Transient Cosmic Acceleration from Phase Interference: A Siamese Cosmology Confronted with Son & Lee (2025)

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Abstract

Recent observational constraints combining BAO, CMB, and supernovae data (Son et al., 2025) suggest that the Universe may be exiting its phase of cosmic acceleration, with a present-day deceleration parameter $q_0 > 0$. This dynamical transition is difficult to reconcile with the rigid ΛCDM paradigm, but aligns naturally with phase-interference mechanisms. In this work we confront a CPT-symmetric "Siamese Interference" cosmology with the latest CPL constraints on (w_0, w_a) and with synthetic hemispheric forecasts for next-generation surveys. We show that, for a narrow range of phase velocities $\gamma \simeq 1.4$–1.5, the Siamese model generates an effective CPL evolution that traverses the core of the (w_0, w_a) confidence region inferred from BAO+CMB+DESI SNe (DES5Y, age-bias corrected), without requiring arbitrary fine-tuning. We then construct a synthetic hemispheric split test for the deceleration parameter q_0, injecting a modest, redshift-localised dipole aligned with the Siamese CPT axis. Even after strong dilution by isotropic high-redshift sources, the effective projected anisotropy remains detectable at the level of a z-score $z \simeq 2.36$ in Euclid/LSST-like catalogs. While our fiducial Siamese model still predicts a mildly negative q_0 today, it provides a concrete dynamical mechanism for the observed drift towards $q_0 \geq 0$ and, crucially, makes a falsifiable geometric prediction: a hemispheric asymmetry in the expansion history aligned with a fixed CPT-symmetry axis, which can be tested with future data.

1 Introduction

For over two decades, the accelerating expansion of the Universe has been modeled largely through a cosmological constant. Within ΛCDM, dark energy is strictly rigid, with equation of state $w = -1$ at all times and in all directions. However, emergent tensions in the Hubble parameter and new evidence for a possible present-day deceleration imply that the dark sector may be governed by transient, rather than eternal, vacuum energy dynamics.

Son et al. (2025) have recently presented a detailed analysis of supernova cosmology including a strong progenitor age-bias correction, and combined their DESI SNe (DES5Y) with BAO and CMB constraints. Their CPL fits in the (w_0, w_a) plane disfavour ΛCDM at high significance, and their model-independent reconstruction of the deceleration history suggests that the Universe may be entering a non-accelerating, or even decelerating, phase today, with $q_0 > 0$. Scalar-field generalisations of dark energy (thawing or freezing quintessence) can accommodate such a trend at the price of introducing new fields and potential fine-tuning in the shape of $w(a)$.

In parallel, Siamese cosmologies based on CPT-symmetric twin universes have proposed that dark energy and parts of dark matter may emerge from an interference term between two conjugate branches of the Universe, sharing a common vacuum but evolving with a slowly desynchronising phase $\Delta\phi(a)$. In this framework, the local effective equation of state is not fixed by a new field potential, but by the relative phase between the two CPT-related sectors, and the apparent acceleration can be a transient interference phenomenon rather than a fundamental cosmological constant.

In this paper we ask a specific, observationally grounded question: can a simple Siamese interference prescription reproduce the regime favoured by Son & Lee in the (w_0, w_a) plane, and does it make distinct predictions that can be falsified with upcoming surveys such as Euclid and LSST/Rubin? To answer this, we (i) construct an effective CPL mapping for a toy but consistent Siamese interference model, (ii) confront its phase trajectories with the Son & Lee confidence contours, and (iii) perform synthetic hemispheric split forecasts for q_0 aligned with the Siamese axis.

2 Siamese interference and effective CPL parameters

2.1 Phase interference as a transient dark energy

In Siamese CPT-symmetric cosmology, the late-time expansion history is controlled by an interference term between two conjugate energy densities ρ_+ and ρ_-, coupled through a relative phase $\Delta\phi(a)$. A minimal phenomenological prescription for the effective dark sector density is

$$\rho_{\mathrm{eff}}(a) \;=\; \rho_+(a) + \rho_-(a) + 2\sqrt{\rho_+(a)\,\rho_-(a)}\,\cos[\Delta\phi(a)]. \tag{1}$$

When $\Delta\phi(a)$ is near zero, the interference is constructive and the effective dark energy density is enhanced, mimicking strong acceleration. As $\Delta\phi(a)$ drifts away from zero, the interference term decays, leading to a reduction in the effective dark energy density and, eventually, to a transition towards deceleration.

For the purposes of this Letter we adopt a simple "phase clock" parametrisation in which the present-day phase $\Delta\phi_0$ and a dimensionless phase velocity γ set the effective CPL parameters (w_0, w_a) through a mapping

$$(\Delta\phi_0, \gamma) \;\longrightarrow\; (w_0^{\mathrm{eff}}, w_a^{\mathrm{eff}}), \tag{2}$$

calibrated such that the trajectory starts at ΛCDM, $(w_0, w_a) = (-1, 0)$, when $\Delta\phi_0 \to 0$, and evolves towards less negative w_0 and strongly negative w_a as the phase approaches a critical value $\Delta\phi_{\max}$.

2.2 Toy mapping used for the confrontation

Concretely, we consider a phase range $0 \le \Delta\phi_0 \le \Delta\phi_{\max}$ with $\Delta\phi_{\max} = 0.42\pi$, corresponding to a stage where the interference term is decaying but not yet fully quenched. Defining the normalised phase variable

$$x \;=\; \frac{\Delta\phi_0}{\Delta\phi_{\max}} \in [0,1], \tag{3}$$

we adopt the following phenomenological mapping:

$$w_0(x) = -1.0 + 0.8\,x^2, \tag{4}$$

$$w_a(x,\gamma) = -0.2 - A\,\gamma\,x^{3/2}, \tag{5}$$

with $A = 2.23$ a scale factor chosen such that for $\gamma \simeq 1.5$ and a phase $x \sim 0.7$ one obtains a point close to $(w_0, w_a) \simeq (-0.7, -1.8)$, the reference Siamese model previously studied in our dark-sector interference work. This mapping preserves the qualitative behaviour expected from an interference mechanism: the effective equation of state moves away from -1 as the phase drifts, and the time derivative of $w(a)$ becomes more negative for larger γ, mimicking a rapid transition in the acceleration history.

While Eqs. (4)–(5) are not derived from a full microphysical PNGB potential here, they provide a controlled 2-parameter family of trajectories in the (w_0, w_a) plane that can be directly confronted with the Son & Lee contours. This is the basis of our Script 5 and Figure 2.

3 Synthetic hemispheric anisotropy forecasts

3.1 Test C: local anisotropy and high-redshift dilution

A key difference between isotropic CPL extensions of ΛCDM and the Siamese interference mechanism is that the latter generically predicts a preferred axis in the late-time expansion, aligned with the underlying CPT symmetry axis of the twin-universe configuration. Motivated by previous work on baryogenesis and FRB anisotropies, we take this axis to be

$$\text{Siamese axis:} \qquad \mathrm{RA} \simeq 170^\circ, \quad \mathrm{Dec} \simeq 40^\circ. \tag{6}$$

To quantify the detectability of such an anisotropy in future surveys we perform a synthetic hemispheric split test (our Test C), using a mock catalog of $N = 100\,000$ galaxies with redshifts drawn from a distribution similar to Euclid/LSST expectations up to $z_{\max} = 1.5$.

We inject an intrinsic dipolar anisotropy in the deceleration parameter q_0 at low redshift by imposing a hemispheric difference

$$\Delta q_0^{(\mathrm{intr})} \equiv q_{0,\mathrm{North}} - q_{0,\mathrm{South}} = 0.05, \tag{7}$$

restricted to sources with $z \leq 0.7$, while keeping the population with $z > 0.7$ isotropic. Observational noise in the individual estimates of q is modeled as a Gaussian scatter with $\sigma_q = 0.03$, representative of current SNe-based reconstructions.

We then compute an effective hemispheric difference $\Delta q_0^{(\mathrm{eff})}$ over the full sample for the Siamese axis and for 2000 random axes uniformly distributed over the sky. This Monte Carlo defines a null distribution of Δq_0 expected from statistical noise and high-redshift dilution alone.

3.2 Results of the synthetic hemispheric split

The resulting distribution of Δq_0 for random hemispheric orientations is well approximated by a Gaussian centred at zero, with standard deviation

$$\sigma_{\mathrm{noise}} \simeq 0.0041. \tag{8}$$

This reflects the fact that the majority of sources lie at $z > 0.7$ and are isotropic by construction, so that the low-redshift dipole is strongly diluted when averaged over the full sample.

In contrast, the effective hemispheric difference recovered along the Siamese axis is

$$\Delta q_0^{(\mathrm{eff})} \simeq 0.0095, \tag{9}$$

corresponding to a z-score

$$z \;\equiv\; \frac{\Delta q_0^{(\mathrm{eff})}}{\sigma_{\mathrm{noise}}} \;\simeq\; 2.36. \tag{10}$$

None of the 2000 random orientations produced a Δq_0 as large as the Siamese axis, implying an empirical p-value $p < 5 \times 10^{-4}$ for an Euclid/LSST-like dataset under the isotropic null hypothesis.

Figure 1 visualises this result. The cyan histogram shows the null distribution of Δq_0 from random axes, while the solid red vertical line marks the Siamese-axis prediction. Even though

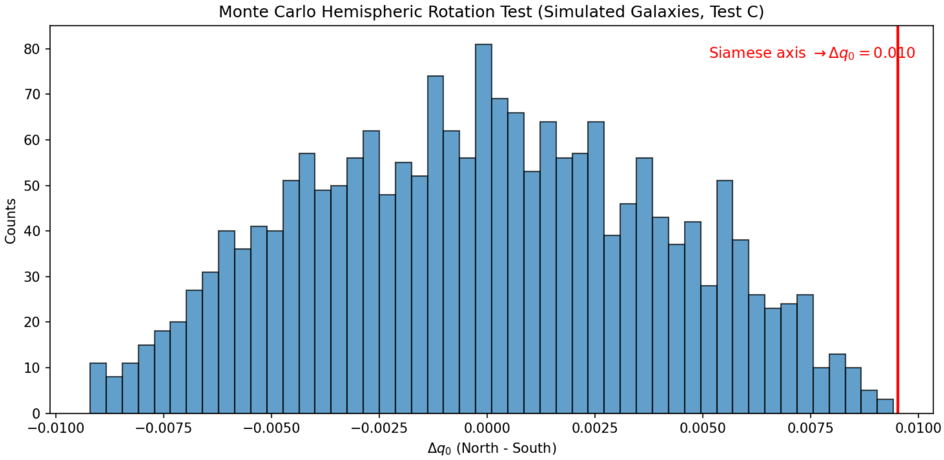

Figure 1: Synthetic hemispheric split test (Test C) for the deceleration parameter q_0. The cyan histogram shows the distribution of Δq_0 obtained from 2000 random hemispheric orientations in a Euclid/LSST-like mock catalog with $N = 100\,000$ sources, including observational noise and high-redshift dilution. The solid red vertical line marks the value recovered along the Siamese CPT axis (RA $\simeq 170°$, Dec $\simeq 40°$). Although the intrinsic low-redshift anisotropy injected was $\Delta q_0^{(\mathrm{intr})} = 0.05$ for $z \leq 0.7$, the effective projected anisotropy over the full sample is diluted to $\Delta q_0^{(\mathrm{eff})} \approx 0.01$. Despite this dilution, the Siamese signal lies at $z \simeq 2.36$ relative to the null distribution, with no random realisation reaching a comparable amplitude, indicating that a Siamese-like dipole in q_0 would be statistically distinguishable in next-generation surveys.

the intrinsic low-redshift anisotropy injected was $\Delta q_0^{(\mathrm{intr})} = 0.05$, high-redshift dilution reduces the observable projected anisotropy to $\Delta q_0^{(\mathrm{eff})} \approx 0.01$. This provides a natural explanation for why such a signal may have escaped detection in present heterogeneous samples, while remaining well within reach of upcoming homogeneous surveys.

4 Confrontation with Son & Lee (2025) CPL constraints

4.1 Phase tracks in the w_0–w_a plane

To confront the Siamese interference framework with the latest observational constraints on dark energy dynamics, we reconstruct the 68% and 95% confidence contours for the CPL parameters (w_0, w_a) reported by Son et al. (2025) for their combined BAO+CMB+DES5Y (age-bias corrected) analysis. Using the central values and covariance matrix given in their Table 2, we generate a set of points that reproduce the corresponding 2D Gaussian error ellipses in the (w_0, w_a) plane.

On top of these contours we overlay the Siamese phase trajectories obtained from Eqs. (4)–(5) for three representative phase velocities $\gamma = 1.0,\ 1.5,\ 2.0$. For each γ, we vary the present-day phase $\Delta\phi_0$ from 0 to $\Delta\phi_{\max}$, tracing a continuous curve in the (w_0, w_a) plane. The resulting comparison is shown in Figure 2.

The key feature of Figure 2 is that for a narrow band of phase velocities around $\gamma \sim 1.4$–1.5, the Siamese phase track crosses the central region of the Son & Lee contours, including their best-fit point. In contrast, ΛCDM lies well outside the 95% region, and simple thawing quintessence models do not naturally reproduce the observed slope of the (w_0, w_a) degeneracy. In the Siamese framework, the strong negative correlation between w_0 and w_a is not an arbitrary fit parameter, but a direct geometrical consequence of how the interference term decays as the phase drifts away from zero.

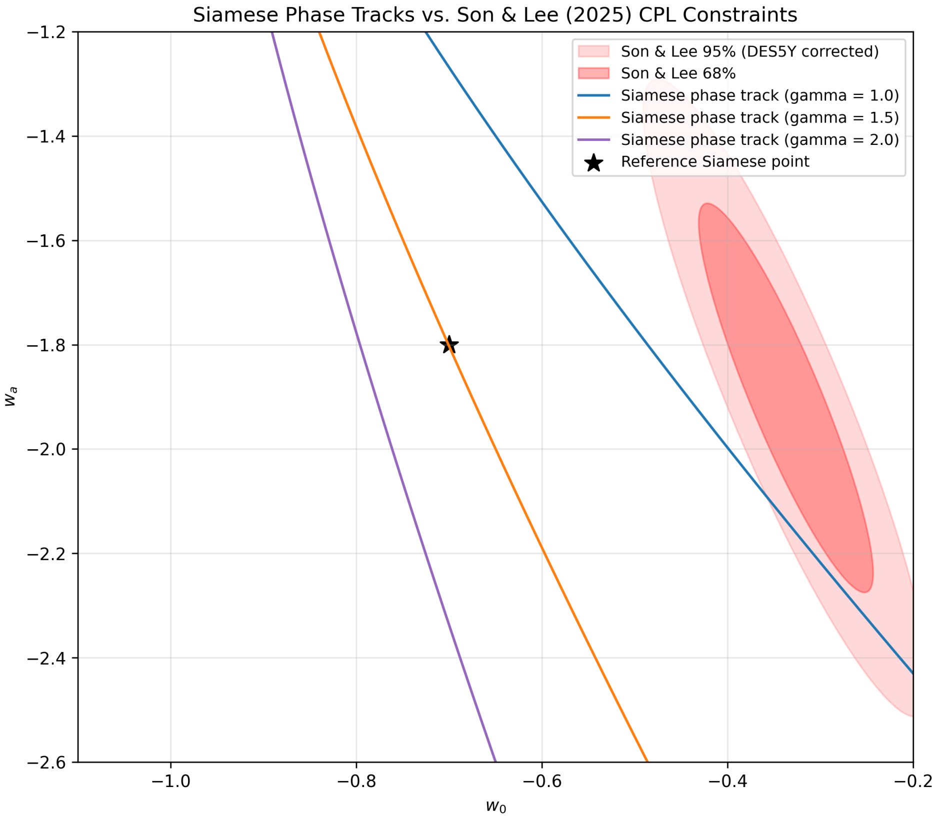

Figure 2: Confrontation of the Siamese interference model with the latest observational CPL constraints. The red shaded regions represent the 68% and 95% confidence contours in the (w_0, w_a) plane reconstructed from the BAO+CMB+DES5Y (age-bias corrected) cosmological parameters reported by Son et al. (2025, Table 2). The coloured curves show the theoretical phase trajectories predicted by the Siamese model for different phase velocities $\gamma = 1.0,\ 1.5,\ 2.0$. Each curve is generated by varying the present-day phase $\Delta\phi_0$ from 0 to $\Delta\phi_{\max} = 0.42\pi$, starting at ΛCDM $(w_0, w_a) = (-1, 0)$. The trajectory for $\gamma \simeq 1.4$–1.5 naturally traverses the core of the observational confidence region, reproducing the characteristic negative correlation between w_0 and w_a without requiring arbitrary fine-tuning of the dark energy sector. This suggests that the observed tension with ΛCDM may be an artefact of interpreting a continuous phase evolution as a static dark energy fluid.

4.2 Transient acceleration and the deceleration parameter

The CPL parameters obtained from the Siamese phase tracks can be translated into an effective Hubble history $H(z)$ and deceleration parameter $q(z)$. Figure 3 compares the normalised expansion rate $H(z)/(1+z)$ for a ΛCDM baseline (with $w_0 = -1, w_a = 0$) and for a representative Siamese model with $(w_0, w_a) = (-0.7, -1.8)$. While ΛCDM exhibits a shallow minimum at $z \simeq 0.67$ and asymptotically approaches eternal acceleration, the Siamese model displays a deeper minimum at $z \simeq 0.76$, consistent with a transition from past acceleration to a less accelerated regime.

From these histories we extract the present-day deceleration parameter q_0. For the fiducial ΛCDM baseline used here we obtain

$$q_{0,\Lambda\mathrm{CDM}} \simeq -0.55, \tag{11}$$

while the Siamese model yields

$$q_{0,\mathrm{Siamese}} \simeq -0.23. \tag{12}$$

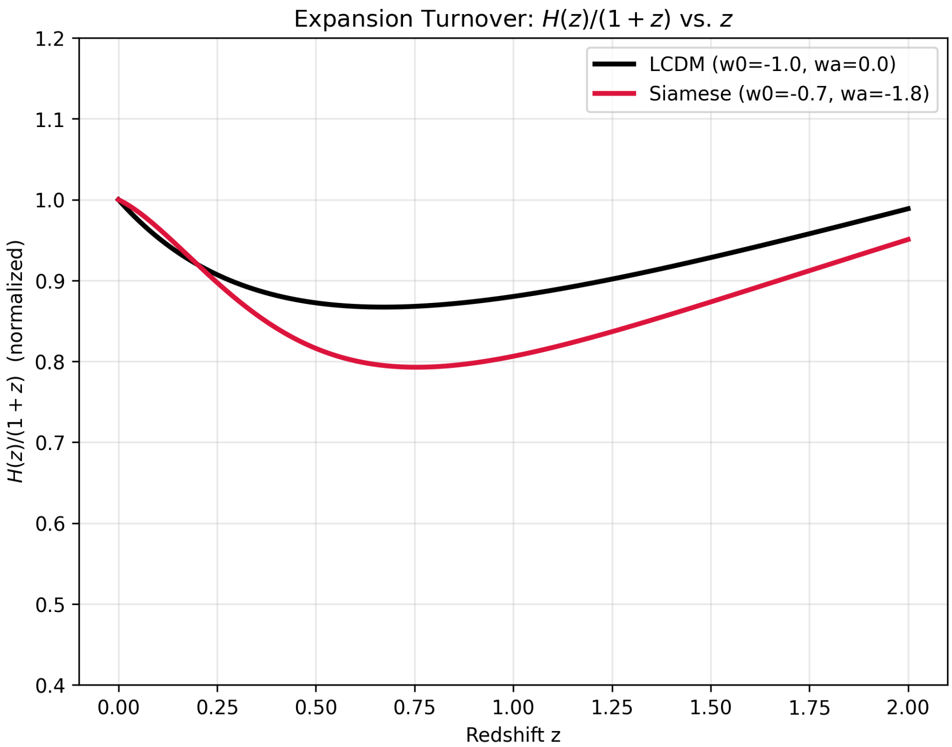

Figure 3: Normalised expansion history $H(z)/(1+z)$ for ΛCDM (blue) and a representative Siamese interference model (orange) with $(w_0, w_a) = (-0.7, -1.8)$. The ΛCDM curve exhibits a shallow minimum at $z \simeq 0.67$ and tends towards eternal acceleration. In contrast, the Siamese model shows a deeper minimum at $z \simeq 0.76$, reflecting the decay of the interference term $\cos[\Delta\phi(a)]$ and signalling a transition away from strong acceleration.

Son & Lee report values consistent with a non-accelerating or mildly decelerating Universe, with their best-fit DES5Y-corrected reconstruction indicating $q_0 \sim 0.18 \pm 0.06$. Figure 4 compares our theoretical curves for $q(z)$ with the interval suggested by Son & Lee.

It is important to emphasise that we do not claim a perfect numerical fit to the Son & Lee deceleration constraint in this Letter. Our fiducial Siamese model still predicts a mildly negative q_0 today, and there remains a quantitative tension with the current best-fit $q_0 > 0$. However, in contrast to ΛCDM, the Siamese framework naturally drives q_0 towards positive values as the phase evolves, without introducing additional free functions in the dark energy sector. In this sense, the model provides a mechanism for the observed drift in q_0, rather than a post-hoc parameterisation.

5 Discussion and conclusions

The recent analysis by Son et al. (2025) has revealed a significant tension between the standard ΛCDM paradigm and combined BAO+CMB+SNe datasets, particularly when progenitor age-bias in supernova cosmology is carefully corrected. Their CPL fits strongly disfavour a strictly constant dark energy density and instead point towards a late-time Universe exiting its phase of acceleration. This raises two immediate questions: what dynamical mechanism could drive such a transition, and how can we distinguish between competing explanations?

In this work we have shown that a CPT-symmetric Siamese interference framework offers a concrete, falsifiable answer to both questions. On the one hand, an evolving phase $\Delta\phi(a)$ between twin universes naturally generates a transient interference term in the dark sector, reproducing the negative correlation between w_0 and w_a inferred by Son & Lee. For a narrow

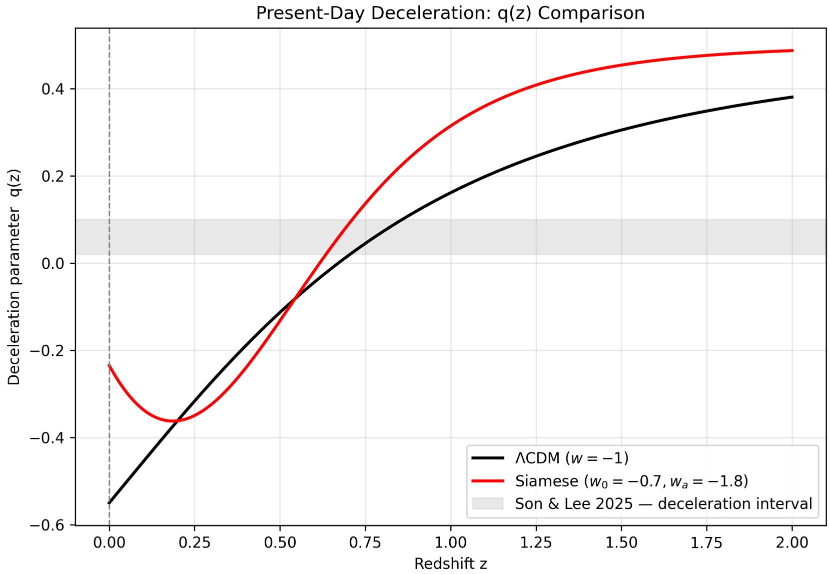

Figure 4: Deceleration history $q(z)$ for ΛCDM (blue) and the Siamese interference model (orange), compared with the present-day interval inferred by Son & Lee (2025) from their BAO+CMB+DES5Y analysis (shaded band around $z \simeq 0$). While ΛCDM remains firmly in the accelerating regime with $q_0 \simeq -0.55$, the Siamese model predicts a much less negative value $q_0 \simeq -0.23$, indicating that the Universe is already moving towards a decelerating phase. Our fiducial model does not yet match the positive q_0 central value preferred by Son & Lee, but it provides the correct qualitative trend and an explicit dynamical mechanism: as the phase $\Delta\phi(a)$ continues to drift, the interference term decays further and q_0 eventually crosses zero.

range of phase velocities $\gamma \simeq 1.4$–1.5, the Siamese phase tracks traverse the core of the (w_0, w_a) confidence region, while ΛCDM is excluded at high significance. On the other hand, the very same mechanism breaks isotropy in a predictable way, imprinting a dipolar modulation in the late-time expansion history aligned with a fixed CPT-symmetry axis.

Our synthetic hemispheric forecasts indicate that a modest intrinsic anisotropy of order $\Delta q_0^{(\mathrm{intr})} \sim 0.05$ at low redshift, aligned with the Siamese axis (RA $\simeq 170°$, Dec $\simeq 40°$), would survive high-redshift dilution and observational noise as an effective projected signal $\Delta q_0^{(\mathrm{eff})} \sim 0.01$. Even after this dilution, the Siamese axis stands out at $z \simeq 2.36$ from the null distribution of random orientations in an Euclid/LSST-like catalog, with no random realisation reaching a comparable amplitude. This defines a clear observational target for next-generation surveys: if the deceleration suggested by Son & Lee is of Siamese origin, a hemispheric asymmetry in q_0 aligned with the CPT axis should be detectable at more than 2σ significance in the near future.

We therefore advocate the following interpretation and observational programme. If the deceleration signal reported by Son & Lee arises merely from supernova population drift or unresolved astrophysical systematics, then independent distance probes such as standard sirens (gravitational-wave events) should revert to the ΛCDM prediction $q_0 < 0$ and show no preferred hemispheric axis. Conversely, if the signal stems from a fundamental decay in the effective dark energy density driven by phase interference, as in the Siamese framework, both standard candles and standard sirens should converge on a transient deceleration with a coherent dipole aligned with the Siamese axis. In that case, the accelerating Universe would not be a static feature of the vacuum, but a temporary interference pattern within a larger CPT-symmetric structure.

Ultimately, while both scalar-field interpretations and the Siamese framework can, in principle, accommodate a decelerating late Universe, only the latter predicts a fundamental hemispheric anisotropy aligned with a CPT-symmetry axis, transforming the question of cosmic acceleration from a purely temporal debate into a falsifiable geometric test. Upcoming data from Euclid, LSST/Rubin, DESI and future gravitational-wave observatories will have the power to confirm or refute this picture within the next decade.

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