Theoretical implications of DESI BAO: the case for Non-minimal Coupling

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23/06/2026

based on:

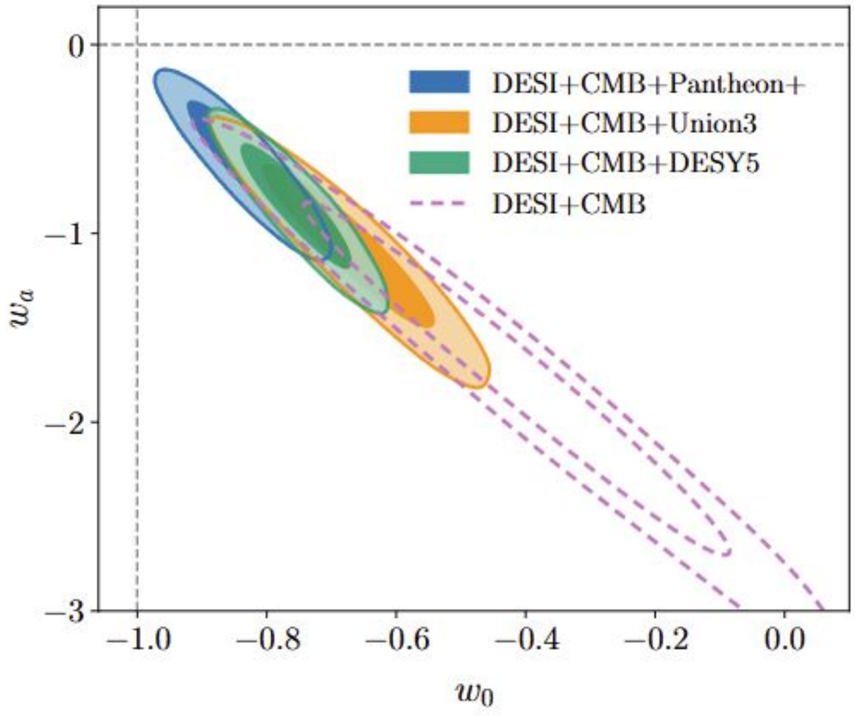
G. Ye, MM, B. Hu, A. Silvestri PRL (2025)

The observational context

DESI BAO results, in combination with external datasets, highlighted a tension with ΛCDM when assuming a CPL parametrization for DE

$$w(a) = w_0 + w_a(1 - a)$$

Internal tests of DESI data have shown this tension to be stable: no easy systematic effect explanation



DESI Collaboration (2025)

Tension with a cosmological constant

The tension is stable also across data combination, with different degrees of statistical significance.

Datasets	$\Delta\chi^2_{\rm MAP}$	Significance	Δ(DIC)
DESI	-4.7	1.7σ	-0.8
DESI+$(\theta_*, \omega_{\rm b}, \omega_{\rm bc})_{\rm CMB}$	-8.0	2.4σ	-4.4
DESI+CMB (no lensing)	-9.7	2.7σ	-5.9
DESI+CMB	-12.5	3.1σ	-8.7
DESI+Pantheon+	-4.9	1.7σ	-0.7
DESI+Union3	-10.1	2.7σ	-6.0
DESI+DESY5	-13.6	3.3σ	-9.3
DESI+DESY3 (3×2pt)	-7.3	2.2σ	-2.8
DESI+DESY3 (3×2pt)+DESY5	-13.8	3.3σ	-9.1
DESI+CMB+Pantheon+	-10.7	2.8σ	-6.8
DESI+CMB+Union3	-17.4	3.8σ	-13.5
DESI+CMB+DESY5	-21.0	4.2σ	-17.2

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Beware of DES recalibration!

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$$\ln \mathcal{Z} = \langle \ln \mathcal{L} \rangle_{\mathcal{P}} - \mathcal{D}_{\mathrm{KL}}$$

goodness of fit

Ockham penalty

	This Work (Bayesian)		DESI Collab. (Frequentist)	
Dataset	$\ln B$	Significance	$\Delta\chi^2_{\mathrm{MAP}}$	Significance
DESI DR2 + CamSpec (lensing) + Pantheon+	-1.70 ± 0.26	n/a	-10.7	2.8σ
DESI DR2 + CamSpec (lensing) + Union3	$+1.37 \pm 0.27$	$2.23 \pm 0.15\,\sigma$	-17.4	3.8σ
DESI DR2 + CamSpec (lensing) + DES-Dovekie	-0.30 ± 0.19	n/a	—	—
DESI DR2 + CamSpec (lensing) + DES-SN5YR	$+3.32 \pm 0.27$	$3.07 \pm 0.10\,\sigma$	-21.0	4.2σ

Ong, Yallup, Handley (2026)

It is not Λ… is this good or bad?

Even with a rescaled Bayesian evidence, the results are exciting! We have a first hint of something different from Λ

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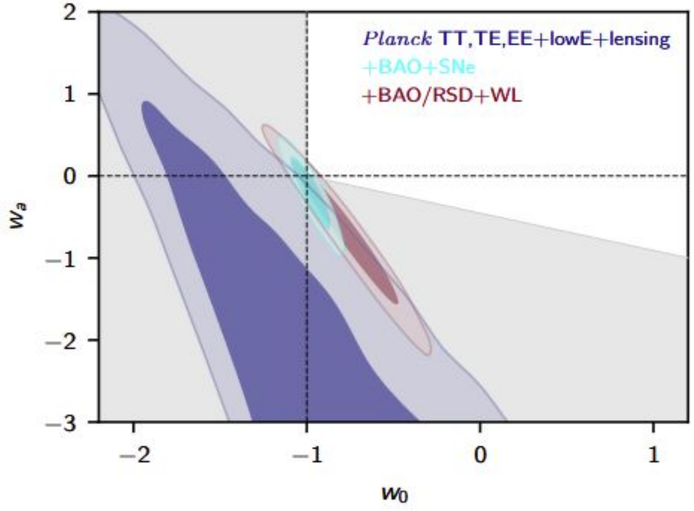

Planck Collaboration (2020)

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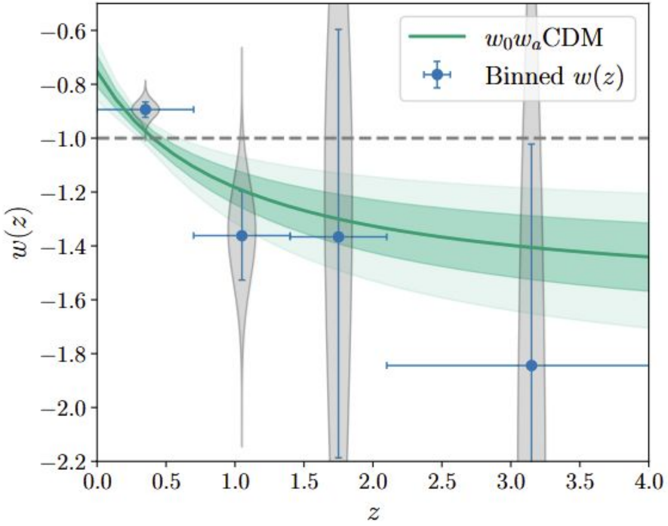
K-essence model can give w<-1, but here we an additional problem: phantom crossing

Both quintessence and K-essence have troubles crossing w=-1 without ghosts or instabilities



DESI Collaboration (2025)

Going beyond simple scalar field: Horndeski theories

We need something that goes beyond our most simple alternatives to Λ

One way to account for a whole class of model is the EFT of DE, which encodes the Lagrangian of models belonging to the Horndeski class, i.e. the most general scalar-tensor theory of gravity with second-order derivatives

$$S = \int d^4x\sqrt{-g}\left\{\frac{m_0^2}{2}\left[1+\Omega(\tau)\right]R + \Lambda(\tau) - c(\tau)a^2\delta g^{00} + \right.$$
$$\left. + \gamma_1(\tau)\frac{m_0^2 H_0^2}{2}(a^2\delta g^{00})^2 - \gamma_2(\tau)\frac{m_0^2 H_0}{2}(a^2\delta g^{00})\delta K^\mu_\mu \right\} + S_m[g_{\mu\nu}, \chi_i]$$

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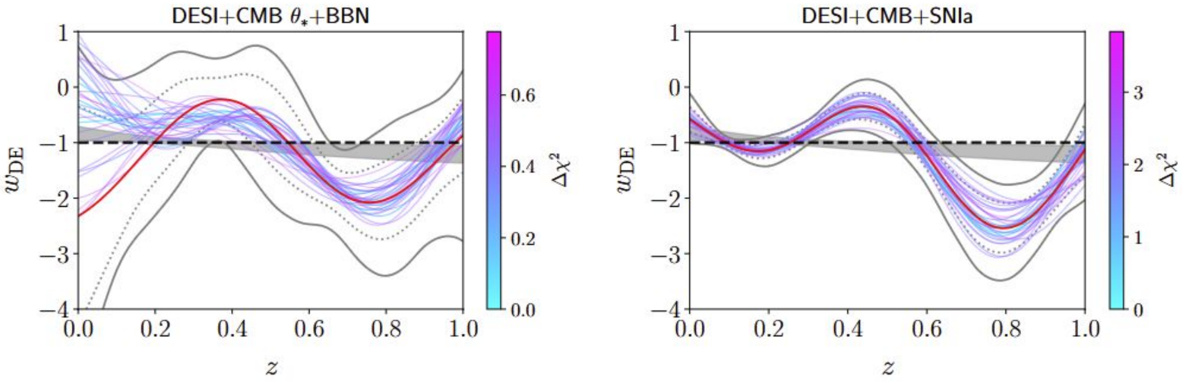
non-minimal coupling

sign of non-standard kinetic terms

Our setup

- We exploit EFTCAMB, a CAMB-based Boltzmann solver that implements the EFT of DE/MG, also allowing to include theoretical priors
- We combine DESI (DR1), CMB (both background and full) and Pantheon+ data
- We first constrain a binned w(z) model, recovering the phantom crossing found by DESI



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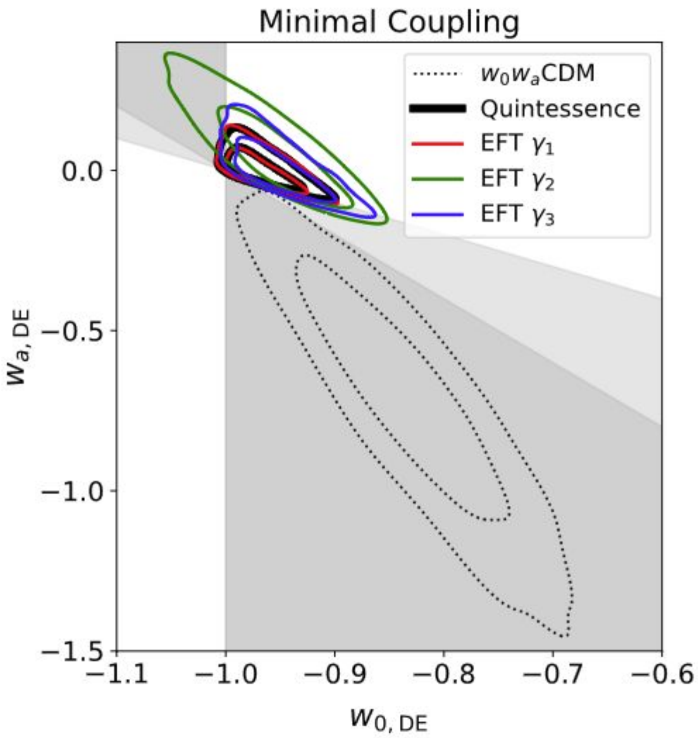
Testing minimally coupled models

We first test models where the background is described by CPL, but including theoretical priors.

As expected, single field quintessence ($\Omega=\gamma_i=0$) does not recover the DESI contours.

Also allowing for perturbations operators ($\Omega=0$, $\gamma_i\neq0$) to be free does not solve the issue.

We need to allow for a non-vanishing Ω, i.e. non-minimal coupling.



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A specific model: thawing gravity

These results suggest that we need a non-minimal coupling.

In addition to the EFT parametrization, we also explore a specific model, Thawing Gravity

$$L = \frac{M_p^2}{2}\left[1 - \xi(\phi/M_p)^2\right] R + X - V_0 e^{-\lambda\phi/M_p}$$

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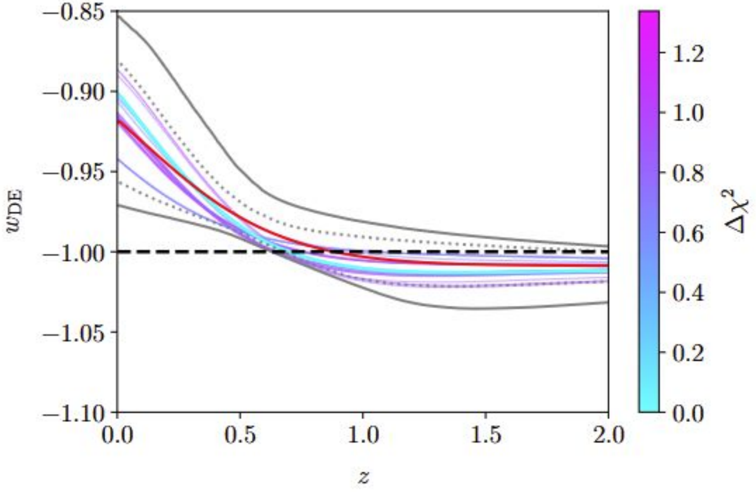

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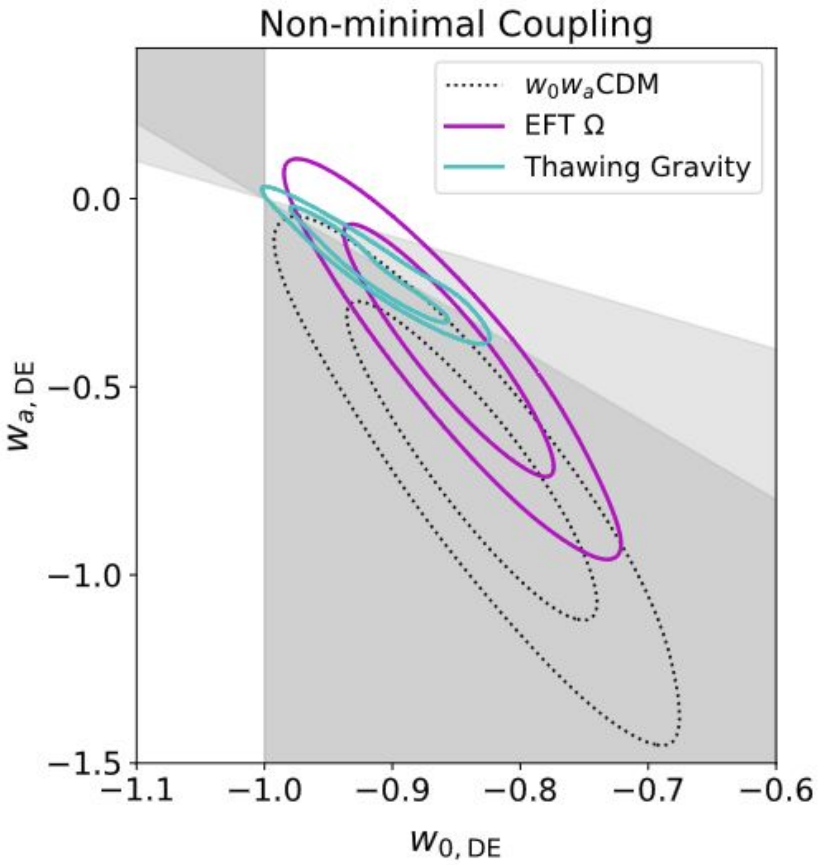
A possible solution

We test both the thawing gravity model and a more generic non-minimally coupled scalar field.

The former yields tight constraints, given the specific nature of the model.

Broader constraints are obtain with the latter, and a non-vanishing Ω allows us to recover contours similar to the CPL ones.



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Conclusion

- DESI data, in combination with external surveys give an exciting hint for a DE not due to a cosmological constant
- While a full Bayesian analysis lowers the significance, this is an interesting features
- When trying to connect the results to a theoretical model, we are in trouble: simple extensions like Quintessence cannot reproduce the measured feature
- To obtain results compatible with DESI CPL constraints, we need non-minimal coupling ($\Omega \neq 0$, thawing gravity, ...)
- Could DESI results be the first hint toward modified gravity?
- Can this kind of model also fit perturbation observables such as LSS data?