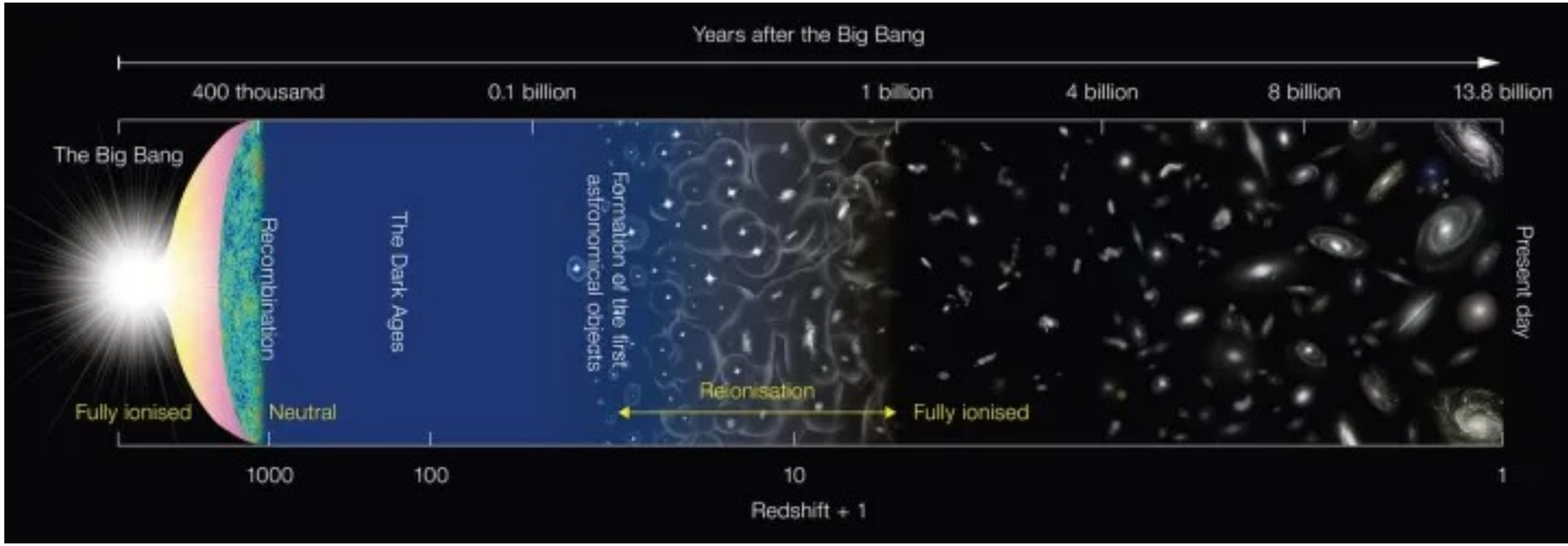
Probing the spatially resolved ISM of LyC leaking galaxies with MUSE

Arjan Bik (Stockholm)

Chinmaya Nagar (Uppsala, now Cologne), Veronica Menacho (Stockholm)

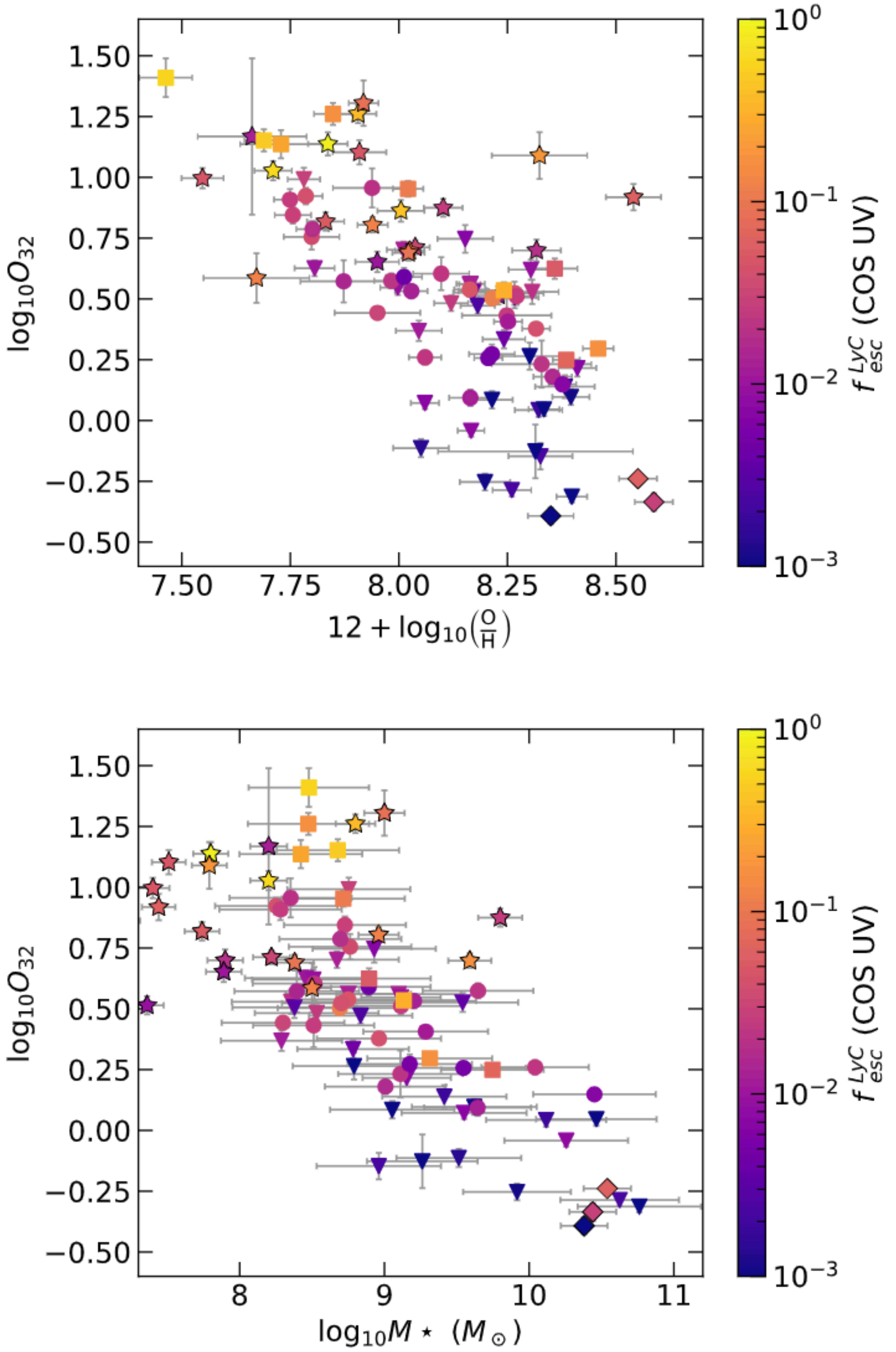
Motivation



- Epoch of Reionization:
  - Consensus: (low-mass) starburst galaxies responsible for re-ionization
  - Cannot detect LyC radiation directly of those galaxies (neutral IGM)
  - Spatially resolution (even with JWST)
  - Nearby galaxies (indirect indicators)

Nearby LyC galaxies

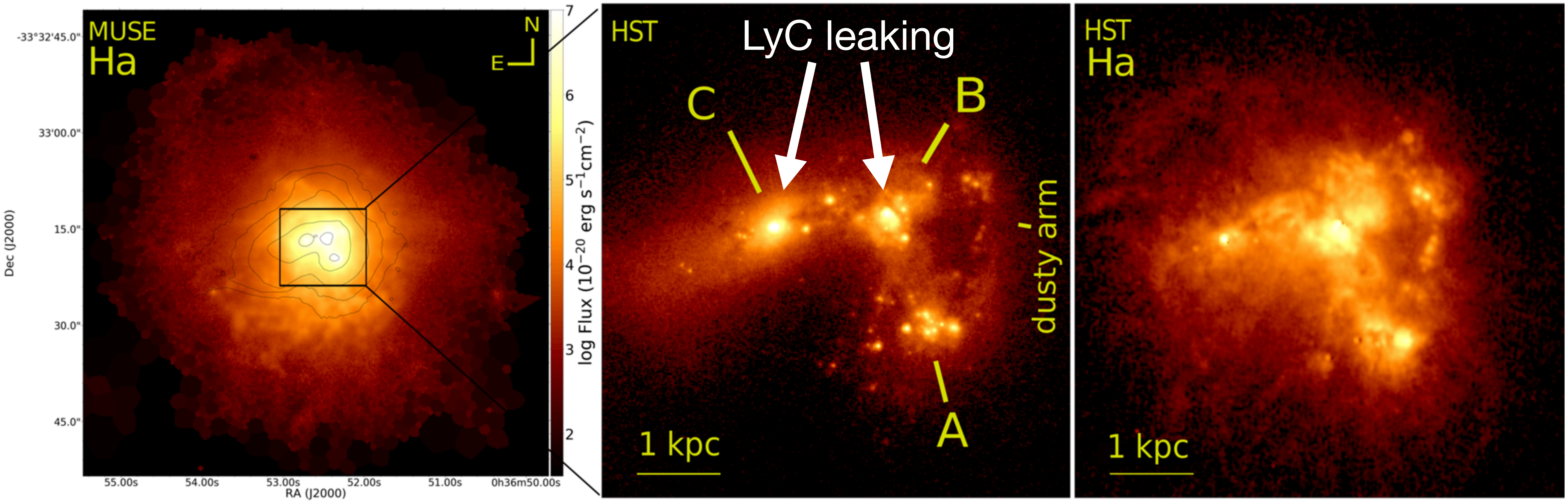
- Extreme starburst galaxies in the local universe
- Highly ionised ISM, Compact, low metallicity
- Selected on e.g. high [OIII]/[OII] ratio (Izotov+, 16a,b, Izotov+ 18a,b): ~ 10 LyC leakers
- Observed with the COS spectrograph at HST: z ~ 0.3
- LzLCS (Flury+22a,b): 35 galaxies with measured LyC radiation.
- F_esc: between few and 50 %



Flury et al, 2022b

Spatially resolved ISM with MUSE

- Nearest LyC leaker: Haro 11, 90 Mpc

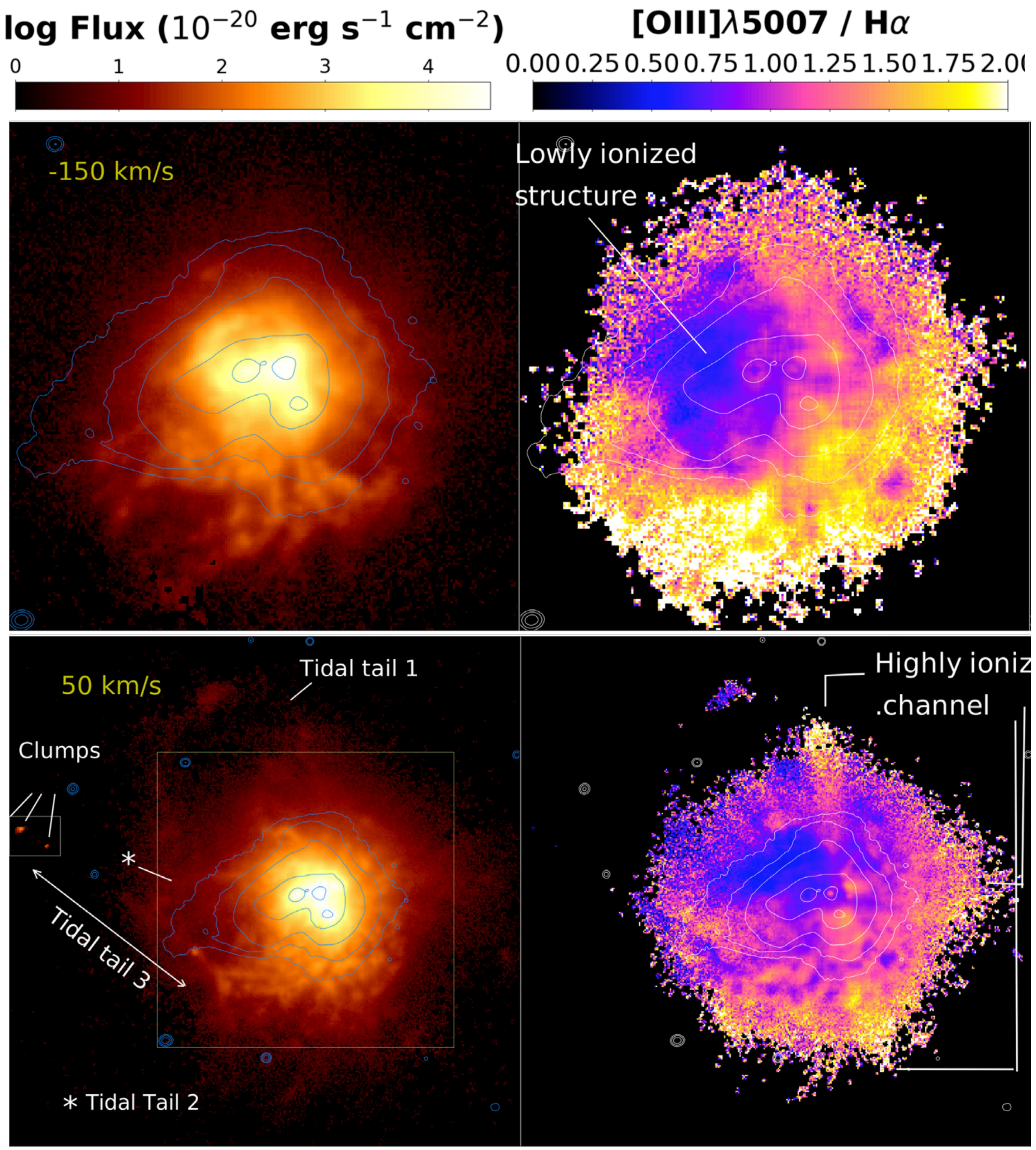


Komarova et al, 2024

Menacho et al, 2019

Velocity sliced line ratios

- Very bright emission lines: channel maps
- Different velocity show different substructure:
- Ionisation channels
- Higher velocity gas: more ionised.
- BlueMUSE: 2x spectral resolution in [OIIII], more velocity details.



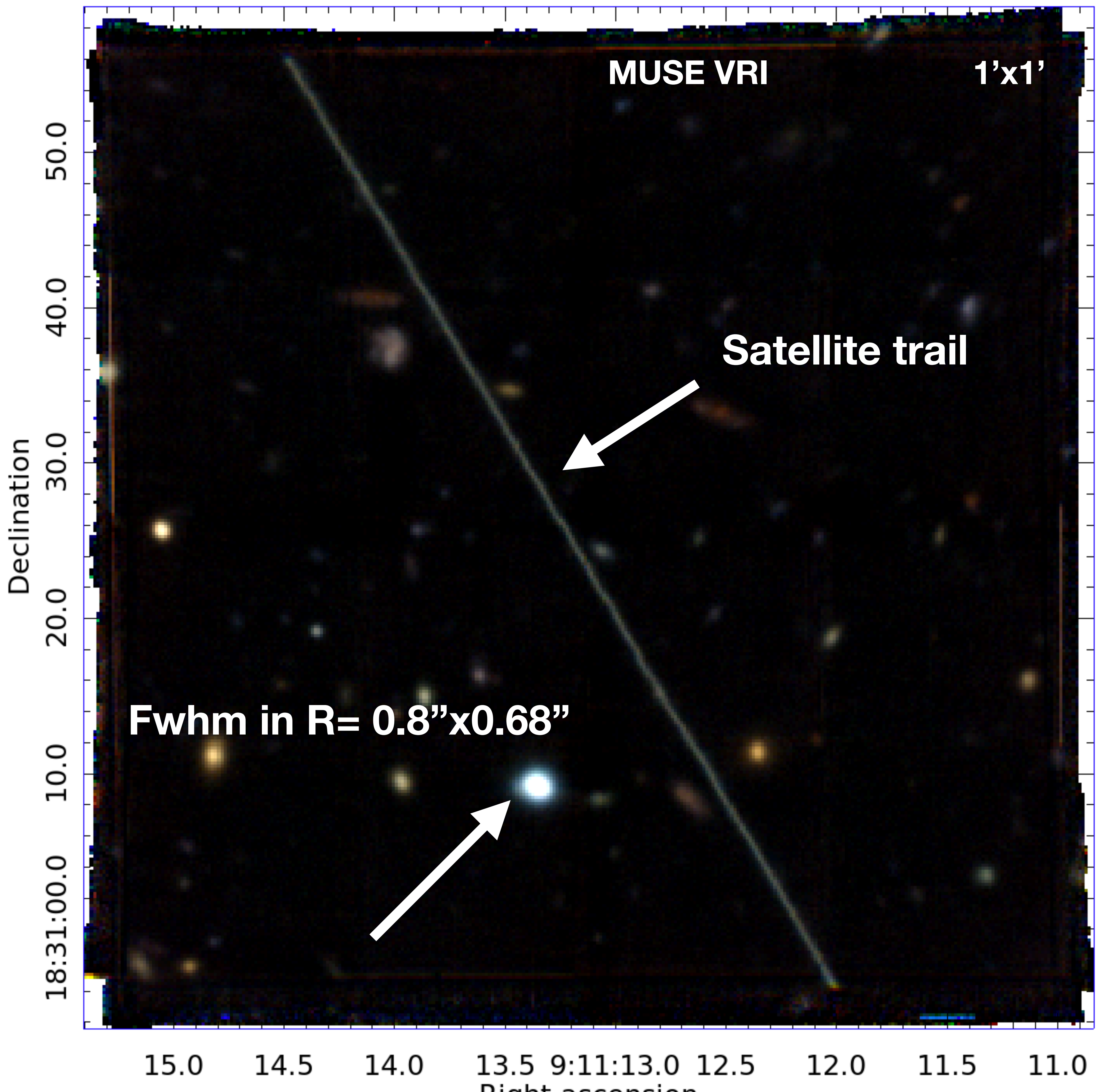
Menacho et al, 2019

MUSE survey LzLCS galaxies

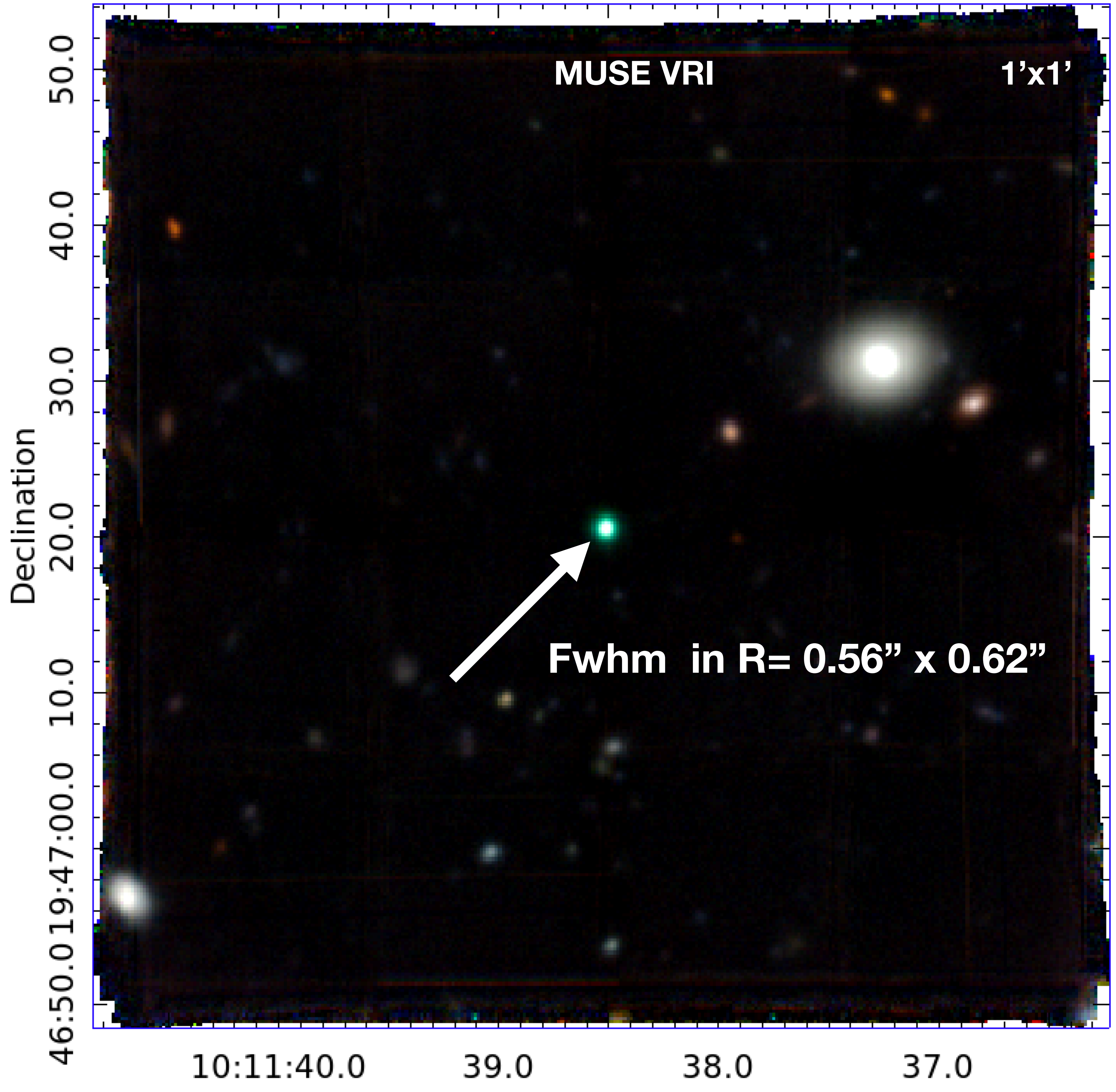
- MUSE, Widefield with AO mode
- 13 galaxies, PI: Göran Östlin
- Ionised gas distribution
- Spatial resolved ionisation maps
- Ionisation channels
- Master thesis Chinmaya Nagar (PhD

Property	Galaxy						
	J0911	J1011	J0925	J0958	J0826	J1314	J1604
Redshift (z)	0.2622	0.3321	0.3142	0.3017	0.2972	0.2961	0.3123
Log stellar mass ($M_\odot$)	10.41	9	8.38	8.696	8.509	10.464	8.93
LyC Flux Density (10^{-19} W m^{-2} nm^{-1}) ‡	7.256	1.994	3.48	0.416	< 0.205	< 0.29	< 0.264
$f_{esc}^{LyC}(H\beta)$	0.083	0.041	0.054	0.012	< 0.012	< 0.005	< 0.006
$f_{esc}^{LyC}(UV)$	0.023	0.09	0.092	0.019	< 0.009	< 0.001	< 0.007
$SFR_{H\beta}$ ($M_\odot$ yr^{-1})	27.54 ± 1.39	28.57 ± 1.31	24.54 ± 1.3	15.63 ± 0.75	6.63 ± 0.48	22.59 ± 1.14	21.87 ± 2.16
$\Sigma_{SFR,\,H\beta}$ ($M_\odot$ yr^{-1} kpc^{-2}) A	22.38 ± 6.03	58.47 ± 28.00	24.09 ± 7.60	15.13 ± 4.07	3.34 ± 0.82	3.84 ± 1.00	32.35 ± 8.41
$\Sigma_{SFR,\,f1100}$ ($M_\odot$ yr^{-1} kpc^{-2}) B	41.40 ± 11.24	50.11 ± 24.23	7.16 ± 2.24	4.70 ± 1.27	5.04 ± 1.27	12.88 ± 3.41	8.35 ± 2.09
$EW_{H\beta}$ (Å)	73.23 ± 1.49	193.74 ± 9.84	172.78 ± 3.99	131.15 ± 6.57	107.82 ± 4.53	35.79 ± 0.64	172.27 ± 5.41
$12 + \log_{10}(O/H)$	8.6 ± 0.037	7.918 ± 0.034	8.22 ± 0.037	7.801 ± 0.037	8.304 ± 0.051	8.334 ± 0.036	8.153 ± 0.064

J0911+18 (LzLCS)
z=0.26
f_esc = ~7%
O32=1.8
12+log(O/H) = 8.14

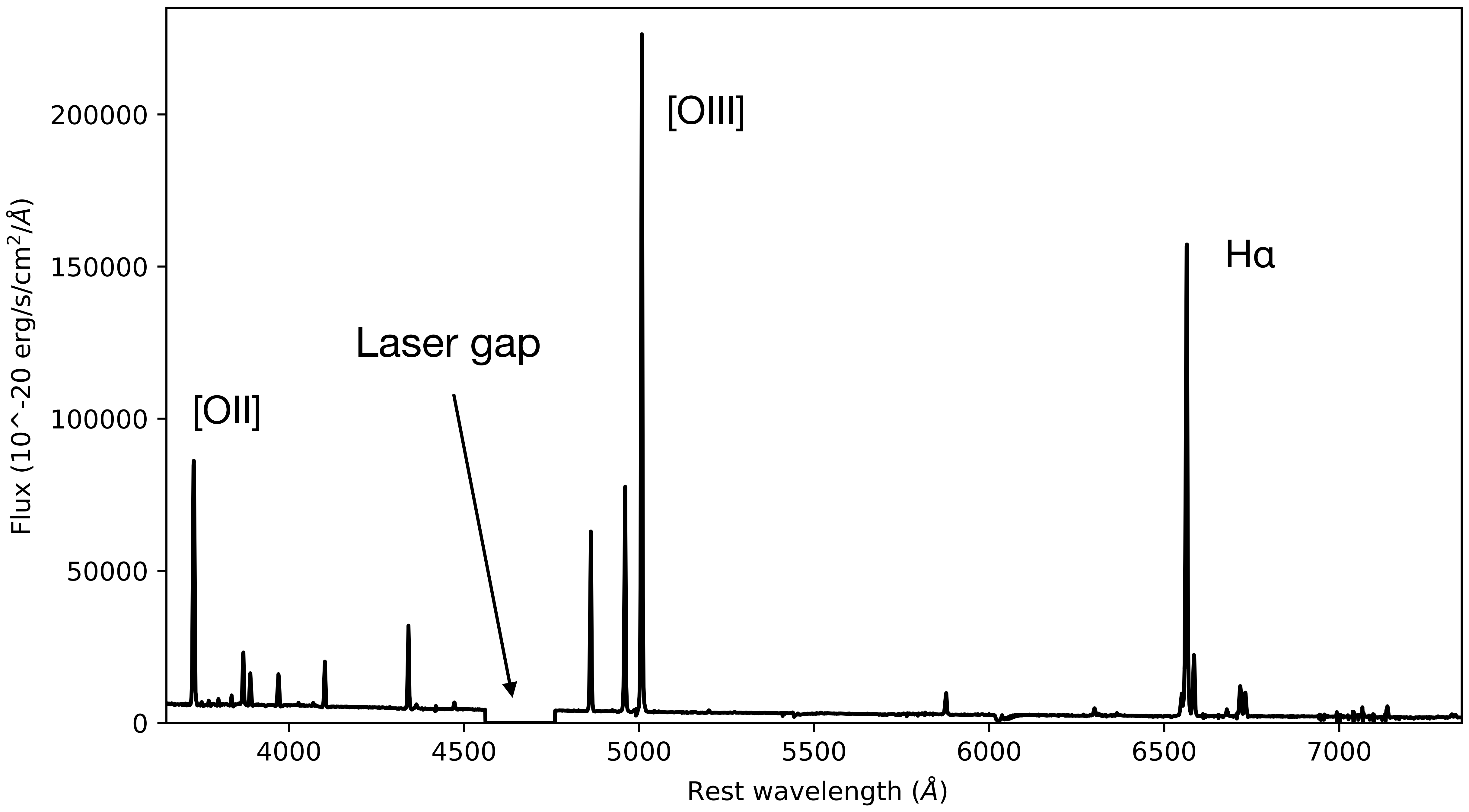


J1011+19 (Izotov)
z=0.33
f_esc = 11.4%
O32=27
12+log(O/H) = 7.99



Integrated spectra (3” diameter)

J0911+18 (LzLCS)
z=0.26
f_esc = ~7%
O32=1.8
12+log(O/H) = 8.14



J1011+19 (Izotov)
z=0.33
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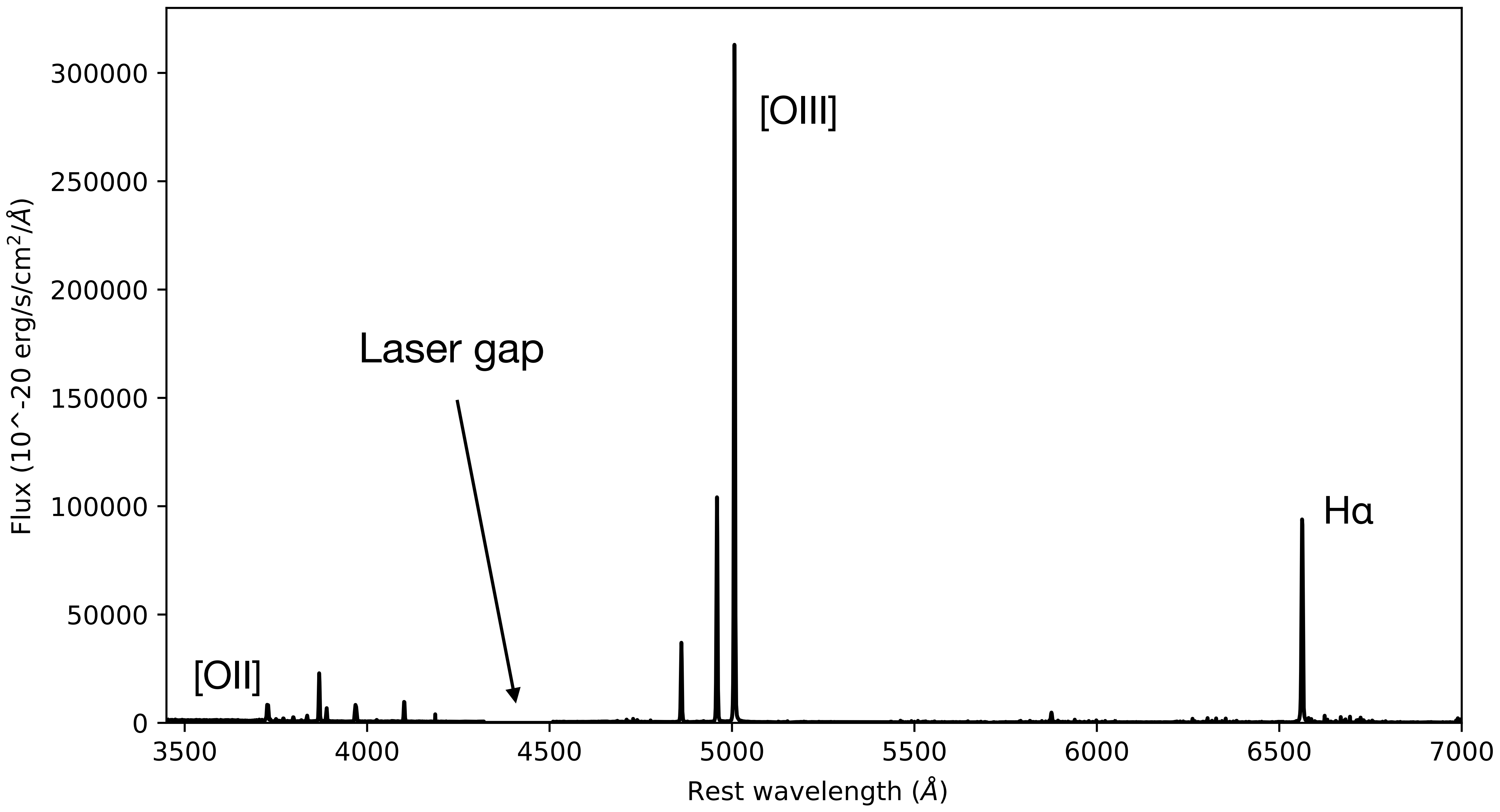
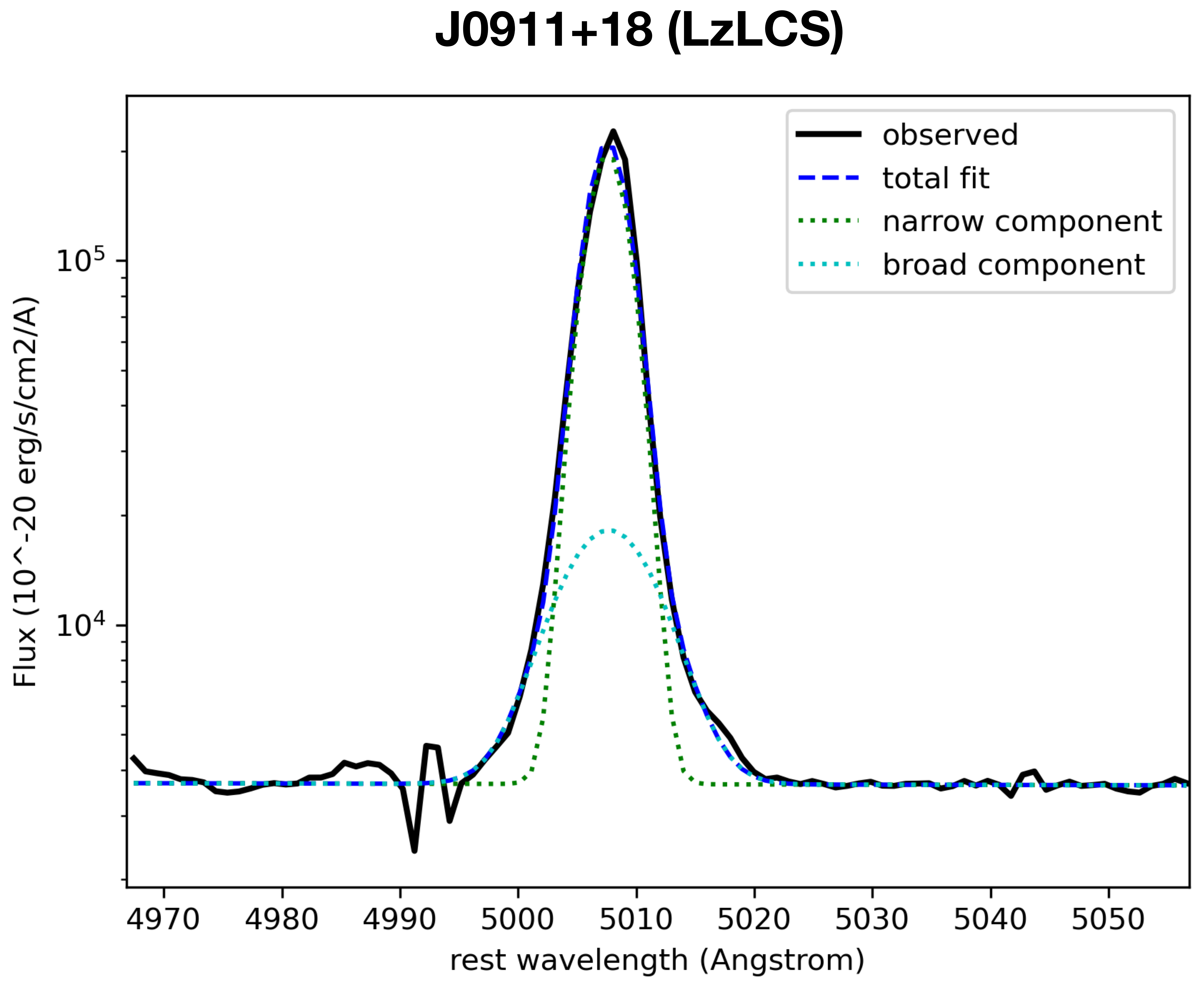
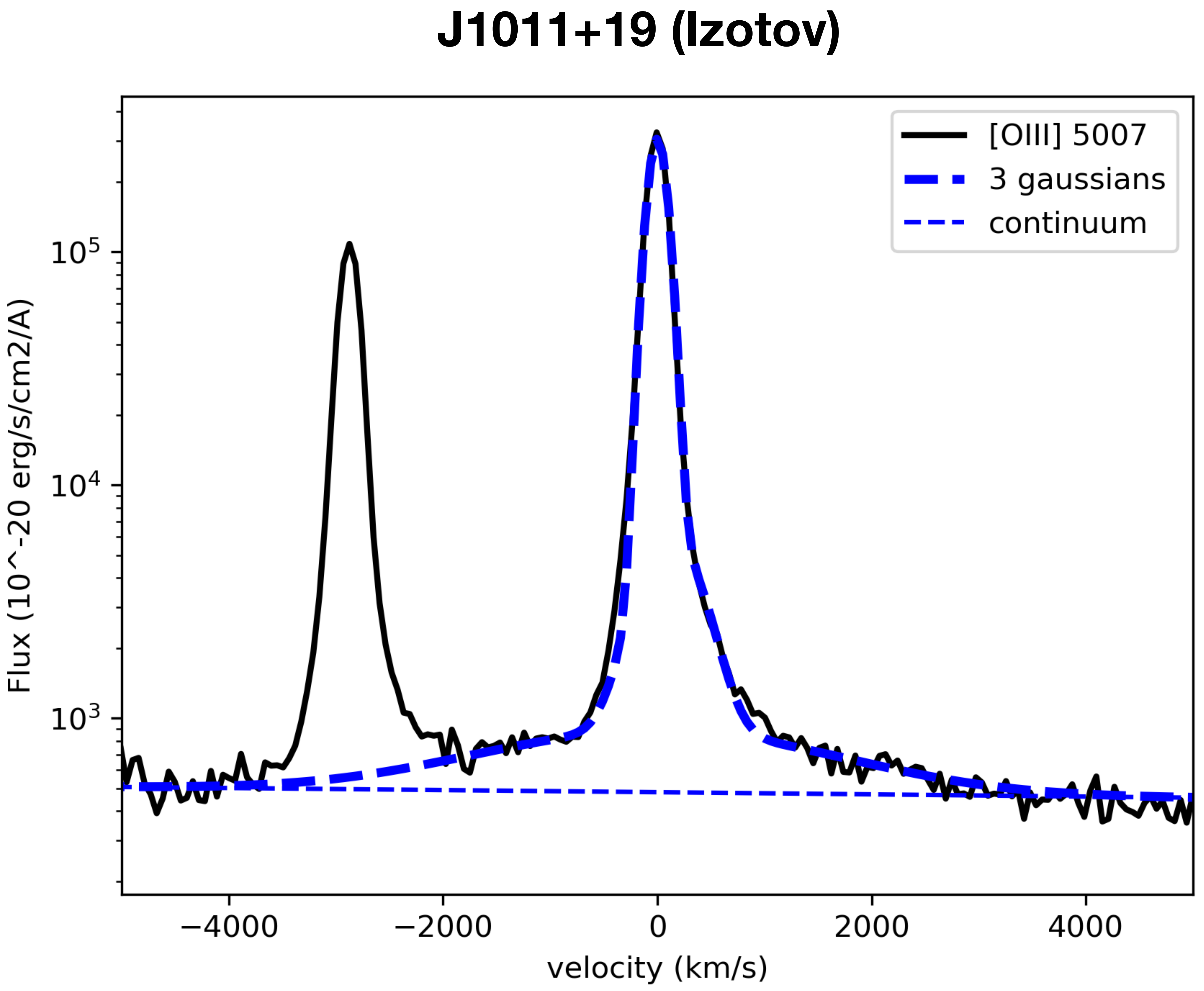


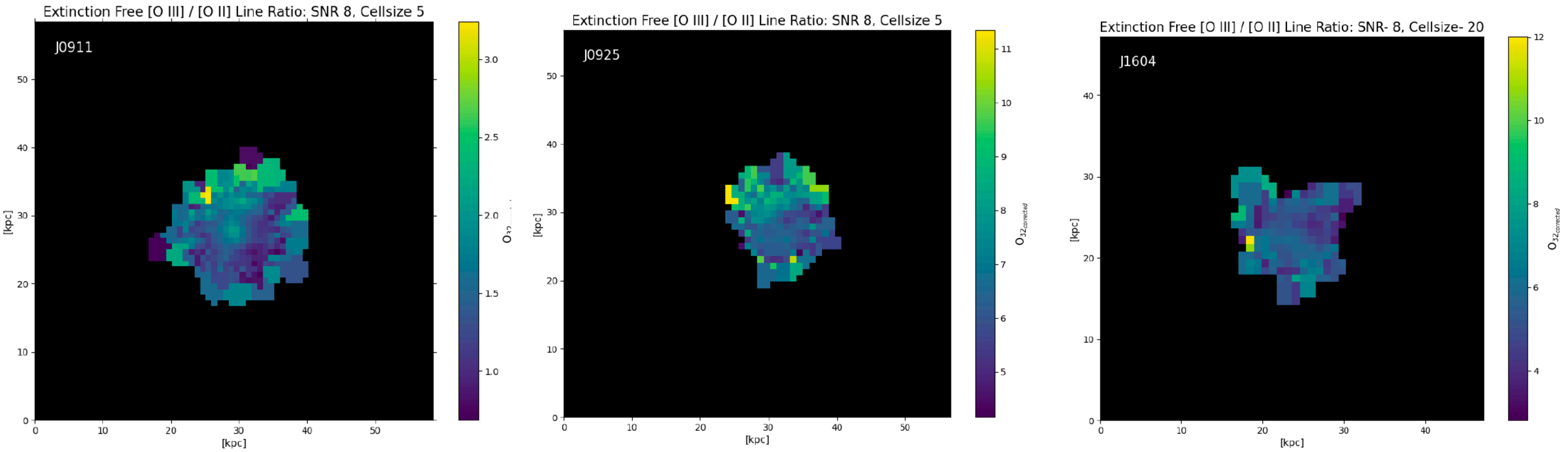
[OIII]5007


J0911+18 (LzLCS)
observed
total fit
narrow component
broad component
Flux (10^-20 erg/s/cm2/A)
10^5
10^4
4970
4980
4990
5000
5010
5020
5030
5040
5050
rest wavelength (Angstrom)


J1011+19 (Izotov)
[OIII] 5007
3 gaussians
continuum
Flux (10^-20 erg/s/cm2/A)
10^5
10^4
10^3
−4000
−2000
0
2000
4000
velocity (km/s)

Spatial resolved ionisation maps

[OIII]/[OII]



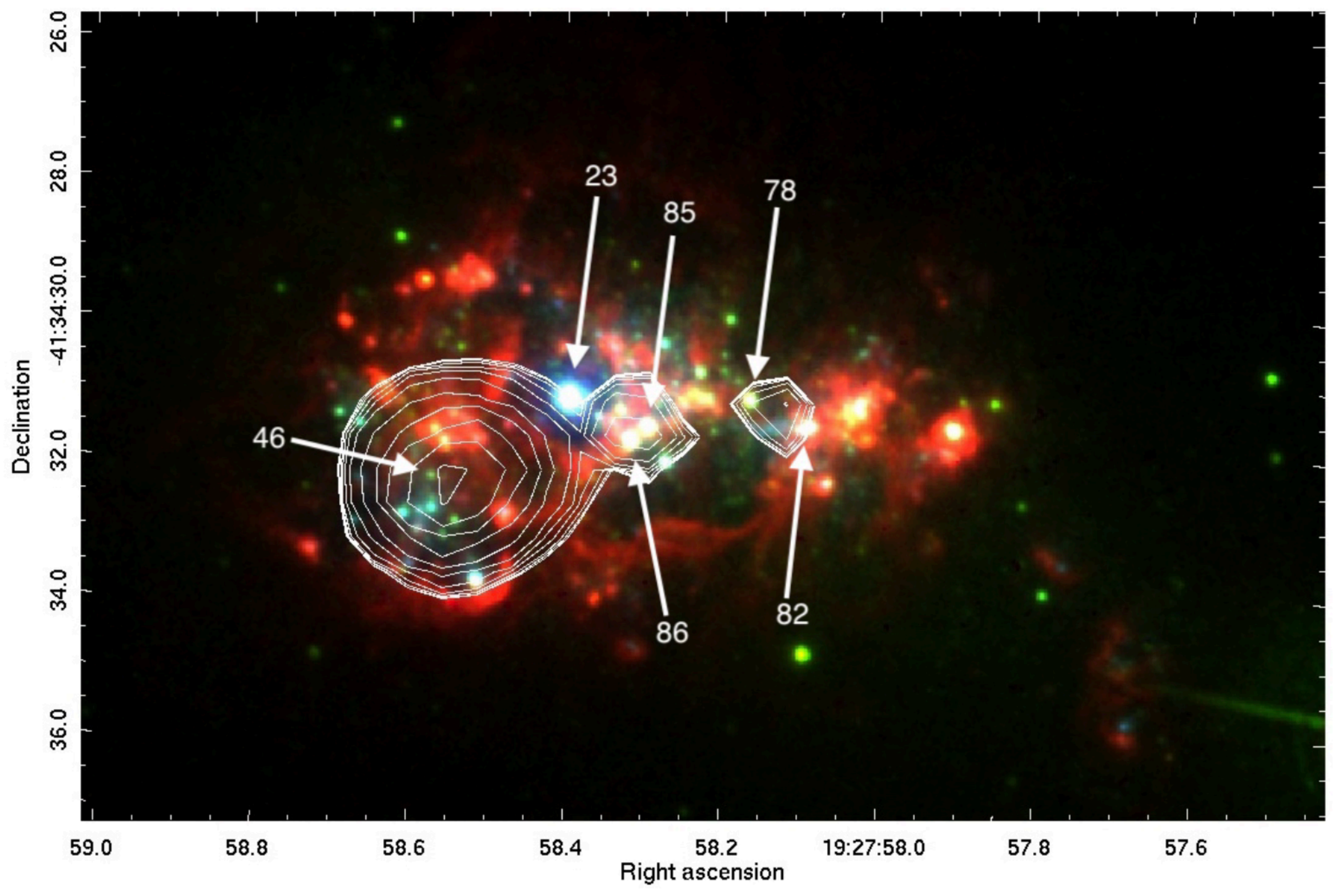
- Ionisation vs density bounded: can LyC escape?

Master thesis Chinmaya Nagar

What will BlueMUSE bring?

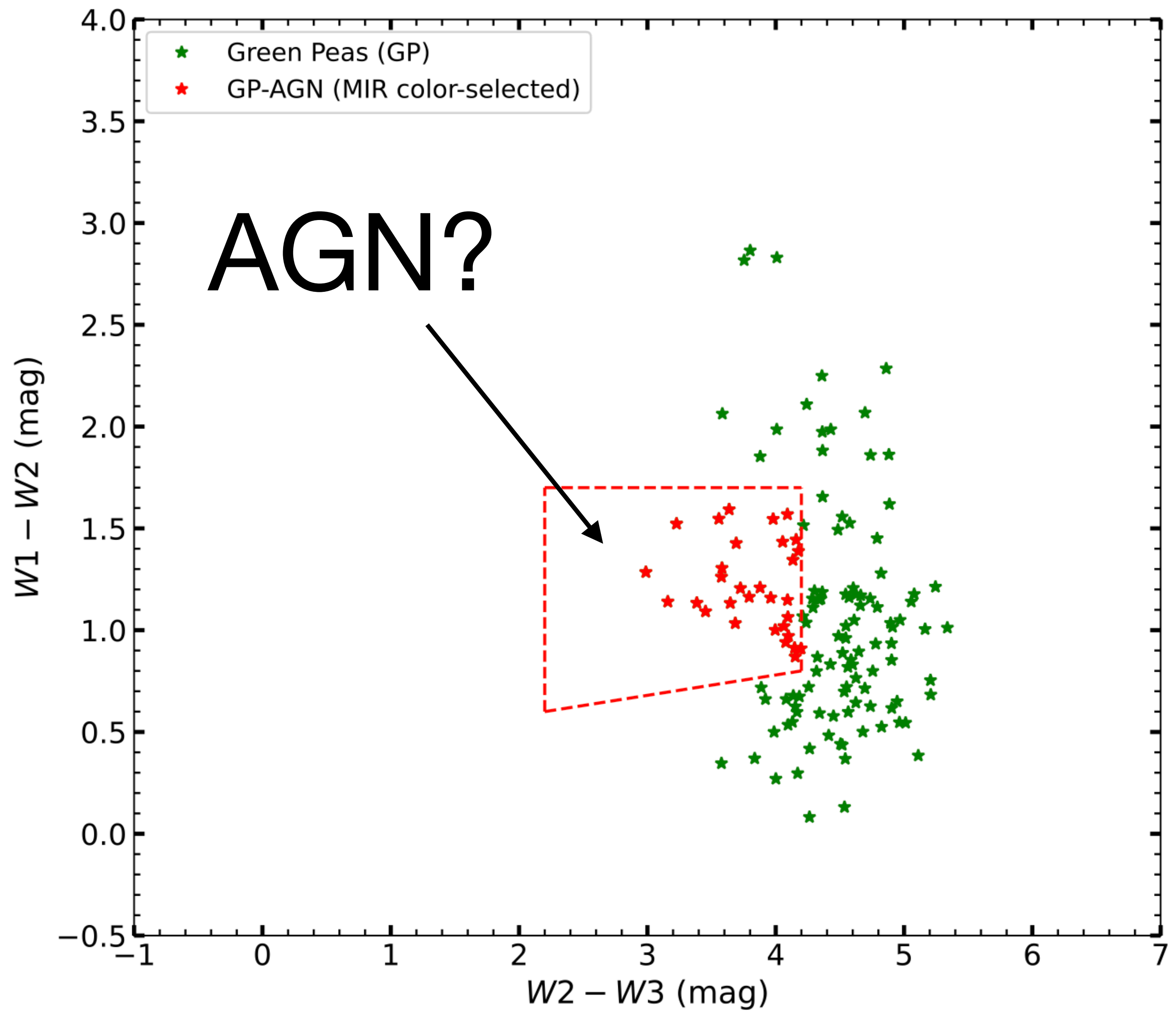
- **Bluer:**
  - [OII] doublet (3726,3729Å): density
  - [OIII] auroral line 4346Å: temperature, **see talk Augusto Lassen**
  - More exotic lines (for slightly higher redshift):
    - [NeV] 3426Å (z=0.05 @ 3600 A). NeV/HeII: AGN contribution: Izotov et al, 2012
    - MgII (2795.5, 2802.7Å) doublet (z=0.28 @ 3600 Å): resonant lines: traces the cool gas like Lyα (e.g. Chisholm et al, 2020)

Non stellar feedback?



ESO 338-IG04: Oskinova, Bik et al, 2019

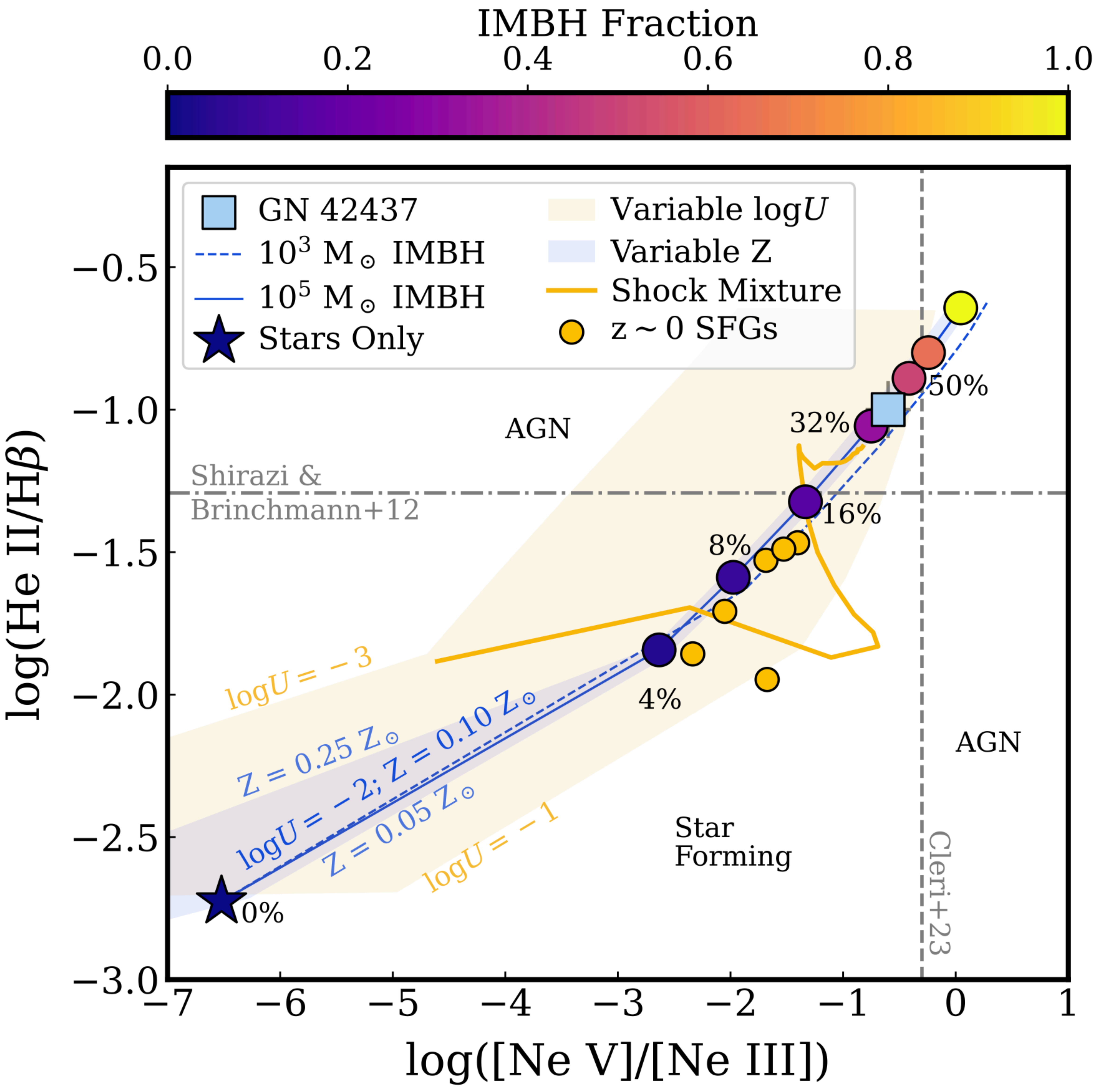
- Contribution of ULXs
- HeII emission in MUSE:
- Contribution of AGNs?
- [NeV] 3426Å (z=0.05 @ 3600 A).



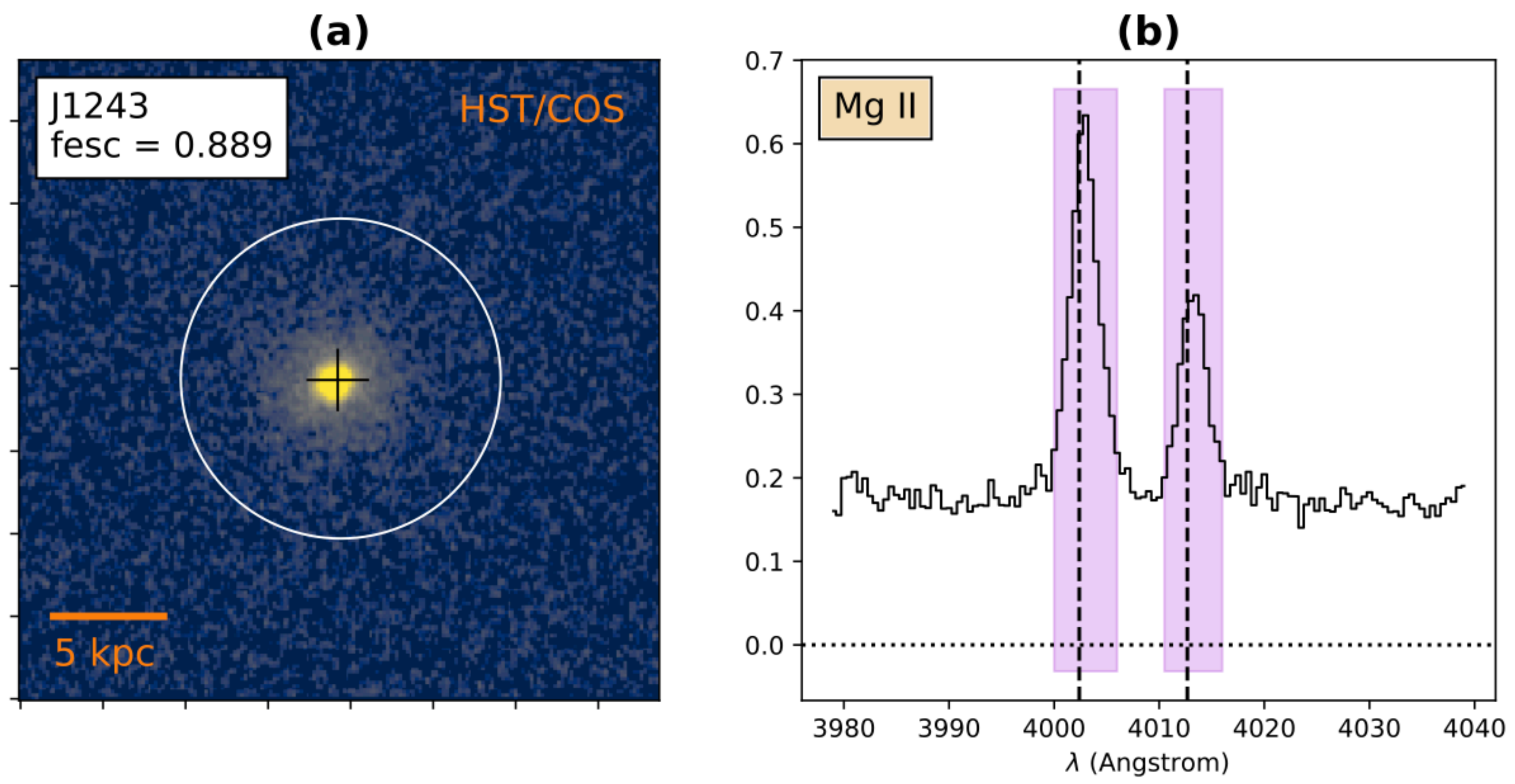
Harris et al, 2021

NeV at high z

- Chisholm et al, 2024
- Evidence of a narrow-line intermediate mass blackhole
- NeV/HeII: AGN contribution: Izotov et al, 2012

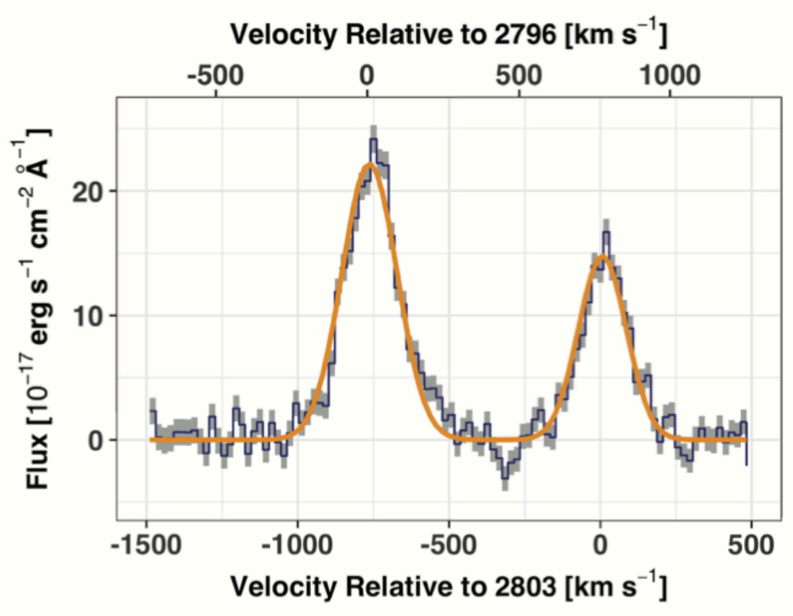


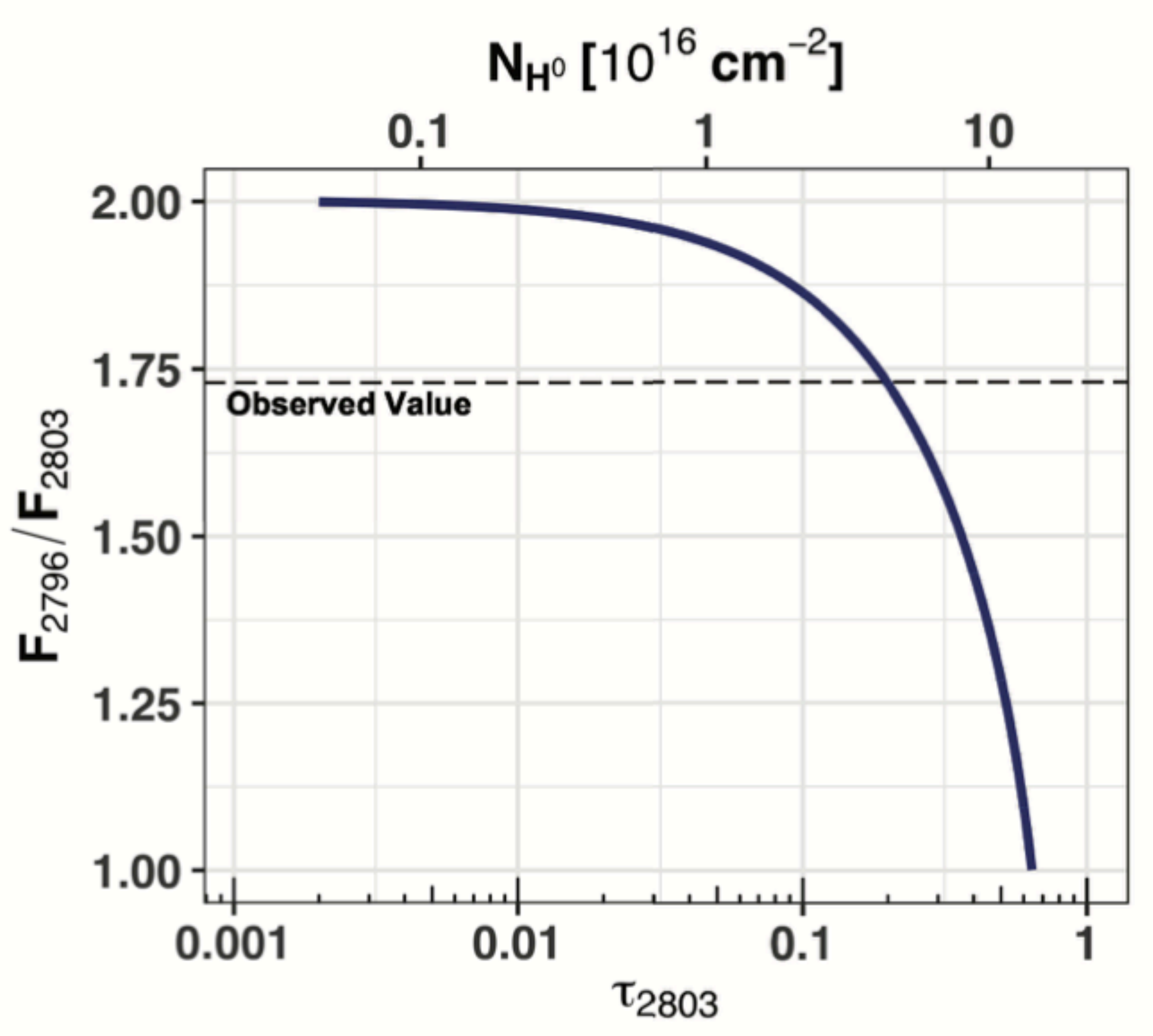
MgII



LzLCS: Leclercq et al., 2024

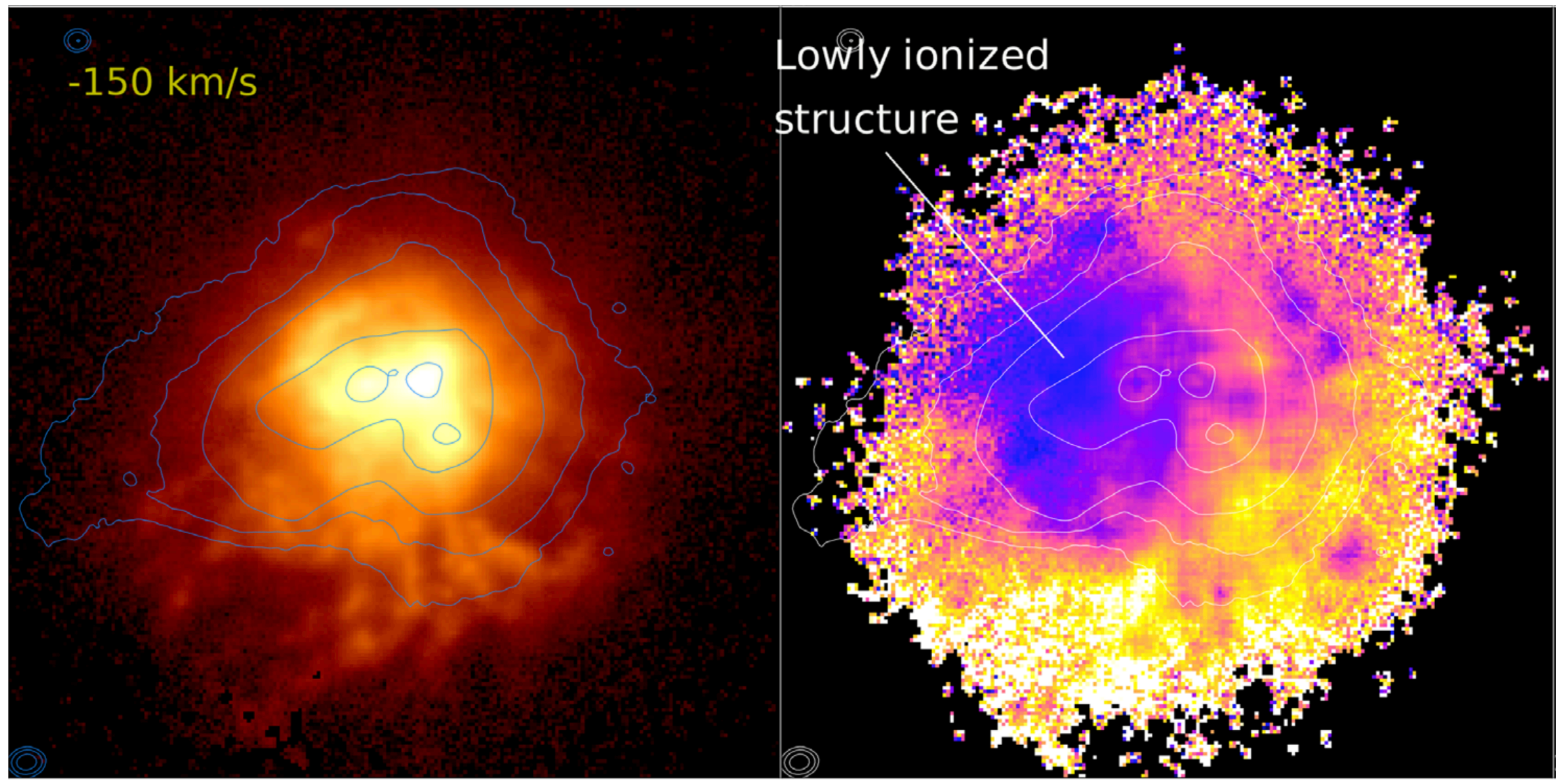
- MgII observations extreme starburst:
- Resonance line (like Lyα)
- Line ratio traces column density neutral hydrogen (knowing the metallicity)
- MgII more extended than ionised gas
- Use as a proxy for LyC escape.
    - $N_{H0} < 10^{17}$ cm^{-2} optically thin for LyC photons

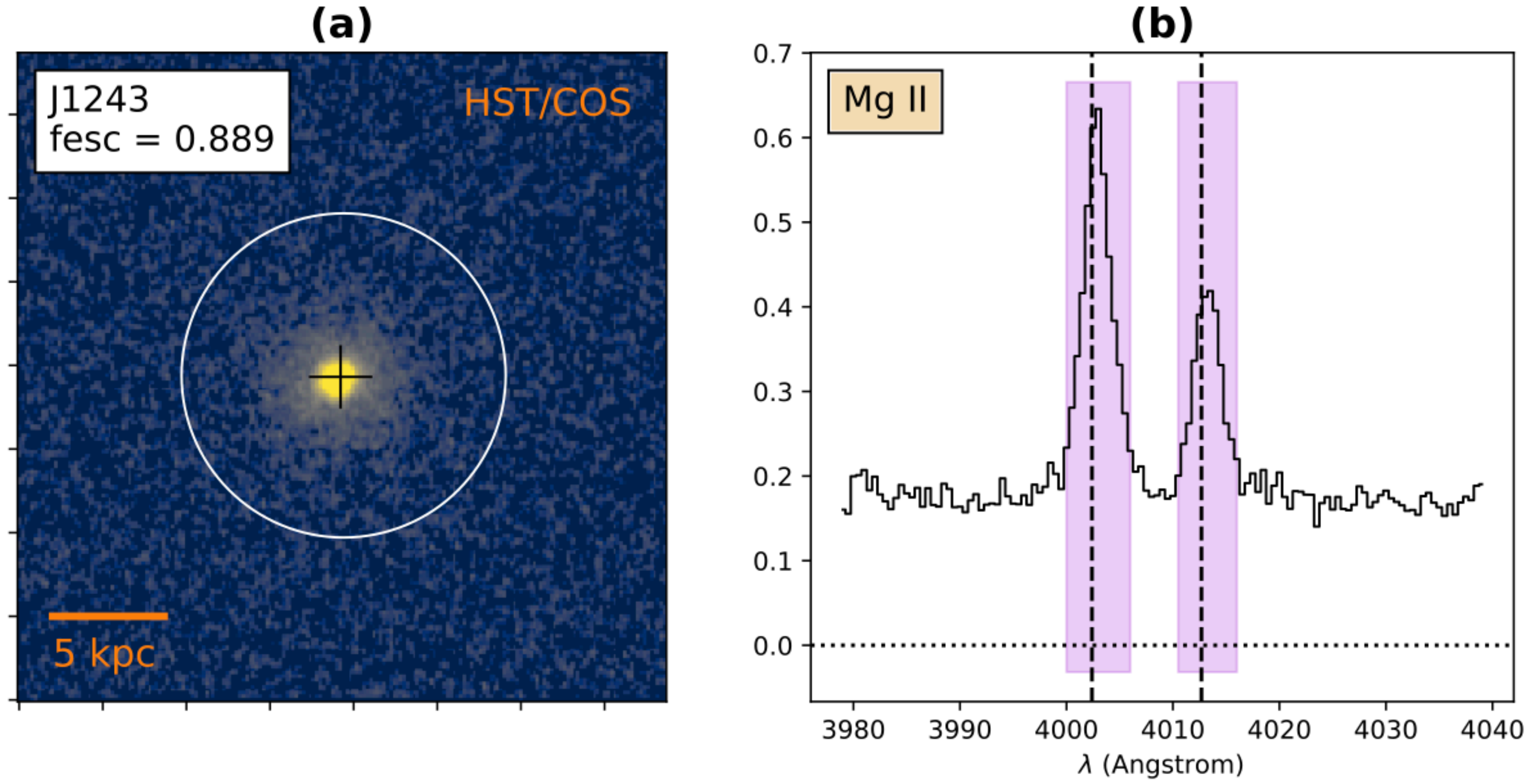


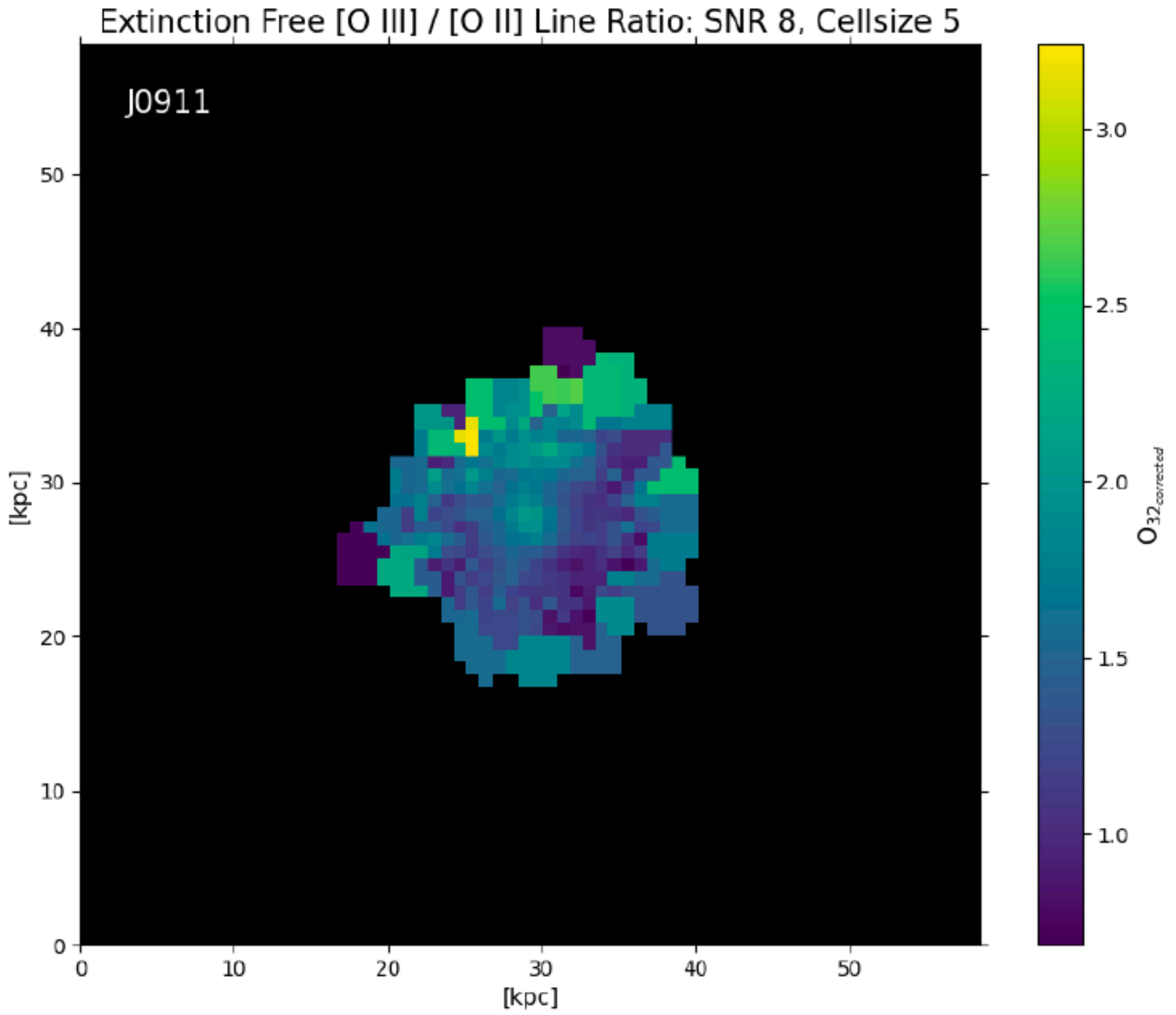


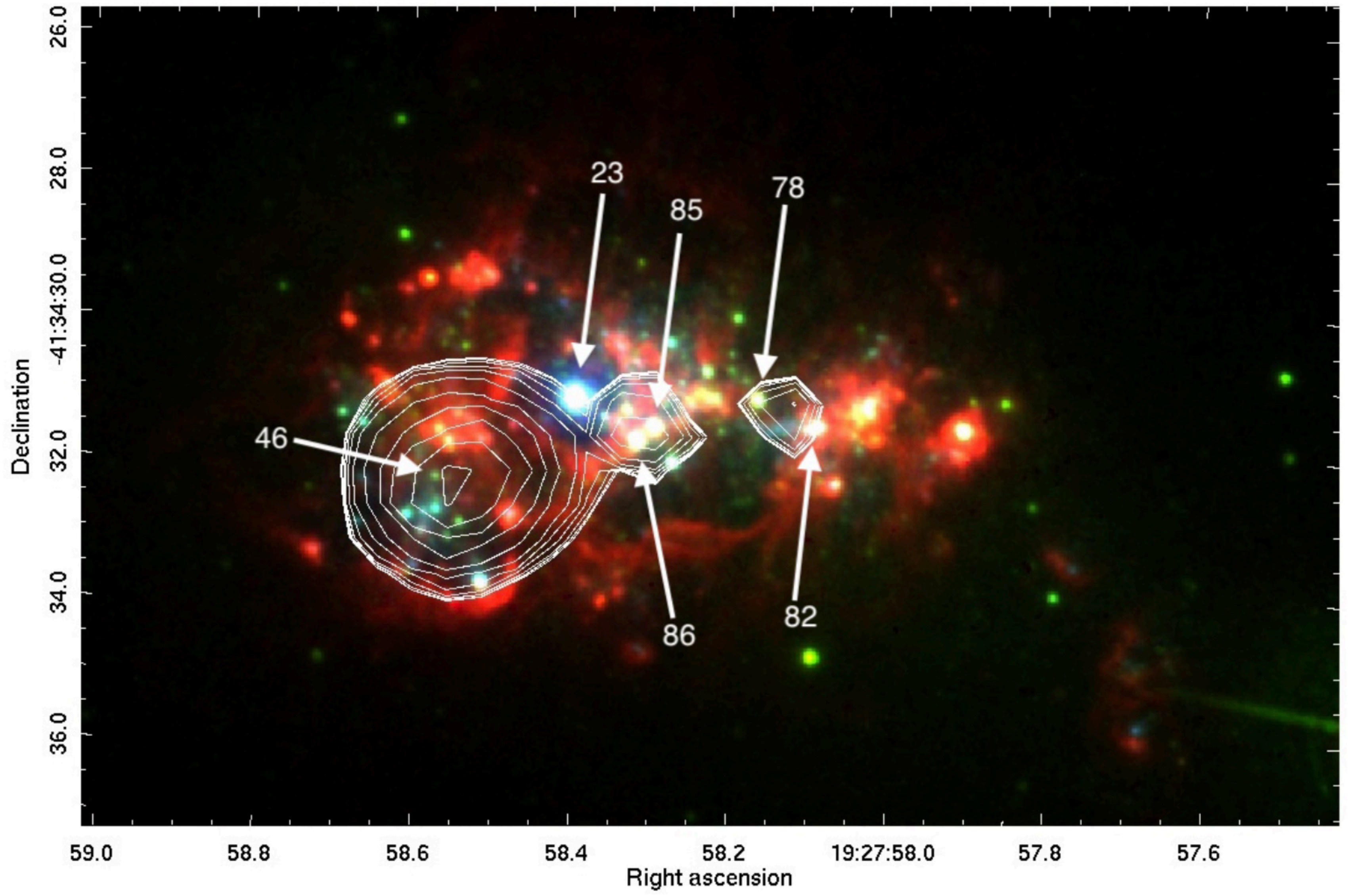
Chisholm et al., 2020

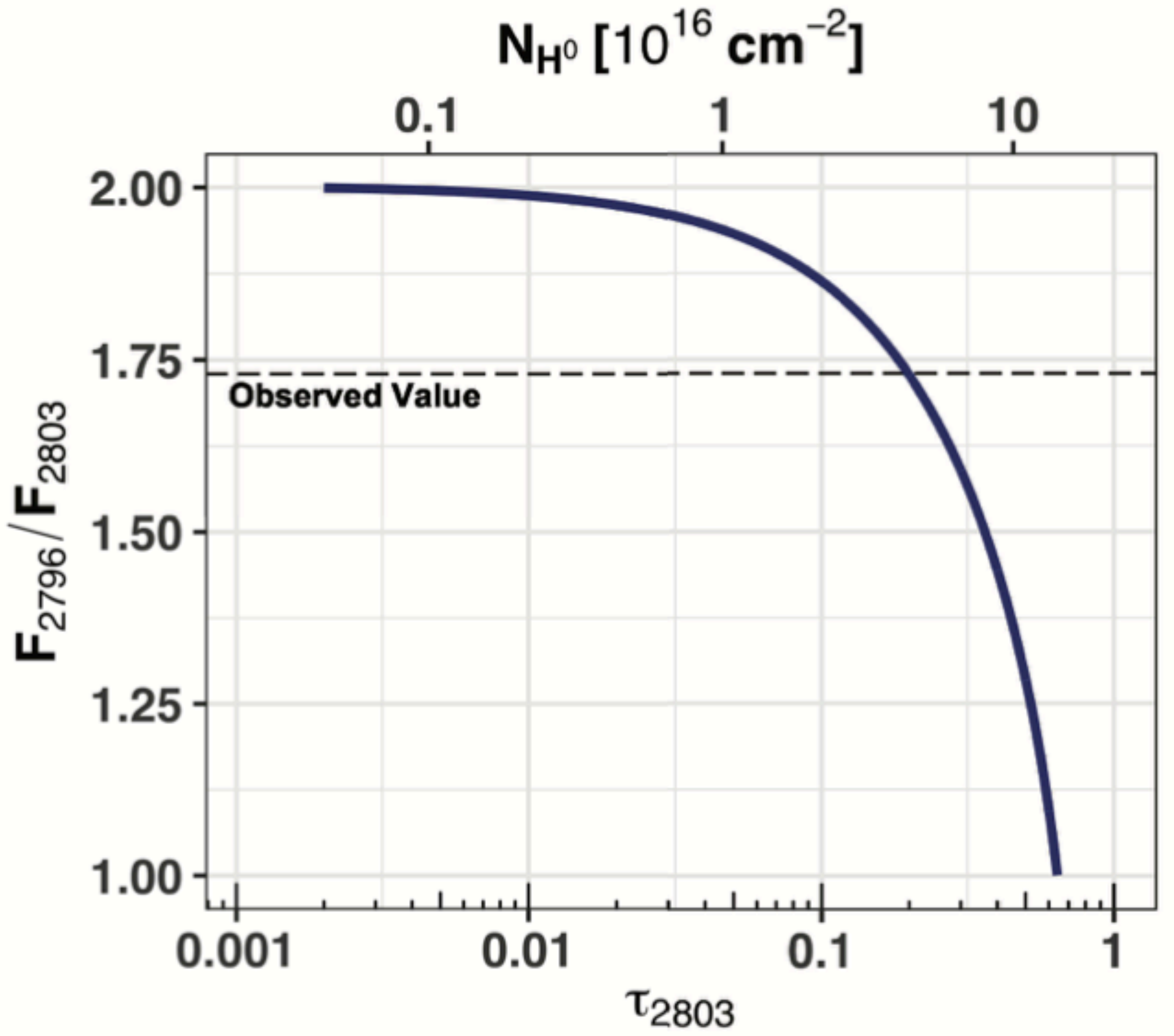
Summary


-150 km/s
Lowly ionized structure


(a)
J1243
fesc = 0.889
HST/COS
5 kpc
(b)
Mg II
λ (Angstrom)


Extinction Free [O III] / [O II] Line Ratio: SNR 8, Cellsize 5
J0911
[kpc]
[kpc]


23
85
78
46
86
82
Declination
Right ascension


N_{H^0} [10^{16} cm^{-2}]
Observed Value
F_{2796}/F_{2803}
τ_{2803}