The Alcock-Paczyński effect from Lyman-α forest: First full-shape measurement and cosmological implications

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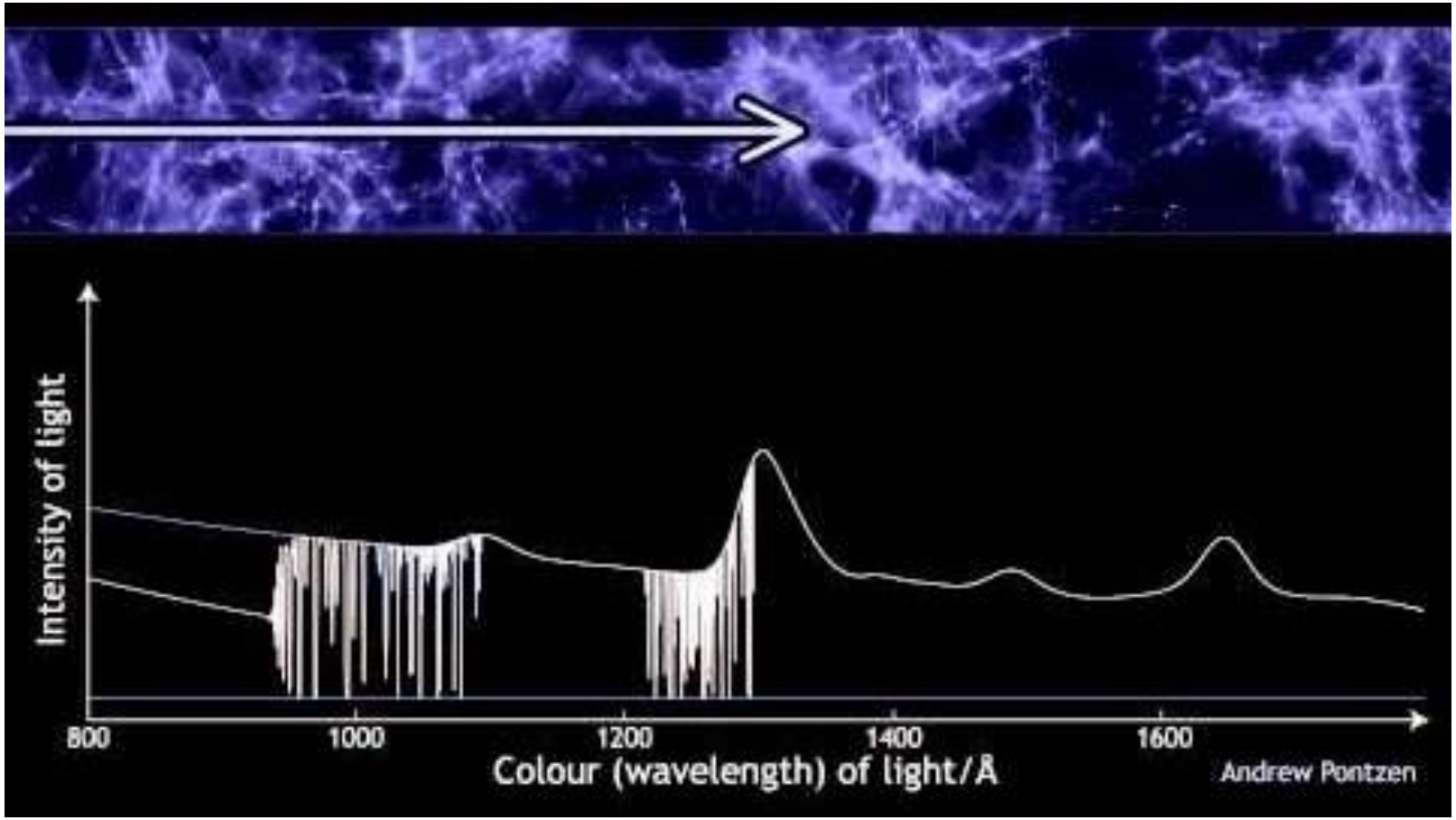
The Lyman-α forest



Video credit: Andrew Pontzen

The flux delta field

- For cosmology we use the statistics of the flux delta field, defined as:

$$\delta_q(\lambda_i) = \frac{f_q(\lambda_i)}{C_q(\lambda_i)\overline{F}(z_i)} - 1$$

- In general, we do not know the quasar continuum, $C_q(\lambda_i)$, and the global mean transmission, $\overline{F}(z_i)$.
- Therefore, we usually fit the product $C_q(\lambda_i)\overline{F}(z_i)$ directly from the data.

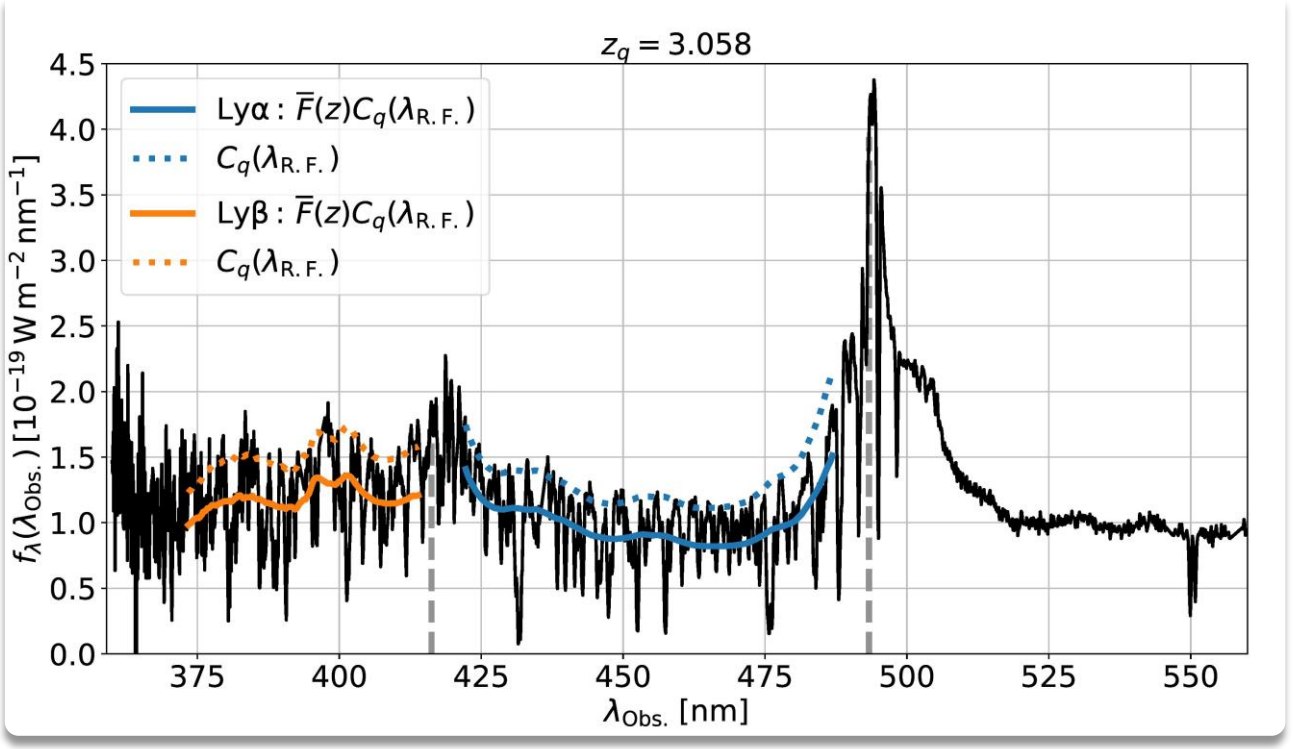
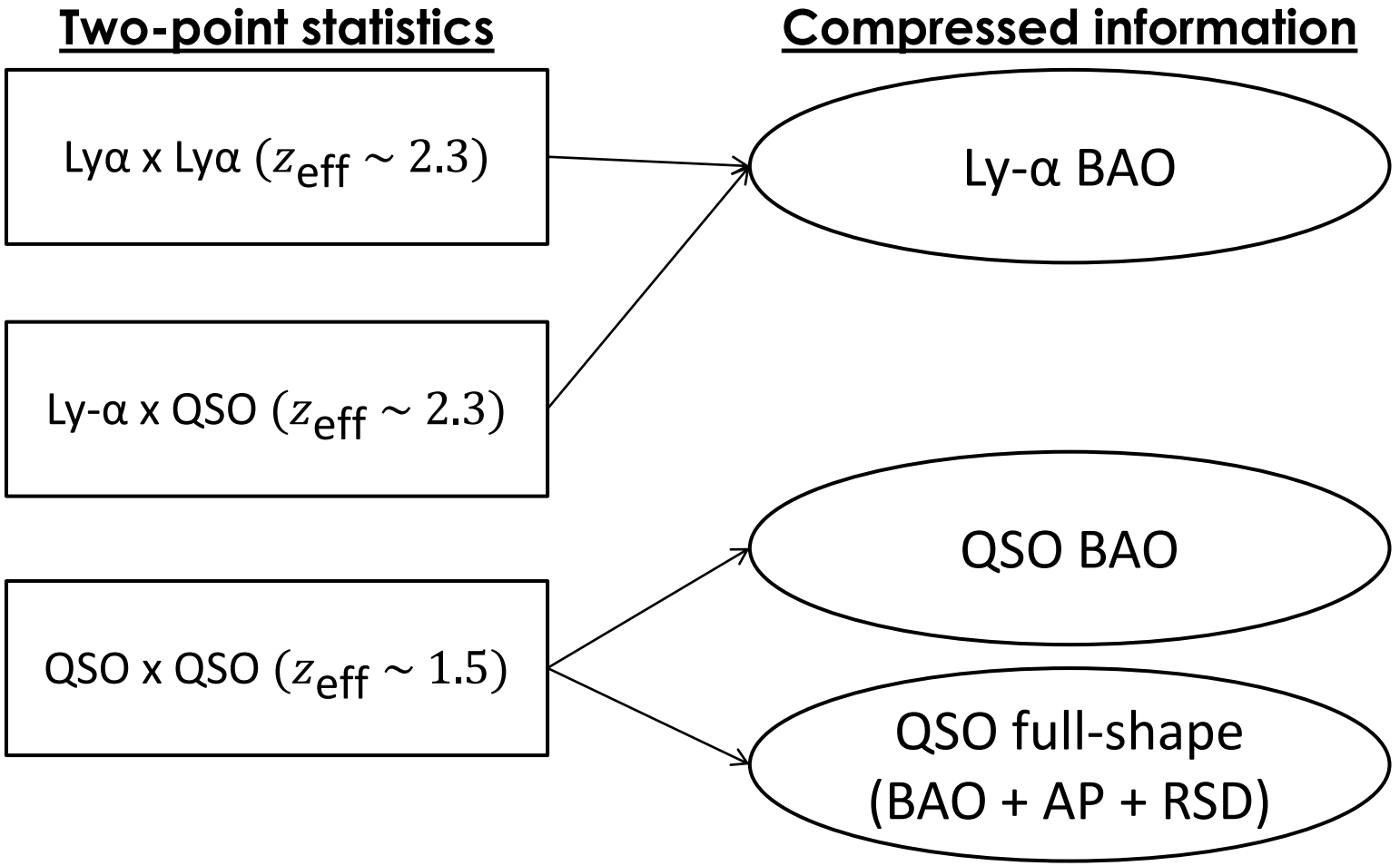


Figure from du Mas des Bourboux et al. 2020 (2007.08995)

The story so far (BOSS/eBOSS)



- BAO: measured using a template where we separate the peak (wiggles) and smooth (no-wiggles) components.
- Full-shape: fit the full shape of the correlation to measure cosmology. Most commonly through redshift space distortions (RSD) and the Alcock-Paczynski (AP) effect.
- Back in 1999, Hui et al. (1999) and McDonald et al. (1999) proposed to measure the Alcock-Paczynski effect using the Lyα forest.

The Alcock-Paczynski (AP) effect

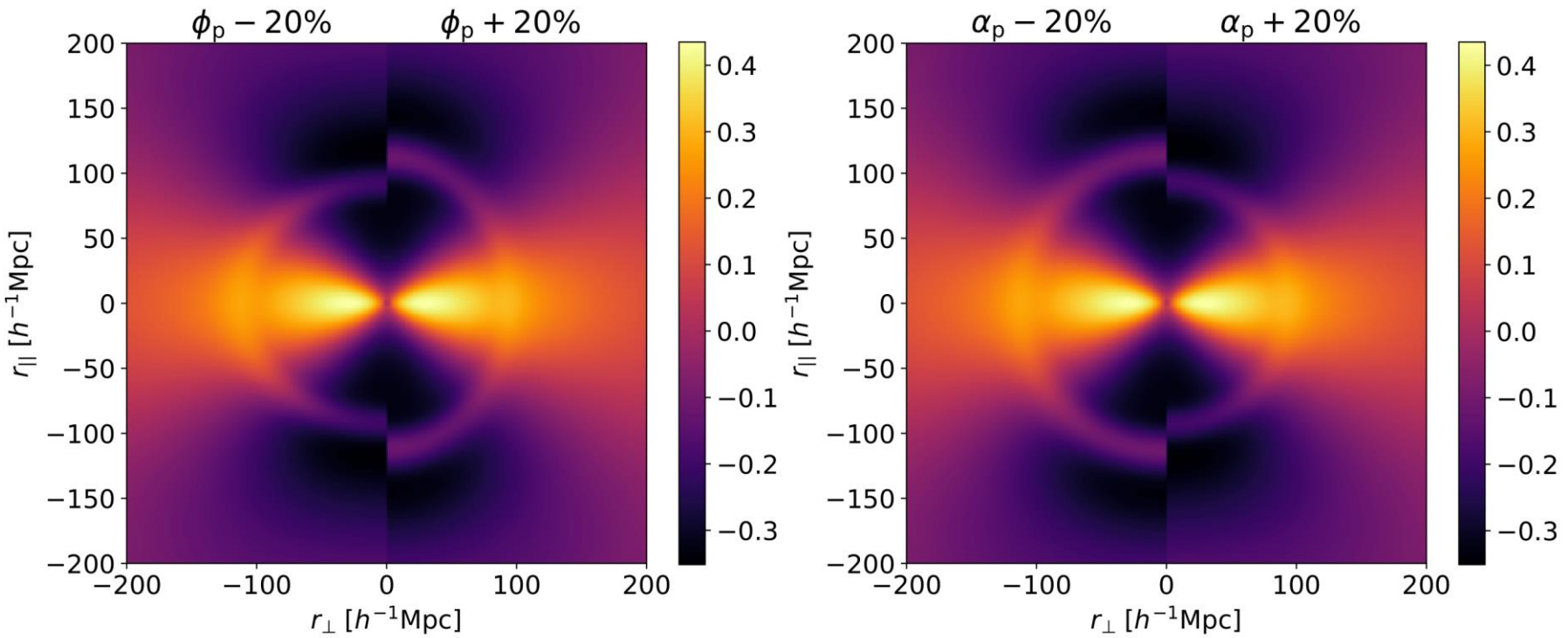
- We assume a fiducial cosmology to transform the angles and redshifts we measure $(\Delta\theta, \Delta z)$ into comoving distances $(r_\parallel, r_\perp)$.
- If the fiducial cosmology is different from the true cosmology, this will produce an anisotropy in the measured 3D correlation function.
- Two scale parameters ($q_\parallel$, $q_\perp$) are generally used to capture this information by rescaling the coordinates of the template:

$$r'_\parallel = q_\parallel r_\parallel \text{ and } r'_\perp = q_\perp r_\perp$$

- A measurement of the ratio $q_\parallel/q_\perp$ corresponds to a measurement of the AP parameter: $F(z) = \frac{D_A(z)H(z)}{c}$.
- For our analysis, we first redefined these parameters to isolate the AP effect:

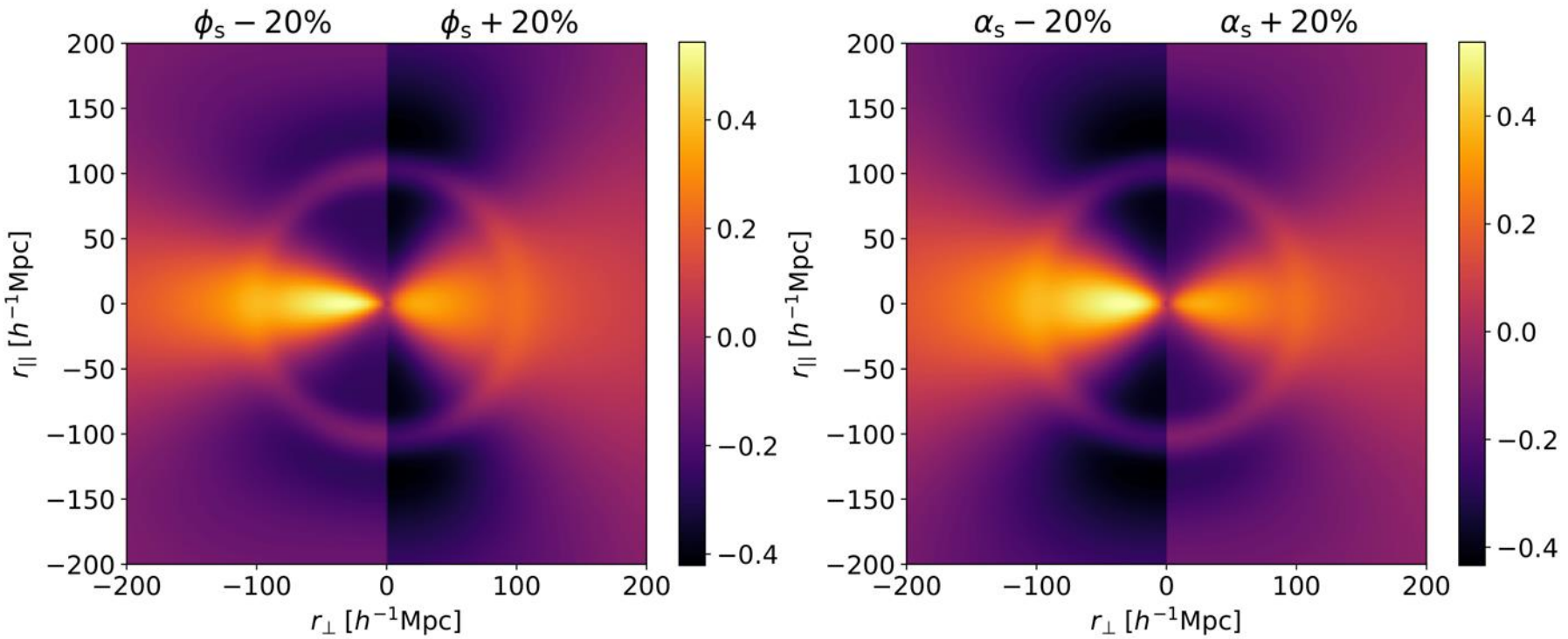
$$\phi = \frac{q_\perp}{q_\parallel} \text{ and } \alpha = \sqrt{q_\perp q_\parallel}$$

Rescaling the peak component



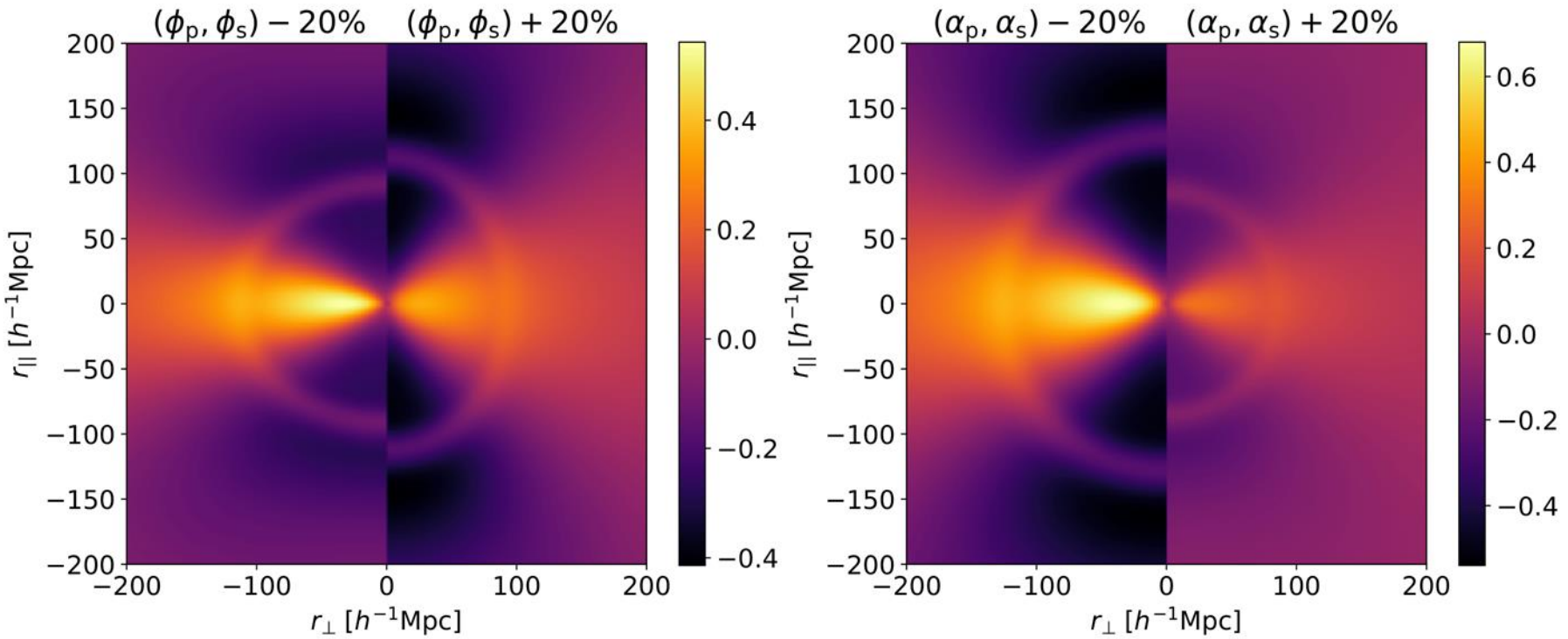
From Cuceu et al. 2021 (2103.14075)

Rescaling the smooth component



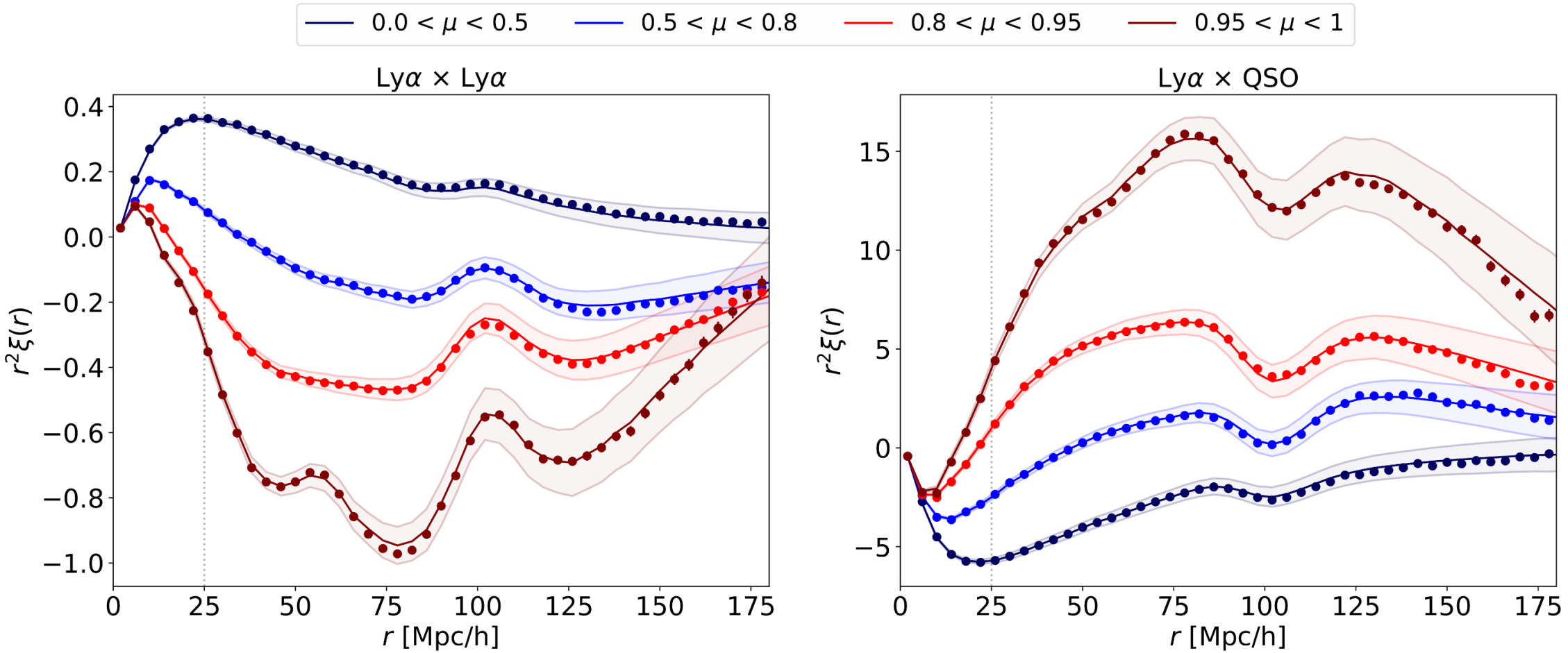
From Cuceu et al. 2021 (2103.14075)

Rescaling the full shape



From Cuceu et al. 2021 (2103.14075)

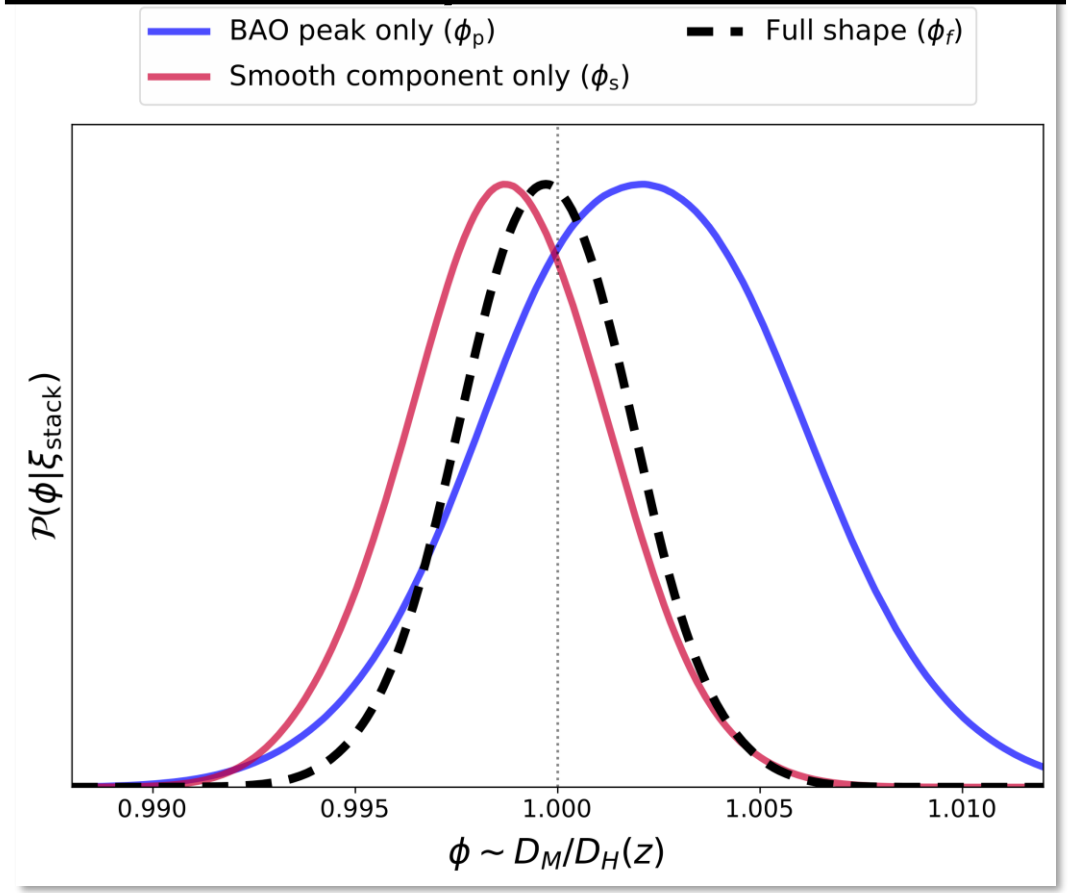
Correlations from 100 eBOSS mocks



Analysis validation using mocks

- We used 100 eBOSS DR16 log-normal mocks to validate our analysis
- These mocks include all the major contaminants affecting Lyα forest correlations

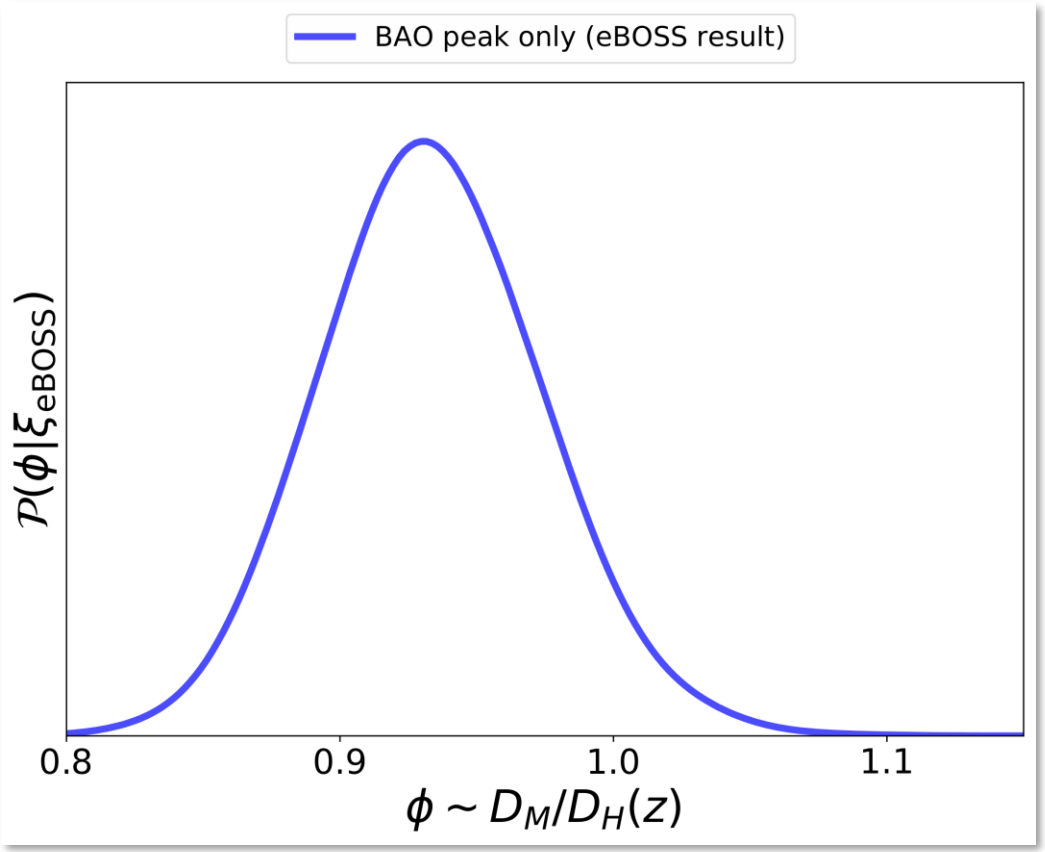
Results from analysis of 100 eBOSS mocks



Lyα BAO from eBOSS

- This is the Lyα BAO measurement from eBOSS DR16
- We performed a blind analysis to measure AP from the full-shape
- We tested different modelling choices to confirm the robustness of the result

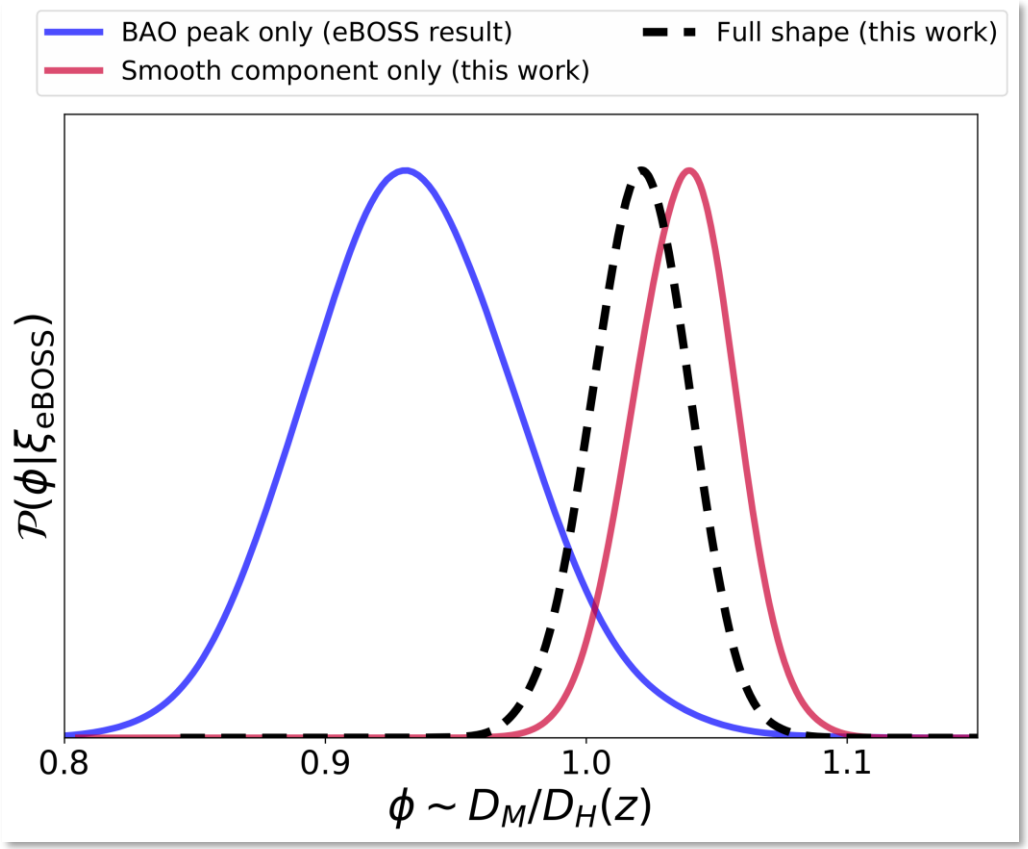
Results from eBOSS DR16 data



Lyα full-shape from eBOSS

- First ever cosmology measurement from the full-shape of Lyα correlations
- The AP constraint from the full-shape gives a factor of 2 improvement over the BAO constraint

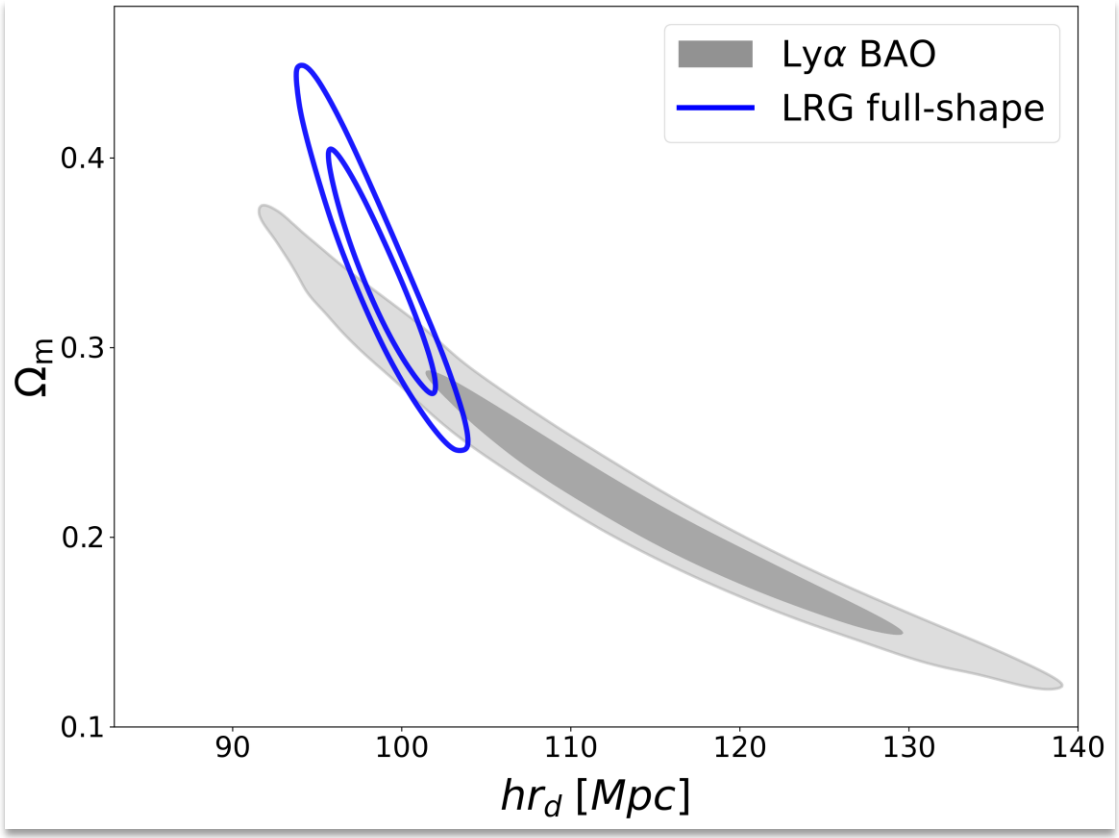
Results from eBOSS DR16 data



Cuceu et al. (in prep)

Implications for cosmology

Results in flat ΛCDM



Implications for cosmology

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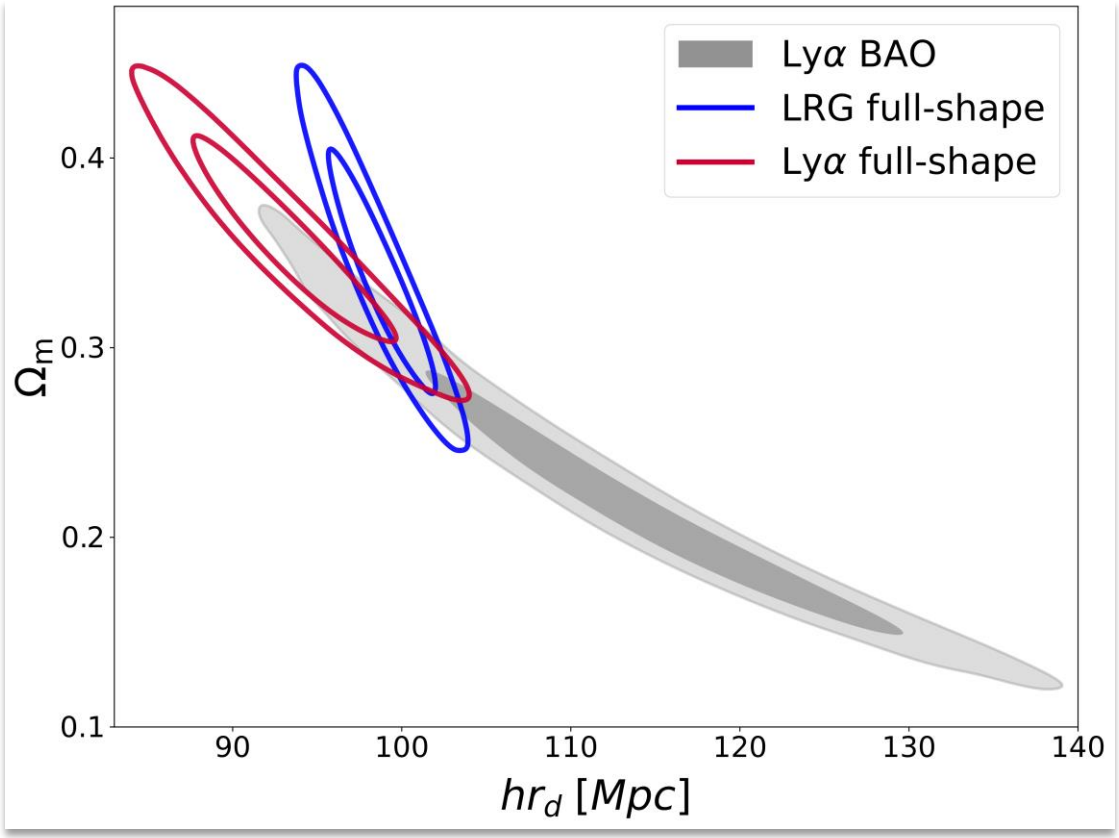

Implications for cosmology

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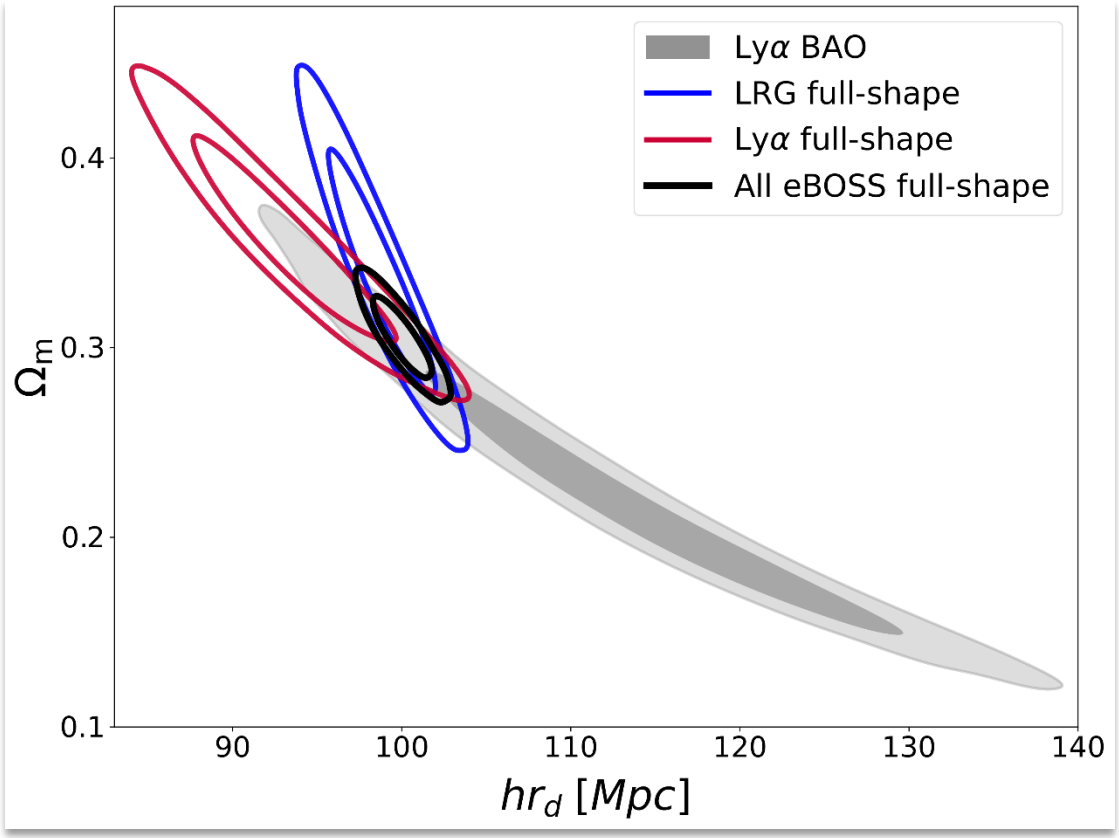
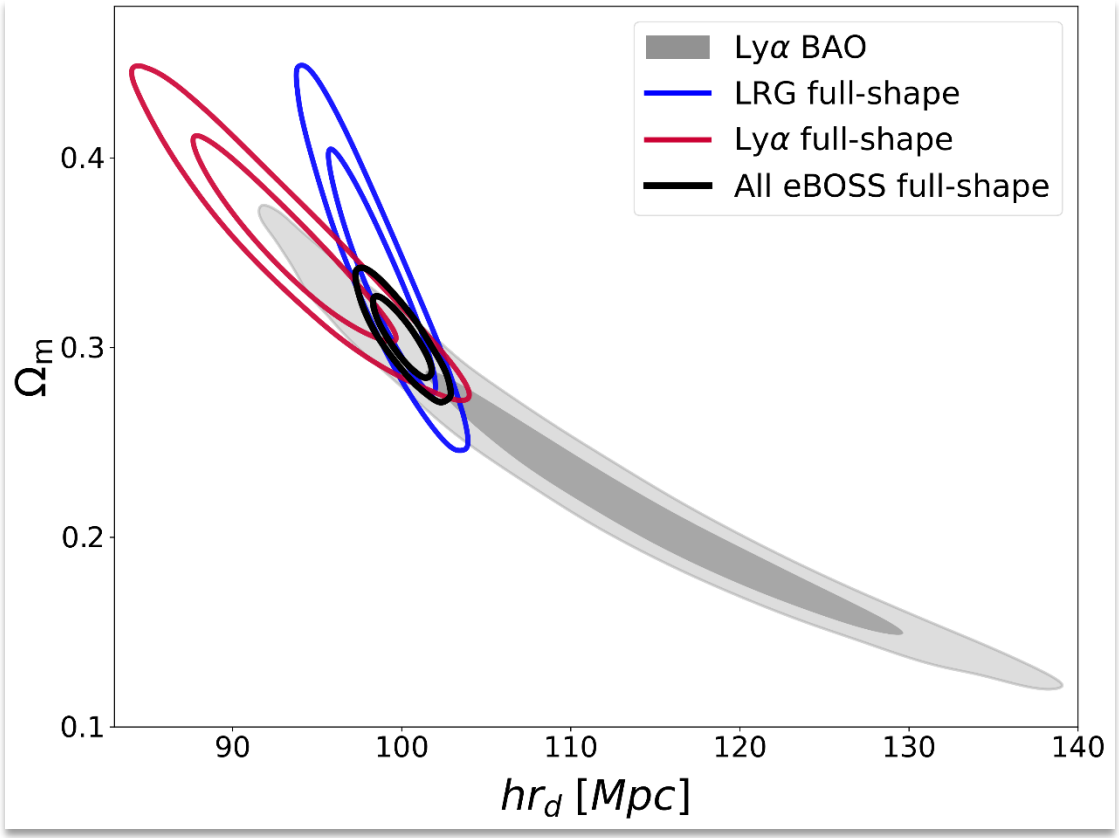
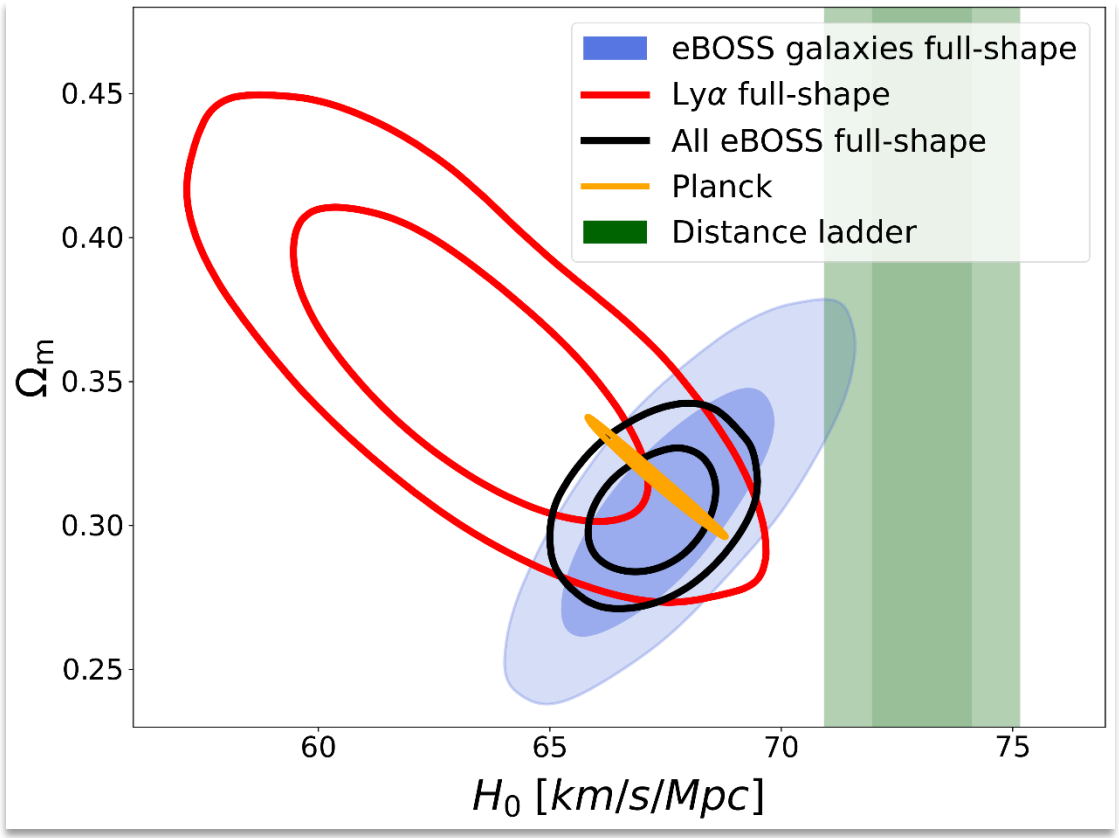


Measuring the Hubble constant

Results in flat ΛCDM



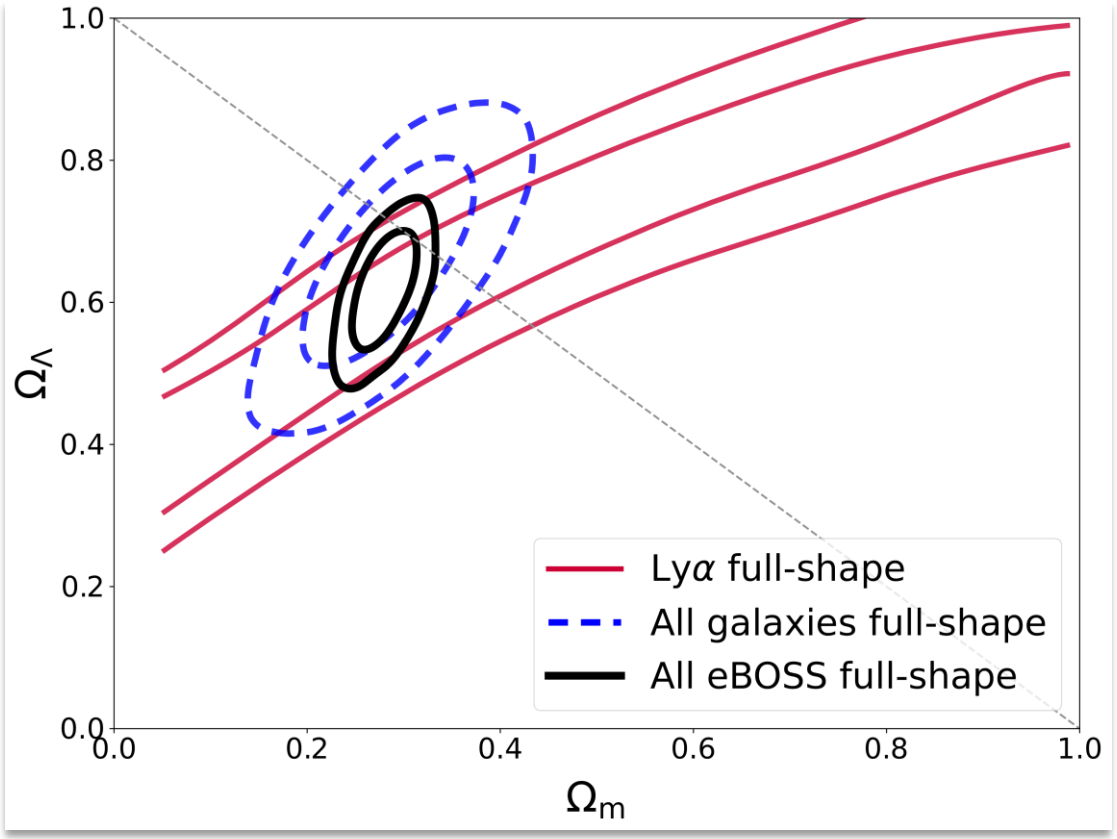
Combined with BBN



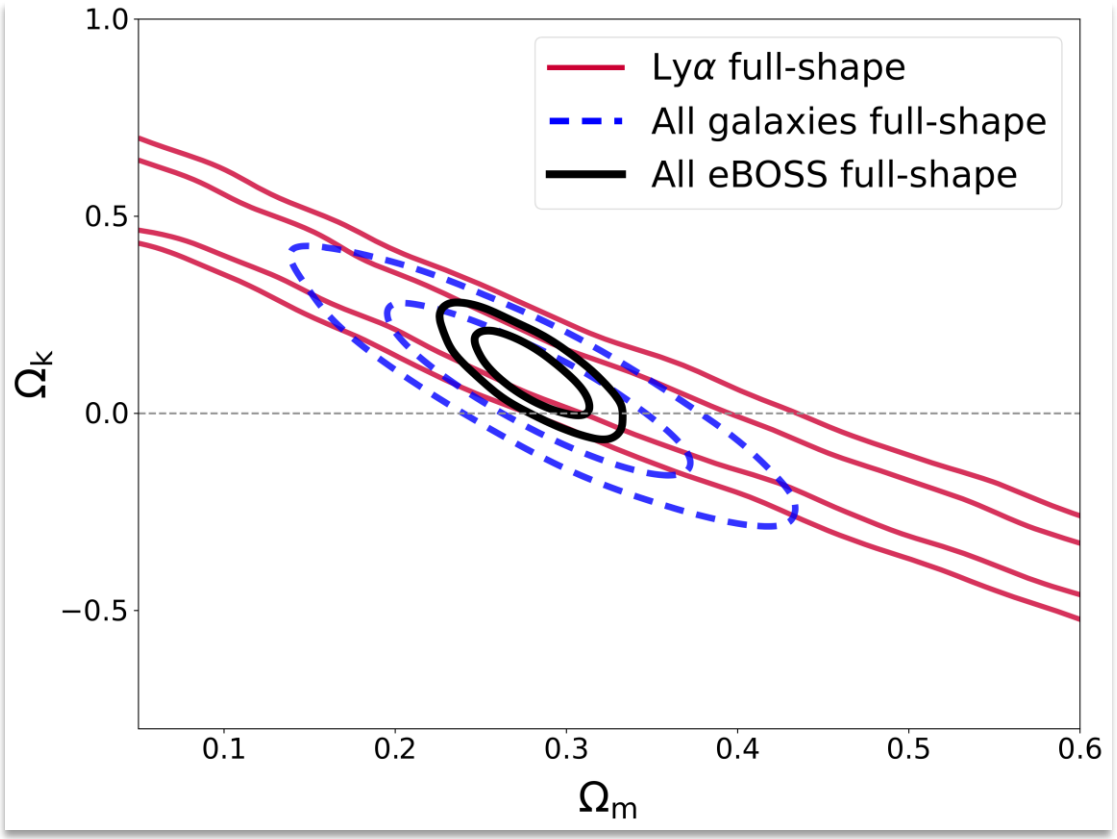
Cuceu et al. (in prep)

Dark energy and curvature

Measuring dark energy



Measuring curvature



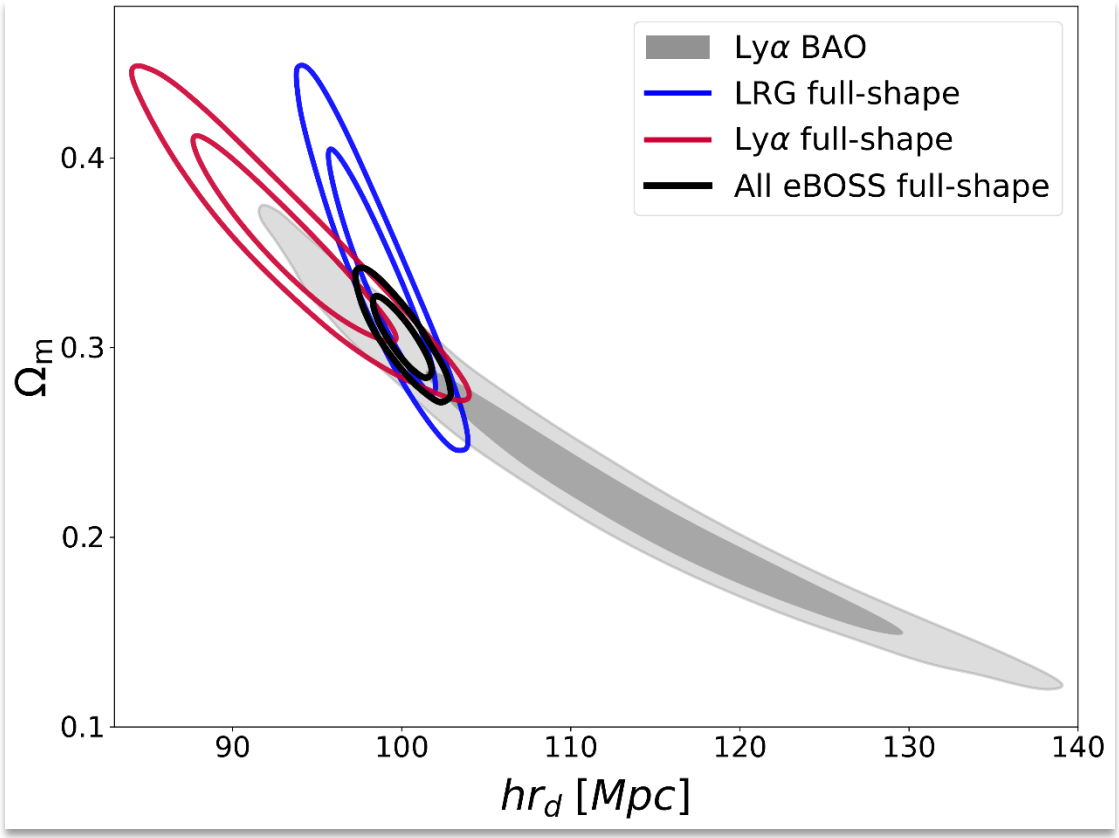
Cuceu et al. (in prep)

Next steps

- We already have Lyα forest correlations from DESI that are as precise as those from all of BOSS + eBOSS
- The main focus is now to understand the data and be able to simulate it accurately in mocks
- Simplistic mocks were the main limitation in this study
- Areas of improvement: effect of redshift errors, modelling of metals and DLAs, modelling of non-linear effects in the cross-correlation,

Looking towards DESI

eBOSS results



DESI Lya forecasts