

# Conformal Continuity and Physical Continuity

A Conceptual Analysis of Cyclic Cosmology

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## Abstract

Conformal Cyclic Cosmology (CCC), proposed by Roger Penrose, offers an elegant geometric solution to certain cosmological puzzles by positing that the universe passes through infinite cycles (aeons), with conformal rescaling connecting the end of one aeon to the beginning of the next. This paper examines the conceptual foundations of CCC, focusing on the distinction between *conformal continuity* (mathematical smoothness of the metric under rescaling) and *physical continuity* (preservation of causal and dynamical structure).

The analysis identifies a category error at the heart of CCC: the conflation of *loss of scale* with *cessation of physical process*. When mass vanishes and scale becomes undefined, CCC interprets this as an opportunity for geometric “restart.” However, conformal transformation is a coordinate operation that relabels existing structure; it does not generate new causal content. The smoothness of a mathematical map does not entail the continuity of the physical processes it represents.

This paper does not propose an alternative cosmological model. Its aim is to clarify the conceptual boundaries of CCC’s claims and to distinguish what the formalism computes from what it describes.

**Keywords:** conformal cyclic cosmology, CCC, Roger Penrose, conformal mapping, cosmology, philosophy of physics, conceptual analysis

**PhilArchive categories:** Philosophy of Physics, Philosophy of Cosmology

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# 1. Introduction

## 1.1 The Appeal of Conformal Cyclic Cosmology

Roger Penrose’s Conformal Cyclic Cosmology (CCC) addresses several long-standing puzzles in cosmology with characteristic geometric elegance. The theory proposes that:

1. The universe passes through an infinite sequence of cycles, called *aeons*
2. Each aeon begins with a Big Bang and ends in an indefinitely expanding, matter-free state
3. As matter decays and only massless particles (photons) remain, the distinction between large and small distances becomes meaningless
4. This scale-free state can be conformally mapped to the hot, dense conditions of the next Big Bang
5. The “end” of one aeon is thus geometrically identical to the “beginning” of the next

The proposal is mathematically sophisticated and physically motivated. It addresses the low-entropy initial condition problem by suggesting that entropy effectively “resets” between aeons. It provides a framework for understanding the apparent fine-tuning of cosmological initial conditions. And it does so using the well-established mathematics of conformal geometry.

## 1.2 The Question This Paper Addresses

Despite its elegance, CCC involves a conceptual move that warrants careful examination. The theory relies on the claim that when physical scale becomes undefined, conformal transformation can serve as a bridge between cosmic epochs. This paper asks: does conformal continuity (the mathematical smoothness of the rescaling operation) entail physical continuity (the preservation of causal and dynamical content)?

We will argue that it does not. The analysis identifies a category error in CCC’s foundational reasoning: the conflation of *loss of measurement scale* with *cessation of physical process*. This conflation allows geometric operations to appear as if they generate physical content, when in fact they merely redescribe existing structure.

## 1.3 Scope and Limitations

This paper is a conceptual analysis, not a proposal for alternative physics. We do not:

- Claim that CCC is mathematically inconsistent
- Propose a different cyclic cosmology
- Deny the elegance of conformal geometry
- Suggest that Penrose has made calculational errors

We do examine:

- The conceptual distinction between conformal and physical continuity
- The interpretive assumptions required to connect geometric smoothness to physical process
- The category of “loss of scale” and its physical implications

# 2. Conformal Geometry and Its Physical Interpretation

## 2.1 What Conformal Transformations Preserve

A conformal transformation preserves angles but not distances. In the context of spacetime geometry, a conformal rescaling multiplies the metric by a smooth positive function:

$$g_{\mu\nu} \rightarrow \Omega^2(x)g_{\mu\nu}$$

Under such a transformation:

- Light cones are preserved (causal structure is unchanged locally)
- Angles between curves are preserved
- Distances and proper times are *not* preserved
- The distinction between “large” and “small” is lost

For massless particles, which travel on null geodesics, conformal transformations preserve the relevant geometric structure. This is the mathematical foundation of CCC’s claim that a massless universe is “scale-free” and thus conformally equivalent to other configurations.

## 2.2 The Interpretive Gap

The mathematical fact that two spacetime configurations are conformally related does not automatically establish that they are *physically* continuous. Conformal equivalence is a relation between geometric structures; physical continuity is a claim about causal and dynamical processes.

Consider an analogy: two maps of a city might be related by a conformal transformation (one is a scaled and rotated version of the other). The maps are mathematically equivalent in a well-defined sense. But this does not mean that traveling in the city according to one map will “continue” into traveling according to the other. The maps describe the same territory; the transformation relates descriptions, not journeys.

Similarly, conformal rescaling in CCC relates geometric descriptions. The question is whether this mathematical relation can bear the physical interpretation Penrose assigns to it.

## 3. Loss of Scale: What It Does and Does Not Mean

### 3.1 The Physical Situation at Aeon’s End

According to CCC, each aeon ends in a state where:

- All massive particles have decayed
- Only massless particles (primarily photons) remain
- The universe has expanded indefinitely
- Proper time becomes ill-defined for the remaining content

In this state, Penrose argues, the distinction between large and small distances becomes meaningless. There is no “clock” to measure time, no “ruler” to measure space. The universe has lost its scale.

### 3.2 What Loss of Scale Means

Loss of scale means that the *apparatus of measurement* has become undefined. Without massive particles, there are no reference frames with proper time. Without proper time, the operational definition of distance collapses. The metric formalism, which requires a scale to assign numbers to intervals, reaches its domain limit.

This is a genuine and important observation. Penrose is correct that in such a state, the usual language of “large” and “small,” “early” and “late,” loses its grounding.

### 3.3 What Loss of Scale Does Not Mean

Loss of scale does *not* mean:

- That physical process has ceased

- That causal structure has vanished
- That “nothing remains”
- That the state is available for arbitrary re-description

The photons that remain still propagate. They still have causal relations to each other. The conformal structure—the pattern of light cones—persists. What has been lost is the *accounting system* for describing this structure in terms of distances and times, not the structure itself.

### 3.4 The Category Error

CCC’s foundational move is to interpret loss of scale as an opportunity for geometric “restart.” The reasoning appears to be:

1. Without scale, the current state cannot be distinguished (metrically) from other states
2. Therefore, it can be conformally mapped to the hot, dense conditions of a Big Bang
3. Therefore, one aeon “becomes” the next

The error lies in step 3. From the fact that two states are metrically indistinguishable (because metrics require scale, which is absent), it does not follow that one state *becomes* the other. Conformal equivalence is a symmetric mathematical relation; physical becoming is an asymmetric causal process.

To put it differently: loss of measurement scale is an epistemic condition (we cannot assign metric values) being treated as an ontological opportunity (reality can be “reset”). This is a category error.

## 4. Conformal Mapping as Coordinate Relabeling

### 4.1 What Conformal Transformations Do

A conformal transformation is a mathematical operation on a geometric description. It takes one way of assigning coordinates and metric values and produces another. The transformation is smooth, invertible, and preserves certain structural features (angles, light cones).

Crucially, conformal transformation does not *generate* anything. It does not create new spacetime points, new causal relations, or new physical content. It redescribes what is already there.

### 4.2 The Asymmetry Problem

Physical processes are asymmetric: causes precede effects, entropy increases, time has a direction. Conformal transformations are symmetric: if configuration A can be mapped to configuration B, then B can be mapped to A.

CCC requires that conformal mapping connect the “end” of one aeon to the “beginning” of the next. But conformal mapping, as a mathematical operation, has no preferred direction. It cannot, by itself, establish that one state *leads to* another.

For CCC to work, something beyond conformal geometry must supply the asymmetry—must determine that the mapping goes from aeon’s end to aeon’s beginning, not vice versa. But CCC provides no such additional structure. The conformal transformation is asked to do work it cannot do.

### 4.3 Coordinate Relabeling Cannot Generate Change

The deepest issue is this: conformal transformation relabels coordinates. It does not generate new physical content. But the transition from one aeon to the next is supposed to be a *genuine physical process*—the “beginning” of a new cosmic epoch.

If conformal transformation is merely coordinate relabeling, then what CCC describes is not a sequence of physical aeons but a single geometric structure viewed under different coordinate choices. The “cycles” are not physical events but descriptive perspectives.

This may be a coherent position, but it is very different from the physical picture CCC appears to offer. The language of “aeons,” “cycles,” and “Big Bangs” suggests genuine physical repetition. The mathematics of conformal transformation provides only redescription.

## 5. Entropy and the Problem of Reset

### 5.1 The Entropy Motivation

One of CCC’s attractions is its apparent solution to the entropy problem. The Big Bang appears to have been a state of extraordinarily low entropy—highly improbable on statistical grounds. Where did this low entropy come from?

CCC suggests that entropy effectively “resets” between aeons. As massive particles decay and only photons remain, the entropy associated with gravitational degrees of freedom is lost. The next aeon begins, in some sense, “fresh.”

### 5.2 The Problem with Entropic Reset

Entropy is a measure of statistical multiplicity: the number of microscopic configurations compatible with a given macroscopic description. For entropy to “reset,” the number of available configurations must decrease. But conformal transformation does not eliminate configurations—it re-describes them.

The photons at aeon’s end have causal histories, correlations, and structure. Conformally mapping them to a “new Big Bang” does not erase this structure. It relabels it. The information is not lost; it is re-coordinated.

For genuine entropic reset, something must be *physically* eliminated or made inaccessible. Conformal transformation, as a smooth and invertible operation, does not eliminate anything. What is mapped can be mapped back.

### 5.3 The Persistence of Correlations

Penrose has suggested that certain patterns in the CMB (“Hawking points”) might be evidence of events from previous aeons—specifically, the evaporation of black holes. But if such correlations can persist through the conformal transition, then the transition does not reset information.

This creates a tension: CCC wants the transition to be smooth enough to preserve conformal structure and certain physical signatures, but also discontinuous enough to reset entropy and begin a “new” aeon. It is unclear whether both requirements can be satisfied simultaneously.

## 6. Geometry as Complete Description

### 6.1 Penrose’s Position

A thread running through Penrose’s work is the view that geometry is fundamental—that physical reality is, at bottom, geometric structure. In CCC, this appears as the claim that when matter vanishes, “only conformal structure remains.”

This is a substantive metaphysical position, not a consequence of the mathematics. It asserts that geometric description exhausts physical reality—that there is nothing to the universe beyond what geometry captures.

## 6.2 The Map and the Territory

Even granting the power and importance of geometric description, there is a distinction between *describing* something and *being* that thing. A map of a city is not the city. A geometric model of spacetime is not spacetime itself.

When Penrose claims that “only conformal structure remains,” he may mean:

1. Epistemically: conformal structure is all we can describe in that state
2. Ontologically: conformal structure is all that exists in that state

The epistemic reading is defensible but weak—it does not support the physical claims of CCC. The ontological reading is strong but requires independent justification.

## 6.3 The Risk of Empty Maps

If geometric description is treated as exhaustive, then loss of metric content (loss of scale) becomes loss of everything *except* conformal structure. But conformal structure without scale is a highly abstract object—a pattern of light cones without any assignment of “size” to them.

Is this a description of a physical state, or is it a mathematical abstraction that has lost contact with physical reality? The question is not rhetorical. A map of a city remains useful as long as it corresponds to something. A “map” that has been abstracted to the point where the territory is no longer represented is no longer a map of anything.

Conformal structure without scale may be in this situation: a mathematical object that has been abstracted beyond its domain of physical applicability.

## 7. What This Analysis Does Not Claim

To be clear about the scope of this critique:

- **We do not claim CCC is mathematically inconsistent.** The conformal geometry is rigorous.
- **We do not claim Penrose has made errors in calculation.** The technical work is sophisticated and careful.
- **We do not claim cyclic cosmologies are impossible.** There may be coherent cyclic models; CCC’s specific mechanism is what we examine.
- **We do not propose an alternative cosmology.** This is conceptual analysis, not theory construction.
- **We do not claim to know what “really happens” at extreme cosmological scales.** We claim only that CCC’s specific claims exceed what its formalism supports.

## 8. Summary and Conclusions

### 8.1 The Central Issue

Conformal Cyclic Cosmology rests on a conceptual move: interpreting loss of measurement scale as an opportunity for geometric restart. This move conflates:

- **Conformal continuity** (mathematical smoothness of geometric transformation) with **physical continuity** (preservation and generation of causal content)
- **Loss of scale** (the metric formalism reaching its domain limit) with **cessation of physical process** (genuine ending that permits new beginning)
- **Coordinate relabeling** (redescribing existing structure) with **physical transition** (generation of new cosmic epoch)

## 8.2 The Category Error

The core issue is a category error: treating a feature of our *description* (loss of metric values) as a feature of *reality* (opportunity for restart). When the metric formalism runs out of scale, this tells us something about the limits of the formalism, not about the availability of reality for re-description.

Conformal transformation is a powerful mathematical tool. It relates geometric structures. It does not generate physical content, establish temporal direction, or reset entropy. CCC asks conformal transformation to do conceptual work it cannot perform.

## 8.3 What Remains

The elegance of conformal geometry remains. The mathematical relationships Penrose identifies are genuine. The problem of cosmological initial conditions remains important.

What does not remain is the interpretation: that conformal smoothness constitutes physical continuity, that loss of scale enables restart, that coordinate relabeling generates new aeons. These interpretive moves exceed what the formalism supports.

## 8.4 Conclusion

CCC does not model cycles of physical reality; it models cycles of geometric description. When scale disappears, Penrose preserves geometry by declaring it all that remains. But a map without scale is not a territory without size—it is a map that has lost contact with its object.

The conformal transition in CCC is a mathematical operation, not a physical process. The “aeons” it connects are coordinate perspectives, not cosmic epochs. The elegance is real; the physics is interpretation.

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### Note on Method

This paper performs conceptual analysis within philosophy of physics. It does not propose new physics but examines the conceptual foundations of existing physical claims. The goal is to distinguish what the formalism computes from what it can be interpreted to describe.

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