New Cosmological Analysis of the eBOSS Lyman-α Forest

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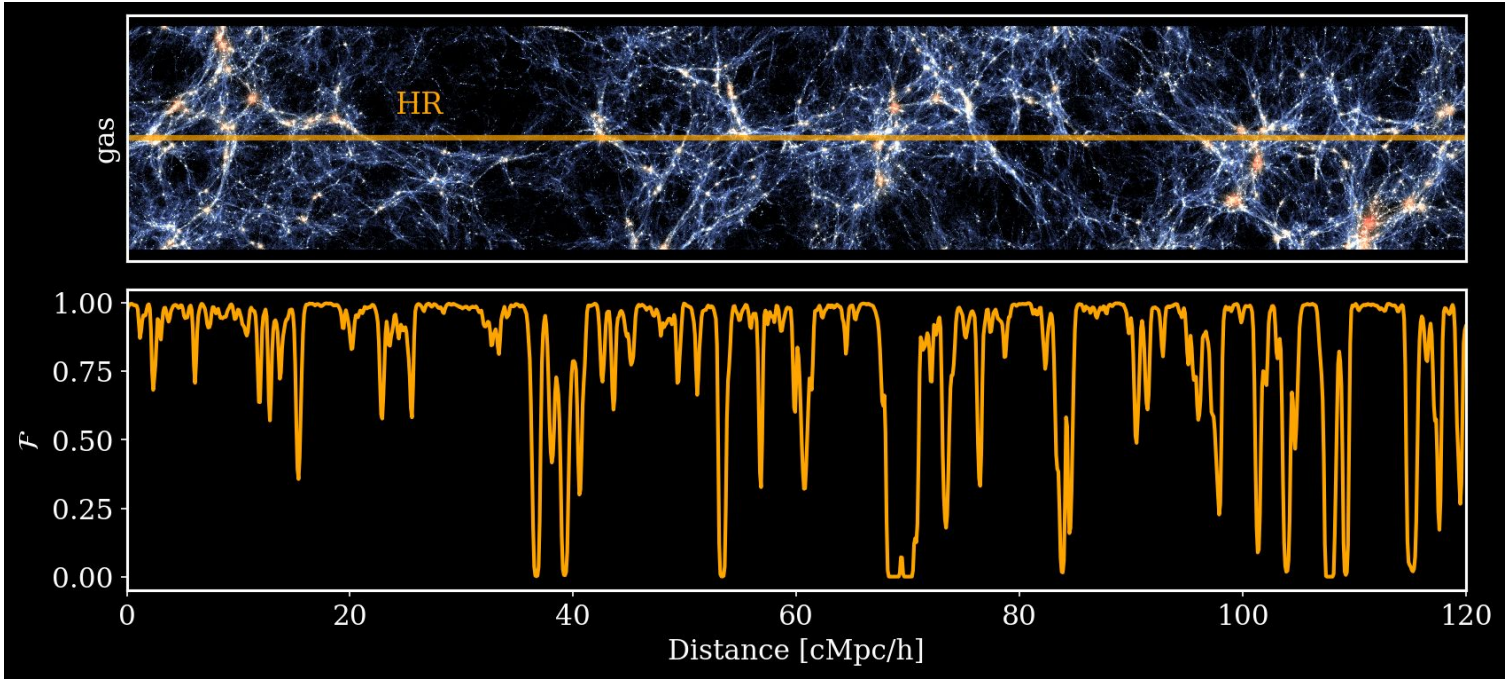
arxiv:2306.05471

What is the Lyman-α forest?

Absorption from neutral hydrogen in quasar

Traces dark matter at z=2-5



eBOSS SDSS DR14

1D Flux power along line of sight to quasar

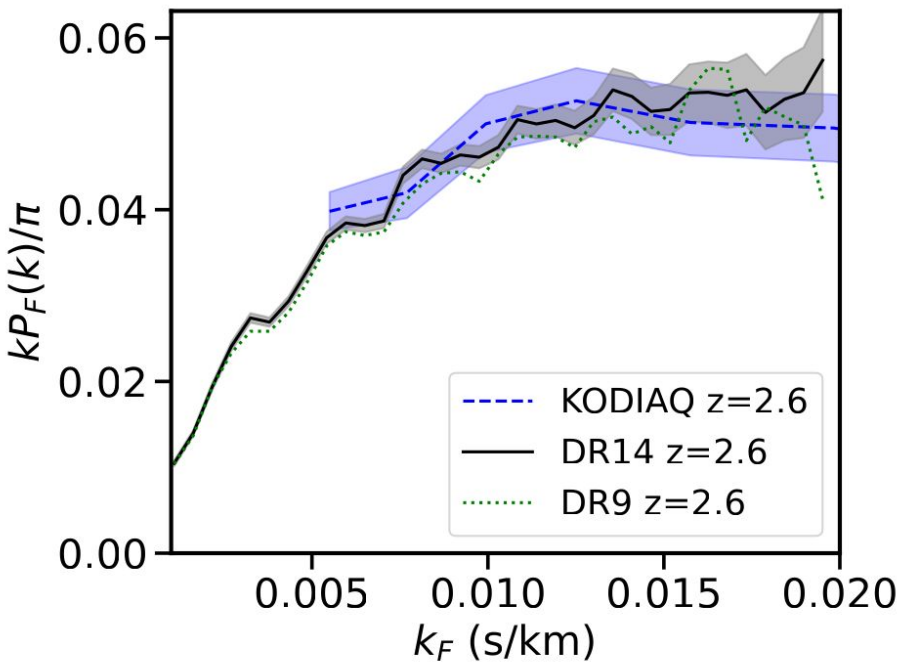
v = H(z) (a r)

At z=3:

k = 0.001 s/km ~ 0.1 h/Mpc

k = 0.02 s/km ~ 2 h/Mpc

Small non-linear scales!

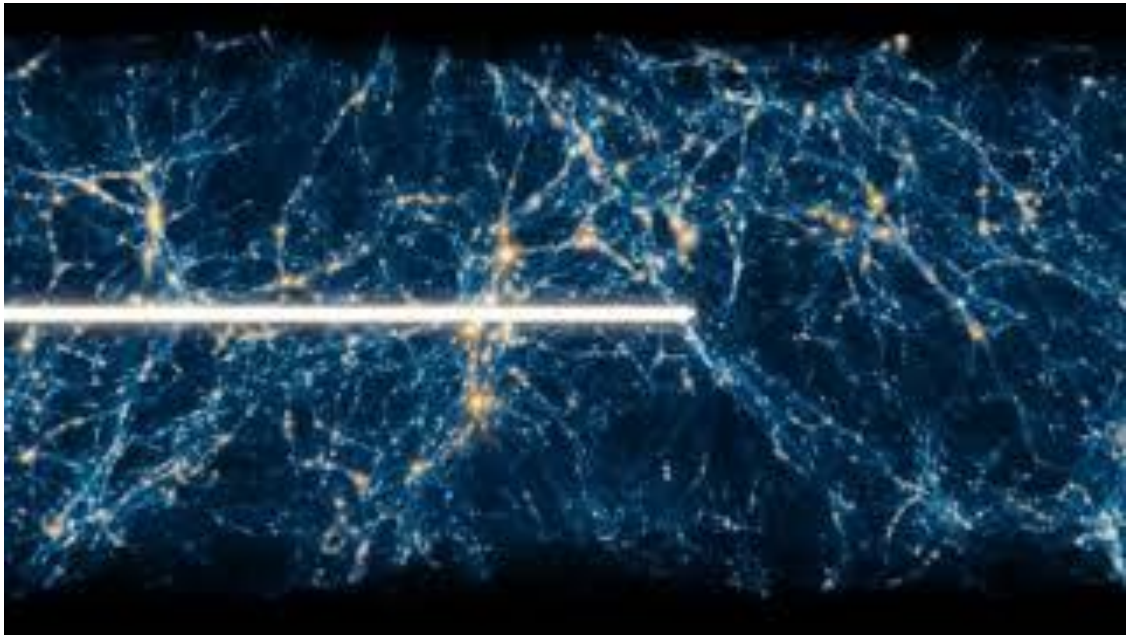


PRIYA Cosmology Suite

Simulations to model growth and gas pressure

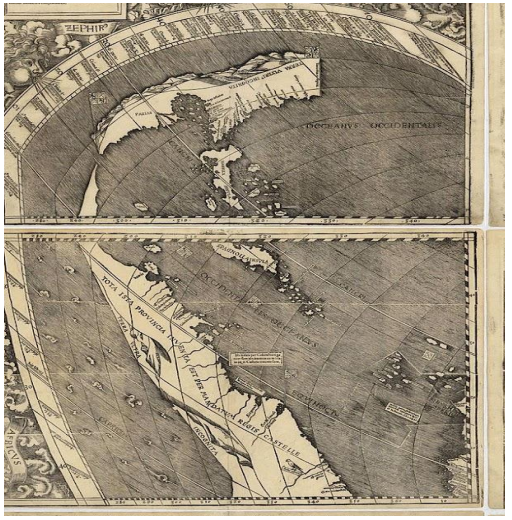
3 High fidelity: 3072^3
48 Low fidelity: 1536^3
120 Mpc/h box

ASTRID galaxy model



Simulation Interpolation

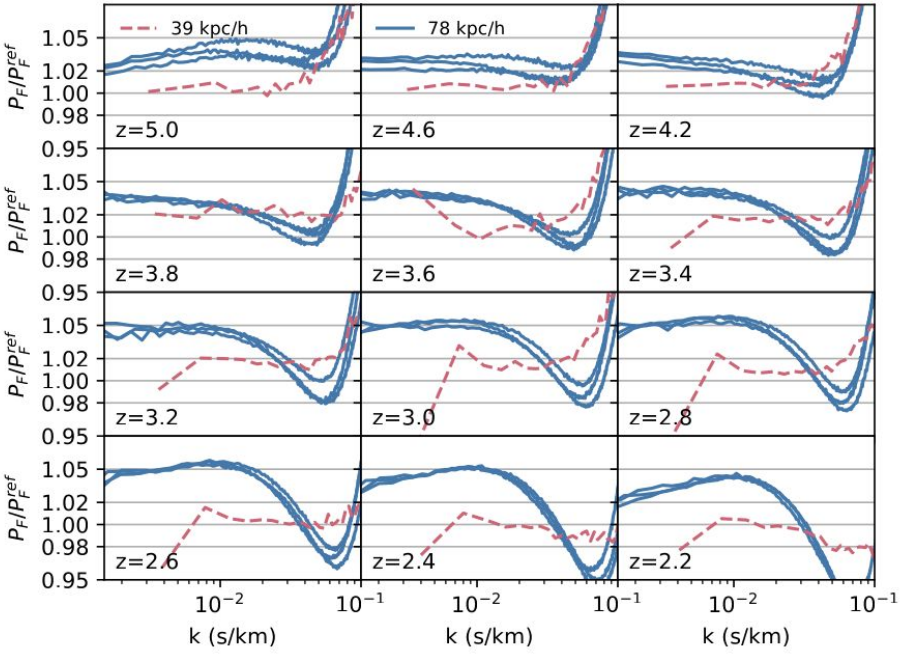
- For inference need simulation output for all cosmologies
- Gaussian Process interpolation using ~50 simulations
- Interpolation needs 50 large simulations



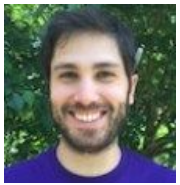
Multi-Fidelity Emulation

Combine simulations at **different resolutions**.

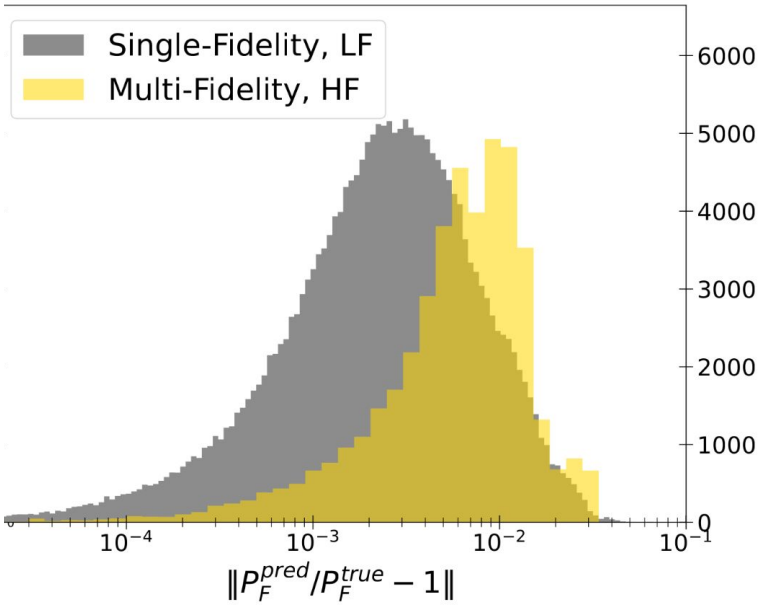
- Low resolution for cosmology
- Correct with high resolution.
- **Cosmology-dependent** correction function.



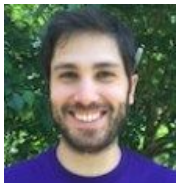
Leave-one-out Validation



Emulation is 1% accurate! Multi-fidelity leave-one-out is missing ⅓ simulations



Lyman-alpha Forest Multi-Fidelity

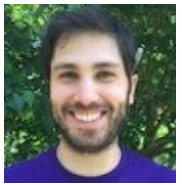


Parameters:

Power spectrum: $$P(k) = A_P \left(\frac{k}{0.78\text{h/Mpc}} \right)^{n_P - 1}$$

Hubble parameter is included, but badly measured
$\Omega_M h^2$ - Growth rate
Helium & hydrogen reionization

Lyman-alpha Forest Multi-Fidelity



Circle: HF. Cross: LF.

Parameters:

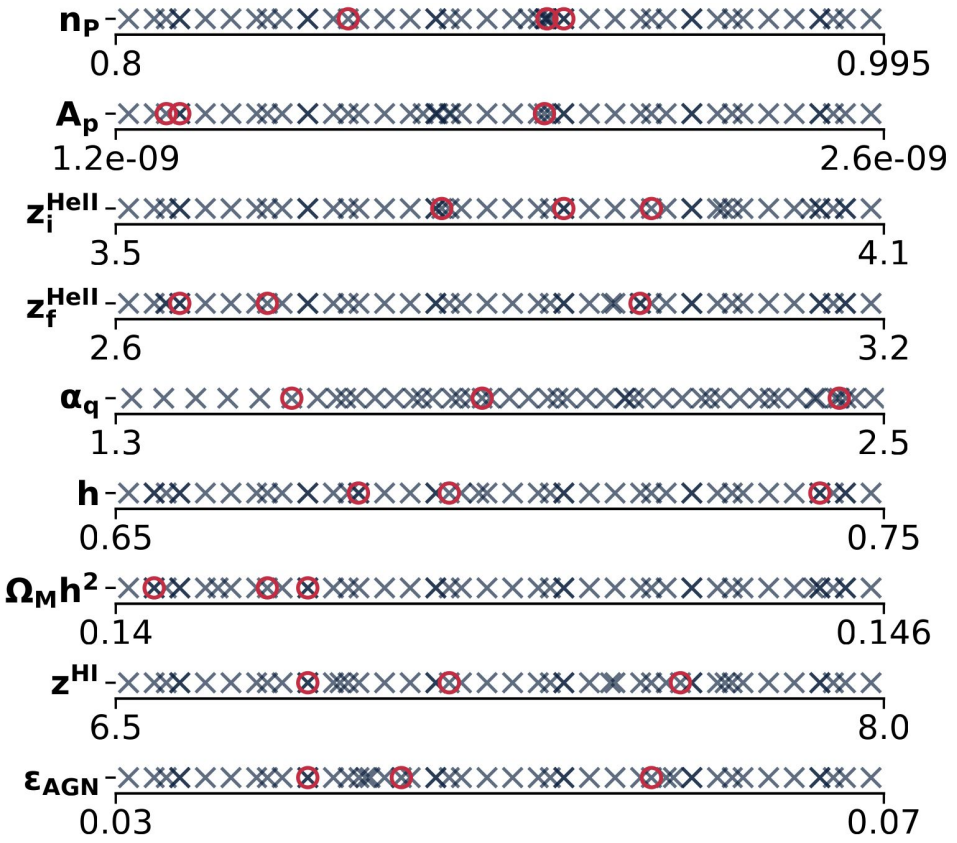
A_p n_p - cosmology

z_i z_f α_q - helium reionization

z_{HI} - hydrogen reionization

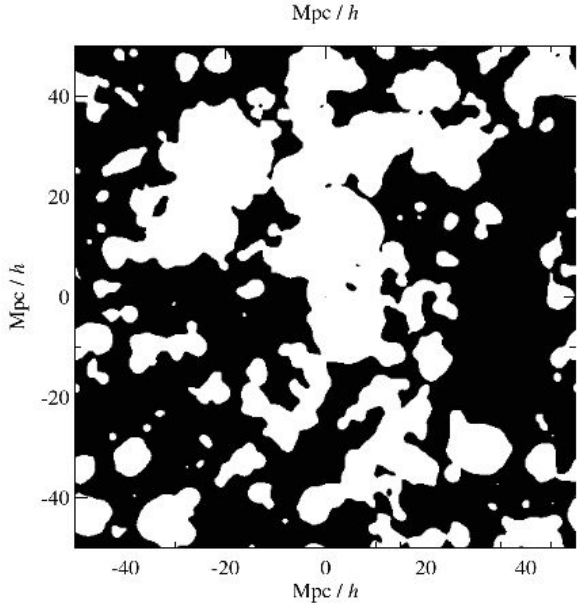
$\Omega_M h^2$ - Growth rate

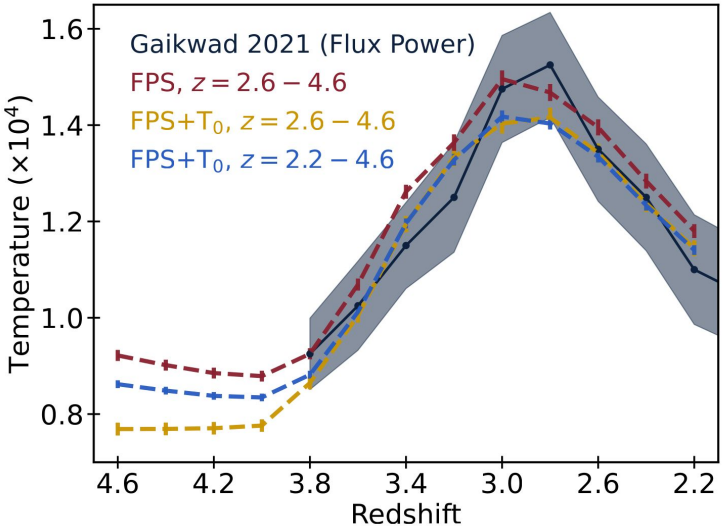
ε_{AGN} - BH feedback



Reionization Models

- Patchy hydrogen reionization model
- Patchy helium ~30 Mpc bubbles z ~ 3.8 - 2.8
- Match gas temperature history

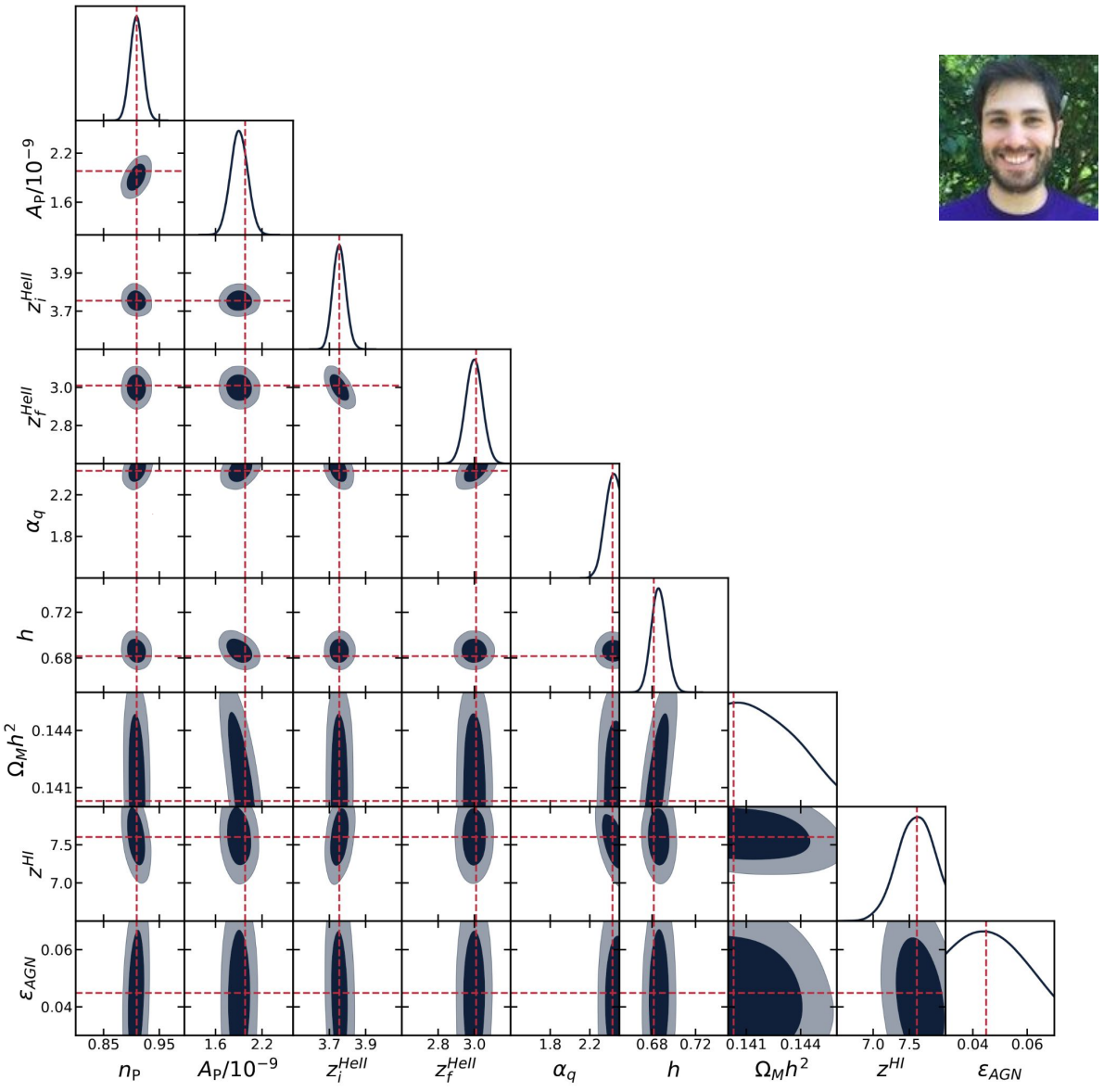




Likelihood function

Posterior constraints with simulated data

Included:
- Metals
- DLAs
- Temperature data



eBOSS SDSS DR14

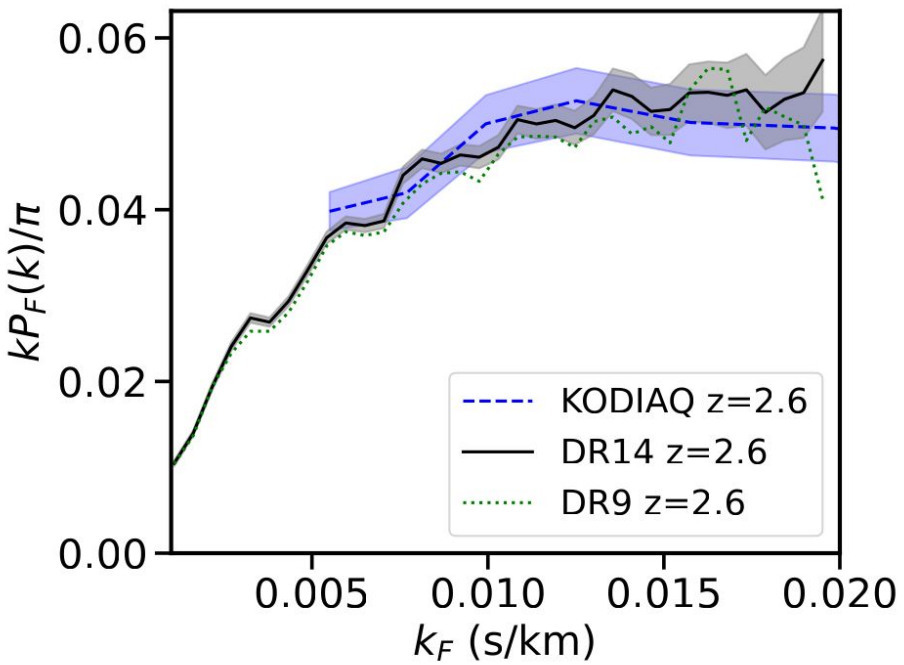
Prefers spectral slope

$n_s = 0.954 \pm 0.006$

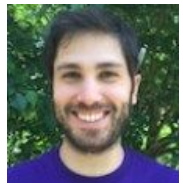
Planck has:

$n_s = 0.965 \pm 0.004$

Slight 2 σ tension: why?



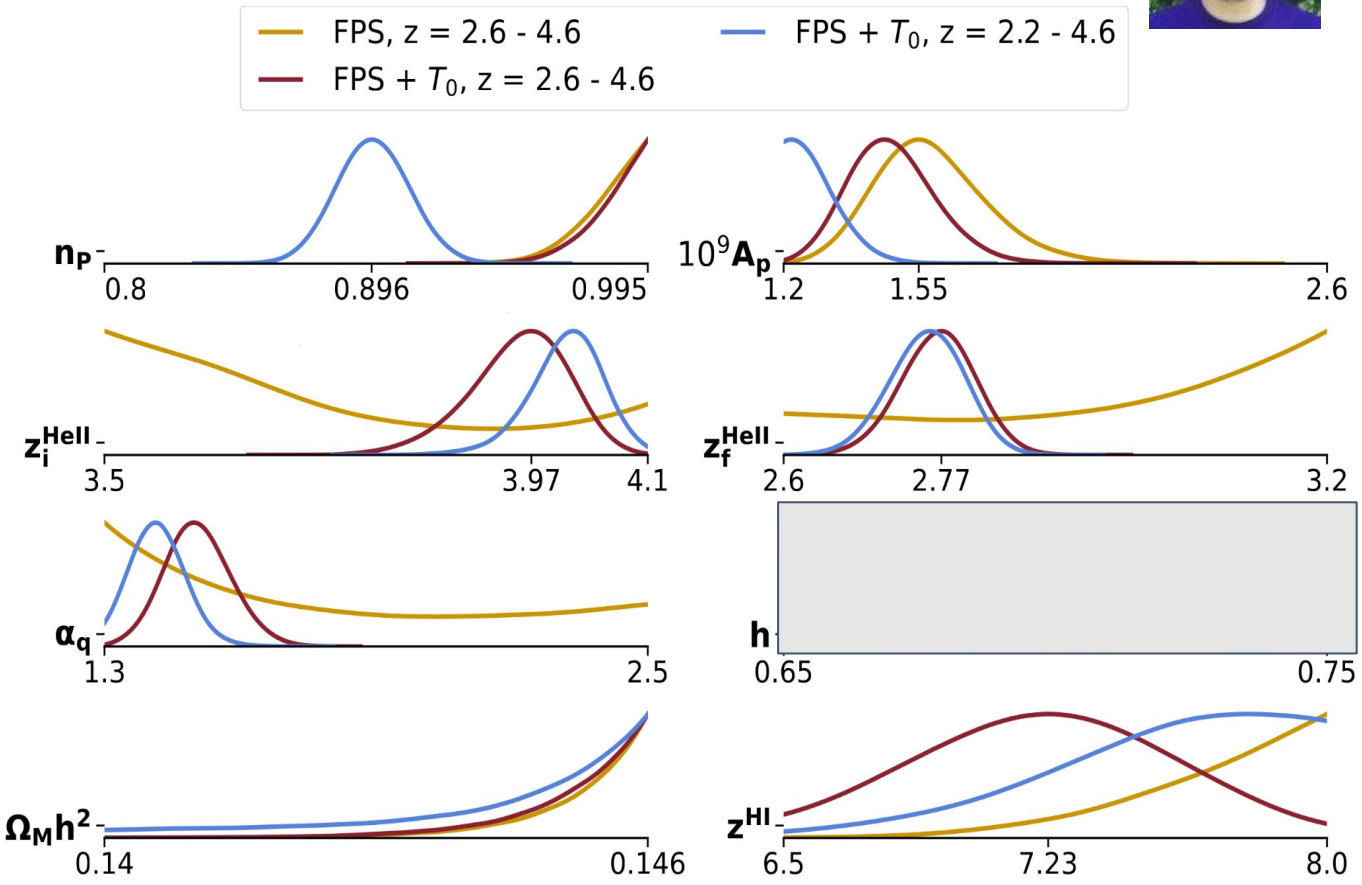
Preliminary DR14



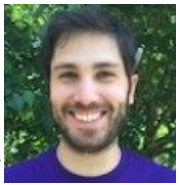
DR14 data:

n_P ~ 0.9! Too low!

Driven by z= 2.2, 2.4



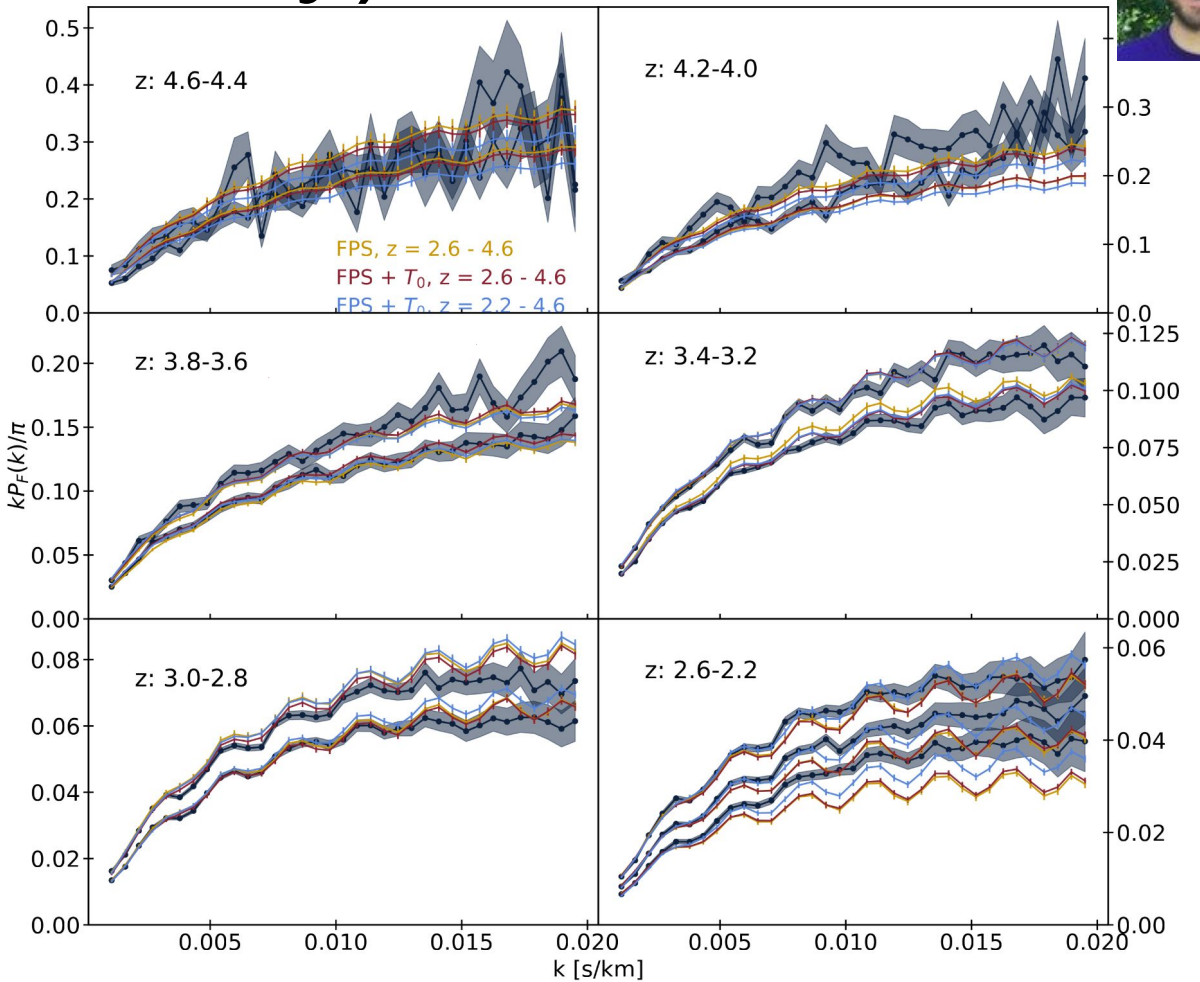
(Preliminary) DR14



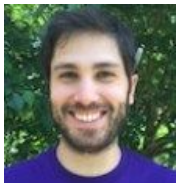
Best-fit power:

z= 2.2 & 2.4 are discrepant with model:

AGN feedback? Systematic?

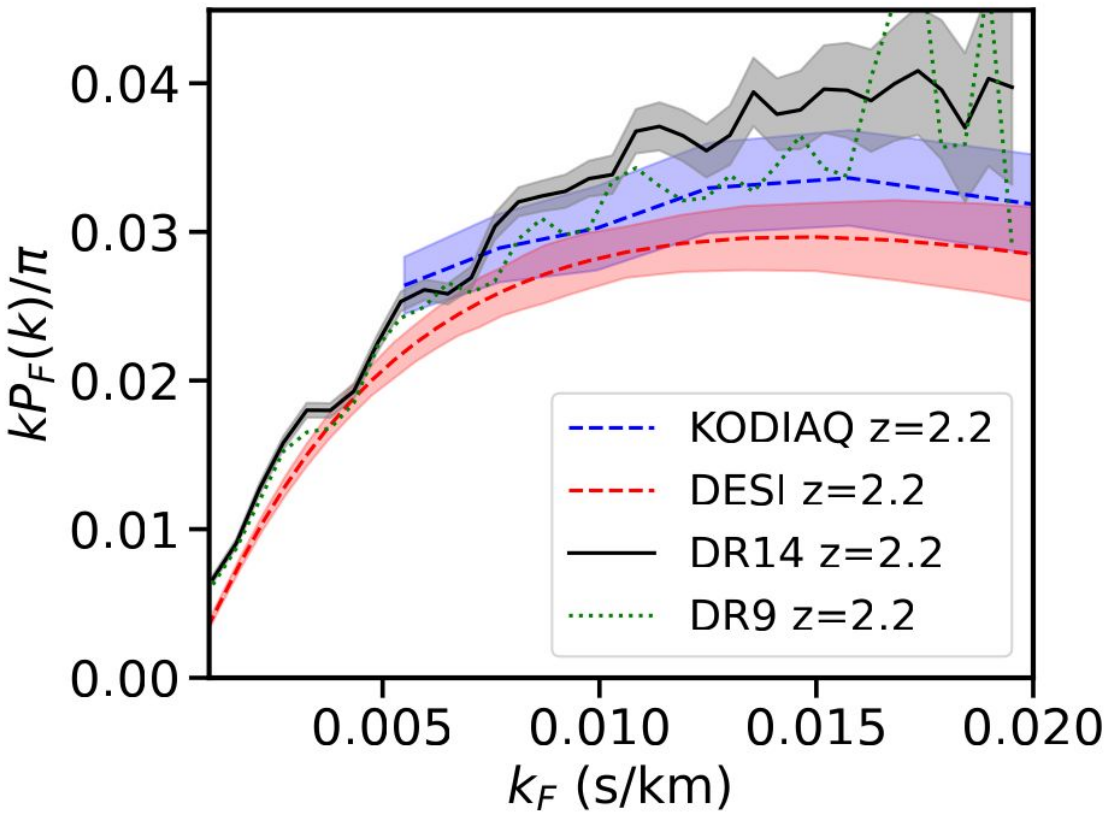


(Preliminary) DR14

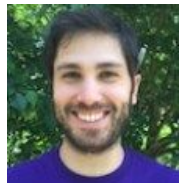


Best-fit power:

Other Lyman alpha data suggests a systematic, but not conclusive



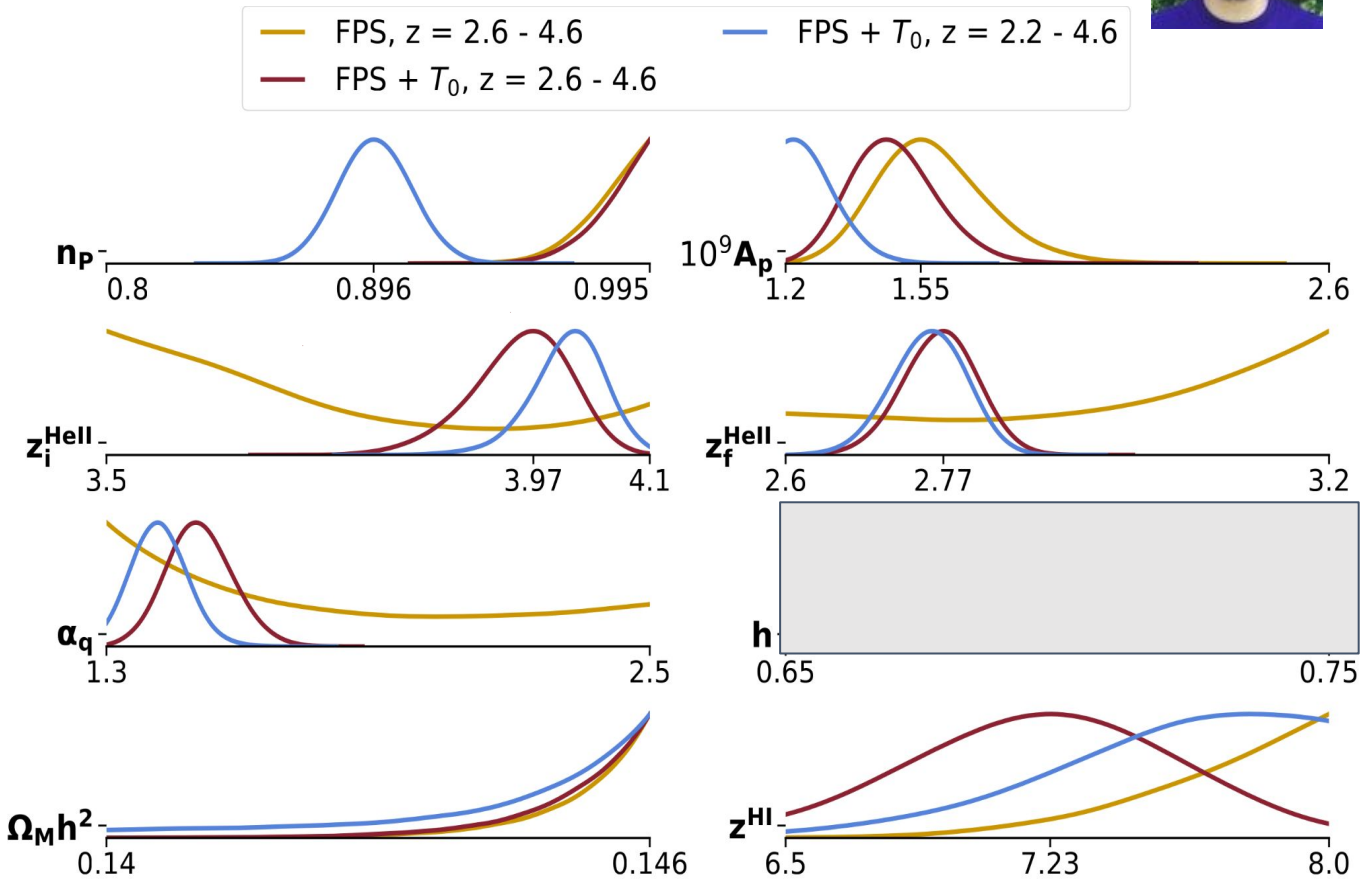
(Preliminary) DR14



DR14 data alone
(not joint chains!)

$n_s \sim 1 - 0.97$

$\sigma_8 \sim 0.8$



Conclusions 2306.05471

Reanalysis of eBOSS Lyman alpha data

PRIYA suite and multi-fidelity emulation

Generally weaker constraints: more room for theorists!

Until DESI!