Insights into Lyα and CIV emission from strongly lensed galaxies observed with MUSE

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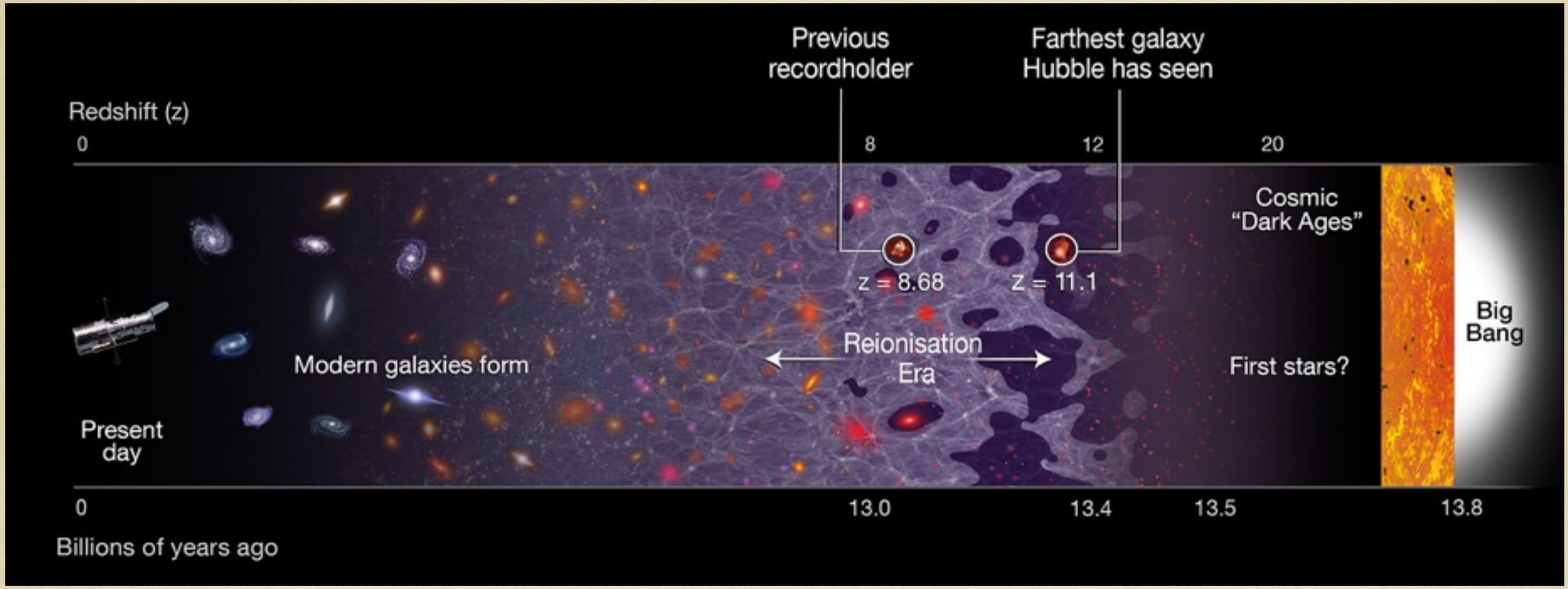
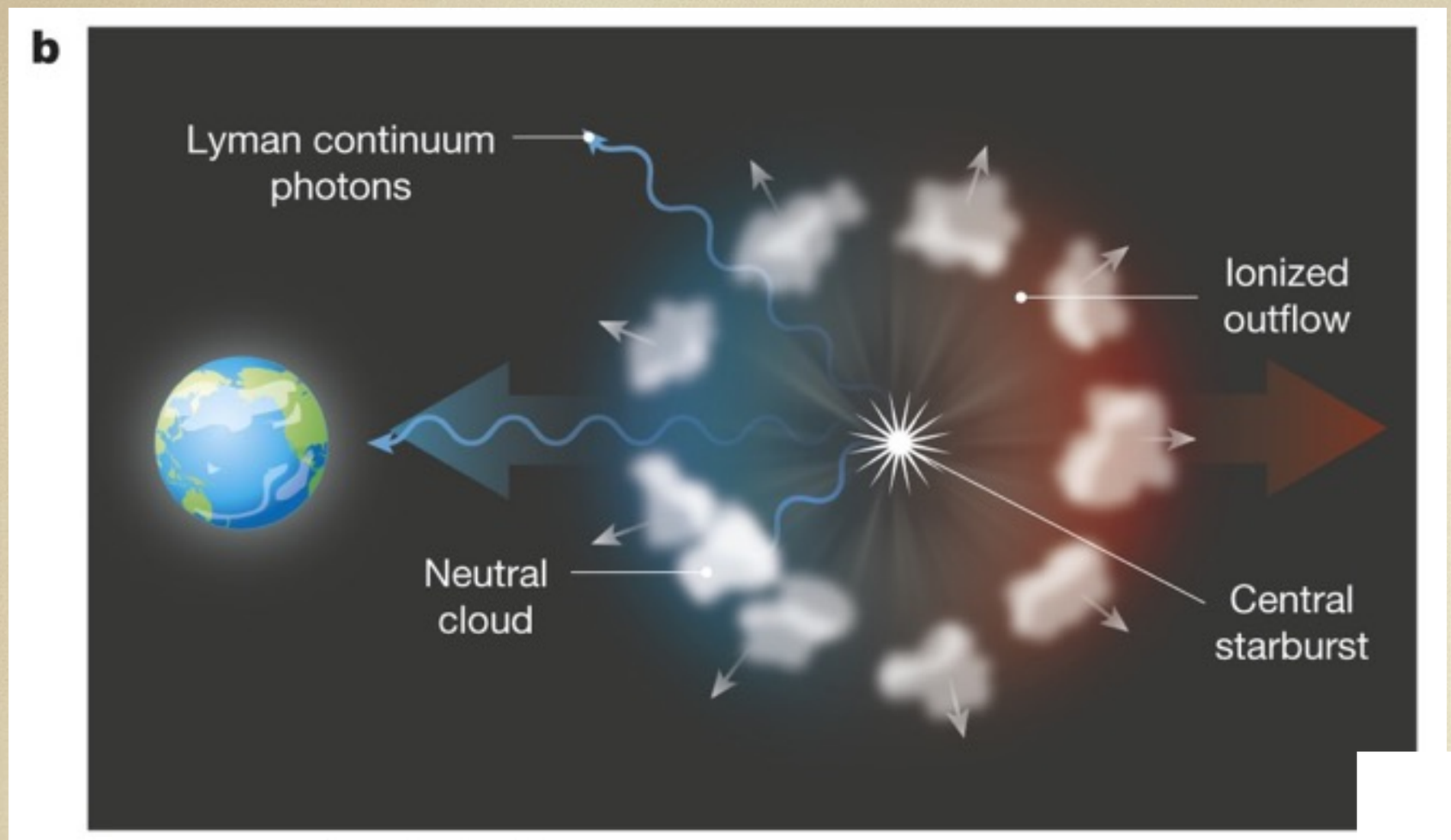
Reionisation studies



Credit: NASA, ESA, and A. Feild (STScI)

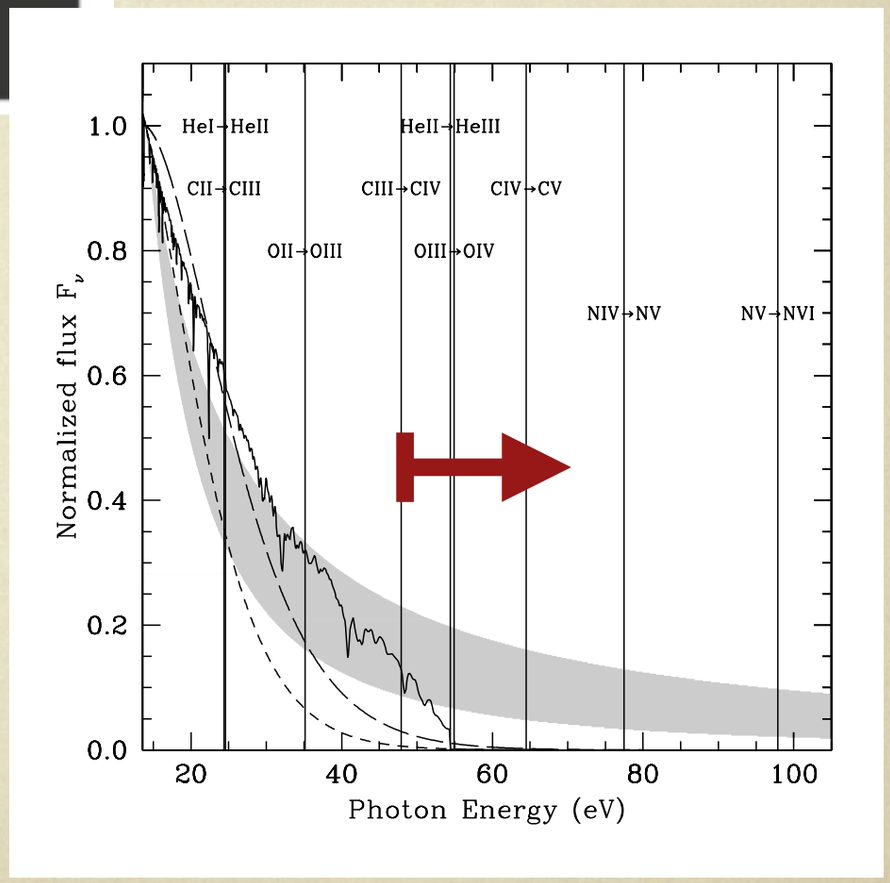
We want to understand: I. Neutral fraction / Lyα prevalence II. Ionising photon budget / ξion III. Escape fraction / covering fractions etc.



Erb at al. 2015

Lyα prevalence is an important constraint for neutral IGM

Nebular emission lines such as CIV provide us with clues about ξion



Stark at al. 2015

Strongly lensed sources at z~3-5 with MUSE optical integral-field spectroscopy

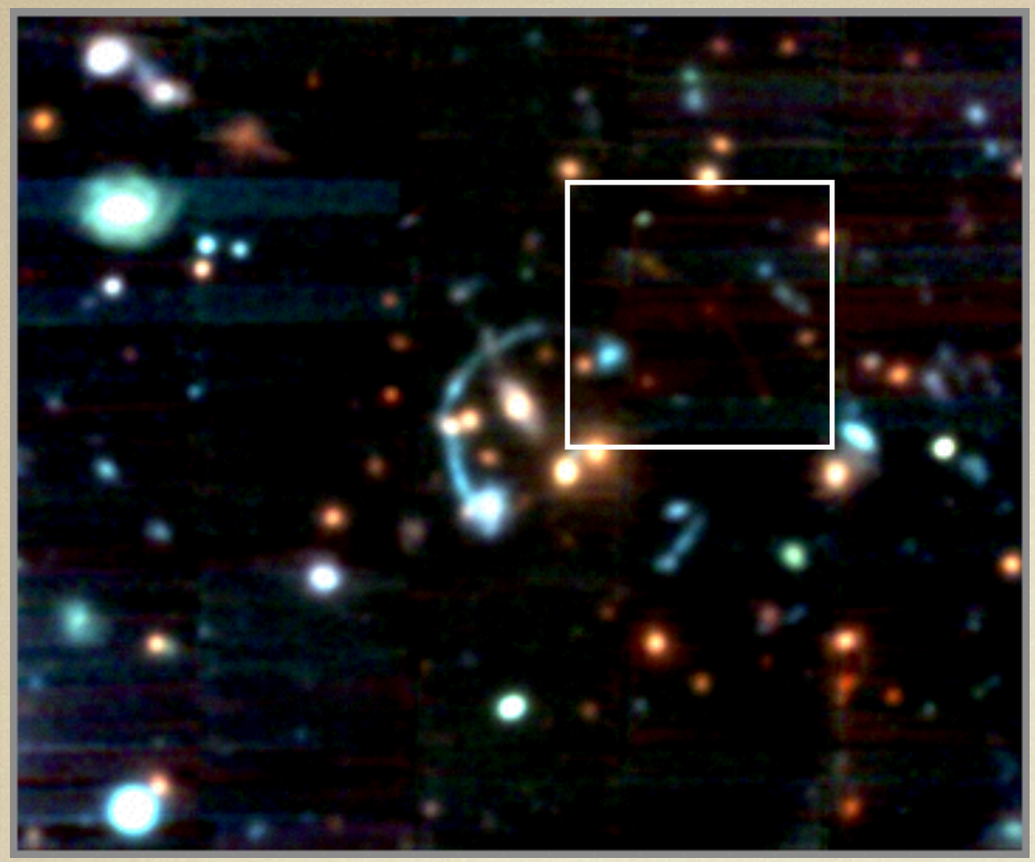
Advantages:

- Strong lensing + IFU spectroscopy reveals the spatial distribution of emission lines
- High S/N + moderate spectral resolution of MUSE (FWHM~100 km/s) disentangles different components contributing to the line profile

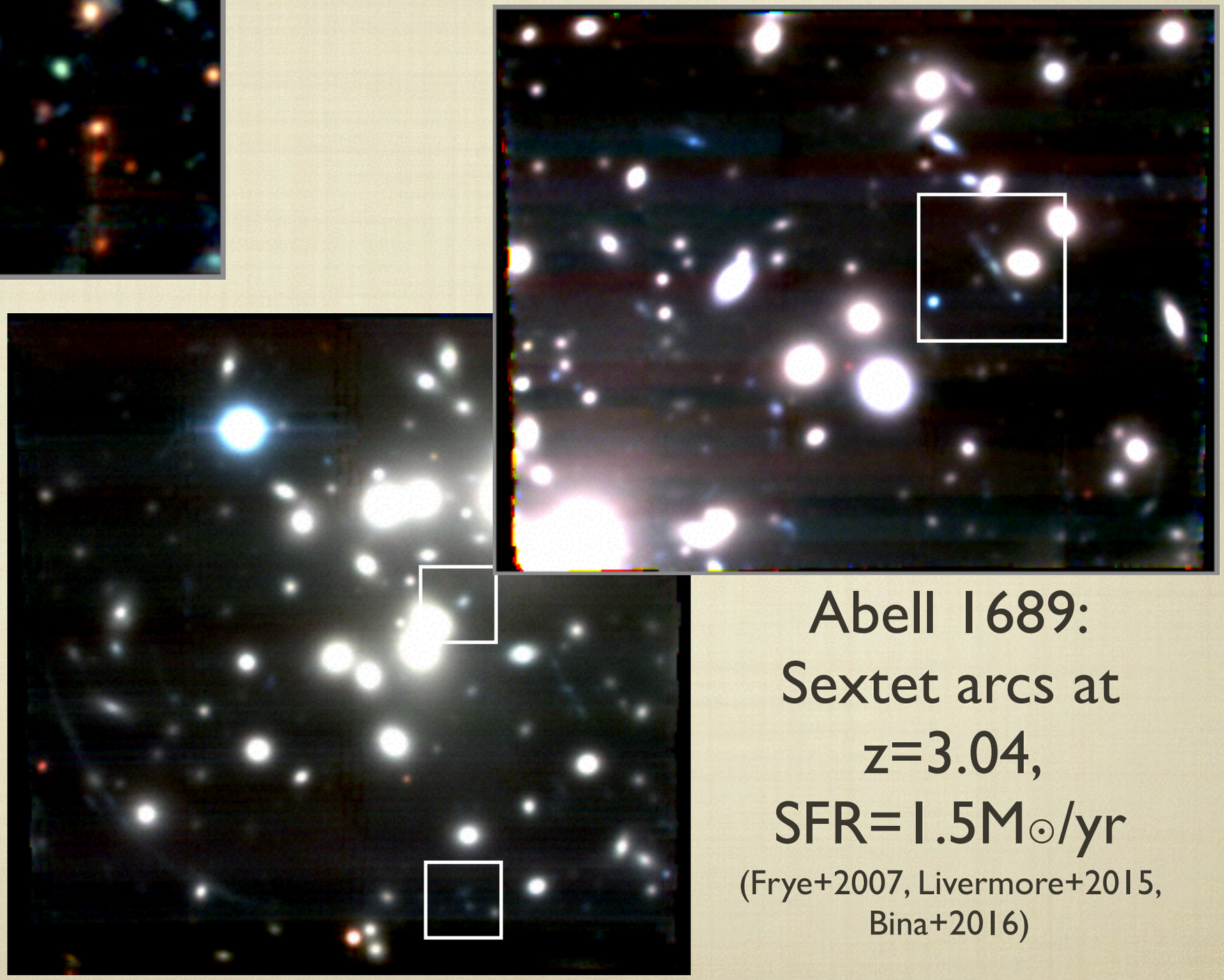
Disadvantage:

- Few very strongly lensed sources known - here I focus on 2 sources

MUSE spectroscopy

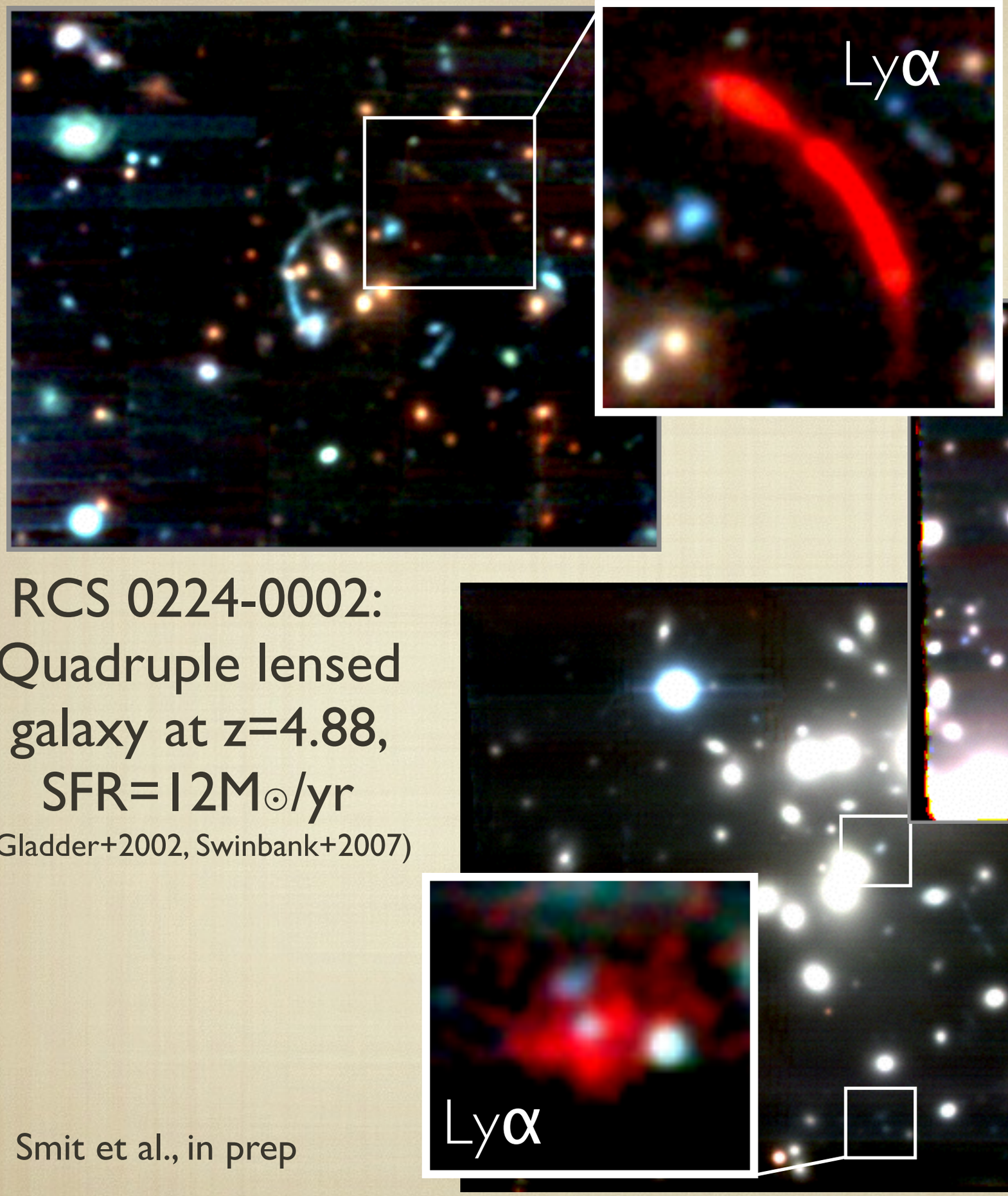


RCS 0224-0002:
Quadruple lensed galaxy at z=4.88, SFR=12M⊙/yr
(Gladder+2002, Swinbank+2007)



Abell 1689:
Sextet arcs at z=3.04, SFR=1.5M⊙/yr
(Frye+2007, Livermore+2015, Bina+2016)

Smit et al., in prep



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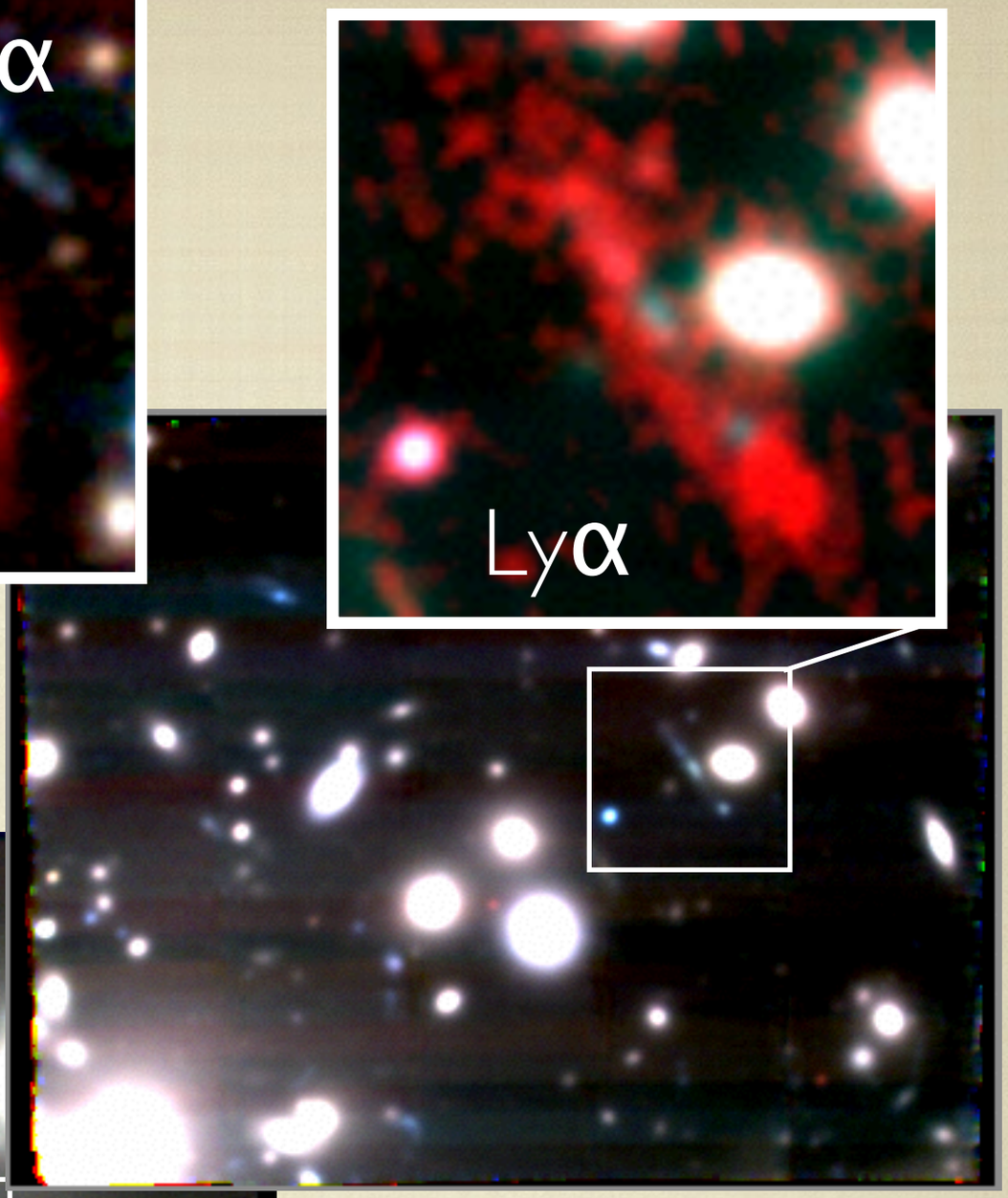

Abell 1689:
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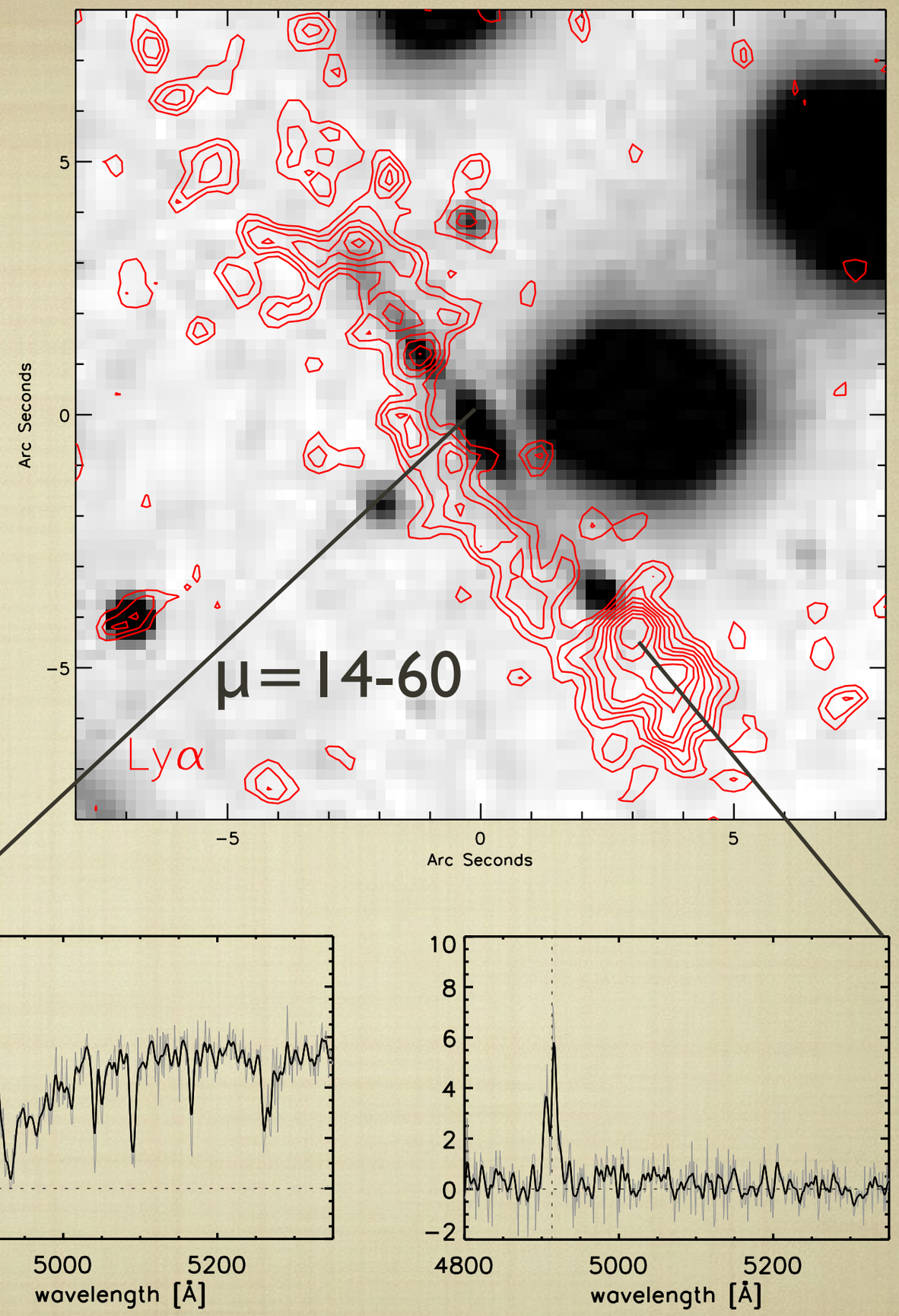
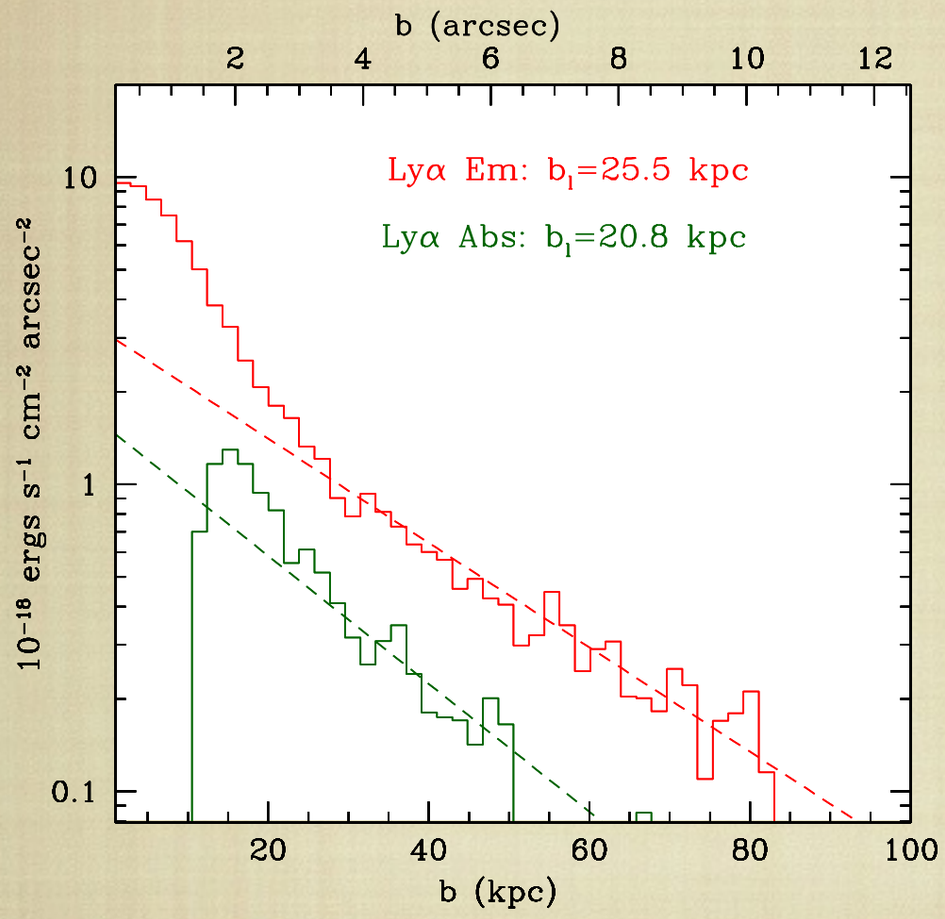
(Frye+2007, Livermore+2015, Bina+2016)

Smit et al., in prep

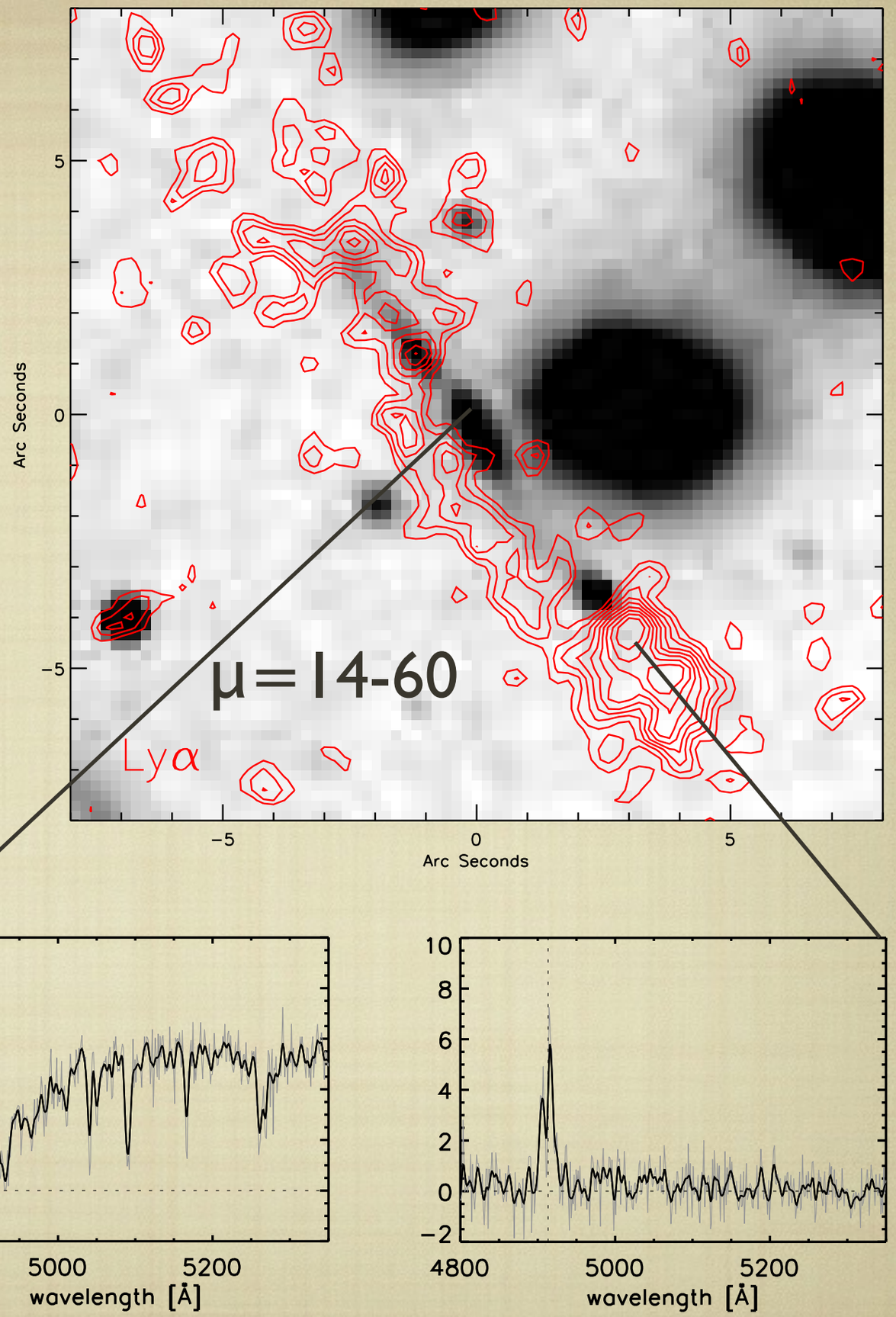
A1689: resonantly scattered Lyα



Lyα absorbers are Lyα emitters on large scales

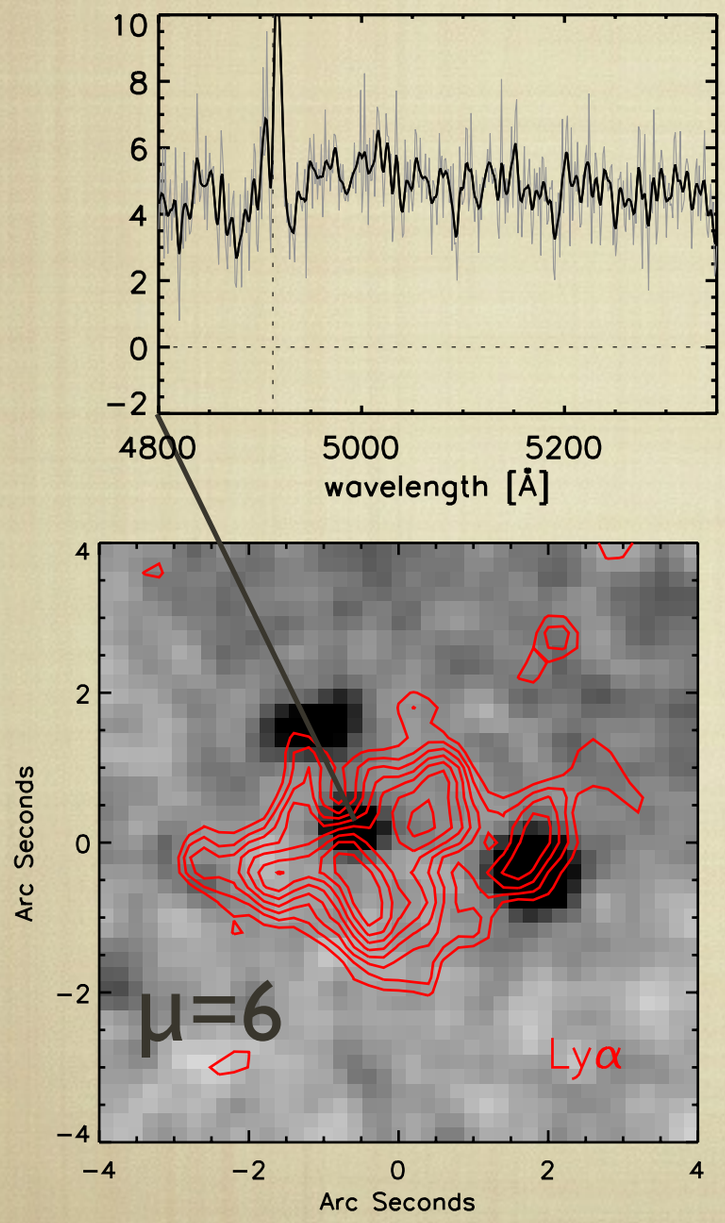


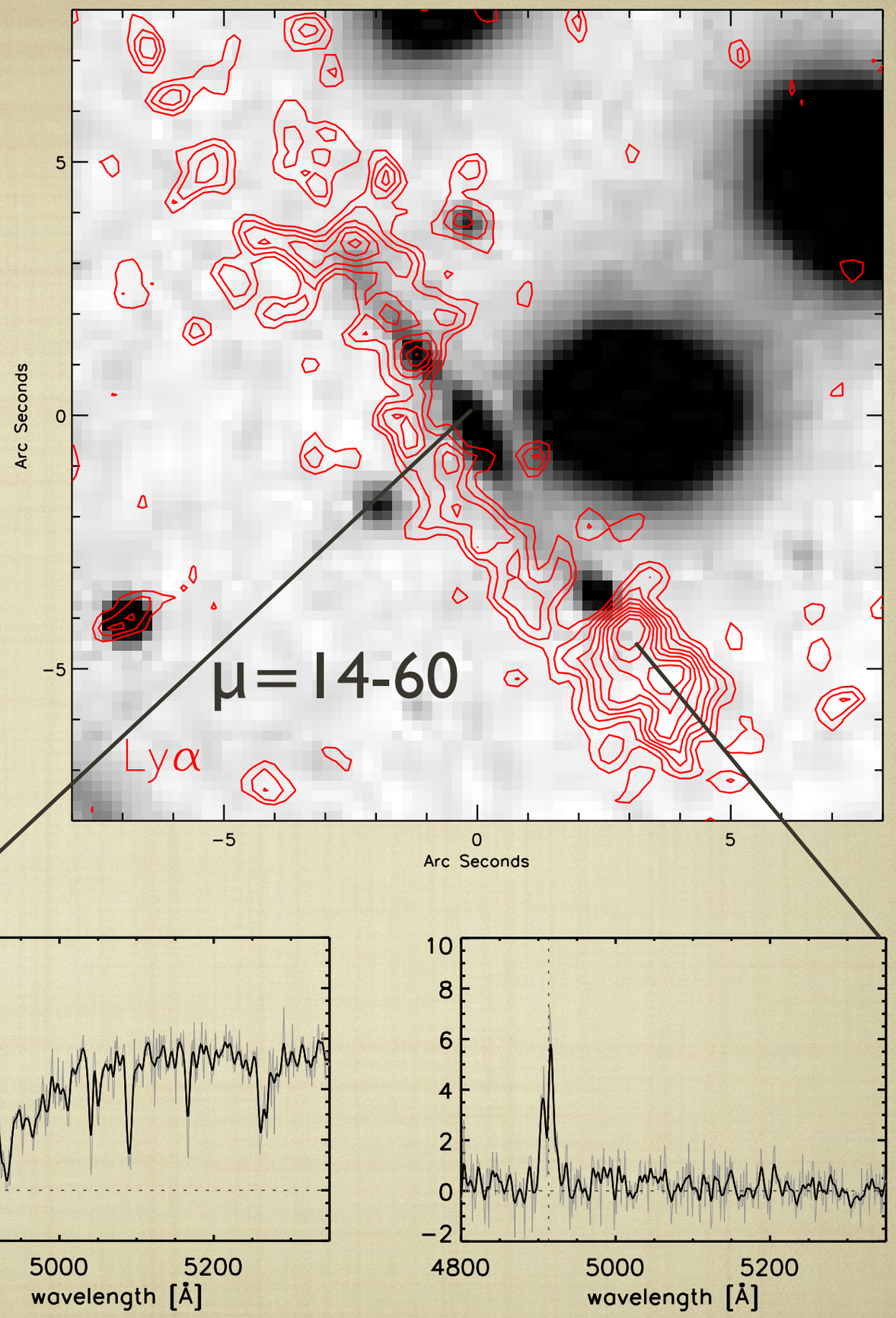
Steidel at al. 2011



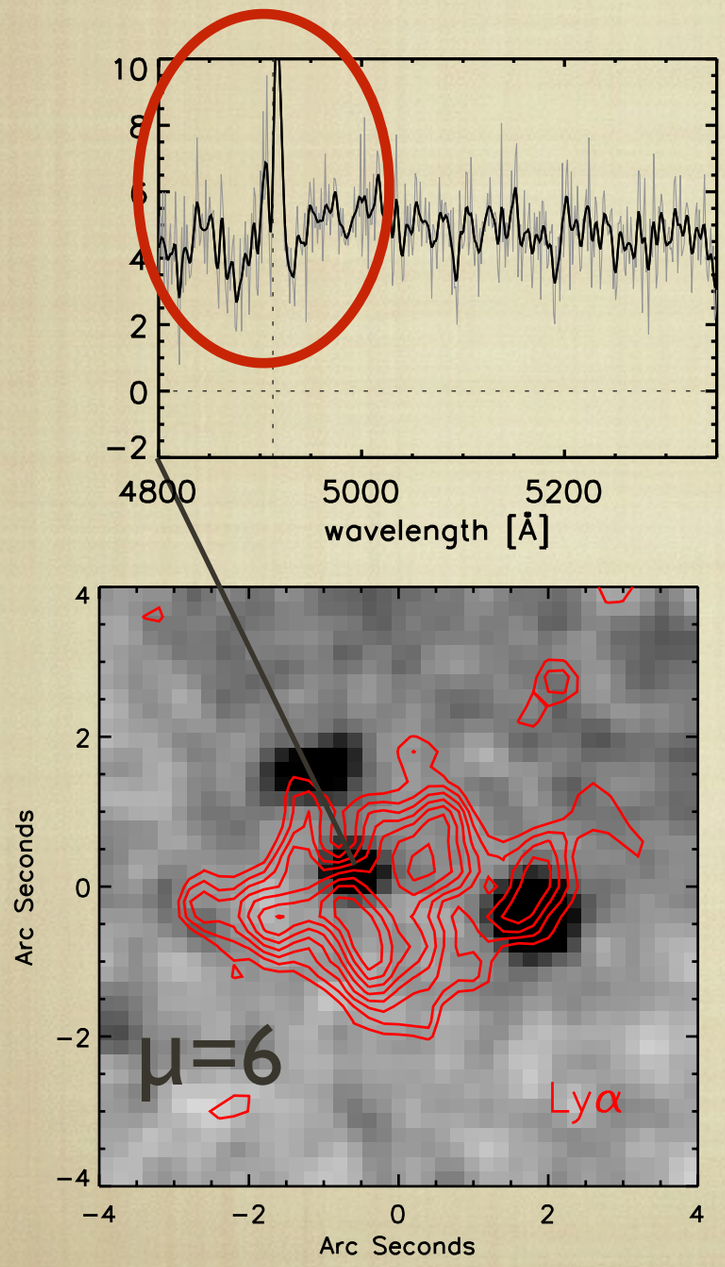
~~Lyα absorbers are Lyα emitters on large scales~~

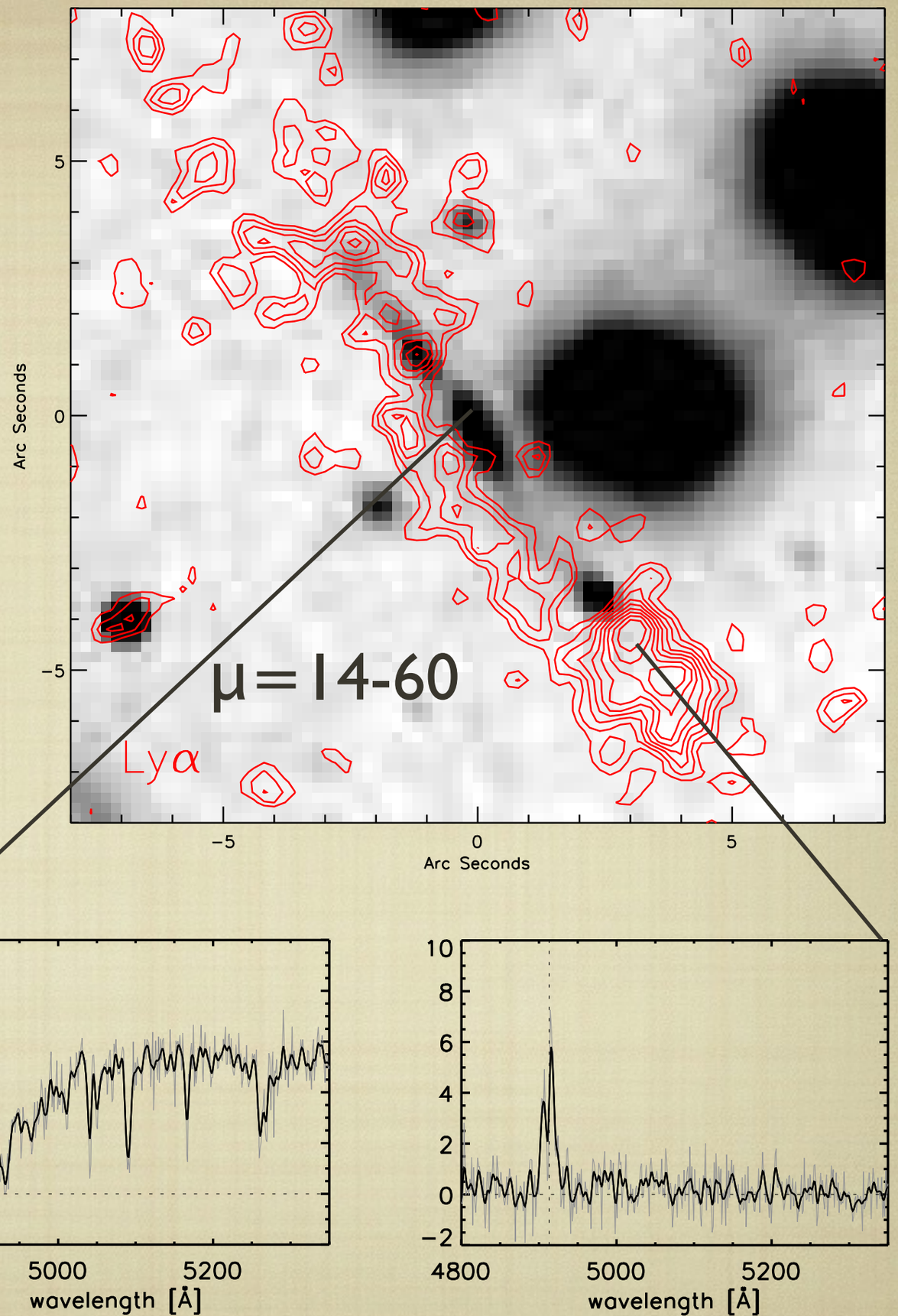
Lyα emitters can be Lyα absorbers on small scales



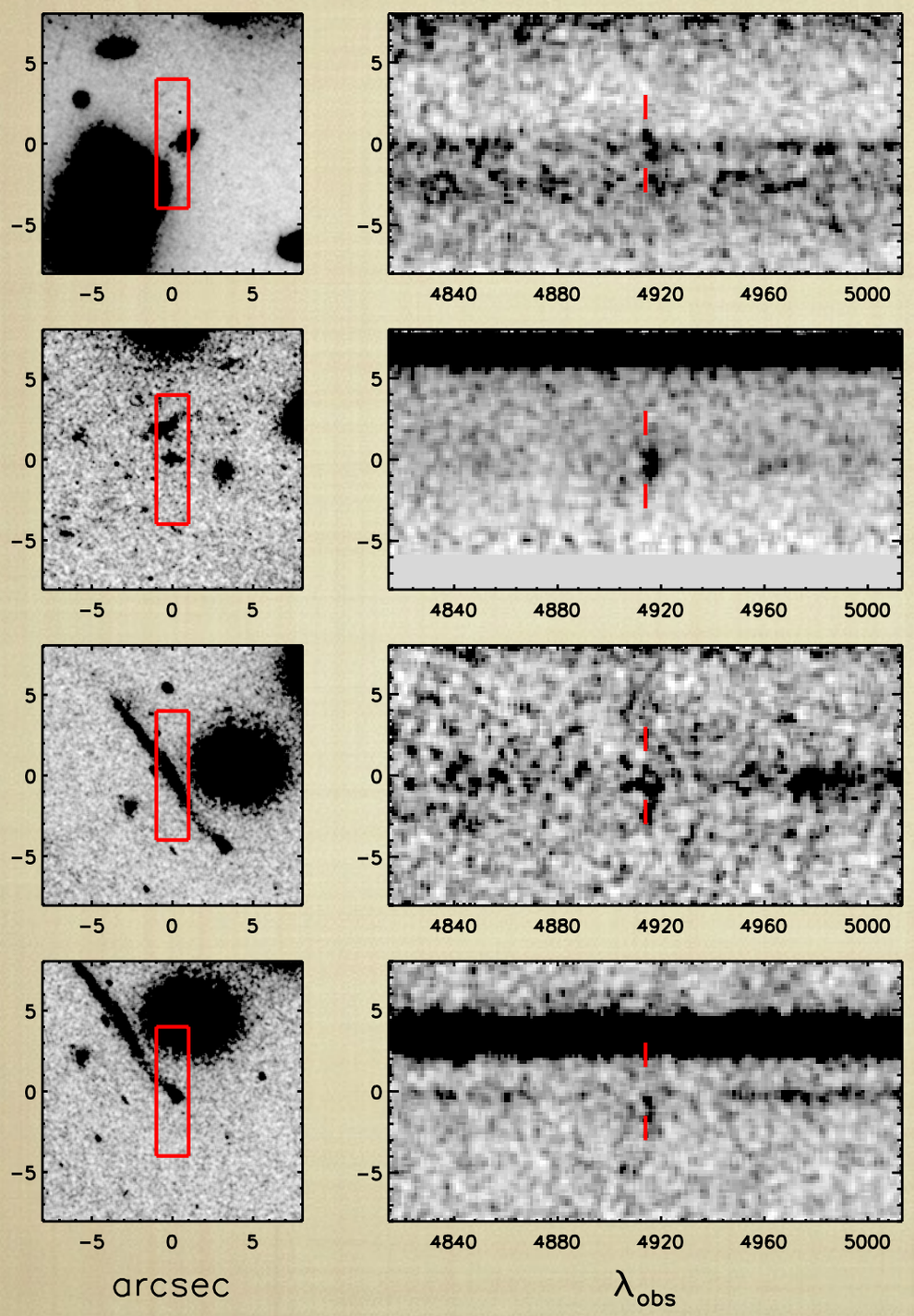


Double peaked Lyα does not reflect the properties of the ISM (e.g. low column density)

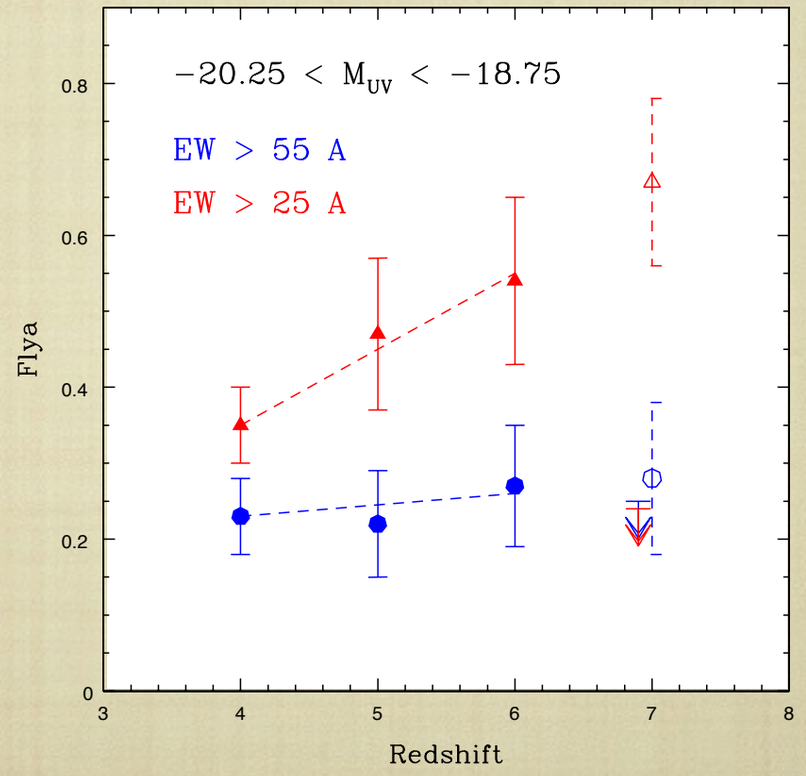




Implications for Lyα studies

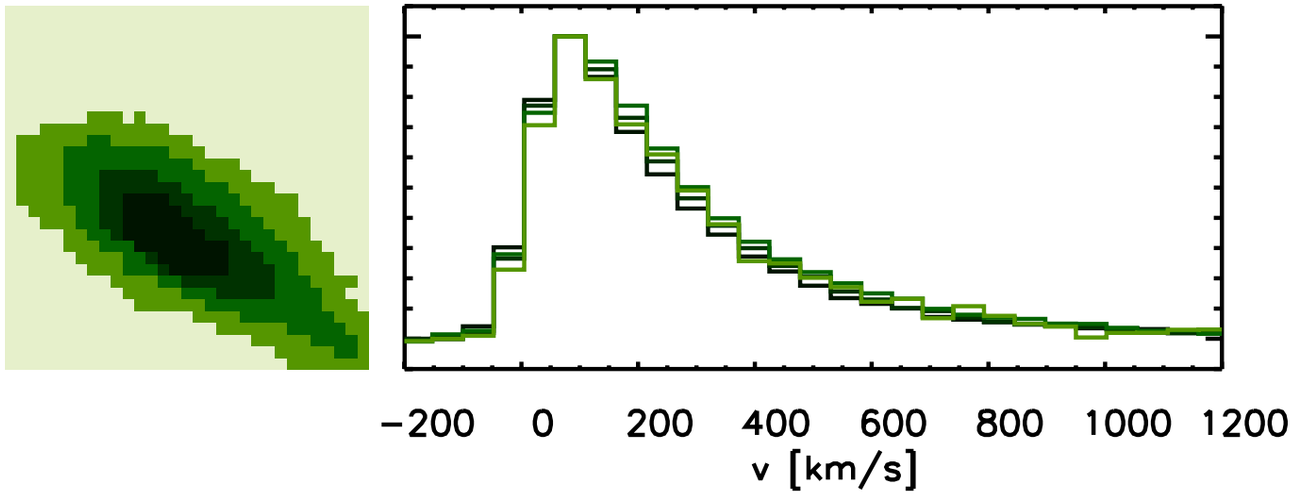


Lyα prevalence can depend on spatial resolution - how will JWST/ELT Lyα science be affected?



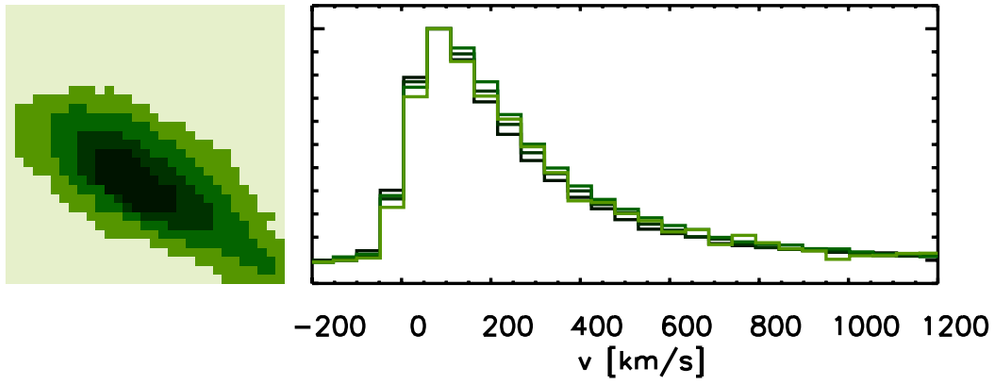
Pentericci at al. 2011

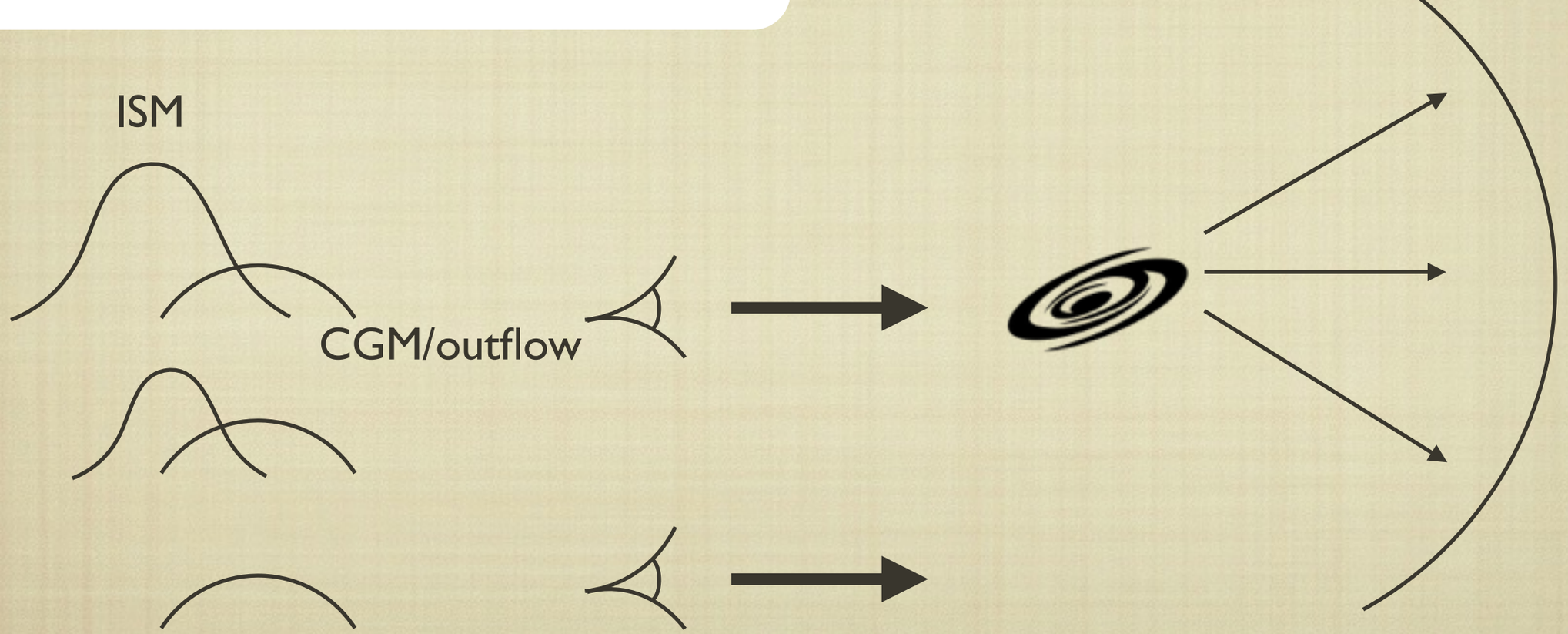
RCS0224: Spatially invariant Lyα velocity profile



Variation is Lyα peak as a function of radius is <60 km/s

RCS0224: Spatially invariant Lyα velocity profile





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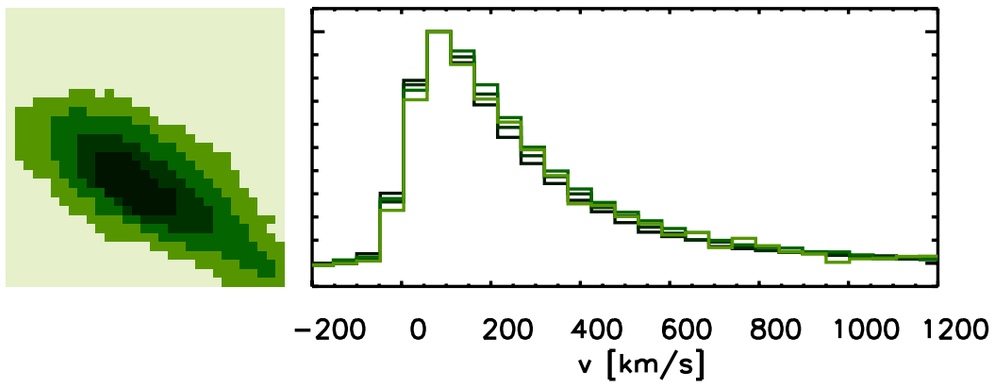
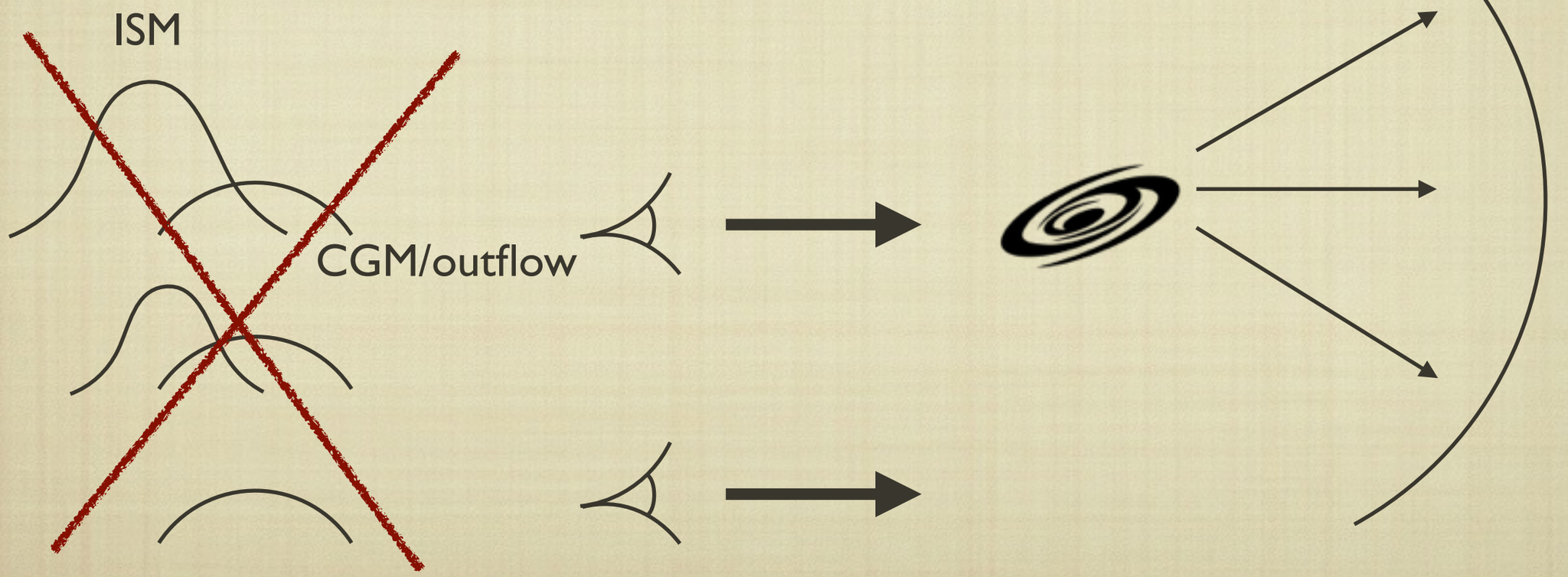
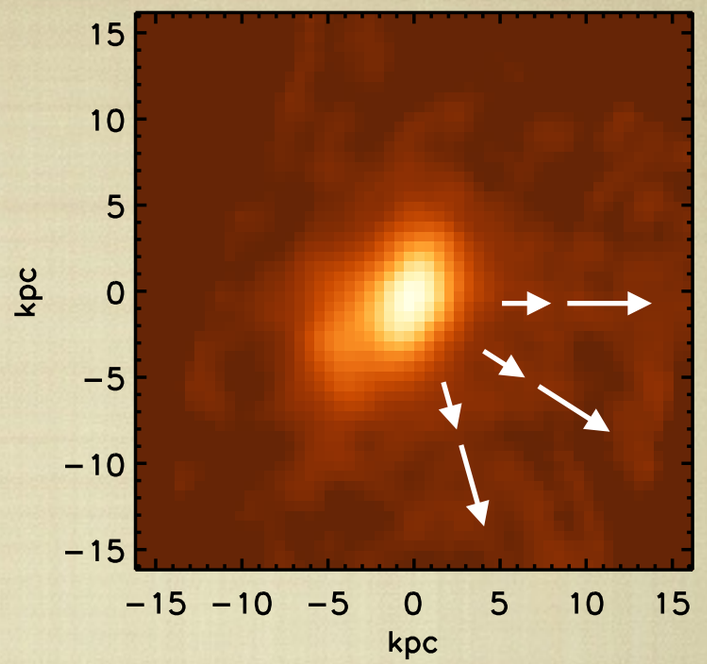


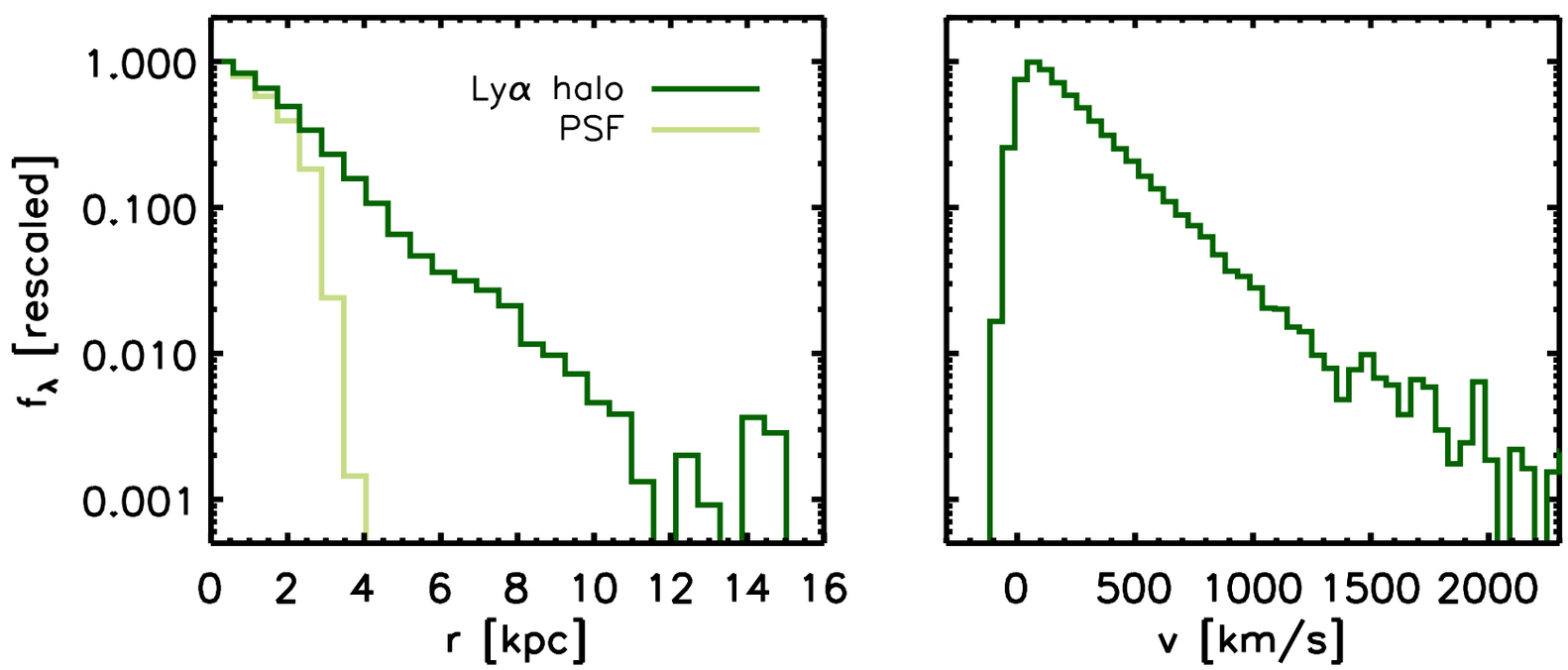
Is Lyα here also dominated by CGM emission?



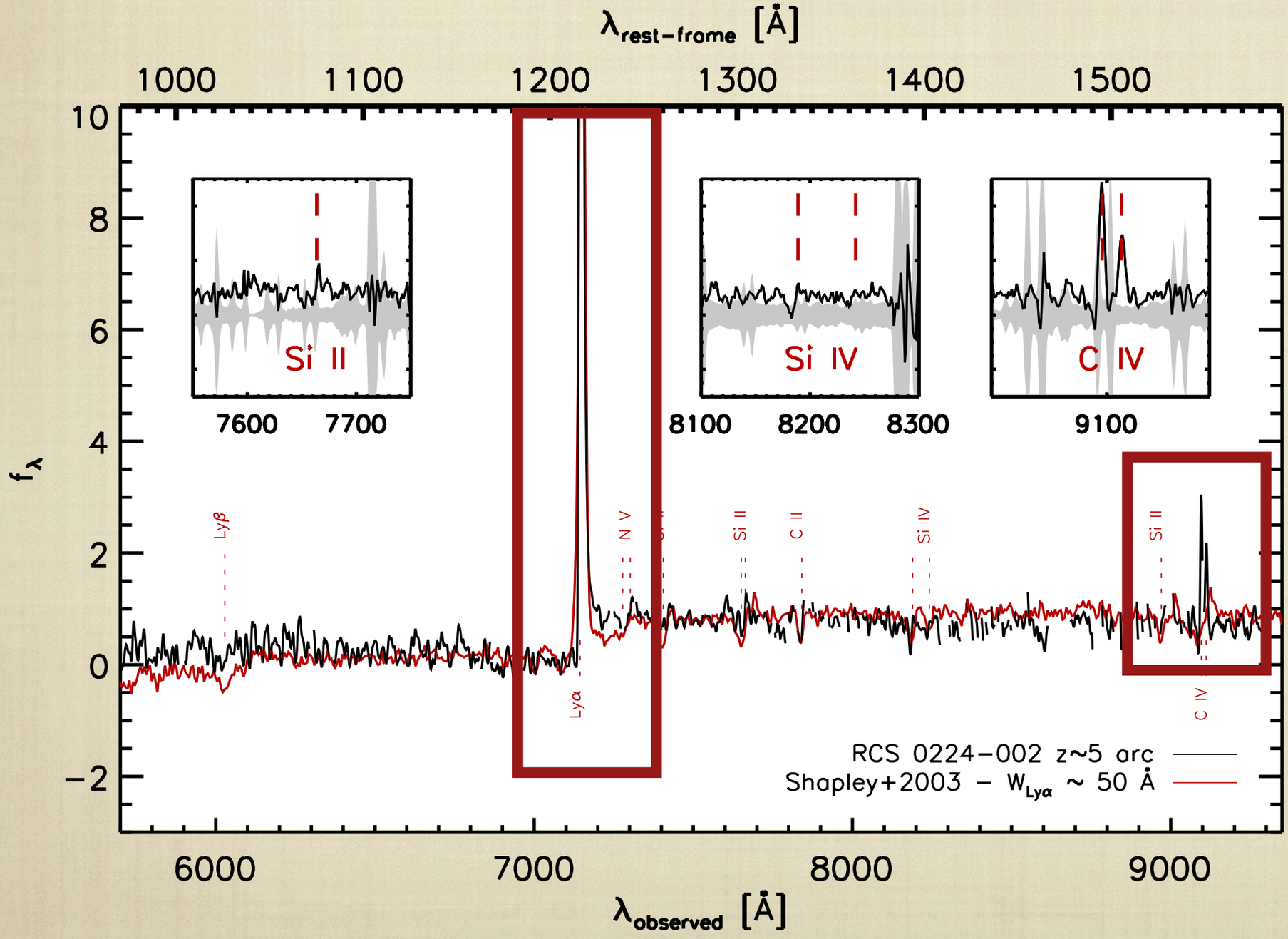
The exponential Ly**α** halo

Lyα emission is best describe by an exponential profile **both** spatially and in velocity space - most easily describe by a smooth velocity gradient



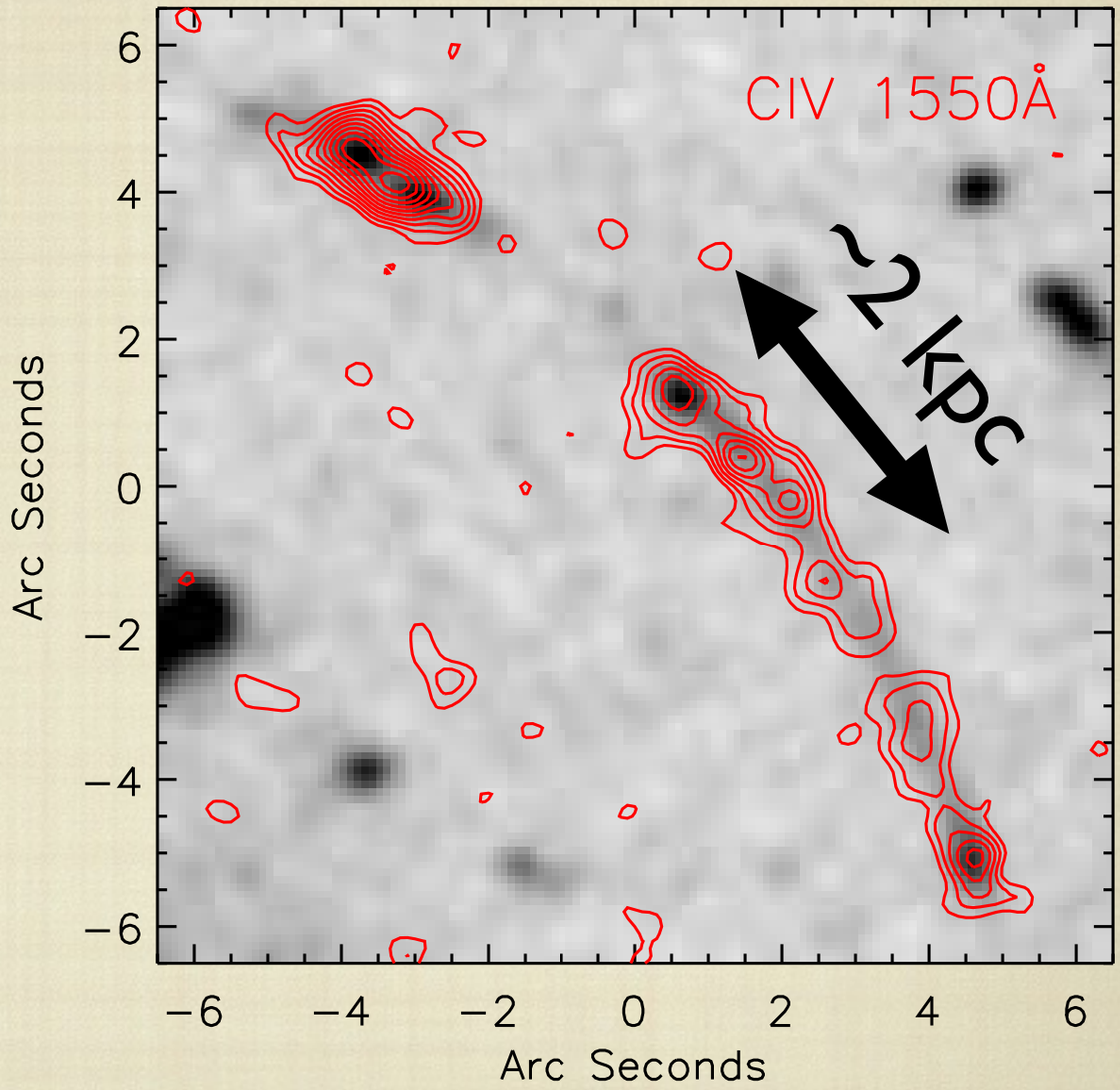


RCS 0224 z=4.88 arc: discovery of a strong CIV doublet



Spatial distribution of CIV

- We can resolve star-forming regions with ~300 pc resolution and find extended CIV emission over ~4 massive star-forming clumps

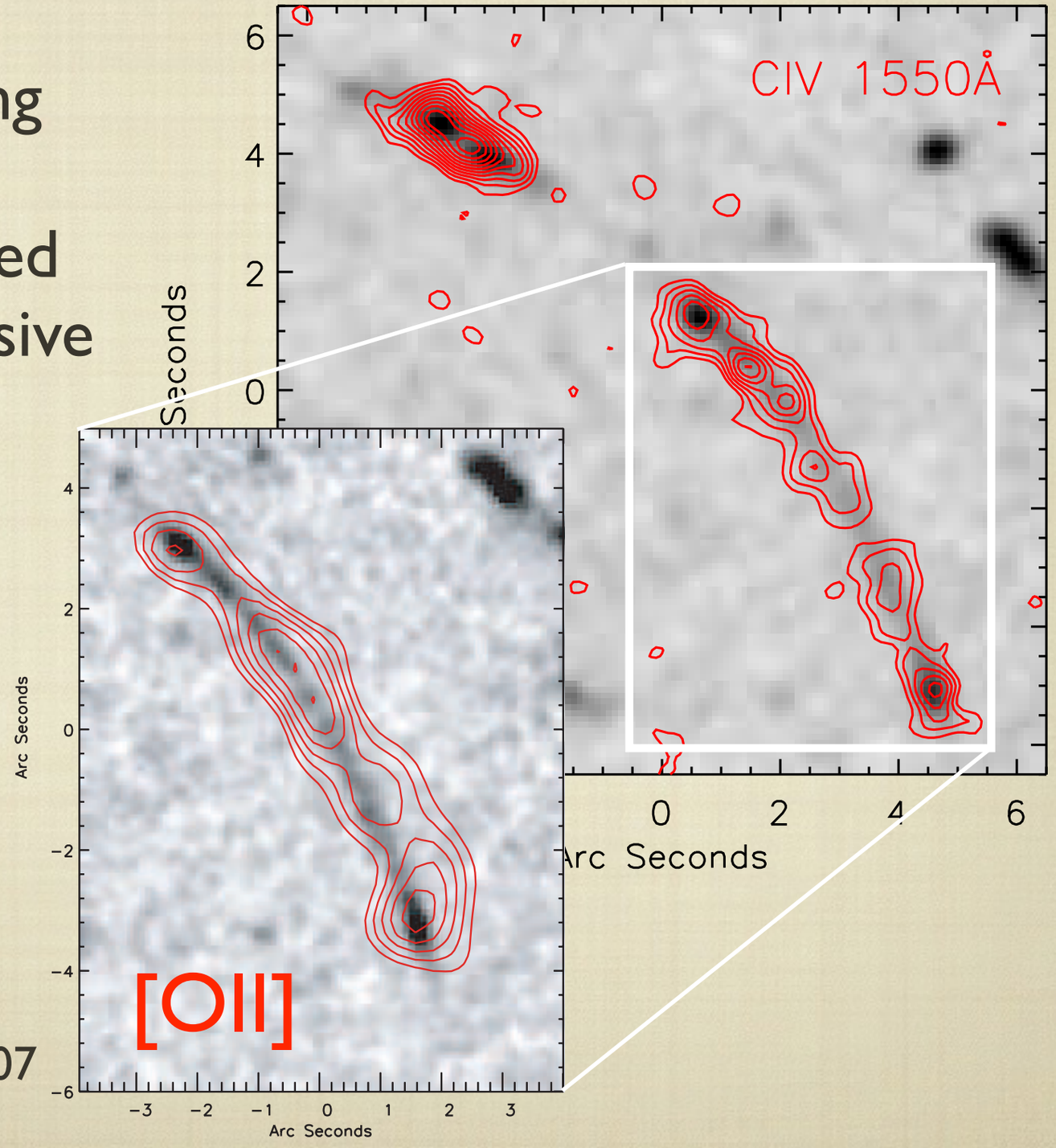


Spatial distribution of CIV

- We can resolve star-forming regions with ~300 pc resolution and find extended CIV emission over ~4 massive star-forming clumps

- CIV follows the spatial distribution of [OII], with $z_{CIV} \sim z_{OII} \sim 4.875$ and $\sigma_{CIV} \sim \sigma_{OII} \sim 50$ km/s

Swinbank et al. 2007



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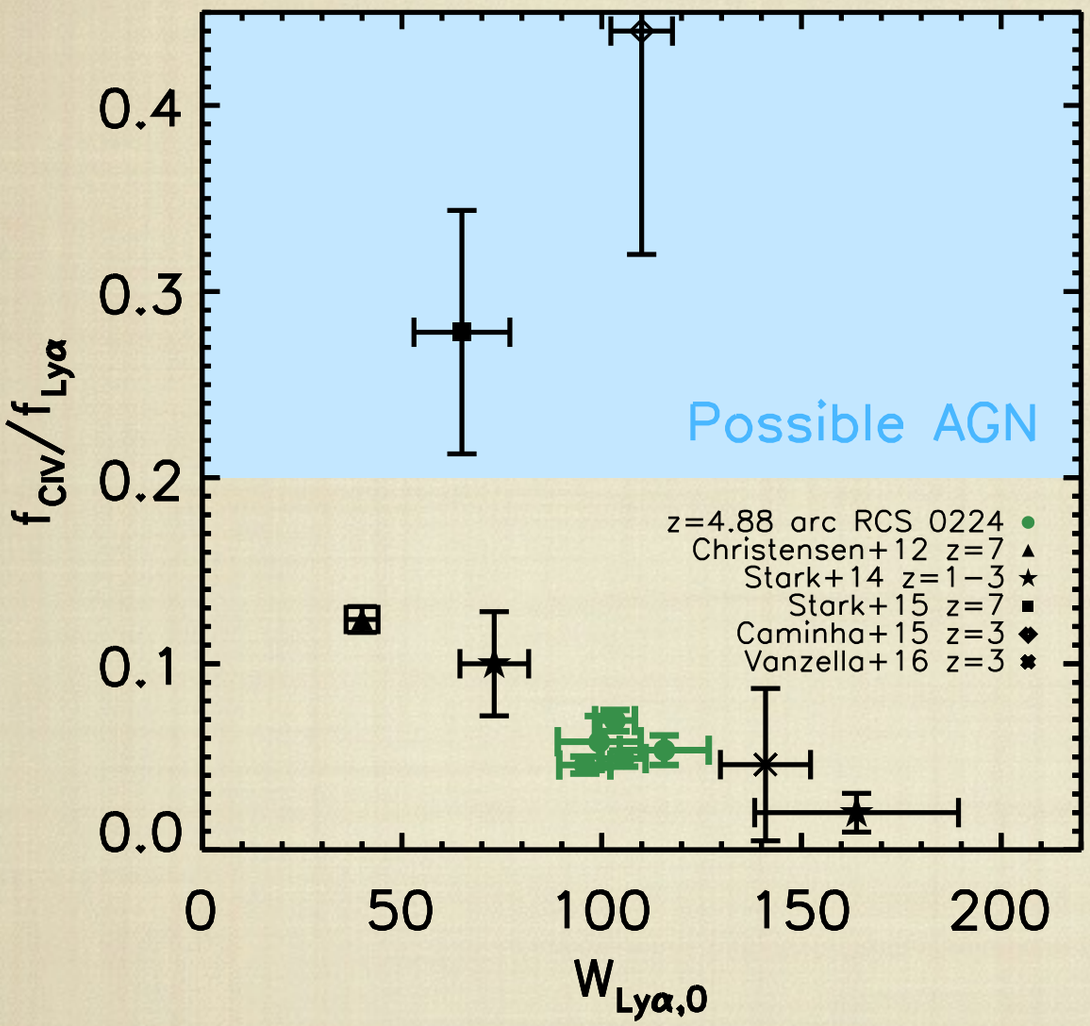
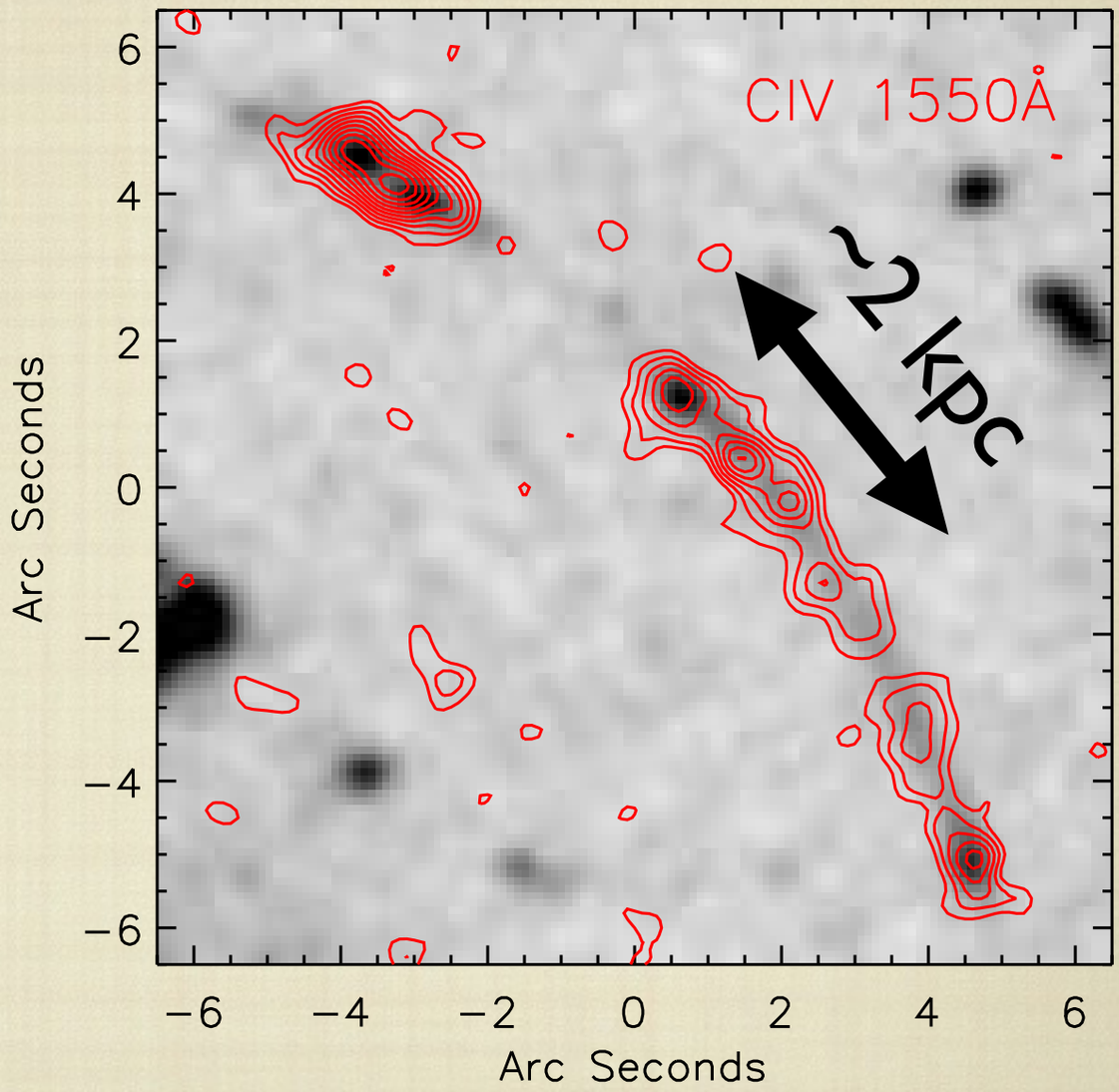
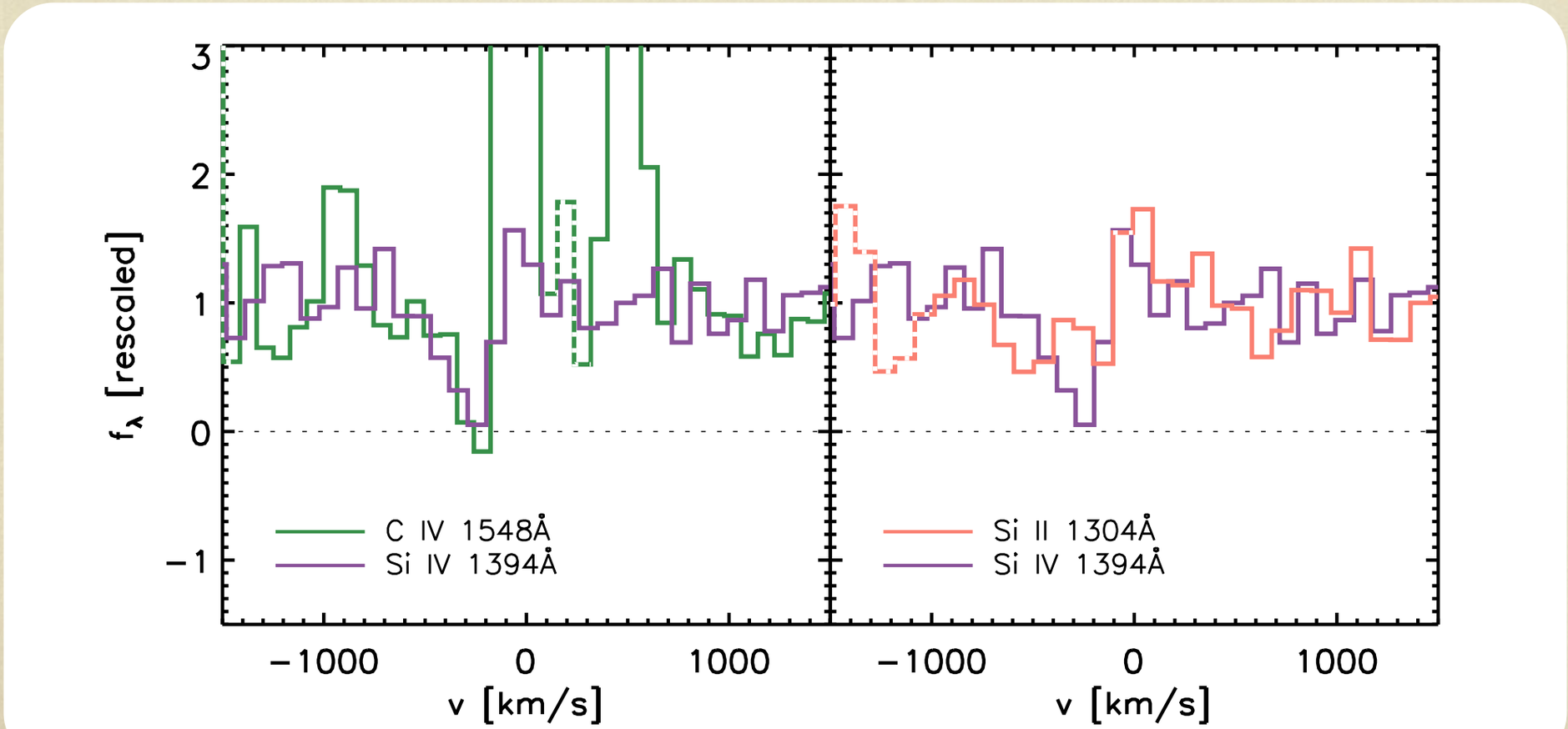




More soon; incoming HST/WFC3,
potentially He II1640, CIII] 1909 spectroscopy

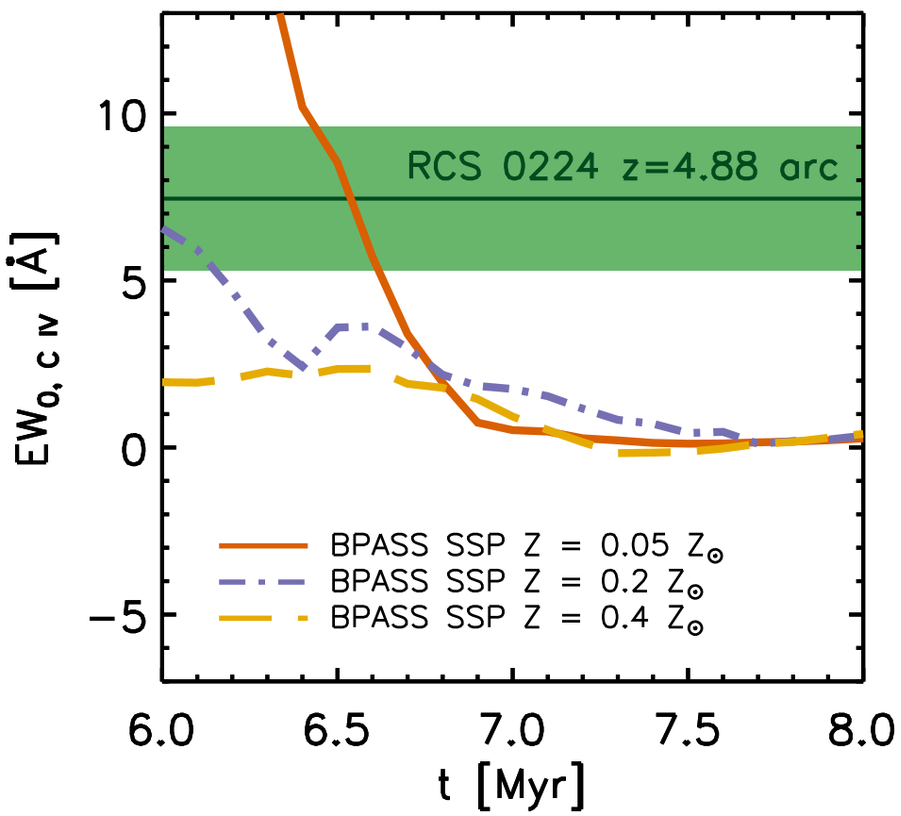
High-ionisation absorption lines

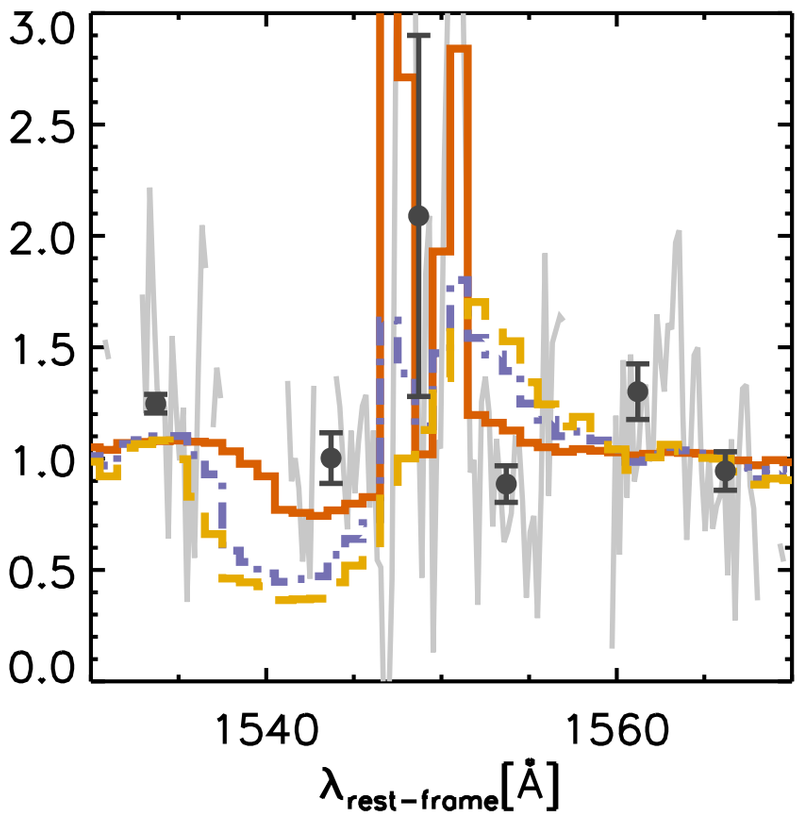
- Narrow blue-shifted absorption is present, but not at the systemic velocity
- Has the starburst in this galaxy efficiently expelled the ISM gas?



Stellar population models

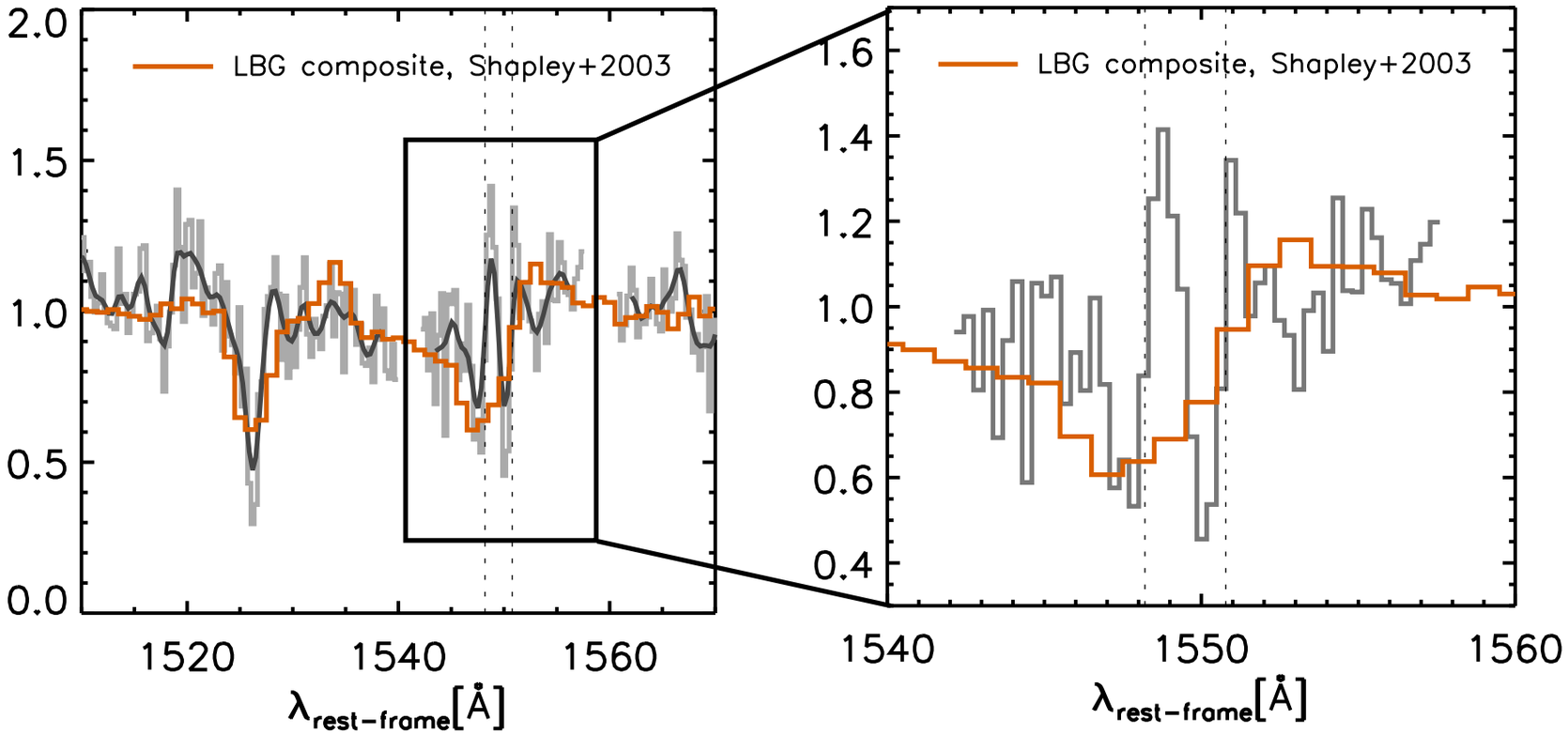
- Low metallicity stellar population (<5% solar) needed for high CIV EW
- No evidence for stellar lines: CIV 'clean' measurement of nebular emission





A1689: weak P-Cygni profile

- Similar to RCS 0224: nebular emission and ISM/ CGM absorption, but no evidence for stellar lines
- High ionisation nebular emission indicates recent SF - but stars need to be metal-poor to not drive winds



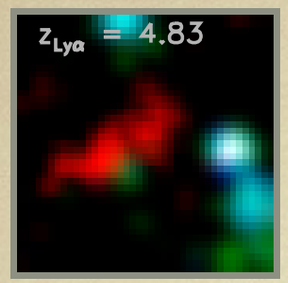
Summary

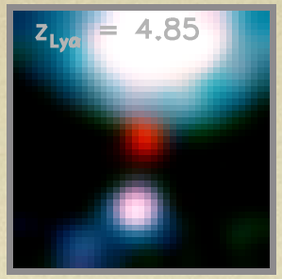
Lyα

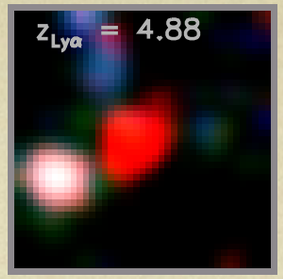
- Lyα appears dominated by a CGM/outer disk component: implications for Lyα prevalence studies and understanding ISM physics
- A simple 'shell model' does not reproduce the spatially resoled velocity structure of the Lyα in RCS 0224

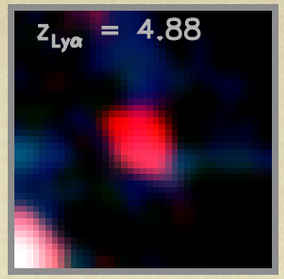
CIV

- Spatially resolved strong emission in RCS 0224 indicates widespread SF as a powering source
- Absence of P-Cygni profiles is an indicator of very low stellar metallicities


$z_{Ly\alpha}$ = 4.83


$z_{Ly\alpha}$ = 4.85


$z_{Ly\alpha}$ = 4.88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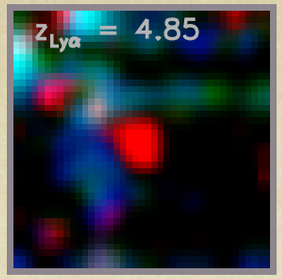
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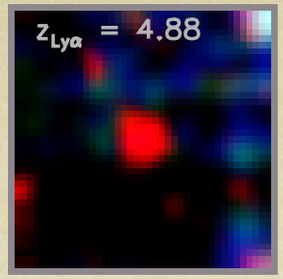
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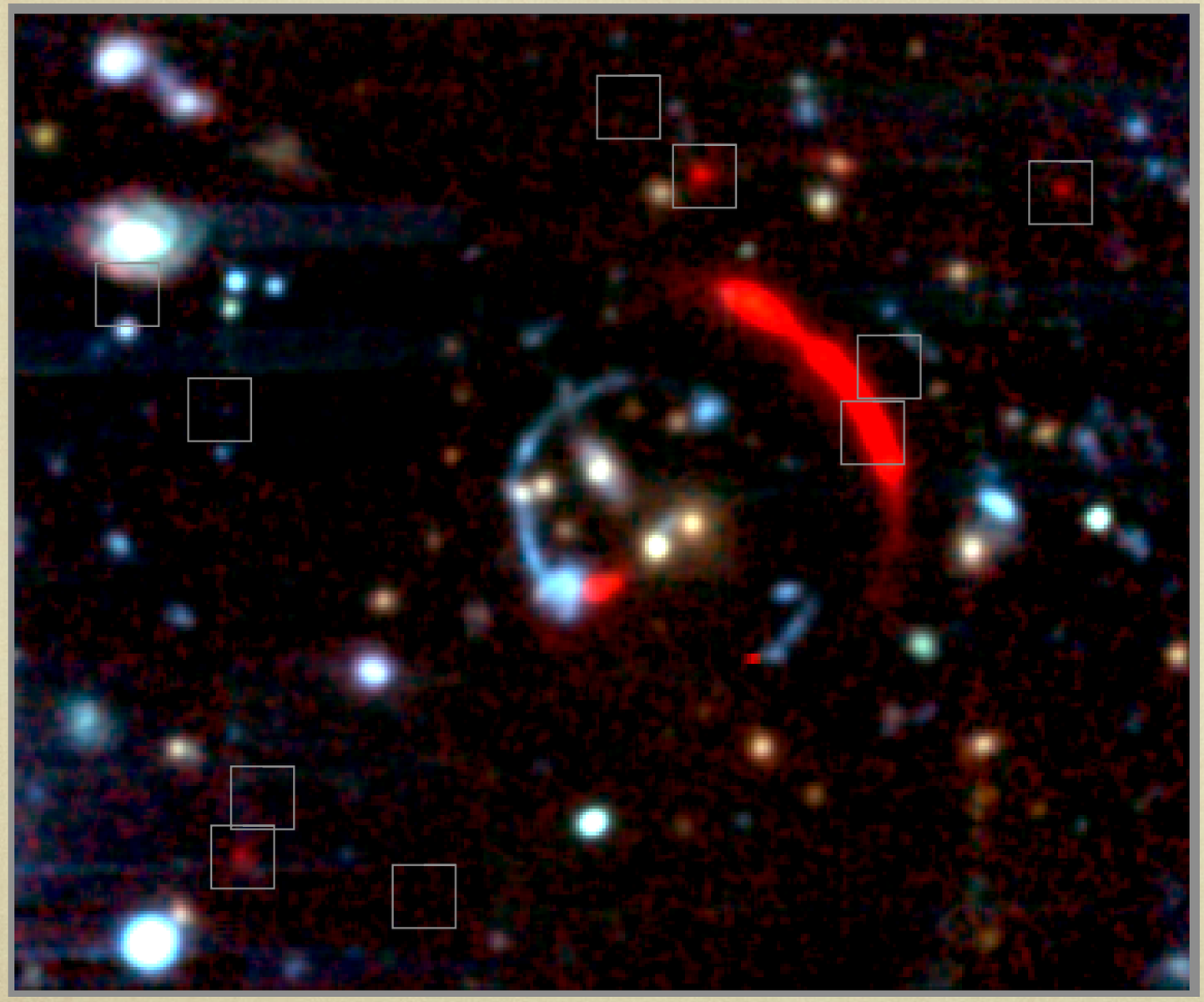
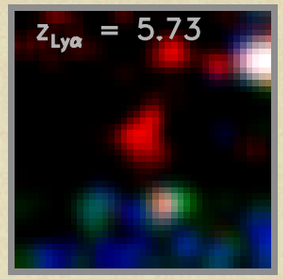
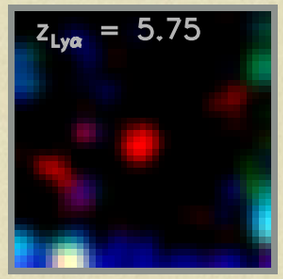
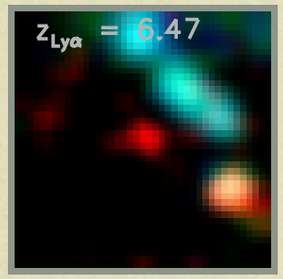
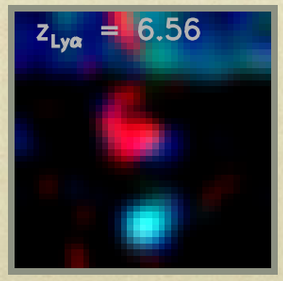



$z_{Ly\alpha}$ = 5.73


$z_{Ly\alpha}$ = 5.75


$z_{Ly\alpha}$ = 6.47


$z_{Ly\alpha}$ = 6.56

High-ionisation absorption lines

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