Dilating Loop Relativity:

Mathematical Derivation for a Gauge-Gravity Spinfoam Mapping

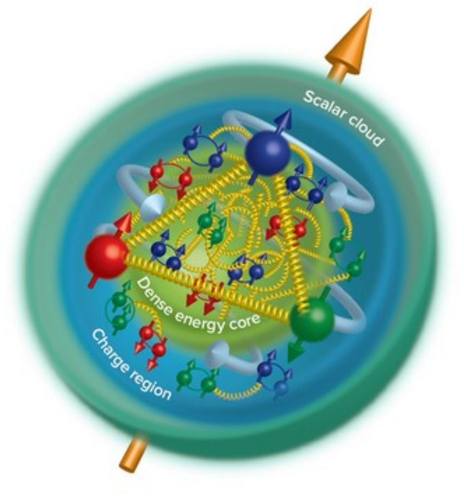
Andrew B. Evans – July 26, 2026 ABEvans@shaw.ca

Abstract: Dilating Loop Relativity (DLR) connects the Bern-Carrasco-Johansson double copy theory[1] with Loop Quantum Gravity (LQG)[2]. The framework recognizes physical mass as the source of unconfined kinematic potential density operating on LQG spinfoam cells[3]. At a spinfoam vertex, this potential triggers localized spatial loop dilations that emerge macroscopically as the Schwarzschild metric[4]. At a black hole, vertex dilation increases continuously down to the black hole centre. The event horizon acts as a filter, where nodes have dilated sufficiently that shorter-wavelength photons cannot execute the discrete hops required for propagation, while ultra-long Hawking radiation wavelengths span the node gaps and escape. Dark matter is the frozen remnant of early fluctuations in the strong force, acting similarly on LGQ spacetime. Finally, we propose a laboratory test using polarized solid hydrogen to detect an anisotropic, equatorial time-dilation signature.

Introduction: Theoretical physicist John Wheeler provided a perfect explanation for the Einstein Field Equations when he said, "Spacetime tells matter how to move, matter tells spacetime how to curve."[5] We are obliged to ask: what exactly is the property of matter that gives rise to this curvature? What property of matter causes gravity?

In our search for the underlying source, we begin by looking for some energy emitted by a massive body that results in this warping. This paper introduces the framework of Dilating Loop Relavity (DLR) and will provide a new explanation for the second half of Wheeler's statement, proposing that the kinematic potential arising from the massive energy of the strong force is the cause of spacetime curvature, leading to gravitational time dilation, gravity and dark matter.

In DLR, we propose that the universe is governed by an unconfined, off-shell kinematic potential (Φ_K), arising from the double copy theory, and its associated density operator ($\hat{\rho}_K(x)$). The physical mechanism of gravity arises because this kinematic potential acts directly on a 4D spinfoam vertex volume cell ($\mathcal{V}_v$) via the Quantum Weight Operator ($\widehat{\mathcal{W}(v)}$) that forces the fundamental spatial loops of Loop Quantum Gravity (LQG) geometry to dilate.

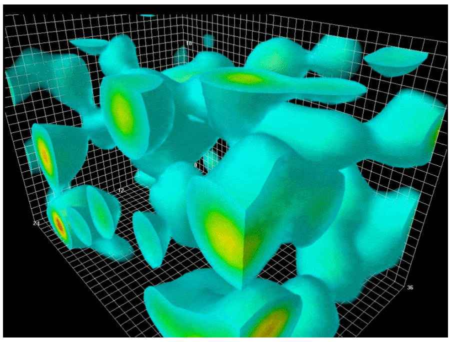


Schematic representation of a single nucleon mapping via the BCJ double copy space. The colour-neutral dense energy core is enveloped by a scalar gluon cloud, inducing localized quantum-geometric metrics in the surrounding spinfoam vacuum.
Argonne National Laboratory

Quantum Field Theory tells us that space is not empty. It is filled with electromagnetic fields and the quark and gluon fields of Quantum Chromodynamics (QCD), the quantum field theory of the strong interactions governing the structure of subatomic matter. Contrary to the concept of an empty vacuum, QCD induces chromoelectric and chromomagnetic fields throughout spacetime.

Charged subatomic particles, such as electrons and gluons, oscillate and have the property of spin or angular momentum that can be described as a moving charge, leading to waves that stretch outwards in the respective fields: virtual photons in the case of electrons and virtual gluons in the case of gluons. In quantum field theory, virtual particles are viewed as excitations of the underlying field but appear only as forces – not as detectable particles. The surrounding fields are "excited" by these forces.

Since electrons are charged particles, their mere presence in the electromagnetic field causes disturbances within it, i.e., virtual particles, which are merely fleeting fluctuations in the surrounding electromagnetic field caused by the motion of the electrons within the magnet. In the case of a bar magnet, the strength of the surrounding magnetic field is directly proportional to the alignment of its internal magnetic domains; the greater the alignment, the greater the strength.



Topological charge density of the chromoelectric field in empty space. This is much more active near a planet or star. Courtesy: D. Leinweber

Through the lens of the Bern-Carrasco-Johansson double copy, the unconfined kinematic potential of the internal gluon cloud maps mathematically to a dual chromoelectric field excitation surrounding a massive body. Gluons, moving at the speed of light, hold tremendous kinematic potential. The oscillations and spin of a gluon generate waves in the spinfoam metric stretching out into space surrounding a gravitational body. It is this kinematic potential, combined with that emanating from the gluons in the other 10^{50} atoms in a typical planet that generates the field excitation necessary to warp space and time.

There are three valence quarks connected by gluons inside each proton and neutron. There is also a large cloud of virtual gluons in a continuous loop of creation and annihilation. Although gluons are massless, they account for more than 99% of the total mass of the nucleon (and any planet or star) through mass/energy equivalence[6] and provide the most energetic possible chromoelectric field. Since mass creates gravity, it is a logical first step to look at the source of mass as the basis of gravity: gluons.

The Gravity Probe B experiment[7] was strong evidence of the existence of a field surrounding Earth, and the concept of gluon kinematic potential generating this field becomes evident. According to GR, the gravitational field produced by a rotating planet can be described by equations with the same form as electromagnetism." That is, a magnet with polarized electron spin moving within a coil induces a vortex in the magnetic field and subsequent electric current. Bini et al. confirmed the same principle holds for gravity: "We find that a special nonstationary metric in GEM can be employed to show explicitly that it is possible to introduce gravitational induction within GEM in close analogy with Faraday's law of induction and Lenz's law in electrodynamics."[8] Through the double copy dictionary, a rotating planet with internal gluon spin maps to a dual frame-dragging effect within the companion single-copy chromoelectric field space.

The question of colour confinement. Quarks and gluons exhibit strange behavior in that they move independently when close together inside a nucleon (asymptotic freedom) but the ties between them become much stronger as they are pulled apart (confinement). It can be compared to connecting them with a rubber band taking the role of the gluon. When quarks are close together inside the nucleus, the rubber band hangs loose and the quarks are free to move. When pulled apart, the rubber band becomes tighter and the quarks lose their freedom. This leads to the concept of confinement, whereby they cannot exist in isolation. Quarks must be in pairs (one quark plus one anti-quark to form mesons) or triplets (one red, green and blue quark to form a proton or neutron) in order to maintain colour-charge neutrality. Gluon colour charge is confined to the diameter of a proton. But this does not impact on the present theory.

The 2023 study "Determining the Proton's Gluonic Gravitational Form Factors"[9] provides the tested evidence. "Using our results, we derived the proton mass radius and scalar radius in each approach, finding the proton mass radius (the gluon flux tubes connecting quarks) to be smaller than its charge radius (the positively charged quarks). Furthermore, the holographic QCD extraction yields a scalar radius (the confining gluon cloud as shown in the image on the front of this paper[10]) of one fermi, substantially larger than the charge radius. This compels us to see the proton's structure as consisting of three distinct regions: an inner core, dominated by the tensor gluonic field structure, providing most of the proton's mass. The charge radius, determined by the relativistic motion of the quarks, extends beyond this inner core. The entirety of the proton is enveloped in a confining scalar gluon density, extending well beyond the charge radius." And from a 2026 paper[11]: "Taken together with quark pressure distributions from lattice QCD or DVCS measurements, our results support a spatial picture in which gluons dominate at larger radii with a confining inward pressure." Under the quark-meson coupling model[12] this scalar gluon cloud does not separately surround each proton or neutron; rather, "The quarks in that nucleon are in turn interacting with the quarks in another, and so on. The nucleus is now seen as quasi-nucleons interacting through forces which involve 2, 3, or even 4 bodies." The atomic nucleus is crowded, with nucleons overlapping by 20%-25% of their volume, and the scalar gluon cloud surrounding the entire group. In a recent paper[13], Meziani and Zahed determined that this scalar gluonic cloud is most responsible for nucleon mass: "This relation provides a direct experimental determination of the scalar gluonic form factor associated with the trace anomaly and therefore with the dominant origin of the proton mass."

The Double Copy theory[14] ties this concept together. "Pure graviton scattering amplitudes can be rewritten as the product of two pure gluon amplitudes, or Gravity equals Gauge Theory squared." In quantum physics, these gravity amplitudes are mathematical equations that calculate the probability of gravitational particles interacting and scattering off one another. This shows that while gluon colour charge is confined, the kinematic dependence of these particles is not. The two properties (colour charge and kinetic numerators) obey parallel algebraic structures, so the colour factors can be replaced by a second copy of the kinematic numerators, giving us the Double Copy of the theory.

When we describe a planet as being surrounded by an "excitation," we are describing a quantum-geometric metric expansion in real space that is mathematically analogous to a chromoelectric field excitation in the copy space. By anchoring our terminology in this dual-space duality, DLR preserves the strict isolation of macroscopic gravity from subatomic QCD confinement while revealing their shared mathematical origin.

When calculating scattering amplitudes for gluons, the math comes down to three factors:

1. Kinematics (motion): How fast the particles are moving, their angles and momentum.
2. Colour (charge): Non-Abelian colour charges that dictate how particles interact.
3. Propagators (space): The distance particles travel between collisions.

Classical Double Copy theory enables us to take the complex spacetime curvature around a planet or star and map it directly to a much simpler Yang-Mills gauge theory. ñ

Dr. Chris White provides an excellent explanation[15]

$$\mathcal{M}_m^{(L)} = i^{L+1}\left(\frac{\mathcal{K}}{2}\right)^{m-2+2L} \sum_i \int \prod_{l=1}^{L} \frac{d^D Pl}{(2\pi)^D} \frac{1}{S_i} \frac{n_i \tilde{n}_i}{\prod_{\alpha_i} \mathcal{P}_{\alpha_i}^2}$$

"It is difficult to exaggerate how remarkable (this equation) is. The traditional calculation of gravity amplitudes, as discussed above, is extraordinarily complicated, involving a forbidding quagmire of algebraic complexity. (This equation), however, suggests that the basic structure of gravity amplitudes is essentially identical to those of gauge theory, despite the fact that the Feynman rules are orders of magnitude more complicated!…The simplest form of the double copy consists of pure Yang-Mills theory being copied with itself. This leads to General Relativity coupled to an additional scalar particle (known as the dilaton), and an antisymmetric tensor field. In four dimensions, the extra particles constitute two degrees of freedom. Combined with the two polarization states of the graviton, this gives four degrees of freedom in total. This matches up with the fact that we have "copied" two gauge theories with 2 degrees of freedom each (the two polarization states of the gluon)."

DLR does not claim that free, colour-charged particles escape the nucleon. Confinement is an algebraic filter that forces the net sum of all colour factors to equal zero at macroscopic scales. However, the double copy framework shows that the kinematic numerators, which represent the off-shell momentum and stress-energy density of the virtual gluon cloud, are governed by a dual kinematic algebra. Because energy-momentum is a universally conserved property, this kinematic footprint cannot be confined. It is translated into a colour-neutral, spin-2 tensor field that propagates freely across infinite distances, altering the geometry of the surrounding vacuum.

In the framework of the Double Copy theory, Yang-Mills theory serves as the single-copy, or baseline gauge theory. It gives the gluon scattering amplitudes that are mathematically squared to construct the scattering amplitudes of general relativity. Yang-Mills is the accepted quantum field theory that describes how gluons and other nuclear forces interact. Any Yang-Mills scattering amplitude can be written as a combination of three components:

- Propagators: the paths that the particles take
- Colour Factors: the gauge theory charges
- Kinematic Numerators: the terms of the momentum, spin and polarization of the gluons

Bern, Carrasco and Johansson[16] found that the kinematic numerators obey the same algebraic layout as the colour factors, known as colour-kinematic duality. By squaring the Yang-Mills kinematics ($n_i \times n_i$) the spin-1 gluons combine to produce the spin-2 gravitons of general relativity, along with a scalar field called the dilaton which directly connects to the fundamental mechanisms of dilating loop relativity.

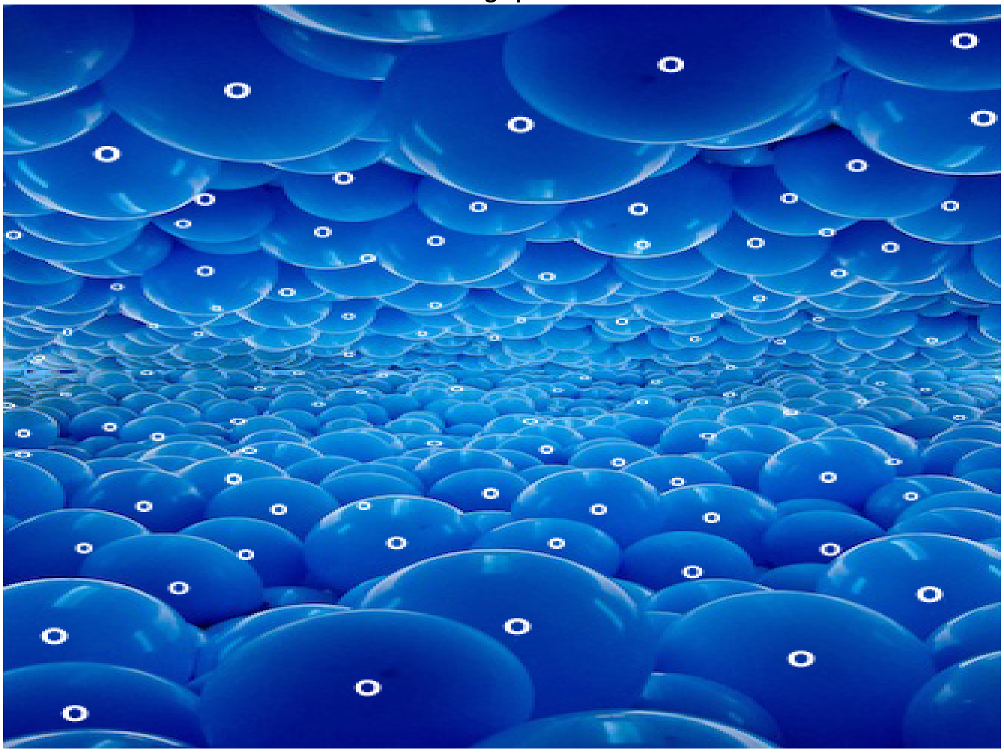
The dilaton is a hypothetical scalar particle of spin-0 that governs the fundamental strength of physical forces.[17] When spin-1 gluons are multiplied in the double copy theory, they mathematically split into three distinct entities:

- Graviton: spin-2 particle of general relativity
- Axion: spin-1 tensor field
- Dilaton: spin-0 scalar field that measures changes in the scale of space itself

The dilaton field causes the overall scale or metric size of space to expand or contract dynamically based on particle motion. This is precisely what the Dilating Loop Relativity theory describes. The modified volume equation $1 + \alpha K \frac{n_i \cdot n_i}{d_v}$ acts as a discrete dilaton field. It is a scalar value calculated at every node that determines how much each must dilate.

Introducing Loop Quantum Gravity: The question becomes, exactly how does this excitation of the surrounding field result in gravity? We propose that this answer lies in particulate space and the theory of loop quantum gravity. In this theory, space is made up of particles or loops, with each being extremely small, on the order of 10^{-35} metres. Physicist Carlo Rovelli, leading research in loop quantum gravity, noted, "The physics of quantum gravity is the physics of the quantum fields that build up spacetime… A region of space can be described by a set of interconnected grains of space… The length of these links is determined by the field itself because geometry is determined by gravity."[18] "What photons are for the electromagnetic field; we think there should be analogous quanta for the gravitational field. Since the gravitational field does not live in spacetime but is spacetime itself, the quanta do not live in spacetime; they are themselves spacetime…The quanta of gravity in loop quantum gravity are the grains out of which space, or the gravitational field, is built. The pixel granular structure is right there at the beginning."[19]

Visualizing Spacetime:



The particulate space of loop quantum gravity has been described as 2-dimensional triangles, tetrahedra or as links in chainmail. Over a period of time, it is described as a soap-like "spinfoam". In DLR, these bubbles expand in size with the addition of energy near a gravitational body, becoming the warping of space. This leads to a stretching of their life cycle. Each bubble contains a node. Light travels from node to node in quantum jumps, each lasting one Planck Time. Hence, the Planck time expands with the expansion of each bubble. This becomes the definition of time dilation and together we arrive at the warping of spacetime as defined in general relativity. Of course these particles are clouds of quantum fuzziness.

Likewise, physicist Jim Baggott noted, “Loop quantum gravity suggested that at the Planck scale, space is discrete, composed of individual units or quanta – the loops themselves. These represent the building blocks of space, which is formed from a weave, but more like chain mail produced by linking individual loops of steel than linen produced by weaving continuous threads. This kind of model suggests that space cannot be continuously variable. At the Planck scale, there must be some kind of ultimate area or volume which cannot be transcended. There can be no area smaller than the smallest area; no volume smaller than the smallest volume.”[20] A different concept of this general idea describes the particles as two-dimensional triangles in a cloud of quantum fuzziness.[21]

Permeability and Permittivity. It occurs that in a different universe, if the size of a space particle was larger or smaller, then the speed of light would itself be slower or faster. This works directly in conjunction with Maxwell’s equations with $c = 1/\sqrt{\mu_0 \varepsilon_0}$. That is, c is inversely proportional to the permeability and permittivity of free space. In this formula, ε_0 (8.8542×10^{-12}) is the permittivity of free space. This can be thought of as the resistance of free space to the formation of fields, or the viscosity of space.

Paraphrasing from Arvin Ash; Why are μ_0 and ε_0 these exact values? These are the constants of nature. These are properties of free space that tell us how fast magnetic fields and electric fields can interact with each other. This sets a limit on how fast these fields can propagate through space. In a different substance, or in a different universe, these constants could be different.[22] We can surmise that if ε_0, the permittivity of space was lower, c would increase. Likewise, if ε_0 was larger, as with the dilation of particulate space, c would decrease, as we see with time dilation in gravity. Paraphrasing from Review of the Universe, “Just as space is defined by a network’s discrete geometry, time is defined by the sequence of distinct moves that rearrange the network. Time flows not like a river but like the ticking of a clock, with ‘ticks’ that are about as long as the Planck time: 10^{-43} second. Or, more precisely, time in the universe flows by the ticking of innumerable clocks - in a sense, at every location in the network where a quantum "move" takes place, a clock at that location has ticked once.”[23]

To show approximations on how this works in a gravitational field, we compare the permittivity of free space against the permittivity of space on the surface of the gravitational body:

- In Free Space: $c = 1/\sqrt{\mu_0 \varepsilon_0}$, where $\mu_0 = 1.25663706 \times 10^{-6}$ and $\varepsilon_0 = 8.85418782 \times 10^{-12}$
- And using the Schwarzschild metric to determine time dilation relative to free space: $t' = t/\sqrt{1 - 2Gm/rc^2}$

On the Earth: Mass=5.9722×10^{24}kg Radius=6.371×10^{6}m
We find a time dilation factor of t_E=1.000,000,000,699,68
$c \times t_E - c = 0.21$
We find a permittivity factor of $\varepsilon_E = \varepsilon_0 \times t_E = 8.85418783 \times 10^{-12}$ or a difference of 21 centimeters per second in the relative speed of light versus free space.

On the Sun: Mass=1.989×10^{30}kg Radius=6.9634×10^{8}m
We find a time dilation factor of t_S=1.000,002,121,041,69
$c \times t_S - c = 636$
We find a permittivity factor of $\varepsilon_S = \varepsilon_0 \times t_S = 8.85420660 \times 10^{-12}$ or a difference of 636 metres per second in the relative speed of light versus free space.

On star R136a1: Mass=6.263×10^{32}kg Radius=2.089×10^{10}m
(The largest known star) We find a time dilation factor of t_R =1.000,022,265,004,83
$c \times t_R - c = 6675$
We find a permittivity factor of $\varepsilon_R = \varepsilon_0 \times t_R = 8.85438498 \times 10^{-12}$ or a difference of 6,675 metres per second in the relative speed of light versus free space.

From these we see the small distortion of spacetime surrounding Earth when compared to the larger distortion around the Sun and much larger distortion surrounding star R136a1.

Dr. Don Lincoln from Fermilab said, "When you add mass and energy, you can distort the shape of the little volumes of quantum space… Bending space and time has a property that you can distort the local definition of space."[24] Likewise, Arvin Ash noted, "How do particles traverse this quantized space? When mass and energy are added to the spin foam, the shape of the volumes of the spin network is distorted. This distorts space and time… This distortion of space and time is what we perceive as gravity."[25]

We are left to surmise that the added energy of the field surrounding a gravitational body causes a dilation, or swelling, of particulate space and subsequent time dilation. This becomes a clear definition of the warping of spacetime (and an understanding of the second half of Wheeler's statement) as used throughout relativity; it defines exactly how matter tells spacetime how to curve.

In a different way to envision this process in loop quantum gravity, we can speak of a photon traveling along a path of nodes in space like a man walking across scattered rocks in a river. These nodes define the quantum nature of space in that a photon can only move instantly from node to node but can never be found in between two nodes. The travel time from node to node is defined as the minimum possible tick of the quantum clock, i.e. 1 Planck time. If, near a planet, space is dilated by an excitation of the field, then the distance between these nodes is increased and it takes longer (in relative terms) for a photon to cross that difference. But the travel period remains defined as 1 Planck time. Referring to Carlo Rovelli, "The central physical result obtained from loop quantum gravity is the evidence for a physical quantum discreteness of space at the Planck scale."[26]

In Loop Quantum Gravity, the building blocks of space and time are typically treated as rigid geometric structures. While this quantizes the fabric of the universe into discrete pixels of area and volume, it does not have any mechanism connecting these quantum grains to the fields that cause gravitational attraction. Dilating Loop Relativity bridges this gap by introducing a mathematical device: the Quantum Weight Operator.

We can think of the operator as a localized quantum scanner. In the macroscopic world of General Relativity, a planet warps the spacetime around it. In the microscopic world of DLR, a planet radiates a cloud of kinematic potential outward into space. The Quantum Weight Operator is the tool that scans these microscopic regions of spacetime and measures the density of this potential cloud. This operator does not measure a smooth, continuous fluid; it functions at the Planck scale. It acts by counting the individual, discrete loops of quantum force threading through a single snapshot event in spacetime (a spinfoam vertex).

Once the operator measures the energy (weight) of the virtual cloud at a specific point, it feeds this data directly into the spacetime equations. Instead of leaving the quantum pixels of space uniform, the presence of this measured energy physically stretches and dilates them. Near a planet, where the virtual gluon cloud is densest, the Quantum Weight Operator registers a higher value. By introducing this operator, DLR provides a clear, physical mechanism that directly generates the spatial warping and time dilation we traditionally observe as gravity.

In developing a mathematical framework for dilating loop relativity, we start with a quest for a precise, gauge-invariant operator to derive a quantum kinematic numerator from the double copy gravitational energy density term ($\hat{\rho}_{grav}$) that acts on the spin network states of LQG. (In DLR, the kinematic numerator (n_i) represents a localized density of energy and momentum originating from the double copy.) We extract the kinematic numerator from the double copy and show it using the geometry of loop quantum gravity: holonomies (along edges) and fluxes (across surfaces). The kinematic operator acts directly along the edges and loops that define the vertices of the graph.

From the double copy framework, the gauge field energy density ρ_{gauge} is extracted from the spatial components of the field strength tensor $F^{\mu\nu}_{ab}$. Stripping the colour indices in the double copy translation; the unconfined gravitational energy density is built from the combination of the fields. This represents the chromoelectric and chromomagnetic energy density. In DLR, this is the unconfined energy driving the dilation of LQG spatial quanta:

$$\rho_{gauge}(x) = \frac{1}{2}\text{Tr}\big(F_{ij}(x)F^{ij}(x)\big)$$

We use a standard LQG regularization technique to project this continuous field onto the spin-network graph Γ. We show that the field strength tensor at point x (denoted $F_{ab}(x)$) is regularized by taking the limit of a holonomy $h_{\alpha_{ab}}$ around a minimal closed loop α_{ab} of area ε^2 spanning the *i* and *j* directions and with ***I*** as the identity matrix:

$$F_{ij}(x) = \lim_{\epsilon\to 0}\frac{h_{\alpha_{ij}} - \boldsymbol{I}}{\epsilon^2}$$

Substituting this loop regularization into the energy density expression, we arrive at the gauge field operator. This equation uses the trace (Tr) of the closed holonomy loop, so it is invariant under local SU(2) gauge transformations at the vertices.

$$\hat{\rho}_K^{\epsilon}(x) = \frac{1}{2\epsilon^4}\sum_{i<j}\text{Tr}\left(\left(\boldsymbol{I} - h_{\alpha_{ij}}(x)\right)\left(\boldsymbol{I} - h_{\alpha_{ij}}(x)\right)^{\dagger}\right)$$

A spin-network edge carries a specific spin representation label j_e (determining its area quantum). The holonomy operator acts on these edges by shifting the spin labels. When the regularized operator acts on a specific edge inside a spin network state $|\Gamma, j_e\rangle$ it creates a localized quantum excitation:

$$\hat{\rho}_e|\Gamma, j_e\rangle = \frac{1}{2\epsilon^4}\left[4 - 2\text{Tr}\big(h_{\alpha_e}\big)\right]|\Gamma, j_e\rangle$$

The edge-based kinematic operator must be regularized along with the volume operator $\hat{V}_v$ at the vertex where the edges meet. We define the kinematic numerator factor $\hat{N}(v)$ for a vertex (v) as the sum of the edge-linked loop excitations, weighted by the local volume.

$$\hat{N}(v) = \sum_{e\in v}\hat{V}_v^2\cdot\hat{\rho}_{K,e}$$

This provides a local kinematic numerator density $\sum n_i^2/d_i$ that modifies the volume equation:

$$\widehat{V}_{dilated,v}|\Gamma\rangle = \widehat{V}_{\upsilon}\left(1 + \alpha k\widehat{N}(v)\right)|\Gamma\rangle$$

The derived energy density of the double copy is no longer a vague background field in smooth space. It is a precise count of holonomy excitations impacting on the edges of the LQG spin network. When $\widehat{N}(v)$ returns a value, it expands the volume of the node, explicitly showing how motion dilates the particulate space of LQG.

In standard loop quantum gravity, the geometry is represented by a spin network state[27]:

$$V|\Gamma, j, t\rangle$$

For a given node ν, the volume operator $\widehat{V}_\nu$ acts on the intertwiner ι at that node. Its eigenvalues V_ν are given by the equation:

$$\widehat{V}_\nu|\Gamma, j, t\rangle = V_\nu|\Gamma, j, t\rangle = \ell_P^3\sqrt{|\hat{q}_\nu|}|\Gamma, j, t\rangle$$

Where:

$\ell_P = \sqrt{\hbar G/c^3}$ is the Planck length

$\hat{q}_\nu = \epsilon_{IJK}\hat{J}^I\hat{J}^J\hat{J}^K$ is a regularized operator from the product of the two flux operators.

Under Dilating Loop Relativity, the volume of an LQG node is dilated proportionally to the unconfined gravitational energy absorbed at the vertex. We modify the standard LQG eigenvalue equation to include the non-linear coupling term:

$$\widehat{V}_{dilated,v} = \widehat{V}_\nu\left(1 + \alpha\frac{\kappa}{\hbar c}\sum_i \frac{n_i(\upsilon)\cdot n_i(\upsilon)}{d_i(\upsilon)}\right)$$

Where:

$\widehat{V}_\nu$ is the unperturbed LQG volume operator

α is a dimensionless coupling constant from dilating loop relativity

$\kappa = 16\pi G/c^4$ is Einstein's gravitational constant

$n_i(\upsilon)$ is the local kinematic numerator at the node's spatial coordinate

$d_i(\upsilon)$ is the spatial part of the Feynman propagator for the node's region

In the double copy framework, squaring gluon amplitudes naturally generates a scalar field called a dilaton, which controls the overall scaling of space; in Dilating Loop Relativity, our node dilation factor acts as the discrete, quantum loop equivalent of this dilaton field. The coupled equation yields:

$$\widehat{V}_{dilated,v}|\Gamma\rangle = \ell_P^3\sqrt{|\hat{q}_\nu|}\left(1 + \alpha\frac{\kappa}{\hbar c}\sum_i \frac{n_i(\upsilon)\cdot n_i(\upsilon)}{d_i(\upsilon)}\right)|\Gamma\rangle$$

Near a planet or star, the escaping kinematic numerator increases due to the localized scattering amplitudes. Far from the planet, the kinematic numerator (n_i) drops to 0. The dilation matrix forces the volume of each node to increase and the overall density drops, creating the metric gradient that shows as the warping of space and time dilation.

To update the core gravity equation (Hamiltonian constraint) for this framework, we plug the newly stretched volume formula directly into the standard quantum gravity model[28]. The kinematic structures from the double copy scale inside the constraint equation to produce the space and time warping of the Schwarzschild metric.

In LQG, the Euclidean part of the Hamiltonian constraint operator is constructed by replacing continuous connections with holonomies (h_α) along small loops of length ϵ_{i} using Thiemann's method:

$$\widehat{H}_E(N) = \sum_{v \epsilon nodes} N(v)\epsilon^{ijk}\mathrm{Tr}\left(h_{\alpha_{ij}} h_k^{-1}[h_k, \widehat{V}_\upsilon]\right)$$

Where:

$\mathrm{h}_{\alpha_{ij}}$ is the holonomy around a loop in the *ij*-plane at node υ.

h_k^{-1} is the holonomy loop along an edge in the *k direction.*

$\widehat{V}_\upsilon$ is the bare volume operator of the node.

When we insert the DLR shift ($\widehat{V}_{dilated}$) we understand that the unconfined double copy energy acts as a localized rescaling of the quantum Hamiltonian density of every spatial node:

$$\widehat{H}_{dilated}(N) = \sum_{\upsilon} N(\upsilon)\left(1 + \alpha\frac{\kappa}{\hbar c}\sum_i \frac{n_i(\upsilon)\cdot n_i(\upsilon)}{d_i(\upsilon)}\right)\epsilon^{ijk}\mathrm{Tr}\left(h_{\alpha_{ij}} h_k^{-1}[h_k, \widehat{V}_\upsilon]\right)$$

The modified Hamiltonian equation rescales the baseline time lapse function N_0 (which governs the flow of time by the scalar dilation factor:

$$N^2(r) = N_0^2(1 - \Phi_K(r)) = \left(1 - \frac{2GM}{c^2 r}\right)$$

This yields the g_{00} time dilation term of the Schwarzschild metric, giving confirmation that the kinematic factors dictate the slowing of time near the planet. When the volume elements are dilated, the radial triads E_i^a inside scale up proportionally to preserve the physical mapping of space. In LQG, the fundamental spatial variable is the densitized triad field ($\boldsymbol{E_i^a}$) which represents the square root of the spatial metric tensor (q_{ij}). Solving the remaining spatial constraint for q_{rr} gives:

$$q_{rr}(r) = \left(1 - \Phi_K(r)\right)^{-1} = \left(1 - \frac{2GM}{c^2 r}\right)^{-1}$$

With this, the metric assembles itself into the classical Schwarzschild metric that provides a formal, mathematical solution for the DLR theory:

$$ds^2 = -\left(1 - \frac{2GM}{c^2 r}\right)c^2 dt^2 + \left(1 - \frac{2GM}{c^2 r}\right)^{-1} dr^2 + r^2 d\Omega^2$$

By embedding the double copy numerator into the quantum volume component of Thiemann's Hamiltonian, the local dilation of LQG nodes naturally forces the emergence of the macroscopic Schwarzschild metric.

In standard physics, a free particle is restricted to its mass-shell (on-shell) meaning that its energy and momentum must obey the equation:

$$E^2 - p^2 c^2 = m^2 c^2$$

On the other hand, virtual particles, such as those generated by the double copy theory, are "off-shell" because they only exist as fleeting, localized disturbances of the field. They are allowed to momentarily cheat the equation due to the Heisenberg Uncertainty Principle ($\Delta E \Delta t \geq \hbar/2$). For a massless, virtual gluon, the off-shell deficit can be written as an invariant metric q^2:

$$E^2 - p^2c^2 = q^2 \neq 0$$

When this off-shell anomaly interacts with the discrete nodes of an LQG spin network, it alters the fundamental spacing of the lattice through spectral modification. It is necessary to examine how the mathematics of an off-shell field dictates the dilation of space under DLR.

Previously, we established that the dilated volume operator $\widehat{V}_{dilated,v}$ is driven by the kinematic numerator of the double copy. We can exchange the generic energy density for a formal off-shell parameter q^2. We change the standard quantum formula for spatial volume by adding a small correction proportional to the off-shell energy deficit of the surrounding virtual gluon cloud.

Where the off-shell mass operator $\widehat{\mathcal{M}}_{off-shell}$ measures the local deviation from the mass-shell.

$$\widehat{\mathcal{M}}_{off-shell}(x) = \left|\widehat{E}^2(x) - \hat{p}^2(x)c^2\right| = \left|q^2(x)\right|$$

Because the virtual particle energy is off-shell, it behaves as an intrinsic, uncompensated tension directly into the vacuum. To understand why this occurs, we look at how the volume operator calculates its eigenvalues. Ashtekar, Lewandowski[29] and Rovelli[30] established that the volume of a node is determined by the relation between the SU(2) angular momentum vectors of the links meeting at that node:

$$\hat{q}_v = \epsilon_{IJK}\hat{J}^I\hat{J}^J\hat{J}^K$$

When an on-shell particle passes through space, it carries a balanced energy-momentum vector that does not deform the underlying space. However, when an off-shell, virtual particle passes, its unbalanced energy relation creates a mismatch. The tension forces a shift in quantum numbers at the vertex; an external stress that shifts the eigenvalues of the flux operators $\hat{J}$.

$$\hat{J}^i \to \hat{J}^i\left(1 + \beta\frac{q^2}{E_P^2}\right)$$

The volume operator takes the square root of the product of three shifted flux operators, leaving the off-shell parameter as a linear multiplier. This equation reveals the exact quantum mechanism of Dilating Loop Relativity:

$$\widehat{V}_{dilated,v} = \ell_P^3\sqrt{\left|\epsilon_{IJK}\hat{J}^I\hat{J}^J\hat{J}^K\right|}\left(1 + \frac{3}{2}\beta\frac{q^2(\upsilon)}{E_P^2}\right)$$

The further off-shell is a virtual gluon, the greater the stress it exerts on the vertex. This stress forces the intertwiner state to expand, inflating the eigenstate of the volume operator and the discrete particle of space to dilate.

This interaction provides a solution to the LQG problem of deriving a smooth macroscopic gravitational potential from a discrete collection of particles. With on-shell particles, the geometry is rigid and behaves as a step function. Virtual, off-shell particles form a continuous, smooth probability density field through space. The particulate lattice of space stretches smoothly and continuously, approaching a gravitational mass, mirroring the spatial volume profiles derived by Khavkine, Loll, and Reska for non-singular mass couplings in background-independent lattice gravity[21]. The step function is softened into the smooth curves of General Relativity."

What about other energy sources? To establish Dilating Loop Relativity as a universal theory of gravity, it must apply to all gauge fields, including the electromagnetic field. Photons fit into DLR using generalized colour-kinematic duality. Substituting the non-Abelian colour algebra with an Abelian kinematic layout, we can show how off-shell photon fields generate the same volume operator on the LQG lattice.

In non-Abelian Yang-Mills theory, the kinematic energy density operator $\hat{\rho}_K$ is derived from the field strength tensor F^c_{ab} by tracing over the Lie algebra indices. For the electromagnetic field, the gauge group is the Abelian $U(1)$. The field strength tensor $F_{ab} = \partial_a A_b - \partial_b A_a$ lacks colour indices, meaning its energy density is unconfined.

We regularize the electromagnetic kinematic density and arrive at a quantum electromagnetic kinematic operator:

$$\hat{\rho}^{\epsilon}_{K,EM}(x) = \frac{1}{2e^2\epsilon^4}\sum_{a<b}\left(\boldsymbol{I} - h_{a_{ab}(x)}\right)^{\dagger}\left(\boldsymbol{I} - h_{a_{ab}(x)}\right)$$

This operator must interface with the double copy framework. When virtual photons interact with space around a charge, the local kinematic potential evaluates to:

$$\Phi_{K,EM}(x) = a_{EM^K}\sum_i \frac{n^2_{i,EM^{(x)}}}{d_i(x)}$$

The quantum electromagnetic operator acts on the edges and vertices of the LQG spin network. When a node is surrounded by a virtual photon cloud, the electromagnetic kinematic numerator operator $\widehat{\mathcal{N}}_{EM}(v)$ acts on the vertex intertwiner:

$$\widehat{\mathcal{N}}_{EM}(v) = \sum_{\epsilon\in v}\hat{V}^2_v \cdot \rho_{K,EM,e}$$

We arrive at the total coupled volume operator by summing the kinematic impacts of both the gluonic and electromagnetic sectors:

$$\hat{V}_{dilated,v} = \hat{V}_v\left(\hat{\Pi} + \alpha_{strong^K}\widehat{\mathcal{N}}_{strong}(v) + \alpha_{EM^K}\widehat{\mathcal{N}}_{EM}(v)\right)$$

The total volume shift becomes:

$$\hat{V}_{dilated,v} = \hat{V}_v\left(1 + \Phi_{K,strong}(v) + \Phi_{K,EM}(v)\right)$$

For an object with mass $\boldsymbol{M}$ and a rest mass/energy from electromagnetics $\boldsymbol{M}_{EM} = \mathcal{E}_{EM}/c^2$ the potentials arrive at:

$$\Phi_{K,strong}(r) = \frac{2GM_{strong}}{c^2r}, \quad \Phi_{K,EM}(r) = \frac{2GM_{EM}}{c^2r}$$

Combining these yields:

$$g_{00} =- \left(1 - \frac{2G\left(M_{strong} + M_{EM}\right)}{c^2r}\right)$$

Using the U(1) loop regularization, we have shown that virtual photons have the same algebraic capacity to dilate the LQG spatial nodes as do virtual gluons, showing that any form of gauge-theoretic virtual energy translates into the identical macroscopic conformal factor.

Four-dimensional spinfoam: To complete the picture of DLR, we must transition from LQG at a single point in time to four-dimensional spacetime and spinfoam; a collection of spatial vertices as they split, merge and evolve over time. A spinfoam is simply the history of a spin network moving through time, where the points and lines sweep out a structure that looks like microscopic soap bubbles. Under DLR, the virtual gluon energy does more than just expand static spatial nodes; it alters how these nodes evolve from one moment to the next. By expanding the volume elements, this energy physically stretches the spinfoam bubbles along the time axis. This local stretching slows down the transitions between states, creating a clear quantum mechanism for the gravitational time dilation we see in the Schwarzschild metric.

The engine that calculates the probability of these transitions (as a single quantum event) is the Spinfoam Vertex Amplitude ($A_{(v)}$ at a specific point in space and time at vertex v). By applying our model to a spinfoam, we can show that a virtual particle cloud changes the probability of spacetime executing a quantum transition, I.e., the transition amplitudes.

We define a 4D quantum weight operator $\widehat{\mathcal{W}}_{EM,Strong}(v)$ that measures the integrated virtual particle density across the transition event:

$$\widehat{\mathcal{W}}(v) = \int_{\mathcal{V}_v} \widehat{d^4x\sqrt{-g}\hat{\rho}_K(x)}$$

The operator on the spin-network boundry states by counting the holonomy loop excitations threading the faces of the spinfoam. Its eigenvalue $\mathcal{W}_v$ is proportional to the dimensionless kinematic potential:

$$\mathcal{W}_v = \sum_{f\in v} \alpha K \frac{n_f^2}{d_f}$$

The Hamiltonian constraint dictates the time-evolution amplitude of the vertices. So, modifying the Hamiltonian with the volume dilation factor means the spinfoam vertex amplitude must be adjusted by the kinematic weight. The DLR Modified Vertex Amplitude assembled into a spinform partition function (Z - the sum over all possible histories), the path integral becomes:

$$Z = \sum_{\Gamma} \prod_{f\in\Gamma} dim(j_f) \prod_{f\in\Gamma} \left[A_v(j_f, \iota_e) \cdot exp\left(-i\lambda_P \sum_{f\in v} \alpha K \frac{n_f^2}{d_f} \right) \right]$$

This equation provides two crucial answers to the theory:

- Dynamical supression/enhancement: The phase factor acts as a dynamic weight. If a spinfoam history attempts to create a metric transition that contradicts the energy distribution of the planet's virtual particle cloud, the phases will destructively interfere and cancel to zero.
- Origin of the action: When we take the limit of this function at a large-spin approximation ($j \to \infty$) the vertex amplitude transitions into the classical Regge action

$e^{iSRegge}$ which mimics Einstein-Hilbert gravity. Under DLR, the extra exponential term merges with it:

$$Z \to \int \mathcal{D}g \; exp\left(\frac{i}{\hbar}[S_{Einstein-Hilbert} + S_{Kinematic\ Interaction}]\right)$$

This proves that the vertex modification recovers the classical action of general relativity coupled to a matter source. The spinfoam does not just track empty space bending; it tracks a lattice whose rate of transition is continuously dilated by the virtual particle density of the matter passing through it.

Why is time dilation a reasonable cause of gravity? The answer is based on the second law of thermodynamics, that all matter tends towards entropy. As an interpretation of this, we can say that in order to increase entropy, all matter wants to give up potential energy.

Nobel laureate Kip Thorne referred to what he calls Einstein's Law of Time Warps. "Everything likes to live where it will age the most slowly. Gravity pulls them there." This concept was proven with the Pound-Rebca experiment using clocks at the base and top of a tower at Harvard University. Einstein's law says that $g=Rc^2/D$ where g is the rate of gravitational acceleration on Earth ($9.8 m/s^2$), R is the fractional difference in clock-ticking rates ($2.43x10^{-15}$) and D is the distance between them (22.3 metres). Pound-Rebca found $2.43x10^{-15}$ x c^2 / 22.3 = 9.8 m/s^2 which is the acceleration due to gravity on Earth. The accuracy of this was improved with the Gravity Probe A experiment using a satellite at 10,000 km altitude and a clock rate of 30 microseconds per day faster than the Earth-bound clock."[31]

This testing shows why gravity is so weak on Earth, where the curvature of time dilation is so small. Near the sun, curvature is greater, and much greater still near a neutron star.

Impact on the speed of light and the rate of time: To understand how the deformed metric impacts on the speed of light (and the rate of time) we look to the constraint algebra.

$$q^{ab}_{effective} = \left(1 + \Phi_K(x)\right)^2 q^{ab}$$

Where:
$q^{ab}_{effective}$: the inverse spatial metric of LQG
$\Phi_K(r) = \frac{2GM}{c^2 r}$: is the unconfined kinematic potential from the planet's gluon cloud

This structure governs the local propagation velocity of fields on the quantum lattice on the microscopic (Planck) and the macroscopic scales.

At the microscopic scale, the classical $E^2 - p^2c^2 = 0$ is modified to include Planck scale corrections proportional to the unconfined gluon energy density:

$$E^2 - p^2c^2\left(1 + \Phi_K(x)\right)^2 \approx 0$$

If we take the derivative to find the velocity of a photon passing through this dilated lattice $v_{group} = \frac{\partial E}{\partial p}$ we get:

$$v_{local(r)} \approx c\left(1 + \gamma\frac{E}{E_P}\Phi_K(r)\right)$$

Where: E_P is the Planck energy

γ is the structural parameter of the LQG graph

At energies less than the Planck scale, the correction term disappears and $v_{local} = c$

At the macroscopic scale, as a beam of light nears a gravitational body, the increasing density of the unconfined kinematic numerator causes the spatial nodes to swell. The light must cross a physically stretched grid. To a distant observer, the speed of light will appear to slow. This matches with the Shapiro time delay and gravitational lensing.[32] By setting the Schwarzschild metric to a null path for light propagation we solve for the radial coordinate speed of light $v_{light}(r) = \frac{dr}{dt}$

$$0 =-\left(1 - \Phi_K(r)\right)c^2dt^2 + \left(1 - \Phi_K(r)\right)^{-1}dr^2$$
$$v_{light}(r) = \frac{dr}{dt} = c\left(1 - \Phi_K(r)\right) = c\left(1 - \frac{2GM}{c^2r}\right)$$

Time dilation within a body: Now that we have an understanding of gravitational time dilation near a planet, we can move to understand how this leads to time dilation within every object resting on that planet. We know that every object, whether that be a ticking clock or an individual cell within the human body, is made up of atoms, made up of electrons, protons and neutrons made up of quarks and gluons. Quantum theory tells us that these electrons, quarks and gluons are waves moving in their respective fields. These waves are subject to the same limits of movement as the light waves described above, and therefore are impacted by the size of LQG particulate space in exactly the same manner. In dilated space, these waves move more slowly in between particles, so the cells in my body move more slowly, I run the 100 metre dash more slowly and I age more slowly than in free space.

Black Holes: The basic concept of black holes in Dilating Loop Relativity is quite simple; the particulate space of LQG continues to dilate down the centre of the black hole. The centre is not a singularity, but is a Planck-sized particle following Rovelli's concept of a Planck Star[33]. This interpretation solves the questions of Hawking radiation and the information paradox.

From the DLR point of view, at the event horizon (Schwarzschild radius) the particles have dilated to such an extent that light can no longer jump between them. In standard general relativity, the event horizon is a coordinate singularity where $g_{00} \to 0$. We reframe this boundary as a physical, quantum phase transition governed by particulate dilation, directly extending the loop quantization of the Schwarzschild interior established by Gambini and Pullin[34].

The ability of a light wave to "hop" from one node to the next depends on the wavelength: λ, that must be at least as large as the physical gap that it needs to cross: $\lambda \geq L(r)$. The black hole event horizon is not a single line where all wavelengths suddenly stop, but an extremely short radial distance where light with shorter wavelengths stops first, followed by visible light, and eventually including even the longest radio waves. This means that at the inner edge of the event horizon, each particle of LQG space has grown to a massive size; 100,000km or more, necessary to stop all light waves from moving.

This provides an explanation for Hawking radiation[35] where extremely long wavelength and cool, low energy radiation is theorized to escape from a black hole. These wavelengths are sized on the order of the black hole itself and would never be trapped by the freezing of time.

In order to derive an equation for this concept, we introduce a transmission coefficient $T(\mathcal{V}_v)$ that dictates how easily a field can propagate across a vertex volume cell $\mathcal{V}_v$. We define T based on the DLR vertex weight W_v:

$$T(r) \propto exp(-\frac{\mathcal{V}_v(r)}{\mathcal{V}_{crit}})$$

At the event horizon, $(r = r_s)$ the cell volume reaches the critical threshold $\mathcal{V}_v$=$\mathcal{V}_{crit}$ driving $T(r)$=0. The vanishing transmission coefficient forces the time-evolution operator of the spinfoam to stall, exactly as predicted by general relativity $g_{00}\rightarrow 0$.

We work with the standard LQG volume, $\ell_p=\sqrt{\hbar G/c^3}$, to define the critical cell volume V_{crit}, the minimum area A_0, and volume V_0.

$$A_0=8\pi\gamma\ell_p^2\sqrt{j(j+1)} \qquad V_0=c_v(8\pi\gamma\ell_p^2)^{3/2}[j(j+1)]^{3/4}$$

Where:

γ is the Immirzi parameter

c_v is a vertex dependent geometric factor (typically close to 1)

The kinematic potential density $\hat{\rho}_K(x)$ dictates the dimensions of the cells. The dilated volume $V_v(r)$ as it approaches the event horizon is scaled by the vertex weight W_v:

$$V_v(r)=V_0 \cdot f(W_v(r))$$

Where:

$$f(W_v(r))=\frac{1}{\sqrt{-g_{00}}}=(1-\frac{2GM}{c^2r})^{-1/2}$$

The lattice spacing $L(r)$ is not constant; it is driven by the unconfined kinematic potential density, where r_s is the Schwarzschild radius. We relate:

$$L(r) = \ell_P \cdot \frac{1}{\sqrt{-g_{00}(r)}} = \ell_P(1-\frac{r_s}{r})^{-1/2}$$

Moving the dilated distance into the transmission equation:

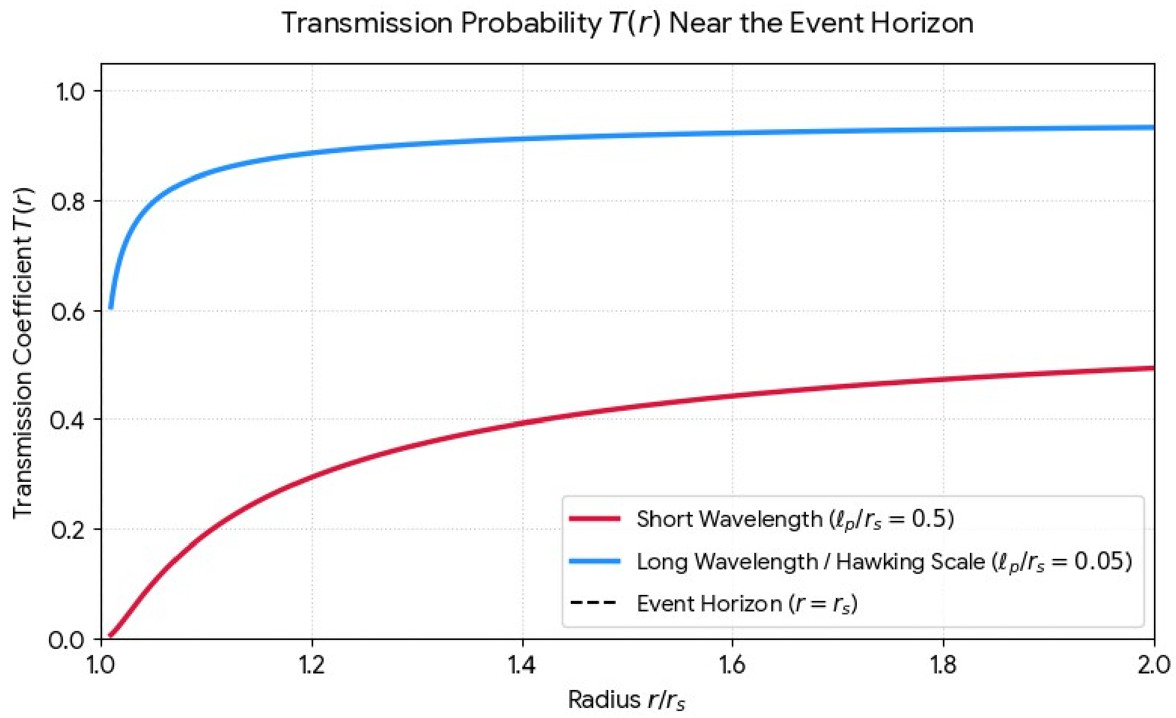
$$T(r) = T_0 exp(-\frac{\ell_P}{\lambda}(1-\frac{r_s}{r})^{-1/2})$$

For the longest wavelength photons trying to cross the event horizon, we evaluate the case:

$$T(r)=T_0 exp(-\frac{\ell_P}{r_S}(1-\frac{r_s}{r})^{-1/2})$$

As light approaches the event horizon from the outside, $r\rightarrow r_S$ the term $(1-\frac{r_s}{r})\rightarrow 0$ so the inverse root moves to infinity $(1-\frac{r_s}{r})^{-1/2}\rightarrow \infty$ and the exponential to negative infinity $T(r_S)=T_0 exp(-\infty)=0$. As light moves to the event horizon, the transmission coefficient moves to zero. Light cannot complete the jump from node to node and time stops.

The graph below demonstrates the sharp drop in transmission probability for incoming short-wavelength photons versus the long-wavelength Hawking radiation modes as they approach the event horizon.



Planck Length: As shown in the previous section, at the event horizon, LQG particles have dilated to an enormous size necessary to stop all light (other than Hawking radiation) from escaping. This also means that the Planck length ℓ_P has increased proportionally to an outside observer. What has been considered as fundamental constants must be reevaluated with the local time-evolution metric component. This becomes obvious if we measure the Planck length as time x speed, knowing that the speed of light remains the same for all local observers:

The standard global Planck Length is defined as:

$$\ell_P = \sqrt{\frac{\hbar G}{c^3}}$$

In an extreme gravitational field, local proper time ticks slower relative to coordinate time by the factor: $\sqrt{-g_{00}(r)}$. Because the speed of light c is a ratio of local distance over local time, the coordinate speed of light scales with the metric. If we map this geometric scaling to the local Planck length, we get:

$$\ell_{P(r)} = \frac{\ell_P}{\sqrt{-g_{00}(r)}} = \ell_P\left(1 - \frac{r_S}{r}\right)^{-1/2}$$

As $r \to r_S$ the term $\sqrt{-g_{00}(r)} \to 0$, forcing the effective local Planck length to diverge macroscopically to 100,000km or more.

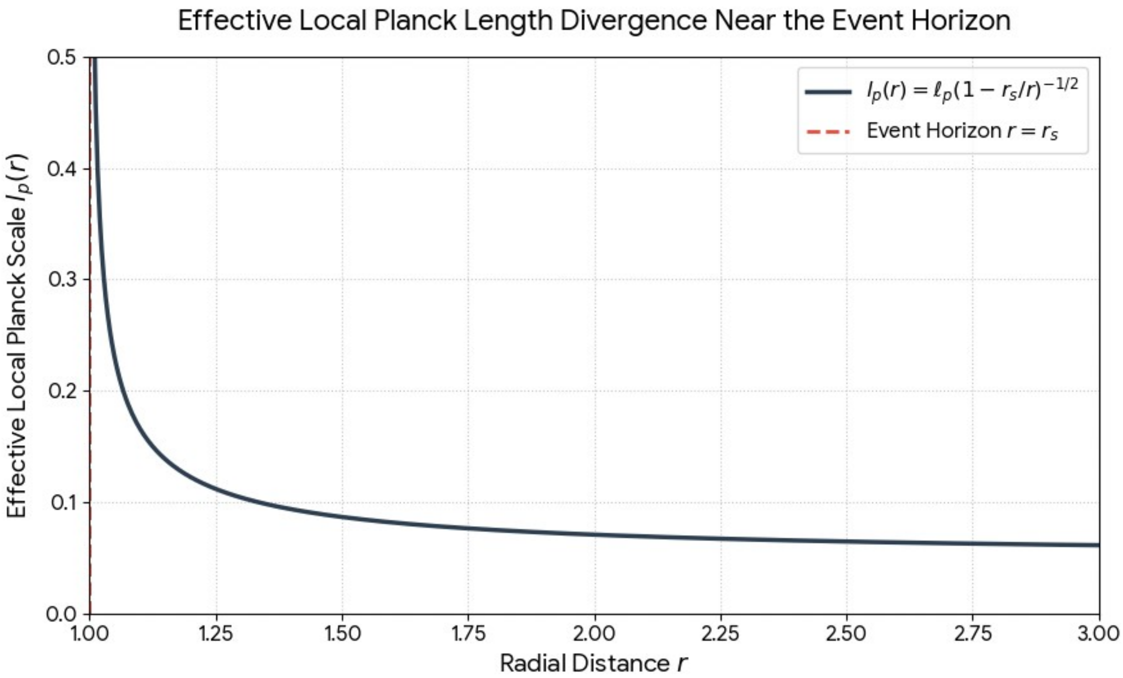
To justify why the constraints shift in this way, we look at the underlying action of the theory. In a variable constant framework, the gravitational constant G and Planck's constant $\hbar$ are treated as scalar fields integrated over the 4D spinfoam volume cells V_v

$$\hbar(r)=\hbar_0 \cdot \Phi_K(r)$$

When we substitute these field-dependent constants back into the local Planck length formula, the unconfined kinematic potential of DLR $\Phi_K(r)$ alters the local ratio:

$$\ell_P(\mathrm{r})=\sqrt{\frac{\hbar(\mathrm{r})G(\mathrm{r})}{c(\mathrm{r})^3}}$$

The kinematic potential density operator $\hat{\rho}_K(x)$ spikes near the event horizon; it rescales the local spacetime metric, ballooning the physical lattice spacing into the macro domain.

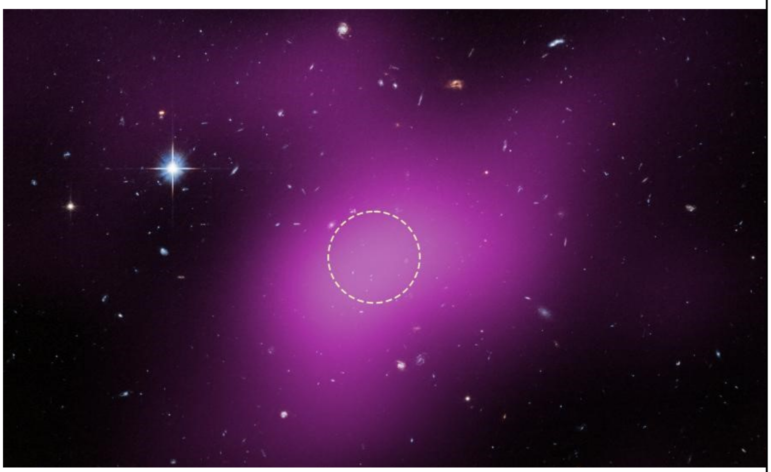


Dark Matter: A recent study from the University of Copenhagen has investigated the state of the universe in the shortest possible time after the Big Bang.[36] They determined that the universe was made up solely of a quark-gluon plasma. Associate Professor You Zhou stated, "We have studied a substance called a quark-gluon plasma that was the only matter during the first microsecond of the Big Bang." It is at this stage, after 10^{-43} seconds, that the effects of gravitational interactions become distinguishable from electronuclear interactions and have an effect on spacetime. Gravity existed before matter and mass. As what actually manipulates spacetime is the propagation of energy. It is only when the strong force separated from the electroweak that we started seeing objects that could be described as "particles," and eventually matter, once electromagnetism separated from weak interaction."

In DLR, dark matter is not some undiscovered particle. Just after the Big Bang, before the formation of atoms and even before electrons appeared, the universe was nothing but a high-density gauge field, I.e. a quark/gluon plasma. During this extremely short period, Heisenberg uncertainty ($\Delta E \cdot \Delta t \geq \hbar/2$) dictated massive fluctuations in the gluon strong-force density across the universe. In DLR, regions with extreme gluon energy density forced local space to dilate permanently. According to Jonathan Allday: "Remarkably, this uncertainty principle seems to be directly responsible for the formation of galaxies. If our current ideas are correct, then early in the universe's history it underwent a period of dramatic expansion governed by a quantum field. The energy/time uncertainty caused variations in the field's energy from one place to the next. As the field collapsed and converted into particles, more were created in high-energy regions than in neighbouring low-energy parts. These density variations eventually gave rise to the large-scale structures that we see now."[37] When the universe cooled and while expansion continued, these dilated regions of space became locked. The 2026 announcement of "Cloud-9"[38], a galaxy made up solely of dark matter and devoid of stars or planets, has provided confirmation that dark matter arose in the instant after the Big Bang and predates normal baryonic matter.

This provides the explanation that no physical matter is required for this gravity to arise; only the excitation of the LQG spinfoam. It was only later that the gravity from these pockets of dilated space attracted the newly formed baryonic matter from which stars and planets were created.

Cloud-9 - a starless galaxy comprised solely of dark matter



This concept aligns very well with a recent paper, "Dark Matter as a QCD Effect in anti de Sitter geometry."[39] "Our scenario is that the colorless gluonic component of the quark epoch which freely subsists after hadronization within an effective AdS environment (QCD effect) is the dark matter… We have tentatively explained dark matter by actually asking a simple question (!): what becomes the huge amount of gluons after the transition from QGP period to hadronization? We propose to consider Dark Matter observed through its gravitational effects, as a pure QCD effect." The author has recognized the key importance of the chromoelectric field in the formation of dark matter. The present theory merely takes this a further step of developing the excitation of the quantum field in dilating the particulate space of loop quantum gravity.

To formalize how Heisenberg Uncertainty seeded the early universe with gluonic energy, we can map primordial energy fluctuations directly to the DLR density operator $\hat{\rho}_K(x)$. This locks quantum fluctuations into frozen, dilated spinfoam geometries during the quark/gluon plasma (QGP) era.

We can model the dark matter energy profile not from particles (as with a planet, star or black hole) but from the primordial vacuum expectation value (VEV) of the gluon field strength tensor: $G^{\alpha}_{\mu\nu}$. The kinematic potential energy density operator $\hat{\rho}_K(x)$ during the inflation/plasma era is driven by the variations on gluon condensate:

$$\hat{\rho}_K(x) \propto \langle 0 | \alpha_s G^{\alpha}_{\mu\nu} G^{\mu\nu}_{\alpha} | 0 \rangle + \delta\hat{\rho}_{\text{Heisenberg}}(\text{x})$$

The continuum limit for an empty dark matter galaxy (such as Cloud 9) relies on the preserved spatial dilation factor of the vertex weight:

$$W_{\upsilon,\,dark}=\sum_{f\in\upsilon}\alpha K\frac{n_f^2}{d_f}\bigg|\,primordial$$

From this we can see why dark matter only interacts gravitationally. There are no particles or fields to couple to the electromagnetic or weak forces. There is only pre-stretched space.

The profile of a single spatial bubble at a correlation time scale $\Delta t=\tau_0$ is governed by a Gaussian distribution showing the quantum probability density of the fluctuation:

$$\delta\hat{\rho}_{\mathrm{Heisenberg}}(\mathrm{r})=\frac{\hbar}{2\tau_o\cdot V_0}\exp(-\frac{\mathrm{r}^2}{2\mathrm{R}_0^2})$$

Where:

τ_0 is the life of the gluon fluctuation before cosmic freeze-out
$R_0=c\tau_0$ defines the initial boundry (radius) of the fluctuation
$V_0=\frac{4}{3}\pi R_0^3$ is the initial spatial volume of the fluctuation zone

In standard quantum field theory, these fluctuations disappear. In DLR, we propose that the kinematic density acts directly on the spinfoam vertex volume cell V_υ via the quantum weight operator $\widehat{W}_\upsilon$. When expansion of the universe outpaces the recombination rate of the plasma, the quantum weight operator converts the transient energy into a permanent geometric feature. Adding in the Gaussian uncertainty profile yields:

$$W_\upsilon(r)=W_{\mathrm{bg}}+\alpha K\left(\frac{\hbar}{2\tau_0}\right)exp(-\frac{r^2}{2R_0^2})$$

Where W_{bg} is the standard background spinfoam weight and αK is the DLR coupling constant.

To see how this acts as dark matter after 14 billion years, we evaluate the modified metric. In DLR, the continuum metric component g_{rr} scales directly with the vertex weight distribution $W_\upsilon(r)$:

$$g_{rr}(r)=1+\beta_{DLR}W_\upsilon(r)$$

Bringing in our uncertainty-derived weight profile shows the metric distortion:

$$g_{rr}(r)=g_{rr,vacuum}+\gamma_{DLR}\frac{\hbar}{\tau_0}exp(-\frac{r^2}{2R_0^2})$$

Where γ_{DLR} absorbs the constant coupling terms.

An external observer measuring galactic rotation uses the standard Einstein field equations to calculate an apparent mass density profile from the metric curvature $\rho_{apparent}(r)$ Calculating the Lapacian of this, we derive the apparent density of the dark matter galaxy:

$$\rho_{apparent}(r)=\frac{\gamma_{DLR}^{\hbar}}{\tau_0R_0^2}(\frac{r^2}{R_0^2}-3)exp(-\frac{r^2}{2R_0^2})$$

Where $\rho_{apparent}$ represents the local effective source contribution to the field equation curvature, rather than a standard positive matter-density distribution, because it represents an uncompensated topological tension in the vacuum.

This profile also directly resolves the core-cusp problem of standard astrophysics[40]. Typical Cold Dark Matter simulations predict a steep, spiky density peak (a cusp) at galactic centers, which contradicts telescope observations showing a flat, constant density plateau (a core).

In DLR, $\rho_{apparent}$ does not track physical particles; it tracks uncompensated topological vacuum tension. As $r \to 0$, the polynomial $(r^2/R_0^2 - 3) \to -3$. This negative value indicates a counter-pressure that flattens the gravitational potential gradient at the centre. The mathematical structure of the frozen spinfoam fluctuation transitions the gravitational cusp into a flattened core, resolving the discrepancy without complex baryonic feedback mechanisms.

This derivation requires no mass or particle fields in the present era. The entire gravitational profile is a frozen relic of the universe's initial uncertainty.

Measurement, Testing and Proof – Manufactured Gravity:
It is known that a quantum field cannot be measured in itself. Nor is it possible to measure the wave function of an individual quantum particle. It is only possible to measure the interaction between a particle and some means of observation at the collapse of that wave function into a particle. For a photon in the double-slit experiment, this interaction takes place on the black screen. For a magnetic field, this interaction takes place with the sprinkling of iron filings or with a Gauss meter.[41] For the present theory, the validation occurs where the double copy kinematic numerator interacts with spinfoam vertices, generating spatial loop dilations and gravity.

A relatively simple means and method of testing this theory can be provided through Manufactured Gravity using polarized frozen hydrogen. Hydrogen freezes to a solid at a temperature of 14°K. It has been shown by Ohta et al[42] that frozen hydrogen can be polarized with respect to internal proton spin by passing an electromagnet back and forth along the block of frozen hydrogen. Likewise, it has been shown that the spins of individual gluons are aligned in the same direction as the spin of the proton they inhabit.[43] We can conclude that the act of polarizing protons in frozen hydrogen will result in a large proportion of polarized gluons.

The theory holds that polarized gluons will behave analogously to polarized electrons within a bar magnet. That is, they will cause a highly specific directional polarization (spin-2 tensor modification) of gravity, rather than a simple scalar amplification. The kinematic numerator spreading away from the block is structurally altered by the artificial spin alignment within the block.[44][45]

Recall the 4D quantum weight operator equation:

$$\mathcal{W}_v = \sum_{f \in v} \alpha_K \frac{n_f^2}{d_f}$$

When this operator scans the spinfoam cells $\boldsymbol{\mathcal{V}_v}$ directly above the polarized block, the eigenvalue $\boldsymbol{W_v}$ will not yield the standard, symmetric Schwarzschild value because the virtual cloud's kinematic numerator has been artificially oriented. The LQG particulate space oriented parallel to the gluon spin axis will have a different rate of volume expansion than those perpendicular to it. Because of this uneven dilation, a clock placed above the block would record a gravitational time dilation that depends on the angle of approach. The underlying gauge field strength tensor $\boldsymbol{F_{ij}^a}$ breaks spherical symmetry, and the isotropic kinematic potential that relies on the spherical Schwarzschild metric is forced into an anisotropic orientation.

We can propose a polarized block, centred at the origin, with spin alignment vector oriented along the z-axis; $\boldsymbol{s^{\mu}} = (\mathbf{0}, \mathbf{0}, \mathbf{0}, \mathbf{1})$ The polarized virtual gluon strength tensor $\boldsymbol{F_{ij}^{a}(x)}$ can be reformulated as an axially symmetric polarization tensor:

$$\boldsymbol{F_{ij}^{a}(x) = F_{ij}^{iso,a}(x) + \mathcal{A}^{a}(s_i x_j - s_j x_i)\psi(r)}$$

Where:

A^a represents the colour-charge amplitude of the aligned gluons
x_i is the spacetime coordinate vector
$\psi(r)$ is a radial function governing the unconfined kinematic potential decay away from the block.

The scalar density of the virtual gluon cloud, evaluated using the gauge-invariant trace, gains an angular dependence relative to the polarization axis θ (where $\cos\theta = z/r$):

$$\Phi_{gluon}(r,\theta) = K \cdot Tr(F_{ij}(x)F^{ij}) = \Phi_0(r)\left[1 + \lambda_{spin}\sin^2\theta\mathcal{X}(r)\right]$$

Where:

$\Phi_0(r) \propto M/r$ represents the unpolarized spherical background

λ_{spin} is the dimensionless polarization fraction of the gluon state

$X^{(r)}$ is a dimensionless structural function governing the spatial distribution of the spin-induced field

The 4D quantum weight operator $\widehat{W}(v)$ integrates this non-spherical field density over the localized spacetime volume cell V_v The resulting macroscopic eigenvalue $W(r,\theta)$ takes on the angular asymmetry:

$$W(r,\theta) = \int_{\mathcal{V}_v} d^4x\sqrt{-g}\hat{\rho}_K(r,\theta) = \mathcal{V}_0\frac{\sigma M}{r}\left[1 + \lambda_{spin}\sin^2\theta\mathcal{X}(r)\right]$$

When this anisotropic weight acts upon the spinfoam vertices directly above the polarized block, it forces a directionally dependent stretching of spacetime transitions. Cells aligned perpendicular to the spin vector ($\theta = \pi/2$) register a modified energy density compared to those along the polarization axis ($\theta = 0$).

To find the corresponding metric deformation, we substitute the anisotropic weight $W(r,\theta)$ back into the DLR time dilation scale factor:

$$\frac{\Delta\tau}{\Delta t} = (1 + \beta_{DLR}W(r,\theta))^{-1} = (1 + \frac{\beta_{DLR}\mathcal{V}_0\sigma M}{r}\left[1 + \lambda_{spin}\sin^2\theta\mathcal{X}(r)\right])^{-1}$$

Applying a first order Taylor expansion to the weak field limit gives the modified ration of proper time to coordinate time. Squaring this relation to remove the time metric, we arrive at:

$$\boldsymbol{g_{00}(r,\theta) \approx -(1 - \frac{2GM}{c^2 r}}\left[1 + \lambda_{spin}\sin^2\theta\mathcal{X}(r)\right]$$

Result: A clock positioned above the polarization pole $\boldsymbol{\theta=0}$ will run at the standard time, unaffected by the polarization. A clock positioned over the equator of the block of frozen hydrogen $\boldsymbol{\theta=\pi/2}$ will experience enhanced time dilation. Though counterintuitive when compared to standard axial field emissions, this equatorial enhancement is a consequence of the antisymmetric tensor structure $F_{ij} \propto (s_i x_j - s_j x_i)$. Because the position and polarization vectors are parallel at the pole, the spin-induced kinematic contribution vanishes, isolating the loop dilation entirely to the equatorial plane.

Conclusion: This paper presents Dilating Loop Relativity as a description of the physical mechanics of gravity within the boundries of General Relativity and quantum field theory. Using a mathematically rigorous formalism, DLR bridges the unconfined kinematic potential density of BCJ double copy theory operating on the spinfoam lattice of Loop Quantum Gravity.

DLR provides a clear explanation for gravitational time dilation; the accepted reason why things fall on any planet. Furthermore, the application of this theory to Black Holes and Dark Matter provides solutions to long-standing astrophysical paradoxes:

Black Hole Horizon Physics: The event horizon is redefined as a quantum phase transition by showing that spatial nodes dilate continuously down to a central maximum. The horizon behaves as a wavelength-dependent filter, explaining both the entrapment of short-wavelength matter fields and the escape of ultra-long wavelength Hawking radiation.

Dark Matter Cosmological Relics: Dark matter galaxies are shown to be caused by primordial energy-time uncertainty fluctuations that locked into the spinfoam canvas during cosmic freeze-out. This vacuum tension naturally flattens potential gradients at galactic centers, offering a purely geometric resolution to the astrophysical cuspy halo problem.

Empirical Verification: Unlike abstract quantum gravity models, DLR introduces a concrete, testable laboratory prediction. By polarizing the constituent gluon spins inside a block of frozen hydrogen, experimentalists can probe for an anisotropic equatorial proper-time dilation signature.

By unifying the gauge-invariant kinematics of the double copy with the discrete quantum geometry of spinfoams, DLR moves quantum gravity away from abstract geometry and brings it into the domain of verifiable, low-energy laboratory physics.

[1] Z. Bern, J. J. M. Carrasco, and H. Johansson, "Perturbative Quantum Gravity as a Double Copy of Gauge Theory," *Phys. Rev. D* **82**, 065003 (2010).

[2] C. Rovelli, *Quantum Gravity* (Cambridge University Press, Cambridge, 2004).

[3] T. Thiemann, *Modern Canonical Quantum General Relativity* (Cambridge University Press, Cambridge, 2007).

[4] A. Perez, "The Spin Foam Approach to Quantum Gravity," *Living Rev. Relativ.* **16**, 3 (2013).

[5] NewScientist, "General Relativity," New Scientist Physics Definitions, https://www.newscientist.com/definition/general-relativity/

[6] Wikipedia, "Quantum chromodynamics binding energy," Wikimedia Foundation, https://en.wikipedia.org/wiki/Quantum_chromodynamics_binding_energy

[7] Wikipedia, "Gravity Probe B," Wikimedia Foundation, https://en.wikipedia.org/wiki/Gravity_Probe_B

[8] D. Bini, C. Cherubini, C. Chicone, and B. Mashhoon, "Gravitational Induction," preprint arXiv:0803.0390v2 (2008)

[9] R. Duran *et al.* [Jefferson Lab Hall C Collaboration], "Determining the proton's gluonic gravitational form factors," *Nature* **615**, 813–816 (2023).

[10] Sci.News, "Physicists Determine Gluonic Gravitational Form Factors in a Proton," Science News Media, Feb 15, 2024.

[11] S. Joosten *et al.*, "Near-Threshold $J/\psi \rightarrow \mu+\mu-$ Photoproduction and the Gluonic Gravitational Form Factors of the Proton," preprint arXiv:2602.14416 (2026).

[12] Thomas Jefferson National Accelerator Facility, "Quarks and Mesons Network Research," Department of Energy, https://www.jlab.org/research/quark_meson

[13] Z.-E. Meziani and I. Zahed, "Experimental Access to the Gluonic Origin of Proton Mass," Argonne National Laboratory, preprint arXiv:2607.07969v1 (2026).

[14] M. Pezzelle, "The Classical Double Copy," Department of Physics, Arizona State University, Public Lecture Series, YouTube Video.

[15] C. D. White, "The double copy: gravity from gluons," *Contemp. Phys.* **59**(2), 109–125 (2018).

[16] Z. Bern, J. J. M. Carrasco, and H. Johansson, "Perturbative Quantum Gravity as a Double Copy of Gauge Theory," *Phys. Rev. D* **82**, 065003 (2010); preprint arXiv:1004.0476.

[17] Physics Stack Exchange, "What is the physical significance of the dilaton in string theory?" Quantum Mechanics & String Theory Forum, June 21, 2012.

[18] C. Rovelli, *Covariant Loop Quantum Gravity: An Elementary Introduction to Quantum Gravity and Spinfoam Theory* (Cambridge University Press, Cambridge, 2014).

[19] C. Rovelli, "On Quantum Gravity and Loop Space Cosmology," Interview by Sean Carroll, *Sean Carroll's Mindscape Podcast*, Episode 7, July 10, 2018.

[20] J. Baggott, *Quantum Space: Loop Quantum Gravity and the Search for the Structure of Space, Time, and the Universe* (Oxford University Press, Oxford, 2018), p. 171.

[21] I. Khavkine, R. Loll, and P. Reska, "Coupling a Point-Like Mass to Quantum Gravity with Causal Dynamical Triangulations," Spinoza Institute, Utrecht University, preprint arXiv:1002.4618v2 (2010).

[22] A. Ash, "Why is the speed of light what it is? Maxwell equations visualized," Physics Explanation Media, YouTube Video, https://www.youtube.com/watch?v=FSEJ4YLXtt8

[23] J. Cho, *Review of the Universe: Structures, Evolutions, Observations and Theories*, Quantum Foam Sector Architecture, http://universe-review.ca/R01-07-quantumfoam.htm

[24] D. Lincoln, "Loop Quantum Gravity," Fermilab Frontiers in Physics Lecture Series, YouTube Video, https://www.youtube.com/watch?v=QMpkFde3euA

[25] A. Ash, "String Theory versus Loop Quantum Gravity: The Cosmic Conflict," Theoretical Physics Documentation, YouTube Video.

[26] C. Rovelli, "Loop Quantum Gravity," *Living Rev. Relativ.* **11**, 5 (2008).

[27] L. Freidel, K. Krasnov, and E. R. Livine, "Holomorphic Factorization for a Quantum Tetrahedron," Perimeter Institute for Theoretical Physics, preprint arXiv:0905.3627 (2009).

[28] Wikipedia, "Hamiltonian constraint of LQG," Wikimedia Foundation, https://en.wikipedia.org/wiki/Hamiltonian_constraint_of_LQG

[29] A. Ashtekar and J. Lewandowski, "Quantum Theory of Geometry II: Volume operators," *Adv. Theor. Math. Phys.* 1, 388–429 (1997).

[30] C. Rovelli and L. Smolin, "Discreteness of area and volume in quantum gravity," *Nucl. Phys. B* 442, 593–619 (1995).

[31] K. S. Thorne, *The Science of Interstellar* (W. W. Norton & Company, New York, 2014), pp. 35, 291.

[32] I. I. Shapiro *et al.*, "Fourth Test of General Relativity: New Radar Results," *Phys. Rev. Lett.* **26**, 1132 (1971).

[33] B. Yirka, "Astrophysicist duo propose Planck star as core of black holes," Phys.org reporting on Rovelli-Vidotto framework, February 14, 2014.

[34] R. Gambini and J. Pullin, "Loop Quantization of the Schwarzschild Black Hole," *Phys. Rev. Lett.* **110**, 211301 (2013).

[35] Wikipedia, "Hawking Radiation," Wikimedia Foundation, wikipedia.org

[36] Y. Zhou, "Hydrodynamic Properties of the Primordial Quark-Gluon Plasma," Niels Bohr Institute, University of Copenhagen, as cited in Phys.org, May 21, 2021.

[37] J. Allday, *Quarks, Leptons and the Big Bang*, 3rd ed. (CRC Press, Taylor & Francis Group, Boca Raton, 2017), p. 68.

[38] G. S. Anand *et al.*, "The First RELHIC? Cloud-9 is a Starless Gas Cloud," *Astrophys. J. Lett.* **993**, L2 (2025).

[39] G. Cohen-Tannoudji and J.-P. Gazeau, "Dark matter as a QCD effect in an anti de Sitter geometry," *SciPost Phys. Proc.* **14**, 004 (2023); preprint hal-03925571.

[40] W. J. G. de Blok, "The Core-Cusp Problem," *Advances in Astrophysics* **2010**, 789293 (2010); preprint arXiv:0910.3538.

[41] Physics Stack Exchange, "What are we measuring in the quantum field when we square the wave function?" Quantum Mechanics Foundation Forum, June 30, 2020.

[42] T. Ohta *et al.*, "Monitoring the build-up of hydrogen polarization for polarized Hydrogen-Deuteride (HD) targets with NMR at 17 tesla," Research Center for Nuclear Physics (RCNP), Osaka University, Annual Report Research Brief (2018).

[43] S. D. Bass, "Spinning Gluons in the Proton," Marian Smoluchowski Institute of Physics, Jagiellonian University, Krakow, preprint arXiv:1703.01815 (2017).

[44] D. de Florian, R. Sassot, M. Stratmann, and W. Vogelsang, "Evidence for Polarization of Gluons in the Proton," *Phys. Rev. Lett.* **113**, 012001 (2014).

[45] N. M. Hunt-Smith *et al.* [JAM Collaboration], "New Data Driven Constraints on the Sign of Gluon Polarization in the Proton," *Phys. Rev. Lett.* **133**, 162001 (2024).