Cosmology with Lyman-$\alpha$ forest

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@ KICC

Kavli Science Day

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Lyman-α forest? $z=4.0$

Scattering of the electron: $n=1 \rightarrow n=2$
Hydrogen transition (Lyman-α)

Absorption in Quasar spectra along the line of sight
Current Status

Lyman-α forest auto-correlation BAO

Amplitude of matter clustering from Ly-α

$\sigma_8$

$100 \text{ Mpc/h}$

$10 \text{ Mpc/h}$

$1 \text{ Mpc/h}$

$100 \text{ kpc/h}$
Large-scales (> 10 Mpc/h)

**BAO → Full-Shape**

Expansion history
Amplitude ($\sigma_8$) and growth ($f\sigma_8$)

**DESI survey**
Roger de Belsunce, VI, George Efstathiou

du Mas de Bourboux et al. 2020 (eBOSS)

**Challenges:**
- Quasar Continuum
- Correlated noise
- Metal absorbers

**Clustering amplitude at the peak of SF?**

Font-Ribera et al. 2017 (BOSS mock data)
Intermediate-scales (1 – 10 Mpc/h)

Amplitude of matter clustering from Ly-α

Amplitude \( P_L(k_p, z_p) \)
and shape \( d \ln P_L / d \ln k(k_p, z_p) \)
of matter clustering

Possible issues:
• High-column density
• UVB fluctuations

Cosmology \( \leftrightarrow \) IGM physics

Determine sum of neutrino masses?

Matteo Esposito, VI, Matteo Viel
Intermediate-scales (1 – 10 Mpc/h)

Amplitude – $P_L(k_p, z_p)$
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of matter clustering

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Cosmology $\leftrightarrow$ IGM physics

Matteo Esposito, VI, Matteo Viel (in prep)
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Cosmology $\leftrightarrow$ IGM physics

Margherita Molaro, VI, James Bolton (astro-ph/2109.06897)
Intermediate-scales ($1 - 10$ Mpc/h)

Amplitude $- P_L(k_p, z_p)$
and shape $- d \ln P_L / d \ln k(k_p, z_p)$
of matter clustering

Possible issues:
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Cosmology $\leftrightarrow$ IGM physics
- Higher order Lyman series
- Higher order statistics

Bayu Wilson, VI, Matthew McQuinn (astro-ph/2106.04837)
Small-scales ($< 1 \text{ Mpc/h}$)

Testing Dark Matter models

- Relative suppression of small-scale clustering
- Robust constraints for variety of models

![Graph showing small-scale clustering analysis](image-url)
Can we rule out large ranges in DM particle mass?

Motivation: non-resonant sterile neutrino (3.5 keV), excluding ultra-light axions with $m_a > 10^{-14} \text{ eV}$

Can we distinguish between DM models?

Motivation: information on production mechanism

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Small-scales (< 1 Mpc/h): Link between Cosmology & Galaxies

Estimated power subtracts metals: $P_{\alpha\alpha} = P_F - P_m$

Metal power $P_m$ measured red-side of Ly$\alpha$ emission

Wilson, Vl+21 (astro-ph/2106.04837)

Correlations of metal doublets

Karacayli, Vl+21 (astro-ph/2108.10870)
Conclusions

• Lyman-α forest as a high-z LSS tracer

• A unique probe of the IGM (redshift range, small scales)

• Large-scales (> 10 Mpc/h): BAO + Full-Shape(?)

• Intermediate-scales (1 – 10 Mpc/h): Amplitude/Slope of matter clustering

• Small-scales (< 1 Mpc/h): Robust constraints on DM models

• With increasing statistical power of the data → access to CGM