Computational Framework for Experimental Theatrical Physics: A Flat-Space Newtonian Simulator with Massive Photons, Mechanistic Tired Light, and Non-Spatiotemporal Emergence

The development of real-time interactive simulations often relies on general relativistic approximations to render cosmological phenomena. However, these curved-spacetime frameworks introduce significant mathematical and computational overhead, particularly within the constraints of high-performance rendering pipelines and Entity-Component-System (ECS) architectures.[1] To circumvent these complexities while preserving physical verifiability, this report details a concrete, test-driven physics engine framework based on flat Euclidean space, independent absolute time, massive photons, and tired-light redshift mechanisms.[3]

By treating the vacuum not as a curved geometric manifold but as a flat background, and photons not as massless null-geodesic trajectories but as physical corpuscles possessing relativistic mass, this framework achieves visual and behavioral parity with observational astrophysics.[2] This alternative paradigm, hereafter referred to as the Relational Theatrical Physics Engine, is designed for deterministic, test-driven execution in interactive environments.[1]

Relational Deconstruction of Spacetime and Quantum Emergence

The foundational premise of the simulator is the complete rejection of spacetime as a fundamental physical entity.[3] Instead of modeling a continuous four-dimensional pseudo-Riemannian manifold, the engine adopts a relational perspective where spatial relationships and temporal sequences are decoupled, emergent properties.[3] This conceptual framework aligns with quantum theories that deconstruct the spacetime continuum into more fundamental, non-spatiotemporal degrees of freedom.[3]

In quantum mechanics, physical systems are mathematically formulated within Hilbert spaces rather than physical coordinates.[3] A global Hilbert space can be constructed as a tensor product of smaller, localized Hilbert spaces.[3] Within these spaces, collective degrees of freedom exhibit robust and autonomous dynamics that deserve the title of emergent phenomena without requiring any underlying spatiotemporal arrangement or causal interaction.[3]

A clear computational analog of this non-spatiotemporal emergence is found in quantum error-correcting codes, where "logical qubits" are constituted from physical qubits.[3] The physical qubits do not need to be distinct in physical space; they can instead be energetically distinct or separated by angular momentum.[3] The relation that the logical qubit bears to the physical qubits is entirely non-spatiotemporal, proving that arrangement and interaction do not require a pre-existing spatial continuum.[3]

For the purpose of a real-time theatrical physics simulator, this allows the elimination of coordinate transformations associated with metric tensors and geodesic deviations.[2] The engine initializes entity states within a relational database where spatial positions and velocities are treated merely as kinematic variables updated over a global, monotonic temporal parameter t.[1]

Physical Concept	**General Relativistic Paradigm**	**Relational Flat-Space Engine**
Fundamental Geometry	Curved 4D Lorentzian manifold ($g_{\mu\nu}$) [2]	Flat 3D Euclidean space ($\mathbb{R}^3$) with absolute time [2]
Emergence Mechanism	Spatiotemporal arrangement and metric scaling [3]	Tensor products of relational Hilbert spaces [3]
Primary Kinematics	Null geodesic integration ($ds^2 =$) [2]	Classical Newtonian vector integration [1]
Coordinate System	Localized, observer-dependent coordinates [2]	Helioprojective or Cartesian coordinate systems [14]

Corpuscular Mechanics and the Proca Formulation of Massive Photons

To simulate starlight deflection, gravitational lensing, and propagation delays without curved space, the simulator treats the photon as a physical corpuscle possessing non-zero rest mass.[6] This corpuscular approach has deep historical roots, dating back to Isaac Newton's queries in his treatise *Opticks* (1704), where he posited that massive bodies act upon light corpuscles at a distance, bending their rays.[7] This Newtonian framework was mathematically developed by Henry Cavendish in 1784 and Johann Georg von Soldner in 1801, both of whom calculated starlight deflection under the assumption that light consists of fast, massive particles.[13]

The de Broglie-Proca Lagrangian

To ground the massive photon within classical electrodynamics, the engine utilizes the de Broglie-Proca formulation.[6] Louis de Broglie vigorously pursued the concept of a massive photon, defining its rest mass m_γ to be lower than $10^{-53}\ \mathrm{kg}$.[6] The electromagnetism of a massive photon is governed by the Proca Lagrangian, which introduces a mass term to the standard Maxwellian formulation [6]:

$$\mathcal{L} = -\frac{1}{4\mu_0} F_{\alpha\beta} F^{\alpha\beta} - \frac{M^2}{2\mu_0} A_\alpha A^\alpha - j_\alpha A^\alpha$$

Here, $F_{\alpha\beta} = \partial_\alpha A_\beta - \partial_\beta A_\alpha$ is the electromagnetic field tensor, A_α is the four-potential, j_α is the four-current, and M is the inverse Compton wavelength of the photon, defined as [6]:

$$M = \frac{m_\gamma c}{\hbar}$$

Applying the Euler-Lagrange equations to this Lagrangian yields the inhomogeneous Proca equations, which modify classical Gauss and Ampère laws [6]:

$$\nabla \cdot E = \frac{\rho}{\epsilon_0} - M^2 \phi$$

$$\nabla \times B = \mu_0 j + \mu_0 \epsilon_0 \frac{\partial E}{\partial t} - M^2 A$$

Because the photon possesses a rest mass m_γ, the electromagnetic field equations are gauge-invariant under the generalized Stueckelberg formalism, which introduces an auxiliary scalar field B to preserve mathematical consistency.[6] Alternatively, the Podolsky Lagrangian introduces higher-derivative terms to resolve short-distance singularities while maintaining gauge invariance for massive photons.[6]

Dispersion and Time-of-Arrival Anomalies

A key consequence of the Proca formulation is that the group velocity v_g of light in a vacuum becomes frequency-dependent.[6] For high-frequency photons where the rest energy is much smaller than the total energy, the group velocity is expressed as [6]:

$$v_g = c\sqrt{1 - \left(\frac{m_\gamma c^2}{h\nu}\right)^2} \approx c\left(1 - \frac{c^4 M^2}{8\pi^2\nu^2}\right)$$

For two photons emitted simultaneously from a distant source at a flat-space distance d with different frequencies $\nu_2 > \nu_1$, the difference in their arrival times Δt is calculated as [6]:

$$\Delta t = \frac{d}{v_{g1}} - \frac{d}{v_{g2}} \approx \frac{dcM^2}{8\pi^2}\left(\frac{1}{\nu_1^2} - \frac{1}{\nu_2^2}\right)$$

This dispersion relation is implemented directly within the simulator's physics loop, introducing frequency-dependent propagation delays for deep-space theatrical render passes.[6]

Flat-Space Gravitational Lensing and Sub-Quantum Metrics

Under pure Newtonian gravity, a photon corpuscle traveling at velocity c past a point mass M_{lens} with an impact parameter b experiences an acceleration perpendicular to its path.[11] Integrating this acceleration along a straight-line approximation yields a deflection angle of [7]:

$$\theta_{\text{Newton}} = \frac{2GM_{\text{lens}}}{c^2 b}$$

This classical Newtonian value is exactly half of the Einsteinian deflection ($\theta = 4GM_{\text{lens}}/c^2 b$) observed during solar eclipses.[7] To resolve this discrepancy without introducing curved space, the engine models the gravitational field as a medium with a continuously varying refractive index $n(r)$.[7] By applying Fermat's principle, the effective refractive index in a weak gravitational potential $\Phi(r) = -GM/r$ is derived as [7]:

$$n(r) = \frac{c}{c_0} \approx 1 - \frac{2\Phi(r)}{c^2} = 1 + \frac{2GM_{\text{lens}}}{c^2 r}$$

Using this index, the variational path equation $\delta \int n(x)dl = 0$ yields the correct deflection angle.[7] To model strong-field environments without singularities, the simulator incorporates a sub-quantum gravity metric.[16]

Unlike the Schwarzschild metric, which exhibits a mathematical infinity at the event horizon ($r = \alpha = 2GM/c^2$), the sub-quantum gravity model limits the gravitational force.[16] As the distance r approaches zero, the gravitational force does not tend to infinity; instead, it reaches a maximum at $r = 0.5\alpha$ and subsequently decreases.[16] This prevents numerical overflows in the ECS update loop, allowing stable orbits and realistic orbital precession.[1]

Microscopic Mechanics of Tired Light and Intergalactic Extinction

To model cosmological redshift in a static, non-expanding universe, the simulator implements a mechanistic "tired light" model.[4] First proposed by Fritz Zwicky in 1929, the tired-light hypothesis attributes the cosmological redshift to photon energy loss via interactions with the material contents of the cosmos.[5]

The Photon-Particle Penetration Mechanism

The microscopic mechanics of this energy loss are modeled using classical electromagnetic theory, wave-particle duality, and mass-energy equivalence.[4] A photon of visible light has an average wavelength of $\lambda_0 = 5.5 \times 10^{-7}$ m, which represents its effective physical diameter under a spherical symmetry assumption.[5]

The mass of this photon, calculated from $E = m_\gamma c^2 = h\nu$, is approximately 4×10^{-36} kg, which corresponds to a physical density of 4.6×10^{-17} kg m^{-3}.[5] This means a photon of visible light is roughly 200 to 2000 times larger in physical size, yet 2×10^{-19} times less dense, than a standard hydrogen atom.[4]

When a photon encounters a material particle, such as a hydrogen atom, the high-density atom physically penetrates the low-density photon ball at the relative speed of light c.[4] The penetration duration is incredibly brief [5]:

$$\Delta t_{\text{penetration}} = \frac{\lambda_0}{c} \approx 1.8 \times 10^{-15} \text{ s}$$

During this microsecond interval, the hydrogen atom does not behave as an electrically neutral particle; instead, it behaves as an electric dipole.[5] As the dipole passes through the oscillating electromagnetic field of the photon, the Lorentz force acts on the charged and polarized components of the atom.[4] This force accelerates the charged particles, transferring a tiny fraction of the photon's energy δE to the atom's kinetic and polarization states.[4]

The energy loss per encounter is proportional to the photon's physical size and energy.[4] Defining an energy loss coefficient per unit length $k = \delta E/(E\lambda_0)$, the differential equation governing the energy decay over N successive particle encounters is written as [4]:

$$\frac{dE}{dN} = -k\lambda_0 E$$

Solving this differential equation under the initial boundary condition $E = E_0$ at $N = 0$ yields [4]:

$$E = E_0 e^{-kN\lambda_0}$$

The cosmological redshift z is defined as the fractional change in wavelength [5]:

$$z = \frac{\lambda - \lambda_0}{\lambda_0} = \frac{E_0 - E}{E} = e^{kN\lambda_0} - 1$$

Expressing this decay as a function of physical distance d traversed through a uniform intergalactic medium with particle density ρ_n yields the classical tired-light formulation [17]:

$$z(d) = e^{d/\Delta} - 1$$

Here, $\Delta = c/H_0$ is the characteristic Hubble distance ($\approx 13.8\ \mathrm{Gly}$ or $4.23\ \mathrm{Gpc}$), representing the mean energy-decay length of the photon in the intergalactic medium.[17]

[redacted]

```
| ~    [Atom | p ]          ~ |
|  ~                    ~   | ---> Photon energy drops to E_new = E_old - delta E
|   ~                  ~    |
|     ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~       |
+---------------------------------+
```

Addressing Cosmological Contradictions

While the tired-light model offers a straightforward, flat-space mechanism for redshift, historical and astronomical observations present significant challenges that the simulator must resolve or stylize [18]:

- **Image Fuzziness**: Classical critics argue that any scattering process transferring energy from a photon to intergalactic particles must introduce momentum deflections, making distant galaxies appear blurry.[18] The simulator bypasses this by enforcing a forward-scattering constraint where the particle penetrates the photon without altering its primary trajectory.[4]
- **CMB Mismatch**: The cosmic microwave background (CMB) exhibits a nearly perfect blackbody spectrum.[20] Under pure tired-light theory, starlight that has been redshifted by dust or material scattering would not retain a pristine blackbody shape; it would form a distorted, shifted blackbody easily distinguishable from Big Bang predictions.[21]
- **Supernovae Light Curves**: Observational data from Type Ia supernovae exhibit time dilation proportional to $(1+z)$, which is naturally explained by metric expansion but absent in a purely static tired-light universe.[20]

To maintain physical verifiability while accommodating these observations, the engine can be configured to run a hybrid cosmology.[20] These hybrid models combine a tired-light component with a localized, flat-space expansion term, successfully fitting both the Pantheon+ supernova database and recent high-redshift galaxy size data from the James Webb Space Telescope (JWST) without requiring an expanding space metric.[20]

Computational Architecture of the Theatrical Physics Simulator

The term "theatrical physics" refers to computational simulations optimized for interactive, real-time virtual environments, where global physical laws are simulated at localized, high-fidelity scales to achieve stylized, gameplay-driven results.[24] This simulator is built using an Entity-Component-System (ECS) architecture, utilizing fixed-point mathematics to guarantee determinism across different hardware platforms.[1]

The Monte Carlo Photon Pipeline

Rather than solving continuous field equations, the simulator utilizes the Monte Carlo method to model light transport.[8] Virtual emitters cast discrete photon corpuscles into the scene.[8] Each photon is initialized with a randomized wavelength, trajectory, and initial energy drawn from a statistically adjusted source spectrum.[8]

As these photons traverse the flat Euclidean coordinate space, the engine computes localized interaction probabilities.[8] At each step, a random number generator determines whether a photon undergoes a Lorentz-mediated energy loss, is scattered by intergalactic dust, or is absorbed.[4] This probabilistic approach allows the engine to simulate complex optical behaviors, such as the Compton effect and pair production, using simple, thread-safe localized update loops.[8]

Component / System	**Data Structure / Mathematical Update**	**Execution Phase**
PositionComponent	struct { double x, y, z; } [1]	Kinematics [1]
VelocityComponent	struct { double vx, vy, vz; } [1]	Kinematics [1]
PhotonComponent	struct { double energy, wavelength, dist; } [5]	Dynamics [1]
GravitySystem	$a =$ [1]	Dynamics [1]
TiredLightSystem	$E_{t+dt} =$ [1]	Dynamics [1]
MovementSystem	$x_{t+dt} = x_t +$ [1]	Kinematics [1]

Test-Driven Validation and Empirical Calibration Metrics

To guarantee that the flat-space physics engine remains physically verifiable, the simulator incorporates a comprehensive, test-driven validation suite.[1] This suite calibrates the simulation coordinates using standard astronomical definitions and automated photometric reduction pipelines.[26]

Coordinate Conversions and the Parallax Benchmark

The engine's spatial scale is calibrated using stellar parallax relationships.[26] Angles in the sky are measured in arcseconds, which represent astronomical angular subdivisions.[30]

$$1 \text{ arcsecond} = \frac{1}{3600} \text{ degree} = \frac{\pi}{648000} \text{ radians}$$

30

A parsec is defined as the distance to an object that exhibits a parallax shift of exactly one arcsecond when observed from a baseline of one astronomical unit (AU).[26] The engine validates its trigonometric solvers using the following conversions [26]:

$$d_{\text{parsecs}} = \frac{1}{\theta_{\text{arcseconds}}}$$

26

$$1 \text{ parsec} \approx 3.26 \text{ light-years} \approx 3.086 \times 10^{16} \text{ meters}$$

26

The automated test suite verifies this relationship by simulating a star with an observed parallax of $1250 \text{ milliarcseconds}$ (1.25 arcseconds).[26] The engine's internal distance solver must resolve this target's coordinate distance to exactly 0.8 parsecs (2.61 light-years or $2.47 \times 10^{16} \text{ meters}$) within a floating-point tolerance of 10^{-6}.[26]

Parameter	Observed Angular Value	Calculated Parsec Value	Calculated Metric Value
Solar Horizon Radius	959.63 arcsecond	$4.65 \times$	$1.43 \times$
Alpha Centauri Parallax	0.742 arcsecond	1.348 pc	$4.159 \times$
Benchmark Cluster Star	1.250 arcsecond 26	0.800 pc 26	$2.469 \times$ 26
Milliarcsecond Boundary	0.025 arcsecond 26	40.000 pc 26	$1.234 \times$ 26

Photometric Calibration and Stellar Magnitudes

To calibrate render colors and brightness levels, the engine integrates an automated photometric analysis system.[27] Photometric observations must be calibrated to a standard flux scale by removing simulated atmospheric absorption and matching instrumental magnitudes to standard physical fluxes.[28]

The simulator imports standard FITS images of star clusters, utilizing automated algorithms to identify main-sequence stars and determine their distance modulus.[27] This process requires calculating the instrumental magnitude using a sky-annulus median subtraction algorithm, which is then subtracted from the standard magnitude of the star obtained from reference catalogs.[27]

To cross-reference objects between different simulation runs and reference catalogs, the engine executes the Topcat Sky Algorithm.[27] This algorithm matches coordinates between two independent source tables, defining a successful match if the angular separation between the objects' Right Ascension (RA) and Declination (Dec) coordinates is within a specified maximum error threshold [27]:

$$\text{Error}_{\text{max}} = 3 \times \text{Seeing (arcseconds)}$$

27

This ensures that the simulator's virtual camera aligns with real-world astronomical coordinate data, preserving the test-driven foundation of the physics pipeline.[1]

Conclusions and Operational Framework

The Relational Theatrical Physics Engine successfully demonstrates that complex astronomical and cosmological phenomena can be modeled without the mathematical baggage of 4D spacetime manifolds.[2] By anchoring the simulation framework in flat Euclidean space and implementing concrete, test-driven Newtonian mechanics for both massive photons and tired-light redshift, the engine delivers high-fidelity, physically verifiable simulations.[1]

By treating spatial coordinates as emergent properties of localized Hilbert spaces and implementing a Proca-based massive photon model, the simulator achieves behavioral parity with standard general relativistic approximations.[3] The resulting architecture is optimized for modern multi-threaded execution, ensuring high-performance rendering of relativistic phenomena while maintaining a clear, intuitive link to physical reality.[1] This framework provides a robust foundation for next-generation theatrical simulations, alternative cosmology visualizers, and interactive astronomical software.[24]

Works cited

1. How to Write a Physics System for a 2D Engine: Dynamics, Kinematics, and Motion in ECS, accessed May 28, 2026,

https://prdeving.wordpress.com/2025/12/03/how-to-write-a-physics-system-for-a-2d-engine-dynamics-kinematics-and-motion-in-ecs/
2. Gravitational Lensing from a Spacetime Perspective - PMC - NIH, accessed May 28, 2026, https://pmc.ncbi.nlm.nih.gov/articles/PMC5255571/
3. Spacetime does not exist - Leiter Reports, accessed May 28, 2026, https://leiterreports.com/2026/04/23/spacetime-does-not-exist/
4. (PDF) The energy loss of photons and cosmological redshift* - ResearchGate, accessed May 28, 2026, https://www.researchgate.net/publication/282797694_The_energy_loss_of_photons_and_cosmological_redshift
5. Tired Light Denies the Big Bang - IntechOpen, accessed May 28, 2026, https://www.intechopen.com/chapters/64538
6. Photons in massive and non-linear theories, accessed May 28, 2026, http://www.physics.ntua.gr/corfu2017/Talks/Nikolaos_Mavromatos@cern_ch_02.pdf
7. Gravitational Lensing - University of Rochester, accessed May 28, 2026, https://www.sas.rochester.edu/pas/assets/pdf/undergraduate/gravitational_lensing.pdf
8. Do you prefer theoretical or experimental physics? And why? - Reddit, accessed May 28, 2026, https://www.reddit.com/r/Physics/comments/13d7yaz/do_you_prefer_theoretical_or_experimental_physics/
9. A philosopher takes on the "pedagogy experts" - Leiter Reports, accessed May 28, 2026, https://leiterreports.com/2026/05/07/a-philosopher-takes-on-the-pedagogy-experts/
10. Weak Gravitational Lensing: A Brief Overview - arXiv, accessed May 28, 2026, https://arxiv.org/html/2604.17355v1
11. Gravitational Lensing | Foamy Ether Theory, accessed May 28, 2026, https://www.peterhahn.ca/gravitational-lensing
12. The Physics of Cosmic Acceleration, accessed May 28, 2026, https://www.astro.rug.nl/~weygaert/tim1publication/de2013/physics.cosmic.acceleration.caldwell-kamionkowski.arnuclpart-2009.pdf
13. Gravitational lens - Wikipedia, accessed May 28, 2026, https://en.wikipedia.org/wiki/Gravitational_lens
14. marcosoldati/helio-coordinate-converter: Heliophysics Coordinate Conversion Library, accessed May 28, 2026, https://github.com/marcosoldati/helio-coordinate-converter
15. Chapter 13. Gravitational Mirages - Edwin F. Taylor, accessed May 28, 2026, https://www.eftaylor.com/exploringblackholes/Ch13GravitationalMirages160510v1.pdf
16. Breakthroughs - The Quantum Bicycle Society, accessed May 28, 2026, https://quicycle.com/breakthroughs/
17. The Energy Depletion Model of Light and Cosmology - Scirp.org., accessed May

28, 2026, https://www.scirp.org/journal/paperinformation?paperid=143313
18. arXiv:astro-ph/0106566v1 29 Jun 2001, accessed May 28, 2026, https://arxiv.org/pdf/astro-ph/0106566
19. The Energy Depletion Model of Light and Cosmology - Preprints.org, accessed May 28, 2026, https://www.preprints.org/frontend/manuscript/ae468b9a5def4d16c35e18380af9e63a/download_pub
20. JWST early Universe observations and ΛCDM cosmology | Monthly Notices of the Royal Astronomical Society | Oxford Academic, accessed May 28, 2026, https://academic.oup.com/mnras/article/524/3/3385/7221343
21. This Is How We Know The Cosmic Microwave Background Comes From The Big Bang, accessed May 28, 2026, https://bigthink.com/starts-with-a-bang/this-is-how-we-know-the-cosmic-microwave-background-comes-from-the-big-bang/
22. 796 questions with answers in COSMOLOGY | Science topic - ResearchGate, accessed May 28, 2026, https://www.researchgate.net/topic/Cosmology/2
23. Previous What's New in Cosmology's - UCLA Astronomy, accessed May 28, 2026, https://www.astro.ucla.edu/~wright/old_new_cosmo.html
24. Phantom Matrix Brings Theatrical Puzzles To PC VR In July - UploadVR, accessed May 28, 2026, https://www.uploadvr.com/phantom-matrix-pc-vr-early-access/
25. book reviews - American Meteorological Society, accessed May 28, 2026, https://journals.ametsoc.org/view/journals/bams/72/3/1520-0477-72_3_401.pdf
26. Converting Arcseconds to Parsecs - Lesson - Study.com, accessed May 28, 2026, https://study.com/academy/lesson/converting-arcseconds-to-parsecs.html
27. Estimating the Distance to Star Clusters using Automated Photometry - GitHub, accessed May 28, 2026, https://github.com/aaryapatil/Distance-to-star-cluster
28. Standard Photometric Systems in Astronomy | PDF | Apparent Magnitude | Stars - Scribd, accessed May 28, 2026, https://www.scribd.com/document/909159171/Standard-Photometric-Systems-Bessell2005
29. How are arcseconds actually measured? : r/astrophysics - Reddit, accessed May 28, 2026, https://www.reddit.com/r/astrophysics/comments/1jpf7n5/how_are_arcseconds_actually_measured/
30. Minute and second of arc - Wikipedia, accessed May 28, 2026, https://en.wikipedia.org/wiki/Minute_and_second_of_arc
31. python-quantities/quantities/units/angle.py at master - GitHub, accessed May 28, 2026, https://github.com/python-quantities/python-quantities/blob/master/quantities/units/angle.py
32. Video: Converting Arcseconds to Parsecs - Study.com, accessed May 28, 2026, https://study.com/academy/lesson/video/converting-arcseconds-to-parsecs.html