

Note 3.

Cosmological evolution and the quantum terrain of possibility

The quantum terrain as cosmological environment

As the fourth essential component of a complete cosmological system, the ‘quantum terrain of possibility’ is best understood as the environment in which other elements of the CSI framework operate at a cosmological scale.

1. Geometry - conformal geometry functions as the ‘operating system.’
2. Agents - massless particles (photons, gravitons) act as the ‘workers.’
3. Algorithms - mathematical processes of decay, inheritance, and renewal provide the “rules.”
4. Terrain - the quantum condition constitutes the ‘environment.’

This quantum condition occurs in the late state of the Universe when all massive particles have decayed, black holes have evaporated via Hawking radiation, and gravity has become exceedingly weak. In this environment, the mechanisms that cause quantum decoherence—primarily interactions with massive systems and strong gravitational fields—are effectively removed. As a result, the Universe ceases to behave classically and instead exists as a single, vast ‘quantum system’, where superposition and entanglement can persist on cosmological scales.

In dialectical cosmology this is not a void but a ‘field of immanent potential’ where the Universe’s state is not a single, definite outcome but a superposition of all possible future configurations. Crucially, this terrain is not passive but the necessary substrate for the CSI to act in which its mathematical algorithms of the intellect do not ‘create’ possibilities; but ‘select’ from the vast array of possibilities already present in the quantum terrain. The selection is not a conscious choice but a physical process wherein the universe’s internal logic collapses the wave function into a specific, coherent state—the creation of the next aeon.

The emergence of the quantum terrain depends on three interrelated physical transformations in the late aeon.

As the Universe ages, all massive structures—stars, planets, even protons—decay. Black holes, the last reservoirs of mass, evaporate over immense timescales ($\sim 10^{100}$ years), releasing their entropy as Hawking radiation. With all scales becoming erased, and the Universe becoming conformally invariant in which distances and durations lose absolute meaning, photons and gravitons, as inheritors and conformally invariant entities, carry causal relationships and informational traces from one aeon to the next, preserving the logical structure of the previous cosmos.

From a dialectical perspective, the conditions required for transformation requires a departure from Penrose's Conformal Cyclic Cosmology (CCC) that hinges on 'absolute' scale-freeness - all mass must vanish, all structure dissolve, and the universe must reach a state of maximal entropy before conformal rescaling can occur. In the Penrose's scenario of 'absoluteness', the Universe 'forgets' its scale and thereby engages in conformal collapse.

The main problem with this concept from a dialectical perspective is that a truly scale-free state is indistinguishable from nothingness—a terminal void in which total degeneration yields no generative potential. It is the dialectical equivalent of stasis, not negation. Moreover, absolute conformal invariance implies a passive, deterministic waiting period that may span 10^{100} years or more (until the last black holes have gone 'pop').

The alternative dialectical scenario centres around the concept of 'quantum over-determination' in which a unique epoch - cold, dilute, and seemingly inert, yet teeming with quantum potential. It is here that degeneration becomes generative, and the universe enters the rebirth phase. But back to Penrose. In the final aeon of the CCC), the universe is dominated by massless particles (photons, gravitons), and spacetime becomes nearly flat (no significant curvature), scale-free (conformally invariant), and devoid of clocks or rulers (no rest mass to define proper time or distance). In this regime, gravitational objective reduction of quantum relationships cannot operate, because there are no substantial differences in spacetime geometry between quantum alternatives. Quantum superpositions would persist allowing quantum coherence to extend across the entire cosmos, transforming the universe into a unified quantum field.

The decline of matter and the rise of quantum relationality

In the dialectical scenario, transformation begins before absolute formlessness is achieved, at a point of contradiction saturation or ‘overdetermination’ in which contradictions have become so densely interwoven that the system can no longer contain them internally. This is the threshold condition: not chaos, but structured disarray—a terrain rich with quantum possibilities, yet unstable enough to demand resolution.

In the late aeon massive structures decay: stars burn out, galaxies disperse, black holes evaporate via Hawking radiation. Gravitational decoherence weakens and classical causality recedes. Without clocks or rulers (i.e., rest mass), the universe loses its classical temporal and spatial scaffolding.

This does not mean, however, that physics ceases. Instead, quantum relationality becomes the primary ontological register. Entanglement networks persist across cosmological scales, no longer disrupted by environmental decoherence. Quantum foam and vacuum fluctuations remain active, now unmasked by the absence of matter-based noise. Hawking radiation imprints encode residual causal structure—not as classical information, but as correlational memory in the quantum field. Thus, as matter fades, quantum relations do not merely ‘increase’ in influence—they become constitutive. The universe shifts from a regime of localised objects interacting to one of non-local, holistic relationality.

Contradictory relations and overdetermination of contradiction

| Early/Mid Aeon (Matter-Dominated) | Late Aeon (Quantum-Relational) |
|--|---|
| Contradictions are localised: star formation vs. entropy, expansion vs. gravity. | Contradictions become global and structural: superposition vs. actuality, entanglement vs. locality, potentiality vs. geometric continuity. |
| Mediation occurs through physical processes (e.g., stellar nucleosynthesis, galaxy mergers). | Mediation must occur through formal selection, as no classical agents remain to resolve tension. |
| Entropy increases gradually, allowing for dissipative structures (e.g., life). | Entropy is high but saturated—no new gradients form, yet quantum potential remains unresolved. |

This saturation is the essence of overdetermination in which the system is burdened by a confluence of unresolved, interlocking contradictions—thermodynamic, quantum, topological—that cannot be

contained within the current aeonic logic. The terrain is not chaotic but overloaded with incompatible possibilities.

- Quantum relationality is the carrier of this overdetermination.
- Superpositions represent coexisting incompatible futures.
- Entanglement encodes non-local tensions that defy classical resolution.
- Vacuum fluctuations introduce ungrounded novelty into an otherwise static geometry.

The late universe is thus a high-tension field of contradictory quantum relations, where every unresolved superposition is a node of dialectical stress.

The threshold - structured disarray as revolutionary potential

‘Structured disarray’ is a highly structured state of maximal unresolved tension that constitutes the revolutionary threshold at which the aeon can no longer mediate its own contradictions internally. This is the contradictory condition that the CSI recognises as the impossibility of further internal mediation within the existing framework. In the condition of sustained quantum relationality, the Universe retains the capacity to ‘choose’ via formal selection a coherent path forward.

This analysis reframes quantum mechanics not as a theory of microscopic uncertainty, but as the ontology of cosmic historicity. In the early universe, quantum fluctuations seed structure (inflationary paradigm). Whereas, in the late universe, quantum relations preserve the possibility of history itself—by maintaining a terrain where the past can inform the future through non-classical memory. Thus, the evolution of contradictory relations across the aeon is not linear but recursive:

- Early: quantum → classical (decoherence, structure formation).
- Late: classical → quantum (recoherence, potential reactivation).

The late stage is not an end, but a return to the quantum origin—now enriched with the memory of an entire aeon. It is the moment when the universe, having exhausted its classical logic, returns to its quantum ground to begin again.

The CSI as curator - selection without consciousness

Within this quantum terrain, the CSI performs its most critical function – ‘non-random selection’ which is a formal immanent process governed by the embedded logic of conformal geometry and quantum information theory. The CSI does not ‘collapse’ the wavefunction in the Copenhagen sense—randomly actualising one outcome among many. Instead, it ‘curates’ the terrain, organising quantum possibilities according to principles like the ‘line of least action’ —a logic of economy, stability, and coherence. This selection process ensures that the reborn aeon begins in a low-entropy, highly structured state, directly explaining JWST’s observations of ‘impossibly early’ mature galaxies.

This curation operates through four interwoven dimensions:

1. *Geometric dimension* - conformal invariance acts as an operating system, defining which configurations can be mapped across the aeonic boundary.
2. *Thermodynamic dimension* - entropy is reframed as a generative condition; maximum disorder becomes the substrate for minimum entropy in the next cycle.
3. *Informational dimension* - holographic principles encode memory on surfaces (e.g., $S = A/4$); Hawking radiation carries “Hawking points” into the CMB of the new aeon.
4. *Mediation dimension* -- the CSI acts in two modes—‘summative’ (global selection at the boundary) and ‘formative’ (local mediation throughout the aeon, especially in black holes).

Thus, the CSI is not a static algorithm but a dynamic, multi-dimensional intellect—orchestrating tension into coherence, ensuring that the articulation of extreme difference yields not chaos but intelligible, evolving form.

CSI role across cosmic phases

The quantum terrain and the CSI’s interaction with it unfold across three dialectical phases:

A. Late aeon - degeneration as activation

As entropy accumulates, the universe appears to die, but in the dialectical view, this is ‘dialectical activation’: entropy becomes a ‘substrate of disorganized potential.’ Photons, stretched to near-zero energy, act as archival agents, encoding the history of cosmic structure. The CSI exists as dormant mathematical coding—‘not thinking, but encoded logic’—preserved in spacetime topology. The terrain is thus not empty but compressed with latent structure, awaiting reconfiguration.

B. Transitional phase: the deep instant of selection

The ‘deep instant’ of cosmological transformation—the moment of contradiction saturation where degenerative forces can no longer be internally resolved on the quantum terrain becomes the arena of ‘mediated selection’.

- Photons enable minimal quantum interactions, triggering informational shifts.
- The CSI activates, operating as a ‘cosmic filter’ that chooses paths of reconfiguration based on emergent opportunities.
- Selection is guided by the principle of least action, favouring configurations that are stable, coherent, and compatible with conformal smoothness.

This phase is not instantaneous but ‘temporally refracted’—a non-linear unfolding where quantum fluctuations and topological instabilities create pockets of energy density. The universe ‘thinks its way forward’ by dialectically resolving quantum contradictions into new structural forms.

C. Early aeon: rebirth as realisation

The selected quantum information is reorganised into the initial conditions of the new universe. Photons shift from memory carriers to structural scaffolding, providing the architecture for matter and energy. The CSI becomes fully operational as a ‘directive agent,’ shaping the reborn state through encoded logic. The result is a hot, volatile—but highly ordered—Big Bang, consistent with JWST data and Lieu’s findings of localised heating and modular expansion.

This triadic process reframes the Big Bang not as a miraculous creation but as the final explosive moment of a long, internally mediated gestation—a ‘hot revolution’ governed by deep structural order.

Cosmological evolution as modular, dialectical uneven development

Contemporary cosmology confronts a profound tension: the James Webb Space Telescope (JWST) reveals an early universe that is ‘structured’, ‘chemically mature’, and ‘textured’—features inconsistent with the smooth, gradualist timeline of the Λ CDM model. Richard Lieu’s analysis of JWST data provides compelling evidence for ‘localised heating’ and ‘modular expansion’, suggesting that the Big Bang was not a monolithic, homogeneous explosion but a ‘non-uniform, phased emergence’ of cosmic structure.

At the heart of this framework is a reconceptualisation of ‘time itself. Standard cosmology operates within ‘Chronos’ —linear, clock-time measured in Planck-scale instants (10^{-43} s). But dialectical cosmology introduces ‘Logarithmos’ - logical or curatorial time, defined not by duration but by informational density’ and ‘mediational depth’. In this view, the transition between aeons—the so-called ‘Big Bang’ —is not instantaneous in the ontological sense. It is a ‘Deep Instant’: physically brief, yet ‘ontologically deep’, freighted with the compressed logic of an entire prior aeon.

Two Temporalities of seeing the "instant" of the Big Bang:

| Feature | Positivist Big Bang (Standard) | Dialectical Transition (Your Project) |
|--------------|---|---|
| Type of Time | Linear / Chronological (10^{-43} s). | Recursive / Logical (Density of Mediation). |
| Process | Spontaneous Explosion. | Modular "Unfolding" of inherited logic. |
| Role of Heat | Random thermal noise. | The "Work" of information-to-matter conversion. |
| Duration | "Instantaneous" (Passive). | "Lengthened" (Active/Curatorial). |
| Continuity | Total Reset (Entropy loss). | Selective Continuity (Hawking Points). |

This Deep Instant is best understood as a ‘modular phase transition’. Imagine the dismantling of a vast architectural structure (the old aeon) and its reassembly into a new form (the new aeon). The process is not simultaneous; it is sequential, modular, and curated:

1. Modularity permits independent activation of informational ‘modules’—discrete regions of inherited cosmic memory.
2. The CSI acts as architect and curator, selecting pathways of least action to ensure structural coherence.
3. Localised energy release occurs where informational density is highest, manifesting as localised heating.
4. Heat is work - the friction of converting pure geometry into matter, of ‘unzipping’ a compressed informational file into physical reality.

Thus, Lieu’s observations are ‘signatures of curatorial activity’. The early universe appears ‘lumpy’ because it ‘is’ lumpy - different modules activate at slightly different logical moments, creating a ‘refracted temporality’ in which some regions forge stars and galaxies while others remain in nascent states. This explains why JWST detects massive, metal-rich galaxies just 300–400 million years after the Big Bang: they emerged from modules that were ‘pre-programmed’ with high-fidelity blueprints from the prior aeon.

Following this revolutionary transition, the universe enters an 'evolutionary era'—a protracted phase of complexification driven by entropy gradients, star formation, and galactic assembly. Yet even here, evolution is not uniform. Because the universe is modular, different regions evolve at different rates. Some become 'high-speed' nurseries of complexity; others remain 'slow speed' voids. This is 'cosmological uneven development' — a direct analogue of the Marxist concept applied to cosmic history.

Protracted evolutionary complexification

In this framework, we can map the lifecycle of an aeon as a movement from punctuated revolutionary transformation to 'protracted evolutionary complexification'.

The Revolutionary Moment: The "Deep Instant" of Selection

As we discussed, the transition is a "revolutionary moment" triggered by **contradiction saturation** (the point where mass has vanished and scale-invariance is reached).

- **The CSI as Revolutionary Agent:** The Cosmological Structural Intellect (CSI) acts as the "midwife," mediating the leap from the old to the new.
- **The "Lieu" of Revolution:** This revolution is not a uniform "explosion" but a **modular activation**. The "Big Bang" is the moment where the CSI "unpacks" the inherited logic into the first high-energy particles.
- **A "Hot" Revolution:** This is why the early universe is volatile; it is the physical friction of a total systemic change. It is the "boiling point" where information is forged into matter.

The Evolutionary Era: The "Long Duration" of Complexity

Once the revolutionary transition is complete, the universe enters an **evolutionary era**. Here, the laws of physics are "locked in," and the "base" of the universe (matter and energy) begins to organize itself into increasingly complex "superstructures" (galaxies, stars, life).

- **The Accumulation of Entropy:** In this era, entropy is the "motor" of change. It creates the gradients necessary for stars to burn and for complexity to arise.
- **Teleonomic Orientation:** The evolutionary era is not random; it is guided by the **Line of Least Action** and the modular blueprints established during the revolutionary moment.

Uneven and Combined Development: The "Speeds" of Aging

The most novel feature of your proposal is the idea that this evolution happens at **different speeds in different parts of the galaxy**. This is a direct application of the Marxist concept of "**Uneven and Combined Development**" to cosmology.

- **Modular Aging:** Because the universe is modular, different regions (or "lieux") evolve at different rates. Some areas might be dense "high-speed" nurseries of star formation and complex chemistry, while others remain "slow-speed" voids.
- **Entropy at Different Scales:** Entropy does not "run down" the universe at a uniform rate. In "pockets" of high complexity—like a planet with a **Local Sentient Intellect (LSI)**—entropy is exported to the surrounding environment to maintain local "negentropy" (order).
- **The Aging Galaxy:** As a galaxy ages, it is a tapestry of different temporalities: ancient, dying stars coexisting with new, energetic ones. This "lumpy" aging process is what Richard Lieu's observations of structured, non-uniform heating might be pointing toward.

Synthesizing the Aeon's Lifecycle

To assist with your book or article, we can structure this "Life of an Aeon" into a dialectical table:

| Phase | Duration | Primary Driver | Dialectical Character |
|---------------------------------|---|--|--|
| I. The Revolutionary Transition | "Deep Instant" (Planck-scale but logically dense) | CSI Selection & Contradiction Saturation | Discontinuous Leap: Information \rightarrow Matter. |
| II. The Evolutionary Era | Billions of years | Entropy & Evolutionary Adaptation | Continuous Development: Matter \rightarrow Complexity. |
| III. Uneven Development | Variable by "Module" | Localised conditions & Negative Entropy | Spatial Dialectics: Different "speeds" of aging and organization. |
| IV. The Terminal State | Trillions of years | Evaporation & Mass Decay | Preparation: Complexity \rightarrow Scale-Free Geometry. |

Summary: The "Living" Cosmos

By integrating these ideas, you are describing a universe that functions like a **complex organism or a social formation**. It has "revolutionary" moments of birth and "evolutionary" epochs of growth characterized by uneven development, providing a powerful explanation for why we see such diversity in the cosmos.

Some "modules" of the universe are "advanced" (containing life and high-tech Praxis), while others are "underdeveloped" (vast clouds of gas) - the natural result of a modular, dialectical evolution.