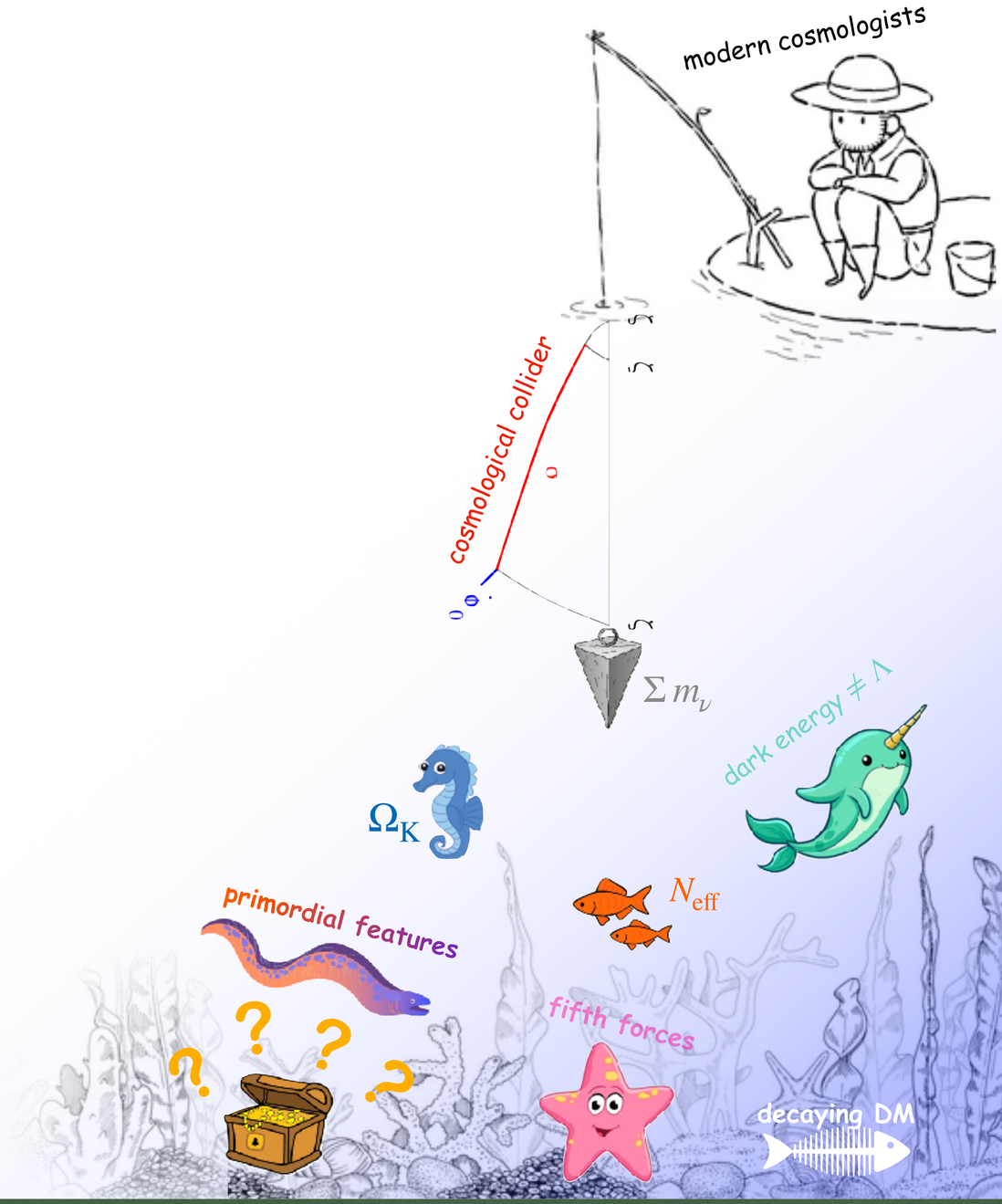
Prospects for high-redshift surveys

Noah Sailer

New Physics from Galaxy Clustering @ GGI

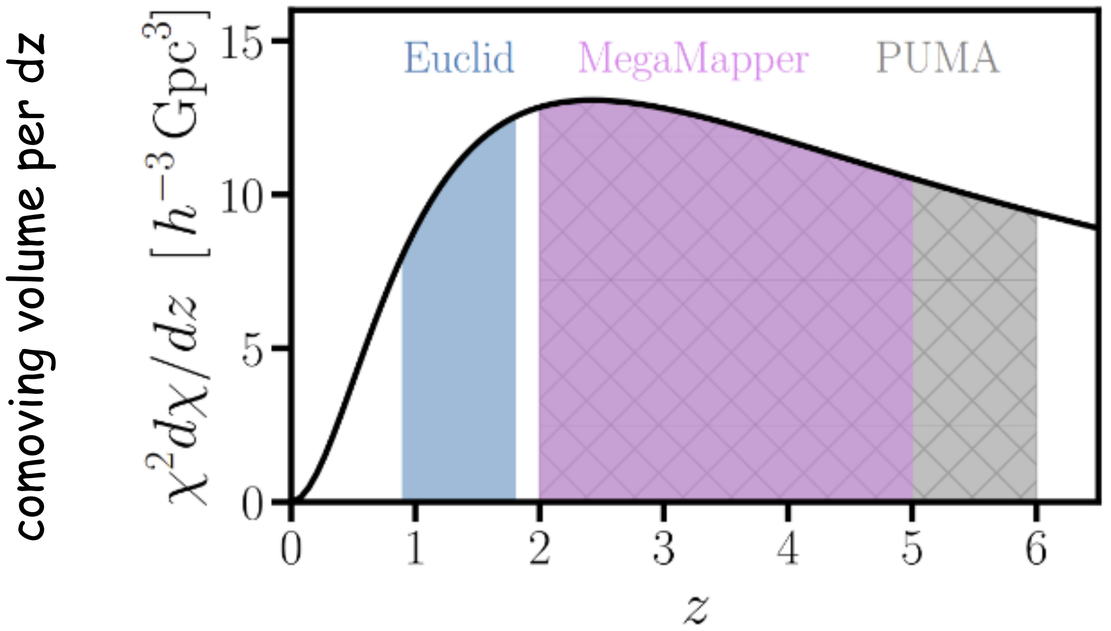
September 22nd 2025



Why high redshifts?

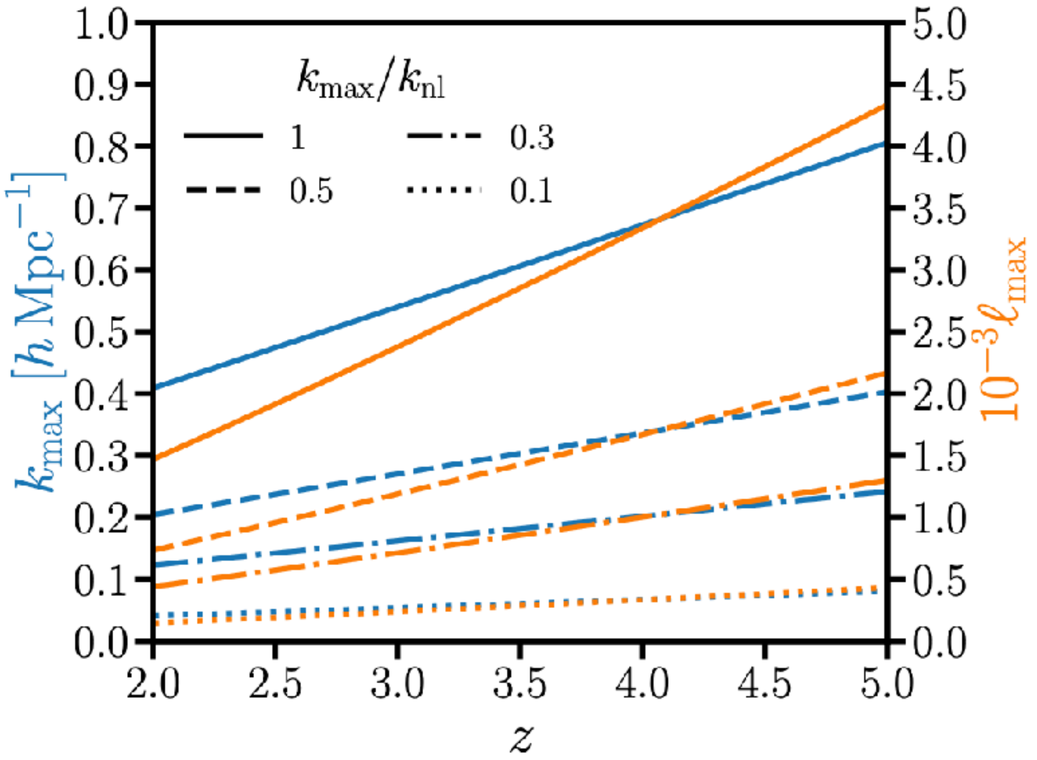
- More volume

$\mathrm{Vol}(2 < z < 6) \simeq 4 \times \mathrm{Vol}(1 < z < 2)$



Why high redshifts?

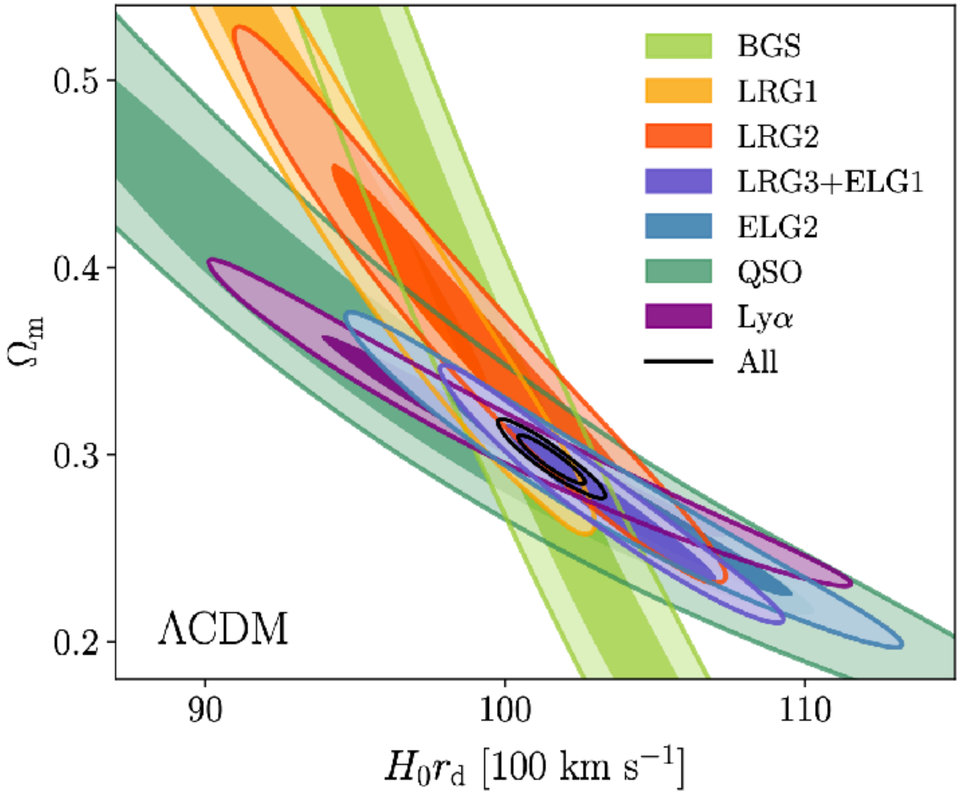
- More volume
- Better correlated with initial conditions



$$k_{\rm nl}^{-2} \equiv \int \frac{dk}{6\pi^2} P_{\rm lin}(k)$$

Why high redshifts?

- More volume
- Better correlated with initial conditions
- Rotation of degeneracy directions



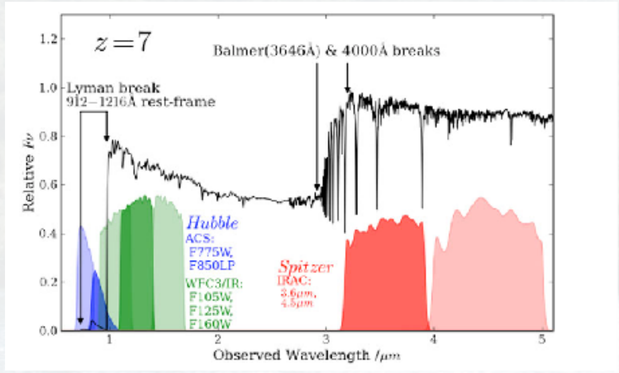
DESI DR2 BAO 2025

Landscape of high-z tracers

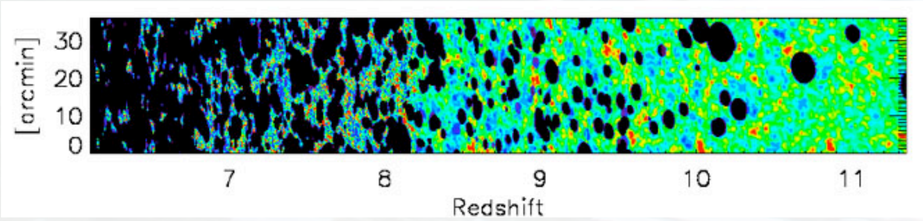
Galaxies

Lyman Break Galaxies (LBGs)

Lyman Alpha Emitters (LAEs)



21 cm



Lyα

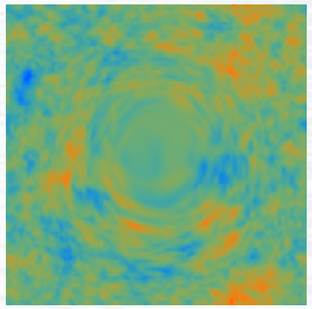
Pros: well established and tested
Cons: not many high-z quasars, line-of-sight operators

Gravitational waves

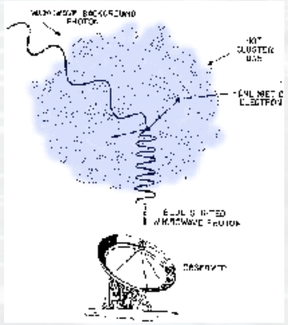
Line Intensity Mapping

Pros: extremely small effective shot noise
Cons: foregrounds order-of-magnitude larger than signal, lots of RND left to do, uncertainties about SNR, …

CMB secondary anisotropies



Lensing



Sunyaev-Zel'dovich effects

~~fantasy land~~ Forecasts

largely based on: **NS**, Castorina, Ferraro, White 2021

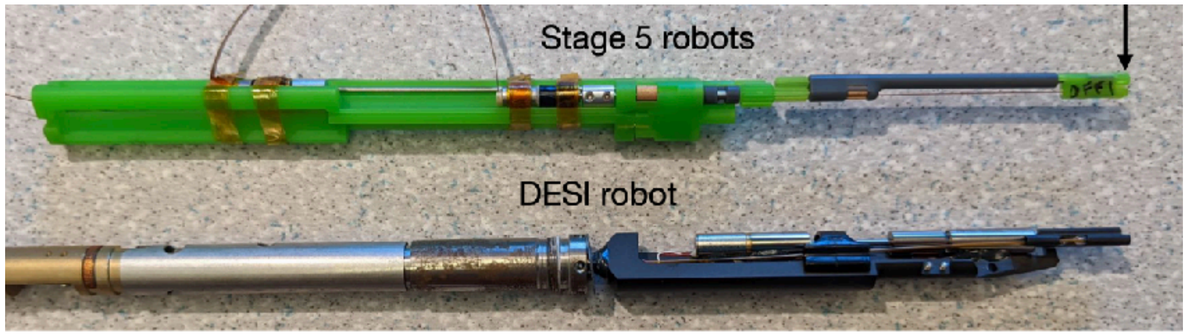
for multi-tracer, see: Ebina & White 2024

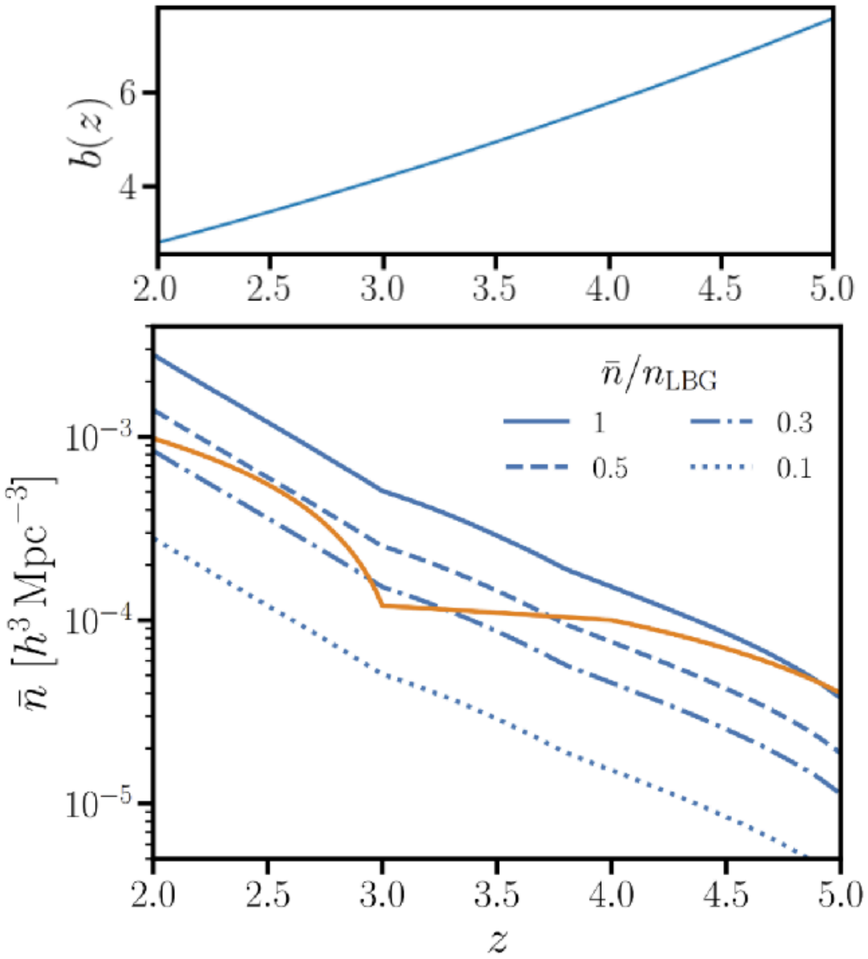
MegaMapper (Stage-5 spectroscopy)

- Primary target: Lyman Break Galaxies (LBGs)
  $2 < z < 5$, 14,000 $\deg^2$
- 24.5 magnitude limited sample

  Wilson & White 2019 Schlegel et al. 2019

  Ferraro et al. 2019
- ~20,000 fiber positioners

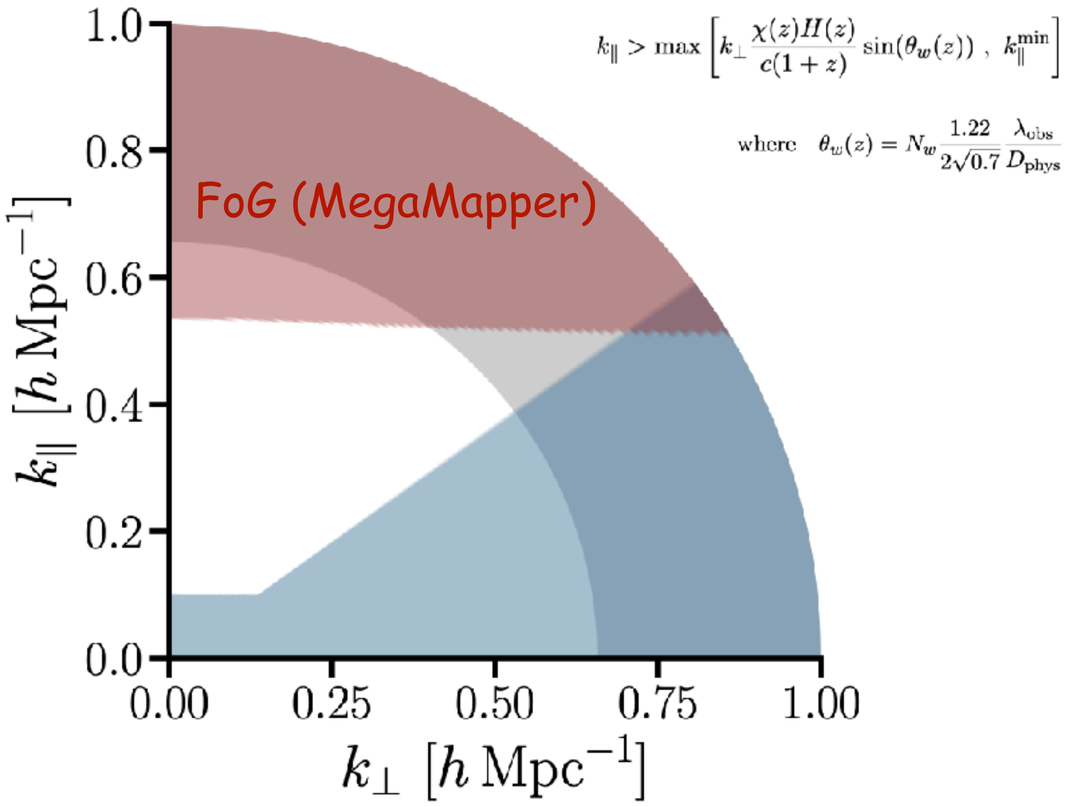




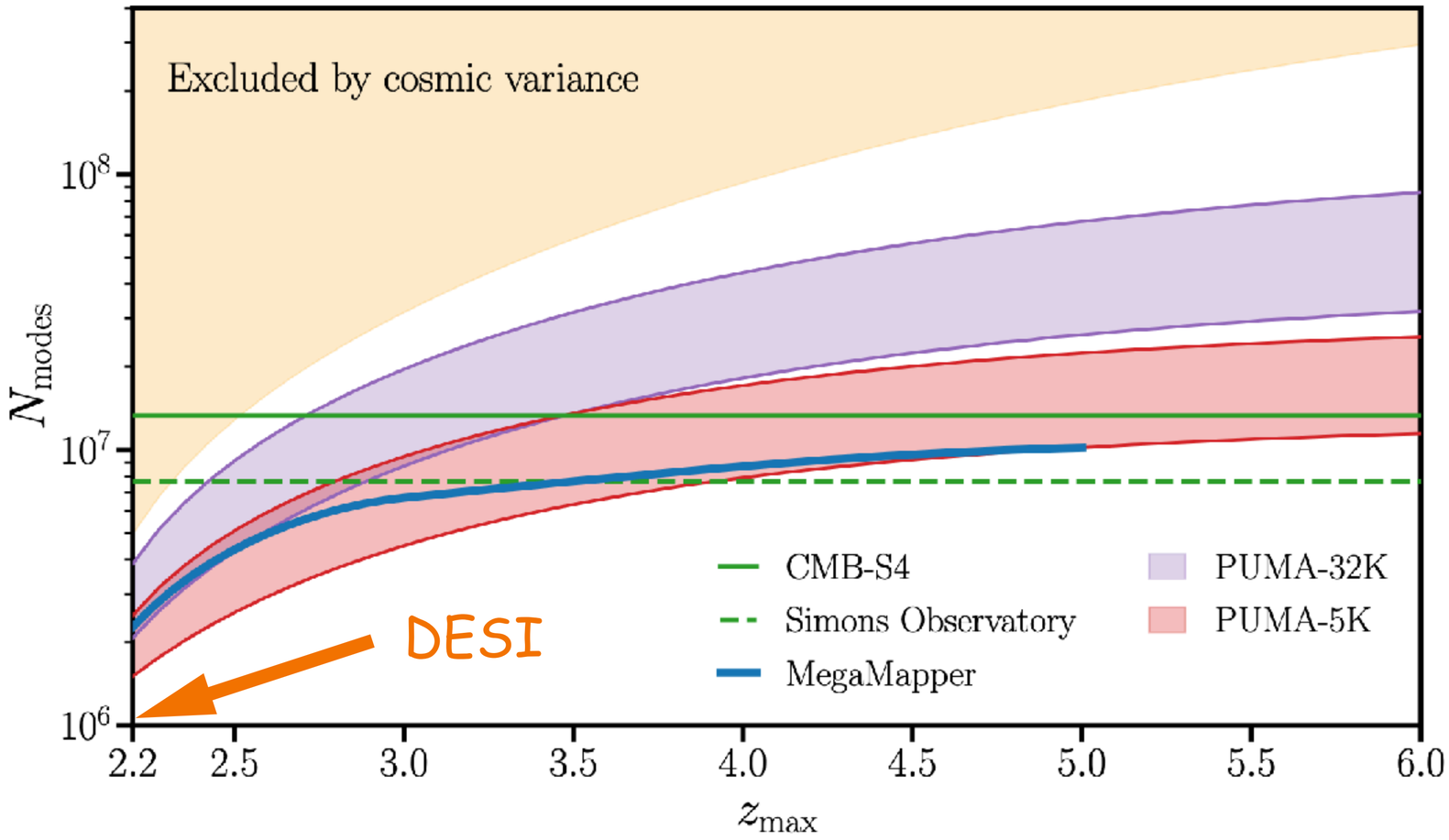
PUMA (21cm interferometry)

Slosar et al. 2019

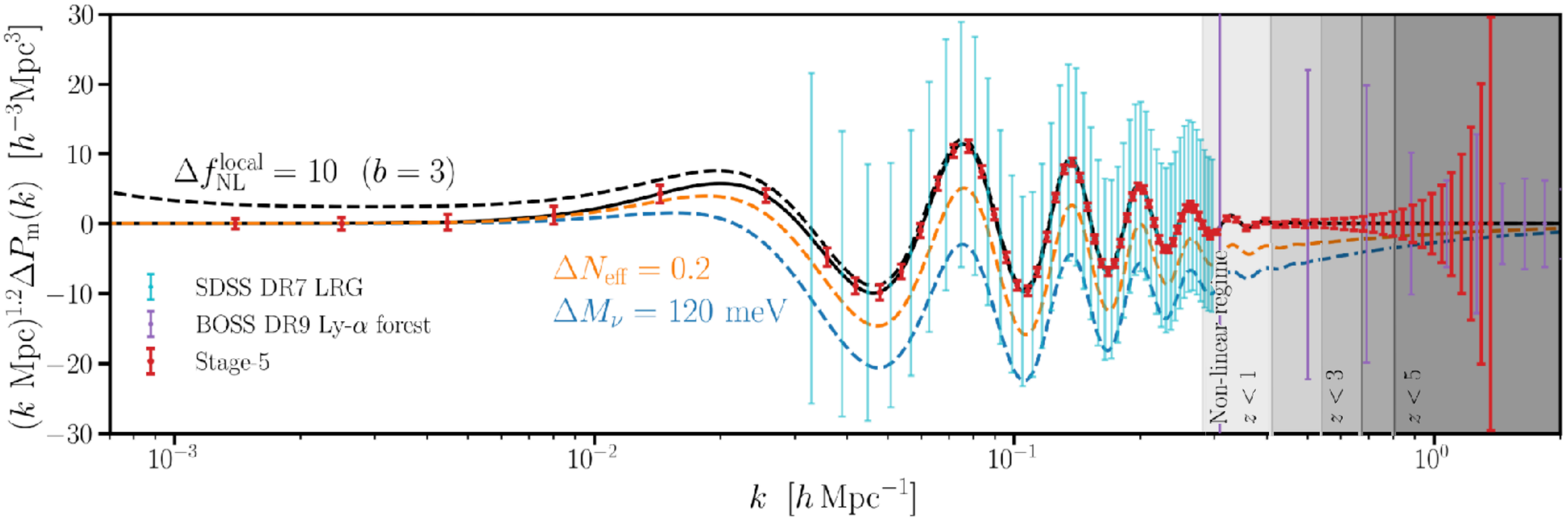
- After reionization neutral hydrogen in dense, self-shielded regions around massive galaxies (low effective shot noise)
- 32,000 (!!!) 6m dishes
- Observe half the sky over 5 years
- 200 — 1100 MHz (z < 6)
- Foreground wedge (optimistic/pessimistic)
  - marginalize over mean brightness temp.



FoM = number of linear modes



High expectations



Forecasting formalism

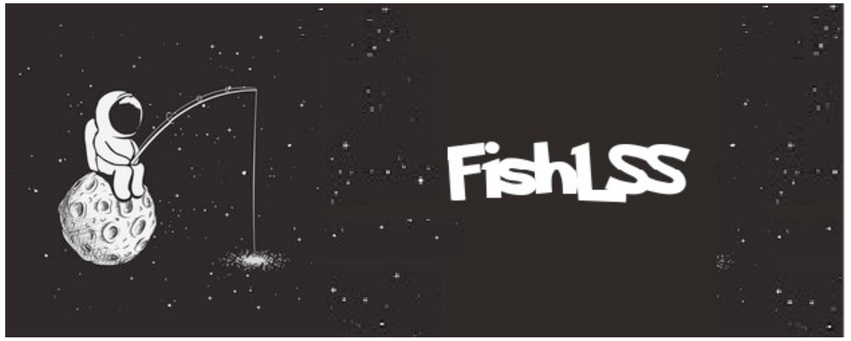
Unless stated otherwise:

- Fisher forecasts throughout
- full-shape power spectrum, CMB lensing (L<500) & cross-correlation, CMB primary

sfschen / velocileptors

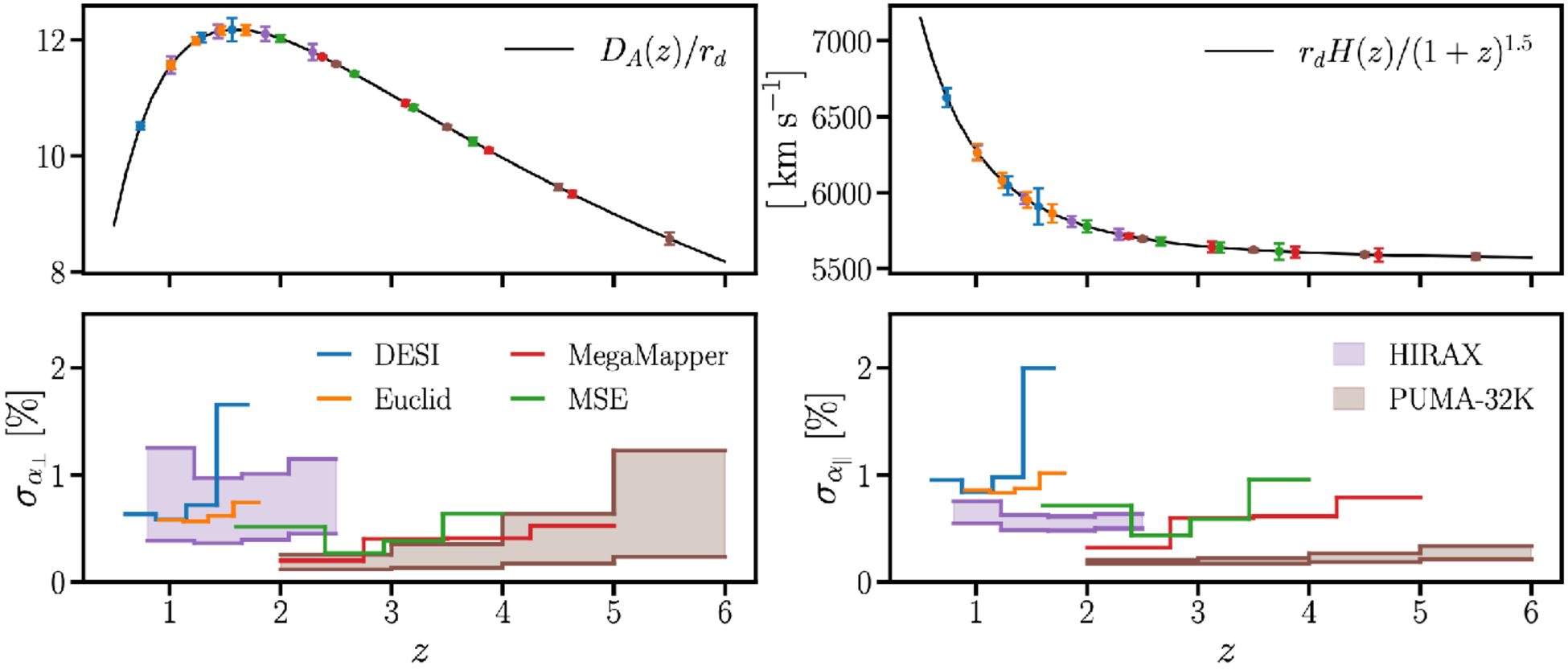
Chen, Vlah & White 2020

- flat (∞'ly broad) priors on all parameters
  - quadratic order in bias expansion
  - three "counterterms" for galaxy-auto $k^2\mu^n P(k)$
  - +1 counter term for lensing cross-correlation
  - three stochastic contributions $(k\mu)^n$



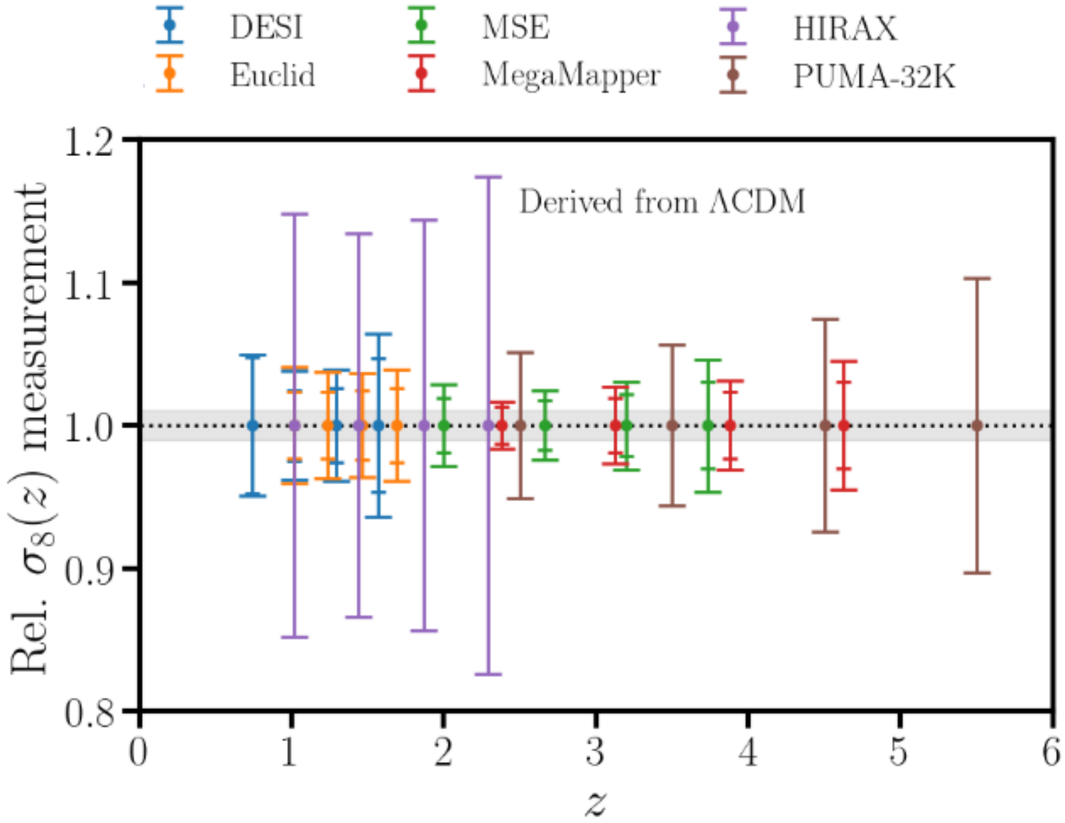
From a modeling standpoint, this is (hopefully) pessimistic

Distance measures (BAO)

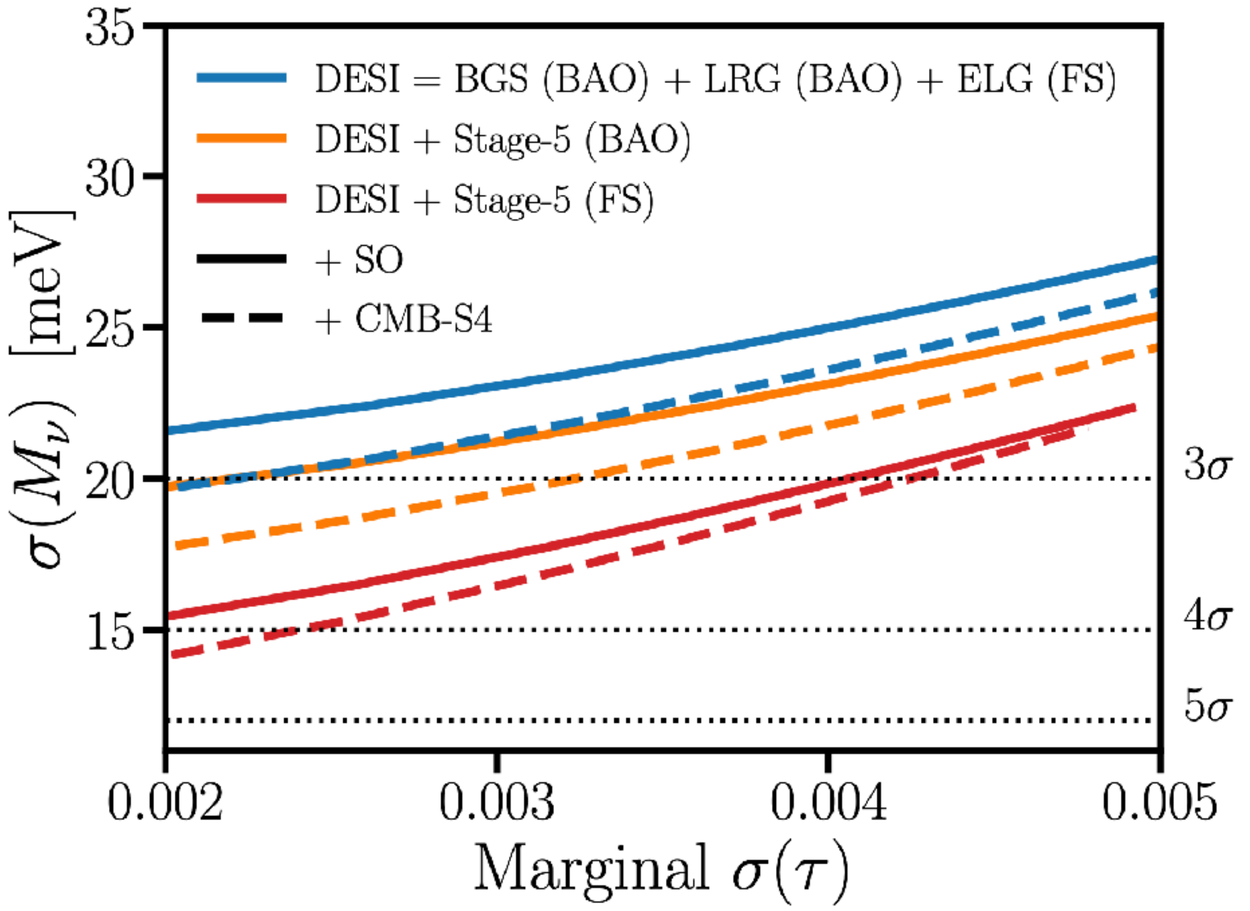


Structure growth

Smaller errorbars include cross-correlation with CMB lensing from SO



Neutrino mass



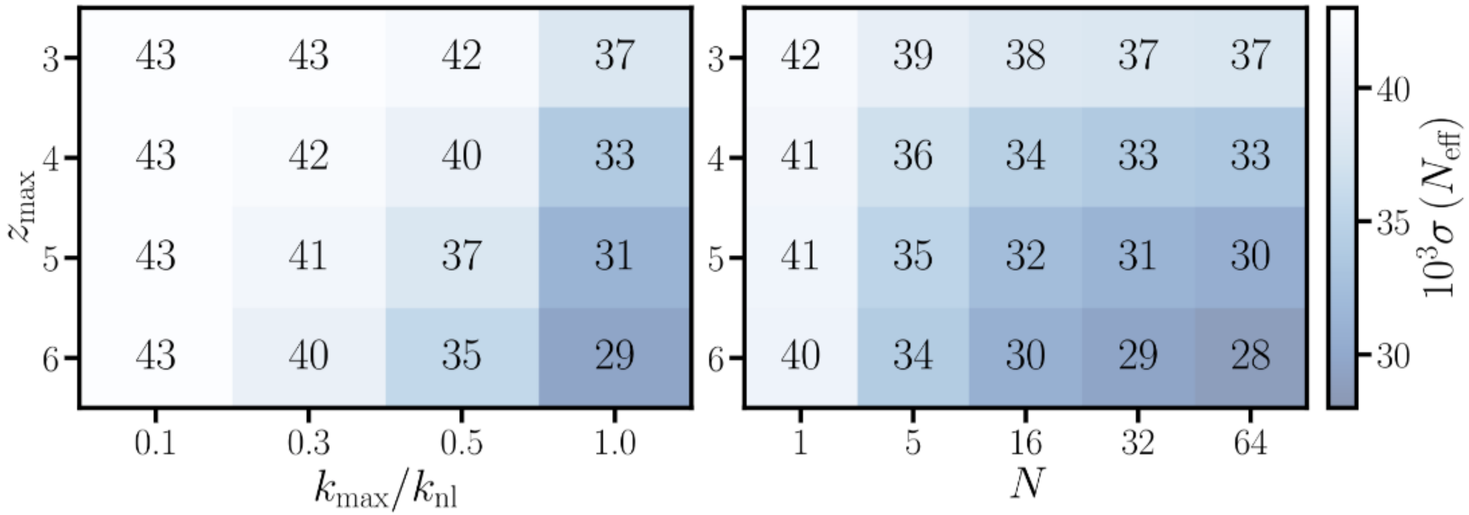
Light relics

$\Delta N_{\rm eff} > 0.027$ (scalar), 0.047 (Weyl fermion), 0.054 (vector boson)

Stage-5: $\sigma(N_{\rm eff}) = 0.036$

LSS insensitive to Y_p !

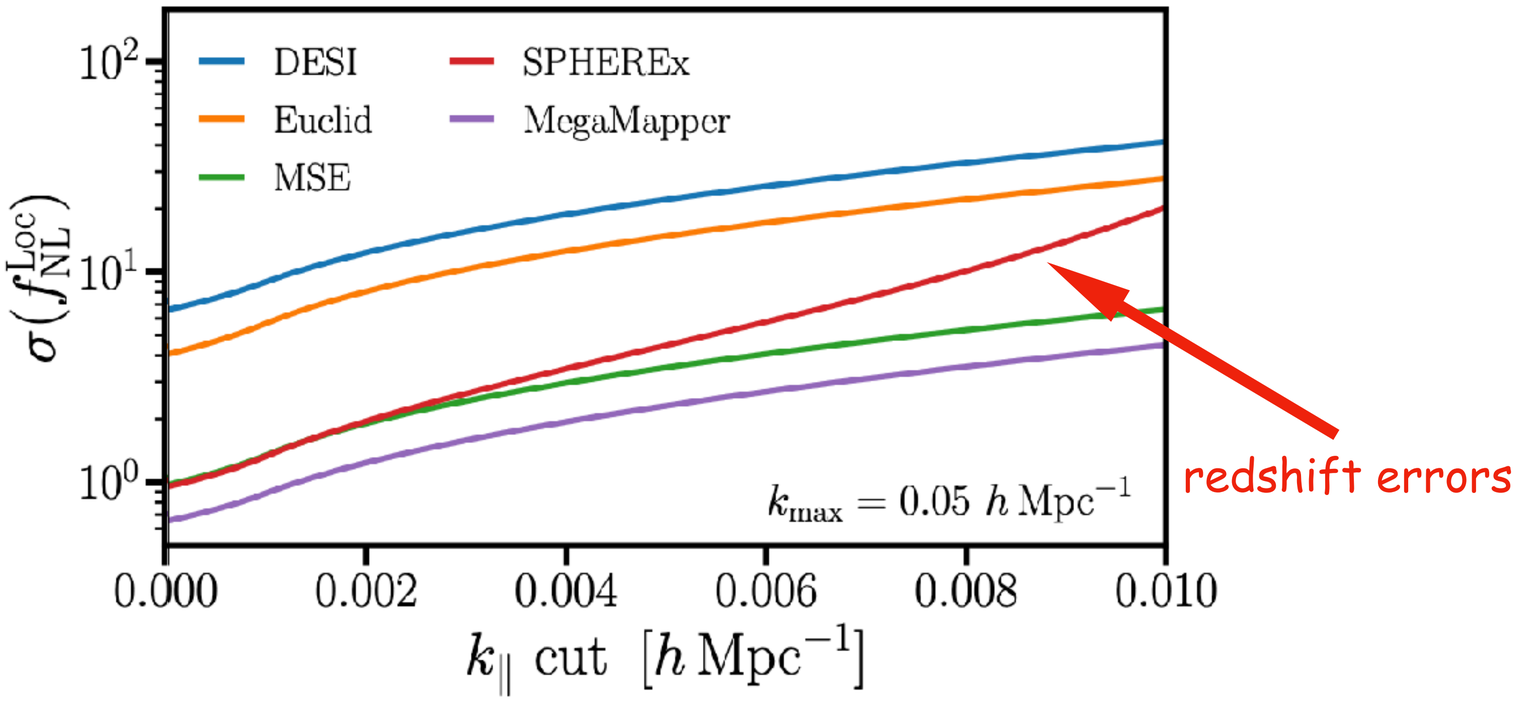
Planck + SO + DESI + PUMA-NK



Inflation: (local) non-Gaussianity

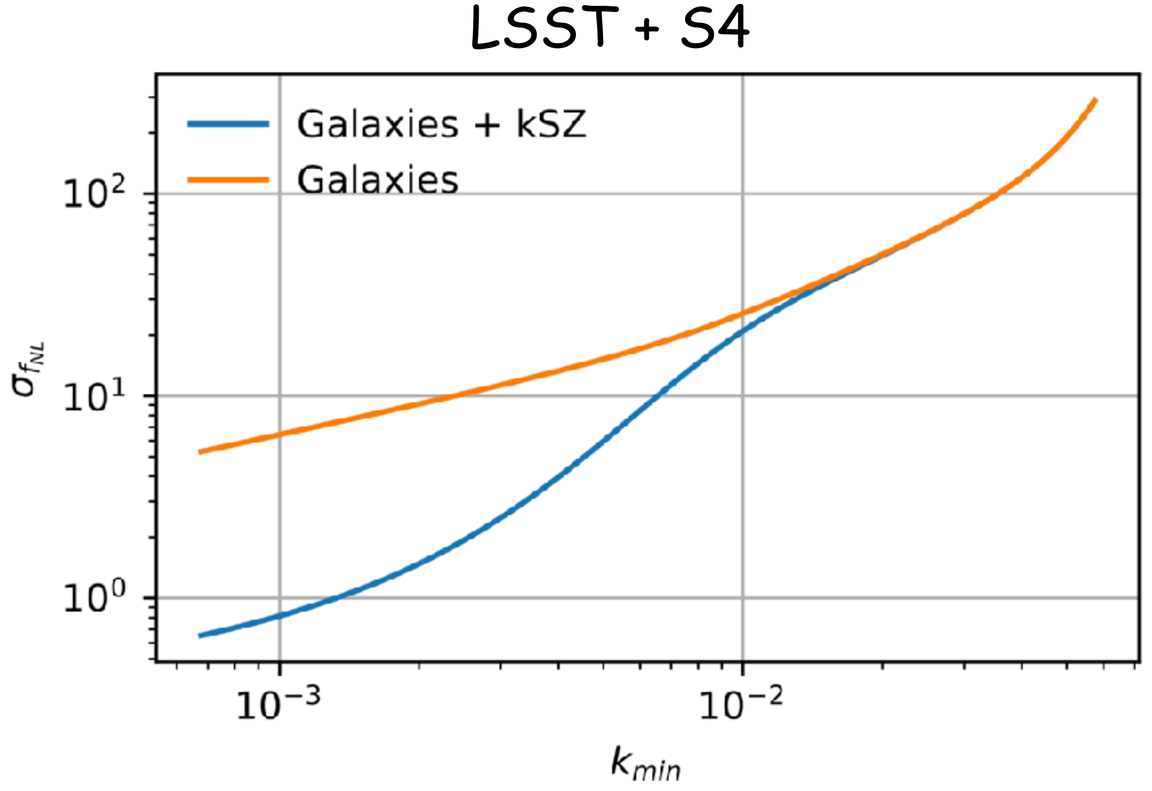
From scale-dependent bias assuming universality relation $\sigma(f_{\rm NL}^{\rm Loc}) \sim 1$

$$\Delta b \equiv \frac{3\Omega_m H_0^2}{2k^2 D(z) T(k)} b_\phi f_{\rm NL}^{\rm Loc}$$



Inflation: (local) non-Gaussianity

Improvements from kSZ velocity reconstruction (Tgg bispectrum) due to sample-variance cancellation

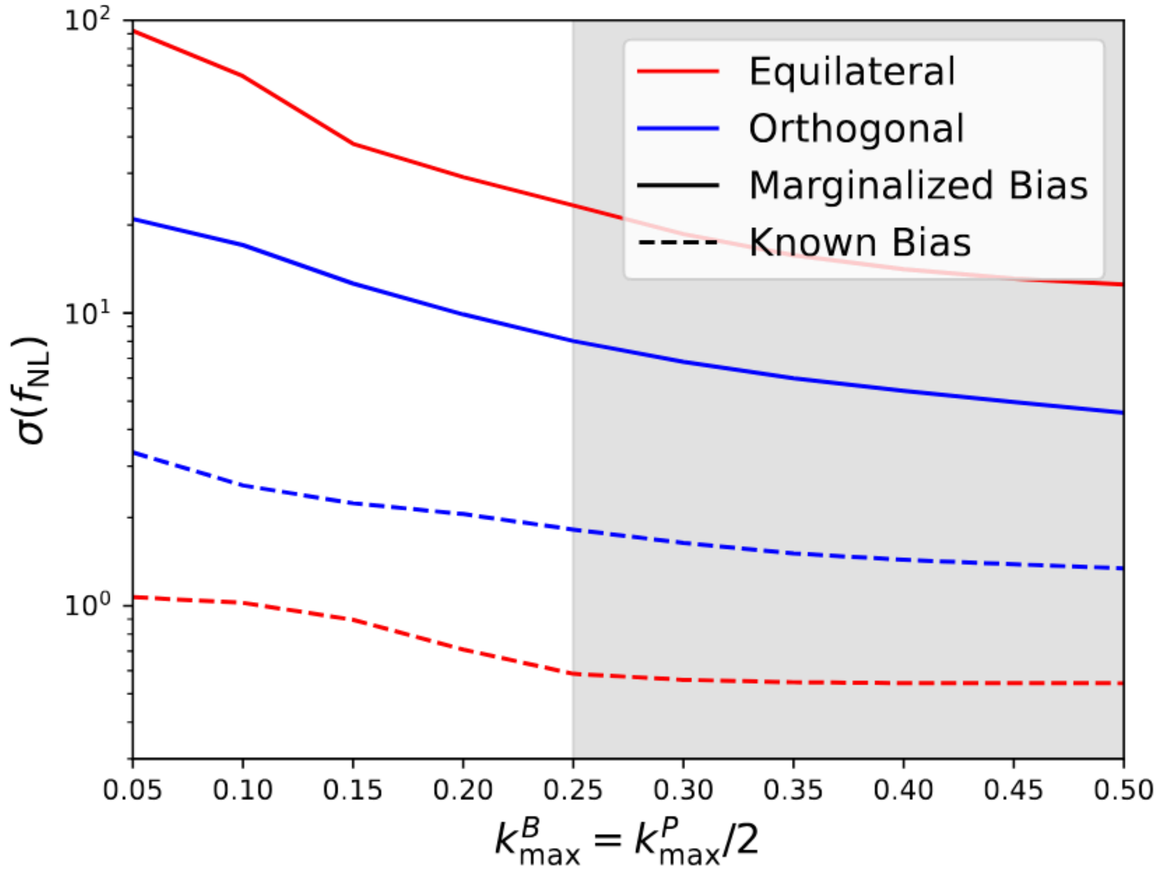


Münchmeyer et al. 2018

Inflation: (non-local) non-Gaussianity

Better than the CMB!

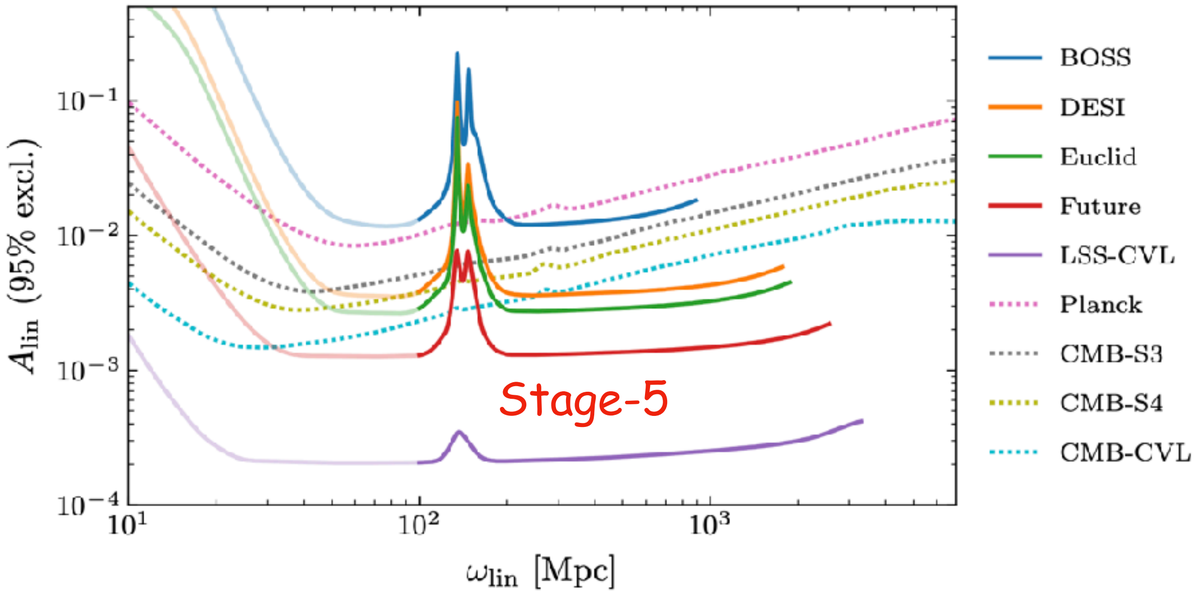
Experiment	$\sigma(f_{\rm NL}^{\rm eq})$	$\sigma(f_{\rm NL}^{\rm orth})$
MegaMapper - A	23	10
MegaMapper - B	22	10
MegaMapper - C	17	8
Planck 2018	47	24
Simons Observatory (SO)	27	14
CMB-S4	21	9
MegaMapper + SO	16	8
MegaMapper + CMB-S4	14	7



Cabass et al. 2022

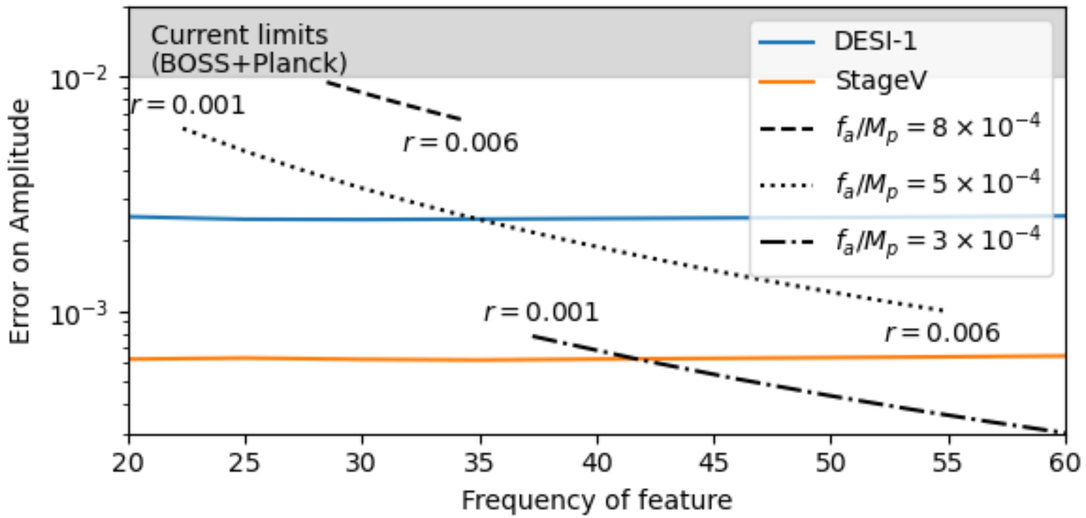
Inflation: primordial features

$$P(k) \to \left(1 + A_{\rm lin}\cos(\omega_{\rm lin}k + \phi_{\rm lin})\right) P(k)$$



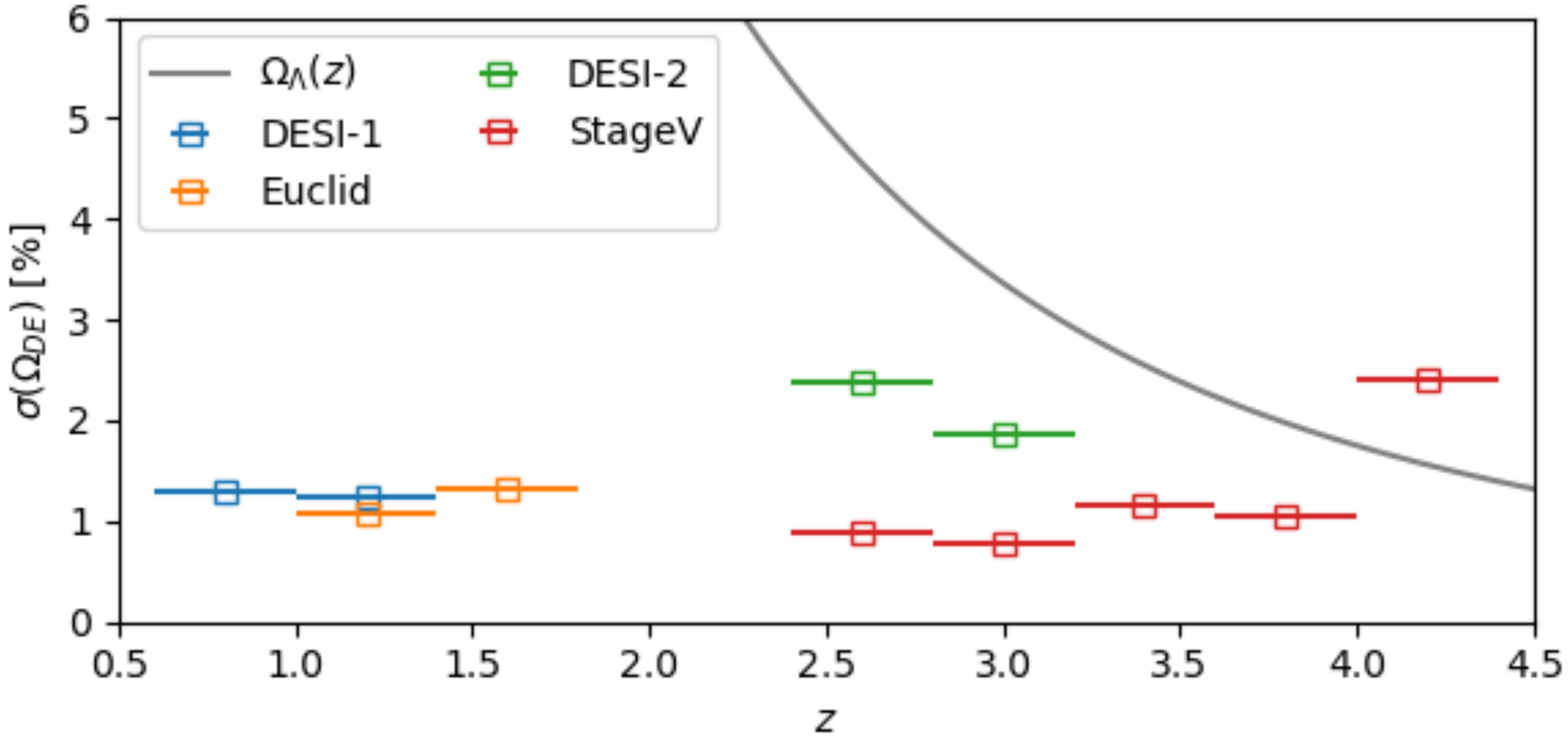
Beutler et al. 2020

axion monodromy



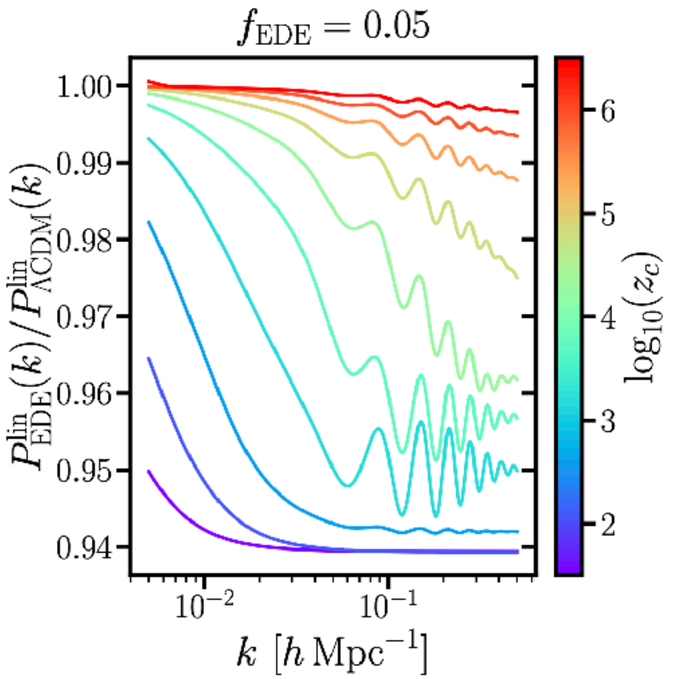
White, Silverstein, Green

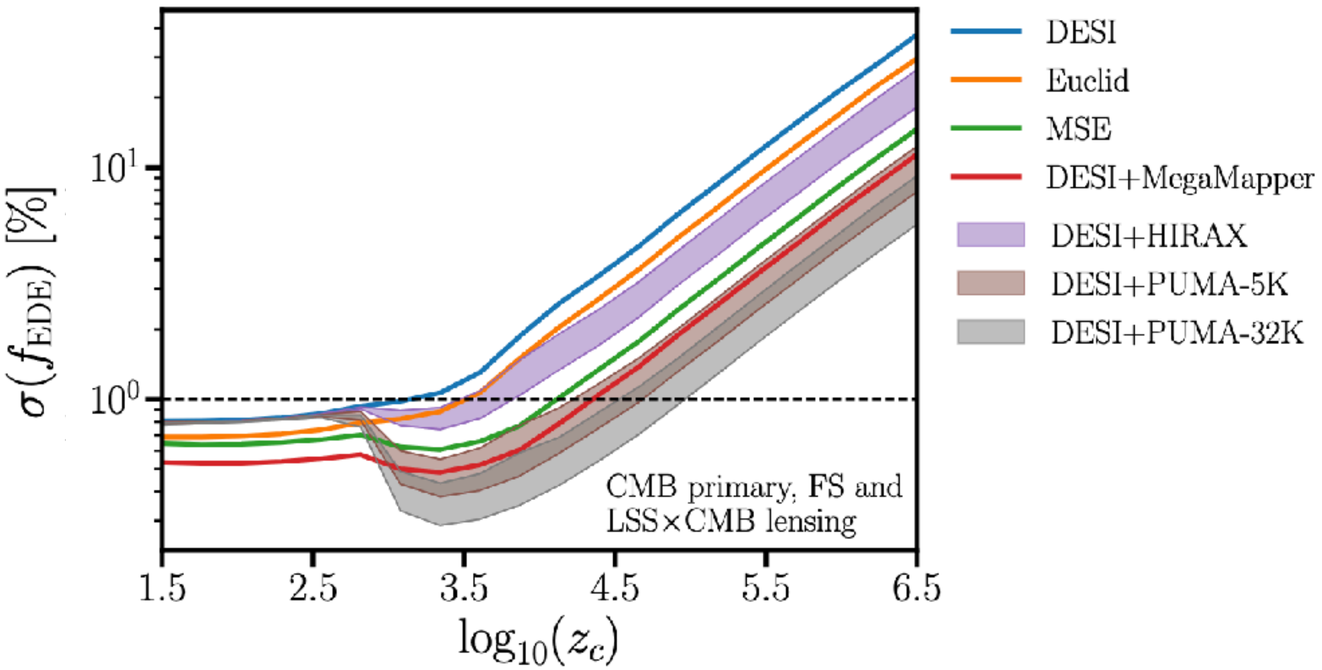
Dynamical dark energy



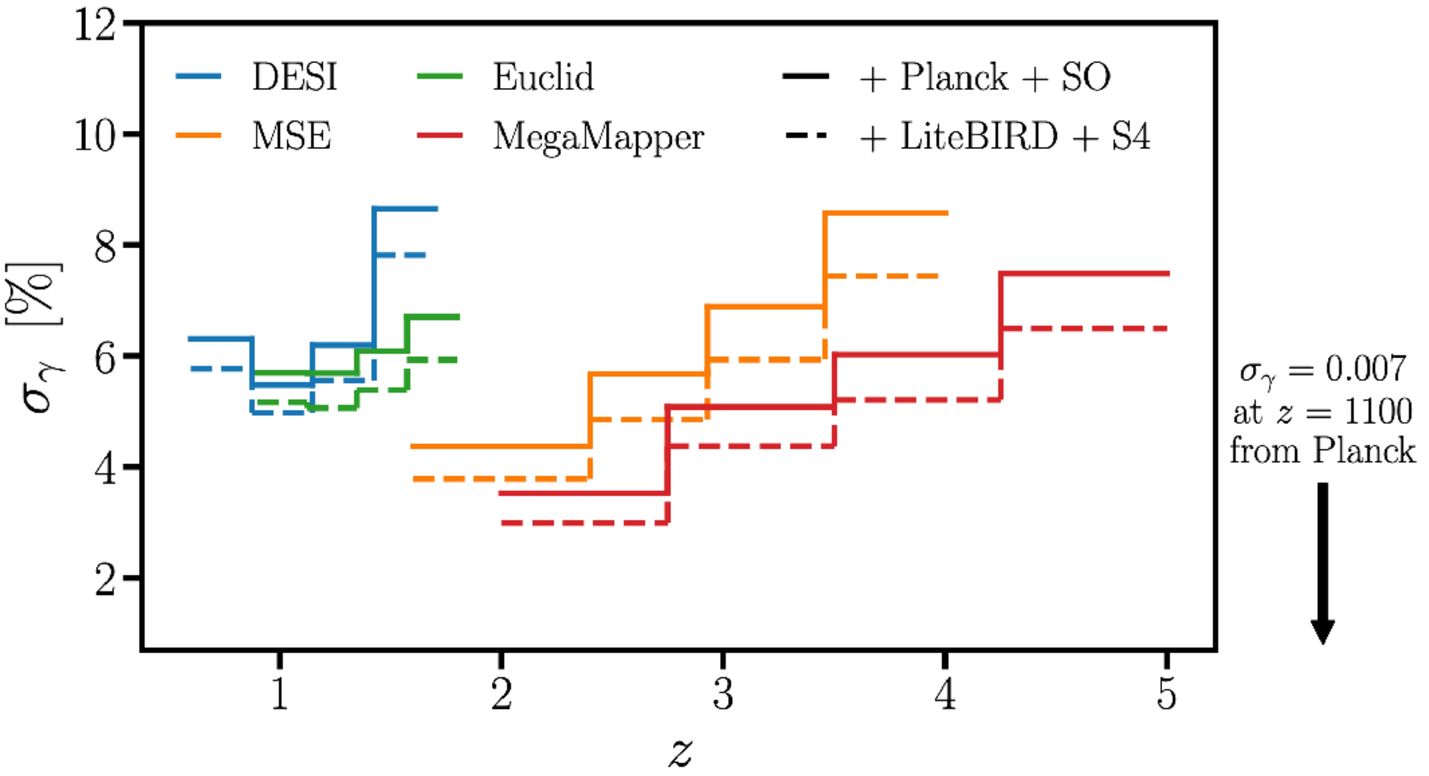
Dynamical (early) dark energy

$$V(\phi) \propto [1 - \cos(\phi/f)]^3$$





Gravitational slip



Not ambitious enough?

Optical depth to reionization from 21cm

21cm power spectrum $\propto$ (brightness temperature)^2

Brightness temp. tracks ionization history, use to predict τ

Liu et al. 2015

Working on perturbative scales (depends on morphology of bubbles)

McQuinn & D'Aloisio 2018
Qin et al. 2022

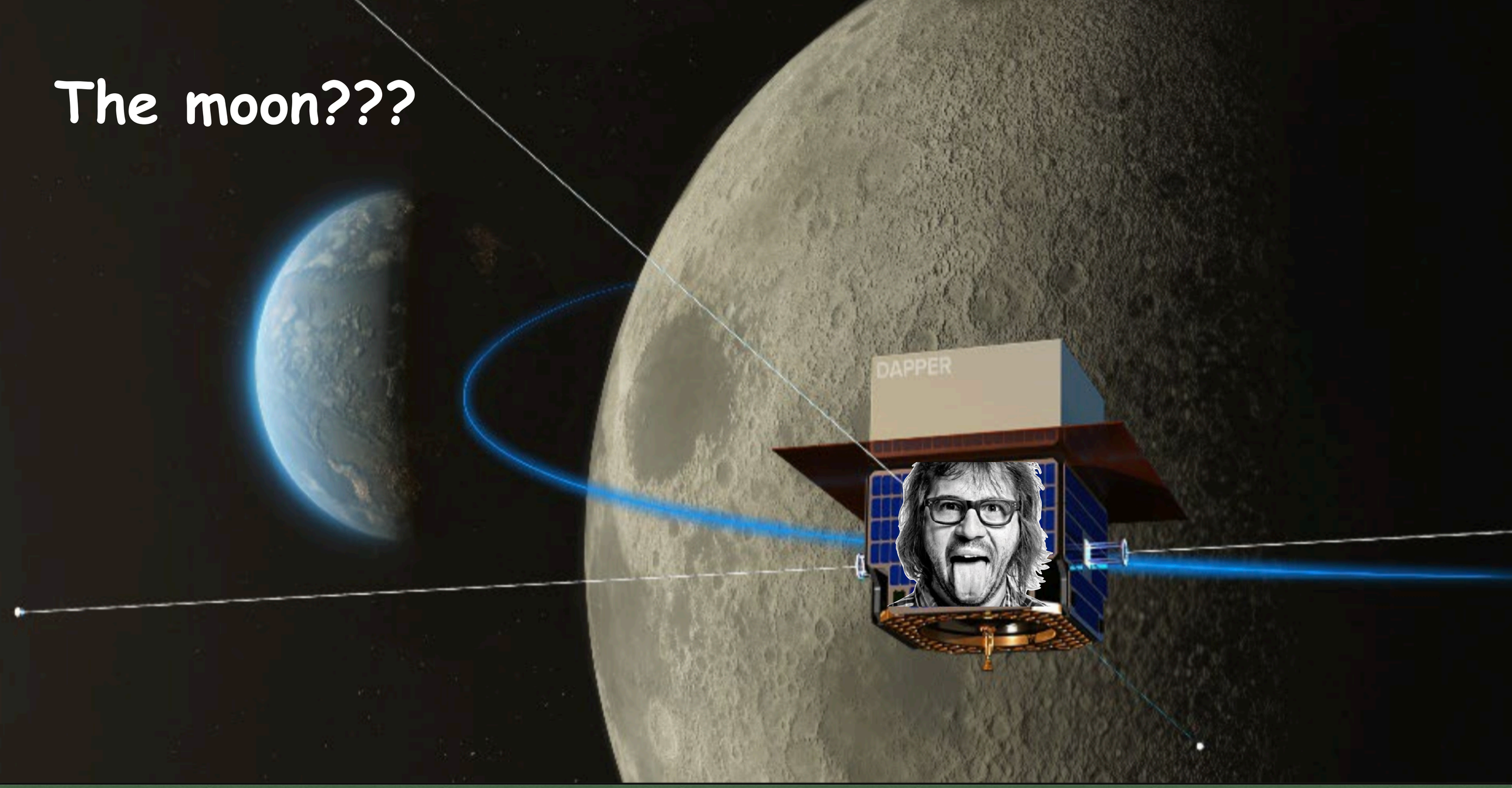
Scenario	1000 dishes				SKA-like
$z_{\rm max}$	12	12	12	**10**	**10**
$z_{\rm min}$	7	7	**9**	7	7
$t_{\rm int}$ [years]	**10**	5	5	5	5
$1000 \times \sigma_\tau$	1.9	3.0	7.0	3.8	0.9

Assuming Weibull functional form for the reionization history

$$x(z) = \mathrm{Exp}\left[-\max\left(\frac{z-a}{b}, 0\right)^c\right]$$

NS, Chen & White 2022

The moon???

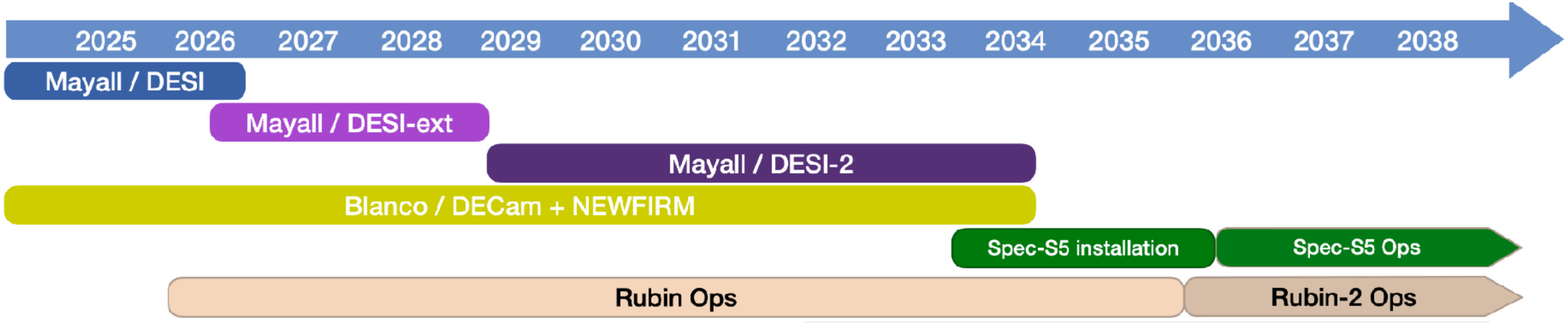


Where are we now?

(for galaxy surveys)

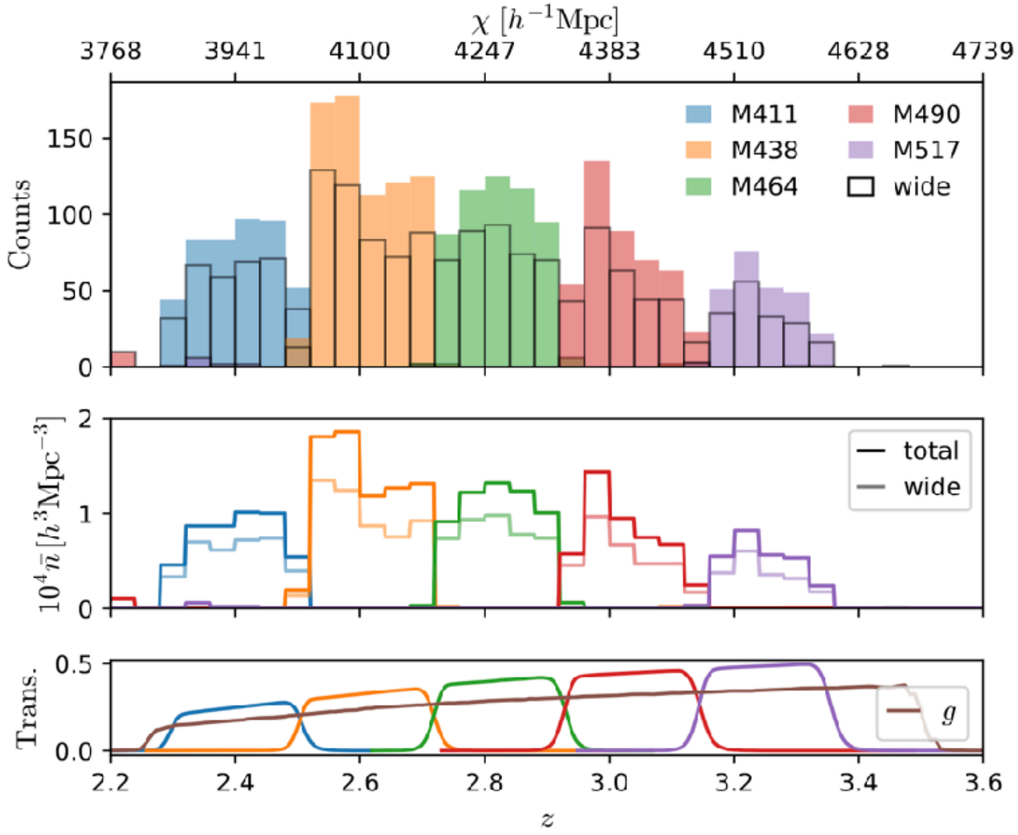
Timeline

✓ Extend DESI footprint to DEC = -20



IBIS medium band imaging → DESI-II

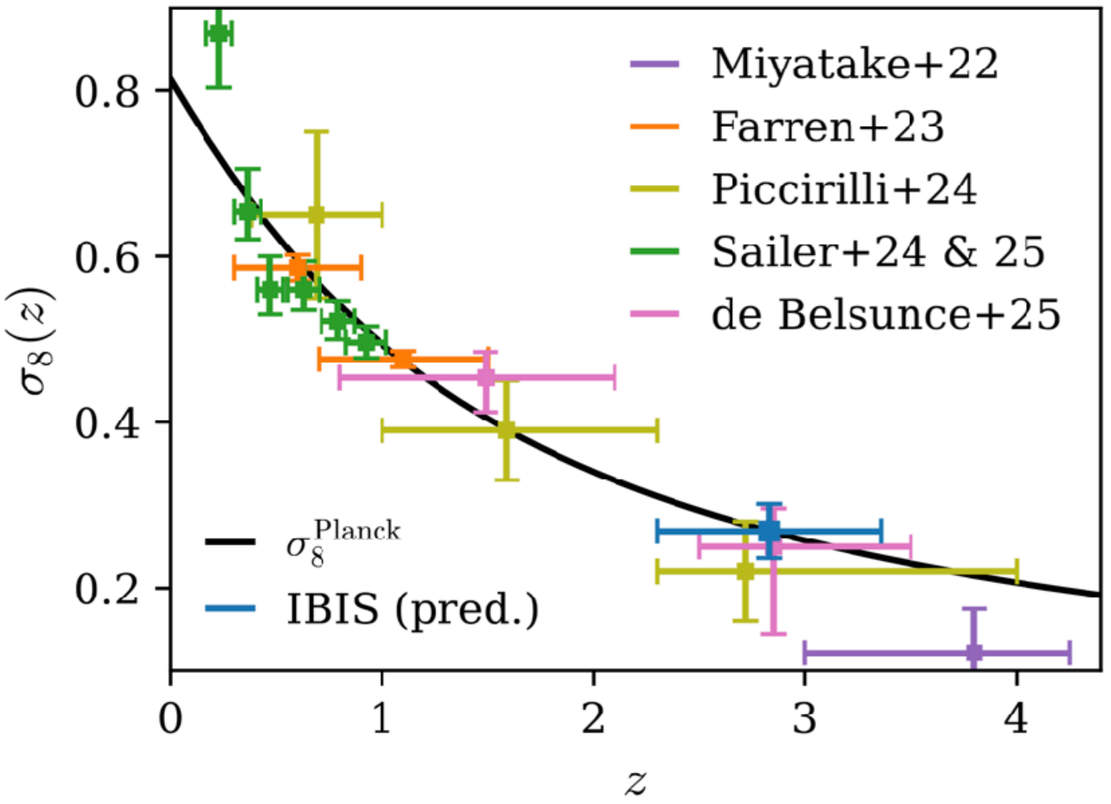
- 5 filters in the g band to select LAEs / LBGs over 2 < z < 3.5
- have collected deep COSMOS & XMM-LSS fields
- Plan for DESI-II: 5000 deg^2 using Blanco/DECam



Ebina et al. 2025 (to appear soon!)

IBIS medium band imaging → DESI-II

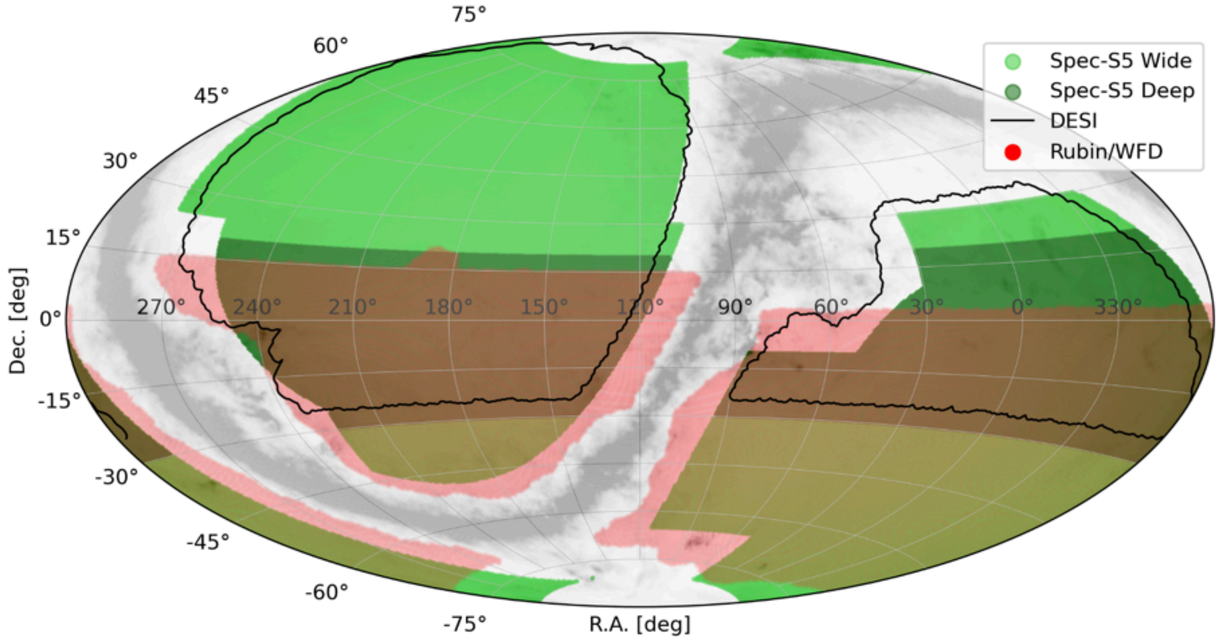
- 5 filters in the g band to select LAEs / LBGs over 2 < z < 3.5
- have collected deep COSMOS & XMM-LSS fields
- Plan for DESI-II: 5000 deg^2 using Blanco/DECam
- (will be) best high-z constraints to-date!



Ebina et al. 2025 (to appear soon!)

Stage-5 (current incarnation)

- Imaging
  - LBGs with Rubin broadband imaging
  - LAEs using medium bands on Rubin after LSST is completed
- Two 4 m telescopes (Mayall & Blanco)
- ~26,000 fibers
- High-z program (z > 2) covers 11,000 deg^2



Besuner et al. 2025

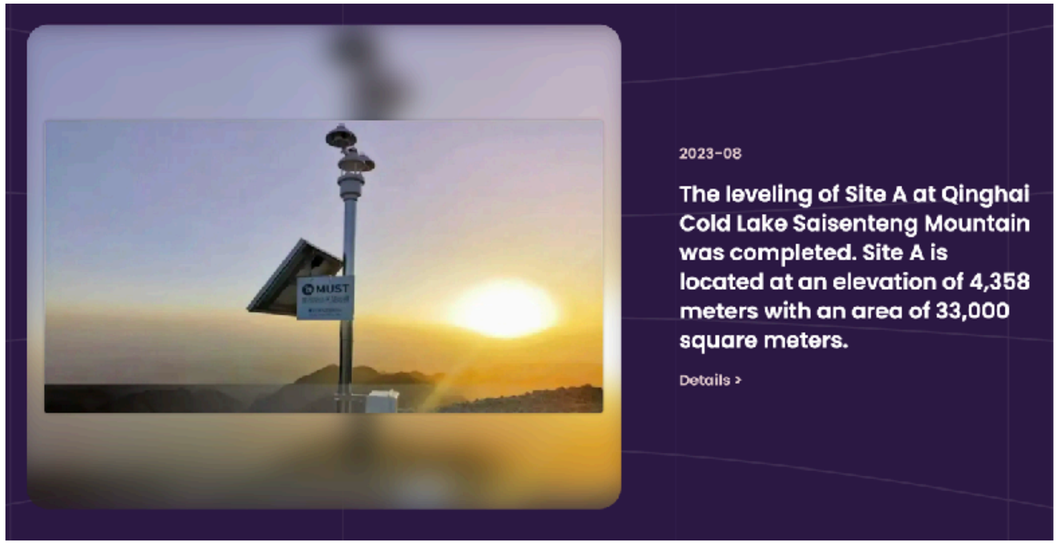
Alternatives

10 m class
telescope in Chile

Bacon et al. 2024

MUltiplexed
Survey
Telescope

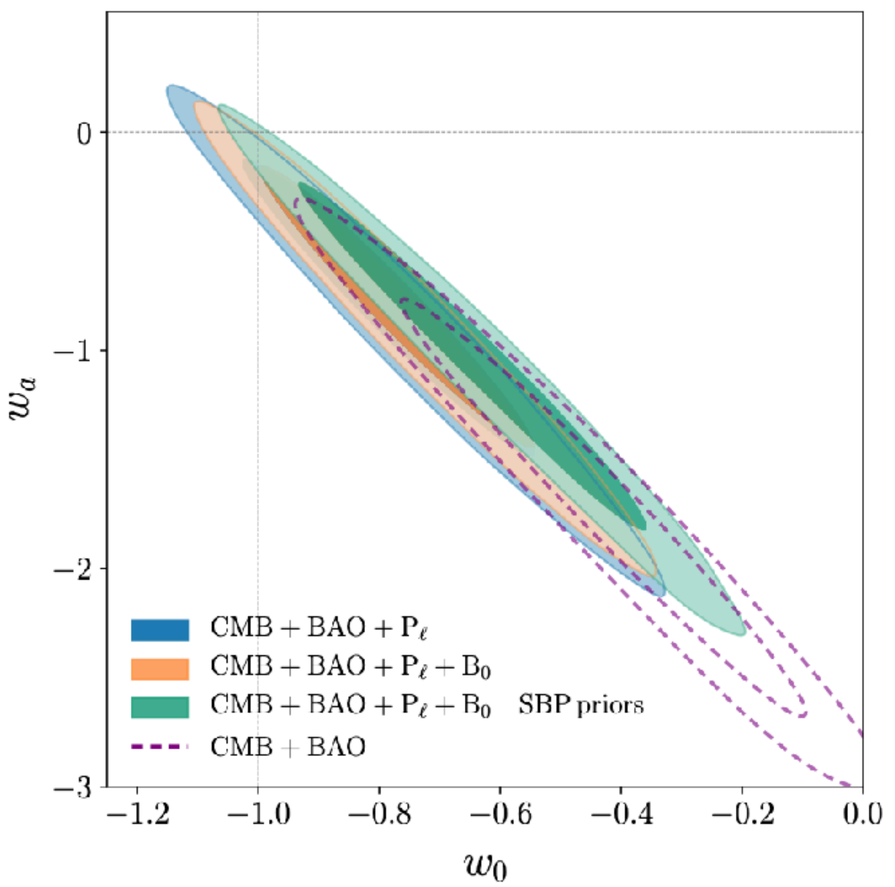
6.5 m telescope in China,
already under construction!



Caveats and Challenges

Caveats

- Forecasts assume cosmological concordance within ΛCDM
- Current DESI / SNe conundrum
  - could just be a fluctuation



Chudaykin, MI, Philcox, to appear

Caveats

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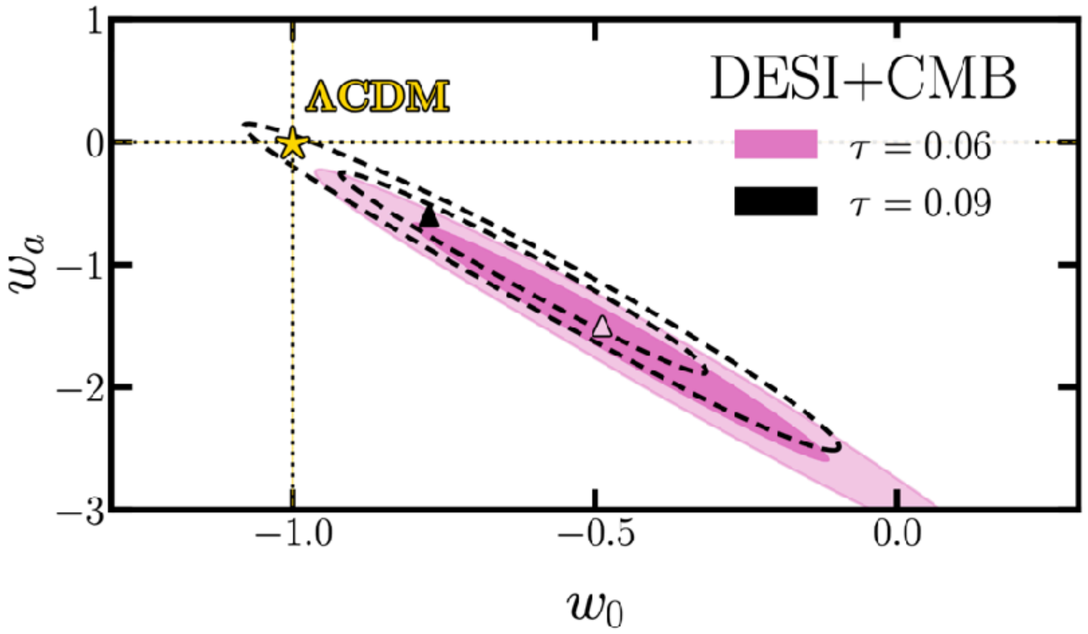
  - systematics in large-scale polarization?



NS, Farren, Ferraro, White 2025

Caveats

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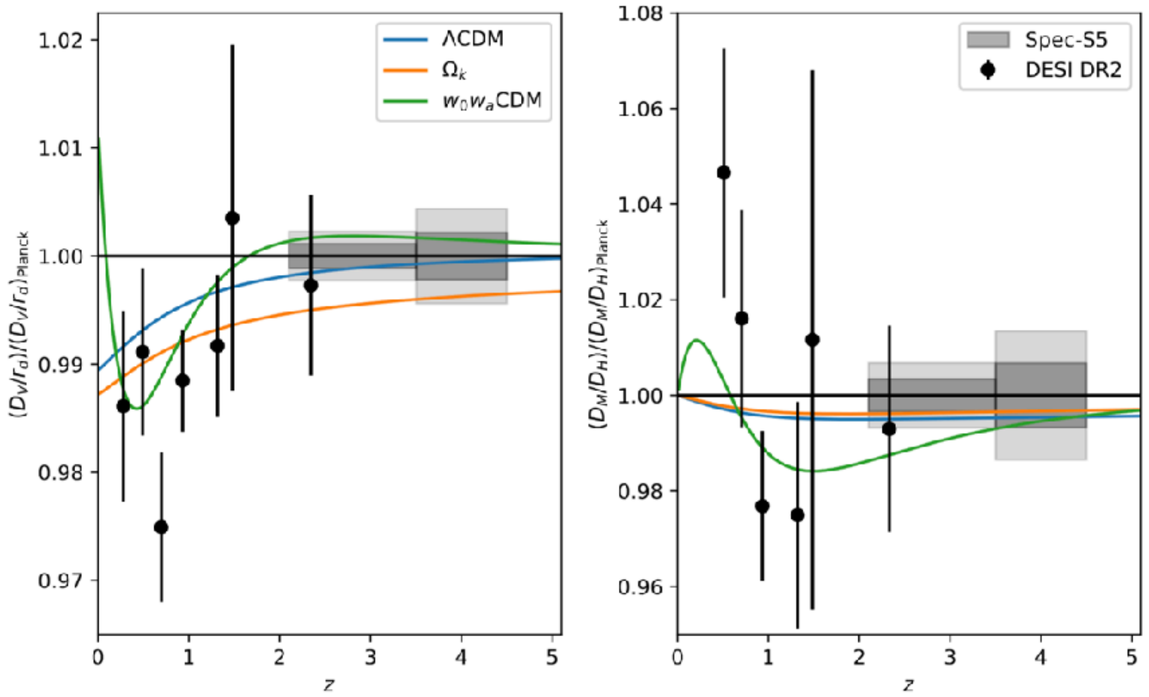

Chen & Zaldarriaga 2025

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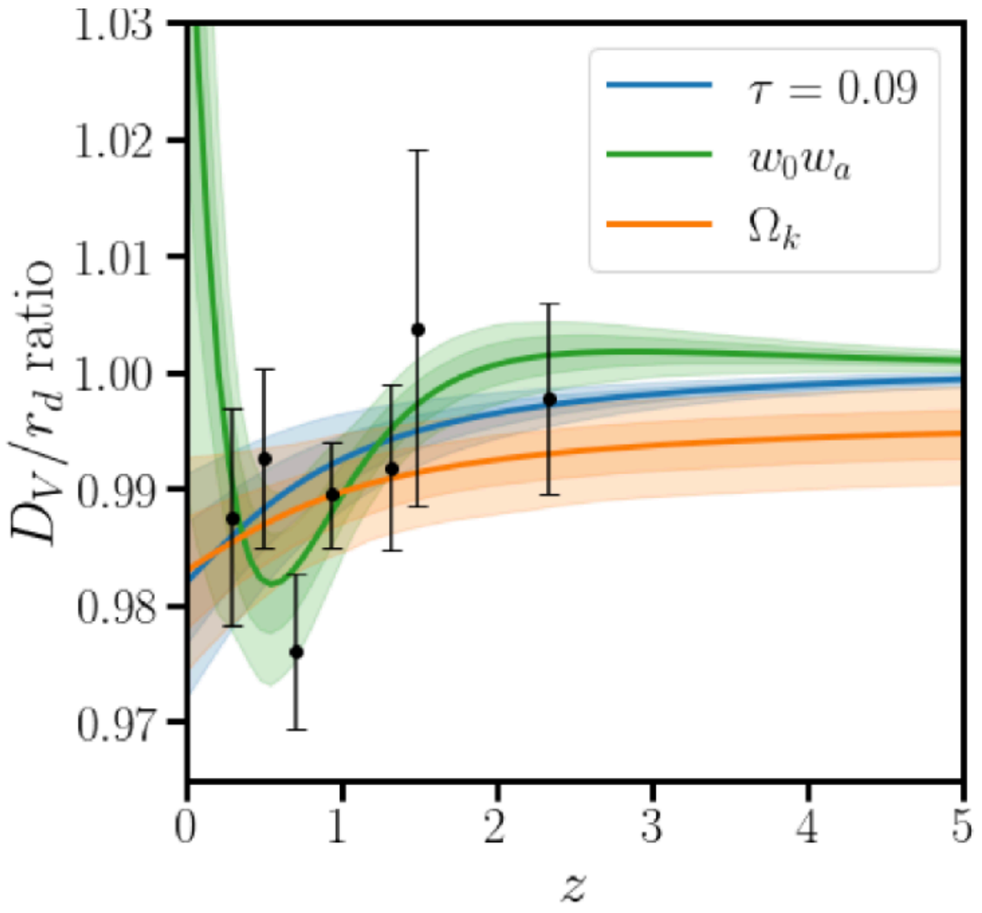

Caveats

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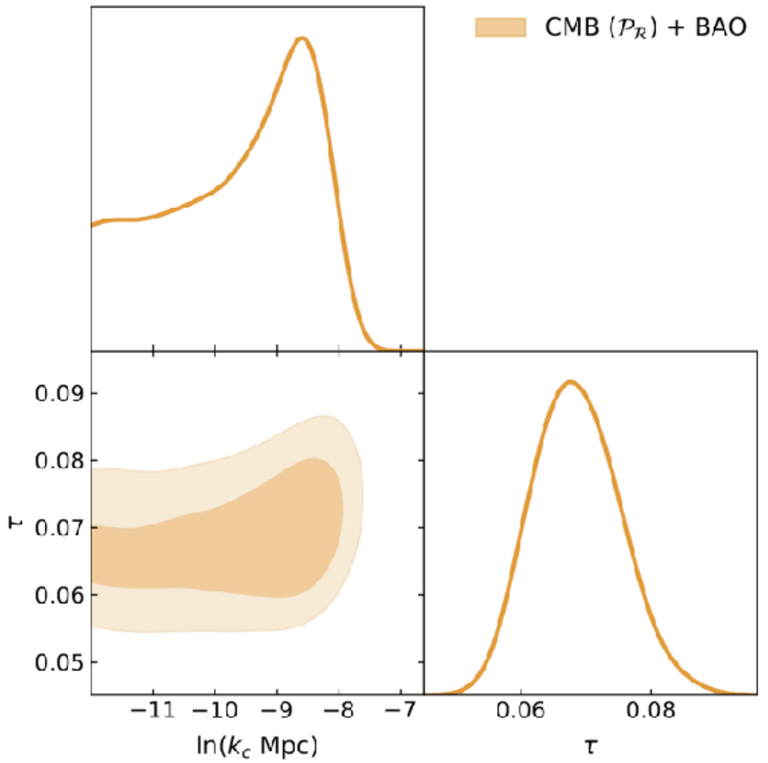
  - curvature?
  - large-scale suppression?

$$P(k) \to \left(1 - e^{-\sqrt{k/k_c}}\right) P(k)$$



Jhaveri, Karwal, Hu 2025

Caveats

- Forecasts assume cosmological concordance within ΛCDM

- Current DESI / SNe conundrum
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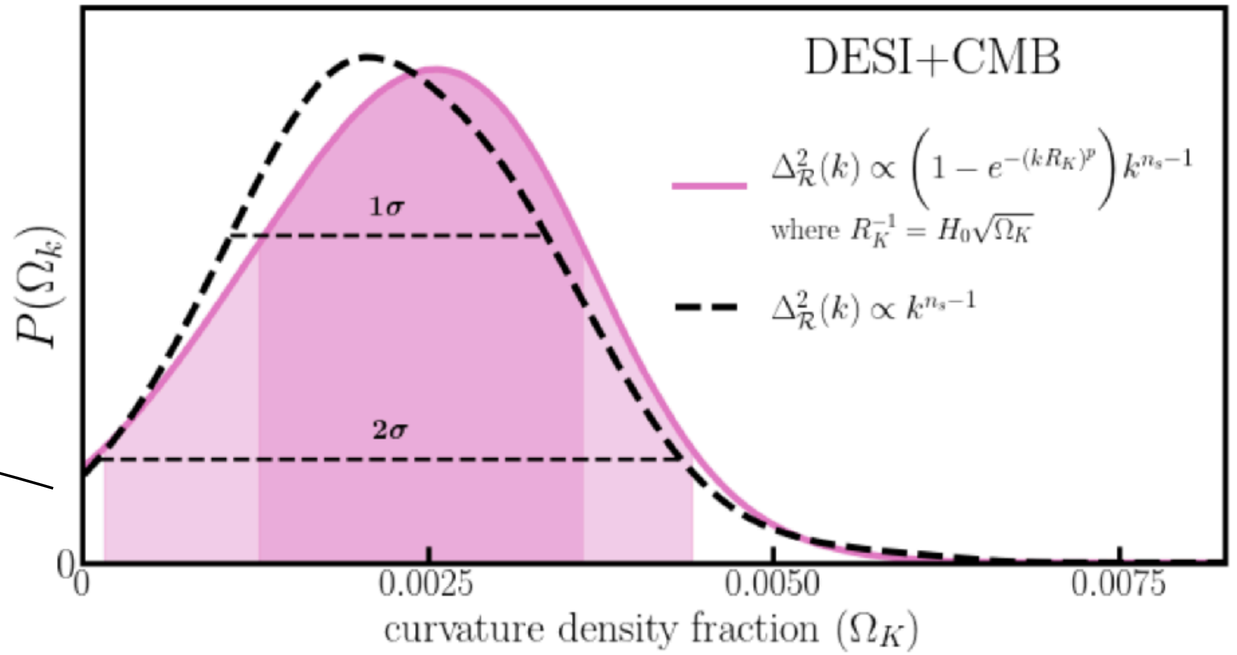
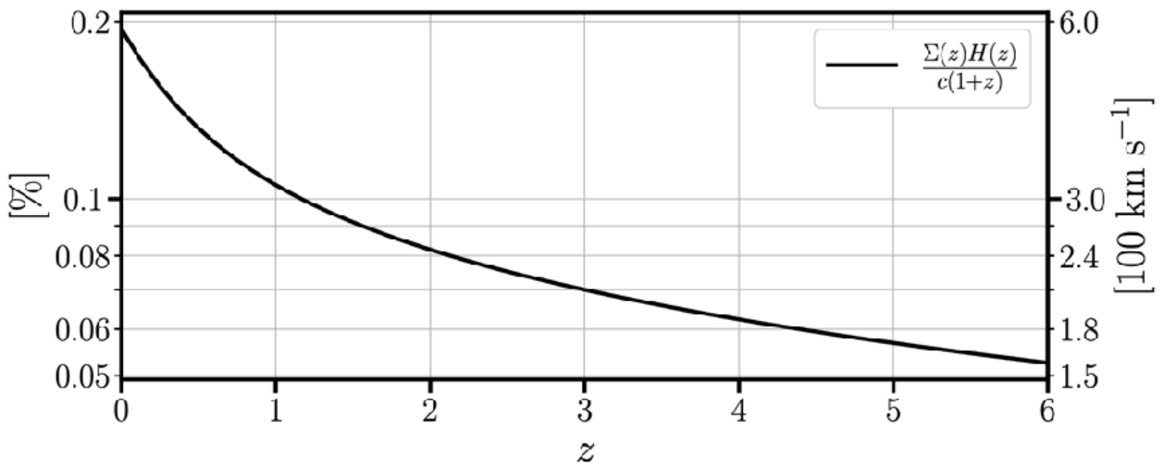
  - systematics in large-scale polarization?
  - curvature?
  - large-scale suppression?

Aside: wishful thinking

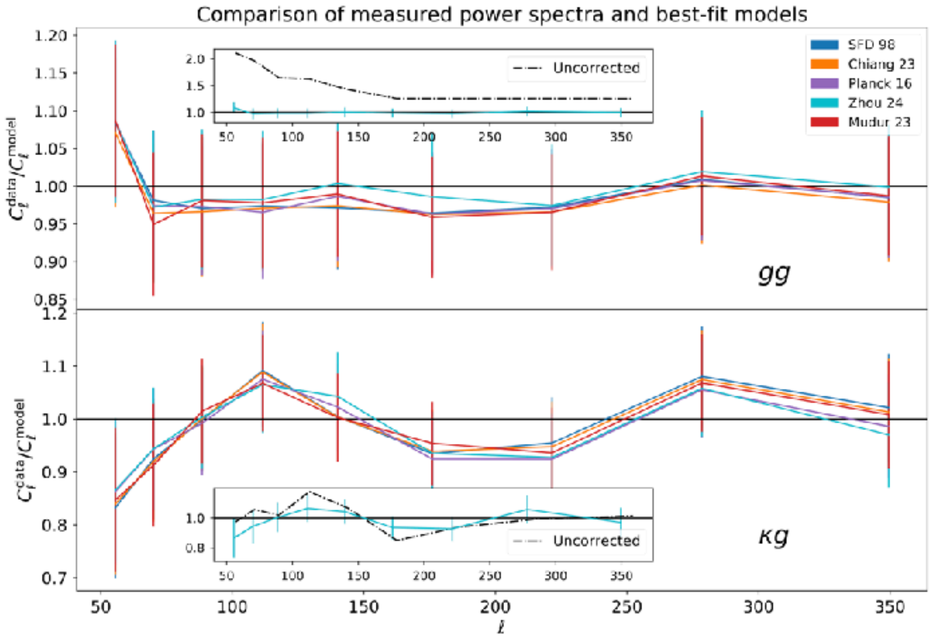


Observational challenges

Redshift errors

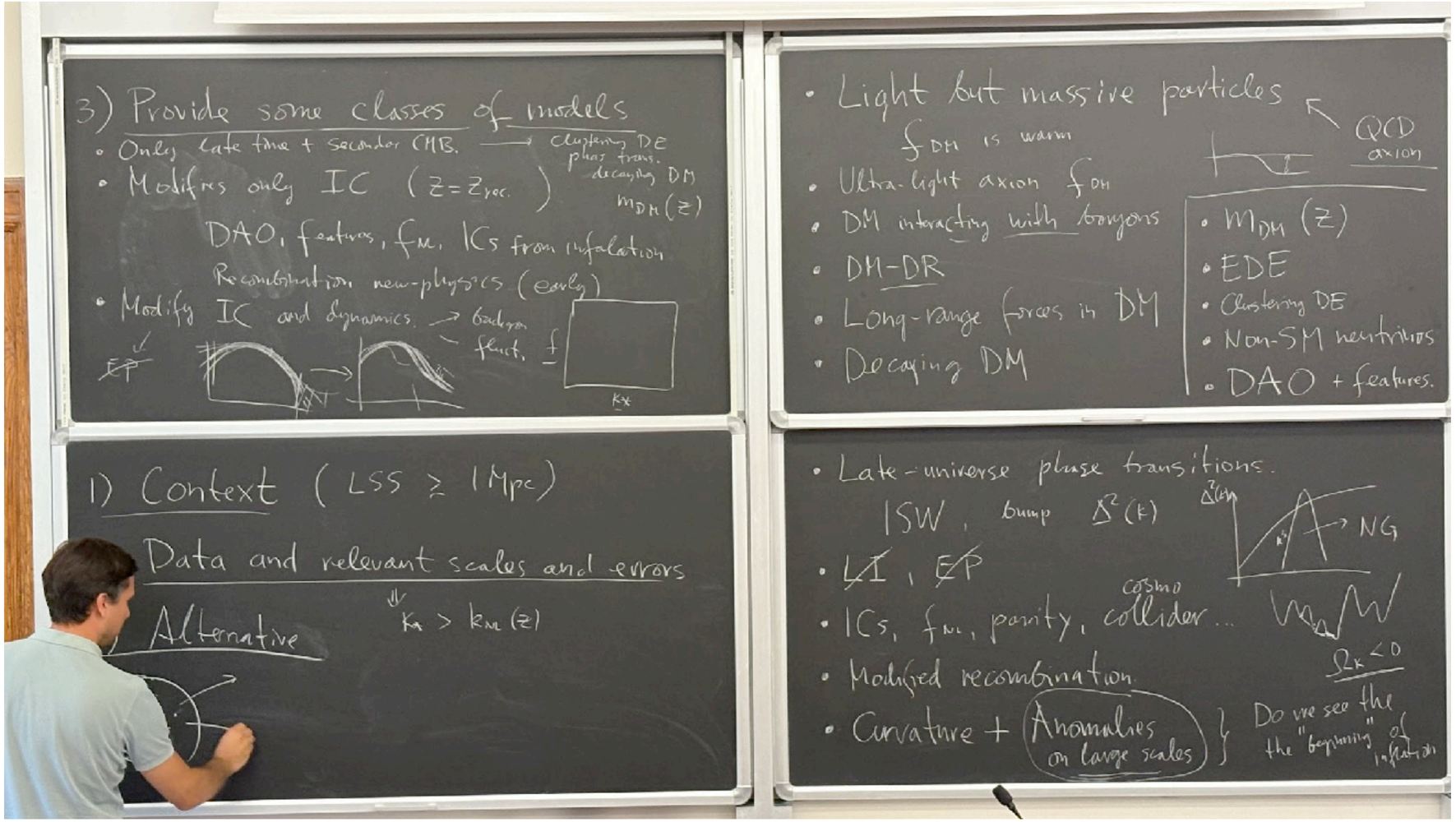


Selection of high-z targets most closely mimics DESI ELGs…systematics!



Karim et al. 2024

Challenges — what is the clear science case?



The End