Running from the Lyman-α forest: Inputs on inflation from small scales

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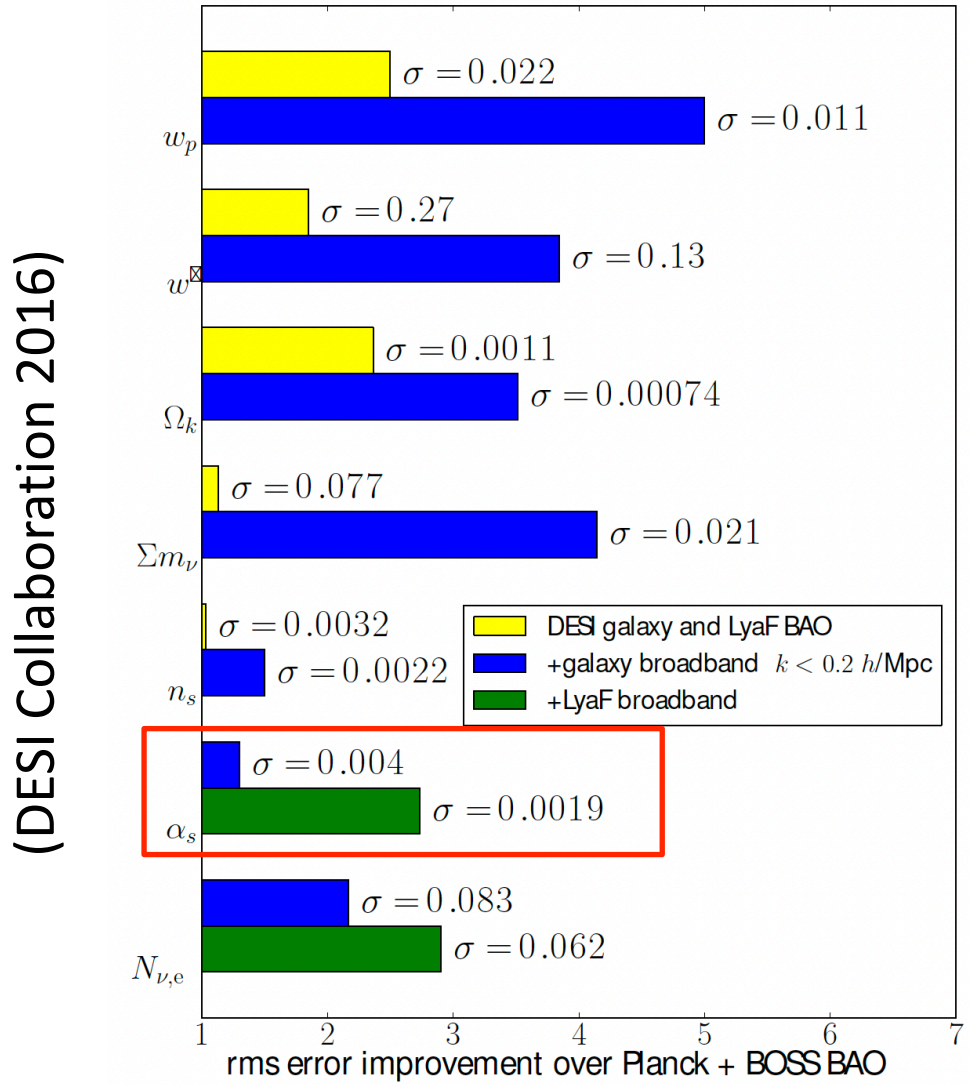
Forecasts for DESI



Most models of inflation predict some running of the spectral index

$$P(k) = P(k_0)(k/k_0)^{n_S(k_0)+\frac{1}{2}\alpha \ln(k/k_0)}$$

DESI will improve the constraints from Planck by a factor of ~3

Forecasts dominated by the small-scale clustering of the Lyman-α forest

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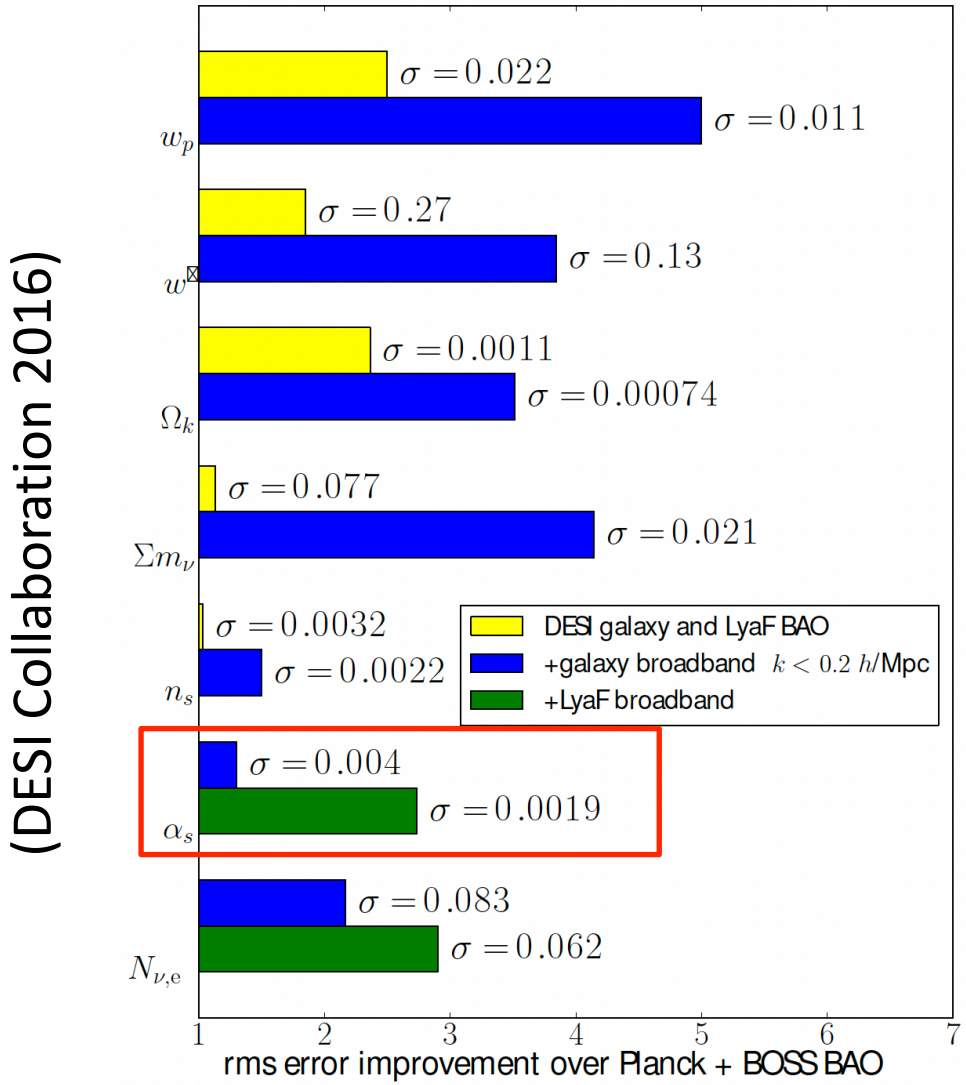
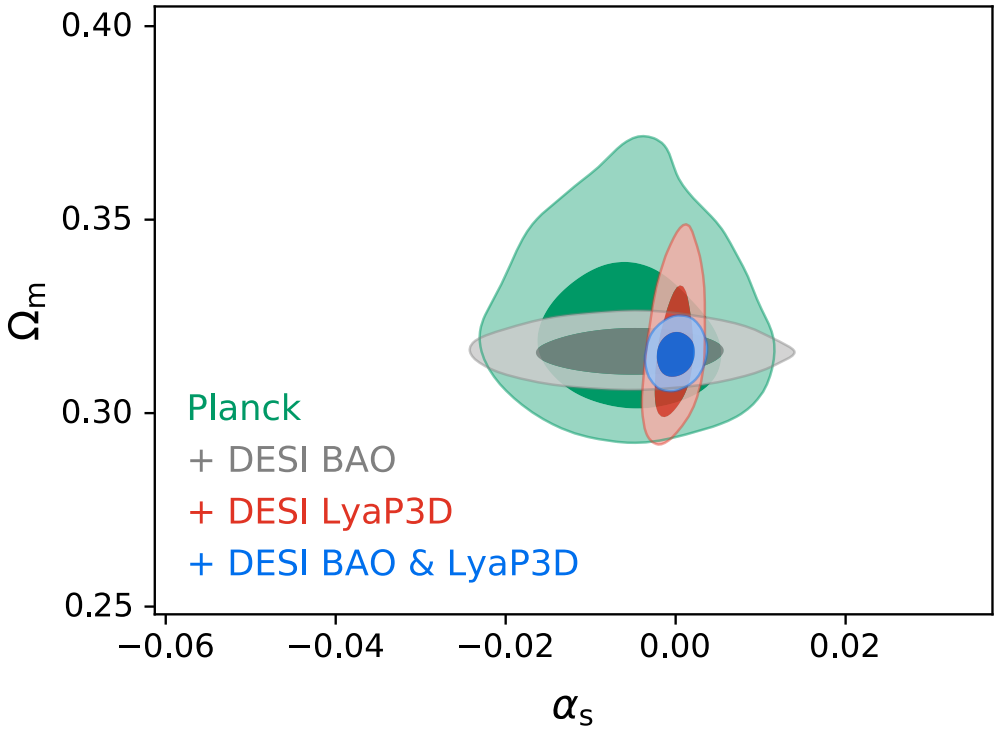
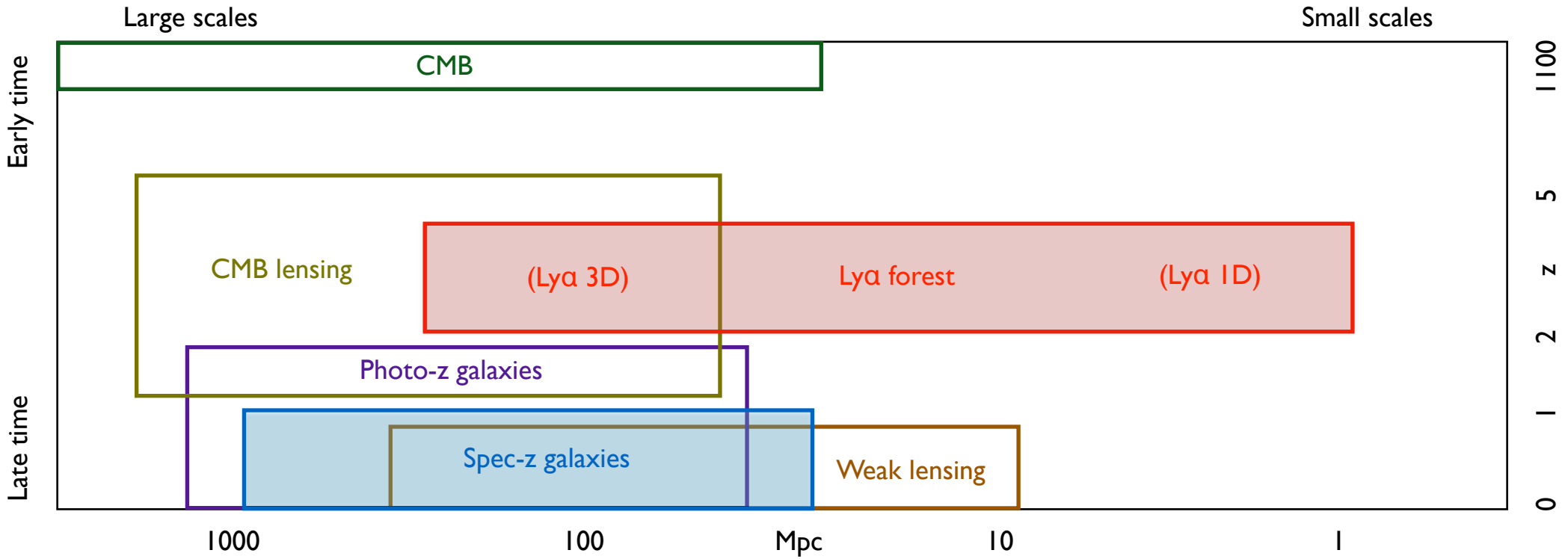
Forecasts for DESI





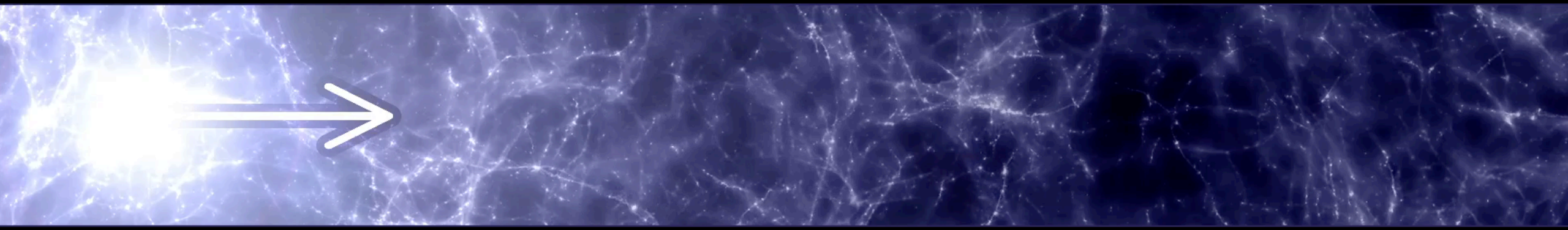
Forecasts dominated by the small-scale clustering of the Lyman-α forest

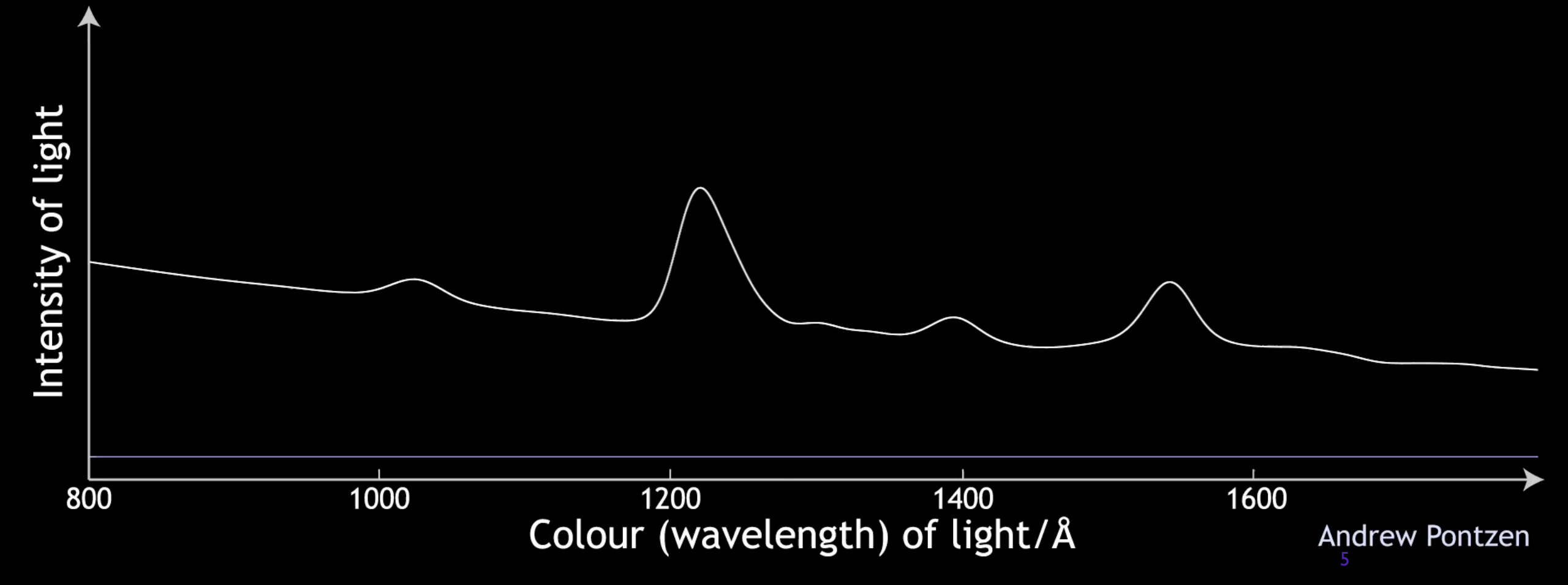
Cosmological probes of linear power



May 2021 - 2026: Dark Energy Spectroscopic Instrument (DESI)

* 35 million spec-z galaxies at $z < 1.5$
* 1 million Lyman-α quasars at $z > 2$




Intensity of light
800
1000
1200
1400
1600
Colour (wavelength) of light/Å
Andrew Pontzen

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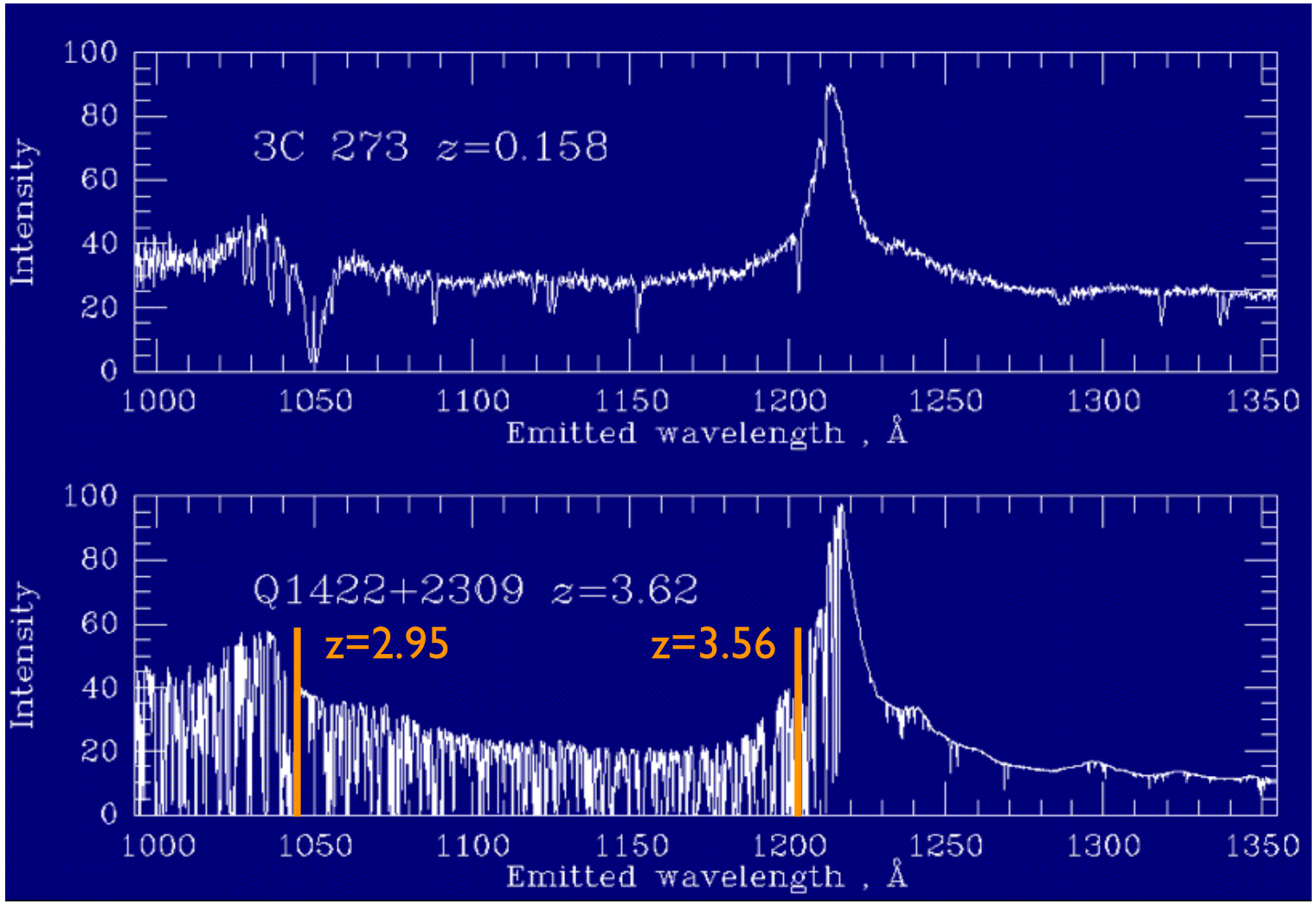
The Lyman-α forest



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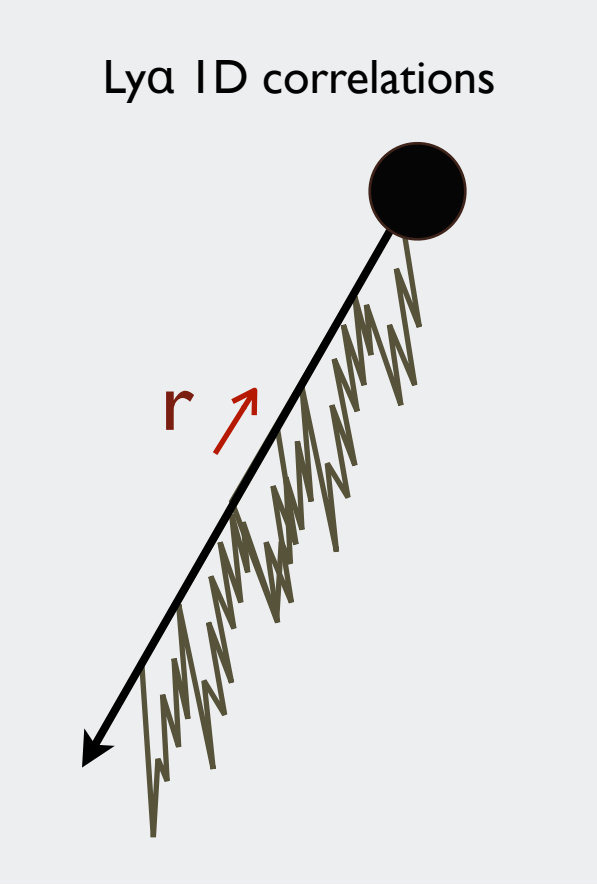
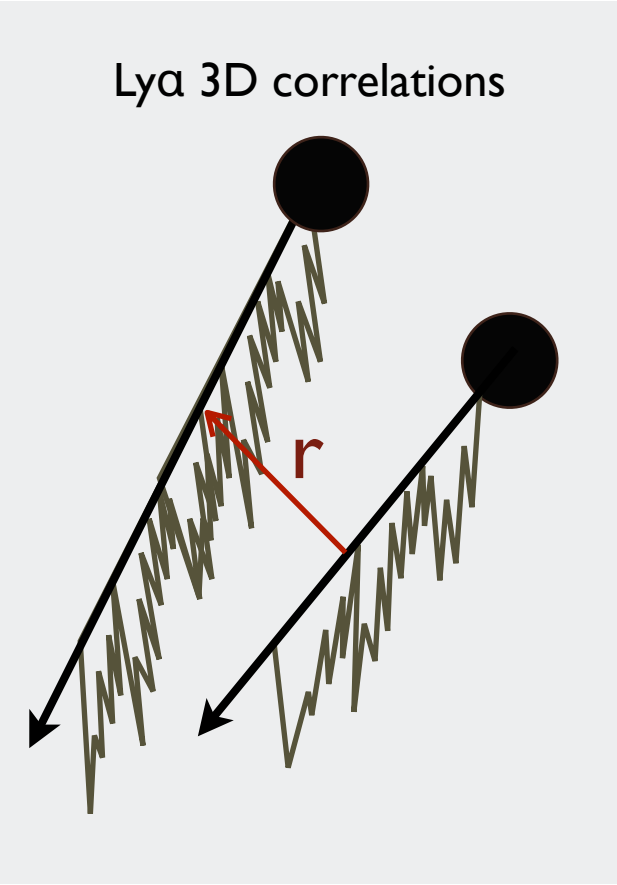
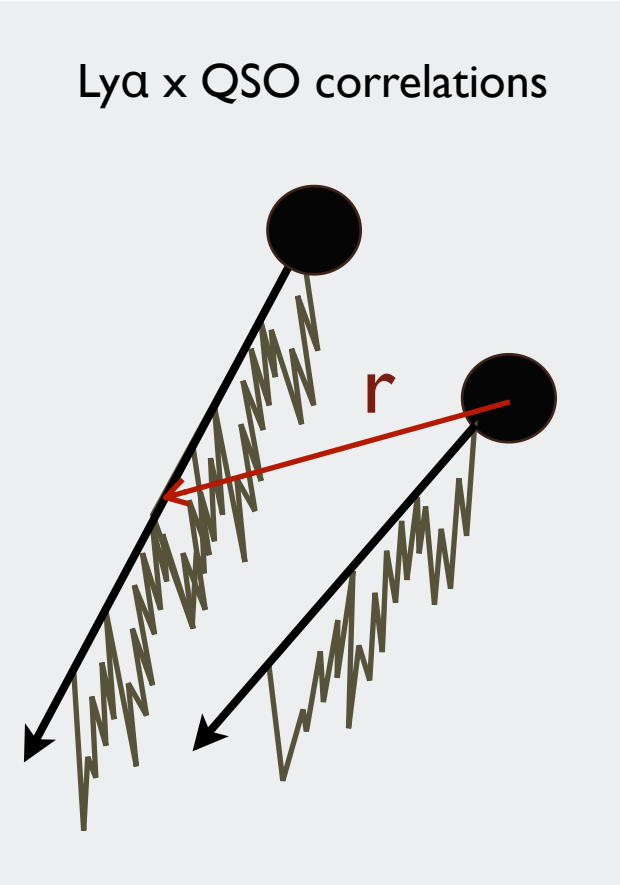
The Lyman-α forest







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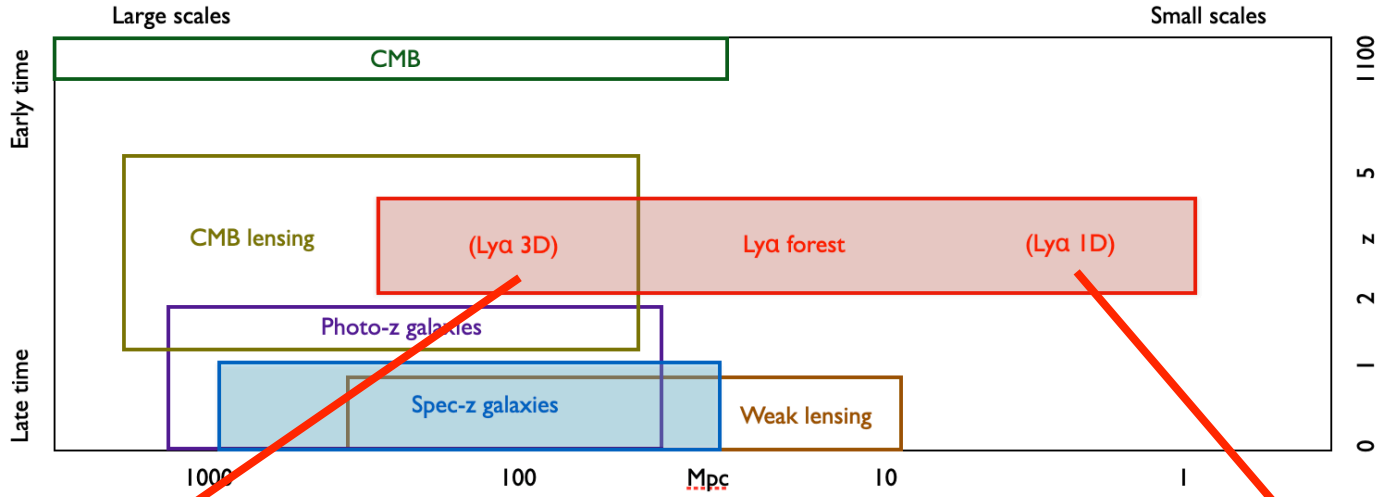
Cosmology with the Lyman-α forest



Lyα 3D

- measure expansion / geometry
- from 3D correlations
- on large scales
- modelling based on linear theory (mostly BAO signal)

Lyα 1D

- measure clustering
- from 1D correlations (P1D)
- on small scales
- non-linear modelling based on hydro sims and emulators

Emulating the Lyman-α forest

Lyman-α Cosmology Emulator (LaCE)

www.github.com/igmhub/LaCE

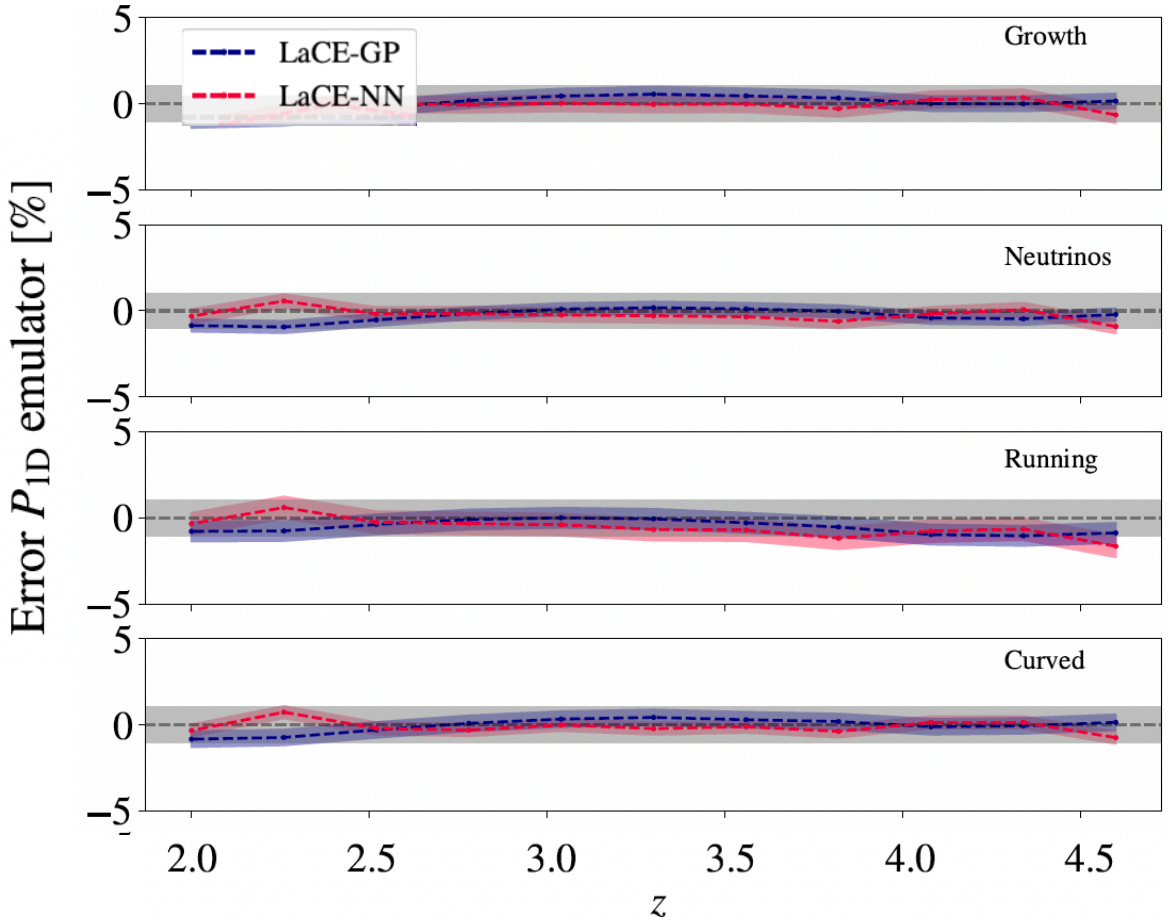
Based on:

- Pedersen, AFR et al. (2021)
- Pedersen, AFR & Gnedin (2023)
- Cabayol-Garcia, Chaves-Montero & AFR (2023)

Trained on LCDM hydro simulations

Emulation as a function of:

- IGM physics (temperature, ionisation)
- Amplitude and slope of linear density power (on megaparsec scales)



Percent performance even for cosmologies not present in the training (including running of 0.015)

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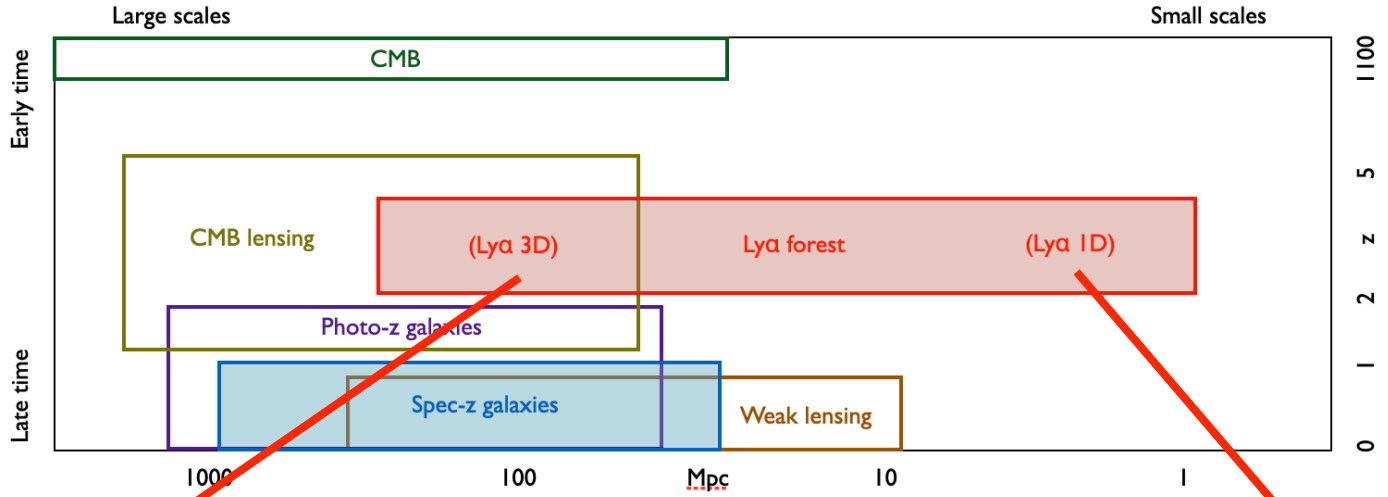
Cosmology with the Lyman-α forest



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Bridging the gap in the forest

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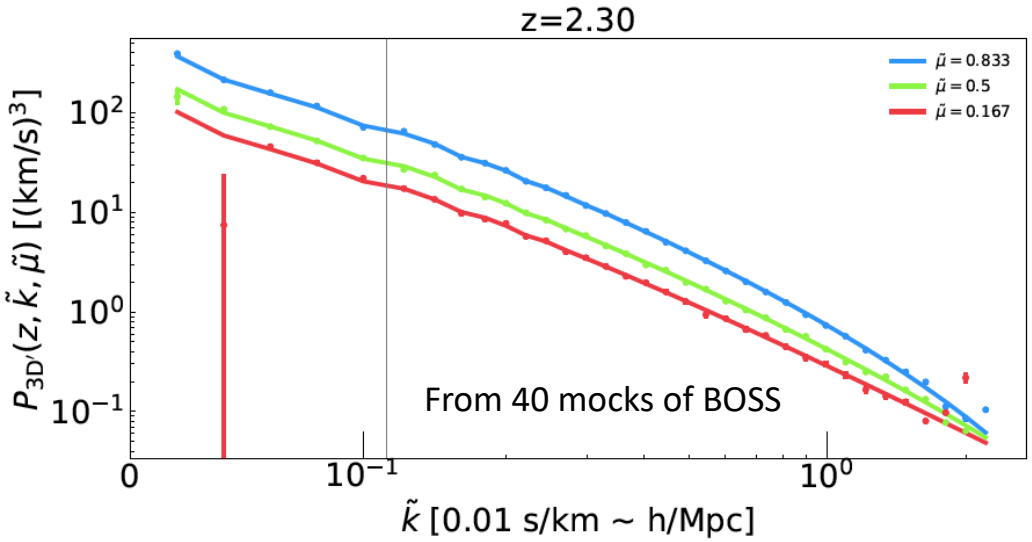
New 3D estimators aiming at smaller scales

- AFR, McDonald & Slosar (2018)



- Abdul-Karim et al. (2023)
- de Belsunce et al. (2024, next talk)
- Horowitz et al. (2024)

Full-shape analyses (beyond BAO)

- Cuceu, AFR et al. (2021, 2023a, 2023b)
- Gerardi, Cuceu, AFR et al. (2022)

Perturbation theory models

- Chen, Vlah & White (2022)
- Ivanov (2023)

Emulators for P3D

- Chaves-Montero et al. (In prep)

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What can Spec-S5 do for us?

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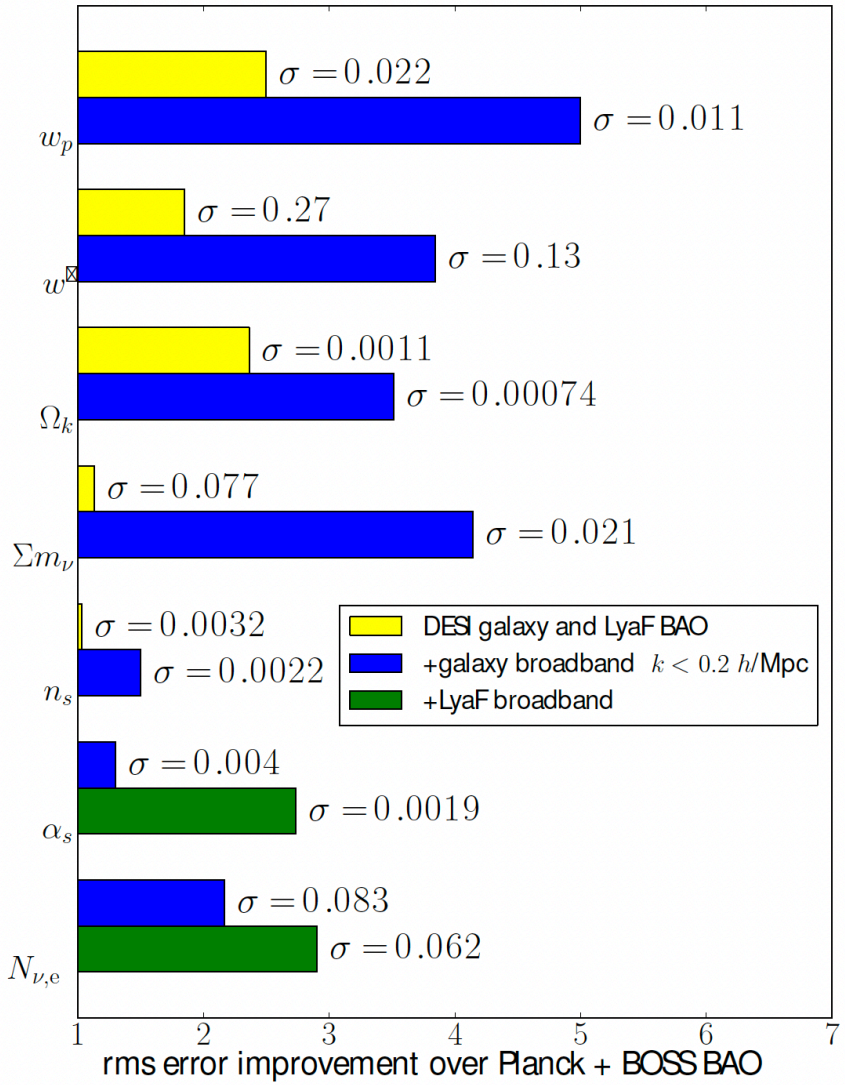
Running from the forest with Spec-S5



Most models of inflation predict some running of the spectral index

$$P(k) = P(k_0)(k/k_0)^{n_S(k_0)+\frac{1}{2}\alpha \ln(k/k_0)}$$

Some of these models predict:

$$\alpha_s \approx -(1 - n_s)^2 \approx -0.001$$

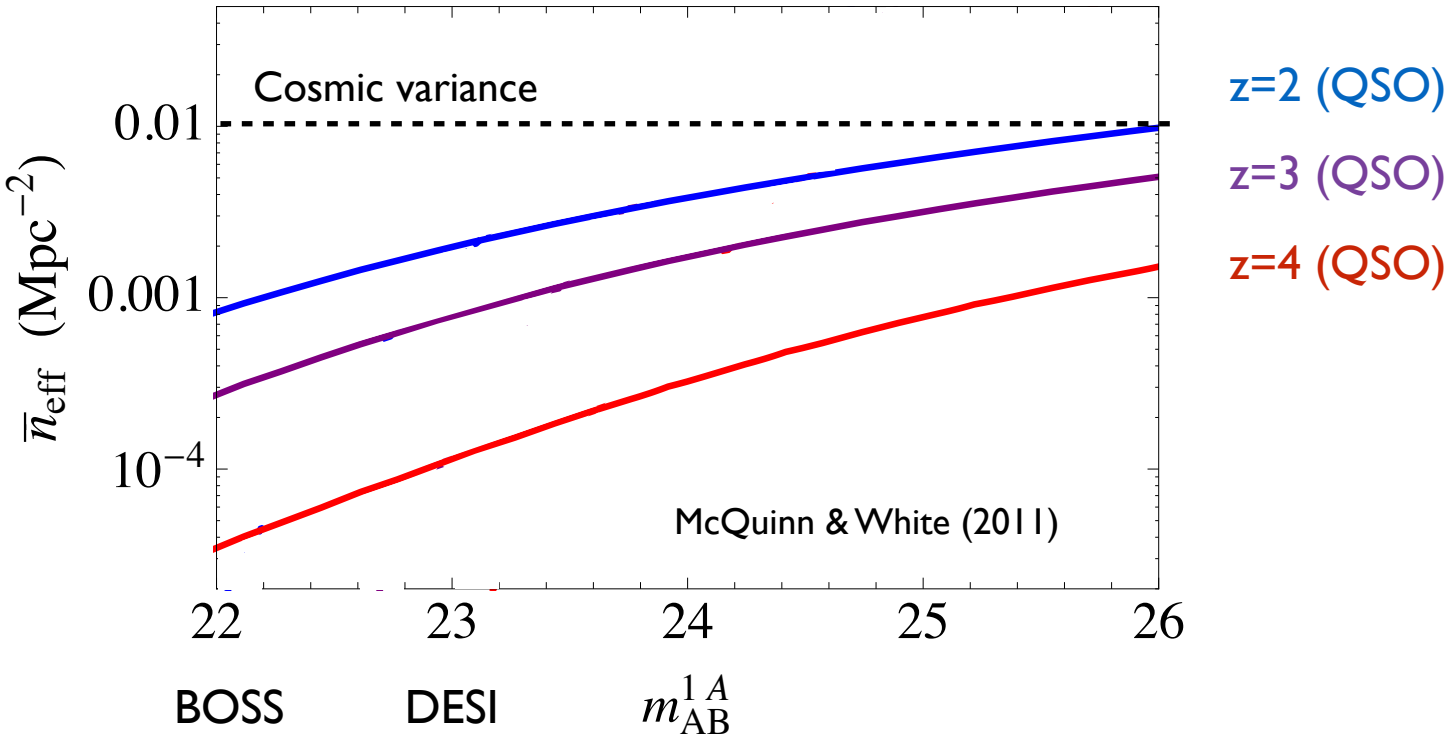
Forecasts from DESI + Planck still a factor of 2 away…

Running from the forest with Spec-S5

Galaxy surveys running out of sky:

DESI cosmic variance limited to z < 1.4

Not the case for Ly-α surveys: errors limited by density of lines of sight



Running from the forest with Spec-S5

Galaxy surveys running out of sky:

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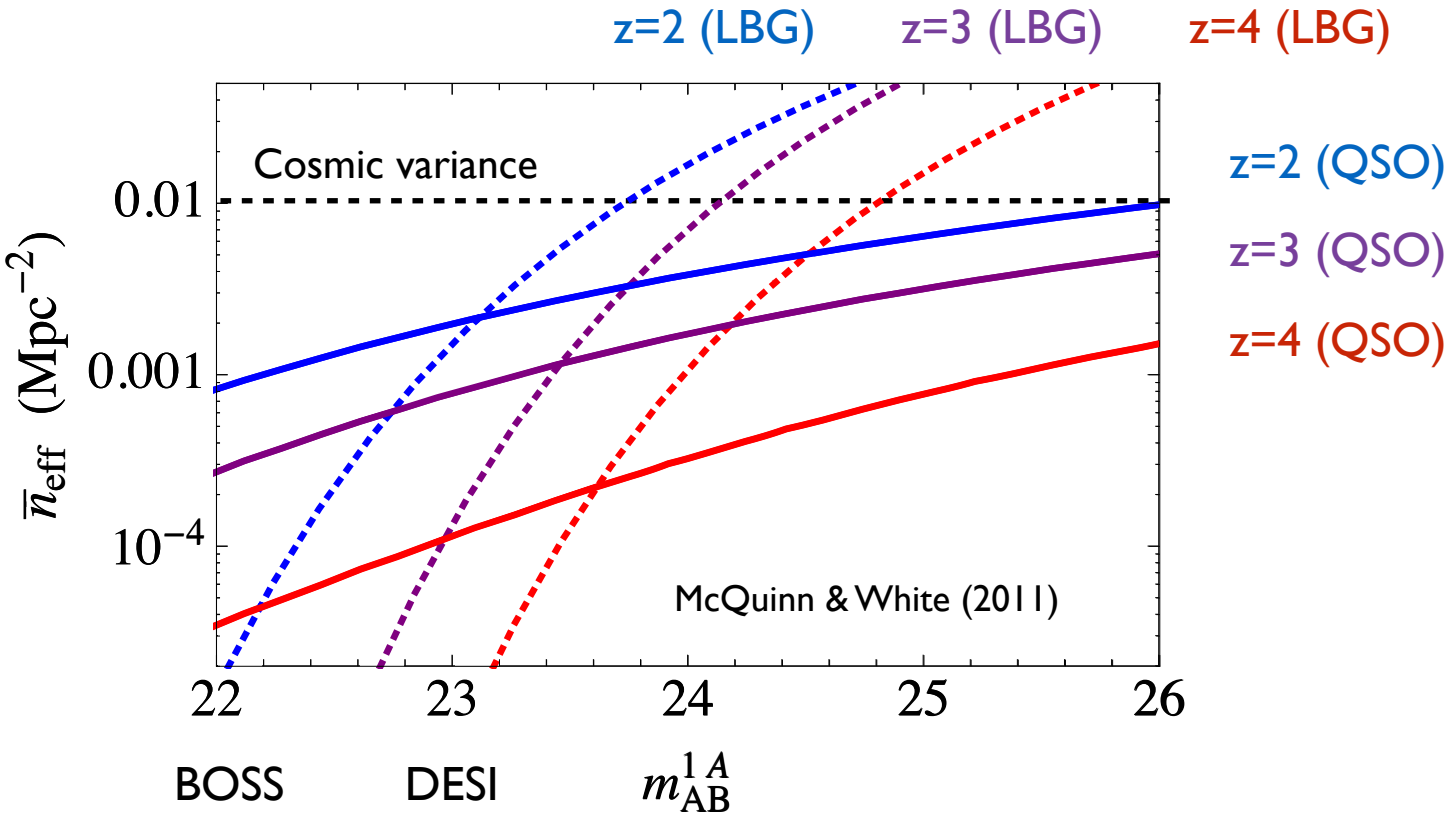
Quasars are rare, but we can also use galaxies as backlight (see CLAMATO, LATIS)



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Summary

- Large-scale 3D correlations in the Lyman-α forest are (as of today) our best probe of the expansion at $z > 2$
- Small-scale 1D correlations are a unique window to the linear power at Megaparsec scales
- In combination with CMB is our best shot at running
- Statistical uncertainties still limited by density of lines of sight, not by cosmic variance. Give us more forests!