# Results from DESI data using BAO (and RSD)

Héctor Gil-Marín - Institut de Ciències del Cosmos (U. Barcelona)

New Strategies for Extracting Cosmology from Galaxy Surveys (Sexten)
2nd July 2024

On behalf of the DESI Collaboration

Institut de Ciències del Cosmos
UNIVERSITAT DE BARCELONA
ICCUB
EXCELENCIA MARÍA DE MAEZTU 2020-2023

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

NSF

NERSC

FROM RESEARCH TO INDUSTRY cea

GOBIERNO DE ESPAÑA · MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

CONACYT

HEISING-SIMONS FOUNDATION

GORDON AND BETTY MOORE FOUNDATION

Science & Technology Facilities Council

Thanks to our sponsors and
72 Participating Institutions!

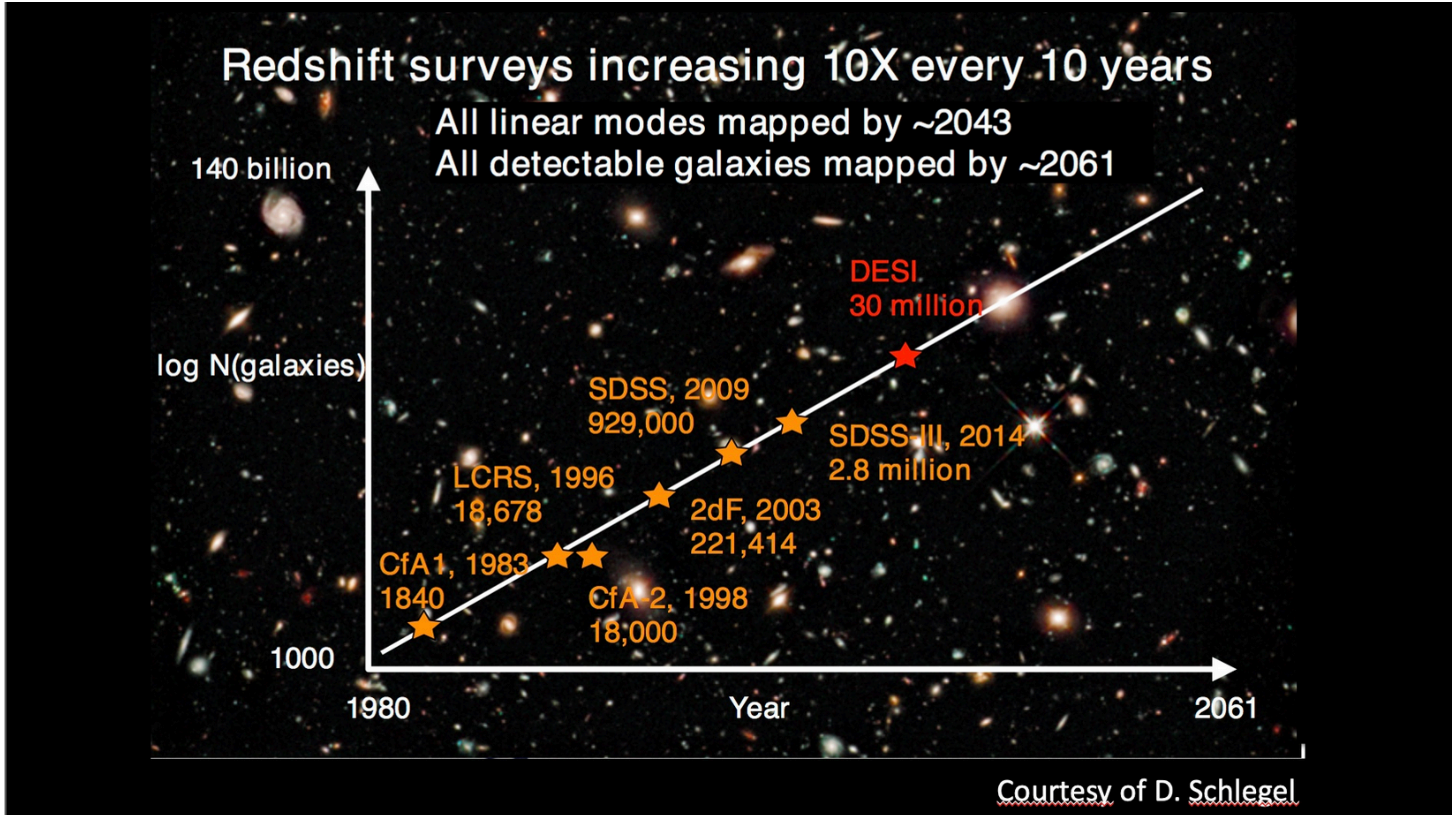
DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# Outline

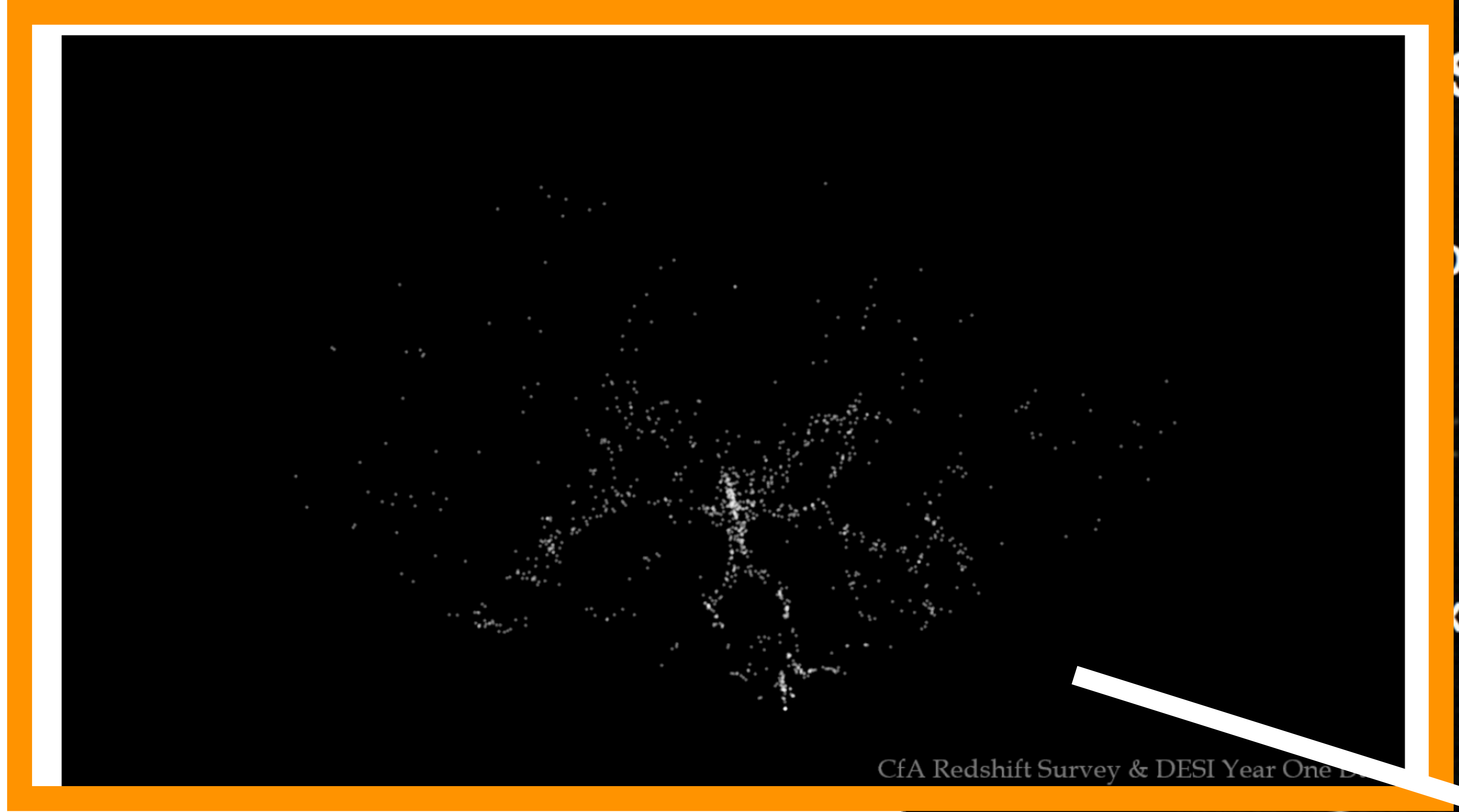
- ✦ The Dark Energy Spectroscopic Instrument
    - ✦ Galaxies, quasars and Ly-α
- ✦ The key science targets: the BAO and RSD
    - ✦ Blind analysis
    - ✦ BAO measurements
- ✦ DESI DR1 cosmology

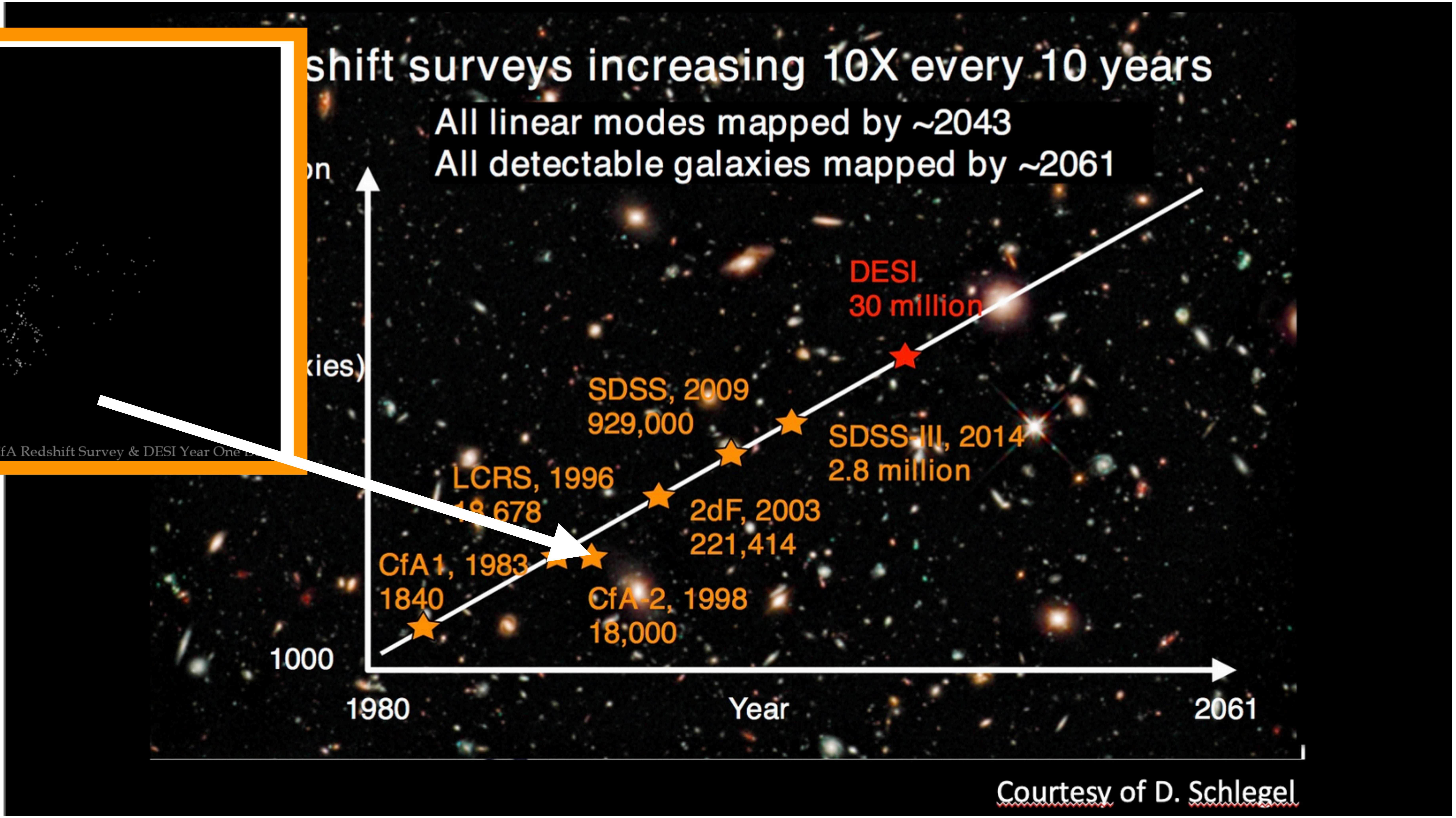
# A brief history of galaxy redshift surveys

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

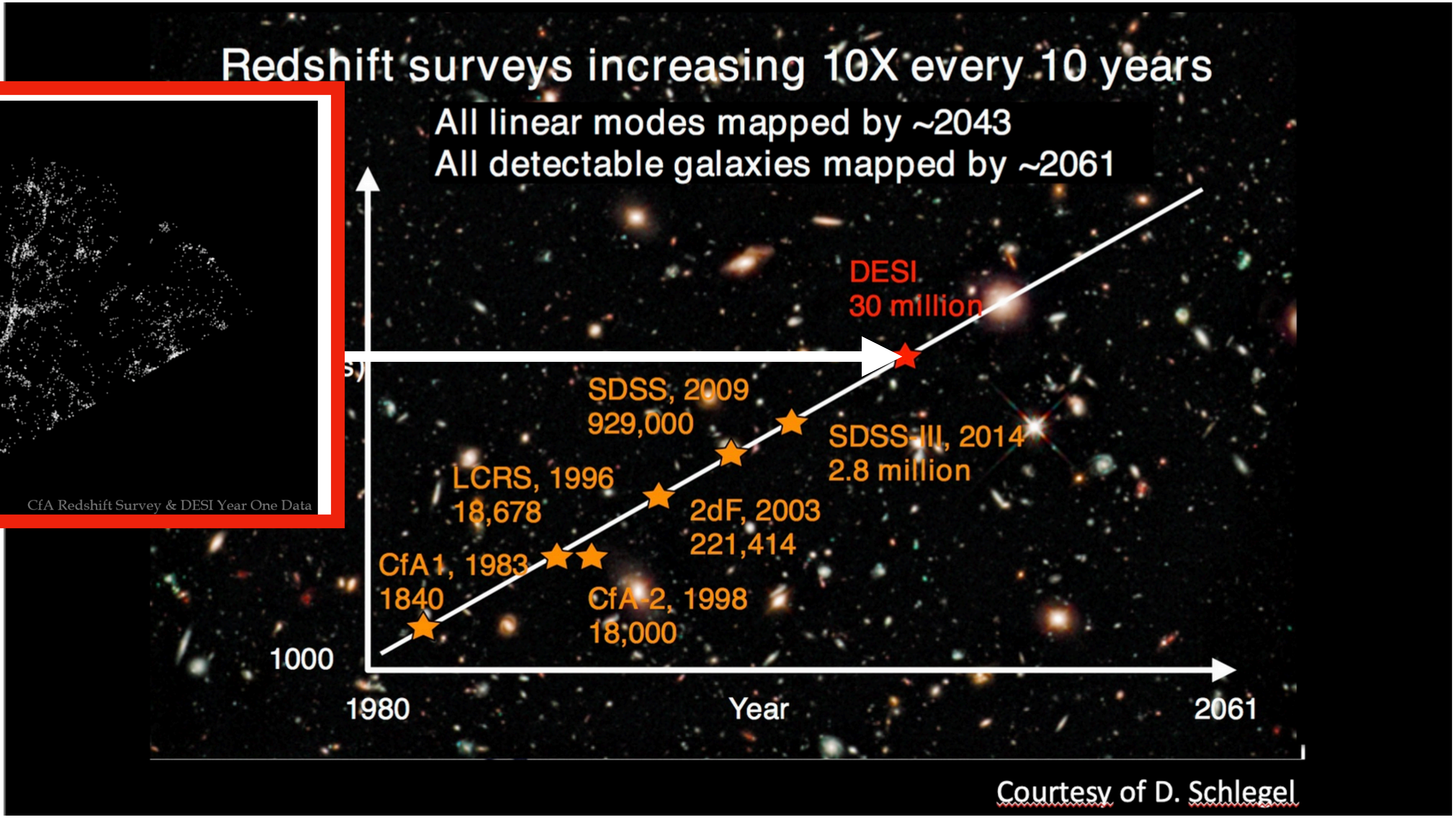


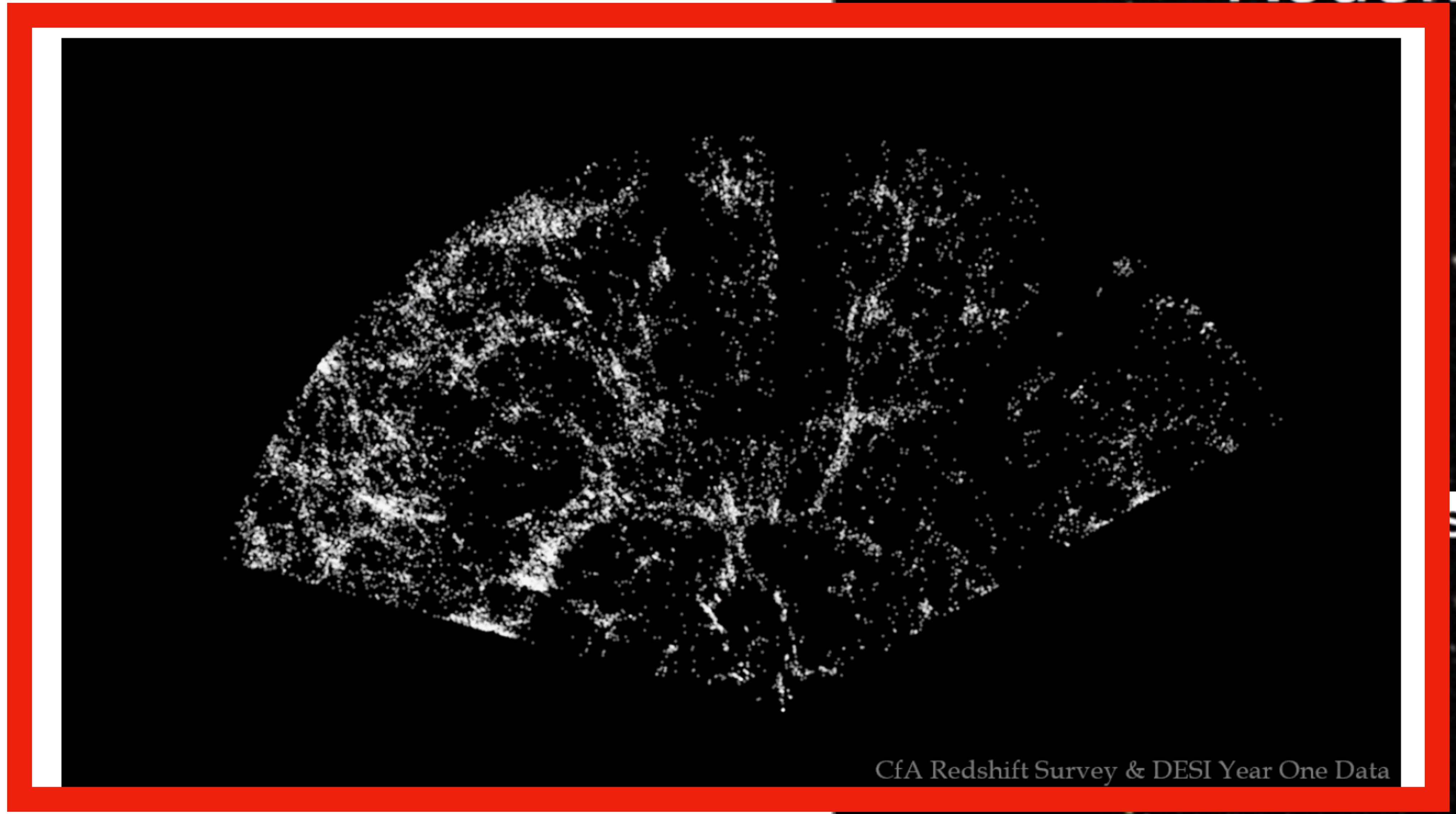
# A brief history of galaxy redshift surveys



# A brief history of galaxy redshift surveys



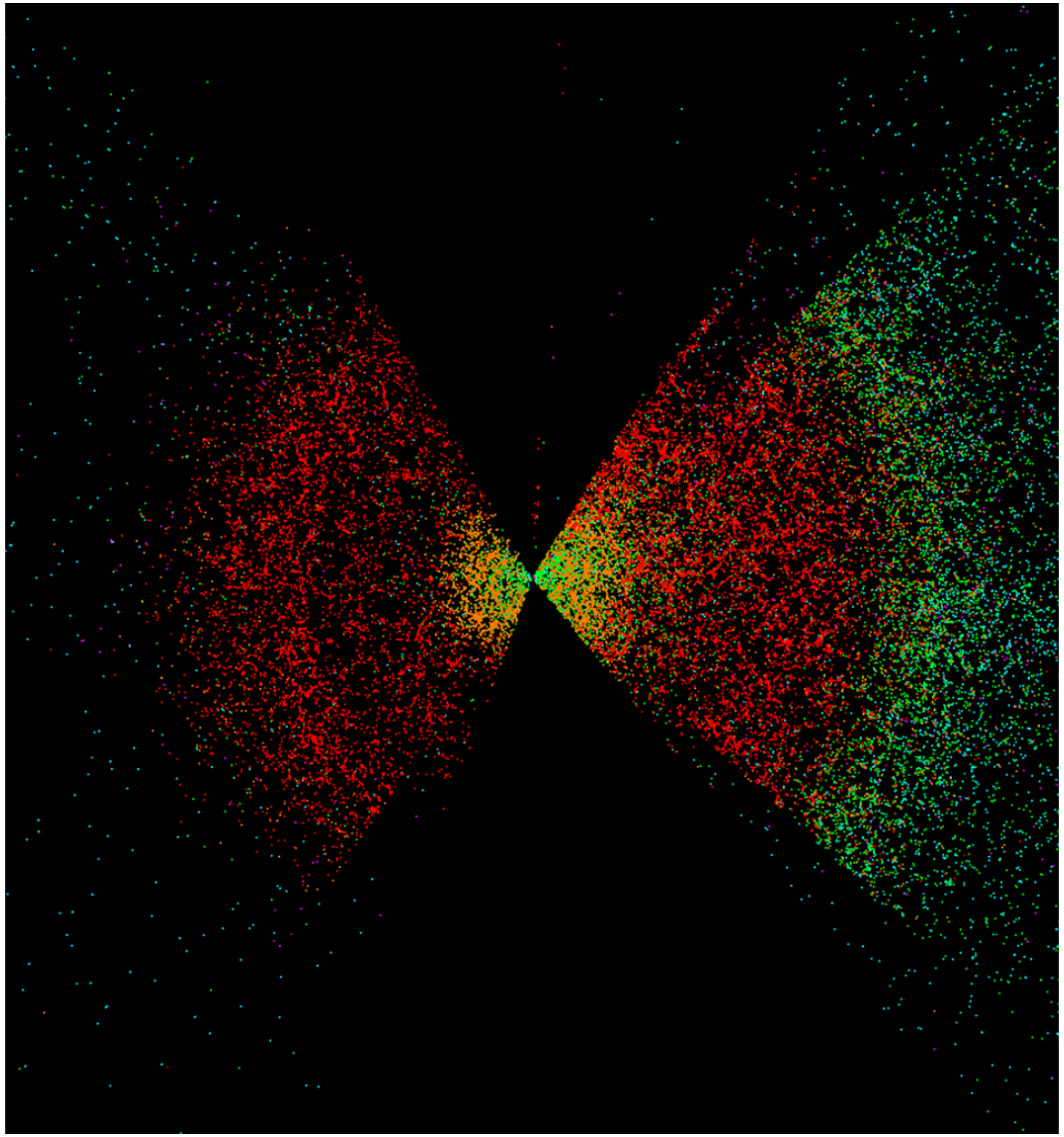



DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# A brief history of galaxy redshift surveys

**SDSS (BOSS+eBOSS)**

DESI DR1



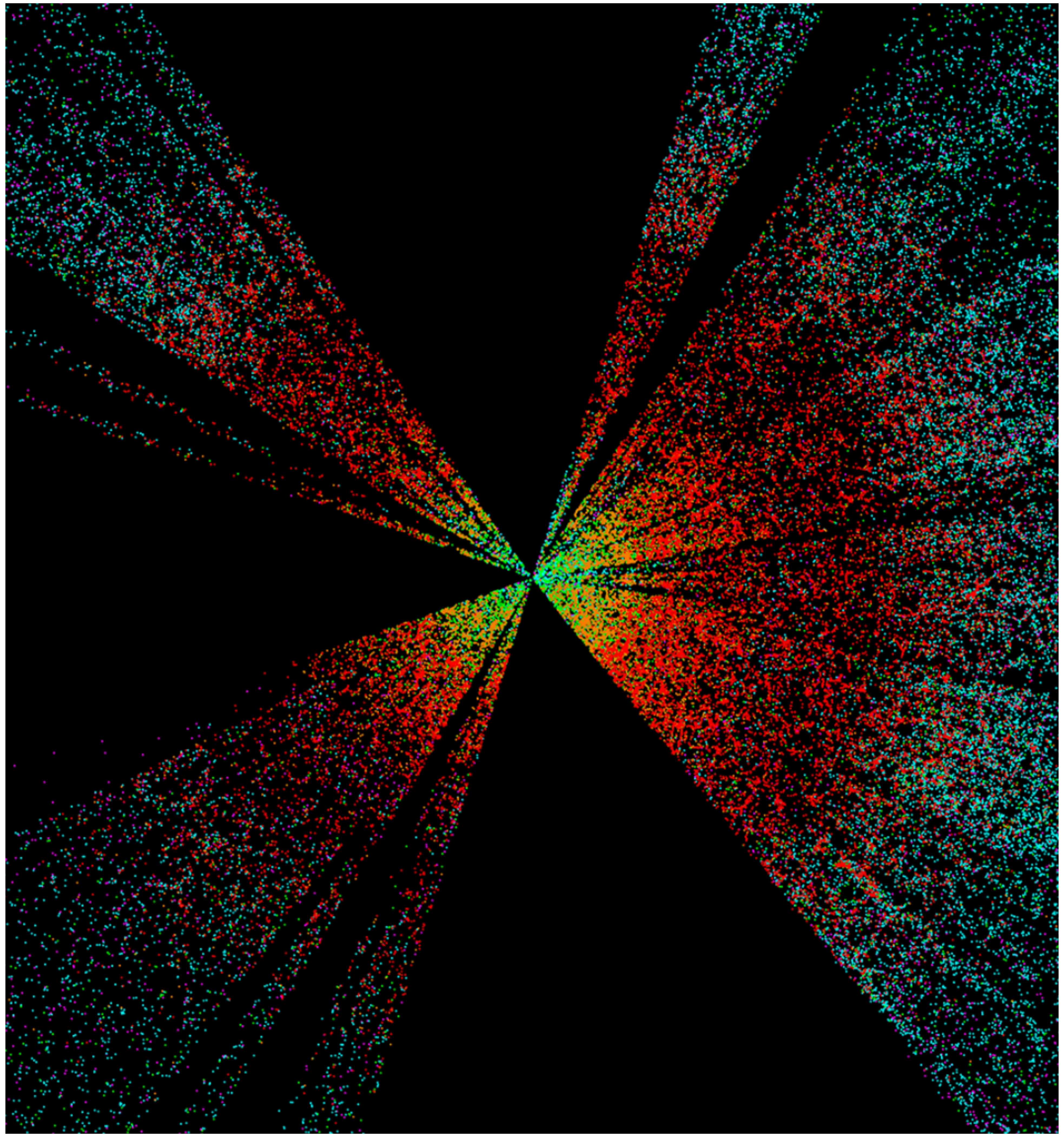
# A brief history of galaxy redshift surveys

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

**SDSS (BOSS+eBOSS)**

↓

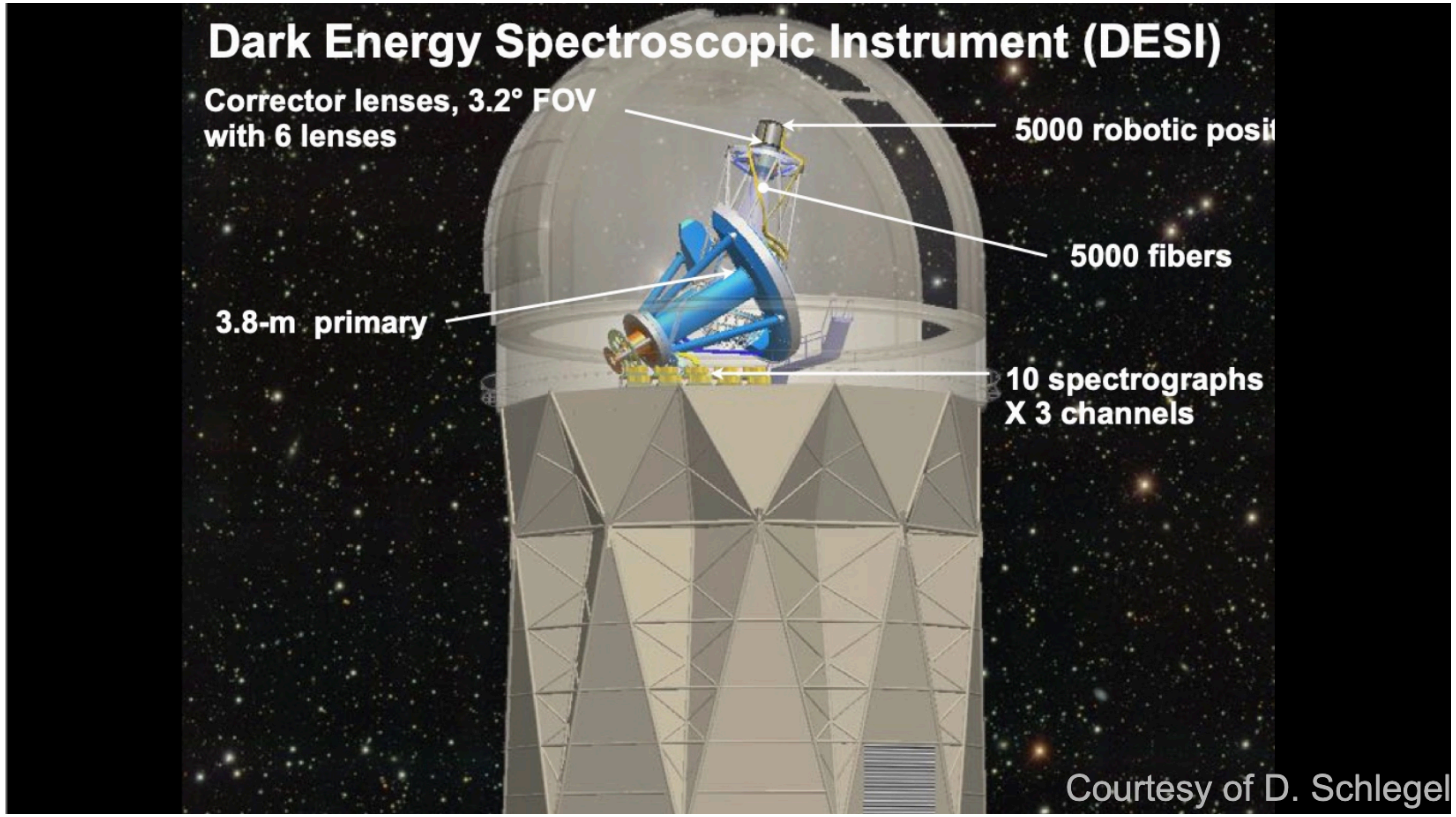
**DESI DR1**



# The Dark Energy Spectroscopic Instrument

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

Located at the Mayal 4-m Telescope @ Kitt Peak (AZ)

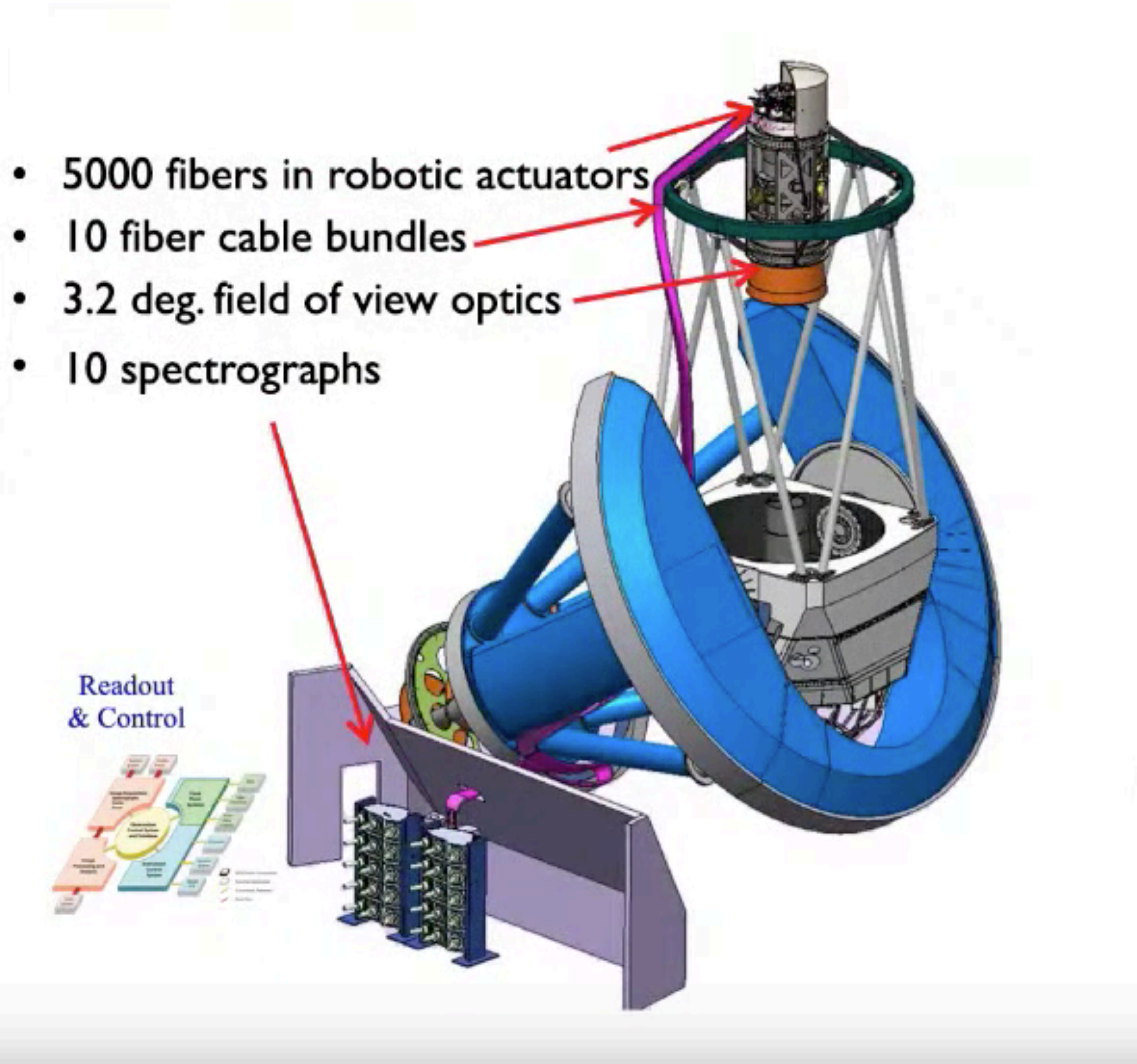


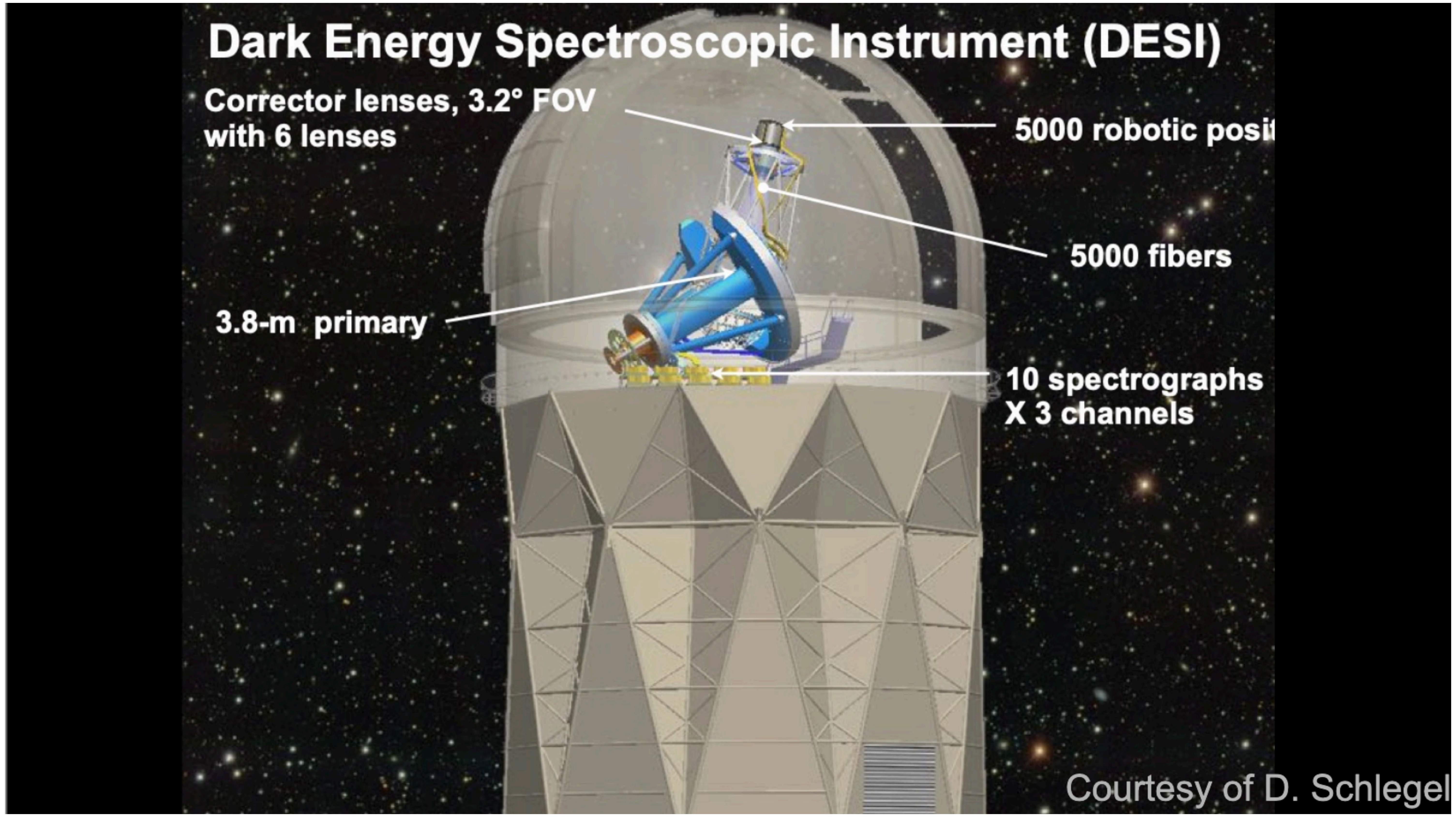
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

# The Dark Energy Spectroscopic Instrument

Located at the Mayal 4-m Telescope @ Kitt Peak (AZ)

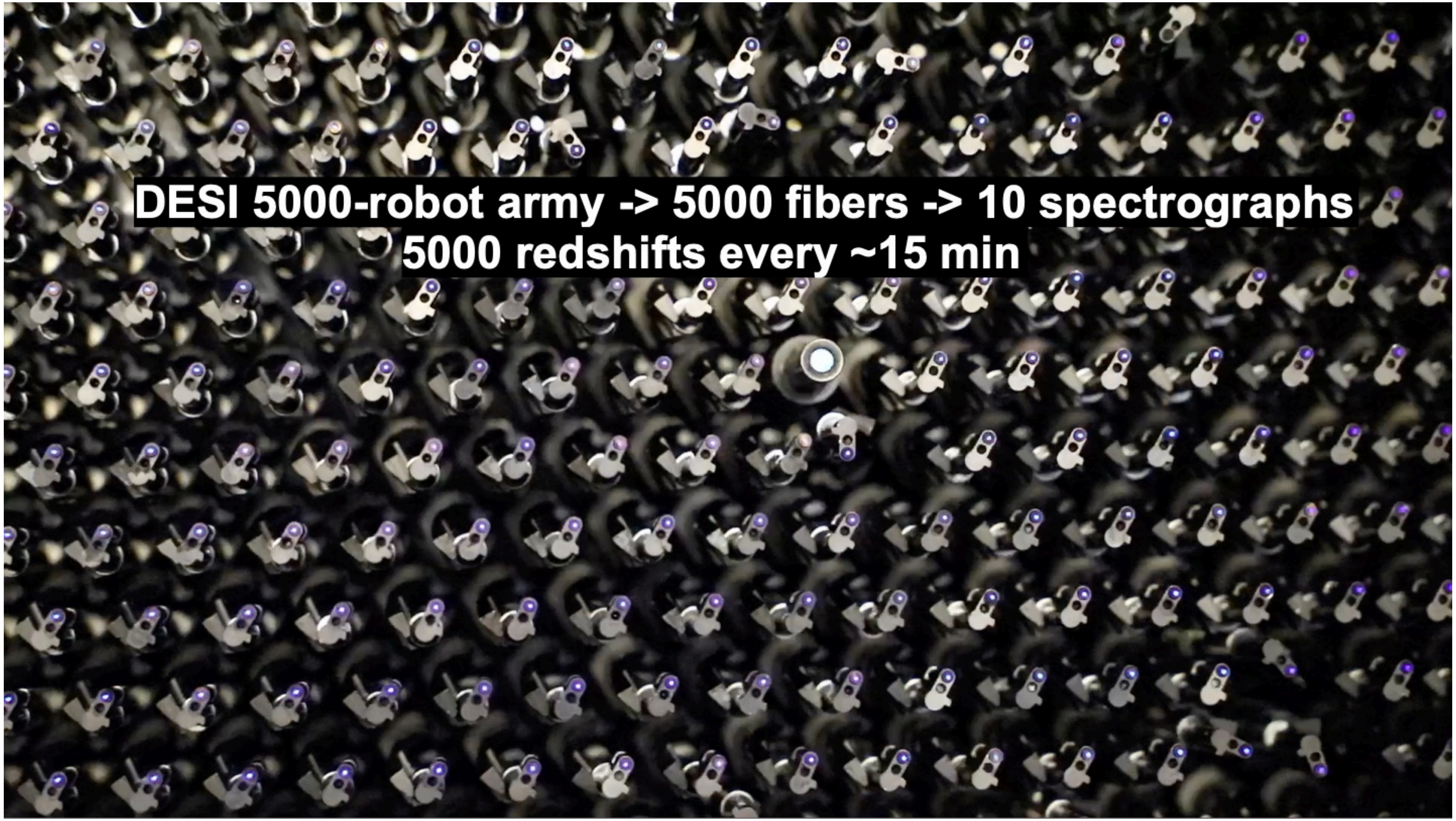


DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

# The Dark Energy Spectroscopic Instrument



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

# The Dark Energy Spectroscopic Instrument

U.S. Department of Energy Office of Science

**10 Multi-Object Spectrographs:**

- 360 - 980 nm range over 3 channels
- Resolution: 2000 (blue) – 5500 (NIR)
- 500 fibers per spectrograph
- 4kx4k CCDs, 60s readout

**Stable PSF**

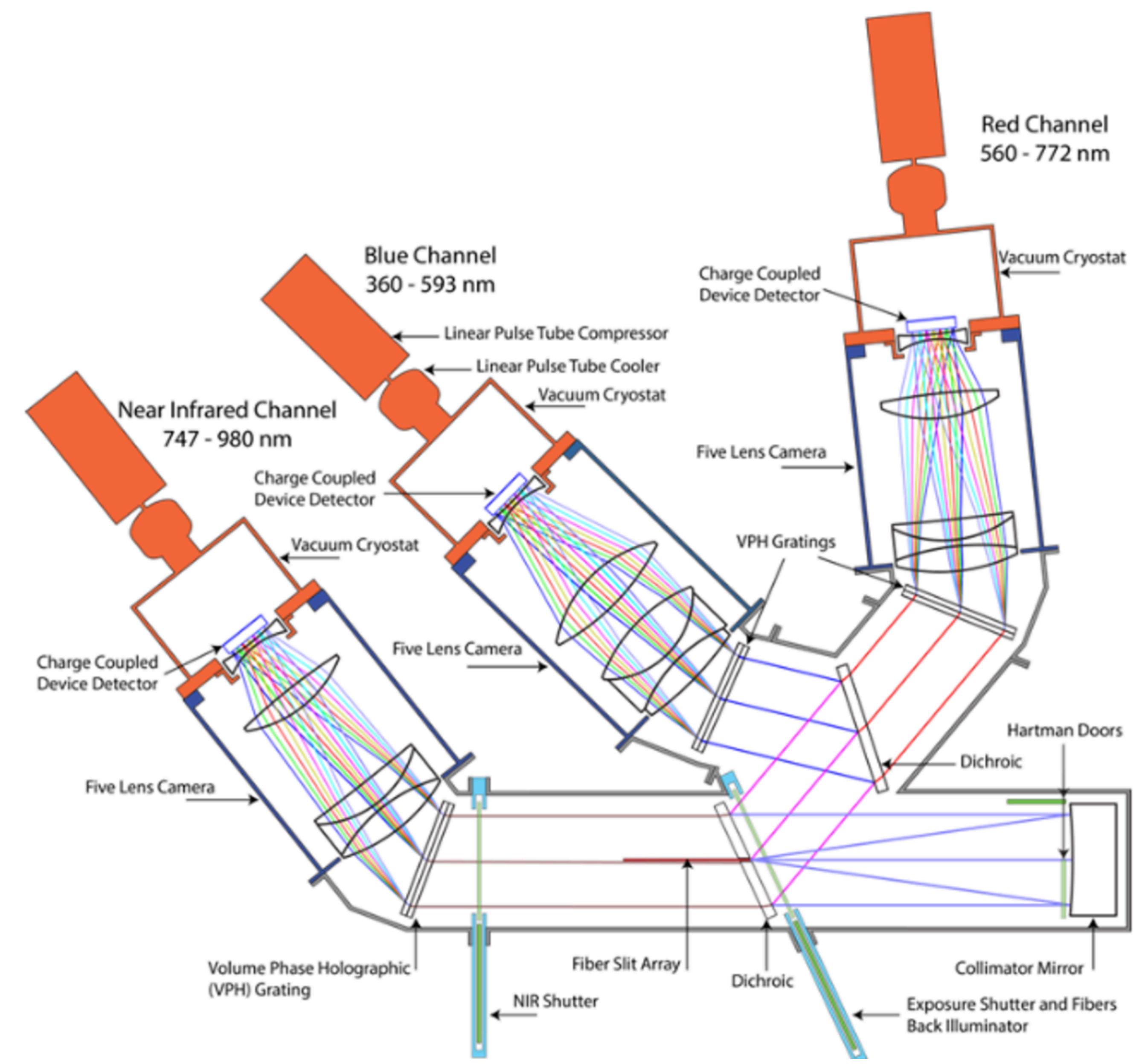
better than 1 % over many days

**Low Read out noise**

~ 3 e-

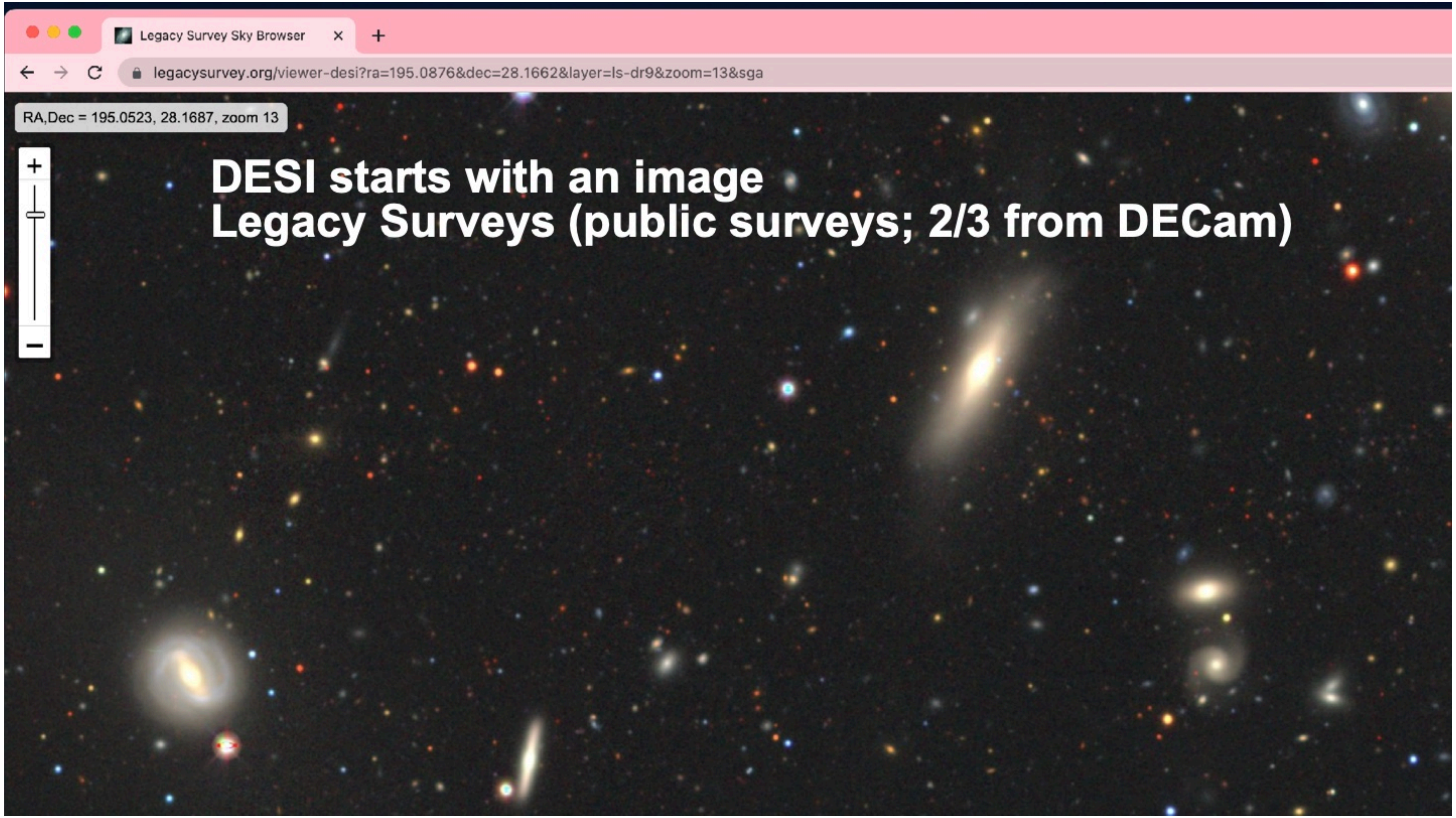
**Throughput of optical chain is excellent**

~40% at 700 nm (total)



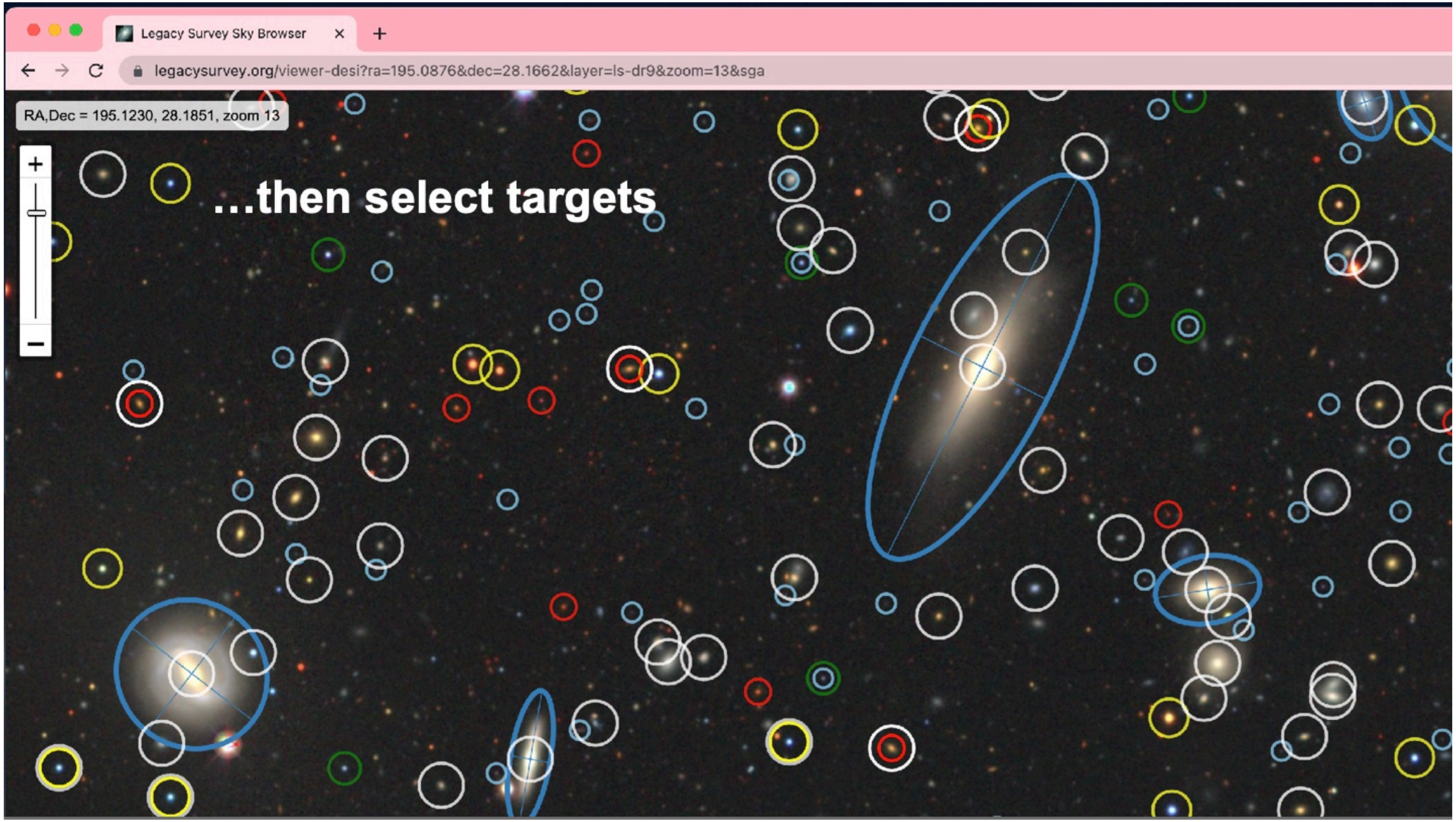

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The Dark Energy Spectroscopic Instrument



DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

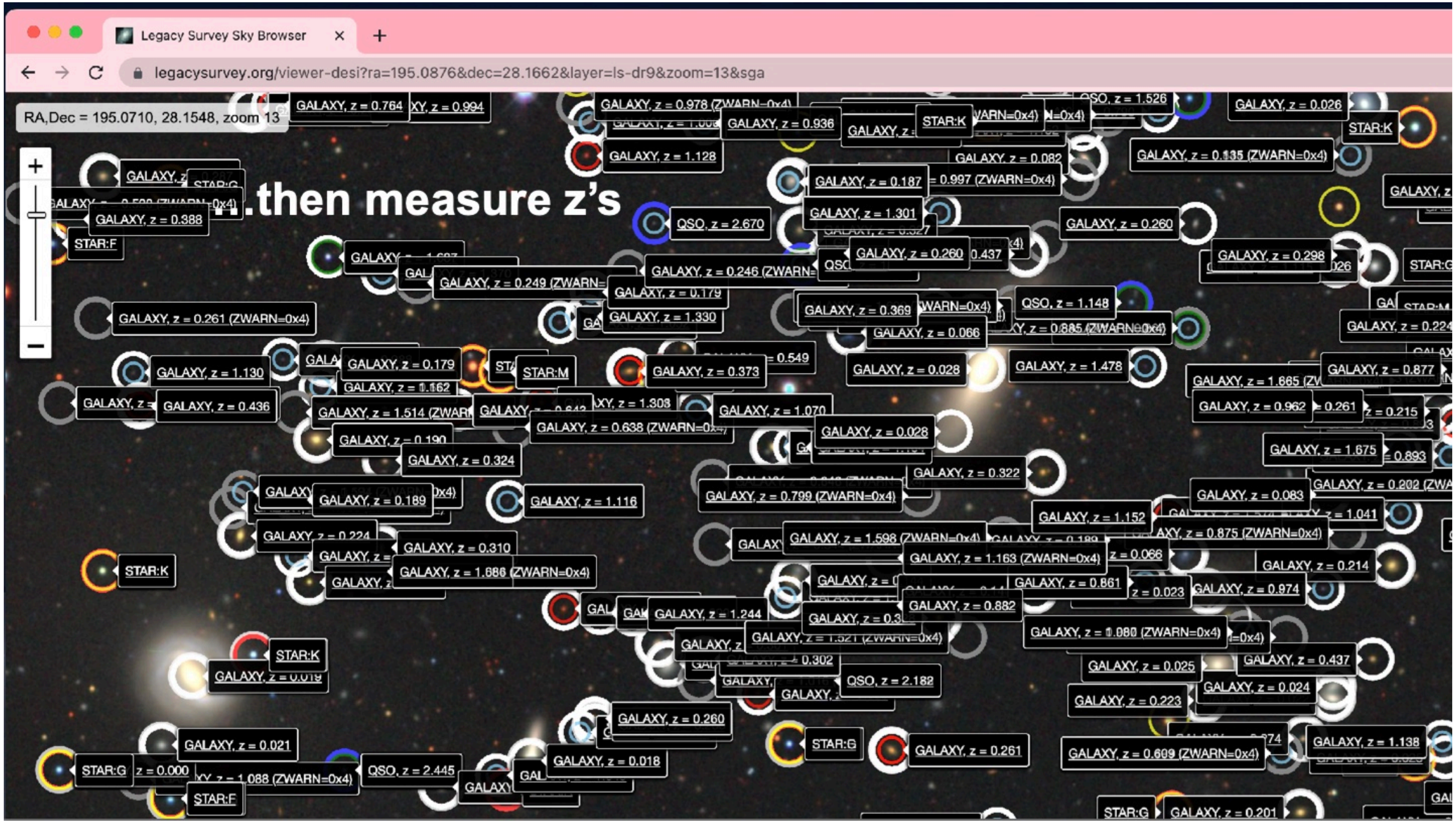
# The Dark Energy Spectroscopic Instrument



DARK ENERGY SPECTROSCOPIC INSTRUMENT

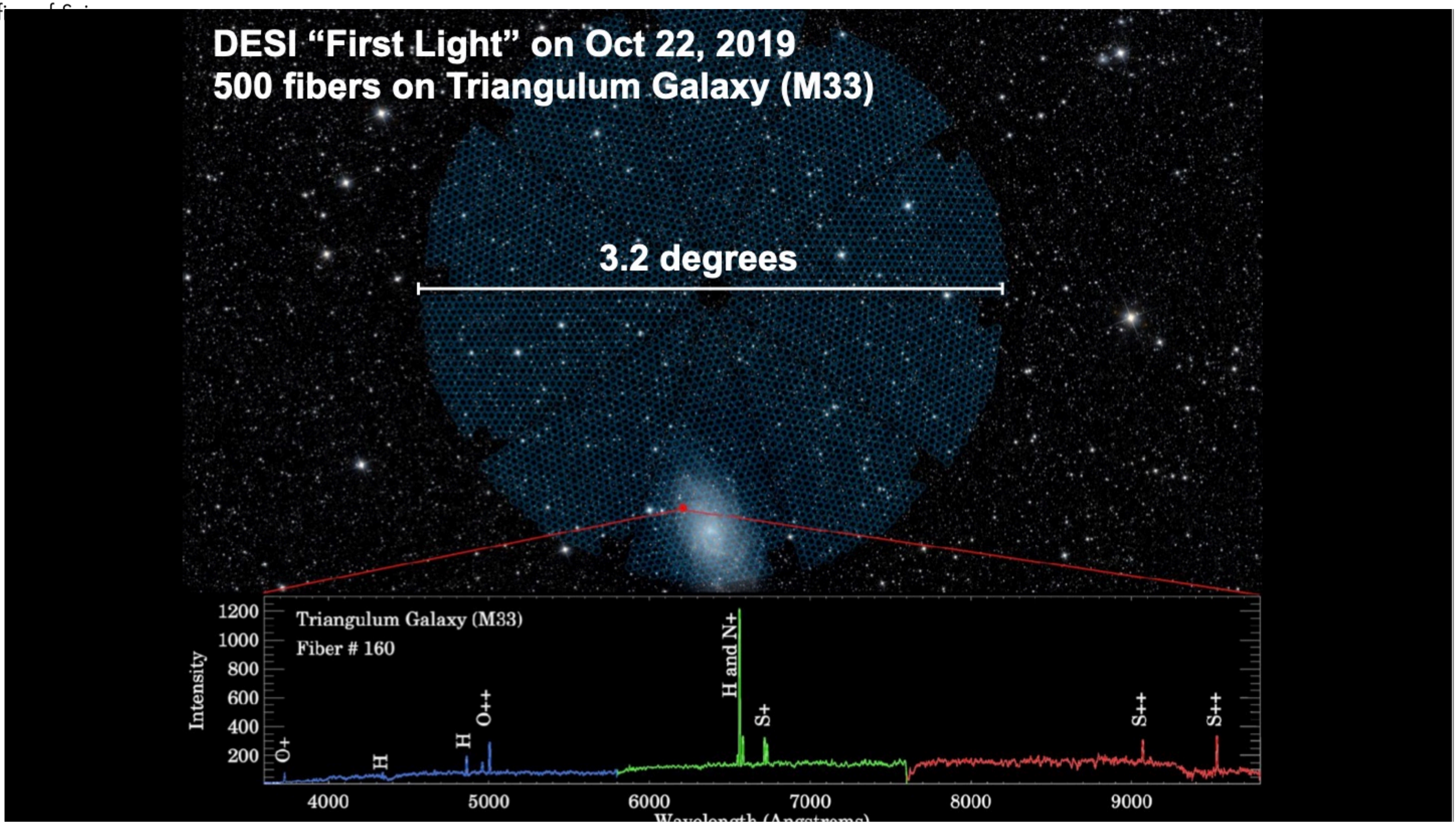
U.S. Department of Energy Office of Science

# The Dark Energy Spectroscopic Instrument



DARK ENERGY
SPECTROSCOPIC
INSTRUMENT
U.S. Department of Energy Offi

# The Dark Energy Spectroscopic Instrument

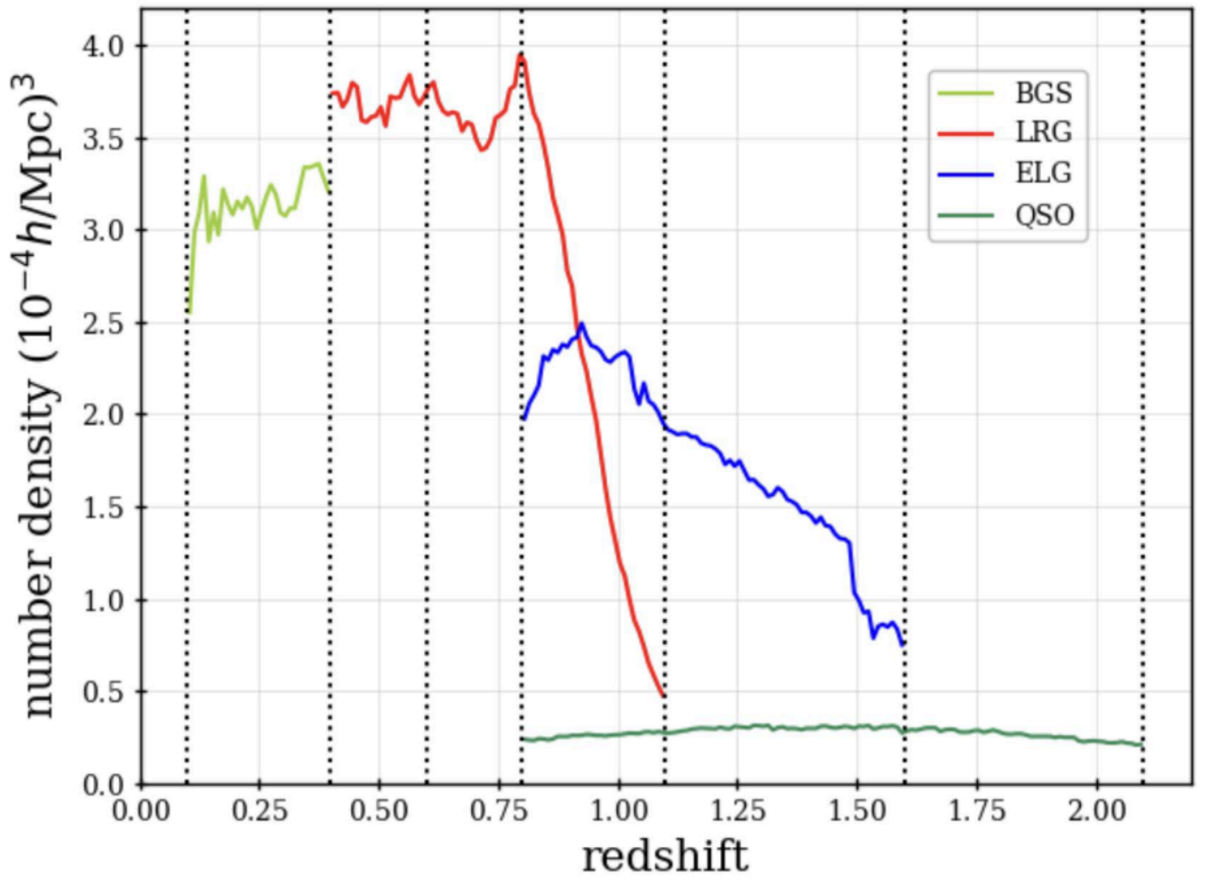


DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The Dark Energy Spectroscopic Instrument

## DESI targets for DR1

| Tracer | redshift range | $N_{\rm tracer}$ | $z_{\rm eff}$ | $P_0(k=0.14)$ | $V_{\rm eff}$ (Gpc$^3$) |
|---|---|---|---|---|---|
| BGS | $0.1-0.4$ | 300,017 | 0.30 | $\sim 9.2\times10^3$ | 1.7 |
| LRG1 | $0.4-0.6$ | 506,905 | 0.51 | $\sim 8.9\times10^3$ | 2.6 |
| LRG2 | $0.6-0.8$ | 771,875 | 0.71 | $\sim 8.9\times10^3$ | 4.0 |
| LRG3 | $0.8-1.1$ | 859,824 | 0.92 | $\sim 8.4\times10^3$ | 5.0 |
| ELG1 | $0.8-1.1$ | 1,016,340 | 0.95 | $\sim 2.6\times10^3$ | 2.0 |
| LRG3+ELG1 | $0.8-1.1$ | 1,876,164 | 0.93 | $\sim 5.9\times10^3$ | 6.5 |
| ELG2 | $1.1-1.6$ | 1,415,687 | 1.32 | $\sim 2.9\times10^3$ | 2.7 |
| QSO | $0.8-2.1$ | 856,652 | 1.49 | $\sim 5.0\times10^3$ | 1.5 |
| Ly-α | 1.77<z | 709,565 | 2.33 | | |




Five target classes
40 million redshifts
in 5 years

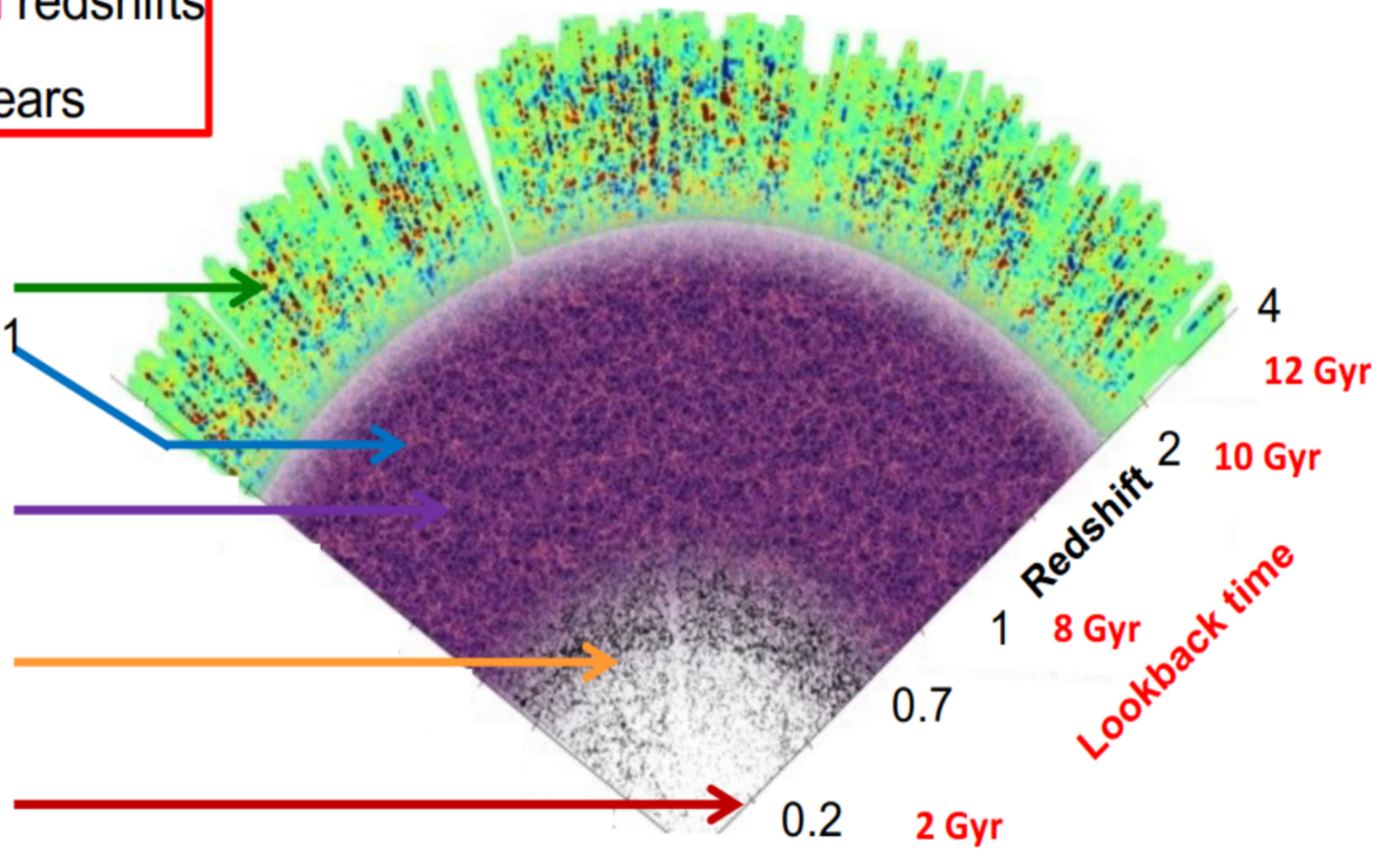
DESI (2021-2026)

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

16 million ELGs
0.6 < z < 1.6

8 million LRGs
0.4 < z < 1.0

13.5 million
Brightest galaxies
0.0 < z < 0.4



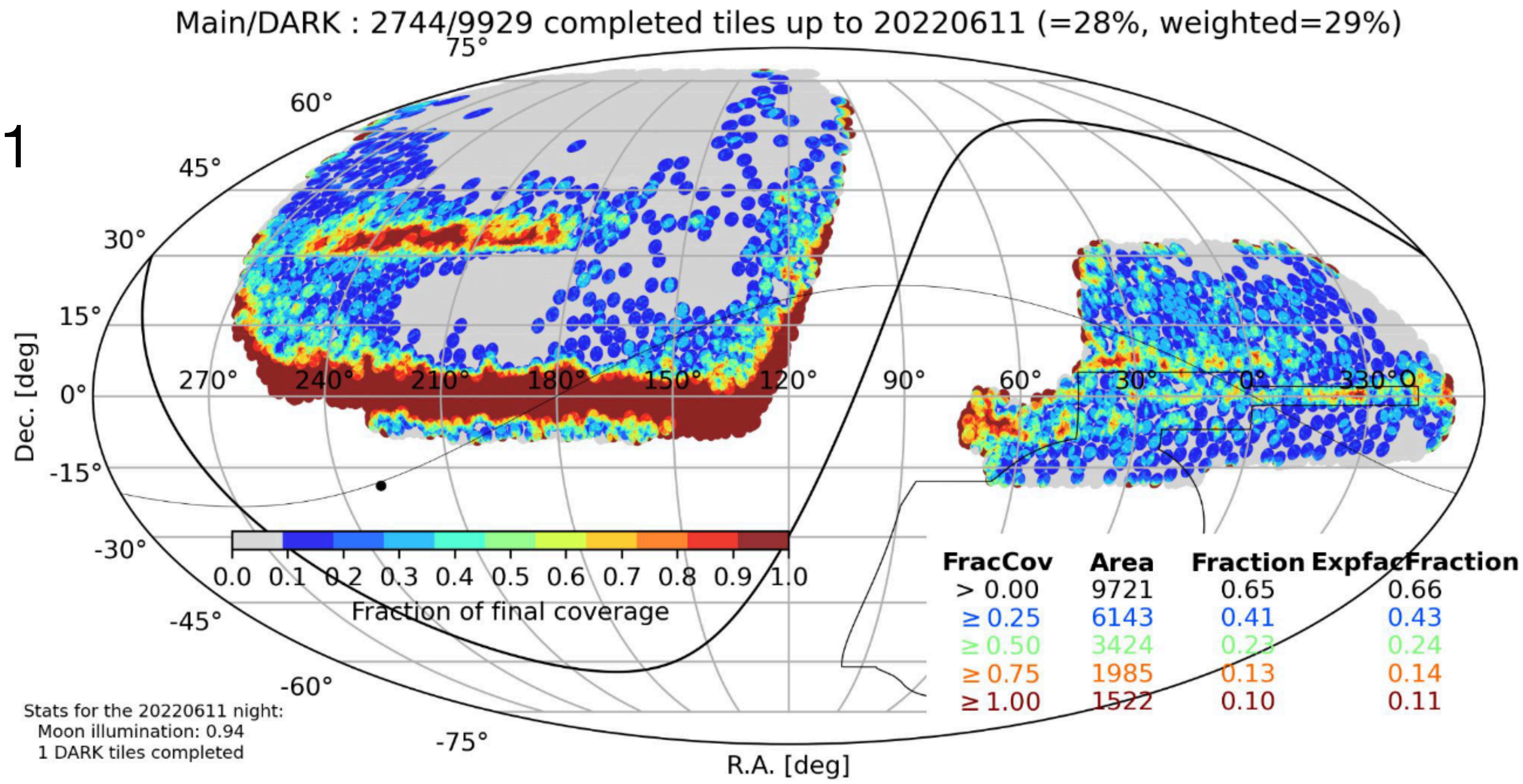
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

# The Dark Energy Spectroscopic Instrument

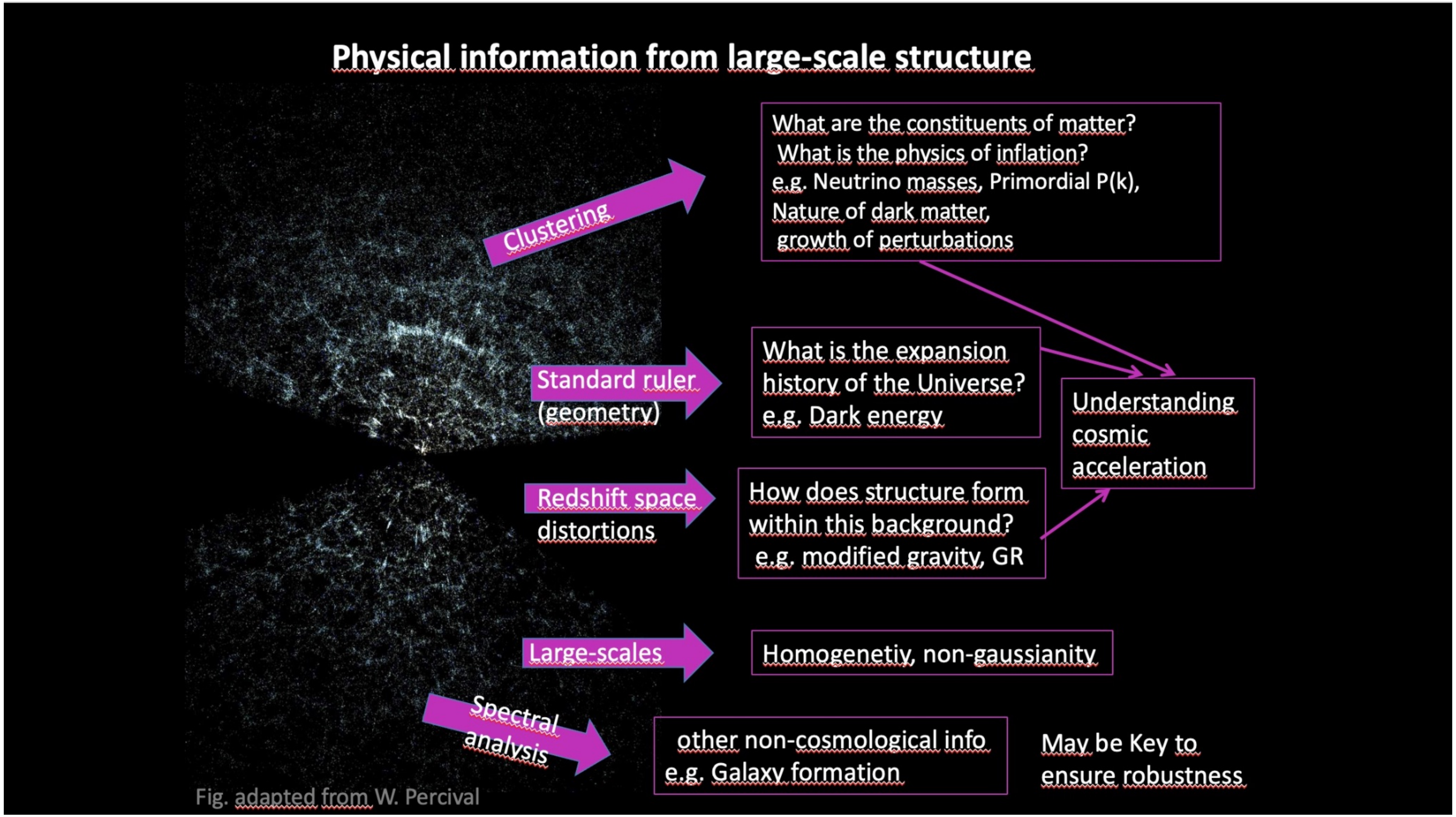
Not just the size+quality of the data, but the size+quality of the <u>survey</u>
Exposure time is dynamically modified to be <u>*constant in depth*</u>, not exposure time

DESI DR1

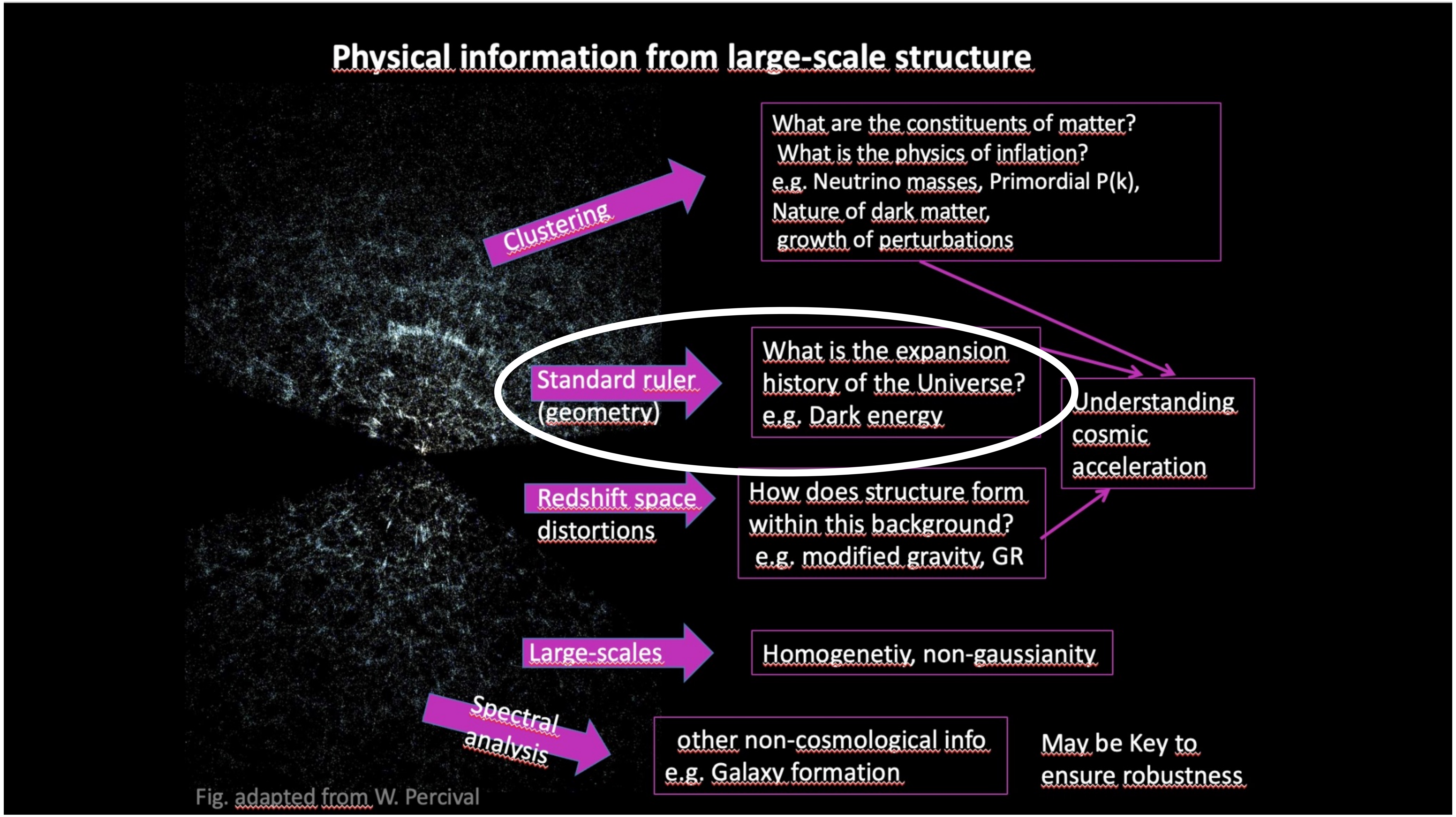


DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The Dark Energy Spectroscopic Instrument



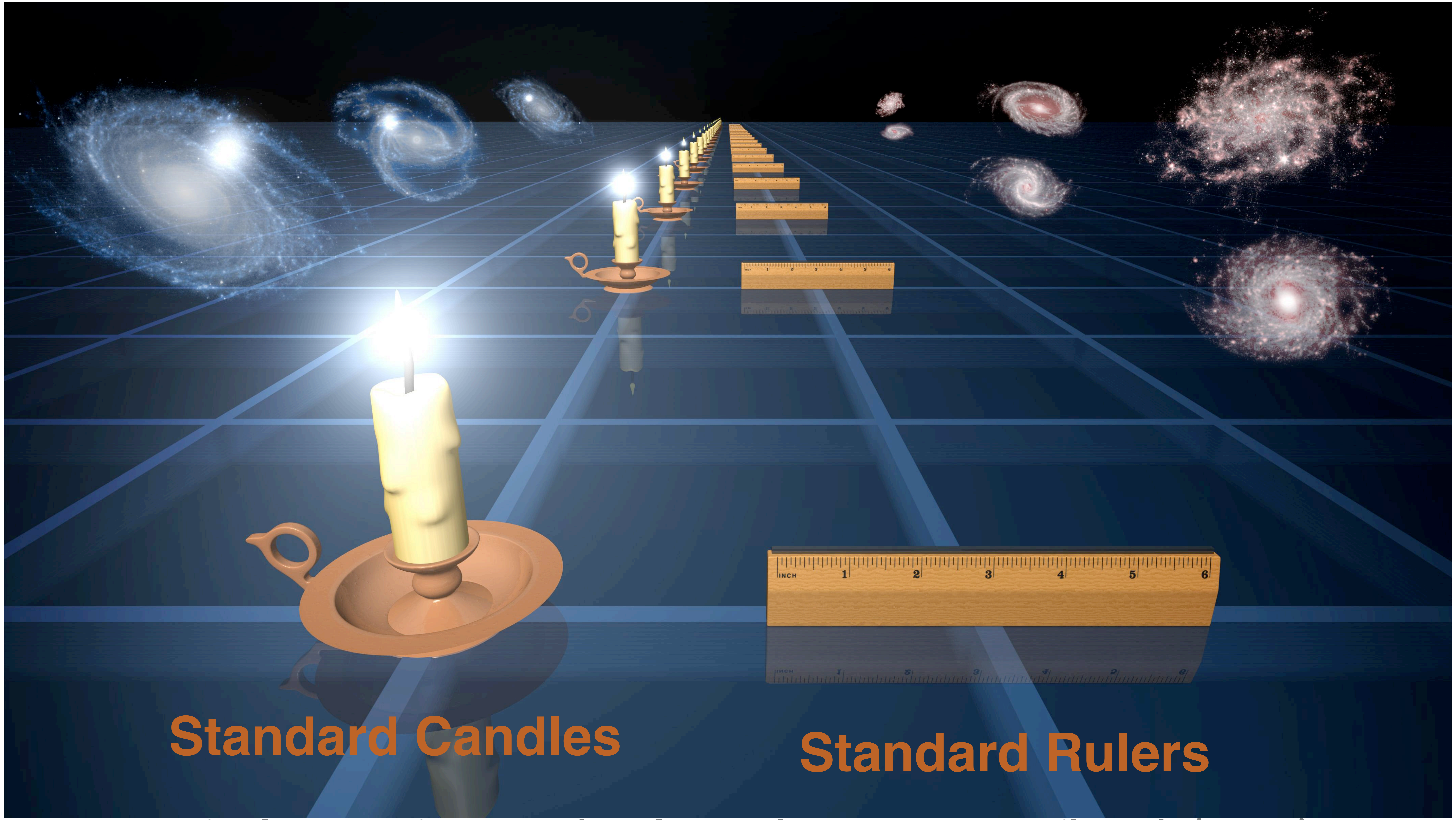
# The Dark Energy Spectroscopic Instrument



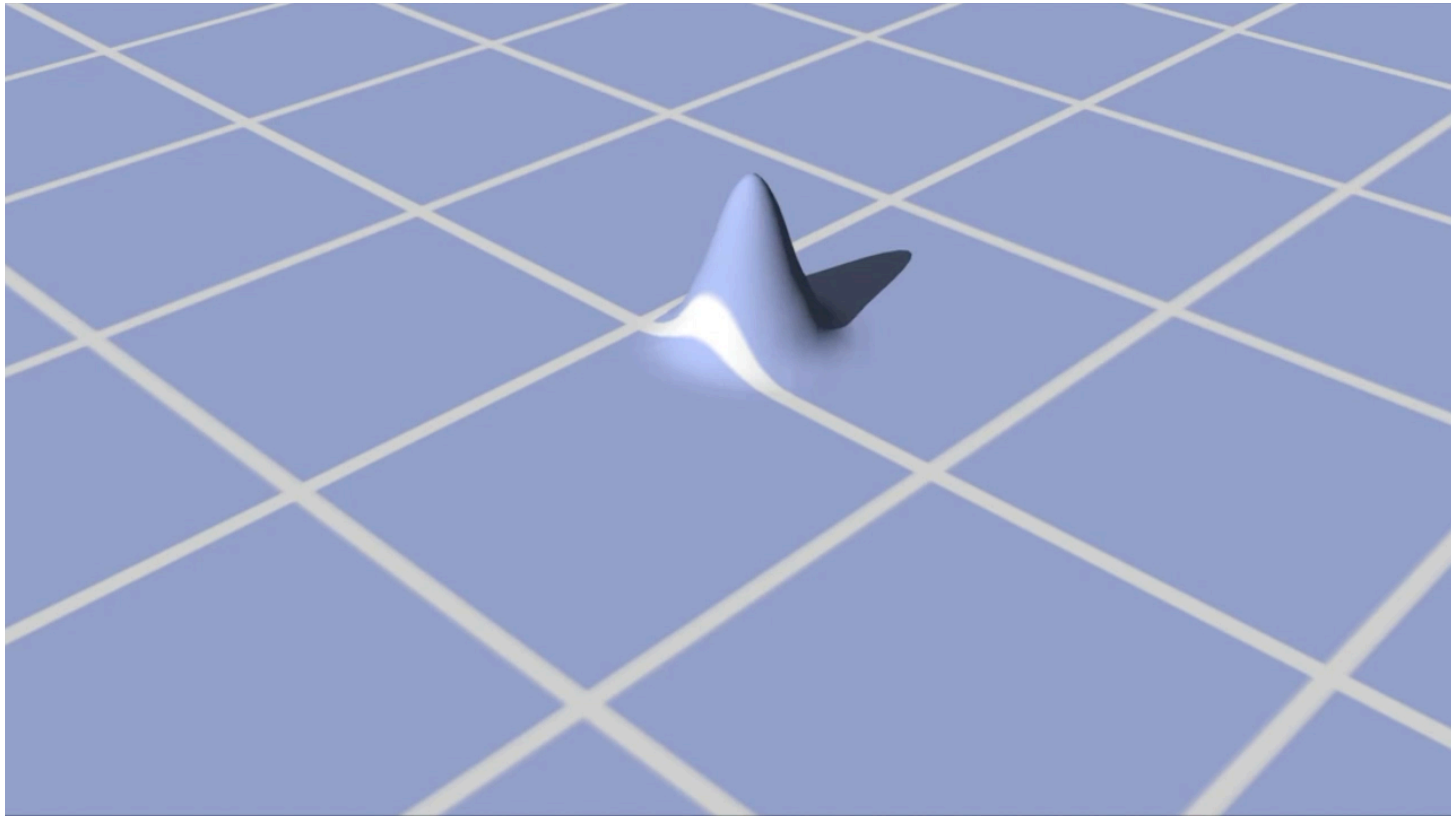
DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The BAO as a standard ruler

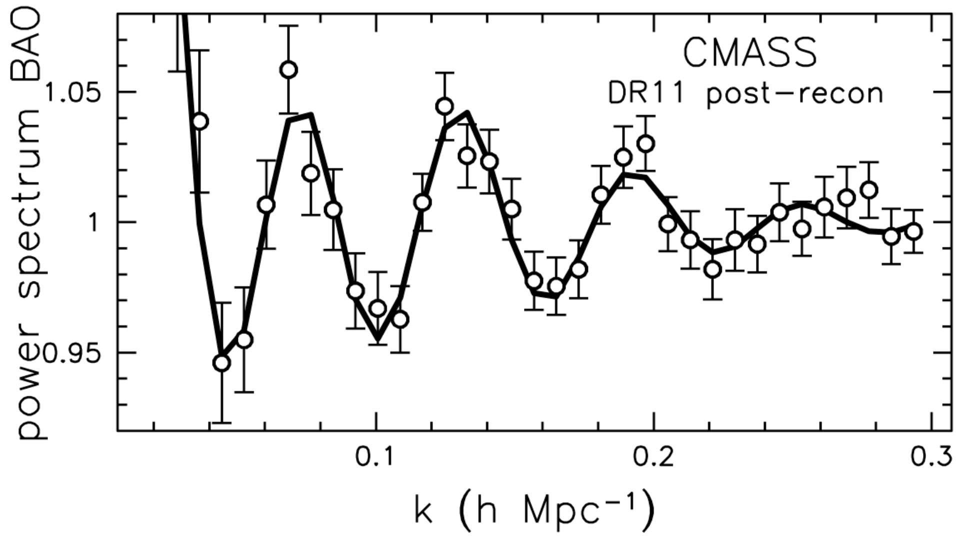
**Distances in cosmology are hard. We need calibrators!**



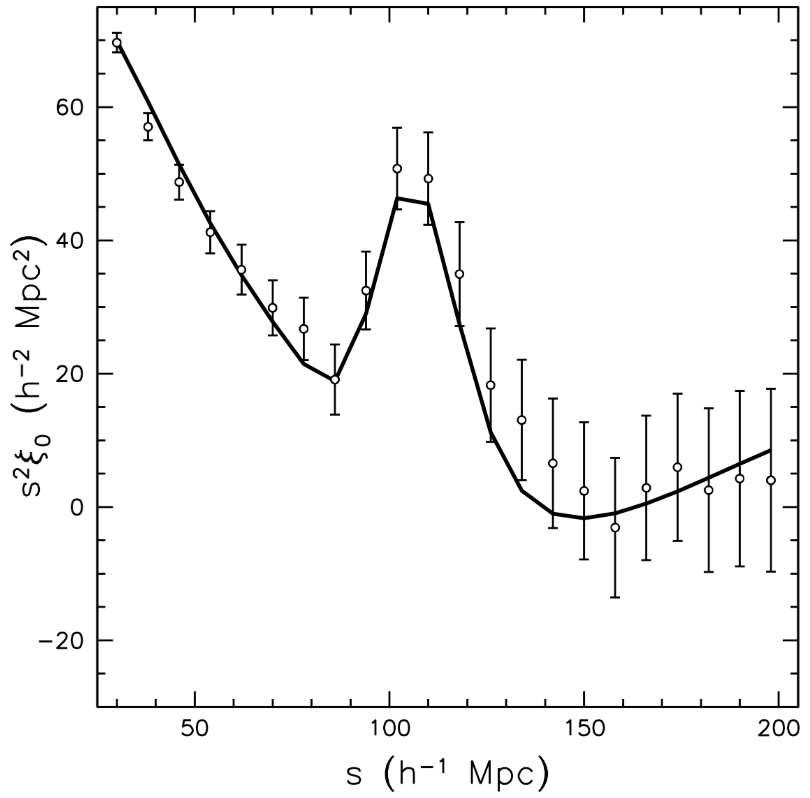
# The BAO as a standard ruler

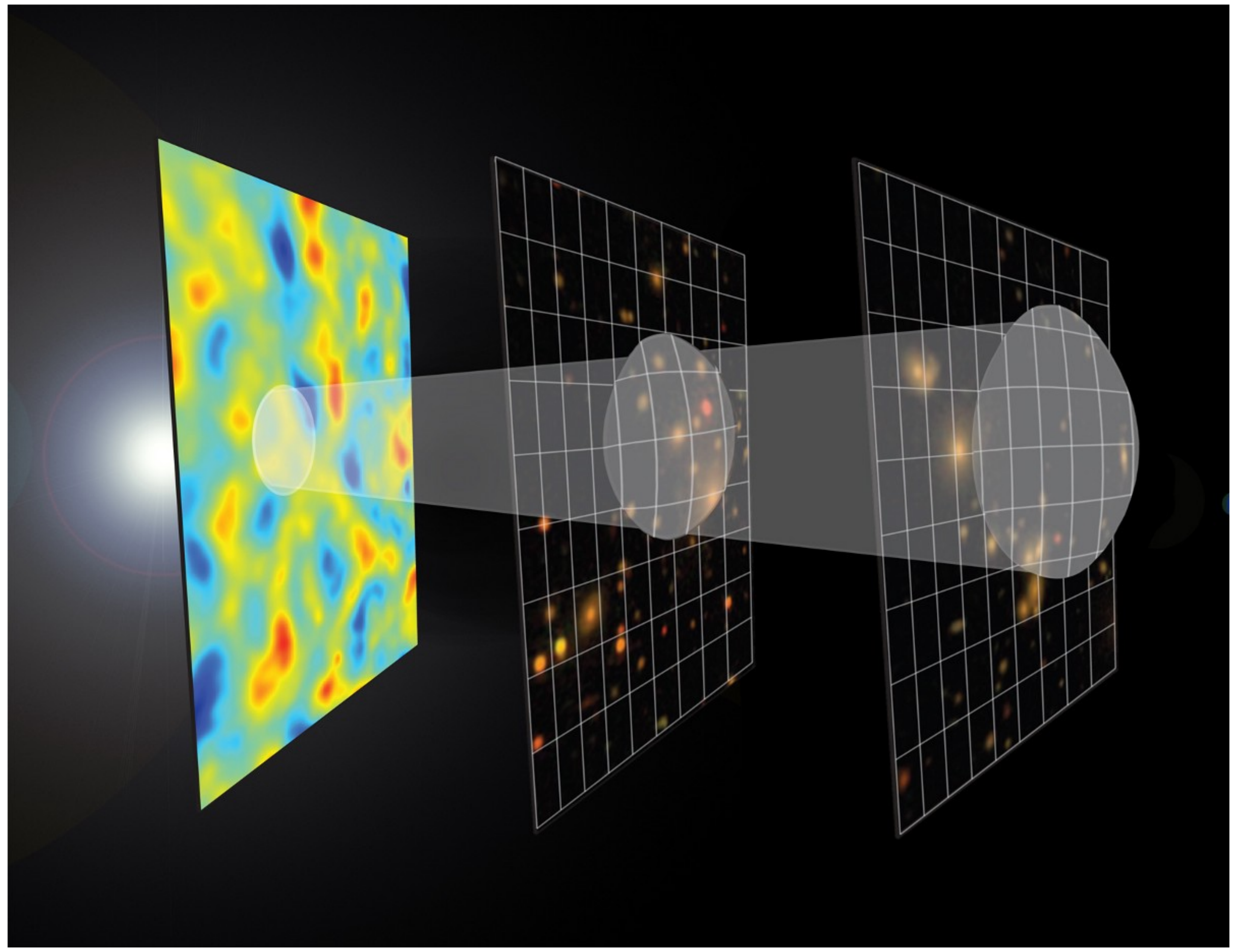


Fourier-space




position-space



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

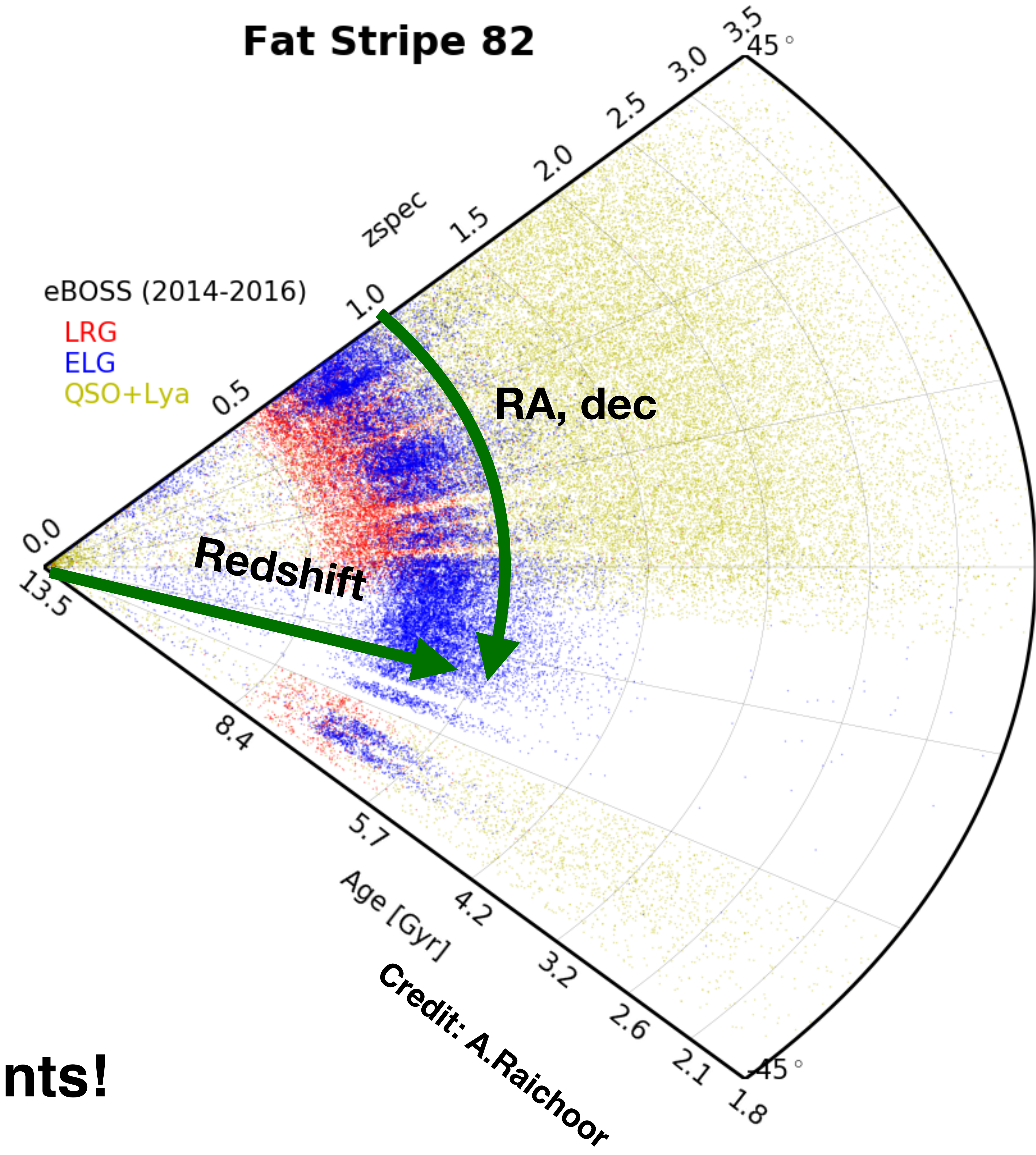
# The BAO as a standard ruler

Spectroscopic surveys: **angles** and **redshifts**

- The redshift survey catalogues deliver: angles and redshifts for each galaxy

- Redshifts are converted to comoving distances **assuming a (reference) cosmological model** and **assuming velocities are due to Hubble flow**

$$r(z) = \int_0^z \frac{c\,dz'}{H(z', \Omega)}$$



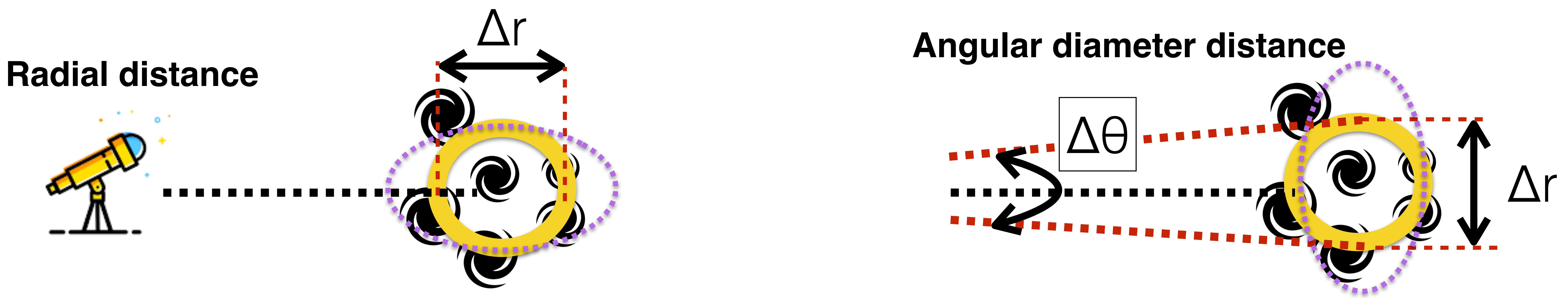

- Produce a 3D map we use to extract information

**We are going to need rulers to calibrate our measurements!**

DARK ENERGY
SPECTROSCOPIC
INSTRUMENT
U.S. Department of Energy Office of Science

# The BAO as a standard ruler

The arbitrary choice of reference cosmology distorts **all** the measured angular and radial scales.

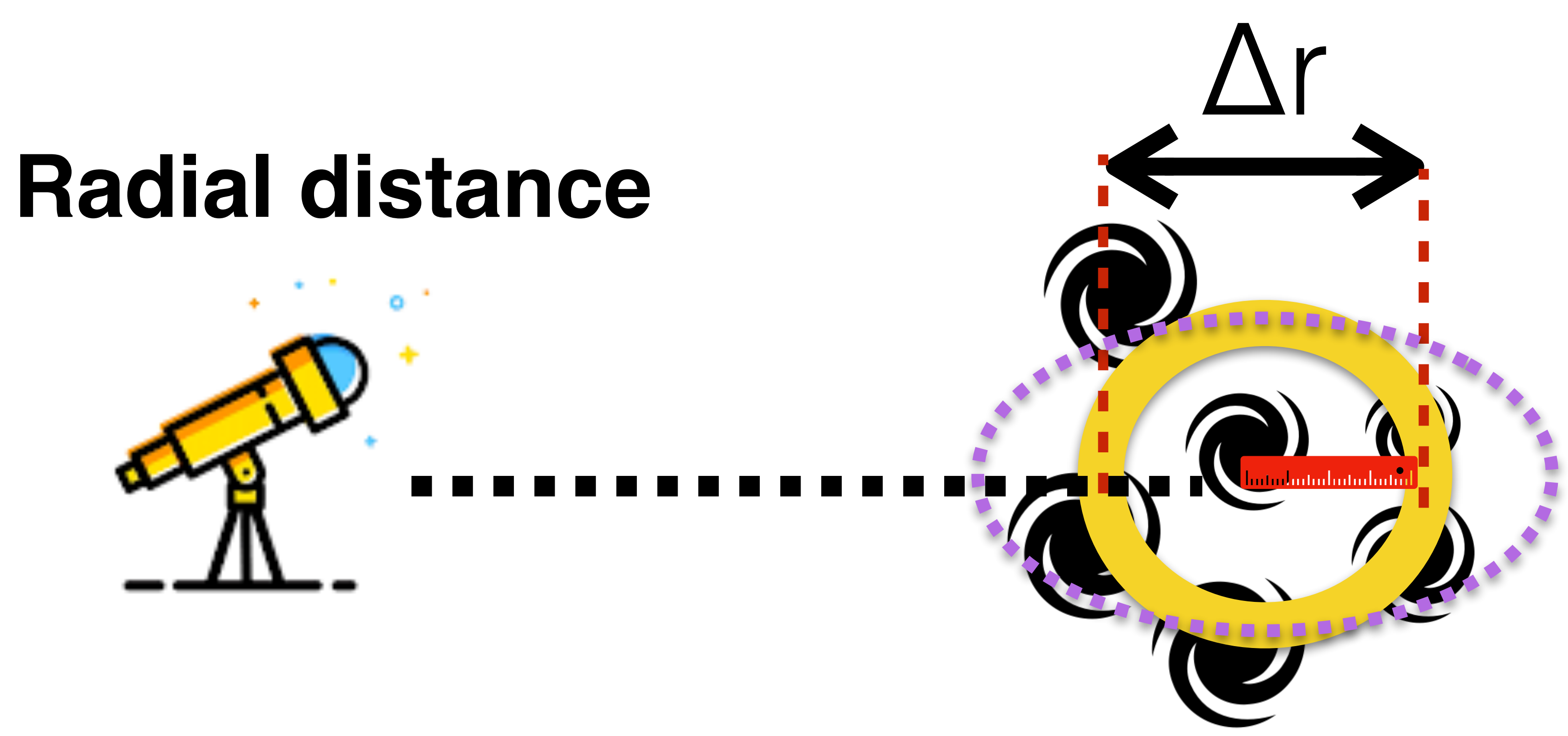


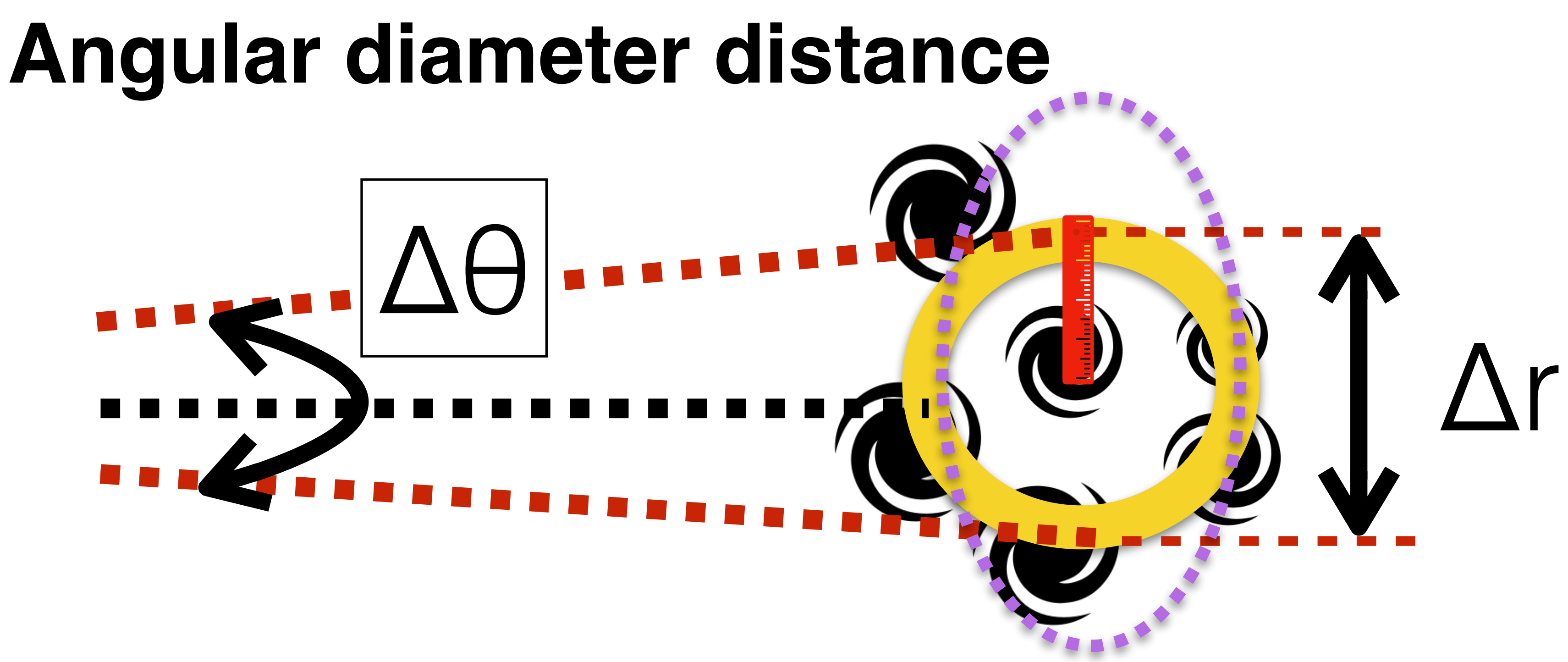

The distortion is different in the line-of-sight direction and in the transverse direction.

Introduces an anisotropy if the **reference or fiducial cosmology** differs from the actual cosmology: Alcock-Paczynski effect

# The BAO as a standard ruler

The arbitrary choice of reference cosmology distorts **all** the measured angular and radial scales.



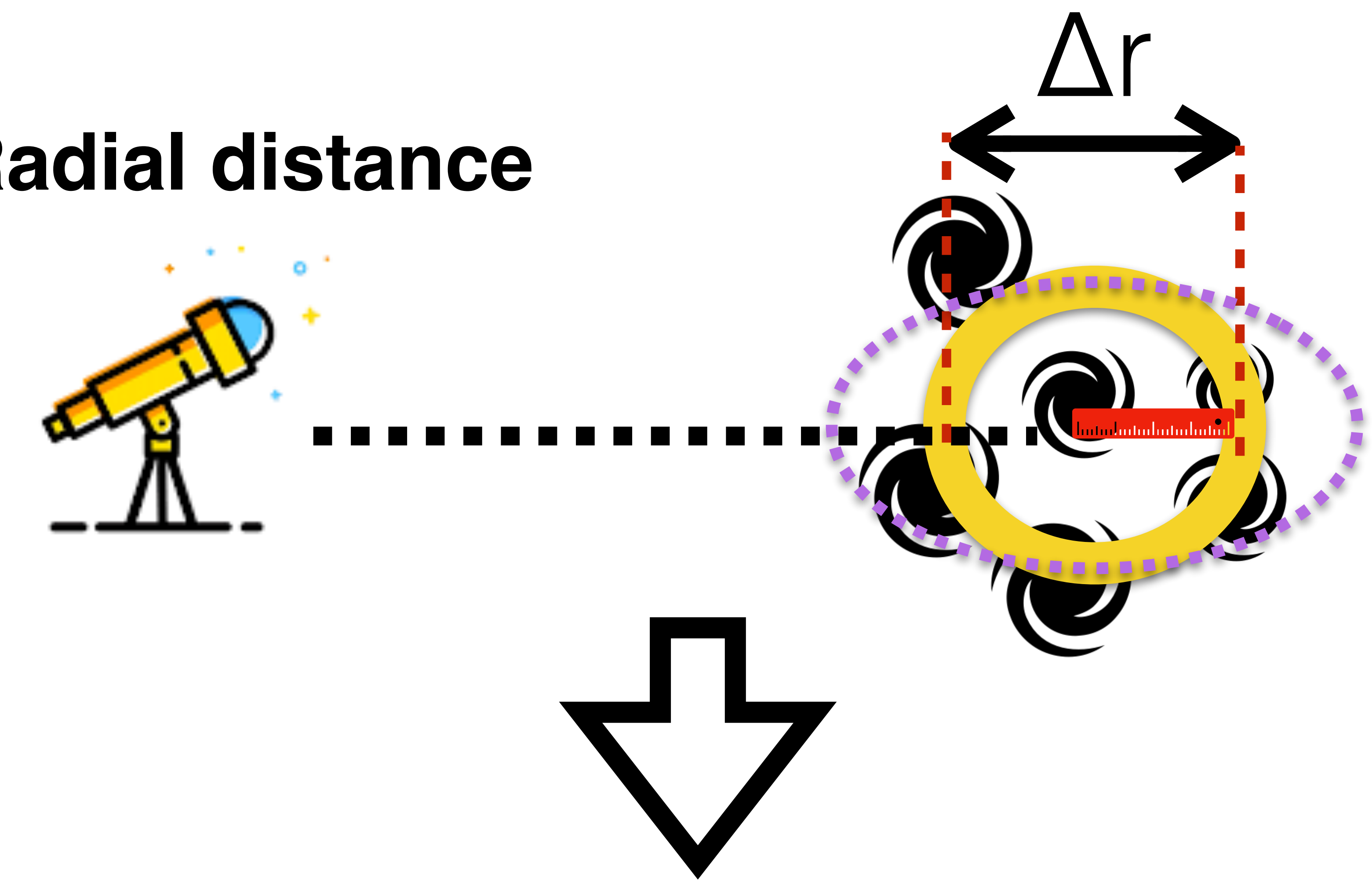




In particular, it's true for the BAO scale: the sound horizon scale at drag epoch: $r_d$

# The BAO as a standard ruler

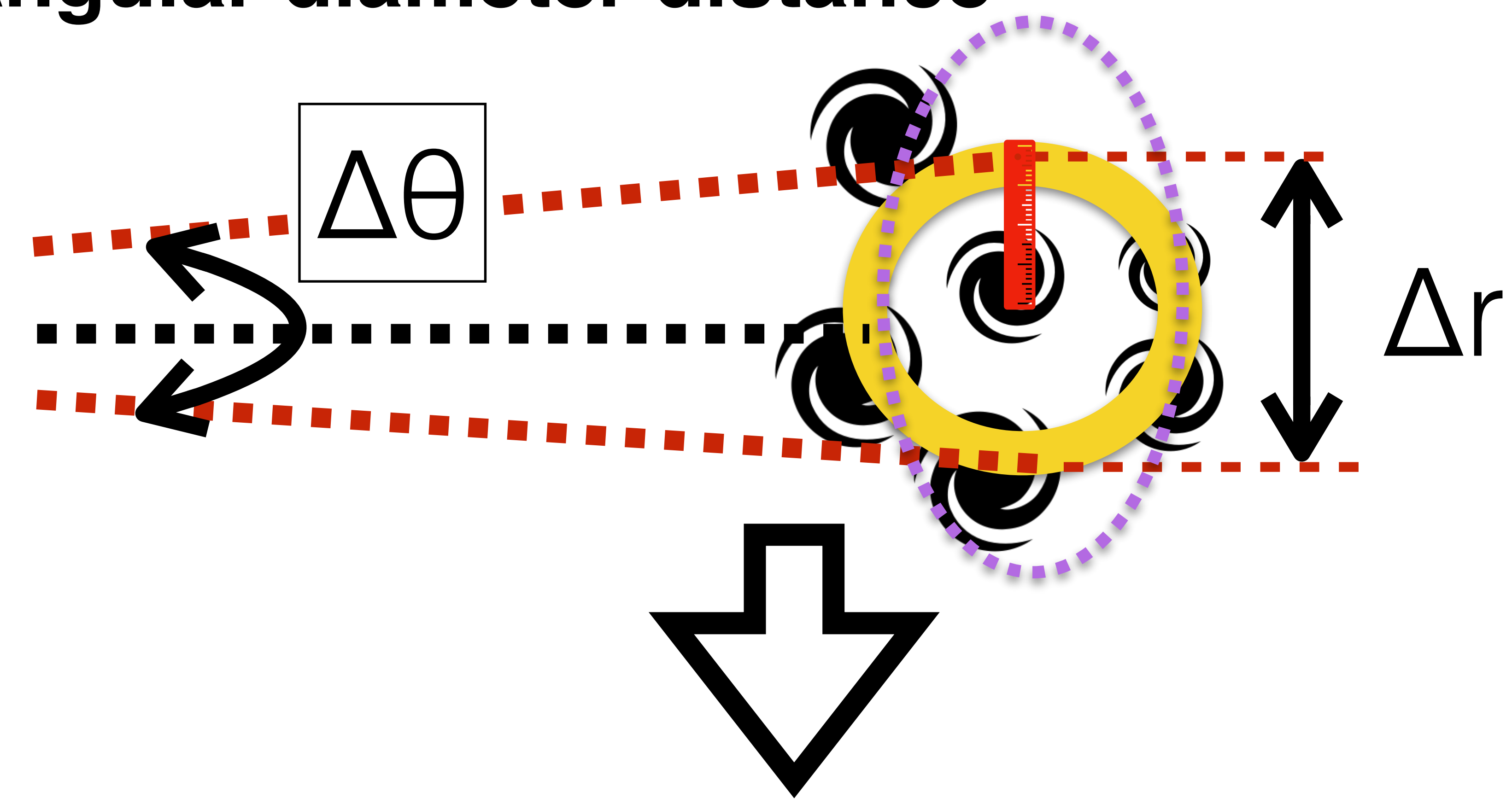
The arbitrary choice of reference cosmology distorts **all** the measured angular and radial scales.

**Radial distance**




$$D_H/r_d$$

**Angular diagonal distance**




$$D_M/r_d$$

For aficionados ⟶
(dilation parameters)

$$\alpha_{\|} = [D_H/r_d]/[D_H/r_d]^{\rm fid}$$

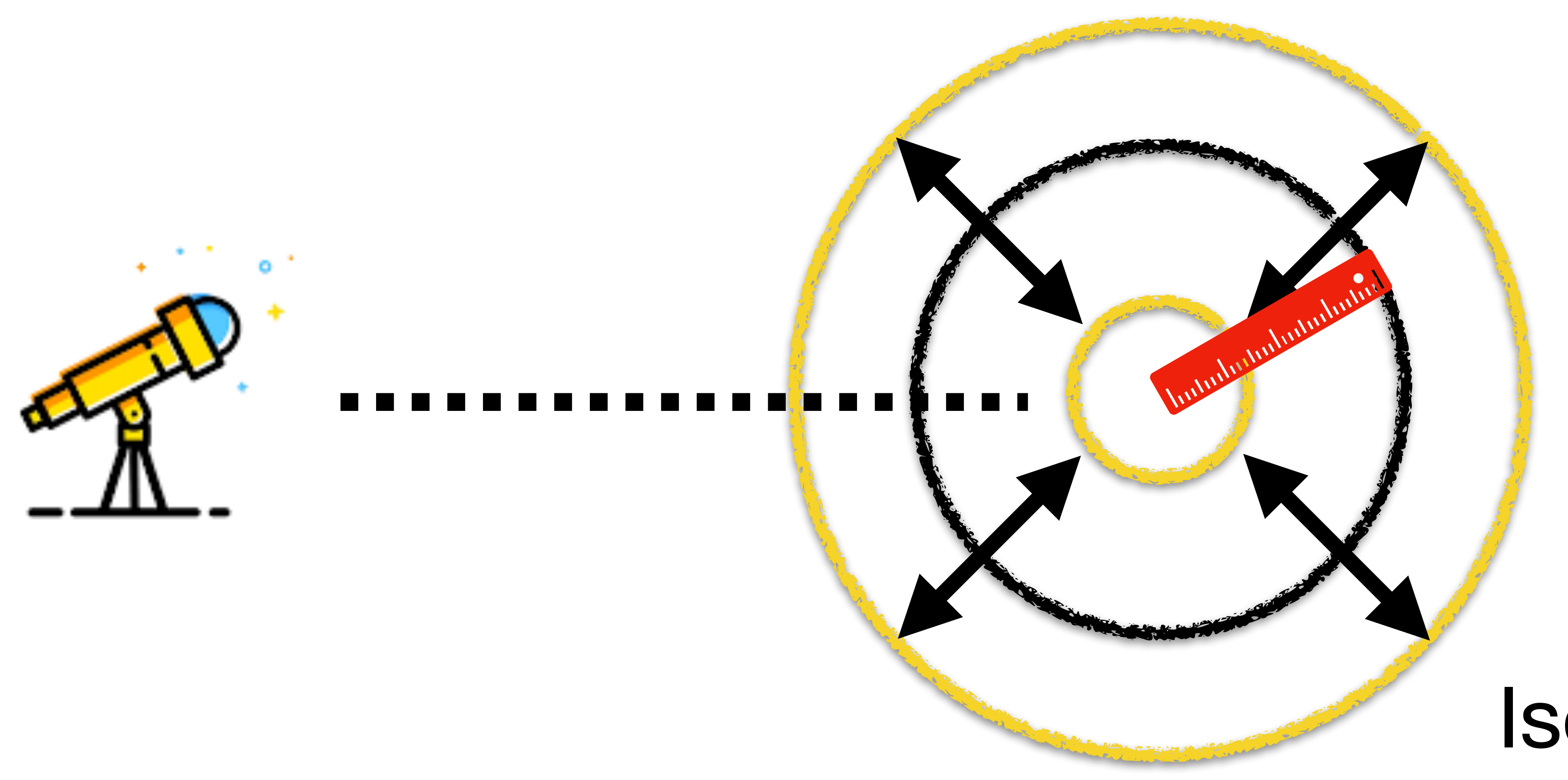
$$\alpha_{\perp} = [D_M/r_d]/[D_M/r_d]^{\rm fid}$$

# The BAO as a standard ruler

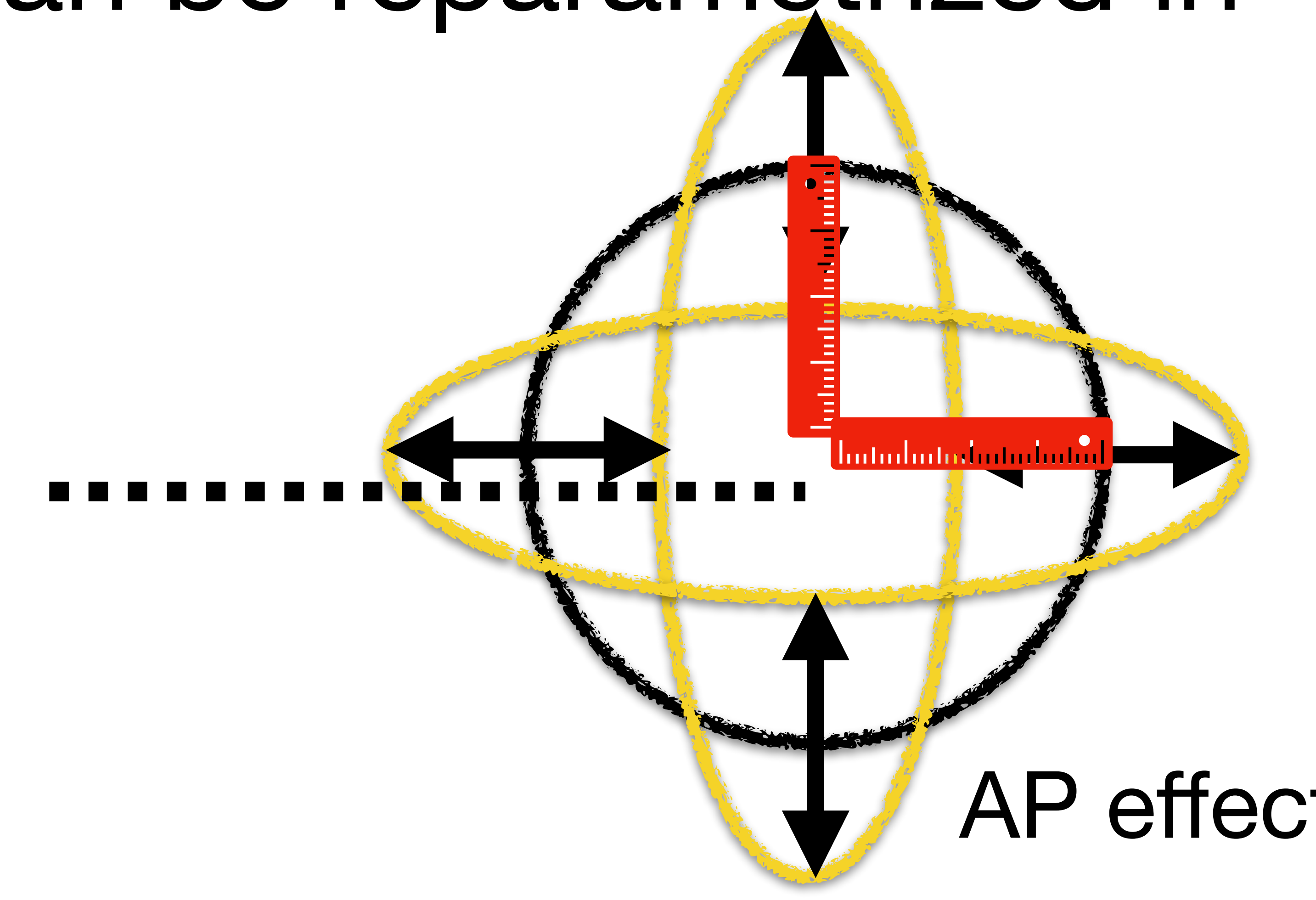
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

The along and across LOS BAO distortions can be reparametrized in



Isotropic re-scaling



AP effect

$$\{[D_M(z)/r_d]^2 D_H(z)/r_d\}^{1/3} \equiv D_V(z)/r_d$$

$$D_M(z)/D_H(z)$$

For aficionados ⟶ $[\alpha_\parallel \alpha_\perp^2]^{1/3} \equiv \alpha_{\rm iso}$

$\alpha_\perp/\alpha_\parallel \equiv \alpha_{AP}$ ↘ Alcock-Paczynski parameter

# The BAO as a standard ruler

Exploiting BAO-only at different redshifts…

## Uncallibrated BAO ($r_d$ unknown)

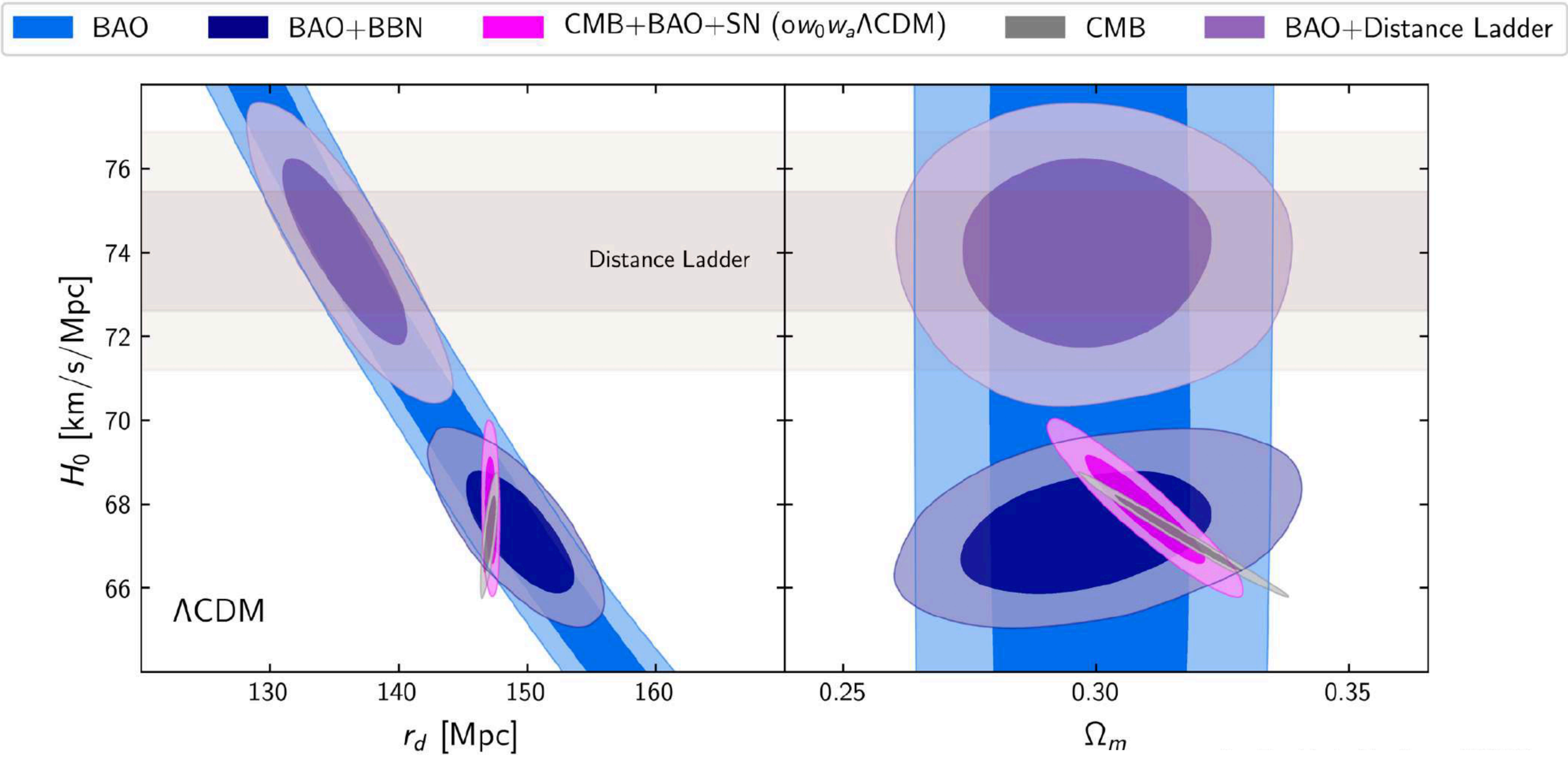
$$D_V(z_1)/D_V(z_2) \quad \& \quad D_M(z_1)/D_H(z_1)$$

Expansion history $E(z)$ ⟶ eg. $\Omega_m$ in LCDM

$H_0$ in units of $r_d$ ⟶ $H_0 r_d$

## Callibrated BAO ($r_d$ known)

If $r_d$ is given by external datasets ⟶ $H_0 \quad \& \quad r_d$

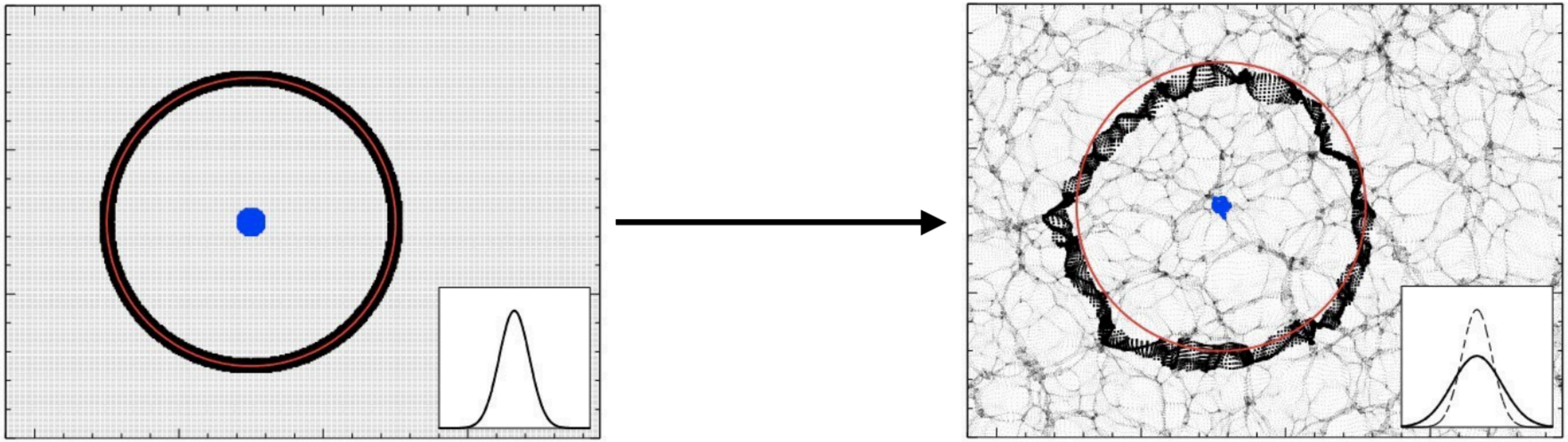



*Credit: Eva-Maria Müller & SDSS*

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The BAO as a standard ruler

Nonlinear evolution blurs and shrinks the BAO peak in the galaxy distribution…

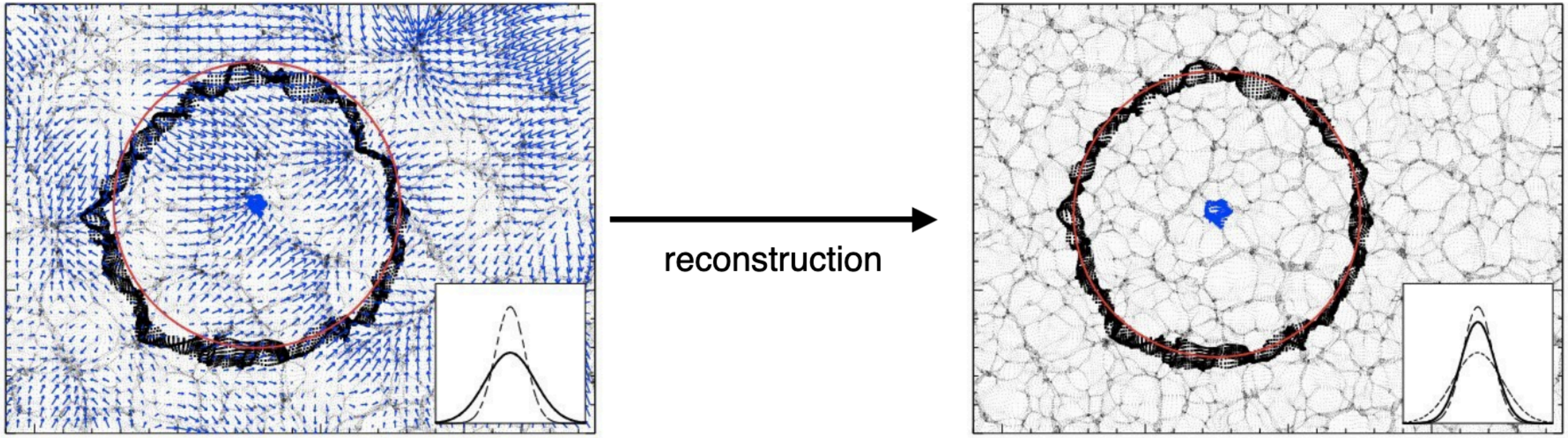


DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The BAO as a standard ruler

## Reconstructing the field through Zeldovich displacements undo the non-linear shift

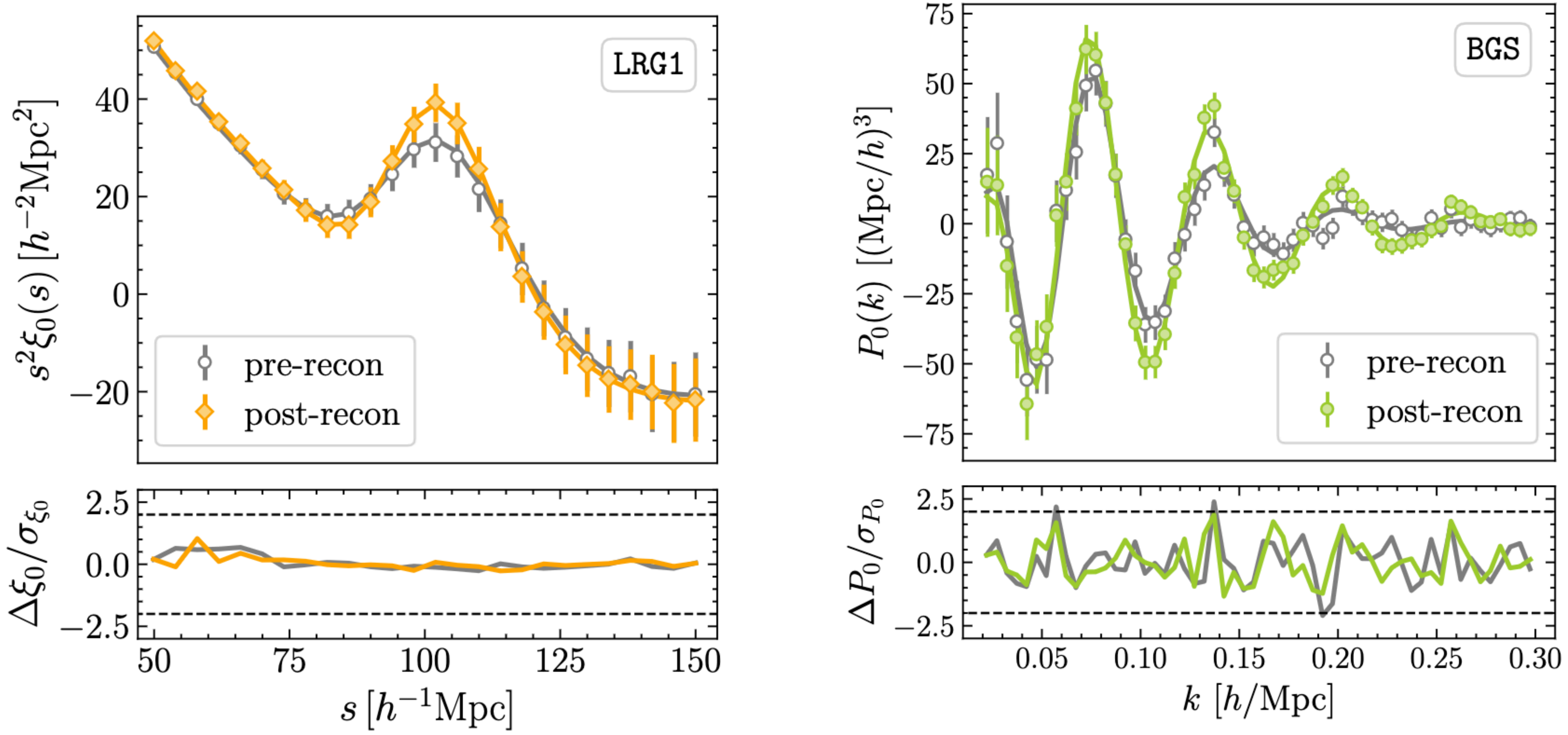
Eisenstein et al 2008, Padmanabhan et al 2012



DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

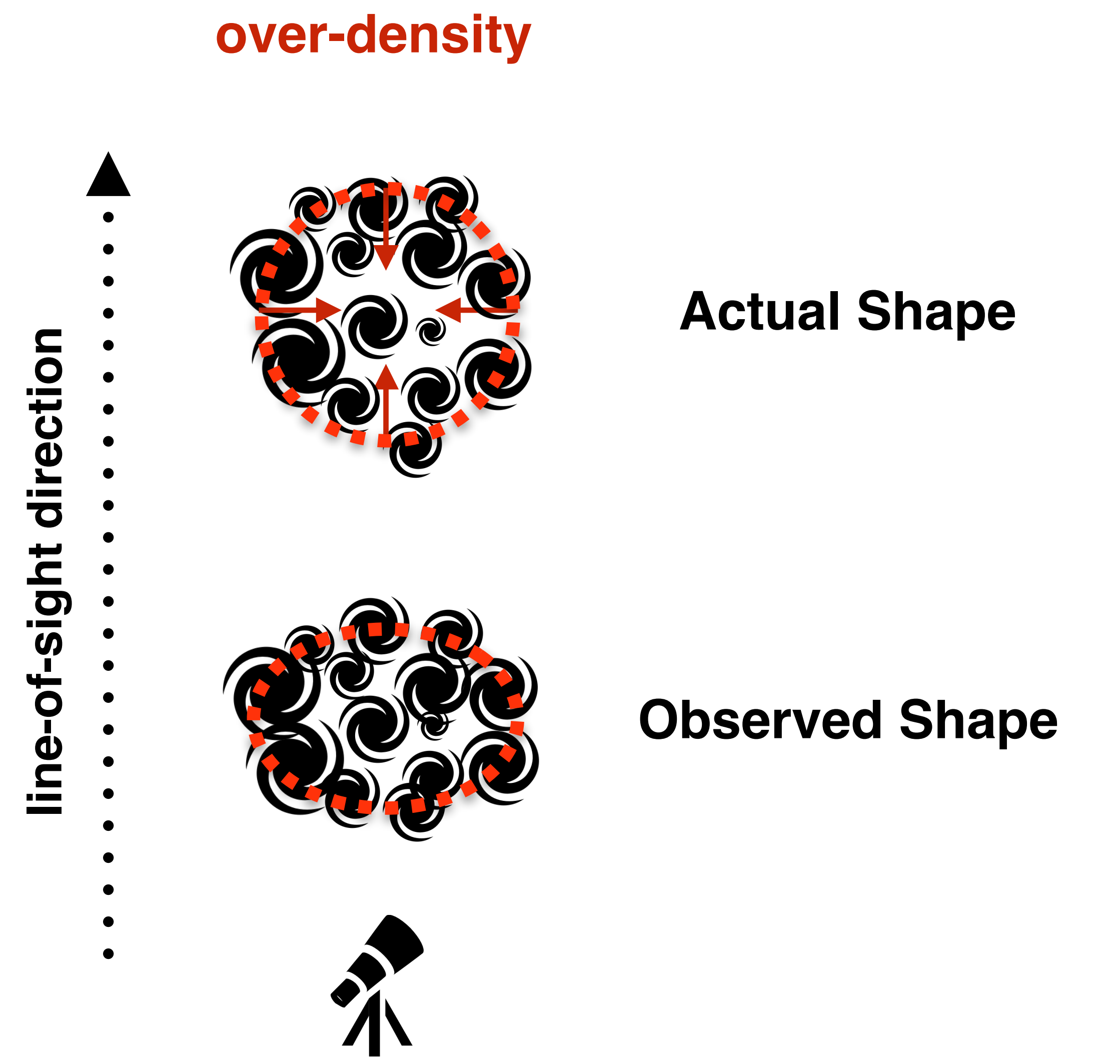
# The BAO as a standard ruler

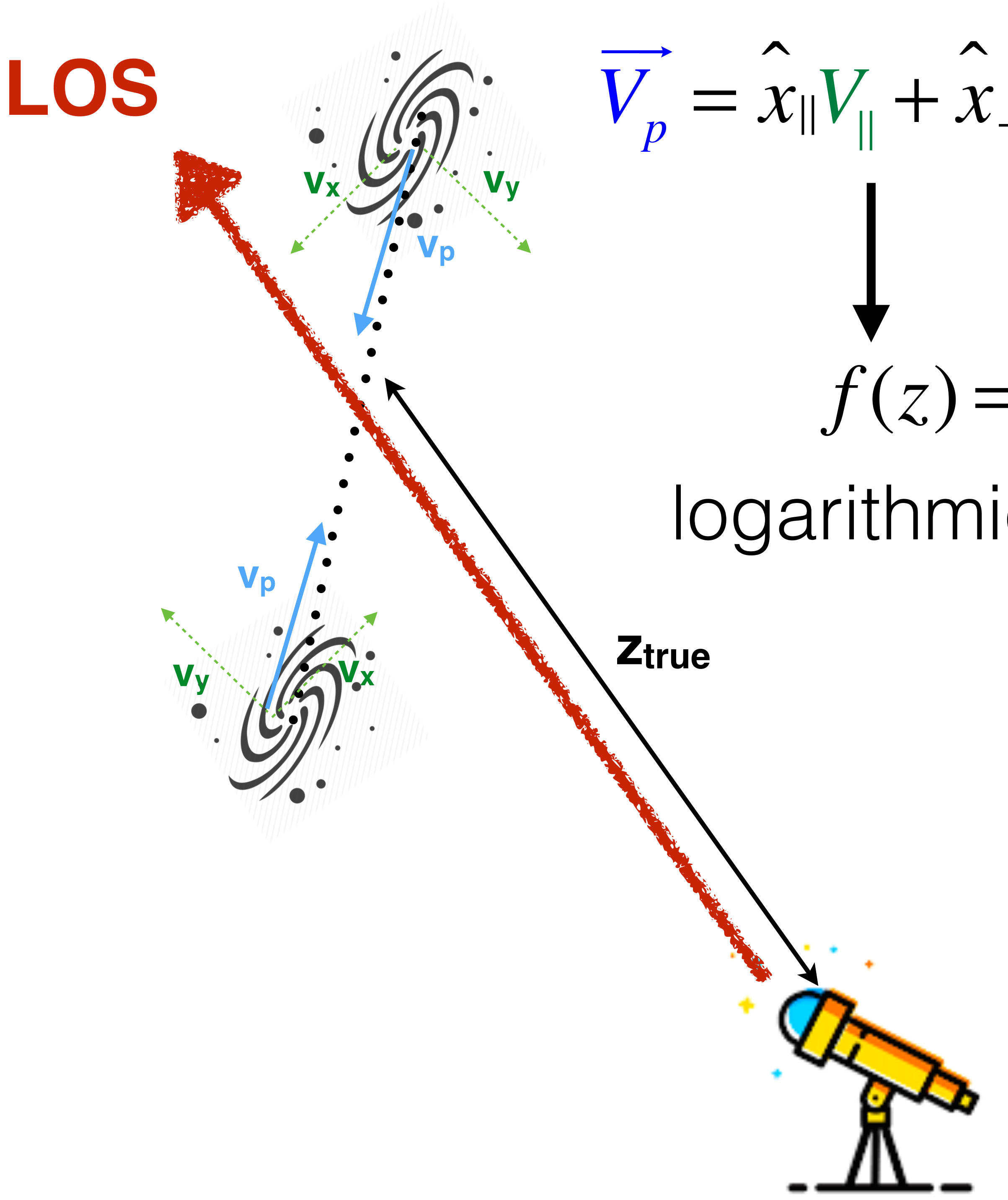
We can improve both precision and accuracy



# The RSD as a gravity probe

- **RSD**: Enhancement / reduction of the clustering along the line-of-sight (LOS) direction due to peculiar velocities (Kaiser 1987)




$$\vec{V}_p = \hat{x}_{\parallel} V_{\parallel} + \hat{x}_{\perp} V_{\perp}$$

$$\downarrow$$

$$f(z) = \Omega_m(z)^{\gamma}$$

logarithmic growth of structure

$$z_{obs} = z_{true} \oplus z_{pec} \equiv \left[(1+z_{true}) \times (1+z_{pec})\right] - 1$$

1. Hubble flow
2. Coherent with growth of structure

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

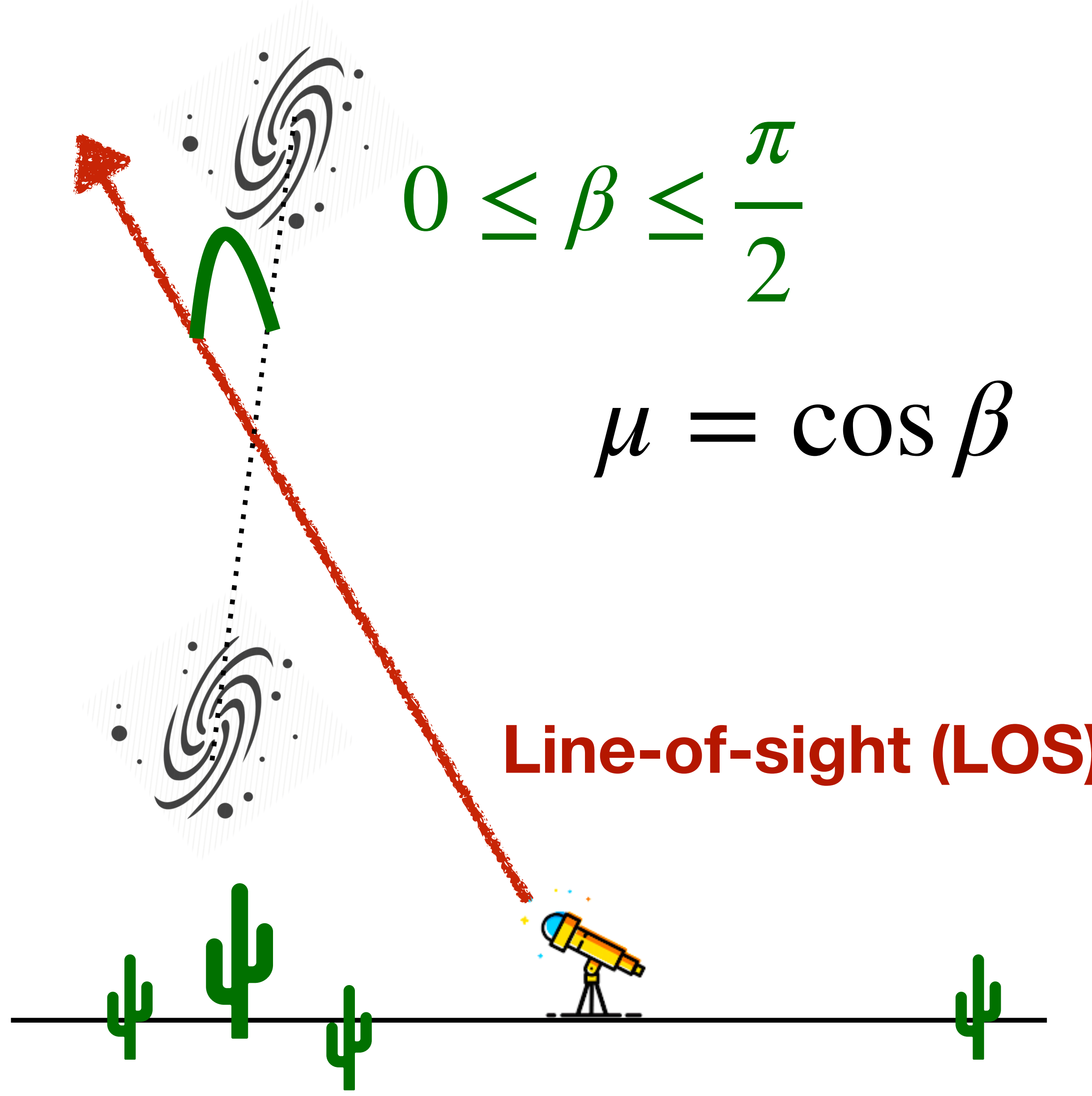
# The RSD as a gravity probe

$$P_g^{(s)}(k,\mu) = \left[b + f\mu^2\right]^2 P_m(k)$$

$$P^{(s)}(k,\mu) = P^{(0)}(k)L_0(\mu) + P^{(2)}(k)L_2(\mu) + P^{(4)}(k)L_4(\mu)$$

monopole — Isotropic signal

quadrupole, hexadecapole — Anisotropic signal




$$P^{(0)}(k,z) = \left(b(z)^2 + \frac{2}{3}b(z)f(z) + \frac{1}{5}f(z)^2\right)P_m(k,z)$$

$$P^{(2)}(k,z) = \left(\frac{4}{3}b(z)f(z) + \frac{4}{7}f(z)^2\right)P_m(k,z)$$

$$P^{(4)}(k,z) = \left(\frac{8}{35}f(z)^2\right)P_m(k,z)$$

$$P_m(k,z) \equiv \sigma_{s8}^2(z)P_m(k,z=0)$$

$\longrightarrow$ $f(z) \times \sigma_{s8}(z)$ & $b(z) \times \sigma_{s8}(z)$

**When $\Omega_m$ from BAO is added....** $f(z) = \Omega_m(z)^\gamma \longrightarrow \sigma_{s8}(z)$

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The RSD as a gravity probe

Which information is extracted from $P(k)$?

$$D_H(z)/r_s, \quad D_M(z)/r_s, \quad f\sigma_{s8}(z)$$

- Alcock-Paczynski & isotropic dilation: background
- Redshift Space Distortions: perturbations

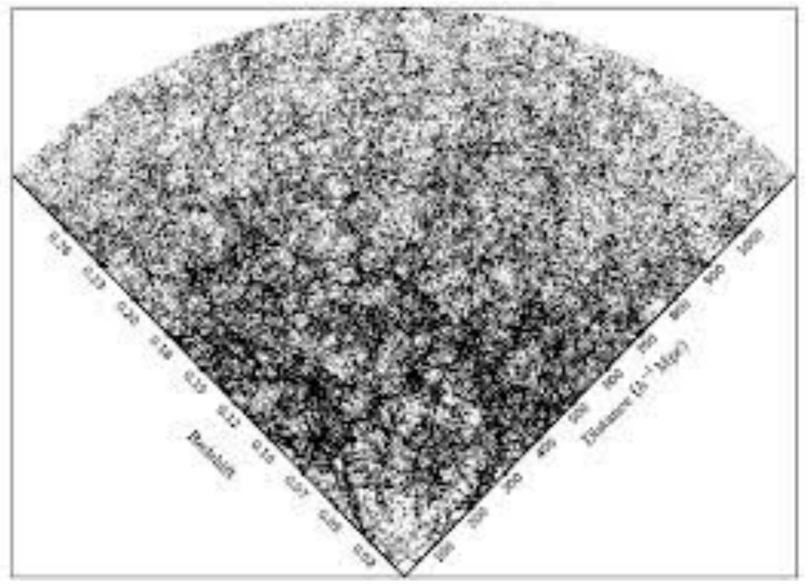
Is there more relevant information?

DARK ENERGY SPECTROSCOPIC INSTRUMENT

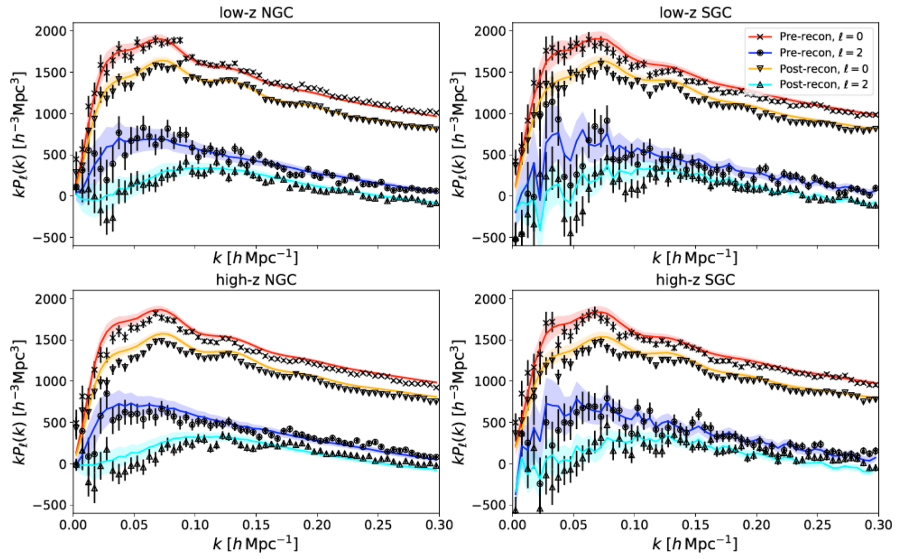
U.S. Department of Energy Office of Science

# ShapeFit & Full Modelling

Galaxy Catalogues



Power Spectra ++




BAO & RSD

Compression

$\{D_H(z)/r_s, D_M(z)/r_s, f\sigma_{s8}(z)\}$

Cosmological interpretation

$\{\Omega_m, A_s, h\}$

Full Modelling (FM)

Cosmological interpretation

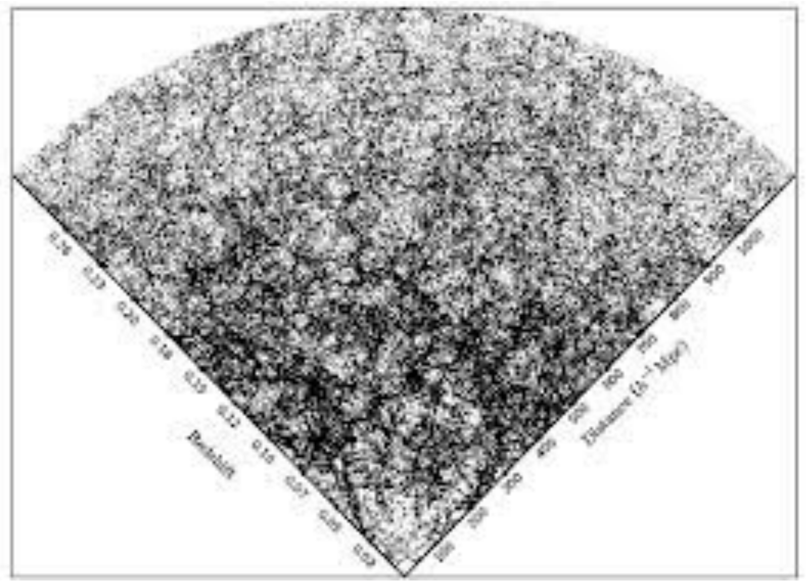
$\{\Omega_m, A_s, h, \ldots\}$

Are these the same?

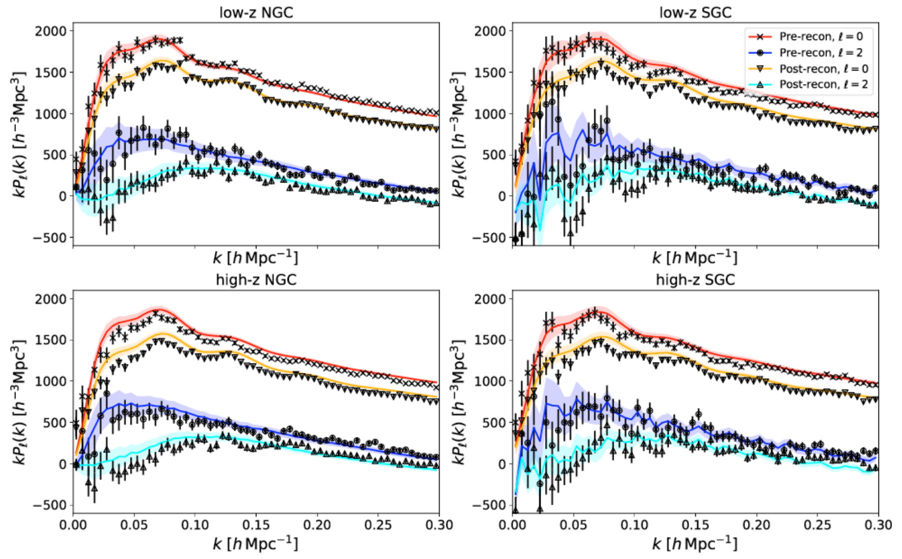
DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# ShapeFit & Full Modelling

Galaxy Catalogues



Power Spectra ++




BAO & RSD

Compression

$\{D_H(z)/r_s, D_M(z)/r_s, f\sigma_{s8}(z)\}$

Cosmological interpretation

$\{\Omega_m, A_s, h\}$

Full Modelling (FM)

Cosmological interpretation

$\{\Omega_m, A_s, h, \ldots\}$

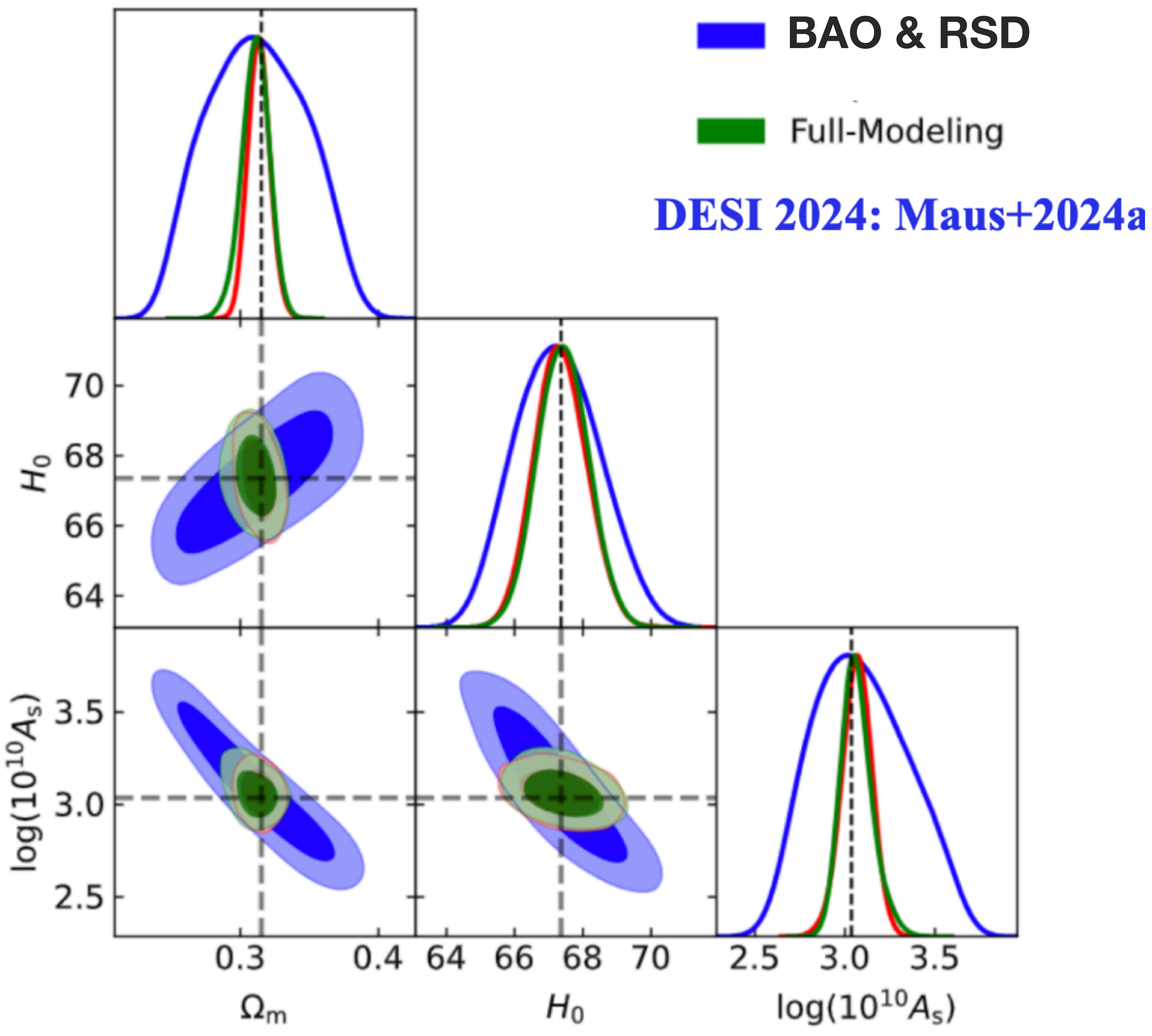
Are these the same?

No!

Why?

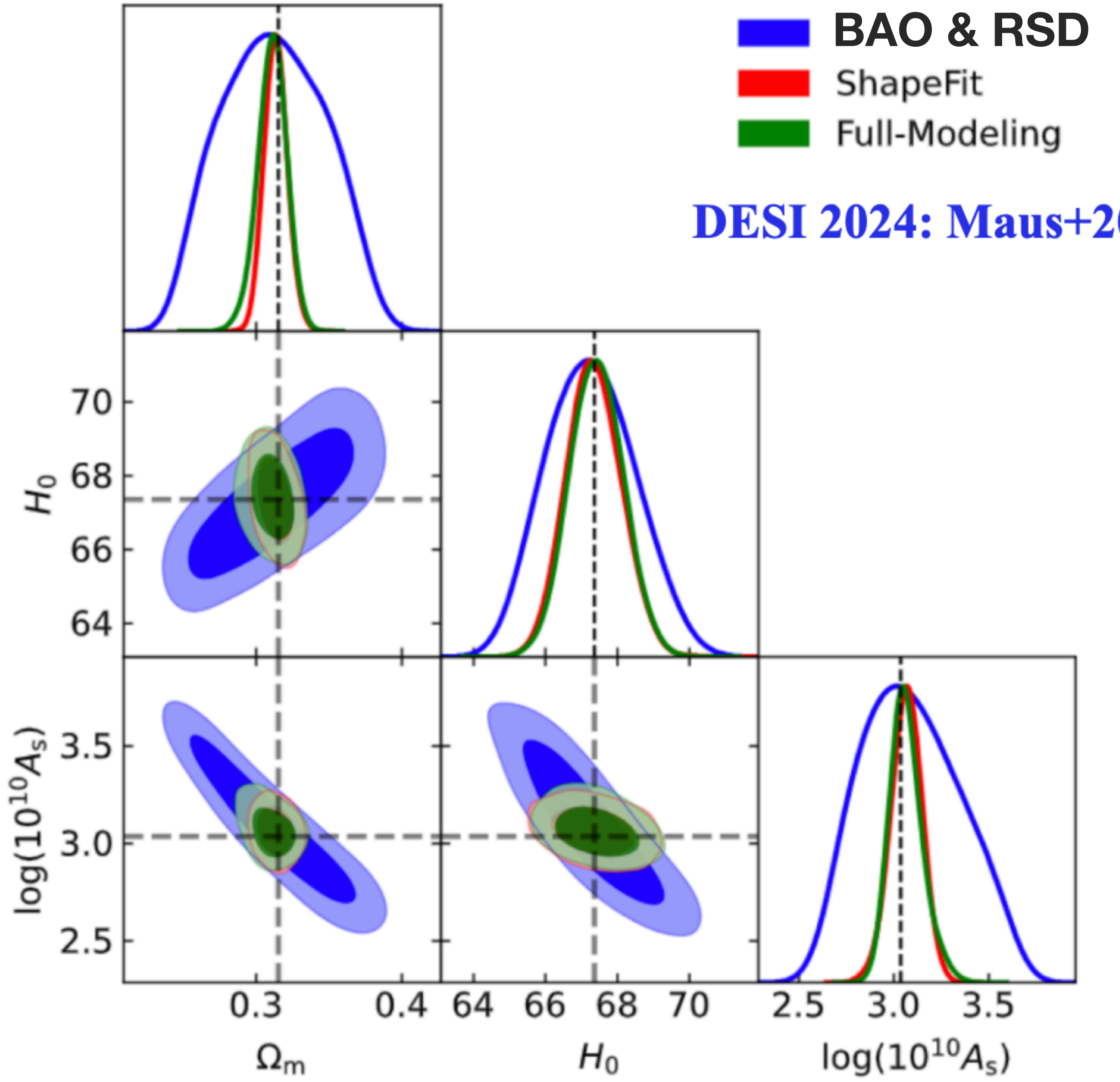
Compression is not lossless

# ShapeFit & Full Modelling



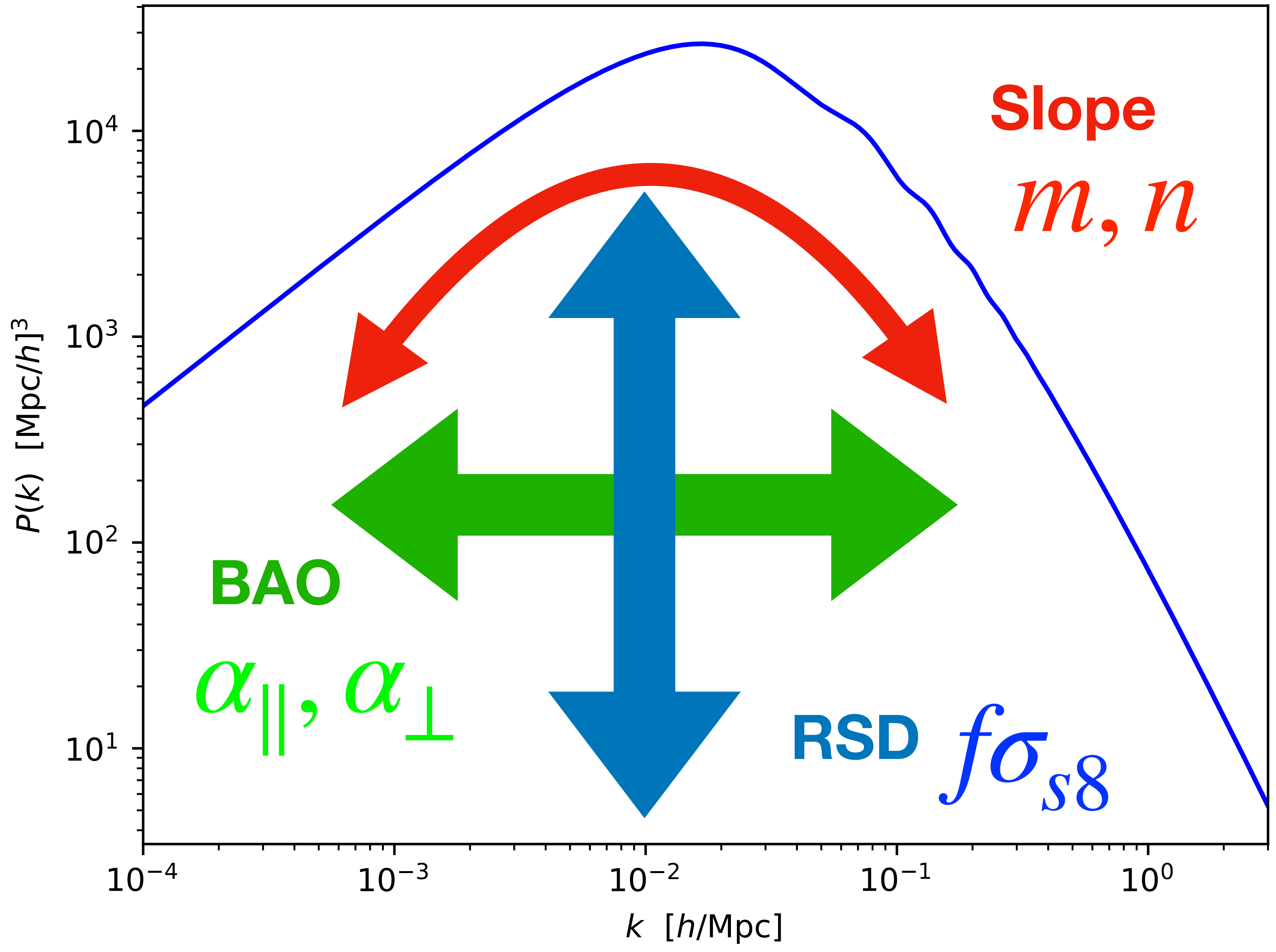

We would like to promote the traditional BAO+RSD to the FM constraining power

# ShapeFit & Full Modelling




**DESI 2024: Maus+2024a**

We would like to promote the traditional BAO+RSD to the FM constraining power



DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# ShapeFit & Full Modelling

## Modelling transfer function dependence: ShapeFit

Compressed Variables — LCDM Variables

**Standard BAO analysis**: $D_H(z)/r_s$, $D_M(z)/r_s$ → $\Omega_m$, $h \cdot r_s$

Late-time quantities (in units of $r_s$)

+

**Standard RSD analysis**: $f(z) \cdot \sigma_{s8}(z)$ → $A_s$

Late-time quantities

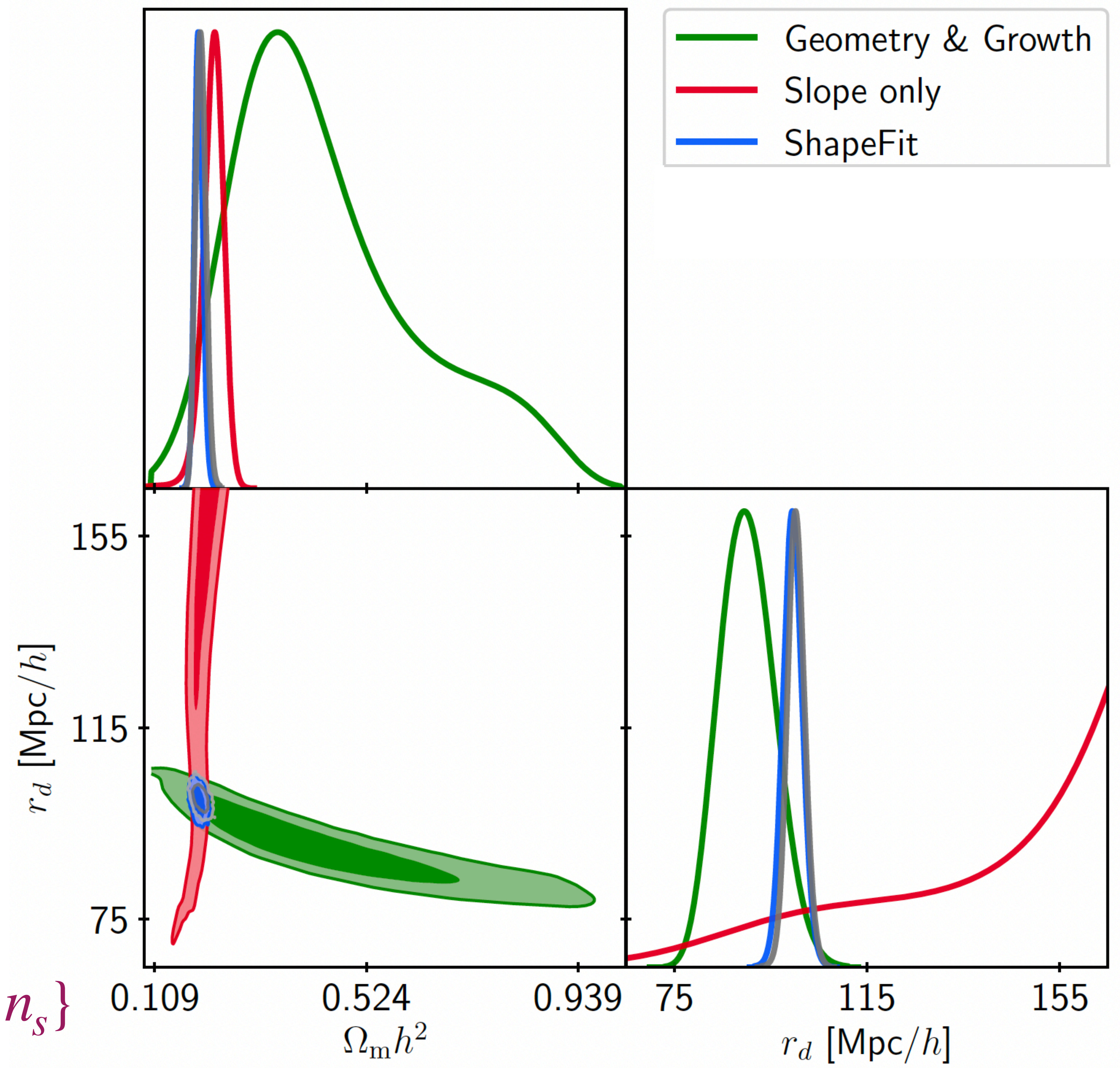
+

**ShapeFit analysis**: $m(z)$ (Shape) → $\Omega_m h^2$

early-time quantity

$\{D_M(z)/r_s, D_H(z)/r_s, f\sigma_{s8}(z), m(z)\}$

$\{\Omega_m, h, A_s\} + \{\Omega_b, n_s\}$




Brieden, HGM, Verde 2021

# Blinding DESI data

What is new about DESI data?

- Is the largest redshift catalogue, both in terms of volume and objects

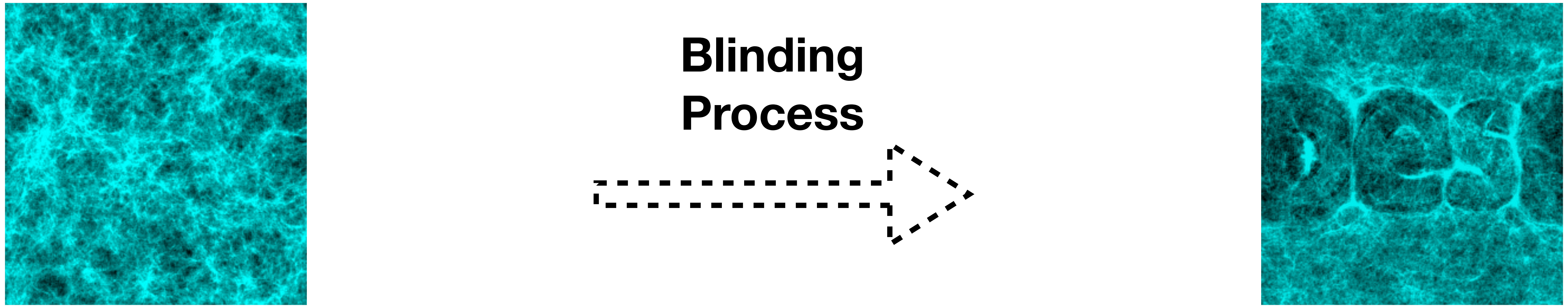
# Blinding DESI data

What is new about DESI data?

- Is the largest redshift catalogue, both in terms of volume and objects.

- This is the first time that redshift survey data is analyzed in a <u>catalogue-based blinded</u>

  - Allow us to mitigate confirmation bias!



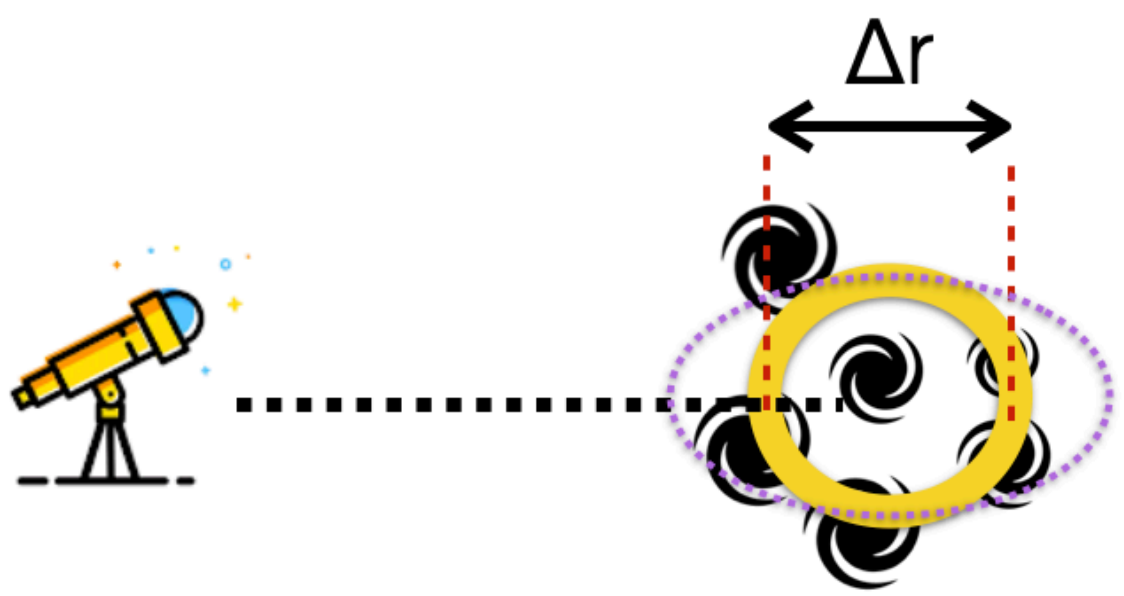
# Blinding DESI data

$(\mathrm{ra}, \mathrm{dec}, z) \xrightarrow{\text{fiducial cosmology}} (X, Y, Z) \xrightarrow{\text{blind cosmology } w_0,\, w_a,\, \Omega_m \text{ (not revealed!)}} (\mathrm{ra}, \mathrm{dec}, z')$

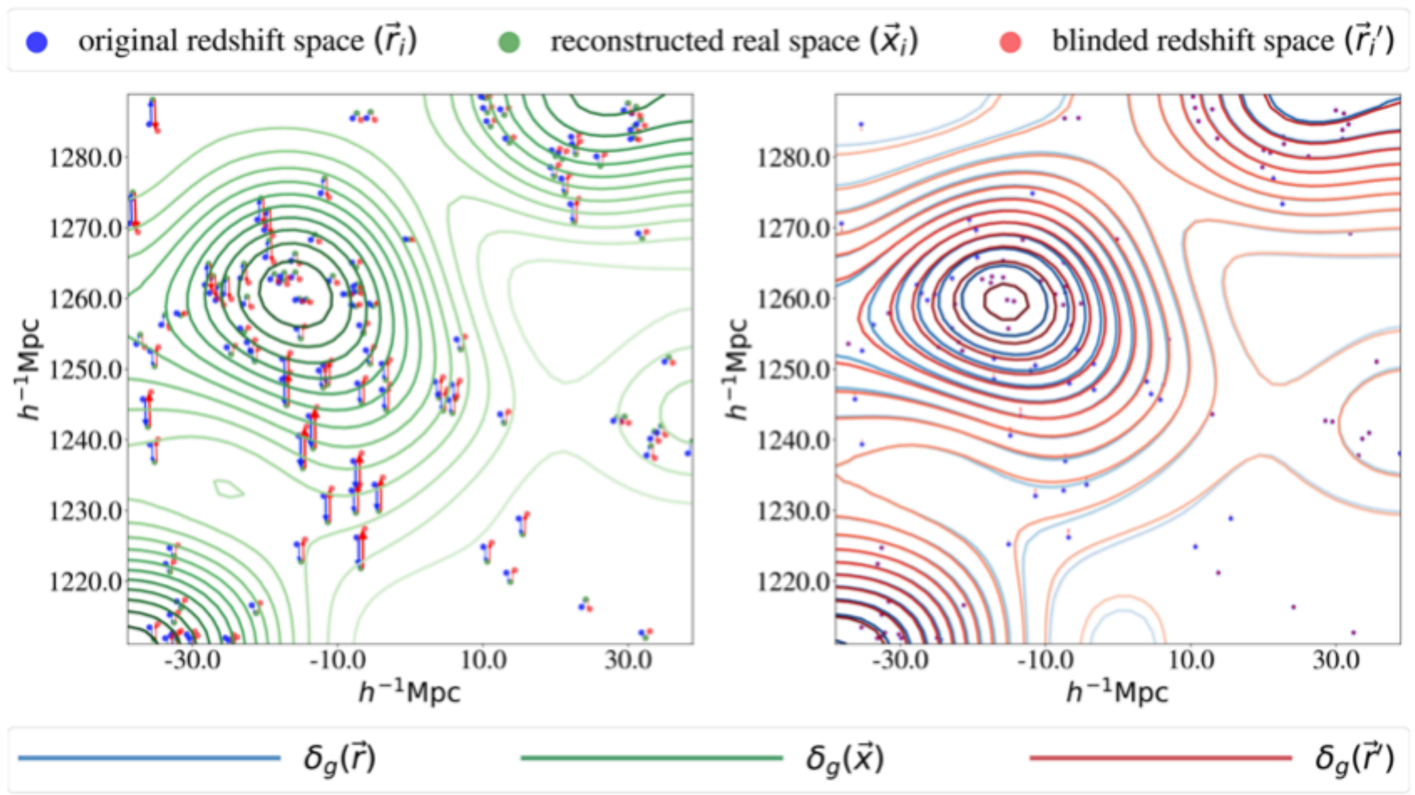
+ change to peculiar velocity contributions to redshift to blind growth rate

+ weights-based blinding for primordial non-Gaussianity $f_{\rm NL}$

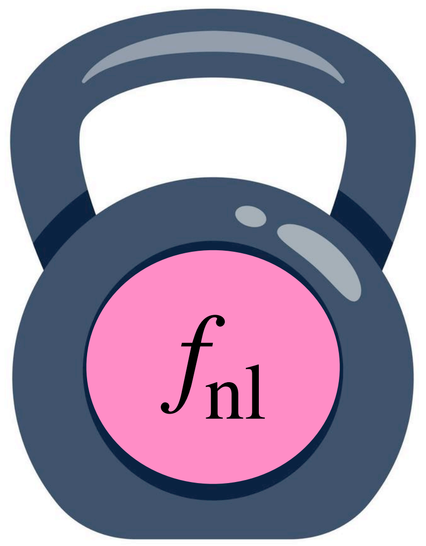
**1. geometrical AP-like shift**




**2. density-dependent RSD-like shift**




**3. Imprint $f_{\rm nl}$ signature in $P(k)$ through galaxy weights**



DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# Blinding DESI data

$$(\text{ra}, \text{dec}, z) \xrightarrow{\text{fiducial cosmology}} (X, Y, Z) \xrightarrow{\text{blind cosmology } w_0,\, w_a,\, \Omega_m} (\text{ra}, \text{dec}, z')$$

fiducial cosmology

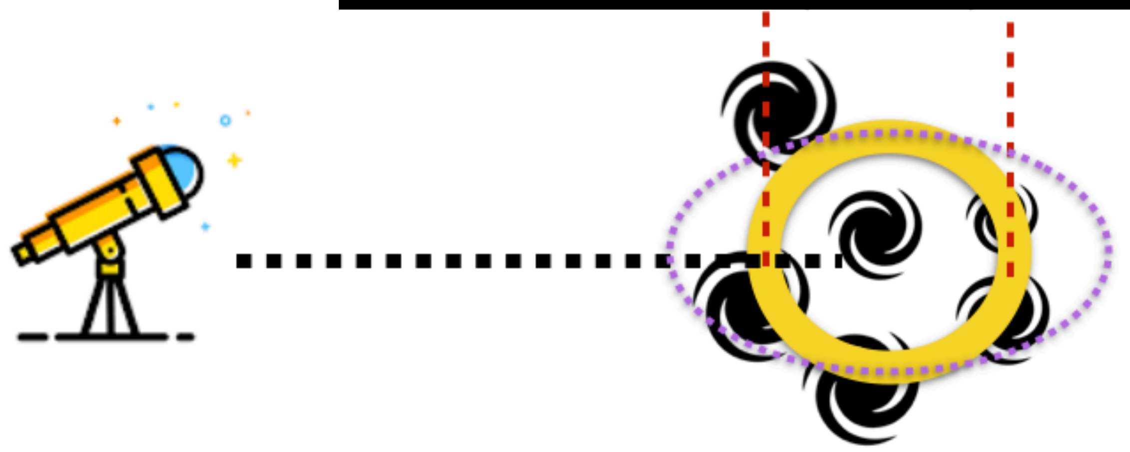
**blind** cosmology $w_0$, $w_a$, $\Omega_m$
(not revealed!)

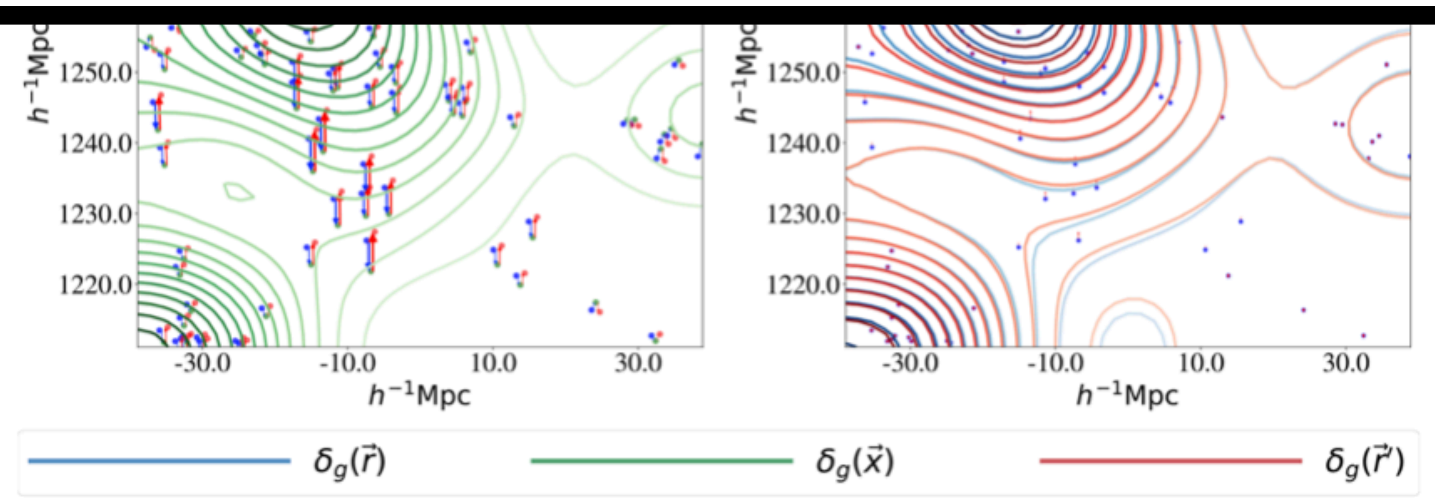
| Test | Results |
|---|---|
| $\chi^2$ acceptable? | Yes |
| $\alpha$ consistent between pre and post? | Yes |
| $\alpha$ consistent between NGC+SGC and NGC? | Yes |
| Consistency between North and South? | Tested at the level of the clustering (Section 2) |
| $\alpha$ consistent across different fiducial cosmologies? | Yes |
| $\alpha$ consistent between $\xi(r)$ and $P(k)$? | Yes |
| Are the error bars reasonable? | Consistent with the mocks |
| $\alpha$ consistent between LRG and ELG $0.8 < z < 1.1$ | Yes |

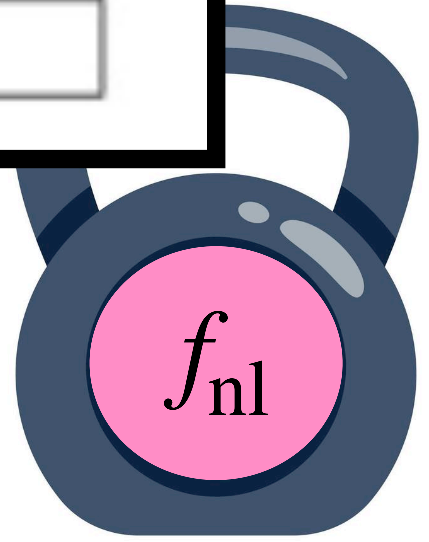
rate

1. geome

nature in $P(k)$
xy weights





# The BAO measurements

Systematic error quantification

- Observational effects (imaging, fibre assigment)
- Accuracy of reconstruction algorithm(s)
- Covariance matrix
- Theory modelling
- Choice of fiducial cosmology
- Impact of galaxy-halo connection (HOD)

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The BAO measurements

## Systematic error quantification

- Observational effects (imaging, fibre assigment)
- Accuracy of reconstruction algorithm(s)
- Covariance matrix

→ no BAO error detected

- Theory modelling
- Choice of fiducial cosmology
- Impact of galaxy-halo connection (HOD)

→

| | Tracer | $\sigma_{\rm BGS}$ | $\sigma_{\rm LRGs,ELGs}$ | | $\sigma_{\rm QSO}$ |
|---|---|---|---|---|---|
| Space | Source | $\alpha_{\rm iso}$ (%) | $\alpha_{\rm iso}$ (%) | $\alpha_{\rm AP}$ (%) | $\alpha_{\rm iso}$ (%) |
| $\xi(r)$ | Theory (Table 7) | 0.1 | 0.1 | 0.2 | 0.1 |
| $\xi(r)$ | HOD (Table 8) | 0.2 | 0.2 | 0.2 | 0.2 |
| $\xi(r)$ | Fiducial (Table 11) | 0.1 | 0.1 | 0.1 | 0.1 |
| $\xi(r)$ | Total | 0.245 | 0.245 | 0.3 | 0.245 |
| $P(k)$ | Theory (Table 7) | 0.1 | 0.1 | 0.2 | 0.1 |
| $P(k)$ | HOD (Table 8) | 0.2 | 0.1 | 0.1 | 0.12 |
| $P(k)$ | Fiducial (Table 11) | 0.1 | 0.1 | 0.1 | 0.1 |
| $P(k)$ | Total | 0.245 | 0.18 | 0.245 | 0.19 |

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The BAO measurements

## Systematic error quantification

- Observational effects (imaging, fibre assigment)
- Accuracy of reconstruction algorithm(s)
-
- Theory modelling
- Choice of fiducial cosmology
- Impact of galaxy-halo connection (HOD)

no BAO error
...ed

**Total systematic error-budget is very small compared to the statistics**

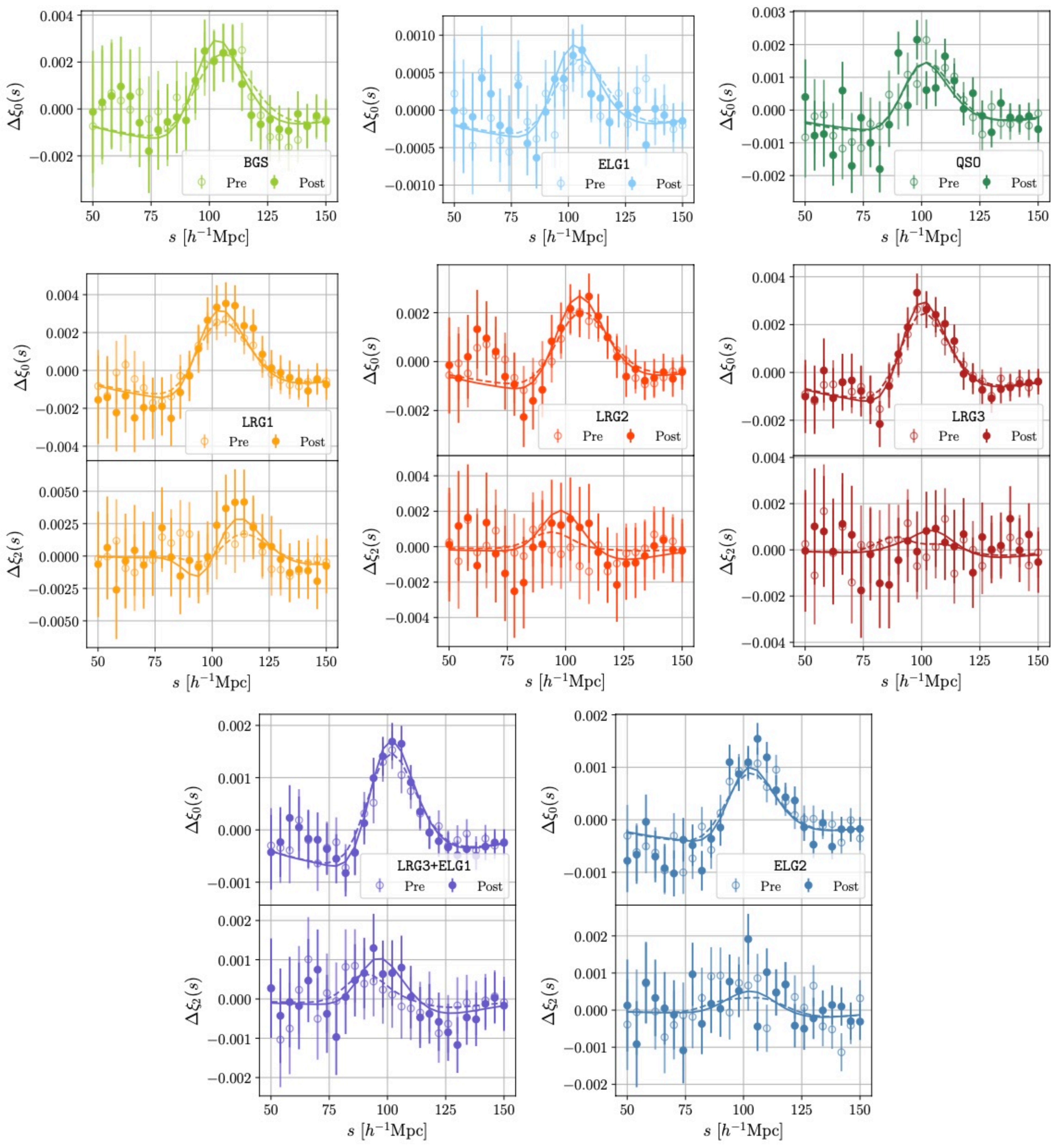
Maximum effect: $\simeq 5\,\%\,, \quad \sigma_{\rm tot} = 1.05\sigma_{\rm stat}$

| | | | | | $\sigma_{\rm QSO}$ |
|---|---|---|---|---|---|
| | | | | %) | $\alpha_{\rm iso}$ (%) |
| $\xi(r)$ | Theory (Table 7) | 0.1 | 0.1 | 0.2 | 0.1 |
| $\xi(r)$ | HOD (Table 8) | 0.2 | 0.2 | 0.2 | 0.2 |
| $\xi(r)$ | Fiducial (Table 11) | 0.1 | 0.1 | 0.1 | 0.1 |
| $\xi(r)$ | Total | 0.245 | 0.245 | 0.3 | 0.245 |
| $P(k)$ | Theory (Table 7) | 0.1 | 0.1 | 0.2 | 0.1 |
| $P(k)$ | HOD (Table 8) | 0.2 | 0.1 | 0.1 | 0.12 |
| $P(k)$ | Fiducial (Table 11) | 0.1 | 0.1 | 0.1 | 0.1 |
| $P(k)$ | Total | 0.245 | 0.18 | 0.245 | 0.19 |

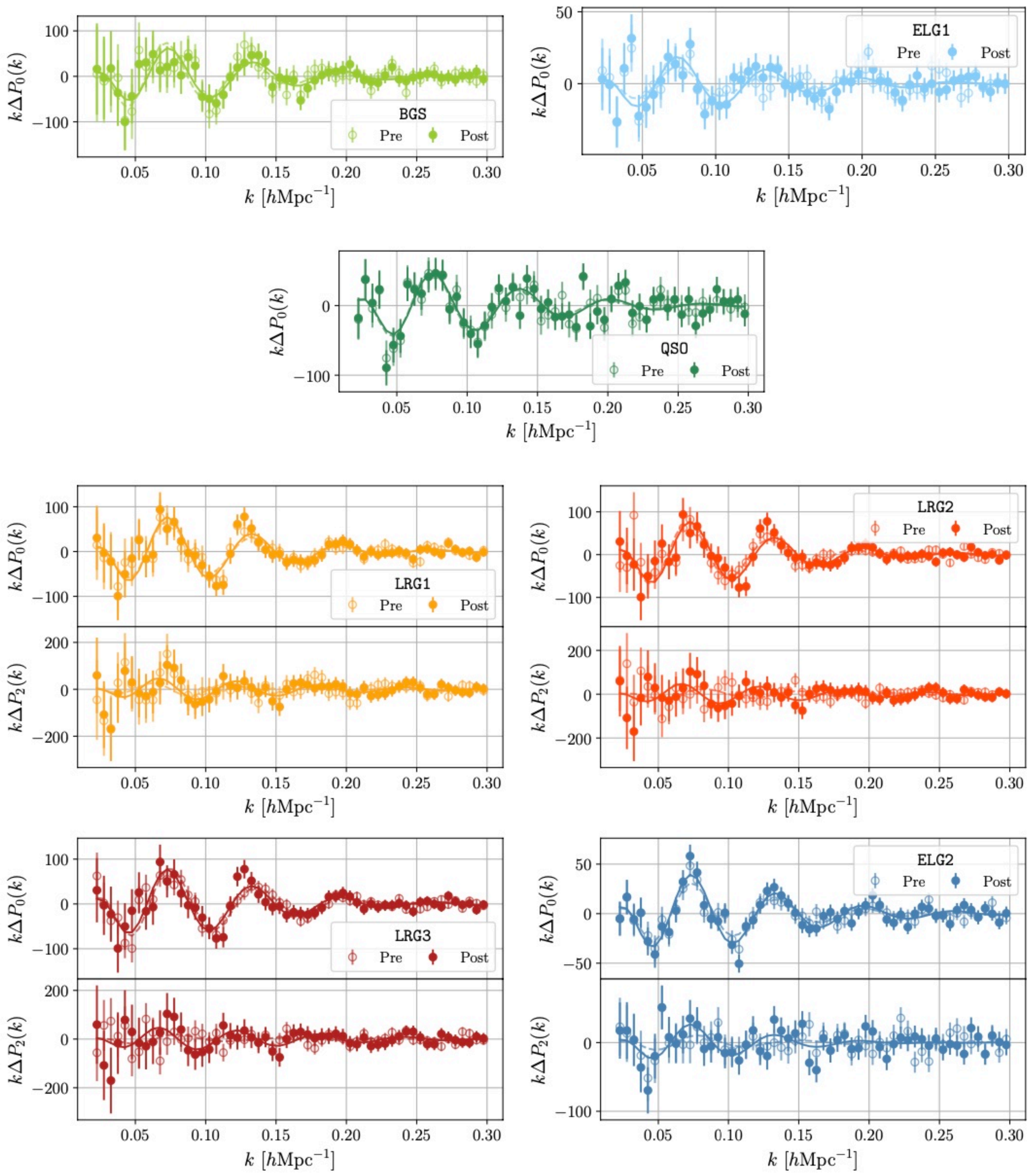
DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The BAO measurements

## Configuration Space



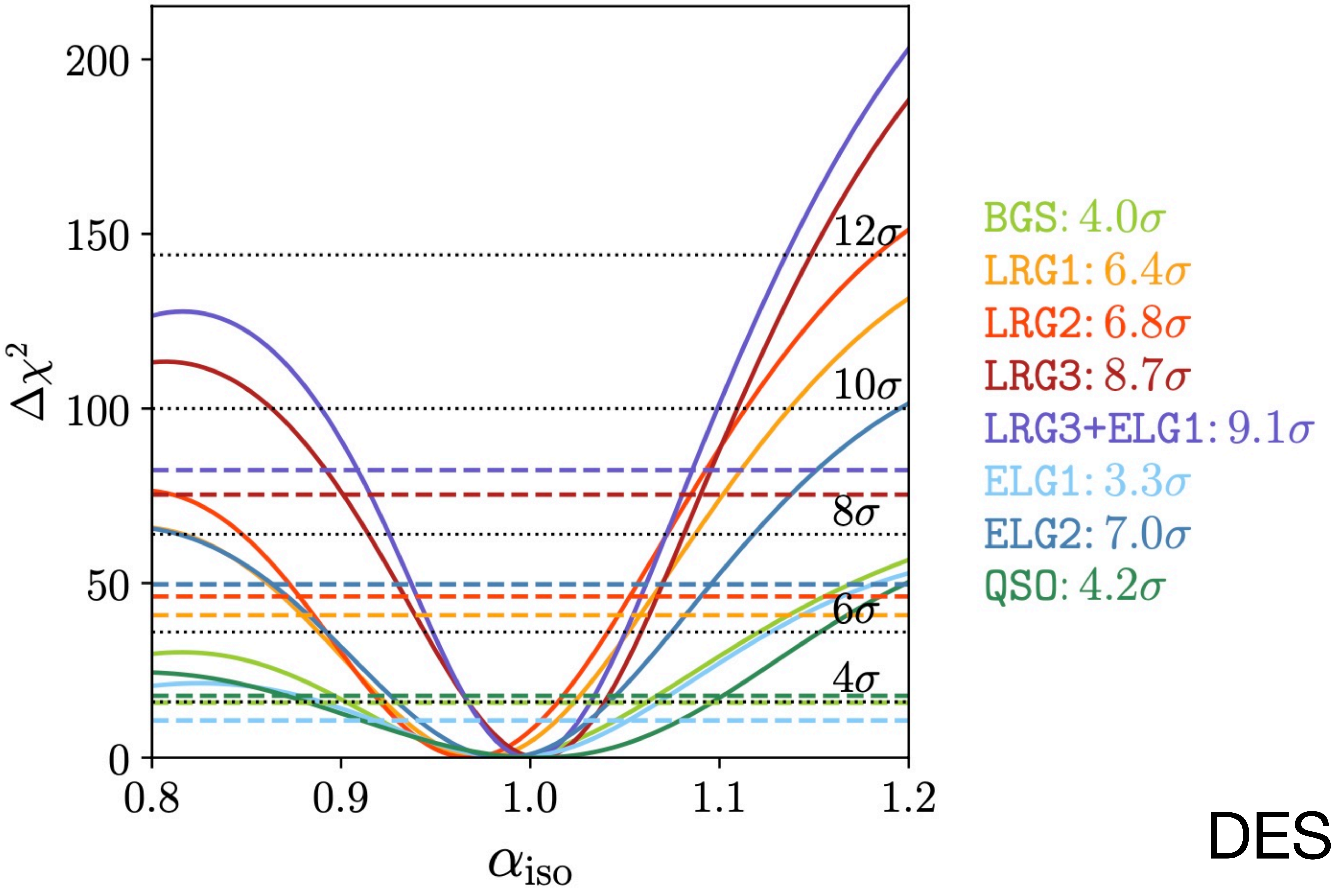

## Fourier Space



DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The BAO measurements

Isotropic dilation $D_V(z)/r_d$




Aggregate distance precision: 0.52%

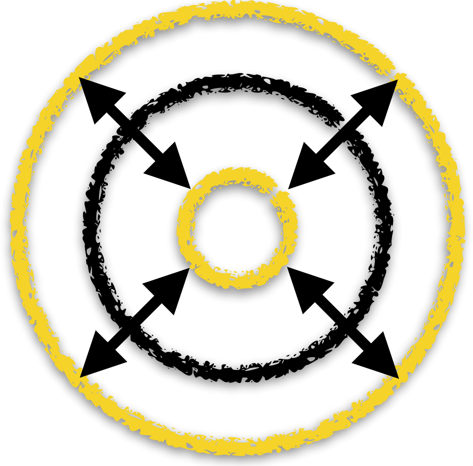
All SDSS galaxy BAO (20 years): 0.64%

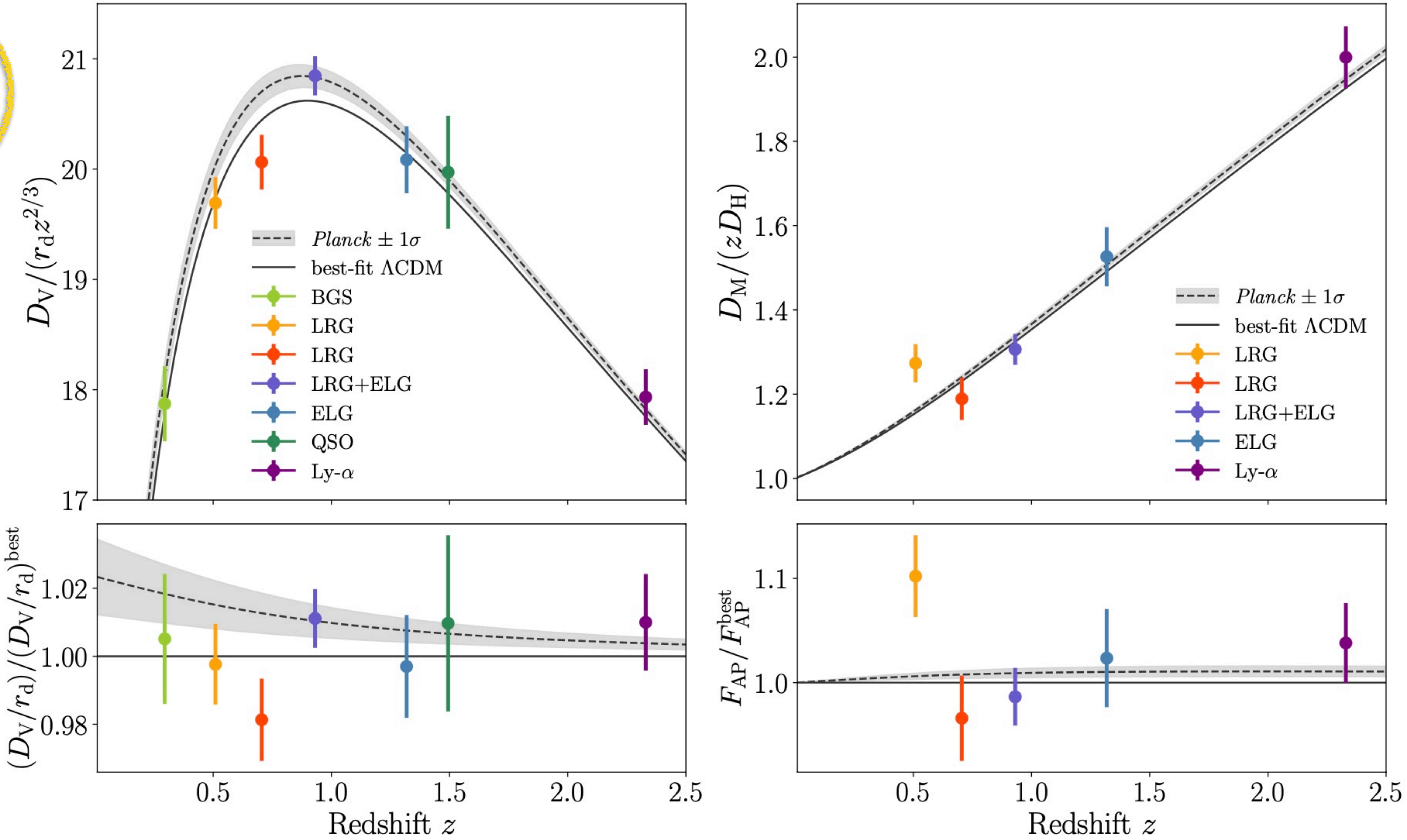
DESI DR1 ~ BOSS DR12 + eBOSS DR16

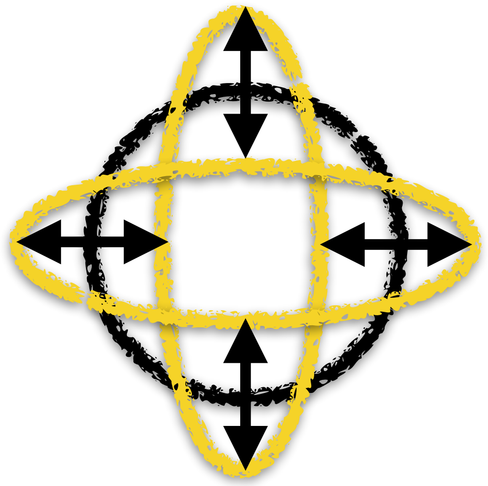
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

# The BAO measurements

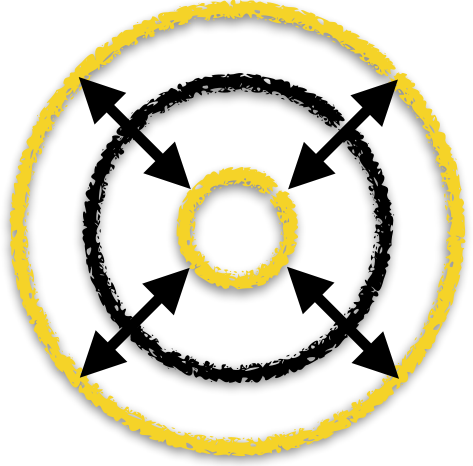


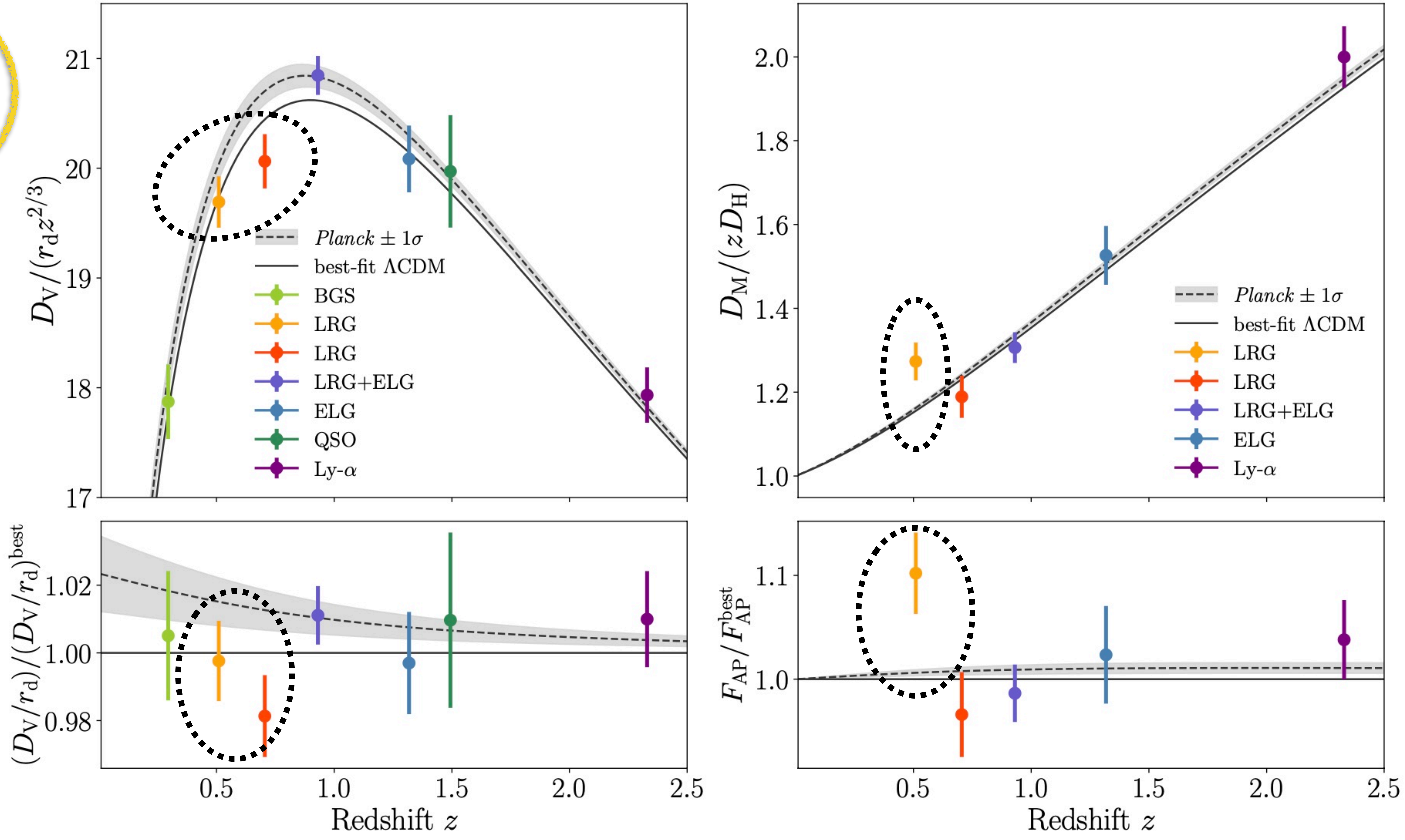


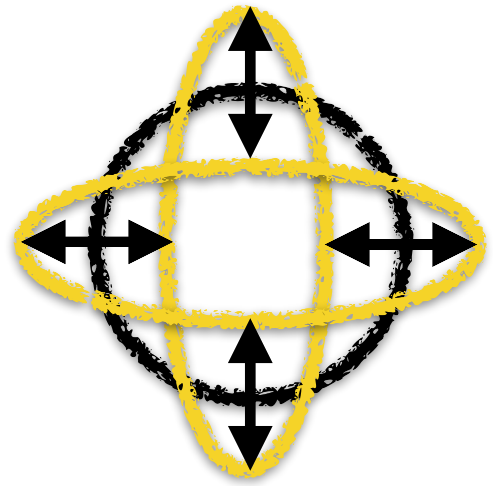



# The BAO measurements

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science



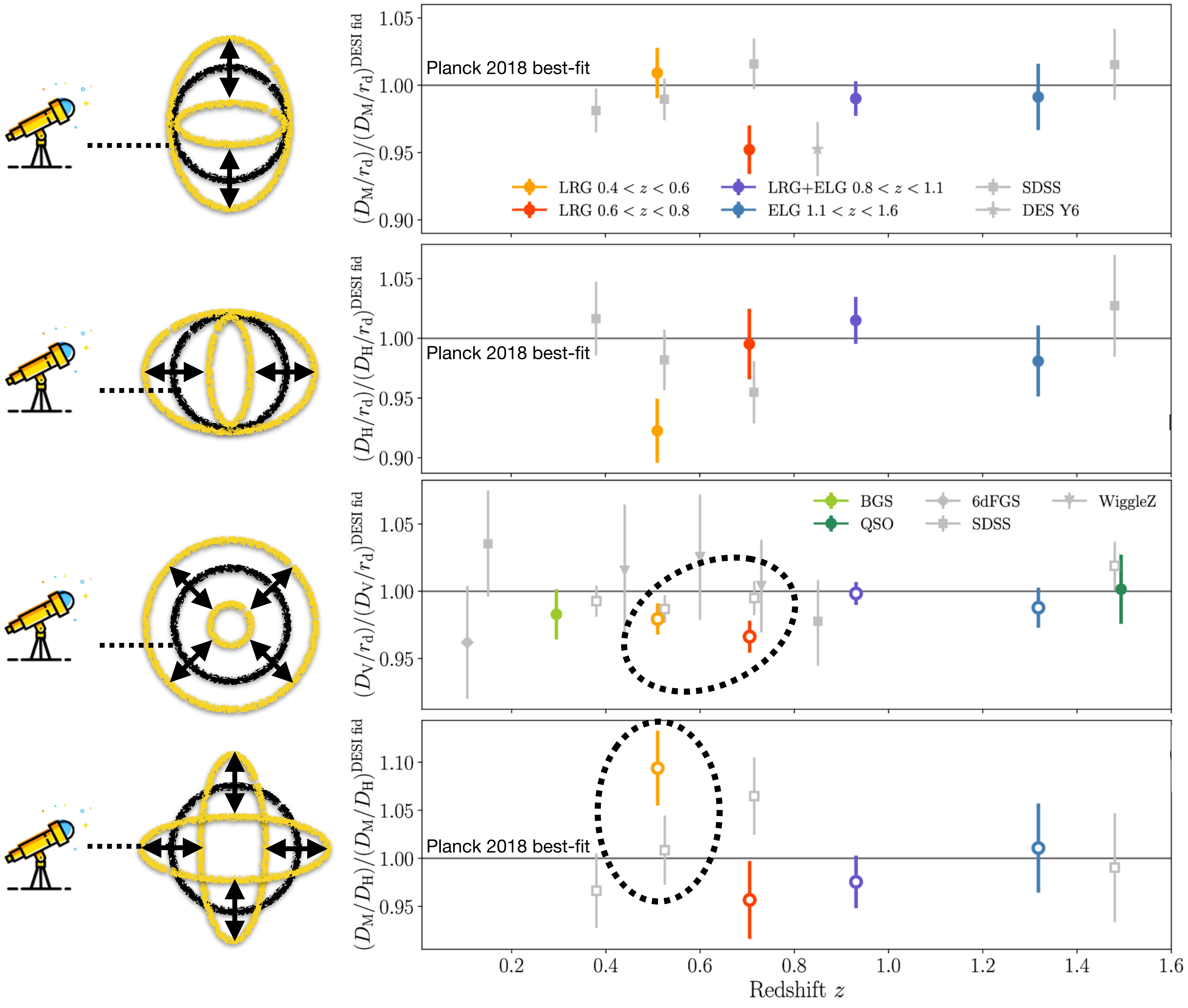


DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The BAO measurements

How this compares to the previous BOSS & eBOSS?



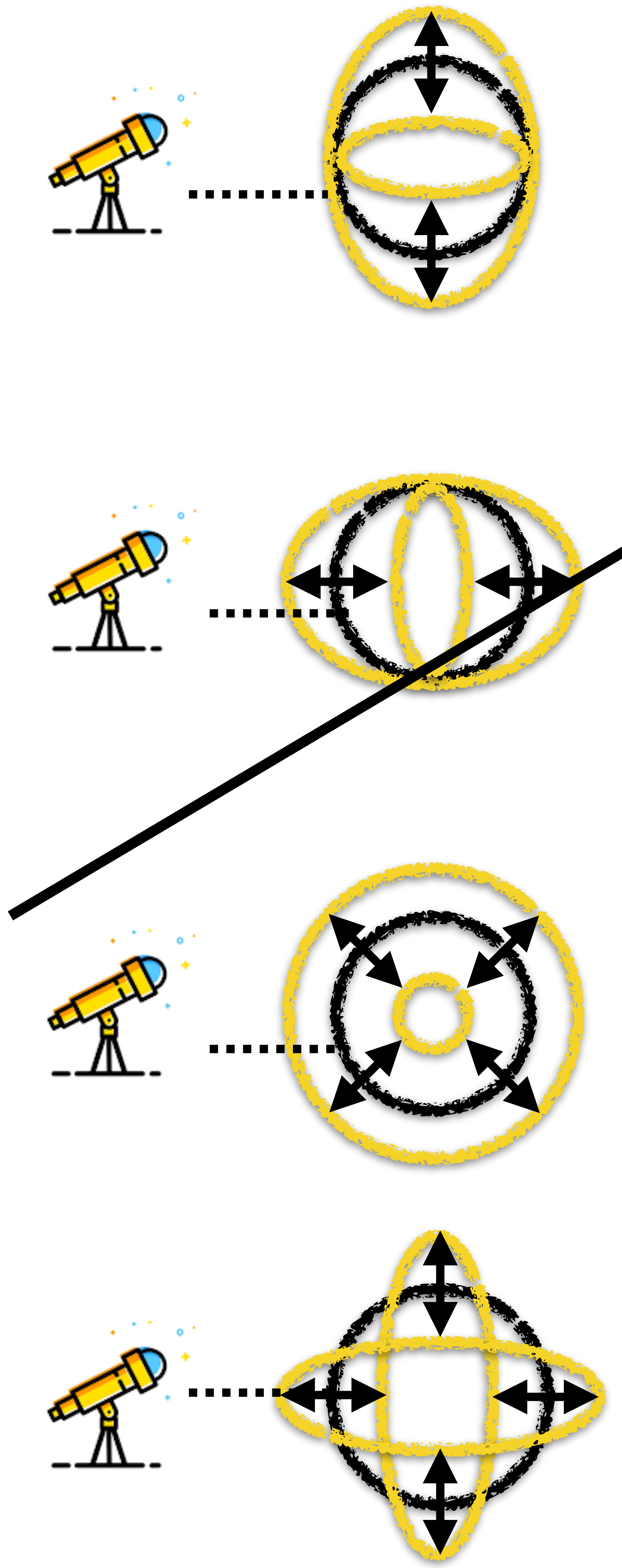
# The BAO measurements

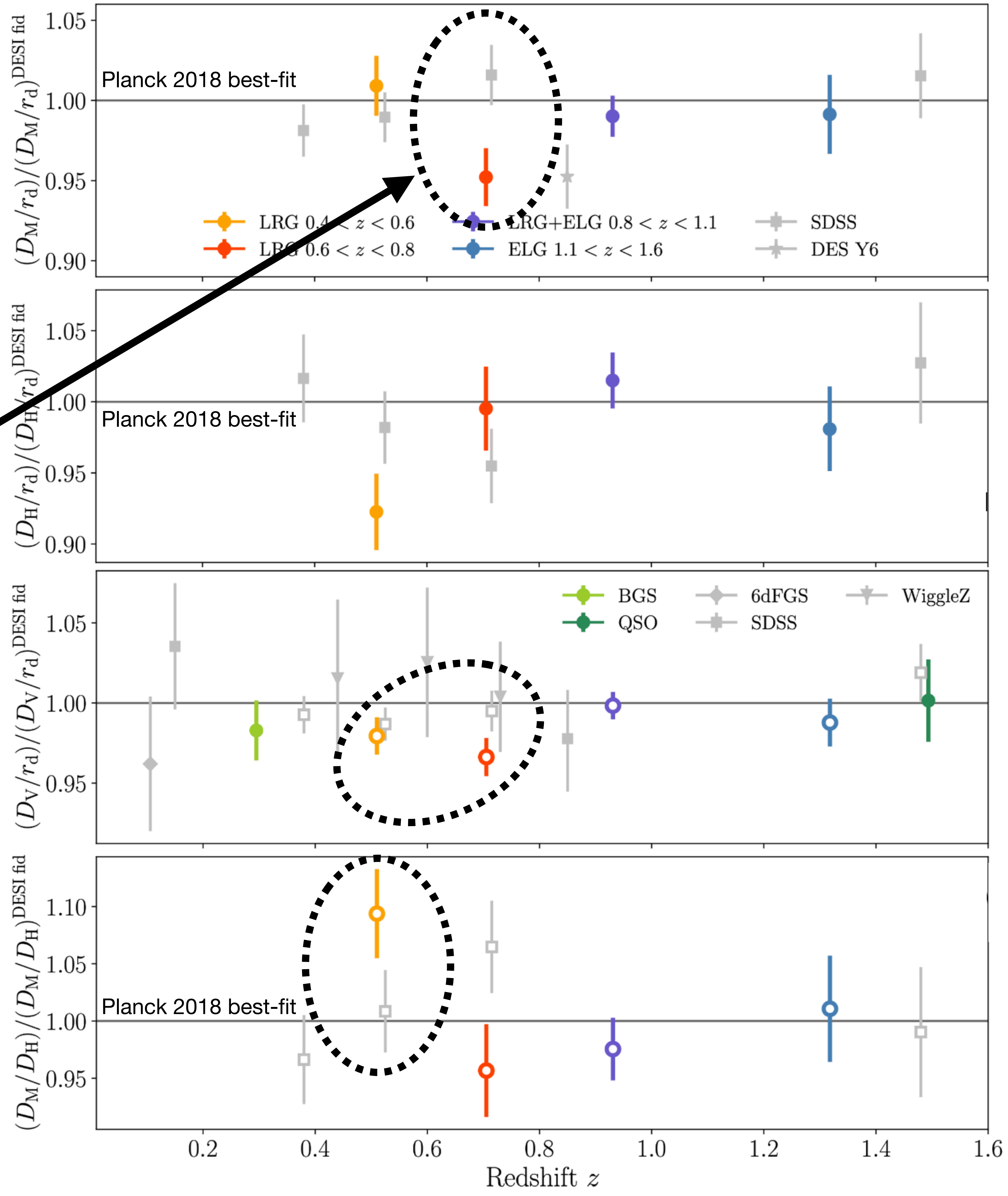
How this compares to the previous BOSS & eBOSS?

Largest differences on
$D_M/r_d$ at $z = 0.71, \ \simeq 2.5\sigma$

DESI - SDSS 20% correlated

Statistical fluke? DR3 will tell





DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

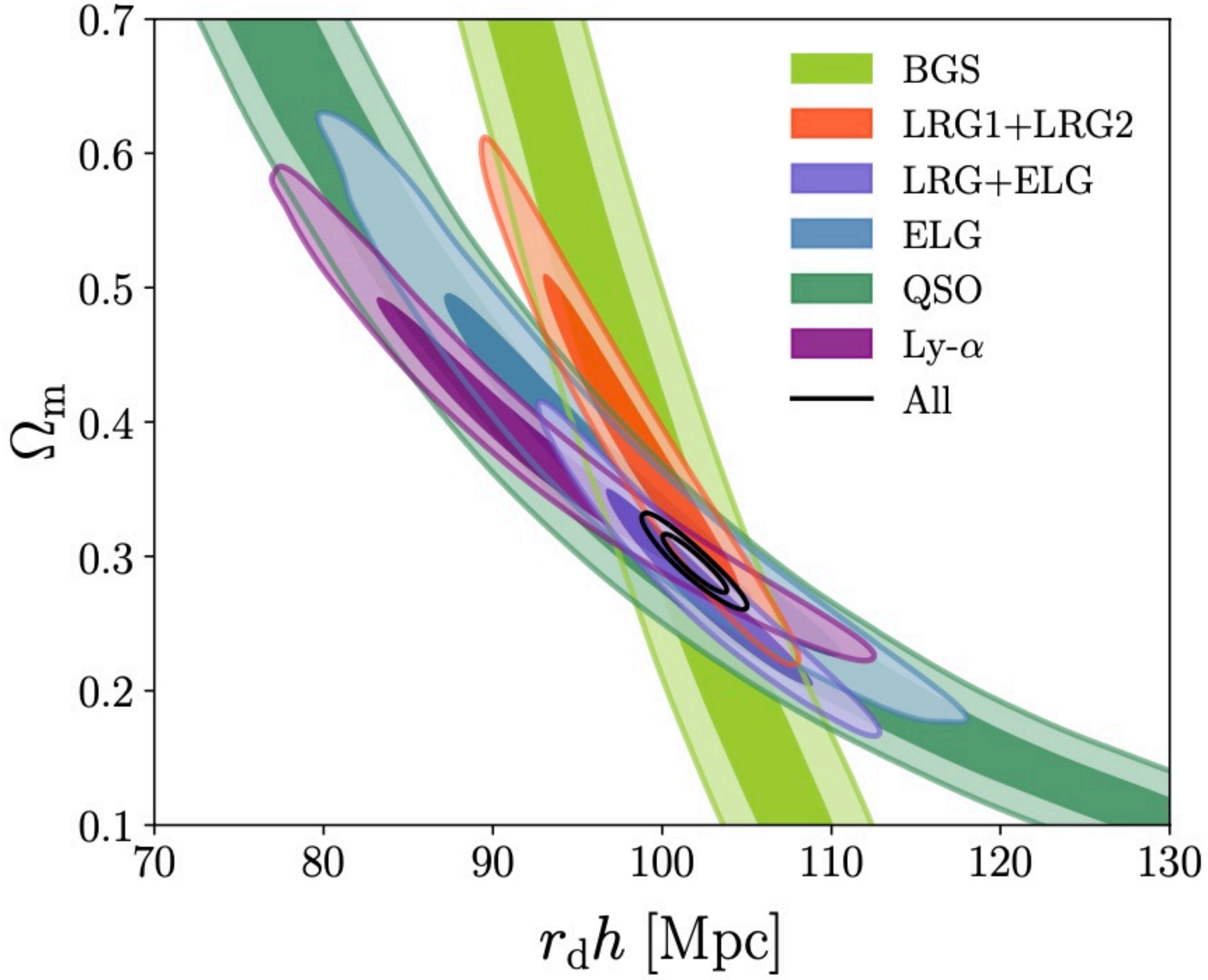
# The DESI cosmology results

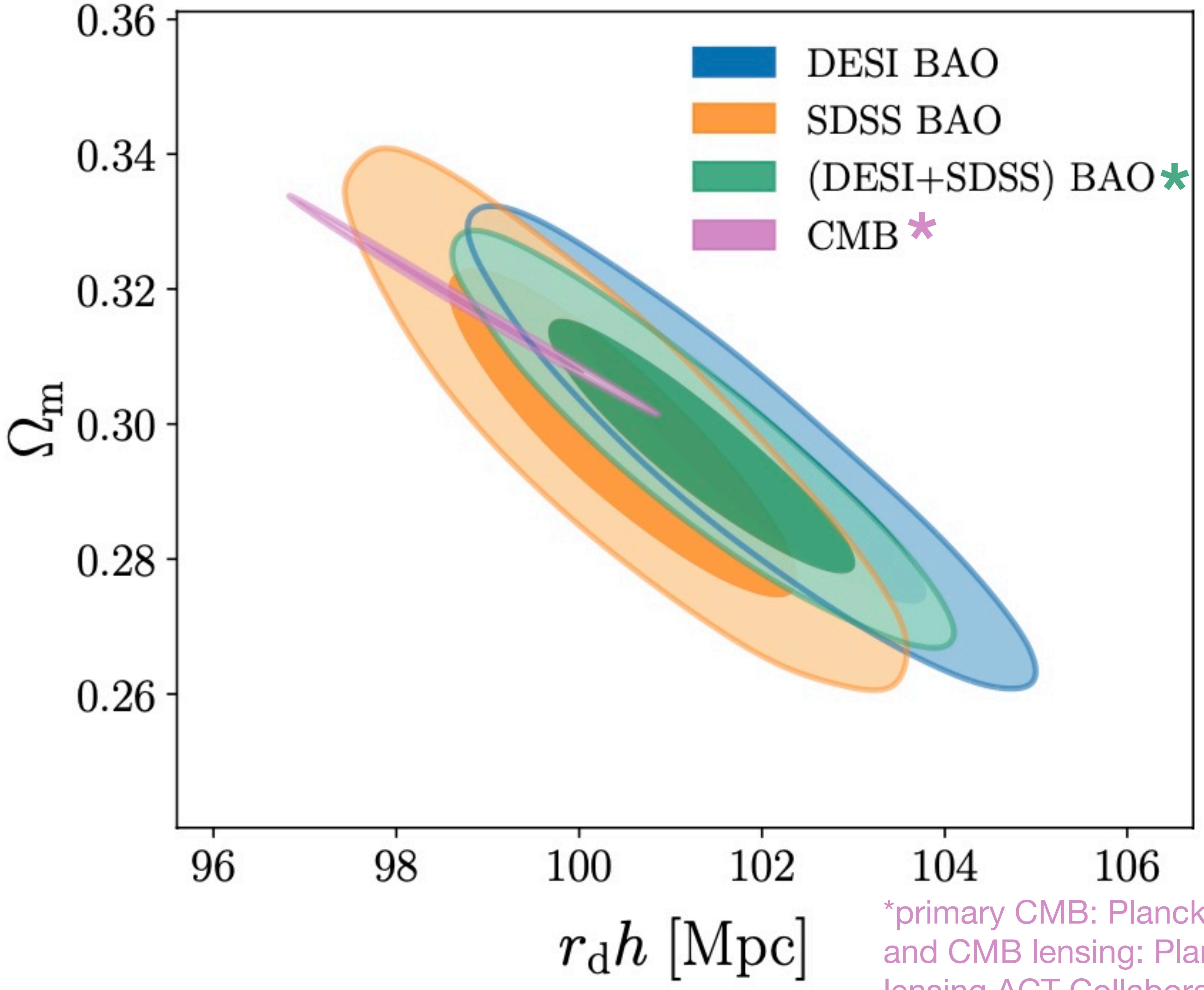
**DESI BAO only**

$$\Omega_m = 0.295 \pm 0.015 \rightarrow (5.1\%)$$

$$r_d h = (101.8 \pm 1.3)\,\mathrm{Mpc} \rightarrow (1.3\%)$$

## Implications for cosmology: $\Lambda$CDM




*Swap the DESI $z < 0.6$ results by SDSS

*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

# The DESI cosmology results

## Implications for cosmology: kCDM

Universe is still flat

**DESI BAO+θ∗:**

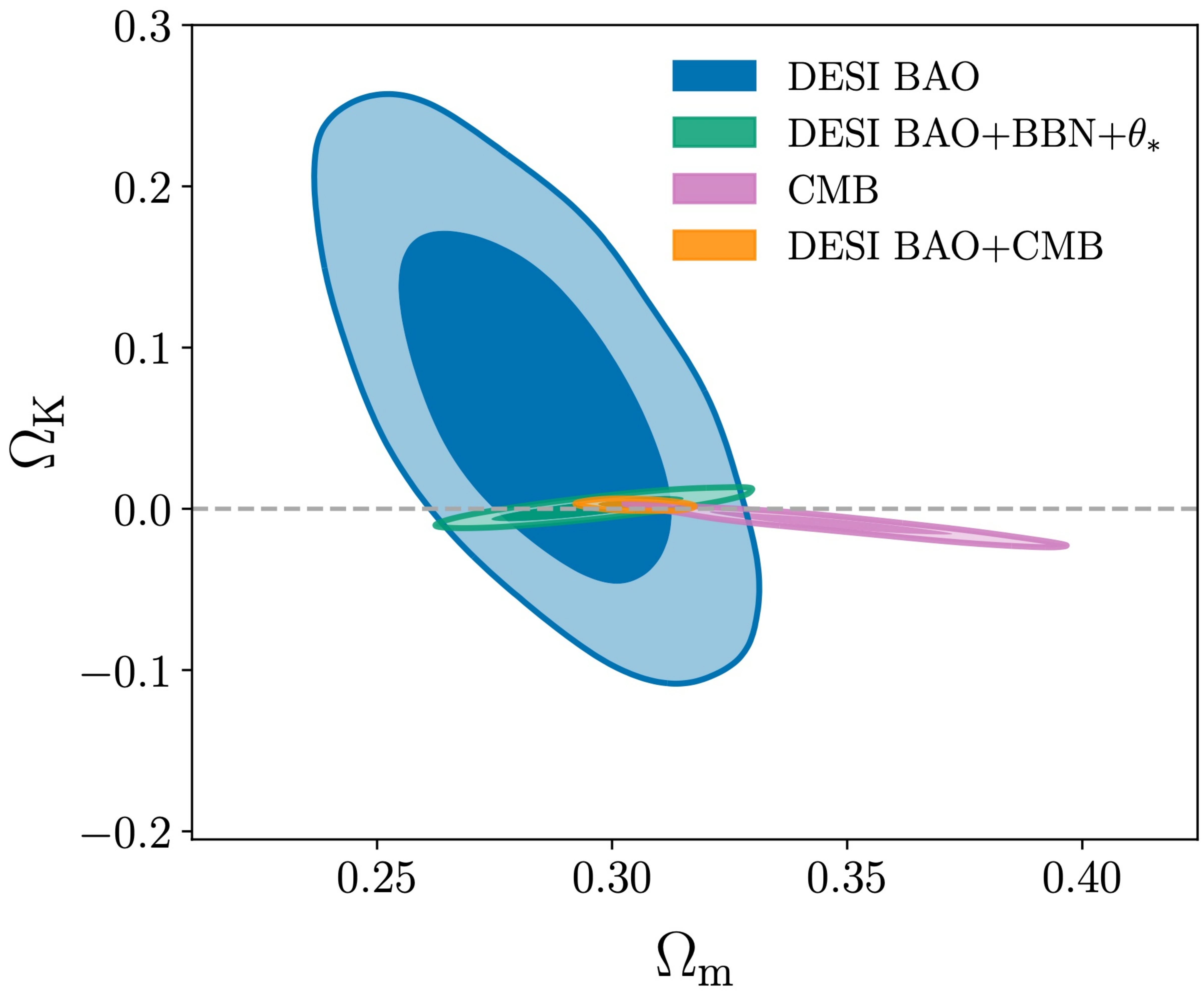
$$\Omega_K = 0.0108^{+0.015}_{-0.0056}$$

**DESI BAO+BBN+θ∗:**

$$\Omega_K = 0.0003^{+0.0048}_{-0.0054}$$

**DESI+CMB:**

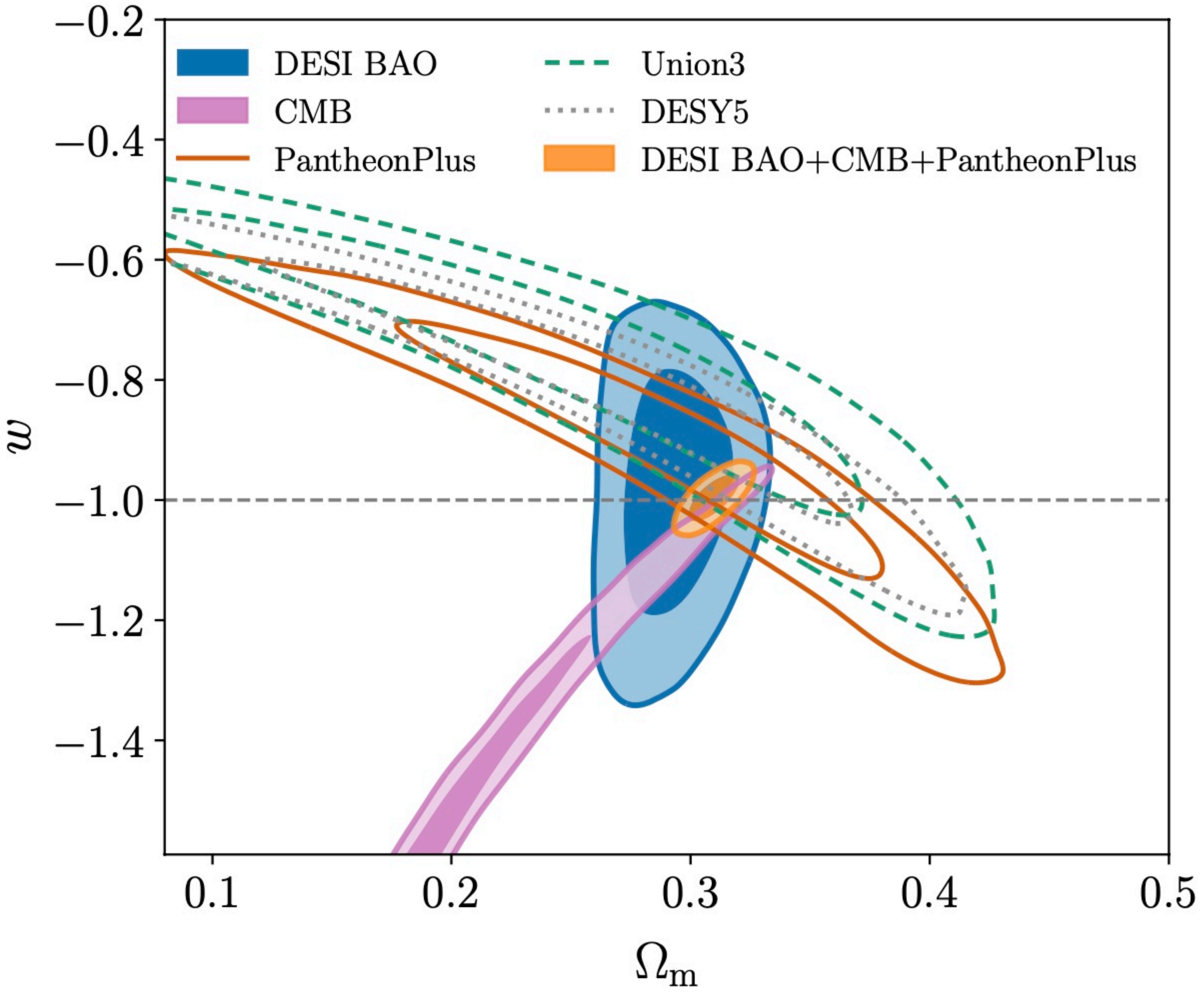
$$\Omega_K = 0.0024 \pm 0.0016$$



# The DESI cosmology results

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

## Implications for cosmology: wCDM



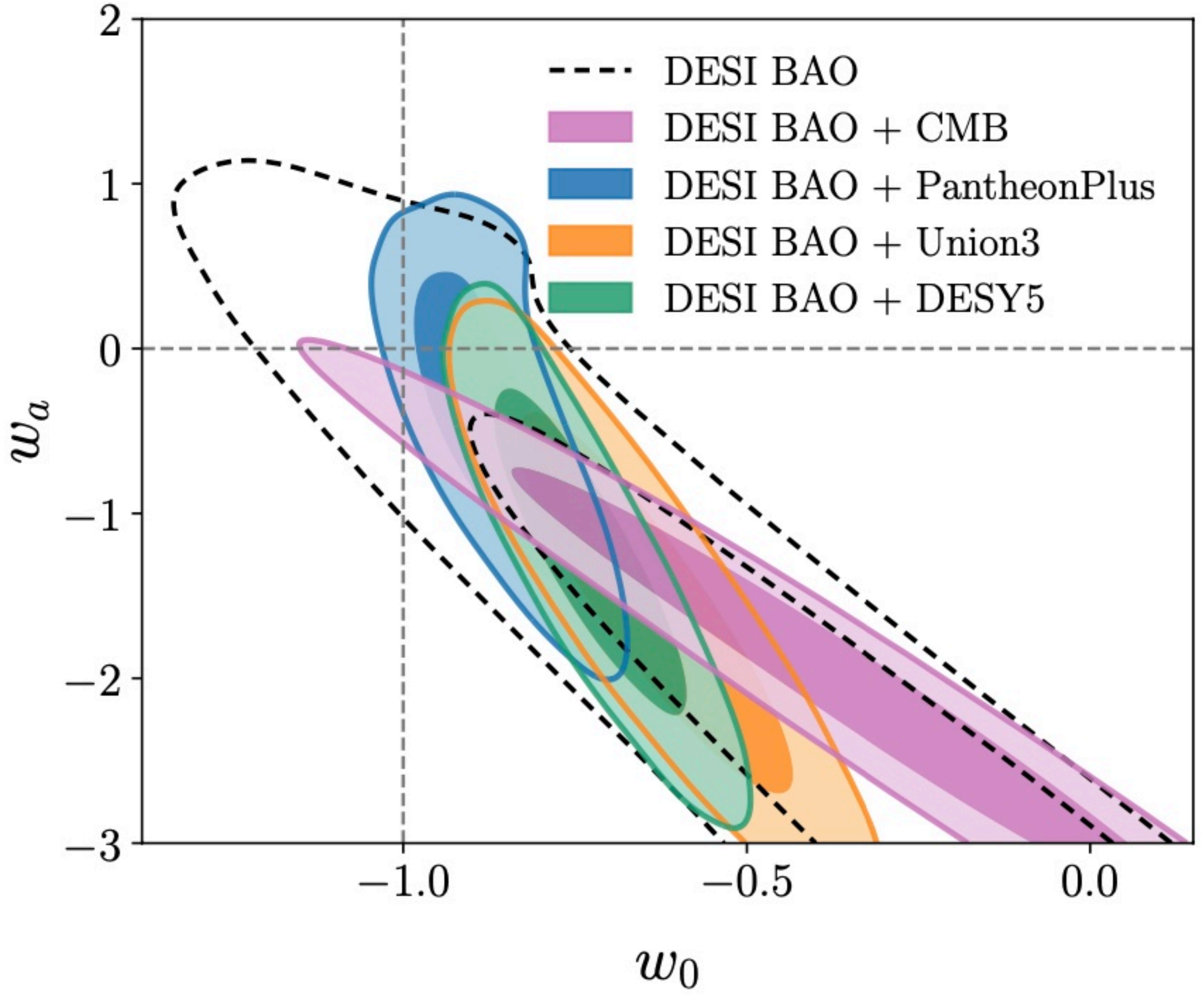

| model/dataset | $\Omega_m$ | $H_0$ $[\mathrm{km\,s^{-1}\,Mpc^{-1}}]$ | W |
|---|---|---|---|
| ***w*CDM** | | | |
| DESI | $0.293 \pm 0.015$ | — | $-0.99^{+0.15}_{-0.13}$ |
| DESI+BBN+$\theta_*$ | $0.295 \pm 0.014$ | $68.6^{+1.8}_{-2.1}$ | $-1.002^{+0.091}_{-0.080}$ |
| DESI+CMB | $0.281 \pm 0.013$ | $71.3^{+1.5}_{-1.8}$ | $-1.122^{+0.062}_{-0.054}$ |
| DESI+CMB+Panth. | $0.3095 \pm 0.0069$ | $67.74 \pm 0.71$ | $-0.997 \pm 0.025$ |
| DESI+CMB+Union3 | $0.3095 \pm 0.0083$ | $67.76 \pm 0.90$ | $-0.997 \pm 0.032$ |
| DESI+CMB+DESY5 | $0.3169 \pm 0.0065$ | $66.92 \pm 0.64$ | $-0.967 \pm 0.024$ |

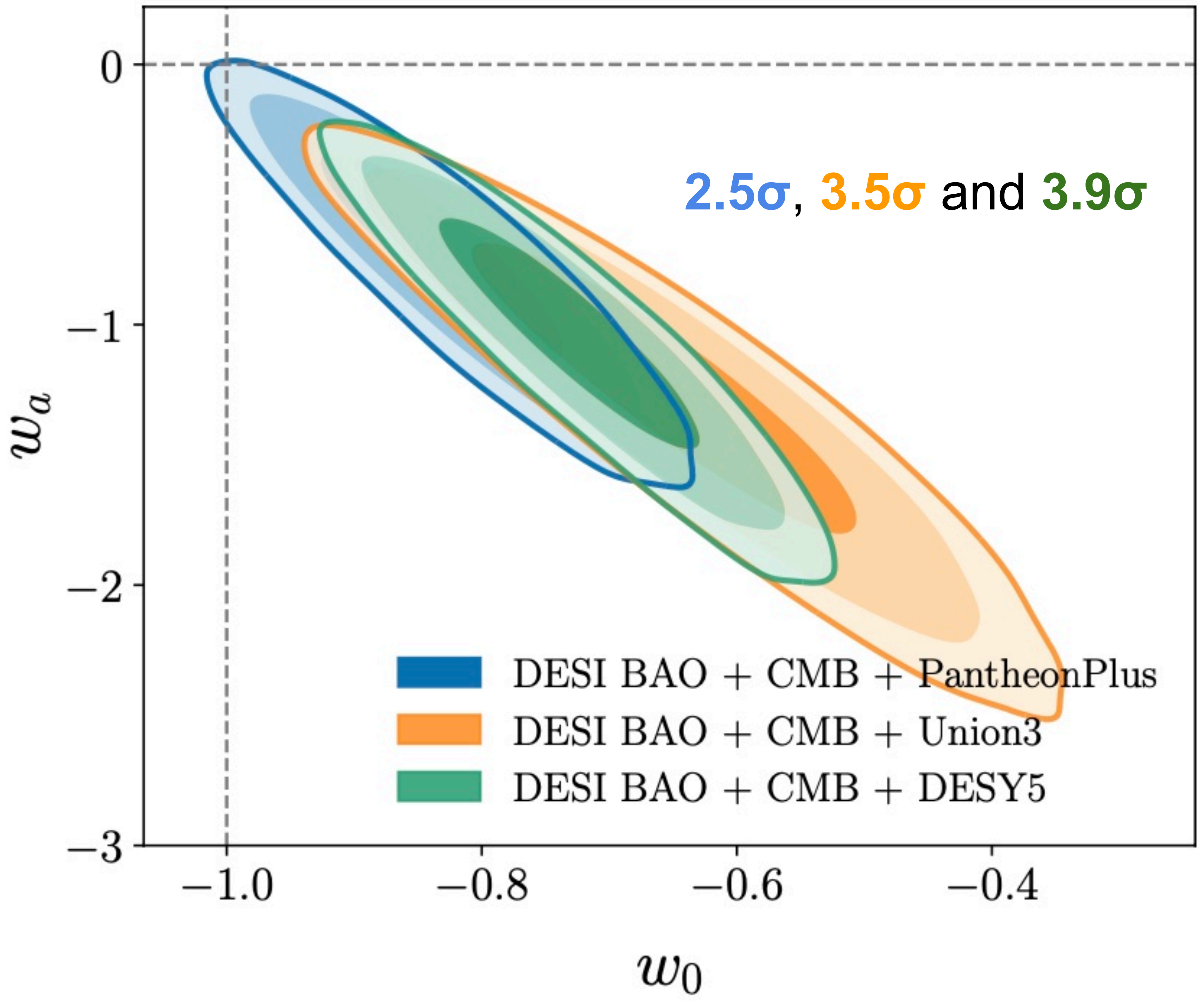
DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The DESI cosmology results

## Implications for cosmology: $w_0 w_a$CDM

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

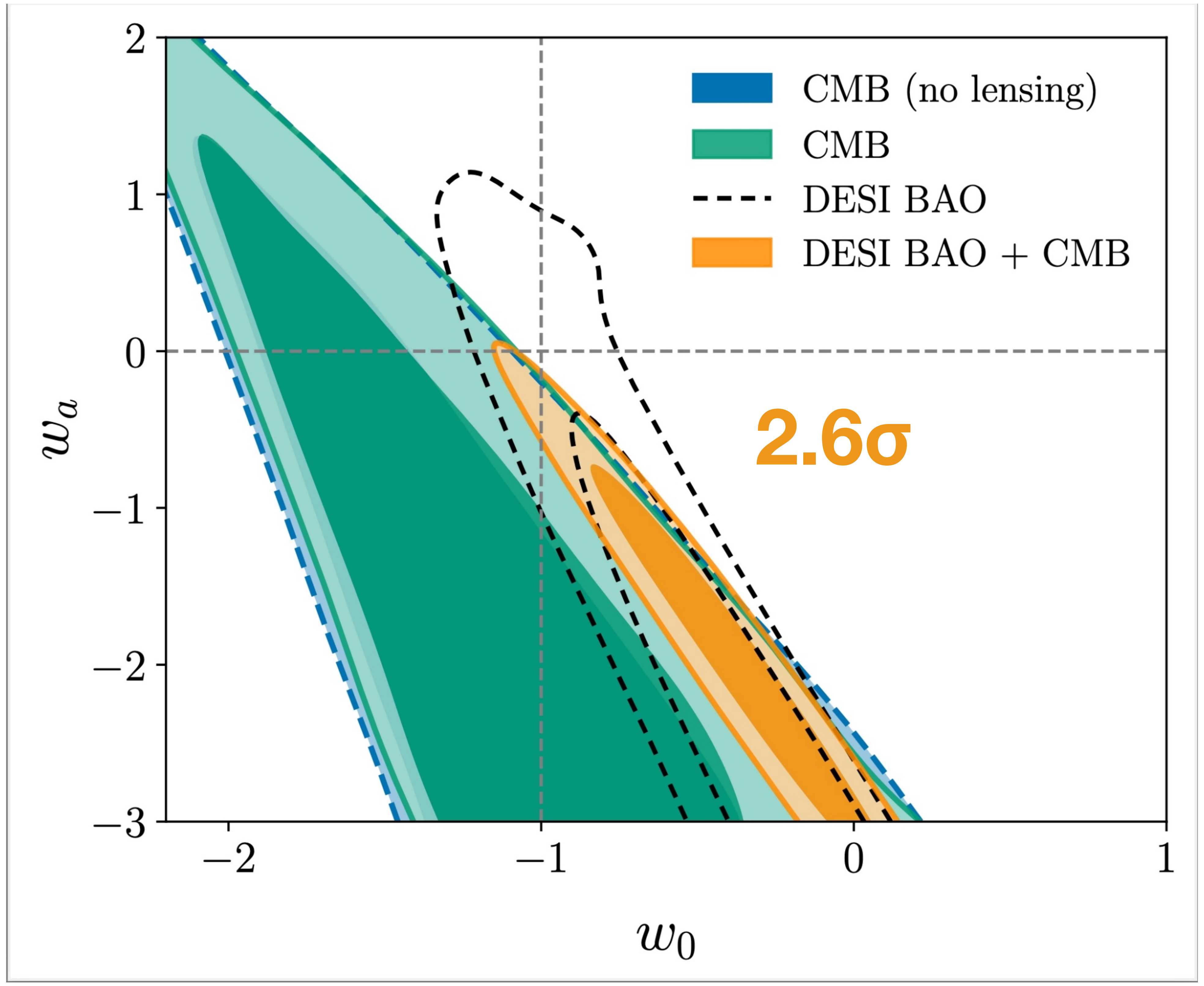


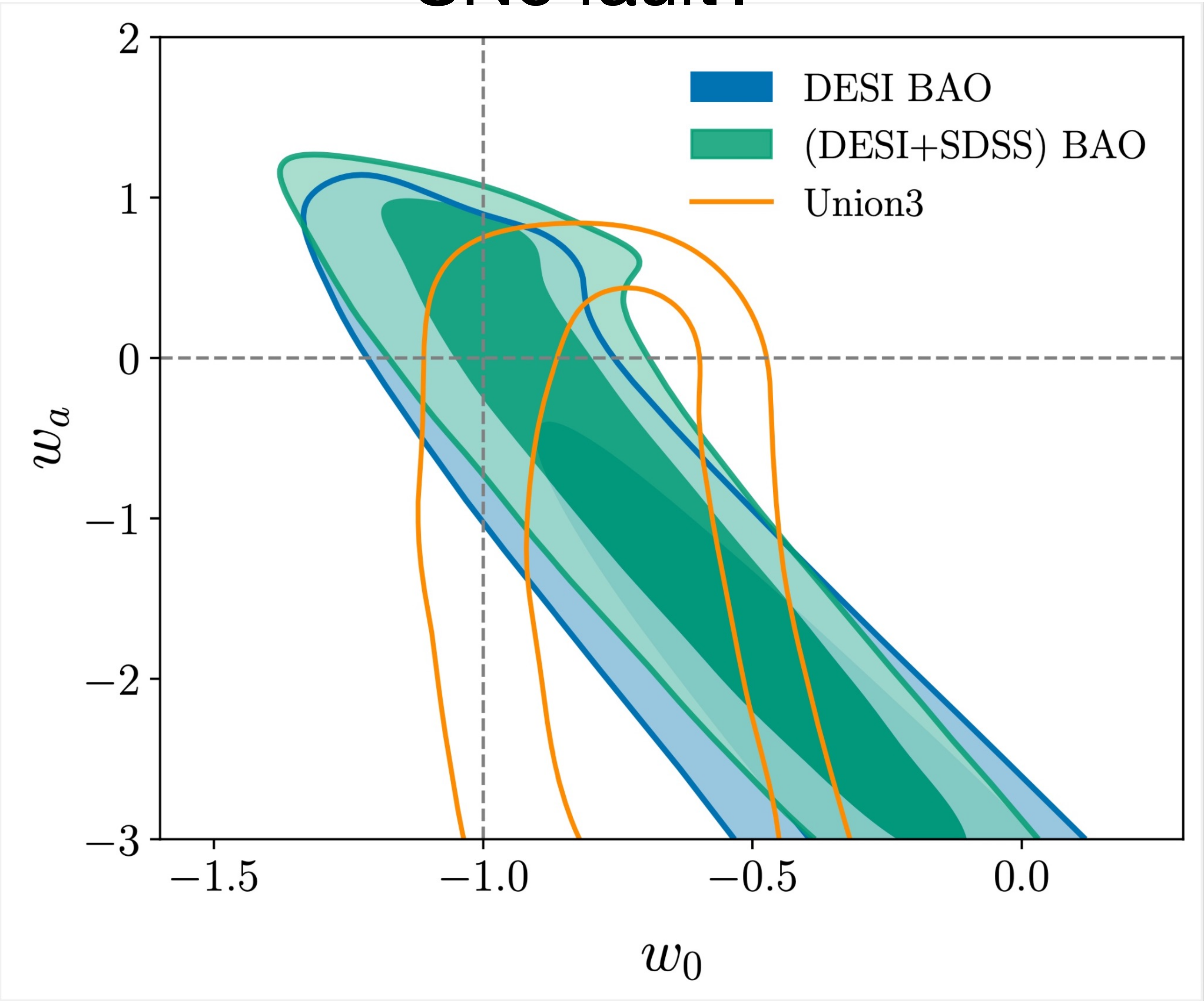
# The DESI cosmology results

What's going on?

CMB fault?




SNe fault?

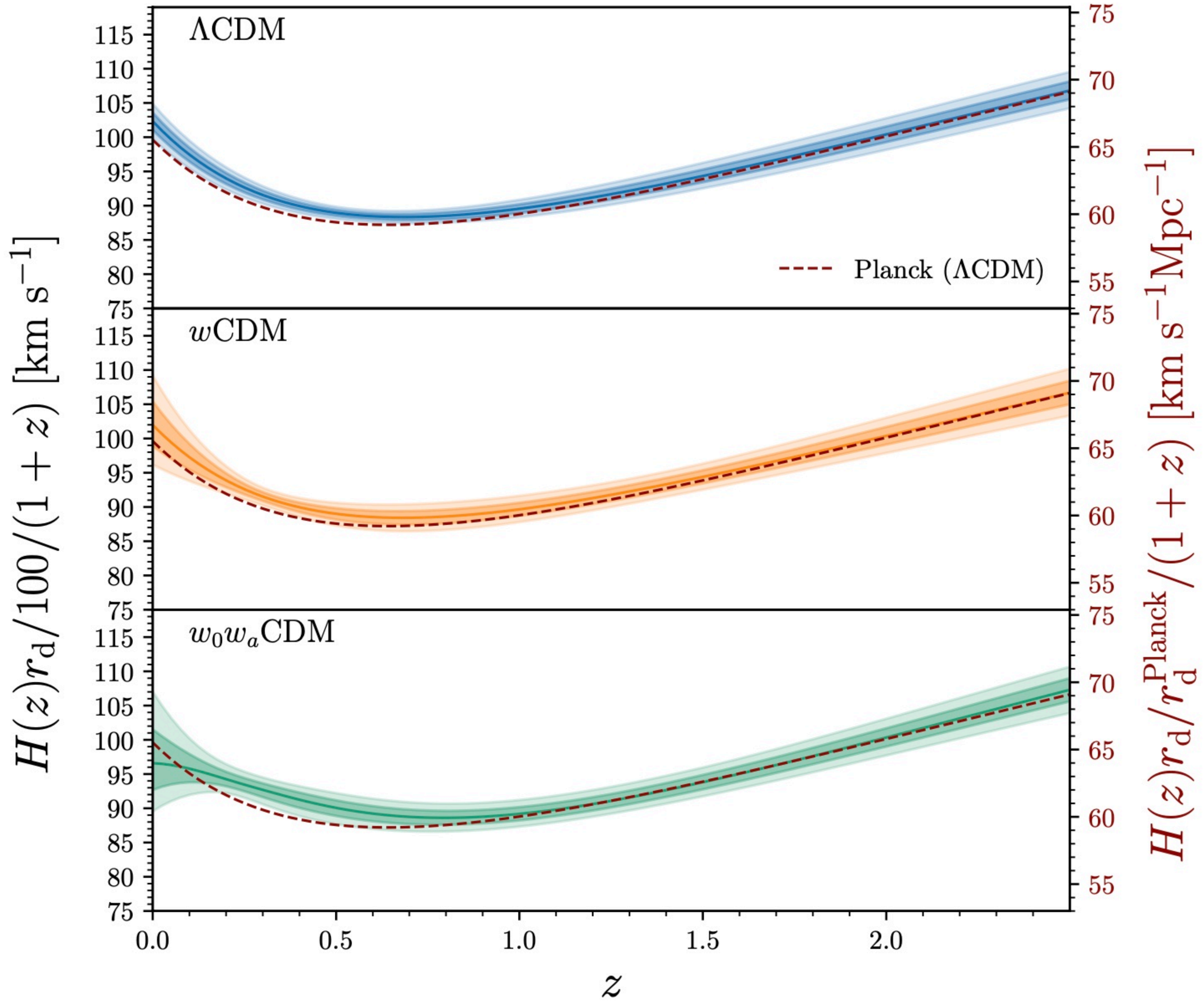


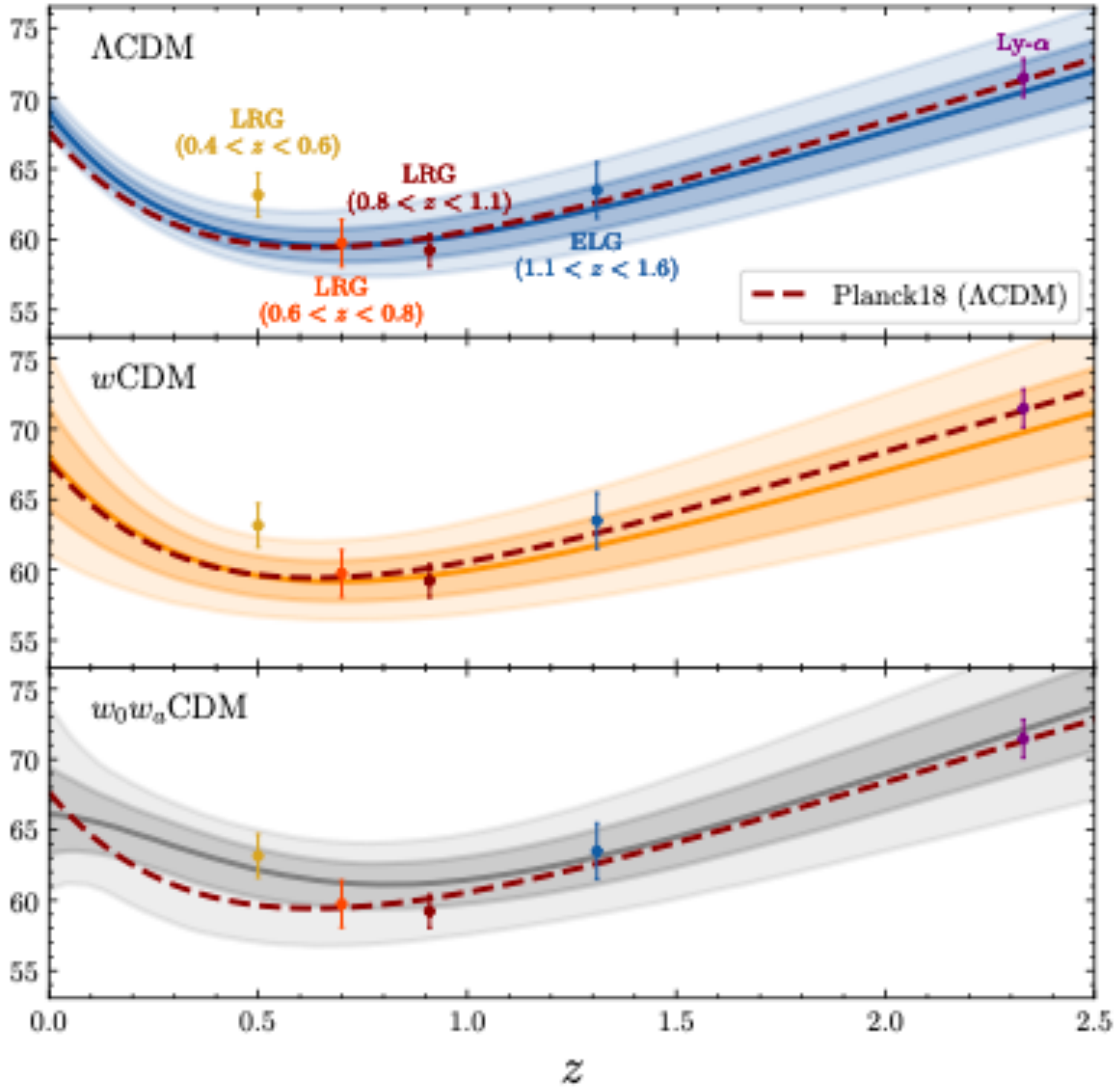
DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The DESI cosmology results

What's going on?

DESI fault?



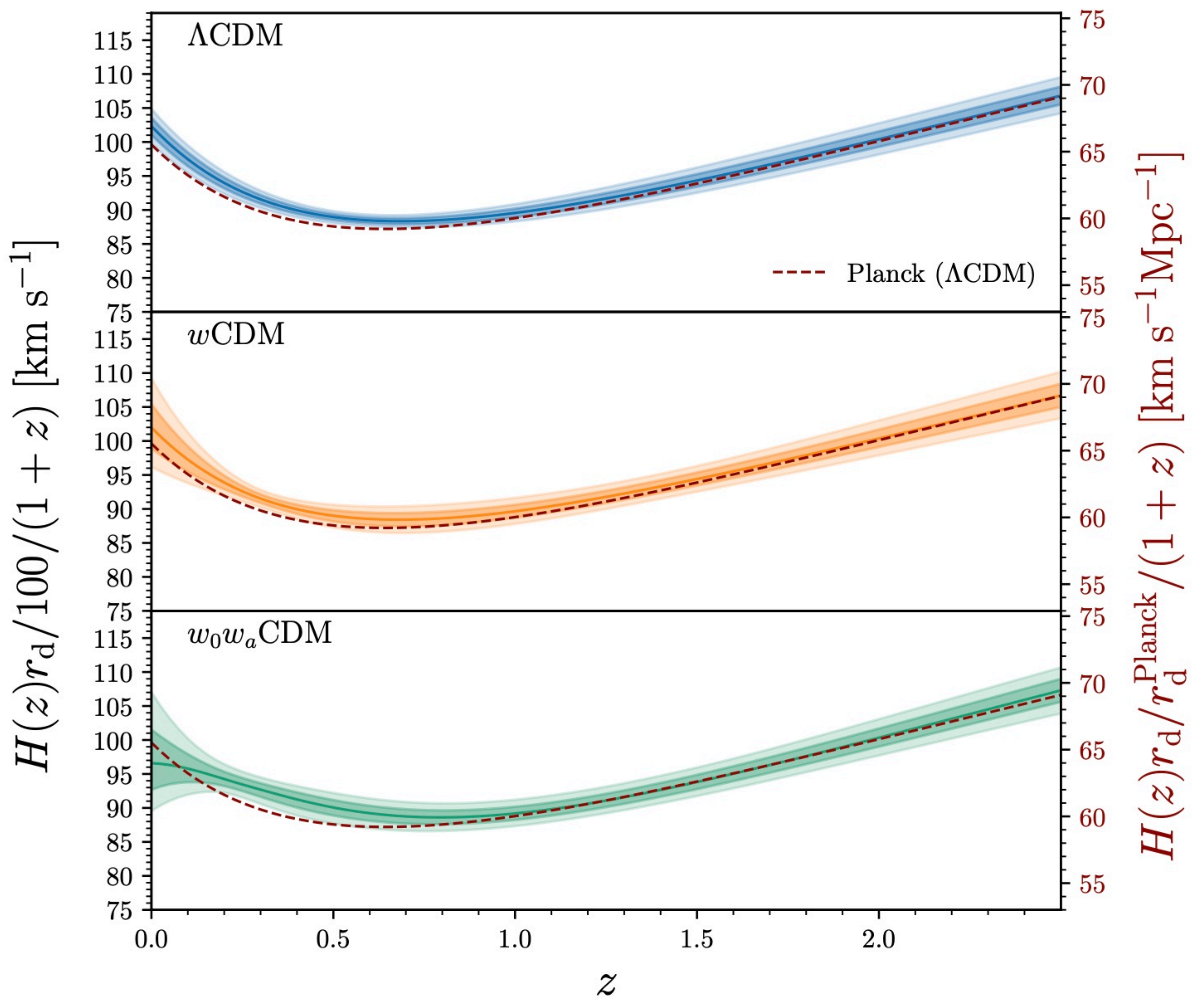



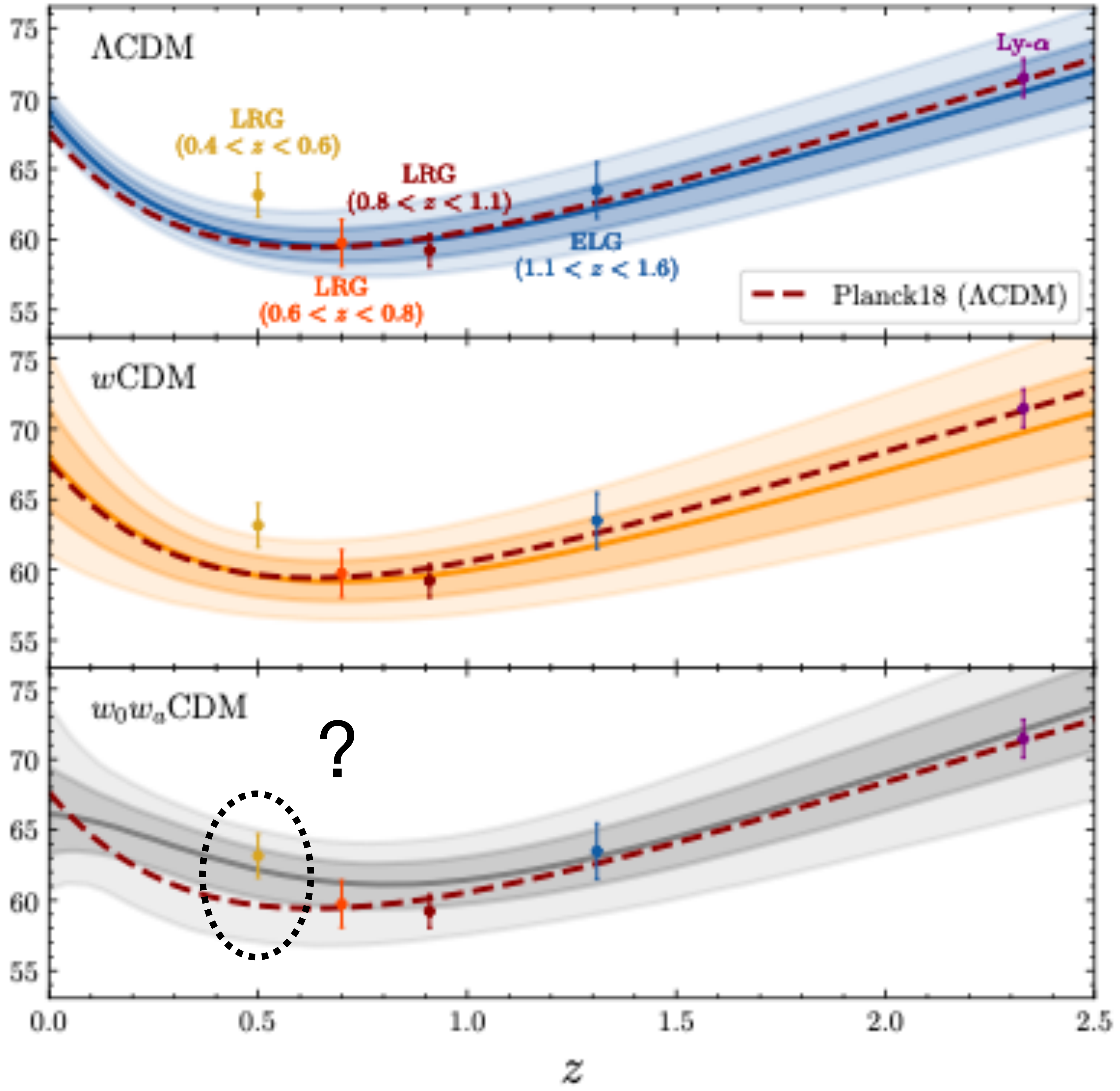
DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The DESI cosmology results

What's going on?

DESI fault?



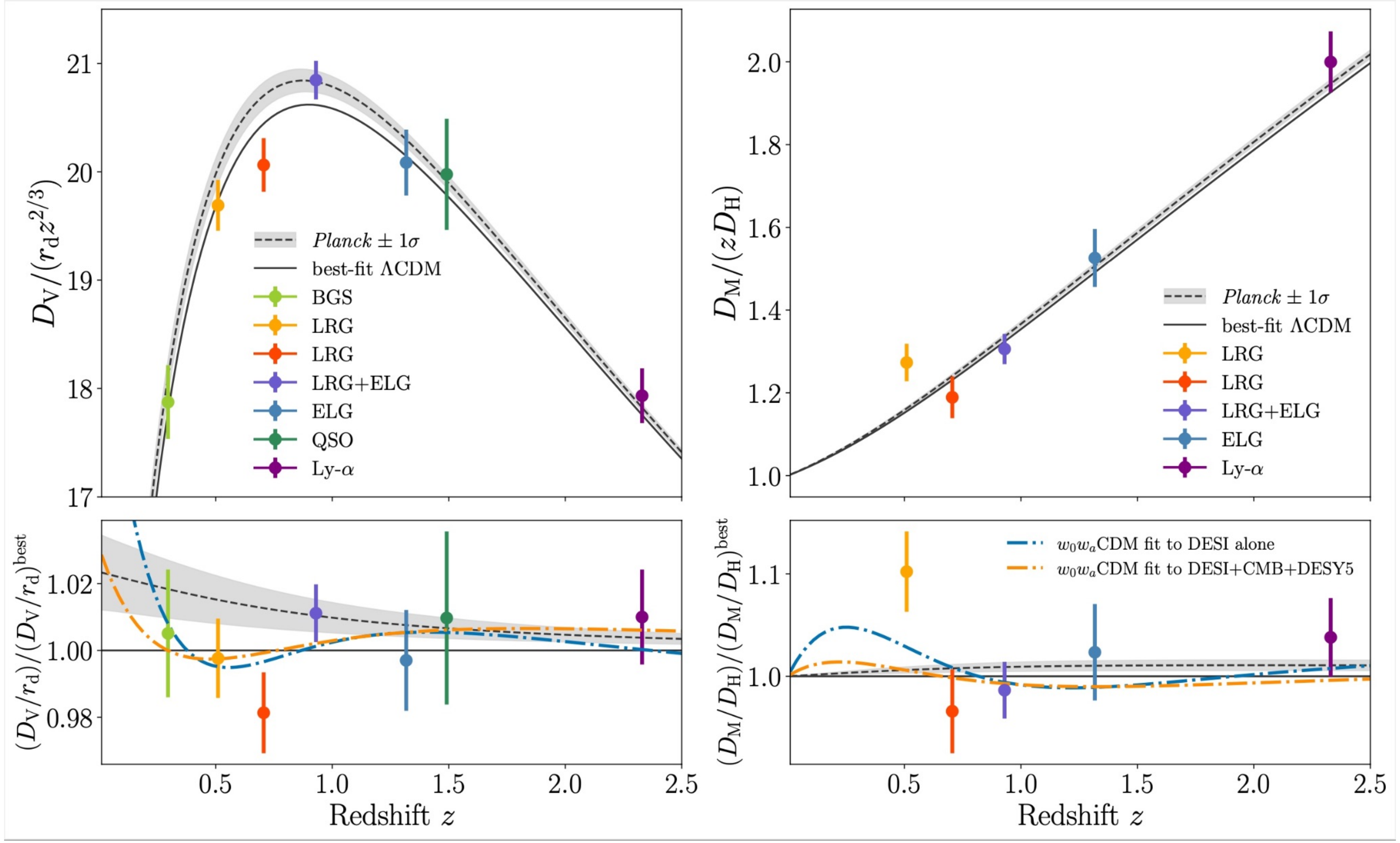



# The DESI cosmology results

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

What's going on?

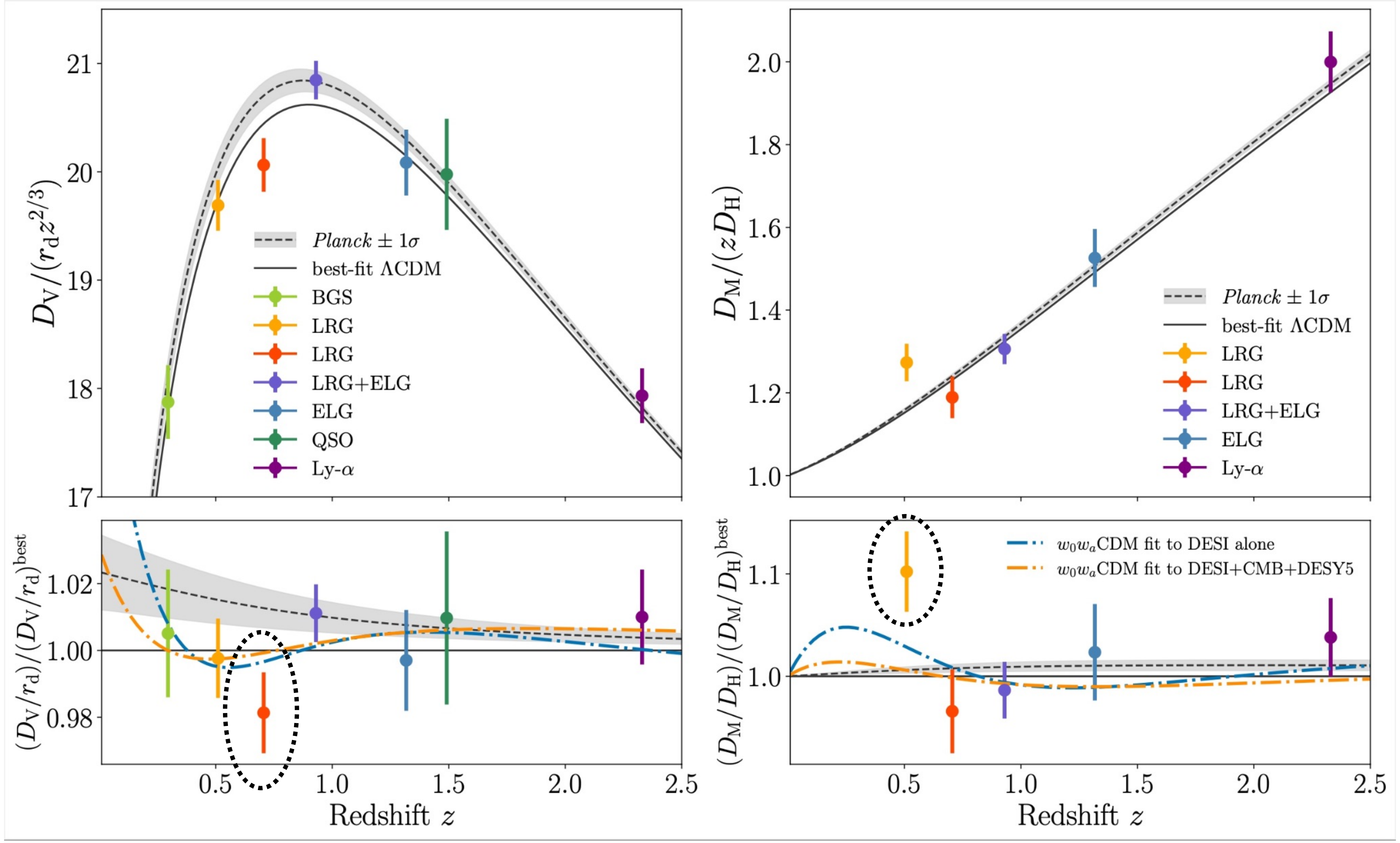


# The DESI cosmology results

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

What's going on?

Both LRG bins seem a bit strange, on in $D_M/D_H$, the other in $D_V/r_d$



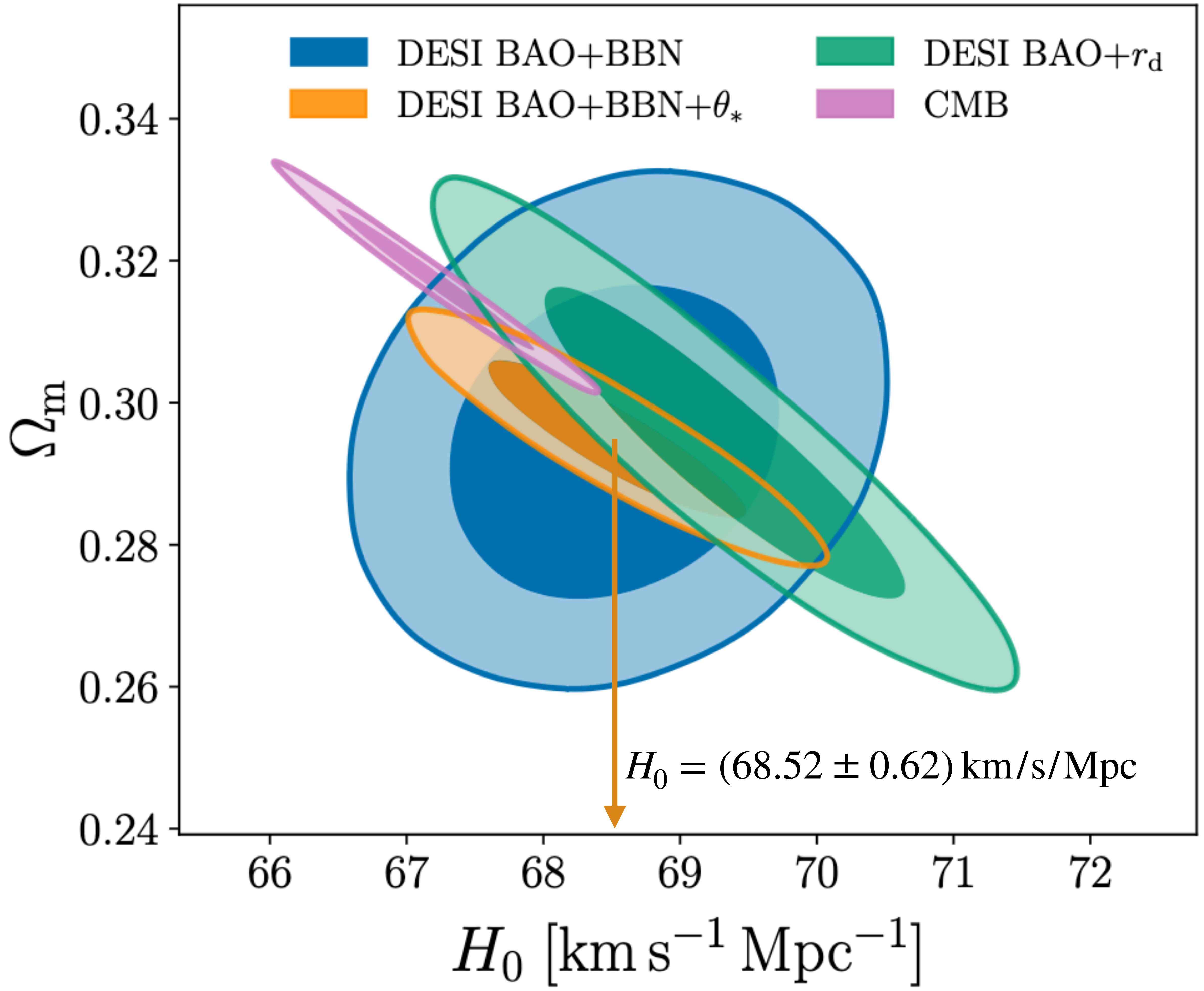
DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The DESI cosmology results

## The $H_0$ parameter

With external datasets we can inform on the value of $r_d$ and measure $H_0$

DESI BAO + ext data prefers a slightly larger value for $H_0$, but consistent with Planck 18.

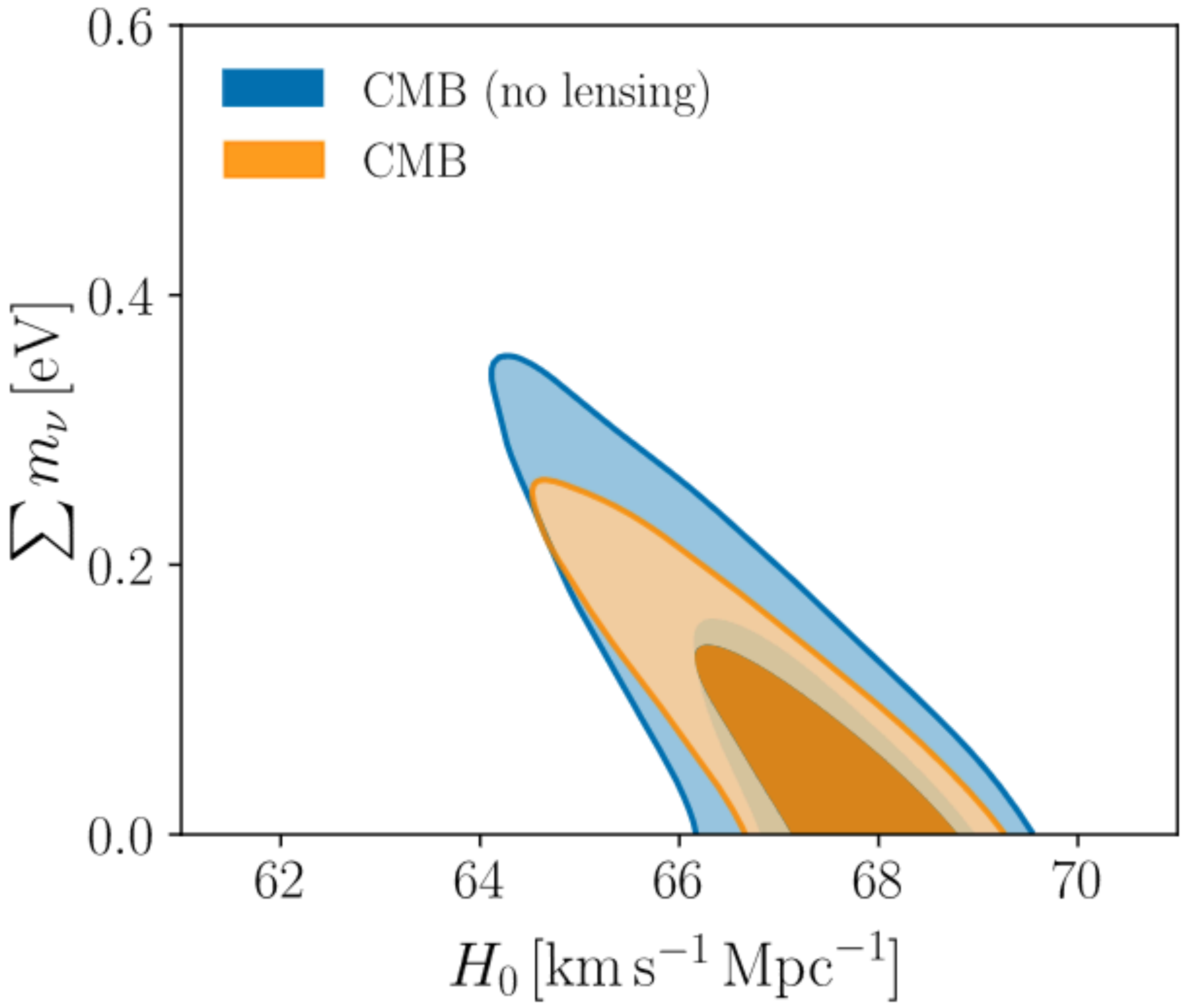


DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

# The DESI cosmology results

## Neutrinos

CMB alone is not able to able to efficiently measure $\sum m_\nu$



# The DESI cosmology results

DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

## Neutrinos

CMB alone is not able to able to efficiently measure $\sum m_\nu$

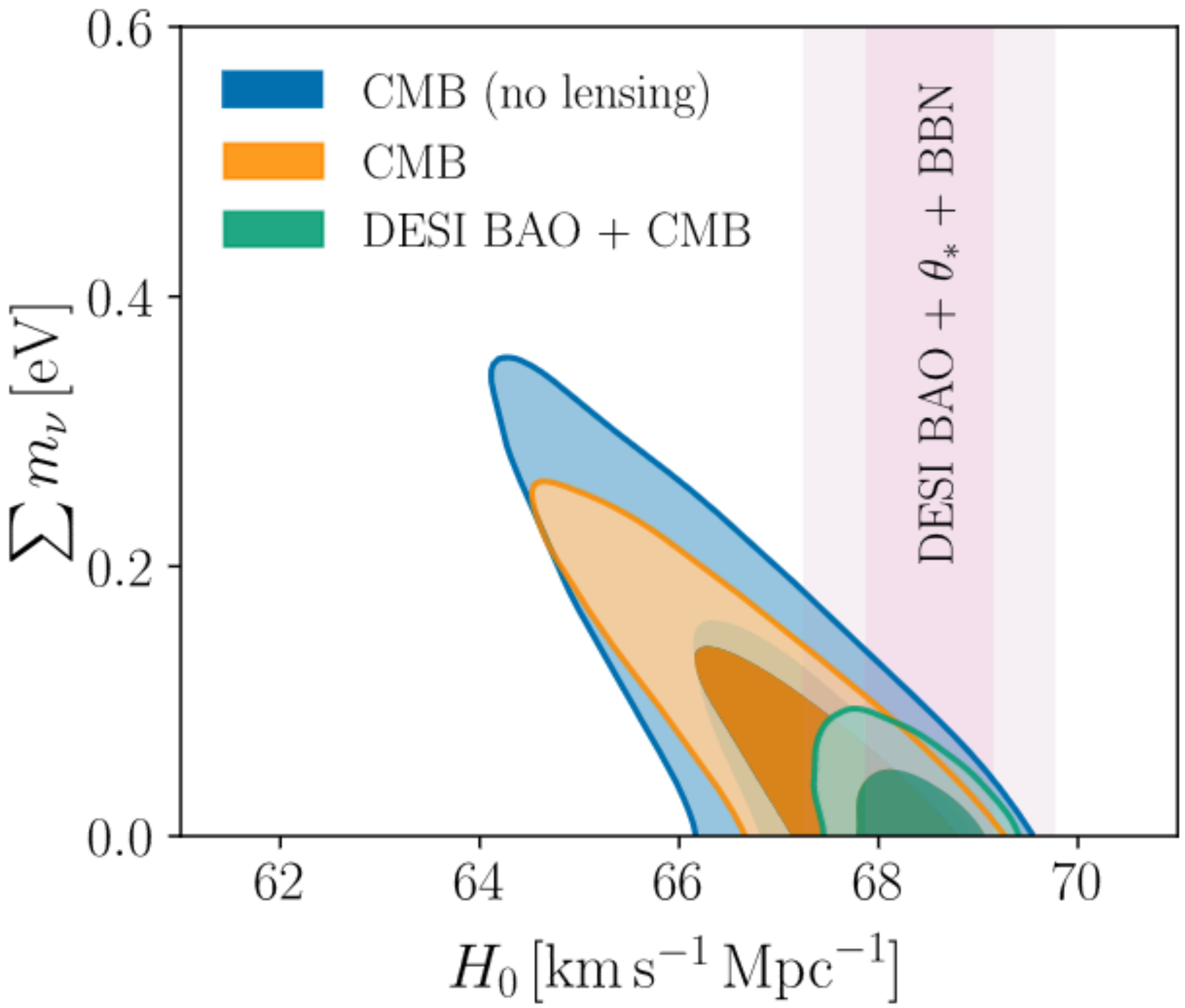
Adding BAO data breaks the degeneracy through $H_0$

Low preferred value of $H_0$ yields

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

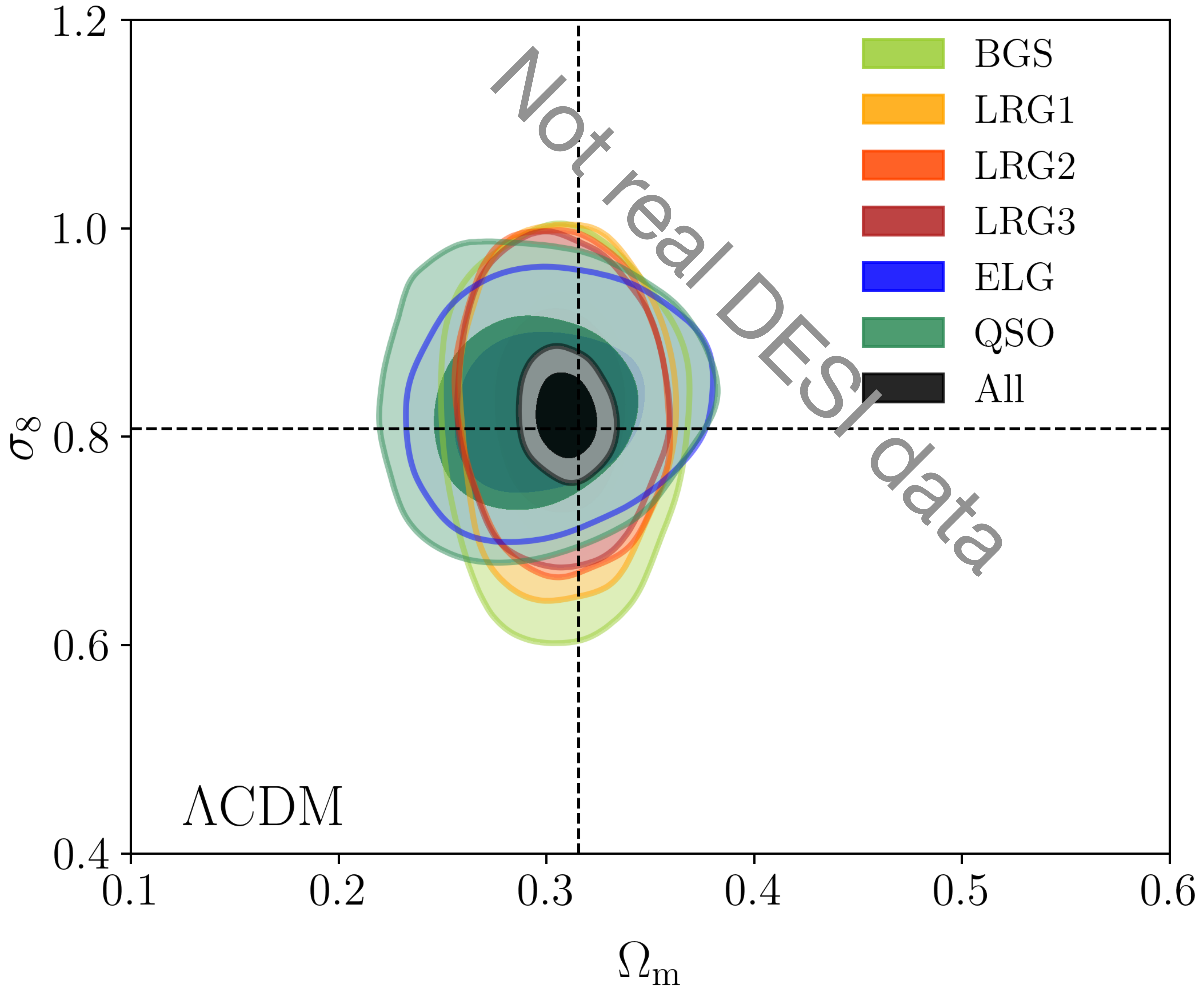
Limit relaxed for extensions to $\Lambda$CDM

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



# The RSD analysis

- Full Shape (FS) measurements were unblinded 3 weeks ago.
- FS will add RSD information ($\sigma_8$), and also add extra information on the expansion history through the broadband shape.
- Stay tuned for the end of 2024



# Summary

- DESI has reported the most precise BAO measurement to date: 0.52%
- DESI + ext. data has measured $H_0$ with $\sim 1\,\%$
- DESI is consistent with a flat $\Lambda$CMD model
- When combined with CMB and some SNe samples, there are hints of time-varying DE EoS.

---

- Full Shape analysis is already unblinded. Results to appear by the end of 2024!
- DR2 (3 years) already taken. New BAO analysis to appear soon.
- DESI has recently been extended till the end of 2028, then DESI II will take over

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

# Summary

First batch of DESI DR1 cosmological analyses are out:

https://data.desi.lbl.gov/doc/papers/

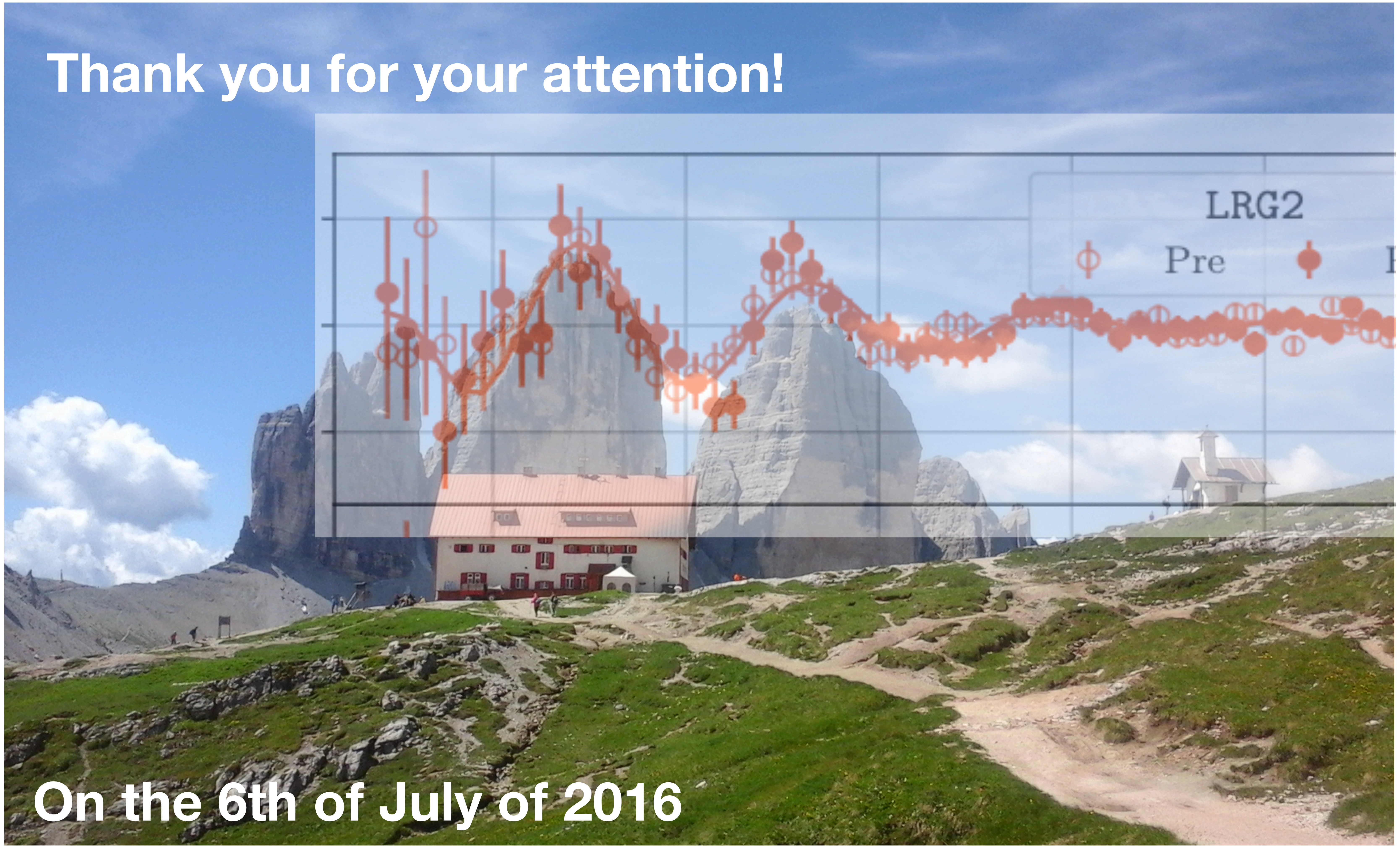
- DESI 2024 I: First year data release
- DESI 2024 II: DR1 catalogs
- **DESI 2024 III: BAO from Galaxies and Quasars at $z < 2$**
- **DESI 2024 IV: BAO from the Lyman-$\alpha$ Forest at $z > 2$**
- DESI 2024 V: RSD from Galaxies and Quasars at $z < 2$
- **DESI 2024 VI: Cosmological constraints from BAO measurements**
- DESI 2024 VII: Cosmological constraints from RSD measurements

**+ 15 companion papers**

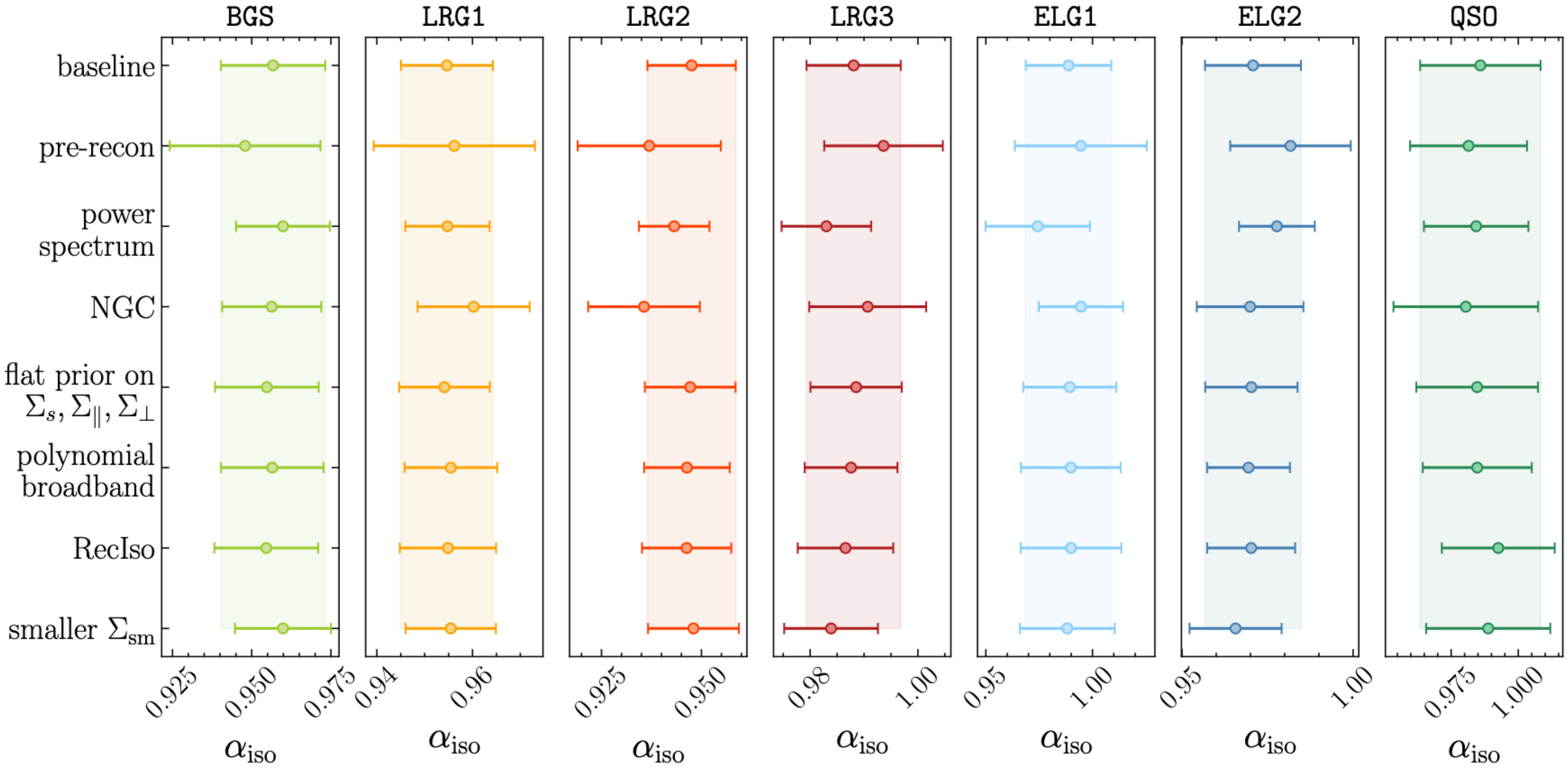
DARK ENERGY
SPECTROSCOPIC
INSTRUMENT
U.S. Department of Energy Office of Science

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science



# Extra slides

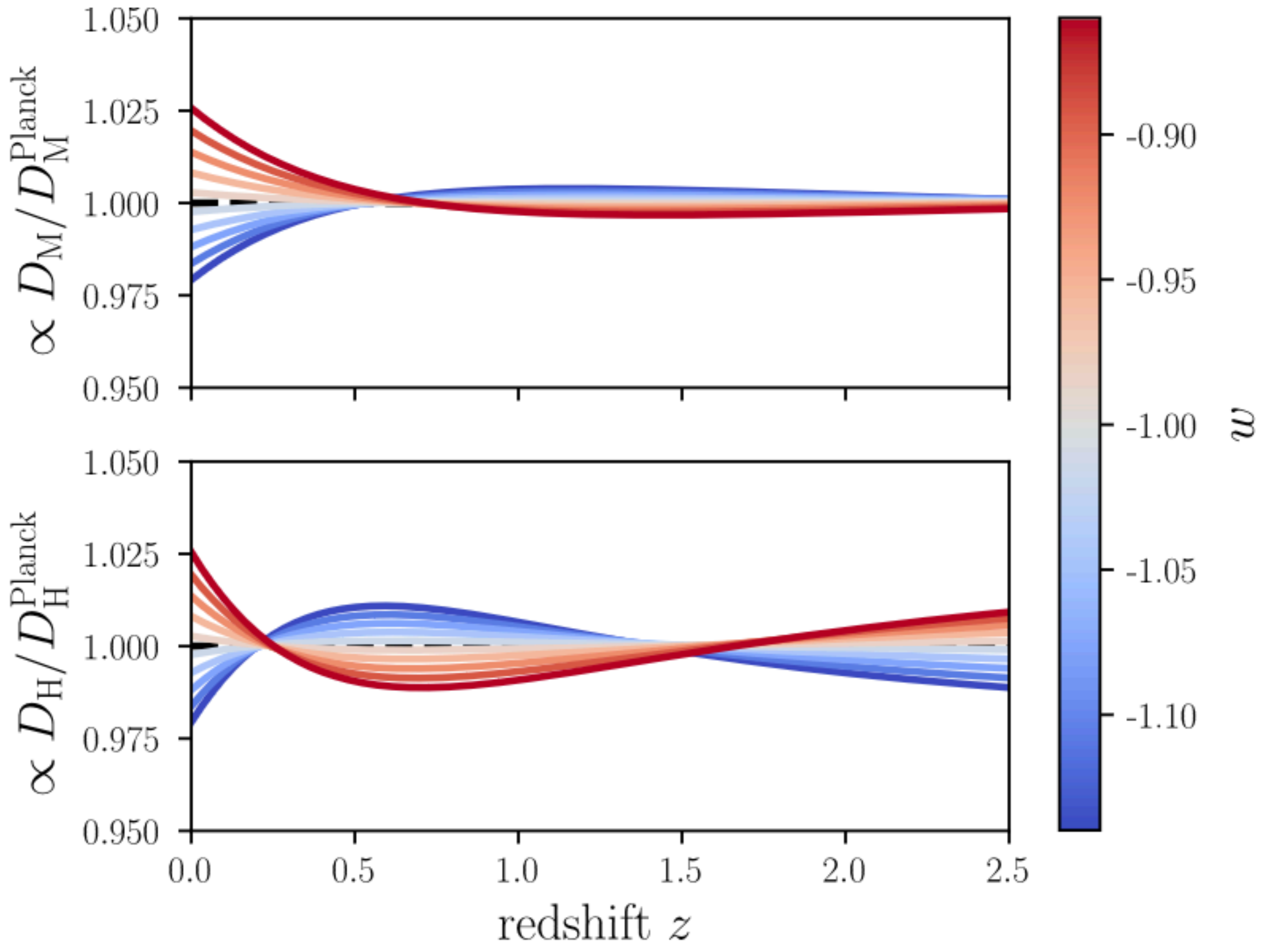


# Extra slides

Dark energy equation of state:

$$P = w\rho$$

- $w$ = constant




Credit: A. De Mattia

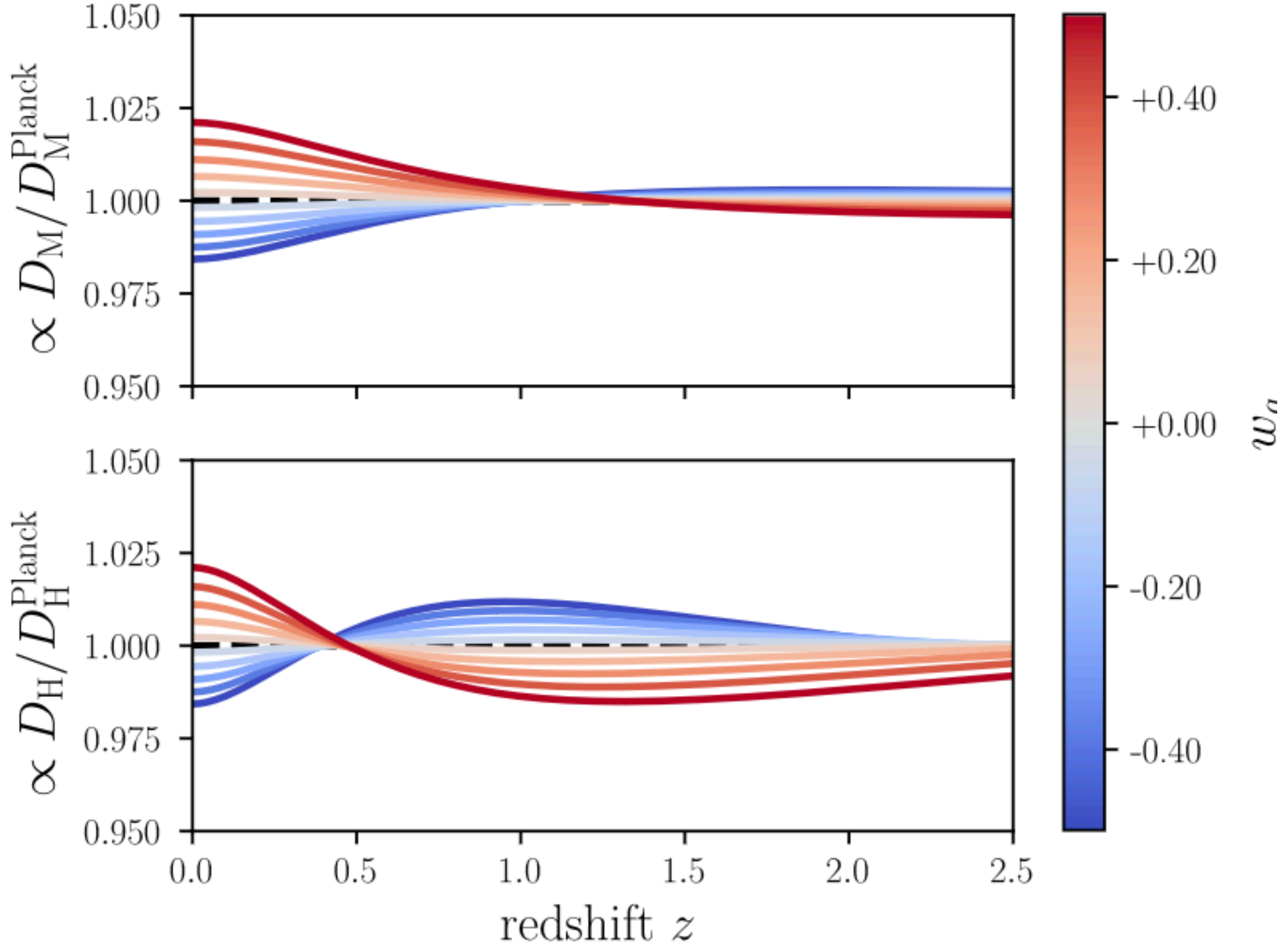
DARK ENERGY
SPECTROSCOPIC
INSTRUMENT
U.S. Department of Energy Office of Science

# Extra slides

Dark energy equation of state:

$$P = w\rho$$

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

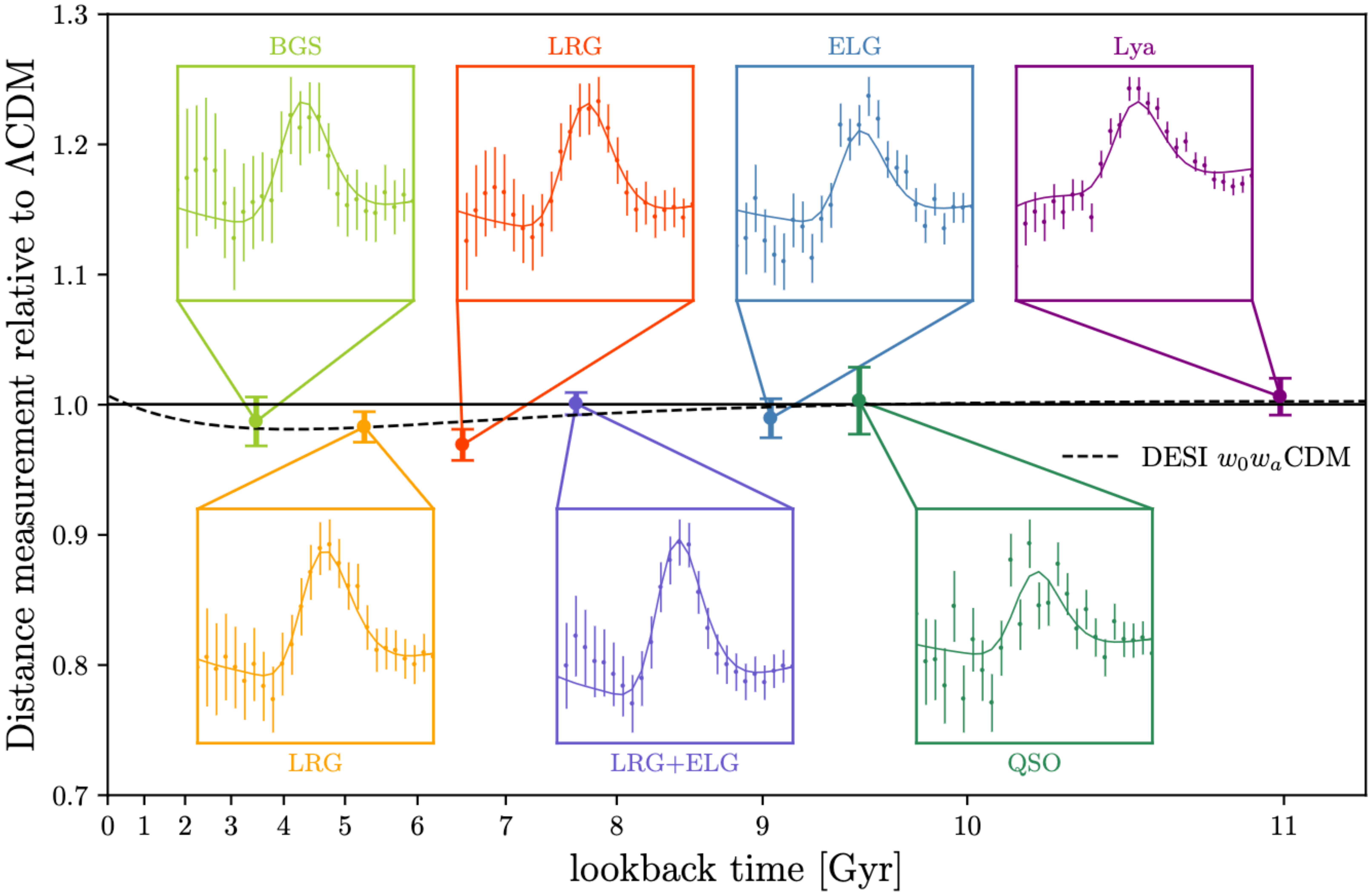



Credit: A. De Mattia

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

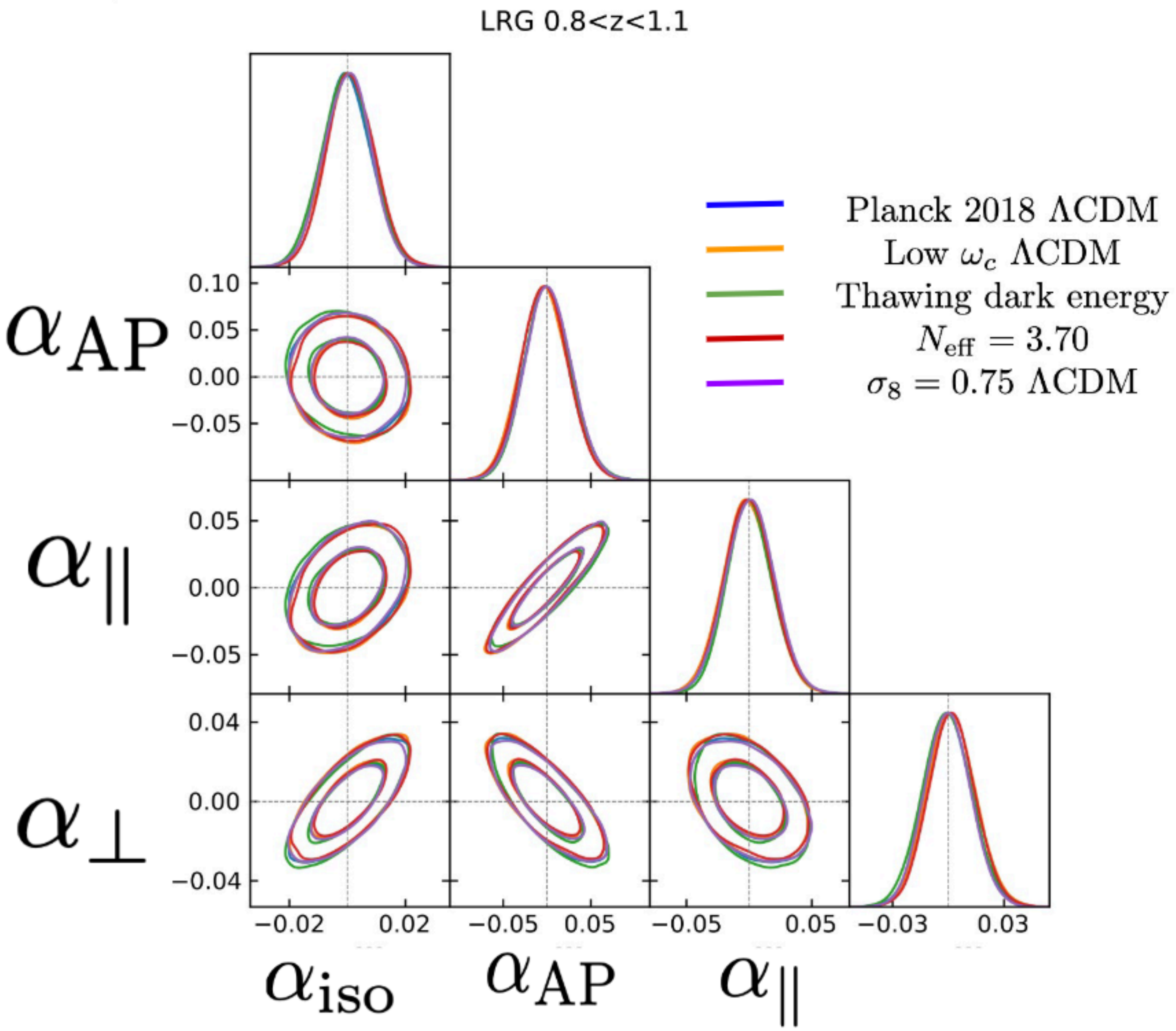
# Extra slides



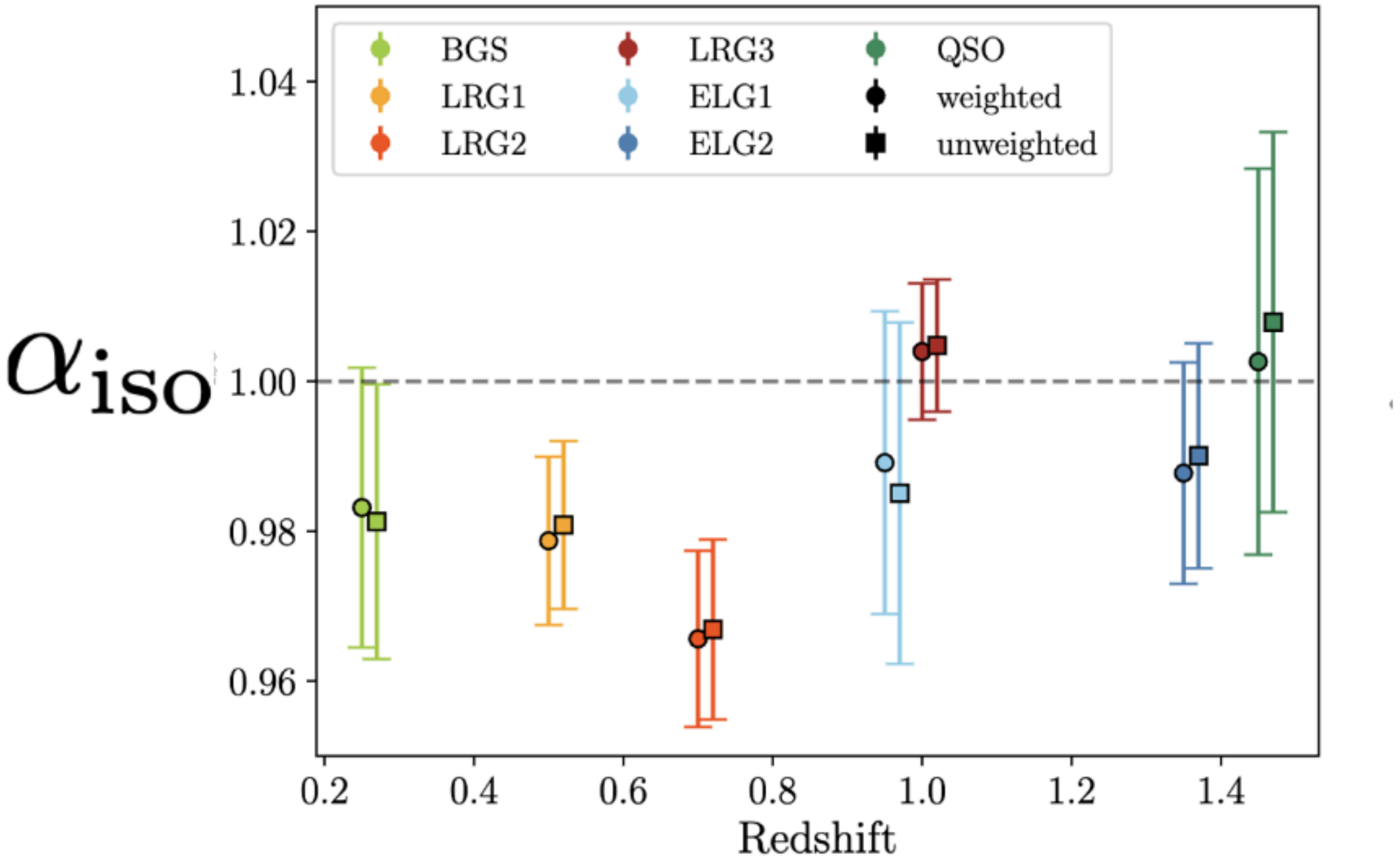
DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

# Extra slides



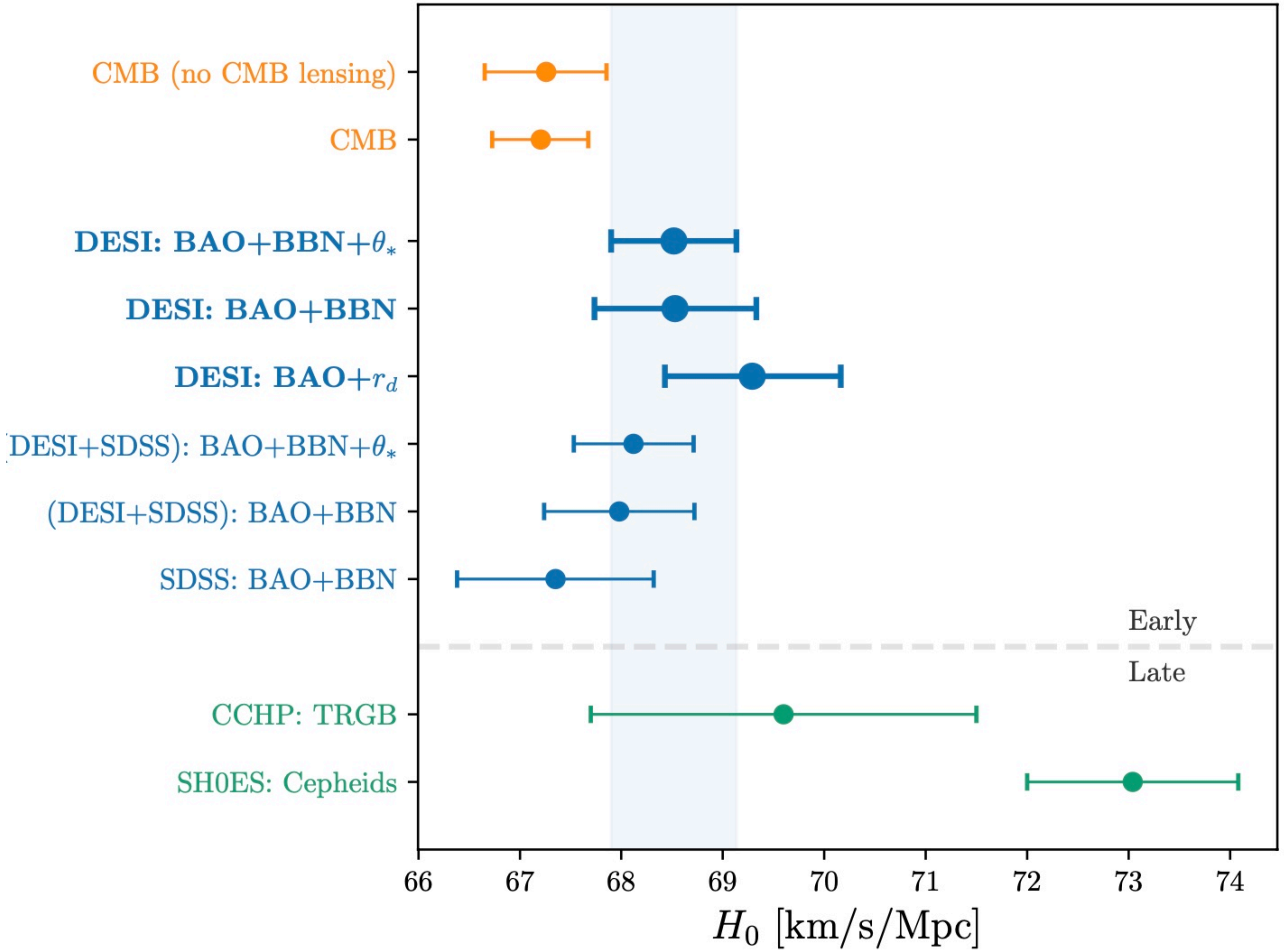

Five fiducial cosmologies tested.
All consistent.



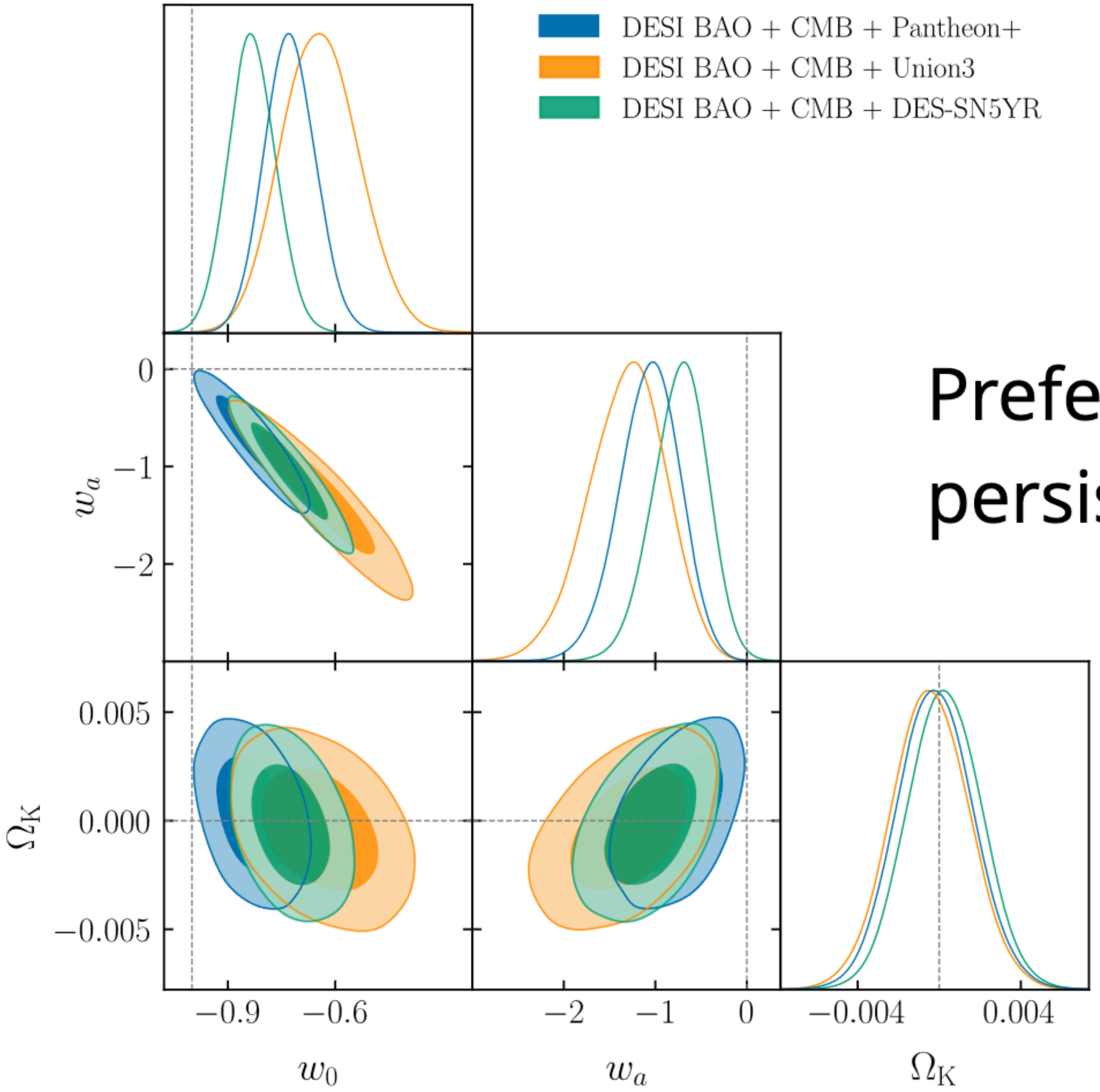

Observational (imaging) systematics

Credit: KP4 WG

# Extra slides

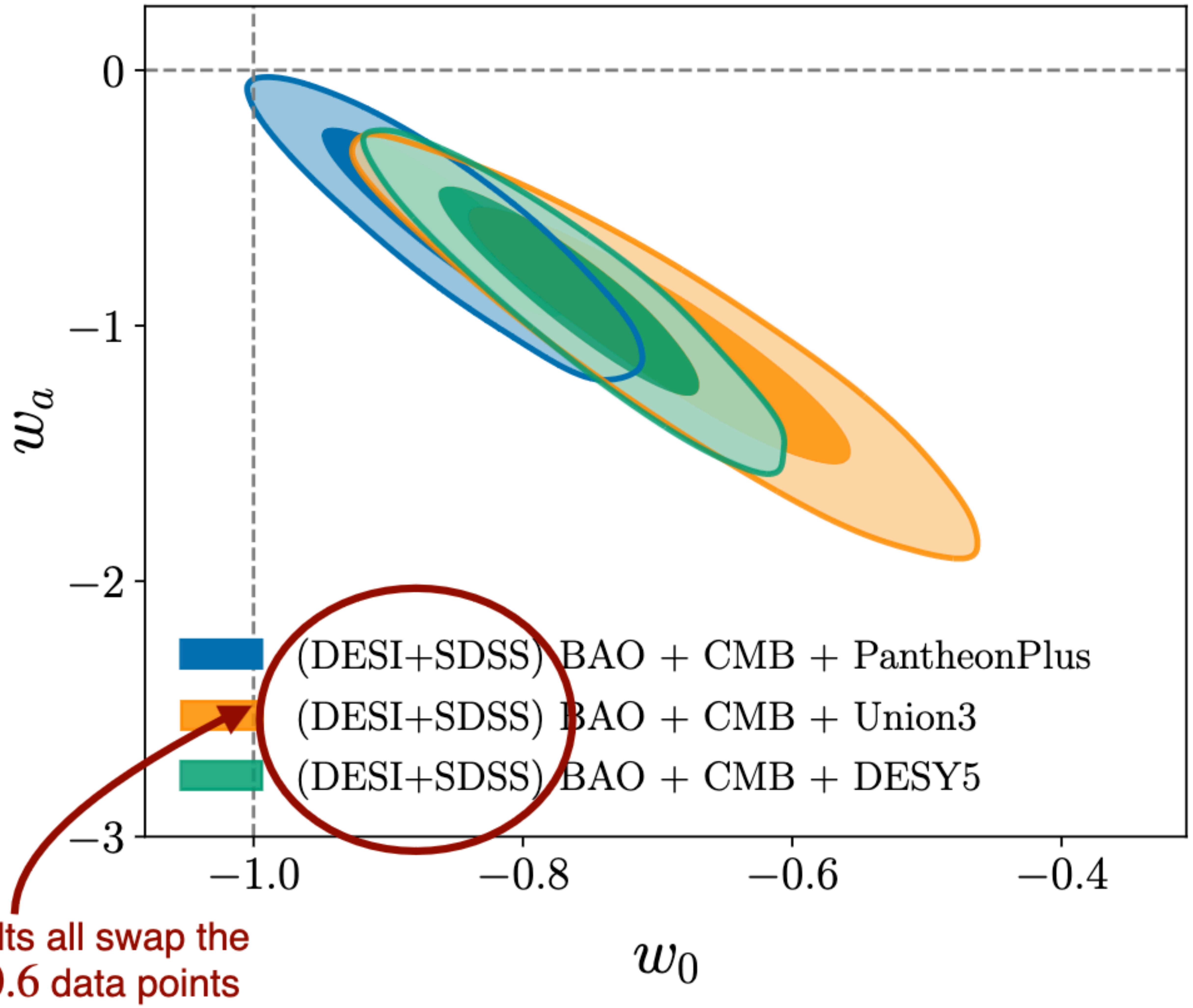


# Extra slides




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

# Extra slides




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