LyC Escape and IGM Tomography Using the 600-900Å Continuum of the Sunburst Arc

Michelle Berg

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Assistant Professor

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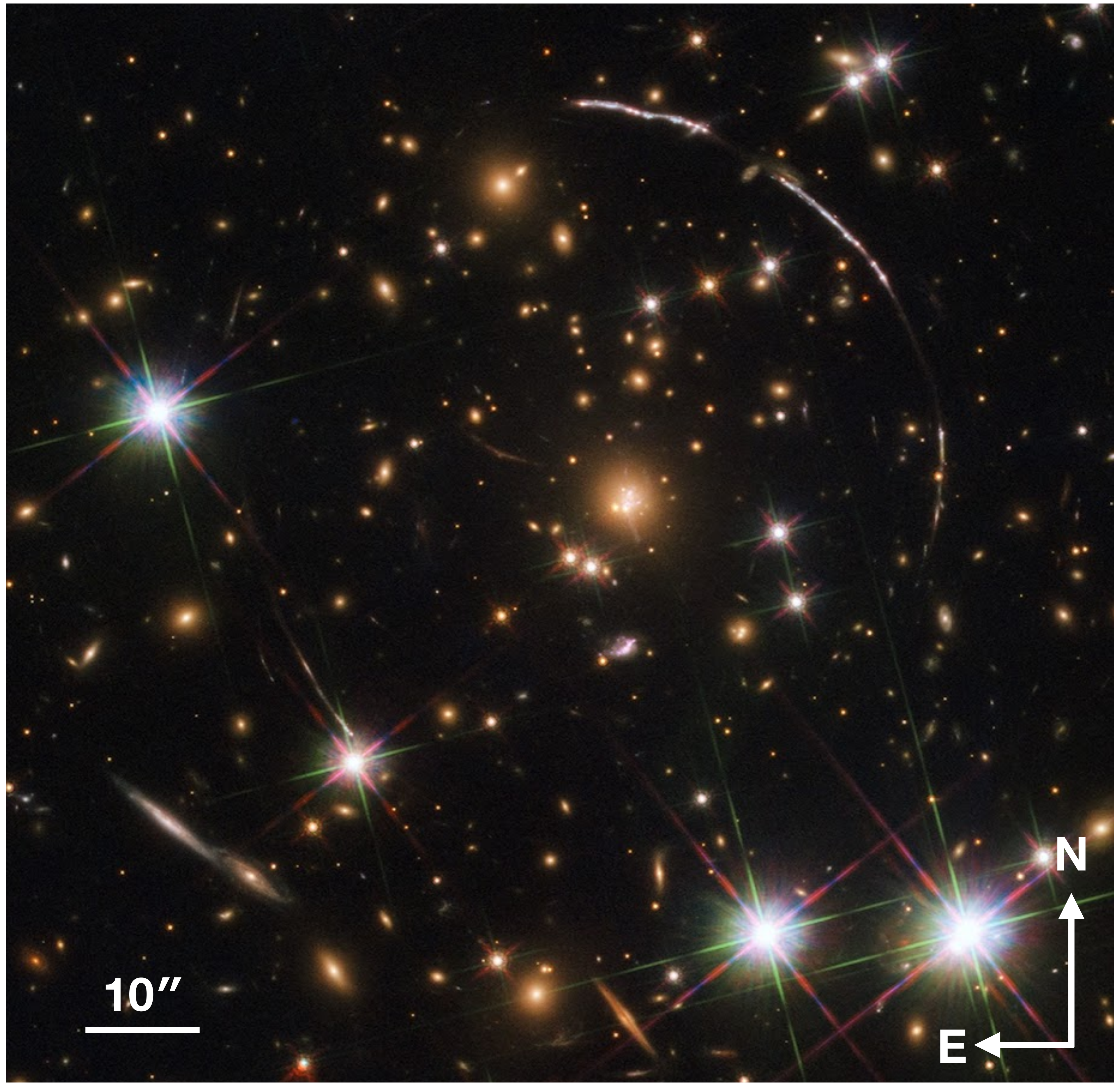
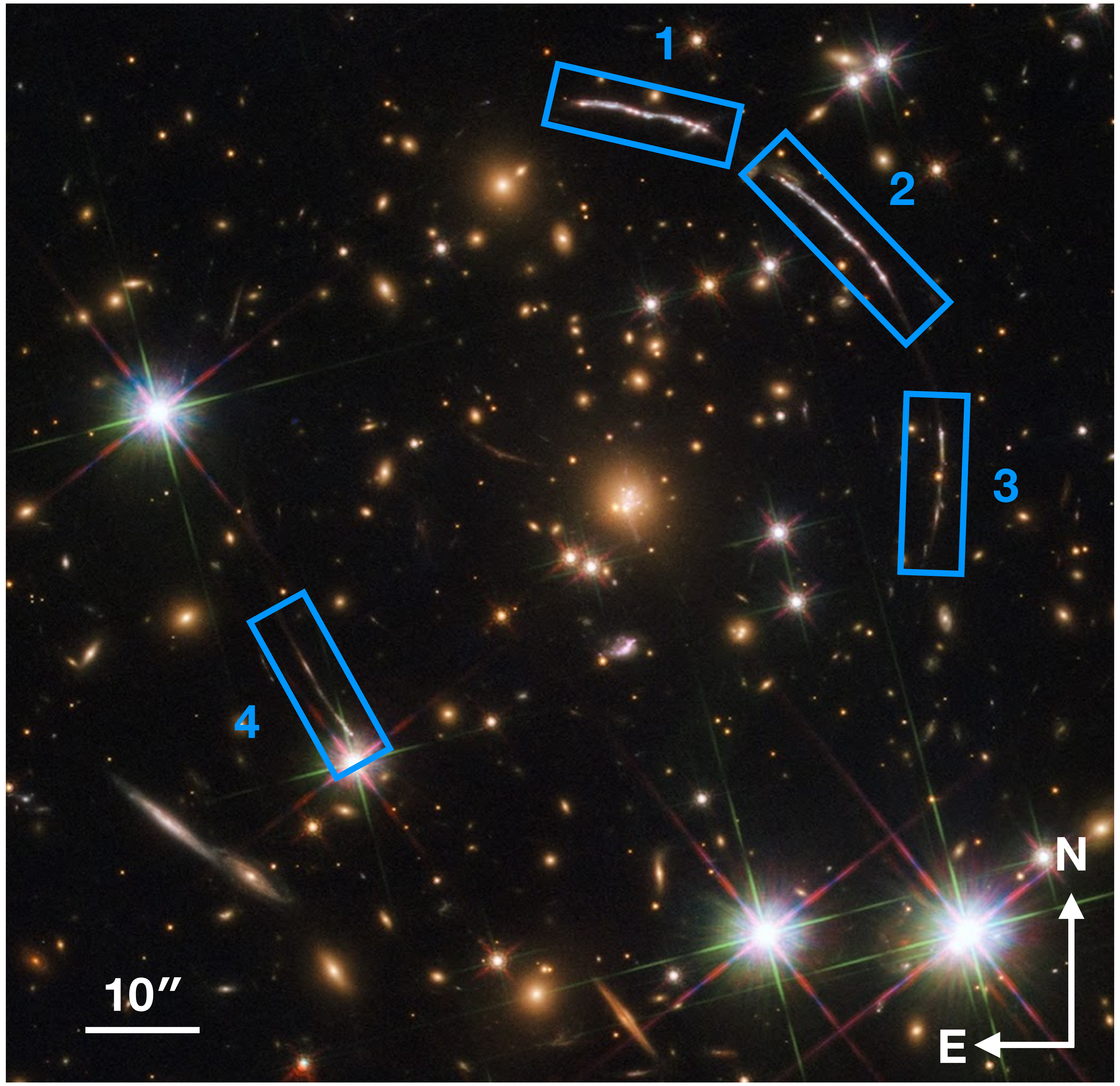
Sunburst Arc



The Sunburst Arc is the brightest lensed galaxy to ever be discovered at R=17.8 mag.

Dahle et al. 2016
Rivera-Thorsen et al. 2019
NASA, ESA and E. Rivera-Thorsen

Sunburst Arc



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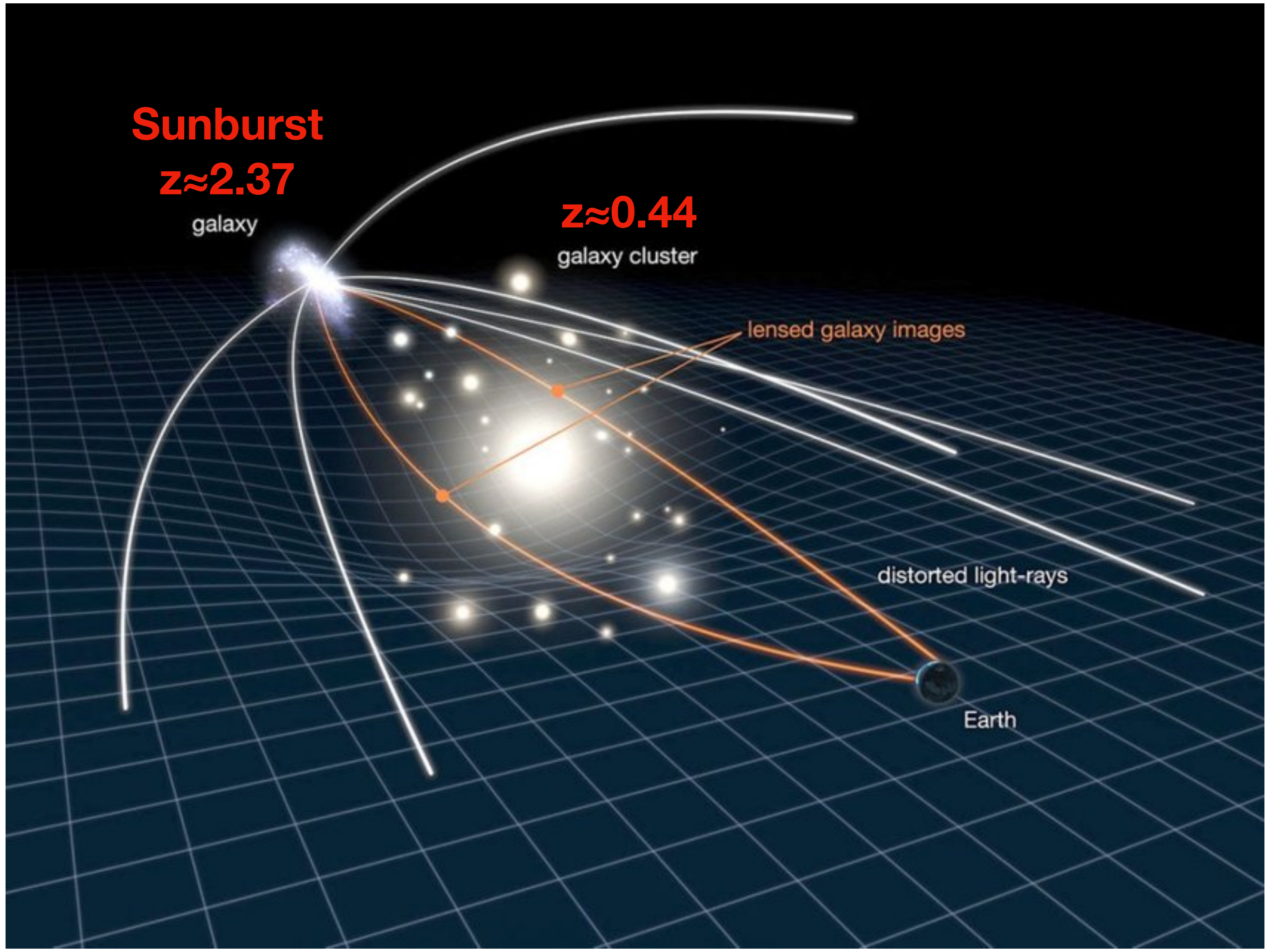
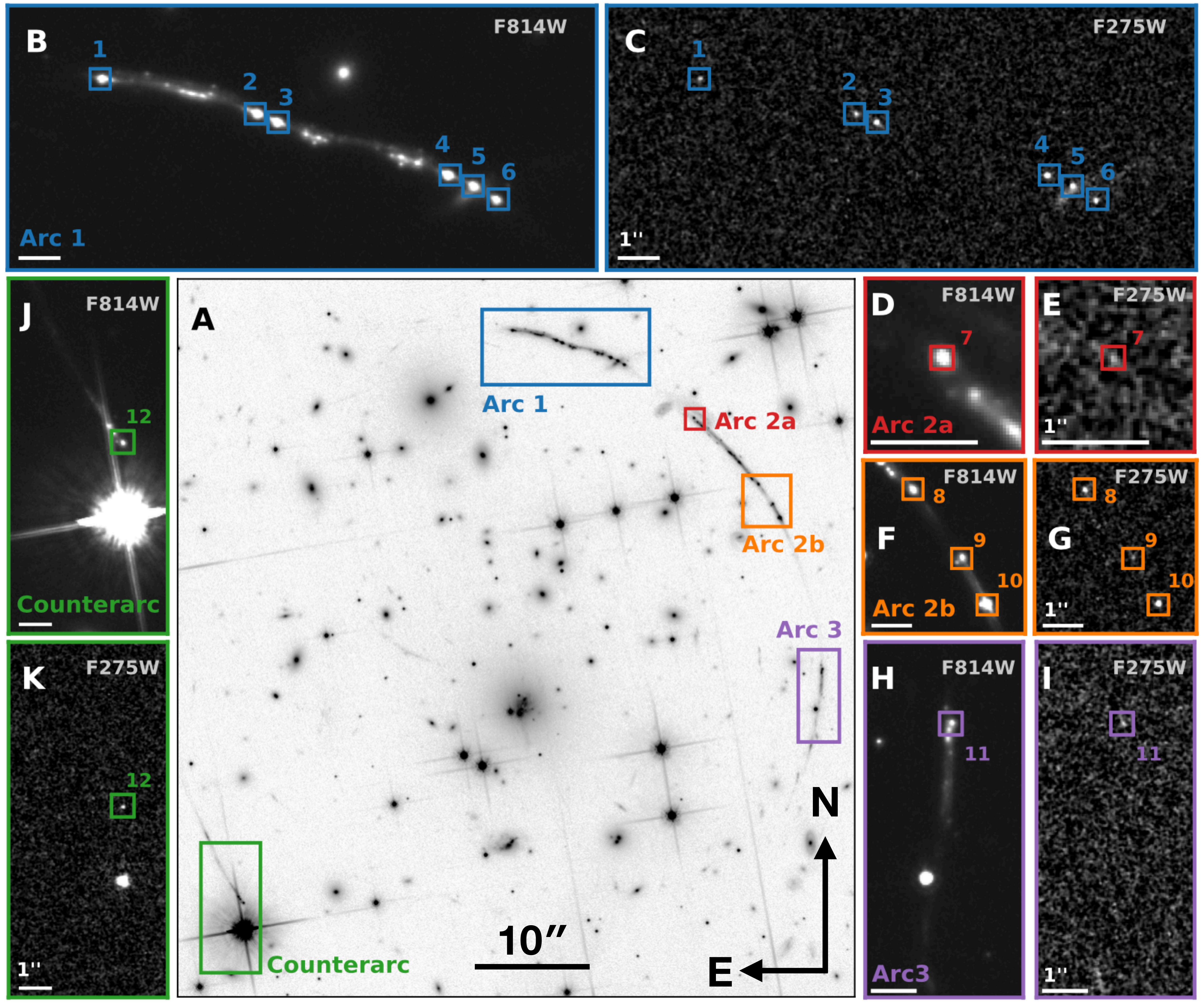
Gravitational Lensing

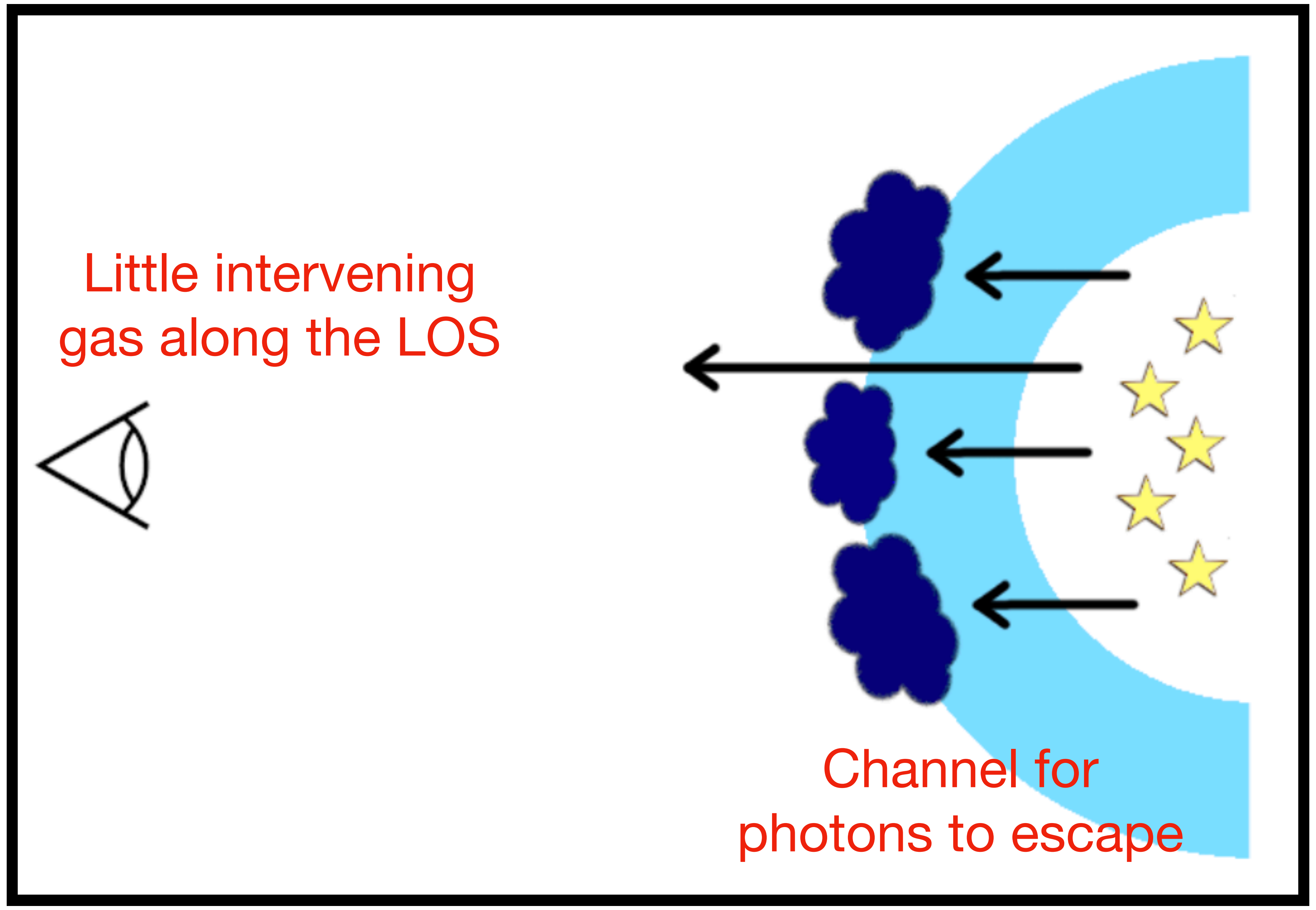


Light from a distant object is bent around a foreground massive object.

NASA, ESA and L. Calçada

A LyC Leaker



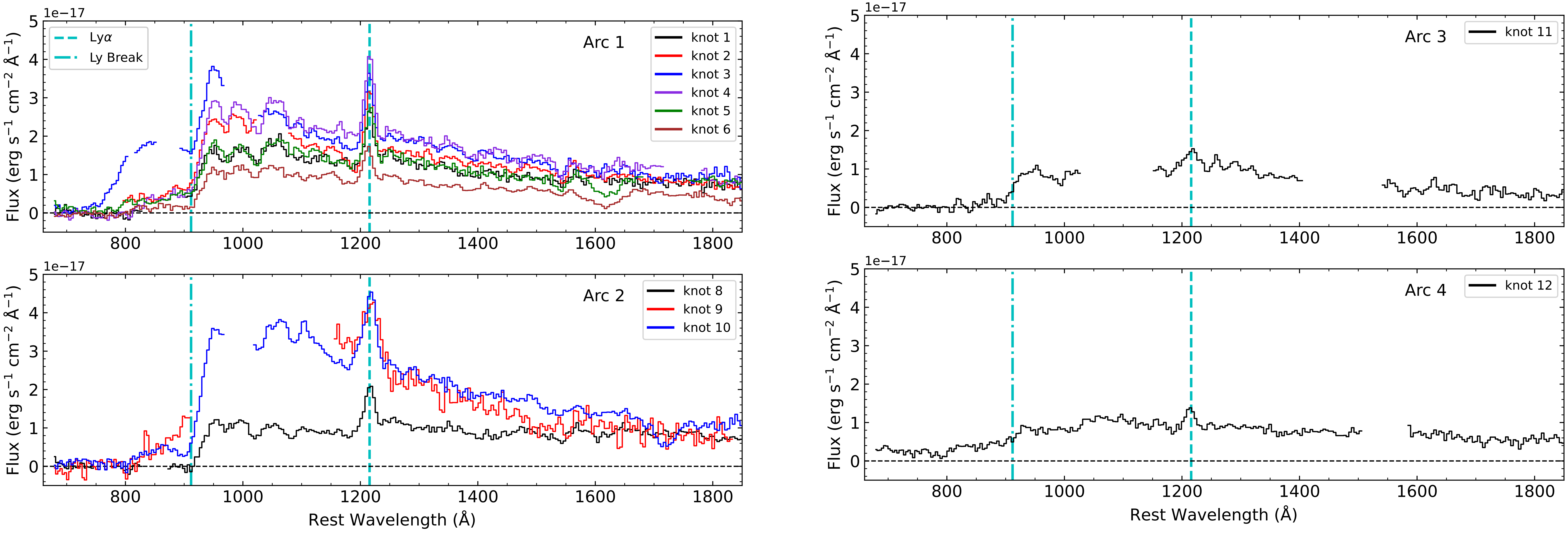


The leaking region is imaged 12 times over the 4 arcs; escape fraction estimates vary widely.

Best chance of observing the ionizing stellar continuum for the first time!

Rivera-Thorsen et al. 2019
Gazagnes et al. 2020

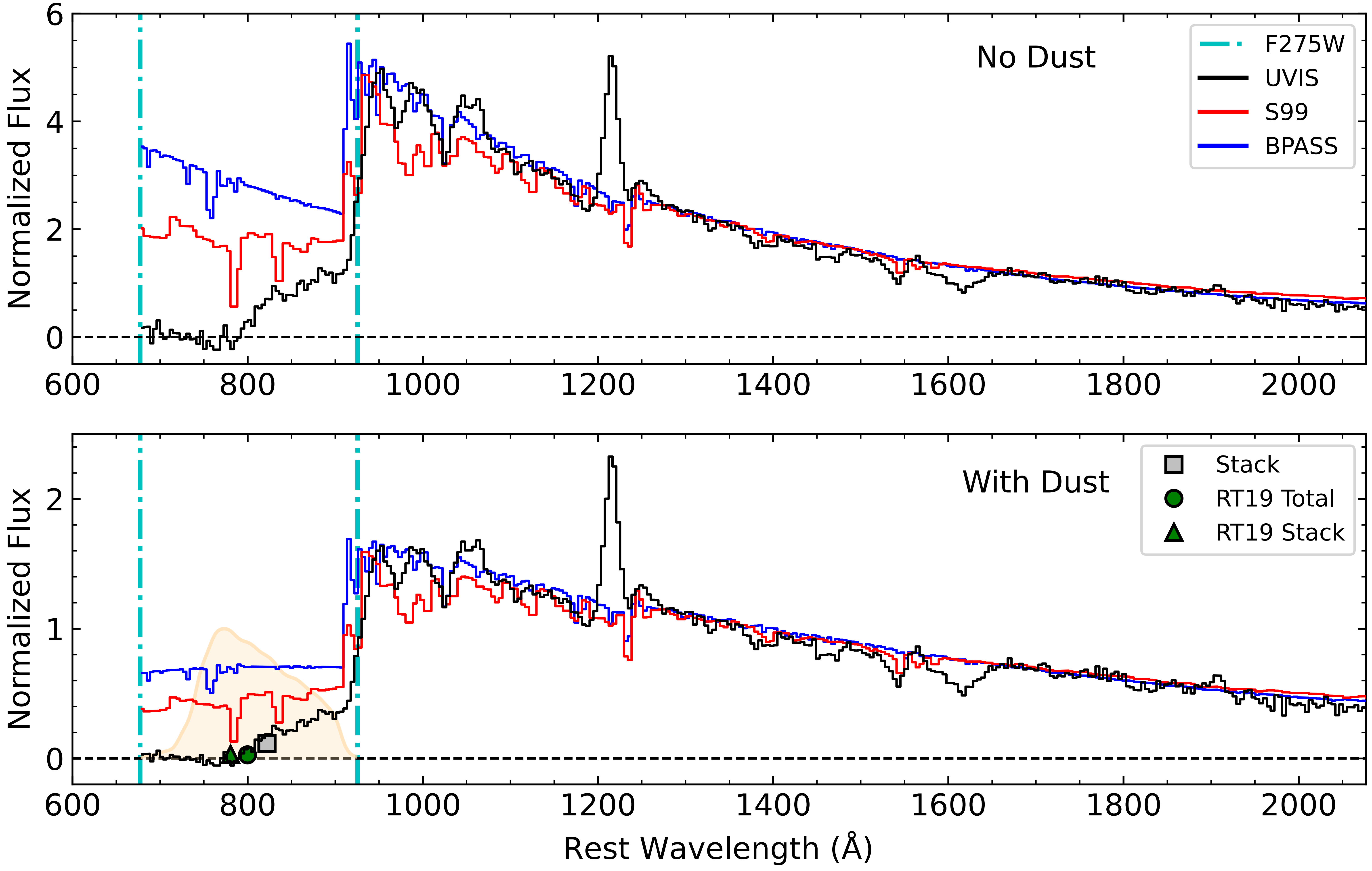
Leaking Images Spectra



The spectral shapes are consistent between the images.
We can measure the ionizing flux from ~800-900Å.

Berg et al. 2025a in prep

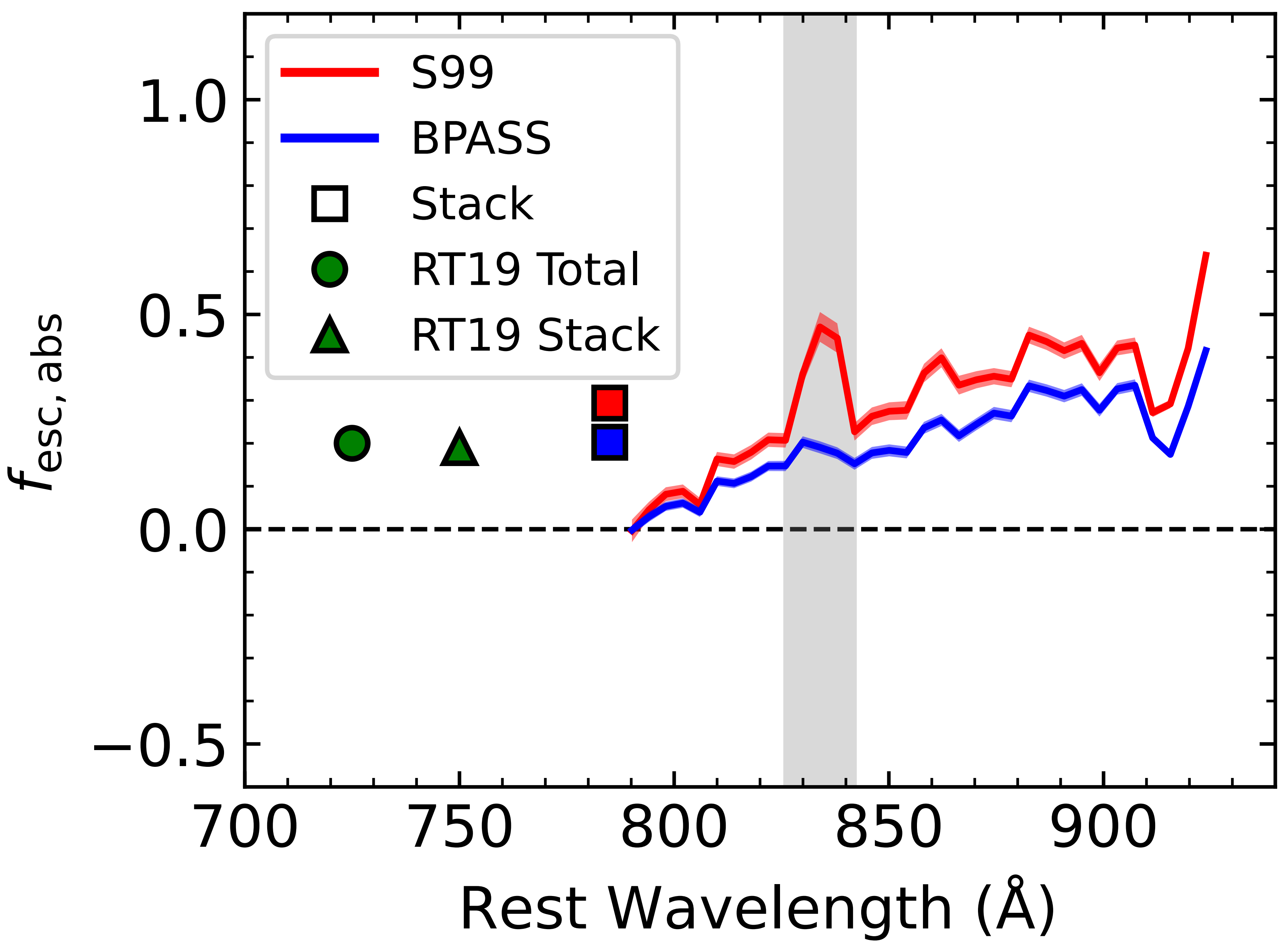
Comparison to Models

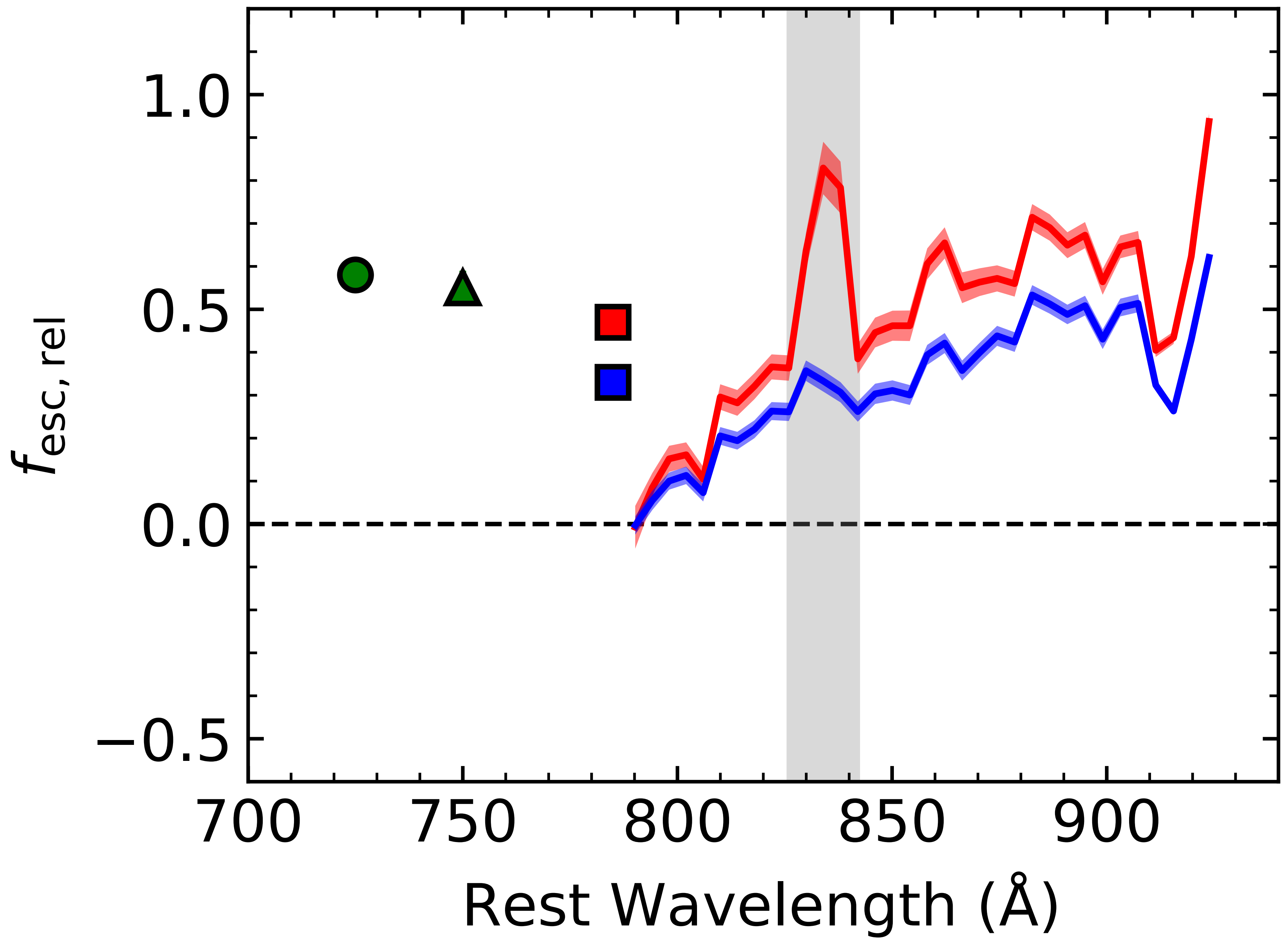


We cannot tell how well the models fit the observations in the ionizing continuum.

Leitherer et al. 1999, 2010
Eldridge et al. 2017
Chisholm et al. 2019
Rivera-Thorsen et al. 2019
Berg et al. 2025b in prep

Escape Fractions





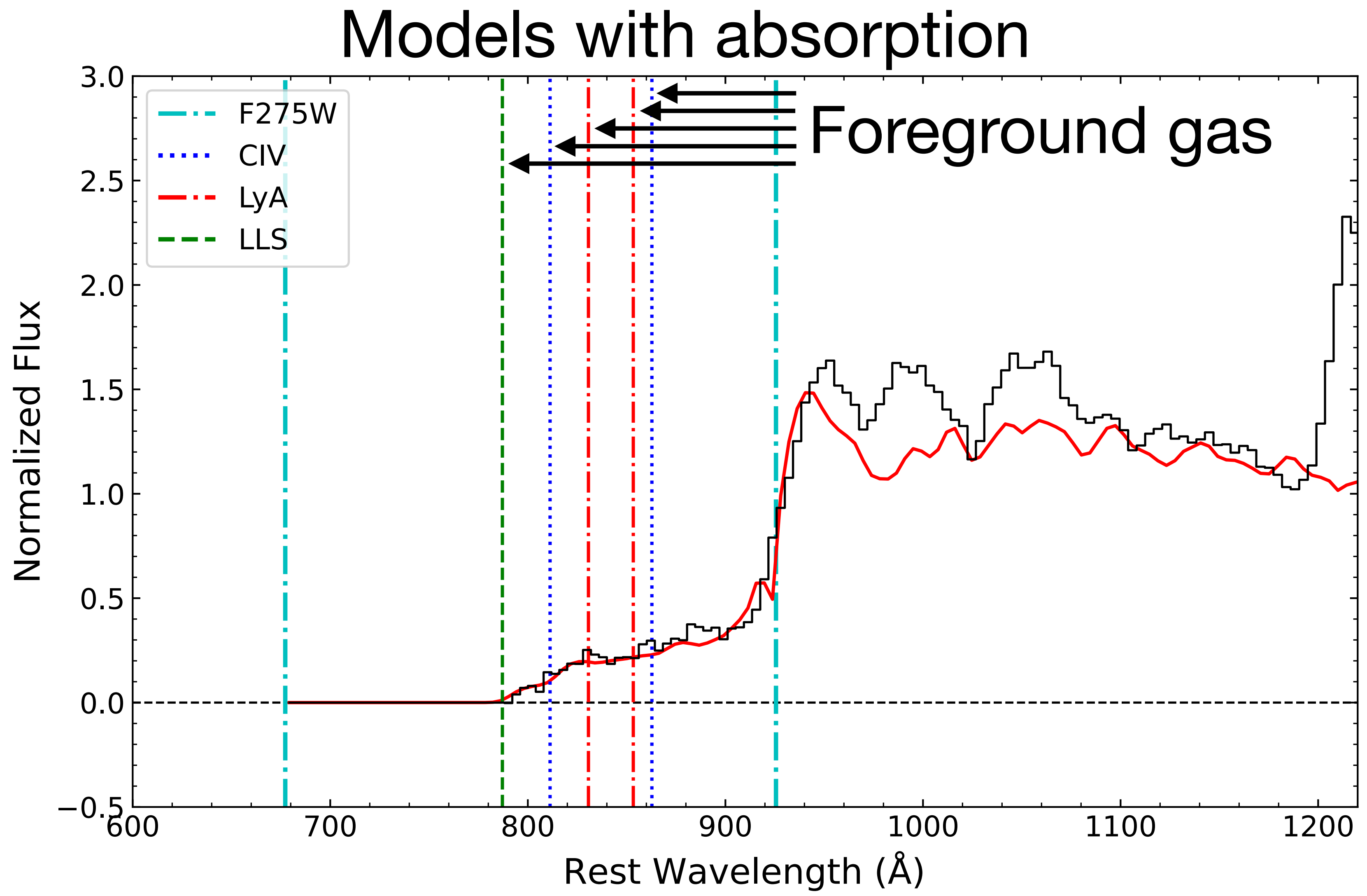
S99 $f_{ecs,abs}$ = 29.4 ± 0.3%
BPASS $f_{ecs,abs}$ = 20.2 ± 0.2%

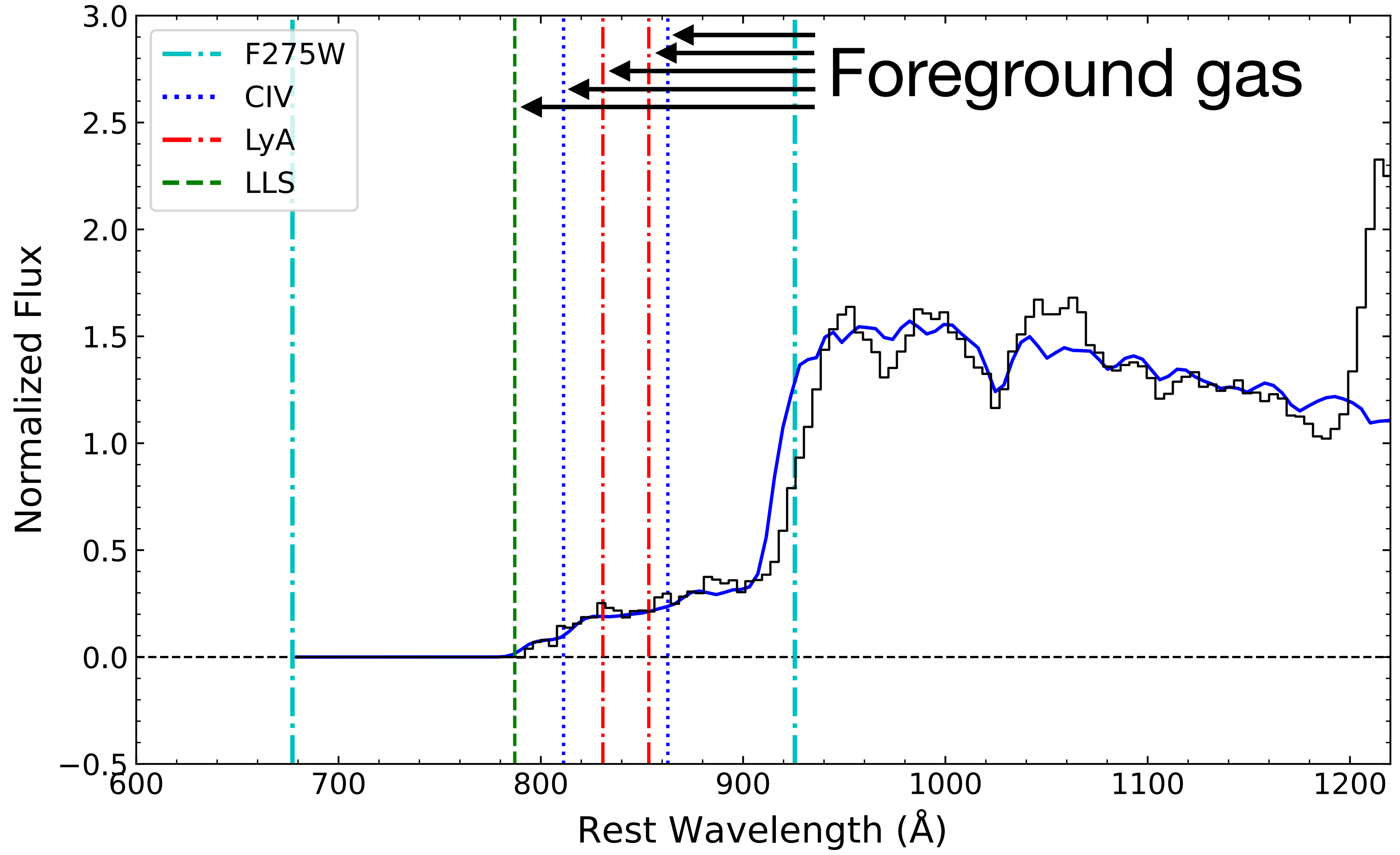
S99 $f_{ecs,rel}$ = 47.0 ± 0.5%
BPASS $f_{ecs,rel}$ = 33.0 ± 0.3%

The Sunburst Arc has a high escape fraction with either model.

Rivera-Thorsen et al. 2019
Berg et al. 2025b in prep

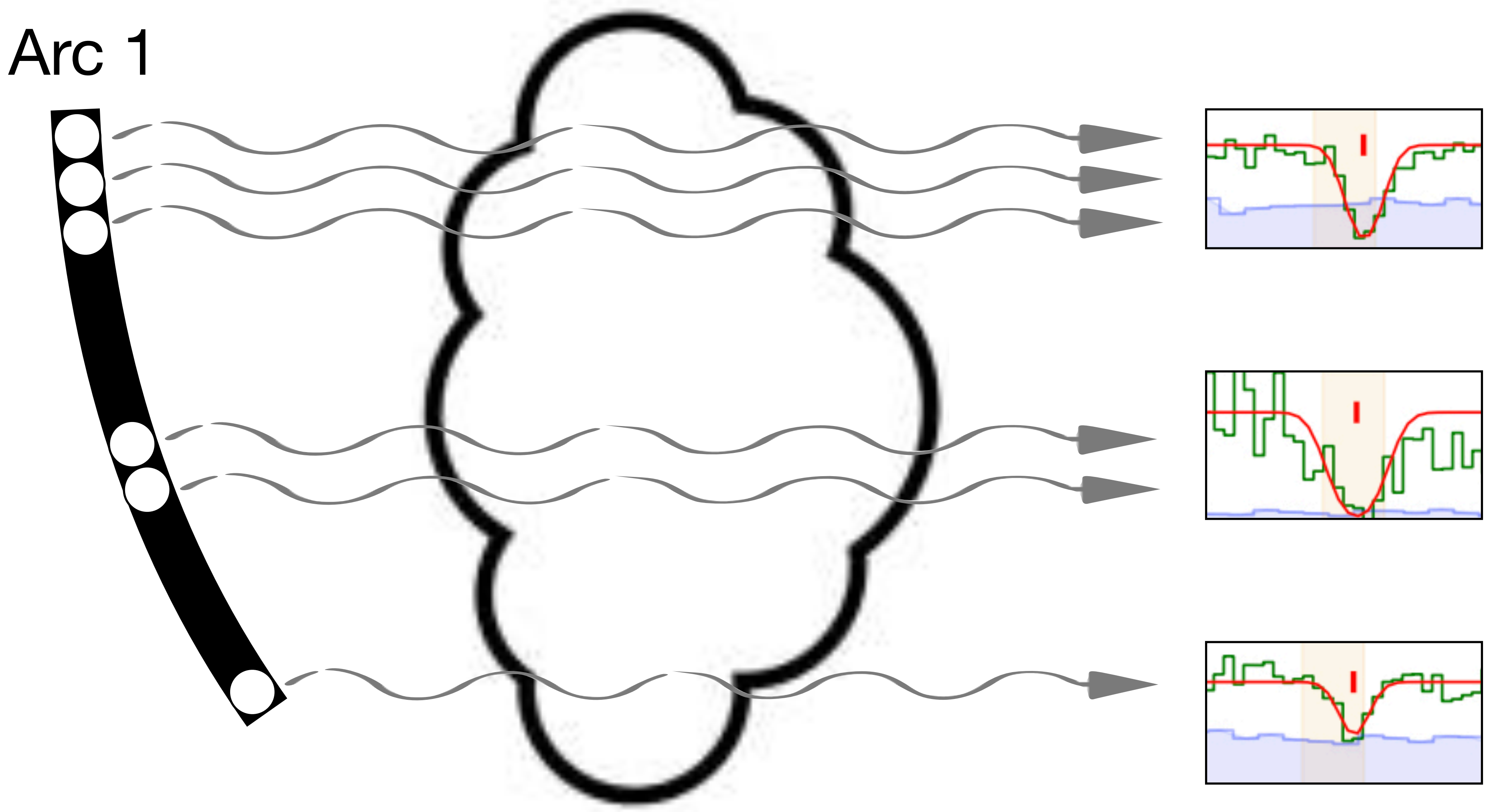
Models with IGM + Galaxy Absorption





Add galaxy and absorber Lyman limit breaks

1. CIV at z=2.18916✱
2. Lyα at z=2.15420✱
3. Lyα at z=2.07030
4. CIV at z=1.99850✱
5. LLS at z=1.90930

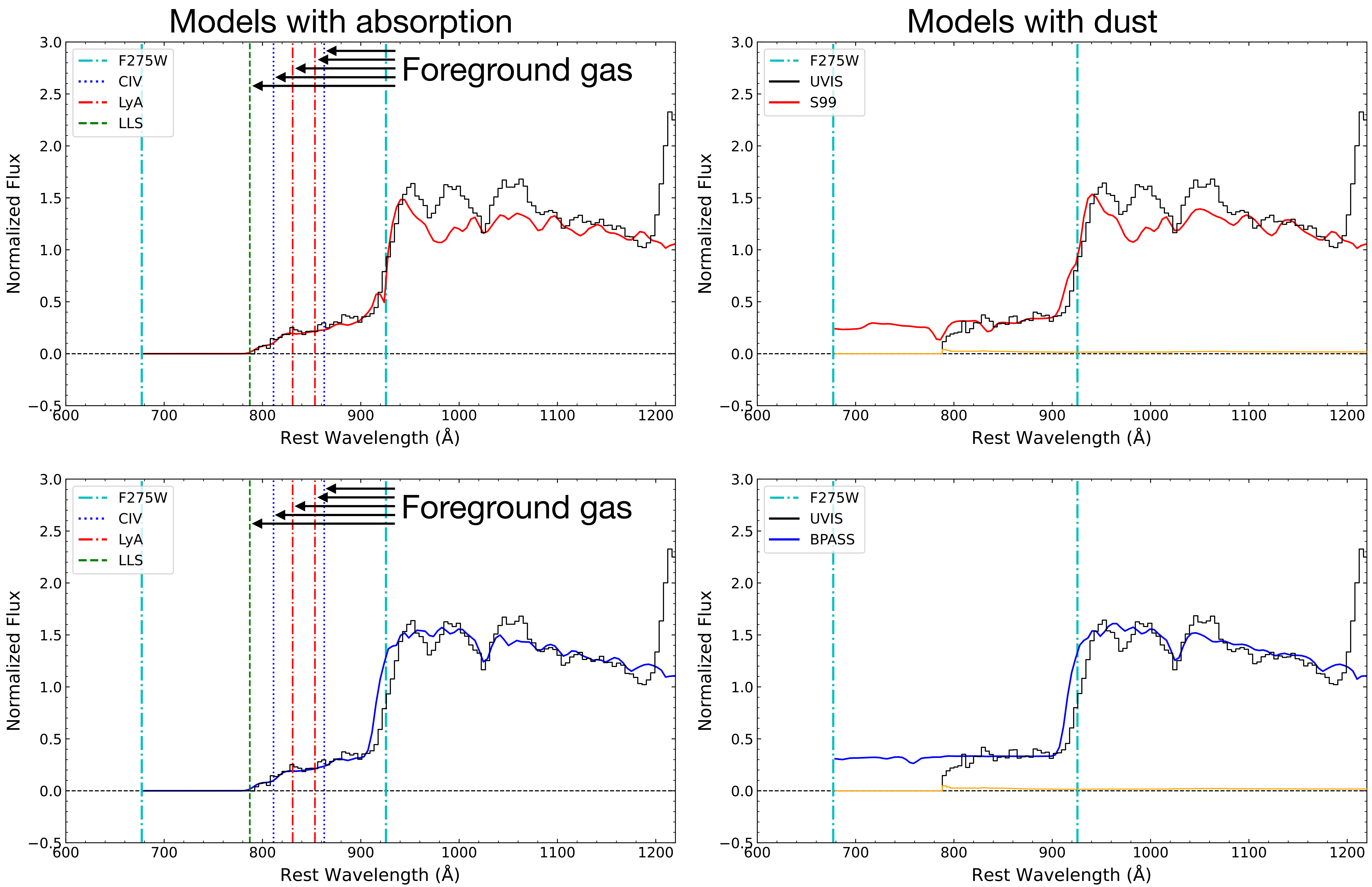


Foreground IGM can be substantially neutral and lower LyC estimates.

T_{ISM} c_f(S99)=36%, c_f(BPASS)=53%

Berg et al. 2025a,b in prep
Rigby et al. 2025 in prep

Models with IGM + Galaxy Absorption



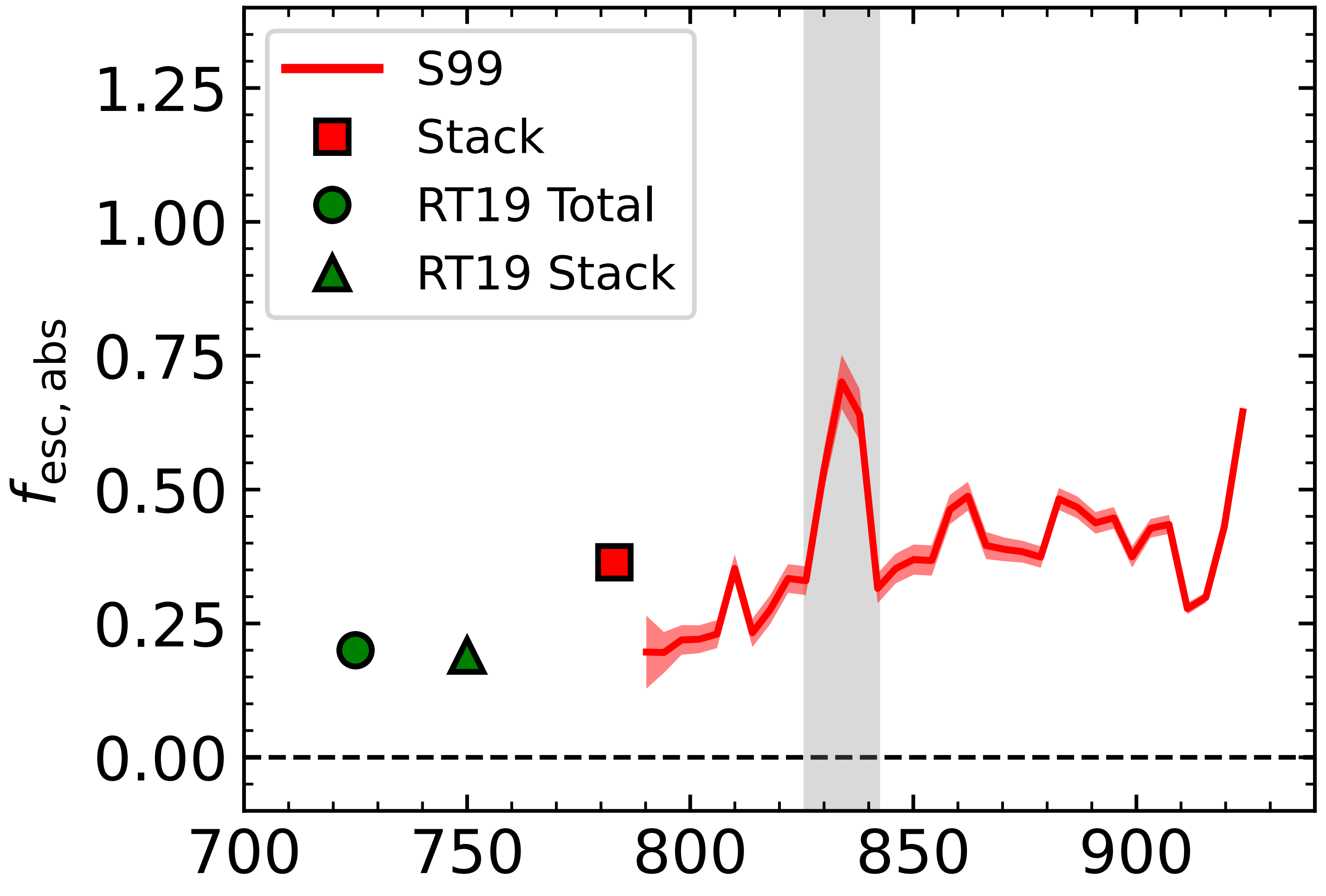
Berg et al. 2025a,b in prep

Models with IGM + Galaxy Absorption

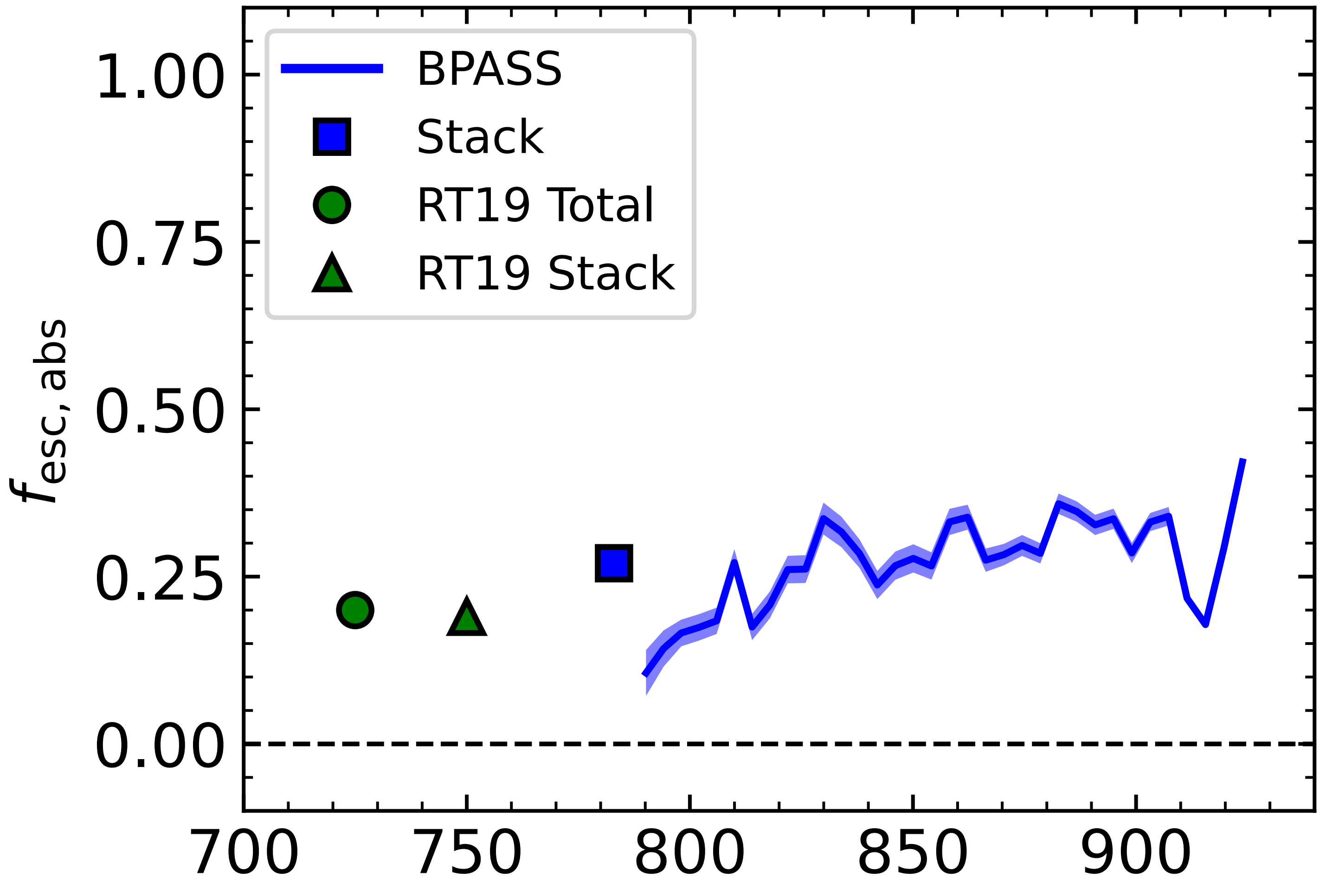
Models with dust fit the observations the best from 790-912Å.

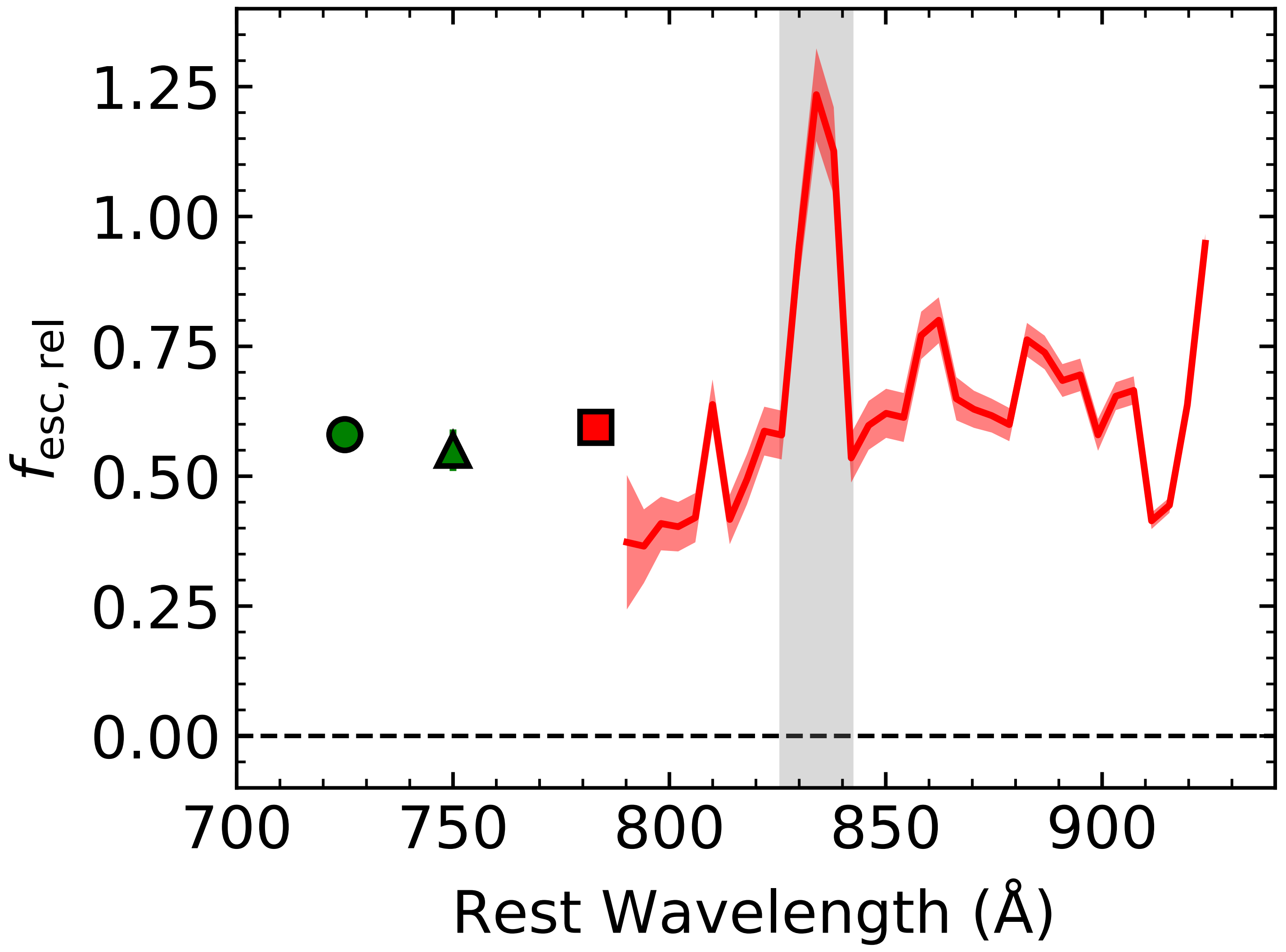
Berg et al. 2025a,b in prep

Updated Escape Fractions

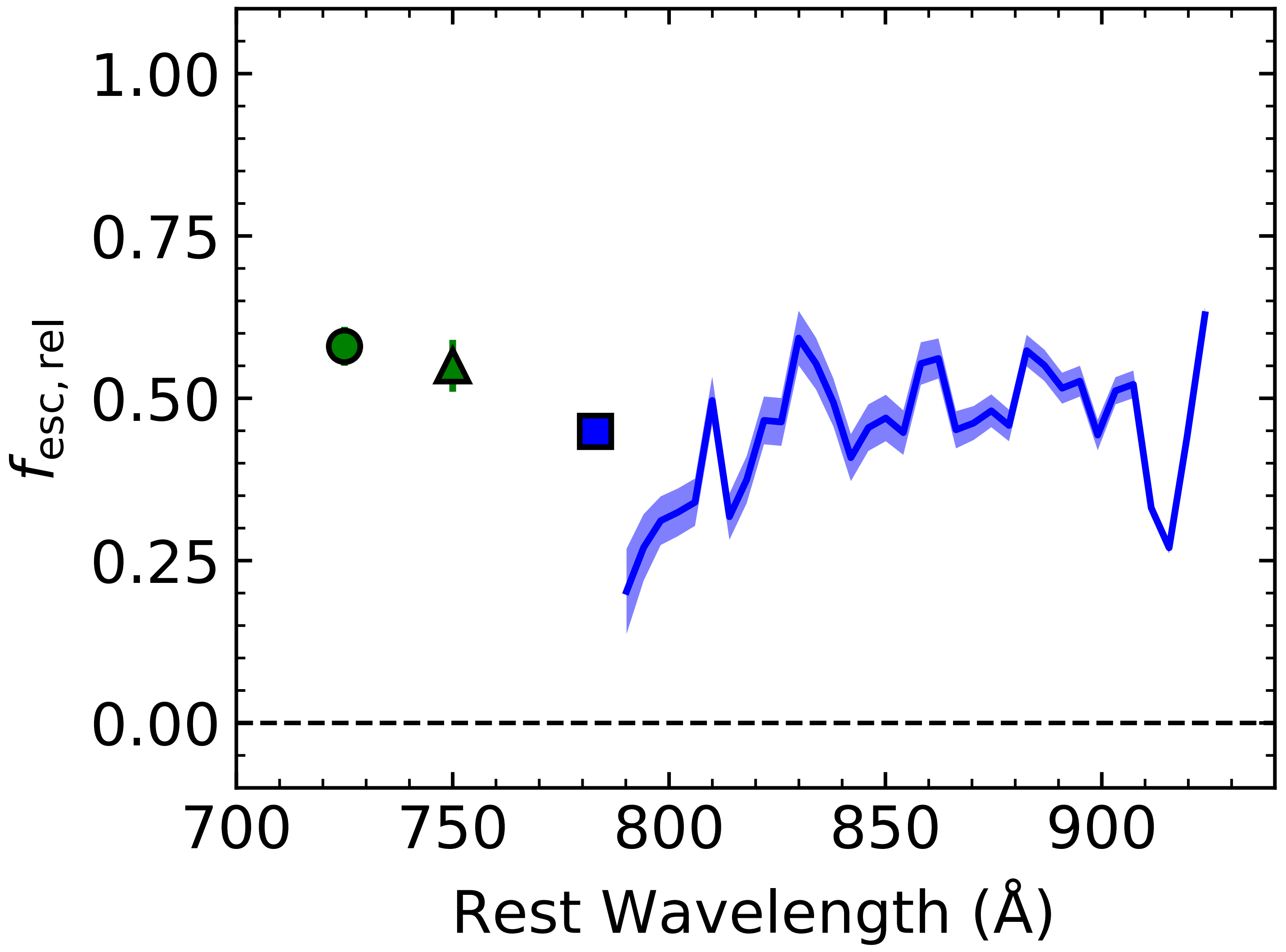


S99 $f_{\rm ecs,abs}$ = 36.4 ± 0.4%
BPASS $f_{\rm ecs,abs}$ = 27.0 ± 0.3%





S99 $f_{\rm ecs,rel}$ = 59.4 ± 0.7%
BPASS $f_{\rm ecs,rel}$ = 45.0 ± 0.5%

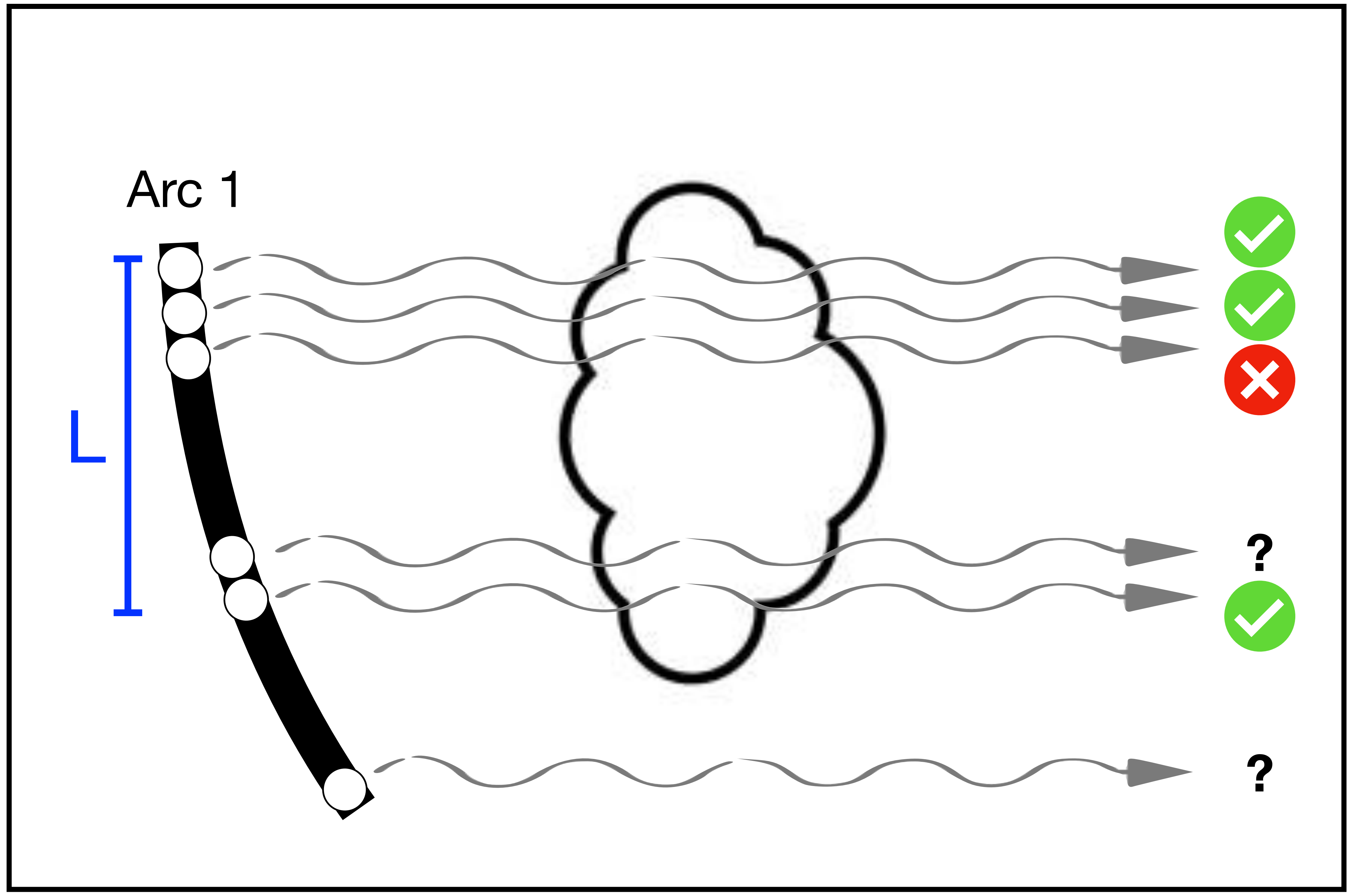


The escape fractions increased by 5-10%.

Berg et al. 2025b in prep

IGM Tomography

Lyα at z=2.15420



We can estimate the size of the foreground absorbers in 2D and the HI mass.

Berg et al. 2025a in prep

IGM Tomography

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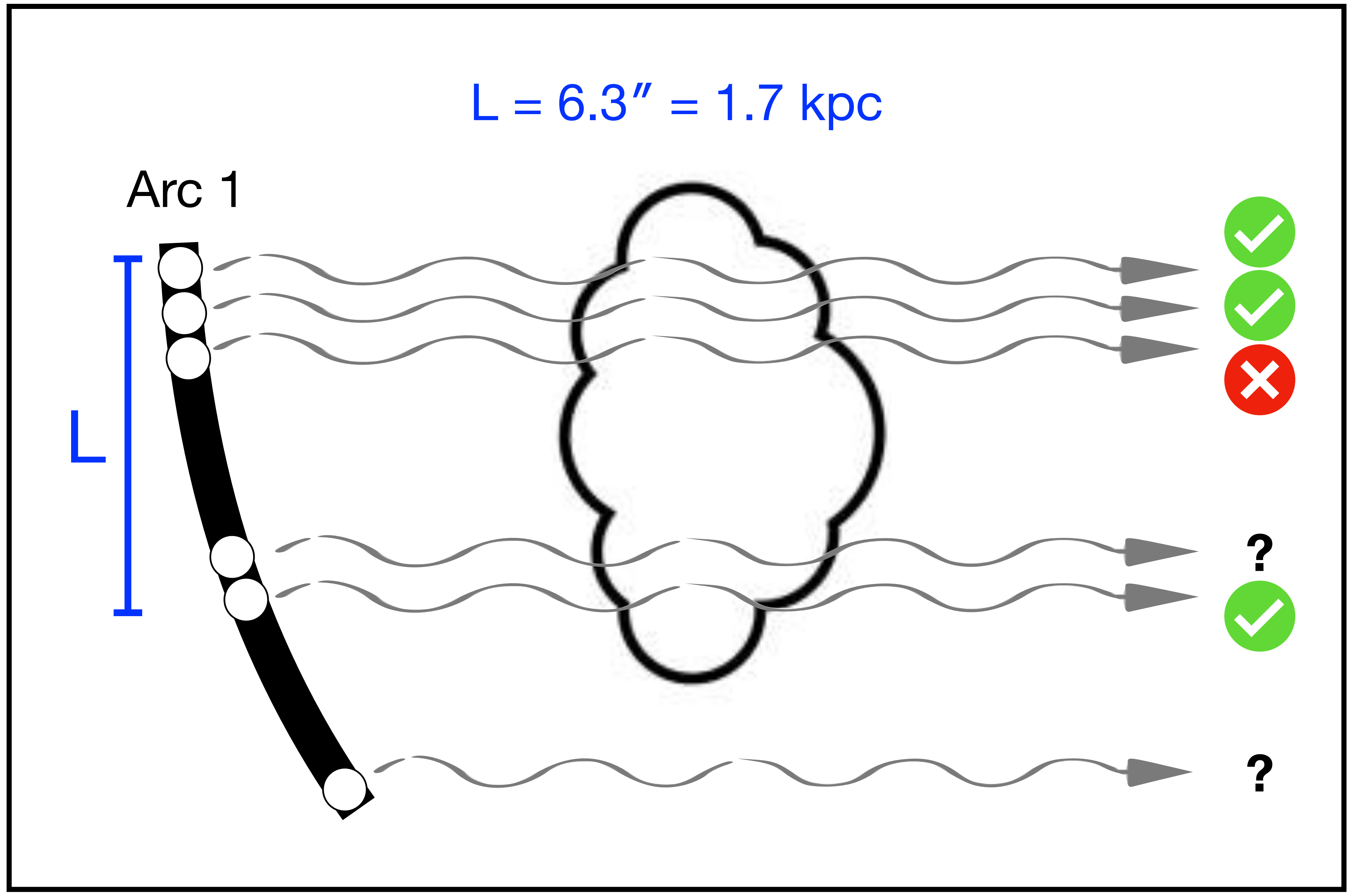

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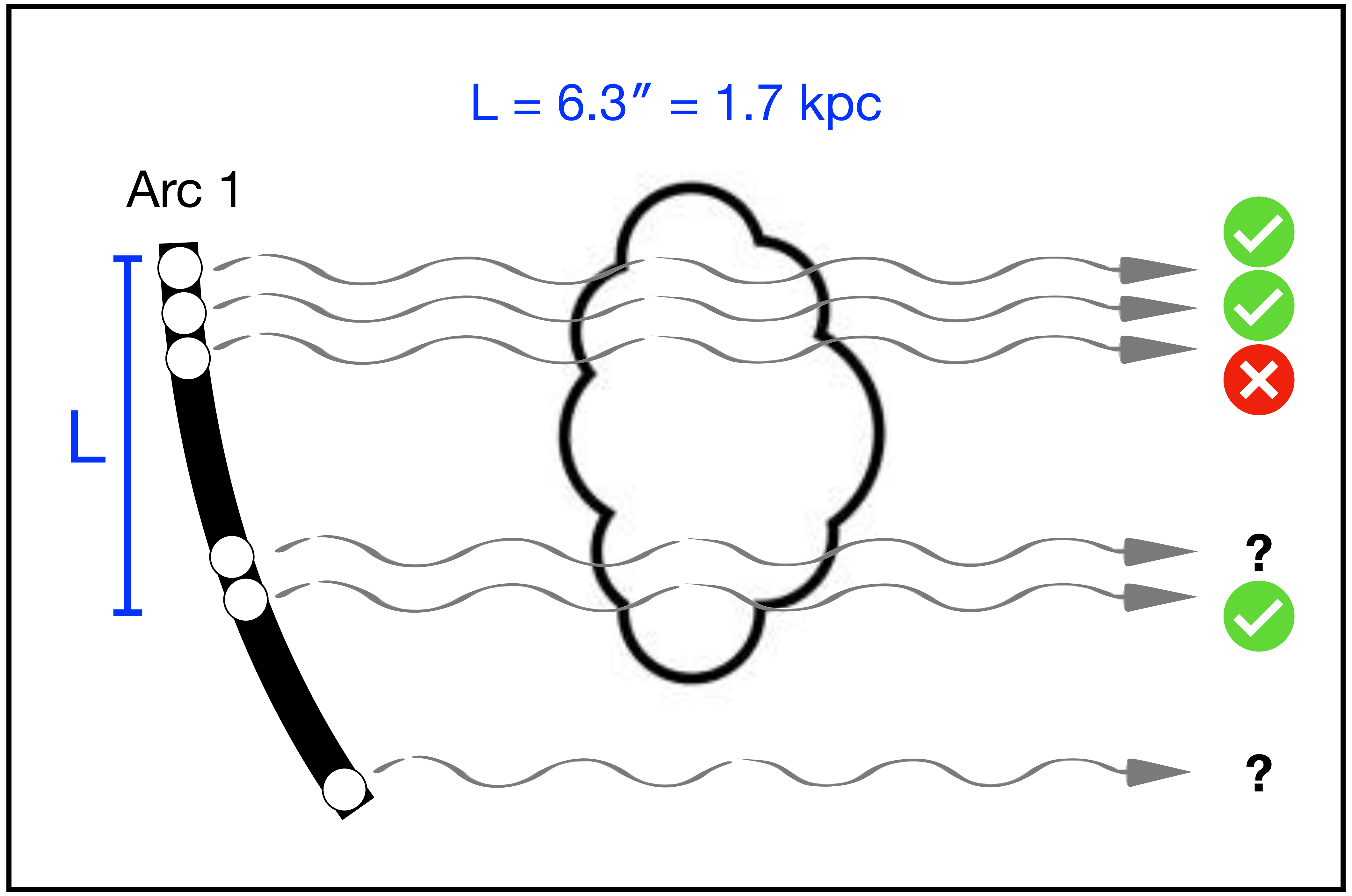

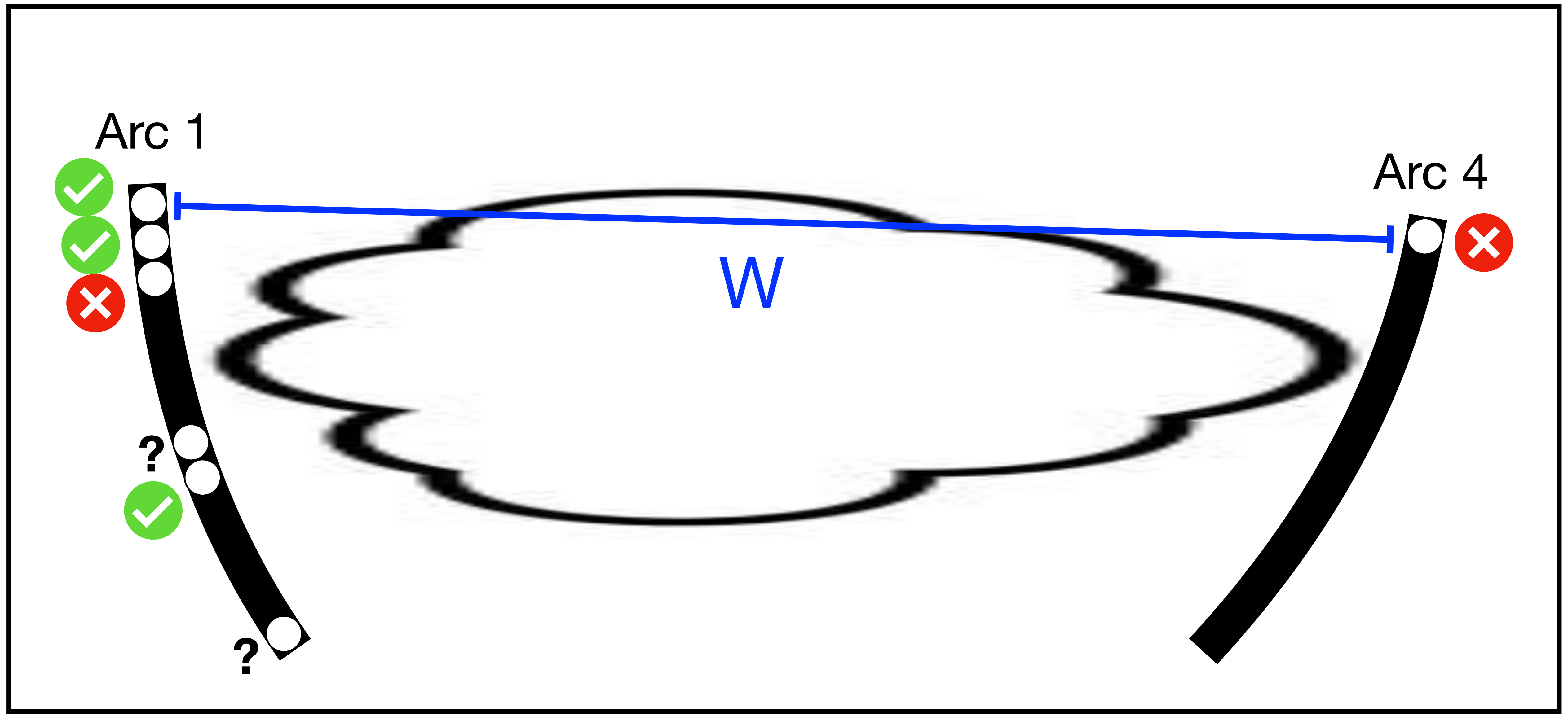

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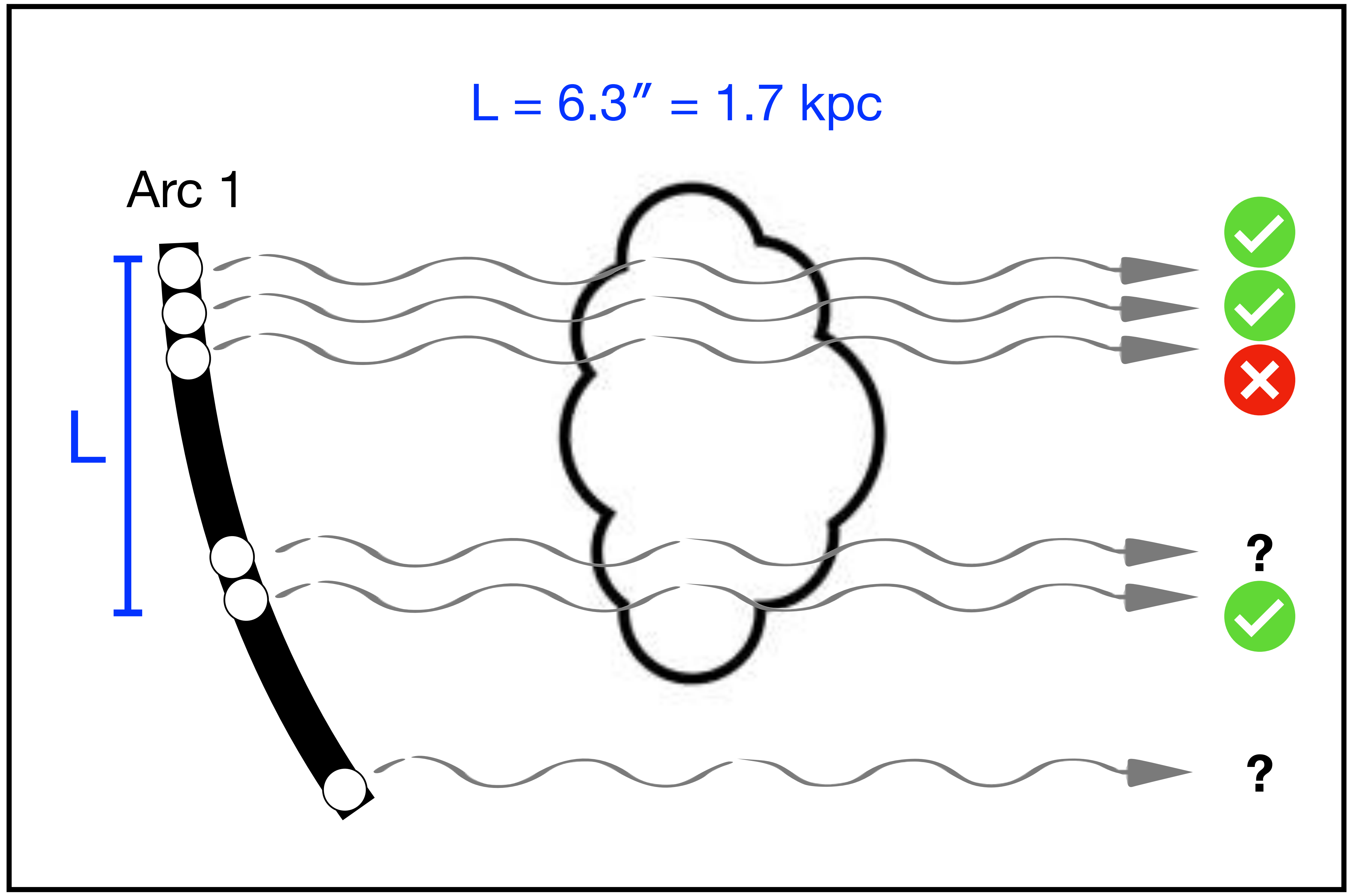
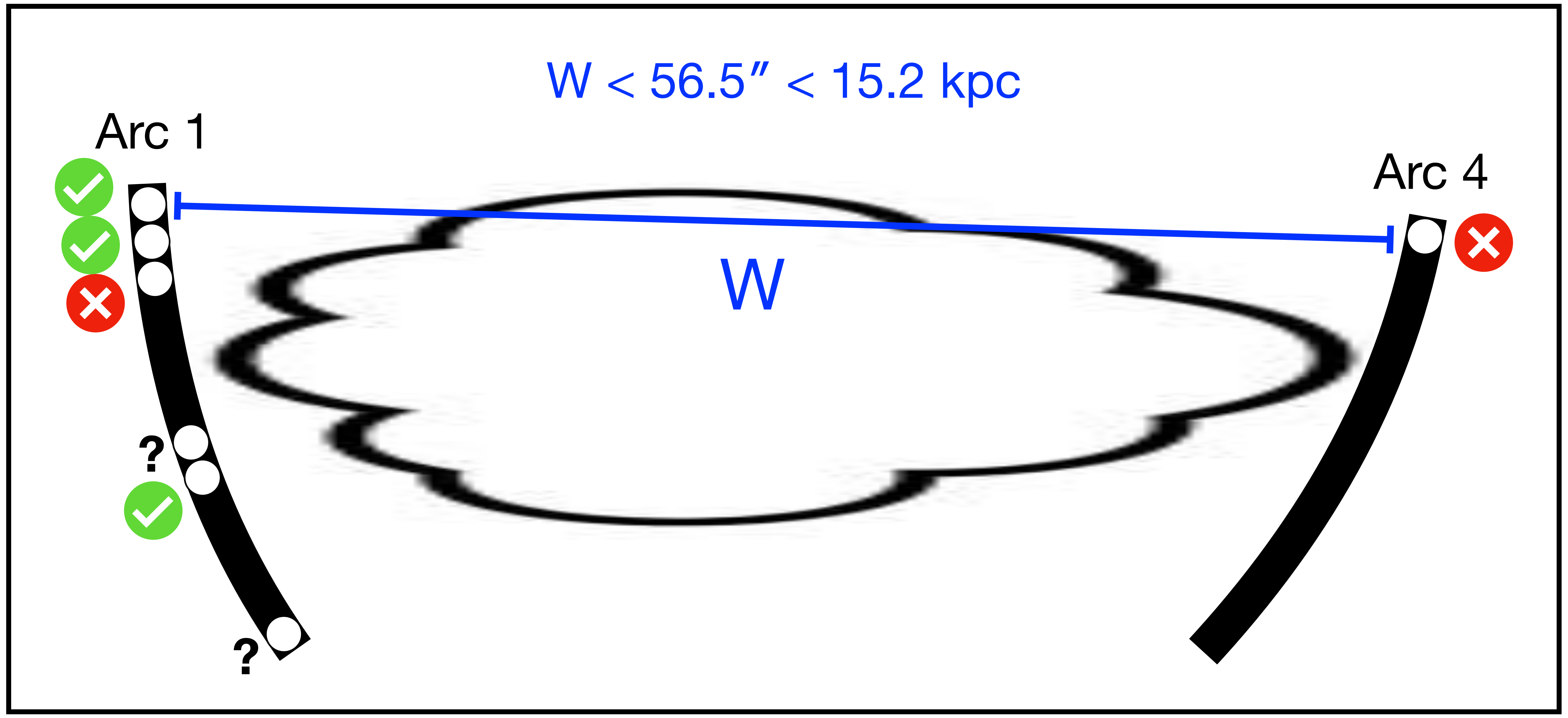


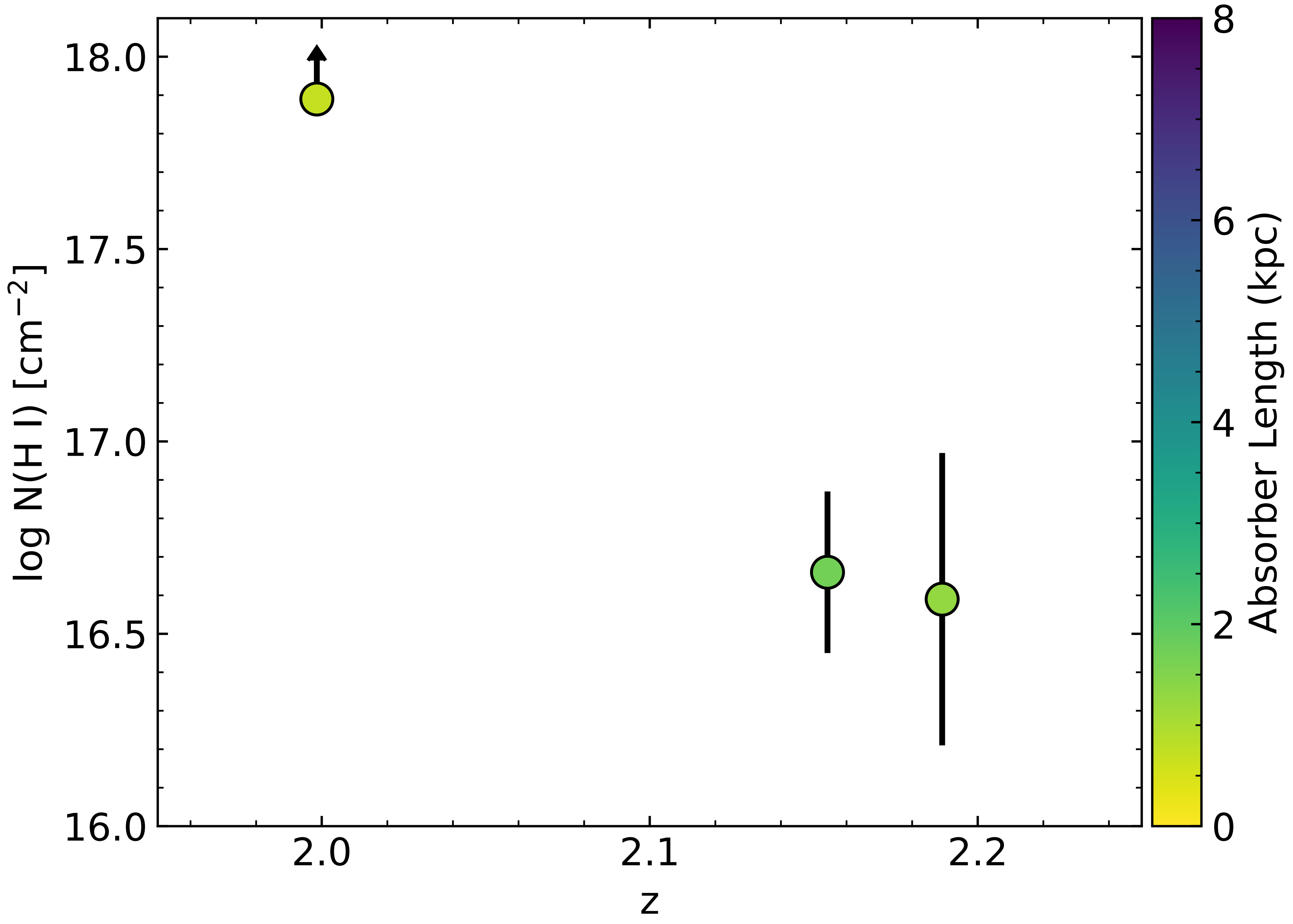


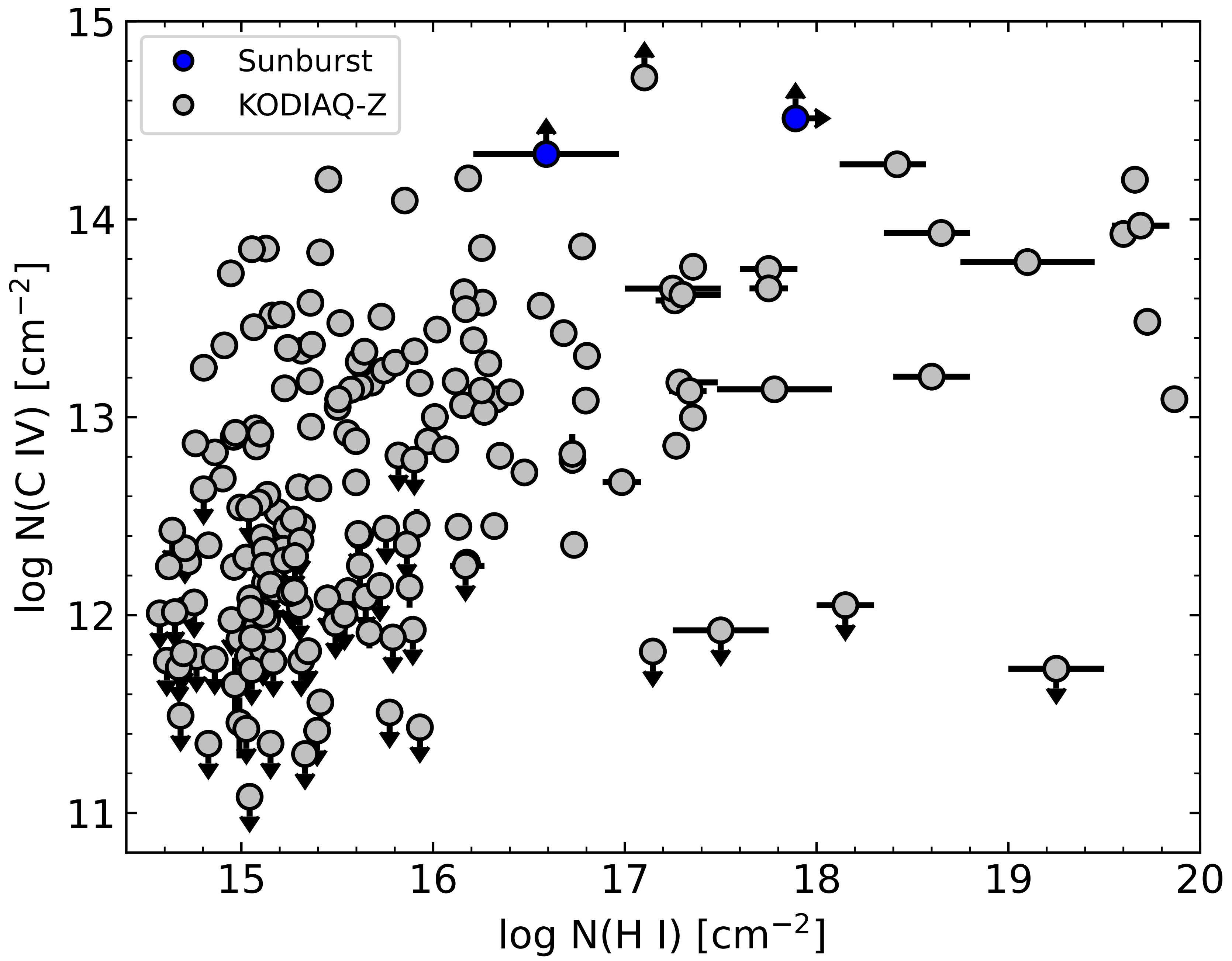
M(HI) = 8×10^{2} — 7×10^{4} $M_\odot$

We can estimate the size of the foreground absorbers in 2D and the HI mass.

Berg et al. 2025a in prep

Absorber Characteristics





This is the first time absorbers at z~2 have been probed at extremely small separations.
These absorbers exhibit IGM and CGM absorber characteristics.

Berg et al. 2025a in prep

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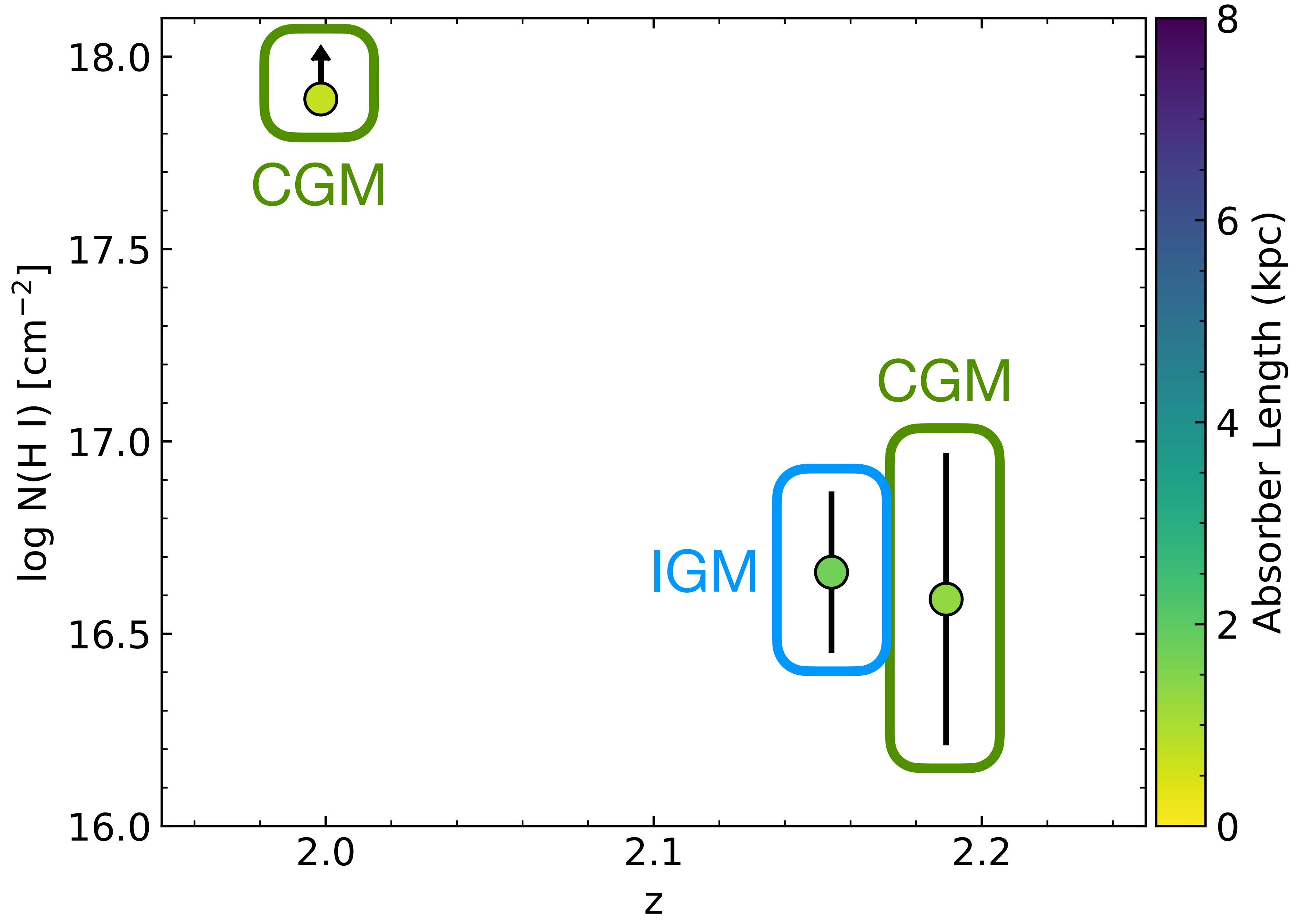

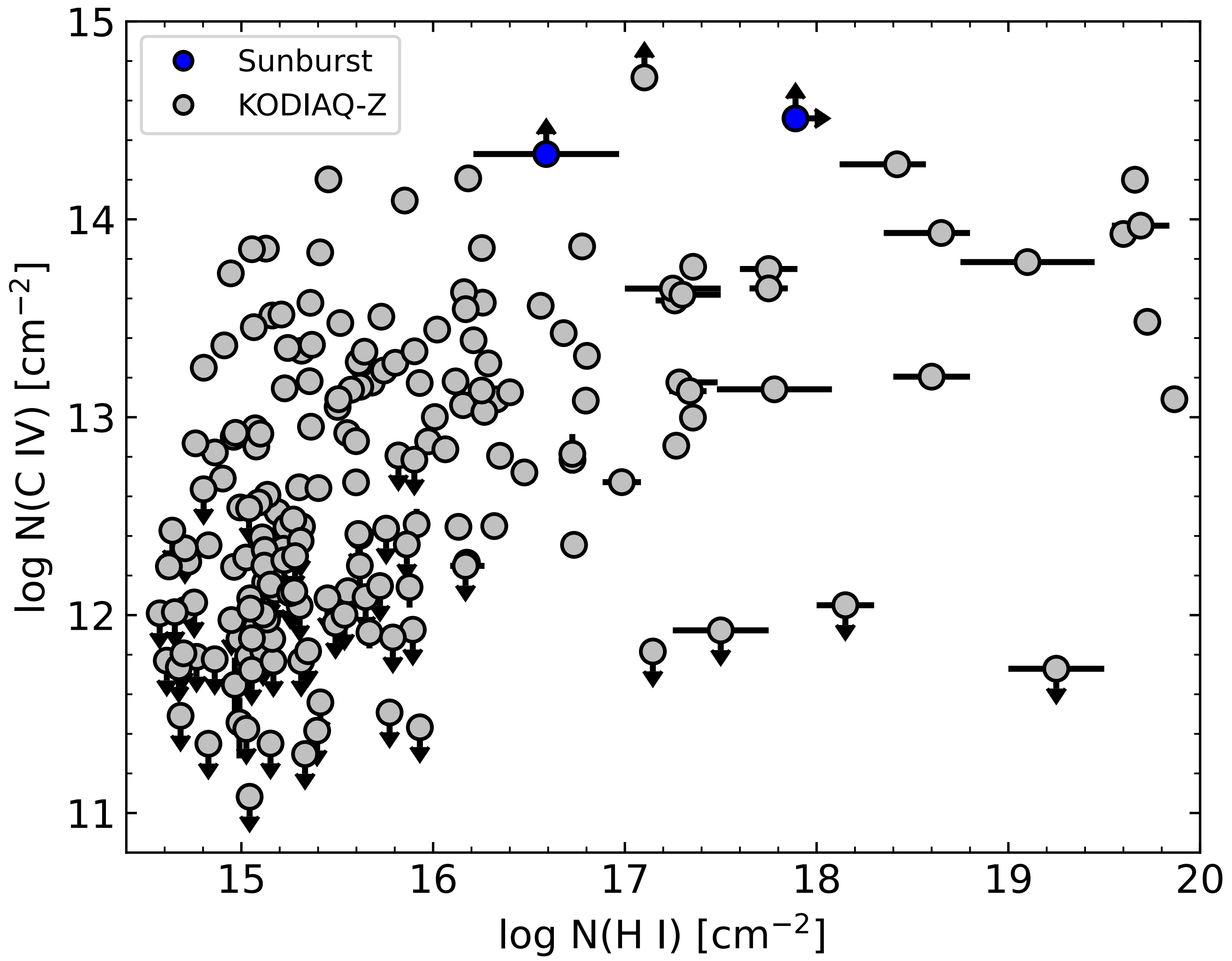

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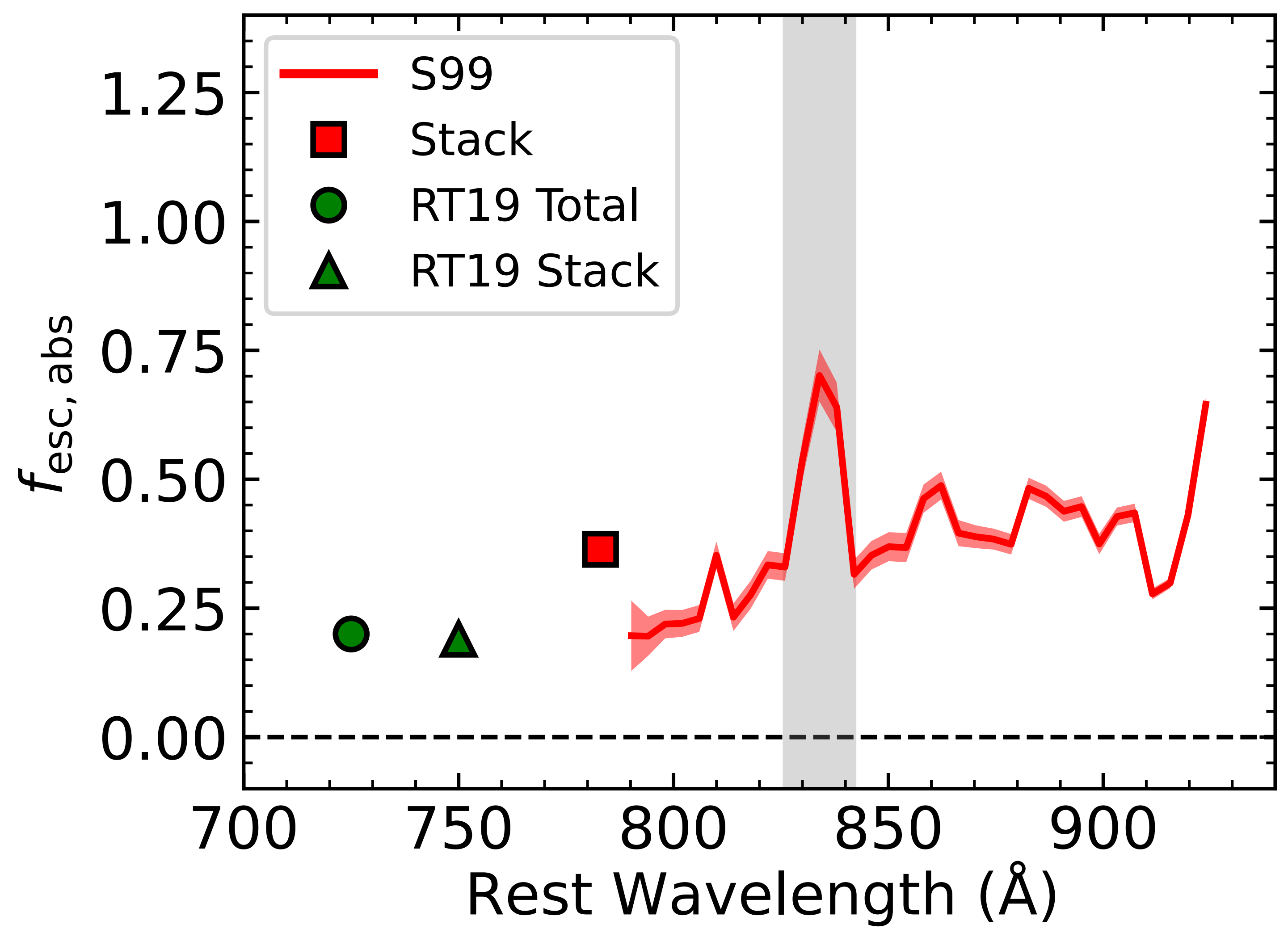
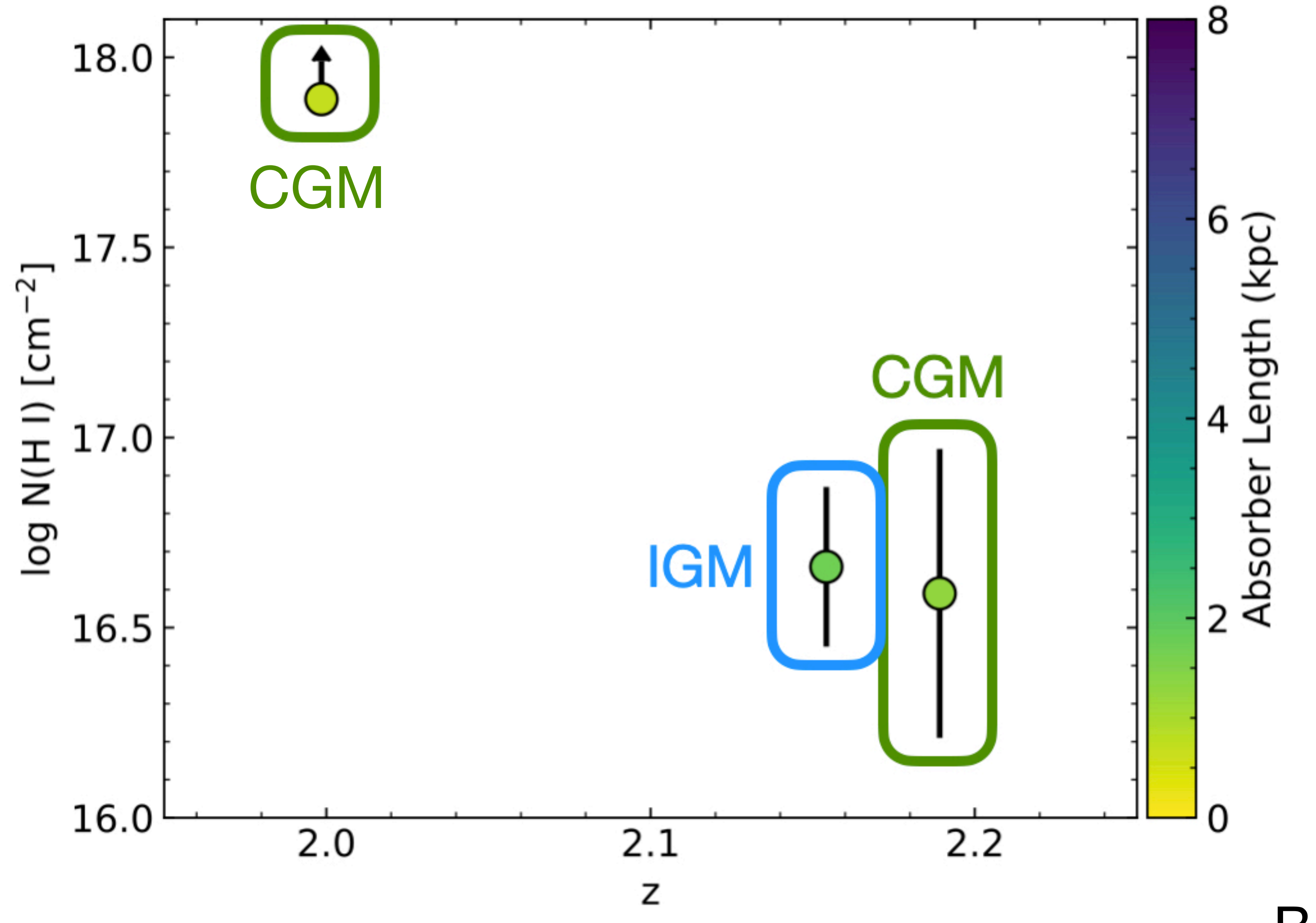
Berg et al. 2025a in prep

Summary

1. We can measure the ionizing stellar continuum of the Sunburst Arc, and we find the absolute escape fractions are high, ranging from 27-36%.



2. We can estimate the size and HI mass of the foreground absorbers at z~2.

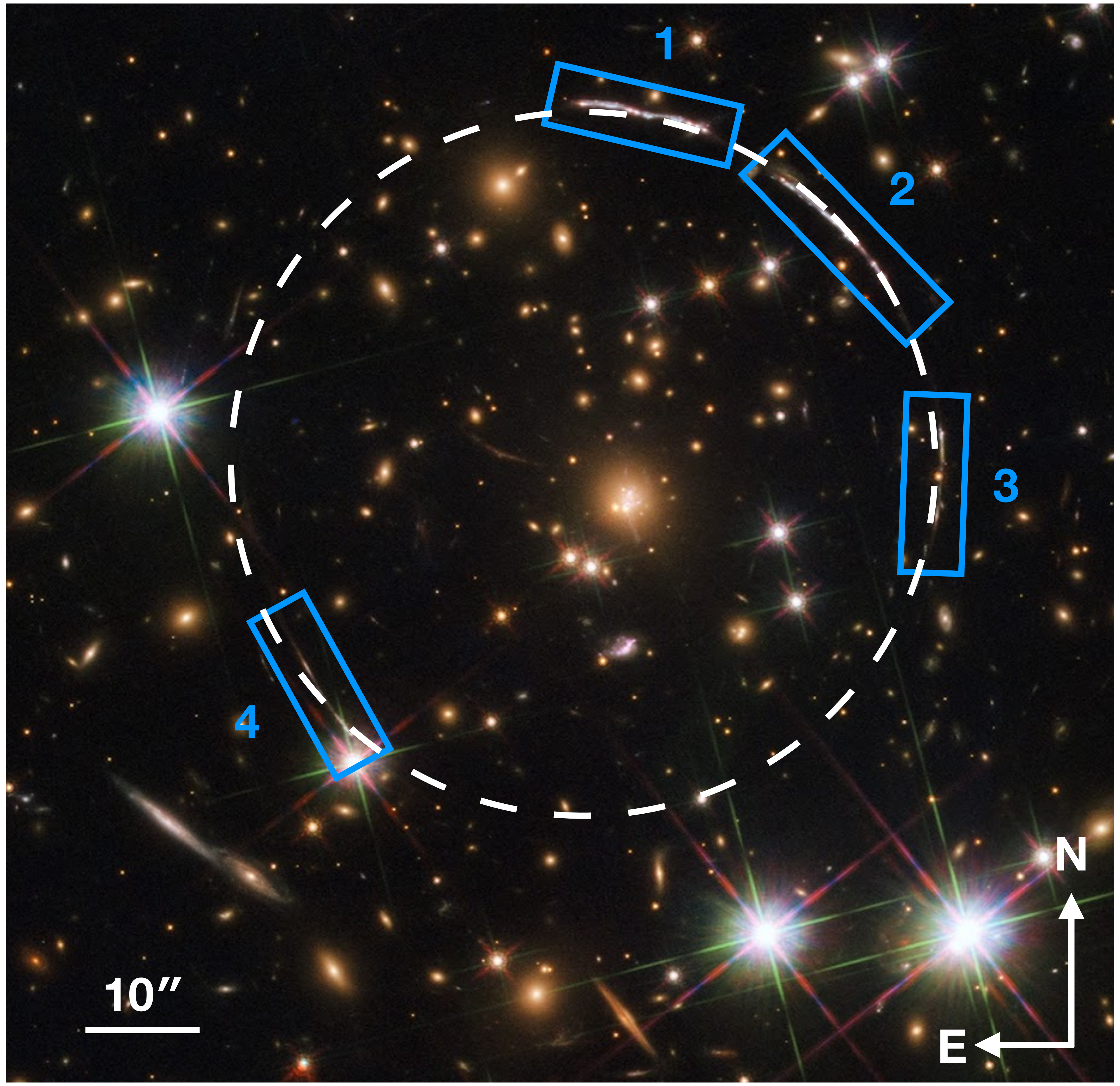


New email: m.a.berg@tcu.edu

Berg et al. 2025a,b in prep

Appendix

Sunburst Arc



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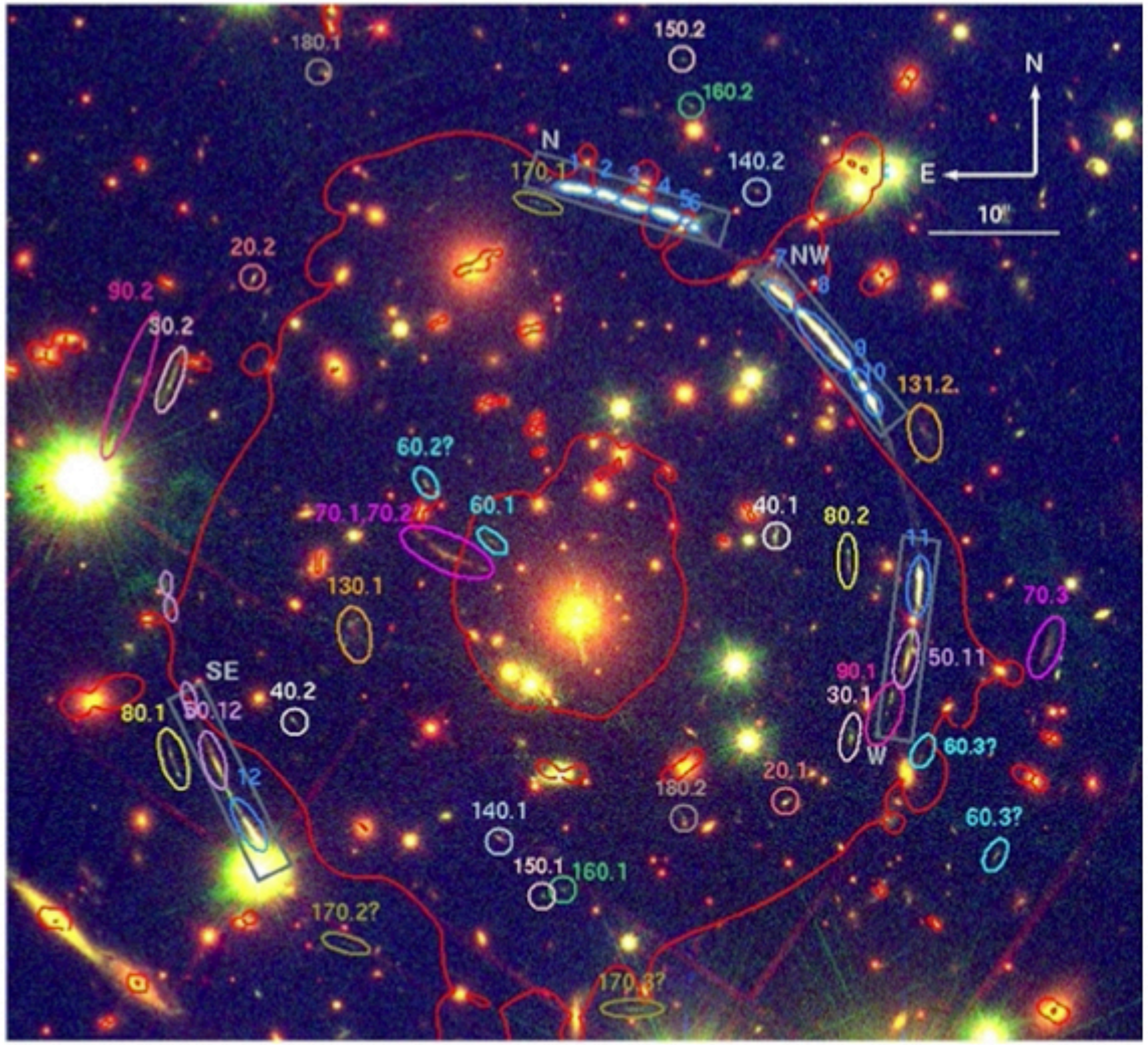
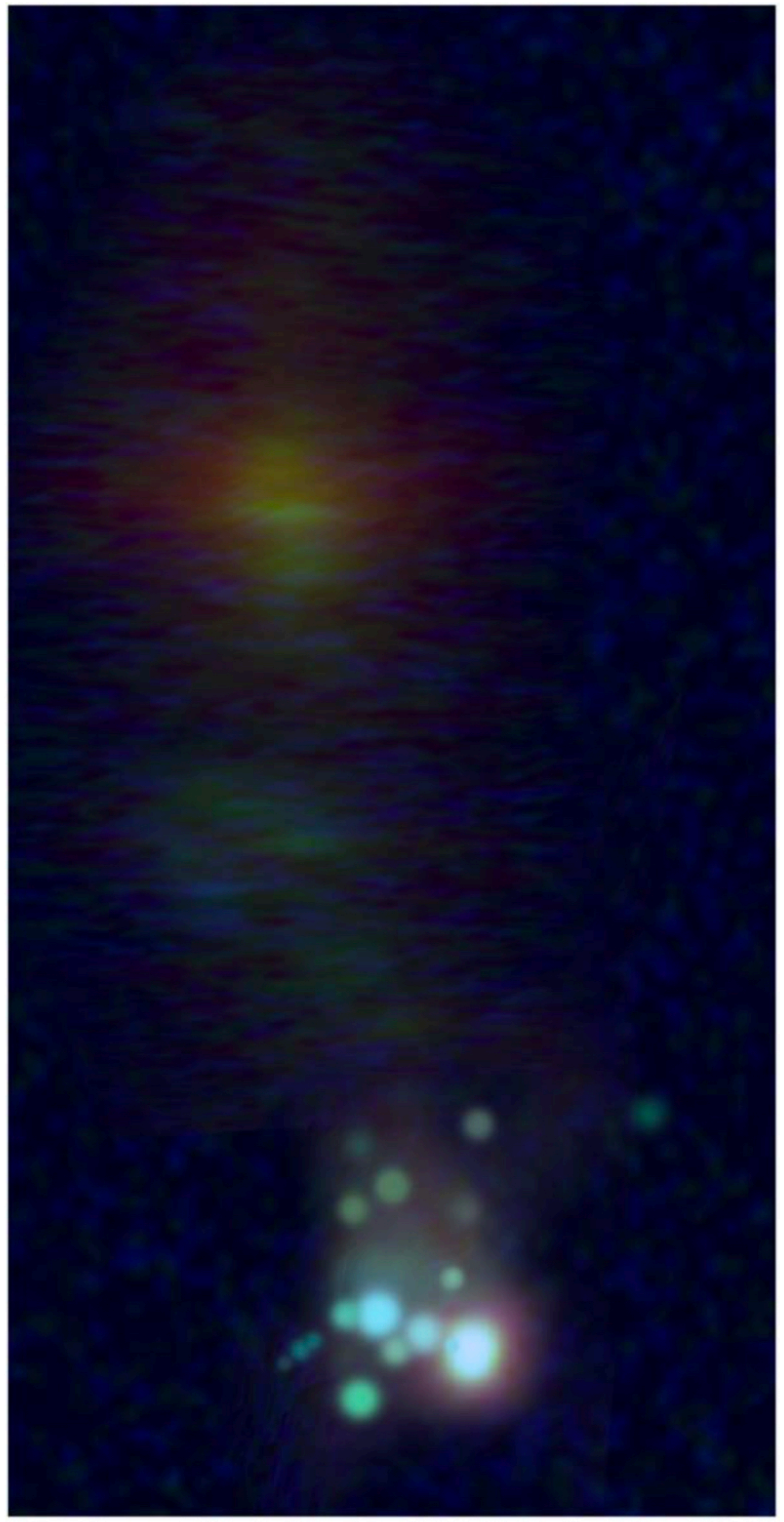
Dahle et al. 2016
Rivera-Thorsen et al. 2019
NASA, ESA and E. Rivera-Thorsen

Lensing Model & Un-lensed Image



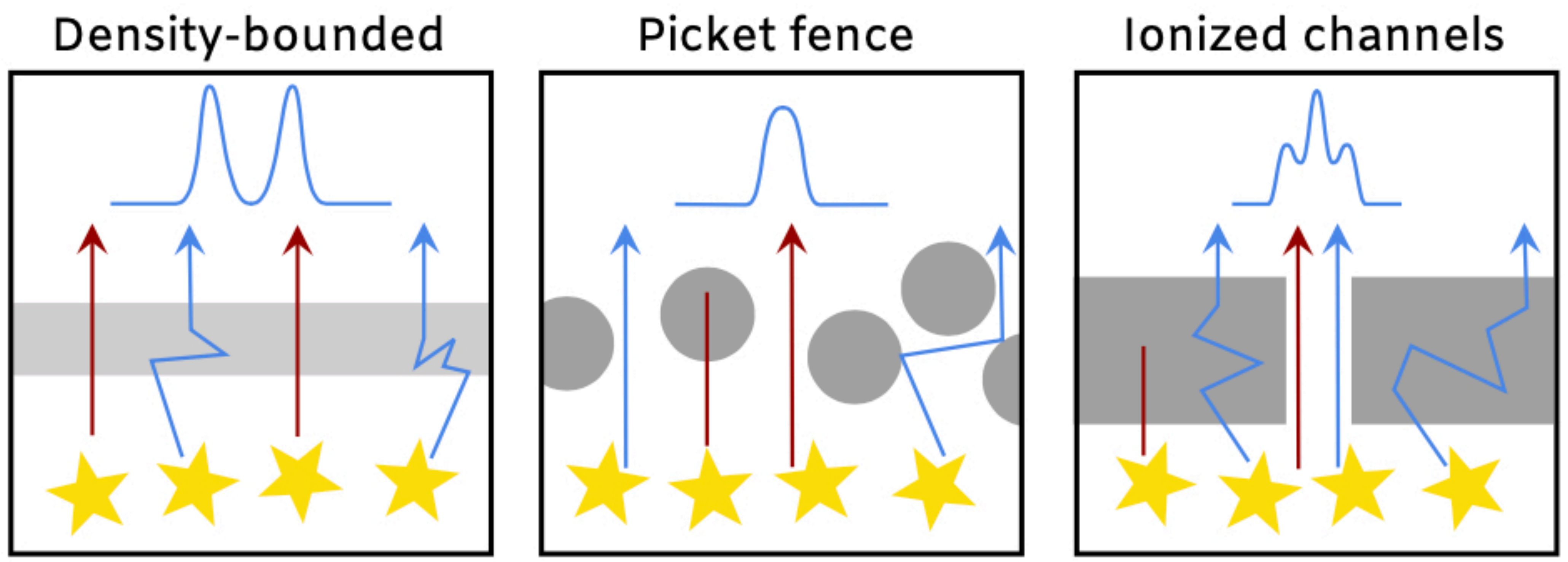


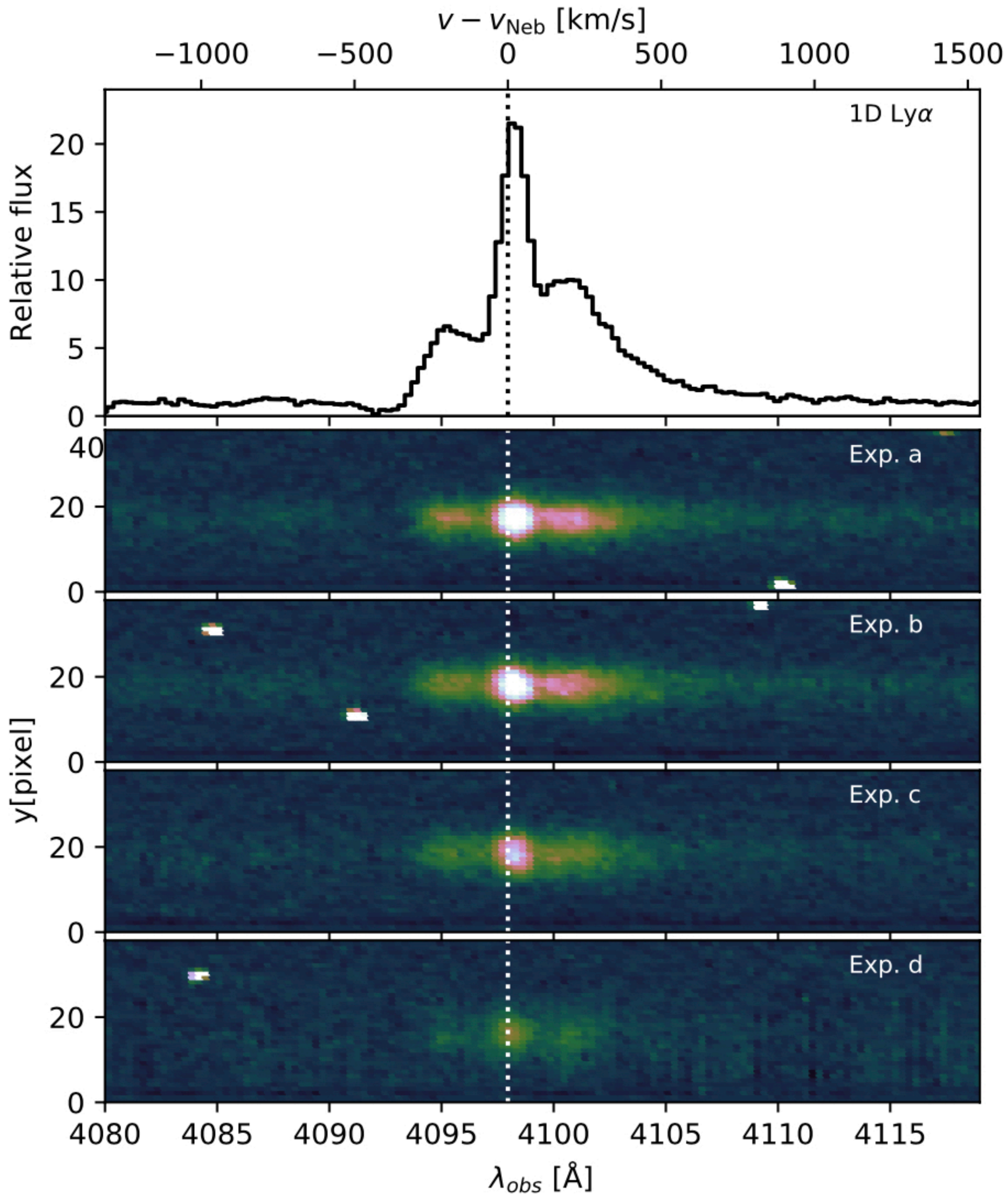
3 Myr age
0.56 $Z_\odot$

20 pc HII region
10^6-10^7 $M_\odot$

Sharon et al. 2022

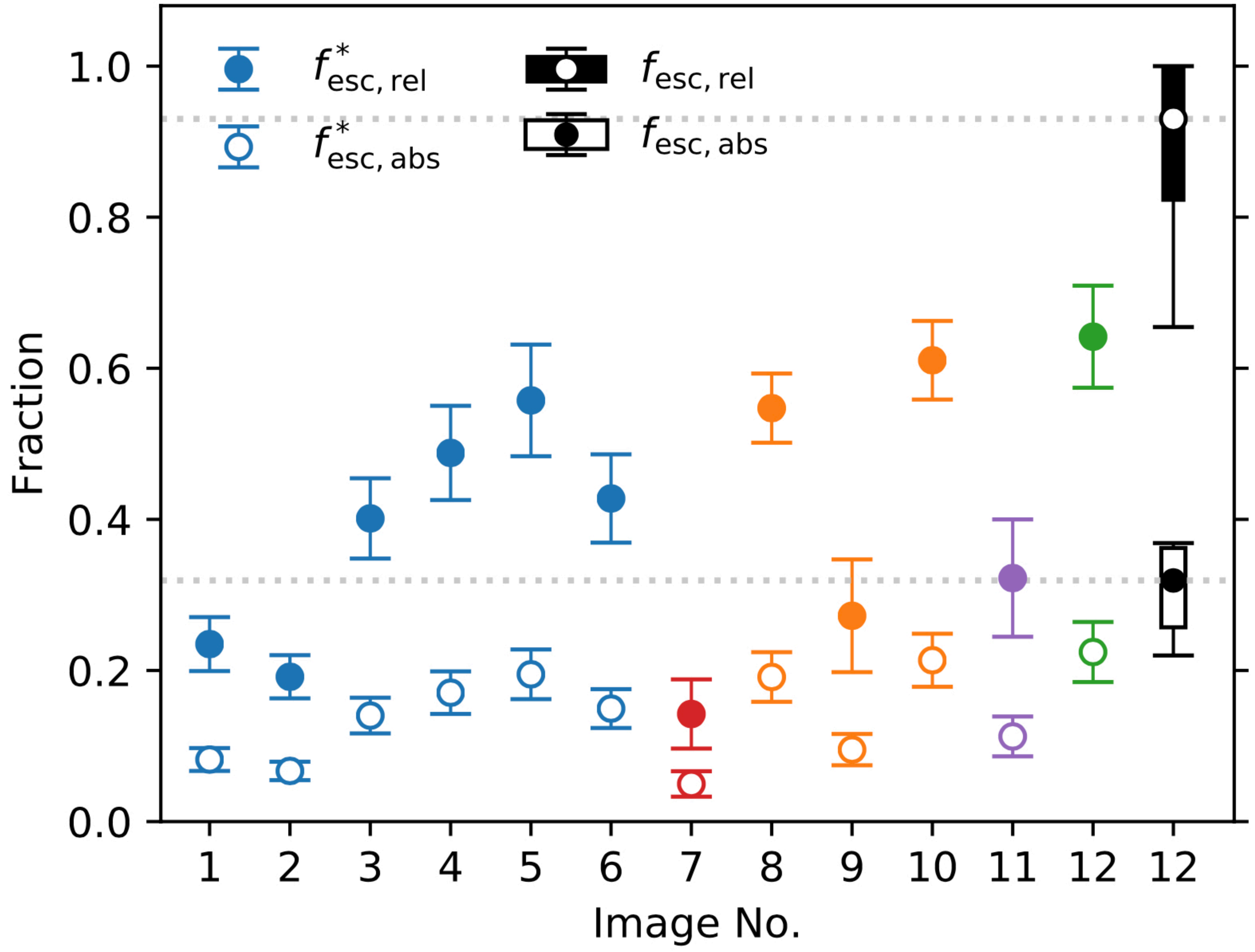
Triple-peaked LyA

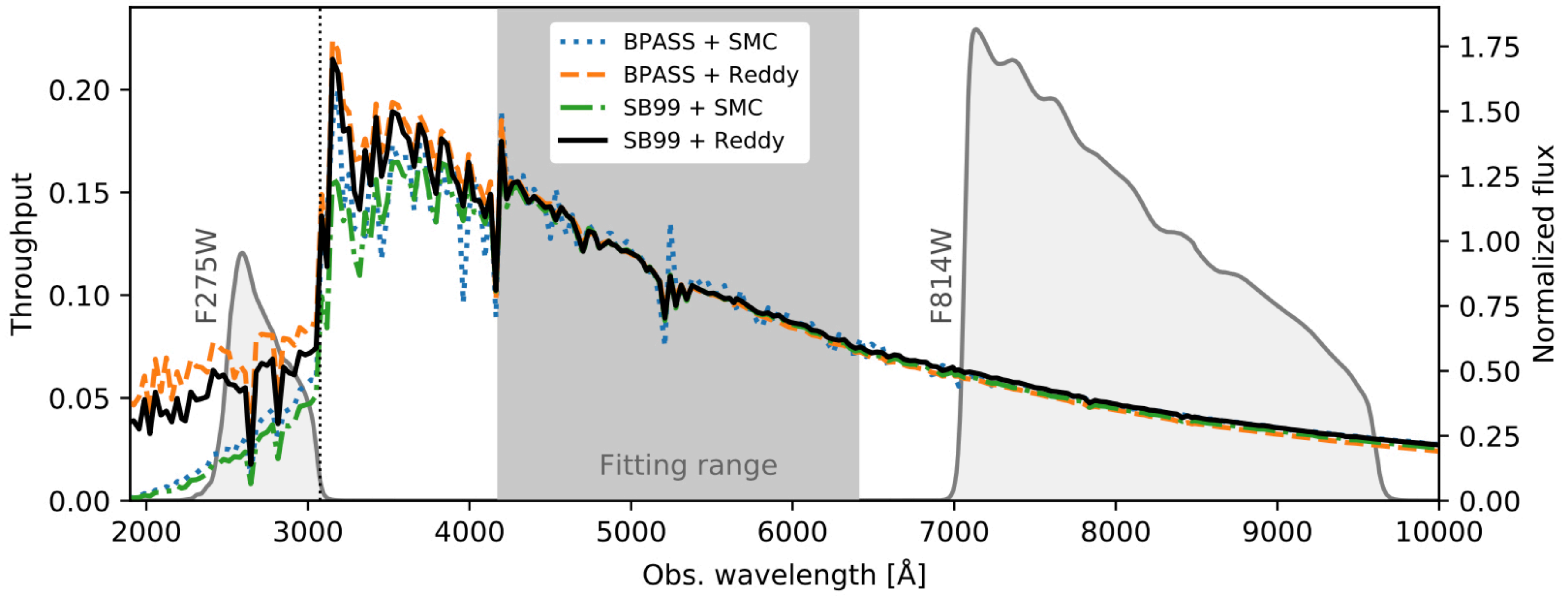




Rivera-Thorsen et al. 2017

Imaging Data





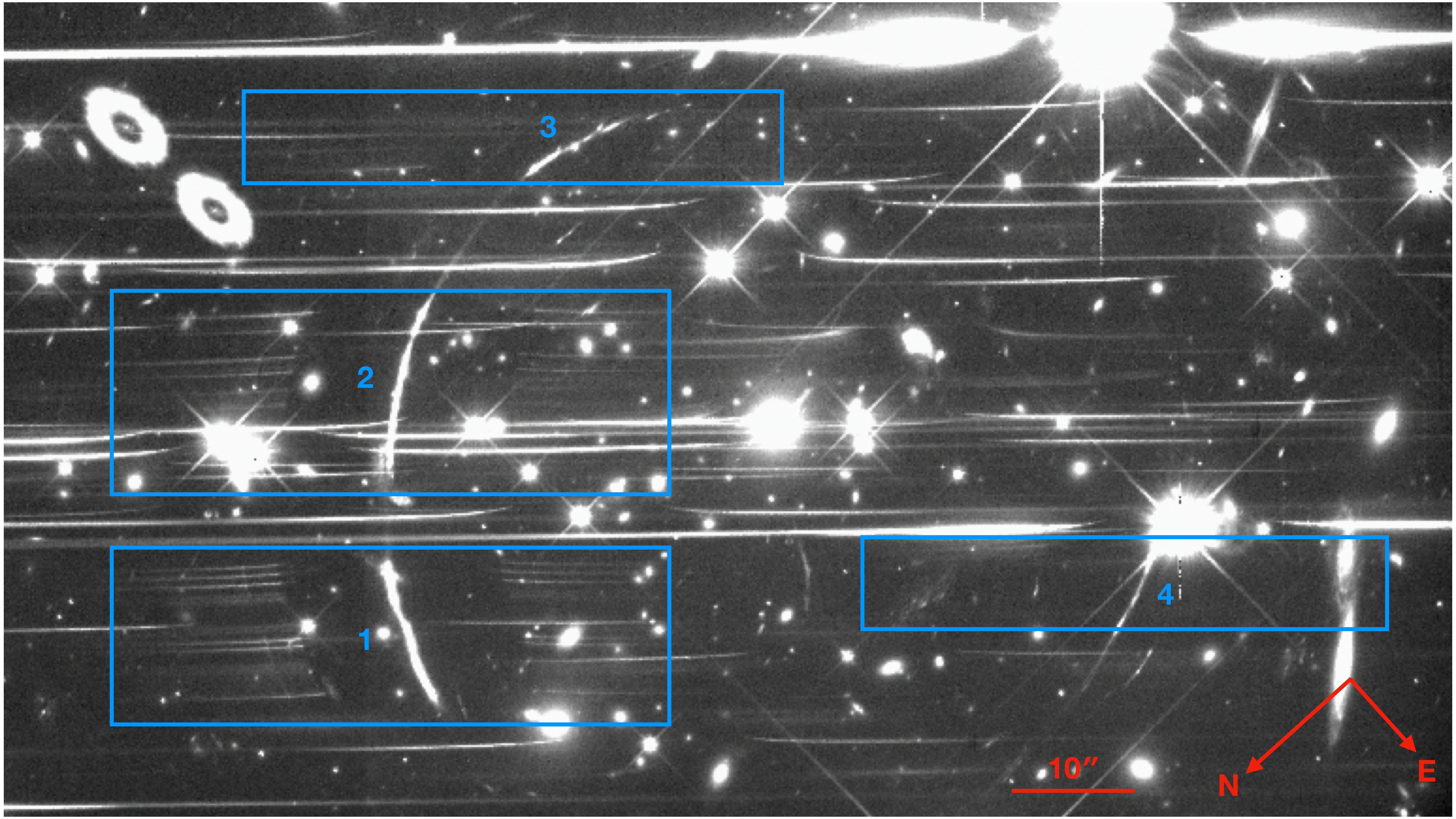
Rivera-Thorsen et al. 2019

Slitless Grism Observations

HST/WFC3
UVIS G280

1900-4500Å

R~70



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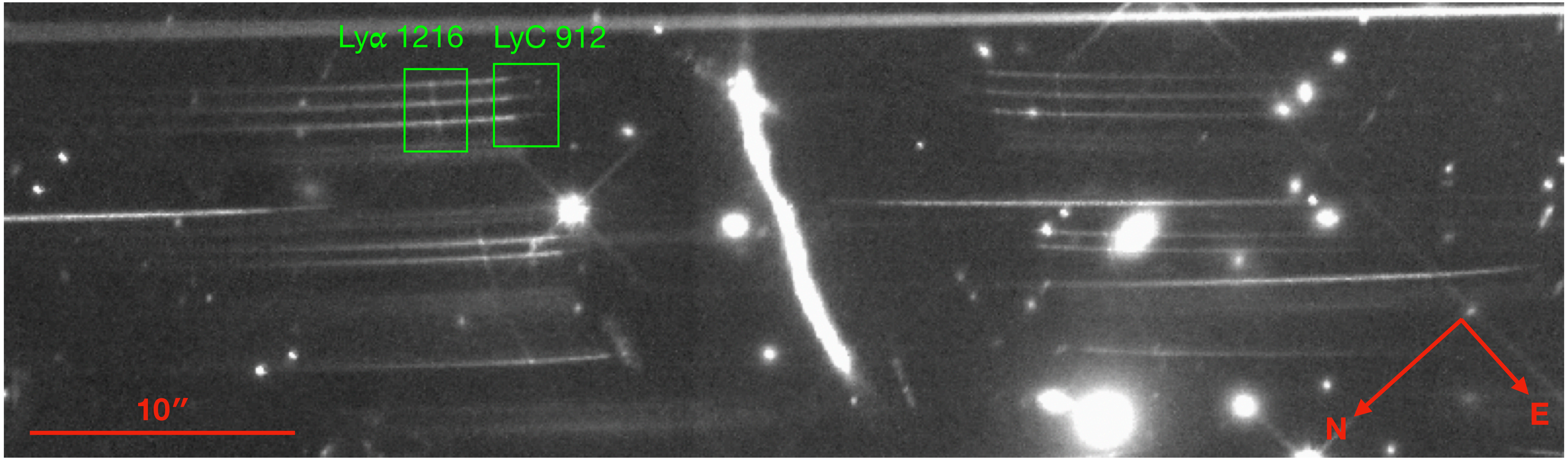
Arc 1

Beam A

Beam C



Red ← Increasing λ Blue

Blue Increasing λ → Red

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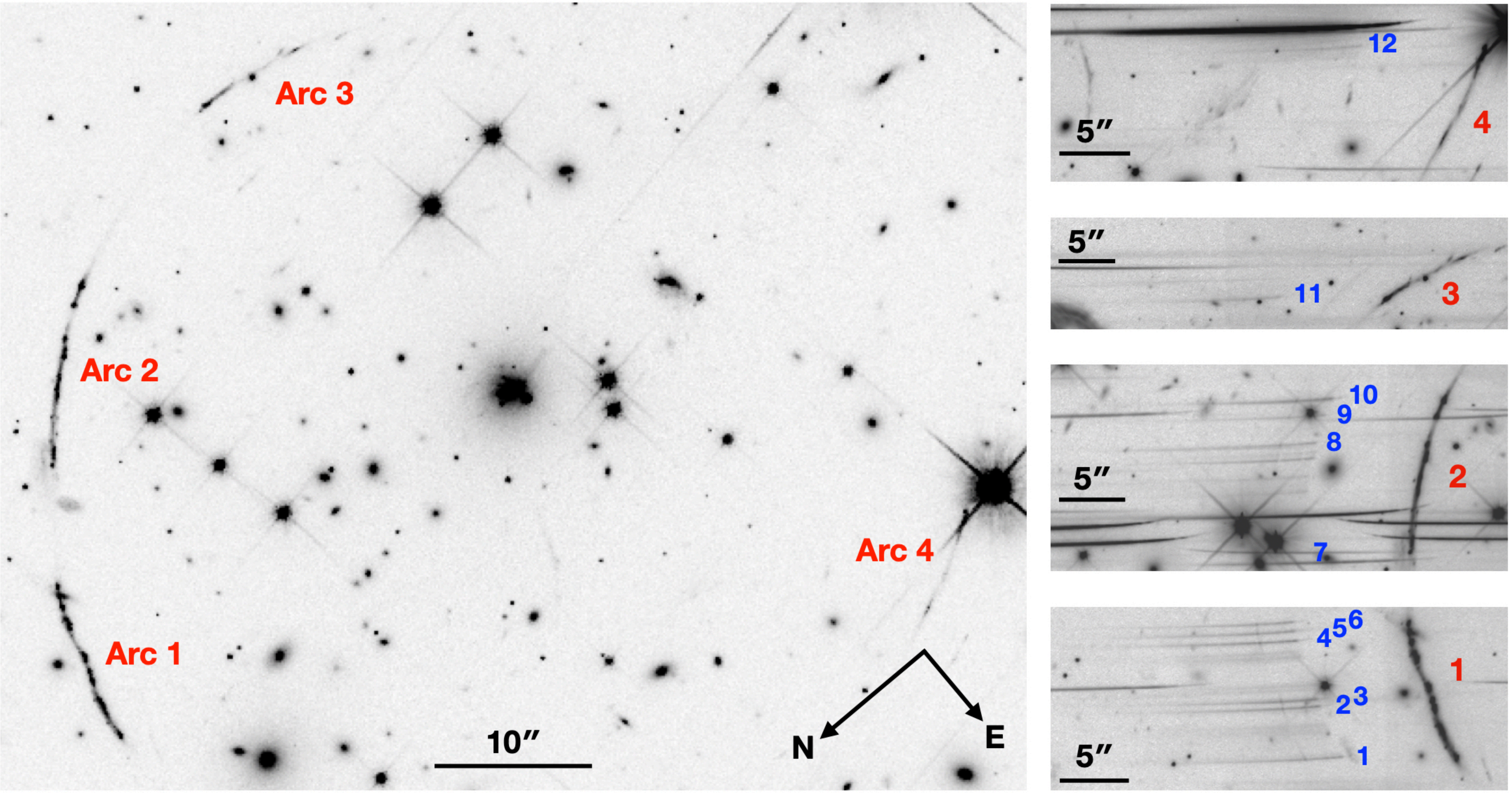
Trace Images



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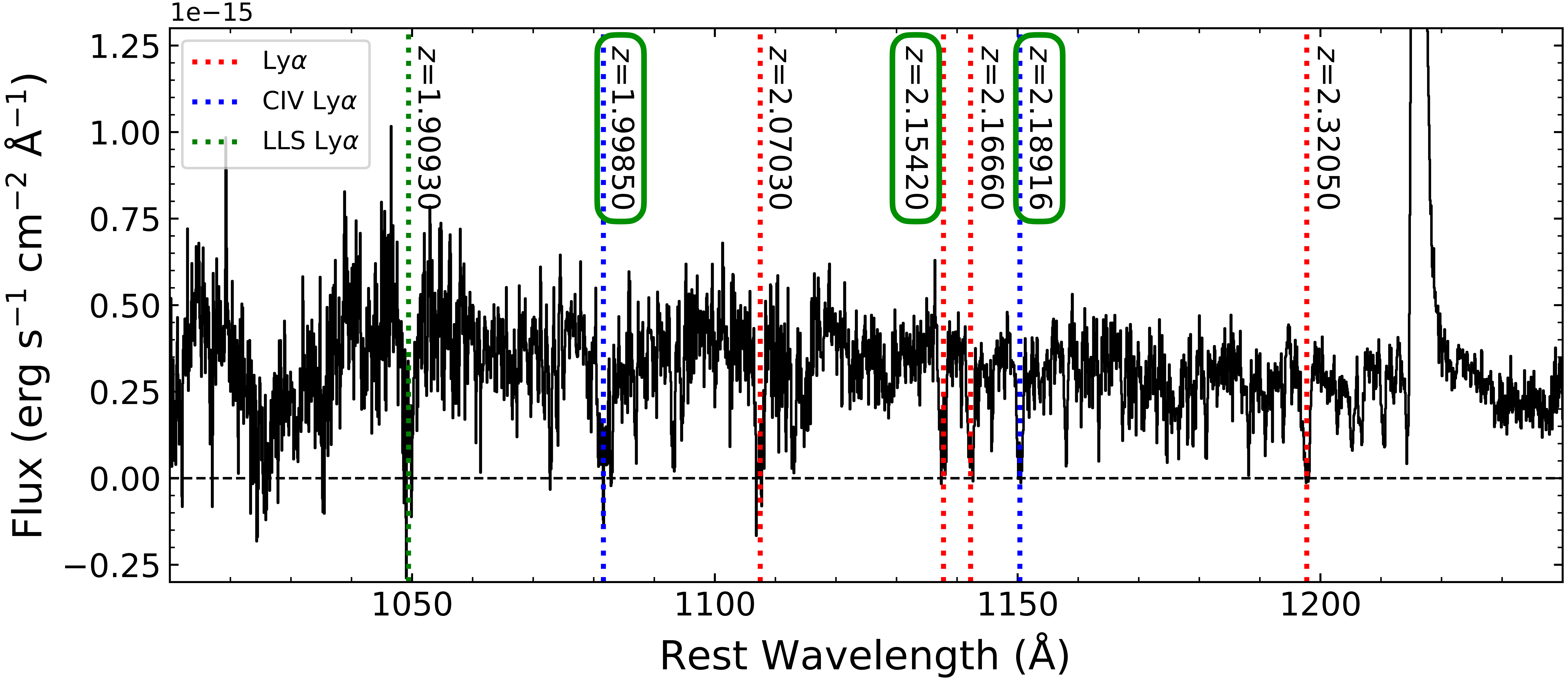
Magellan/MagE Spectrum



Berg et al. 2025a in prep
Rigby et al. 2025 in prep

Absorber Information

S99

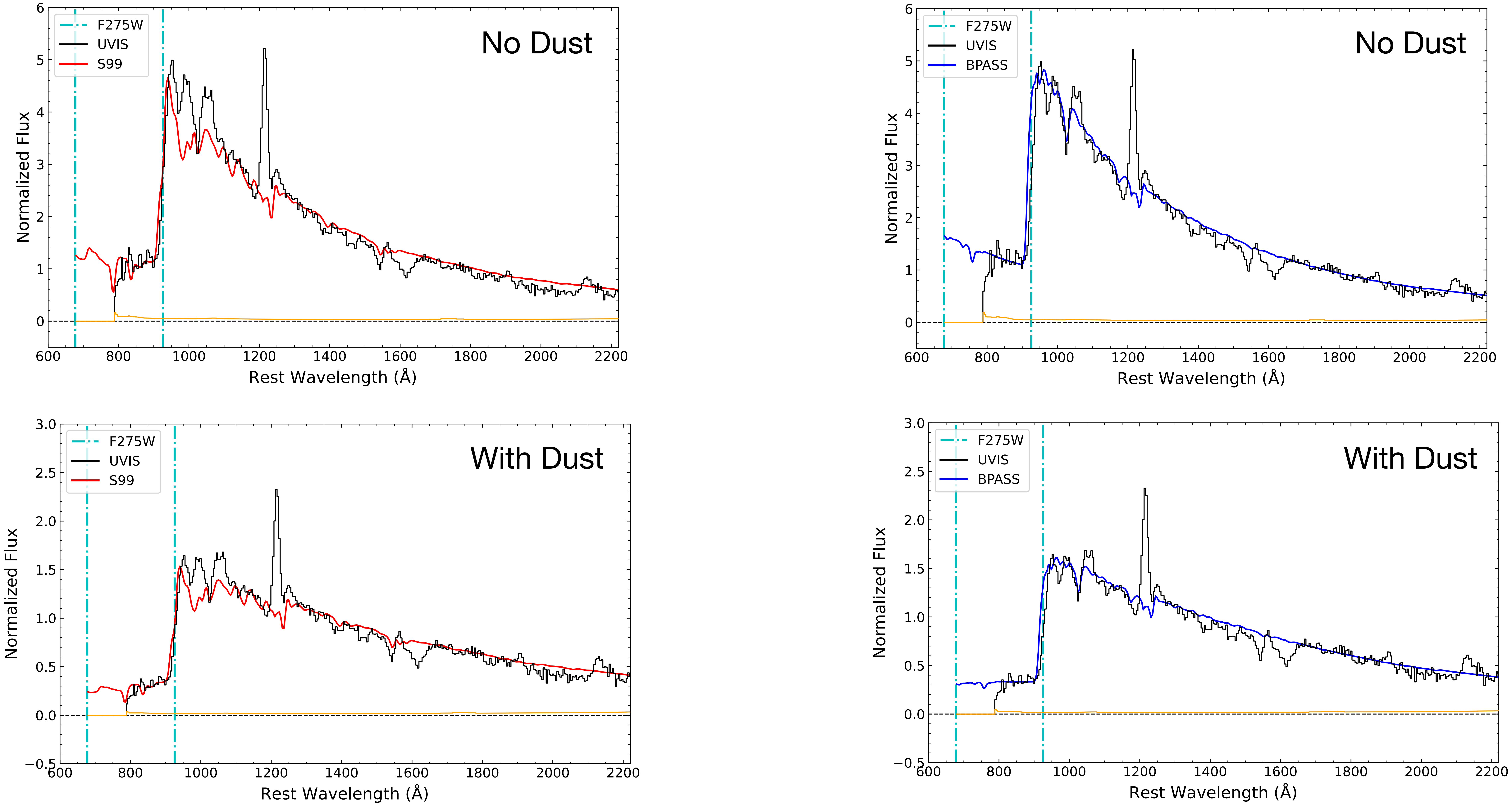
Galaxy logNHI: >18.5
T_{ISM} c_f: 36 ± 3%
T_{IGM} (non): 105 ± 5%
T_{IGM} (ion): 102 ± 39%
CIV at z=2.18916 logNHI: 16.31 ± 0.57
Lyα at z=2.15420 logNHI: 16.59 ± 0.38
Lyα at z=2.07030 logNHI: 17.26 ± 0.13
CIV at z=1.99850 logNHI: >17.79
LLS at z=1.90930 logNHI: 17.23 ± 0.19

BPASS

Galaxy logNHI: 18.7–19.8
T_{ISM} c_f: 53 ± 1%
T_{IGM} (non): 95 ± 5%
T_{IGM} (ion): 96 ± 37%
CIV at z=2.18916 logNHI: 16.59 ± 0.19
Lyα at z=2.15420 logNHI: 16.66 ± 0.29
Lyα at z=2.07030 logNHI: 17.27 ± 0.13
CIV at z=1.99850 logNHI: >17.89
LLS at z=1.90930 logNHI: 17.33 ± 0.15

Berg et al. 2025a,b in prep

Updated Comparison to Models



Berg et al. 2025b in prep