

The Earliest Reconstructible Universe

CHO-001 · Cosmic History and Its Observers

A Chronological Scientific History from the Early Universe to the Present

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Structured abstract

Context. A chronological history of the Universe must begin where chronology itself is least secure. The coordinate t_{BB} is obtained by extending a hot, expanding cosmological model backward; its zero is not a directly observed event and is not, by itself, proof of creation.

Scope. This article covers the formal lower boundary of the CHO chronology through the order-of-magnitude handoff at 10^{-11} s. It examines what observations actually constrain, why inflation is influential but not uniquely established, how reheating and baryogenesis connect proposed primordial regimes to later thermal history, and why Planck-scale, singularity, anthropic and quantum-observer language must be handled with care.

Evidence. The strongest empirical access is indirect. Cosmic microwave background anisotropies and large-scale structure preserve statistical information about primordial perturbations. Their interpretation requires dynamical models and a chain of inference across later cosmic evolution. Current data support an almost scale-invariant, predominantly adiabatic primordial spectrum and tightly restrict many inflationary models, but they do not select a unique inflaton, reheating history or physical beginning.

Conclusion. The earliest defensible CHO state is not “nothing becoming something.” It is an epistemically layered boundary: reliable late-time records, model-based retrodiction, multiple viable high-energy mechanisms and an unresolved domain where tested theories no longer suffice. No biological or conscious observer is evidenced in the interval considered. Only N_0 applies: present observers encounter physical traces produced without awareness.

Keywords: early universe; Big Bang; inflation; reheating; baryogenesis; primordial perturbations; Planck scale; anthropic reasoning; observer; cosmological inference

1. Chronological orientation

CHO uses t_{BB} for model-dependent cosmic time after the formal hot-Big-Bang extrapolated coordinate boundary. The notation is deliberately austere. It orders the narrative, but it does not convert an extrapolation into an observation. In a classical Friedmann–Lemaître description, the density diverges in the ordinary matter- or radiation-dominated classical extrapolation toward a finite coordinate limit [6]. That failure signals that the classical description has left its tested domain; it does not supply a photograph of a first instant.

The upper boundary, 10^{-11} s, is also editorial rather than event-like. It is an order-of-magnitude handoff chosen before the electroweak crossover treated in CHO-002. Inflation, if it occurred, and reheating cannot be assigned universal start and end times independently of their models. A single horizontal timeline would therefore be misleading. The appropriate chronology is nested:

Layer	What is ordered	Evidential meaning
Formal coordinate	$t_{\text{BB}} \rightarrow 0$ to 10^{-11} s	Backward parameter in specified cosmological models
Dynamical regimes	quantum-gravity proposals, inflation, reheating, baryogenesis	Model families with uncertain or non-unique temporal placement
Empirical record	primordial spectra inferred from CMB and structure	Later measurements interpreted through a cosmological model

The central question is consequently not “What happened at exactly zero?” It is “How far can evidence-bearing models be carried backward, and where do different kinds of warrant cease to coincide?”

2. Initial state: no inherited physical snapshot

CHO-001 has no preceding spine article. Its initial state is the state of knowledge at the stated literature cutoff: a mature but incomplete cosmological framework, precise measurements of a much later Universe, tested particle physics at energies vastly below proposed primordial scales, and competing attempts to join general relativity to quantum theory.

The hot Big Bang model is exceptionally successful once a hot, dense, expanding plasma is established. Expansion, primordial light-element abundances, the cosmic microwave background and the growth of structure form a mutually constraining network. Yet success at later stages does not verify every backward extrapolation. The phrase “Big Bang” can refer to the hot early phase, the mathematical boundary of a classical solution, or a hypothesised absolute beginning. CHO accepts the first as a well-supported historical framework, uses the second only as a coordinate convention, and treats the third as an open metaphysical and physical question.

3. From a classical boundary to inflationary models

3.1 Why inflation was proposed

Standard decelerating expansion makes the observed large-scale uniformity and near-flat spatial geometry difficult to understand from generic initial conditions. Inflation introduces a period during which the scale factor accelerates. In the simplest implementations, a slowly evolving field-like degree of freedom temporarily dominates the energy density. A sufficiently long accelerated phase can place regions now widely separated inside an earlier causal domain, dilute spatial curvature and unwanted relics, and stretch microscopic fluctuations to astronomical scales.

Guth’s 1981 proposal demonstrated the explanatory power of this mechanism while also exposing an exit problem in its original form [3]. Later slow-roll and related models changed the microphysics. “Inflation” is therefore not one theory but a family whose members differ in fields, potentials, initial conditions, duration, ending mechanism and relation to high-energy physics.

3.2 What the sky supports

Inflation is evaluated chiefly through the statistics of primordial perturbations. Planck’s 2018 baseline TT,TE,EE+lowE+lensing analysis measured a scalar spectral index $n_s = 0.9649 \pm 0.0042$ at 68% confidence, rejecting exact scale invariance within that model space [4,5]. It found no compelling evidence for running or engineered features over the scales it could test. The same analysis constrained tensor contributions and disfavoured several once-prominent potentials. Later BICEP/Keck observations tightened the upper bound on primordial tensor modes [1].

These results are consistent with broad slow-roll expectations, but consistency is not unique confirmation. A reconstructed primordial spectrum is not a direct meter reading from an inflationary laboratory. Foregrounds, instrument models and likelihood choices are handled observationally; the mapping from the spectrum to a field potential additionally assumes a perturbation theory, an expansion history and a reheating relation. Many microphysical models remain compatible, and non-inflationary alternatives attempt to generate similar large-scale correlations.

3.3 The beginning remains outside the result

Inflation does not automatically eliminate a past boundary. Borde, Guth and Vilenkin showed that spacetimes satisfying a positive averaged expansion condition along appropriate past-directed geodesics are past-incomplete [2]. Past-incomplete means that the relevant geodesics cannot be extended indefinitely within that spacetime descrip-

tion. It does not mean that the theorem derives creation from nothing, nor does it identify what replaces the boundary. Bounce, tunnelling, no-boundary, emergent and cyclic constructions propose different extensions or replacements, each with assumptions and unresolved tests.

Similarly, the Planck time is the derived dimensional scale $t_P = \sqrt{\hbar G / c^5}$, about 5.4×10^{-44} s with the CODATA constants [9]. Its definition does not identify an observed first event. Calling it “the first moment” would commit two errors: assigning observational status to a derived scale and assuming that unknown quantum-gravity dynamics preserve the same time coordinate.

4. Reheating: establishing a hot Universe

Accelerated expansion strongly dilutes ordinary particles. To connect inflation to the later hot Big Bang, stored energy must be transferred into excitations that interact and approach a thermal state. This family of processes is called reheating. Depending on the model, energy transfer can begin through perturbative decays, resonant particle production or other non-equilibrium dynamics; full thermalisation can occur later.

Reheating matters because it controls the relation between a comoving scale observed today and the stage at which that scale left the inflationary horizon. Assumptions about the reheating equation of state and temperature therefore feed back into inflation-model constraints. The inference is circular only if hidden. Made explicit, it is a legitimate joint constraint with substantial model dependence. In the attractor analysis, the horizon-exit relation depends explicitly on the average reheating equation of state [10].

In the cited attractor and low-reheating calculations, the reheating temperature is inferred under explicit model assumptions; their constraints do not identify a common observed reheating event [10,11]. Compatibility with Big Bang nucleosynthesis, treated in CHO-003, supplies a lower-temperature constraint within the adopted thermal history [11]. The CHO seam at 10^{-11} s must not be read as the end of reheating. It marks the point at which the main chronological spine transfers to the Standard Model thermal transitions of CHO-002.

5. Why matter survived: the baryogenesis problem

The observable Universe contains far more matter than antimatter. In an initially symmetric thermal state, known equilibrium processes do not simply leave the required excess. In the standard baryogenesis scenarios summarized by the Particle Data Group, the three Sakharov conditions are baryon-number violation, violation of charge-conjugation and combined charge-parity symmetries, and departure from thermal equilibrium [6].

Those conditions organise a research programme; they do not identify the historical mechanism [6]. High-scale baryogenesis, leptogenesis followed by electroweak conversion, electroweak baryogenesis and other proposals place the decisive asymmetry in different regimes. The magnitude inferred from later cosmological evidence is real evidence for an asymmetry, but not a timestamp for its production.

CHO-001 owns this unresolved mechanism problem. CHO-002 owns the electroweak crossover and later particle thermal history. At their seam, wording must distinguish a mechanism whose decisive dynamics might occur near electroweak temperatures from the thermal background in which it operates. No candidate is promoted to the actual history without evidence that separates it from competitors.

6. Evidence, dating and resolution limits

The early-time coordinates discussed here are model reconstructions rather than directly dated material samples. Early-universe chronology is inferred by combining several transformations:

1. instruments measure frequency-dependent sky signals;
2. foreground and calibration models yield CMB temperature and polarization maps;
3. angular correlation functions and power spectra summarise those maps;
4. a cosmological model connects the spectra to primordial perturbations;
5. an inflationary or alternative dynamical model connects perturbations to an earlier regime;
6. assumptions about reheating map scale and e-fold number to temperature or time.

Uncertainty expands backward along this chain. Statistical intervals on parameters do not include all uncertainty about the model family. Conversely, model dependence does not make the evidence arbitrary: incompatible spectra,

excessive tensor modes, large isocurvature components or strong non-Gaussian signatures can eliminate particular proposals.

“Direct” and “indirect” should therefore not be used as synonyms for “certain” and “uncertain.” CMB photons are directly detected, but their early-universe significance is reconstructed. Inflationary parameters are constrained, but the constraints are conditional. Quantum-cosmology boundary proposals remain largely speculative because observational discriminants are weak or non-unique.

7. Observer status: N0, traces without awareness

No living detector, nervous system, subject or scientific community is evidenced in this interval. CHO classifies it as N0: no observer capacity, only trace records. The patterned Universe later supplied physical states from which observers could extract information, but information-bearing structure is not itself evidence of experience.

Physics uses “observer” in several technical senses: a reference frame, an idealised measuring apparatus, a system that becomes correlated with another, or an agent assigning probabilities. None requires that consciousness caused the event. Decoherence describes how interactions disperse phase relations into environmental degrees of freedom and stabilise robust records without a biological witness [8]. Interpretations of quantum mechanics disagree about what else this achieves, but CHO does not import a consciousness requirement into cosmic history.

Present scientists are historical observers looking backward. Their instruments register late-arriving radiation, and their models ask which earlier states could have produced it. The observer is thus part of the evidential chain in 2026, not a causal ingredient in the primordial dynamics.

8. Contingency and contemporaries

At this stage, there is no evidenced biological community to describe. The following comparison concerns alternative model histories, not a claim that these alternatives coexisted physically. Different vacuum states, field contents, symmetry-breaking paths and reheating channels could yield different later particle abundances or structures. Some inflationary scenarios generate eternal self-reproduction; some alternatives replace inflation with contraction or a bounce. Most possibilities are not observed worlds. They are counterfactual branches in theory space.

Nothing in the current evidence shows that a Universe capable of producing life was inevitable, typical or intended. Selection effects matter: observers necessarily measure conditions compatible with their existence [7]. But conditional sampling alone does not provide a unique probability distribution over universes, nor does it explain why the underlying laws or ensemble exist.

9. Competing interpretations and unresolved questions

The principal open questions are structural:

- Did an inflationary phase occur, and if so which degrees of freedom drove it?
- What fixed its initial conditions and brought it to an end?
- How did reheating proceed, and what was its effective temperature and equation of state?
- Which process generated the matter-antimatter asymmetry?
- Did spacetime extend through a bounce, emerge from a quantum state, or possess a boundary not describable by classical time?
- Are apparently tuned parameters explained by dynamics, selection in an ensemble, deeper necessity, or an incomplete formulation of the problem?

The answers have different epistemic statuses. Primordial-spectrum parameters are measured through a specified model. Inflation is a powerful reconstructed mechanism class. Particular inflaton and reheating models are more strongly model-dependent. A unique account of $t_{\text{BB}} = 0$ remains speculative.

10. Claim-class statement

Class	CHO-001 use
E1, directly measured	Instrumental CMB and polarization data within specified pipelines; laboratory particle-physics inputs
E2, reconstructed	Primordial perturbation statistics and the hot early state inferred from convergent evidence
E3, model-dependent	Inflationary dynamics, reheating history, mapping between scale and early time, baryogenesis mechanisms
E4, actively contested	Explanatory uniqueness of inflation, boundary models, anthropic and fine-tuning interpretations
E5, speculative/open	Detailed quantum origin, pre-geometric states and any absolute beginning claim

These codes describe propositions, not whole sources, and are not confidence percentages.

11. Boundaries and exclusions

CHO-001 ends at the BOOK seam 10^{-11} s. CHO-002 owns the electroweak crossover, QCD transition, hadronic and leptonic thermal history, neutrino decoupling and electron-positron annihilation. CHO-003 alone owns the Big Bang nucleosynthesis network and primordial light-element yields.

This article does not adjudicate metaphysical creation, divine action or ultimate purpose. It does not claim that the Big Bang was an explosion into pre-existing space, that the Planck time was observed, that inflation is a single settled theory, or that conscious observation is required by quantum mechanics. Anthropic reasoning is presented as conditional inference whose explanatory force depends on a defined ensemble and measure.

12. Closing state passed to CHO-002

The handoff is a hot, expanding physical regime approached through uncertain earlier dynamics. Whatever generated primordial perturbations and whatever reheating path occurred, the next article begins when Standard Model thermal processes can be discussed with increasing physical specificity. The exact onset is not a single universal timestamp. CHO uses 10^{-11} s to preserve an orderly spine while labelling the seam as editorial.

At the handoff no observer in the biological or conscious sense is evidenced. There are interacting fields and particles, expanding spacetime and correlations that can later become records. The history now moves from the least empirically accessible regime toward transitions whose physics can be connected more directly to tested particle theory.

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Disclosure

This document is a scholarly synthesis; it is not primary research and has not been peer reviewed. Juan Segurola is the sole author. He approved the final text and is responsible for its content.