanics, relying on a local clock introduces philosophical paradoxes and computational constraint violations. Therefore, a universal, clockless chronology must be established to provide the stable denominator required to calculate velocities in parsecs per year.[1]

The framework defines time as an emergent property strictly derived from changing geometric configurations, known as the "shapes" of the universe's constituents.[1] In the Constant Mean Curvature (CMC) gauge, a global, absolute parameter known as York Time (τ) is mathematically extracted.[1] York time serves as the canonical momentum conjugate to the spatial volume of the entire universe, allowing physics engines to computationally step forward in perfect synchronization without localized relativistic distortions.[1]

Furthermore, to establish the arrow of time, the framework integrates the Janus Point hypothesis.[1] This posits that time flows due to the growth of complexity and structural change in a system with vanishing total energy and angular momentum, entirely bypassing localized thermodynamic entropy arguments.[1] Using a generalized formulation of Jacobi’s action principle, Generalized Local Ephemeris Time (GLET) emerges algorithmically from the mass-weighted, relational displacement of all active particles.[1] This robust timekeeping isolates the simulation's tick-rate from localized relativistic distortions, granting a stable platform to map galactic velocities natively in parsecs.

Kinematics on the Parsec Scale: Translating Local Velocities

Astronomical kinematics necessitate a velocity scale that natively integrates with pure geometric distance. While terrestrial and local-system velocities are frequently measured in kilometers per second (km/s), mapping galactic structures demands calculations expressed in parsecs per year (pc/yr) or parsecs per million years (pc/Myr).

For local stellar mapping and deep-space engine calculations, velocity values expressed in parsecs per year are infinitesimally small—often hovering around one millionth of a parsec per year.[3] However, these minute fractional values enormously simplify gravitational and navigational computations when the parsec operates as the fundamental base unit for all spatial dimensions in the International Astronomical Union's structural catalogs.[3] When scaled to a million years, the velocity metrics align elegantly with terrestrial standards, providing an intuitive mathematical bridge between local kinematic physics and cosmological-scale motion. The conversion between kilometers per second and parsecs per million years is remarkably symmetrical, making computational processing highly efficient:

Terrestrial Velocity Metric	**Cosmological Velocity Metric**	**Contextual Source**
$1.000\ \mathrm{km}/$	$\approx$	Standard approximation [8]
$4.740\ \mathrm{km}/$	$\approx$	Proper motion derivation constant [7]
$35.00\ \mathrm{km}/$	$\approx$	Upstream cloud interaction velocity [11]

This near 1:1 ratio allows for rapid mental and computational scaling without referencing electromagnetic propagation. For instance, the Sun moves with respect to the Local Interstellar Cloud (LIC) at approximately $5\ \mathrm{pc/Myr}$, structurally equivalent to $5\ \mathrm{km/s}$.[11] Similarly, the adjacent interstellar cloud complex demonstrates an upstream relative velocity to the Solar System of approximately $35\ \mathrm{pc/Myr}$. This kinematic modeling indicates dynamic, fluid-like gas exchanges across local parsec scales that evolve over epochs of 10^4 to 10^5 years, likely causing the adjacent cloud to replace the LIC as the dominant structure surrounding the heliosphere.[11]

Proper Motion and Tangential Velocity Derivations

The observable movement of stars across the celestial sphere relative to a fixed distant background is defined as proper motion (μ), typically measured in arcseconds or milliarcseconds per year.[3] The historical origins of this tracking date back to Edmund Halley in 1718, who first recorded the subtle proper motions of Arcturus and Sirius.[5] Modern astrometry tracks extreme cases, such as Barnard's Star in the constellation Ophiuchus, which exhibits a proper motion so massive it is classified as a "run-away" star, though calculating its exact movement still requires deep-time photographic comparisons bridging decades.[5]

However, because proper motion is strictly a two-dimensional angular velocity, it must be cross-referenced with geometric distance to extract true tangential velocity (v_t)—the real kinematic velocity of the stellar object across the observer's line of sight.[5] The standard relation between tangential velocity and proper motion is strictly calculated using the following equation:

$$v_t = 4.74\mu d$$

Where v_t is the tangential velocity in km/s , μ is the proper motion magnitude in $arcsec/yr$, d is the relational distance in parsecs, and 4.74 is the fundamental conversion constant.[4] This constant, precisely calculated as 4.74047 , is derived mathematically from the geometry of the astronomical unit relative to a parsec, multiplied by the temporal conversion factor for seconds within a single standard year.[4]

When mapping the kinematics of the Solar Neighborhood using these principles, data reveals that over 99.8 percent of local stars share the Milky Way's rotational velocity.[12] This structural motion is characterized mathematically as a Schwarzschild velocity ellipsoid.[12] The mean heliocentric velocity vector is defined along the Galactic (U, V, W) coordinate system with specific Gaussian dispersions (typically [43, 31, 25 km/s]), allowing for the computational prediction of two-dimensional proper motion projections seamlessly integrated over the celestial sphere.[12] By keeping distances strictly in parsecs, the resulting velocity models map sparse OB associations and gravitationally bound open clusters with extreme precision.[4]

Stellar Encounters and Intergalactic Kinematics

Kinematic modeling in parsecs per million years is uniquely critical for projecting long-term stellar encounters. Utilizing astrometric records like the Gaia DR2 dataset, physicists track convergent vectors for systems such as Scholz's star (WISE J072003.20-084651.2).[14] Analyzing these trajectories infers a statistical frequency of roughly 2.5 close stellar encounters within 0.5 parsecs per million years.[14] These precise kinematic models indicate that significant gravitational disruptions due to stellar proximity occur in the local neighborhood separated by epochs of 400,000 to 500,000 years, providing critical data for tracking Oort cloud perturbations.[14]

When extrapolating these metrics to theoretical intergalactic travel, such as the kinematics modeled in simulators like Space Engine, traditional km/s or astronomical units per day quickly fail to convey meaningful transit times. Propellantless transit must be expressed in parsecs per second to maintain mathematical coherence across intergalactic voids.[15] For example, translating the speculative "Warp" speeds of popular science fiction into pure geometric metrics reveals the immense scale of the cosmos. A velocity of Warp 5 (traditionally defined as 215 times the speed of light) represents an agonizingly slow transit on the cosmological scale, while Warp 9 (1516 times the speed of light) achieves only fractional parsecs per day.[15] Thus, traversing between distinct galactic topologies requires velocities measuring in the hundreds of kiloparsecs per second, underscoring the absolute necessity of utilizing the parsec to maintain a comprehensible scale for intergalactic simulation architecture.[15]

Area and Surface Density: Two-Dimensional Distribution in Square Parsecs

Understanding the distribution of baryonic mass, luminosity functions, and localized star formation rates necessitates measuring area strictly in square parsecs (pc^2). Unlike linear scalar distance, square parsecs allow astrophysicists to quantify the density, extinction, and intensity of diffuse spatial regions, bridging the gap between singular stellar nodes and massive galactic planes.

In computational and observational models, relative magnitude—a historical logarithmic scale—is often deprecated in favor of normalized intensity, allowing for direct algebraic manipulation of surface brightness.[16] When the relational distance (d) to a stellar object is measured in parsecs, the intensity (I) of the energy entering a collection apparatus on Earth is expressed directly as power per square parsec.[16] This intensity perfectly obeys the inverse-square law, inversely proportional to the distance squared ($I \propto 1/d^2$).[16]

For a stellar node emitting one solar luminosity situated exactly one parsec away, the normalized intensity is computed natively as solar luminosities per square parsec. This demands that the receiving area of advanced telescope arrays also be measured natively in square parsecs for direct structural and algebraic alignment, bypassing convoluted logarithmic conversions entirely.[16]

Mapping Starburst Regions and Extinction

A primary application of the square parsec metric is found in the deep analysis of intense starburst regions, such as the dense infrared structures of NGC 6334. Deep infrared observations utilizing advanced imagers reveal thousands of Young Stellar Objects (YSOs) displaying excess emission above normal photospheric levels.[17] By utilizing standard Kroupa initial mass functions and inferring half-lives of approximately 2 million years for Class II YSOs, the total stellar mass content is precisely calculated.[17]

In the case of NGC 6334, the active star formation rate is measured at approximately $4900 M_{\odot} Myr^{-1}$.[17] When distributed over the observed celestial region covering exactly 600 square parsecs, this translates to a massive star formation rate surface density of 8.2 to $4.2 M_{\odot} Myr^{-1} pc^{-2}$.[17] Utilizing the square parsec in this manner allows physics engines to map visual extinction through inter-stellar clouds natively. The resulting extinction maps saturate around $A_V = 30$, dynamically generating surface density gradients that remain mathematically stable, entirely avoiding the infinite-density singularities that plague standard models of galactic cores.[17]

When analyzing massive galactic discs and diffuse star formation regions, such as those monitored using Wide Field Imagers (WFI) on 2.2-meter telescopes, angular dimensions (e.g., 15×15 arcminutes) are transformed directly into square parsecs to process Pre-Main Sequence (PMS) objects.[18] To convert observed surface brightness measured in Vega magnitudes per square arcsecond into absolute units per square parsec, a precise conversion factor of 21.572 is applied to the logarithmic output, allowing for large-scale structural rendering of diffuse star formation boundaries.[19]

Volumetric Metrology: From Cubic Parsecs to Megaparsecs

Expanding from two-dimensional surface mapping to three-dimensional morphological classification, the framework scales upward to the cubic parsec (pc^3) and the megaparsec (Mpc). The megaparsec (10^6 parsecs) is the fundamental unit for analyzing large-scale cosmic structures, galaxy clusters, and the vast volumetric voids between them.

Local Stellar Nurseries: The Orion Nebula

The Orion Nebula (designated NGC 1976 or M42) serves as the optimal baseline for localized volumetric scaling. Situated within the constellation Orion, it remains one of the most intensely scrutinized stellar nurseries in the local universe, revealing the exact fluid mechanisms by which protostellar disks and brown dwarfs coalesce from clouds of ionized gas and dust.[20]

Operating strictly on geometric parallax metrics, the Orion Nebula is situated at a relational distance of roughly 389 to 460 parsecs from the Solar System.[20] Its physical size subtends an apparent angle of approximately 60 to 66 arcminutes, which translates geometrically to a transverse radius of about 4 parsecs.[21]

By defining the nebula strictly through its 4-parsec radius and 389-parsec distance, astrophysicists can map the intense and turbulent fluid dynamics of its photo-ionizing O and B class stars. The central Trapezium cluster's radiant influence on the surrounding 4-parsec radius dictates the kinetic energy dispersal, ram-pressure stripping, and the sweeping of neutral gas out of the local cubic-parsec volume, particularly affecting structures like the Dark Bay—a thick cloud of neutral, un-ionized gas situated at the nebula's periphery.[21]

The Megaparsec and Galaxy Clusters

Moving beyond local galactic coordinates into the deep cosmological field, the megaparsec scale seamlessly encompasses entire galaxy clusters and superclusters. The Virgo Cluster, the nearest massive collection of galaxies to the Milky Way, forms the central gravitational anchor of the wider Virgo Supercluster.[24]

The metrology of the Virgo Cluster demonstrates the immense scale of the megaparsec:

- **Geometric Distance:** The core of the Virgo Cluster is situated at a distance of approximately 16.5 to 17.0 megaparsecs from the Local Group.[24]

- **Dimensions and Mass:** The primary cluster commands a massive radius of about 2.2 megaparsecs, encapsulating a total gravitational binding mass of roughly $1.2 \times 10^{15} M_{\odot}$ out to 8 degrees from the cluster's core.[26]
- **Volumetric Surface Mapping:** The Extended Virgo Cluster Catalog (EVCC), analyzing Sloan Digital Sky Survey (SDSS) data, maps an incredible area of 725 square degrees, translating to 60.1 square megaparsecs (Mpc^2).[27] This deep survey reaches out to 3.5 times the cluster's standard virial radius to catalog 1589 confirmed and infalling dwarf structures based strictly on spatial morphology.[27]

The precision of the megaparsec allows for exact mapping of structural substructures within the cluster, differentiating the major subcluster containing the giant elliptical galaxy M87 from the secondary, less dense concentration surrounding M49.[28] By mapping the broader Virgo Supercluster, physicists establish the boundaries of neighboring structures, such as the Hydra-Centaurus Supercluster, which starts at a distance of roughly 30 Mpc and extends outward to 60 Mpc along massive filamentary lines.[25] By employing the decoupled geometric propagation model to ascertain these distances, the spatial distribution and luminosity functions of these superclusters are rendered with absolute spatial clarity, entirely unaffected by relativistic light-travel distortions.[1]

Cosmic Voids and the Scale of Emptiness

Conversely, the megaparsec is uniquely instrumental in quantifying the sheer emptiness of the cosmos. The Boötes Void, colloquially known as "The Great Nothing" and designated as a true "supervoid," is a massive, highly spherical region of space containing abnormally low densities of galactic structures.[29]

Discovered by astronomer Robert Kirshner in 1981, the Boötes Void spans an astonishing radius of approximately 62 megaparsecs, establishing a total diameter well in excess of 120 megaparsecs.[29] To contextualize the scale of a 62 -megaparsec radius void, one must compare it against the standard distribution density of the universe. In an equivalent volume randomly selected elsewhere in the local cosmos, astrophysicists would expect to observe over $2,000$ massive galaxies.[30] However, the Boötes Void contains only about 60 confirmed galactic islands.[30]

Theoretical morphology suggests these supervoids are generated over immense spans of York Time by the gravitational clearing of dark matter haloes and baryonic matter. As gravity pulls matter into dense filamentary borders (such as the Hercules Supercluster forming the near edge of the void), the vast interior—spanning hundreds of thousands of cubic megaparsecs—is left nearly entirely evacuated.[30] This structure is not inconsistent with cosmological evolution models; rather, it highlights the self-similar scale invariance of dark matter distribution, provided distances are strictly mapped in megaparsecs rather than redshift-distorted optical illusions.[30] According to structural mapping, if the Milky Way were situated in the absolute center of a 62 -megaparsec radius void, observational constraints would have prevented the detection of external galaxies entirely until the mid-20th century.[30]

Gigaparsecs: Measuring the Observable Universe

At the absolute macro-scale of cosmological analysis, the megaparsec yields to the gigaparsec (Gpc), representing one billion parsecs. The gigaparsec is strictly utilized to define the ultimate boundaries, comoving radii, and the total immense volume of the observable universe.[33]

Philosophically, definitions of the universe's limits reflect the perspective of the observer. As Protagoras noted, "humankind is the measure of all things," leading to specific morphological definitions of the "local universe" operating at roughly 1.5 gigaparsecs (conceptually equating to the age of the solar system without linking to time-dependent units).[33] However, applying the Copernican principle states that humanity holds no special or privileged position; our observational boundary is merely representative of an average vantage point constrained by the ultimate flow of causality.[34]

The radius of the observable universe, defined as the maximum comoving geometric distance from which causality could potentially interact with a central observer, is measured at 14.26 gigaparsecs in any direction.[35] This establishes a spherical observable boundary with a massive total diameter of 28.5 gigaparsecs.[35]

When treating space as fundamentally flat—a Euclidean relational topology—the total comoving volume of the observable universe is computed precisely at 1.22×10^4 cubic gigaparsecs (Gpc^3).[35] Within this colossal volume, the density of total energy is exceptionally low, averaging roughly $8.5 \times 10^{-27} kg/m^3$, which equates to merely five protons per cubic meter of space.[35] The total mass of all ordinary baryonic matter within the 14.26 gigaparsec radius is statistically estimated at 1.5×10^{53} kg, distributed across billions of superclusters and filaments that appear as mere fine grains when the gigaparsec scale is visualized.[35]

Cosmic Expansion and the Hubble Constant

The most complex application of the gigaparsec and megaparsec scales lies in calculating the perceived expansion rate of the universe, quantified historically by the Hubble Constant (H_0). Traditionally, H_0 is expressed in kilometers per second per megaparsec ($km/s/Mpc$).

However, in a framework that explicitly rejects the continuous expansion of a substantivalist spacetime metric, the interpretation of H_0 requires fundamental revision.[1]

Reevaluating Metric Expansion Mechanics

In standard Lambda-CDM cosmology, H_0 implies that for every megaparsec of distance from the observer, spatial expansion causes an object to physically recede faster, driving estimates of distances via optical redshift.[37] However, local metric expansion is completely undetectable in gravitationally bound systems. According to Cooperstock et al., the radius of the Earth's orbit does not expand relative to H_0; if it followed the cosmological scaling function $a(t)$, the earth's orbit would have expanded by millions of kilometers since the era of the dinosaurs.[37] Instead, the general-relativistic effect is calculated to be smaller than the diameter of an atomic nucleus, demonstrating that metric expansion is theoretically isolated to deep cosmological scales beyond local gravitational cohesion.[37]

Under the revised relational framework, the apparent expansion indicated by redshift is fully decoupled from the physical stretching of an absolute background grid. Instead, the redshift is mathematically treated via Fritz Zwicky's tired light mechanics coupled intimately with the Proca substrate attenuation.[1] Because the photon energy $E(d)$ loses energy exponentially over an attenuation coefficient μ, the resulting wavelength elongation mimics metric expansion perfectly.[1] Therefore, the Hubble Constant does not represent physical spatial velocity, but rather a direct measure of electromagnetic energy degeneration across megaparsecs. By logging vast catalogs of supernovae across 40 years, modern efforts have merely mapped the decay rate of electromagnetic propagation over scalar distances.[38]

Gravitational Waves as Absolute Standard Sirens

To accurately measure distances to high-redshift events without relying on the decayed properties of electromagnetic radiation, the framework utilizes gravitational waves as absolute "standard sirens".[1] Unlike fragile photons subject to Proca substrate drag, gravitational waves traverse the relational spatial lattice unimpeded by intergalactic media or attenuation coefficients.[1]

The propagation velocity of gravitational waves (v_{GW}) is hardcoded in the physics model as an unattenuated, absolute constant [1]:

$$v_{GW} = c_0 = 299,792,458 \text{ m/s}$$

Because this velocity never changes (traveling at roughly 1080000000 kilometres per hour globally), the transit time (t_{GW}) over a scalar distance d is therefore calculated completely linearly [1]:

$$t_{GW} = \frac{d}{c_0}$$

When binary neutron stars or supermassive black holes coalesce, they emit massive gravitational waves. By executing linearized gravity field equations strictly within the far-field limit, the simulation mathematically extracts the phase evolution of the wave to determine the system's "chirp mass".[1] Comparing this derived intrinsic amplitude against the observed strain amplitude provides an exact, physically absolute distance in megaparsecs, entirely bypassing optical redshift uncertainties and bypassing historical monitoring constraints like the COSMOGRAIL collaboration's reliance on microlensing and time delay models from the Millenium Simulation.[1]

Multi-Messenger Calibration

To ensure the parsec framework remains physically robust, observations of multi-messenger transients are utilized to aggressively calibrate the density-dependent deceleration of electromagnetic waves against the absolute propagation of gravitational waves. Using the fundamental observation equation:

$$\Delta t_{obs} = \Delta t_{prop} + \Delta t_{emit}$$

the following megaparsec-scale calibrations are established to track the exact variance of electromagnetic propagation [1]:

Transient Event	Geometric Distance	EM Deceleration (α)	Calculated Temporal Delay
GW170817	$40\ \mathrm{Mpc}$	$1.65 \times$	$1.72\ \mathrm{s}$ intrinsic delay matched to observation [1]
GW150914	$410\ \mathrm{Mpc}$	Density-dependent line-of-sight integral	$<$ delay via propagation through cosmic voids [1]
GW190521	$1.478\ \mathrm{Gpc}$	High-redshift density scaling	$34\ \mathrm{days}$ intrinsic delay matched to source emission [1]

In the specific case of GW150914, situated at a relational distance of 410 megaparsecs, applying a static deceleration constant would incorrectly predict an optical propagation delay of over two seconds.[1] However, by computationally integrating the Proca substrate density along the photon's path, the engine accounts for the signal traveling through lower-density cosmic voids (akin structurally to the Boötes Void). This severely reduces the refractive index along the flight path, effectively aligning the simulated optical arrival with the observed sub-second delay of the gravitational wave.[1] For high-redshift, gigaparsec-scale events like GW190521 at 1.478 gigaparsecs, the framework scales naturally to accommodate massive multi-day emission discrepancies without breaking causal physics.[1]

Propellantless Kinematics in the Parsec Framework

The establishment of an absolute, relational parsec framework enables the highly precise simulation of advanced aerospace propulsion concepts designed to traverse these massive geometric distances. Theoretical models, such as the ArcSecs Dark Matter Drive Simulator, map propellantless kinematics by manipulating fundamental cosmic constants natively within the pc/Myr and megaparsec scales, stripping away the paradoxes of time-dilation inherent in continuous spacetime mechanics.[1]

Quantized Inertia and Rindler Deformation

Within this framework, inertia is not treated as an inherent, static property of mass resting in a continuous spacetime metric. Instead, it is modeled as an active, dynamic interaction with the cosmic horizon via Unruh radiation—a rigorous theoretical concept known as Quantized Inertia (QI).[1] When a macroscopic object accelerates, it generates a Rindler information horizon trailing behind it. Because the acceleration exceeds the threshold of causal information transfer, information from beyond the horizon cannot causally reach the vessel.[1]

To generate propellantless thrust capable of traversing parsec-scale distances, the simulated drive mechanism dampens the Unruh radiation specifically on the forward axis of the vessel. This creates an intense quantum vacuum gradient—a literal deformation of local Rindler space—that physically pushes the ship forward. This generates momentum without expellant mass, greenhouse emissions, or relying on the paradox-ridden Alcubierre warp metric (though 4-dimensional relativistic raytracing handles localized effects when approaching Lorentz limits).[1]

Furthermore, the simulation engine natively utilizes Weber's relational force law to compute inertia. By dynamically modulating interaction coefficients, the vessel reduces its relational inertia (the gravitational drag emanating from the distant cosmic shell) to near zero. Simultaneously, it utilizes the precise time derivative of the localized vector potential to generate immense electromotive thrust directly against the ambient Proca substrate.[1]

Haloscope Sailing and Dark Matter Wind Harvesting

As the simulated vessel achieves high kinematic velocities measured in parsecs per year, it interacts with the particulate dark matter paradigm, encountering the complex, highly directional "dark matter wind" characteristic of the Milky Way's vast halo—particularly around the Solar Circle.[1] Because the dark matter halo density profile is mathematically proportional to $\frac{1}{a^2+r^2}$ (where a is a constant core radius and r is the exact geometric distance from the galactic center in parsecs), the simulator precisely maps the particulate density, entirely avoiding the generation of infinite-mass singularities at the galactic core.[1]

To extract momentum, the vessel functions as an immense axion haloscope, modeling the physical processes of the real-world ADMX experiment. By deploying massive localized magnetic fields combined with Superconducting Quantum Interference Devices (SQUIDs), the ship converts low-mass dark matter axions into detectable microwave photons.[1] Though the absolute energy harvested from this conversion is minuscule—measured on the scale of yoctowatts (one octillionth of a standard light bulb's power output)—when this continuous ram-scoop effect is integrated over a velocity of parsecs per million years, it accumulates the limitless momentum required to navigate the voids between megaparsec-scale structures like the Virgo Cluster and the Boötes Void.[1] The simulation models the necessary J-factors (the line-of-sight integral of the dark matter density squared) to trace annihilation physics flawlessly.[1]

Computational Architecture for Parsec-Scale Simulations

To render a completely decoupled, geometric universe spanning 14.26 gigaparsecs down to individual parsec radii, legacy CPU computing architectures and traditional WebGL pixel-color encoding are fundamentally insufficient. The bottleneck of rendering massive point-cloud distributions requires a total structural migration to WebGPU, employing dedicated compute shaders capable of handling arbitrary, highly parallel mathematical operations across millions of coordinates natively expressed in parsecs.[1]

N-Body Physics and Teleparallel Integration

Replacing General Relativity's complex Levi-Civita connection, the simulator utilizes the Weitzenböck connection to manage gravitational interactions.[1] Under this teleparallel gravity model, Riemann curvature is mathematically stripped away, vanishing globally ($R^{\alpha}_{\beta\gamma\delta} = 0$). Instead, all gravitational degrees of freedom are perfectly encoded in the non-vanishing torsion tensor ($T^{\alpha}_{\beta\gamma} \neq 0$).[1] Gravity therefore acts solely as a translational gauge force within a completely flat relational space. This allows the parallel transport of massive objects across megaparsecs to be globally path-independent, vastly reducing computational overhead.[1]

To calculate the N-Body interactions of trillions of baryonic mass nodes across millions of cubic megaparsecs, the simulation engine entirely replaces unstable explicit Euler integrations with a highly stable semi-implicit Euler integrator.[1] This mathematical stabilization allows the computation of extremely precise orbital mechanics—such as the quantizer-frequency derivation required to resolve the anomalous advance of Mercury's perihelion at exactly 574 arcseconds per century and Venus at 8.6233460 arcseconds per century—without recursive iterative decay destroying the model's integrity.[1]

Spatial Hashing, AVBD Solvers, and Rendering

Calculating real-time gravitational lensing, Rindler space deformation, and haloscope axion harvesting requires unparalleled VRAM optimization. To handle structural rendering across gigaparsec boundaries, the simulator utilizes Morton codes to execute spatial hashing, sorting particle data strictly along a mathematical Z-curve.[1]

This massive architectural optimization drastically improves VRAM spatial locality. Rather than performing direct-summation $O(N^2)$ calculations across every single particle within a megaparsec volume, the specialized compute shaders query only neighboring particles localized explicitly on the Z-curve.[1] Combined with the implementation of an Augmented Vertex Block Descent (AVBD) style solver, the architecture allows for the real-time, browser-based rendering of incredibly complex structures.[1] This includes the fluid evolution of gigaparsec-scale superclusters, procedurally generated ultra-diffuse galaxies (such as UDG 32 in the Hydra I cluster, sporting the size of the Milky Way but 100 times less stellar mass), and the fluid tracking of ram-pressure stripped gas filaments, all rendered in absolute geometric parity without once referencing the speed of light.[1]

Syntheses on Geometric Cosmological Frameworks

The comprehensive transition away from time-dependent, electromagnetic-based spatial metrics toward a purely geometric, discrete framework utilizing the parsec, megaparsec, and gigaparsec resolves a multitude of systemic contradictions in modern theoretical astrophysics and computational physics.

By aggressively deconstructing the substantivalist spacetime continuum and acknowledging the exponential decay and variable propagation of electromagnetic waves within a Proca substrate, the reliance on light-travel time to define vast cosmic distances is rendered mathematically obsolete. In its place, trigonometric parallax, the small-angle approximation, clockless York Time, and the unattenuated propagation of gravitational waves serve as the absolute foundations of scale and distance calibration.

This robust parsec-centric ontology unifies kinematics across all imaginable macro-scales. From the localized $5\ \mathrm{pc/Myr}$ fluid dynamics of the Solar Neighborhood to the immense 62-megaparsec expanses of the Boötes supervoid, and ultimately extending out to the precise 14.26-gigaparsec radius of the observable universe, spatial metrology is perfectly standardized. When fully integrated into advanced teleparallel physics engines, semi-implicit Euler integrators, and WebGPU compute shaders, this framework not only accurately models the universe's topology with unprecedented digital stability but also serves as the precise navigational bedrock required for theorizing future propellantless transit across the cosmic web.

Works cited

1. New Universe Framework_ Time and Distance.md
2. How do we know that gravitationally-bound objects are not expanding with spacetime?, accessed May 31, 2026, https://www.reddit.com/r/Physics/comments/1it8svd/how_do_we_know_that_gravitationallybound_objects/
3. HYG Database - Additional Details - AstroNexus, accessed May 31, 2026, https://astronexus.com/projects/hyg-details
4. Kinematics of stellar associations: the epicycle approximation and the convergent point method | Monthly Notices of the Royal Astronomical Society | Oxford Academic, accessed May 31, 2026, https://academic.oup.com/mnras/article/352/4/1199/1075441
5. The purpose of this exercise is to measure the proper motion of Barnard's star and use this, accessed May 31, 2026, https://www.phys.lsu.edu/staff/karen/lab/exercises/propermotion.pdf
6. World and Science - Niels Bohr Institutet, accessed May 31, 2026, https://nbi.ku.dk/english/theses/masters-theses/john-e-niclasen/Niclasen_thesis-world-science.pdf
7. units, constants, and conversion factors, accessed May 31, 2026, https://www.ngdc.noaa.gov/stp/space-weather/online-publications/miscellaneous/afrl_publications/handbook_1985/Appendix.pdf
8. accessed May 31, 2026, https://10minuteastronomy.wordpress.com/2017/02/15/from-kms-to-parsecs-per-million-years/#:~:text=1%20km%2Fs%20is%20almost,seconds%20in%20a%20million%20years.
9. From km/s to parsecs per million years | 10 Minute Astronomy - WordPress.com, accessed May 31, 2026, https://10minuteastronomy.wordpress.com/2017/02/15/from-kms-to-parsecs-per-million-years/
10. Astronomy 1144: Lecture 6, accessed May 31, 2026, https://www.astronomy.ohio-state.edu/thompson.1847/1144/Lecture6.html
11. arXiv:astro-ph/0302037v3 3 May 2003, accessed May 31, 2026, https://arxiv.org/pdf/astro-ph/0302037
12. NStars2: Proper motions, accessed May 31, 2026, https://www.stsci.edu/~inr/nstars2.html
13. How are the transverse velocity and proper motion of a star related?, accessed May 31, 2026, https://physics.stackexchange.com/questions/365571/how-are-the-transverse-velocity-and-proper-motion-of-a-star-related
14. Two Close Stellar Passes - Centauri Dreams, accessed May 31, 2026, https://www.centauri-dreams.org/2022/07/08/two-close-stellar-passes/

15. Warp Speed: How Fast do you have to go to get the Stars to Sail by? - M. Q. Allen, accessed May 31, 2026, https://mqallen.wordpress.com/2014/01/15/warp-speed-how-fast-do-you-have-to-go-to-get-the-stars-to-sail-by/
16. Astronomy college course/Introduction to stellar measurements - Wikiversity, accessed May 31, 2026, https://en.wikiversity.org/wiki/Astronomy_college_course/Introduction_to_stellar_measurements
17. NOAONewsletter - NATIONAL OPTICAL ASTRONOMY OBSERVATORY - NOIRLab, accessed May 31, 2026, https://noirlab.edu/public/media/archives/noaonewsletter/pdf/noaonewsletter108.pdf
18. The Accretion Discs in Hα with OmegaCAM (ADHOC) Survey - Eso.org, accessed May 31, 2026, https://www.eso.org/sci/publications/messenger/archive/no.173-sep18/messenger-no173-17-21.pdf
19. stellar halo and tidal streams of Messier 63 | Monthly Notices of the Royal Astronomical Society | Oxford Academic, accessed May 31, 2026, https://academic.oup.com/mnras/article/454/4/3613/992725
20. Orion Nebula - NASA Science, accessed May 31, 2026, https://science.nasa.gov/asset/hubble/orion-nebula-2/
21. Orion Nebula - Wikipedia, accessed May 31, 2026, https://en.wikipedia.org/wiki/Orion_Nebula
22. M42/M43, NGC 1976, Orion Nebula - NOIRLab, accessed May 31, 2026, https://noirlab.edu/public/images/noao-02677/
23. astronomical society of the pacific 255 the distance of the orion nebula, accessed May 31, 2026, https://adsabs.harvard.edu/pdf/1931PASP...43..255T
24. Virgo Cluster | Max Planck Institute for Radio Astronomy, accessed May 31, 2026, https://www.mpifr-bonn.mpg.de/3234989/virgo_galaxies
25. Virgo Supercluster - Wikipedia, accessed May 31, 2026, https://en.wikipedia.org/wiki/Virgo_Supercluster
26. accessed May 31, 2026, https://en.wikipedia.org/wiki/Virgo_Cluster
27. The Extended Virgo Cluster Catalog - ADS, accessed May 31, 2026, https://ui.adsabs.harvard.edu/abs/2014ApJS..215...22K/abstract
28. Virgo Cluster, accessed May 31, 2026, https://ned.ipac.caltech.edu/level5/ESSAYS/Binggeli/binggeli.html
29. Boötes Void - Wikipedia, accessed May 31, 2026, https://en.wikipedia.org/wiki/Bo%C3%B6tes_Void
30. Boötes void | Astronomy Wiki | Fandom, accessed May 31, 2026, https://astronomical.fandom.com/wiki/Bo%C3%B6tes_void
31. TIL of the "Bootes Void" in space. An area of 300 million light years that is almost completely Void of galaxies - Reddit, accessed May 31, 2026, https://www.reddit.com/r/todayilearned/comments/1jnl43n/til_of_the_bootes_void_in_space_an_area_of_300/
32. structure of voids | Monthly Notices of the Royal Astronomical Society - Oxford

Academic, accessed May 31, 2026, https://academic.oup.com/mnras/article/344/3/715/1011814

33. Larger-Scale Astronomical Distance Natural Units AKA Characteristic Size Scales - UNLV Physics, accessed May 31, 2026, https://www.physics.unlv.edu/~jeffery/astro/cosmol/astronomical_distances_larger.html
34. I am confused about the concept of “observable universe” : r/cosmology - Reddit, accessed May 31, 2026, https://www.reddit.com/r/cosmology/comments/1jrsv1g/i_am_confused_about_the_concept_of_observable/
35. accessed May 31, 2026, https://en.wikipedia.org/wiki/Observable_universe
36. Gigaparsecs - The Everyday Prayer, accessed May 31, 2026, https://theeverydayprayer.com/2019/09/14/gigaparsecs/
37. Can the Hubble constant be measured locally? - Physics Stack Exchange, accessed May 31, 2026, https://physics.stackexchange.com/questions/70047/can-the-hubble-constant-be-measured-locally
38. There's a mystery in our universe's expansion rate and the Hubble Space Telescope is on the case, accessed May 31, 2026, https://www.space.com/universe-expansion-rate-hubble-telescope-measurements
39. Hubble Reaches New Milestone in Mystery of Universe's Expansion Rate - NASA Science, accessed May 31, 2026, https://science.nasa.gov/missions/hubble/hubble-reaches-new-milestone-in-mystery-of-universes-expansion-rate/
40. Speed of light - Wikipedia, accessed May 31, 2026, https://en.wikipedia.org/wiki/Speed_of_light
41. Speed of gravity - Wikipedia, accessed May 31, 2026, https://en.wikipedia.org/wiki/Speed_of_gravity
42. The Hubble Constant - PMC, accessed May 31, 2026, https://pmc.ncbi.nlm.nih.gov/articles/PMC5253801/