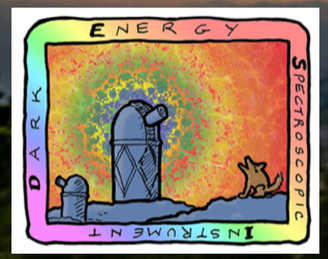
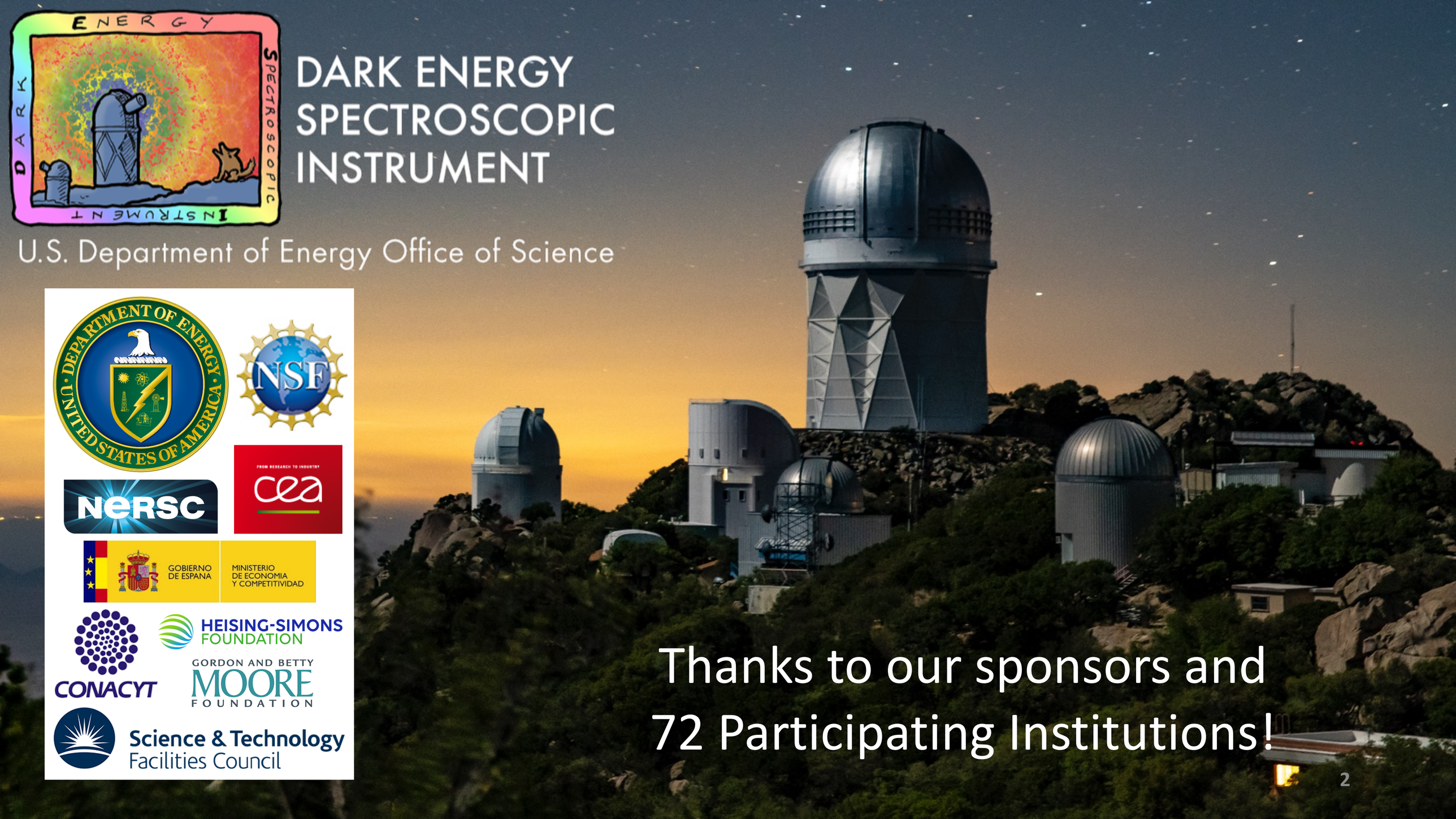
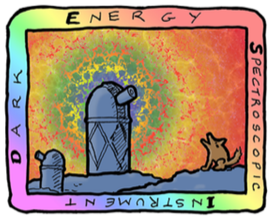
DESI Lyman-alpha forest results
cosmology at z ~ 2.3

E. Armengaud (CEA Saclay)

Colloque national WG Dark Energy
3 Nov. 2026




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Outline

- DESI Lyα samples and measurements
- New DR2 BAO in 3 redshift bins: **testing the Einstein – de Sitter regime**
  arXiv:2607.19619
- DR2 full-shape analysis: **percent-level Alcock-Paczynski test**
  arXiv:2607.27410
- DR1 P1D: testing the power-law form of the **linear spectrum at high k**
  arXiv:2601.21432
- Conclusion & outlook

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Cosmology with the Lyman-α forest

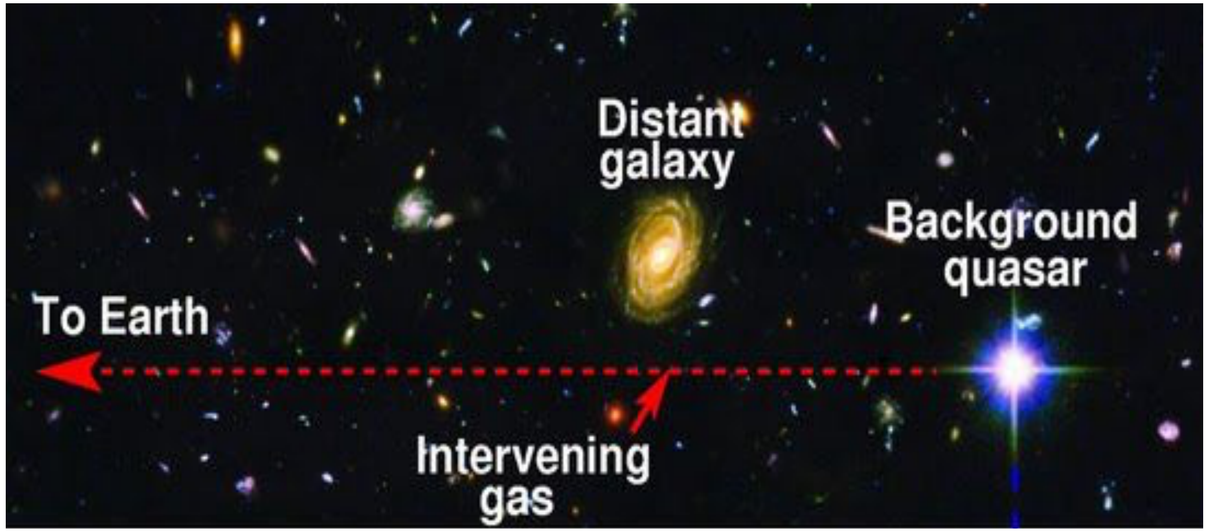
Not enough galaxies in the main DESI survey at z>2 ⇒ **use the Lyman-α forest**:

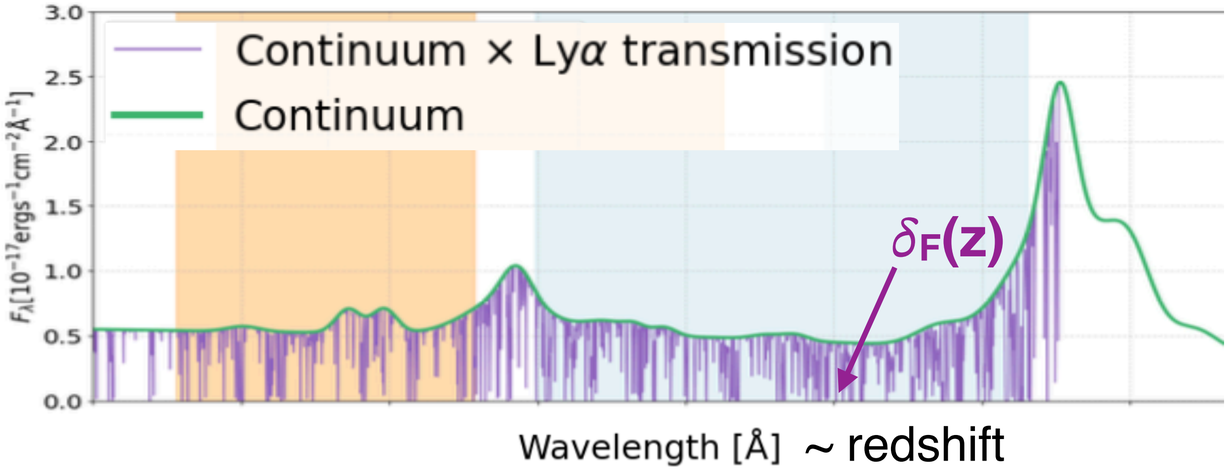
Resonant absorption of quasar's light by neutral hydrogen in the intergalactic medium

δ_F **: excellent tracer of matter density fluctuations at z > 2**

- Quasi-linear down to ~few Mpc scales

- Contaminants: QSO continuum, metals, high-column density systems (HCDs)





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Cosmology with the Lyman-α forest

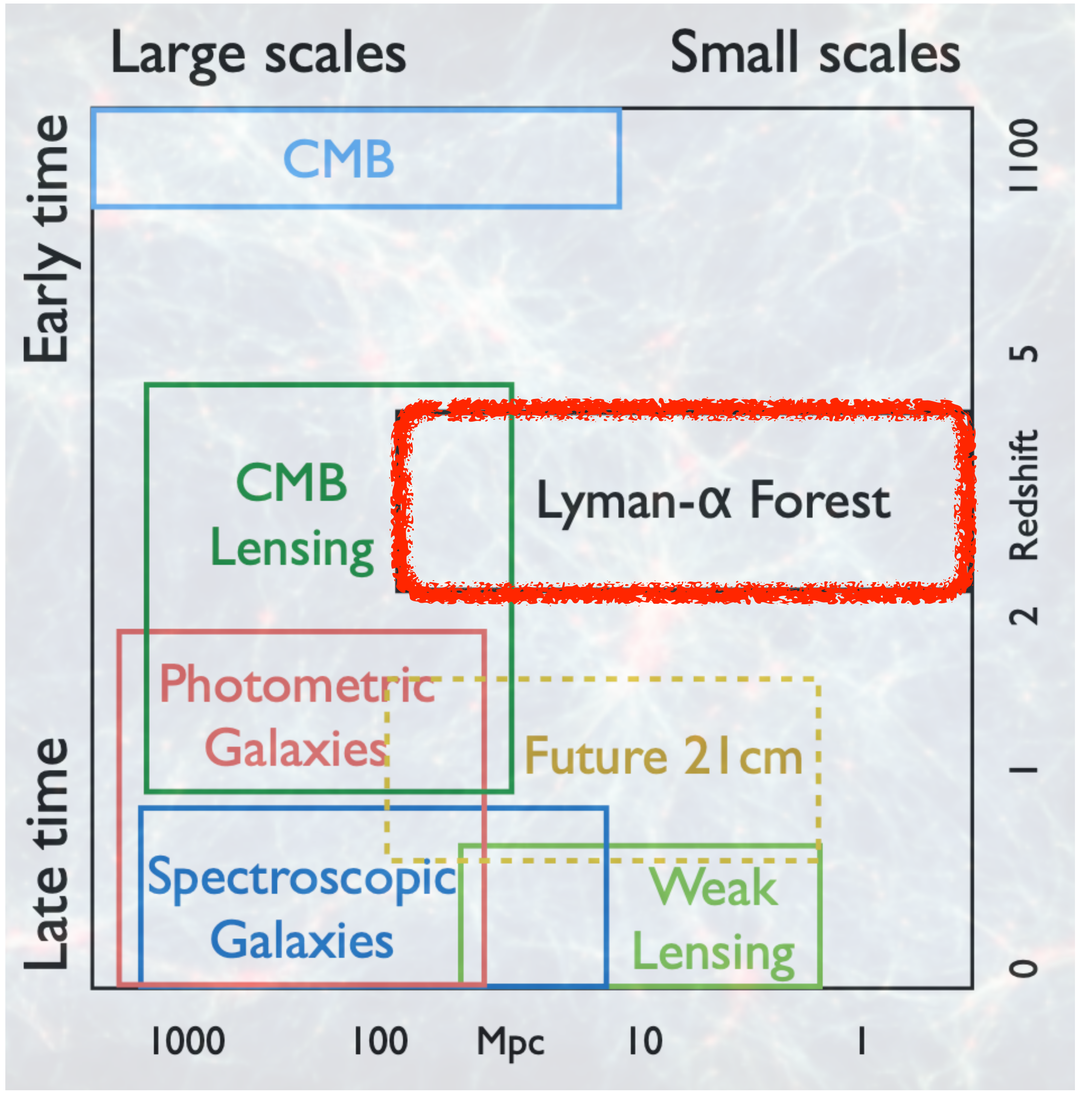
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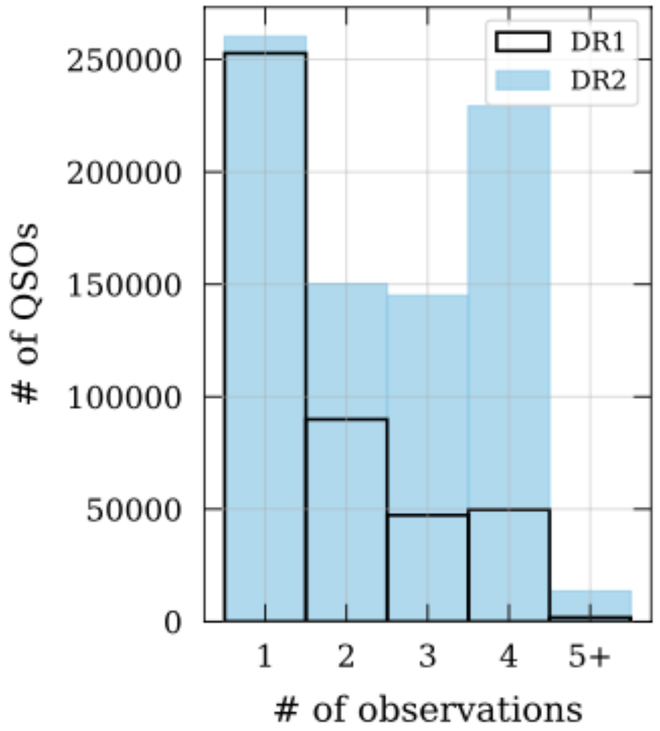
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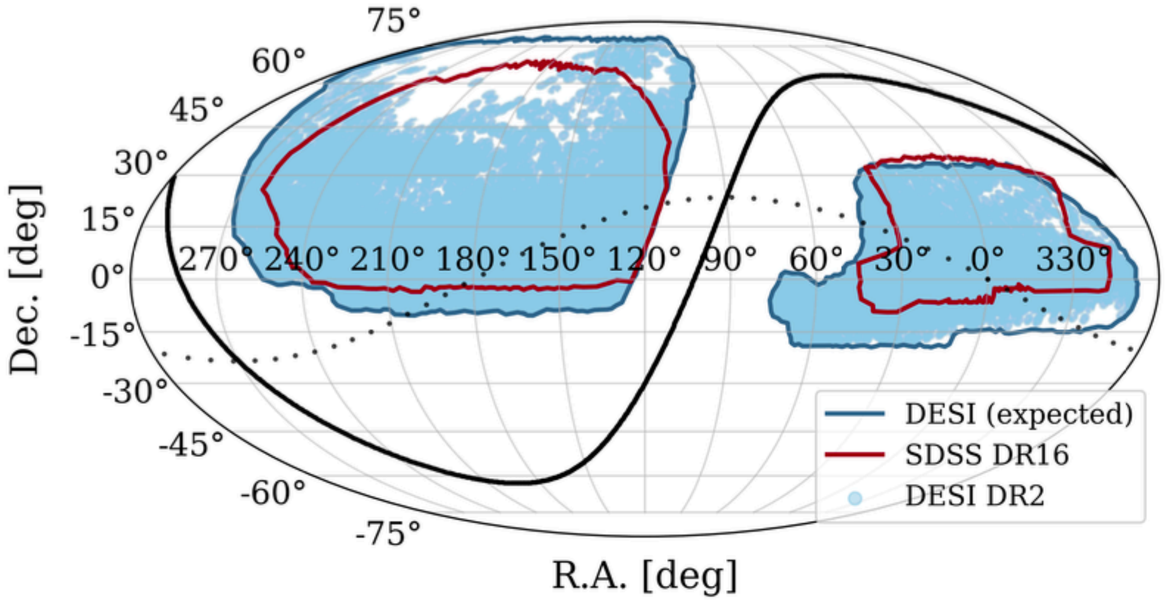
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DESI Lyman-α samples

DESI Lyα data @ z_{eff} = 2.33 :

- large density of lines-of-sight ~ 60/deg^2
- relatively low SNR ⇒ several observations



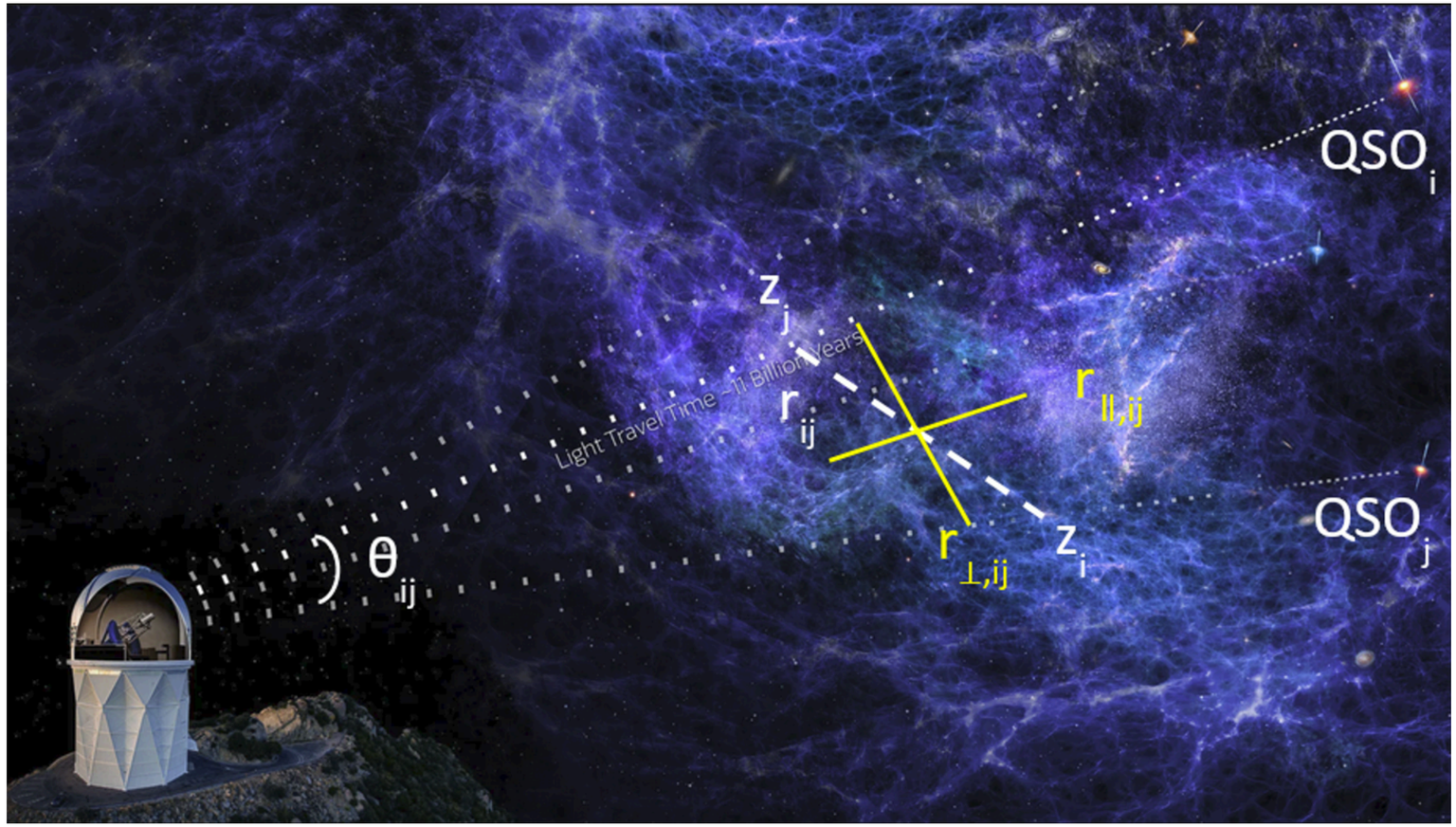


- **DR1**: public post-processed "delta-files" (δ_F) available as a VAC
  Adame+ arXiv:2404.03001 https://data.desi.lbl.gov/doc/releases/dr1/vac/lya-deltas/
- **DR2**: 820,000 Lyα spectra (z_{QSO}>2.1) + 1.2M tracer quasars (z_{QSO} > 1.77)
  Abdul-Karim+ arXiv:2503.14739
- **DR3**: ~ 1M spectra, SNR increased
- **DESI Run2**: more QSO spectra (~90/deg^2), new LBG spectra

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From Lyα correlations to cosmology



3D correlations

$$\xi(r_\parallel, r_\perp) = \langle \delta_F(\vec{x}) \delta_F(\vec{x} + \vec{r}) \rangle \qquad (r_\perp \neq 0)$$

→ quasi-linear model

⇒ **BAO, large scales (AP, growth)**

1D power spectrum

$$P_{\rm 1D}(k_\parallel) = \mathcal{F}_{\rm 1D} \left[\langle \delta_F(\vec{x}) \delta_F(\vec{x} + \vec{r}_\parallel) \rangle \right]$$

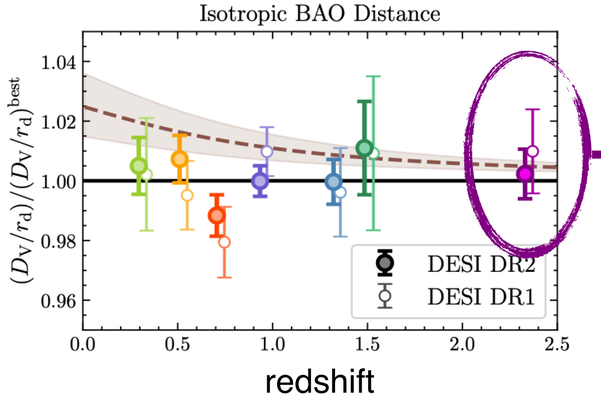
→ hydro-sim-based model

⇒ **(amplitude, slope) of the matter power spectrum at k ~ 1 Mpc^{-1}**

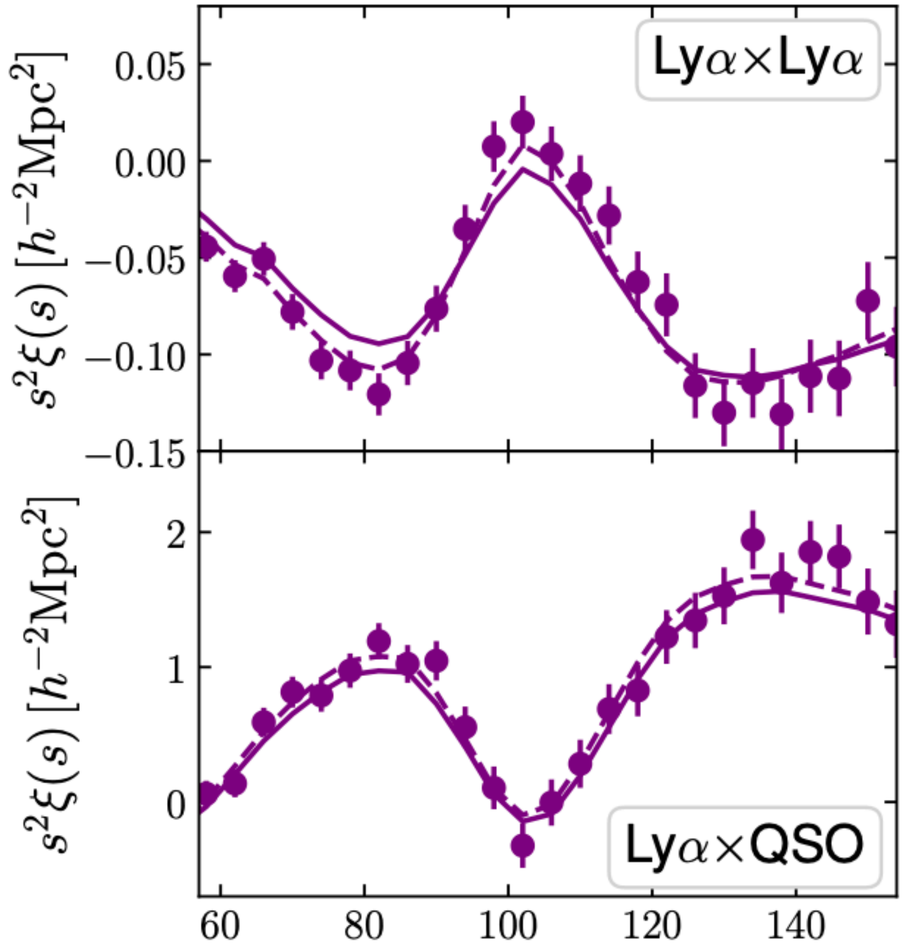
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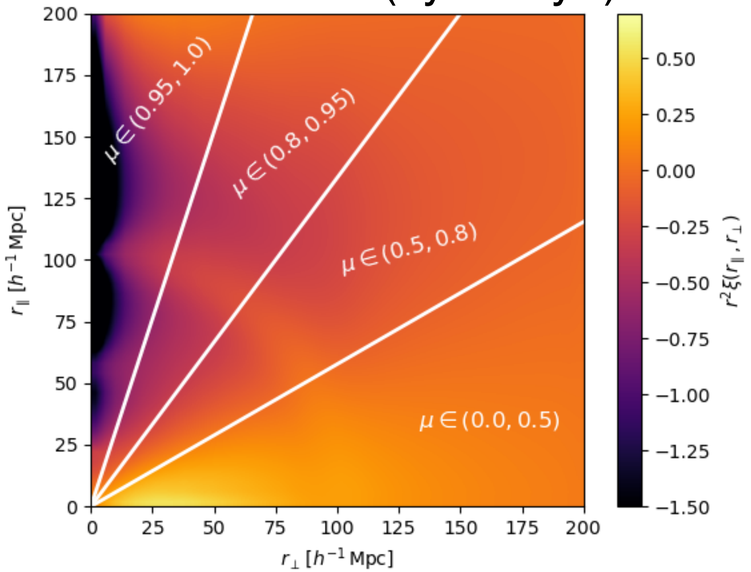
DESI DR2 BAO measurement



σ(isotropic BAO) = 0.7%



best-fit model (Lyα x Lyα)



Abdul-Karim+ arXiv:2503.14739
Brodzeller+ arxiv:2503.14740
Casas+ arxiv:2503.14741

Model = [Power spectrum + Contaminants] ⊗ (continuum-fitting distortion matrix)

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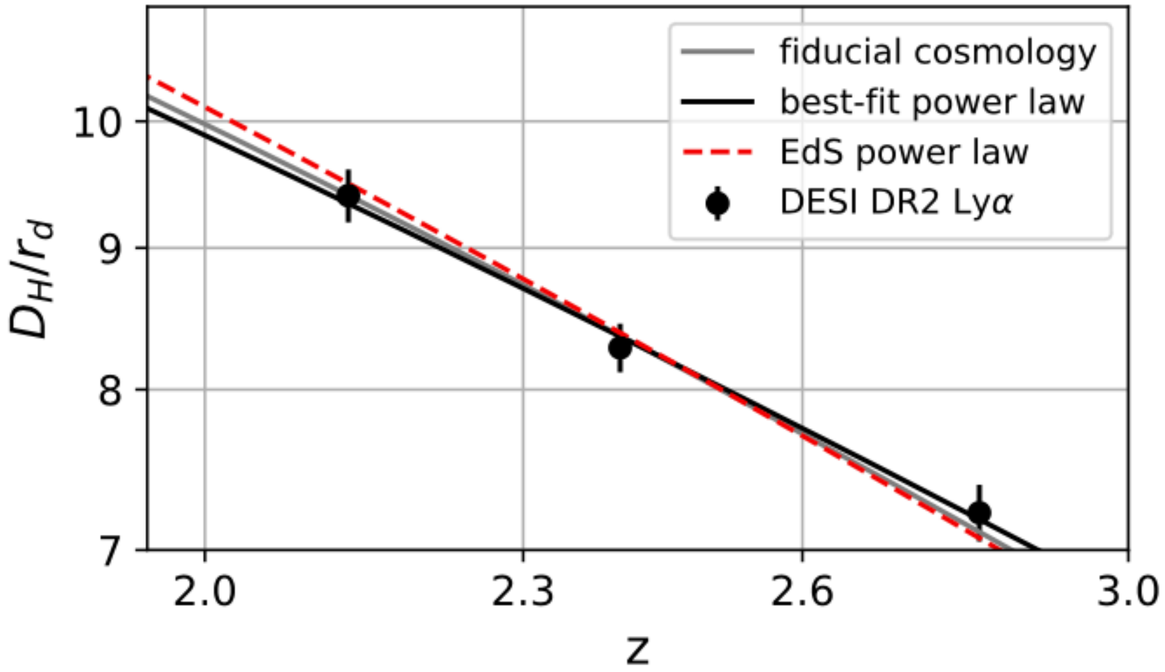
DR2 Lyα BAO in 3 redshift bins

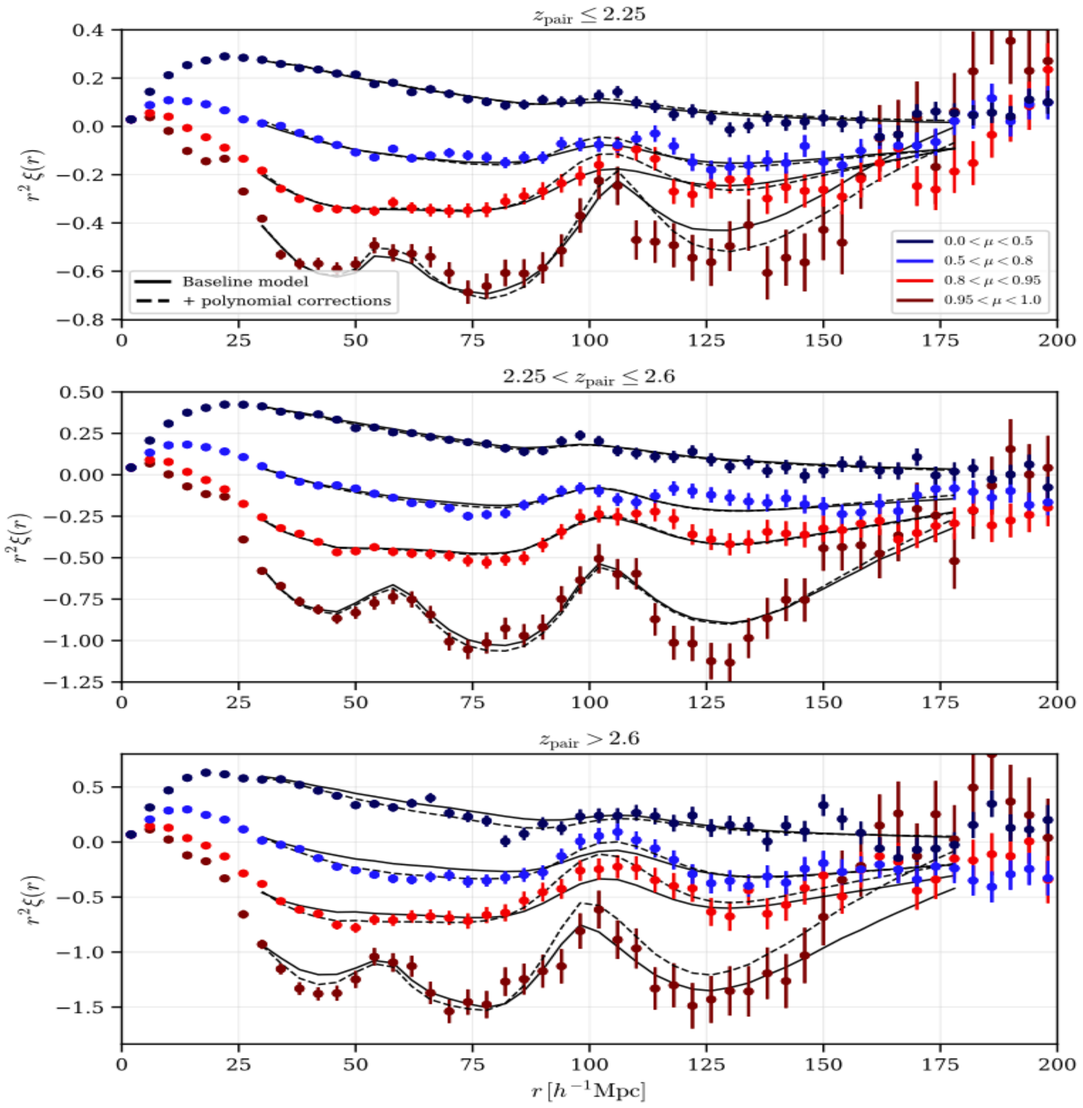
Herrera+ arXiv:2607.19619

- z_{eff} = 2.13, 2.40, 2.81
- Isotropic BAO precision 1.1 – 1.2% per bin
- Power-law fit from the longitudinal BAO scale:

$$H(z) \propto (1+z)^{1.34 \pm 0.16}$$

⇒ **consistent with Einstein – de Sitter (1+z)$^{3/2}$**





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Lyα full-shape: Alcock-Paczynski measurement

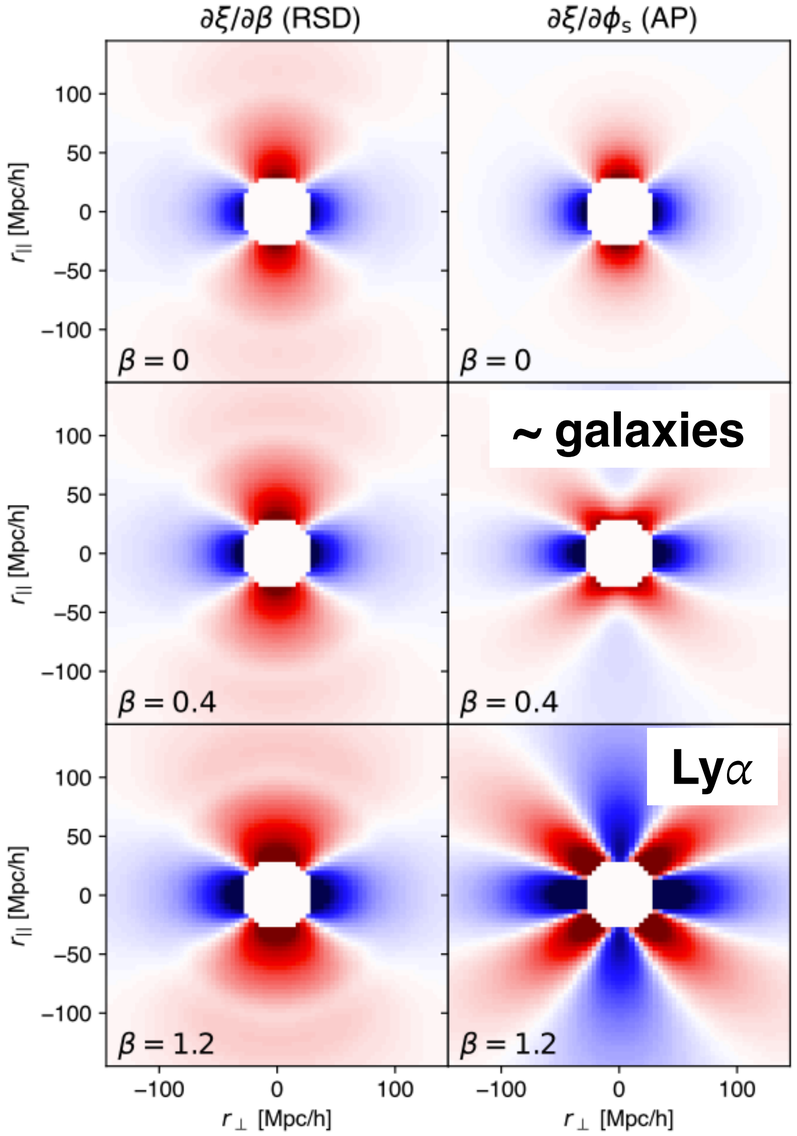
Cuceu+ arXiv:2509.15308

- **Large-scale Lyα correlations**
- Template-based model for fit:

$$\xi(r_\parallel, r_\perp) = \xi_s(q_\parallel^s r_\parallel, q_\perp^s r_\perp) + \xi_p(q_\parallel^p r_\parallel, q_\perp^p r_\perp)$$

broadband BAO

- Focus on AP from the broadband $\phi_s = \frac{q_\perp^s}{q_\parallel^s}$
- For Lyα, AP is not degenerate with RSD
- Blind measurement, validation with mocks, data splits and variations (same pipeline and data vector as BAO)



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DR2 full-shape: fit and validation

Adame+ arXiv:2607.27410

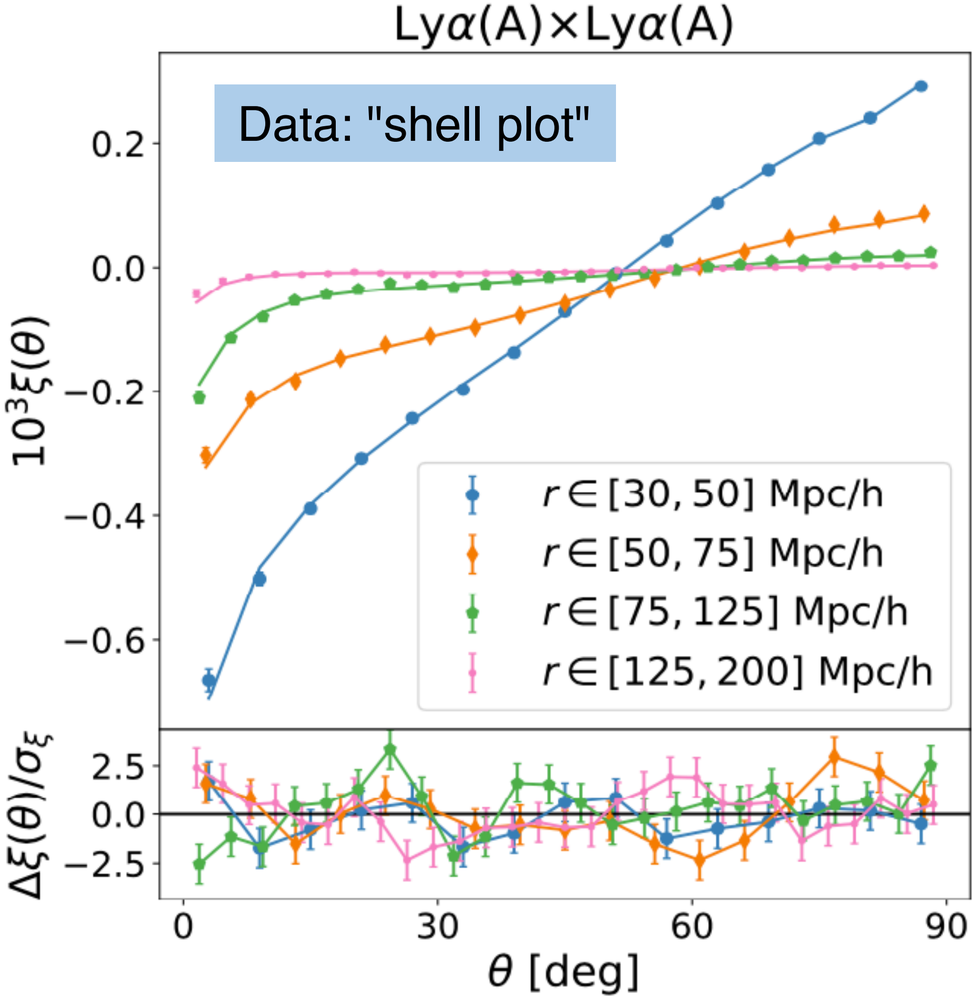
- r_{min} = 30 (auto), 40 Mpc/h (cross)
- chi2/dof=11492/(11388-21), PTE=0.20

- Non-linear correction fixed from P1D measurement

- Continuum-fitting-induced "distortions":

$$\xi_{\rm meas} = D \cdot \xi_{\rm model}$$

⇒ Small-Scale Marginalization (SSM) method



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DR2 full-shape: fit and validation

2LPT mocks vs data

Adame+ arXiv:2607.27410

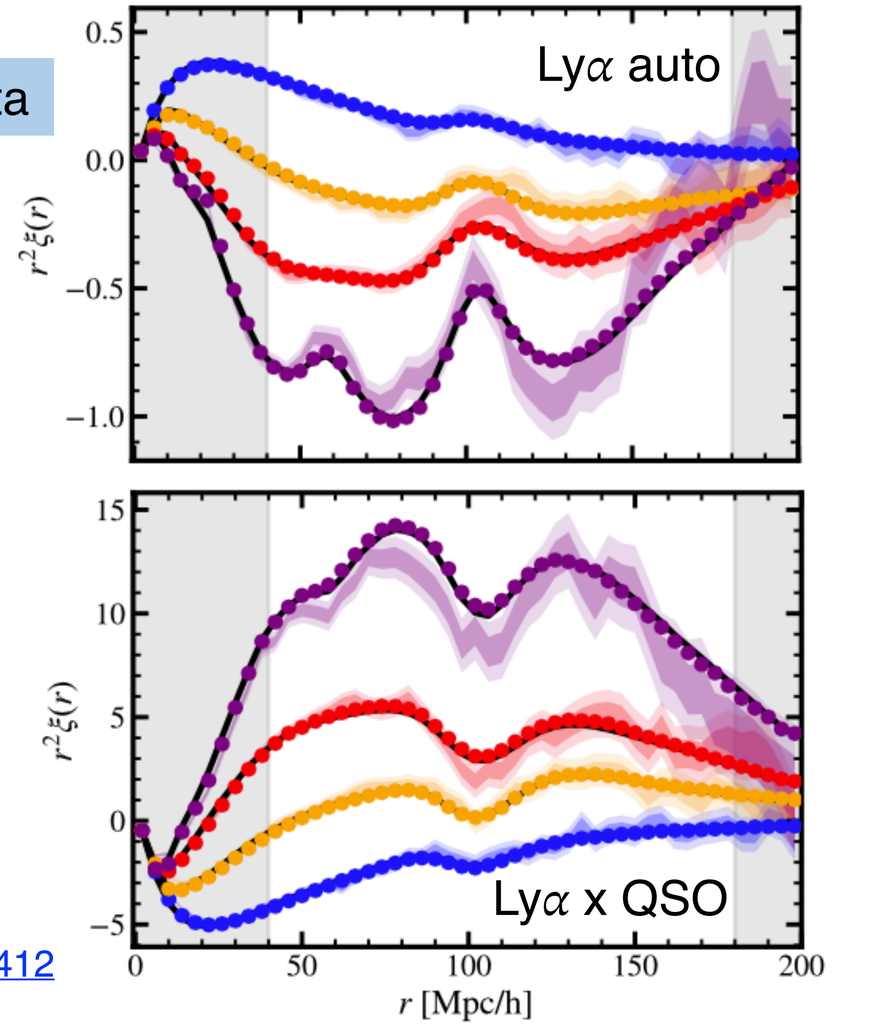
- r_{min} = 30 (auto), 40 Mpc/h (cross)
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$$\xi_{\rm meas} = D \cdot \xi_{\rm model}$$

⇒ Small-Scale Marginalization (SSM) method



Ruiz-Herrera+ arXiv:2607.27412

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DR2 full-shape: fit and validation

Adame+ arXiv:2607.27410

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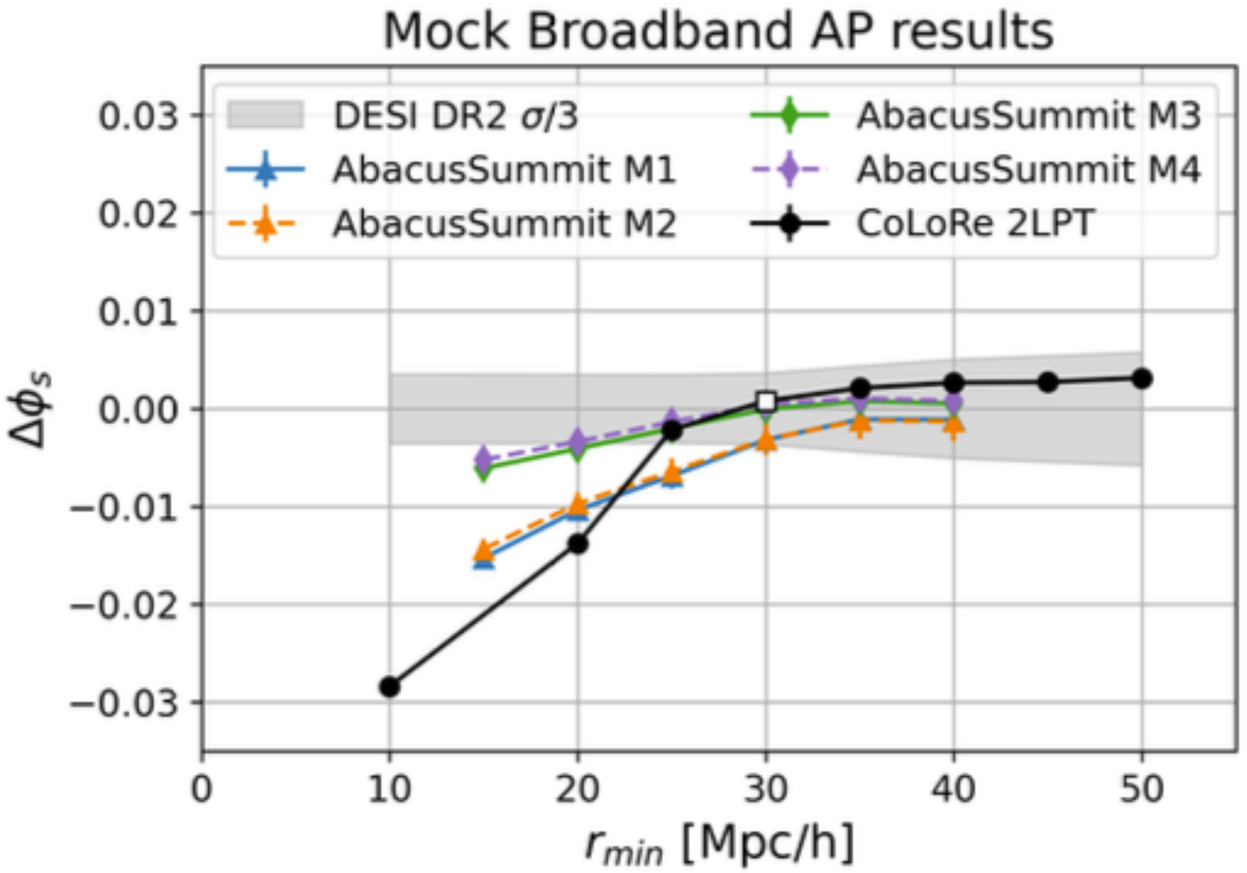
- Non-linear correction fixed from P1D measurement

- Continuum-fitting-induced "distortions":

$$\xi_{\rm meas} = D \cdot \xi_{\rm model}$$

⇒ Small-Scale Marginalization (SSM) method

Bias on AP in mocks



Herbold+ arXiv:2607.27411

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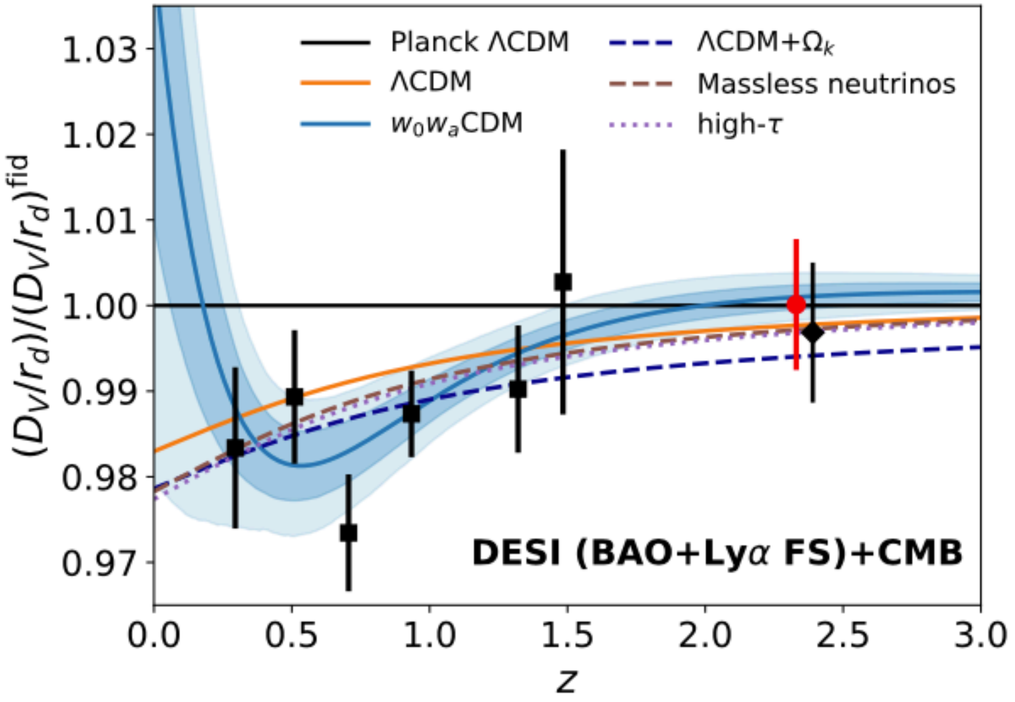
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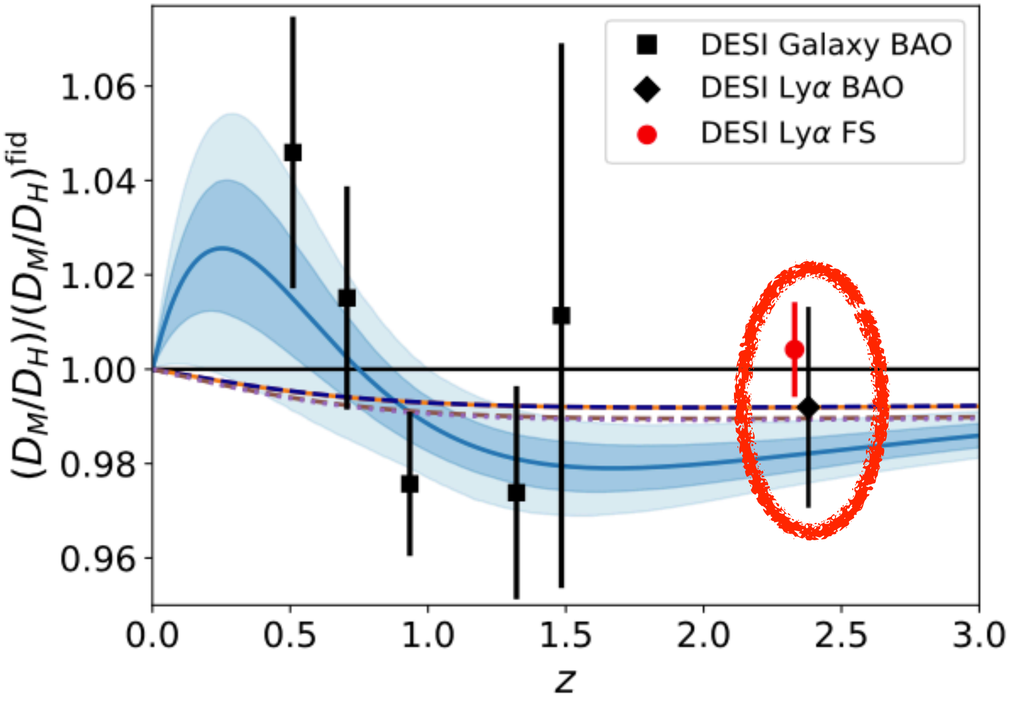
DR2 full-shape results

- **AP parameter at 1.1% (stat.) (AP from BAO ~ 2%):** $\phi_s = 1.007 \pm 0.011$ consistent with Planck ΛCDM

- UV-background fluctuation detected at ~ 3-5 σ

(scale dependent bias with transition at ~ 300 h^{-1} Mpc)

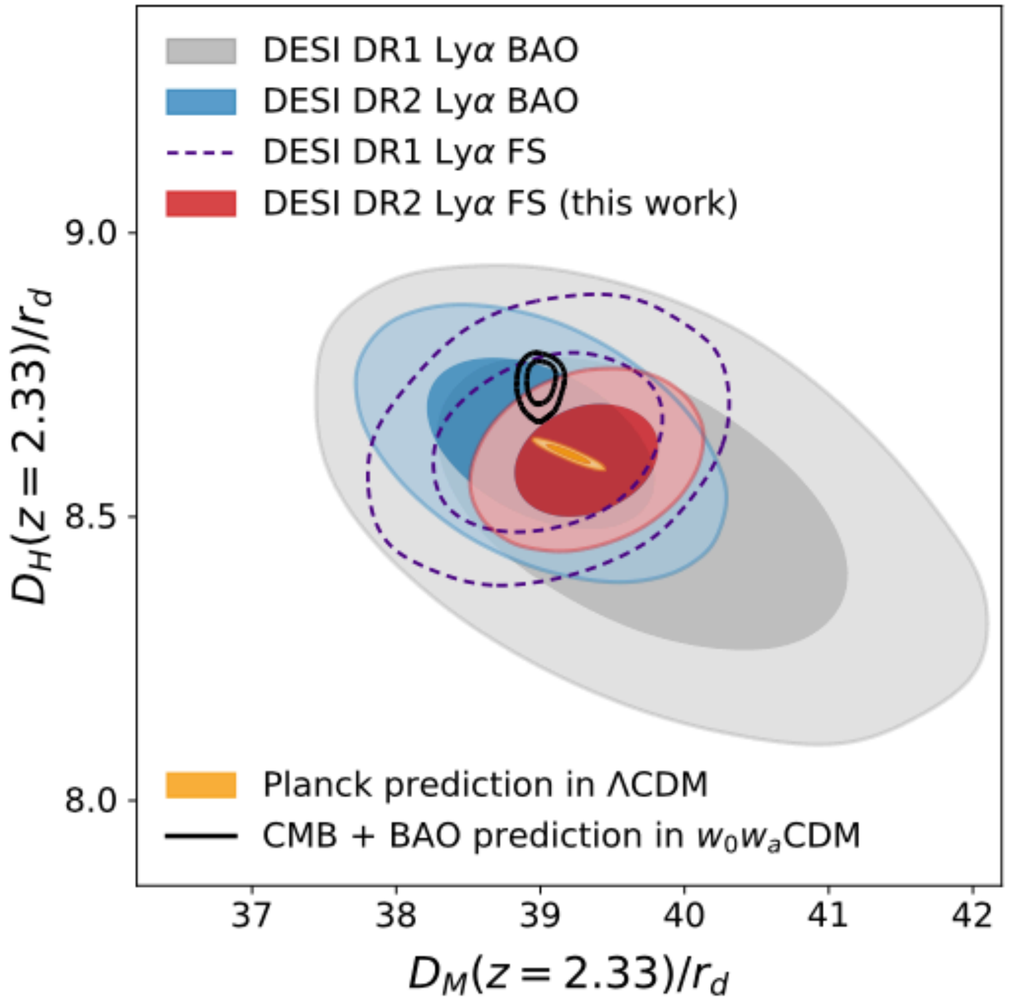


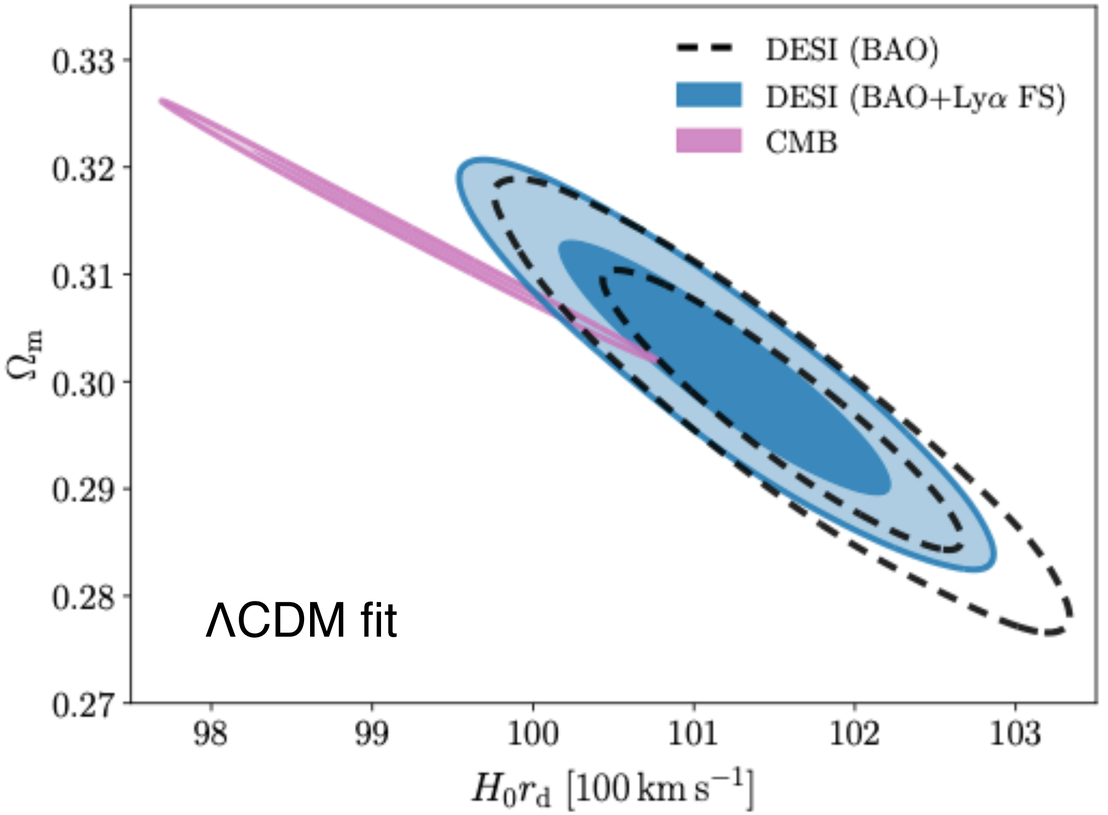


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DR2 full-shape results





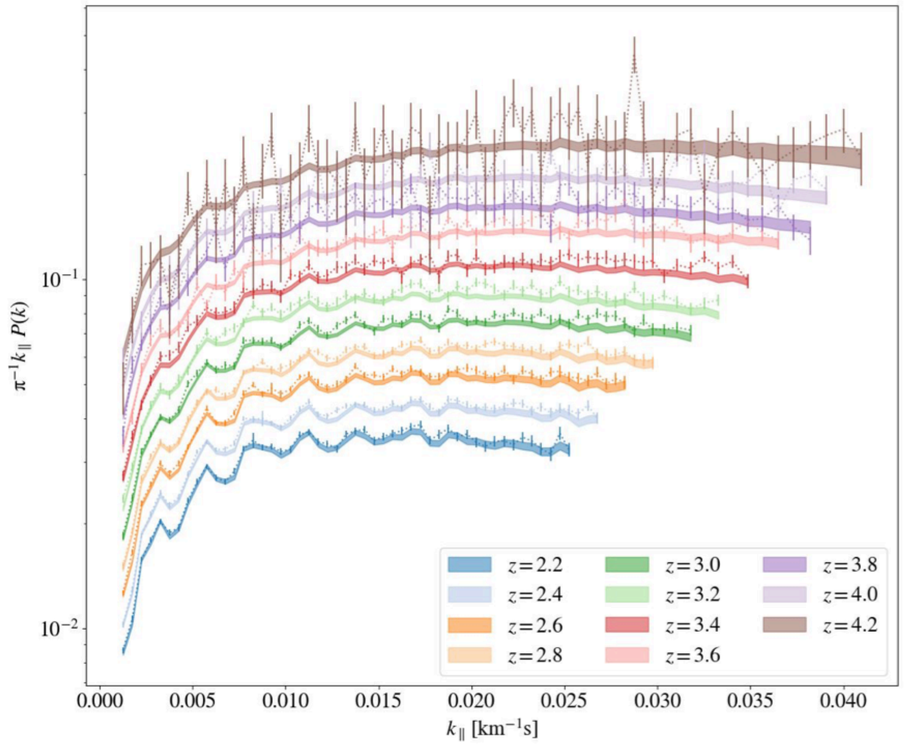
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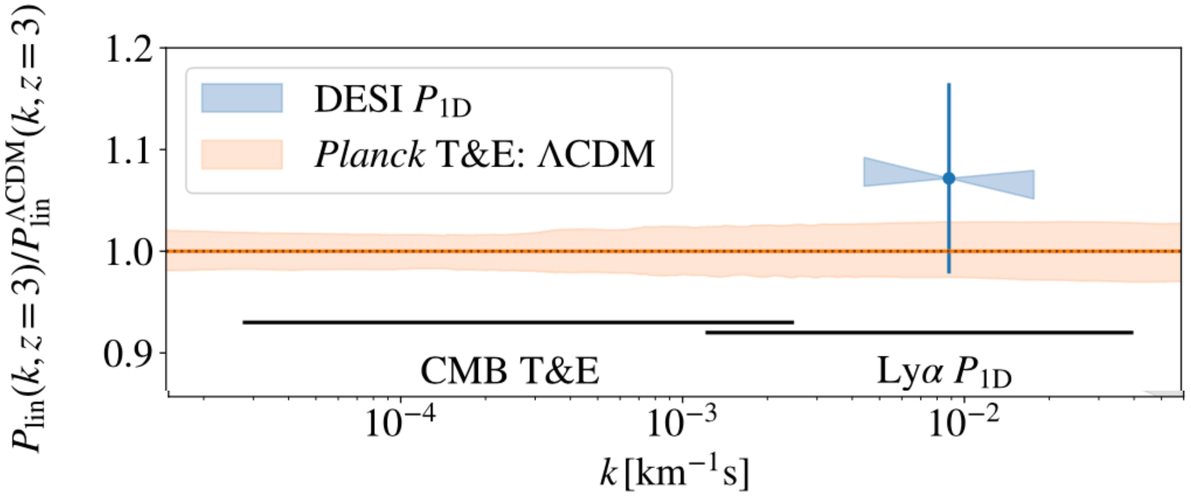
DESI DR1 Lyα small-scale P1D

- $P_{1D}(k)$ measurements in 11 redshift bins 2.2<z<4.2
- Down to **very small scales k ~ 4 Mpc^{-1}**

- Fit with hydrodynamical simulations (IGM physics)



Ravoux+ arXiv:2505.09493, Karaçayli+ arXiv:2505.07974
Chaves-Montero+ arXiv:2601.21432



~1% (resp. ~10%) **precision on the slope** (resp. amplitude) **of the linear power** at $z_\star = 3$, $k_\star = 9\text{x}10^{-3}$ s/km ≃ **1.0 h Mpc^{-1}** :

$$n_\star = -2.31 \pm 0.02$$

$$\Delta^2_\star = 0.38 \pm 0.03$$

⇒ consistent with CMB

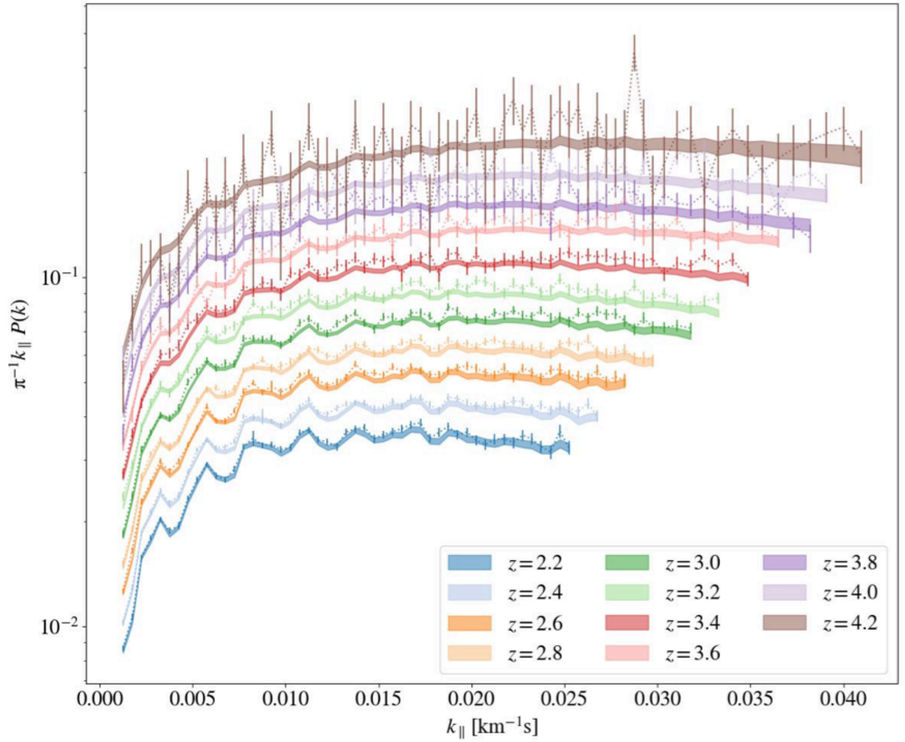
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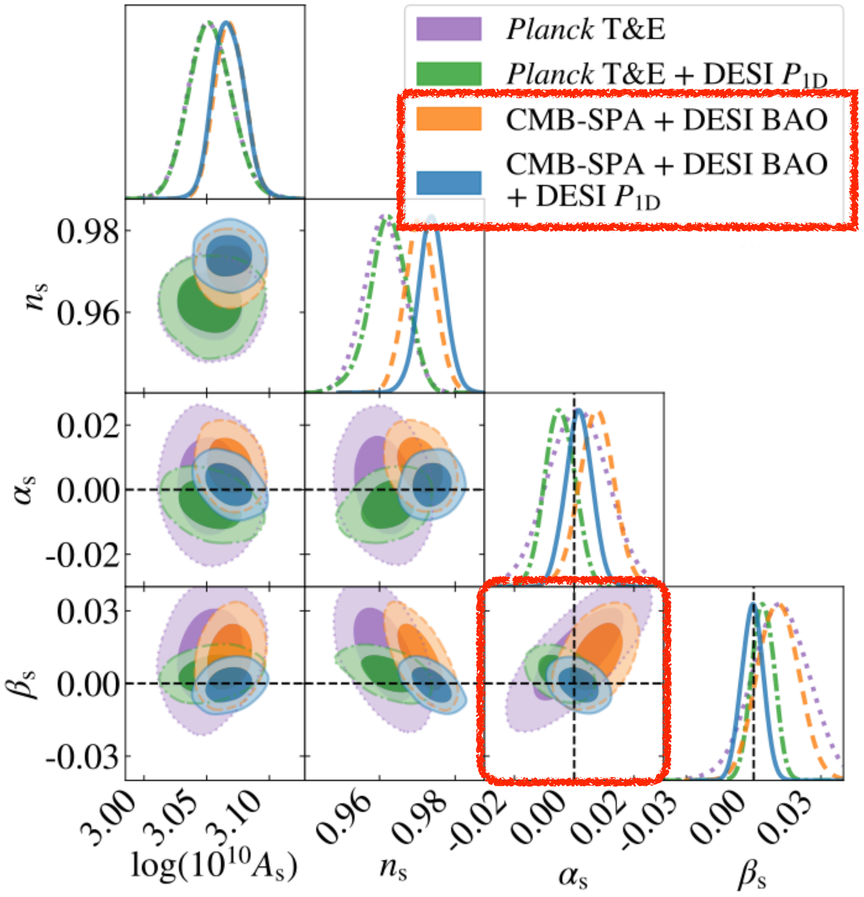
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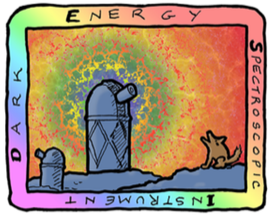


Ravoux+ arXiv:2505.09493, Karaçayli+ arXiv:2505.07974
Chaves-Montero+ arXiv:2601.21432



Implication for inflation:
No running of the primordial power spectrum (α_s, β_s):

$$\log \Delta^2_{\mathcal{R}}(k) = \log A_s + (n_s - 1)\log(k/k_s) + \frac{\alpha_s}{2}\log(k/k_s)^2 + \frac{\beta_s}{6}\log(k/k_s)^3$$



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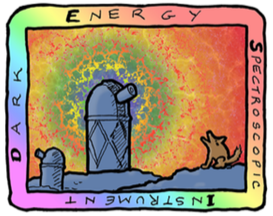
Conclusion and outlook

Results

- **0.7% BAO measurement at $z_{eff} = 2.33$**
  - $H(z) \propto (1+z)^{1.34\pm0.16}$ **direct test of near-EdS expansion**
- **1.1% AP measurement** from broadband correlation signal**: consistent with CMB**
  - Hint of UVB fluctuations
- ~1% measurement of power spectrum slope at $k = 1\ h\ Mpc^{-1}$

Outlook

- Holistic small- and large-scale approach:
  - Modelling (**EFT framework**)
    de Belsunce+ arXiv:2412.06892
  - Measurements (**Lyα cross-power spectrum** between nearby lines-of-sight)
    Abdul Karim+ arXiv:2310.09116
- **Cross-correlations** with other LSS probes at z>2 (CMB lensing, 21cm IM, high-z spectro- or photo-galaxies)
- DESI Run2: Lyα forest with **LBG spectra**
  Herrera+ arXiv:2507.21852



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