DESI, PhantomX and Dark Energy EOS

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COSMOLOGY

Dark Energy May Be Weakening, Major Astrophysics Study Finds

Quantamagazine

Dark
Energy
Spectroscopic
Instrument
Claim

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!!!!

Quantamagazine

Dark
Energy
Spectroscopic
Instrument
Claim

Our principal point is to highlight a so-far-unquantified dependence on model priors.

This new cosmic coincidence [...] *indicates the chosen prior is not a good representation of the underlying physics*

Cortês and Liddle (2024)

What is DESI?

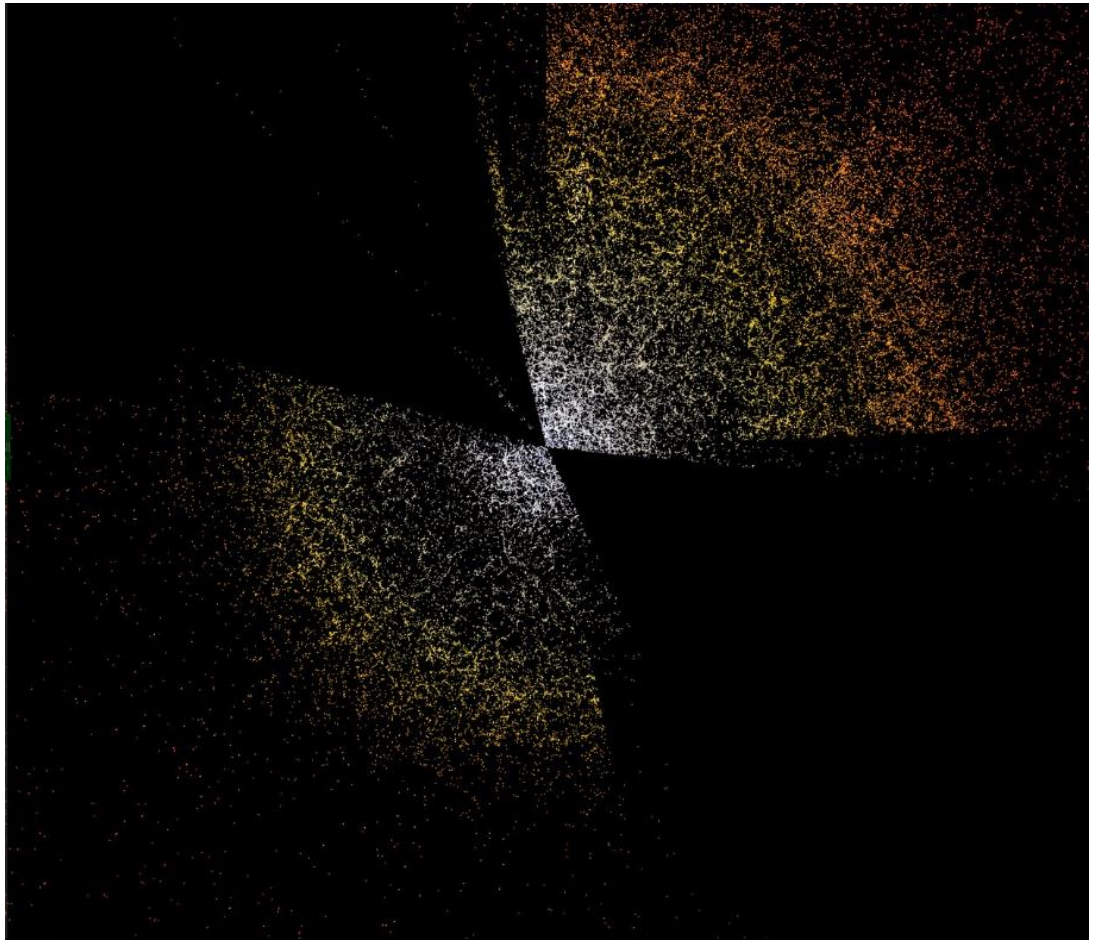
What is the claim?

DESI: Instrument

5000 Robotic Eyes at the Sky

DESI Team (2024)

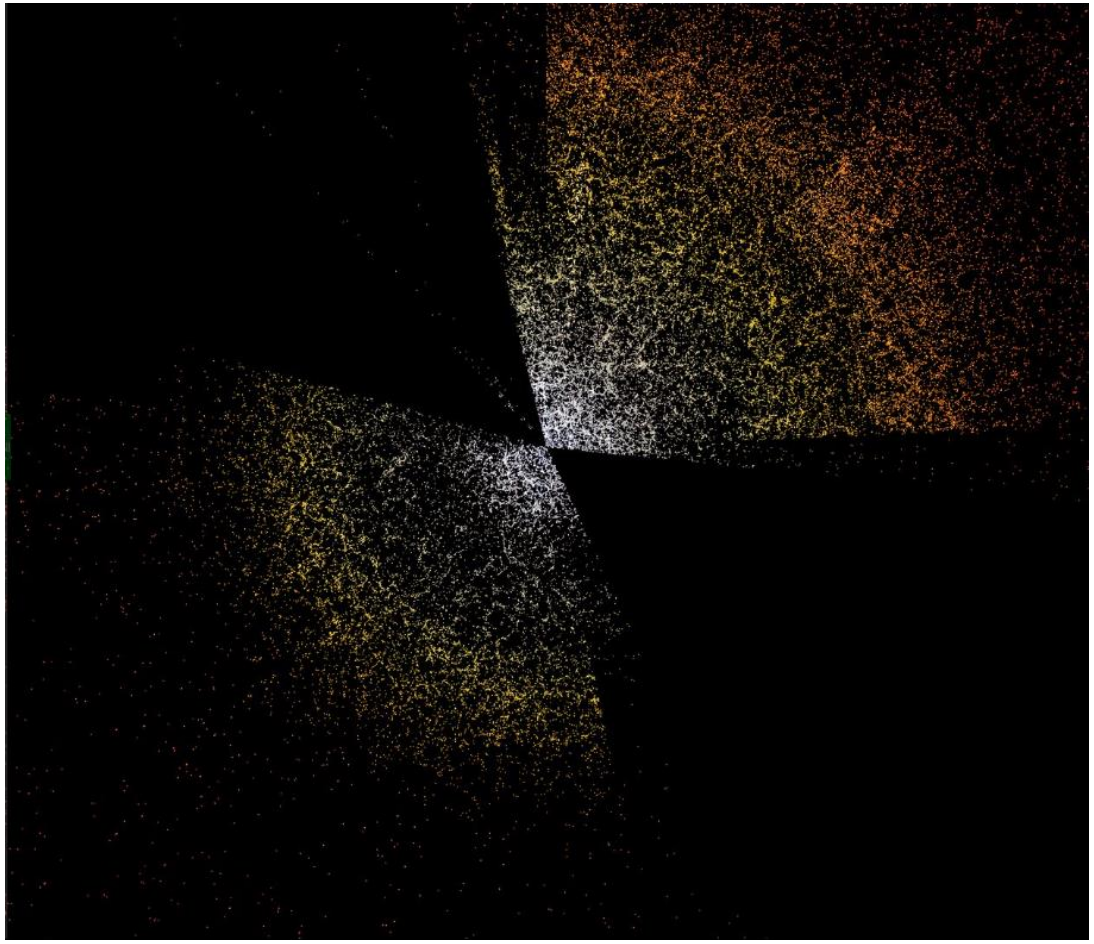
DESI: Instrument



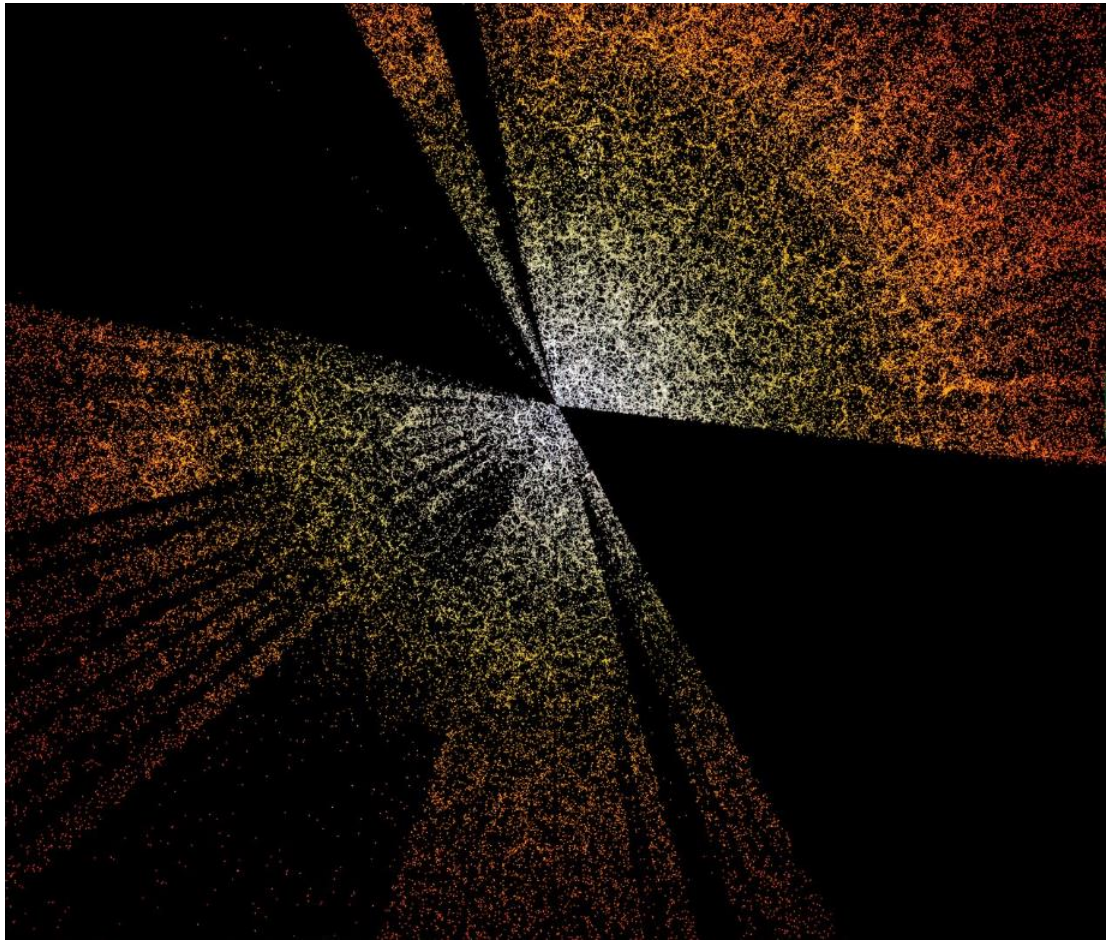
SDSS: 20 Years

NOIRLab (2024)

DESI: Instrument

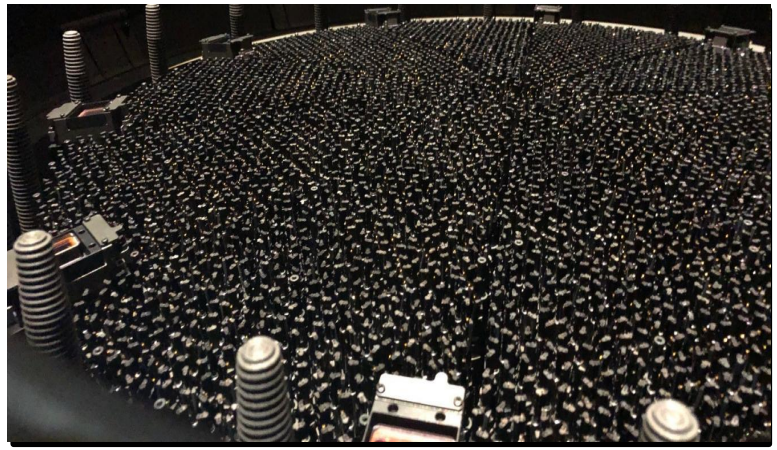


SDSS: 20 Years



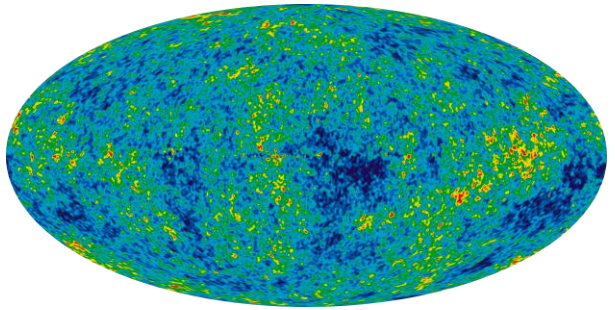
DESI: 7 Months

NOIRLab (2024)



DESI Survey

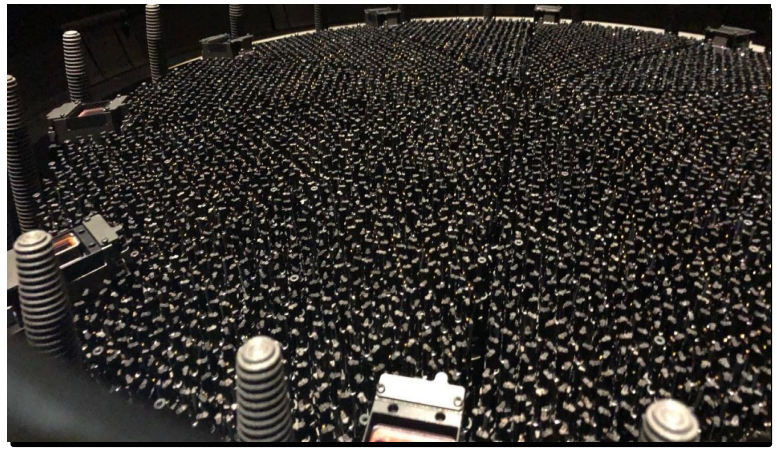
+



Planck CMB

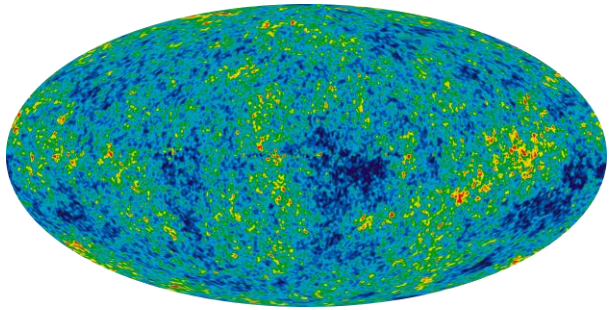
+

Several SNIa



DESI Survey

+



Planck CMB

+

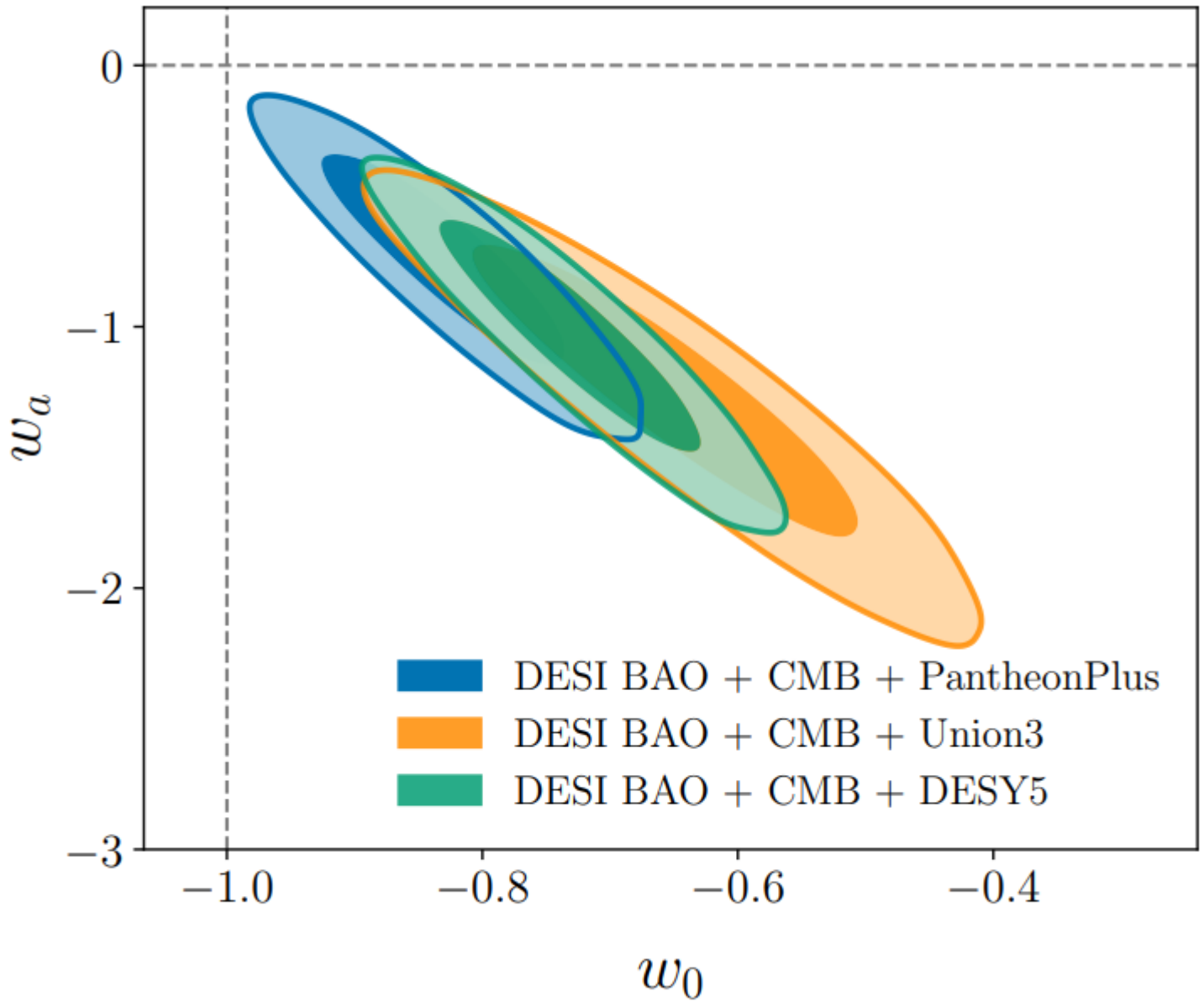
Several SNIa

=> 2.5σ–3.9σ preference for evolving DE over ΛCDM

$$\rho \propto a^{-3(1+w)}$$

w0waCDM

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



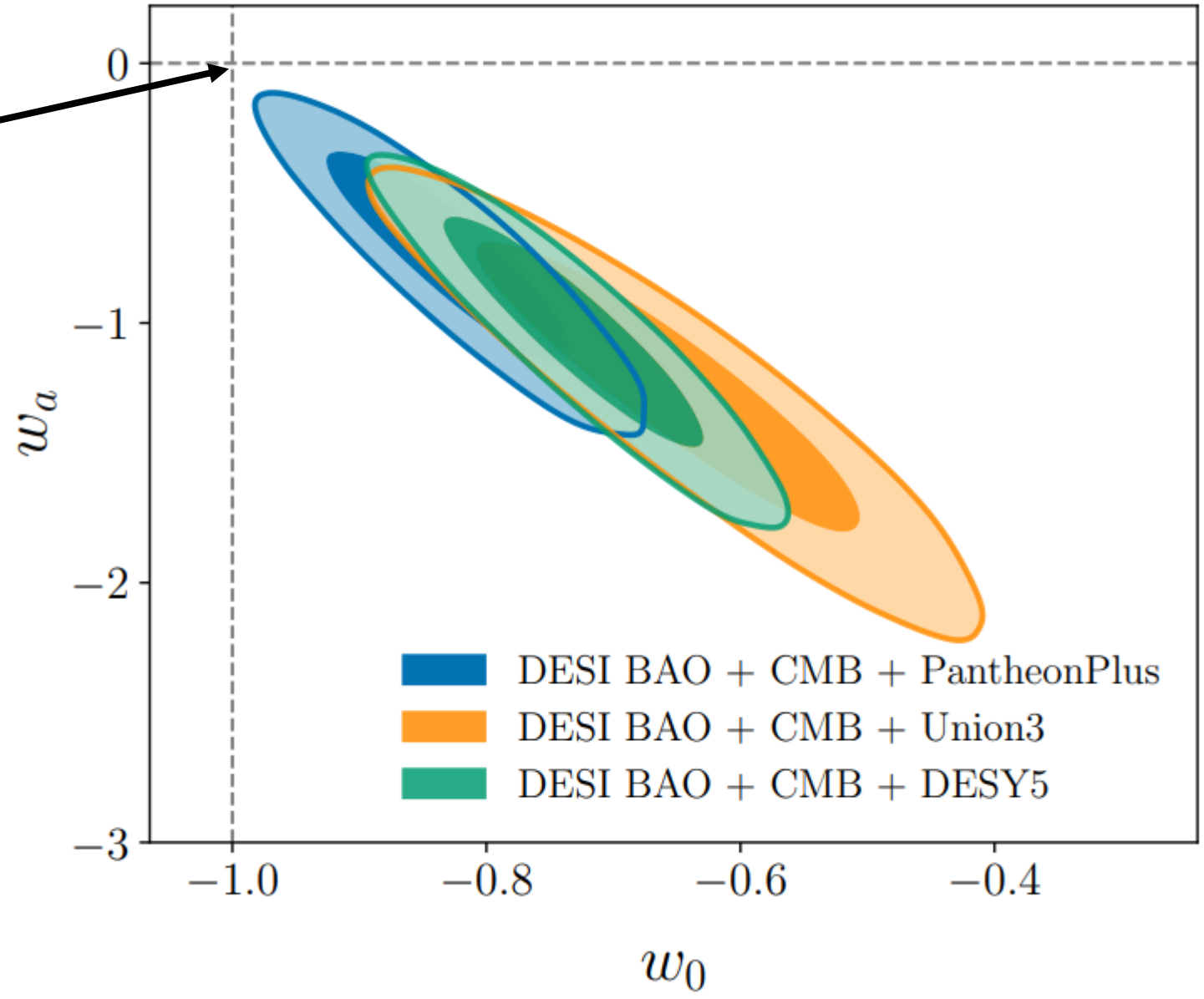
DESI Team (2024)

ΛCDM

$$\rho \propto a^{-3(1+w)}$$

w0waCDM

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



DESI Team (2024)

PhantomX Coincidence

raises concerns about the claim

Fields with ‘negative kinetic energy’ (vacuum stability issues)

Non-phantom regime simpler to model (e.g. Quintessence)

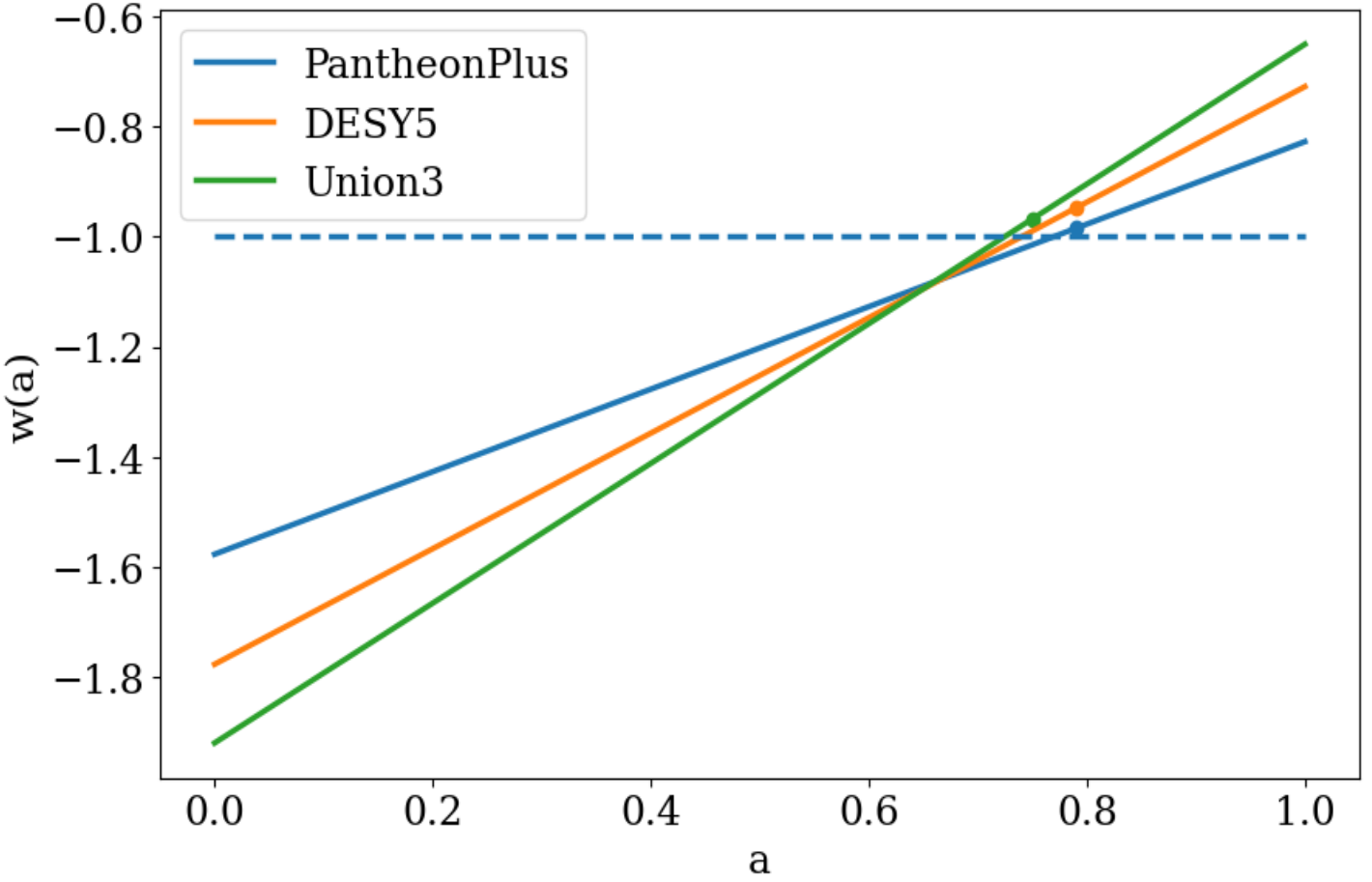
PhantomX

Coincidence

$w < -1$

PhantomX Coincidence

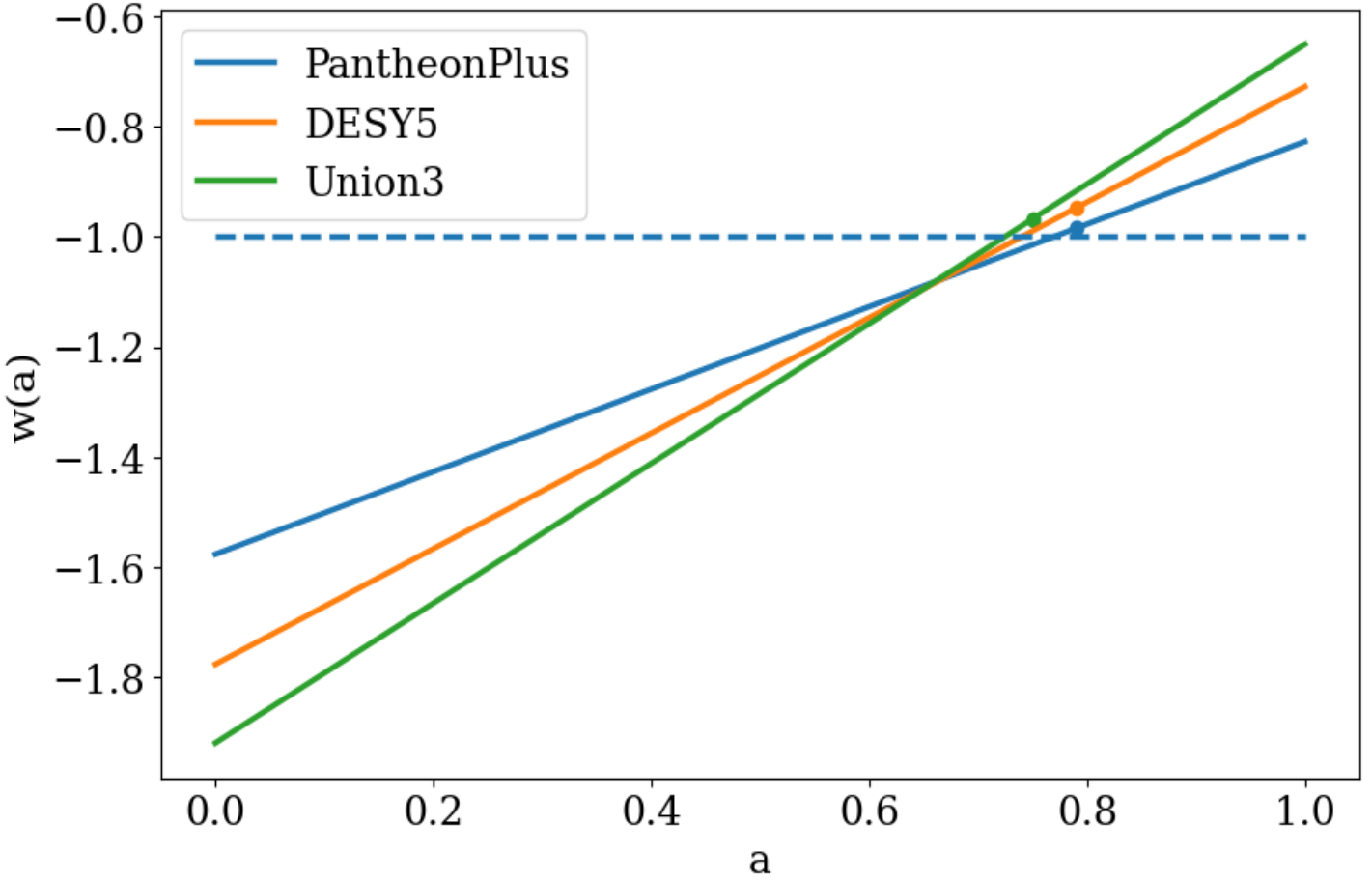
Crossing between the two regimes requires a special interpolation



PhantomX

Coincidence

Crossing happens in the observation epoch (by a few hundredths)



PhantomX Coincidence

The maximum value dark energy density that would ever reach

happens to lie where data best constrains the model

Substantial Unstated Dependence on Priors

w_0	$\mathcal{U}[-3, 1]$
w_a	$\mathcal{U}[-3, 2]$

Models using special interpolations, a priori, as likely as physically motivated ones

Substantial Unstated Dependence on Priors

$$w_0 \qquad \mathcal{U}[-3, 1]$$

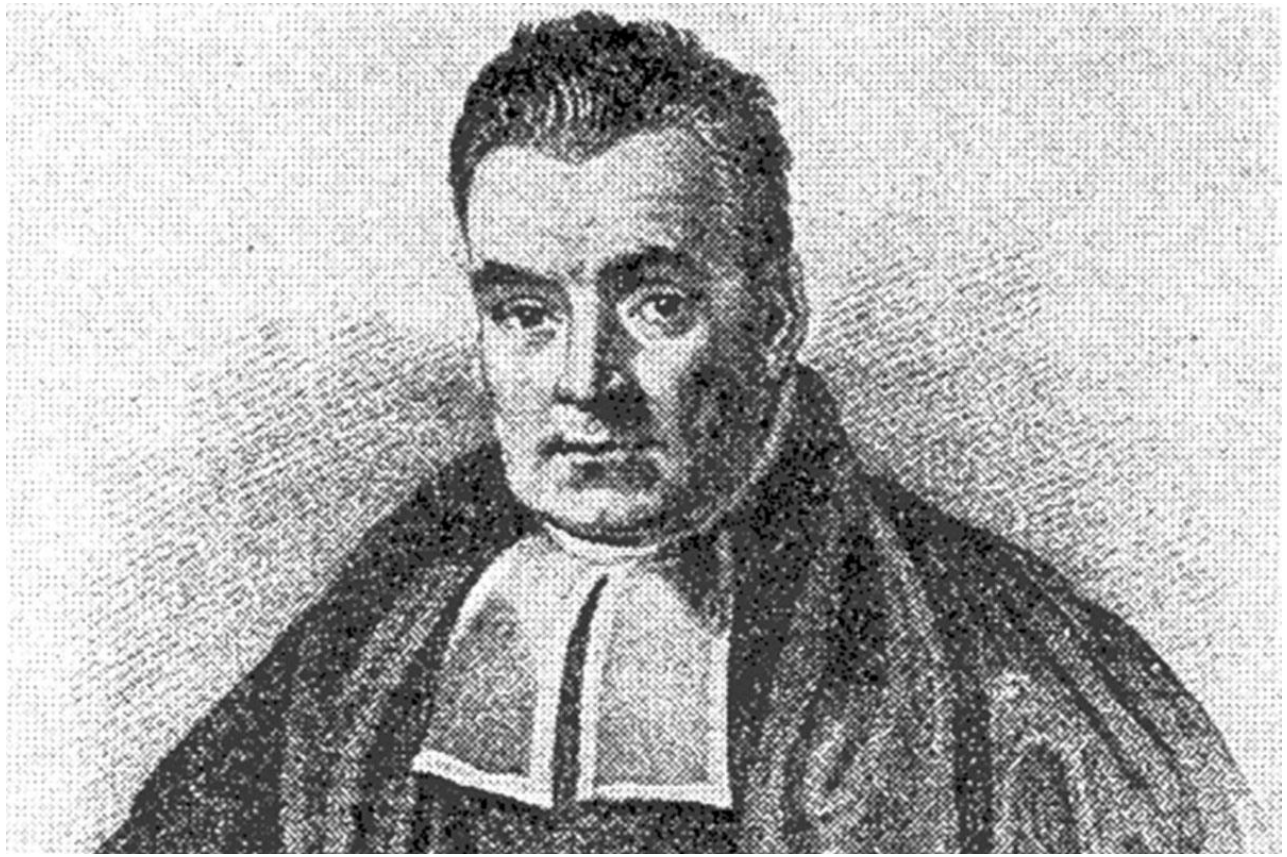
$$w_a \qquad \mathcal{U}[-3, 2]$$

Models using special interpolations, a priori, as likely as physically motivated ones

‘Tapering [priors] may lessen the coincidence [but] … reduce discrepancy from ΛCDM’

No right or wrong priors

But assess robustness against reasonable changes to priors

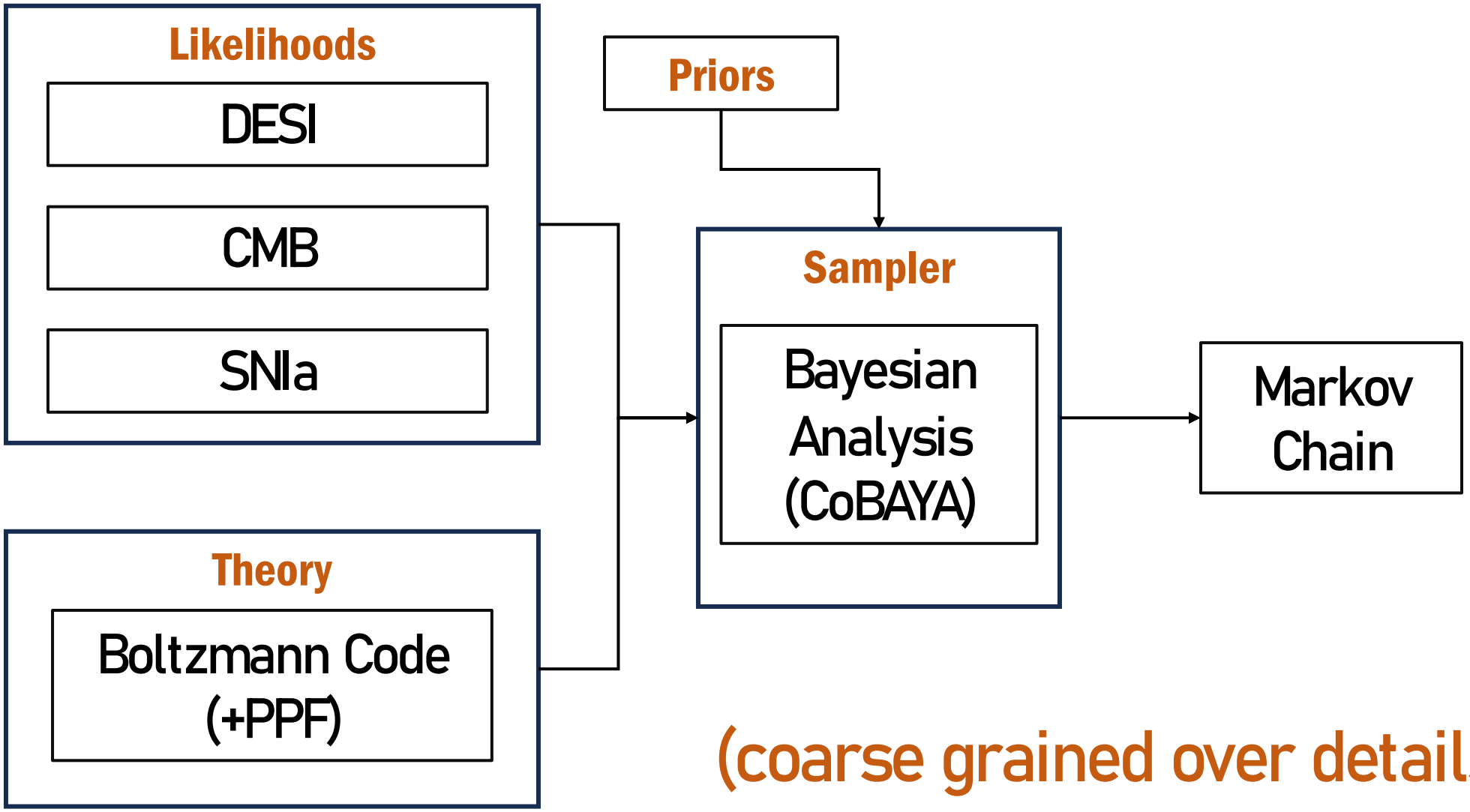


Thomas Bayes

II

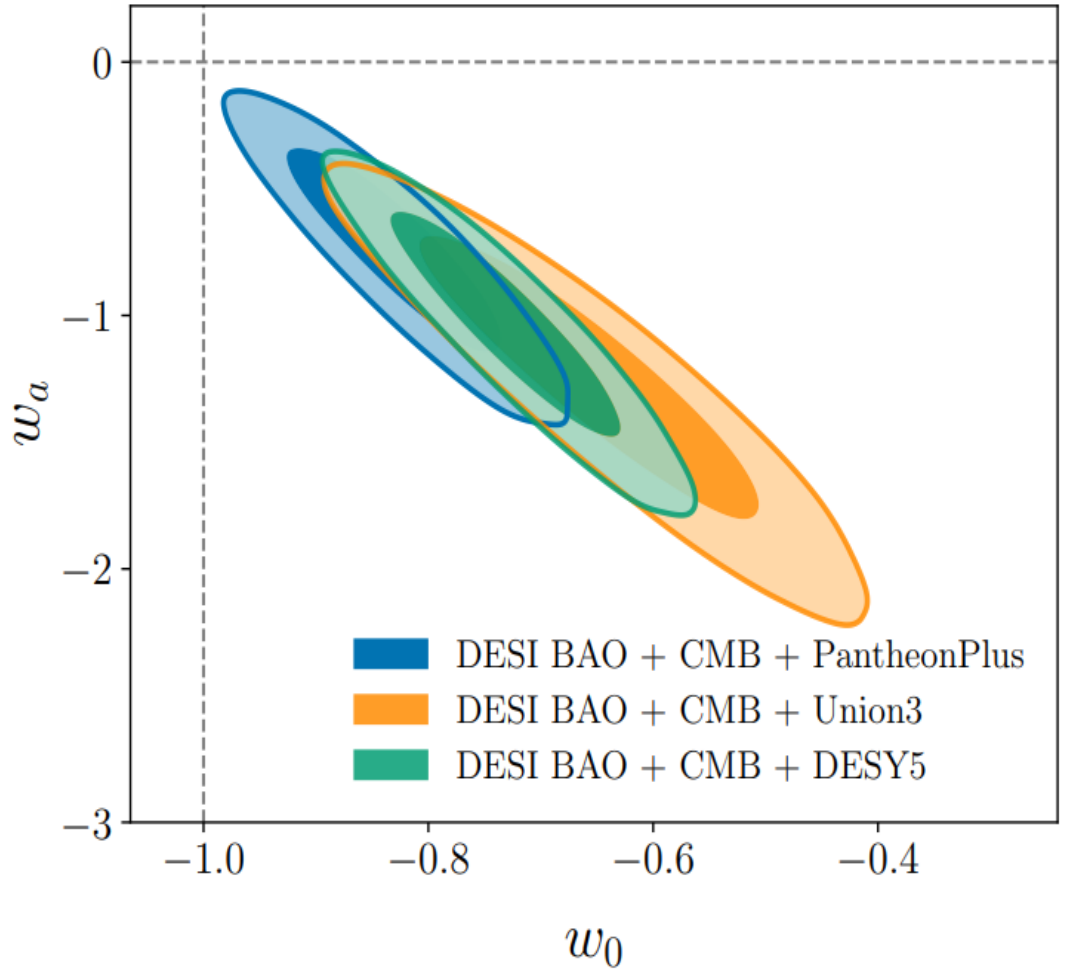
Replicate DESI Results

to, then, investigate influence of priors

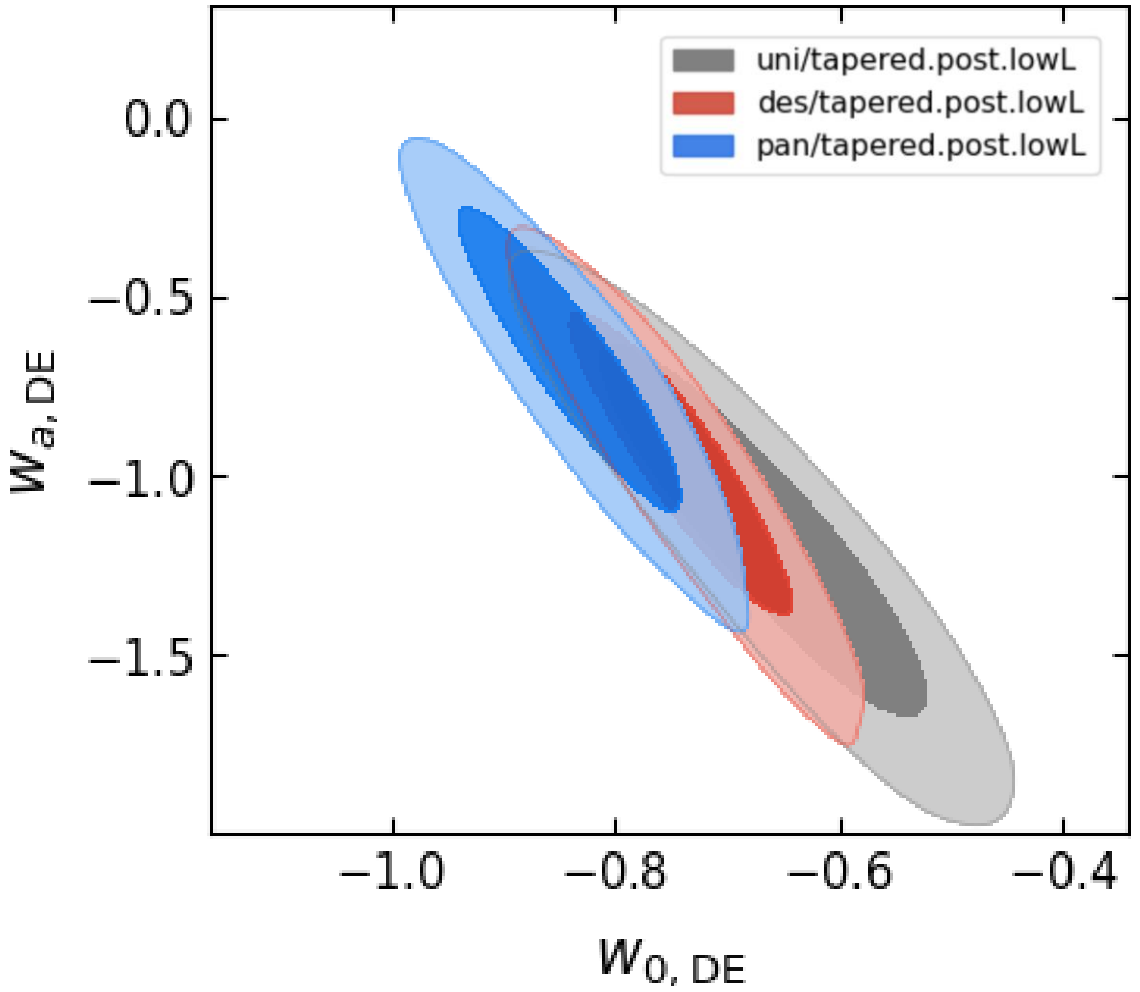


(coarse grained over details)

DESI

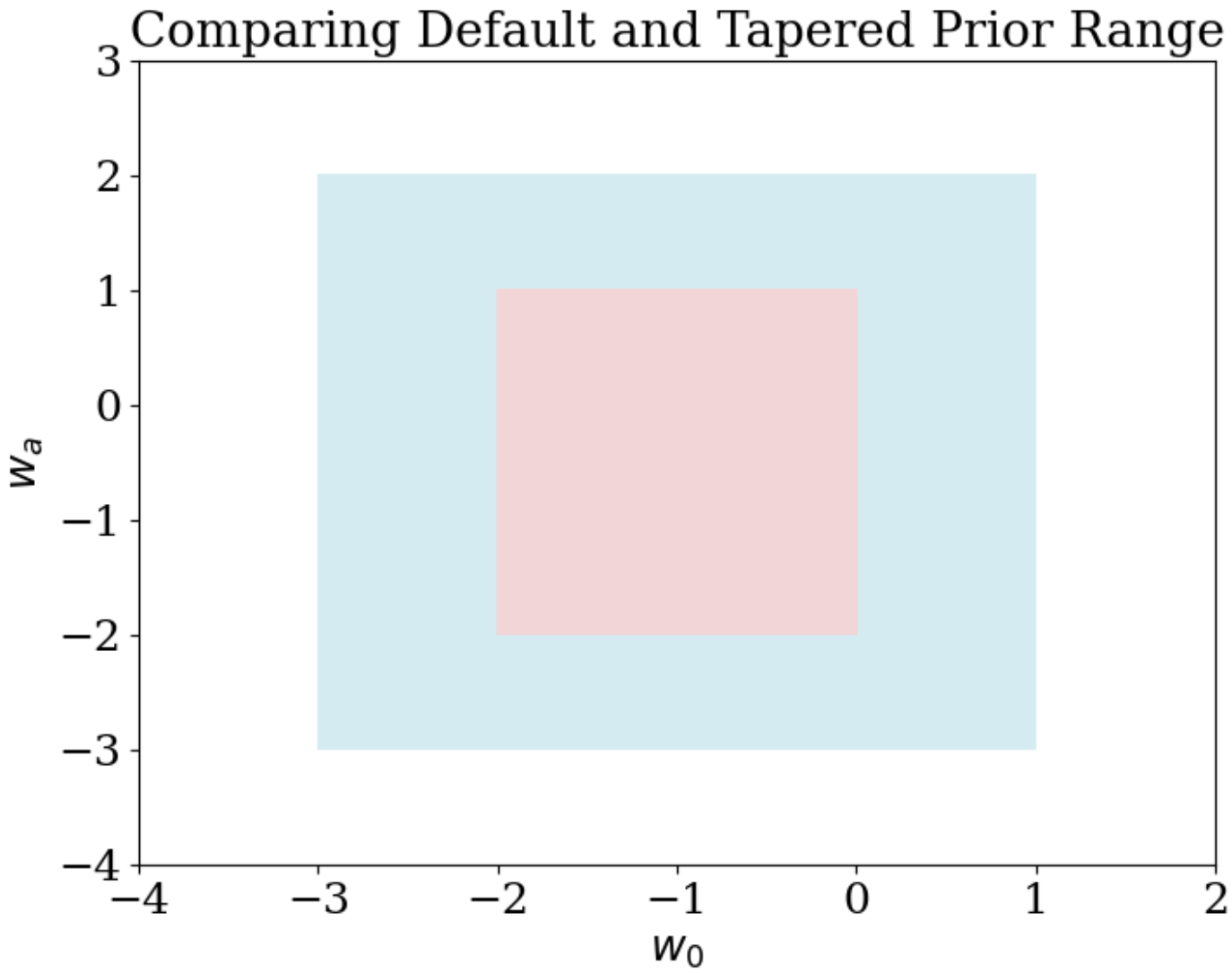


Replication



Tapering the extension of priors into deep phantom regime may

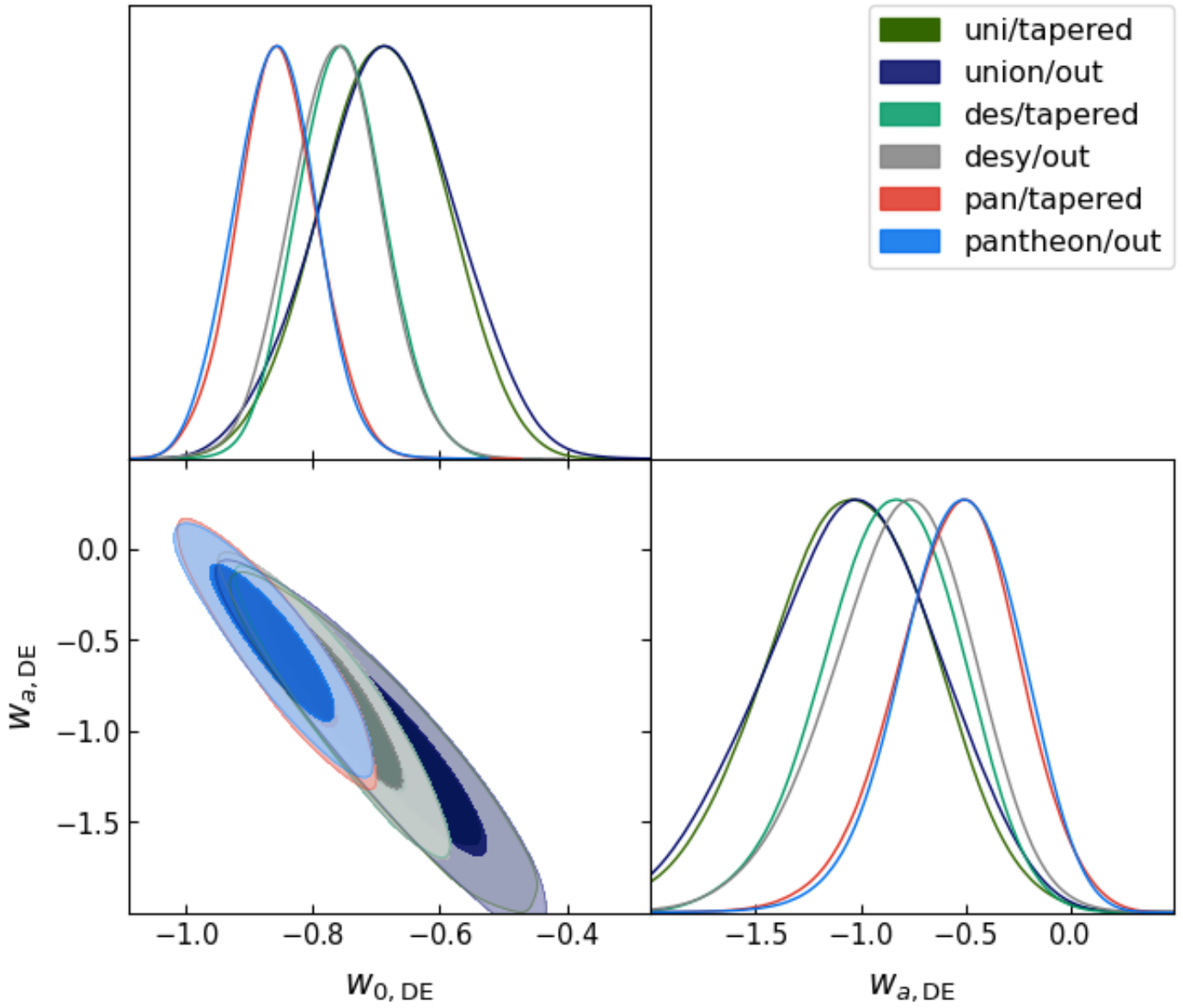
1. Lessen the coincidence
2. Reduce discrepancy from ΛCDM

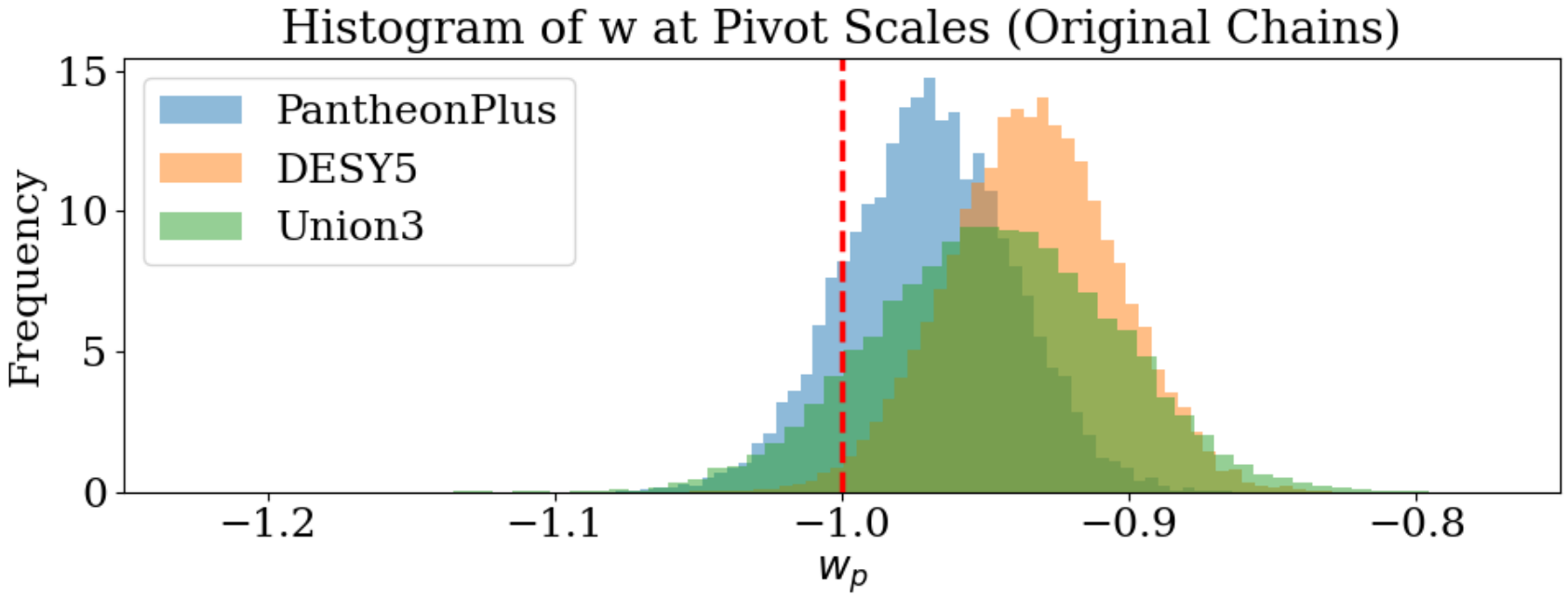


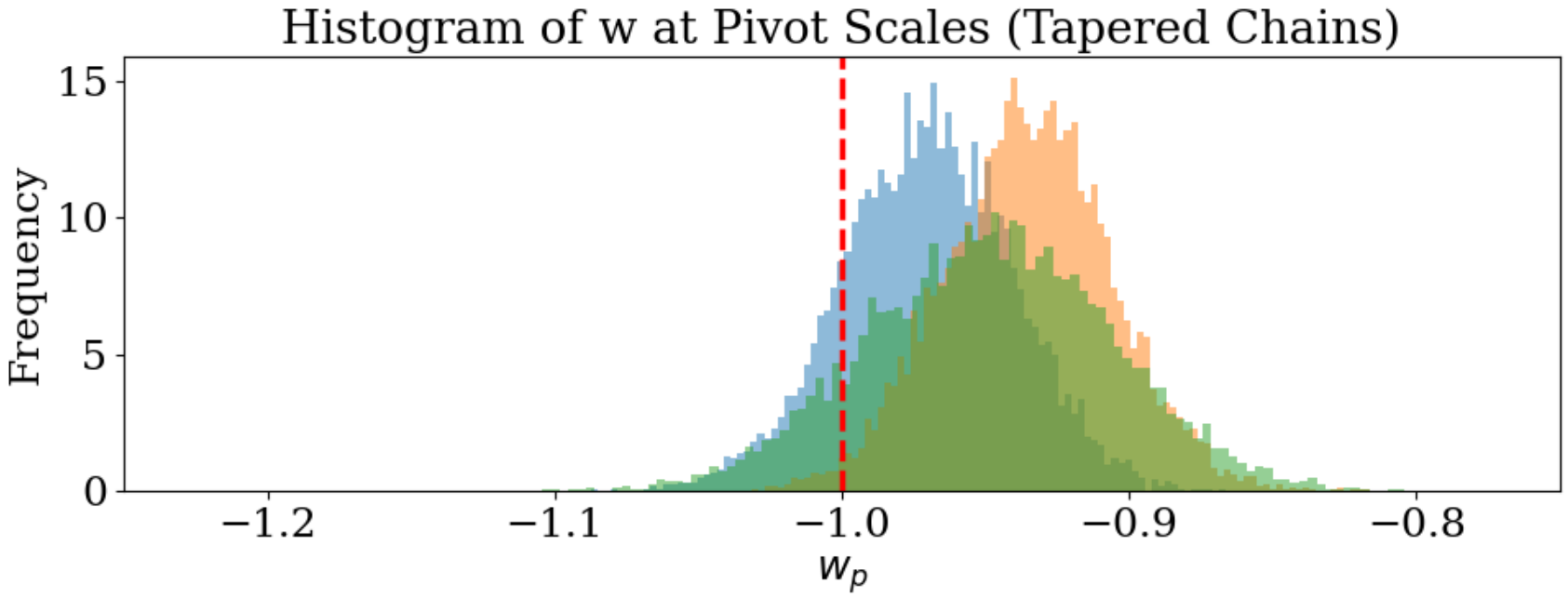
Drastically changed prior
(~70% reduction)

but

Insignificantly
changed posterior



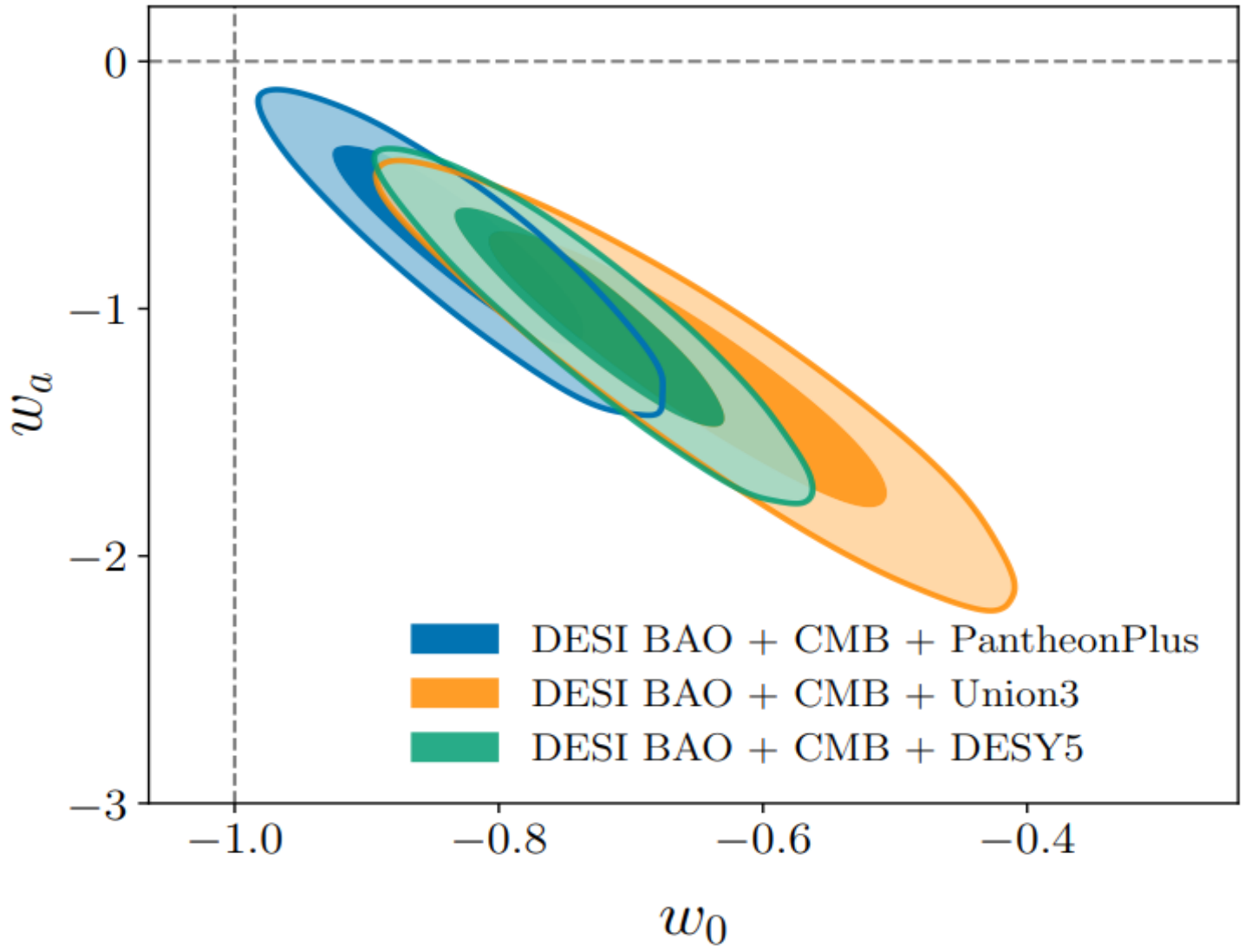




Insignificant reduction in coincidence as well

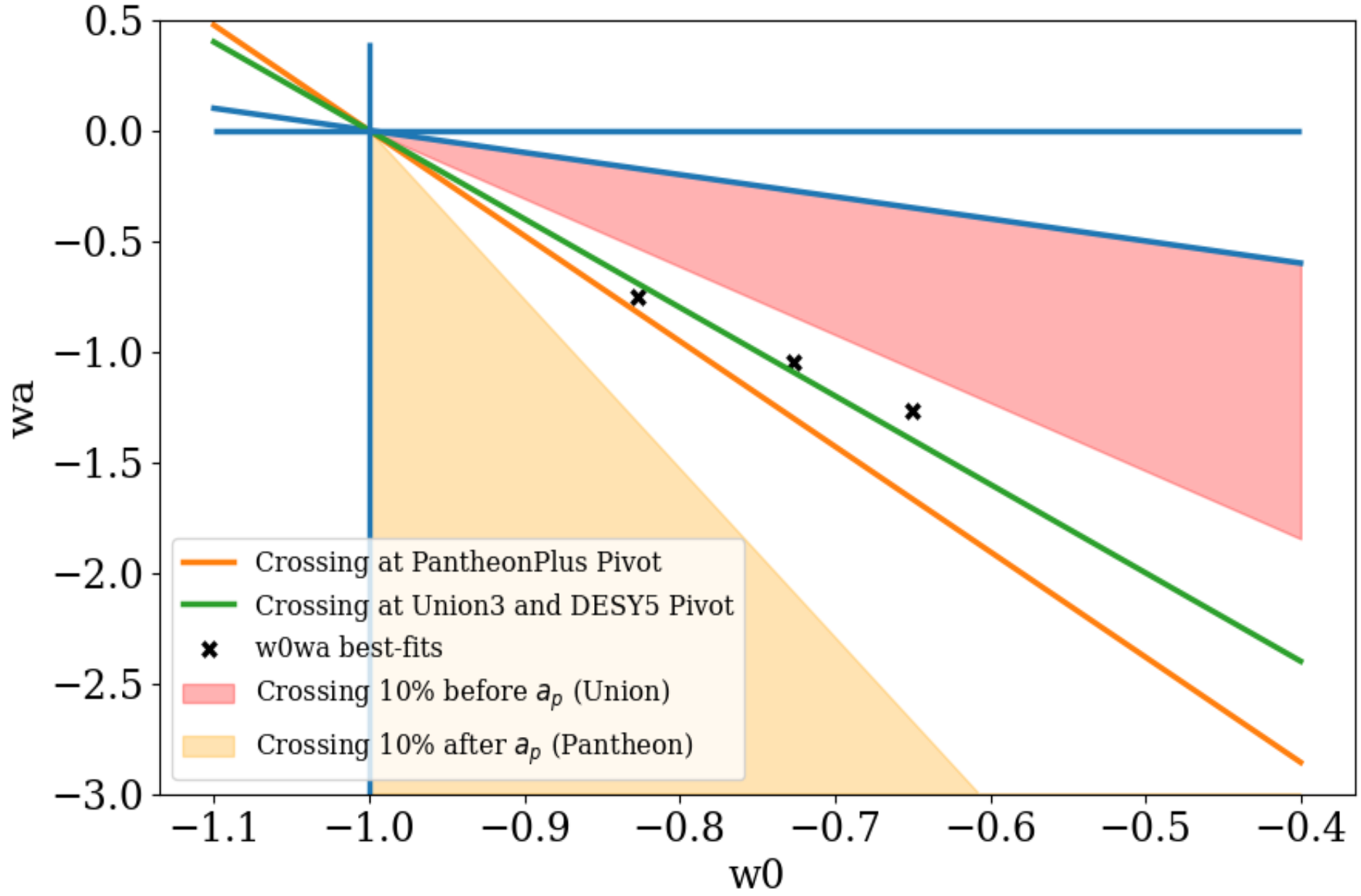
Can we do better?

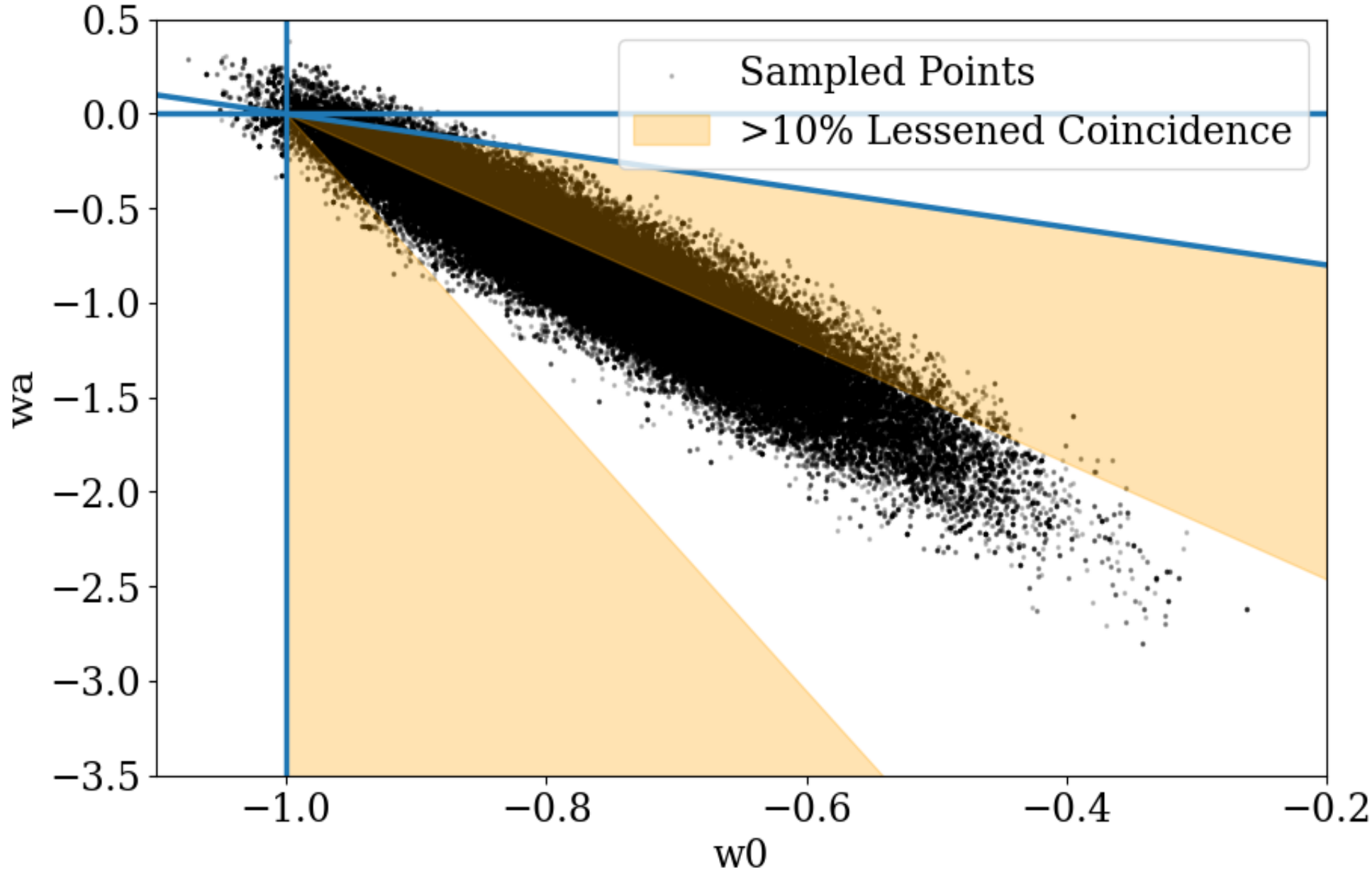
Reverse engineer priors for lessened coincidence

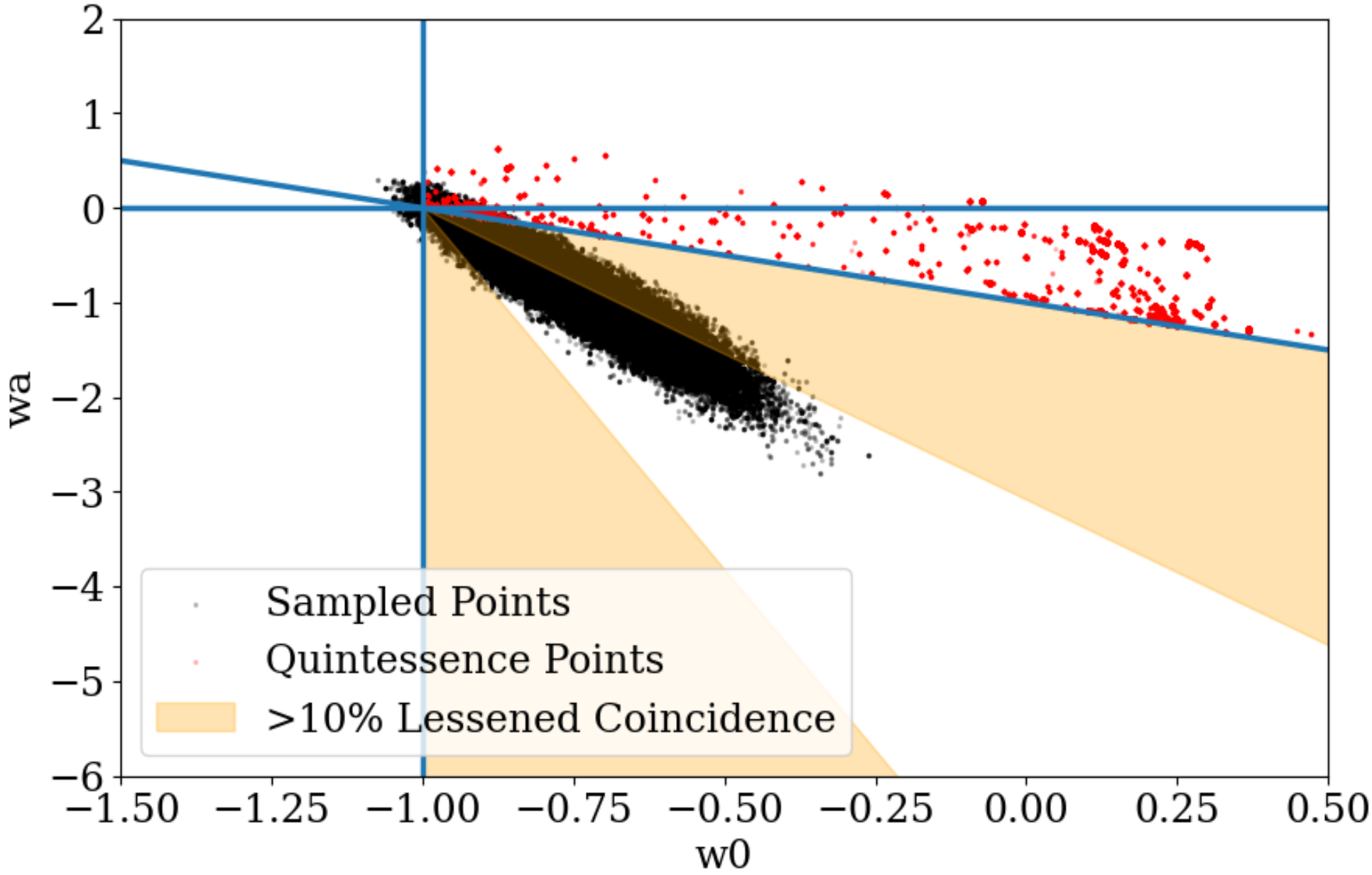


To “down weight solutions that lie farthest from theoretical expectation”

We must understand the structure of the parameter space better

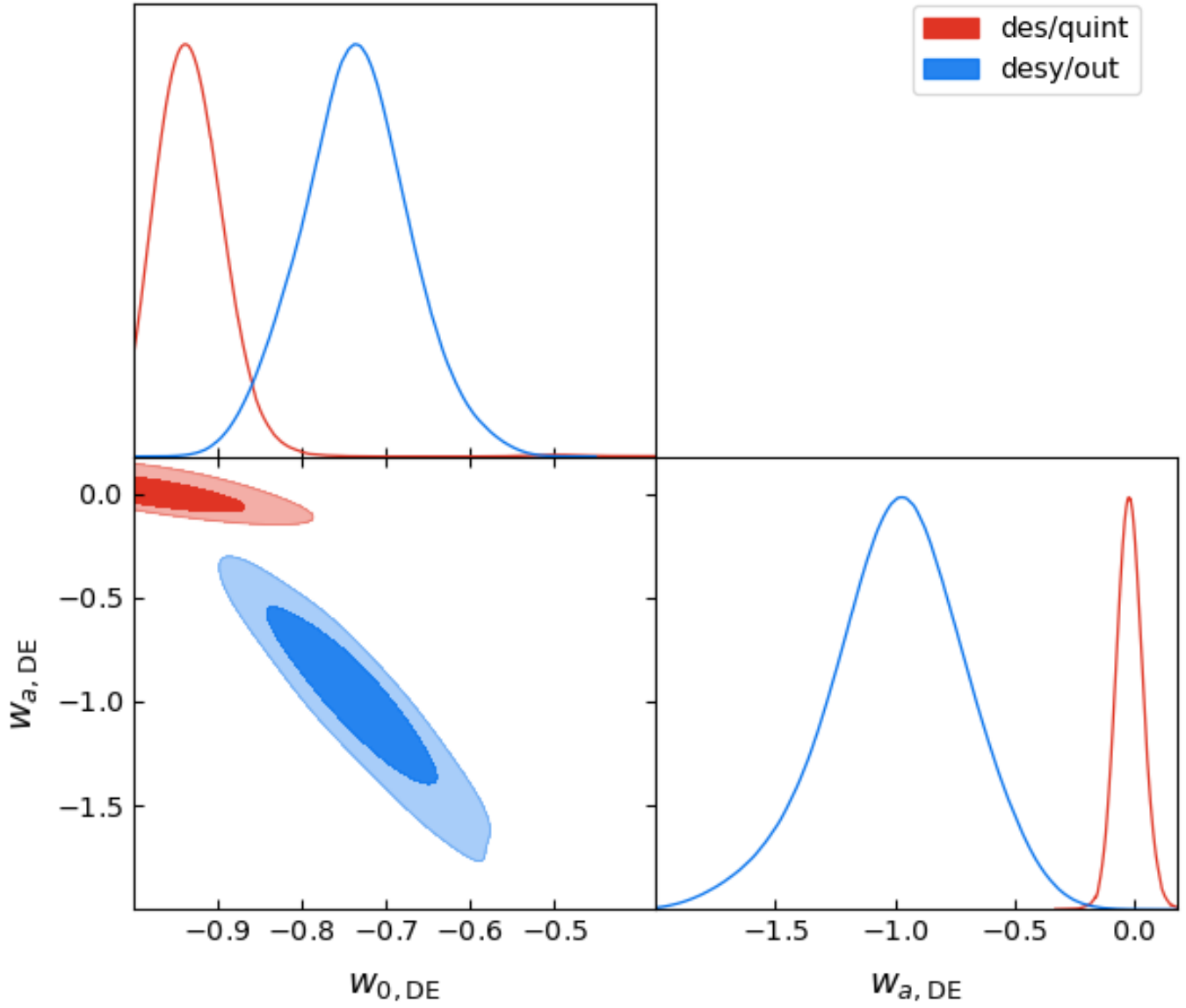

0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
wa
−1.1
−1.0
−0.9
−0.8
−0.7
−0.6
−0.5
−0.4
w0
Crossing at PantheonPlus Pivot
Crossing at Union3 and DESY5 Pivot
w0wa best-fits
Crossing 10% before a_p (Union)
Crossing 10% after a_p (Pantheon)

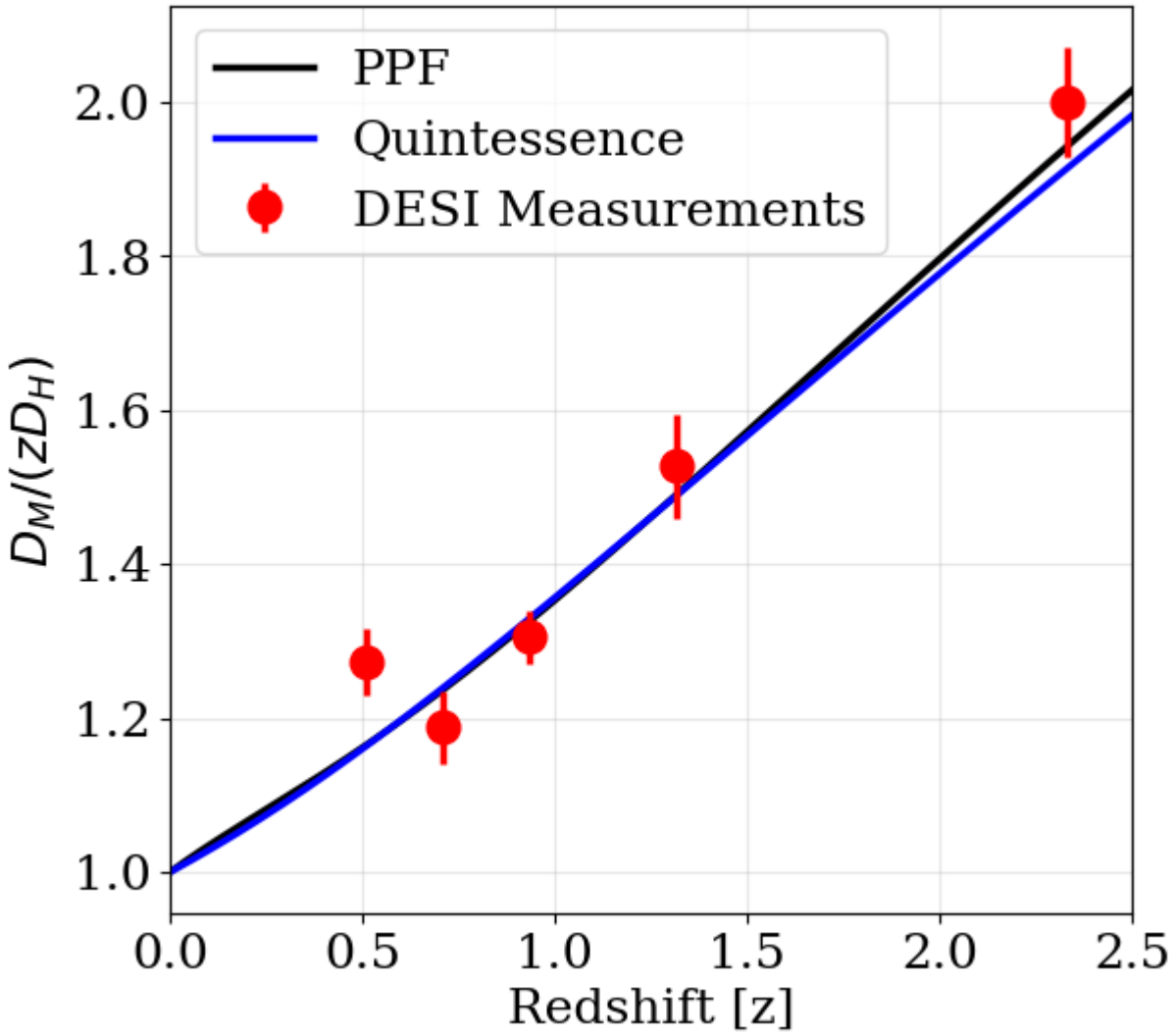

Sampled Points
>10% Lessened Coincidence
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
−3.5
wa
−1.0
−0.8
−0.6
−0.4
−0.2
w0


2
1
0
−1
−2
−3
−4
−5
−6
wa
−1.50
−1.25
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
w0
Sampled Points
Quintessence Points
>10% Lessened Coincidence

Restricting to quintessence compatible solutions pulls us closer to ΛCDM

(quintessence chain partially converged





Major discrepancy at high-z (corresponds to Lyman-Alpha tracer)

Un-converged Chains = Take this with a grain of salt

Internship Outcomes: Science

- PPF solutions preferred strongly over physical models, even against drastic changes in priors

- Quintessence compatible evolving DE solutions lie closer to Lambda-CDM

- Nature of w0-wa parameter space

Internship Outcomes: Learning

- Concepts: PPF, Quintessence, Sensitivity analysis, etc.

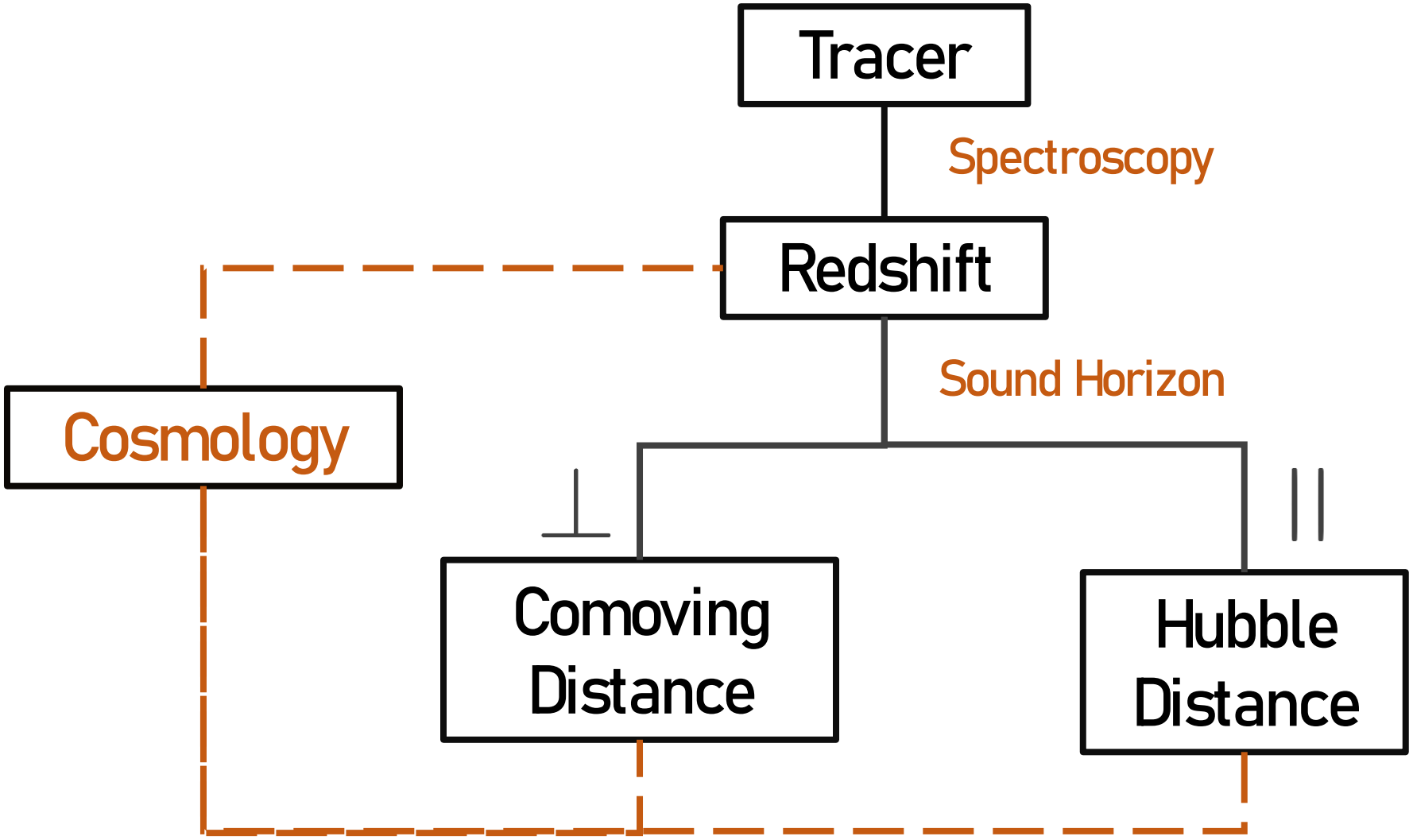
- Creating custom likelihoods for cobaya

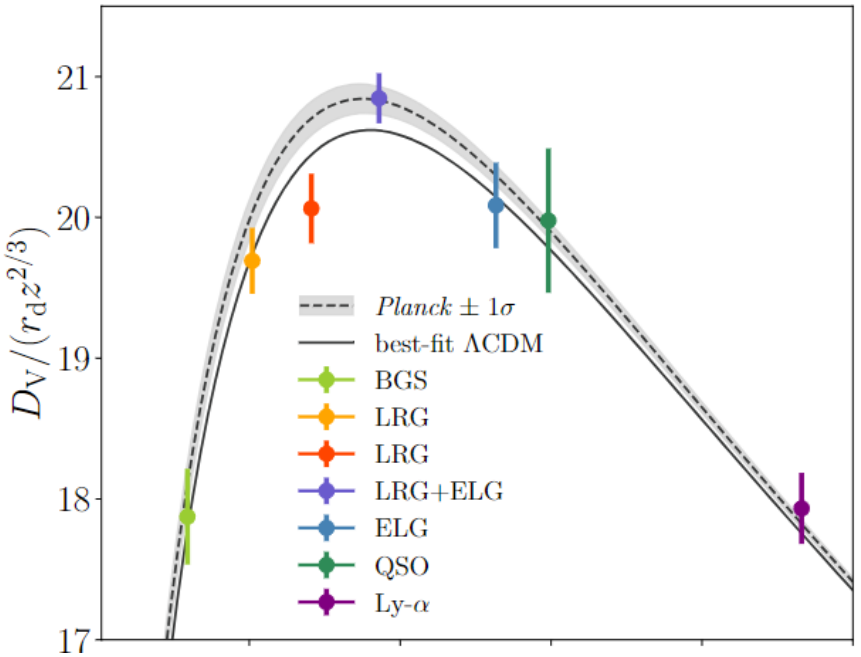
- BONUS: Defining constraints on derived parameters somewhat convoluted. Developed a small script for this (possible pull request, maybe?)

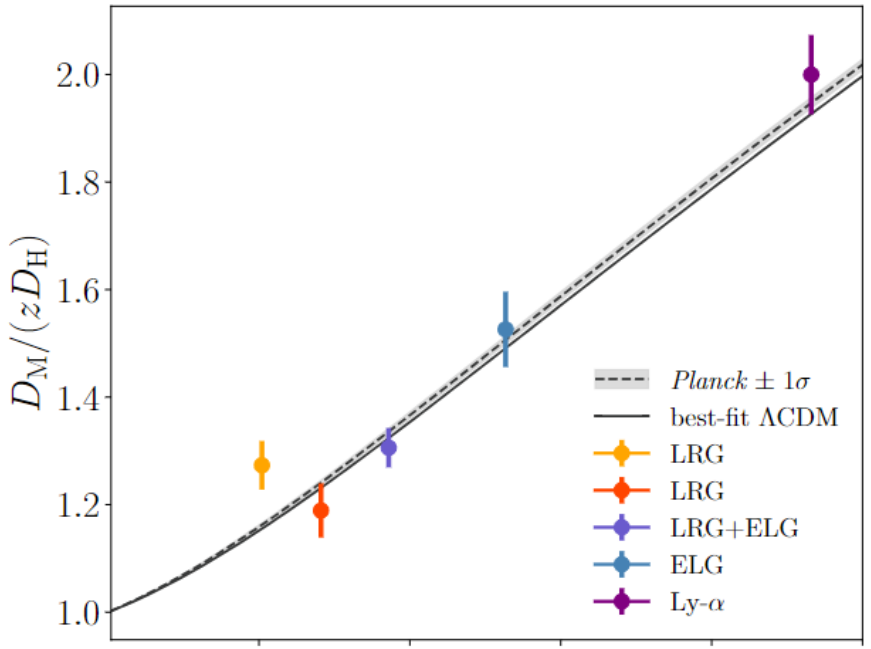
Thank You

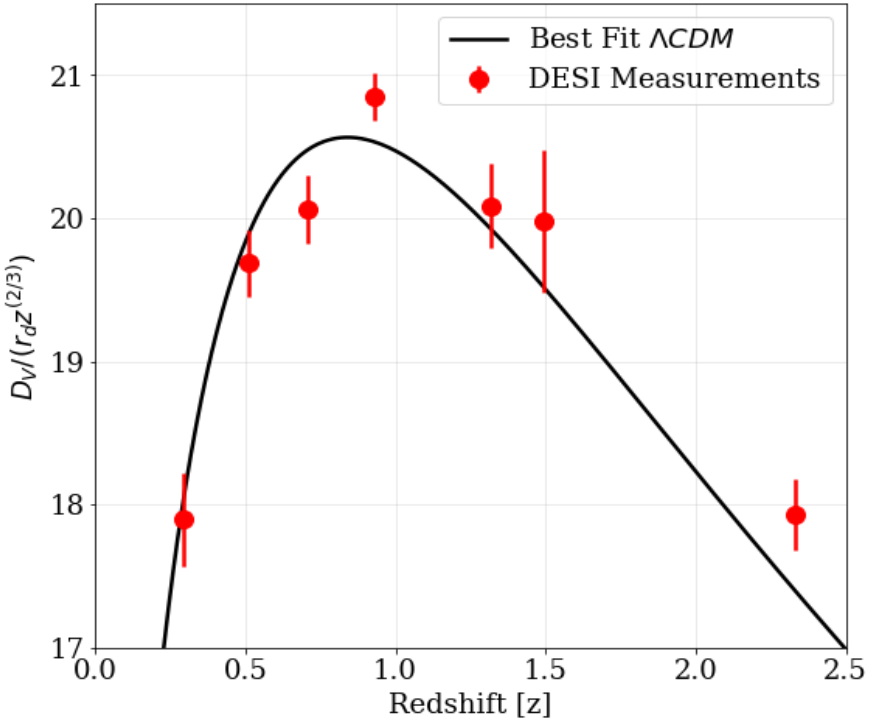
github.com/krtktwri
kartiktiwari.com

DESI: Survey


Tracer
Spectroscopy
Redshift
Sound Horizon
Cosmology
Comoving Distance
Hubble Distance







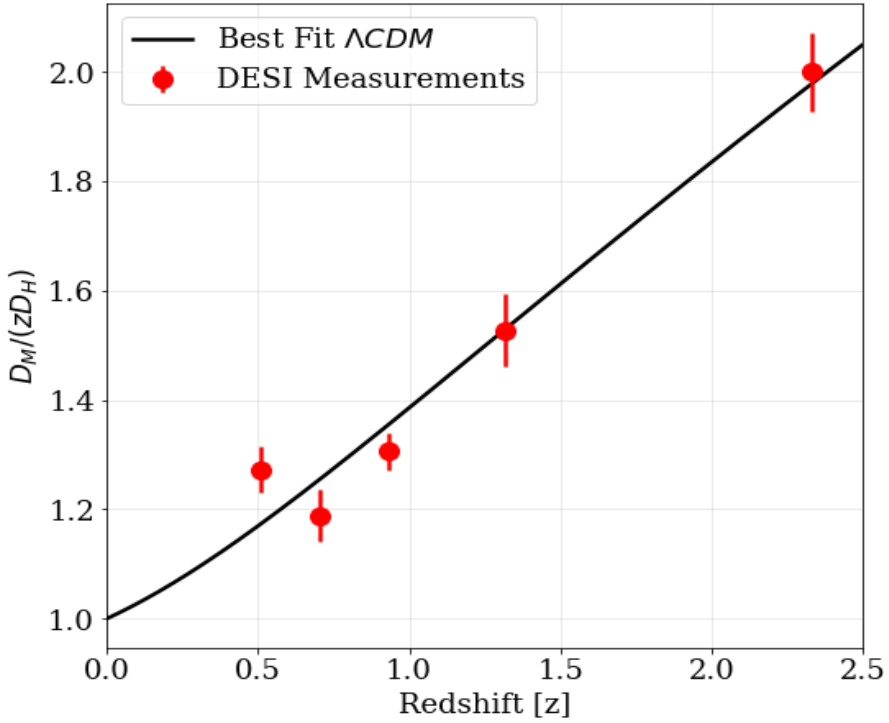


Fig 1 in DESI 2024 VI

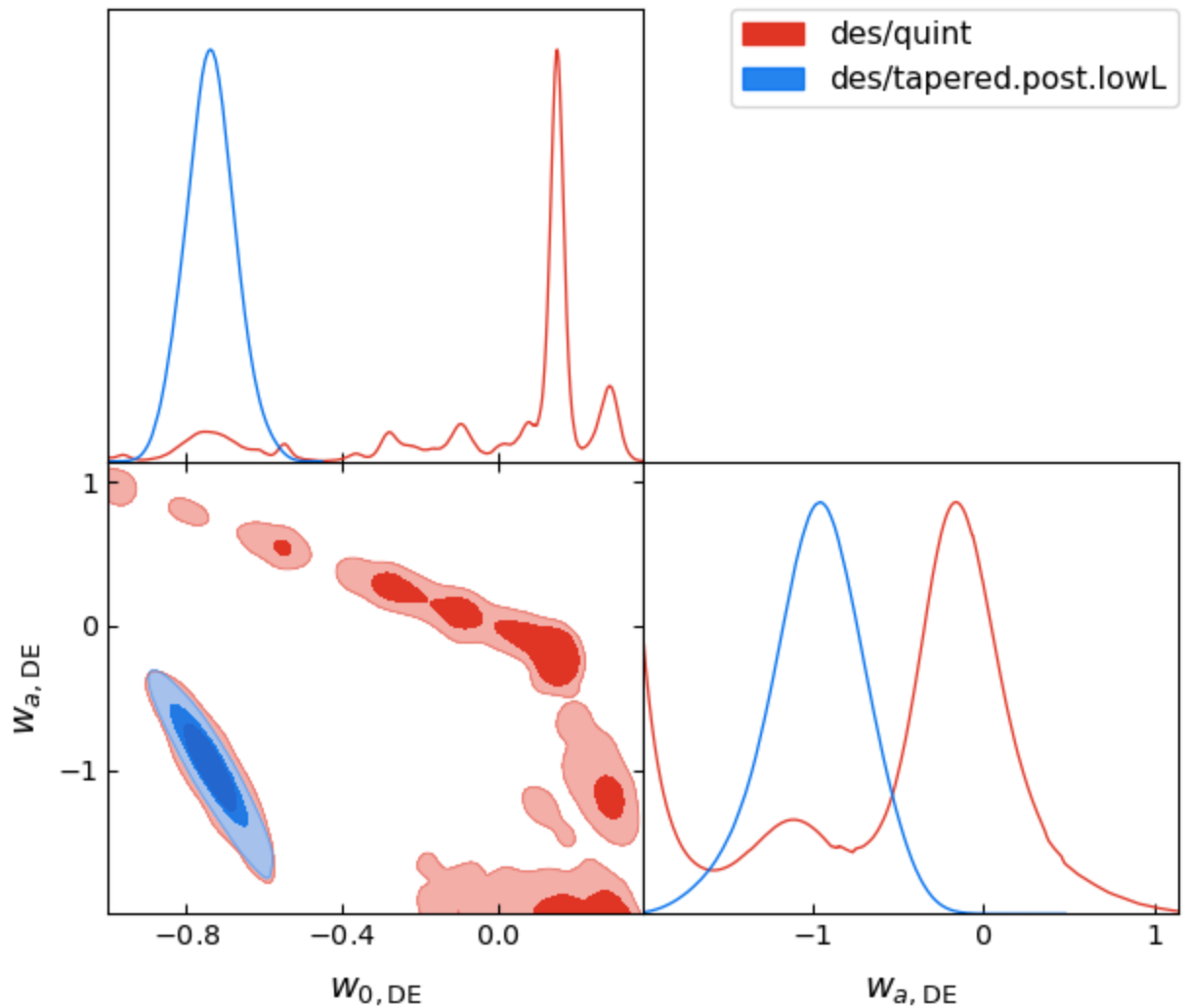
$$D_V(z) = \left(zD_M(z)^2 D_H(z)\right)^{1/3}$$

Regenerated after sampling 1250 points (~15 hours)

R-1 criteria not met

wCDM					
DESI	0.293 ± 0.015	—	—	$-0.99^{+0.15}_{-0.13}$	—
DESI+BBN+$\theta_\star$	0.295 ± 0.014	$68.6^{+1.8}_{-2.1}$	—	$-1.002^{+0.091}_{-0.080}$	—
DESI+CMB	0.281 ± 0.013	$71.3^{+1.5}_{-1.8}$	—	$-1.122^{+0.062}_{-0.054}$	—
DESI+CMB+Panth.	0.3095 ± 0.0069	67.74 ± 0.71	—	-0.997 ± 0.025	—
DESI+CMB+Union3	0.3095 ± 0.0083	67.76 ± 0.90	—	-0.997 ± 0.032	—
DESI+CMB+DESY5	0.3169 ± 0.0065	66.92 ± 0.64	—	-0.967 ± 0.024	—
w_0w_aCDM					
DESI	$0.344^{+0.047}_{-0.026}$	—	—	$-0.55^{+0.39}_{-0.21}$	< -1.32
DESI+BBN+$\theta_\star$	$0.338^{+0.039}_{-0.029}$	$65.0^{+2.3}_{-3.6}$	—	$-0.53^{+0.42}_{-0.22}$	< -1.08
DESI+CMB	$0.344^{+0.032}_{-0.027}$	$64.7^{+2.2}_{-3.3}$	—	$-0.45^{+0.34}_{-0.21}$	$-1.79^{+0.48}_{-1.0}$
DESI+CMB+Panth.	0.3085 ± 0.0068	68.03 ± 0.72	—	-0.827 ± 0.063	$-0.75^{+0.29}_{-0.25}$
DESI+CMB+Union3	0.3230 ± 0.0095	66.53 ± 0.94	—	-0.65 ± 0.10	$-1.27^{+0.40}_{-0.34}$
DESI+CMB+DESY5	0.3160 ± 0.0065	67.24 ± 0.66	—	-0.727 ± 0.067	$-1.05^{+0.31}_{-0.27}$

Value	Energy density scaling	Time scaling	Phenomena described	Examples	Topological defect dimensions	Topological defect described
$w = 1$	$\rho \propto a^{-6}$	$a \propto t^{\frac{1}{3}}$	Free scalar field	Higgs field, dilatons[*citation needed*]	-	-
$w = 1/3$	$\rho \propto a^{-4}$	$a \propto t^{\frac{1}{2}}$	Ultra-relativistic particles	Photons, ultra-relativistic neutrinos, cosmic rays	-	-
$w = 0$	$\rho \propto a^{-3}$	$a \propto t^{\frac{2}{3}}$	Non-relativistic particles	Cold baryonic matter, cold dark matter, cosmic neutrino background	0	Magnetic monopoles
$w = -1/3$	$\rho \propto a^{-2}$	$a \propto t$	Curvature	Curvature of spacetime	1	Cosmic strings
$w = -2/3$	$\rho \propto a^{-1}$	$a \propto t^2$	-	-	2	Domain walls
$w = -1$	$\rho \propto a^0$	$a \propto e^{Ht}$	Cosmological constant	Dark energy	-	-
$w < -1$	-	-	Phantom energy	-	-	-


des/quint
des/tapered.post.lowL
1
0
−1
$w_{a,\mathrm{DE}}$
−0.8
−0.4
0.0
$w_{0,\mathrm{DE}}$
−1
0
1
$w_{a,\mathrm{DE}}$