



Detecting Ly α Emission from the Circumgalactic Medium of a Submillimeter Galaxy & two Background Quasars

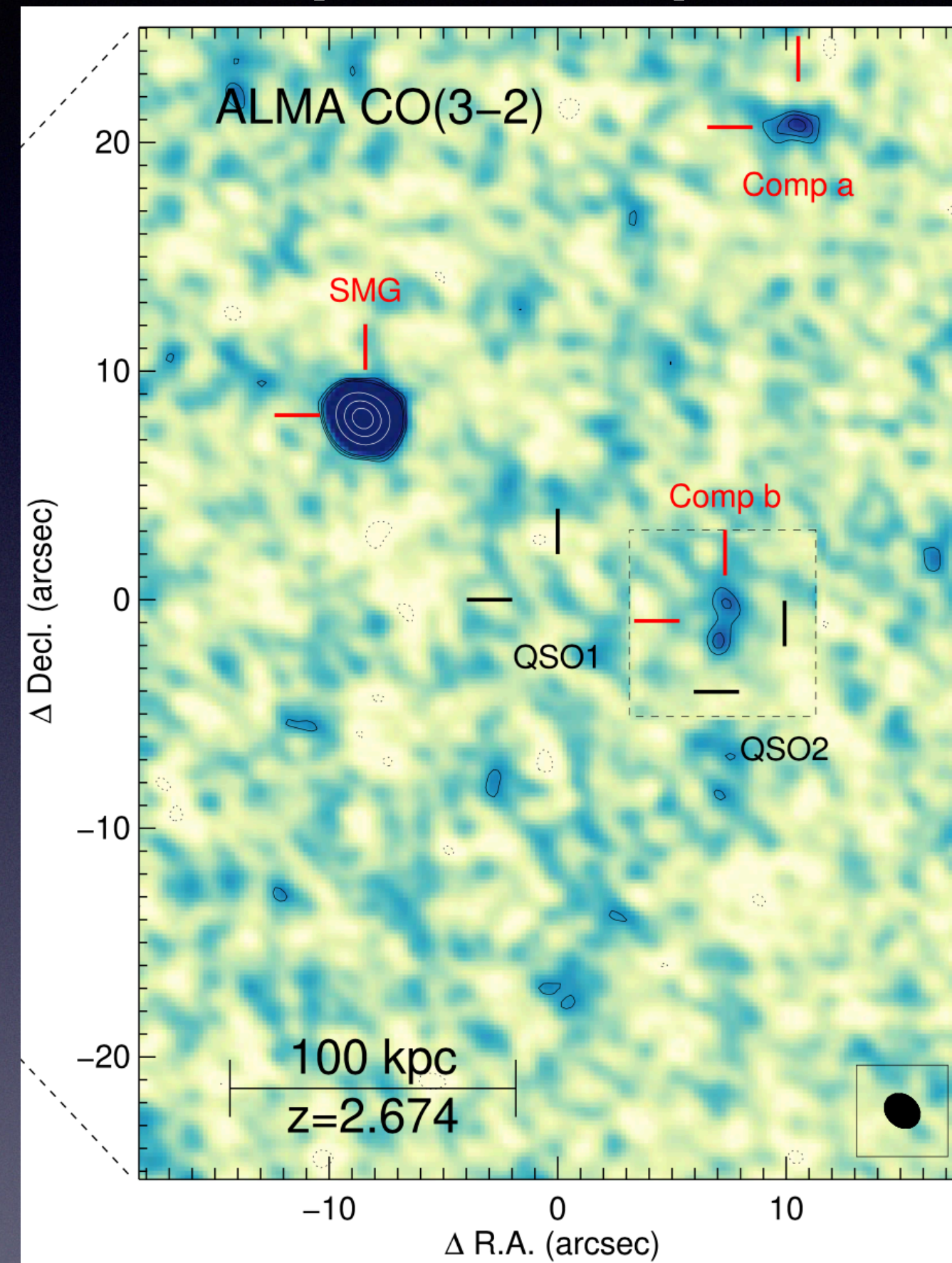
Kevin Hall

Work Supported by NSF Grant AST-2103251

Submillimeter Galaxies (SMGs)

(Fu+2021)

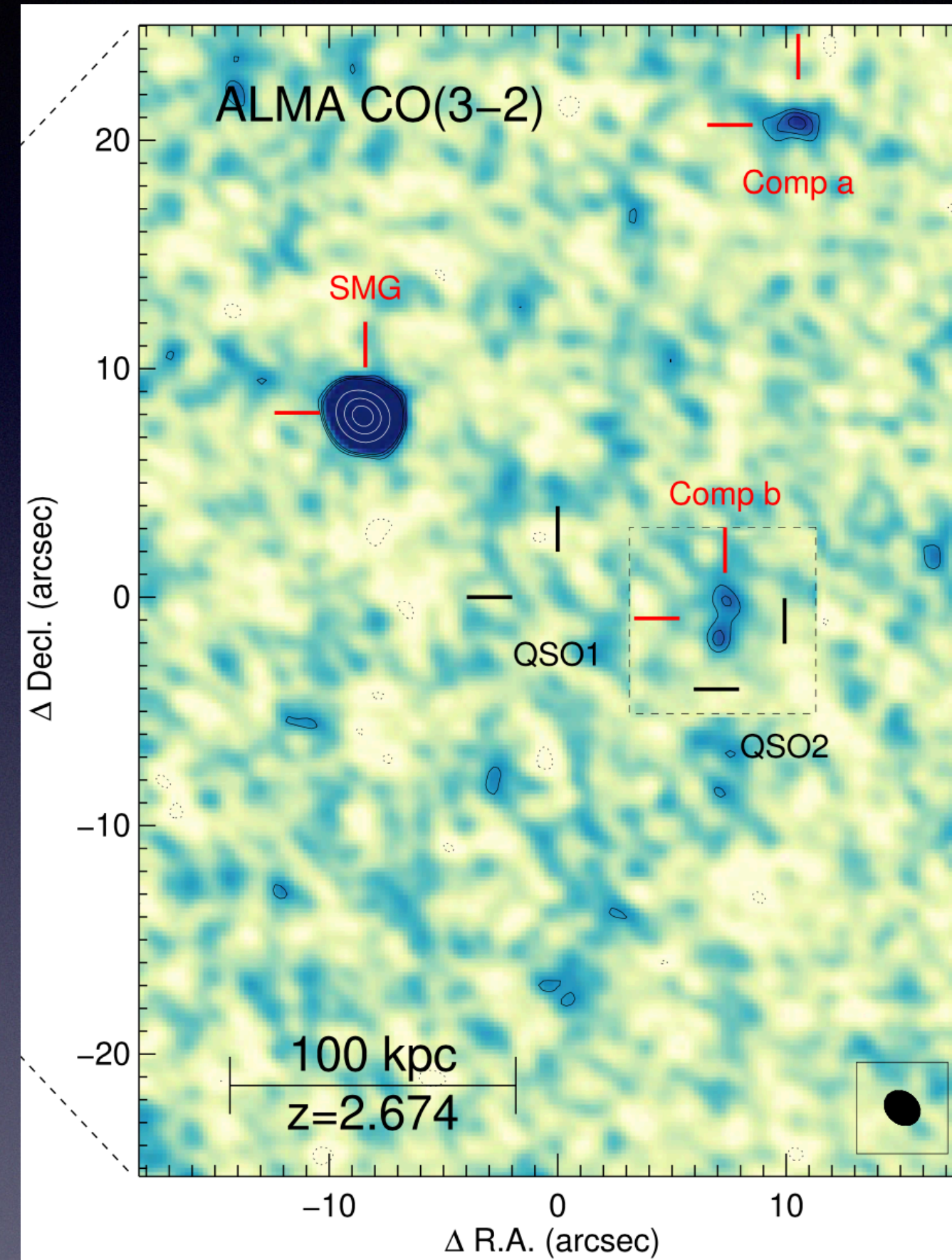
- Ancient Dusty Galaxies with Incredibly high Star Formation Rates (SFR)
- Dust obscures optical wavelengths, but strong emission in radio from dust emission
- “Cold Mode” Accretion (Cold: $\sim 10^4$ K, Hot: $\sim 10^6$ K)
- These large external structures reside within the Circumgalactic Medium



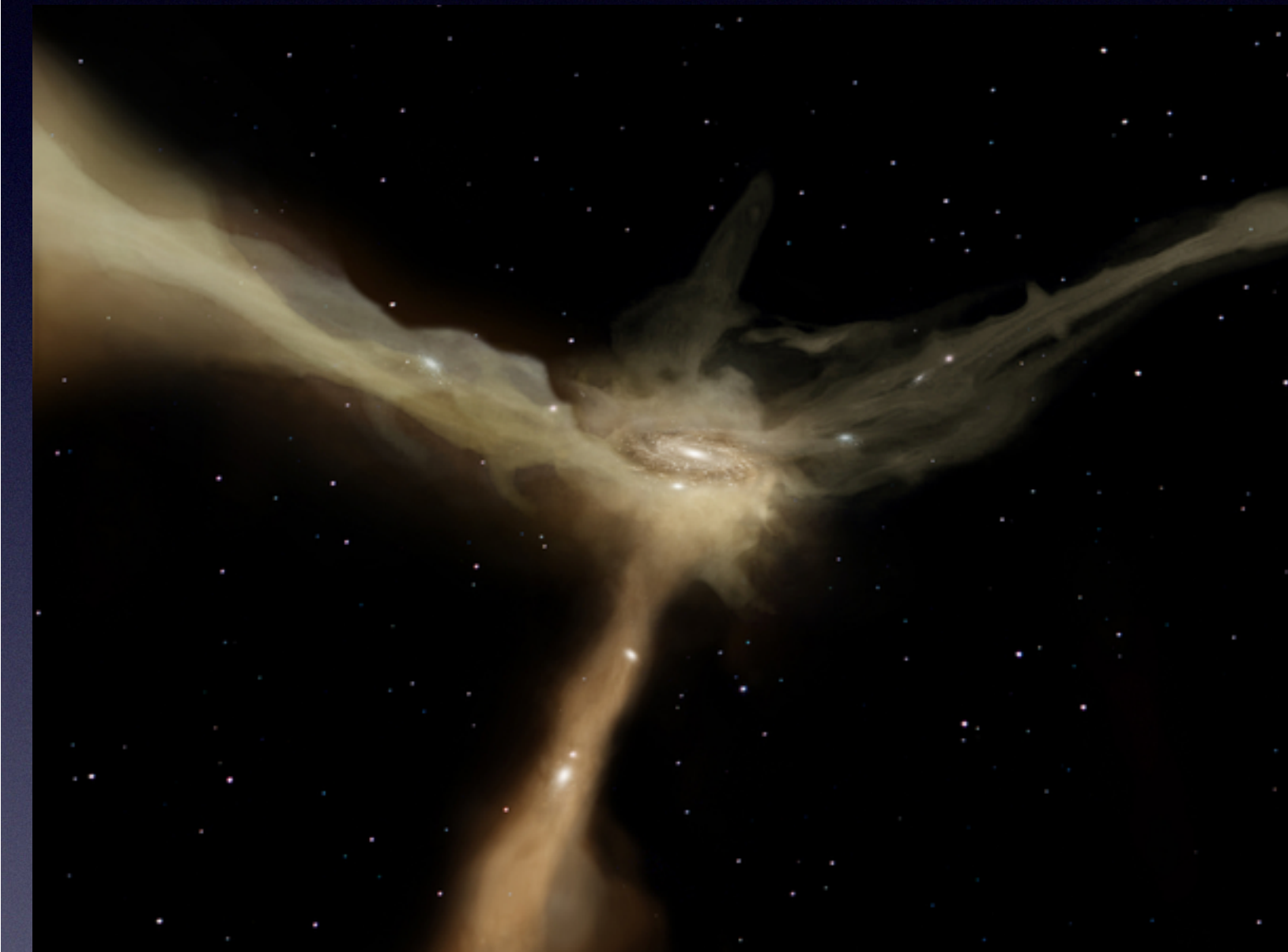
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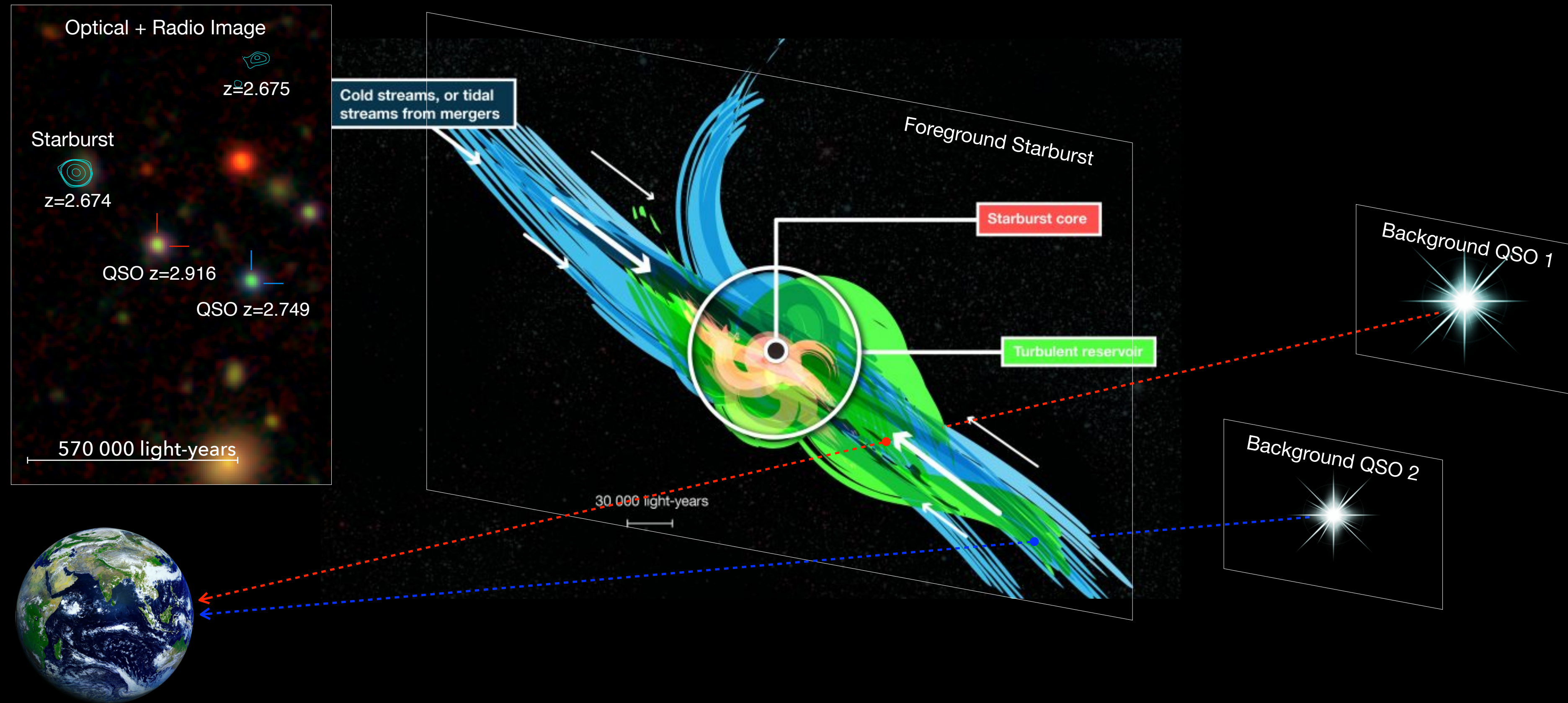
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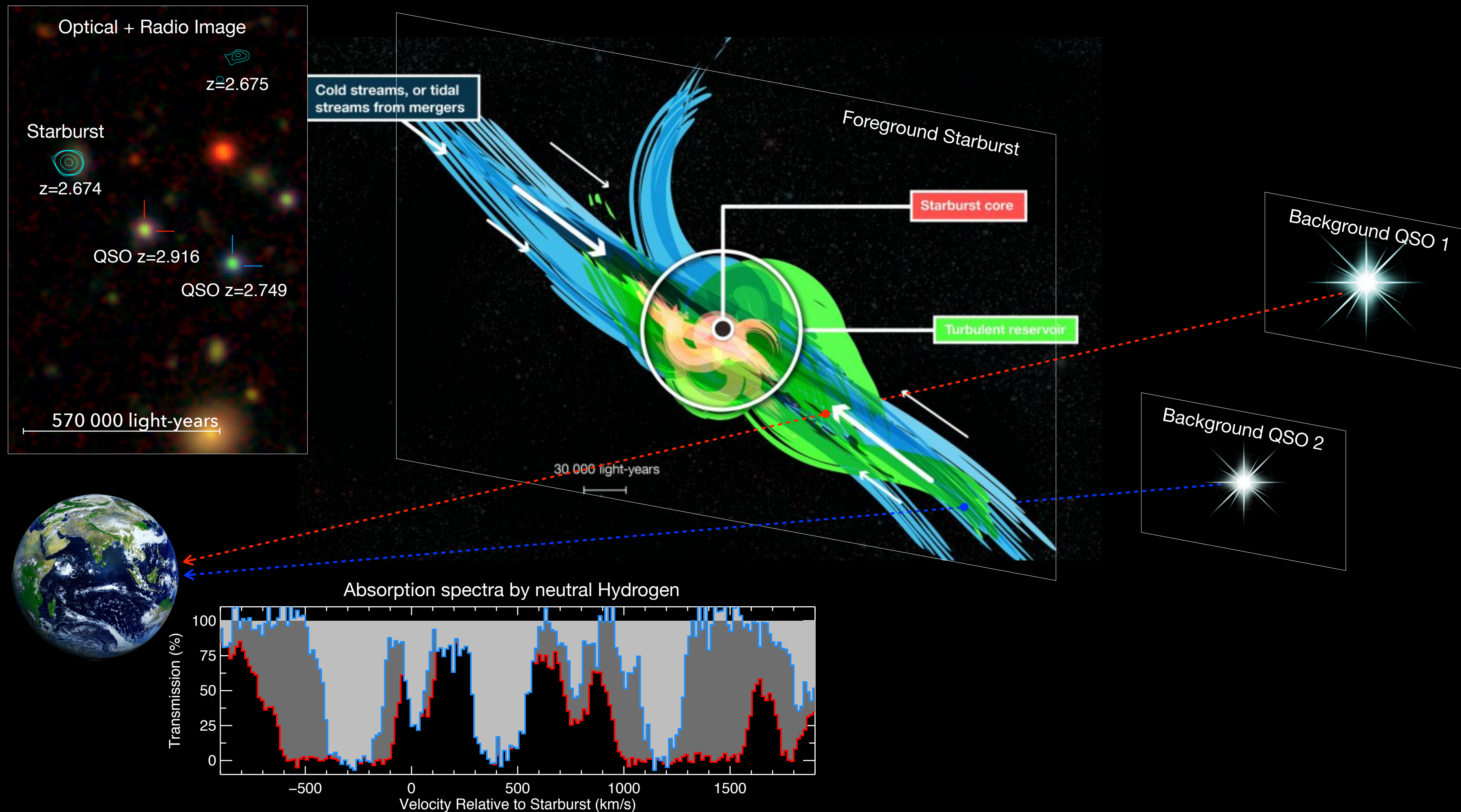
Cold Gas Accretion



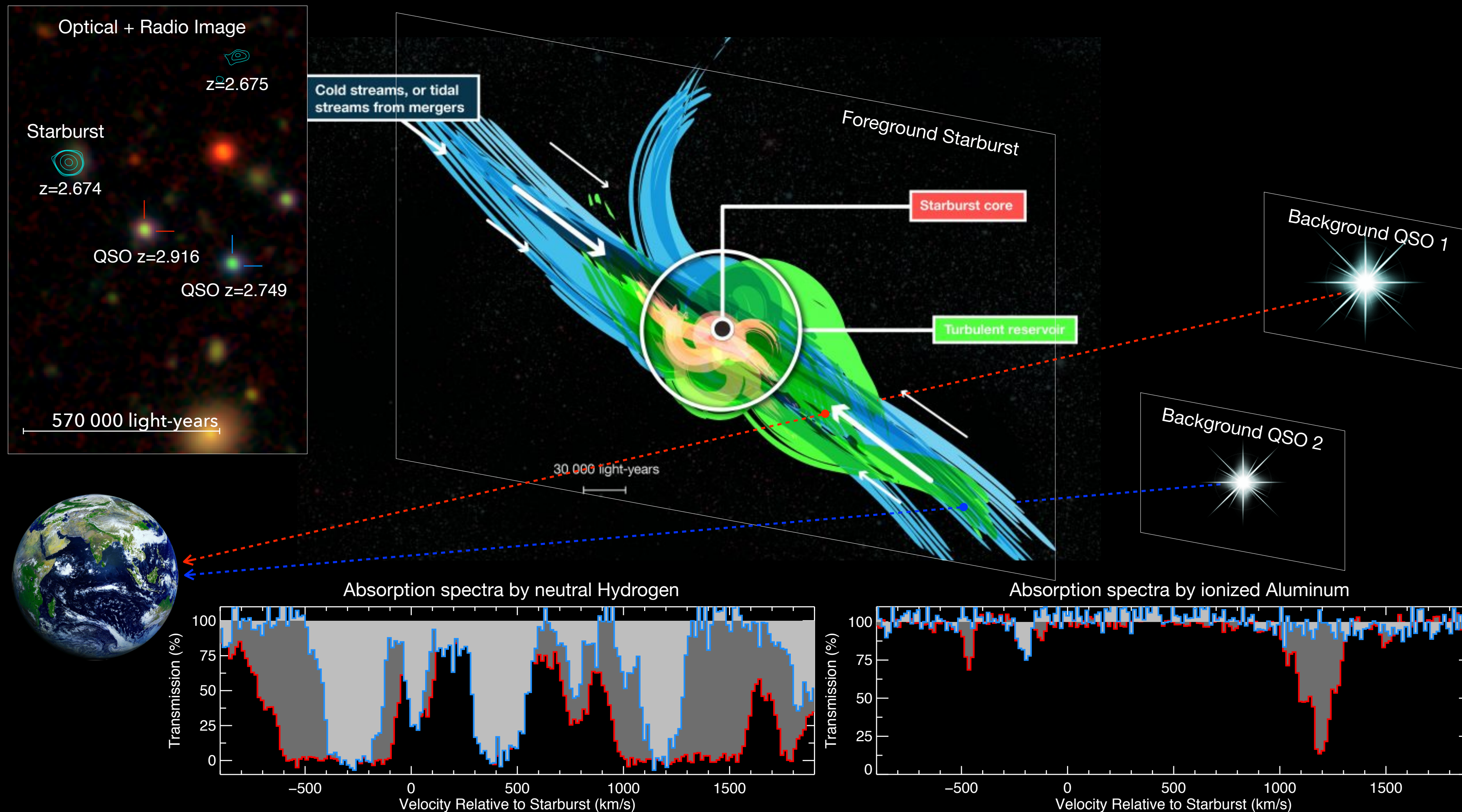
Detection of a 200-kpc-long, 1% Solar metallicity, Cool Gas Stream in a Massive Halo at $z = 2.7$ (Fu+2021)



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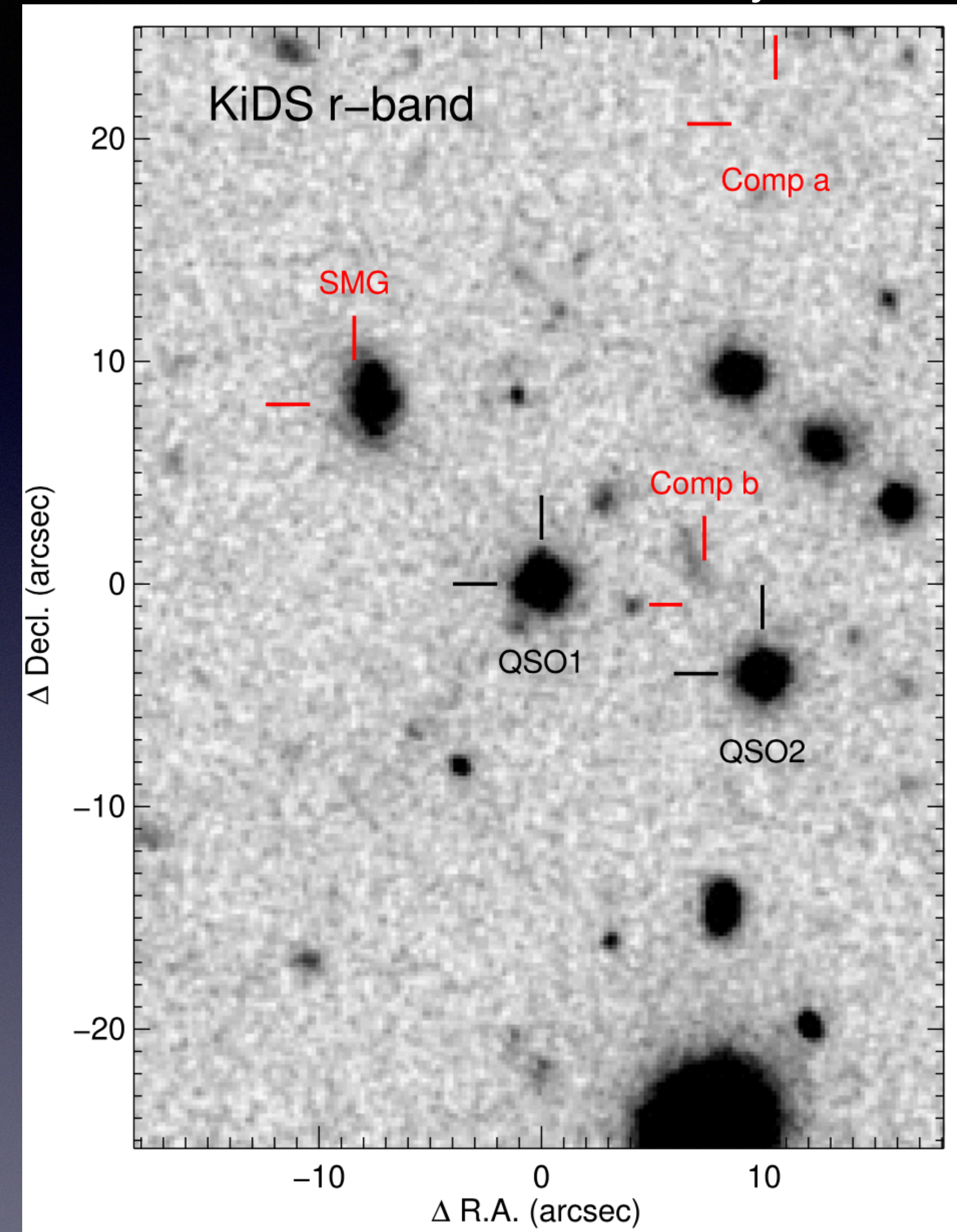


Our Story Begins Here

- Submillimeter Galaxy (SMG)
- Two Quasars (QSO) in the background of the SMG

Target	RA	DEC	$\text{Log}\left(\frac{L_{\text{bol}}}{L_{\odot}}\right)$	z
SMG	138.4147767	-1.1156772	-	2.65
QSO1	138.4124260	-1.1179280	~12.7	2.916
QSO2	138.4096520	-1.1190520	~12.6	2.75

The GAMA J0913-0107 System



Goal: Detect Hydrogen Lyman-alpha Emission

Lab λ : 1215.67 Å

At $z \sim 2.8$, $\lambda \sim 4600$ Å

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Possible Power Mechanisms

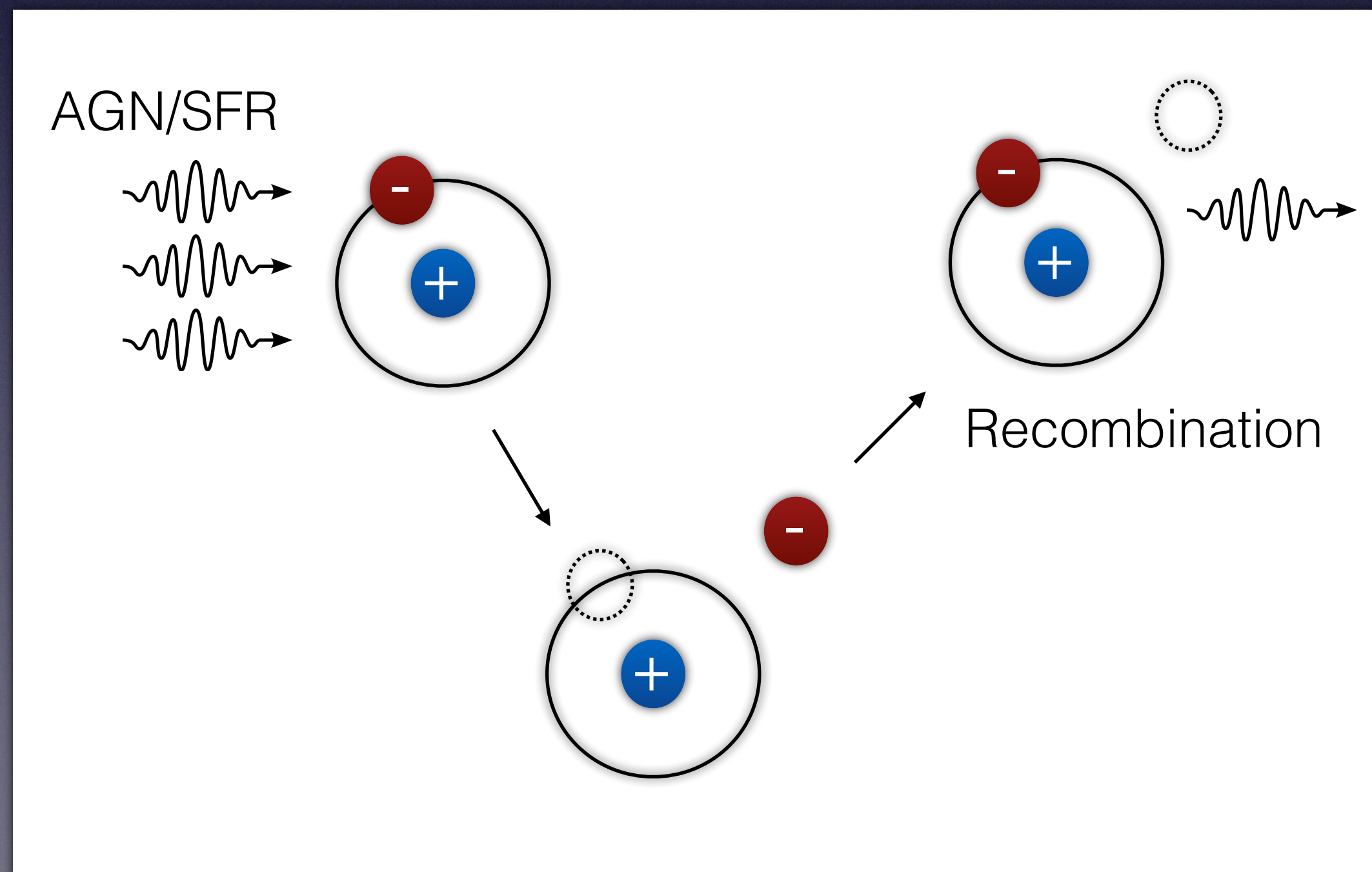
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Possible Power Mechanisms

Photoionization



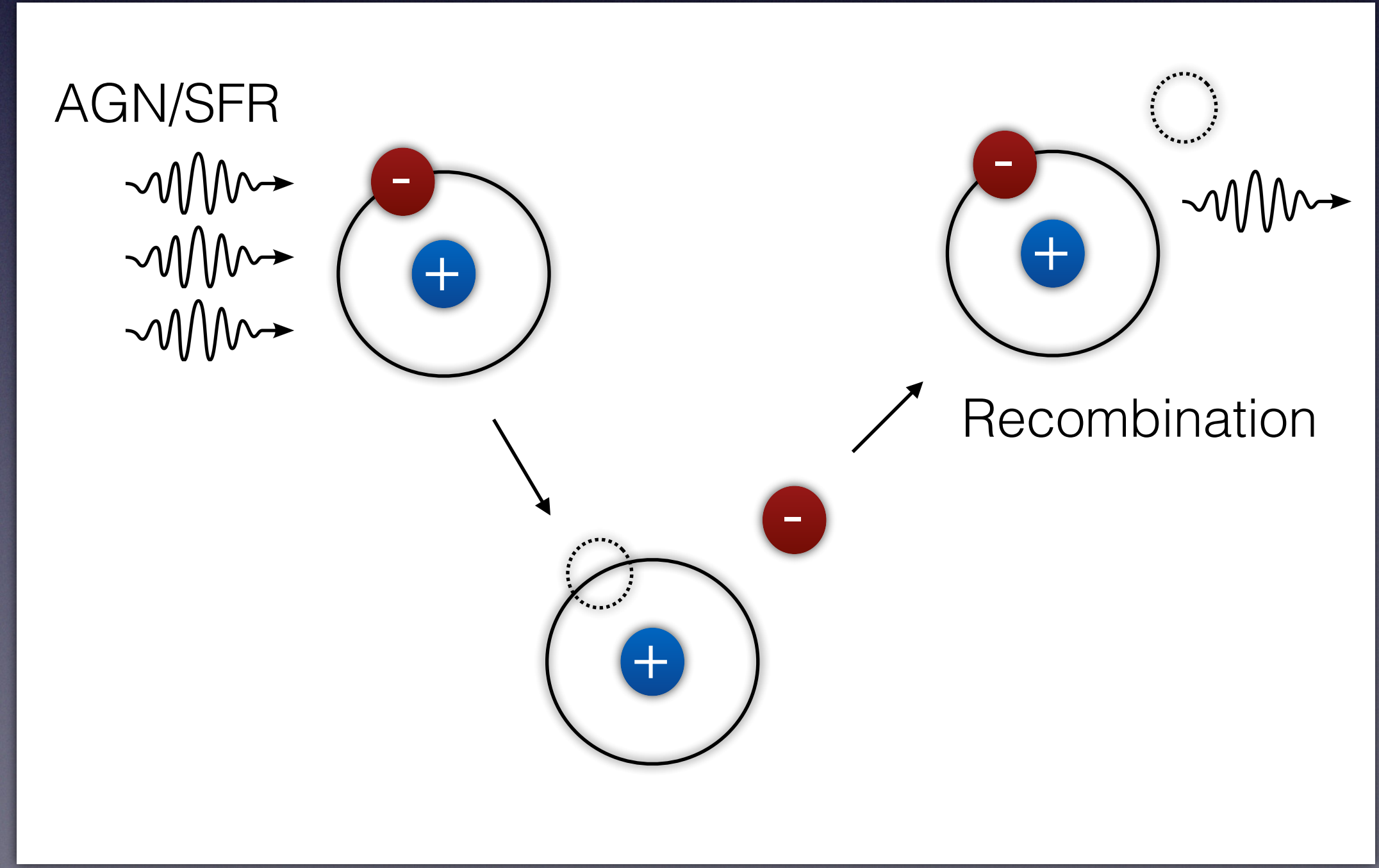
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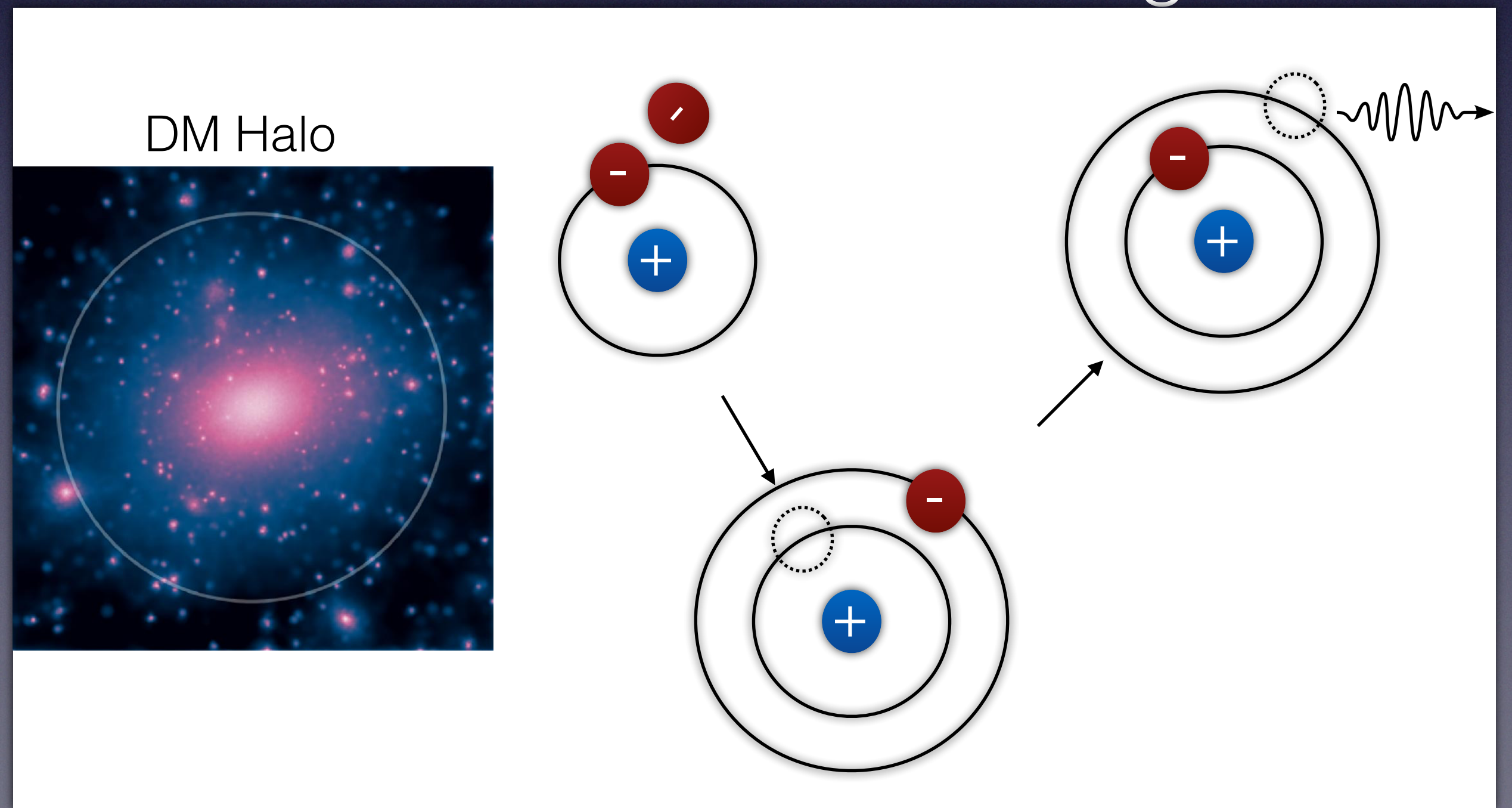
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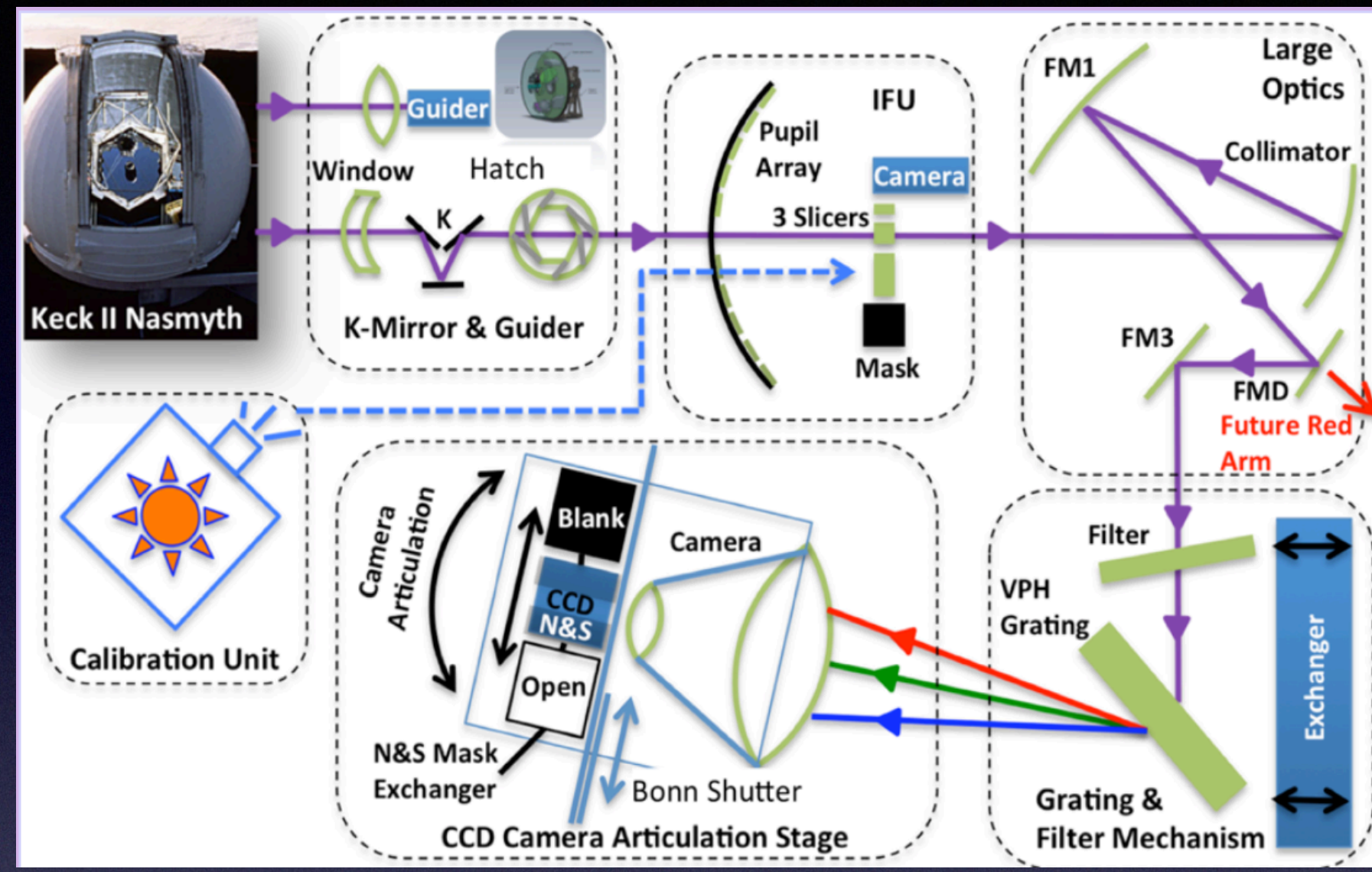


Gravitational Cooling



Keck Cosmic Web Imager (KCWI)

Integral Field Spectrograph



Configuration

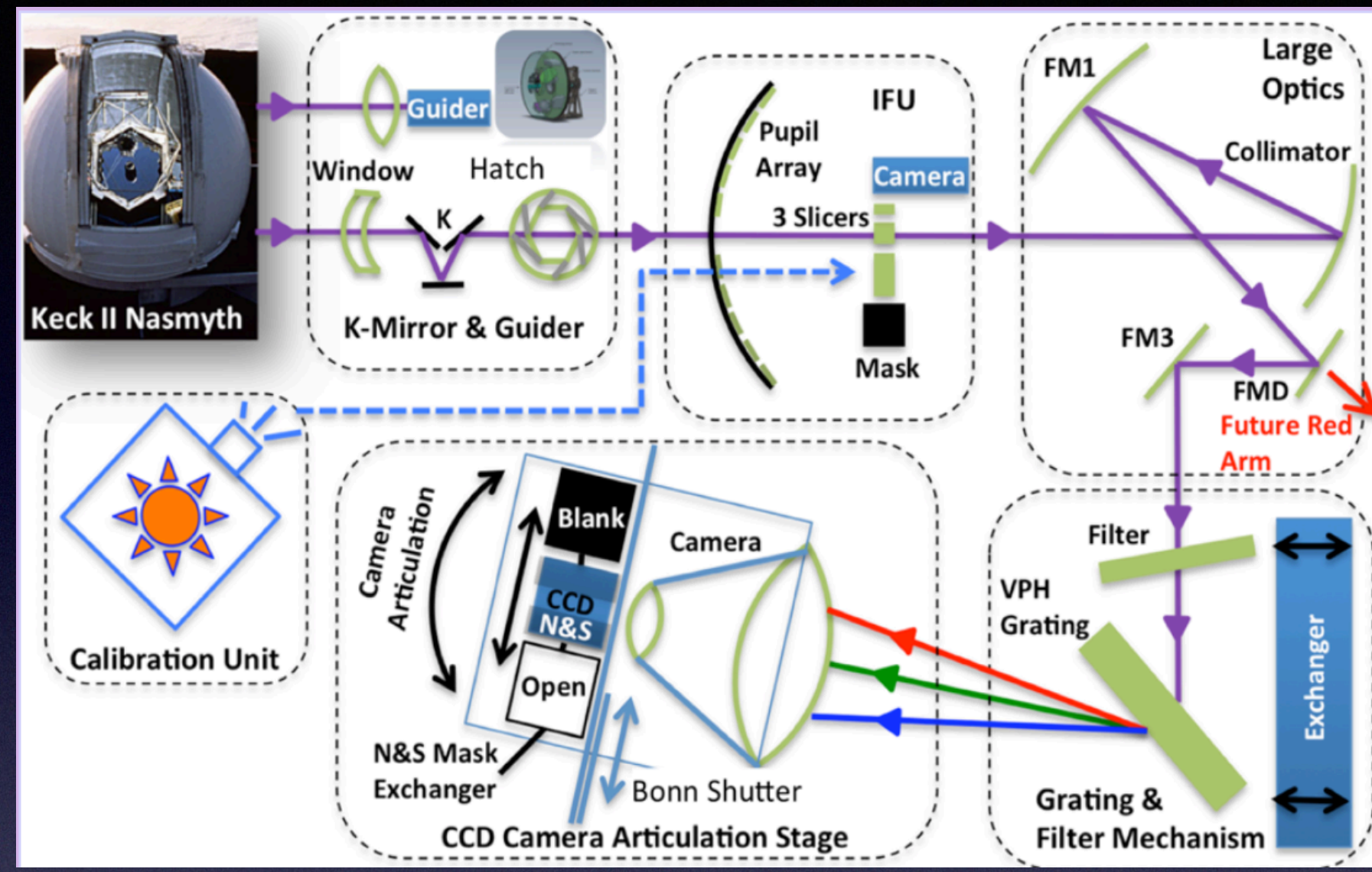
Grating	FOV	$\Delta\lambda$ (\AA)	Slicer	Slice Width
BM	33" x 20.4"	0.5	Large	1.35"

λ Coverage : 3500-5500 \AA



Keck Cosmic Web Imager (KCWI)

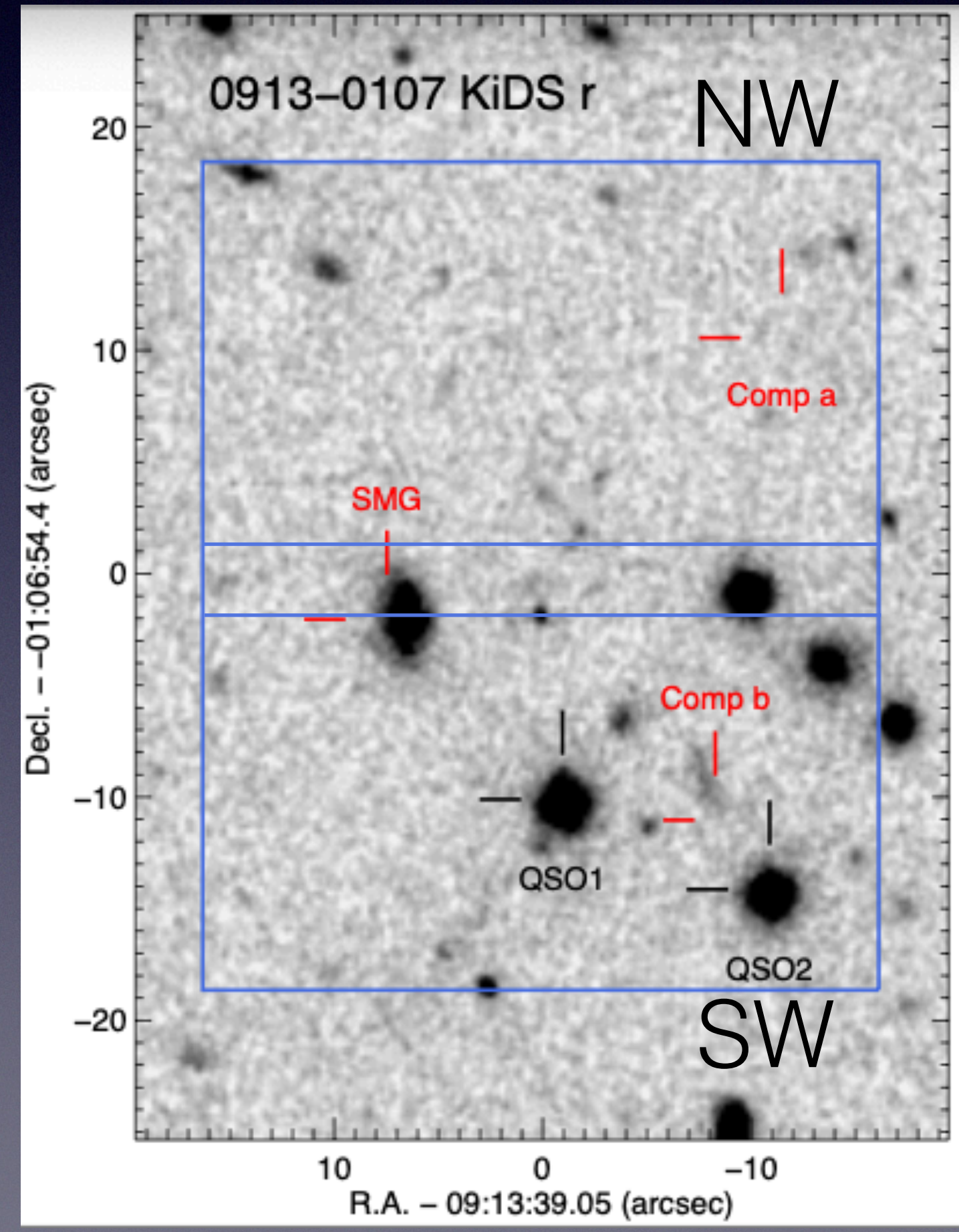
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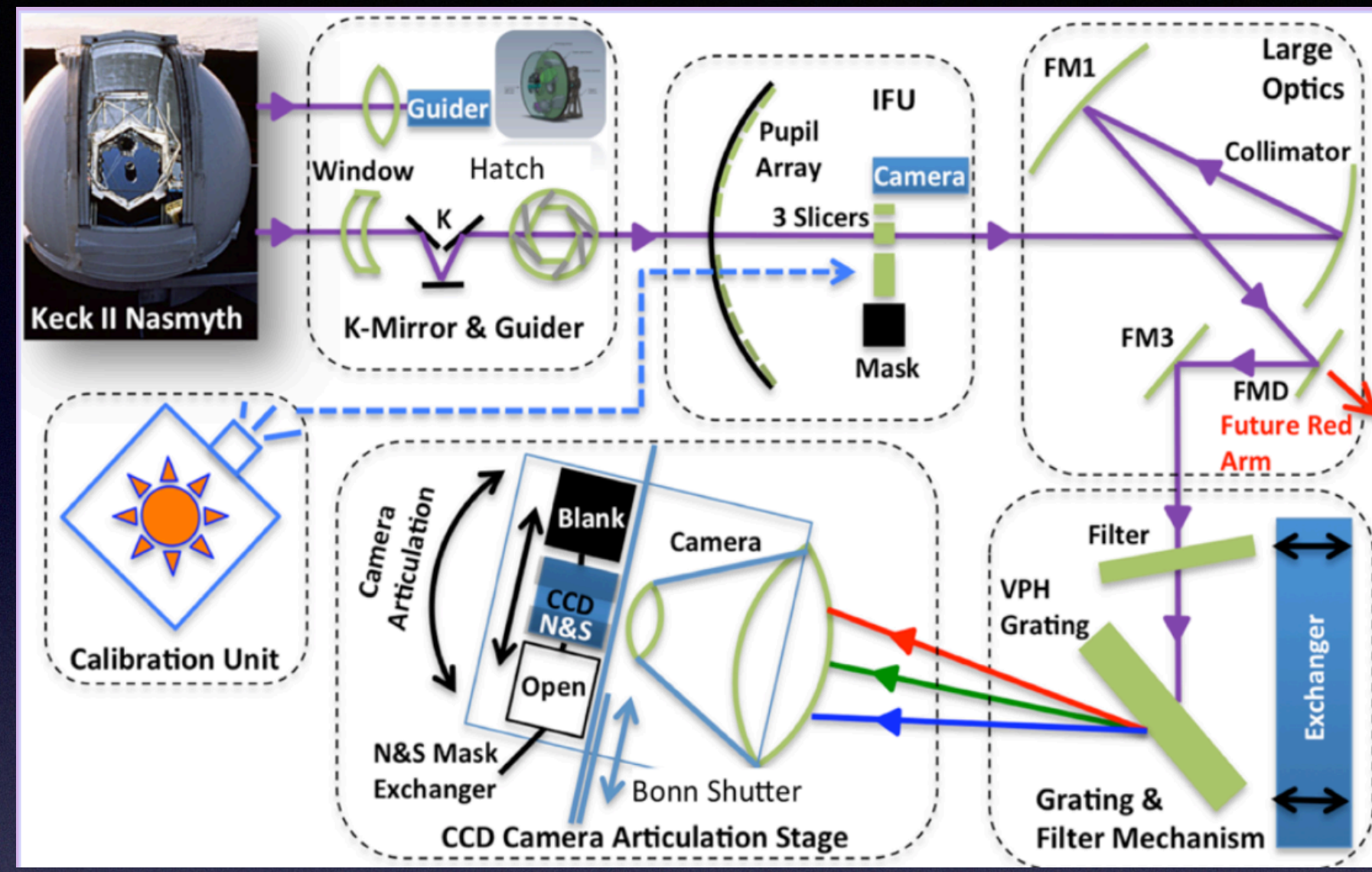
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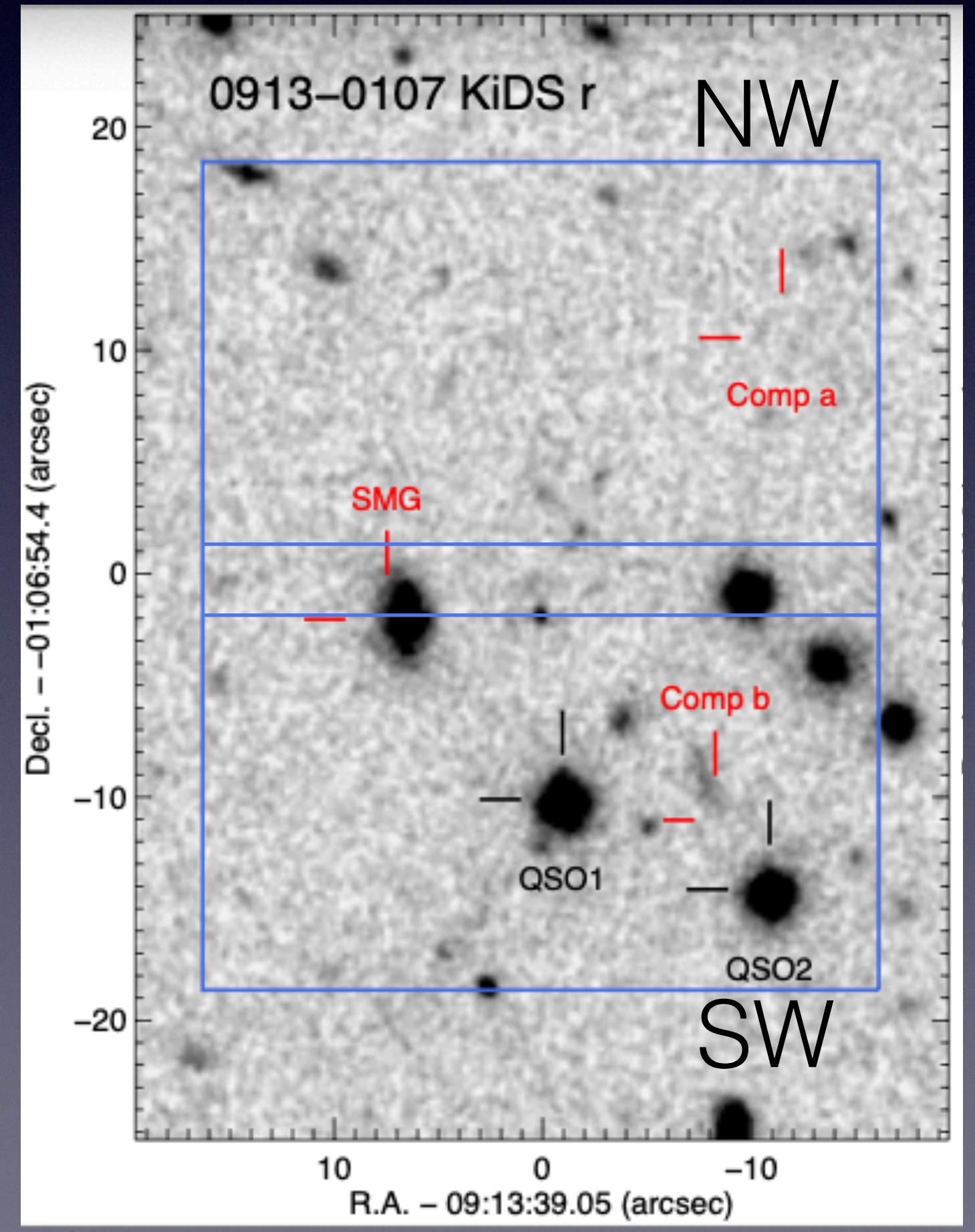


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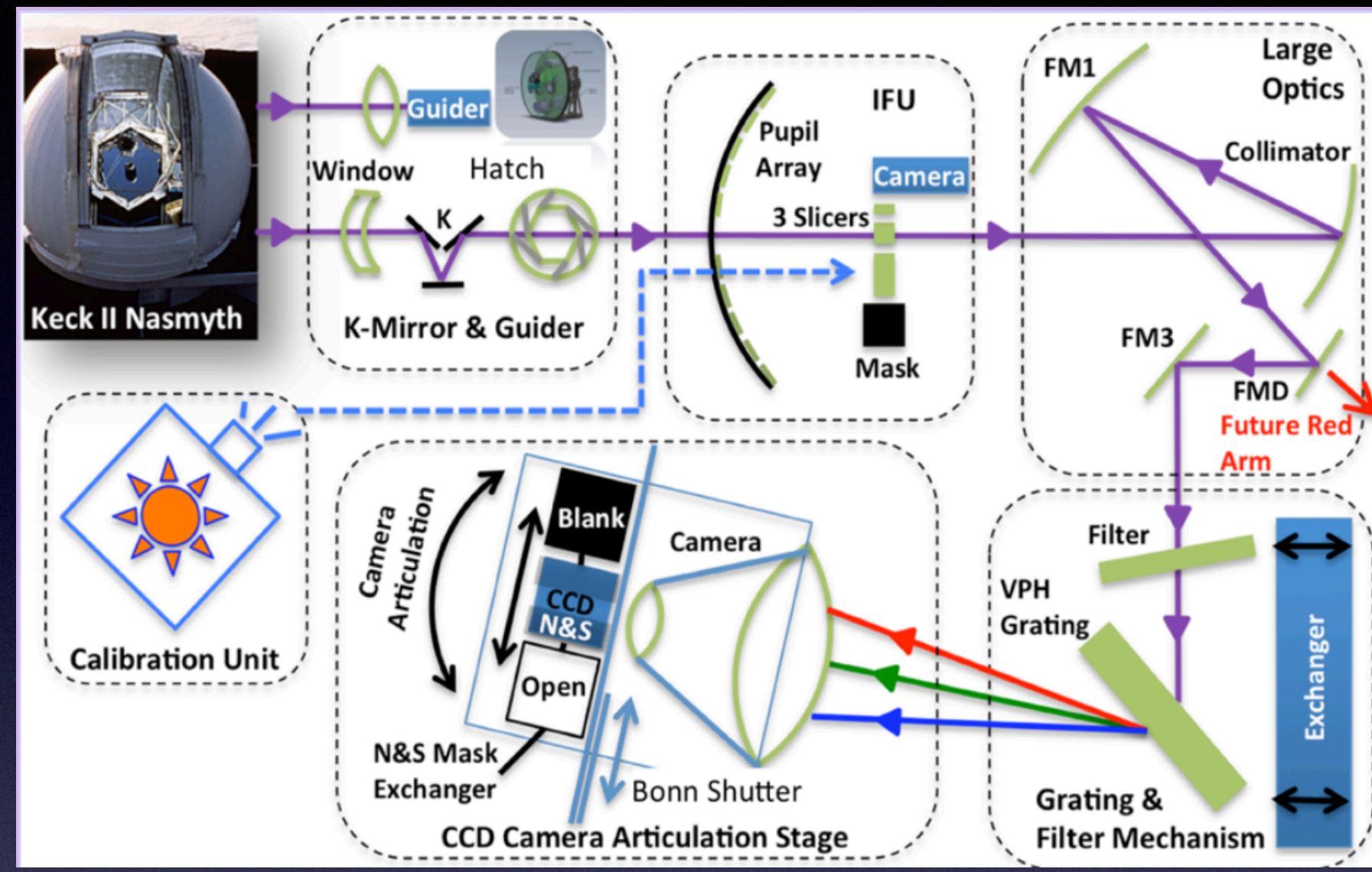
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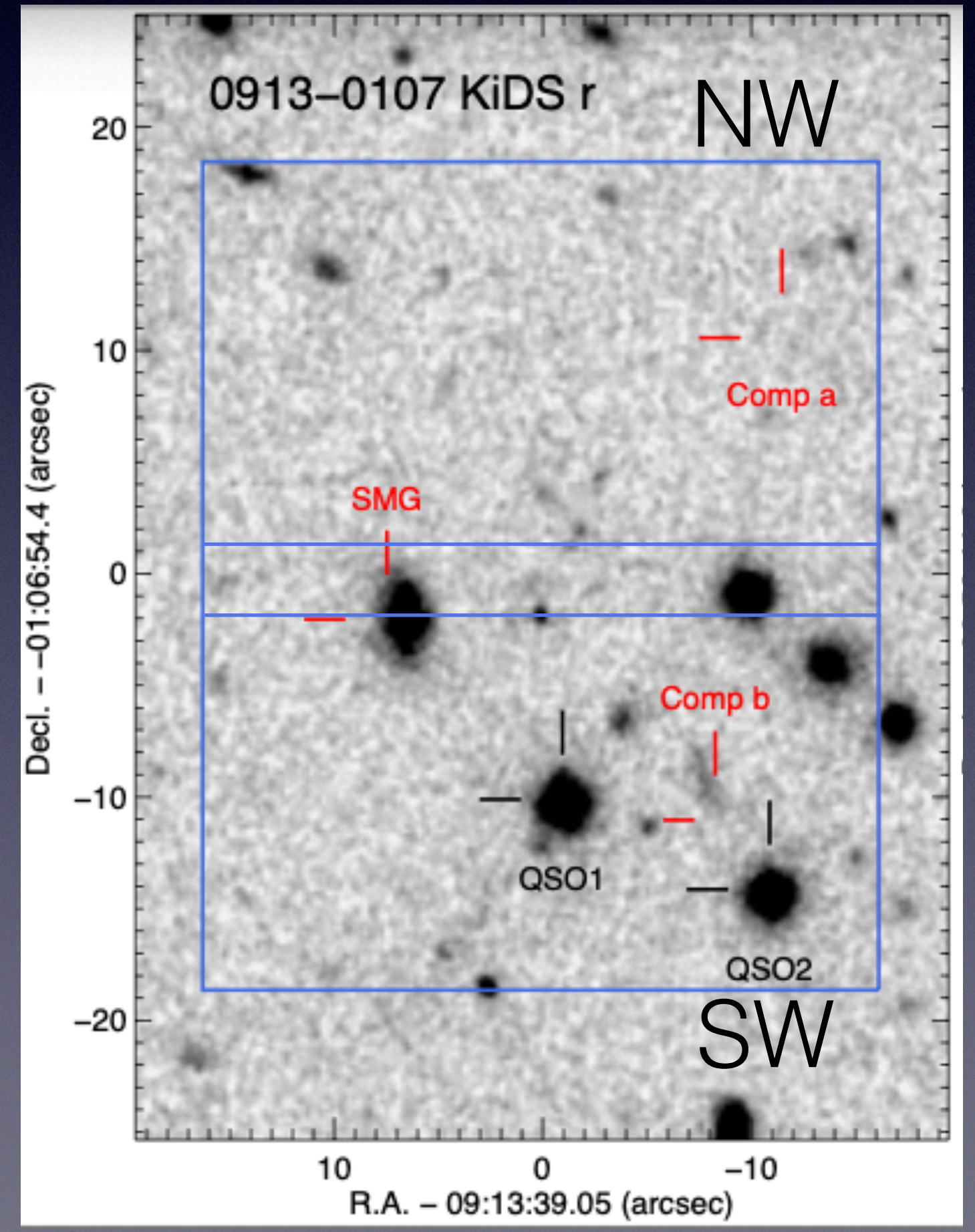
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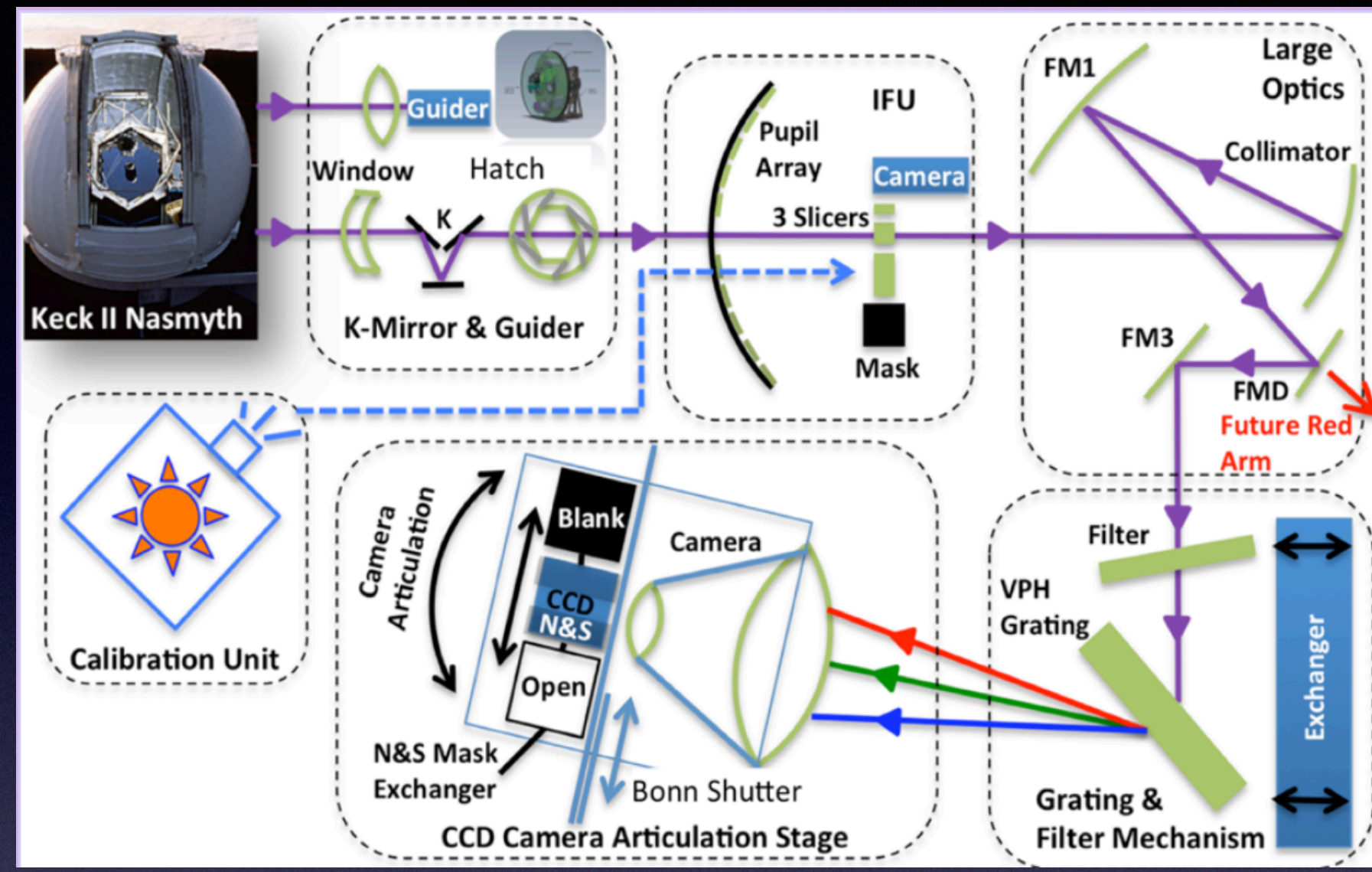
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Field	# of Frames (20 Minutes)	Total Exposure Time (hours)
NW	6	2
SW	7	2.33
NW + SW	-	4.33



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Integral Field Spectrograph



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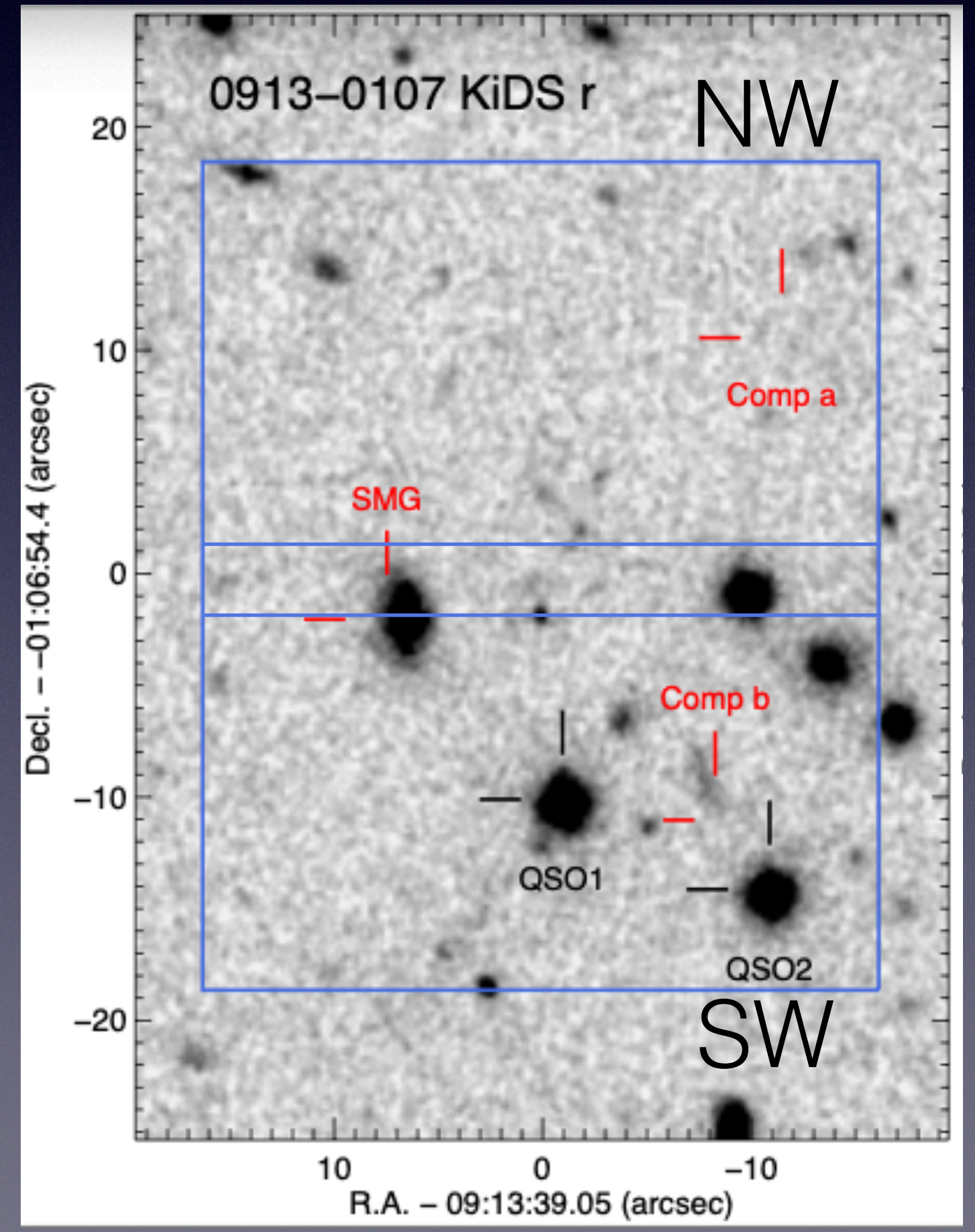
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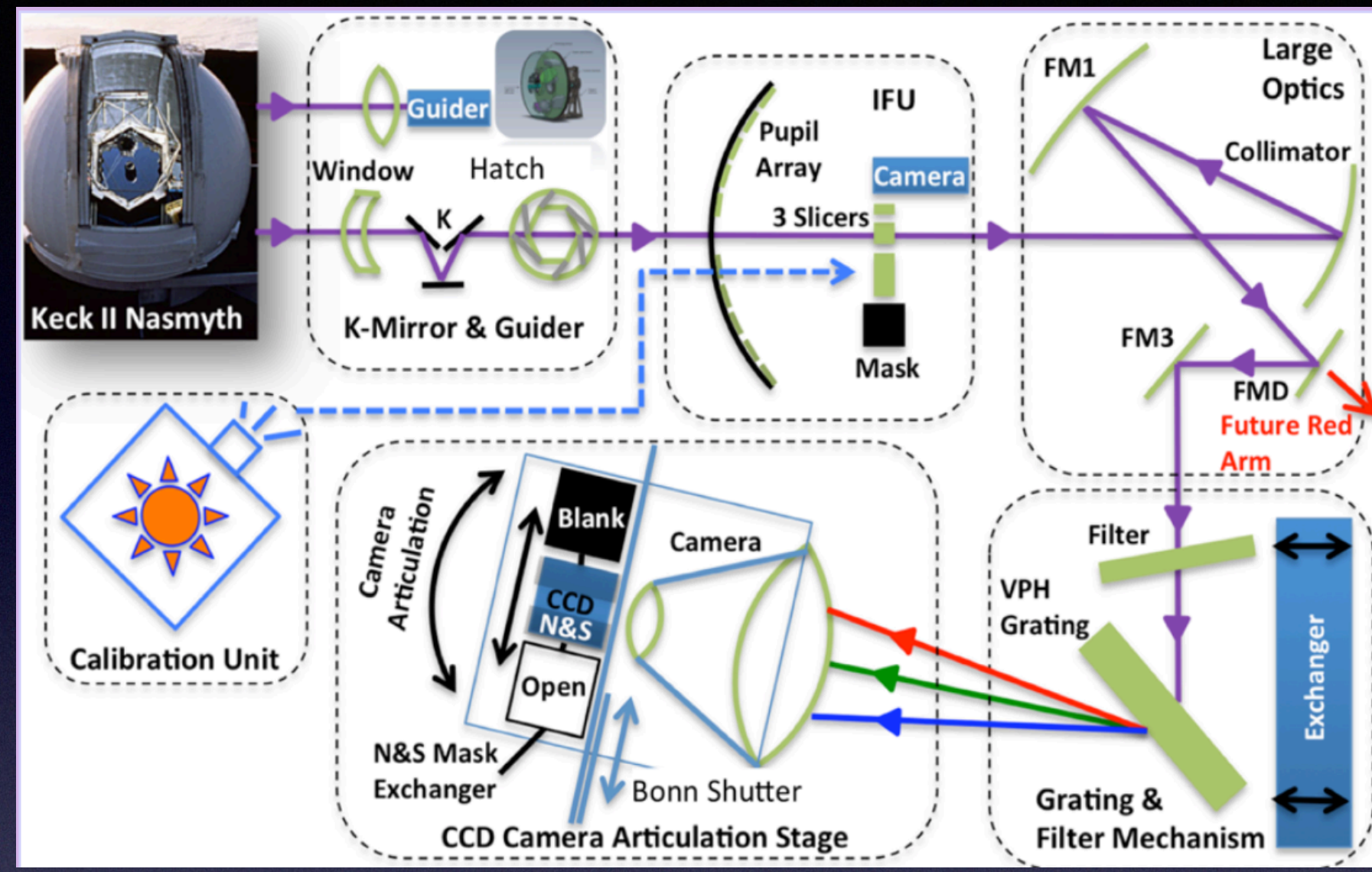
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Lost a NW Frame from a passing satellite



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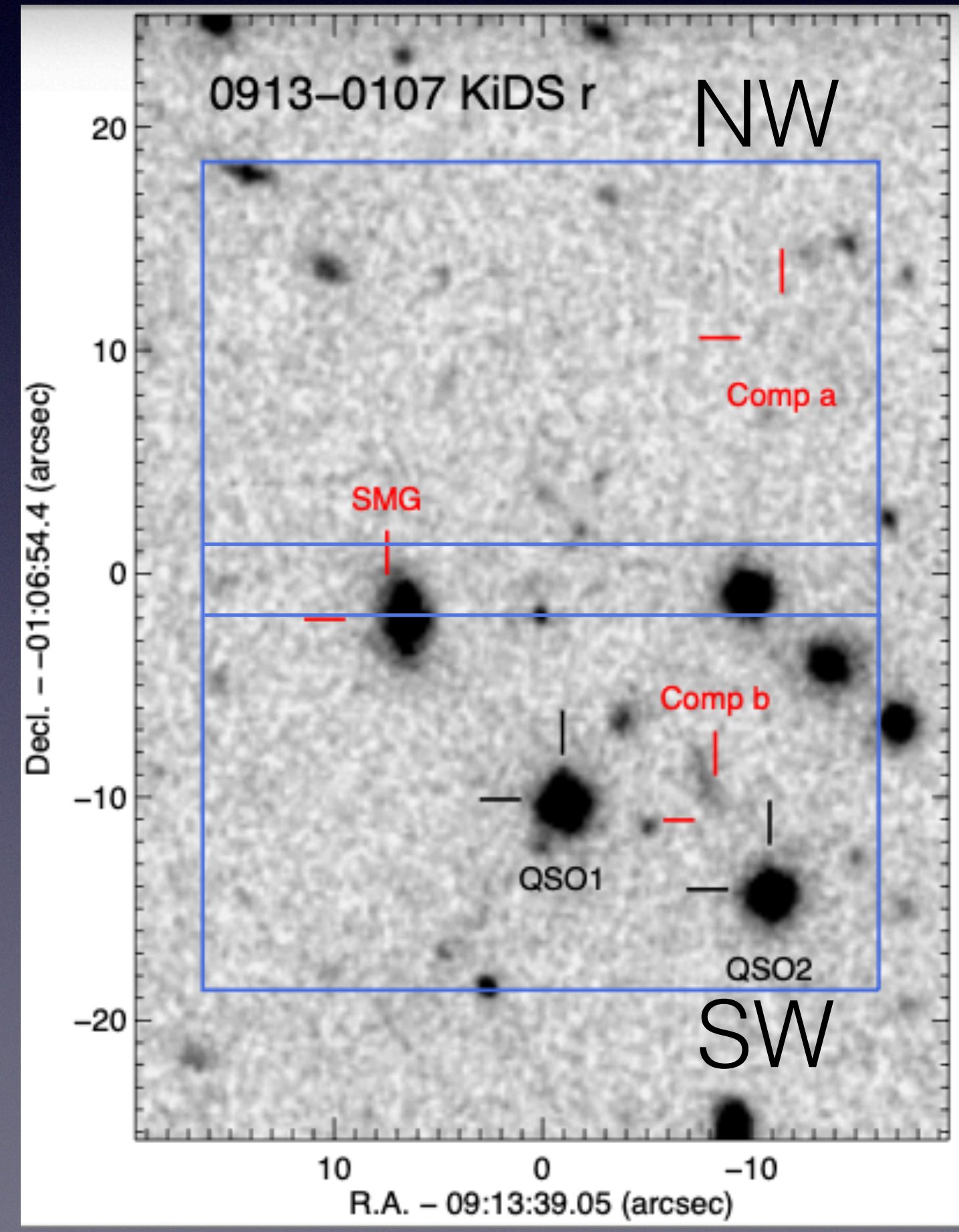
Observing Night: Jan 31 2022



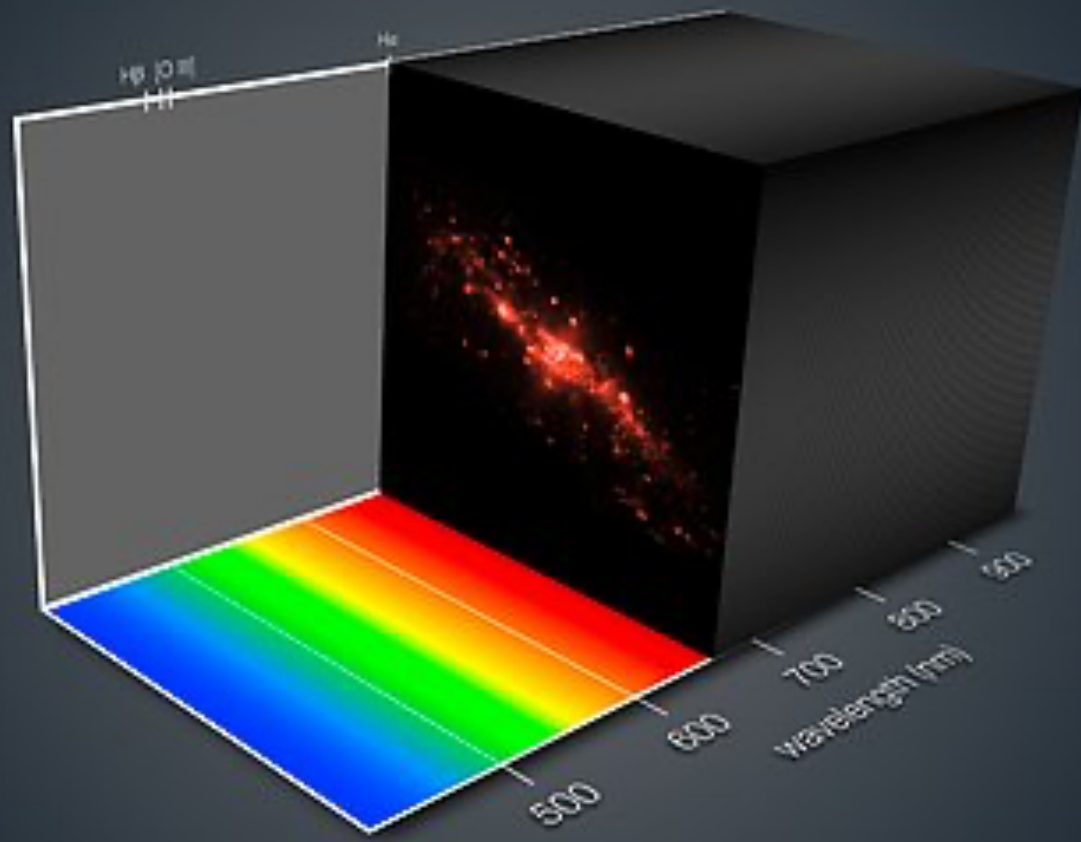
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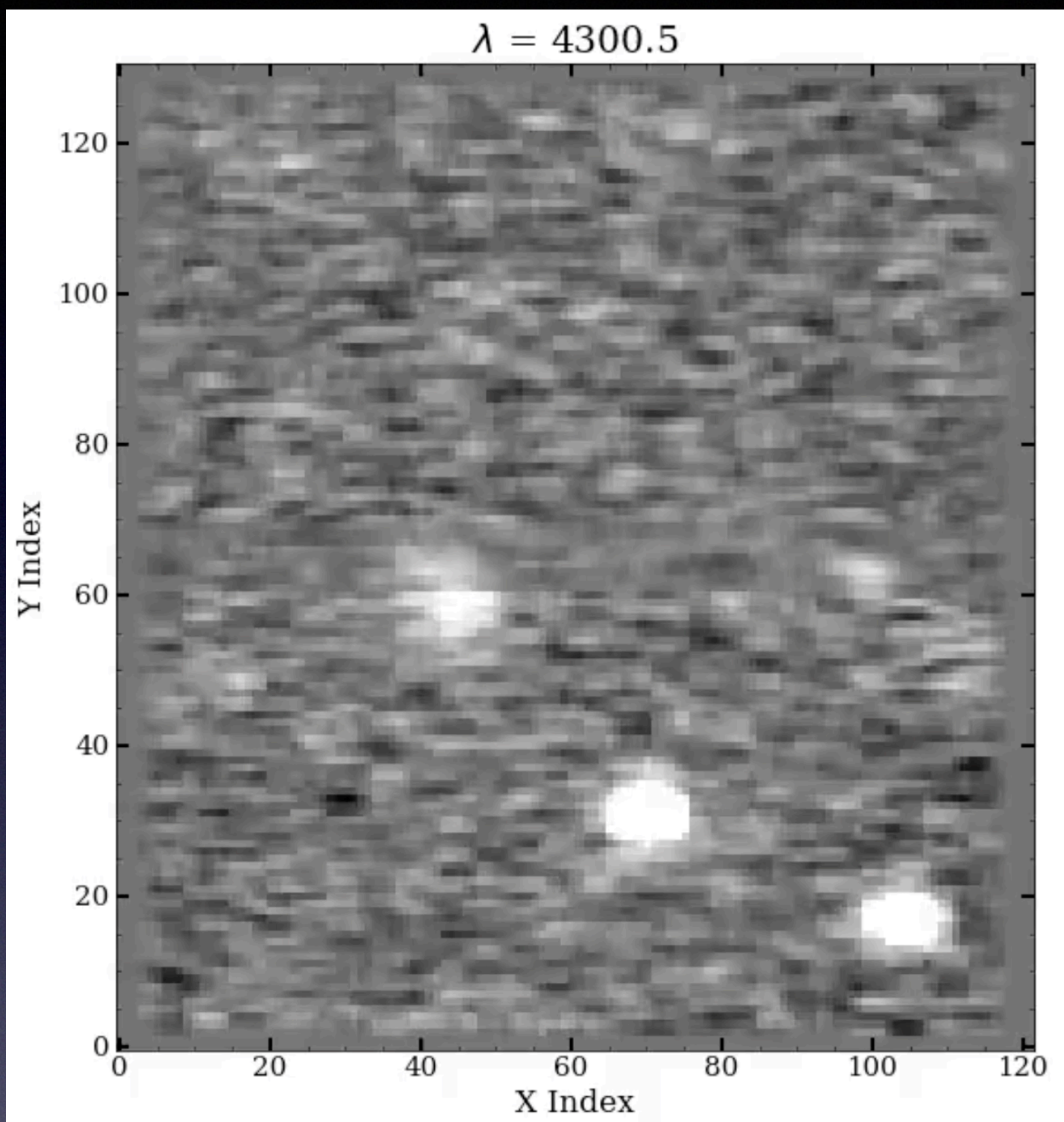
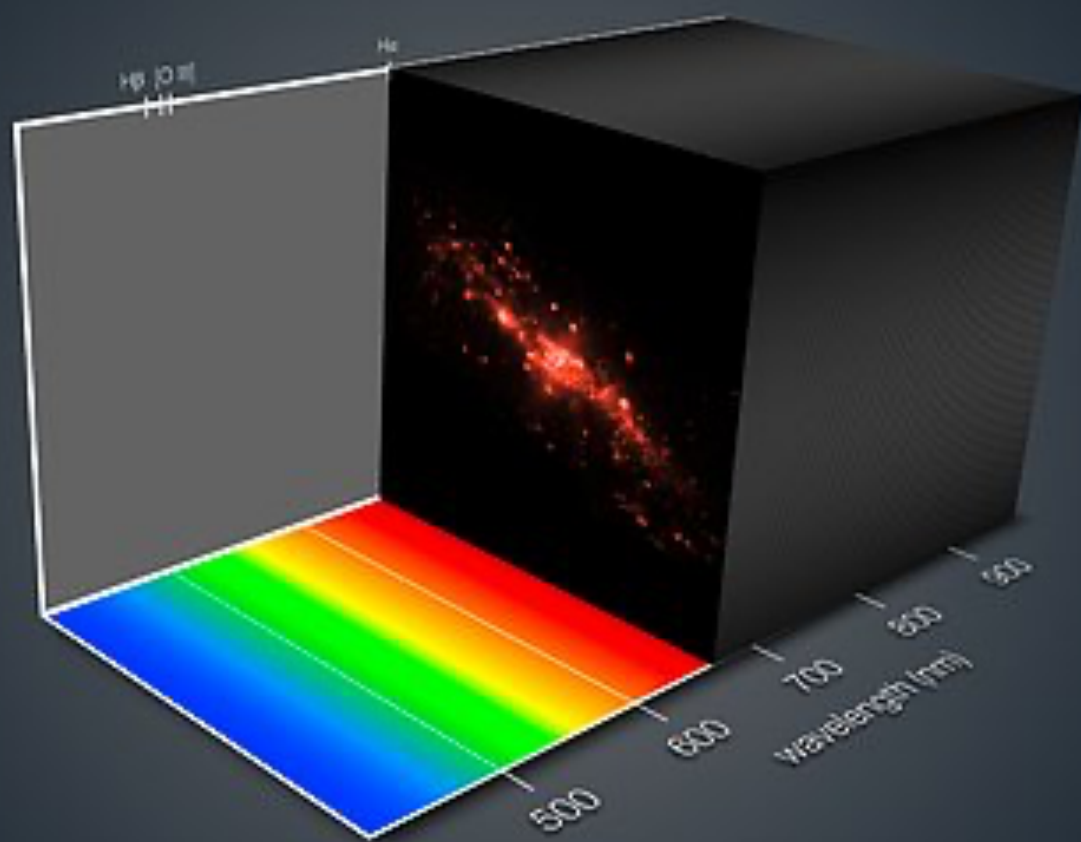
Lost a NW Frame from a passing satellite



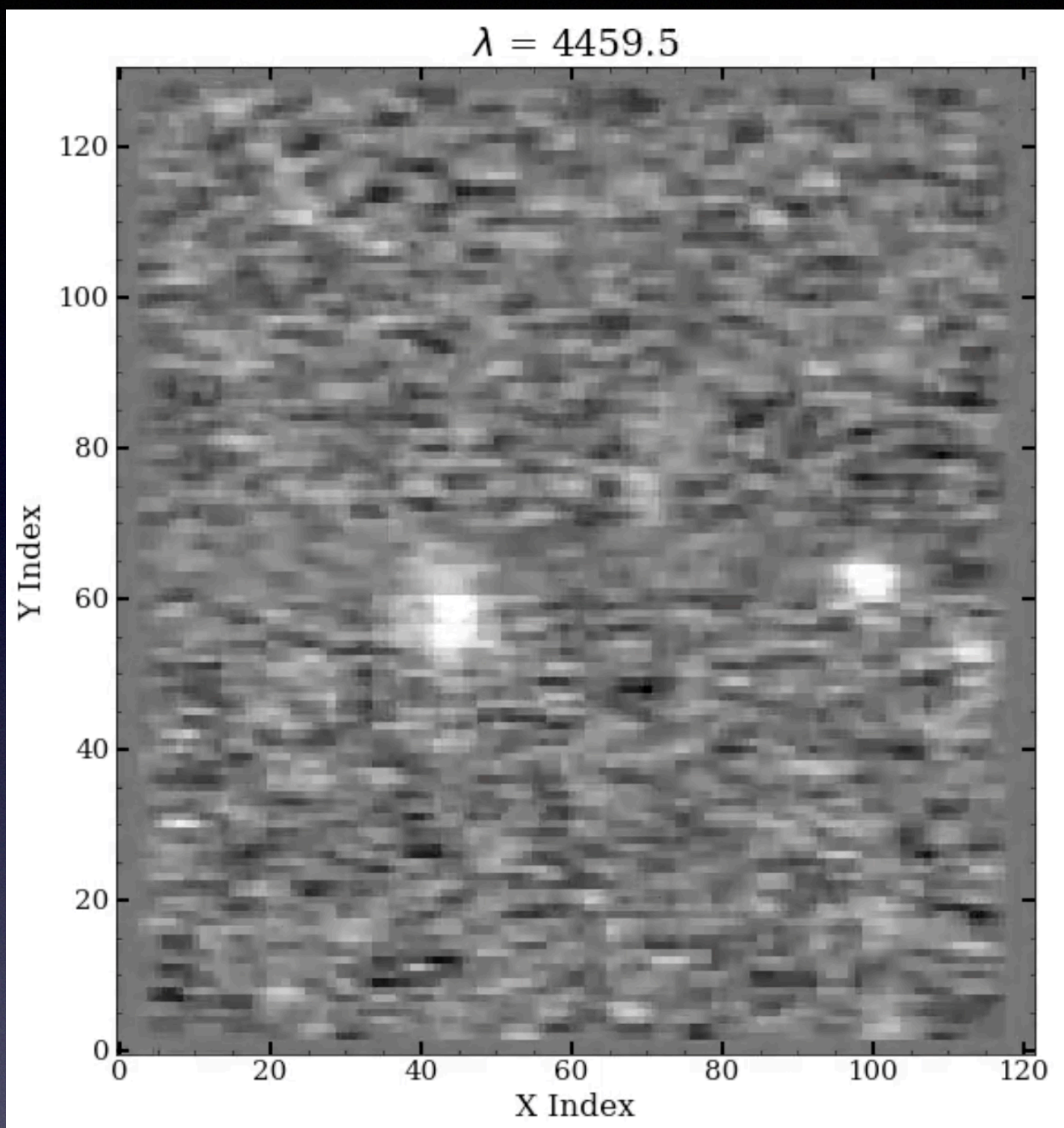
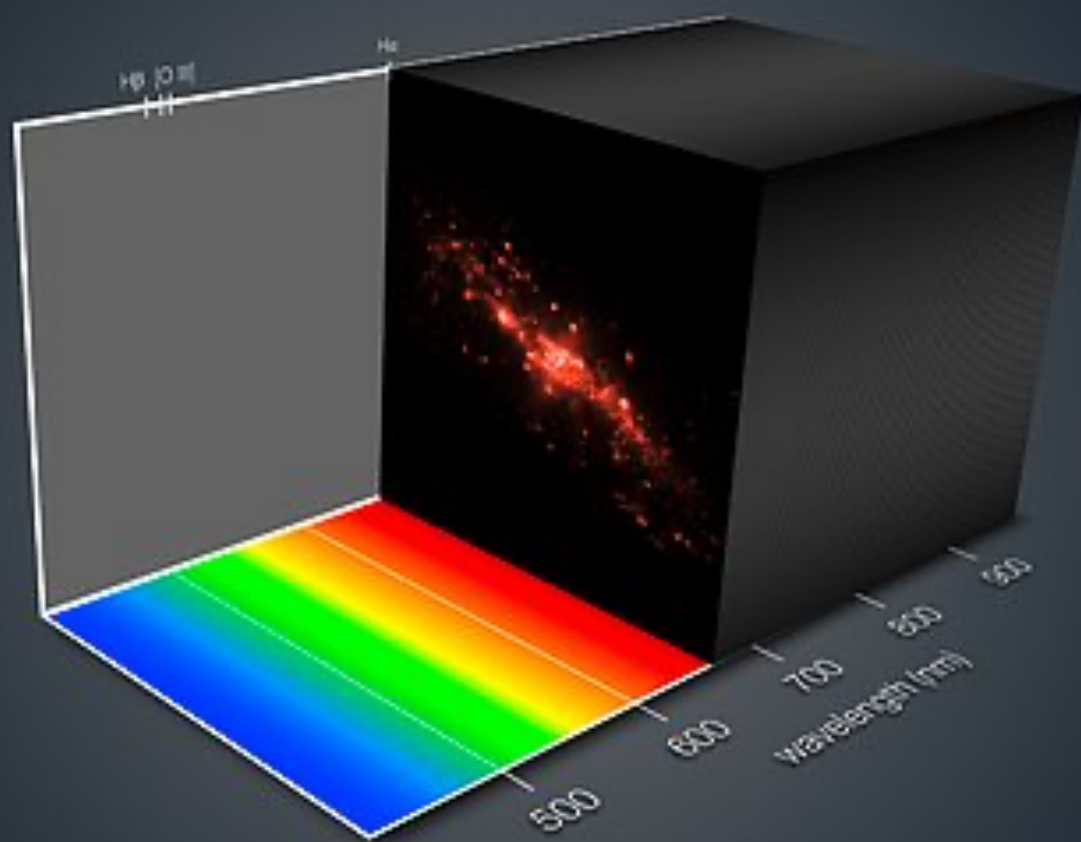
3D Datacube



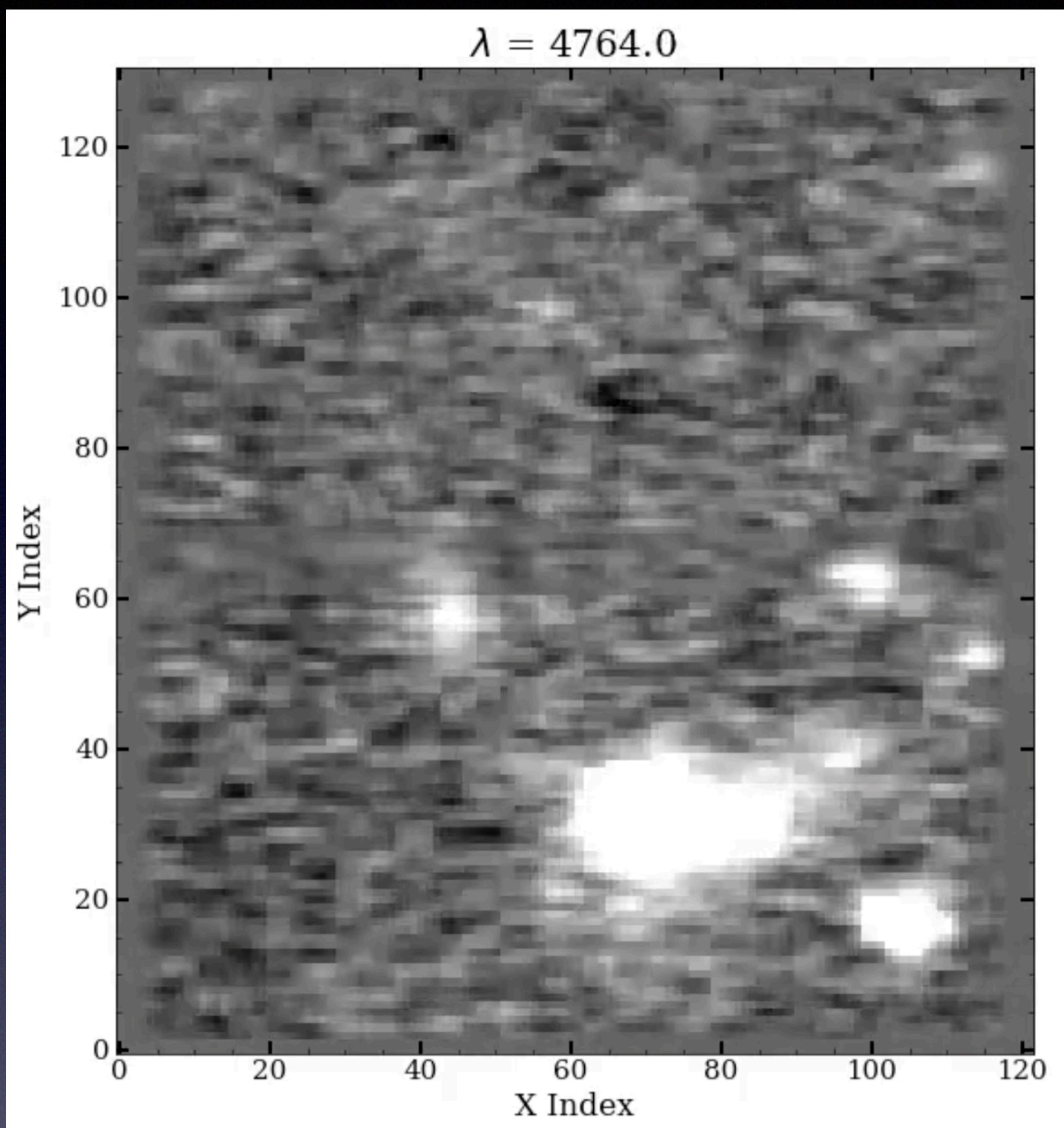
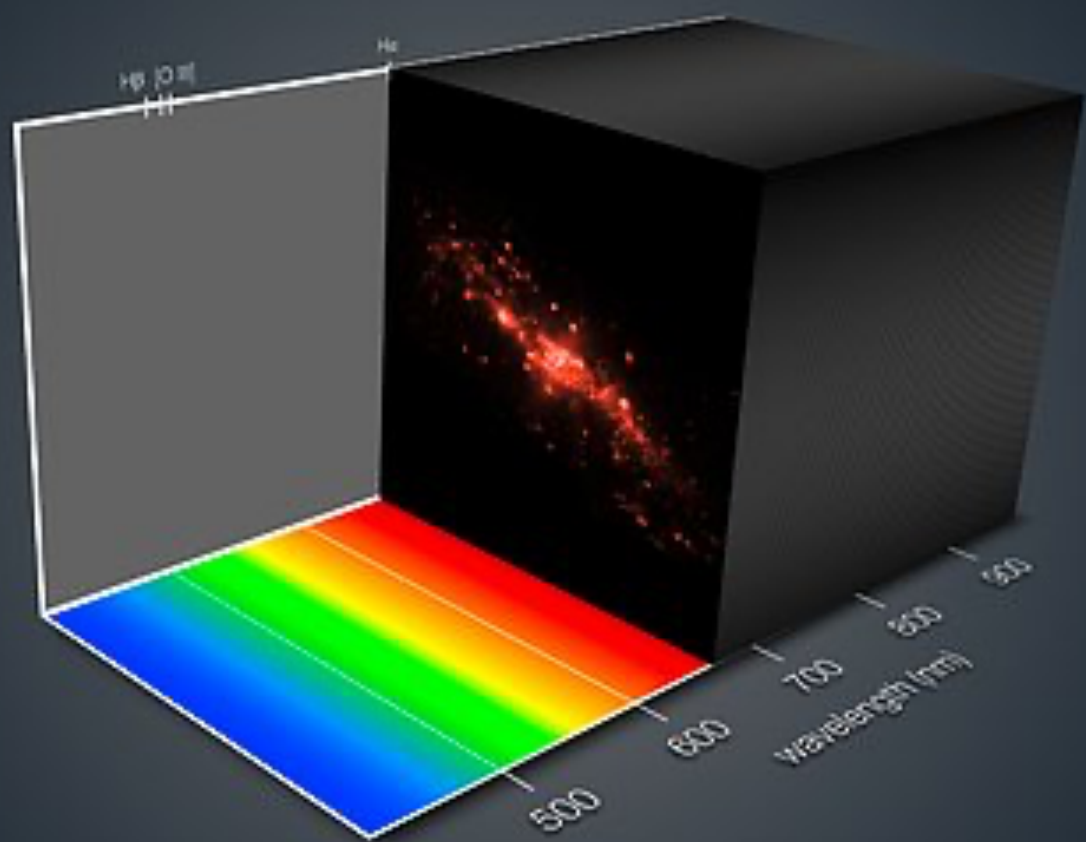
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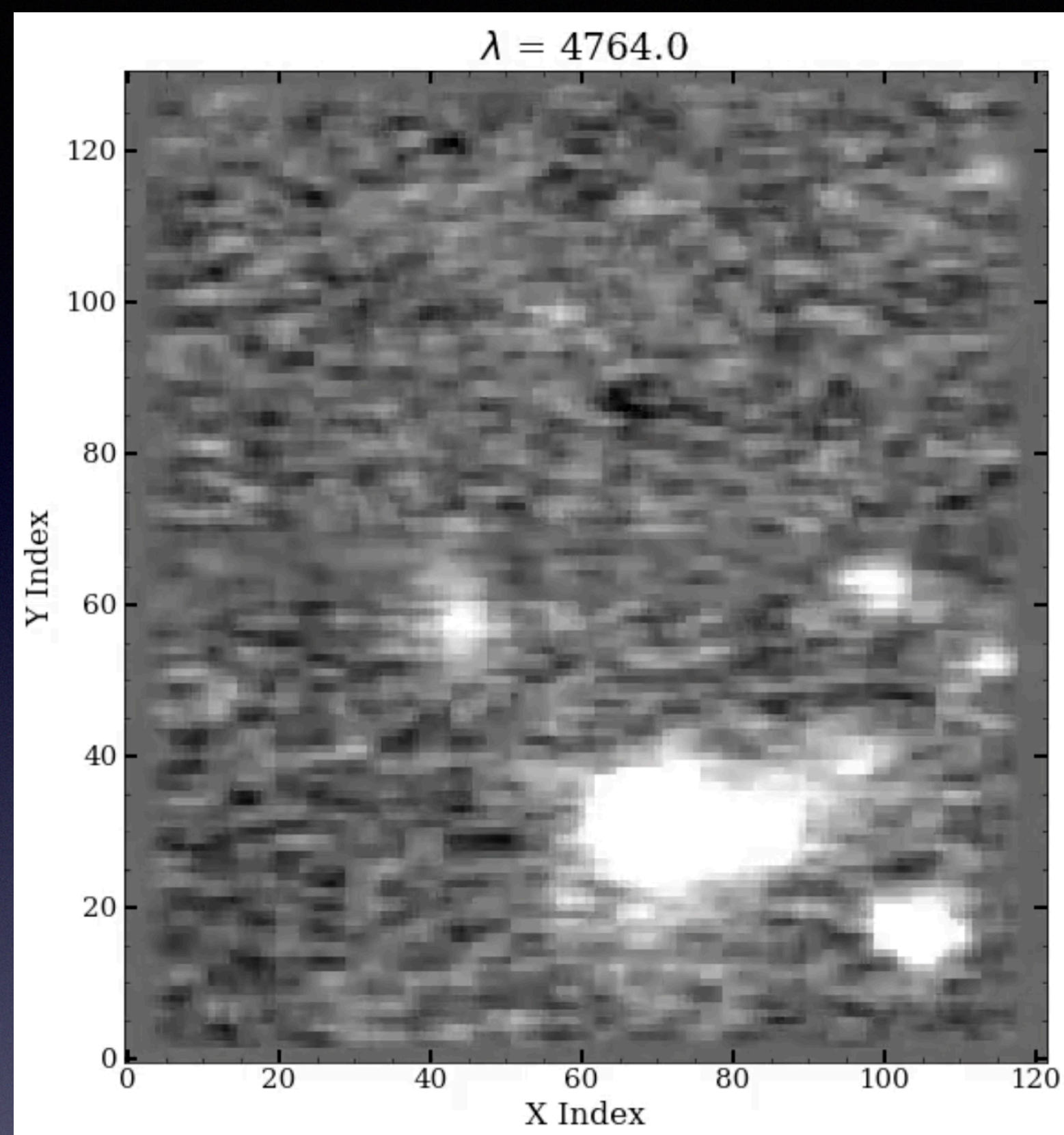
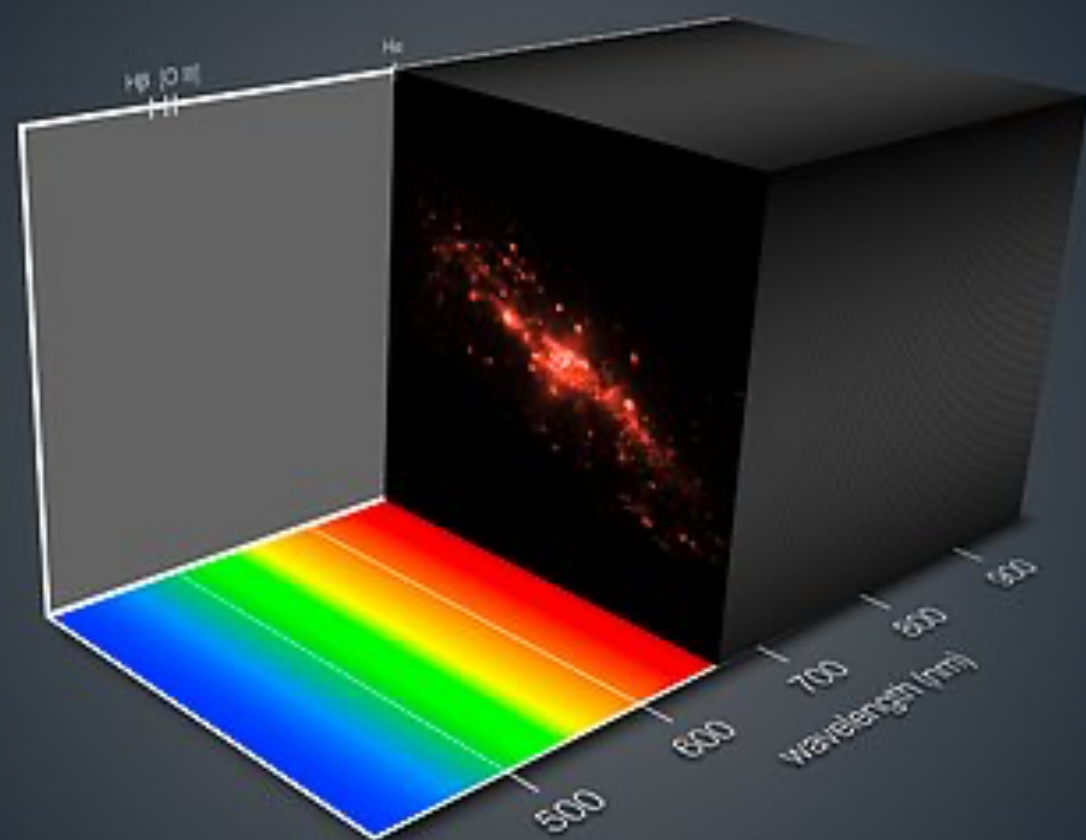
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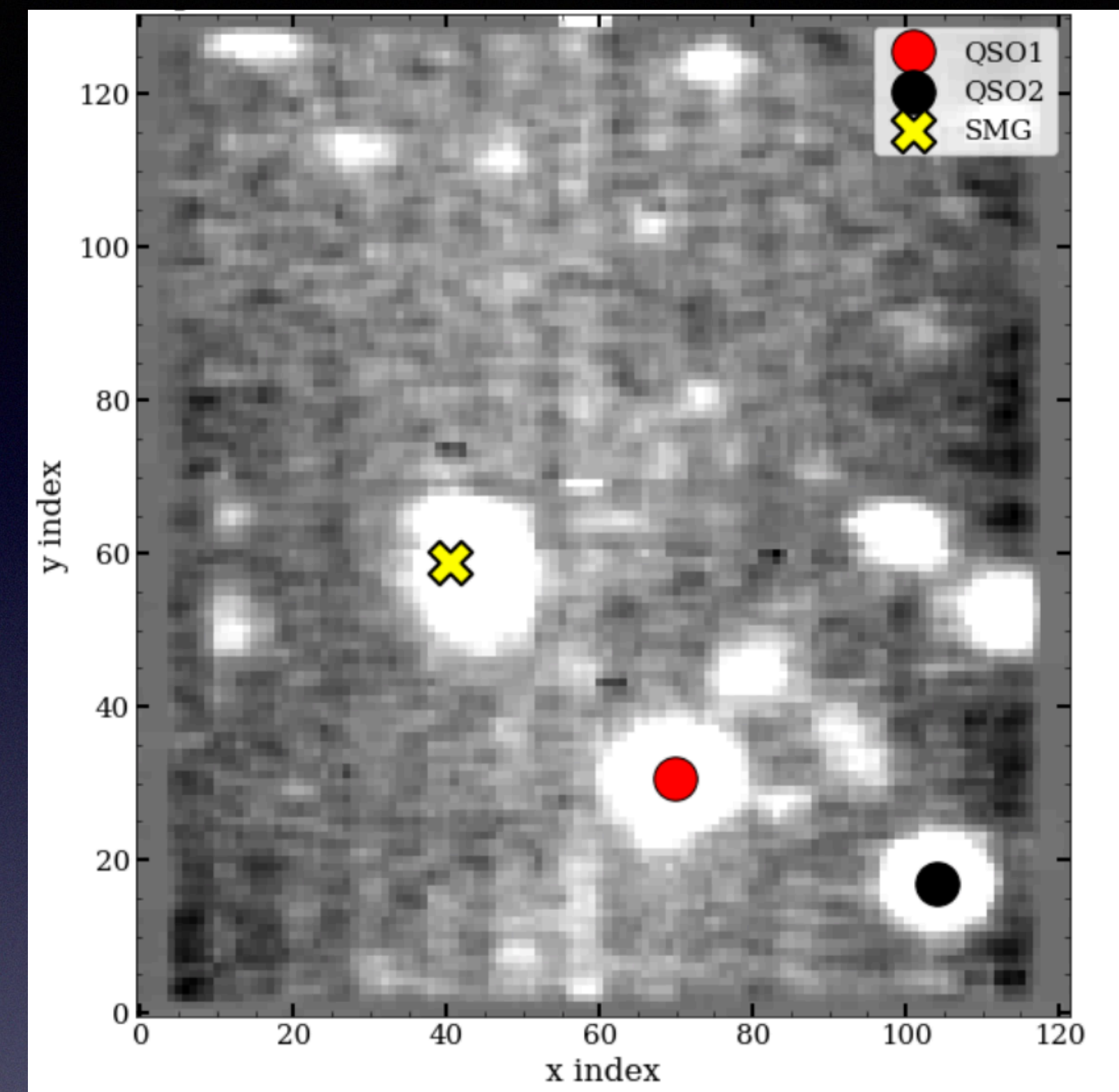
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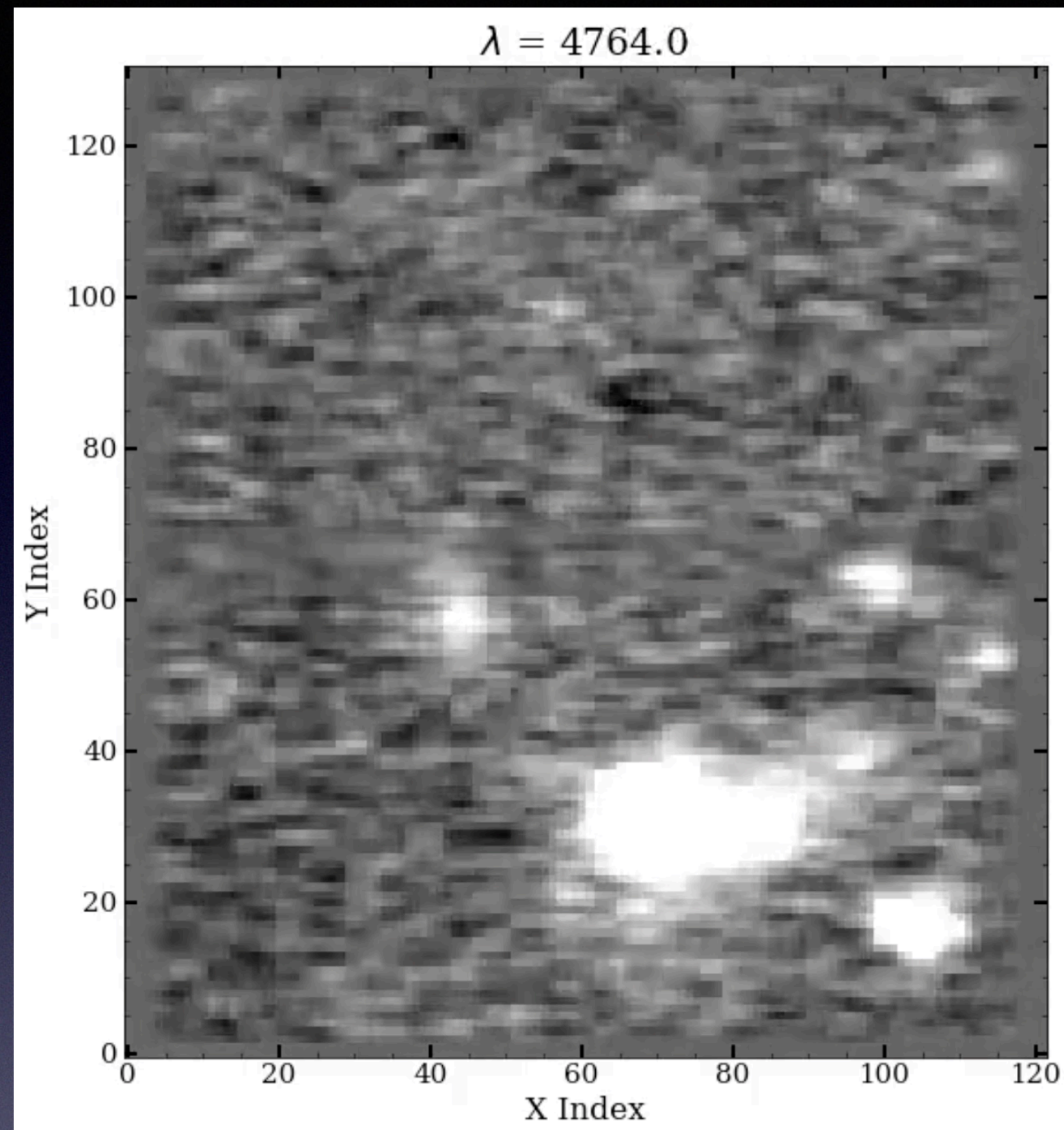
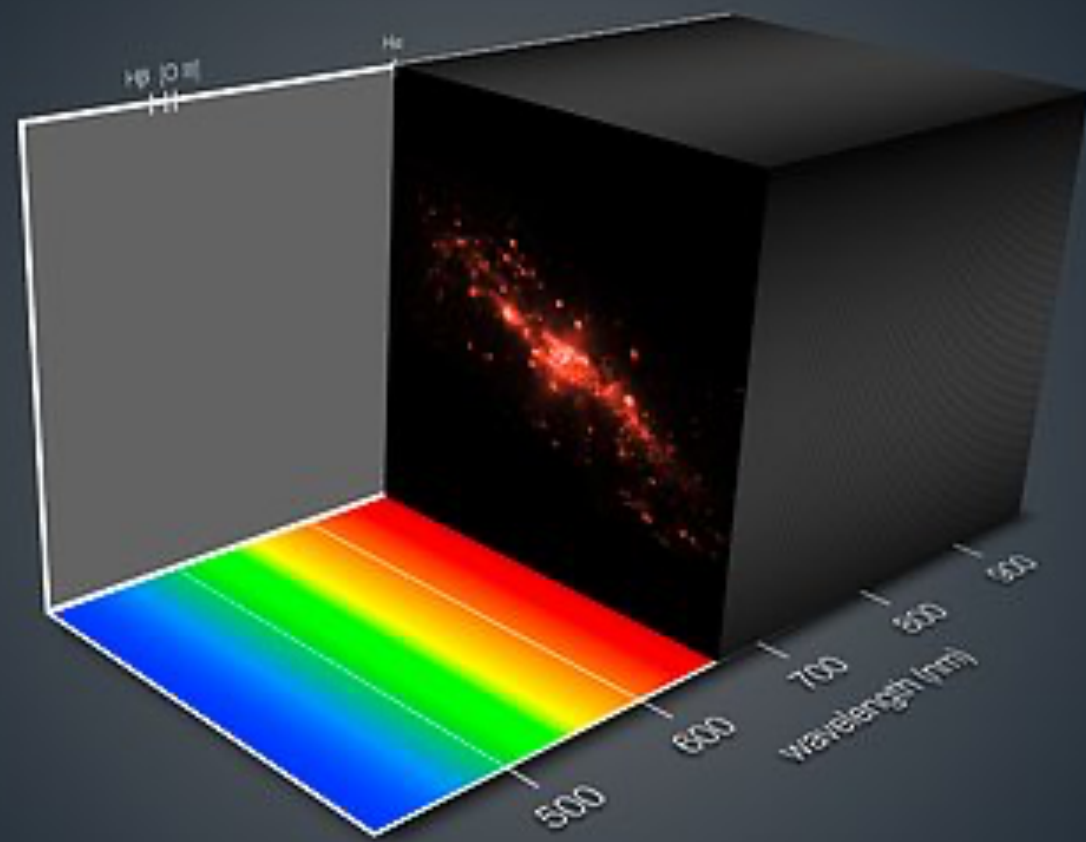
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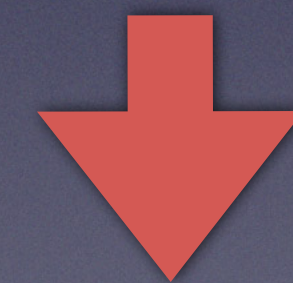
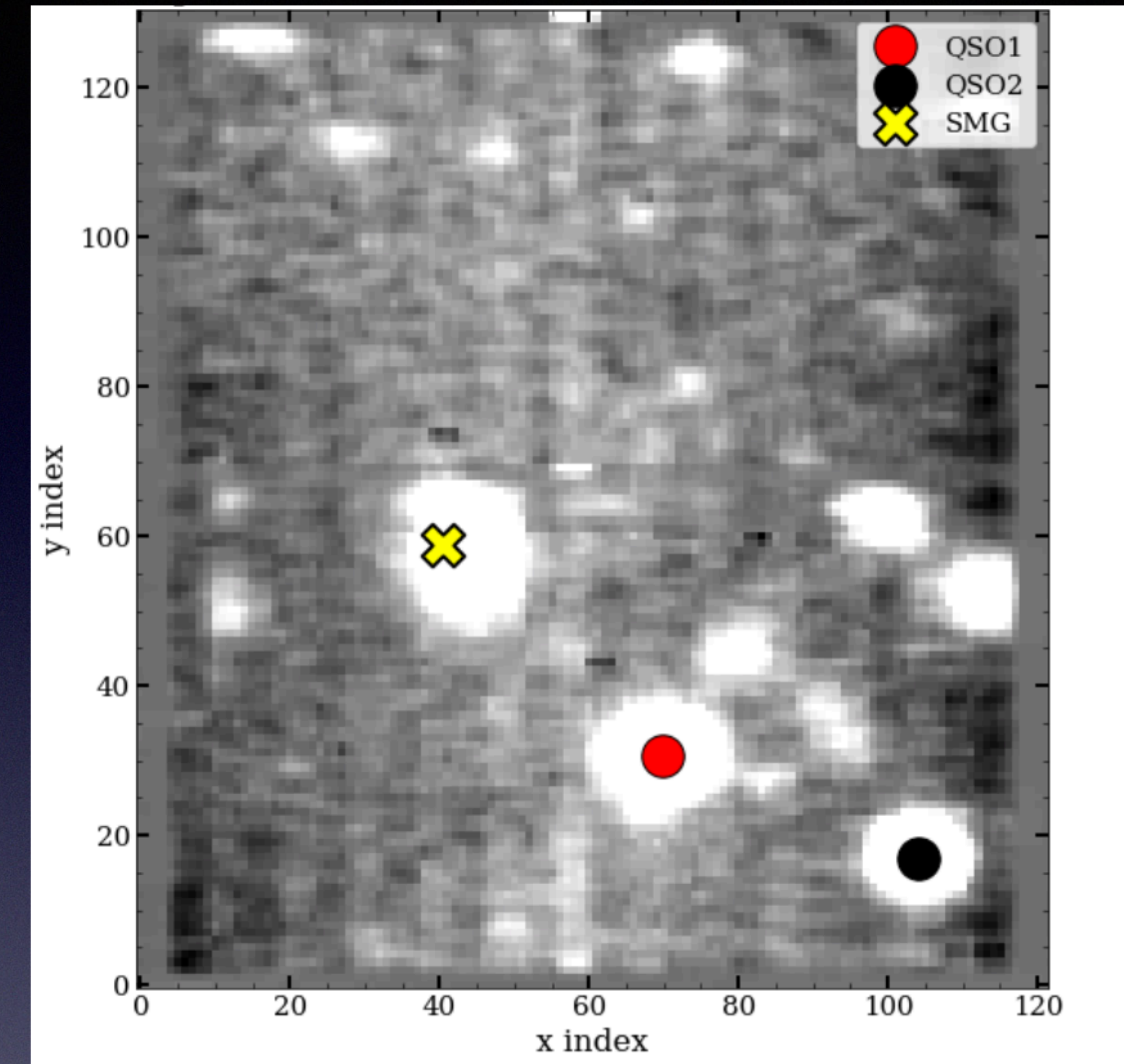
"Collapsed" KCWI Datacube



3D Datacube



“Collapsed” KCWI Datacube

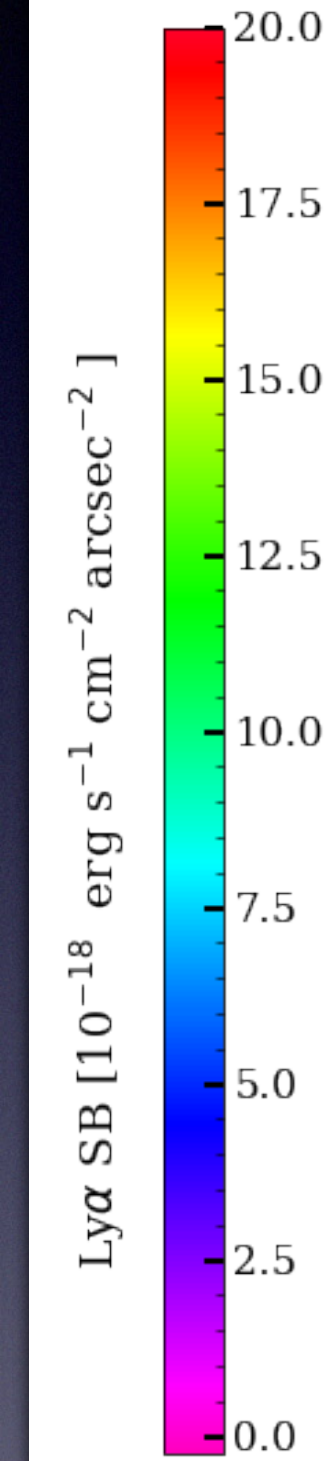


Need to extract emission from “busy” cube

Analytical Method Applied to Datacube

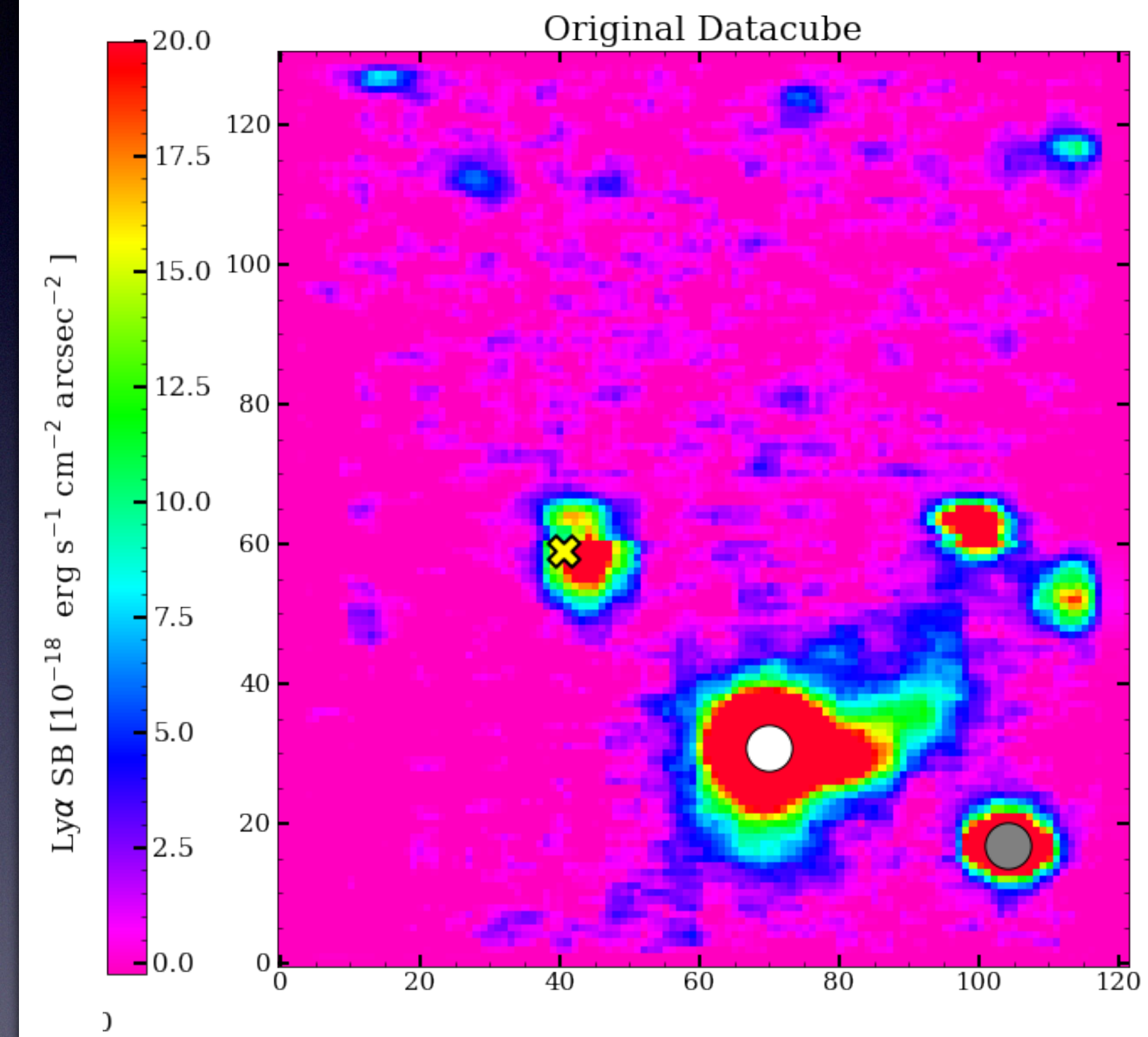


Analytical Method Applied to Datacube

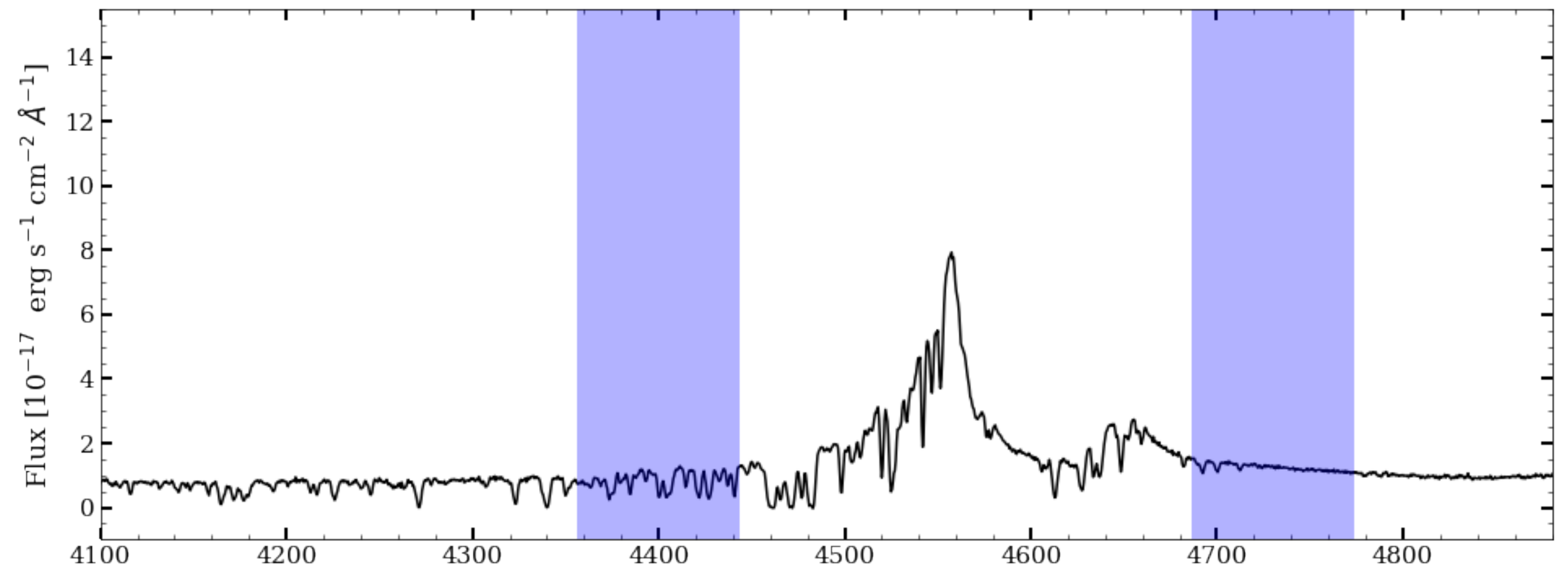
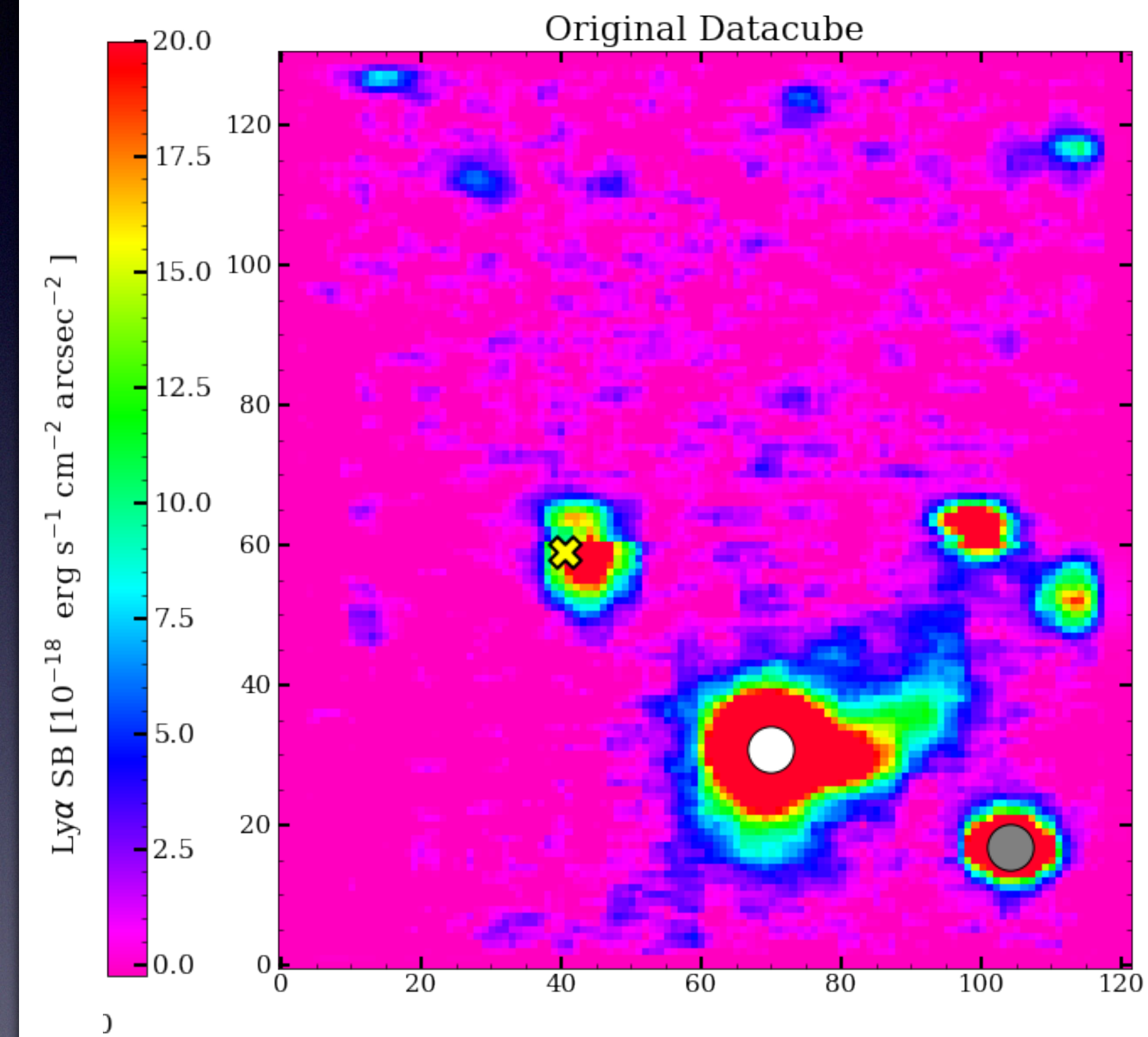


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Analytical Method Applied to Datacube

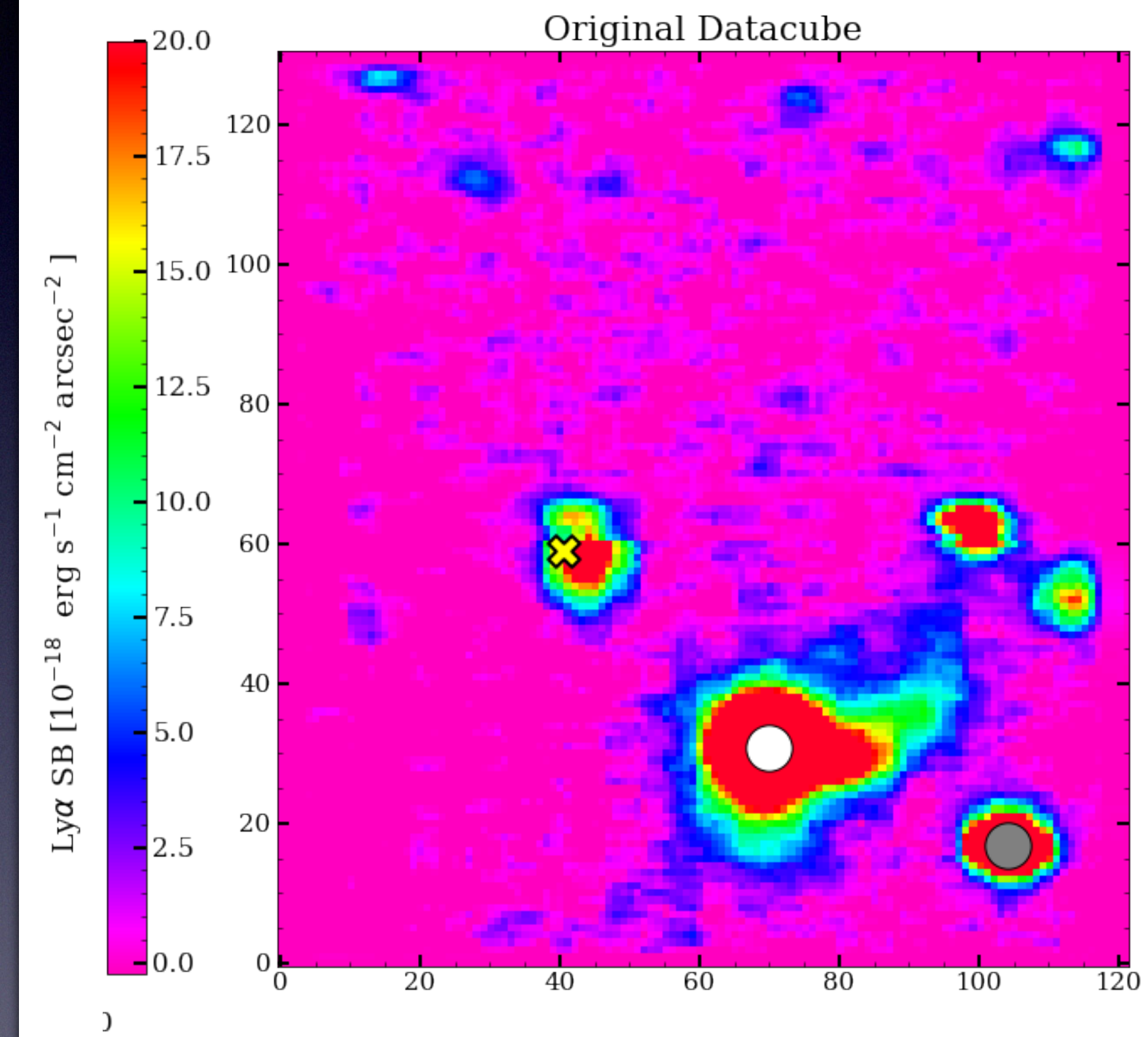


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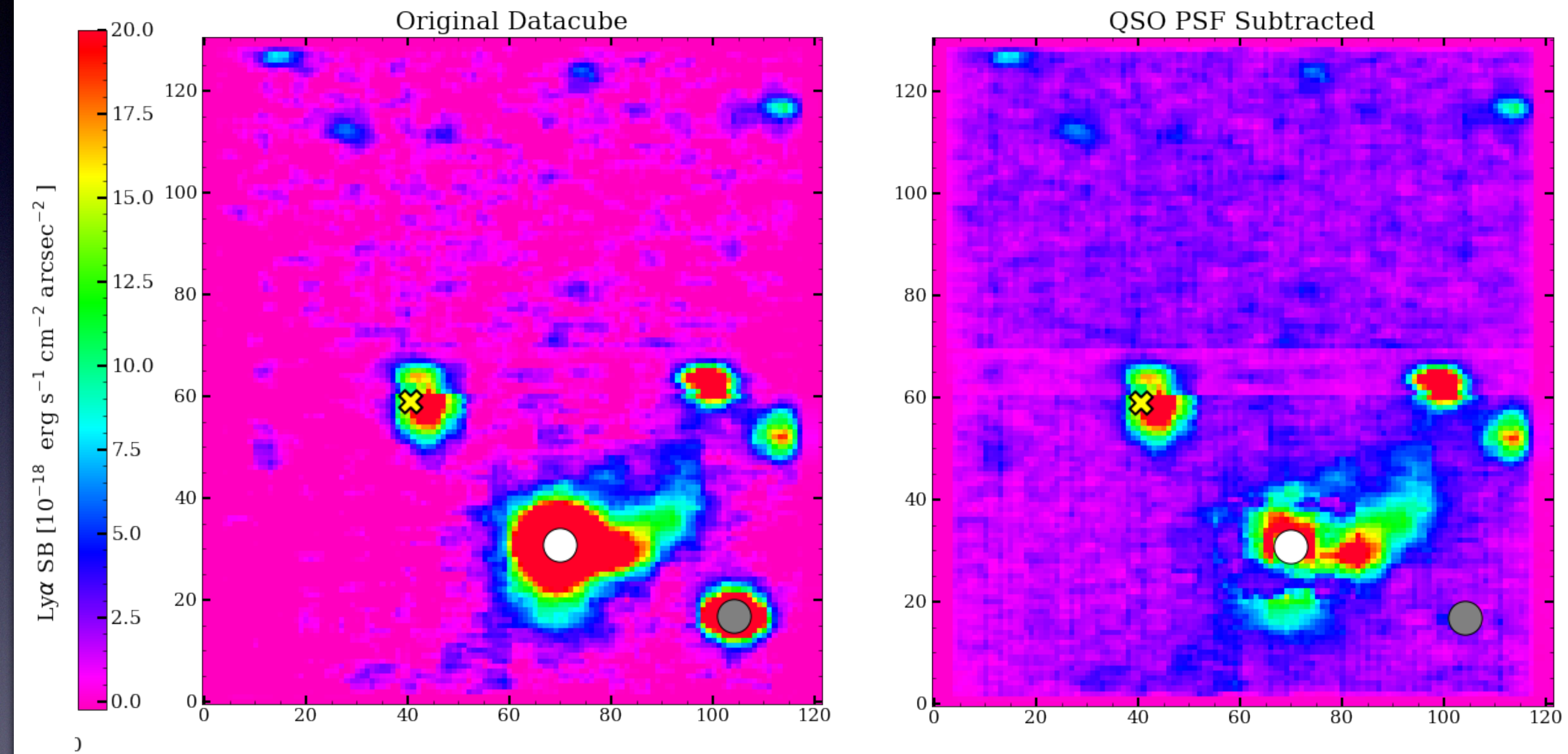


Build Empirical QSO PSF
& subtract out

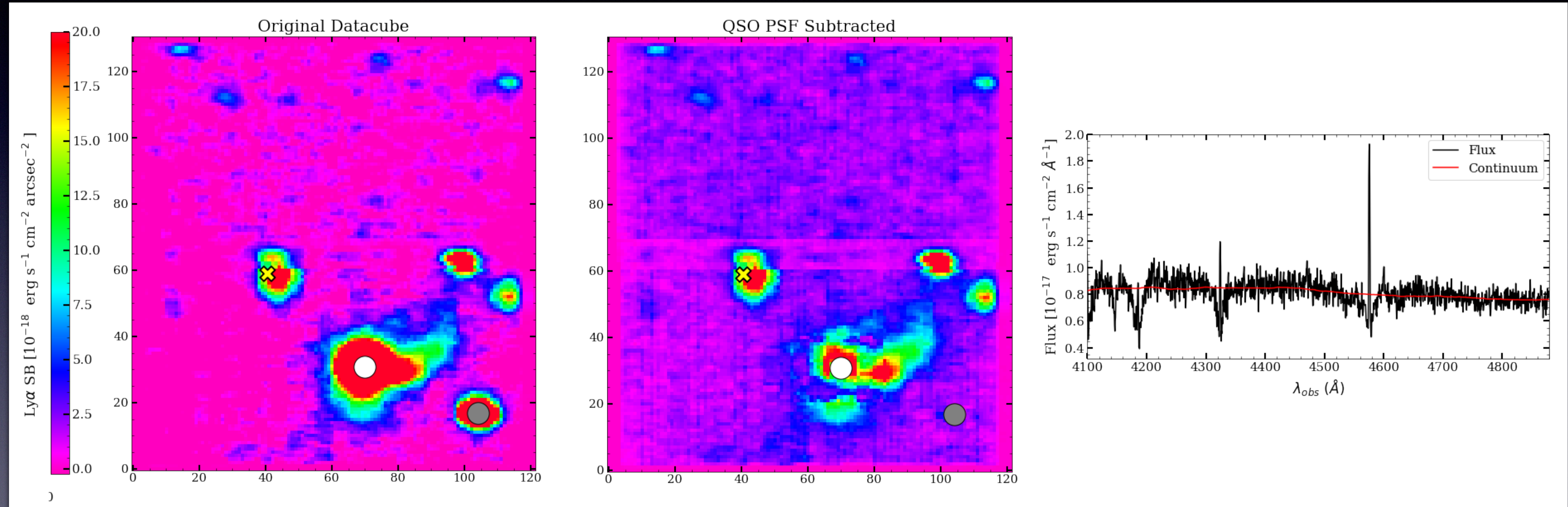
Analytical Method Applied to Datacube



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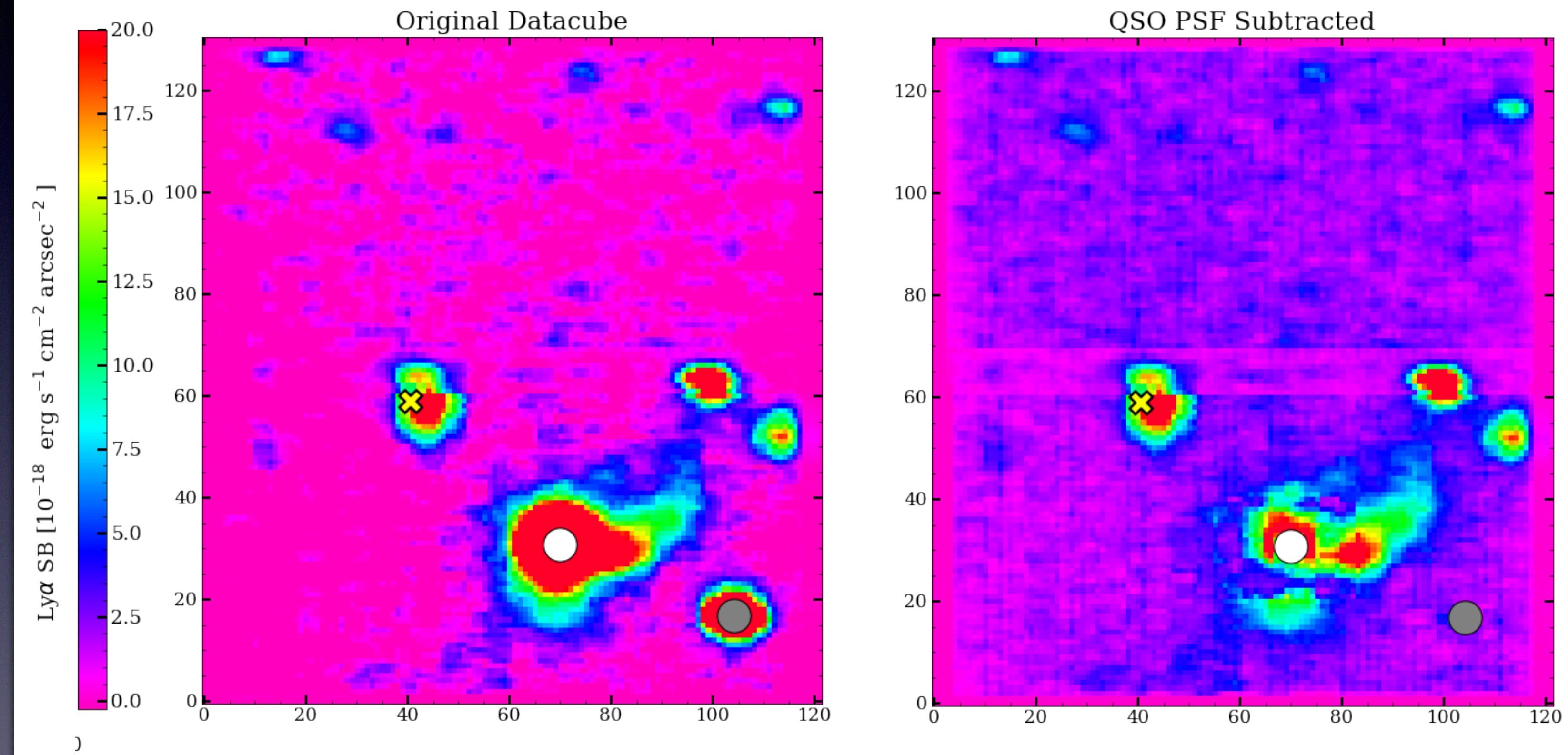


Analytical Method Applied to Datacube

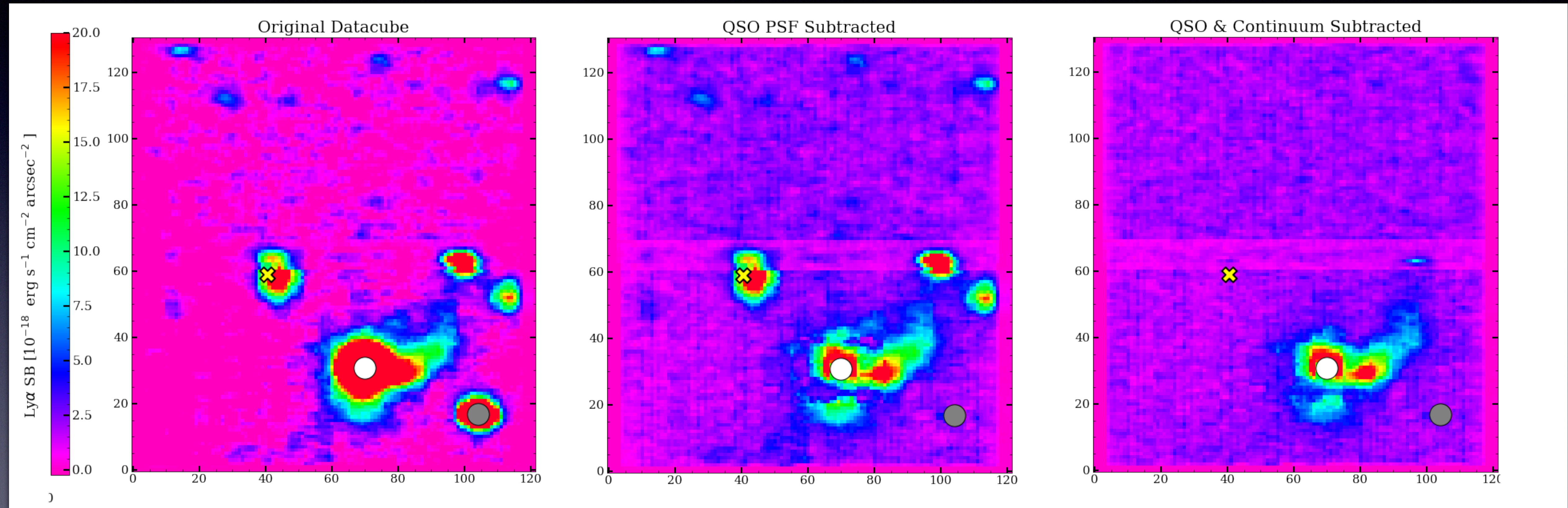


Subtract out Remaining
Continuum Sources

Analytical Method Applied to Datacube

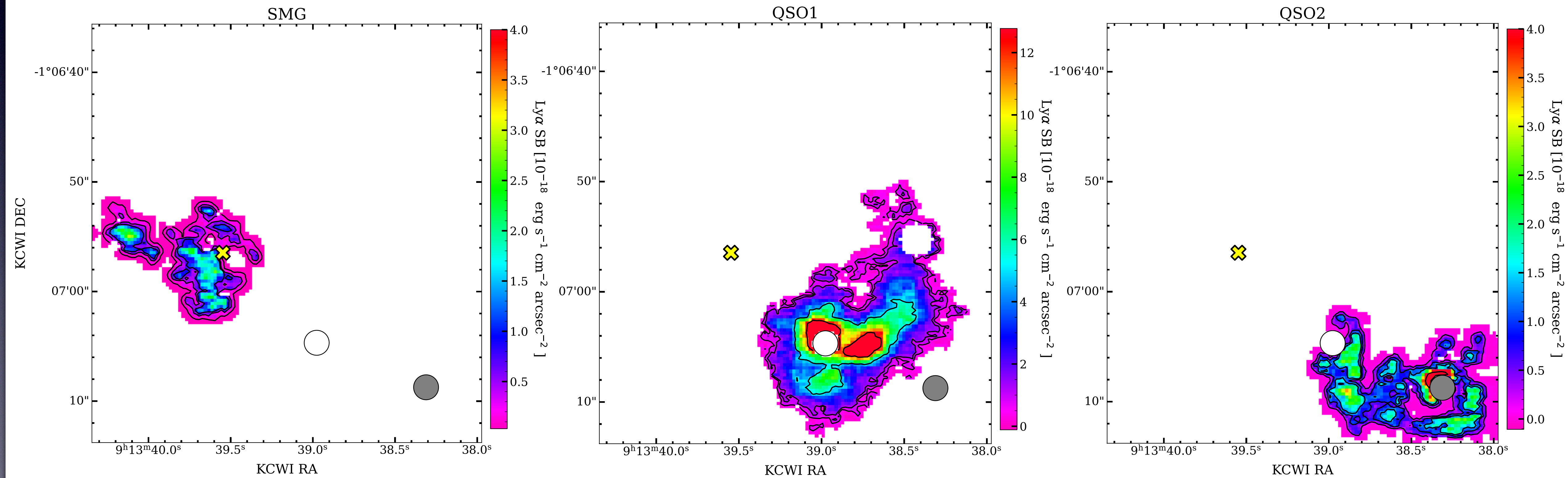


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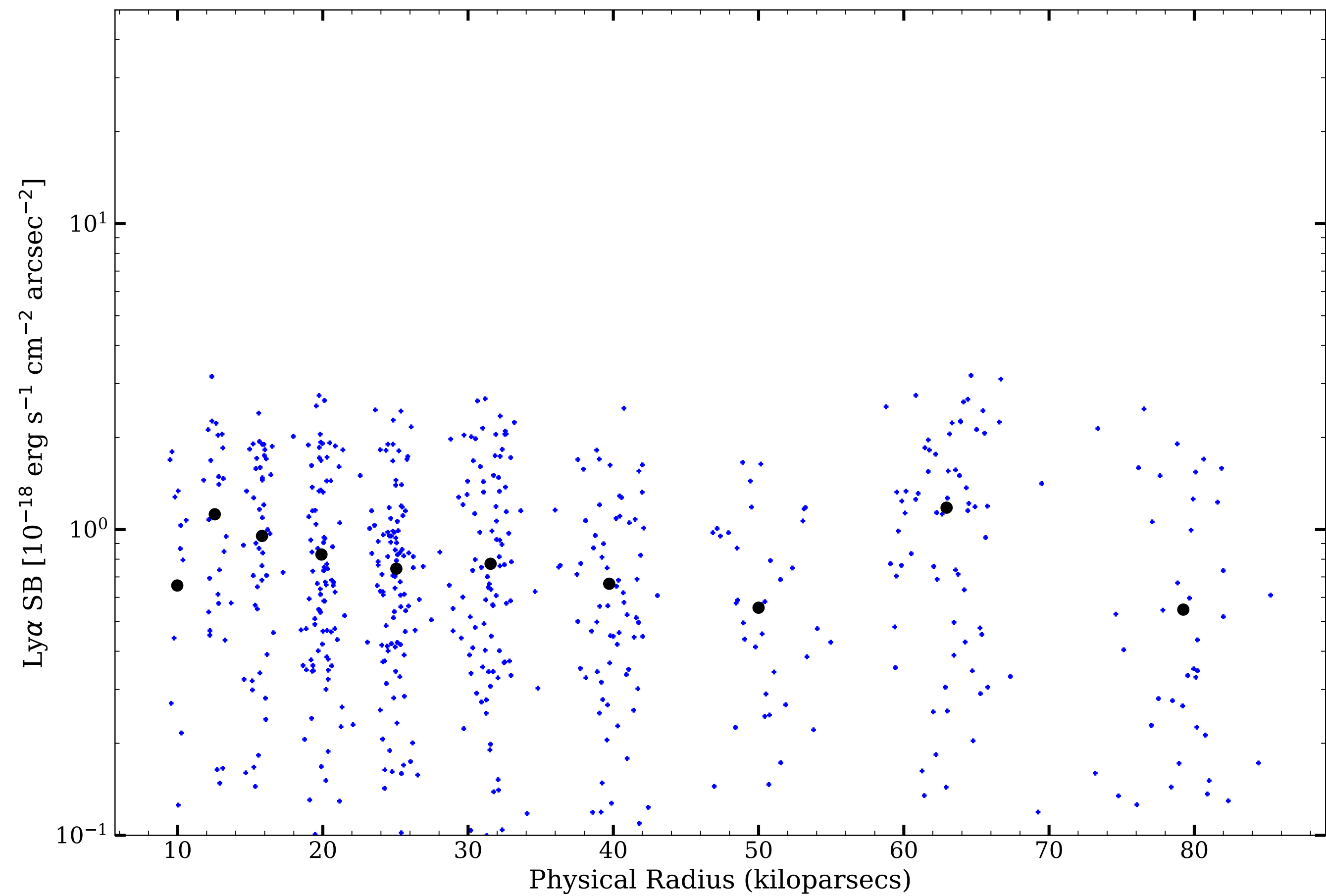
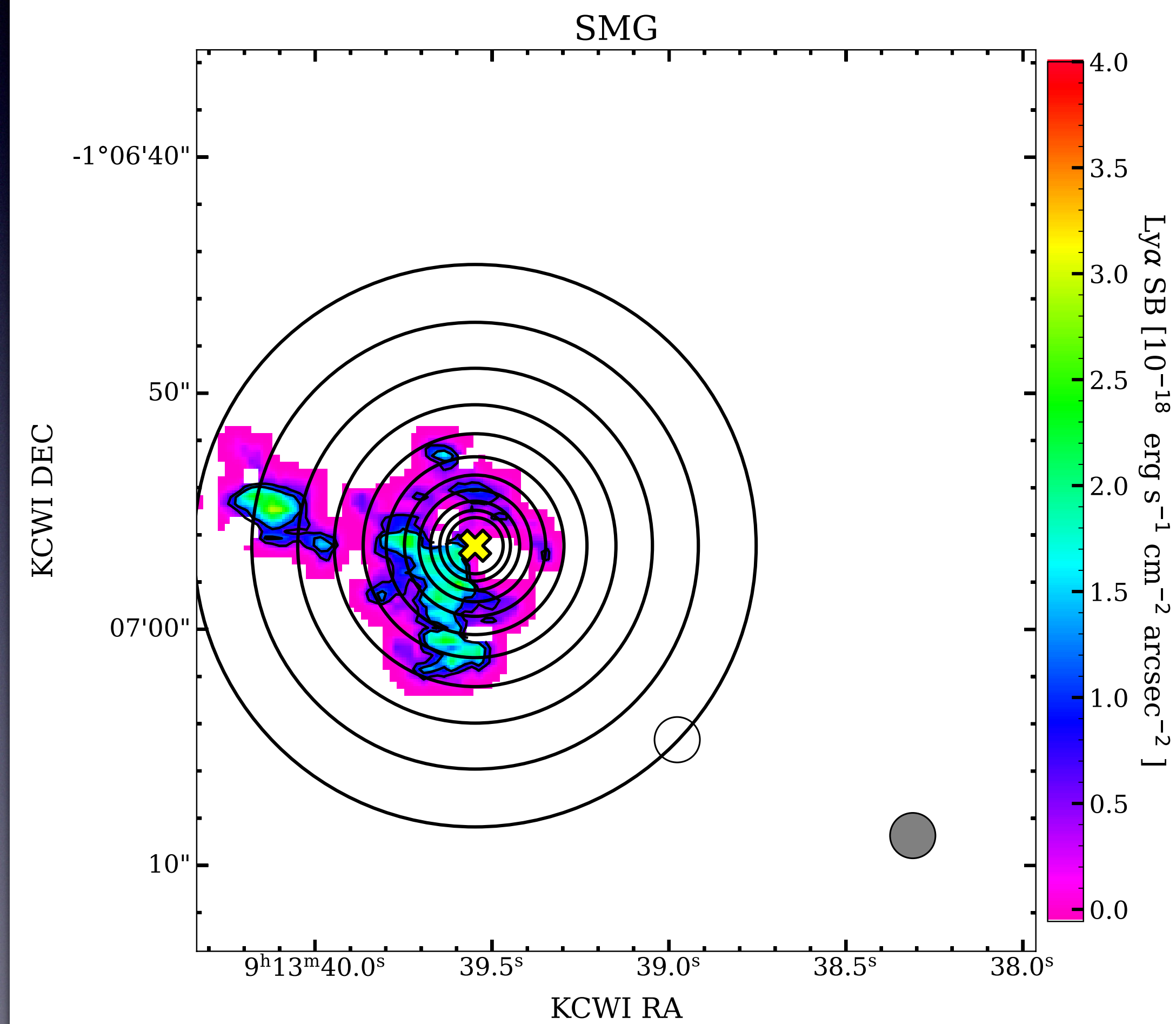


$\text{Ly}\alpha$ Surface Brightness Maps

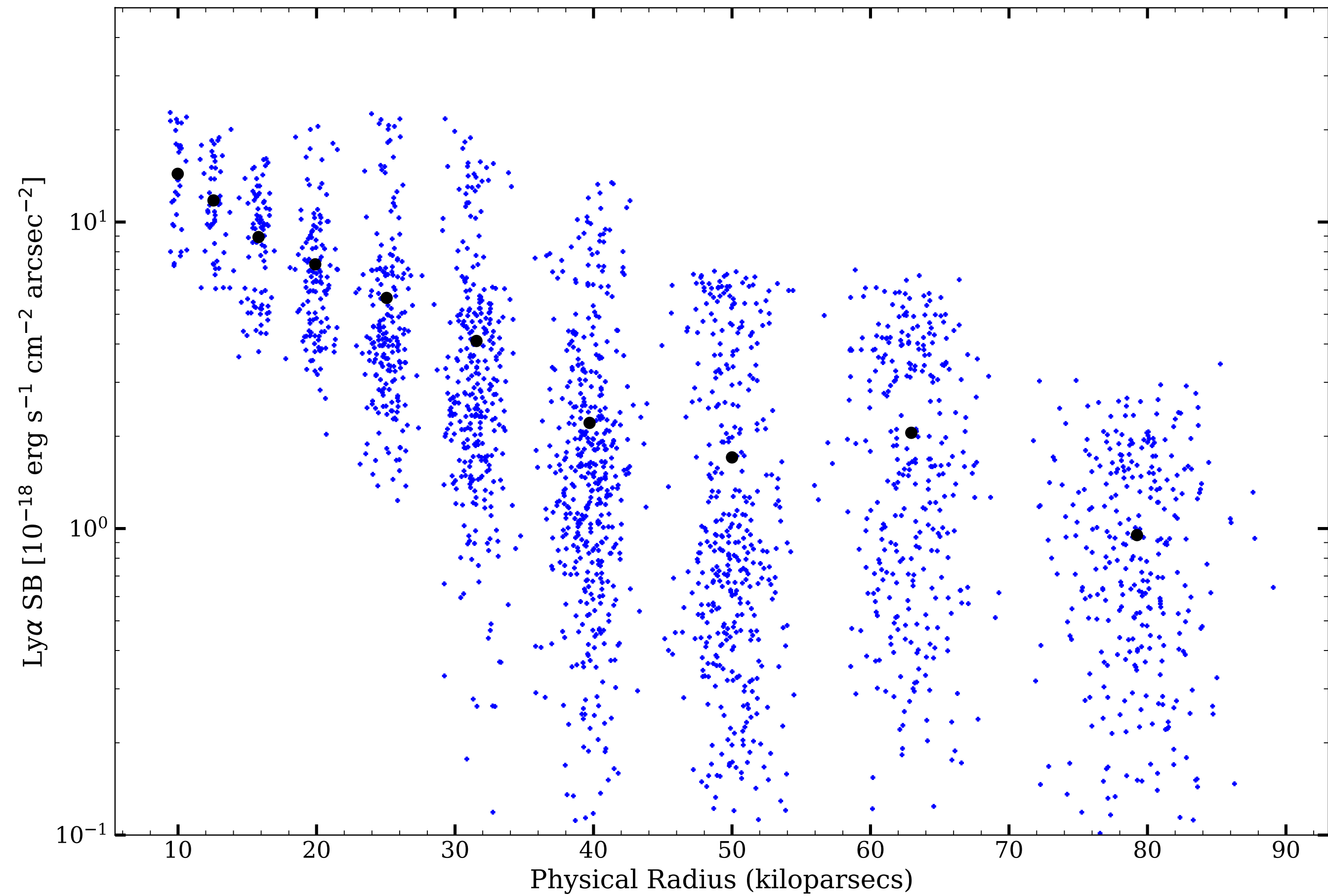
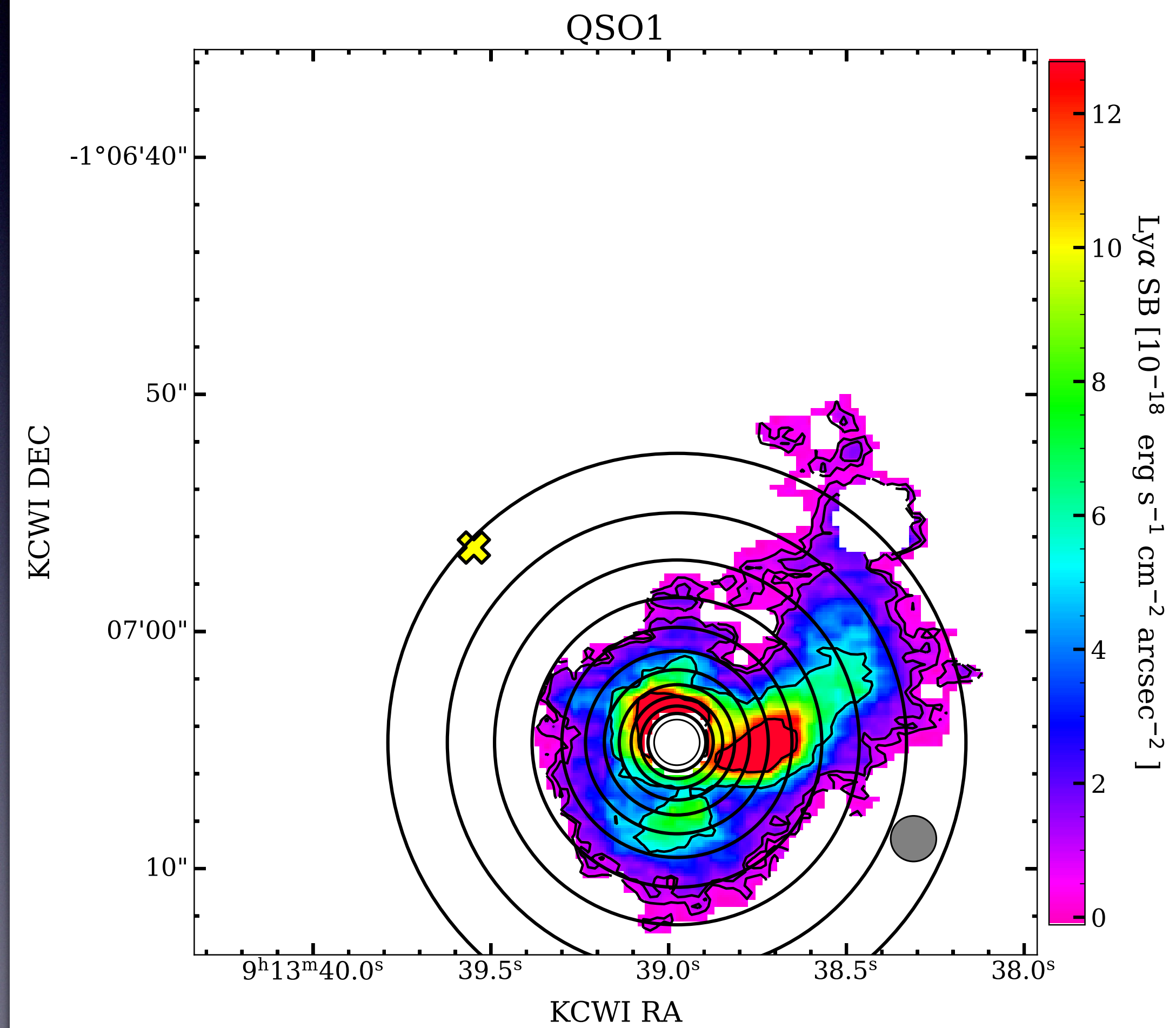
Integrated across the λ range of each emission



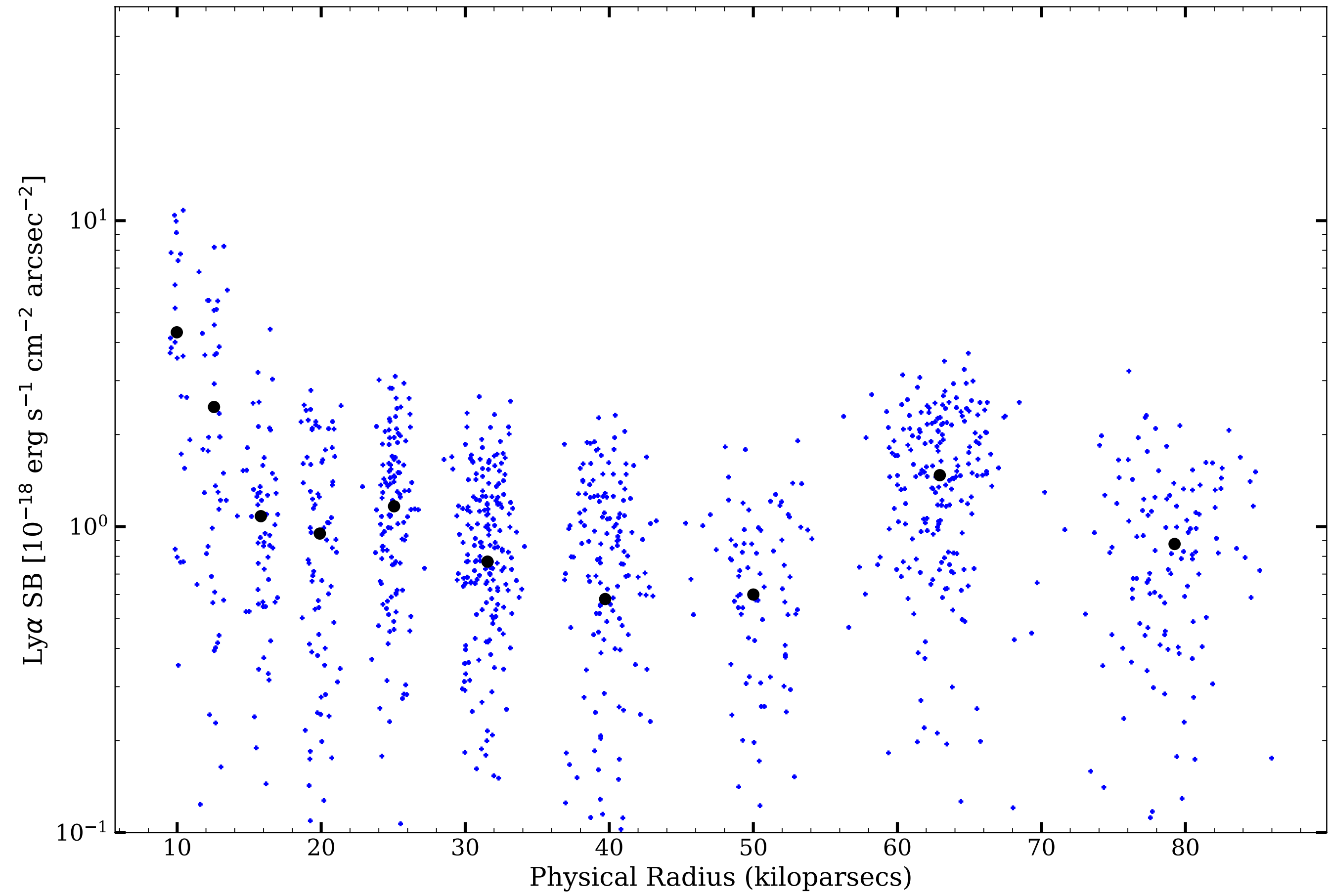
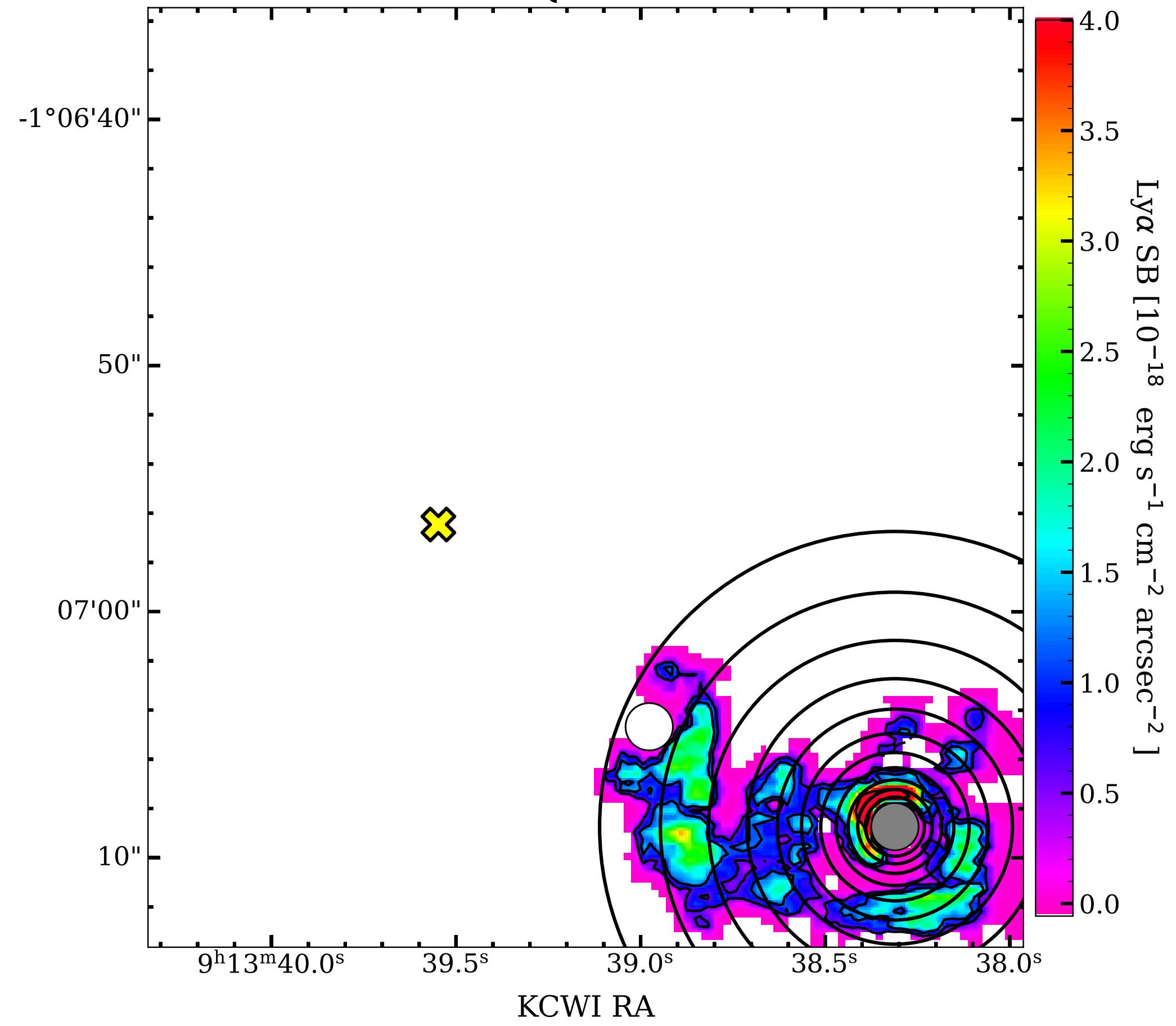
Surface Brightness Profile of Extended Ly- α Emission: The SMG at $z = 2.674$



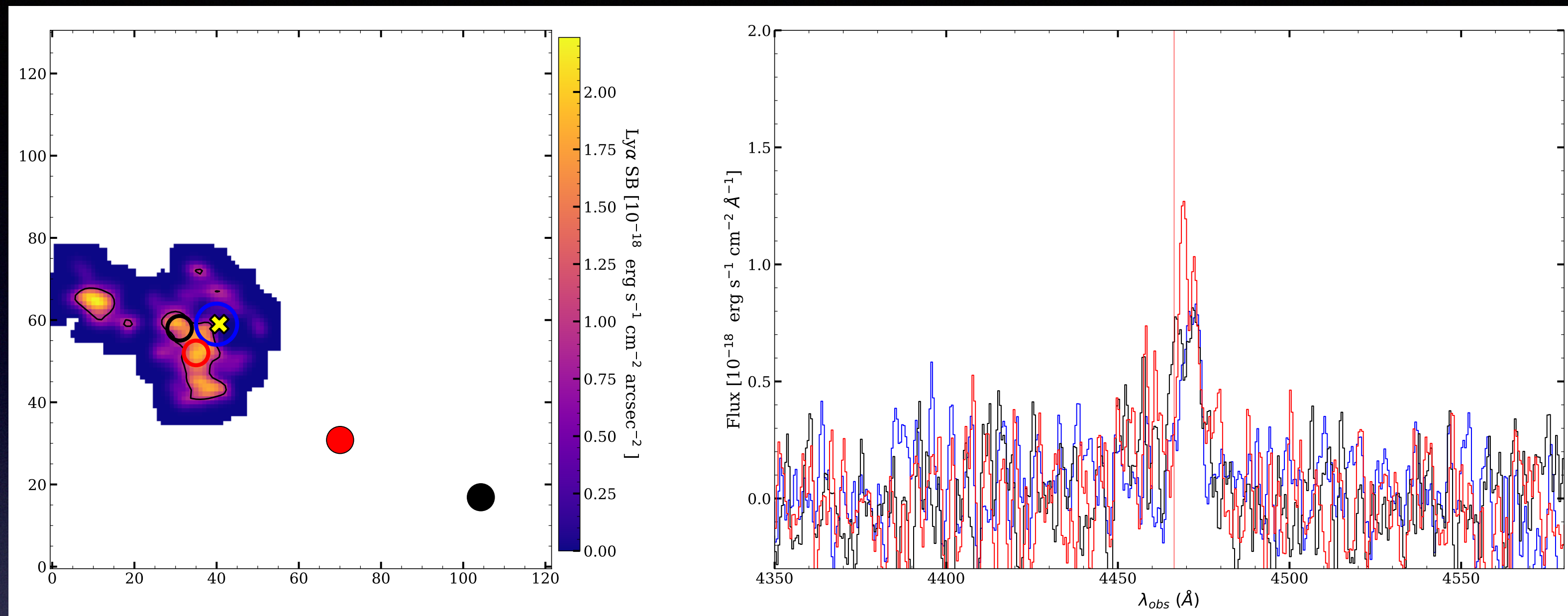
$\text{Ly}\alpha$ Surface Brightness Profile



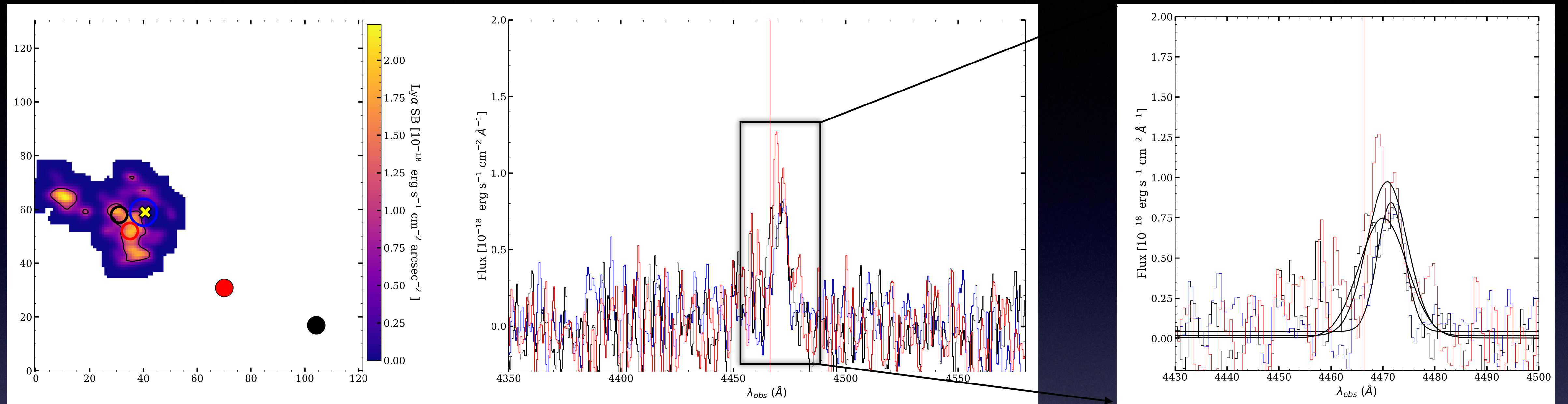
QSO2



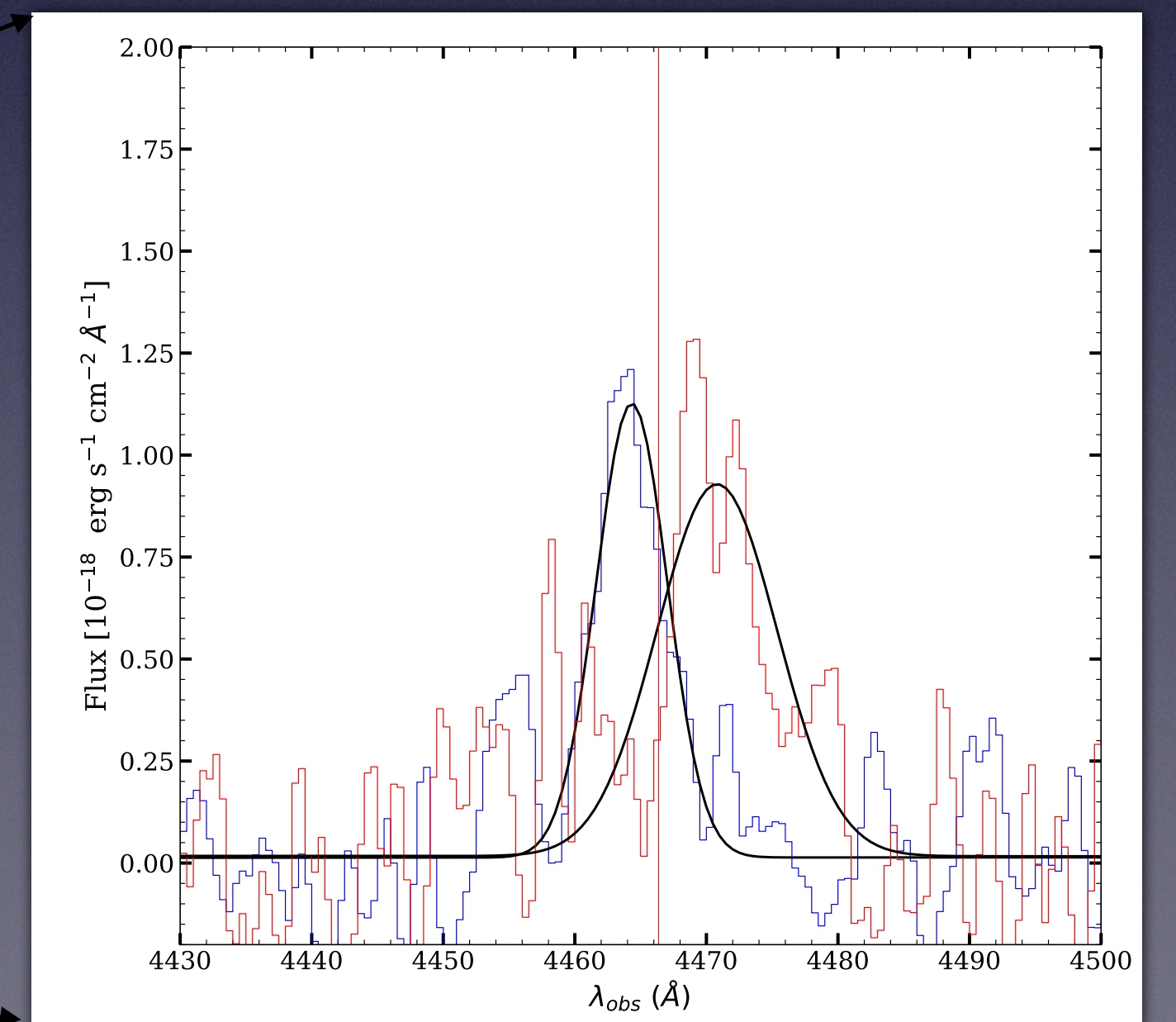
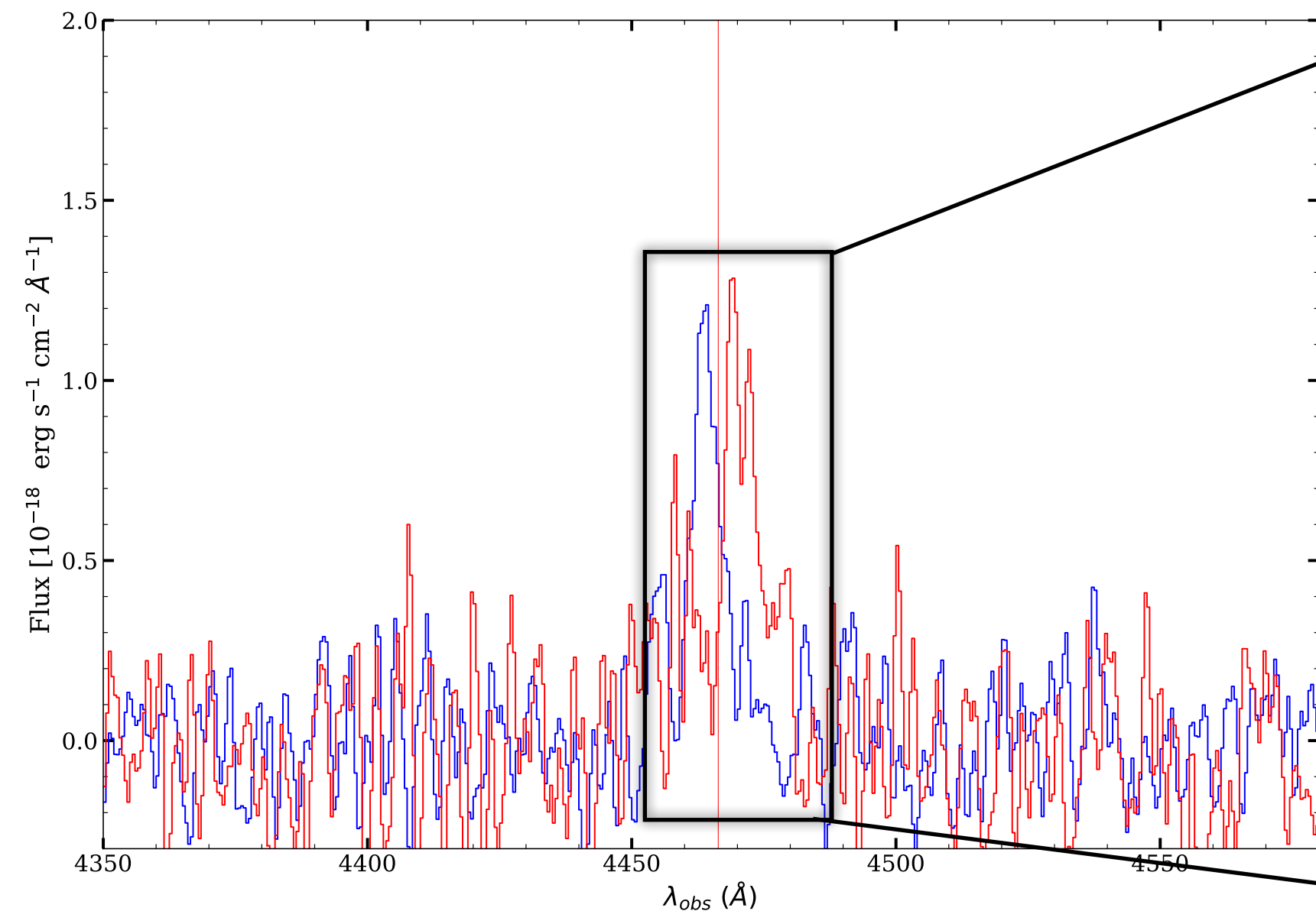
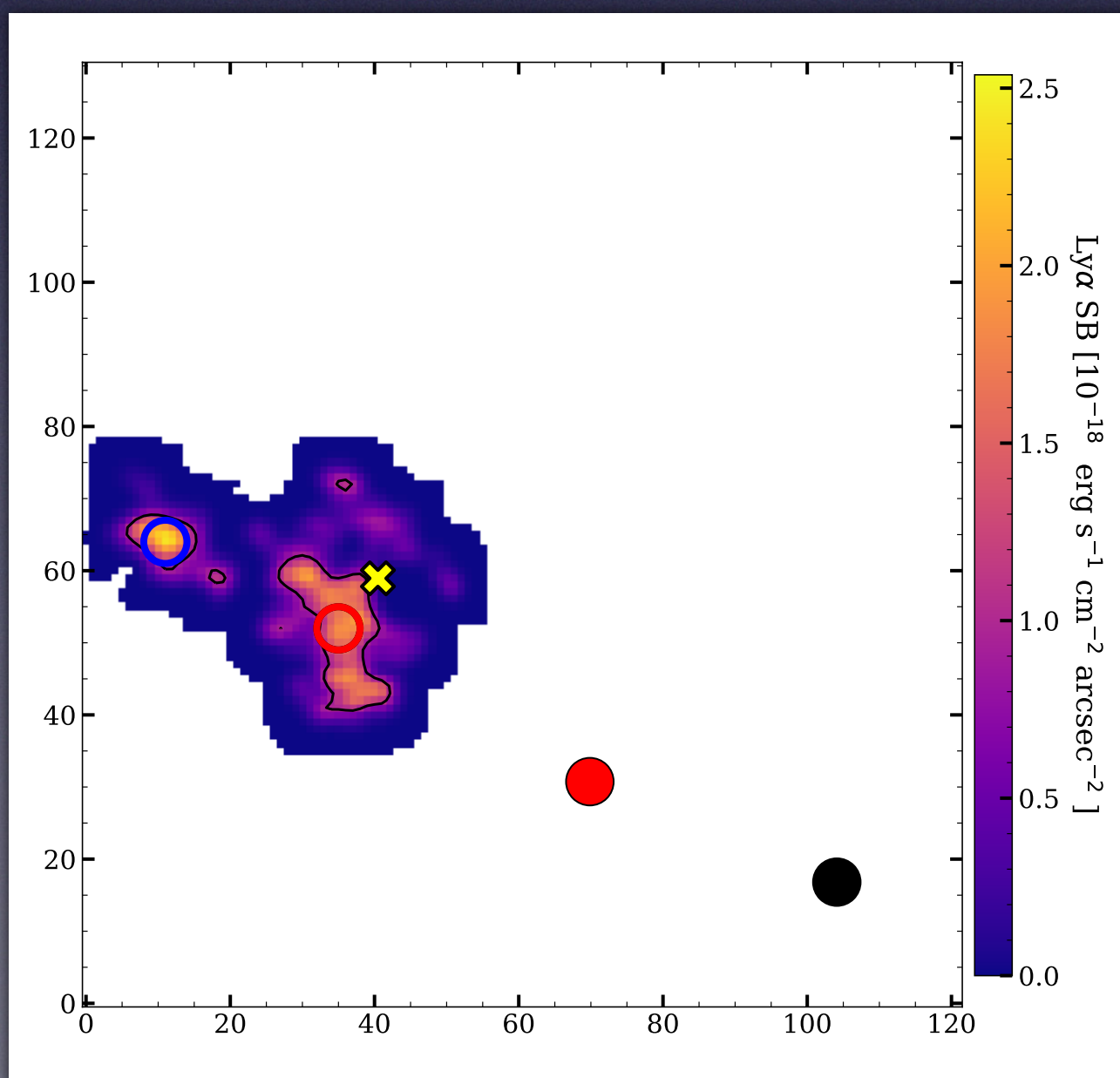
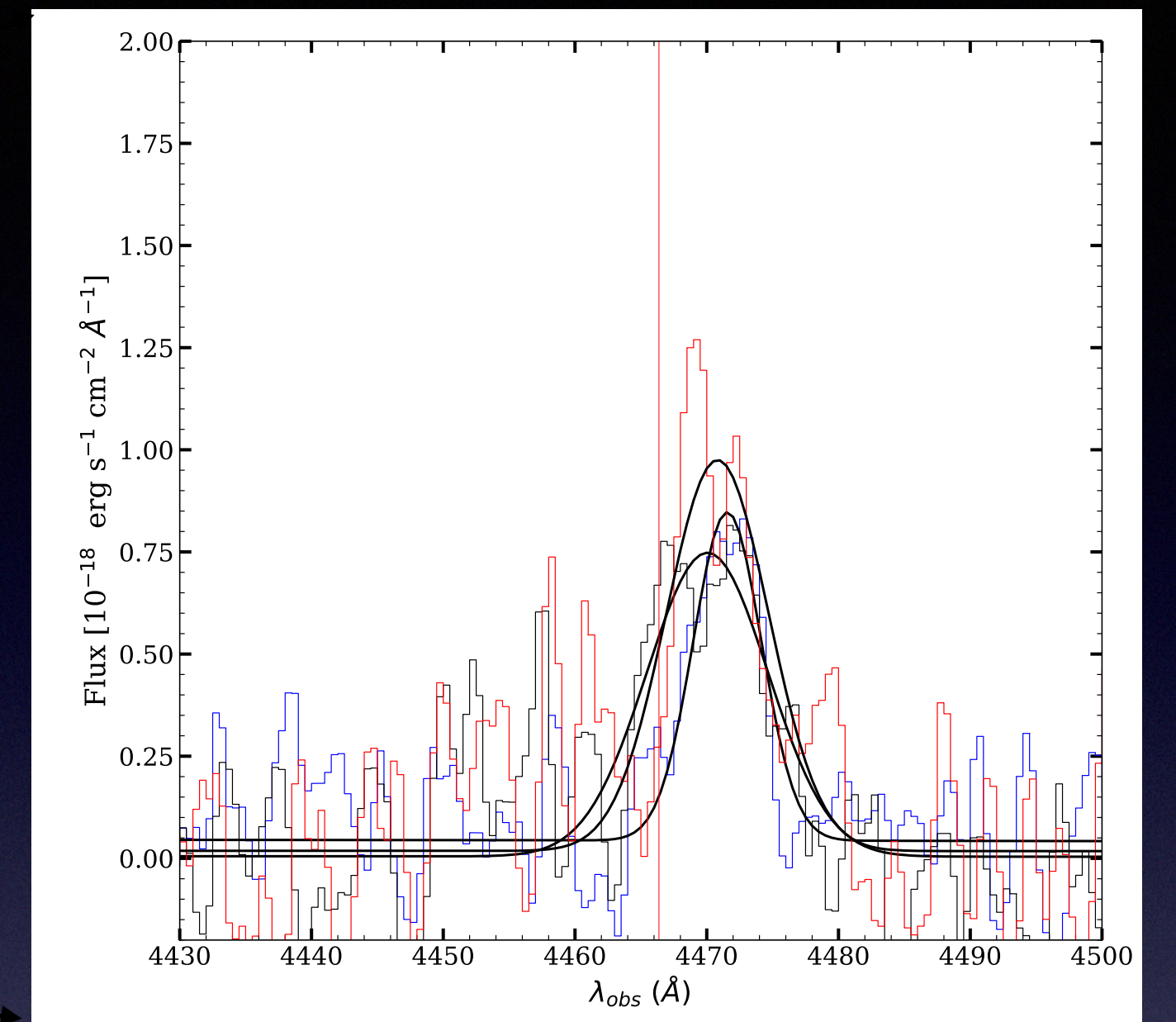
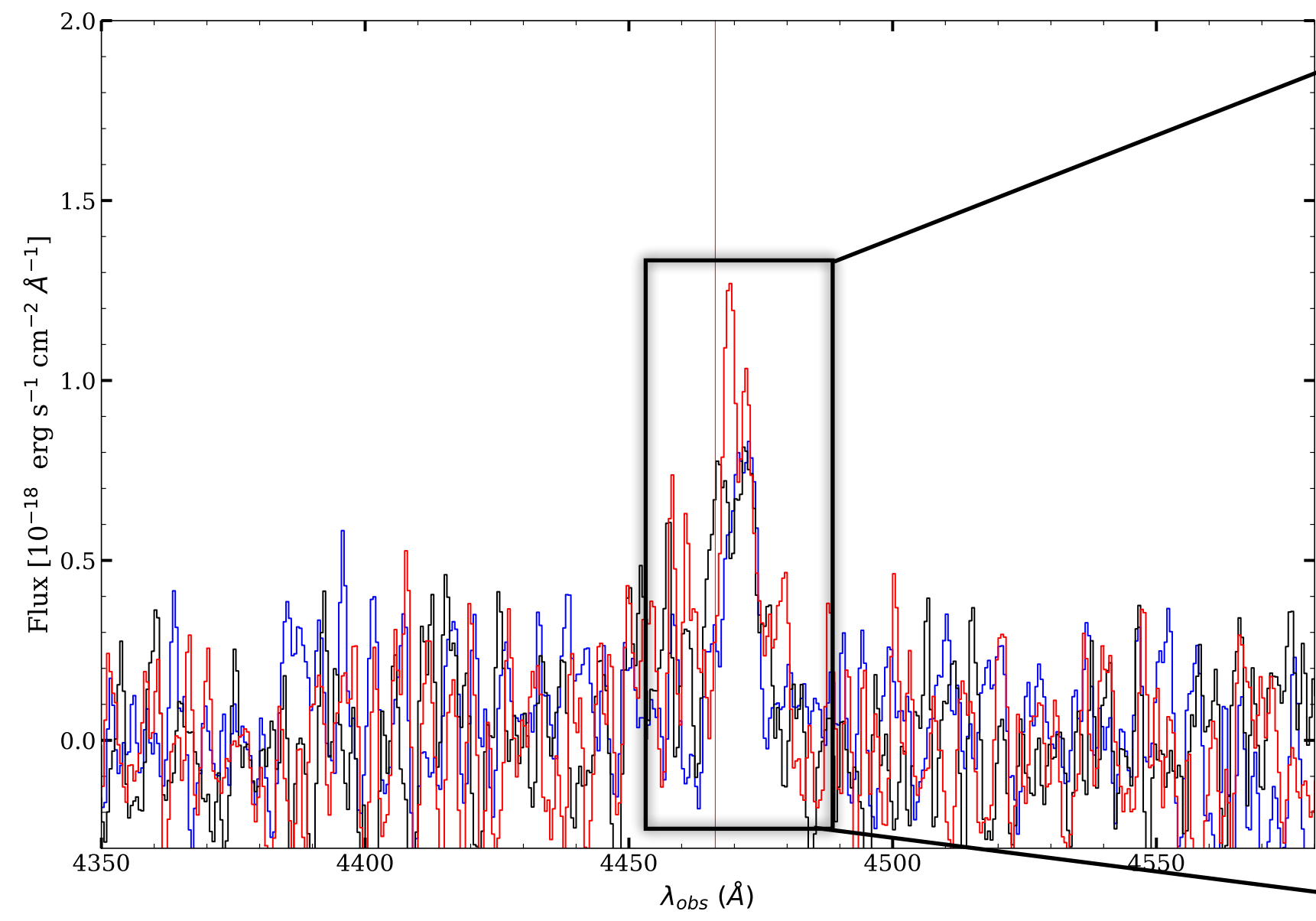
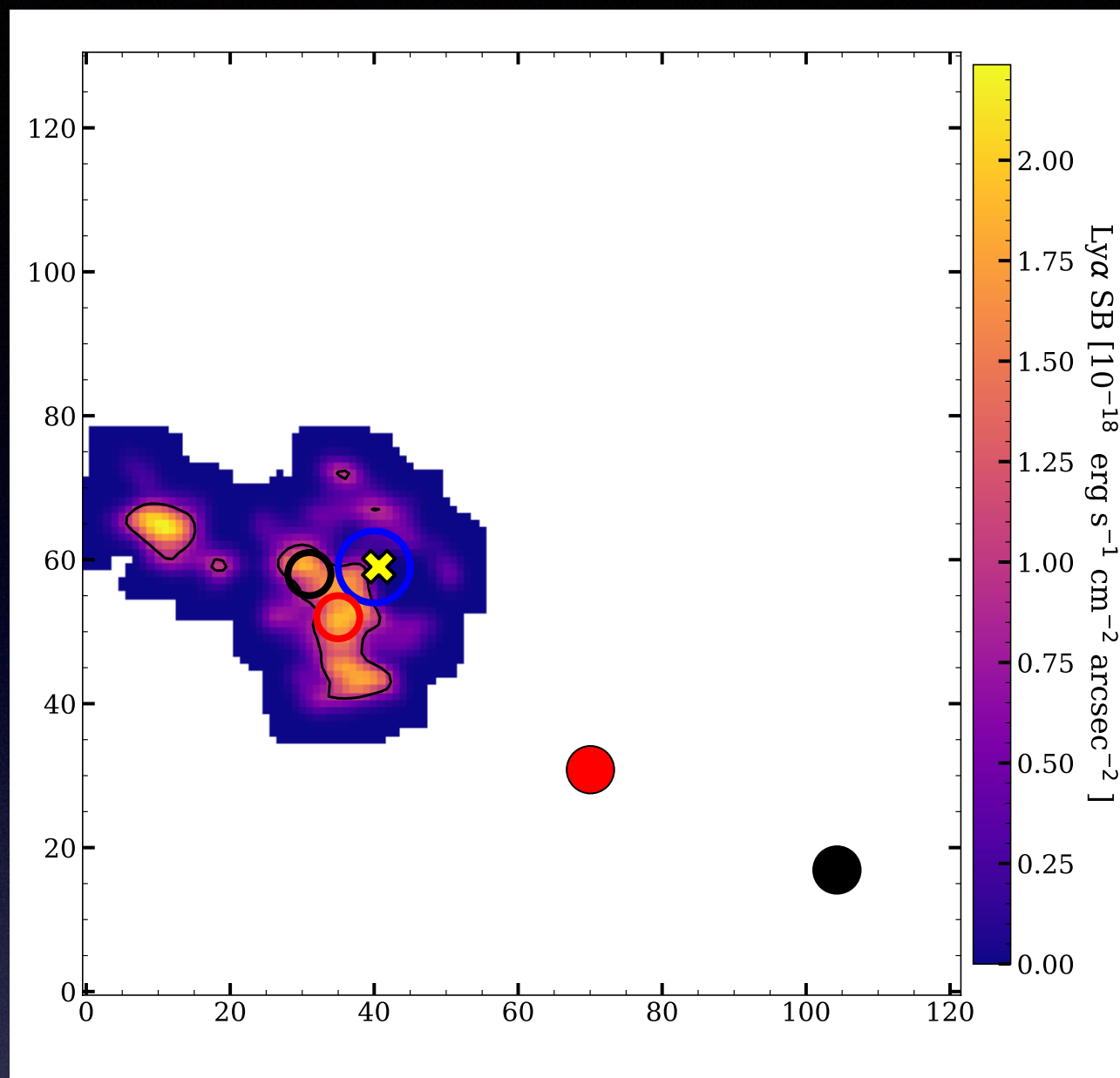
Ly α Emission at SMG



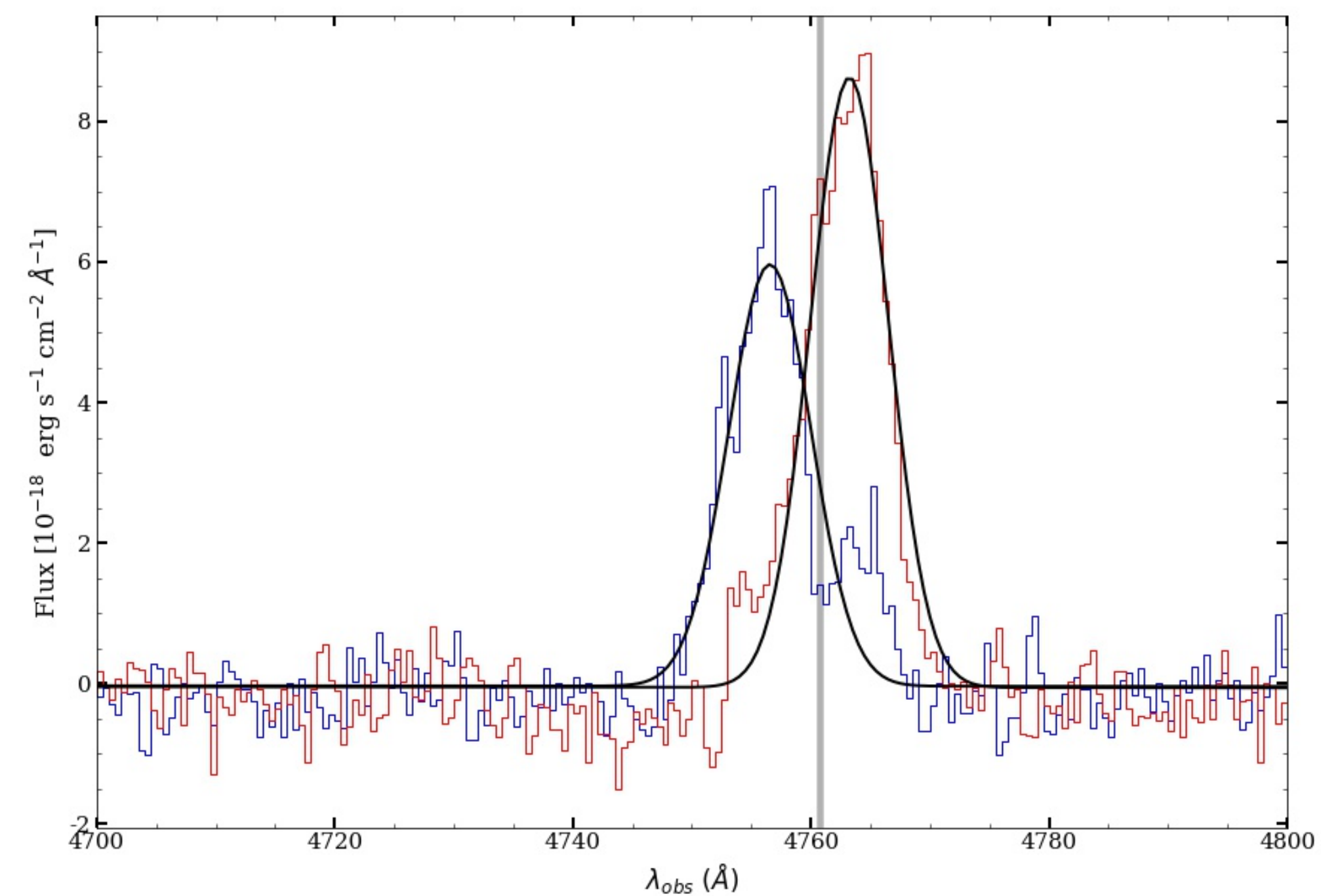
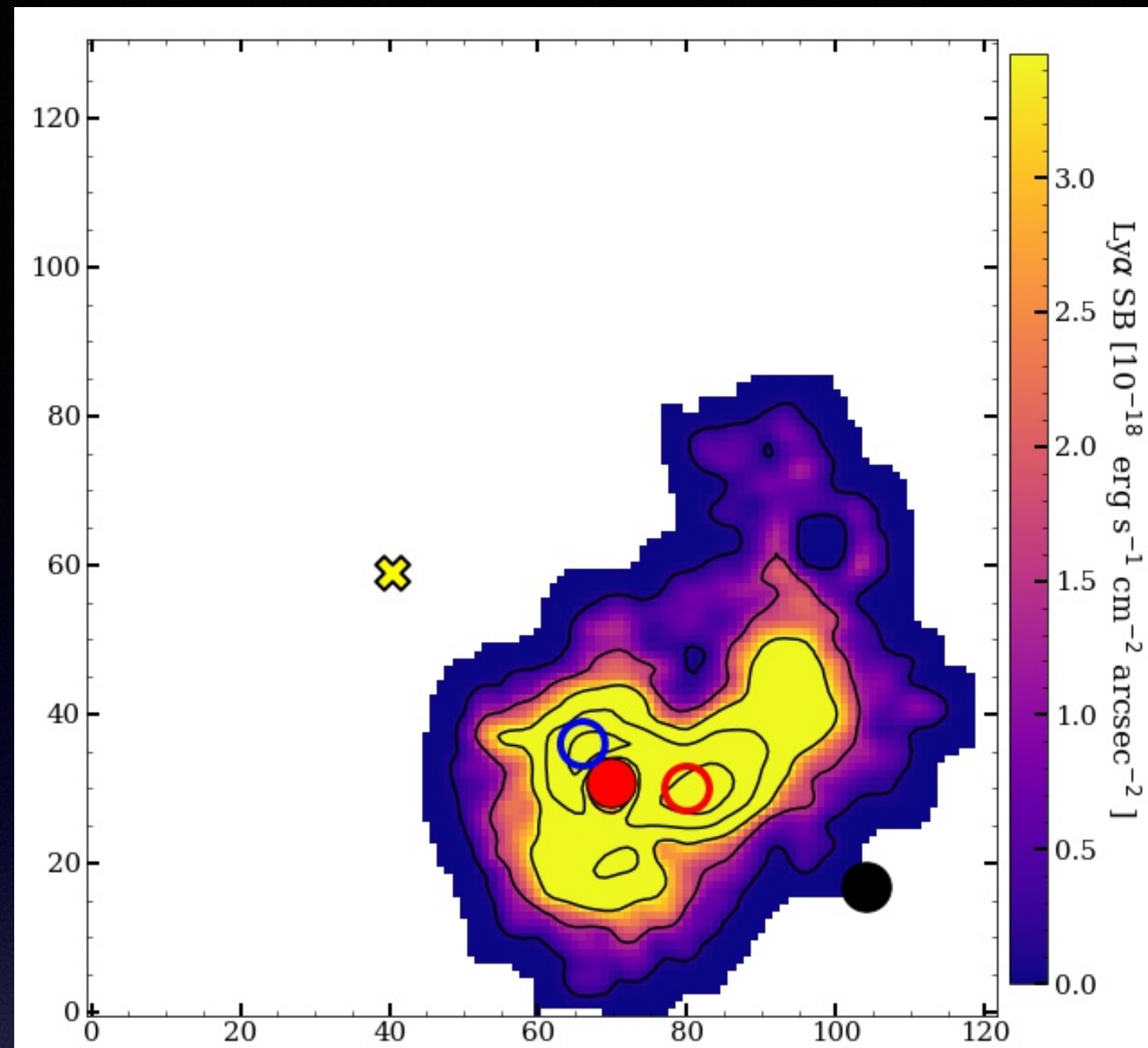
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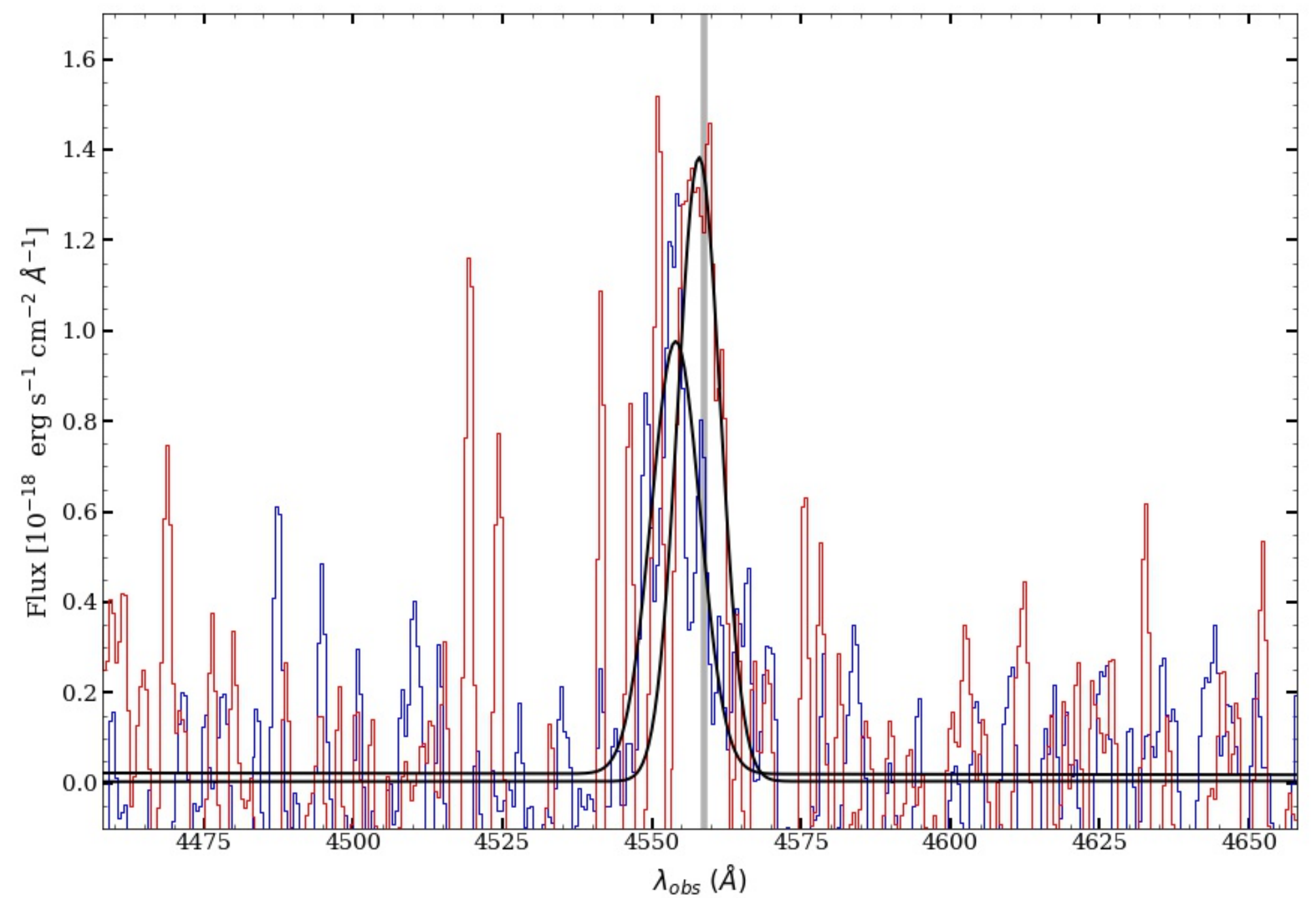
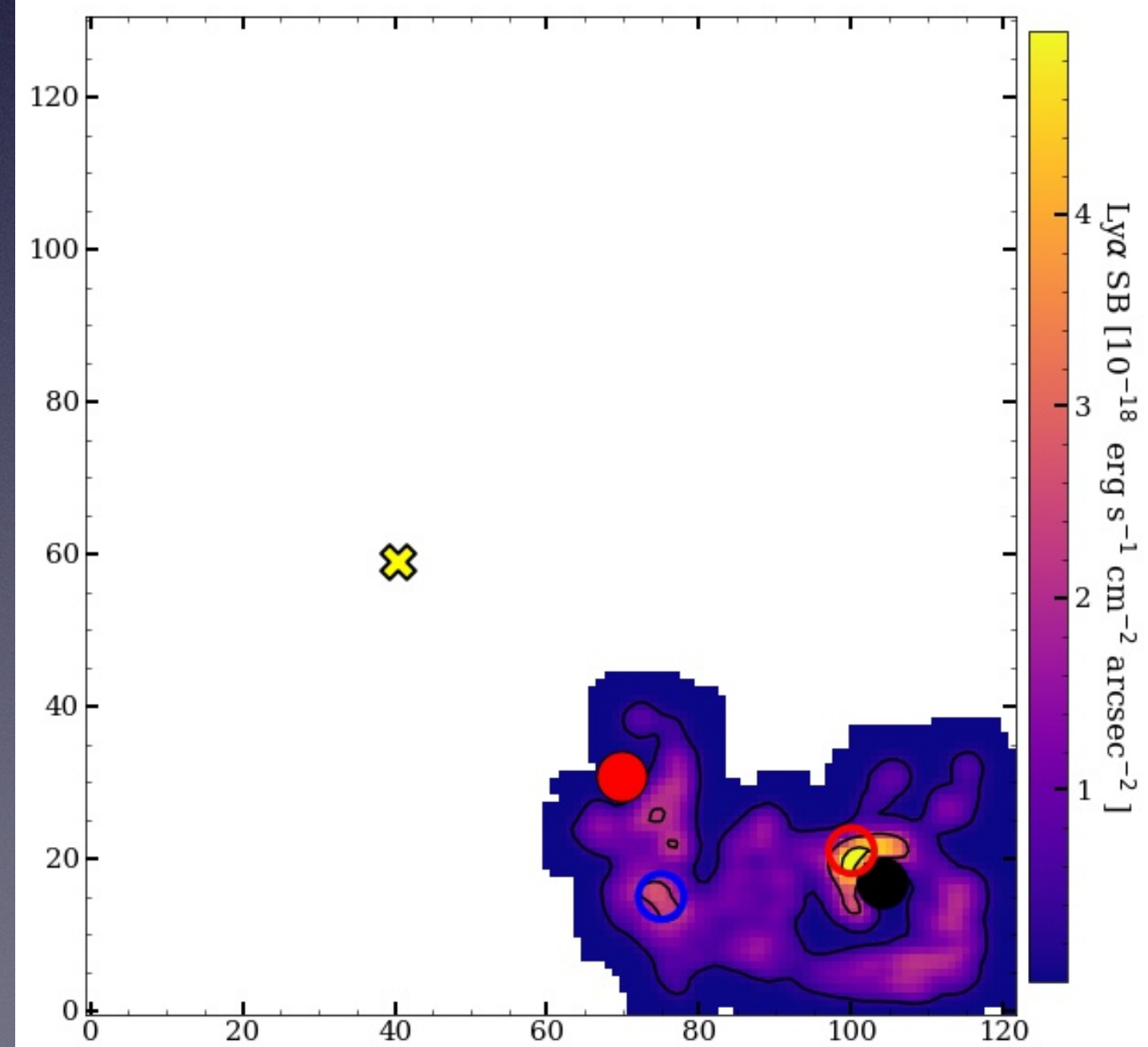
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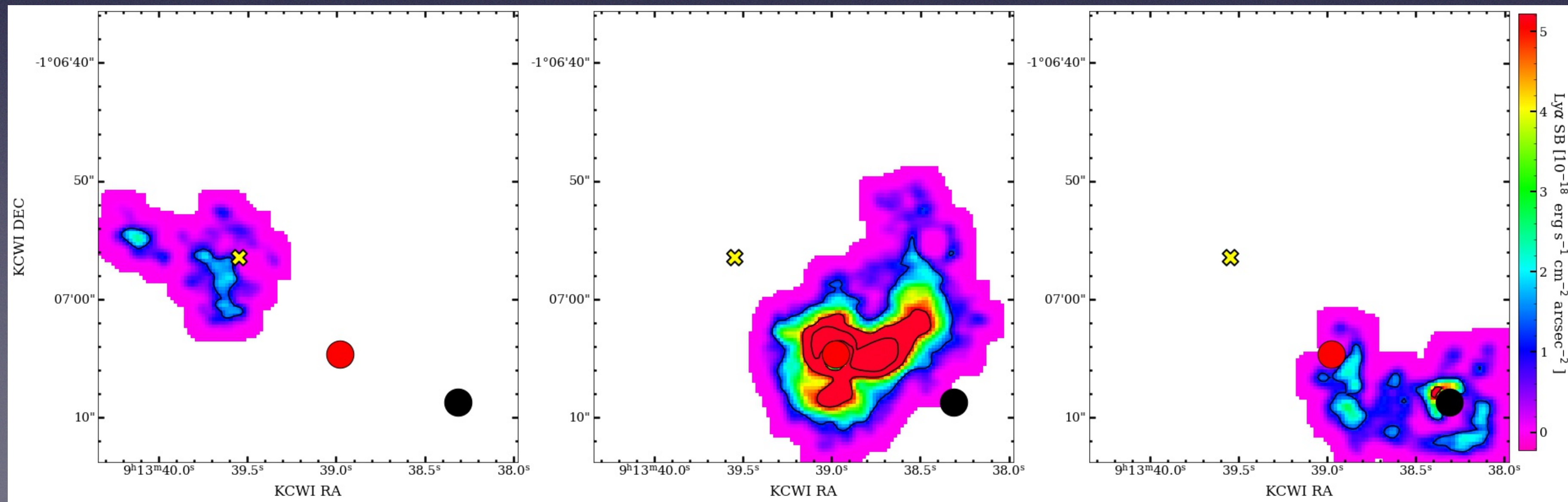
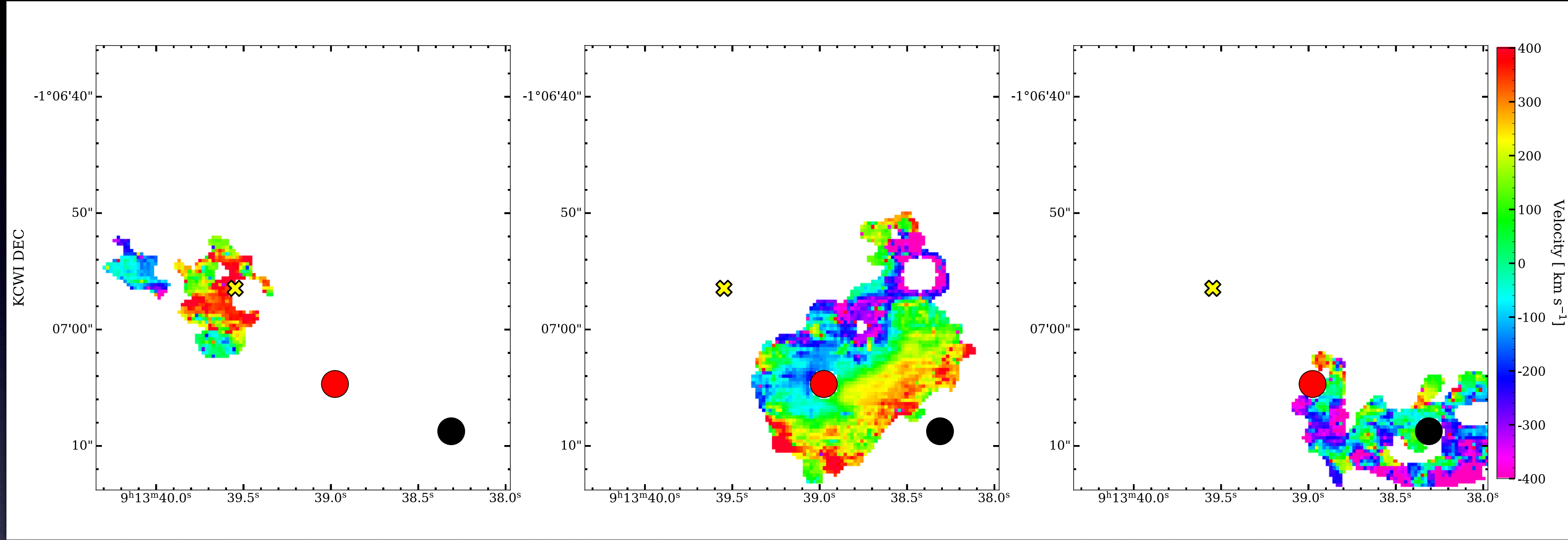
QSO1 has strong
 $\text{Ly}\alpha$ emission at
different velocities



QSO2 has
much fainter
 $\text{Ly}\alpha$ halo

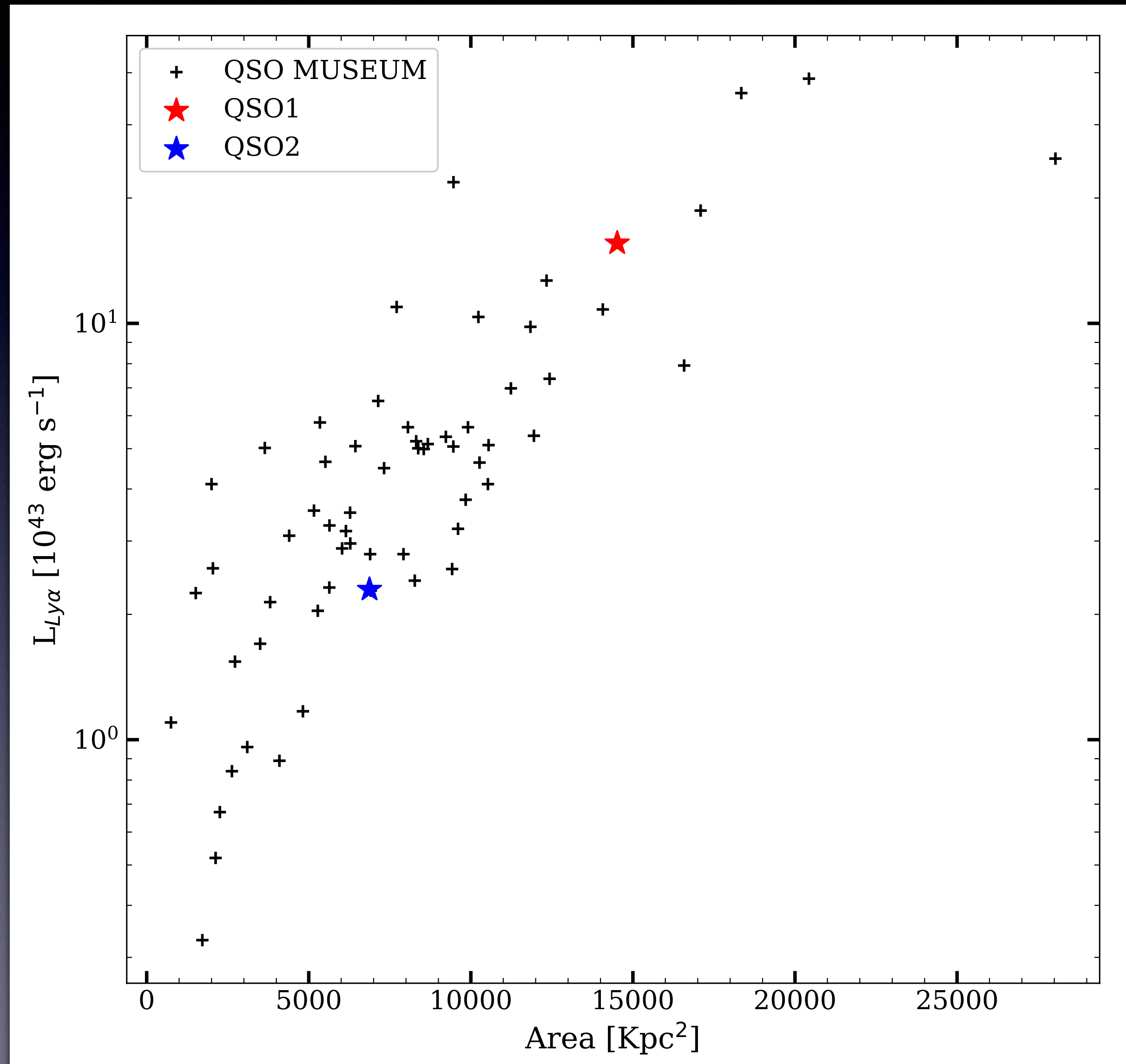


Velocity Map



Comparison

QSO MUSEUM
(F. Arrighi Battaia et al. 2018)

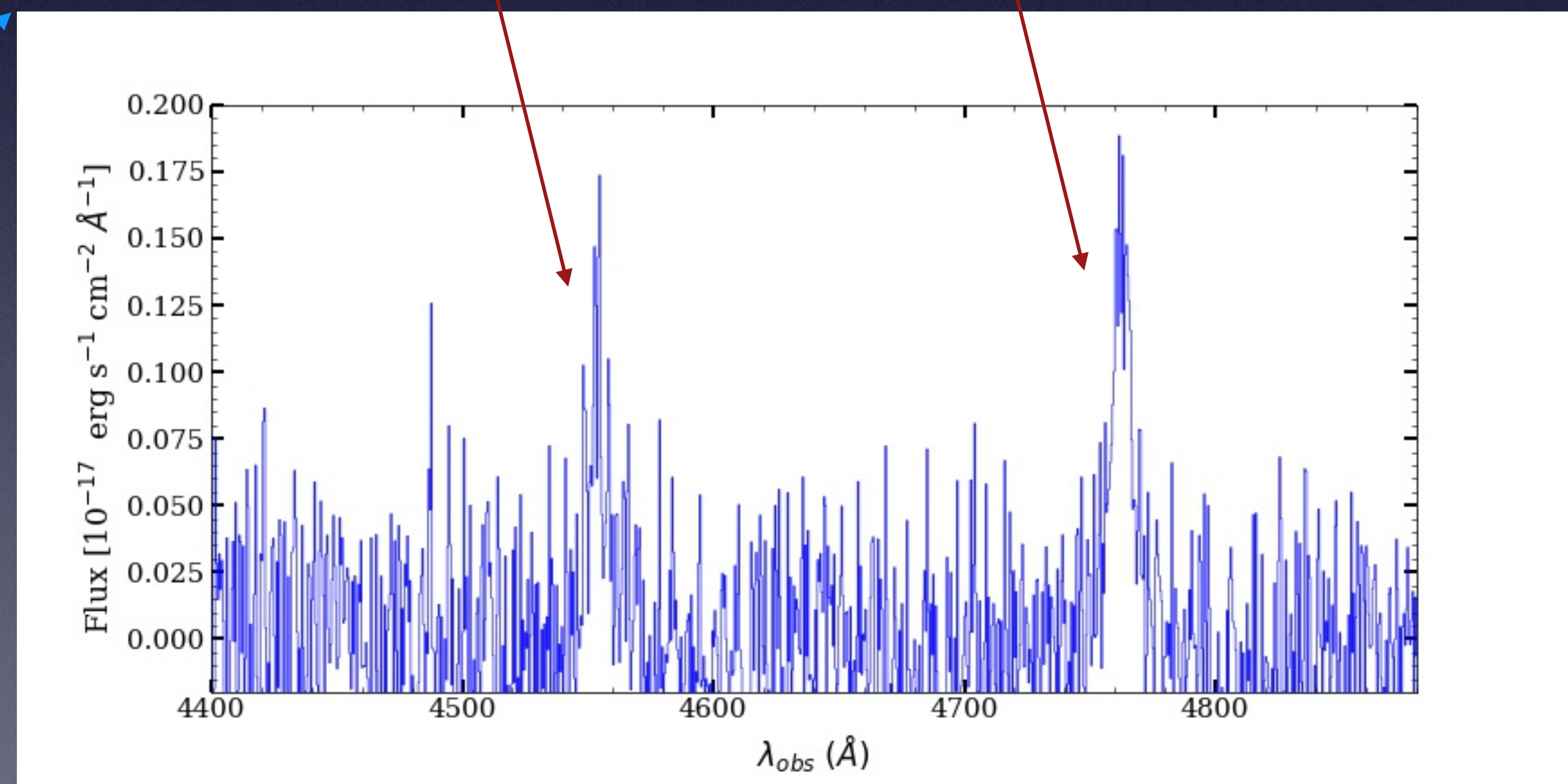
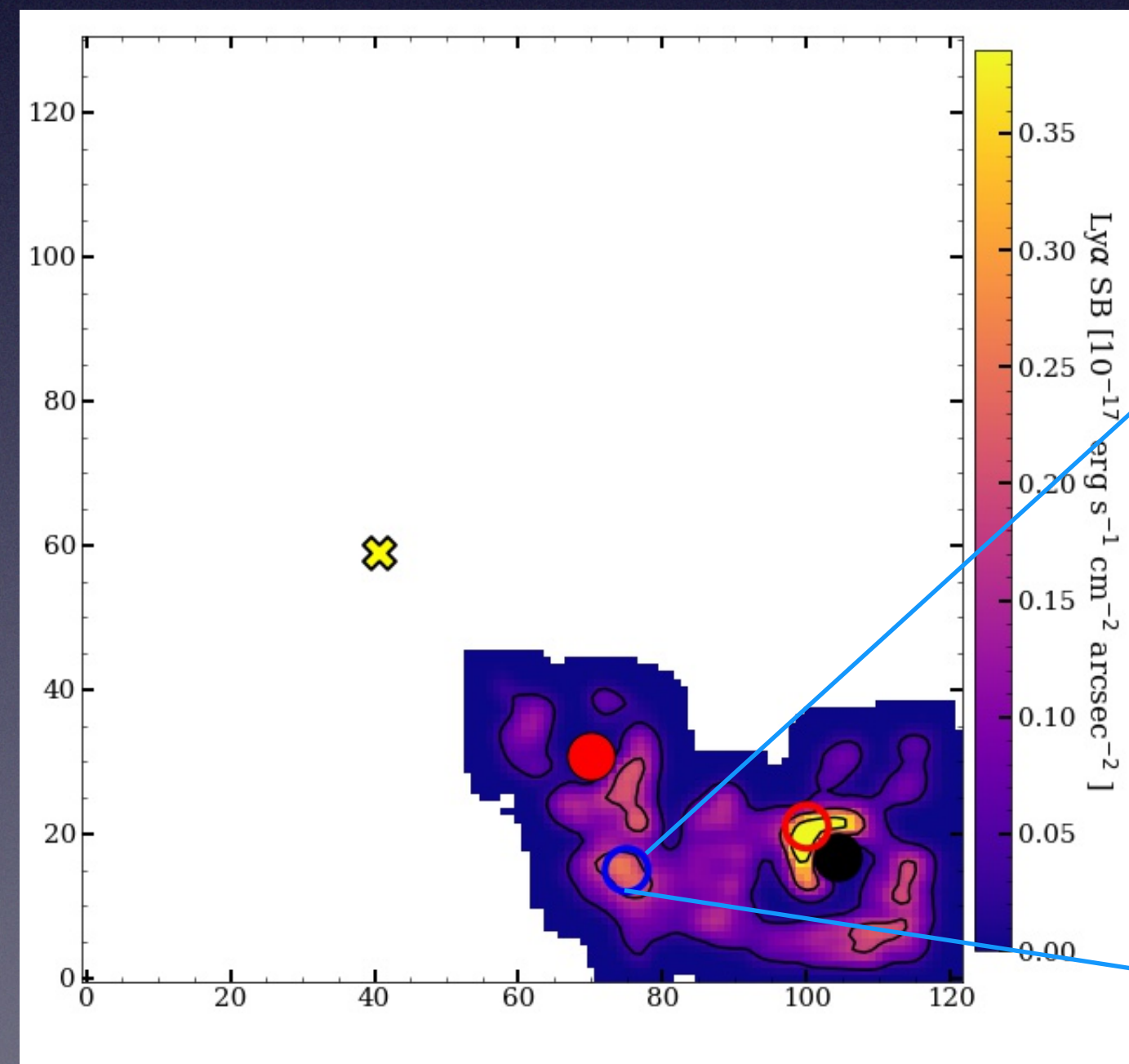


Summary

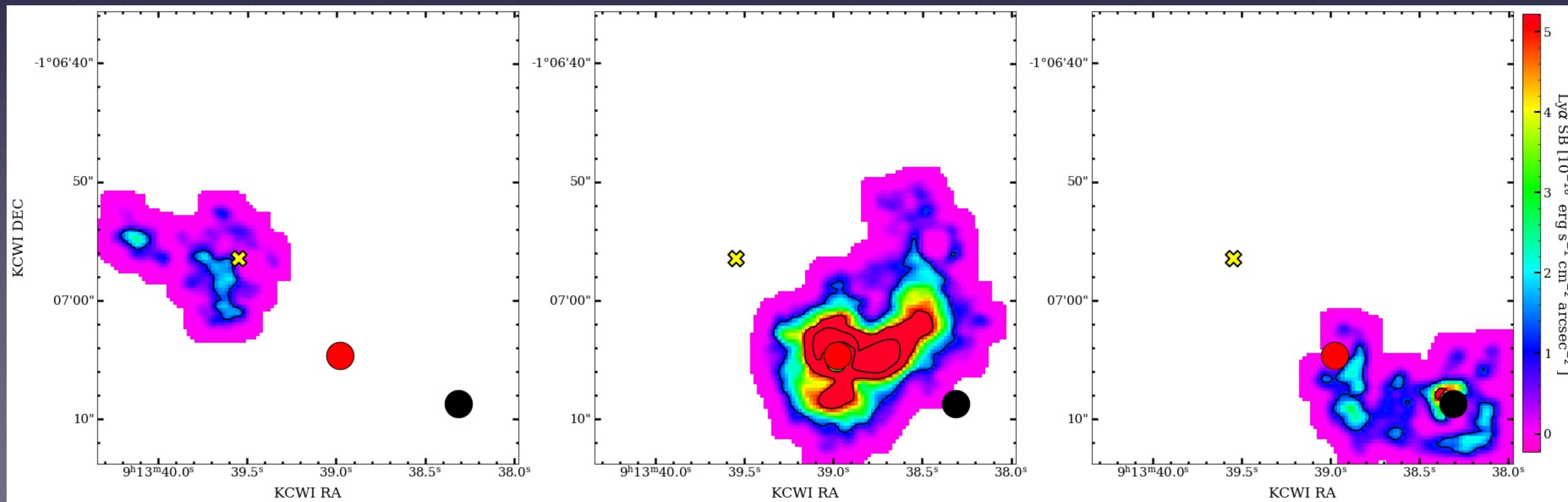
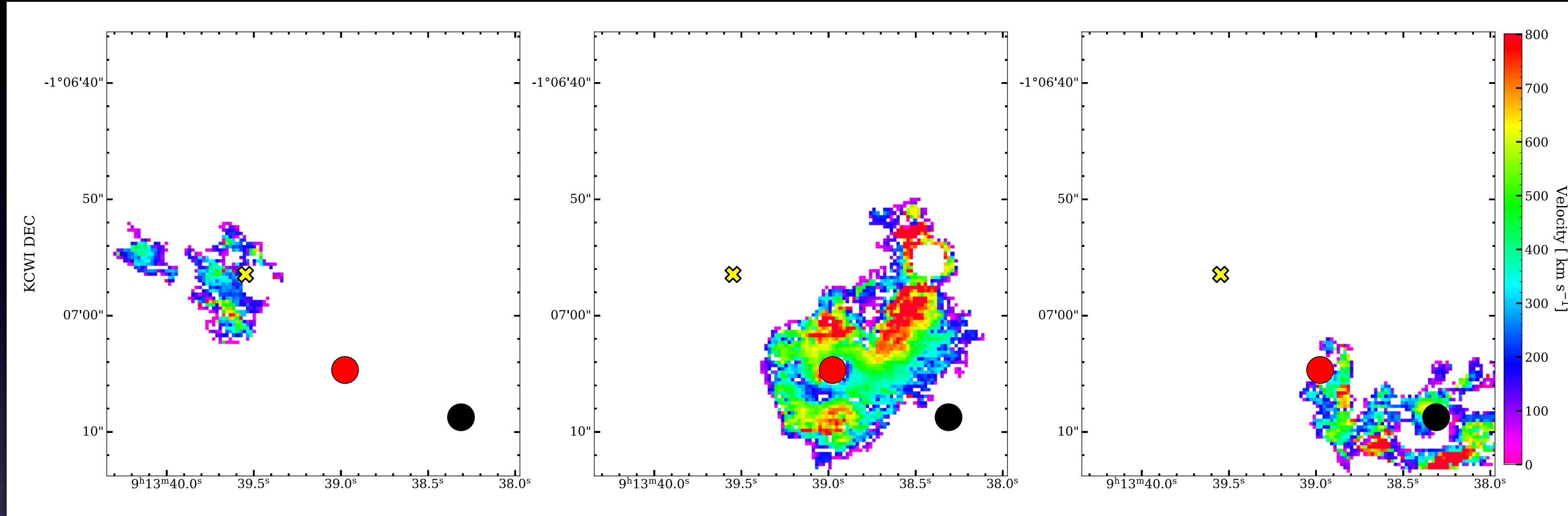
- Obtained deep images of the CGM at the redshift of the SMG
- Our Preliminary Results show extended Ly α emission with an offset from the SMG location
- One of the first detections of a Ly α nebula around a SMG
- Our two QSOs have different Ly α Halos despite possessing similar Luminosities. Suggests different extended environments

Work Supported by NSF Grant AST-2103251

Connection Between QSO1 & QSO2



Velocity Dispersion Map



Possible Power Mechanisms for Ly α Emission

- **Resonant Scattering:** As the Ly α photons travel out from the host quasar or galaxy, they can undergo resonant scattering with the surrounding gas leaving the observed Ly α emission.
- **Photoionization:** The central AGN or high star formation rates will emit light in the UV and the surrounding gas undergoes recombination.
- **Shocks:** here may be significant turbulence from outflows that can cause collisional excitation and emit Ly α photons.
- **Gravitational Cooling:** The host galaxies are surrounded by large Dark Matter halos. As a result, the matter will condense and collisional excitation will occur allowing gravitational potential energy to radiate away.