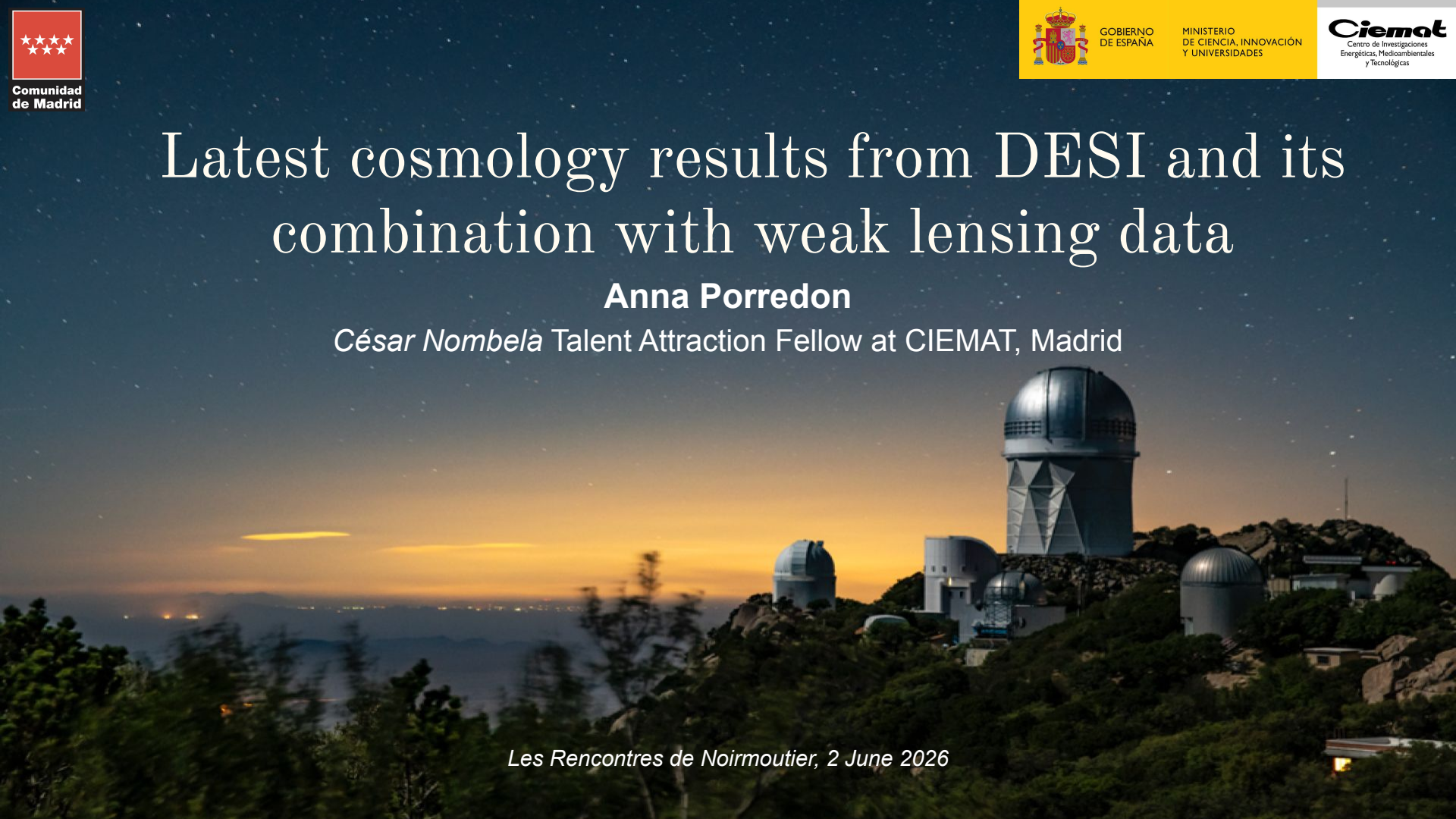
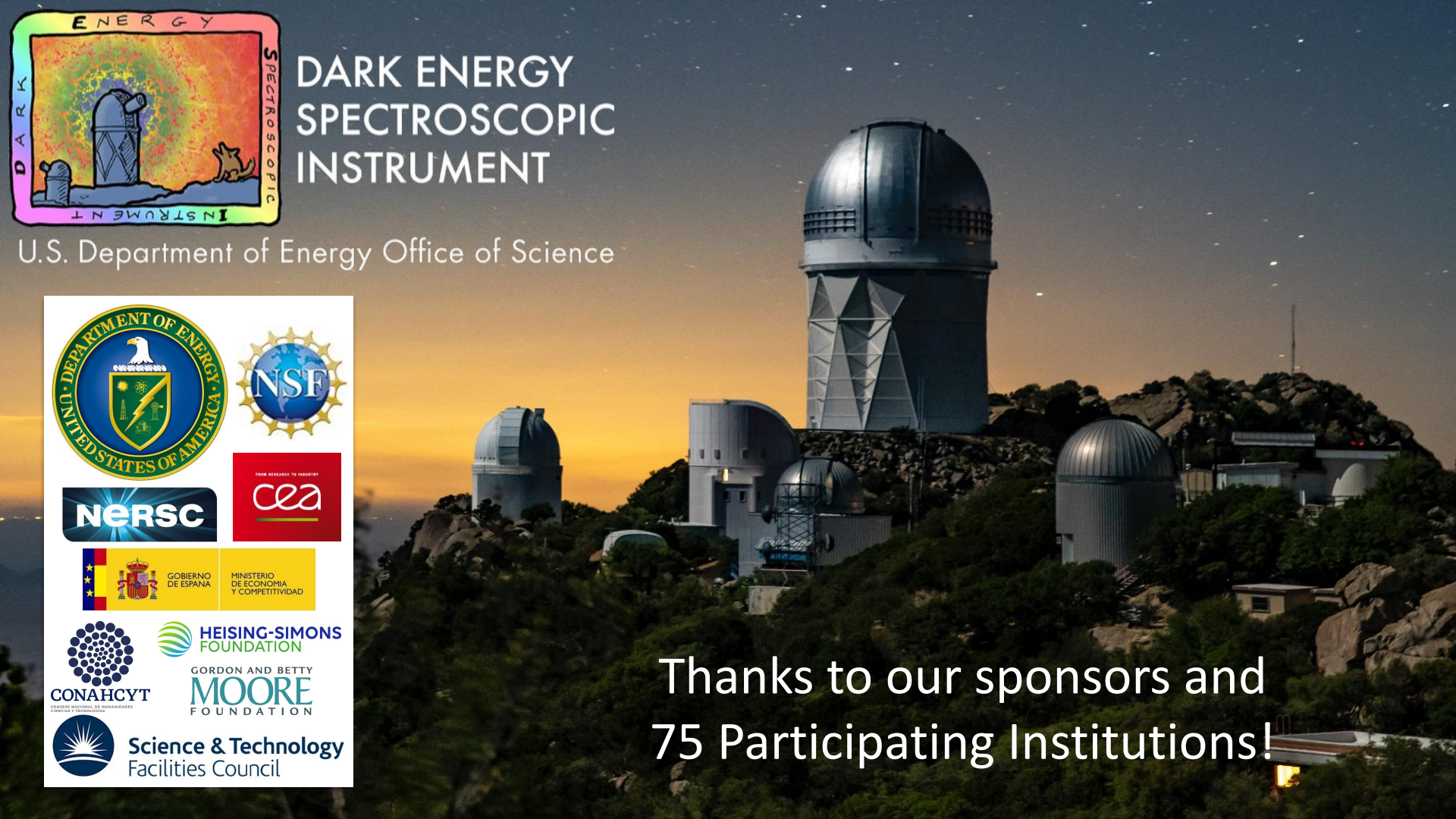


Latest cosmology results from DESI and its combination with weak lensing data

Anna Porredon

César Nombela Talent Attraction Fellow at CIEMAT, Madrid

Les Rencontres de Noirmoutier, 2 June 2026


ENERGY
DARK
SPECTROSCOPIC
INSTRUMENT
DARK ENERGY
SPECTROSCOPIC
INSTRUMENT
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CONAHCYT
GORDON AND BETTY MOORE FOUNDATION
Science & Technology Facilities Council
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Testing ΛCDM: Are the late time observations compatible with those from the early universe?

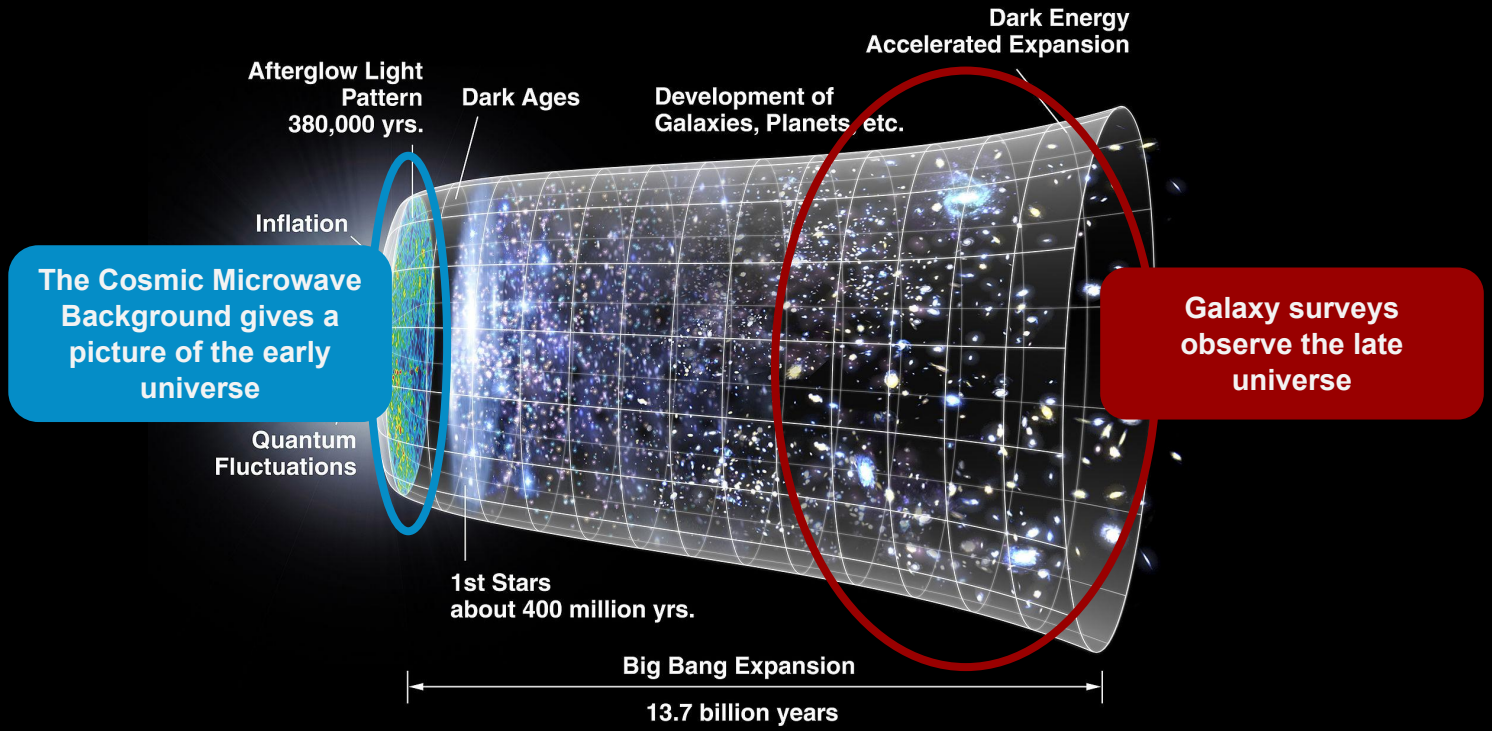
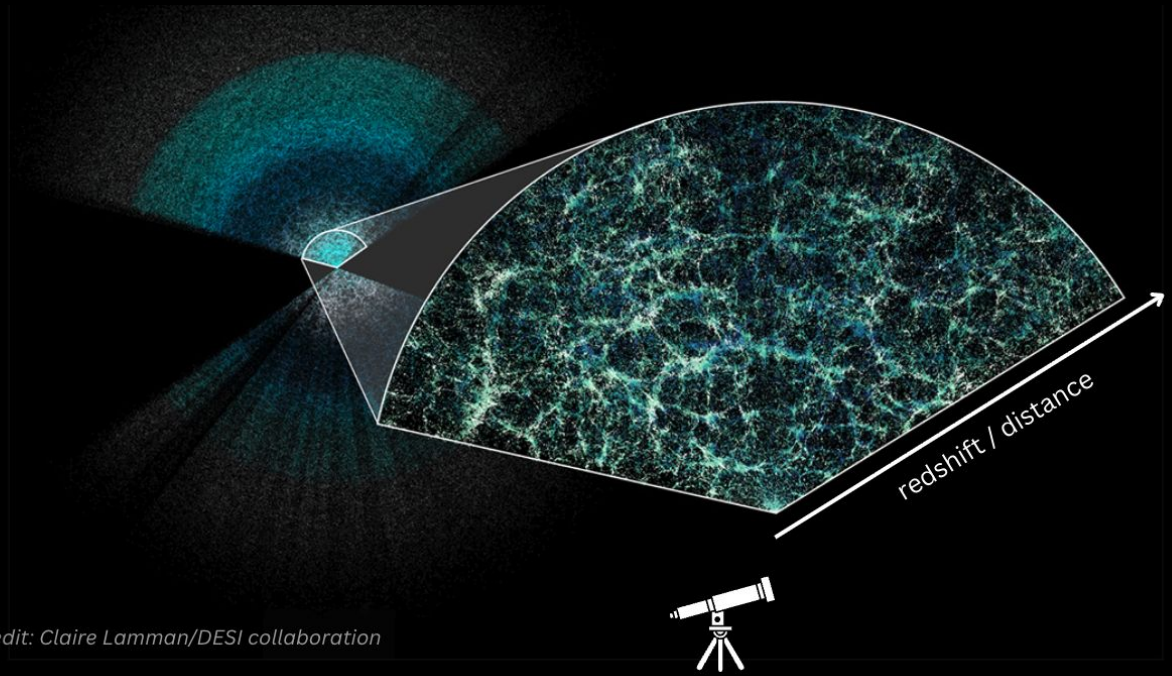


Image Credit: NASA / LAMBDA Archive / WMAP Science Team

Large scale structure and galaxy clustering

We can learn more about dark matter and dark energy by **mapping the distribution of the large scale structure (tracer of the matter distribution in the Universe)**

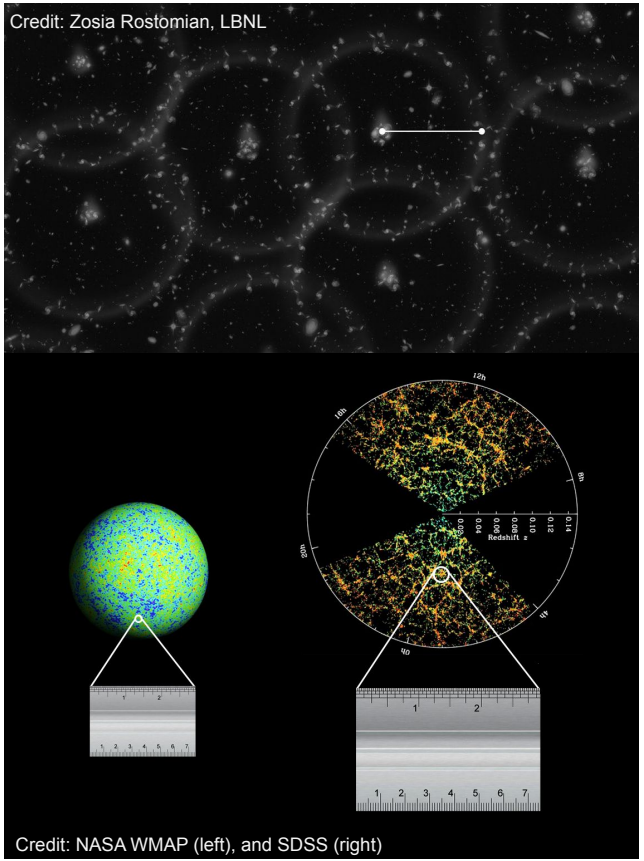


Credit: Claire Lamman/DESI collaboration

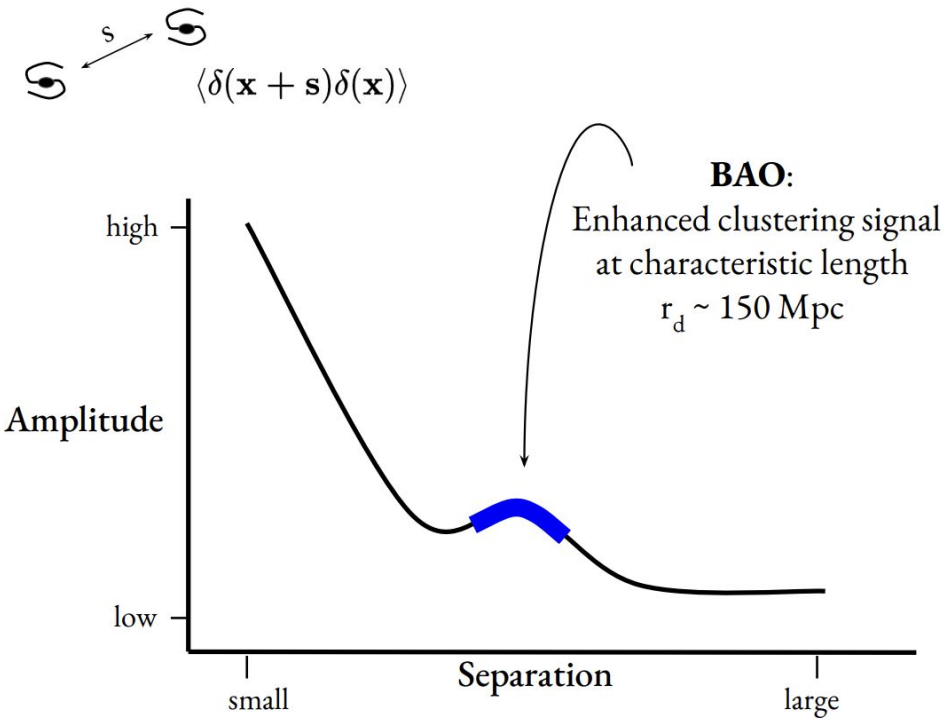
- The positions of galaxies are tracers of the underlying matter distribution
- We use two-point statistics to characterize the distribution of the positions of galaxies (**galaxy clustering**)

Baryon Acoustic Oscillations (BAO)

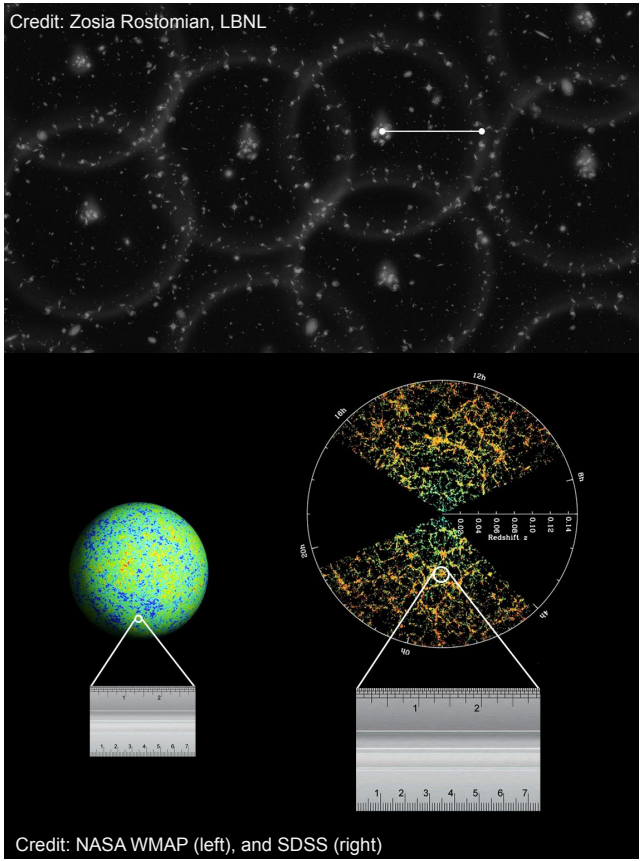
- The interplay between gravity and pressure in the early-Universe hot plasma generated sound waves that propagated through it
- At the time of decoupling, the waves froze, leaving an imprint on the spatial distribution of matter
- This particular scale can still be observed today in the distribution of matter and serves as a standard ruler



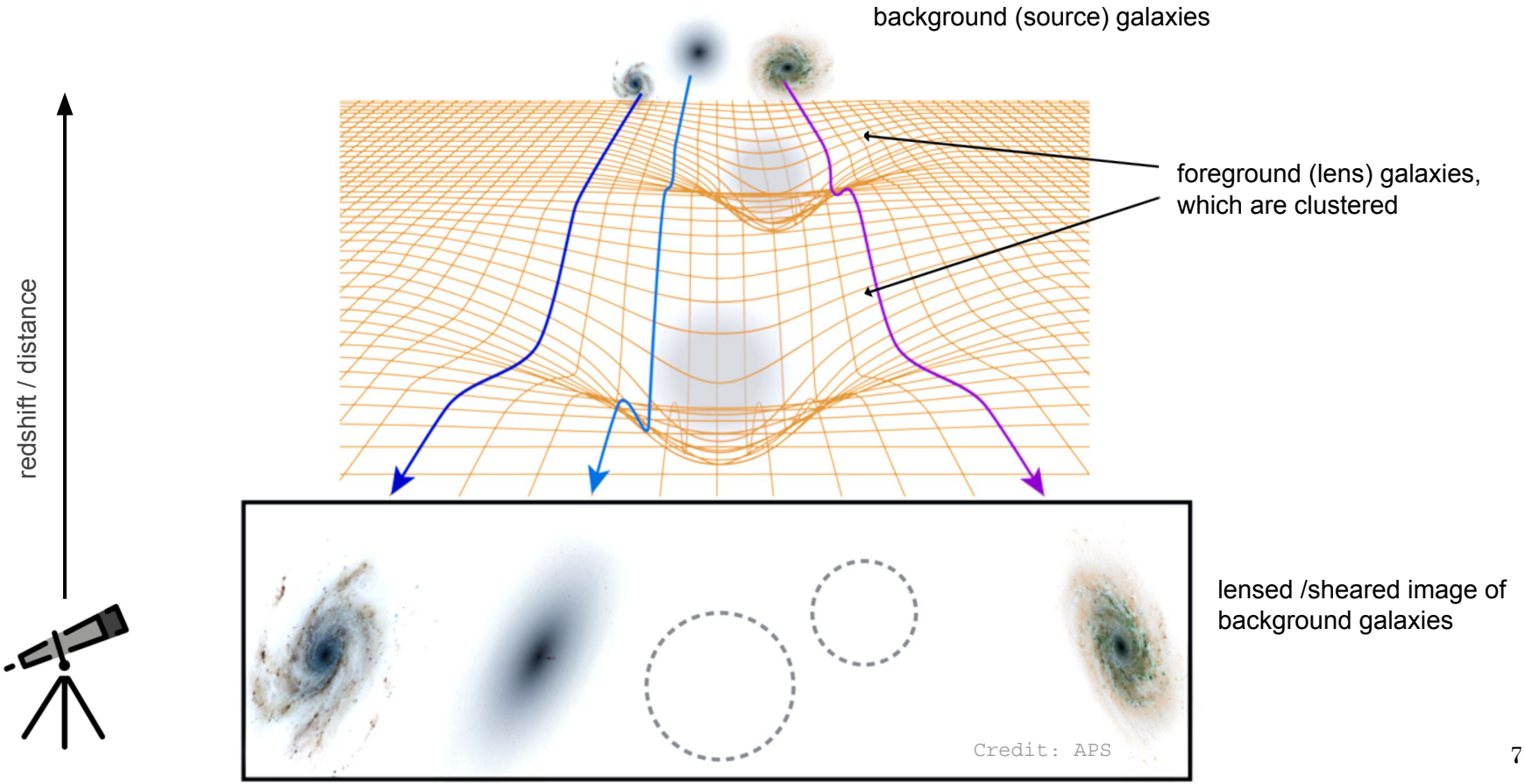
Baryon Acoustic Oscillations (BAO)

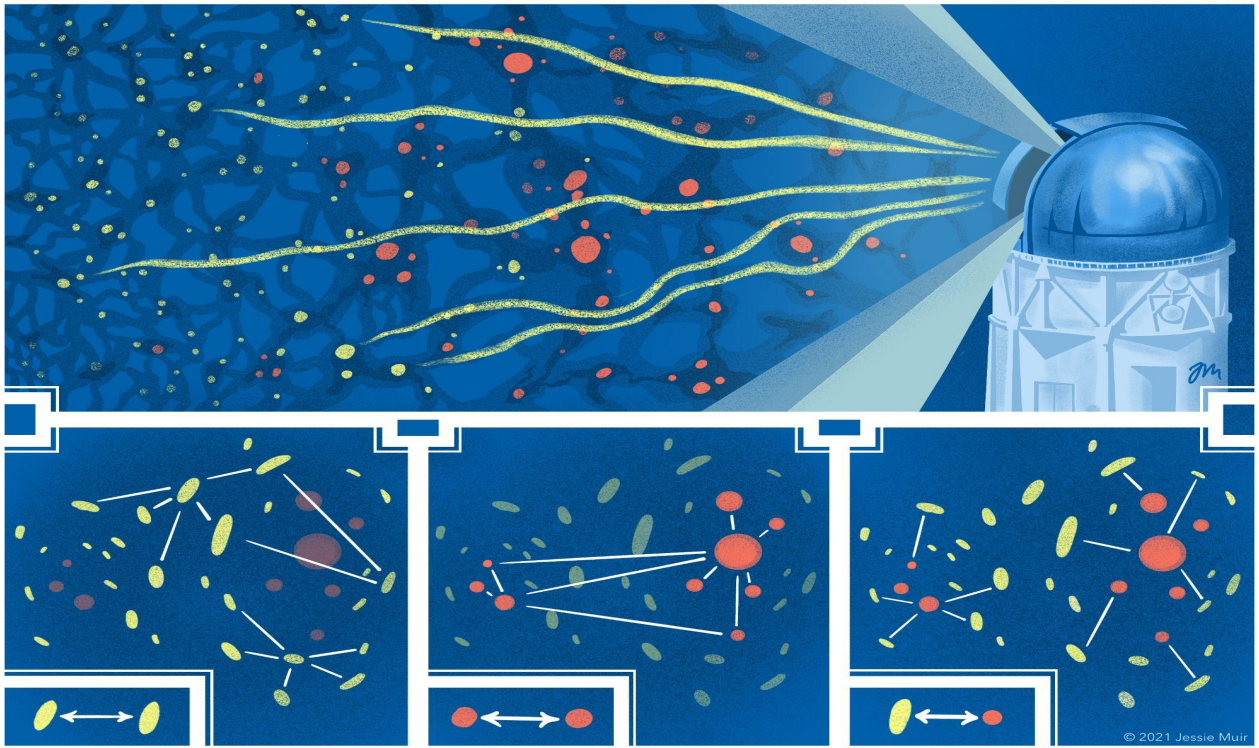


Credit: Rafaela Gsponer



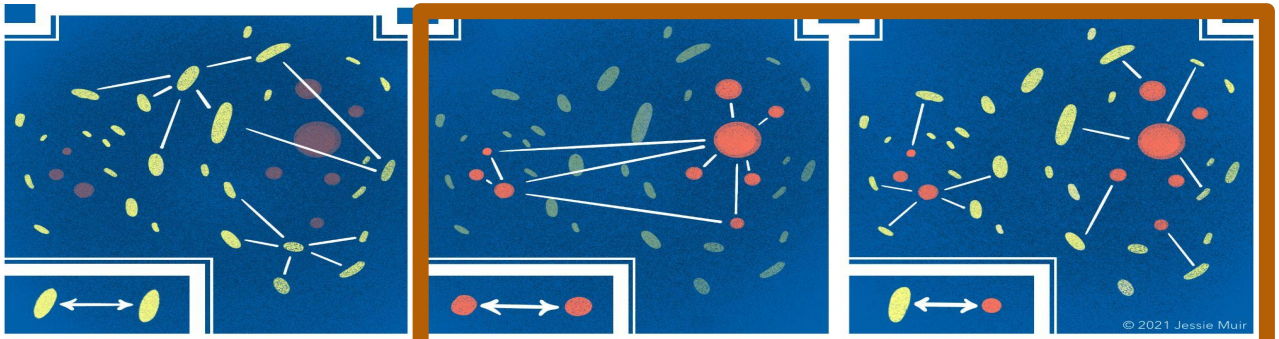
Weak gravitational lensing





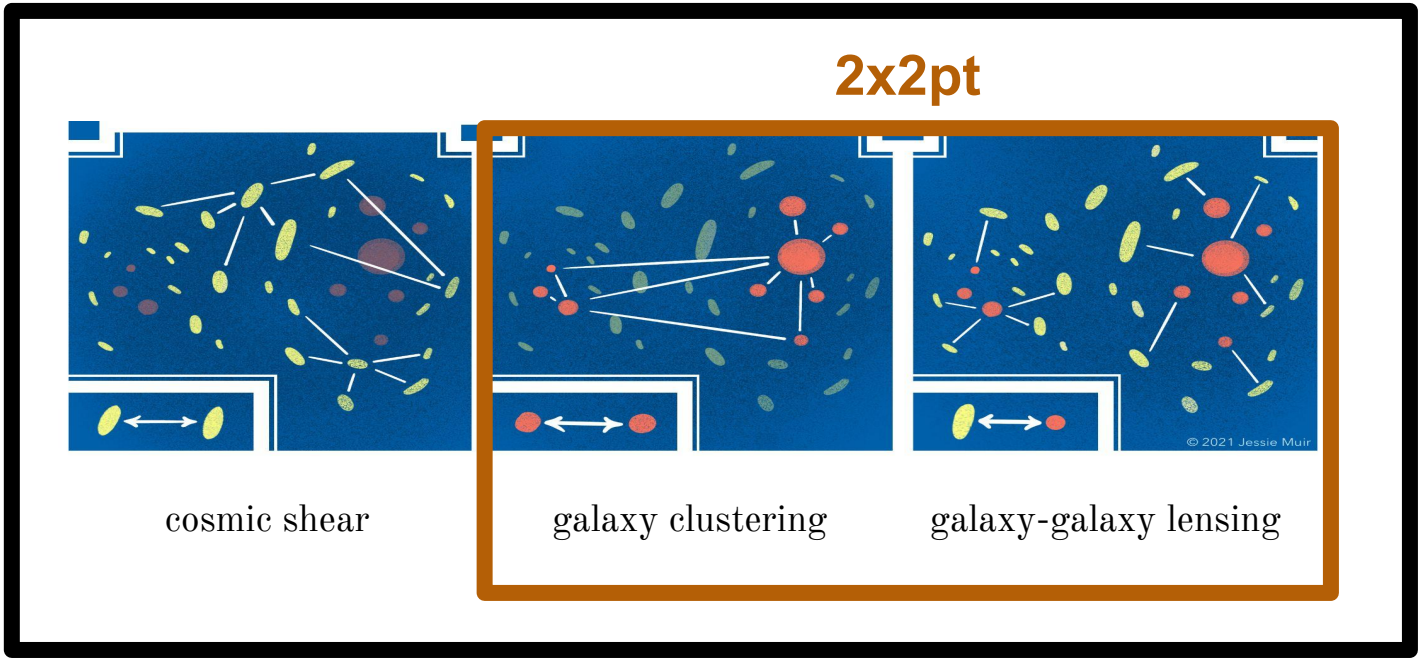
cosmic shear	galaxy clustering	galaxy-galaxy lensing
correlation in the shapes of (source) galaxies	correlation in the positions of (lens) galaxies	correlation between positions of the lenses and shapes of the sources

2x2pt

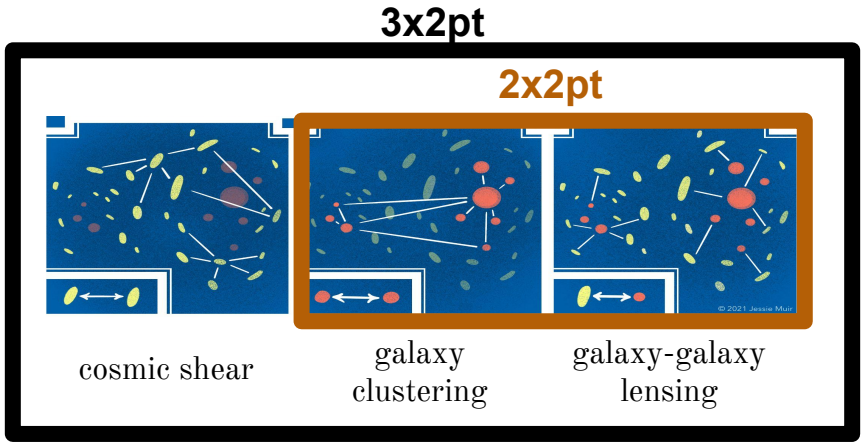


cosmic shear | galaxy clustering | galaxy-galaxy lensing

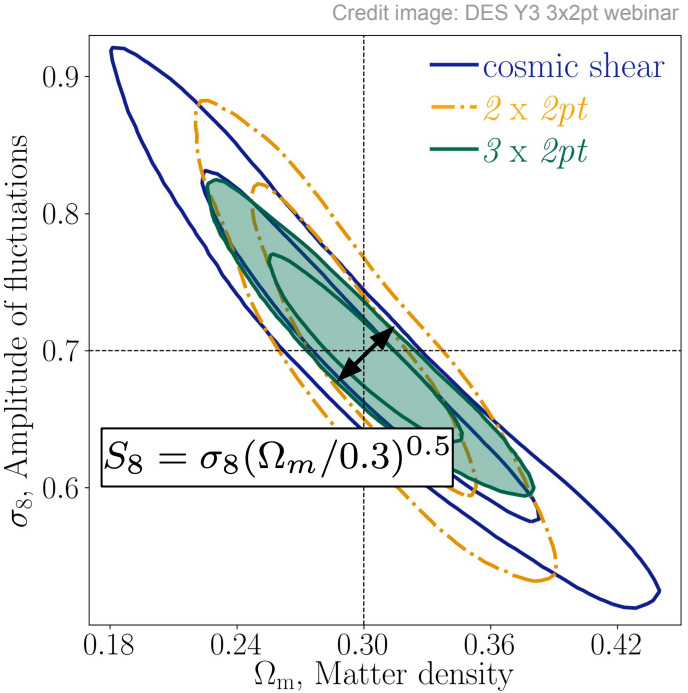
3x2pt


2x2pt
© 2021 Jessie Muir
cosmic shear
galaxy clustering
galaxy-galaxy lensing

3x2pt cosmology

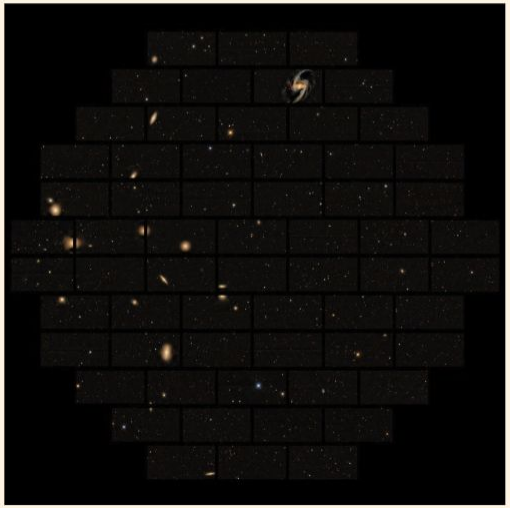


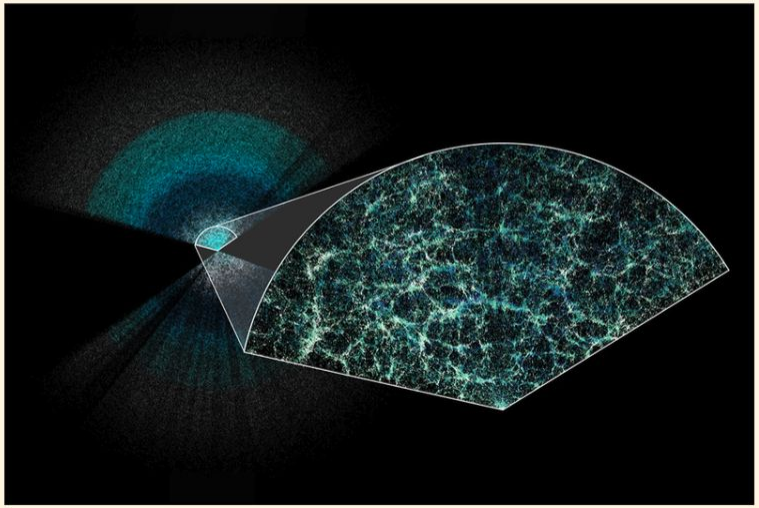
Credit image: DES Y3 3x2pt webinar



A joint analysis maximizes the cosmological information and robustly constrains astrophysical & observational systematics in the analysis!

SURVEYS
photometric vs spectroscopic

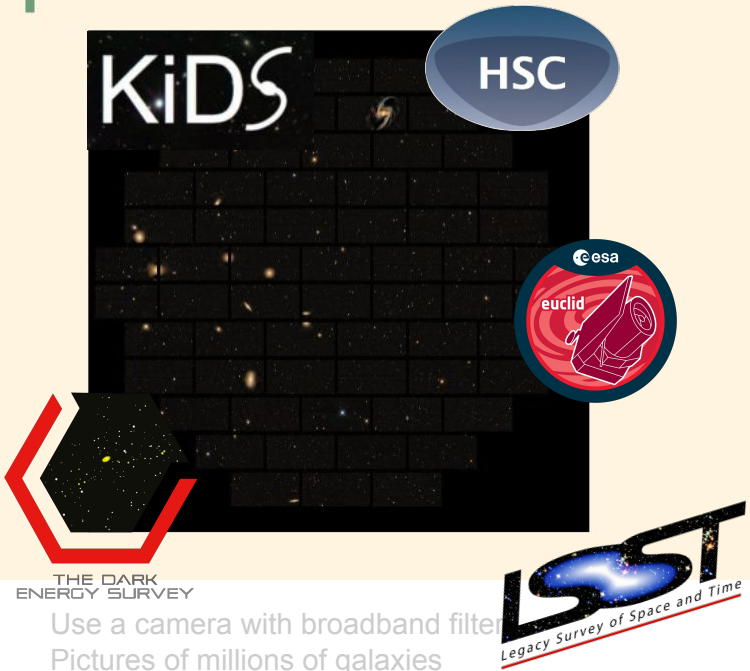




- Use a camera with broadband filters
- Pictures of millions of galaxies
- Allows to measure **weak gravitational lensing** of galaxies
- Needed to find the targets for spectroscopic surveys
- Worse precision for the redshift of galaxies

- Obtain the spectra from each object/galaxy
- Allows to measure the redshift of galaxies with high precision
- Allows to measure **galaxy clustering with high precision**

SURVEYS
photometric vs spectroscopic



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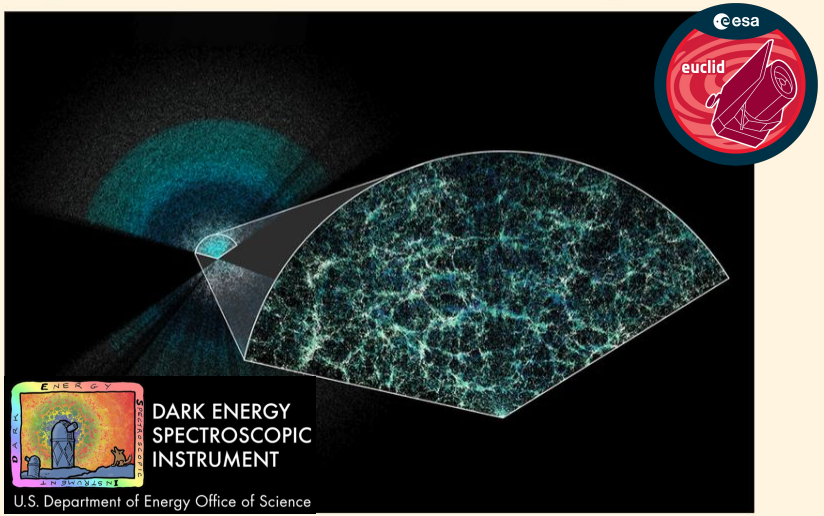


- Obtain the spectra from each object/galaxy
- Allows to measure the redshift of galaxies with high precision
- Allows to measure **galaxy clustering with high precision**

Dark Energy Spectroscopic Instrument

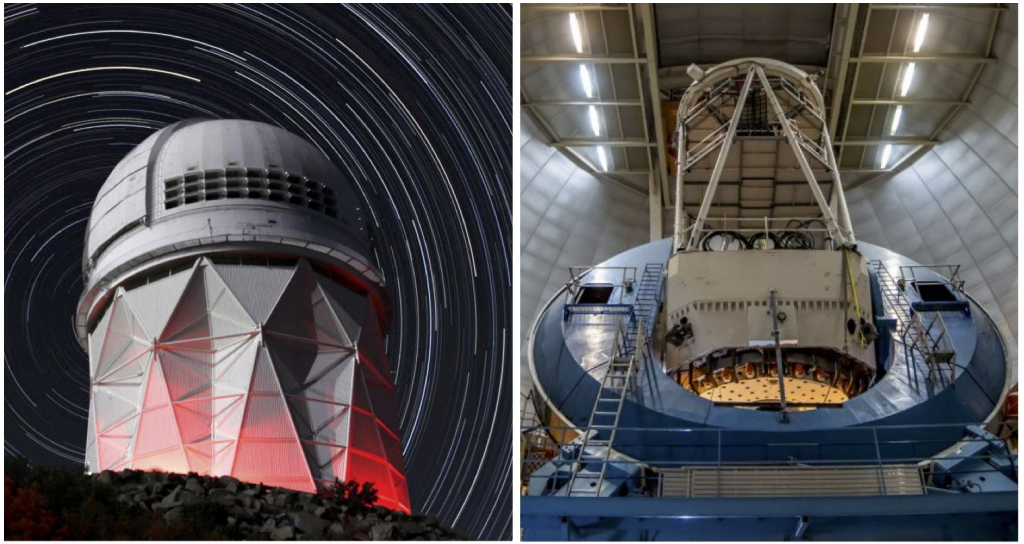
DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

Stage IV 5-year spectroscopic survey using the Mayall 4-meter telescope at Kitt Peak National Observatory, Arizona (USA)

The DESI survey started in May 2021 and just finished the first 5 years of observations

The instrument has **5000 robotically-controlled optical fibres**. In total, it's expected to catalogue redshifts from over **60 million galaxies** in 8 years, covering 17,000 sq. deg.

Image credit: DESI



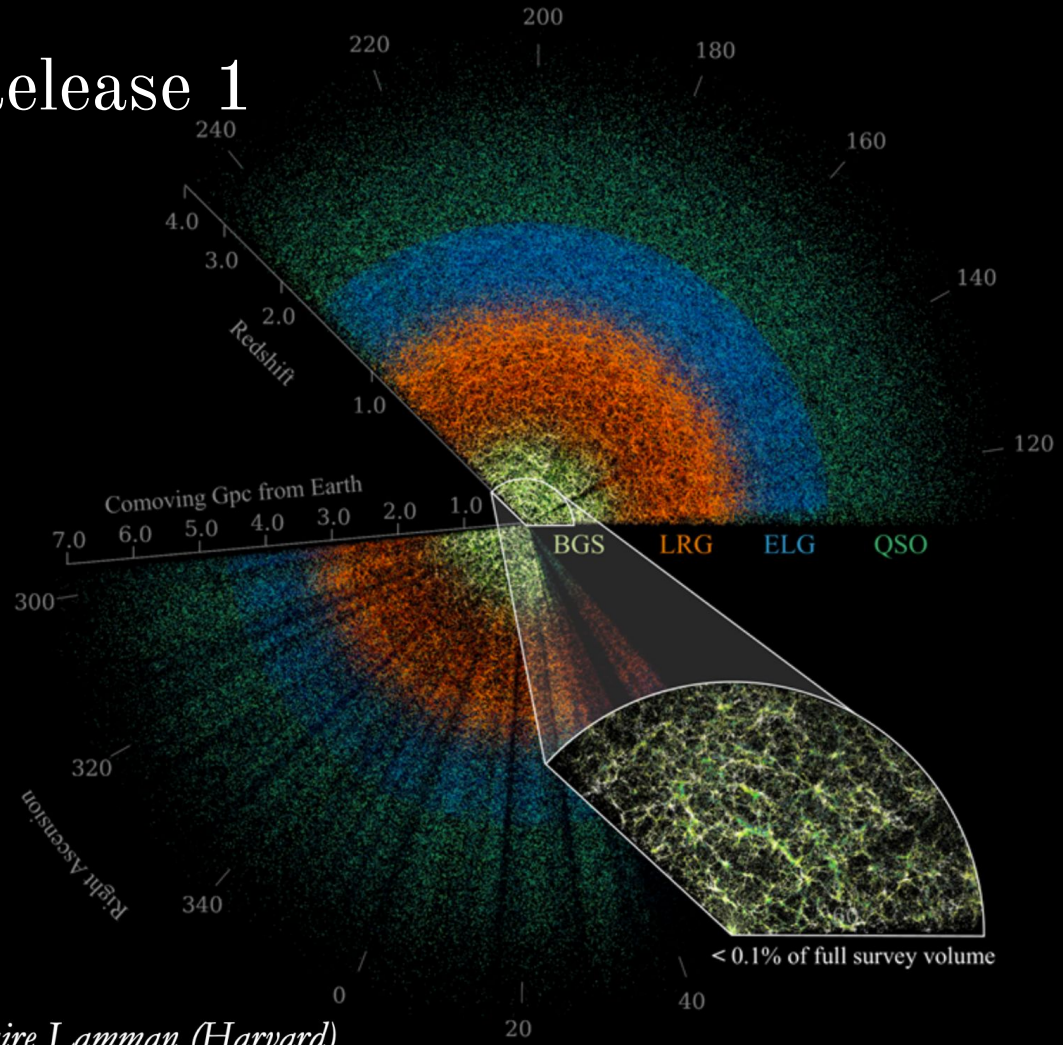
4m Mayall at Kitt Peak, Arizona. Twin to the Blanco, CTIO

DESI Data Release 1

DESI collaboration 2025
https://arxiv.org/abs/2503.14745

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

DR1: 13.1M galaxy redshifts released in March 2025



Credit: Claire Lamman (Harvard)

DESI DR1 footprint and coverage

DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

First year of observations

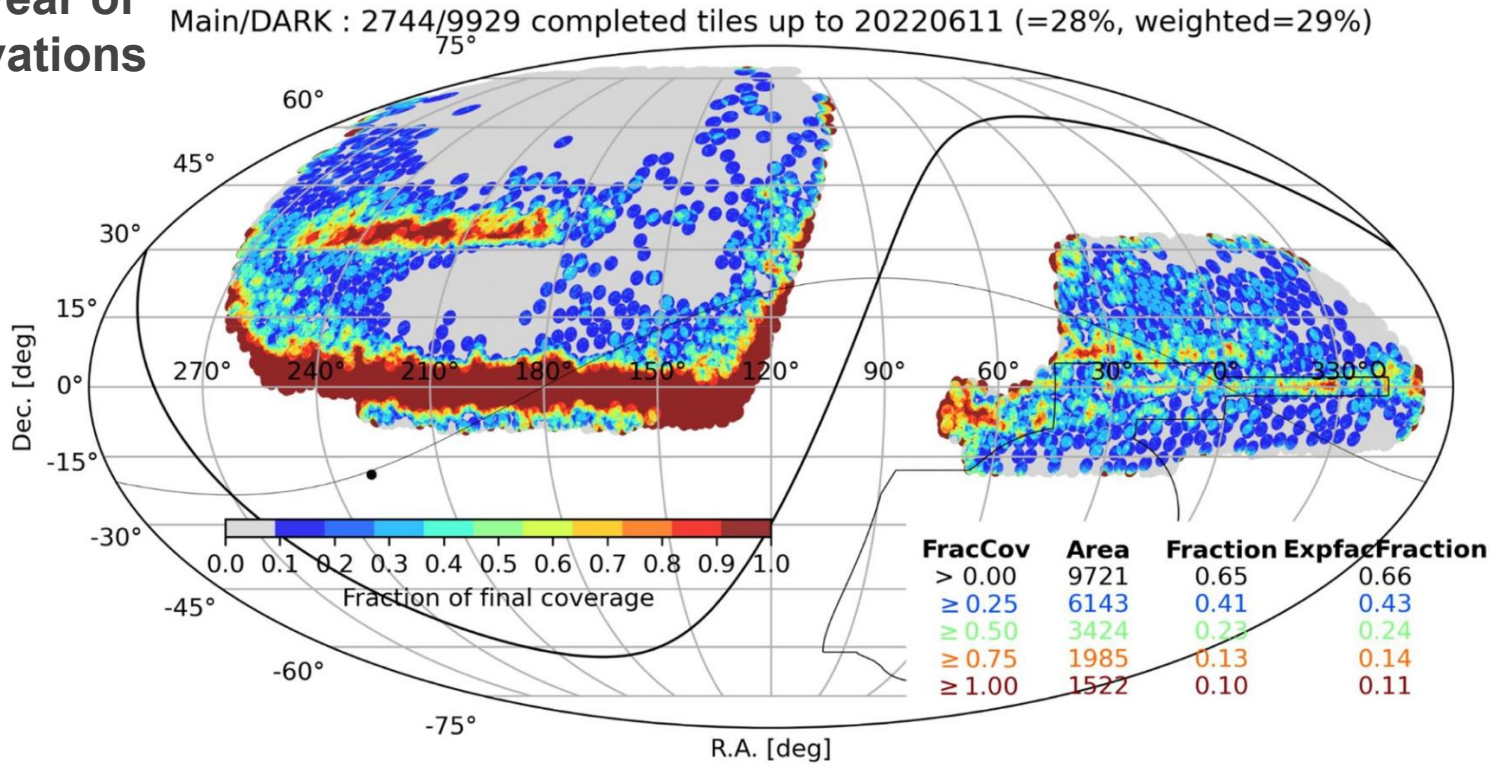


Image credit: DESI

DESI DR2 footprint and coverage

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

First 3 years of observations

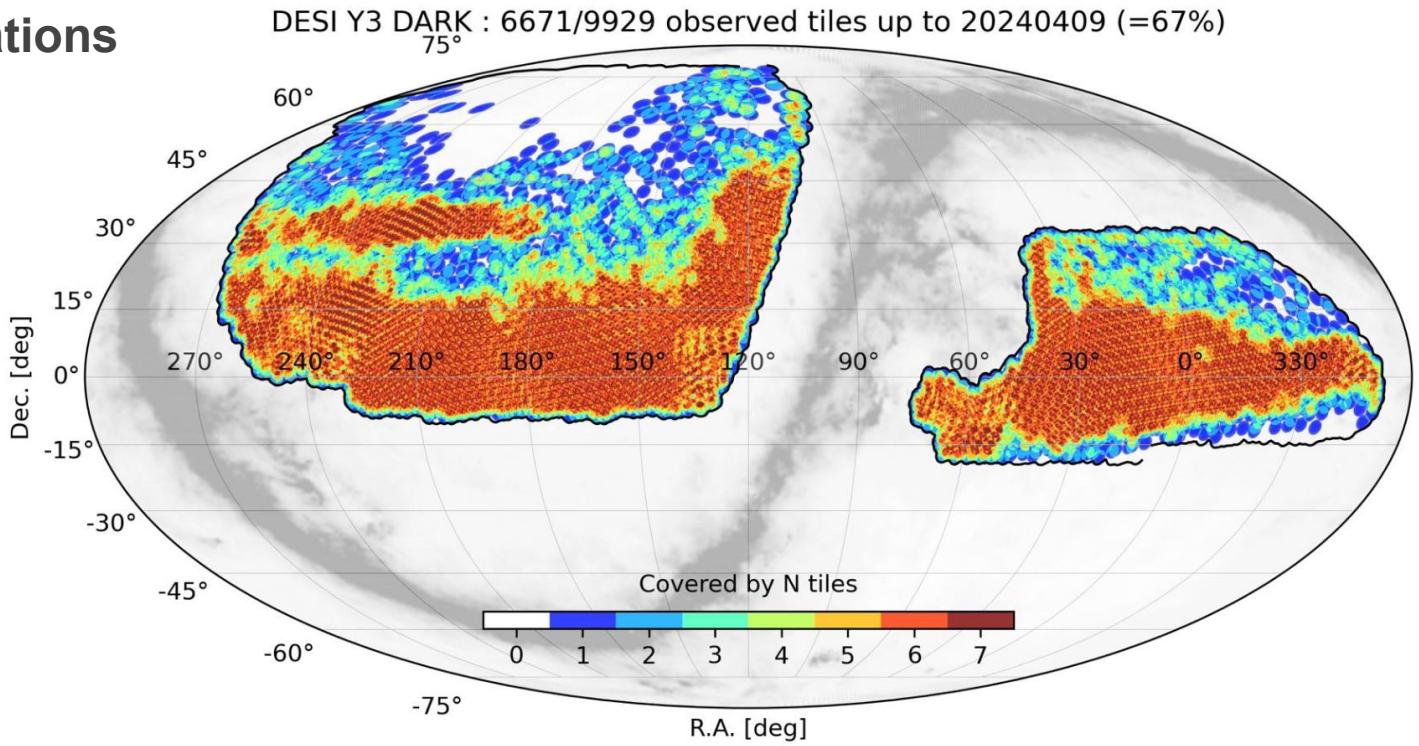


Image credit: DESI

DESI DR3 footprint and coverage

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

First 5 years of observations

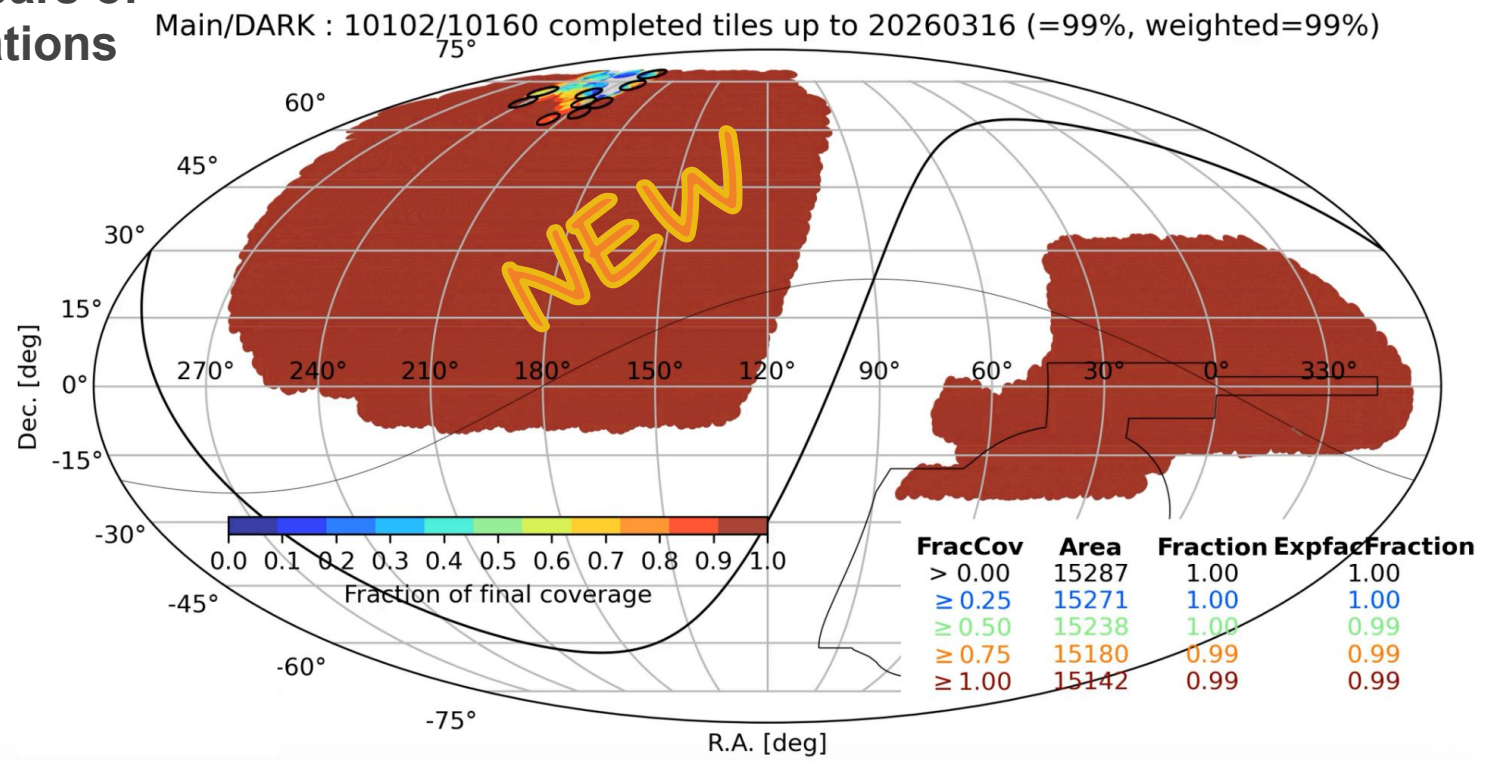
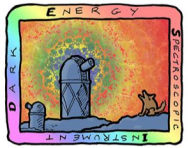


Image credit: DESI

DESI data releases



DARK ENERGY SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Office of Science

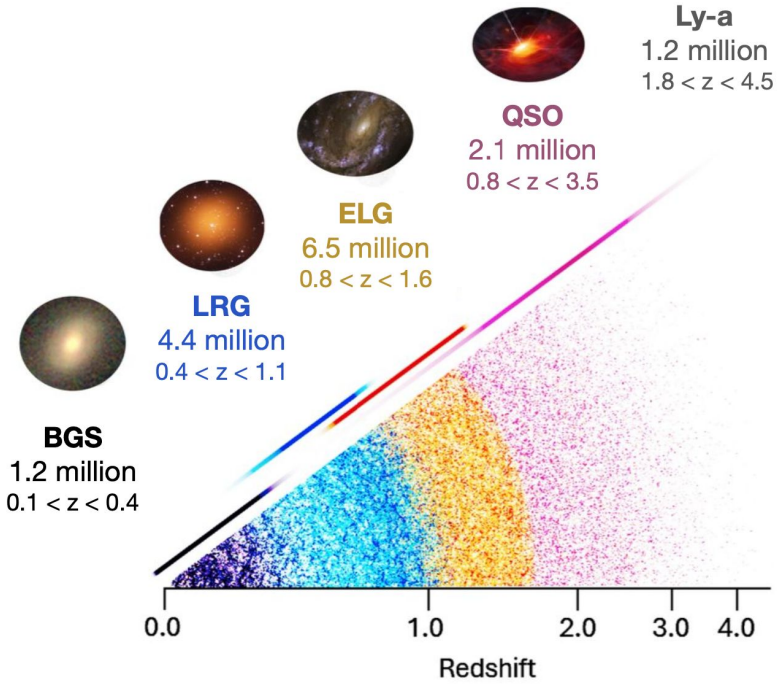
- Two data samples currently analysed: DR1 and DR2
- 5.7M redshifts made public in DR1
- 14.3M redshifts in DR2 (currently being analyzed by collaboration)
- Selected from over 30M galaxy and quasar redshifts in 3 years of operation
- Compared to public DR1, **DR2 represents a factor of 2.4 improvement in data volume**

Tracer	DR1	DR2
BGS	300,043	**1,188,526**
LRG	2,138,627	**4,468,483**
ELG	2,432,072	**6,534,844**
QSO	1,223,391	**2,062,839**
Total	6,094,133	**14,254,692**

DESI Data Release 2 (DR2)

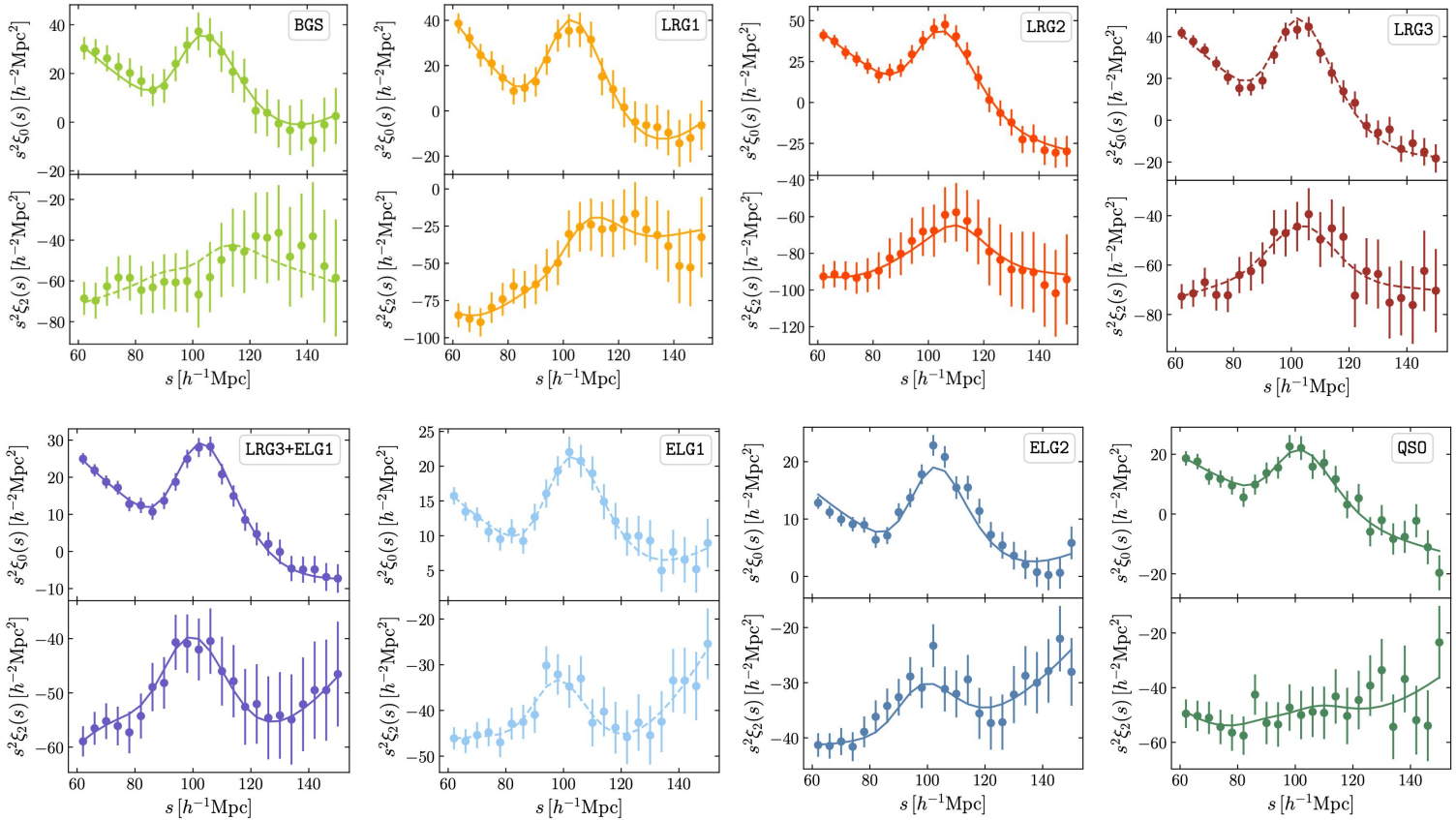
DARK ENERGY SPECTROSCOPIC INSTRUMENT
U.S. Department of Energy Office of Science

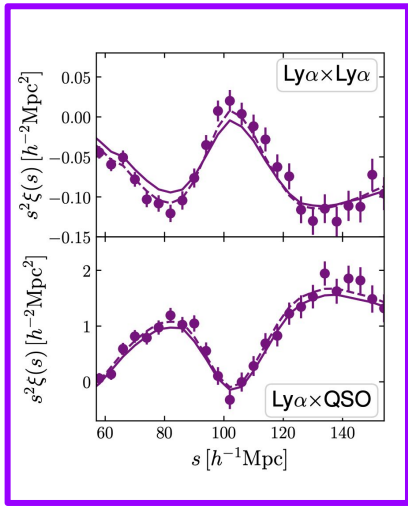
- DESI DR2 BAO analysis completed! (arxiv/2503.14738 & 14739)
- Remaining DR2 analysis to be finalised this year, including:
  - Galaxy clustering full shape
  - Cross-correlations with weak lensing
  - Cross-correlations with CMB lensing
  - Growth of structure from peculiar velocities
- DR3 BAO expected by April 2027



DESI DR2 BAO measurements

DESI DR2 BAO paper: DESI collaboration 2025, arXiv:2503.14738



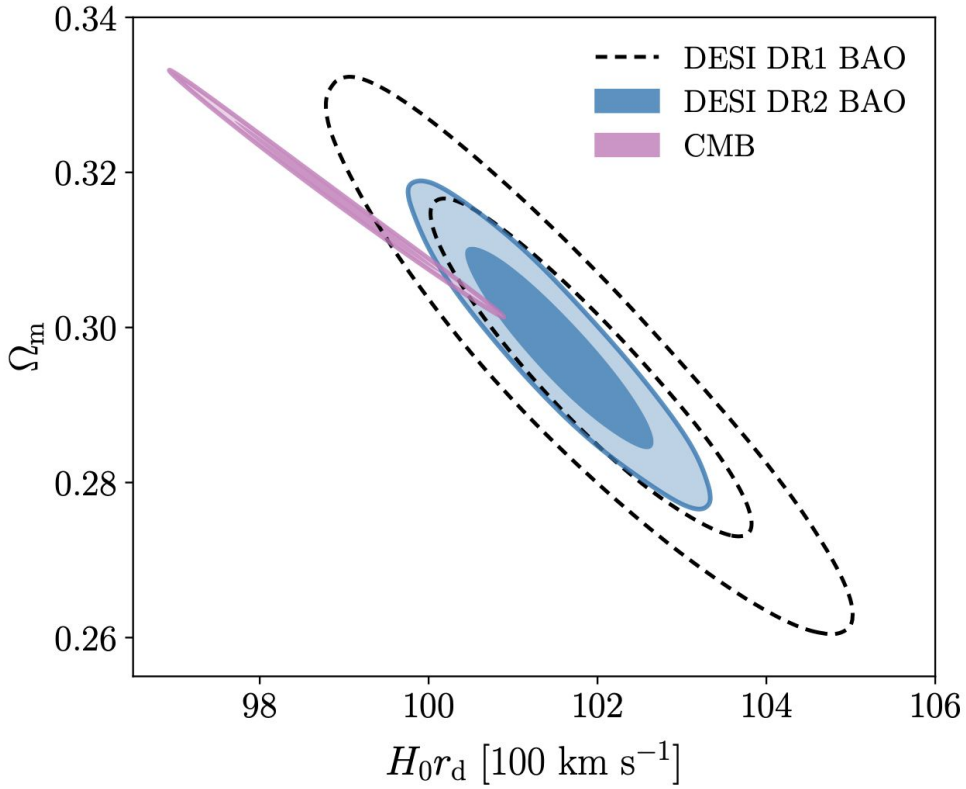


See talk by Éric Armengaud on Friday afternoon

DESI DR2 BAO cosmology

DESI DR2 BAO paper: DESI collaboration 2025, arXiv:2503.14738

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



- 40% improvement in the constraints compared to DR1
- Discrepancy between BAO and CMB has increased:

  1.9σ (DR1) → 2.3σ (DR2)

CMB = Planck + ACT lensing

DESI DR2 BAO cosmology

DESI DR2 BAO paper: DESI collaboration 2025, arXiv:2503.14738

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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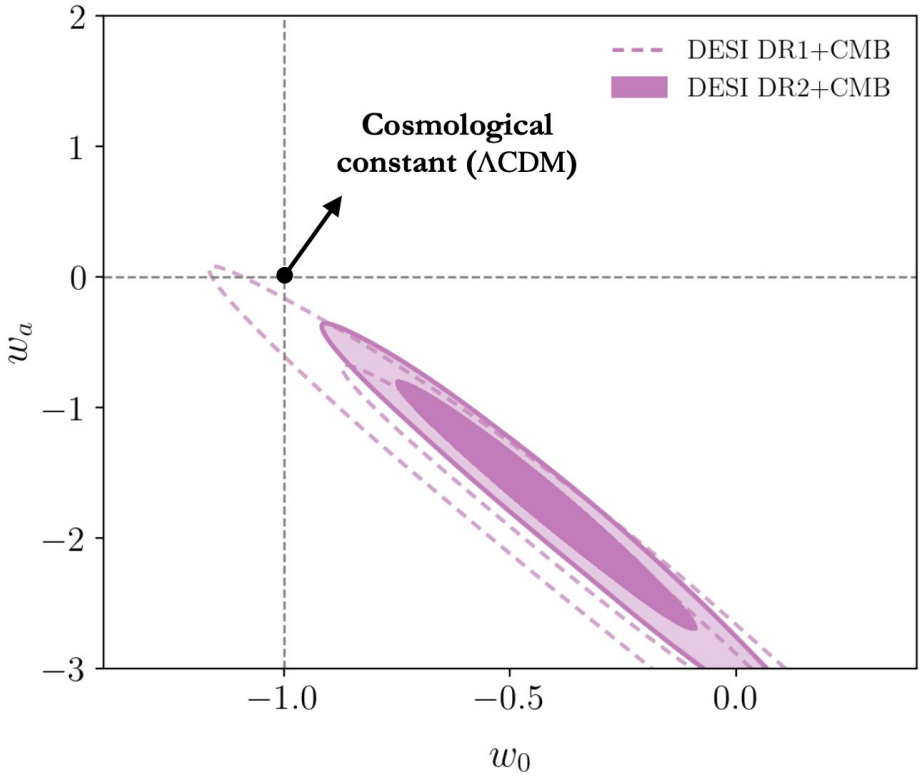


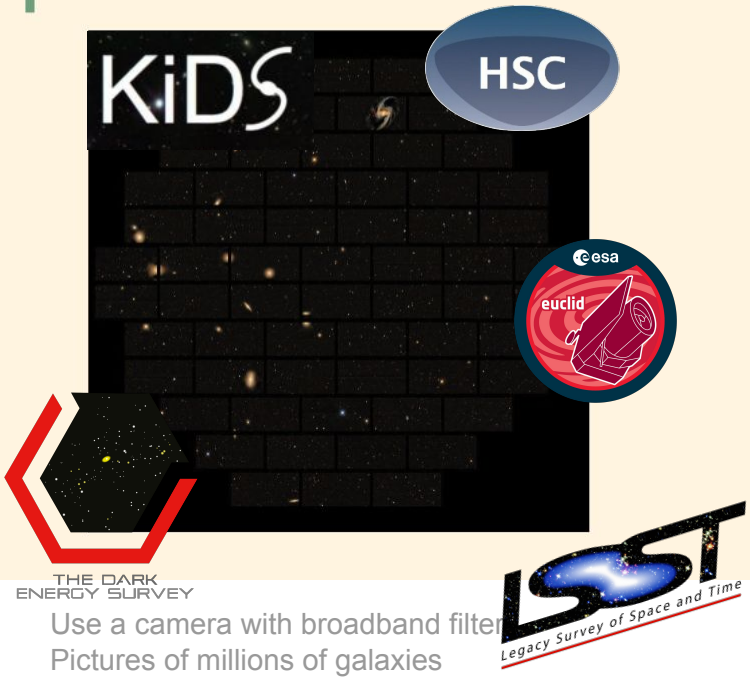
- Preference for dynamical dark energy from DESI BAO + CMB increased:

  2.6σ (DR1) → 3.1σ (DR2)

- Up to 3.4σ preference when SN are included (after recent recalibrations)

CMB = Planck + ACT lensing

SURVEYS
photometric vs spectroscopic



- Use a camera with broadband filters
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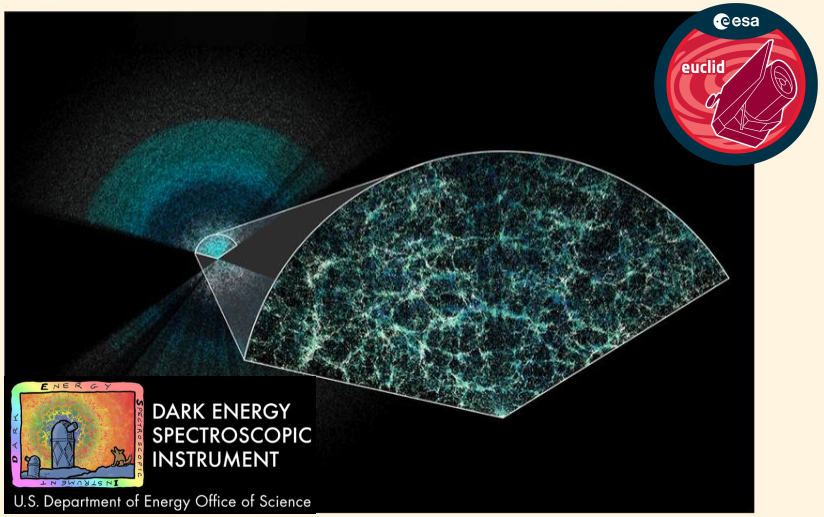


- Obtain the spectra from each object/galaxy
- Allows to measure the redshift of galaxies with high precision
- Allows to measure **galaxy clustering with high precision**

DESI and weak lensing surveys

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

Focus on combined-probe analyses of DESI spectroscopic samples with public weak lensing data

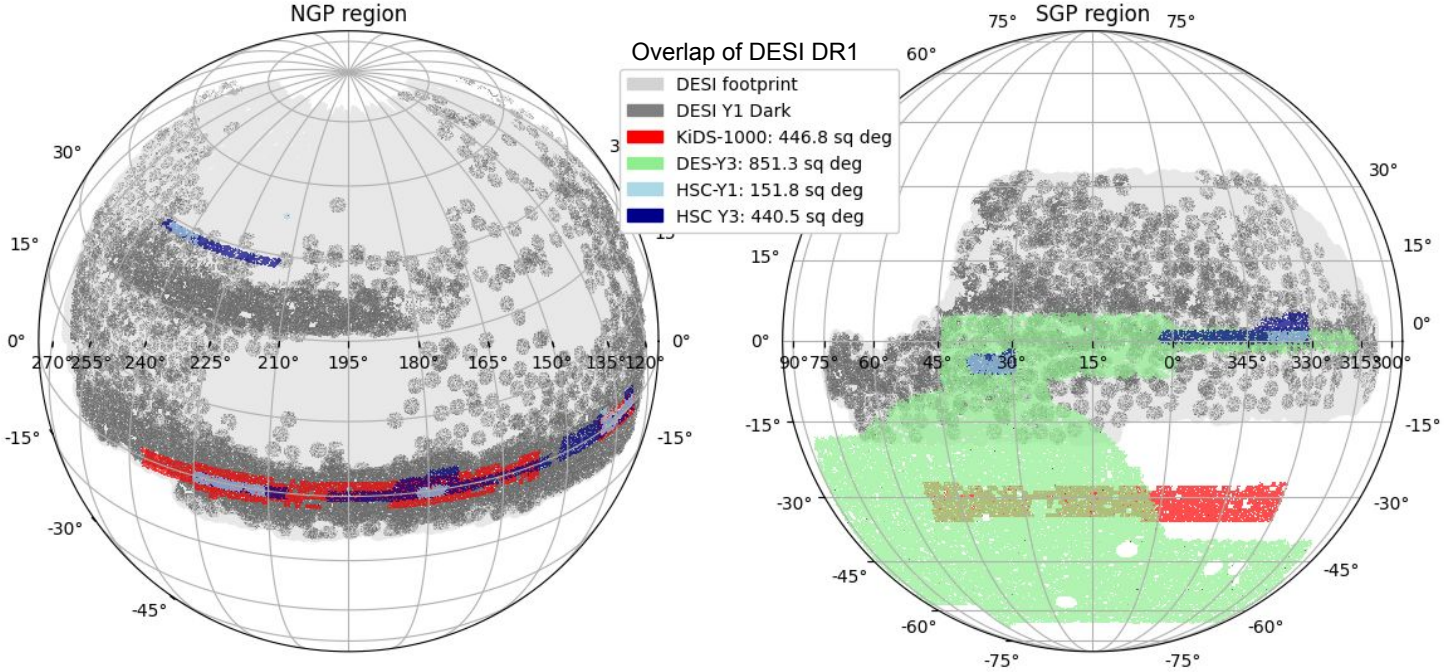
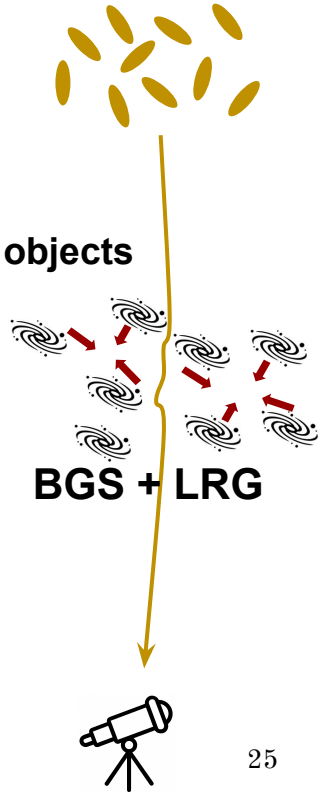


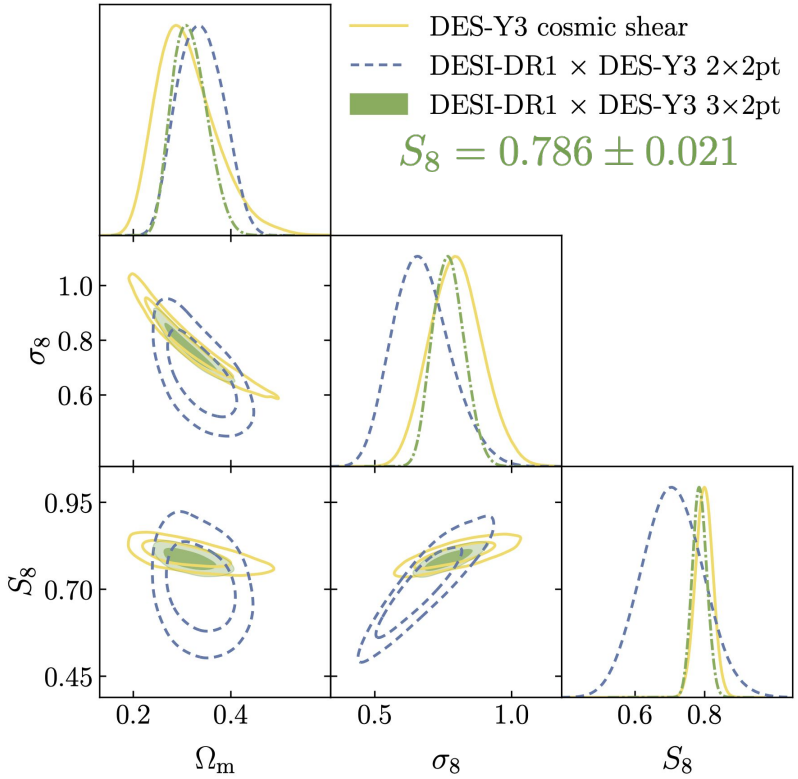
Figure credit: Chris Blake

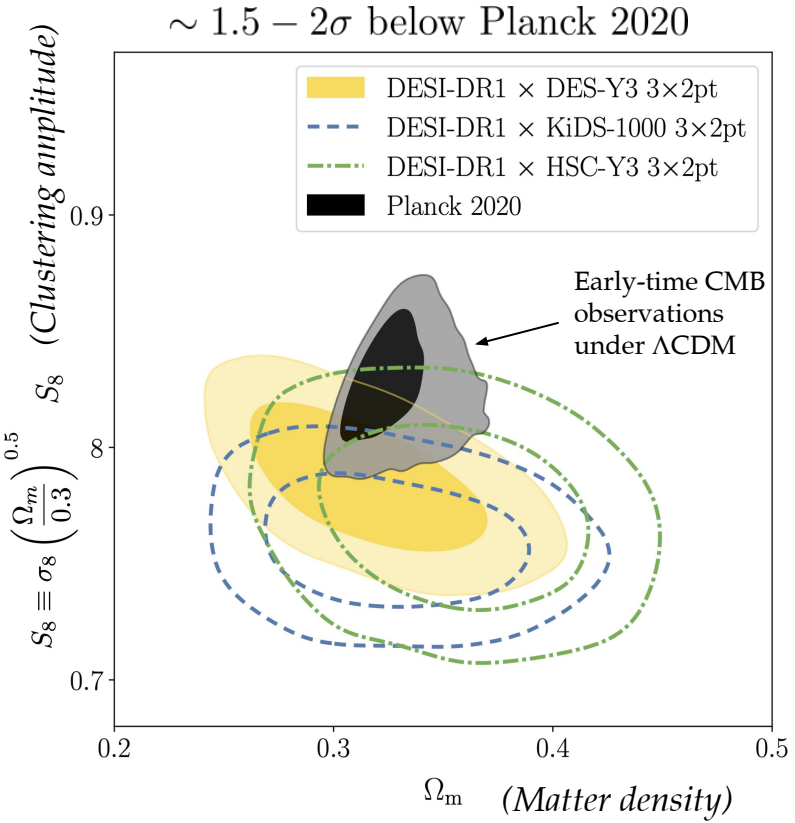


DESI DR1 3x2pt analysis

Porredon et al. 2026
https://arxiv.org/abs/2512.15960

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

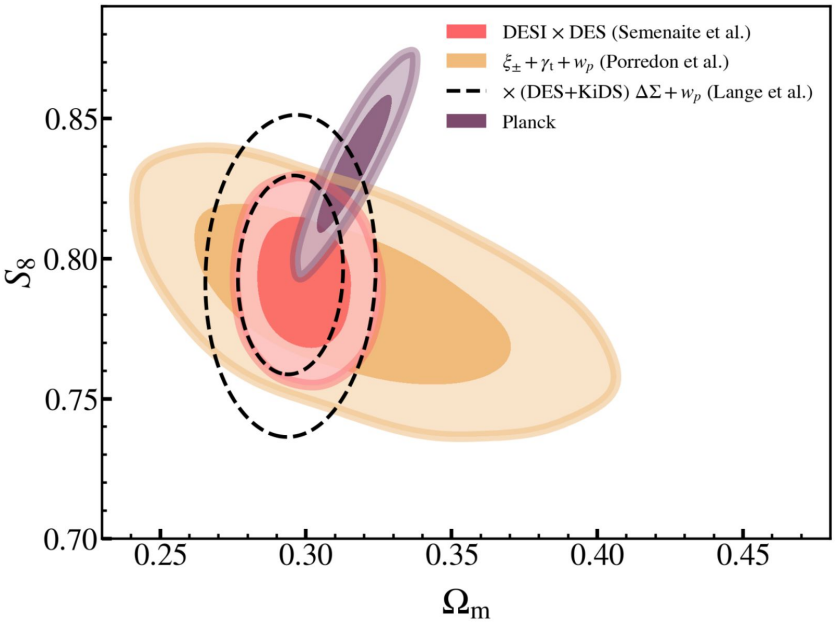




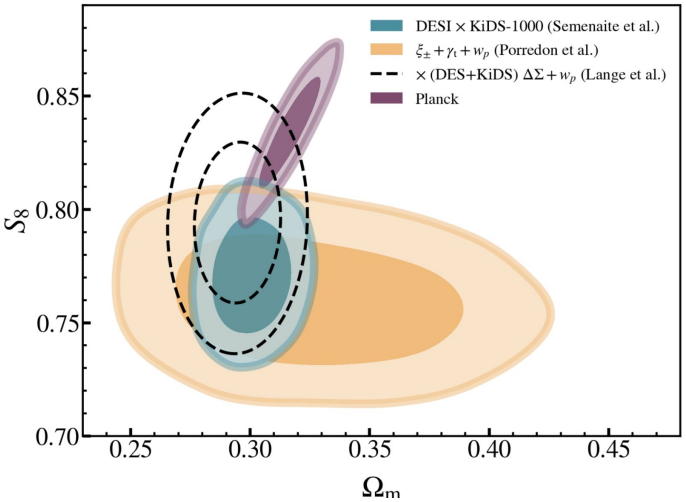
DESI DR1 x weak lensing cosmology papers

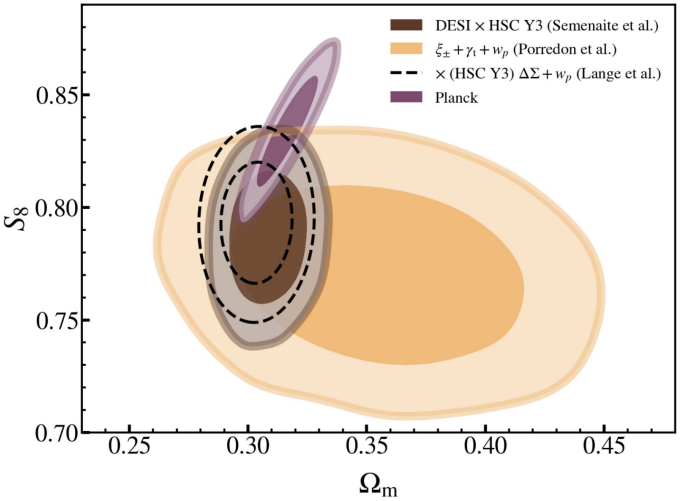
- **Porredon** et al., 2026 - 3x2pt with projected two-point functions (2D), most similar to DES 3x2pt.
- **Semenaite**, Blake, Porredon et al., 2026 - using full 3D information for the galaxy clustering part
- **Lange** et al., 2025 - simulation-based analysis with a frequentist approach. 2D, but not including cosmic shear.

DESI-DR1 results comparison



Very different scales, priors, and assumptions, but highly consistent results!





Comparison with other analyses

Cosmic shear

https://arxiv.org/abs/2512.15960

DES-Y3 $\xi_\pm$ (this work)

DES-Y3 $\xi_\pm$ hybrid

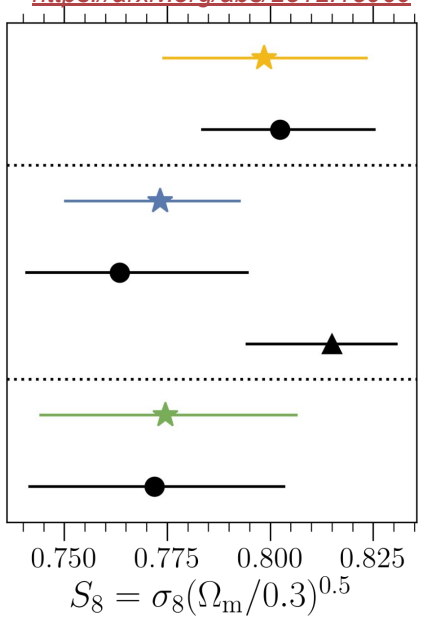
KiDS-1000 $\xi_\pm$ (this work)

KiDS-1000 COSEBIs hybrid

KiDS-Legacy COSEBIs fiducial

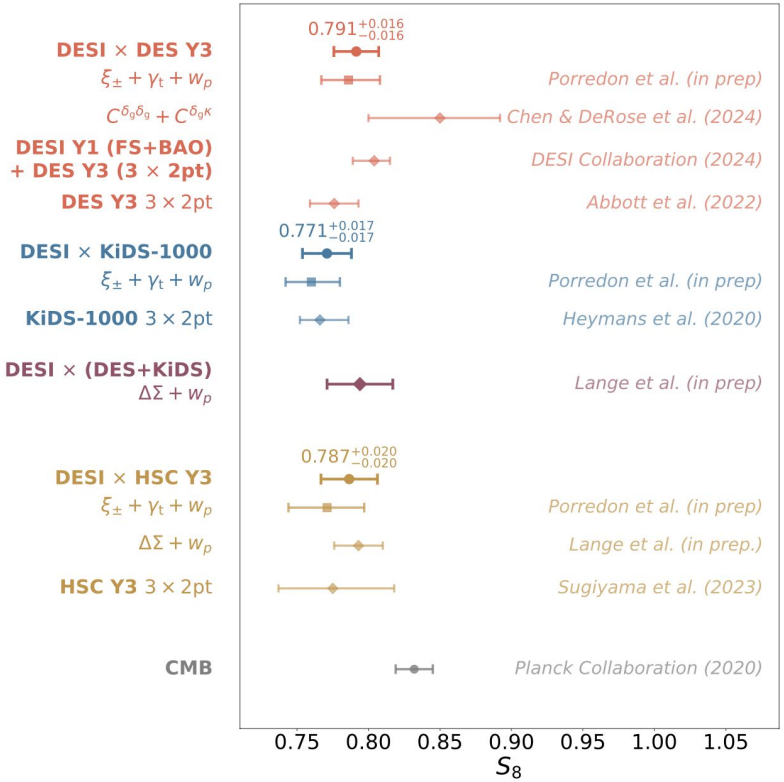
HSC-Y3 $\xi_\pm$ (this work)

HSC-Y3 $\xi_\pm$ hybrid



Clustering and WL combinations

https://arxiv.org/abs/2512.15961



DR2 cross-weak lensing key project

DARK ENERGY SPECTROSCOPIC INSTRUMENT
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Constraining power will improve significantly with DESI-DR2 data (first 3 years)

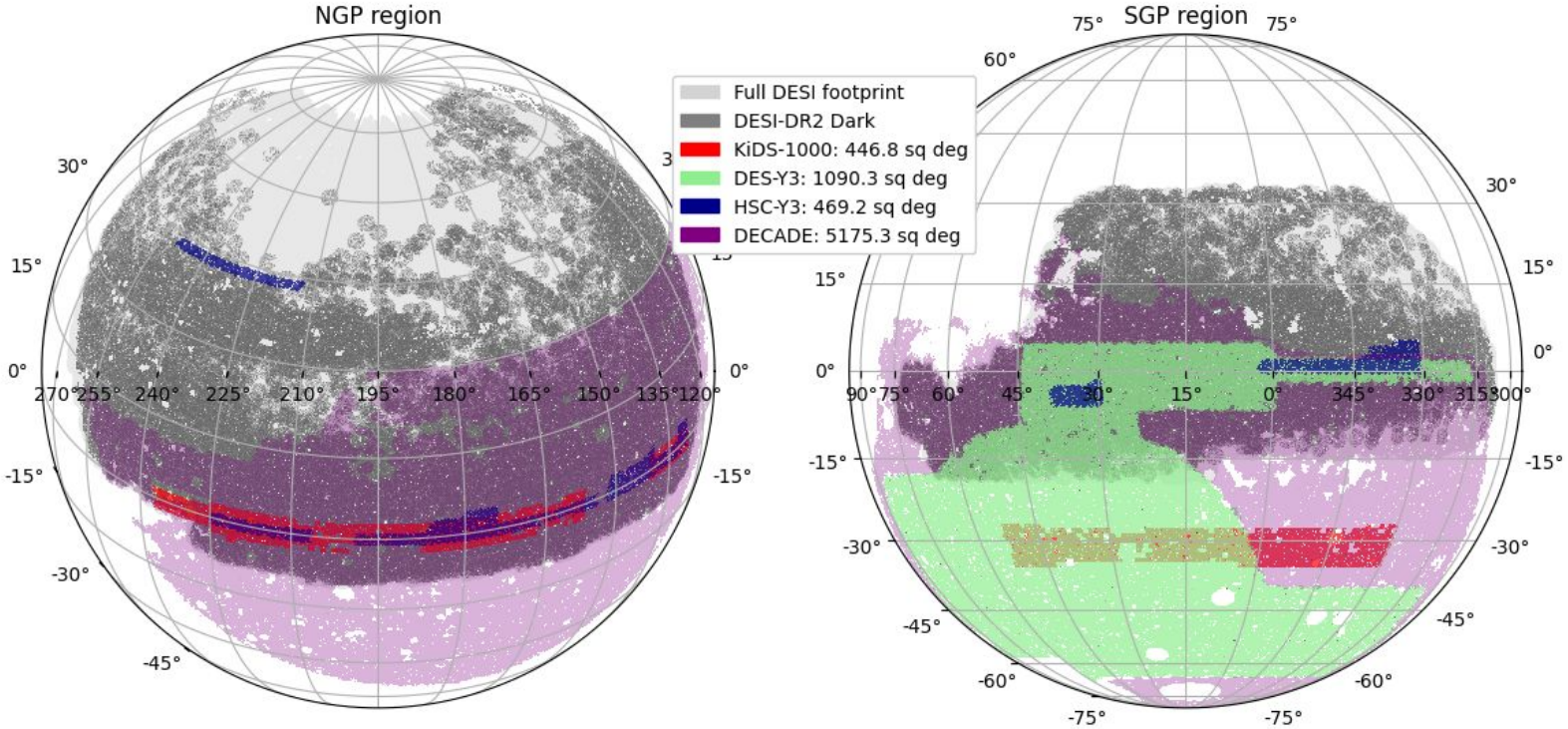


Figure credit: Chris Blake

Looking ahead: Euclid x DESI

About ~200 sq. deg. of overlap with DR1, which will increase significantly with further Euclid and DESI data releases

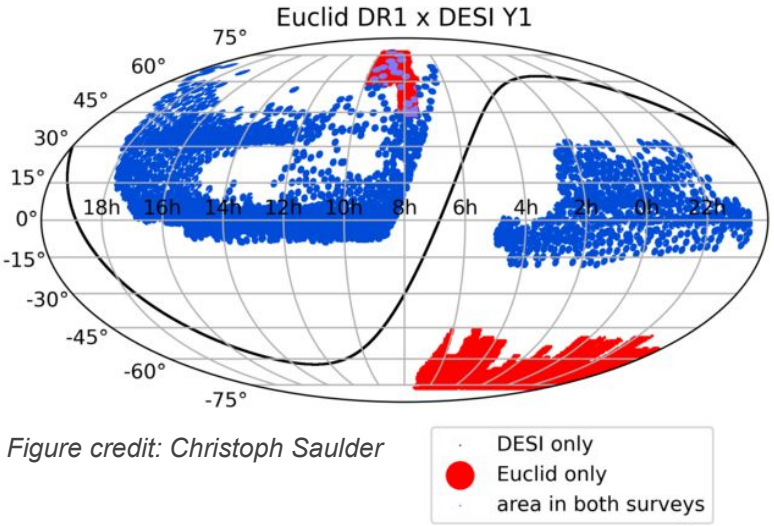
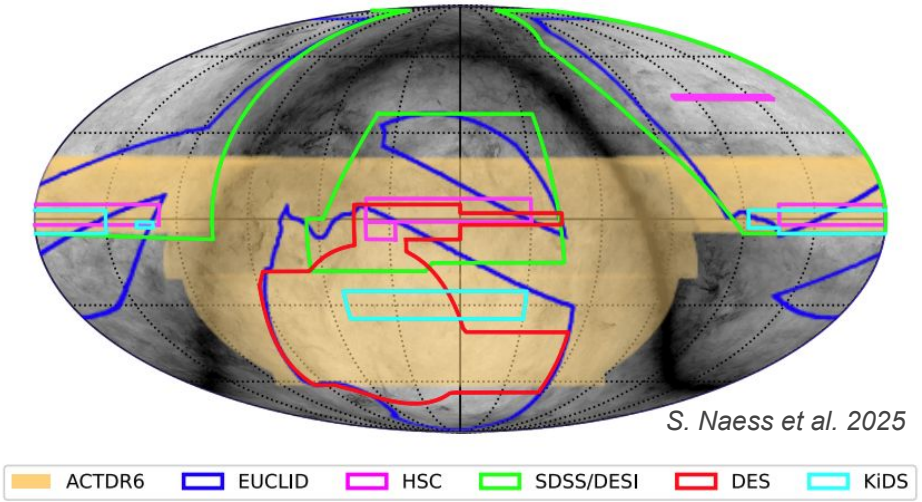


Figure credit: Christoph Saulder



S. Naess et al. 2025

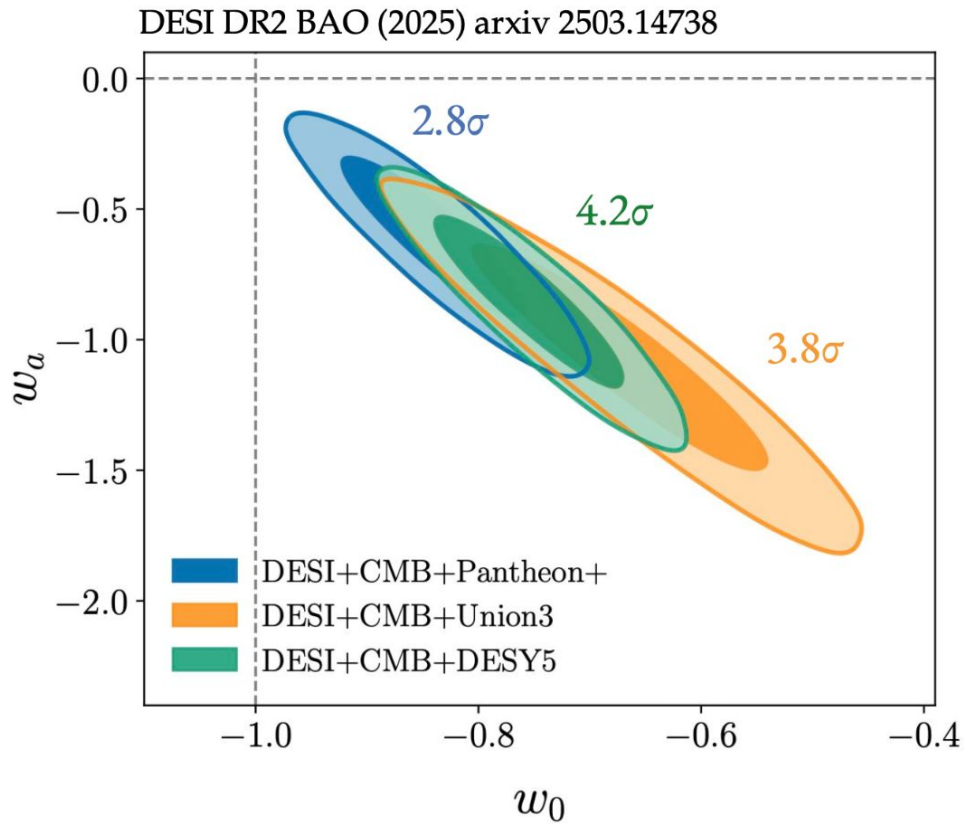
Conclusions

- Several **inconsistencies at the 2-3σ level** when considering galaxy surveys and the CMB.
- It is essential to analyse data from multiple surveys with a unified pipeline to assess the robustness and consistency of their cosmological constraints.
- We have obtained **cosmological constraints from the combination of KiDS, DES, and HSC weak lensing data with DESI-DR1 galaxy clustering**, finding in general consistent results between surveys and with each survey's fiducial results.
- Exciting future ahead with upcoming data from DESI, Euclid, LSST and more!

annamaria.porredon@ciemat.es

Extra slides

Individual datasets are well fitted by ΛCDM but their combination shows hints of departure



Three datasets combinations:

CMB from Planck + ACT lensing

BAO from DESI DR2

SNIa from :

1. Pantheon+
2. Union3
3. DES Y5 (phometric)

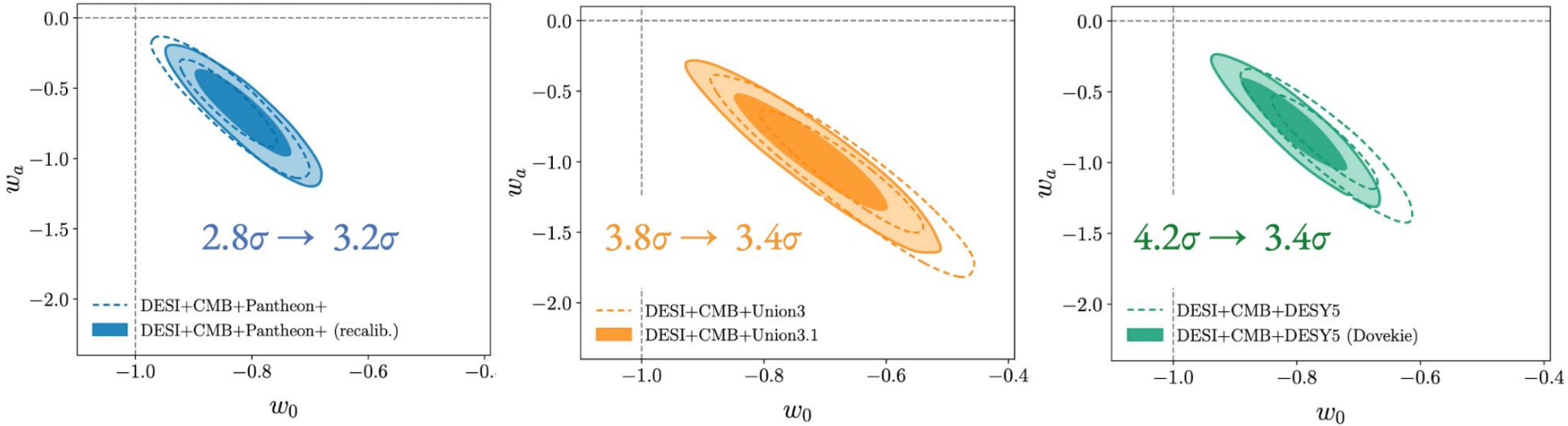
Significance based on

$$\Delta\chi^2 = \chi^2_{\rm MAP}(\Lambda{\rm CDM}) - \chi^2_{\rm MAP}(w_0 w_a{\rm CDM})$$

Latest SNIa re-calibrations

Hoyt et al. 2026 : recalibration of SNe Ia host-galaxy mass at low redshift in both Pantheon+ and Union3

Popovic et al. 2025 : improved (global) photometric cross-calibration between DES and other low-z SN + improvement on absolute calibration using white dwarfs, + retraining the SALT3 light curve model ..



- Considerably more consistency across SNe Ia dataset
- DESI + CMB is 3.1σ (if including CMB lensing)

Figs credit : DESI Collab internal

BGS for DESI DR1 weak lensing cross-correlations

Sven Heydenreich, Alexie Leauthaud ++

https://arxiv.org/pdf/2506.21677

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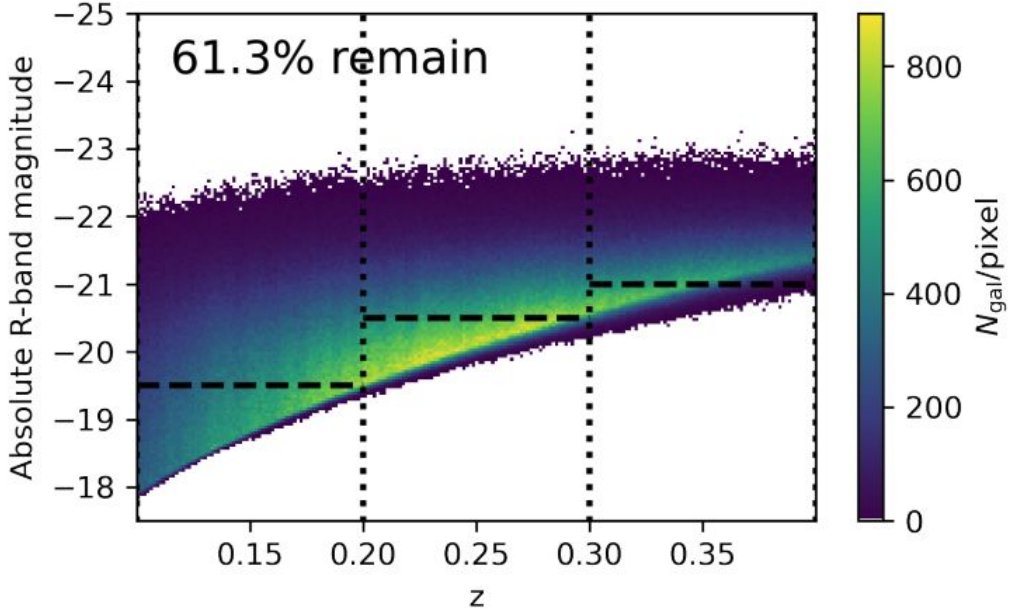
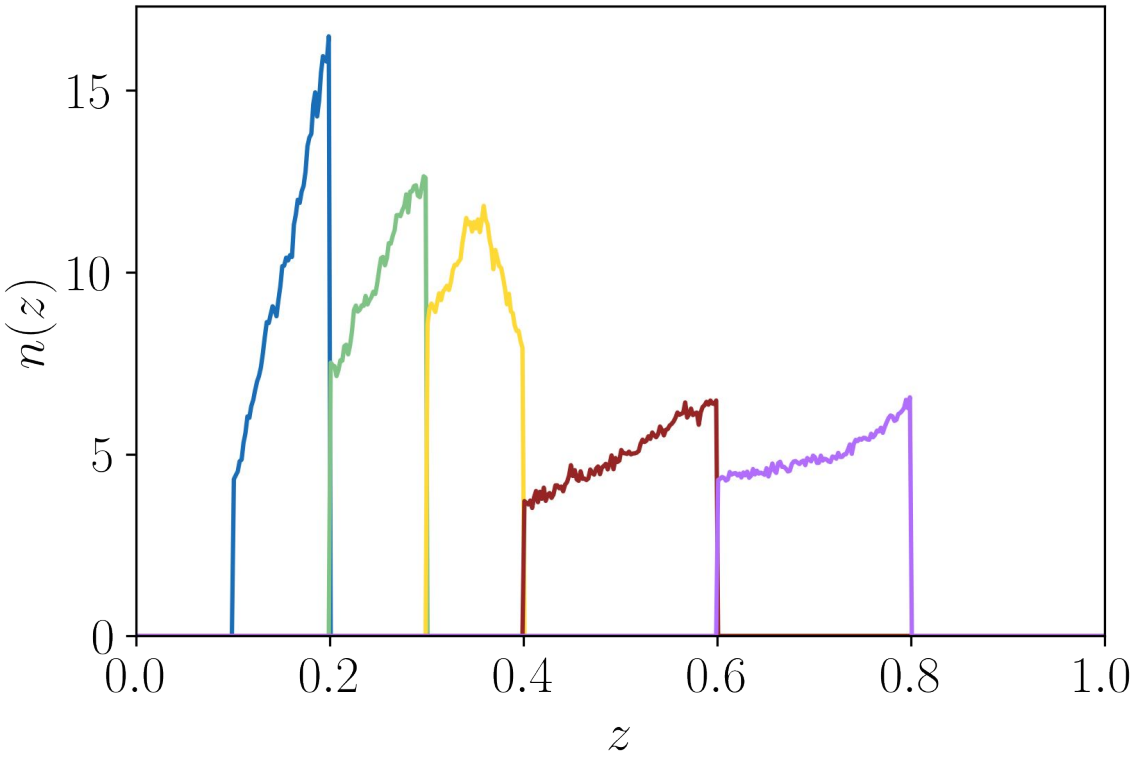


Figure 2. Absolute magnitudes of DESI DR1 BGS as a function of redshift. The galaxies that pass the magnitude cut described in Sect. 2.1 are the ones above the dashed lines. In total, 61% of all galaxies pass the magnitude cut.

DESI DR1 3x2pt analysis: lenses



BGS 0.1 < z < 0.2
BGS 0.2 < z < 0.3
BGS 0.3 < z < 0.4
LRG 0.4 < z < 0.6
LRG 0.6 < z < 0.8

Bright Galaxy Sample Luminous Red Galaxies

DESI DR1 3x2pt analysis: observables & pipeline

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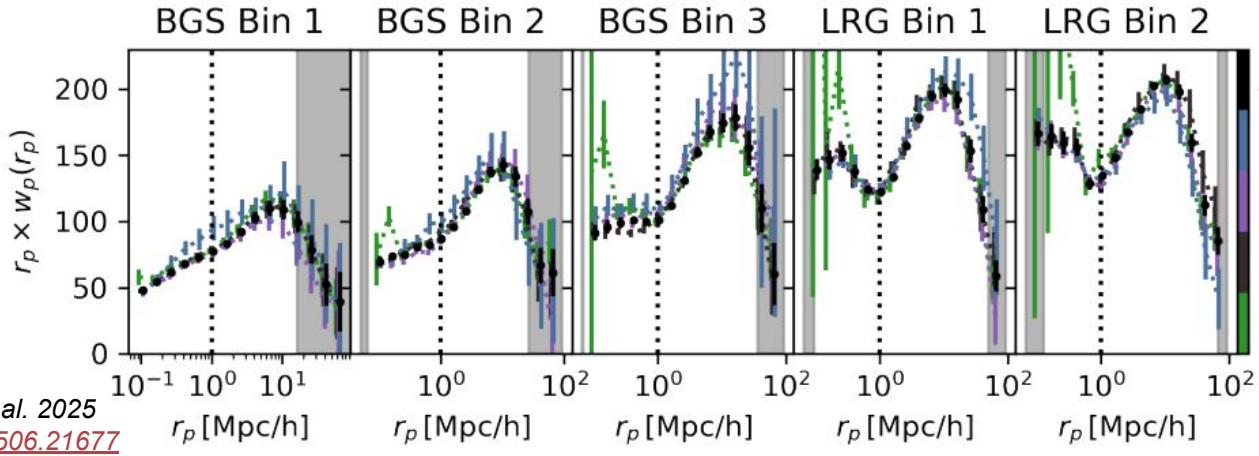
Observables:

- cosmic shear: xi+/xi- (publicly released by each WL survey)
- galaxy-galaxy lensing: γ_t
- galaxy clustering: w_p

Pipeline: CosmoSIS (already used in DES, KiDS, and HSC), validated against 3 other pipelines using Cobaya and CosmoMC

Modelling choices: Following DES-Y3 fiducial and DES+KiDS hybrid pipeline



Sven Heydenreich et al. 2025
https://arxiv.org/pdf/2506.21677

DESI DR1 3x2pt analysis: scale cuts

Ni Emas, Anna Porredon, Chris Blake, Joe DeRose et al. 2025

https://arxiv.org/abs/2510.05539

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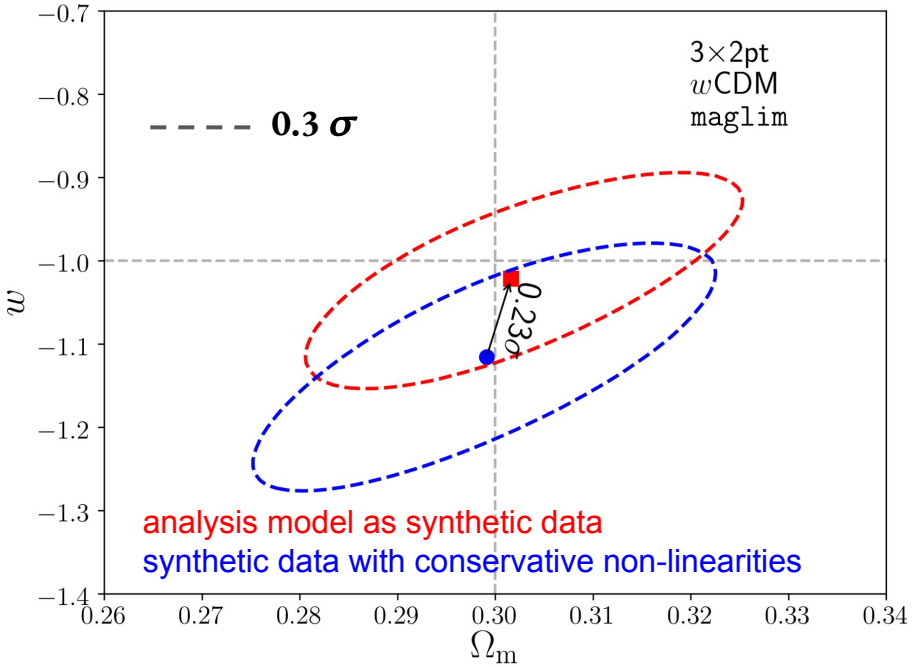
Analysis restricted to scales such that non-linear modeling uncertainties bias cosmology constraints by < 0.3σ in 2D or < 0.5σ in 1D constraints

DES Y3 3x2pt methods: E. Krause++ 2021



DESI DR1 3x2pt analysis: scale cuts

Ni Emas, Anna Porredon, Chris Blake, Joe DeRose et al. 2025

https://arxiv.org/abs/2510.05539

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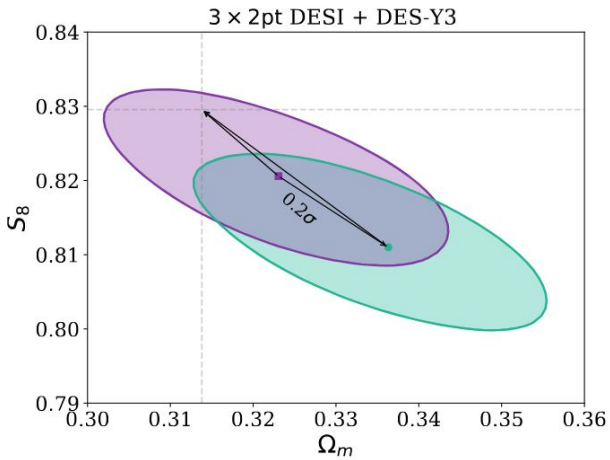
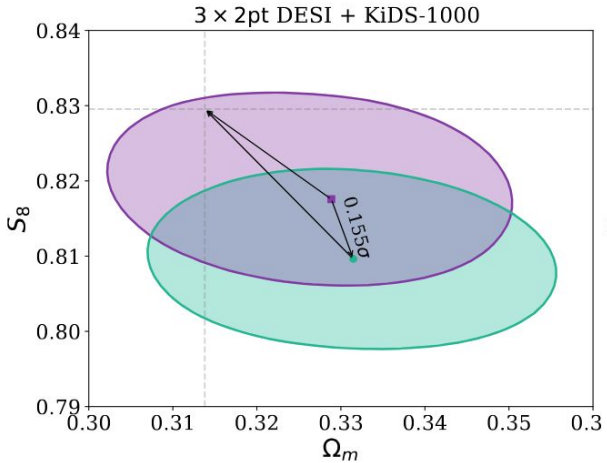
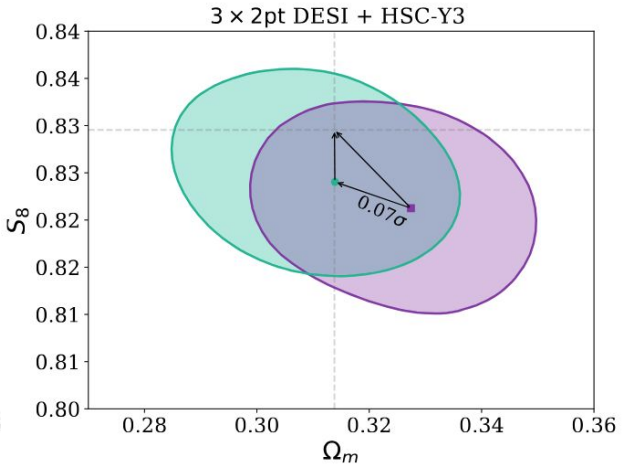
Scale cuts validated for all survey combinations: DES-Y3, KiDS-1000, HSC-Y1, HSC-Y3.

Robust against modelling of the non-linear matter power spectrum, non-linear galaxy bias and baryonic feedback effects

- Cosmic shear: fiducial scale cuts from each survey, with minor change for KiDS-1000
- Galaxy-galaxy lensing and projected galaxy clustering: 6 Mpc/h for γ_t and 8 Mpc/h for w_p





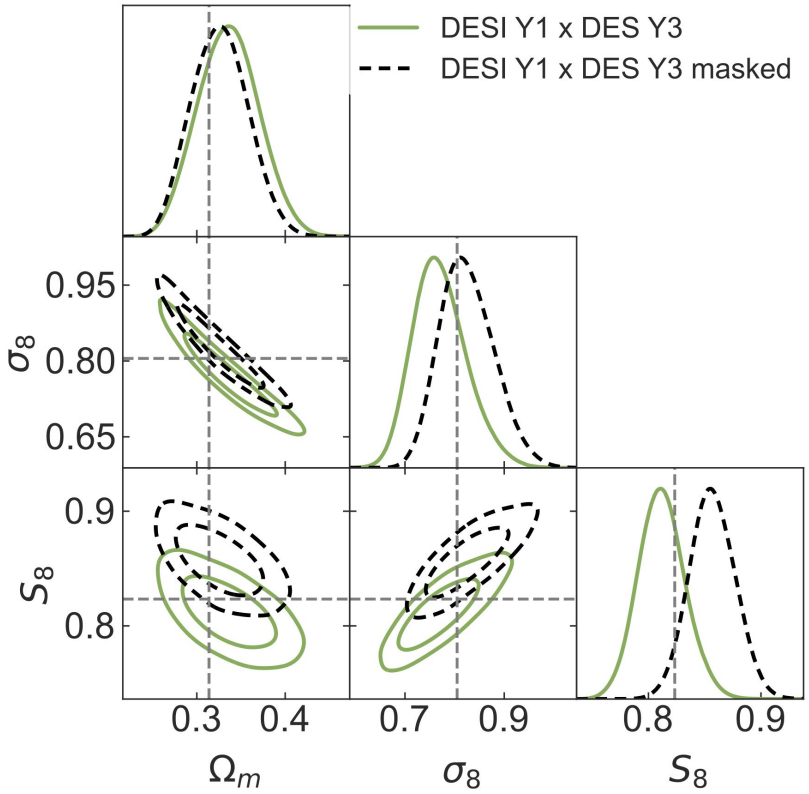


DESI DR1 3x2pt analysis: blinding

Porredon et al. 2025
https://arxiv.org/abs/2512.15960

In order to avoid confirmation biases, we validate the whole analysis in a blind way, and we first run the pipeline on data vectors with a shifted value of S_8

The blinding methodology has been developed by Johannes Lange following the DES 3x2pt approach (Jessie Muir et al. 2020)



Similar results for the other surveys

DESI DR1 3x2pt analysis

Porredon et al. 2025
https://arxiv.org/abs/2512.15960

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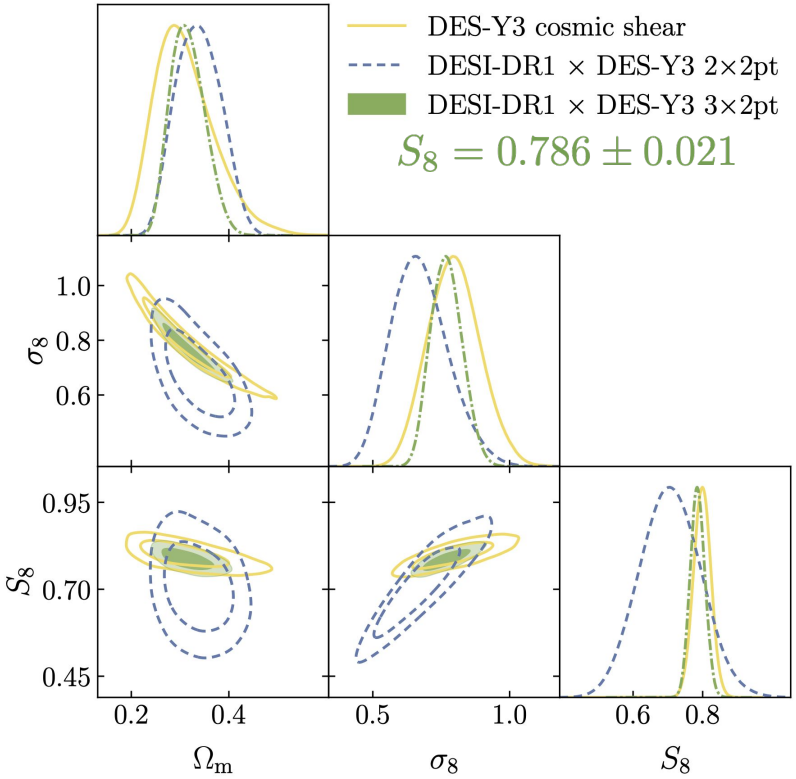

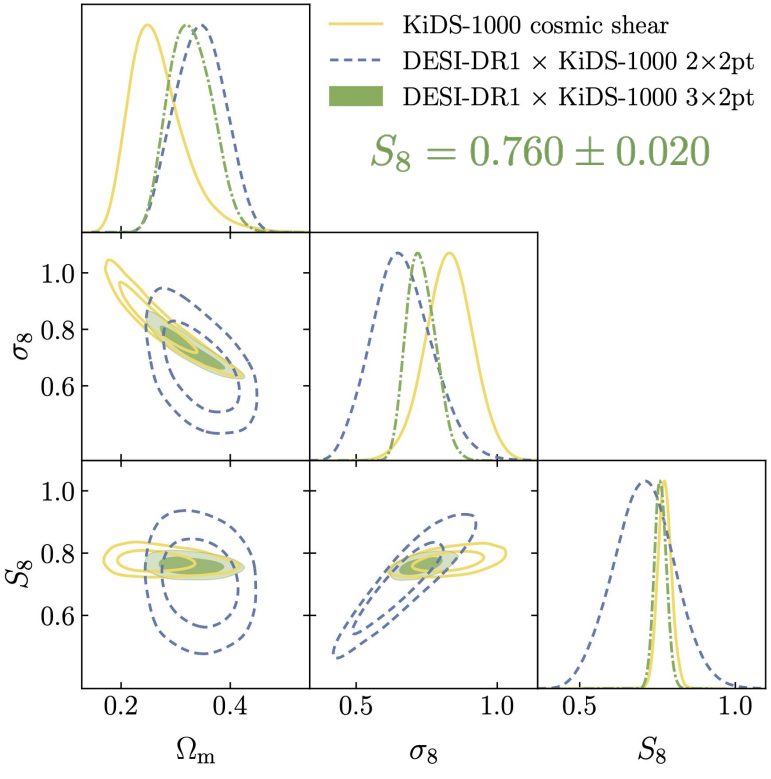

DESI DR1 3x2pt analysis

Porredon et al. 2025
https://arxiv.org/abs/2512.15960

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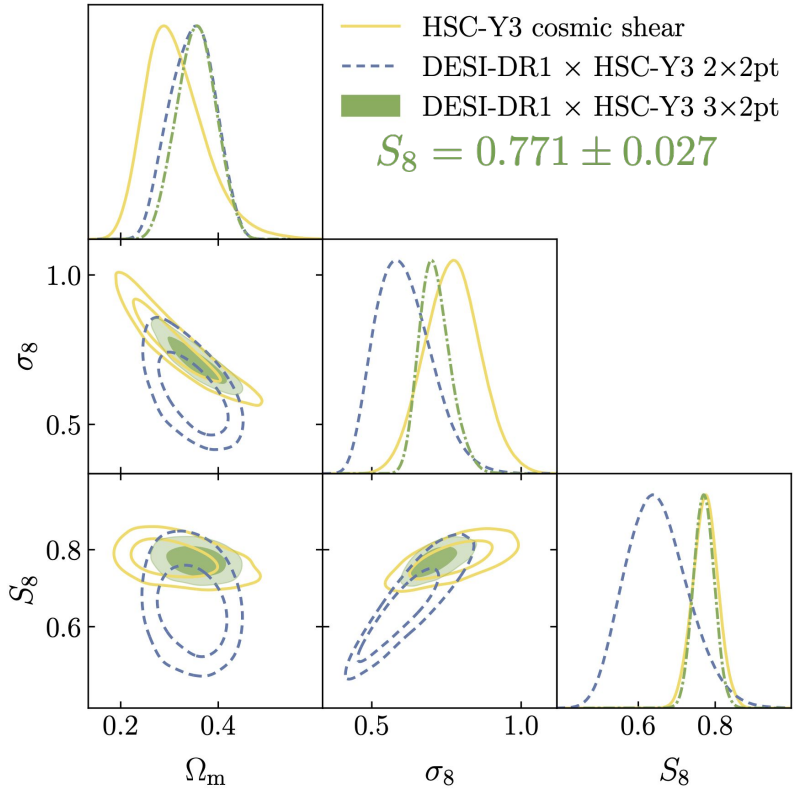

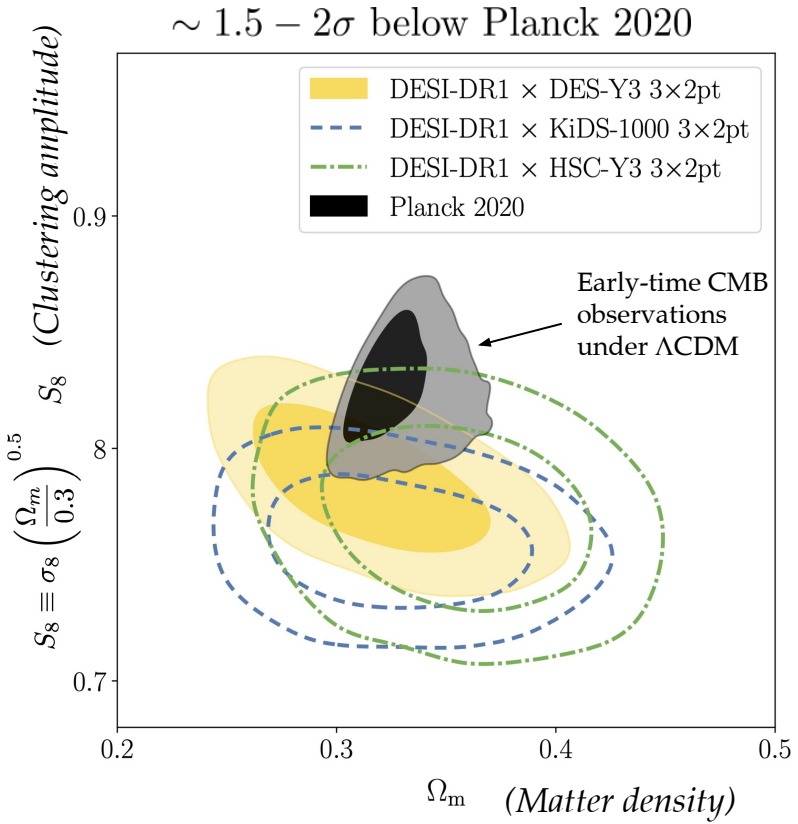

DESI DR1 3x2pt analysis: robustness

Porredon et al. 2025
https://arxiv.org/abs/2512.15960

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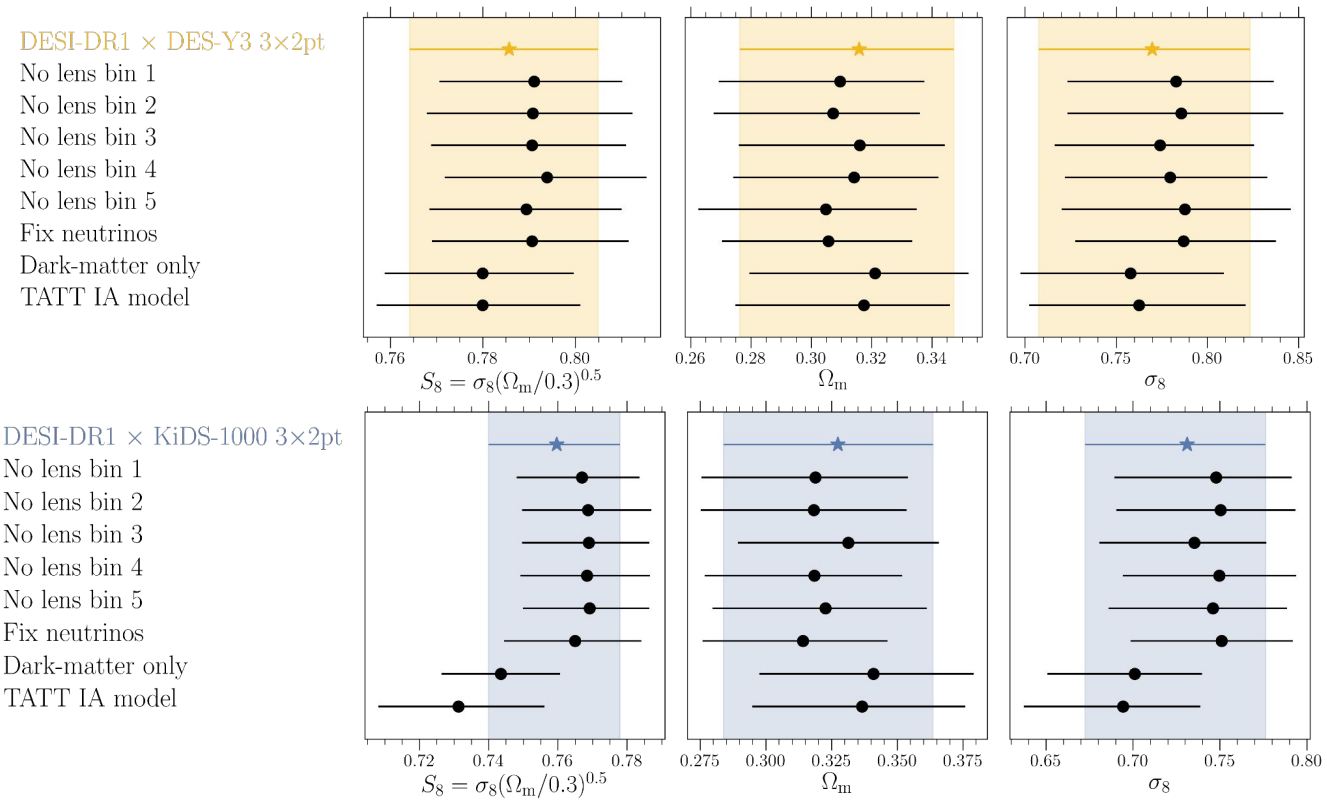

(similar results for DESI-DR1 x HSC)

DESI DR1 3x2pt analysis: robustness

Porredon et al. 2025
https://arxiv.org/abs/2512.15960

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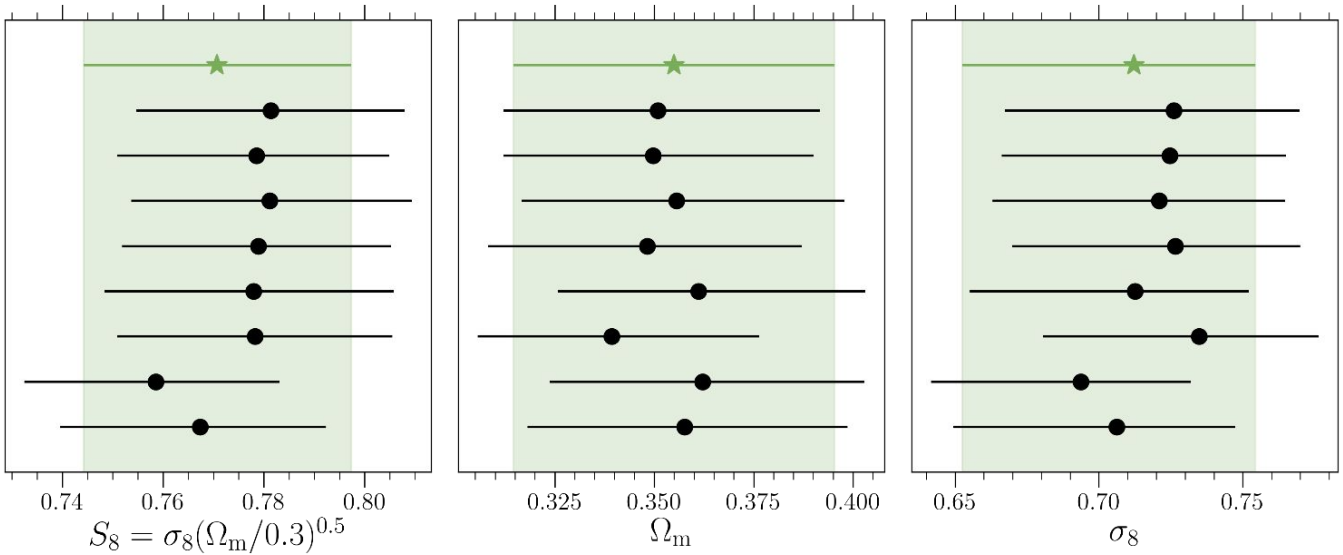
DESI-DR1 × HSC-Y3 3×2pt
No lens bin 1
No lens bin 2
No lens bin 3
No lens bin 4
No lens bin 5
Fix neutrinos
Dark-matter only
TATT IA model



Comparison with other analyses

https://arxiv.org/abs/2512.15960

DESI DR1 × DES-Y3 3×2pt

DES-Y3 3×2pt fiducial

DESI DR1 × KiDS-1000 3×2pt

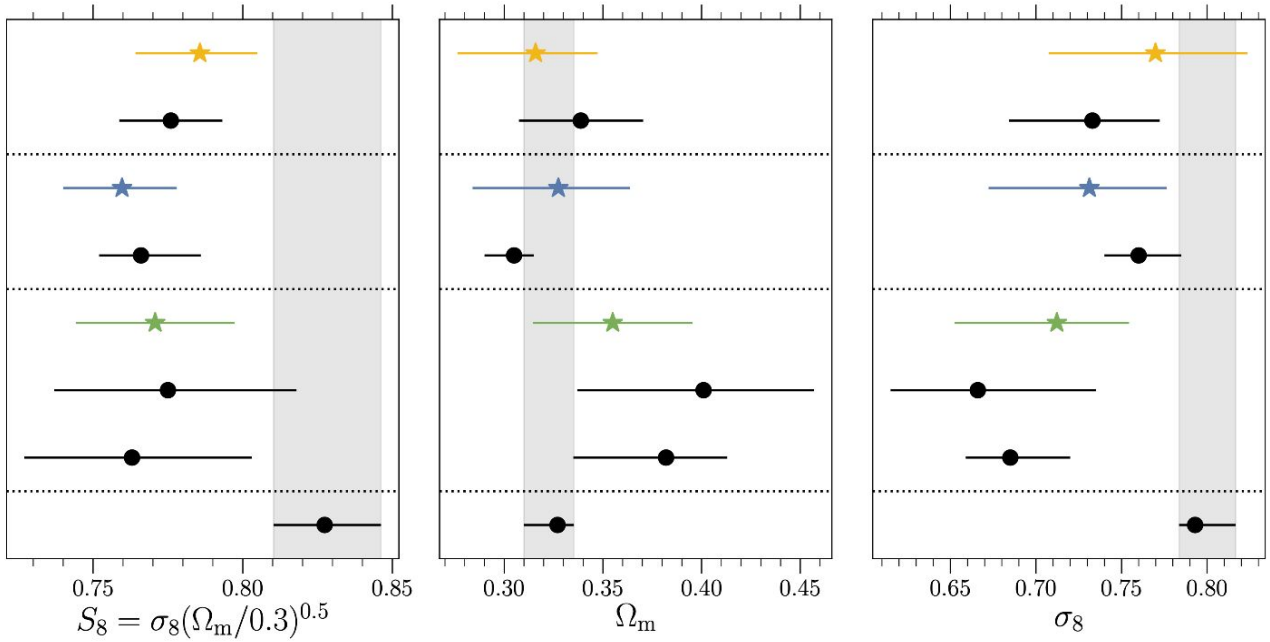
KiDS-1000 shear × RSD fiducial

DESI DR1 × HSC-Y3 3×2pt

HSC-Y3 3×2pt large scales fiducial

HSC-Y3 3×2pt small scales fiducial

CMB Planck 2020: TT+EE+TE



Modelling choices for 3x2pt large-scale data analysis

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Following DES-Y3 fiducial and DES+KiDS hybrid pipeline

- **Cosmological parameters and priors:** DESY3-like, sampling A_s and with free neutrinos
- **Non-linear Pk model + neutrino model:** HMcode2020 in CAMB
- **Baryonic feedback:** scale cuts and flat prior on T_agn parameter
- **Intrinsic alignments:** NLA with redshift dependence (2 parameters)
- **Lens magnification:** Gaussian priors using the measurements and uncertainty estimates from Sven Heydenreich et al. 2025
- **Point-mass marginalization:** included for γ_t
- **Galaxy bias**: linear model with one amplitude parameter per z-bin
- **Nuisance parameters:** shear calibration and source photo-z parameters as used in fiducial analyses of the WL surveys
- **Sampler:** Nautilus
- **Fiducial cosmology**: DESI fiducial (matches Abacus and Planck 2018)

Pipeline and modelling choices: correlation function multipoles

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Pipeline: CosmoSIS + COMET emulator (for galaxy clustering, interfaced with CosmoSIS)

Modelling choices for galaxy clustering: using COMET, directly emulating the multipoles in redshift space.

- **Redshift space distortions:** EFT + VDG model, from Eggemeier et al. 2025 (arXiv:2501.18597)
- **Galaxy bias**: one-loop bias expansion, marginalizing over b1 and b2 (linear and quadratic bias terms), and fixing the tidal bias parameters in terms of the linear bias b1 (Semenaite et al. 2022)