FIRST SCIENCE WITH HETDEX

Seen through the lens of:
why you should care about Lyman-alpha equivalent width distributions

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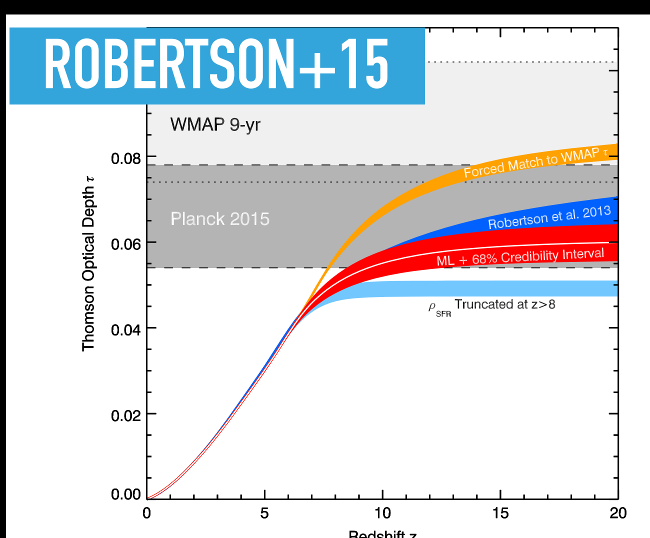
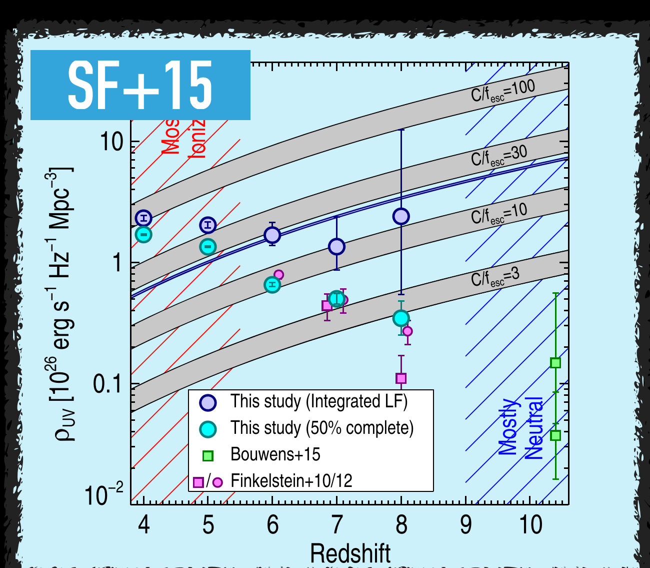
for the HETDEX team
PI: Gary Hill (UT Austin) **Project Scientist: Karl Gebhardt (UT Austin)**

THERE IS A MYSTERY AT THE END OF REIONIZATION! LYMAN-ALPHA CAN HELP!

- Many models can successfully complete reionization by z~6 and still match constraints of a significant neutral fraction at z >7.



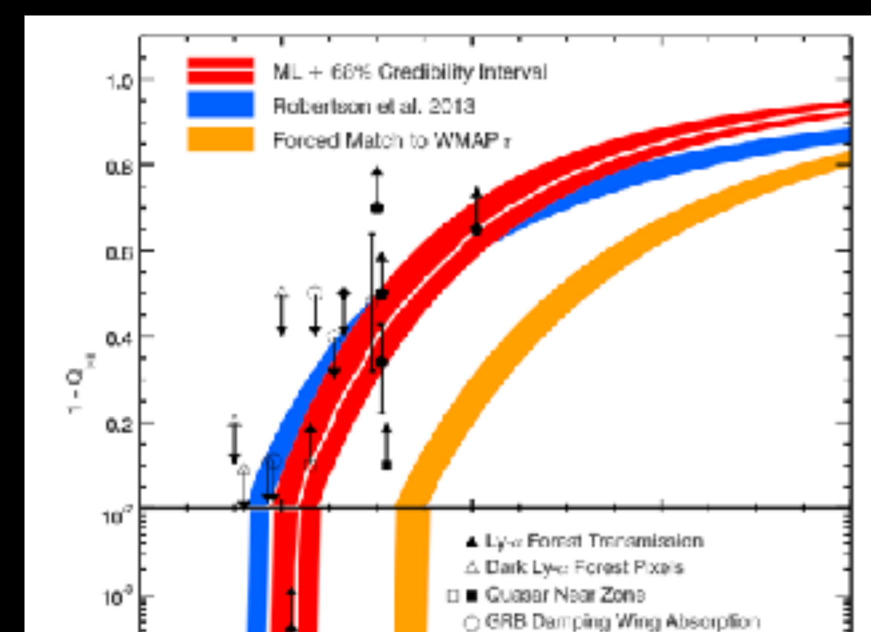


Galaxies are the source

f_{esc}=10-20%,

M_{lim}=-13,

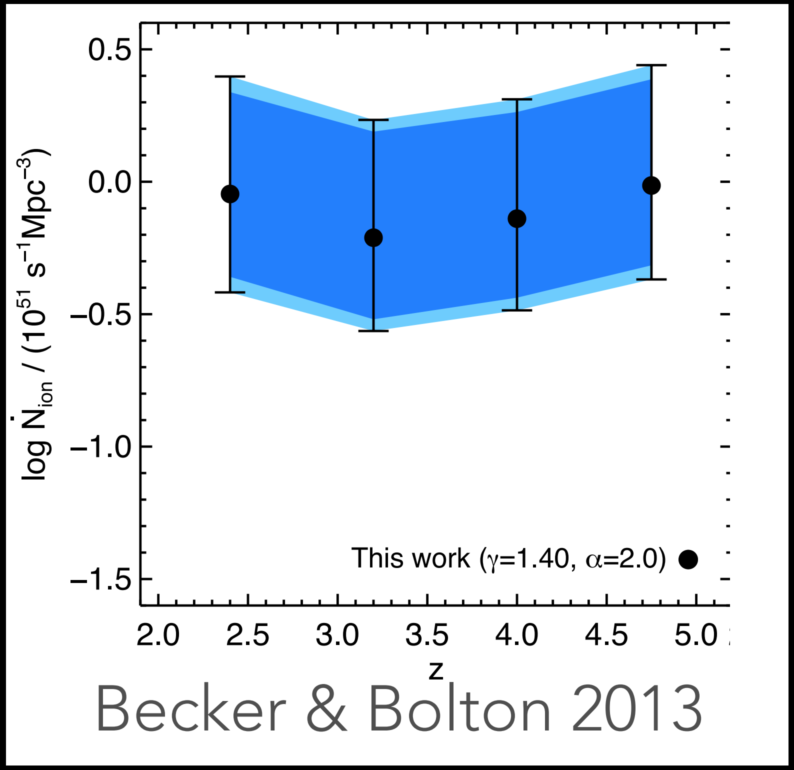
log ξ_{ion} ~ 25.2



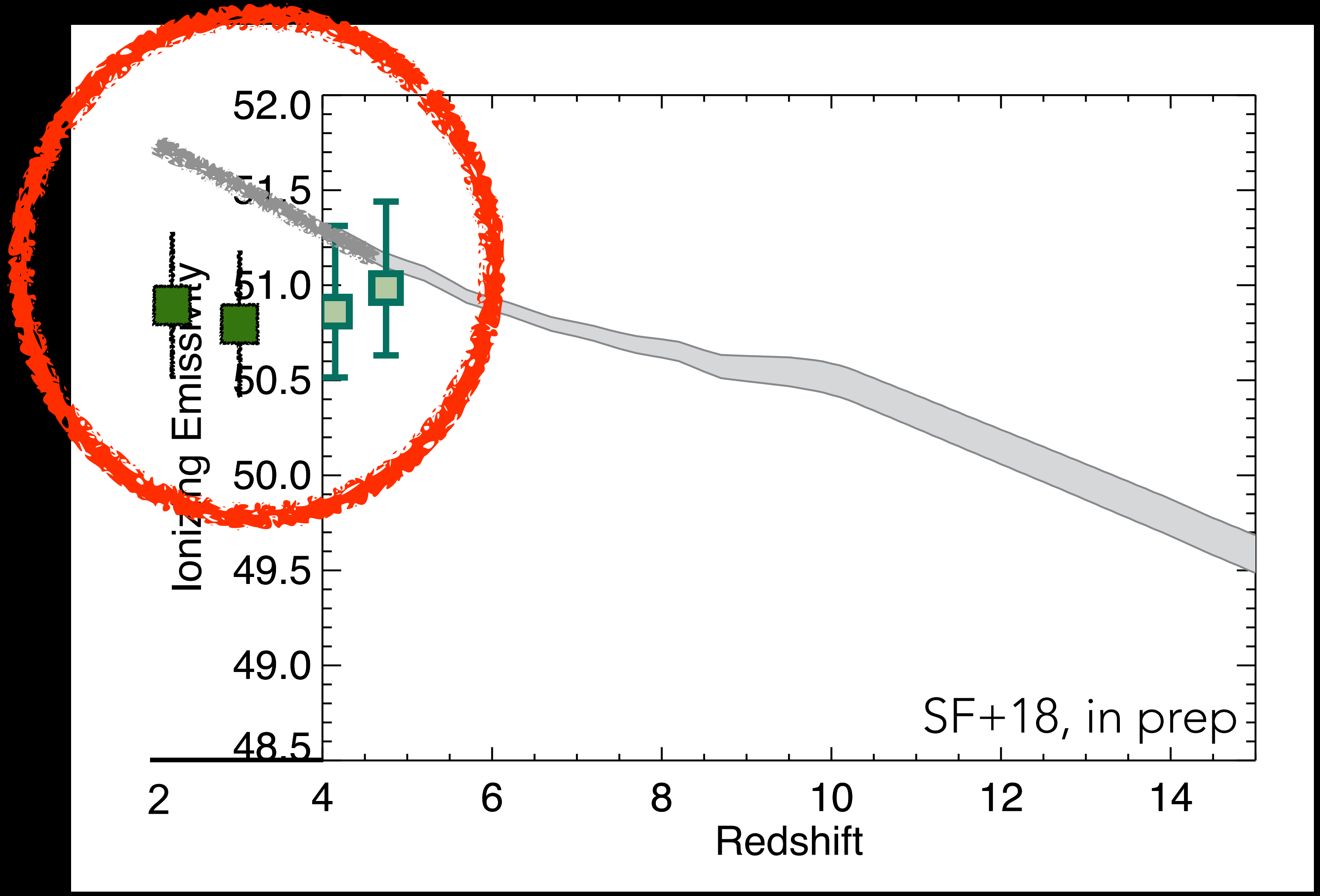
Most galaxies have very low escape fractions (<2%), with a small fraction with higher (>10%) escape fractions, and/or that f_{esc} varies with mass/luminosity.

THIS LEADS TO A DISCREPANCY WITH THE MEASURED IONIZING EMISSIVITIES

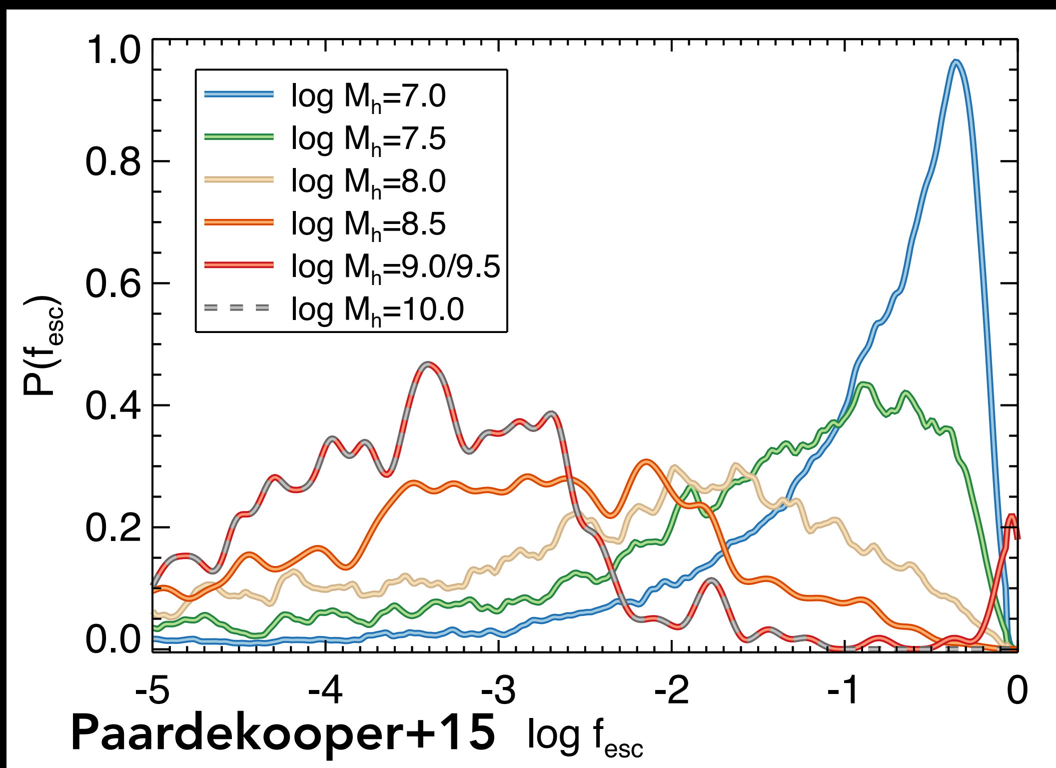
Direct measurements of the total ionizing emissivity

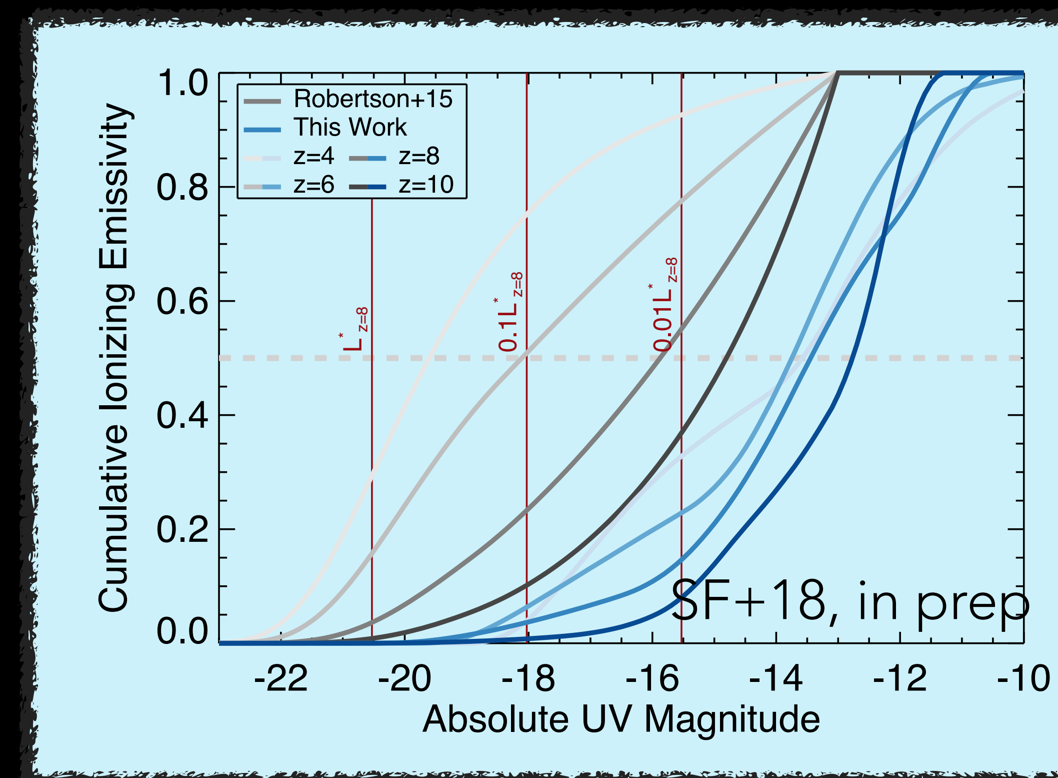


This doesn't even consider AGNs, which we know are there at z < 4!

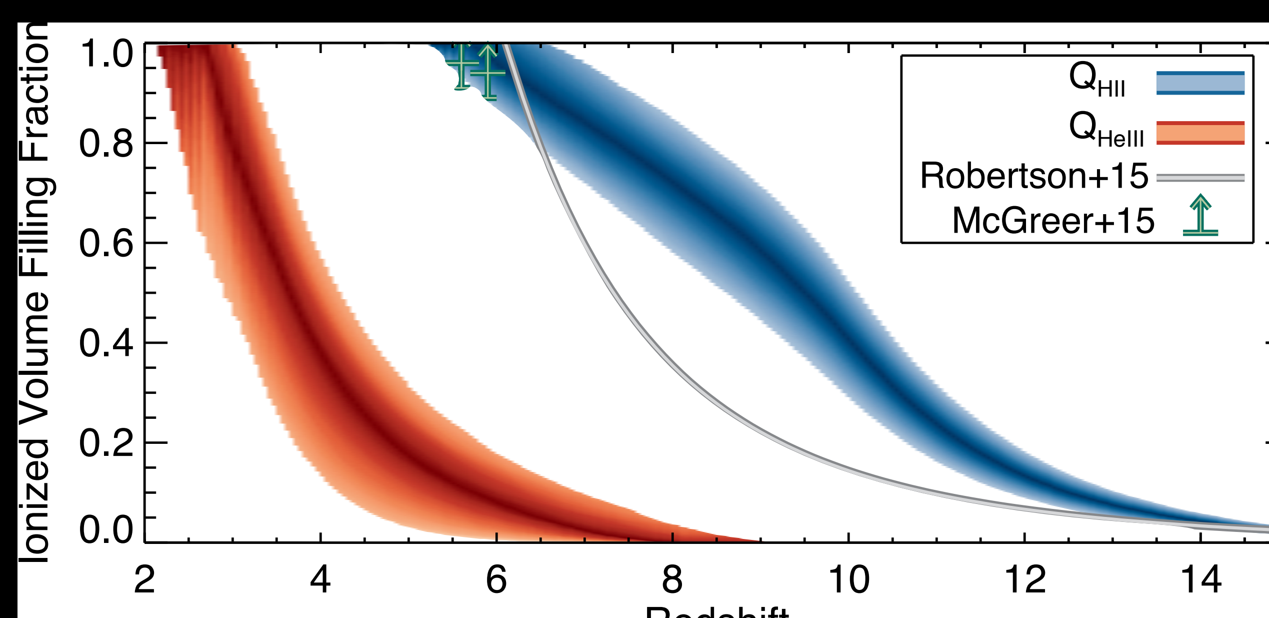


KILL TWO BIRDS WITH ONE MODEL: COMPLETING THE IGM WITH LOWER GALAXY ESCAPE FRACTIONS





This leads to *very* faint galaxies being the dominant contributor

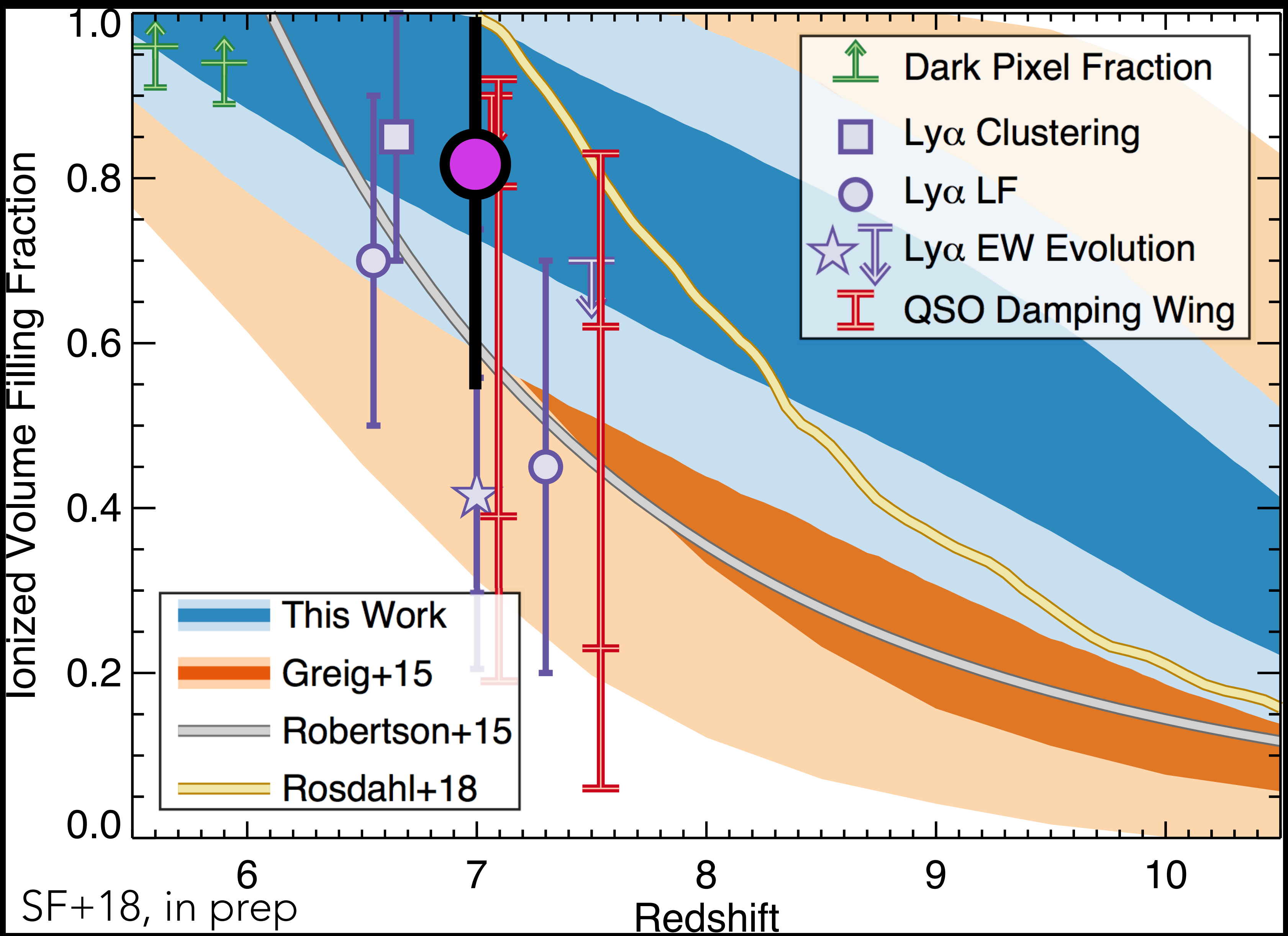


It does successfully complete reionization with $\langle f_{esc} \rangle < 5\%$, and matches emissivity constraints

First Lyα slide

ALL IS WELL?

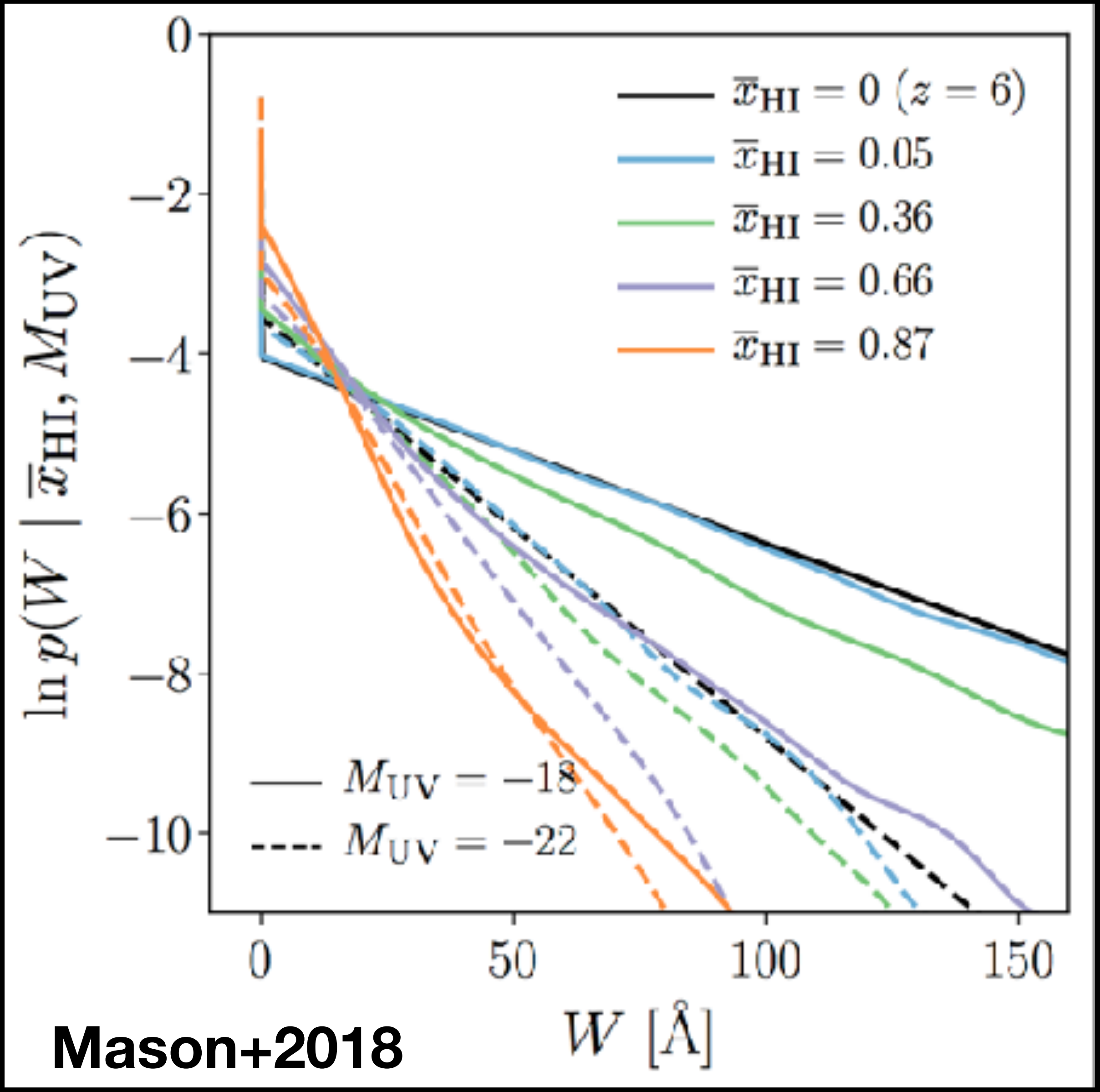
- The constraints used in this analysis (dark pixels from McGreer+15, emissivities from Becker+13, and Planck 2015 optical depth) do not prohibit this reionization history.



Existing Lyα measurements at z ~ 7 prefer a lower ionized fraction (~50%)

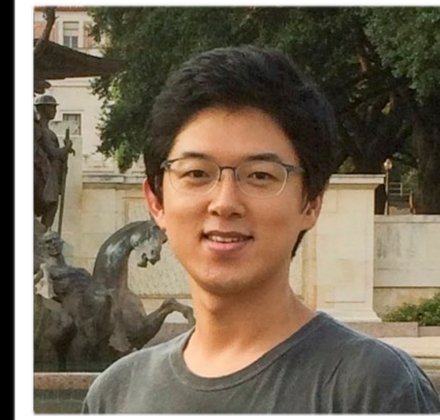
LYMAN-ALPHA AS A PROBE OF REIONIZATION

- Lyα photons are resonantly scattered by neutral HI gas, and so should be a unique tracer of the evolution of the IGM neutral fraction during reionization (e.g., Miralda-Escude+98, Malhotra & Rhoads 04, 06; Dijkstra+07).
- This has often been traced by exploring the "Lyman-alpha" fraction.
  - This measure doesn't include the continuum brightness of the galaxy, so analyses often split into multiple bins.
- The EW distribution (P[W]) is a more straightforward way to trace this evolution.
  - Now being used, see Pentericci+2018, Mason+2018, Jung+2018



Texas Spectroscopic Search for Lyα Emission at the End of Reionization I. Constraining the Lyα Equivalent Width Distribution at $6.0 < z < 7.0$

Intae Jung,[1] Steven L. Finkelstein,[1] Rachael C. Livermore,[1,2] Mark Dickinson,[3] Rebecca L. Larson,[1] Casey Papovich,[4,5] Mimi Song,[6] Vithal Tilvi,[7] and Isak Wold[1]



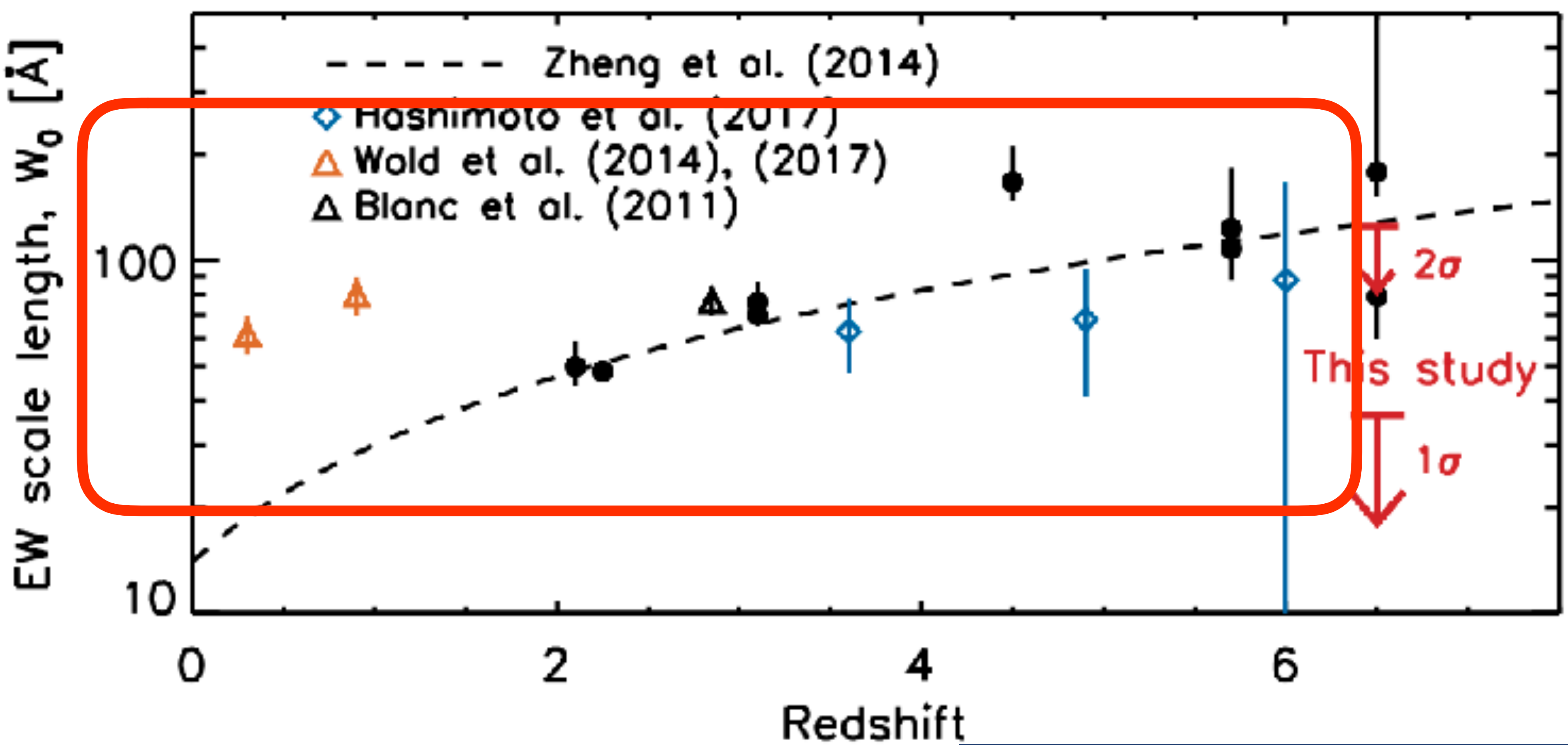
For each mock emission line,

i) We assi

ii) We assign th

iii) determine t

Baseline measurements at lower redshift are critical to interpret these epoch of reionization Lyα results



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SEE POSTER BY INTAE

THE HOBBY EBERLY TELESCOPE DARK ENERGY EXPERIMENT

- We're creating the largest spectroscopic map of the distant universe through a blind spectroscopic survey on the 10m Hobby Eberly Telescope (HET), tracing structure via Lyα emission at $1.9 < z < 3.5$.

- Our instrument VIRUS is 78 spectrograph pairs (R=750 from 350nm – 550nm), covering 1/5th of the focal plane with 35,000 fibers, which is currently being assembled on the upgraded HET (new top-end, upgrading FOV from 4′ to 22′).

- Our fiducial survey is 450 square degrees over 3 years (taken in ~6000 pointings of 20 minutes each) at 1/5 fill, for nearly 100 deg^2 with spectra.

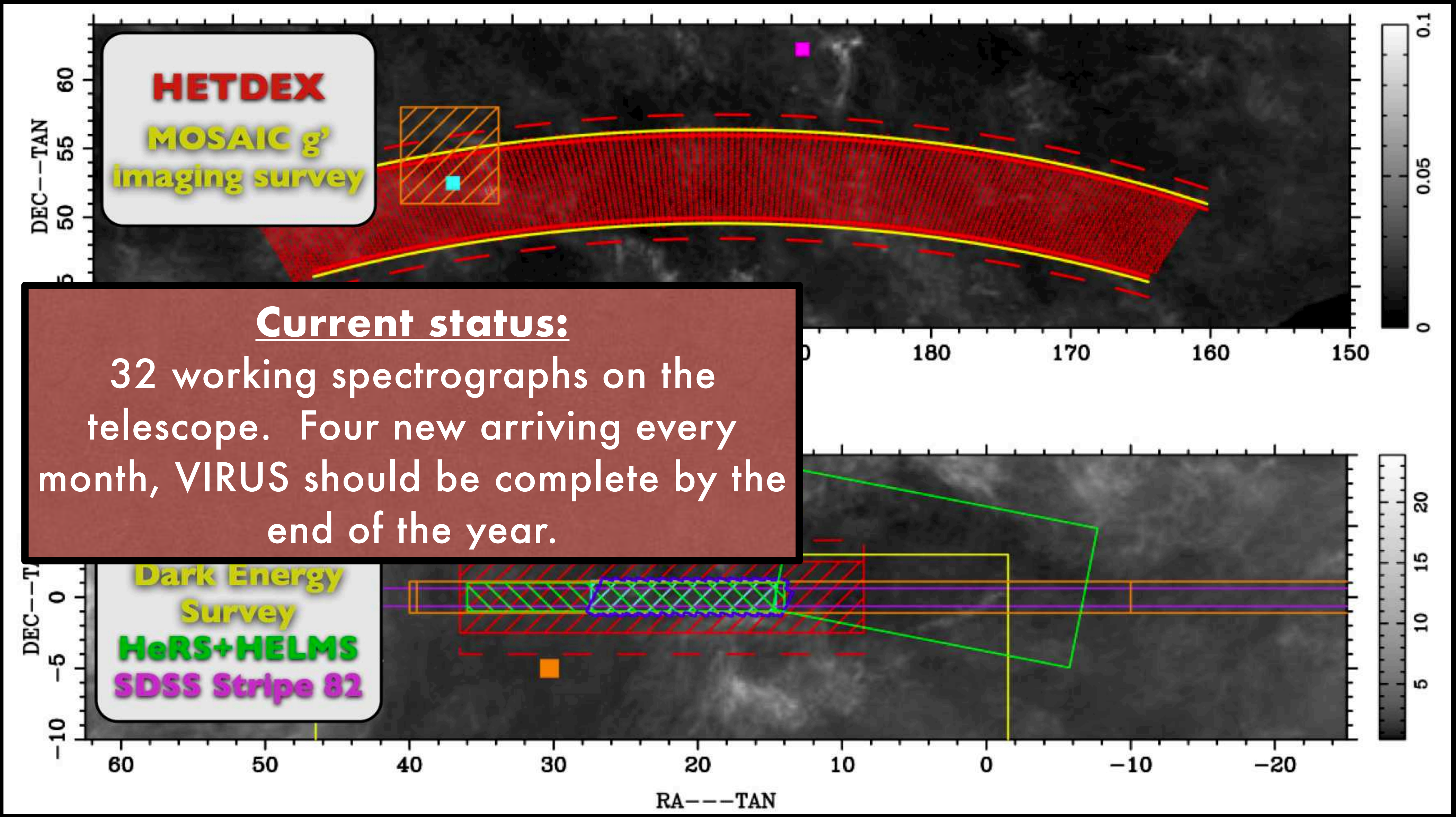
  - Expect ~1 million redshifts from $1.9<z<3.5$ via Lyα

  - >1 million redshifts from $0<z<0.5$ via [OII]

- HETDEX will enable the creation of a baseline dataset for comparison with high redshift!

SEE POSTER BY GARY HILL

THE SURVEY FIELDS



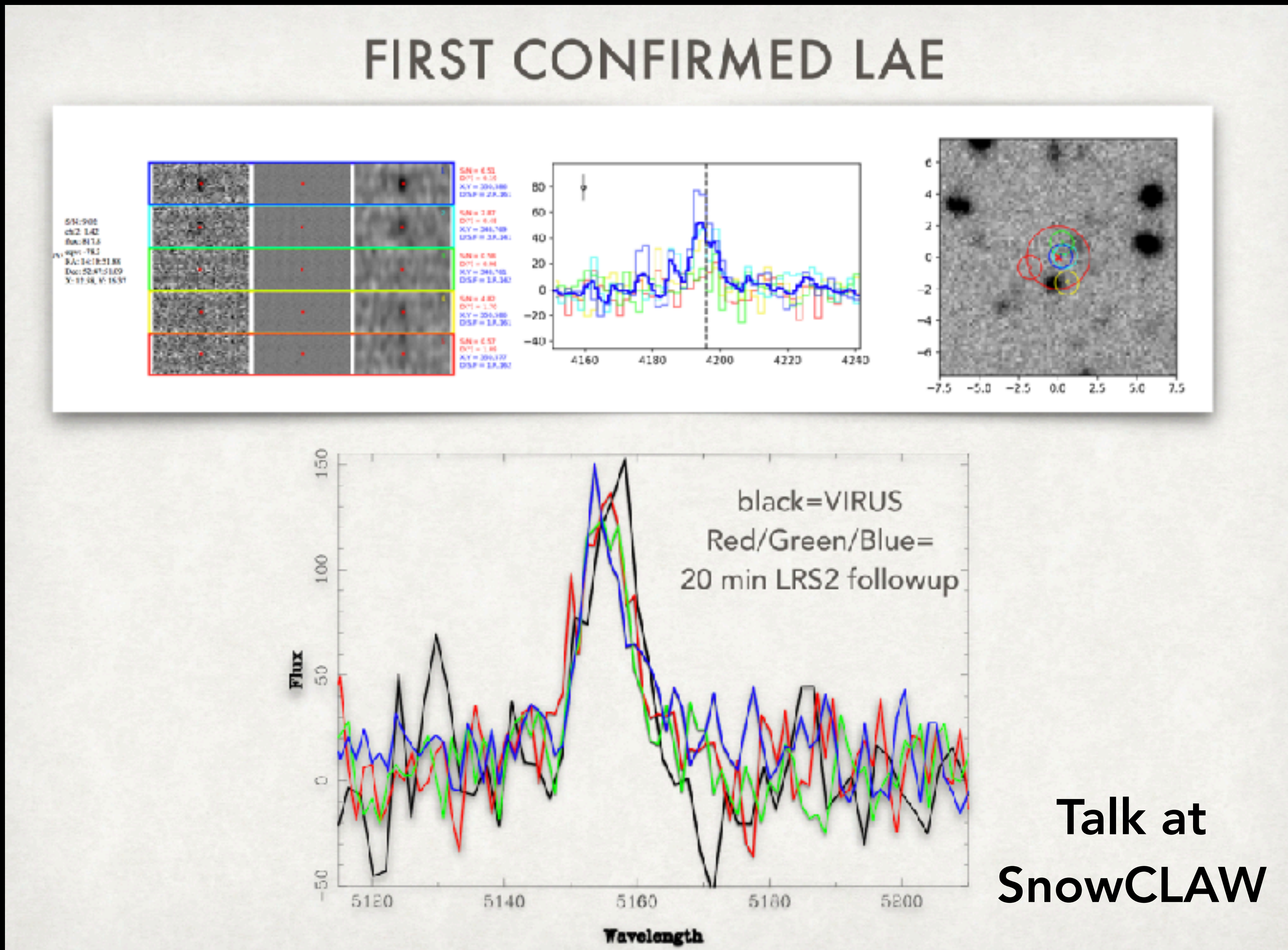
Current status:
32 working spectrographs on the telescope. Four new arriving every month, VIRUS should be complete by the end of the year.

Spring field:
300 deg^2 in the North (in Ursa Major)

Fall field:
150 deg^2 in Stripe 82

NB: At least single-band imaging data needed to constrain EWs to distinguish between LAEs at [OII] emitters (line will not be resolved).

WHERE WE WERE AT A YEAR AGO:



WHERE WE ARE AT TODAY:

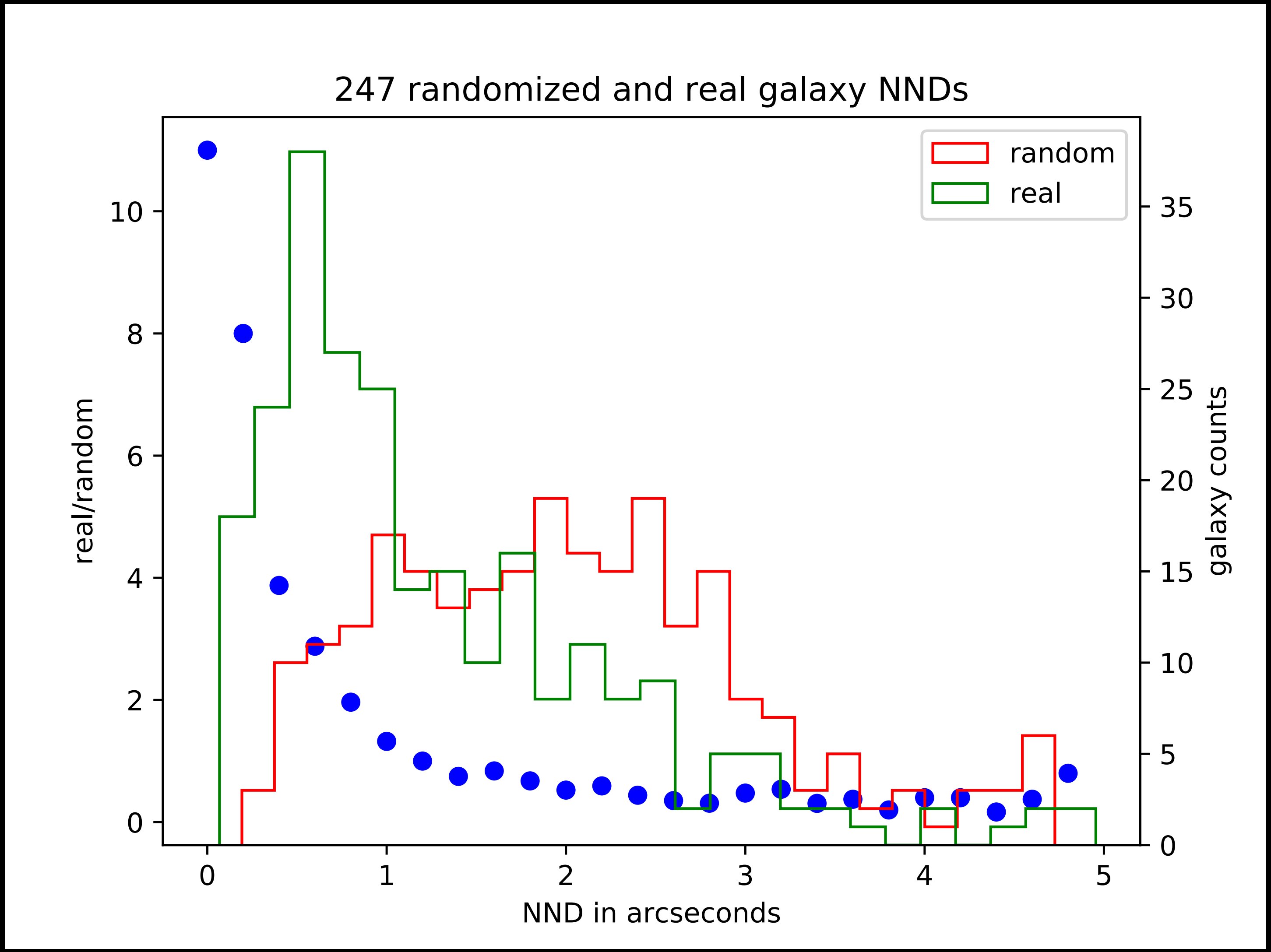
- We have been performing science verification observations in well-known deep fields: GOODS-N, EGS and COSMOS.
- We are using the deep-field observations to help optimize our emission-line selection algorithms, characterize detection limits.
  - This is not trivial with these data!
    - Currently working on optimal combination of fibers to centroid object, matching with imaging counterpart, and optimal removal of sky emission.
  - We have also started general survey observations in both spring and fall fields.

WHERE IS THE CONTINUUM COUNTERPART?

- In fields with deep HST imaging (m_{limit}~28), assuming an EW scale length of 70 A, we should see counterparts to ~99% of our sources.

- This can be very useful for understanding the positional accuracy of our emission line centroiding!

  - Current UT undergrad Yaswant Devarakonda has been exploring this in the CANDELS EGS field.

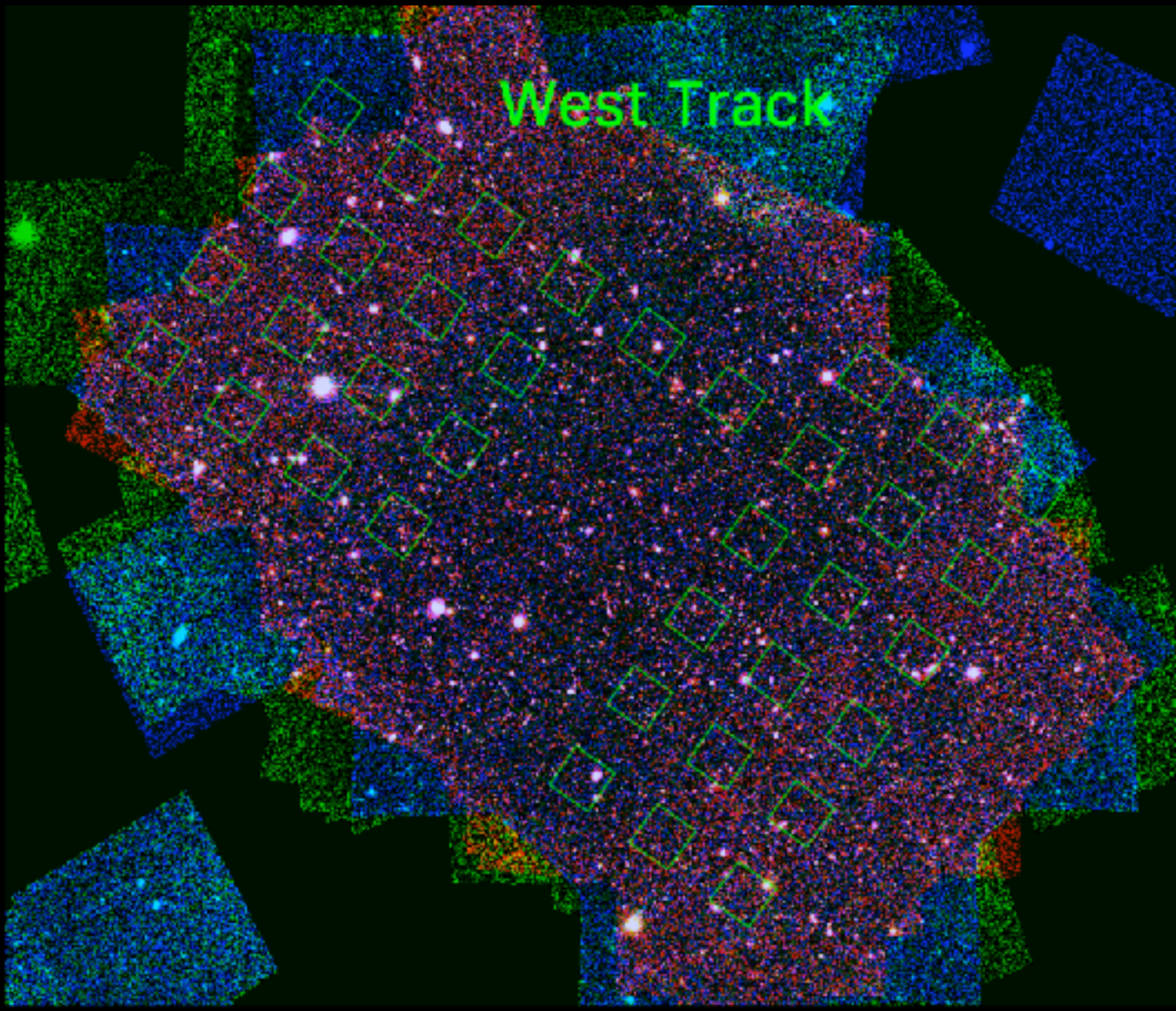


**Conclusion:
Matches at < 1"
are likely correct, but
not always…**

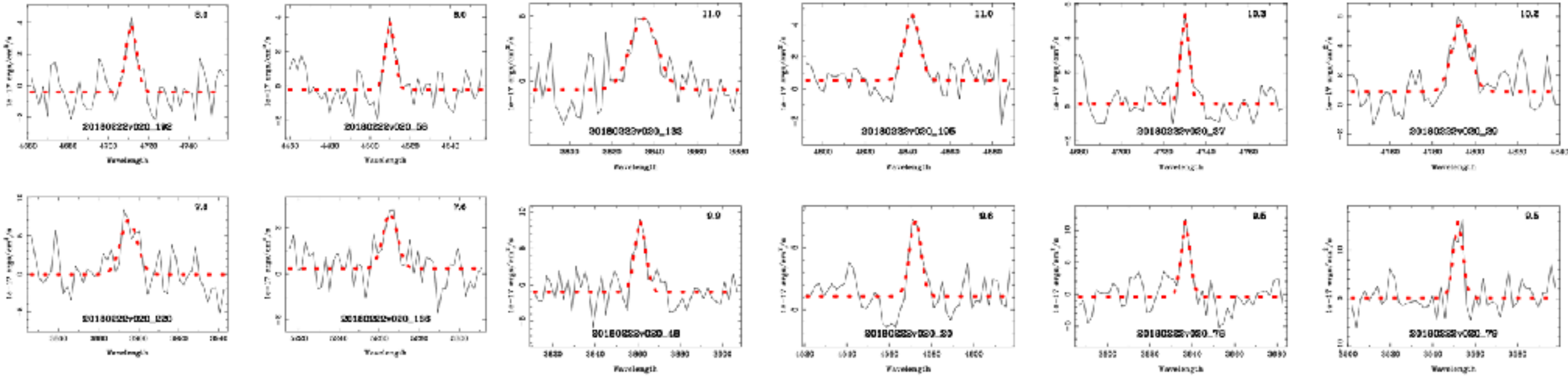
THE POWER OF VIRUS

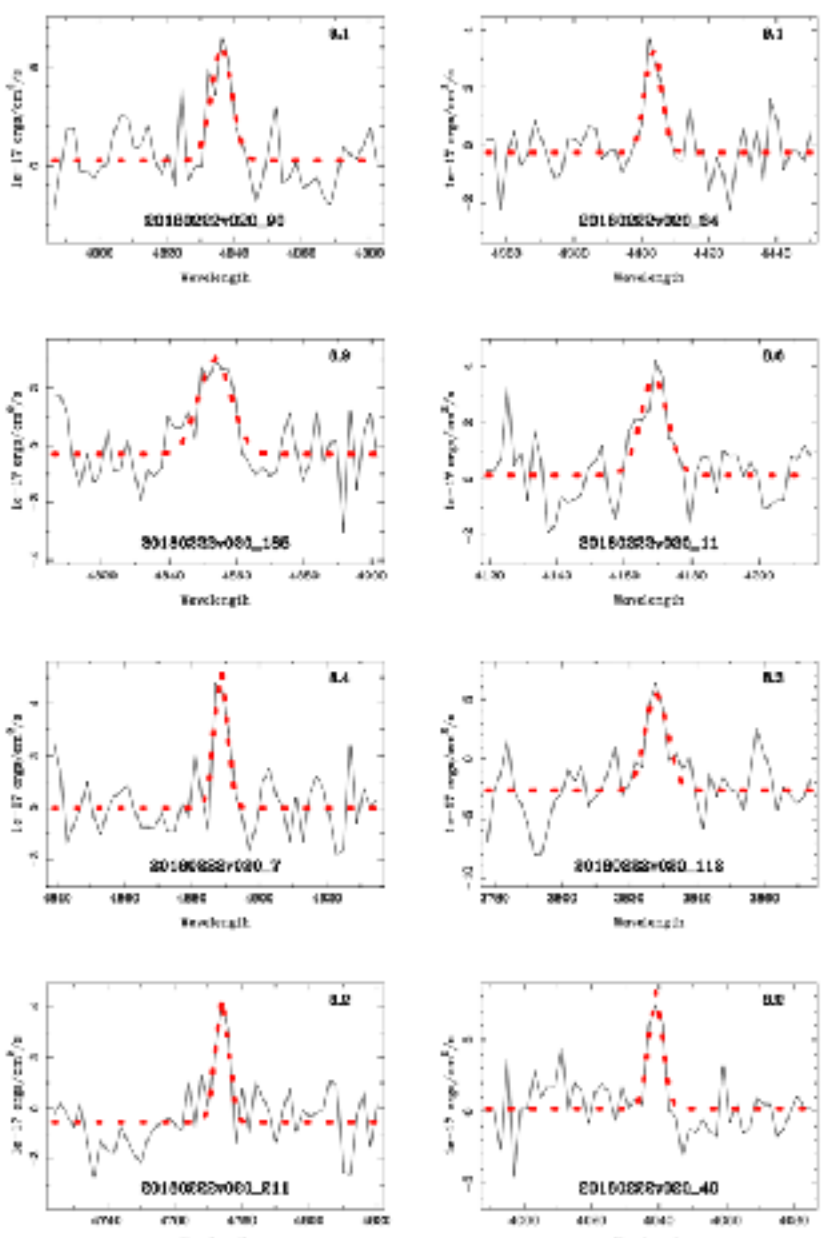
- These green squares show the layout of a deep observation (4X HETDEX depth) we performed in GOODS-N, which obtained data in 20 IFUs.

- We cover a similar volume as the MUSYC CDFS pointing to a similar depth (<~L_{Lya}*), in 20X less integration time!!
  - Full VIRUS will cover 4X the volume in the same amount of time.

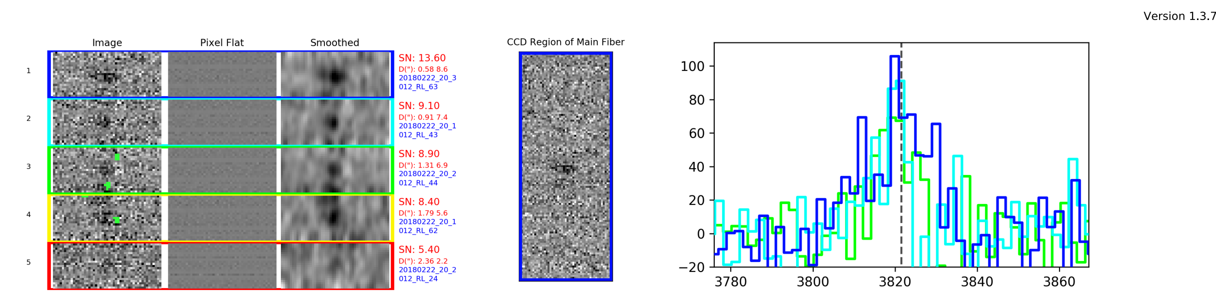


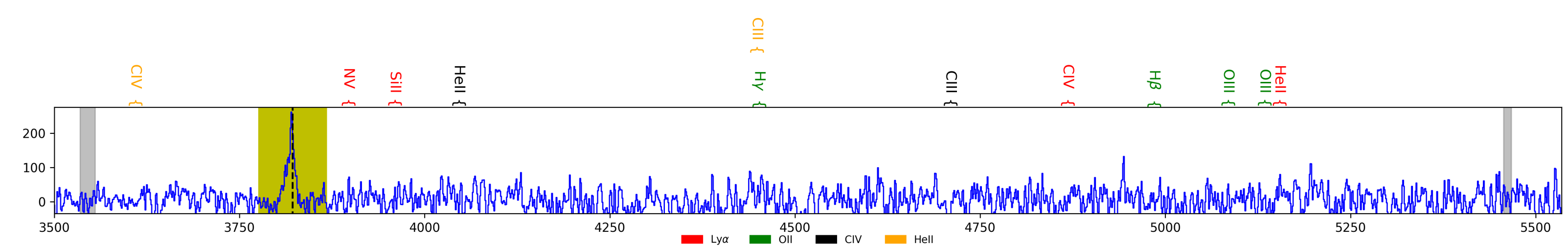
Some emission lines in GOODS-N



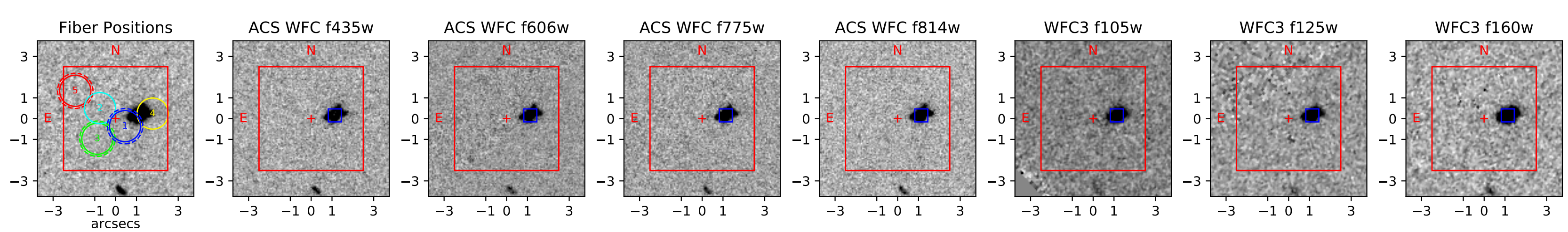


20180222v020_219.pdf
Obs: 20180222v20_289
Entry ID (219), Detect ID (289), Line# (219)
Primary IFU Slot 106
RA,Dec (189.501110,62.260880)
Sky X,Y (-21.620000,7.340000)
λ = 3821.54Å
EstFlux = 6.3e-16 DataFlux = 1478/1
EstCont = 2.77e-18 EW_obs = 227Å
S/N = 13.6
P(LAE)/P(OII) = 999 Score = 5.0 (31.67)
LyA Z = 2.14271 OII Z = 0.0253662

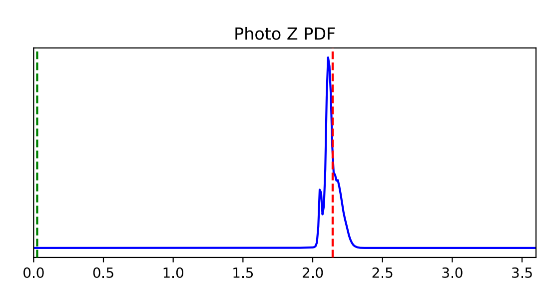




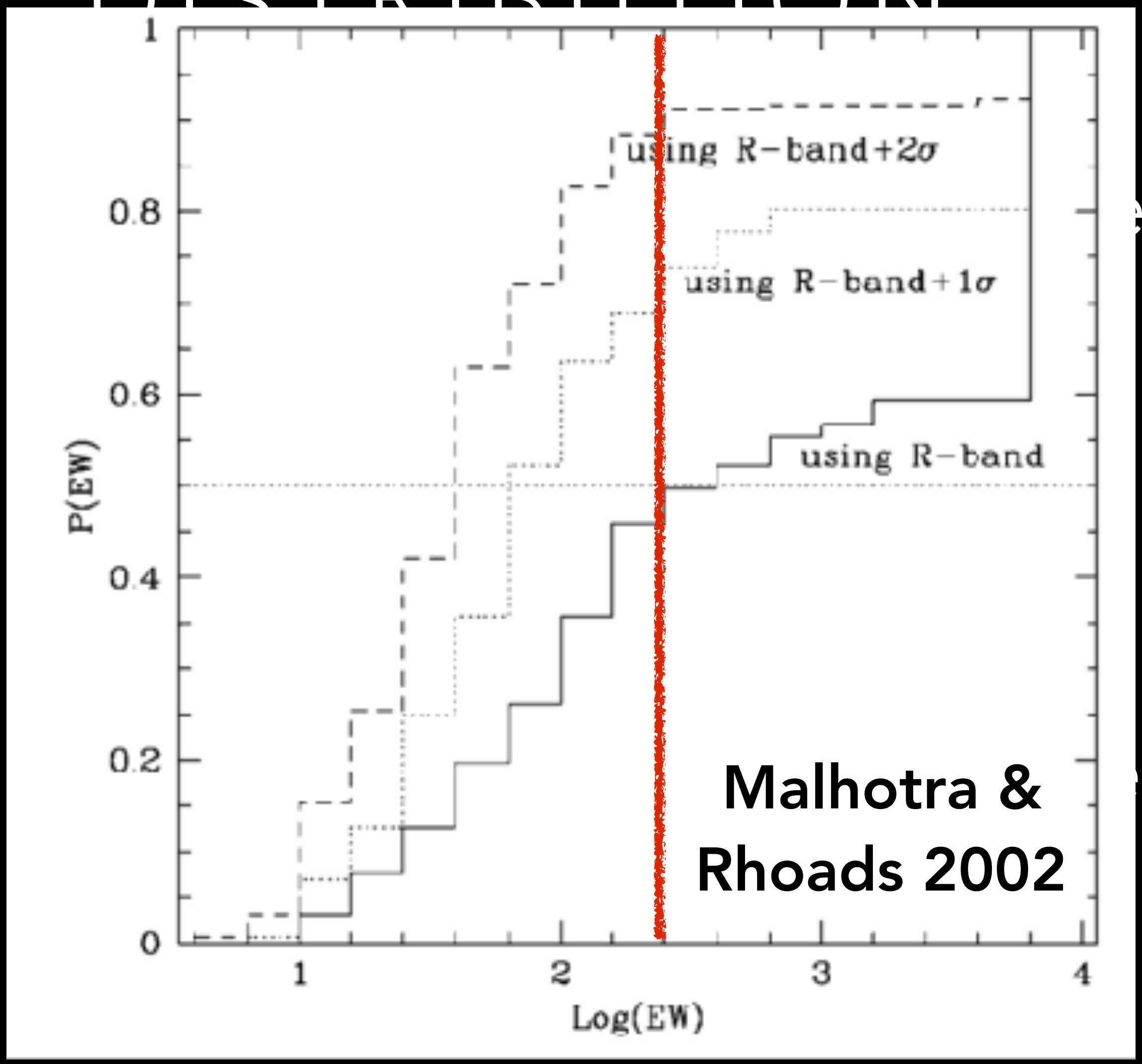
GOODS-N : Possible Matches = 1 (within +/- 2.5") Minimum (no match) 3σ rest-EW: LyA = 23849.8 Å OII = 73098.8 Å

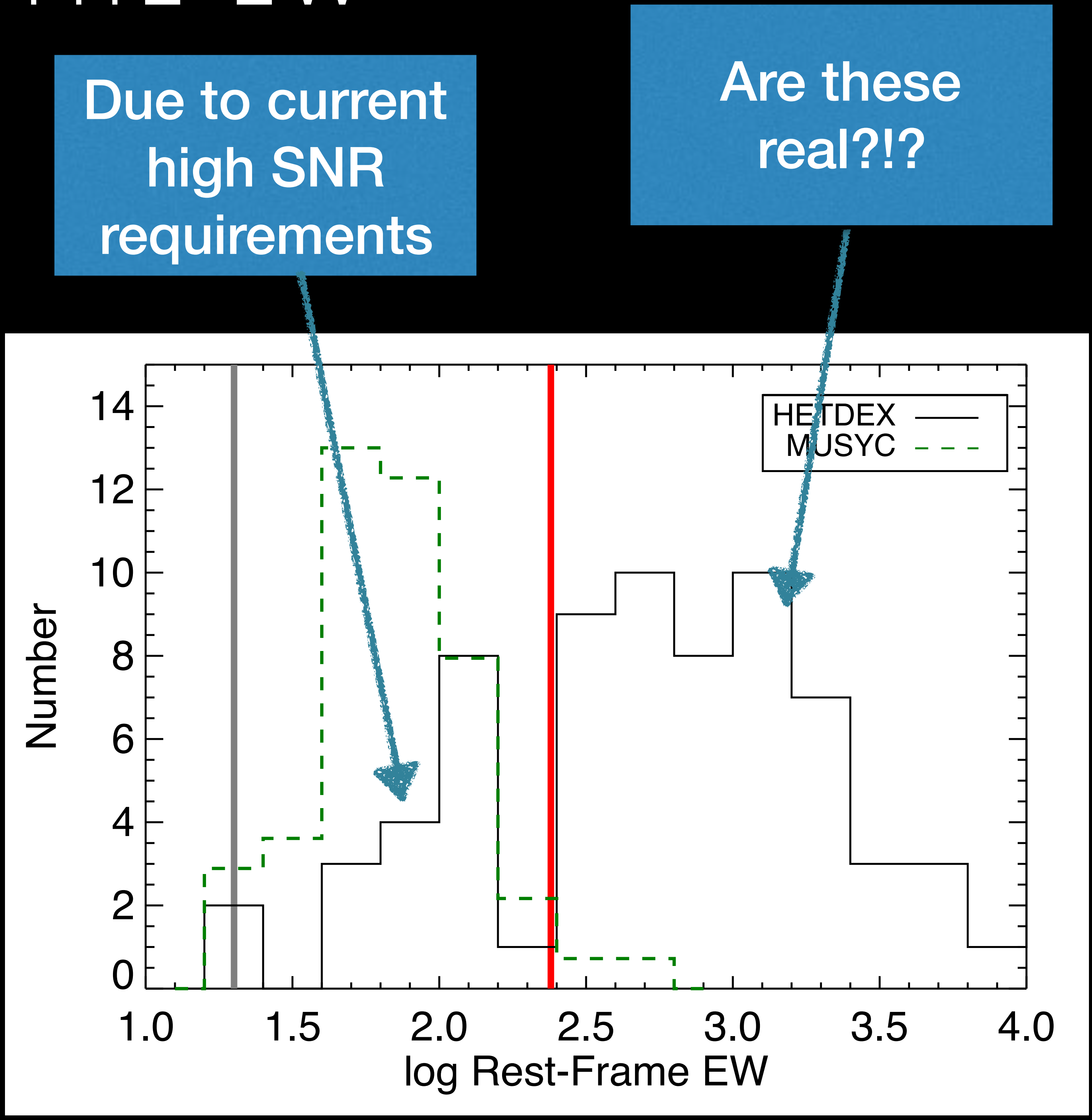


Separation	1.14546"
RA, Dec	189.500433, 62.260925
Spec Z	N/A
Photo Z	2.134
Est LyA rest-EW	76.4089 Å
Est OII rest-EW	234.191 Å
ACS WFC f606W Flux	1.27725(0.02188) μJy
P(LAE)/P(OII)	999



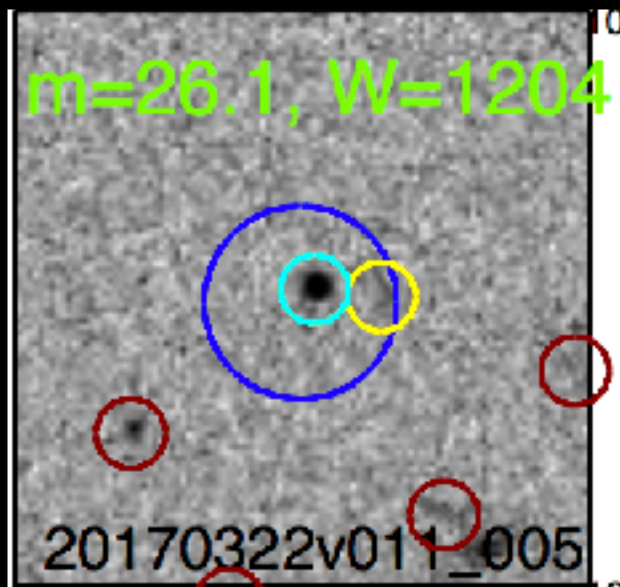
EARLY LOOK INTO THE EW DISTRIBUTION

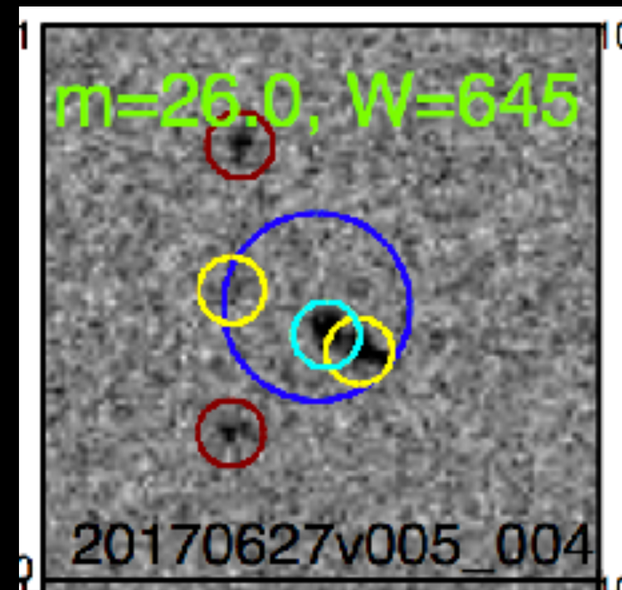


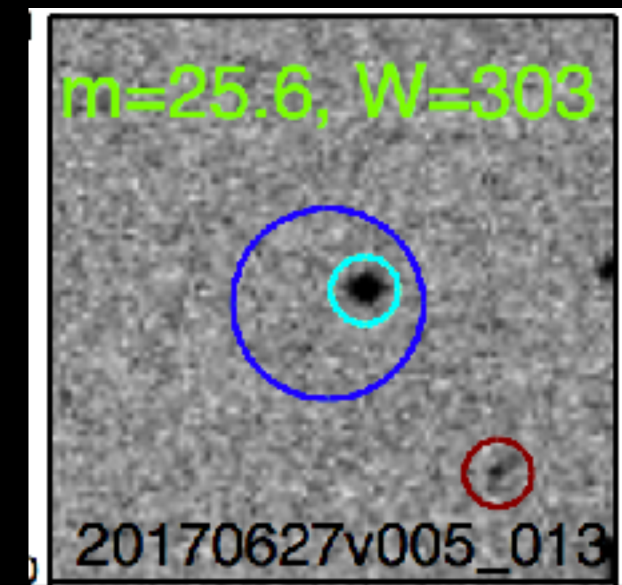


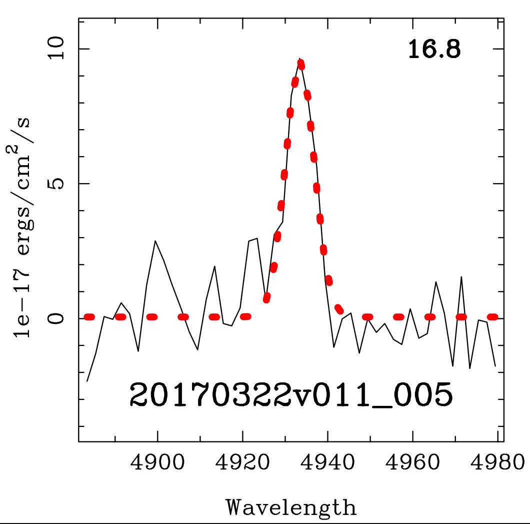
- There are ~20 others in this sample, but need further reliability checks.

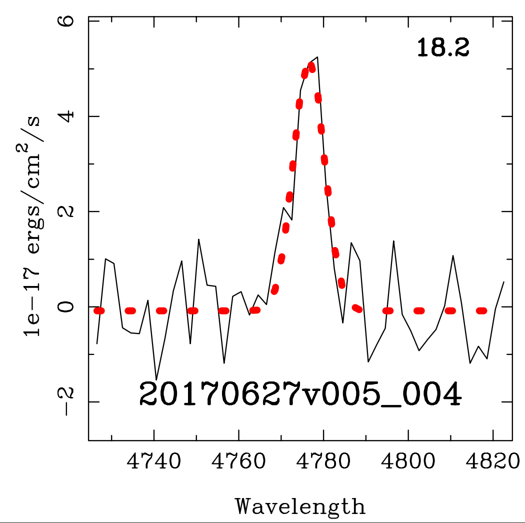
Here are some sources with W > 300 A, and a counterpart with a matching photo-z

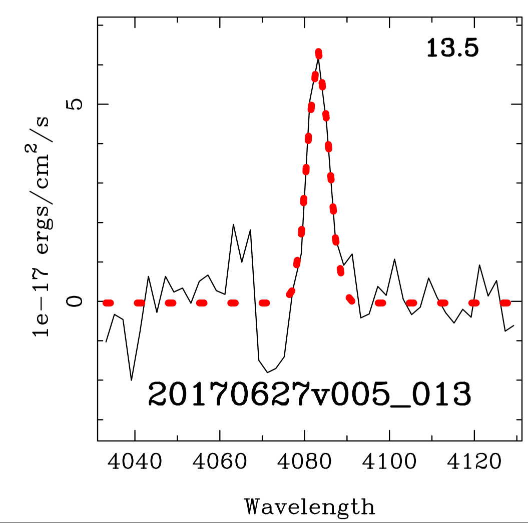












What does this mean? ***More work needs to be done to verify***, but it could indicate that the EW distribution extends out to higher values than previously thought.

If this is true, we will characterize this extremely well with HETDEX.

Physical explanations? Extreme starbursts, AGN, low metallicities, other causes of increased ionization (top-heavy IMF, binary stars, etc), more inclusive of lower-SB emission?

The Cosmic Evolution Early Release Science (CEERS) Survey

PI: Steven Finkelstein (UT Austin)

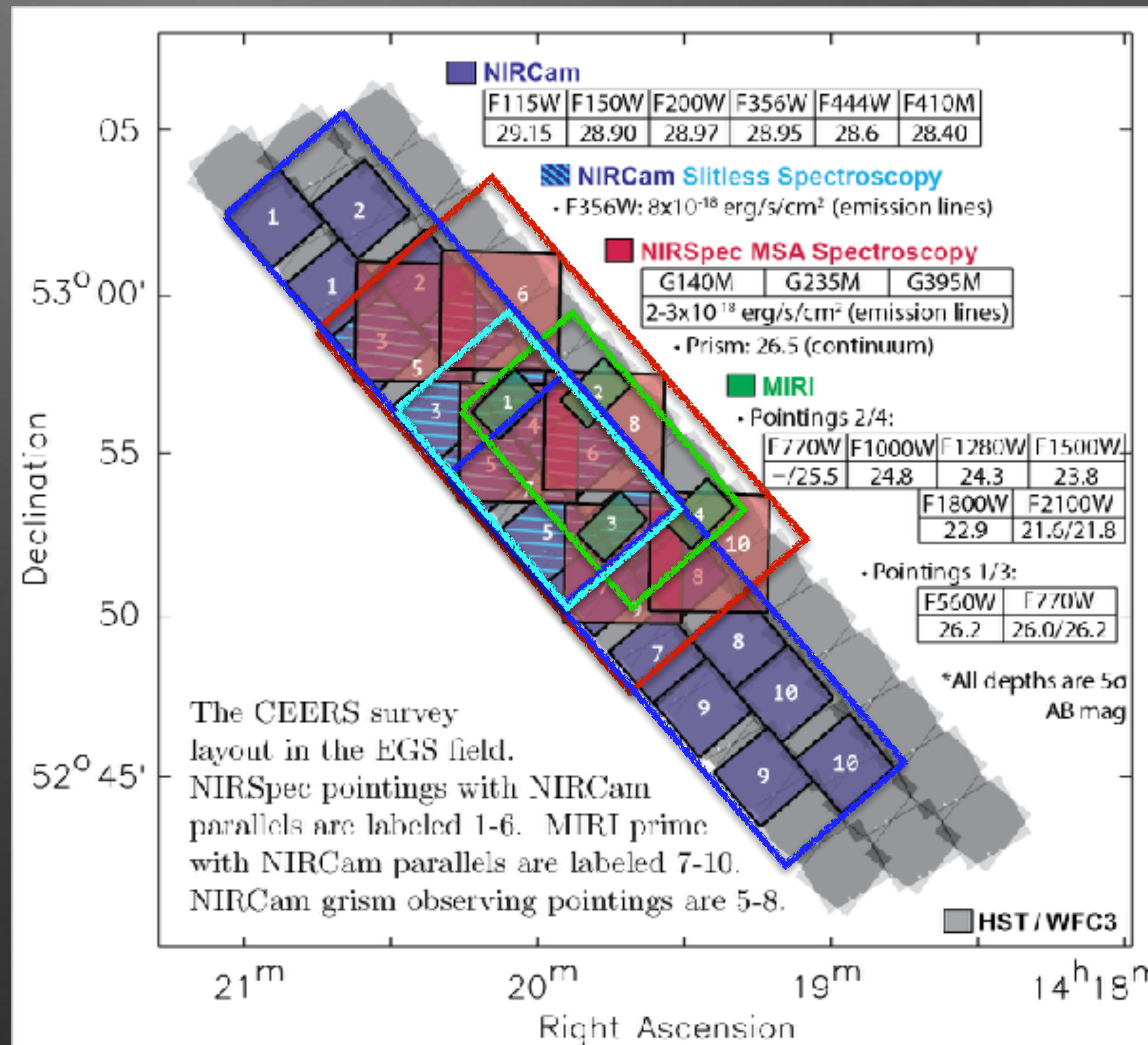
Co-I's: Mark Dickinson (NOAO), Harry Ferguson (STScI), Andrea Grazian (Rome), Norman Grogin (STScI), Jeyhan Kartaltepe (RIT), Lisa Kewley (ANU), Dale Kocevski (Colby), Anton Koekemoer (STScI), Jennifer Lotz (STScI), Casey Papovich (Texas A&M), Laura Pentericci (Rome), Pablo Perez-Gonzalez (Madrid), Nor Pirzkal (STScI), Swara Ravindranath (STScI), Rachel Somerville (Rutgers), Jon Trump (UConn) & Steve Wilkins (Sussex)

Full CEERS team: 105 scientists over 10 countries, including 28 institutions

APT file is available by searching program #1345 at:
https://jwst.stsci.edu/observing-programs/program-information

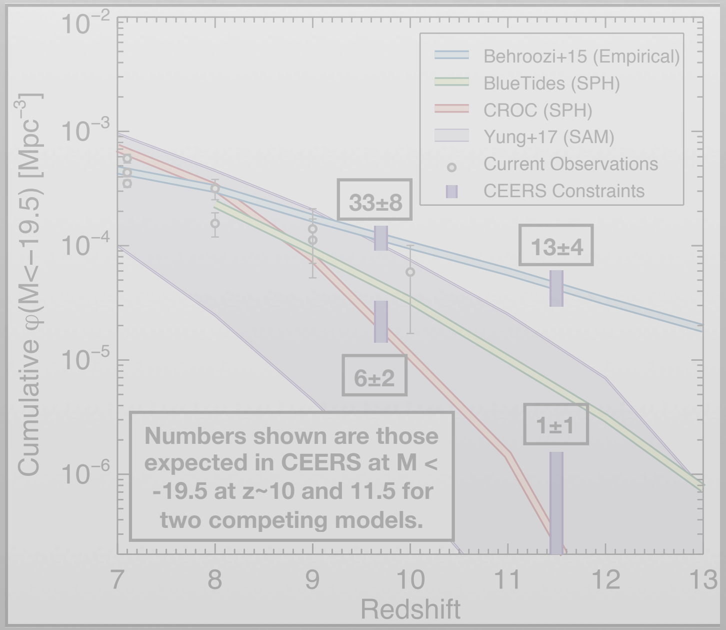
CEERS Observing Plan

- Primary Field: EGS
  - Image shows our reconfigured observations assuming a Spring 2019 launch, and observations in Dec 2019.
- 6 pointings: NIRSpec prime with NIRCam parallel
  - Imaging in 5-6 filters (1.2-4.5 µm).
  - R~1000 spectroscopy in all six pointings, R~100 in four pointings.
- 4 pointings: MIRI prime w/ NIRCam in parallel
  - MIRI: 2 pointings deep F560W & F770W, 2 pointings shallower obs out to 21 µm.
- 4 pointings: NIRCam grism prime (F356W)

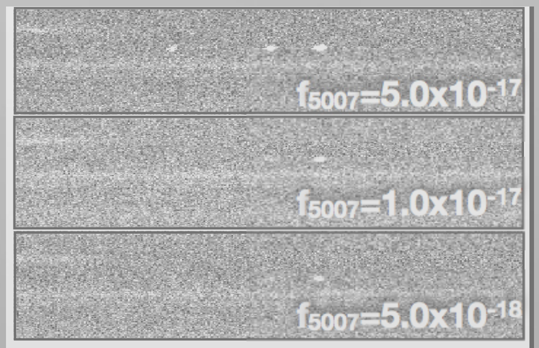


CEERS: Primary Science Goals

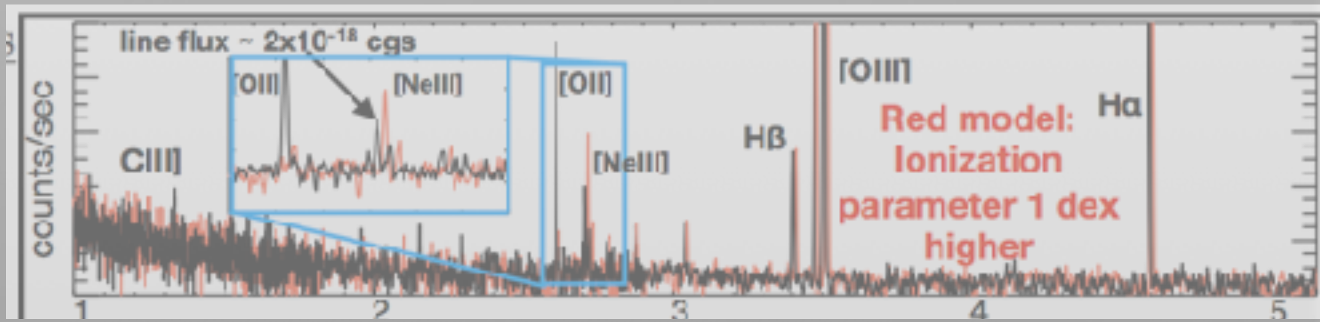
1) CEERS should detect ~5-50 galaxies at z > 10, distinguishing between models which assume different star-forming efficiencies, in addition to finding high-priority targets for Cycle 2.



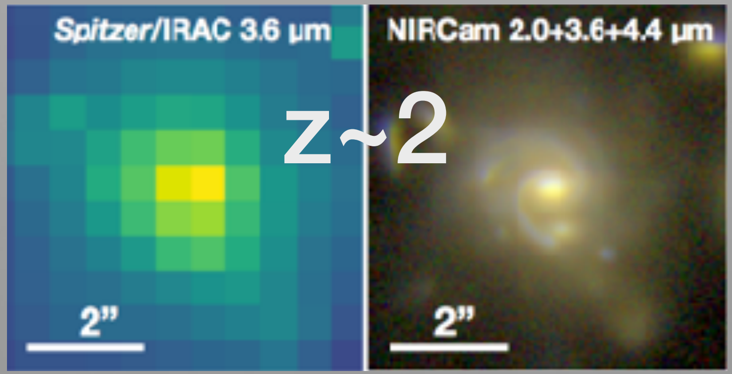
2) CEERS NIRSpec and NIRCam grism will detect numerous lines out to z~10, allowing spectroscopic confirmation and measurement of key physical properties, including ionization parameter, metallicity, and AGN presence.

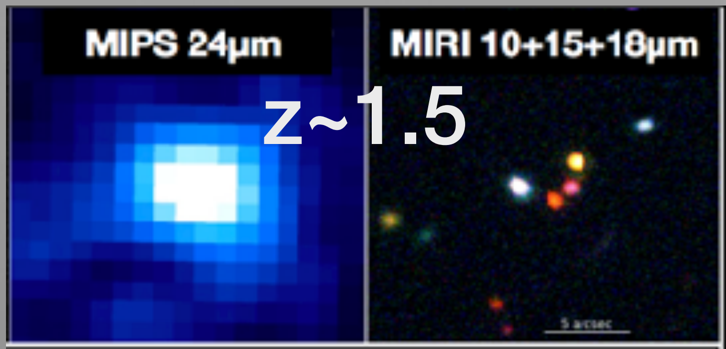


Grism sims by Nor Pirzkal

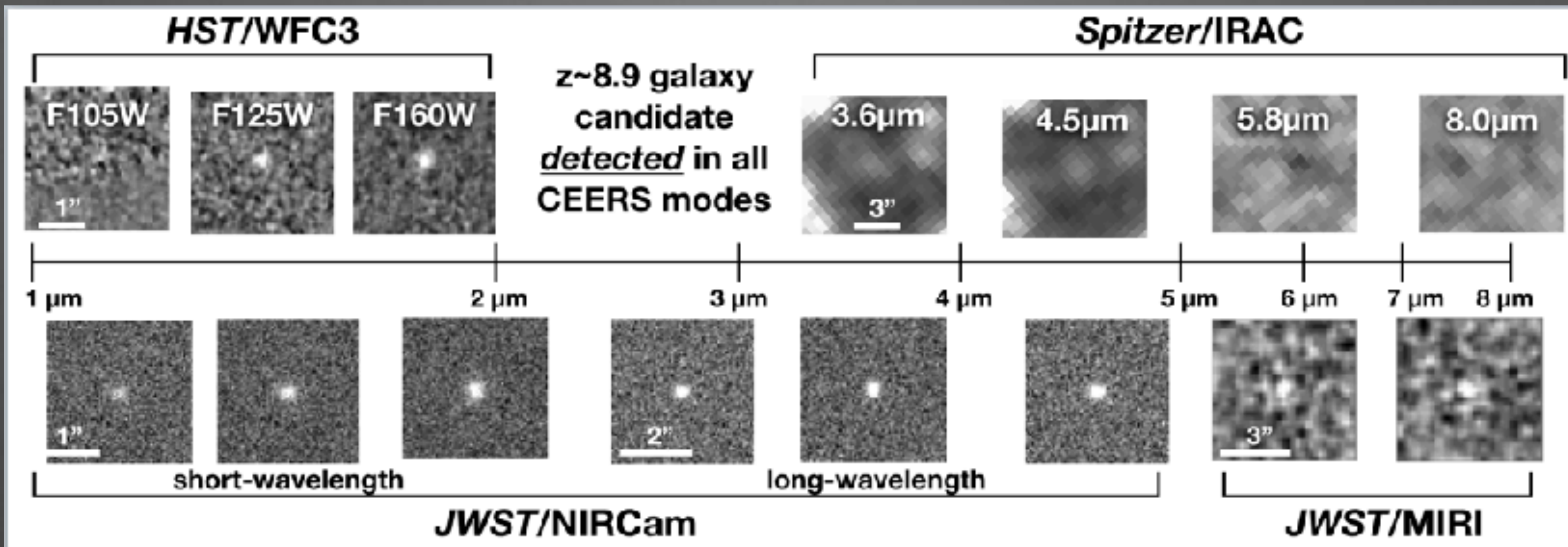


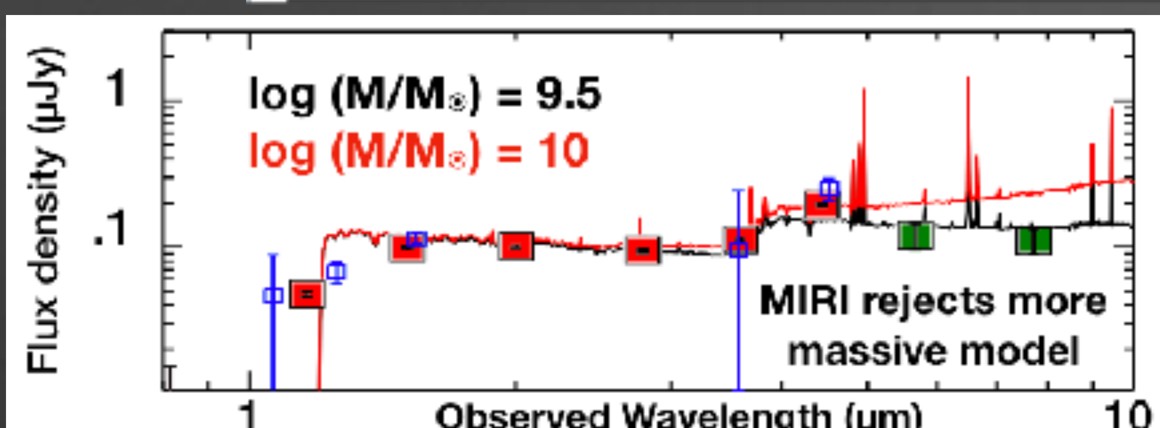
3) CEERS will unveil high-resolution rest-optical morphologies for modestly-high redshift galaxies, and high-resolution imaging in the PAH/hot-dust continuum for galaxies at moderate redshifts.

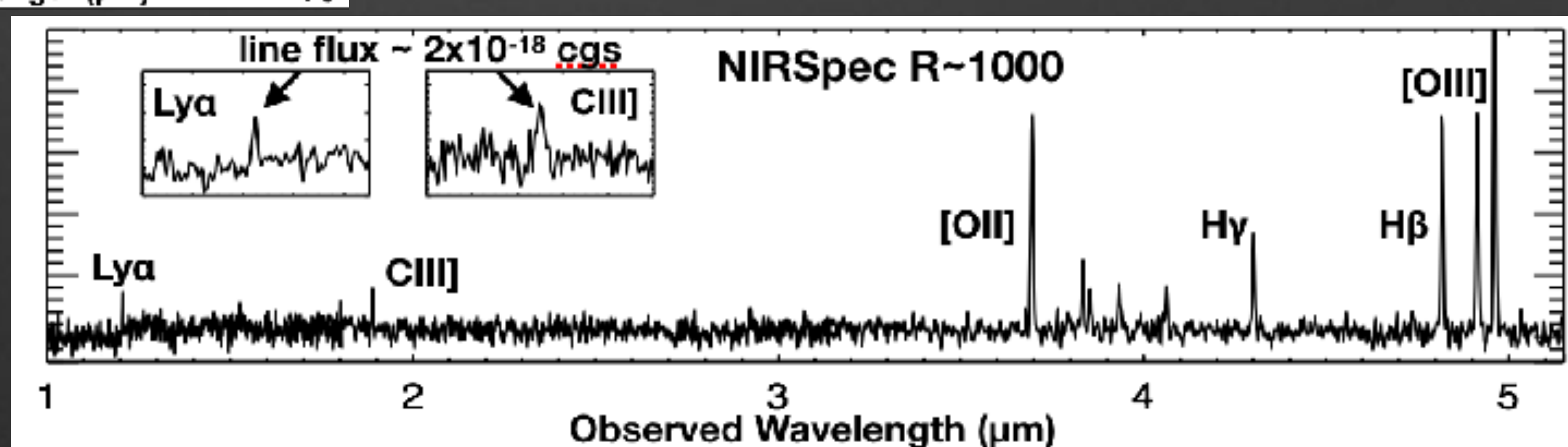




Example z~9 Observation







Deliverables

Milestone	Deliverables
Pre-Launch	Build and release simulated CEERS datasets. Make updated HST mosaics & catalogs. Also will communicate to community, including blog detailing our interaction with the data (simulated and real), and “CEERS briefings”
3 months post-data acquisition (by Cycle 2 Call)	v0.5 image mosaics for NIRCam and MIRI - v0.5 reduced 2D and 1D spectra for NIRSpec and NIRCam grism
6 months post-data acquisition (by Cycle 2 deadline)	v1 image mosaics and 2D and 1D spectra PSF-matched photometry catalog HST+NIRCam, MIRI v1 Spectroscopic catalog (line fluxes and spectroscopic redshifts) Release sample of $z > 9$ galaxy candidates
12 months post-data acquisition	v2 image mosaics and 2D and 1D spectra Publish multi-wavelength catalog, including photo-z, M*, SFR v2 Spectroscopic catalog (line fluxes and spectroscopic redshifts) F200W morphology catalog Publication of slit-loss analysis

CONCLUSIONS

- Lyα is beginning to fulfill its "destiny" as a tracer of the evolution of reionization, but a robust baseline sample of objects at lower redshifts is needed to help the interpretation.
- HETDEX is well on its way, and will provide very large samples of LAEs which can be used to create such a baseline.
  - Early HETDEX data show signs of an interesting population of high-EW LAEs
- JWST observations (like CEERS) can be used to understand the physical mechanisms promoting this emission.