# Optically Thick Gas and MUSE

Lorrie Straka
EWASS 2017 - Prague

# Optically Thick Gas: GTO Programs

Hubble Deep Field - South (PI: Bacon)

MUSE-Wide (PI: Wisotzki)

QSO Nebulae (PI: Cantalupo)

Ly-alpha Fluorescence (Marino+17)

MUSE QuBES (PI: Schaye)

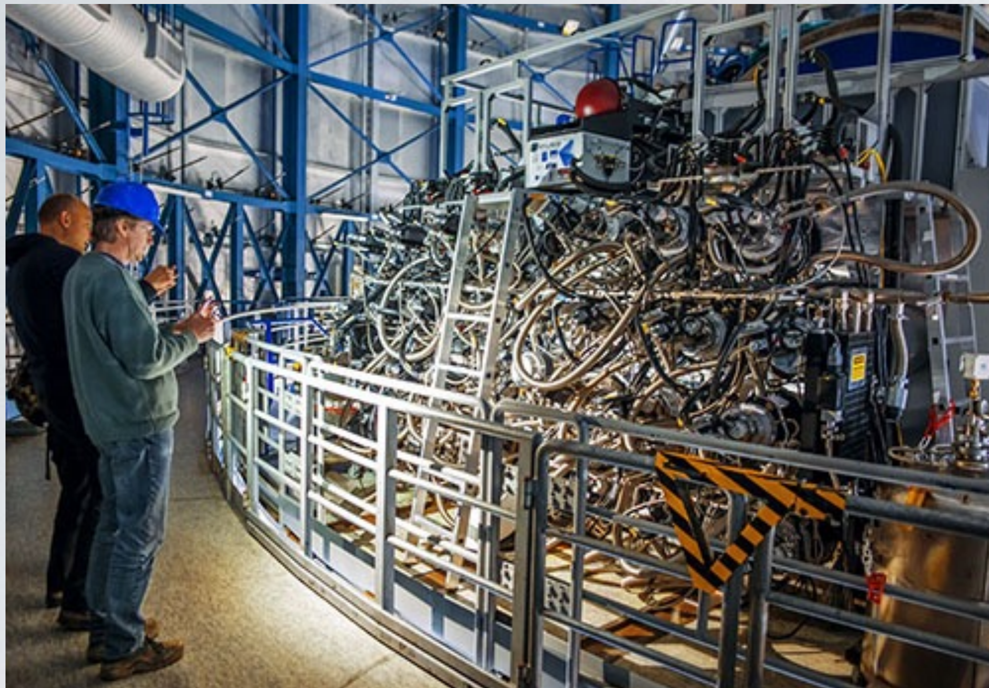
………

to name only a FEW!

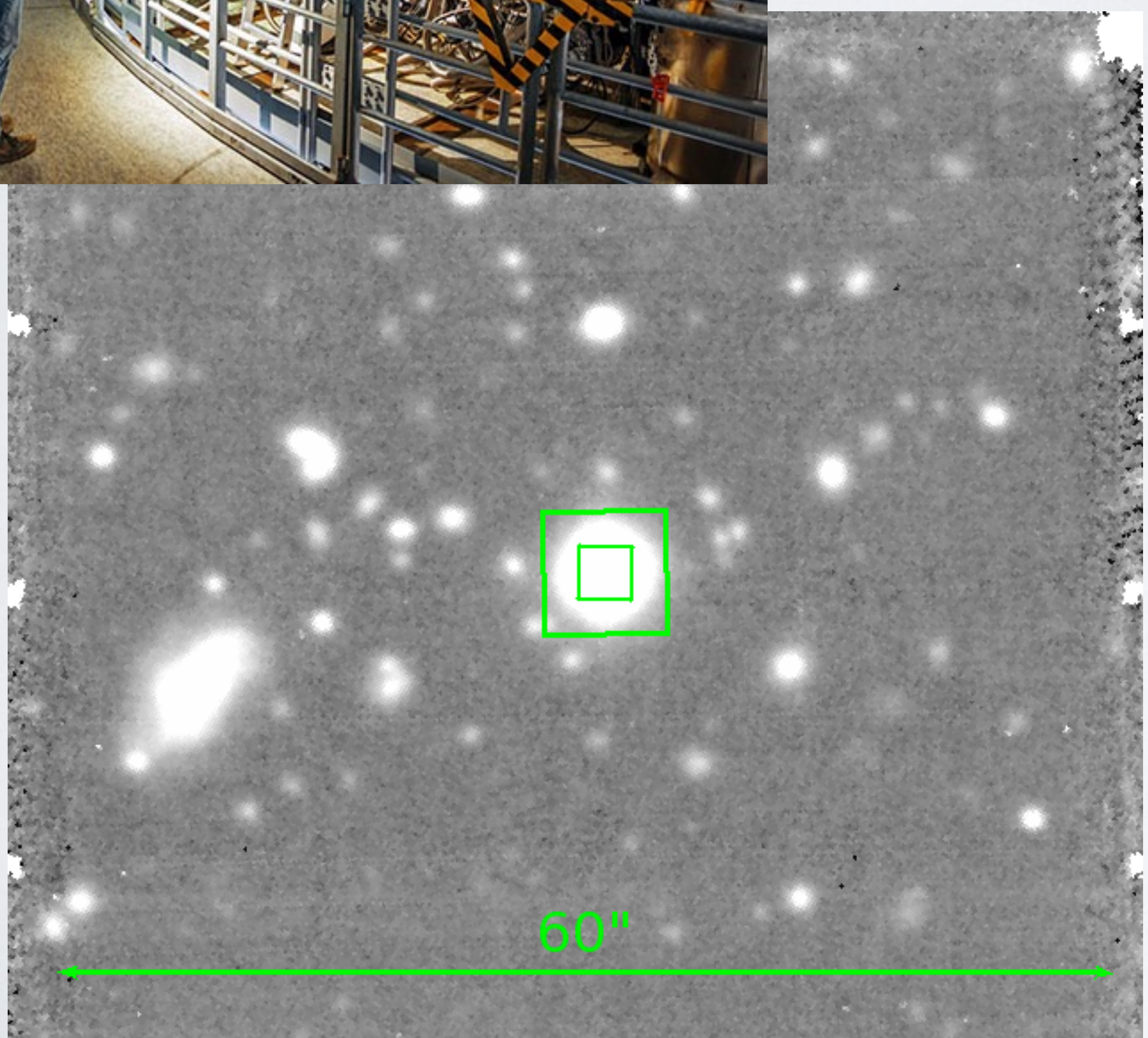
# Absorption Host Galaxy Detection


- Spectroscopic follow-up of these yields fewer than 4 galaxies per unit redshift within 250 kpc of the QSO (LBGs; Steidel+10)
  - Absorption: 30 metal absorber per unit redshift!

# MUSE

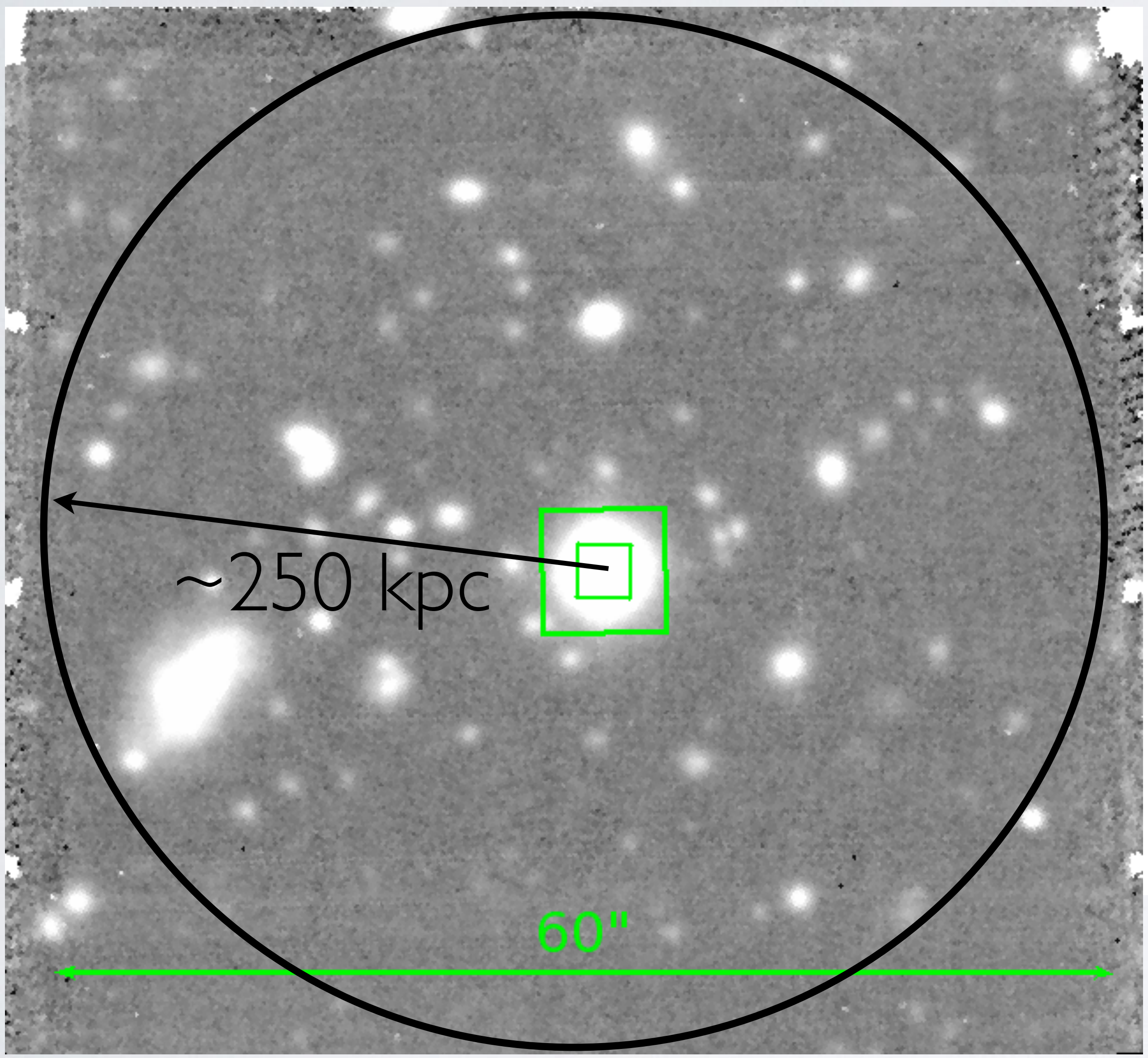


Bacon+10




- Real Estate: MUSE field of view probes out to ~250 kpc (1'x1')!
- Plate scale: 0.2''/pixel
- Wavelength coverage: 4750A - 9300A
  - Ly-alpha: 3<z<6.5
  - [O II]: 0.27<z<1.5
- Flux limit in 30 hours: $\lesssim$ 1e-19 erg/s/cm$^2$/arcsec$^2$

# MUSE

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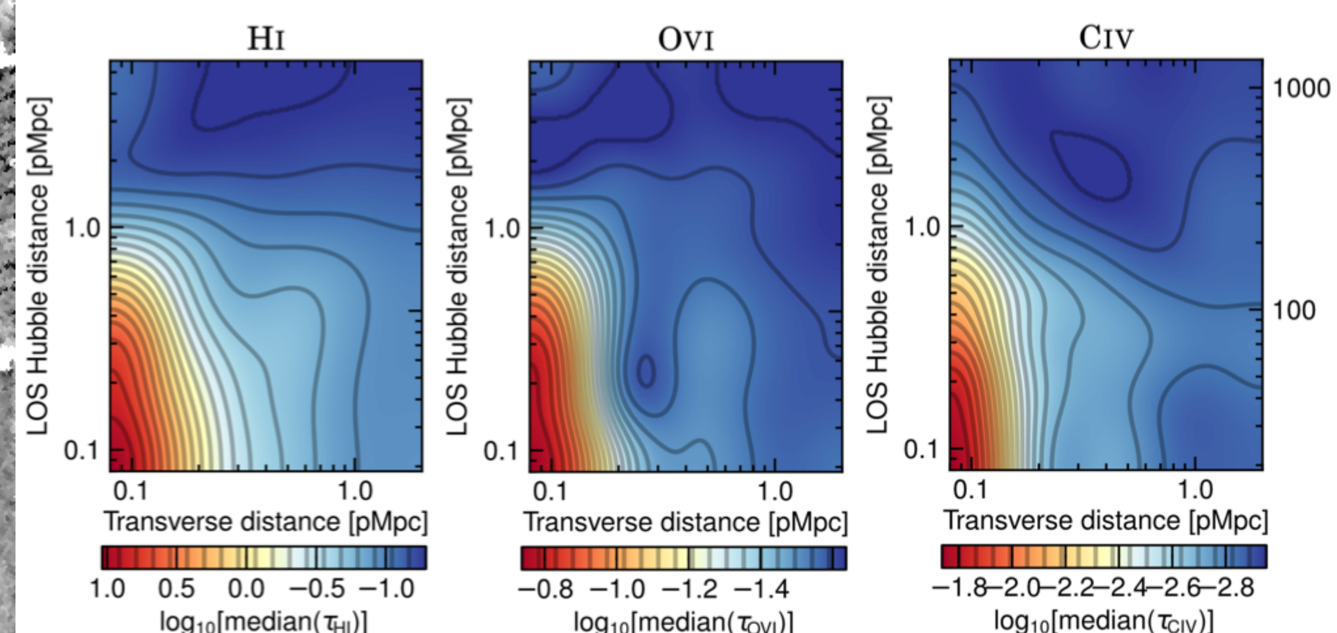
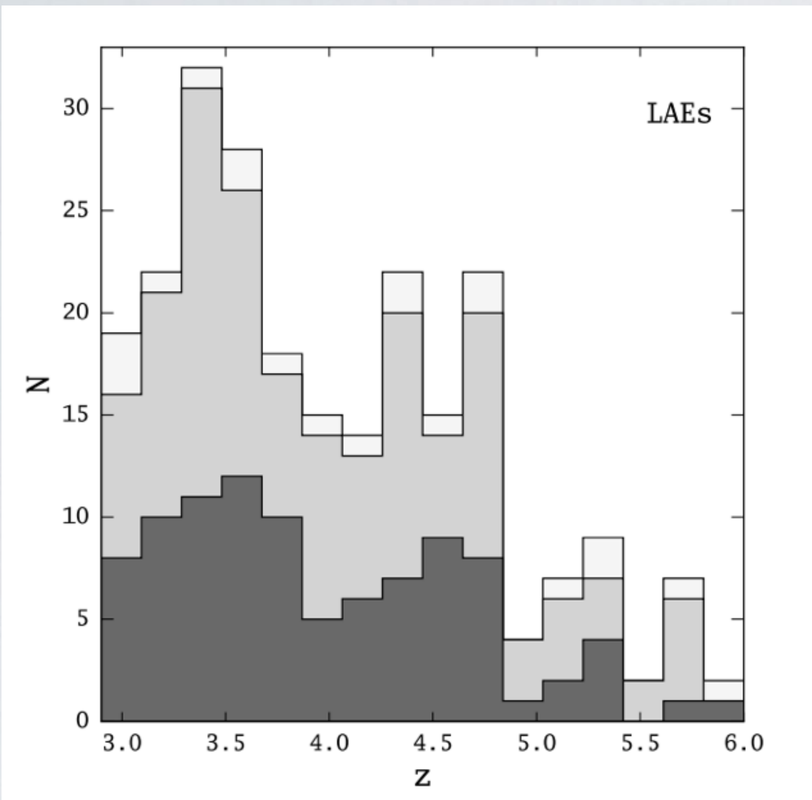
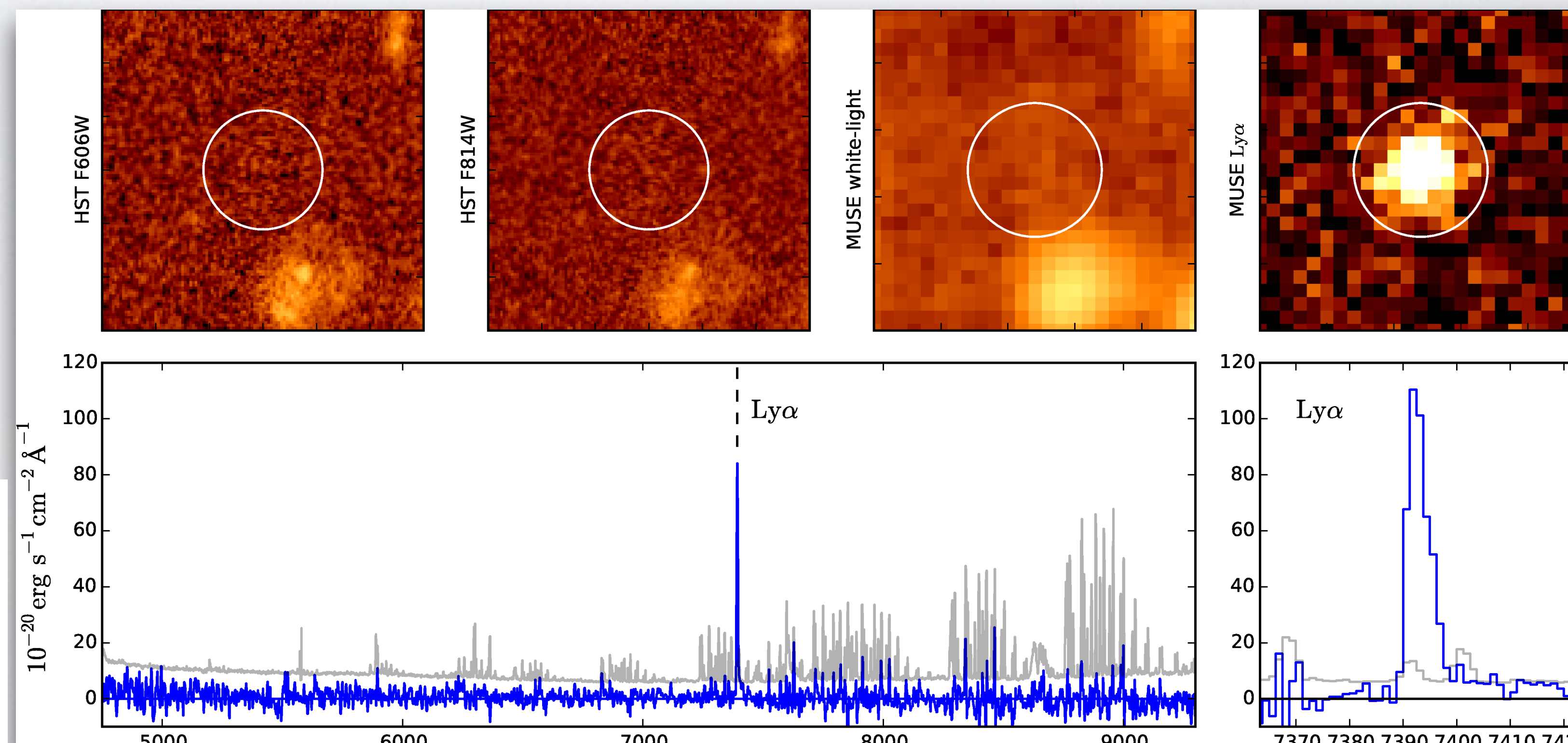


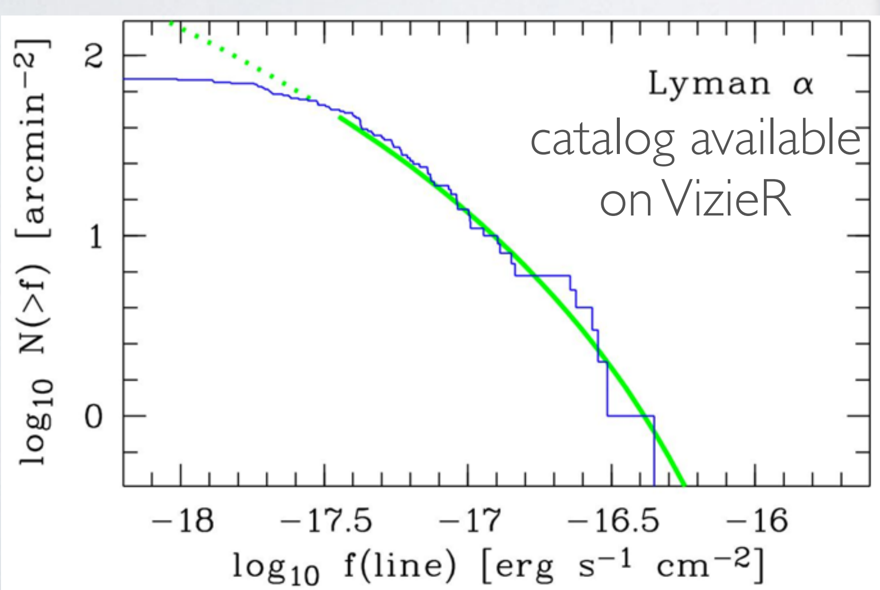

Turner+14

# Detection of Ly-alpha Emitters




24' x 1' MUSE Wide
1 hour, Herenz+17
PI: Wisotzki



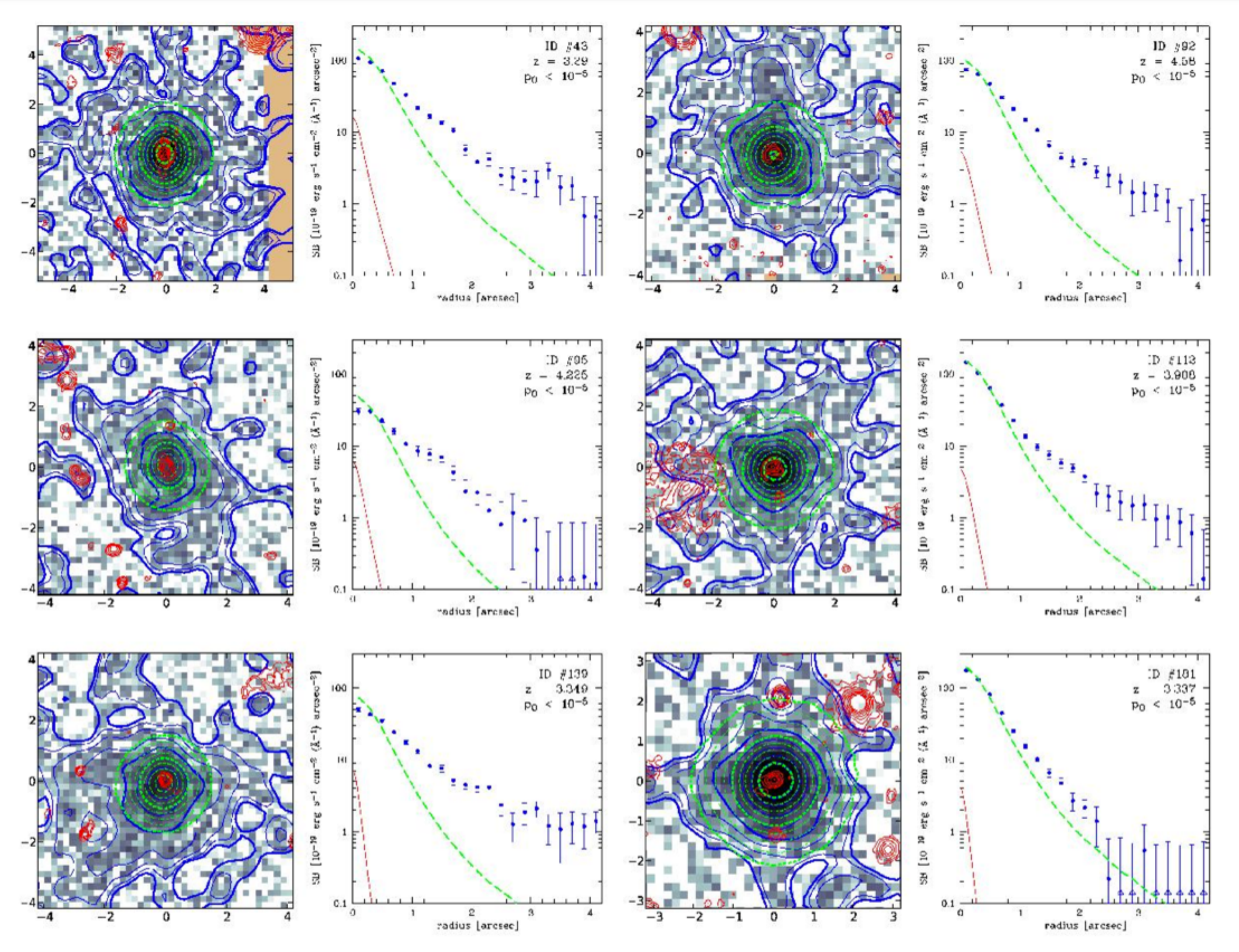




catalog available
on VizieR

MUSE 3D View of the HDF-S
Bacon+15
27 hours deep!

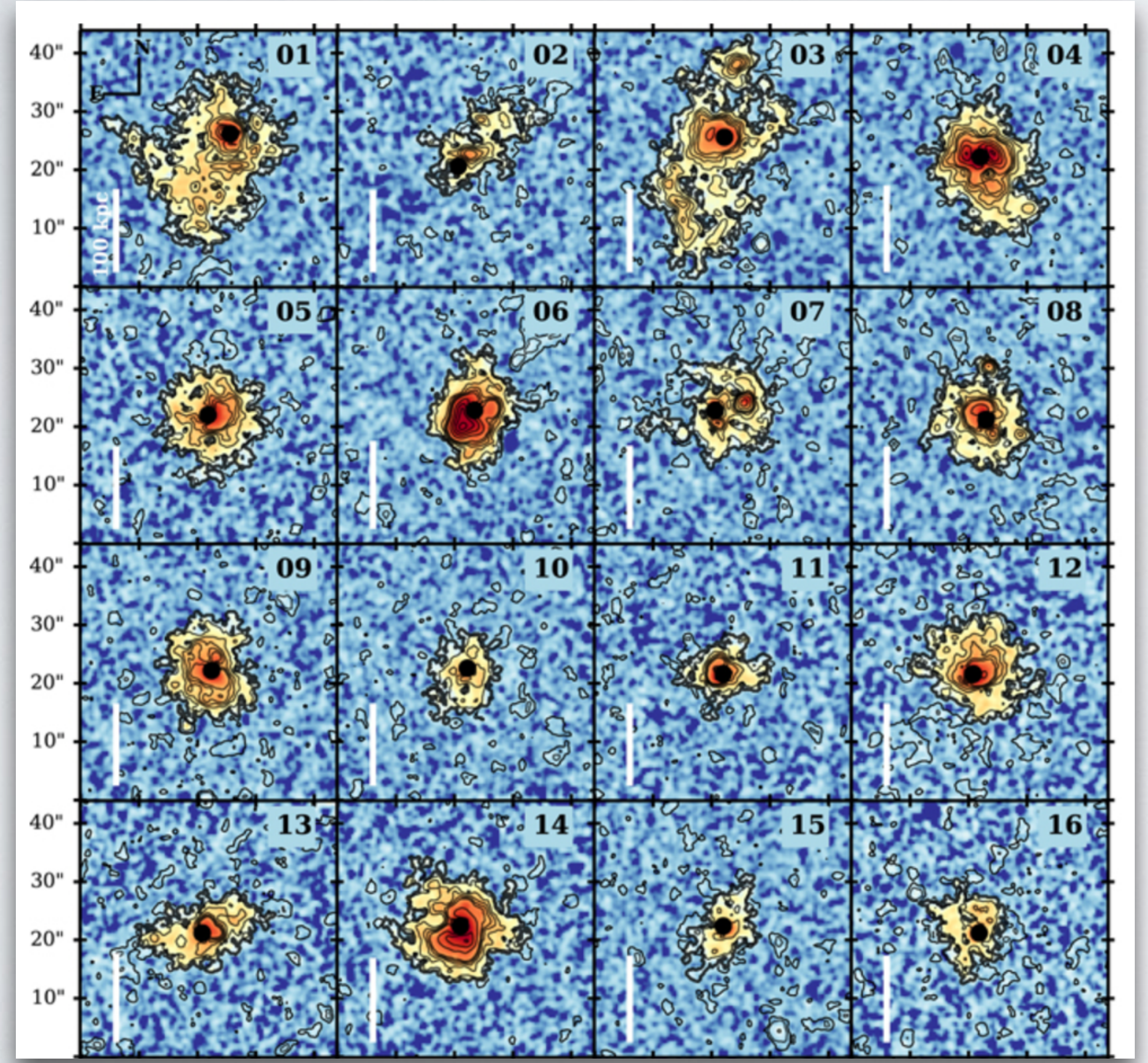
# Ly-alpha Halos

- Direct probe of neutral gas in the CGM of low-mass galaxies at z>3
- Ly-a halos are ubiquitous around even low-mass ($10^8$-$10^9$ $M_{sol}$) galaxies
- Extent is 5-15 times that of the UV continuum, scale lengths 1-7 pkpc
- Consistent with stacking, e.g. Steidel+11, Momose+14, and consistent with ABSORPTION, e.g. Chen+01, Turner+14




Extended Lyman-alpha Halos
in the HDF-S
Wisotzki+16

# Ly-Alpha Fluorescence

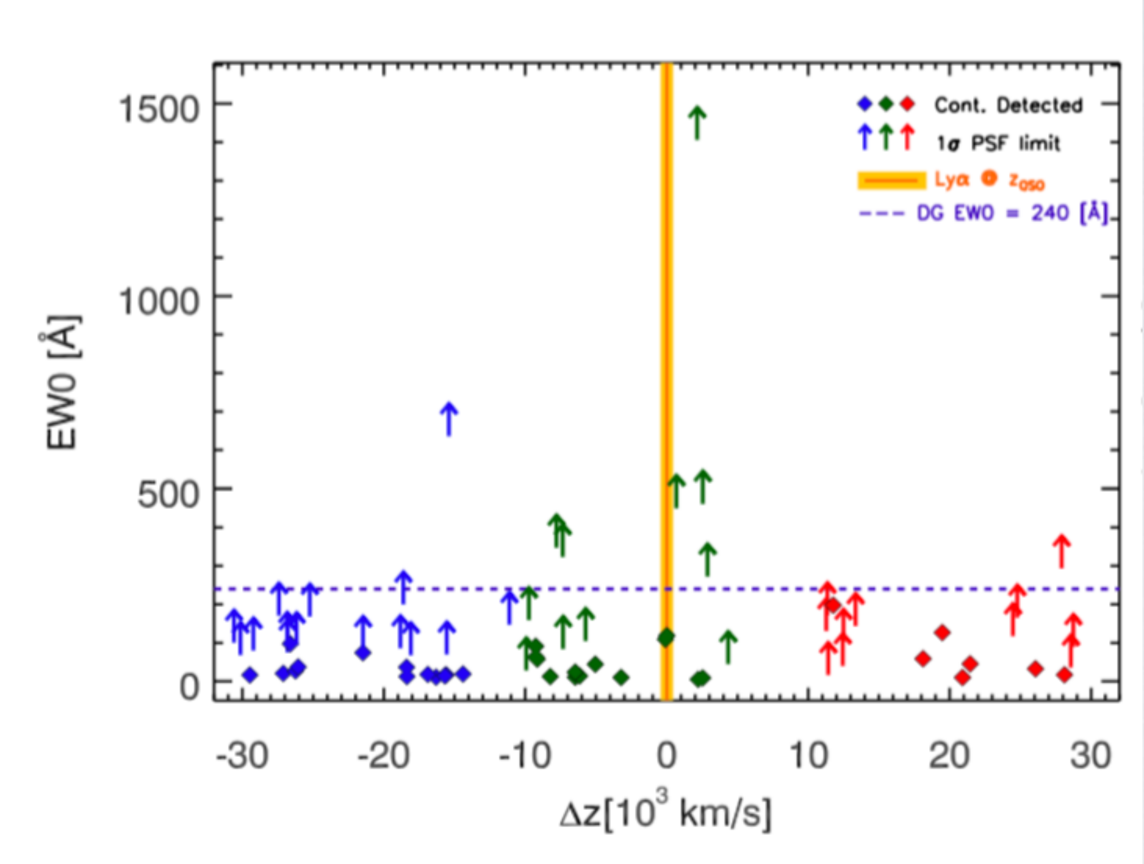



Borisova+16, Marino+ in prep.

- Fluorescently illuminated Ly-alpha emission surrounds 100% of QSOs for hundreds of pkpc
- Cold gas (<$10^4$ K) extends 50 - 300 kpc, independent of radio loud or radio quiet

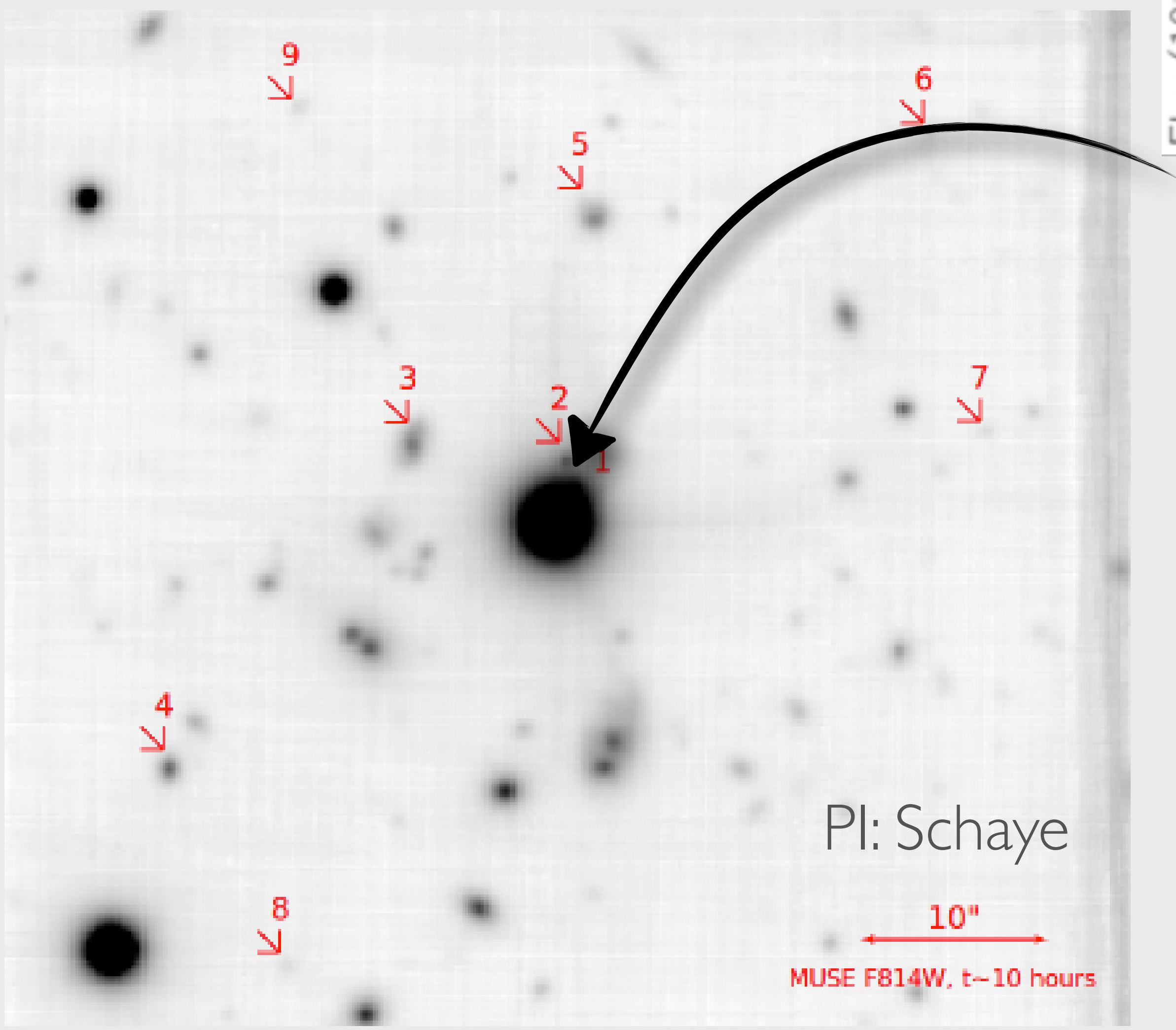
# Ly-Alpha Fluorescence

- Dark galaxies — Marino+17, submitted
- EW0 > 240 A … no continuum!
- SFE < 2 x $10^{-11}$ $yr^{-1}$
- Representative of optically thick, pristine galaxies otherwise undetectable outside fluorescent zone

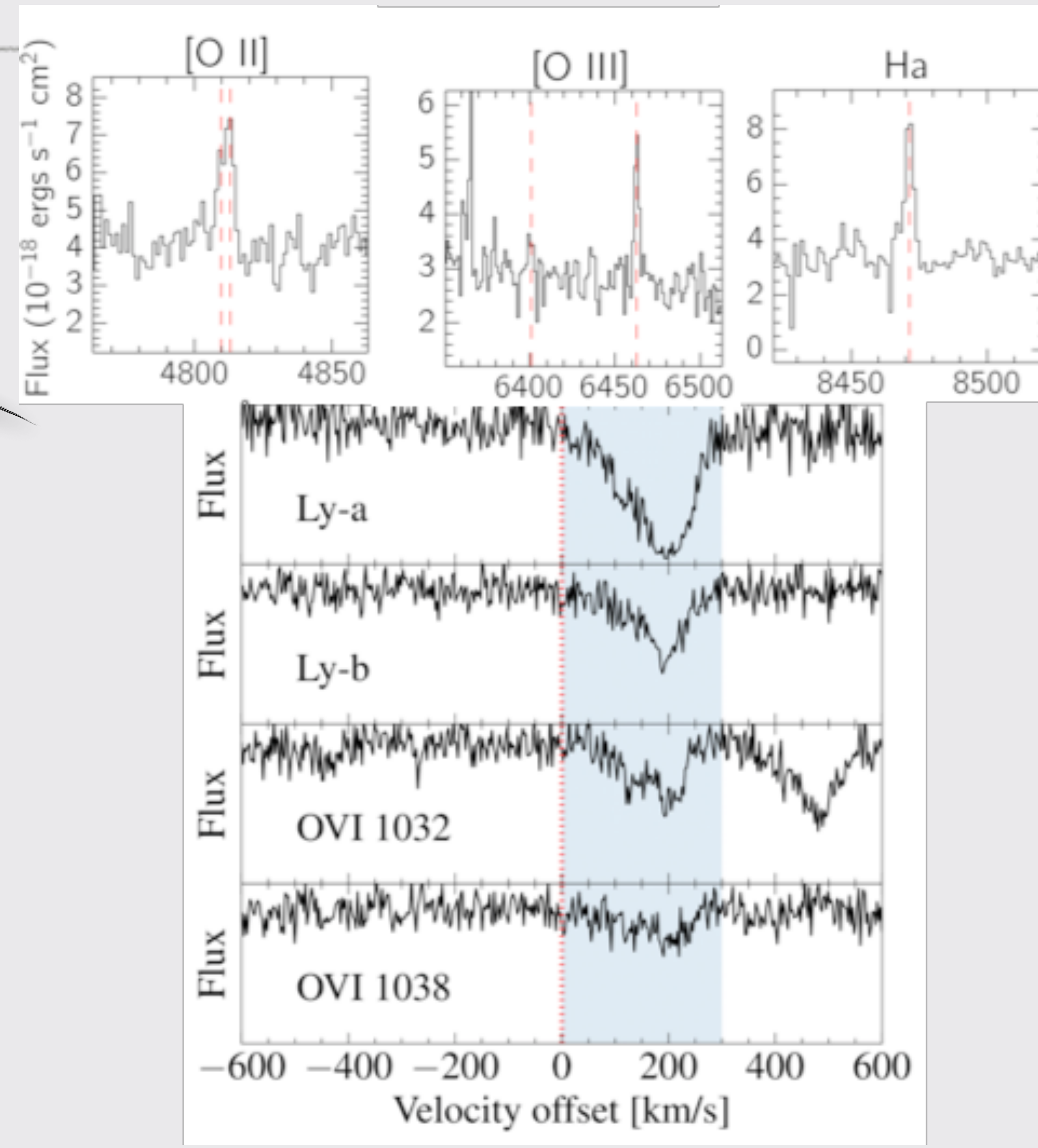


# MUSE QuBES:
# MUSE Quasar Blind Emitter Survey

Joop Schaye, Lorrie Straka, Marijke Segers,
Martin Wendt, Sowgat Muzahid, Sean Johnson,
+ MUSE GTO




Quasar field: MUSE galaxies




Quasar absorption spectrum

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For the first time, the number density of detected emitters in a field will allow us to match most absorber systems to their host galaxies instead of a sporadic few.

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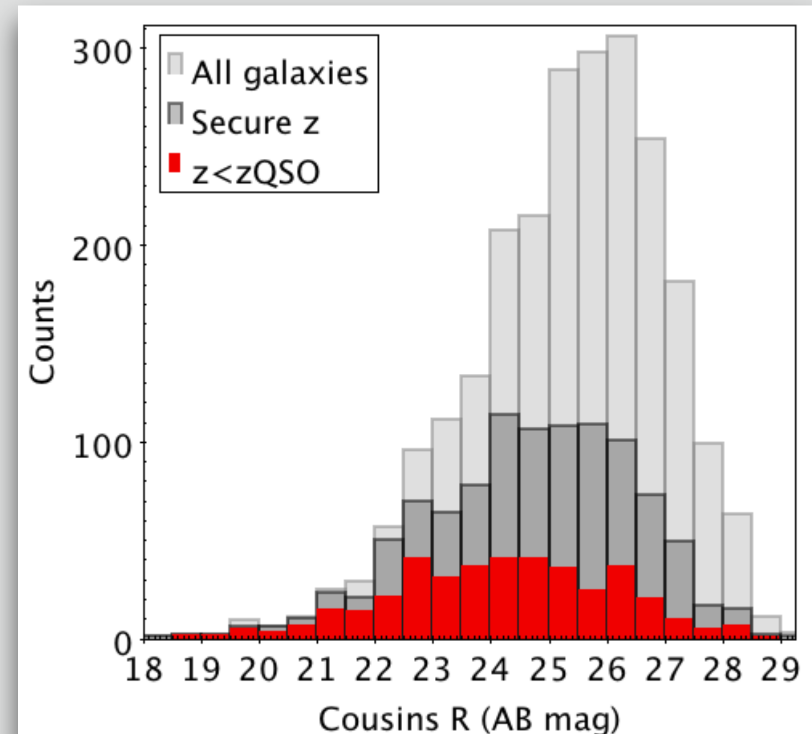
SS14.6 Martin Wendt
"The CGM traced in absorber-emitter pairs in MUSE QuBES"

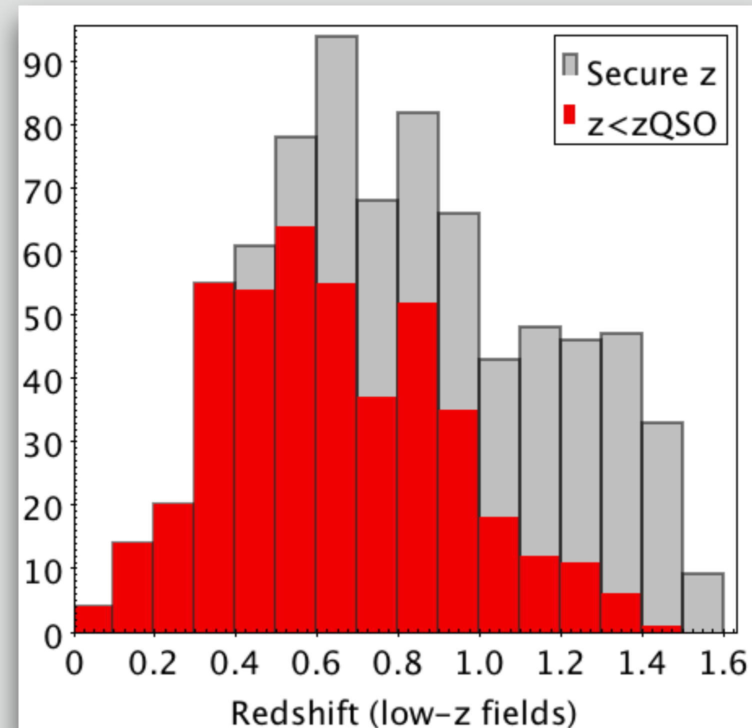
# Sample

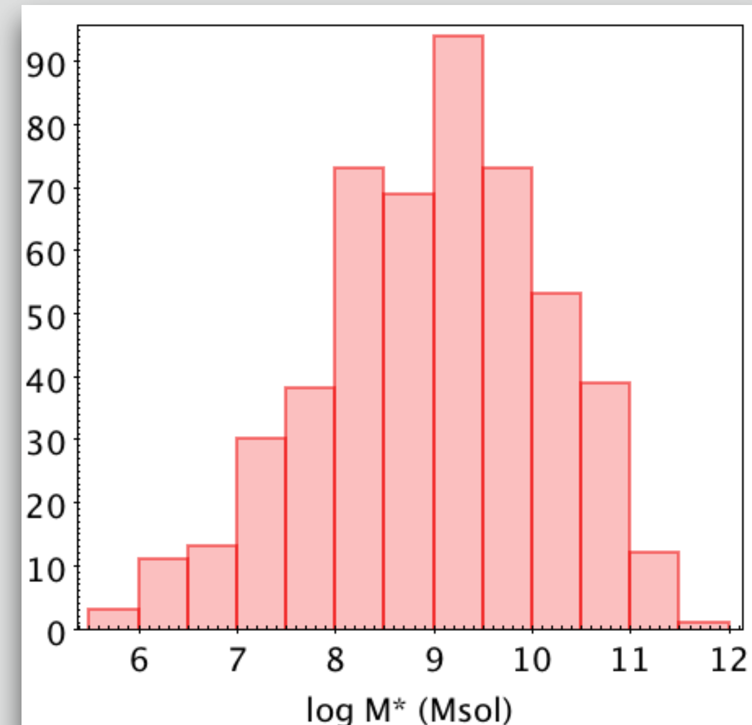
- low redshift sample:
  - 16 z=0.45 - 1.5 QSOs centered in the MUSE FOV
  - HST/COS archival QSO spectra (S/N>10)

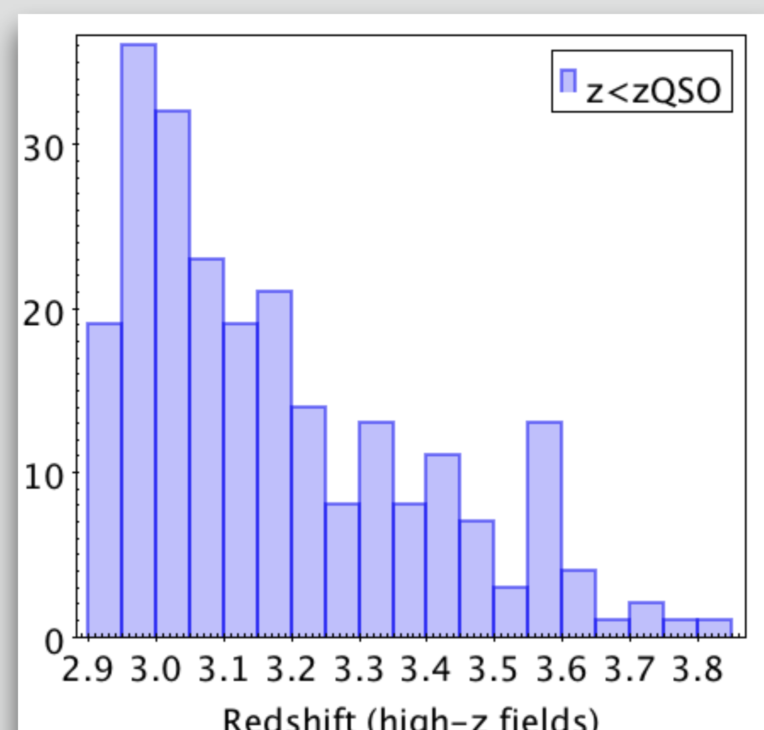
- high redshift sample:
  - 8 z=3.5 - 4.0 QSOs centered in the MUSE FOV
  - VLT/UVES archival+new QSO spectra

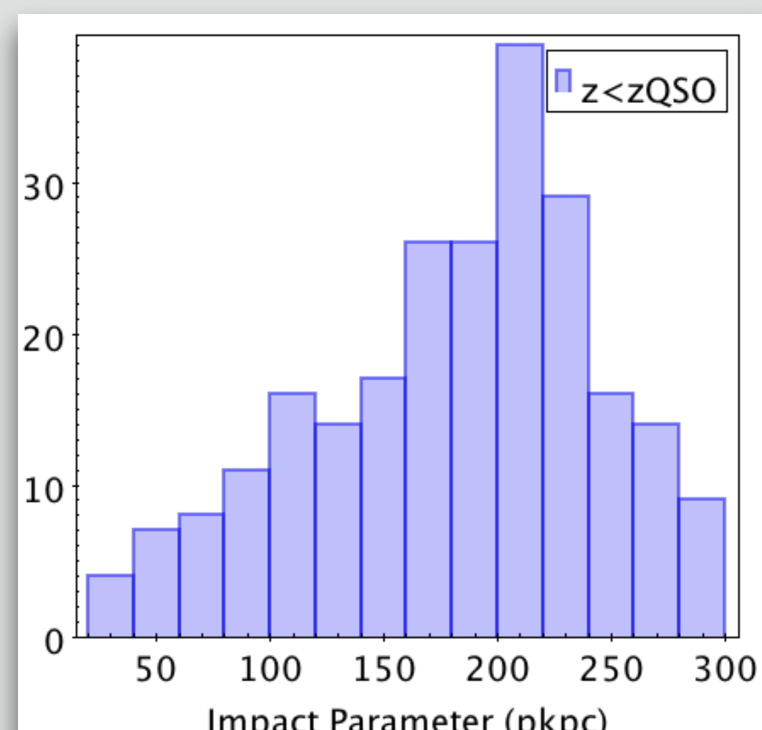
# Galaxy Catalogs



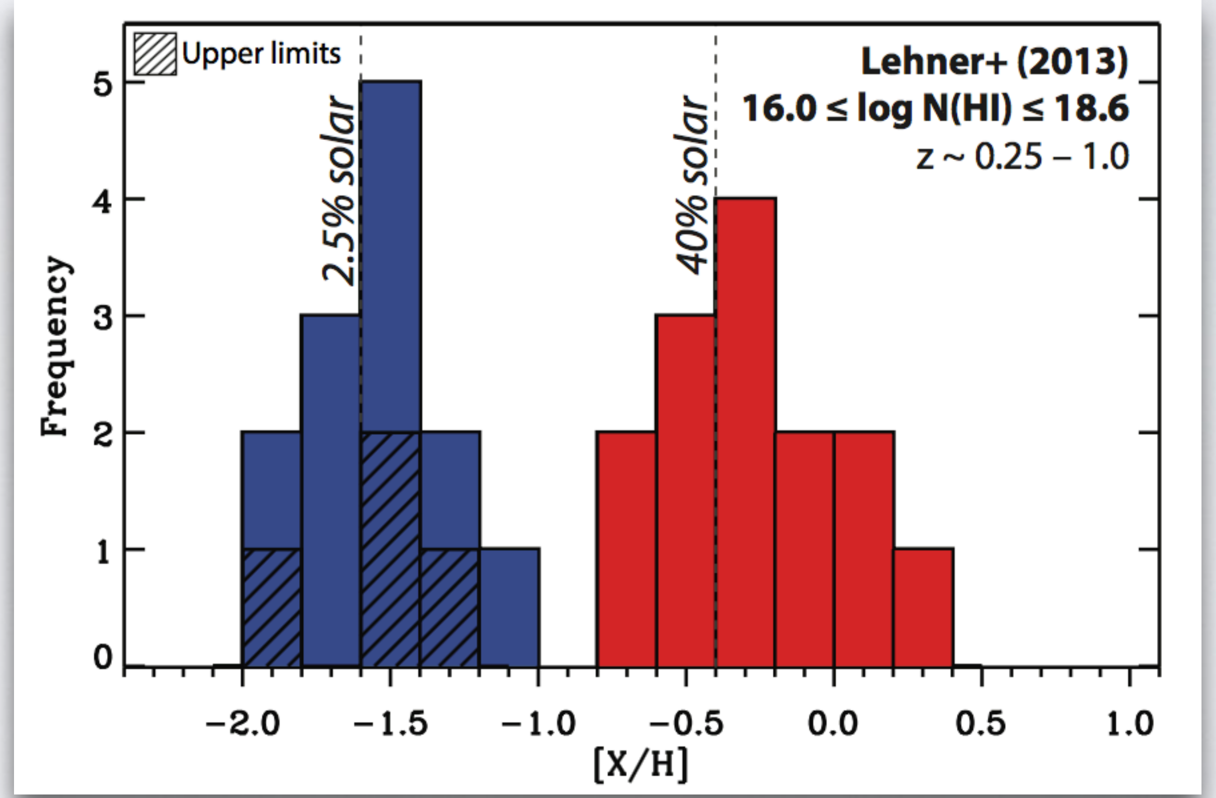



# Detecting LLS Host Galaxies

- Bimodality in metallicity for LLSs
- BASIC: Bimodal Absorption System Imaging Campaign
  - 8/30 LLS observed with MUSE



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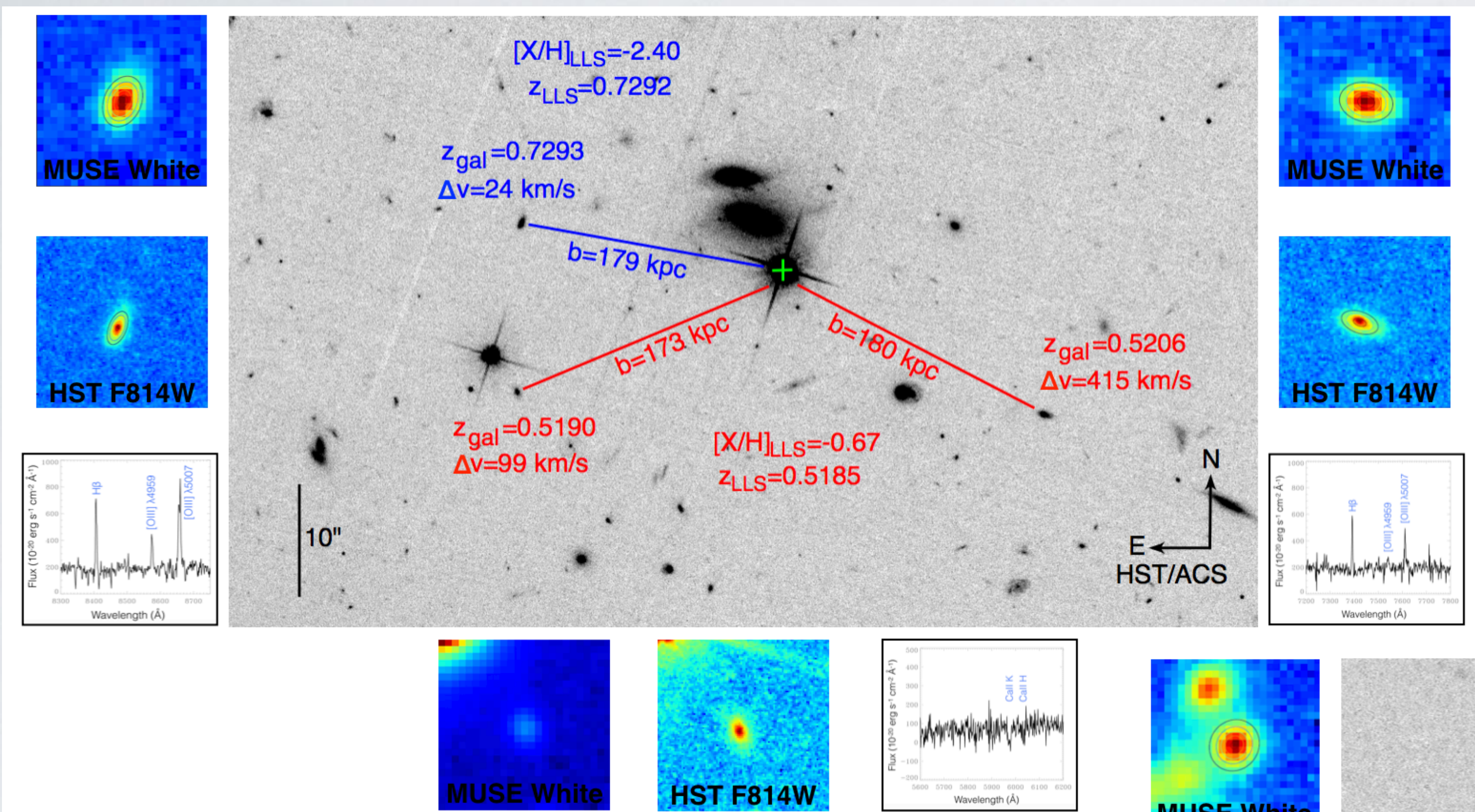
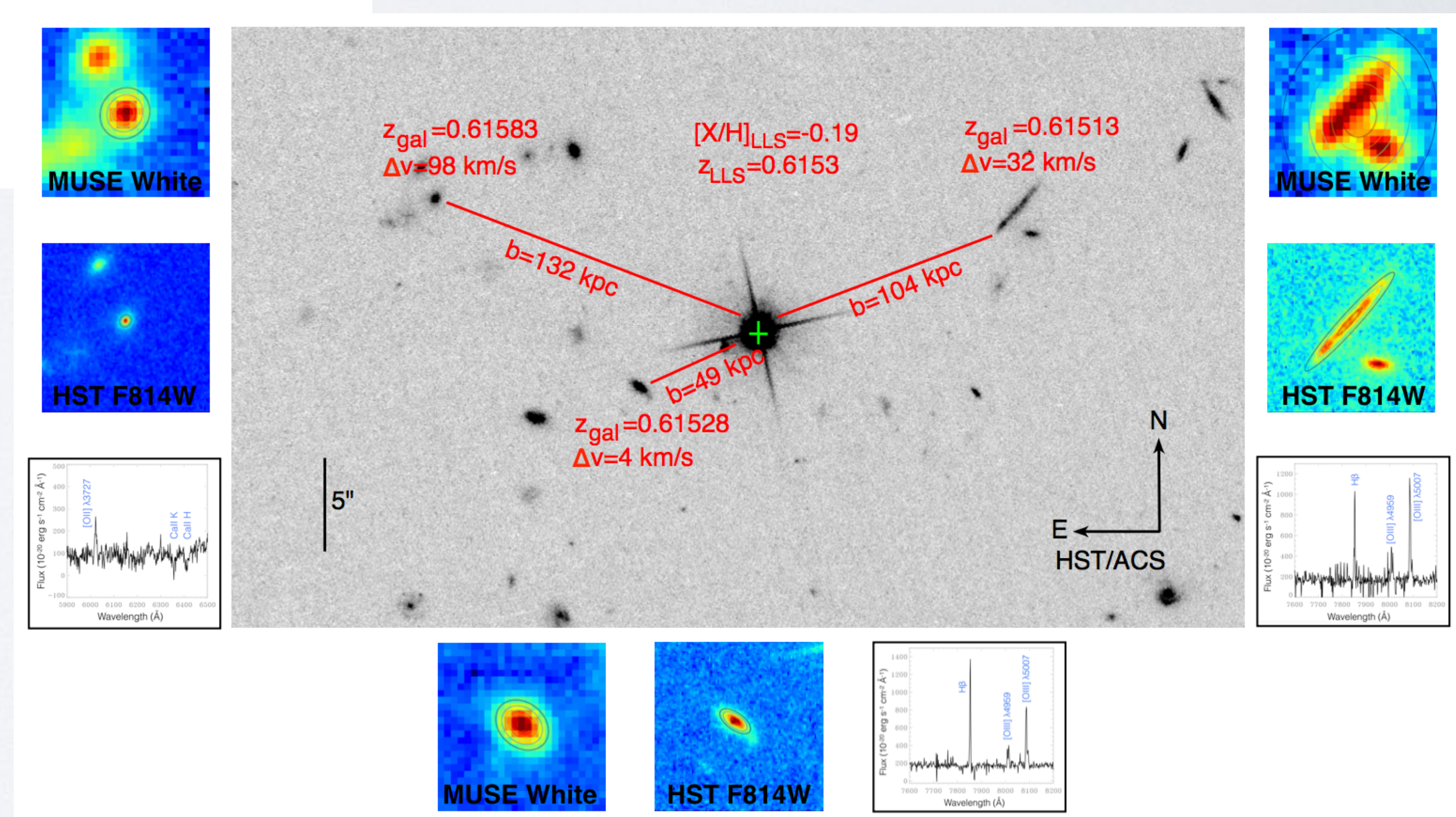


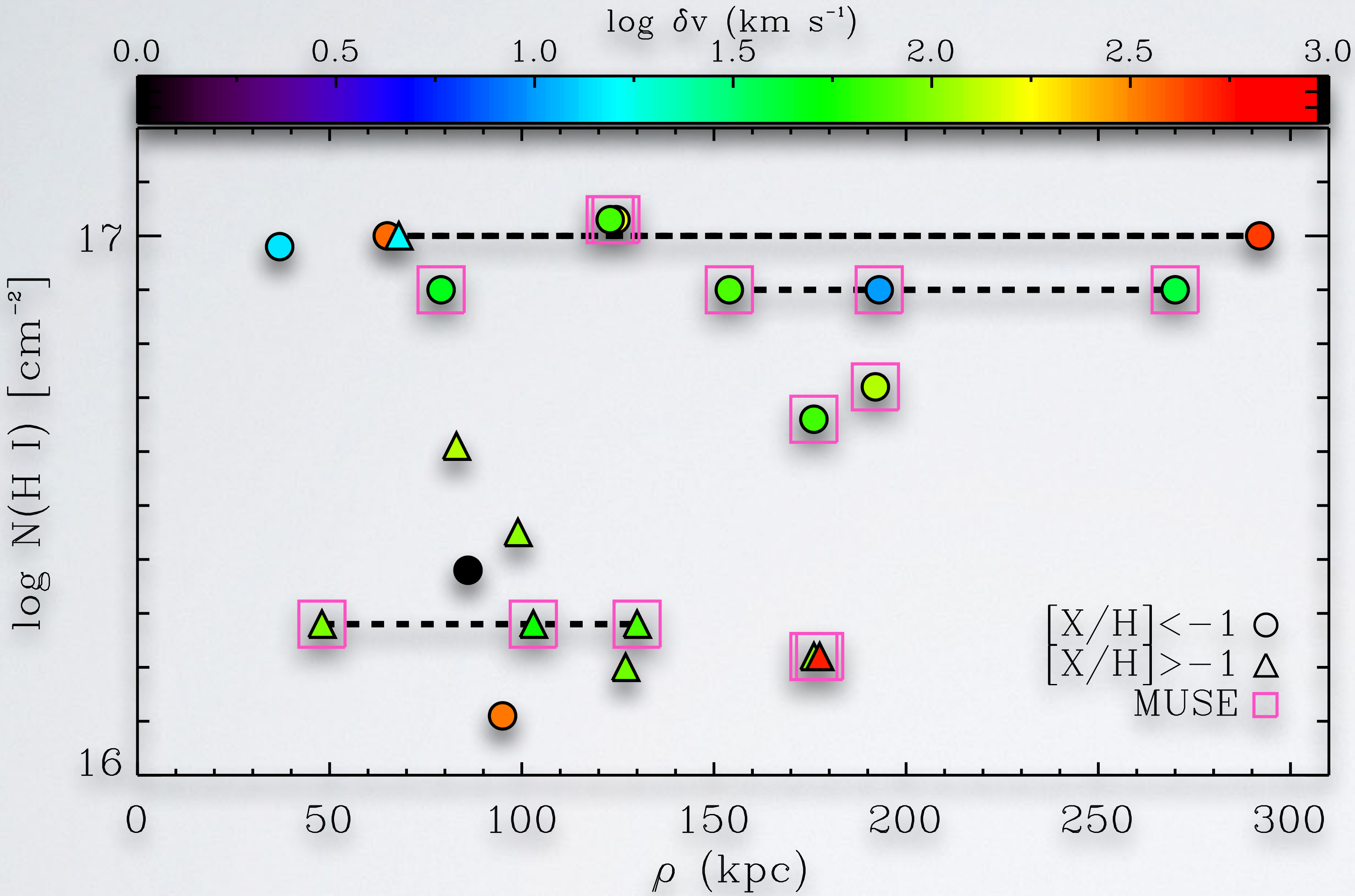

Example: Two fields, three LLS

Michelle Berg+ in prep.




Are the LLS probing a filament?

# Detecting LLS Host Galaxies

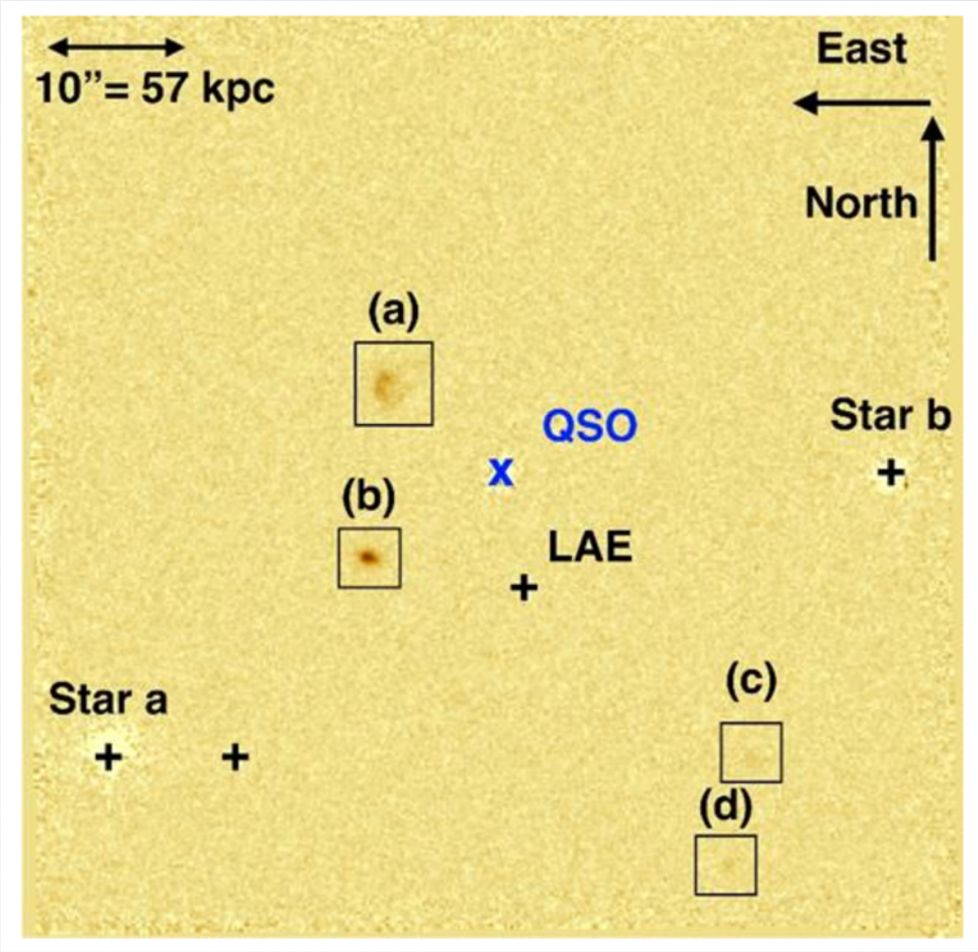



Michelle Berg+ in prep.

Arrangements of multiple galaxies happen in both branches of the metallicity bimodality!

# LLS Host Galaxy Environments

- log N(HI) = 19.5
- [X/H] = -0.54 +/- 0.18
- FOUR galaxies!
- How does "number of neighbors" affect the metallicity?
    - (e.g., Stocke+17, Pointon +17, Wakker+05…)




Peroux+16

Hadi Rahmani @ 16:45!

# Summary

- IFS studies push the detection limits of optically thick gas in emission to previously unheard of lows (~$10^{-20}$ ergs $s^{-1}$ $cm^{-2}$ in 10 hour deep MUSE cubes)

- Environments: the pre-existing picture where galaxy environment is correlated with absorption properties is evolving rapidly under the new direction of efficient IFS surveys

    - kinematics, SFR, stellar mass, precise redshift, and more!

- Filaments: where do LLS fit into the emerging observational models of the cosmic web?