DARK ENERGY SPECTROSCOPIC INSTRUMENT
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1D Lyman-alpha forest power spectrum from DESI early data

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Lyman-alpha forest

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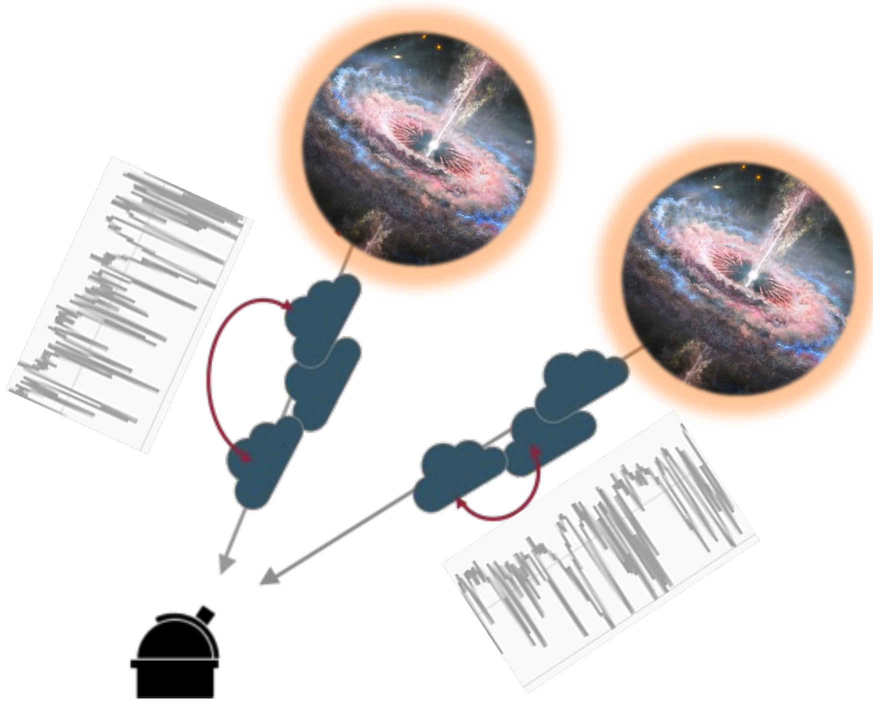
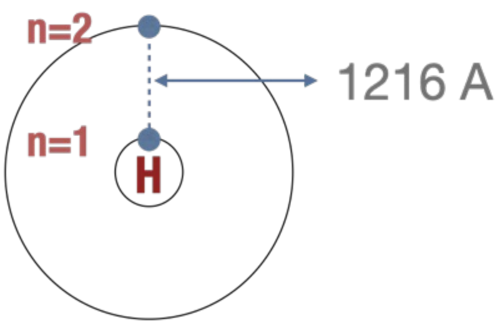


Image credits: NASA, ESA and J. Olmsted (STScI)

- A quasar is a very bright, distant and active supermassive black hole.
- The neutral hydrogen scatters the light emitted from quasars, which forms absorption lines.



Power spectrum

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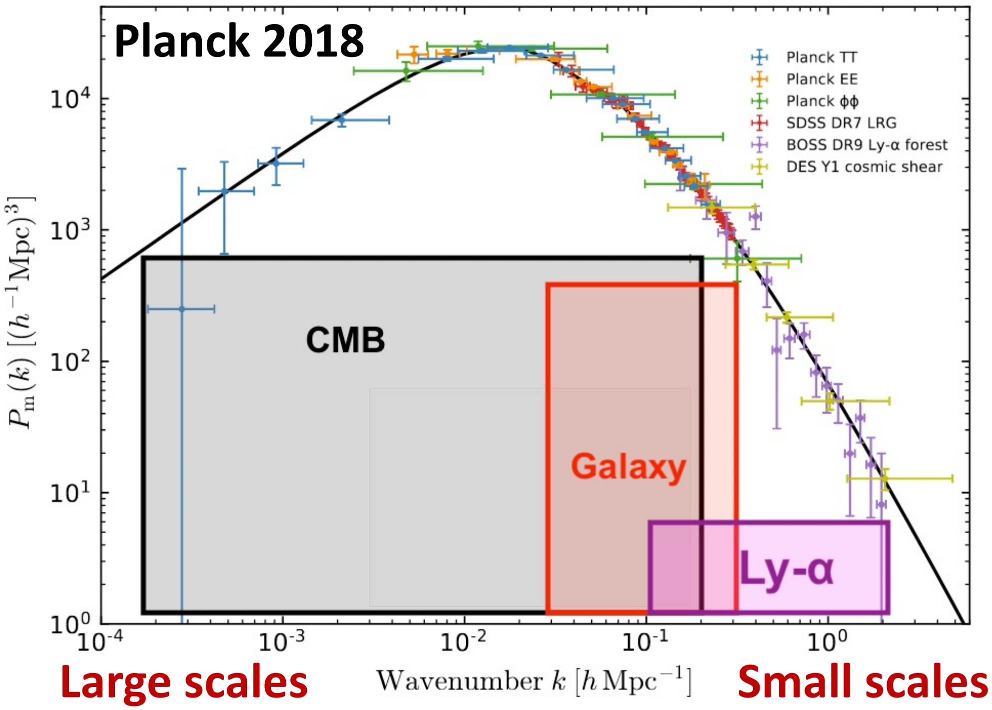

Power spectrum quantifies the amplitude of density fluctuations.

The model (black line) agrees with the data, which spans ~10 Gyr in time and 3 decades in scale.

- T_CMB: 370k years
- T_Lya: 1.5 -- 3 Gyr
- T_Galaxy: > 10 Gyr

Lya forest is sensitive to small scales.

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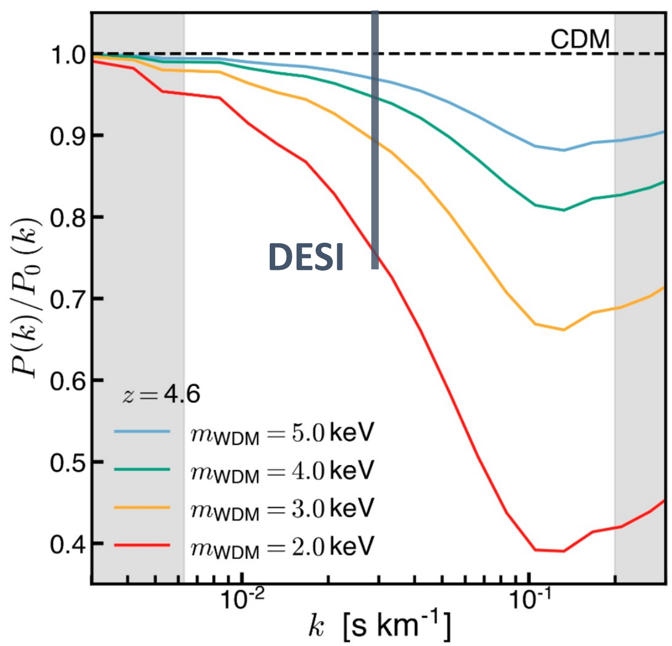
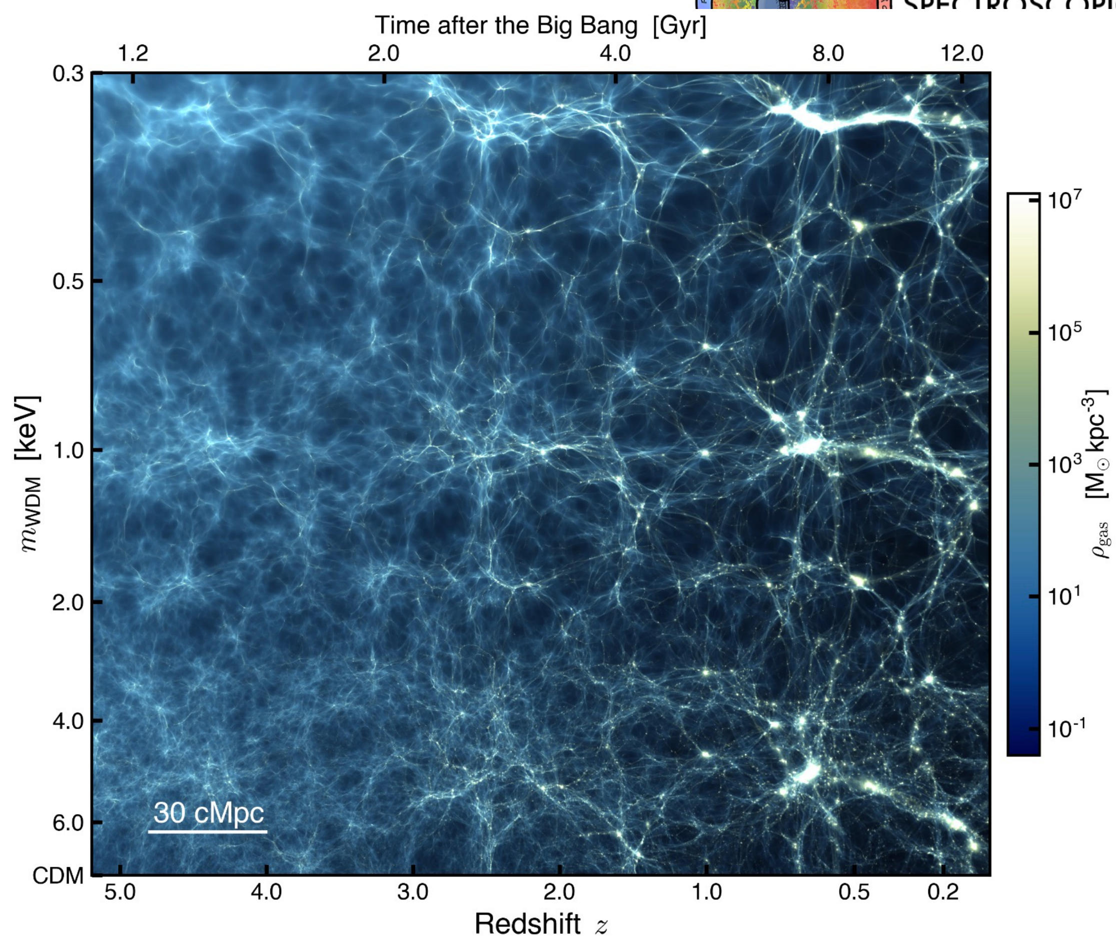
Warm dark matter

Villasenor et al. 2023

$m_{\text{WDM}} > 3.1$ keV

- 4.2 < z < 5.2 from 15 quasars

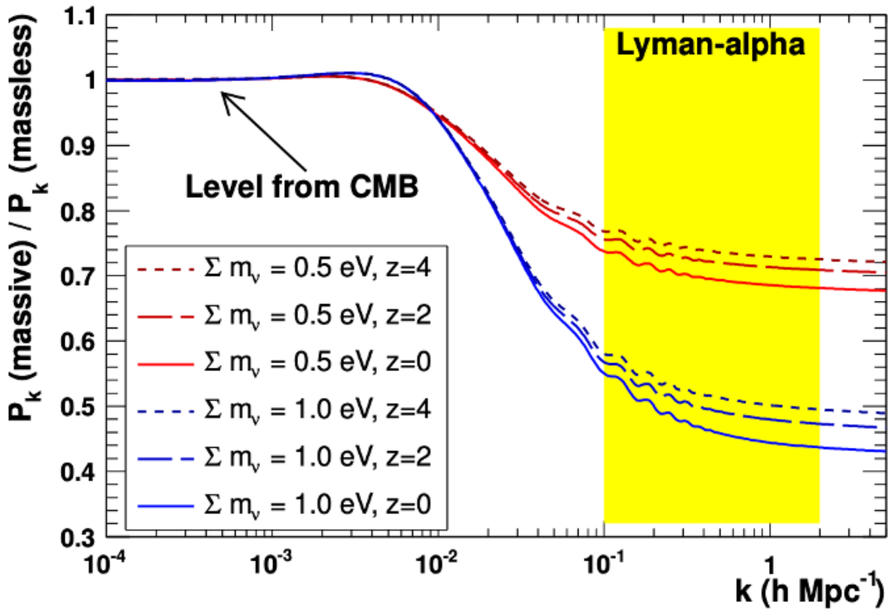




The sum of the neutrino masses

Palanque-Delabrouille et al. 2015

$\sum m_\nu < 0.12$ eV (BOSS + CMB)



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Minimum mass

- Normal hierarchy: 0.057 eV
- Inverted hierarchy: 0.097 eV

DESI Forecast:

$$\sigma_{\sum m_\nu} = 0.02 \text{ eV}$$

Science, Targeting, and Survey Design:
https://arxiv.org/abs/1611.00036 (2016)

DESI Early Data*

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Data

- Survey validation spectra

\+ 2 months of “main” survey (normal operations)

1% Survey (SV3)	7,173
Main (Guadalupe)	47,427
Total	**54,600**

Paper outline

- Method – Optimal quadratic estimator
- Validation – Tests on 1D and 2D simulations
- Systematics
- Results

Karaçaylı et al. 2023, arXiv:2306.06316

DESI Iron TARGETID: 39627785269943777

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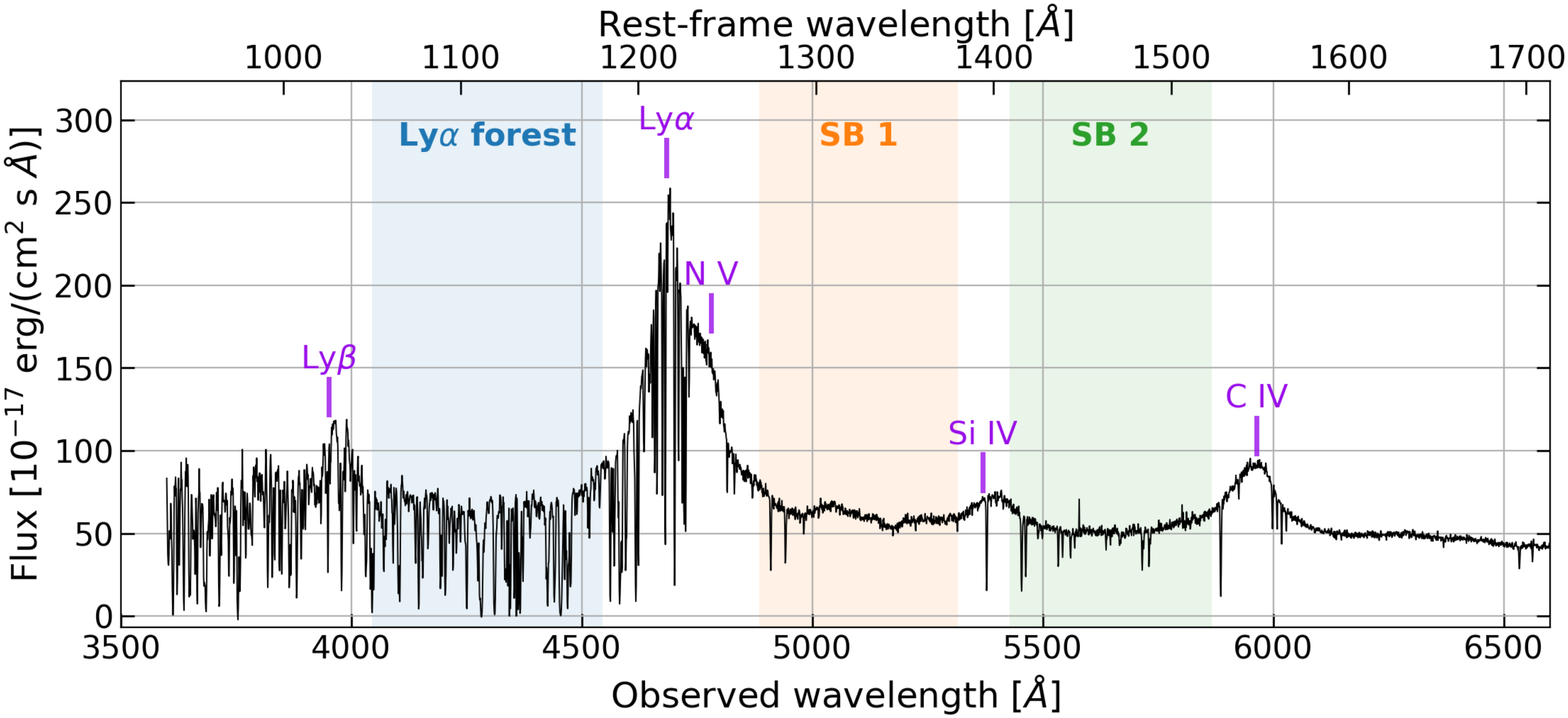

DESI Iron TARGETID: 39628488927348682

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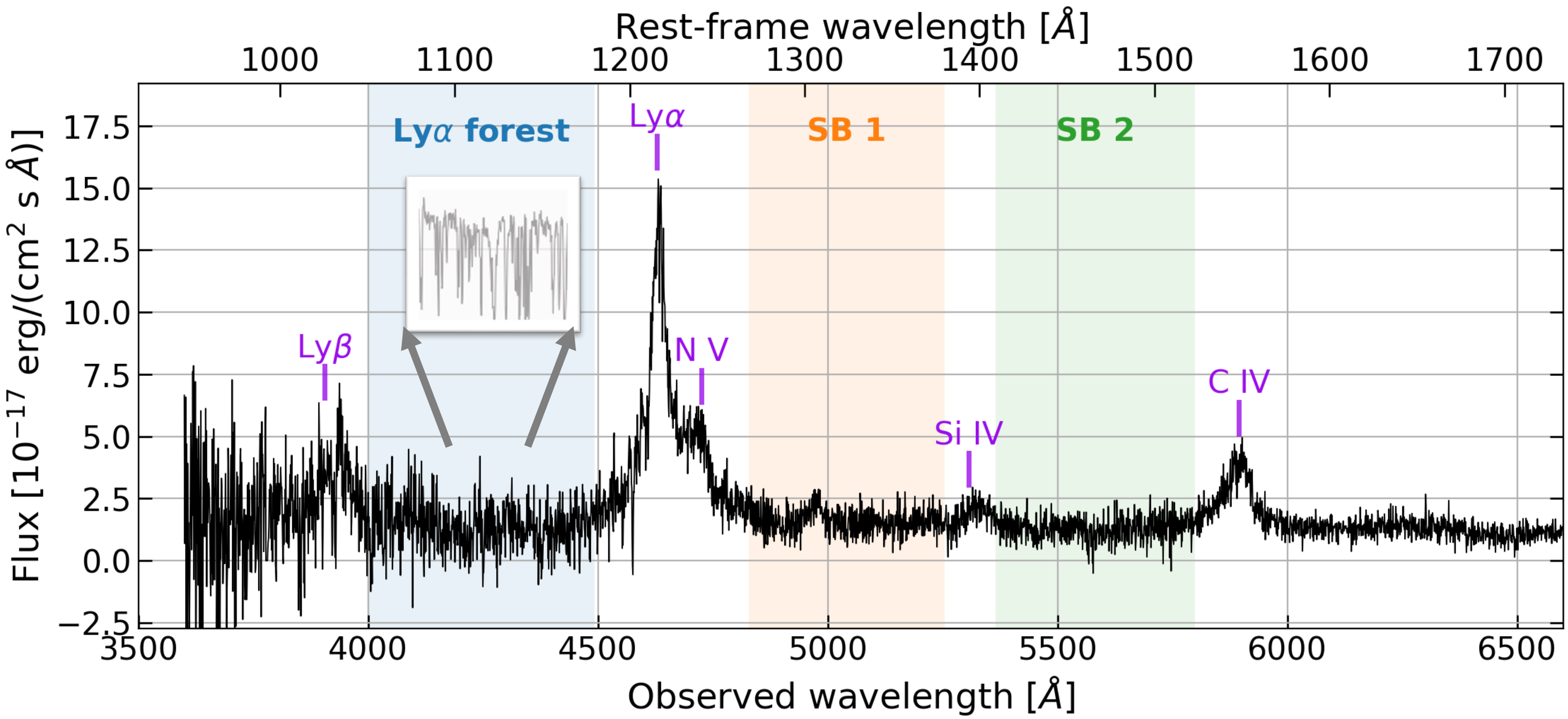
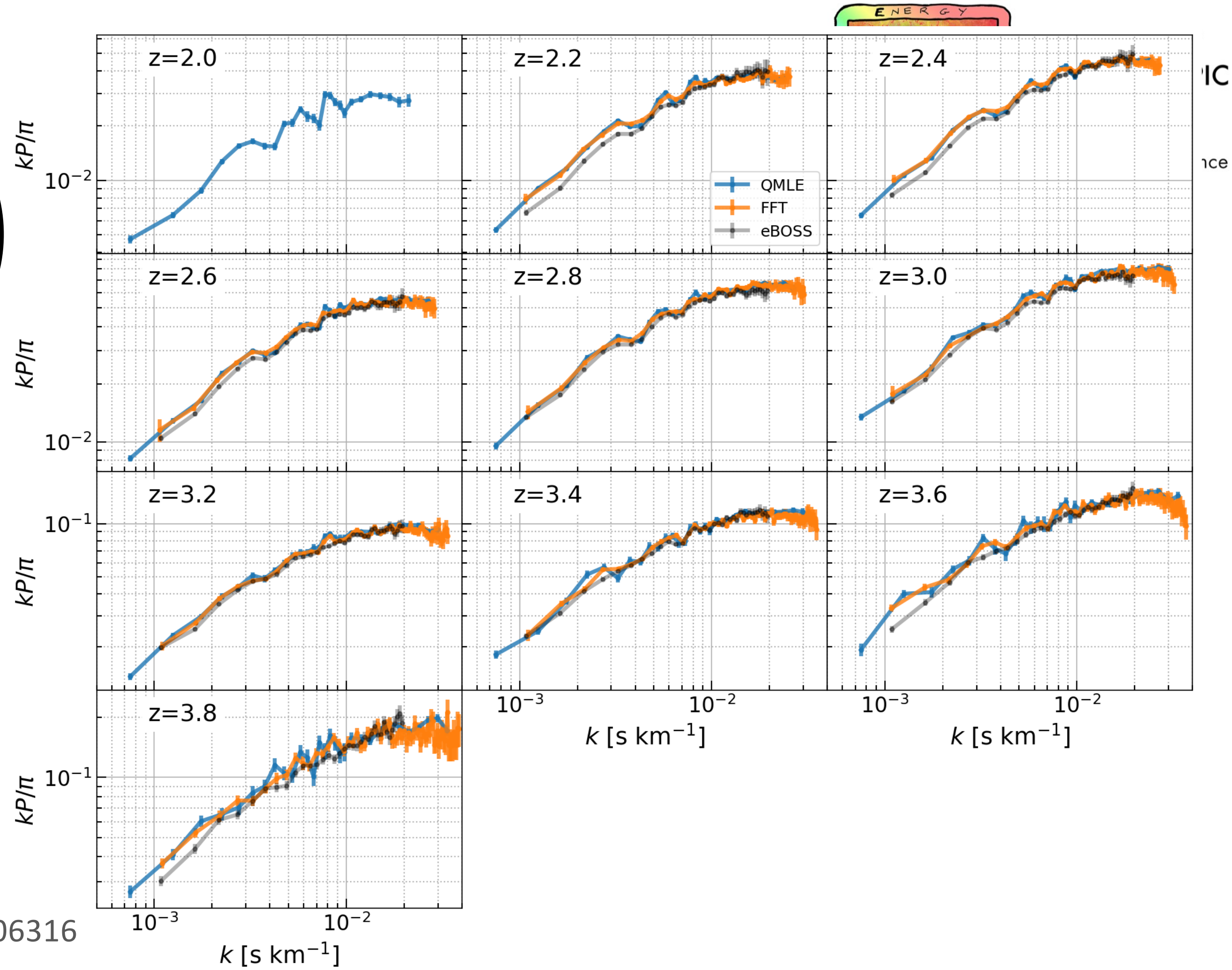


Comparison with eBOSS, FFT



Good agreement with the FFT result, which is on similar data and a different analysis pipeline!

Karaçaylı et al. 2023, arXiv:2306.06316

Two DESI challenges

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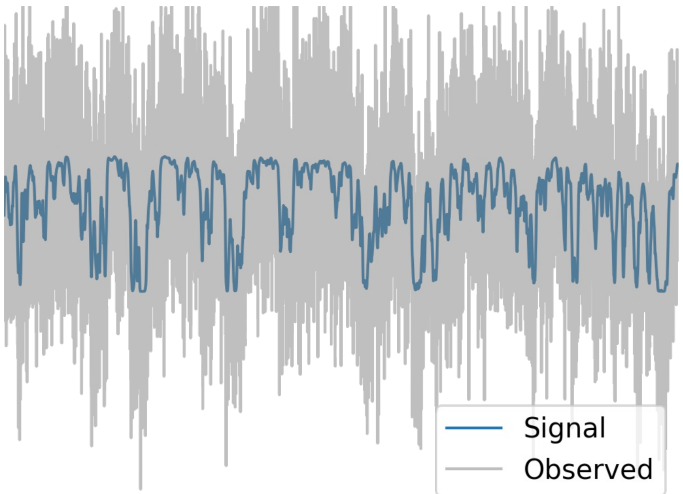
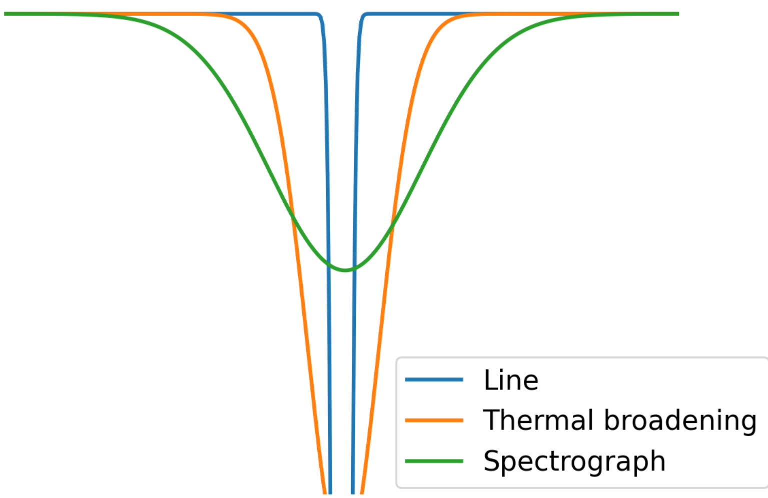
1. Signal is buried under noise. Accuracy of noise calibration is crucial.



2. Spectrograph resolution is comparable to thermal broadening.



Recalibrate pipeline noise estimate

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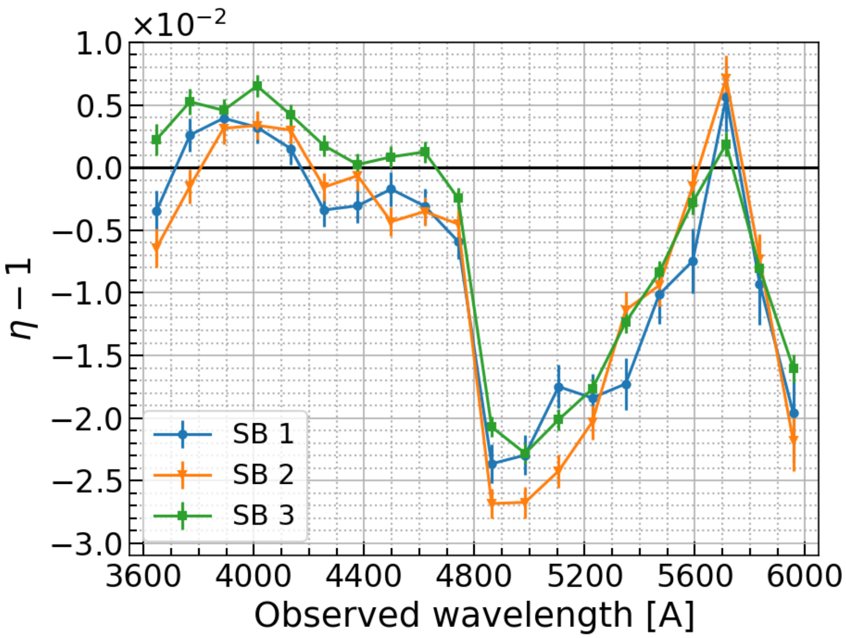
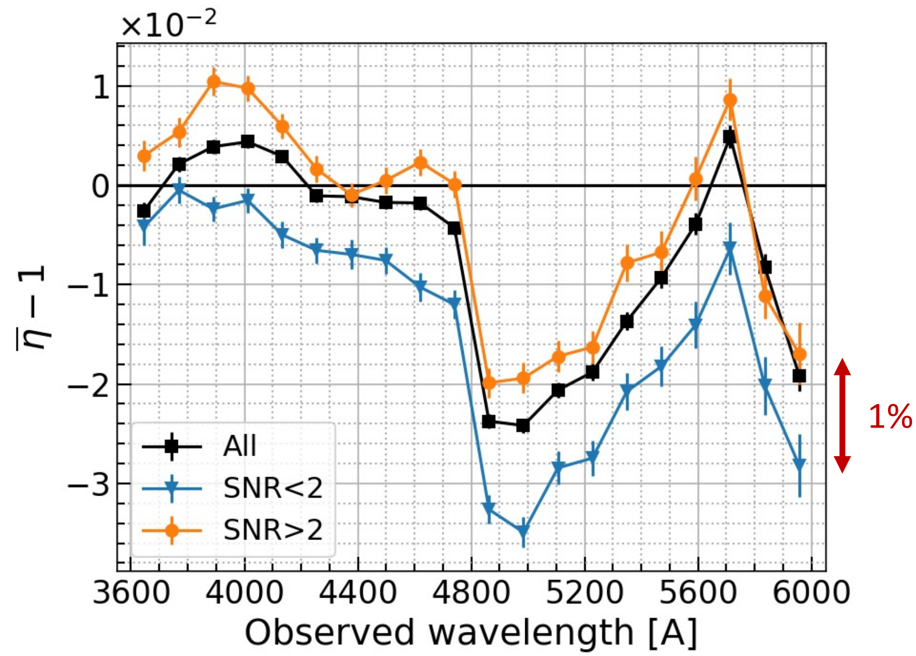
Noise calibration correction



SNR dependence of this correction



Karaçaylı et al. 2023, arXiv:2306.06316

Effects on parameters (The bad)

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Systematics	Increase in error A	n	α
Noise	49.8%	6.9%	0.7%
Resolution	34.0%	89.1%	26.5%
DLA	0.9%	2.8%	30.5%
All	74.3%	99.9%	62.5%

Table 2. Percentage increase in error given by the minimizer for each systematics at $z = 2.8$. The precision of the amplitude A is nearly equally affected by noise and resolution systematics, whereas for n, it is thoroughly affected by resolution systematics.

$$P_{\mathrm{base}}(k) = \frac{A\pi}{k_0}\left(\frac{k}{k_0}\right)^{2+n+\alpha \ln k/k_0}$$

Karaçaylı et al. 2023, arXiv:2306.06316

Next stage

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54,600 quasars -> 450,000 Lya quasars!

- More work into systematics

We identified possible solutions to noise and resolution systematics.

Other projects for Y1:

- CMB lensing x P1D
- Repeat metal model analysis

Noise calibration SNR dependence

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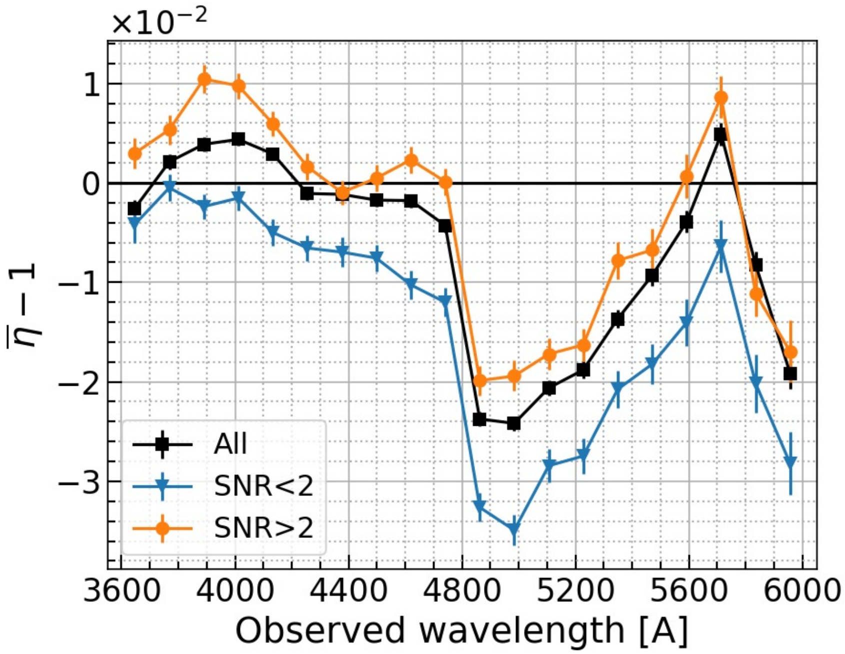

$$\sigma^2(\lambda_p) = \eta(\lambda_p)\sigma^2_{\mathrm{pipe}}(\lambda_p) + \sigma^2_{\mathrm{LSS}}(\lambda_p)$$

- ~ 1 million quasars in Y1 for eta analysis
- Quantify eta in multiple SNR bins

$$\eta = \eta(\lambda, \mathrm{SNR})$$

- Spectrograph splits

The ugly

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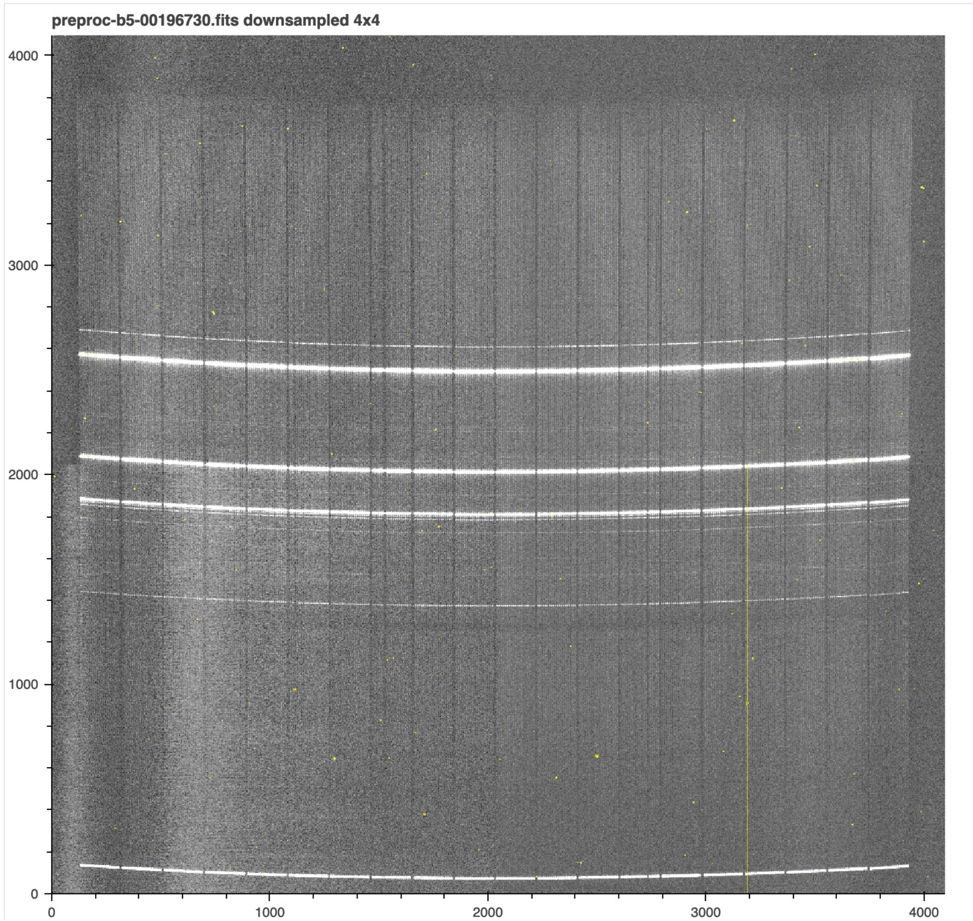

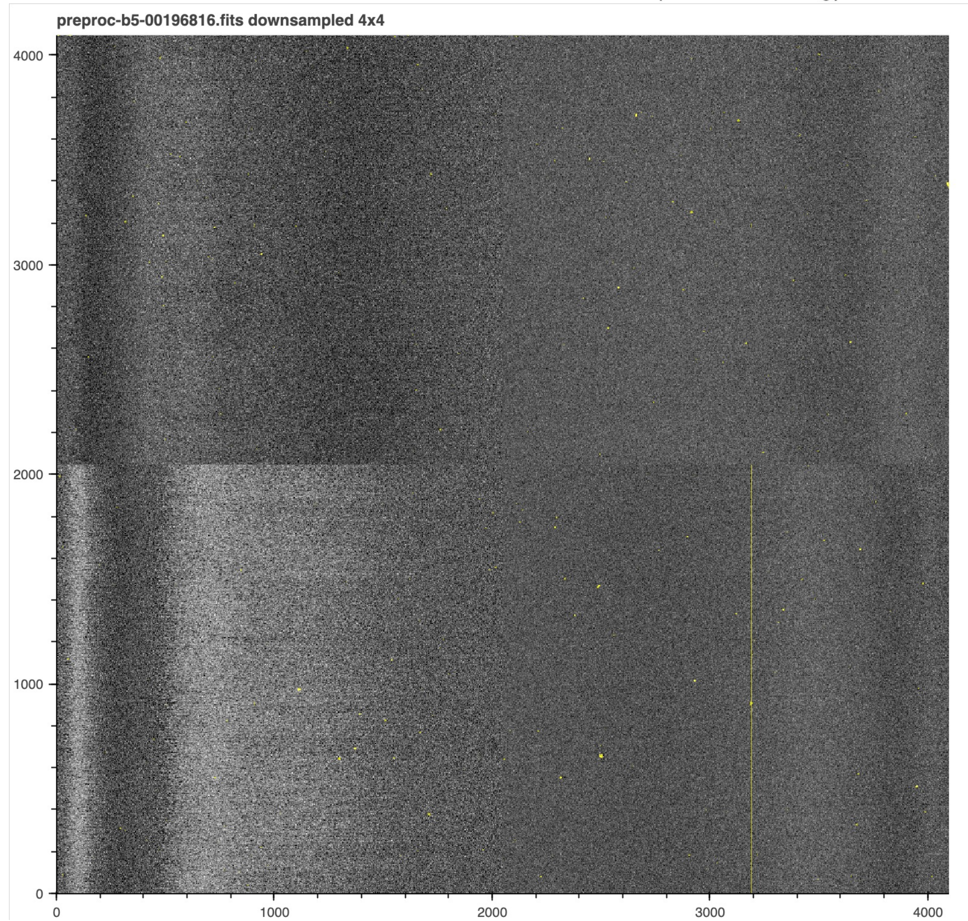

Summary

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- DESI will have the statistical power to tightly constrain the sum of the neutrino masses.

$$\sigma_{\sum m_\nu} = 0.02 \text{ eV}$$

- P1D from DESI EDR+ (54,600 quasars).
- We identified the major systematics error sources, noise and resolution. The systematics are comparable to statistical errors.
- There is a plan to reduce these errors.

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We are honored to be permitted to conduct scientific research on Iolkam Du'ag (Kitt Peak) in Arizona, a mountain with particular significance to the Tohono O'odham Nation.

Thanks to our sponsors and 69 Participating Institutions!

- DESI will have the statistical power to tightly constrain the sum of the neutrino masses.

$$\sigma_{\sum m_\nu} = 0.02 \text{ eV}$$

- But we need to control the systematics on the measurement to realize that goal.
- Noise calibration errors, resolution correction errors…