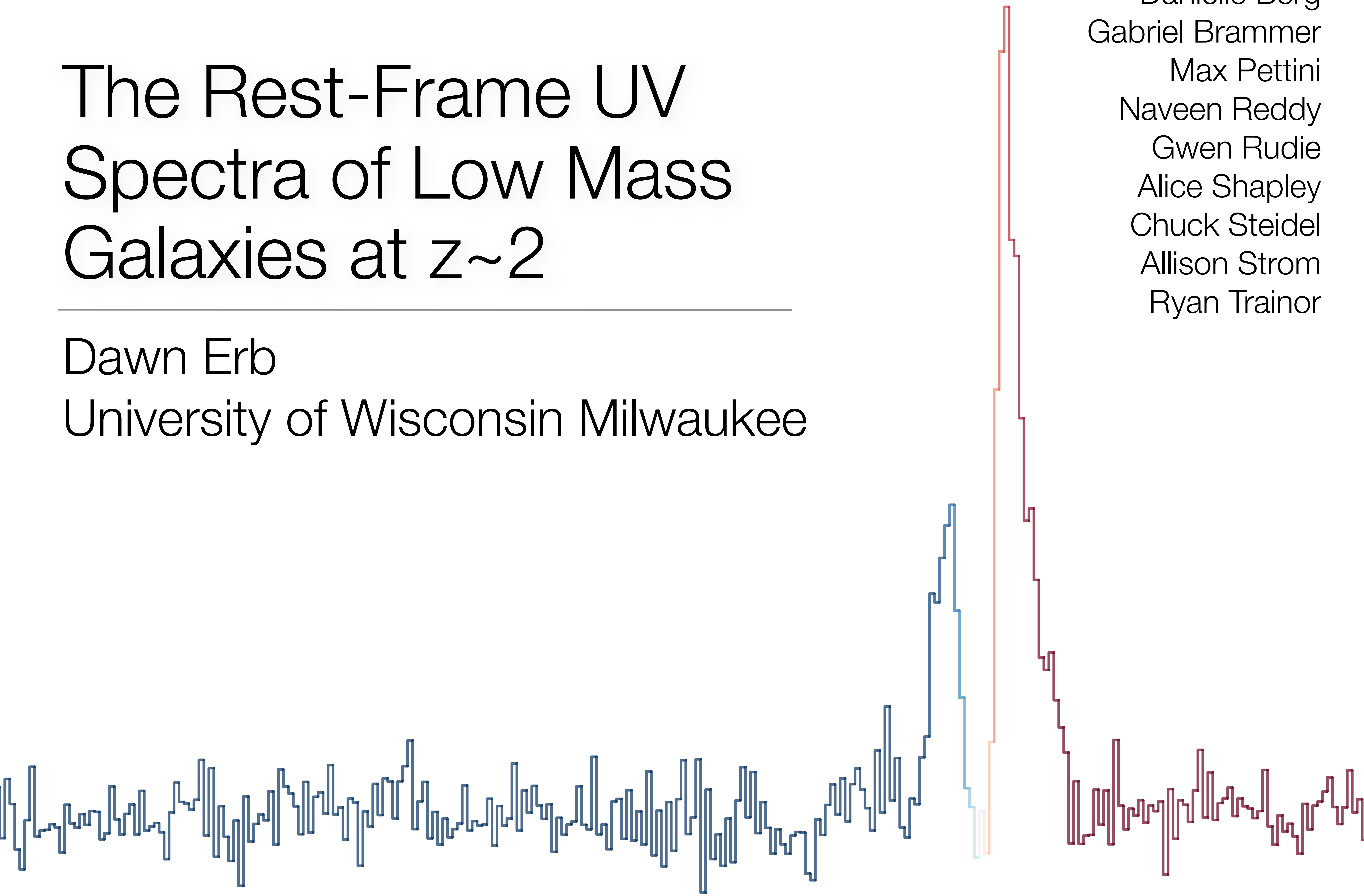
The Rest-Frame UV Spectra of Low Mass Galaxies at z~2

Dawn Erb
University of Wisconsin Milwaukee

Danielle Berg
Gabriel Brammer
Max Pettini
Naveen Reddy
Gwen Rudie
Alice Shapley
Chuck Steidel
Allison Strom
Ryan Trainor



32nd Institut d'Astrophysique de Paris Colloquium

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z~2 analogs of primeval galaxies?

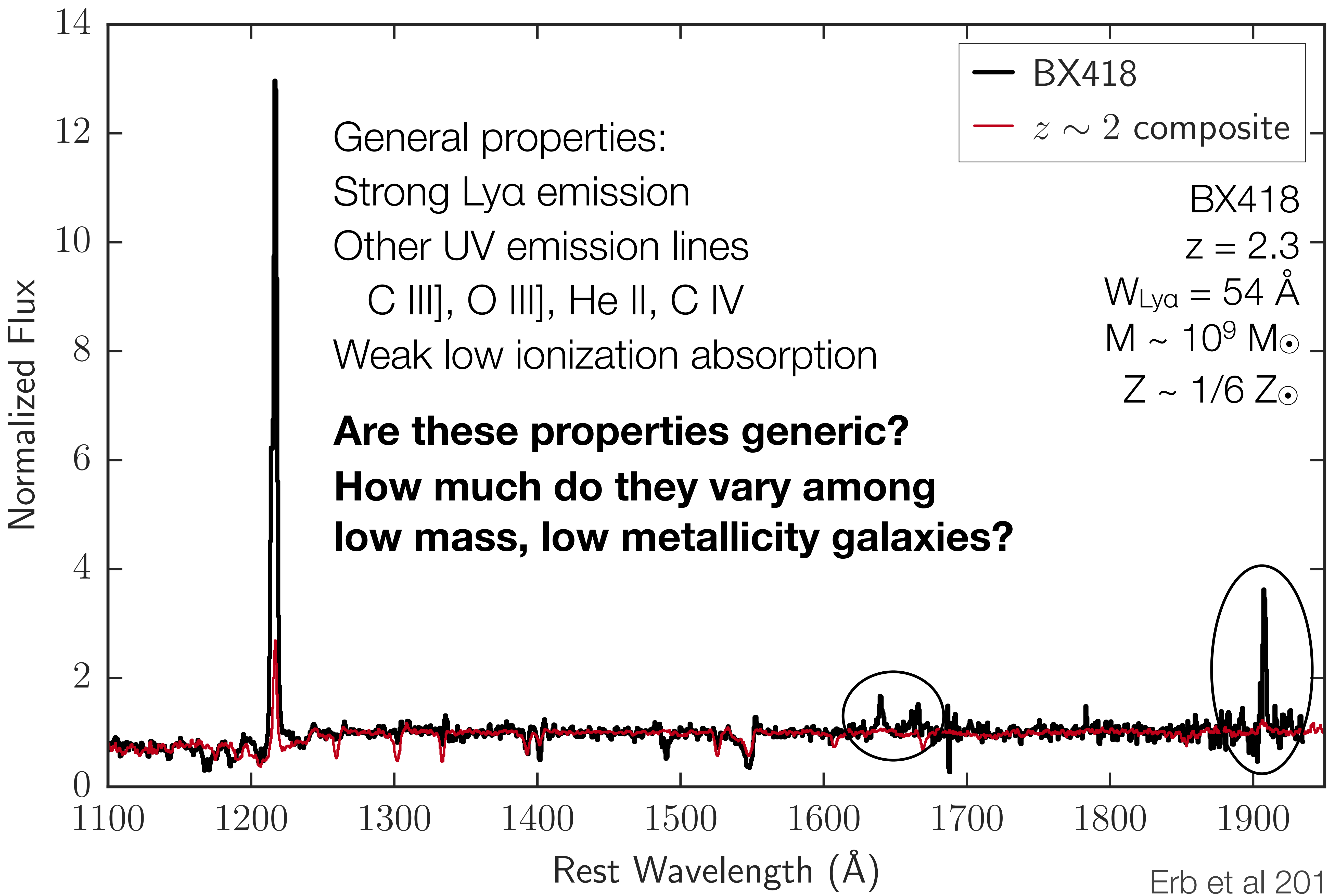
Why z ~ 2?

- Peak epoch of star formation
- Galaxies strongly star forming, may be relatively unevolved
- Access to nebular emission lines + UV
- High quality spectra possible

What does "low mass" mean?

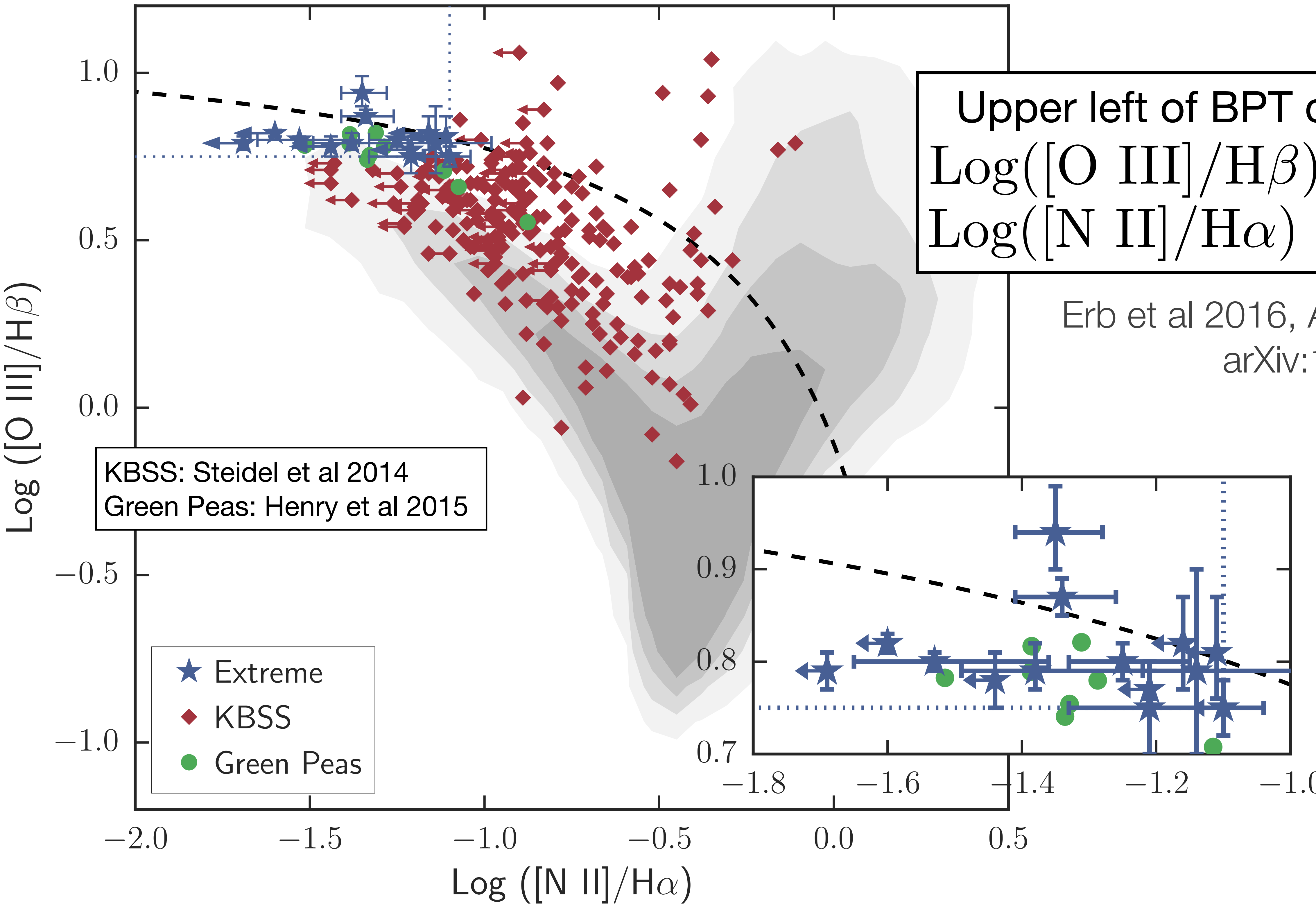
- Low mass continuum selected: ~10^9 $M_\odot$
- Lensed: ~10^8 $M_\odot$

Low mass, low metallicity galaxies at z~2



Erb et al 2010

Selecting low metallicity, highly ionized galaxies



Upper left of BPT diagram:

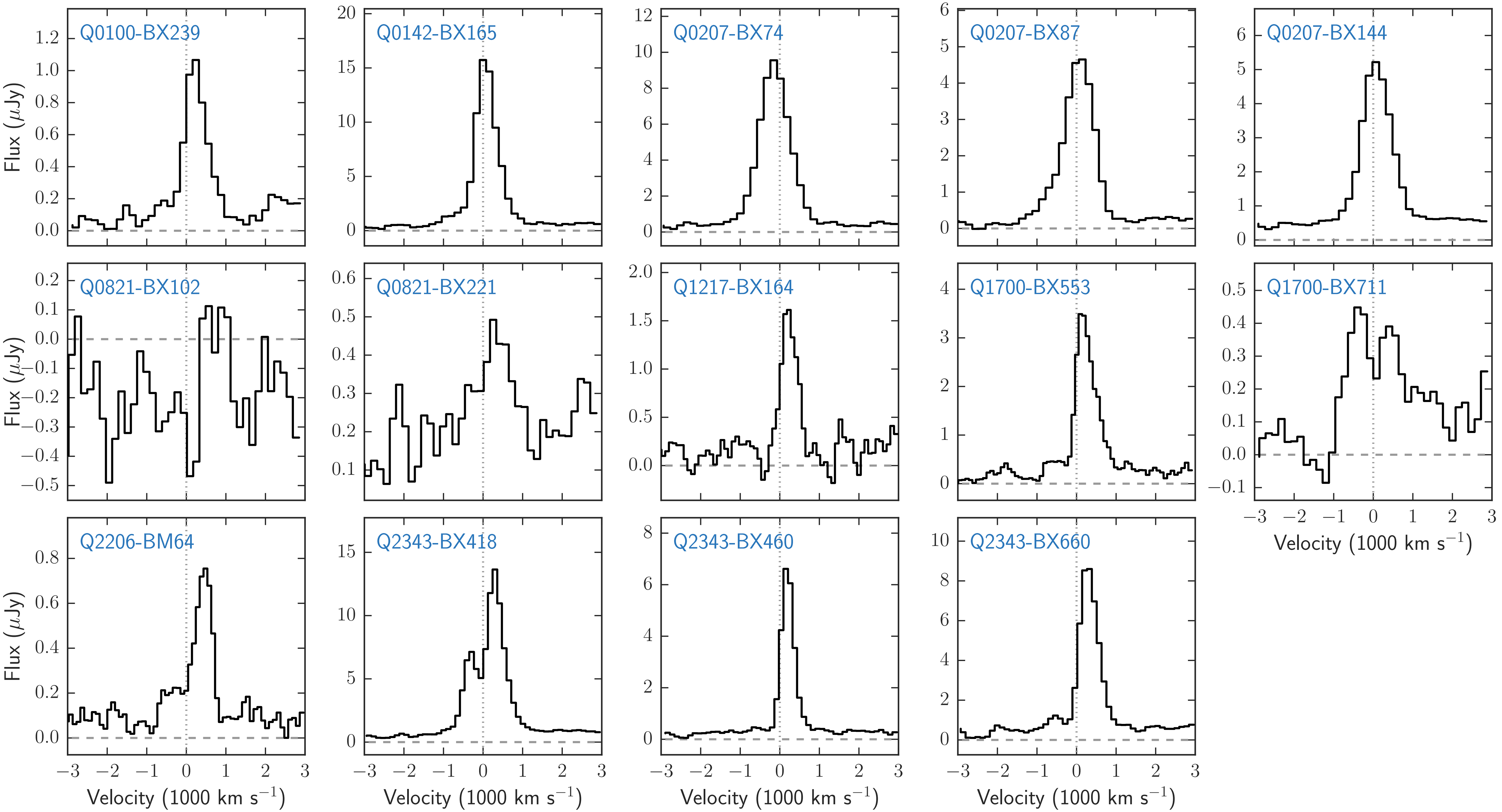
$\mathrm{Log}([\mathrm{O\ III}]/\mathrm{H}\beta) \geq 0.75$

$\mathrm{Log}([\mathrm{N\ II}]/\mathrm{H}\alpha) \leq -1.1$

Erb et al 2016, ApJ in press
arXiv:1605.04919

Typical metallicities 12+log(O/H) ~ 8.0 (~20% solar)

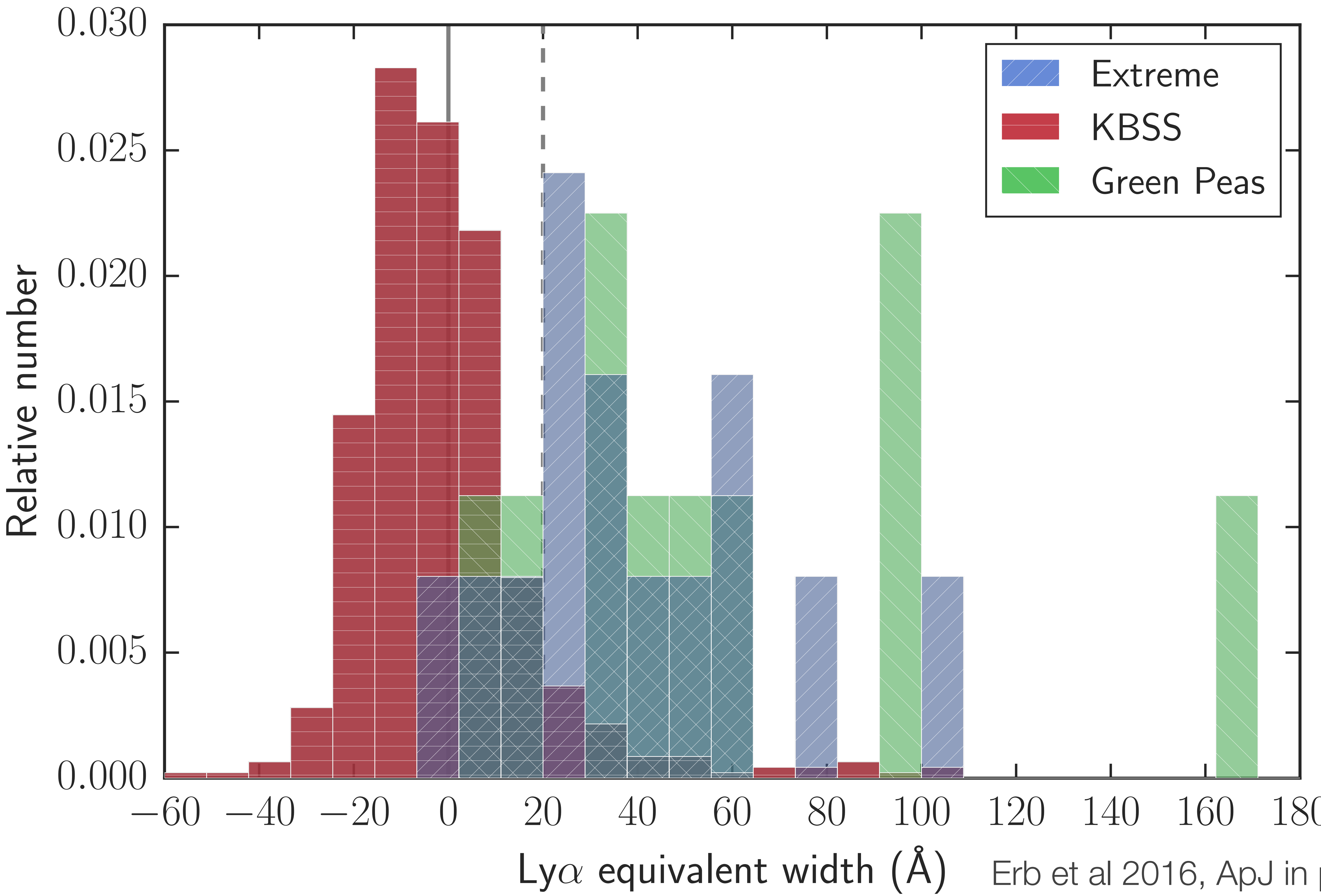
Most extreme BPT galaxies have strong Lyα emission



See also Ryan Trainor's talk

Erb et al 2016, ApJ in press
arXiv:1605.04919

Lyα equivalent width distributions



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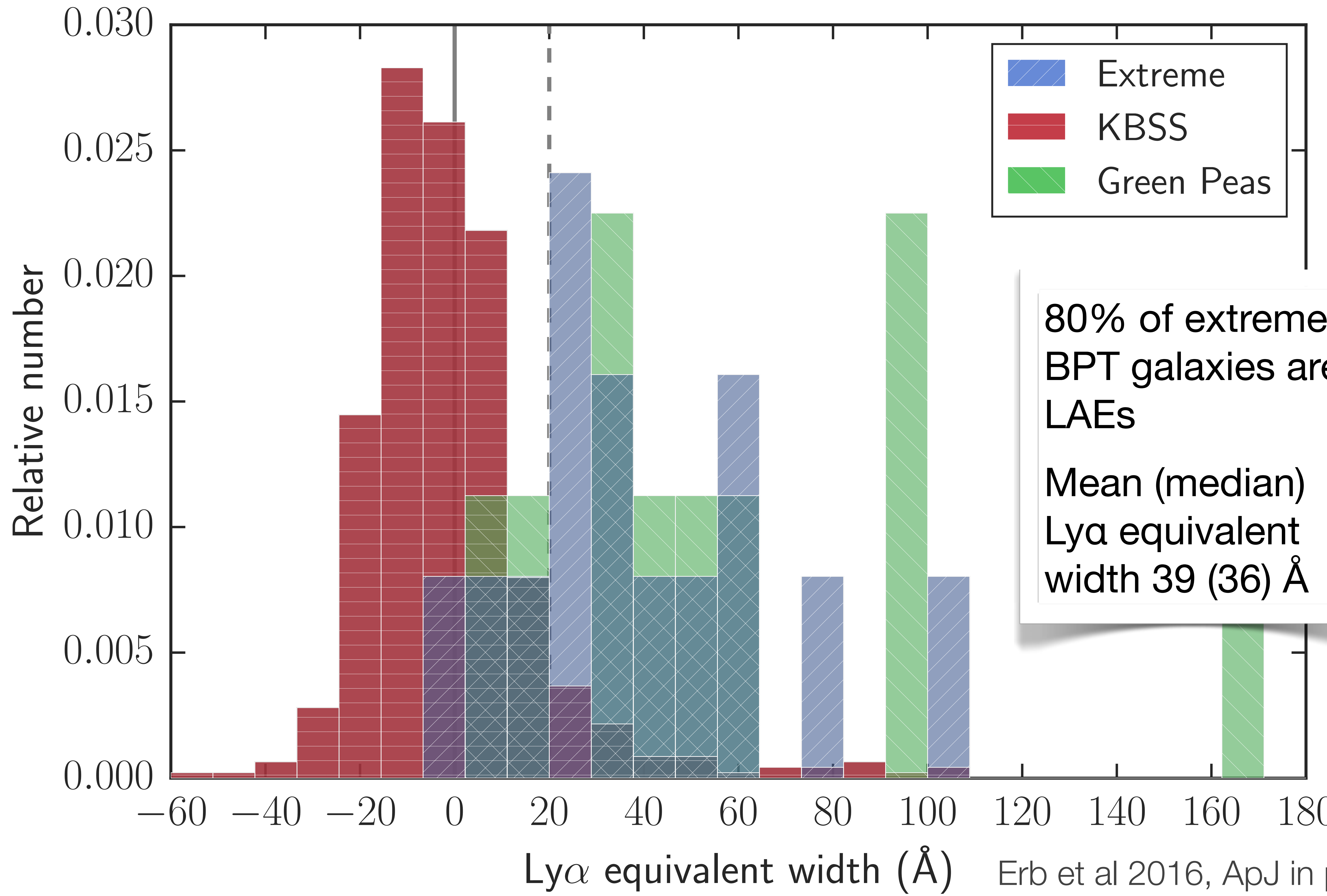
Lyα equivalent width distributions

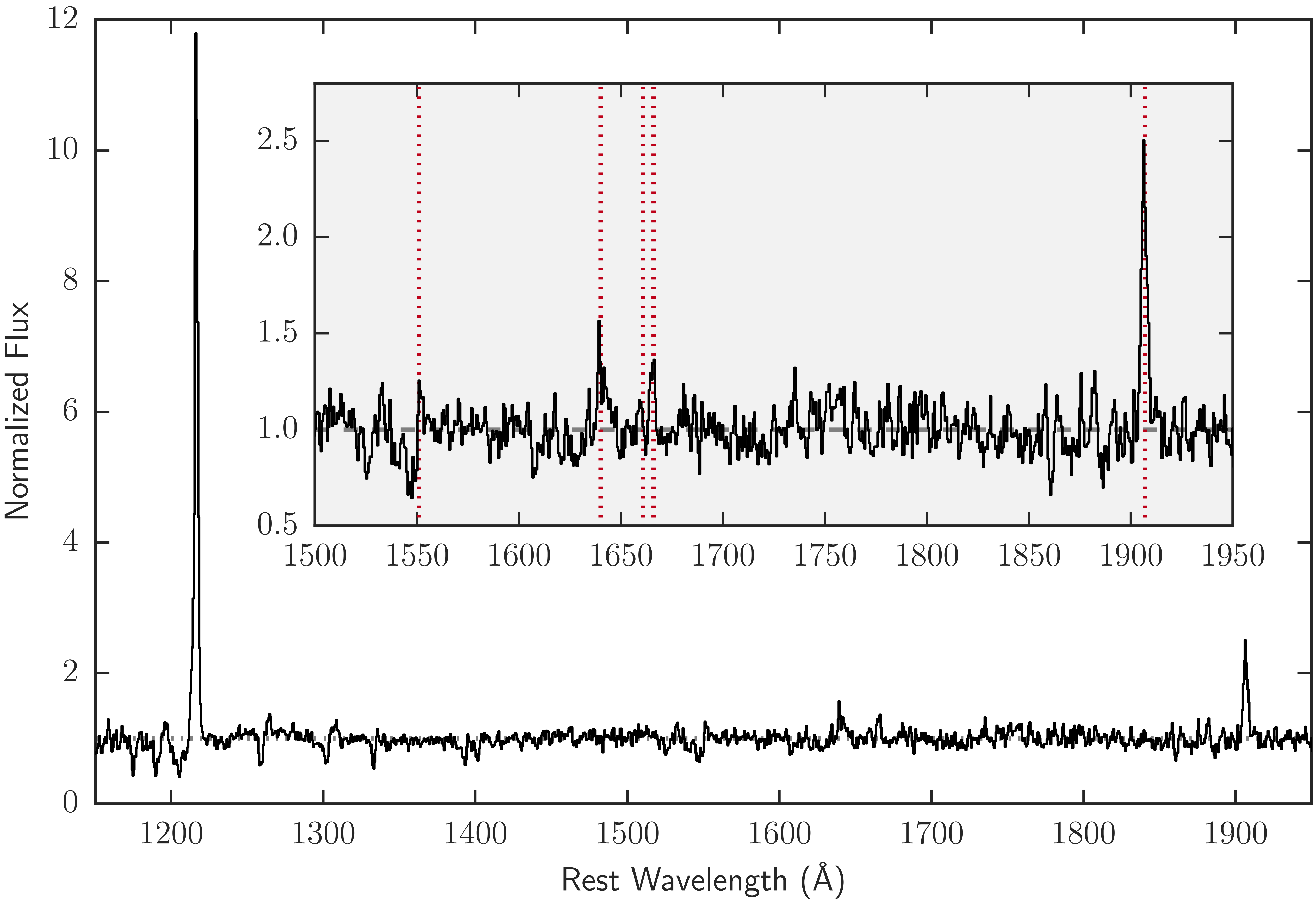


80% of extreme BPT galaxies are LAEs

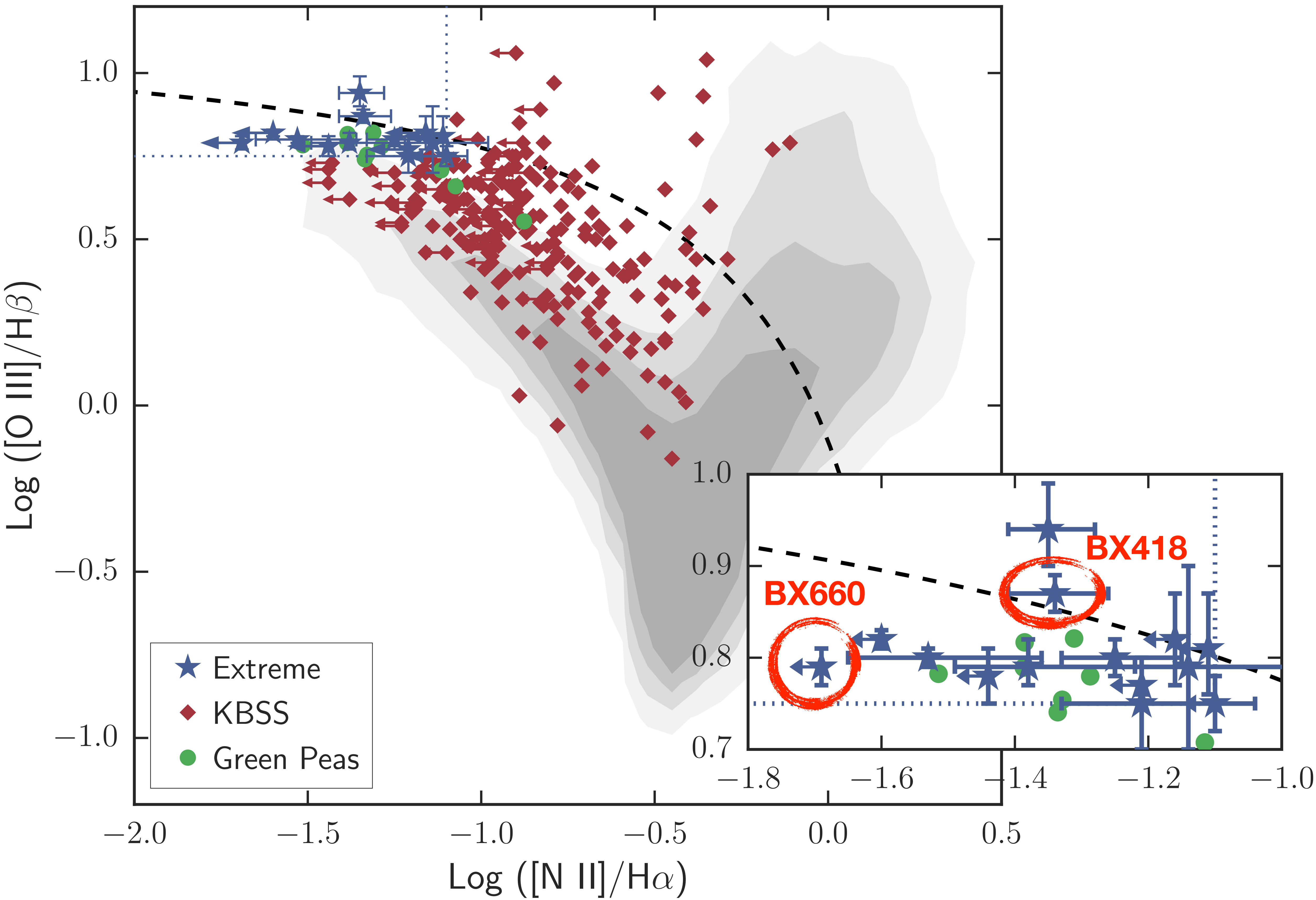
Mean (median) Lyα equivalent width 39 (36) Å

Erb et al 2016, ApJ in press
arXiv:1605.04919

Extreme BPT galaxies: composite UV spectrum



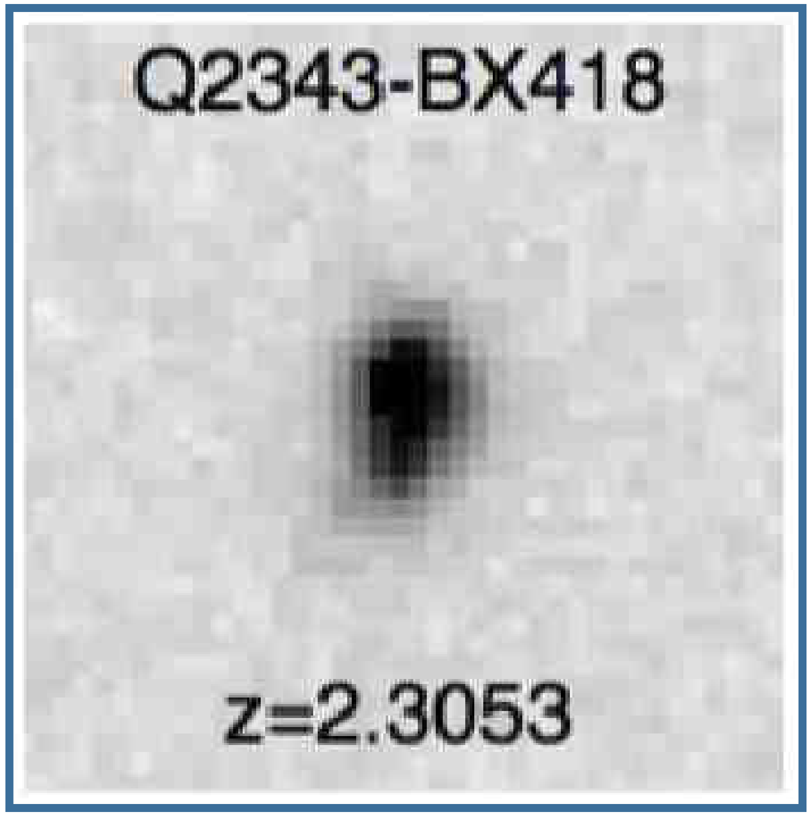
Individual galaxies: a closer look

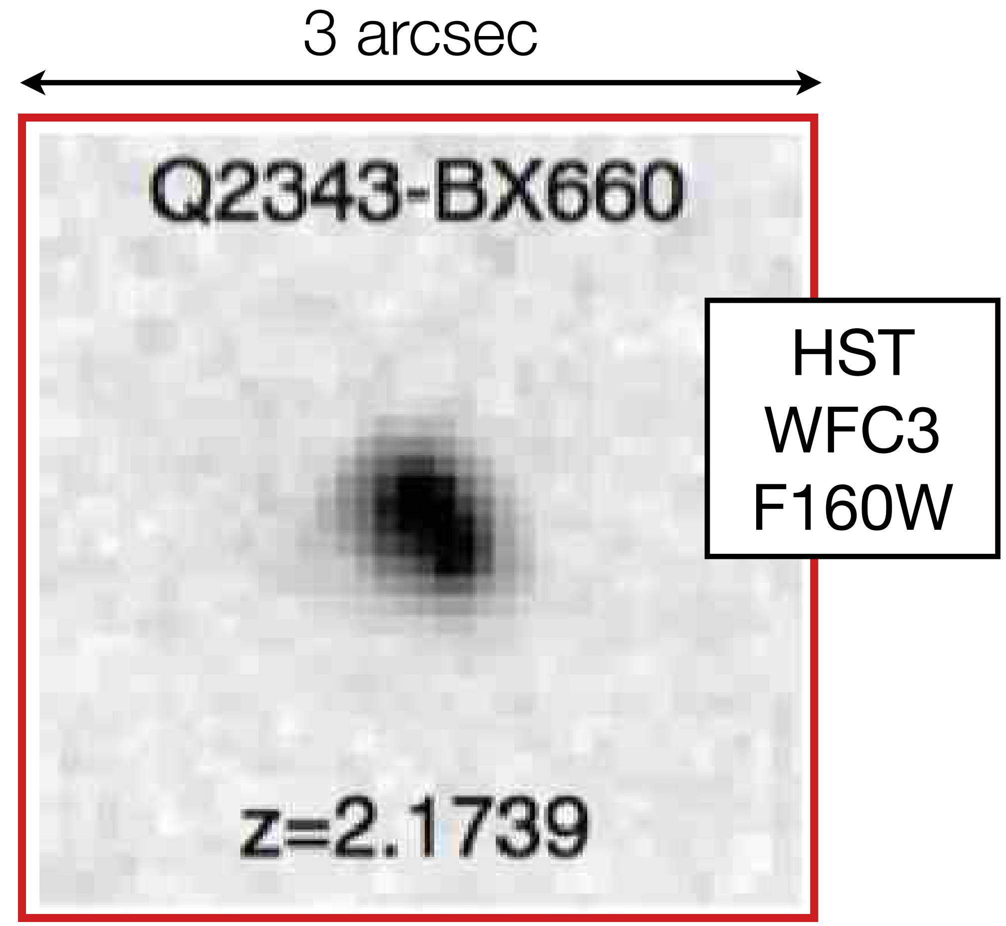


Erb et al in prep

Individual galaxies: a closer look

Law et al 2012



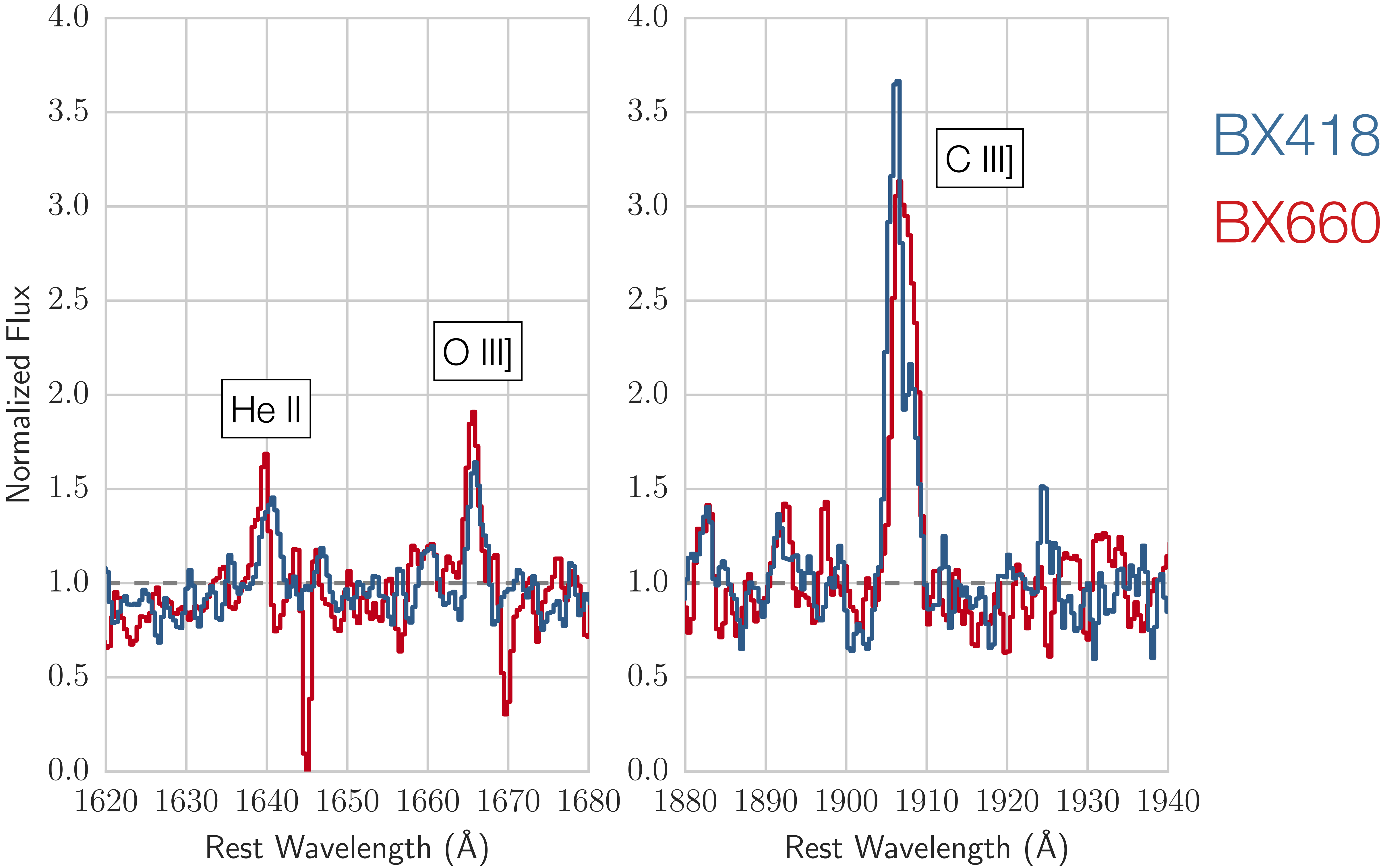


Q2343-BX418
$M_\star = 2 \times 10^9\ M_\odot$
SFR = $50\ M_\odot\ yr^{-1}$
SSFR = $18\ Gyr^{-1}$
12 + log(O/H) = 8.08 (T_e)
O32 = 9.66

Q2343-BX660
$M_\star = 5 \times 10^9\ M_\odot$
SFR = $23\ M_\odot\ yr^{-1}$
SSFR = $4\ Gyr^{-1}$
12 + log(O/H) = 8.13 (T_e)
O32 = 10.98

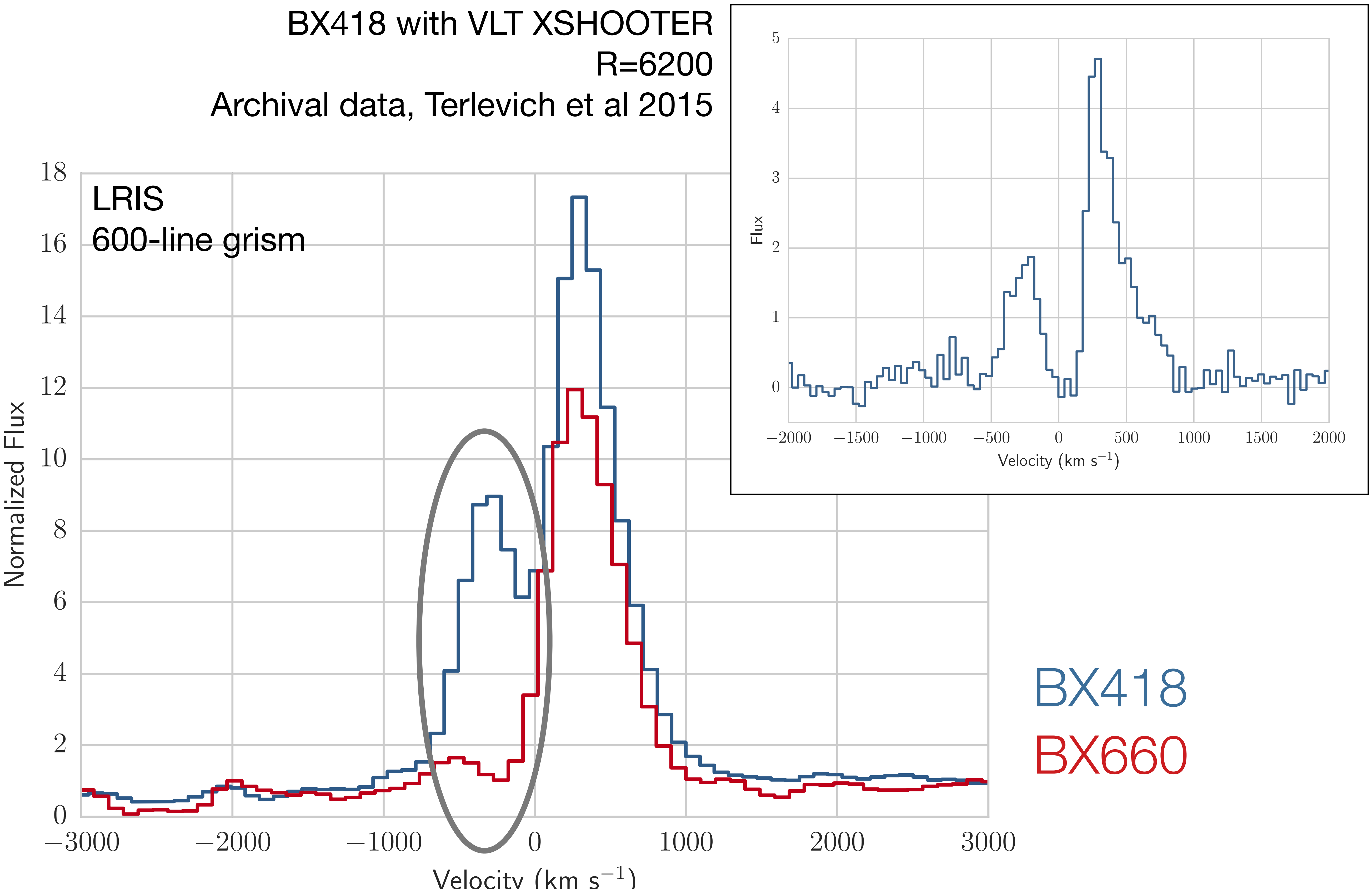
O/H, O32 from Steidel et al 2014

Strong UV emission lines



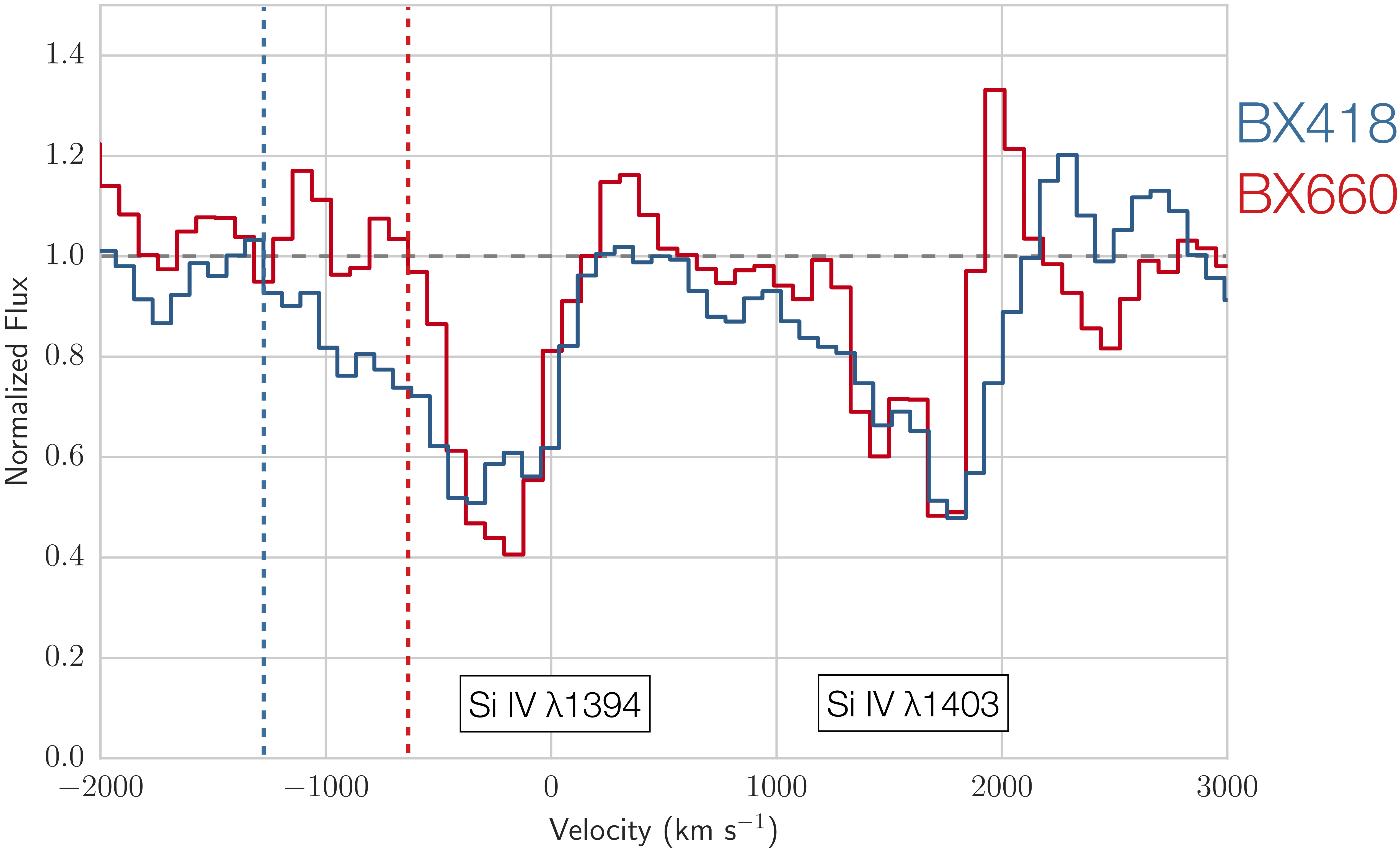
Erb et al in prep

Lyα emission profiles



Erb et al in prep

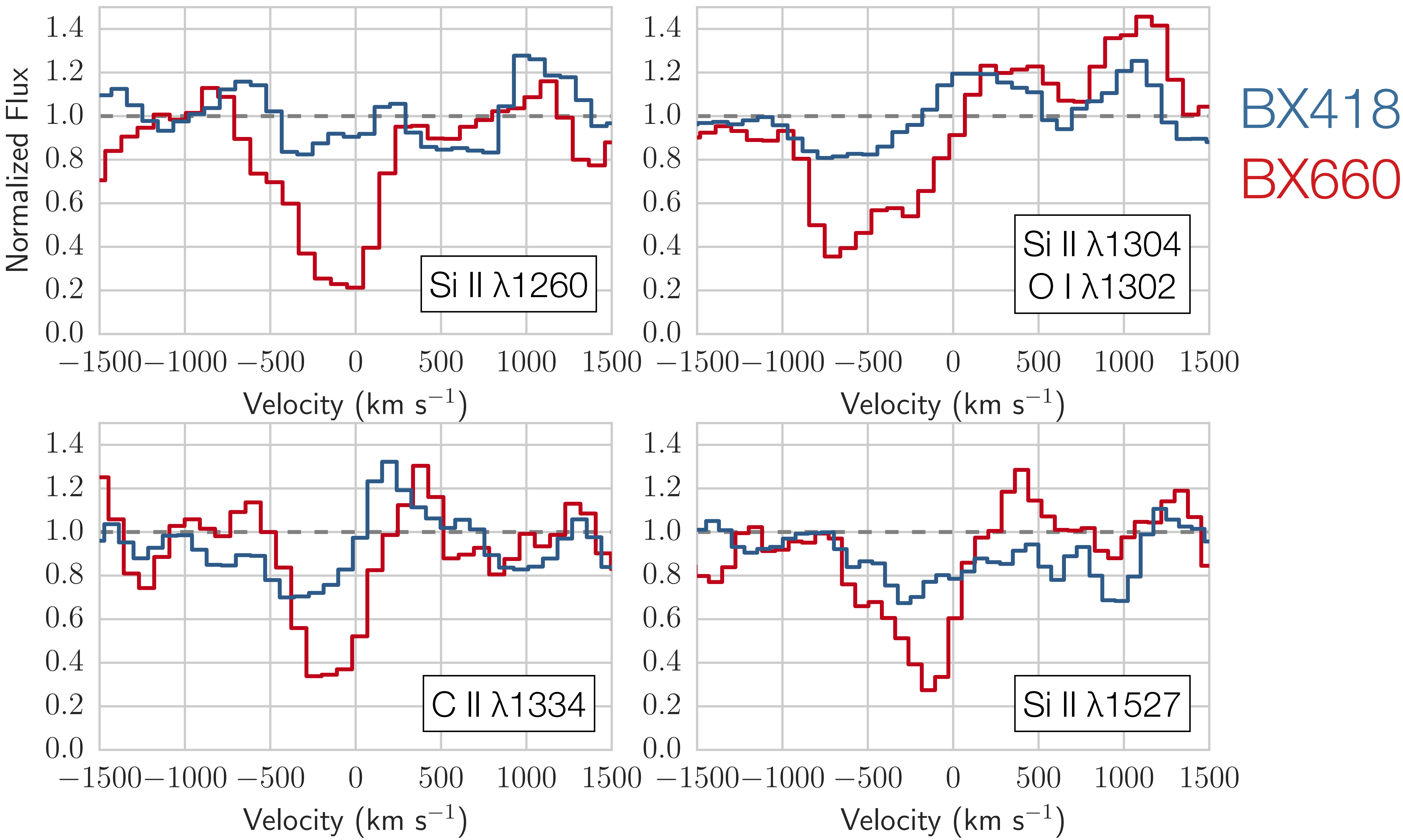
High ionization absorption lines vary in velocity



Maximum blueshifted velocities:
~1300 km s^{-1} (BX418), ~600 km s^{-1} (BX660)

Erb et al in prep

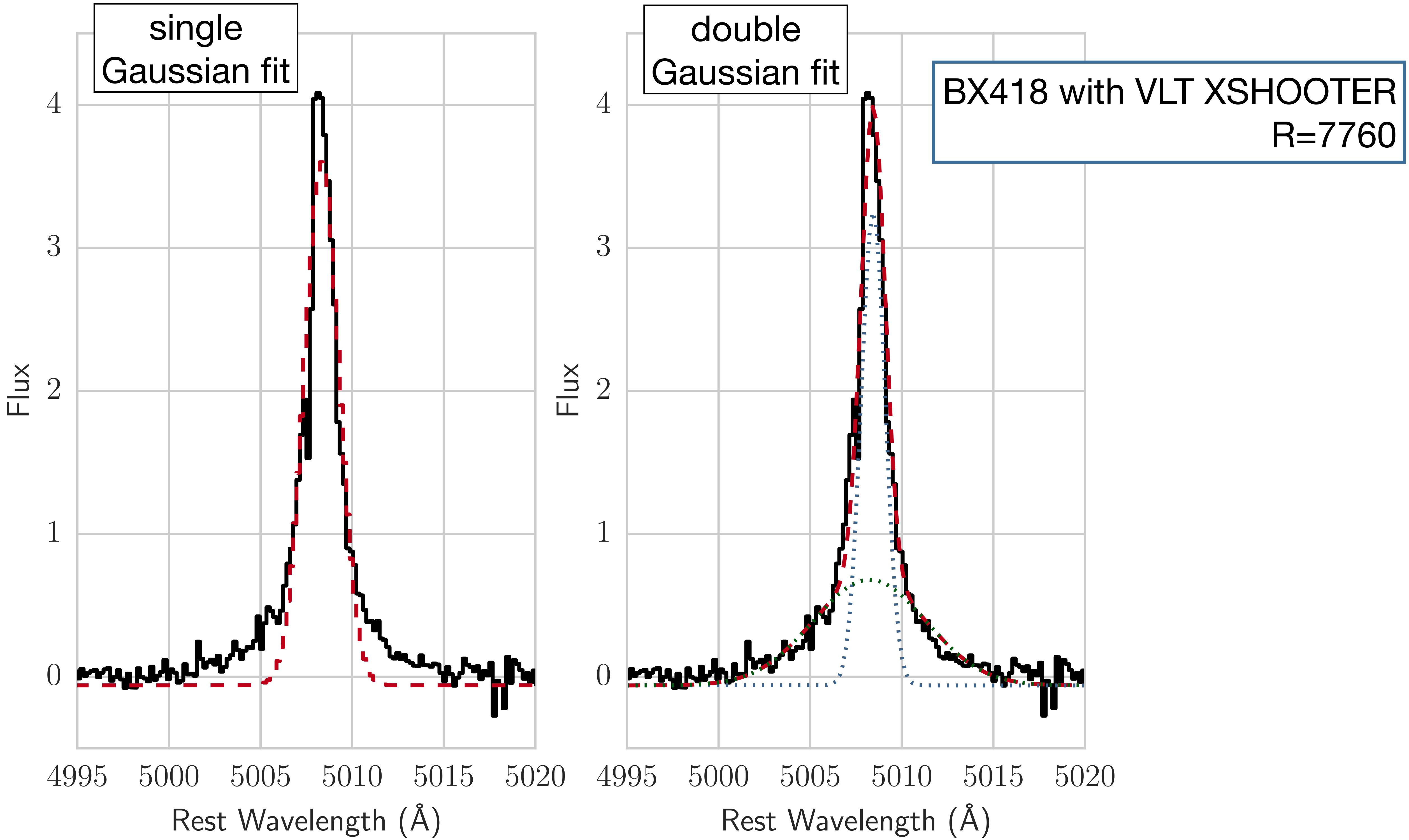
Low ionization absorption lines vary in strength



BX660: much stronger low ionization absorption

Erb et al in prep

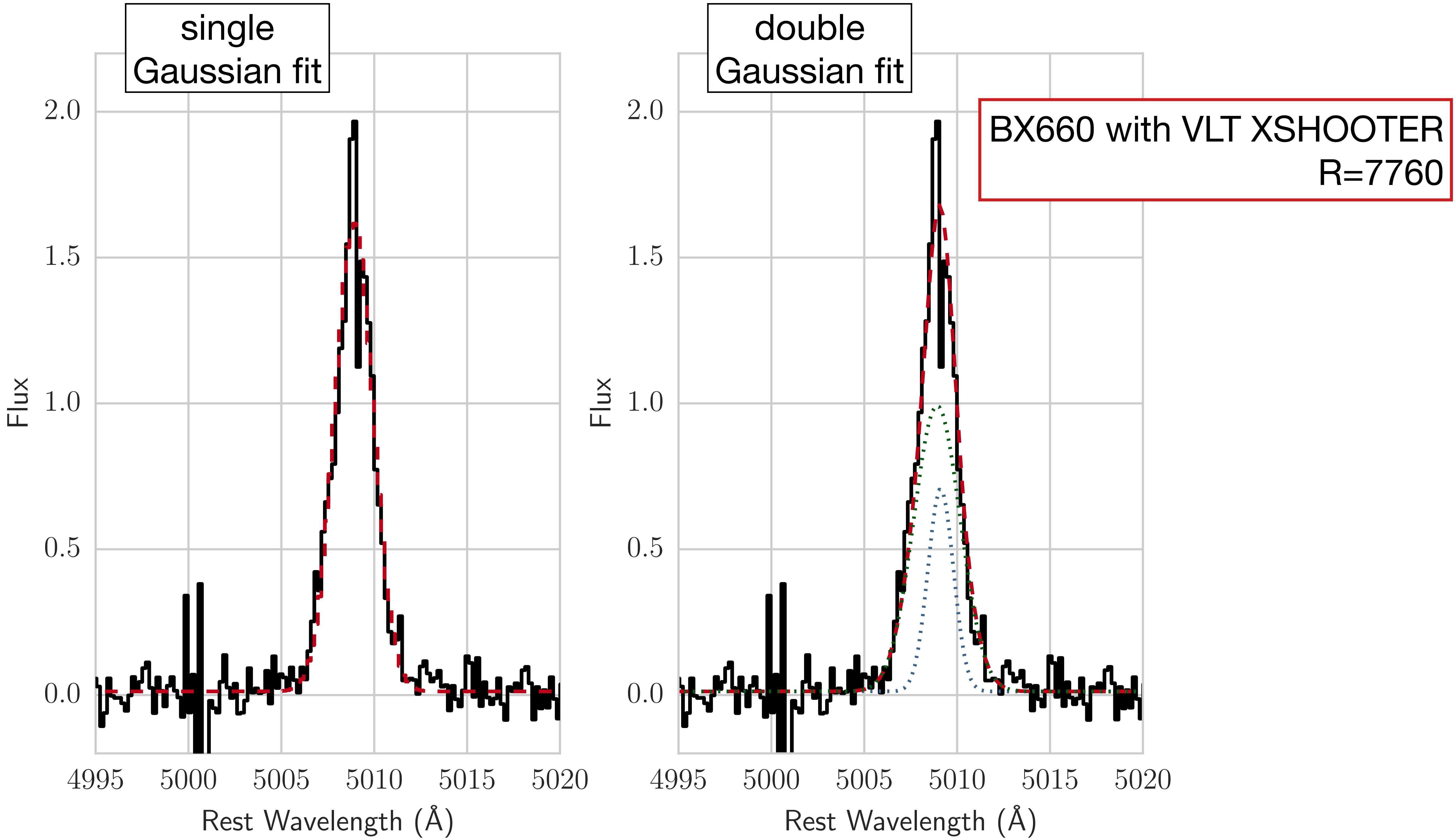
[OIII] λ5007 Emission Profiles



Broad [OIII] emission with FWHM ~ 435 km s^{-1}
Narrow component has FWHM ~ 92 km s^{-1} (σ = 39 km s^{-1})

Erb et al in prep

[OIII] λ5007 Emission Profiles



No evidence for broad [OIII] emission

FWHM = 175 km s^{-1} (σ = 75 km s^{-1})

Erb et al in prep

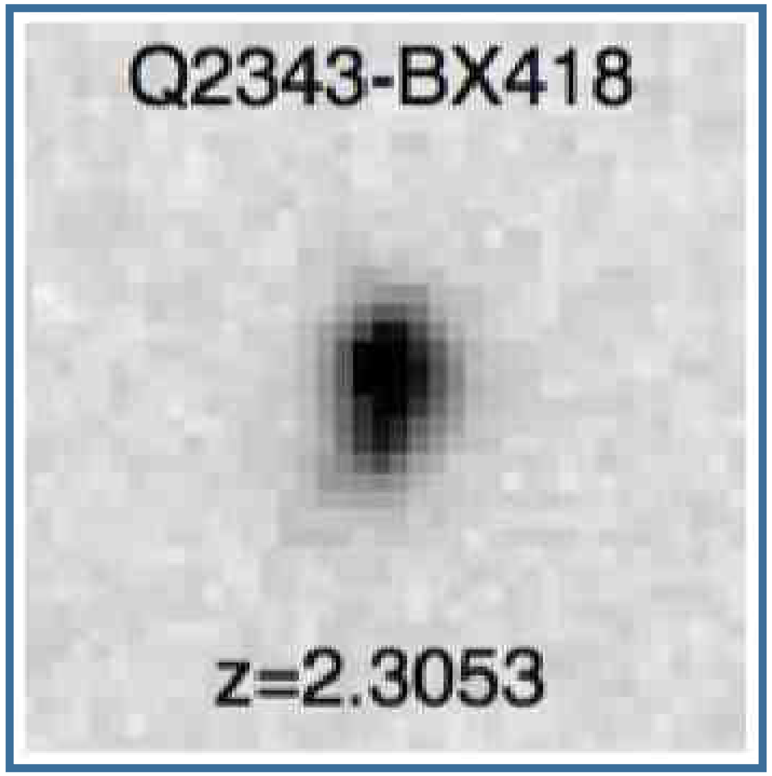
BX418 vs BX660: implications

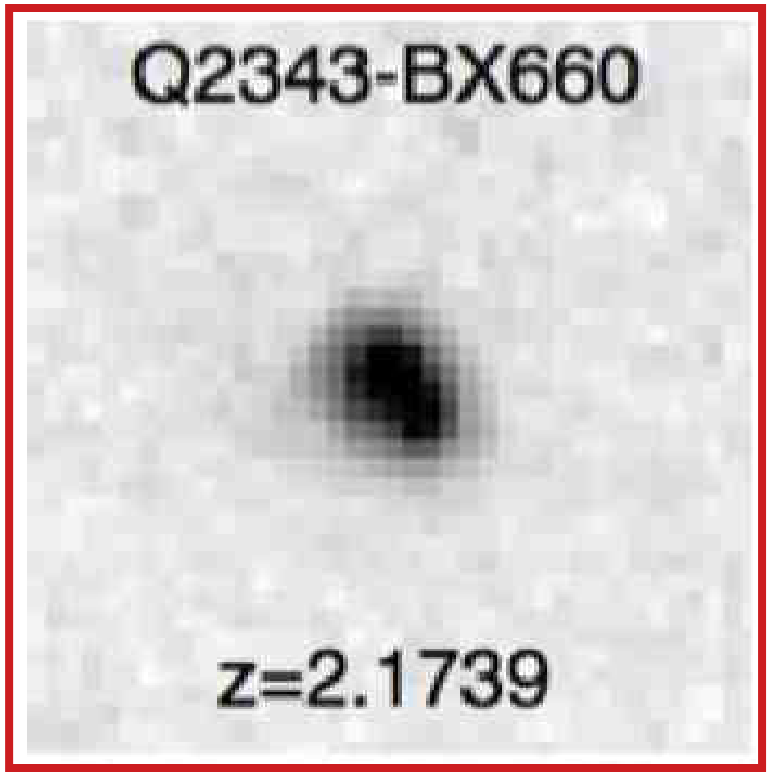
Galaxies with similar metallicities, masses, morphologies and extreme emission line ratios may have significantly different outflow properties and Lyα profiles

Likely due to geometry, covering fraction/column density of neutral hydrogen

Signatures of most extreme objects:

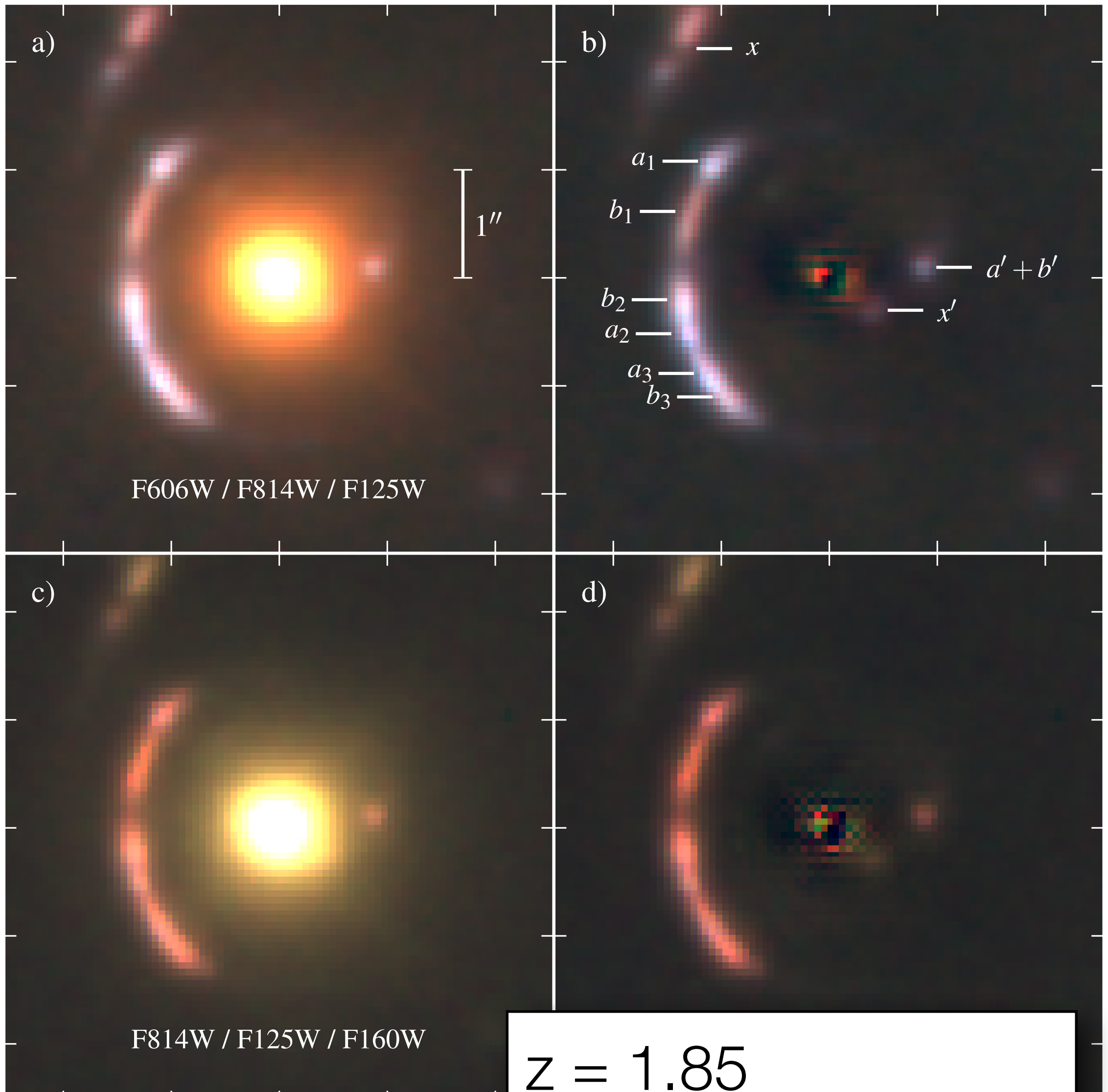
- High velocity, highly ionized outflow
- Weak low ionization absorption: low covering fraction of neutral gas
- Broad component to nebular emission
- Blueshifted Lyα emission
- Most likely LyC emitters?



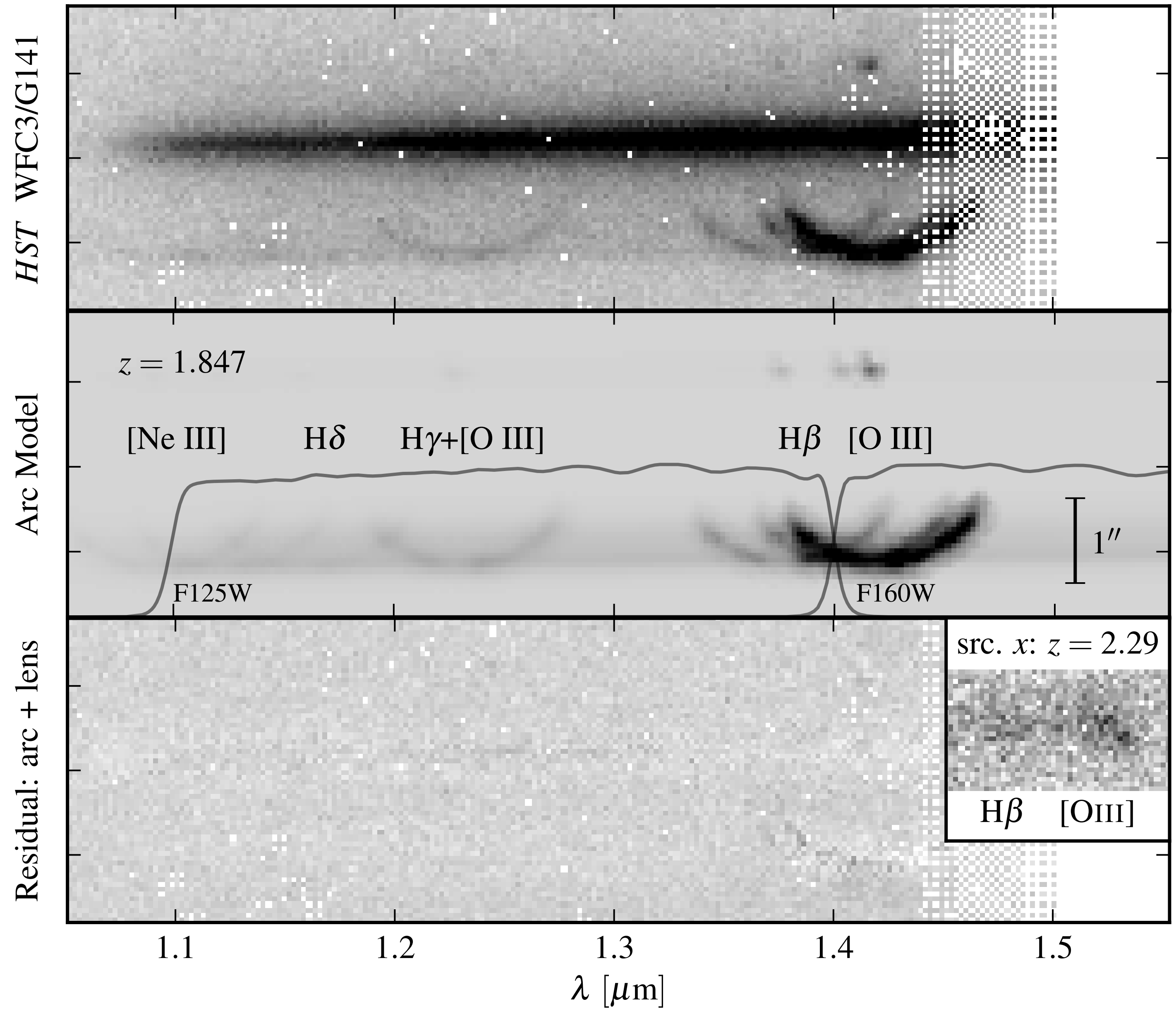


Law et al 2012

A low mass, low metallicity lensed galaxy at z~2



z = 1.85
M = 9 x 10^7 M$_\odot$
12 + log(O/H) = 7.5

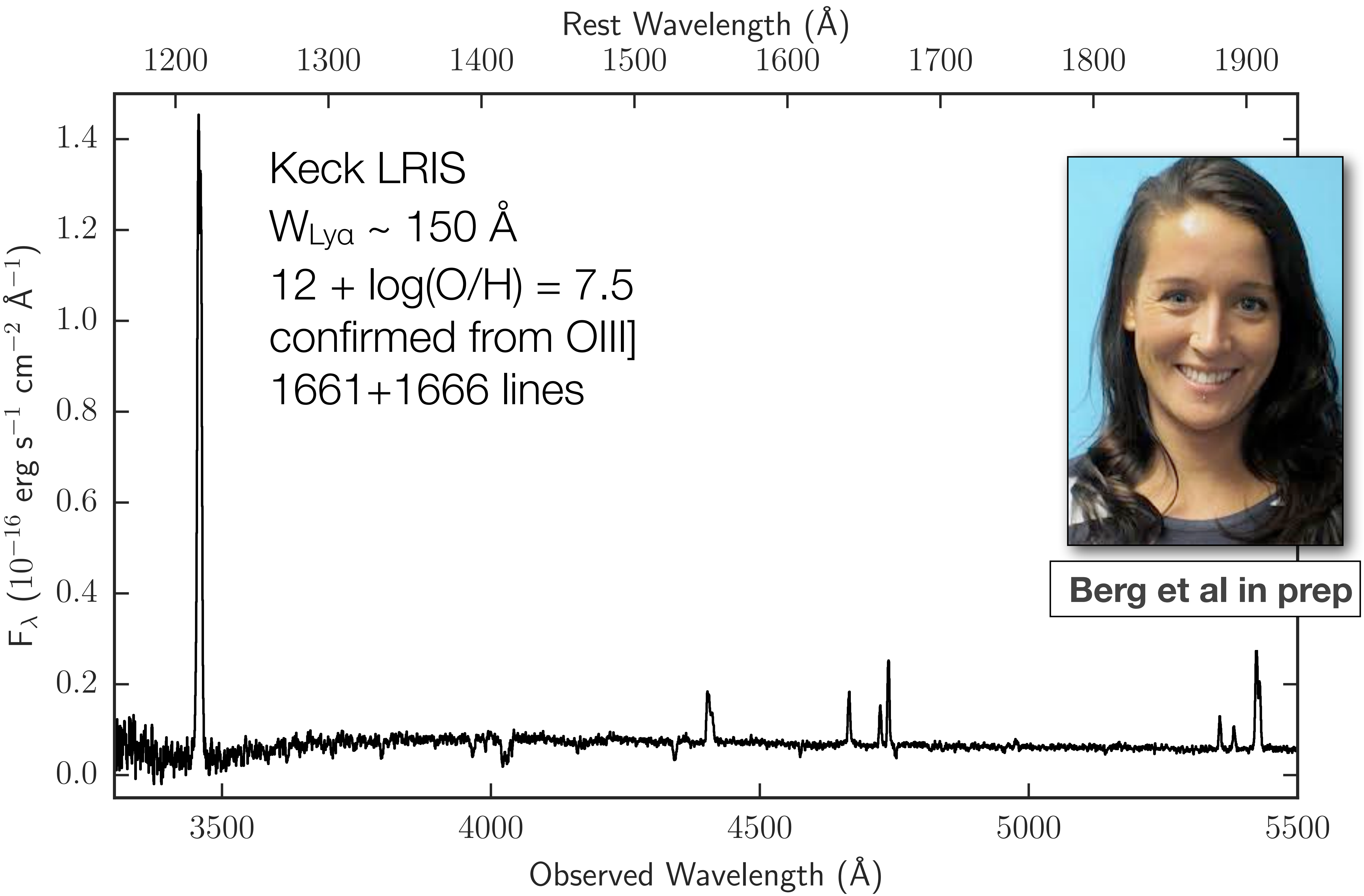


Rest-frame optical spectrum from 3DHST grism survey (Brammer et al 2012)

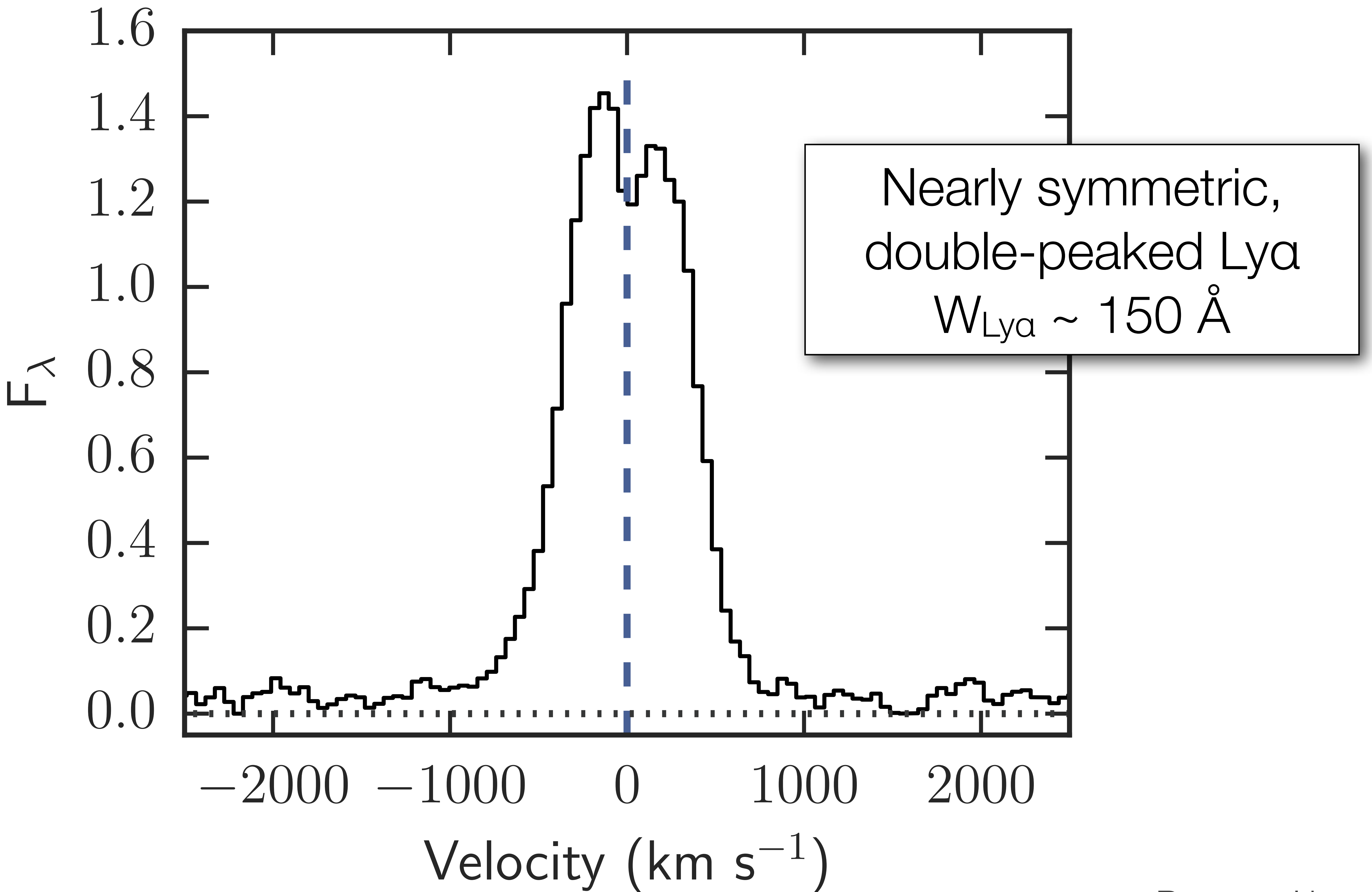
Very high EW [OIII] (~2000 Å rest-frame) and Hβ emission (~500 Å)

Very high sSFR ~100 Gyr^{-1} (~8 Myr to form all stars at current rate)

Rest-frame UV spectrum

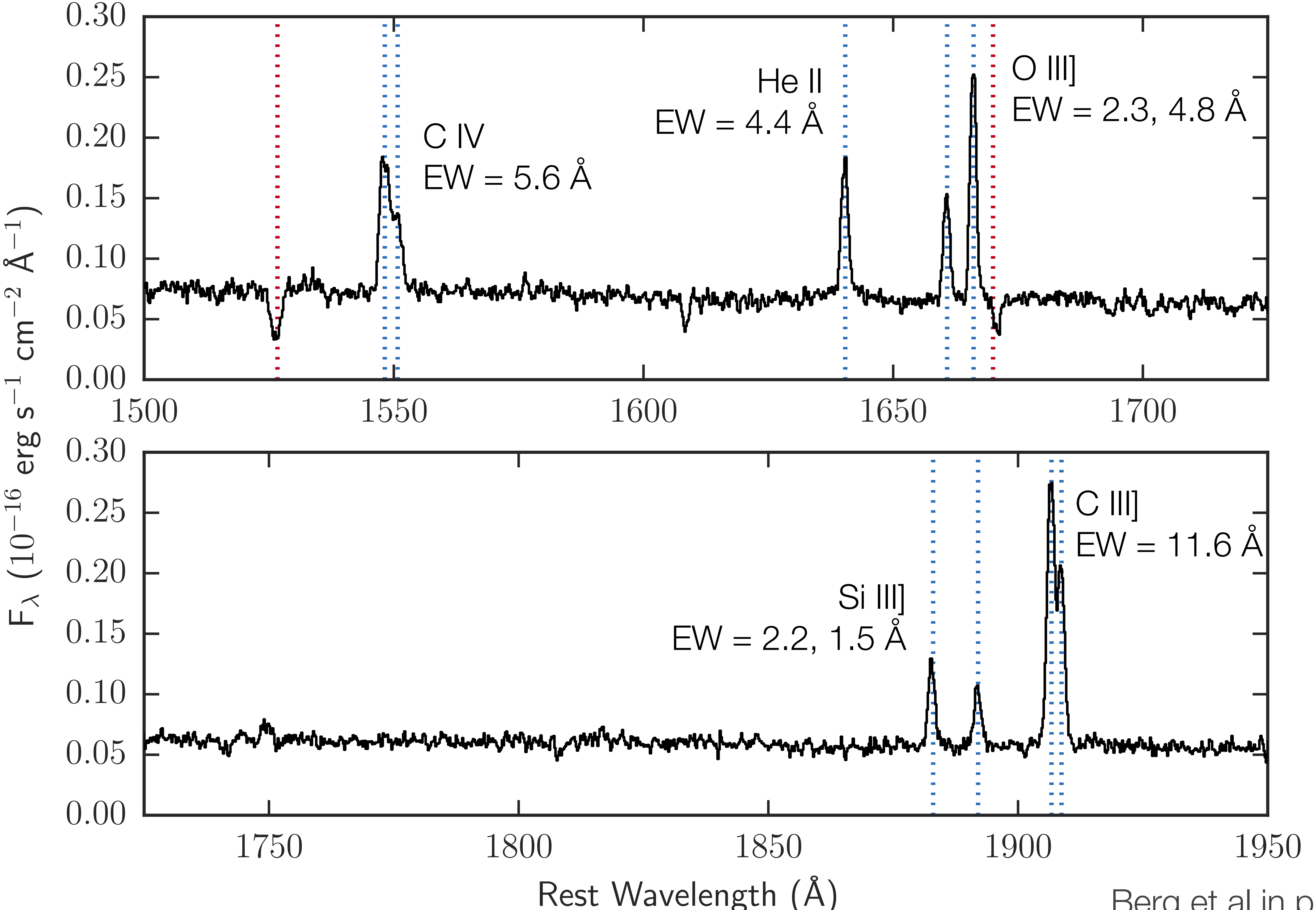


Lyα emission



Berg et al in prep

Strong UV emission lines



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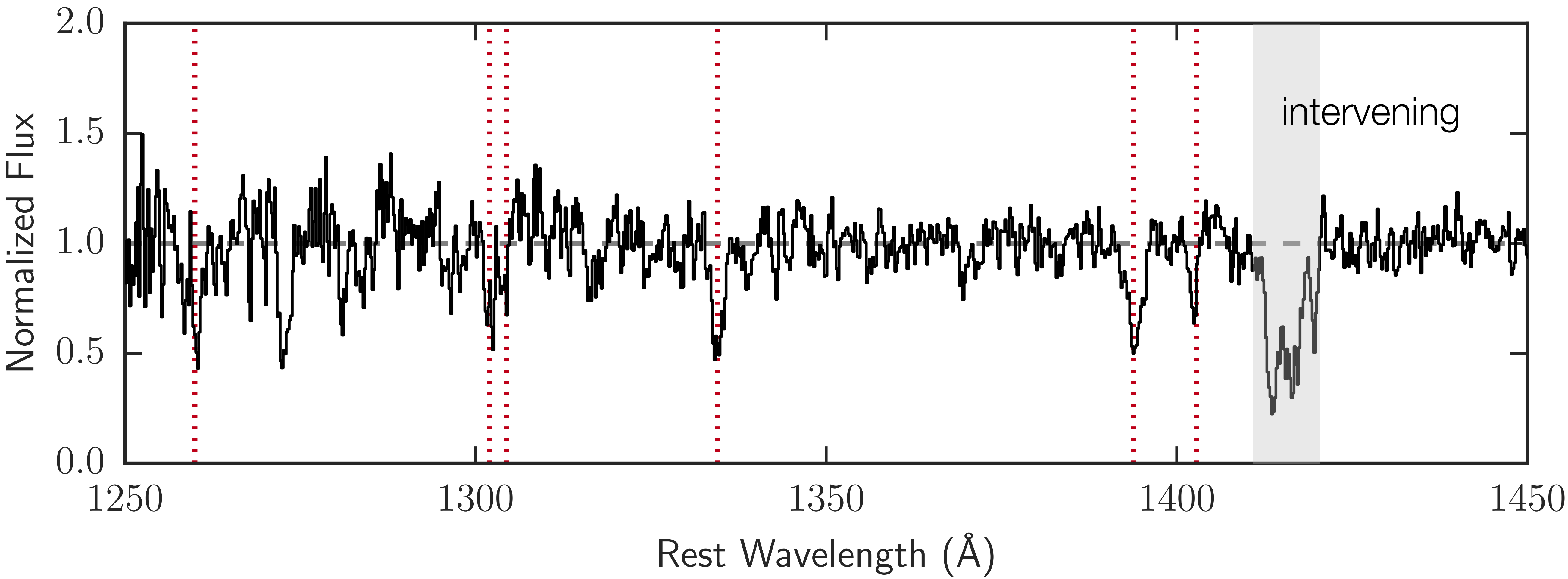
Interstellar absorption lines

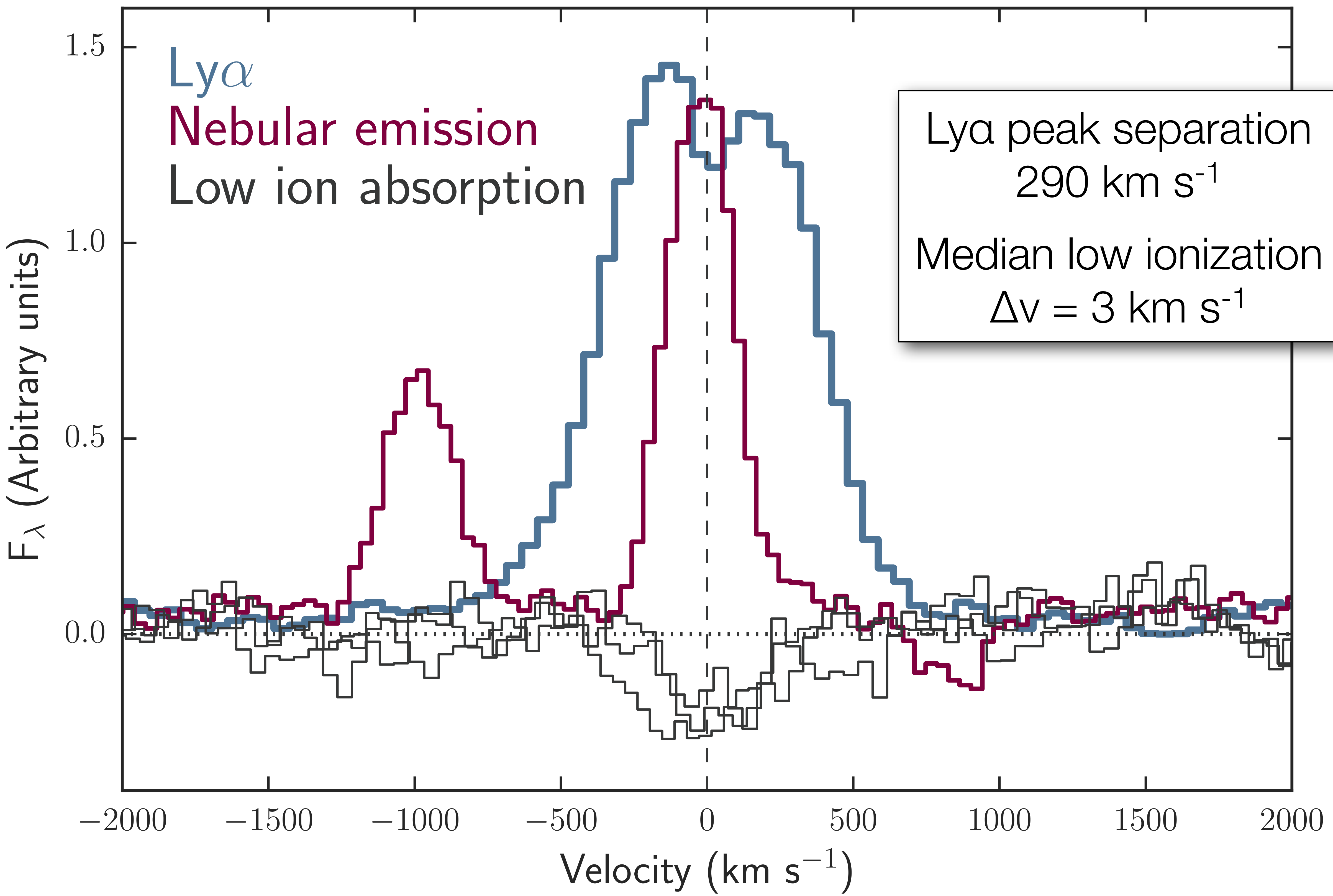


Interstellar absorption lines relatively weak (EW ~ 0.5 - 1 Å), narrow

Weak or no outflows (and Σ_{SFR} = 20 M$_\odot$ yr^{-1} kpc^{-1})

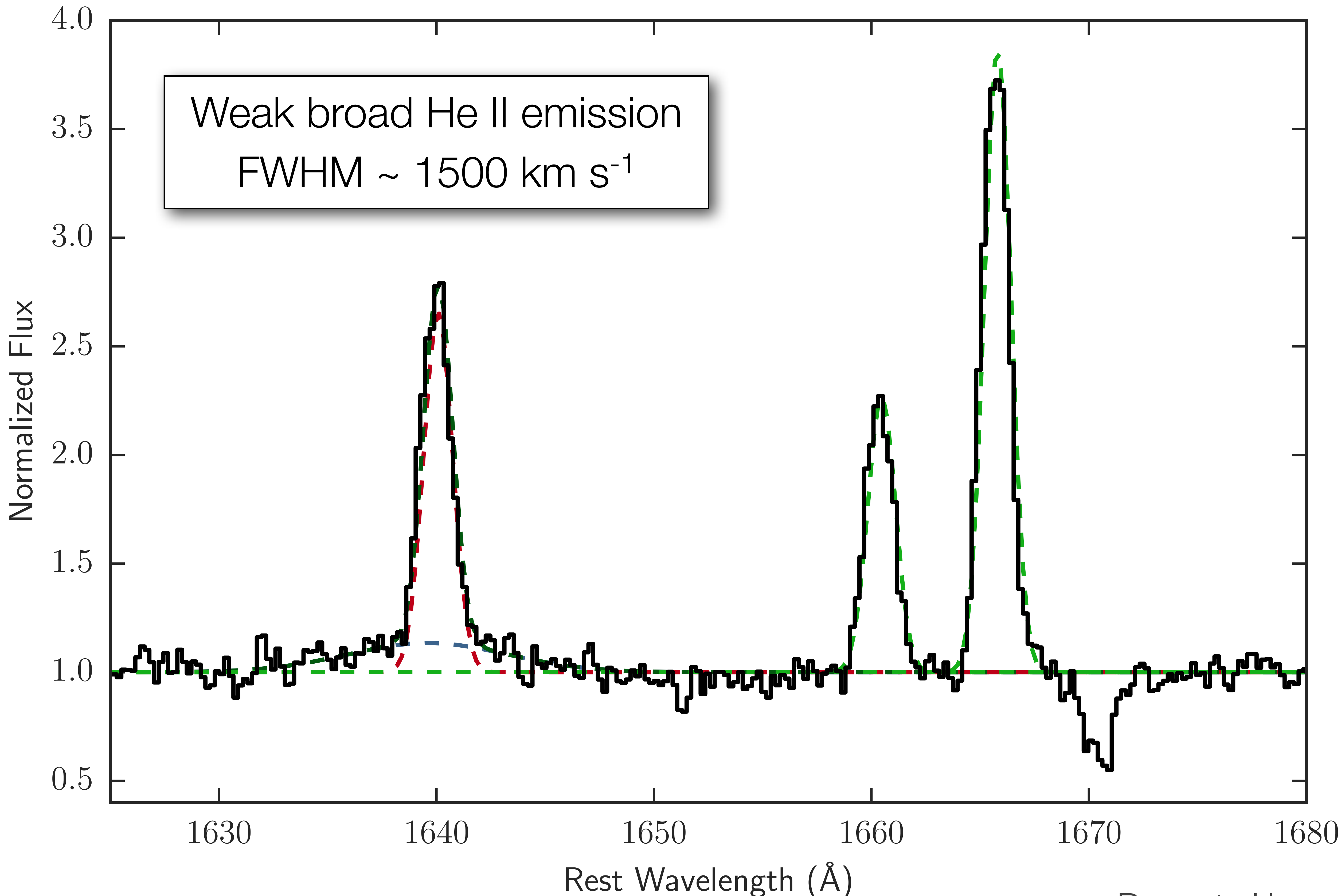
Berg et al in prep

Kinematics



Berg et al in prep

Stellar + nebular He II emission



Berg et al in prep

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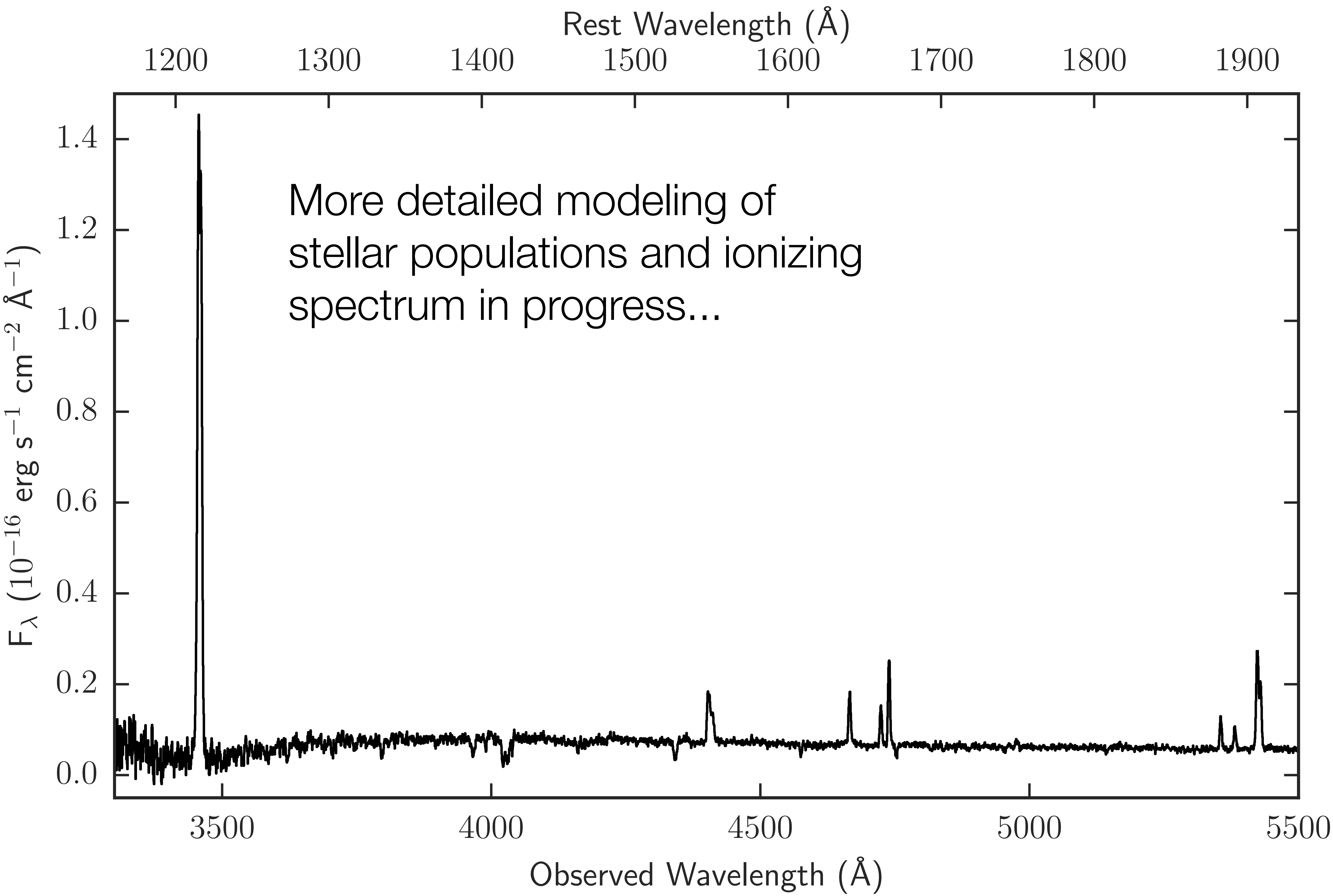


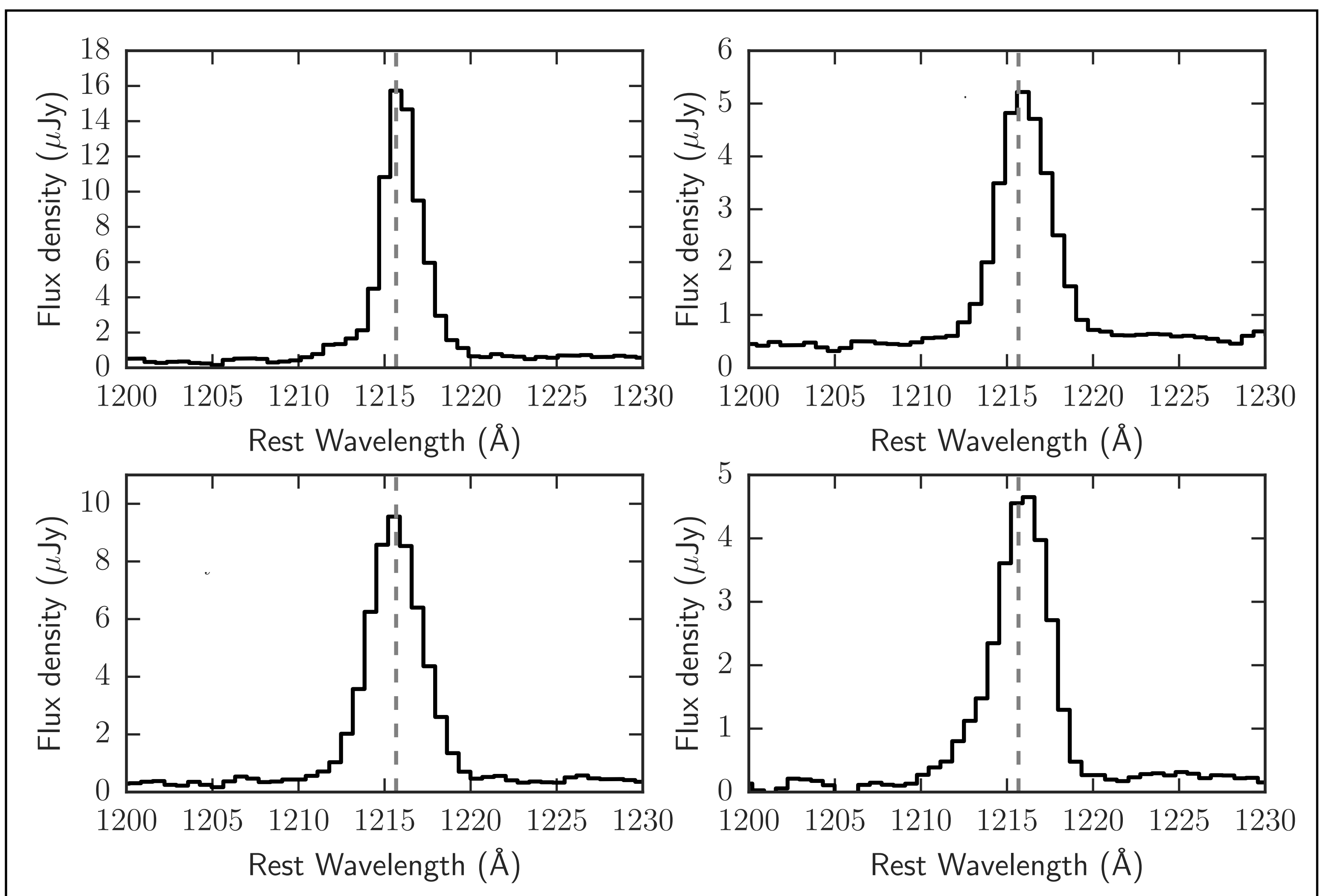
Berg et al in prep

Conclusions

Low mass, low metallicity galaxies show consistently strong UV emission lines, but Lyα and interstellar absorption properties may vary widely

These properties likely most closely tied to LyC escape

More high S/N, high resolution spectra required



Coming soon:
deep LRIS + X-shooter spectra of additional galaxies with extreme optical line ratios, strong Lyα and UV emission lines