Title: Cosmological implications from DESI Y1 BAO and Future Forecasts

Speakers: Hanyu Zhang

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

Date: July 17, 2024 - 3:15 PM

URL: https://pirsa.org/24070071

Abstract:

We present key cosmological findings from the Dark Energy Spectroscopic Instrument (DESI)’s first year baryon acoustic oscillations (BAO) measurements. DESI's BAO provide robust measurements of the transverse comoving distance and Hubble rate across seven redshift bins, spanning a redshift range of $0.1 < z < 4.2$. DESI BAO data alone align well with the flat ΛCDM model with $\Omega m=0.295\pm0.015$. Paired with a baryon density prior from Big Bang Nucleosynthesis and the acoustic angular scale from the cosmic microwave background (CMB) data, we find $H0=68.52\pm0.62$ km/s/Mpc. Combined analyses with CMB anisotropies and lensing from Planck and ACT yield $\Omega m=0.307\pm0.005$ and $H0=67.97\pm0.38$ km/s/Mpc. Extending the baseline model with a constant dark energy equation of state parameter, w, results in $w=-0.99+0.15-0.13$. In a dark energy model with time-varying equation of state parametrized by w0 and wa, combined with various supernovae data, indicate deviations from ΛCDM at significance levels up to 3.9σ. For flat ΛCDM with the sum of neutrino mass free, DESI and CMB establish an upper limit of $\sum m\nu$ 0 (0.059) eV prior. We will also show forecasts for Y3 and Y5 results as well as prospects with DESI II.

Y1 Cosmology Results and Path Forward for DESI

Hanyu Zhang (University of Waterloo, Waterloo Center for Astrophysics)
On behalf of DESI Collaboration

July 17th, 2024, Waterloo, Ontario
50 Years of Horndeski Gravity: Exploring Modified Gravity

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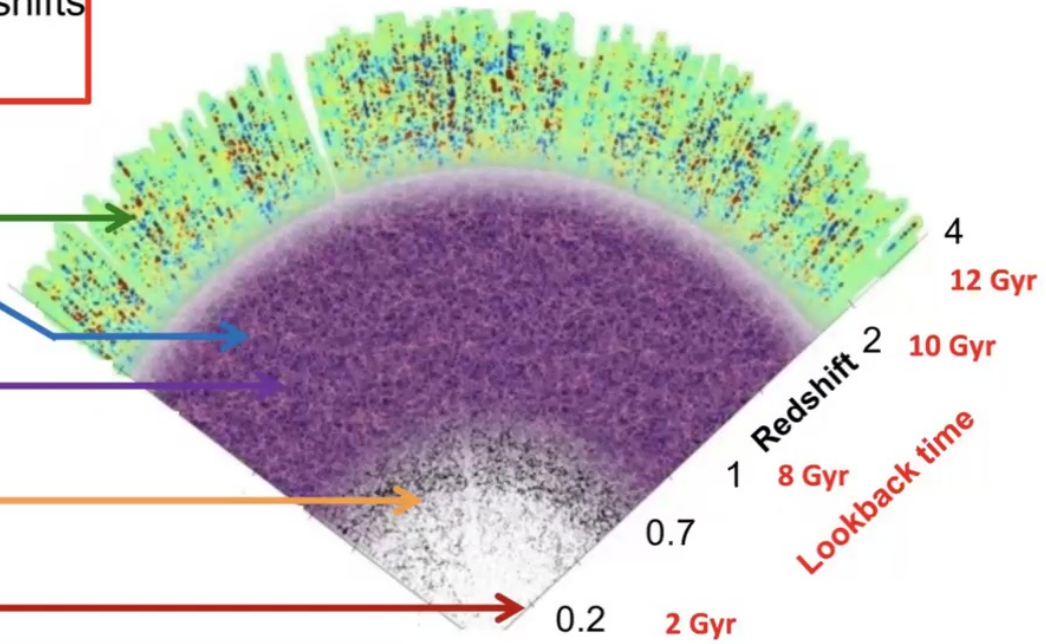
DESI: the survey

Five target classes

~40 million redshifts

in 5 years

DESI (2021-2026)



3 million QSOs
Lya z > 2.1
Tracers 0.9 < z < 2.1

16 million ELGs
0.6 < z < 1.6

8 million LRGs
0.4 < z < 1.0

13.5 million
Brightest galaxies
0.0 < z < 0.4

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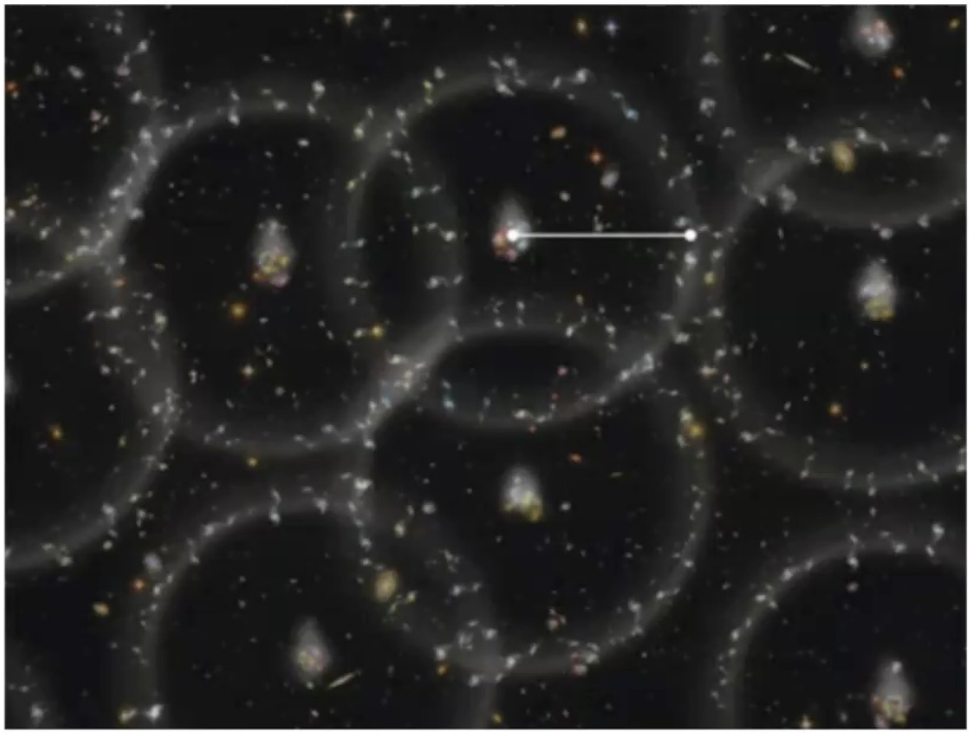
Baryon Acoustic Oscillations (BAO)

More detail on DESI 2024 III: Baryon Acoustic Oscillations from Galaxies and Quasars

Characteristic scale imprinted in matter distribution at sound horizon scale, r_d ~ 150 Mpc



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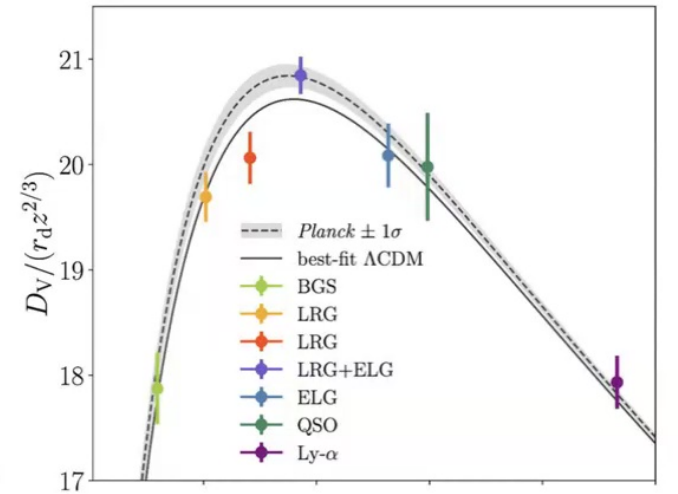
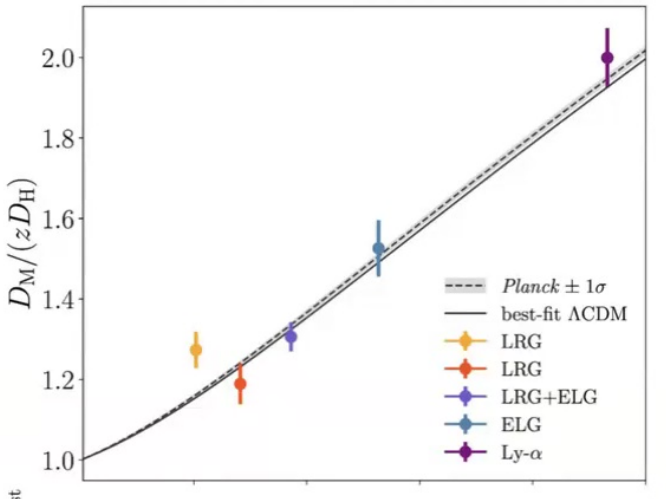
DESI Y1 BAO





overall scale of std ruler

anisotropy of std ruler

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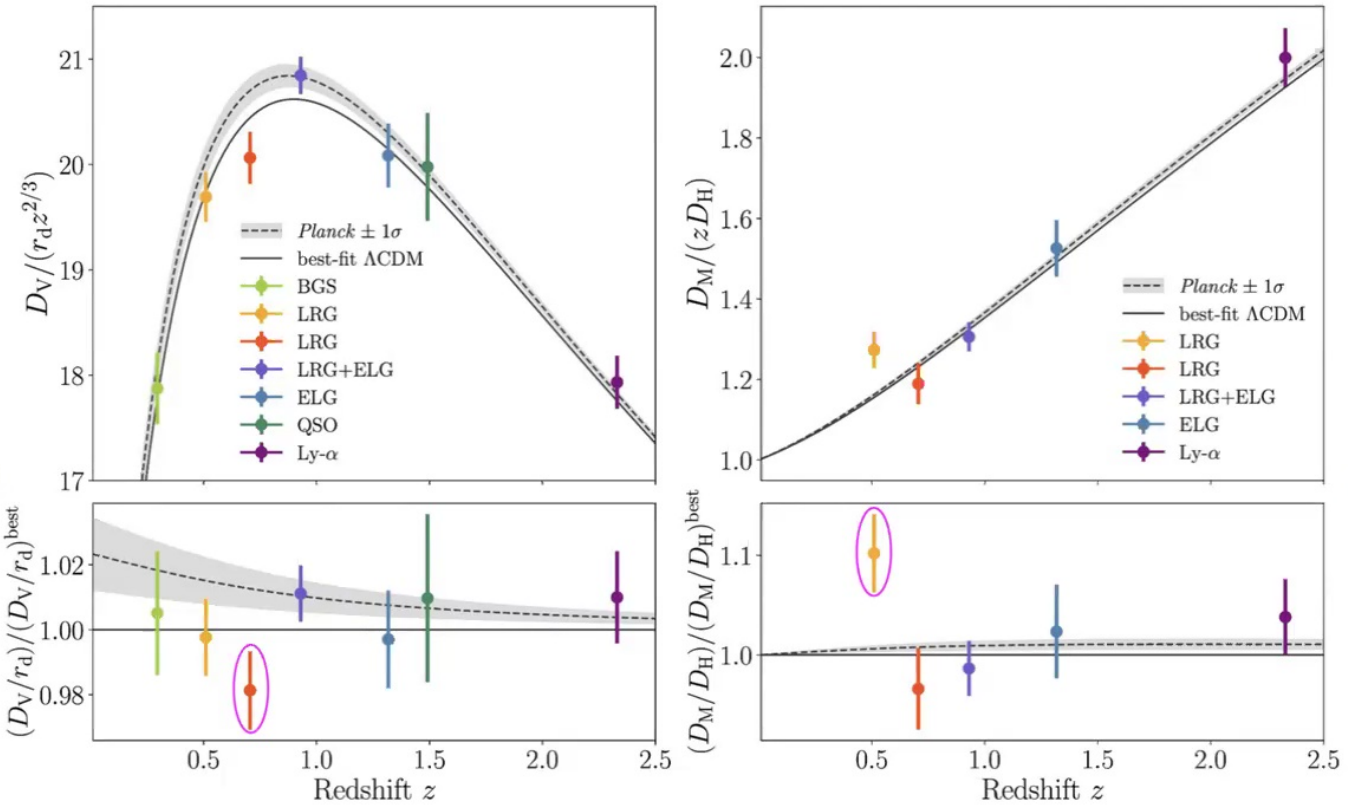
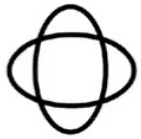
DESI Y1 BAO

overall scale of std ruler





anisotropy of std ruler

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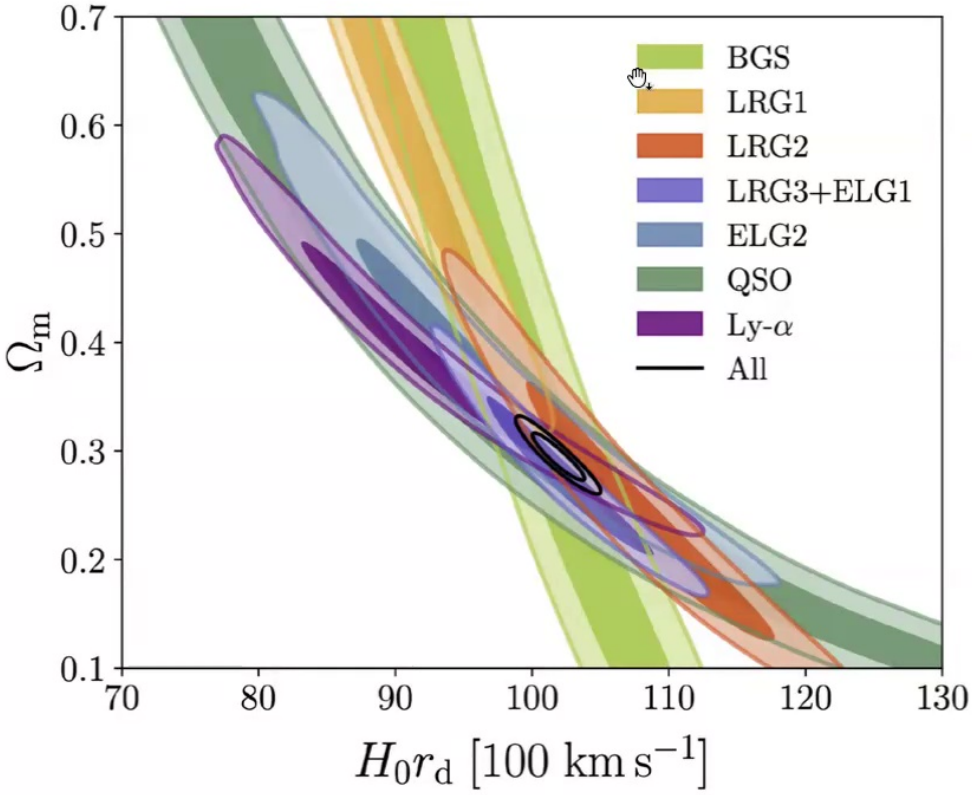
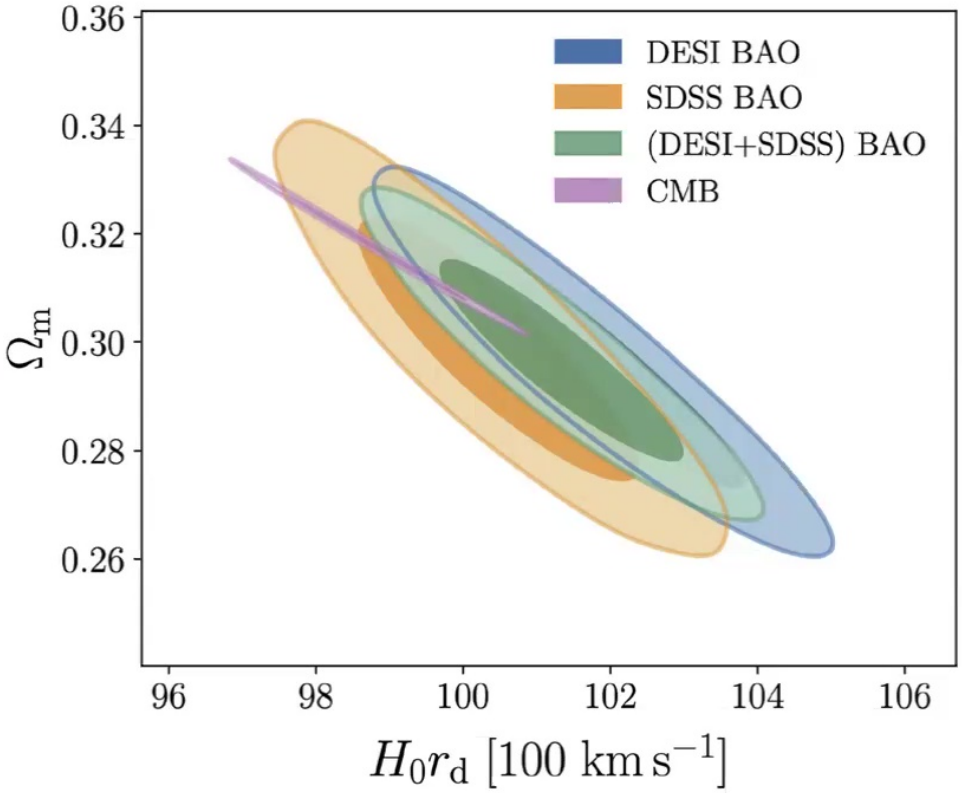
Flat ΛCDM results

$$\Omega_{\rm m} = 0.295 \pm 0.015$$
$$H_0 r_{\rm d} = 101.8 \pm 1.3\ [10^2\ {\rm km\,s^{-1}}]$$



Flat ΛCDM results

DESI BAO prefers a slightly higher $H0rd$



*CMB = *Planck* [plik] temp. + pol. + (*Planck* PR4 + ACT DR6) CMB lensing

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Neutrino masses

$\sum m_\nu < 0.072\,\mathrm{eV}$

$(95\,\%, \mathrm{DESI\ BAO{+}CMB})$

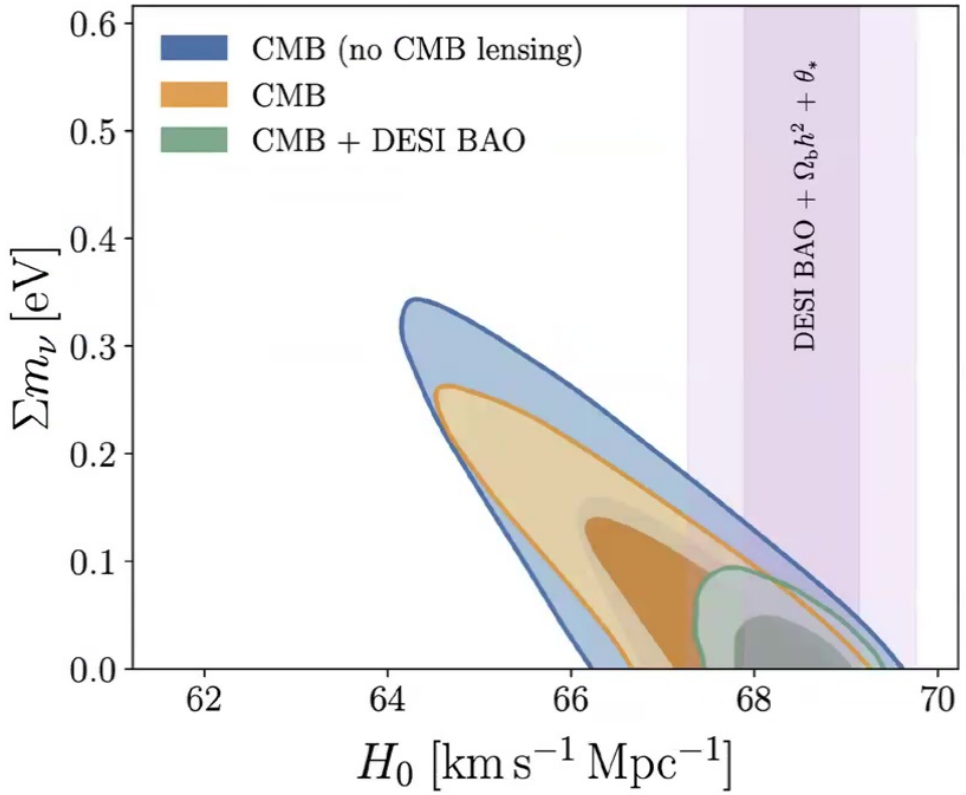
Background-dependent

$\sum m_\nu < 0.195\ \mathrm{eV}$

If allowing for

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

Also prior-dependent



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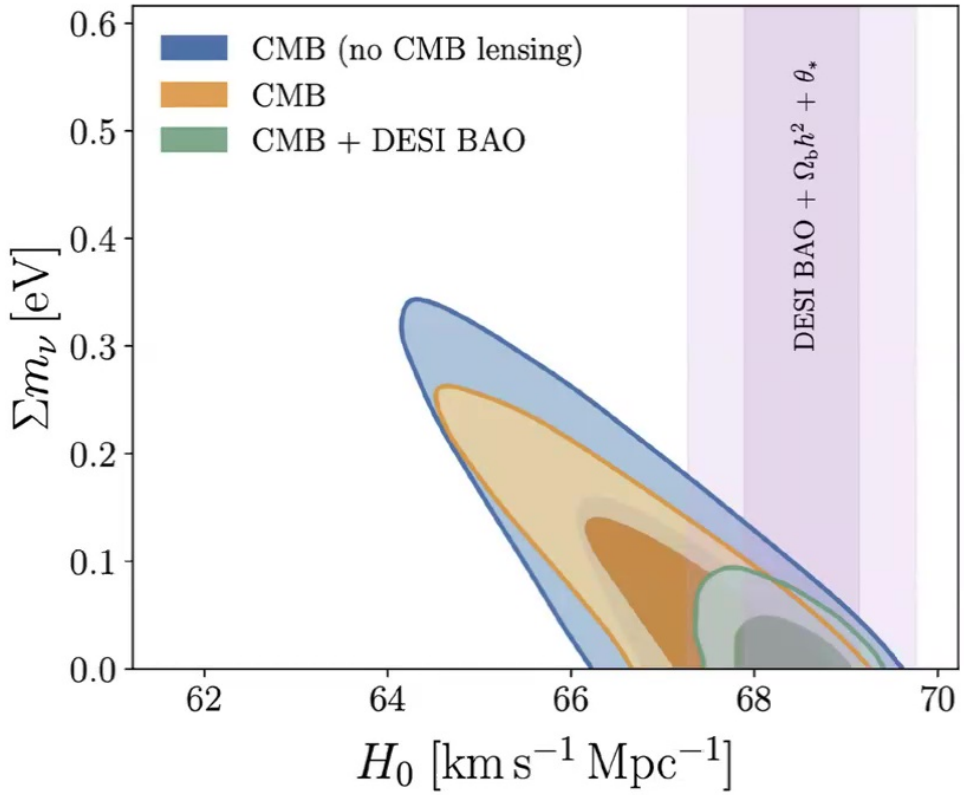

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Dark Energy

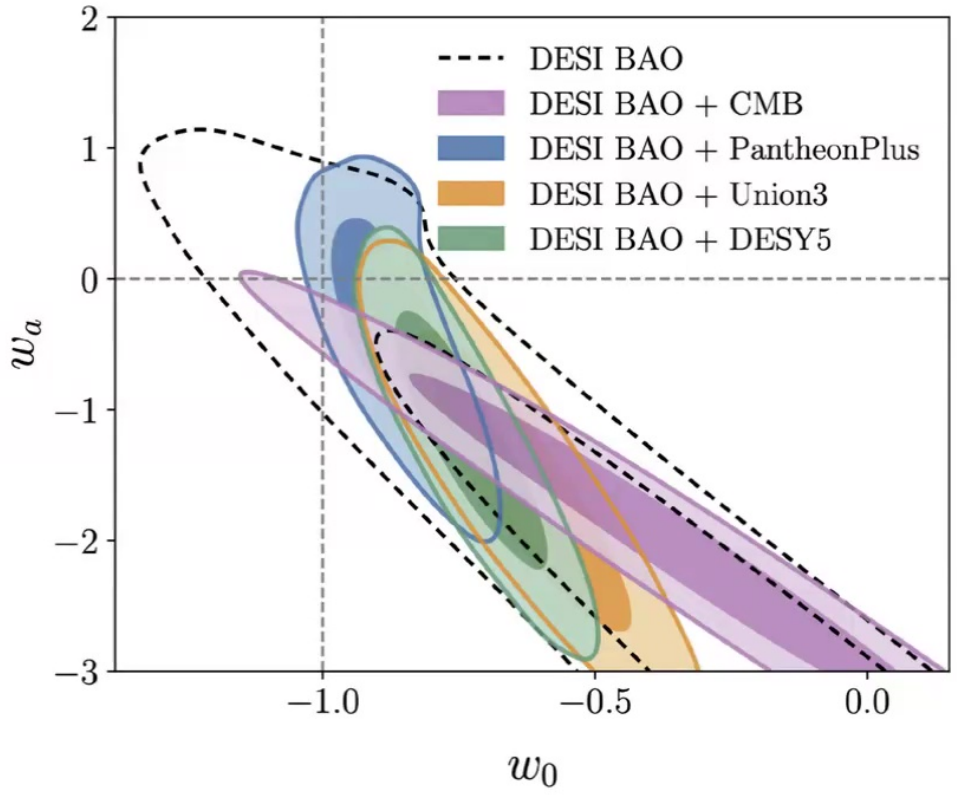
With time-varying equation of state model

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

PantheonPlus (Scolnic et al 2022)

Union3 (Rubin et al 2024)

DESY5SN (DES Collaboration 2024)



Dark Energy

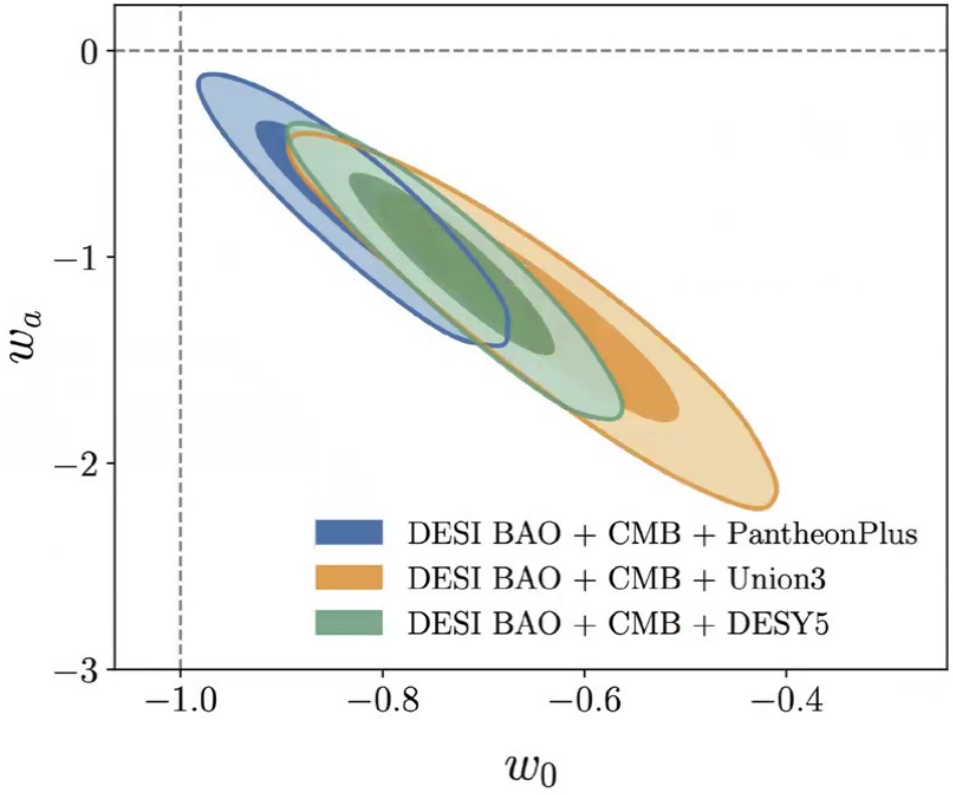
With time-varying equation of state model

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

Level of discrepancy with ΛCDM:

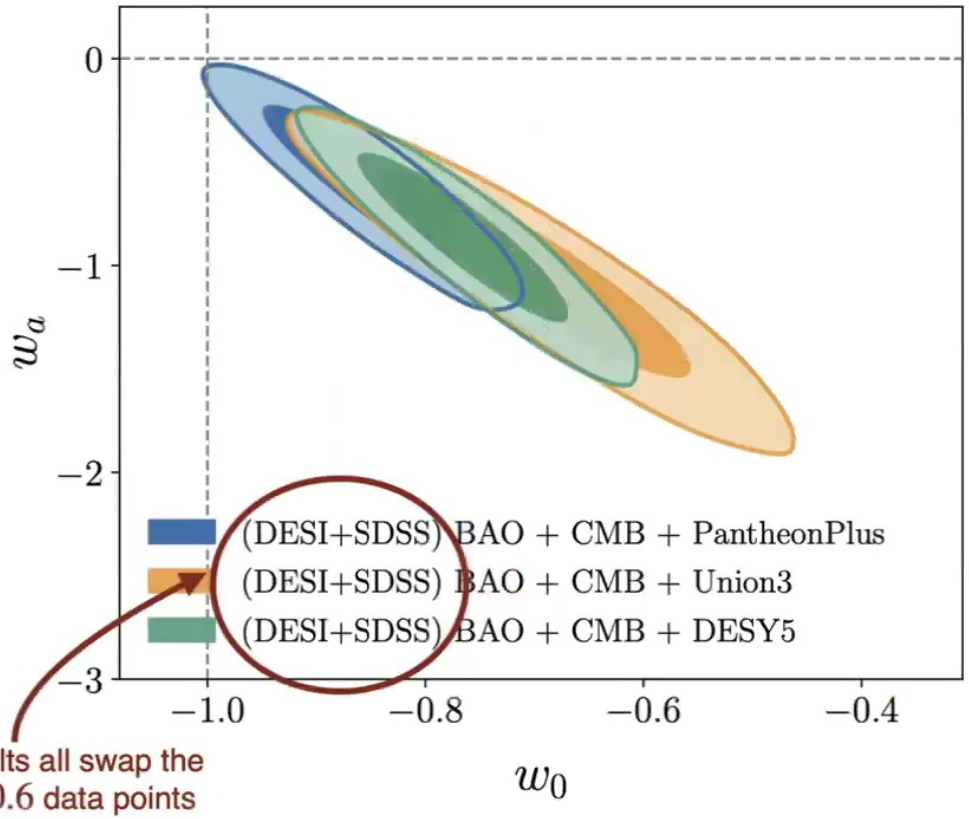
- DESI+CMB+PantheonPlus: **2.5σ**
- DESI+CMB+Union3: **3.5σ**
- DESI+CMB+DESY5SN: **3.9σ**

Preference for $w_0 > -1$ and $w_a < 0$ quadrant



Is DE driven by the z = 0.51 point?

Not that much! Check Fig 12 in the paper



These results all swap the DESI $z < 0.6$ data points for SDSS/BOSS ones

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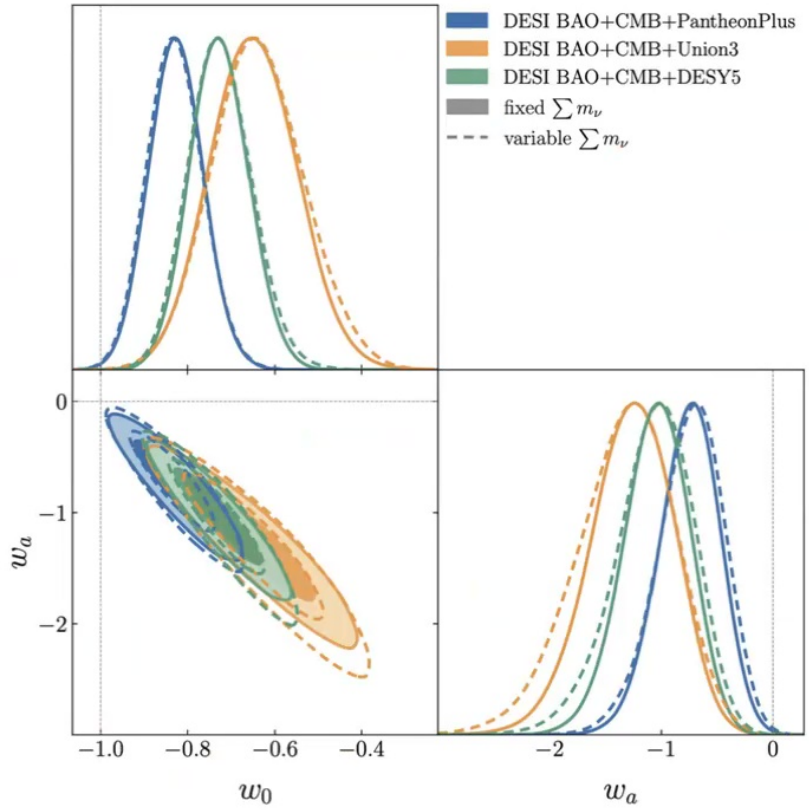
What happens when mnu is free?

Not a lot…



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First batch of DESI results and DE related paper

April 4th release, https://data.desi.lbl.gov/doc/papers/
Check the paper for more discussion and results of spatial curvature, Neff etc.

DE related paper from DESI and outside DESI

K. Lodha, A. Shafieloo, R.Calderón, E. V. Linder et al. 2024 (2405.13588)

R.Calderón, K. Lodha, A. Shafieloo, E. V. Linder et al. 2024 (2405.04216)

GB. Zhao et al. (in prep)

D. Shlivko, P. Steinhardt (2405.03933)
W. Giarè, M.Sabogal, R.Nunes and E.Valentino (2404.15232)
and more…

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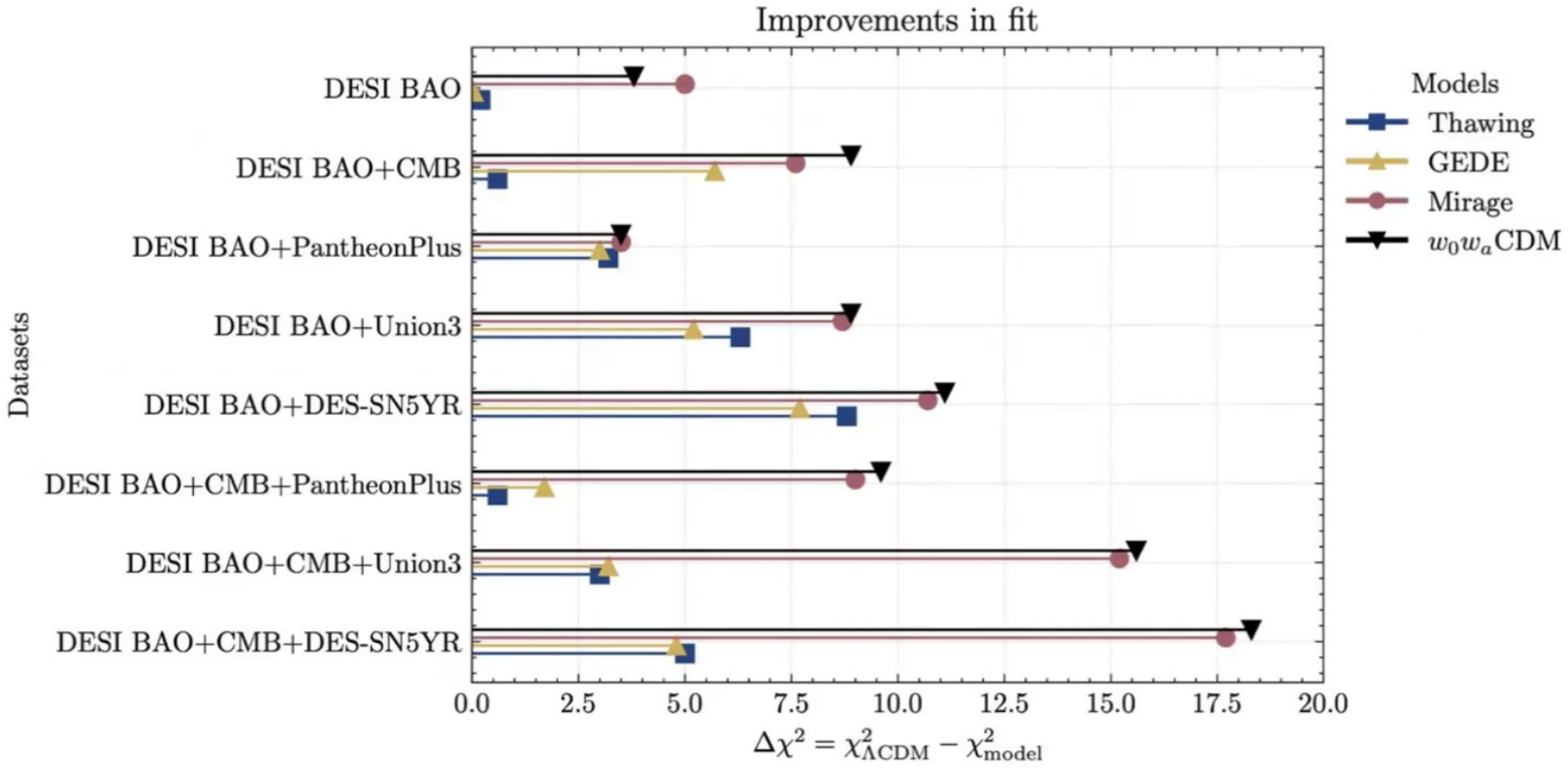
K. Lodha et al. (2405.13588)



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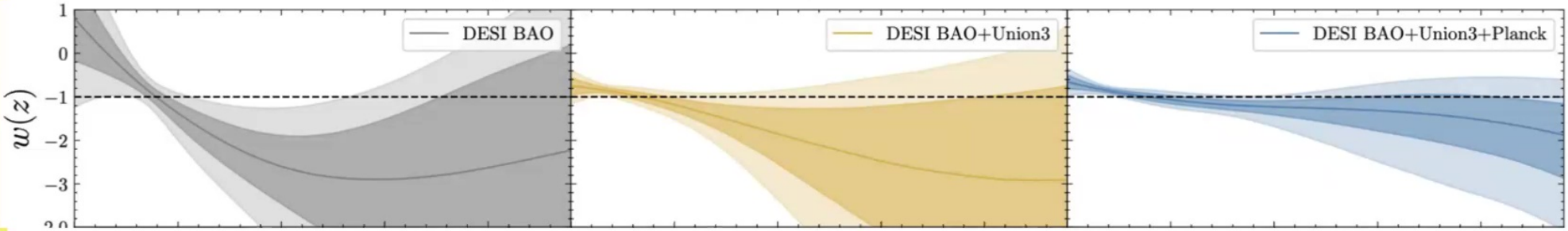

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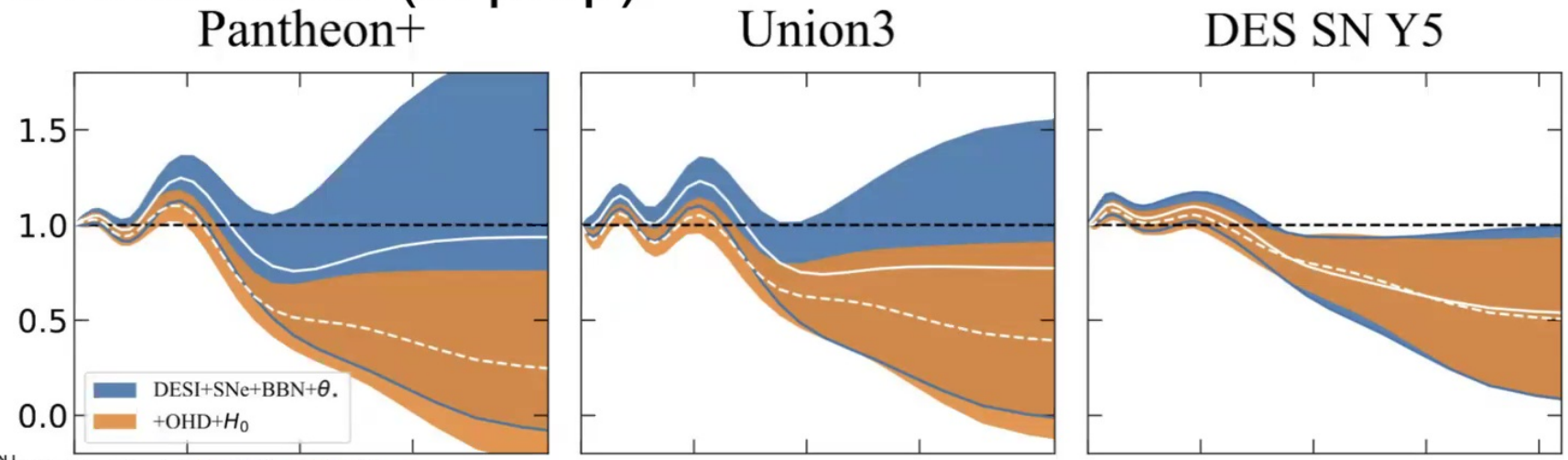
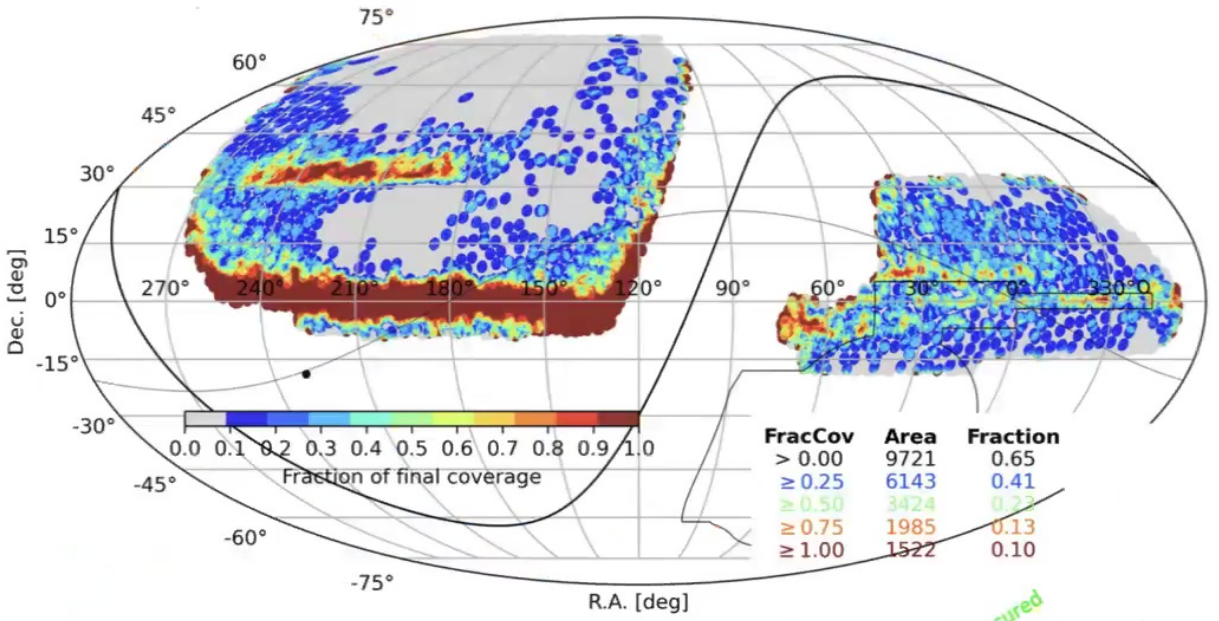
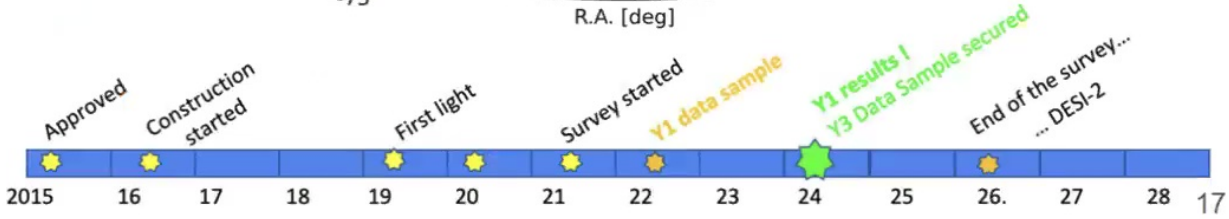


DESI Y3 Y5?

- Biggest ever BAO dataset
- 5.7million redshifts for Y1 already
- Effective cosmic volume ~ 18 Gpc^3
- Final DESI dataset will be ~3x larger than current

DESI DR1 includes data taken from May 14th (2021) to June 12th (2022)





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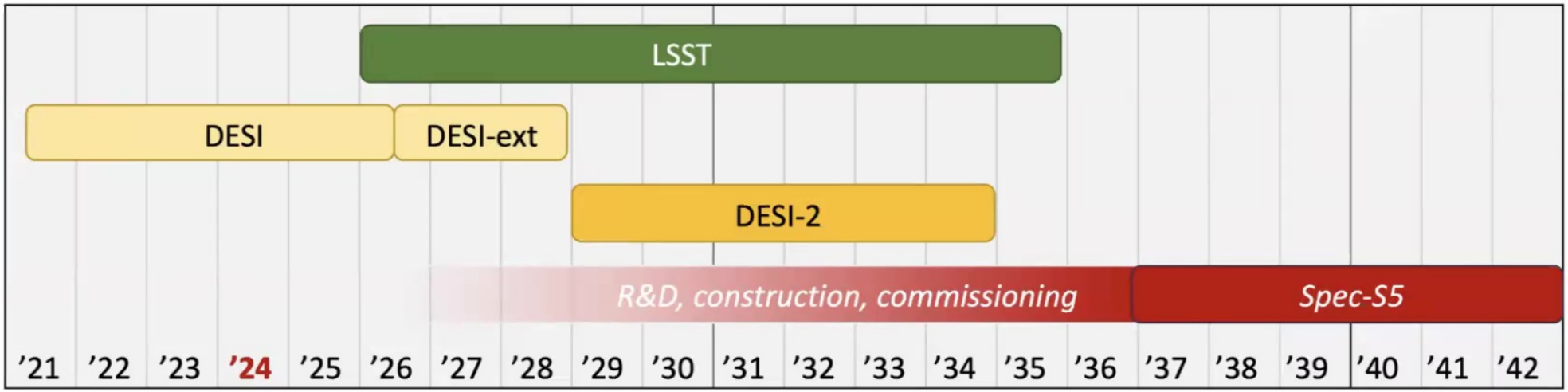
DESI-ext and DESI-2



DESI-ext:

- 20% more survey area
- From 40m redshifts to 63m

DESI-2

- High-density survey at low z (z<1)
- High-z survey (z>2)
- Pathfinder for Spec-S5

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DESI-2

Upgraded instrument based on DESI

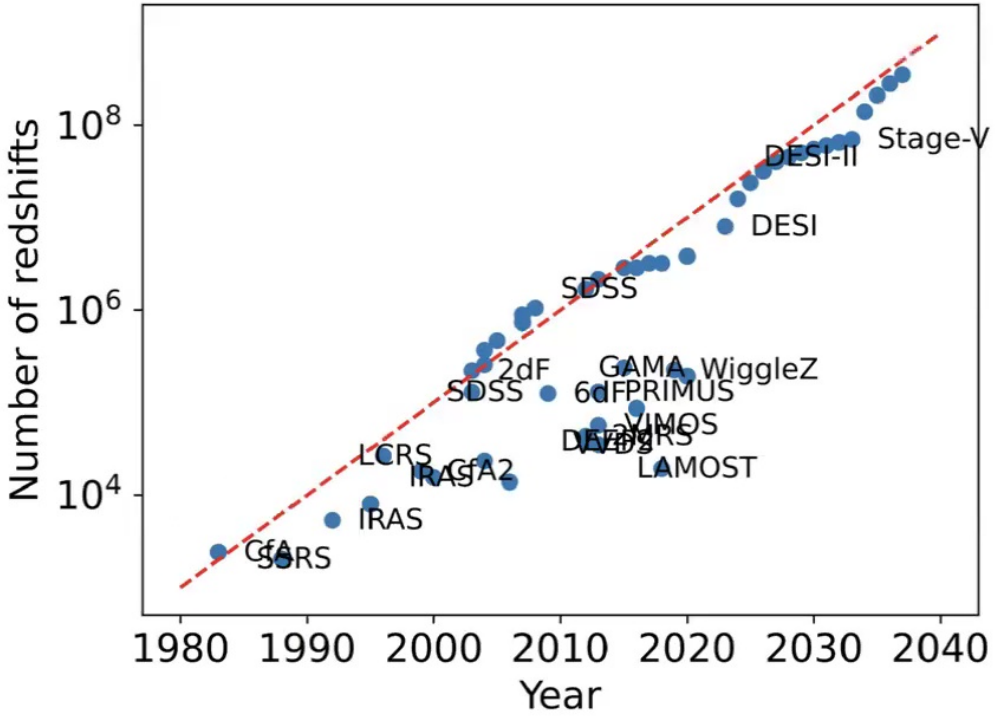
Science goals:

- High-z galaxy redshift survey
- High-density galaxy redshift survey at lower z
- Milky Way Survey / Dwarfs

Low construction cost but high scientific return

Beyond dark energy and dark matter

Extending DESI dark energy, constraints deeper into the matter-dominated regime



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DESI-II

Report of the **P**article **P**hysics **P**roject **P**rioritization **P**anel (P5)

P5 recommends DESI-II

Index: Operation Construction R&D, Research P: Primary S: Secondary

§ Possible acceleration/expansion in more favorable budget situations

Science Experiments

Timeline 2024–2034	Neutrinos	Higgs Boson	Dark Matter	Cosmic Evolution	Direct Evidence	Quantum Imprints	Astronomy & Astrophysics
	Science Drivers						
LHC		P	P		P	P	
LZ, XENONnT			P				
NOvA/T2K	P				S		
SBN	P				S		
DESI/DESI-II	S		S	P			P
Belle II			S		S	P	
IceCube	P		S				P
SuperCDMS			P				
Rubin/LSST & DESC	S		S	P			P
Mu2e						P	
DarkSide-20k			P				
HL-LHC		P	P		P	P	
DUNE Phase I	P				S	S	S

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Summary

- Y1 provide best BAO dataset already
- DESI Y1 BAO consistent with CMB in Flat ΛCDM
- Hints on time varying dark energy equation of state
- Hubble tension, neutrino masses, spatial curvature, Neff + more in paper

- Y1 full-shape analysis to come
- Even better constraining power from Y3 and Y5
- DESI-II is one major step toward a large Stage-5 program

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