

2 – Reassessing late-time cosmic acceleration in light of supernova progenitor age bias

Why late-time acceleration should not be treated as a secure cosmological premise

Ian Salisbury, Oxford, December 2025, revised July 2026 and September 2026.

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Abstract

Recent analyses of Type Ia supernova data incorporating progenitor-age effects have indicated that the empirical case for persistent late-time cosmic acceleration is weaker than is commonly assumed. Corrections motivated by stellar population physics reduce the inferred acceleration signal while remaining consistent with independent baryon acoustic oscillation (BAO) distance measurements. This paper reviews the evidential basis for that reassessment, drawing on recent supernova analyses and their agreement with BAO constraints.

Progenitor age is now demonstrably implicated in the residual dependence of standardised Type Ia supernova luminosity on host-galaxy properties, although the magnitude of the resulting cosmological bias remains disputed. Independent reanalysis has found that the age–luminosity correlation survives allowance for progenitor-age uncertainty, while recent work has shown that conventional host-mass correction may remove only

part of the underlying age dependence. Conversely, other analyses argue that modern mass and bias corrections already render the residual effect cosmologically negligible. The issue is therefore not settled. This matters because late-time acceleration is an inference from standardised luminosity distances rather than a directly observed quantity. The existence of a physically motivated, redshift-dependent systematic whose cosmological significance remains actively contested is sufficient reason not to treat persistent acceleration as an unquestionable empirical premise. It does not establish TSPC or any other alternative cosmology. It does, however, justify reopening the assumptions from which the standard cosmological interpretation proceeds and asking whether phenomena conventionally represented through additional cosmological components might instead arise from the admissible structure of spacetime itself. That question provides the starting point for the TSPC investigation developed in the papers that follow.

1. Introduction

The claim that the Universe is undergoing late-time accelerated expansion rests on inference rather than direct observation. Acceleration is deduced principally from the luminosity–distance relation of Type Ia supernovae interpreted within a particular calibration framework.¹ Other cosmological probes, notably baryon acoustic oscillations

¹ Seikel, M., Clarkson, C., & Smith, M., *Reconstruction of dark energy and expansion dynamics using Gaussian processes*, Journal of Cosmology and Astroparticle Physics 06, 036 (2012). Demonstrates that the cosmic expansion history, and hence acceleration, is a reconstructed quantity whose inference depends upon the modelling assumptions adopted, rather than a directly observed quantity.

(BAO), constrain cosmic geometry but do not themselves establish acceleration. The evidential status of acceleration therefore depends critically upon the assumptions underlying supernova standardisation.

Type Ia supernovae are treated as standardisable candles after empirical corrections for light-curve shape and colour. While these corrections substantially reduce scatter, they assume that any remaining dependence on progenitor properties can be absorbed as nuisance parameters without affecting the inferred expansion history. Over the past decade this assumption has become increasingly difficult to sustain. A substantial body of observational work has demonstrated correlations between supernova luminosity and host-galaxy properties, most naturally interpreted as reflecting progenitor age and stellar population history.² Because progenitor demographics evolve systematically with redshift, any associated luminosity bias is necessarily time-dependent and potentially degenerate with cosmological inference.

Recent analyses by Junhyuk Son and collaborators treat progenitor age as a physical variable rather than an empirical correction.³ Their results show that once progenitor-age effects are incorporated explicitly, the empirical evidence for persistent late-time acceleration is substantially weakened while remaining consistent with independent BAO measurements.⁴ Because progenitor demographics evolve systematically with redshift, any luminosity dependence associated with progenitor age can imprint a correspondingly redshift-dependent bias on the inferred distance scale. The magnitude and detailed form of that effect depend upon the progenitor-age distribution and upon the standardisation procedure adopted; they cannot be inferred from population evolution alone.

The purpose of this paper is evidential rather than model-specific. It does not seek to establish that cosmic acceleration is absent, still less that TSPEC is correct. It asks whether persistent late-time acceleration is sufficiently secure observationally to be treated as a necessary premise for subsequent cosmological explanation. If a physically motivated, redshift-dependent systematic remains capable of materially changing the supernova distance–redshift relation, and its treatment remains disputed in the current literature, then that premise warrants reconsideration.

² Sullivan, M. et al., *The dependence of Type Ia supernovae luminosities on their host galaxies*, Monthly Notices of the Royal Astronomical Society, 406, 2010. Demonstrates statistically significant correlations between SN Ia luminosity and host galaxy mass and star-formation properties, motivating physical rather than purely empirical calibration.

³ Son J., Lee Y.-W., Chung C., Park S., Cho H. (2025a), *Strong Progenitor-Age Bias in Supernova Cosmology – I: Evidence for Systematic Luminosity Drift*, MNRAS 543, 2152–2165. DOI: 10.1093/mnras/staf1342. Shows that supernova luminosity residuals correlate with host population age, establishing the underlying bias.

⁴ Son J., Lee Y.-W., Chung C., Park S., Cho H. (2025b), *Strong Progenitor-Age Bias in Supernova Cosmology – II: Alignment with DESI BAO and Signs of a Non-Accelerating Universe*, MNRAS 544, 975–987. DOI: 10.1093/mnras/staf1685. Demonstrates that correcting for the age bias yields a present-epoch deceleration parameter near zero and removes the supernova evidence for late-time acceleration.

The implication is methodological. A model should not acquire immunity from reconsideration merely because its parameters successfully accommodate observations interpreted under the assumptions of that model. If the supernova evidence which originally motivated late-time acceleration remains sensitive to an unresolved astrophysical standardisation problem, it is reasonable to reopen the assumptions from which its cosmological interpretation proceeds. That does not presuppose an alternative explanation, but it changes the question. Rather than asking what additional component must be introduced to reproduce an inferred phenomenon, one may first ask whether the same phenomenology can arise from a different restriction on the geometry itself. That is the question with which the TSPC investigation begins.

2. Progenitor age bias as an evidential issue

2.1 Empirical correlations and their physical interpretation

Type Ia supernovae are standardised through empirical correlations between peak luminosity, light-curve shape, and colour. While this procedure substantially reduces scatter, it does not eliminate all systematic dependence on environment. A large and consistent body of observational work has established that residual luminosity correlations remain with host galaxy properties, including stellar mass, star-formation rate, and local environment. These correlations persist across surveys and analysis pipelines, indicating that they are not artefacts of specific fitting choices.

Such host correlations are most naturally interpreted as reflecting underlying differences in progenitor systems. In particular, they point to a dependence of supernova luminosity on progenitor age and stellar population history.⁵ Delay-time distribution studies support this interpretation, linking the occurrence and properties of Type Ia supernovae to the age distribution of their progenitor populations.⁶ From a physical perspective, this dependence follows naturally from variation in progenitor composition, binary evolution pathways, and ignition conditions with stellar age and metallicity.

More recent work has strengthened the empirical case that progenitor age is not merely one of several interchangeable host-galaxy proxies. Chung et al. (2025), using direct stellar-population age estimates for supernova host galaxies over a broader redshift range, reported a correlation between standardised supernova magnitude and host age

⁵ Rigault, M., et al.; *Evidence of environmental dependencies of Type Ia supernovae from the Nearby Supernova Factory*; Astronomy & Astrophysics 560, A66 (2013). Shows that local star-formation environment, used as a proxy for progenitor age, systematically affects Type Ia supernova luminosities even after standardisation.

⁶ Childress, M., et al.; *Host galaxies of Type Ia supernovae and the delay-time distribution*; Monthly Notices of the Royal Astronomical Society 437, 338–353 (2014). Establishes a physical connection between supernova properties and progenitor age through delay-time distributions, supporting a causal interpretation of population effects.

Maoz, D., Mannucci, F., and Nelemans, G., *Op cit.*

reaching 5.5σ in one of their samples.⁷ Subsequent work by Park et al. (2026) examined whether this dependence is already absorbed by the conventional host-mass correction. They found that applying the mass-step correction reduced, but did not eliminate, the luminosity difference between age-defined populations: in their G11 sample the Hubble-residual difference fell from 0.141 ± 0.034 mag to 0.075 ± 0.033 mag, with a statistically meaningful residual offset remaining.⁸ Conversely, correcting for age largely suppressed the mass-related offset. Park et al. therefore interpret progenitor age as the underlying physical variable of which the familiar host-mass and specific-star-formation-rate steps are projected manifestations.

This distinction is important because progenitor age, unlike host mass itself, evolves substantially with cosmic time. The relative contribution of younger and older progenitor populations therefore changes systematically with redshift. A residual luminosity dependence on age can consequently introduce a coherent redshift-dependent bias into the supernova distance scale even where a conventional host-mass correction has already been applied. The empirical issue is thus no longer simply whether standardised Type Ia luminosities correlate with host properties, but whether the present standardisation procedure adequately removes the physical variable responsible for those correlations.

2.2 Redshift evolution and degeneracy with cosmological inference

The luminosity distance relation inferred from supernova observations is sensitive to any effect that introduces a redshift-dependent bias in apparent brightness. If progenitor-age bias evolves with redshift, its contribution to the distance–redshift relation is mathematically degenerate with changes in the inferred expansion history. Progenitor-age effects therefore alter the shape of the inferred distance–redshift relation rather than merely adding noise.

Stellar-population evolution is intrinsically redshift-dependent. Consequently, a luminosity bias associated with progenitor age need not enter the Hubble diagram as additional random scatter; it can alter its shape coherently with redshift and thereby become degenerate with cosmological inference. Establishing the precise form of that

⁷ Chung, C., Lee, Y.-W., Son, J., Park, S., & Cho, H. (2025), *Strong progenitor age bias in supernova cosmology – I. Robust and ubiquitous evidence from a larger sample of host galaxies in a broader redshift range*, Monthly Notices of the Royal Astronomical Society, 538, 3340–3350. DOI: 10.1093/mnras/staf497. Reports a significant correlation between standardised SN Ia magnitude and directly estimated host stellar-population age, reaching 5.5σ in the R19 sample. See also the correction published in MNRAS 550 (2026), stag1210, DOI: 10.1093/mnras/stag1210, correcting the data column used in one host-age comparison figure; the reported age–Hubble-residual correlation is unaffected.

⁸ Park, S., Lee, Y.-W., Chung, C., Yoon, S.-J., Son, J., Cho, H., & Kim, Y.-L. (2026), *Strong progenitor age bias in supernova cosmology – III. Progenitor age as the physical origin of the Type Ia supernova magnitude steps with host properties*, Monthly Notices of the Royal Astronomical Society, 549, stag935. DOI: 10.1093/mnras/stag935. Finds that the conventional host-mass correction only partially suppresses the age dependence of standardised SN Ia magnitudes, whereas correction for age substantially suppresses the host-mass step, supporting progenitor age as the physical variable underlying conventional host-property correlations.

contribution requires a quantitative model of the evolving progenitor population. The important evidential point here is narrower: such an effect cannot safely be assumed to average away merely because the individual supernovae have been standardised.

Standard supernova analyses assume that such evolution can be marginalised without altering cosmological conclusions. If the dominant source of residual bias evolves coherently with redshift, marginalisation does not remove its imprint on the inferred expansion history but redistributes it across fitted parameters. In this situation, apparent acceleration can emerge as a projection of astrophysical evolution rather than as a direct reflection of cosmological dynamics.

2.3 From nuisance correction to physical constraint

Treating progenitor-age bias as a nuisance parameter presumes that its effects are subdominant and unstructured; treating it as a physical variable reverses this logic. Once progenitor age is recognised as an evolving property of the supernova population, its influence on inferred distances becomes constrained by stellar evolution rather than by statistical convenience.

This shift has an important evidential implication. A redshift-dependent population effect can enter the inferred distance–redshift relation coherently rather than merely increasing its scatter. Its magnitude and form must therefore be established physically and observationally before the resulting residual can safely be attributed to cosmological dynamics.

The question is therefore not simply whether progenitor-age bias exists; the evidence for an age dependence is now substantial. The more important question is whether its physical consequences are sufficient to alter qualitative cosmological inference.

An important independent test was provided by Wang, Huang & Huang (2023), who revisited the earlier age-dependence result using a fully Bayesian treatment incorporating uncertainties in progenitor age.⁹ The inferred dependence was weakened but not removed: they reported a 3.5σ correlation. Its cosmological consequence depended materially upon the treatment of intrinsic scatter. With intrinsic scatter included, Λ CDM remained a good fit; without it, age bias could account for the principal extra dimming of distant supernovae and Λ CDM was challenged.

The significance of this result is not that it establishes an alternative expansion history, but that an analysis expressly designed to test the robustness of the age effect continued to find it. More recent analyses have examined whether its magnitude is sufficient to affect cosmological inference. Those results, together with their consistency with

⁹ Wang, Y., Huang, L., & Huang, Q.-G. (2023), *Revisiting progenitor-age dependence of Type Ia supernova luminosity standardization process*, Monthly Notices of the Royal Astronomical Society, 525, 751–757. DOI: 10.1093/mnras/stad2331. Reanalyses the progenitor-age dependence using a Bayesian treatment incorporating age uncertainties; finds that the correlation is weakened but remains at approximately 3.5σ , while its cosmological significance depends materially on the treatment of intrinsic scatter.

independent geometric probes and the continuing dispute over their interpretation, are considered in the following section.

3. Recent supernova re-analyses and consistency with BAO geometry

3.1 Progenitor-age-corrected supernova distances

Recent work by *Junhyuk Son et al.* has provided a systematic re-analysis of Type Ia supernova data in which progenitor age is treated as a physical variable rather than absorbed into empirical calibration terms.¹⁰ Their approach incorporates independent indicators of stellar population age and reassesses the resulting luminosity distance relation without imposing late-time acceleration as a prior.

The principal result of this analysis is a substantial weakening of the inferred acceleration signal at low redshift. When progenitor-age effects are included explicitly, the reconstructed expansion history no longer requires a persistently accelerating phase in order to achieve an acceptable fit to the supernova data. This reduction in inferred acceleration does not arise from degraded statistical performance or from the exclusion of particular subsets of the data, but follows directly from the altered interpretation of supernova luminosities once population evolution is taken into account.

The analysis therefore demonstrates that the cosmological inference is materially altered when progenitor-age evolution is incorporated. It does not by itself establish that the age correction is uniquely required, or that the resulting expansion history represents the true cosmology. Its significance for the present argument is narrower: a physically motivated treatment of an observed supernova population dependence is sufficient to remove the requirement for present-epoch acceleration within the analysis performed.

An independent test has since been reported by Sah, Rameez & Sarkar (2026), who applied the same redshift-dependent progenitor-age correction to Pantheon+ within a cosmographic analysis of the deceleration parameter.¹¹ The correction shifted the isotropic monopole component of (q_0) towards positive values, corresponding to deceleration, while leaving the previously identified local dipole essentially unchanged.

¹⁰ Son, J., Lee, Y.-W., Chung, C., Park, S., & Cho, H. (2025), *Strong Progenitor-Age Bias in Supernova Cosmology – II: Alignment with DESI BAO and Signs of a Non-Accelerating Universe*, Monthly Notices of the Royal Astronomical Society, 544, 975–987. DOI: 10.1093/mnras/staf1685. Applies a redshift-dependent progenitor-age correction to Pantheon+ and DES-SN5YR and finds that the inferred present-epoch acceleration is substantially reduced, with combined fits yielding a deceleration parameter consistent with a presently non-accelerating or decelerating expansion history.

¹¹ Sah, A., Rameez, M., & Sarkar, S. (2026), *Is the local cosmic dipole still anomalous after correcting for supernova progenitor age?*, Monthly Notices of the Royal Astronomical Society, 549, 2869–2878. DOI: 10.1093/mnras/stag844. Applies the progenitor-age correction independently to Pantheon+ in a cosmographic analysis; finds that the isotropic monopole of the deceleration parameter shifts towards positive values while the previously identified local dipole remains essentially unchanged. The authors note that the validity and magnitude of the age correction remain under discussion.

The analysis does not independently establish the validity of the age correction, which the authors acknowledge remains under discussion, but it shows that its effect on the inferred acceleration is not peculiar to the fitting procedure adopted by Son et al.

3.2 The present dispute

The cosmological significance of progenitor age is actively contested. Wiseman et al. (2026) reanalysed the issue using modern supernova standardisation and argued that the host-mass and bias corrections already applied in Pantheon+ remove any significant residual relation between standardised luminosity and host age.¹² They further argued that the inferred evolution in progenitor age had been overstated by conflating host-galaxy age with the age of the particular supernova progenitor. In their analysis, the measured evolution of the host-mass effect in DES is consistent with zero and has negligible influence on the inferred dark-energy equation of state.

Chung et al. (2026) have since published a counter-analysis.¹³ They argue that Wiseman et al.'s broad redshift interval suppresses the measured age–Hubble-residual slope because mean host age itself evolves across the interval; that applying the host-mass correction while testing an age dependence suppresses the quantity being tested; and that the Pantheon+ dust prescription underlying that correction is difficult to reconcile with measured galaxy attenuation laws. They also test different delay-time distributions and argue that a smaller inferred evolution in progenitor age is accompanied by a steeper age–luminosity relation, leaving the resulting redshift-dependent magnitude correction broadly unchanged.

These mutually opposed peer-reviewed analyses prevent a simple conclusion that the progenitor-age problem has either been demonstrated to explain cosmic acceleration or demonstrated to be negligible. For the present purpose, however, the existence of the dispute is itself consequential. The interpretation of the supernova Hubble diagram continues to depend upon astrophysical assumptions concerning host properties, progenitor populations, dust and standardisation. Persistent late-time acceleration cannot therefore be regarded as wholly independent of those assumptions.

¹² Wiseman, P., Popovic, B., Sullivan, M., Riess, A. G., Scolnic, D., Chen, R. C., Davis, T. M., Galbany, L., Hook, I. M., Jha, S. W., Kelsey, L., Murakami, Y. S., Rigault, M., Rose, B. M., Schmidt, B., Smith, M., & Vincenzi, M. (2026), *Still accelerating: Type Ia supernova cosmology is robust to host galaxy age evolution*, Monthly Notices of the Royal Astronomical Society, 549, stag797. DOI: 10.1093/mnras/stag797. Argues that the progenitor-age dependence, its redshift evolution and their combined cosmological effect are either negligible or already accounted for by modern supernova standardisation, including the host-mass and bias corrections applied in Pantheon+.

¹³ Chung, C., Son, J., Park, S., Yoon, S.-J., Cho, H., Lim, D., & Lee, Y.-W. (2026), *Still non-accelerating: age-bias correction in supernova cosmology is robust to host–progenitor age mapping*, Monthly Notices of the Royal Astronomical Society, 551, stag1513. DOI: 10.1093/mnras/stag1513. Responds to Wiseman et al., arguing that their broad redshift range and application of the Pantheon+ host-mass correction suppress the inferred age–Hubble-residual relation, and that alternative delay-time distributions change both the inferred progenitor-age evolution and the age–luminosity slope in compensating directions, leaving the resulting redshift-dependent correction broadly unchanged.

3.3 Alignment with baryon acoustic oscillation constraints

Baryon acoustic oscillations provide an independent measure of cosmic distances that is largely insensitive to the astrophysical properties of supernovae.¹⁴ Recent high-precision measurements from DESI constrain the expansion history over a redshift range that overlaps substantially with current supernova surveys. These measurements therefore provide a cross-check on any reassessment of supernova-based inference.

A key feature of the progenitor-age-corrected supernova analyses is that the correction does not create a new inconsistency with BAO geometry. In the analysis of Son et al.,¹⁵ correcting Pantheon+ and DES-SN5YR for progenitor-age bias moves the combined supernova, BAO and CMB constraints towards those obtained from BAO and CMB alone. The agreement between the probes therefore improves rather than deteriorates when the age correction is applied.

This comparison does not establish that the progenitor-age correction is uniquely required, nor do BAO measurements independently demonstrate a non-accelerating expansion history. It establishes the narrower point relevant here: substantially weakening the supernova evidence for present-epoch acceleration need not be purchased at the cost of disagreement with an independent geometric distance probe. The conventional supernova inference is therefore not required merely to preserve cross-probe consistency.

3.4 Evidential implications for the acceleration epoch

Taken together, these analyses do not establish that cosmic acceleration is absent. They do establish that the inferred late-time expansion history is materially sensitive to the treatment of an observed dependence of standardised Type Ia supernova luminosity on stellar population age. When a physically motivated redshift-dependent correction is applied, present-epoch acceleration is substantially weakened or removed, and the resulting distances remain compatible with independent BAO constraints.

The magnitude of the required correction remains disputed. Wiseman et al. argue that existing host-mass and bias corrections render its cosmological effect negligible, while Chung et al. argue that those procedures partly suppress the age dependence being tested and underestimate its redshift evolution. The dispute therefore concerns not the existence of host-population dependence in supernova standardisation, but its physical interpretation and cosmological magnitude.

The evidential consequence is correspondingly limited but important. Persistent late-time acceleration cannot presently be separated cleanly from the astrophysical

¹⁴ DESI Collaboration; *Early cosmological constraints from the Dark Energy Spectroscopic Instrument*; The Astrophysical Journal Letters 954, L11 (2023). Provides high-precision BAO distance measurements that constrain cosmic geometry independently of supernova astrophysics.

¹⁵ Son, J., Lee, Y.-W., Chung, C., Park, S., & Cho, H.; *Op cit*.

assumptions entering the supernova distance scale. It should therefore be treated as a cosmological inference whose robustness remains under examination, rather than as a direct observational fact to which every alternative cosmological framework must necessarily conform.

4. Evidential summary: a premise worth reopening

The results reviewed in the preceding sections warrant a reassessment of the empirical status of late-time cosmic acceleration, which is inferred from distance measurements interpreted under specific astrophysical and cosmological assumptions.¹⁶ When those assumptions are altered in a physically motivated way, the inferred expansion history changes correspondingly.

The evidence does not establish that progenitor-age evolution accounts for the supernova acceleration signal. It establishes that an observed dependence of standardised Type Ia supernova luminosity on stellar population age can materially affect cosmological inference, while the extent to which present standardisation procedures remove that dependence remains disputed. Applying a physically motivated age correction substantially weakens or removes present-epoch acceleration without compromising consistency with independent BAO geometry.

The present disagreement is therefore itself evidentially significant. Persistent late-time acceleration cannot presently be separated cleanly from the astrophysical assumptions entering the supernova distance scale. It should accordingly be regarded as a cosmological inference whose robustness remains under examination, rather than as a model-independent observational fact.

This conclusion neither establishes a non-accelerating Universe nor adjudicates between cosmological frameworks. It establishes the narrower point required here: there is sufficient empirical uncertainty in one of the principal observational foundations of dark energy to justify reopening the cosmological assumptions built upon it.

5. Conclusion

Recent supernova analyses have reopened a question that appeared to have been settled by the original discovery of late-time cosmic acceleration. Standardised Type Ia supernova luminosities retain measurable dependencies on host-galaxy and stellar-population properties, and there is substantial evidence that progenitor age is implicated in those dependencies. The cosmological magnitude of the resulting bias remains disputed.

That dispute matters. Independent reanalysis has found that the age dependence survives allowance for progenitor-age uncertainty; subsequent work indicates that

¹⁶ Seikel, M., Clarkson, C., & Smith, M.; *Op cit*

conventional host-mass correction may remove only part of it; and applying an explicit redshift-dependent age correction materially alters the inferred expansion history without creating disagreement with BAO geometry. Conversely, other analyses conclude that modern standardisation already renders the residual effect cosmologically negligible. The present evidence does not justify treating either position as settled.

The consequence is methodological rather than model-specific. Late-time acceleration is not directly observed but inferred from standardised luminosity distances. Where the standardisation remains sensitive to a physically motivated, redshift-dependent astrophysical effect whose magnitude is actively disputed, persistent acceleration should not be treated as an inviolable empirical premise from which all subsequent cosmological explanation must proceed.

That distinction opens a more fundamental question. If a phenomenon conventionally represented by an additional cosmological component is not uniquely required by the observations themselves, the appropriate response need not be to seek a different component or to modify its dynamics. It is legitimate first to ask whether the assumptions under which the observations have been interpreted are themselves unnecessarily restrictive. In particular, one may ask whether some of the phenomena presently represented through additional contents of the Universe might instead arise from the admissible structure of spacetime itself.

This does not establish TSPC. Nothing in the supernova evidence presented here selects a time-symmetric parity constraint, and TSPC must stand or fall on its own mathematical consistency and observational consequences. What the present analysis does is remove an unnecessary prior requirement: a new cosmological framework need not reproduce persistent late-time acceleration merely because that behaviour is built into the standard interpretation of the supernova Hubble diagram.

The investigation can therefore begin from a different starting point. Rather than taking the standard cosmological inventory as given and asking what further ingredients are required to reproduce its inferred behaviour, the paper that follows begins with geometry and asks what follows from imposing a single additional admissibility condition on spacetime itself. That condition is the Time-Symmetric Parity Constraint. The remainder of this series examines where that starting point leads, and whether its consequences survive confrontation with observation.

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