muse

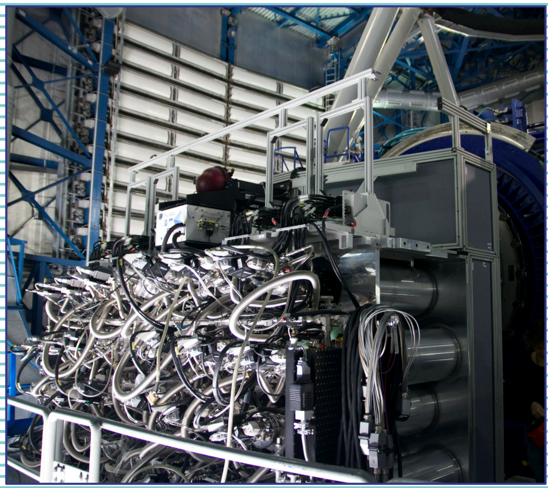
multi unit spectroscopic explorer

MUSE: first science results

J. Richard, R. Bacon
and the MUSE Consortium

Journées du PNCG,
25-26 November 2014

MUSE: identity



Name: MUSE

Category: integral field spectrograph

Size: 1x1 arcmin^2

Spatial sampling: 0.2”

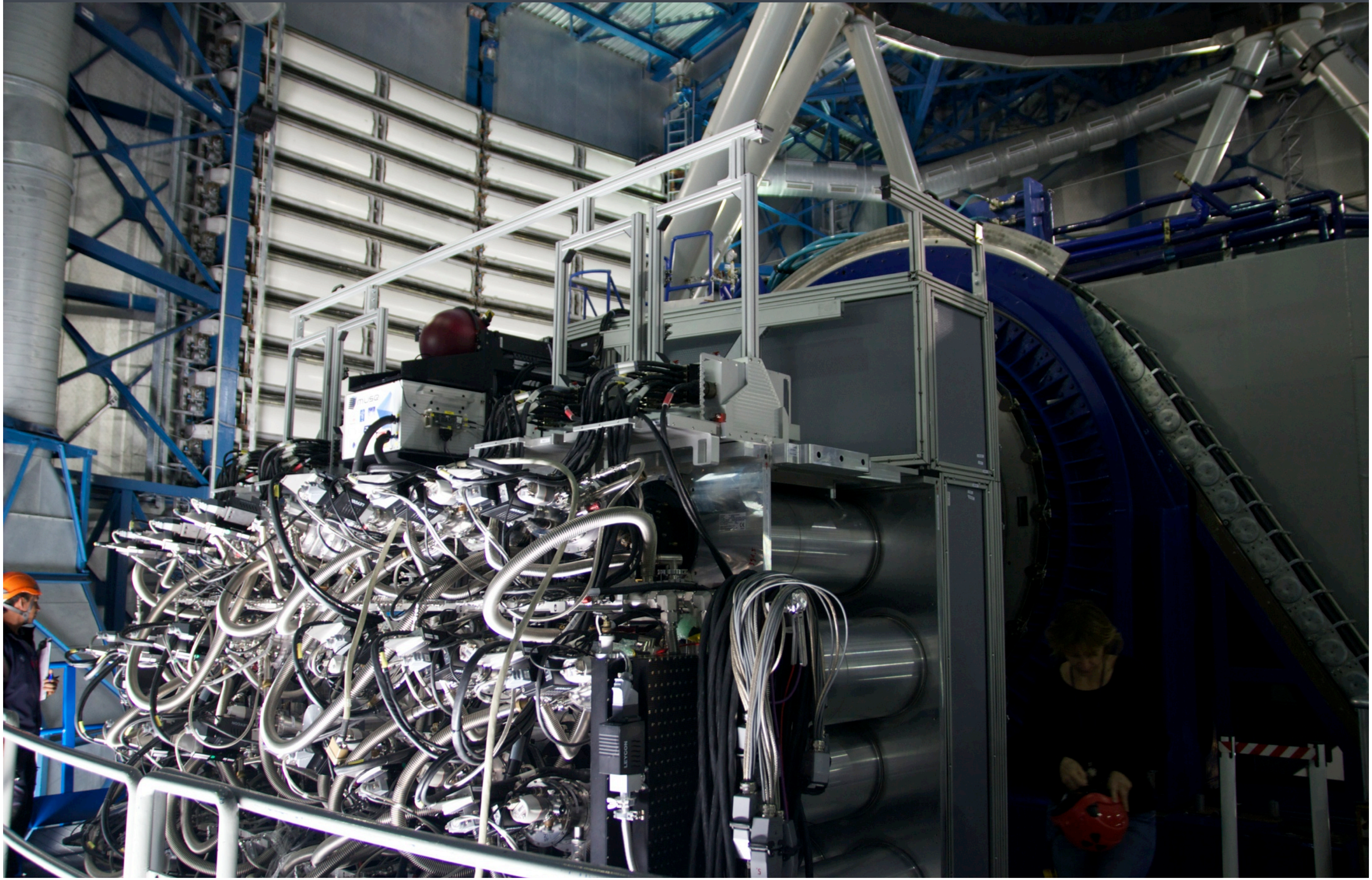
Image Quality: <0.2”

Coverage: 4650-9300 Å

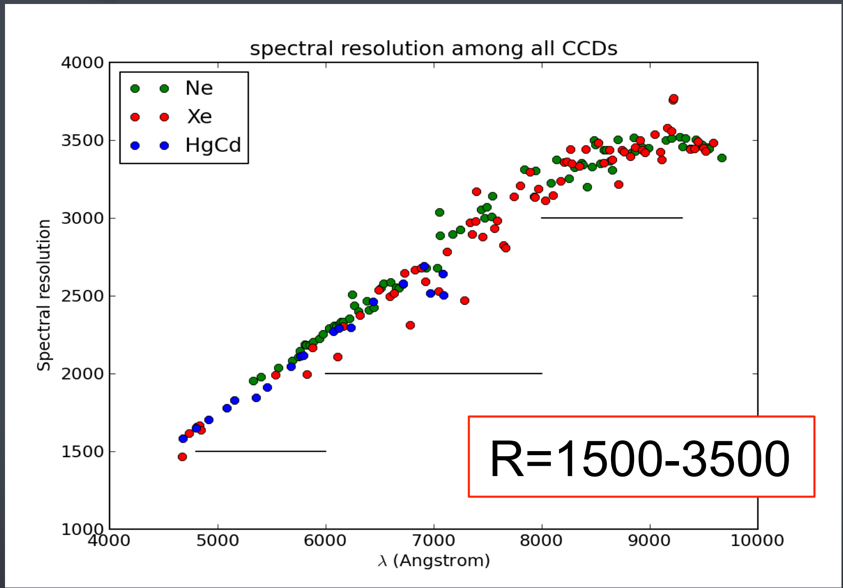
Resolution: 1500-3500

Throughput: 35% end-to-end

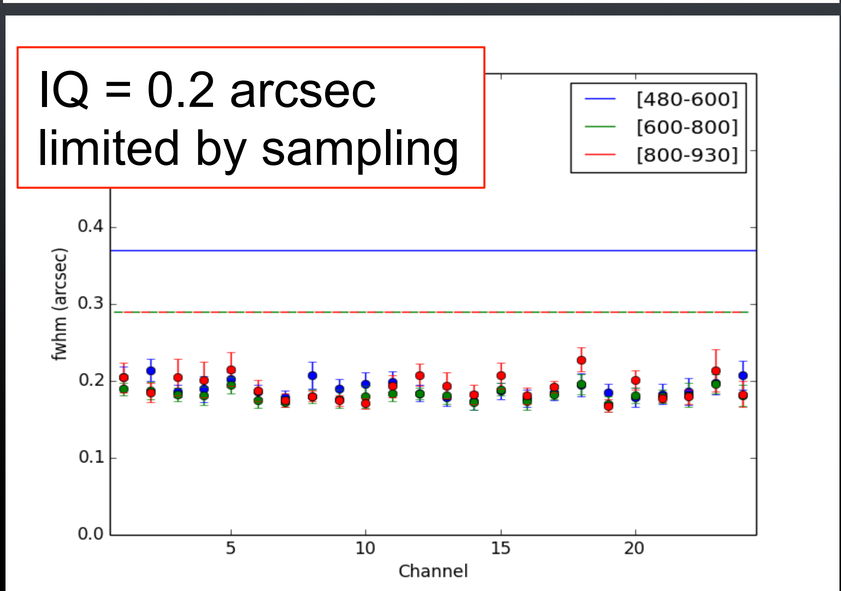
19 Jan 2014: MUSE land on UT4 Nasmyth Platform



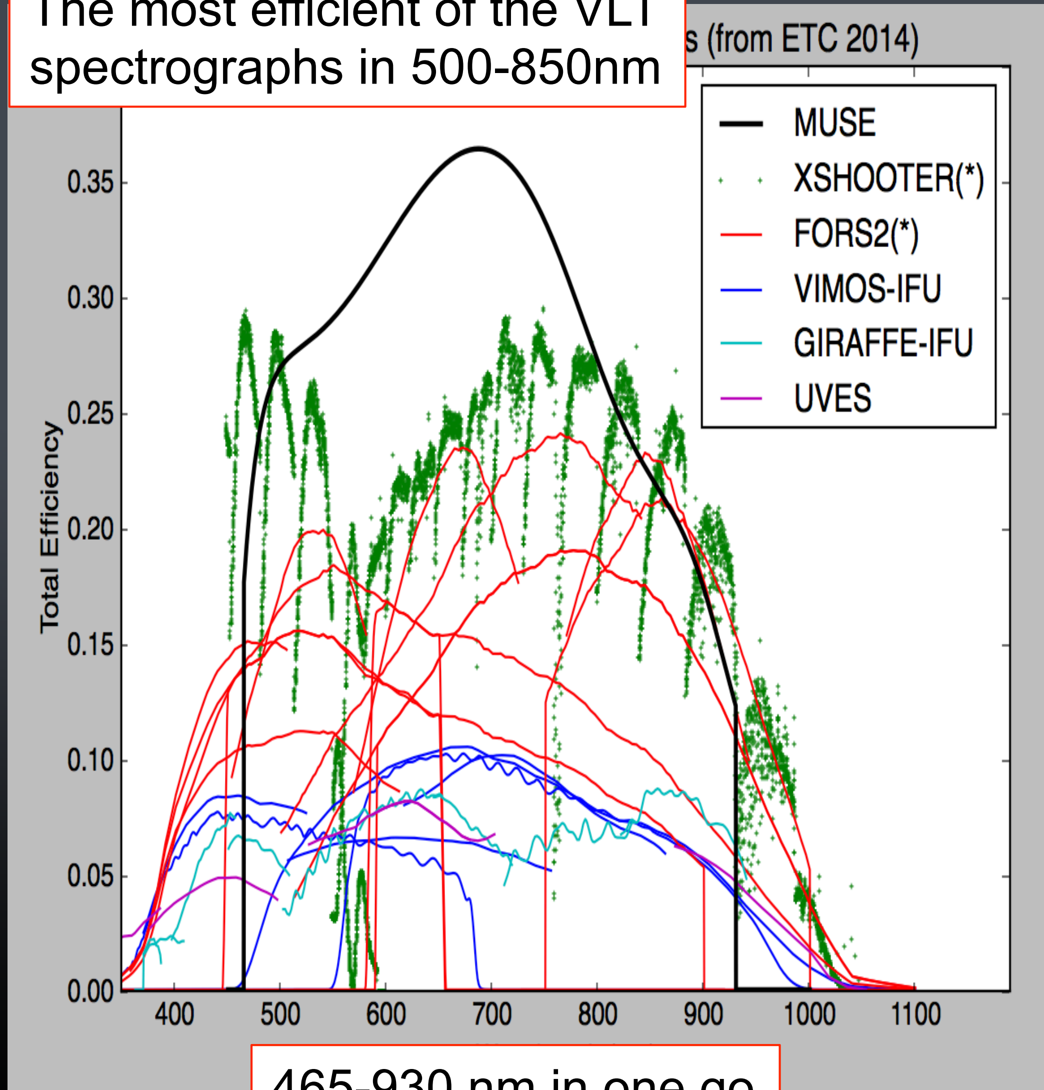
Instrument Performances



R=1500-3500



IQ = 0.2 arcsec limited by sampling

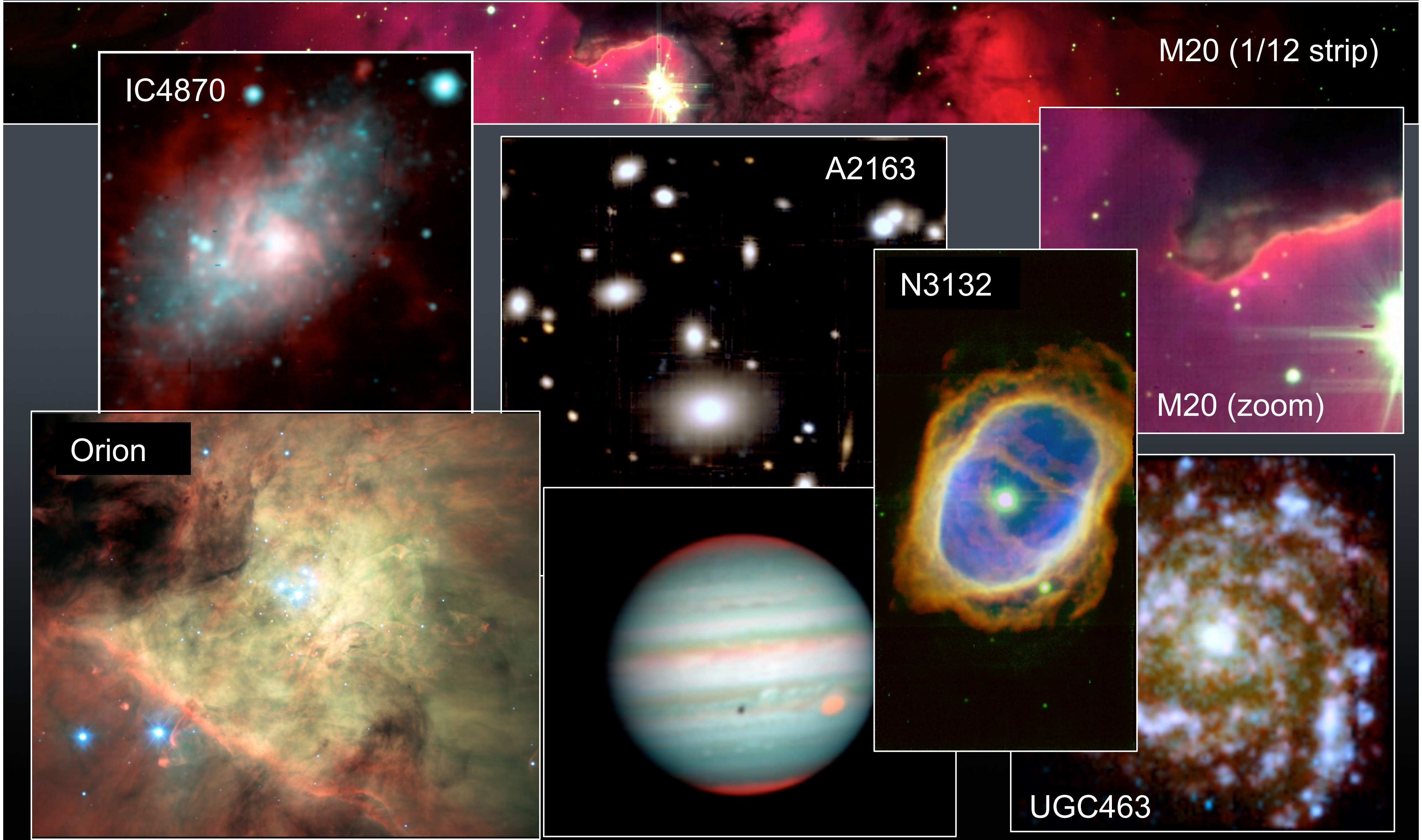


The most efficient of the VLT spectrographs in 500-850nm

465-930 nm in one go

(*) 17% Slit loss included in FORS2 & XSHOOTER (e.g. 1 arcsec slit with 0.8 arcsec seeing)

The MUSE gallery



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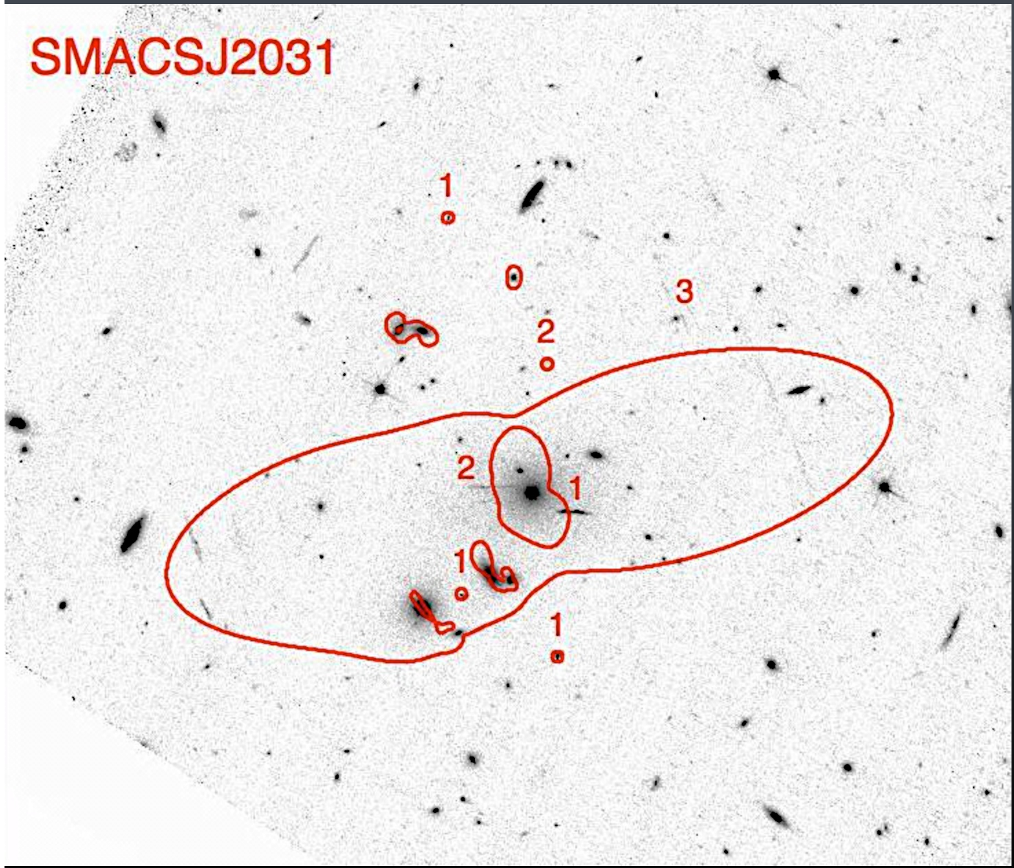
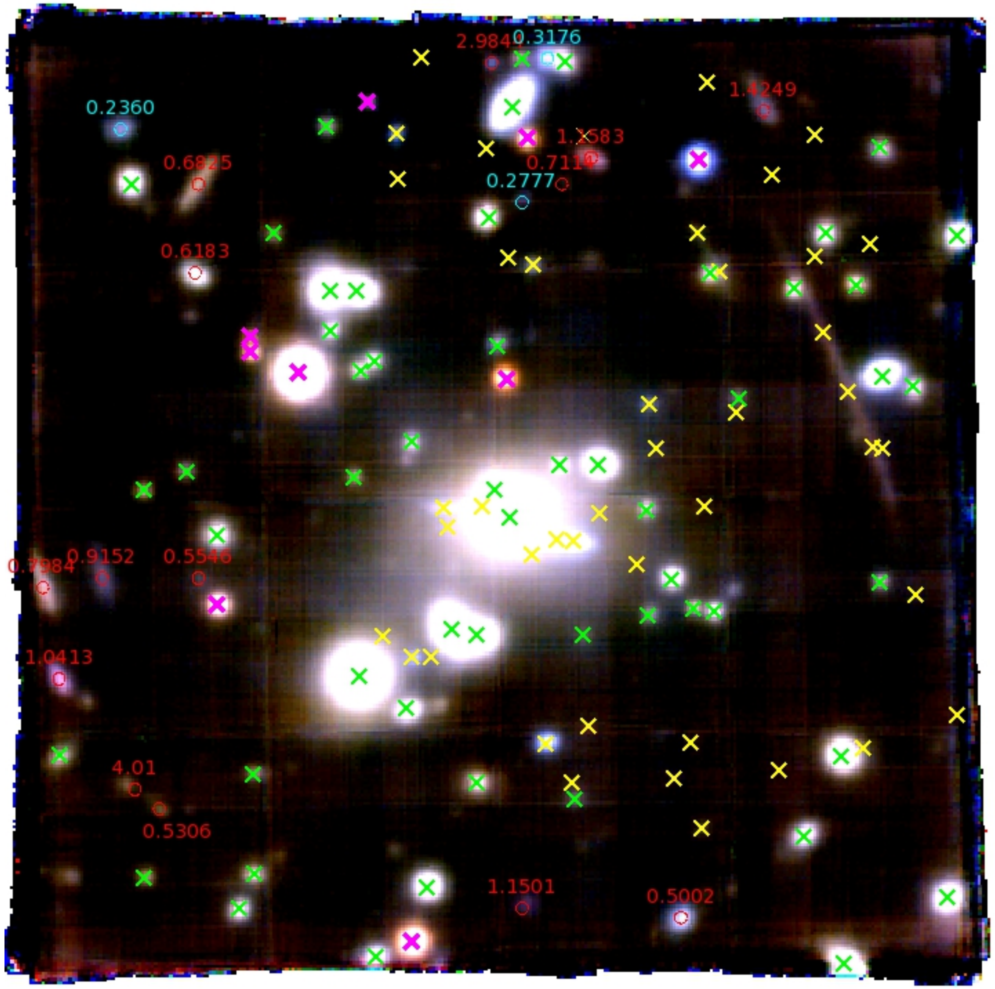
Lensing cluster test case: SMACSJ2031.8-4036

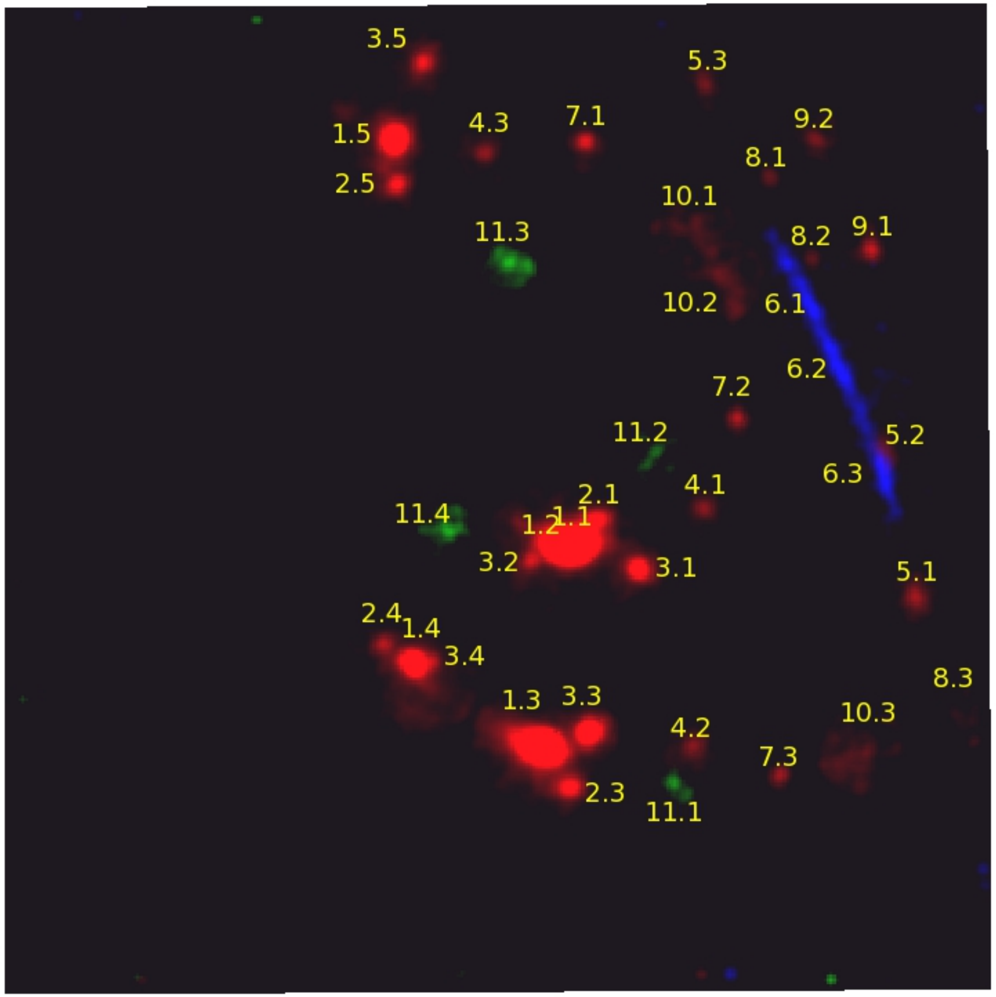


- Massive galaxy cluster at z=0.331
- HST imaging F606W/F814W
- Strong lensing constrained by 3 multiple systems
- 1 specz @ z=3.5073 (*Christensen et al. 2012a,b*)
- MUSE commissioning: 10 hrs in ~1.0-1.1” seeing

muse

Richard et al. 2015, MNRAS 446L, 16





Continuum color image **Composite narrow-band image**

Lyα CIII] [OII]

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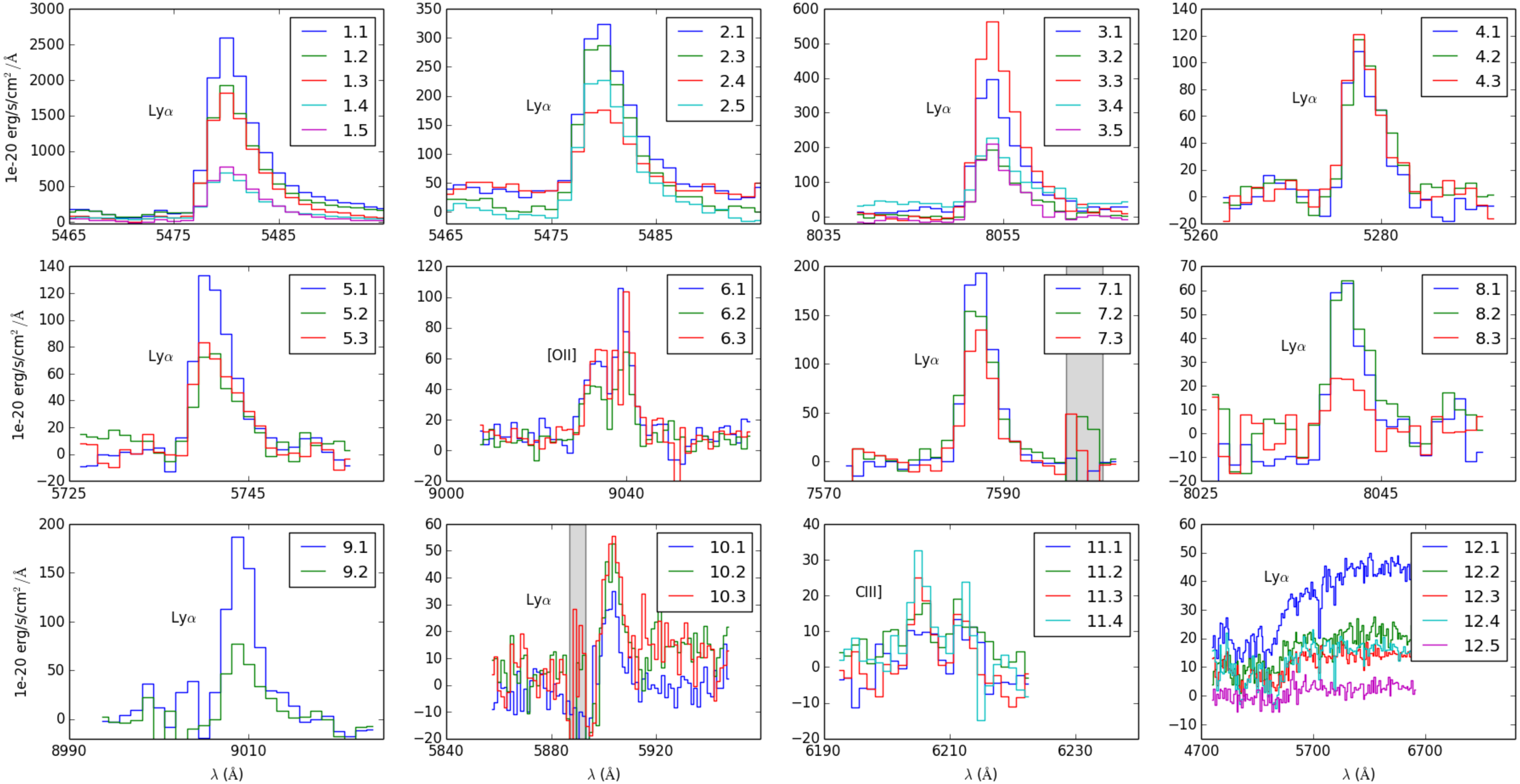
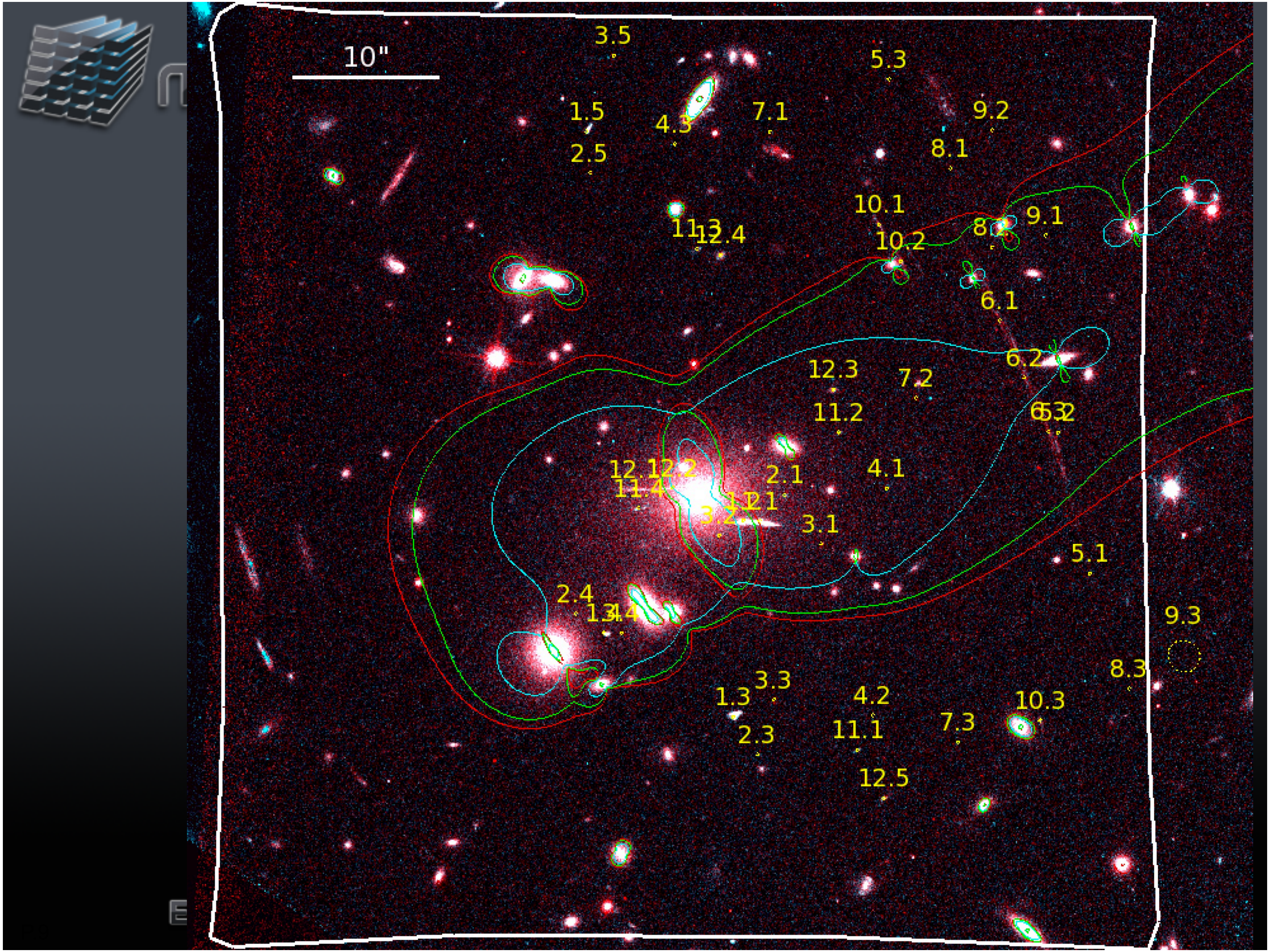
Richard et al. 2015, MNRAS 446L, 16

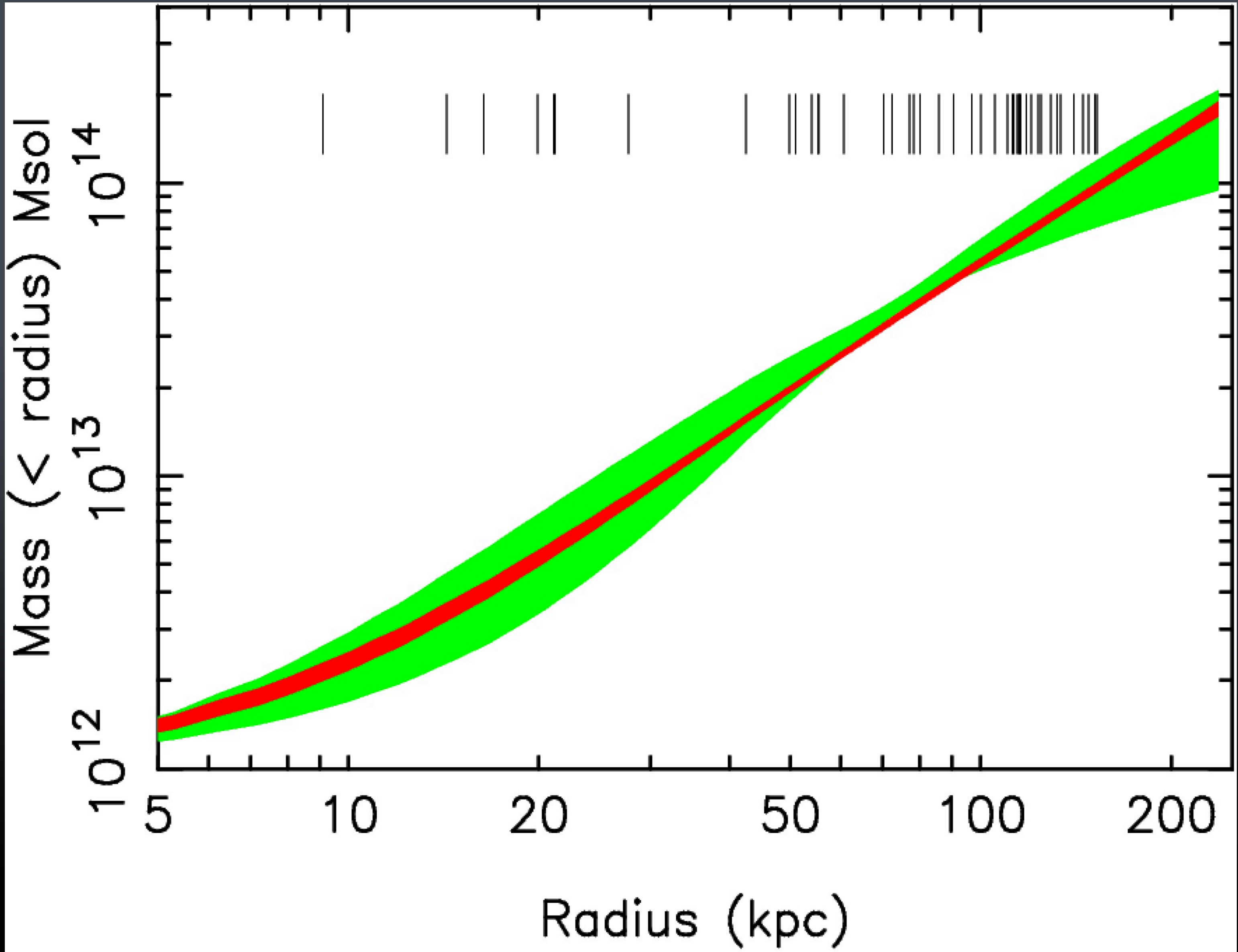


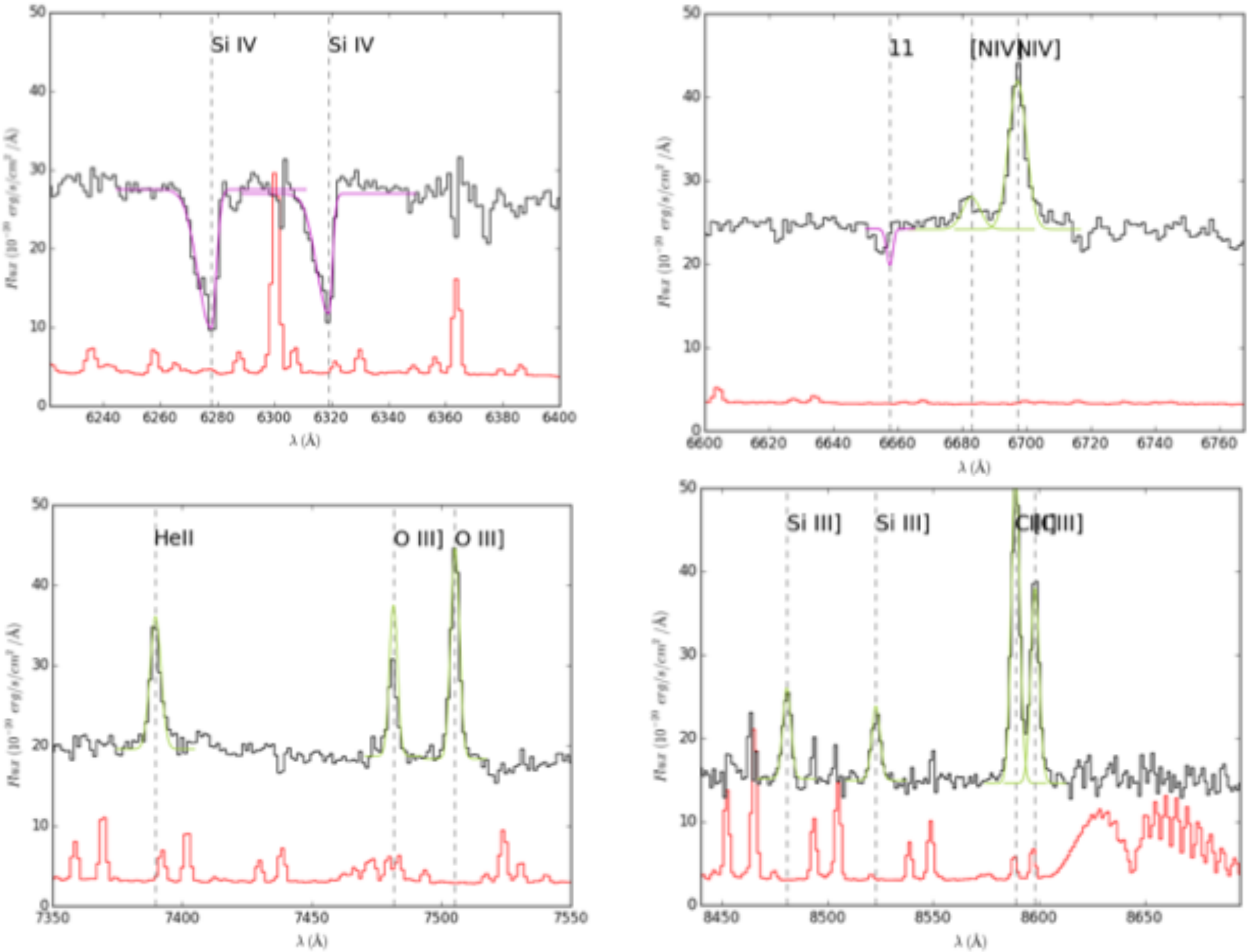
Confirmation and spectroscopic redshifts for 11 systems



10"
3.5
5.3
1.5
4.3
7.1
9.2
2.5
8.1
10.1
9.1
10.2
6.1
12.3
7.2
6.2
11.2
4.1
2.1
3.1
5.1
2.4
9.3
8.3
3.3
1.3
4.2
10.3
7.3
2.3
11.1
12.5

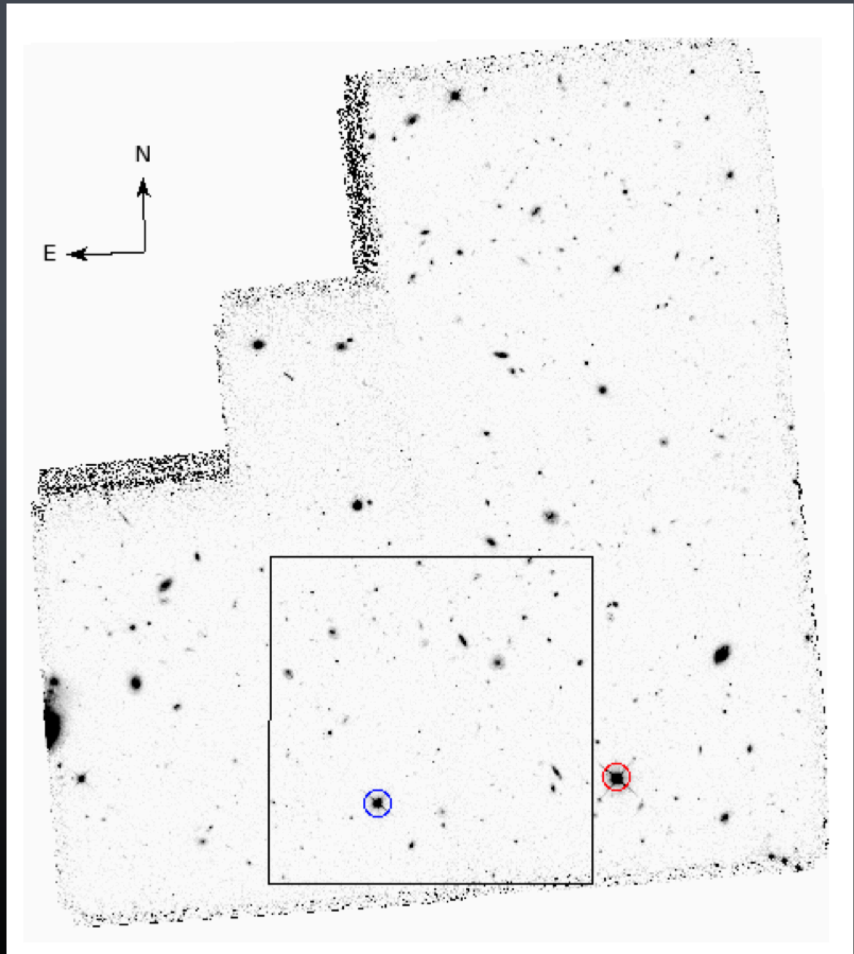
Richard et al. 2015, MNRAS 446L, 16




Si IV
Si IV
11
[NIV]
NIV]
HeII
O III]
O III]
Si III]
Si III]
CIII]
[CIII]
flux (10^{-20} erg/s/cm^2/Å)
λ (Å)

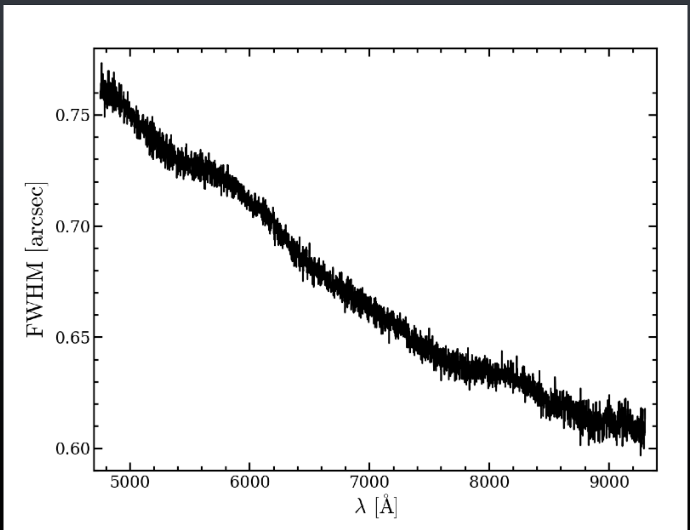
The Hubble Deep Field South

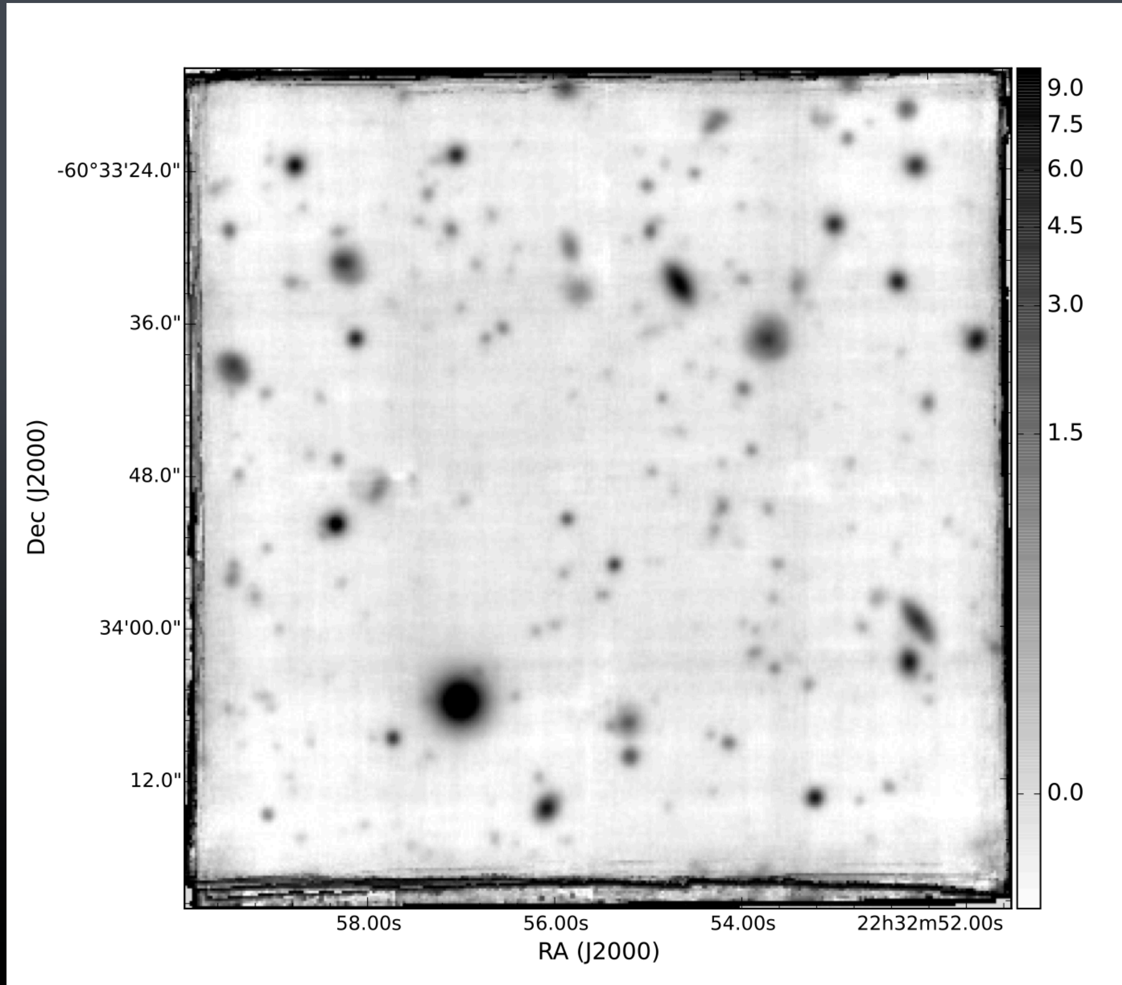
- **WFPC2 & NICMOS deep observations**
  - Williams R.et al (2000), Casertano, S. et al. (2000)
  - Limiting magnitude $AB_{F814W} > 29$
- **MUSE observations**
  - July 2014 during Comm2B run
  - 27 hours (54 exposures)



HDFS

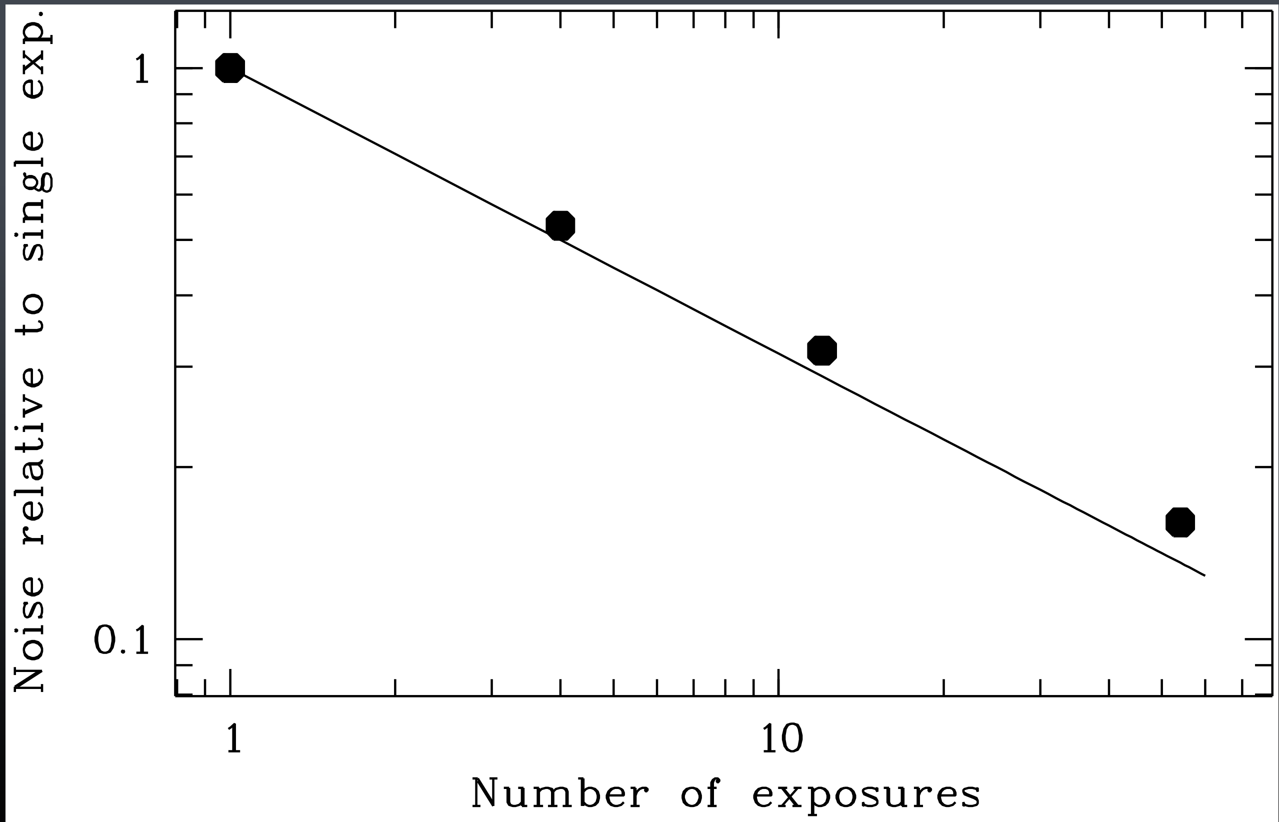
- White light image
  - Moffat FWHM 0.61-0.76 arcsec





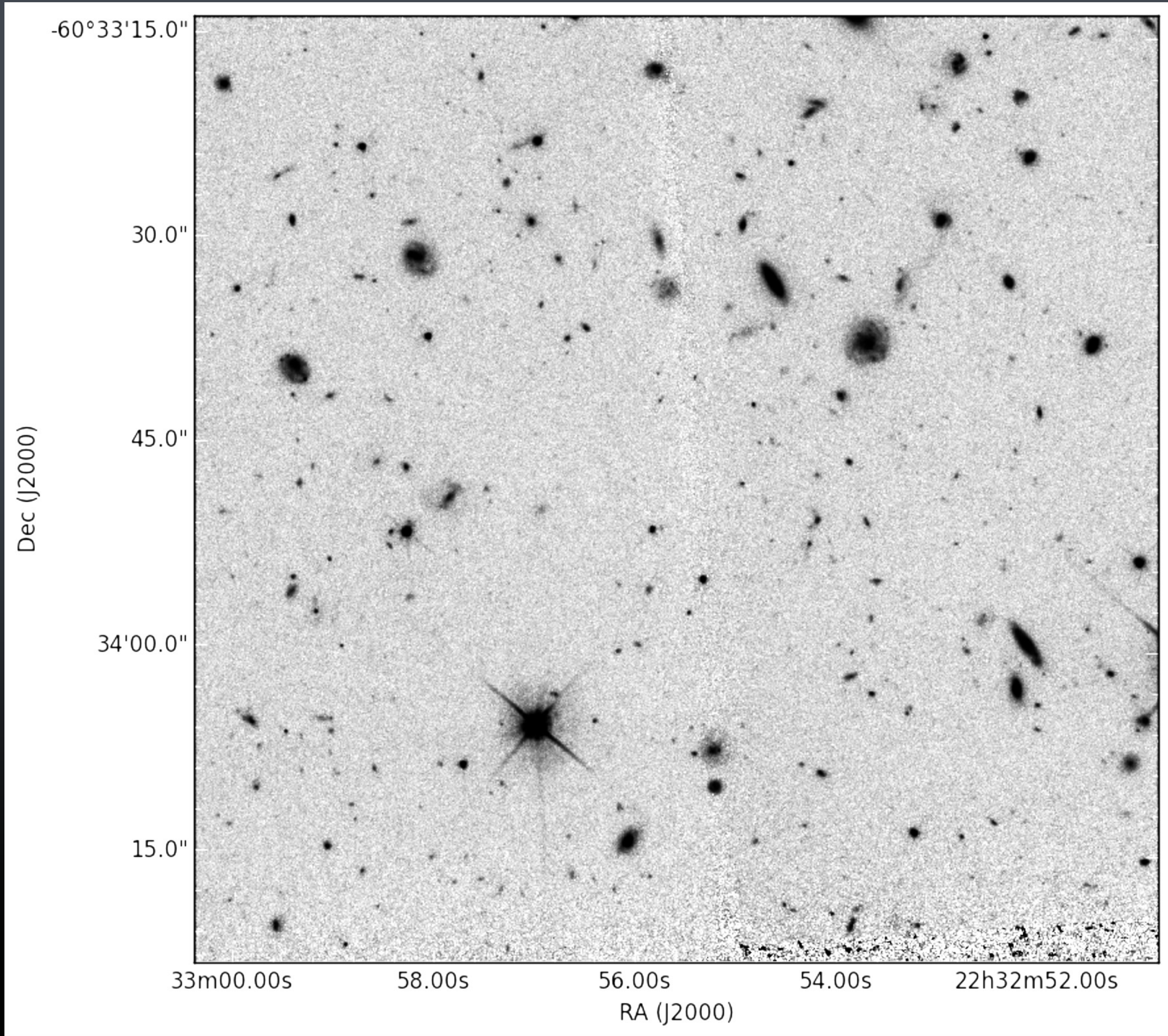
Noise properties

Limiting Line Flux (SNR=5) : 3 10^{-19} $erg.s^{-1}.cm^{-2}$



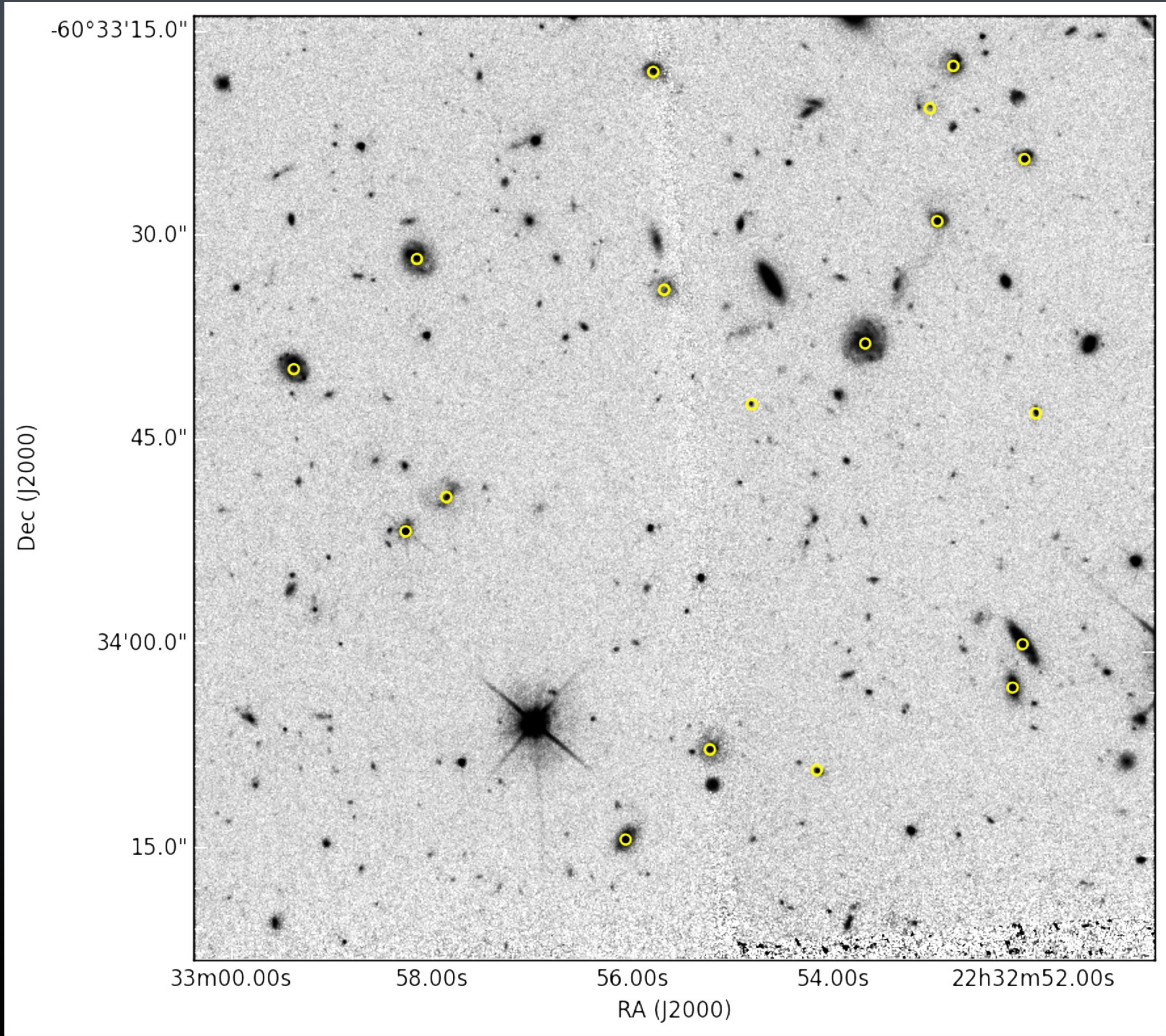
Census of MUSE HDFS Field

- ✓ **HST WFPC2 F814W**



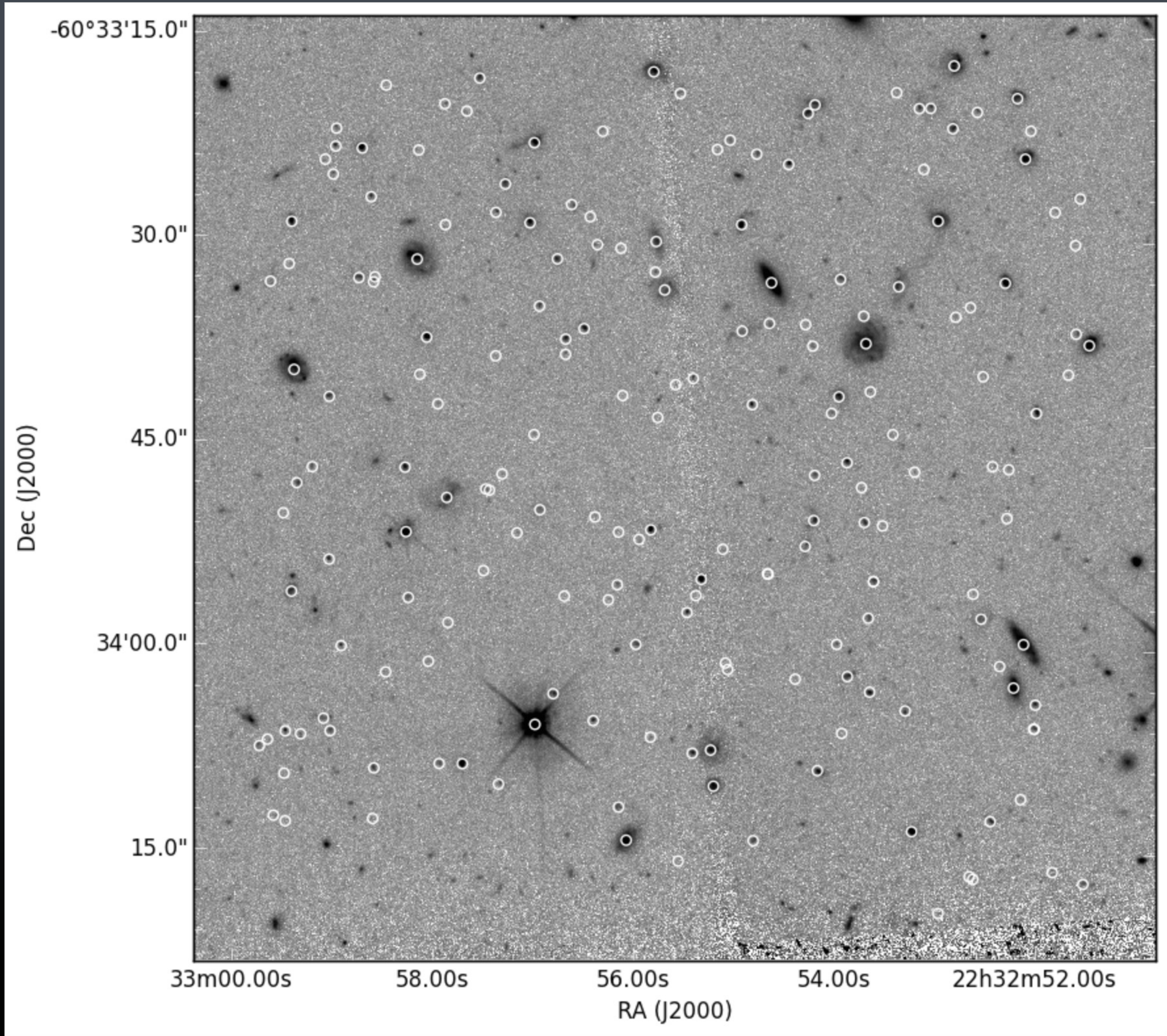
Census of MUSE HDFS Field

- ✓ HST WFPC2 F814W
- ✓ 18 Known Spectroscopic Redshifts



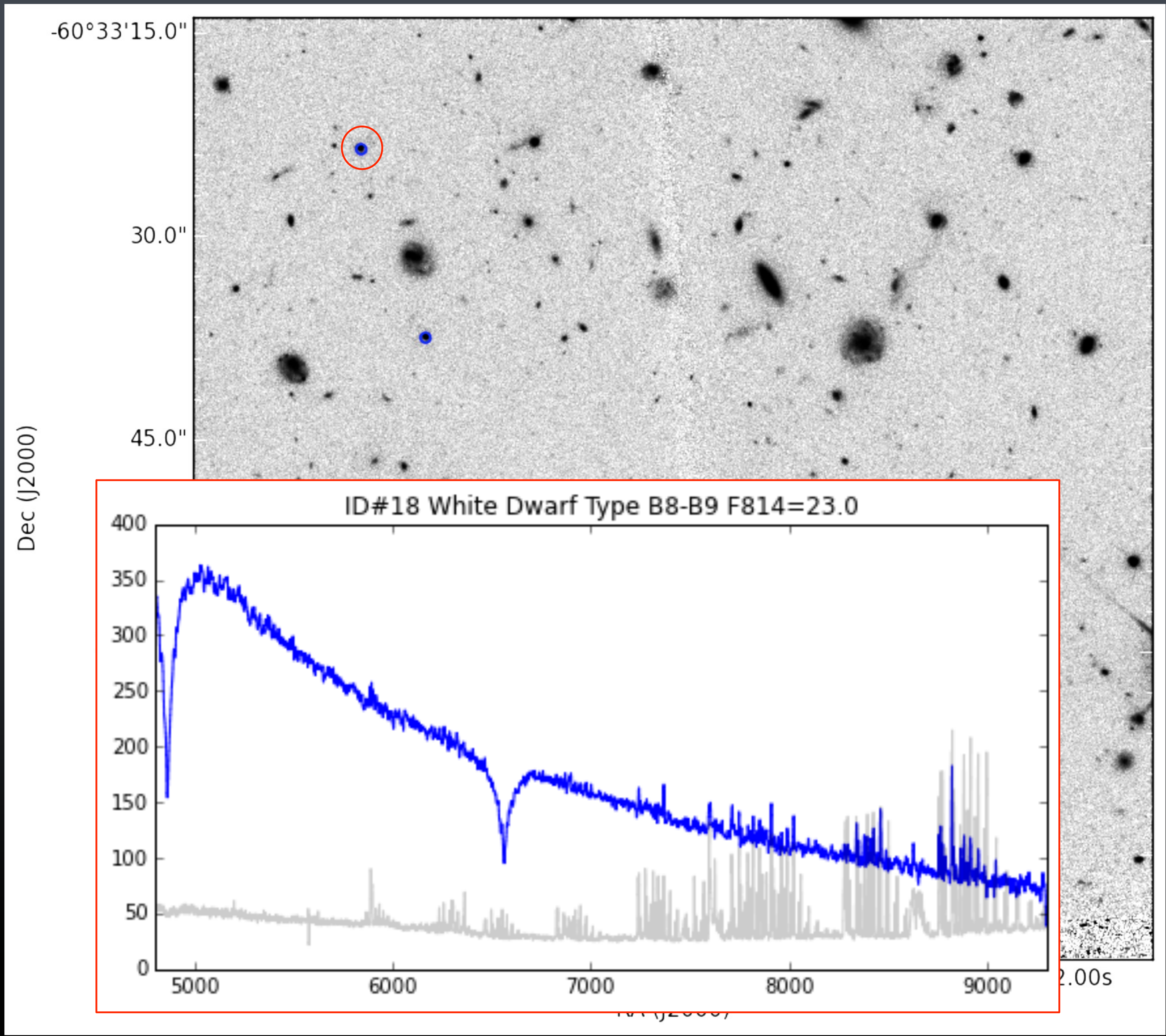
Census of MUSE HDFS Field

- ✓ HST WFPC2 F814W
- ✓ 18 Known Spectroscopic Redshifts
- ✓ 189 sources identified in MUSE data cube



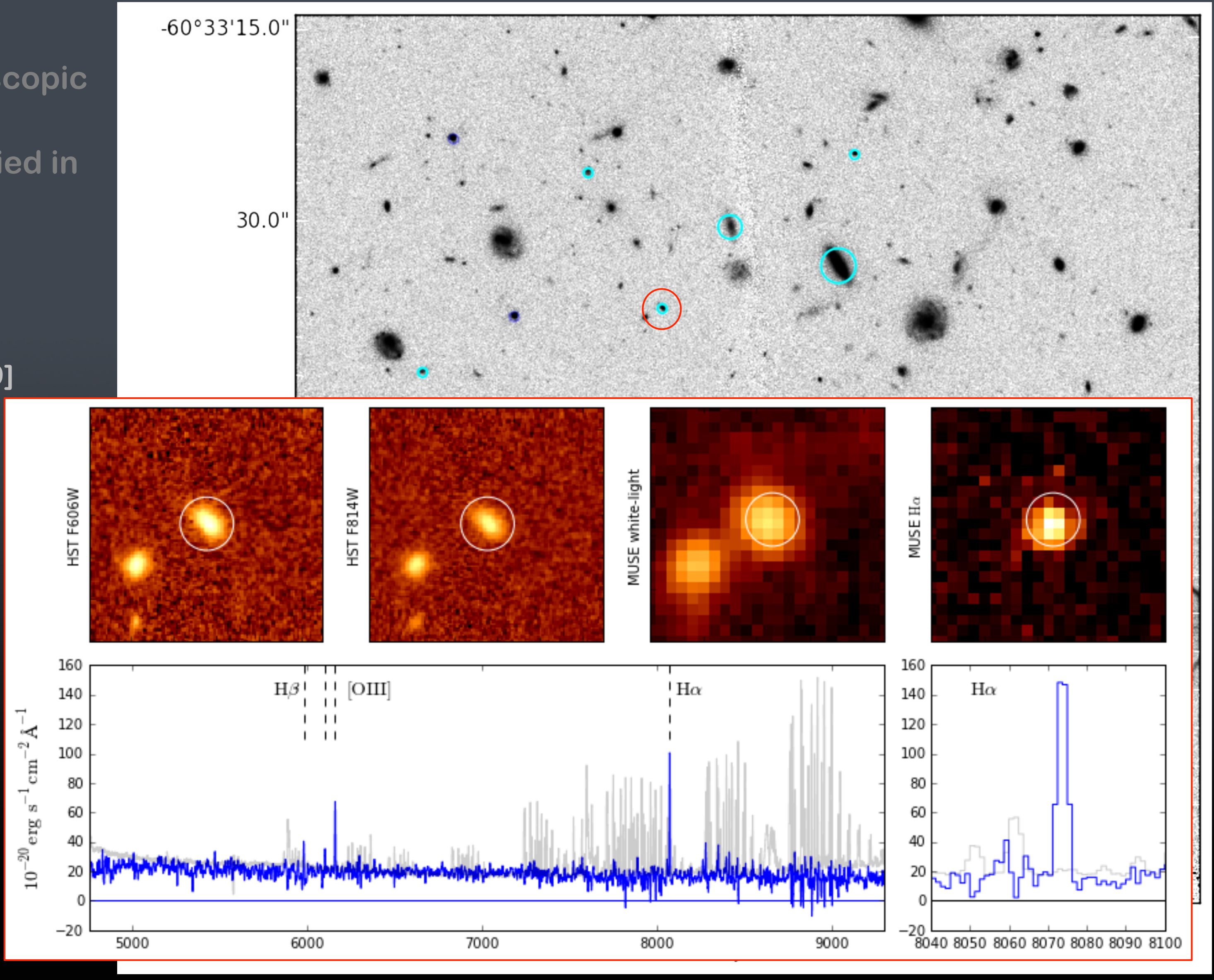
Census of MUSE HDFS Field

- ✓ HST WFPC2 F814W
- ✓ 18 Known Spectroscopic Redshifts
- ✓ 189 sources identified in MUSE data cube
- ✓ 8 stars
  - ✓ F814W = [18.6 – 23.9]
  - ✓ 7 already identified using proper motion (Kilic et al, 2005)



Census of MUSE HDFS Field

- ✓ HST WFPC2 F814W
- ✓ 18 Known Spectroscopic Redshifts
- ✓ 189 sources identified in MUSE data cube
- ✓ 8 stars
- ✓ **7 nearby galaxies**
  - ✓ Z = [0.12 – 0.28]
  - ✓ I_{814} = [21.2 – 25.9]

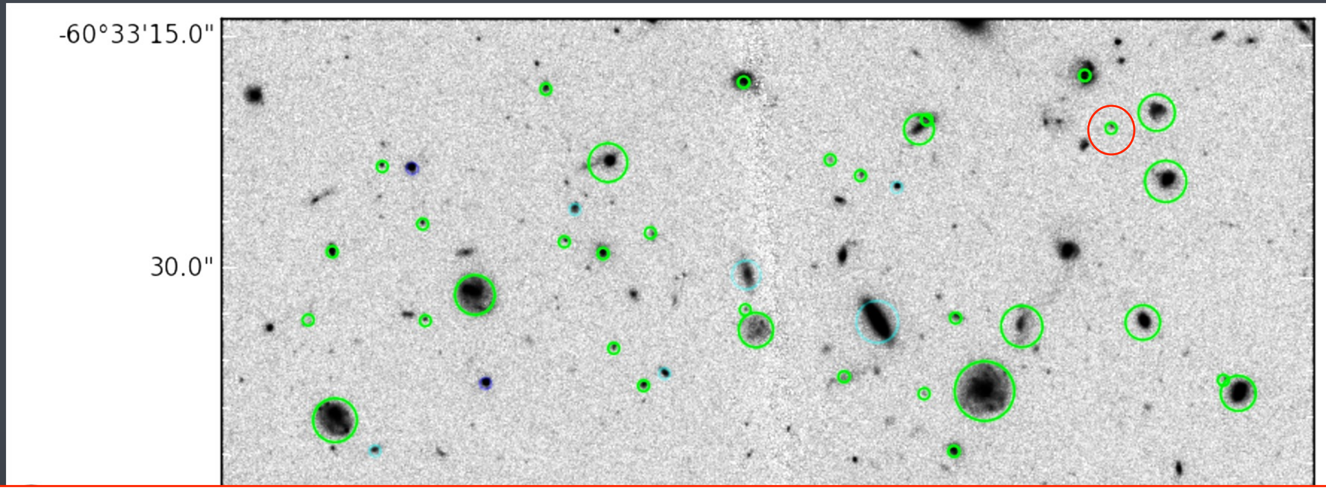


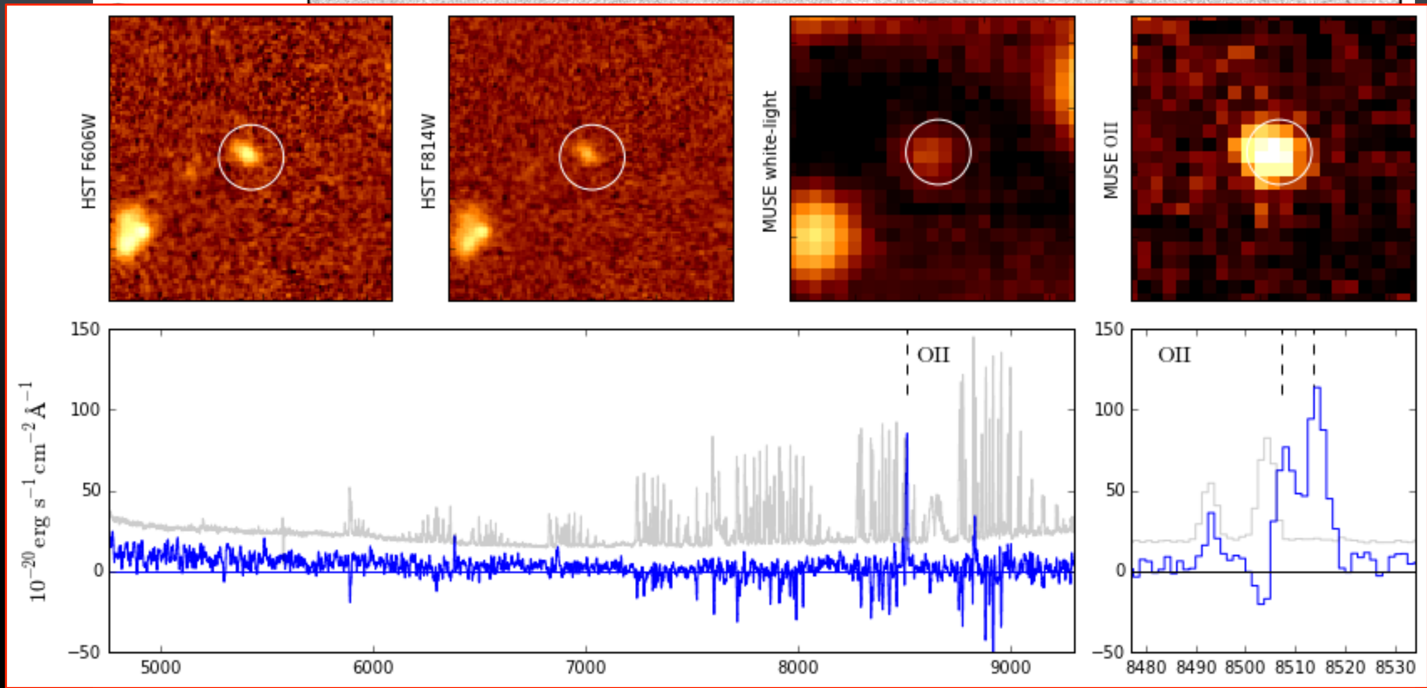
ID#53

Z = 0.23
I_{814} = 24.9
M ≈ 2 10^7 $M_\odot$

Census of MUSE HDFS Field

- ✓ HST WFPC2 F814W
- ✓ 18 Known Spectroscopic Redshifts
- ✓ 189 sources identified in MUSE data cube
- ✓ 8 stars
- ✓ 7 nearby galaxies
- ✓ **61 [OII] 3727 emitters**
    - ✓ Z = [0.29 – 1.48]
    - ✓ I_{814} = [21.5 – 28.5]





ID#160

Z = 1.28
I_{814} = 26.7
M ≈ 2 10^9 $M_\odot$

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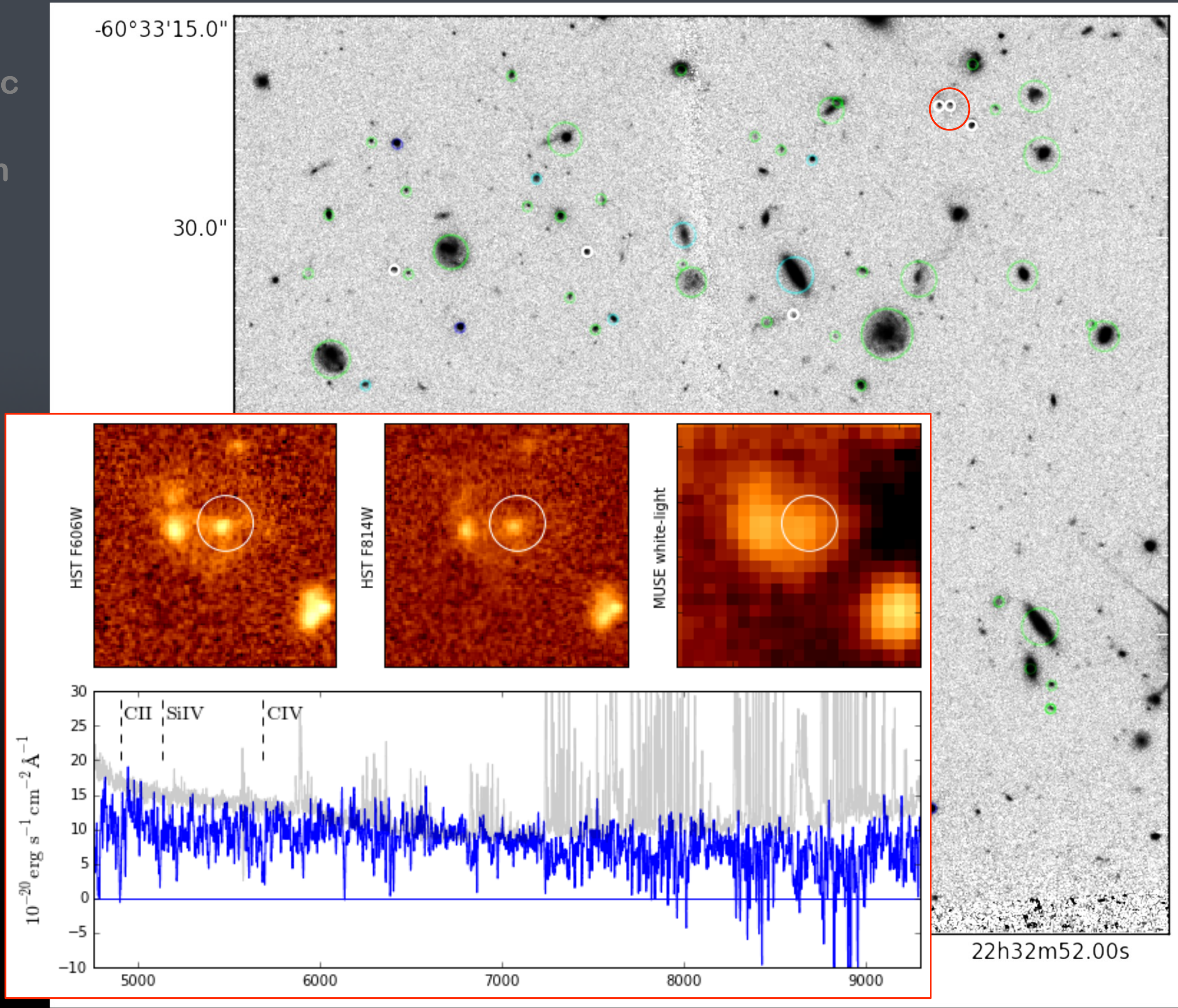
Census of MUSE HDFS Field

- ✓ HST WFPC2 F814W
- ✓ 18 Known Spectroscopic Redshifts
- ✓ 189 sources identified in MUSE data cube
- ✓ 8 stars
- ✓ 7 nearby galaxies
- ✓ 61 [OII] 3727 emitters
- ✓ **10 absorption lines galaxies**
  - ✓ Z = [0.83 – 2.90]
  - ✓ I_{814} = [24.9 – 26.2]

ID#55

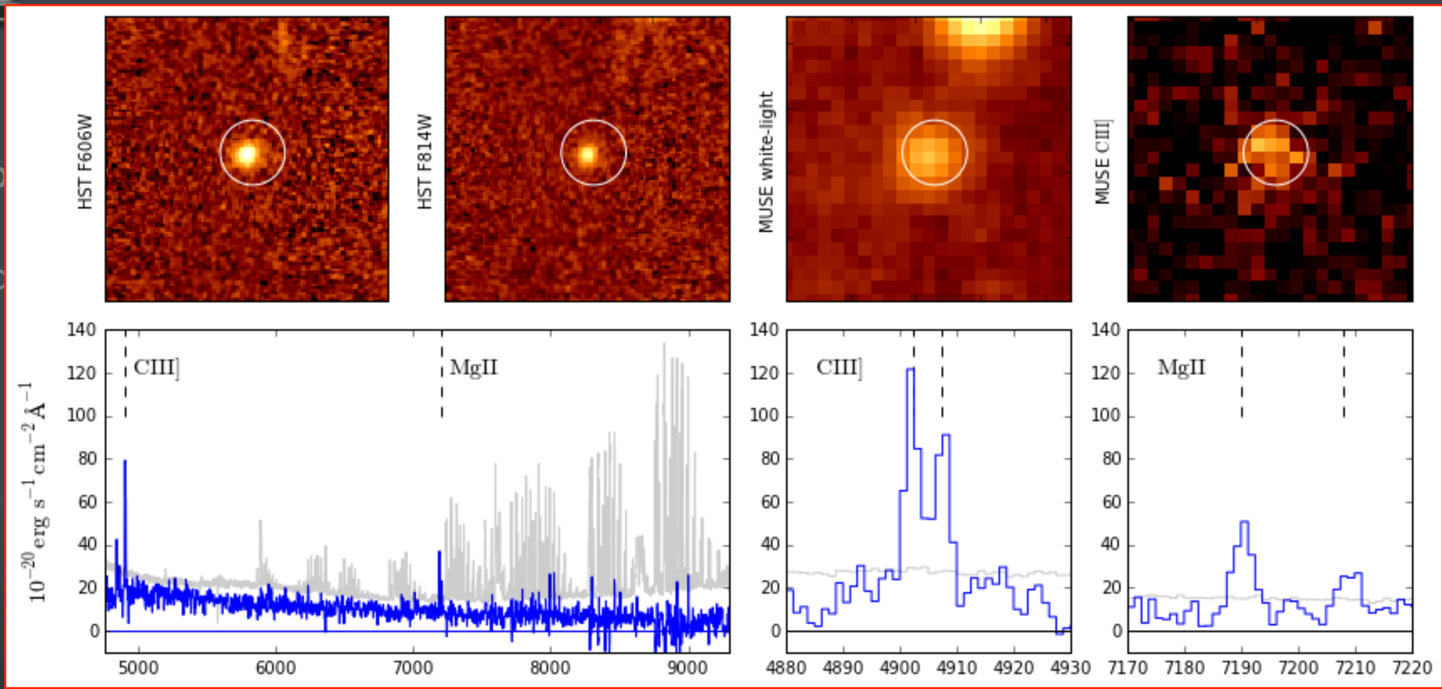
Z = 2.67

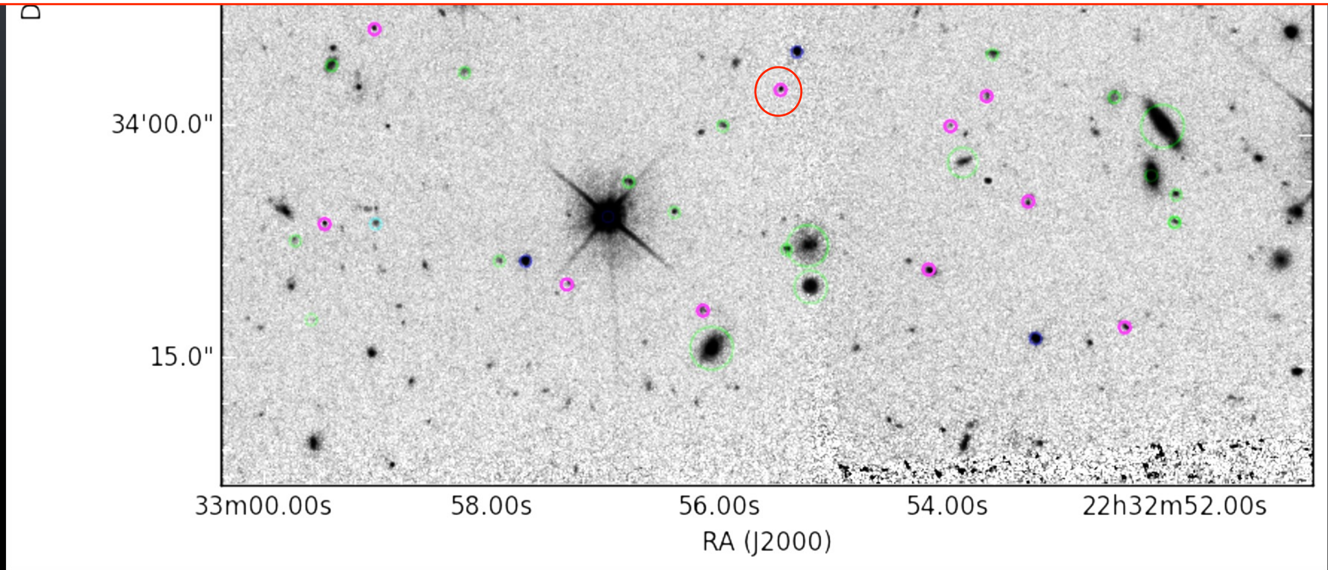
I_{814} = 24.8



Census of MUSE HDFS Field

- ✓ HST WFPC2 F814W
- ✓ 18 Known Spectrosco Redshifts
- ✓ 189 sources identified MUSE data cube
- ✓ 8 stars
- ✓ 7 nearby galaxies
- ✓ 61 [OII] 3727 emitters
- ✓ 10 absorption lines galaxies
- ✓ **12 CIII] 1909 emitters**
  - ✓ Z = [1.57 – 2.67]
  - ✓ I_{814} = [24.6 – 27.2]





ID#97

Z = 1.57
I_{814} = 25.9

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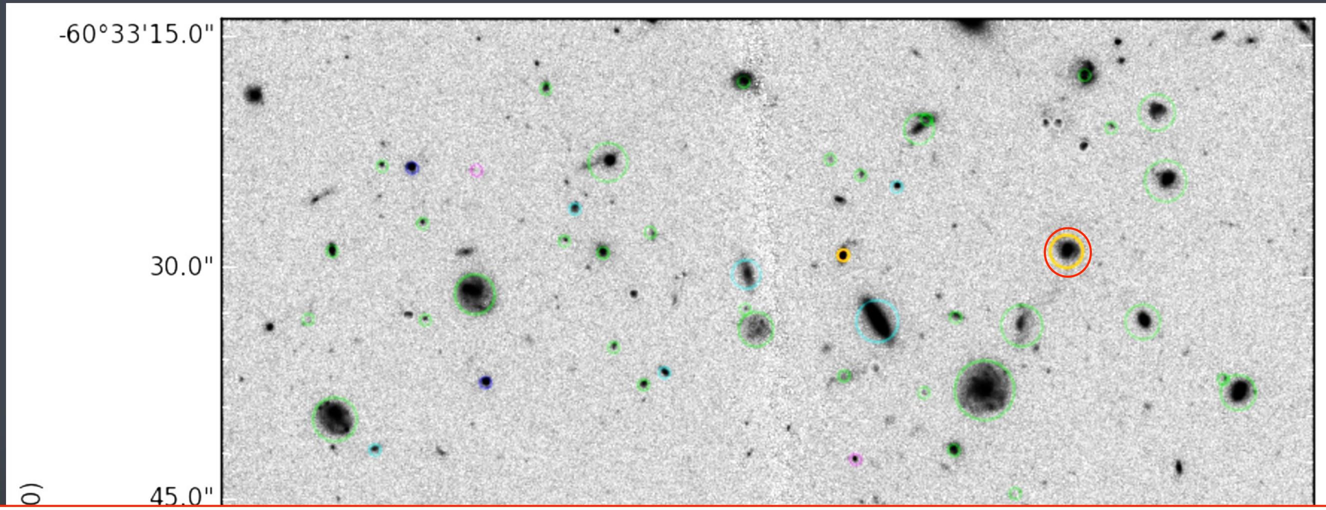
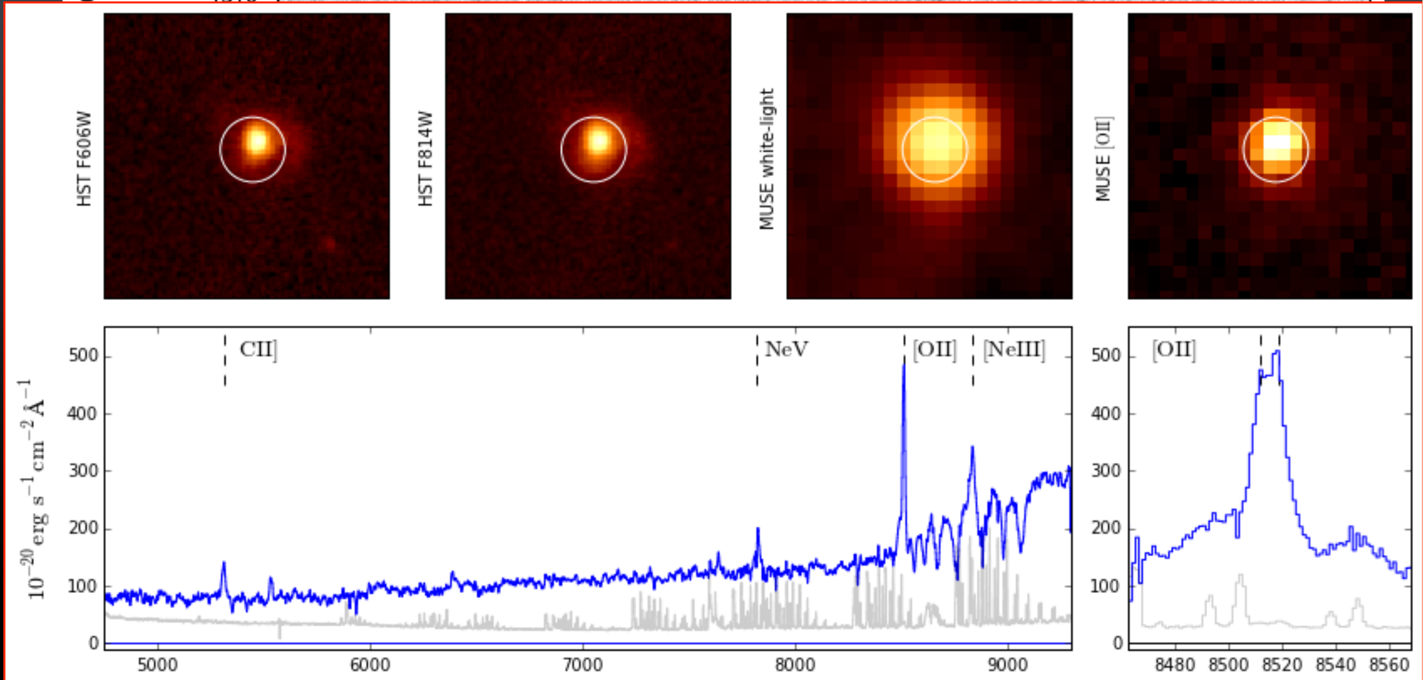
Census of MUSE HDFS Field

- ✓ HST WFPC2 F814W
- ✓ 18 Known Spectroscopic Redshifts
- ✓ 189 sources identified in MUSE data cube
- ✓ 8 stars
- ✓ 7 nearby galaxies
- ✓ 61 [OII] 3727 emitters
- ✓ 10 absorption lines galaxies
- ✓ 12 CIII] 1909 emitters
- ✓ **2 AGNs**
  - ✓ Z = 1.28
  - ✓ I_{814} = 22.6, 23.6

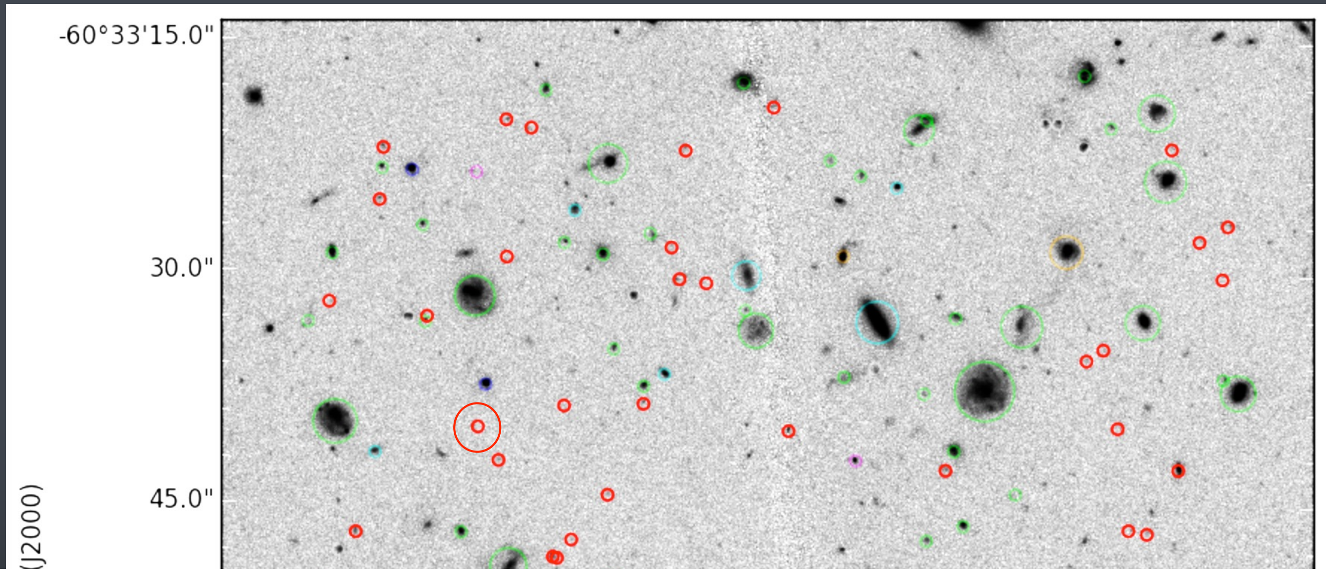


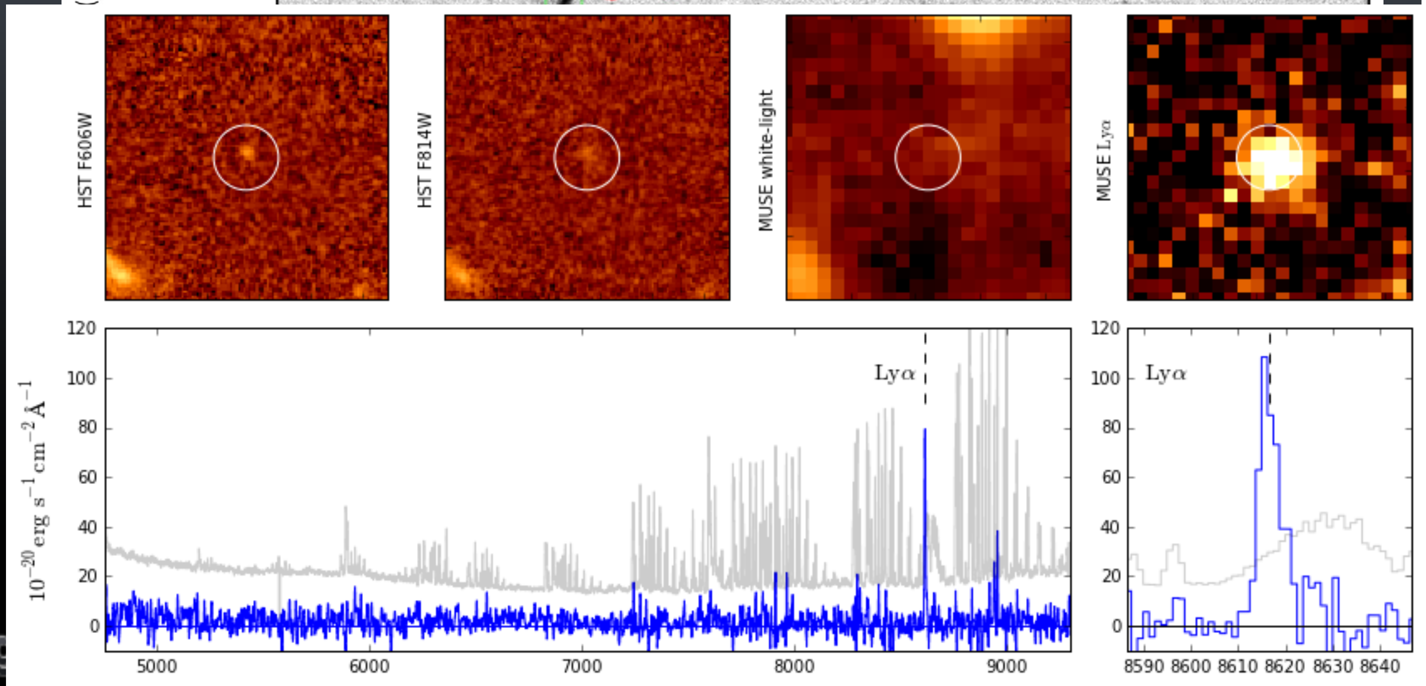


ID#10

Z = 1.28
I_{814} = 22.5

- ✓ HST WFPC2 F814W
- ✓ 18 Known Spectroscopic Redshifts
- ✓ 189 sources identified in MUSE data cube
- ✓ 8 stars
- ✓ 7 nearby galaxies
- ✓ 61 [OII] 3727 emitters
- ✓ 10 absorption lines galaxies
- ✓ 12 CIII] 1909 emitters
- ✓ 2 AGNs
- ✓ **63 Lyα emitters**
  - ✓ Z = [2.95 – 6.28]
  - ✓ I_{814} = [24.5 – 29.6]



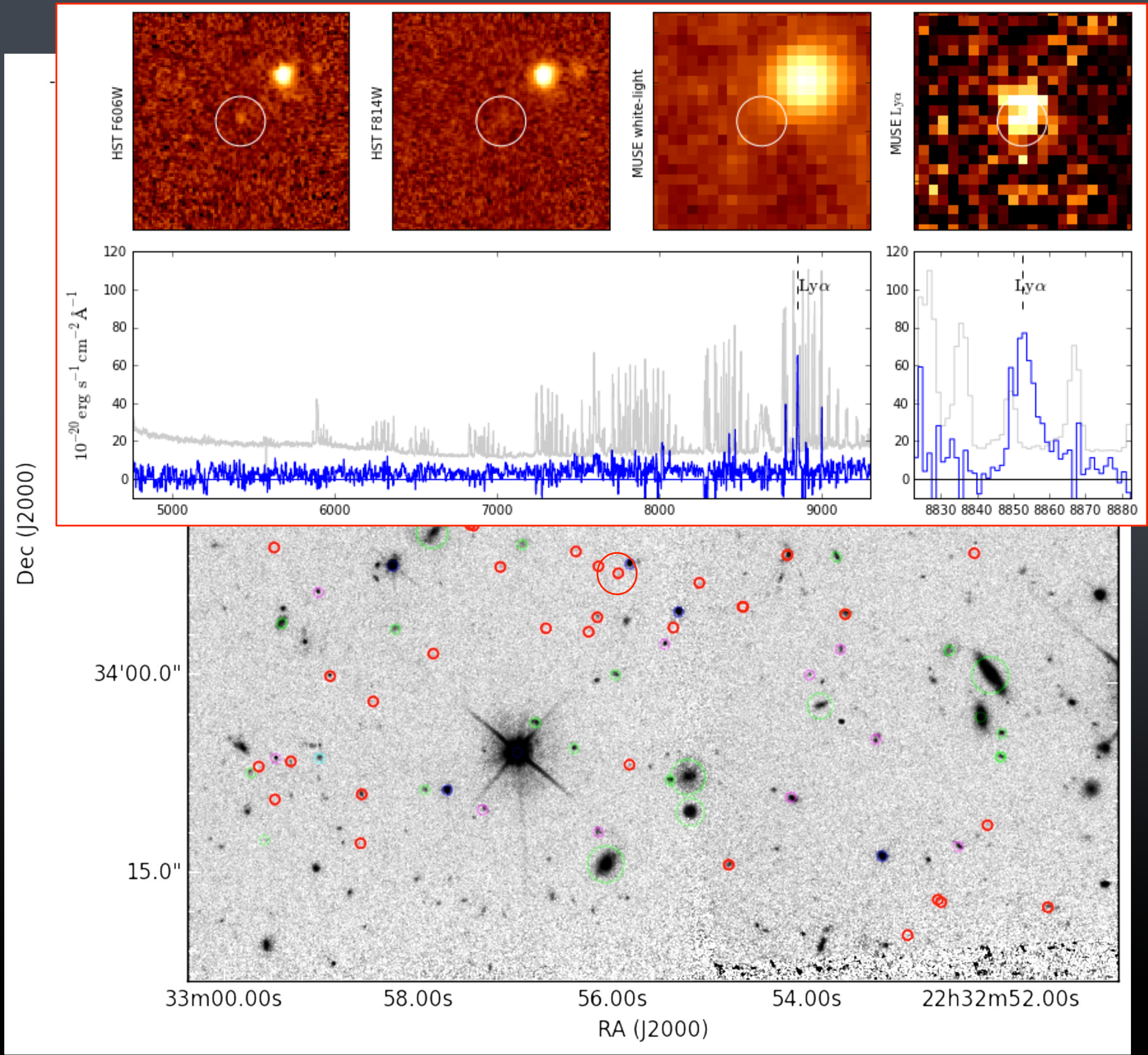


ID#290

Z = 6.08
I_{814} = 27.8

MUSE

- ✓ HST WFPC2 F814W
- ✓ 18 Known Spectroscopic Redshifts
- ✓ 189 sources identified in MUSE data cube
- ✓ 8 stars
- ✓ 7 nearby galaxies
- ✓ 61 [OII] 3727 emitters
- ✓ 10 absorption lines galaxies
- ✓ 12 CIII] 1909 emitters
- ✓ 2 AGNs
- ✓ **63 Lyα emitters**
  - ✓ Z = [2.95 – 6.28]
  - ✓ I_{814} = [24.5 – 29.6]



ID#430

Z = 6.28
I_{814} = 28.6

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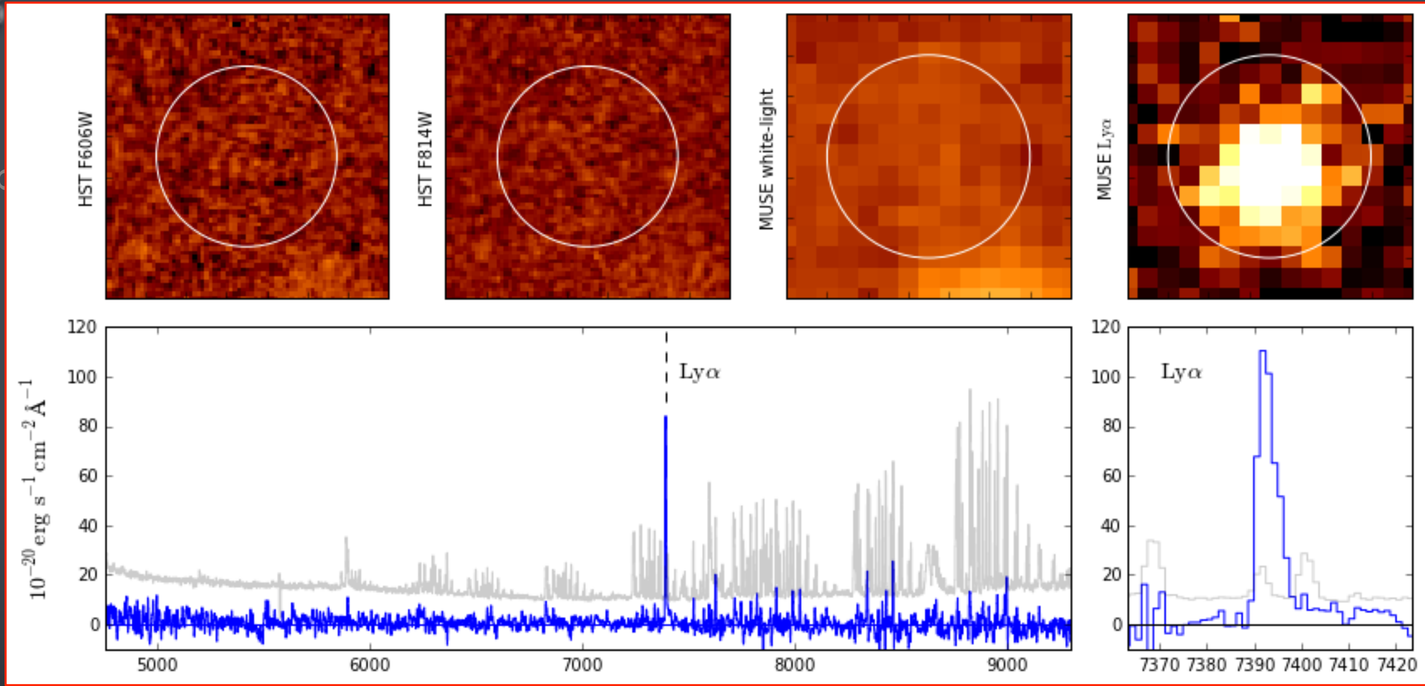
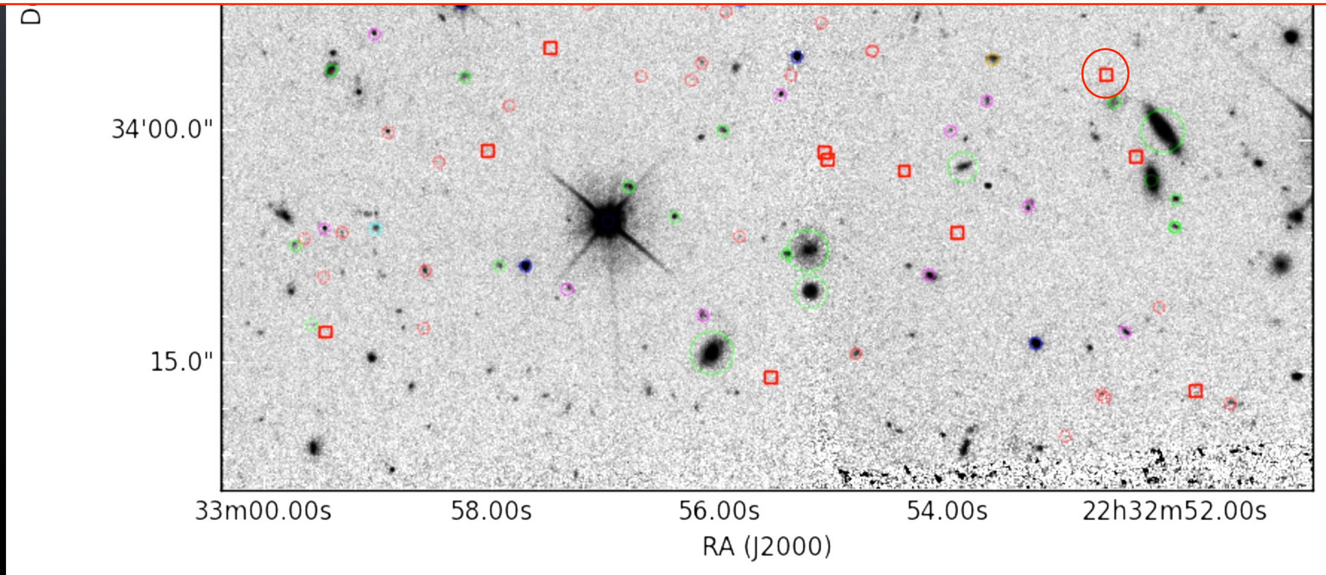
Census of MUSE HDFS Field

ID#553

Z = 5.08
$I_{814} > 29.8$

- H
- 1
  R
- 1
  M
- 8 stars
- 7 nearby galaxies
- 61 [OII] 3727 emitters
- 10 absorption lines galaxies
- 12 CIII] 1909 emitters
- 2 AGNs
- 63 Lyα emitters
- **26 Lyα emitters without HST counterpart**
  - Z = [3.12 – 6.27]
  - $I_{814} > 29.8$



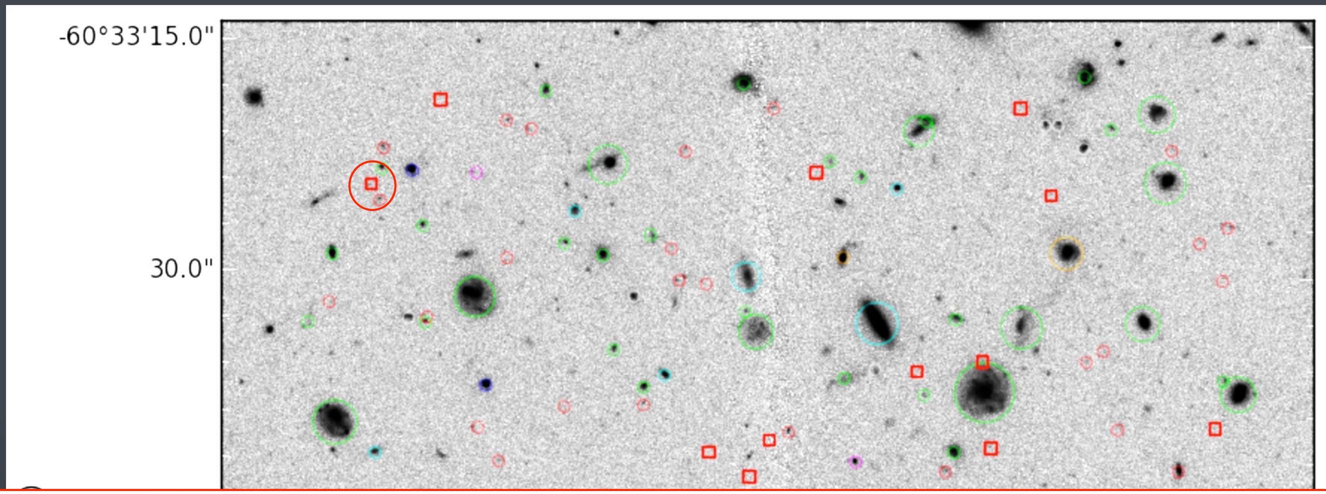


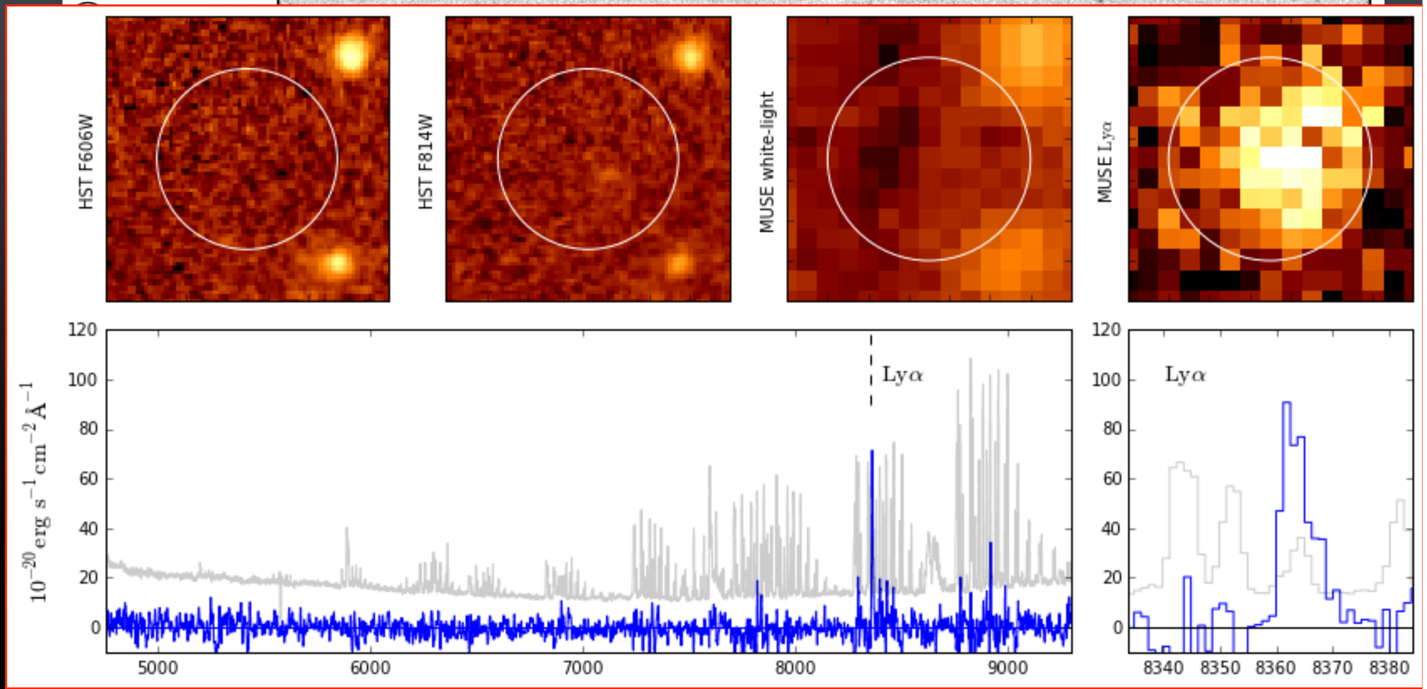
Census of MUSE HDFS Field

- ✓ HST
- ✓ 18 k
  Red
- ✓ 189
  MU
- ✓ 8 stars
- ✓ 7 nearby galaxies
- ✓ 61 [OII] 3727 emitters
- ✓ 10 absorption lines galaxies
- ✓ 12 CIII] 1909 emitters
- ✓ 2 AGNs
- ✓ 63 Lyα emitters
- ✓ **26 Lyα emitters without HST counterpart**
  - ✓ Z = [3.12 – 6.27]
  - ✓ $I_{814} > 29.8$

ID#560

Z = 5.88
$I_{814} > 29.8$





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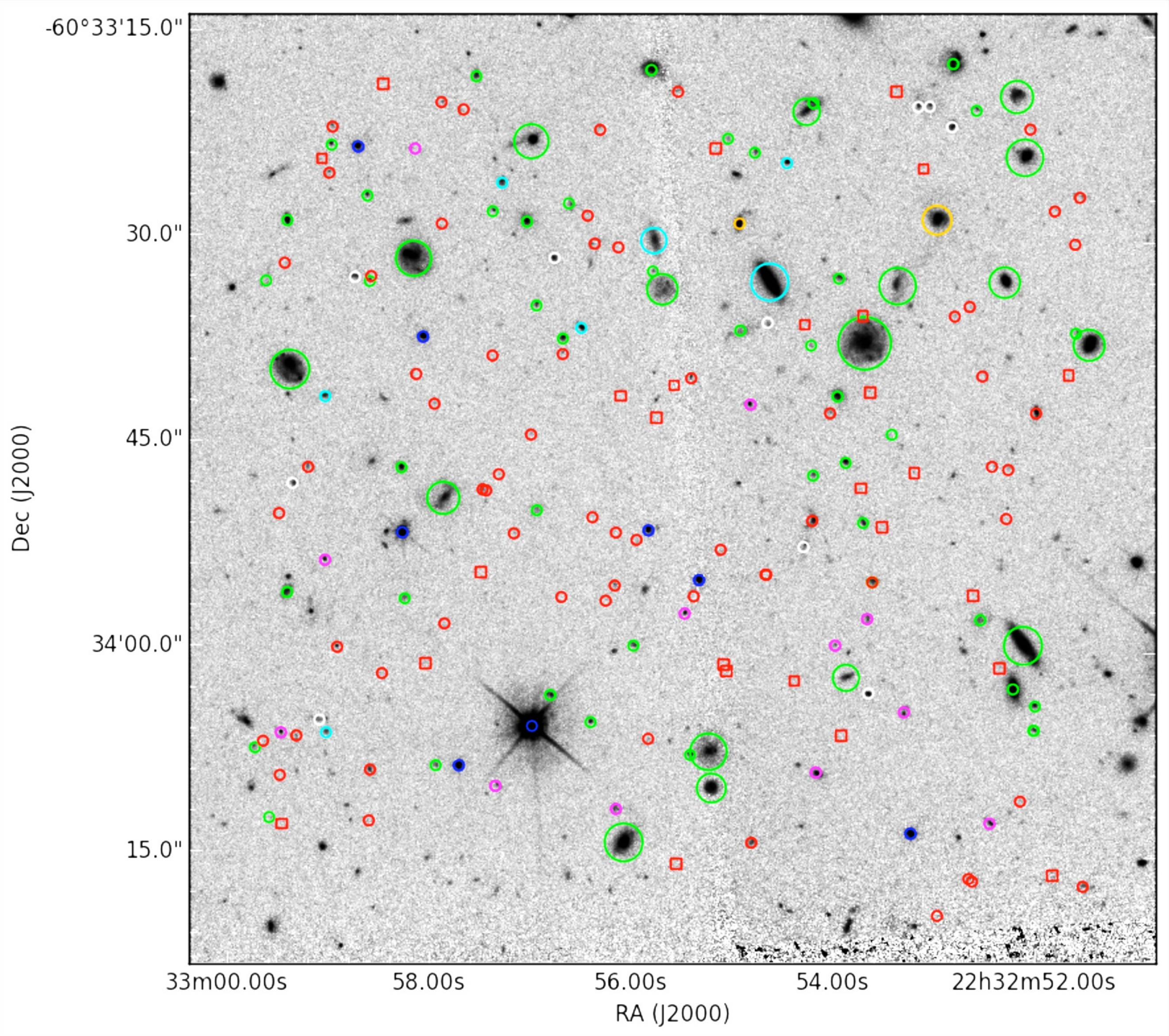
Census of MUSE HDFS Field

- ✓ HST WFPC2 F812W
- ✓ 18 Known Spectroscopic Redshifts
- ✓ 189 sources identified in MUSE data cube
- ✓ 8 stars
- ✓ 7 nearby galaxies
- ✓ 61 [OII] 3727 emitters
- ✓ 10 absorption lines galaxies
- ✓ 12 CIII] 1909 emitters
- ✓ 2 AGNs
- ✓ 89 Lyα emitters



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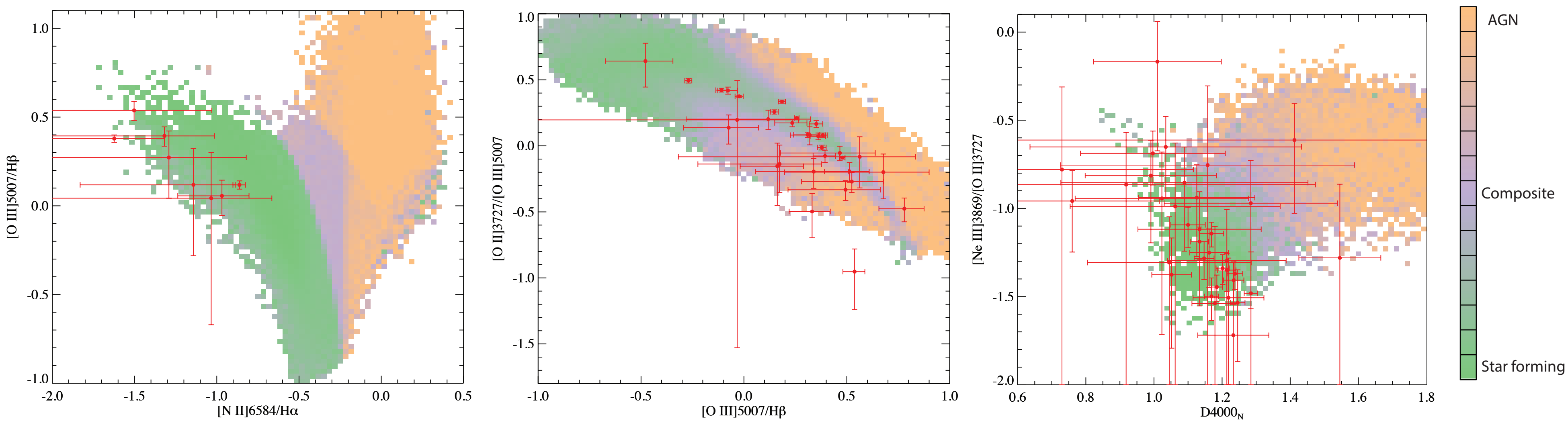
Diagnostic Diagrams



[NII]/Hα vs [OIII]/Hβ

[OIII]/Hβ vs [O II]/[OIII]

D4000N vs [NeIII]/[OII]

Most HDFS galaxies (z < 1.3) are star-forming galaxies

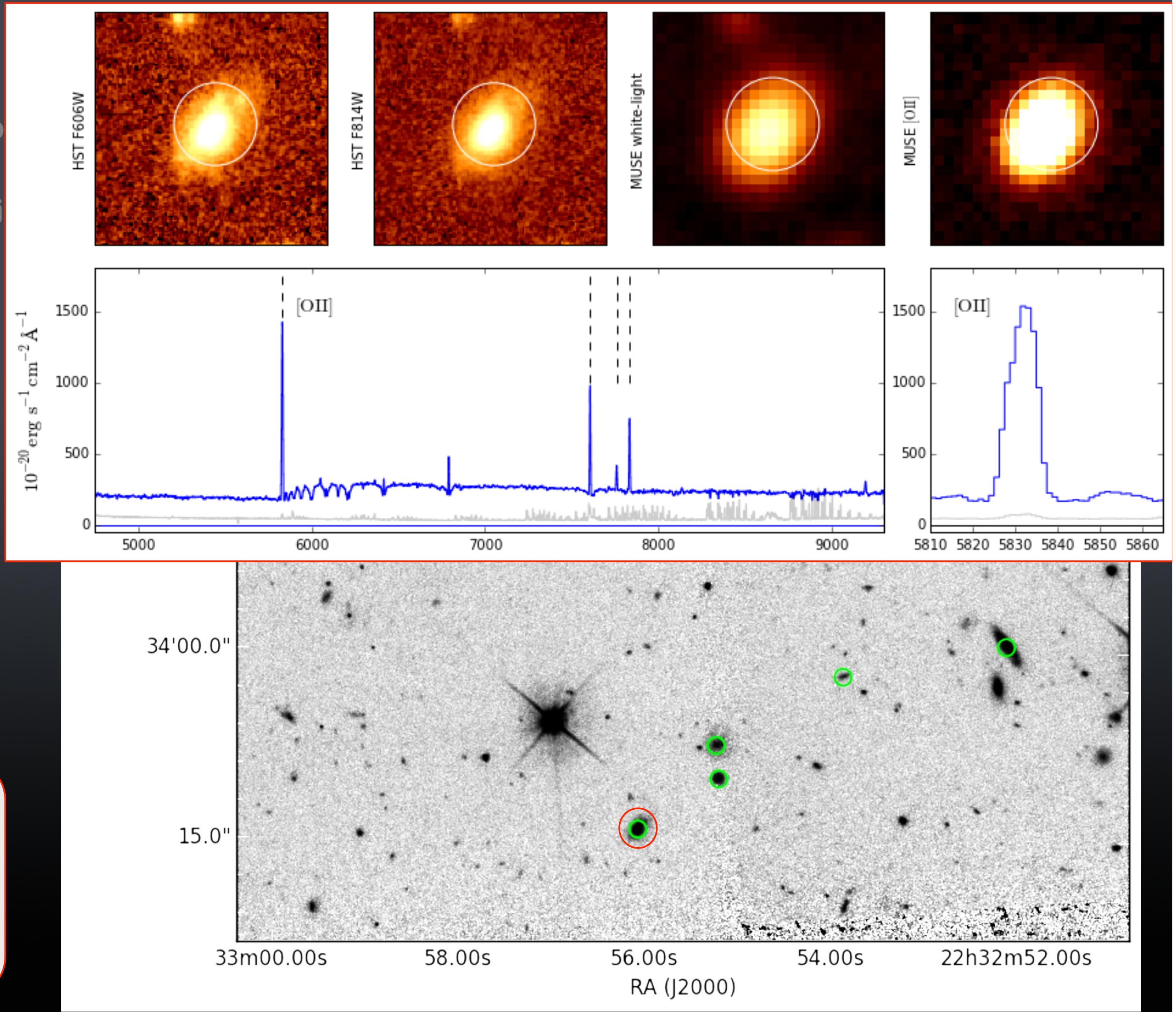
Census of MUSE HDFS Field

- ✓ HST WFPC2 F812W
- ✓ 18 Known Spectroscop
  Redshifts
- ✓ 189 sources identified i
  MUSE data cube
- ✓ 8 stars
- ✓ 7 nearby galaxies
- ✓ 61 [OII] 3727 emitters
- ✓ 10 absorption lines
  galaxies
- ✓ 12 CIII] 1909 emitters
- ✓ 2 AGNs
- ✓ 89 Lyα emitters

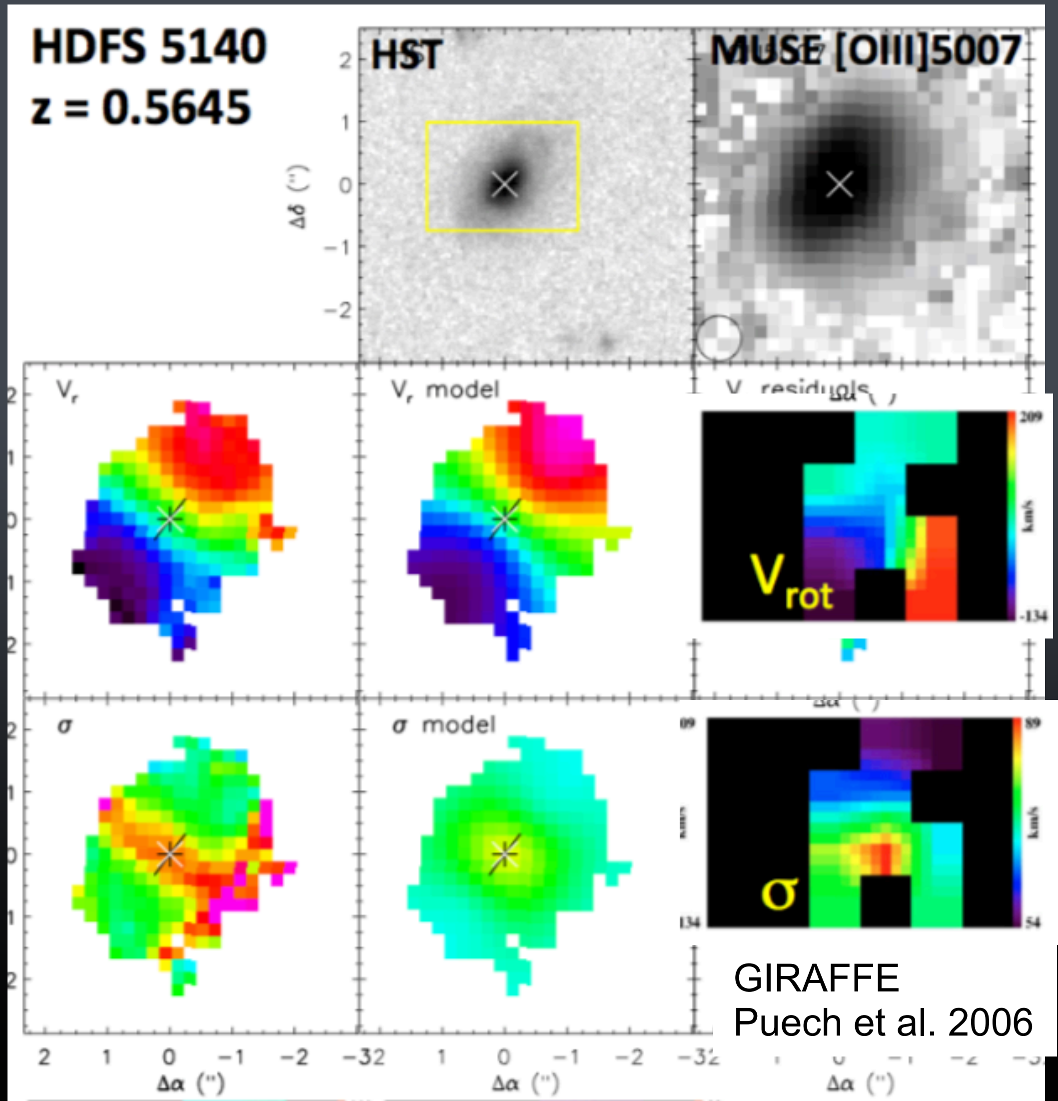
- ✓ **20 Spatially Resolved Galaxies**

ID#9

Z = 0.56
I_{814} = 22.1



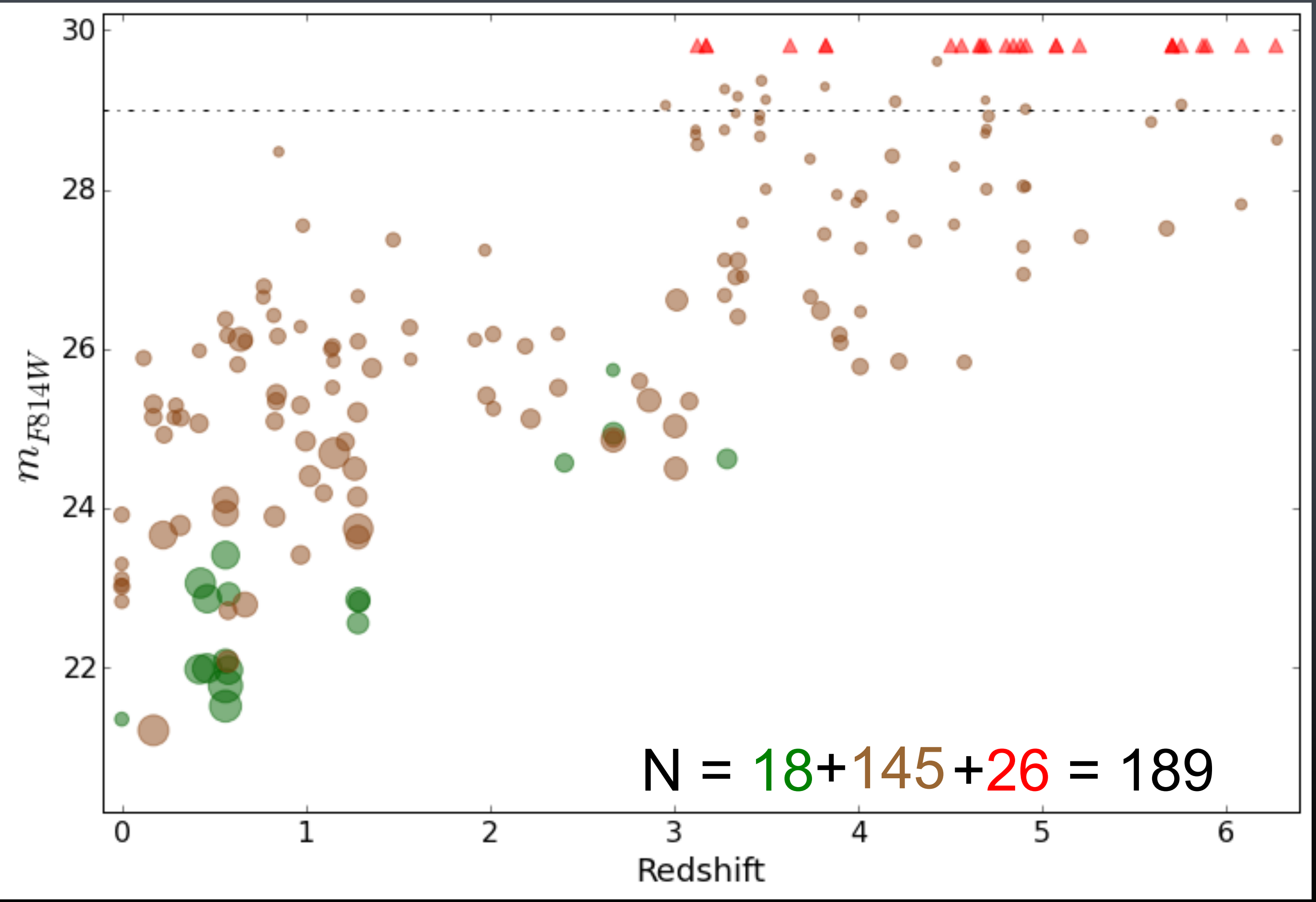
Census of MUSE HDFS Field



ID#9

Z = 0.56
I_{814} = 22.1

Redshift Distribution

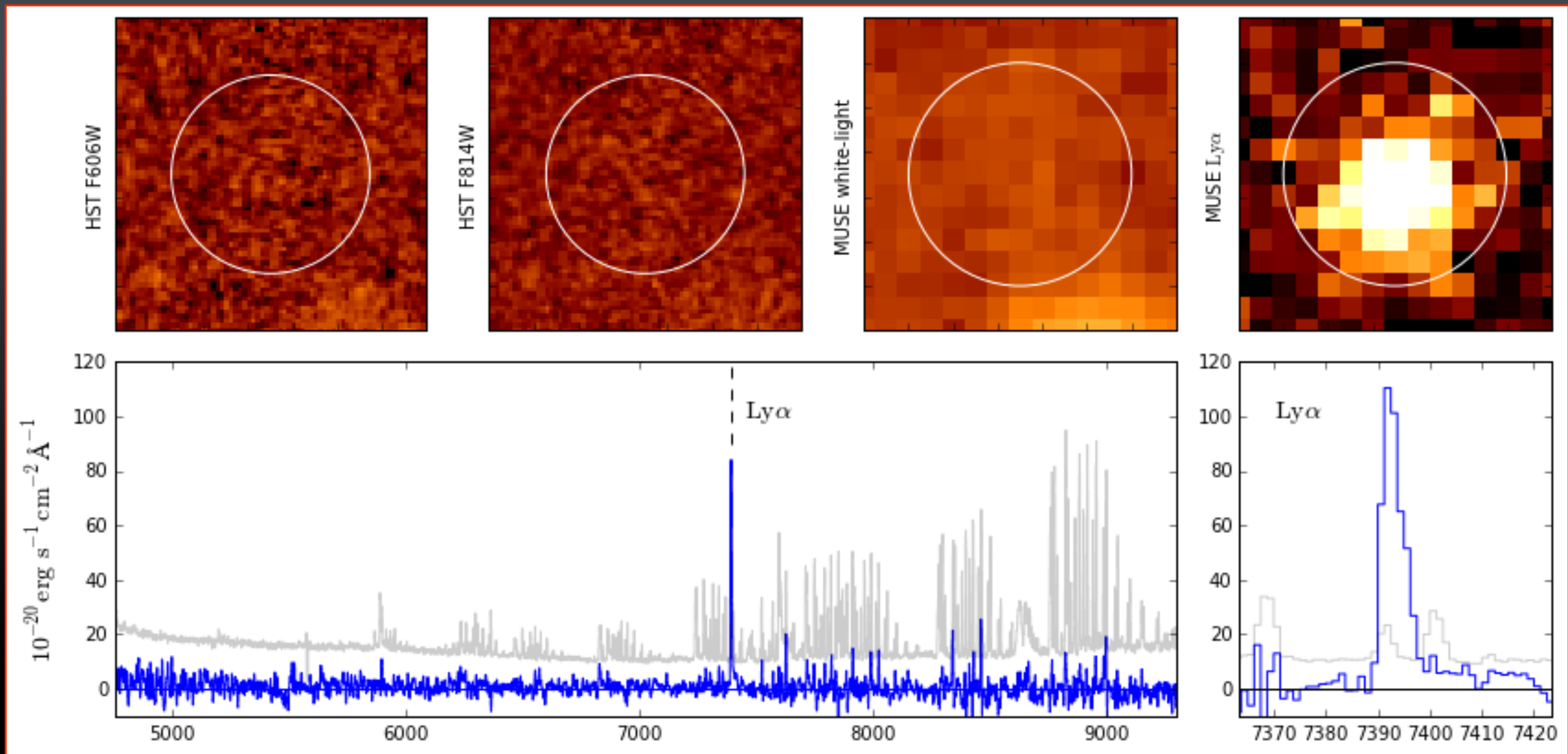


Conclusions

- In 4 equivalent nights of observations of the HDFS with MUSE
  - We have multiplied by 10 the number of measured spectroscopic redshifts
  - We observe a nearly flat redshift distribution in z = [3-6] range
  - We have reached 50% completeness of the redshift distribution wrt HST at I_{814}~26, and 20% at I_{814}~28
  - We have found a large population of Lya emitters fainter than HST detection limit (I_{814}>30)
  - We have demonstrated that we can get spatially resolved kinematics for 20 galaxies at z ~0.5-1.0

In 4 equivalent nights of observations of the HDFS with MUSE

We have demonstrated that the VLT can go deeper than the HST



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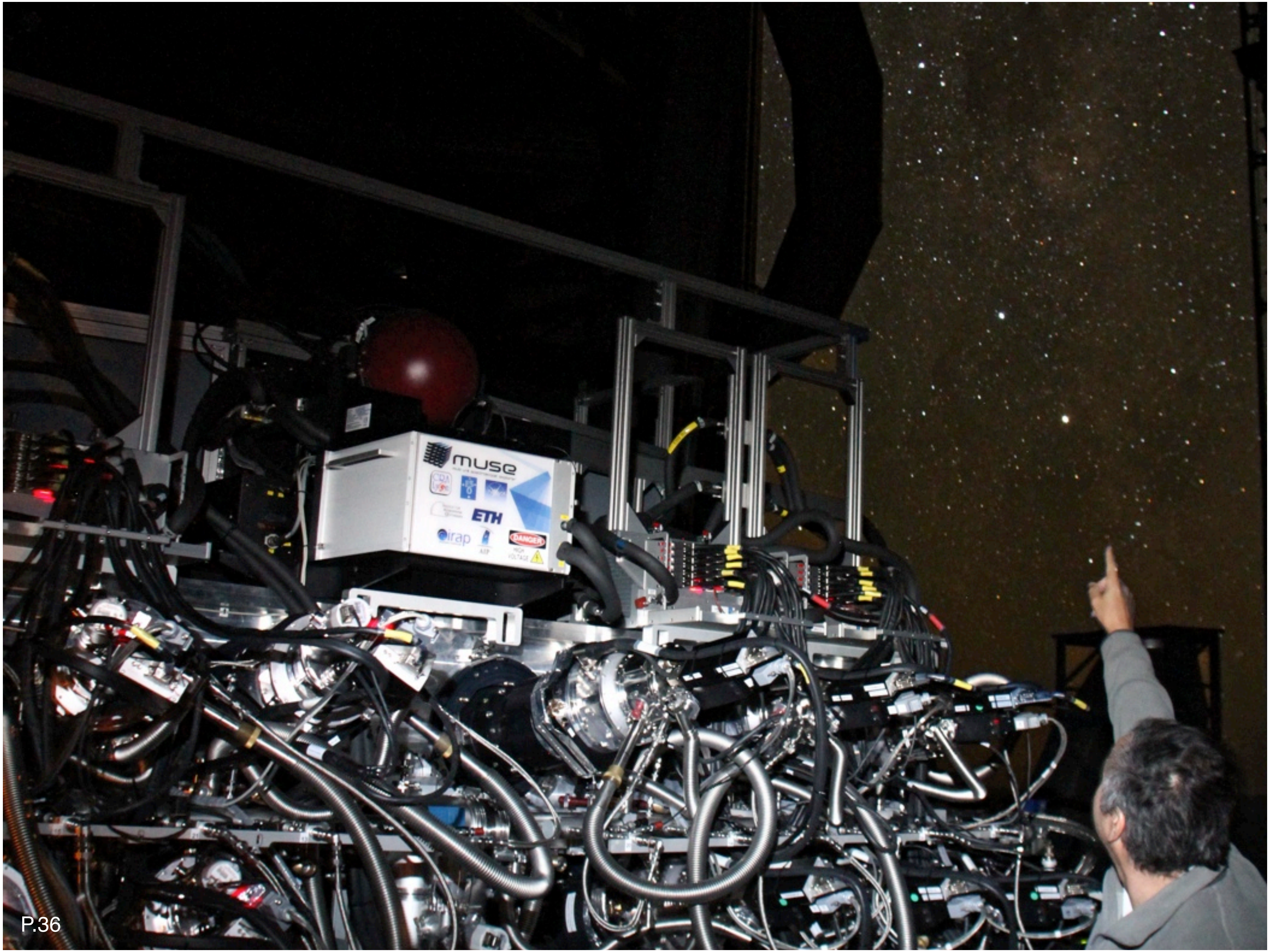
What's next

- Paper to be submitted this week!
- UDF is part of the GTO
  - Full coverage of the 3x3 $arcmin^2$ at 10+ hours depth
  - One field 1x1 $arcmin^2$, overlapping with ALMA deep-field, at 30+ hours
  - On going, to be completed in 2015
- AOF/GALACSI in 2016-2017
  - ~50% better seeing, 0 impact on throughput, minimal impact in overhead
  - A new public deep field at 0.5 arcsec spatial resolution ?


muse
ETH
irap
DANGER