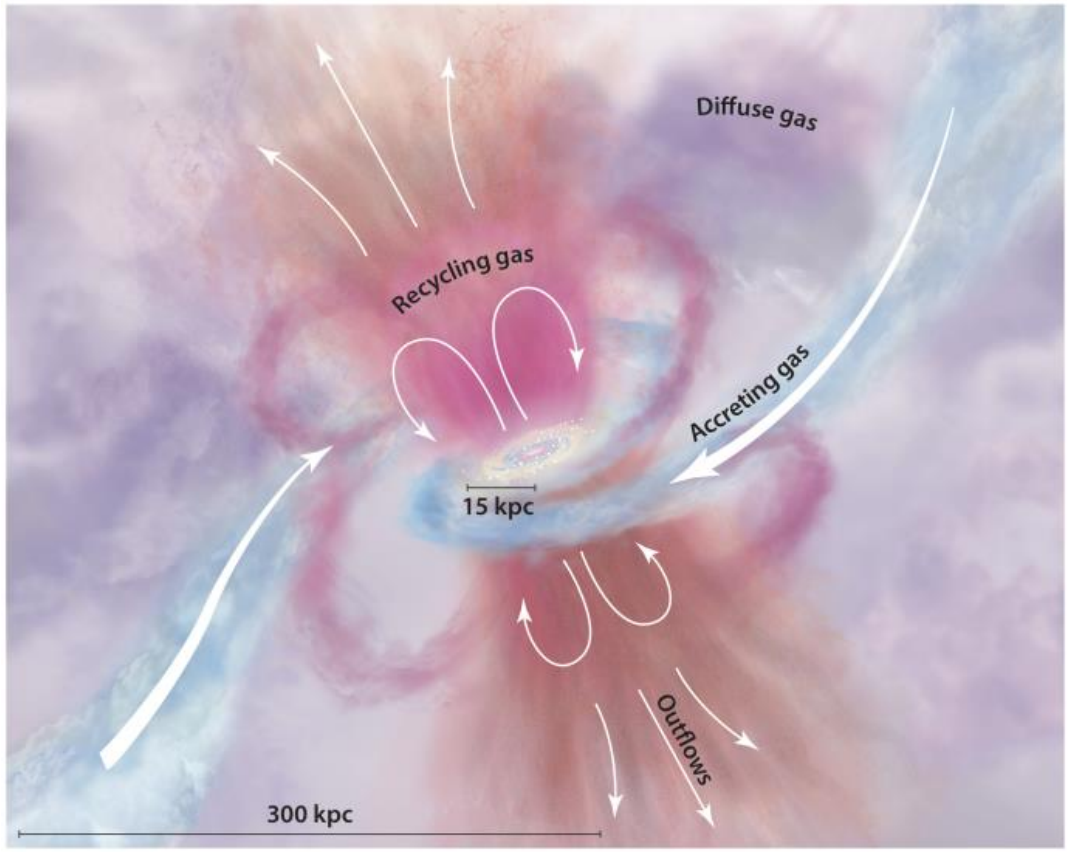
Studying Damped Lyman-alpha Systems Using Quasar Spectra

Natalie Meyer

Mentor: Dr. Grecco Oyarzun

Gas and Dust in Galaxies

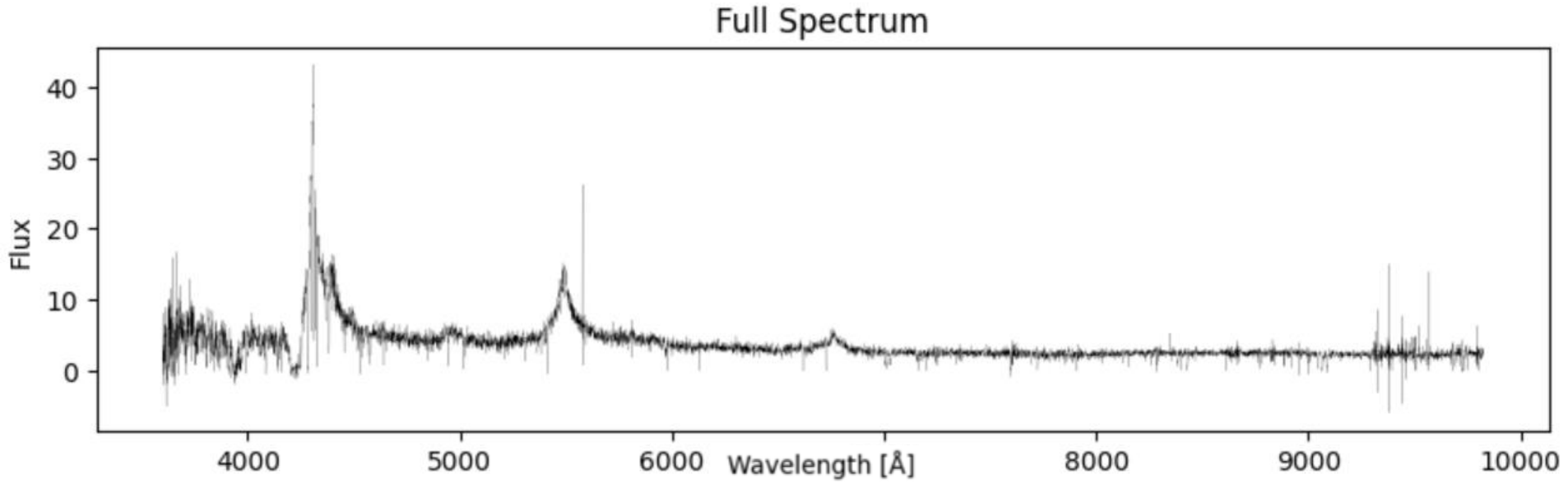
- Galaxies contain clouds of gas and dust beyond visible regions
- Drives star formation and galaxy evolution
- Studying gas and dust tells us:
  - Properties of the galaxy
  - History and evolution of the galaxy
  - How gas affects star/galactic formation and evolution

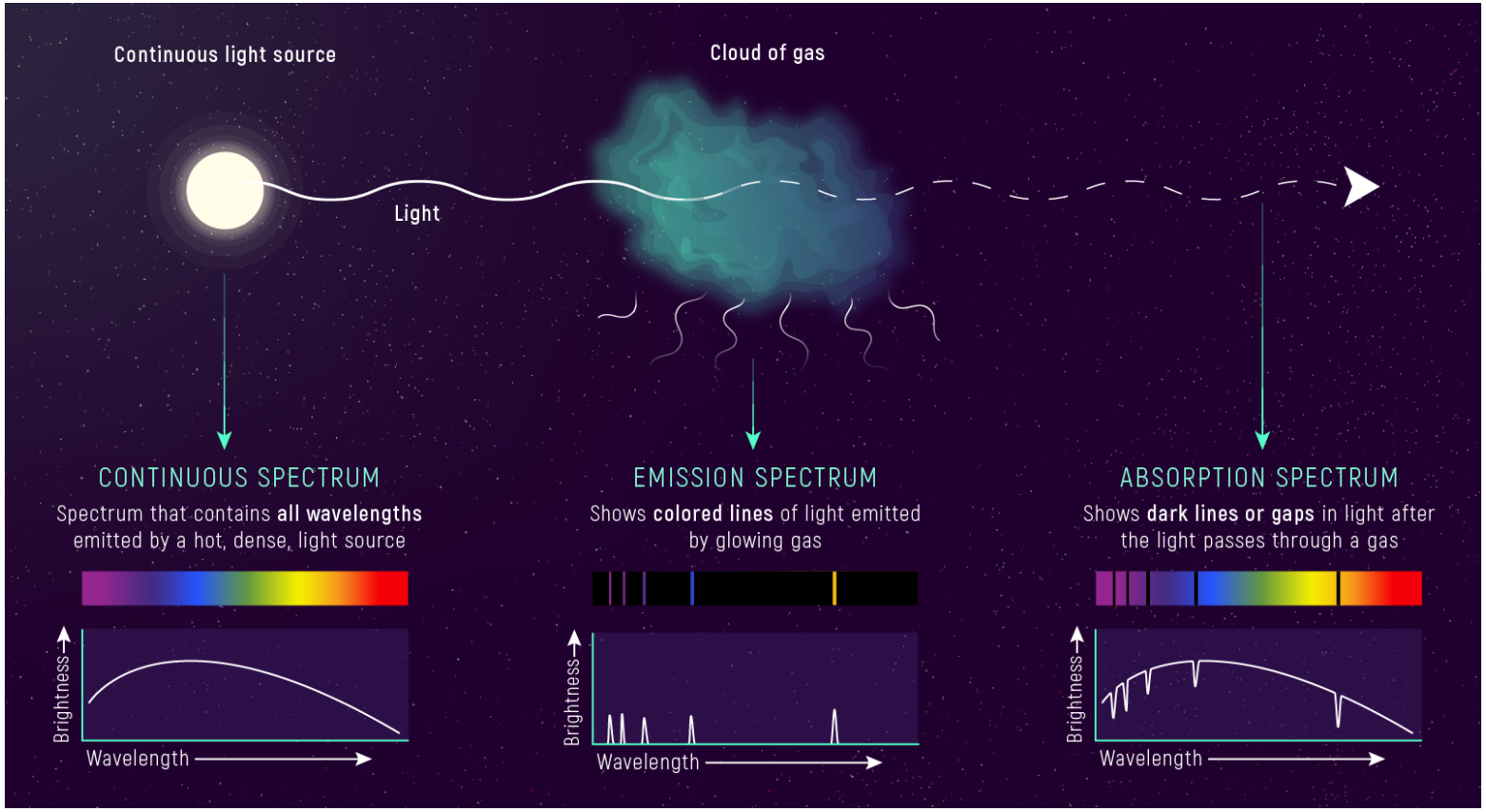


Tumlinson, J., Peeples, M. S., & Werk, J. K. (2017). The circumgalactic medium. *Annual Review of Astronomy and Astrophysics*, *55*, 389-432.

Quasars

- Quasars are luminous active galactic nuclei (AGN)
- Quasar spectra have a peak at the Lyman-alpha transition – the Hydrogen transition from n = 2 to n = 1
- 1216 angstroms at z = 0 (no redshift)





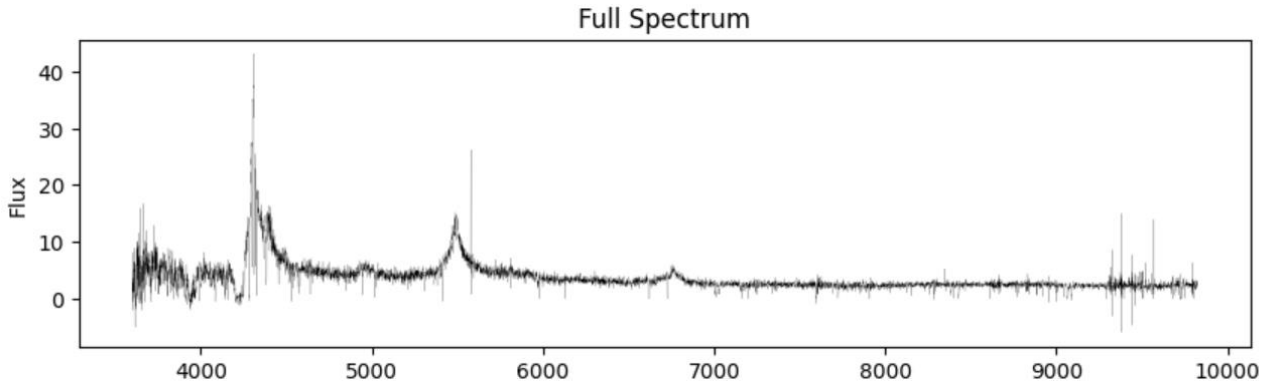
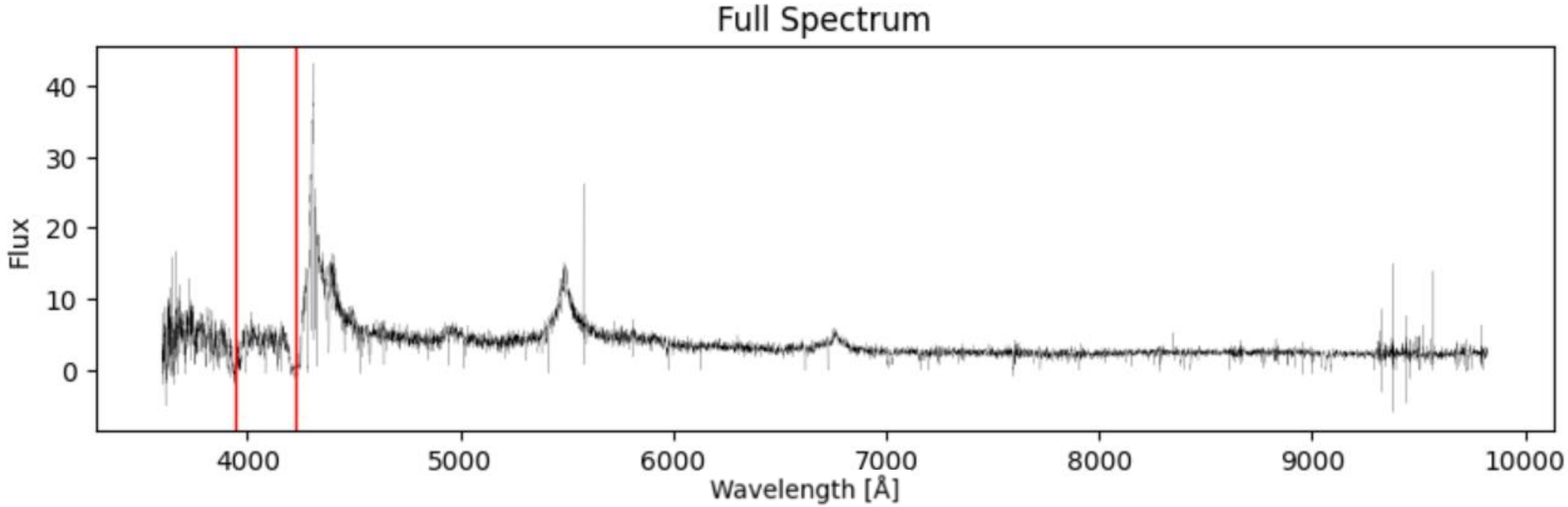


Illustration: NASA, ESA, CSA, Leah Hustak (STScI)

Damped Lyman-Alpha Systems

- Damped Lyman-alpha (DLA) systems are areas of high absorption of Lyman-alpha radiation
- Dips in flux to the left of the spectrum are typically caused by galaxies
- 1216 angstroms redshifted depending on how far the galaxy is

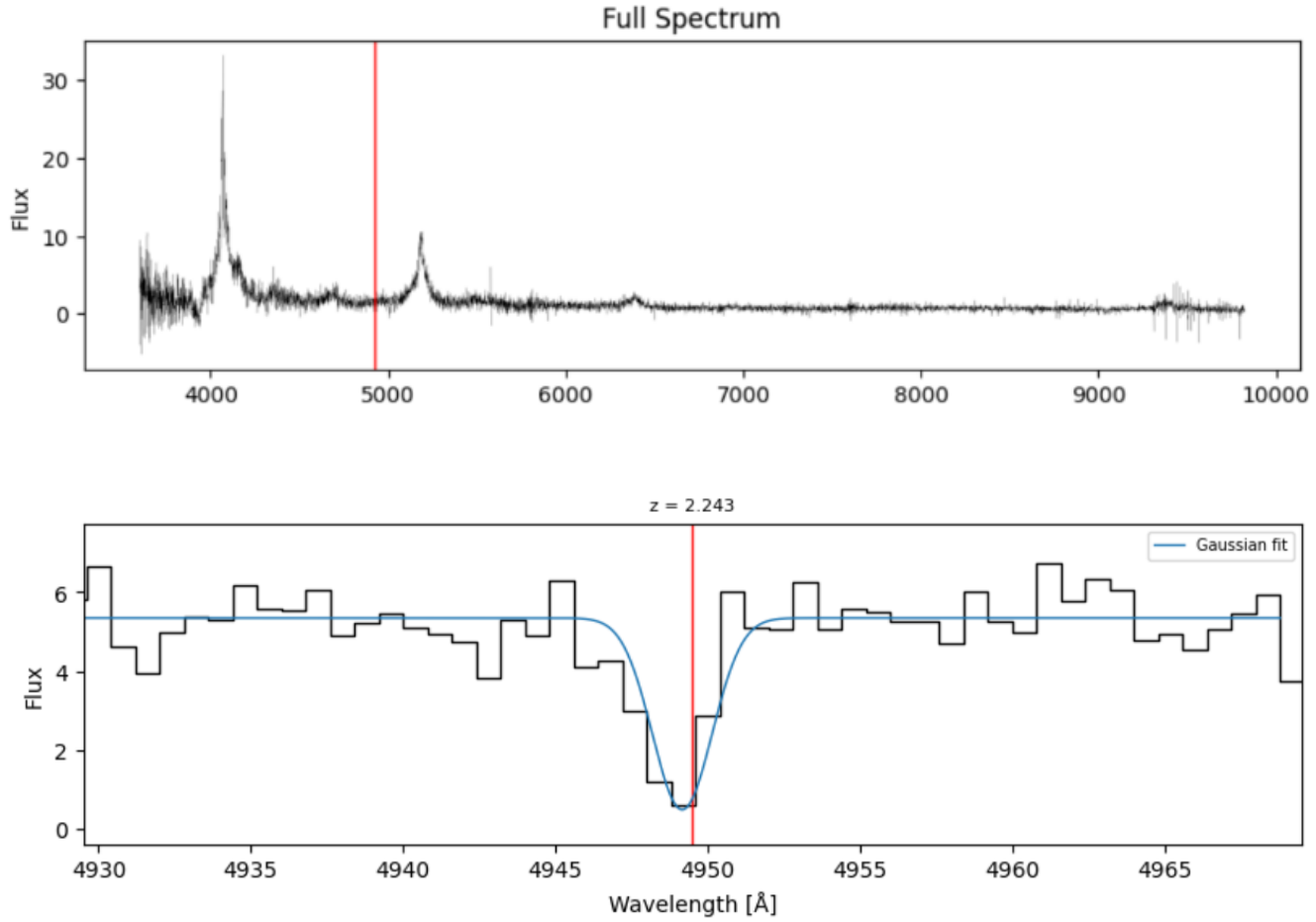


Damped Lyman-Alpha Systems

- Used the Dark Energy Spectroscopic Instrument (DESI) data to obtain thousands of quasar spectra
  - Used spectra with known DLAs
- Includes parameters like redshift of quasars, redshift of DLAs, right ascension, declination, and column density
- Goal is to measure:
  - Metallicity
  - Reddening (dust content)
- Look for correlations between metallicity and amount of dust

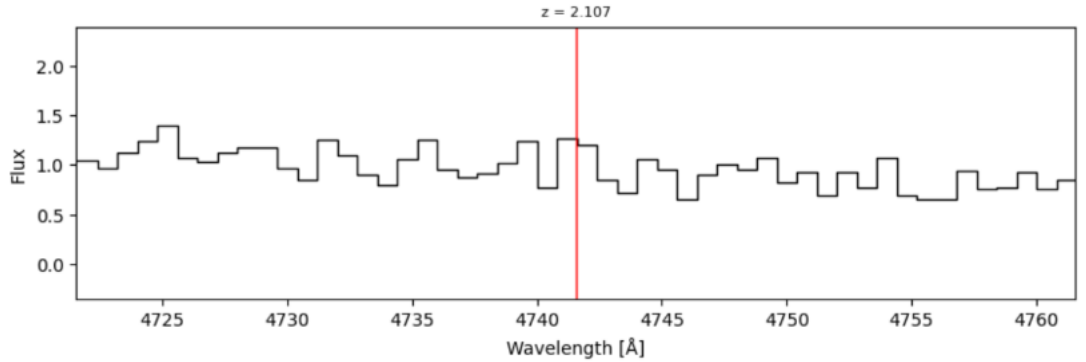
Silicon Absorption

- Absorption lines of metals lie on the right of the quasar spectrum
- Redshifted based on the redshift of the galaxy
- Absorption means the metal is present in the galaxy

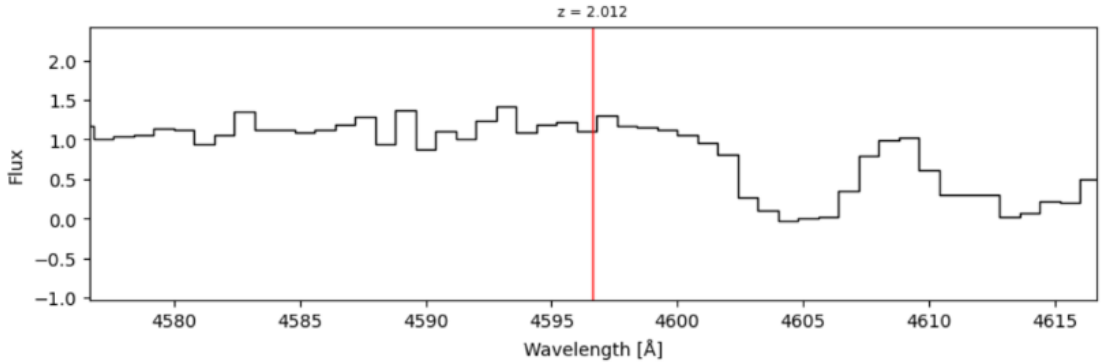


Examples of No Absorption

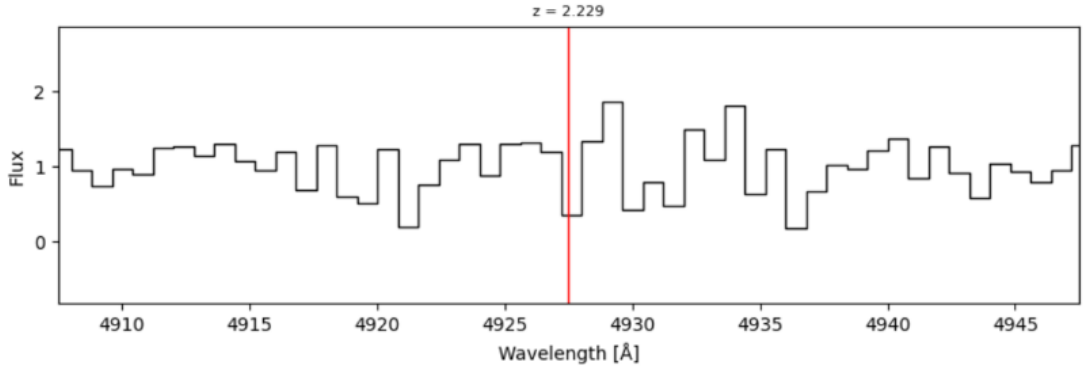
No dip in flux present



Dip in flux > 5 Å from expected absorption

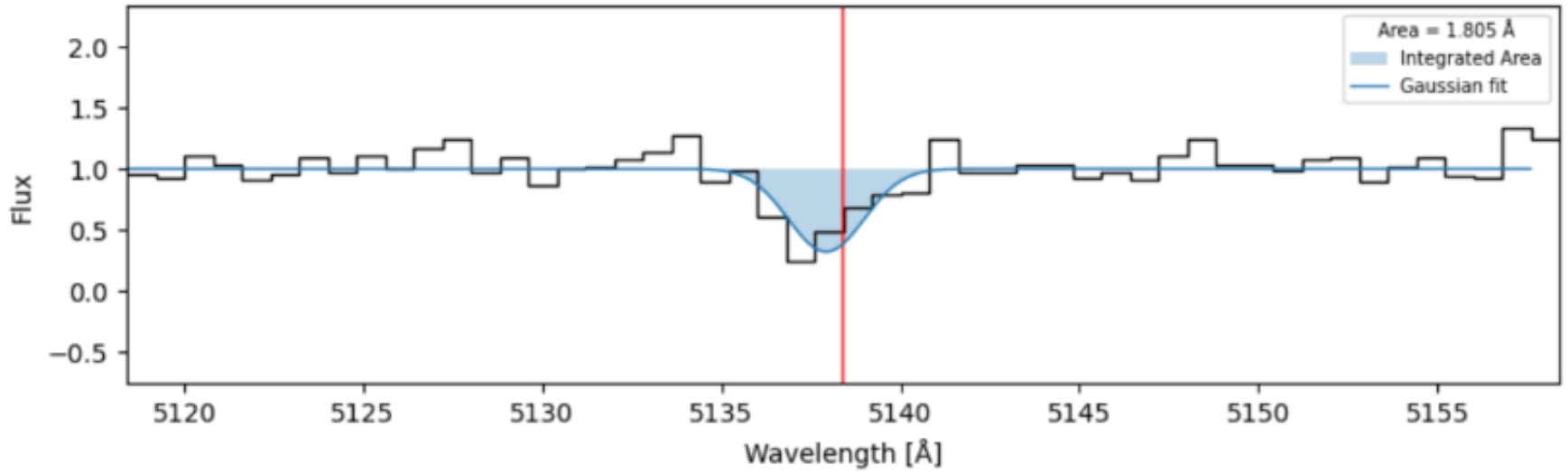


Noise mimicking a dip in flux



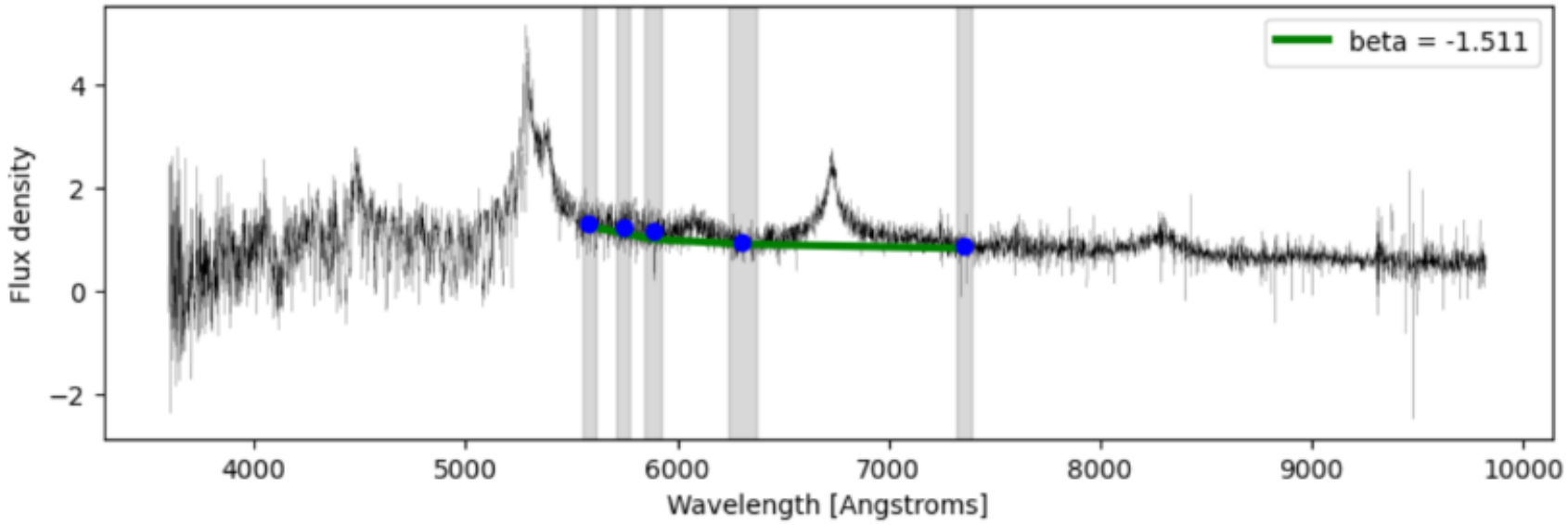
Metallicity Calculation

- Area set to zero if no absorption
- If absorption is present, computed Gaussian and area of absorption



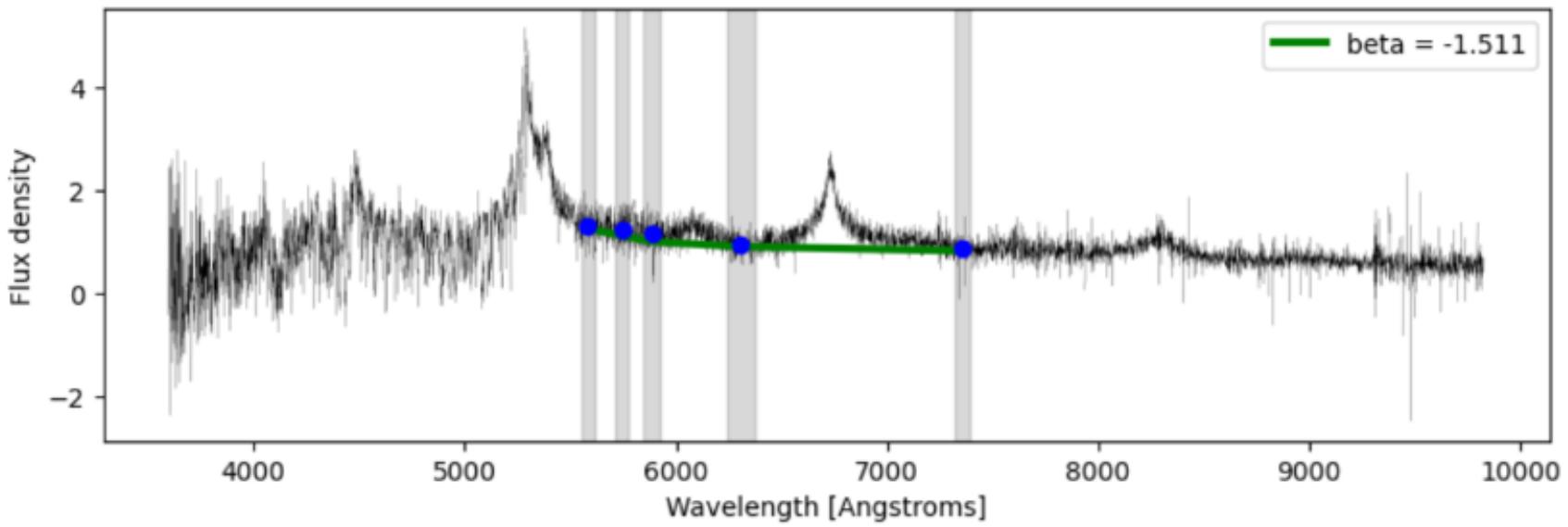
Reddening

- Measure dust content through reddening
- Dust scatters blue light, meaning we observe more red light in areas with higher dust content
- Means higher flux density at higher wavelengths



Reddening

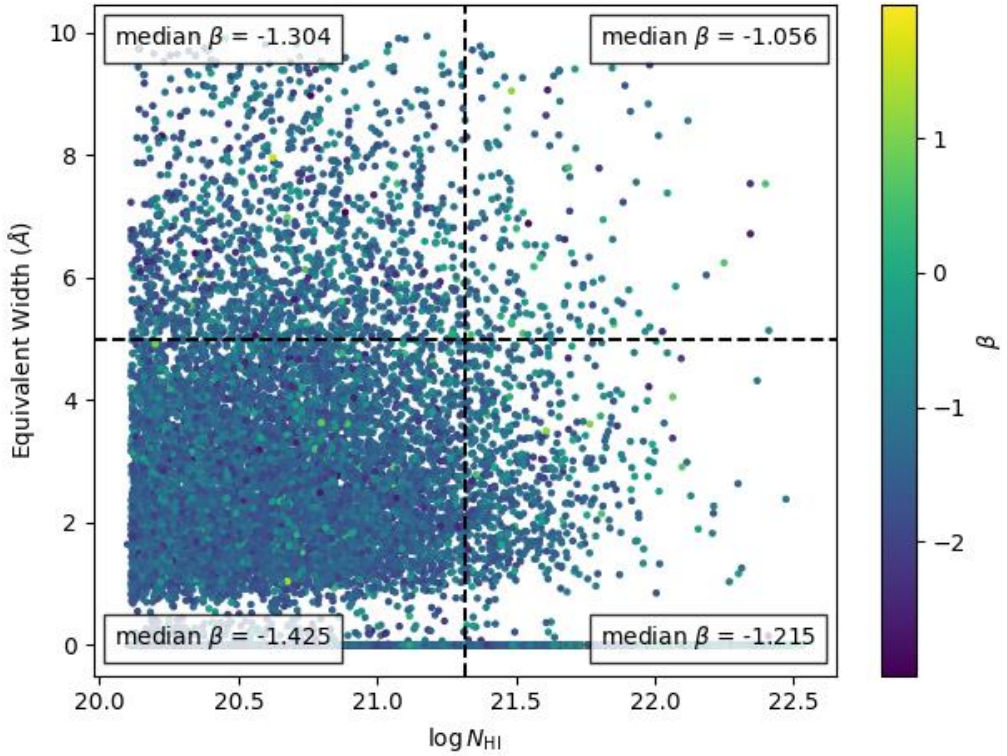
- Measured the flux at the five grey regions
  - These regions are less affected by emission lines from the quasar spectrum[1]
- $f_\lambda \propto \lambda^\beta$
- If beta fitting failed, set value to nan



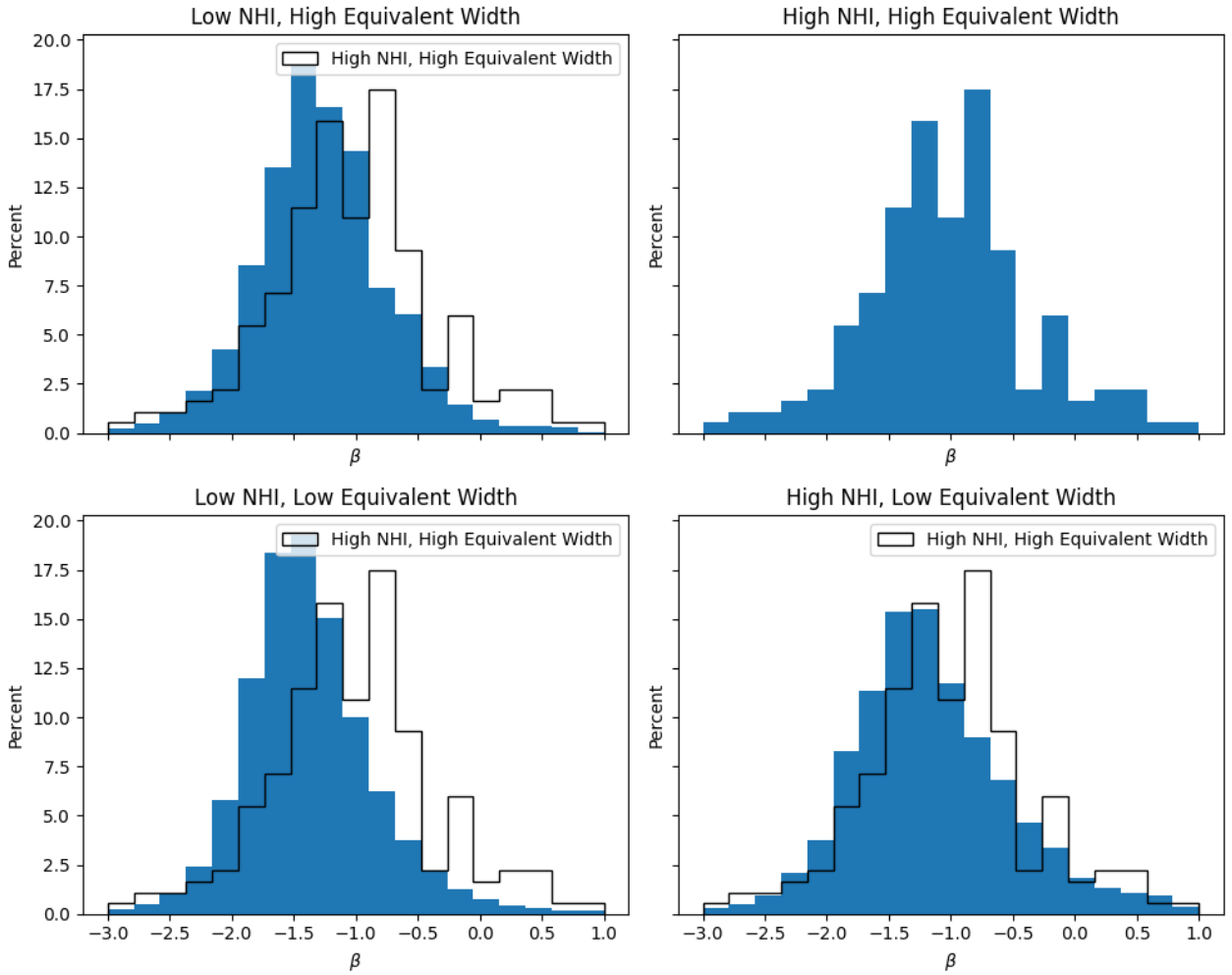
[1]Murphy, M. T., & Bernet, M. L. (2015). The dust content of damped Lyman-alpha systems in the Sloan Digital Sky Survey. *Monthly Notices of the Royal Astronomical Society, 455,* 1043-1059.

Results

- Measured metallicity and dust for 32,484 DLAs
- After removing failed betas and unphysical outliers, had 32,329 DLAs



Results


Low NHI, High Equivalent Width
High NHI, High Equivalent Width
Percent
β
Low NHI, Low Equivalent Width
High NHI, High Equivalent Width
Percent
β
High NHI, Low Equivalent Width
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Percent
β

Summary

- Higher dust content is more likely to be found in high metallicity, high column density galaxies

- Any unobserved quasars are more likely to be associated with these DLAs

- Since dust is more prevalent in the centers of galaxies, measurements from within the galaxies are more likely to have higher metallicities