Galactic Nebular Emission in QSO Spectra

Lorrie Straka

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Outline

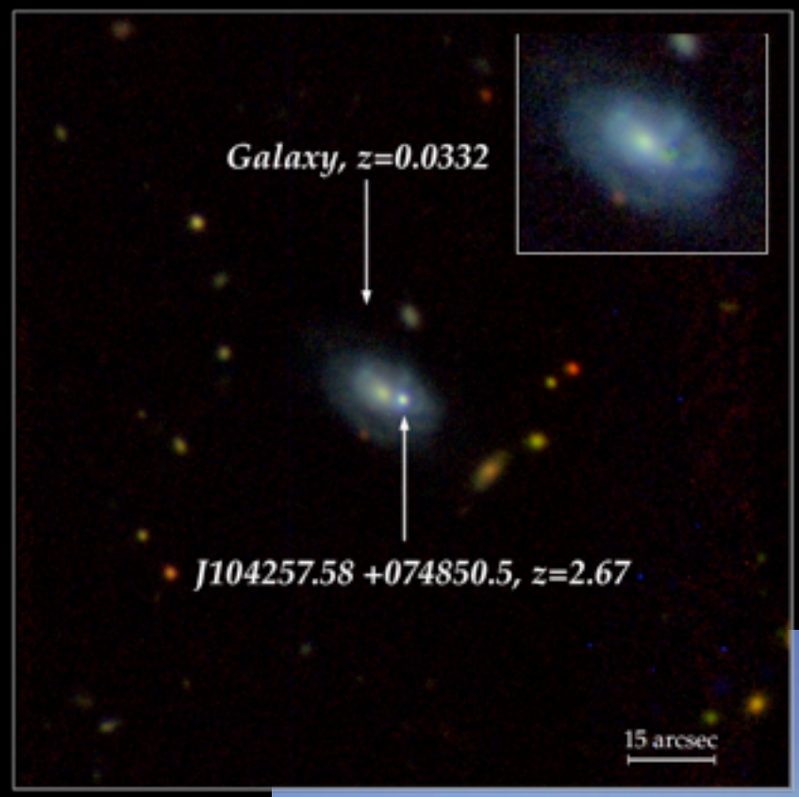
- What are Galaxies on Top of QSOs (GOTOQs)?
- Searching for GOTOQS
- Properties of GOTOQs
- The future: utilizing MUSE in absorption line studies

What are GOTOQs?

- Low-z quasar-galaxy pairs found in the SDSS

- Some or all of the galaxy falls within the 3 arcsecond spectral fiber centered on the quasar

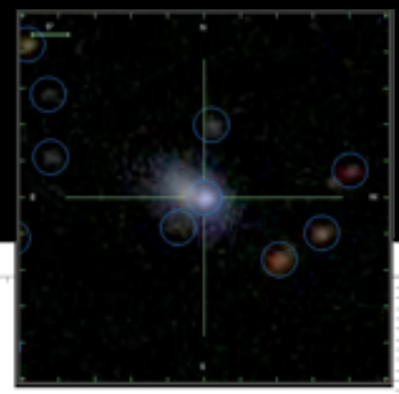
- Q1042+0748 (Borthakur et al. 2010)

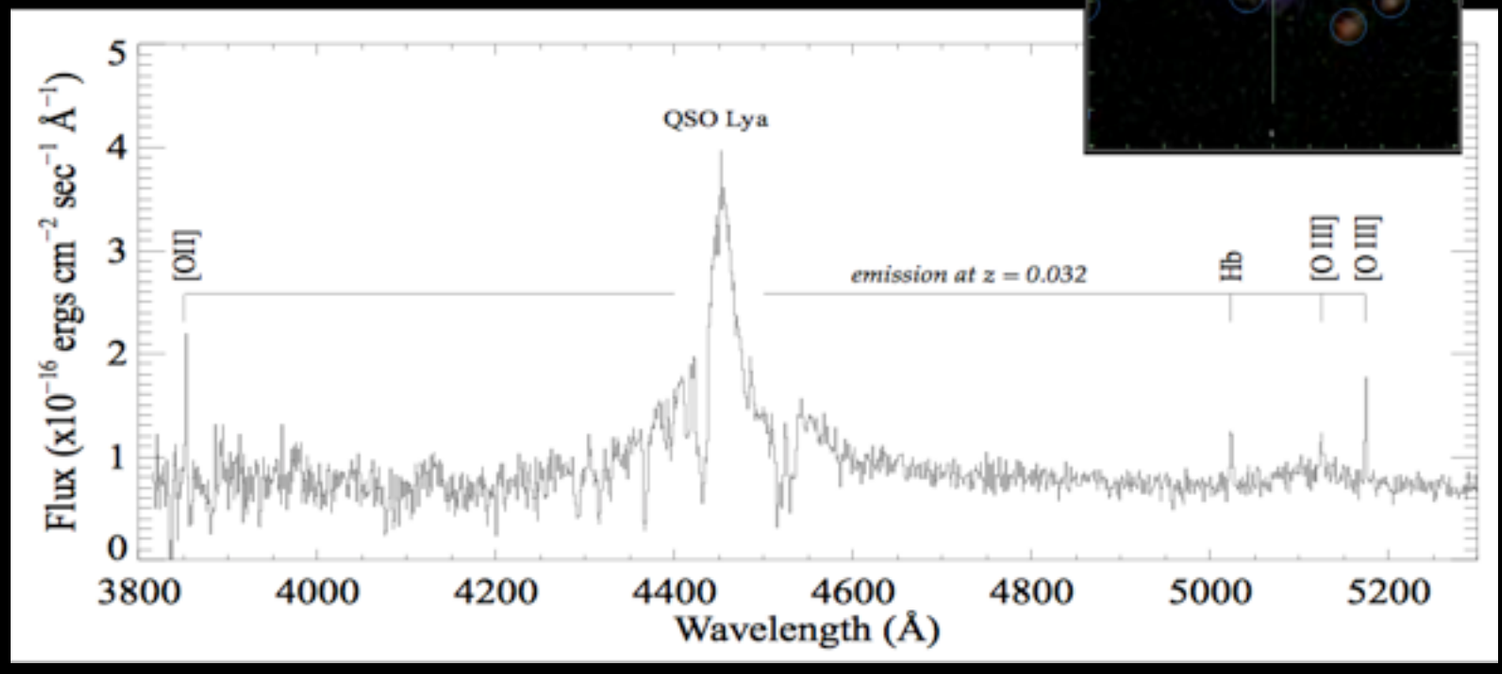


Searching for GOTOQs

- QSO spectra have overlapping narrow emission lines indicating the presence of intervening galaxies within 1.5”
- >100,000 QSO spectra searched
- Sample of 103 late-type galaxies
  - Full photometric and spectroscopic set of measurements

Galactic emission lines:
[OII], Hb, [OIII],[NII], Ha, [SII]





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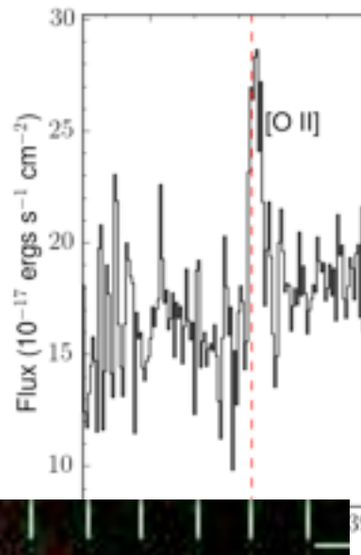
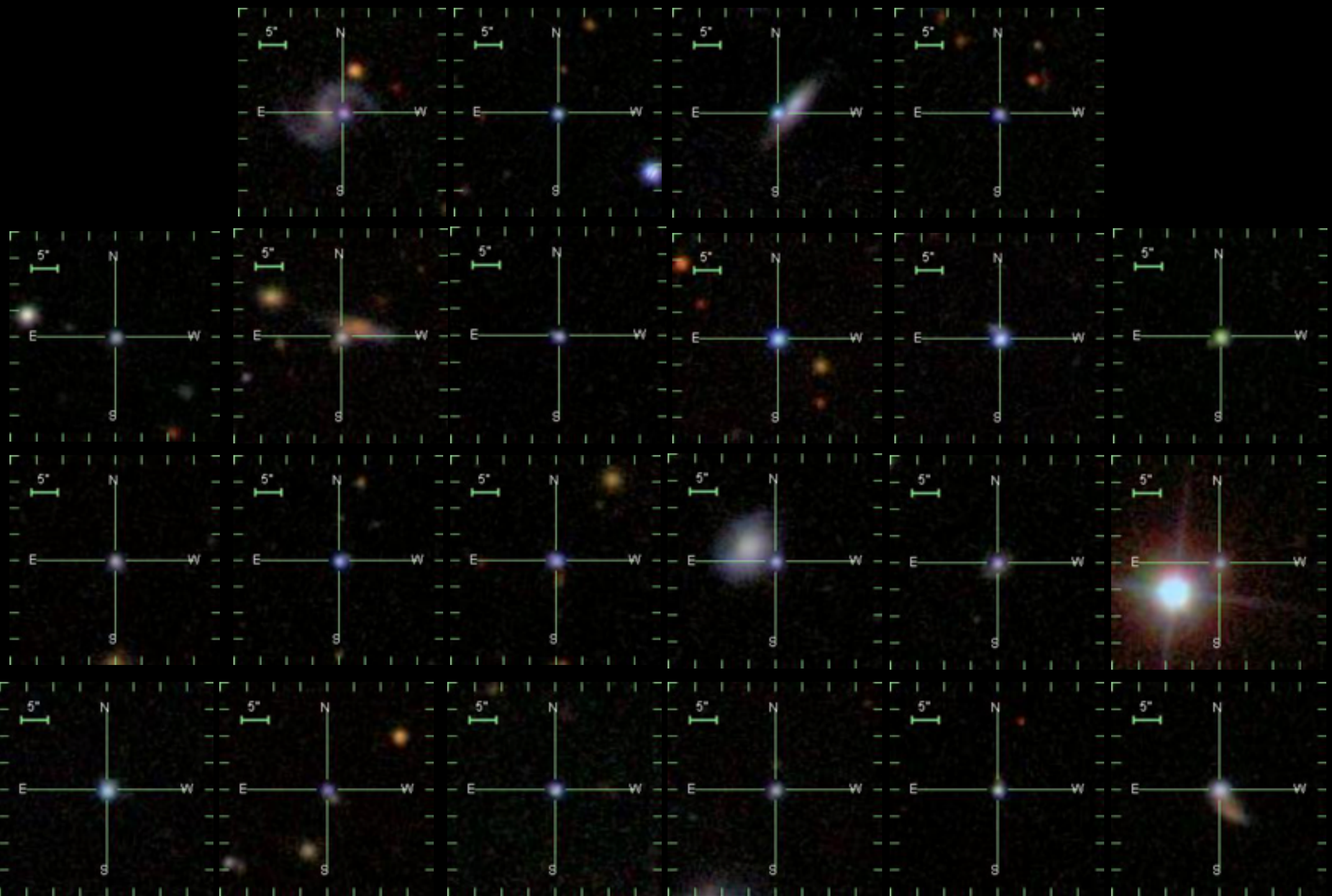


z(em)=0.046

Role reversal: compile a catalog of low-z GOTOQs detected in emission, and then search for absorption



Questions to Address

- What are the environments along quasar lines of sight?
- What are the roles of outflows and inflows?
- Photometric and spectroscopic properties
- How are emission and absorption properties connected?
- How are low-z absorption systems related to higher-z absorption systems?

Questions to Address

- What are the environments along quasar lines of sight?
  - Effect of groups or isolation, IGM
- What are the roles of outflows and inflows?
- Photometric and spectroscopic properties
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Questions to Address

- What are the environments along quasar lines of sight?
- What are the roles of outflows and inflows?
  - Orientation and inclination angle
- Photometric and spectroscopic properties
- How are emission and absorption properties connected?
- How are low-z absorption systems related to higher-z absorption systems?

Questions to Address

- What are the environments along quasar lines of sight?
- What are the roles of outflows and inflows?
- Photometric and spectroscopic properties
  - Morphology, luminosity, SFR, metallicity
- How are emission and absorption properties connected?
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  - Evolutionary processes

Why GOTOQs?

- Low-z galaxies are more easily detectable in emission (spectroscopically and in imaging!)
- At low redshifts, the strongest observable absorption features are Ca II and Na I
- Mg II, Mg I, and Fe II are other strong features to seek at z>0.4

Results

- 58 of 103 GOTOQs have visible galaxy and absorption
- 10 with no visible galaxy and no Ca II or Na I absorption at $z<0.4$
- All impact parameters < 12 kpc
- Low luminosities : ~50% of the sample have L* values in the dwarf range (L*<0.2)
- Typical SFR < 5 $M_{sol}\ yr^{-1}$

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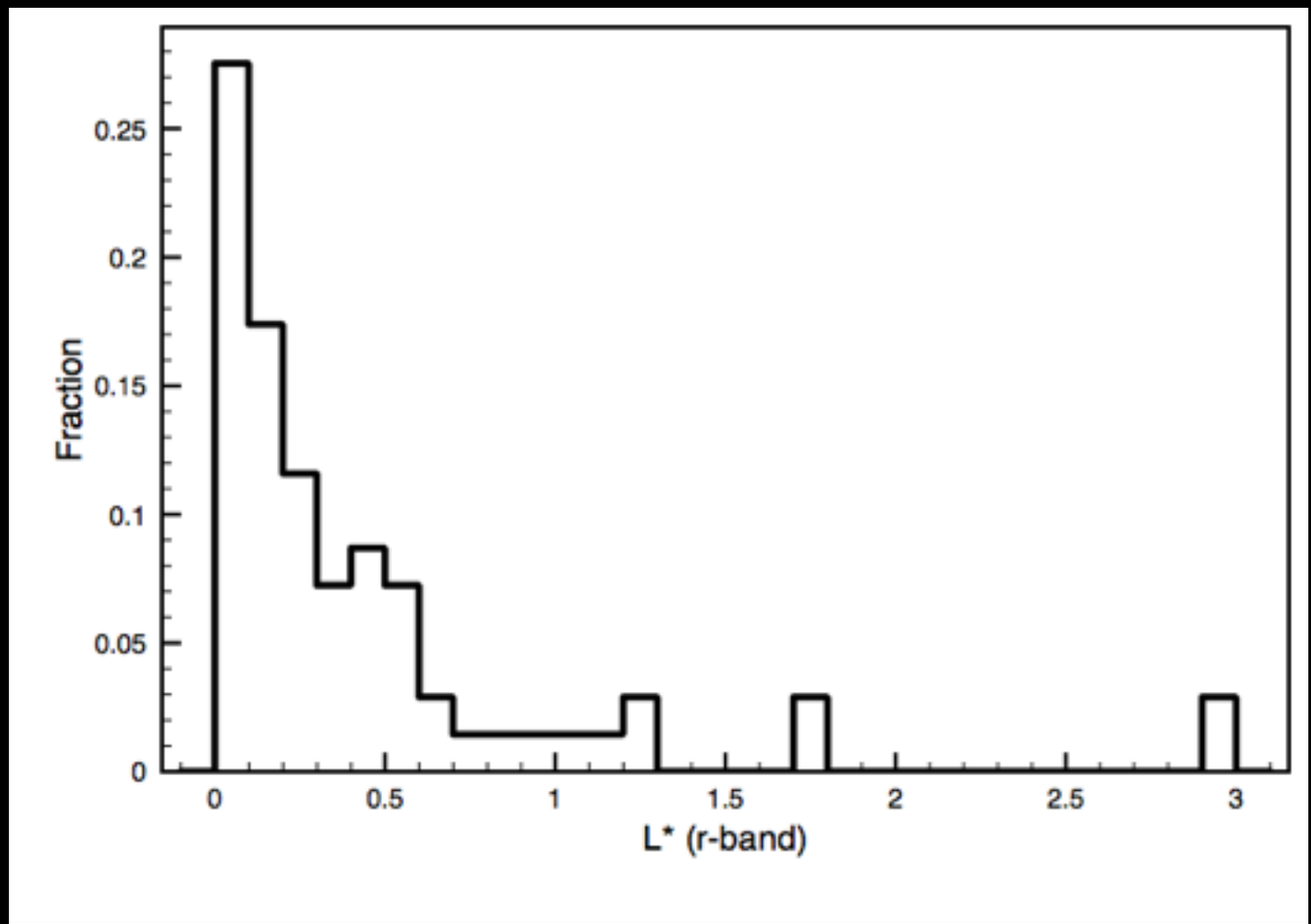

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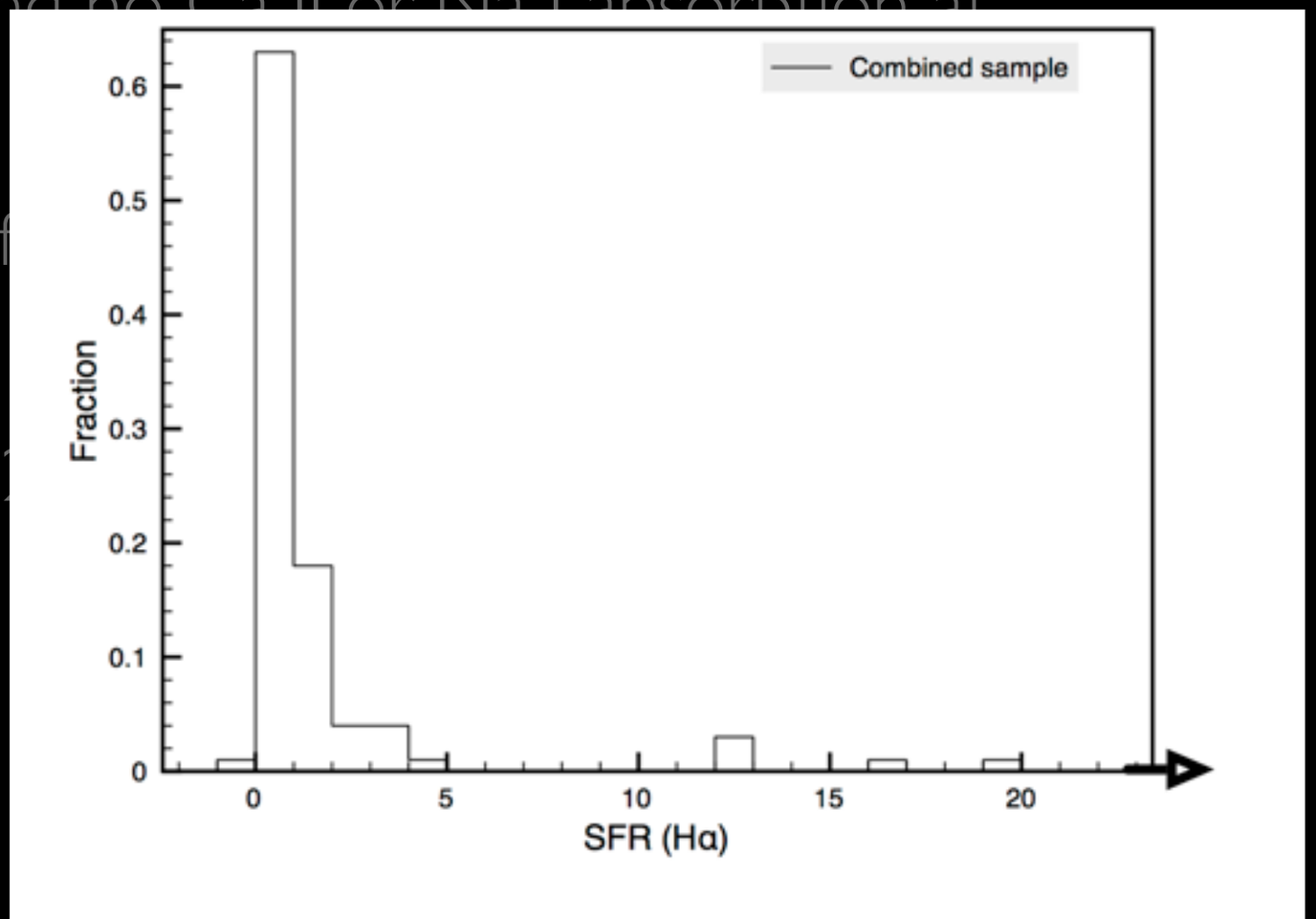
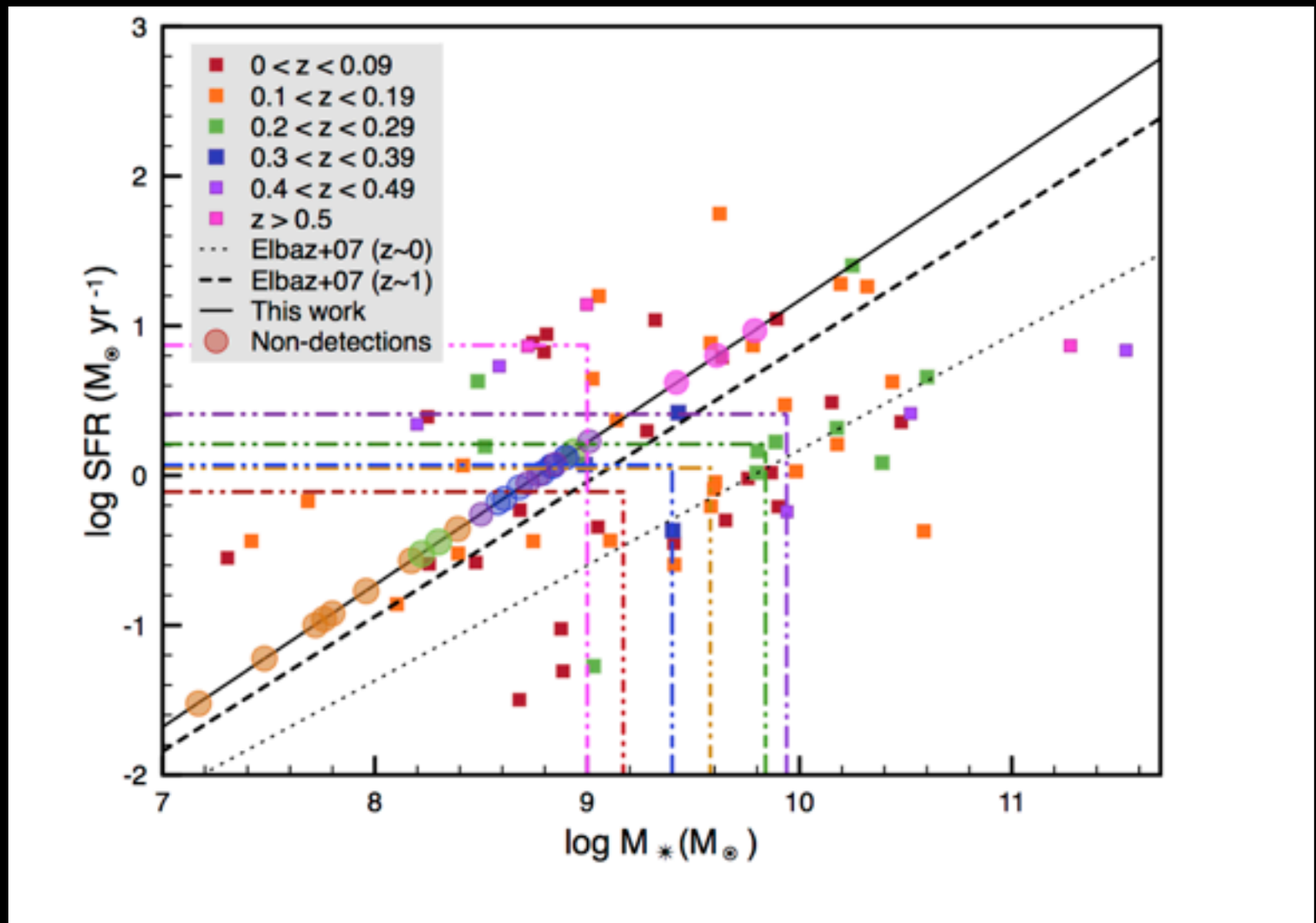


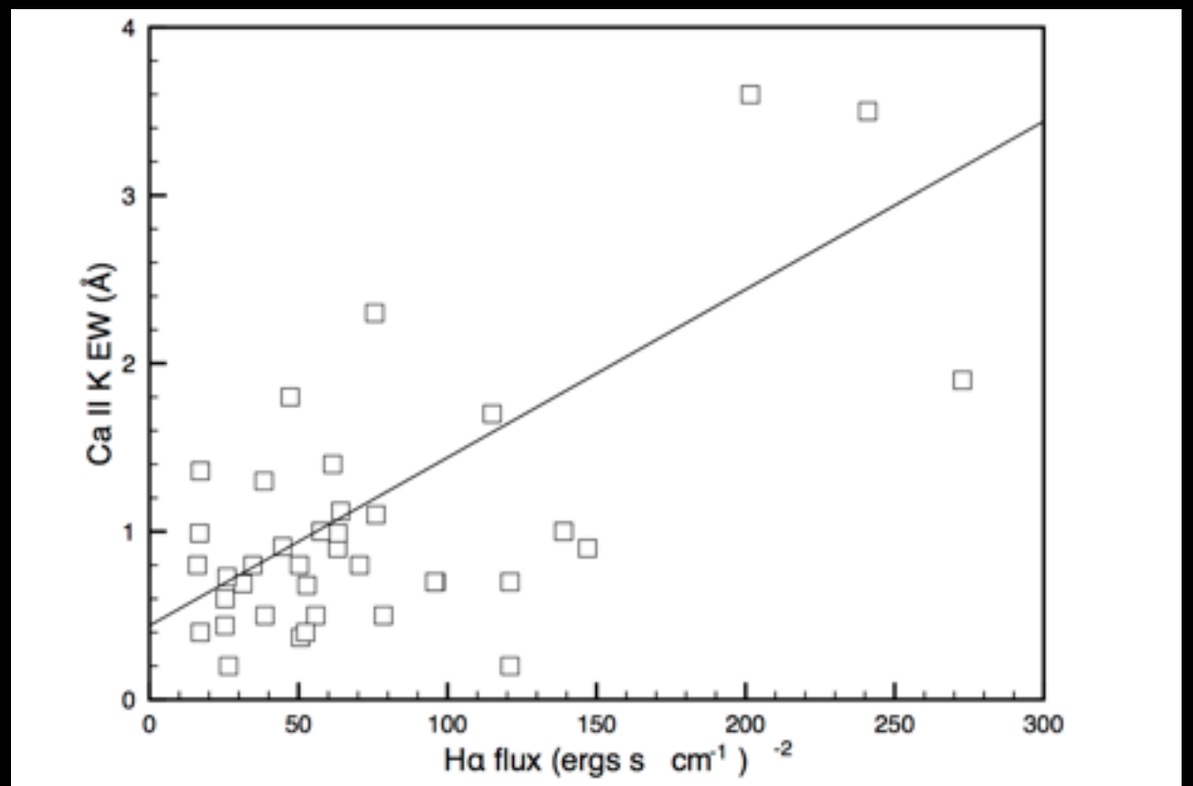
Results

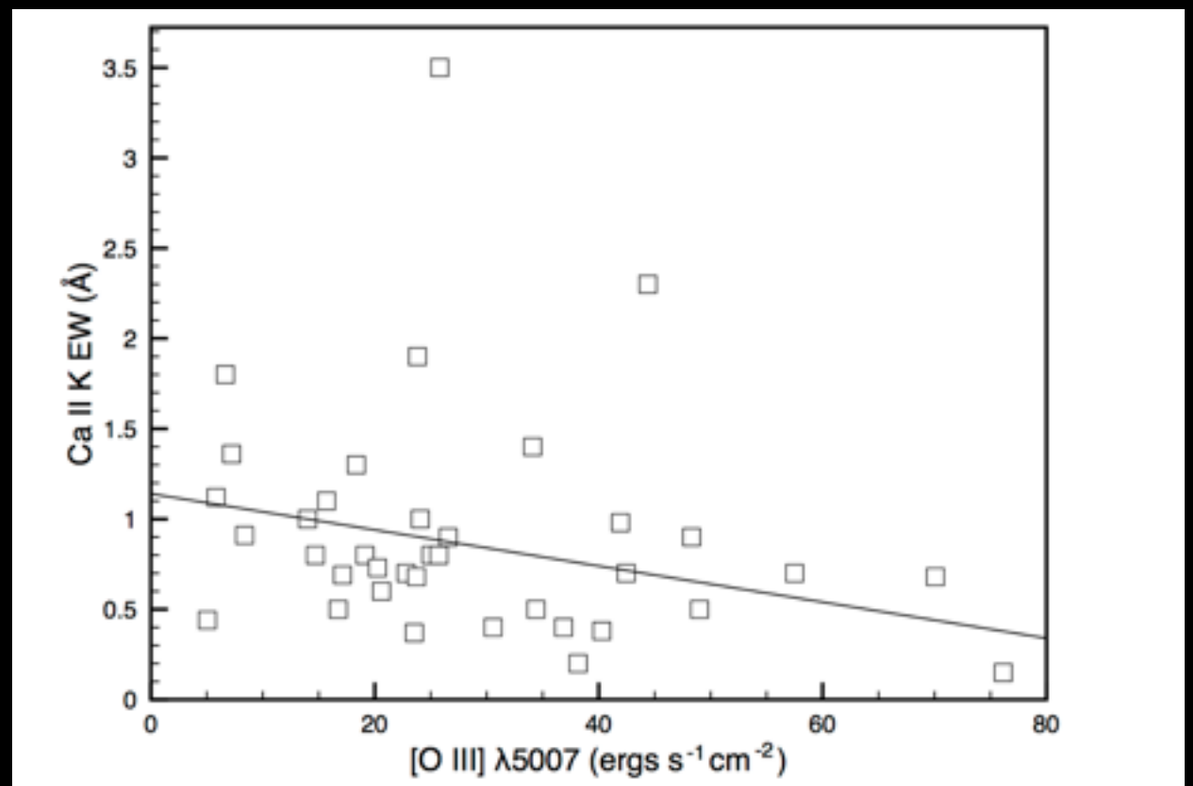
- Stellar mass estimates via HyperZ cover a wide range

- Imaging non-detections due to low surface brightness



Results





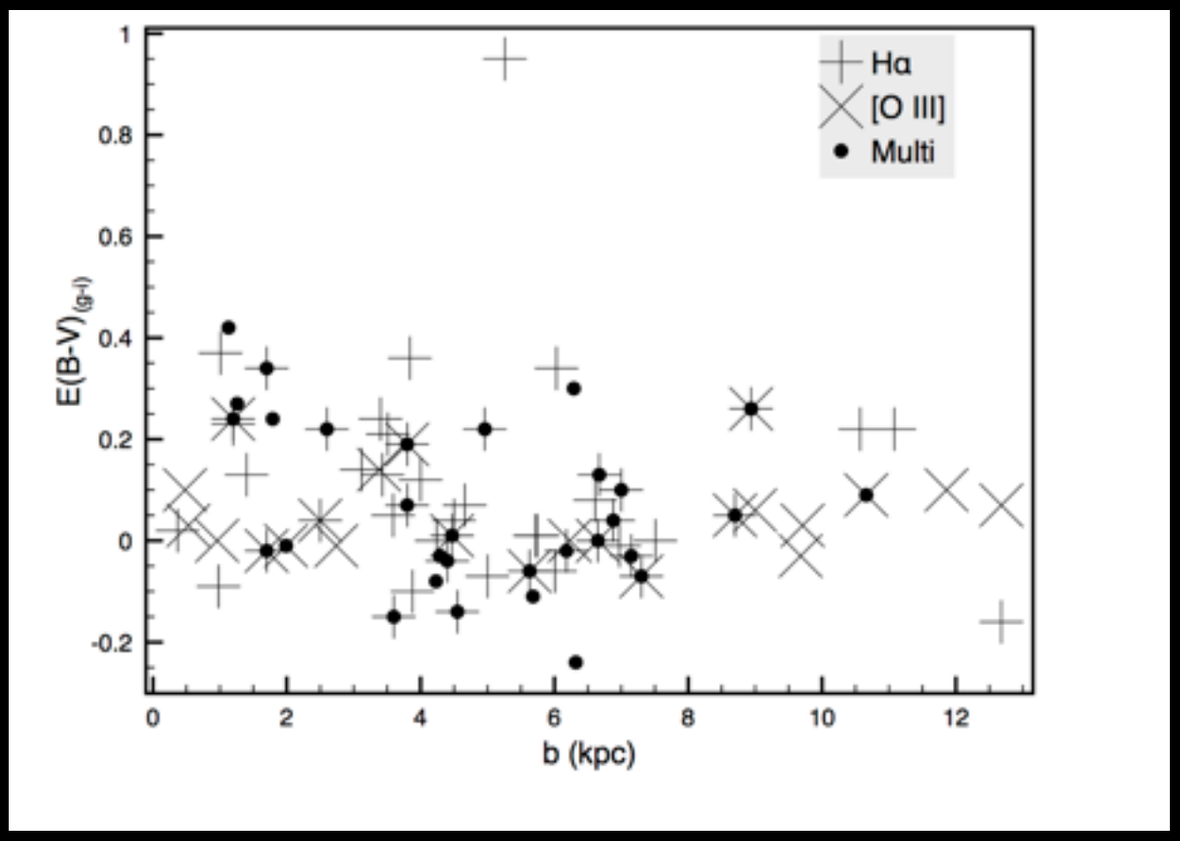
Ca II EW and Ha flux:
Ca II traces dusty environments!
H-alpha direct indicator of SF

Ca II EW and [O III] flux:
[O III] dependent on n_e , T_e; indirect indicator of SF

Results

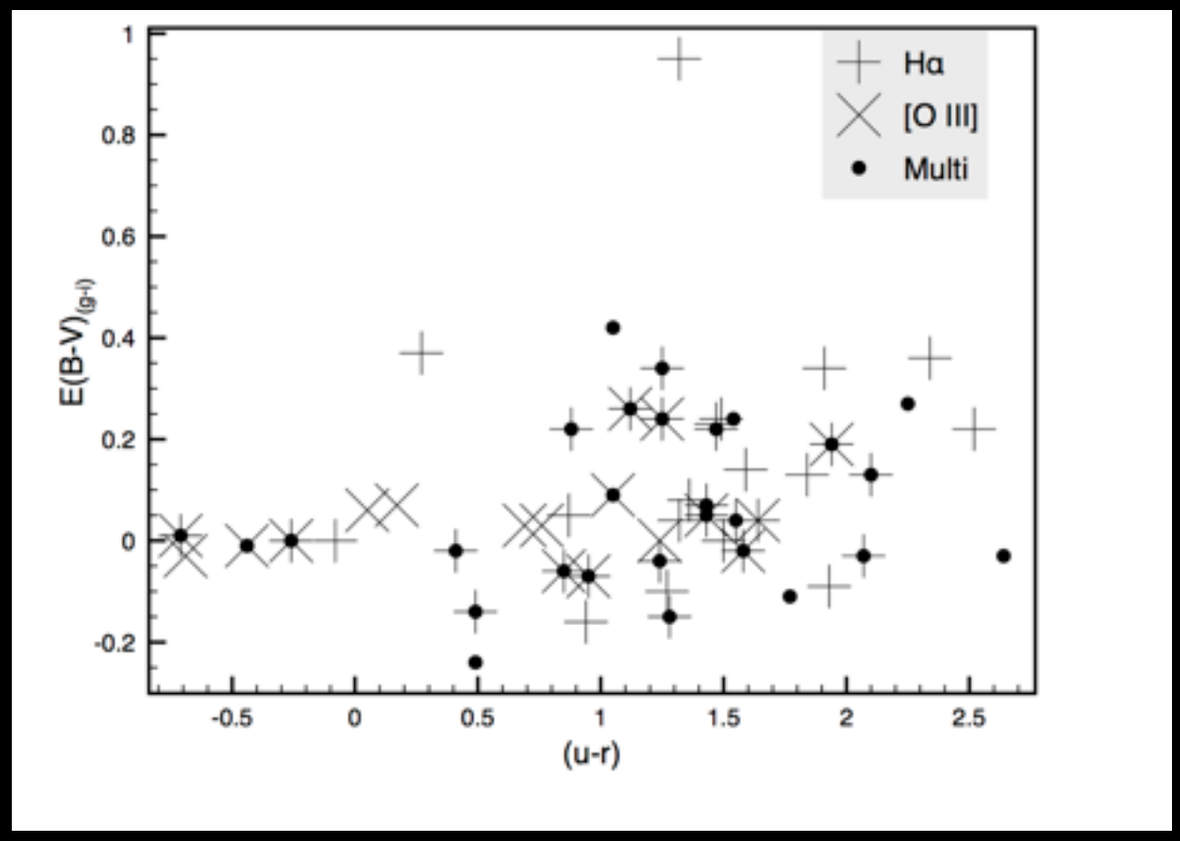
Color excess vs. impact parameter:

Higher dust content near the centers of galaxies.



Color excess vs. galaxy color:

Dustier systems are systematically more red (no surprise)



Resulting Publications

- Borthakur et al. 2010
- Noterdaeme et al. 2010
- York et al. 2012
- Srianand et al. 2013
- Straka et al. 2013
- Straka et al. 2015

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Galactic nebular lines in the fiber spectra of background QSOs: Reaching a hundred QSO-galaxy pairs with spectroscopic and photometric measurements

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ABSTRACT

We present photometric and spectroscopic measurements of 53 QSO-galaxy pairs from the Sloan Digital Sky Survey, where nebular emission lines from a $0 < z < 0.84$ foreground galaxy are detected in the fiber spectra of a background QSO, bringing the overall sample to 103 QSO-galaxy pairs detected in the SDSS. We here study the nature of these systems. Detected foreground galaxies appear at impact parameters between 0.37 kpc and 12.68 kpc. The presence of oxygen and Balmer emission lines allows us to determine the emission line metallicities for our sample, which are on average super-solar in value. Star formation rates for our sample are in the range $0.01 - 12$ $M_{\odot}\,yr^{-1}$. We utilize photometric redshift fitting techniques to estimate the M_* values of our galaxies (log M_* = 7.34 - 11.54), and extrapolate this relationship to those galaxies with no imaging detections. Where available, we measure the absorption features present in the QSO spectrum due to the foreground galaxy and the relationships between their rest equivalent widths. We report an anti-correlation between impact parameter and $E(B\text{-}V)_{(g-i)}$, as well as a correlation between galaxy color $(u-r)$ and $E(B\text{-}V)_{(g-i)}$. We find that our sample is one of late-type, star forming galaxies comparable to field galaxies in a similar redshift range, providing important clues to better understand absorption systems. These galaxies represent a sample of typical galaxies in the local Universe for which abundances, extinction, morphology, and absorption properties may be measured using background QSOs with great potential for follow-up observations.

Key words: cosmology:observations — galaxies:evolution — galaxies:photometry — quasars:absorption lines

Summary

- GOTOQs selected by emission are primarily isolated late-type galaxies with low SFR
- High reddening indicating the presence of dust
- Correlations between b, (u-r) and $E(B-V)_{(g-i)}$; Ca II EW and H-alpha, [O III]
- No correlations between Ca II EW and b, $E(B-V)_{(g-i)}$
- Future work: refer to the list of questions! (+HST)