Core, disc and clump formation: do galaxies grow inside out in the first billion years?

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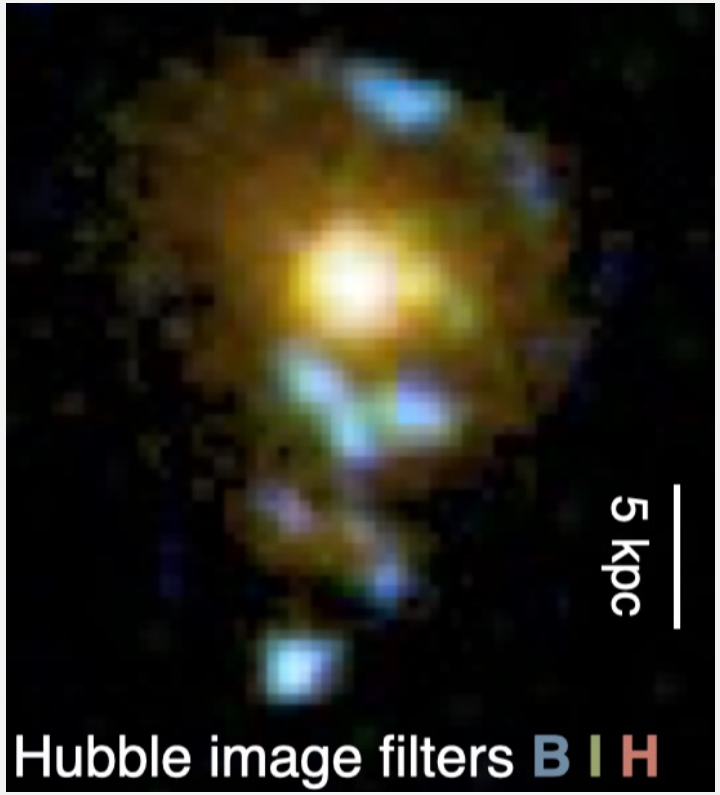
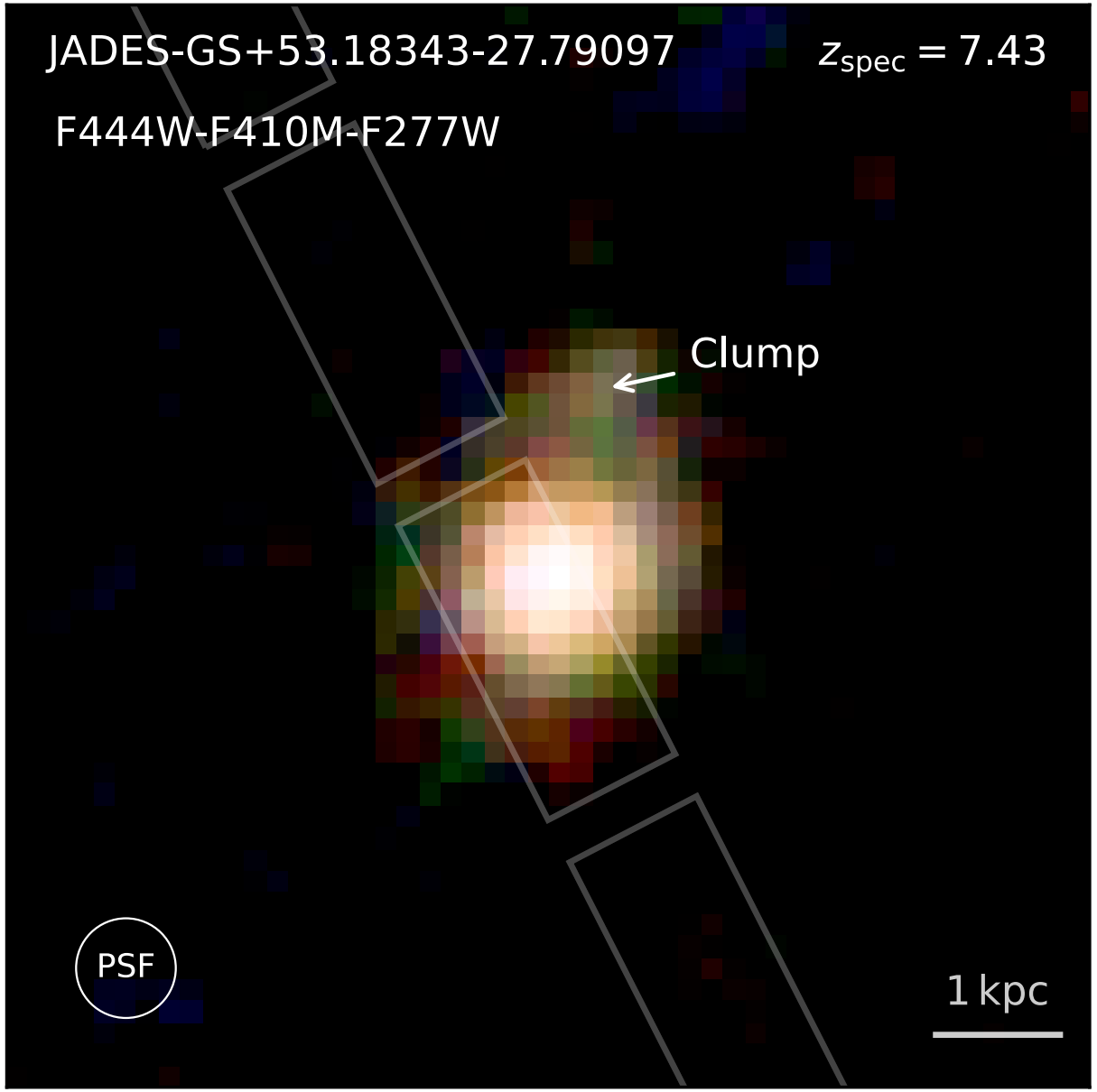
Local to redshift z∼2 universe

- We see many (quiescent) bulge and (star-forming) disc galaxies locally (Kormendy+2004, Simmard+2011 and many others)
- But of course: local spiral galaxies are not the progenitors of local ellipticals
- To find these progenitors we need to probe much more distant galaxies
- Multiple bulges at redshift 2, Lang+2014, Tacchella+2015, How do they assemble?



Tacchella+2015



We find this 3-component galaxy at z=7.4 !

- Spectroscopic NIRSpec confirmed redshift of **7.4**
- Central core component
- Surrounding disc component
- Clump offset from the disc component

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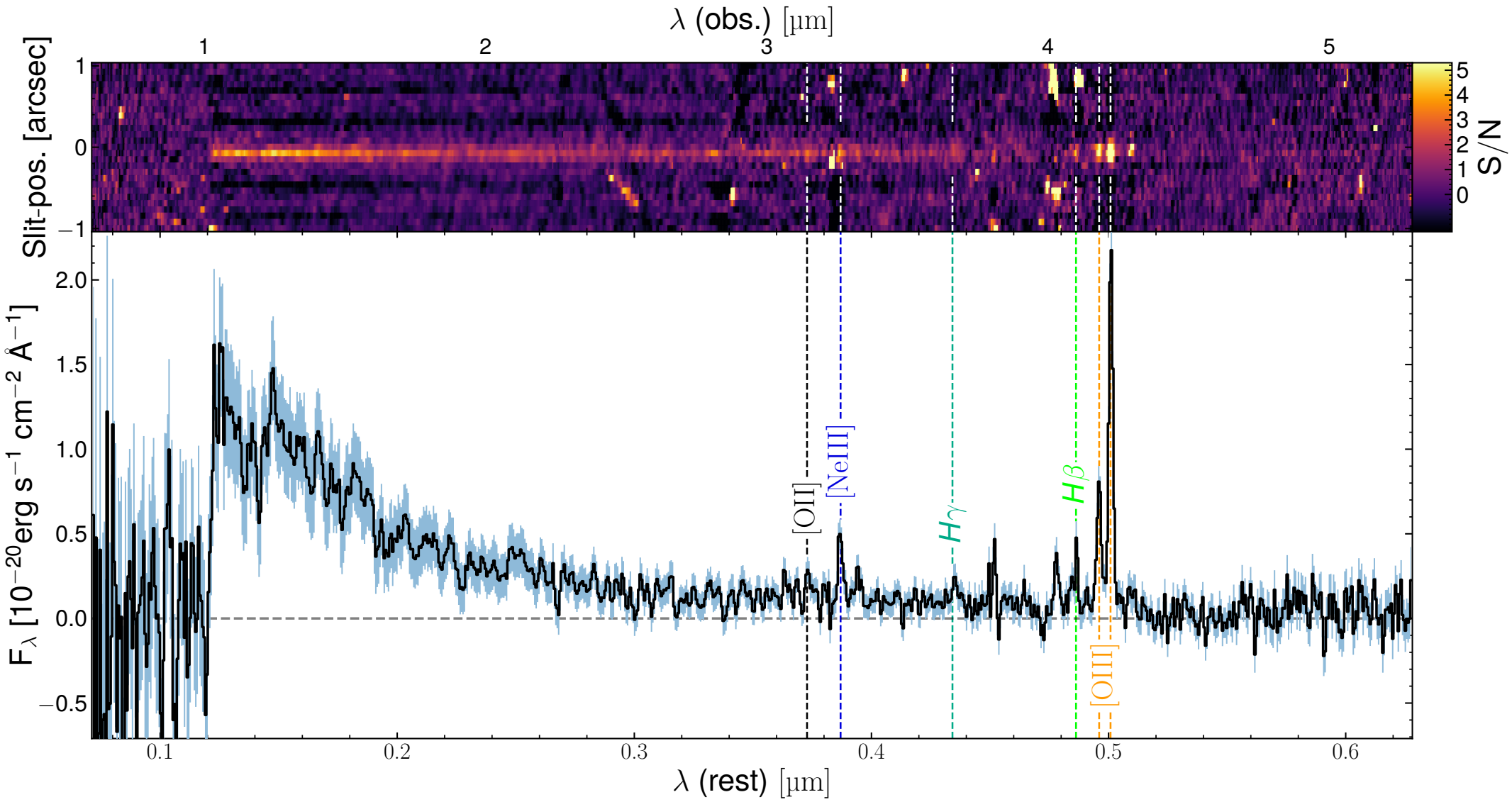
NIRSpec Spectrum



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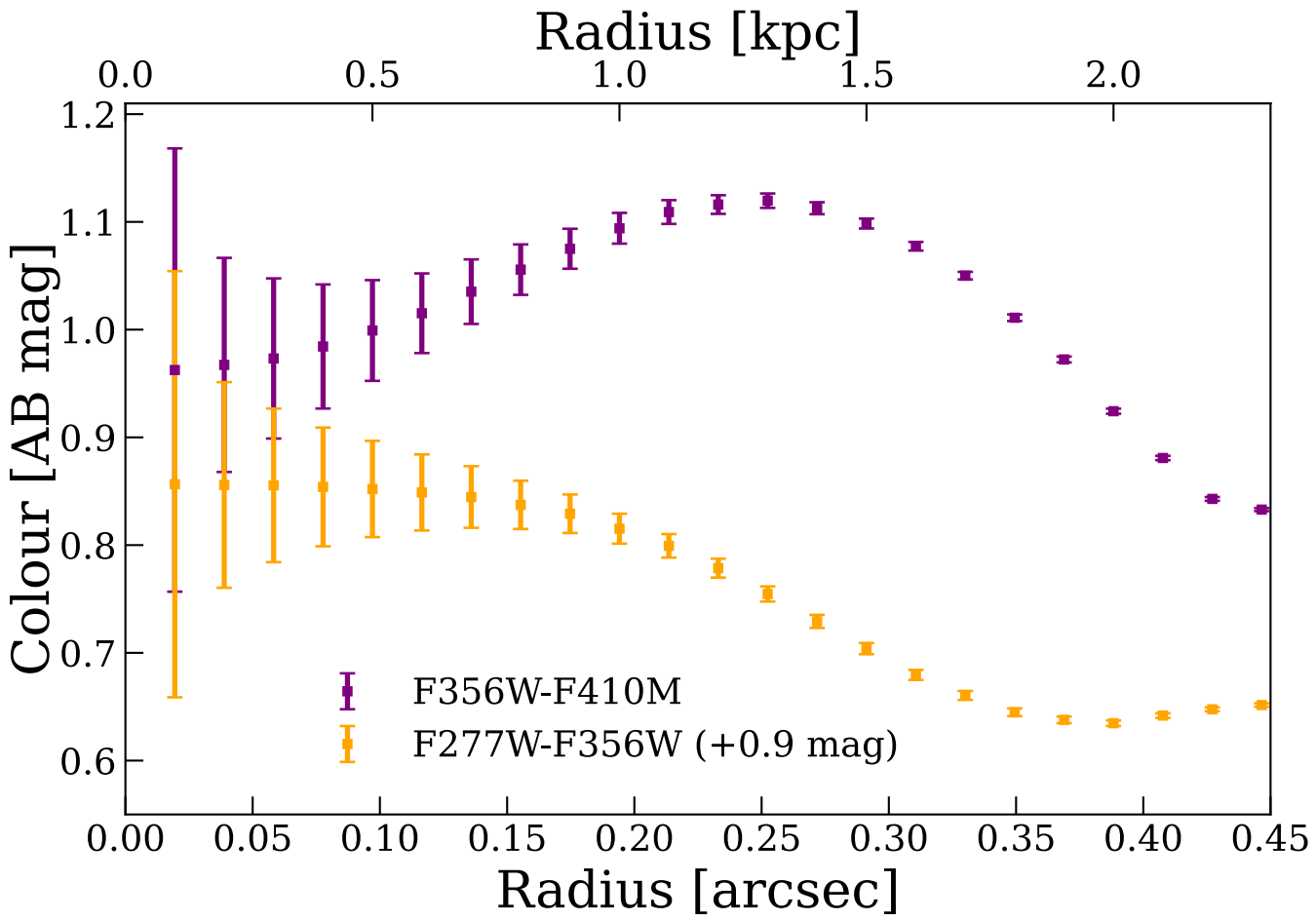
Colour gradients

- Clearly visible colour-gradient



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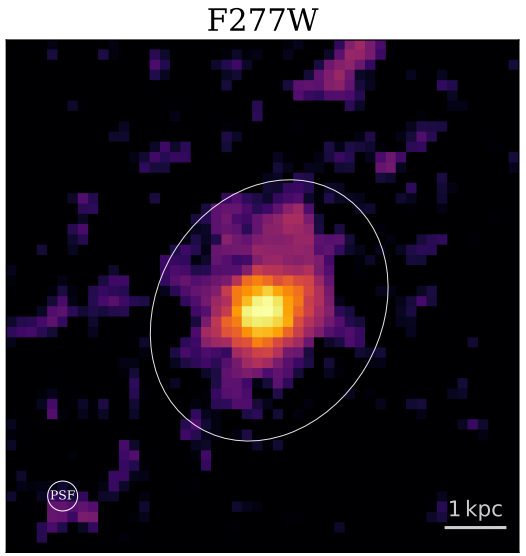

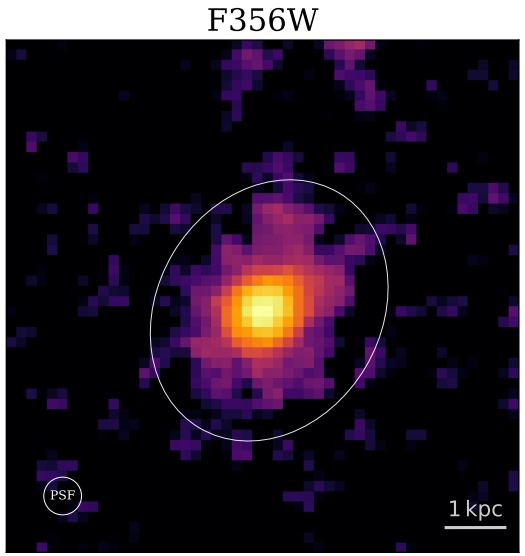

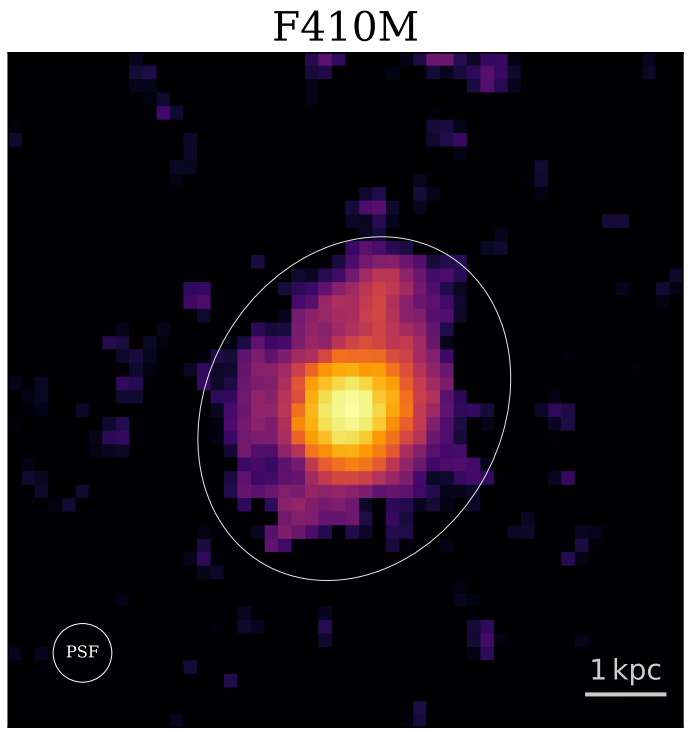

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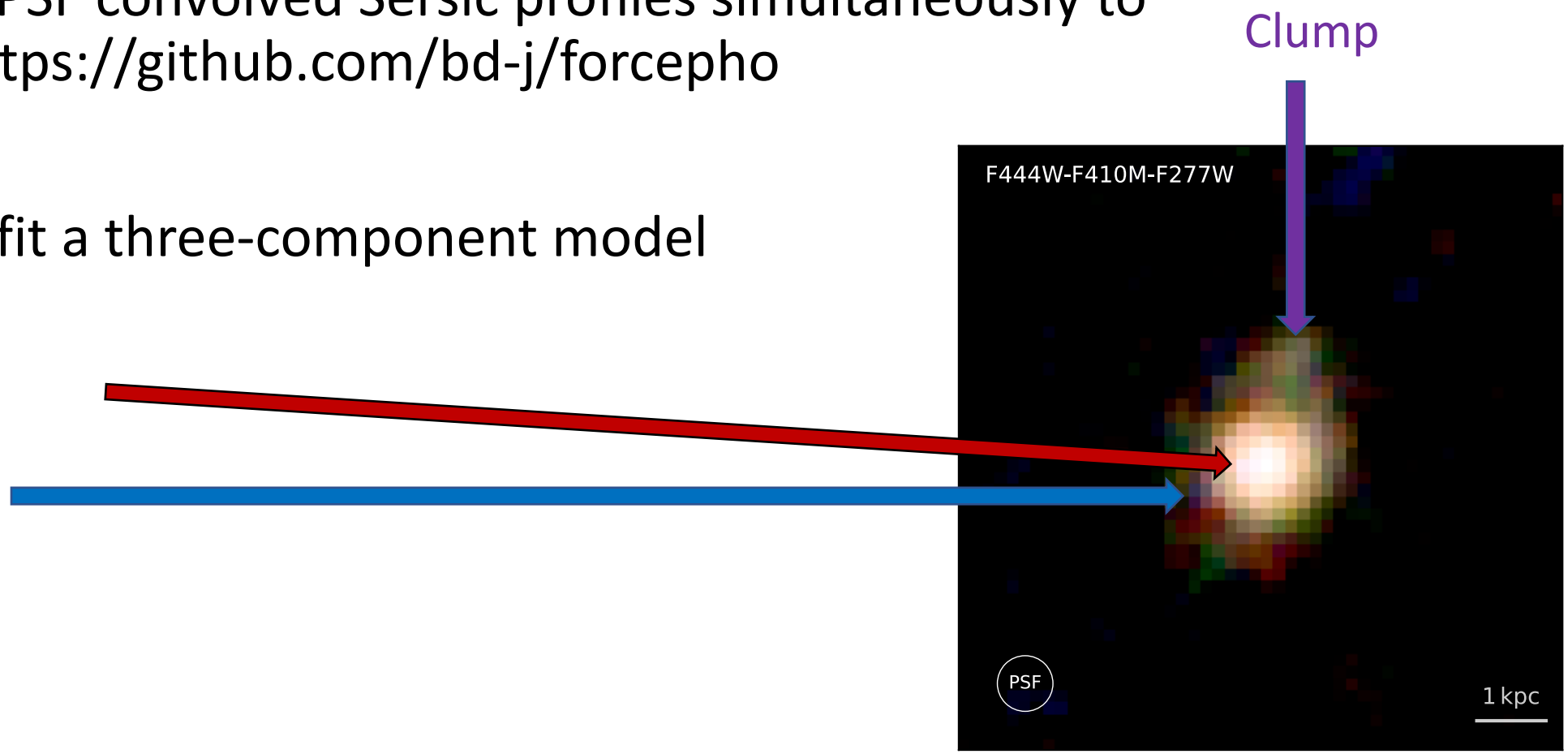
ForcePho

- ForcePho (Johnson+ in prep) is a forced photometry tool that fits multiple PSF convolved Sersic profiles simultaneously to each filter https://github.com/bd-j/forcepho

- We use it to fit a three-component model

- Central Core
- + Disc
- + Clump



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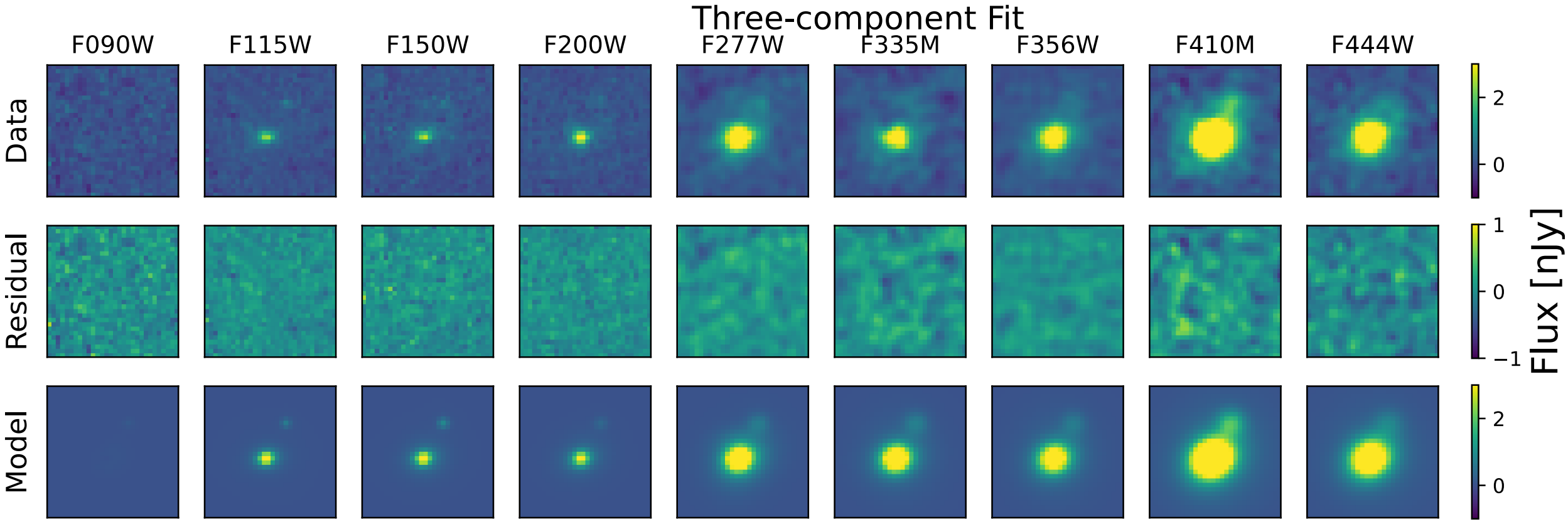
ForcePho fits

- Can see how ForcePho models the components well in each band



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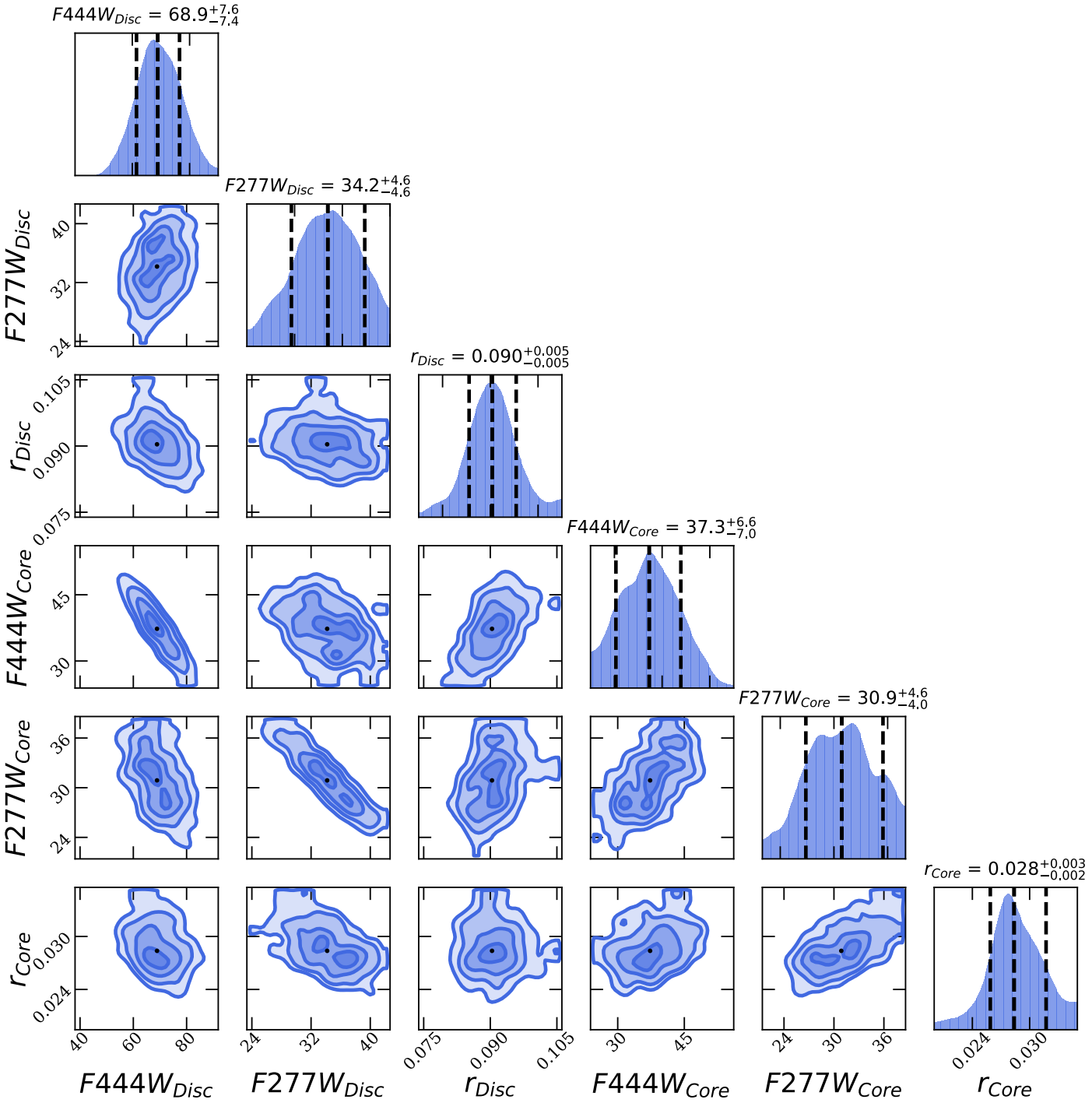

ForcePho Fits

- Corner fit showing fluxes and sizes for the Core and Disc components

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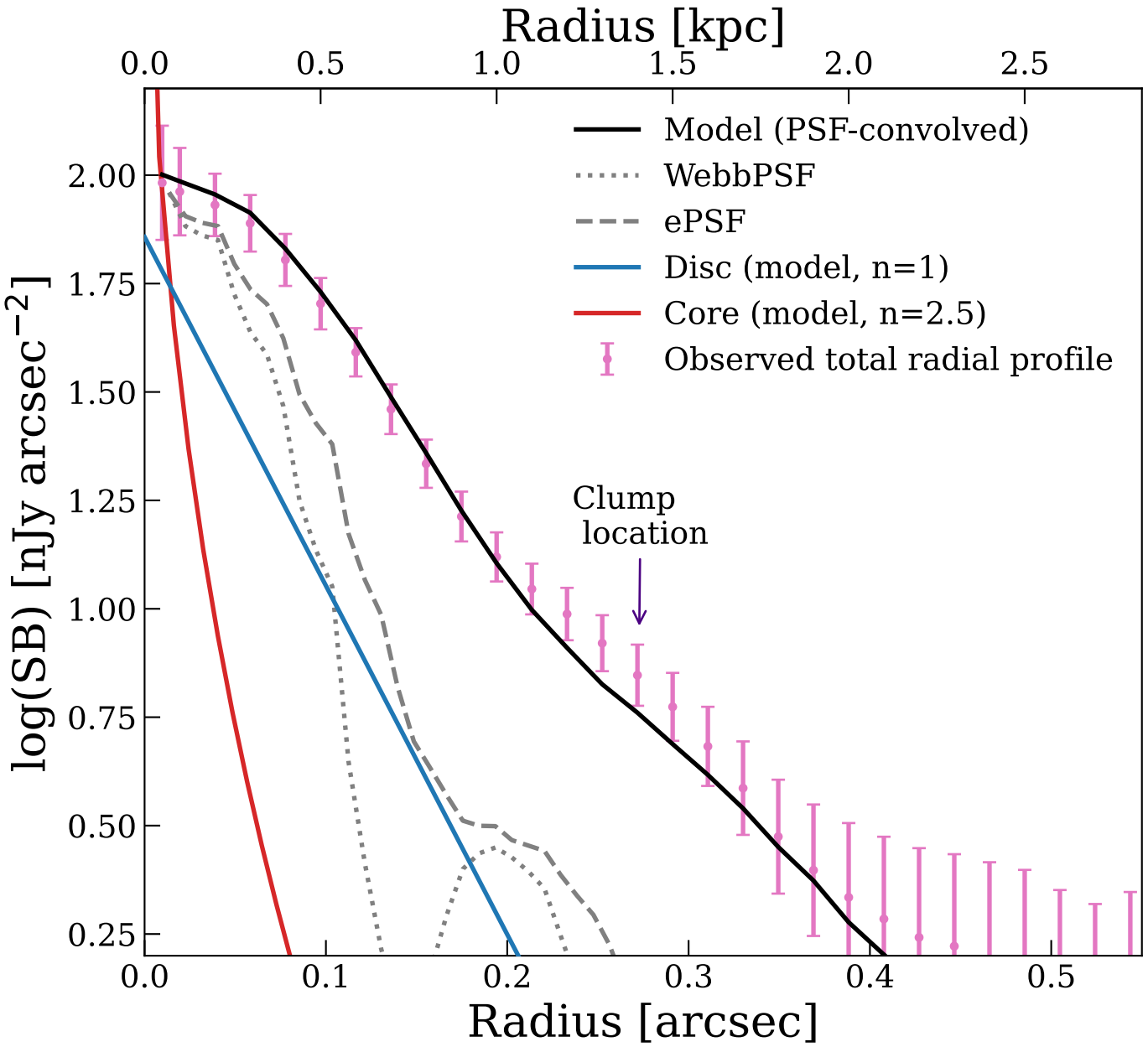
Surface Brightness Profile

- PSF convolved model fits the data well (F356W)
- Can see how PSF smears out Core and Disc to larger radii



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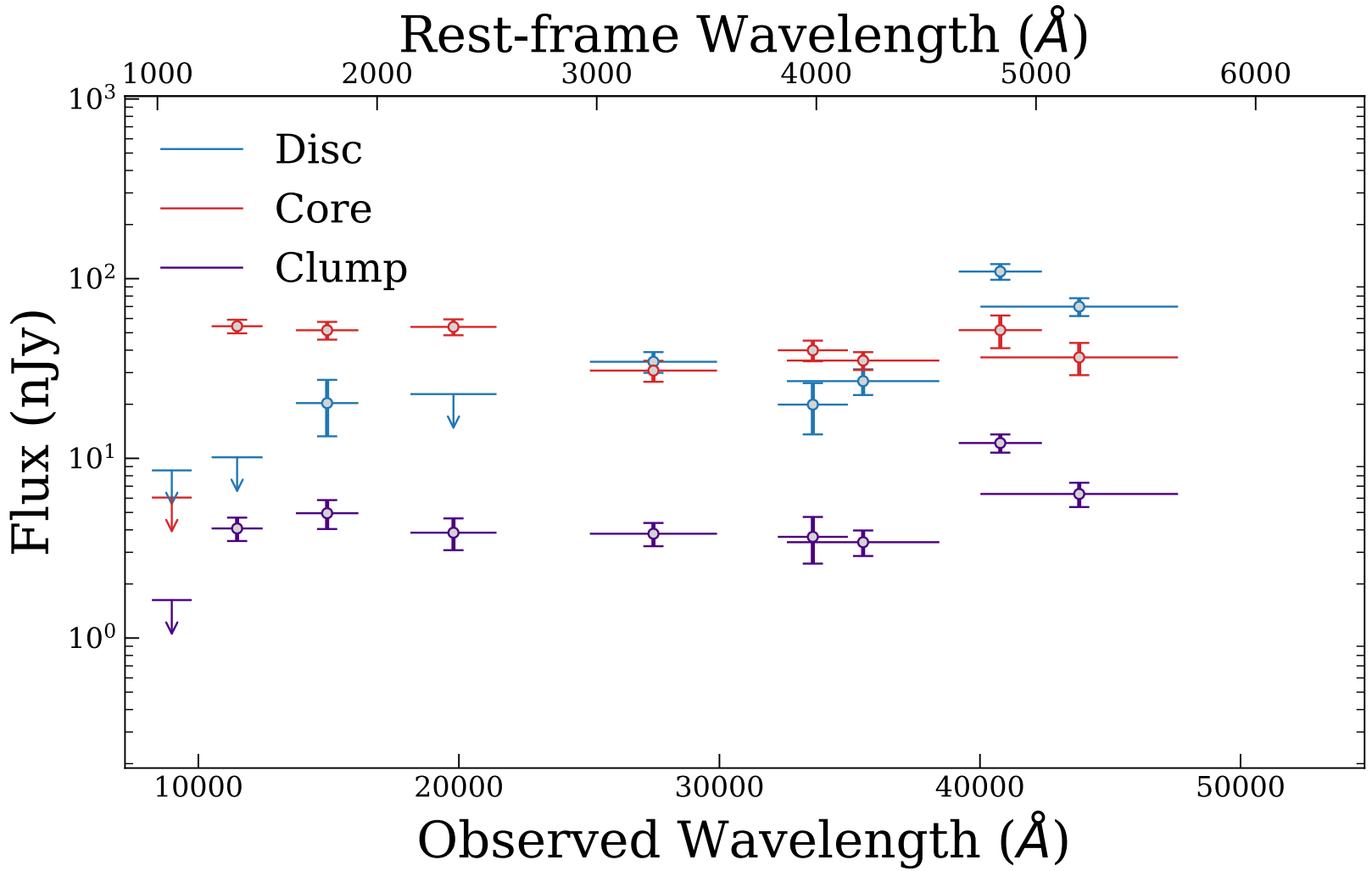
SEDs



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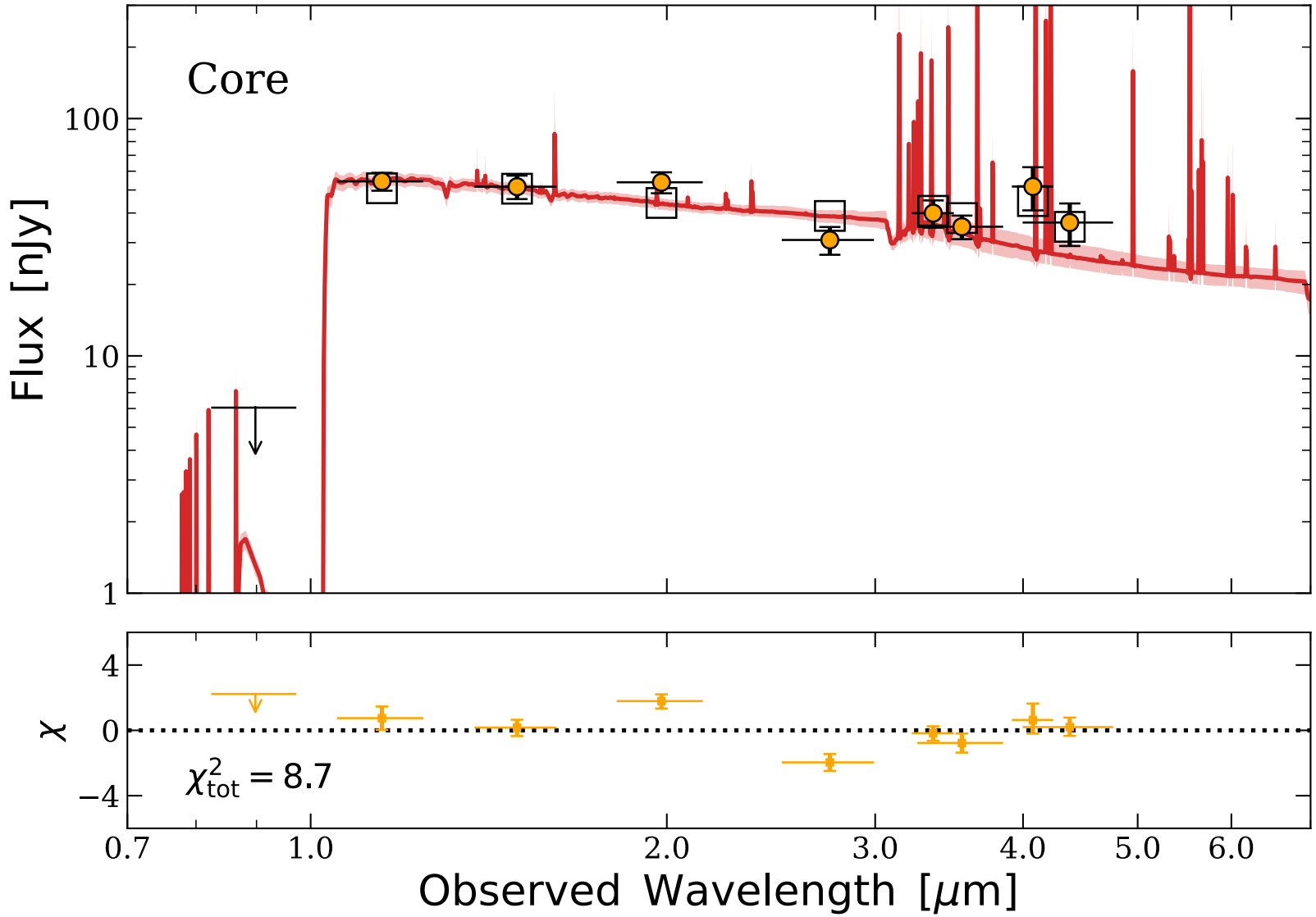
Core Component

- SED fitting with Prospector (Johnson+ 2021)
- Non-parametric SFH (Continuity prior, Leja+ 2019)
- $\log(M_*/M_\odot)$= 8.39
- $t_{half} \approx$ 51Myr
- SFR$\approx 3\ M_\odot$/yr



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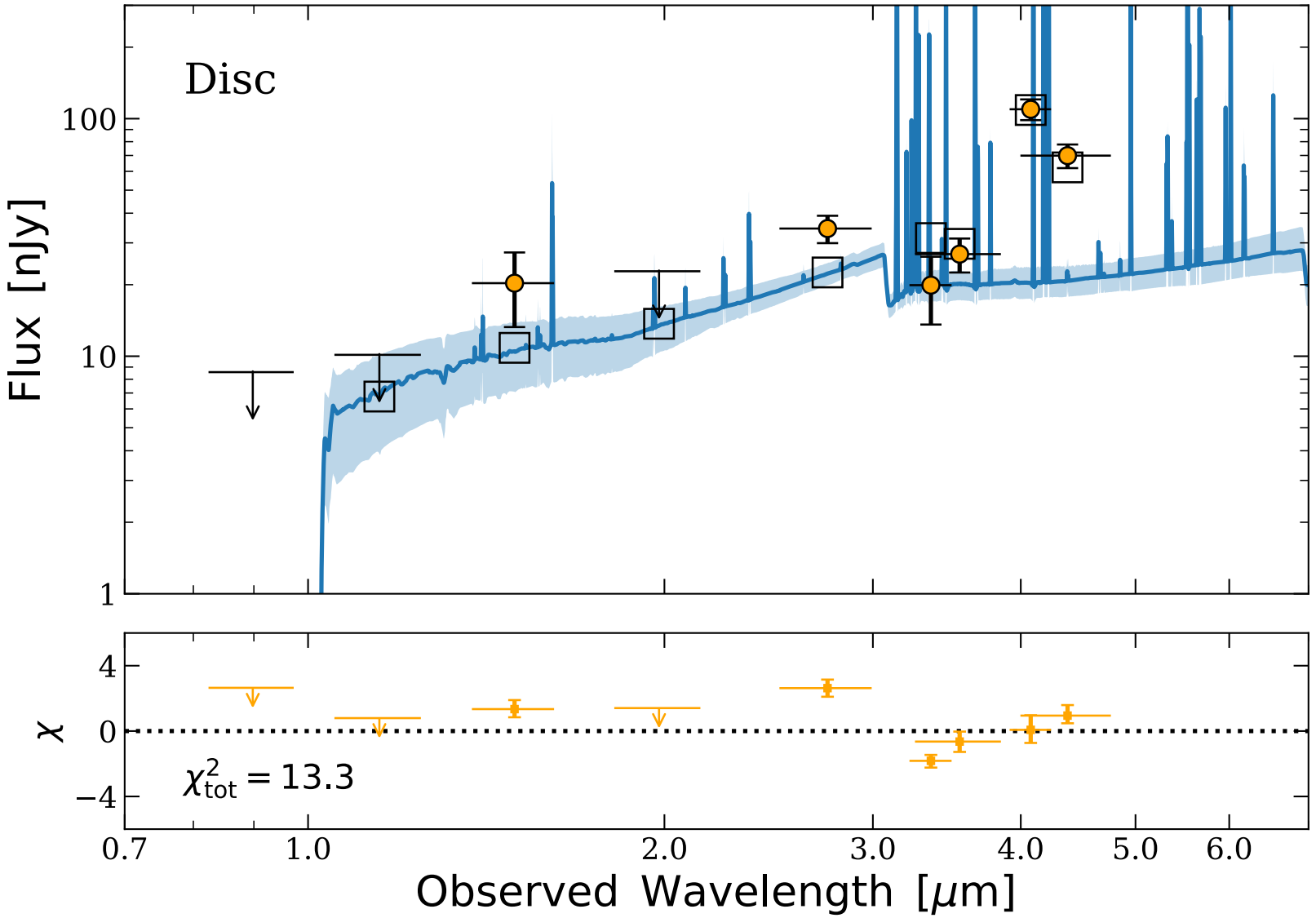
Disc Component

- Fit independently, but with the same fitting routine
- $\log(M_*/M_\odot)$= 8.3
- Relatively young ($t_{half} \approx 23$Myr)
- SFR$\approx 10\ M_\odot$/yr



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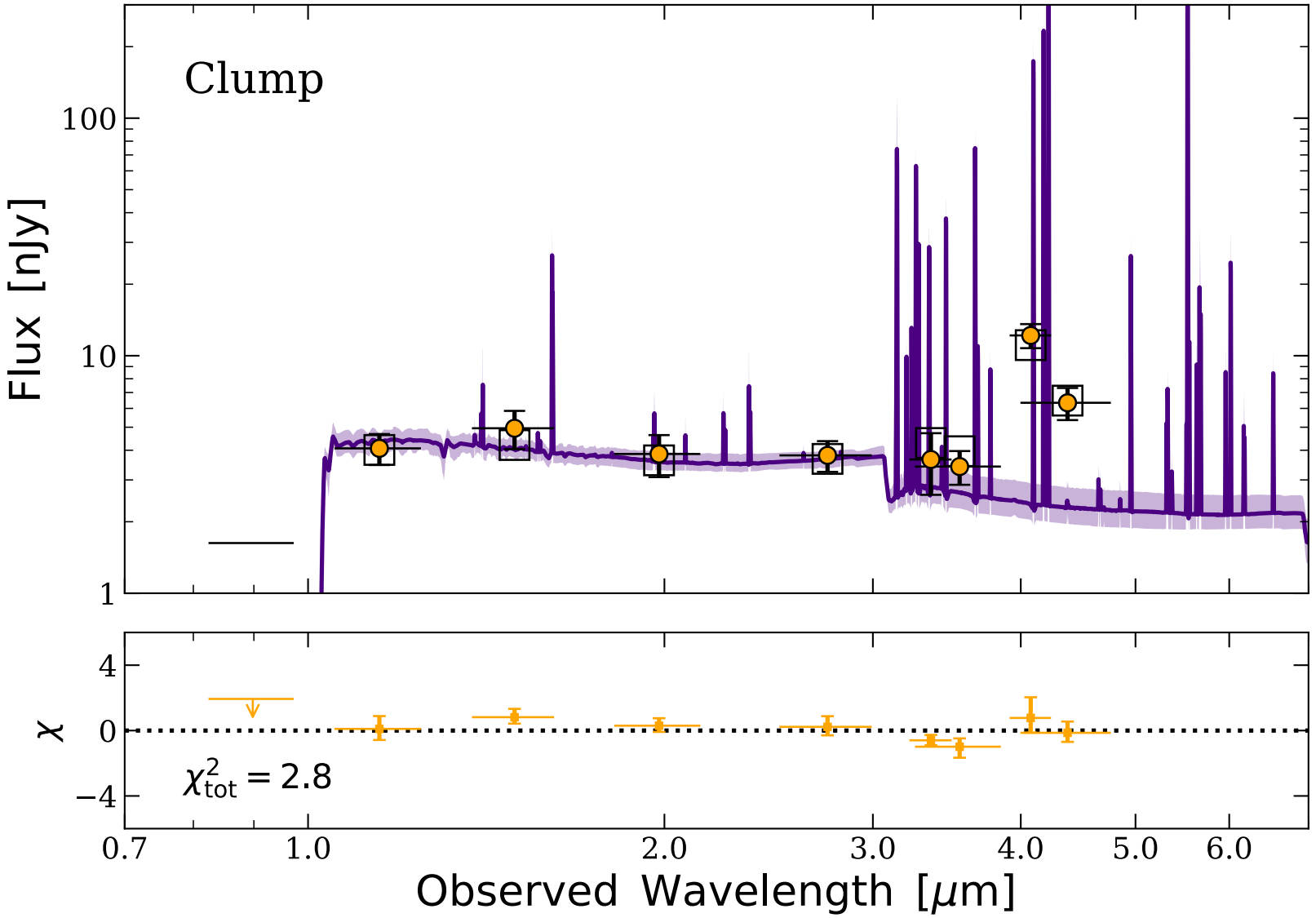
Clump Component

- Fit independently, but with the same fitting routine
- Can see that the clump has a distinct stellar population → might be a small merging galaxy?
- $\log(M_*/M_\odot)$= 7.2



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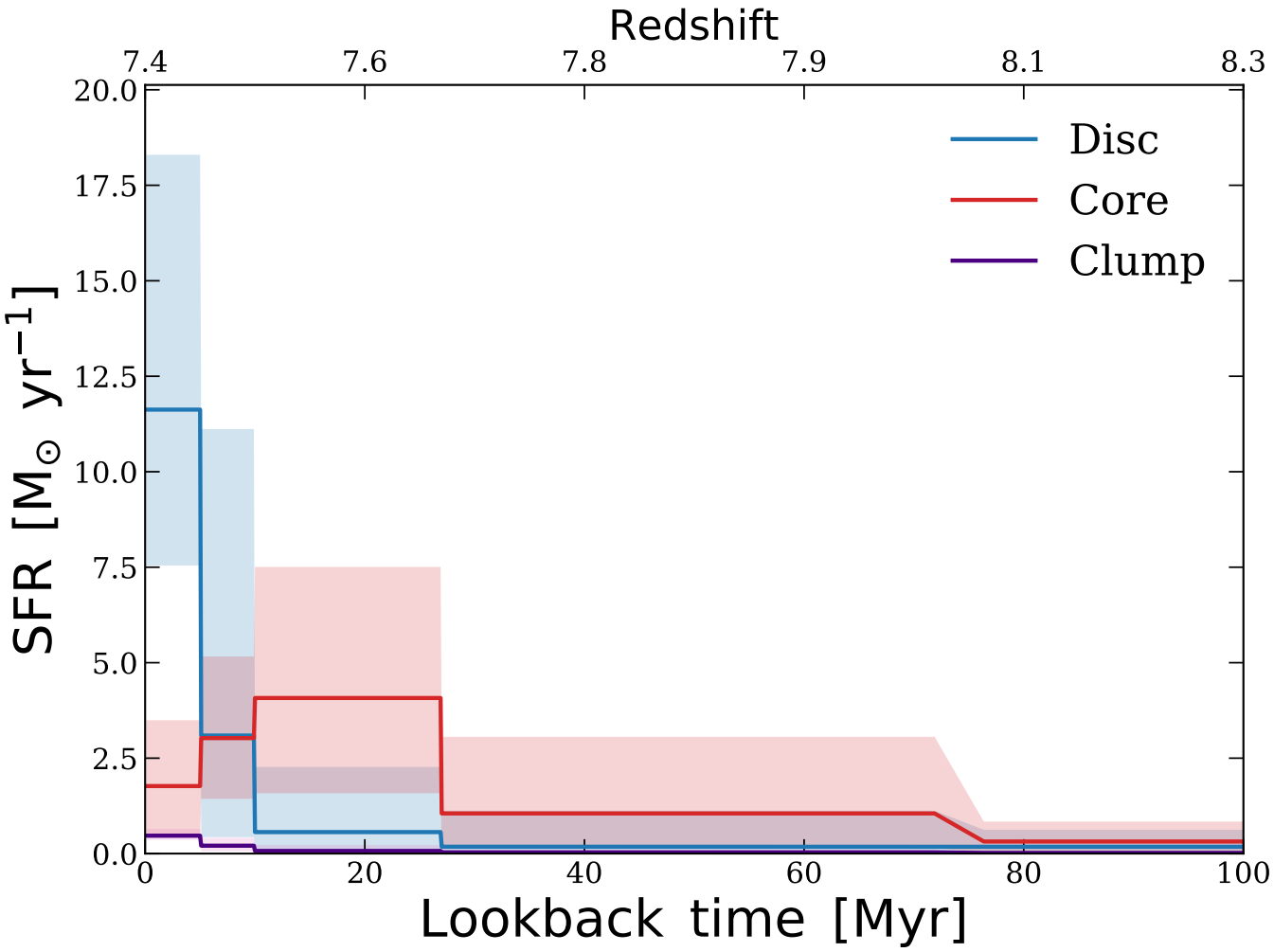

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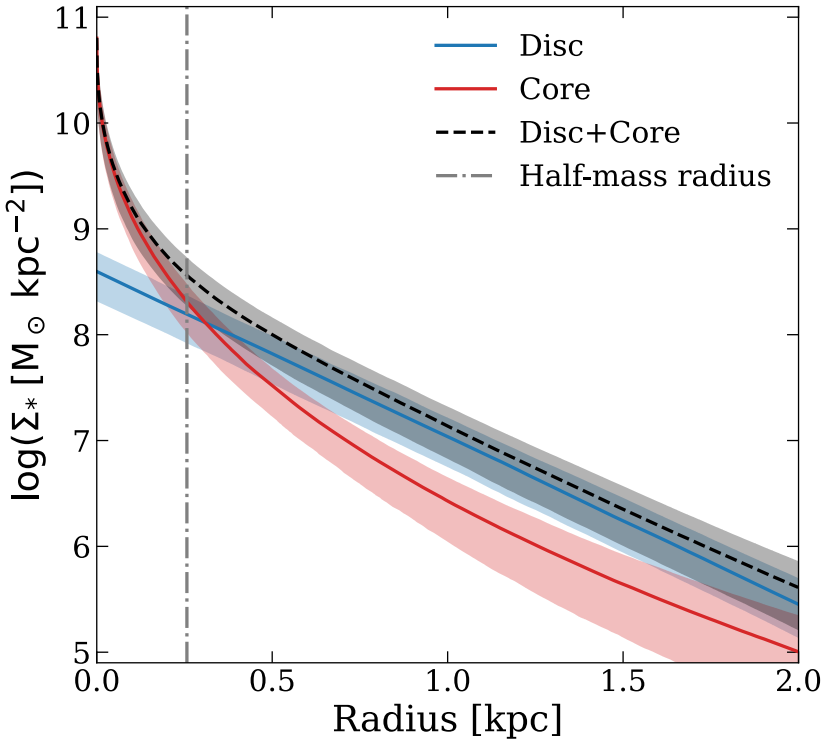
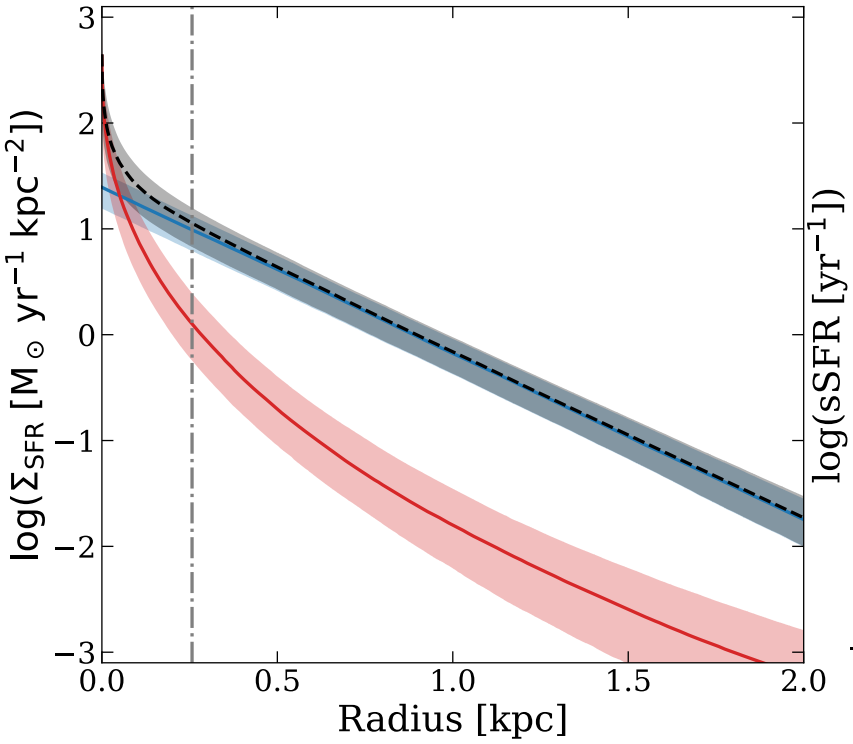
Star-formation histories

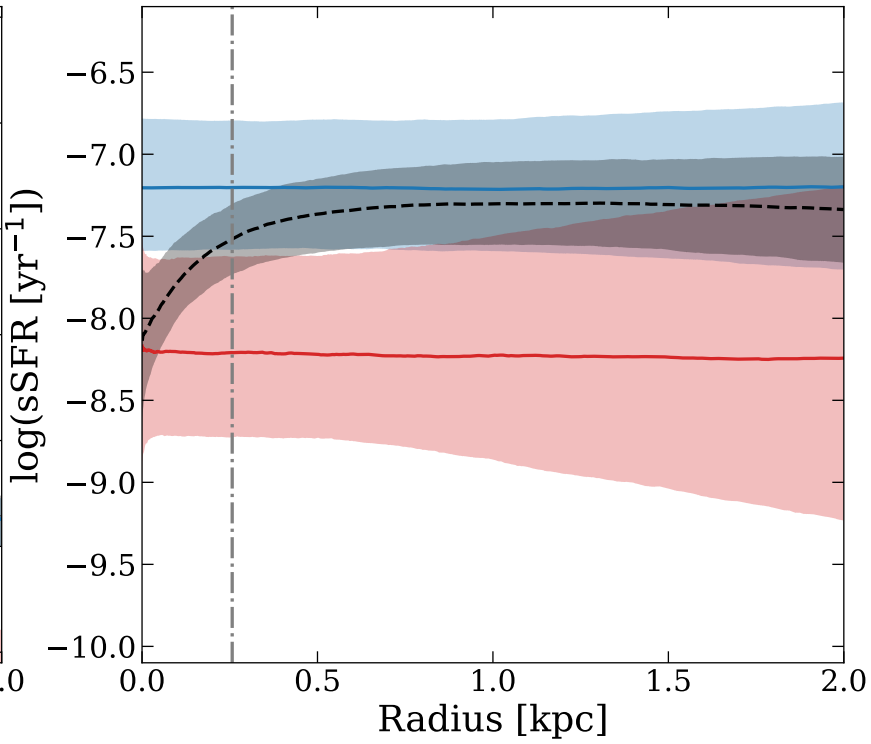
- Disc appears to be undergoing a recent burst
- Core appears to be decreasing in SFR
- Core and Clump appear to be older, Disc appears to be younger

Surface Density profiles

- Disc responsible for most star-formation seen, but Core responsible for most of the stellar mass in the central region → inside-out growth?







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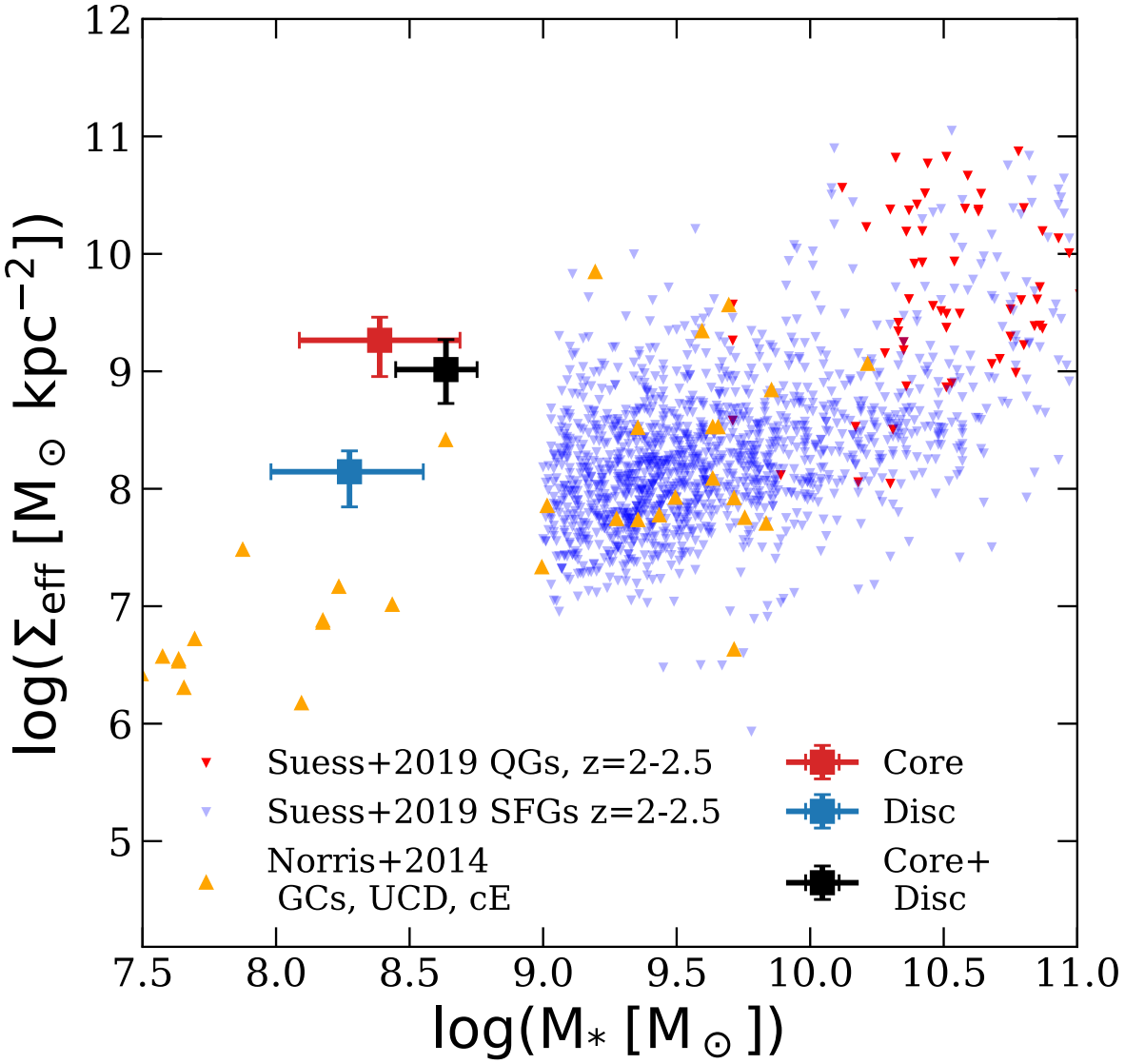
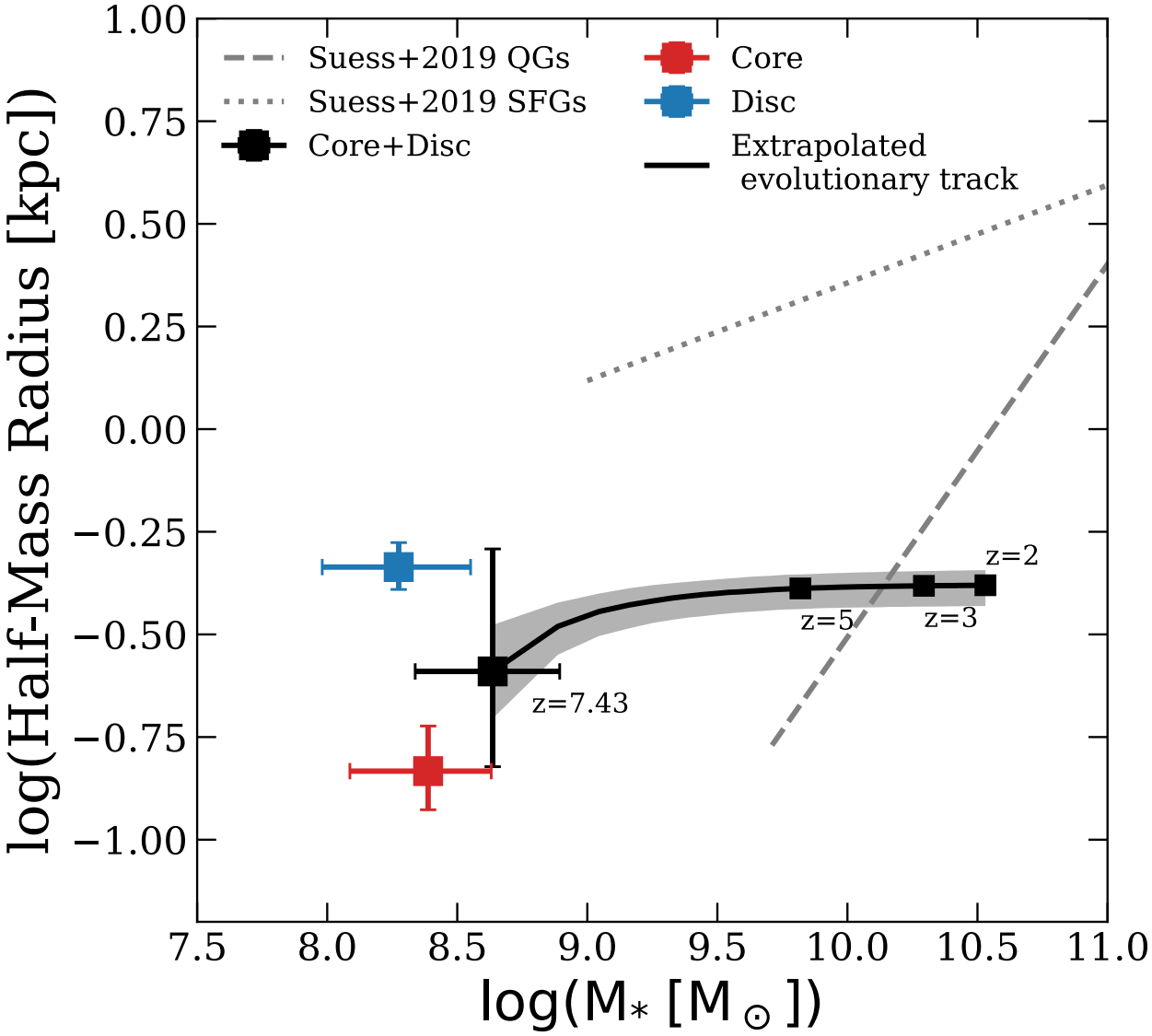
Mass-size





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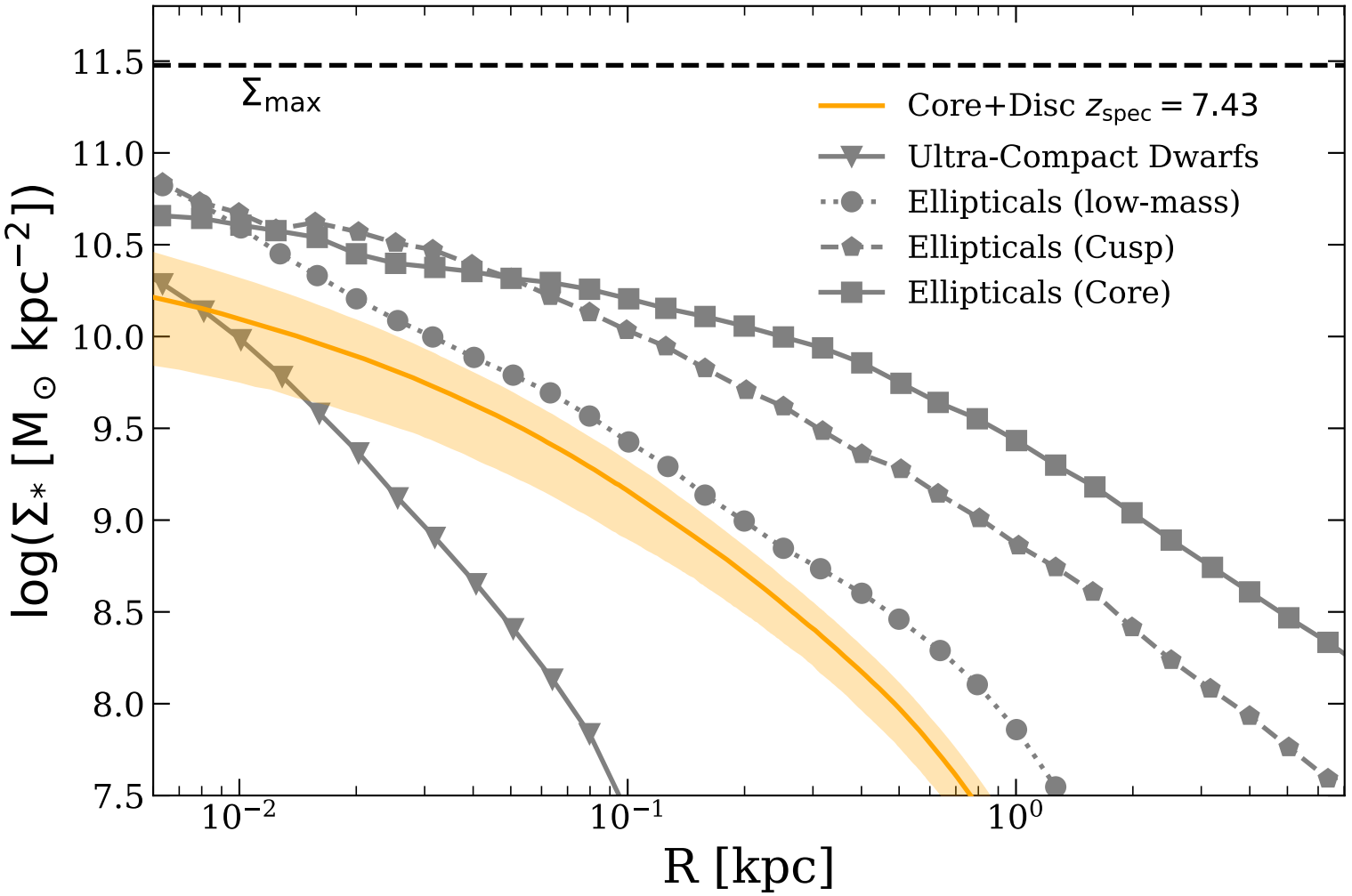
How does this compare to the local universe?

- The core+disc plotted against local analogues (Hopkins et al. 2010)
- Core: pretty massive and dense!
- Within x2 of local massive ellipticals despite 1000x less massive overall



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Conclusions

- Find Core, Disc and Clump components in a spectroscopically confirmed redshift 7.4 galaxy

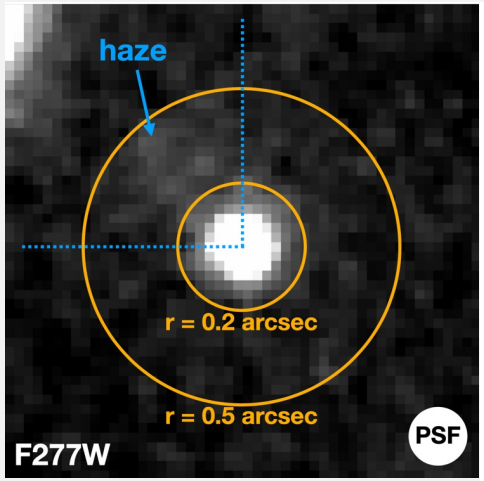
- Disc is relatively young ($t_{half} \approx 23$Myr) and strongly star forming (SFR$\approx 8\ M_\odot$/yr)

- Core appears to be older ($t_{half} \approx 51$Myr) and more massive ($\log(M_*/M_\odot)$= 8.39) - possibly a proto-bulge?

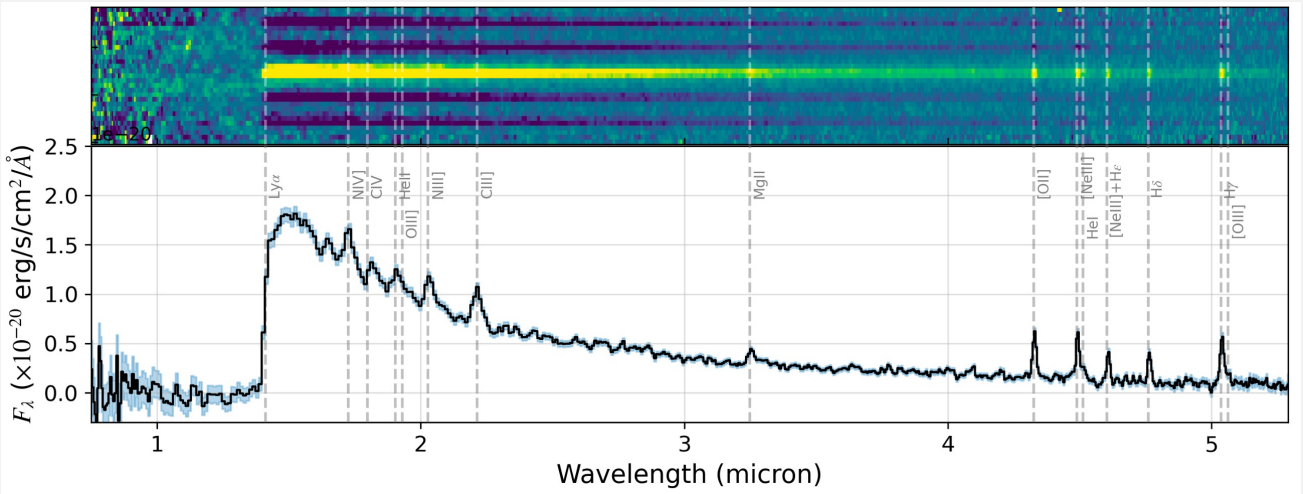
- Likely a progenitor of the kind of much more massive galaxy we see in the local universe!

JADES – JWST Advanced Deep Extragalactic Survey

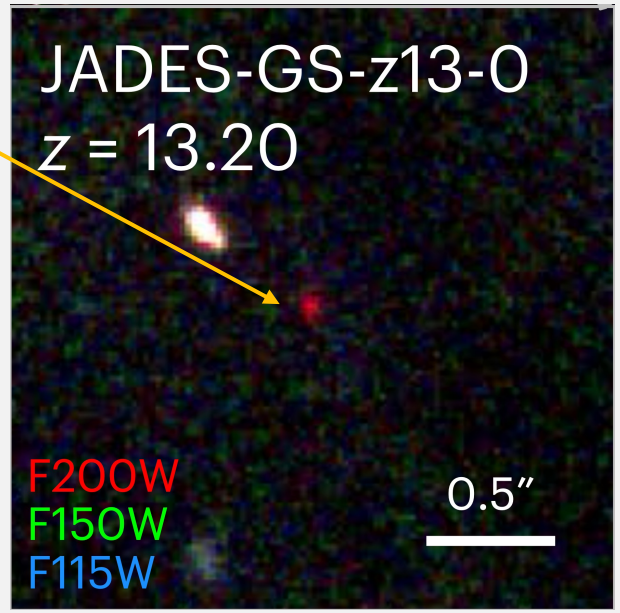
- NIRCam + NIRSpec GTO teams
- Deep imaging and spectroscopy of GOODS-S and GOODS-N
- Recent JADES papers, Robertson+2023, Curtis-Lake+2023 → current highest (spectroscopically confirmed) redshift galaxy
- Bunker+2023, Tacchella+2023, Gnz11
- Also see Saxena+ 2023, Looser+2023, Witstok+2023 and many more!



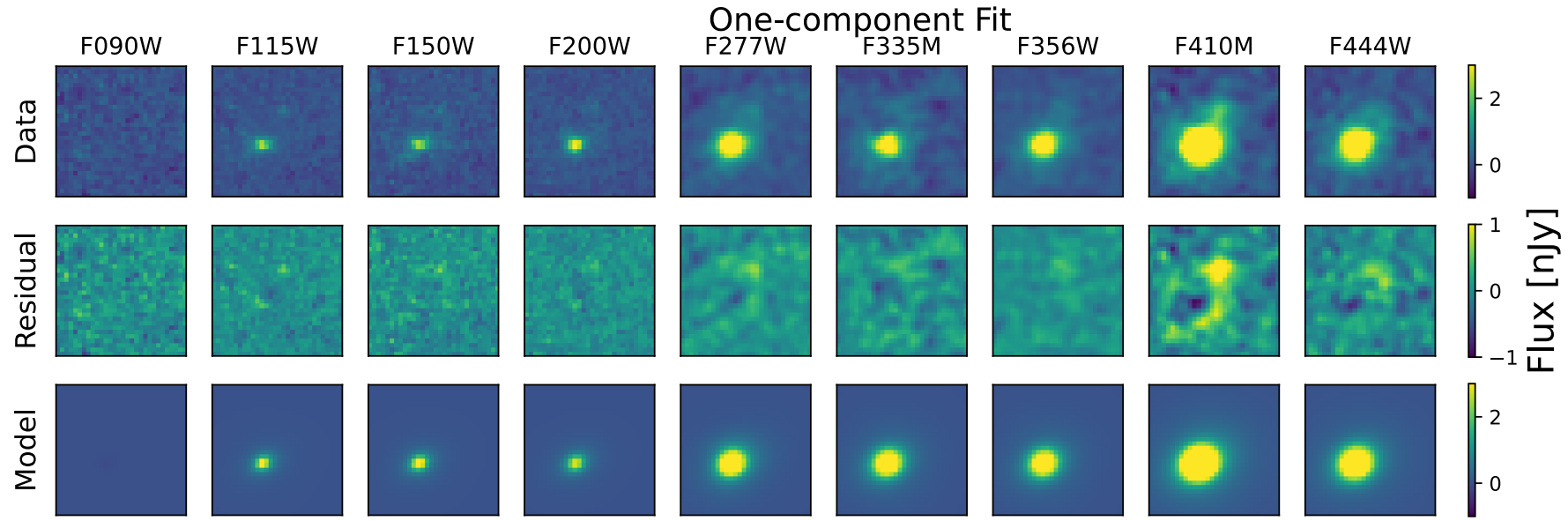
Tacchella+2023

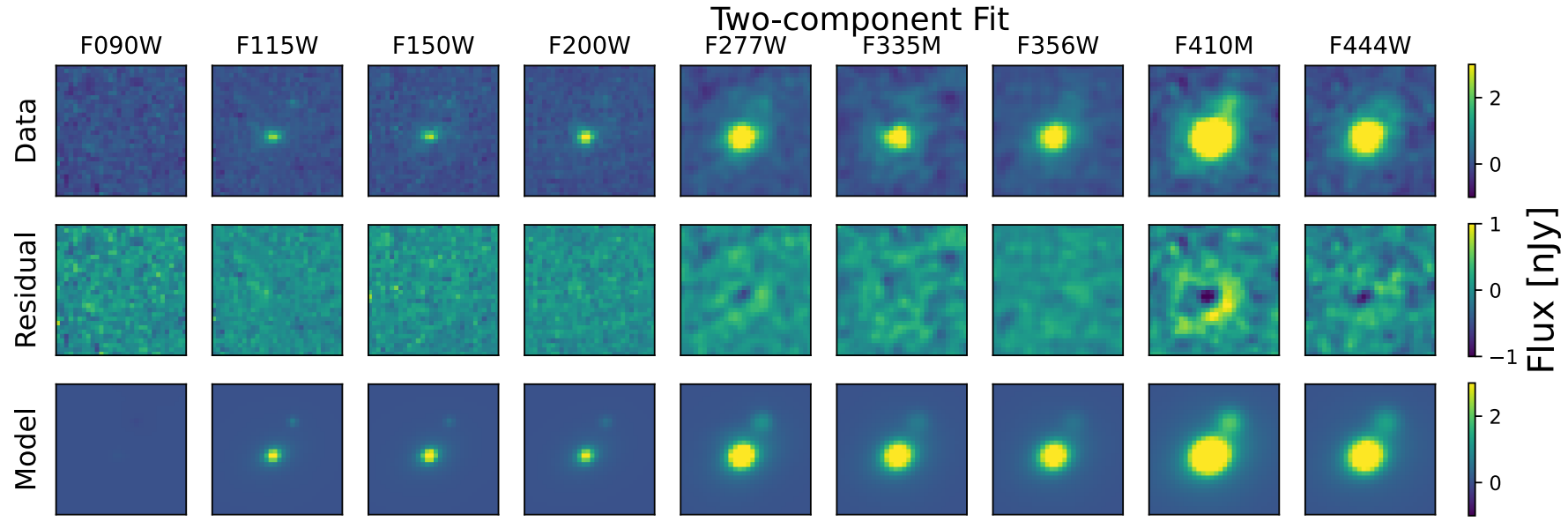


Bunker+2023



Robertson+2023





One and two component fits

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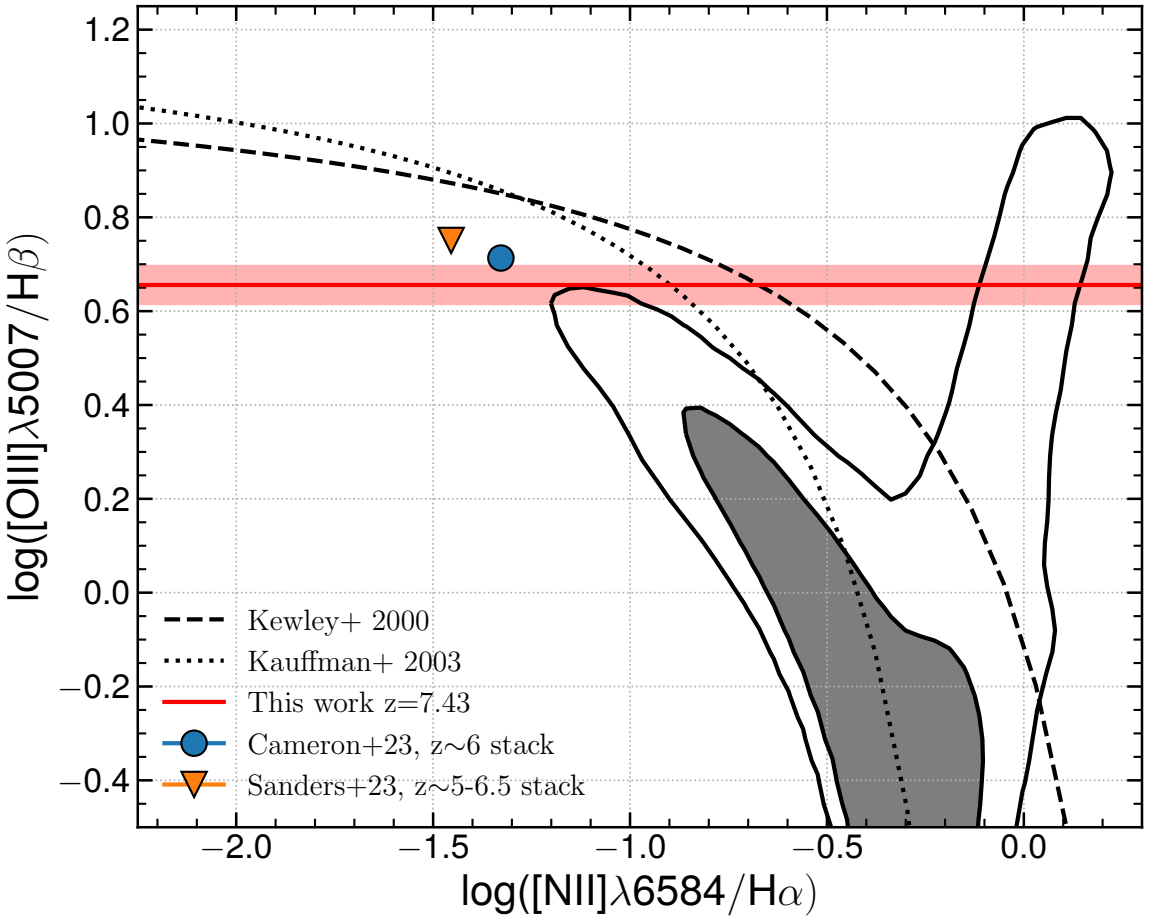
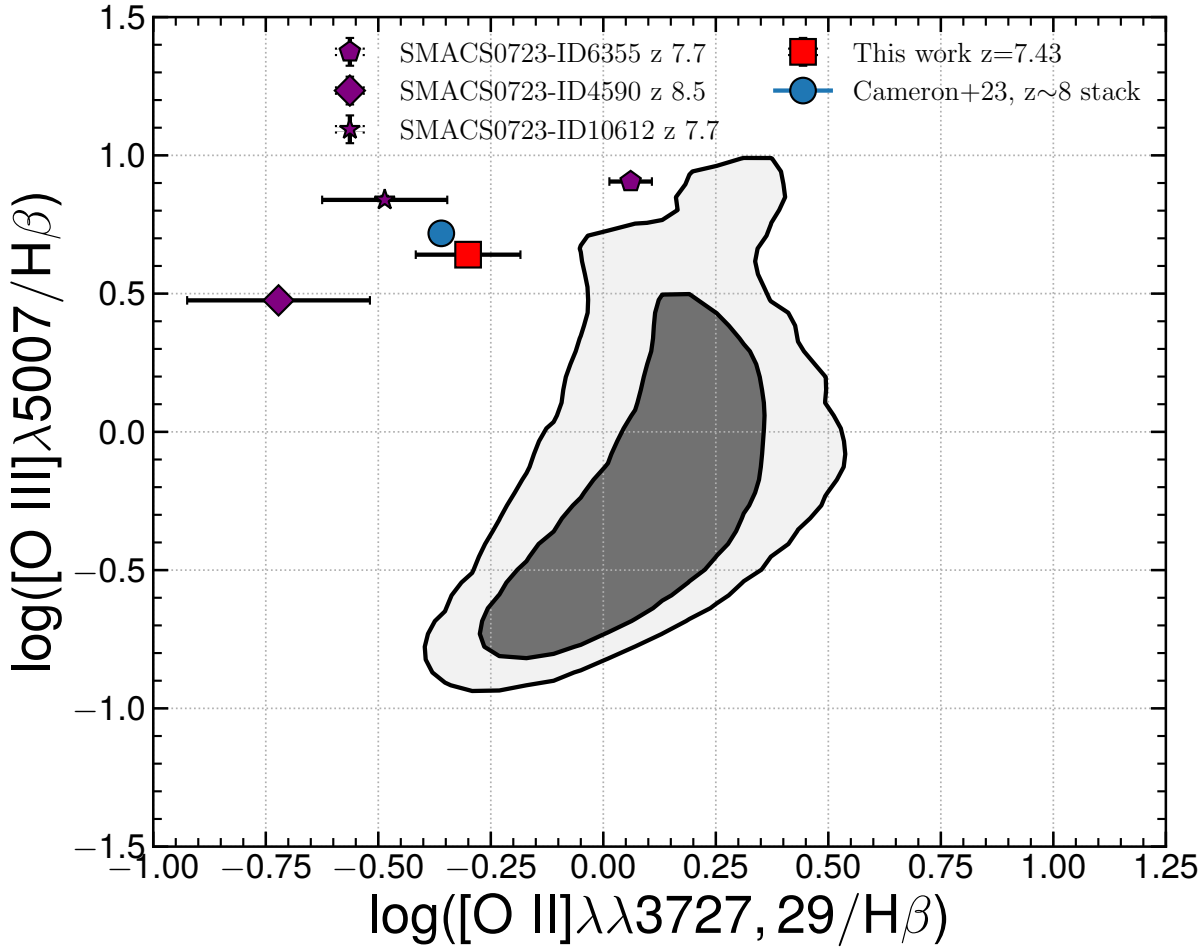
AGN? – probably not





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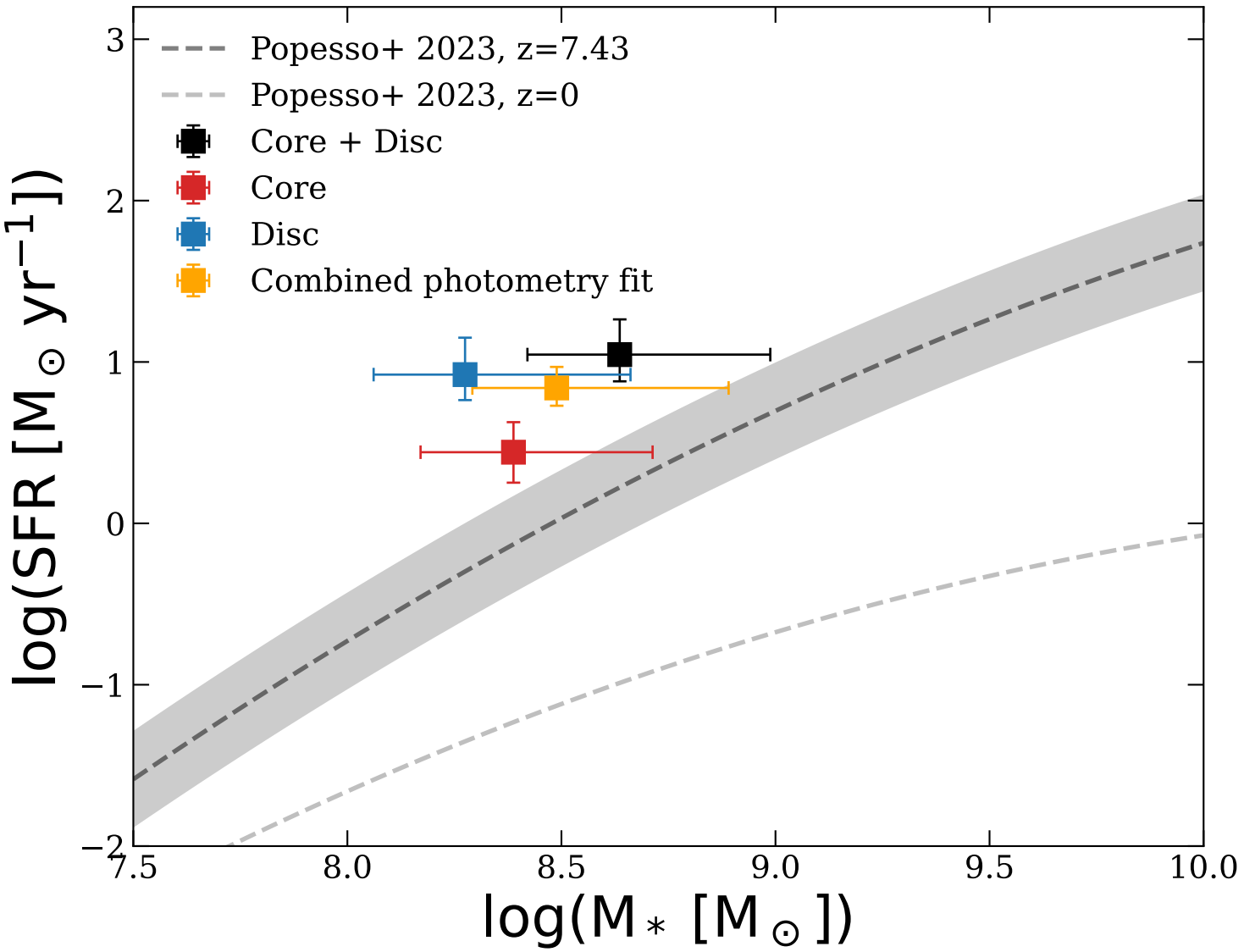
SFMS



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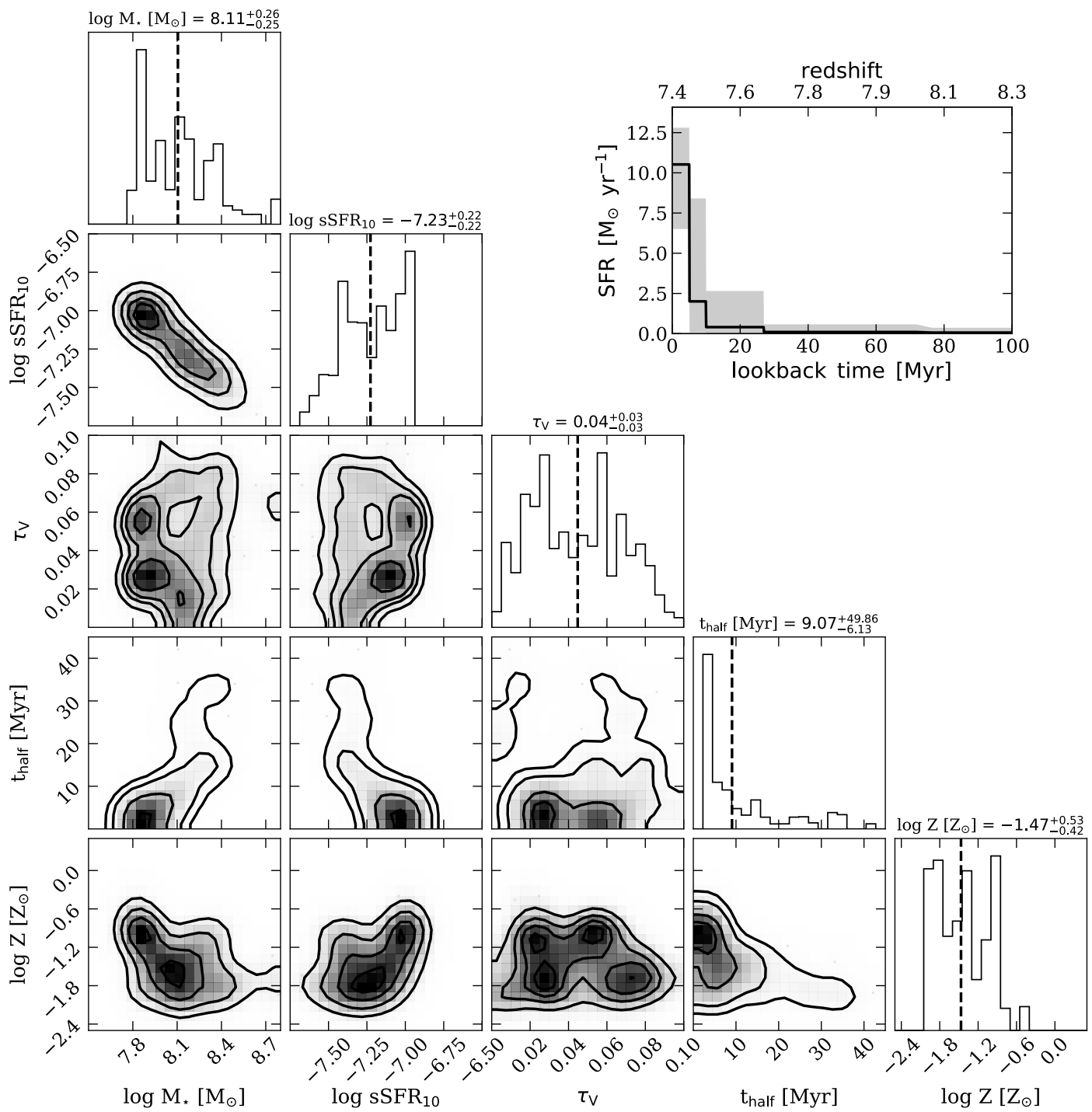
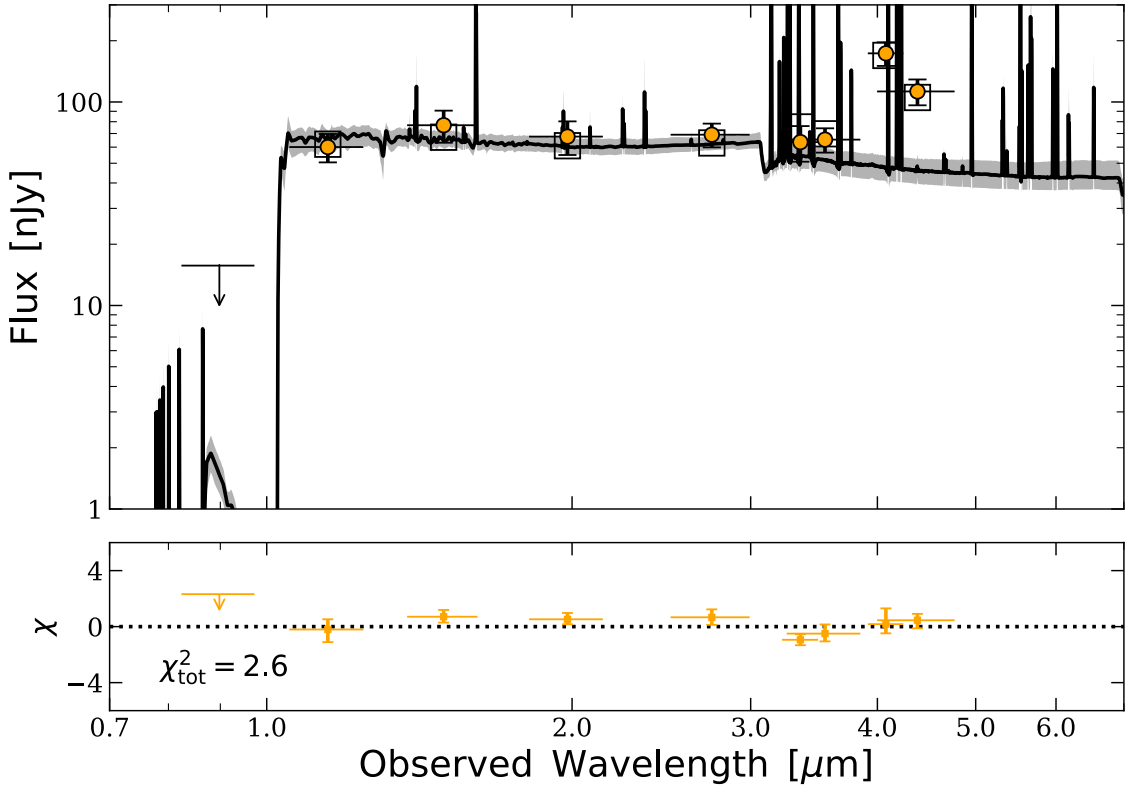
Combined Photometry





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