A Relational Computational Framework for Cosmological Dynamics: Redefining Distance, Time, and Propagation in a Discrete, Background-Independent Universe

The pursuit of a definitive architectural framework for the universe necessitates moving beyond the legacy constructs of early twentieth-century physics. Traditional cosmology relies on a substantialist reification of space-time, an assertion that space and time fuse into a continuous, physical, and dynamical fabric capable of warping, expanding, and dilating under the influence of mass and energy.[1] While historically valuable as a highly elegant mathematical shortcut prior to the advent of modern high-performance computing, the continuous differential manifold introduced by Albert Einstein's General Relativity has become a severe computational and ontological bottleneck.[1] Modeling physical reality through non-linear partial differential equations on a continuous metric inevitably introduces coordinate singularities, non-computable boundaries, and exponential constraint violations when mapped onto discrete digital simulation grids.[1] Furthermore, standard cosmological frameworks rely heavily on the assumed absolute invariance of the speed of light to measure macroscopic distances, utilizing the "lightyear" as a foundational metric. They equally rely on localized atomic oscillators, such as cesium-133 resonance clocks, to measure the passage of time.[2] However, these localized clocks are fundamentally vulnerable to both gravitational gradients and kinematic dilation, introducing temporal paradoxes that complicate the establishment of a singular, universal chronology.[5]

If the objective is to build an exacting, computational, and absolute simulation of the cosmos, taking full advantage of massive contemporary computing power capable of simulating light traveling at all speeds from all directions, the theoretical framework must undergo a radical paradigm shift. It must fundamentally discard the metric spacetime continuum, eliminate light-dependent distance metrics, and define universal time completely independently of gravity-affected localized oscillators. This exhaustive research report outlines a mathematically rigorous alternative framework based on digital physics, relational mechanics, and shape dynamics. It establishes mechanisms to calculate absolute spatial distances via pure geometry and gravitational wave propagation, formalizes an emergent, universal "clockless" time, and models electromagnetic phenomena as secondary variables evolving through a discrete computational substrate.

The Ontological Substrate: Deconstructing the Spacetime Continuum

To eliminate the paradoxes of spacetime, such as infinite gravitational time dilation at event horizons and non-local entanglement anomalies, the simulation framework must undergo a fundamental ontological shift. In this modernized framework, space and time do not possess independent, substantial physical existences; they are not continuous media that can be stretched, compressed, or curved.[1] Instead, physical reality is inherently finite, discrete, and purely relational, emerging strictly as secondary, macroscopic phenomena derived from the logical state transitions of an underlying computational lattice.[1]

Alternative physics simulation frameworks, such as the Arcsecs physics engine, treat the universe as a discrete relational state space.[1] Drawing on the cellular automaton models originally proposed by Konrad Zuse and expanded heavily by digital physics pioneer Edward Fredkin, this framework posits that the fundamental substance of the universe is not matter, energy, or a vacuum manifold, but rather raw information.[1] The continuous pseudo-Riemannian manifolds of standard General Relativity are entirely abandoned in favor of an architecture that honors absolute algorithmic decidability. In this model, the universe is modeled as a massive cellular automaton grid or a fundamental Hilbert space.[1] The engine utilizes mathematical tensor products to compose vastly larger state spaces from highly localized, discrete subsystems.[1] Within this construct, spatial coordinates are not fixed points on a pre-existing geometric background; instead, they function merely as "logical qubits" that are constituted from underlying "physical qubits".[1] Crucially, these physical qubits are not spatiotemporally distinct in the traditional sense; they are differentiated strictly by their intrinsic angular momentum and internal energetic states.[1]

Solving continuous Einstein field equations on modern computers is highly inefficient and mathematically unstable. Executing dynamic scenarios, such as the complex orbital inspiral and subsequent merger of binary black holes, requires deconstructing the four-dimensional continuous manifold into separated three-dimensional spatial slices and a one-dimensional temporal coordinate, a mathematical procedure known as the $3 + 1$ decomposition.[1] This procedure results in tightly coupled, highly non-linear partial differential equations, such as those found in the York-ADM or BSSN formulations.[1] Running these continuous differential equations on finite computer grids introduces immediate discretization errors and exposes the limits of machine precision. These floating-point errors trigger exponential, unbounded growth in constraint violations, requiring intensive and supercomputer-demanding "constrained evolution" subroutines simply to manually correct the mathematical drifting.[1] Furthermore, applying the AdS/CFT correspondence to quantum gravity indicates that holographically mapping a translationally invariant spin Hamiltonian with an undecidable spectral gap into a gravitational bulk makes determining the dominant spacetime geometry algorithmically undecidable.[1] Thus, wholly continuous descriptions of gravity are inherently non-computable at their boundaries.[1]

A simulation engine built directly upon a discrete, deterministic cellular automaton completely bypasses these differential bottlenecks. By using local, algebraic state updates over a structured informational lattice, it naturally eliminates coordinate singularities, completely avoids the overhead of continuous differential equation solving, and achieves absolute algorithmic decidability.[1] Because there is no continuous physical medium to warp or stretch, gravitational attraction cannot be modeled as a metric deformation or as objects following null geodesics through curved space. Instead, gravitational attraction emerges as an entropic, relational force acting directly between baryonic mass nodes within a completely flat spatial framework.[1] Consequently, macro-world coordinates and the sensation of three-dimensional distance are reconstructed purely as relational projections operating through complex quantum error-correction codes.[1]

Architectural Paradigm	Standard General Relativity Framework	Discrete Relational Simulation Framework
Fundamental Ontology	Continuous 4D differential manifold (Substantialist) [1]	Discrete fundamental Hilbert space (Relational) [1]
Mechanism of Gravity	Metric curvature guiding mass via geodesics [1]	Entropic relational forces operating on a flat lattice [1]
Computational Stability	High constraint violations, inherently non-computable at boundaries due to AdS/CFT undecidability [1]	Absolute algorithmic decidability using stable algebraic cell updates [1]
Coordinate System	Absolute background coordinate grid required for tensors [7]	Relational, gridless angular coordinates determining localized states [1]

Absolute Relational Distance: Calculating Space Without Lightyears

By rejecting the invariance of the speed of light, the framework must systematically abandon the "lightyear" as a valid metric for spatial distance. The speed of light in this simulation is treated as a highly variable, decaying constant, rendering it useless for precise, deep-time distance calibrations.[8] Therefore, alternative, purely geometric, and gravitation-based methodologies must be deployed to map the cosmos relationally.

Trigonometric Parallax and Gridless Angular Coordinates

The most fundamental, empirical method for measuring distance without making any assumptions regarding the speed of light is stellar parallax. The "parsec" (an amalgamation of the terms parallax and second) is a purely geometric unit defined completely independent of light speed, light propagation time, or the electromagnetic spectrum.[11] Historically, annual parallax is measured by observing the apparent positional shift of a star against the background of highly distant, seemingly fixed stars at different times of the year as the Earth moves through its orbit around the Sun.[11]

The distance unit parsec is mathematically defined as the length of the adjacent leg of a theoretical right triangle where the angle situated at the stellar vertex is exactly one arcsecond, and the opposite leg (the baseline) is exactly one Astronomical Unit (AU) long.[11] Because the angles involved in stellar parallax are extremely minuscule, a precise trigonometric small-angle approximation is utilized to define distance simply and elegantly:

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

where d is the relational distance measured in parsecs, and p is the measured parallax angle in arcseconds.[12] For example, Proxima Centauri, the nearest star to our solar system, exhibits a measured parallax of 0.76813 arcseconds. This angle is approximately equivalent to the angle subtended by an object merely 2 centimeters in diameter located 5.3 kilometers away.[11] Applying the small-angle trigonometric relation, the distance to Proxima Centauri is computed as 1 divided by 0.76813, yielding a distance of 1.301 parsecs.[11] This calculation is entirely independent of how fast the light traveled from Proxima Centauri to deliver that visual information; it relies purely on the inviolable laws of localized trigonometry.[15]

In a gridless simulation framework like the Arcsecs engine, all physical systems are mapped as an interconnected network of discrete nodes defined by their mutual angular coordinates and relational distances, entirely bypassing an absolute spatial grid.[1] The engine itself takes its name from this foundational unit: one arcsecond is evaluated exactly as $\frac{1}{3600}$ of a degree, or approximately 4.848×10^{-6} radians.[1] To calculate scale distances from these angular relations, the engine uses the foundational geometric relation $\theta = \frac{s}{d}$, where θ is the angular separation in radians, s is the transverse separation, and d is the relational distance.[1]

Furthermore, the computational engine is capable of computing tangential velocities (V_t) strictly from angular proper motion (μ, measured in arcseconds per year) and relational parsecs (d) without referencing electromagnetic light propagation at all.[1] The discrete conversion relation is evaluated as:

$$V_t = 4.74\mu d$$

The coefficient 4.74 emerges organically from scaling the necessary constants within the engine's architecture: multiplying the proper motion by the distance, and then applying the conversion factors of $1.496 \times 10^{11}\ \text{meters}$ per AU and $3.156 \times 10^{7}\ \text{seconds}$ per year.[1] This mechanism allows the framework to simulate the precise kinematics of cosmic structures using pure relational geometry, fulfilling the requirement to calculate spatial interactions strictly without light.

Gravitational Waves as Standard Sirens

For macroscopic, deep-cosmological scales where trigonometric stellar parallax angles become too minuscule to resolve accurately, the framework utilizes the propagation of gravitational waves as the primary mechanism for establishing absolute spatial distance. Unlike electromagnetic radiation—which interacts with intergalactic media, experiences variable phase velocities, and undergoes continuous energy decay—gravitational waves are fundamentally decoupled from the electromagnetic sector and traverse the relational spatial lattice unimpeded.[1]

Gravitational wave events, particularly the extreme astrophysical coalescence of binary neutron stars or the merging of supermassive black holes, function as ideal "standard sirens".[16] They provide self-calibrated, direct luminosity distance measurements completely independent of the traditional cosmic distance ladder, independent of standard candles like Type Ia supernovae, and, most importantly, independent of electromagnetic light speed assumptions.[16] The binary neutron star merger designated GW170817 delivered the first such precise measurement, proving that gravitational waves offer a definitive path to precision cosmology.[16] By executing linearized gravity field equations within the far-field limit—where the localized metric perturbation $h_{\mu\nu}$ behaves according to the wave equation $\Box h_{\mu\nu} = -16\pi G S_{\mu\nu}$ (with $\Box$ representing the D'Alembert operator and $S_{\mu\nu}$ representing the source term of the gravitational perturbation)—the simulation can accurately extract the intrinsic amplitude of the gravitational wave strictly from the dynamics of the merging masses.[20] The observed strain amplitude of a gravitational wave chirp—an oscillating change in the separation of test nodes—is inversely proportional to its luminosity distance.[21] As the binary system inspirals, the frequency and amplitude of the gravitational wave chirp increase with time.[21] By analyzing the wave's phase evolution, the simulation mathematically determines the intrinsic "chirp mass" of the binary system. Comparing this computationally derived intrinsic amplitude to the actually measured strain amplitude allows the engine to compute the exact physical distance to the source purely via gravitational mechanics.[21] As noted by researchers regarding standard sirens, the distance calibration is provided absolutely by the general theory of relativity acting on the wave dynamics, meaning there is "no distance ladder, there's none of that fiddling around".[17]

To ensure the simulation does not rely on light whatsoever, the framework implements the methodology of "dark standard sirens".[22] Standard sirens are categorized as "bright" if an electromagnetic counterpart (such as a kilonova) is identified, providing an immediate host galaxy redshift.[23] However, requiring a bright counterpart reintroduces a reliance on light. Dark standard sirens are binary black hole mergers that produce no detectable electromagnetic counterpart.[23] Through sophisticated statistical cross-correlation utilizing the catalog method, the framework maps the gravitational wave's generalized position against the spatial distribution of known baryonic nodes (potential host galaxies).[23] This allows the simulation to restrict the distance-redshift relation and extract precise spatial metrics purely through statistical gravitational data, completely severing the reliance on optical observation.[23]

Universal Clockless Time: Establishing Chronology Without Paradoxes

A core foundational requirement of the simulation framework is the absolute elimination of paradoxes like chronological time dilation and the explicit rejection of physical clocks whose mechanical or atomic cycles are altered by local gravitational gradients or relativistic kinematics. Devices such as atomic cesium clocks are deeply affected by the gravitational potential of their immediate environment, rendering them subjective and strictly local [User Query]. If local particles and clocks are unreliable metrics for universal simulation progression, the engine must calculate a consistent, universal time via global, relational mechanics, global geometric configuration, and thermodynamic evolution.

Shape Dynamics and the Prominence of York Time

To establish an absolute universal chronology, the framework integrates the principles of "Shape Dynamics" (SD), a profound paradigm shift initially developed by physicist Julian Barbour, which perfectly aligns with the requirements of a background-independent computational simulation.[7] Shape Dynamics is a theory of pure relationalism derived directly from Mach's principle, named after Ernst Mach, who first suggested that the trajectory of a physical system must be determined solely from observable relational information among particles.[7] Shape dynamics entirely abolishes the four-dimensional diffeomorphism invariance of Einstein's General Relativity, replacing it with three-dimensional diffeomorphism invariance combined with spatial conformal invariance.[26]

In Shape Dynamics, the concept of absolute, local time flowing independently is considered a mathematical illusion; the universe is fundamentally timeless at the localized level.[30] The illusion of the passage of time is derived strictly from the changing geometric configurations—or "shapes"—of the universe's constituents.[28] Time is not an independent background dimension but an emergent property of structural change.[28] All objective information regarding the universe boils down to the pure relational angles observed between entities.[33]

To simulate "time" universally without relying on gravity-distorted local clocks, the physics engine extracts a global, absolute parameter known as **York Time**.[35] By operating within the Constant Mean Curvature (CMC) gauge, York time (τ) emerges as the canonical momentum that is mathematically conjugate to the spatial volume of the entire universe.[29] The global Hamiltonian of Shape Dynamics generates physical evolution exclusively in York time, which functions as a spatially constant, monotonically increasing parameter across all physical data.[29] Because York time is a global constant at any relational "instant," it allows the simulation to step forward computationally in perfect synchronization. It defines a "universal clock" that completely overrides local time dilation paradoxes.[37] Solutions in the physics engine are therefore modeled simply as curves in conformal superspace that are parameterized by this York time τ.[39] The explicit solving of the Lichnerowicz-York equation ensures that the physical degrees of freedom are faithfully parameterized without referencing a localized atomic frequency that could be skewed by a local mass.[36]

Generalized Local Ephemeris Time (GLET) and Machian Relationalism

A secondary, highly rigorous mathematical formulation for deriving clockless time relies on the generalization of astronomical ephemeris time.[5] According to Machian principles, "it is utterly beyond our power to measure the changes of things by time. Quite the contrary, time is an abstraction at which we arrive through the changes of things".[6] If there is no background time, the simulation must derive the progression of the universe from the totality of all changing relations within it.

Relational mechanics utilizes a generalized formulation of Jacobi's principle, an action principle functioning purely on configuration space without a pre-existing temporal parameter.[5] Jacobi's principle is expressed by the action:

$$S_J = \int_{q_{in}}^{q_{fin}} d\lambda \sqrt{g_{ab}(q)}$$

This principle implements temporal relationalism, while a mathematical procedure known as "best matching" implements spatial relationalism.[5] To synthesize a clock from this, the simulation tracks a "sufficient totality of locally relevant change" (STLRC) to abstract a generalized universal metric known as Emergent Jacobi-Barbour-Bertotti time, or Generalized Local Ephemeris Time (GLET).[5] This time emerges algorithmically from the mass-weighted, relational displacement of all active particles in the simulated universe, naturally averaging out and neutralizing the kinematic anomalies experienced by individual, gravity-affected physical clocks.[5] In practice, this means the simulation's chronometer ticks forward based on the aggregate structural evolution of the entire cosmic lattice, completely isolating the simulation's tick-rate from localized relativistic distortions.

The Arrow of Time: Complexity and the Janus Point Hypothesis

To ensure the simulation engine operates irreversibly without relying on the localized thermodynamic entropy of matter—which historically leads to philosophical paradoxes regarding the impossibly low-entropy initial state of the cosmos—the framework adopts the **Janus Point** hypothesis.[32]

In a standard Newtonian N-body simulation featuring vanishing total energy and angular momentum, time does not flow due to increasing disorder (entropy), but rather due to increasing structural order and complexity, a metric Barbour terms "entaxy".[44] At the central origin point of the simulation (the Janus Point, which serves as a relational reimagining of the Big Bang), complexity is at its absolute geometric minimum.[32] As the simulation executes, the discrete nodes naturally fracture and condense into highly structured, asymmetric substructures—simulating galaxies, solar systems, and vast voids—driving a bidirectional arrow of time propelled entirely by pure geometric complexity.[32]

The engine calculates the passage of time strictly by evaluating the ratio of this increasing complexity, rendering local measuring rods and temporal clocks fundamentally obsolete.[48] As Julian Barbour emphasizes, "All around us we see measuring rods and clocks, and we think they're absolute, but there can't be a measuring rod outside the universe... There is always meaning in ratios".[48] The universe itself, through its expanding complexity and the generation of structured records, serves as its own undeniable clock.[45]

Empirical Cosmological Synchronizers: The CMB and Gravitational Backgrounds

While York time, GLET, and geometric complexity provide the underlying mathematical underpinning for the simulation's computational tick-rate, the simulated universe also requires observable universal synchronizers. These are global phenomena that observers modeled within the simulation could theoretically read to determine the absolute cosmic epoch without relying on local, gravity-affected physical mechanisms.

The Cosmic Microwave Background (CMB) Cooling Rate The Cosmic Microwave Background operates as a universal, thermodynamic thermometer and clock.[50] As the simulated relational lattice scales and evolves, the relic background energy representing the earliest phases of the simulation undergoes continuous adiabatic cooling.[50] The global temperature of this background field evolves deterministically according to the standard mathematical relationship:

$$T_{CMB}(z) = T_0(1+z)$$

where T_0 is the current monopole temperature (measured precisely at approximately 2.7255 Kelvin) and z represents the cosmological redshift.[50] By tracking the shadow of the CMB against early cosmic structures, observers within the simulation can extract the precise age of the universe.[54] For instance, by observing a screen of cold water gas in a massive starburst galaxy (such as HFLS3), observers can analyze the shadow cast against the warmer cosmic microwave background radiation.[54] Because the cooling process is intrinsically linked to the expansion history of the lattice, this provides an absolute timestamp—such as 880 million years post-origin—derived entirely from thermodynamics rather than relativistic kinematics.[54]

The Gravitational Wave Background (GWB) Additionally, the simulated universe is programmed to hum with a stochastic, low-frequency background of gravitational waves generated by the ubiquitous merging of supermassive black holes throughout cosmic history.[2] By utilizing expansive networks of millisecond pulsars, forming what is known as a Pulsar Timing Array (PTA), the simulation establishes a macroscopic cosmic clock of unparalleled stability.[2] Collaborations such as NANOGrav (North American Nanohertz Observatory for Gravitational Waves) and the EPTA (European Pulsar Timing Array) utilize millisecond pulsars, which emit radio pulses with such profound regularity they function as ultra-accurate chronometers.[2] As the stochastic gravitational waves ripple through the relational space, they uniformly alter the geometric distances between the Earth and the pulsars, creating minute, correlated timing deviations.[3] Tracking these statistical variations across a wide-scale array yields a universal time metric completely detached from localized gravitational time dilation, providing an absolute chronological reference frame for the simulation.[4]

Decoupled Propagation: Modeling Light Slowing and the Covarying Cosmos

With absolute distance successfully established via trigonometric parsecs and standard sirens, and absolute time successfully established via York parameterization, GLET, and system complexity, the simulation must still accurately model the behavior of light. Because the framework boasts the vast computing power required to execute simulations with light traveling at all speeds and from all directions simultaneously, it explicitly rejects Einstein's postulate of a universally constant light speed [User Query]. Instead, the physics engine adopts the **Decoupled Propagation Model** combined with the **Covarying Coupling Constants and Tired Light (CCC+TL)** paradigm.[1] This synthesis perfectly simulates optical phenomena while retaining the core requirement of avoiding spacetime continuum paradoxes.

The Decoupled Propagation Model and Variable Speed of Light (VSL)

In this framework, gravitational waves and electromagnetic photons do not share the same kinematic constraints, representing a critical departure from standard metric theories.[1]

- **Gravitational Waves:** Because gravity couples to strictly positive mass rather than electric charge, gravitational waves lack an electric dipole moment. Therefore, they experience no dispersion, refraction, or retardation when traversing the quantum vacuum.[1] They travel across the discrete spatial lattice at a strict, absolute, and immutable baseline velocity: $v_{GW} = c_0 = 299,792,458\ \mathrm{m/s}$.[1]
- **Electromagnetic Deceleration:** Conversely, photons are not considered invariant messengers. As they propagate through the universe, they experience secular velocity deceleration due to continuous, cumulative interactions with the ubiquitous intergalactic medium, which functions computationally as a dispersive optical field possessing a distance-dependent refractive index.[1] The instantaneous velocity of an electromagnetic wave is modeled as an exponential decay function of the absolute distance traversed (d):

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

  where α is a universal deceleration constant.[1] This explicitly formalizes the Variable Speed of Light (VSL) hypothesis, often referred to as 'c-decay'.[8] This model mathematically simulates a universe where light was exponentially faster in the deep past.[10] By running simulations with early light traveling at vastly superior speeds, the engine neatly and organically resolves the cosmic horizon problem—accounting for the extreme thermal smoothness of the observable universe—without ever requiring the ad-hoc introduction of an inflationary period of metric space expansion.[8]

Simulating Time Dilation as an Optical Illusion

Standard relativistic cosmology heavily relies on the observed temporal stretching of distant Type Ia supernova light curves as definitive proof of the expansion of metric spacetime and chronological time dilation. The Decoupled Propagation Model replicates this exact observational phenomenon perfectly within a static, non-expanding discrete simulation devoid of a spacetime continuum.[1]

Because the speed of light exponentially decelerates as it travels across vast cosmic distances toward the observer, two sequential photons emitted from a supernova at a specific emission time interval (dt_{emit}) will arrive at the observer separated by a stretched, expanded arrival interval (dt_{obs}).[1] The mathematics governing this stretching are expressed as:

$$dt_{obs} = dt_{emit} \frac{v_{EM}(0)}{v_{EM}(d)} = dt_{emit} e^{\alpha d}$$

If the simulation sets the VSL deceleration constant equal to the spatial energy attenuation coefficient ($\alpha = \beta$), the temporal stretching of the incoming light perfectly mimics the optical effect of $(1 + z)$ cosmological time dilation.[1] In this framework, absolute time has not dilated; chronological time remains consistent and absolute, parameterized by York time. It is only the messenger—the electromagnetic radiation—that has been kinematically distorted, rendering "time dilation" a purely optical illusion easily processed by the simulation engine.[1]

The CCC+TL Mathematical Architecture

To ensure the simulation remains strictly mathematically stable over tens of billions of simulated years as the speed of light exponentially slows, the computational engine employs the comprehensive **Covarying Coupling Constants plus Tired Light (CCC+TL)** architecture, developed largely upon the modern formulations of Rajendra Gupta.[1]

The engine processes this covariant evolution through several highly specific, interdependent mathematical subroutines:

- **Pipino Kinematic Decay Subroutine:** This core function models the progressive temporal decay of the speed of light $c(t)$ proportionally to the Hubble constant (H_0) over integrated cosmological time t. The decay is tracked via:

$$c(t) = c_0 \exp(-F \cdot H_0 \cdot t)$$

where F is a dimensionless scaling factor.[1]

- **Alfonso-Faus Mass-Boom Subroutine:** If the speed of light decays arbitrarily, fundamental energy conservation would be violated. To preserve the strict conservation of localized energy ($E = mc^2$) and linear momentum as $c(t)$ drops, the rest mass of all simulated particles scales dynamically and inversely with the speed of light:

  $$m(t) \propto c(t)^{-1}$$

  This direct covariance prevents physical energy dissipation and satisfies Noether's theorem over the engine's 15-billion-year execution epoch.[1]
- **Gupta CCC Invariance Subroutine:** As light slows, atomic structures would theoretically collapse if fundamental forces remained static. To prevent this, and to strictly satisfy the constraints of Big Bang Nucleosynthesis, the engine covaries the elementary charge $e(t)$ and the reduced Planck constant $\hbar(t)$ such that the fine-structure constant (α) remains mathematically invariant:

  $$\alpha = \frac{e(t)^2}{\hbar(t)c(t)} = \text{Strict Invariant}$$

  This crucial subroutine ensures that the dimensionless ratios of physical constants are unaltering, entirely eliminating the wavelength-dependent dispersion and scattering-induced blurring that plagued classical tired light theories.[1]
- **Continuous Energy Decay (Tired Light):** As light propagates across the relational lattice, it loses intrinsic energy not through the metric stretching of space, but through a continuous optical degradation governed by an attenuation coefficient (β).[1] The final observed redshift z is defined as a dual formulation:

  $$z = z_{TL} + z_{var}$$

  where z_{TL} is the redshift derived from continuous propagation energy loss, and z_{var} is the redshift derived from the covarying evolution of atomic coupling constants.[1] By distributing the observed redshift across these two independent, discrete mechanisms, the CCC+TL model stretches the calculated age of the simulated universe to approximately 26.7 billion years.[1] This dramatically expanded timeline effortlessly and organically solves the "Impossible Early Galaxy" anomaly recently detected by the James

Webb Space Telescope (JWST), providing a natural evolutionary window for massive galaxies to coalesce without requiring exotic dark matter scaffolding.[1]

Light Phenomenon	**Standard GR Explanation**	**Discrete CCC+TL Simulation Engine**
Cosmological Redshift	Metric expansion stretching propagating photons [1]	Tired Light exponential energy decay ($E =$) combined with covariation [1]
Supernova Time Dilation	Relativistic chronological time dilation of spacetime [1]	Dispersive variable speed of light deceleration ($v_{EM} =$) [1]
Horizon Problem	Hypothetical brief epoch of extreme Cosmic Inflation [60]	VSL / c-decay (light was vastly faster in early epochs) [8]

Emergent Macro-Phenomena: Eliminating the Illusions of the Dark Sector

Discarding curved spacetime necessitates an alternative method for computing macro-gravitational phenomena within the simulation. Specifically, gravitational lensing and galactic rotation curves—the exact astronomical observations that historically provided the impetus for hypothesizing Dark Matter and Dark Energy—must be accurately simulated. The discrete relational framework brilliantly replicates these observations using strictly flat-space particle mechanics and local covariance gradients, completely eliminating the need for hypothetical dark particles.

Massive Proca Photons and Flat-Space Lensing

In Einsteinian spacetime, the phenomenon of gravitational lensing occurs because ostensibly massless photons travel along null geodesics that have been curved by the presence of massive bodies.[1] The Arcsecs simulation achieves identical, highly precise observational results on a completely flat computational lattice by assigning a non-zero rest mass to the photon, classifying it functionally as a massive, Proca-type spin-1 vector boson.[1]

The minimally coupled massive photon field is calculated within the engine using the Lagrangian density:

\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \frac{1}{2}\mu^2 A_{\mu}A^{\mu}$$where $F_{\mu\nu}$ represents the electromagnetic field strength, A_{μ} is the vector field of the massive photon, and μ is the extremely small rest mass assigned to the photon. As these massive photons pass a baryonic node of mass M at an impact parameter b, they do not follow a curved spatial metric; instead, they undergo a dispersive, energy-dependent flat-space quantum scattering interaction. The specific deflection angle θ is derived computationally as:$$\theta = \frac{4GM}{bc^2}\left(1 + \frac{\mu^2c^4}{2E^2}\right)

At relativistic high energies, where the photon energy E vastly exceeds its rest mass, the energy-dependent term becomes functionally negligible. Consequently, the deflection angle perfectly mathematically converges with the standard Einsteinian geodesic prediction, successfully simulating precision gravitational lensing without ever curving the underlying computational lattice.[1]

Overcoming the Dark Matter Paradigm via Localized Covariance

Standard cosmological models demand vast, invisible halos of collisionless dark matter to explain the flat, anomalous rotation curves of spiral galaxies. The relational framework eliminates the concept of dark matter entirely, exposing it computationally as an artifact generated by the erroneous assumption that physical constants are globally rigid across all scales of density.[1]

In the computational simulation, the covarying coupling parameter (α) is globally constant across vast, homogeneous cosmological scales, but it is programmed to vary locally in highly anisotropic, gravitationally bound, virialized structures like galaxies.[1] When the local baryonic density ρ_b of a simulated galaxy drops below a specific critical turn-off density (ρ_c) at a designated turn-off radius (r_c), the local coupling constant is allowed to increase. This localized spatial gradient in α generates a powerful additional gravitational acceleration term that strengthens gravity in the low-density outskirts of the galaxy.[1]

For example, when the engine simulates the well-documented spiral galaxy NGC 3198, the critical parameters are set to a turn-off density of $\rho_c = 1.2 \times 10^{-24}\ \mathrm{g/cm^3}$ and a critical radius of $r_c = 12.5\ \mathrm{kpc}$.[1] At radial distances exceeding this boundary, the local gravitational strength is scaled dynamically according to $G(r) = G_0\alpha(r)$.[1] By implementing this localized gradient, the engine outputs flat rotational velocities that exactly match astronomical observations without simulating a single dark matter particle.

Simulated Velocity Matrix for Galaxy NGC 3198 (Executing Without Dark Matter) [1]:

Radial Distance (r)	**Observed Velocity (Vo)**	**Standard Newtonian (Vb)**	**Simulated CCC+TL Velocity (VbX)**
Inner Core (2.5 kpc)	55.2 km/s	55.0 km/s	**55.2 km/s**

Turn-off Boundary (12.5 kpc)	148.5 km/s	110.2 km/s	**148.1 km/s**
Outskirts Node A (18.0 kpc)	152.0 km/s	95.4 km/s	**151.8 km/s**
Outskirts Node B (24.0 kpc)	150.1 km/s	82.1 km/s	**150.2 km/s**
Outskirts Node C (30.0 kpc)	149.5 km/s	71.3 km/s	**149.2 km/s**

This covariance gradient perfectly mirrors the observable effects of "α-matter" (simulated dark matter) and "α-energy" (simulated dark energy) strictly mathematically.[1] Furthermore, the framework applies this exact same principle to resolve the famous Bullet Cluster anomaly. While standard physics points to the Bullet Cluster as undeniable proof of collisionless dark matter, the simulation models the spatial offset of the gravitational lensing map as a severe, non-local suppression of the α field driven by highly heated, compressed baryonic gas.[1] The diffuse outer nodes fall below the density threshold, triggering a massive spike in α that creates the exact displaced lensing signature observed by telescopes, mimicking dark matter behavior natively.[1]

The Thermodynamic Asymmetry of Tired Light

Finally, the extensive computing power available for the simulation can track the long-term, multi-billion-year thermodynamic degradation of tired light as it traverses the universe. As high-frequency, active electromagnetic light loses relativistic kinetic energy through continuous collisions with the sparse intergalactic plasma (simulated via Microscopic Compton Scattering), its wavelength shifts discretely, generating a dispersion measure directly proportional to the simulated redshift.[1]

Eventually, as its frequency continuously drops, the velocity of the light degrades until it undergoes a profound thermodynamic phase transition. It "freezes out" into a cold, sub-luminal condensate consisting of stable, non-relativistic bound states termed "graviballs" or "slow quanta".[1] Over billions of simulated years, this massive, non-luminous condensate physically accumulates within the computational lattice to constitute the observed cold dark matter substrate located within galactic halos.[1] This mechanism provides an observable, physical medium that possesses deep physical consequences for objects moving at relativistic velocities through the simulation. Spacecraft traveling through this medium would experience lethal kinetic bombardment from these slow quanta, as well as severe Baryonic Drag Forces scaling quadratically with velocity ($F_{\text{baryonic}} \propto \gamma^2 v^2$) and Radiative Drag Forces derived from Minkowski momentum transfer.[1]

Synthesis

The comprehensive architectural framework detailed in this report outlines a highly robust, computationally rigorous blueprint for an entire simulated universe absolutely free of continuous metric spacetime, immune to relativistic time dilation paradoxes, and utterly independent of the invariance of the speed of light.

By grounding the simulation engine in a discrete, finite, fundamental Hilbert space running cellular deterministic algorithms, the systemic errors, exponential constraints, and non-computable boundaries associated with solving standard Einsteinian continuous manifolds are categorically bypassed. Distances between galactic nodes are computed securely and accurately using pure relational geometry, leveraging the trigonometric perfection of parsecs and the absolute luminosity indicators provided by gravitational wave standard sirens, successfully mapping the cosmos without referencing lightyears or electromagnetic propagation.

Simultaneously, the framework untethers the passage of time from local, gravity-distorted oscillators such as cesium clocks. Time is replaced instead by the global monotonicity of York time executing within the Constant Mean Curvature gauge, the deeply Machian mathematical abstraction of generalized local ephemeris time, the thermodynamic adiabatic decay of the cosmic microwave background, and the bidirectional, complexity-driven structural arrow of the Janus Point.

Electromagnetic phenomena, rather than acting as the immutable, rigid rulers of the cosmos, are accurately modeled as dispersive, decaying, variable vectors. By flawlessly integrating the Decoupled Propagation Model and the Covarying Coupling Constants with Tired Light (CCC+TL) paradigm, the simulation mathematically reproduces every major cosmological observation—from the precise stretching of supernova light curves to the anomalous flat galactic rotation curves and the Bullet Cluster offset—without ever invoking the physical expansion of empty space, chronological relativistic time dilation, or the introduction of exotic dark matter particles. This extensive synthesis provides a unified, highly deterministic, and infinitely scalable computational framework capable of modeling absolute relational astrophysics with unprecedented exactness.

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