Characterizing the abundance, properties, and kinematics of the cool circumgalactic medium (CGM) of galaxies in absorption with SDSS DR16

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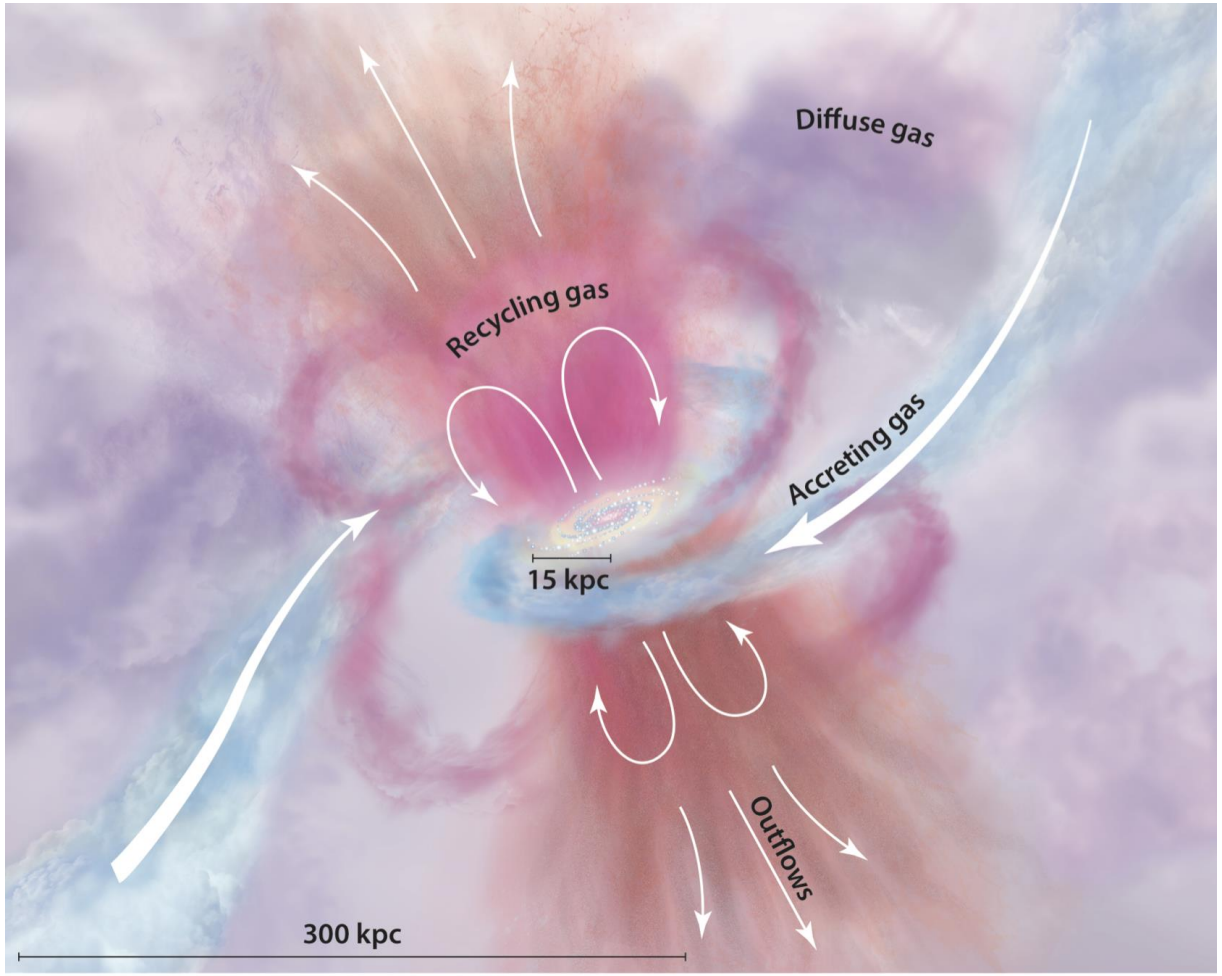
Outline

- Background
- Method – pipeline
- Results
  - Mg II Absorbers
  - Galaxy Connections
- Summary

Background - CGM

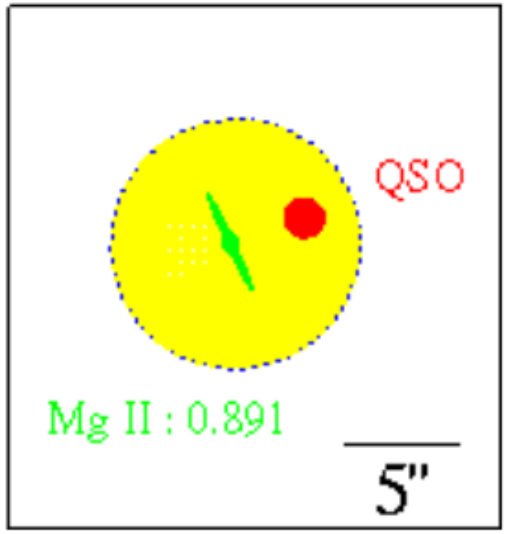
- What: Gas surrounding galaxies **outsides their disks or ISM** and **insides their virial radii**, is known as Circumgalactic medium (CGM)
  - Multiphase, rich dynamics
  - Source for galaxy's **star-forming** fuel
  - Venue for **galactic feedback and recycling**
  - perhaps the key regulator of the **galactic gas supply**

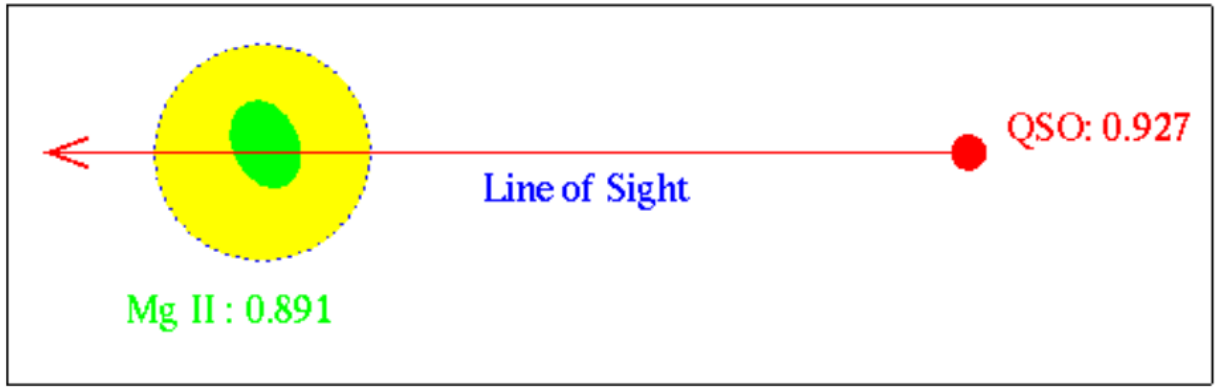


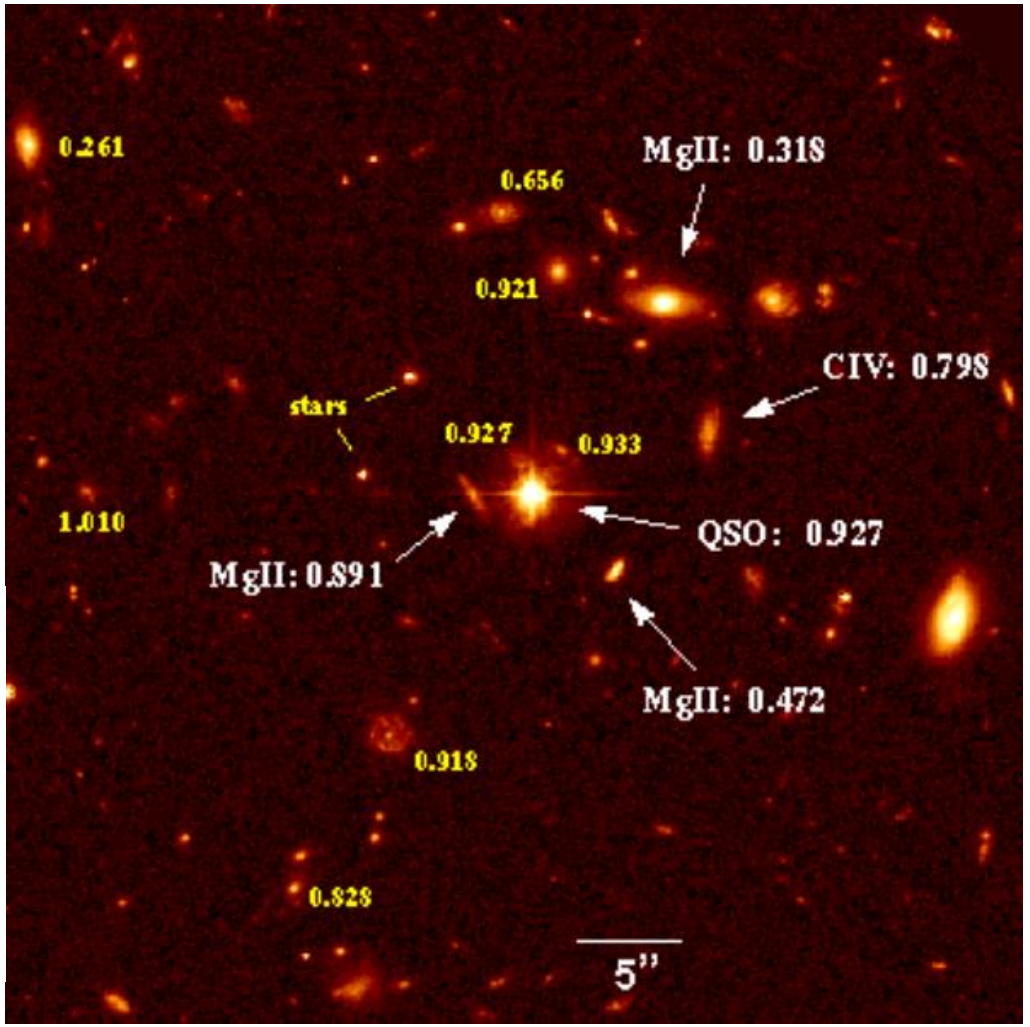
Background – CGM?

- Why: play an important role in several key processes in **galaxy formation**
  - determining the **timescales** of gas depletion and star formation
  - origin of the way in which **quenching** occurs
  - distribution of the **baryonic budget**
  - distribution of **metal content** of the gas surrounding galaxies
- How: one of the most powerful method ~ through metal absorbers
  - Mg II $\lambda\lambda$2796, 2803 doublet ~ trace cold gas ($\leq 10^4\ k$)
  - C IV $\lambda\lambda$1548, 1550 ($\sim 10^5\ k$)
  - Ly α absorbers

Background – Mg II Absorption line



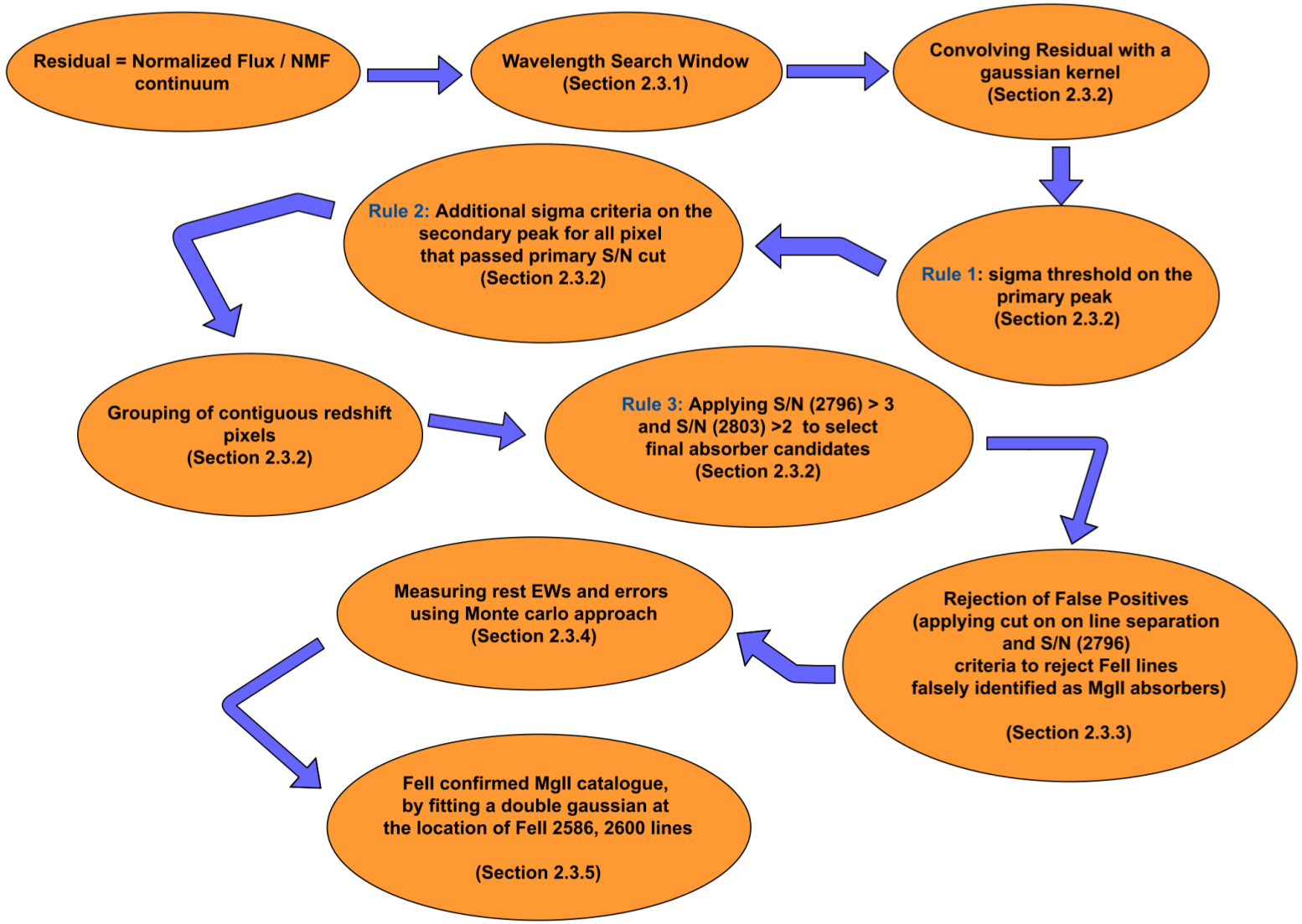




Credit: http://astronomy.nmsu.edu/cwc/Research

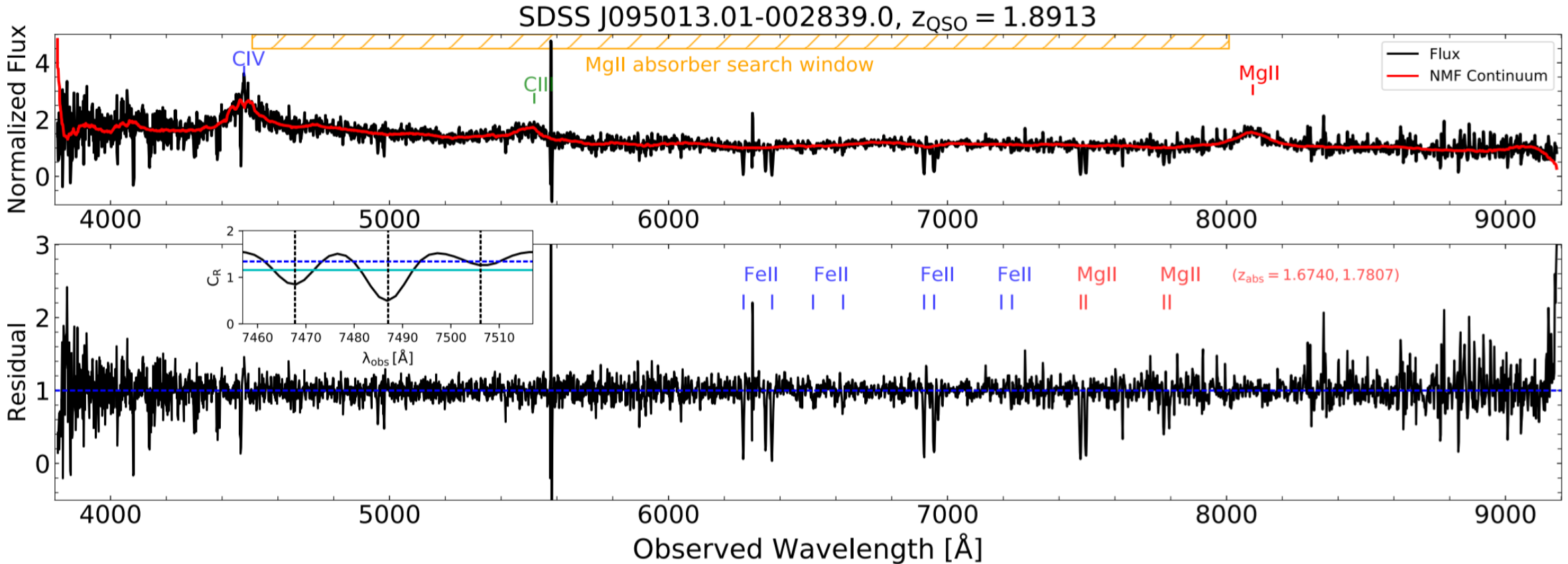
Method

- Pipeline



Method

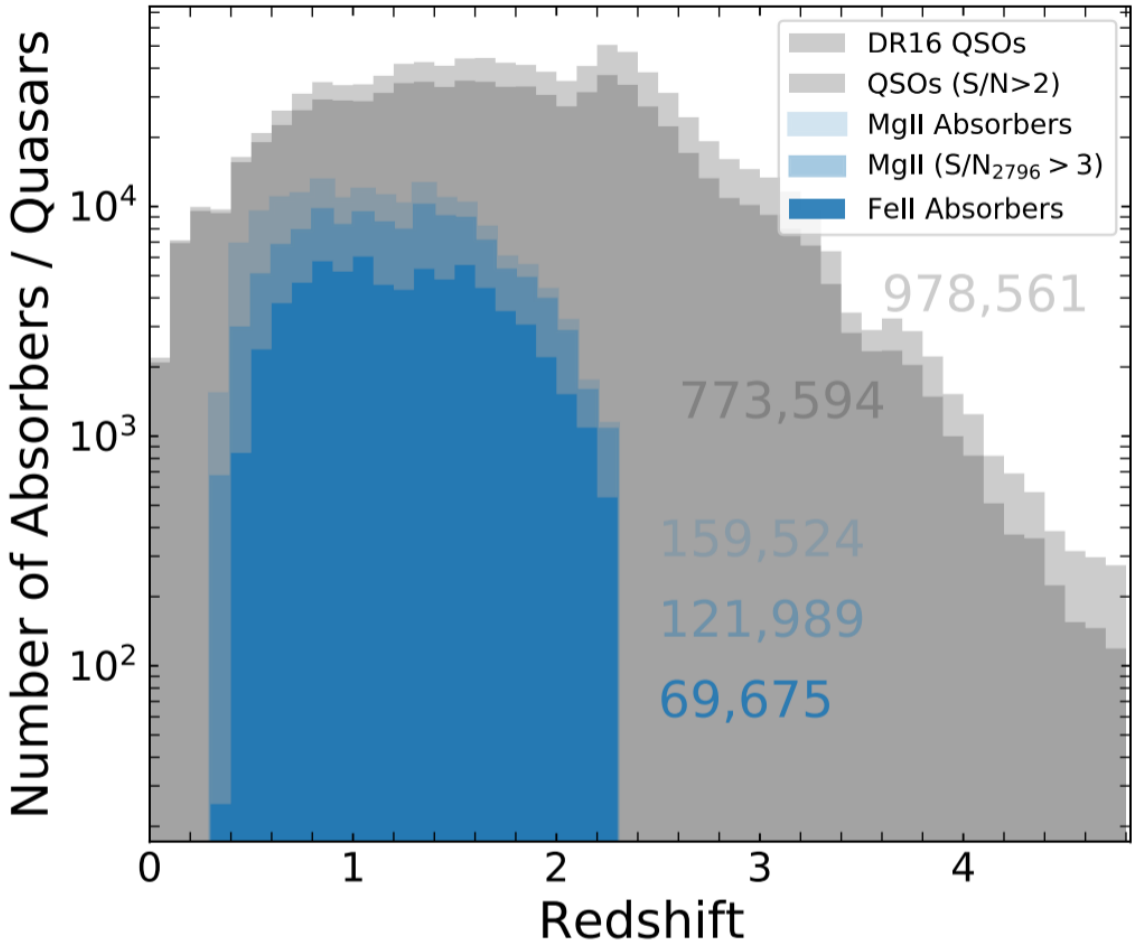
- Continuum Estimation (Previous: PCA; Improved: NMF) : —
- Automatic Detection of Absorber
- Confirmed by Fe II



Results – Detected Objects

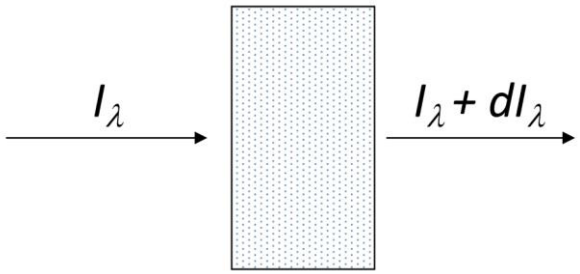
- QSOs ~ 9.8×10^5
- QSOs (S/N > 2) ~7.7×10^5
- QSOs (S/N < 2) are removed for consistency

Objects	DR12	DR14	DR16
QSOs	297,301[a]	526,356[b]	983,317[c]
QSOs ($S/N_{QSO} > 1$)	-	-	941,939
QSOs ($S/N_{QSO} > 2$)	-	-	773,594
LRGs	-	$\lesssim$ 1 million	1,252,722[c]
ELGs	-	35,094[c]	269,889[c]
Mg II Absorbers	39,219*	-	**159,524**†
Mg II ($S/N_{2796} > 1$)	38,327*	-	**158,725**†
Mg II ($S/N_{2796} > 2$)	37,763*	-	**150,236**†
Mg II ($S/N_{2796} > 4$)	33,376*	-	**94,403**†

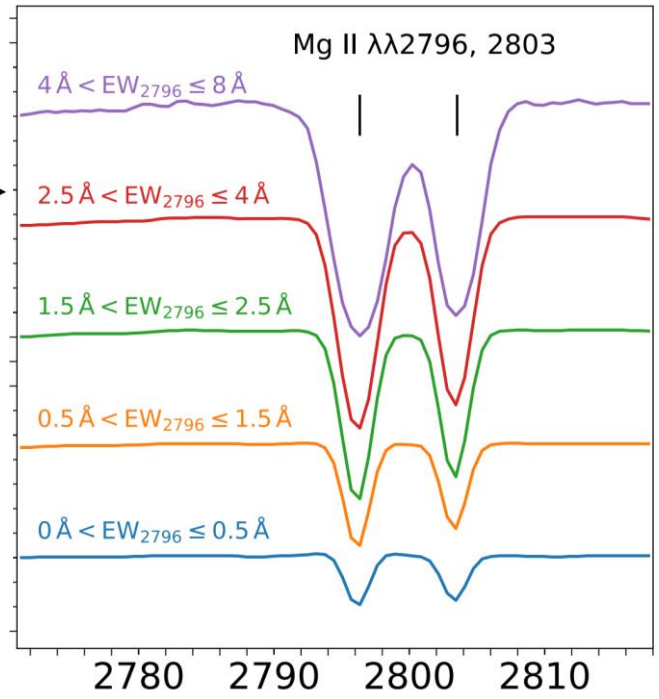


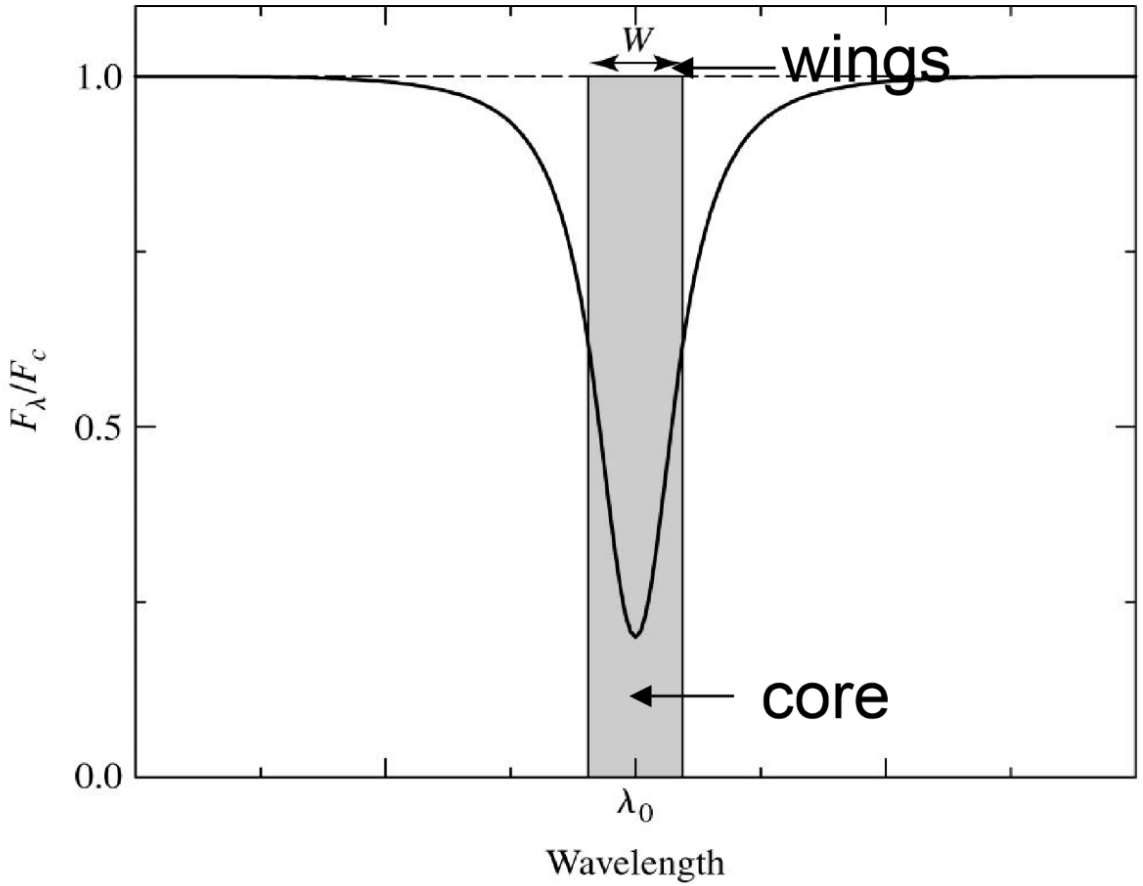
Results - Properties of Individual Absorber

- Saturated: Doublet Ratio = 1
- Unsaturated: Doublet Ratio = 2

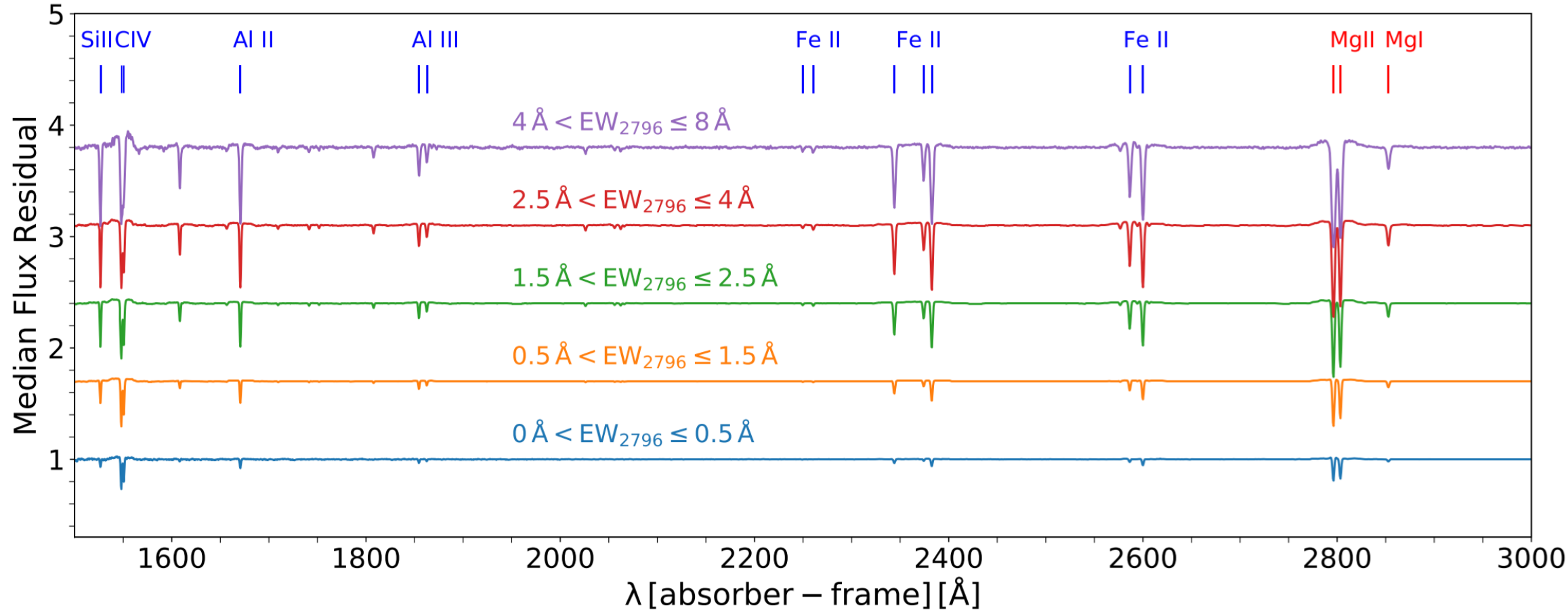


$$I_\lambda = I_{\lambda_0} e^{-\kappa_\lambda \rho s}$$



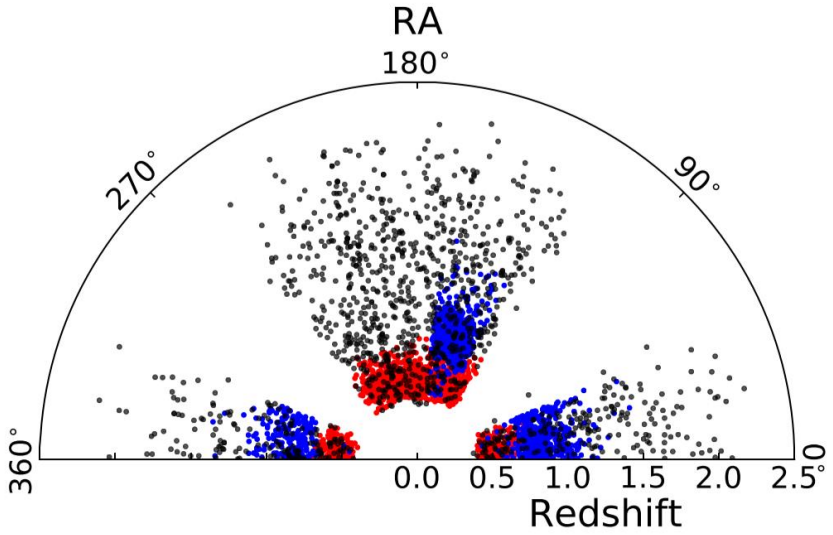


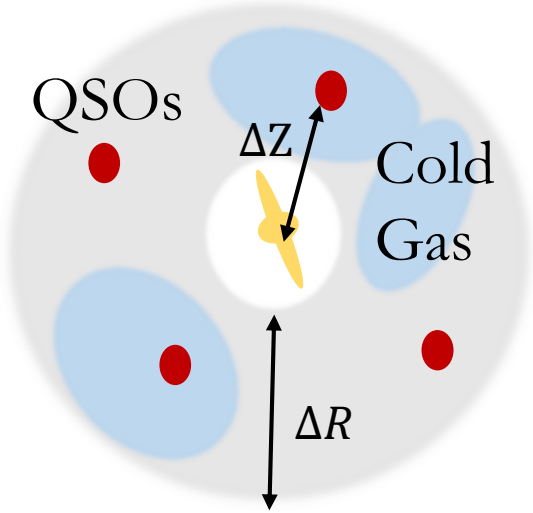
Results - Properties of Absorber in Stacked Spectra



Results – Connection to Galaxy

- Emission Line Galaxies (ELGs)
  - Strong gas emission lines [O II], [O III], H β
  - Hot and Young ~ Blue
  - Star Formation Rate (SFR): 1~20 $M_\odot\ yr^{-1}$
- Luminous Red Galaxies (LRGs)
  - Low SFR + Old Stellar Population ~ Red
- A statistical quantity: **Covering Fraction**

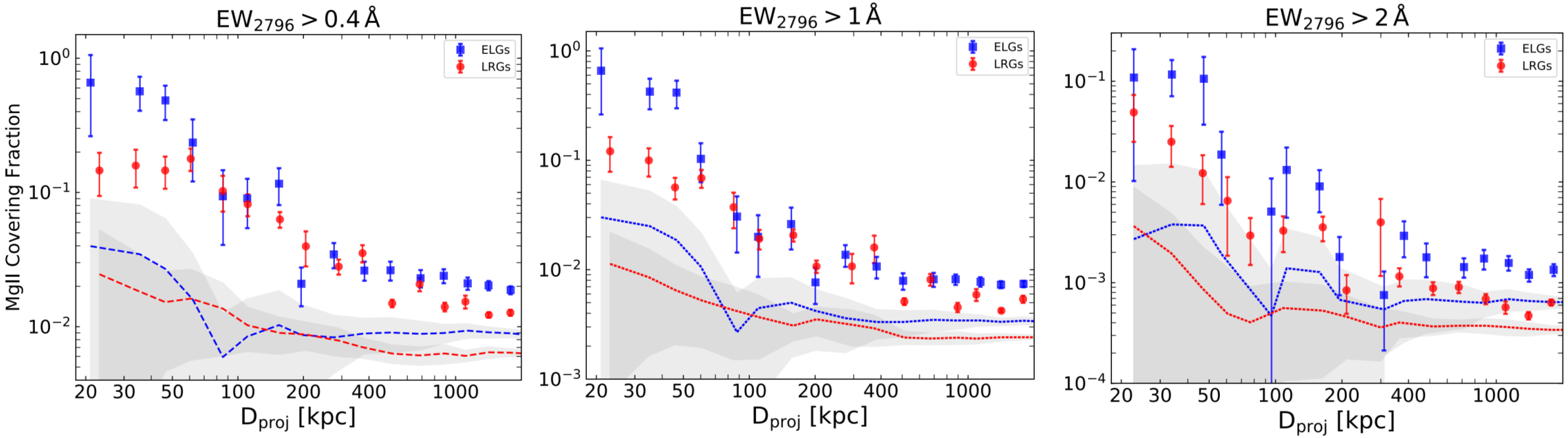




$$f_c'|_{\Delta R} = \frac{\mathrm{N(sightlines\ with\ absorbers)}}{\mathrm{N(QSO\ sightlines)}} = \frac{\sum_j \mathrm{N}^{\mathrm{abs}}_{\mathrm{gal,\,j}}|^{\Delta z}_{\Delta R}}{\sum_j \mathrm{N}^{\mathrm{QSO}}_{\mathrm{gal,\,j}}|_{\Delta R}}.$$

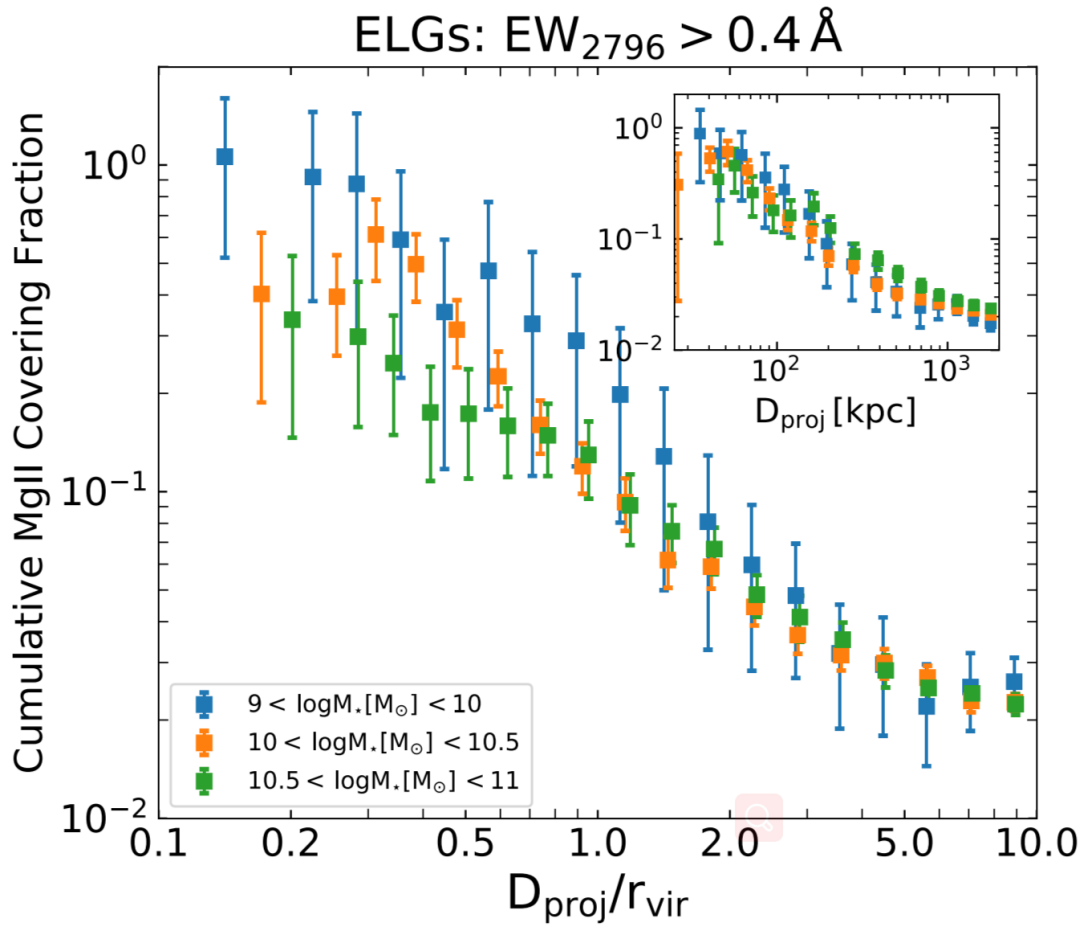
Results – Galaxy-Absorber Correlation

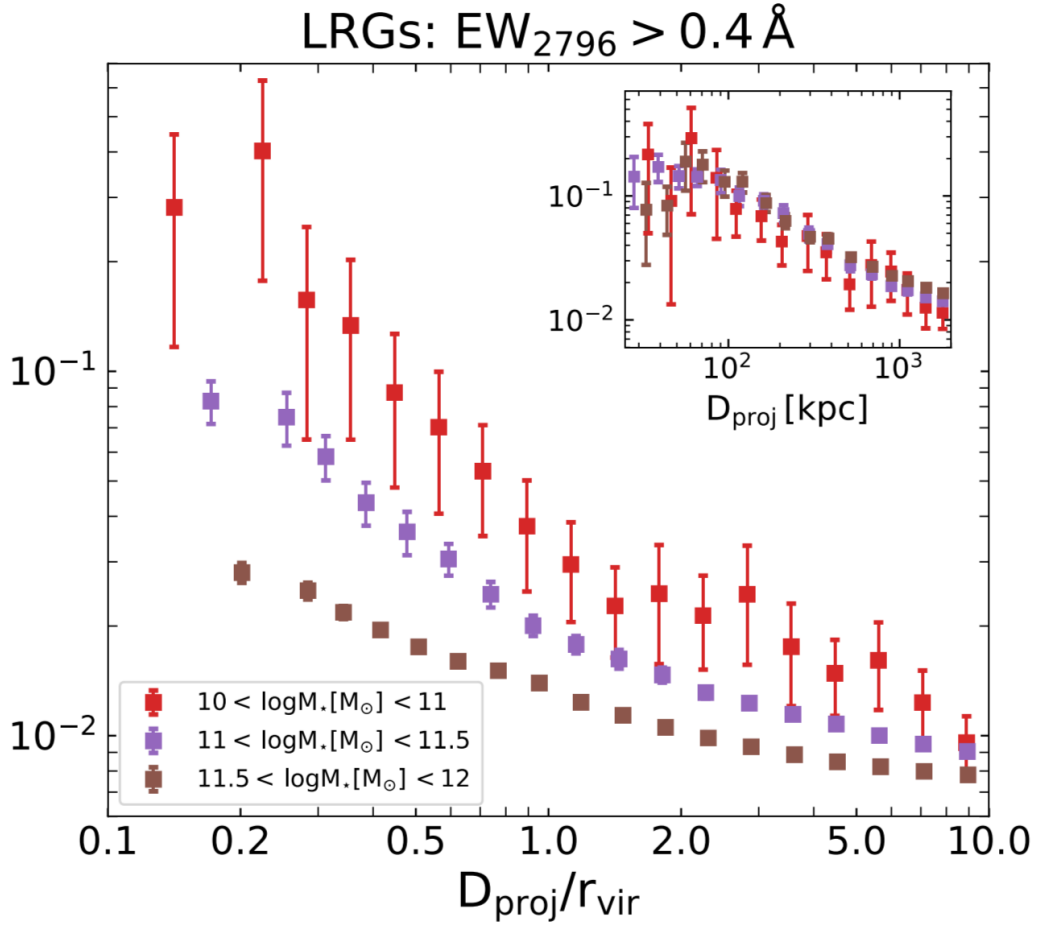
- A clear anti correlation between f_c and EW_{2796} ~ rarity of strong absorbers around galaxies



Results – Stellar and Halo Mass

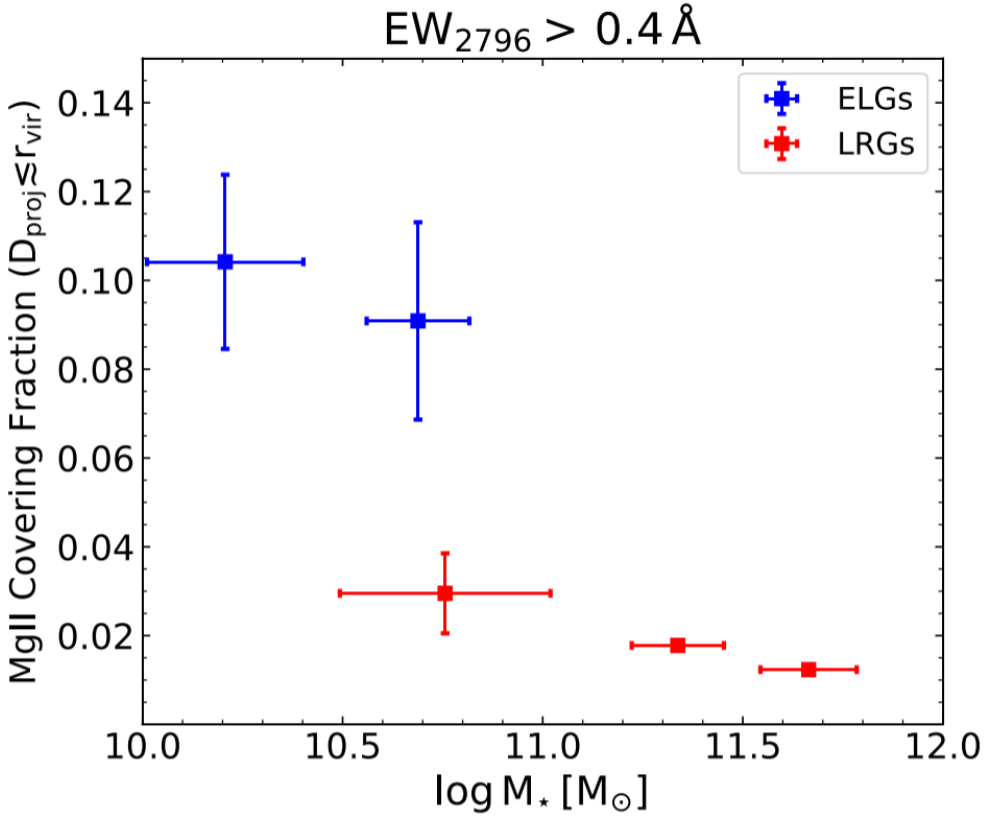
- More massive galaxies host less cool gas on average …?

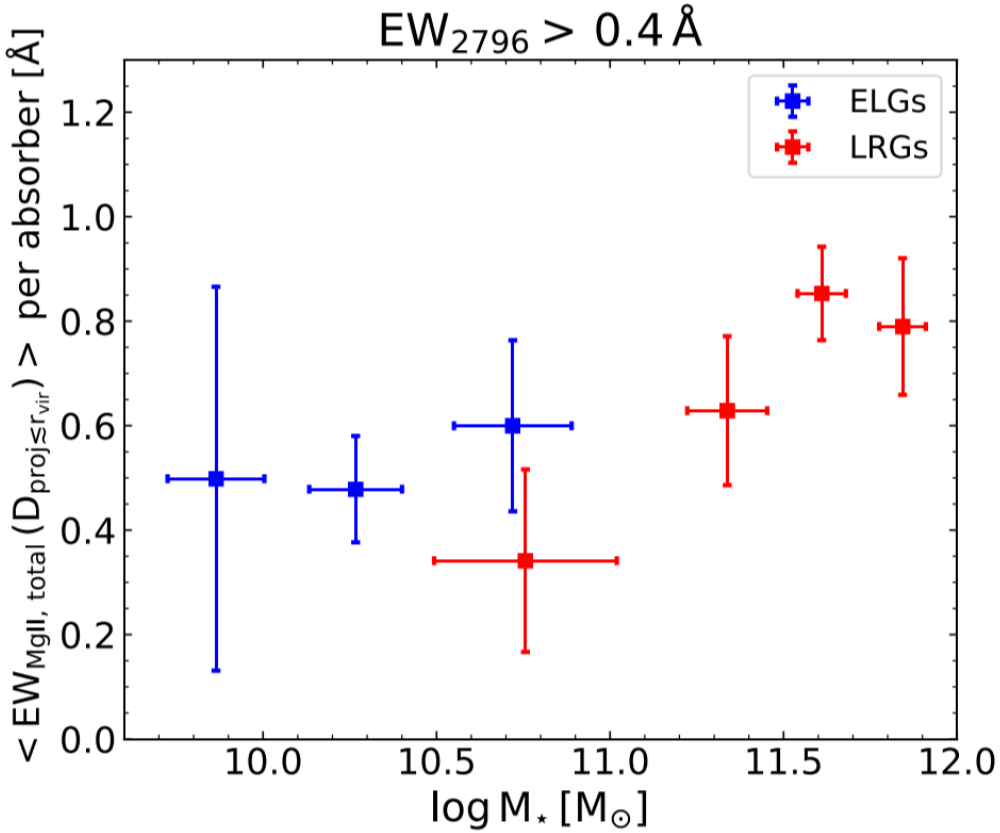




Results – Stellar and Halo Mass

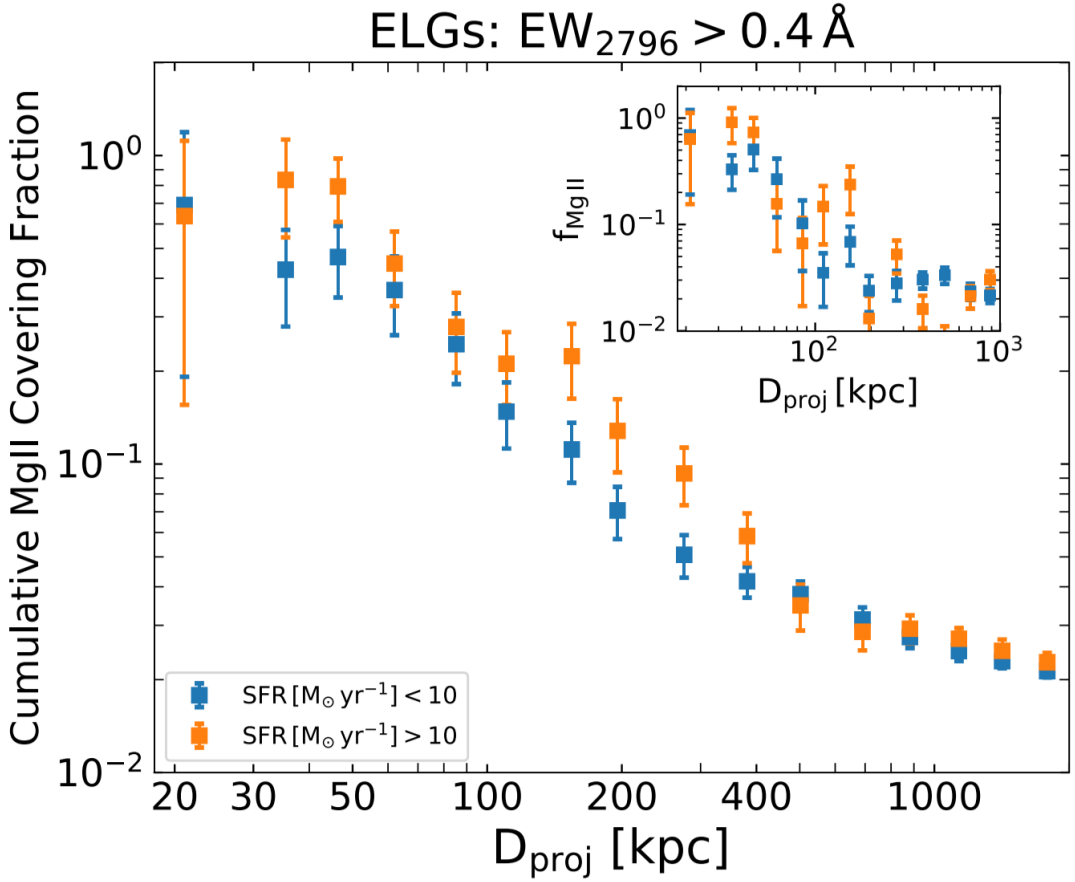
- Cumulative value ~ larger Ews around more massive galaxies

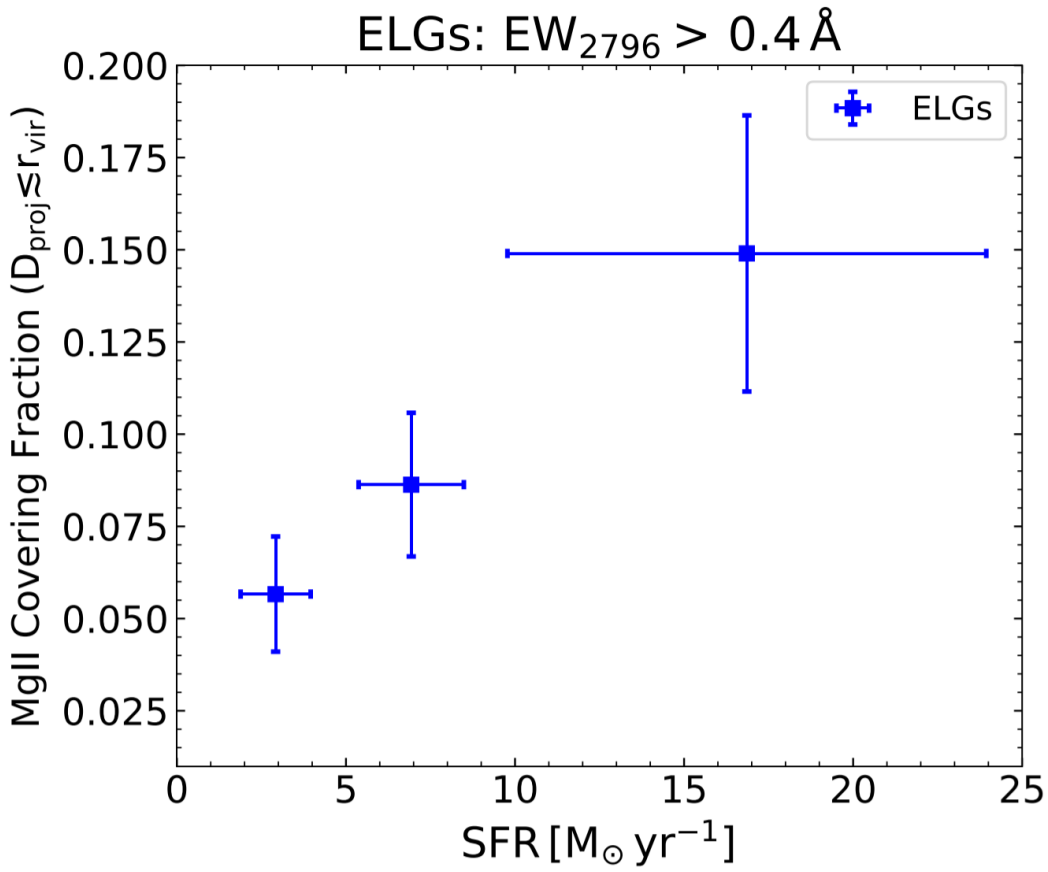




Results – Dependence on SFR

- SF activity in ELGs plays an important role in enriching the cold gas in their CGM.





Summary

- A pipeline is constructed to identify the **Mg II absorption lines.**
- They applied this pipeline into latest DR16 of SDSS to get a **huge** number of high SNR data, which makes their results to be **more accurate** than previous studies.
- ELGs have **larger covering fraction** than LRGs have at $D_{\mathrm{proj}} < 50$ kpc
- Qualitatively, Mg II absorbers have **positive correlation** with SFR, and **negative correlation** with projected distance and stellar mass, validating the theory that SF processes consume cold gas.

Questions

- 1. Why did the author choose the Mg II research window from C IV to Mg II of QSOs intrinsic emission lines?
- 2. Why did the author choose ELGs and LRGs as the classification of galaxies?
- 3. Why is there a dip in f_c of MgII at D_{proj}~ 50kpc?
- 4. Based on the results of this study alone, is the conclusion reliable that 'more massive galaxies host less cool gas on average' ?
- 5. Does cold gas contribute to the SFRs in galaxies or vice versa?