DESI 2024: Survey overview and first cosmological results

- survey
- BAO results
- Full Shape is coming

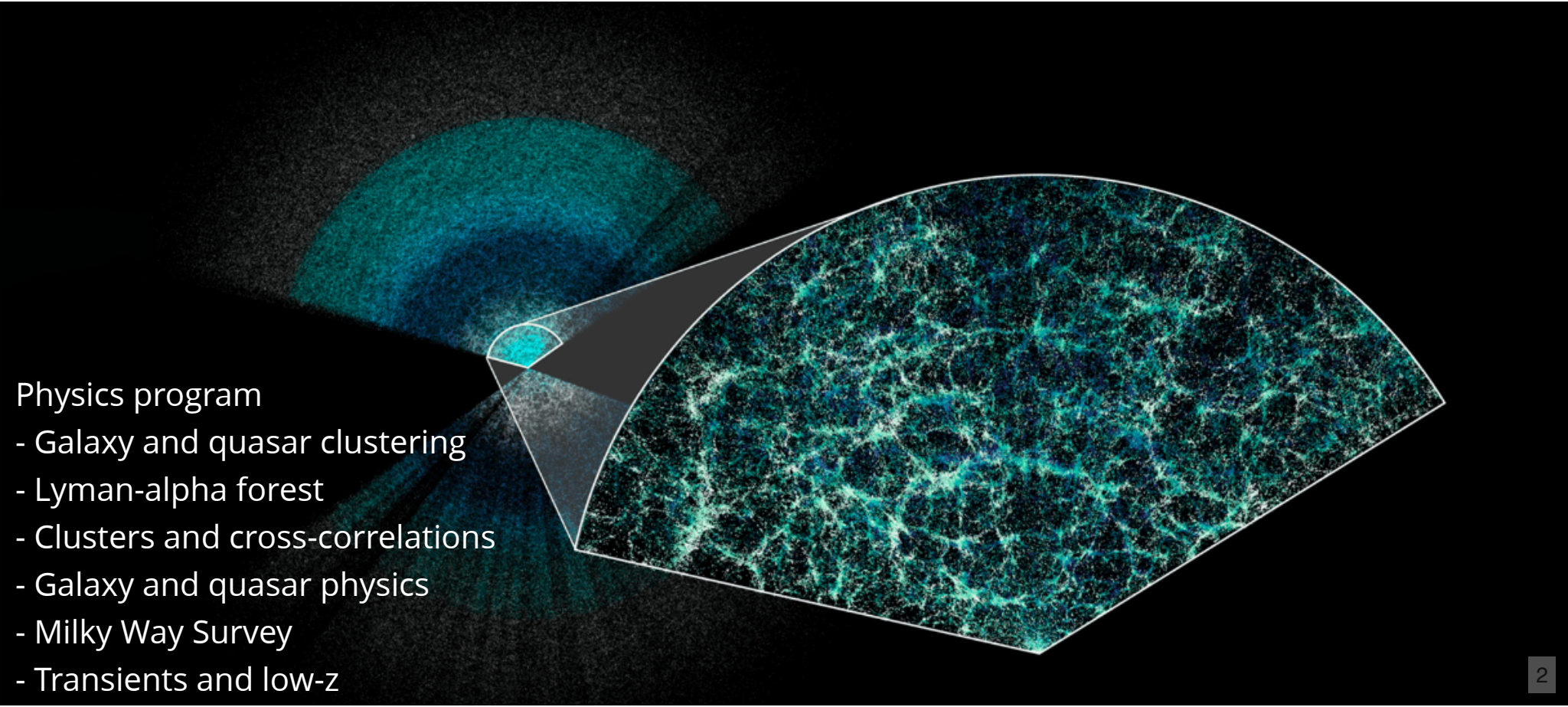
Arnaud de Mattia - CEA Saclay

Paris, October 29th

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI 3D Map



Physics program
- Galaxy and quasar clustering
- Lyman-alpha forest
- Clusters and cross-correlations
- Galaxy and quasar physics
- Milky Way Survey
- Transients and low-z

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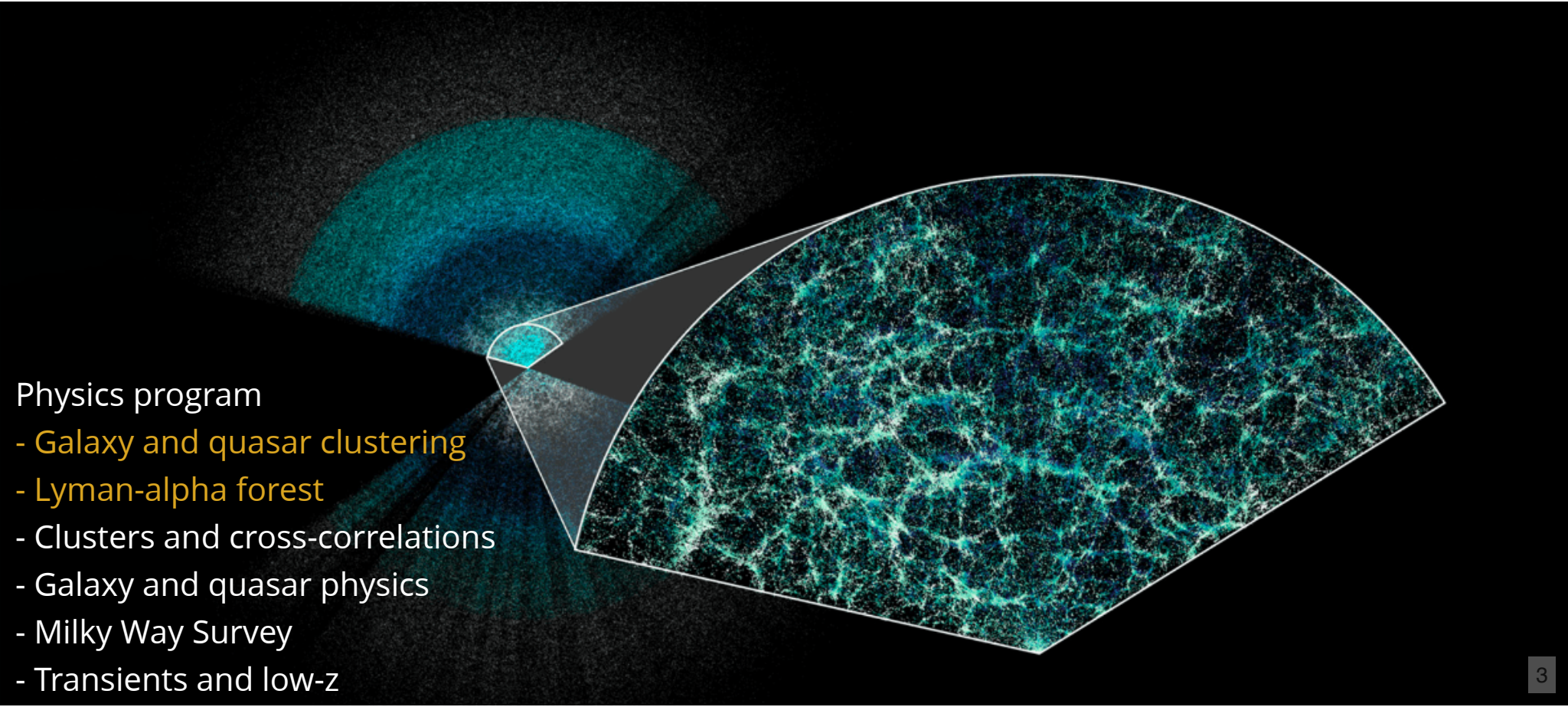

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DESI Y5 galaxy samples

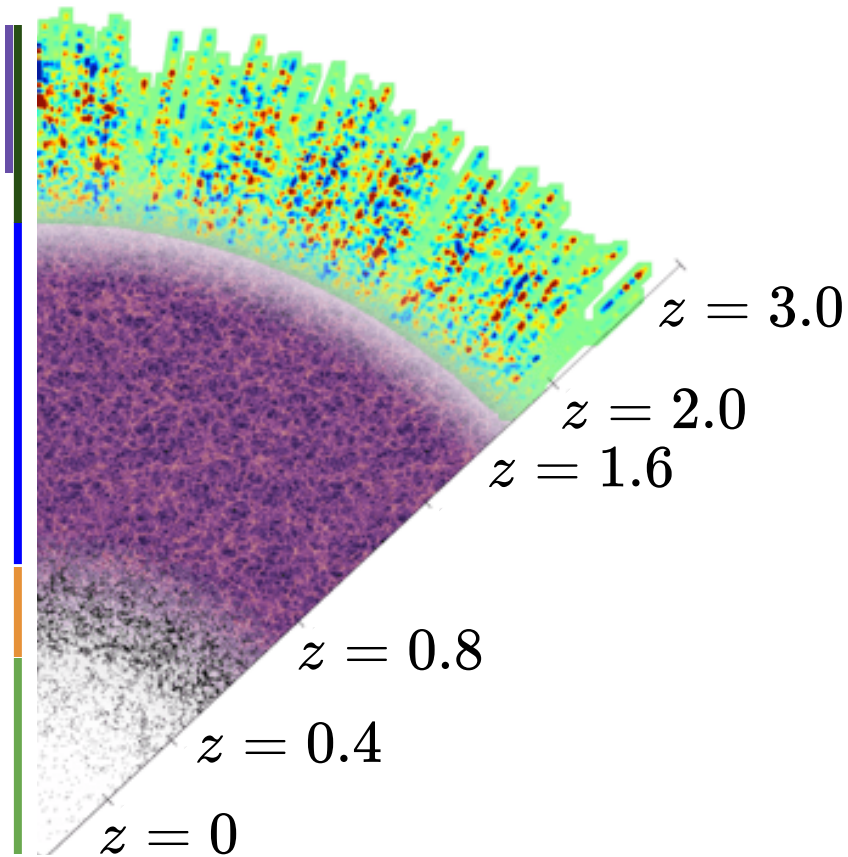
Y5 $\sim$ 40M galaxy redshifts!

QSO: 3M *(SDSS: 500k)*
Lya $1.8 < z$
Tracers $0.8 < z < 2.1$

ELG: 16M *(SDSS: 200k)*
0.6 < z < 1.6

LRG: 8M *(SDSS: 1M)*
0.4 < z < 0.8

Bright Galaxies: 14M *(SDSS: 600k)*
0 < z < 0.4



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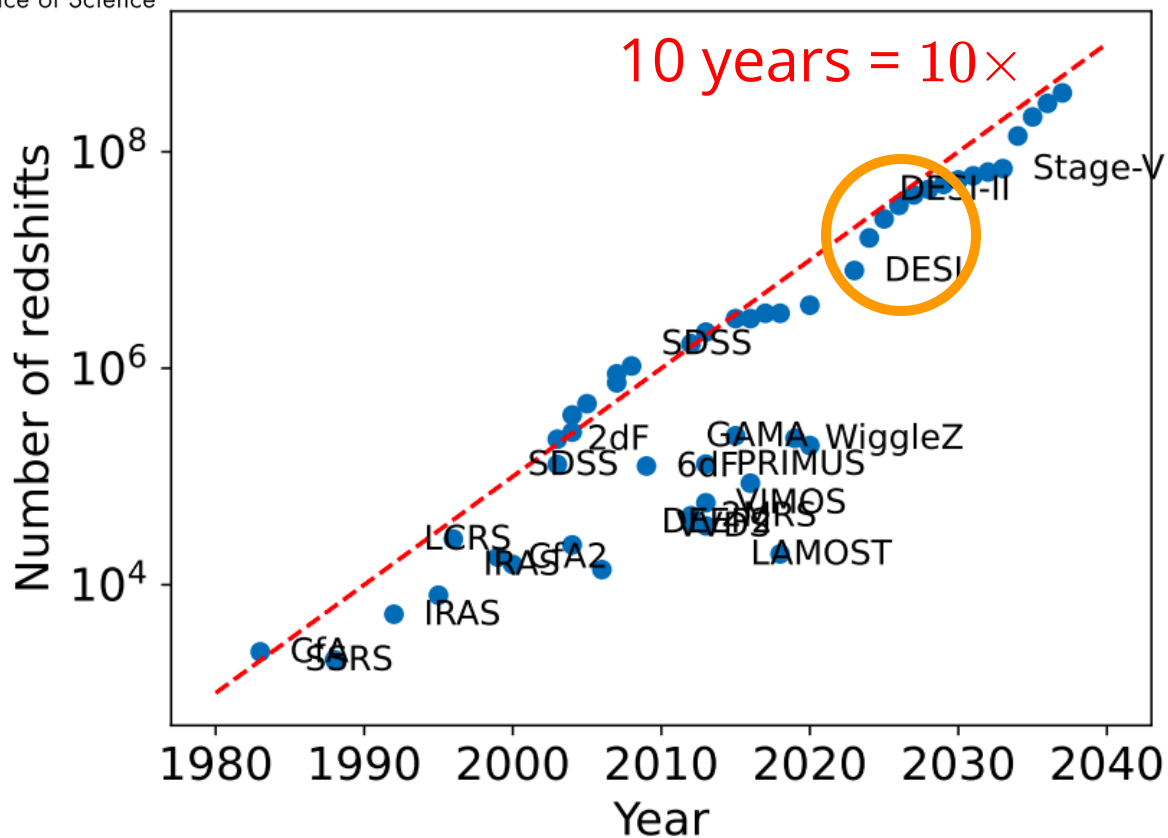
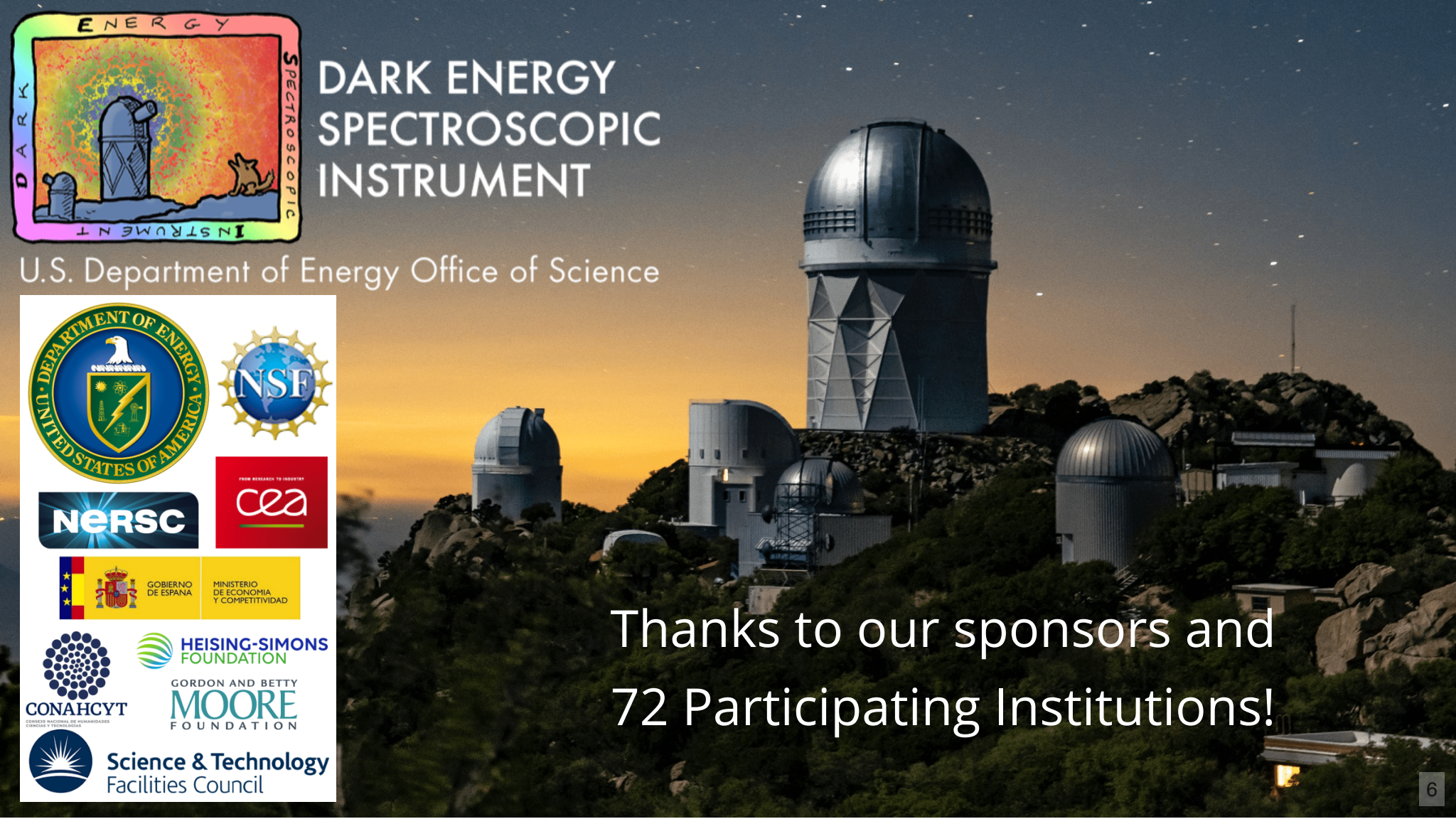
DESI: a stage IV survey



Schlegel et al. 2022, arXiv:2209.03585


DARK ENERGY SPECTROSCOPIC INSTRUMENT
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NSF
NERSC
cea
GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMIA Y COMPETITIVIDAD
CONAHCYT
HEISING-SIMONS FOUNDATION
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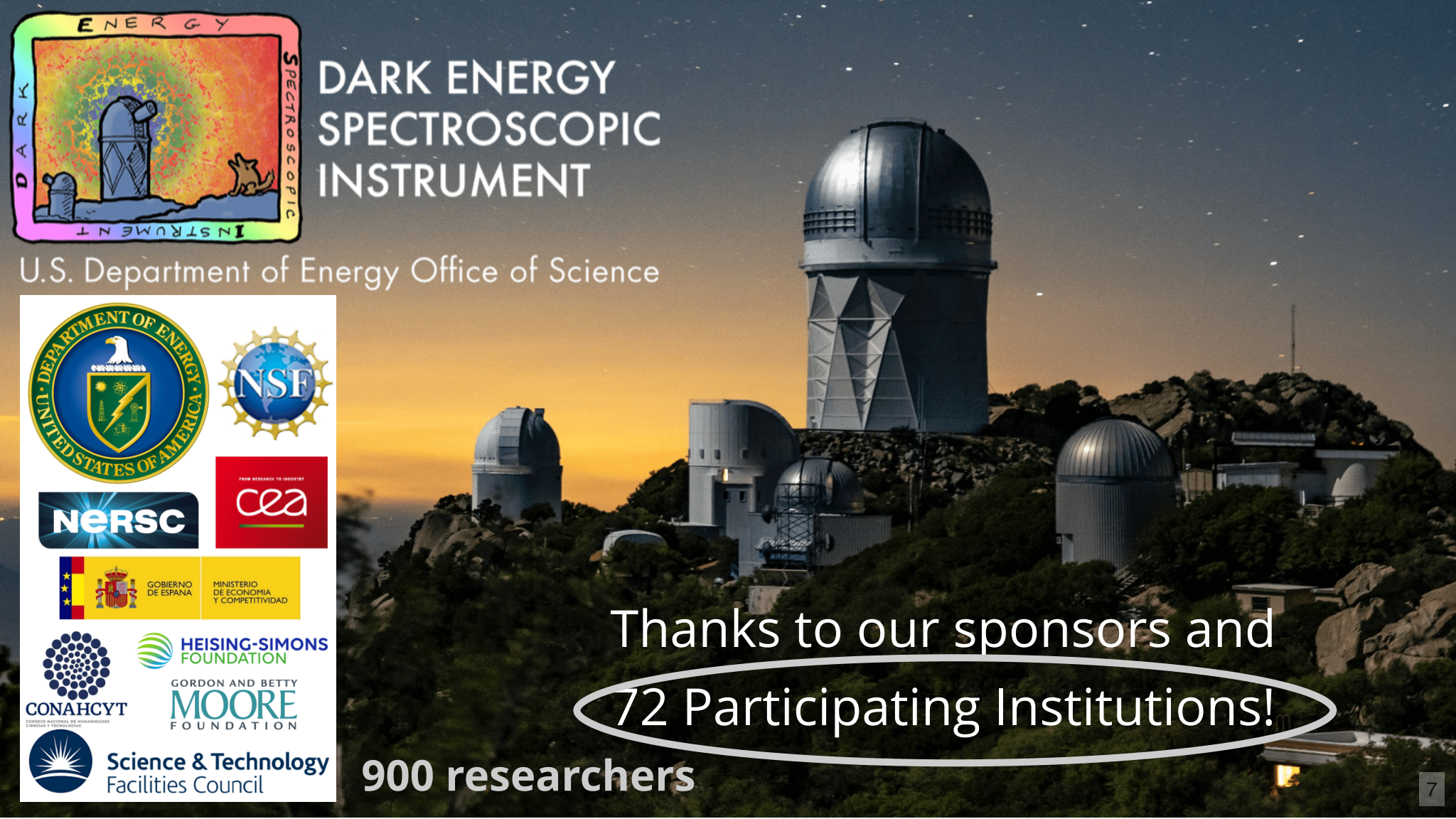
Thanks to our sponsors and
72 Participating Institutions!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900 researchers

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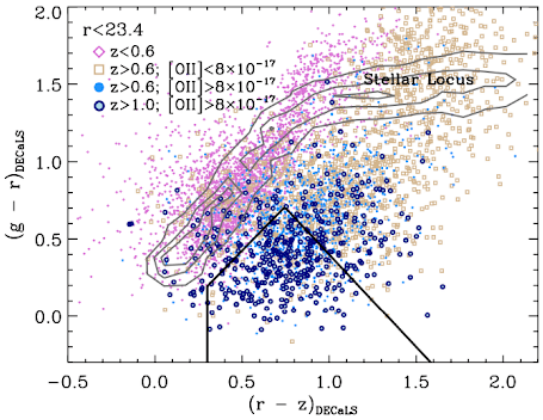
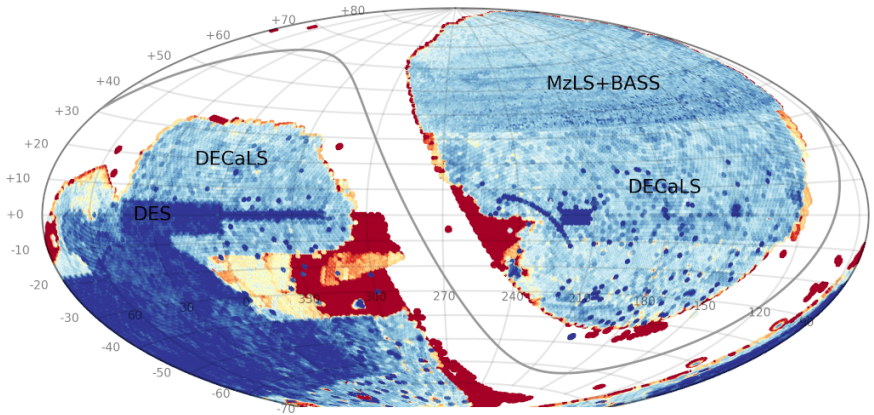
From images to redshifts

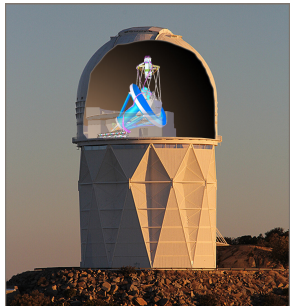
target selection

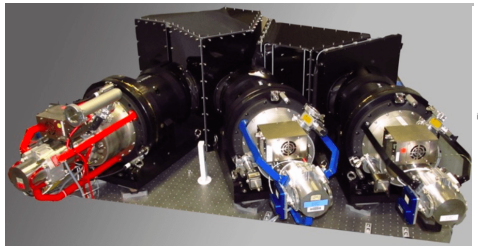


imaging surveys (2014 - 2019) + WISE (IR)

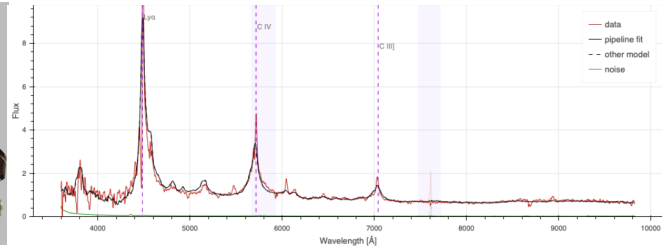


spectroscopic observations





spectra and redshift measurements



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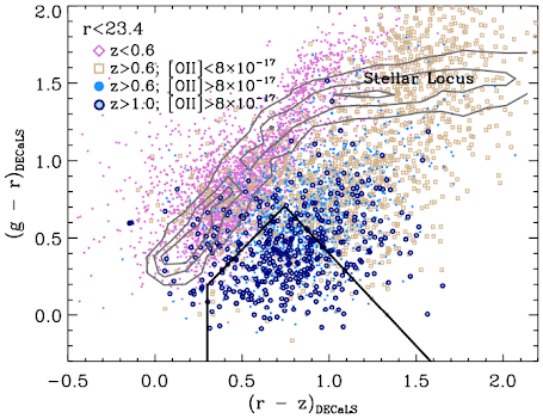

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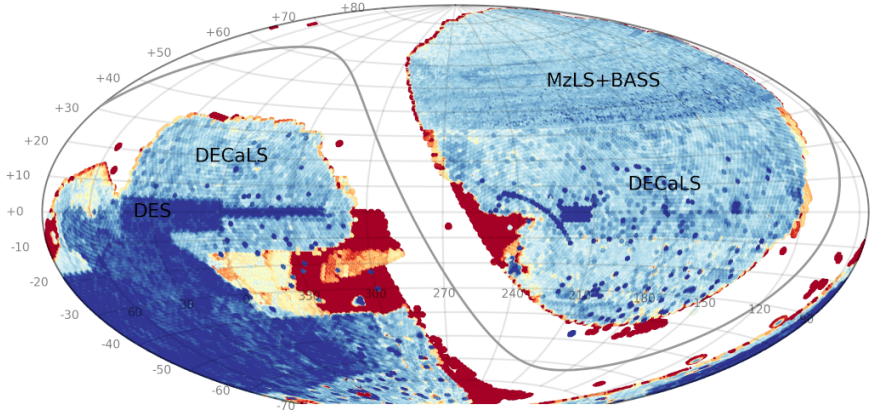

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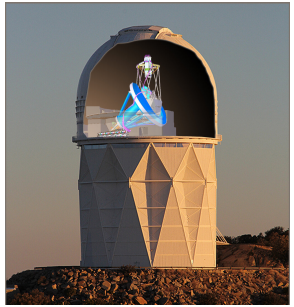

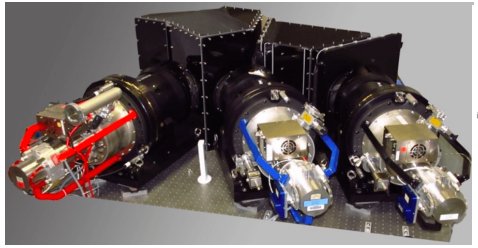

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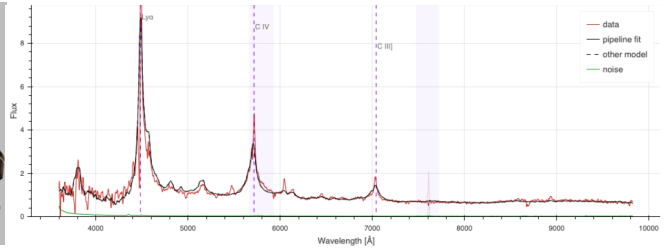

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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Mayall Telescope

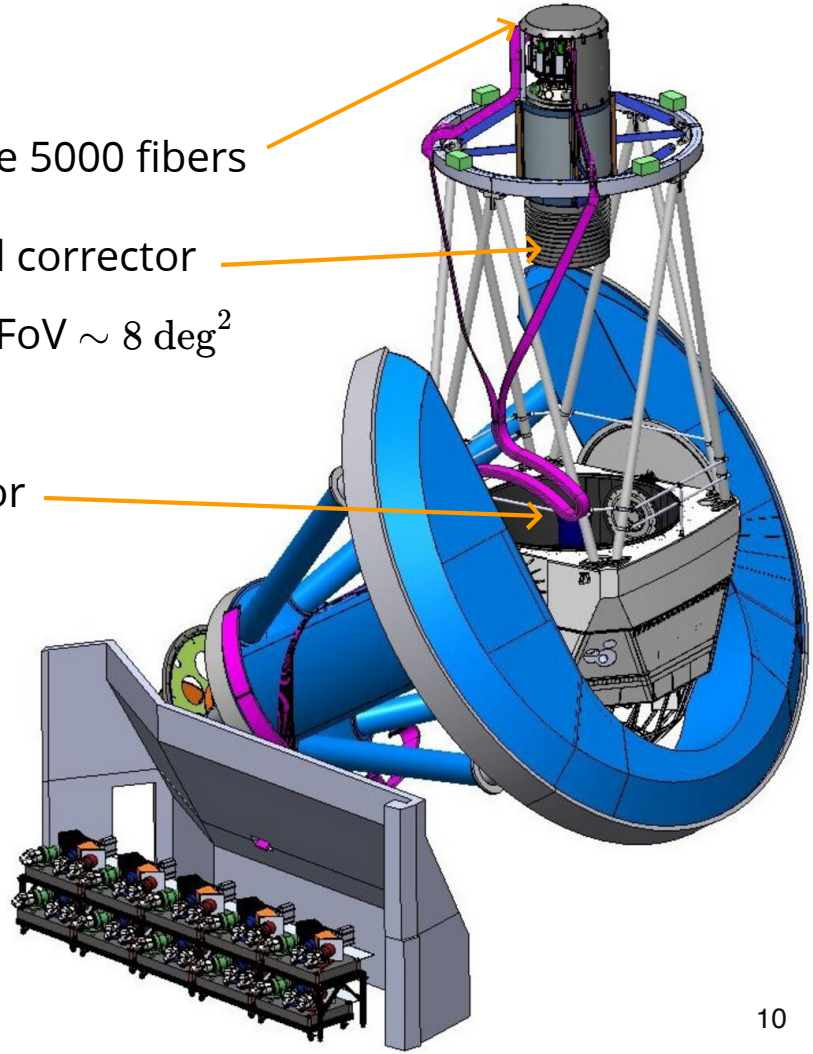
Kitt Peak, AZ

focal plane 5000 fibers

wide-field corrector

6 lenses, FoV $\sim 8\ \mathrm{deg}^2$

4 m mirror



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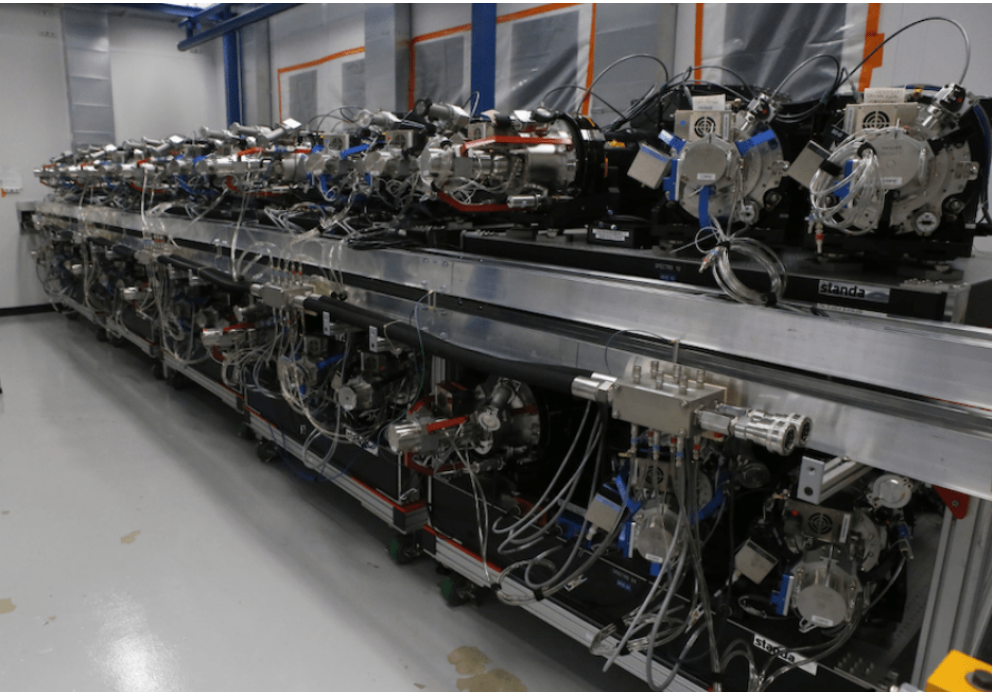
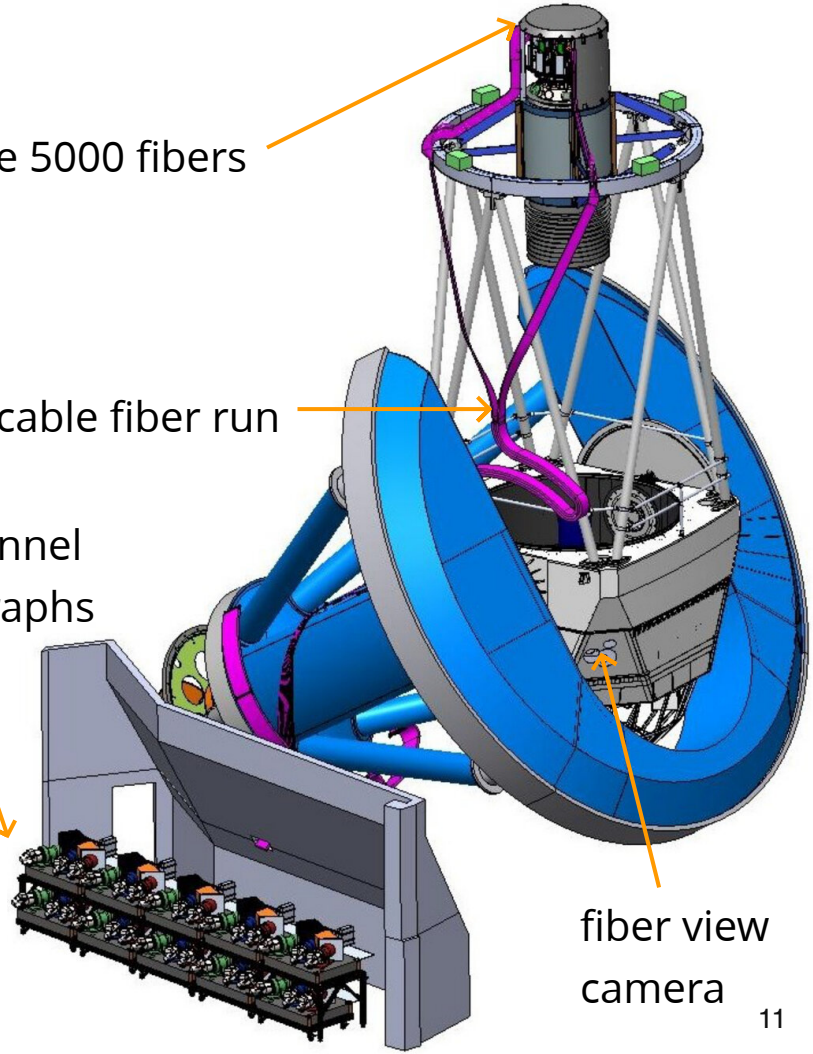
Kitt Peak, AZ





DARK ENERGY SPECTROSCOPIC INSTRUMENT

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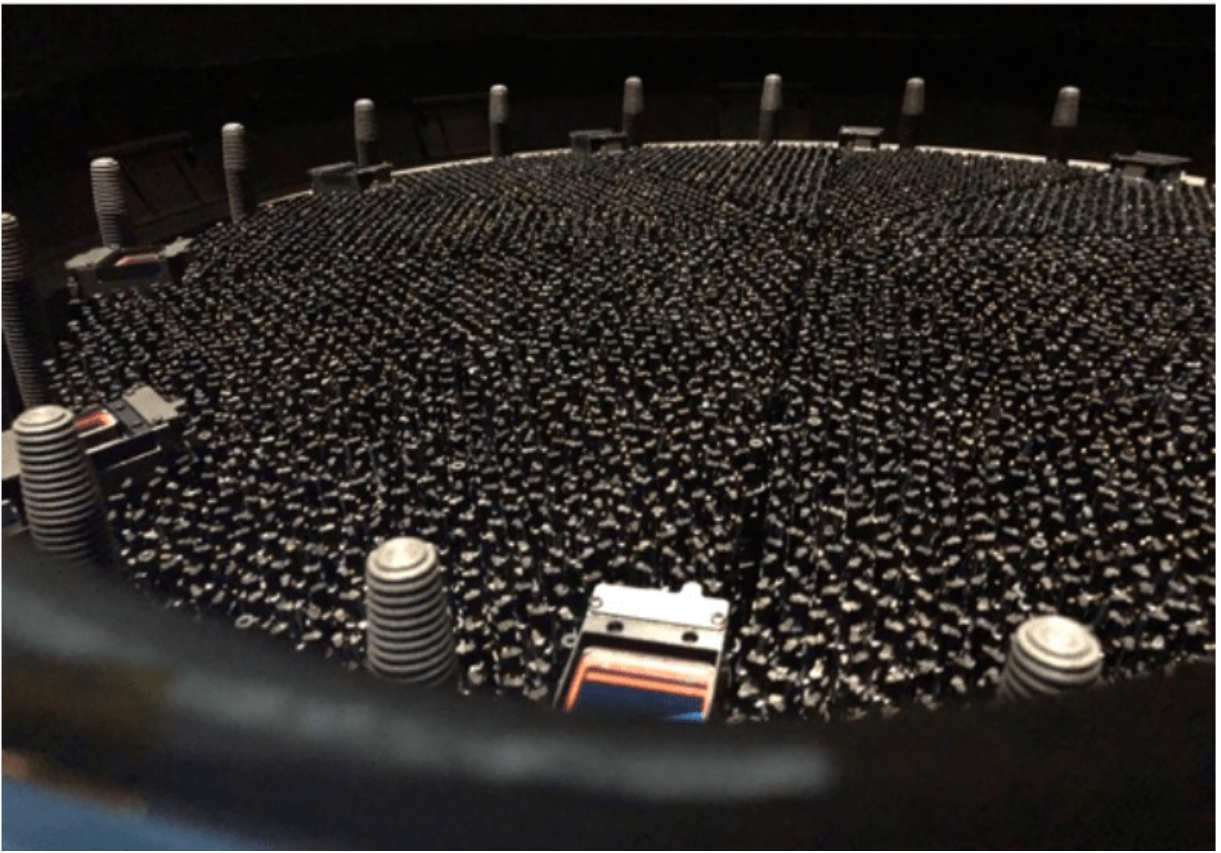
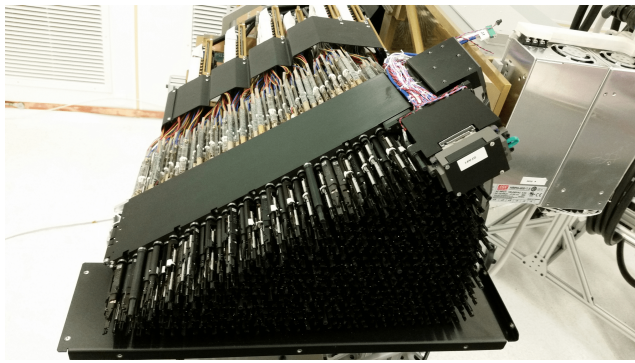
Focal plane: 5000 robotic positioners





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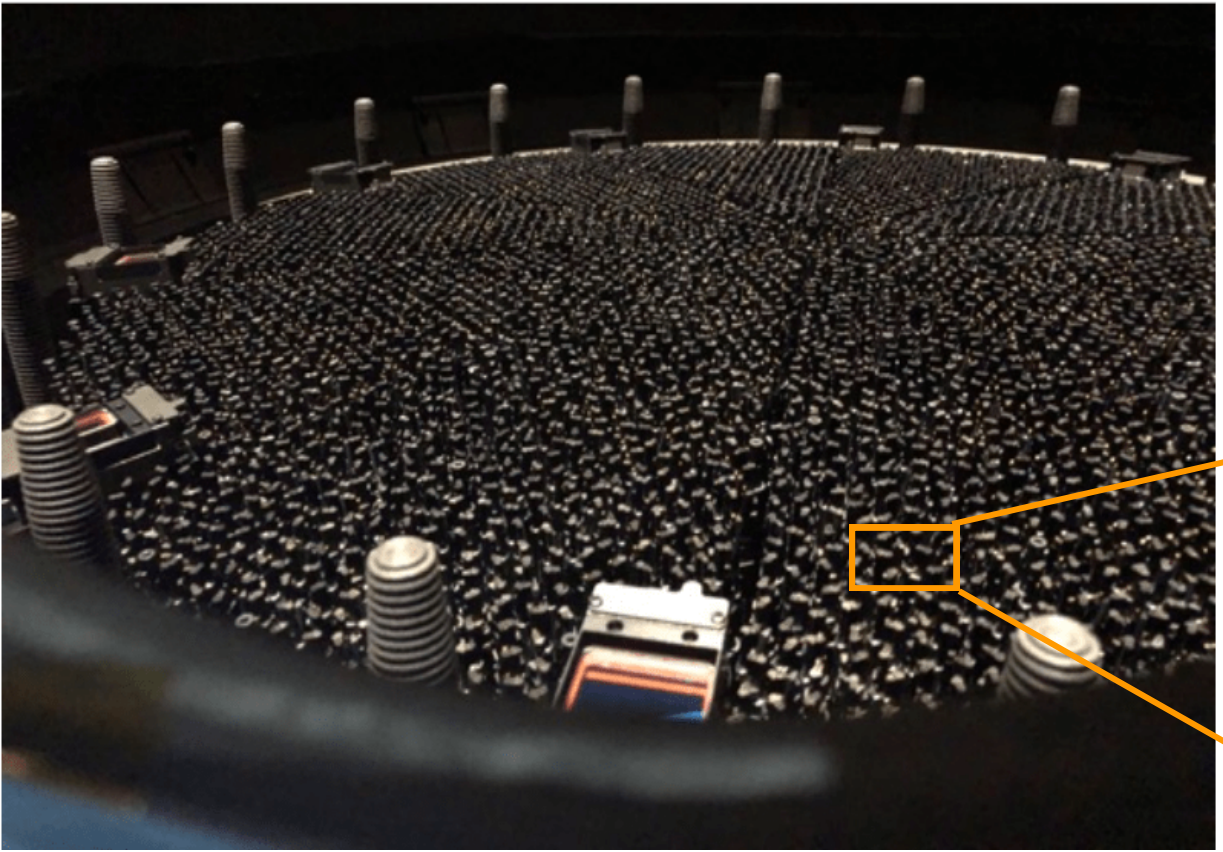

Exposure time (dark): **1000 s**

Configuration of the focal plane	**140 s**
CCD readout	
Go to next pointing	

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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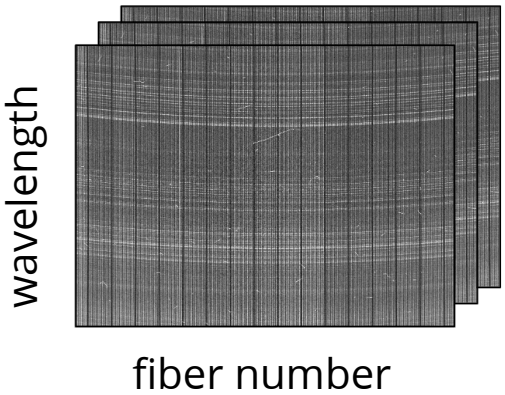
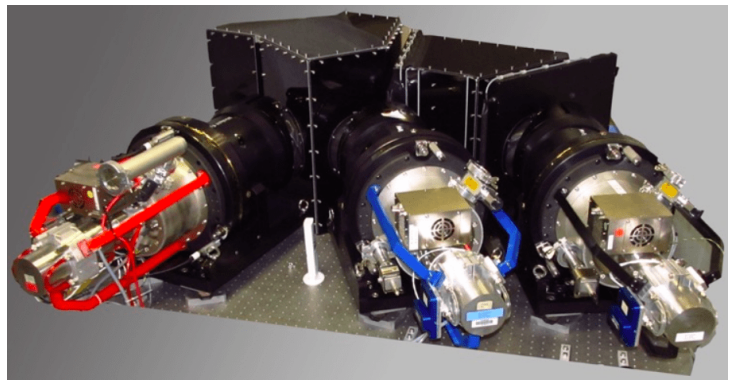
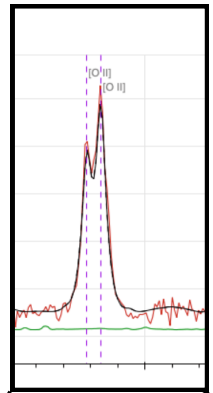
Spectroscopic pipeline

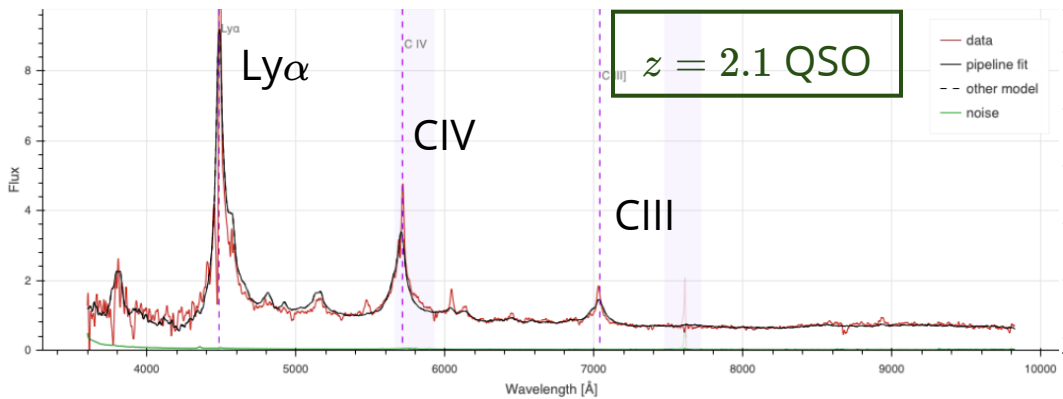


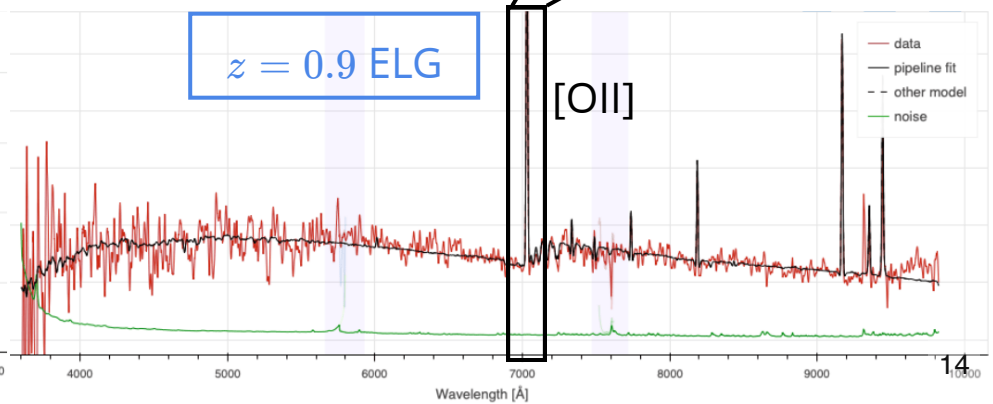


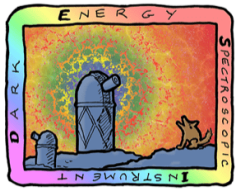


Lyα at $1216\mathring{A}$ down to $z = 2.0$

[OII] doublet at $2727\mathring{A}$ up to $z = 1.6$







DARK ENERGY SPECTROSCOPIC INSTRUMENT

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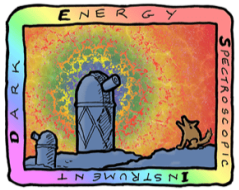
Release of DESI DR1 (BAO) results

April 4th 2024

First batch of DESI Y1 cosmological analyses
data.desi.lbl.gov/doc/papers/

- DESI 2024 I: First year data release
- DESI 2024 II: DR1 catalogs
- DESI 2024 III: BAO from Galaxies and Quasars
- DESI 2024 IV: BAO from the Lyman-Forest
- DESI 2024 V: RSD from Galaxies and Quasars
- DESI 2024 VI: Cosmological constraints from BAO measurements
- DESI 2024 VII: Cosmological constraints from RSD measurements



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Y1KP4 leads
Hee-Jong Seo
Nikhil Padmanabhan

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- **DESI 2024 III: BAO from Galaxies and Quasars**
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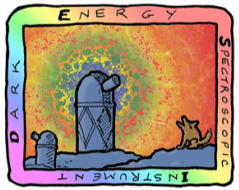

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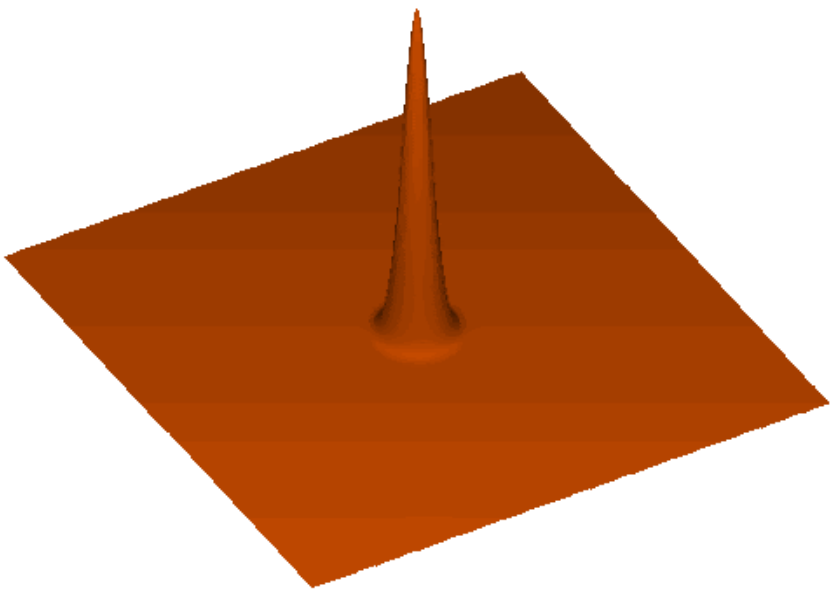
Baryon acoustic oscillations

Sound waves in primordial plasma



At recombination ($z \sim 1100$)

- plasma changes to optically thin
- baryons decouple from photons
- sound wave stalls

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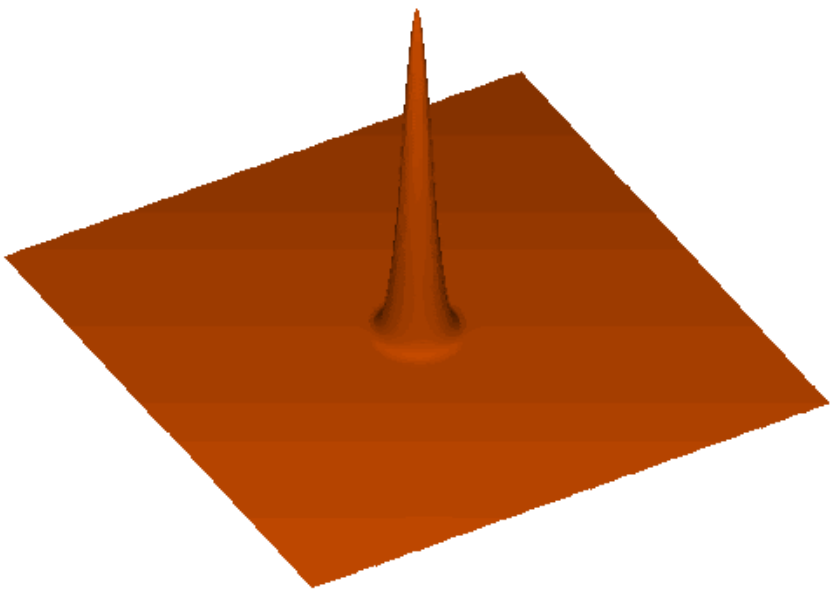

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spherical shell in the distribution of galaxies, of radius the distance that sound waves travelled

= **sound horizon scale at the drag epoch** $r_{\rm d} \sim 150\ {\rm Mpc} \sim 100\ {\rm Mpc}/h$

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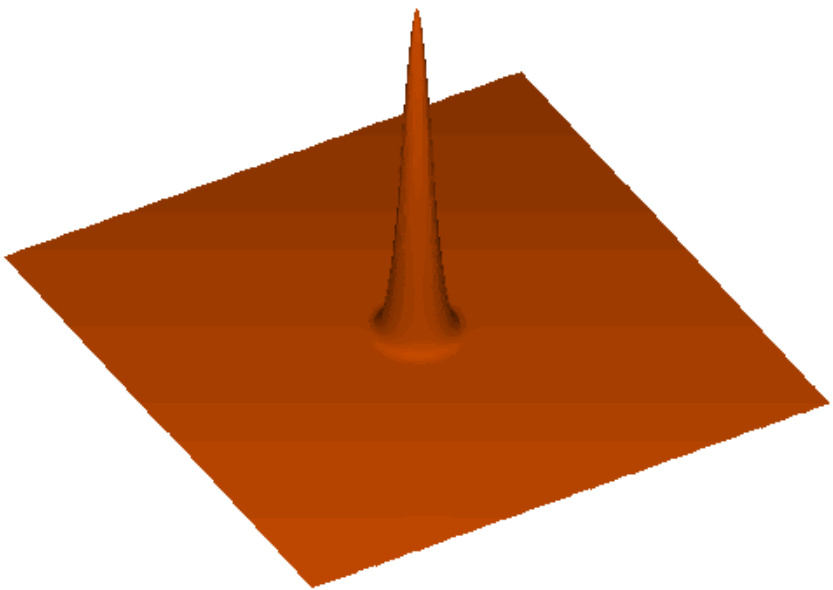

standard ruler

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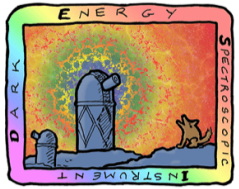

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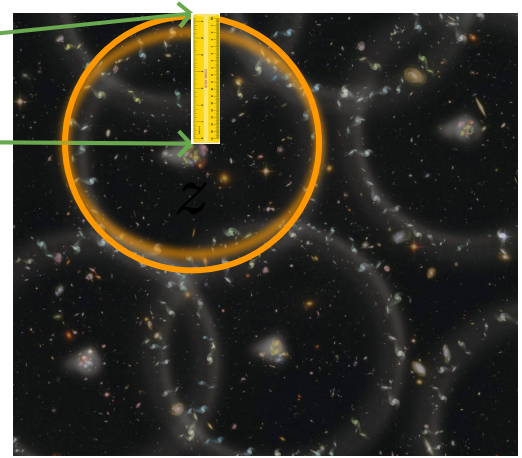
BAO measurements

- transverse to the line-of-sight: $D_{\mathrm{M}}(z)/r_{\mathrm{d}}$

$$\theta_{\mathrm{BAO}} = r_{\mathrm{d}}/D_{\mathrm{M}}(z)$$



sound horizon r_d transverse comoving distance

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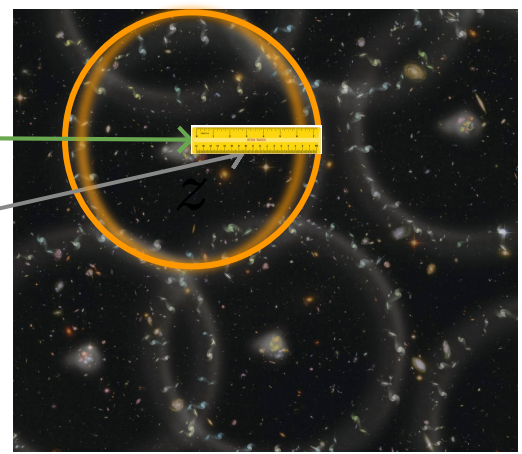
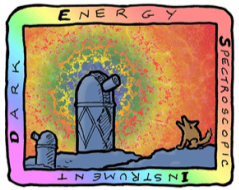
BAO measurements

- transverse to the line-of-sight: $D_{\rm M}(z)/r_{\rm d}$
- along the line-of-sight: $D_{\rm H}(z)/r_{\rm d} = c/(H(z)r_{\rm d})$

$$\Delta z_{\rm BAO} = r_{\rm d}/D_{\rm H}(z)$$



sound horizon r_d Hubble distance



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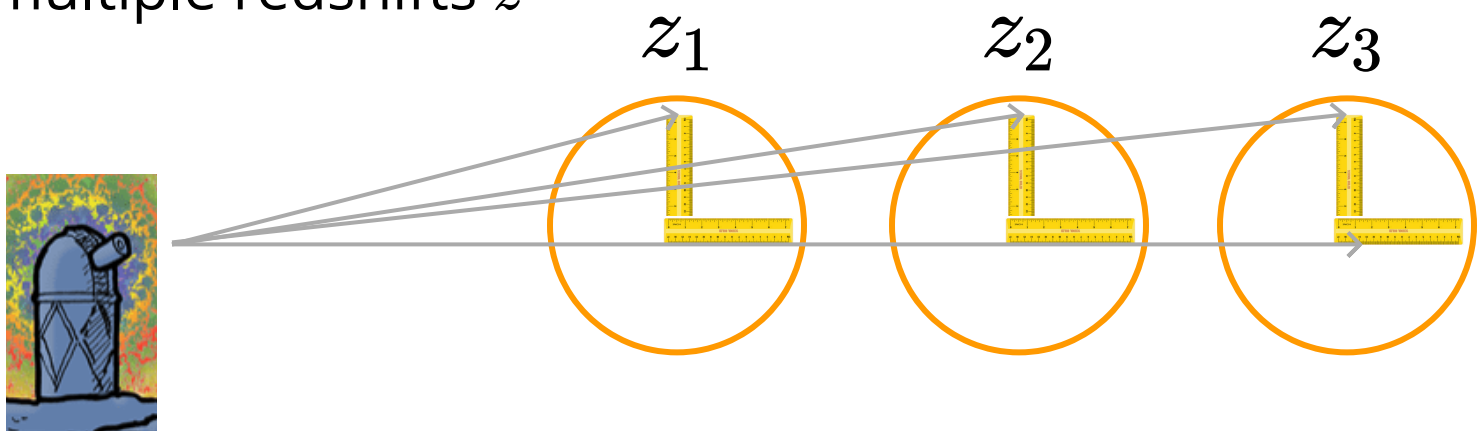
At multiple redshifts z



Probes the expansion history, hence the energy content

Absolute size at $z = 0$: $H_0 r_d$

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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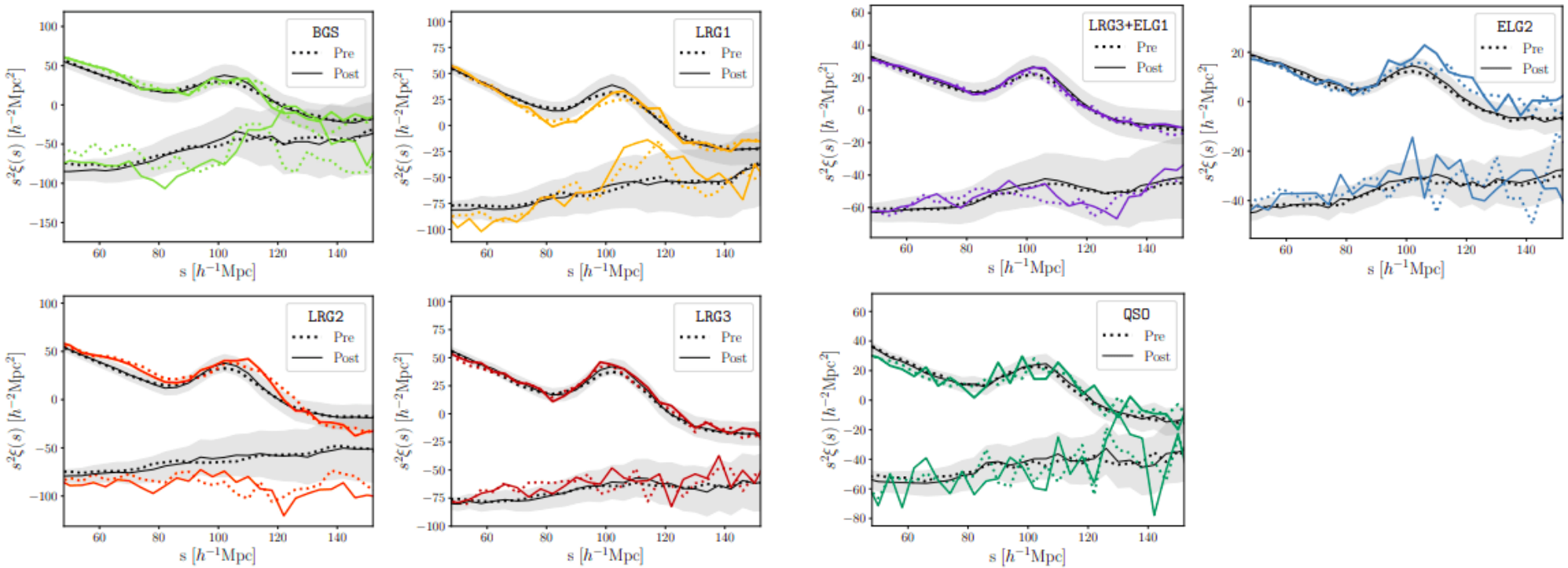
Correlation functions

Excess probability to find 2 galaxies separated by a separation s



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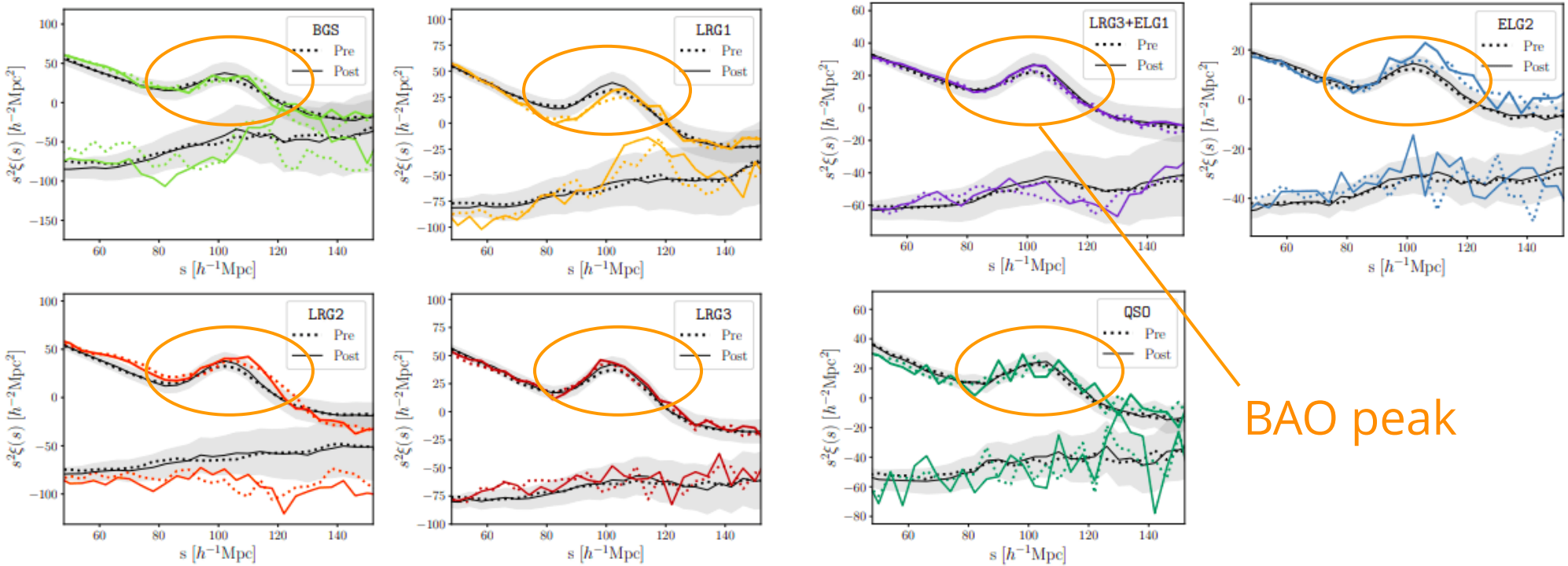

BAO peak

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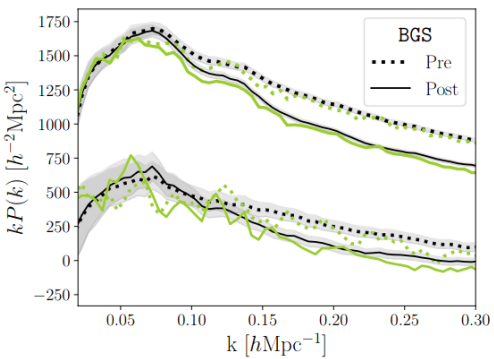
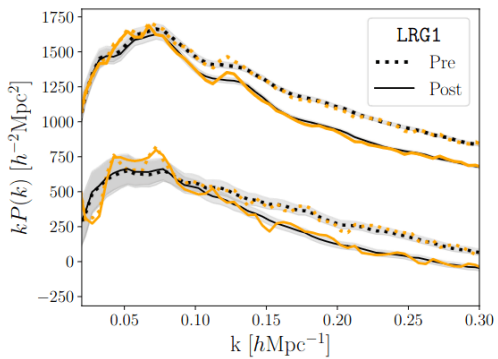
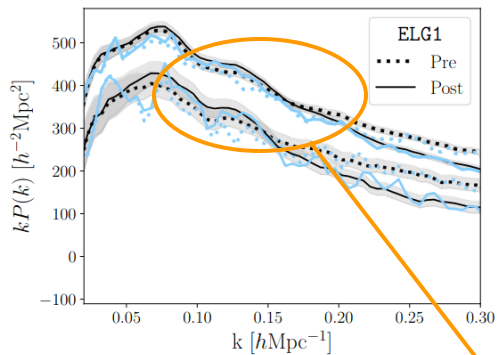
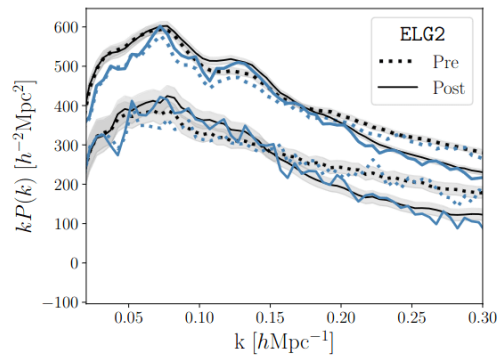
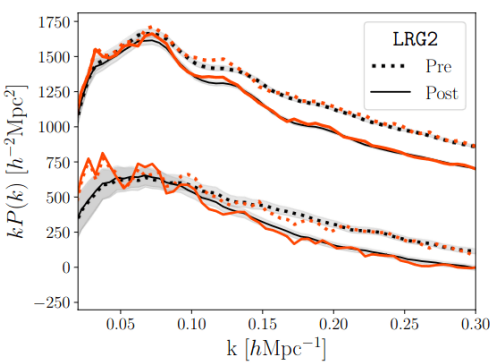
Power spectra

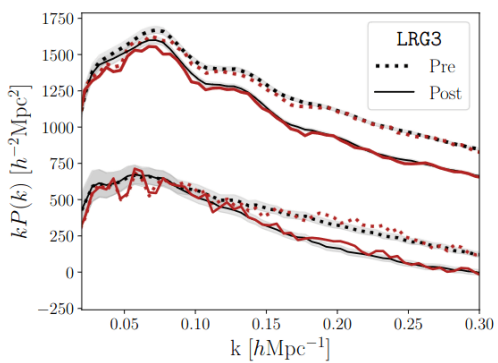


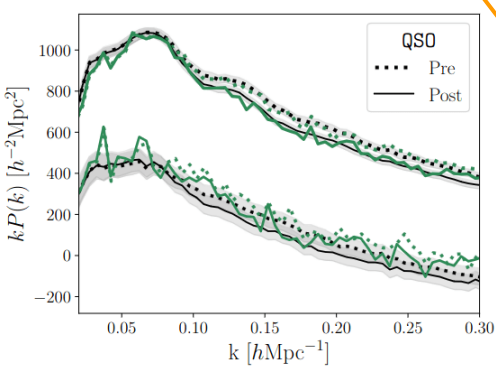












BAO wiggles

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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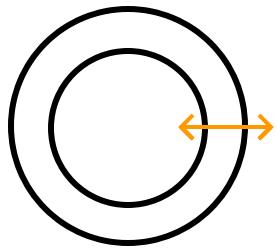
Some fits: configuration space

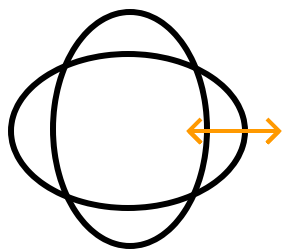
isotropic measurement

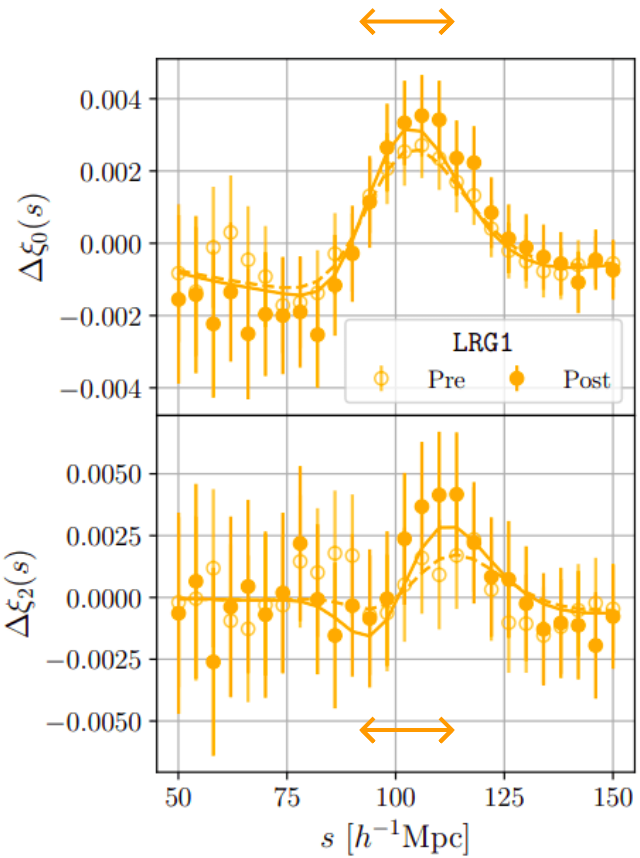
$$\propto (D_{\rm M}^2(z) D_{\rm H}(z))^{1/3}/r_{\rm d}$$



anisotropic measurement

$$\propto D_{\rm M}(z)/D_{\rm H}(z)$$





DARK ENERGY SPECTROSCOPIC INSTRUMENT

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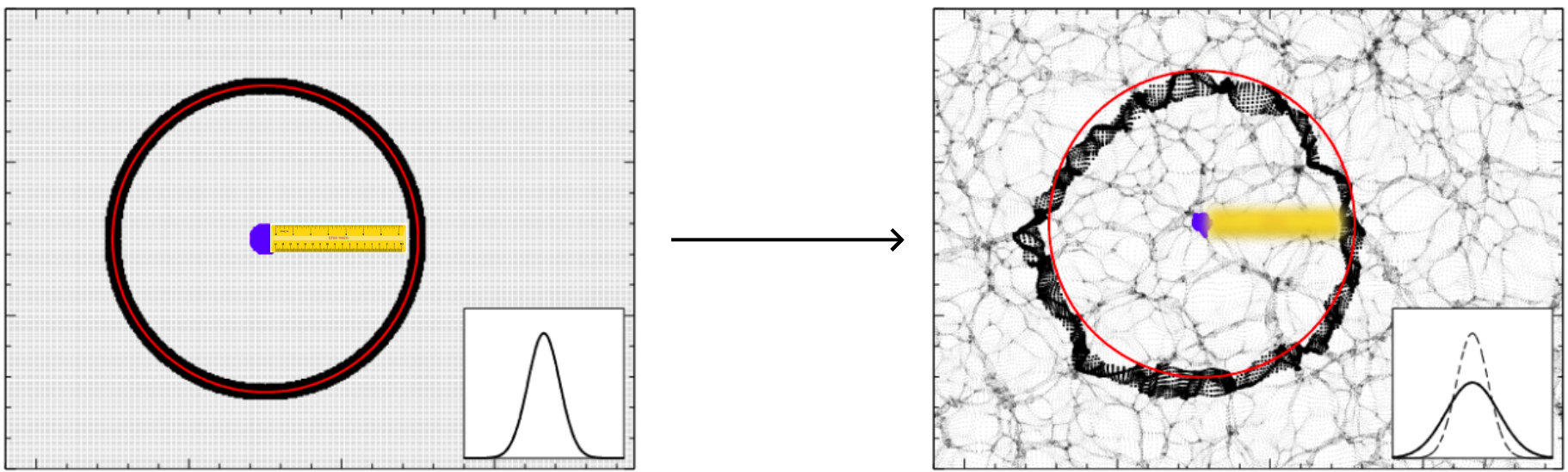
Non-linear evolution

Non-linear structure growth and peculiar velocities **blur** and **shrink** (slightly) the ruler

Eisenstein et al. 2008, Padmanabhan et al. 2012



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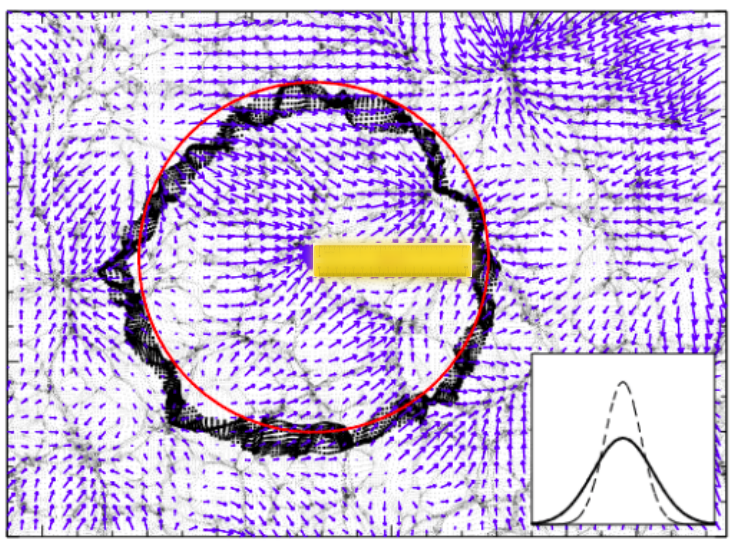
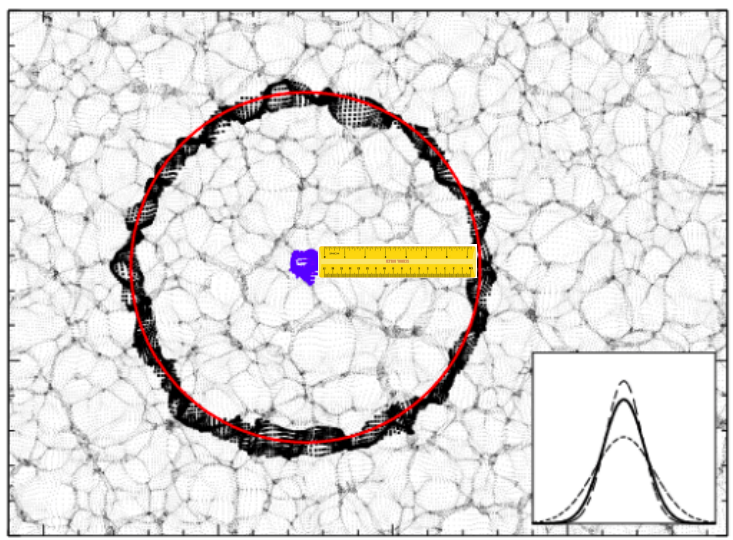
Density field reconstruction

Estimates Zeldovich displacements from observed field and moves galaxies back: **refurbishes the ruler** (improves precision and accuracy)



reconstruction



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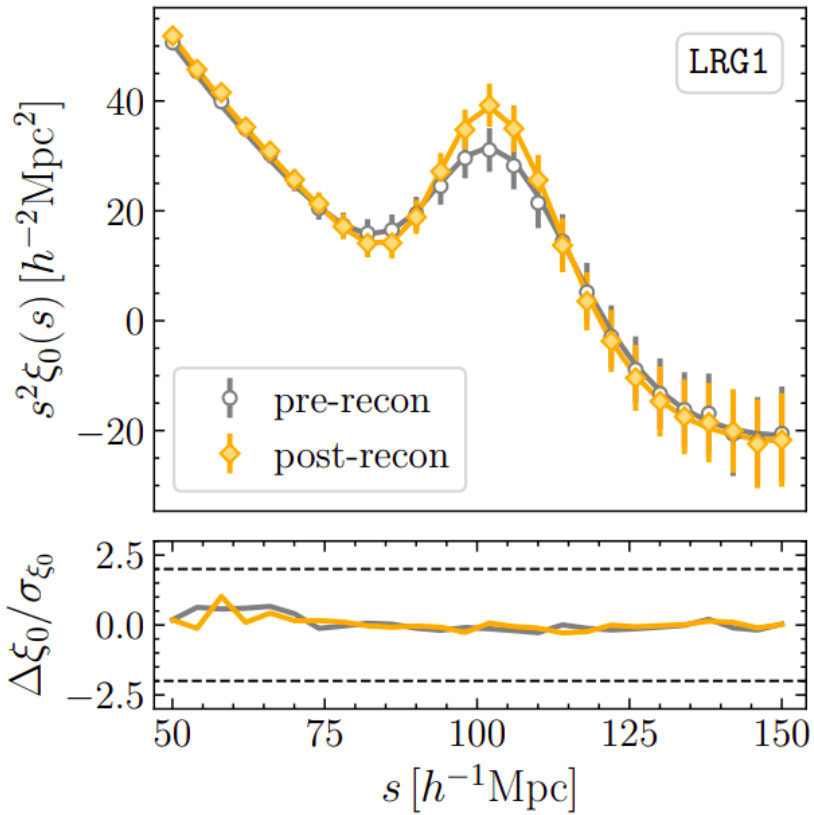
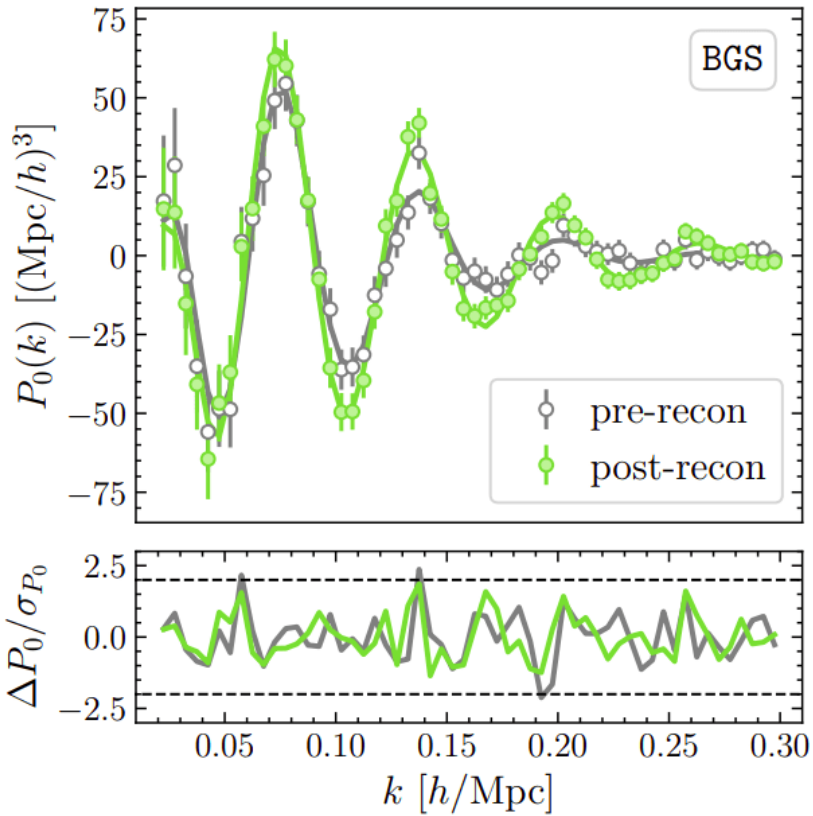


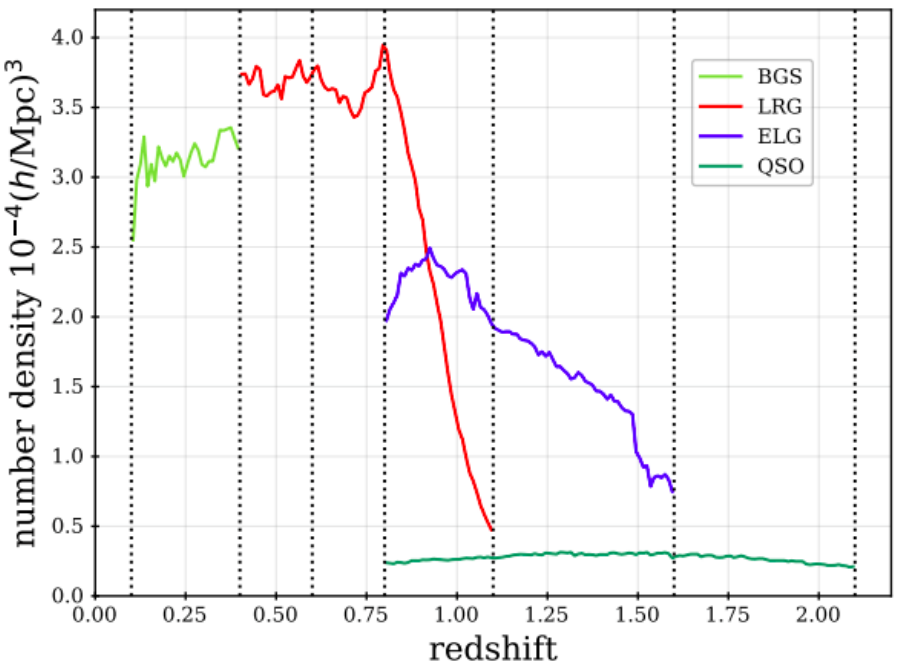


DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI Y1 BAO analysis

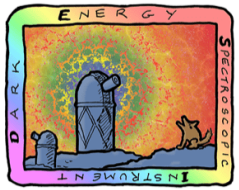
- **Biggest ever spectroscopic BAO dataset** ($N_{\rm tracer}$ and V)



5.7 million unique redshifts

Effective volume $V_{\rm eff} = 18\ \mathrm{Gpc}^3$

3× bigger than SDSS!



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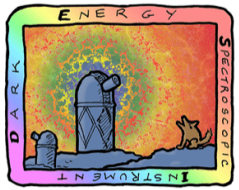
$$(\mathrm{R.A.}, \mathrm{Dec.}, z) \Longrightarrow (x, y, z) \Longrightarrow (\mathrm{R.A.}', \mathrm{Dec.}', z')$$

fiducial cosmology

blinded cosmology ($\Omega_{\mathrm{m}}, w_0, w_a$)

(random & unknown)



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fiducial cosmology

blinded cosmology ($\Omega_{\rm m}, w_0, w_a$)

(random & unknown)

+ **RSD blinding**: change reconstructed peculiar velocities

+ $f_{\rm NL}^{\rm loc}$ **blinding**: add clustering-dependent signal on large scales with weights

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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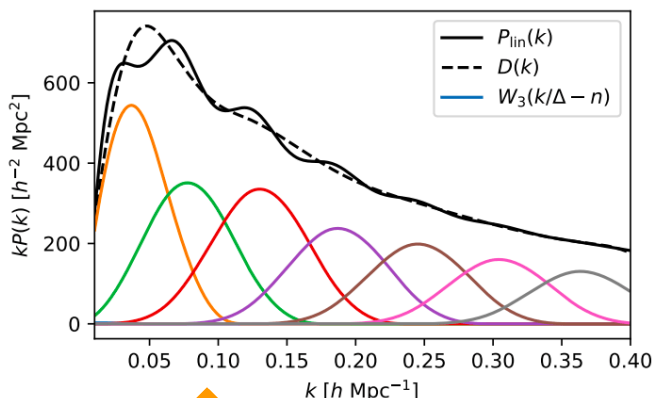
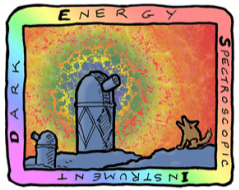
DESI Y1 BAO analysis

- **Biggest ever spectroscopic BAO dataset** ($N_{\rm tracer}$ and V)
- **Blind analysis** to mitigate observer / confirmation biases (catalog-level blinding)
- Theory developments in BAO fitting code

Chen, Howlett et al. 2024, arXiv:2402.14070



$$P_{\rm gg}(k,\mu) = \mathcal{B}(k,\mu)P_{\rm nw}(k) + \mathcal{C}(k,\mu)P_{\rm w}(k) + \mathcal{D}(k,\mu)$$



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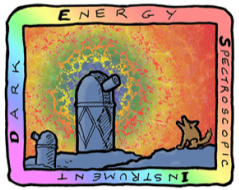
- Theory developments in BAO fitting code
- New and improved reconstruction methods
- New combined tracer method used for overlapping galaxy samples (LRG and ELG in $0.8 < z < 1.1$)



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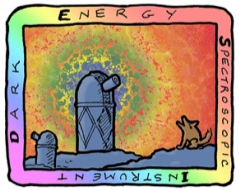
- Theory developments in BAO fitting code
- New and improved reconstruction methods
- New combined tracer method used for overlapping galaxy samples (LRG and ELG in $0.8 < z < 1.1$)
- **Unified BAO pipeline** applied to all (discrete) tracer / redshift bins consistently



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Tests of systematic errors

Considered many possible sources of systematic errors using simulations and data:

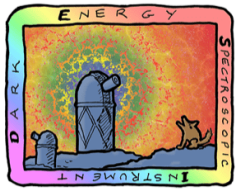
- observational effects (imaging systematics, fiber collisions)
- BAO reconstruction (2 algorithms compared)
- covariance matrix construction

no systematics detected

- incomplete theory modelling
- choice of fiducial cosmology
- galaxy-halo (HOD) model uncertainties

systematics << statistics

Max effect: $\sigma_{\text{stat.+syst.}} < 1.05\sigma_{\text{stat.}}$



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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Release of DESI Y1 (BAO) results

April 4th 2024

First batch of DESI Y1 cosmological analyses
https://data.desi.lbl.gov/doc/papers/

Y1KP6 leads
Alma Gonzalez
Julien Guy
Andreu Font-Ribera

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- DESI 2024 VII: Cosmological constraints from RSD measurements

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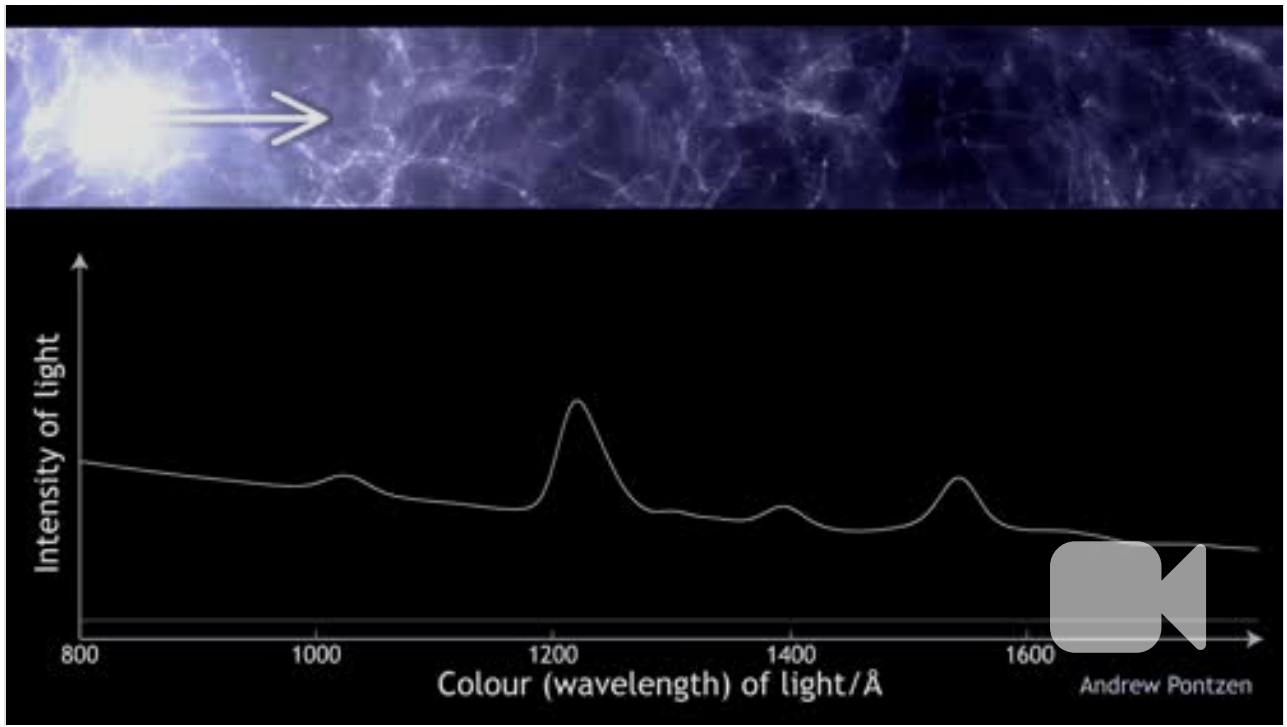
Lyα forest

credit: Andrew Pontzen



Absorption in QSO spectra by neutral hydrogen in the intergalactic medium: $\lambda_{\rm abs} = (1 + z_{\rm HI}) \times 1215.17\ \mathring{A}$

Transmitted flux fraction $F = e^{-\tau}$ probes the fluctuation in neutral hydrogen density, $\tau \propto n_{\rm HI}$

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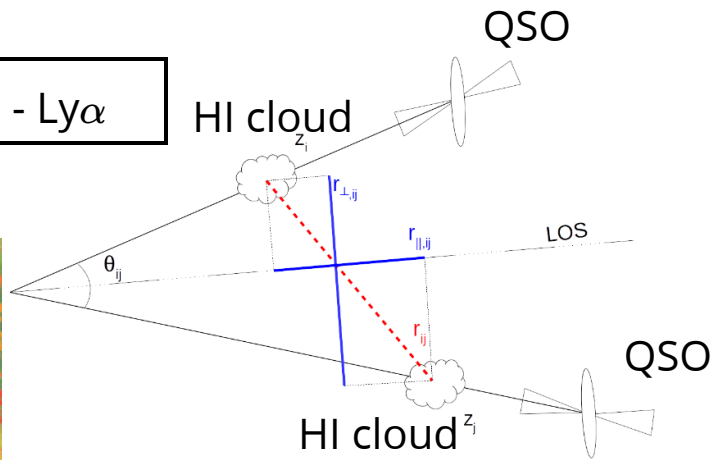
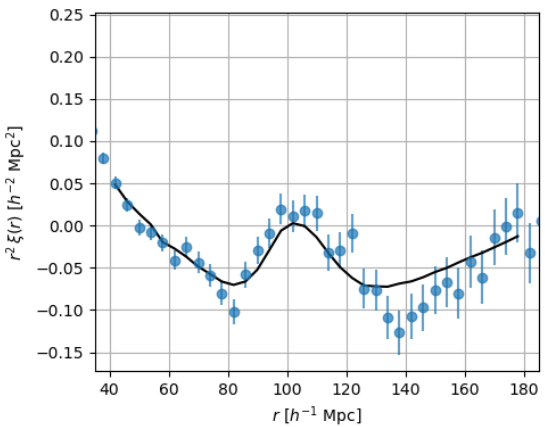
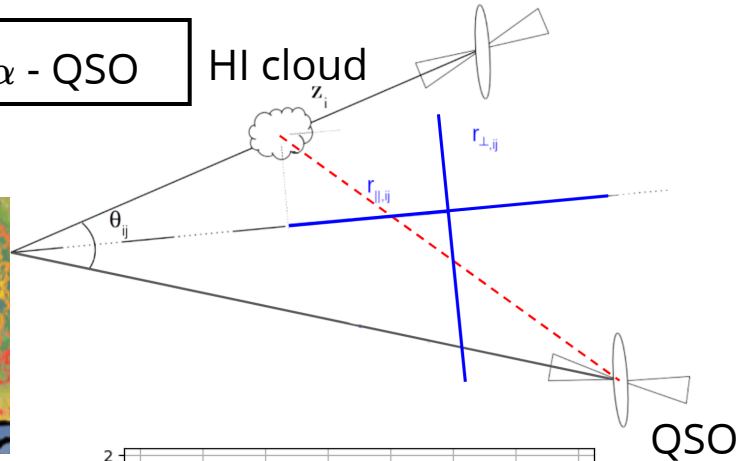
Lyα correlation functions in DESI Y1

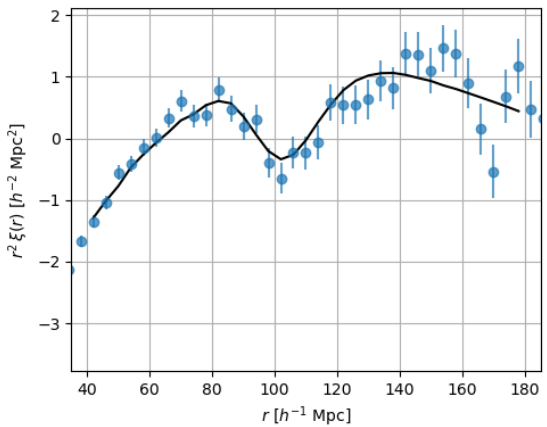
Lyα - Lyα

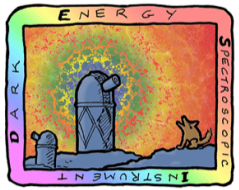




Lyα - QSO







DARK ENERGY SPECTROSCOPIC INSTRUMENT

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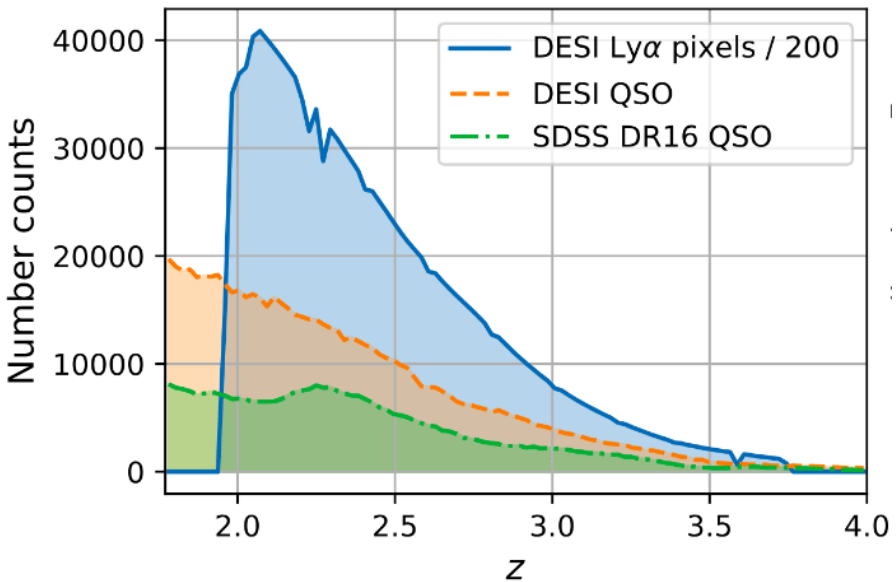
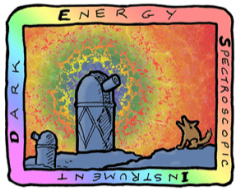
DESI Y1 Lyα BAO analysis

- **Biggest ever Lyα dataset** (N_{tracer})



>420,000 Lyα QSO at z > 2.1

2$\times$ more than SDSS!



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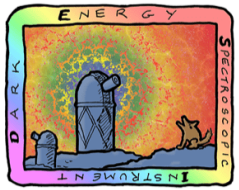

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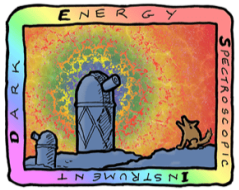
- Modelling of the correlation function: cosmological signal, and many contaminants!



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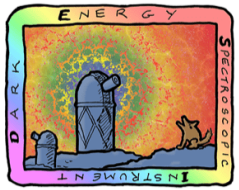
- **Biggest ever Lyα dataset** (N_{tracer})
- **First blind analysis** to mitigate observer / confirmation biases (correlation function-level blinding)
- Modelling of the correlation function: cosmological signal, and many contaminants!
- Very stable results, systematic uncertainty neglected



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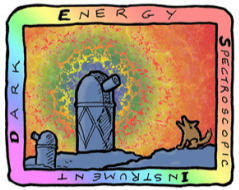

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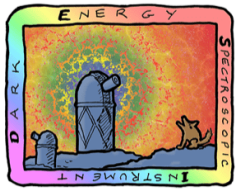
BAO measurements

BAO measures ratios of distances over the sound horizon scale at the drag epoch ["standard ruler"] r_d

- transverse to the line-of-sight: $D_\mathrm{M}(z)/r_\mathrm{d}$
- along the line-of-sight: $D_\mathrm{H}(z)/r_\mathrm{d} = c/(H(z)r_\mathrm{d})$
- low S/N, isotropic average: $D_\mathrm{V}(z)/r_\mathrm{d} = (zD_\mathrm{M}^2(z)D_\mathrm{H}(z))^{1/3}/r_\mathrm{d}$



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BAO measurements

These quantities directly relate to base cosmological parameters

Let's factor out the h terms:

- $[D_{\rm M}(z)h](\Omega_{\rm m}, f_{\rm DE}, \Omega_{\rm K}, ...)/[r_{\rm d}(\Omega_{\rm m}h^2, \Omega_{\rm b}h^2)h]$
- $[D_{\rm H}(z)h](\Omega_{\rm m}, f_{\rm DE}, \Omega_{\rm K}, ...)/[r_{\rm d}(\Omega_{\rm m}h^2, \Omega_{\rm b}h^2)h]$

BAO measurements **at different z** constrain:

- energy content $(\Omega_{\rm m}, f_{\rm DE}, ...)$
- constant-over-z product $r_{\rm d}h$ i.e. $H_0 r_{\rm d}$

$h = H_0/[100\ {\rm km/s/Mpc}]$

$\Omega_{\rm m}$ fractional energy density of matter

$f_{\rm DE}$ dark energy

$\Omega_{\rm K}$ curvature

Ω_b baryons

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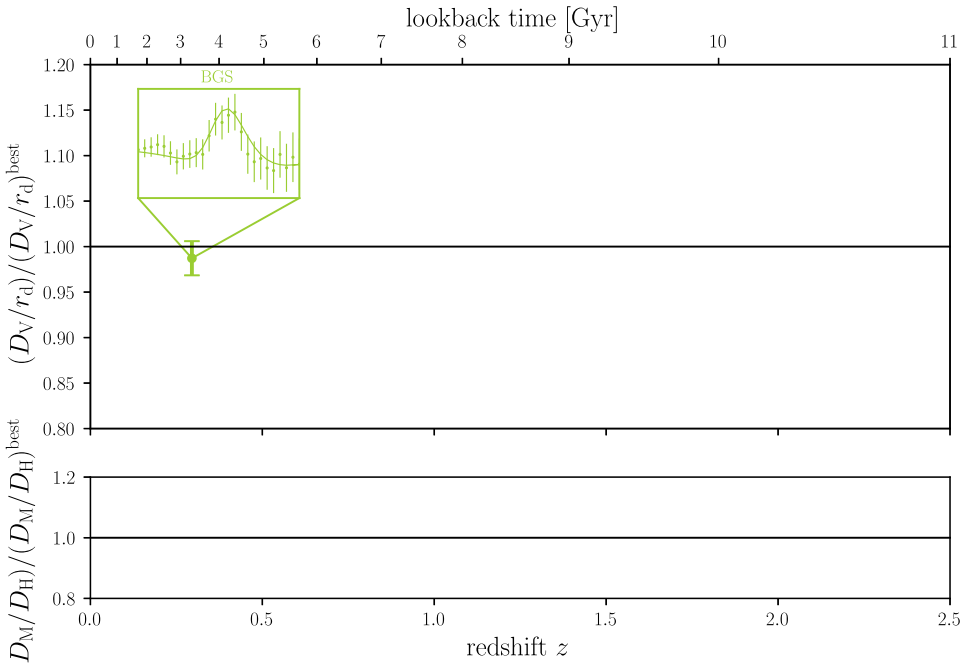
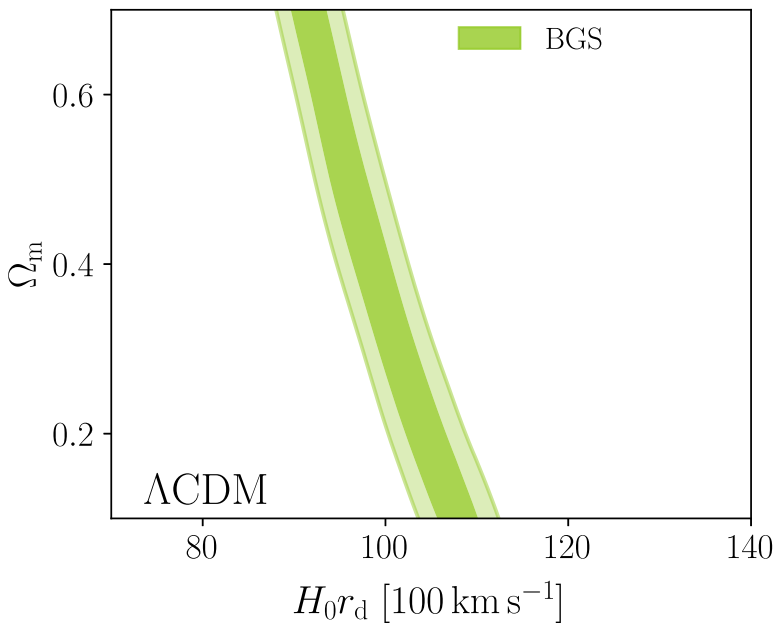
DESI Y1 BAO

DESI BAO measurements





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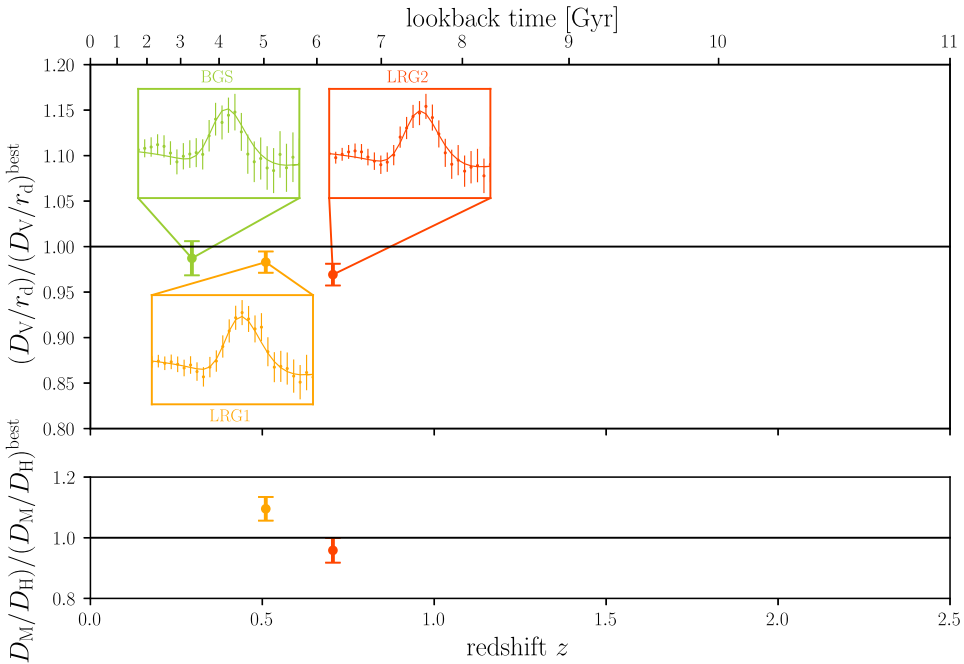
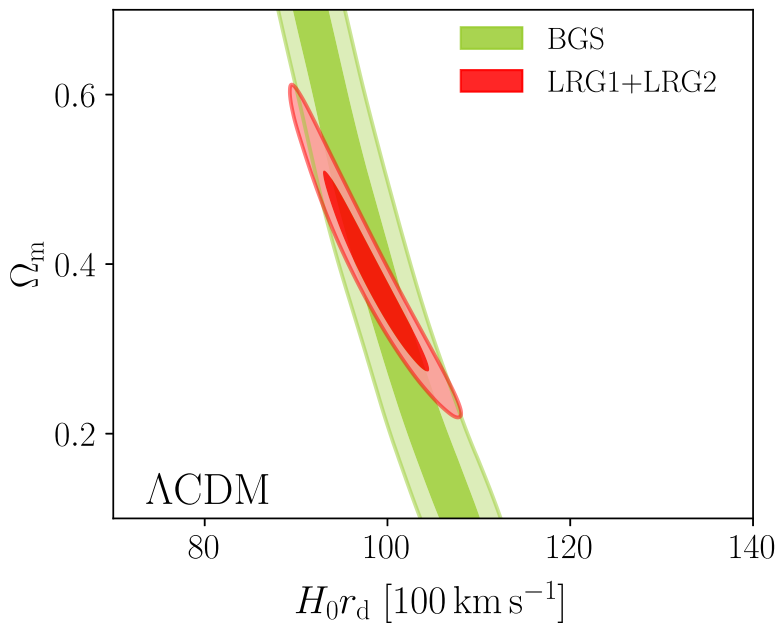
DESI Y1 BAO

DESI BAO measurements





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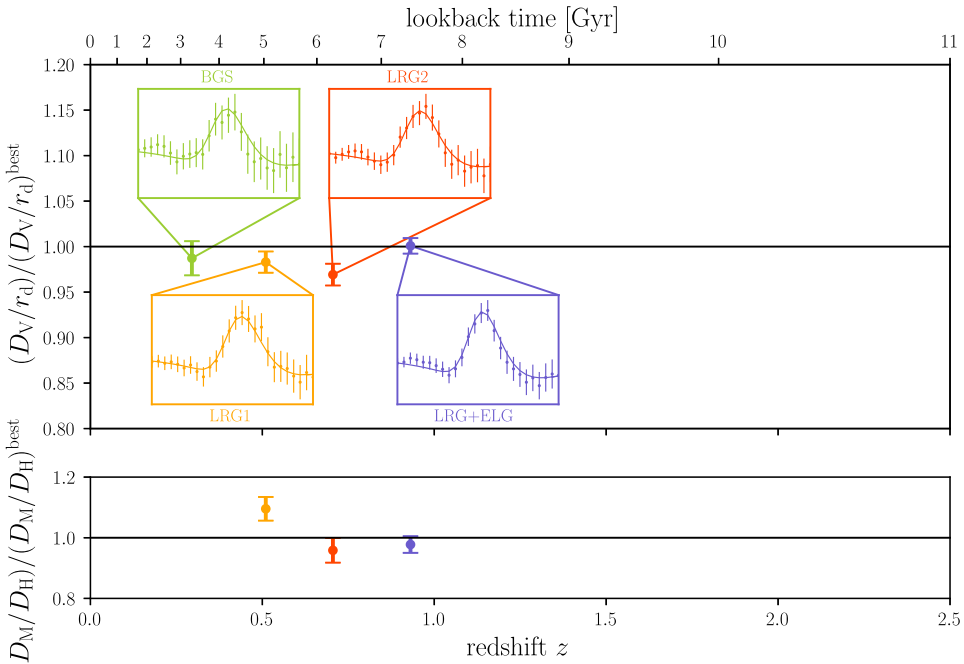

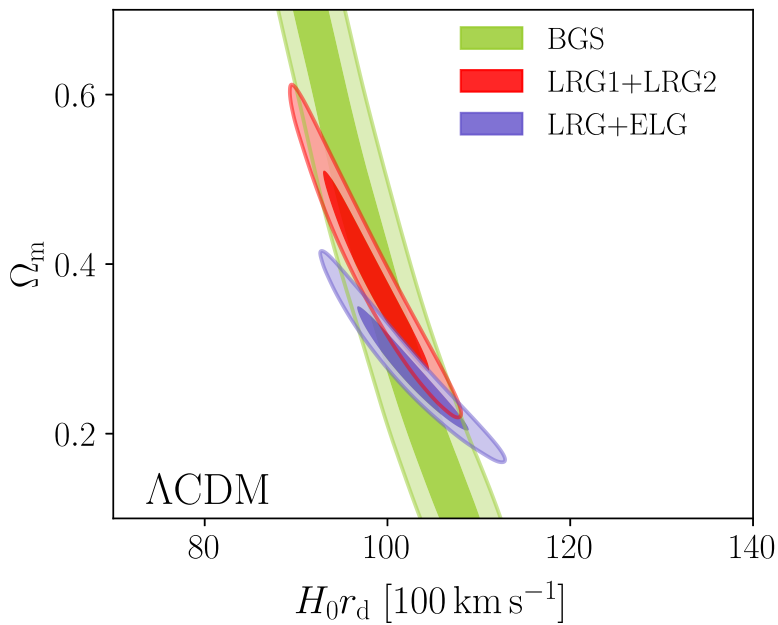

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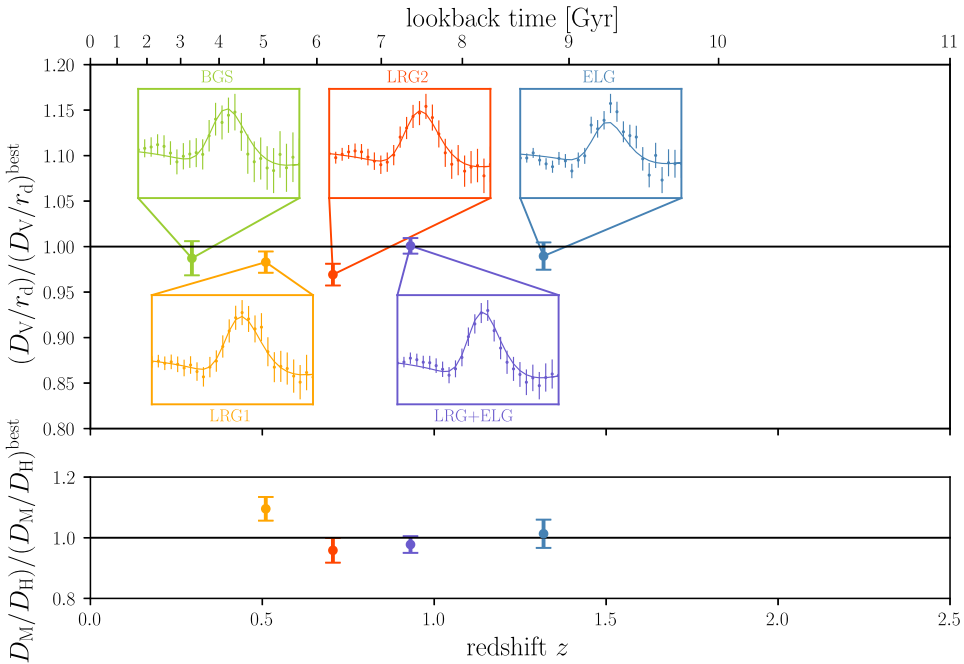
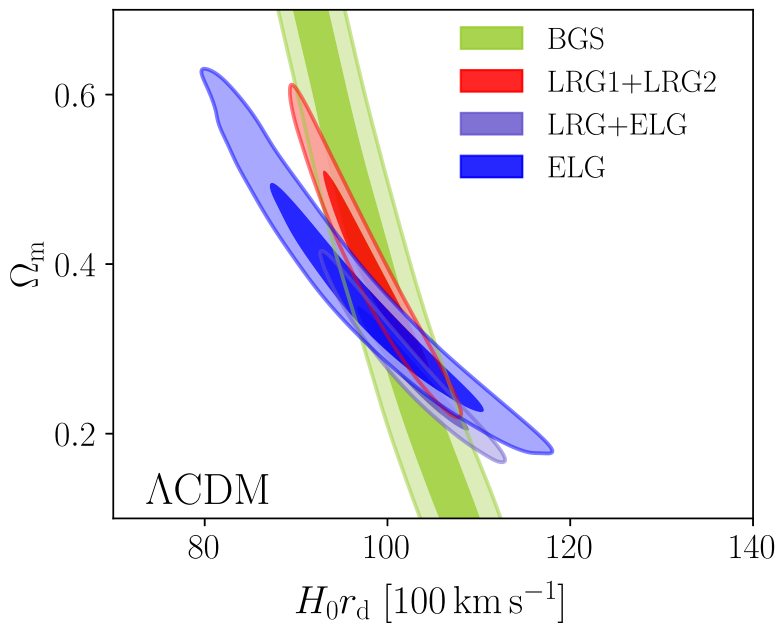
DESI BAO measurements



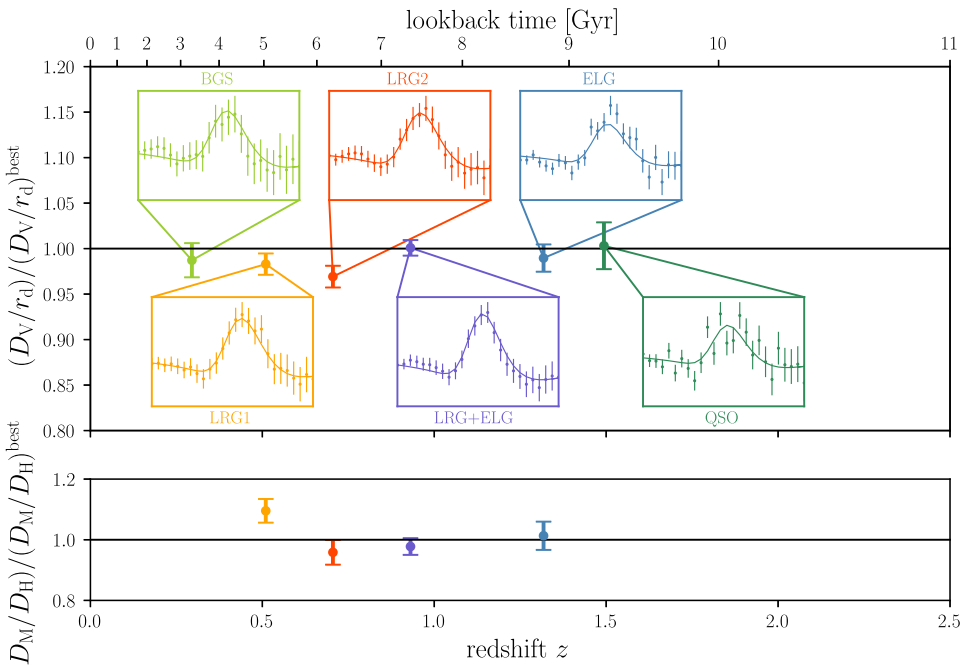


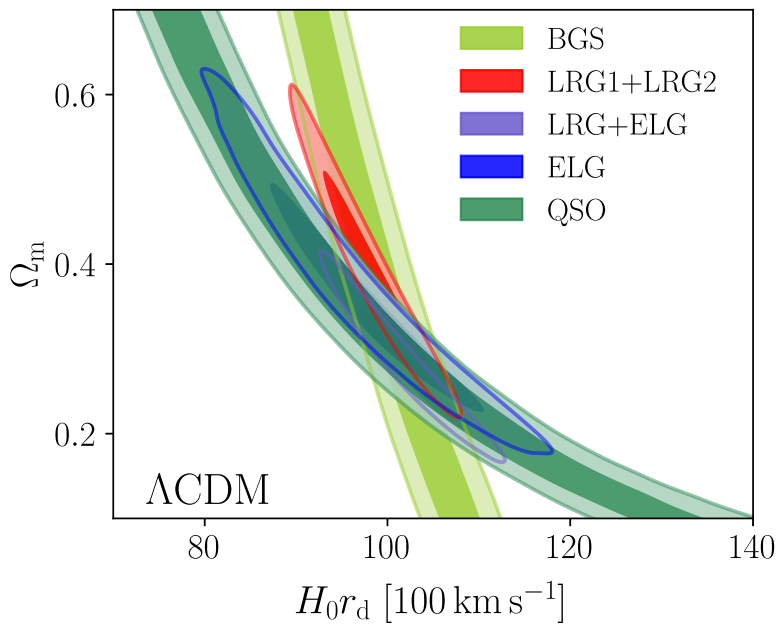
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI Y1 BAO

DESI BAO measurements



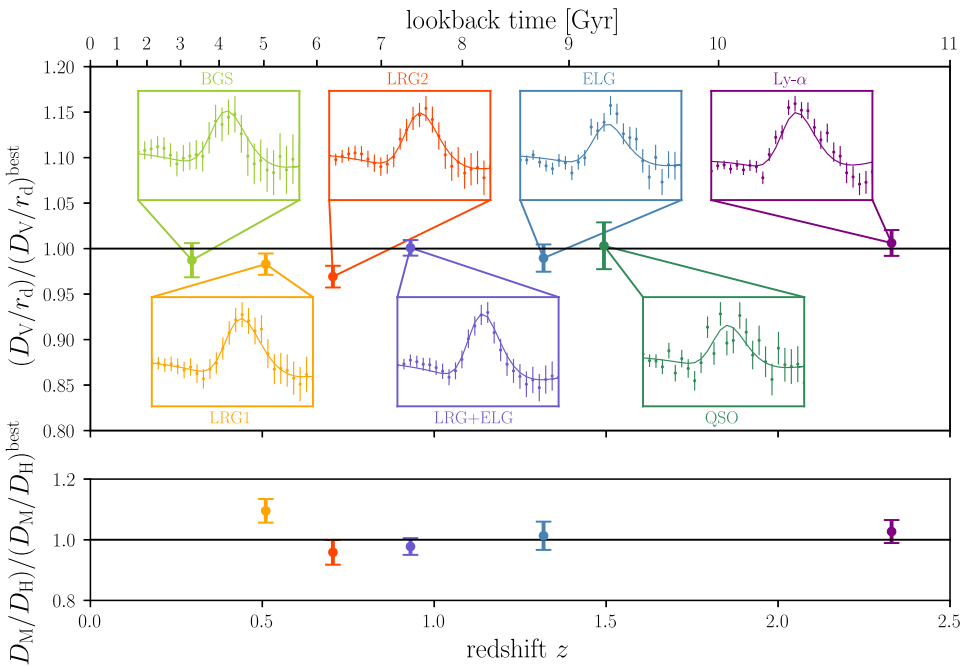


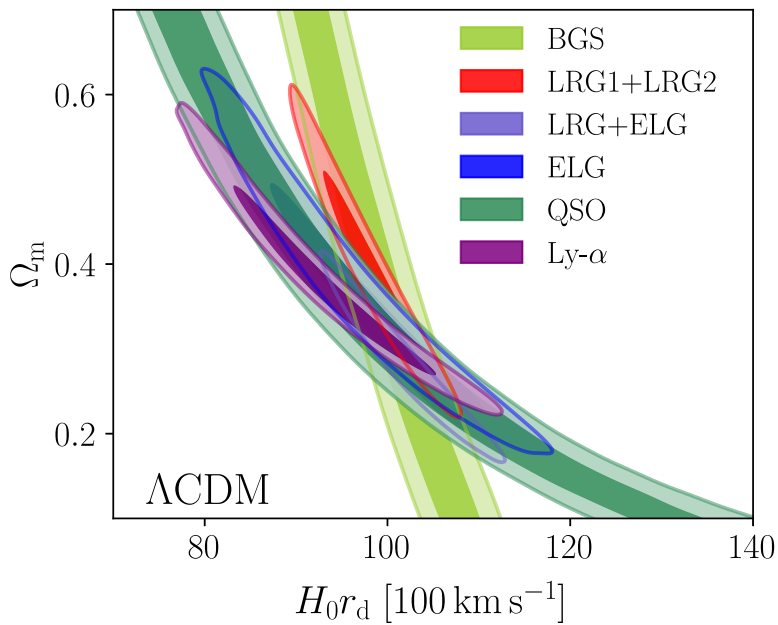
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI Y1 BAO

DESI BAO measurements





DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI Y1 BAO

DESI BAO measurements

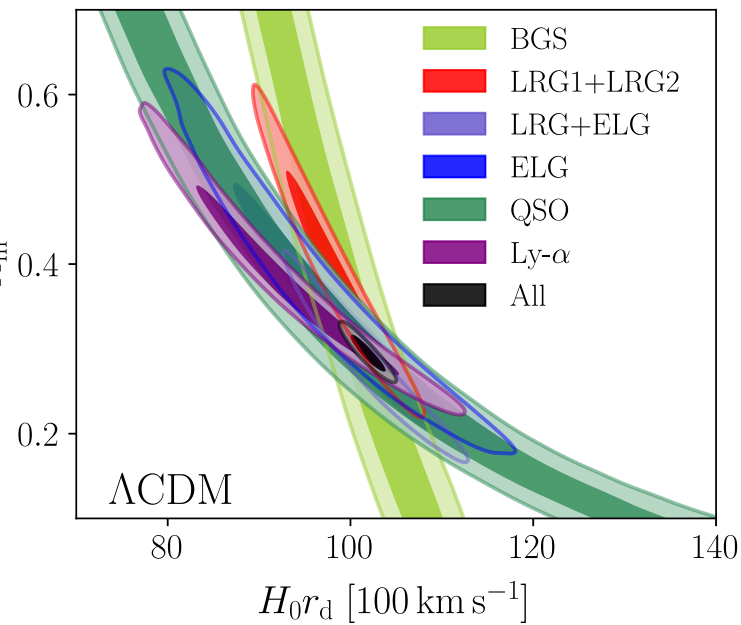
Consistent with each other,

and complementary

$$\Omega_{\rm m} = 0.295 \pm 0.015 \quad (\mathbf{5.1\%})$$

$$H_0 r_{\rm d} = (101.8 \pm 1.3)\,[100\,{\rm km\,s^{-1}}] \quad (\mathbf{1.3\%})$$

$$\underbrace{\qquad\qquad}_{\rm DESI}$$

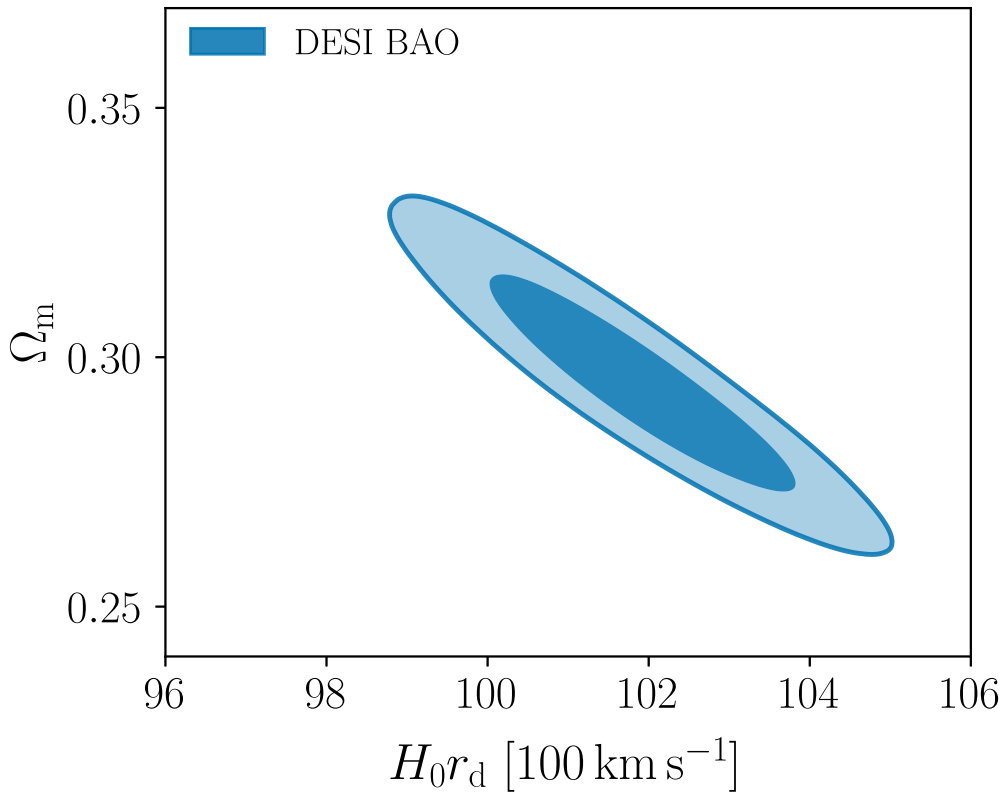


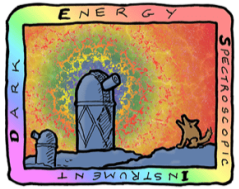
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Consistency with other probes

DESI Y1 BAO consistent with:





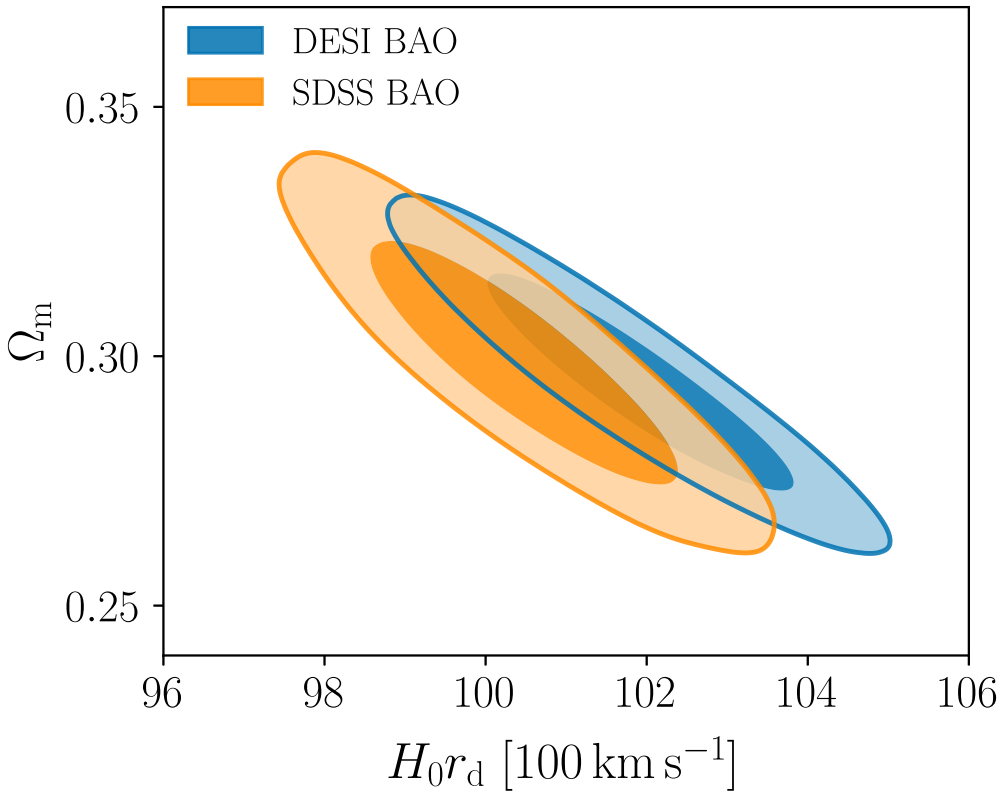
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Consistency with other probes

DESI Y1 BAO consistent with:

- SDSS eBOSS Collaboration, 2020



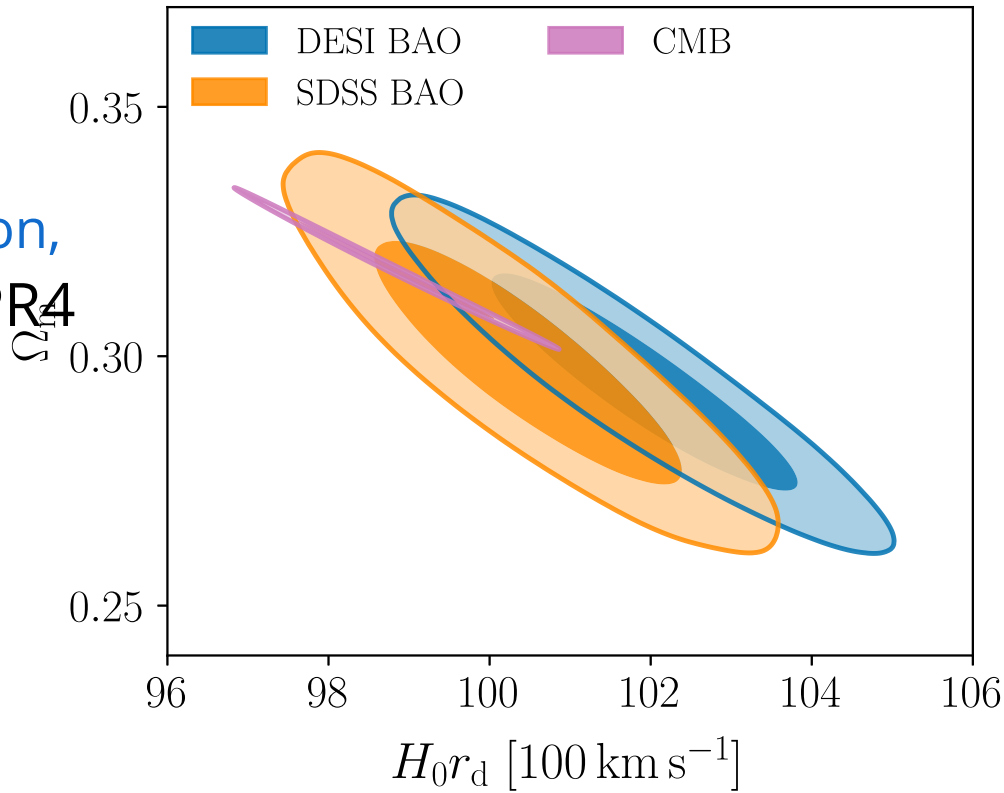
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Consistency with other probes

DESI Y1 BAO consistent with:

- SDSS eBOSS Collaboration, 2020
- primary CMB: Planck Collaboration, 2018 and CMB lensing: Planck PR4 + ACT DR6 lensing ACT Collaboration, 2023, Carron, Mirmelstein, Lewis, 2022



DARK ENERGY SPECTROSCOPIC INSTRUMENT

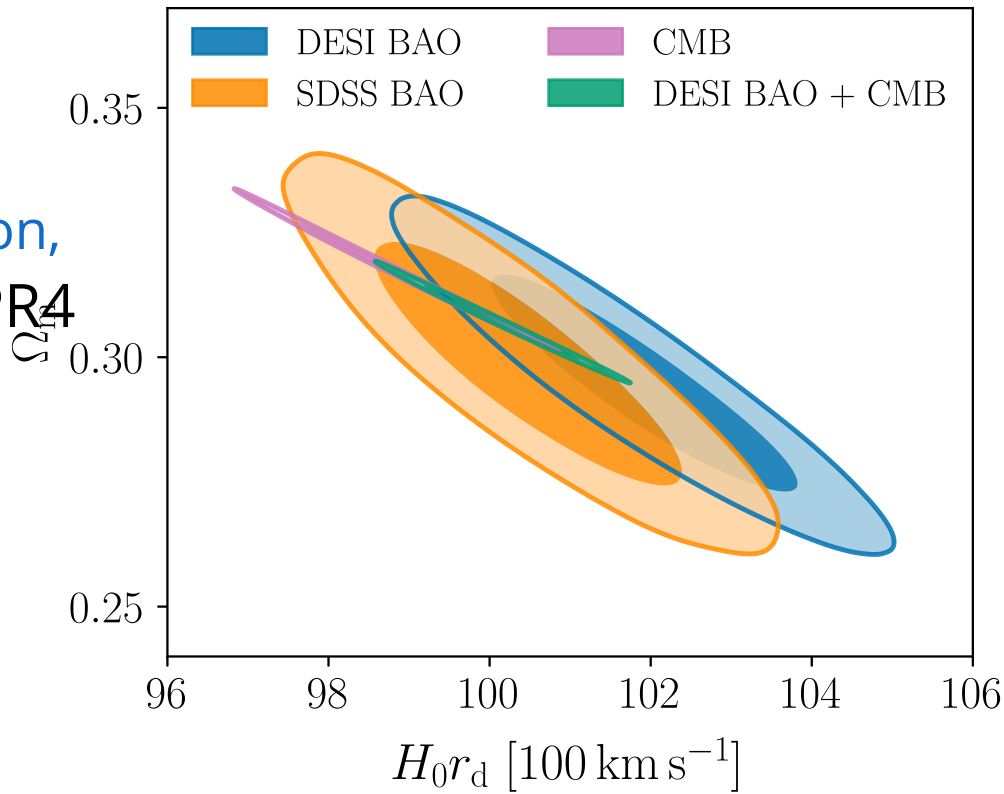
U.S. Department of Energy Office of Science

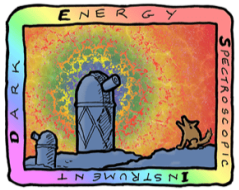
Consistency with other probes

DESI Y1 BAO consistent with:

- SDSS eBOSS Collaboration, 2020
- primary CMB: Planck Collaboration, 2018 and CMB lensing: Planck PR4 + ACT DR6 lensing ACT Collaboration, 2023, Carron, Mirmelstein, Lewis, 2022

$$\underbrace{\Omega_{\rm m} = 0.3069 \pm 0.0050\ (\mathbf{1.6\%})}_{\text{DESI + CMB}}$$





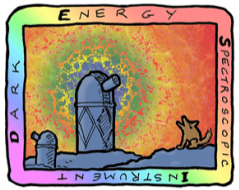
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Hubble constant

- BAO constrains $r_{\mathrm{d}}(\Omega_{\mathrm{m}}h^2, \Omega_{\mathrm{b}}h^2)h$
- Ω_{m} constrained by BAO at different z
- $\Omega_{\mathrm{b}}h^2$ can be constrained by light element abundance from Big Bang Nucleosynthesis (BBN): Schöneberg et al., 2024

$\Longrightarrow$ constraints on h i.e. $H_0 = 100h\ \mathrm{km/s/Mpc}$



DARK ENERGY SPECTROSCOPIC INSTRUMENT

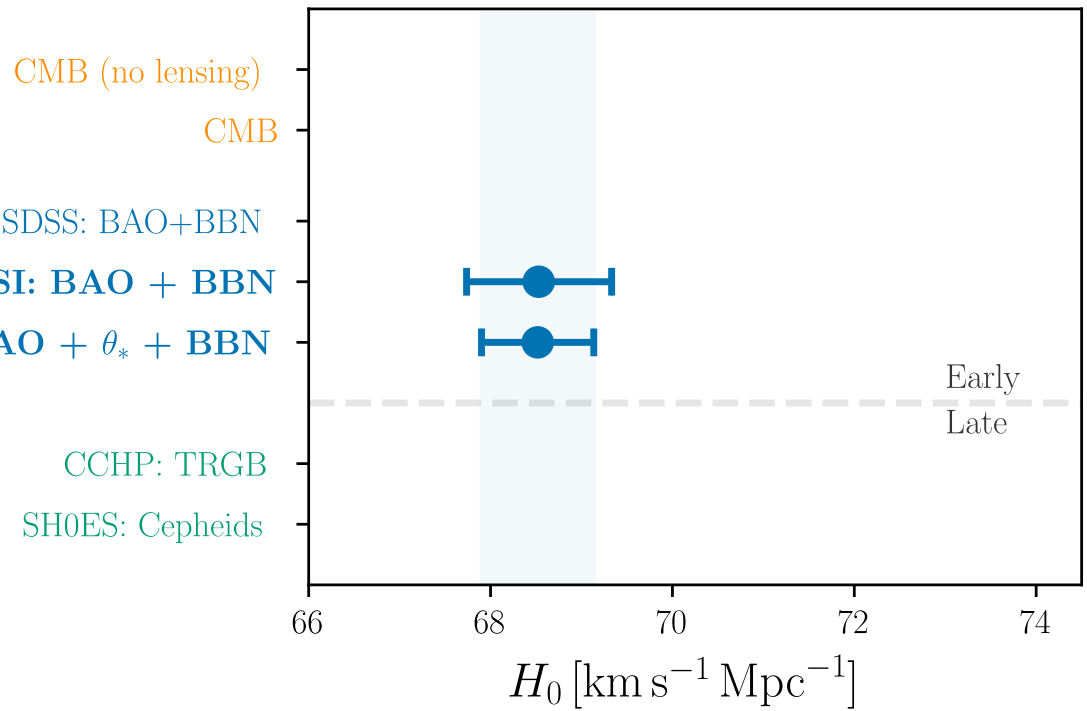
U.S. Department of Energy Office of Science

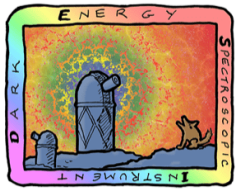
Hubble constant

$$\underbrace{H_0 = (68.53 \pm 0.80)\,\mathrm{km\,s^{-1}\,Mpc^{-1}}}_{\mathrm{DESI + BBN}}$$

$$\underbrace{H_0 = (68.52 \pm 0.62)\,\mathrm{km\,s^{-1}\,Mpc^{-1}}}_{\mathrm{DESI + \theta_* + BBN}}$$

θ_* CMB angular acoustic scale





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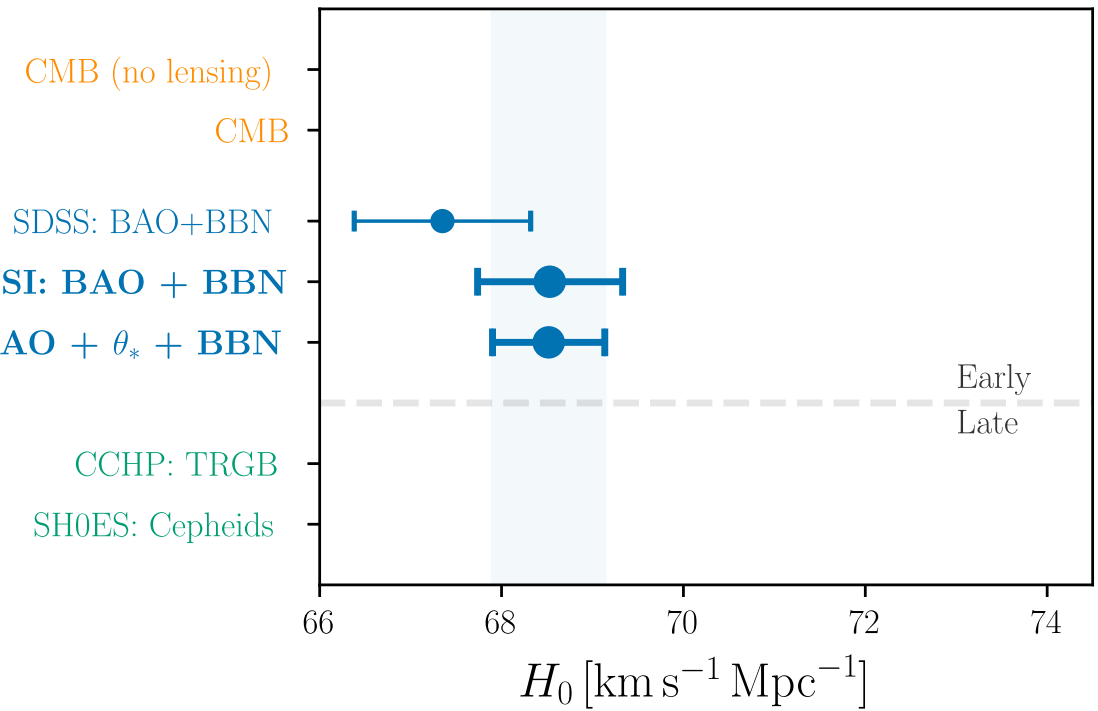
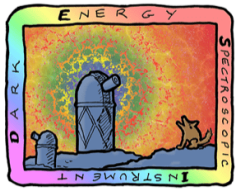
$$\underbrace{H_0 = (68.52 \pm 0.62)\,\mathrm{km\,s^{-1}\,Mpc^{-1}}}_{\mathrm{DESI + \theta_* + BBN}}$$

- Consistency with SDSS





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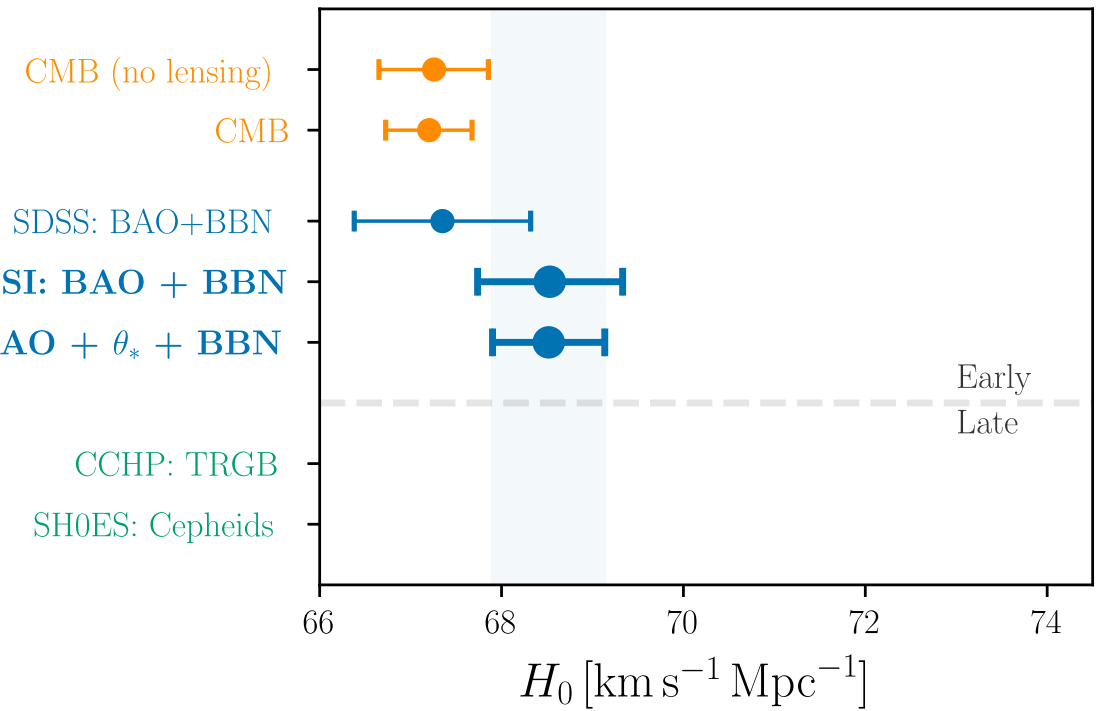
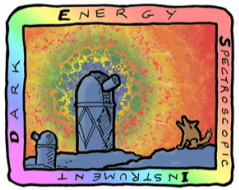
- Consistency with SDSS
- In agreement with CMB





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U.S. Department of Energy Office of Science

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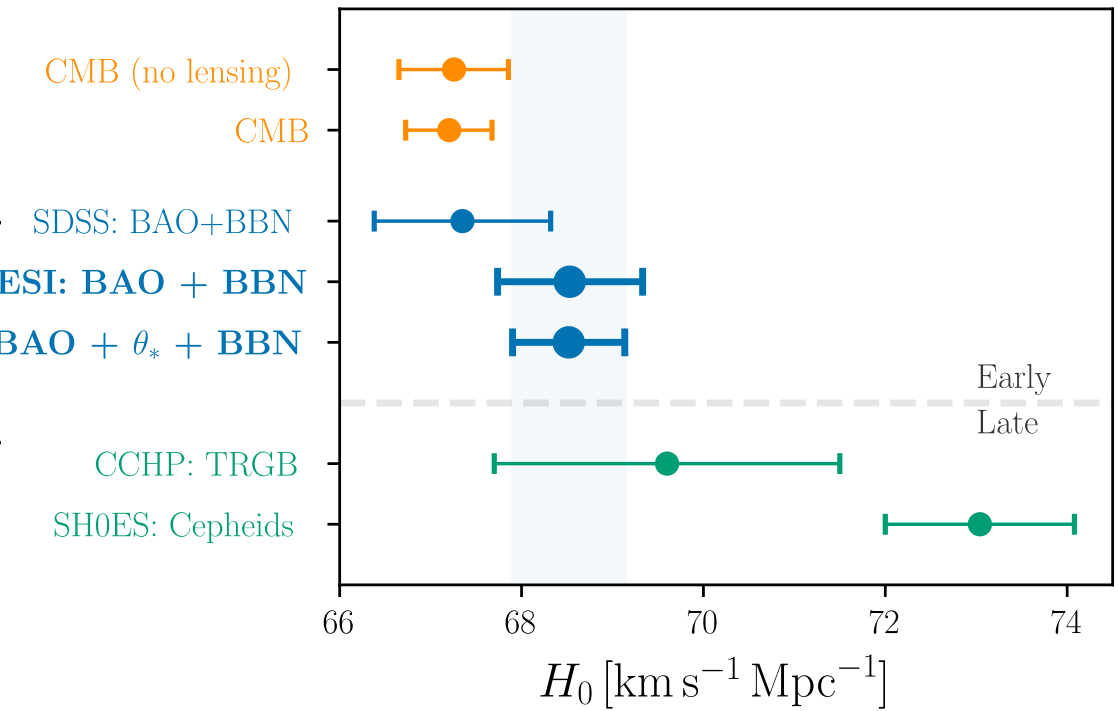
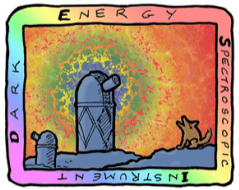
$$\underbrace{H_0 = (68.52 \pm 0.62)\,\mathrm{km\,s^{-1}\,Mpc^{-1}}}_{\mathrm{DESI + \theta_* + BBN}}$$

- Consistency with SDSS
- In agreement with CMB
- In 3.7σ tension with SH0ES





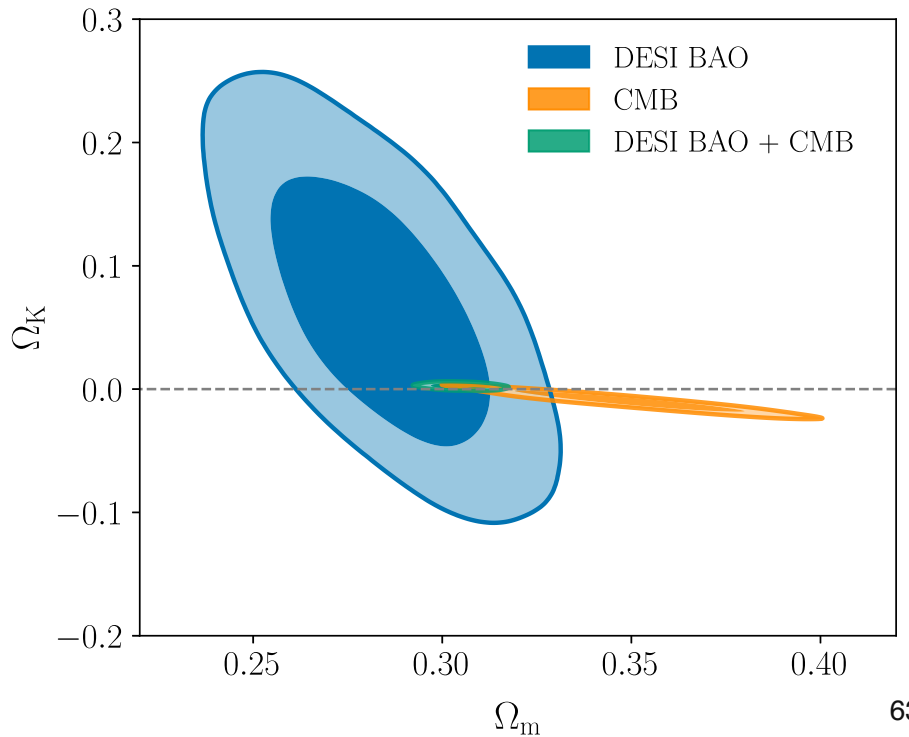
DARK ENERGY SPECTROSCOPIC INSTRUMENT

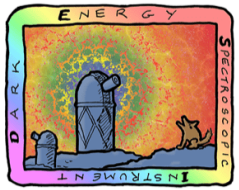
U.S. Department of Energy Office of Science

Spatial curvature

DESI + CMB measurements favor a flat Universe

$$\Omega_K = 0.0024 \pm 0.0016 \ (\mathrm{DESI + CMB})$$





DARK ENERGY SPECTROSCOPIC INSTRUMENT

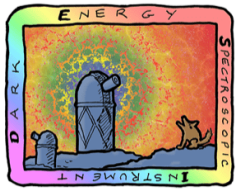
U.S. Department of Energy Office of Science

Dark Energy Equation of State

Dark Energy fluid, pressure p, density ρ

Equation of State parameter $w = p/\rho$

Linked to the evolution of Dark Energy $w(z) = -1 + \frac{1}{3}\frac{d\ln f_{\rm DE}(z)}{d\ln(1+z)}$



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

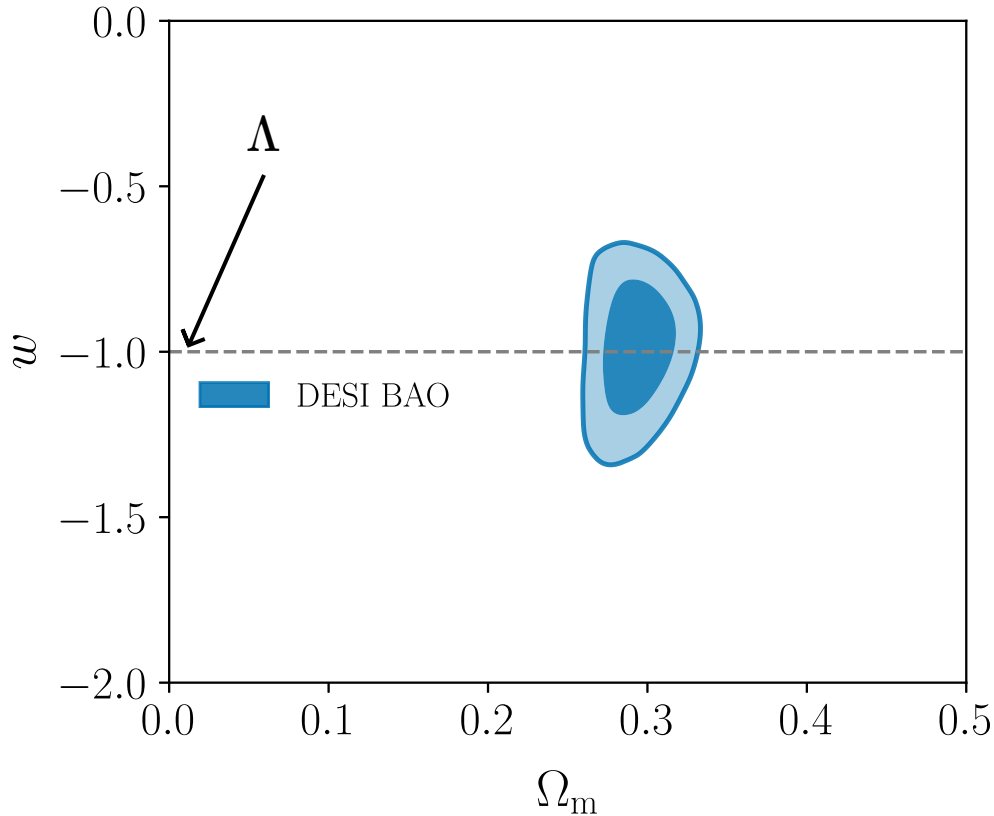
Dark Energy Equation of State

Constant EoS parameter $w = p/\rho$

$$\Omega_{\rm m} = 0.293 \pm 0.015 \quad (\mathbf{5.1\%})$$

$$w = -0.99^{+0.15}_{-0.13} \quad (\mathbf{15\%})$$

DESI



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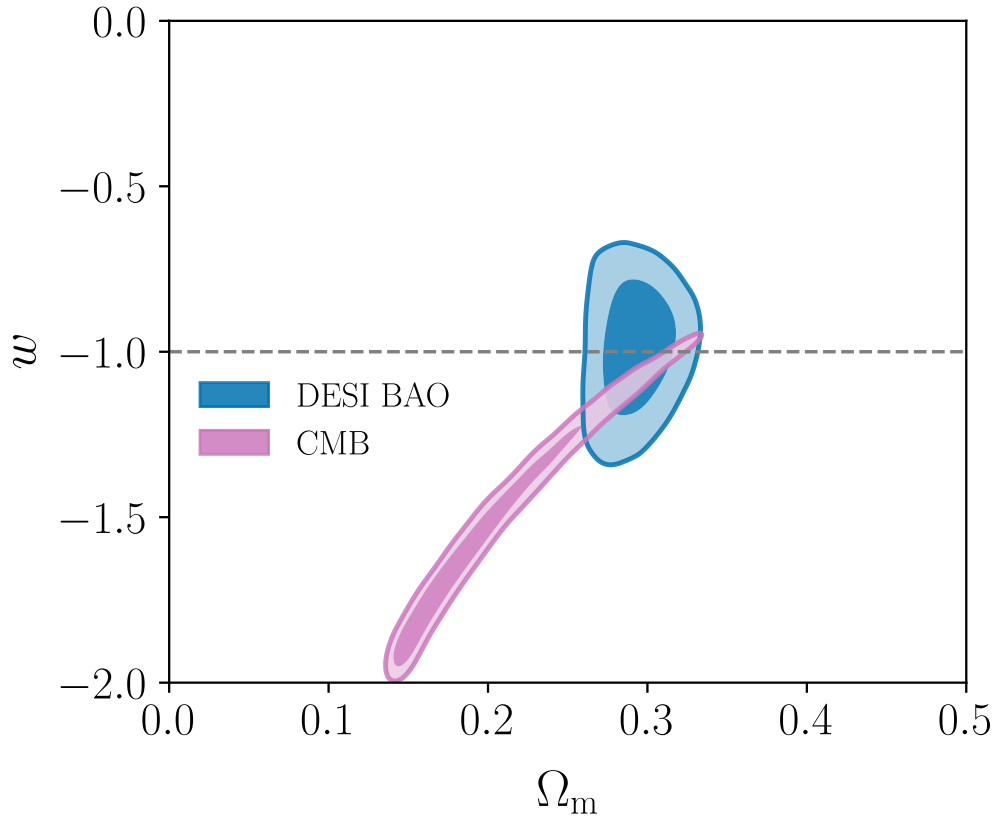

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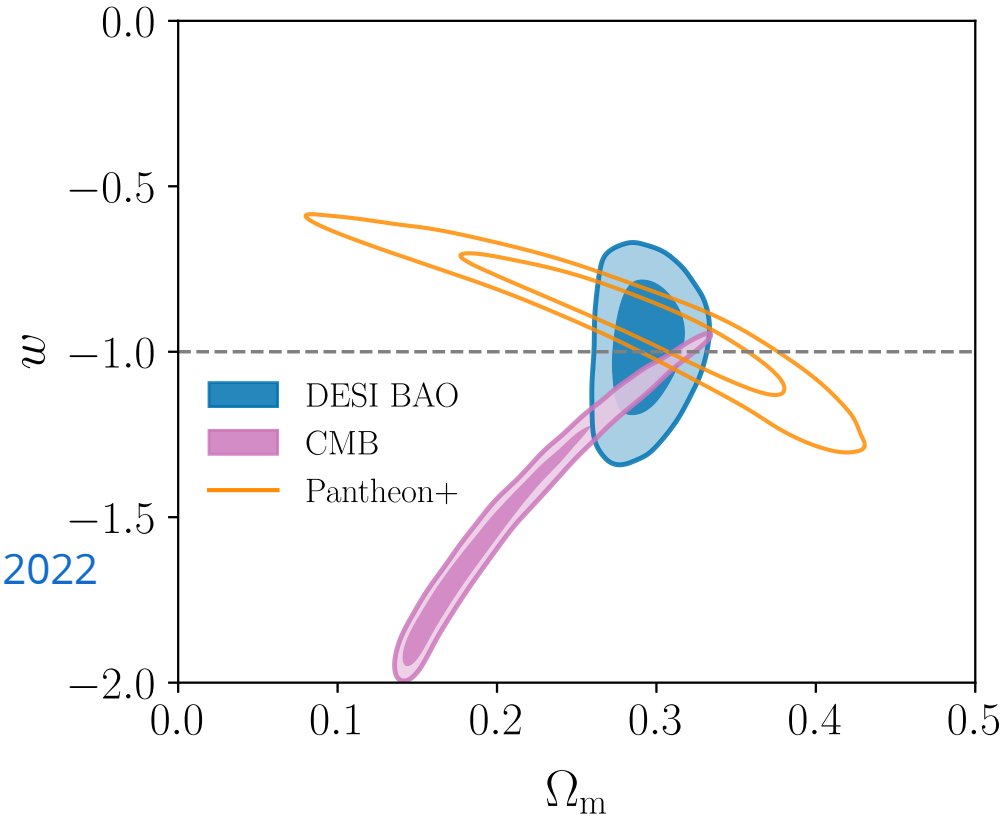
$$w = -0.99^{+0.15}_{-0.13} \quad (\mathbf{15\%})$$

DESI

SNe (uncalibrated):

- Pantheon+ Brout, Scolnic, Popovic et al., 2022



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

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DESI

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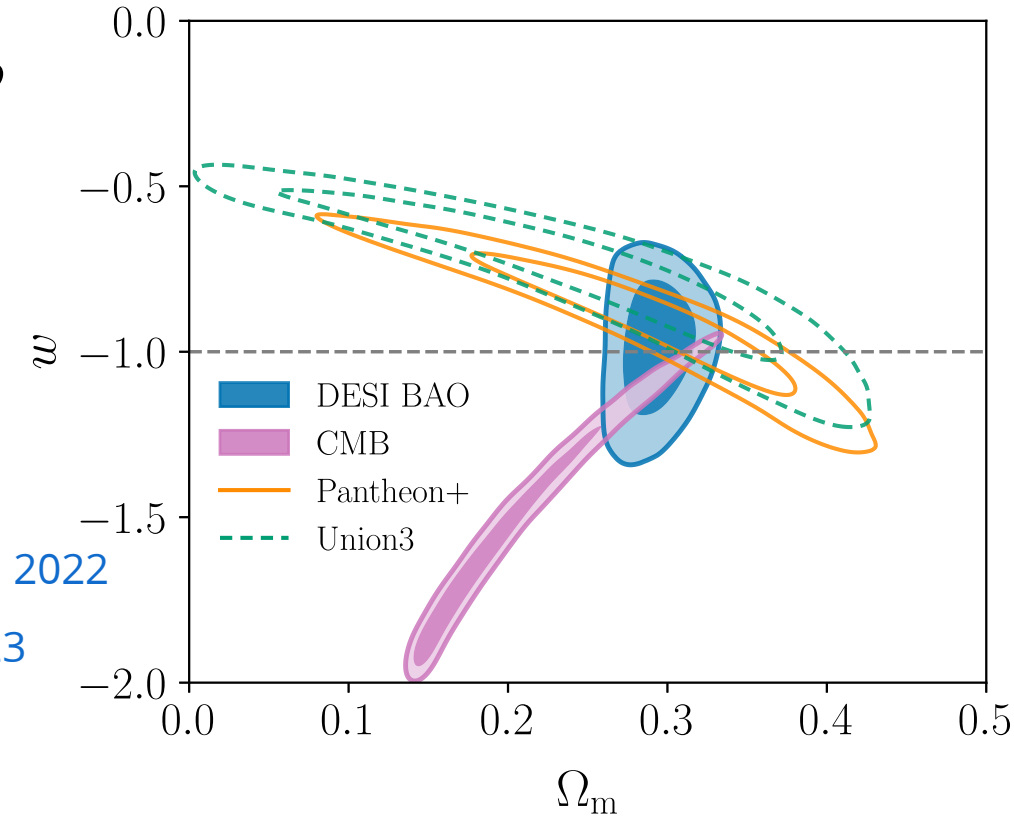
- Pantheon+ Brout, Scolnic, Popovic et al., 2022
- Union3 Rubin, Aldering, Betoule et al. 2023



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U.S. Department of Energy Office of Science

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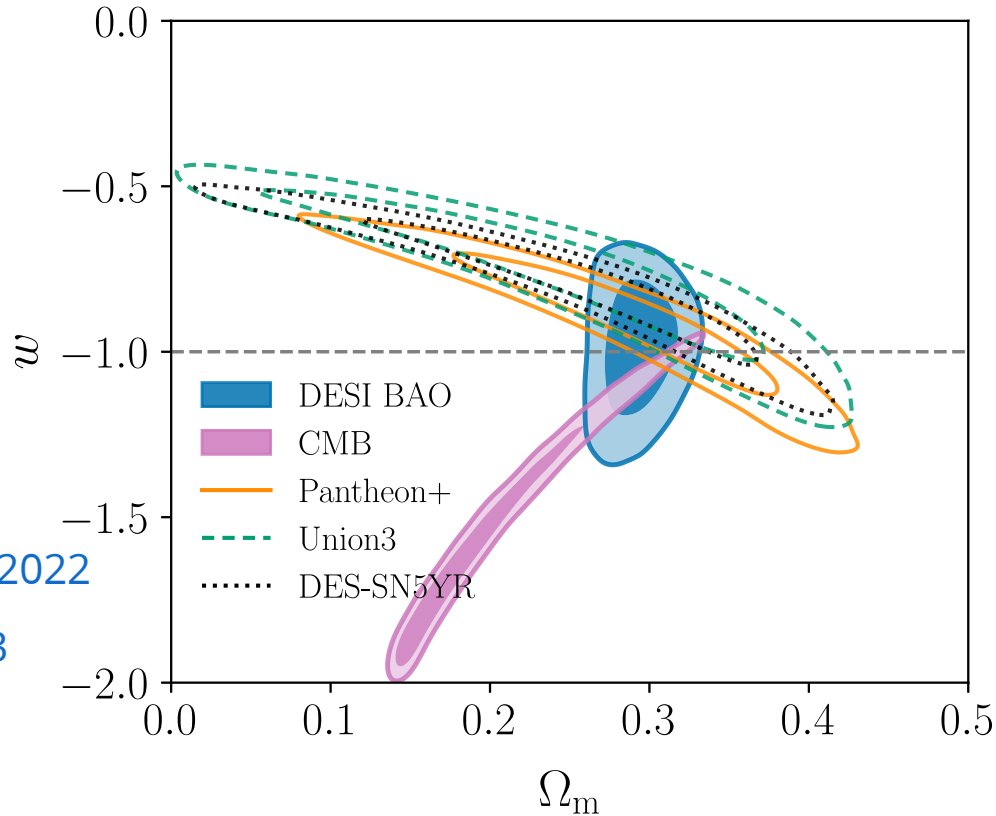
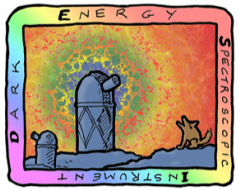
- Union3 Rubin, Aldering, Betoule et al. 2023
- DES-SN5YR DES Collaboration et al. 2024





DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Dark Energy Equation of State

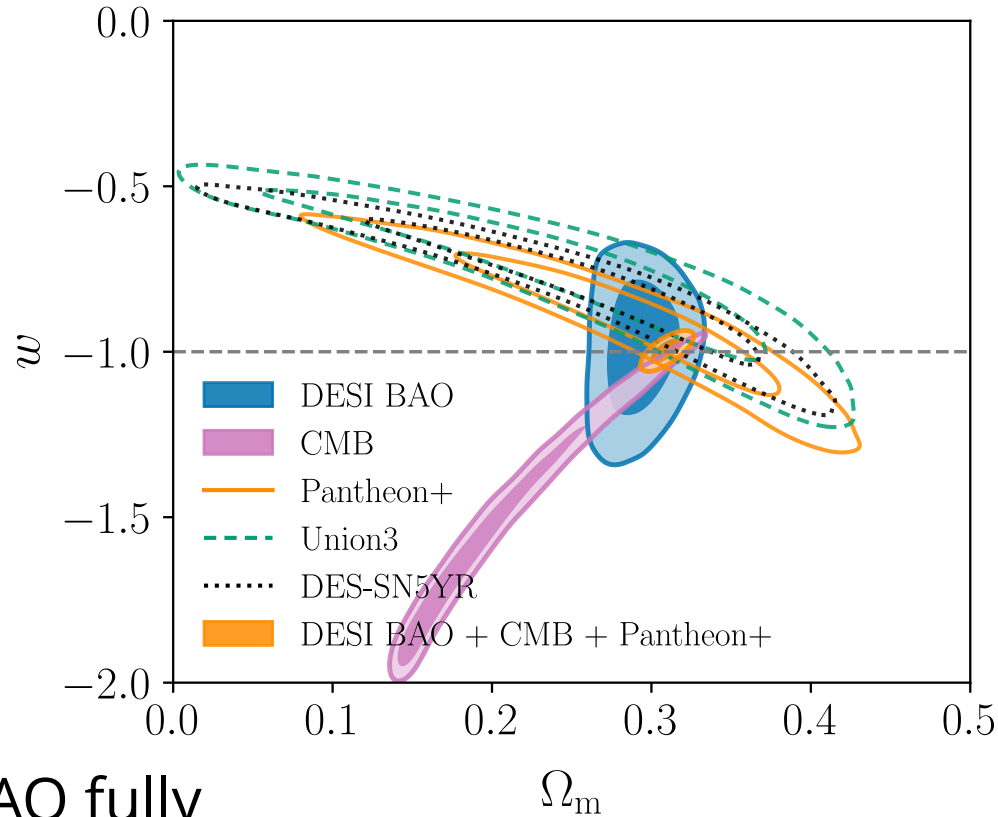
Constant EoS parameter $w = p/\rho$

$$\Omega_{\rm m} = 0.293 \pm 0.015 \quad (\mathbf{5.1\%})$$
$$w = -0.99^{+0.15}_{-0.13} \quad (\mathbf{15\%})$$

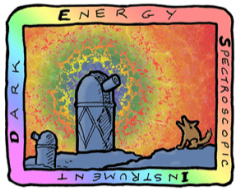
DESI

$$\Omega_{\rm m} = 0.3095 \pm 0.0065 \quad (\mathbf{2.1\%})$$
$$w = -0.997 \pm 0.025 \quad (\mathbf{2.5\%})$$

DESI + CMB + Pantheon+



Assuming a **constant** EoS, DESI BAO fully compatible with a cosmological constant...



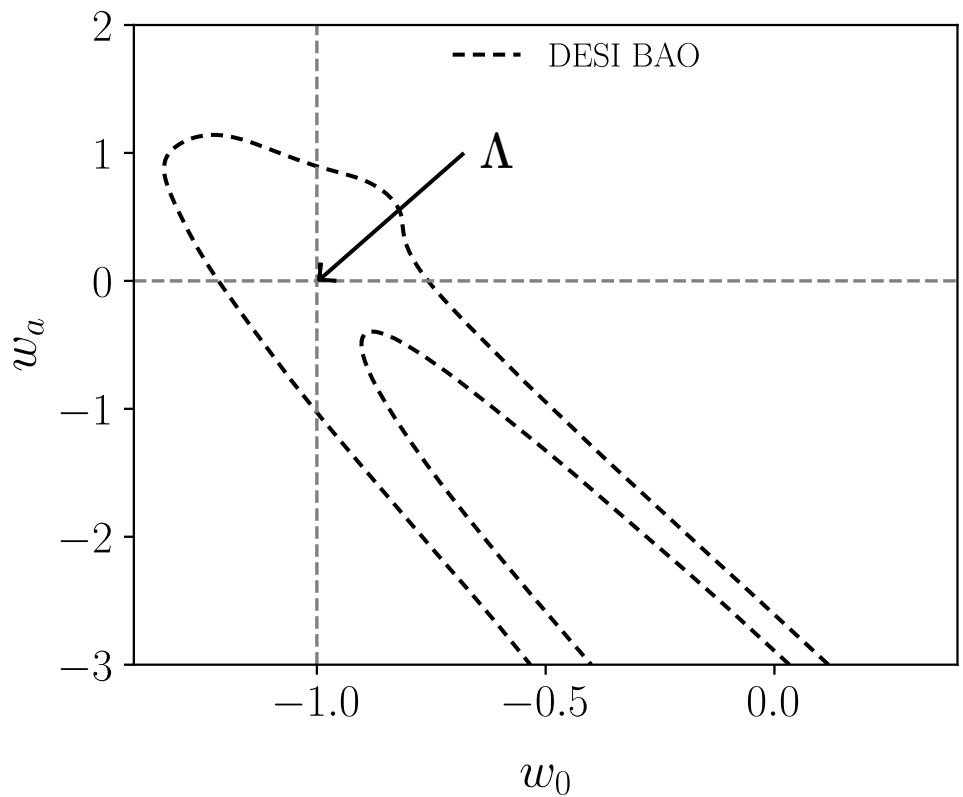
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Dark Energy Equation of State

Varying EoS

$$w(z) = w_0 + \frac{z}{1+z} w_a \qquad \text{(CPL)}$$



DARK ENERGY SPECTROSCOPIC INSTRUMENT

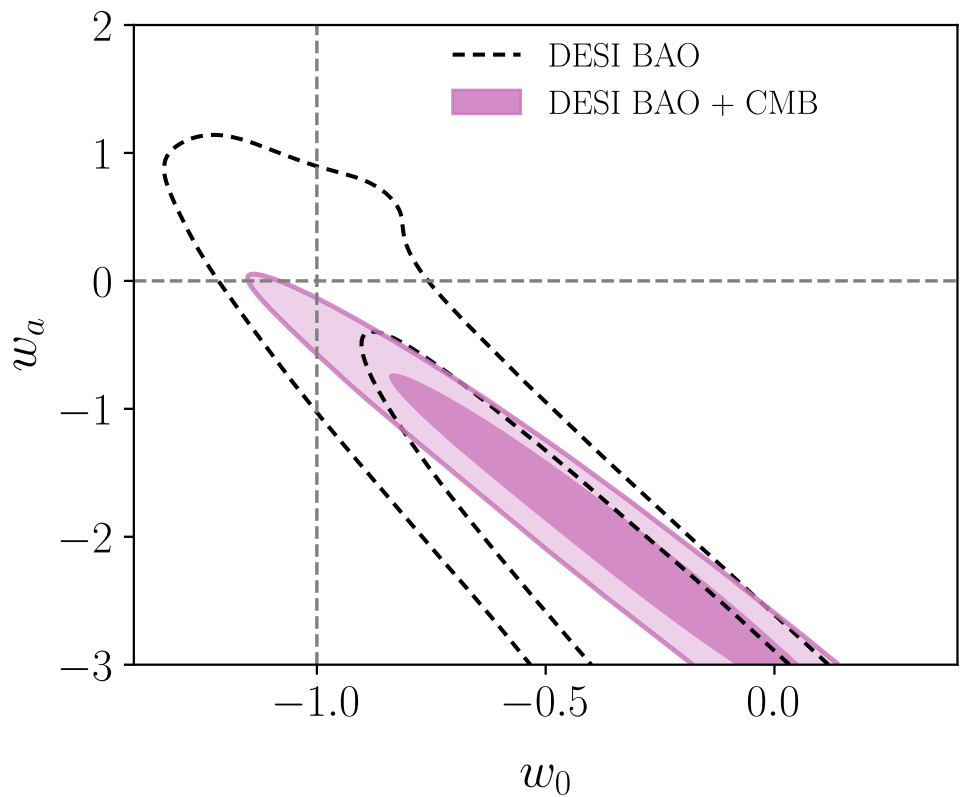
U.S. Department of Energy Office of Science

Dark Energy Equation of State

Varying EoS

$$w(z) = w_0 + \frac{z}{1+z} w_a \qquad \text{(CPL)}$$

$$\underbrace{w_0 = -0.45^{+0.34}_{-0.21} \qquad w_a = -1.79^{+0.48}_{-1.00}}_{\text{DESI + CMB} \implies 2.6\sigma}$$



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

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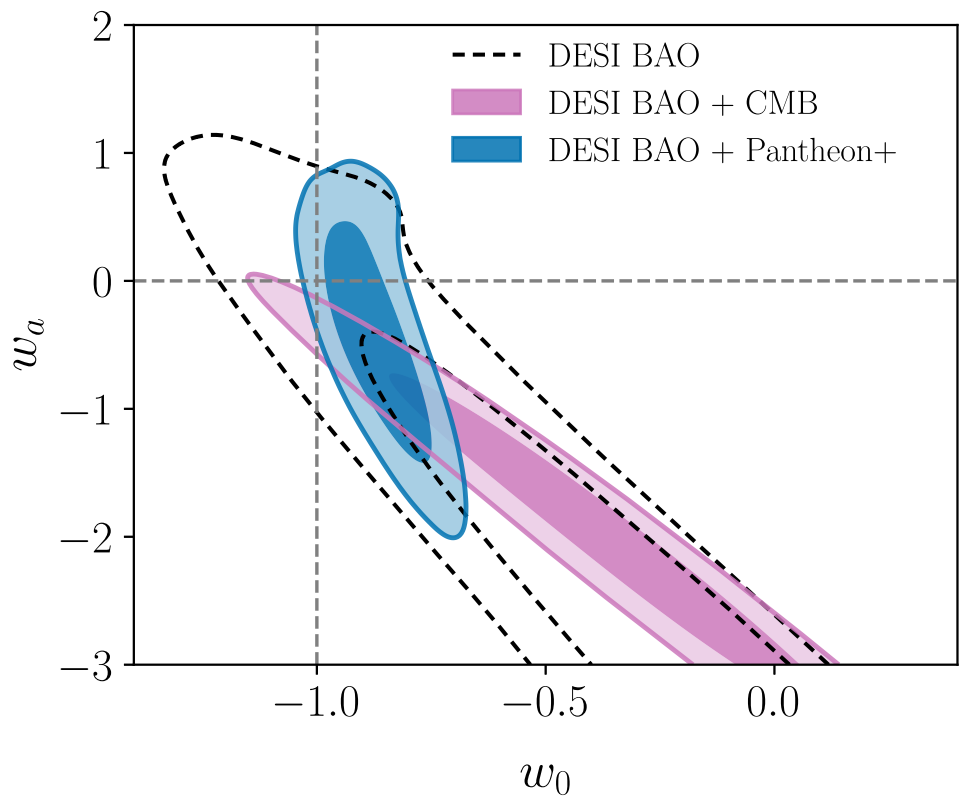

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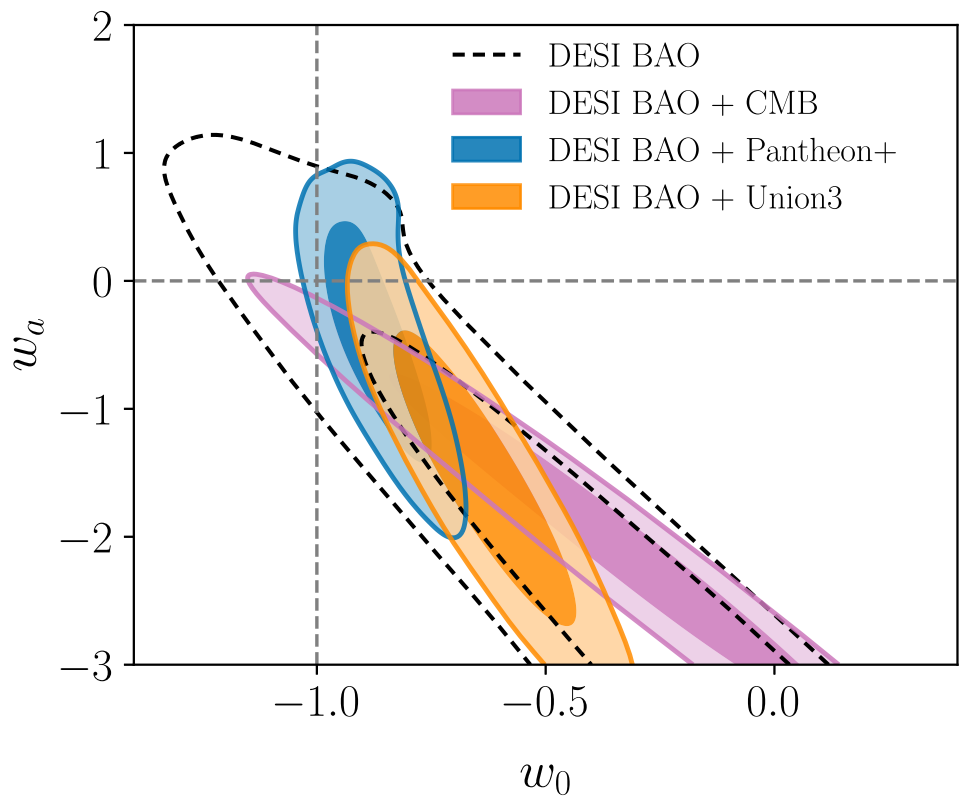

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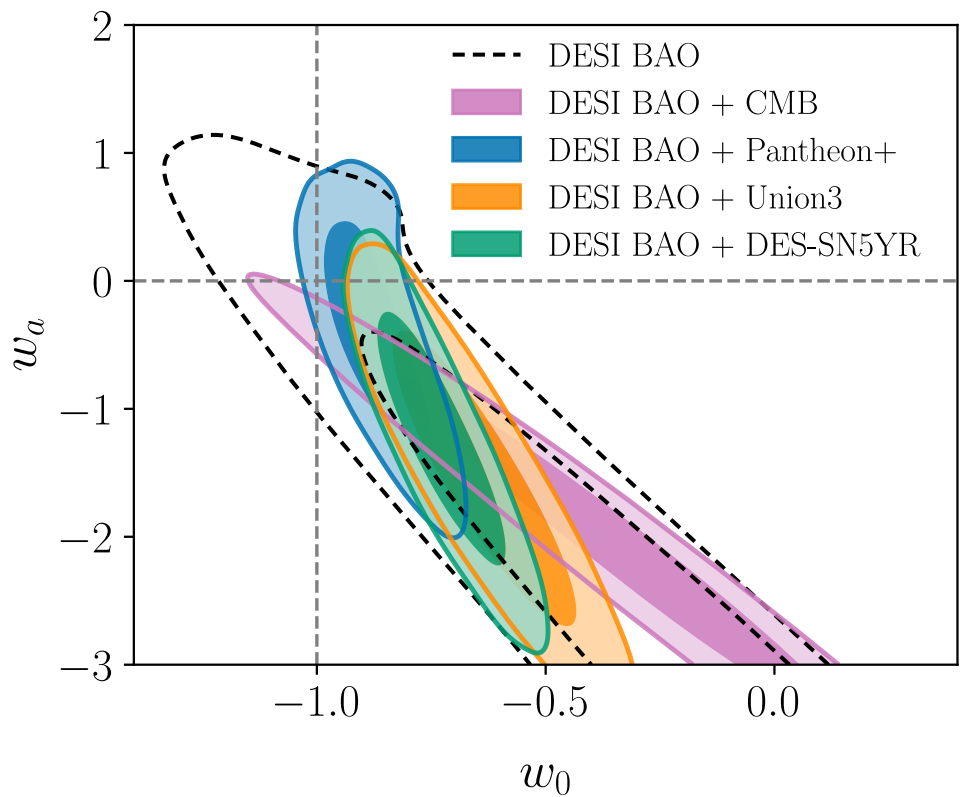


DARK ENERGY SPECTROSCOPIC INSTRUMENT

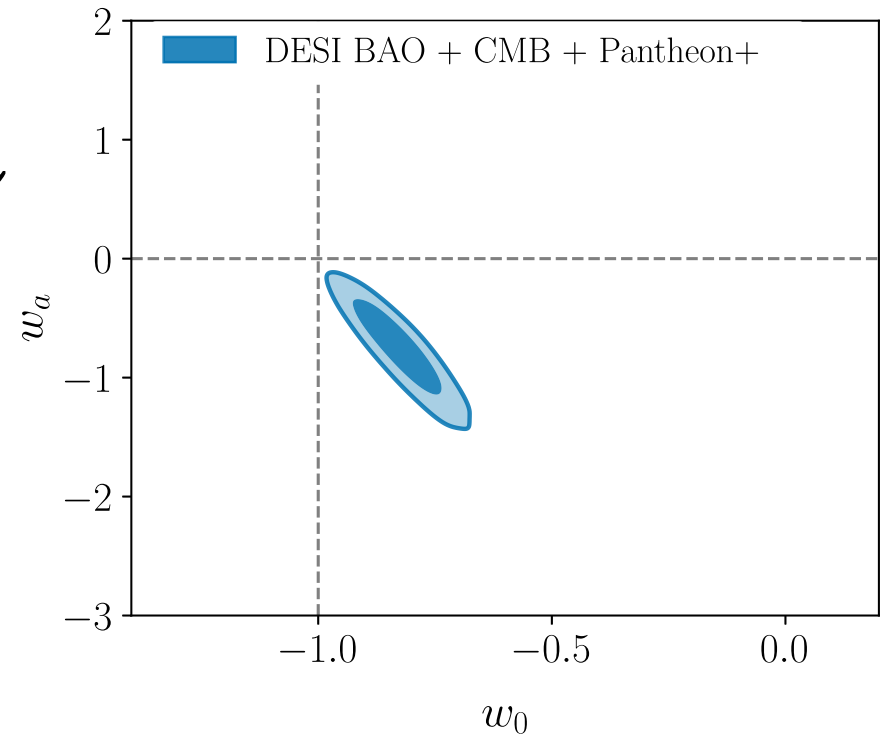
U.S. Department of Energy Office of Science

Dark Energy Equation of State

Combining all DESI + CMB + SN

$$w_0 = -0.827 \pm 0.063 \qquad w_a = -0.75^{+0.29}_{-0.25}$$

$$\text{DESI} + \text{CMB} + \text{Pantheon+} \implies 2.5\sigma$$



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U.S. Department of Energy Office of Science

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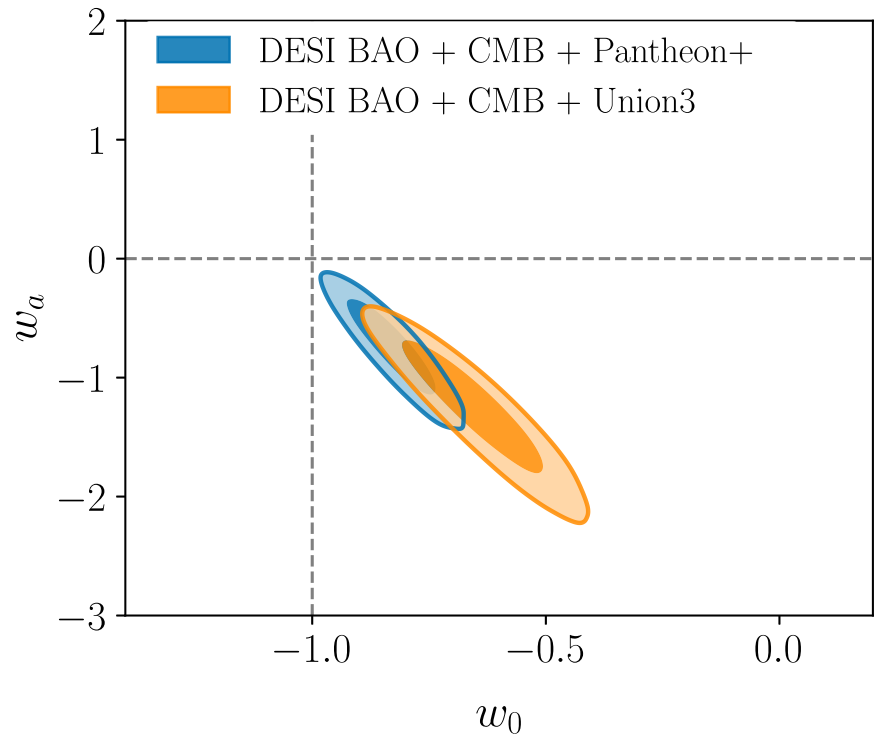
$$w_0 = -0.64 \pm 0.11 \qquad w_a = -1.27^{+0.40}_{-0.34}$$

$$\text{DESI} + \text{CMB} + \text{Union3} \implies 3.5\sigma$$



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Dark Energy Equation of State

Combining all DESI + CMB + SN

$$w_0 = -0.827 \pm 0.063 \qquad w_a = -0.75^{+0.29}_{-0.25}$$

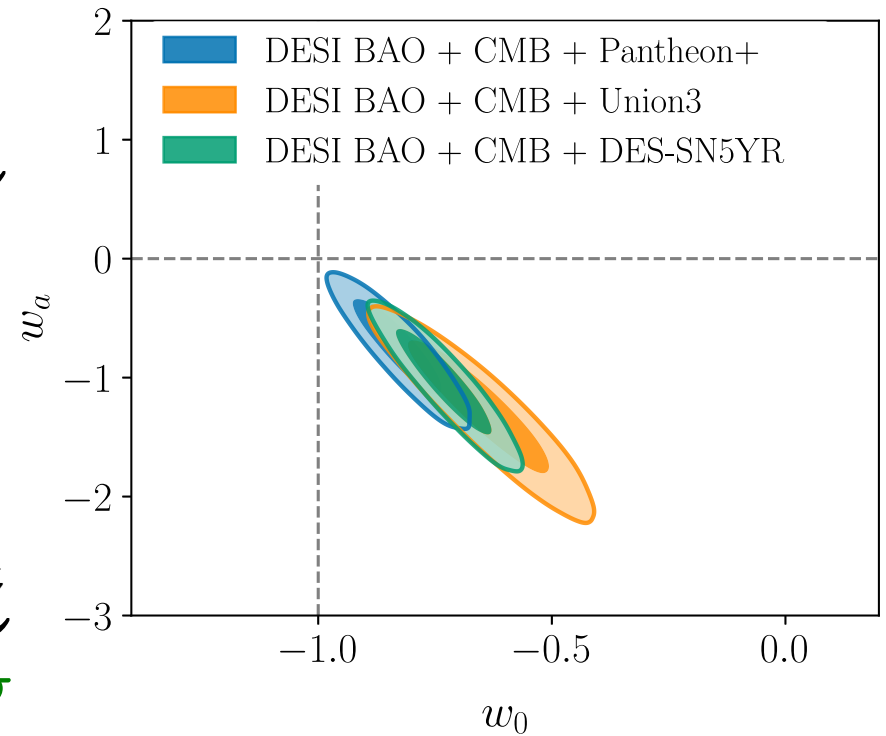
$$\text{DESI} + \text{CMB} + \text{Pantheon+} \implies 2.5\sigma$$

$$w_0 = -0.64 \pm 0.11 \qquad w_a = -1.27^{+0.40}_{-0.34}$$

$$\text{DESI} + \text{CMB} + \text{Union3} \implies 3.5\sigma$$

$$w_0 = -0.727 \pm 0.067 \qquad w_a = -1.05^{+0.31}_{-0.27}$$

$$\text{DESI} + \text{CMB} + \text{DES-SN5YR} \implies 3.9\sigma$$



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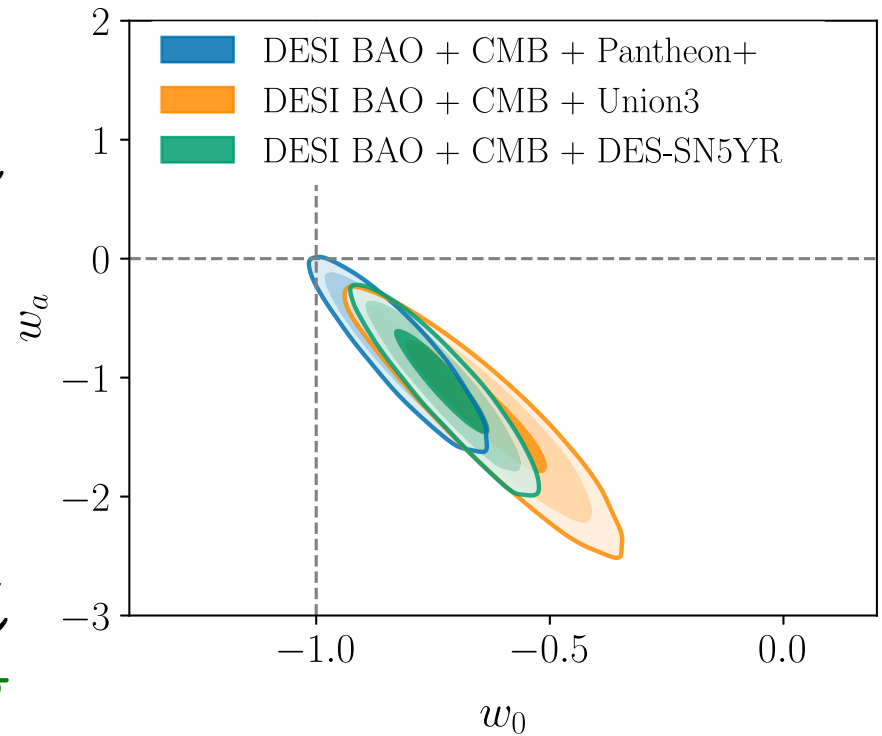

$w_0 > -1, w_a < 0$ favored, level varying on the SN dataset

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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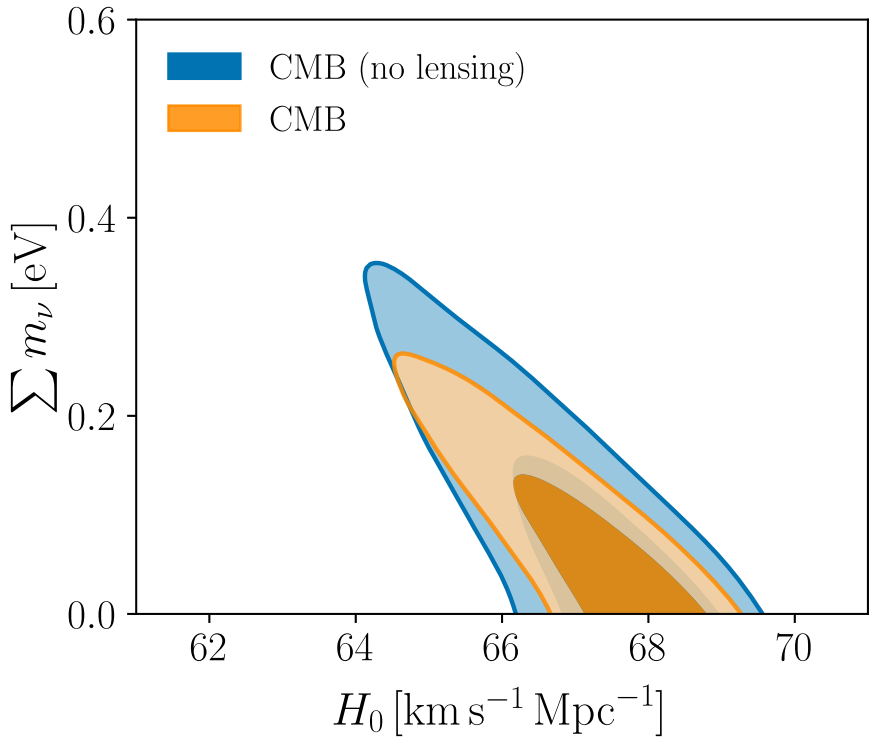
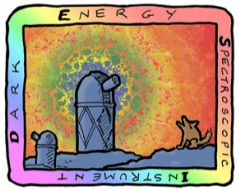
Sum of neutrino masses

Internal CMB degeneracies limiting precision on the sum of neutrino masses





DARK ENERGY SPECTROSCOPIC INSTRUMENT

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Sum of neutrino masses

Internal CMB degeneracies limiting precision on the sum of neutrino masses

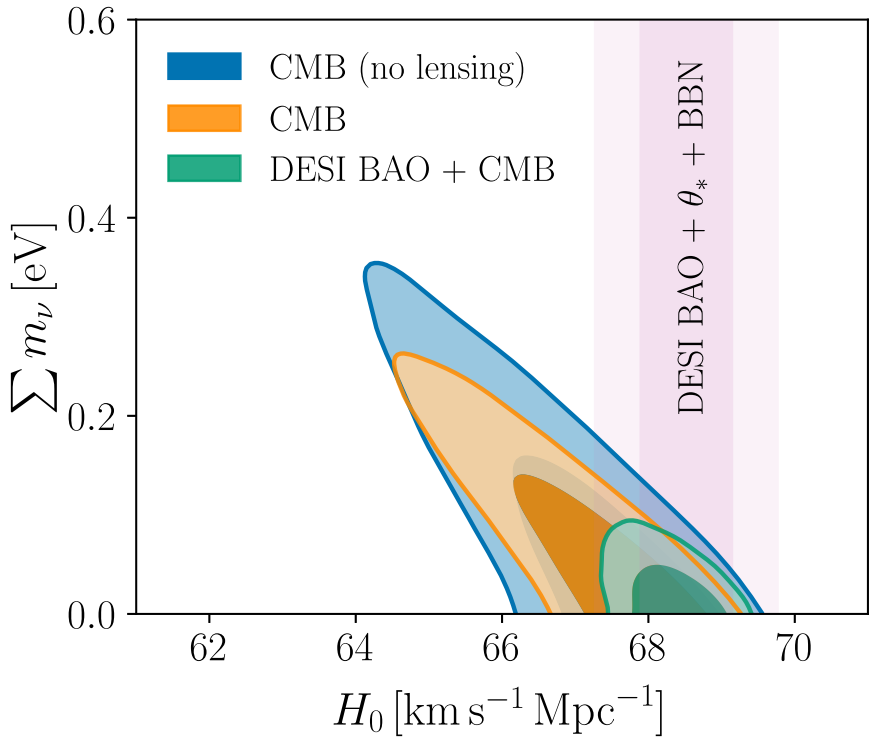
Broken by BAO, especially through H_0

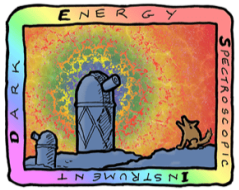
Low preferred value of H_0 yields

$\sum m_\nu < 0.072\,\mathrm{eV}$ (95%, DESI + CMB)

Limit relaxed for extensions to ΛCDM

$\sum m_\nu < 0.195\,\mathrm{eV}$ for $w_0 w_a$CDM





DARK ENERGY
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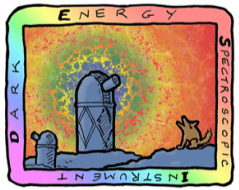
Y1 BAO constraints: a summary

DESI already has the most precise BAO measurements ever



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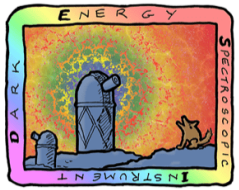

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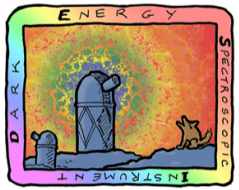

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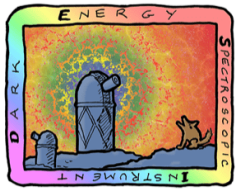
Some hint of time-varying Dark Energy equation of state especially when combined with supernovae measurements



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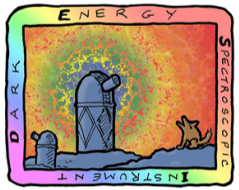
What's next?

Y3 data on disk... and BAO analysis on-going! Stay tuned :)

But Y1 has not yet revealed its full potential!



DARK ENERGY
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But Y1 has not yet revealed its full potential!

Full shape is coming!

Y1KP5 leads: Pauline Zarrouk, Hector Gil-Marin

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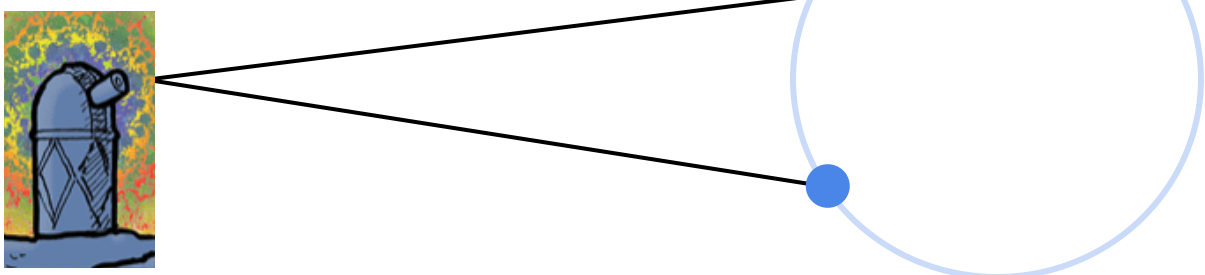
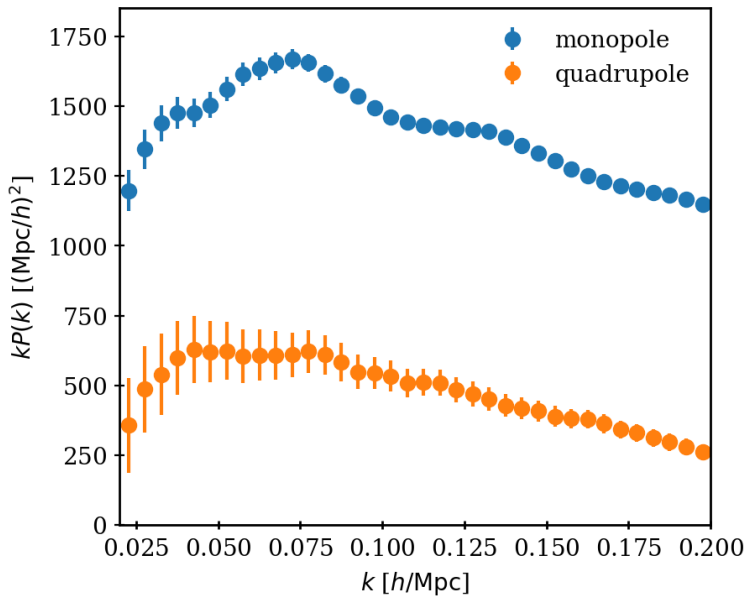
Full shape analysis

observed redshift = Hubble flow





DARK ENERGY SPECTROSCOPIC INSTRUMENT

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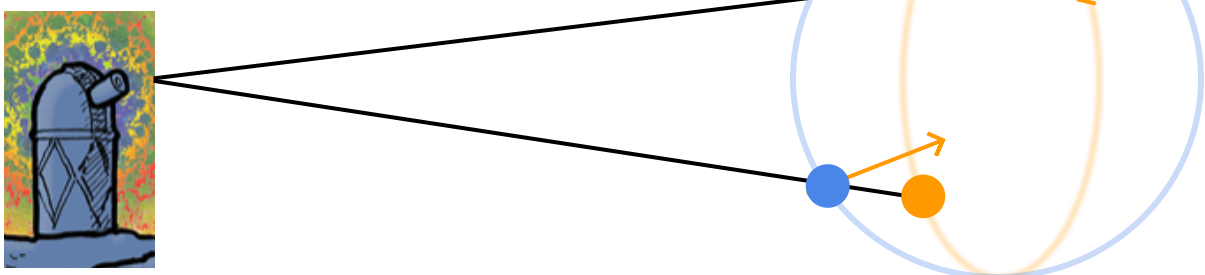
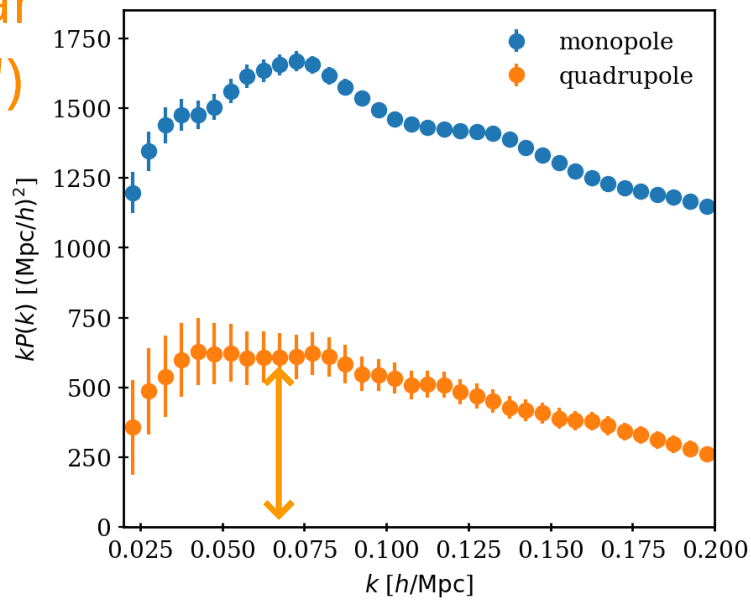
Full shape analysis

observed redshift = Hubble flow and peculiar velocities (RSD = "redshift space distortions")





RSD probes growth of structure $f\sigma_8$, sensitive to gravity, DE, ν

Full shape also driven by primordial physics ($\omega_{\rm cdm}, \omega_{\rm b}, n_s, f_{\rm NL}^{\rm loc}, \ldots$)

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Full shape analysis

Three power spectrum Effective Field Theory models considered:

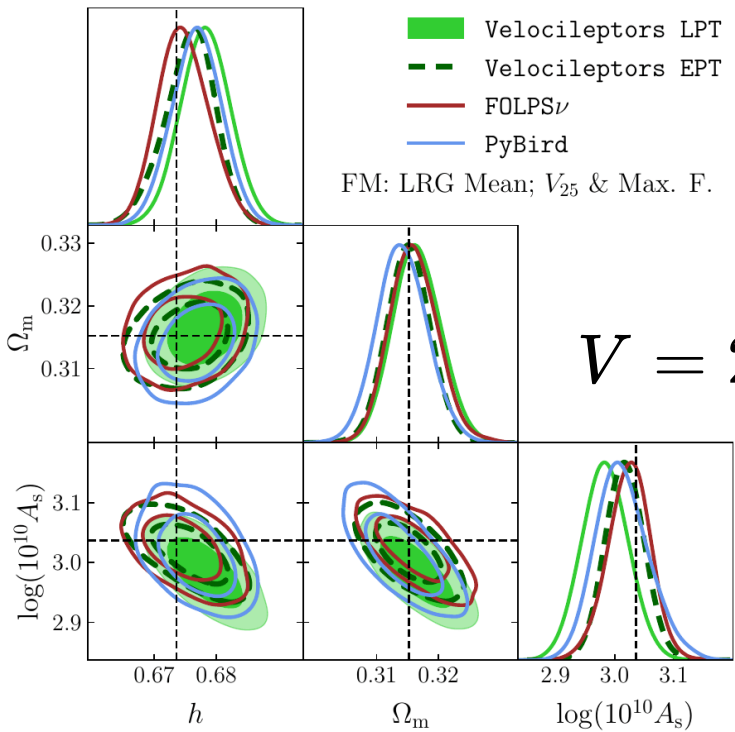
- pybird
- velocileptors
- folps

Maus et al. 2024

Lai et al. 2024

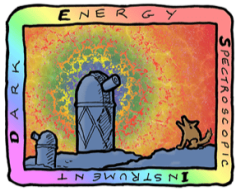
Noriega et al. 2024

Maus et al. 2024



$$V = 200\ [\mathrm{Gpc}/h]^3$$

credit: Mark Maus, Hernan Noriega, Yan Lai



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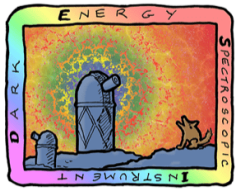
Full shape analysis - tests

- maximum fitting scale $k_{\rm max}$
- galaxy - halo connection, bias parametrization, prior choices
- projection effects
- fiducial cosmology
- covariance matrix



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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Full shape analysis - tests

- maximum fitting scale k_{max}
- galaxy - halo connection, bias parametrization, prior choices
- projection effects
- fiducial cosmology
- covariance matrix
- imaging systematics
- spectroscopic systematics
- **"fiber collisions"** Mathilde Pinon et al. 2024

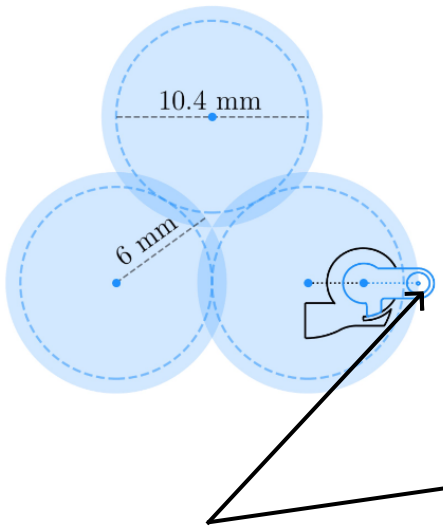
DARK ENERGY SPECTROSCOPIC INSTRUMENT

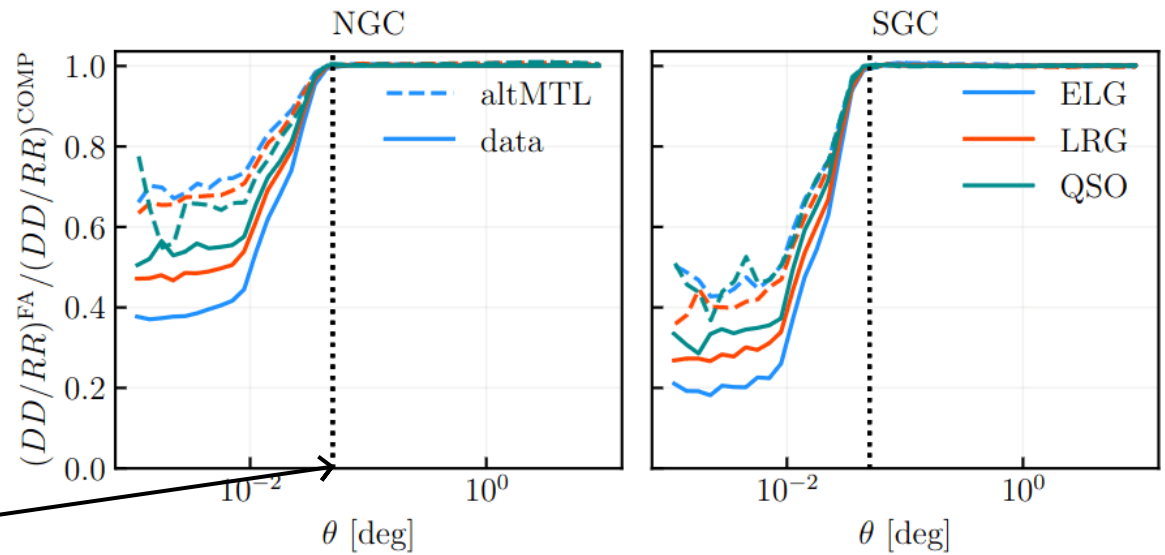
U.S. Department of Energy Office of Science

Fiber collisions

Pinon et al. 2024

Groups of galaxies too close to each other cannot all receive a fiber





Pinon et al. 2024, arXiv:2406.04804

$0.05^\circ \simeq$ positioner patrol diameter

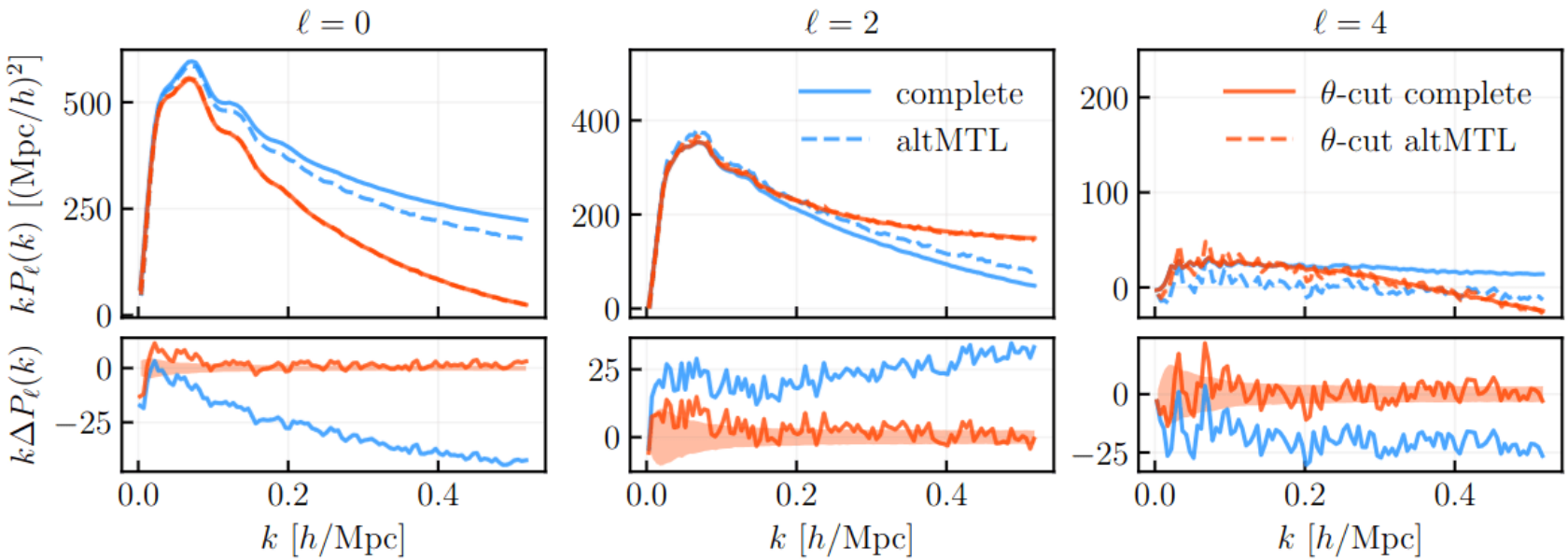
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Fiber collisions

Pinon et al. 2024

Impacts power spectrum measurements (altMTL vs complete)



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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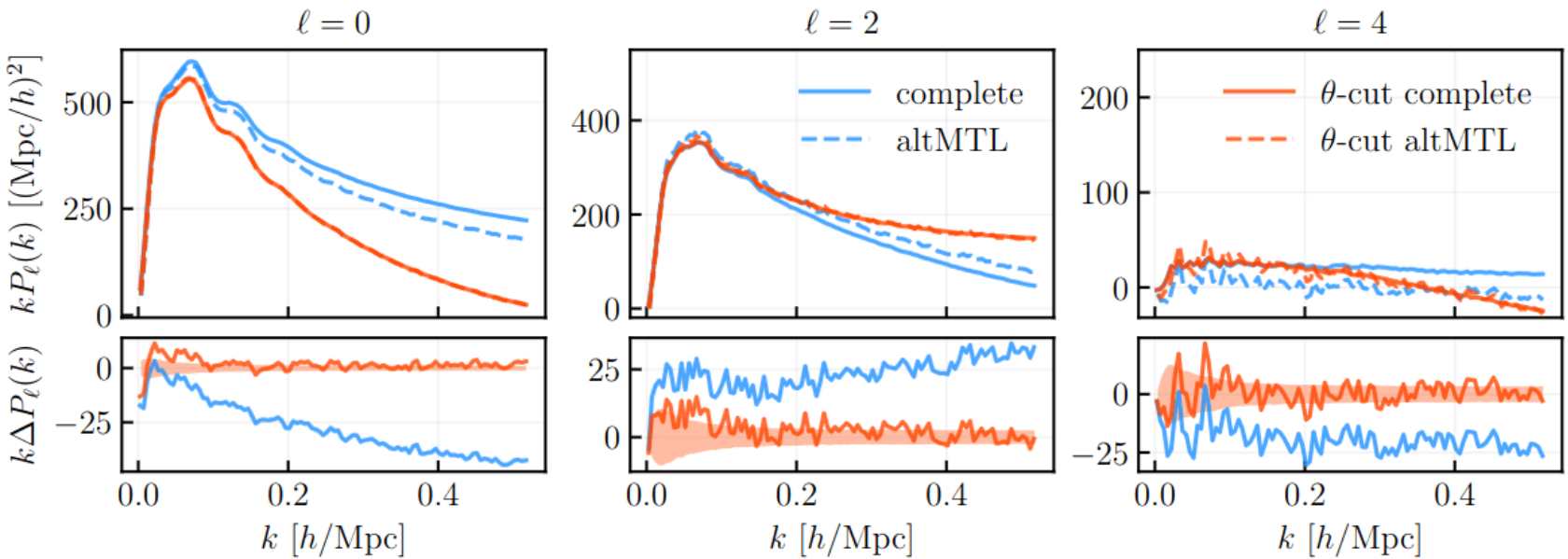
Pinon et al. 2024

Impacts power spectrum measurements (altMTL vs complete)

Solution: θ-cut = remove all pairs $< 0.05°$, new window matrix



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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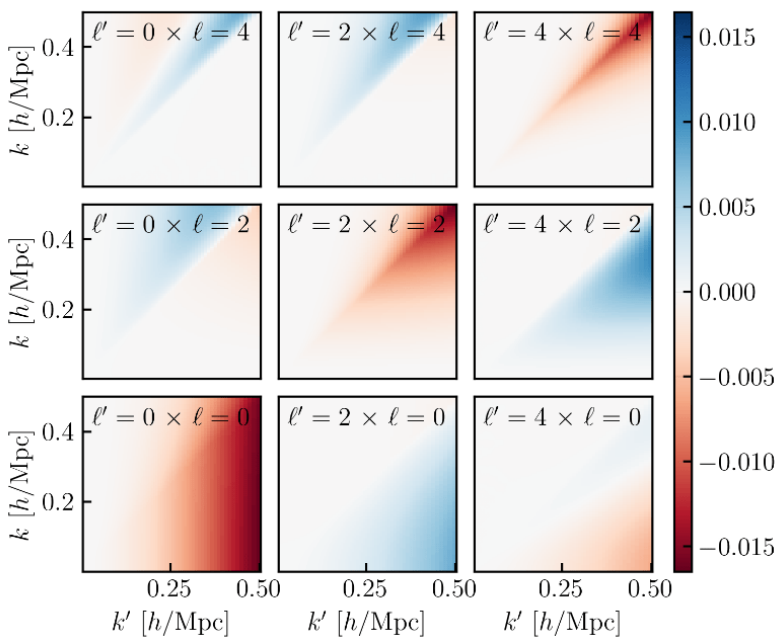
Fiber collisions

Pinon et al. 2024

New window matrix $W^{\rm cut}$; $\langle P_o(k)\rangle = W^{\rm cut}(k,k')P_t(k')$



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U.S. Department of Energy Office of Science

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Pinon et al. 2024

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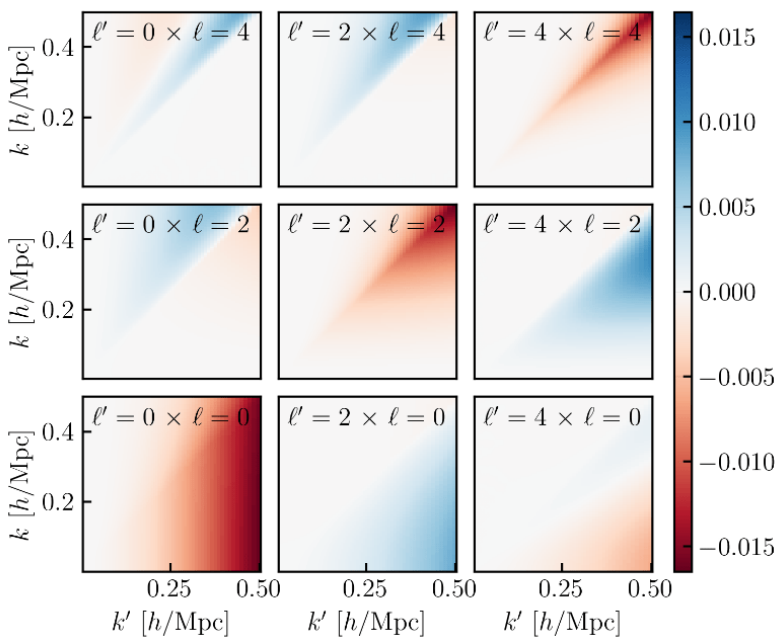
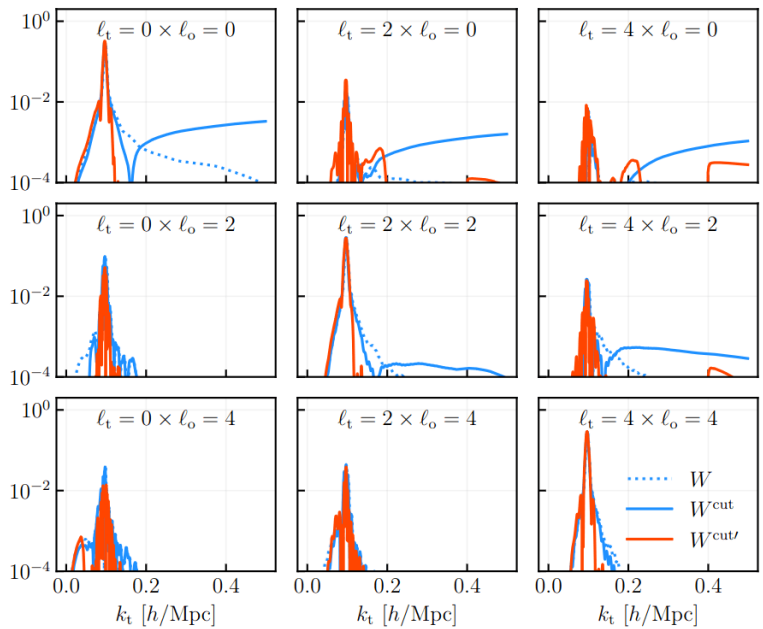
Very non diagonal: let's "rotate" it





DARK ENERGY SPECTROSCOPIC INSTRUMENT

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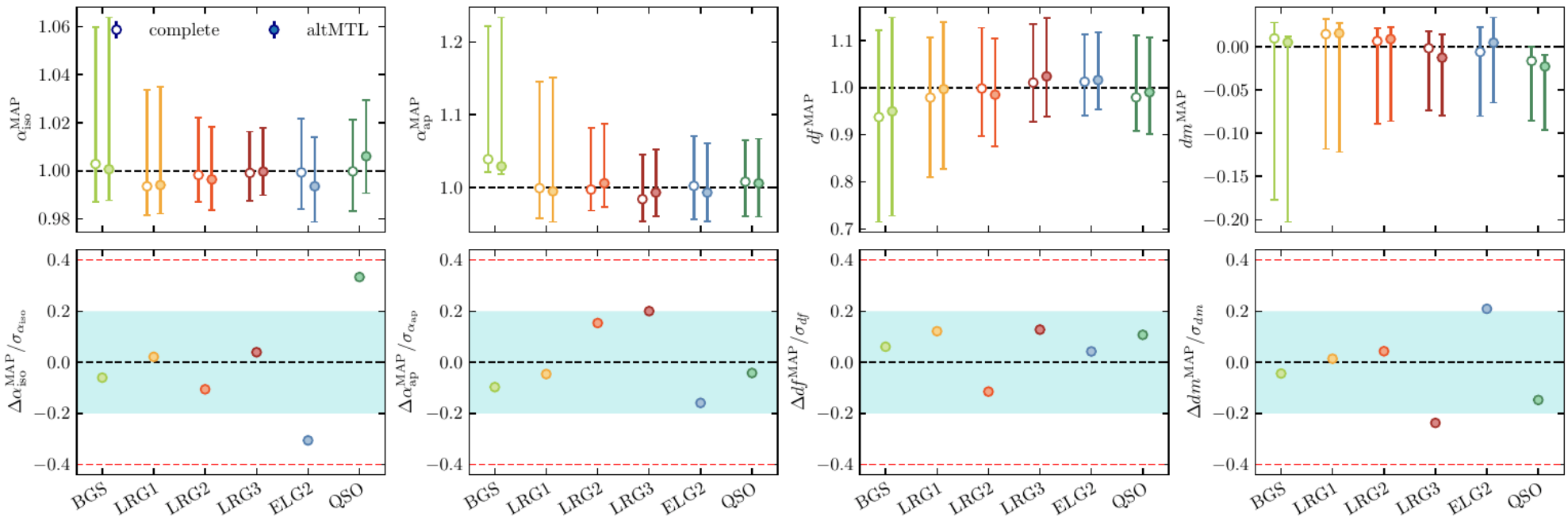
Fiber collisions

Pinon et al. 2024

Successfully removes the $> 1\sigma$ bias



credit: Ruiyang Zhao

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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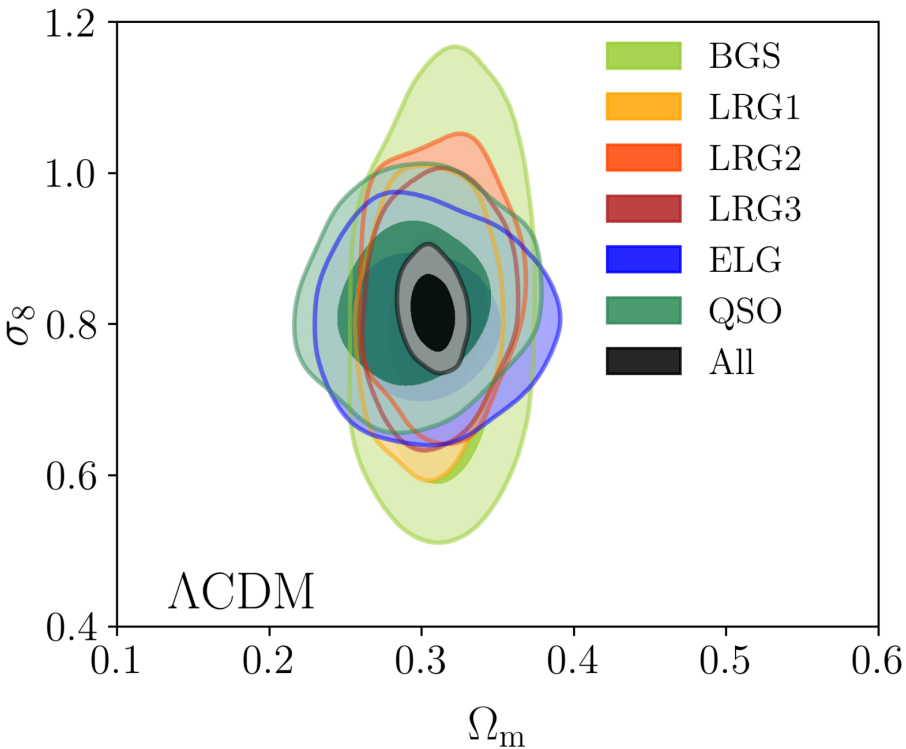
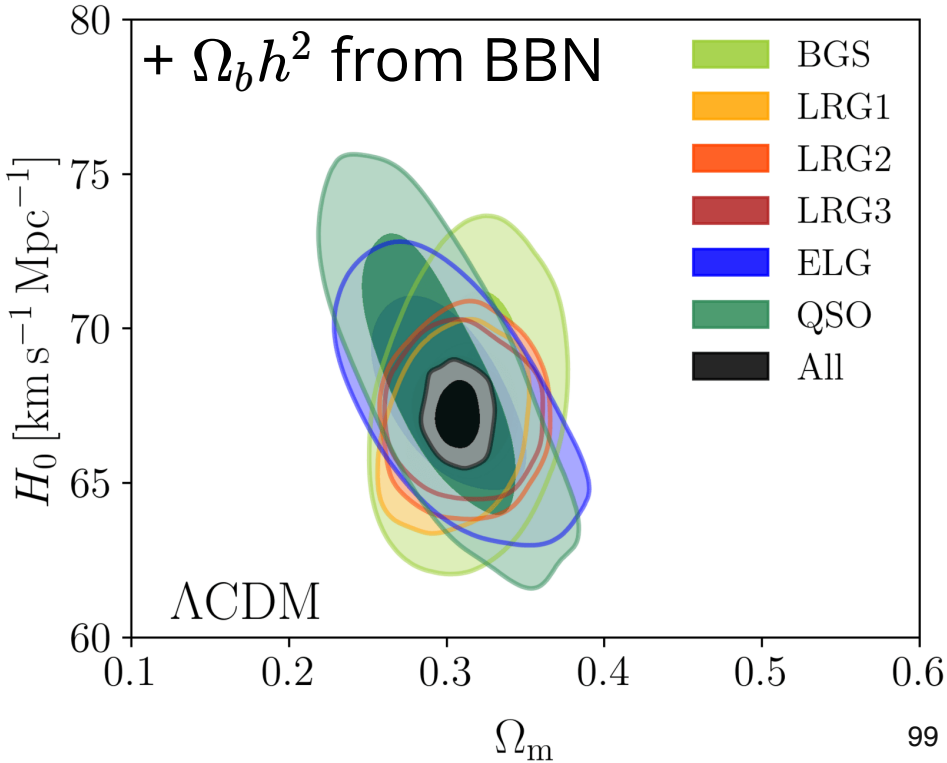
Full shape - mock constraints

DR1: $\sigma(\sigma_8) \sim 0.034$, $\sigma(\Omega_m) \sim 0.0095$





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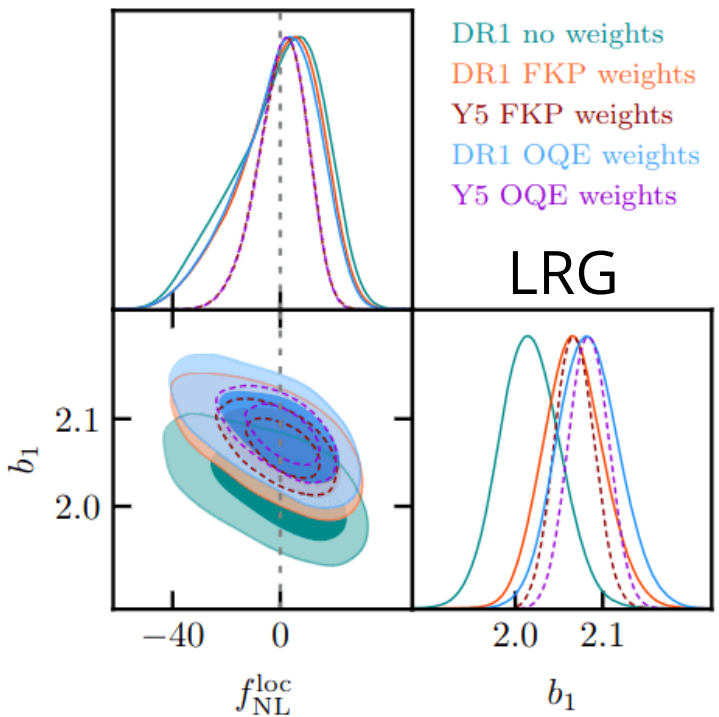
$f_{\rm NL}^{\rm loc}$ - mock constraints

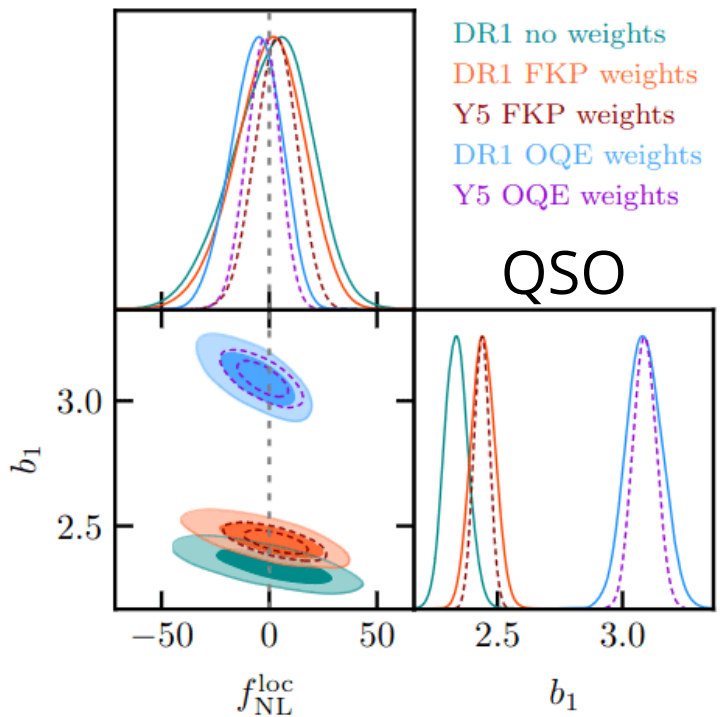
Chaussidon et al. 2024, *in prep*

DR1: $\sigma(f_{\rm NL}^{\rm loc}) \sim 10$

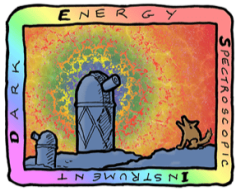
SDSS: $\sigma(f_{\rm NL}^{\rm loc}) \sim 20$



(a) LRG with $b_\Phi(b_1) = 2\delta_c(b_1 - 1)$.



(b) QSO with $b_\Phi(b_1) = 2\delta_c(b_1 - 1.6)$.



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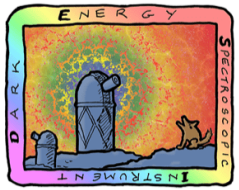
What I haven't talked about

Y1 supporting papers: BAO and Full Shape theory modelling, covariance matrices, BAO reconstruction, etc., see data.desi.lbl.gov/doc/papers/

DESI EDR data public (including 1%: 140 deg^2, 1.2M extragalactic redshifts): DESI Collaboration 2023 arXiv:2306.06308

A bunch of science papers: Lyα, small scale clustering (HOD), etc., see: data.desi.lbl.gov/doc/papers/edr/



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Conclusions

DESI runs beautifully!

Y1 full shape analysis and $f_{\rm NL}^{\rm loc}$ unblinded, papers in a few weeks

Many alternative analyses! DE reconstruction, H_0 without BAO, modified gravity, higher order statistics, alternative statistics, etc.

DR1 catalogs to be publicly available next year

Y3 data on disk, BAO analysis starting!

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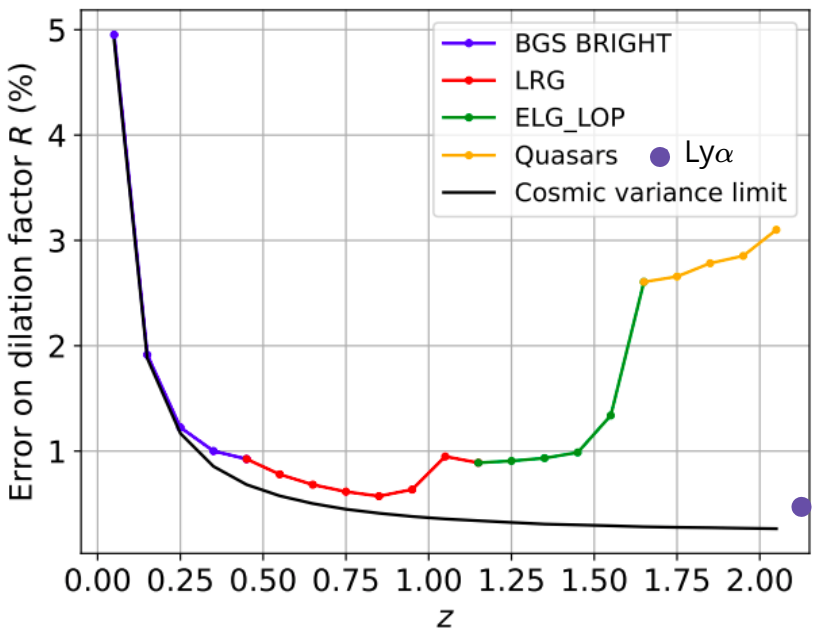
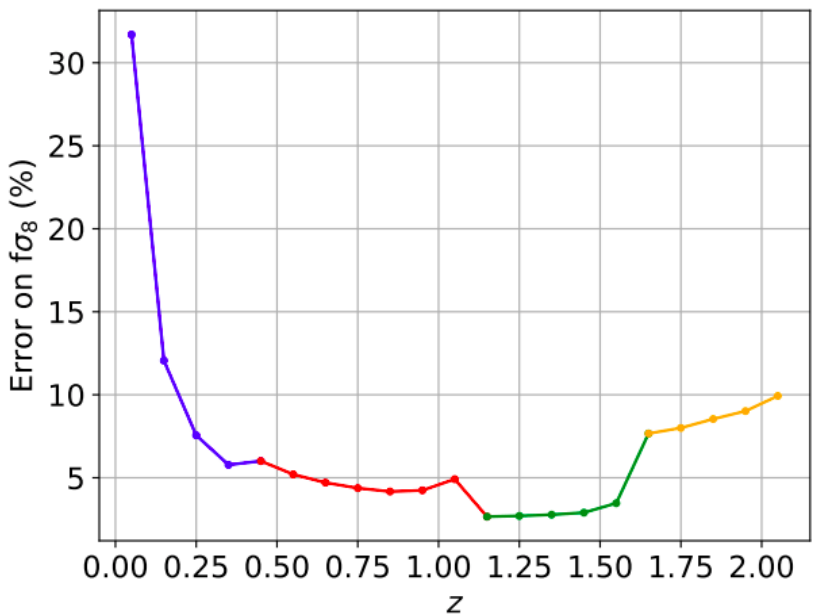
DESI Y5 forecasts

Survey Validation (DESI Collaboration, arXiv:2306.06307)

BAO and RSD constraints at the end of the survey ($\Delta z = 0.1$)





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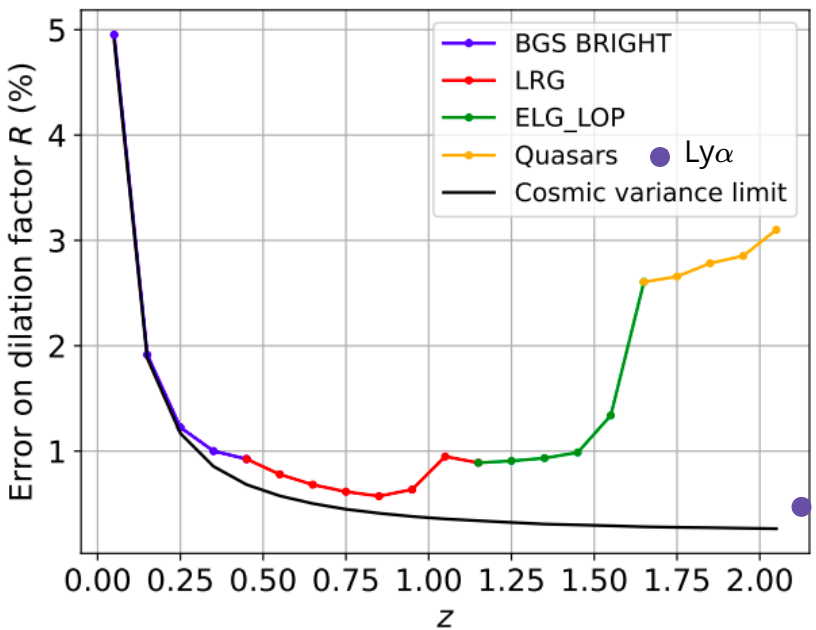

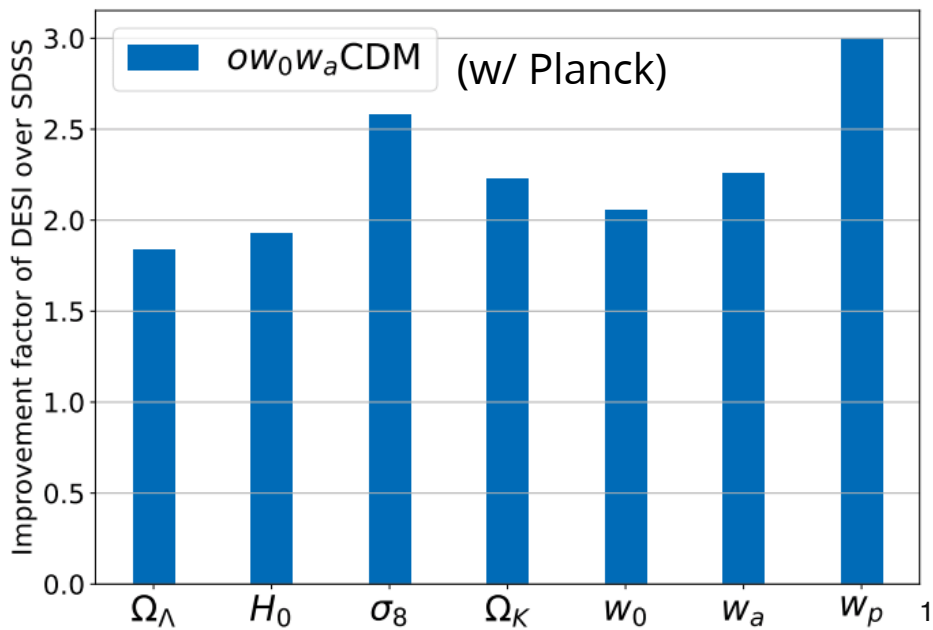

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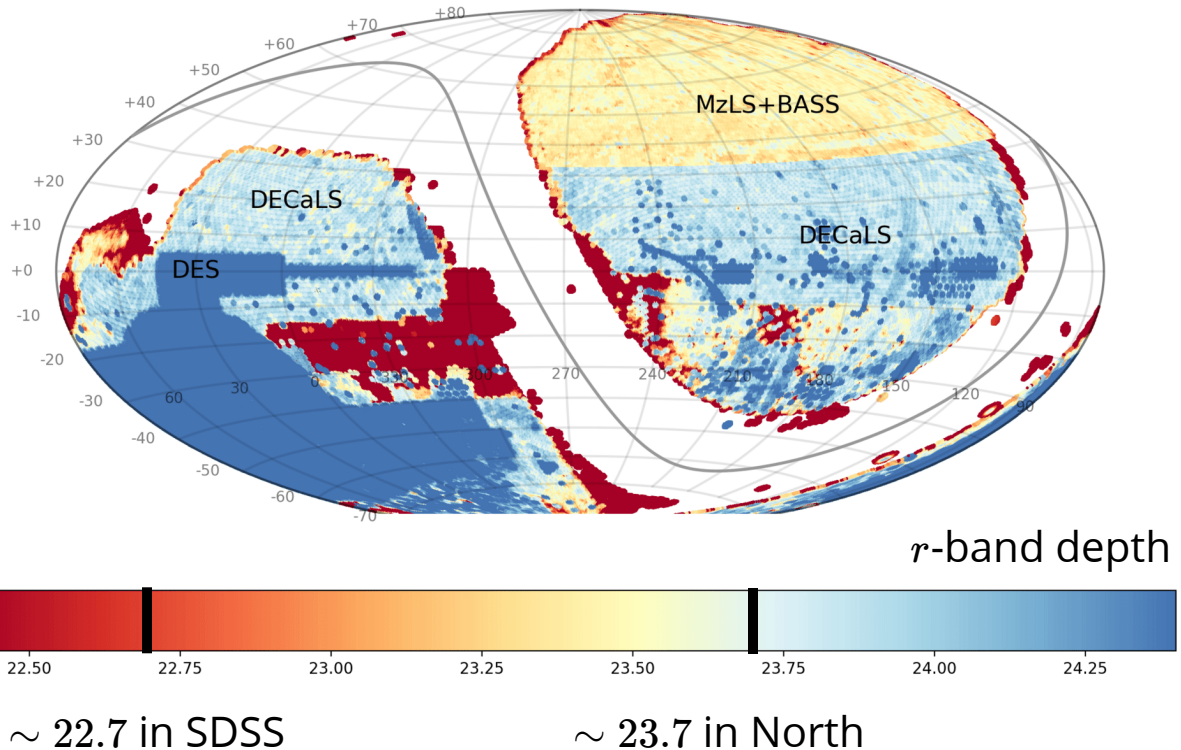
Imaging surveys used by DESI

Optical surveys (grz)

North (5.2k deg^2)

- BASS (gr): 2016 - 2018
- MzLS (z): 2015 - 2019

credit: NOIRLab



~ 22.7 in SDSS

~ 23.7 in North

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Imaging surveys used by DESI

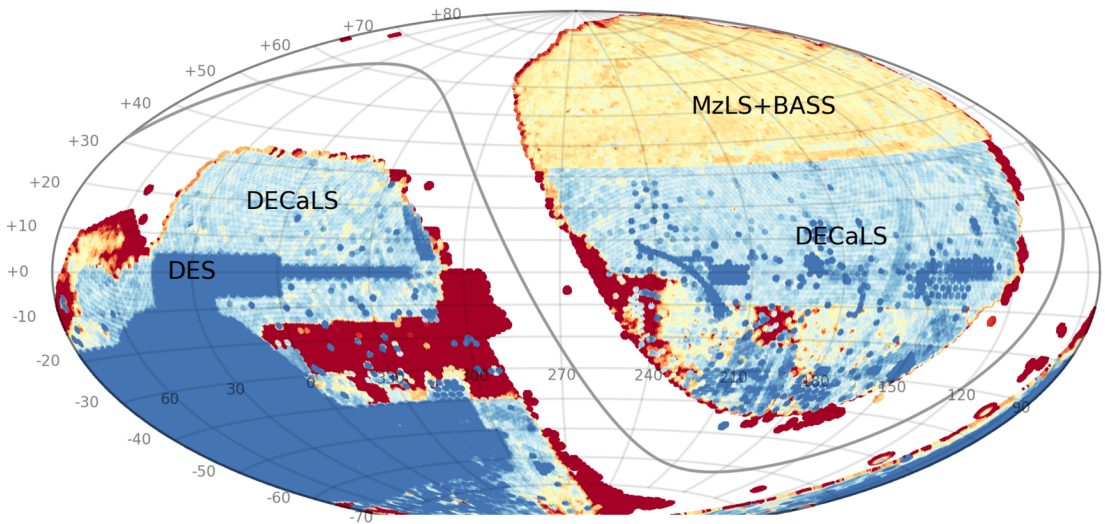
Optical surveys (grz)

North (5.2k deg^2)

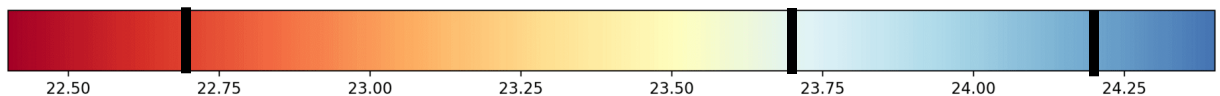
- BASS (gr): 2016 - 2018
- MzLS (z): 2015 - 2019

South (11.7k deg^2)

- DECaLS (grz): 2014 - 2019



r-band depth



~ 22.7 in SDSS

~ 23.7 in North ~ 24.2 in South

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Imaging surveys used by DESI

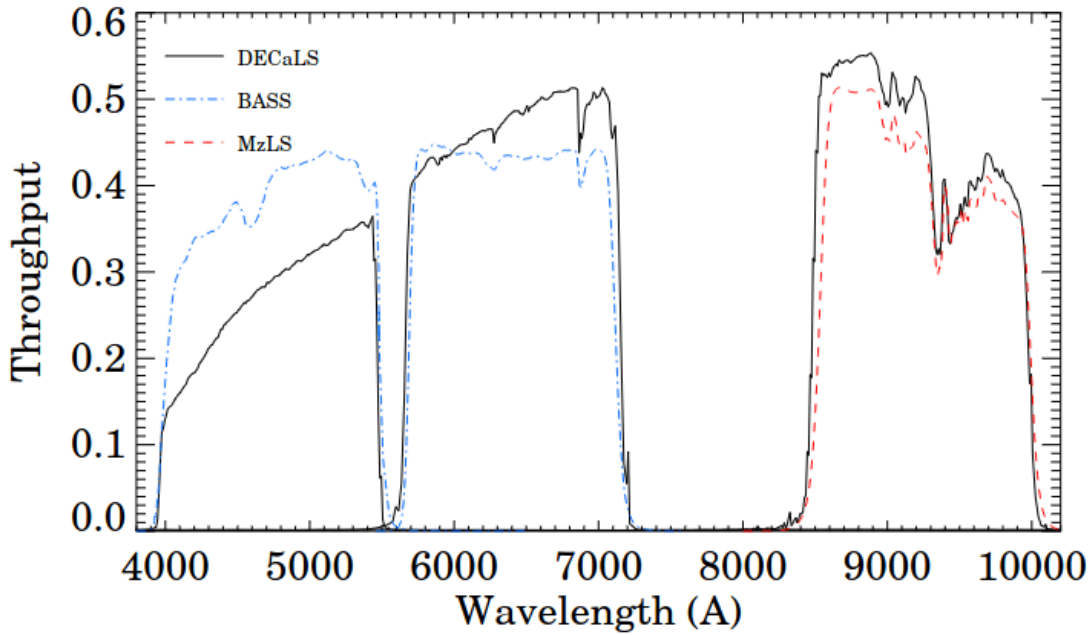
Optical surveys (grz)

North (5.2k deg^2)

- BASS (gr): 2016 - 2018
- MzLS (z): 2015 - 2019

South (11.7k deg^2)

- DECaLS (grz): 2014 - 2019



Dey et al. 2019

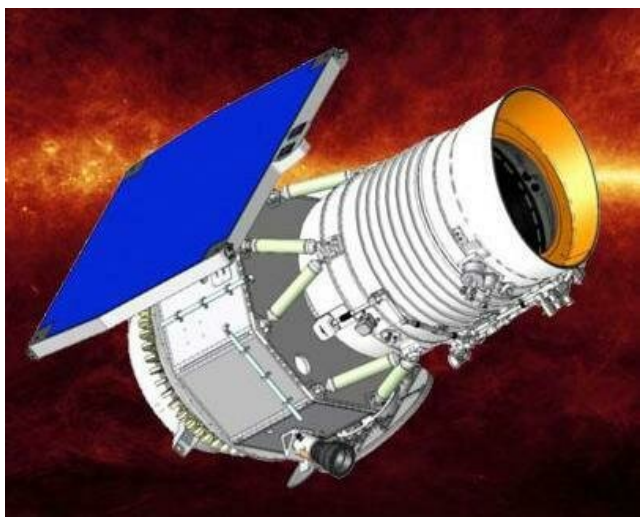
DARK ENERGY SPECTROSCOPIC INSTRUMENT

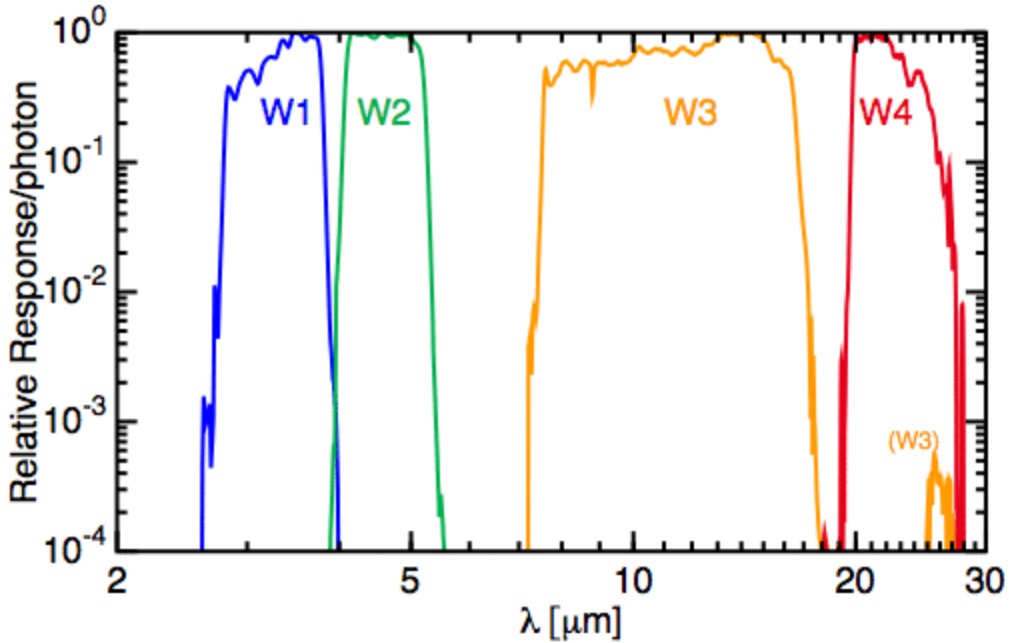
U.S. Department of Energy Office of Science

Imaging surveys used by DESI

Infrared survey

WISE & NEOWISE (**W1, W2**, W3, W4): 2010 - 2020



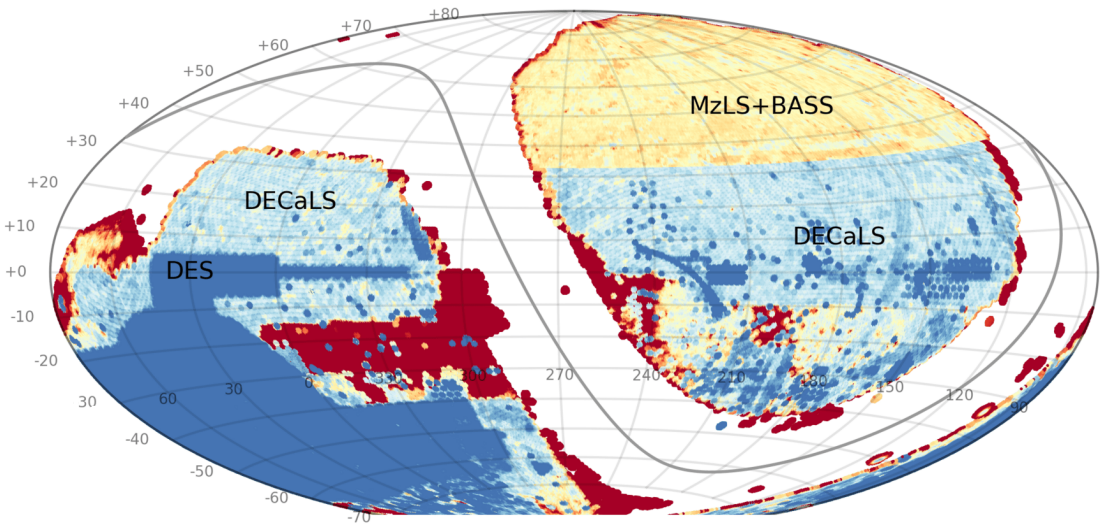


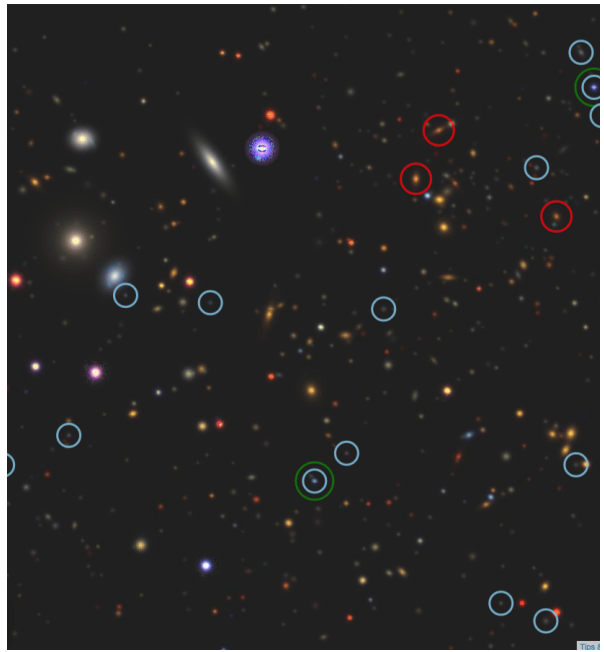
Wright et al. 2010

DARK ENERGY SPECTROSCOPIC INSTRUMENT

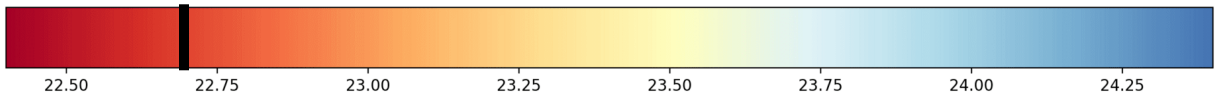
U.S. Department of Energy Office of Science

Target selection





r-band depth

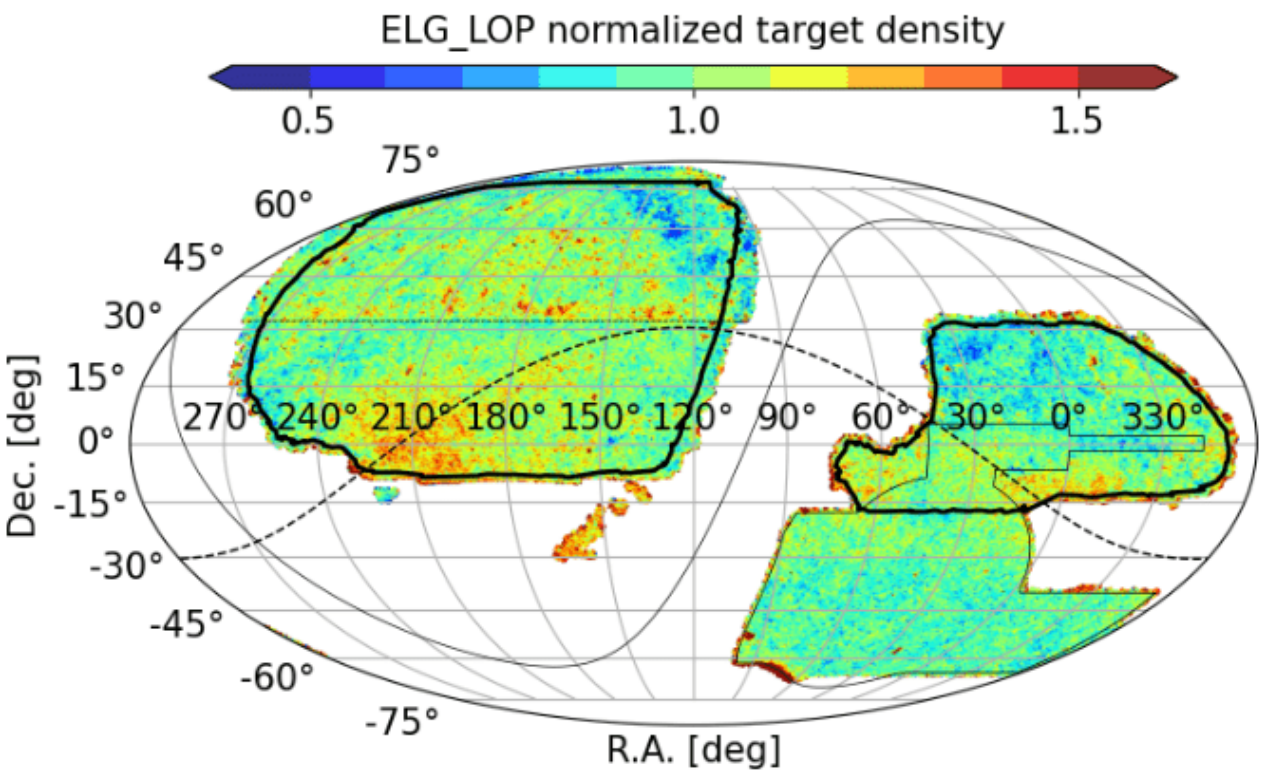


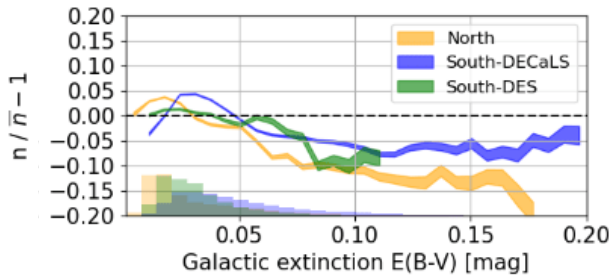
~ 22.7 in SDSS

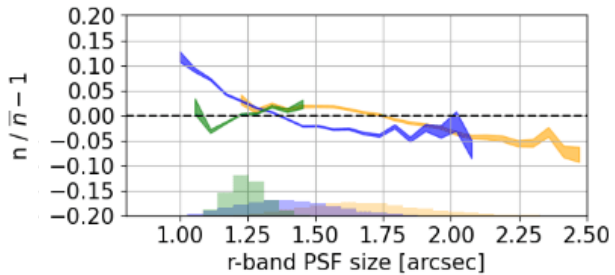
DARK ENERGY SPECTROSCOPIC INSTRUMENT

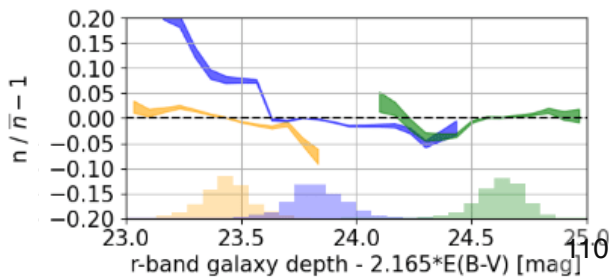
U.S. Department of Energy Office of Science

Target selection









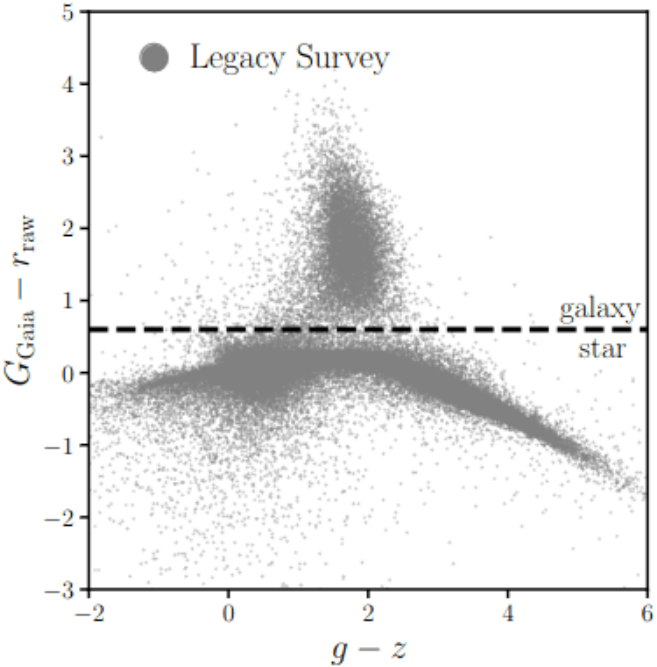
Raichoor et al. 2022 arXiv:2208.08513

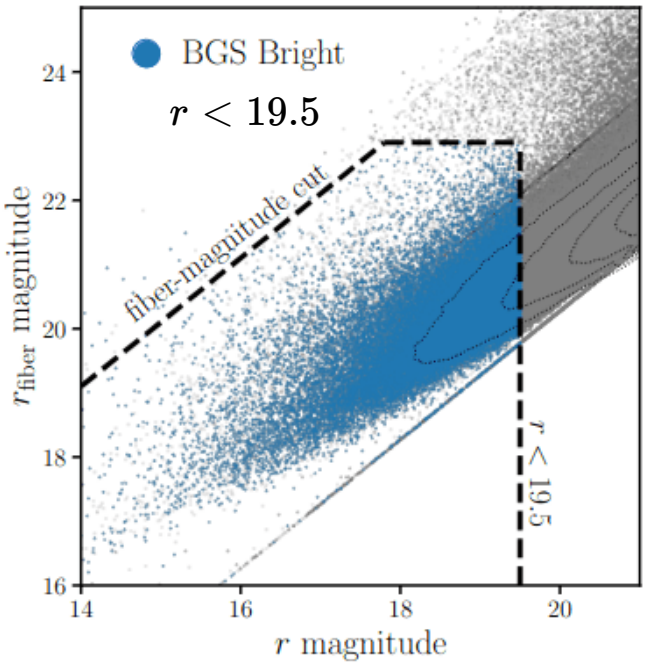
DARK ENERGY SPECTROSCOPIC INSTRUMENT

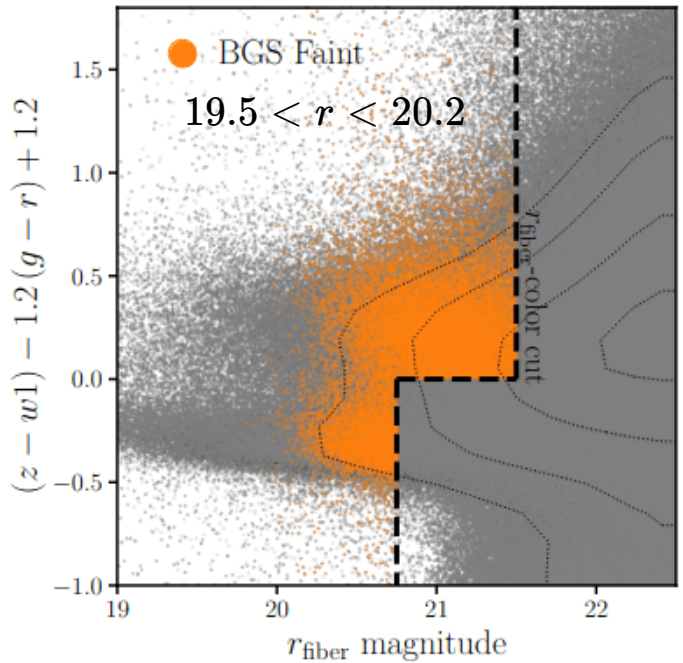
U.S. Department of Energy Office of Science

Target selection - BGS ($0.1 < z < 0.4$)

DESI Collaboration, arXiv:2306.06307







BGS bright $\simeq 850$ targets $\deg^{-2}$

BGS faint $\simeq 520$ targets $\deg^{-2}$

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Target selection - LRG ($0.4 < z < 1.1$)

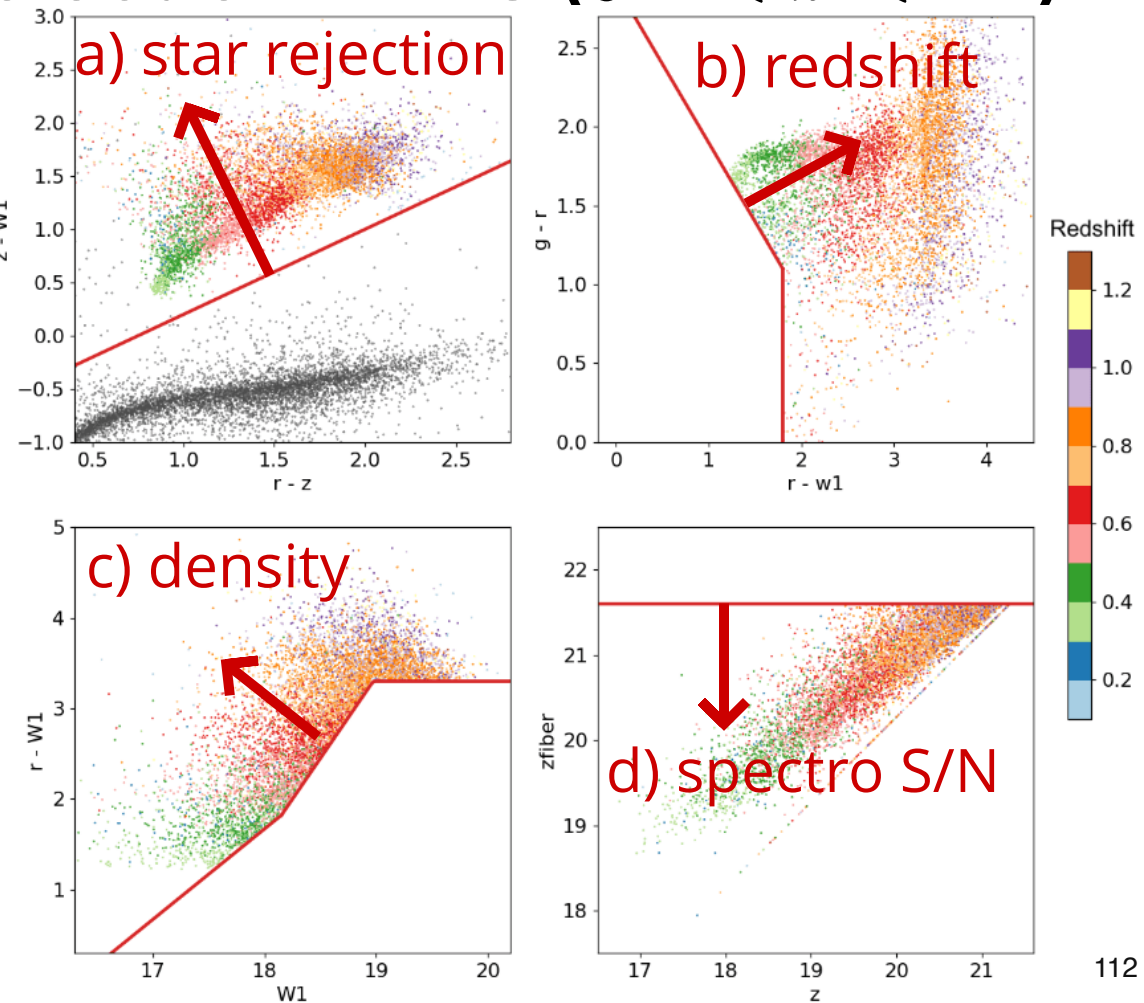
a) star rejection with WISE

b) $g - W1 > 2.9$ selects targets with $z > 0.3$

c) slope of $r - W1$ vs $W1$ chosen to produce ~ constant number density $0.4 < z < 0.8$

d) spectro S/N with z-fiber cut

$\simeq$ 640 targets deg^{-2}



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Target selection - ELG ($0.6 < z < 1.6$)

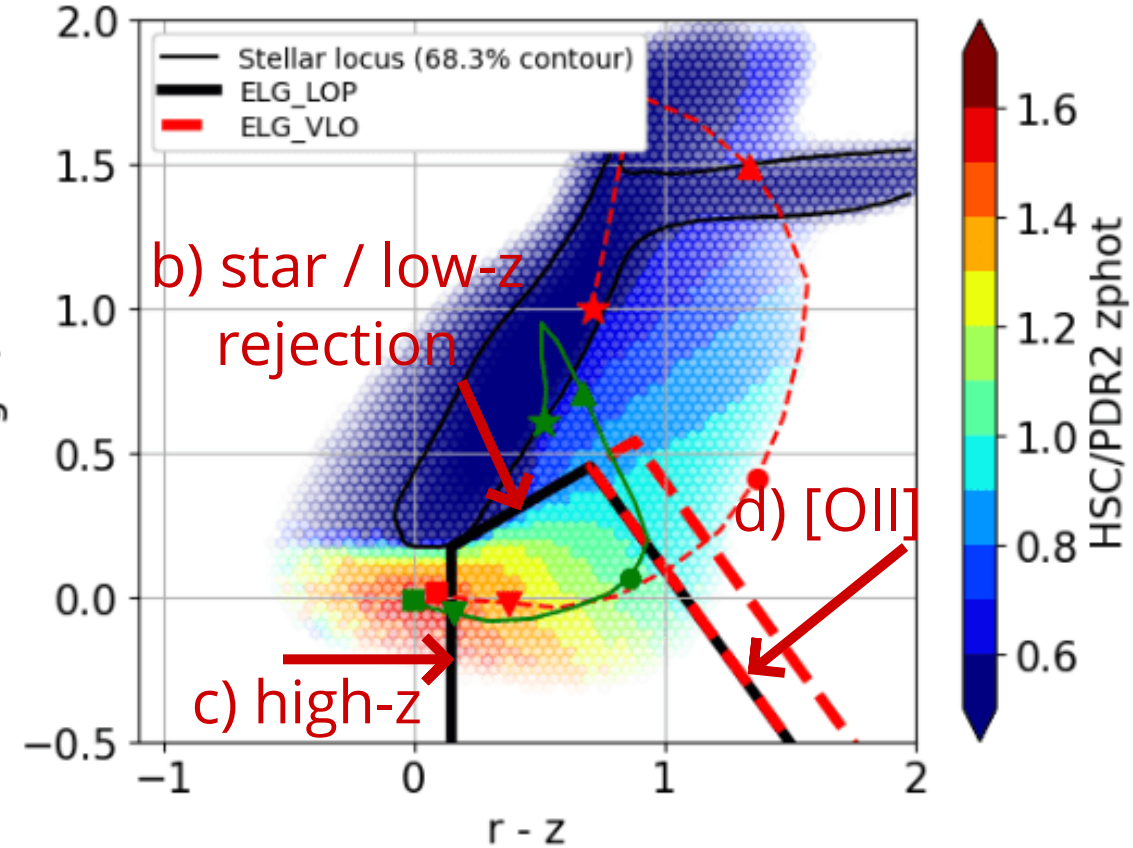
a) number density tuned with $g\text{fiber} < 24.1$

b) star / low-z rejection with $g - r$ vs $r - z$

c) rejection of $z > 1.6$ with $g - r$ cut

d) high [OII] with $g - r$ vs $r - z$

$\simeq$ 1940 targets deg^{-2}



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

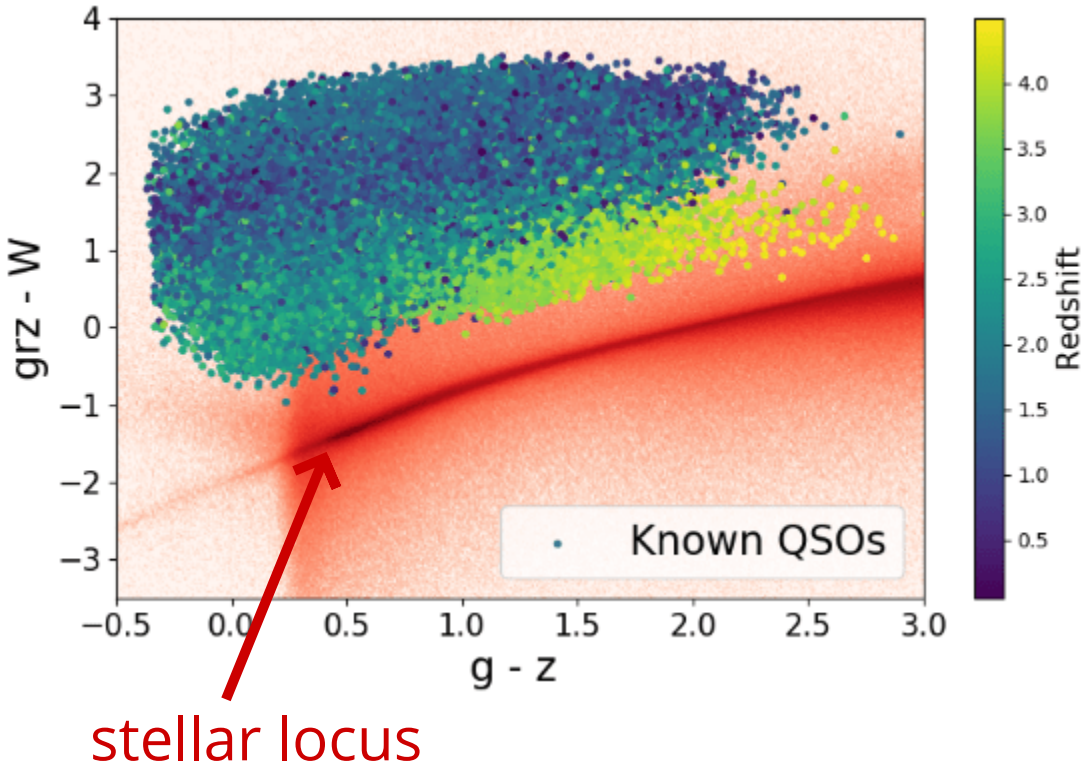
Target selection - QSO ($0.8 < z < 3.5$)

a) PSF-type objects

b) 16.5 < r < 23 cut to remove bright stars, low S/N spectro

c) QSO separated from stars with excess infrared from the dusty torus: W1, W2 > 22.3 and random forest trained on grzW1W2 colors

$\simeq$ 310 targets deg^{-2}



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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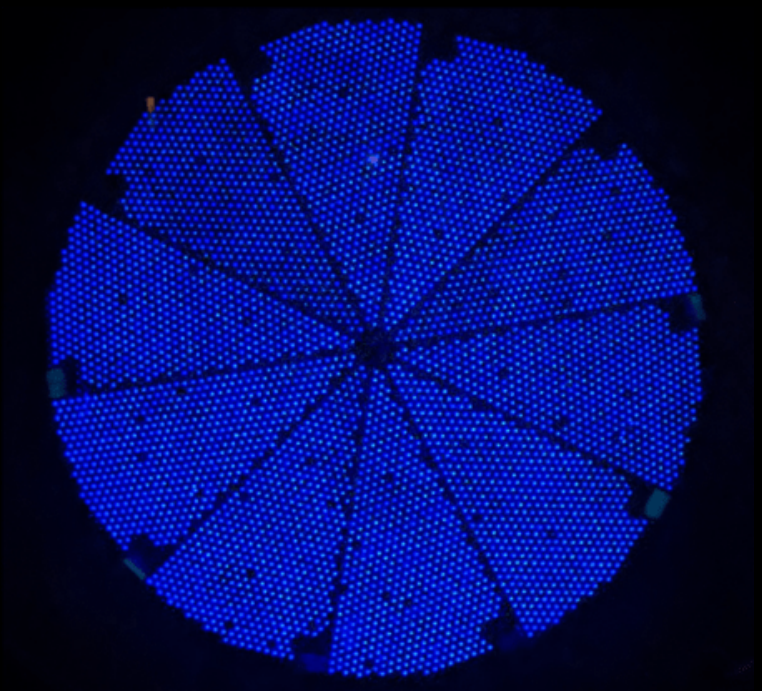
Fiber view camera

fibers illuminated from spectrographs

FVC takes image through the corrector



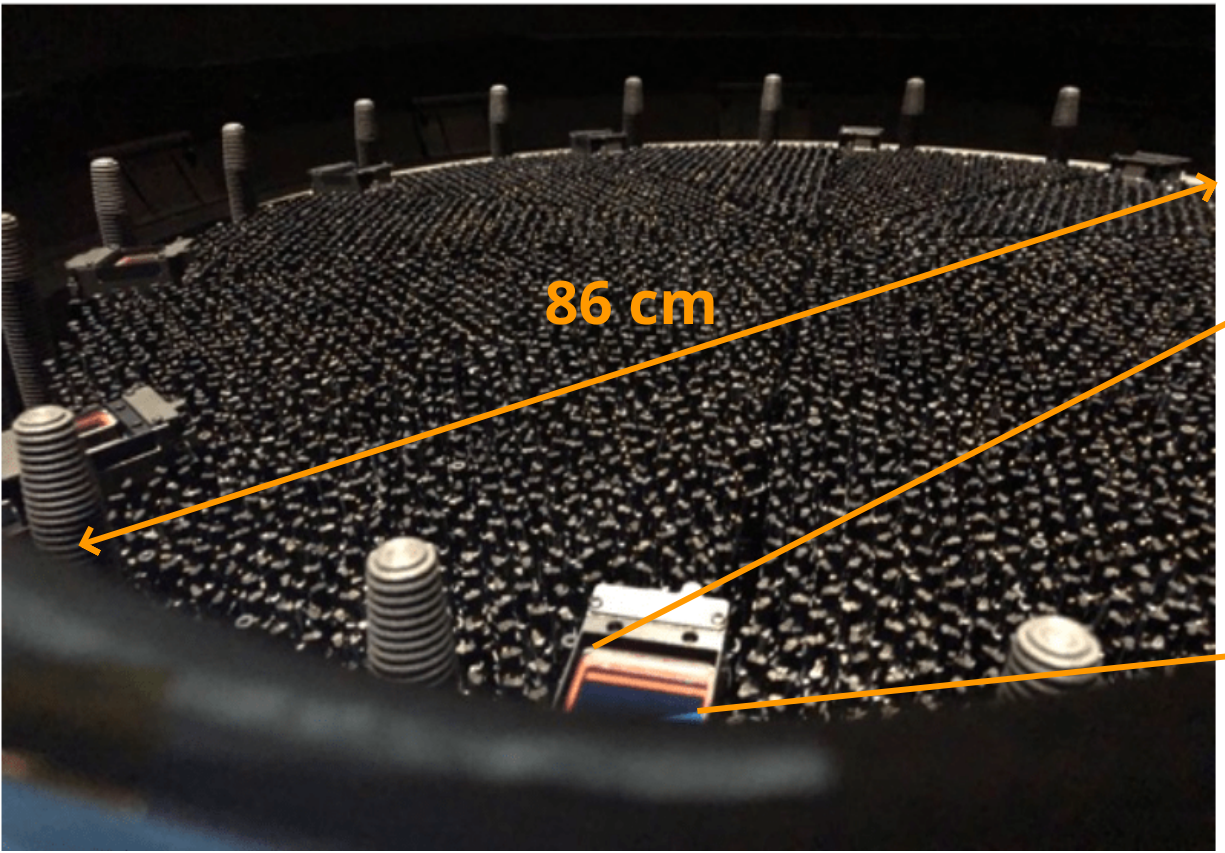
positioning: "blind" move (50μm)

"correction" move (6μm)

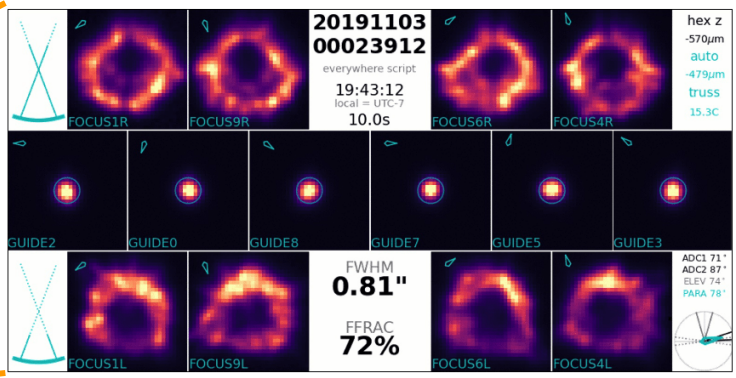
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Focal plane: 5000 robotic positioners



GFA: Guide/Focus/Alignment



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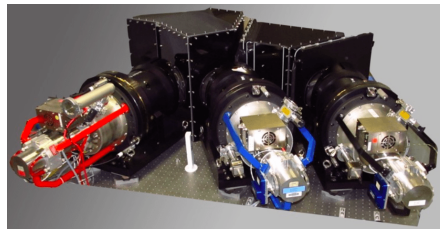
Spectrographs



10 identical 500 fiber spectrographs

3 arms (red, blue, NIR)

Linear Pulse Tube cooled

French technical contribution (CEA, CNRS)

Vendor (French!) Winlight

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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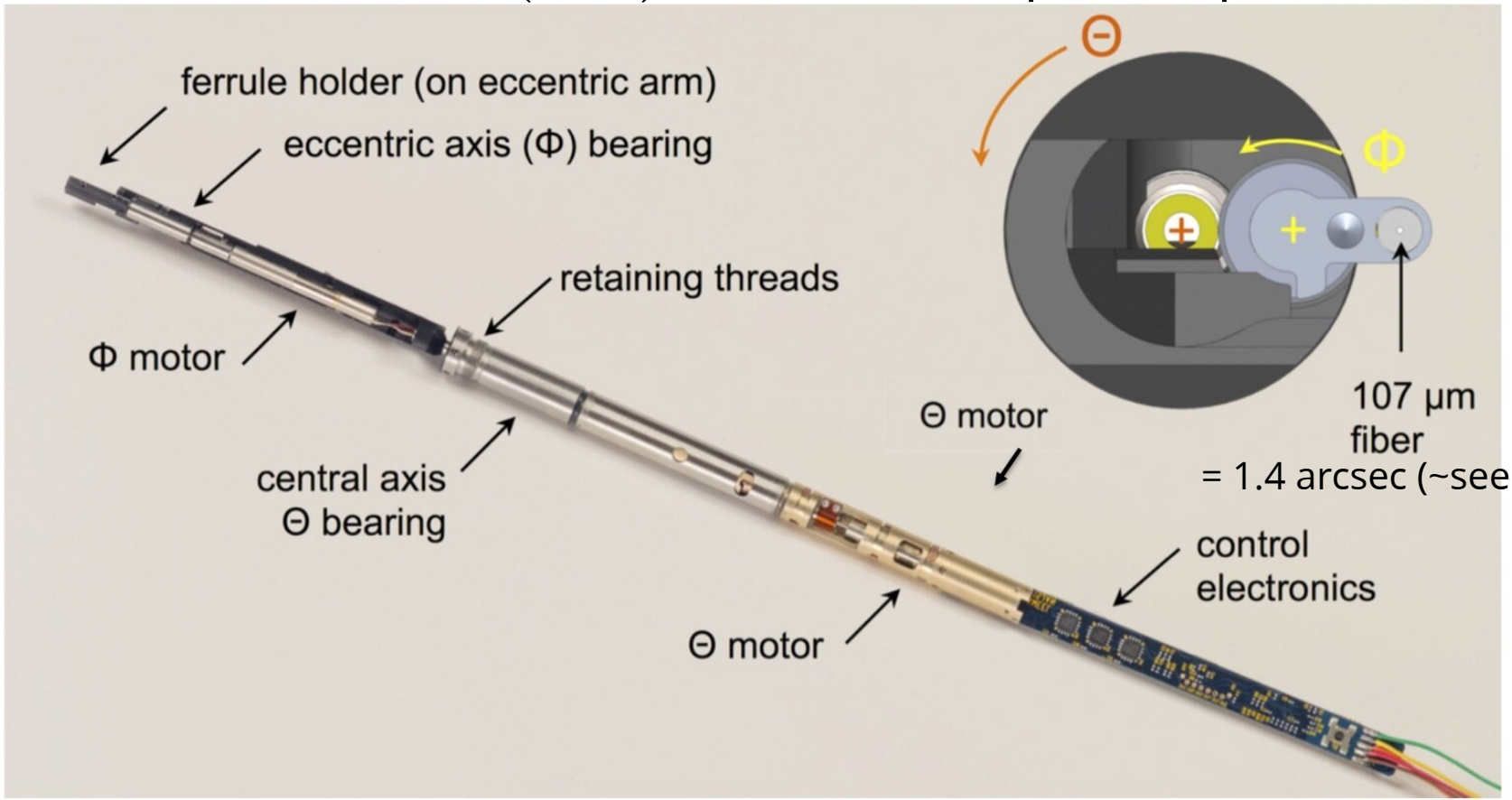
Robotic positioner

2 DoF (Θ, Φ): 2 motors in open-loop



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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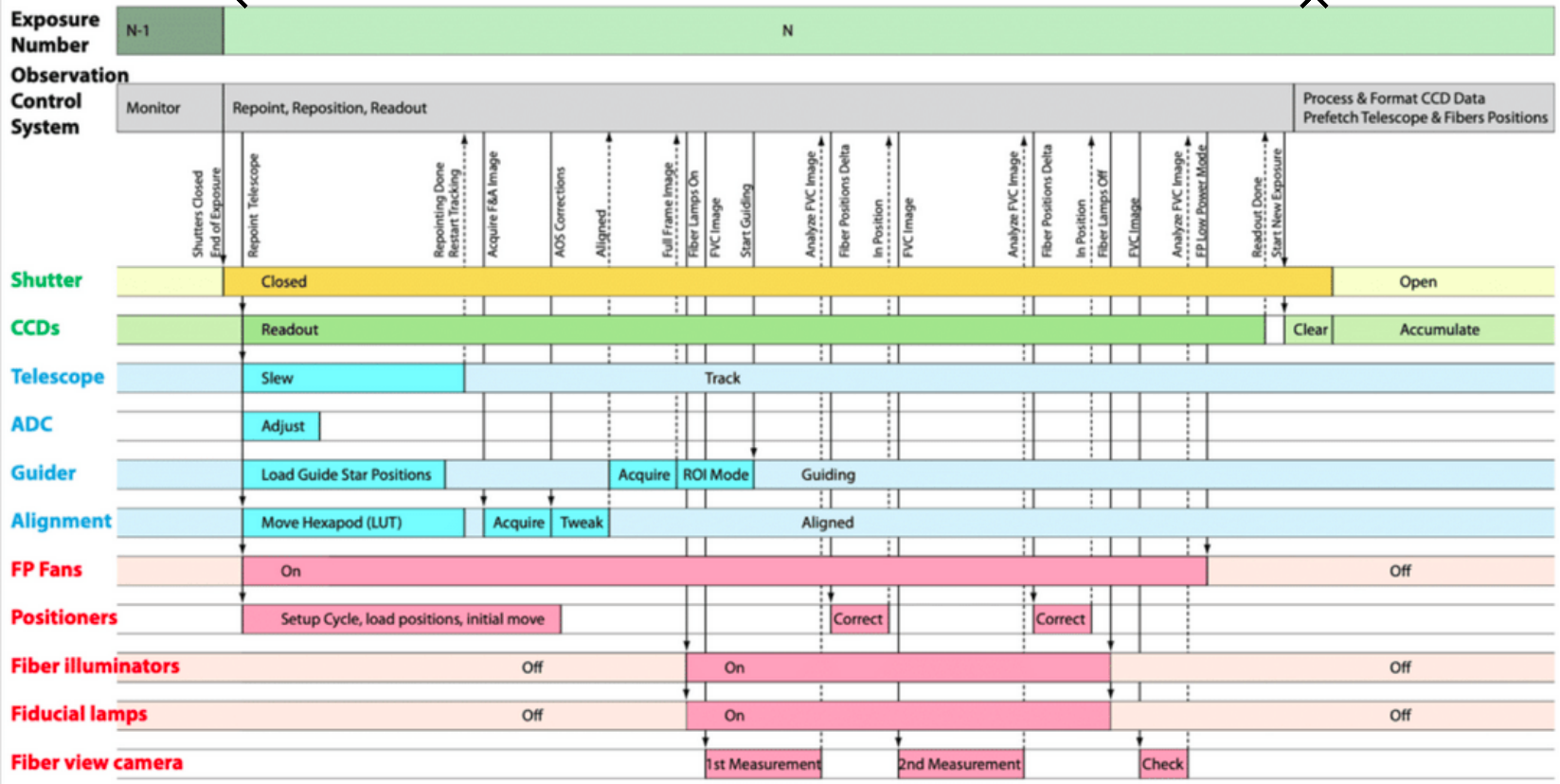
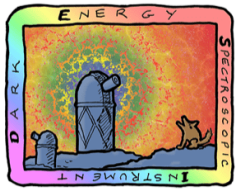
Observing sequence

Reposition & readout in **<2min**!

Exposure time (dark) **1000 s**





DARK ENERGY SPECTROSCOPIC INSTRUMENT

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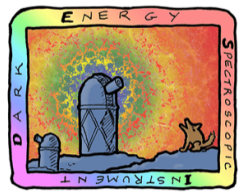
DESI vs SDSS



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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Mirror diameter	2.5 m	4 m
Number of fibers	1000	5000
Troughput	~20%	20%-50%
Spectro resolution	1560 - 2650	2000 - 5000

x20 survey speed and x2 resolution!

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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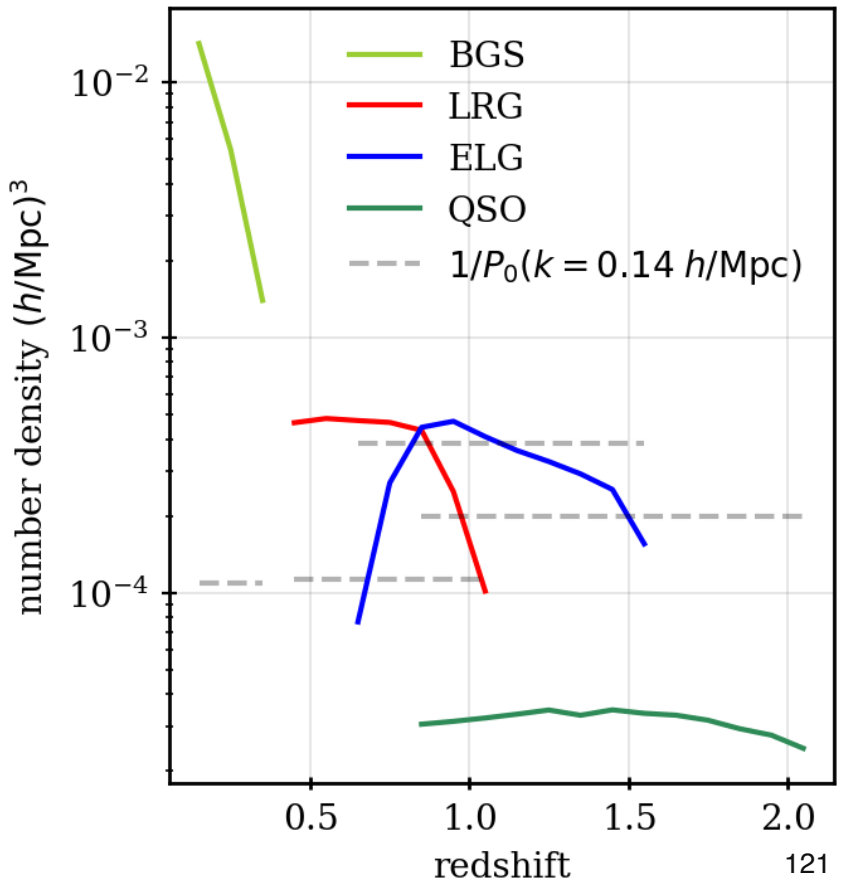
Survey strategy

$$\frac{\sigma_P}{P} \propto \frac{1}{V}\frac{P + 1/\bar{n}}{P}$$

Full Survey: 14,000 deg^2

	asgn. comp. (Y5)	z. comp.	#good z (Y5)
BGS	80%	99%	13.8M
LRG	90%	99%	7.5M
ELG	60%	73%	15.7M
QSO	99%	67%	2.9M



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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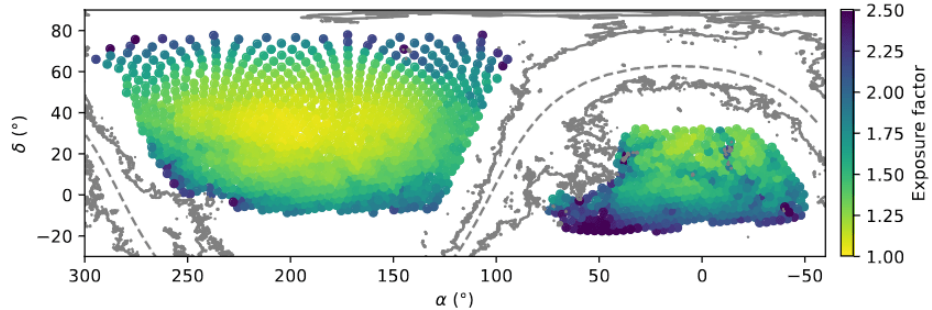
Survey strategy

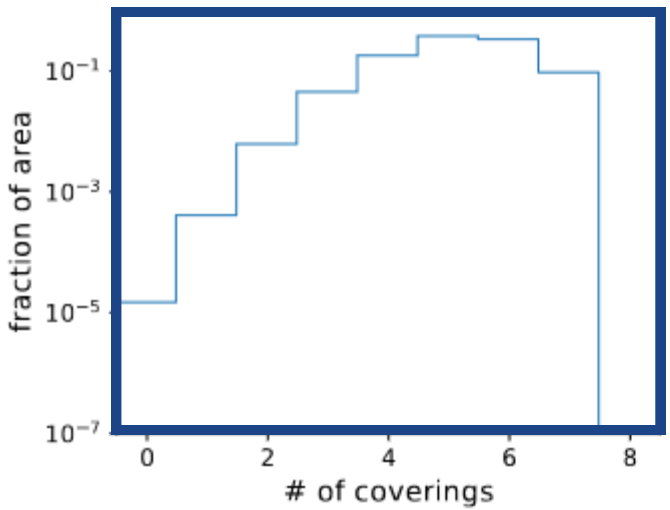
Schlafly et al. 2023 arXiv:2306.06309



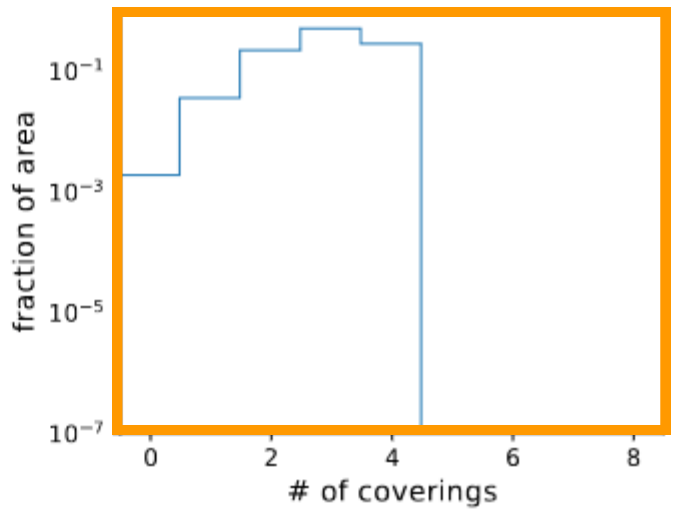
Full Survey: 14,000 deg^2

Field of view: 8 deg^2 $\simeq$ 42 full moon

dark time: LRG, ELG, QSO - 7 passes



bright time: BGS - 4 passes



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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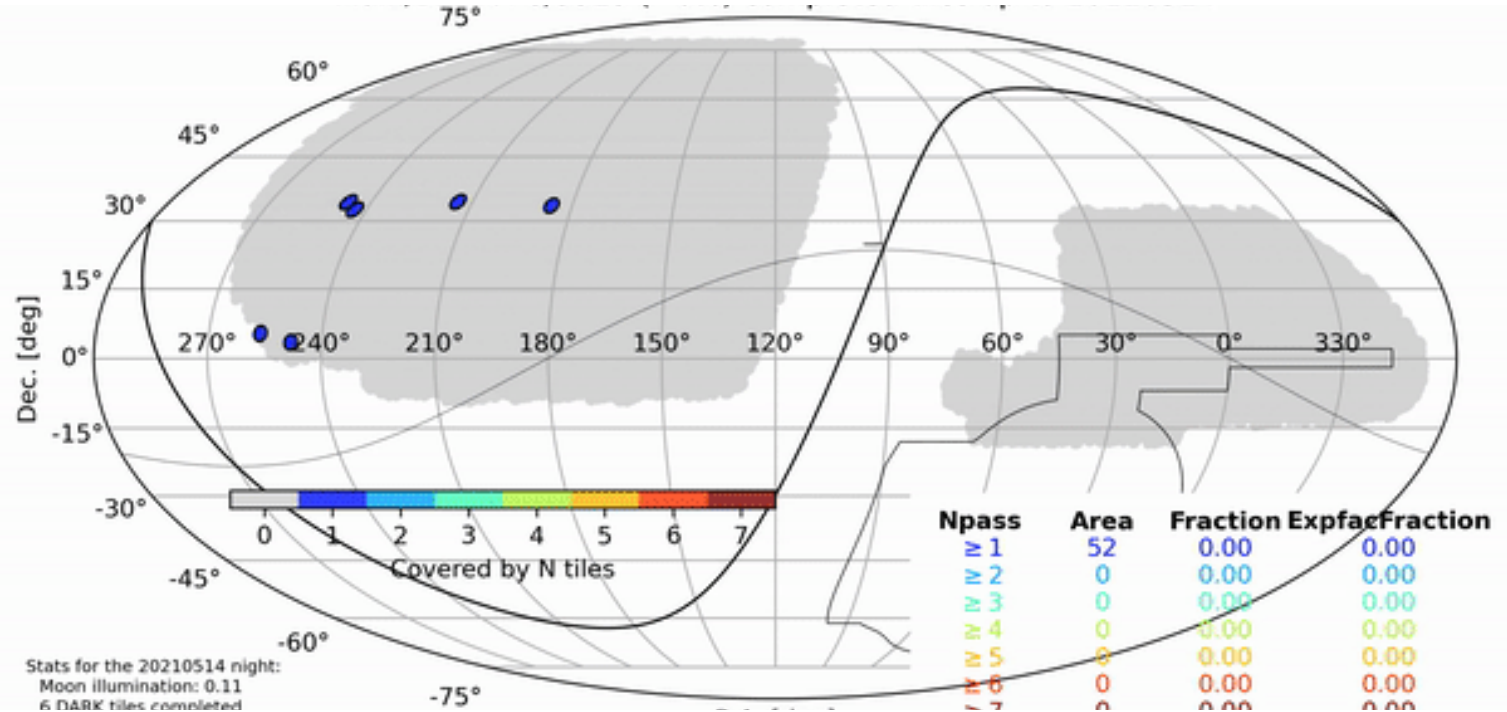
DESI data release 1 (DR1)

Observations from May 14th 2021 to June 12th 2022



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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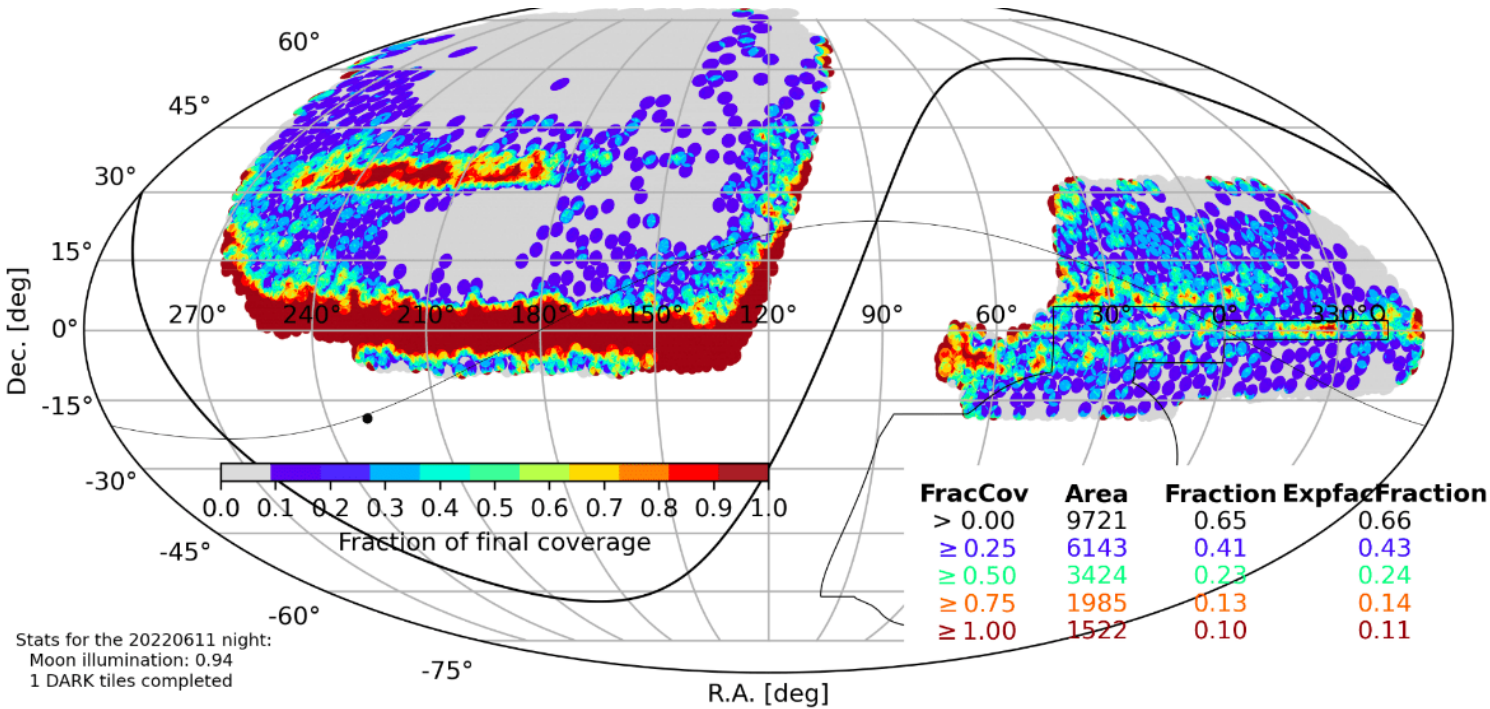
DESI data release 1 (DR1)

Observations from May 14th 2021 to June 12th 2022



	asgn. comp.	Y1 / Y5
BGS	64%	40%
LRG	69%	30%
ELG	35%	21%
QSO	87%	50%

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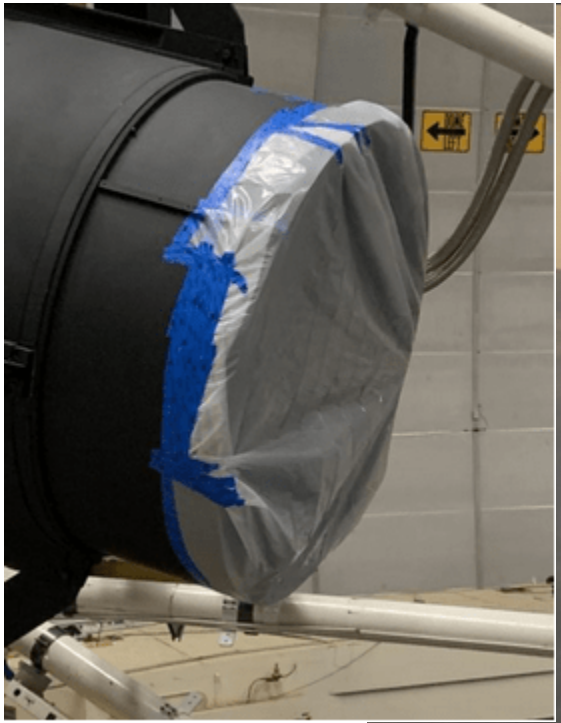
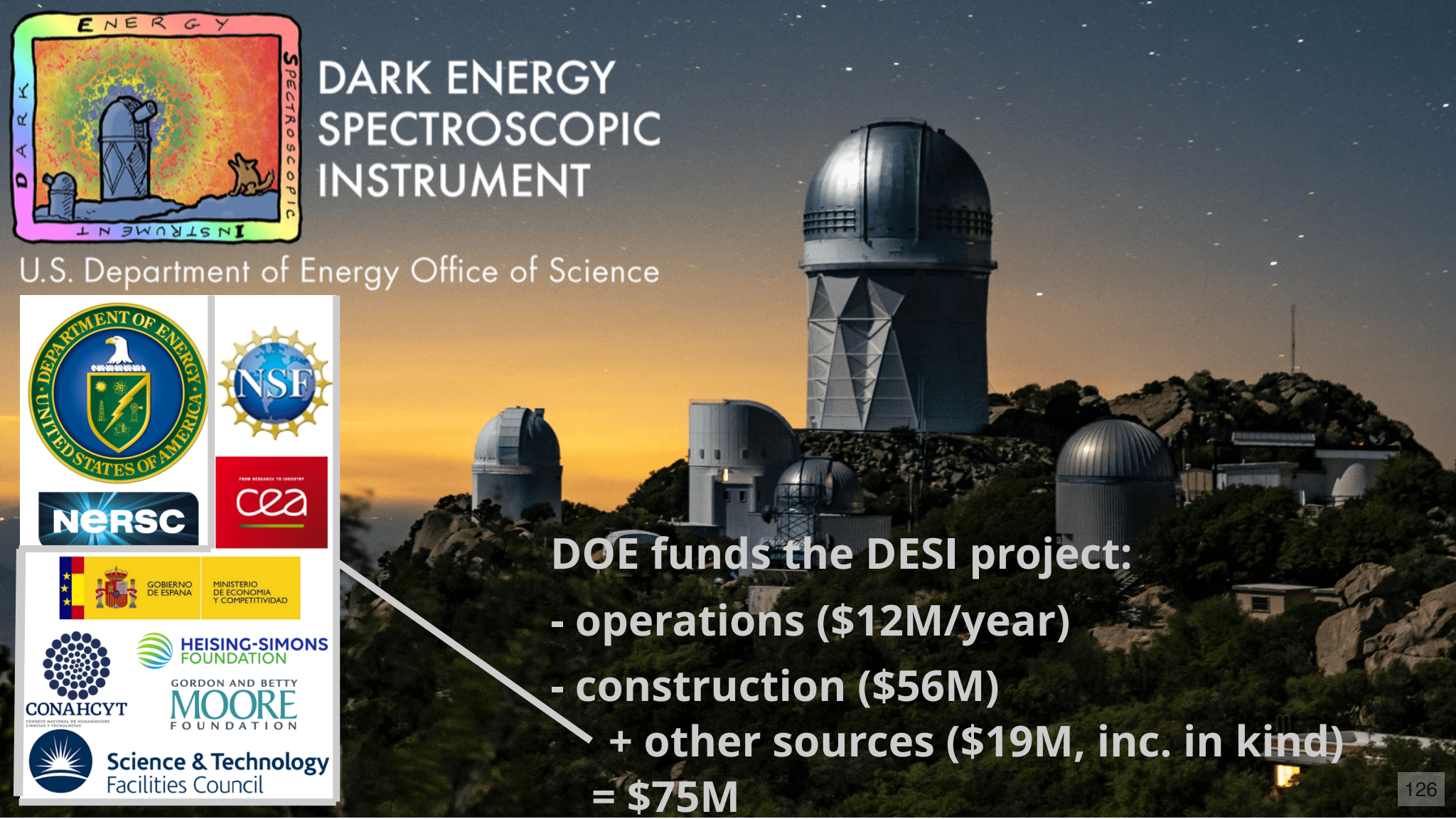
The Contreras Fire (June 11 - 17 2022)



Credit: Bob Stupak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FROM RESEARCH TO INDUSTRY
GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMIA Y COMPETITIVIDAD
CONAHCYT
CONSEJO NACIONAL DE HUMANIDADES CIENCIAS Y TECNOLOGÍAS
HEISING-SIMONS FOUNDATION
GORDON AND BETTY MOORE FOUNDATION
Science & Technology Facilities Council
DOE funds the DESI project:
- operations ($12M/year)
- construction ($56M)
+ other sources ($19M, inc. in kind)
= $75M

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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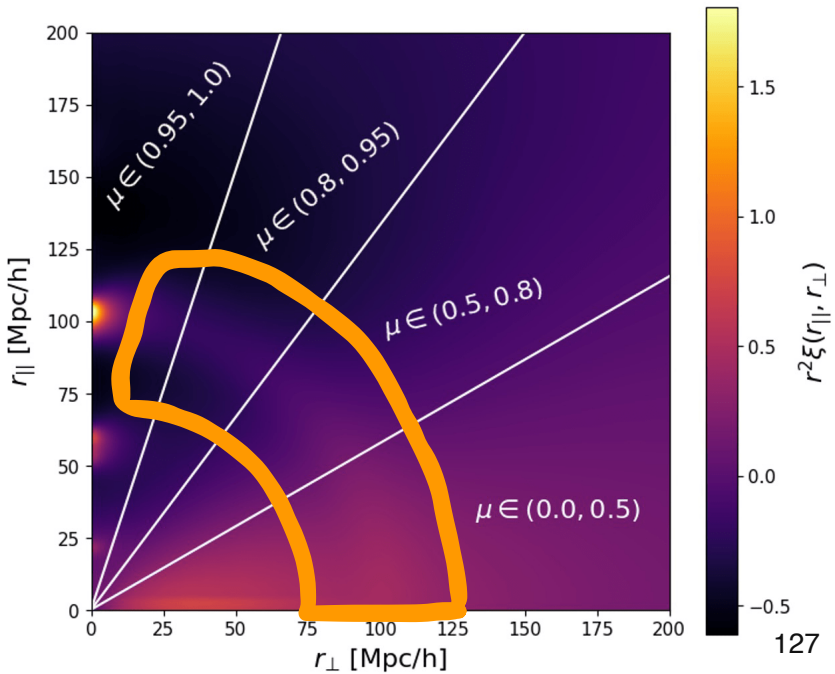
DESI DR1 Lyα BAO analysis

- **Biggest ever Lyα dataset** ($N_{\rm tracer}$)
- **First blind analysis** to mitigate observer / confirmation biases (correlation function-level blinding)
- Modelling of the correlation function:
  - cosmo signal

$$\mu = r_\parallel / \sqrt{r_\parallel^2 + r_\perp^2}$$

$$P_{\rm Ly\alpha}(k,\mu) = b^2(1+\beta\mu^2)^2 P_{\rm lin}(k,\mu) F_{\rm NL}(k,\mu)$$

linear bias + RSD BAO hydro-sim

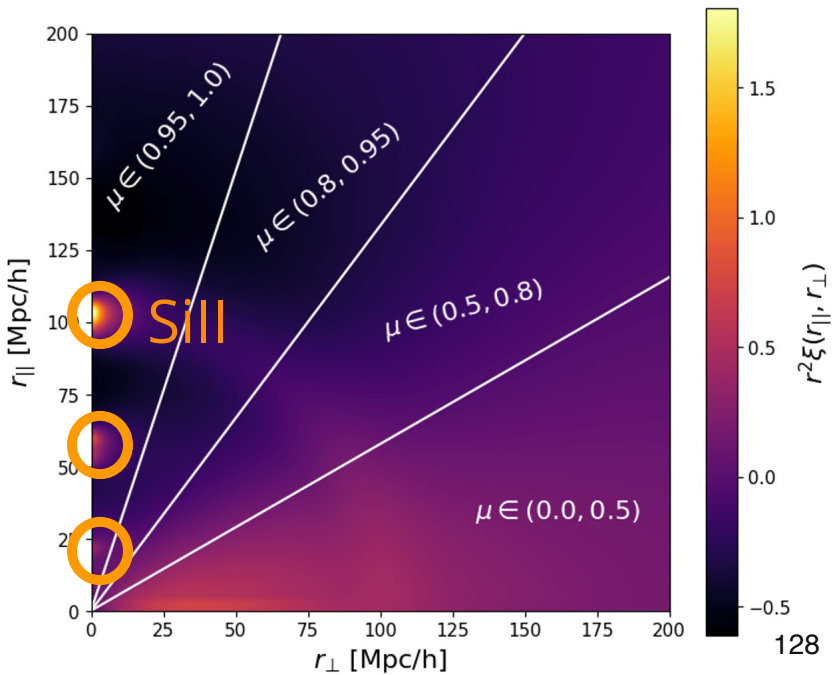


DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI DR1 Lyα BAO analysis

- **Biggest ever Lyα dataset** (N_{tracer})
- **First blind analysis** to mitigate observer / confirmation biases (correlation function-level blinding)
- Modelling of the correlation function:
  - cosmo signal
  - high-column density
  - metal absorbers $r_{\parallel} \propto \left| \frac{1}{\lambda_{\mathrm{Ly}\alpha}} - \frac{1}{\lambda_{\mathrm{metal}}} \right|$

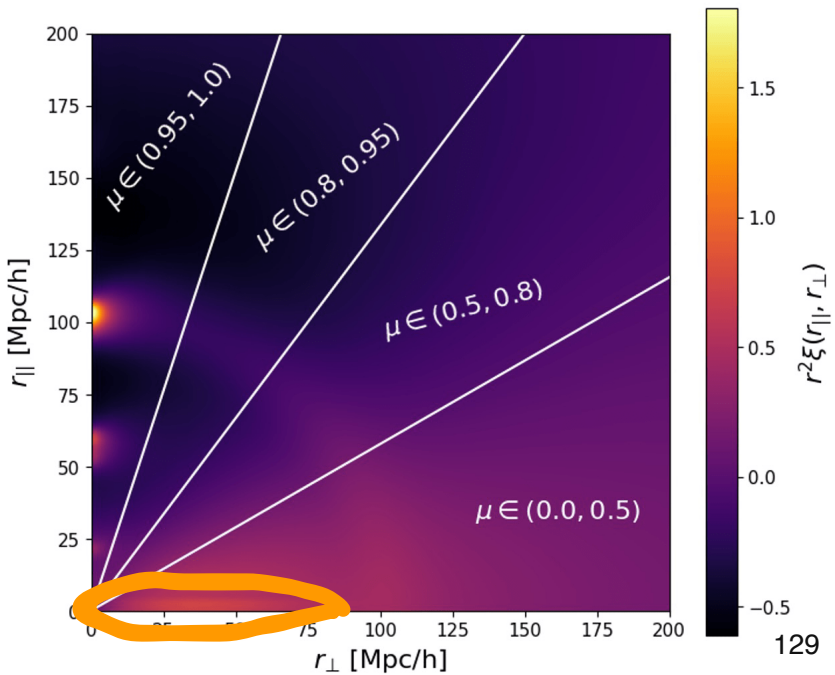


DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DESI DR1 Lyα BAO analysis

- **Biggest ever Lyα dataset** (N_{tracer})
- **First blind analysis** to mitigate observer / confirmation biases (correlation function-level blinding)
- Modelling of the correlation function:
  - cosmo signal
  - high-column density
  - metal absorbers
  - correlated noise (sky subtraction)



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

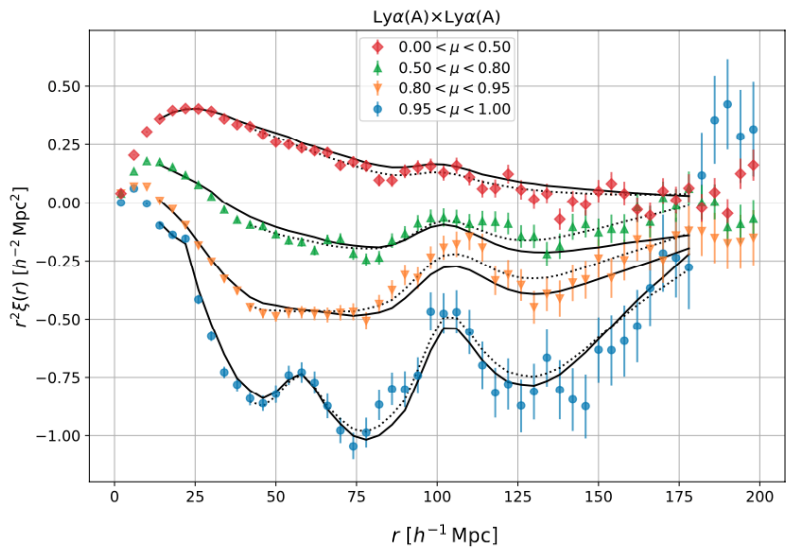
DESI DR1 Lyα BAO analysis

- **Biggest ever Lyα dataset** ($N_{\rm tracer}$)
- **First blind analysis** to mitigate observer / confirmation biases (correlation function-level blinding)
- Modelling of the correlation function

broadband: $< 0.1\sigma$

—— physical model fit

..... + broadband polynomial



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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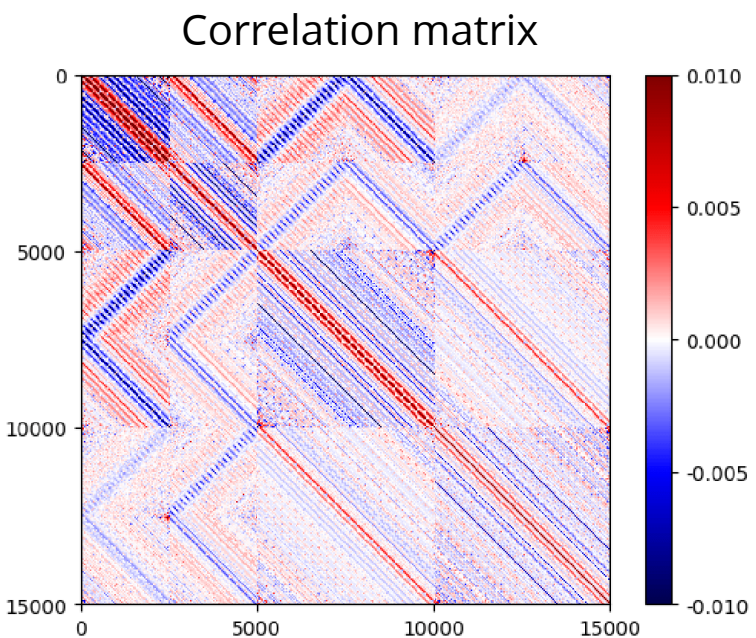
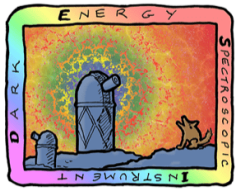
DESI DR1 Lyα BAO analysis

- **Biggest ever Lyα dataset** (N_{tracer})
- **First blind analysis** to mitigate observer / confirmation biases (correlation function-level blinding)
- Modelling of the correlation function
- Cross-covariance matrix

  smoothed jackknife, validated with mocks

  10% impact on BAO uncertainty





DARK ENERGY SPECTROSCOPIC INSTRUMENT

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DESI DR1 Lyα BAO analysis

- **Biggest ever Lyα dataset** (N_{tracer})
- **First blind analysis** to mitigate observer / confirmation biases (correlation function-level blinding)
- Modelling of the correlation function
- Cross-covariance matrix
- Very stable results, systematic uncertainty neglected

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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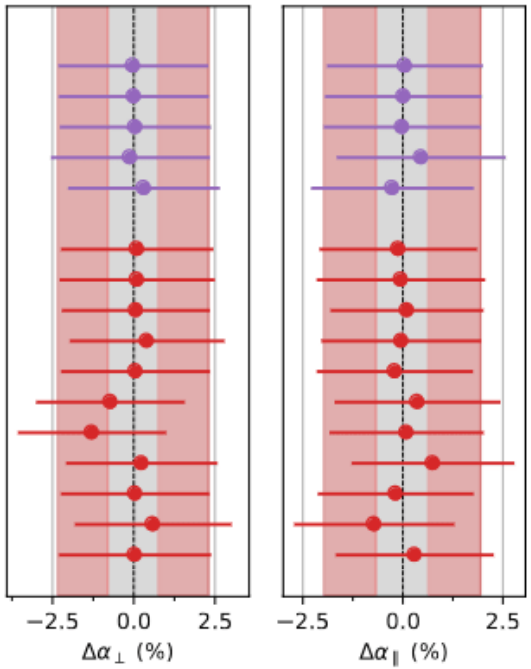
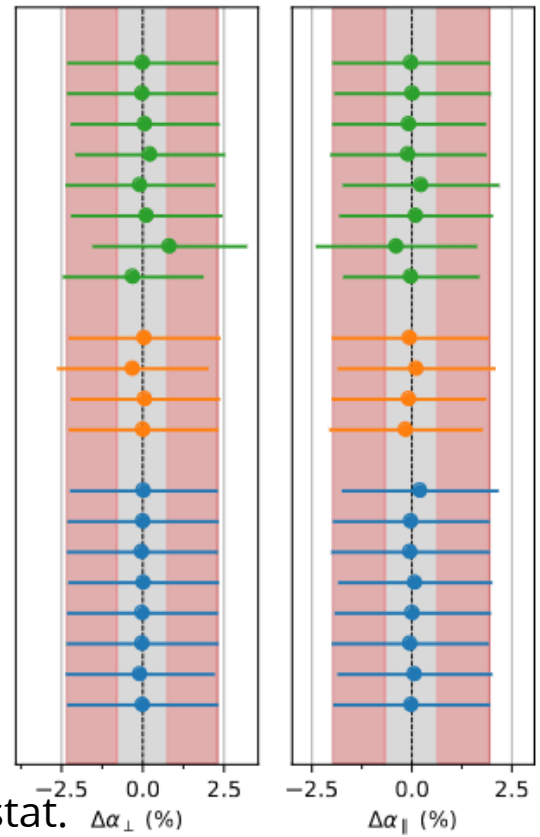
Tests of systematic errors



no calibration
$\eta_{pip} = 1$
ϵ free
$\eta_{LSS} = 3.5$
$\Delta\lambda = 2.4\,Å$

$\lambda_{obs} < 5500\,Å$
$\lambda_{obs} > 3650\,Å$
$\lambda_{RF} < 1200\,Å$
$z_Q < 3.78$
> 50 pixels in forest
original redshift estimates
mask-Lya redshift estimate
only quasar targets
DLAs SNR > 1
weak BALs
no sharp lines mask



dmat $r_\parallel < 200$ Mpc/h
dmat 2%
dmat model 4 Mpc/h
$\Delta\lambda = 3.2\,Å$
$\Delta\lambda = 1.6\,Å$
nside = 32
$\Delta r = 5$ Mpc/h
no cross-covariance

$r < 200$ Mpc/h
$r < 160$ Mpc/h
$r > 20$ Mpc/h
$r > 40$ Mpc/h with priors

eBOSS metals
vary L_{HCD}
$L_{HCD} = 10$ Mpc/h
$L_{HCD} = 3$ Mpc/h
Gaussian redshift errors
weak CIV bias prior
no small-scales correction
UV fluctuations

tests with same dataset (not red): shifts $< \sigma_{stat}/3$

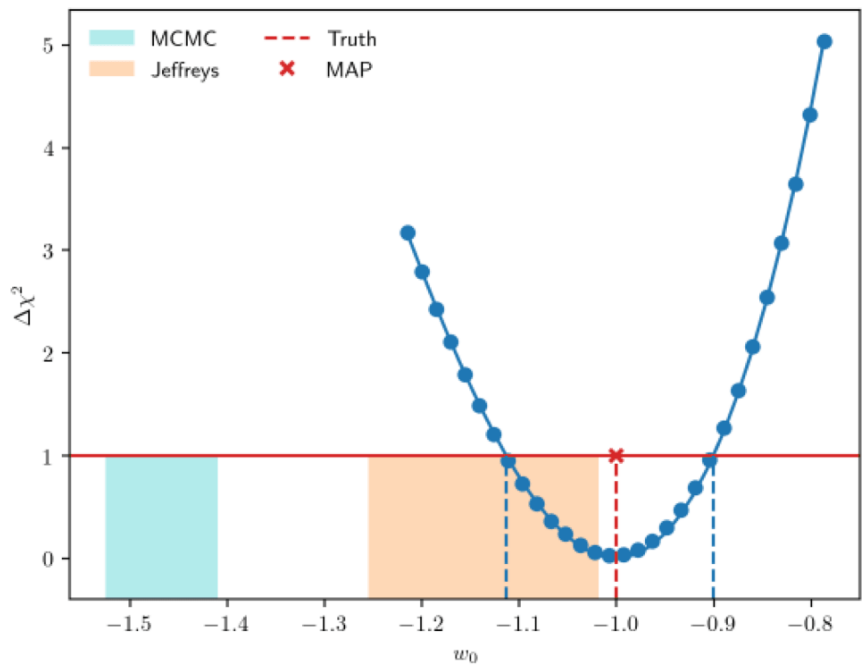
tests with varying datasets (red): shifts consistent with stat.

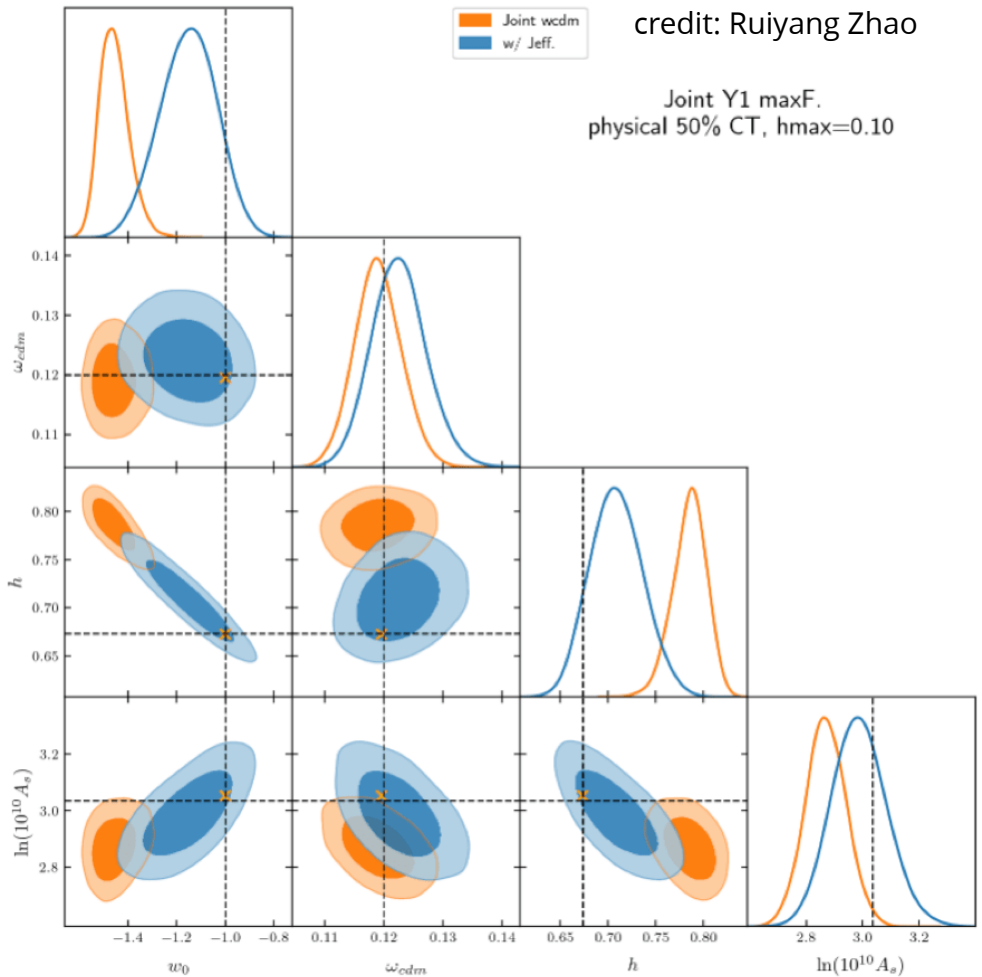
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Full shape analysis

Prior volume effects





credit: Ruiyang Zhao

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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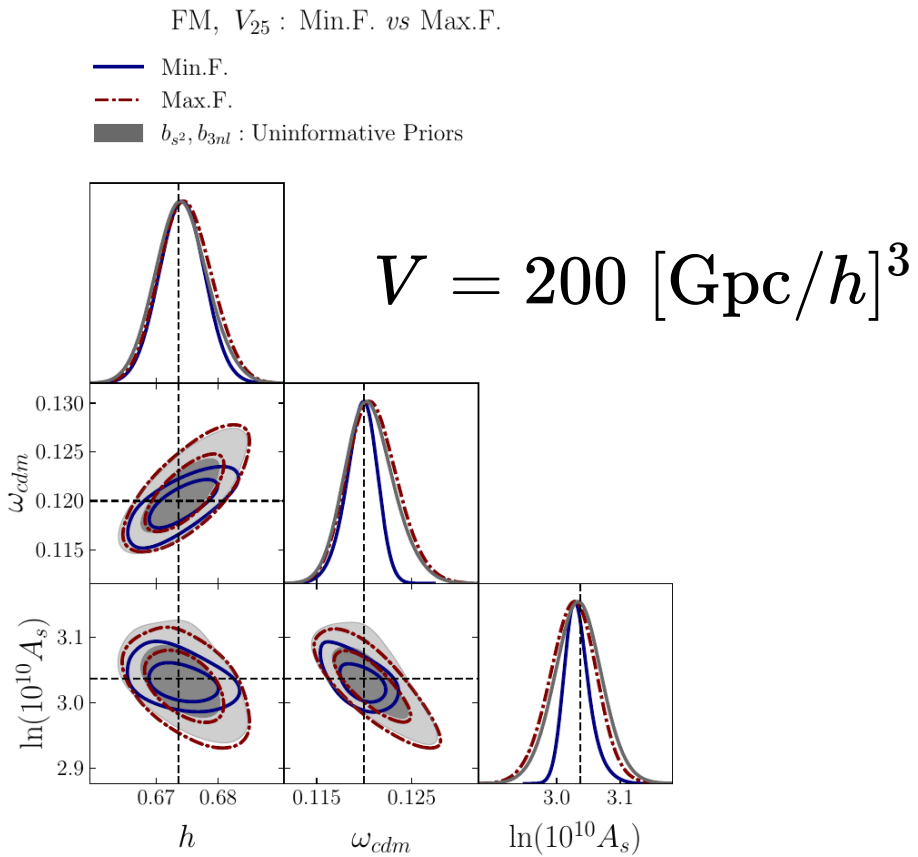
Full shape analysis

Tests: bias parameterization

- *maximal freedom*: all 4 bias parameter free
- *minimal freedom*: b_s, b_3 fixed (co-evolution)



credit: Hernan Noriega

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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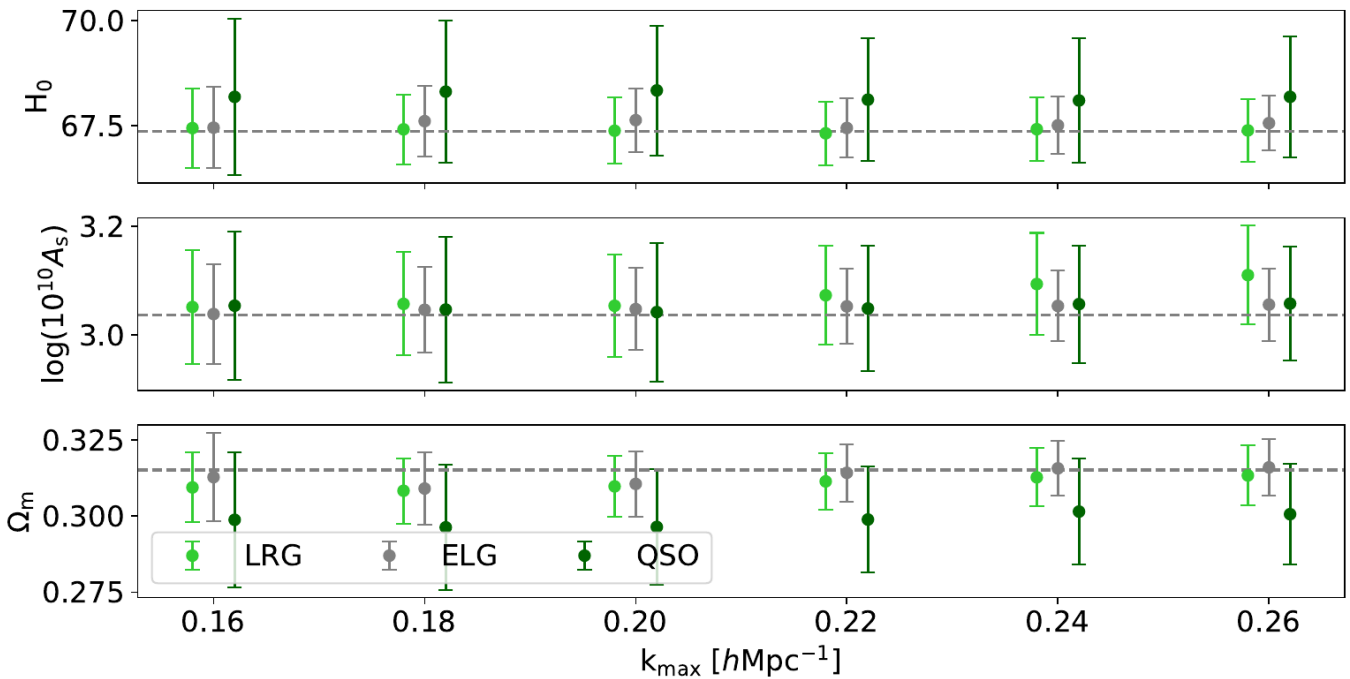
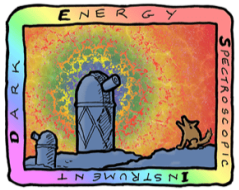
Full shape analysis

Tests: stability with $k_{\rm max}$

$$V = 8\ [{\rm Gpc}/h]^3$$



credit: Mark Maus



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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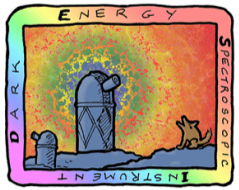
Other datasets

- SDSS BAO (for comparisons only): eBOSS Collaboration, 2020
- Primary CMB: Planck Collaboration, 2018
- CMB lensing: Planck PR4 + ACT DR6 lensing ACT Collaboration, 2023, Carron, Mirmelstein, Lewis, 2022
- BBN: Schöneberg et al., 2024
- SN: Pantheon+ Brout, Scolnic, Popovic et al., 2022, Union3 Rubin, Aldering, Betoule et al. 2023, DES-SN5YR DES Collaboration



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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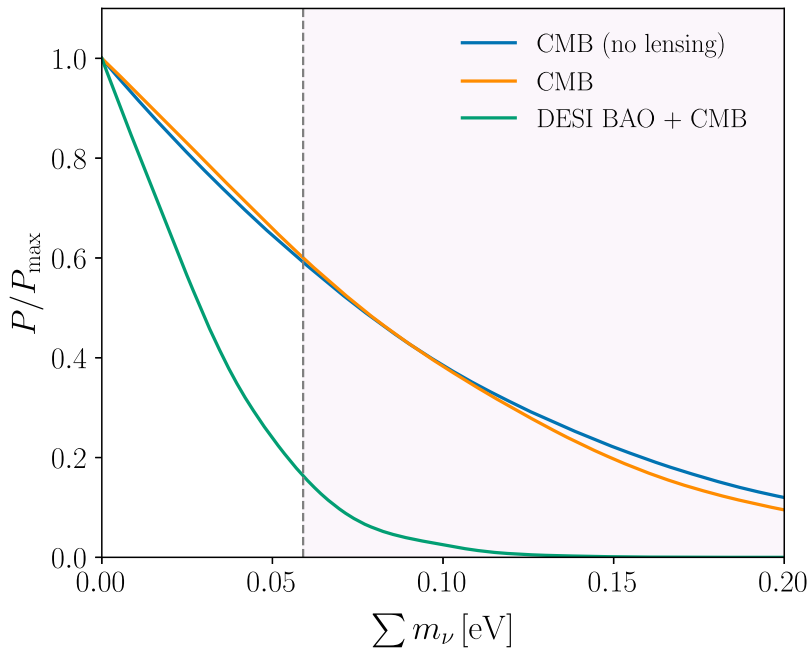
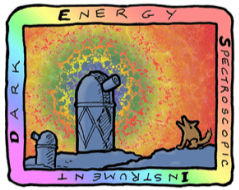
Neutrino mass hierarchies

With $> 0.059\,\mathrm{eV}$ prior (NH)

$$\sum m_\nu < 0.113\,\mathrm{eV}\ (95\%, \mathrm{DESI} + \mathrm{CMB})$$





DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

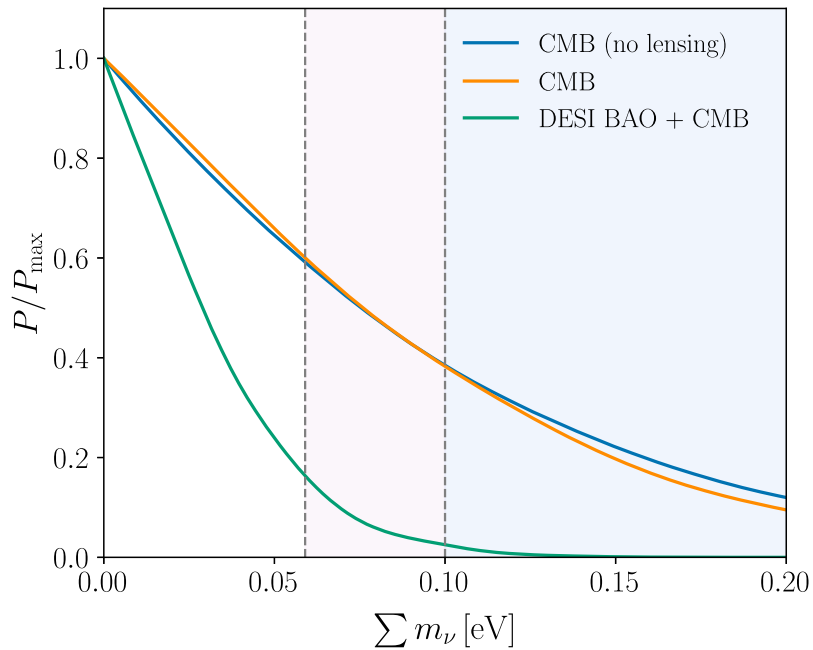
Neutrino mass hierarchies

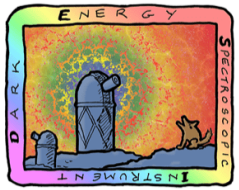
With $> 0.059\,\mathrm{eV}$ prior (NH)

$$\sum m_\nu < 0.113\,\mathrm{eV}\ (95\%, \mathrm{DESI} + \mathrm{CMB})$$

With $> 0.1\,\mathrm{eV}$ prior (IH)

$$\sum m_\nu < 0.145\,\mathrm{eV}\ (95\%, \mathrm{DESI} + \mathrm{CMB})$$





DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Neutrino mass hierarchies

With $> 0.059\,\mathrm{eV}$ prior (NH)

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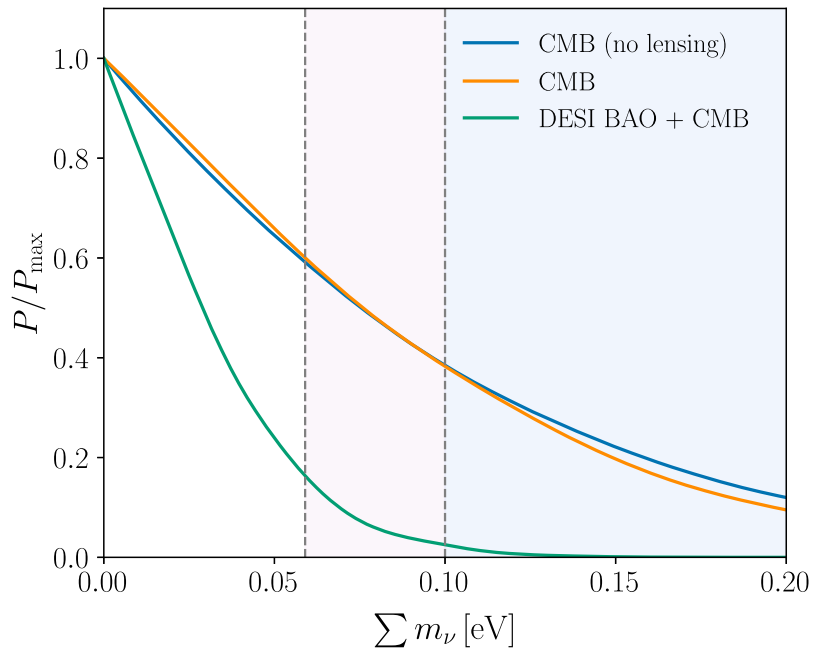
$$\sum m_\nu < 0.145\,\mathrm{eV}\ (95\%, \mathrm{DESI} + \mathrm{CMB})$$



Current constraints do not strongly favor normal over inverted hierarchy ($\simeq 2\sigma$)

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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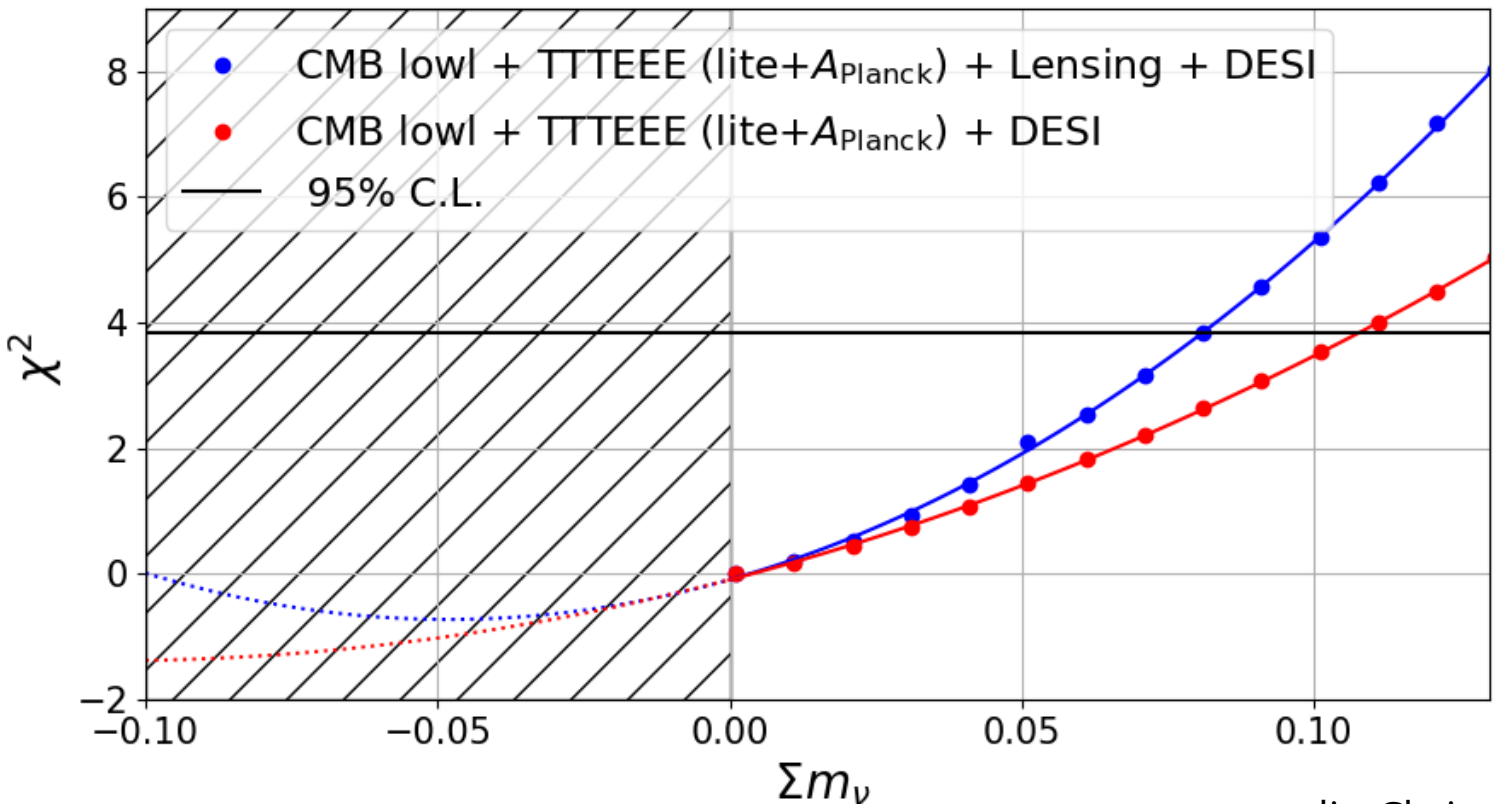
$\sum m_\nu$

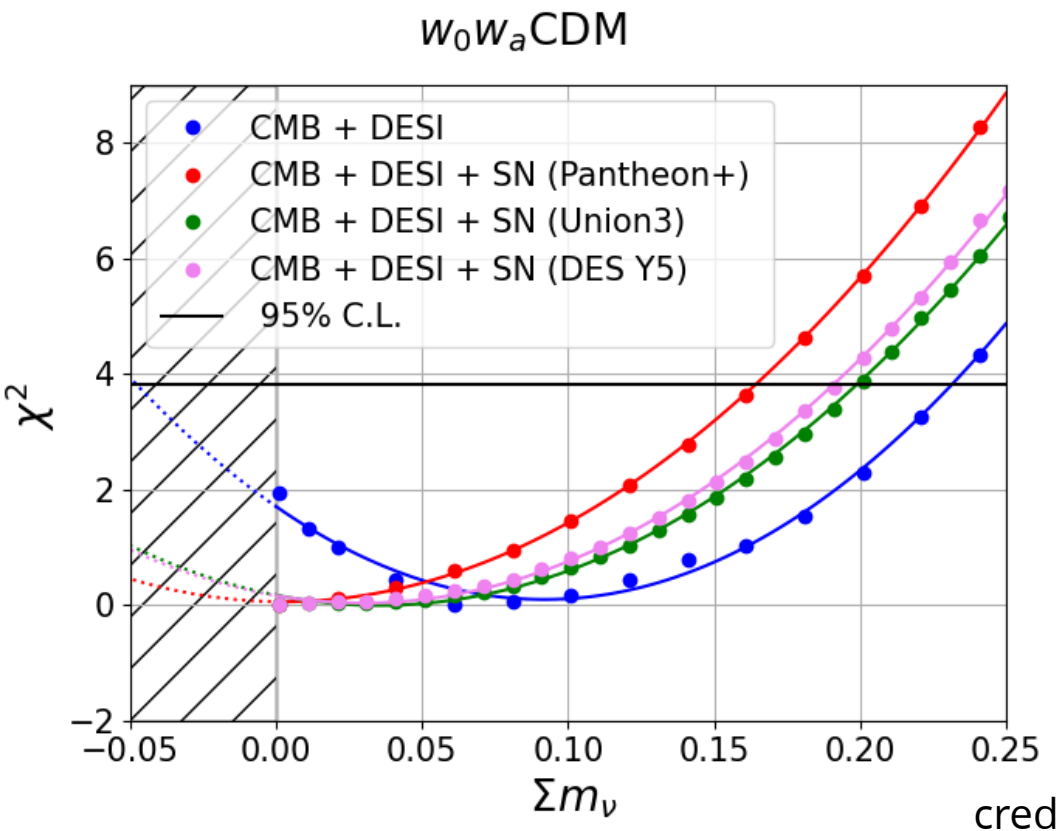


credit: Christophe Yèche

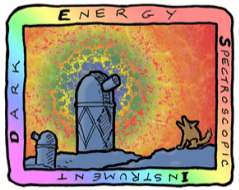
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

$\sum m_\nu$



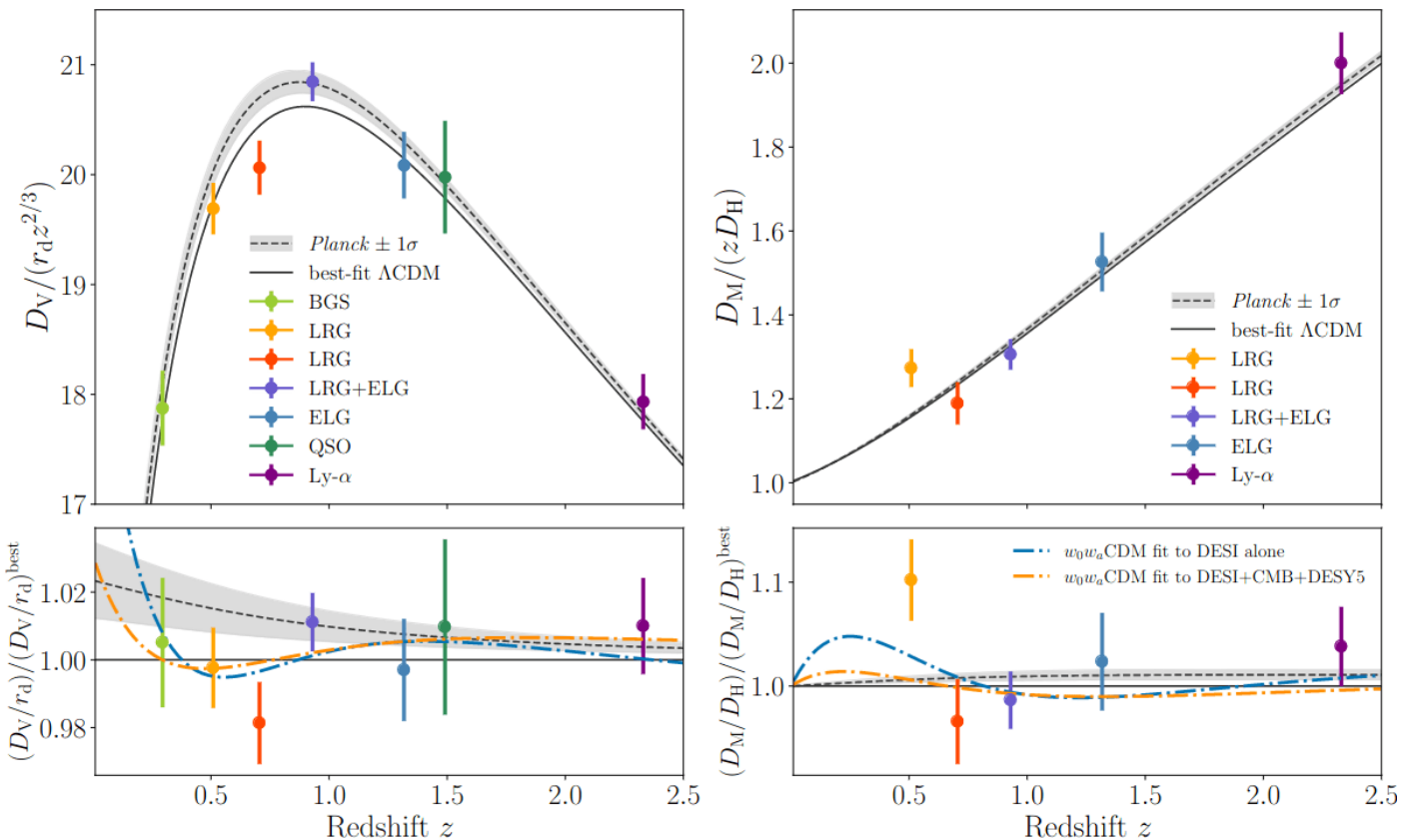
credit: Christophe Yèche



DARK ENERGY SPECTROSCOPIC INSTRUMENT

$w(z)$

U.S. Department of Energy Office of Science



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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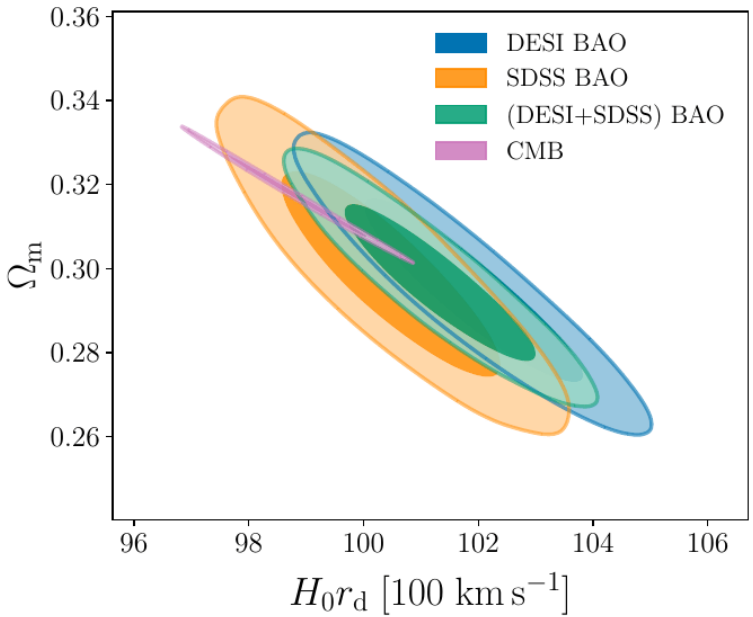
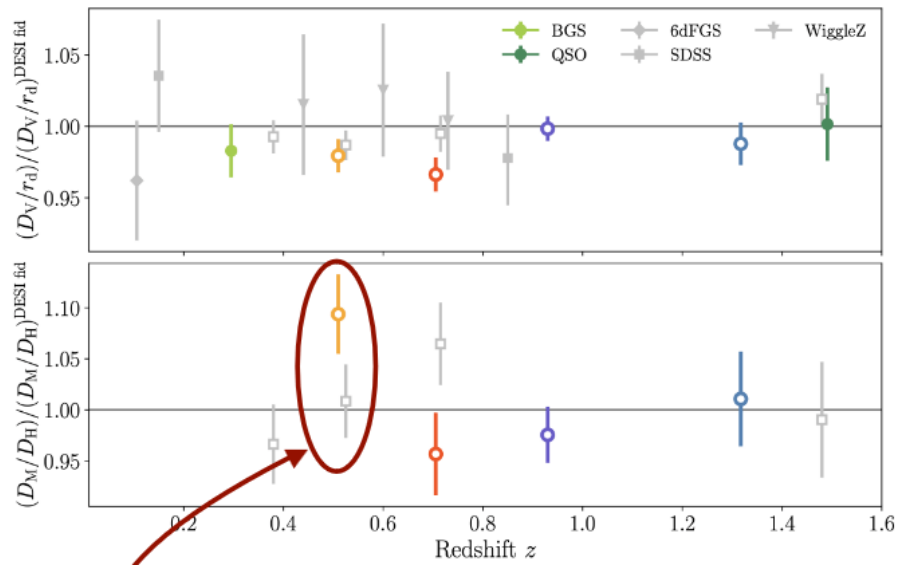
DESI - SDSS consistency (Ω_m)



Perfectly consistent!



Using these 2 points alone moves Ω_m by $< 2\sigma$

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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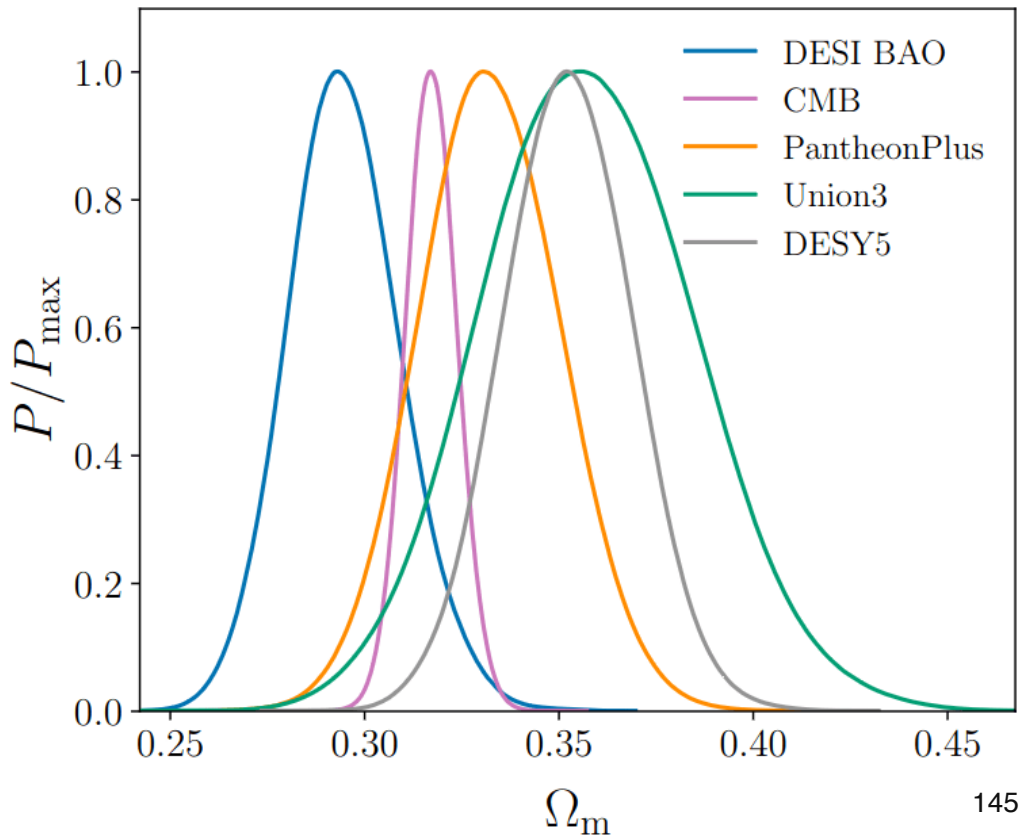
Are SN Ω_m consistent?

Not so much in flat ΛCDM...

(so we do not combine them in this model!)



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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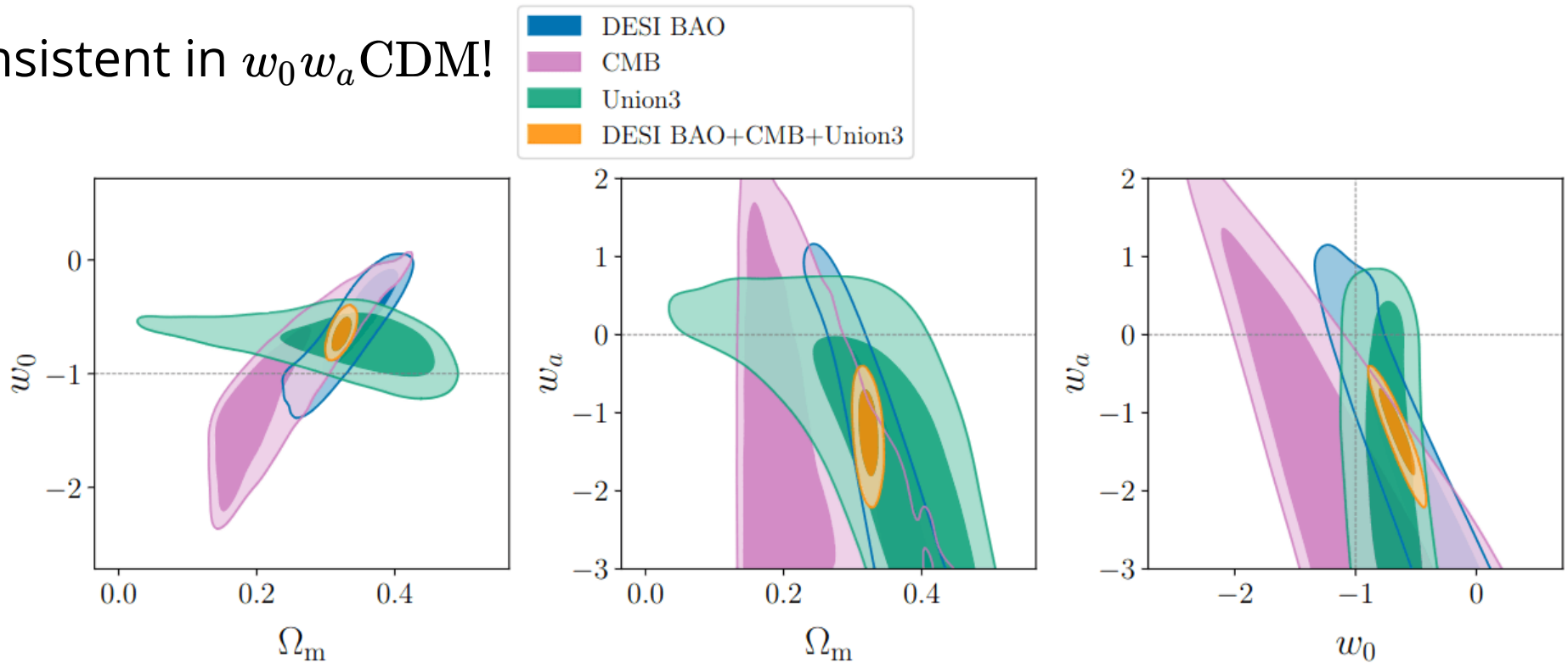
Are SN Ω_m consistent?

Consistent in $w_0 w_a$CDM!



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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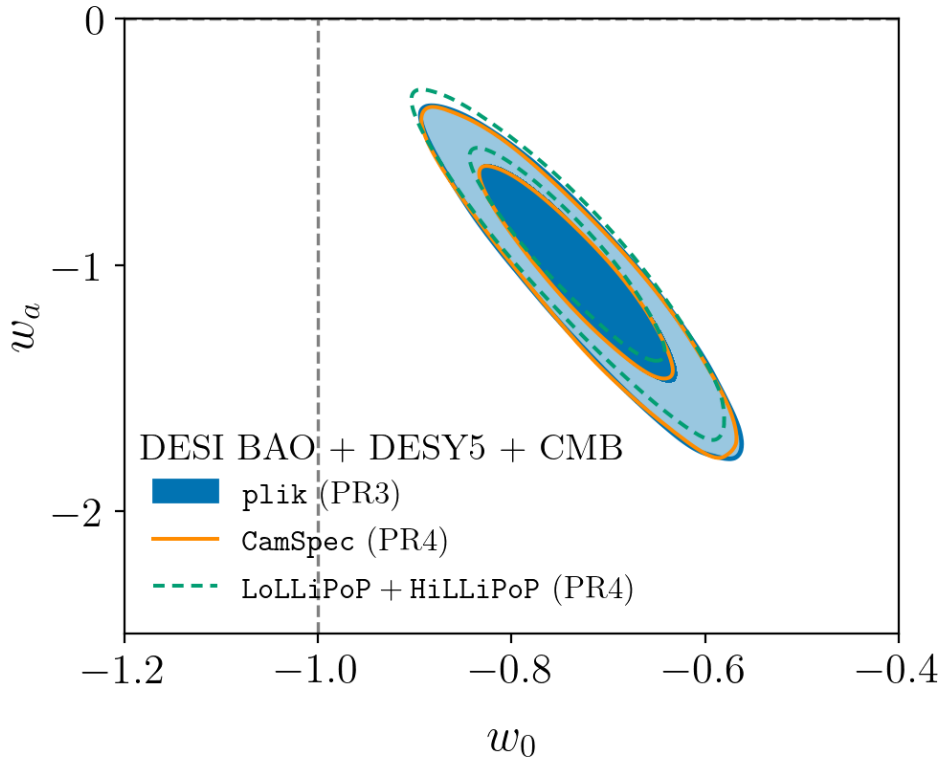
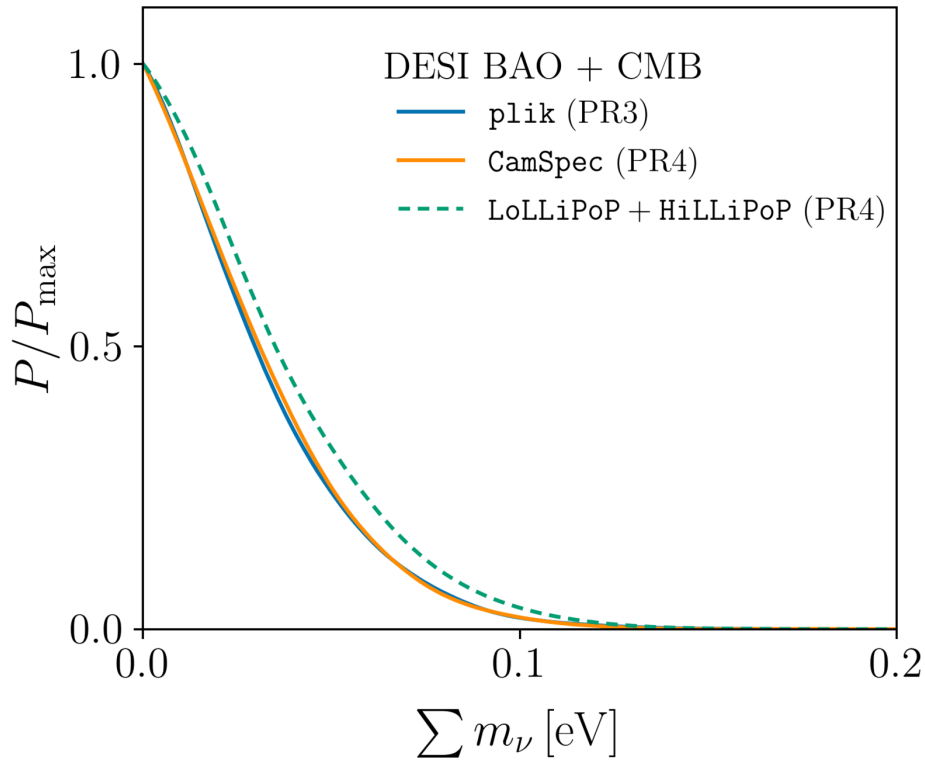
plik (PR3) vs PR4 Planck likelihoods

Appendix B





DARK ENERGY SPECTROSCOPIC INSTRUMENT

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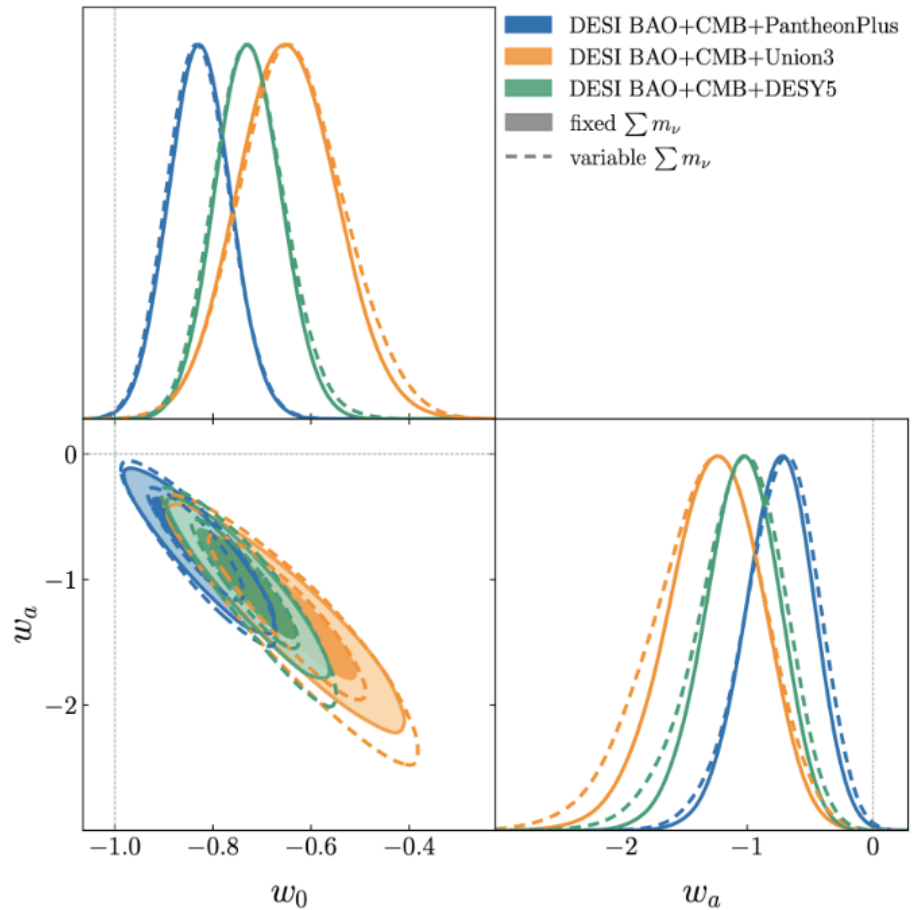
$w_0 - w_a$ with $\sum m_\nu$ free



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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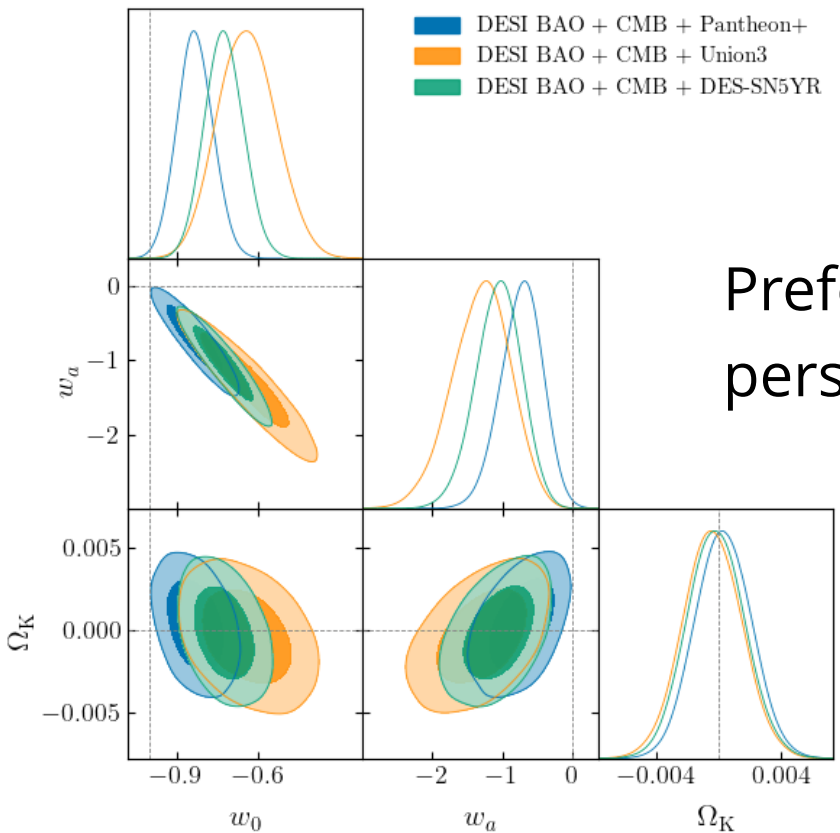
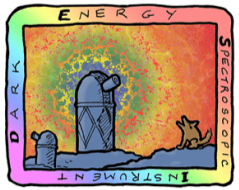
$w_0 - w_a$ with Ω_K



Preference for $w_0 > -1, w_a < 0$ persists when curvature is left free



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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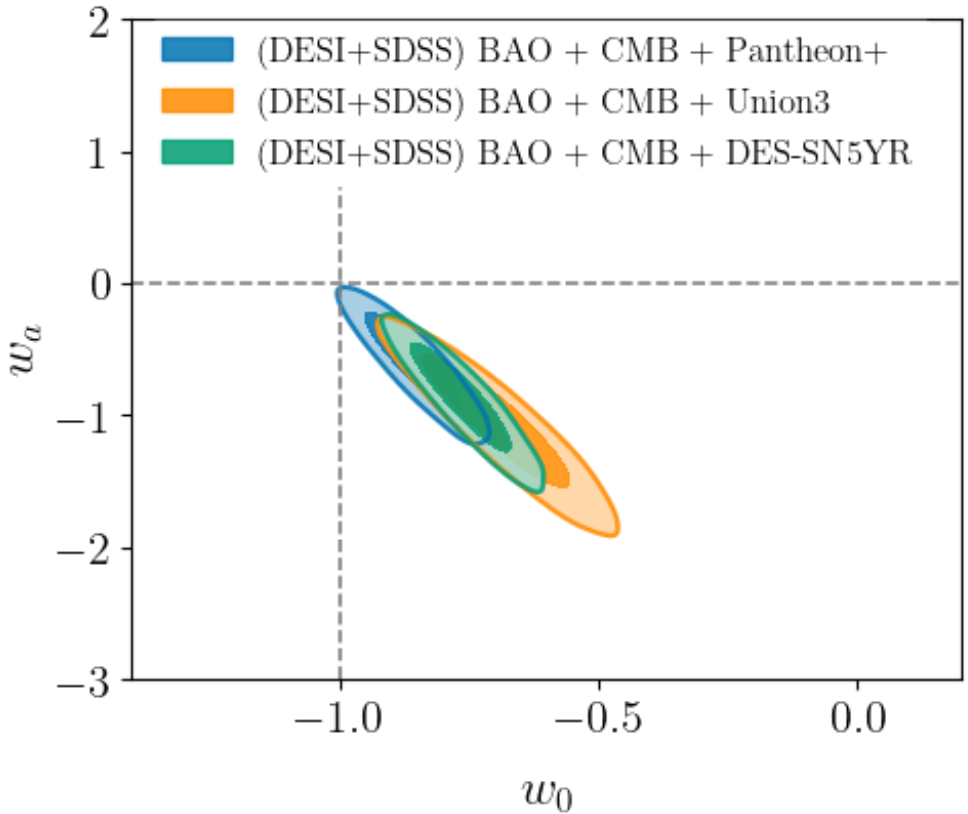
DE constraints driven by low-z ?

Not that much!

DESI + SDSS swaps DESI measurements with SDSS for $z < 0.6$

-0.4σ compared to DESI only



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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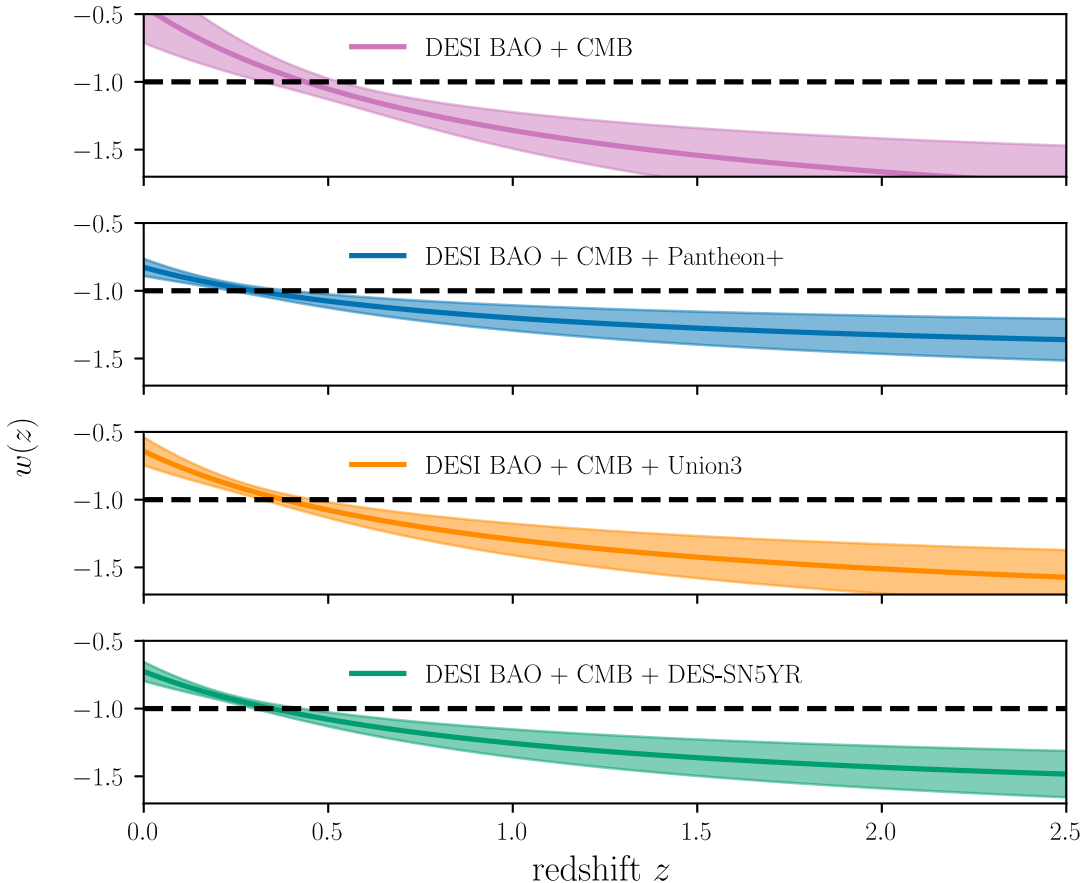
$w(z)$



DARK ENERGY SPECTROSCOPIC INSTRUMENT

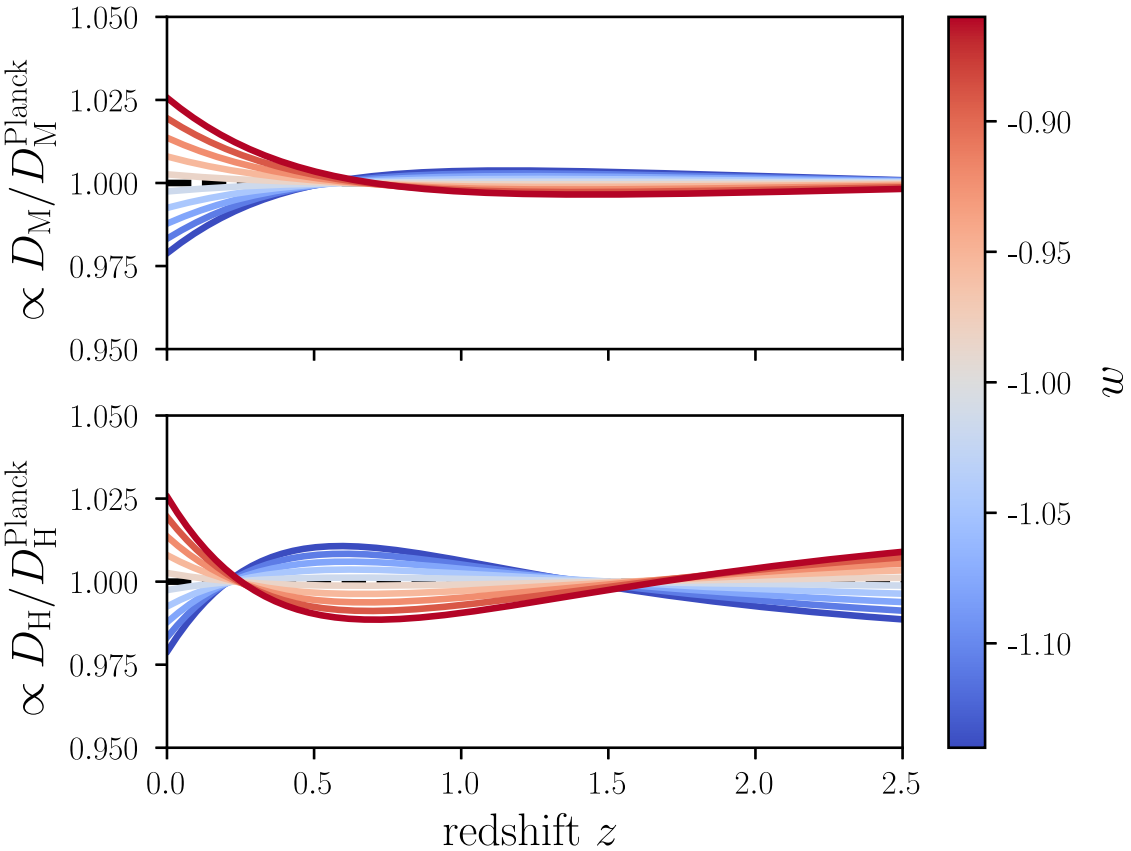
U.S. Department of Energy Office of Science

BAO measurements: dark energy

Dark energy equation of state:

$$P = w\rho$$

- w = constant



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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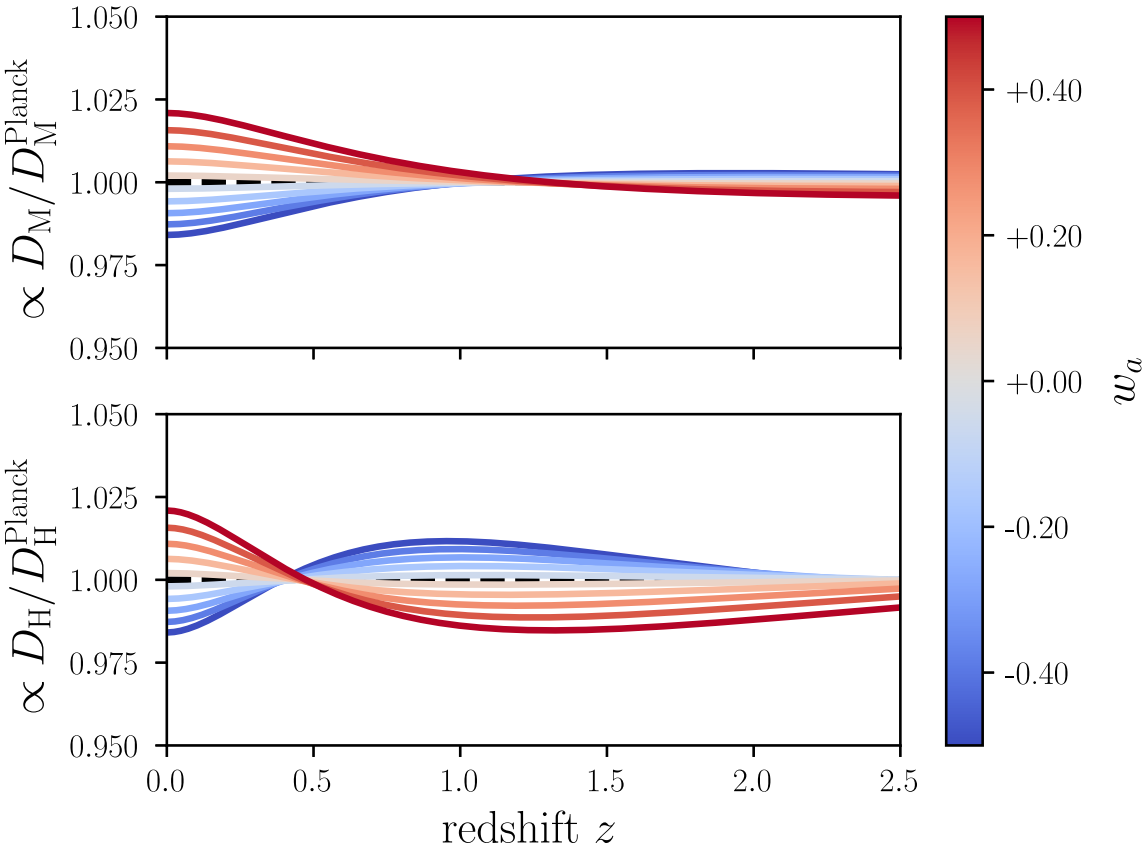
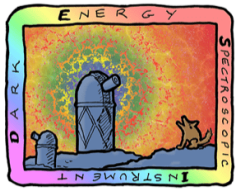
BAO measurements: dark energy

Dark energy equation of state:

$$P = w\rho$$

- CPL parameterization:
  $w(a) = w_0 + (1-a)w_a$



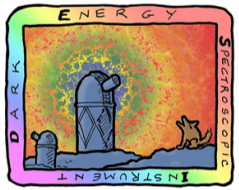


DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Full tables

model/dataset	$\Omega_{\rm m}$	H_0 $[{\rm km\,s^{-1}\,Mpc^{-1}}]$	$10^3\Omega_{\rm K}$	w or w_0	w_a
Flat ΛCDM					
DESI	0.295 ± 0.015	—	—	—	—
DESI+BBN	0.295 ± 0.015	68.53 ± 0.80	—	—	—
DESI+BBN+θ_*	0.2948 ± 0.0074	68.52 ± 0.62	—	—	—
DESI+CMB	0.3069 ± 0.0050	67.97 ± 0.38	—	—	–
ΛCDM+$\Omega_{\rm K}$					
DESI	0.284 ± 0.020	—	65^{+68}_{-78}	—	—
DESI+BBN+θ_*	0.296 ± 0.014	68.52 ± 0.69	$0.3^{+4.8}_{-5.4}$	—	—
DESI+CMB	0.3049 ± 0.0051	68.51 ± 0.52	2.4 ± 1.6	—	—



DARK ENERGY SPECTROSCOPIC INSTRUMENT

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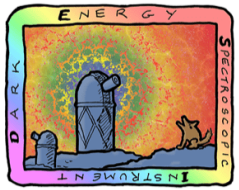
Full tables

model/dataset	$\Omega_{\rm m}$	H_0 $[\,{\rm km\,s^{-1}\,Mpc^{-1}}]$	$10^3\Omega_{\rm K}$	w or w_0	w_a
wCDM					
DESI	0.293 ± 0.015	—	—	$-0.99^{+0.15}_{-0.13}$	—
DESI+BBN+θ_*	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+θ_*	$0.338^{+0.039}_{-0.029}$	$65.0^{+2.3}_{-3.6}$	—	$-0.53^{+0.42}_{-0.22}$	< -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	$-1.05^{+0.31}_{-0.27}$
w_0w_aCDM+$\Omega_{\rm K}$					
DESI	0.313 ± 0.049	—	87^{+100}_{-85}	$-0.70^{+0.49}_{-0.25}$	< -1.21
DESI+BBN+θ_*	$0.346^{+0.042}_{-0.024}$	$65.8^{+2.6}_{-3.5}$	$5.9^{+9.1}_{-6.9}$	$-0.52^{+0.38}_{-0.19}$	< -1.44
DESI+CMB	$0.347^{+0.031}_{-0.025}$	$64.3^{+2.0}_{-3.2}$	-0.9 ± 2	$-0.41^{+0.33}_{-0.18}$	< -1.61
DESI+CMB+Panth.	0.3084 ± 0.0067	68.06 ± 0.74	0.3 ± 1.8	-0.831 ± 0.066	$-0.73^{+0.32}_{-0.28}$
DESI+CMB+Union3	$0.3233^{+0.0089}_{-0.010}$	66.45 ± 0.98	-0.4 ± 1.9	-0.64 ± 0.11	$-1.30^{+0.45}_{-0.39}$
DESI+CMB+DESY5	0.3163 ± 0.0065	67.19 ± 0.69	-0.2 ± 1.9	-0.725 ± 0.071	$-1.06^{+0.35}_{-0.31}$

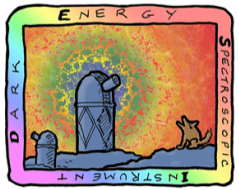


DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Full tables

model / dataset	$\Omega_{\rm m}$	H_0 [km s^{-1} Mpc^{-1}]	Σm_ν [eV]	$N_{\rm eff}$
ΛCDM+$\sum m_\nu$				
DESI+CMB	0.3037 ± 0.0053	68.27 ± 0.42	< 0.072	—
ΛCDM+$N_{\rm eff}$				
DESI+CMB	0.3058 ± 0.0060	68.3 ± 1.1	—	3.10 ± 0.17
wCDM+$\sum m_\nu$				
DESI+CMB	0.282 ± 0.013	$71.1^{+1.5}_{-1.8}$	< 0.123	—
DESI+CMB+Panth.	0.3081 ± 0.0067	67.81 ± 0.69	< 0.079	—
DESI+CMB+Union3	0.3090 ± 0.0082	67.72 ± 0.88	< 0.078	—
DESI+CMB+DESY5	0.3152 ± 0.0065	67.01 ± 0.64	< 0.073	—
wCDM+$N_{\rm eff}$				
DESI+CMB	0.281 ± 0.013	$71.0^{+1.6}_{-1.8}$	—	2.97 ± 0.18
DESI+CMB+Panth.	0.3090 ± 0.0068	67.9 ± 1.1	—	3.07 ± 0.18
DESI+CMB+Union3	0.3097 ± 0.0084	67.8 ± 1.2	—	3.06 ± 0.18
DESI+CMB+DESY5	0.3163 ± 0.0067	67.2 ± 1.1	—	3.09 ± 0.18



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

Full tables

model / dataset	$\Omega_{\rm m}$	H_0 [km s^{-1} Mpc^{-1}]	Σm_ν [eV]	$N_{\rm eff}$
w_0w_aCDM+$\sum m_\nu$				
DESI+CMB	$0.344^{+0.032}_{-0.026}$	$64.7^{+2.1}_{-3.2}$	< 0.195	
DESI+CMB+Panth.	0.3081 ± 0.0069	68.07 ± 0.72	< 0.155	—
DESI+CMB+Union3	0.3240 ± 0.0098	66.48 ± 0.94	< 0.185	—
DESI+CMB+DESY5	0.3165 ± 0.0069	67.22 ± 0.66	< 0.177	—
w_0w_aCDM+$N_{\rm eff}$				
DESI+CMB	$0.346^{+0.032}_{-0.026}$	$63.9^{+2.2}_{-3.3}$	—	2.89 ± 0.17
DESI+CMB+Panth.	0.3093 ± 0.0069	67.5 ± 1.1	—	2.93 ± 0.18
DESI+CMB+Union3	0.3245 ± 0.0098	65.9 ± 1.3	—	2.91 ± 0.18
DESI+CMB+DESY5	0.3172 ± 0.0067	66.6 ± 1.1	—	2.92 ± 0.18