

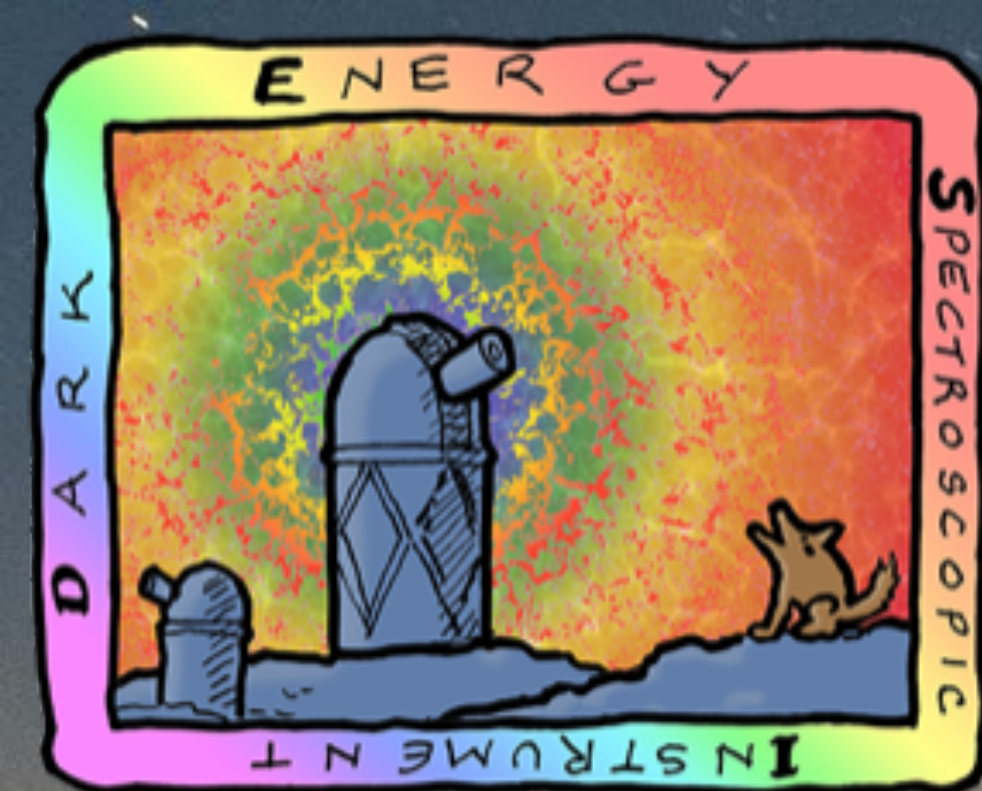
The Dark Energy Spectroscopic Instrument (DESI): An Overview

Domitille Chebat, CEA / DPhP

GdR CoPhy Episode 4

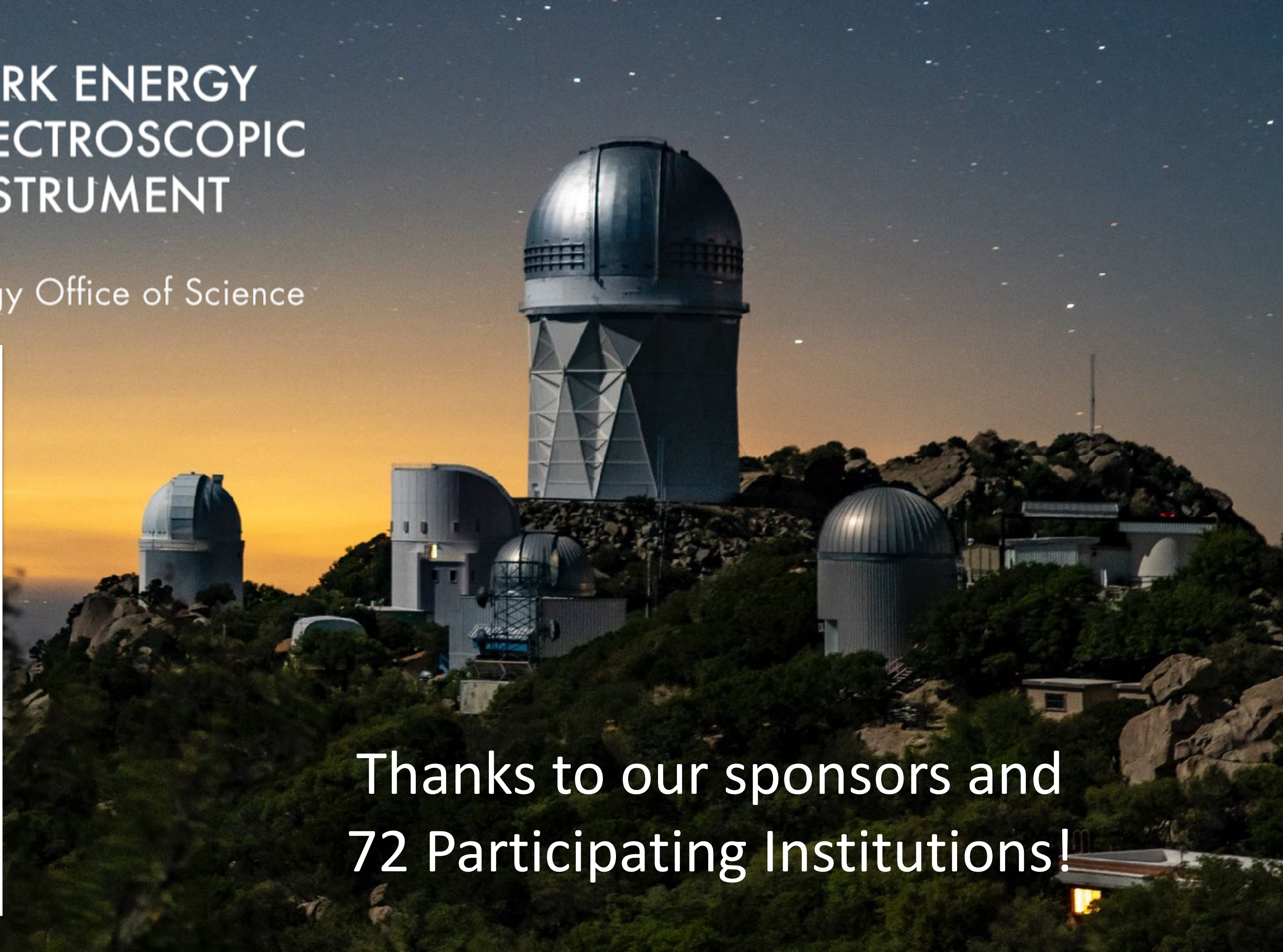
Clermont-Ferrand, 03/06/2026





DARK ENERGY SPECTROSCOPIC INSTRUMENT

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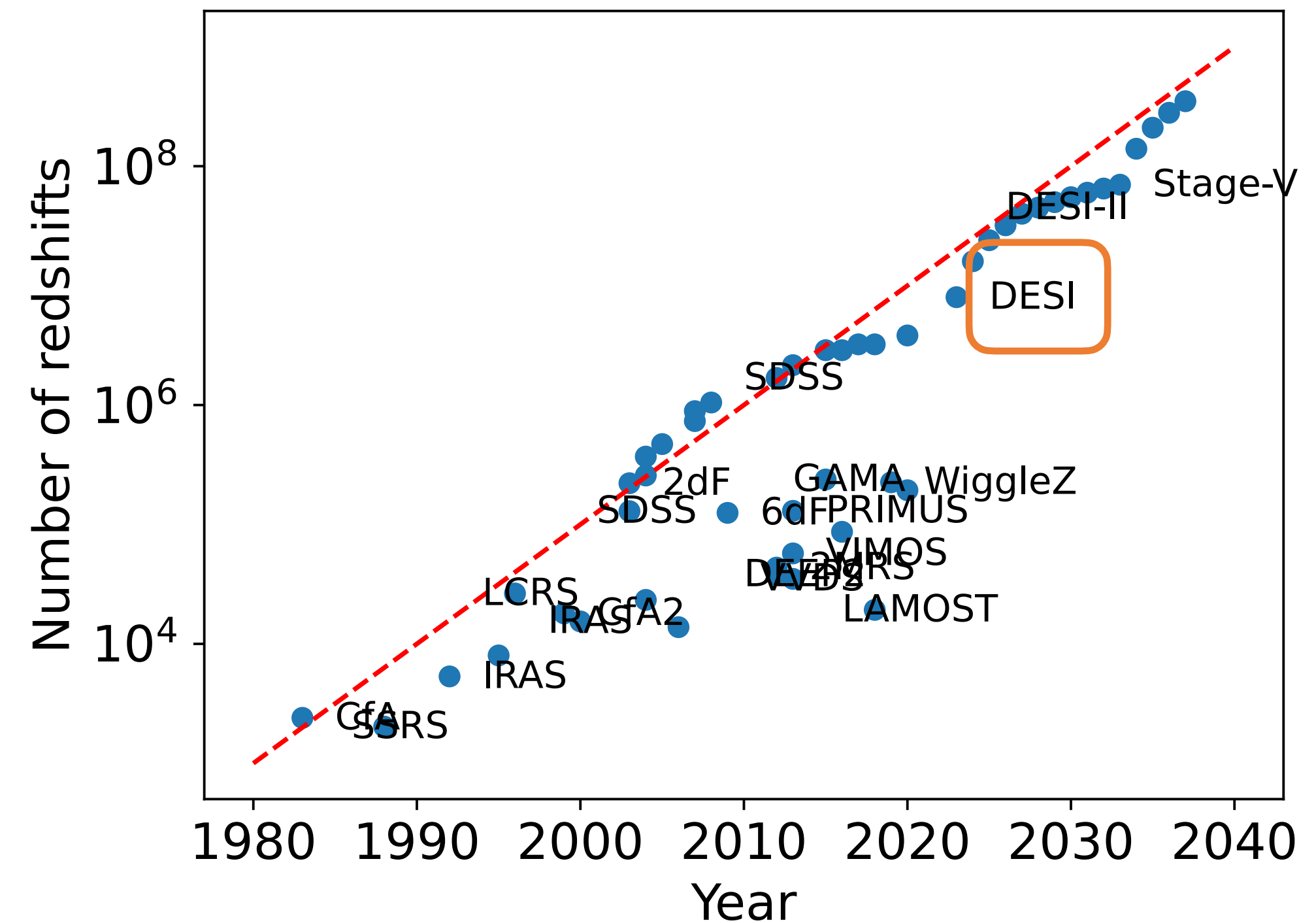
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72 Participating Institutions!



DESI: a stage IV redshift survey

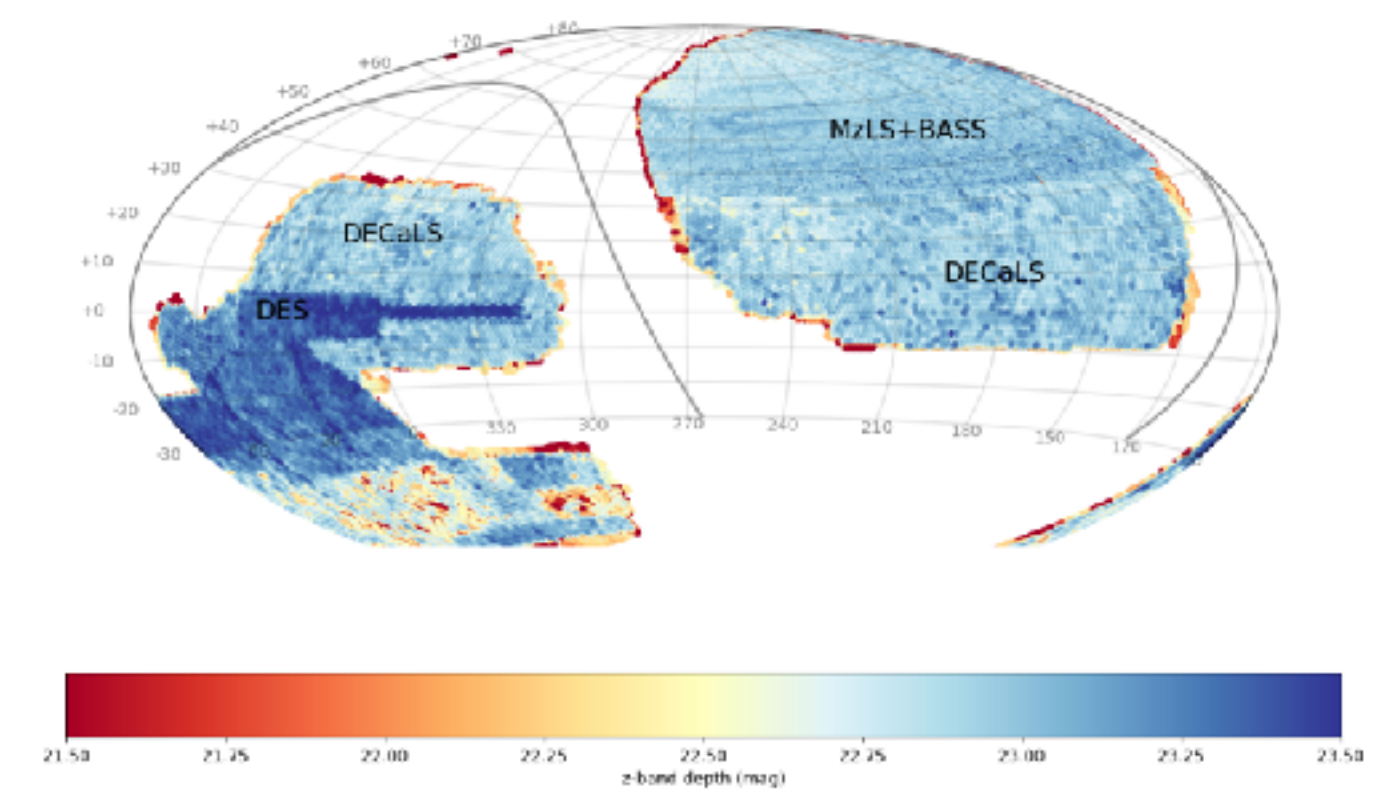
- Stage IV spectroscopic survey
- First light 2019, survey started in 2021
- Over 40 million galaxy redshifts over initially planned 5 years
- 3 data releases:
 - DR1 = Y1, 2024
 - DR2 = Y3, 2025
 - DR3 = Y5, in prep

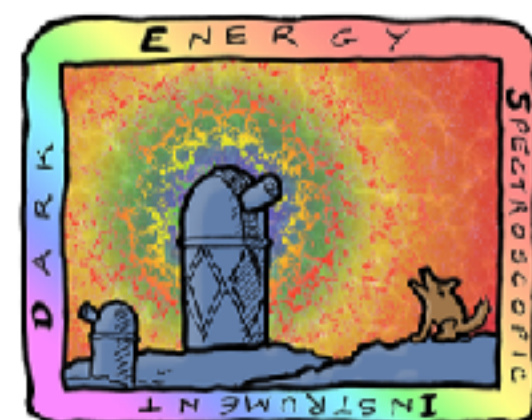


Schlegel et al, 2022, 2209.03585

Redshift surveys 101

Photometry survey (DESI Legacy)



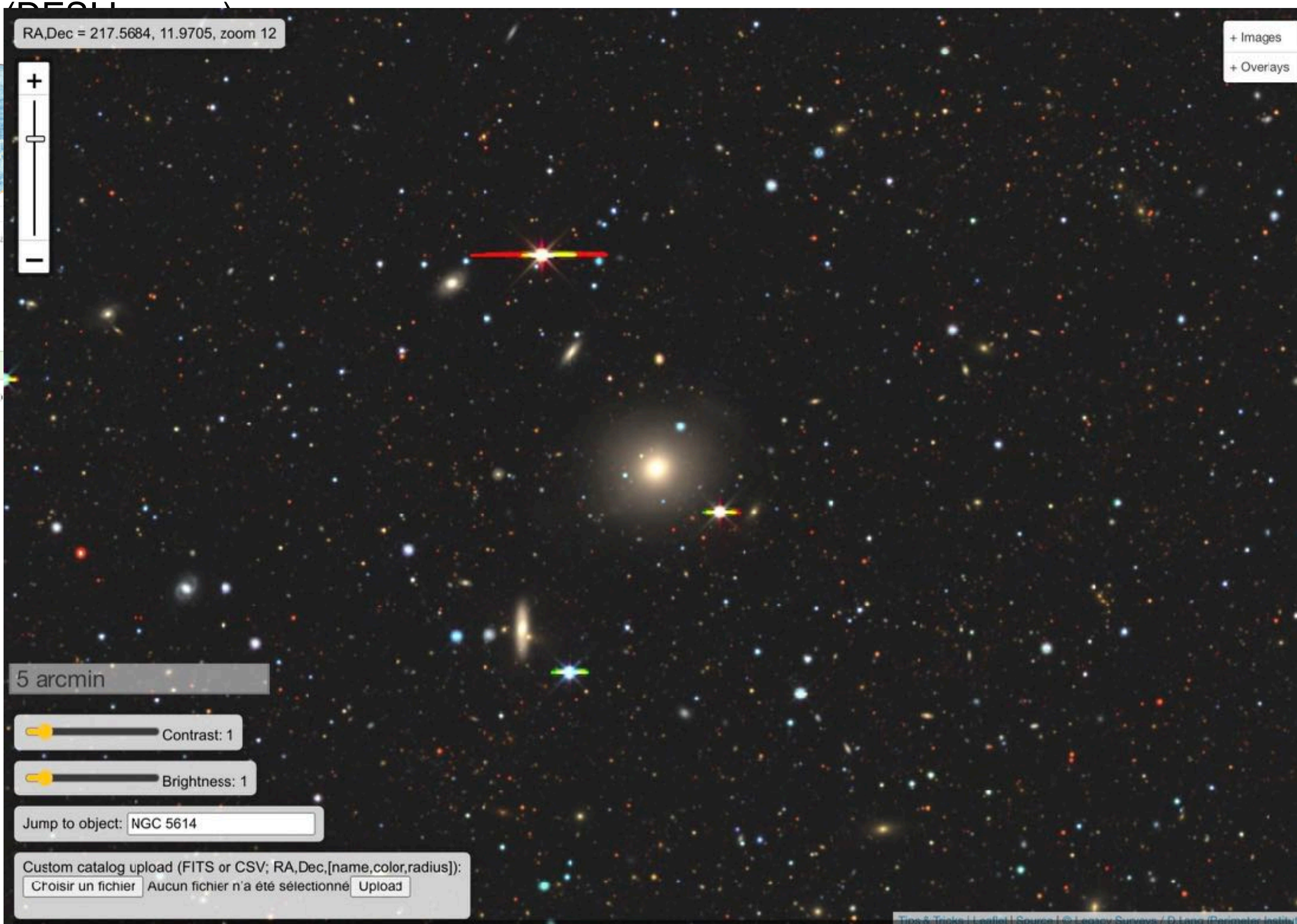
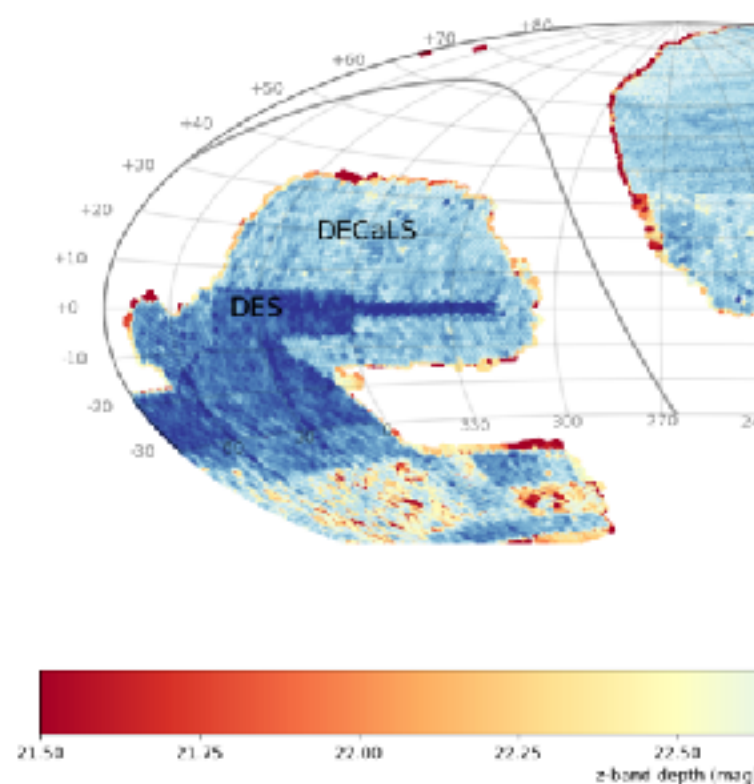


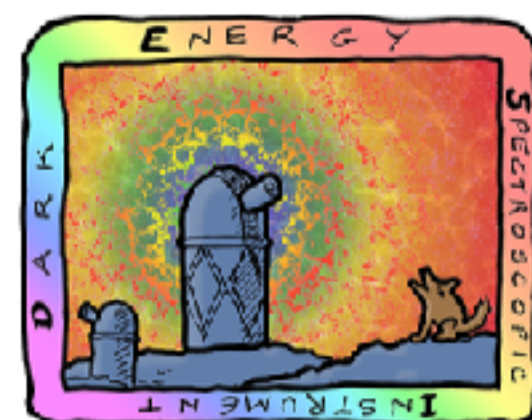
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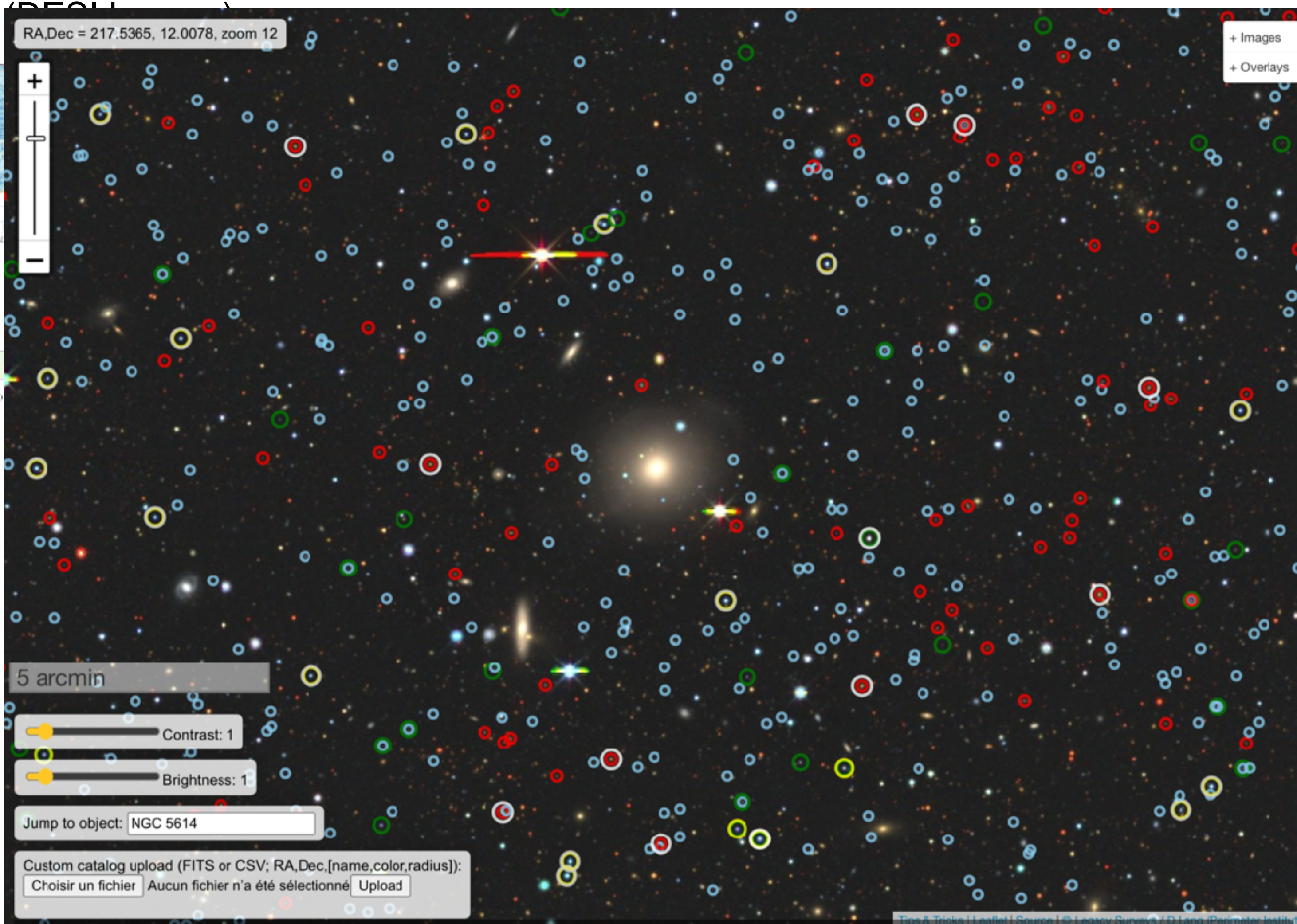
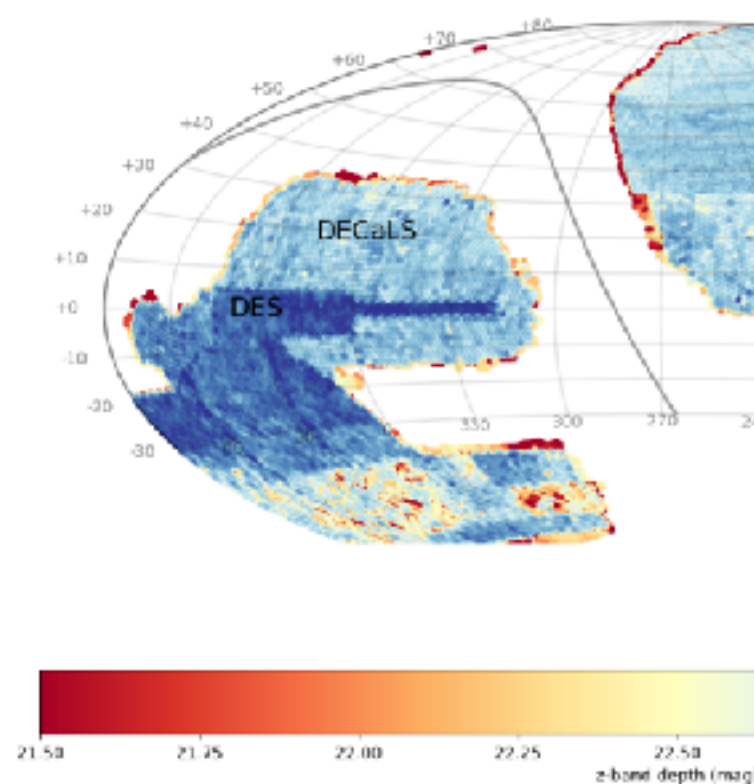


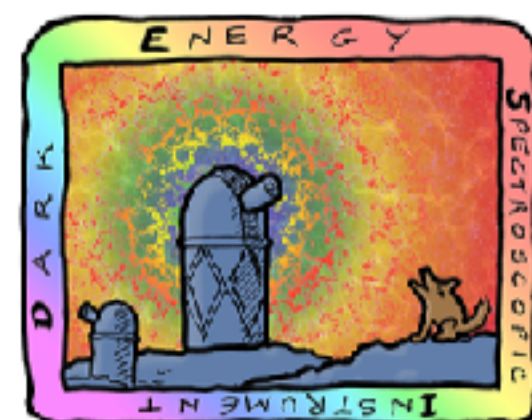
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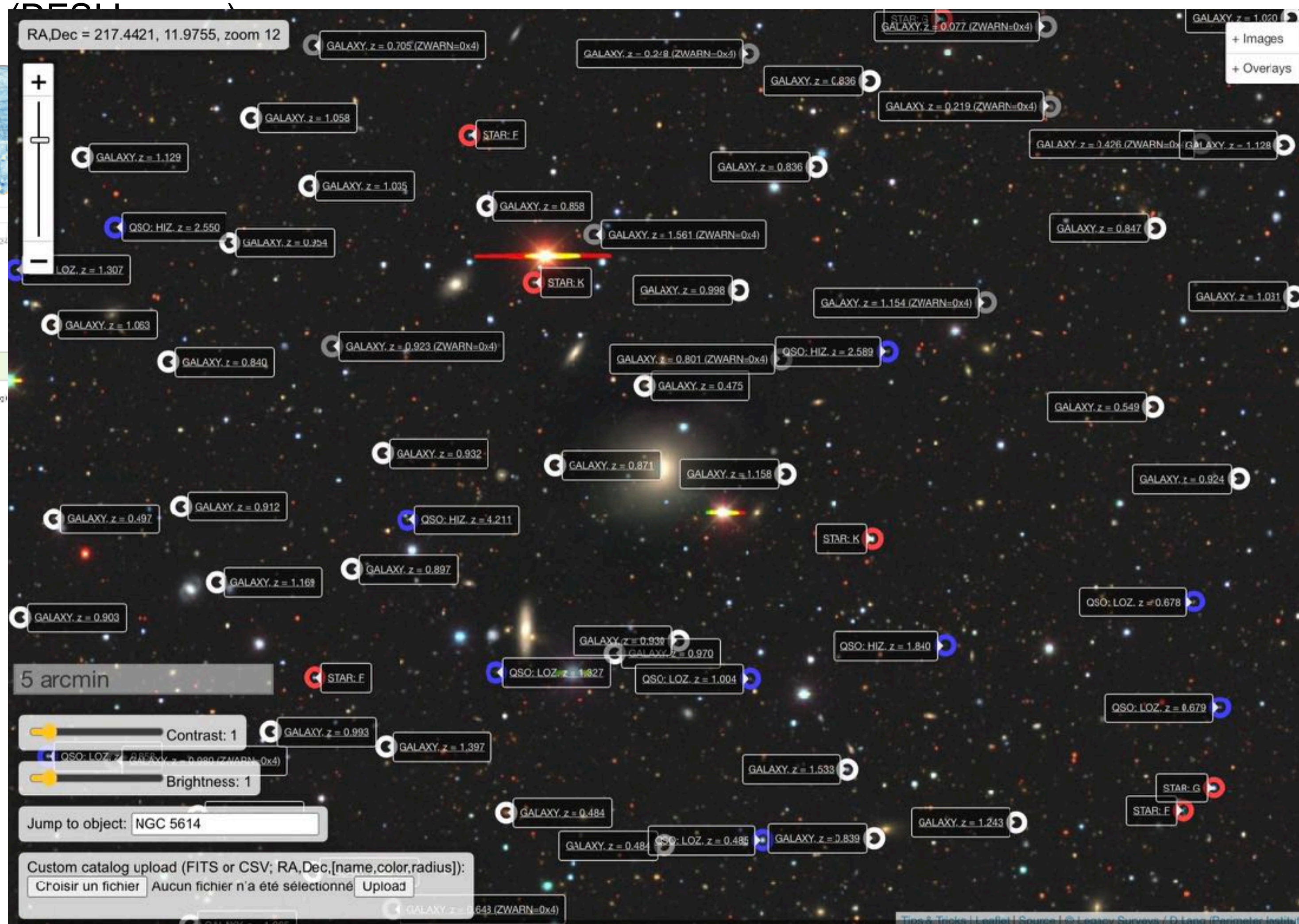
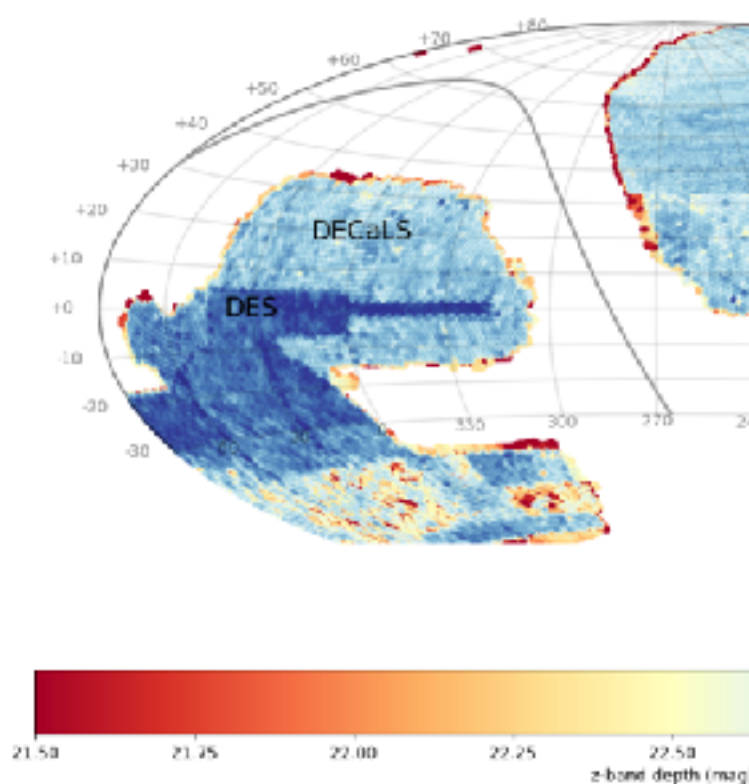


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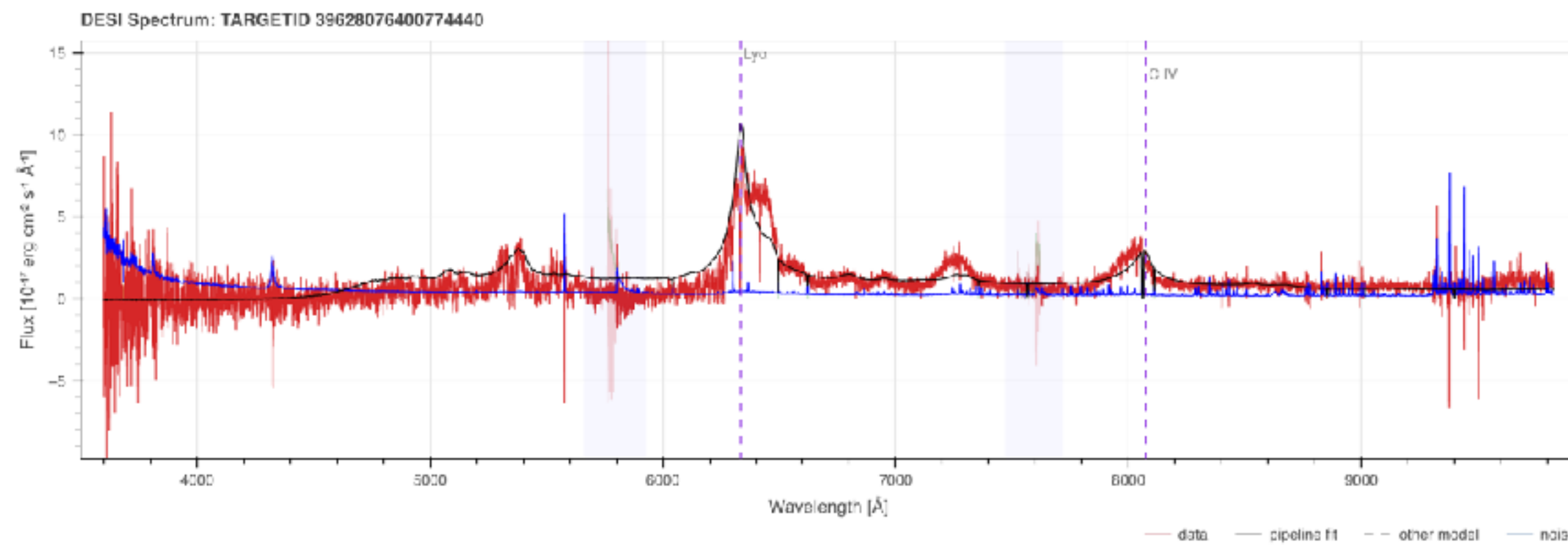
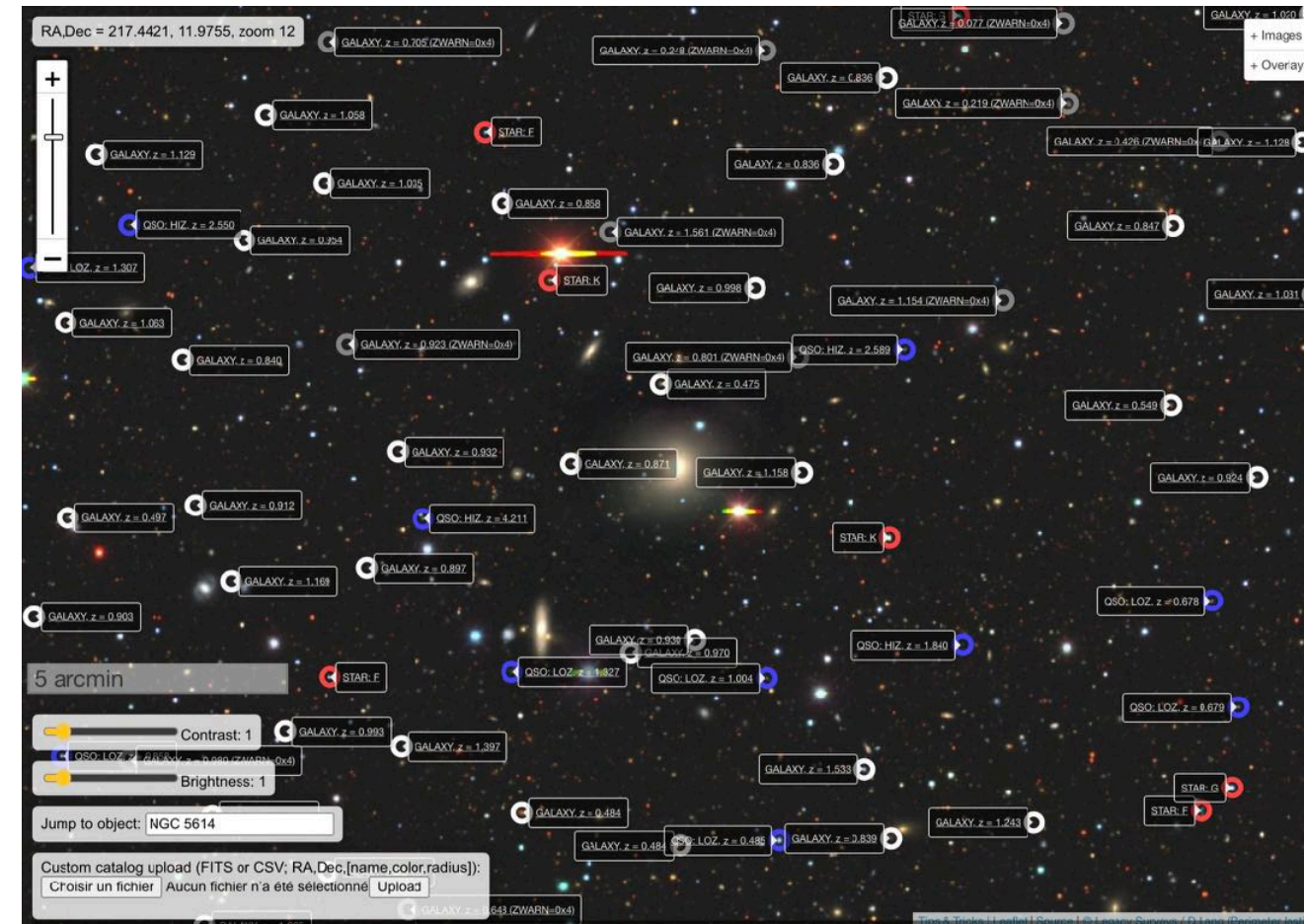
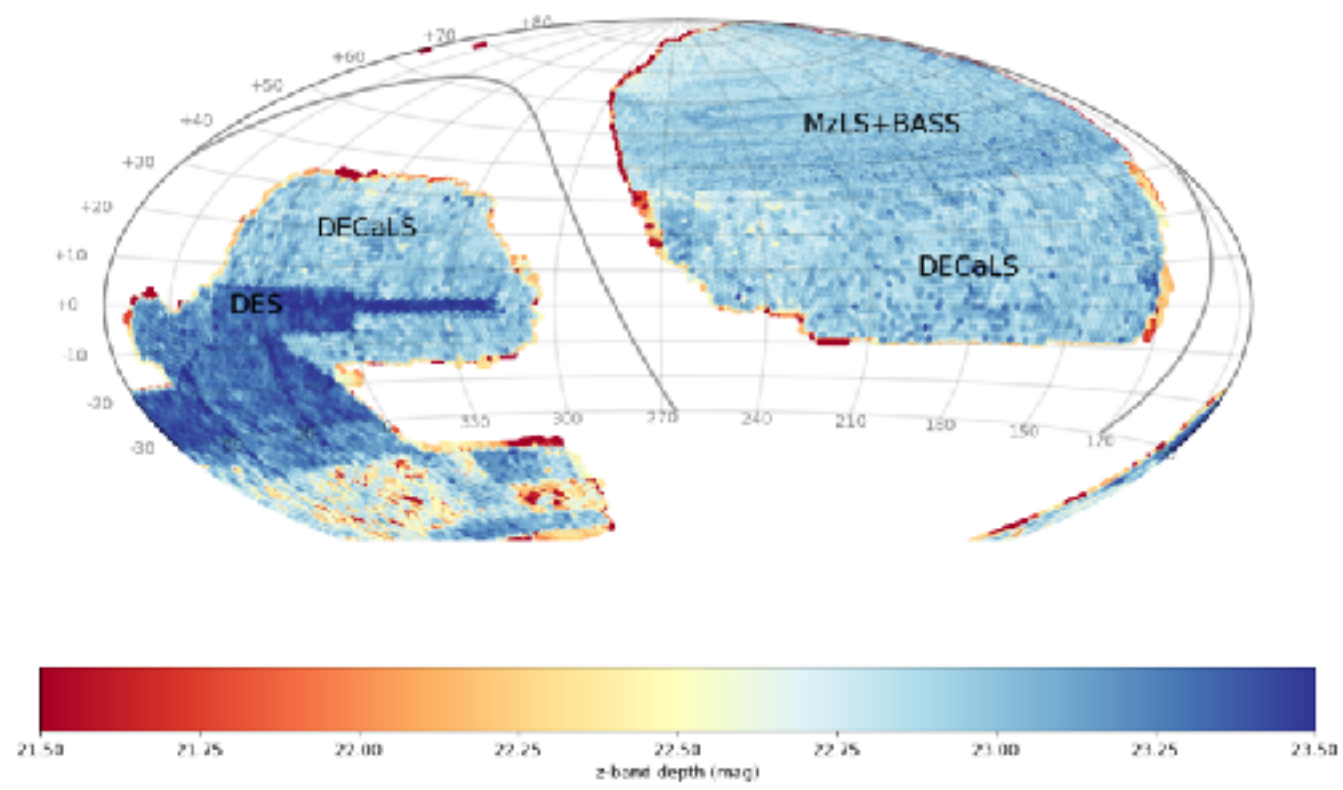
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Photometry survey (DECaLS)



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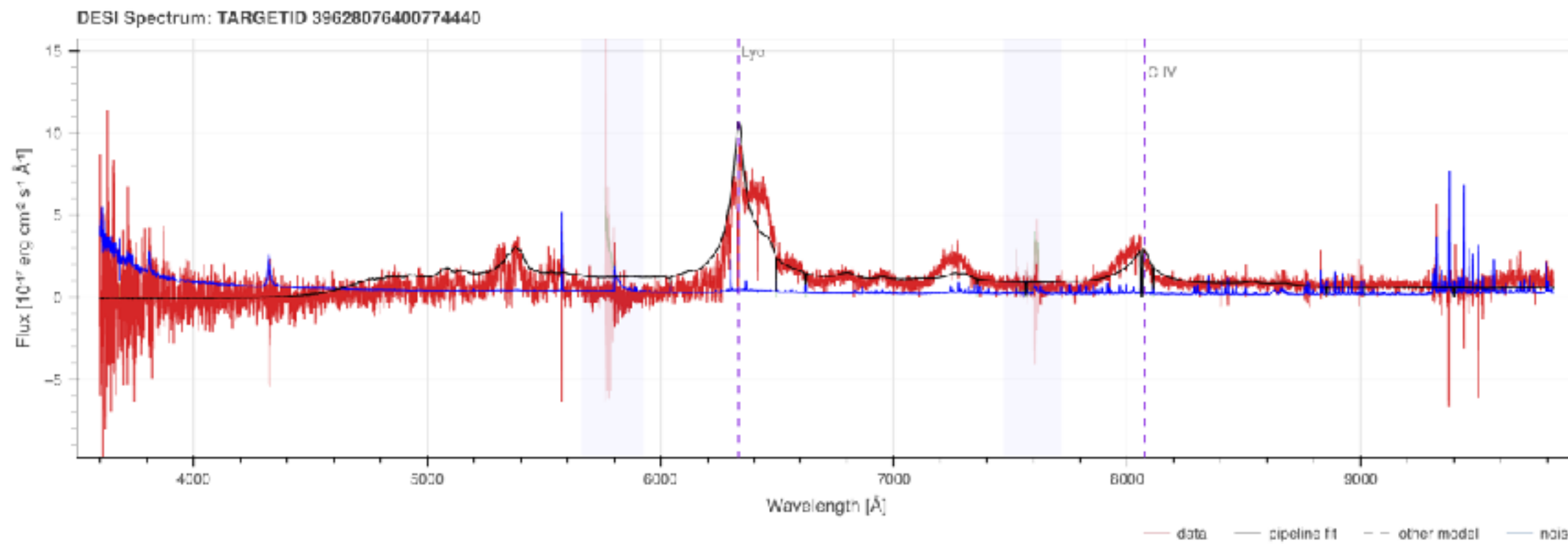
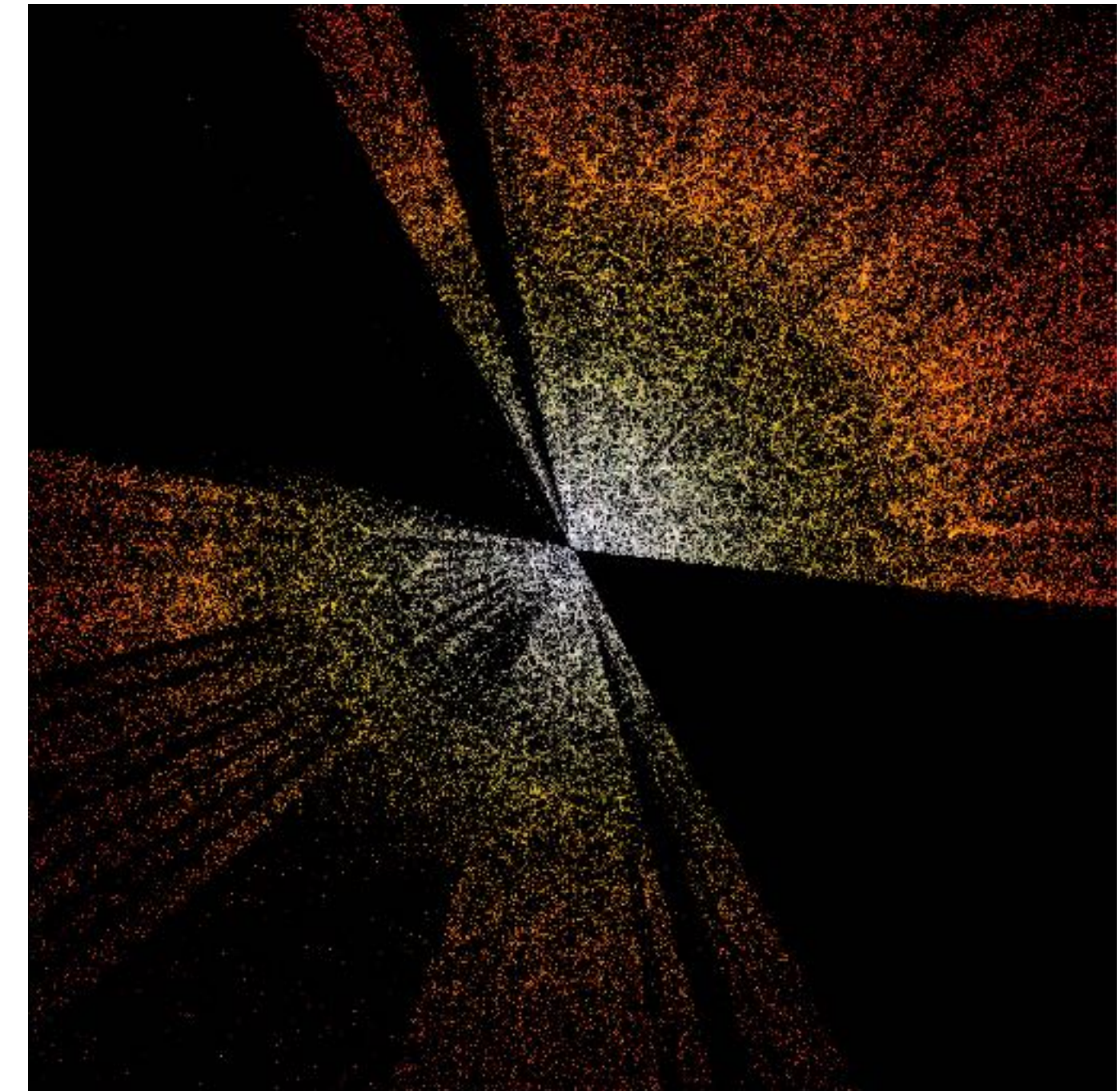
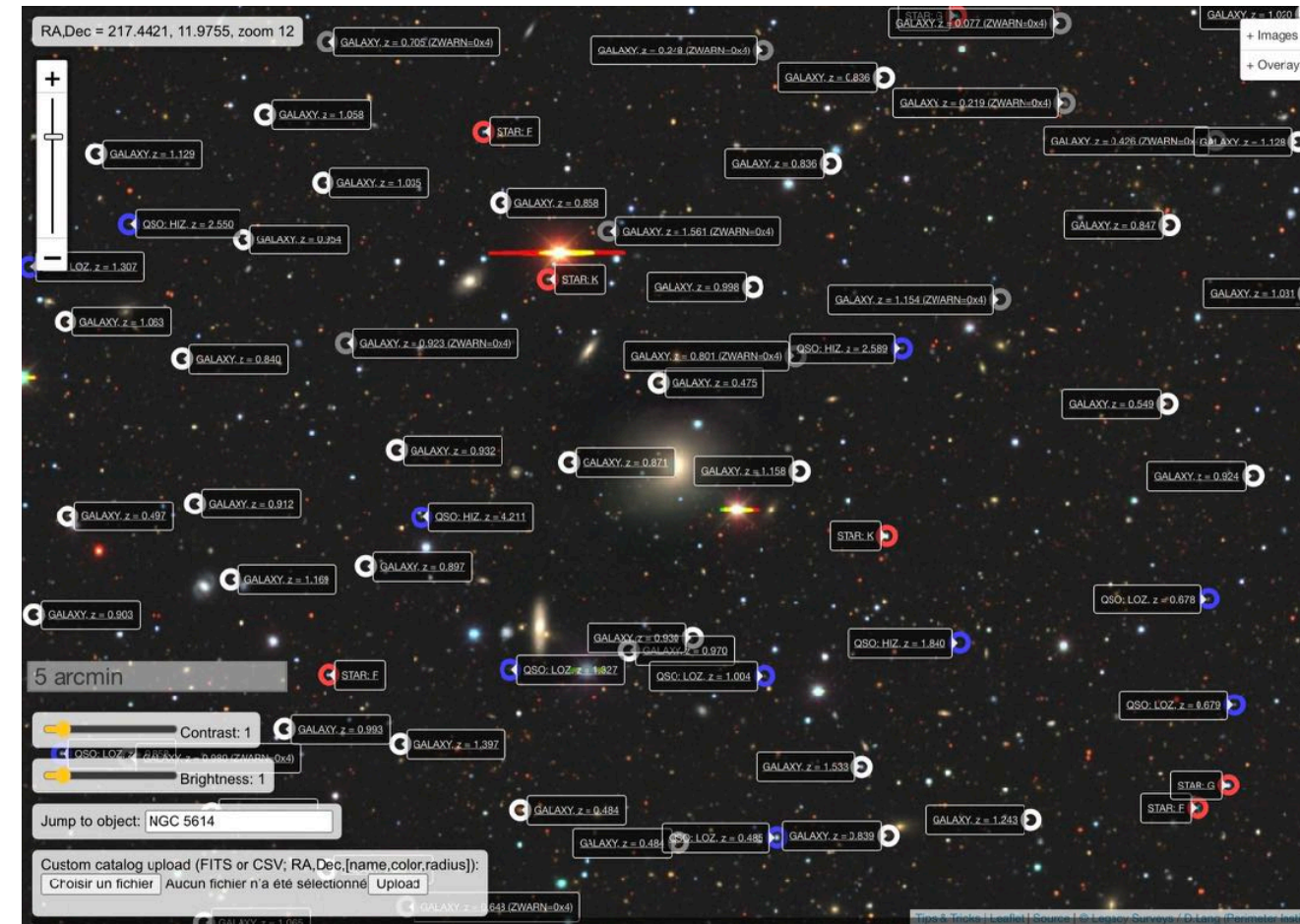
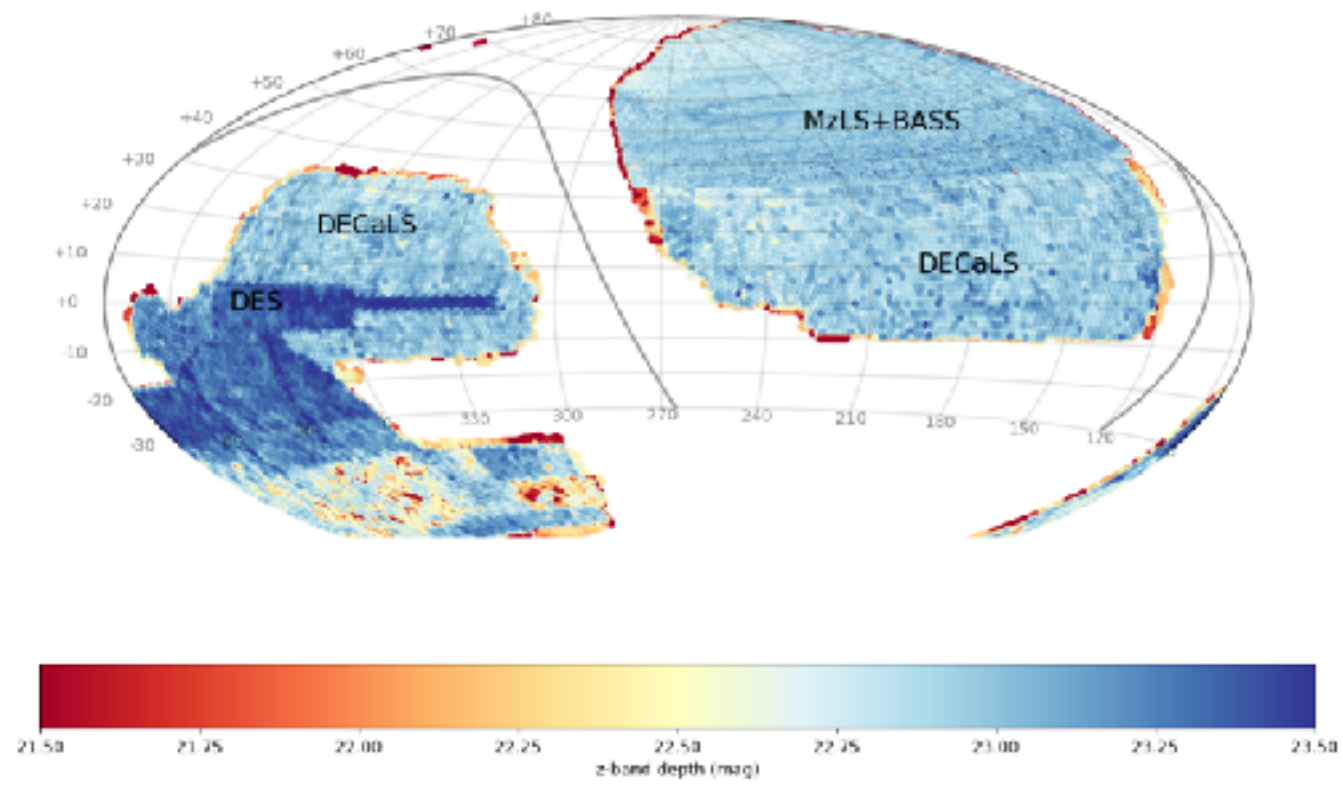
Photometry survey (DESI Legacy)



Spectrography

Redshift surveys 101

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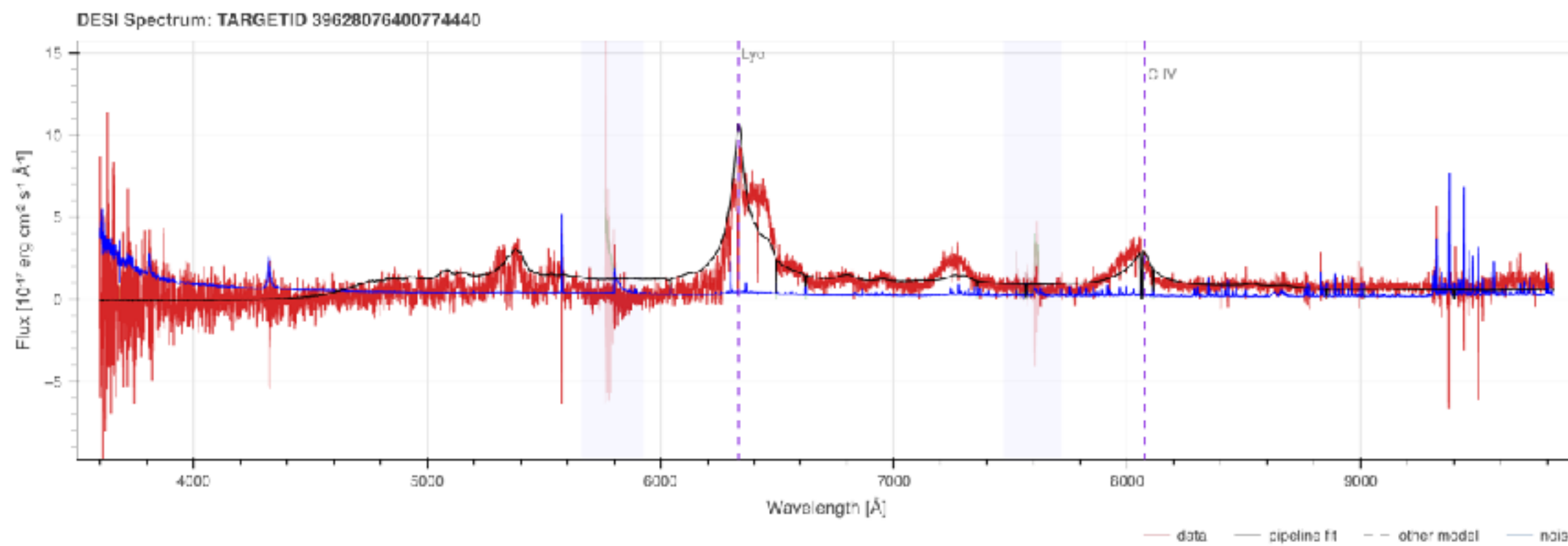
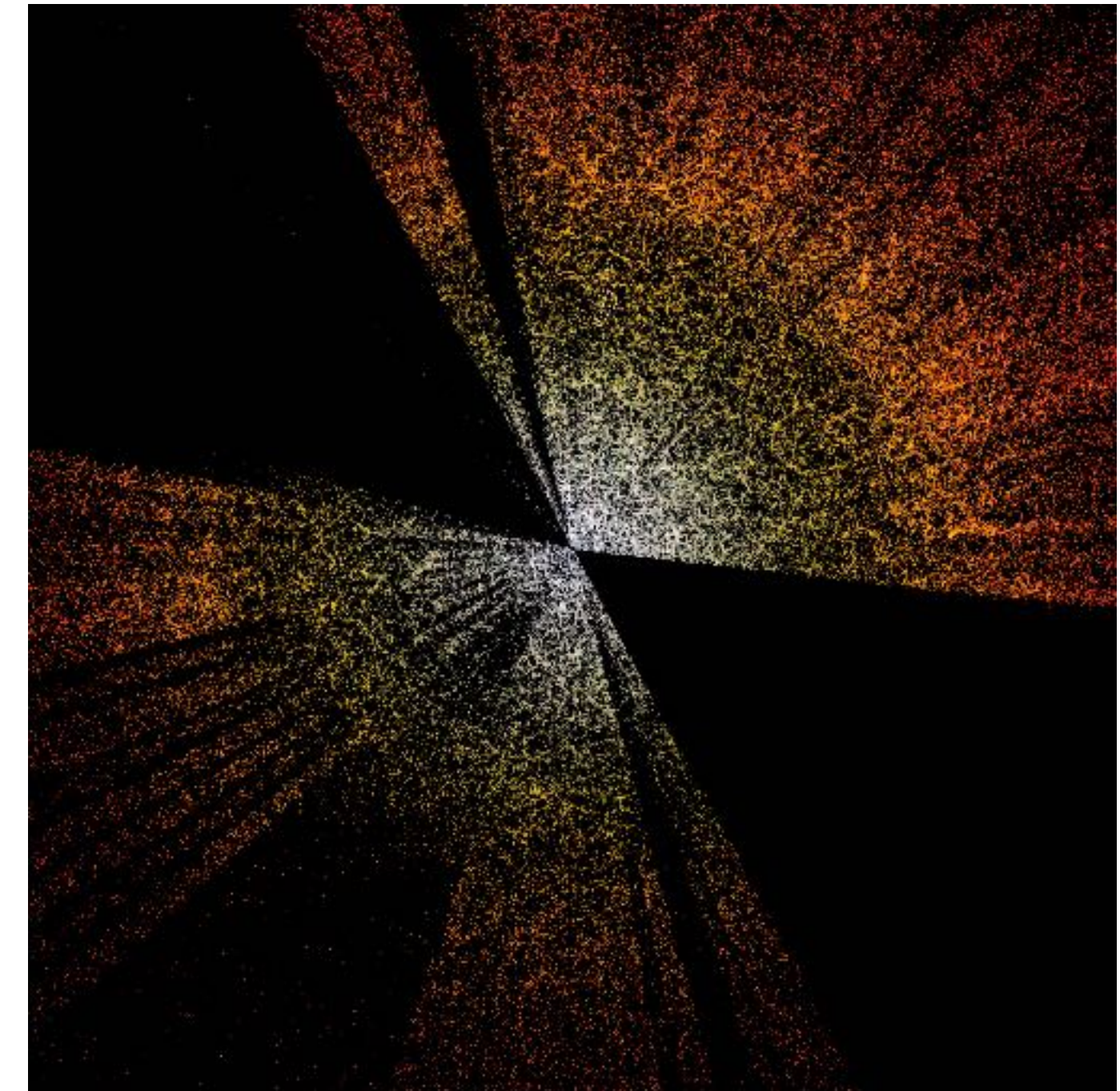
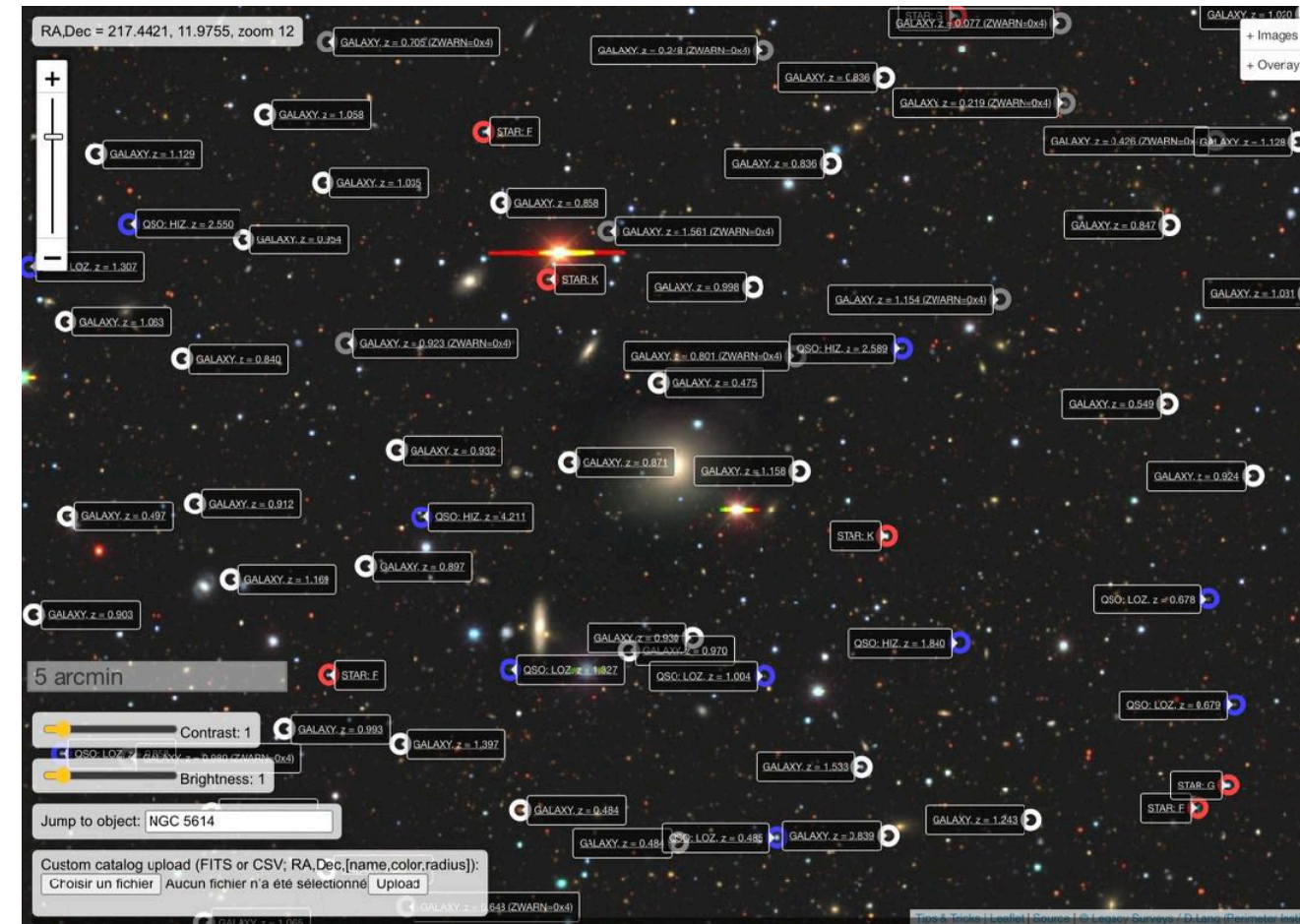
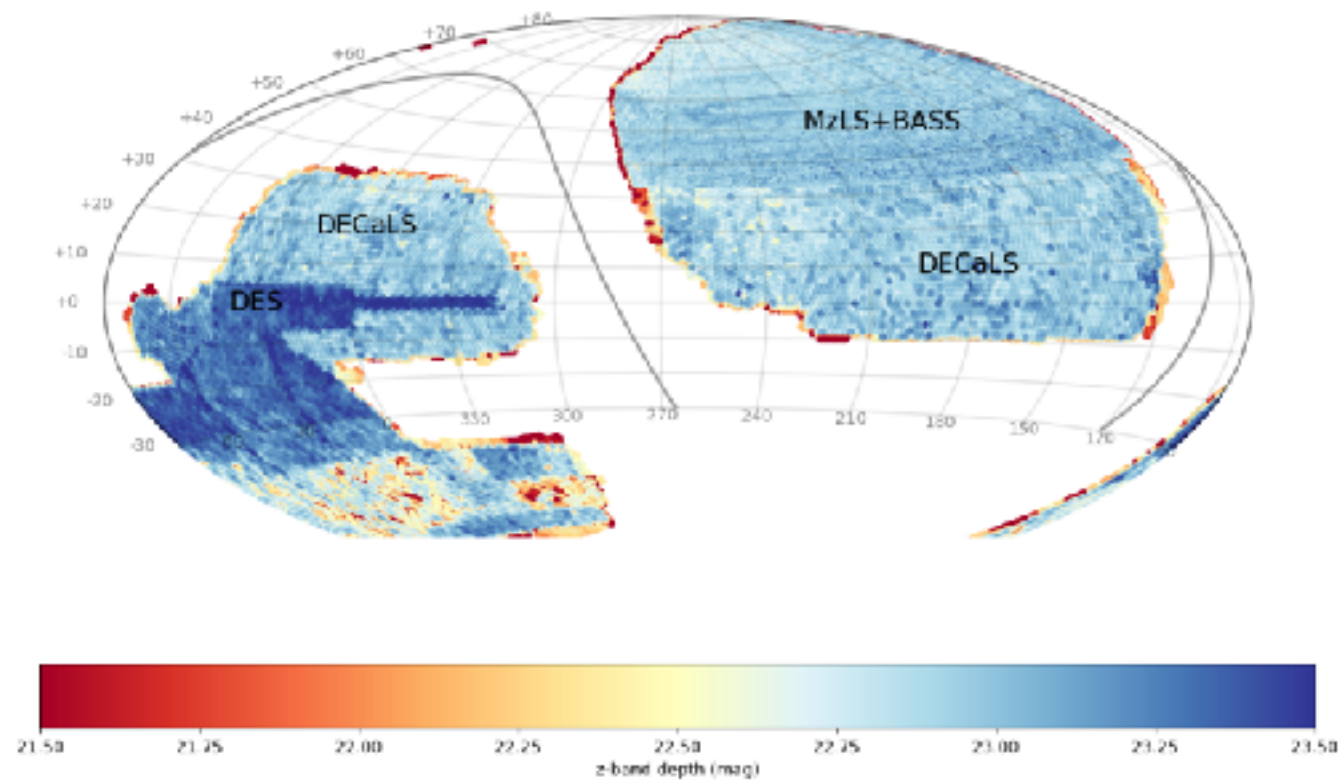


Spectrography

Redshift catalog

Redshift surveys 101

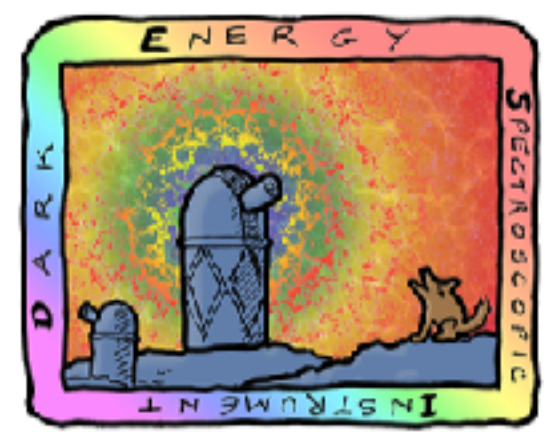
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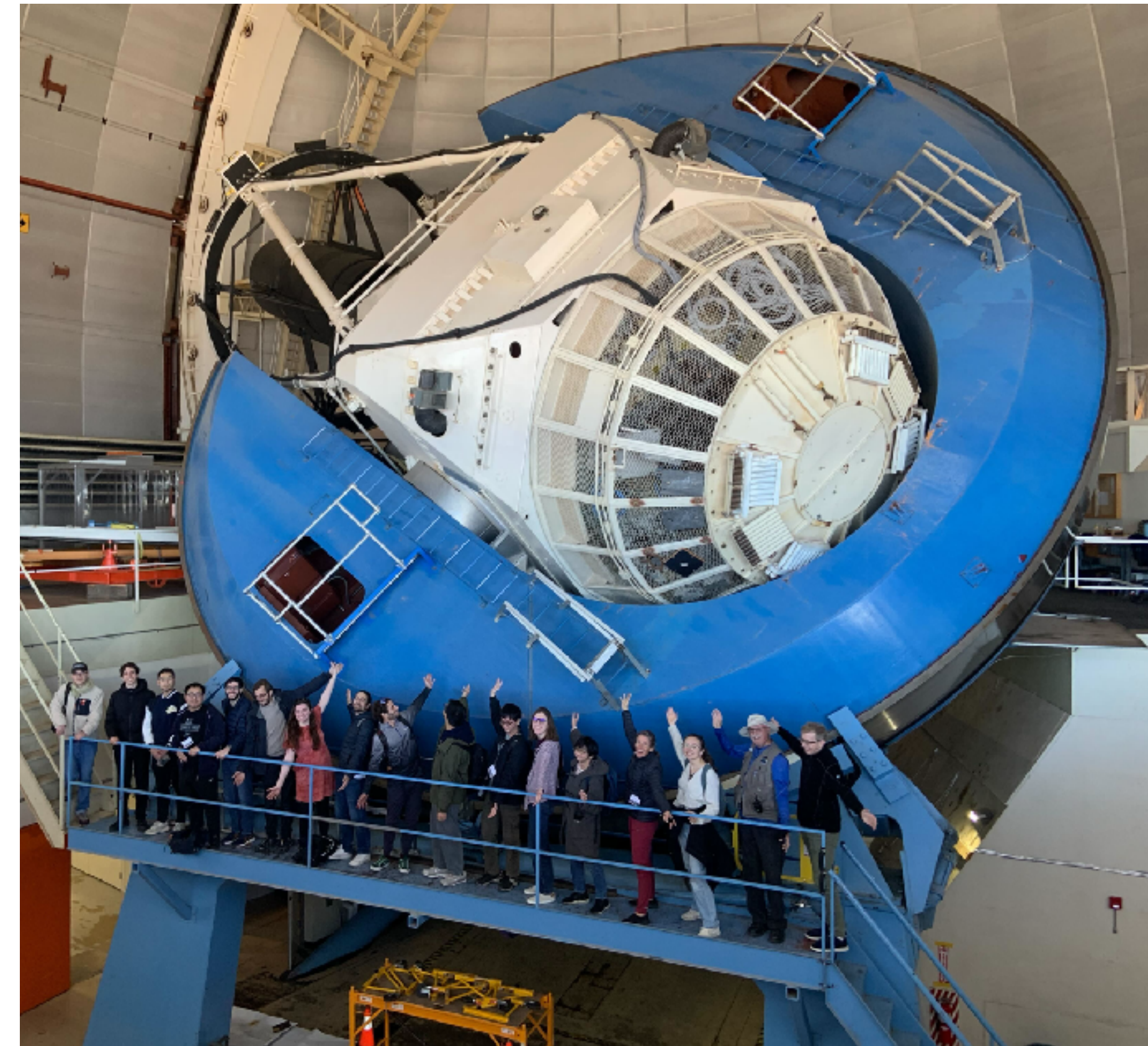
<https://www.legacysurvey.org/viewer>

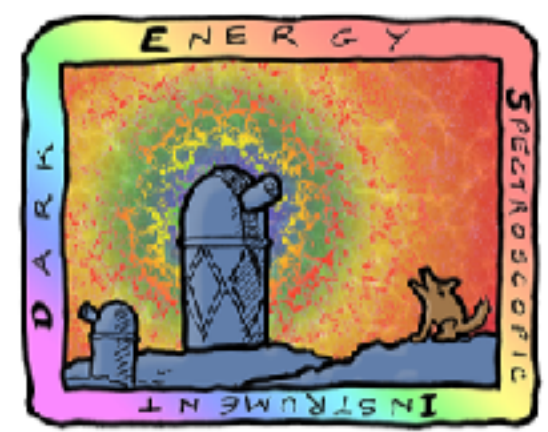


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DESI and Mayall





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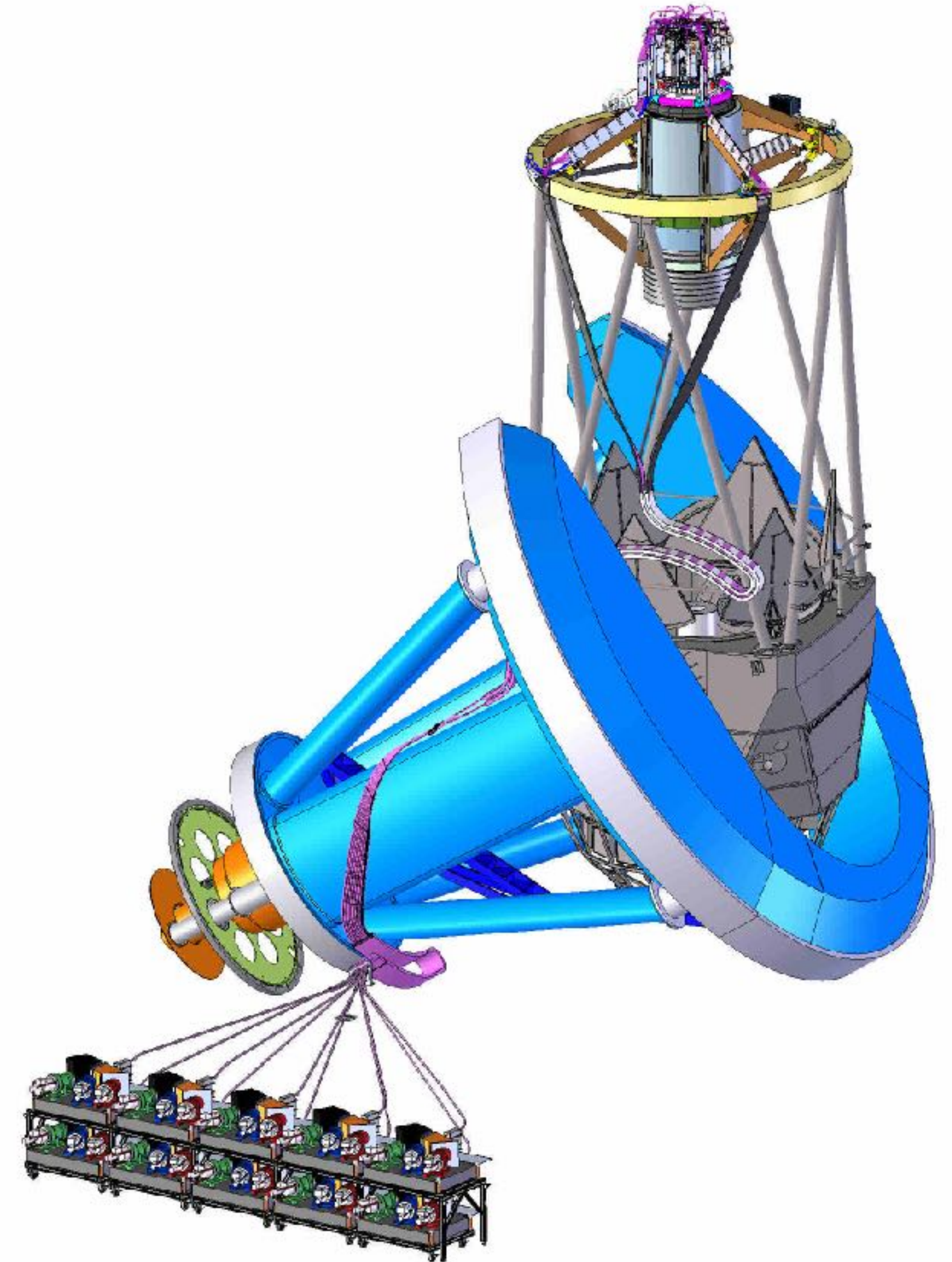
DESI and Mayall

- Mounted on 4m Mayall telescope (Kitt Peak, AZ, USA)



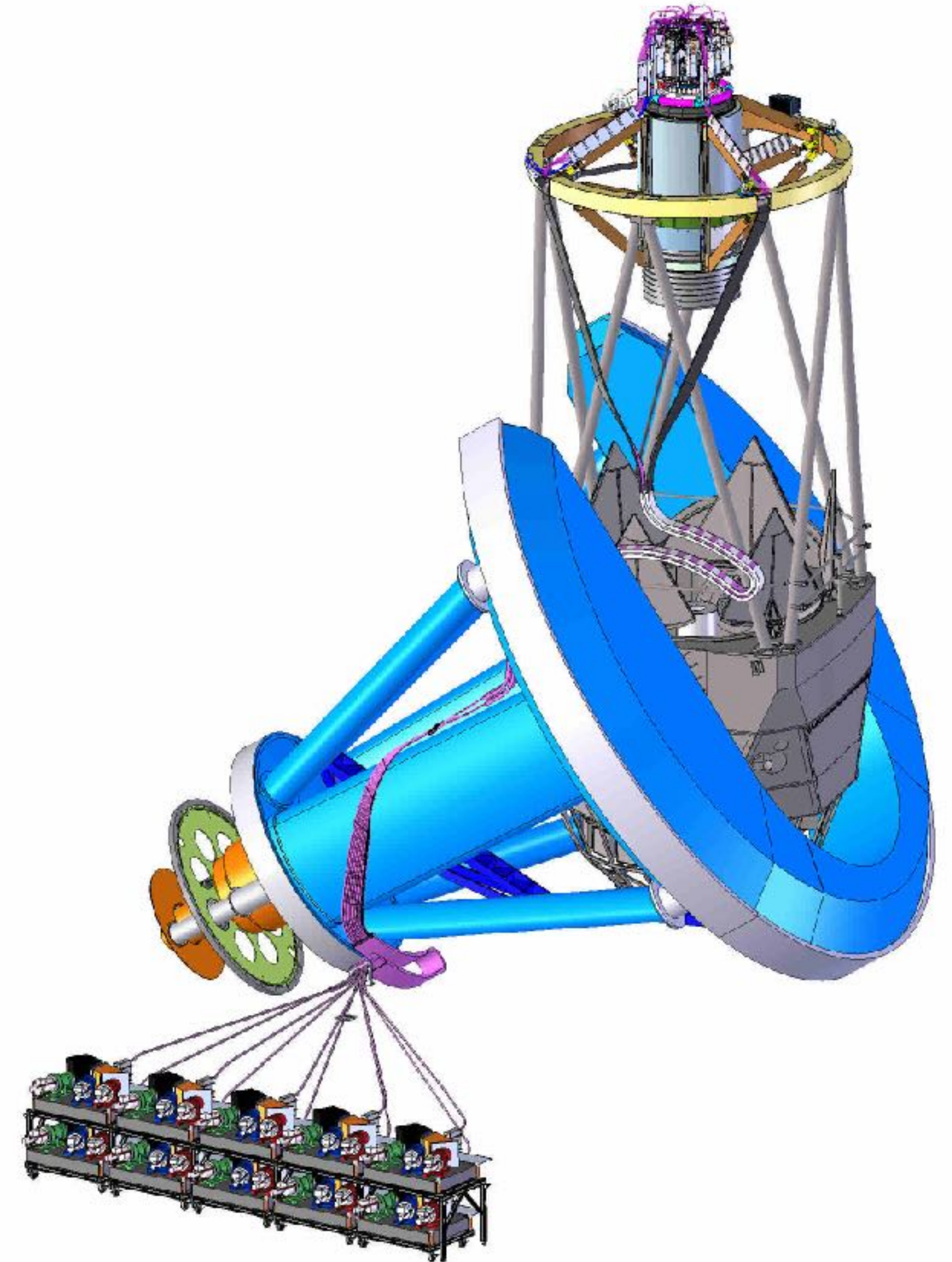
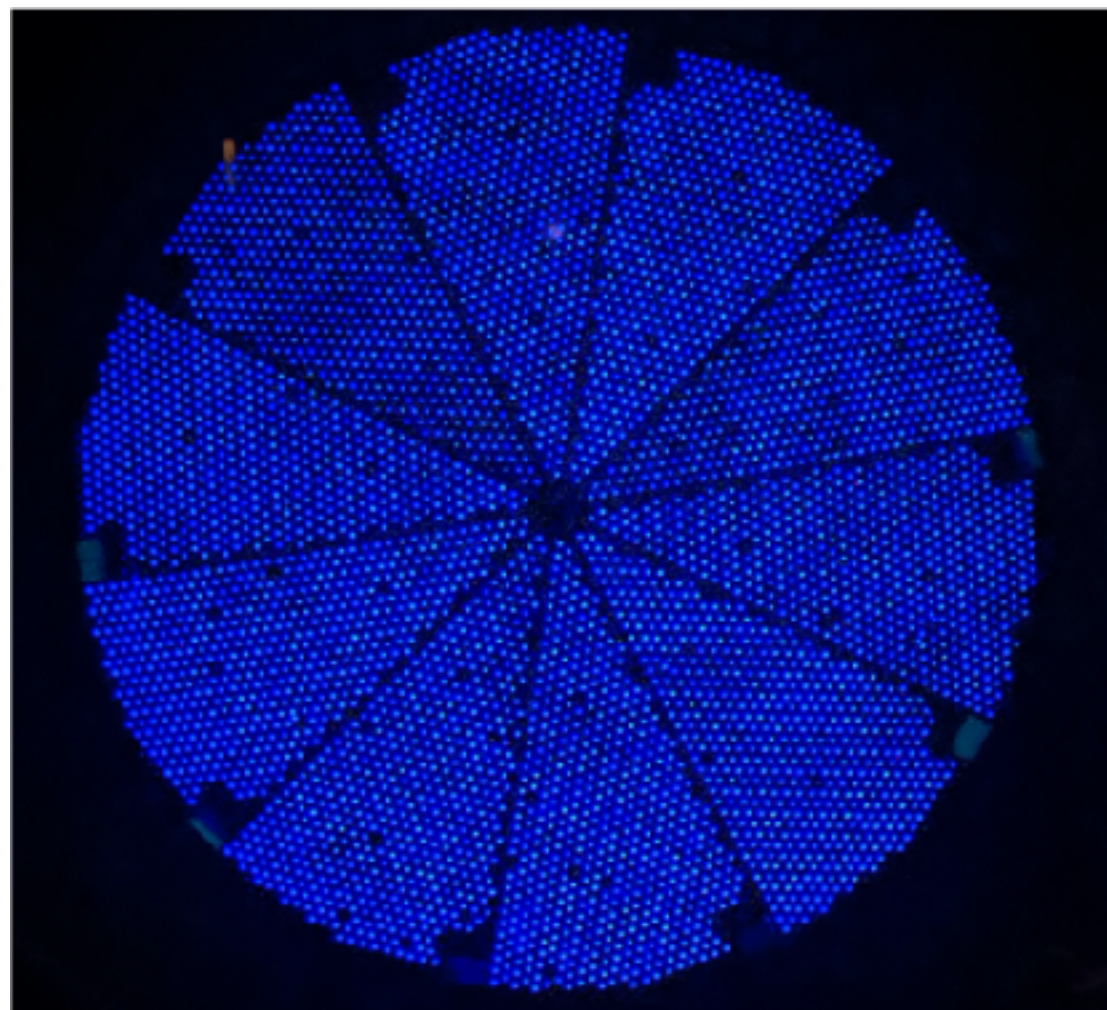
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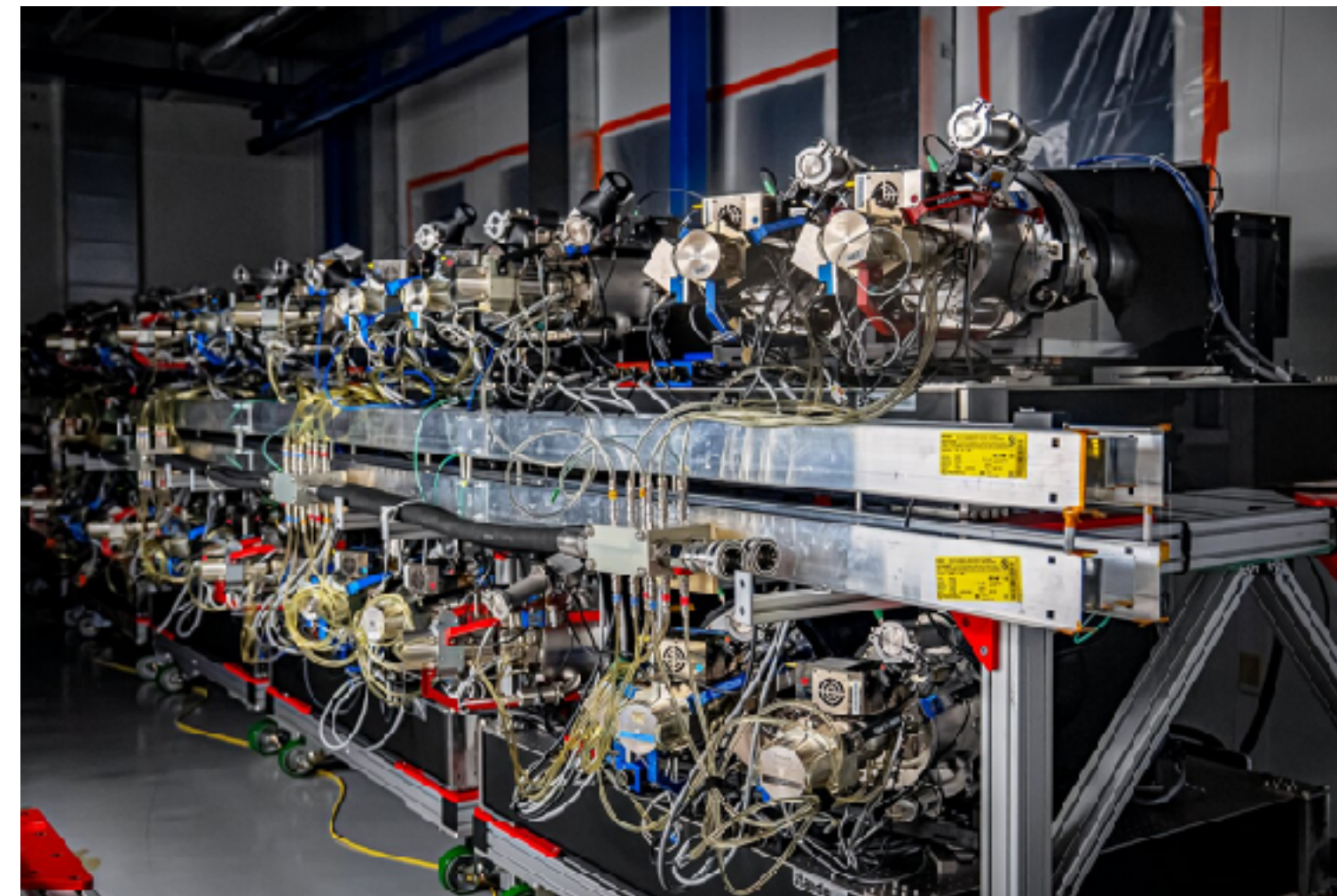
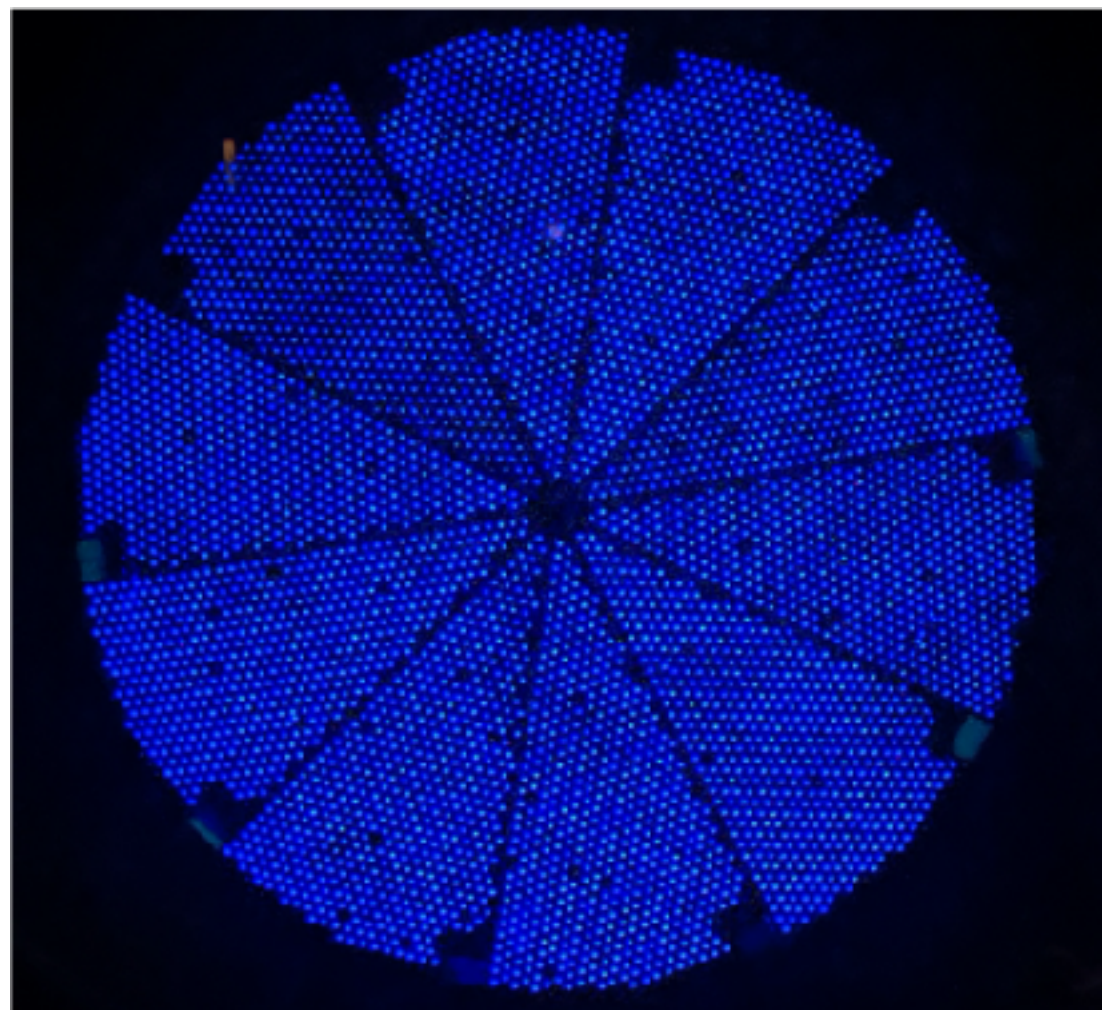
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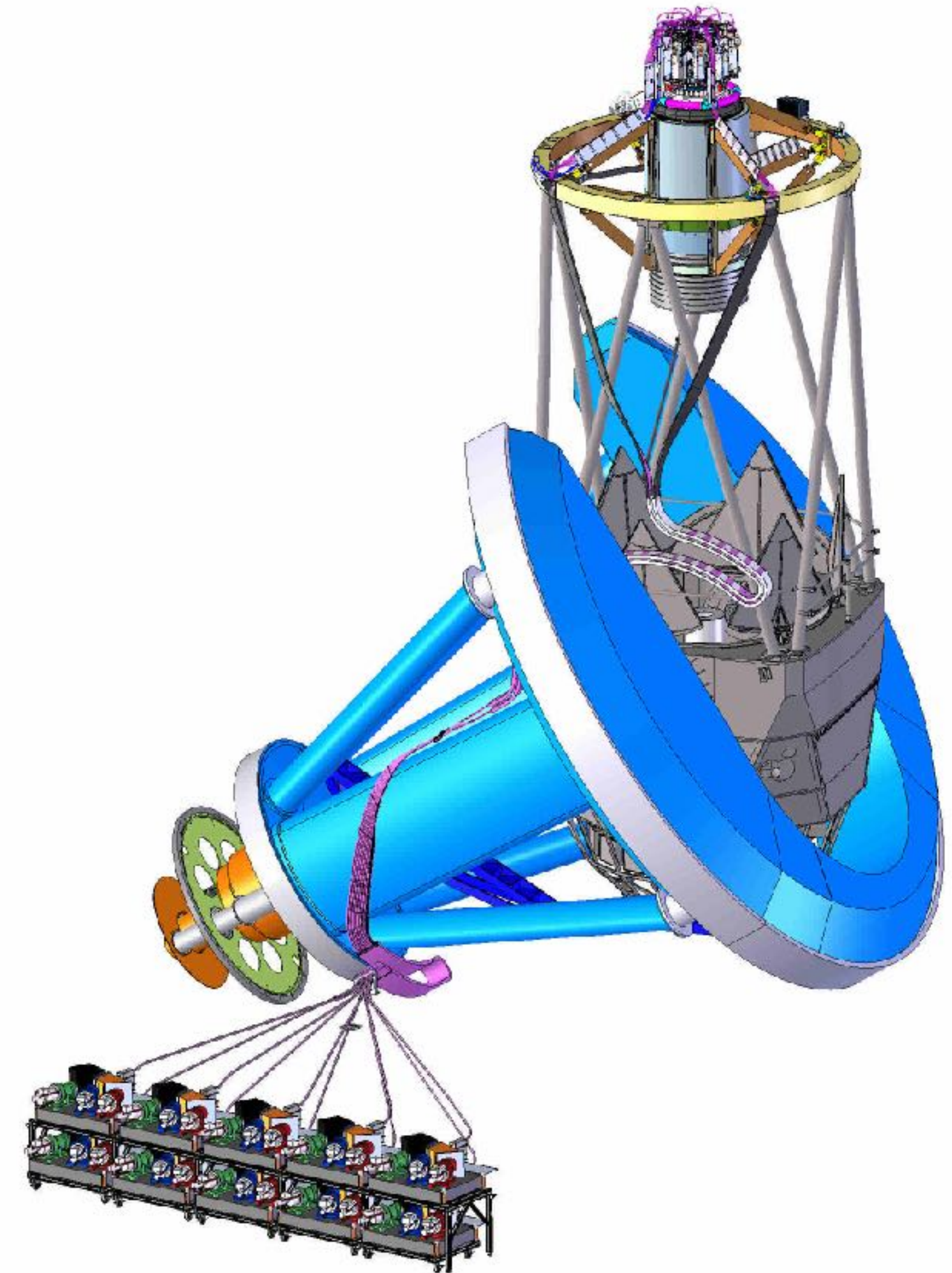


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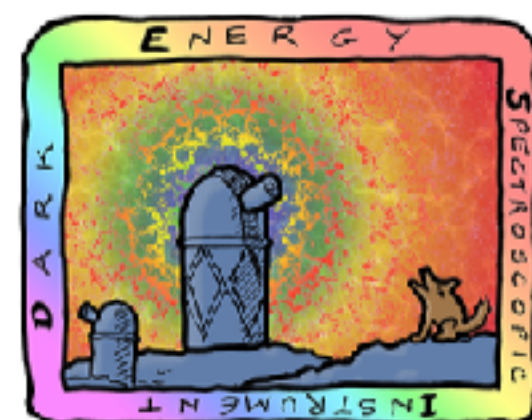
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DESI Collaboration/DOE/KPNO/NOIRLab/NSF/AURA/M. Sargent



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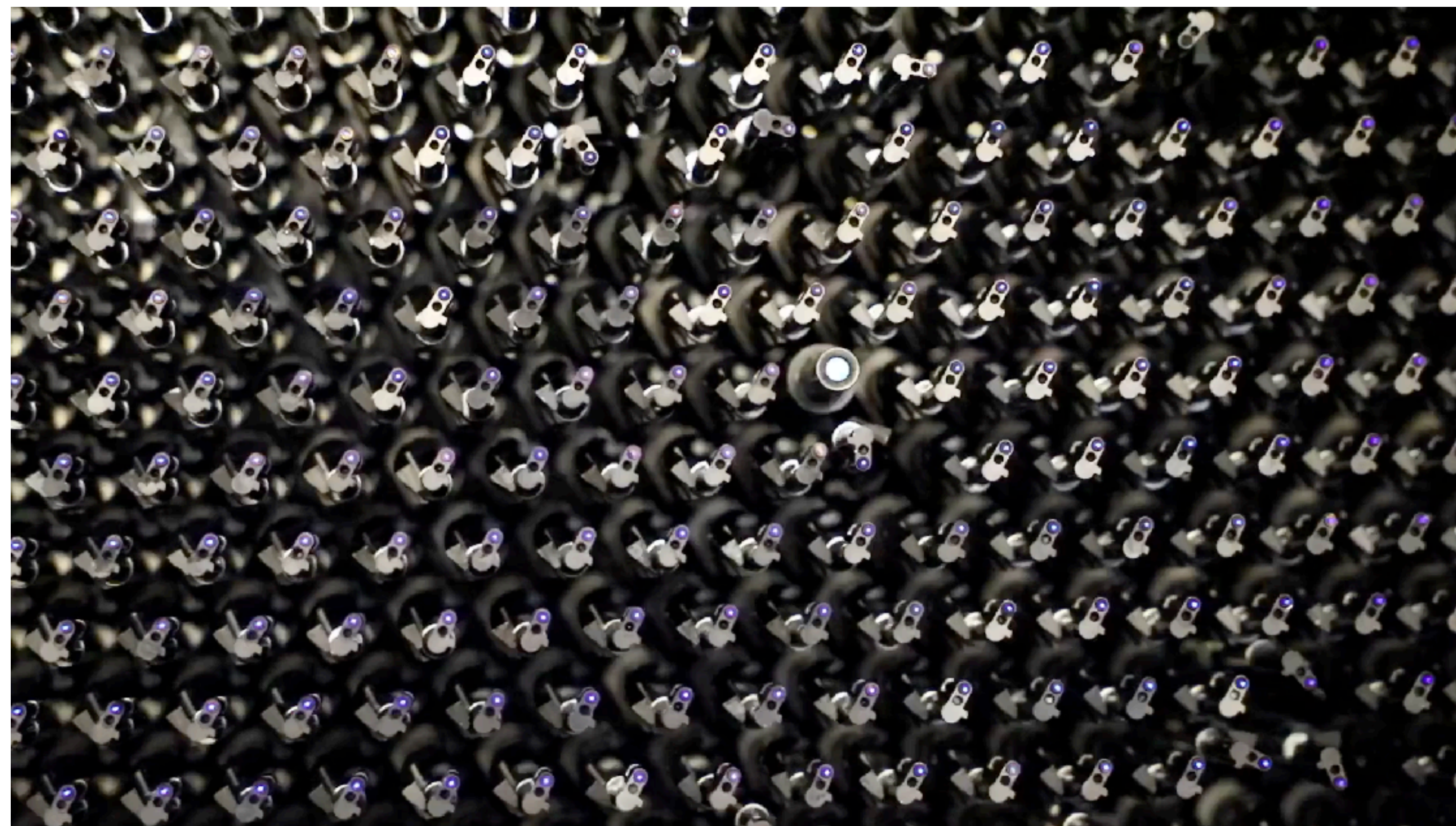


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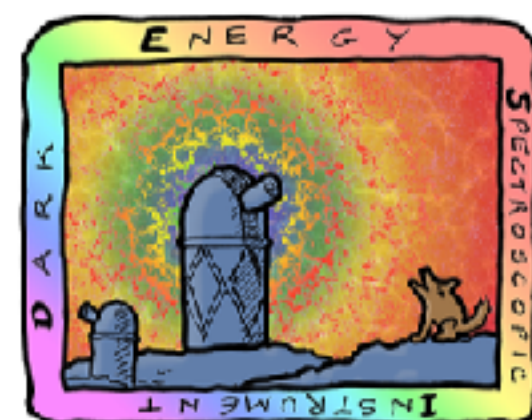
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The DESI focal plane

- 5000, $107\mu\text{m}$ fibers
- Position accuracy better than $5\mu\text{m}$
- During CCD readout: plane configuration + go to next pointing in $< 140\text{s}$



Credit: Claire Popett

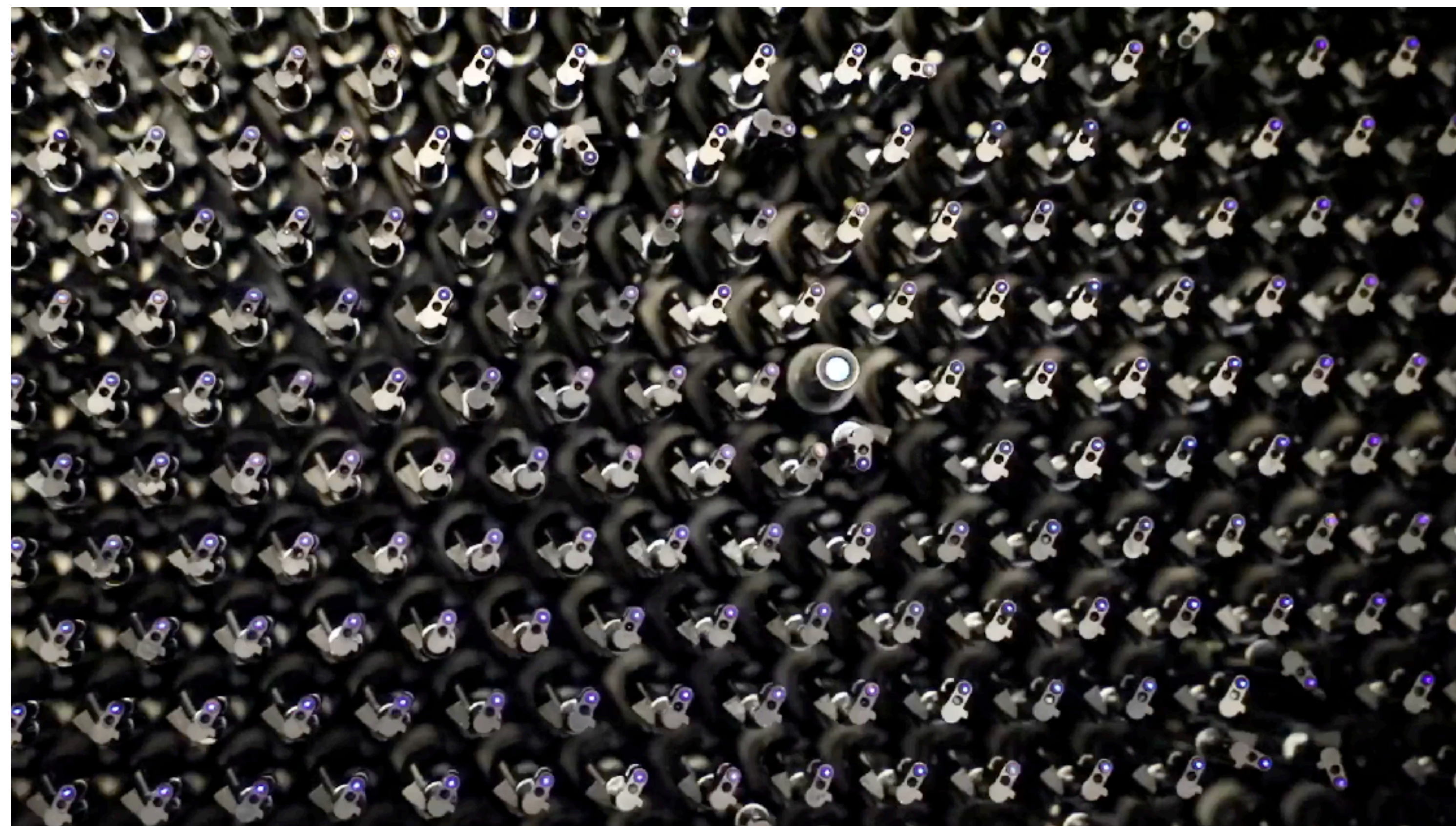


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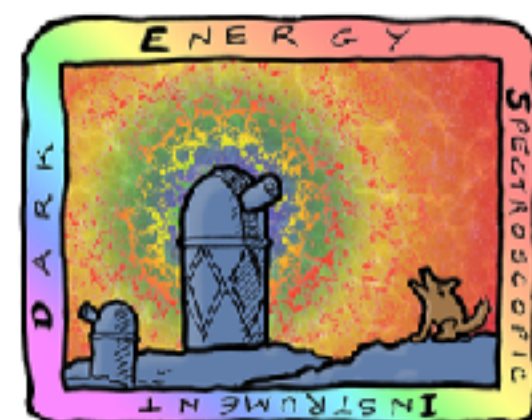
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The DESI focal plane

- 5000, 107 μm fibers
- Position accuracy better than 5 μm
- During CCD readout: plane configuration + go to next pointing in < 140s



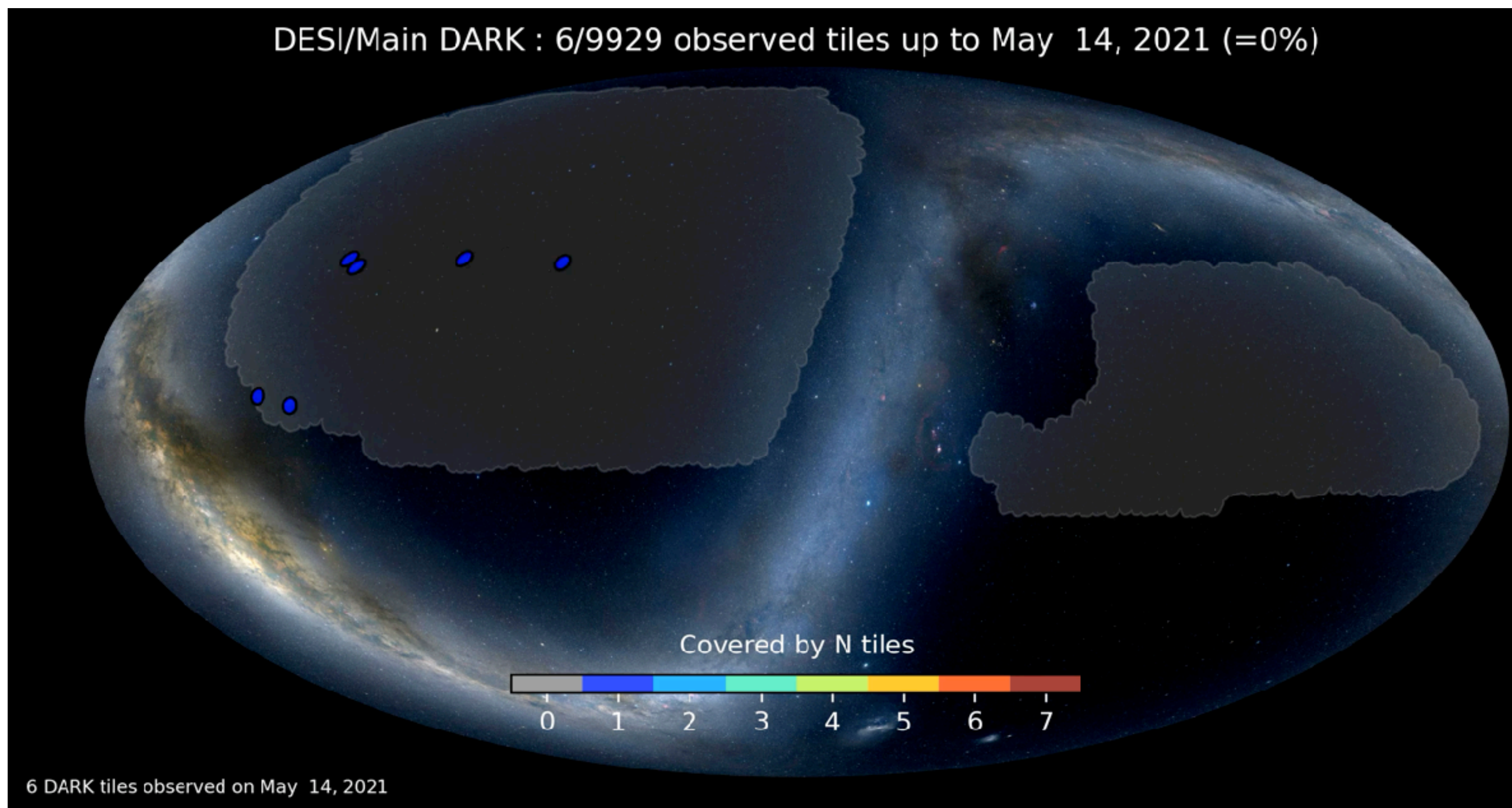
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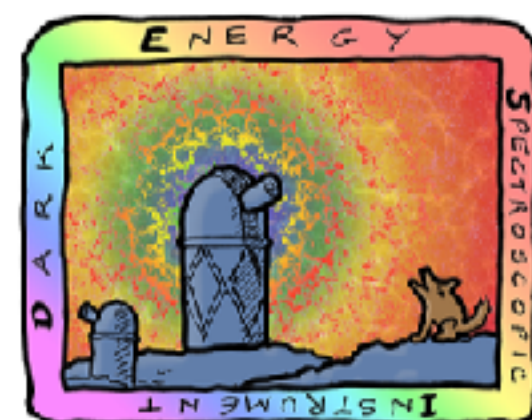
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5 years of observations in 30s



Credit: DESI data: Anand Raichoor/DESI collaboration; Sky map: Axel Mellinger, A Color All-Sky Panorama Image of the Milky Way, Publ. Astron. Soc. Pacific 121, 1180-1187 (2009)

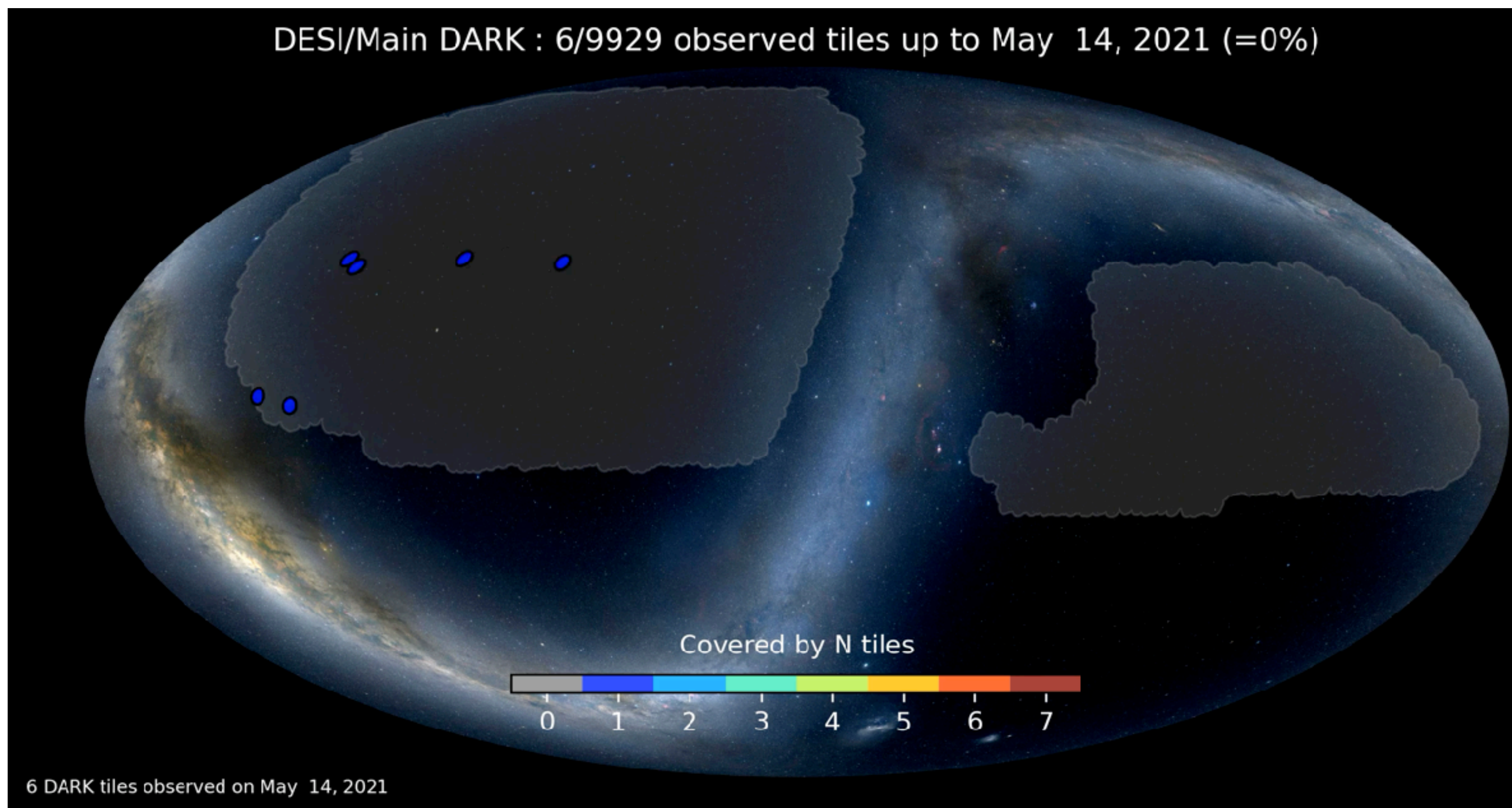
**Complete Y5
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April this year!**



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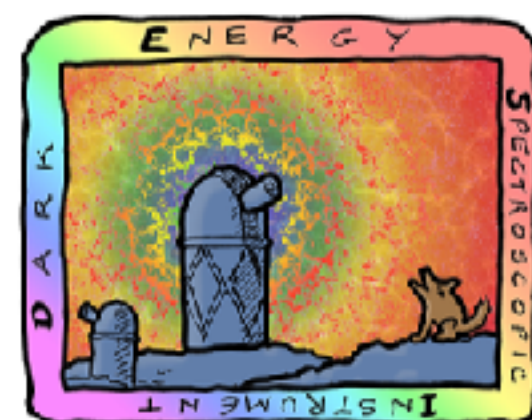
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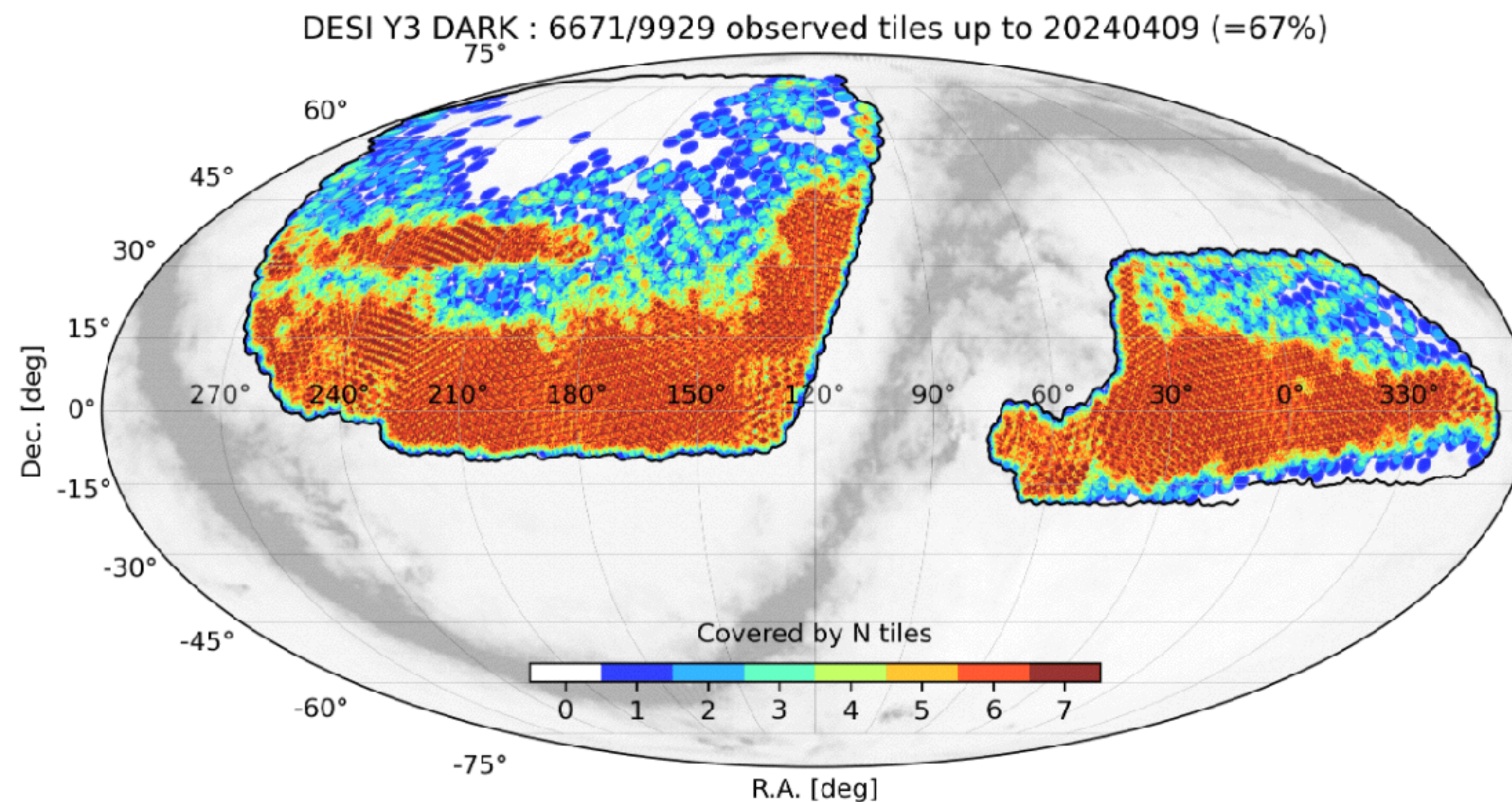


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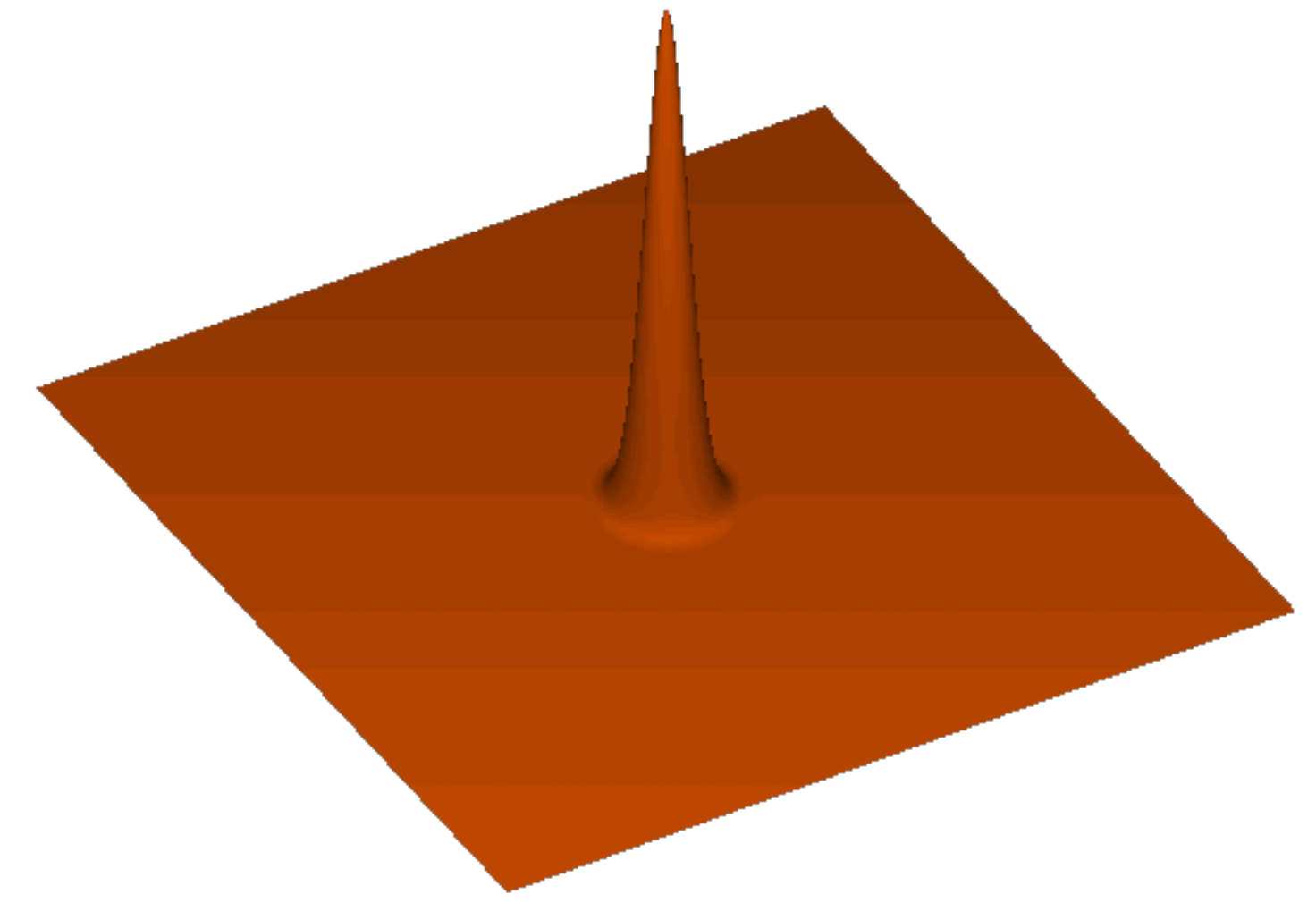
DESI Data Release 2

- About 70% of final 14 000 square degrees footprint
- 14 million galaxies
- 800 0000 Lyman-alpha forests



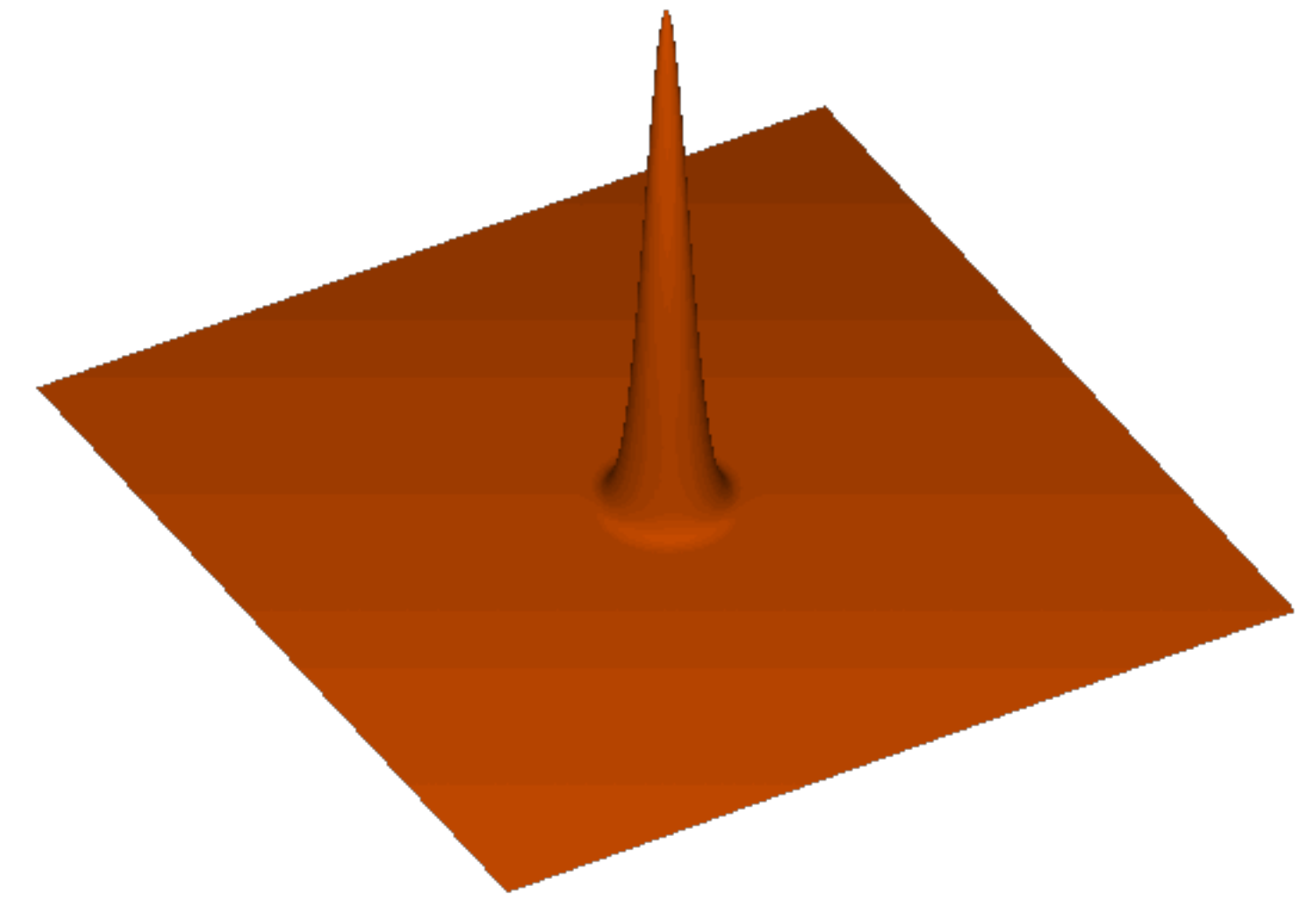
Baryonic Acoustic Oscillations

- Sound waves in primordial plasma



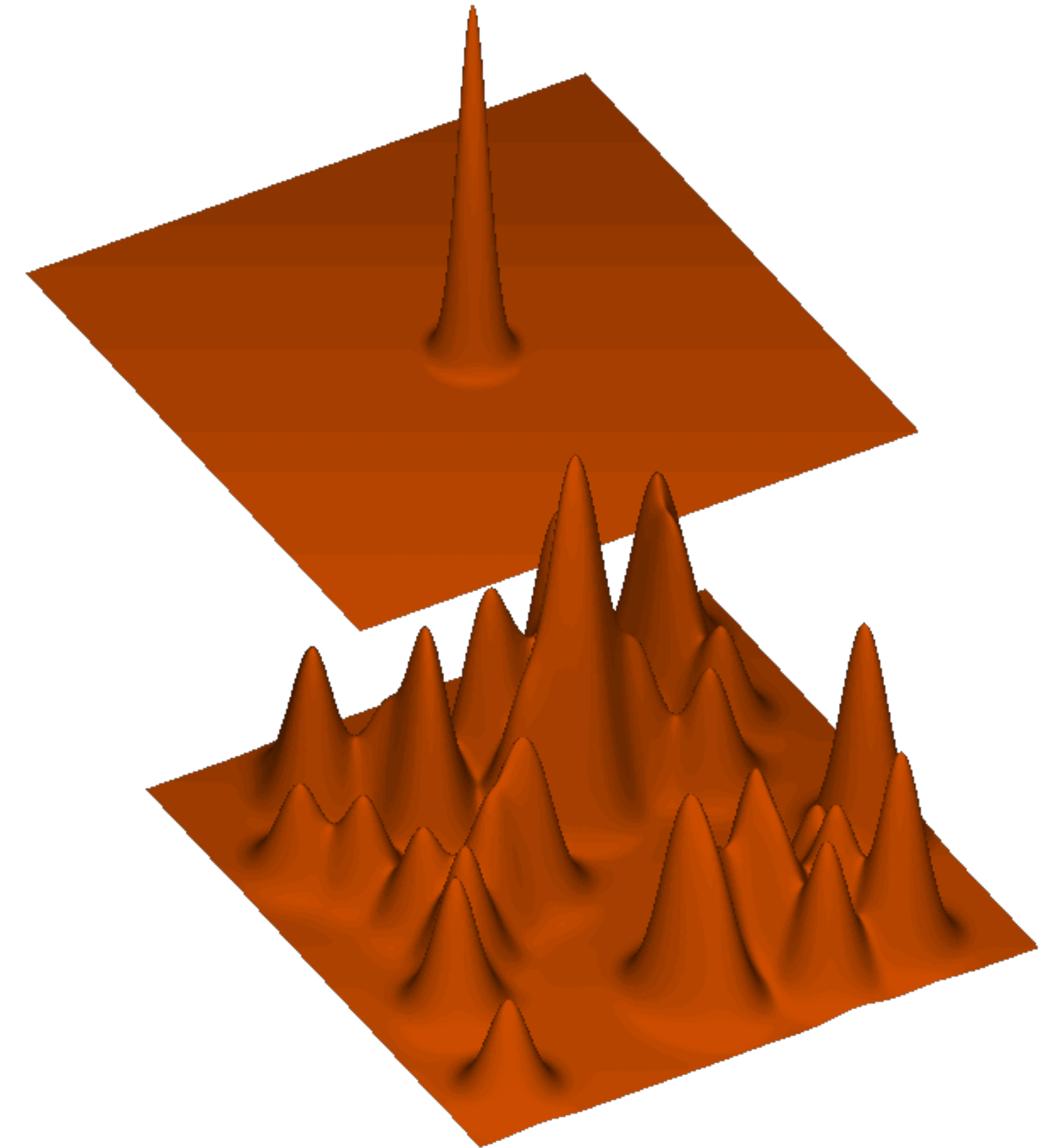
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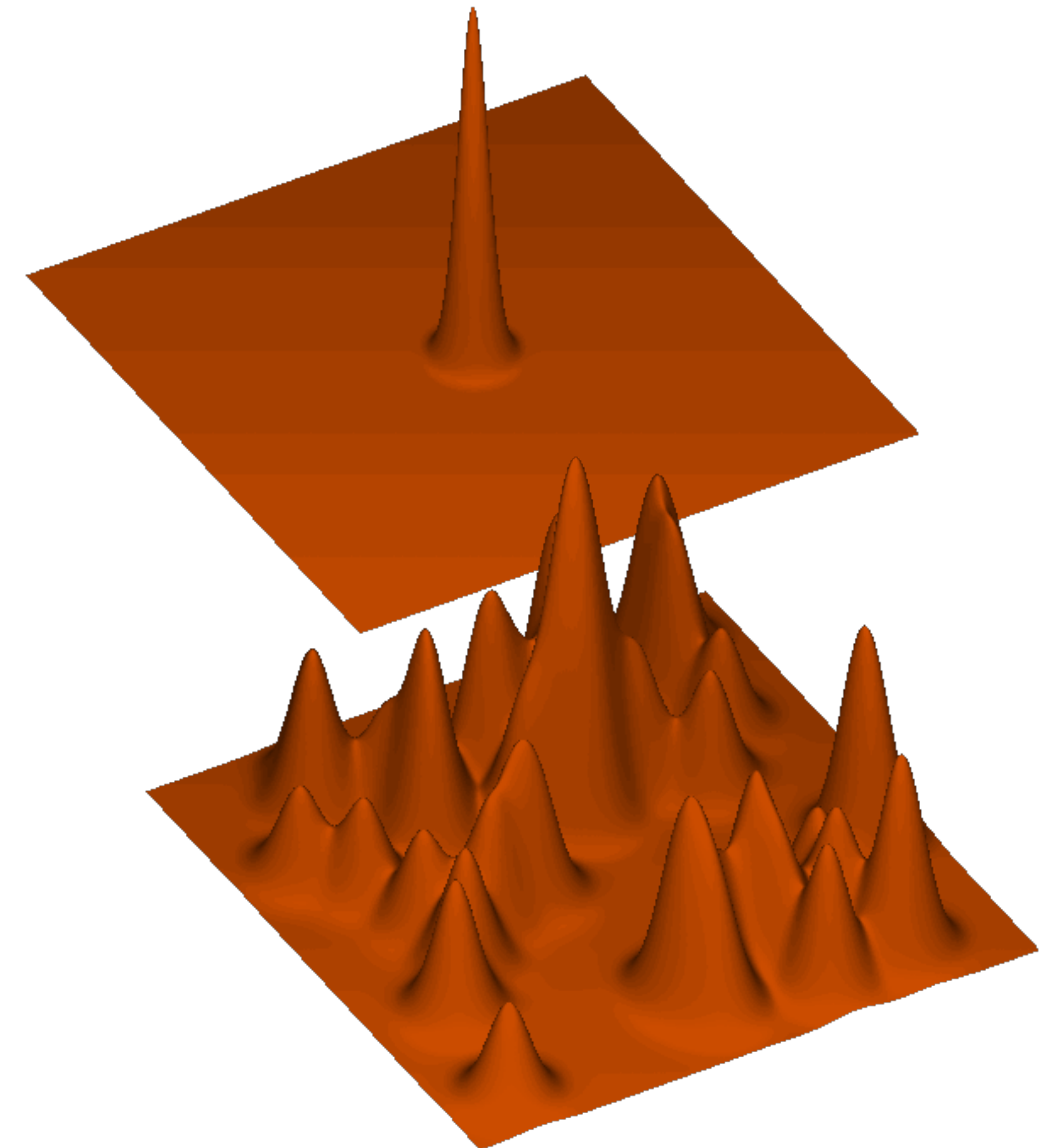
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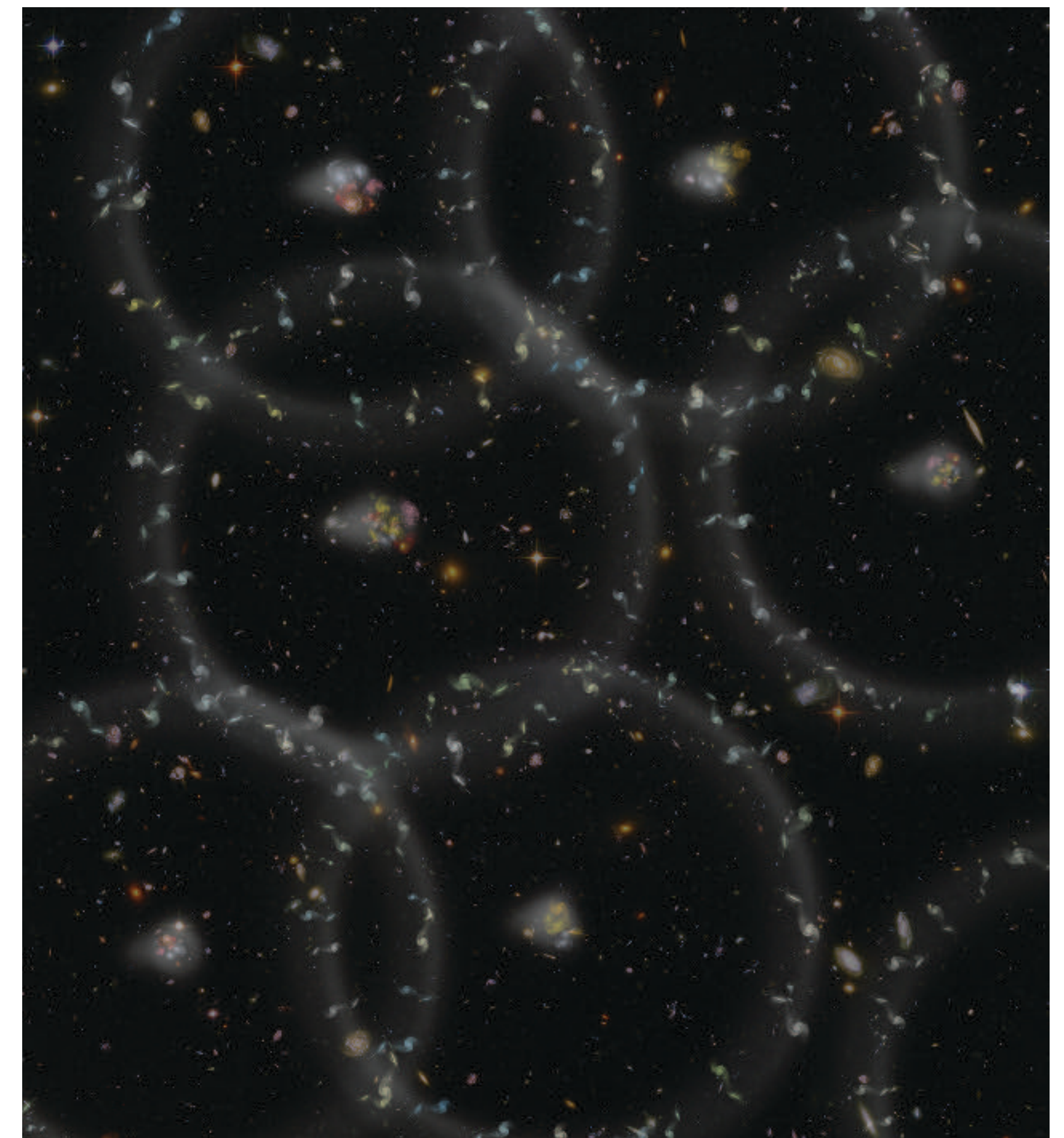
Baryonic Acoustic Oscillations

- Sound waves in primordial plasma
- At recombination ($z \sim 1100$):
 - Pressure-providing photons decouple from baryons
 - Wave stalls at $r_d = \int_{z_d}^{\infty} \frac{c_s(z)}{H(z)} \sim 150 \text{ Mpc}$



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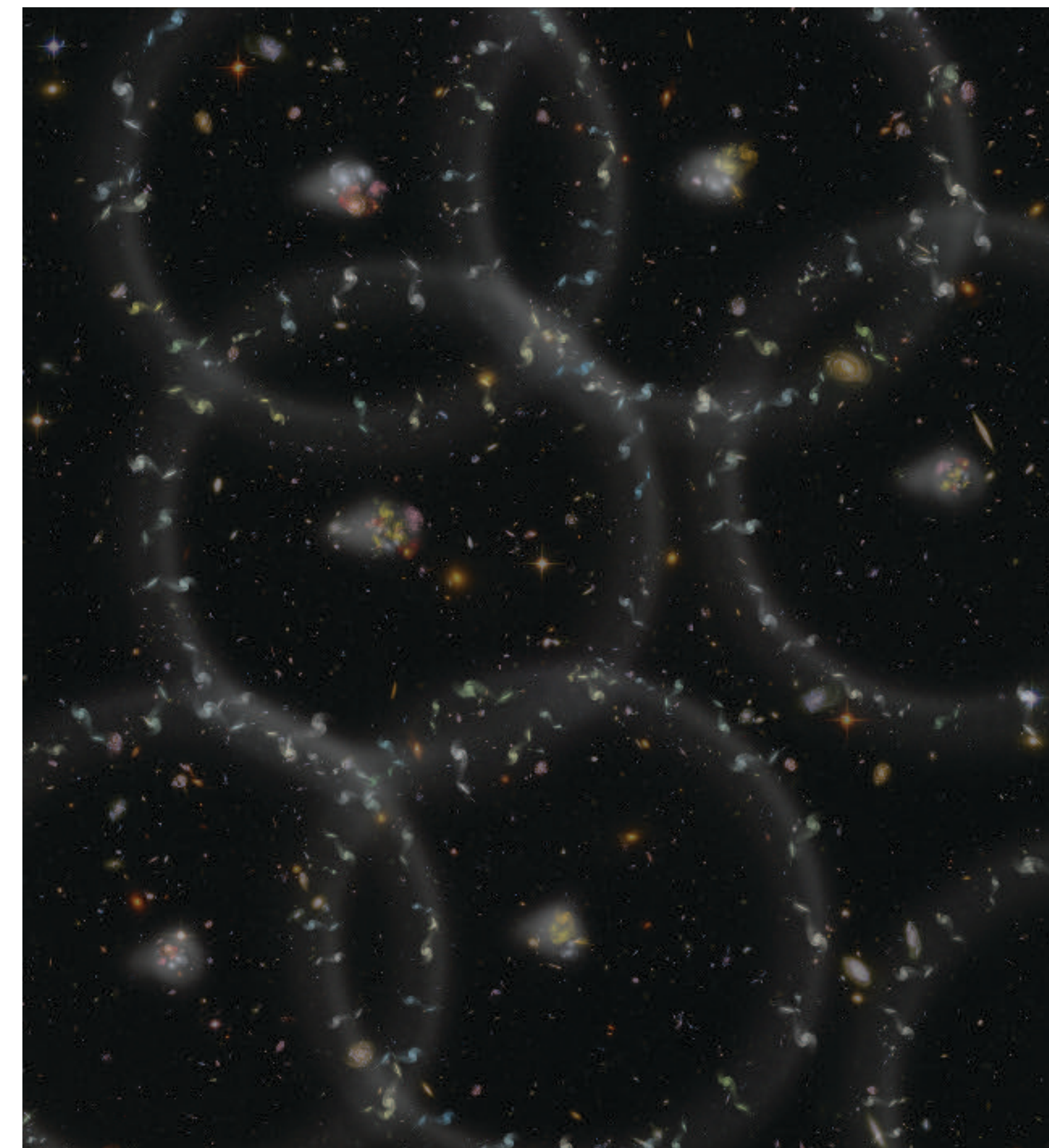


Simplified effect of BAO on galaxy distribution

Zosia Rostomian, Lawrence Berkeley National Laboratory

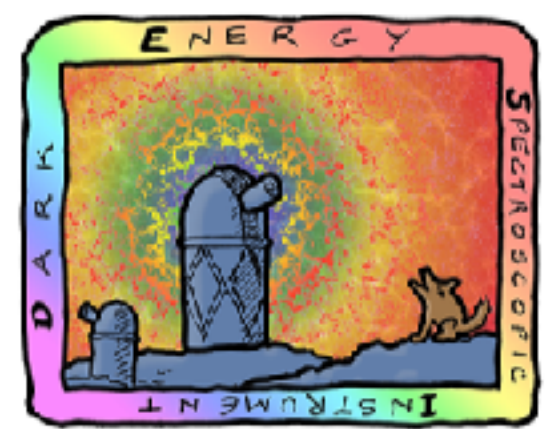
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- Dark matter overdensities seed galaxy formation with preferred separation r_d
- Standard 150 Mpc “ruler” at all times
 - Depends on $c_s(z) = c \left[3 \left(1 + \frac{3\rho_B(z)}{4\rho_\gamma(z)} \right) \right]^{-1/2}$



Simplified effect of BAO on galaxy distribution

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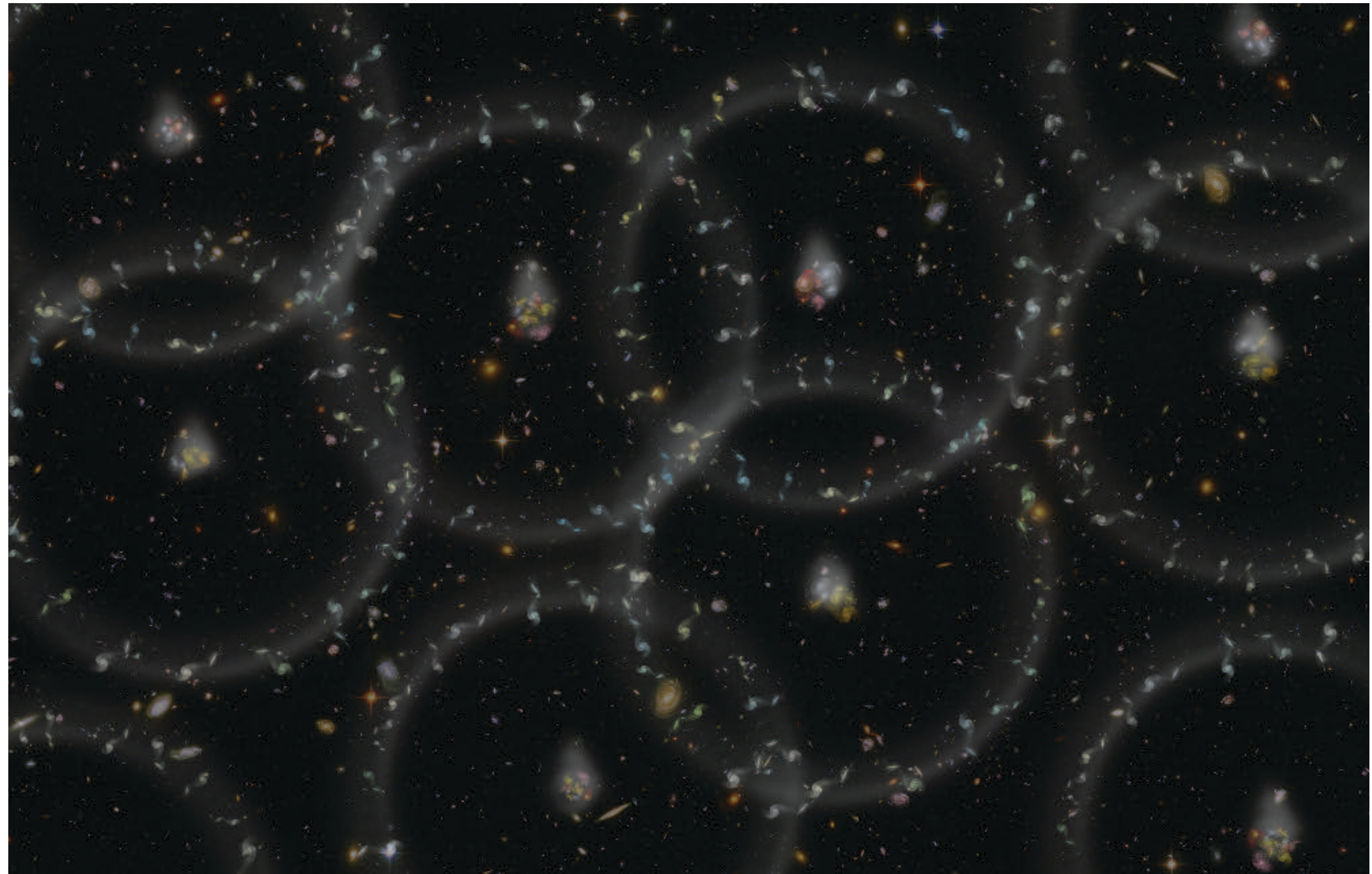
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BAO with DESI

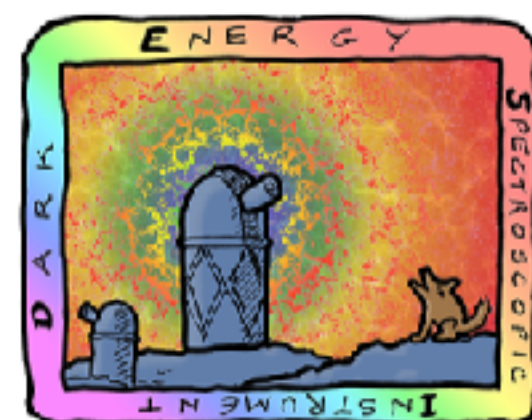
- At multiple redshifts:

BAO with DESI

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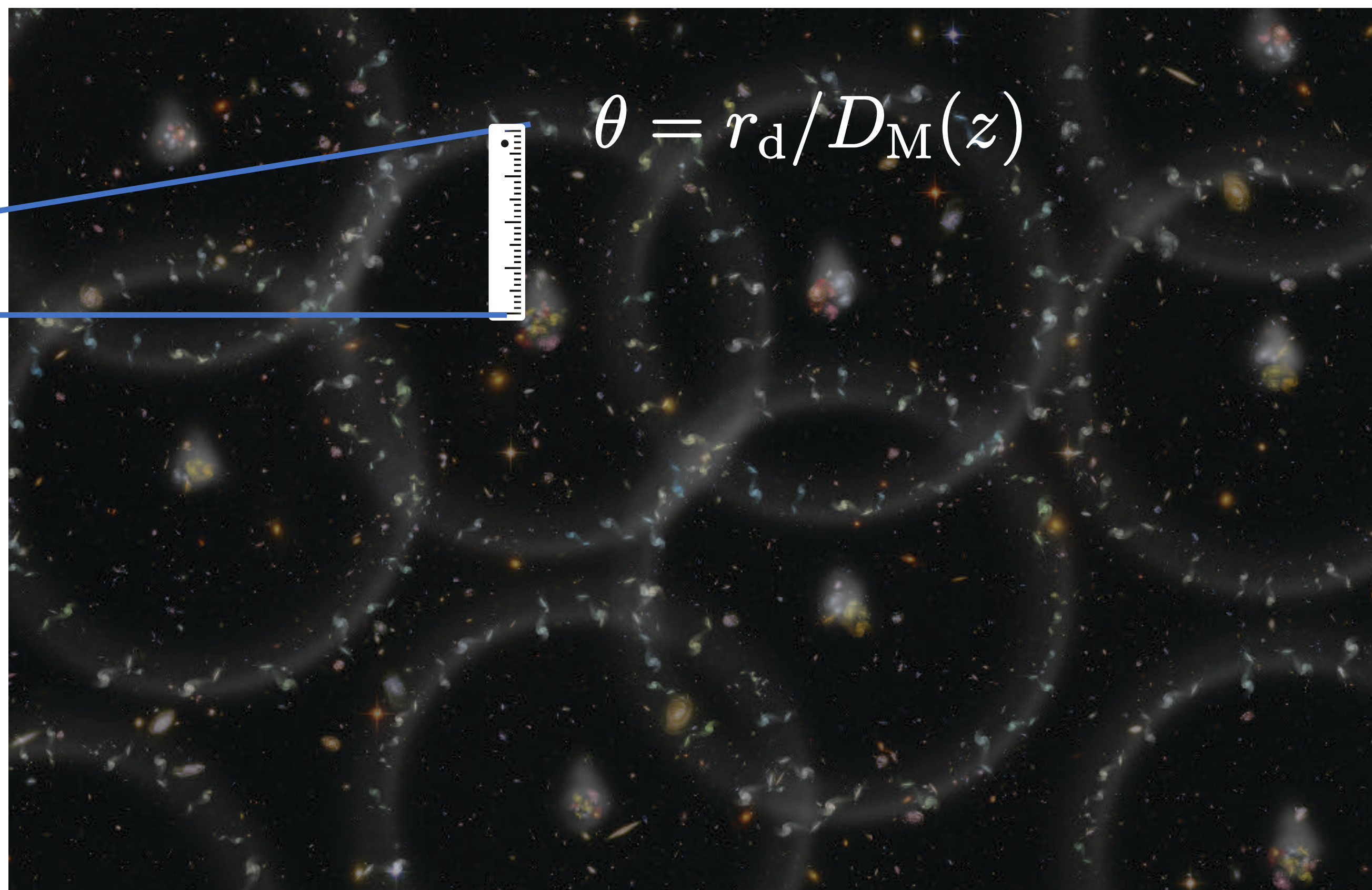


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BAO with DESI

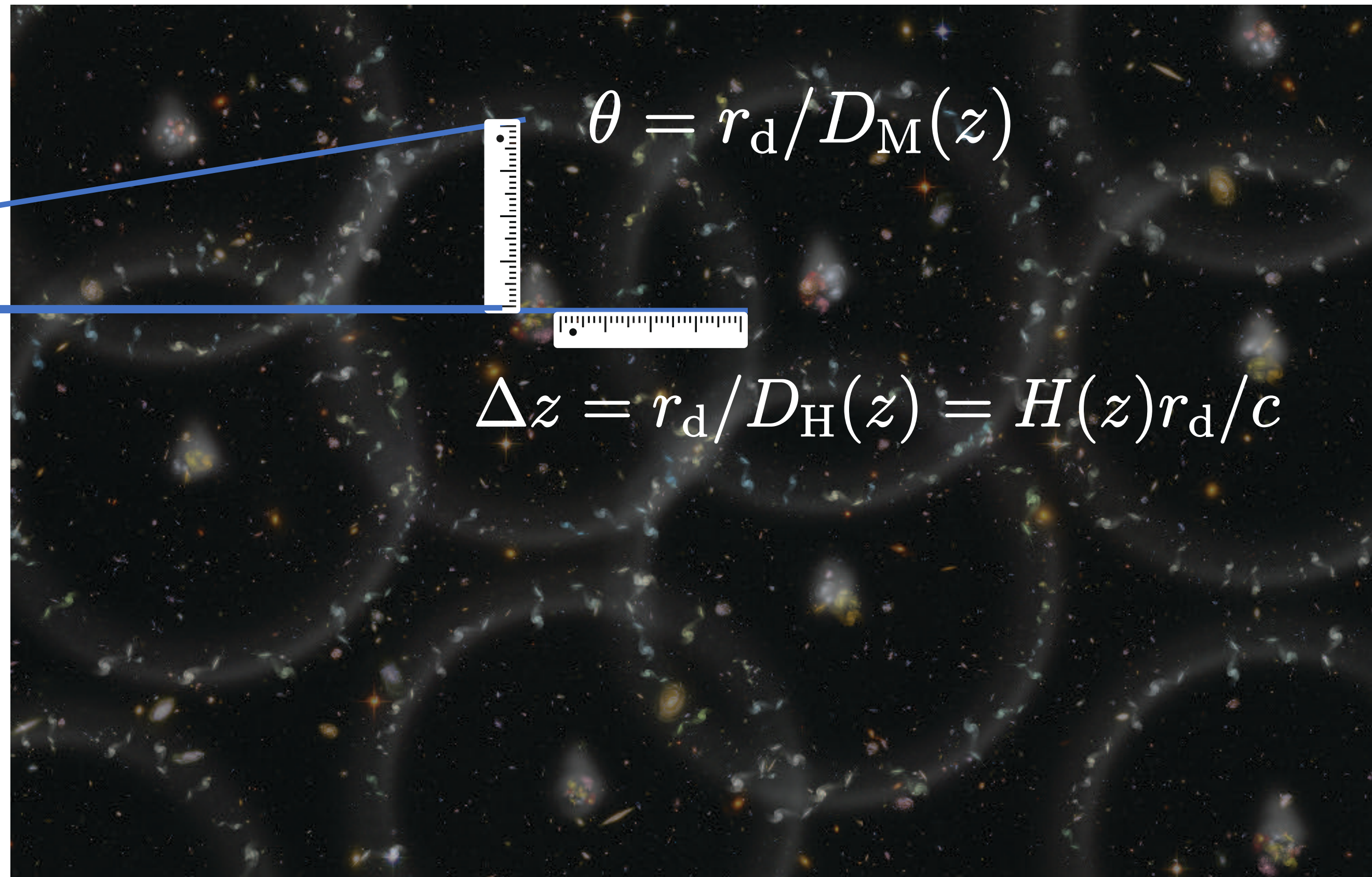
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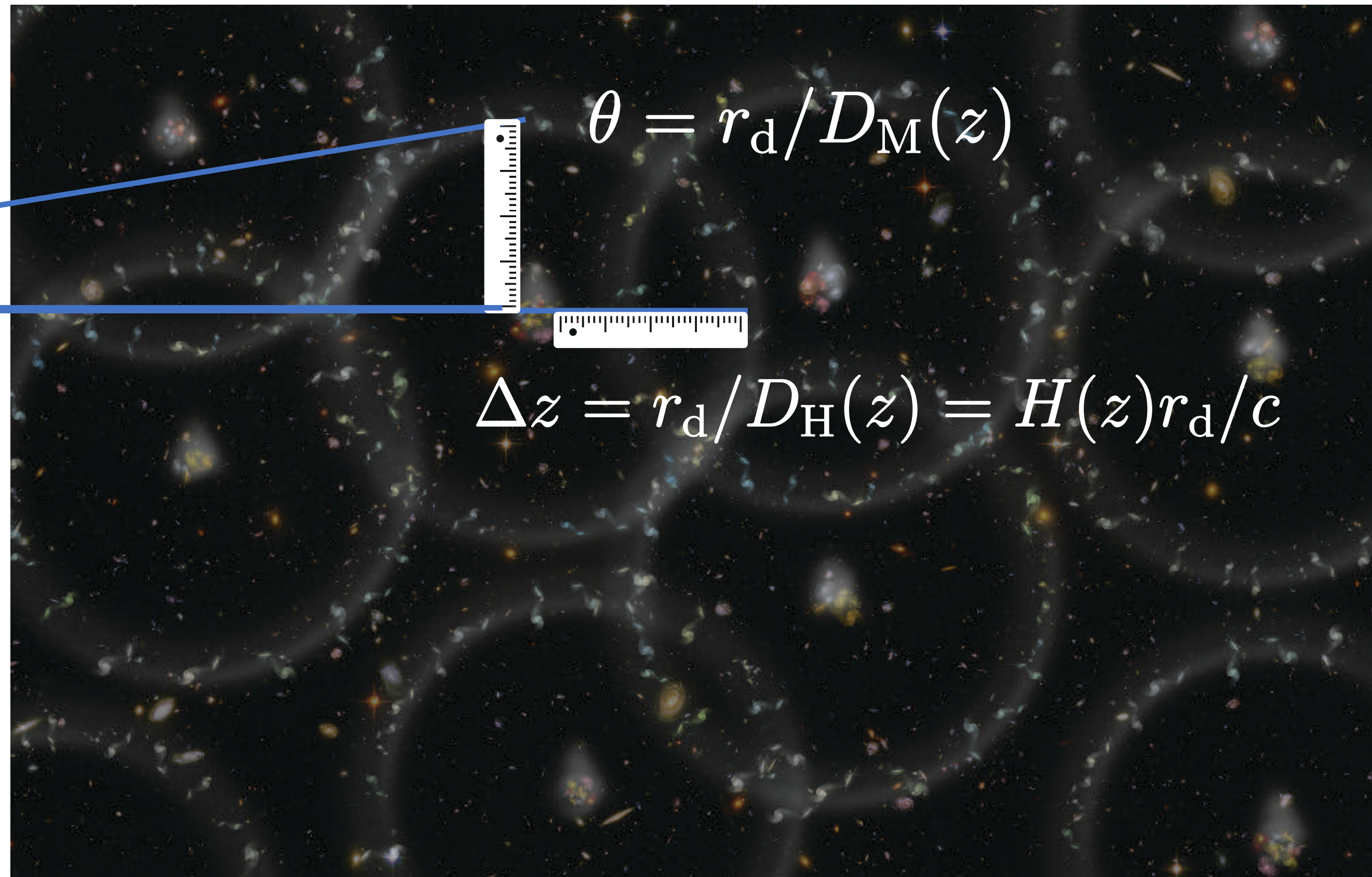
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BAO with DESI

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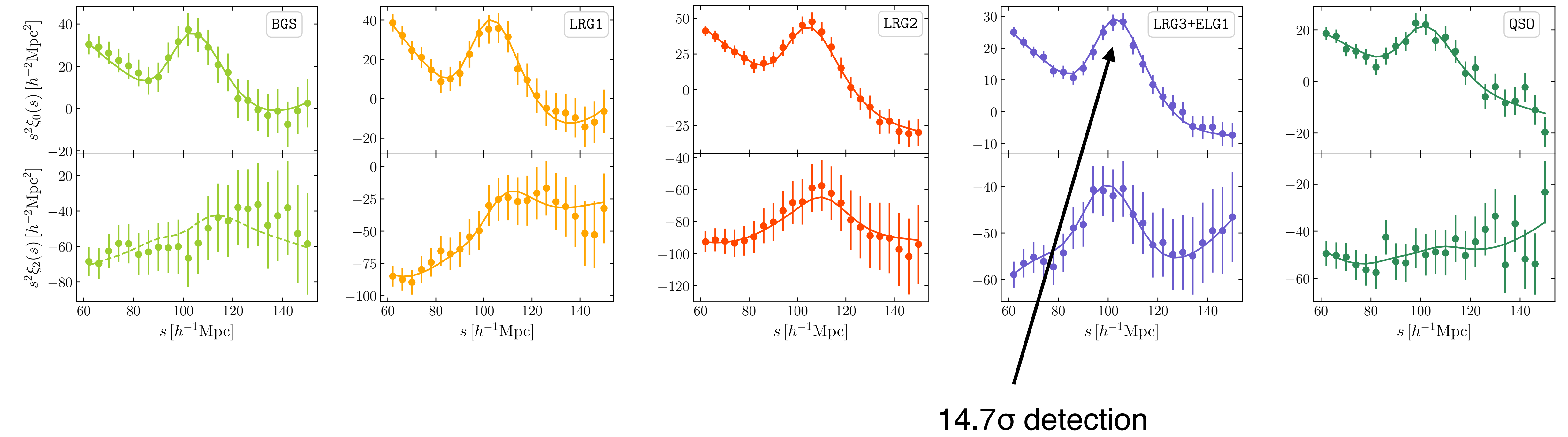
- Probes expansion history \rightarrow dark energy

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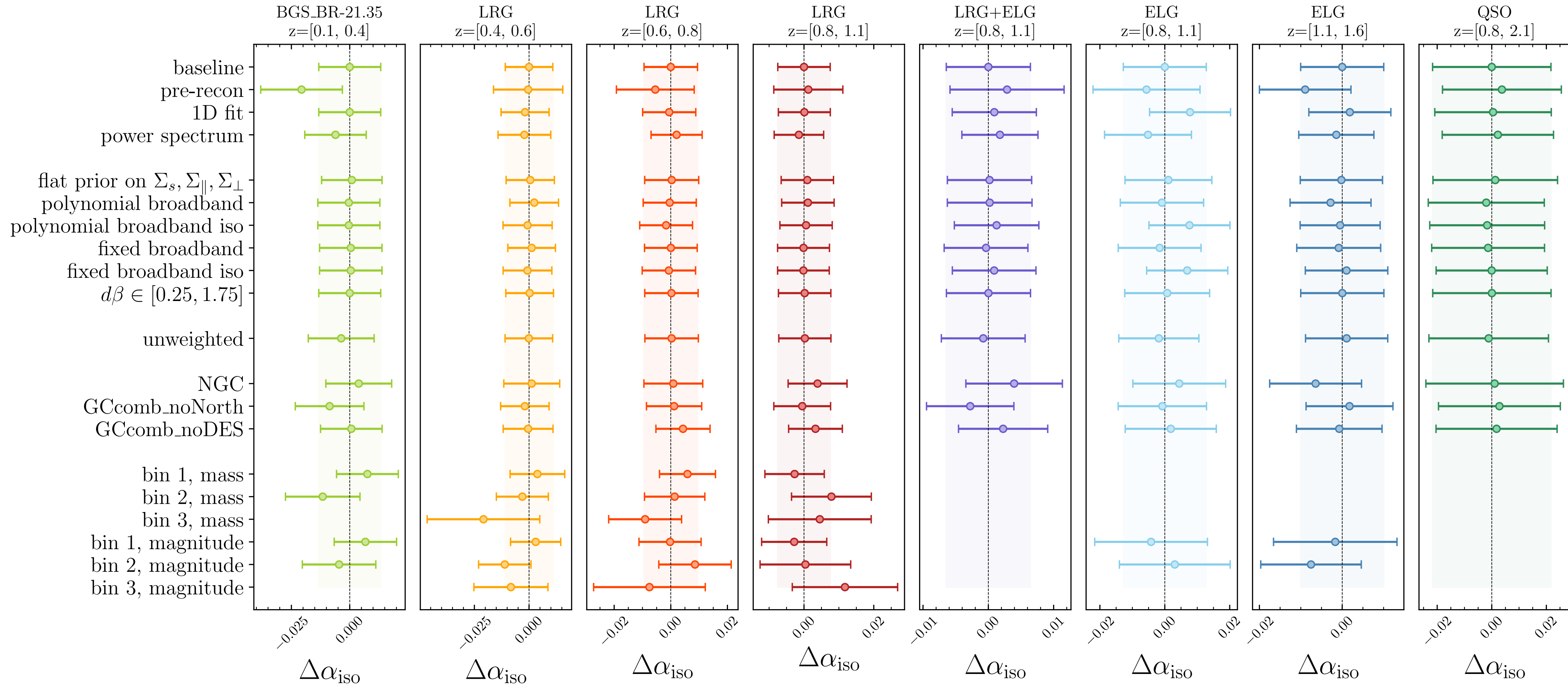
BAO with DESI

- BAO feature = bump in the 2-point correlation function

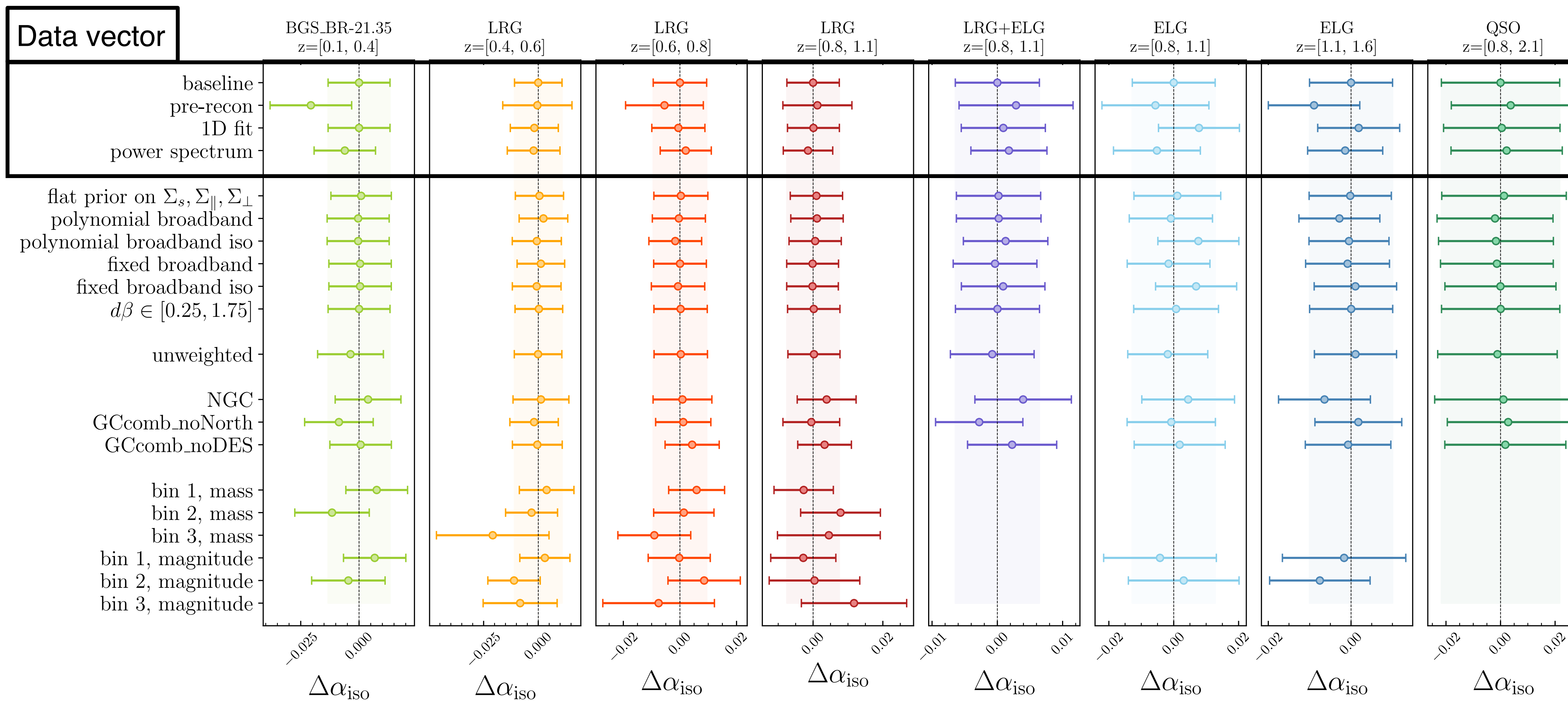
Increasing redshift

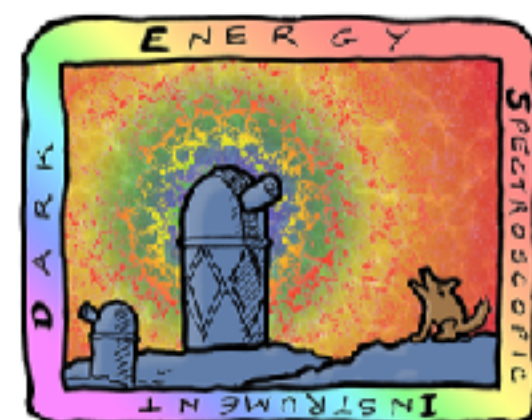


Robustness checks



Robustness checks

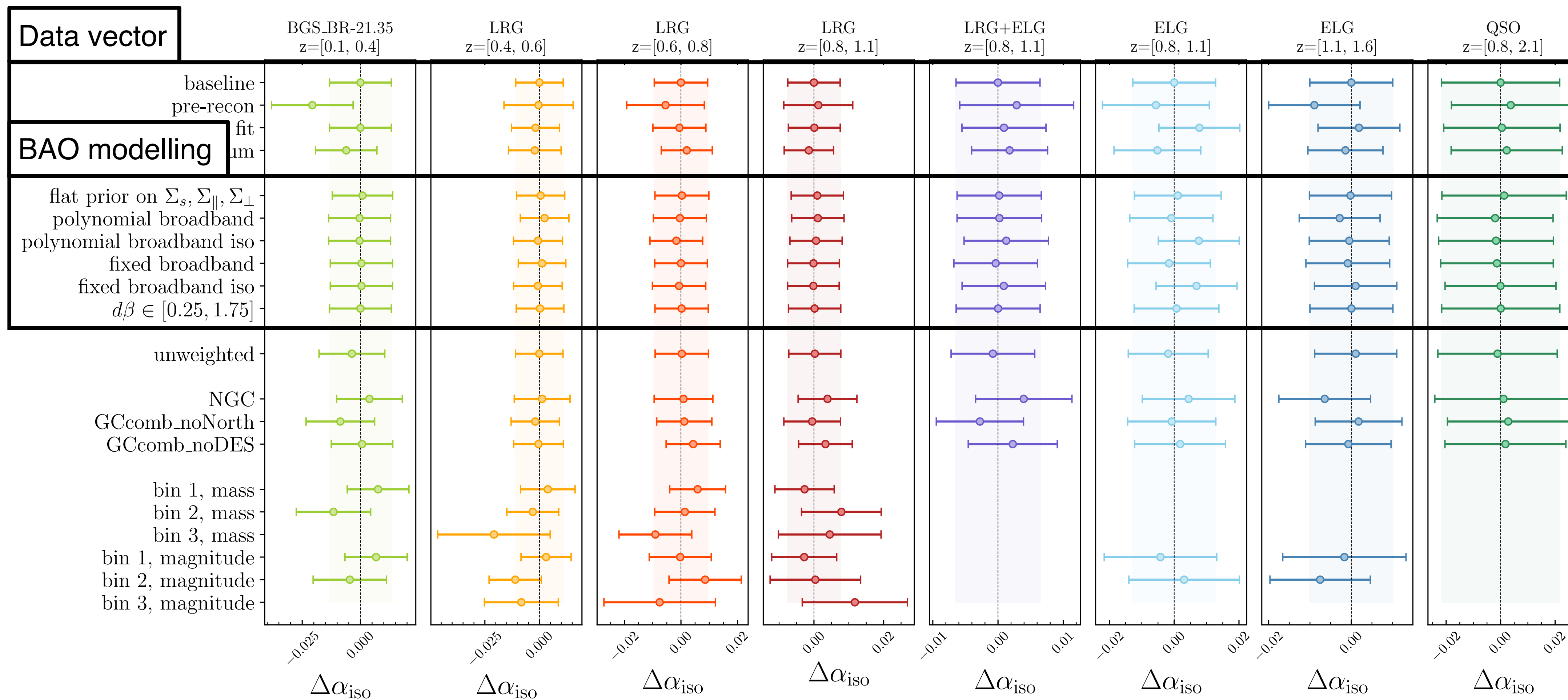




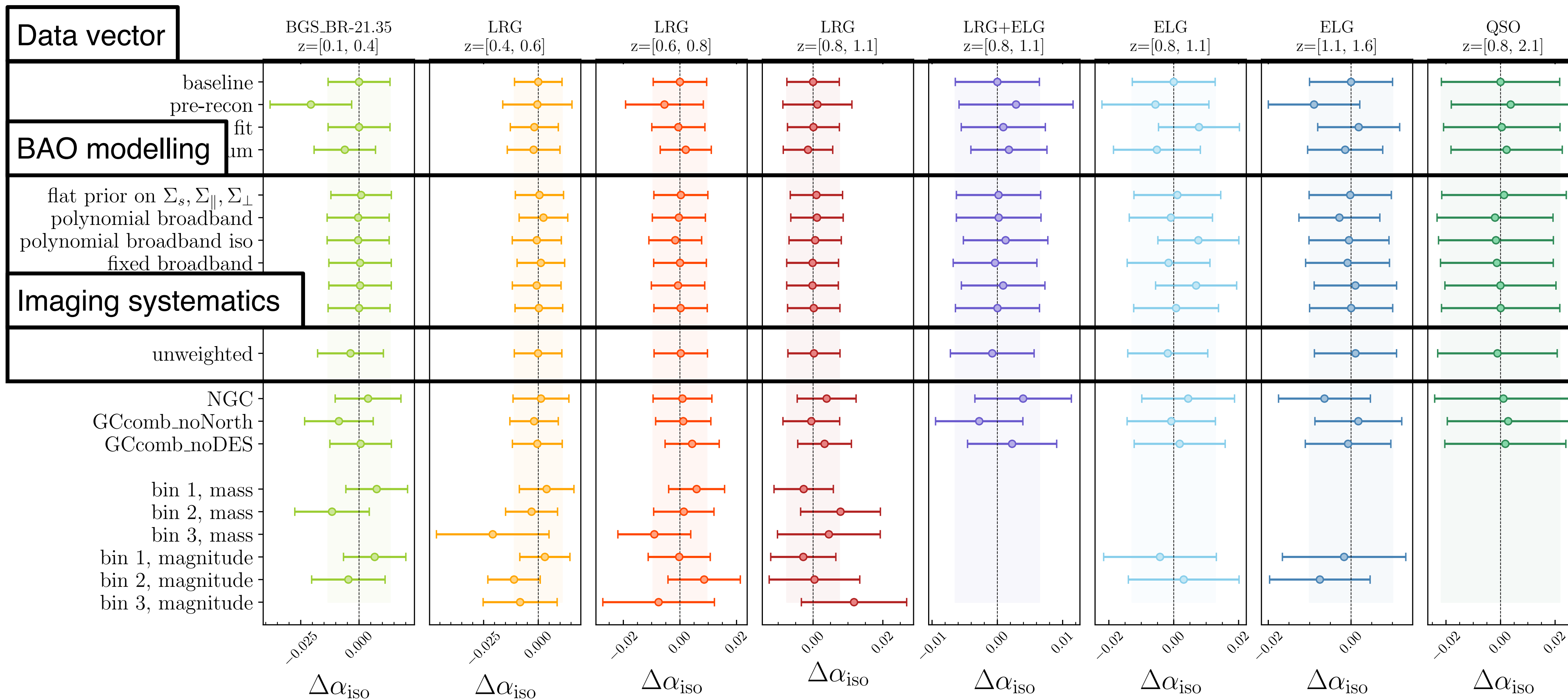
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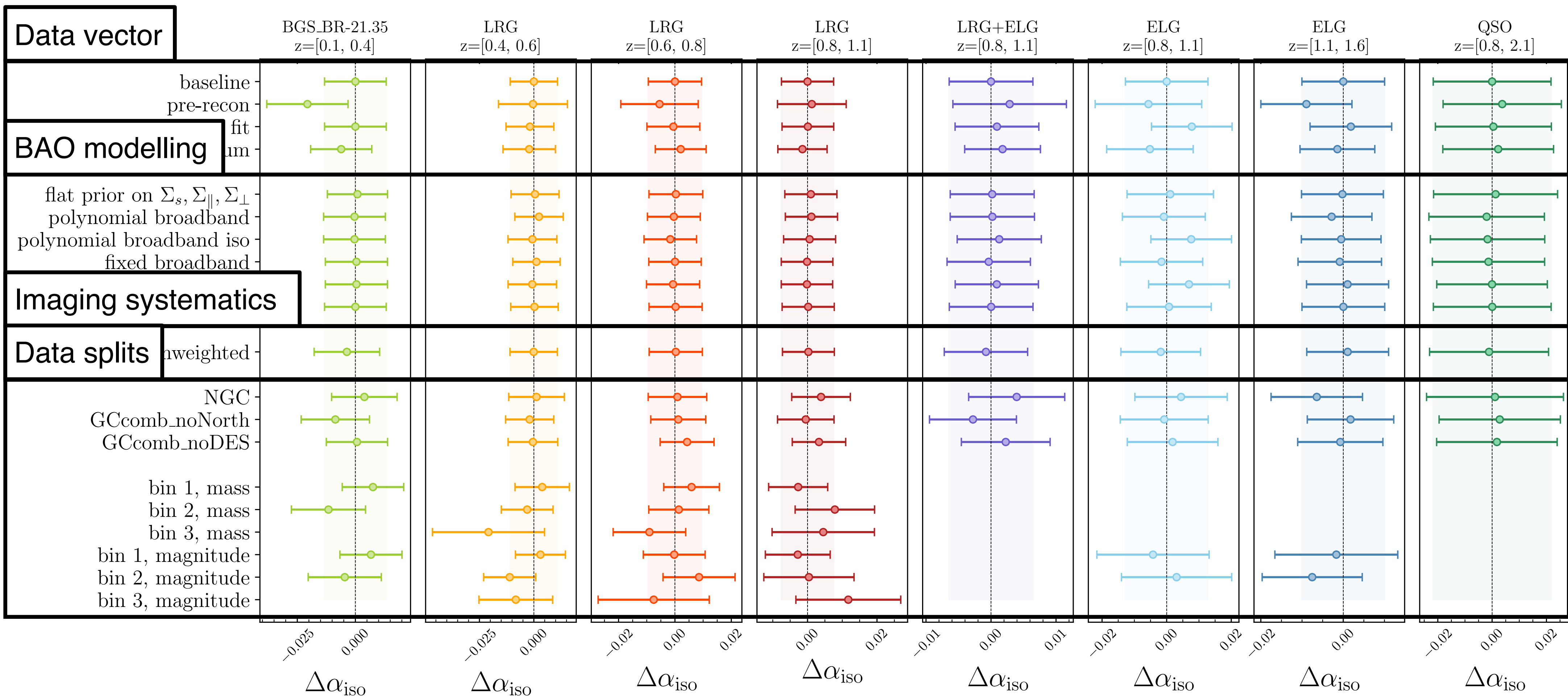
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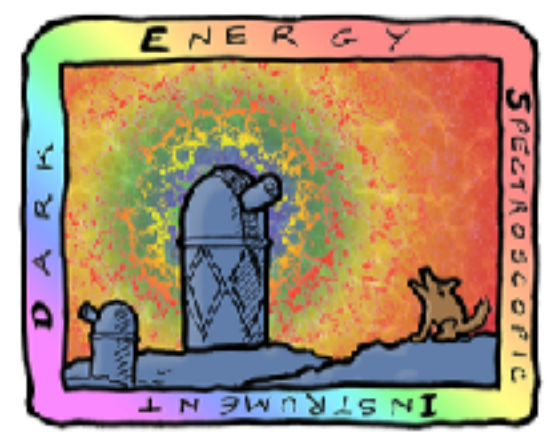


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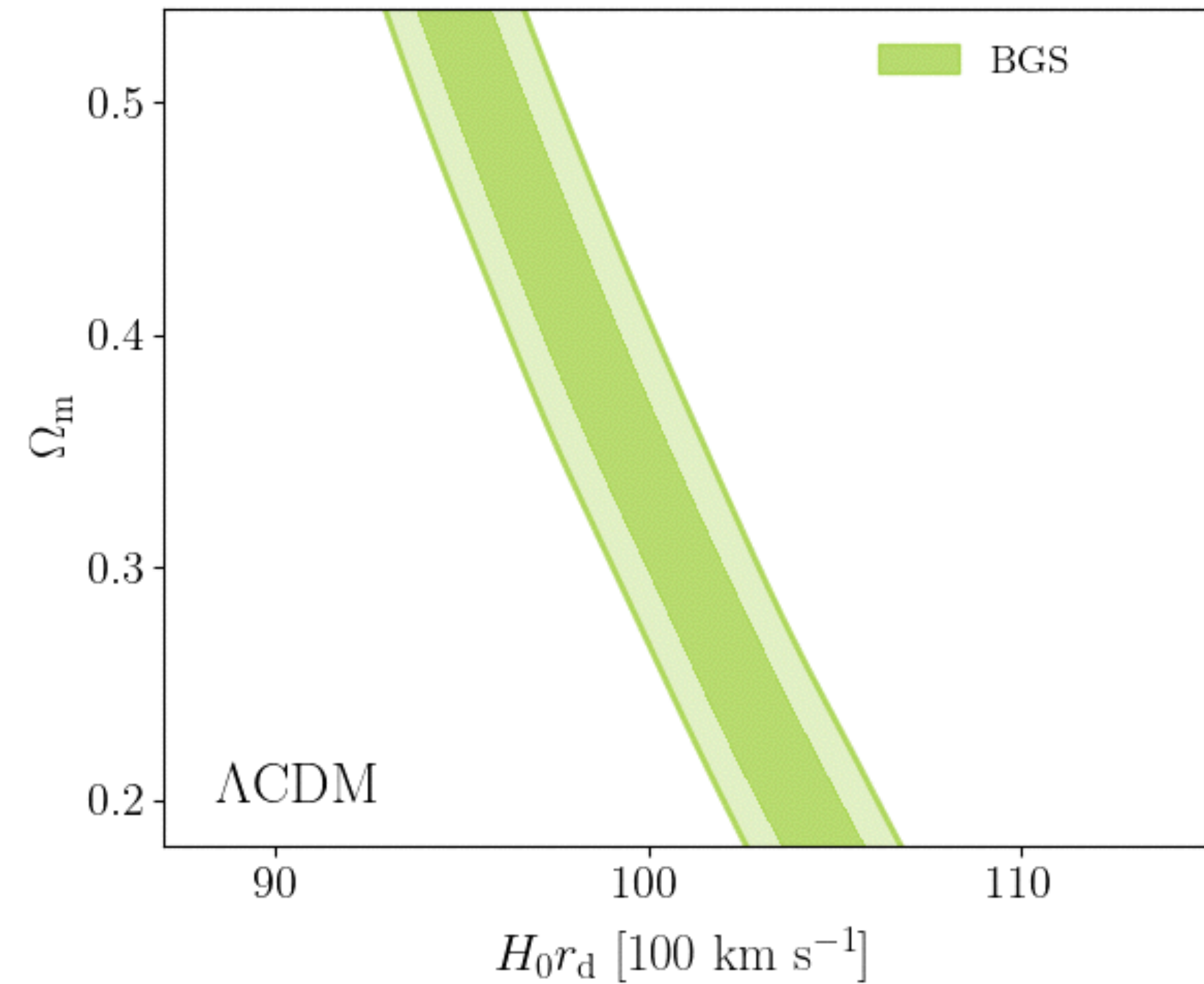
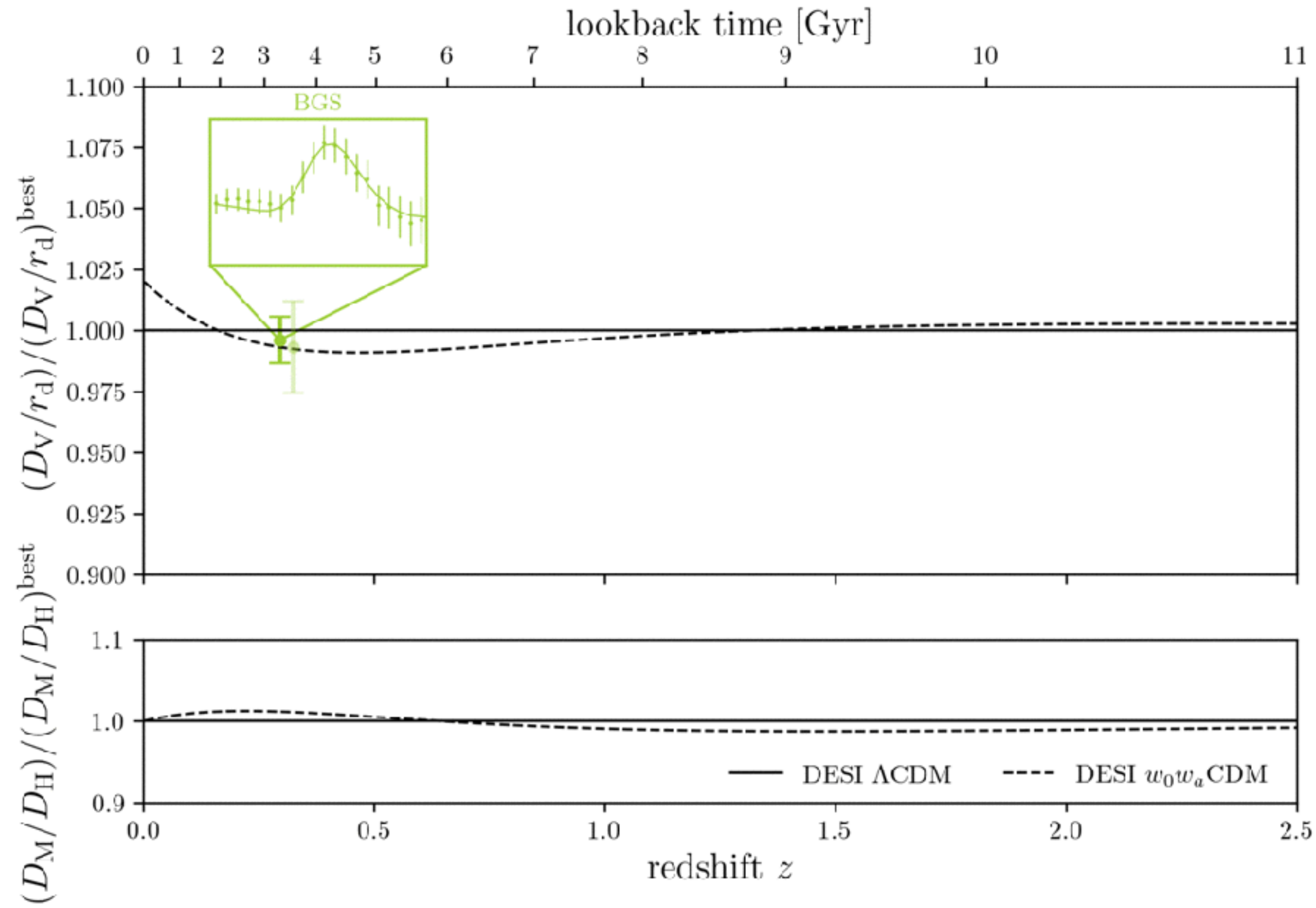


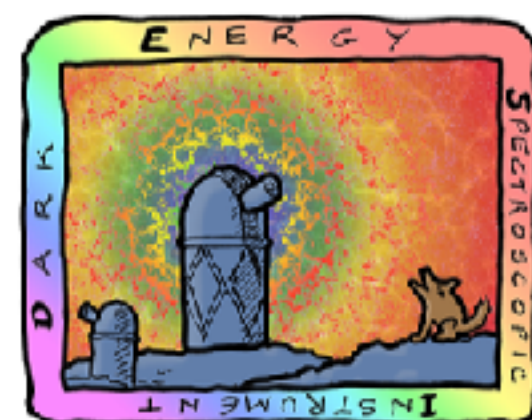


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DESI DR2 BAO results

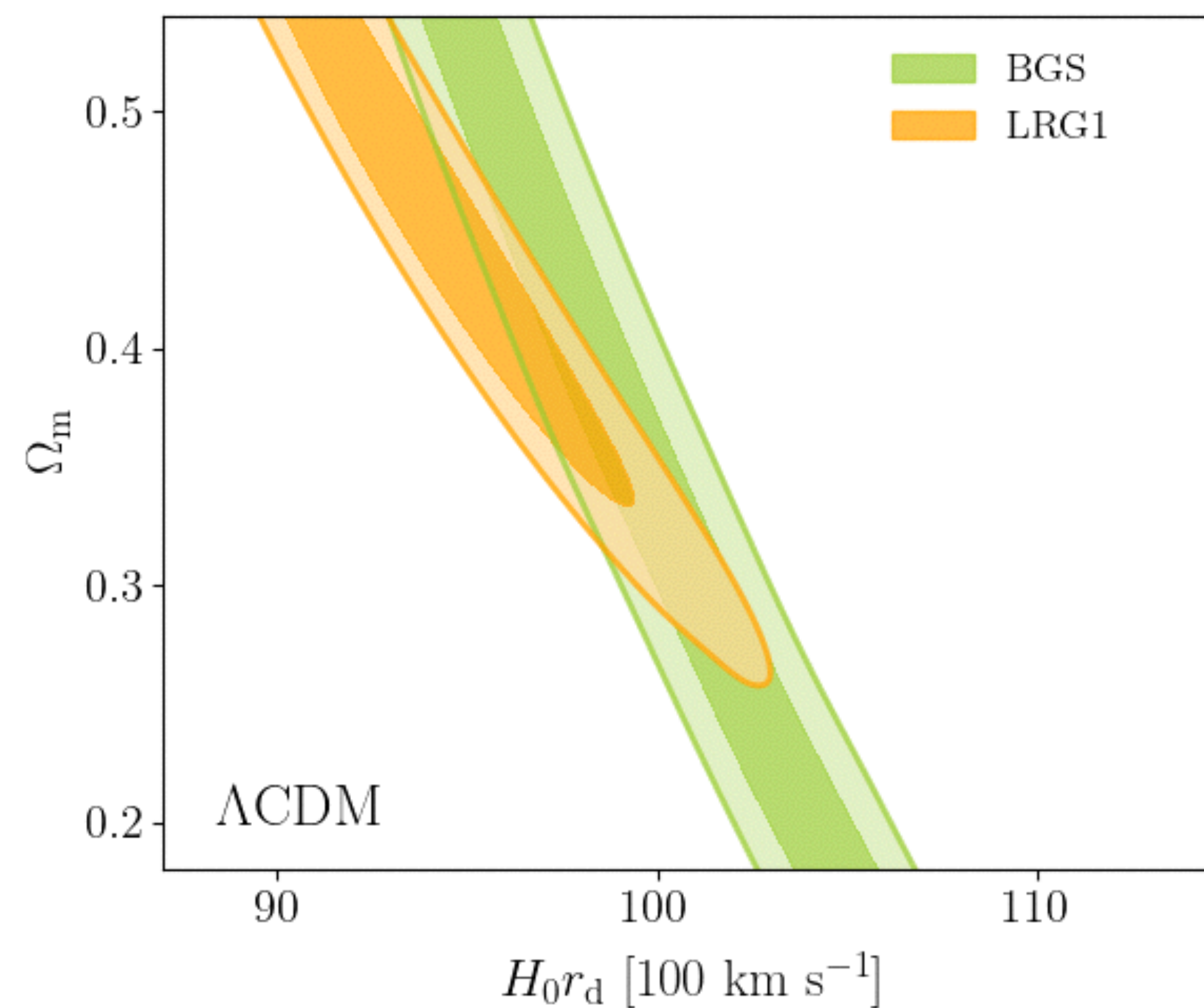
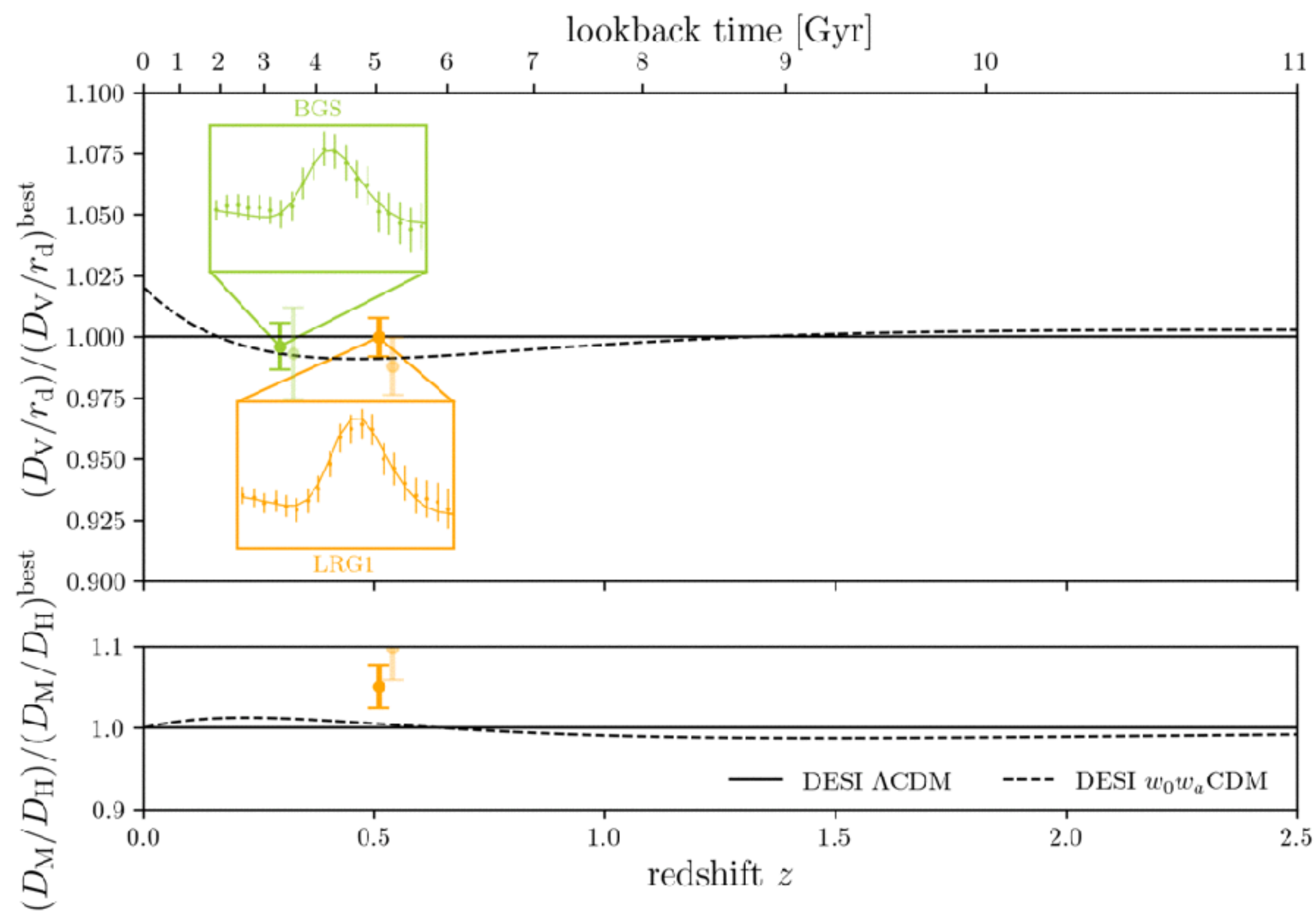


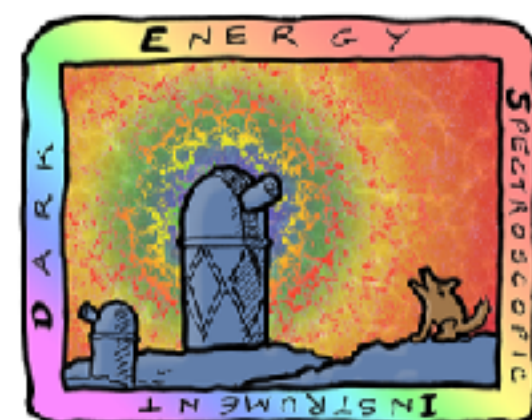


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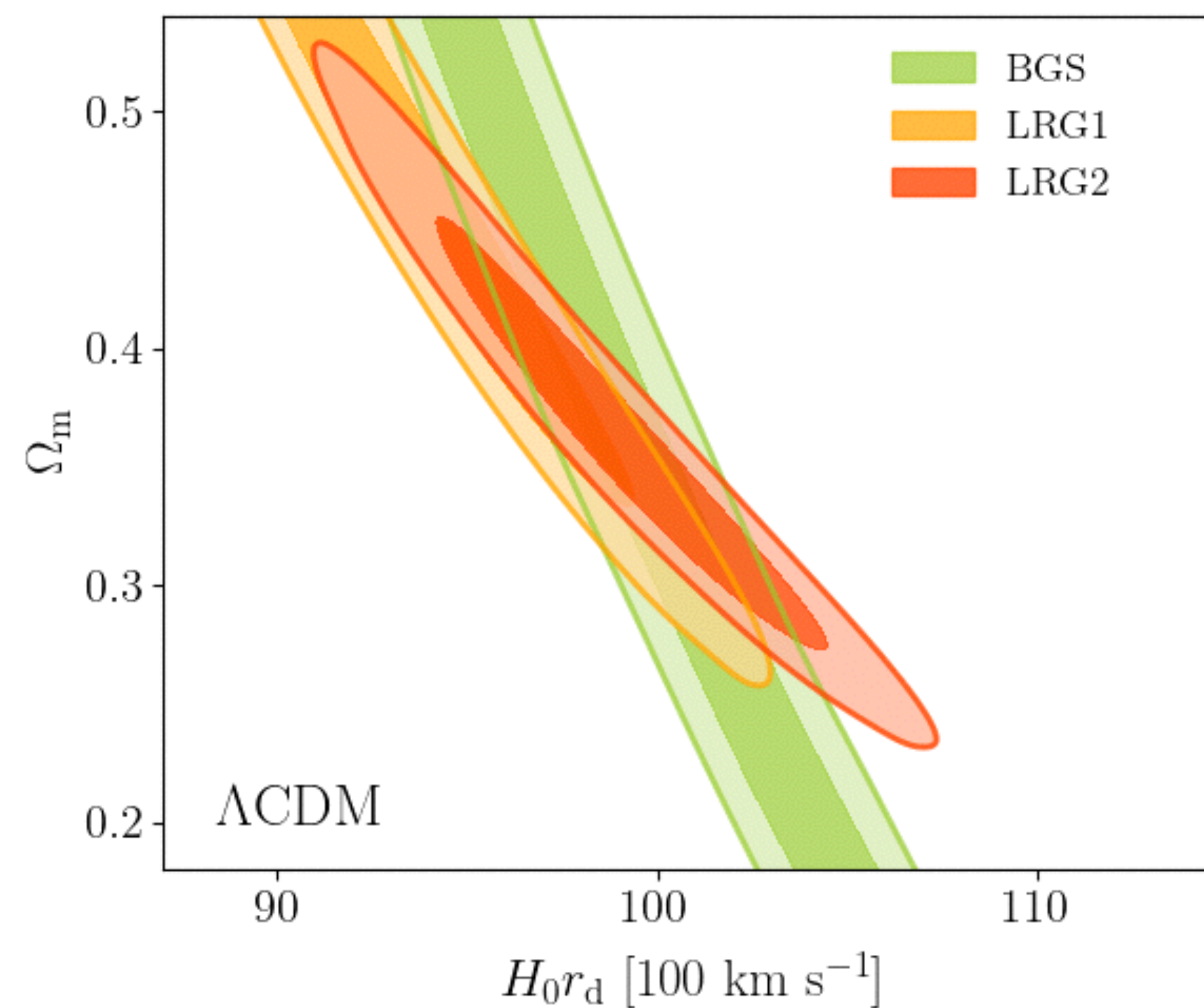
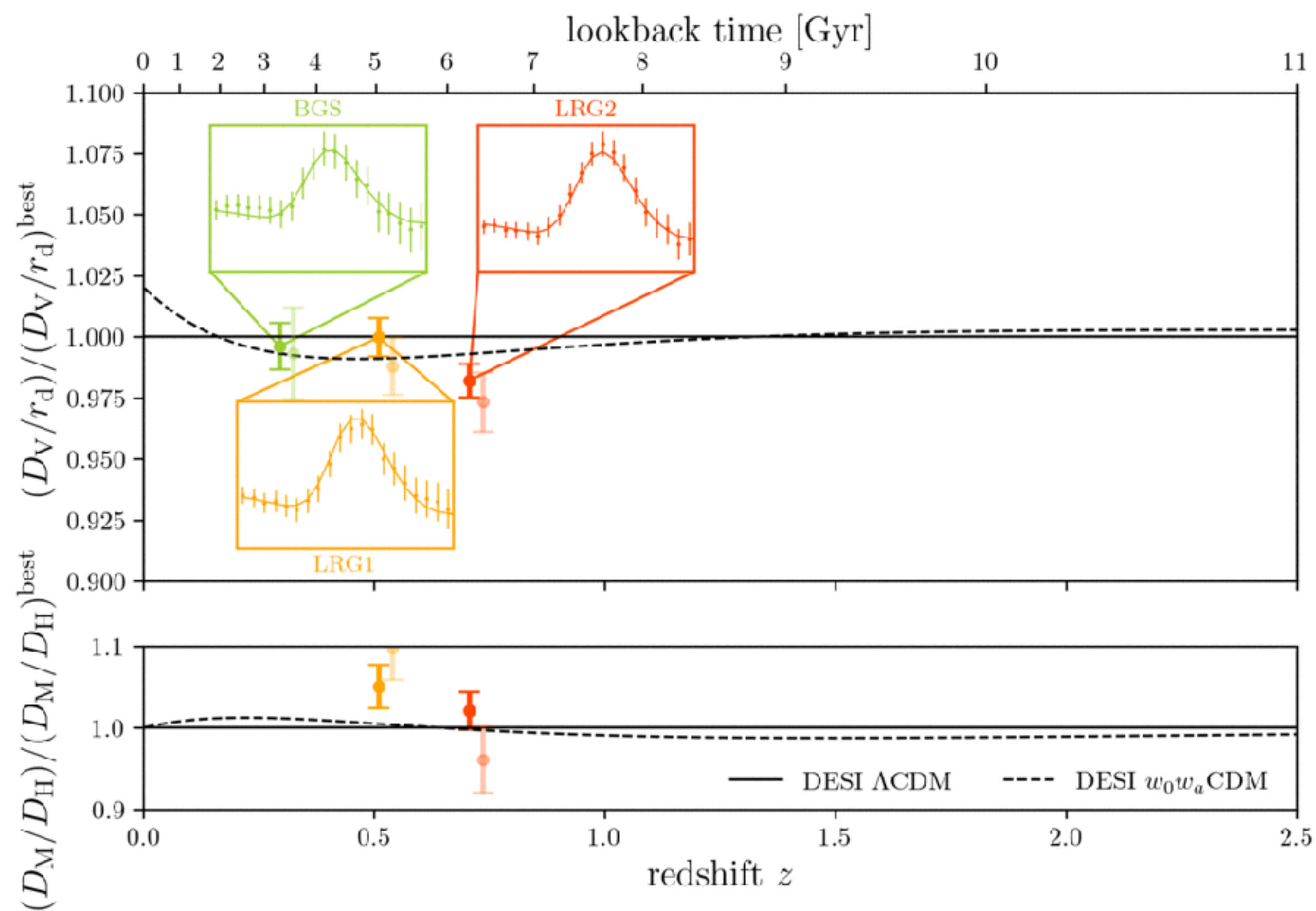


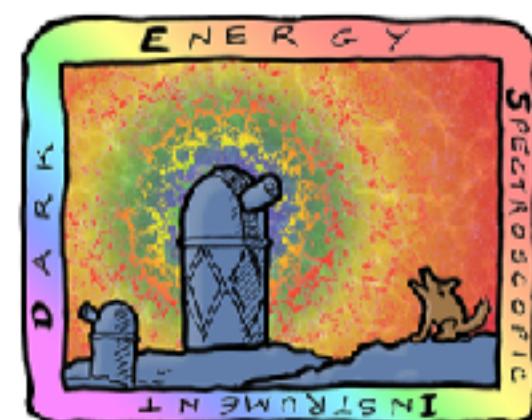


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INSTRUMENT

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DESI DR2 BAO results

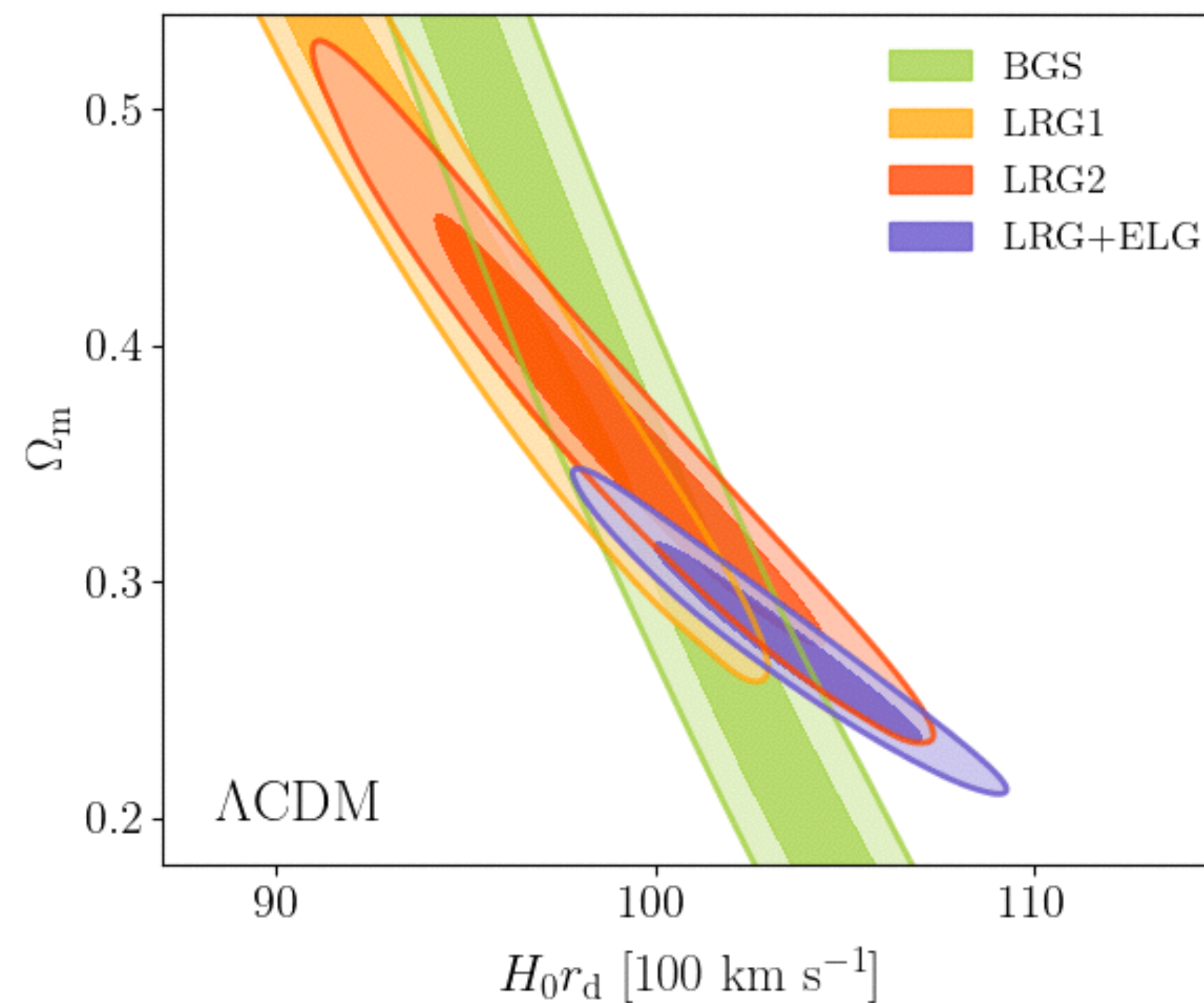
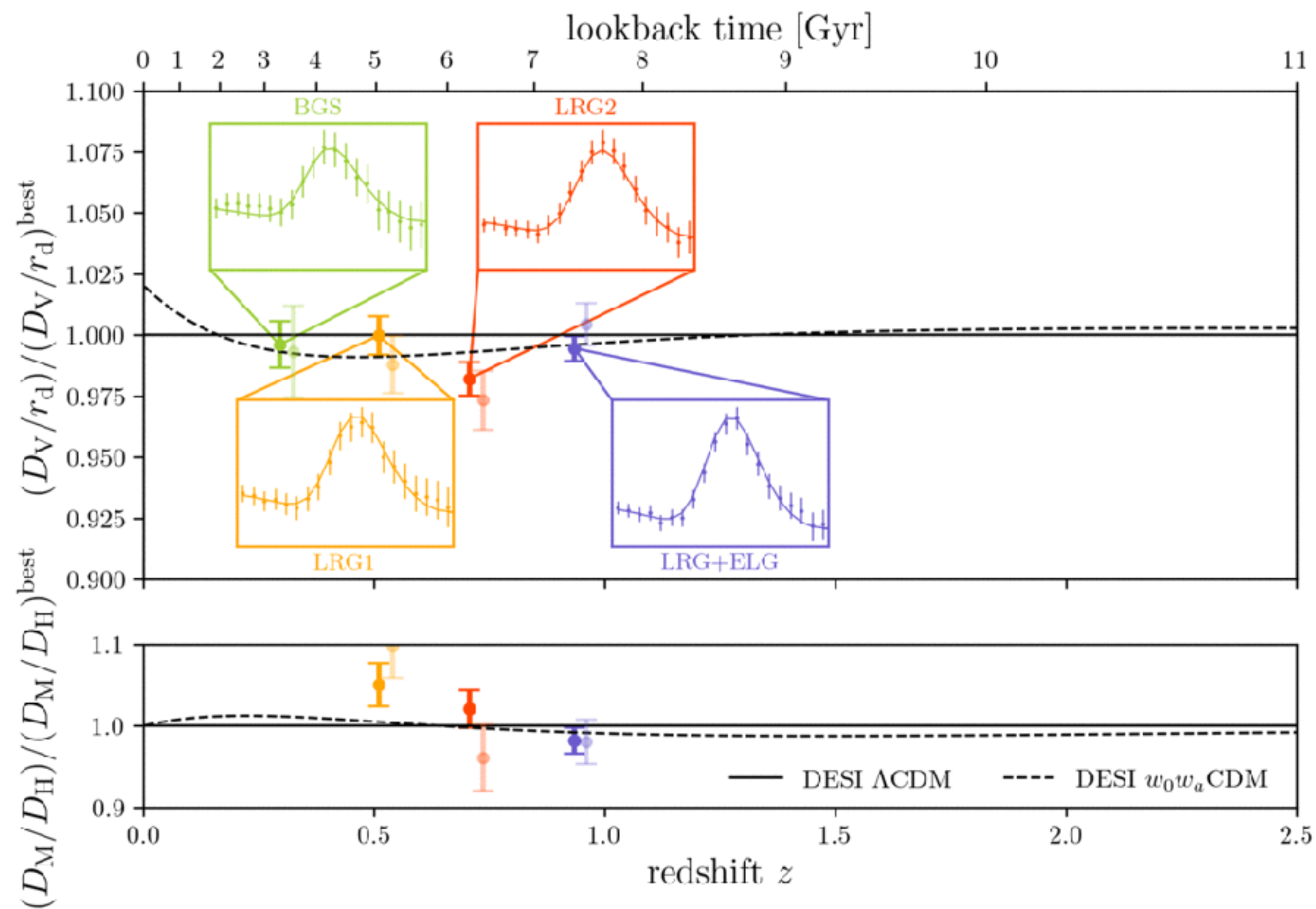


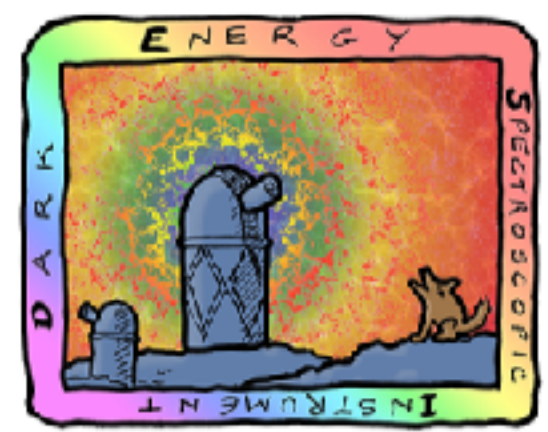


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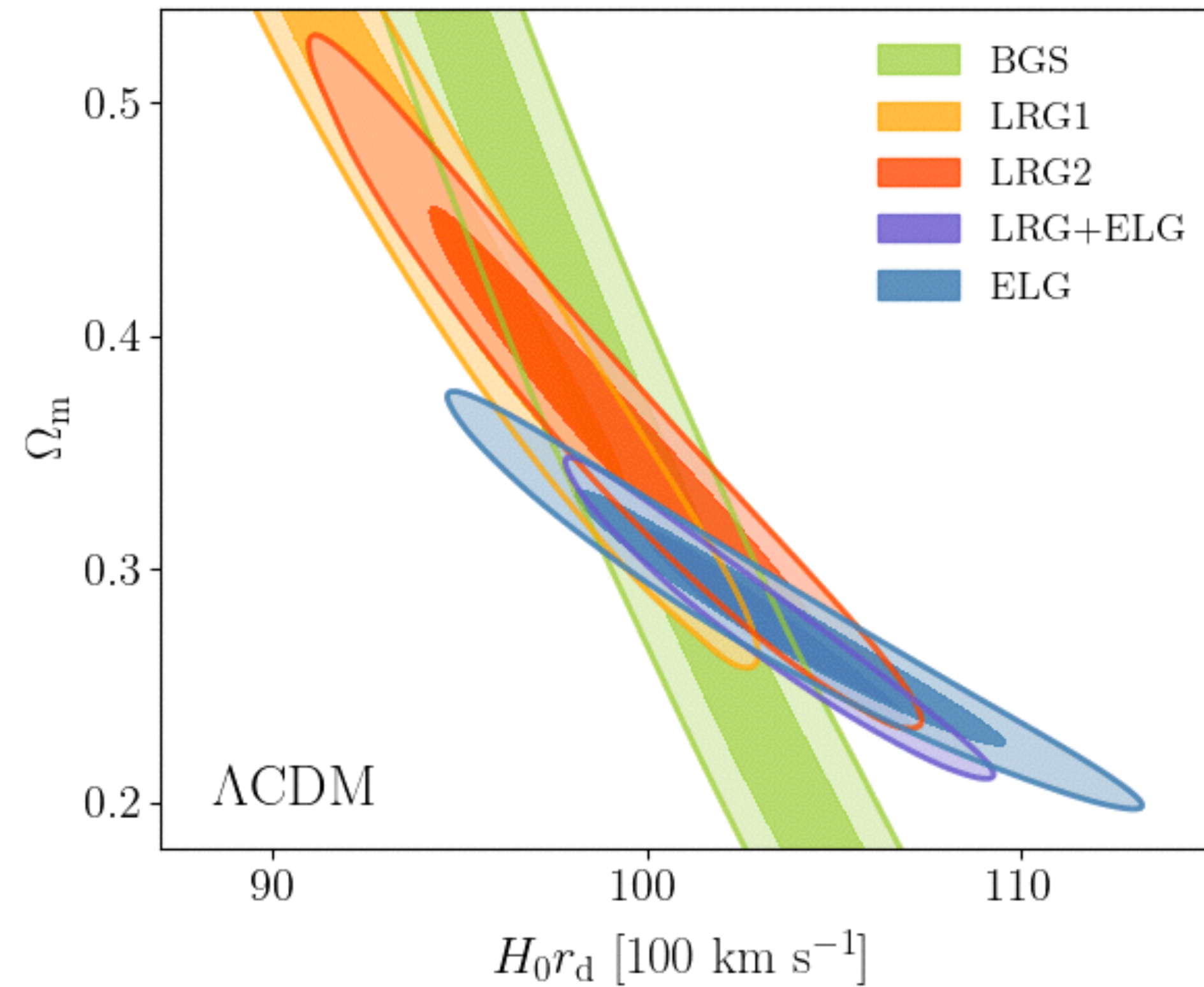
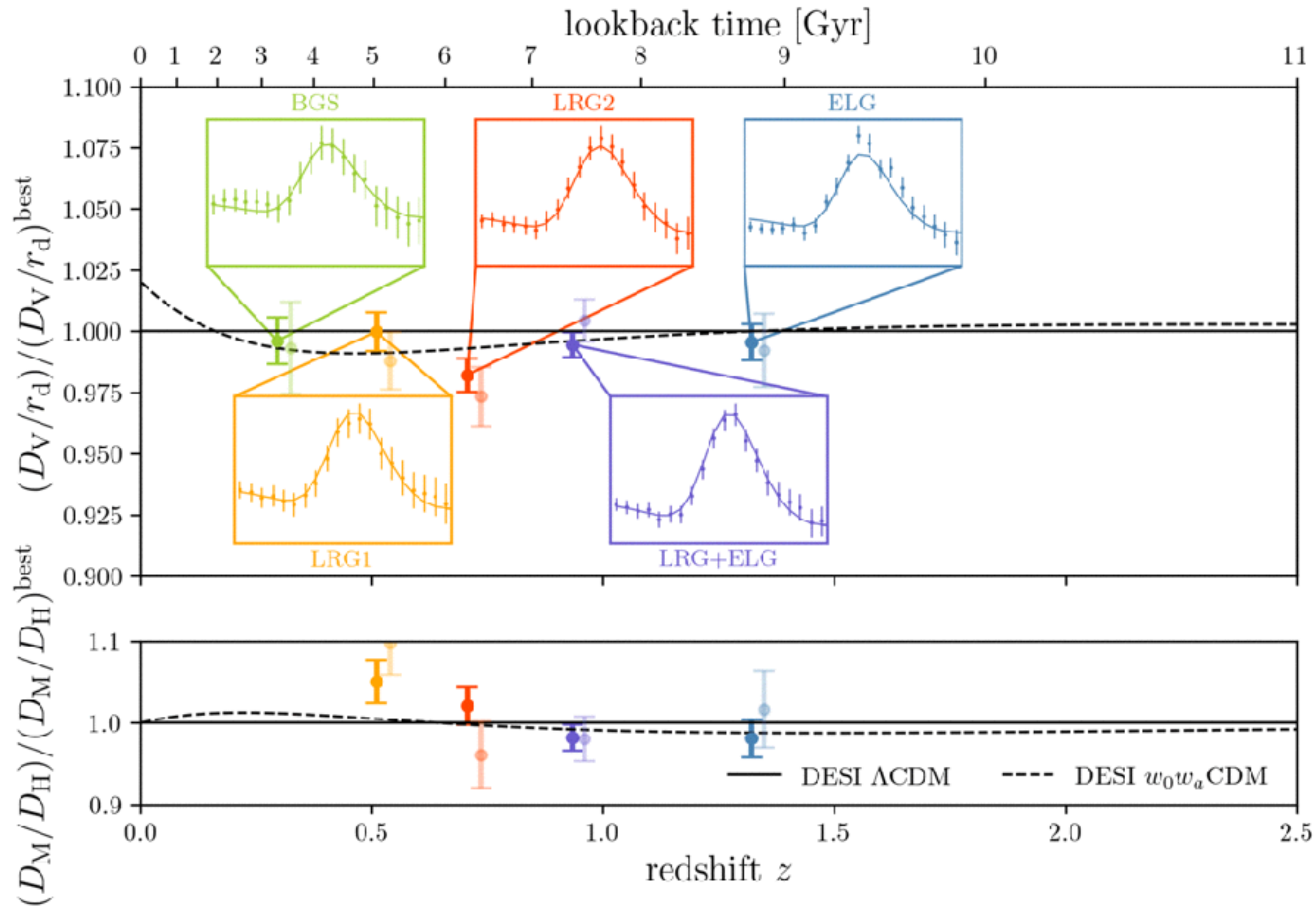


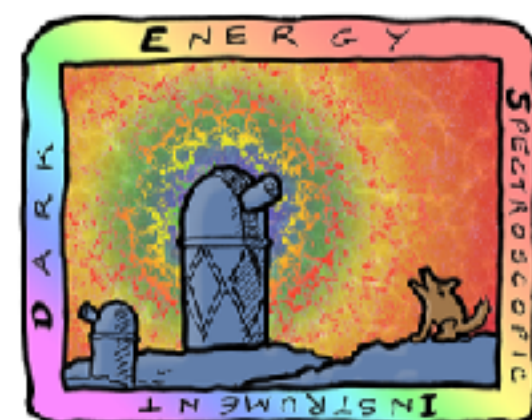


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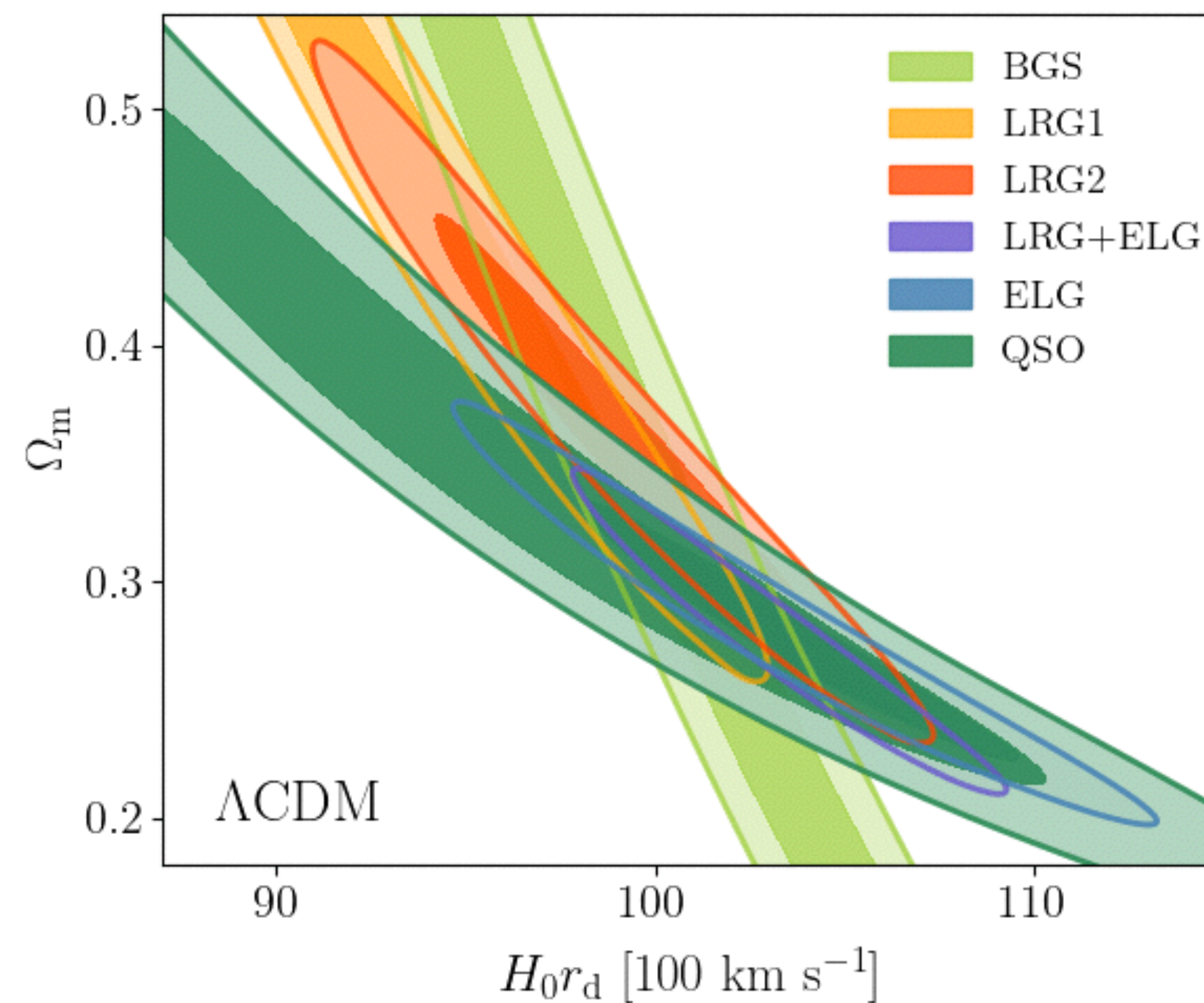
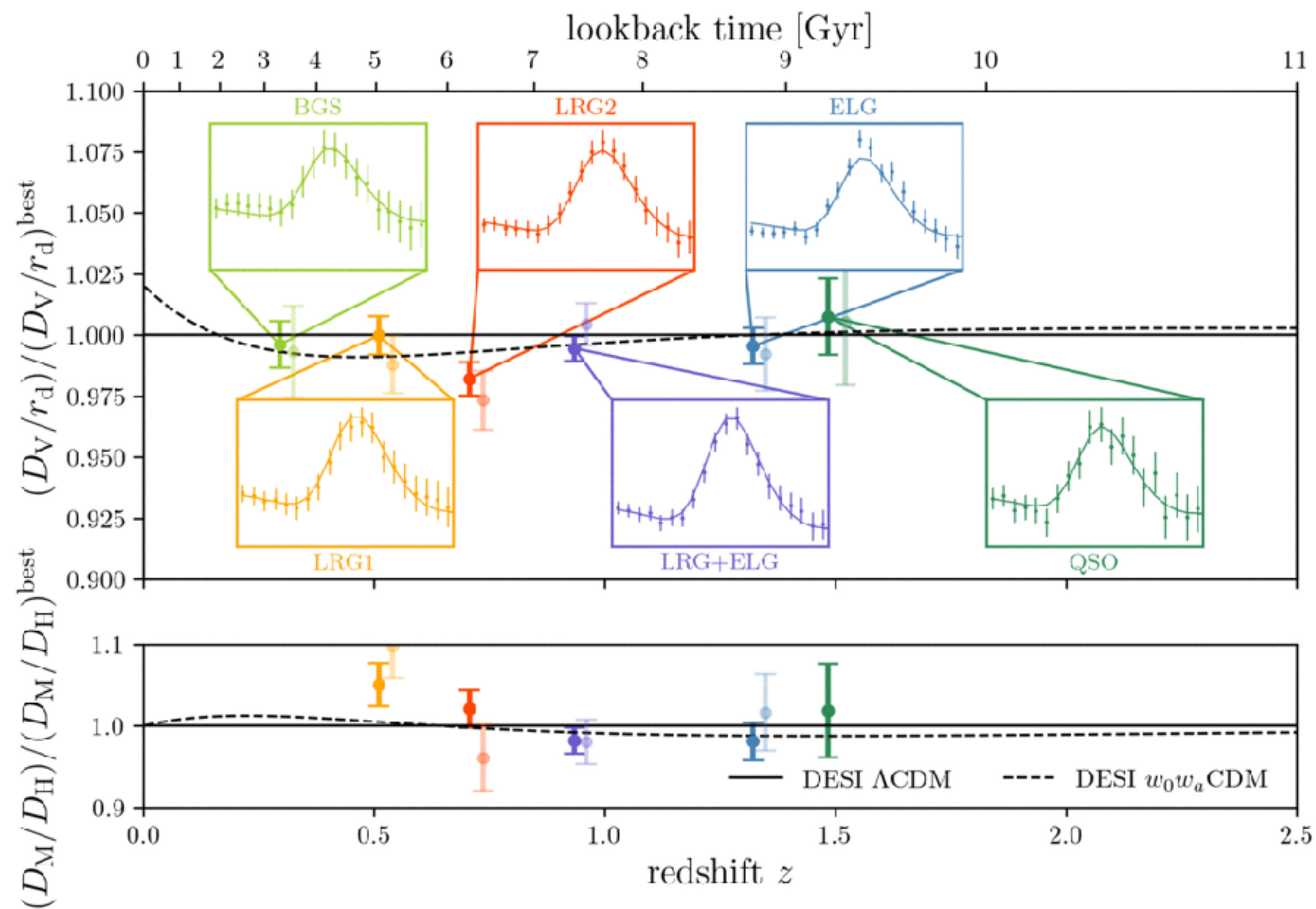


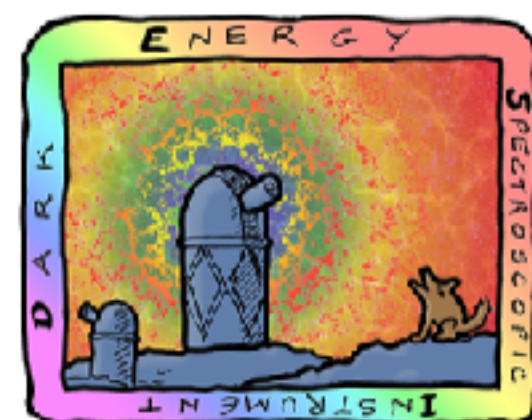


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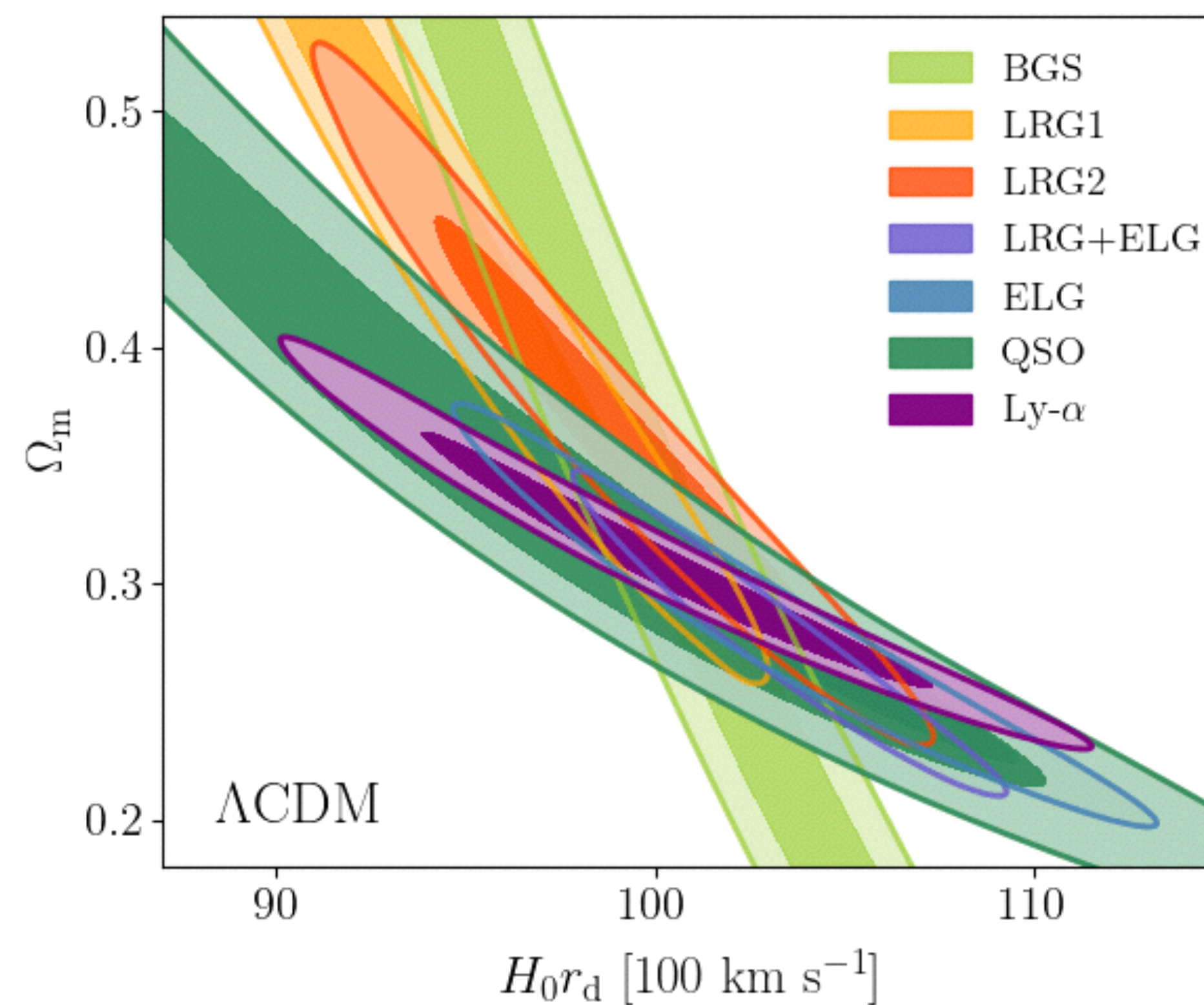
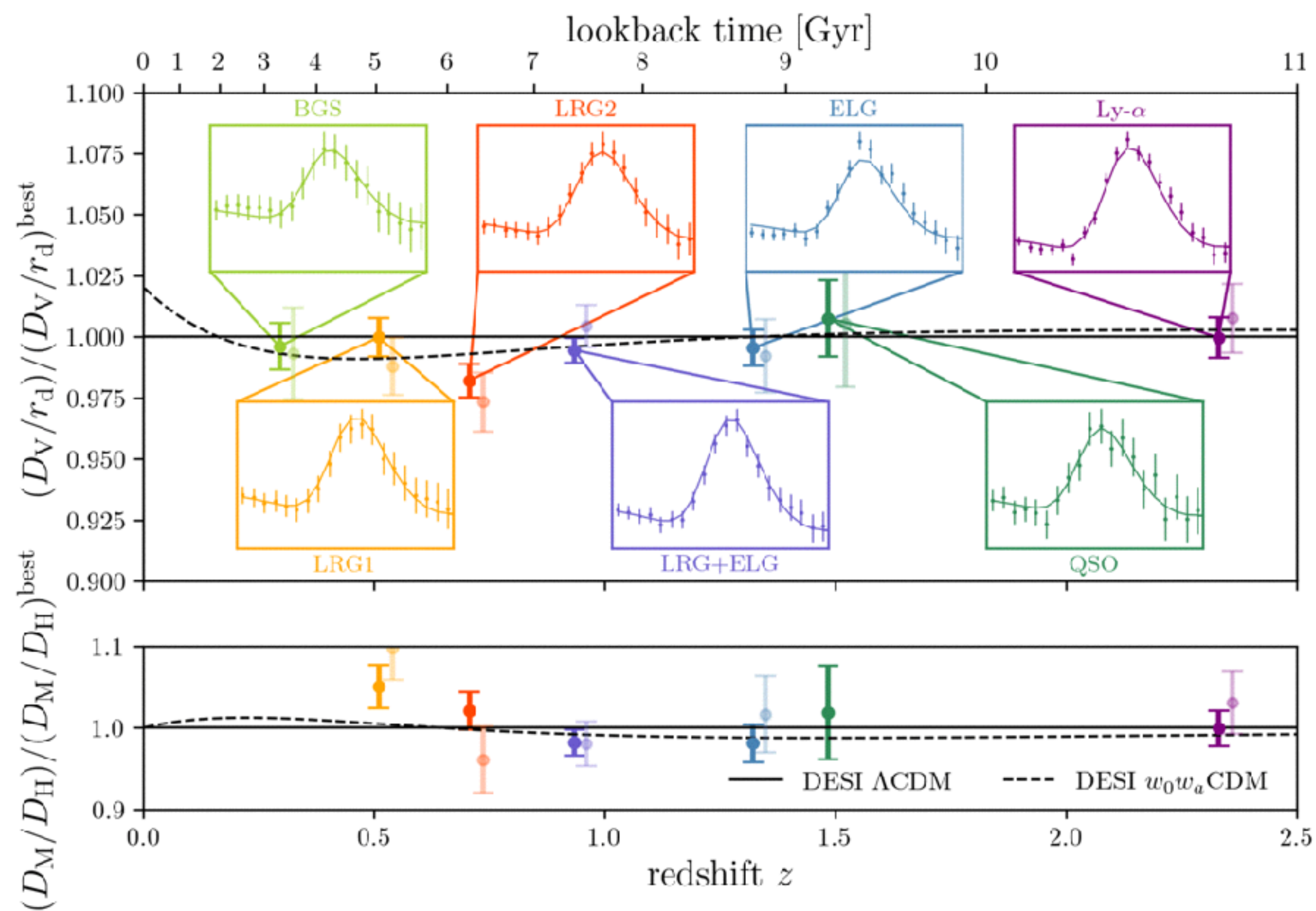




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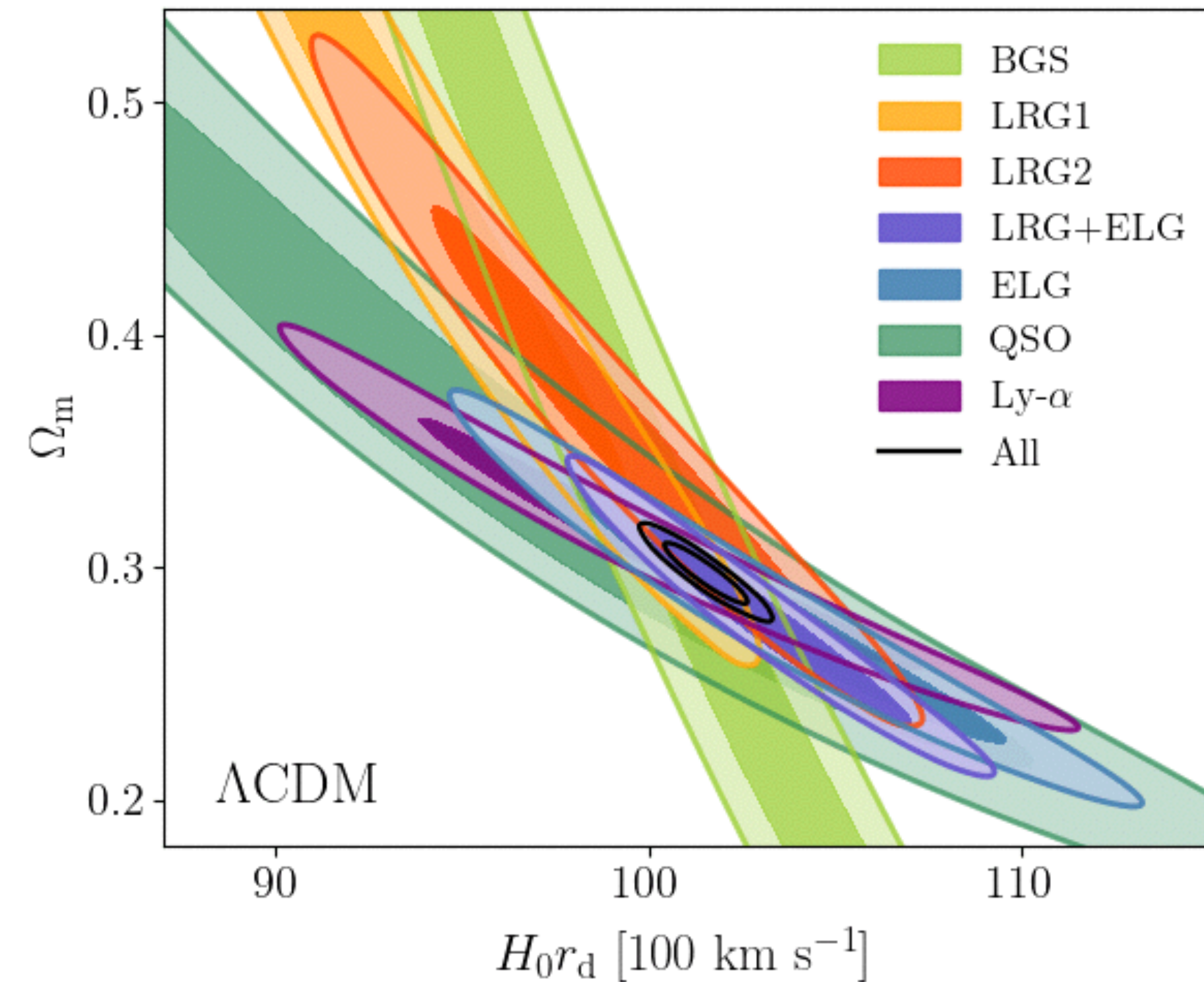


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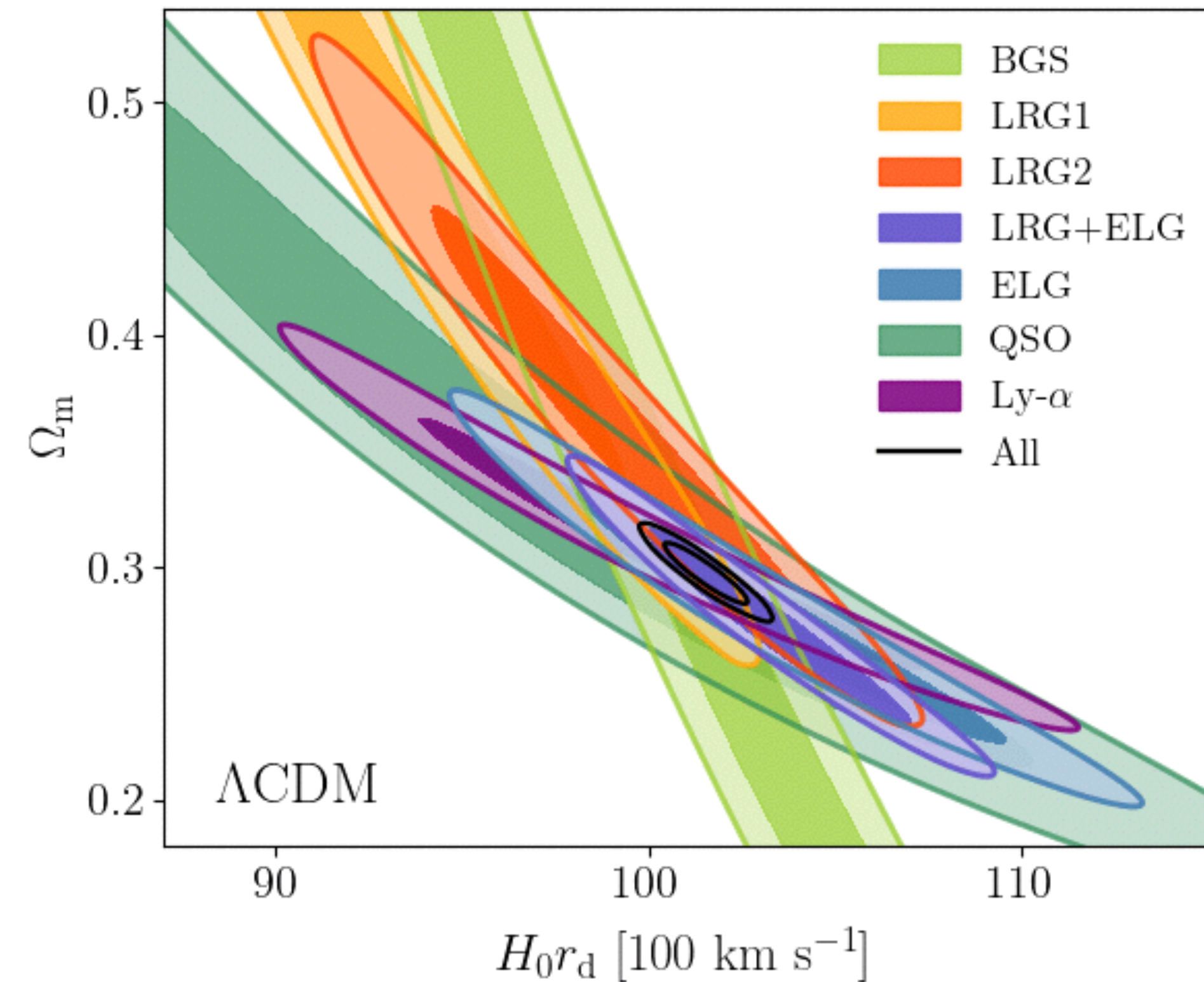
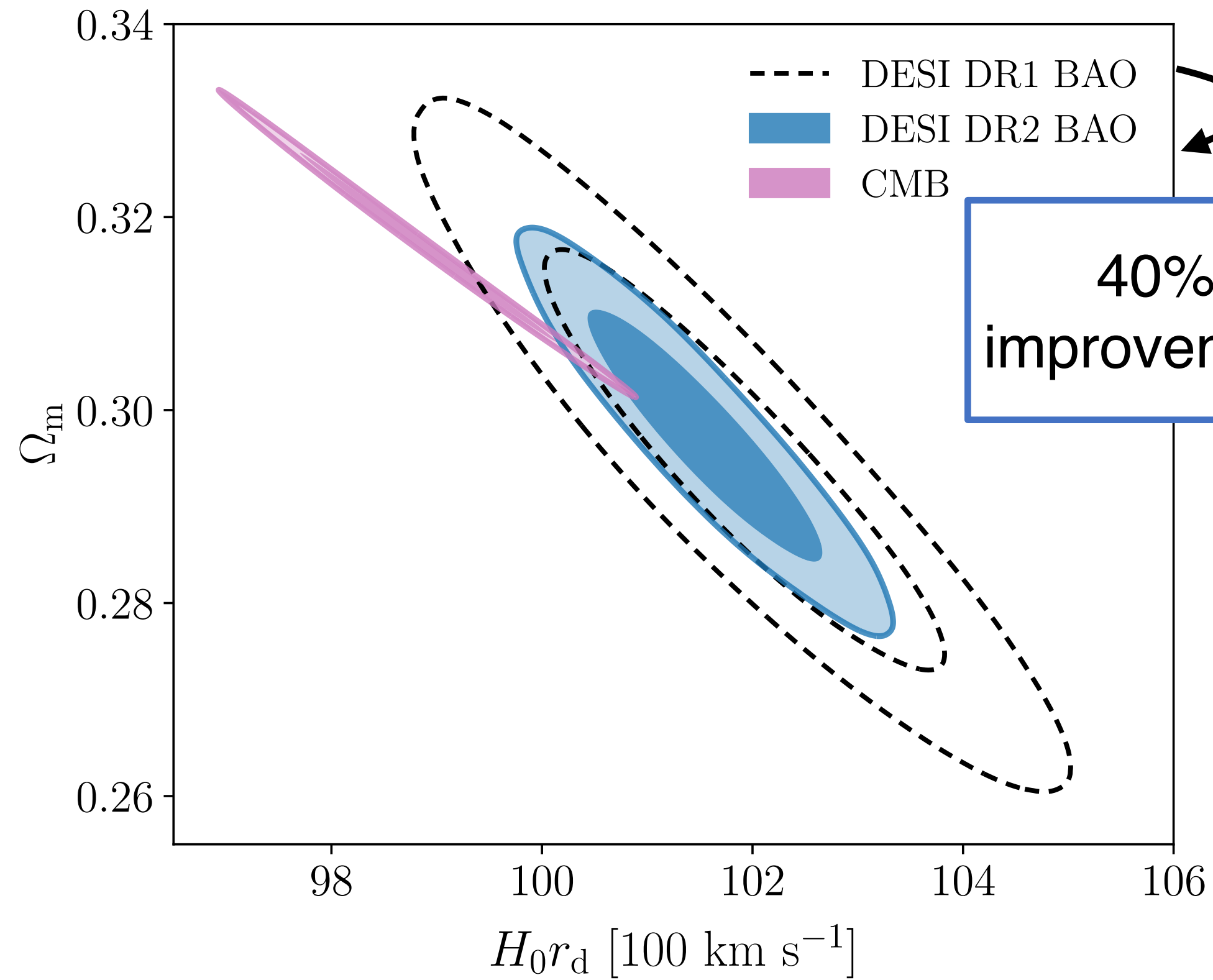
Final combined result:

$$\Omega_m = 0.2975 \pm 0.0086$$

$$H_0 r_d = (101.54 \pm 0.73)[100 \text{ km/s}] \text{ Mpc}$$



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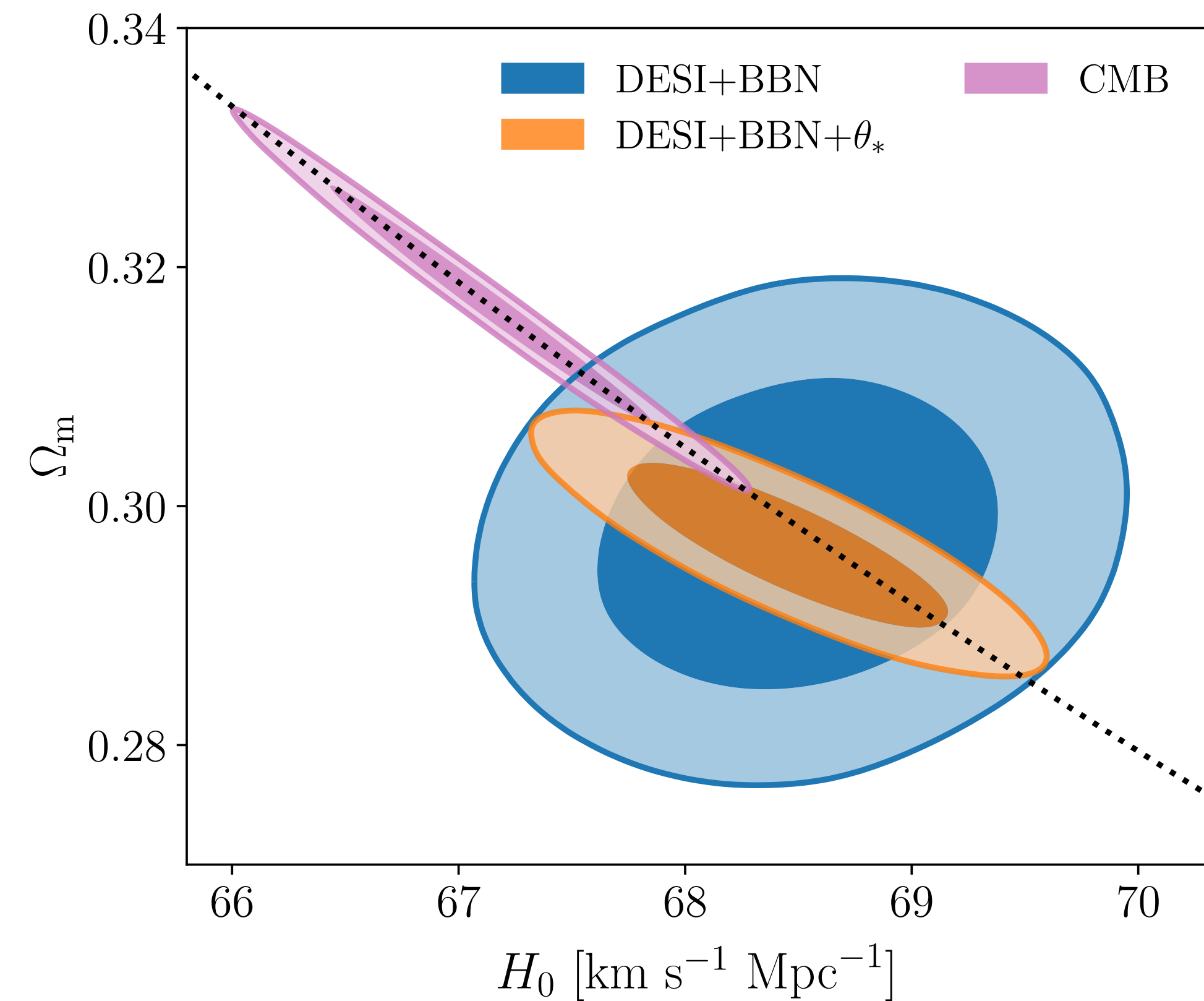


(As of march 2025; CMB = Planck PR4, CMB lensing = ACT DR6)

Tensions: Hubble constant

- Perhaps the strongest cosmology tension right now
- Calibrated BAO measurement with BBN $\Omega_b h^2$:

$$H_0 = (68.51 \pm 0.58) \text{ km s}^{-1} \text{ Mpc}^{-1}$$

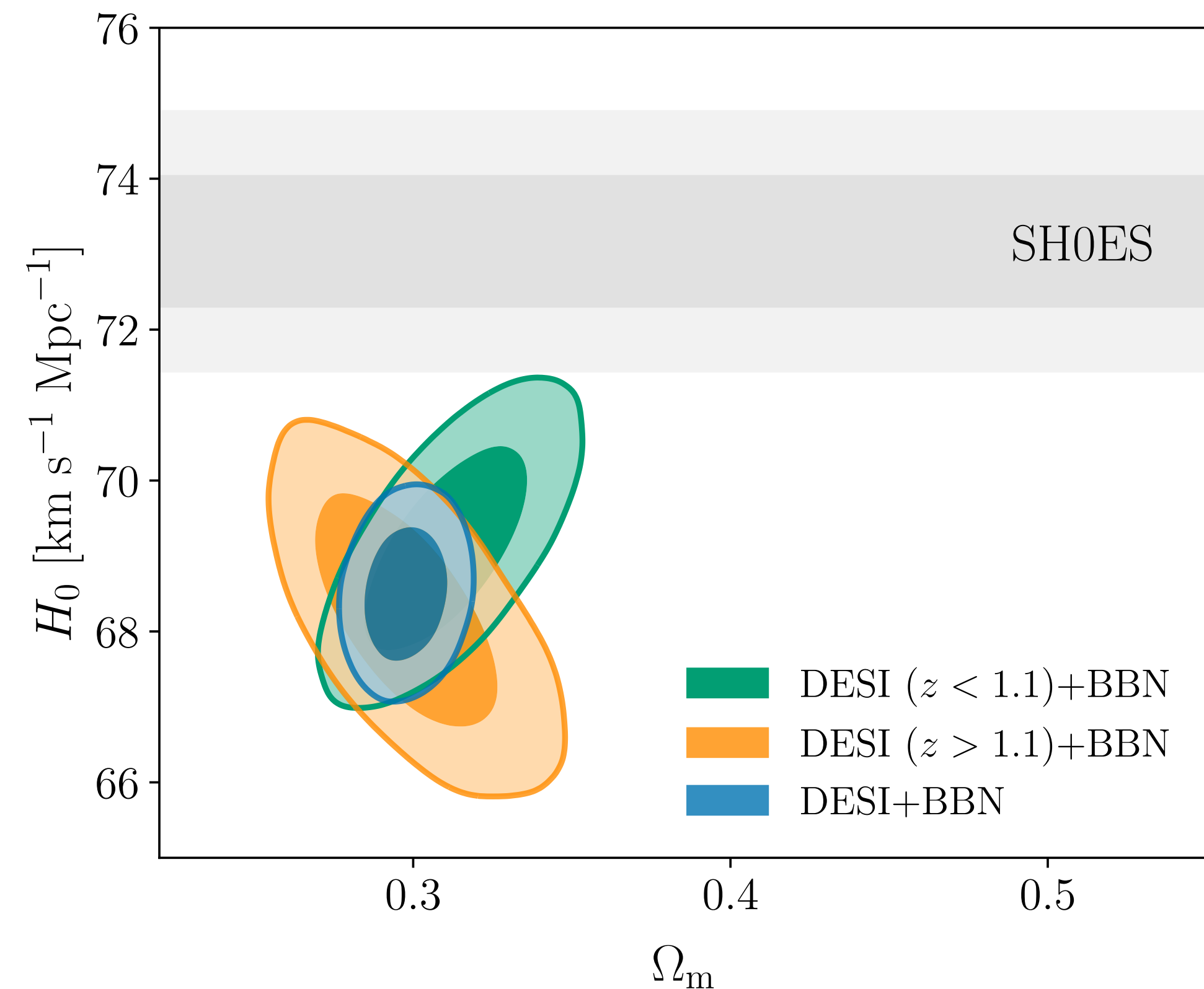


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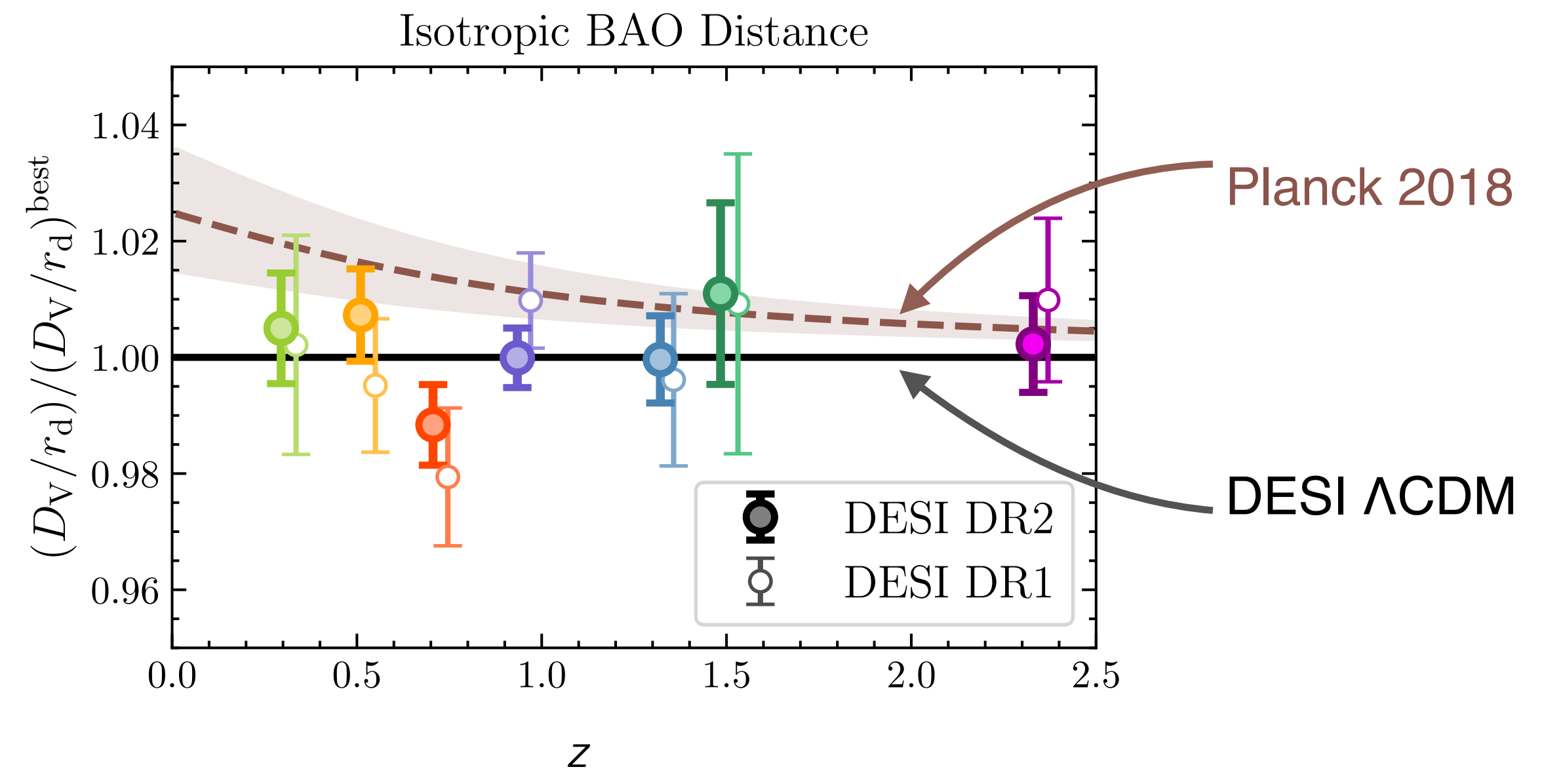
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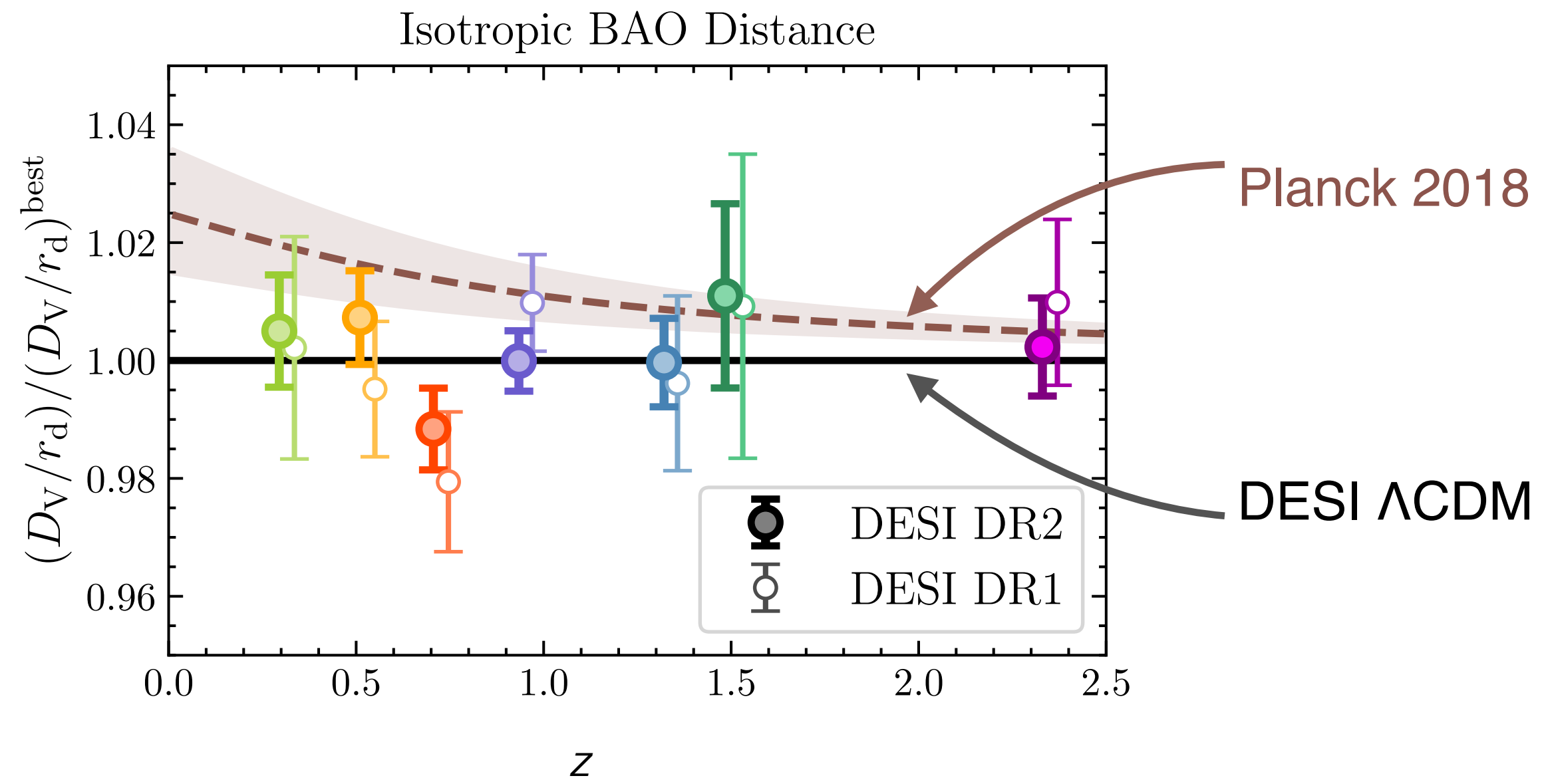
- 4.5σ tension with SHOES, independent of CMB



Tensions: CMB

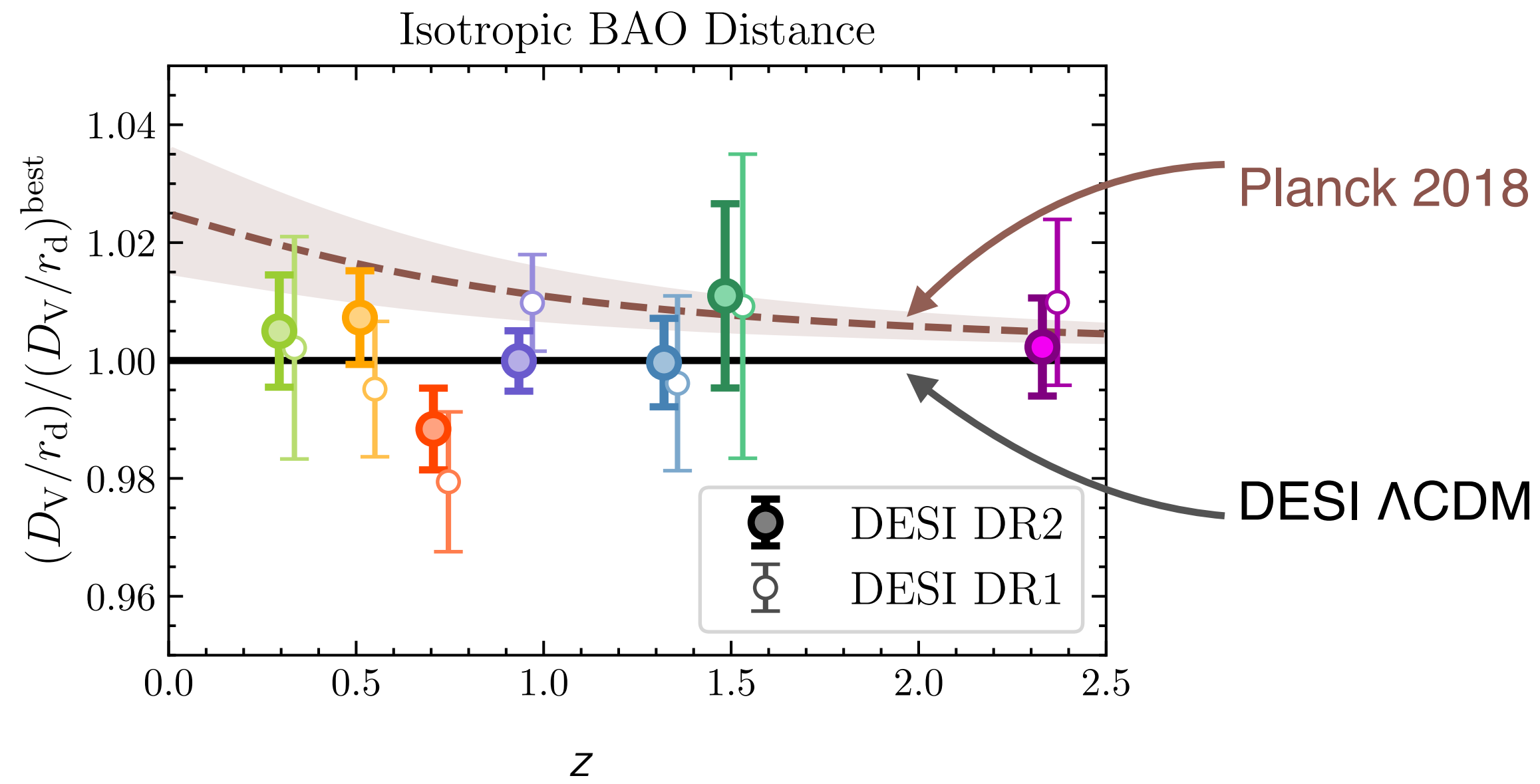


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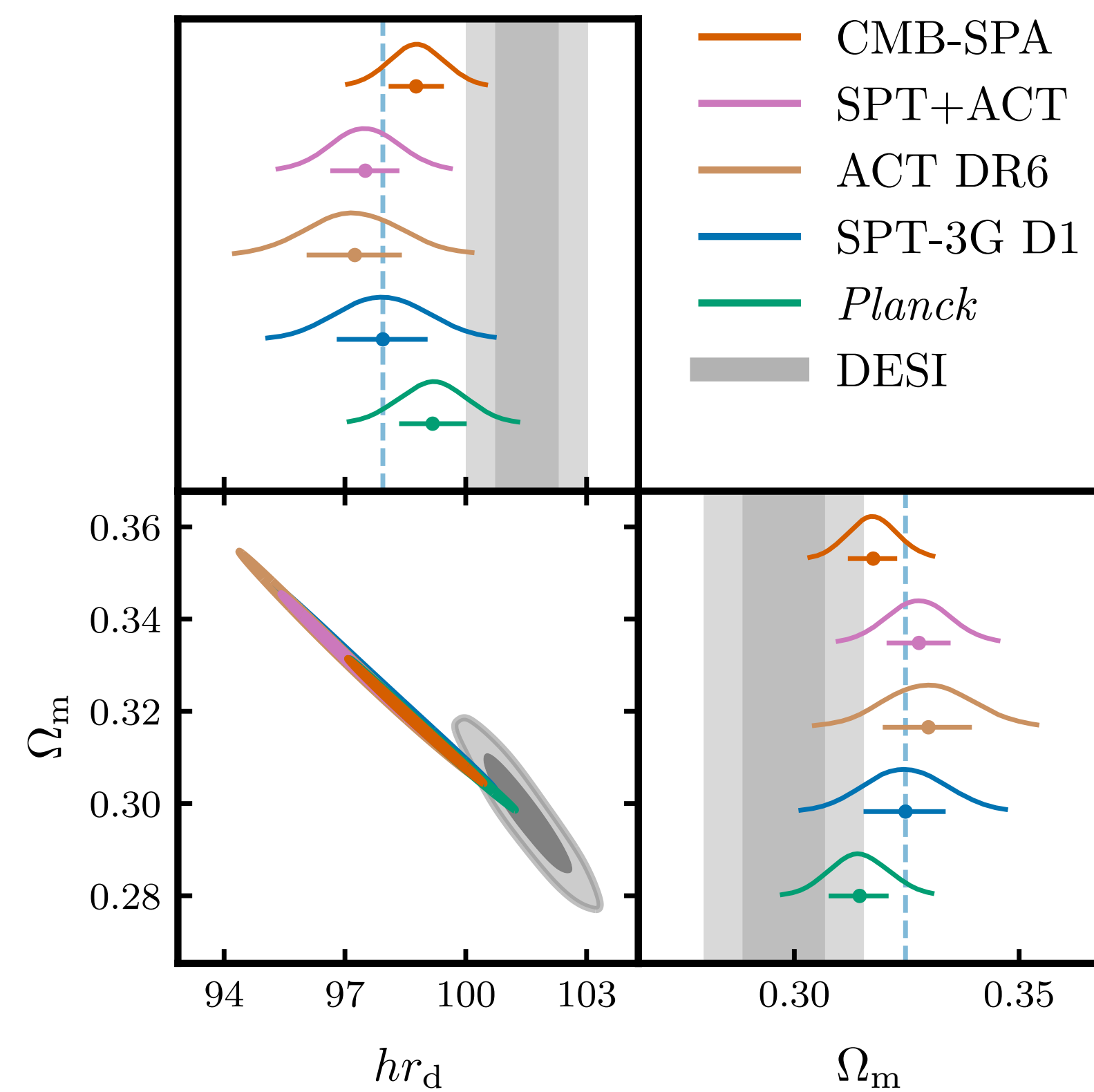
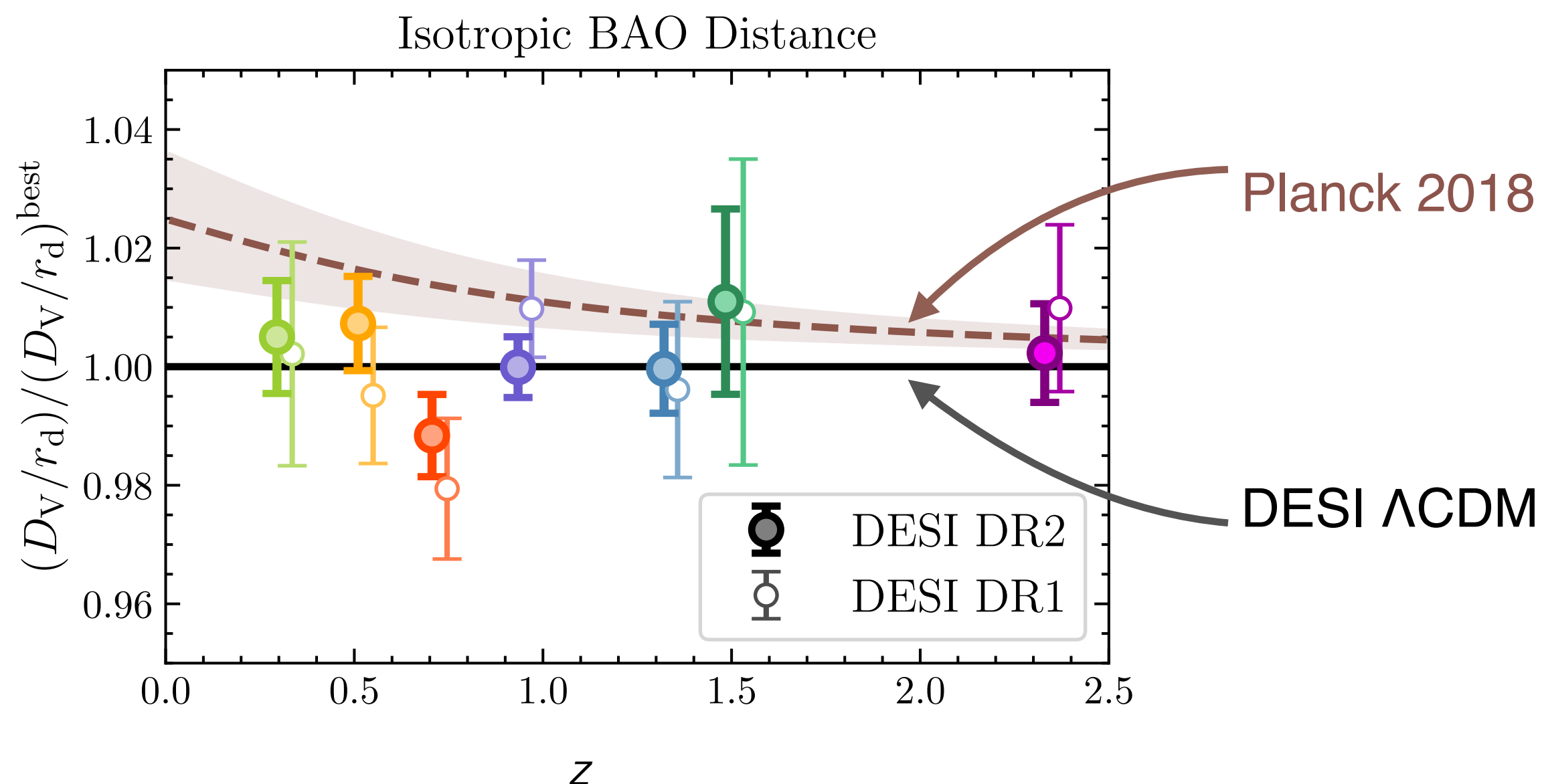
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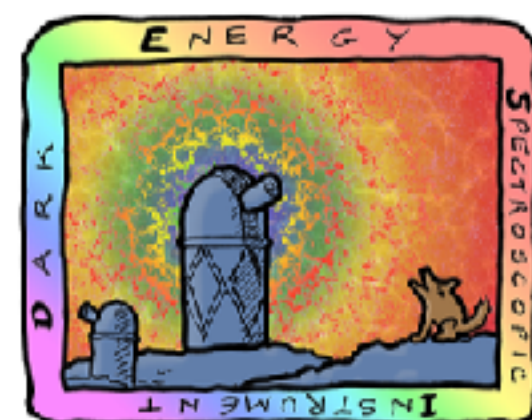
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- Now worse, Planck+SPT+ACT: 2.8σ

Camhuis et al, 2026, [doi:10.1103/7wt3-9v2y](https://doi.org/10.1103/7wt3-9v2y)



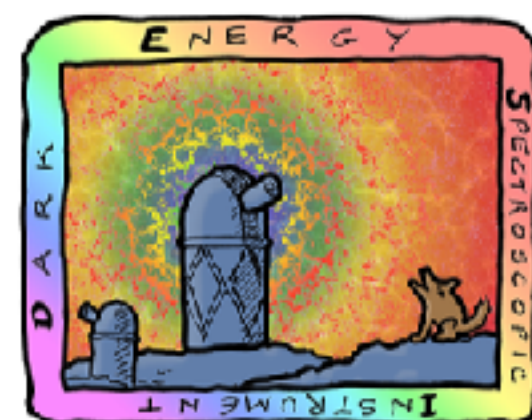
DARK ENERGY
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Dark Energy

- Dark energy equation of state CPL parametrization:

$$p/\rho = w = w_0 + (1 - a)w_a$$



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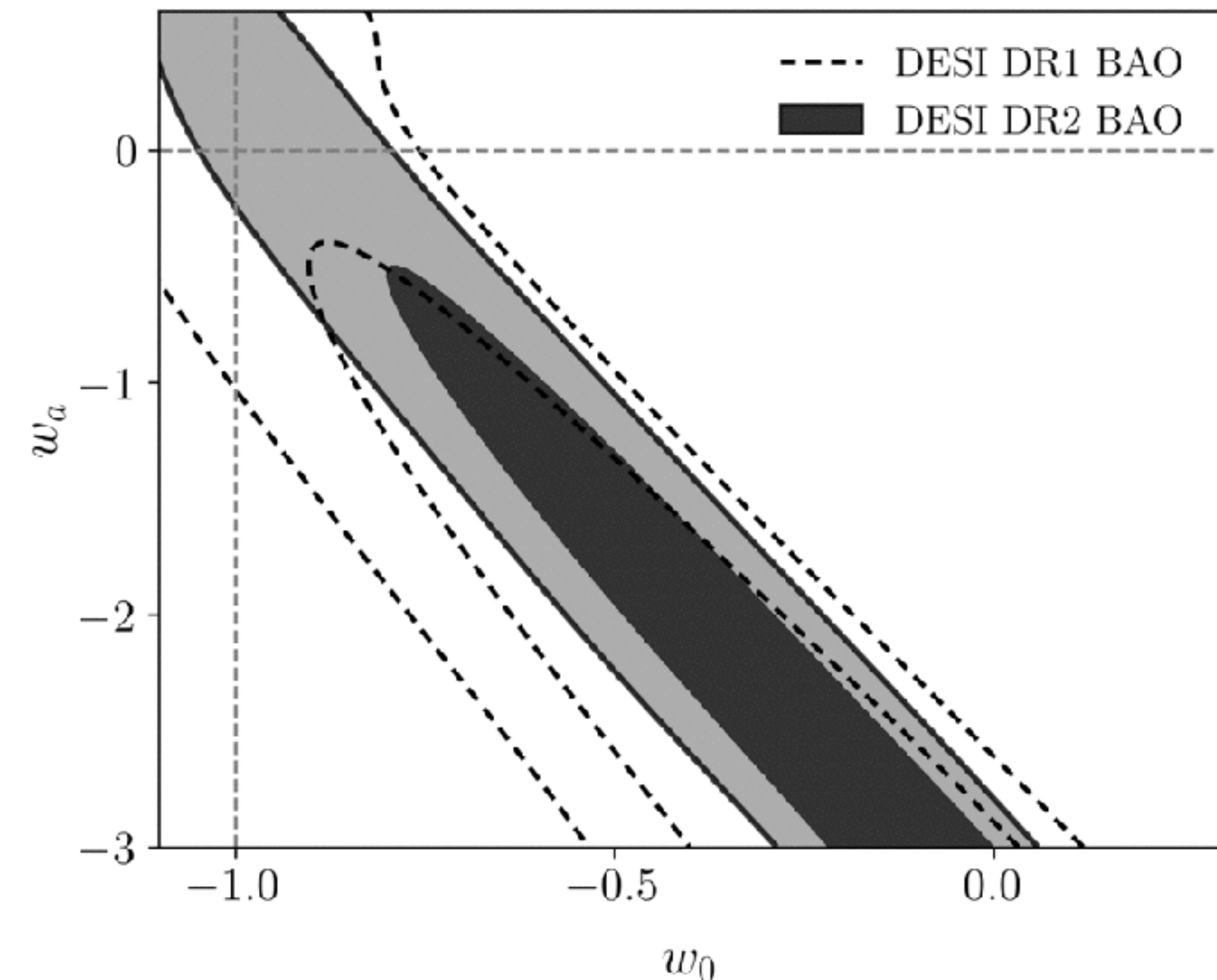
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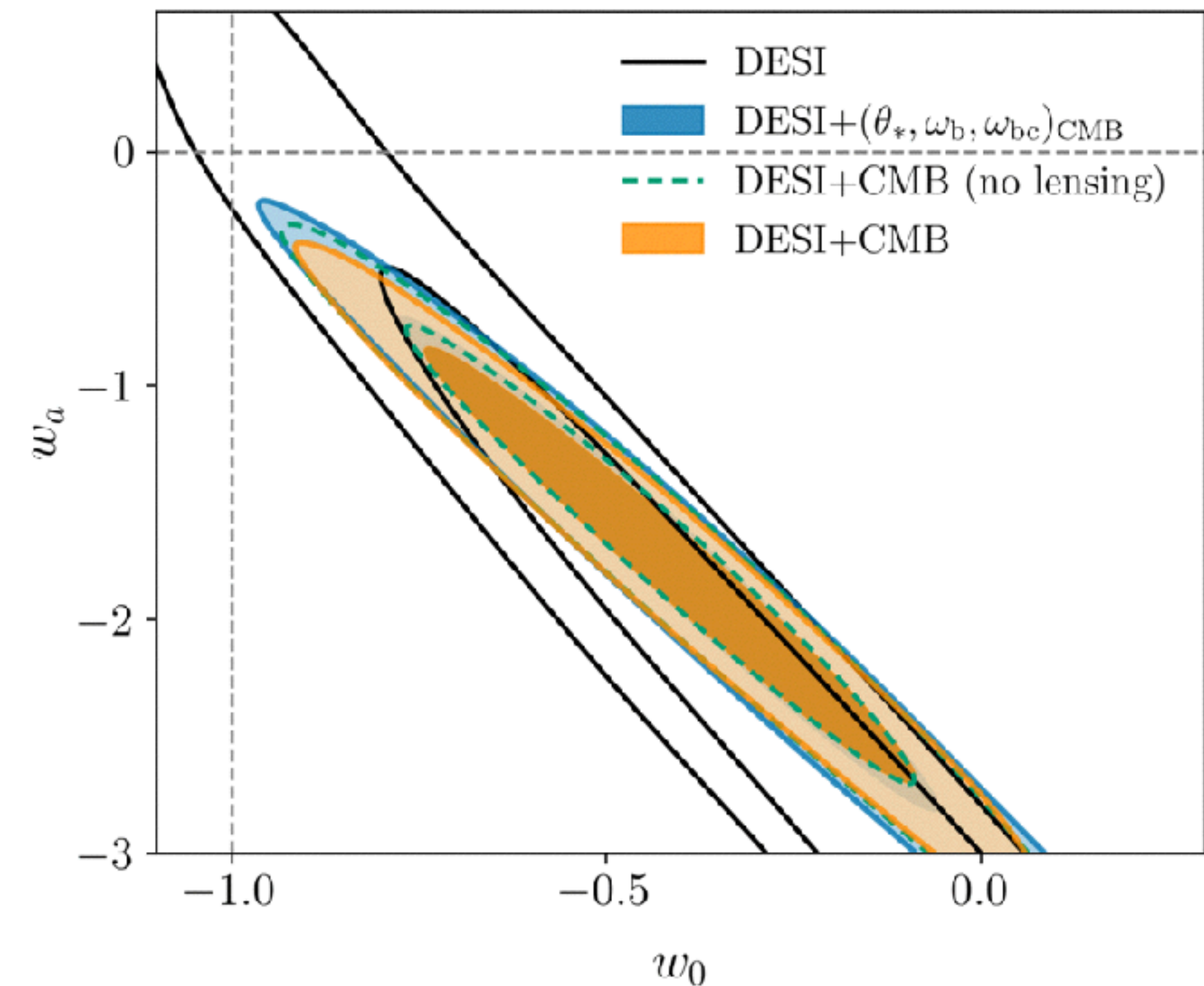


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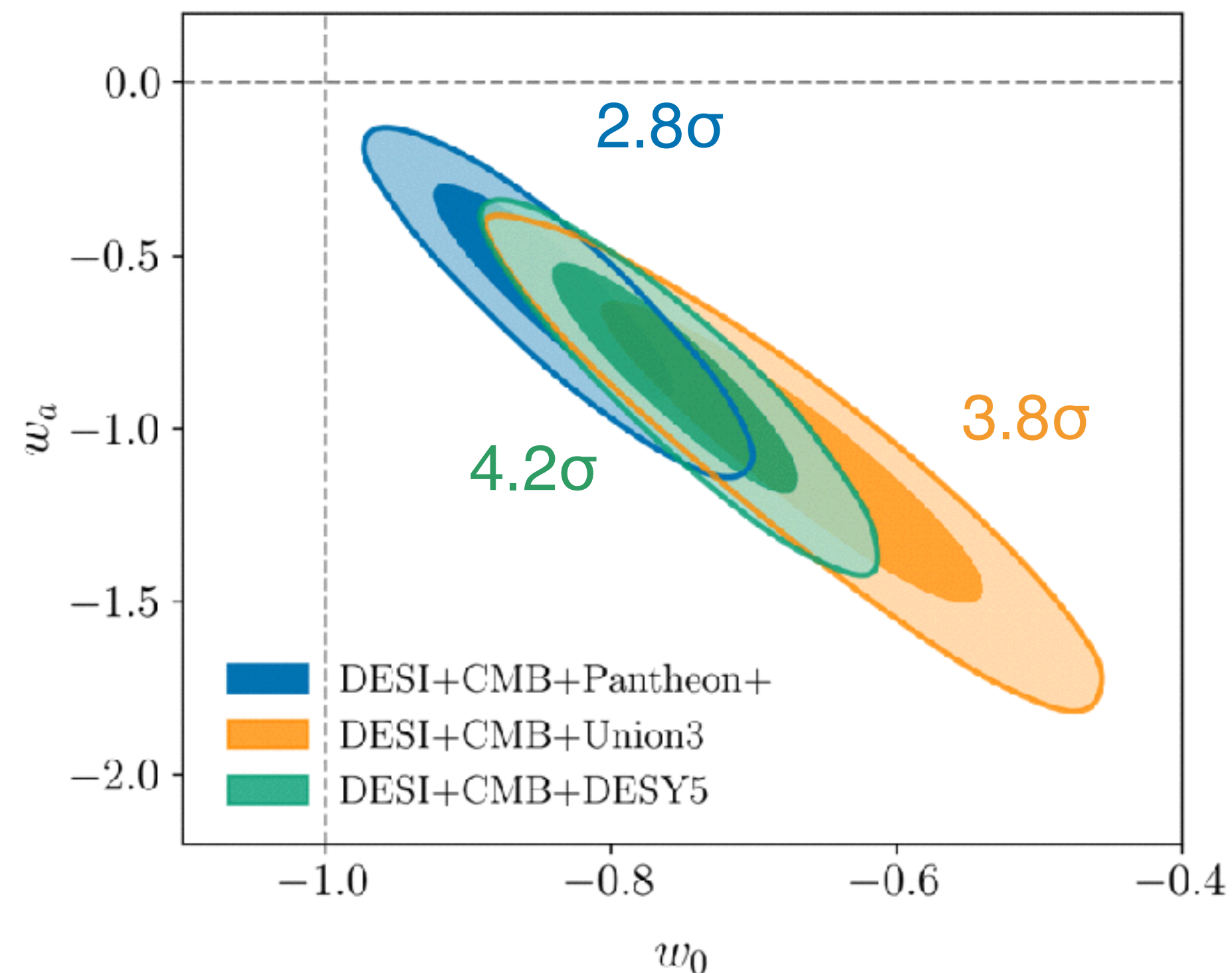


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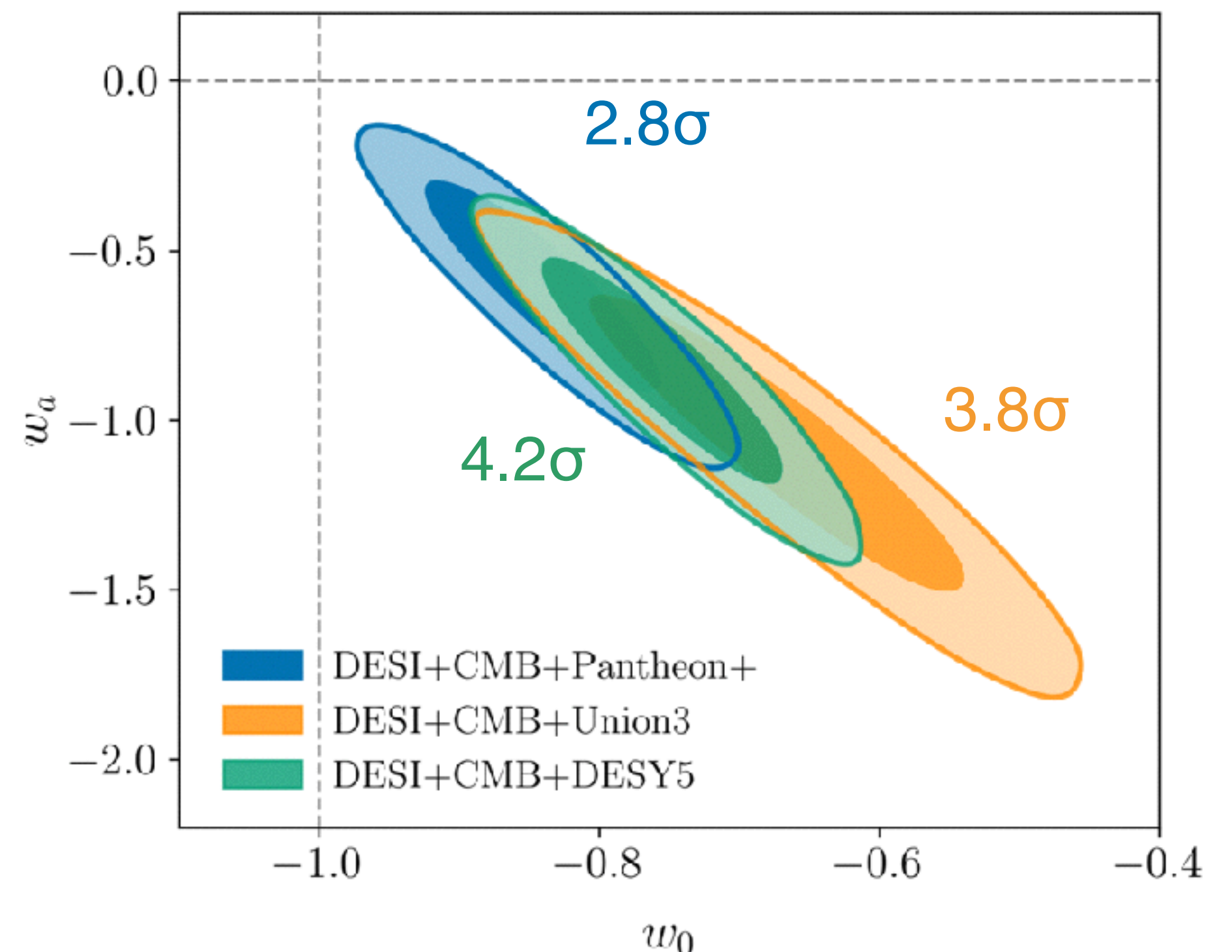
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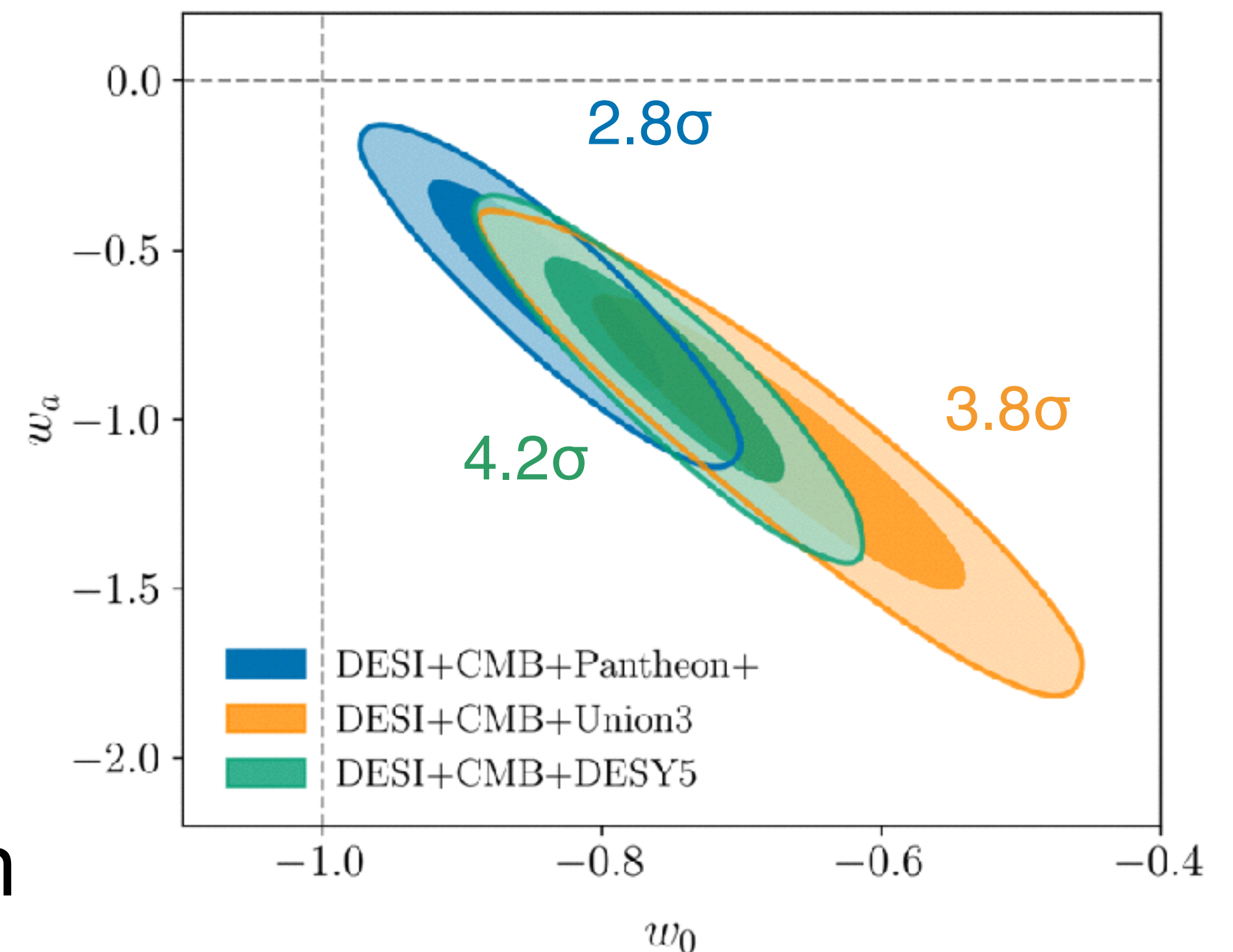


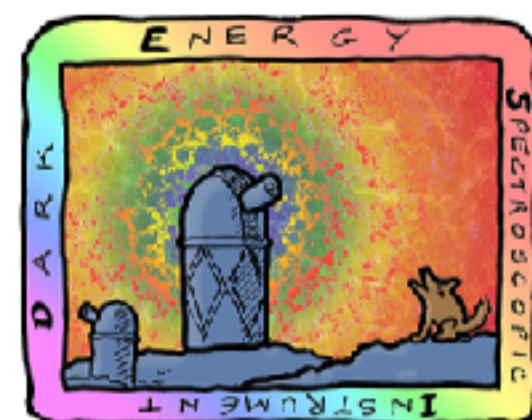
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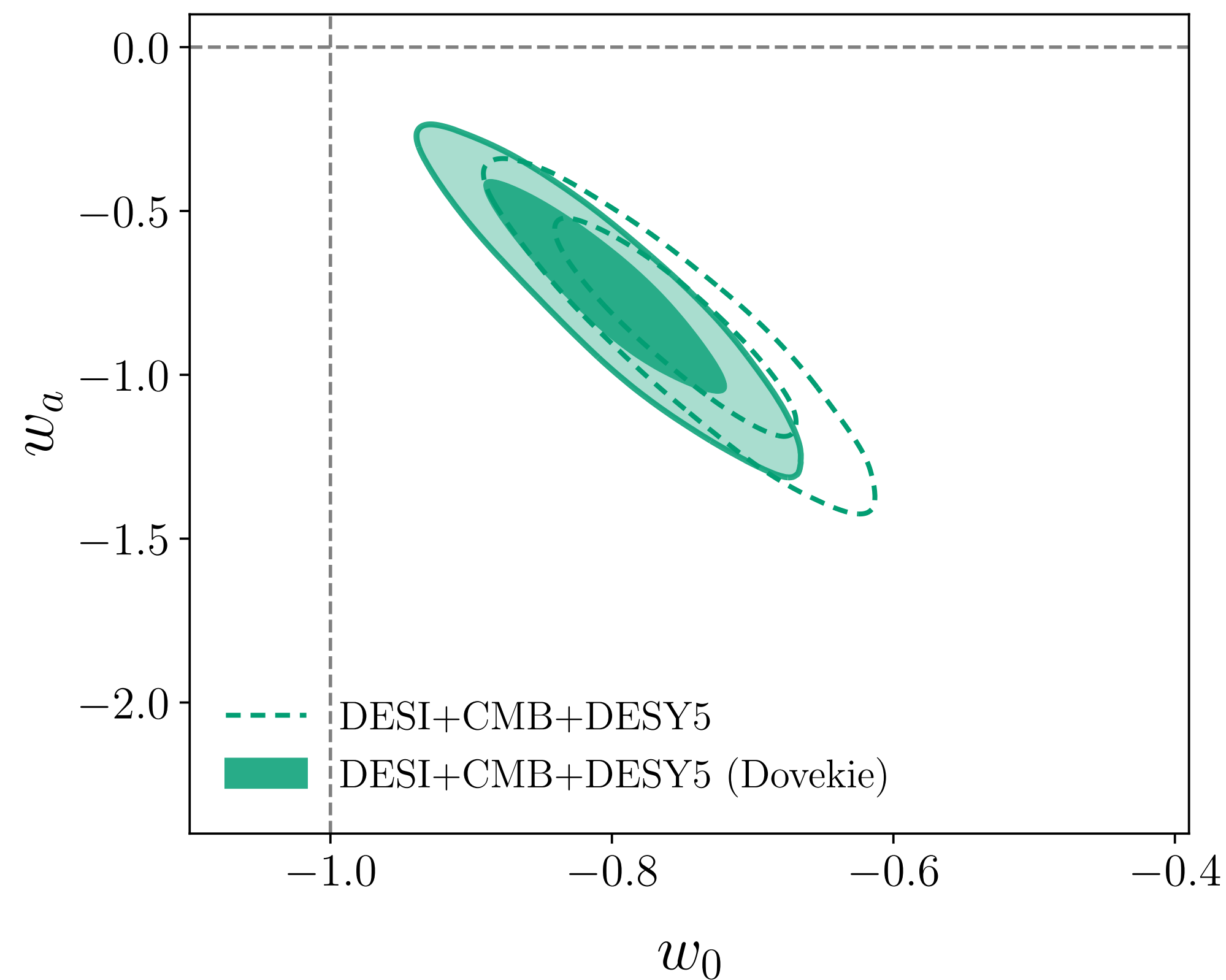
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SN Ia updates

- All supernovae likelihoods have since been updated:

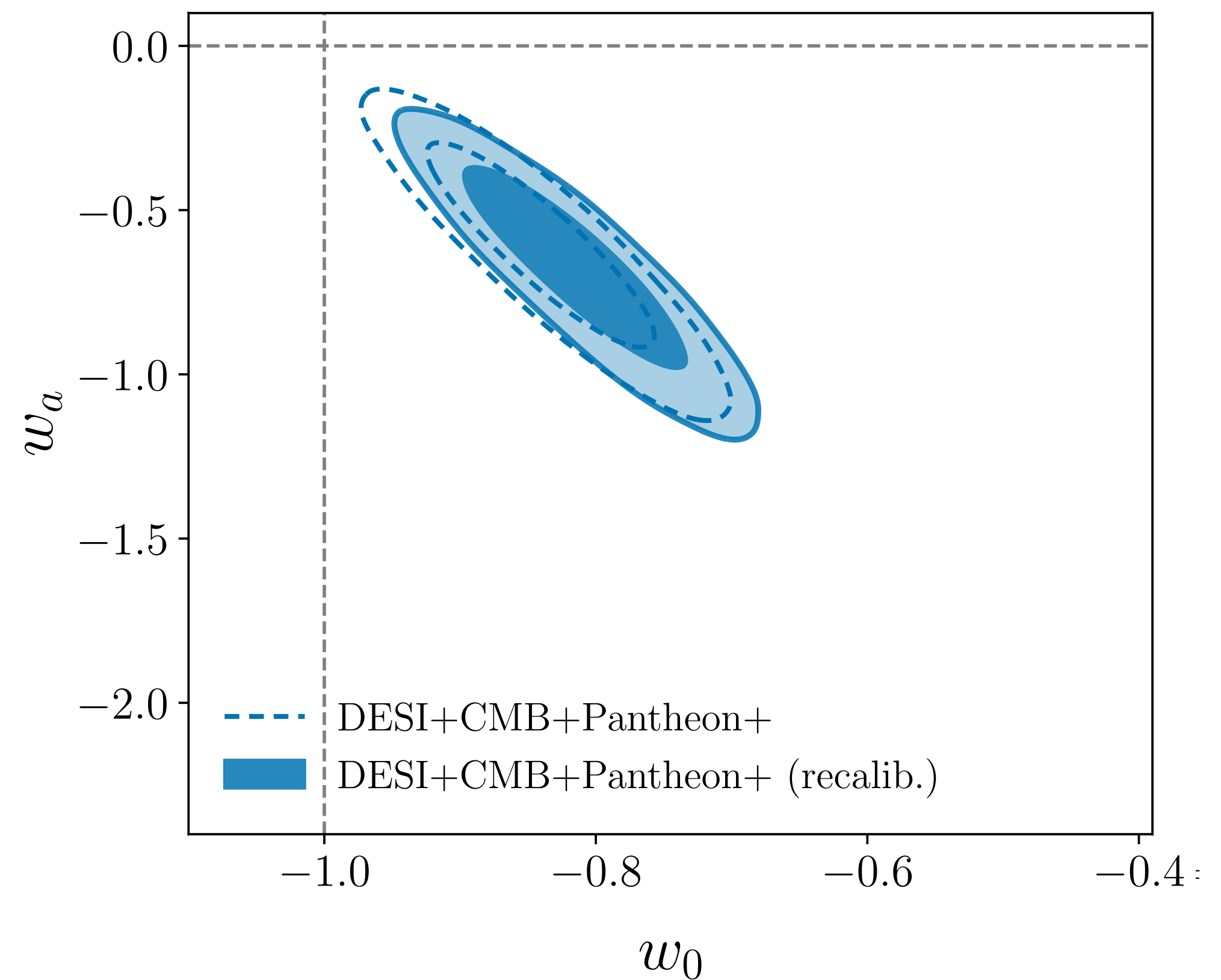
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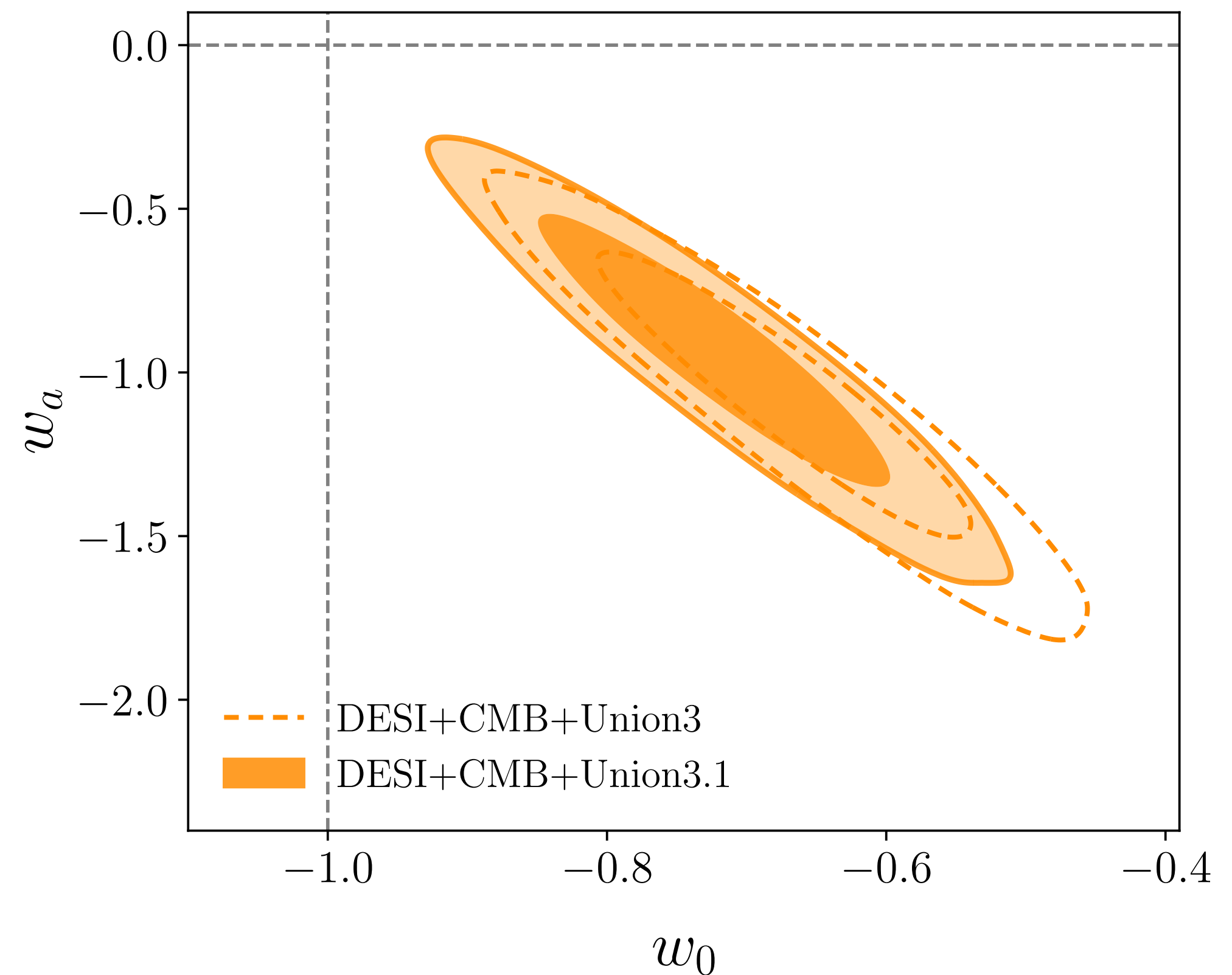
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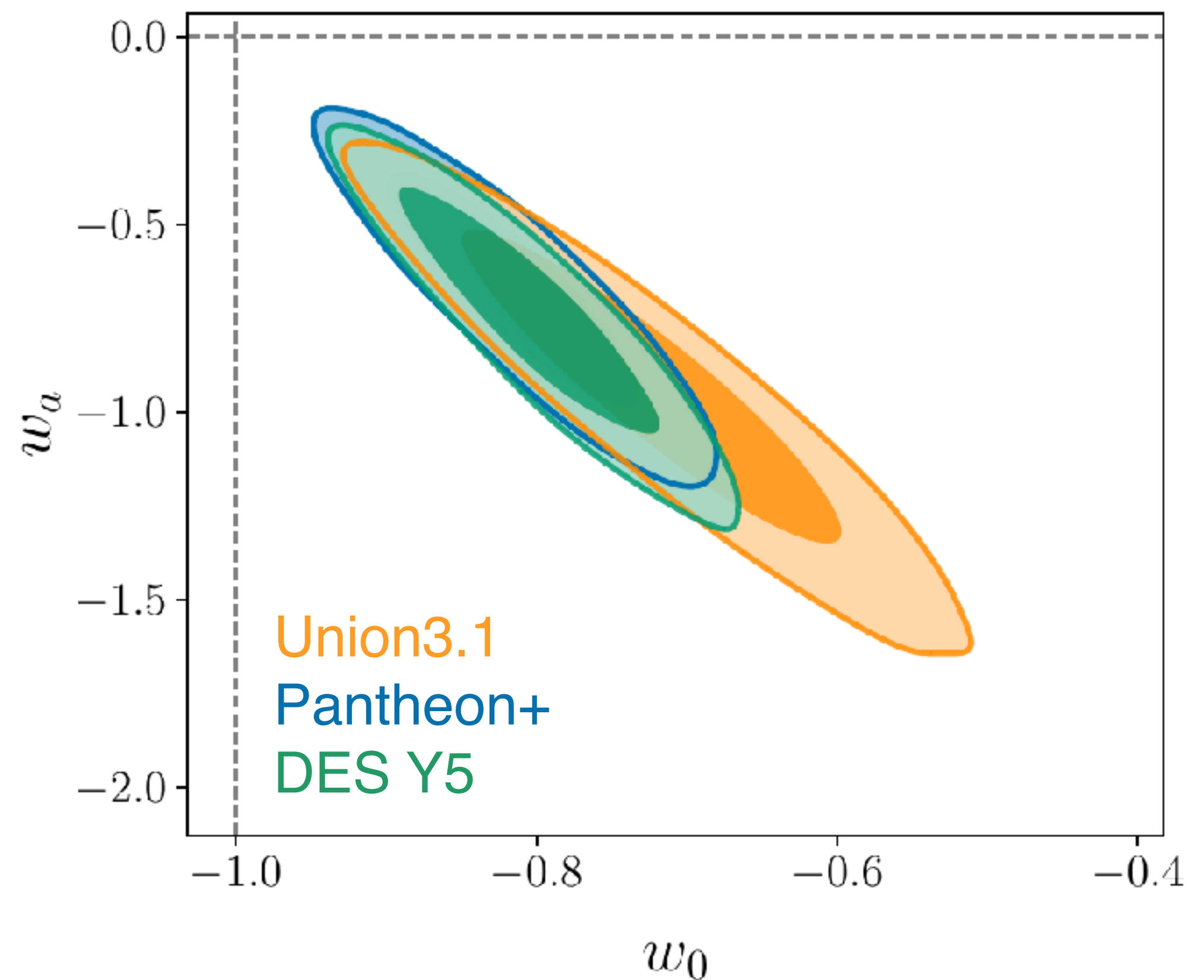
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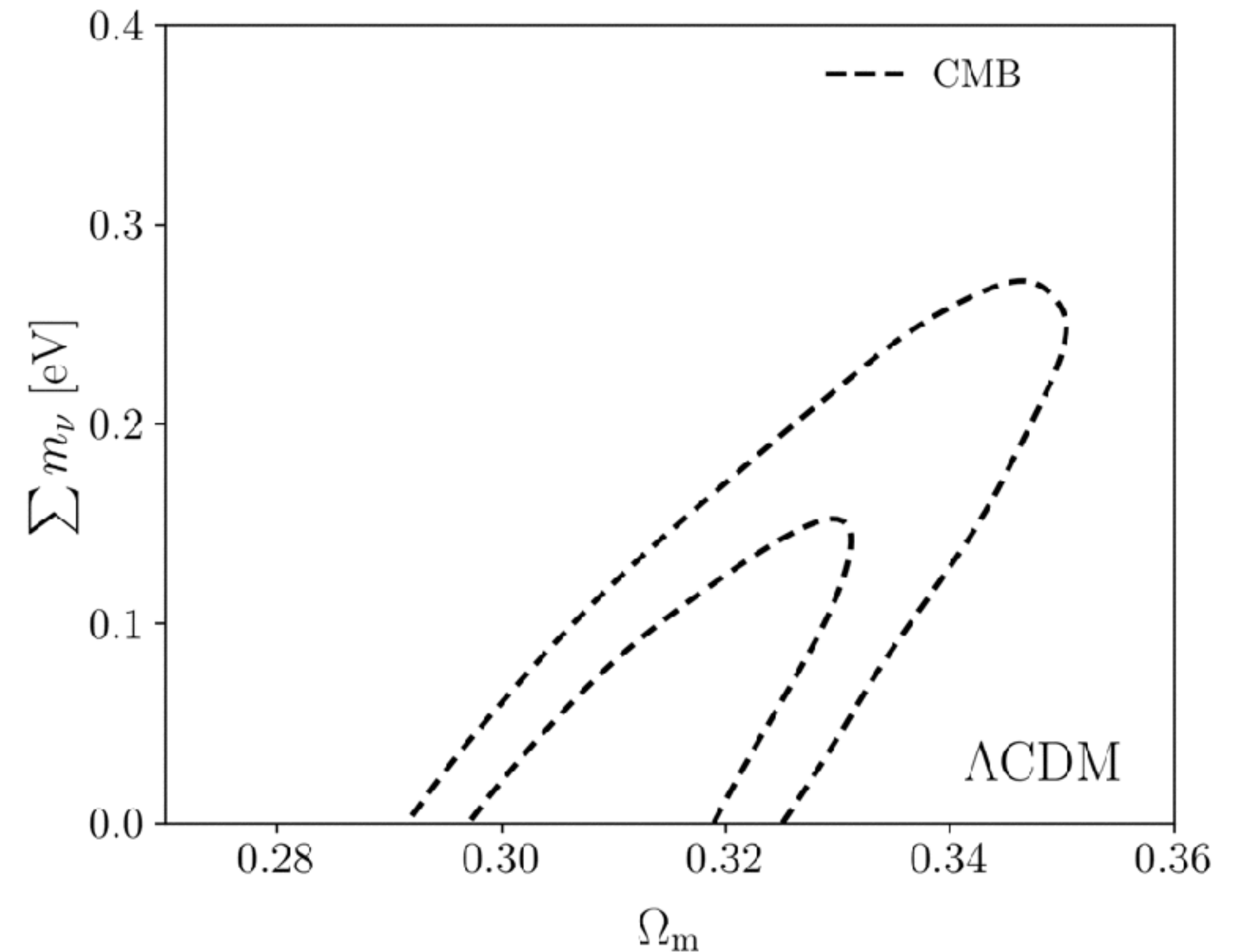
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- Tension has “stabilized” at about $3.2\text{-}3.4\sigma$



Neutrino mass

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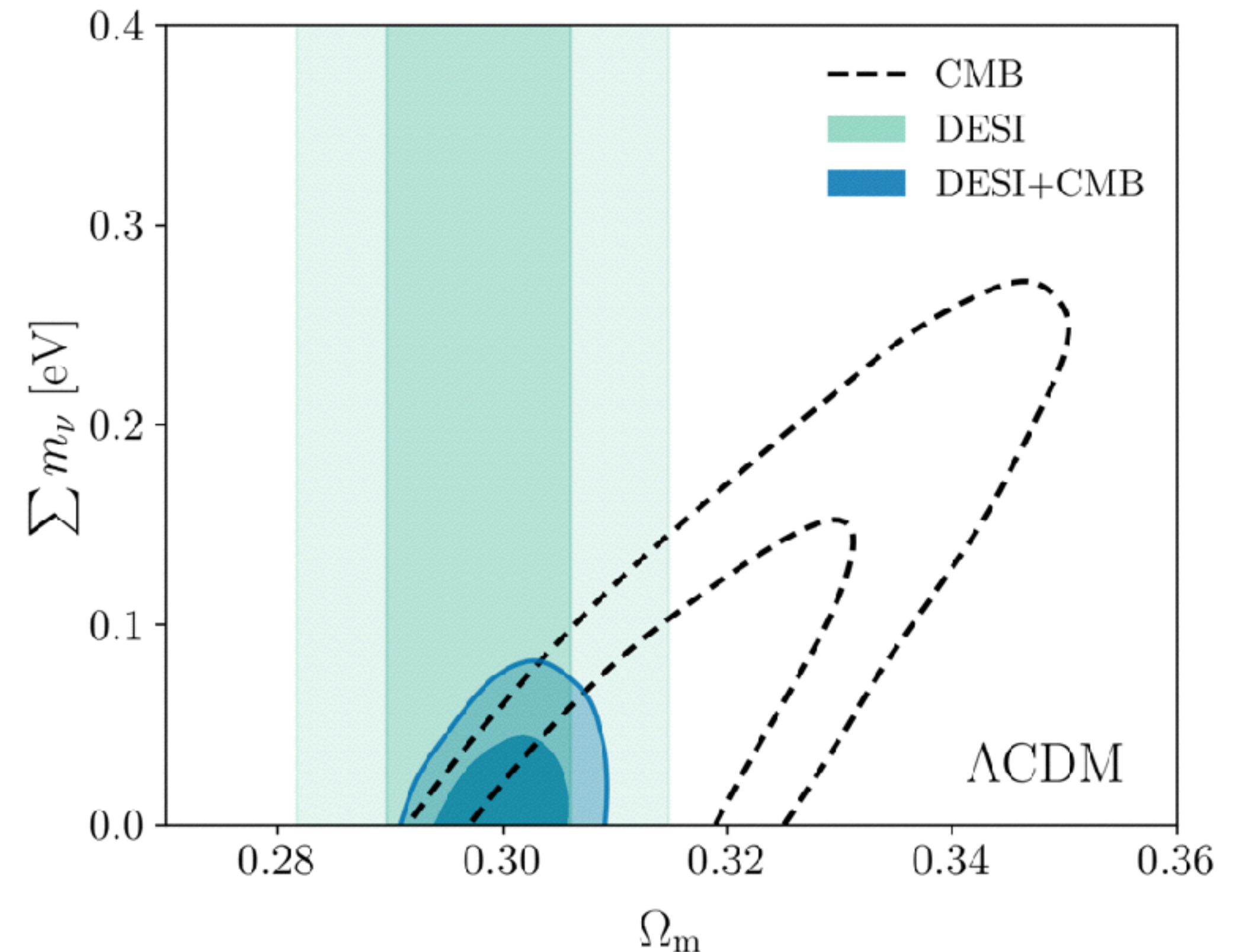


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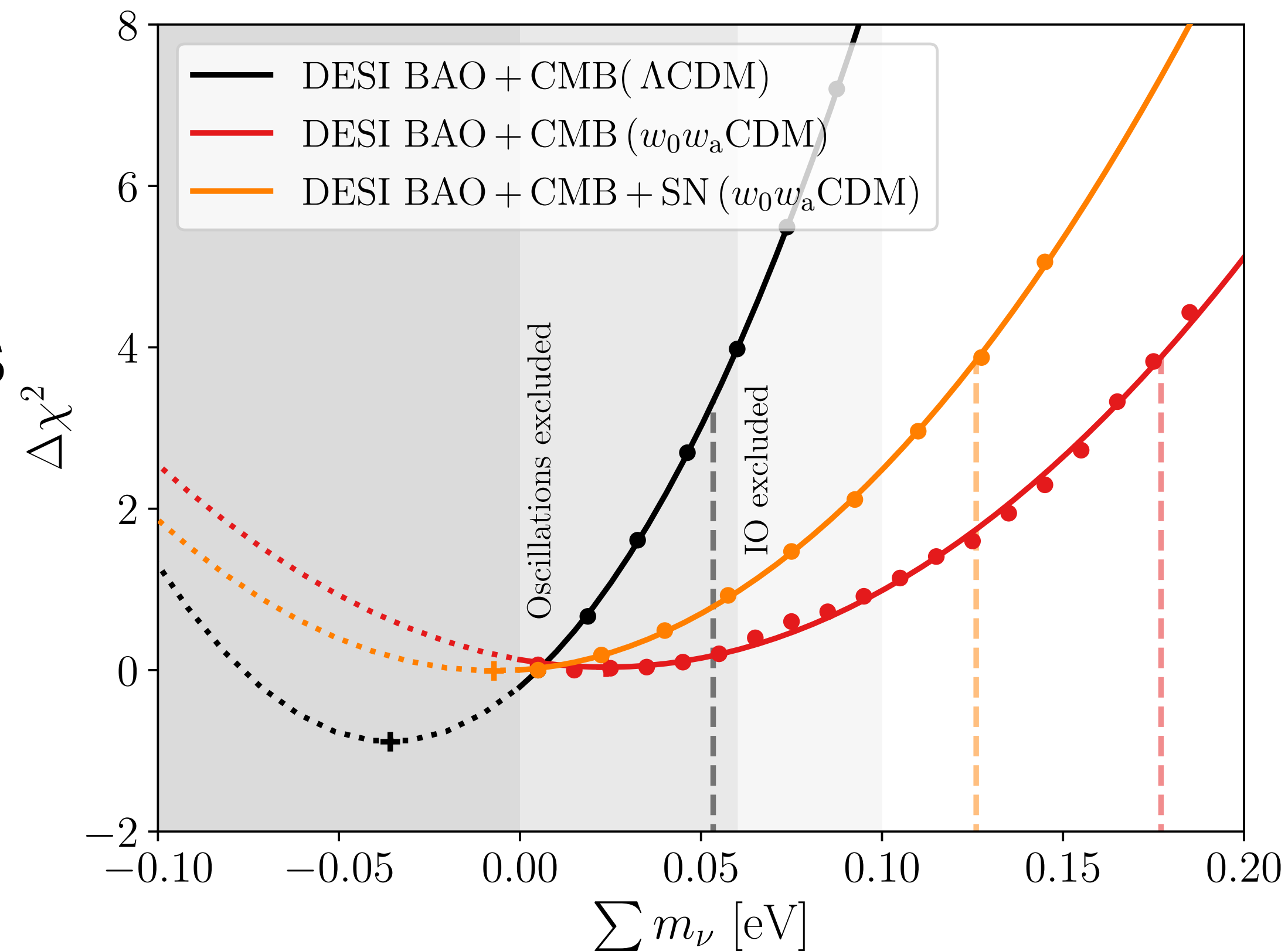


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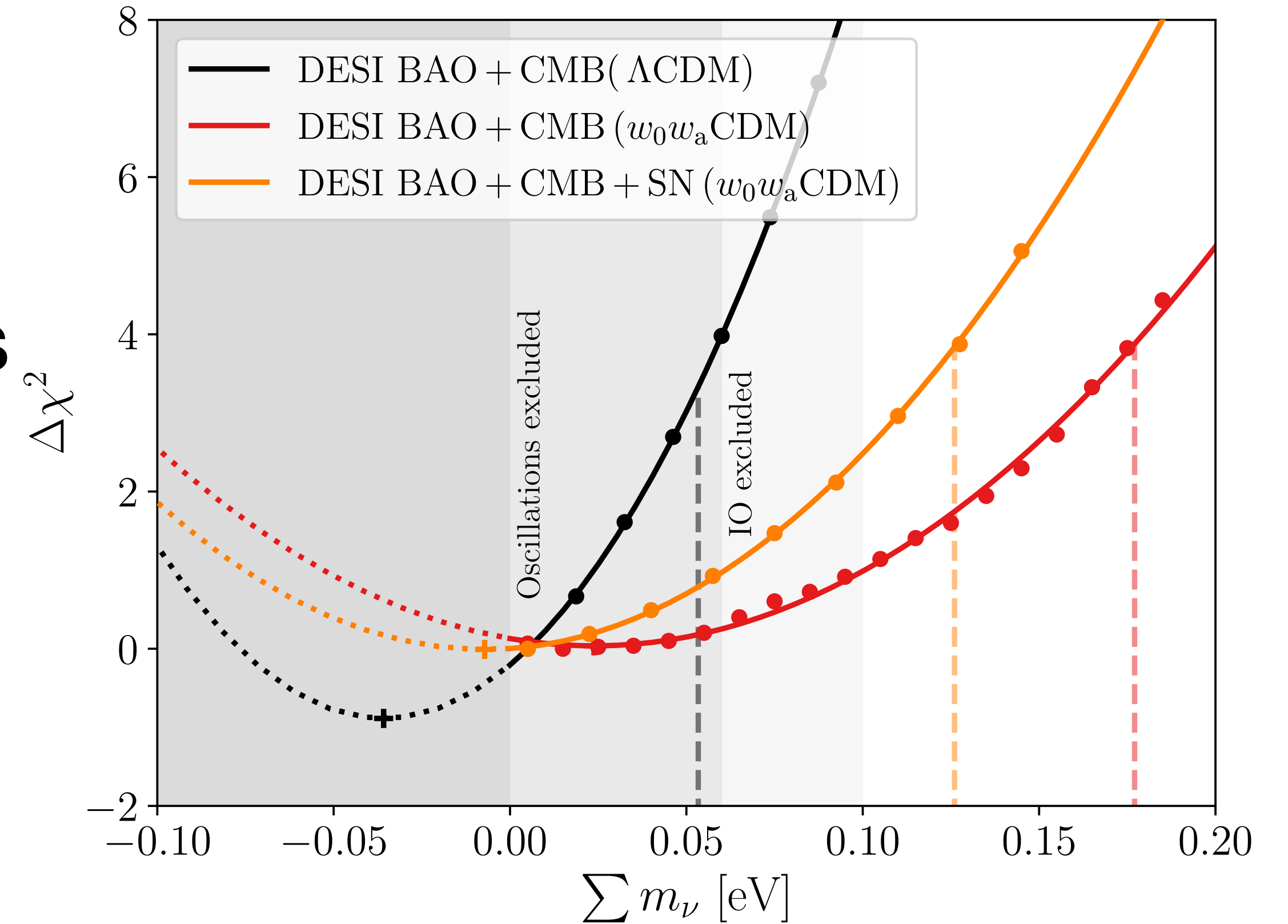
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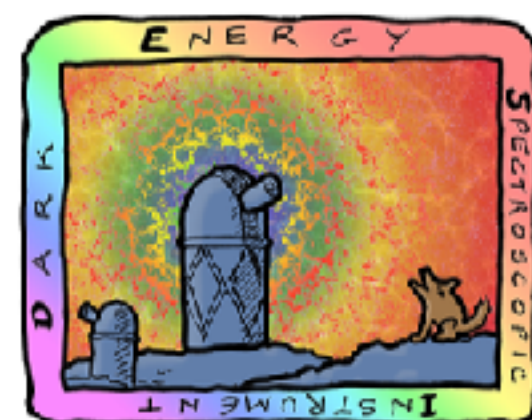
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- Relaxed by $w_0 w_a \text{CDM}$...



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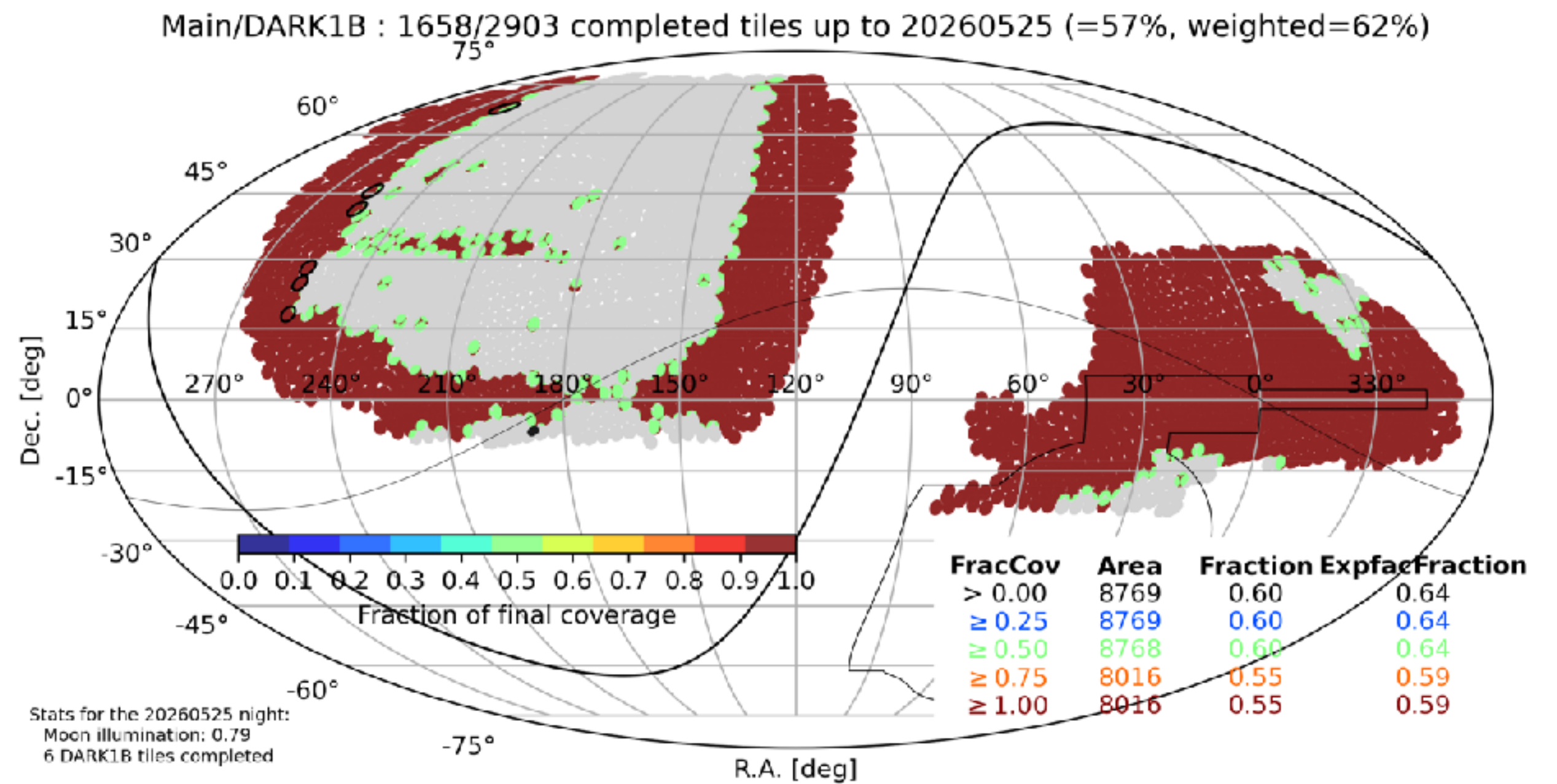
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Chat with me
about this! 😊

📄 DR2 PNG / local f_{NL} , Chaussidon et al, in prep
📄 Window matrix forward modeling, Chebat et al, in prep

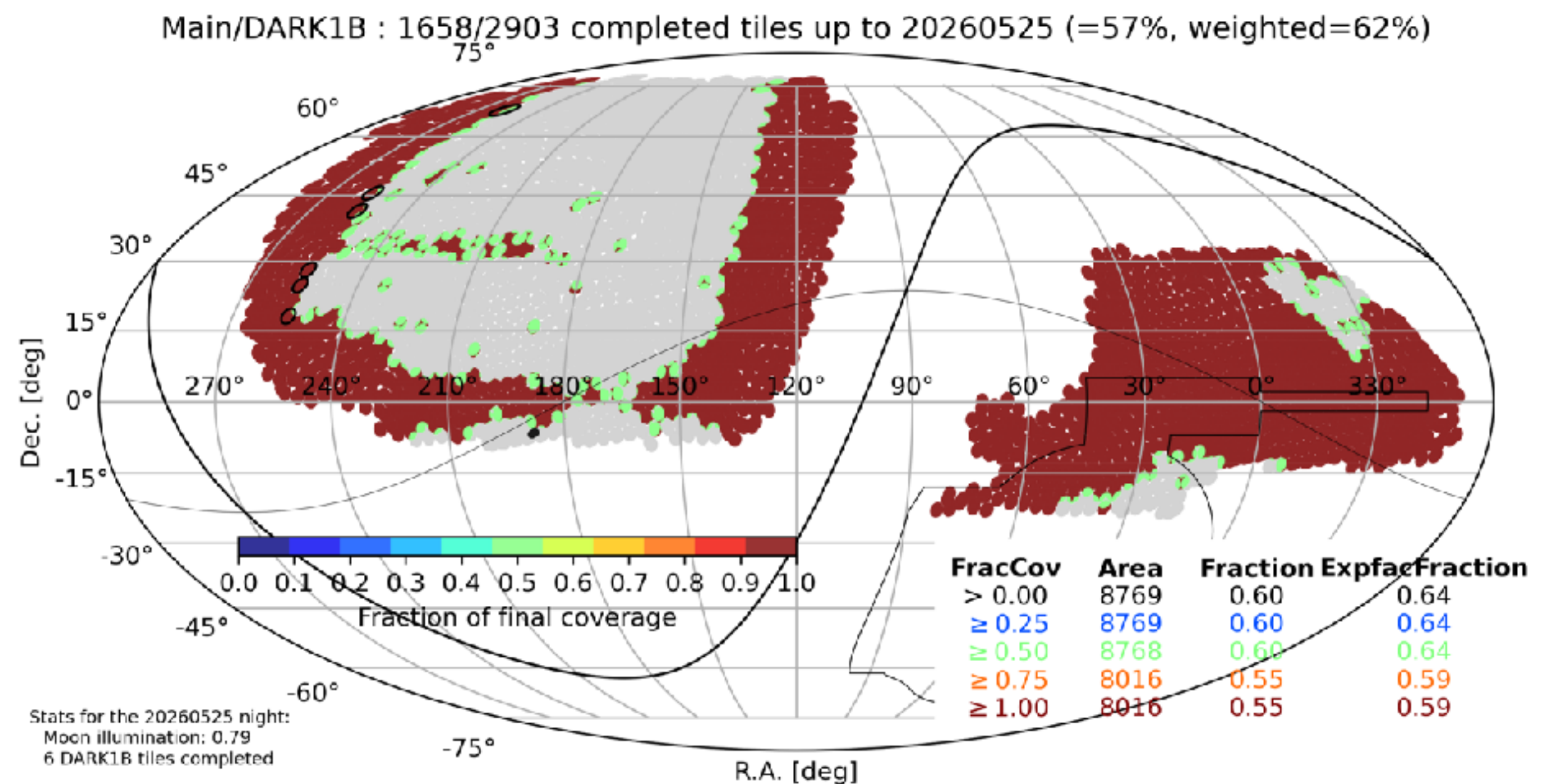
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- DR3 with five years of observations (from 2027 onwards)



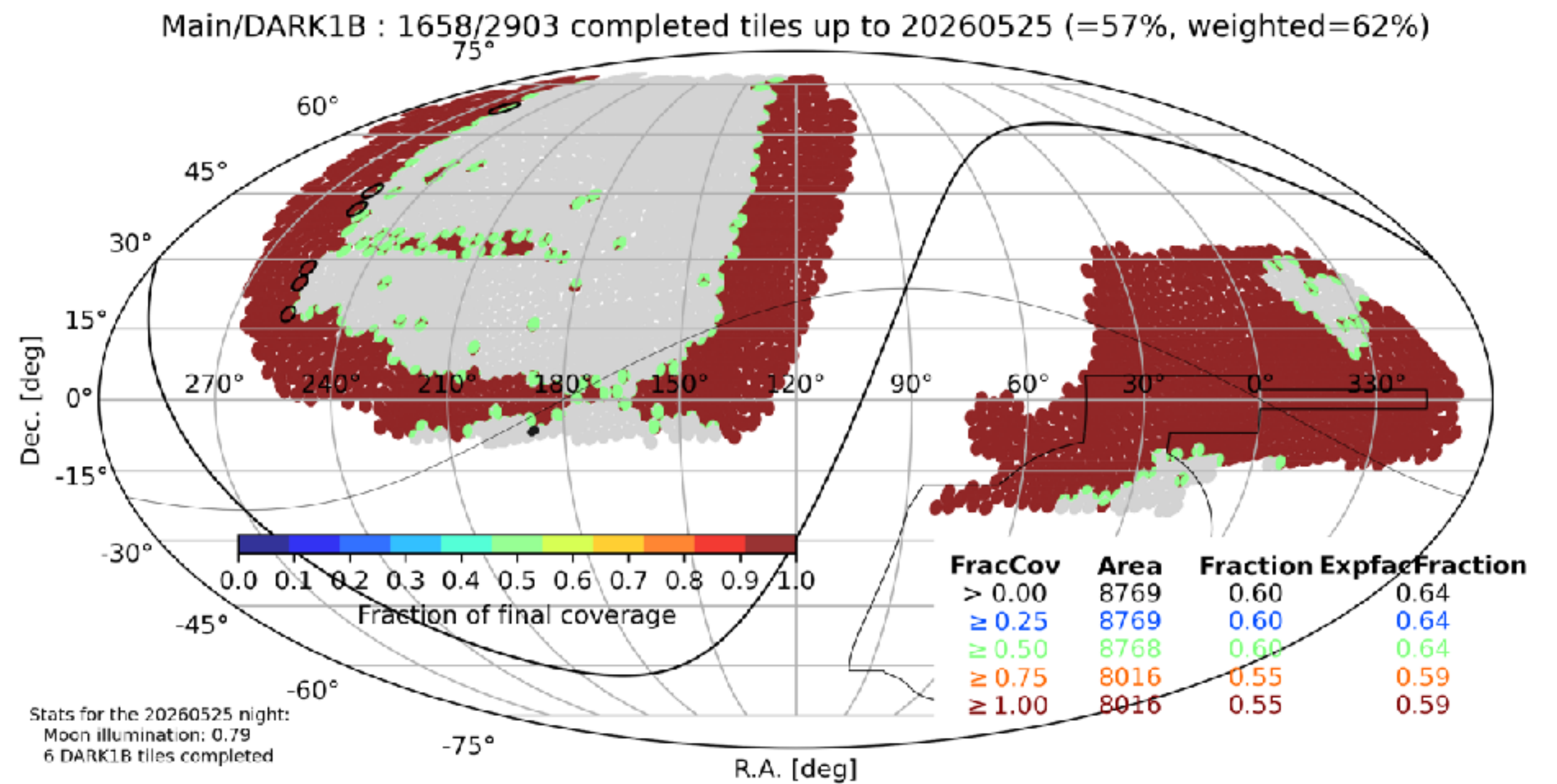
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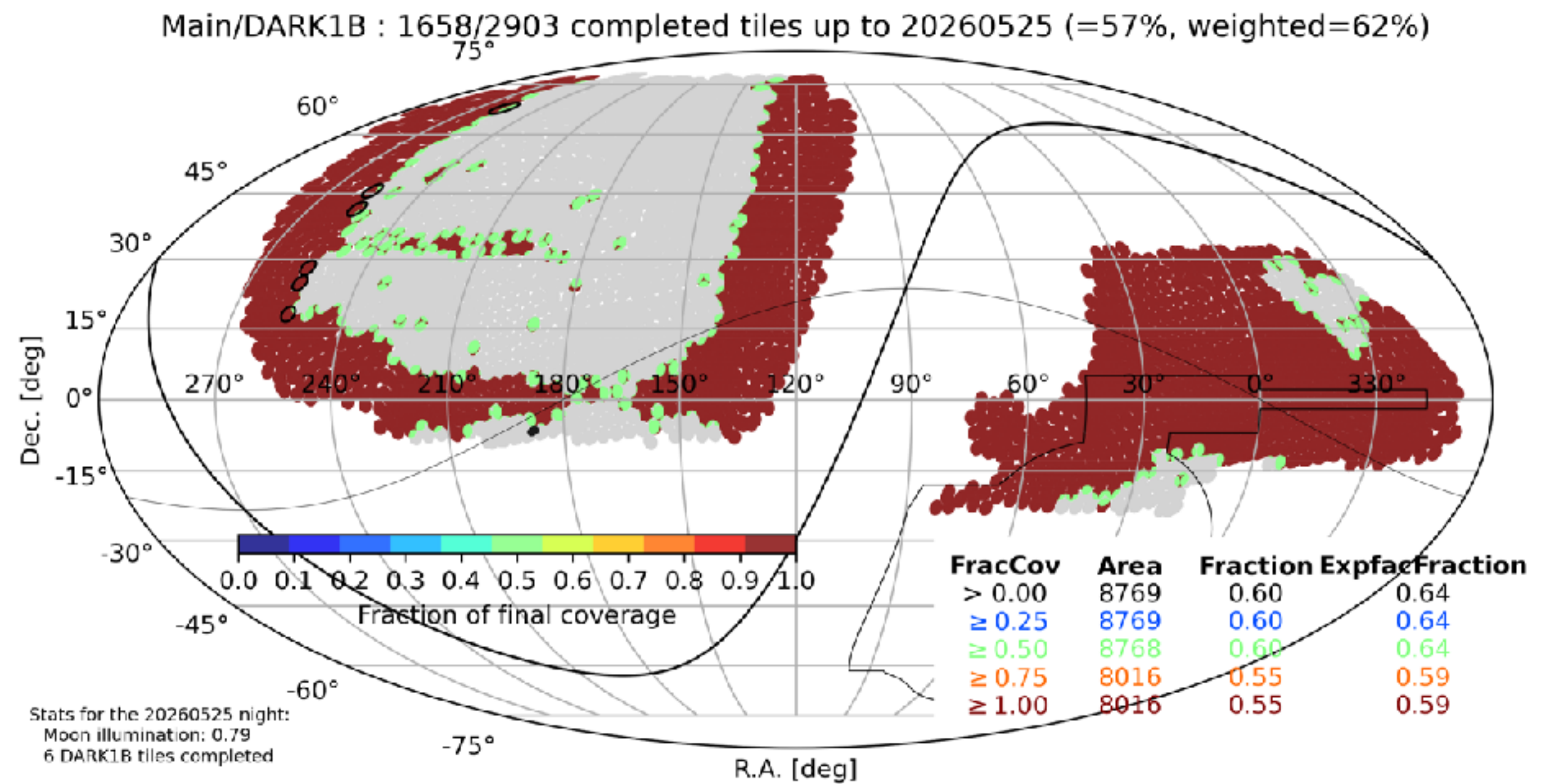
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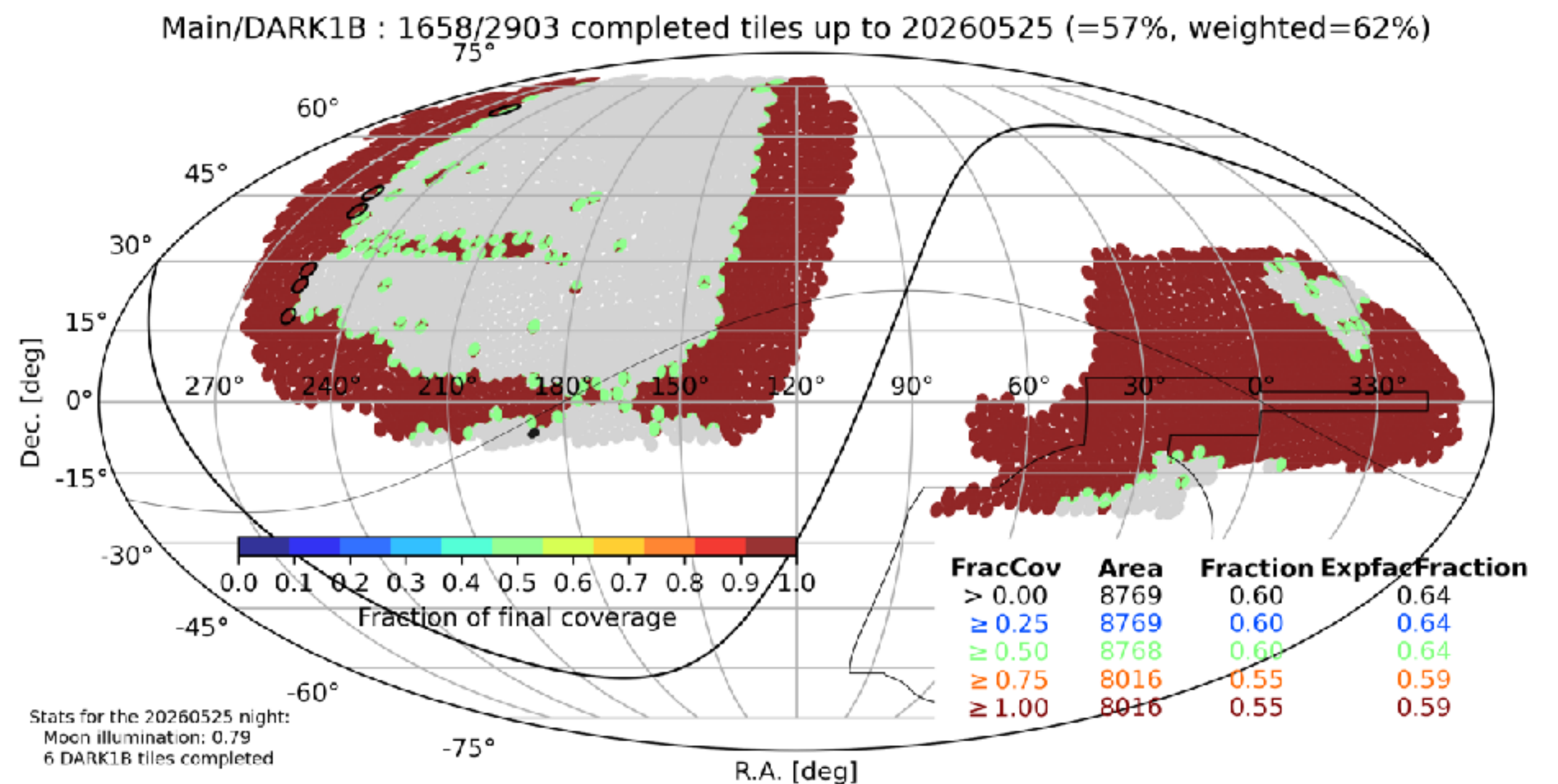
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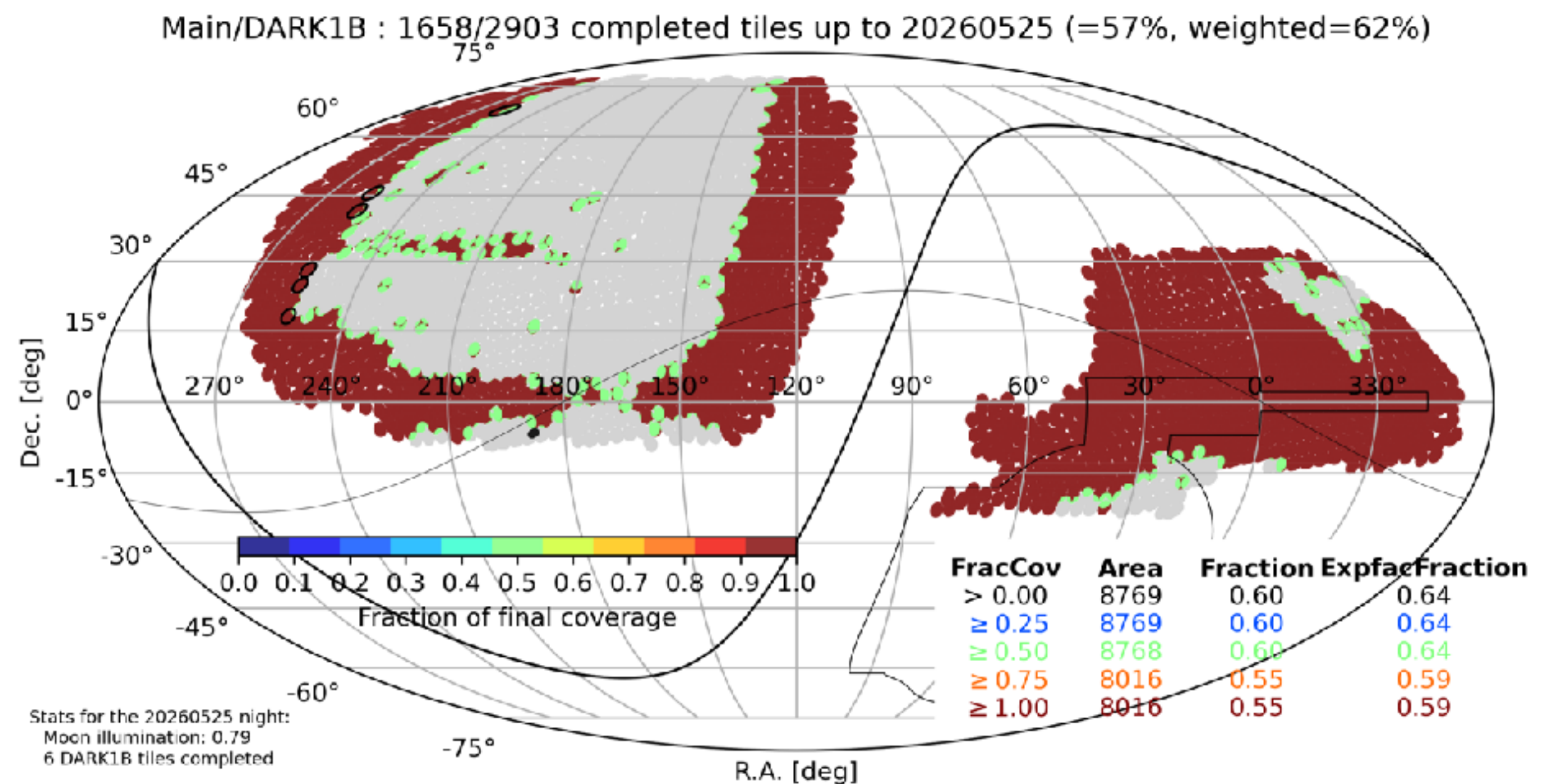
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- Stay tuned for DESI DR5!

