Star Formation and Feedback in Low Mass Galaxies at z~2

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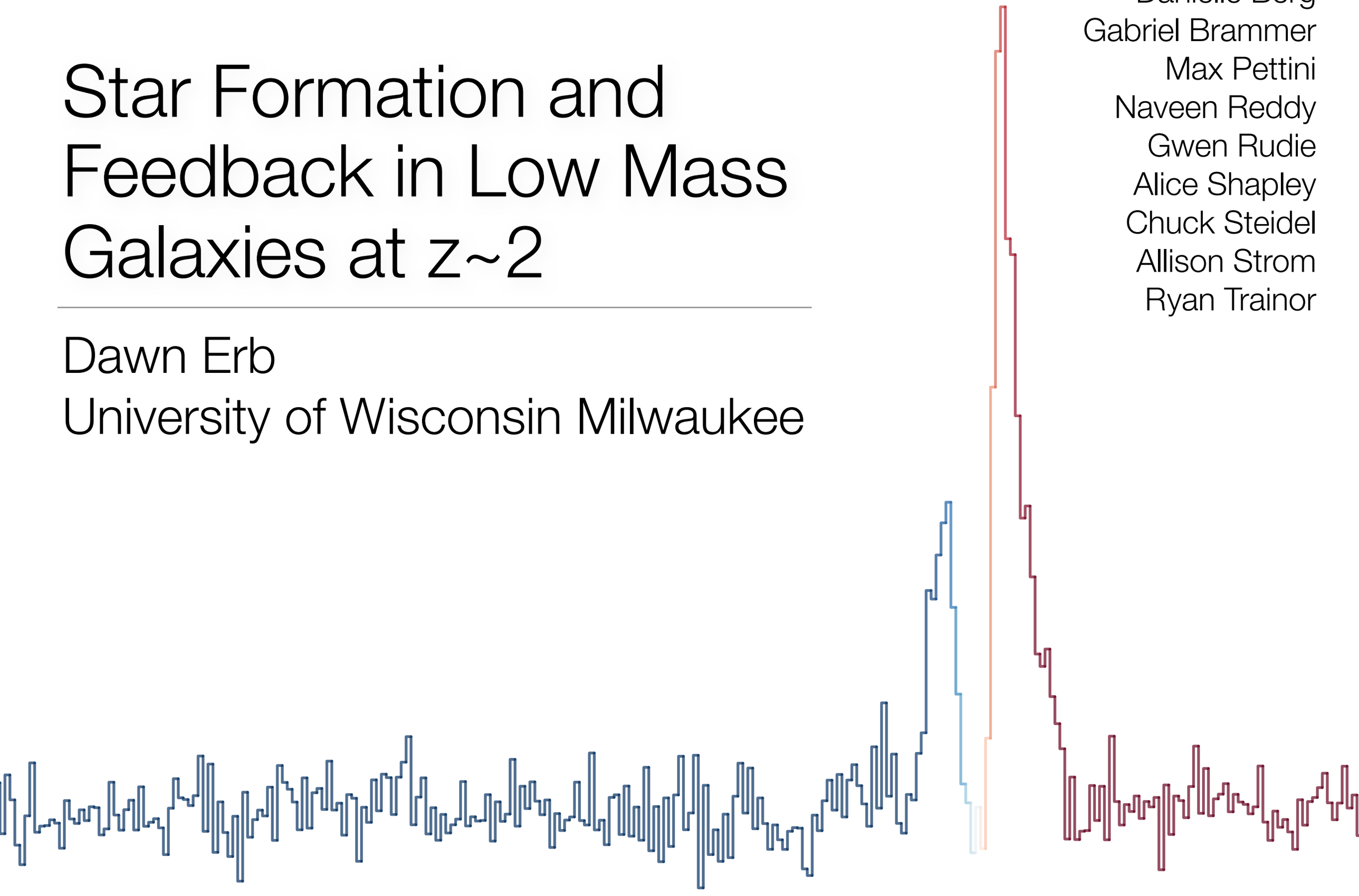
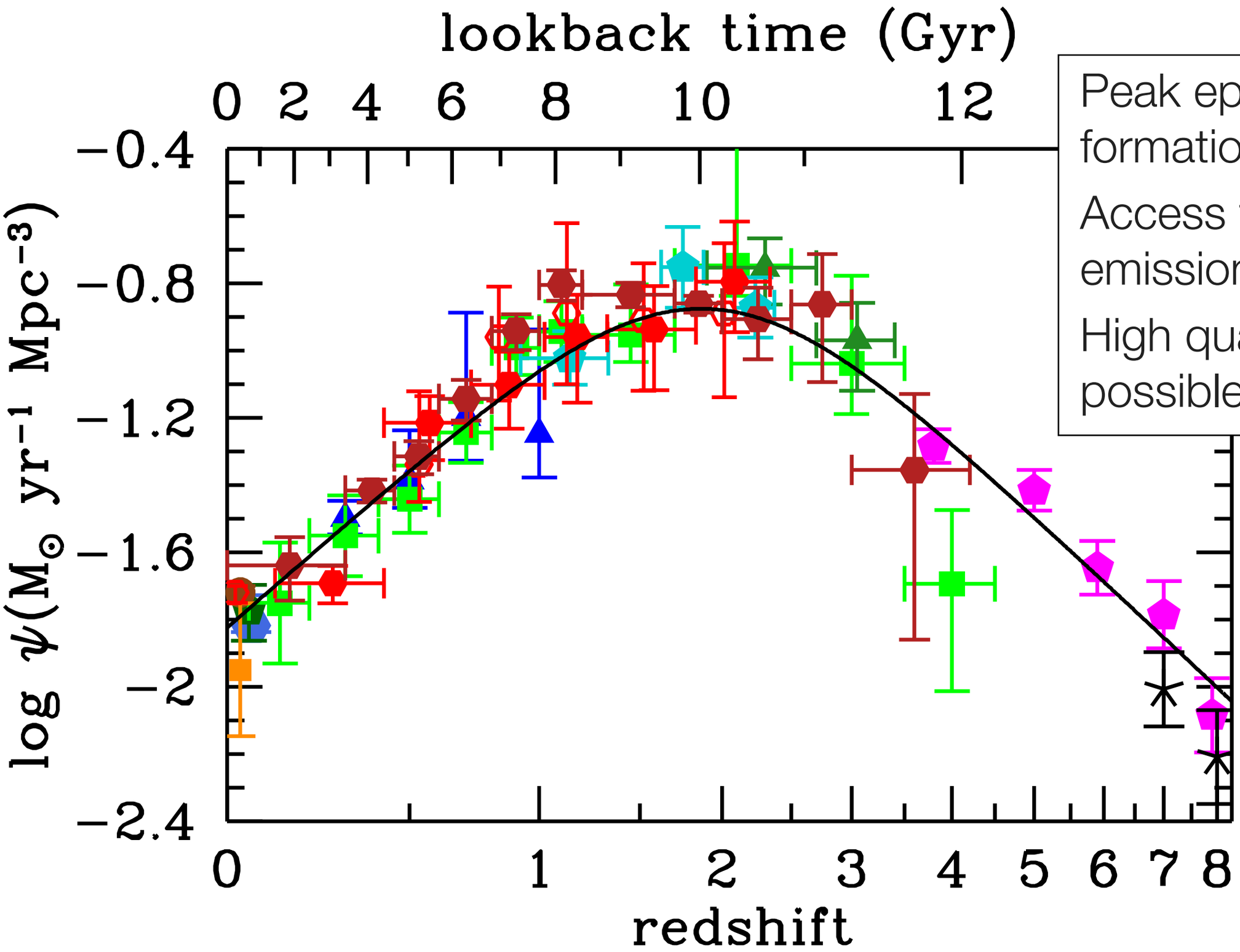


How Galaxies Form Stars, Stockholm University 25 August 2016

Star formation and feedback at *z*~2



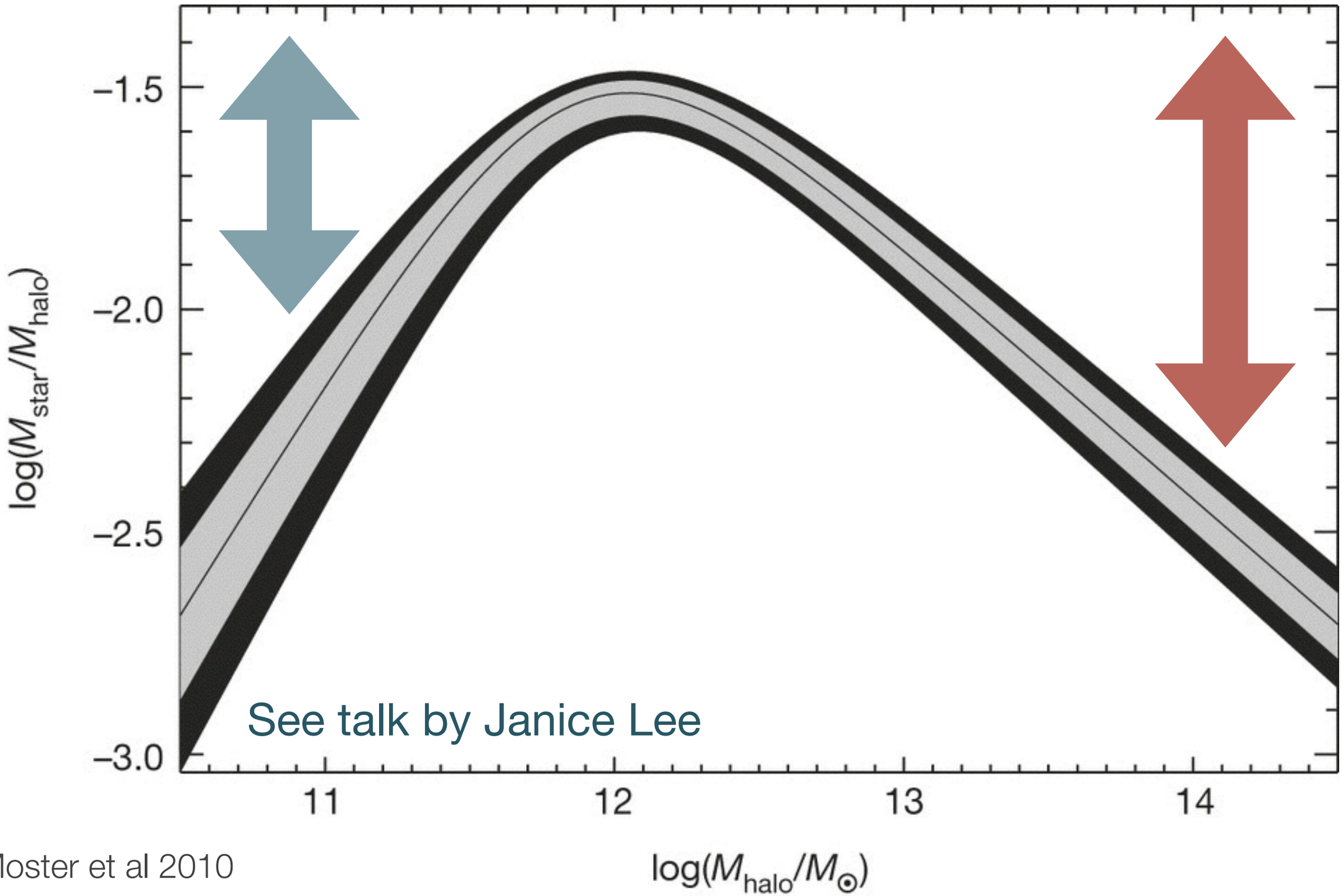
Peak epoch of star formation

Access to nebular emission lines + UV

High quality spectra possible

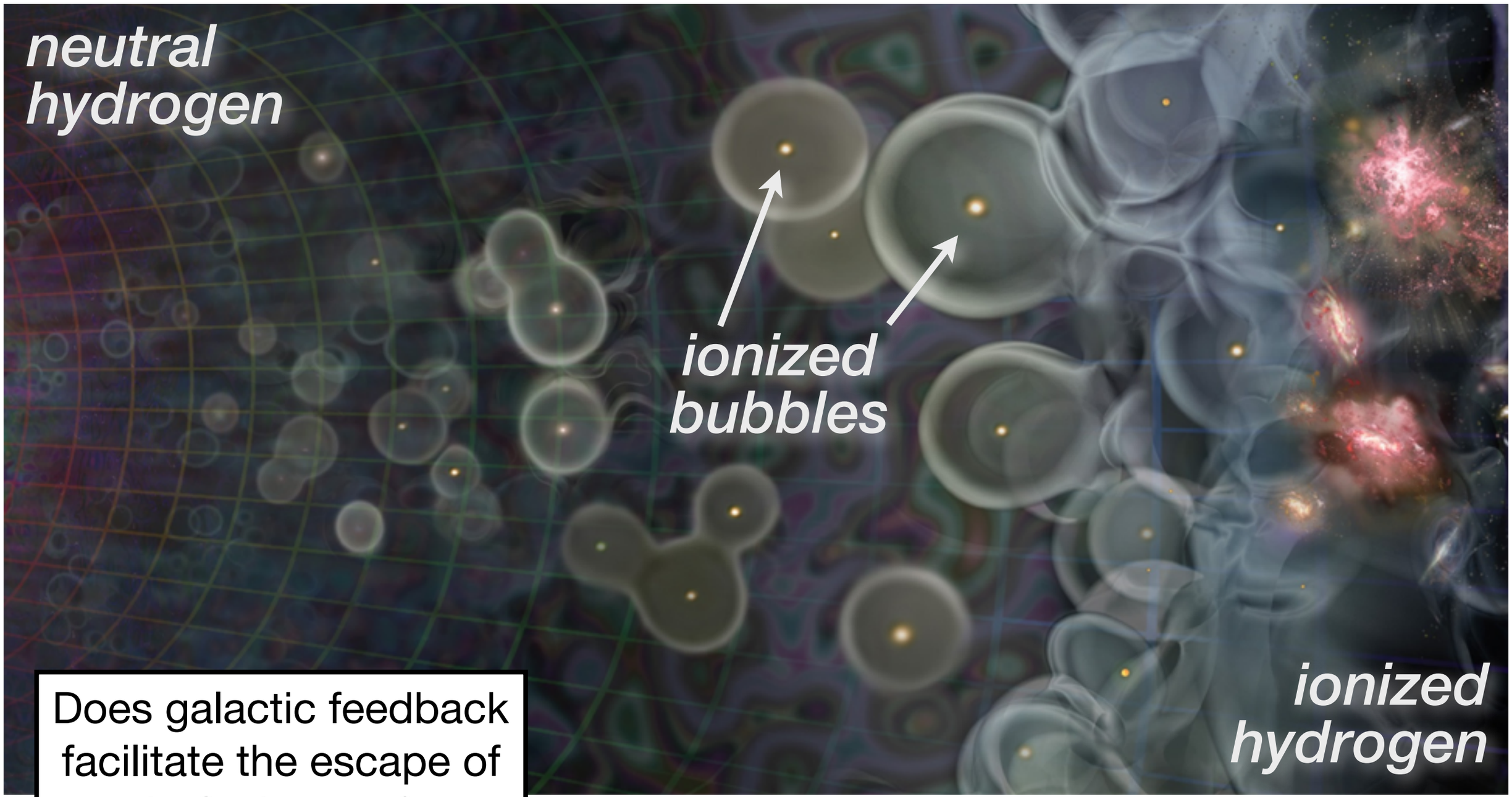
Madau & Dickinson 2014

Feedback in low mass galaxies



Moster et al 2010

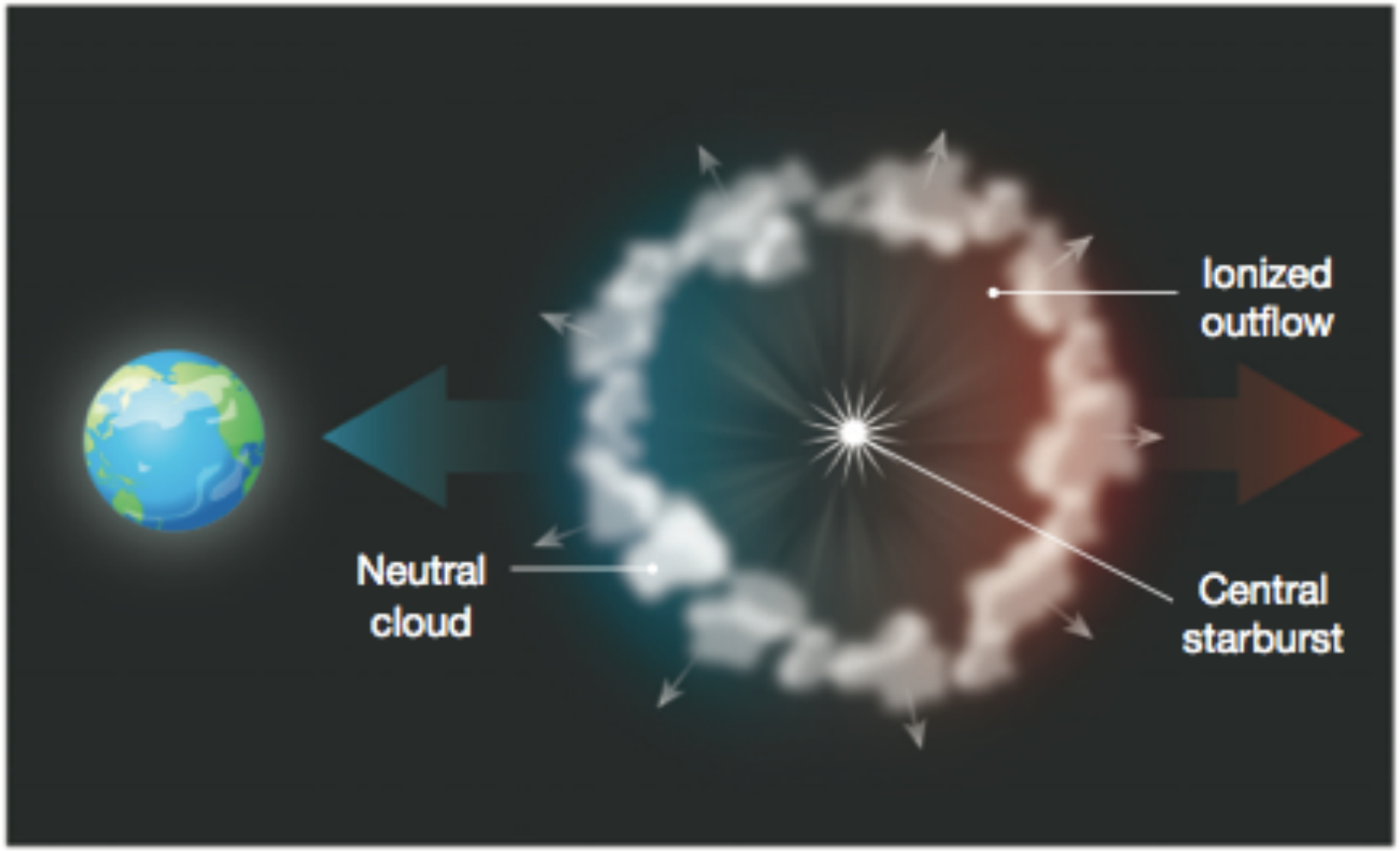
Low mass galaxies (probably) reionized the universe



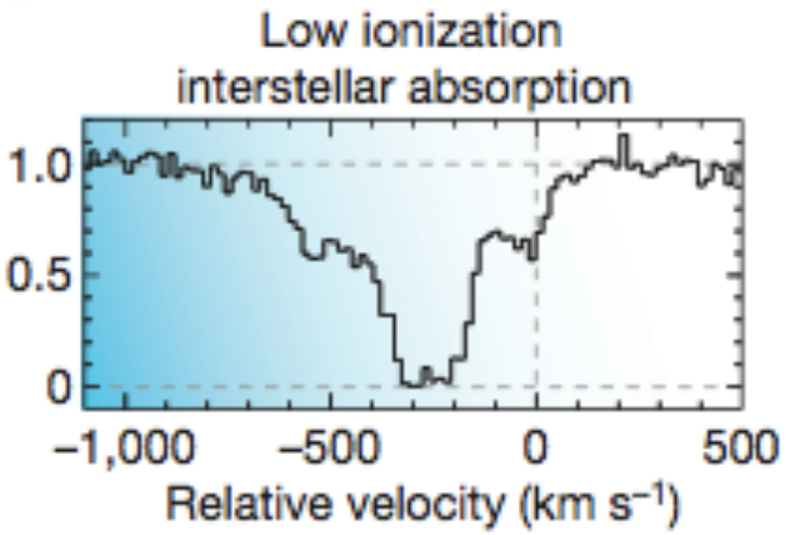
Does galactic feedback facilitate the escape of LyC photons?

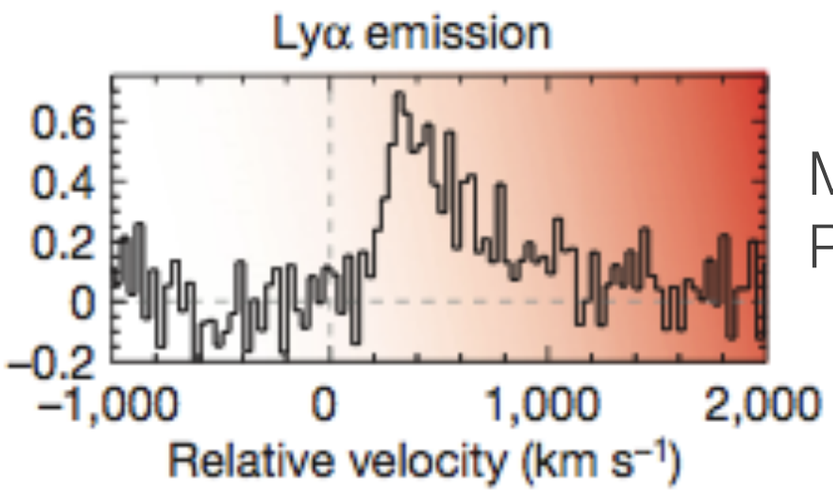
TIME

Galactic outflows ubiquitous at high redshifts



What are the properties of galactic outflows in low mass galaxies at high redshifts?

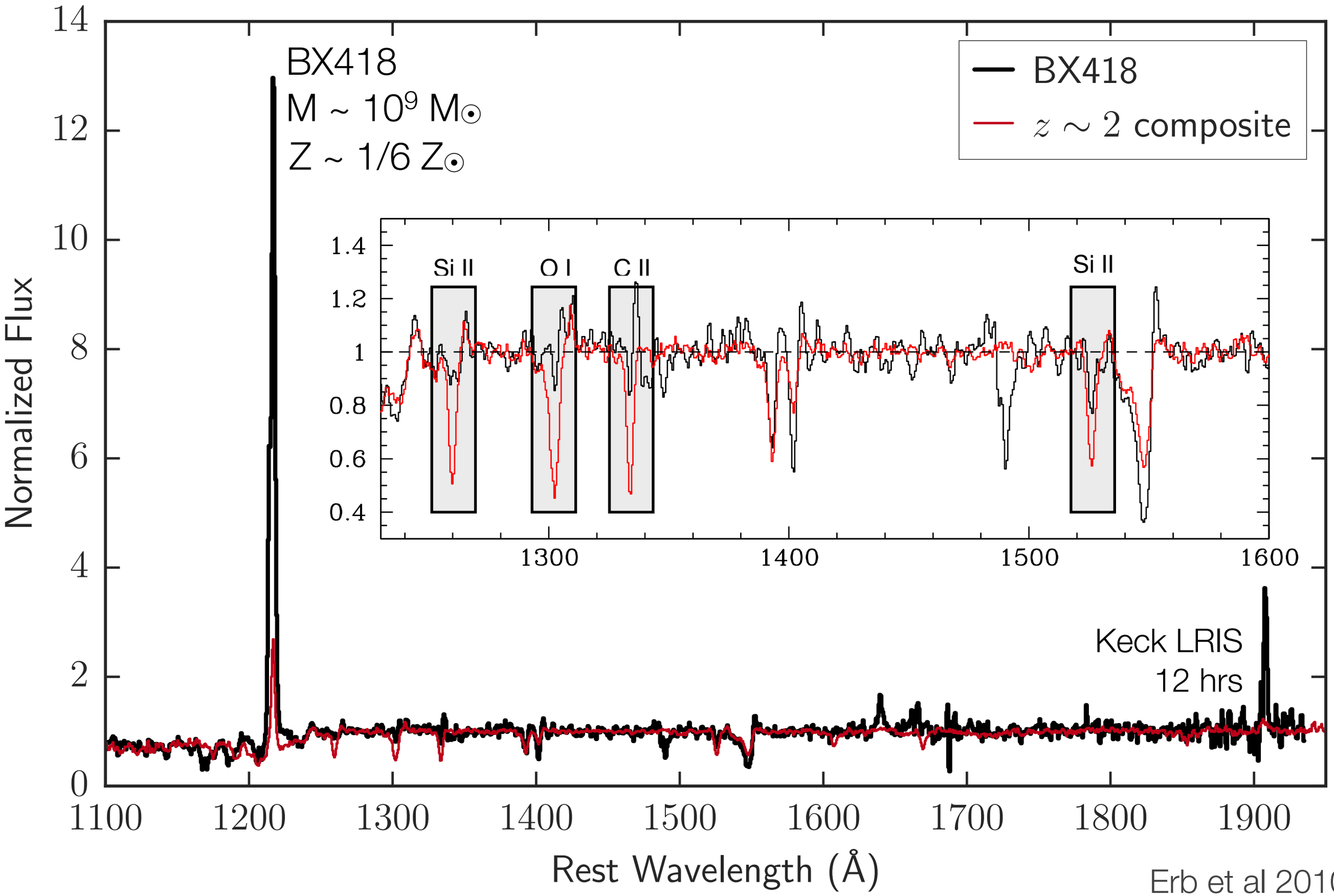




MS1512-cB58
Pettini et al 2002

Erb 2015

A low mass z~2 galaxy: rest-frame UV spectrum



Erb et al 2010

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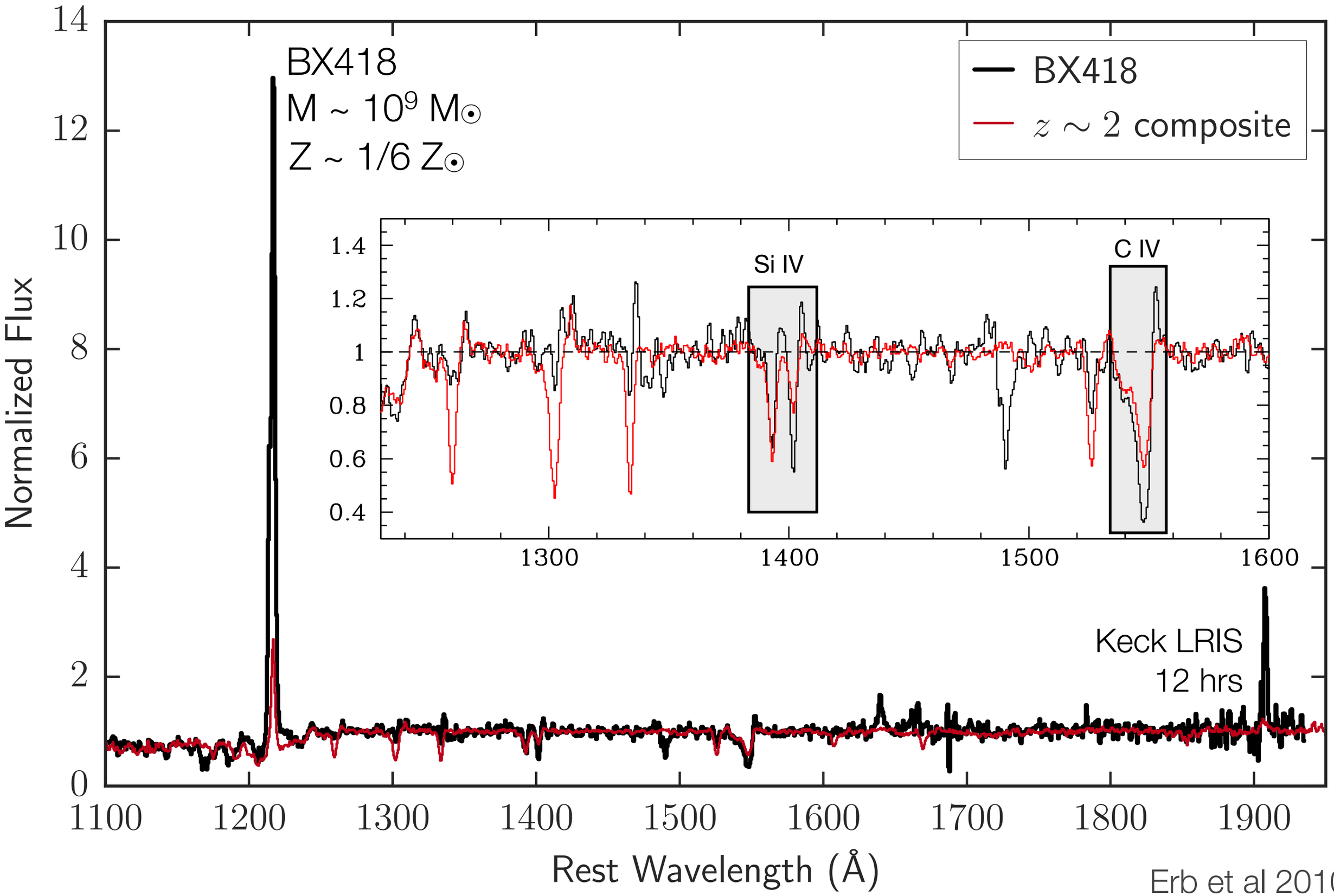

Erb et al 2010

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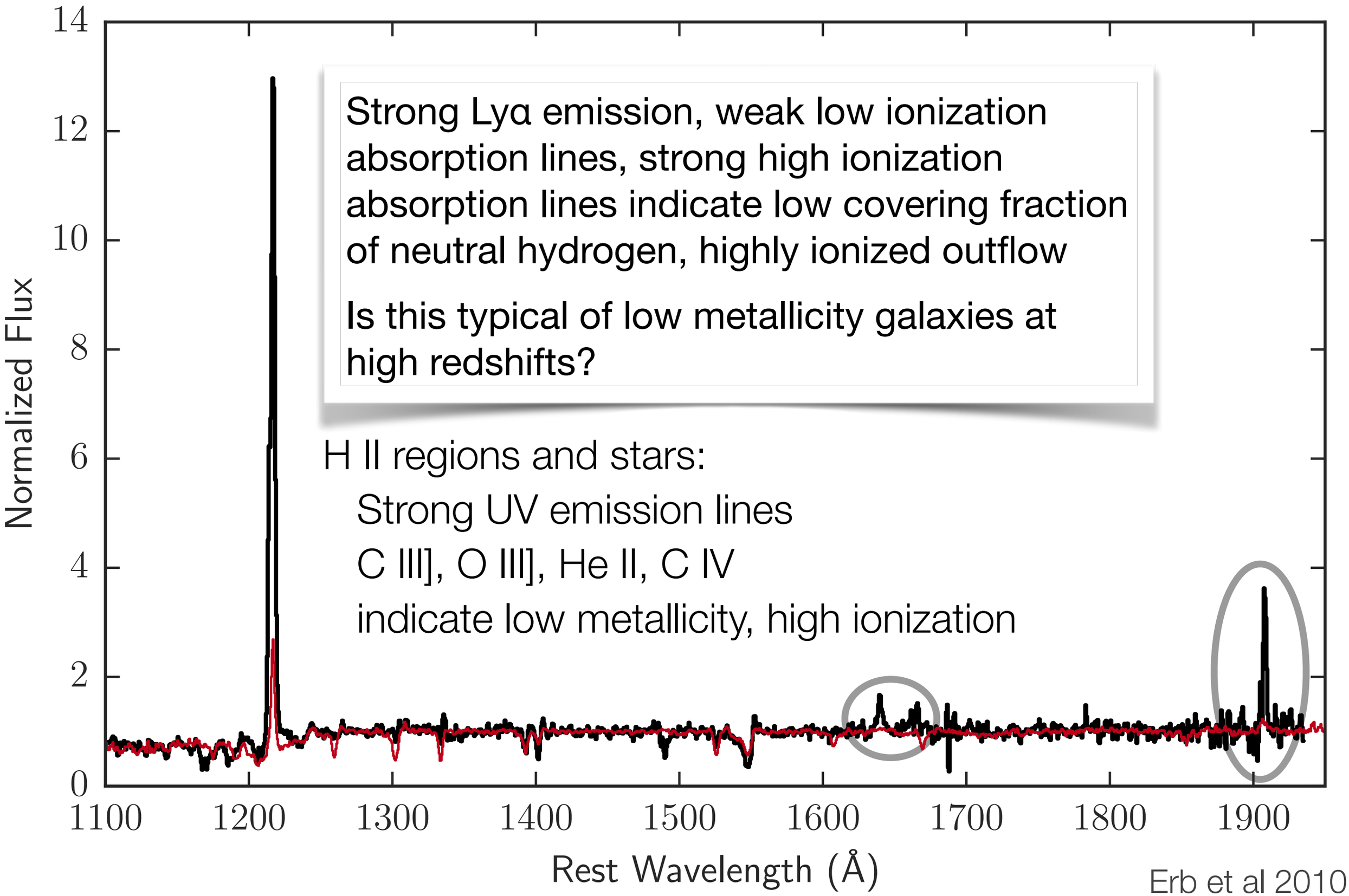
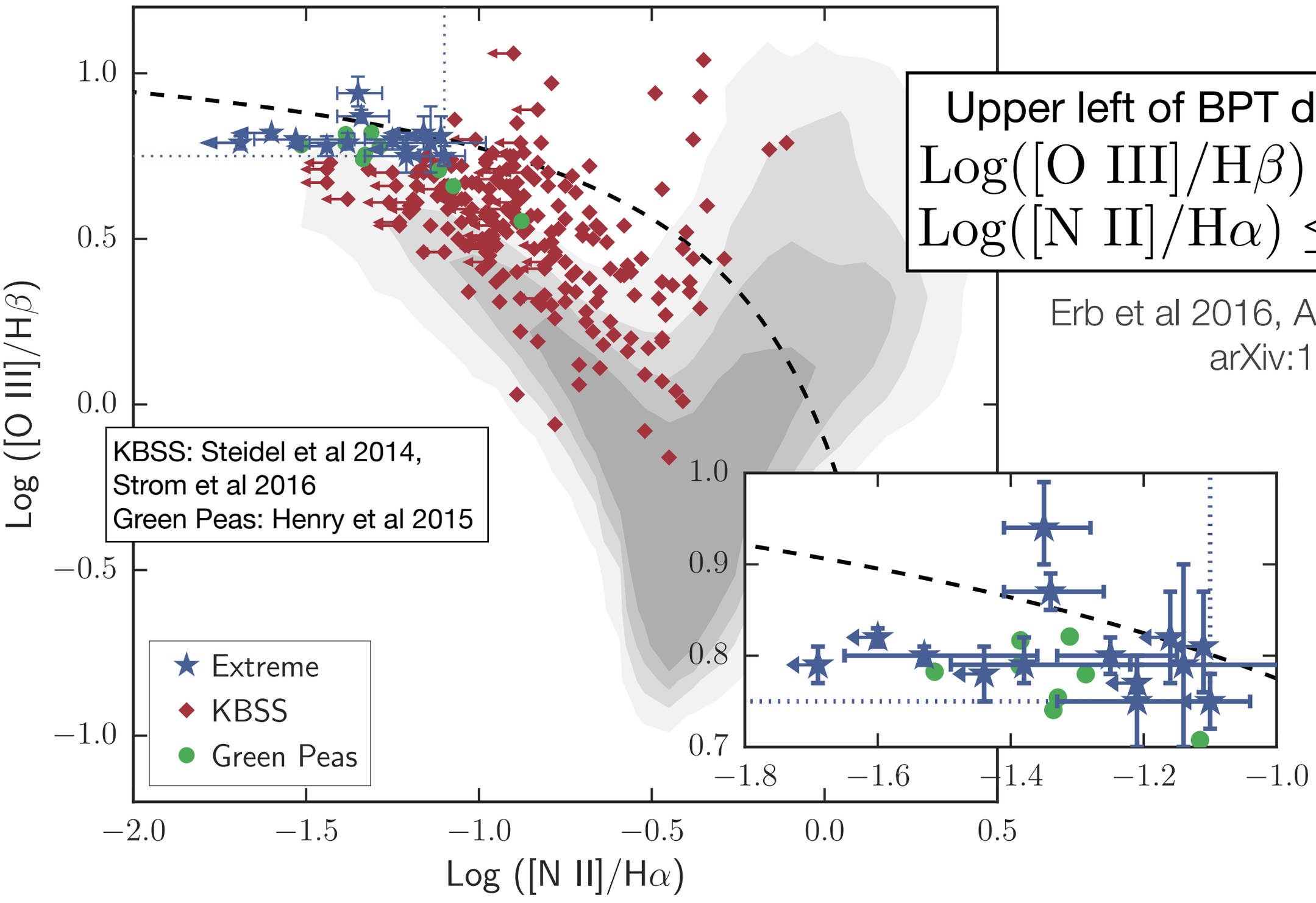


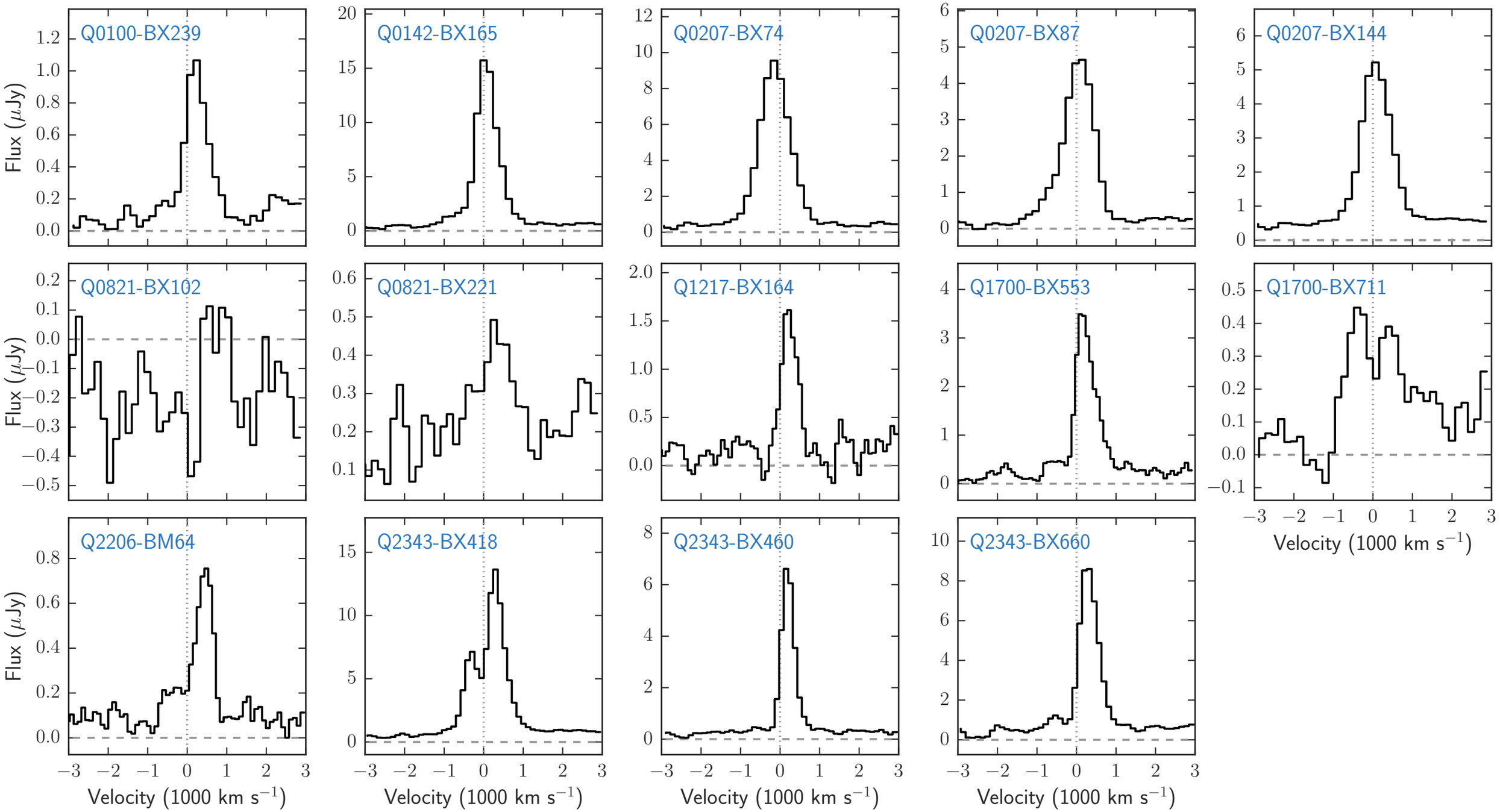
Erb et al 2010

Selecting low metallicity, highly ionized galaxies



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

Most extreme BPT galaxies have strong Lyα emission



Erb et al 2016, ApJ in press
arXiv:1605.04919

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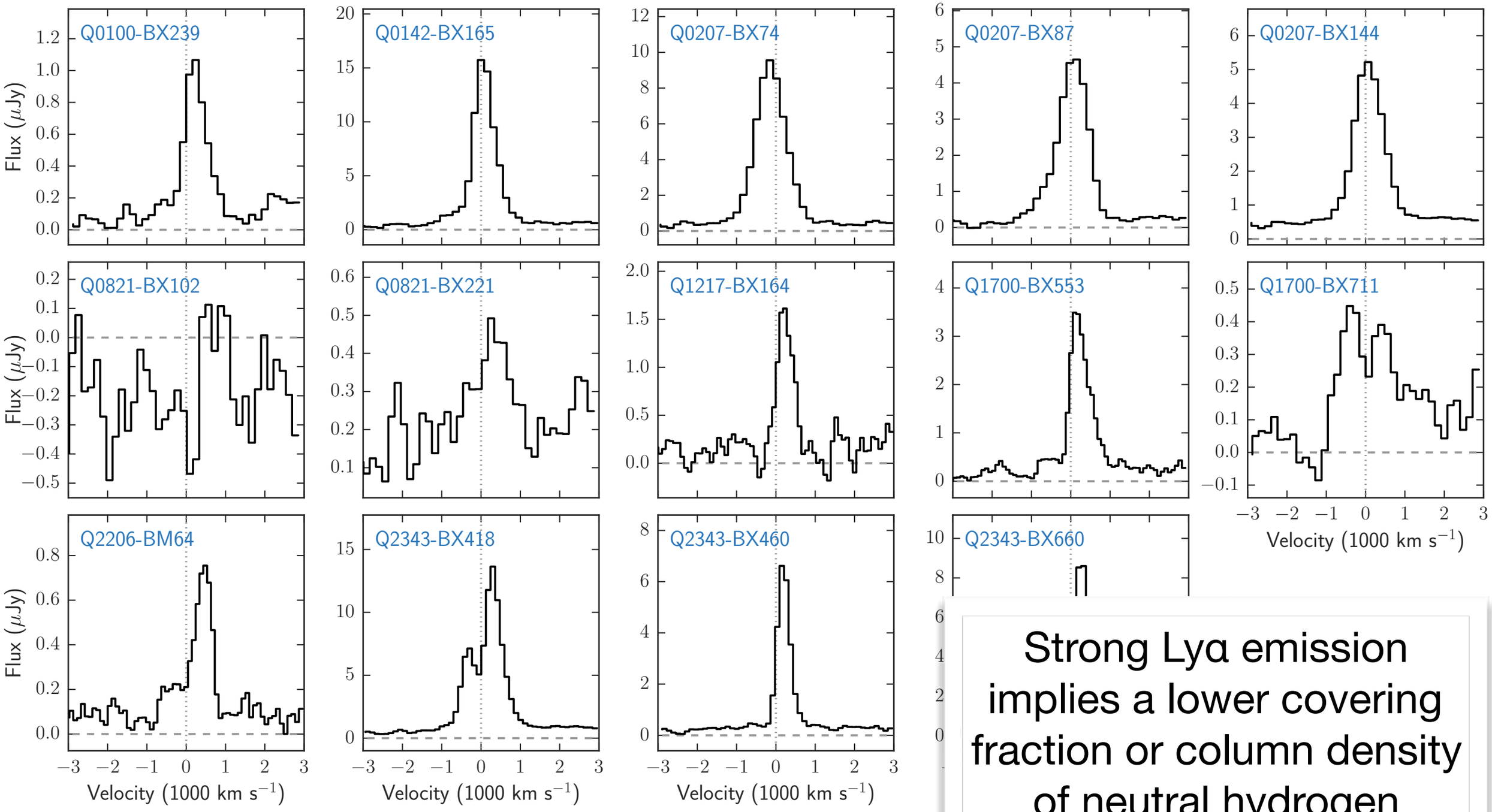
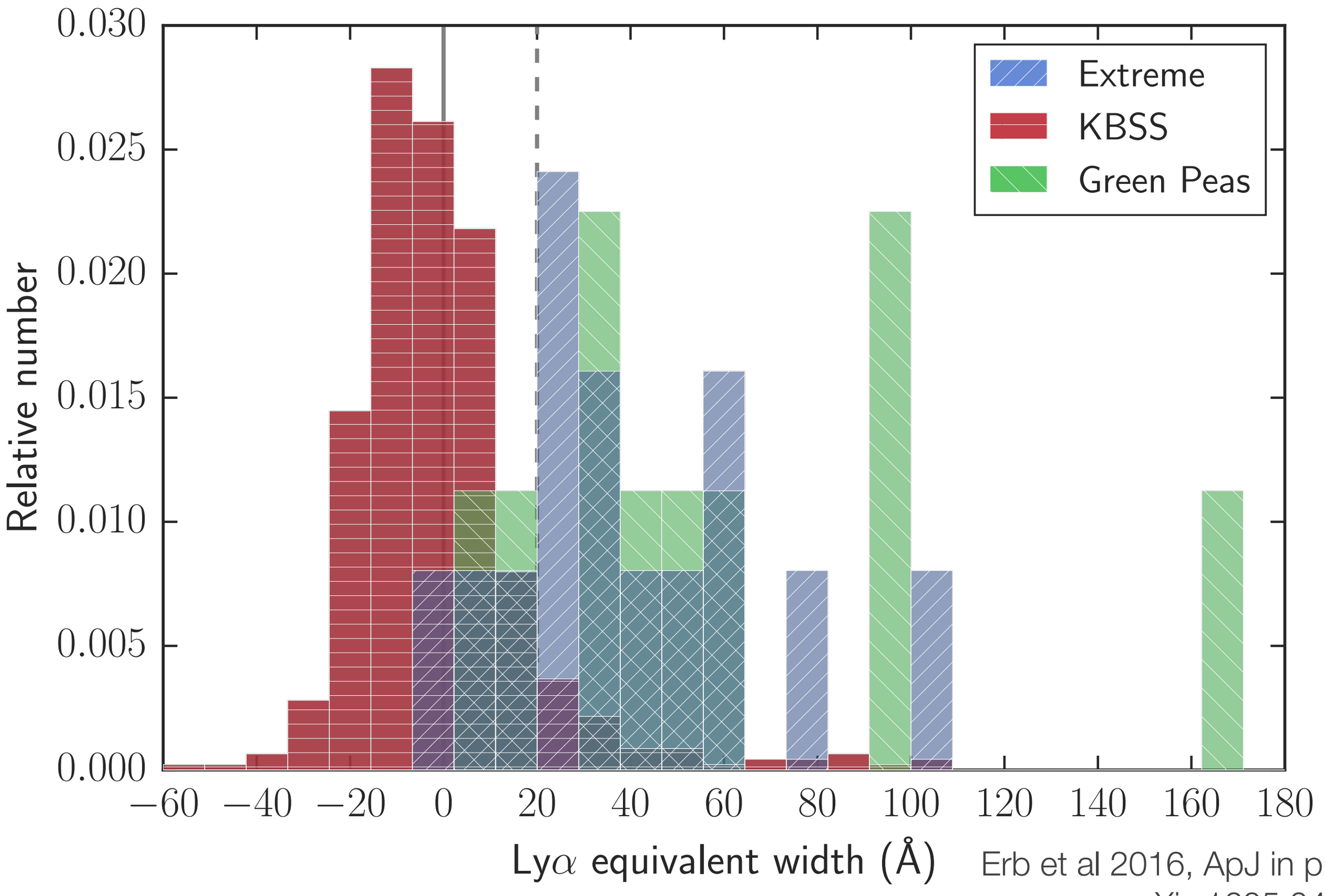


Strong Lyα emission implies a lower covering fraction or column density of neutral hydrogen

Erb et al 2016, ApJ in press
arXiv:1605.04919

Lyα equivalent width distributions



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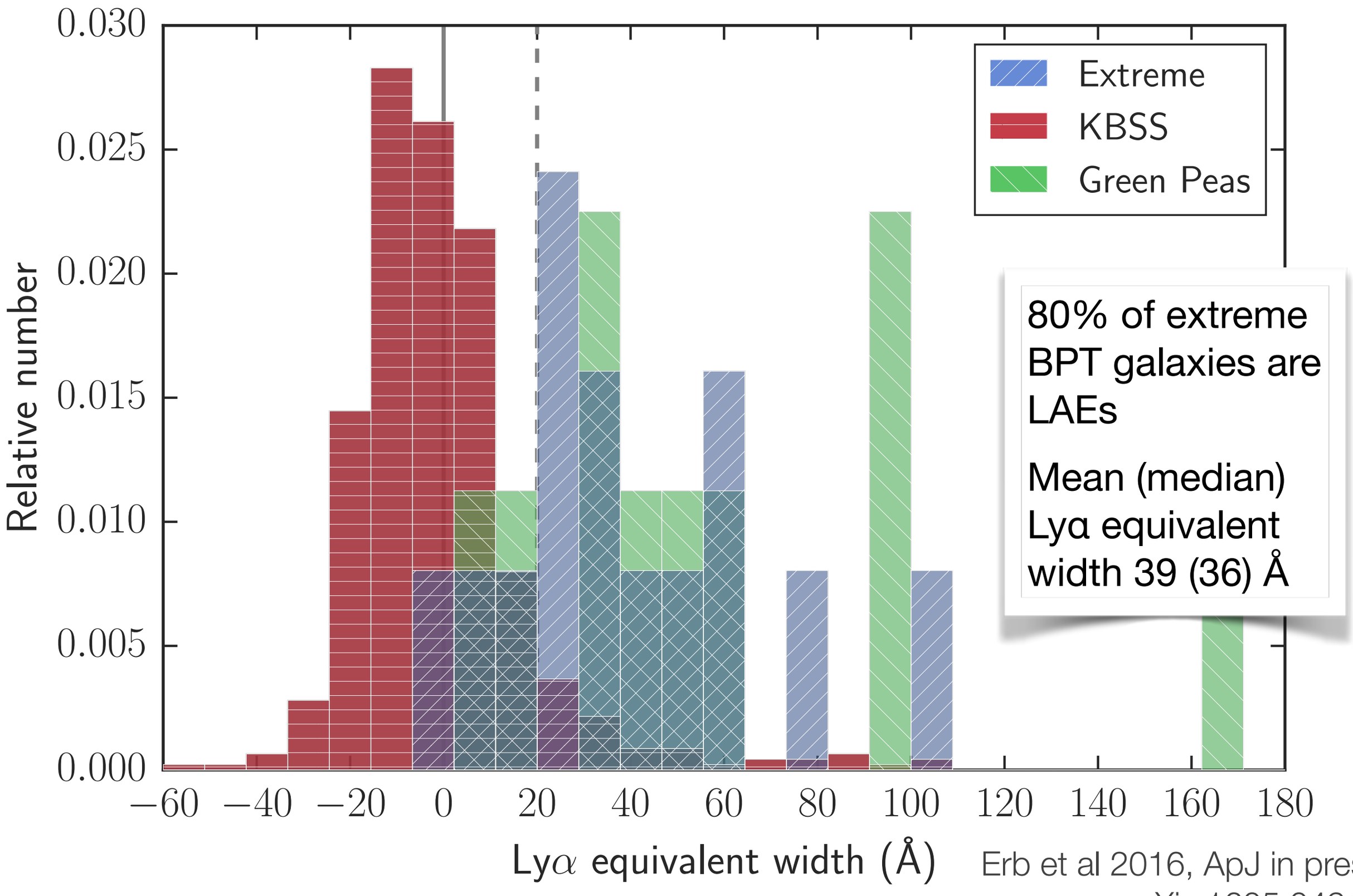
Lyα equivalent width distributions



Erb et al 2016, ApJ in press
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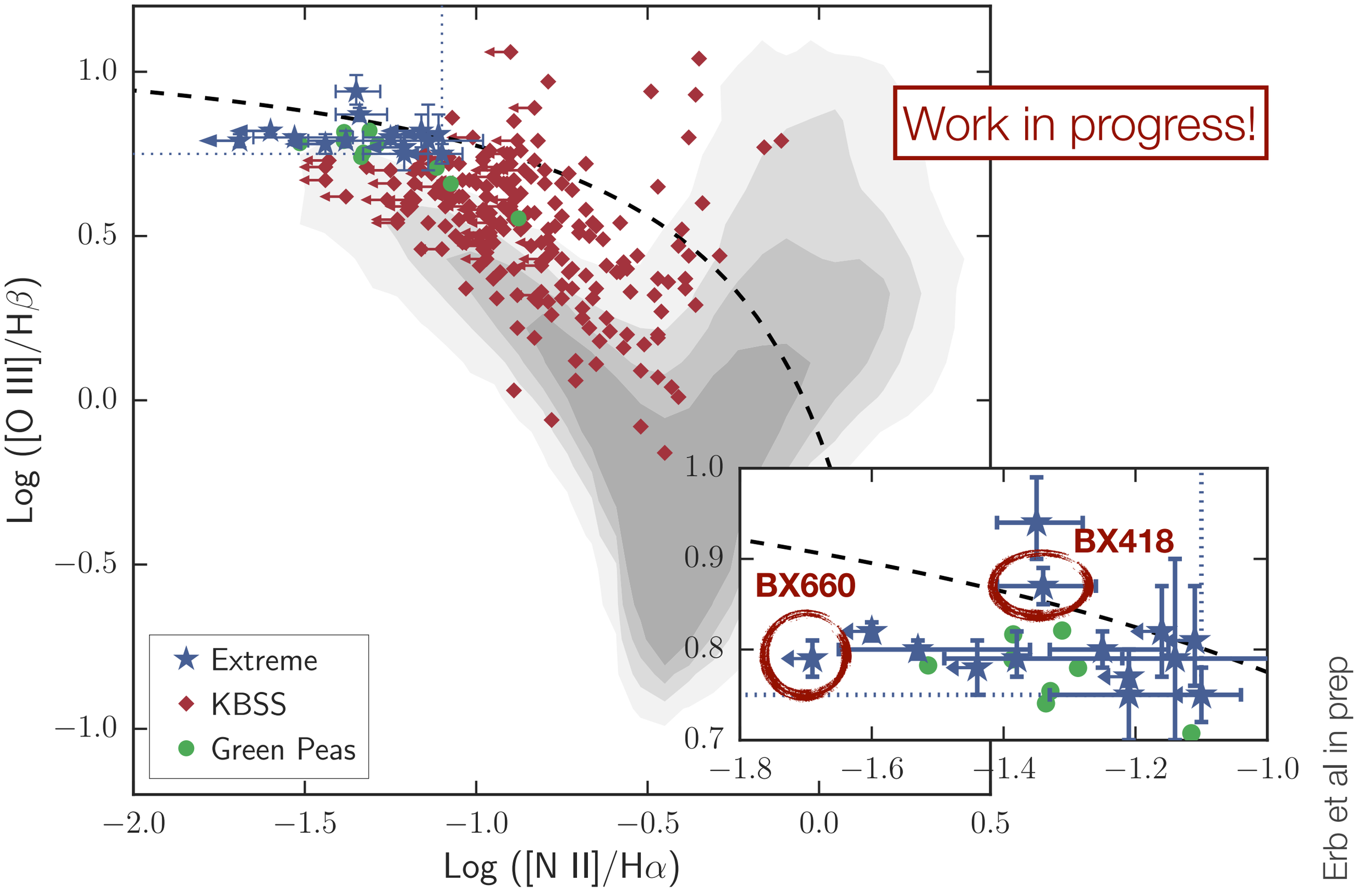
Individual galaxies: a closer look



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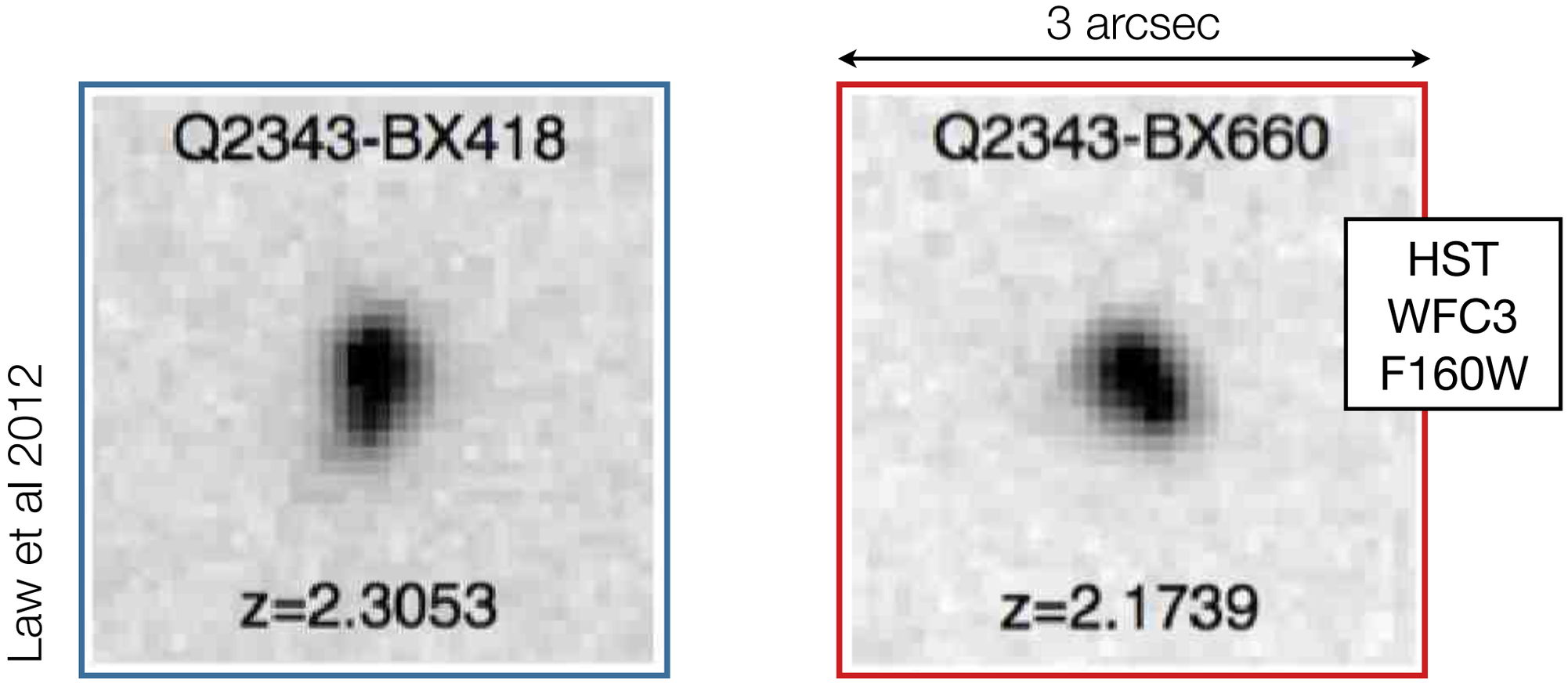


Q2343-BX418

$M_\star = 2 \times 10^9\ M_\odot$

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 $M_\odot\ yr^{-1}$

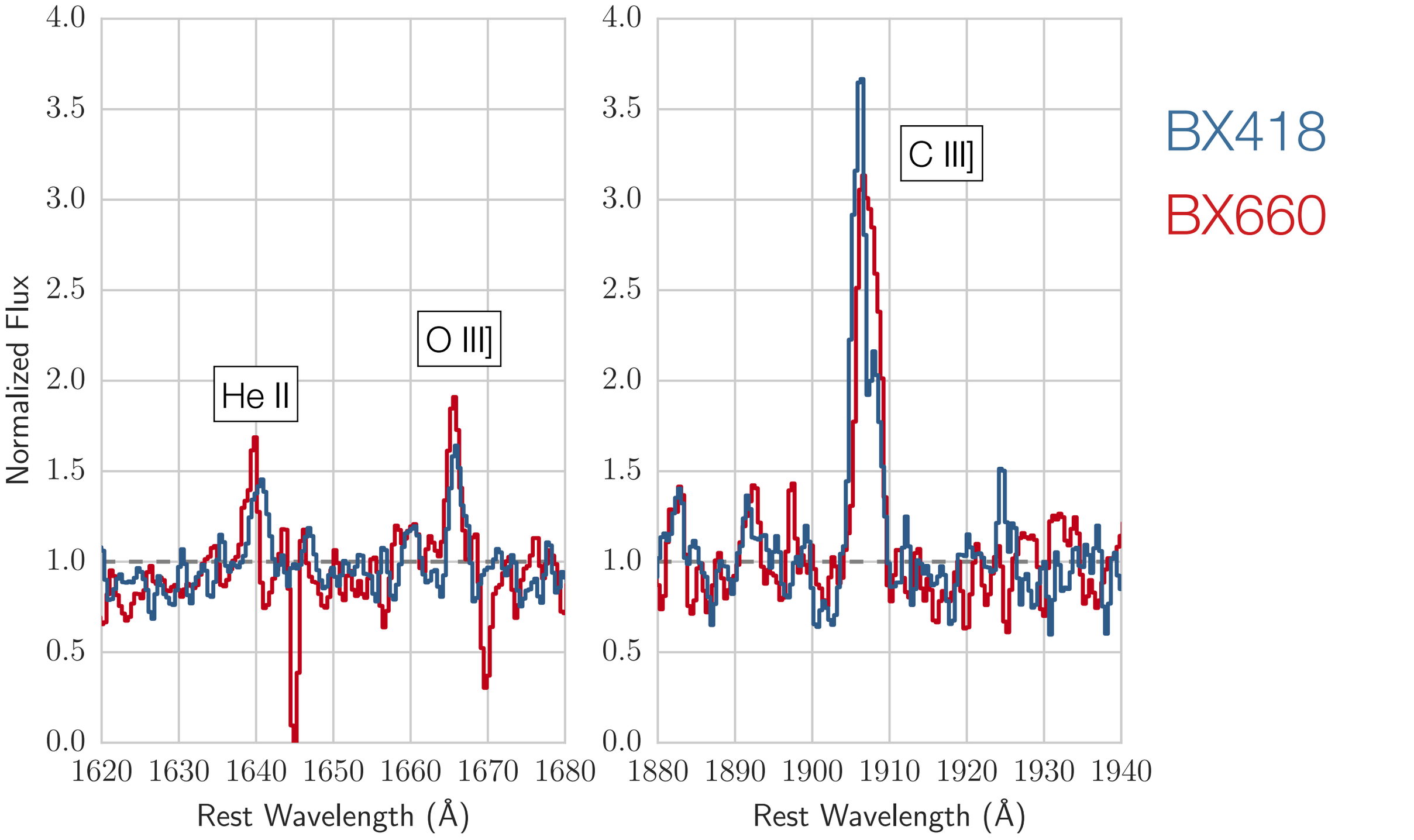
SSFR = 4 Gyr^{-1}

12 + log(O/H) = 8.13 (T_e)

O32 = 10.98

O/H, O32 from Steidel et al 2014

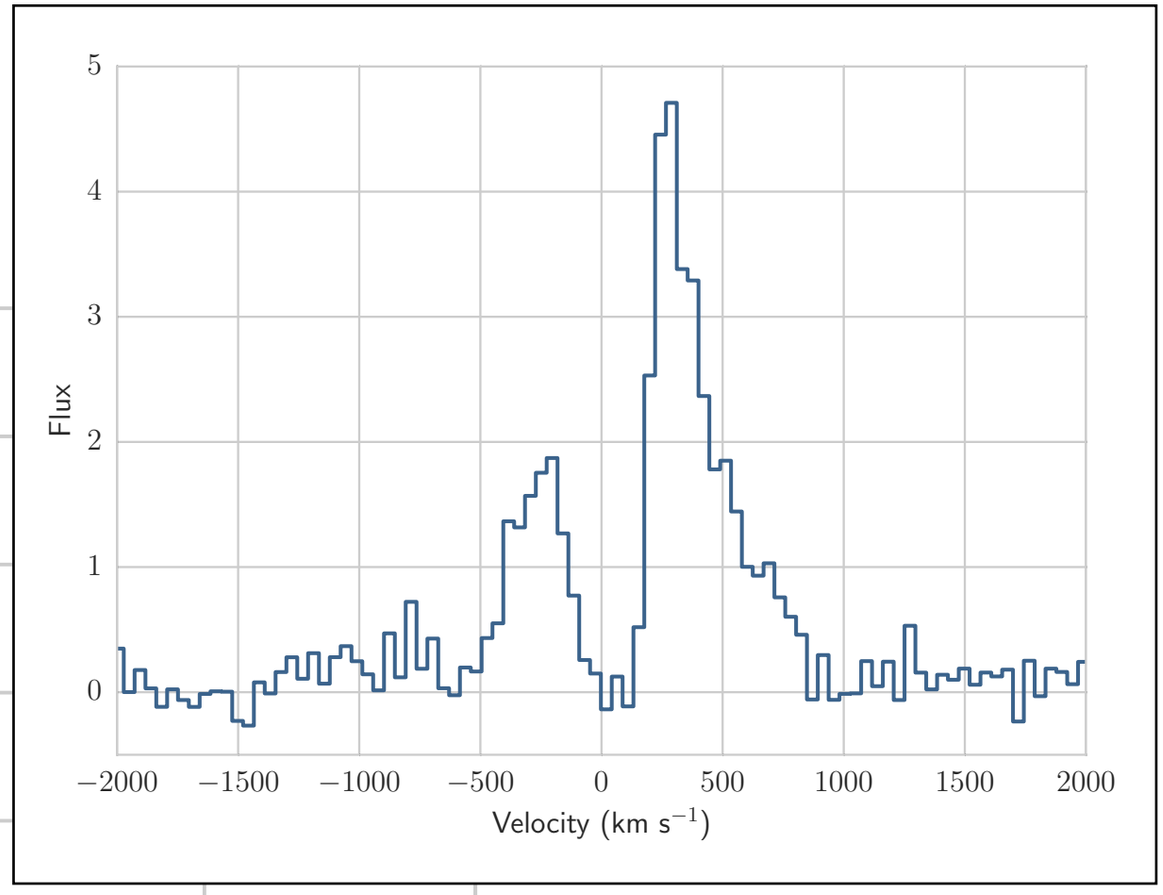
Strong UV emission lines

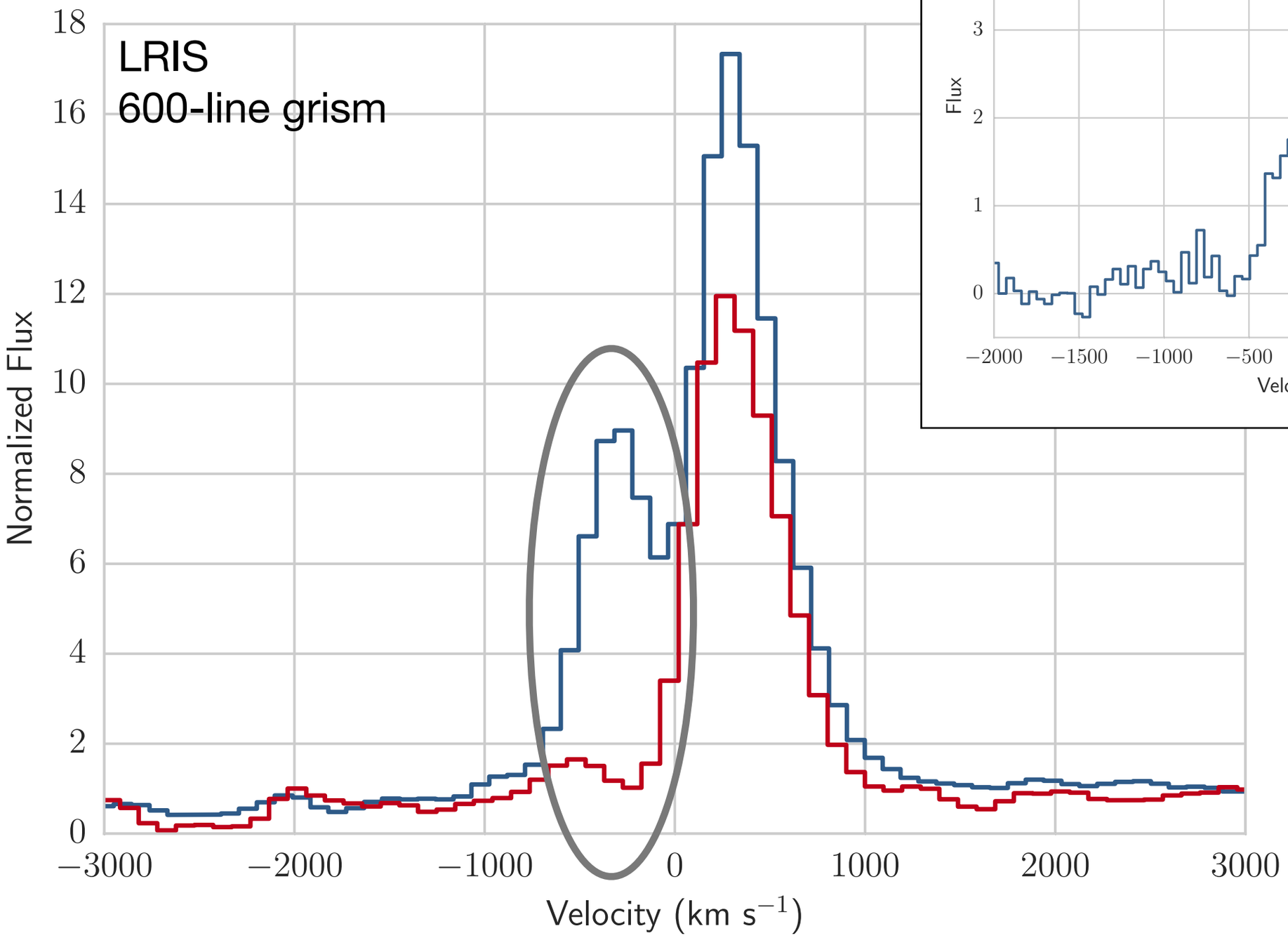


Erb et al in prep

Lya emission profiles

BX418 with VLT XSHOOTER
R=6200
Archival data, Terlevich et al 2015

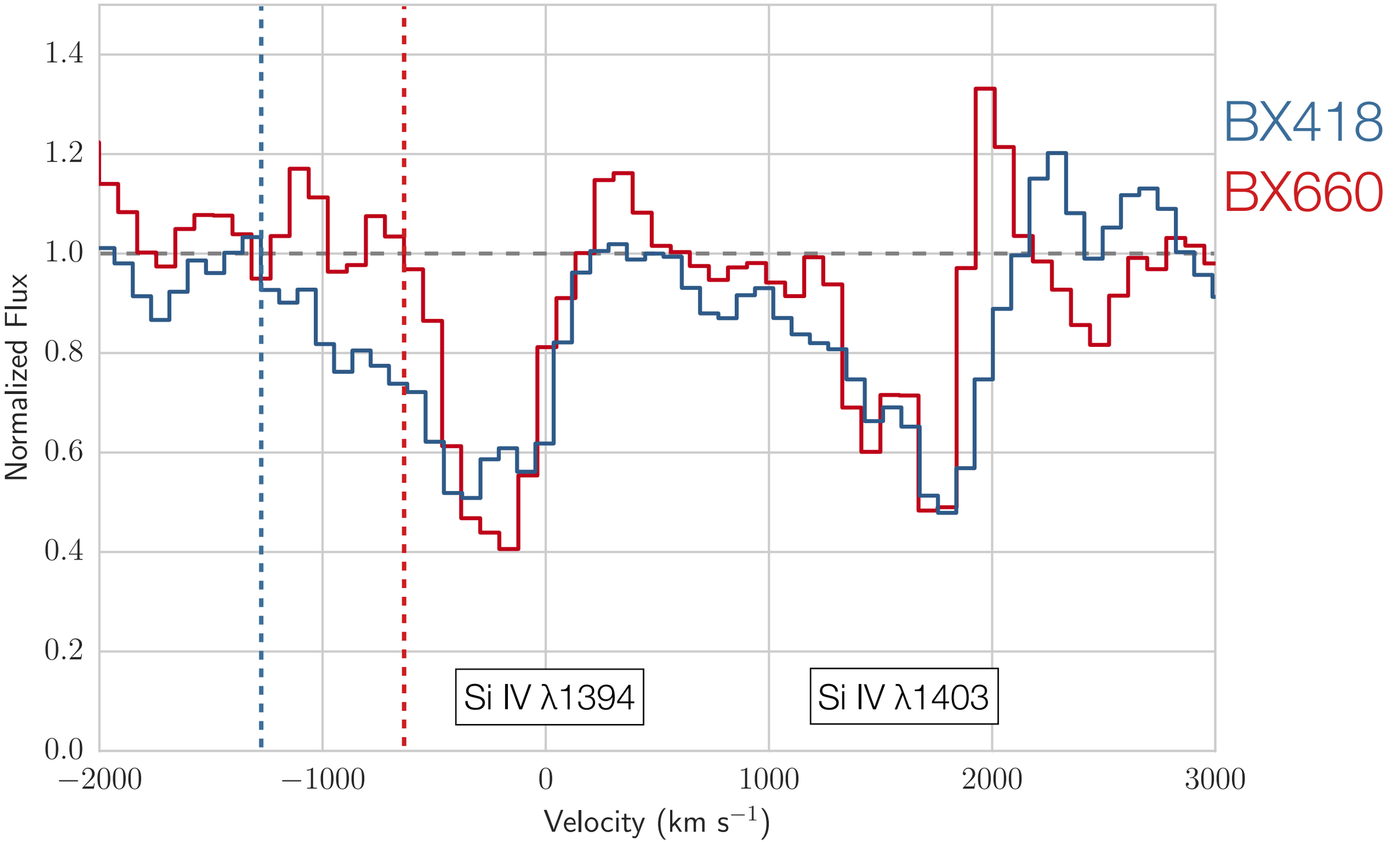




BX418
BX660

Erb et al in prep

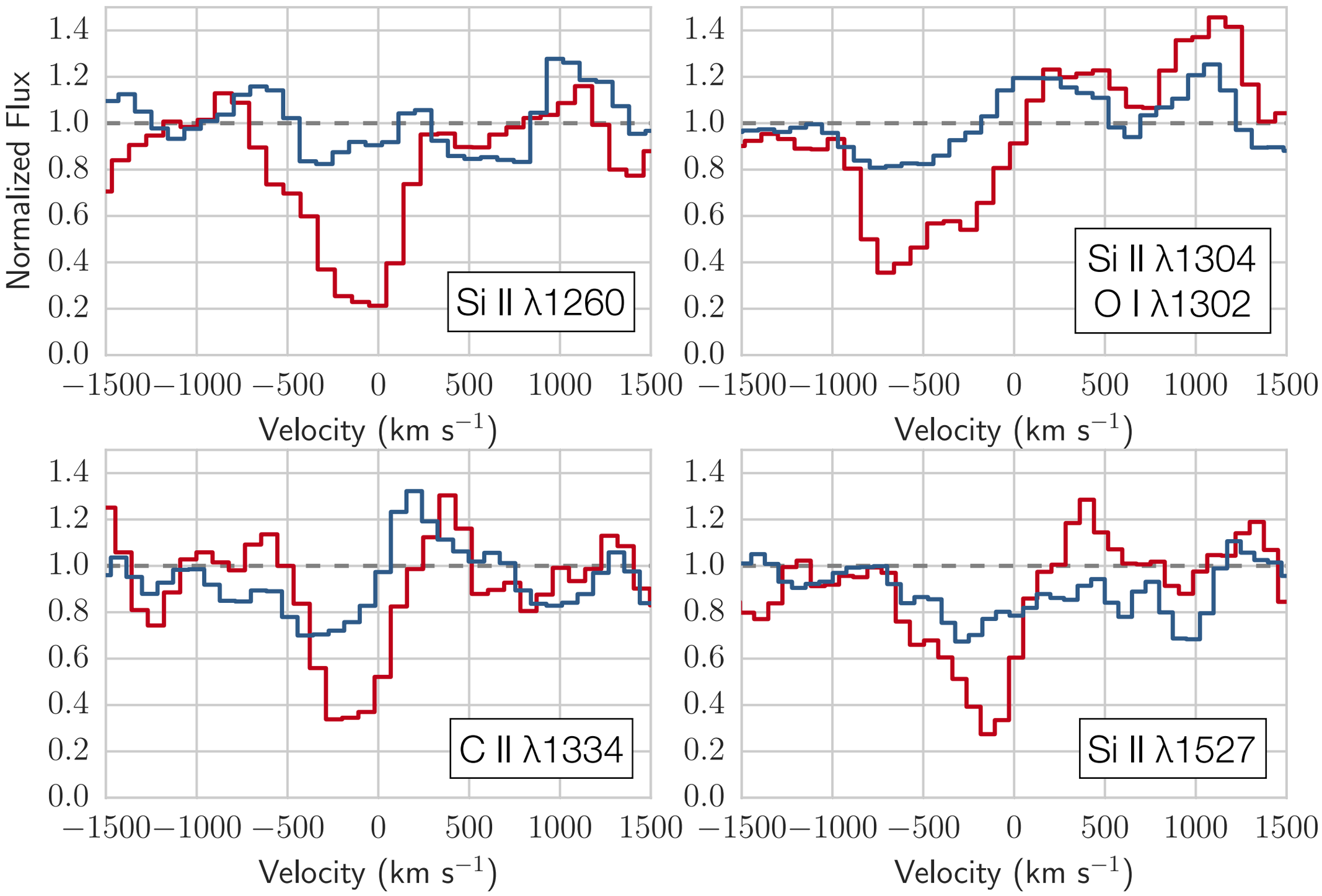
High ionization absorption lines vary in velocity



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

BX418 vs BX660: implications

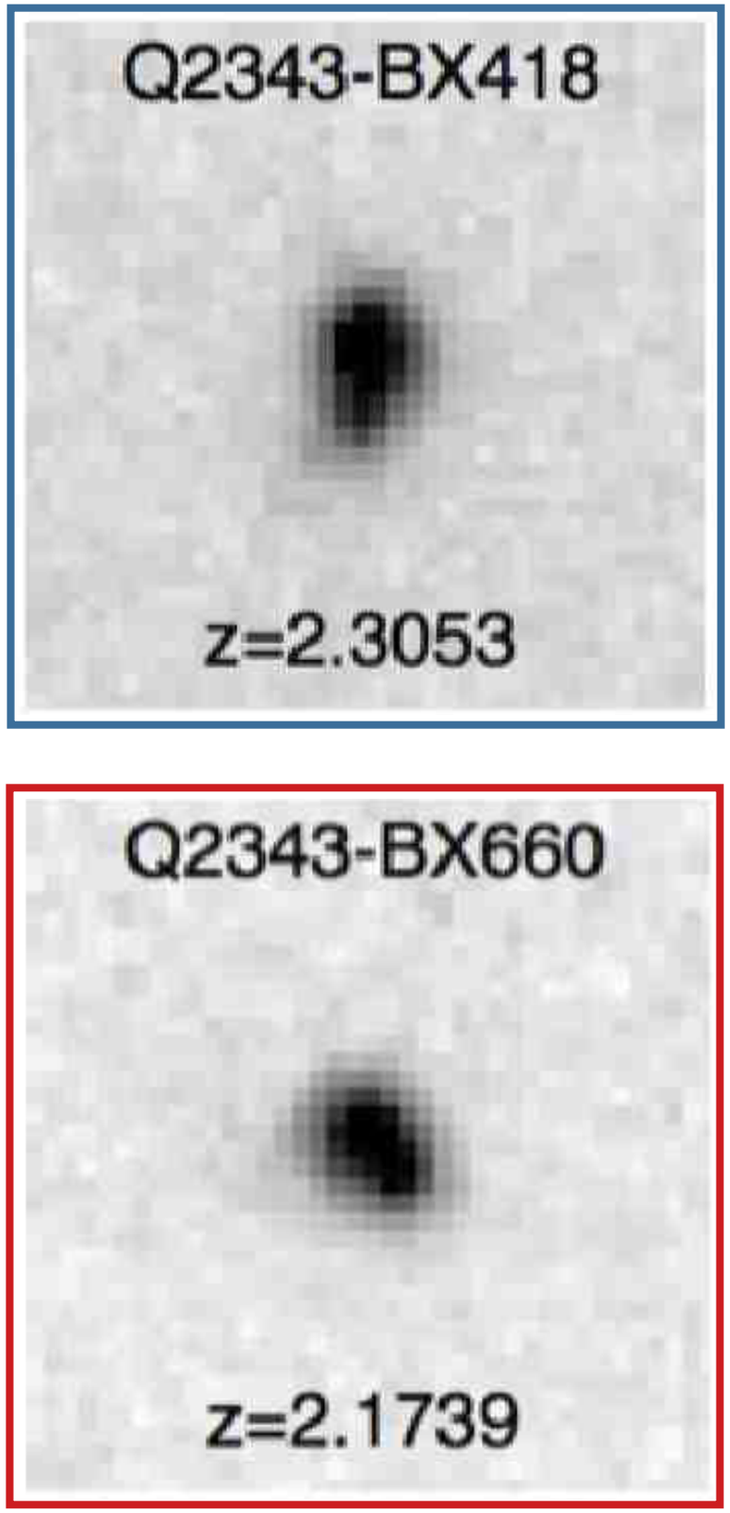
Galaxies with similar metallicities, masses, morphologies and extreme emission line ratios may have significantly different outflow properties and Lya profiles

See talk by Anne Jaskot

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

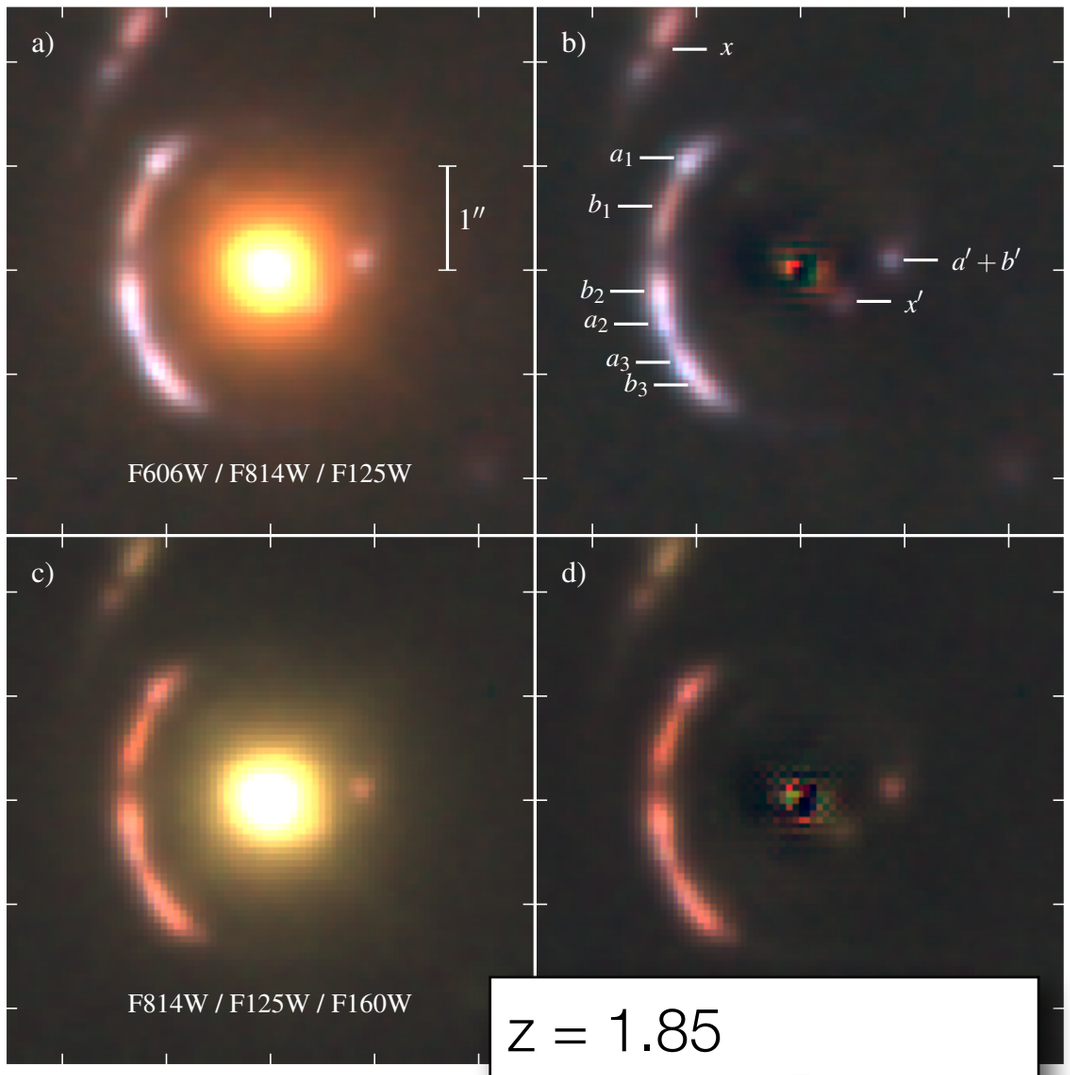
Signatures of most extreme objects:

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

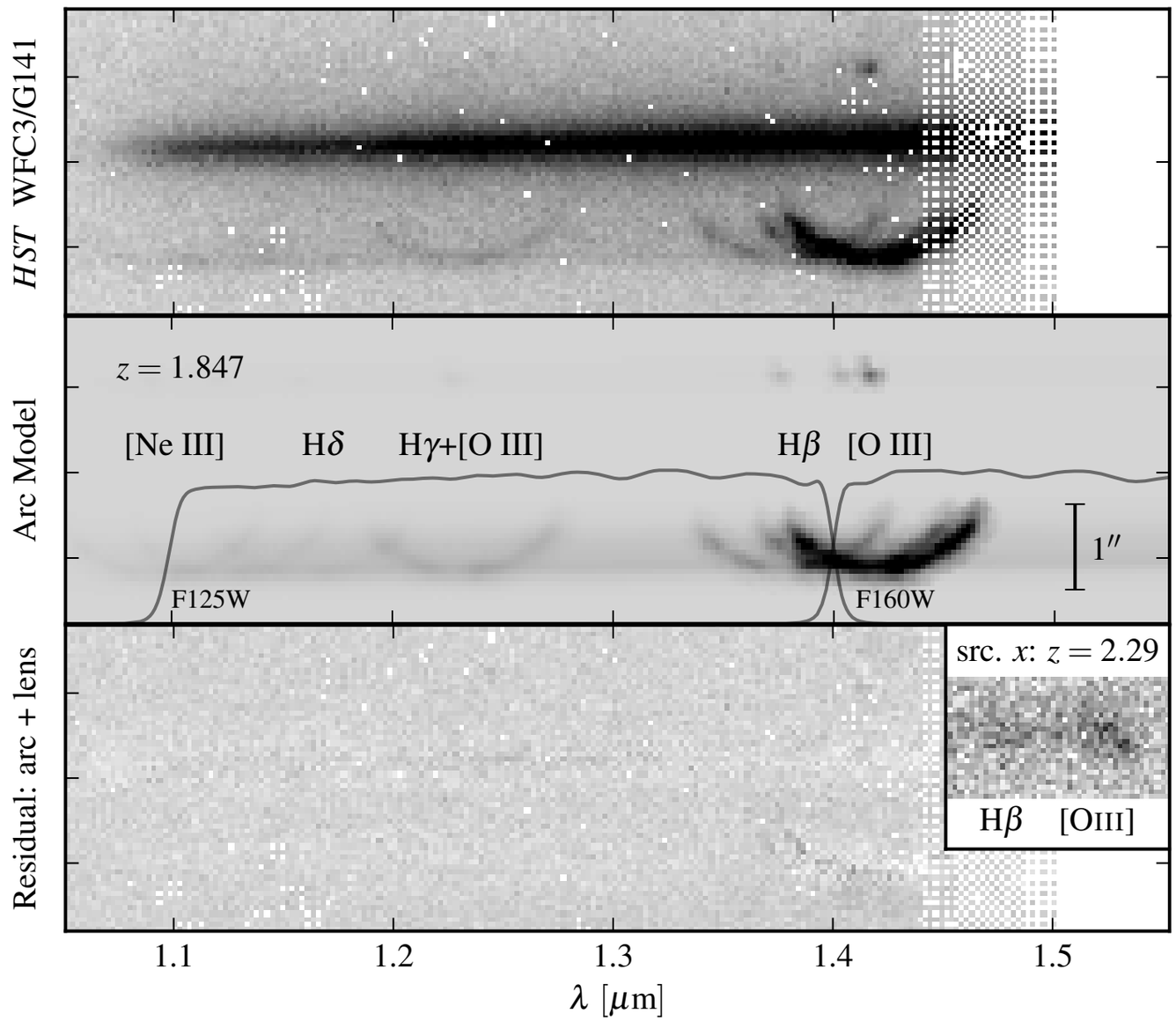


Law et al 2012

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

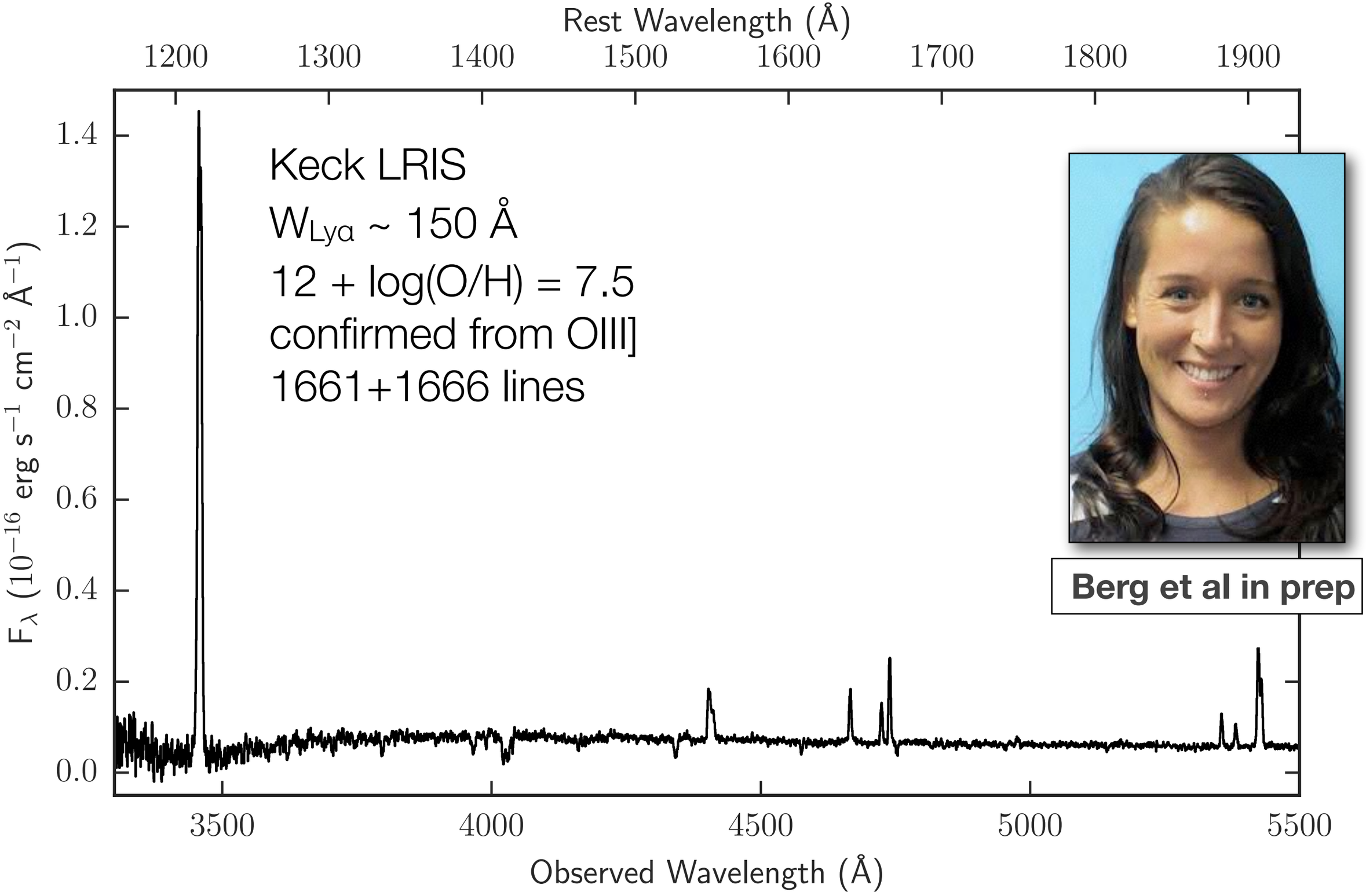


Rest-frame optical spectrum from 3DHST grism survey (Brammer et al 2012)

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

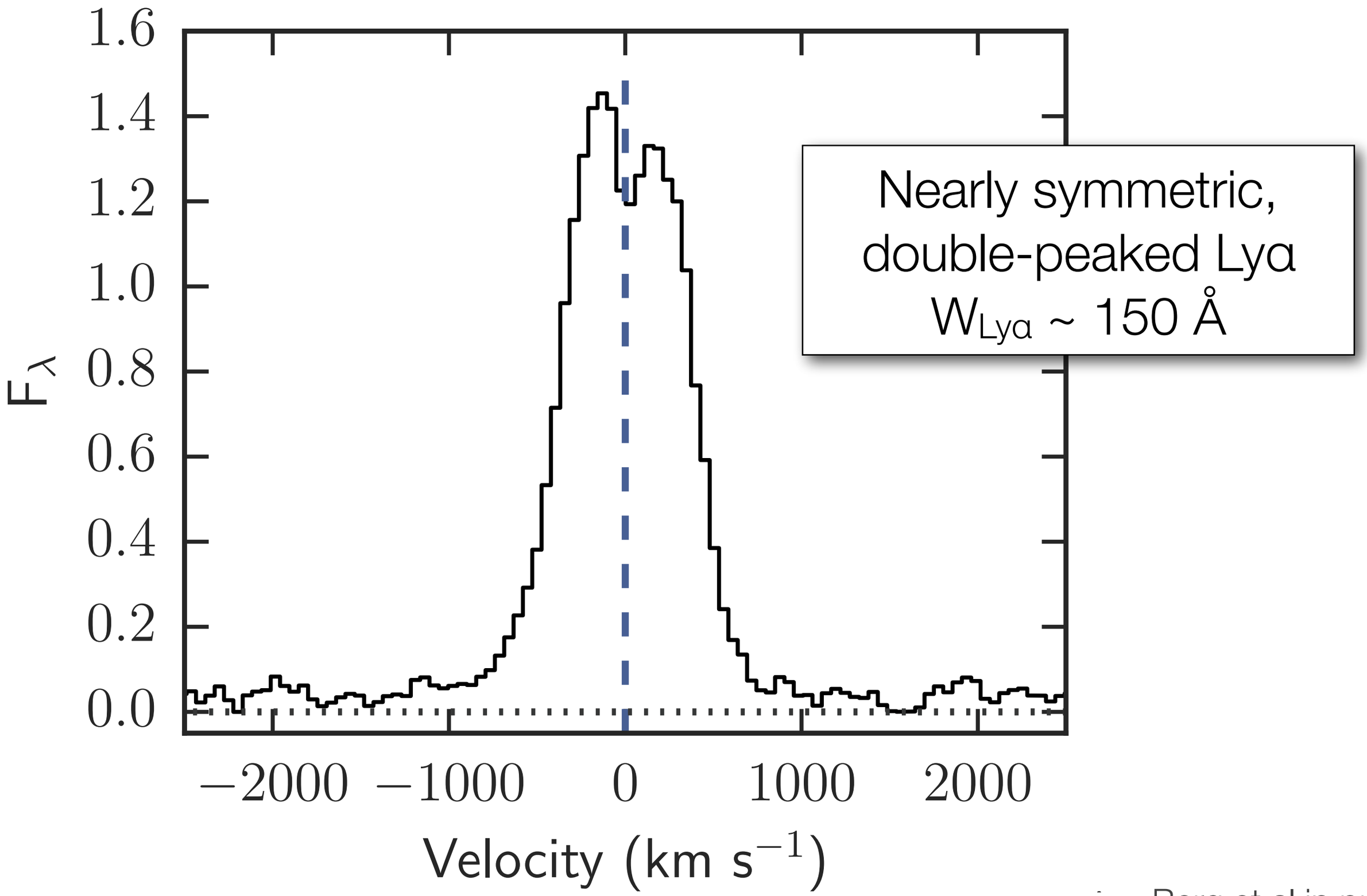
Very high sSFR ~100 Gyr^{-1} (~8 Myr to form all stars at current rate)

Rest-frame UV spectrum



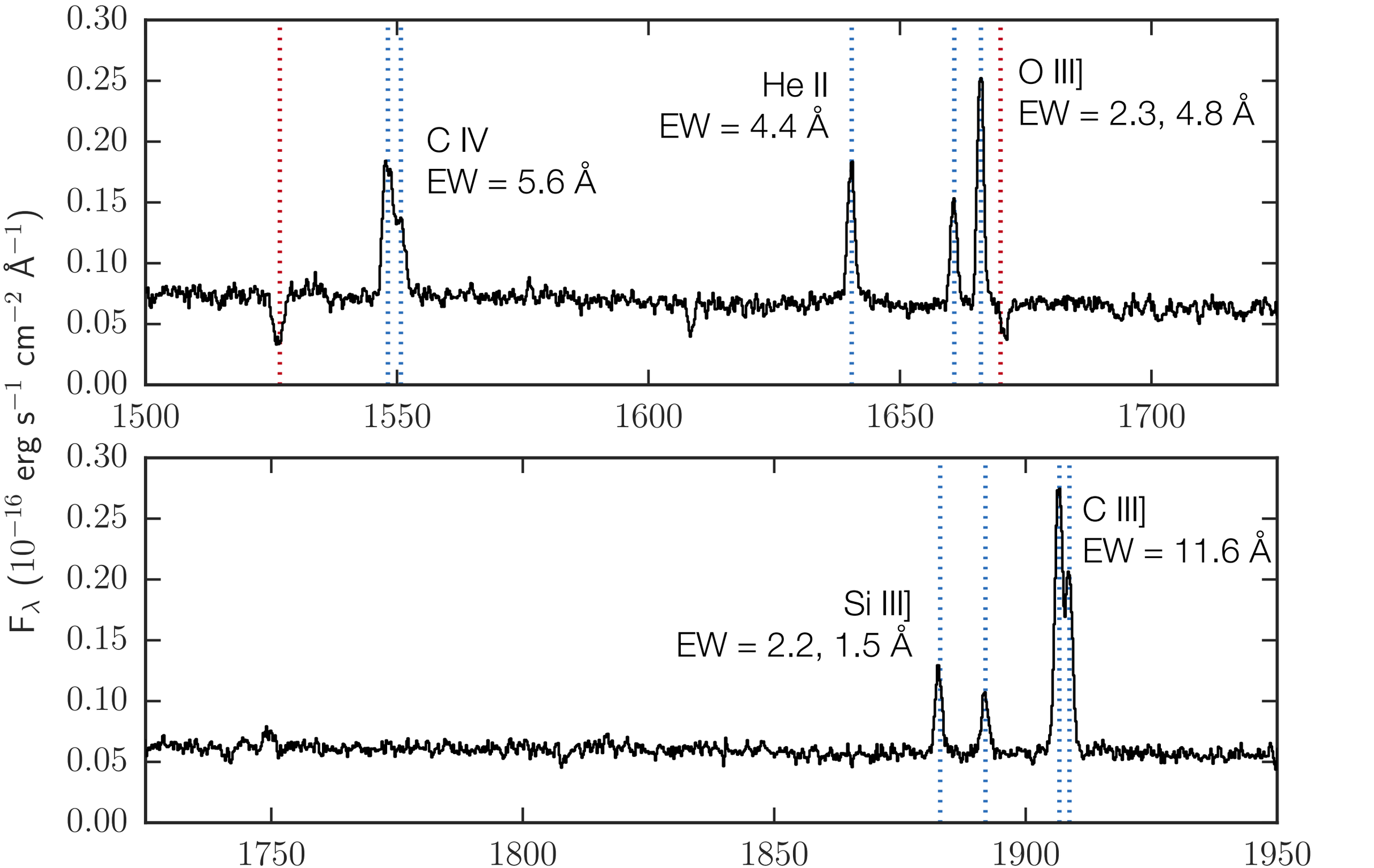
Berg et al in prep

Lya emission



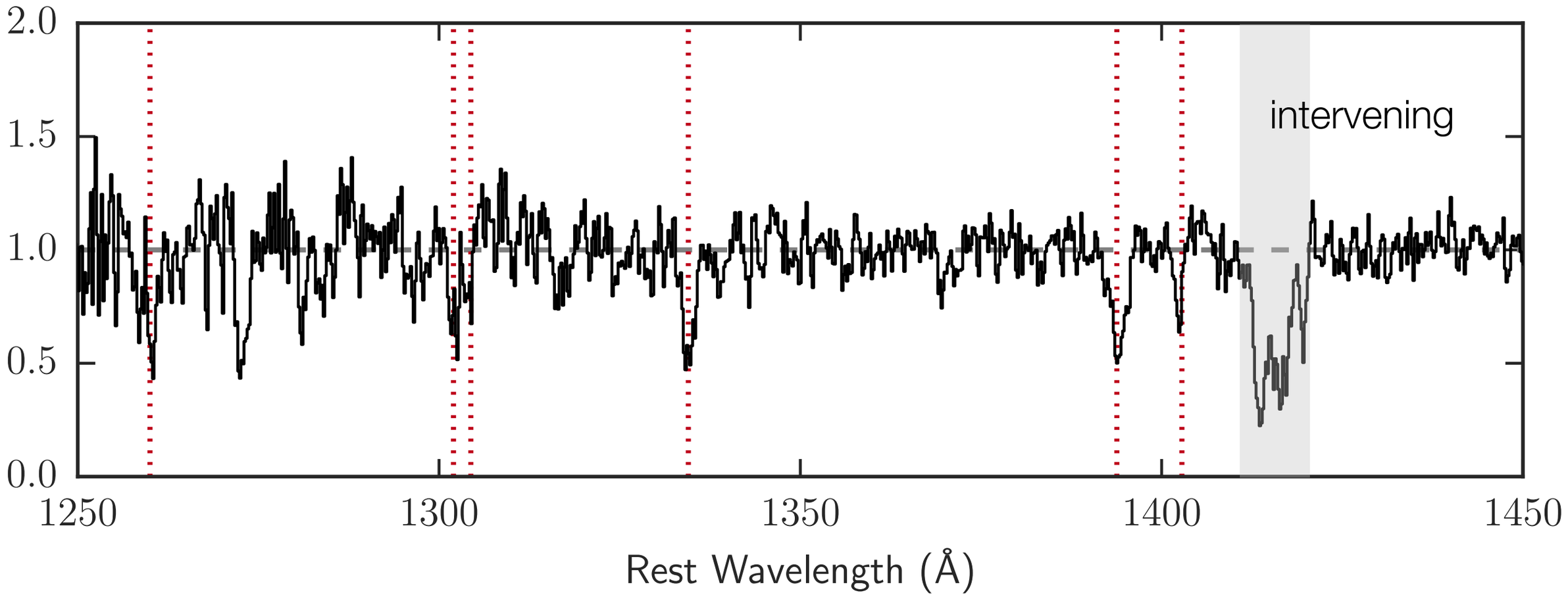
Berg et al in prep

Strong UV emission lines



Berg et al in prep

Interstellar absorption lines

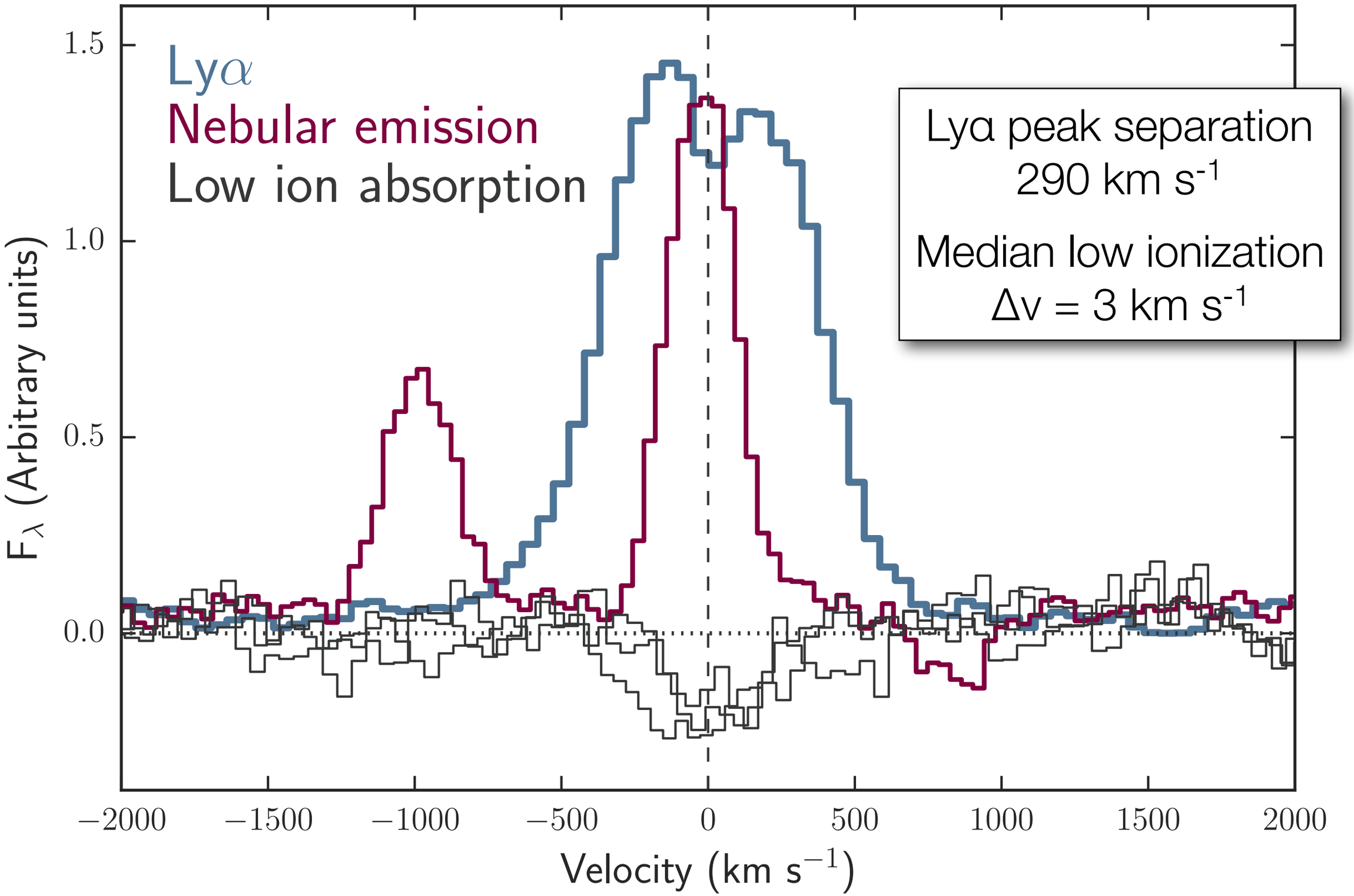


Interstellar absorption lines relatively weak (EW ~ 0.5 - 1 Å), narrow

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

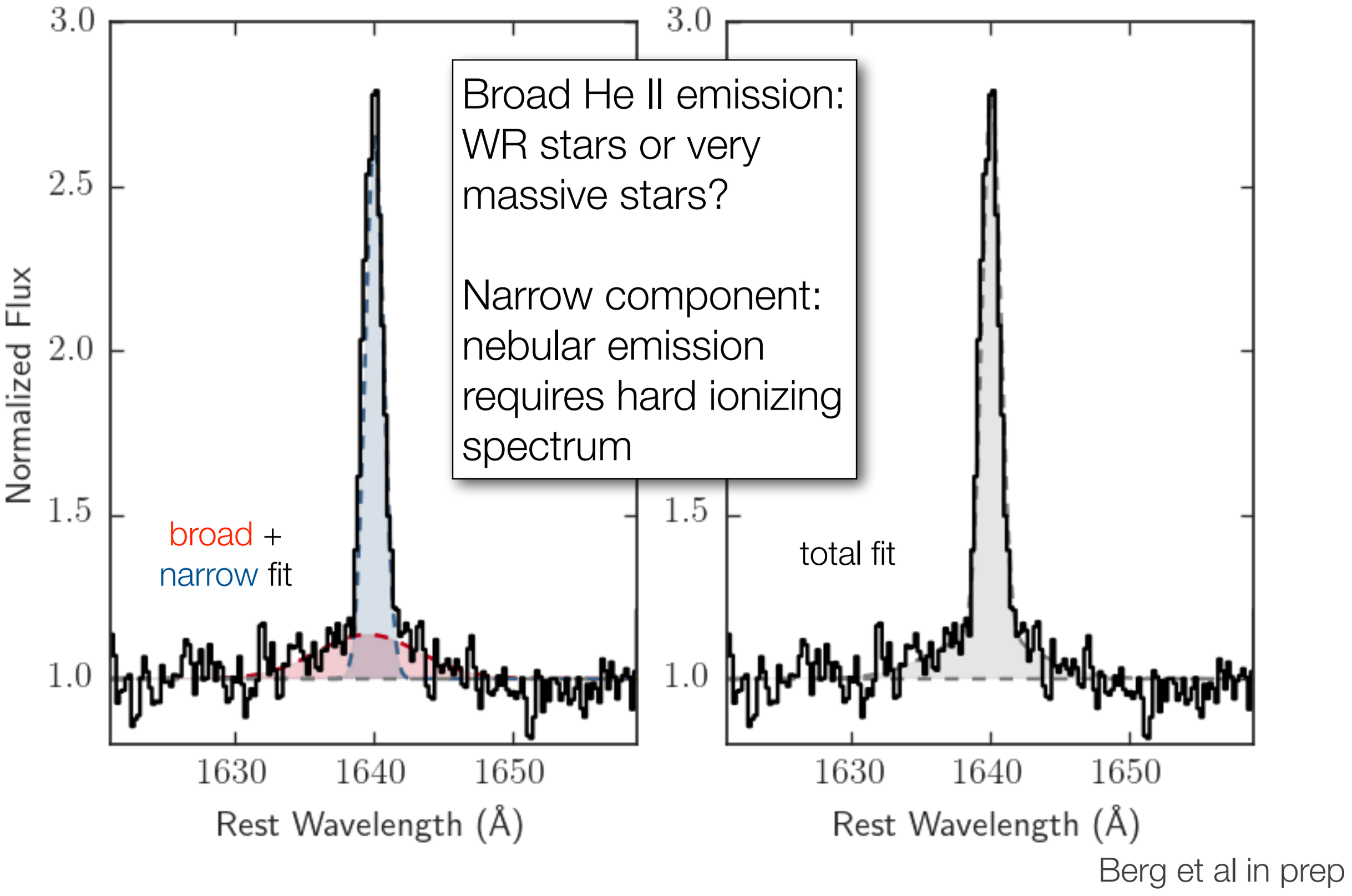
Berg et al in prep

Kinematics



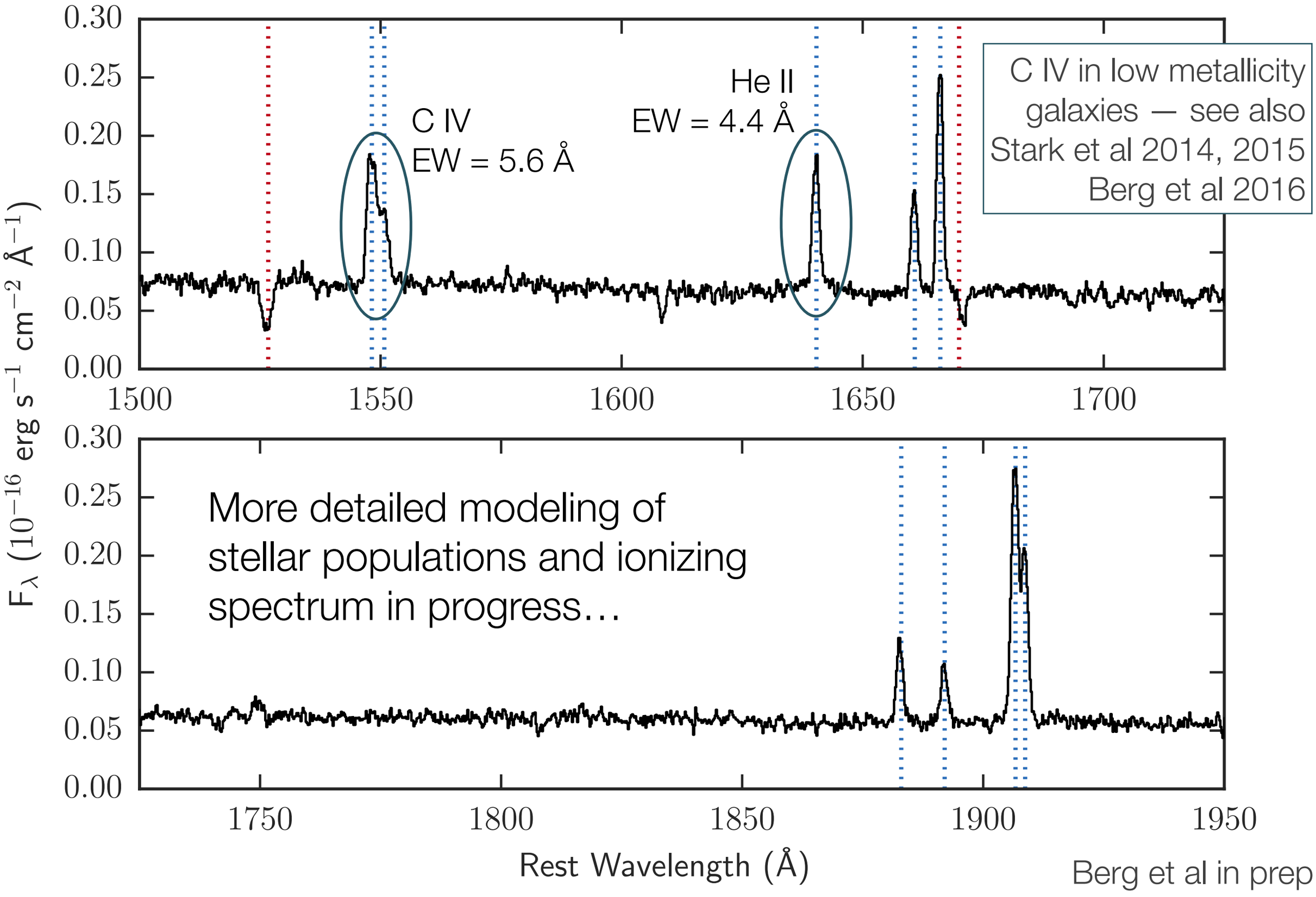
Berg et al in prep

Stellar + nebular He II emission



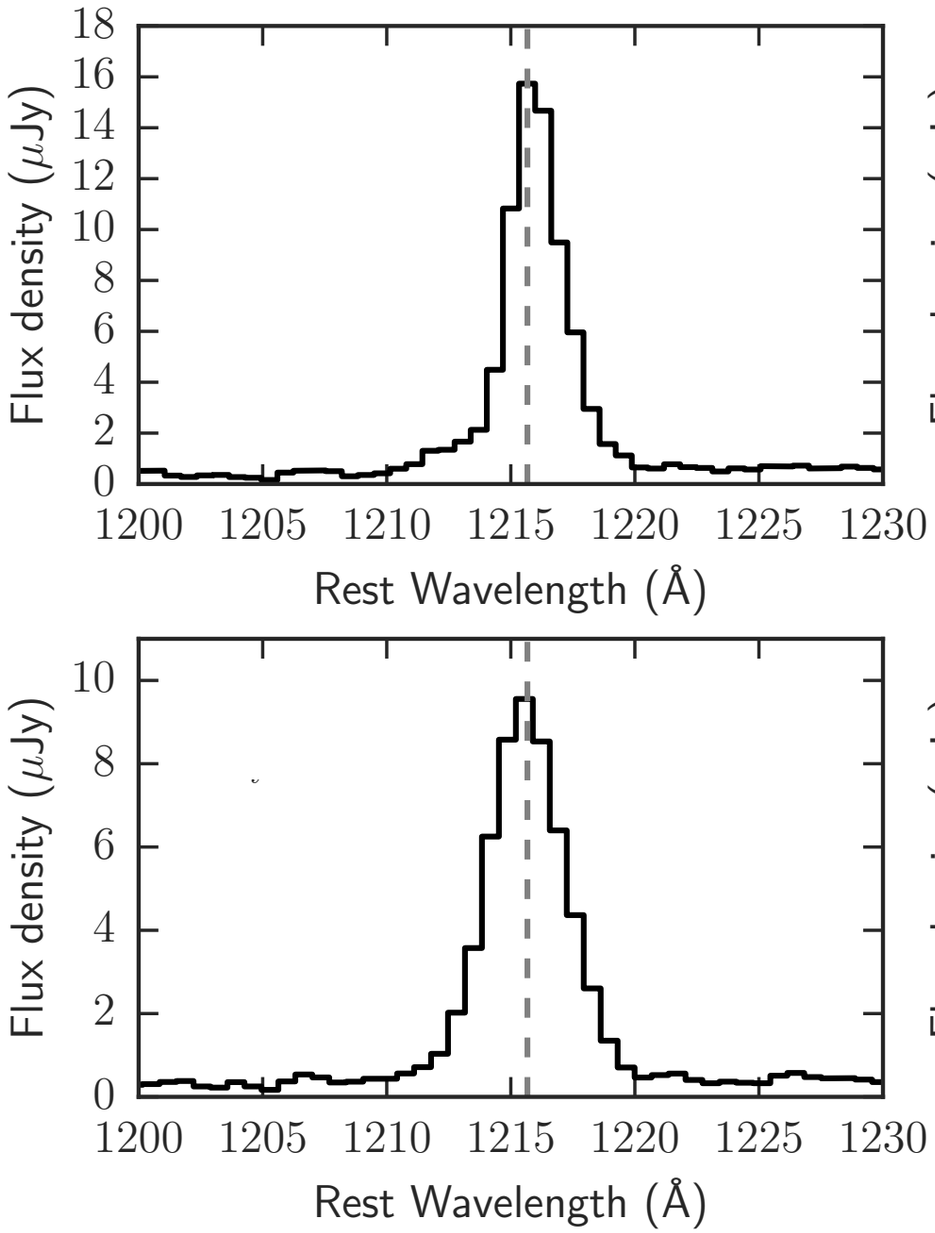
Berg et al in prep

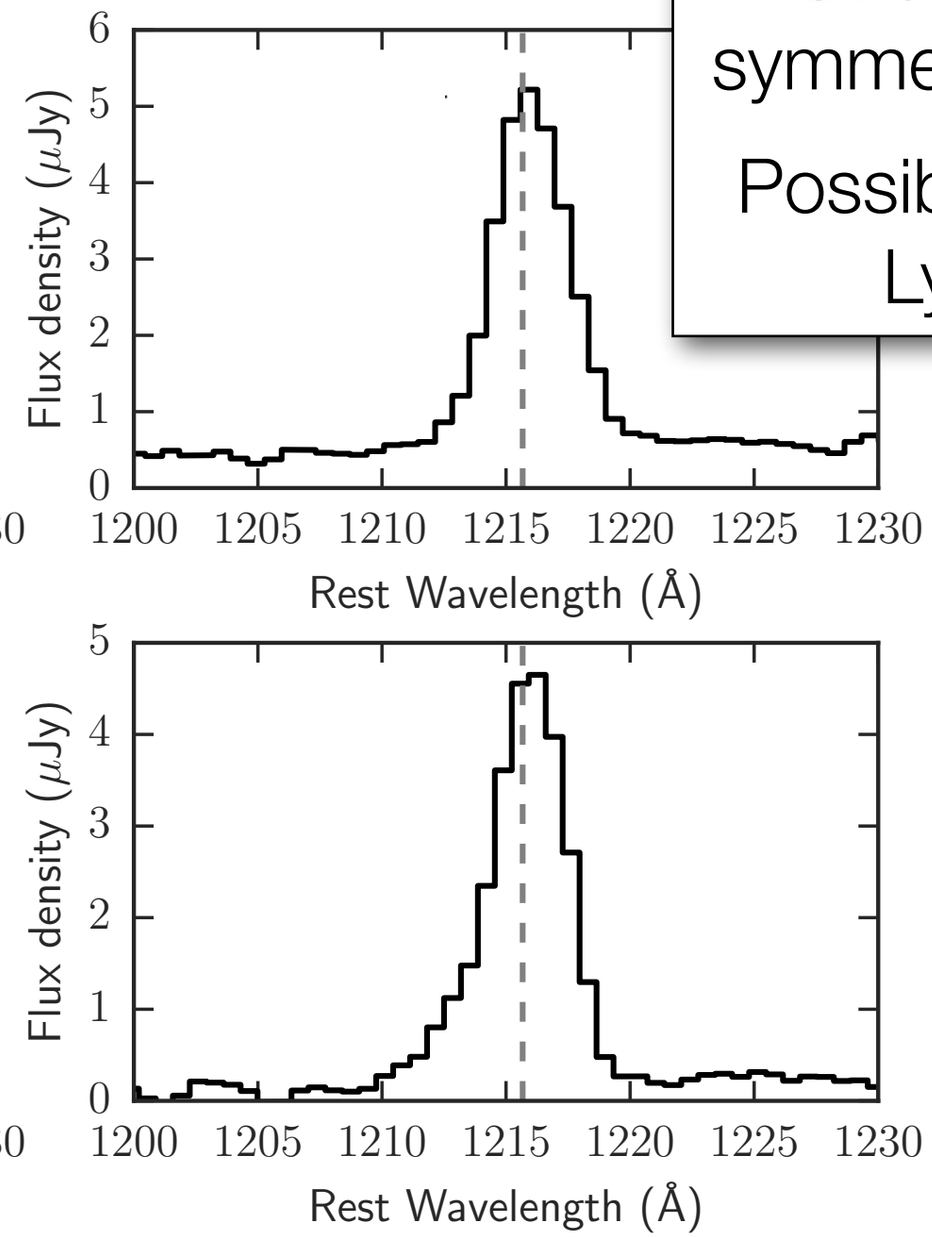
Hard ionizing spectrum required



Berg et al in prep

Observations of more galaxies coming soon





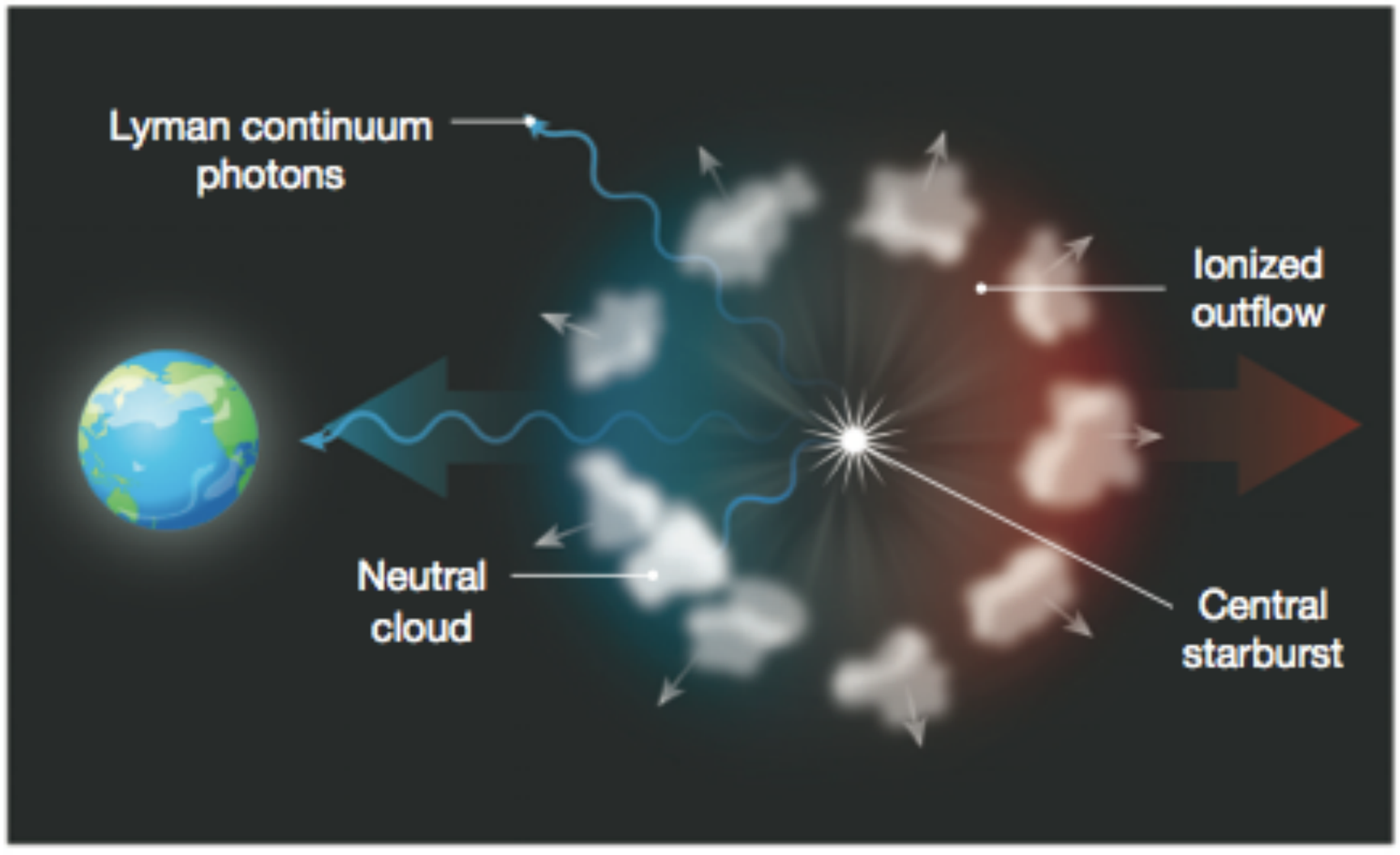
Strong, unusually symmetric Lyα profiles

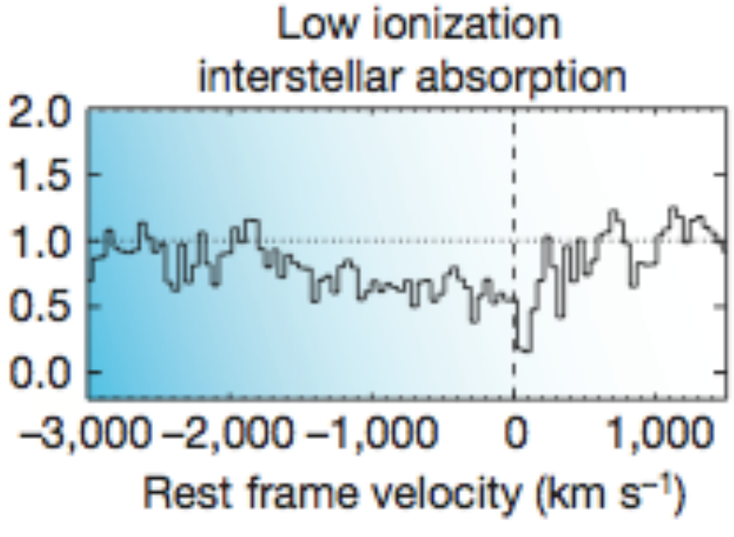
Possible signature of LyC escape

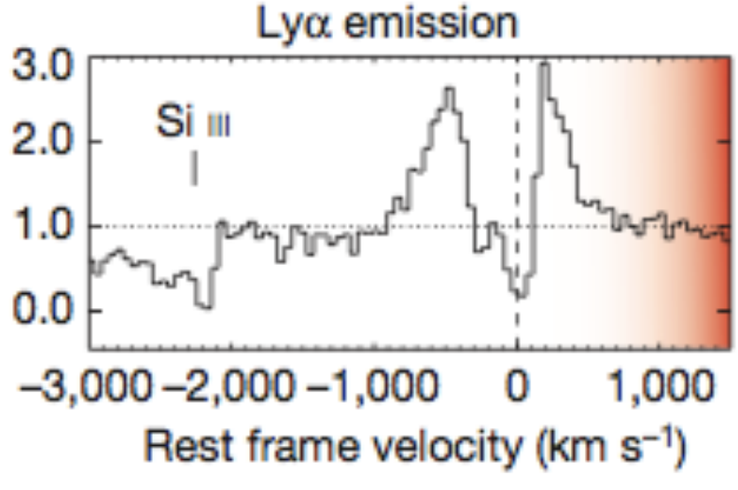
More low mass, low metallicity z~2 galaxies:

X-shooter and deep LRIS observations scheduled

Summary: feedback in low mass galaxies at z~2







Among low mass galaxies with similar metallicities and ionization states, feedback properties inferred from interstellar absorption lines and Lyα vary widely

Timescales? Geometric effects?

Statistical sample needed

Erb 2015