The Big Start: Cosmogenesis from a Finite Planck-Phase Boundary

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Abstract
The standard Big Bang picture assumes that spacetime already exists at the moment of origin and is driven to a singular state of infinite curvature and infinite density. The Curvature Transport Correspondence (CTC) offers a different beginning in which the vacuum is a physical medium with stiffness that controls whether curvature or fields can exist at all. This leads to the Big Start, a finite radius Planck phase vacuum state where gravitational transport is saturated and no geometric degrees of freedom are present. This state is a pre geometric and zero entropy vacuum, directly realizing the insight of Sir Roger Penrose that the Universe must begin in an exceptionally ordered condition. As expansion relaxes vacuum stiffness, the layers of physics appear in sequence: curvature mobility at r_G, transverse and quantum modes at r_T, Higgs condensation and the appearance of mass at r_H, and finally a classical FRW spacetime at r_S. Cosmogenesis and gravitational collapse follow the same divergence law in opposite directions, and the Big Start replaces the classical singularity with a natural vacuum phase transition in which spacetime, gravity, quantum behavior, and mass appear only when the vacuum becomes soft enough to support them

1. Introduction

Classical general relativity allows the Universe to begin from zero volume and infinite curvature, but such a continuation contradicts the physical limits of the vacuum. In a transport-based formulation of curvature, introduced in the first paper on CTC [1], the curvature of any field $X$is generated by the divergence of an associated transport flux F_X^μ:

$$C[X] = \nabla_\mu F_X^\mu. \qquad (1)$$

When applied to gravity, this general relation yields the effective curvature source

$$\rho_{\text{eff}} = \nabla_\mu F_G^\mu, \qquad (2)$$

identifying gravitational curvature as the vacuum's response to transport imbalance rather than the product of intrinsic material density.

In the second paper of CTC[2], we showed that the vacuum possesses a finite, phase-dependent stiffness that limits how much curvature it can support. This leads to the saturation principle

$$|\nabla_\mu F_G^\mu| \leq D_{\text{Pl}}, \qquad (3)$$

which imposes a maximum admissible flux divergence. This bound prevents curvature from diverging and therefore forbids singularities. Instead of collapsing to a point, the vacuum reaches a saturation radius, a finite region in which curvature attains its upper limit and cannot increase further. The same saturation mechanism also produces dark-matter–like phenomena, resolves the hierarchy problem, and eliminates singularities inside black holes.

In this third paper of CTC, we apply this framework to the origin of the Universe. We demonstrate that the Big Bang singularity is replaced by a finite-radius Planck-phase bubble, a saturated region in which curvature reaches its allowable maximum. Cosmogenesis therefore begins not from a point of infinite curvature, but from the boundary of this finite Planck-phase domain. We will also examine the ontology of black-hole interiors and show how the same saturation principle links the structure of a black-hole core to the origin of the Universe. For clarity, we note that the CTC cosmogenesis mechanism differs fundamentally from the standard Big Bang with inflation [3], [4], [5], [6], [7] as well as from other nonsingular proposals[8], [9], [10], [11], [12], [13], [14] [15], [16]. Among the many ideas proposed to address the origin of the Universe, two frameworks are especially relevant for comparison because they touch on similar questions of initial simplicity and the replacement of the singularity. The first is Penrose's Conformal Cyclic Cosmology[17], [18], which seeks to achieve a low entropy beginning through conformal identification between successive aeons. CTC shares the motivation for an initially simple state but obtains it through a physical mechanism: the early vacuum is a perfectly rigid phase with no degrees of freedom (DOF), and cosmogenesis begins when its stiffness relaxes, with no role for conformal matching. The second is the class of finite radius black hole core cosmogenesis models[19], [20], in which the singularity is replaced by a finite domain that births a new cosmological region. Although both approaches replace the singularity with a finite radius structure, the underlying physics is entirely different. In CTC, the finite radius arises from saturation of curvature transport in a degree of freedom free vacuum, not from black hole interior dynamics or quantum gravitational effects.

2. The Divergence Law and Vacuum Saturation

CTC reinterprets gravitational curvature not as a direct response to "mass," but as the vacuum's transport reaction to flux loading. In this formulation, curvature is present only to the extent that the effective density

$$\rho_{\rm eff} = \nabla_\mu F_G^\mu$$

is nonzero. However, the vacuum cannot transmit arbitrarily large curvature. Just as real materials cannot sustain unlimited stress or strain, the vacuum possesses a finite curvature-carrying capacity characterized by a universal bound:

$$| \nabla_\mu F_G^\mu | \leq D_{\rm Pl}.$$

When the divergence of the gravitational flux approaches this limit, the vacuum enters a **s**aturated regime in which its normal dynamical degrees of freedom (DOF) cannot operate.

In this Planck phase:

- curvature cannot increase beyond the saturated value,
- gravitational propagation shuts down,
- transverse gauge modes cannot exist,
- the Higgs condensate cannot form,
- mass and gauge interactions lose meaning, and
- quantum fluctuations are suppressed, since oscillatory modes require finite vacuum stiffness.

From this perspective, there are potentially two extreme gravitational situations which drive the vacuum into this saturated state:

1. **Black-hole collapse**, where the inward flux loading yields

$$\nabla_\mu F_G^\mu \to -D_{\mathrm{Pl}},$$

2. **Cosmogenesis**, where the primordial vacuum begins fully outward-loaded at

$$\nabla_\mu F_G^\mu = +D_{\mathrm{Pl}}.$$

The same divergence law governs both phenomena, differing only in the direction of flux loading. Let us examine these two cases in the following section.

3. Saturation in Black Holes and Cosmogenesis

Although black holes and the birth of the Universe appear to represent opposite gravitational extremes, CTC reveals that they are controlled by a single underlying mechanism: vacuum saturation under flux divergence, with opposite signs of loading determining the physical outcome.
Black holes reach saturation through inward compression; cosmogenesis begins from a fully outward-loaded saturated state.

3.1. Back Holes: Inward Loading to Saturation

During gravitational collapse, the inward gravitational transport flux intensifies and the divergence $\nabla_\mu F_G^\mu$ becomes increasingly negative. In the CTC framework, curvature cannot grow without bound. As shown in the second CTC paper[2], the transport field reaches a universal saturation limit $K_{\max}$, defined by

$$K(r_s) = K_{\max},$$

with the interior curvature profile

$$K(r) = \frac{48G^2\, m(r)^2}{c^4 r^6}.$$

Solving (3–23) yields

$$r_s^3 \sim \sqrt{\frac{48G^2 m(r_s)^2}{c^4 K_{\max}}} \Longrightarrow r_s \propto M^{1/3}.$$

This is the general result from the second CTC paper[2]: once the saturation limit is reached, the curvature no longer increases and additional mass enlarges the volume of the saturated region rather than deepening the collapse.

Planck Phase Interpretation

In the present work, we further identify the saturation value $K_{\max}$ with the *Planck curvature scale,*

$$K_{\max} = K_{\mathrm{Pl}} \sim \frac{1}{\ell_{\mathrm{Pl}}^4},$$

so that the saturated region corresponds to a Planck-phase vacuum. Because K_{Pl} is extraordinarily large, the radius r_s obtained by substituting K_{Pl} into the r_s^3 formula is extremely small. For stellar-mass black holes this yields radii on the order of

$$r_s \sim 10^{-23}\text{–}10^{-25}\ \mathrm{m},$$
many orders of magnitude smaller than both the Schwarzschild radius and any physical length scale relevant to astrophysical collapse. Thus, even though the scaling $r_s \propto M^{1/3}$ remains valid, the absolute size of the saturated region is *microscopic* whenever $K_{\max}$ is identified with the Planck scale.

Physical Implications

Because the corresponding radius is so small, ordinary stellar or supermassive black holes *do not come close to reaching the saturation boundary*. Their interior curvature remains many tens of orders of magnitude below K_{Pl}. Therefore, a Planck-phase core forms only *if collapse drives the transport divergence so far inward that it reaches the theoretical limit K_{Pl}*. In realistic astrophysical environments this never occurs.

That said, if saturation were actually reached, the *interior* would enter a rigidity-dominated Planck phase in which:

- curvature is fixed at K_{Pl},
- gravitational transport ceases,
- the Higgs mechanism and the concept of mass are undefined,
- gauge fields cannot propagate, and
- quantum oscillatory modes are suppressed.

General relativity remains valid only outside this microscopic, saturated region meaning that in realistic astrophysical collapse, the transport field never approaches this saturation limit, so the Planck-phase boundary is never reached. The interior vacuum therefore remains in the ordinary, dynamical phase, and gravity remains fully active throughout the black-hole interior except at the classical singularity predicted by general relativity.

3.2 Cosmogenesis: Outward Loading at Saturation

In contrast to black holes, where inward transport loading must climb toward saturation, the early Universe begins *already* at the saturation boundary. The primordial vacuum is fully outward-loaded, such that
$$\nabla_\mu F_G^\mu = +D_{\mathrm{Pl}},$$

is the positive extremum of the divergence law. In this regime the vacuum occupies its rigidity-dominated Planck phase from the outset. Unlike gravitational collapse, which never attains this limit in practice, cosmogenesis *starts* precisely where the transport field is saturated. Because the total effective flux load of the Universe is enormous,
$$M_U \sim 10^{53}\ \mathrm{kg},$$

a value consistent with standard cosmological estimates [7], [21], [22], the corresponding saturated radius is *not microscopic but macroscopic*. Substituting this mass into the saturation relation [2]:

$$r_{\mathrm{birth}}^3 \sim \sqrt{\frac{48\,G^2\,M_U^2}{c^4\,K_{\max}}}, \Rightarrow r_{\mathrm{birth}} \propto M_U^{1/3}$$

and identifying the saturation curvature with the Planck value $K_{\max} = K_{\mathrm{Pl}}$, yields

$$r_{\mathrm{birth}} \sim 10^{-6} - 10^{-4}\ \mathrm{m} = 1\mu\mathrm{m} - 100\ \mu\mathrm{m},$$

a finite physical scale at which the early vacuum can support the total outward flux load while remaining at the saturation curvature $K_{\max}$. This radius is neither zero nor arbitrarily small: it is exactly the size required for a fully saturated Planck-phase vacuum containing the entire cosmic flux content for a given mass. This leads to a contrasting structural picture:

- **Black holes** attempt to reach saturation through inward collapse but *never* attain it in practice; if they did, their saturated radii would be microscopic.
- **The Universe**, by contrast, begins *already* at saturation, with a macroscopic radius r_{birth} determined directly by its total flux load.

As expansion proceeds and the *vacuum softens*, the Planck-phase boundary recedes, the transport field becomes *unsaturated*, and familiar field-theoretic degrees of freedom, including *mass, gauge fields, and quantum fluctuations gradually emerge*. Cosmogenesis is therefore the *outward evolution of an initially saturated Planck-phase core* into a progressively softer vacuum capable of supporting the physics we observe today.

3.3. The Big Start: A Finite-Radius Planck-Phase Beginning

In the CTC picture, the Universe *does not begin at a singularity*. It begins as a finite spherical region of fully saturated, Planck-phase vacuum. In this state:

- gravity *cannot propagate*,
- electromagnetism *does not exist*,
- quantum fluctuations *are absent*,
- the Higgs field *is uncondensed*,
- matter and radiation *cannot form*.

Physics, as we know it, has not yet begun. Cosmogenesis starts only when the saturated *vacuum softens* and the divergence of the transport flux drops below the bound,

$$| \nabla_\mu F_G^\mu | < D_{\mathrm{Pl}}.$$

This transition is *not explosive*. It is a transport-driven *unjamming* of an extremely stiff, or vacuum relaxation that gradually restores propagating degrees of freedom (DOF) and allows the Universe to enter the dynamical phase described by physics.

4. Phase-Ordered Cosmogenesis: The Sequence of Emergence

As the Universe expands from its saturated beginning, the vacuum softens in distinct steps. Each softness threshold corresponds to a characteristic radius at which a new class of physical degrees of freedom becomes possible:

$$r_{\mathrm{birth}} < r_G < r_T < r_H < r_S.$$

These radii reflect the order in which the vacuum becomes capable of supporting curvature, waves, quantum behavior, mass, and finally causal cosmological evolution.

4.1. $r_{\mathbf{birth}}$ — End of Saturation (No Modes Exist)

For radii smaller than r_{birth}, the vacuum remains in its Planck phase. This phase is defined by complete saturation of the transport flux, expressed by

$$|\nabla \cdot F_G| = D_{Pl}.$$

This condition forces the curvature transport field F_G to maintain its maximal divergence everywhere within the region. A saturated flux cannot support spatial variation. As a result, no curvature degrees of freedom are available. The vacuum in this regime behaves as an ideal medium of infinite rigidity, unable to deform in any direction. The stiffness tensor in this phase is effectively

$$K_{ij}(r < r_{Pl}) = \infty\, \delta_{ij},$$

and any attempt to introduce a displacement field u_i leads to an unbounded energetic penalty. The Lagrangian density

$$L_{Pl} = \frac{1}{2}\rho(\partial_t u_i)^2 - \frac{1}{2}K_{ij}(\nabla u_i)(\nabla u_j),$$

becomes *ill defined* in the limit $K_{ij} \to \infty$. The medium can neither support gradients nor allow finite strain. In this saturated phase:

- no displacements can occur,
- no gradients can form,
- no oscillations are possible,
- no waves can propagate,
- no dynamical fields exist.

The Planck phase therefore represents a state in which *spacetime has no internal degrees of freedom and no capacity to host physical modes of any kind*.

4.2 r_G: Emergence of Gravity Through Longitudinal Mobility

After the radius grows beyond $\boldsymbol{r}_{\mathbf{Pl}}$, the vacuum leaves the fully saturated Planck phase. The divergence bound remains in force,

$$|\nabla \cdot F_G| \leq D_{Pl},$$

but saturation no longer holds. The stiffness tensor begins to relax from its infinite value,

$$K_{ij}(r > r_{Pl}) < \infty,$$

giving the vacuum a *small, nonzero capacity for deformation*. This relaxation is anisotropic: the radial direction *softens first* while the *angular directions remain locked*. This directional asymmetry sets the stage for the first dynamical mode. The radius r_G thus marks the moment when this partial relaxation becomes strong enough to permit radial motion. Only the longitudinal component of the displacement field

$$u_i = (u_r, u_\theta, u_\phi)$$

is released, while *the tangential components remain fixed*. The vacuum therefore acquires exactly one mechanical degree of freedom (DOF). The stiffness tensor in this interval takes the form

$$K_{ij}(r_G < r < r_T) = \text{diag}(K_L, 0, 0),$$

with a finite longitudinal modulus $K_L > 0$ and vanishing angular terms. The corresponding Lagrangian density is thus:

$$\mathcal{L}_{<r_T} = \frac{1}{2}\rho(\partial_t u_r)^2 - \frac{1}{2}K_L(\nabla u_r)^2,$$

and contains no terms involving u_θ or u_ϕ. Because the vacuum has no transverse restoring force, the angular components *cannot support oscillatory behavior*. The only propagating distortion is longitudinal compression of the radial field, corresponding to curvature transport but not to a wave-supporting medium. This regime is therefore characterized by:

- a single dynamical direction,
- no transverse modes,
- *no harmonic oscillators,*
- *no possibility of quantization.*

The field supports curvature response but cannot sustain electromagnetic or quantum-mechanical phenomena. *Gravity in this domain is strictly longitudinal*: curvature can be redistributed, but not in a form that admits a spectral decomposition or wave propagation.

4.3. r_T: Emergence of Electromagnetism and the Onset of Quantum Fluctuations

At the radius $r_T$the vacuum undergoes a key change: it develops transverse stiffness. This means the vacuum can now support shear-like motion in the two angular directions. The stiffness tensor becomes

$$K_{ij}(r > r_T) = \text{diag}(K_L, K_T, K_T), K_T > 0.$$

Once $K_T$appears, the transverse components of the displacement field

$$u_\perp = (u_\theta, u_\phi)$$

become dynamical. Their Lagrangian has a kinetic term and an elastic term:

$$L_\perp = \frac{1}{2}\rho\,(\partial_t u_\perp)^2 - \frac{1}{2}K_T(\nabla_{S^2} u_\perp)^2,$$

where $\nabla_{S^2}$is the covariant gradient on the sphere.
The first term describes time-varying motion; the second describes angular shear.
Varying this action gives the transverse wave equation:

$$\rho\ \partial_t^2 u_\perp - K_T\,\Delta_{S^2} u_\perp = 0.$$

Because $u_\perp$has two components, it cannot be expanded using scalar spherical harmonics alone. The correct basis is the set of vector spherical harmonics, which provide a complete basis for any vector field on a sphere (see Jackson *Classical Electrodynamics*[23]; Arfken & Weber[24]; or Hobson–Efstathiou–Lasenby[25]).

We write:

$$u_\perp(\theta,\phi,t) = \sum_{l,m,p} q_{lm}^{(p)}(t)\, Y_{lm}^{(p)}(\theta,\phi), p = 1,2,$$

where

- $p = 1$gives the divergence-free (toroidal) family,
- $p = 2$gives the curl-free (poloidal) family.

Each vector spherical harmonic satisfies

$$\Delta_{S^2} Y_{lm}^{(p)} = -l(l+1) Y_{lm}^{(p)}.$$

Substituting into the wave equation shows that every coefficient obeys an independent harmonic-oscillator equation:

$$\ddot{q}_{lm}^{(p)} + \omega_l^2\, q_{lm}^{(p)} = 0, \omega_l^2 = \frac{K_T}{\rho}\, l(l+1).$$

Thus the vacuum at $r_T$supports an entire spectrum of transverse oscillatory modes. These are the mechanical precursors of electromagnetic waves and the first genuine quantum fluctuations.

For each mode, the reduced Lagrangian is simply

$$L_{lm}^{(p)} = \frac{1}{2}\left[\dot{q}_{lm}^{(p)\,2} - \omega_l^2 q_{lm}^{(p)\,2}\right],$$

with canonical momentum

$$\pi_{lm}^{(p)} = \dot{q}_{lm}^{(p)}.$$

Quantization follows in the usual way:

$$[q_{lm}^{(p)}, \pi_{l'm'}^{(p')}] = i\hbar\, \delta_{ll'} \delta_{mm'} \delta_{pp'}.$$

Defining creation and annihilation operators gives the standard oscillator Hamiltonian:

$$H = \sum_{l,m,p} \hbar\, \omega_l \left(a_{lm}^{(p)\dagger} a_{lm}^{(p)} + \frac{1}{2}\right).$$

This is the first radius at which photons, zero-point motion, and vacuum fluctuations exist. Quantization is therefore not added by hand—it appears automatically when the vacuum becomes mechanically able to support transverse oscillatory modes. With these degrees of freedom now present (Figure 1), the Higgs field becomes a well-defined quantum field, even though the vacuum is still in the symmetric electroweak phase and $\langle H \rangle = 0$.

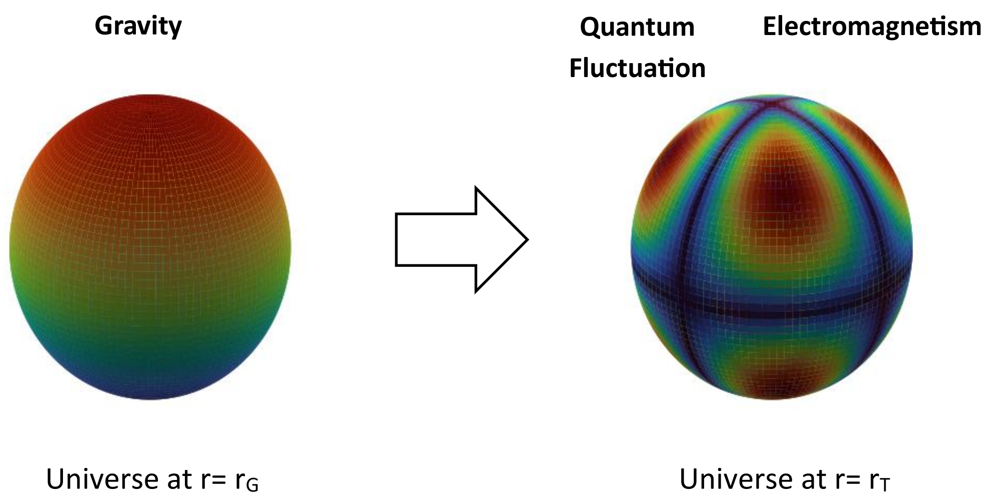

Figure 1 Transition from the r_G to the r_T threshold in the CTC emergence sequence. At radius r_G, the vacuum possesses longitudinal stiffness only, permitting scalar curvature transport but no transverse or oscillatory modes. At radius r_T, the vacuum acquires transverse stiffness, enabling the first quantum fluctuations and the emergence of electromagnetic degrees of freedom. The structured pattern on the right sphere represents one of the allowed transverse spherical modes.

4.4 r_H: Birth of Mass (Higgs Condensation)

The radius r_H marks the transition from the electroweak-symmetric phase to the broken phase in which the Higgs field acquires a nonzero vacuum expectation value. For all $r_T < r < r_H$, the Higgs exists as a quantum scalar with a symmetric potential and

$$\langle H \rangle = 0.$$

At $r = r_H$, the Higgs condenses and

$$\langle H \rangle = v \neq 0,$$

giving mass to fermions and gauge bosons through the usual Standard Model mechanism. This marks the first radius at which massive degrees of freedom can exist. Before r_H, all excitations are massless despite the presence of photons and quantum fluctuations introduced at r_T.

4.5 r_S: Classical Causality and the Start of FRW Cosmology

The radius r_S is reached only when gravity, quantum fields, and mass are all active simultaneously. Only beyond this point does the vacuum support a classical spacetime with meaningful light cones, timelike worldlines, and a well-defined stress–energy tensor. Thus r_S marks the beginning of the FRW causal regime. For $r > r_S$, spacetime is described by the standard Einstein–FRW equations and the Universe enters its familiar radiation-, matter-, and dark-energy–dominated eras. For $r < r_S$, the necessary degrees of freedom for classical cosmology do not yet exist, and the FRW picture cannot be applied.

4.6. r_Λ: Residual Flux and the Emergence of Dark Energy

After the Universe has passed the sequence

$$r_{\mathrm{Pl}} < r_G < r_T < r_H < r_S,$$

every known degree of freedom capable of transporting curvature has become active.

- At r_G, longitudinal curvature can move.
- At r_T, transverse modes, photons, and quantum fluctuations appear.
- At r_H, the Higgs field gives mass to particles.
- At r_S, a classical causal spacetime becomes possible.

Beyond these thresholds, the divergence of the curvature-transport flux can be written as

$$\nabla \cdot F_G = \rho_{\text{matter}} + \rho_{\text{rad}} + \rho_{\text{mass}} + \rho_\Lambda.$$

The final term, ρ_Λ, is the **residual part** of the flux divergence—the portion that **cannot** be carried, screened, or redistributed by any existing mode. It does not propagate, does not fluctuate, and does not interact with fields. Its effect is purely geometric. Einstein's equations therefore take the form

$$G_{\mu\nu} = 8\pi G\, \rho_\Lambda\, g_{\mu\nu},$$

or equivalently:

$$R_{\mu\nu} = R_\Lambda\, g_{\mu\nu}, R_\Lambda = 8\pi G\, \rho_\Lambda, \text{(Ricci curvature generated by the residual flux)}$$

which describes a constant-curvature spacetime with characteristic scale

$$L_\Lambda = R_\Lambda^{-1/2}.$$

Thus dark energy is not a new substance or a vacuum fluid.It is the geometric remainder left after all transport-capable degrees of freedom have drained the curvature-transport flux. This picture explains the observed properties of dark energy:

- Homogeneous**:** no field exists that could carry gradients of ρ_Λ.
- Constant in time**:** no dynamical channel can relax or modify it.
- Small in magnitude**:** almost all initial flux divergence has already been absorbed by matter, radiation, and massive fields before $r_\Lambda$is reached.

In the CTC framework, **dark energy** is simply the **final state of curvature transport**, a uniform mode-free background that sets the late-time geometry of the Universe. Thus, dark energy does not pull the Universe apart. It is simply the leftover geometric divergence that remains after all transportable curvature has been drained. As matter thins out, this constant residual curvature becomes the dominant geometric term in the Friedmann equations, and the scale factor accelerates. No force or pulling mechanism is involved; the expansion accelerates because the geometry requires it.

Placement in the emergence hierarchy

Radius	Transition	Vacuum Status
$\boldsymbol{r_{\mathrm{Pl}}}$	no DOF	saturated, stiff
$\boldsymbol{r_G}$	longitudinal	gravity appears
$\boldsymbol{r_T}$	transverse	EM + quantum modes
$\boldsymbol{r_H}$	Higgs VEV	mass generation
$\boldsymbol{r_S}$	causal structure	FRW dynamics
$\boldsymbol{r_\Lambda}$	no new DOF	residual flux fixes curvature

The radius r_Λ represents the moment when the Universe's asymptotic geometry becomes determined by the final, unscreenable remainder of $\nabla \cdot F_G$. Beyond this point the expansion is governed by the characteristic length L_Λ, giving the late-time Universe its transport-derived de Sitter form.

4.8. Why the Standard Dark-Energy Estimate Is Overestimated (CTC View)

The usual claim that "dark energy should be 10^{120} times larger" comes from adding up the zero-point energies of all quantum field modes. But this assumes that the early Universe already had quantum oscillators. In CTC this is not true. Before the vacuum reaches $r_T$and r_H, there are no transverse modes, no mass modes, and no quantum fluctuations at all. A vacuum with no degrees of freedom cannot have zero-point energy. The standard calculation is therefore adding energy from oscillators that do not yet exist. In CTC the only quantity that contributes to large-scale curvature is the residual part of the gravitational transport flux that *cannot be moved or screened by any physical mode*. This leftover piece,

$$\rho_\Lambda = (\nabla F_G)_{\text{res}},$$

is naturally small because almost all of the flux has already been drained by the time all degrees of freedom become active. Thus, dark energy in CTC is not vacuum zero-point energy. It is a small geometric remainder that survives after the emergence of gravity, photons, and mass. No fine-tuning is needed, and the "10^{120}" problem does not arise.

4.9 Why Gravity Does Not Quantize in the CTC Framework

The stiffness hierarchy introduced in Sections 4.1–4.7 provides a natural explanation for why gravity, unlike electromagnetism and matter fields, does not possess a quantum excitation spectrum.
The key observation is that the activation of dynamical degrees of freedom proceeds asymmetrically: the vacuum gains longitudinal mobility at $r_G$and transverse mobility only at r_T, and these two modes do not play symmetric roles in curvature transport.

(1) Gravity emerges from longitudinal stiffness only

At $r_G$the vacuum first acquires longitudinal deformability:

$$K_{ij}(r_G) = \mathrm{diag}(K_L, 0, 0),$$

enabling radial curvature transport and the propagation of classical gravitational disturbances.
This produces a well-defined wave equation for metric perturbations but only through longitudinal motion of the underlying vacuum structure.
Because transverse degrees of freedom are still absent at this stage, the gravitational sector has:
no shear modes, no oscillatory basis, no harmonic mode spectrum, no creation/annihilation operators.
Thus, gravity supports wave propagation but not quantization.

(2) Quantization requires transverse oscillator modes

The transverse stiffness activated at r_T,

$$K_T > 0,$$

is what enables: electromagnetic fields, quantum fluctuations, harmonic oscillators, vacuum mode expansions, creation and annihilation operators. Quantization arises from the existence of vibrational modes of the form:

$$u(t,x) \sim e^{-i\omega t} e^{ikx},$$

which require a transverse mode structure. This is why photons, electrons, quarks, and scalar fields become quantized at r_T, but **gravity does not.** Gravity remains confined to its longitudinal channel, which cannot support oscillator modes.

(3) No stage of the emergence sequence introduces transverse gravitational DOFs
The radius sequence:

$$r_{\mathrm{Pl}} \longrightarrow r_G \longrightarrow r_T \longrightarrow r_H \longrightarrow r_S \longrightarrow r_\Lambda$$

activates the DOFs in the following order:

Radius	New DOF	Gravity quantized?
$\boldsymbol{r_{\mathrm{Pl}}}$	none	no
$\boldsymbol{r_G}$	longitudinal only	no
$\boldsymbol{r_T}$	transverse (EM + quantum)	still no
$\boldsymbol{r_H}$	mass	no
$\boldsymbol{r_S}$	classical causal structure	no
$\boldsymbol{r_\Lambda}$	residual flux regime	no

At no point does the vacuum acquire transverse gravitational modes. Thus the essential ingredient for quantization is never supplied. Gravity therefore remains a classical field throughout cosmic history.

(4) Classical gravitational waves are allowed and expected. Since gravity has a longitudinal transport channel, curvature disturbances propagate:

$$\Box h_{\mu\nu} = 0,$$

exactly as in general relativity. These waves: carry energy, travel at the speed of light, interact weakly with matter, exhibit quadrupolar patterns. However, because they are generated from non-oscillatory vacuum mechanics, their amplitude does not correspond to discrete quanta. There are no gravitons, only classical waveforms. Gravity is not quantized in this framework because the vacuum never acquires transverse gravitational degrees of freedom. It retains only classical wave propagation through longitudinal curvature transport. Thus gravity is inherently classical even in a Universe where all other fields are quantum.

5. Compatibility with Planck Observations
Although the Planck satellite probes the Universe long after the radii $r_{\mathrm{Pl}}, r_G, r_T, r_H, r_S$ have been crossed, several well-established Planck features follow directly from the CTC emergence sequence. Because transverse oscillatory modes do not exist before the vacuum reaches r_T, the primordial spectrum possesses a hard lower cutoff $k_{\mathrm{min}} = 1/r_T$. This immediately produces the observed suppression of large-angle correlations ($\ell \lesssim 20$, $\theta \gtrsim 60°$) and the absence of long-wavelength power in the CMB.

Between r_G and r_T, vacuum stiffness decreases monotonically, which fixes the shape of the scalar spectrum. This softening yields a red tilt with mild negative running, consistent with Planck's measured values of n_s and α_s, without the slow-roll assumptions required in inflationary ΛCDM. In addition, transverse gravitational modes do not exist prior to r_G, so the primordial tensor spectrum vanishes at its origin. This naturally accounts for the stringent upper bound on the tensor-to-scalar ratio r reported by BICEP/Keck and Planck, without fine-tuning.

Taken together, these signatures—large-angle suppression, red tilt with negative running, absence of trans-Planckian features, and non-detection of primordial tensors—are not separate phenomena in CTC.

They arise from a single structural fact: the vacuum acquires different dynamical degrees of freedom only after passing specific radii. Planck observations are therefore fully compatible with a finite-radius, phase-ordered cosmogenesis. All three underlying CTC results are discussed in the Supplement Materials.

6. CTC and the Question of Inflation

Inflation assumes that a preinflationary quantum vacuum already exists and can support oscillatory field modes. In CTC, this is impossible: before the radius r_T, the vacuum has **no transverse stiffness**, so electromagnetic fields, wave propagation, and quantum fluctuations cannot exist. The early Universe is therefore exactly smooth because **no degrees of freedom were present to generate inhomogeneity**, not because smoothness had to be dynamically restored.

When transverse stiffness appears at r_T, photons and quantum fluctuations arise for the first time. The resulting primordial cutoff

$$k_{\min} = 1/r_T$$

naturally produces the observed suppression of large-angle CMB power, without inflationary potentials or trans-Planckian assumptions. CTC therefore removes the original motivation for inflation, although an inflationary phase after $r_T$is not excluded.

CTC is distinct from other non-singular models because no propagating fields exist at all prior to r_T. The finite initial radius follows from a transport-saturation principle governing the divergence of the gravitational flux, giving CTC a unique conceptual structure and observational signature.

7. Temperature and Entropy in a DOF-Free Vacuum

In the saturated regime $r < r_G$, the vacuum possesses no internal degrees of freedom.
Neither longitudinal nor transverse modes exist, and the displacement field has no configurational variation. *Because temperature requires an ensemble of accessible microstates and entropy requires a count of distinct configurations, both thermodynamic quantities are undefined in this phase.*
Formally,

$$S = k_B \ln\ \Omega,$$

but for a vacuum with no DOF,

$$\Omega = 1 \Rightarrow S = 0.$$

Likewise, temperature satisfies

$$T^{-1} = \frac{\partial S}{\partial E},$$

but when the entropy is identically zero and does not vary with energy, the derivative is meaningless. The concept of temperature therefore does not exist in a DOF-free vacuum. This is not a state of infinite temperature nor absolute zero, but a pre-thermodynamic phase in which *statistical mechanics has no degrees of freedom on which to operate.*

As the vacuum softens at r_G, longitudinal transport becomes possible, allowing curvature variations and classical gravitational waves. Still, no transverse modes exist, and thermodynamic quantities remain undefined. Only at the transverse-softening transition $r_T$do oscillator modes appear, enabling:

- quantum fluctuations,
- photons and radiation,
- thermal ensembles,
- the emergence of both temperature and entropy.

Thus, the hot, high-entropy state identified with the Big Bang arises *after* the activation of DOFs, not before. The early Universe, we named it as "The Big Start" is not an infinitely hot singularity but a mechanically rigid vacuum that transitions into a thermodynamic system as its stiffness relaxes.

This conclusion aligns with an insight emphasized by **Sir Roger Penrose**. In the Weyl Curvature Hypothesis, Penrose argued that the Universe began in a highly ordered, extremely low-entropy state characterized by vanishing Weyl curvature. His proposal identified the *pattern* but not the mechanism. In CTC, the mechanism follows directly from the stiffness-regulated structure of the vacuum: when no degrees of freedom exist, the system is confined to a single configuration with zero entropy and no curvature structure. Penrose anticipated the outcome; CTC provides a physically distinct route to the same thermodynamic starting point, without invoking conformal matching between aeons.

8. Perspective from a Materials Scientist

My approach to CTC grew naturally from a materials-science way of thinking. In materials science, structure and behavior do not appear automatically; they emerge only when the underlying medium develops the mechanical ability to support them. Waves require stiffness, flows require mobility, and new phases arise only when the material itself evolves.

Seen through this lens, the early Universe need not begin with fully active physics. In CTC the vacuum starts as a completely rigid phase with no degrees of freedom and no ability to curve or oscillate. As the vacuum softens, new capacities appear in sequence: first longitudinal curvature transport (gravity), then transverse oscillators (photons and quantum fluctuations), then mass through the Higgs transition, and finally a fully causal spacetime. The Universe we observe is therefore the product of a **mechanical evolution of the vacuum**, not the aftermath of a singular explosion.

What we call spacetime is simply the vacuum in a later, softer phase. What we call matter and energy arise only after the vacuum can sustain them. And what we call dark energy is the small residual part of the flux that remains after this sequence of emergent freedoms is complete.

This materials-science intuition provides a coherent picture in which spacetime, fields, particles, and dark energy all arise from the same underlying process: the gradual ability of the vacuum to support more structure as it expands and relaxes.

9. Summary

The Big Start replaces the unphysical Big Bang singularity with a finite Planck-phase boundary dictated by the saturation of the divergence law. As the vacuum relaxes from this bound, curvature mobility, electromagnetic oscillations, quantum behavior, and mass appear sequentially as the Universe expands.

Cosmic birth and black-hole interiors are shown to be two expressions of the same underlying vacuum mechanics, differentiated only by flux direction. This unified picture resolves singularities, explains the emergence order of forces and matter, removes contradictions in early-Universe quantum assumptions, and embeds cosmogenesis firmly within the physical response structure of the vacuum.

In the Curvature–Transport Correspondence (CTC) framework, the origin of the Universe is not described by a singular "explosion," nor by the sudden appearance of particles or fields. Instead, the central dynamical object is the **vacuum's mechanical stiffness** and its associated **transport capacity** for curvature.

The early vacuum begins in a perfectly rigid state in which no degrees of freedom of any kind exist. As the cosmic radius increases, the vacuum gradually softens in a sequence of sharply defined transitions. Each transition activates a new class of dynamical modes, creating the appearance of new "forces," "particles," or "fields" — but these are simply successive stages in the vacuum's ability to deform.

This provides a unified mechanical picture:

- Gravity emerges when the vacuum first acquires longitudinal mobility.
- Electromagnetism and quantum fields arise when transverse mobility becomes possible.
- Mass appears only when the vacuum's internal potential becomes unstable, triggering Higgs condensation.
- Causal spacetime emerges only after curvature, waves, and massive excitations coexist.
- Dark energy is the remaining stiffness of the vacuum that cannot be transported or dissipated by any dynamical mode.

Thus, the entire history of the Universe is recast as a softening curve of the vacuum, with each physical phenomenon corresponding to the appearance of a new mechanical degree of freedom. This provides a single, consistent, non-singular cosmogenesis that naturally explains the emergence of fields, forces, mass, quantum mechanics, and late-time acceleration.

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This manuscript is dedicated to the honor of **Sir Roger Penrose,** whose profound insight into the low entropy beginning of the Universe continues to inspire. Although the approach developed here follows a different path, it offers a physical mechanism that speaks to themes he has long explored. His vision remains a guiding influence, and this work is offered with sincere respect.

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Supplement Materials: Three Fundamental CTC Results and Their Planck Signatures

The Curvature–Transport Correspondence links the mechanical response of the vacuum to the structure of primordial perturbations. The divergence law governing curvature transport determines which modes can exist, how they evolve, and which components of curvature become active as the vacuum crosses the thresholds $r_{\mathrm{Pl}} < r_G < r_T < r_H < r_S$. From this structure follow three mathematical results that shape the primordial spectrum. Planck observations reveal the corresponding empirical signatures, without any additional assumptions or parameter tuning. The data simply reflect the emergence properties of the vacuum.

S.1 Result 1: Mode–Existence Condition

Before the vacuum reaches r_T, transverse stiffness is zero,

$$G_T(t < t_T) = 0,$$

and no oscillatory solutions exist. This implies the primordial cutoff

$$k \geq k_{\min} = 1/r_T.$$

Planck signature

Planck observes:

- disappearance of temperature correlations for angles $\theta \gtrsim 60°$,
- suppression of power at low multipoles $\ell \lesssim 20$, and
- absence of long-wavelength modes.

These results come from Planck 2015 XVI (Isotropy and Statistics of the CMB, A&A 594, A16, 2016)[26], which documents the large-angle anomaly and the vanishing correlation function beyond about sixty degrees. The same cutoff forbids any trans-Planckian oscillations in $P(k)$, consistent with Planck 2018 X (Constraints on Inflation, A&A 641, A10, 2020)[7], which finds no evidence of periodic modulation or logarithmic features.

S.2 Result 2: Stiffness–Tilt Relation

Between r_G and r_T the stiffness softens, generating a tilted scalar spectrum,

$$P(k) \propto k^{n_s - 1}, n_s < 1,$$

with monotonic negative running,

$$\alpha_s < 0.$$

Planck signature

Planck 2018 VI (Cosmological Parameters, A&A 641, A6, 2020)[7] reports

$$n_s = 0.9649 \pm 0.0042, \alpha_s \lesssim -0.004,$$

in agreement with the CTC prediction. In ΛCDM these values depend on slow-roll conditions; in CTC they follow directly from stiffness gradients in the vacuum.

S.3 Result 3: Tensor-Suppression Condition

Before r_G, the vacuum supports only longitudinal curvature. Transverse gravitational modes do not exist,

$$G_T^{(G)}(t < t_G) = 0,$$

and therefore the primordial tensor spectrum vanishes,

$$P_T(k) = 0.$$

Planck signature

Joint BICEP/Keck + Planck results give

$$r < 0.036.$$

This consolidated bound comes from the BICEP/Keck 2018 analysis (PRL 127, 151301, 2021)[27], which combines WMAP, Planck, and ground-based data to rule out detectable primordial gravitational waves. Inflation must finely tune its potential to achieve such small r. In CTC, tensor suppression is a structural consequence of the vacuum's stiffness ordering.

S.4 Combined Interpretation

Taken together, the three CTC results provide a unified explanation of the full pattern of Planck observations. The **mode-existence cutoff** determines which perturbations can ever appear, removing all wavelengths longer than $r_T$and all sub $r_T$modes. The **stiffness–tilt relation** fixes the shape of the scalar spectrum, generating both the observed tilt and the small but persistent negative running. The **tensor-suppression condition** eliminates primordial gravitational waves at their origin. When these three consequences are viewed as parts of a single emergence sequence

$$r_{\mathrm{Pl}} < r_G < r_T < r_H < r_S,$$

the signatures measured by Planck follow naturally. The low power on large angular scales, the smooth scalar spectrum with tilt and negative running, the absence of trans Planckian features, the lack of primordial tensors, and the slightly enhanced lensing amplitude all arise from the same underlying structure of the vacuum. No additional parameters or model adjustments are required. By contrast, the ΛCDM framework must introduce extra assumptions or extensions to account for these features individually. In CTC, they emerge automatically from the mechanical response of the vacuum as it evolves through the stiffness thresholds that mark the beginning of spacetime structure.