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δ-CDM

A Minimal Deformation of ΛCDM with Scalar Field Reconstruction

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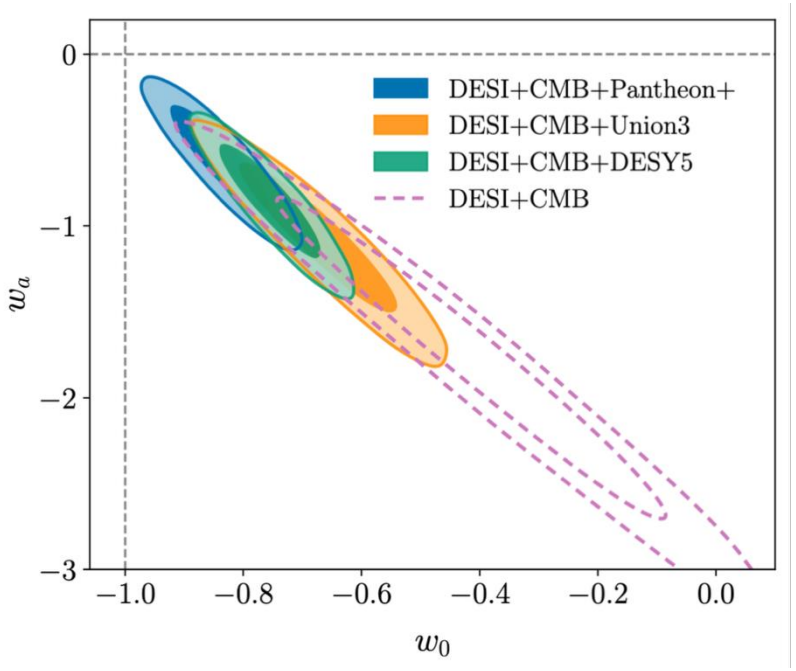
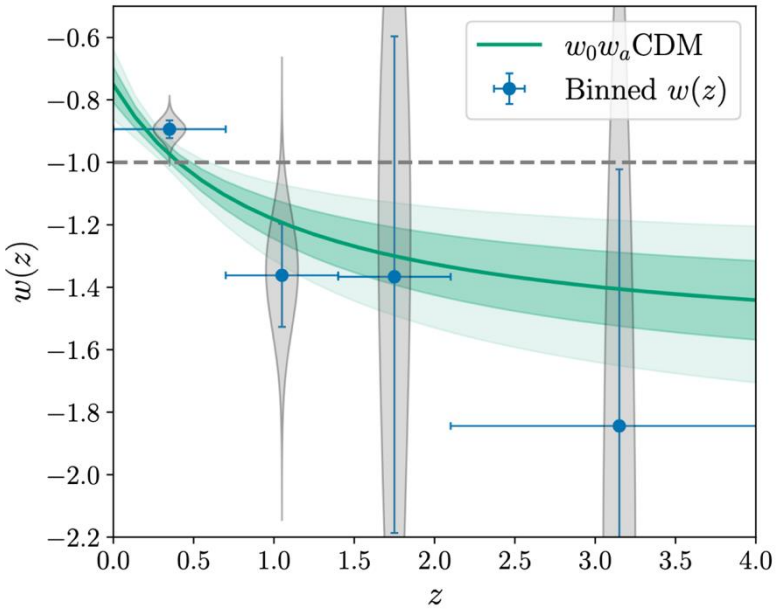
Motivation: DESI hints at evolving dark energy

DESI Collaboration, arXiv:2503.14738 (2025)





The w_0w_a parametrization captures a possible evolution of dark energy but does not specify its underlying physical origin.

- CPL form: $w(a) = w_0 + w_a(1 - a)$
- ΛCDM is a single point: $w_0 = -1$, $w_a = 0$

- Best-fit regions suggest evolution across the phantom divide, $w = -1$.
- For canonical single-field quintessence, smooth crossing is not available without extra physics.

δ-CDM: deform ΛCDM with a physical handle

Problem with a pure parametrization

w_0w_a is excellent for fitting data, but its parameters are not tied to a unique scalar field, fluid microphysics, or modified-gravity action.

$$w\_de(z) = -1 + \delta(z)$$

$$\delta(z) = 0 \Rightarrow \Lambda CDM$$

δ(z) is a controlled redshift-dependent deviation. The task is to reconstruct it from an underlying physical model, then test the resulting effective fluid against data.

Scalar-field reconstruction: same δ(z) from quintessence and phantom

Unified scalar field
ε = +1: quintessence
ε = −1: phantom

→

Thawing limit
w ≈ −1 early
small late departure

→

Fluid EoS
test with data

$$\delta(z) = \tilde{w}_a(1+z)^{\tilde{w}_0}$$

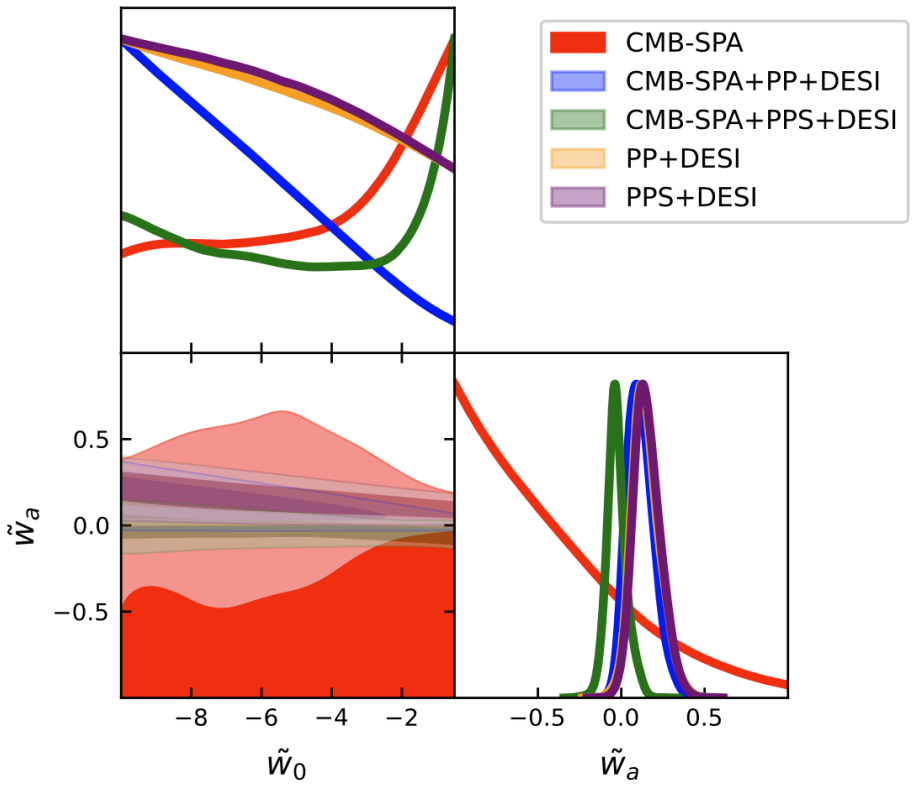
$$W_{de}(z) = -1 + \tilde{w}_a(1+z)^{\tilde{w}_0}$$

- The reconstructed δ(z) does not depend on the switching parameter ε.
- Therefore, the same effective form is obtained from thawing quintessence and thawing phantom inputs.
- After reconstruction we treat the model as a fluid; this makes it a platform for other physics, not only one scalar-field example.

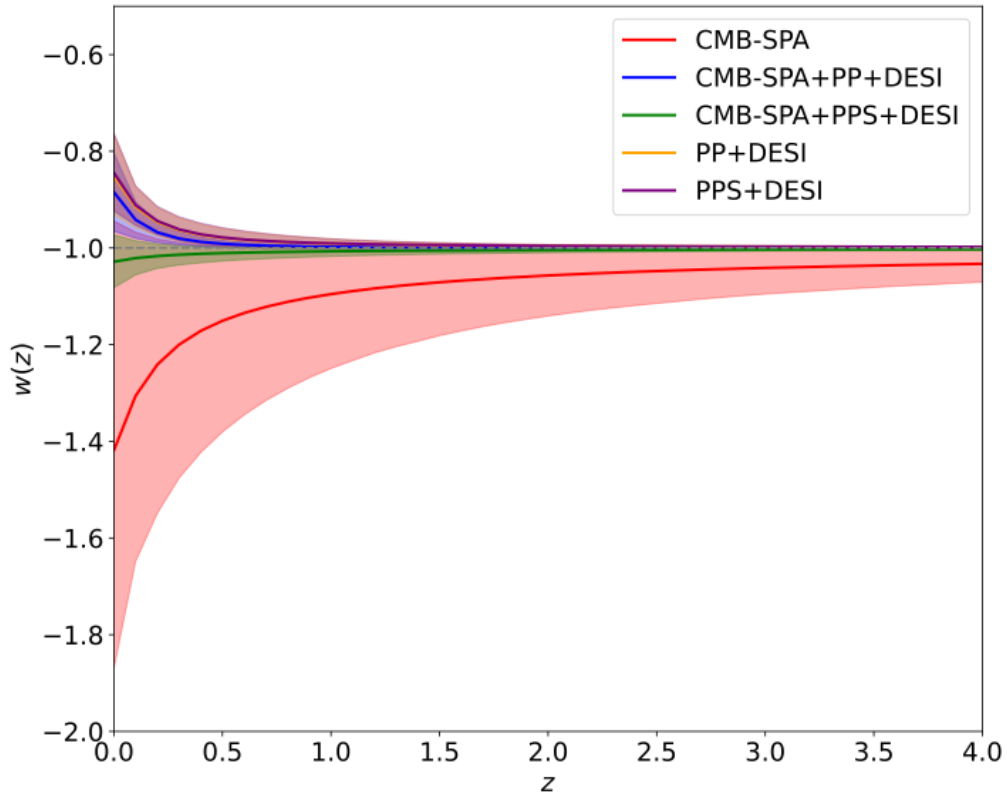
Our δ-CDM constraints and reconstructed evolution

Figures from this work

Parameter constraints for δ-CDM



Reconstructed w(z)



Most datasets stay close to w = −1; CMB-SPA tends phantom-like, while low-redshift combinations favor mild quintessence-like behavior.

Model comparison

Model / dataset	$\Delta\chi^2_{min}$	ΔAIC
w_0w_a · CMB-SPA+PP+DESI	−8.3	−4.3
w_0w_a · CMB-SPA+PPS+DESI	−12.6	−8.6
δ-CDM · CMB-SPA+PP+DESI	−1.1	+2.9
δ-CDM · PP+DESI	−3.2	+0.8
δ-CDM · PPS+DESI	−3.5	+0.5

- δ-CDM gives a physically motivated minimal deformation of ΛCDM.
- The framework can be extended to other dark-energy and modified-gravity models.