Title: Town Hall - New generation of LSS surveys and modified gravity/dark energy

Speakers: Hanyu Zhang, Jessie Muir, Kazuya Koyama, Martin Kunz

Collection/Series: 50 Years of Horndeski Gravity: Exploring Modified Gravity

Subject: Cosmology, Strong Gravity, Mathematical physics

Date: July 17, 2024 - 4:00 PM

URL: https://pirsa.org/24070045

Abstract:

Lead: Alex Krowlewski

DESI dynamical dark energy?

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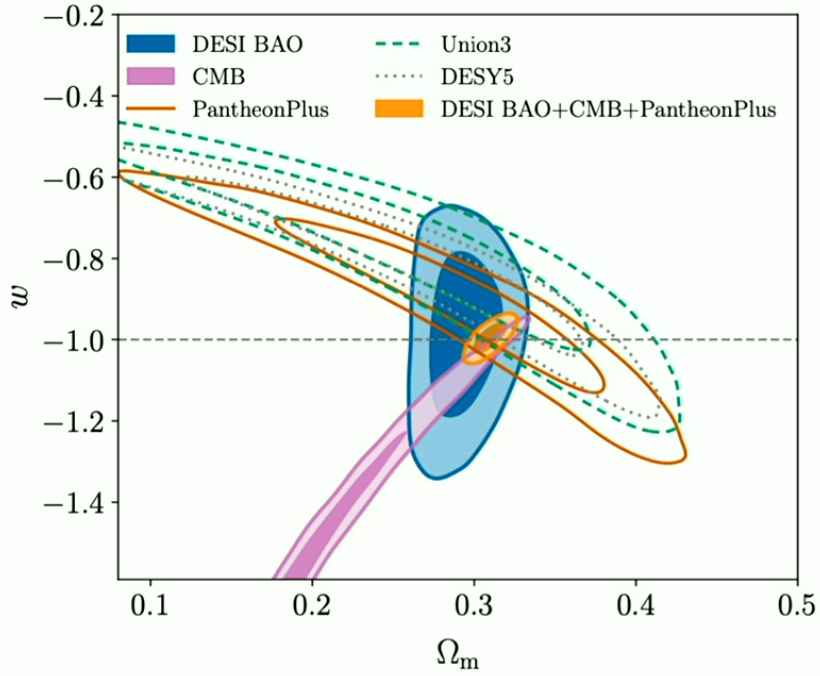
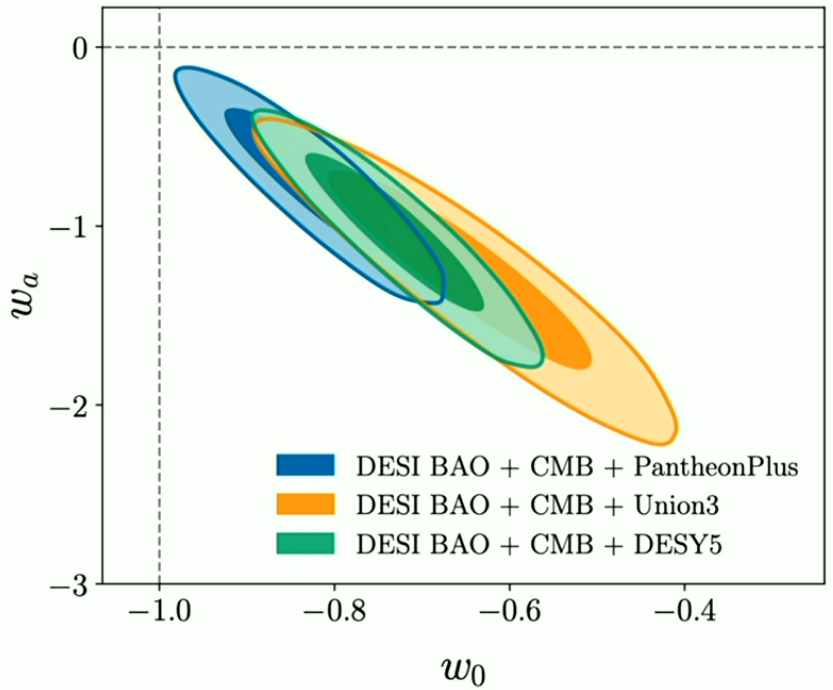


$$\left.\begin{aligned}\Omega_m &= 0.3095 \pm 0.0069,\\ w &= -0.997 \pm 0.025,\end{aligned}\right\} \text{DESI+CMB +PantheonPlus.}$$

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



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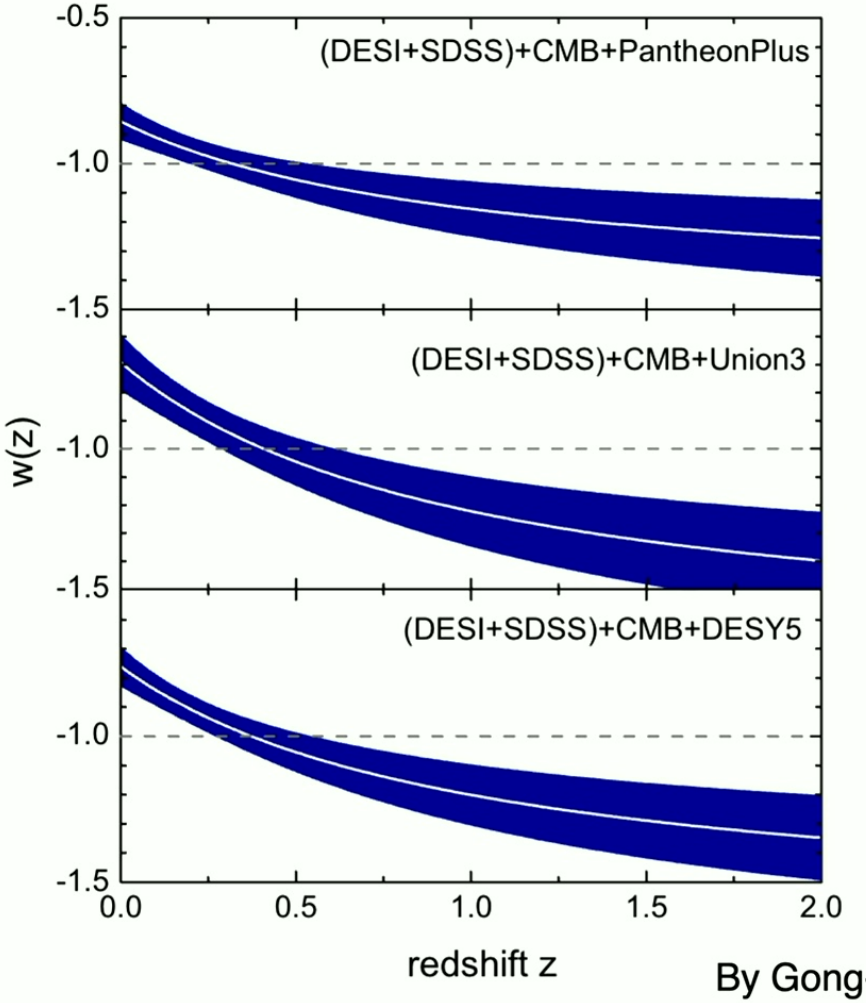
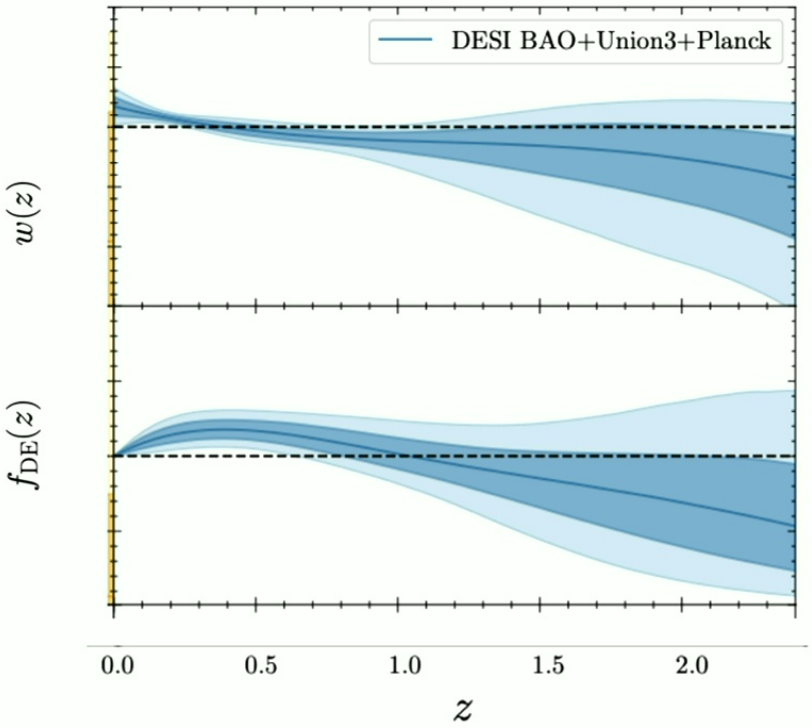




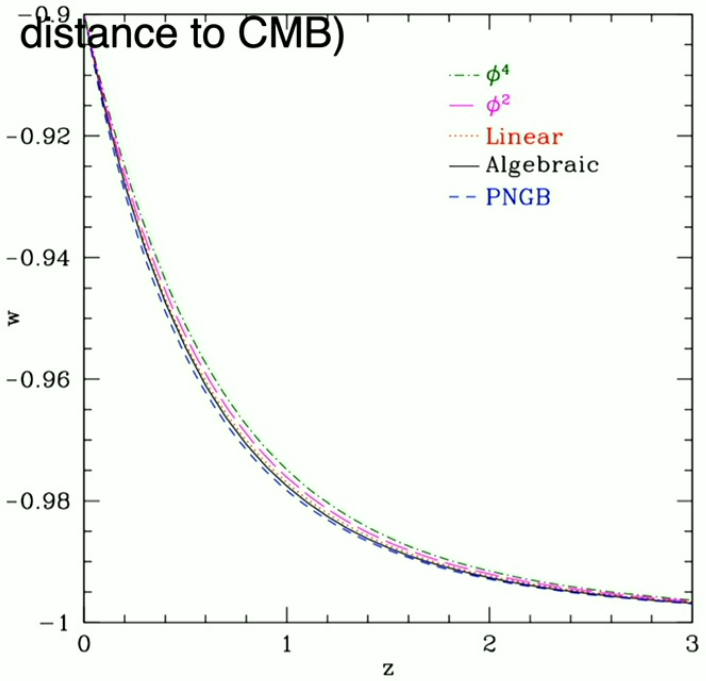
Reconstruction of w(z)
DESI collaboration 2405.04216

By Gong-bo Zhao

Priors

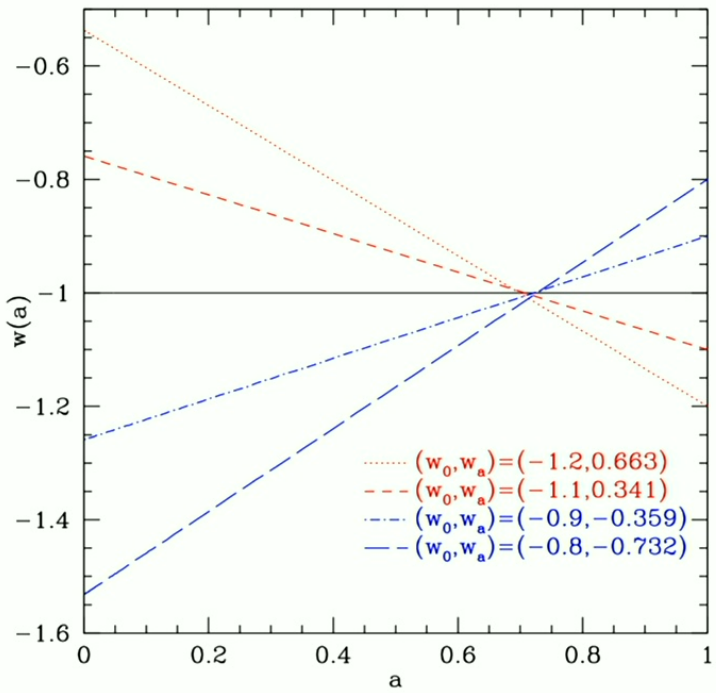
DESI collaboration 2405.13588

Thawing dark energy



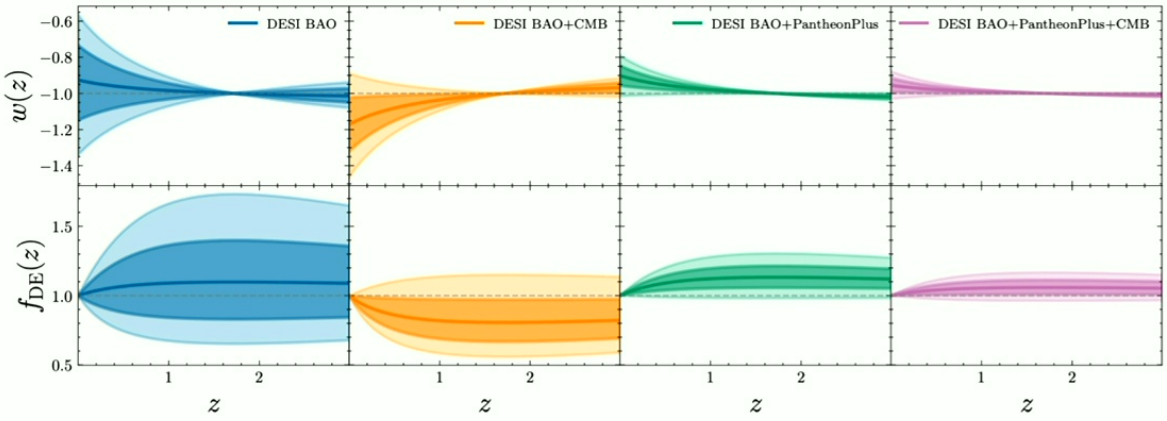
$$w_a \approx -1.58\,(1+w_0)\ .$$

Mirage (the same distance to CMB)

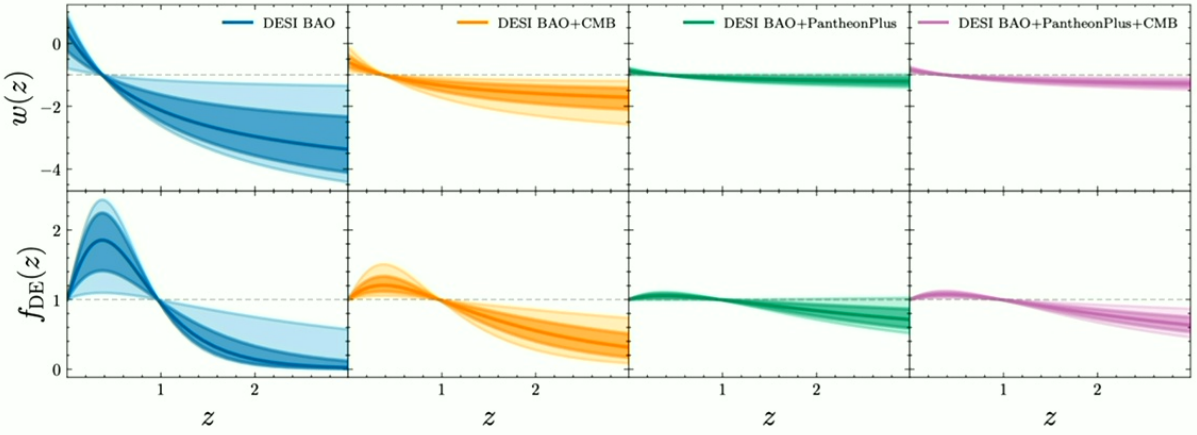


$$w_a = -3.66\,(1+w_0)$$

DESI collaboration 2405.13588



Data	$\Delta\chi^2_{\rm Thawing}$
DESI BAO	-0.2
+CMB	-0.6
+PantheonPlus	-3.2
+Union3	-6.3
+DES-SN5YR	-8.8
+CMB+PantheonPlus	-0.6
+CMB+Union3	-3.0
+CMB+DES-SN5YR	-5.0



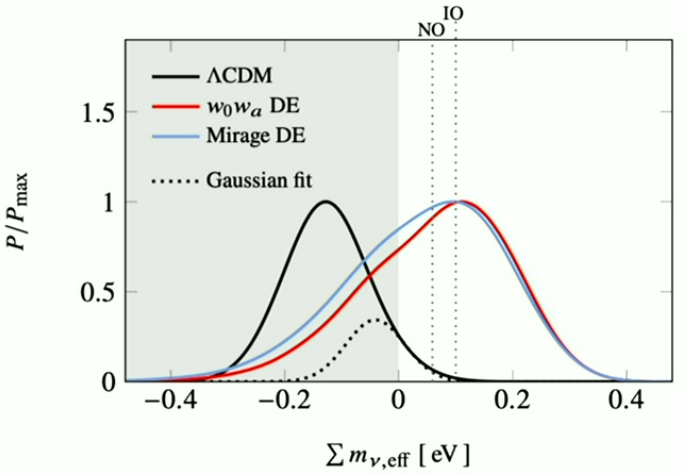
$\Delta\chi^2_{\rm Mirage}$	$\Delta\chi^2_{w_0w_a}$
-5.0	-3.8
-7.6	-8.9
-3.5	-3.5
-8.7	-8.9
-10.7	-11.1
-9.0	-9.6
-15.2	-15.6
-17.7	-18.3

Lessons

- A simple parametrisation could miss interesting hints of deviations from LCDM
  (i.e. w = constant)
- (Physical) priors make a significant impact on the constraints
- It is useful to identify the phenomenological features that alternative theories would need to have through parametrisations or reconstruction
  i.e. massive neutrinos mass

$$X_\theta^{\sum m_{\nu,\mathrm{eff}}} \equiv X_\theta^{\sum m_\nu = 0} + \mathrm{sgn}\left(\sum m_{\nu,\mathrm{eff}}\right)\left[X_\theta^{|\sum m_{\nu,\mathrm{eff}}|} - X_\theta^{\sum m_\nu = 0}\right]$$

arXiv: 2407.10965

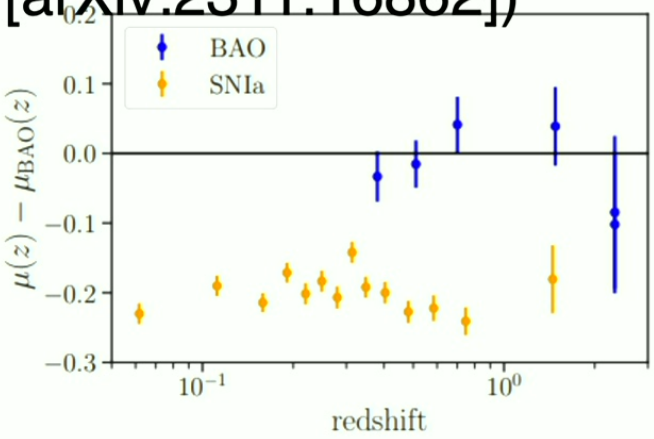


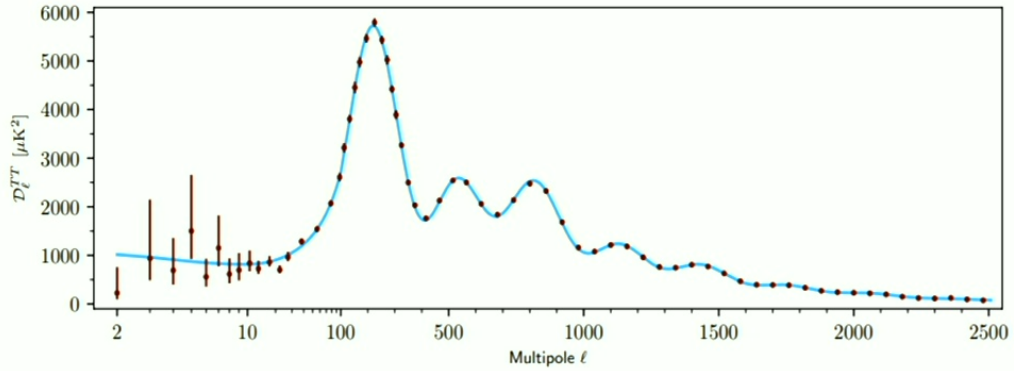
Why I think that LCDM is right

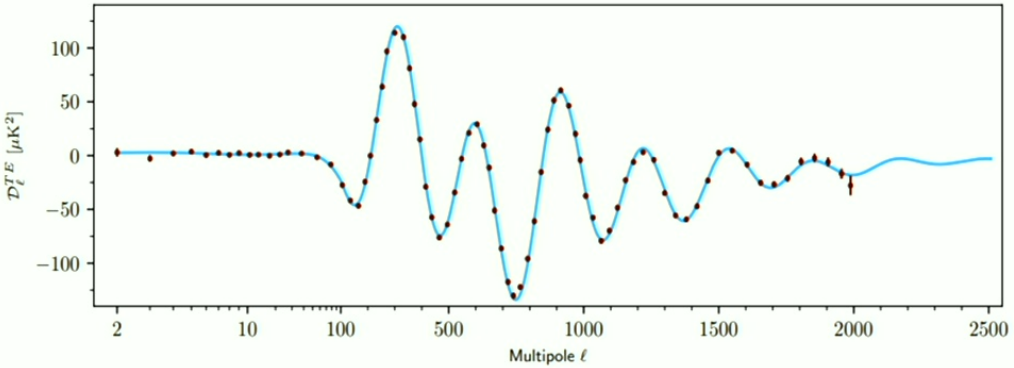
- Planck
- No convincing deviations ?

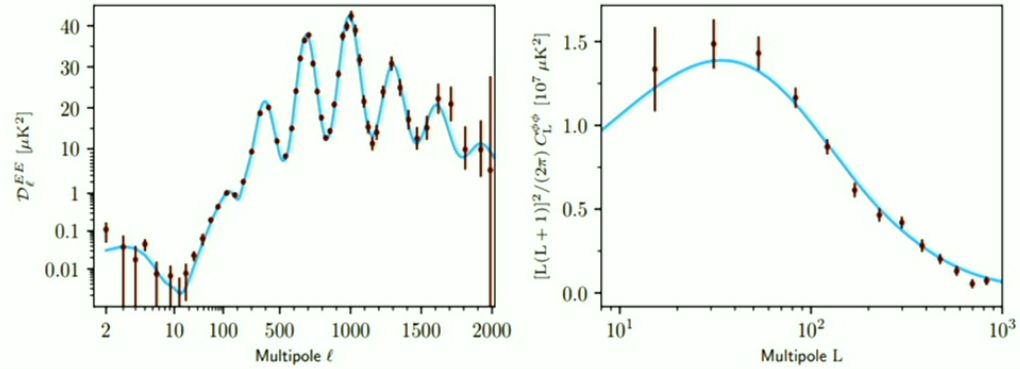
(H_0: high z see Planck,

mid-z distance duality [arXiv:2311.16862])





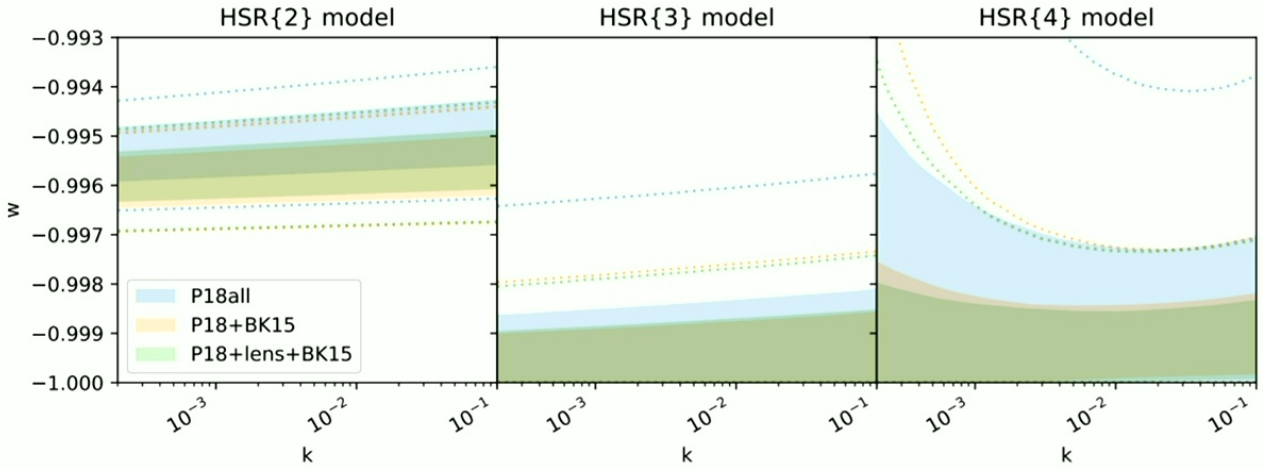




Why I think DE is not a cosmological constant

- All the usual problems of Lambda
- What string ppl say
- Inflation (Ilic, Castello, MK, arXiv:1002.4196 & 2104.15091):

$$1+w=\frac{2}{3}\epsilon_H = 24\,r \qquad 2\eta_H=(n_s-1+4\epsilon_H) \qquad \frac{d\ln(1+w)}{dN}=\frac{d\ln\epsilon_H}{dN}=2(\eta_H-\epsilon_H)$$



Model / *data*	$B_{\{i\}\{2\}}$ [wide]	$B_{\{i\}\{2\}}$ [SR]	$\Delta\chi^2$
P18all			
HSR{2}	1	1	0
HSR{3}	0.090	2.3	−5.9
HSR{4}	0.011	2.3	−6.5
P18+BK15			
HSR{2}	1	1	0
HSR{3}	1.3	31	−13.4
HSR{4}	0.14	33	−14.0
P18+lens+BK15			
HSR{2}	1	1	0
HSR{3}	2.4	61	−13.8
HSR{4}	0.22	62	−14.0

Phenomenology vs theory (vs AI? ☺)

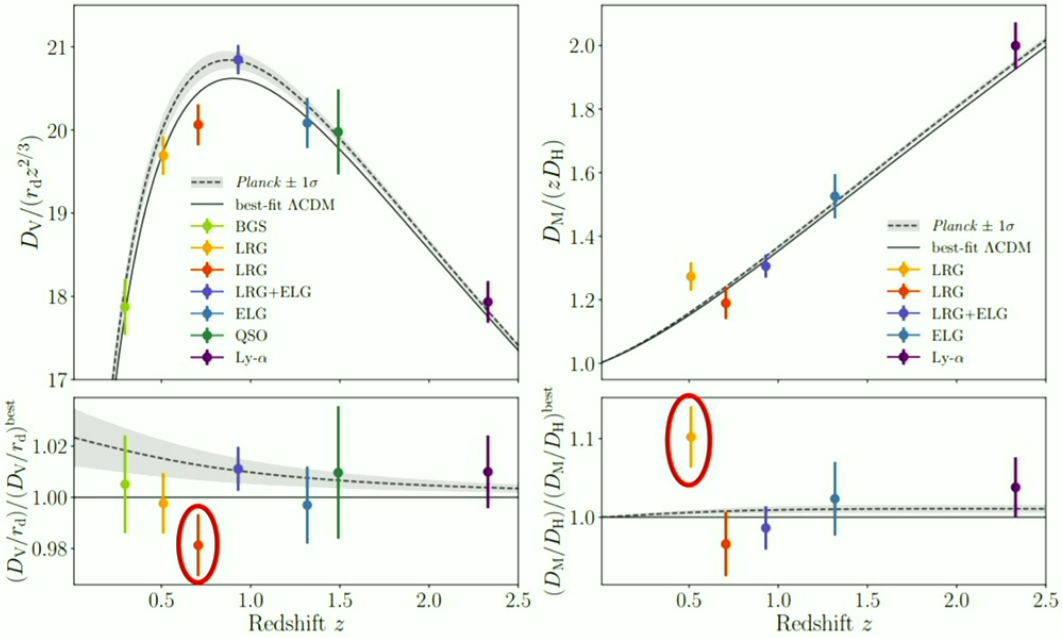
w, mu, Sigma

- Not a theory but makes sense on all scales (Gpc to mpc).
- Can be fitted to data (but care must be taken to leave the 'right' amount of freedom). [*]
- Can be predicted from theories
- Kind of unavoidable to analyze data?
- [*] Can we let the data decide?

Theories (including EFT)

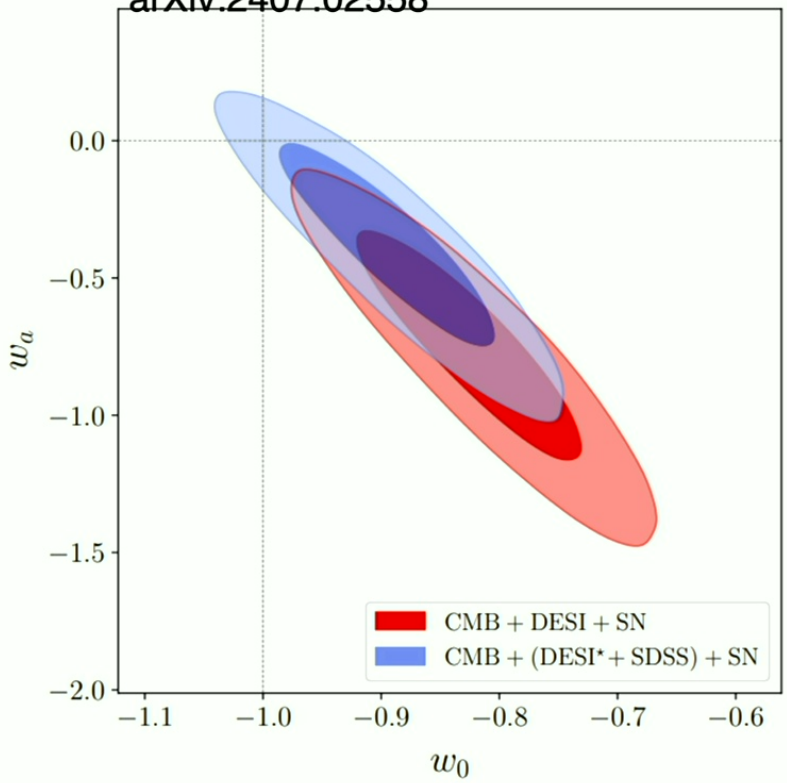
- Using the right theory is best.
- Using the wrong theory can be very misleading.
- Everything is an E(F)T?
- We **must** study theories of course to understand the world and have an idea of the space of possibilities.

DESI #2



DESI data paper, arXiv:2404.03002

Chudaykin & MK,
arXiv:2407.02558



Comment on DESI and phantom crossing

- Kazuya's slide and Anton's tries: DESI wants phantom crossing at nearly the same level that it deviates from LCDM.
- This we can determine with a phenomenological prescription.
- But if we want to test/constrain **theories** (quintessence, EFT, whatever) then we should respect the theory predictions, i.e. quintessence does **not** cross w=-1, some other models can.
- Theories can then be compared e.g. with Bayesian model comparison (which will disfavour e.g. quintessence due to the non-crossing).
- But, maybe it's a bit early to get too excited about this? ☺

Topics for discussion

Discussion Questions

1. Is dark energy a time-dependent field? Is the data pointing in this direction robust? Or is a cosmological constant still the best bet? What confidence level would be needed for the community to "abandon" Λ in ΛCDM?

2. What is the best way to learn about dark energy and modified gravity, cosmologically? Fitting parameterized equations of state, like w_0-w_a or Mu, Sigma — is this the best strategy? Or should there be more focus on fitting theoretically motivated models of dark energy/modified gravity? Or should we just fit effective field theory parameters?

   2b. Does the recent DESI result favor models with phantom crossing that violate the NEC at early times? More generally, should we limit our constraints to models that obey the NEC at all times?

3. What's the deal with priors (e.g., on the dark energy equation of state parameter *w*)? Should observers fit the data in the most agnostic way? Or should we try to put more contraining, theoretically motivated priors on certain parameters like *w*?

4. What are the prospects for testing modified gravity from quasi-linear and/or nonlinear scales, i.e. scale-dependent growth? Put more concretely, what would it take for you to believe a measurement on quasi-linear scales favoring modified gravity over LCDM from Euclid or LSST?

Martin

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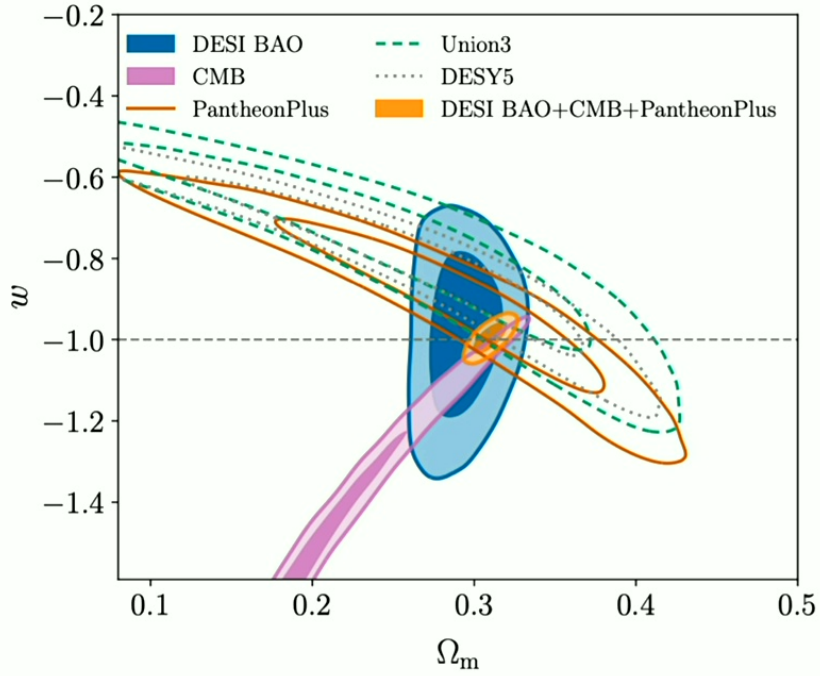

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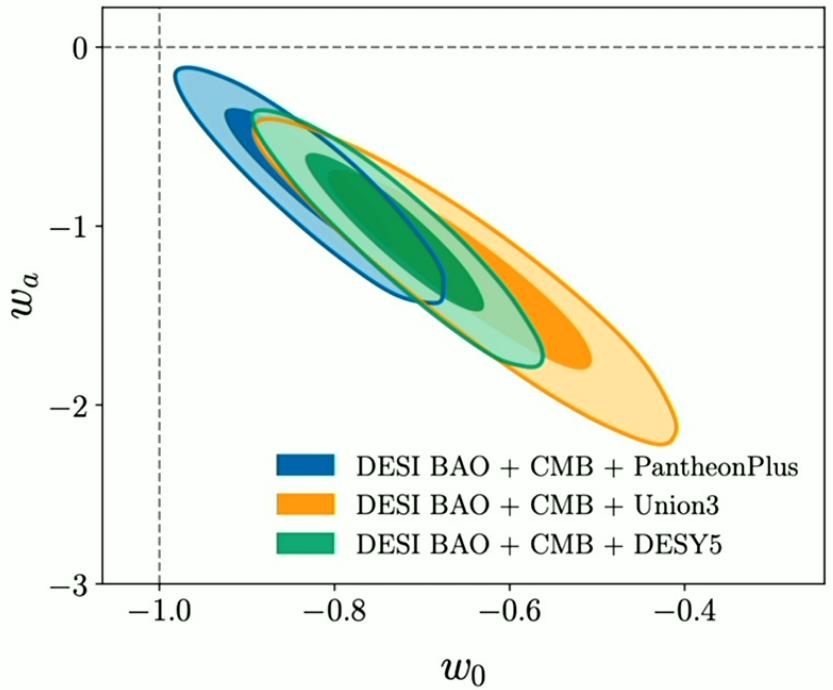

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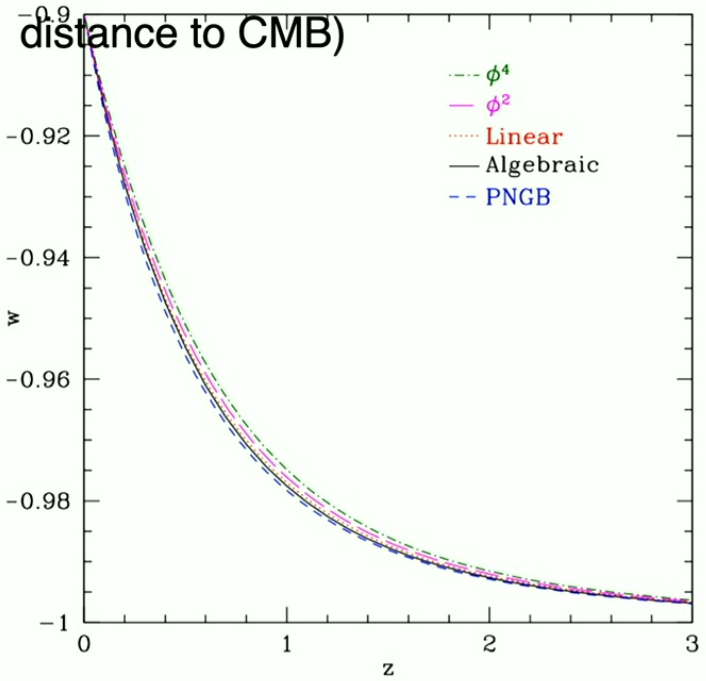

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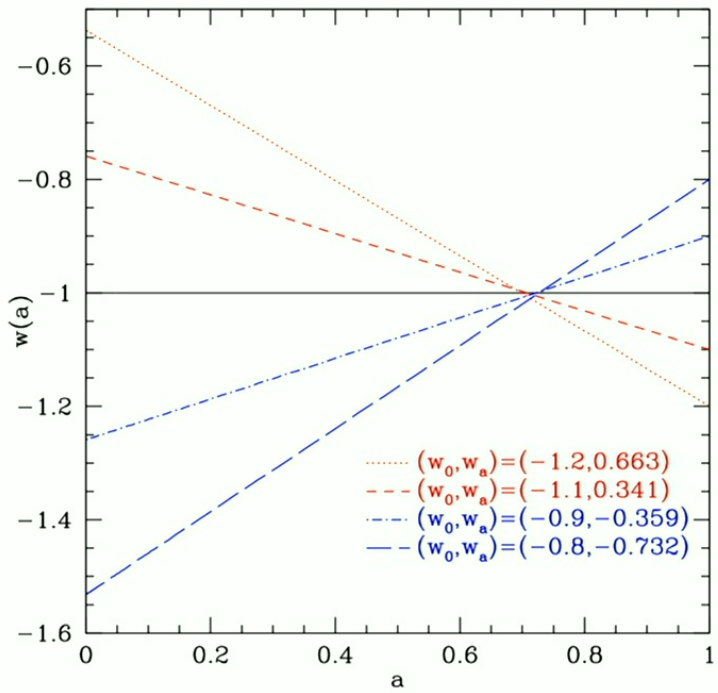

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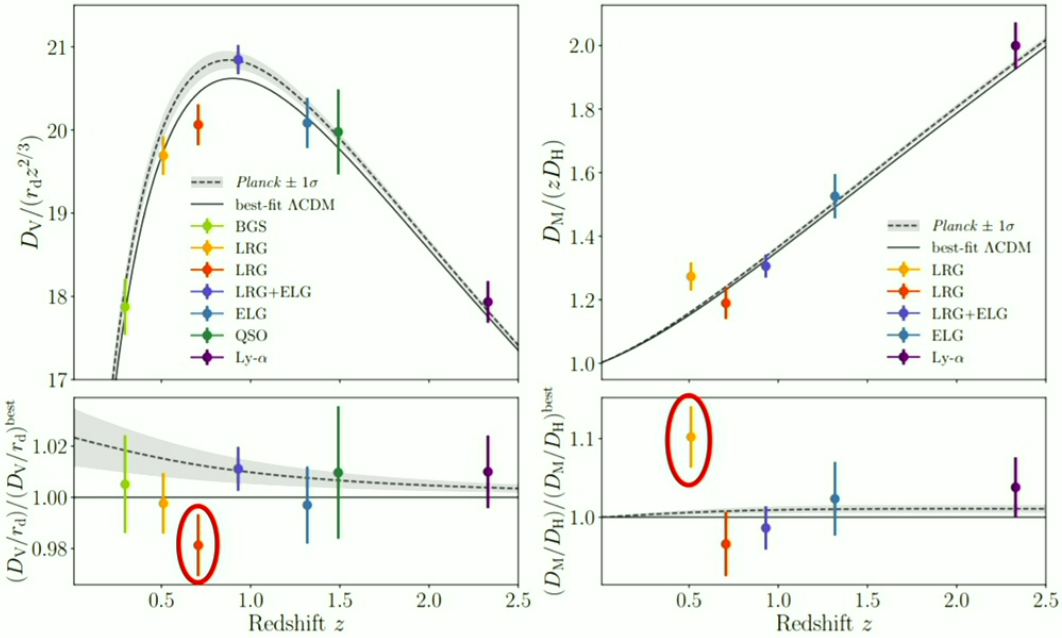

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