Quintessential Dark Energy crossing the PHANTOM DIVIDE

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Based on [2508.19101]

1

Motivation

What is the evidence for Dynamical Dark Energy?

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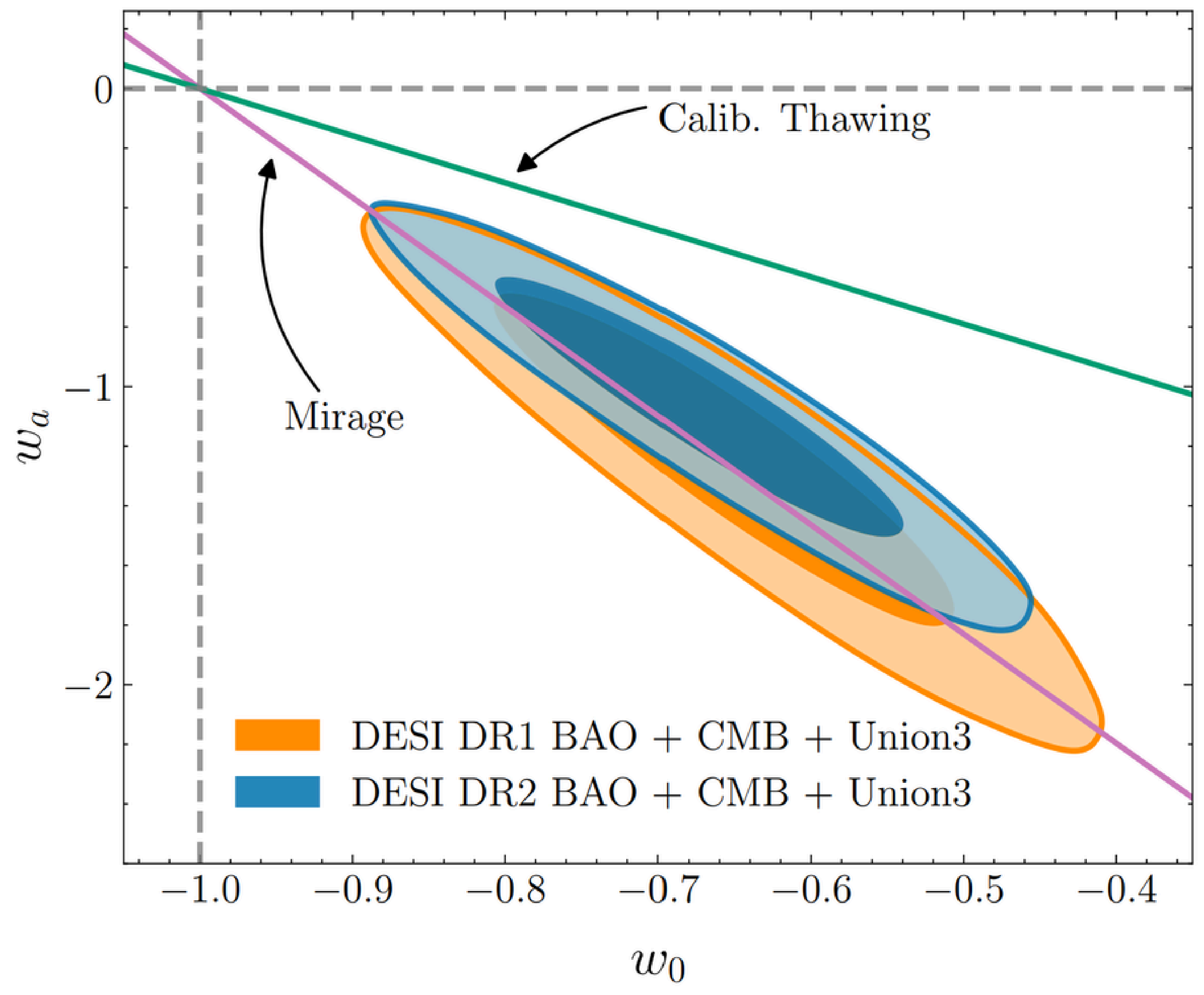

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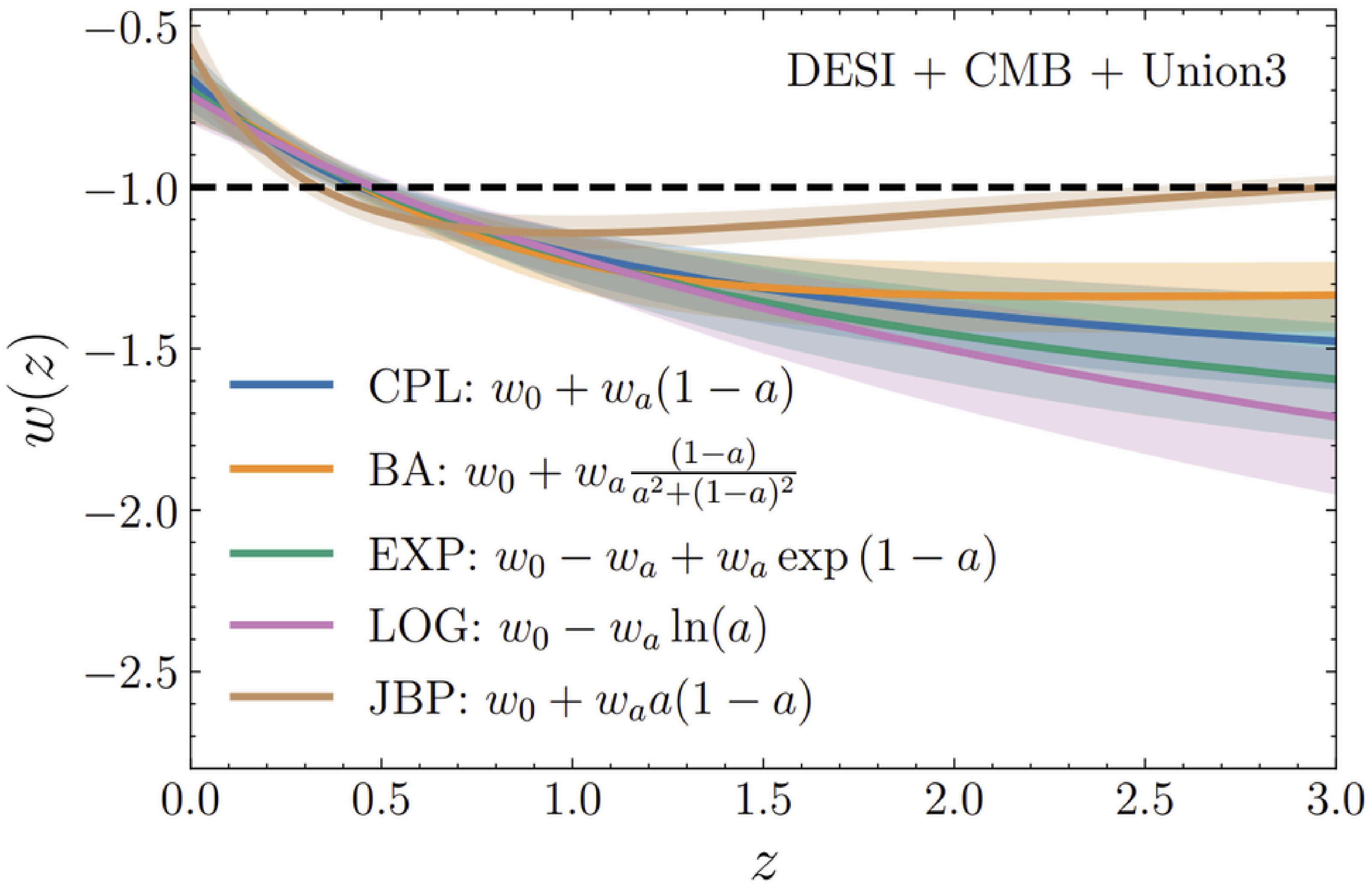

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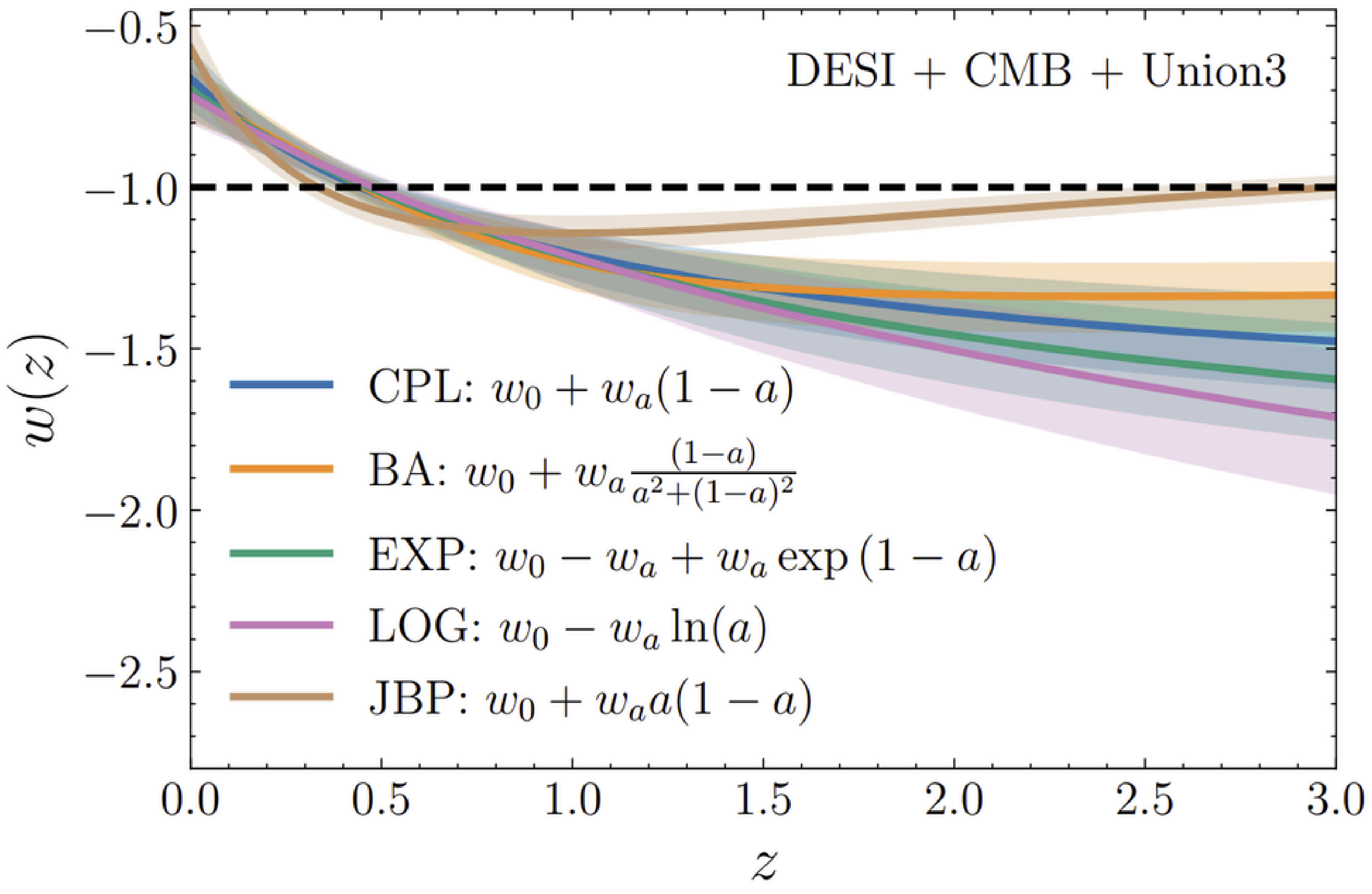
Dark Energy is not only dynamical but also has an equation of state < -1.

Violates the Null Energy Condition (NEC)

$$\rho + p \geq 0.$$



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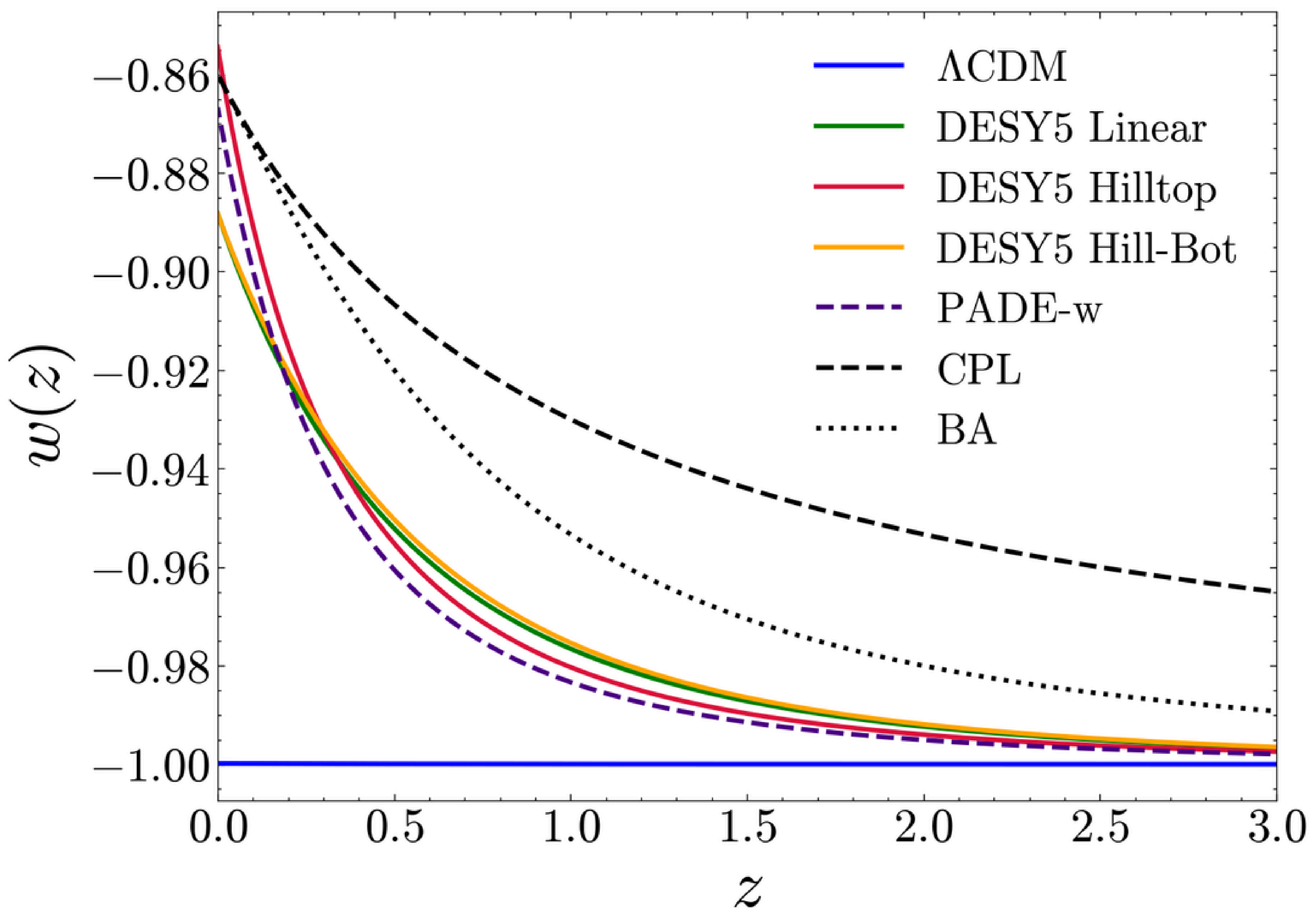
→ Unphysical!

Quintessence Field

Figure from 2506.13047.



Equation of state vs redshift for quintessence models. The PADE-w parametrization with $\epsilon_0 = 0.2, \eta_0 = 3$ and CPL and BA with $w_0 = -0.86, w_a = -0.14$ are also shown.

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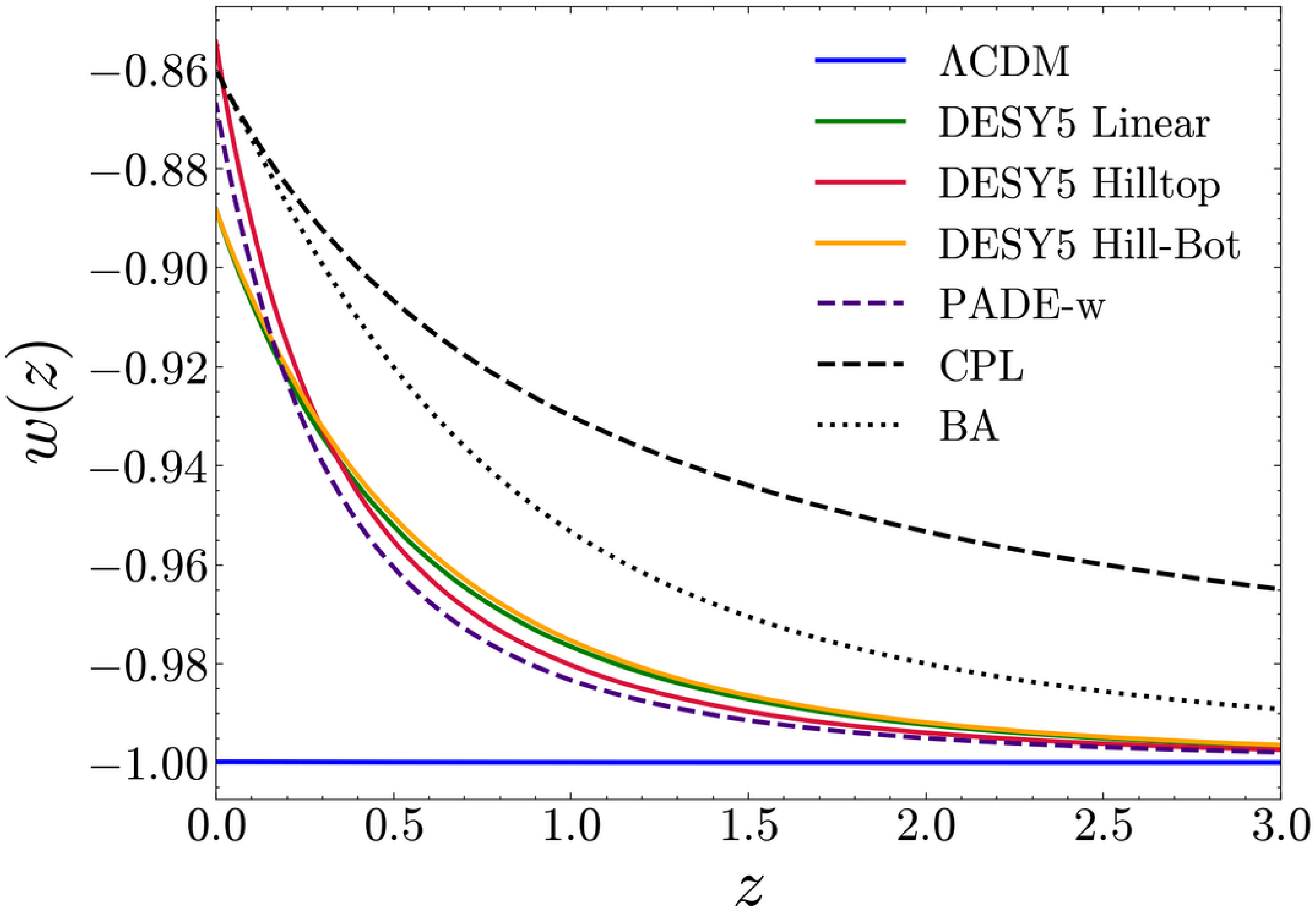

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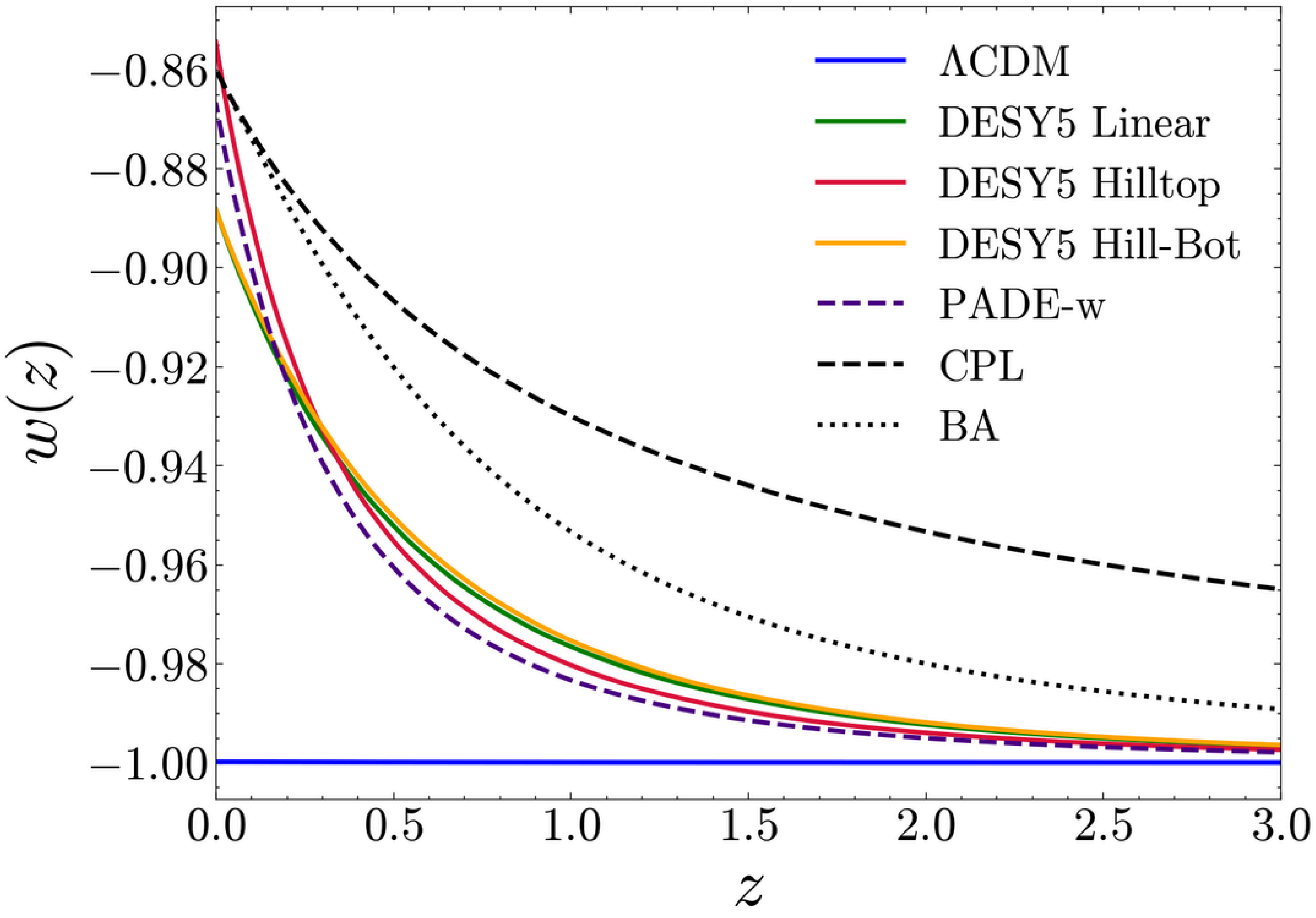

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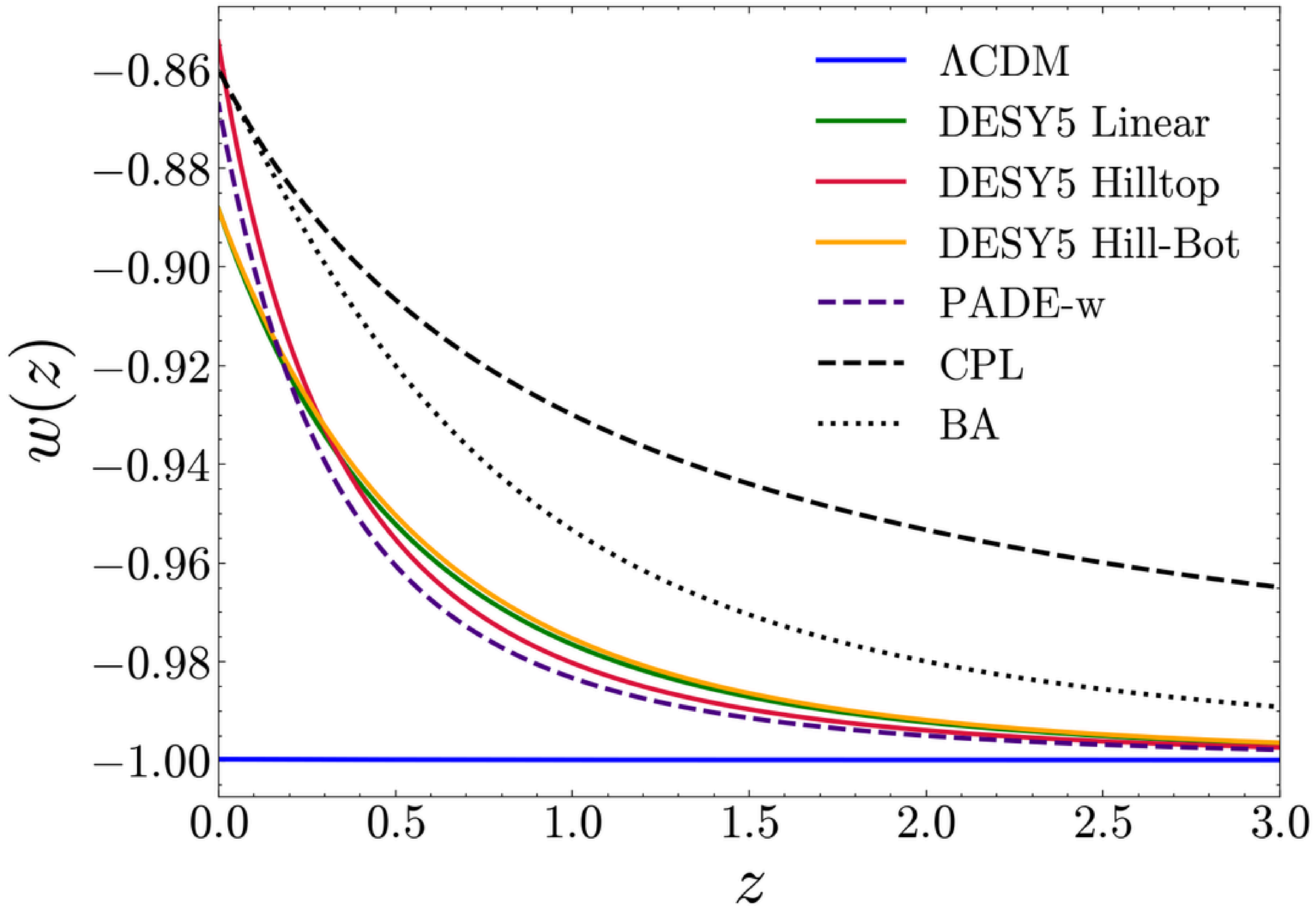

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Need phantom crossing to explain DESI results!

2

Motivation

How could one get
Phantom ($w < -1$) Dark Energy?

Interacting DM-DE

Suppose the dark matter mass varies with the field, which could occur through renormalizable operators such as $\phi^2 S^2$ for scalar DM or $\bar{\chi}\phi\chi$ for fermionic DM (Farrar and Peebles, 2003).

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Where,

$$V_{\rm eff} = V(\phi) + \rho^0_{\rm dm} a^{-3}(g(\phi) - 1) = V(\phi) + \bar{g}(\phi) a^{-3}.$$

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Hence, the effective equation of state of dark energy becomes

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Thus, the dark energy "effectively" crosses into the phantom regime as the field evolves and the dark matter was less massive in the past.

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Analysis

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4 free parameters including the initial field velocity π_0.

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Datasets used

- Planck 2018 CMB + Lensing
- DESI 2024 BAO
- Union3 Type 1A SN.

Results

Dataset	$\Delta\chi^2$	ΔAIC	H_0
Scalar	-12.1	-3.1	$-66.55^{+0.81}_{-0.81}$
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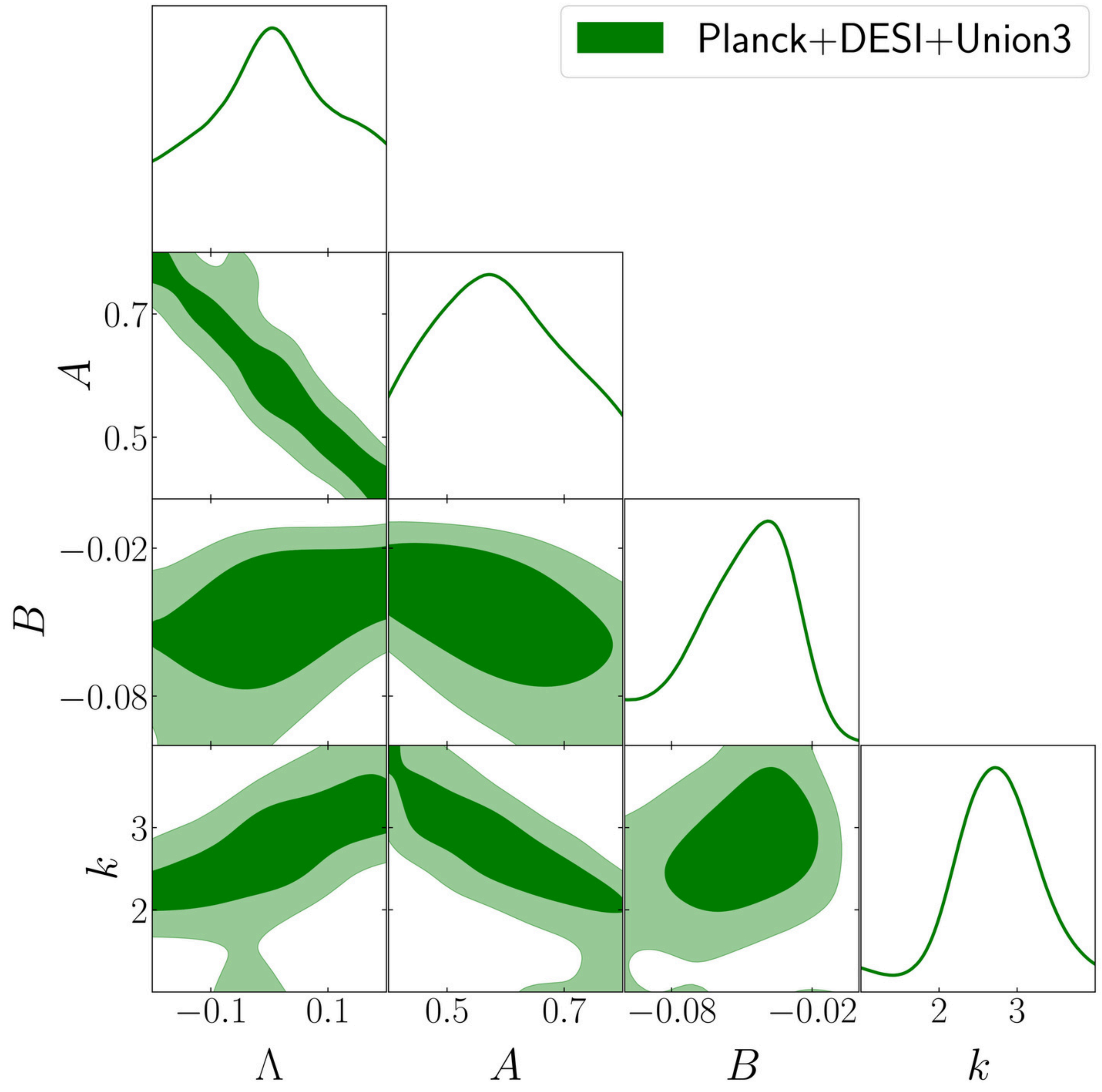

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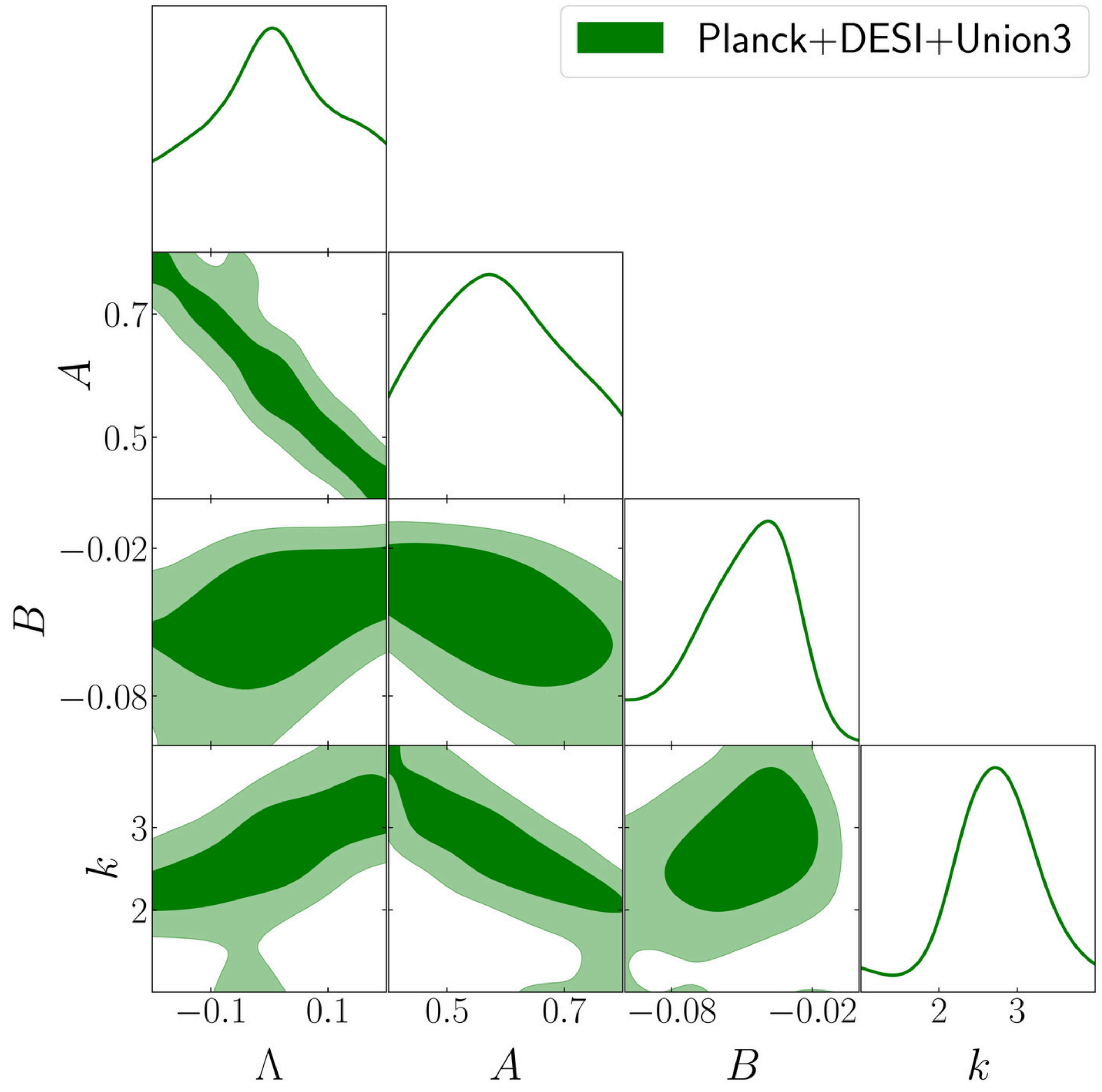

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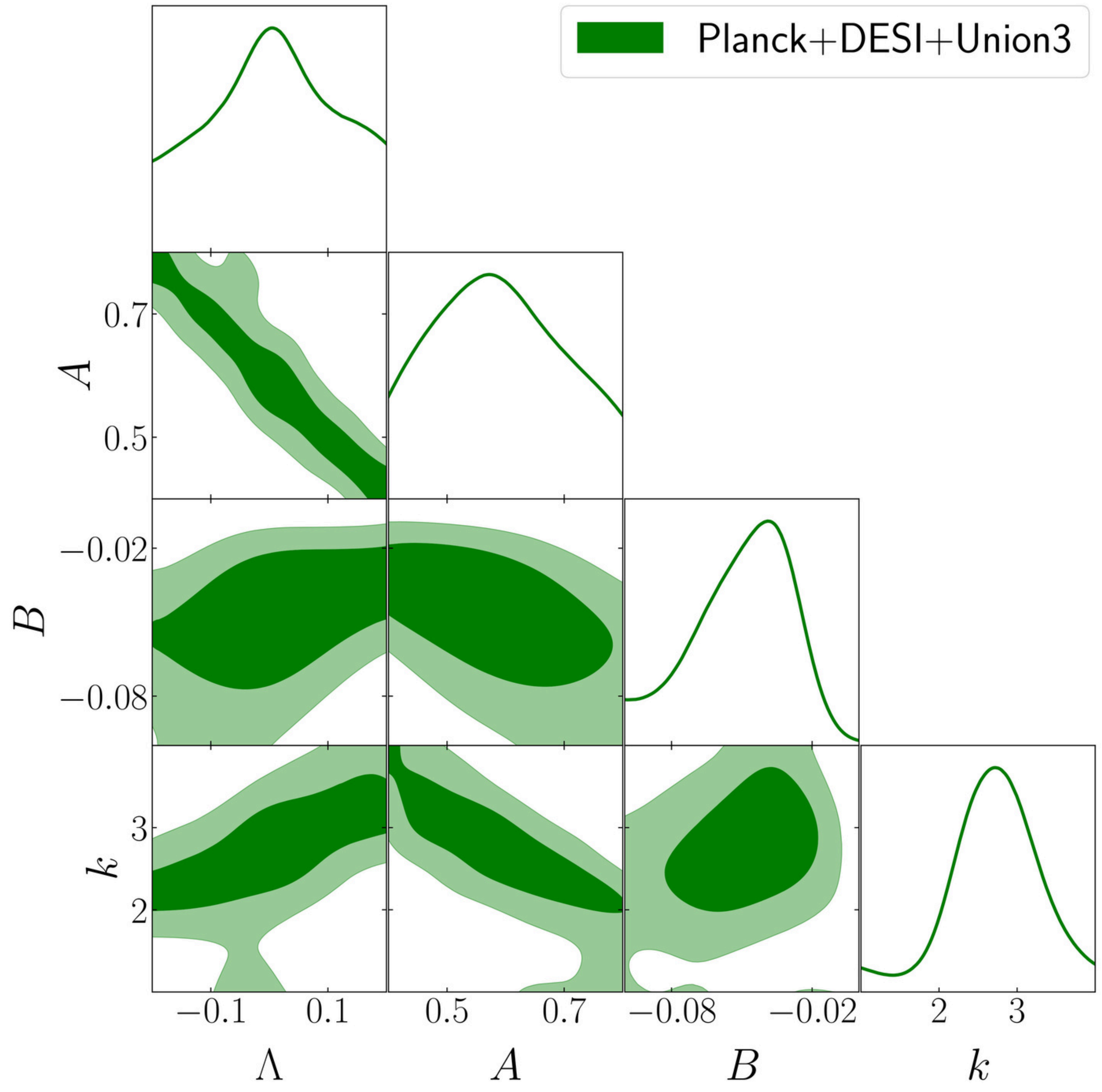
But there's also another catch!



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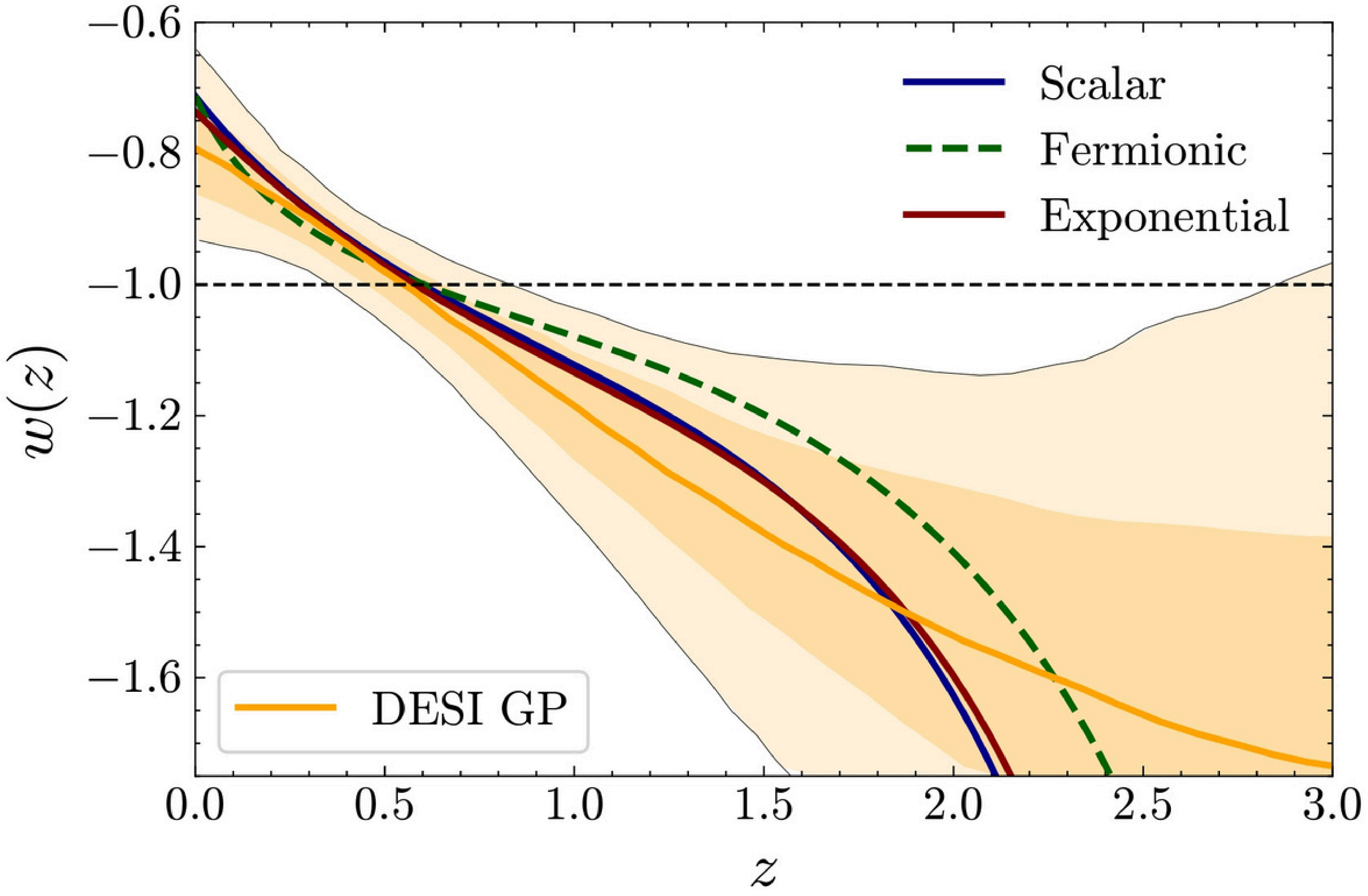

Equation of state vs Redshift for the 3 models. The DESI Gaussian processs (GP) reconstructed 1σ and 2σ contours are given in yellow.

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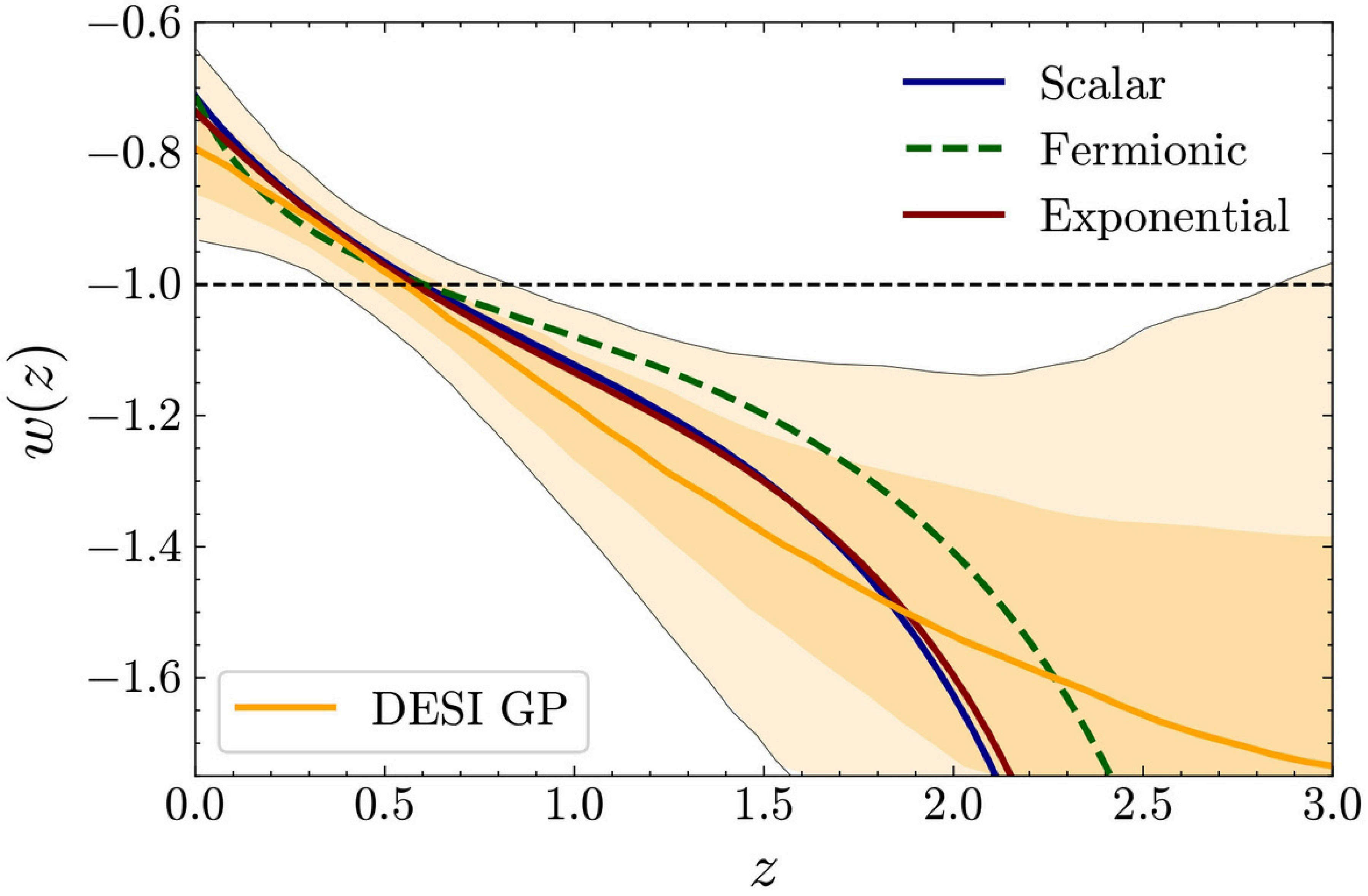

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The 3 models cross into the phantom regime around redshift 0.5 just like DESI and recreate the evolution history upto $z \approx 2.5$.

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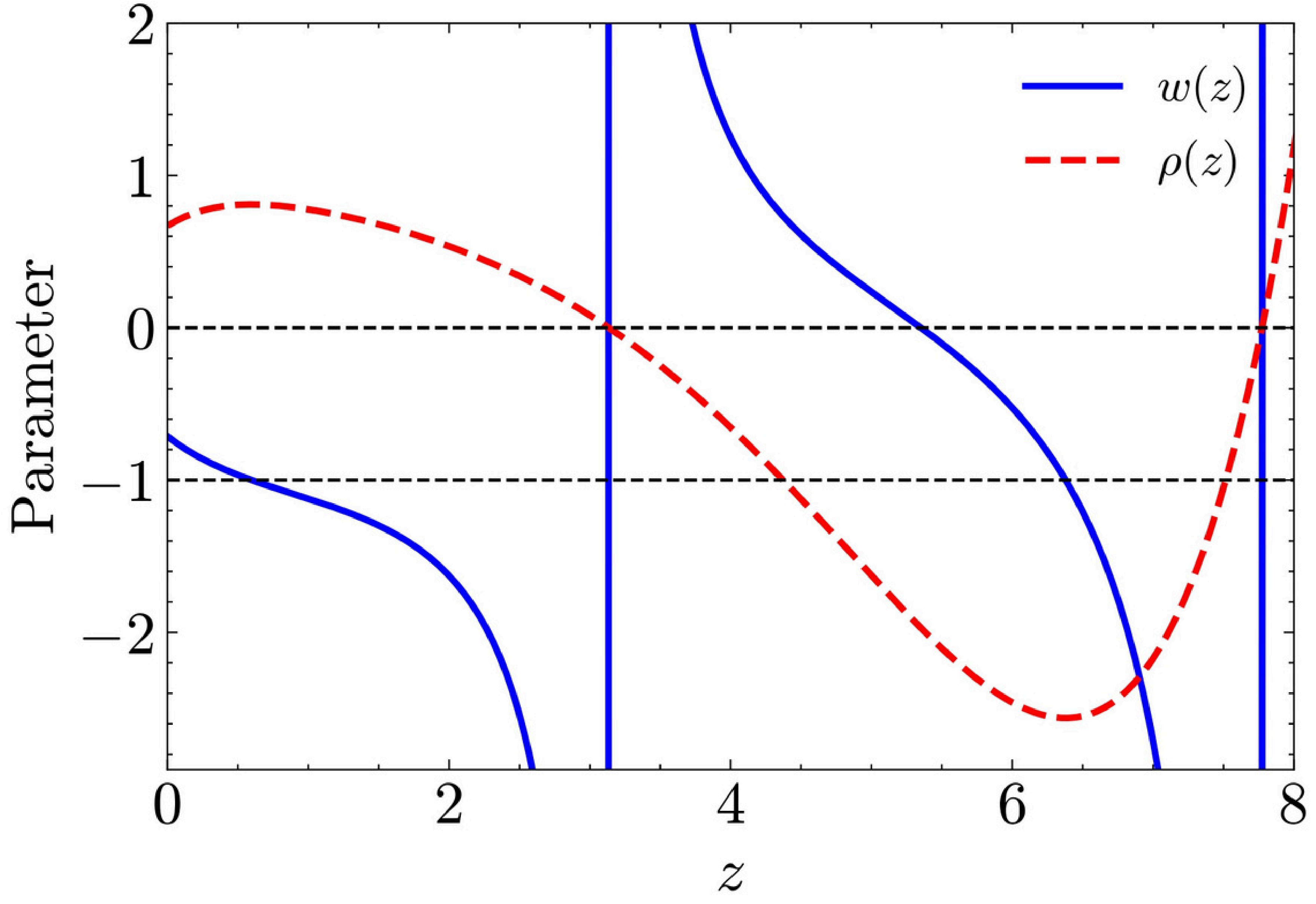

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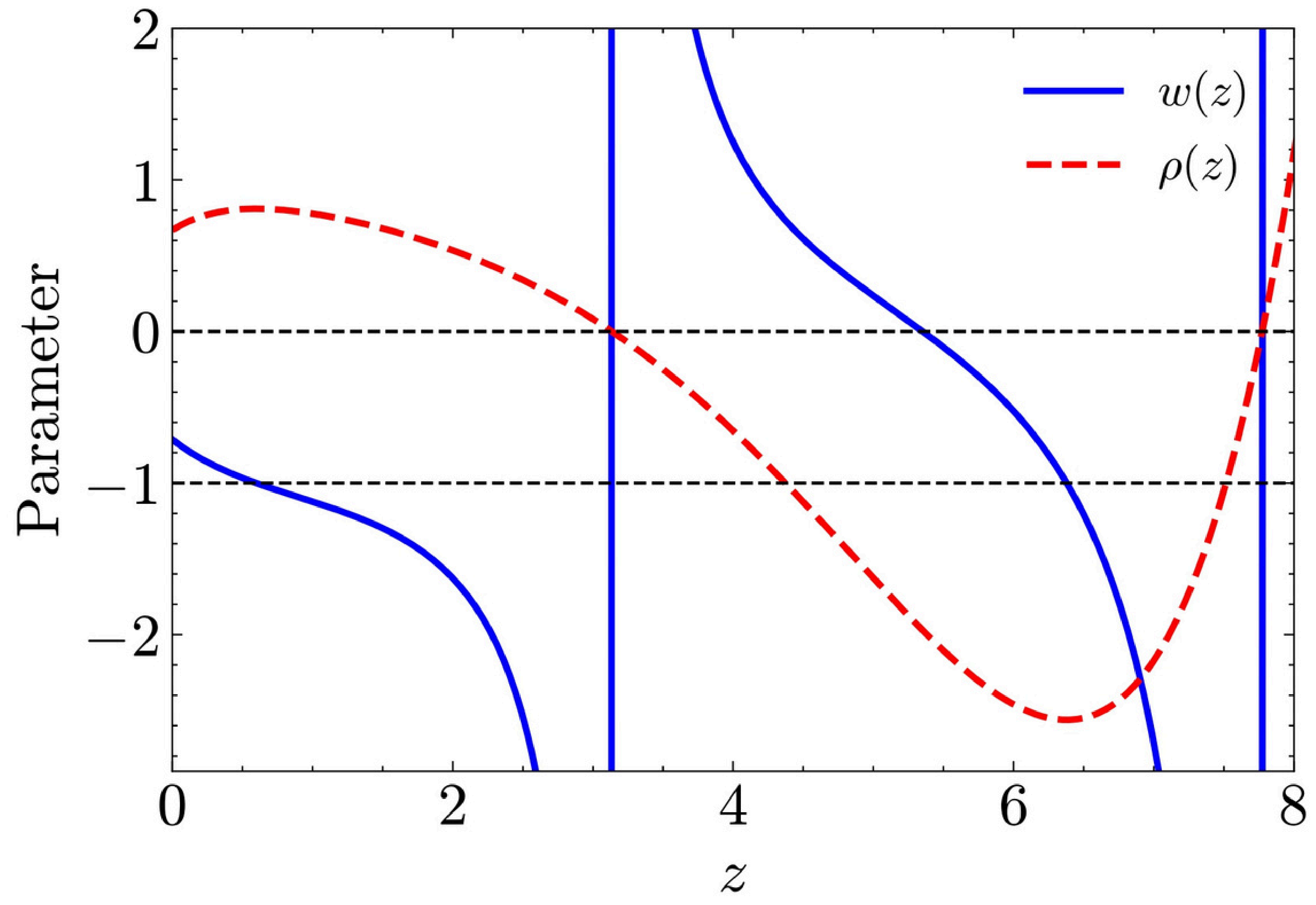

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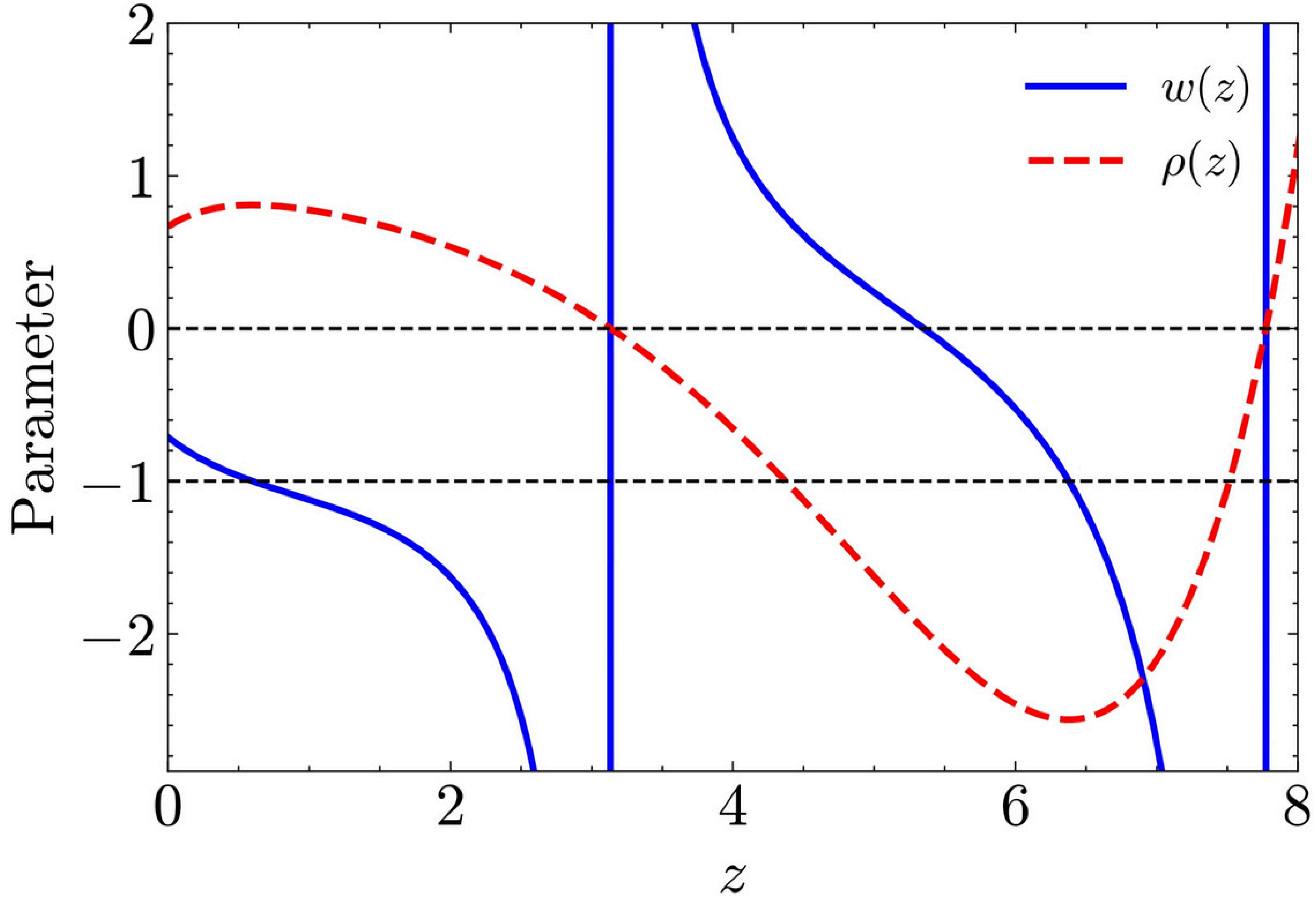

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But wait, there's more!

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Model	β
Scalar	$\gtrsim 0.6$
Fermionic	0.03
Exponential	$0.006 - 0.01$

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Discussion

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- Almost all phantom models make the Hubble tension worse. True even for parametrizations :(.

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    - Systematic Errors? [2504.16932]

Thank You!