Inside-out growth in the early Universe

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Why study high-z galaxy growth?

- In the local galaxy population, we see blue, disc-like star-forming, galaxies and red, spheroidal quiescent galaxies
- How do star-forming galaxies stop, i.e. quench, star-formation?
- Appears to be linked to bulge growth → need to probe high-z progenitors
- In short, high-z galaxies are progenitors to current day galaxies

Credit: PHANGS

Credit: NASA, ESA,

What about at cosmic noon?

- Many studies have looked into the z~2 universe to explore this, e.g. Lang+2014, Tacchella+2016

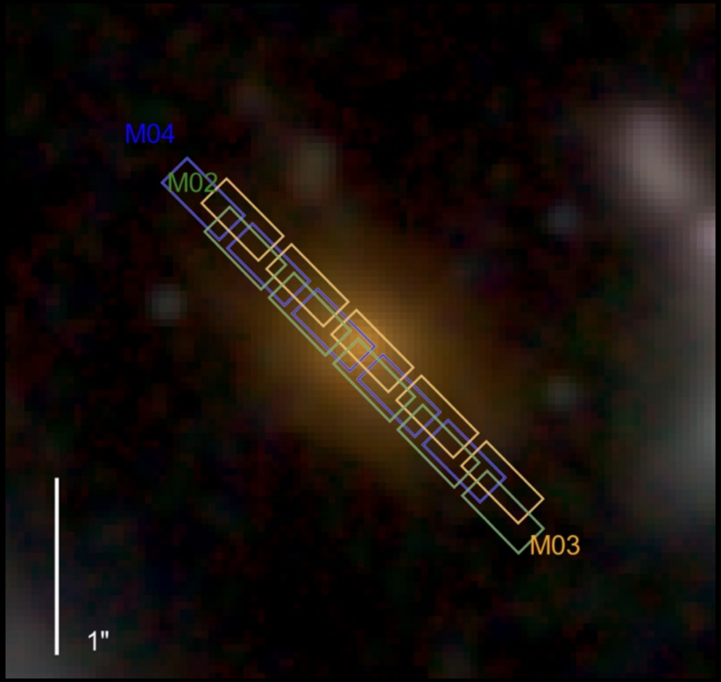
- Find bulges already assembled by z~2

Tacchella+2015

But quiescent galaxies appear at even higher-z

- E.g. Carnall+23,24, De Graaff+24, Setton+24
- Whilst others appear to have quenched very early on e.g. Glazebrook+24
- Want to probe their progenitors → but these galaxies often have tiny sizes → how can we resolve structure?

Carnall+2023

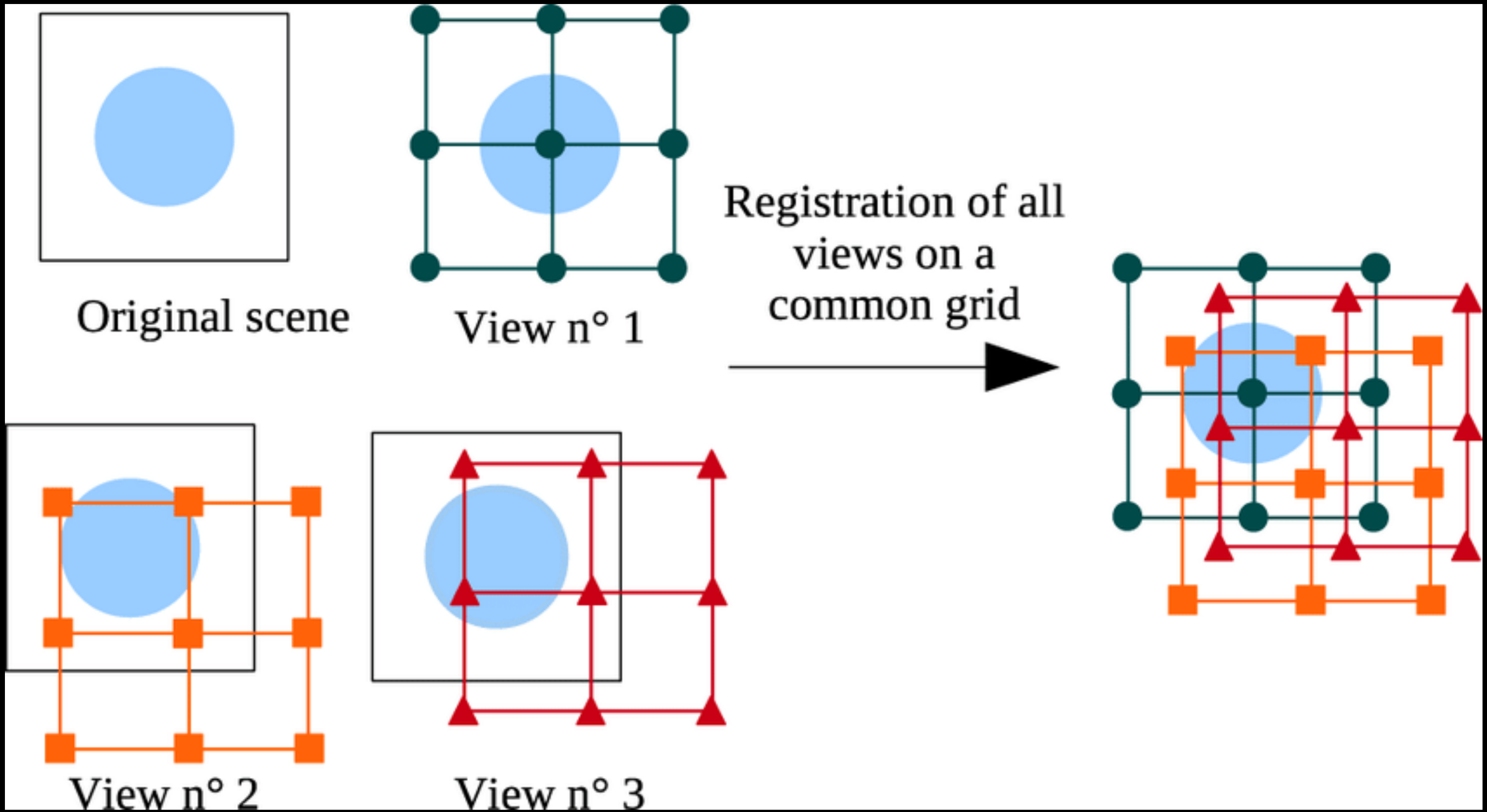


Setton+2024

Key is dithering – enabling sub-pixel resolution

→we want to use the individual raw exposures not the mosaics

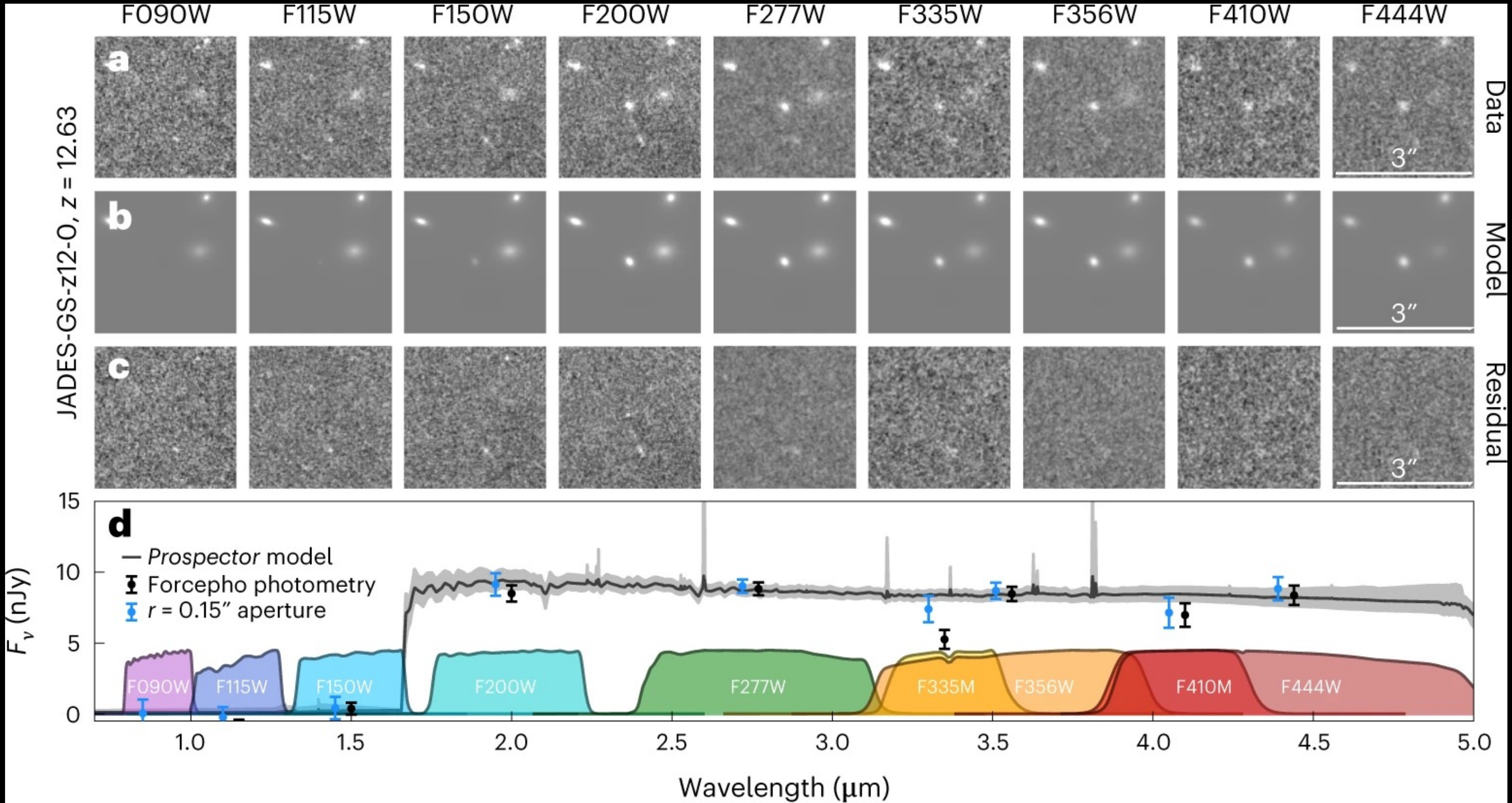
→Crucial new tool required to do this – ForcePho!



Wallach+2012

How does ForcePho work?

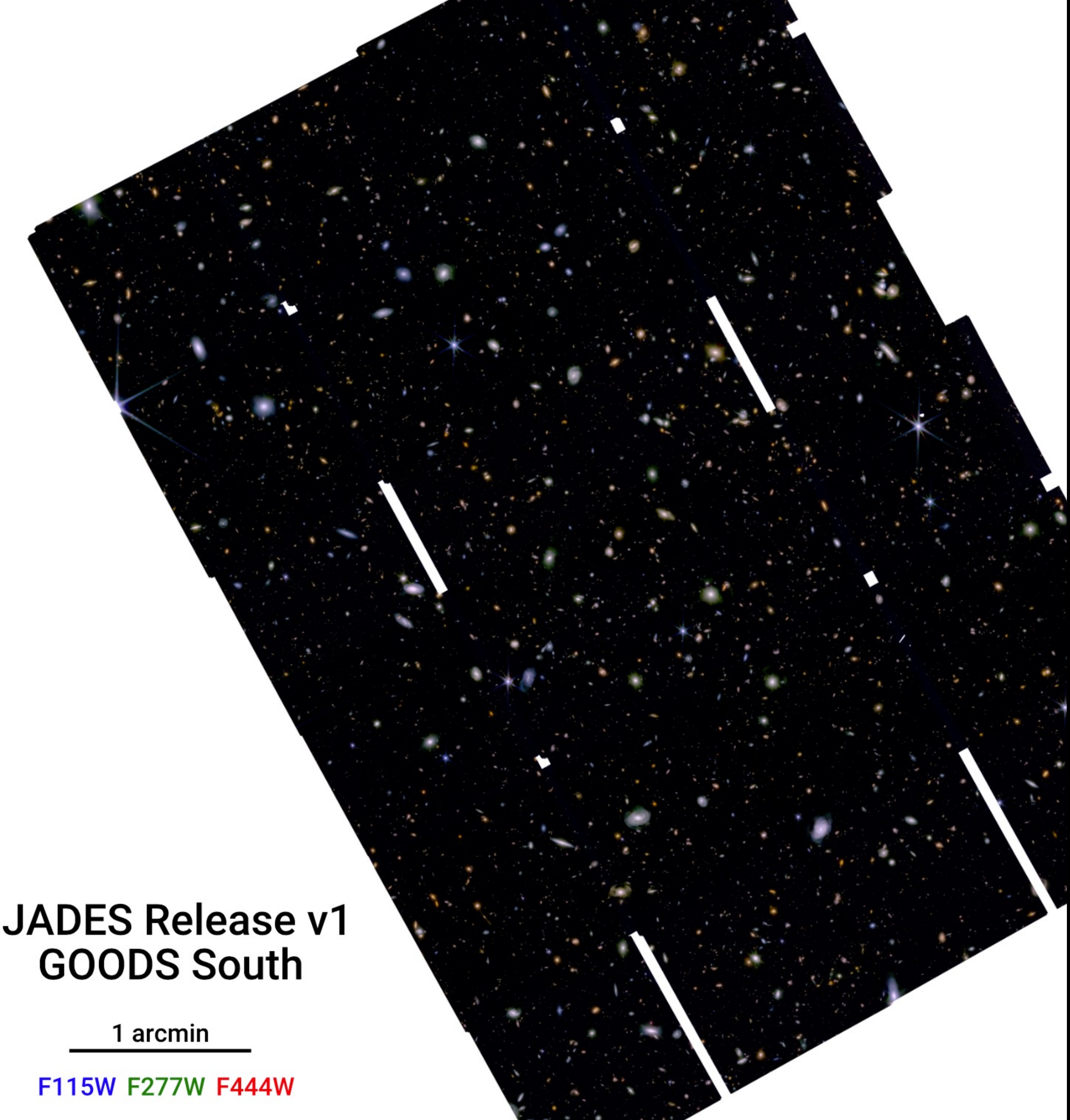
- Model all exposures simultaneously, allowing flux to vary but fitting the structural parameters based on the information in all exposures
- Forward model the light distribution using a convolution of gaussians
- Exact filter coverage will be important for SED modelling



Robertson+2023

JADES – JWST Advanced Deep Extragalactic Survey

- NIRCam+NIRSpec GTO teams ~800hr observing with NIRCam and NIRSpec, e.g. Rieke+2023,Eisenstein+2023



Search through JADES imaging for galaxies with visible structure

- Looking primarily in the redshift range 7-7.8

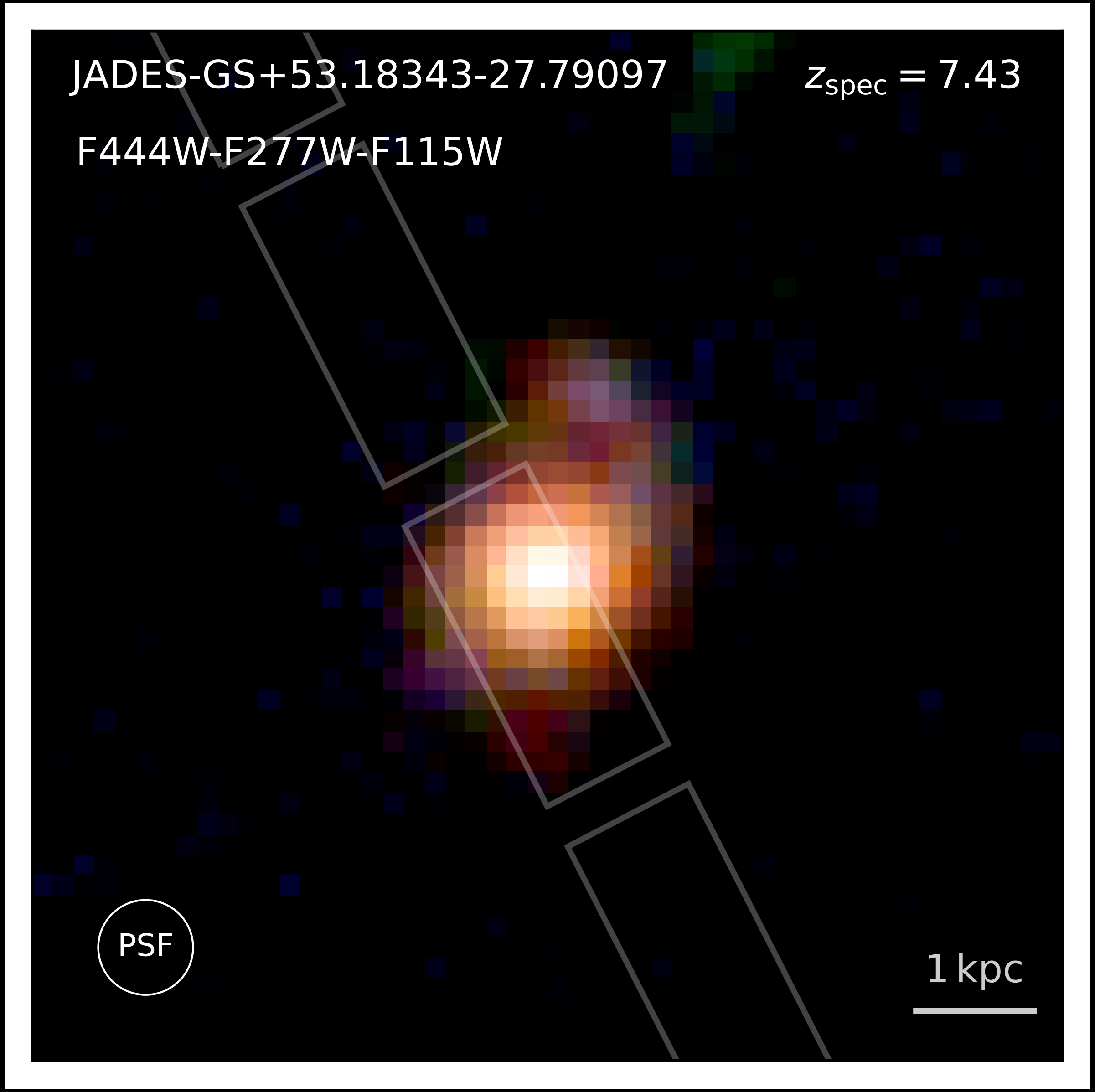
→ want it to be high enough redshift to probe progenitors

→ but also want to ensure medium band coverage of the Balmer break to accurately model the stellar populations

Rieke+2023

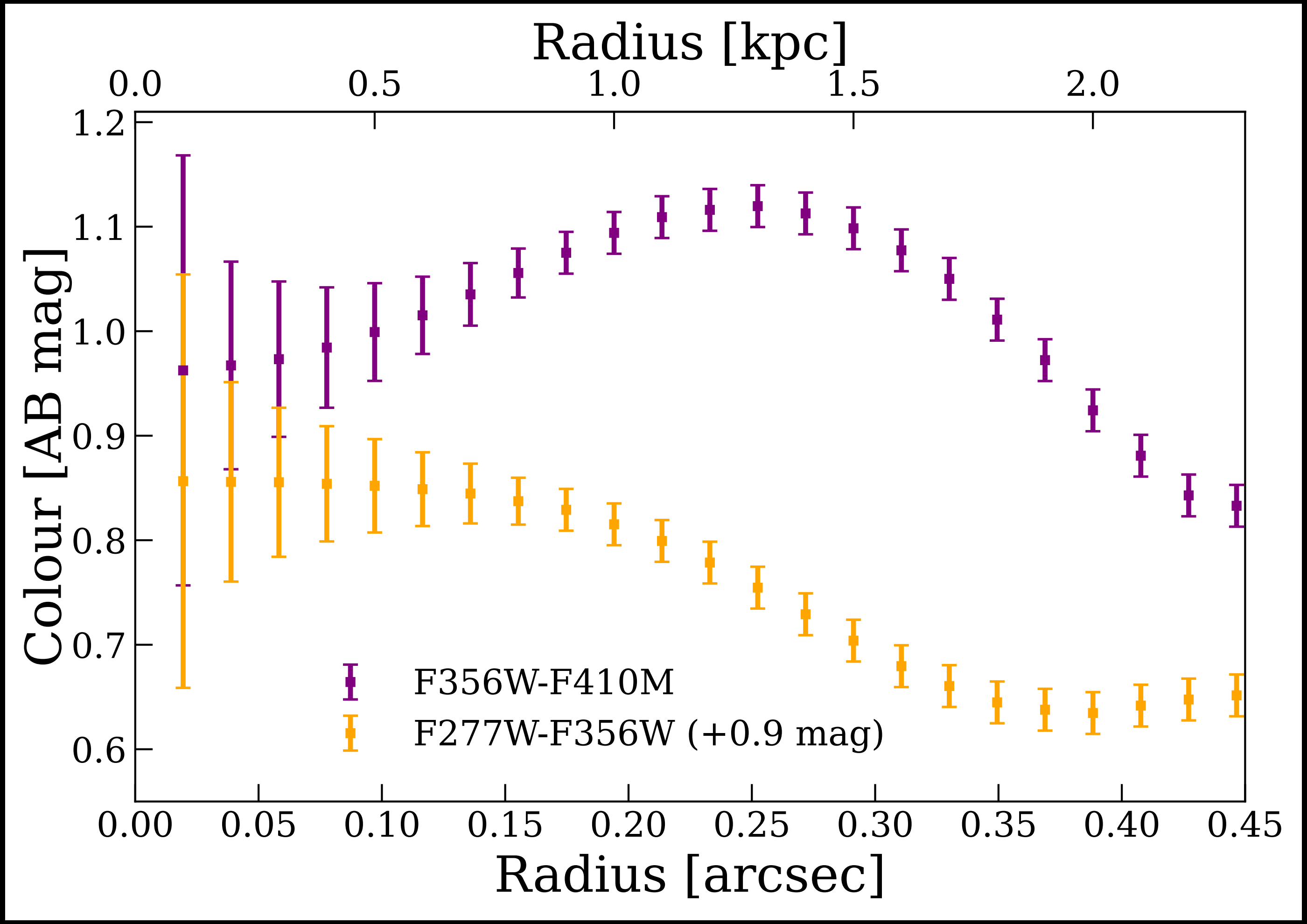
We find this galaxy at z=7.43

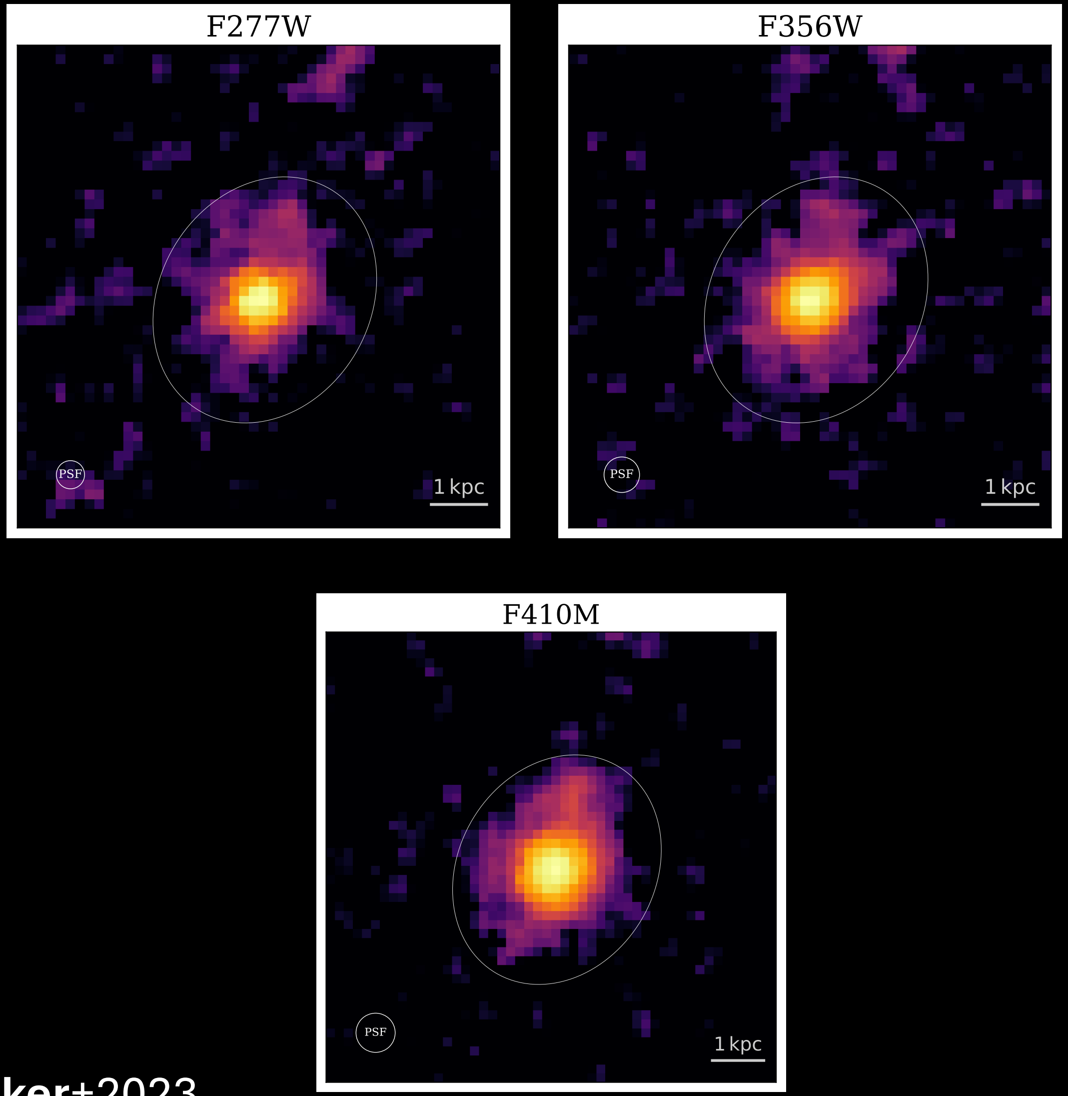
Central Core component and surrounding Disc!



Baker+2023

Clear colour gradient showing multi-component structure



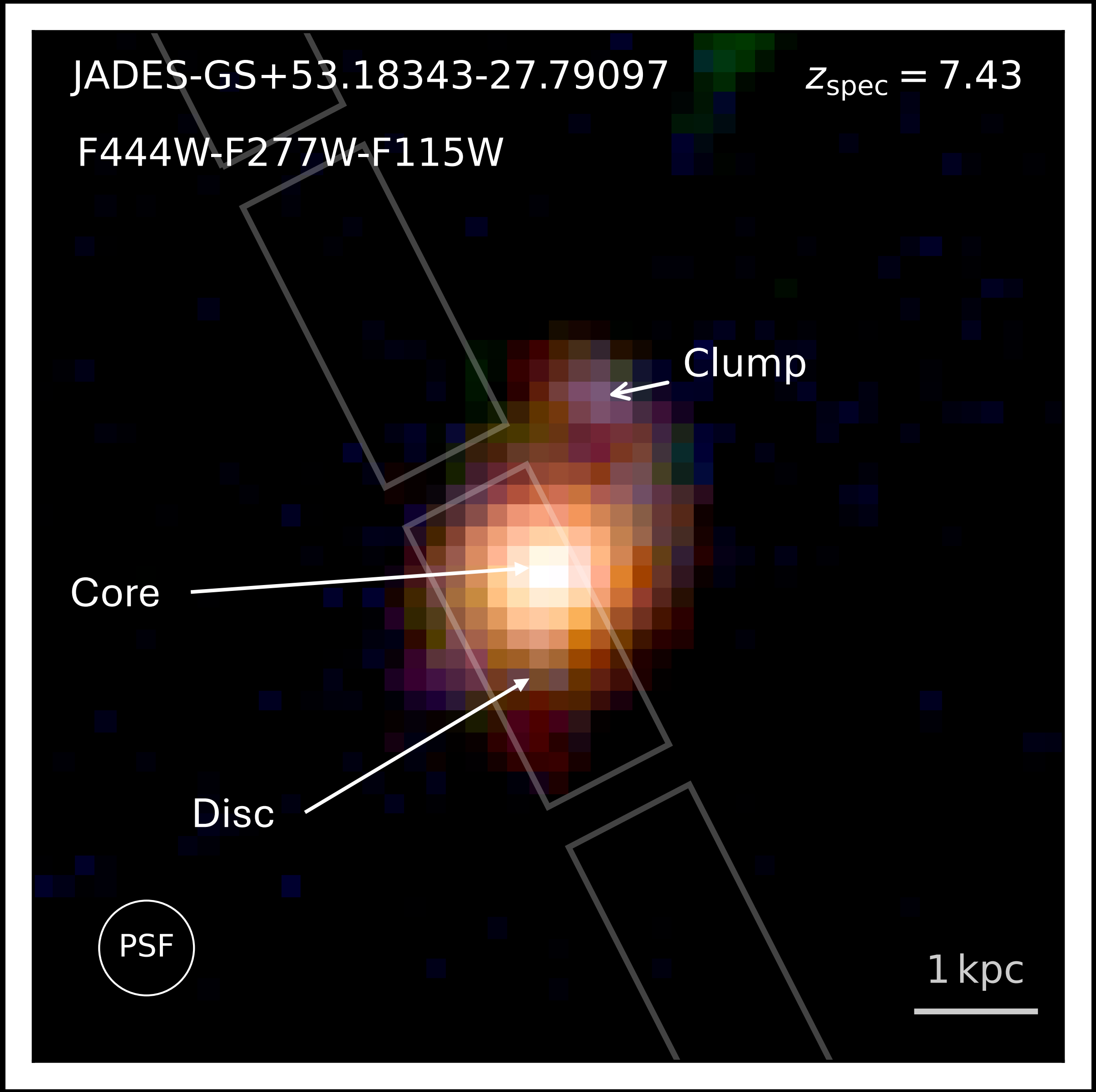


Baker+2023

How can we model high-z multicomponent structure?

Using ForcePho, we model the galaxy as a combination of three Sersic profiles

An exponential disc, a bulge-like core, and a point source clump



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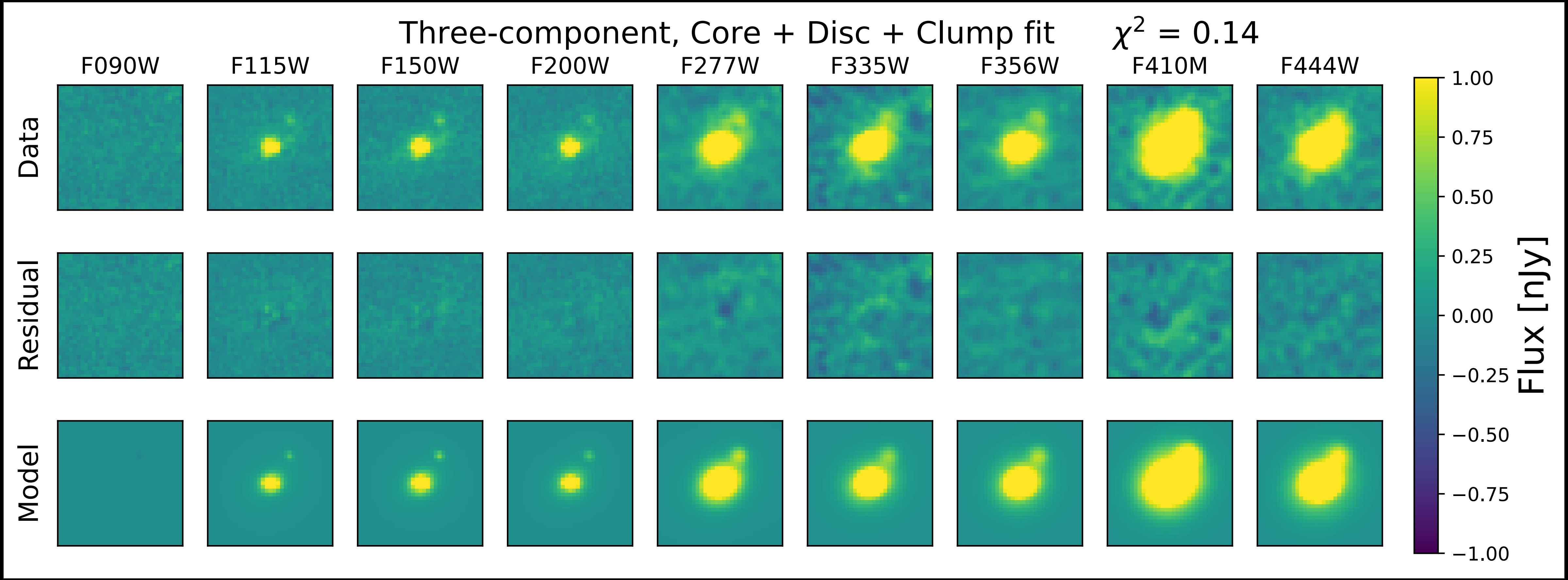
How good is the ForcePho fit?



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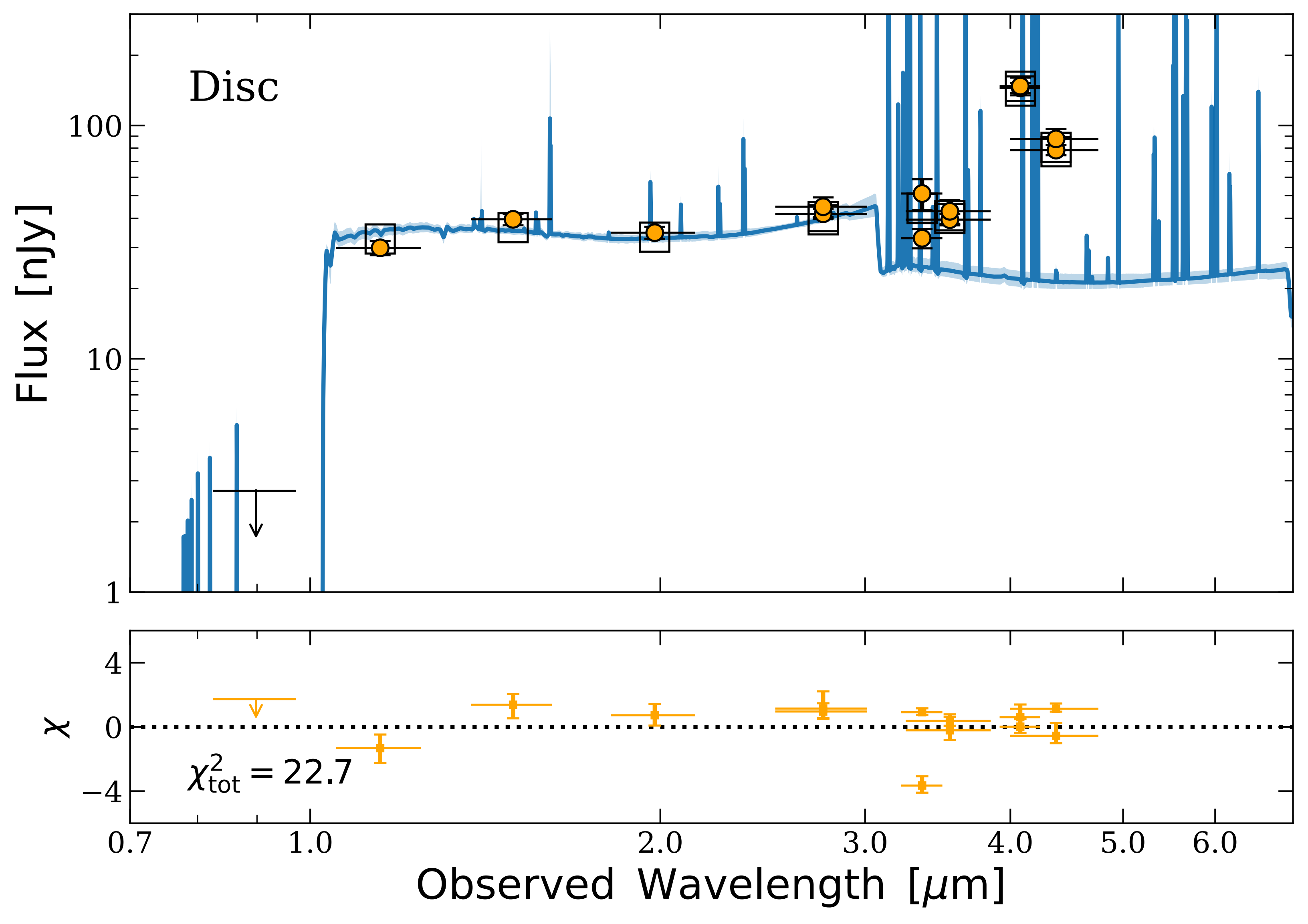
Model the SEDs with Prospector



- Bayesian Inference using Dynesty – forward modelling model spectra from FSPS to fit the photometry

- Fit for the disc
- $\log(M_*/M_\odot)$= 7.98
- SFR ≈ 5 $M_\odot$ /yr
- Size ~ 468pc

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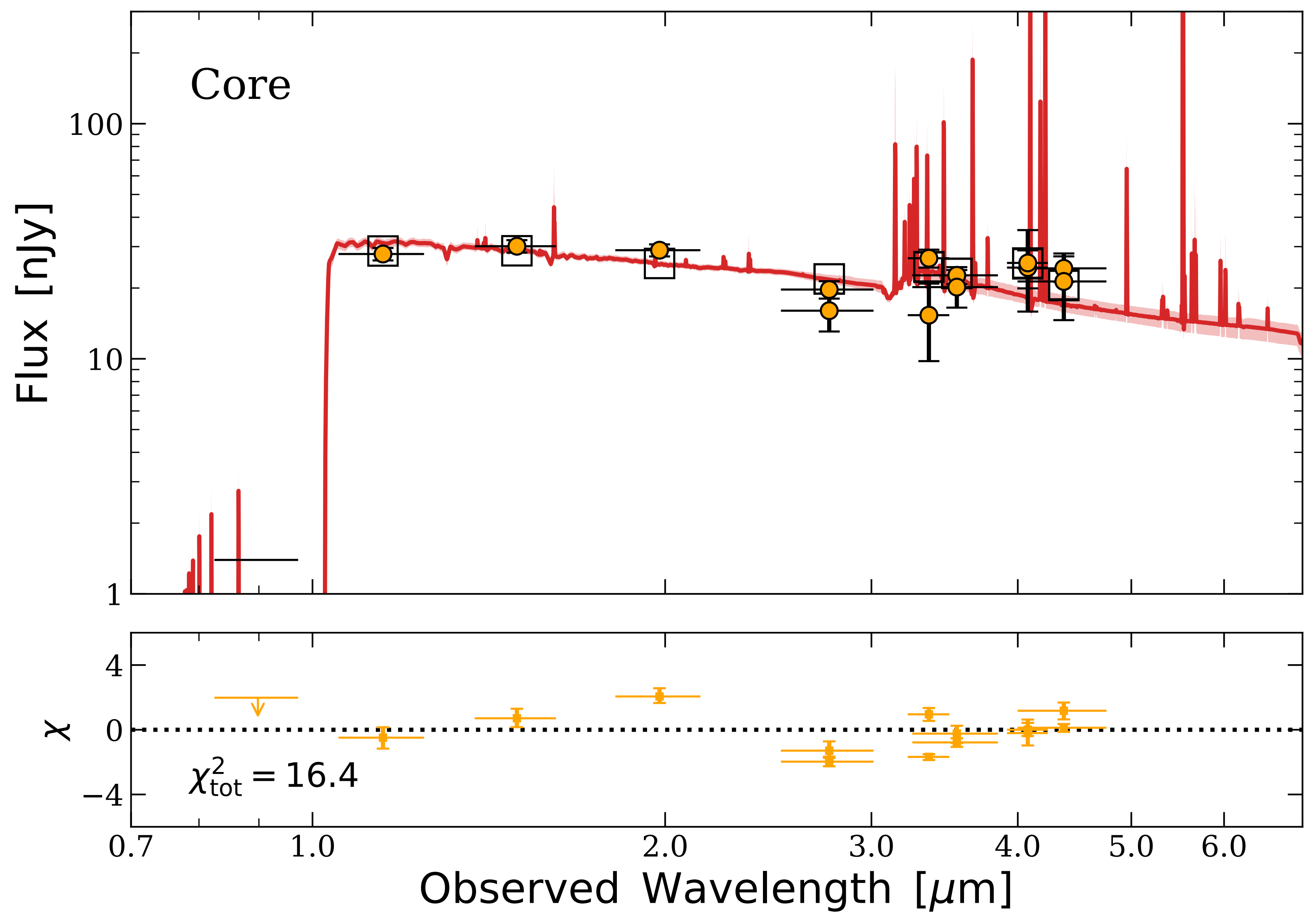
The core component



- $\log(M_*/M_\odot)$= 8.38
- SFR≈ 1 $M_\odot$ /yr
- Size ~ 144pc

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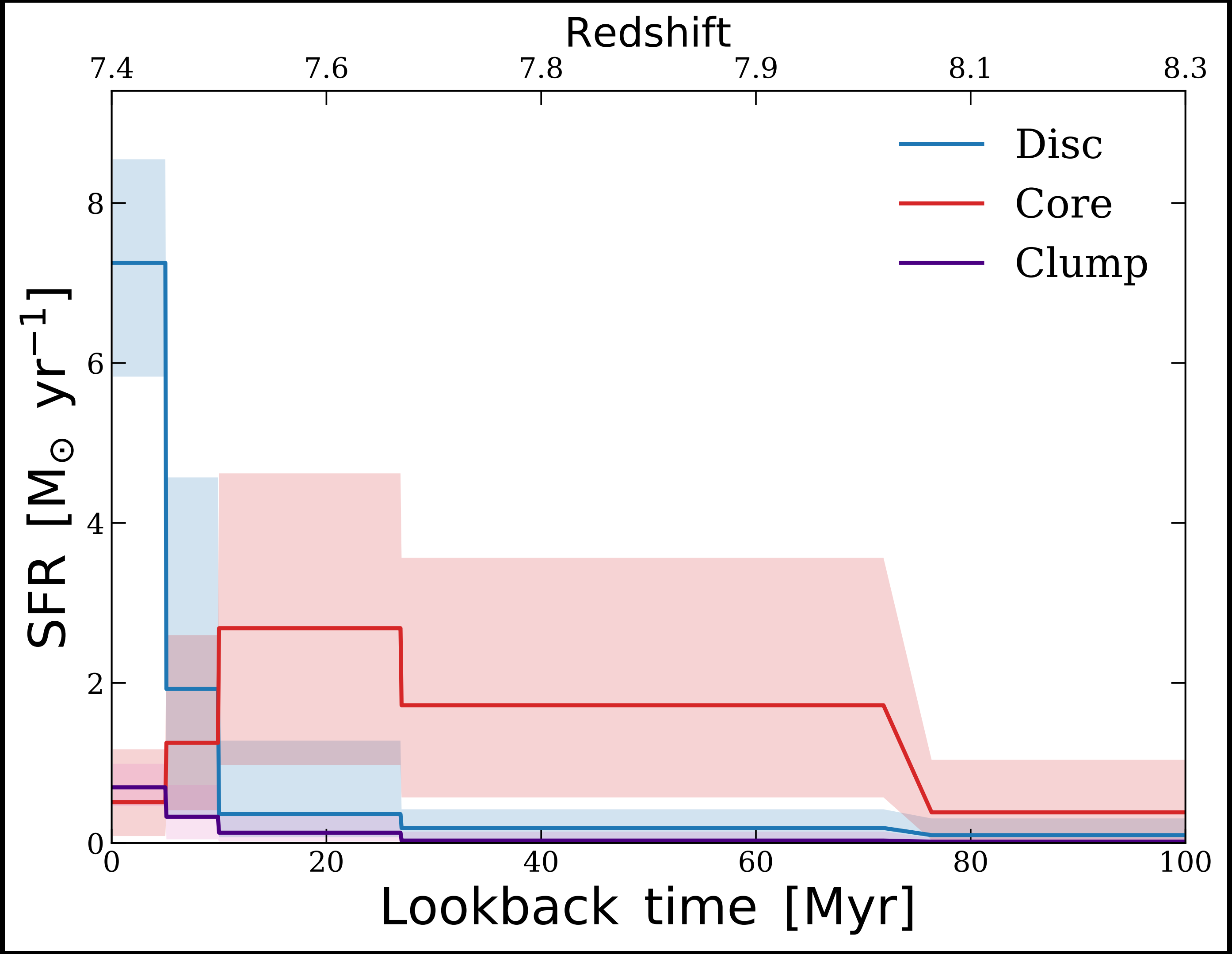
History of star-formation



- Core appears to be older, disc appears to be younger
- Core has a decreasing SFR
- Disc appears to be undergoing a recent burst

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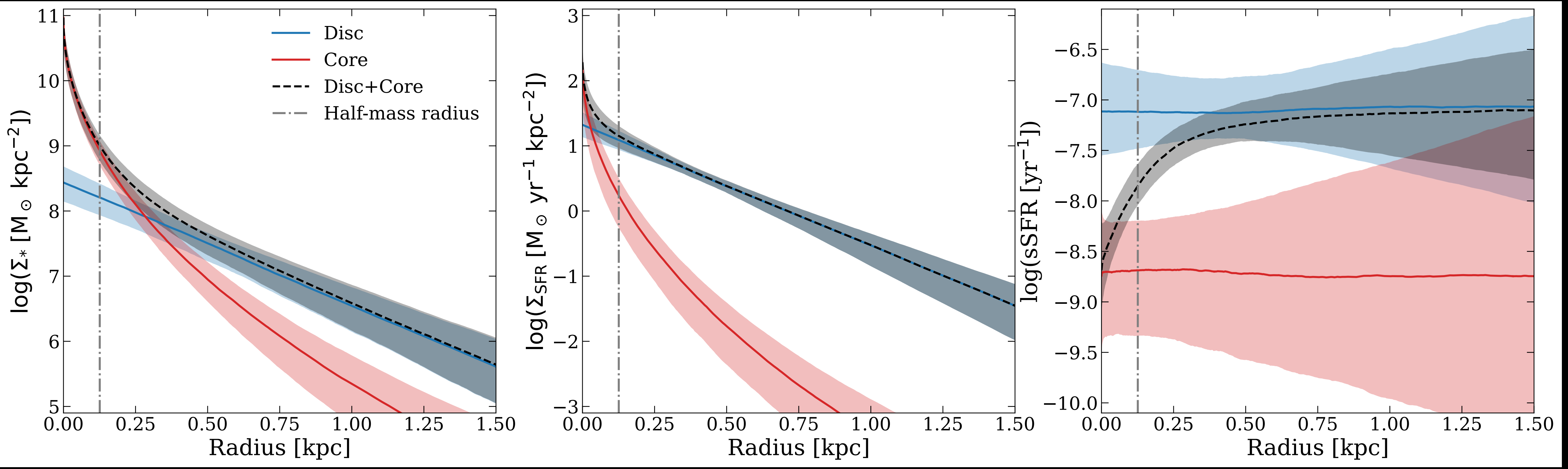
Modelling the Radial Profile of the components

- Star-formation rate is dominated by disc, stellar mass by core
- Small half-mass radius due to dense core



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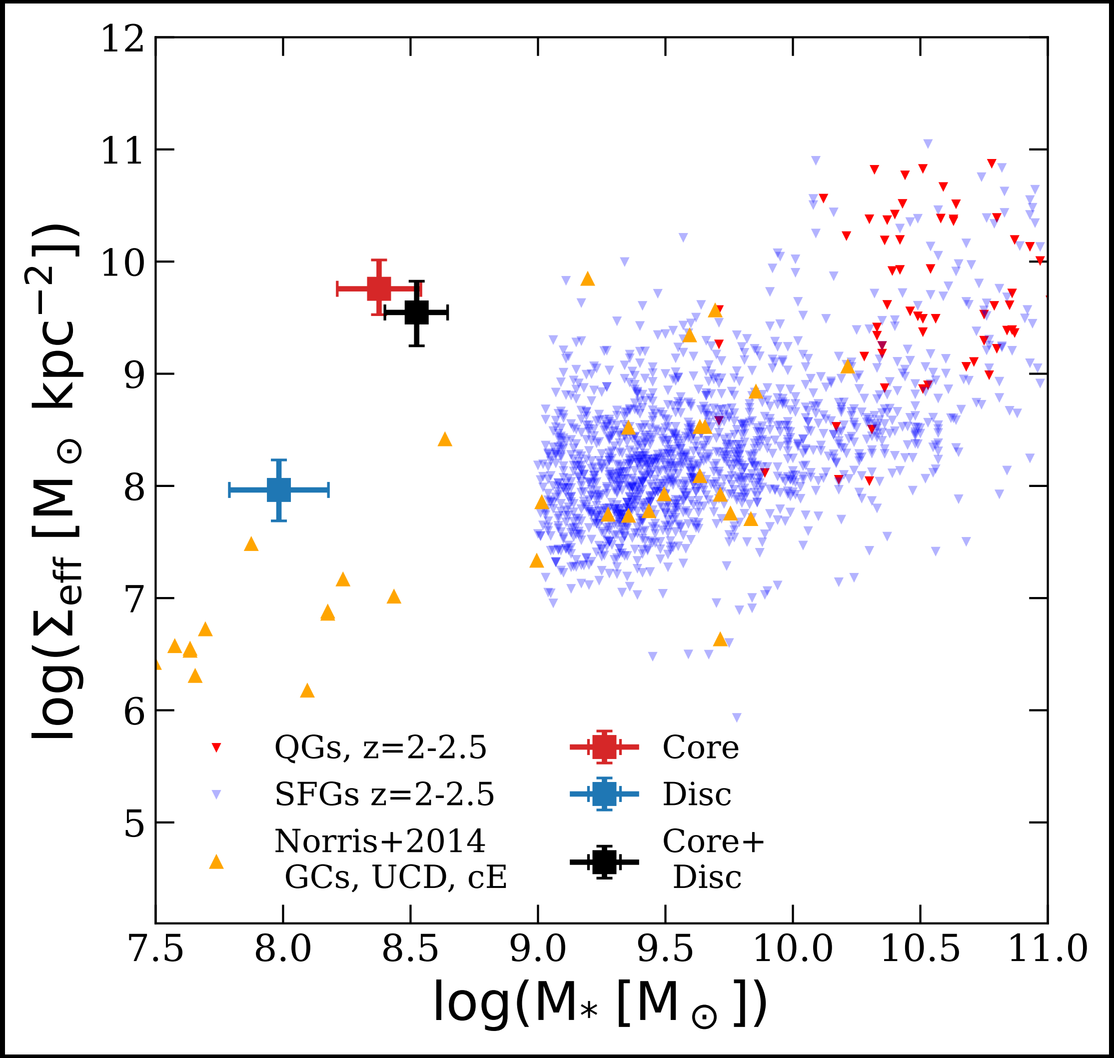
What can we say about this galaxy compared to lower z?



- Comparison to effective surface densities of z~2 star-forming and quiescent galaxies
- Core consistent with z~2 quiescent galaxies
- Disc consistent with z~2 star-forming galaxies
- Obviously, significantly less massive overall
- $\log(M_*/M_\odot)$~ 8.6

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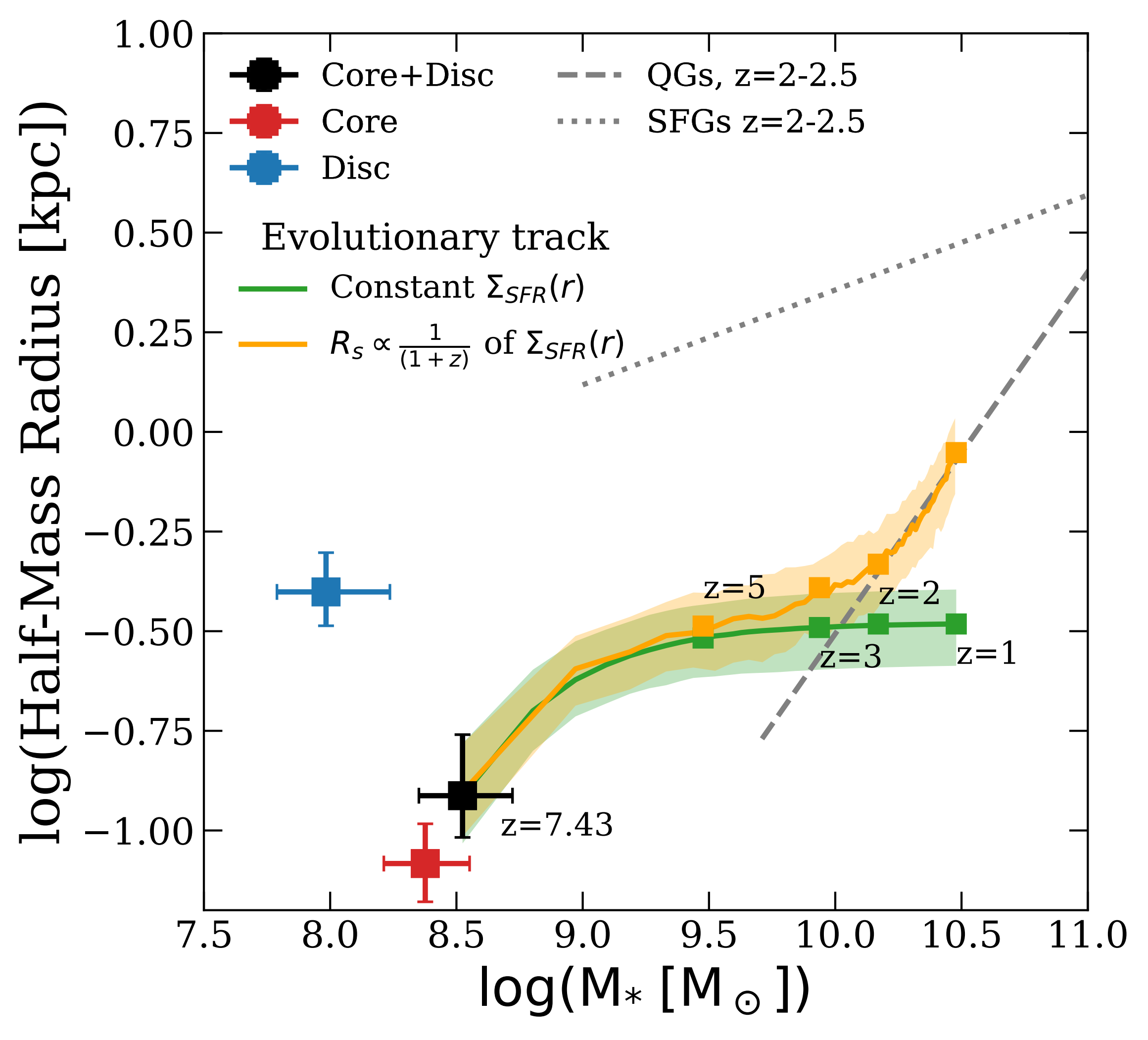
What if we model its size-growth with redshift?



- Extrapolations based on current SFR rate
- Two models – one with half mass radius proportional to redshift
- By z~3-2, consistent with quiescent galaxy population

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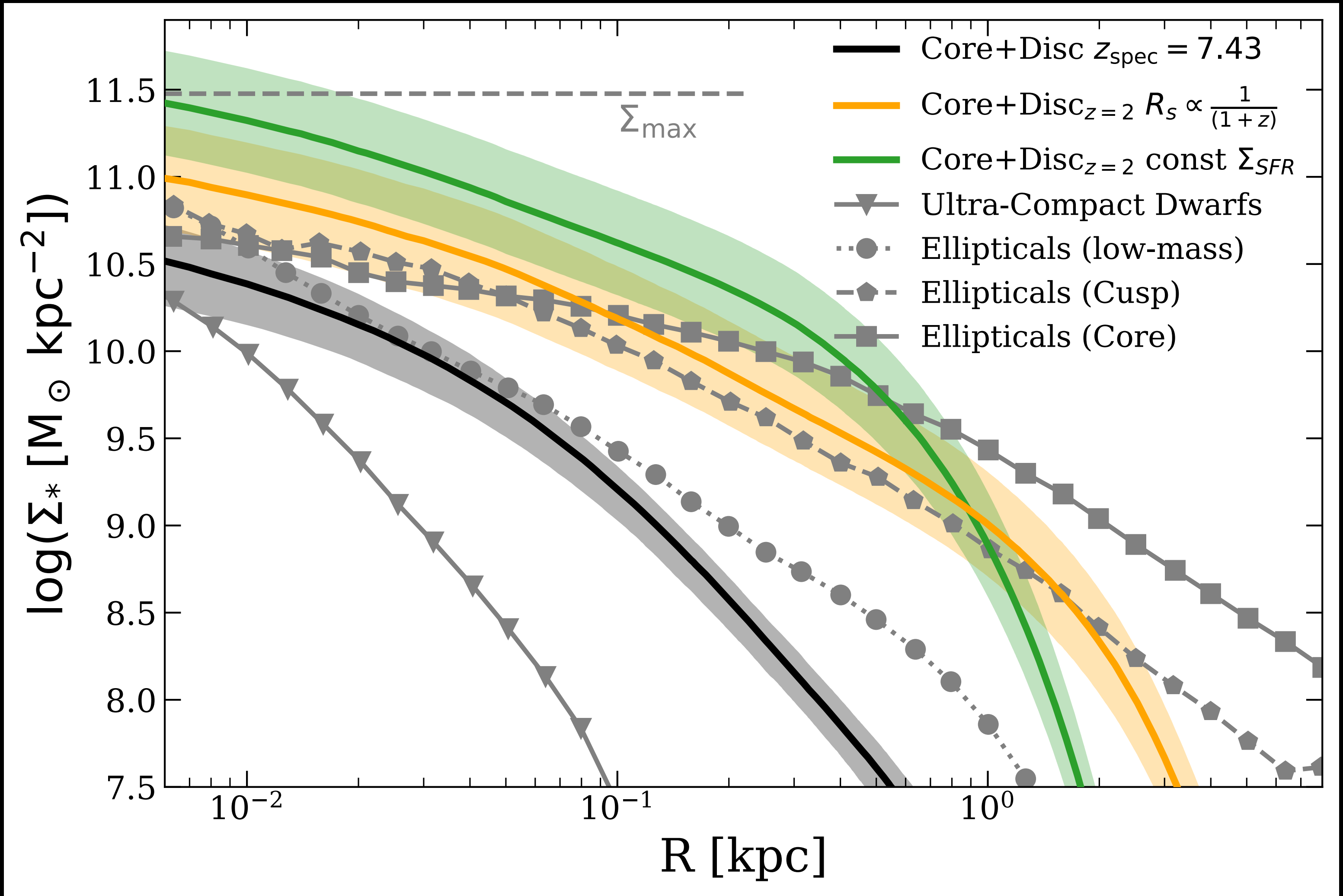
Comparison of the central region to local galaxies



- Core very dense in the centre
- Only 0.2-0.3dex off local massive ellipticals (despite being 1000x less massive overall!)
- Extrapolation finds it consistent with most massive ellipticals profile at z=2

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Summary

- Discover a core and a disc in a z=7.4 galaxy with JWST
- Core is compact and very dense

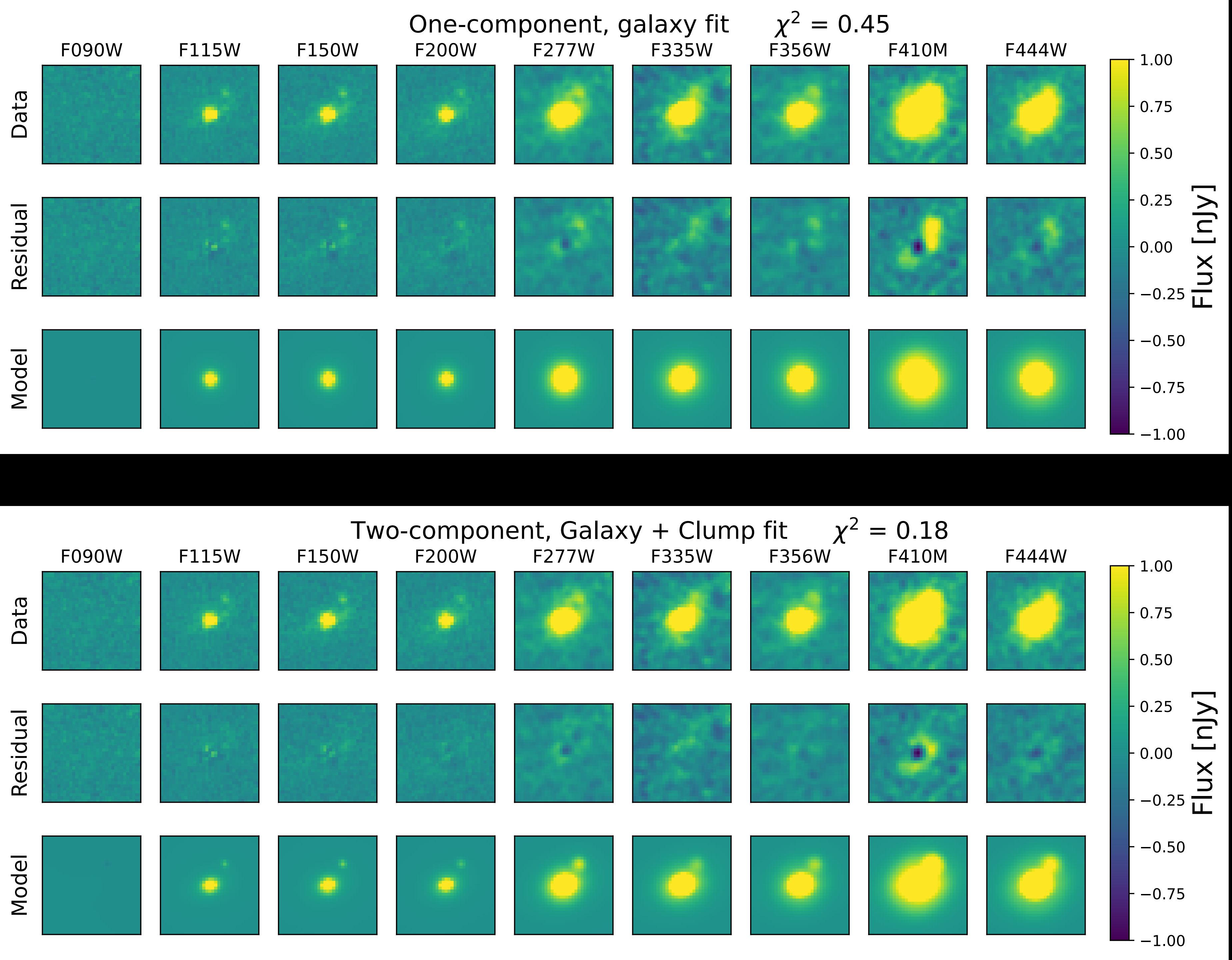
- Sharp rise in sSFR from centre to outskirts → detection of inside-out growth in the early universe

- Modelling the expected growth → the galaxy is likely a progenitor of the kind of much more massive quiescent galaxy we see at redshift 2 and in the local universe

- Suggests the core is a proto-bulge and that we are probing what will become a massive elliptical galaxy

- Next stage → expand and explore a population

Thank you for listening!



Other comparisons

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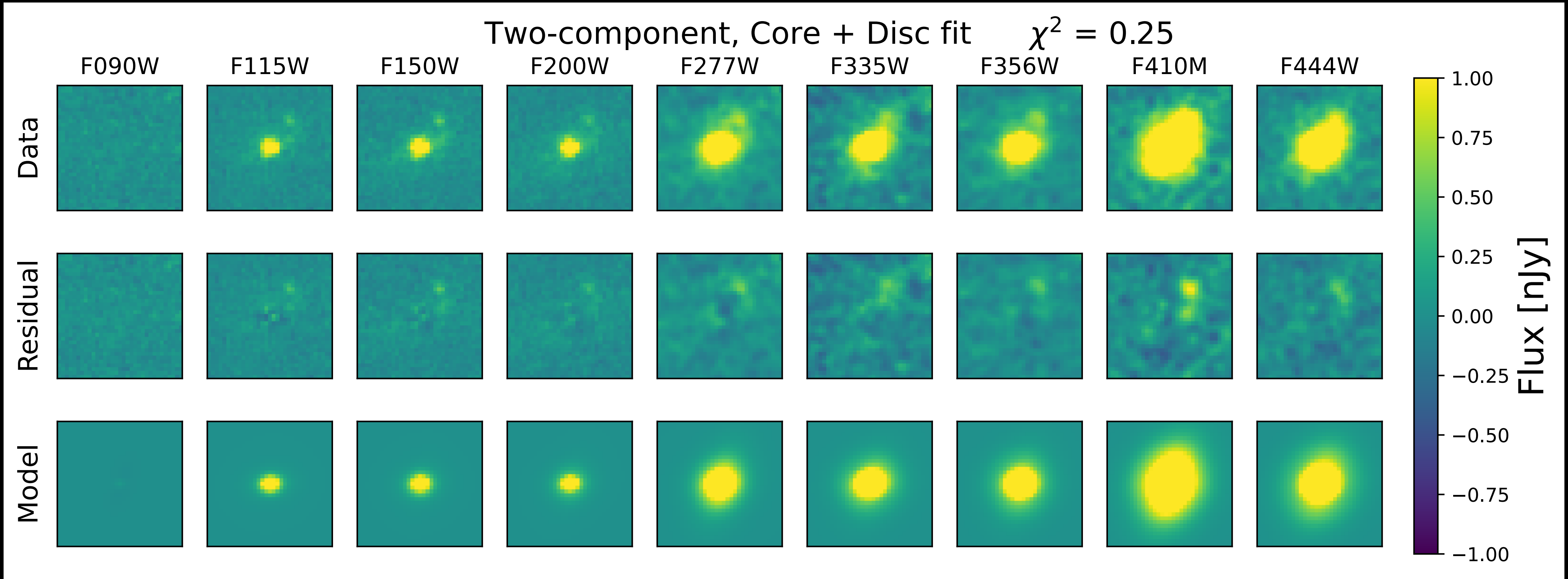
No Clump fit



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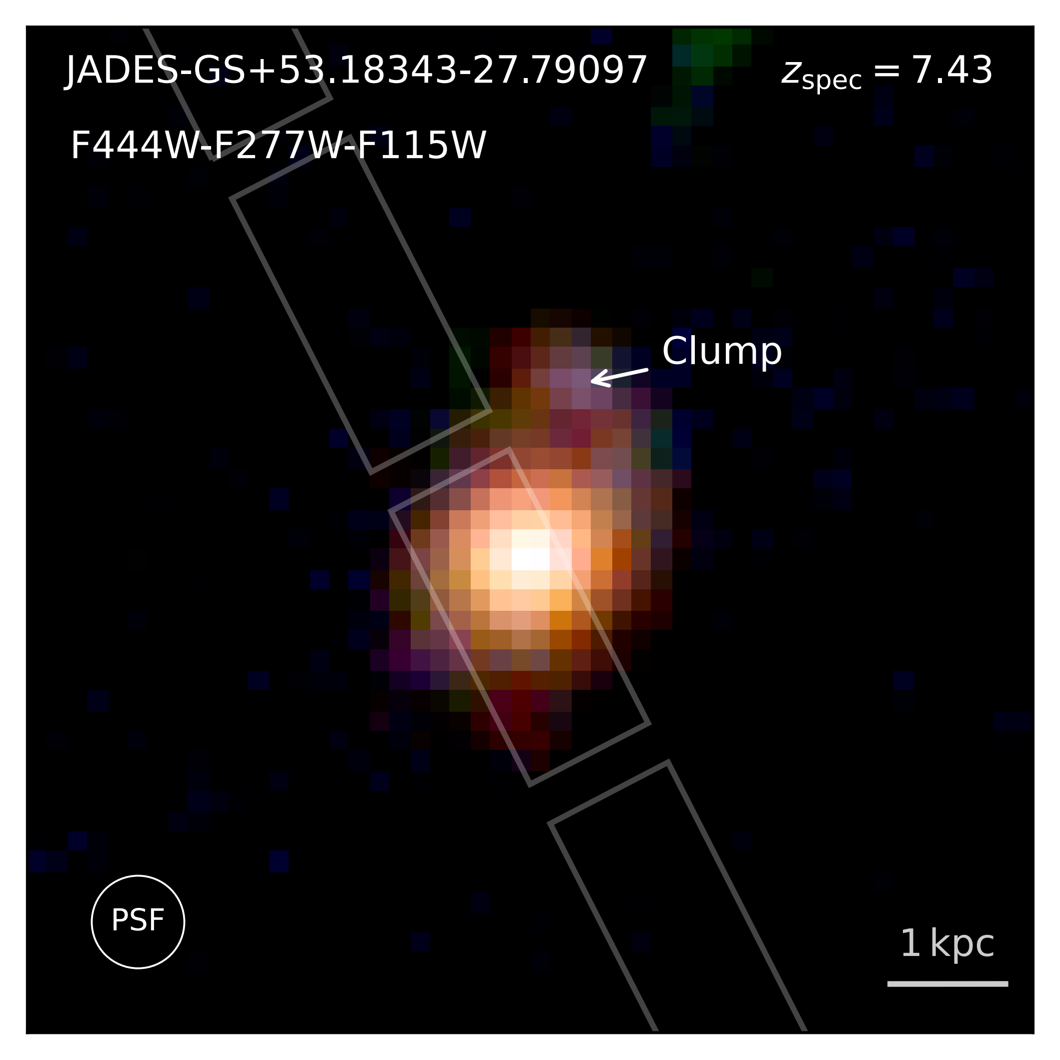
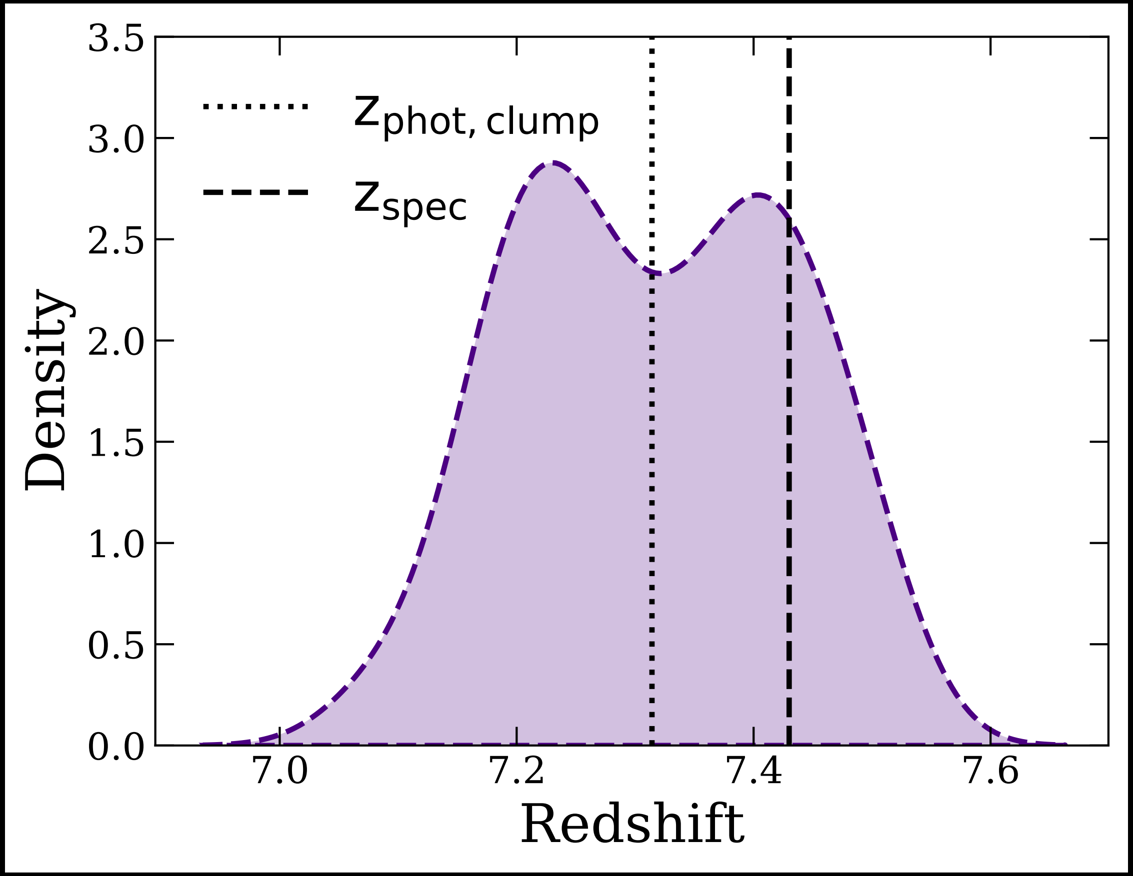
What can we say about the clump?





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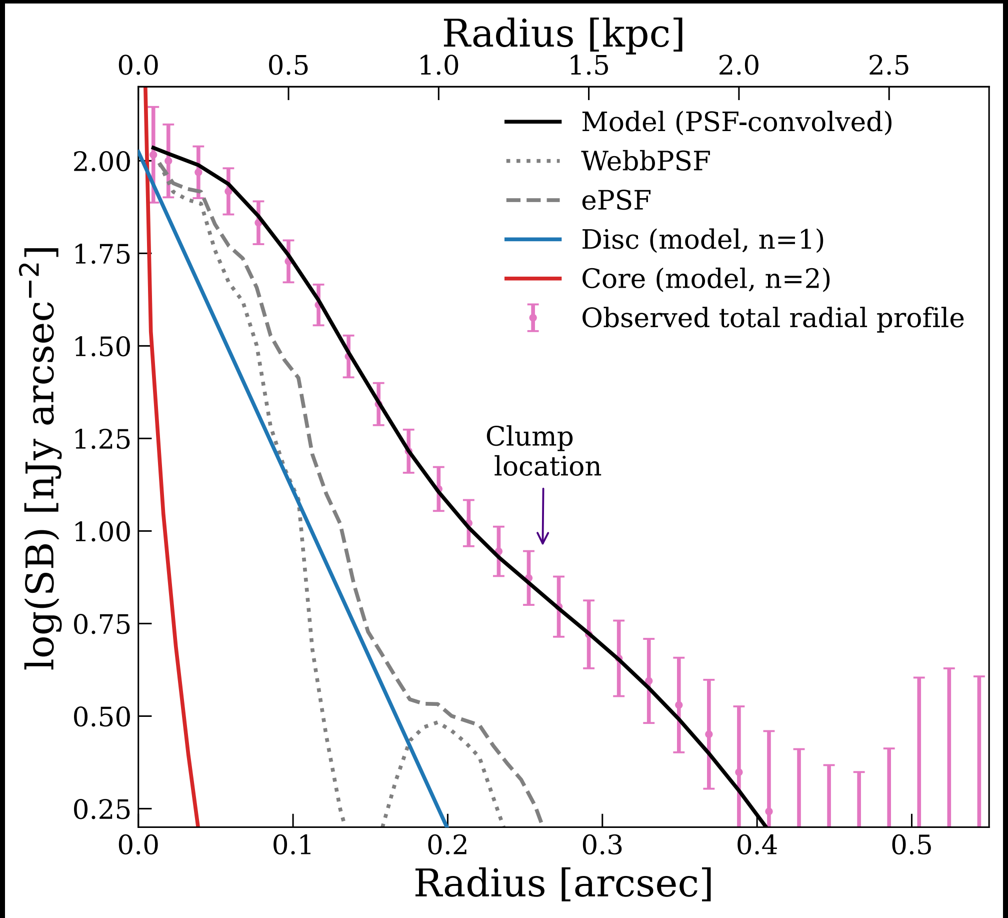
Surface brightness profile



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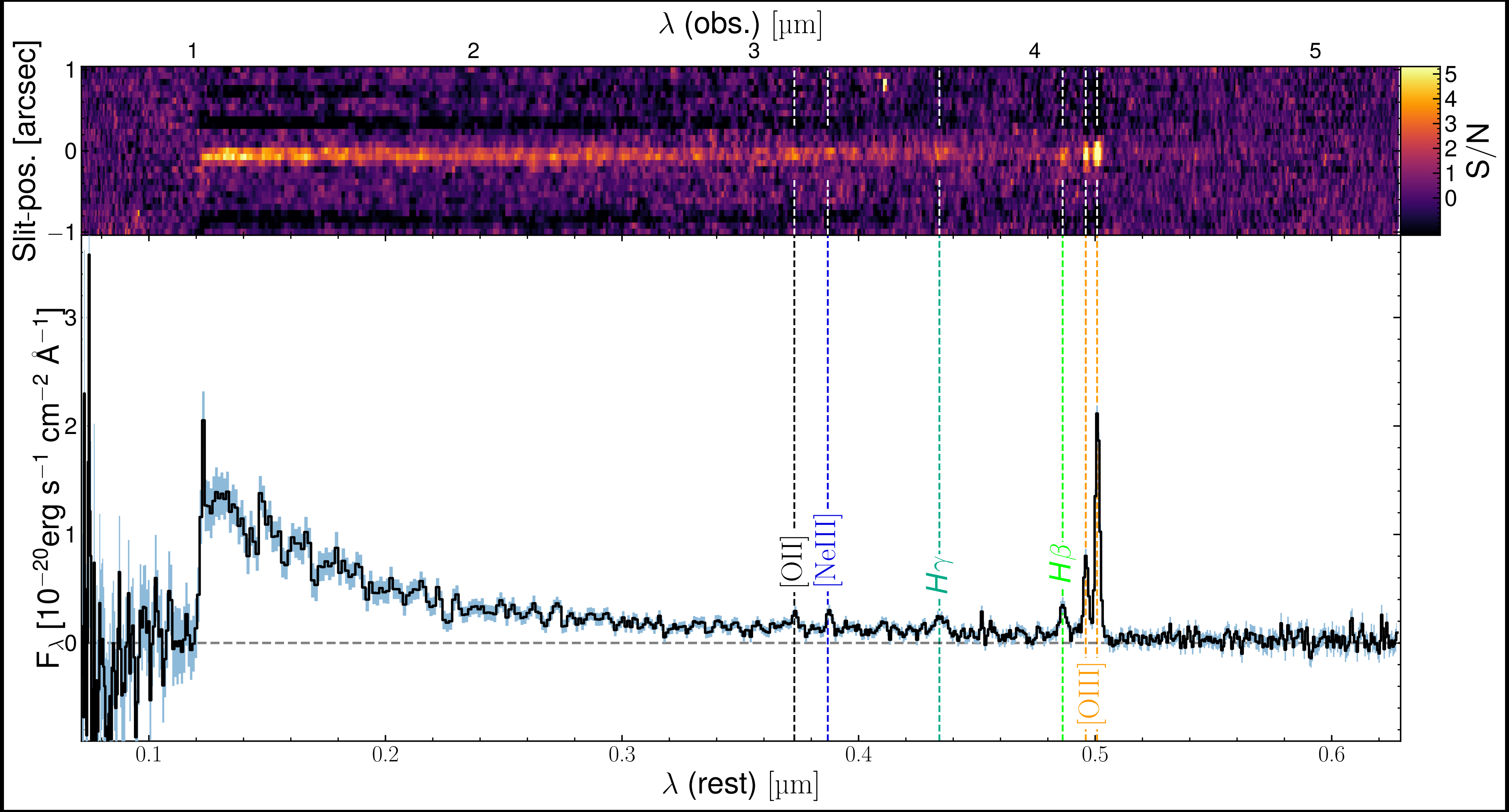
Spectrum



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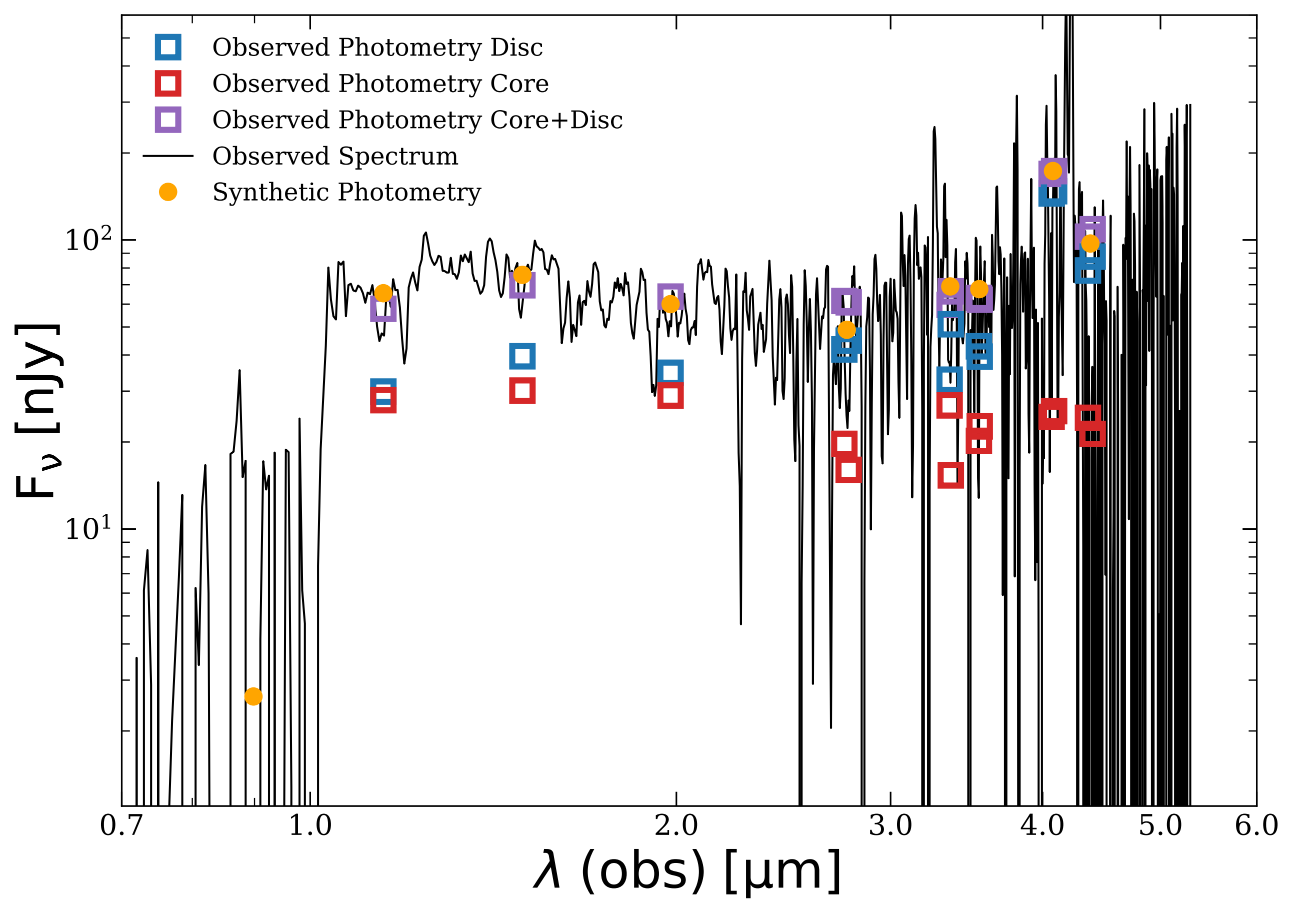
Matching photometry to spectrum



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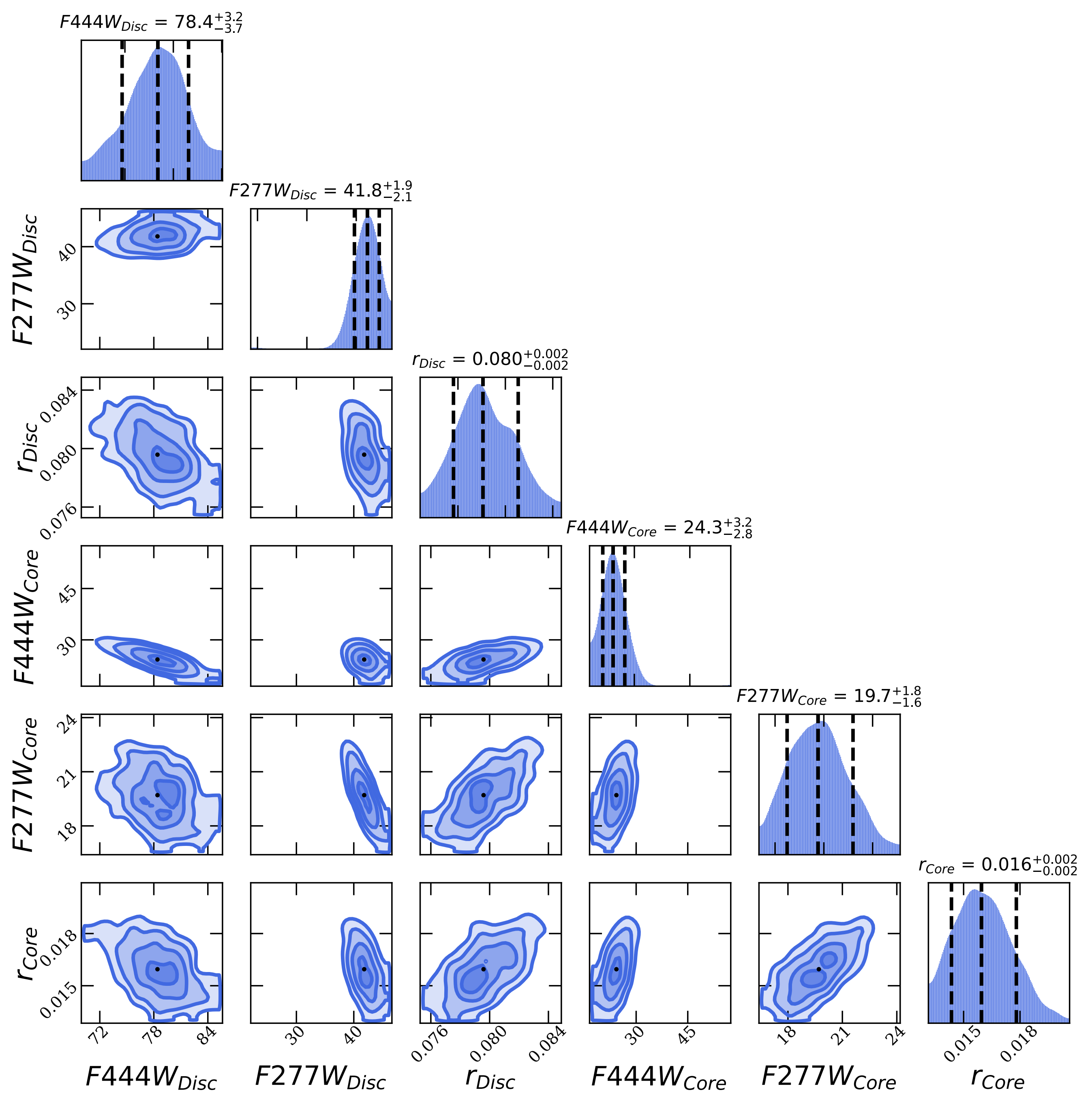
Covariances



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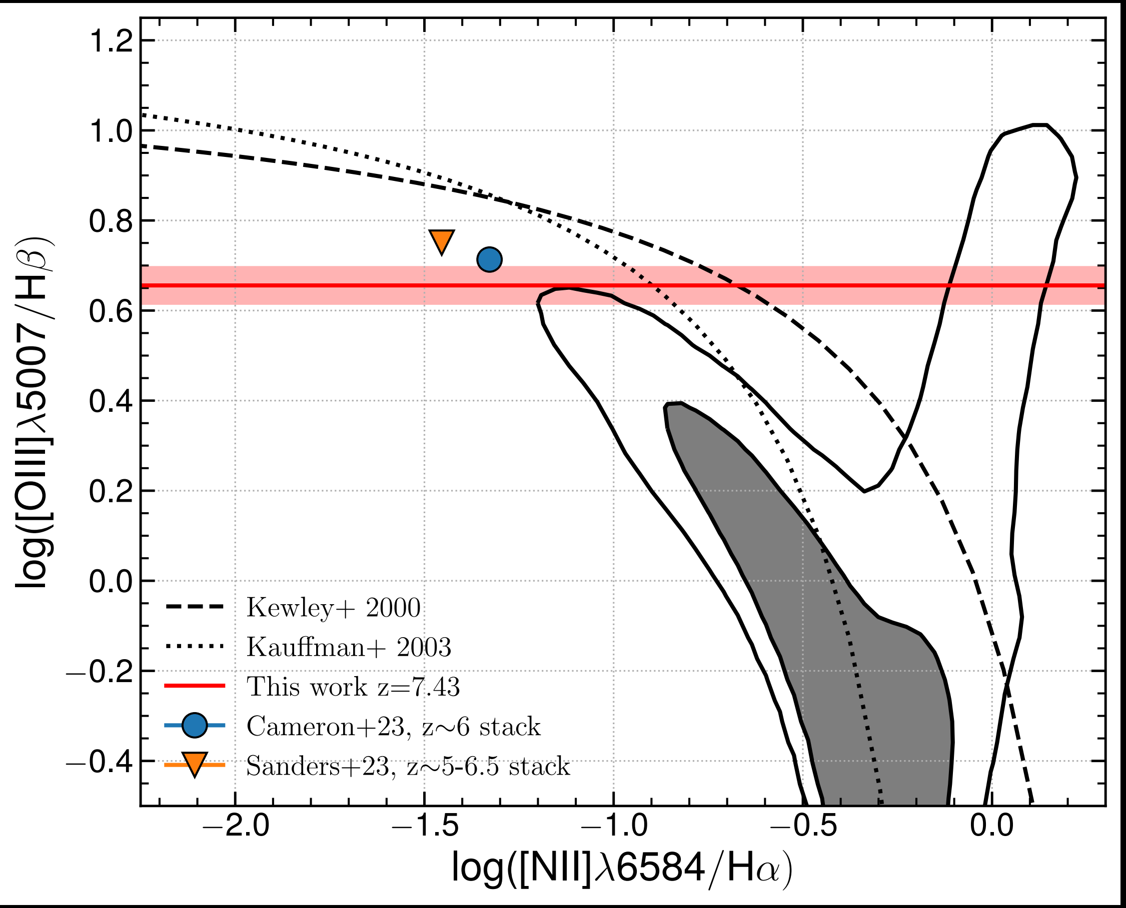
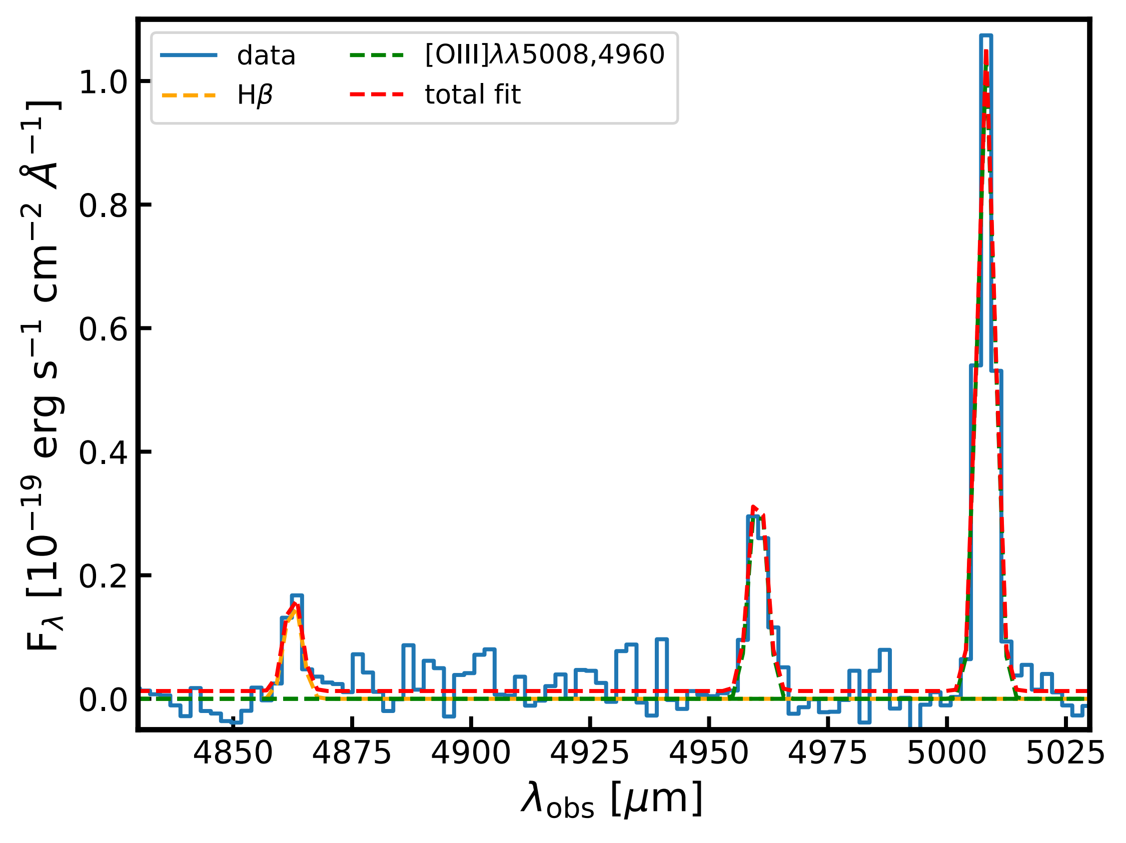
AGN?





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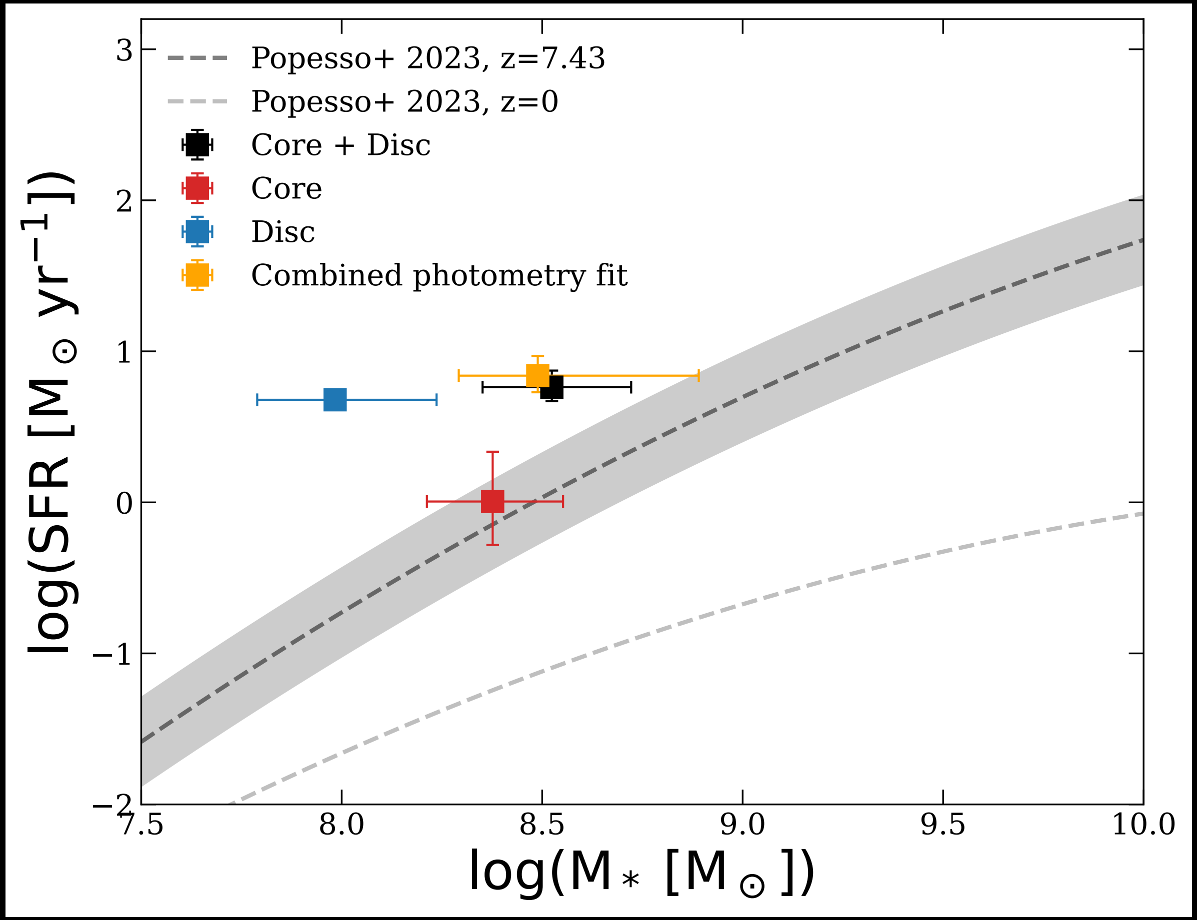
Relation to SFMS



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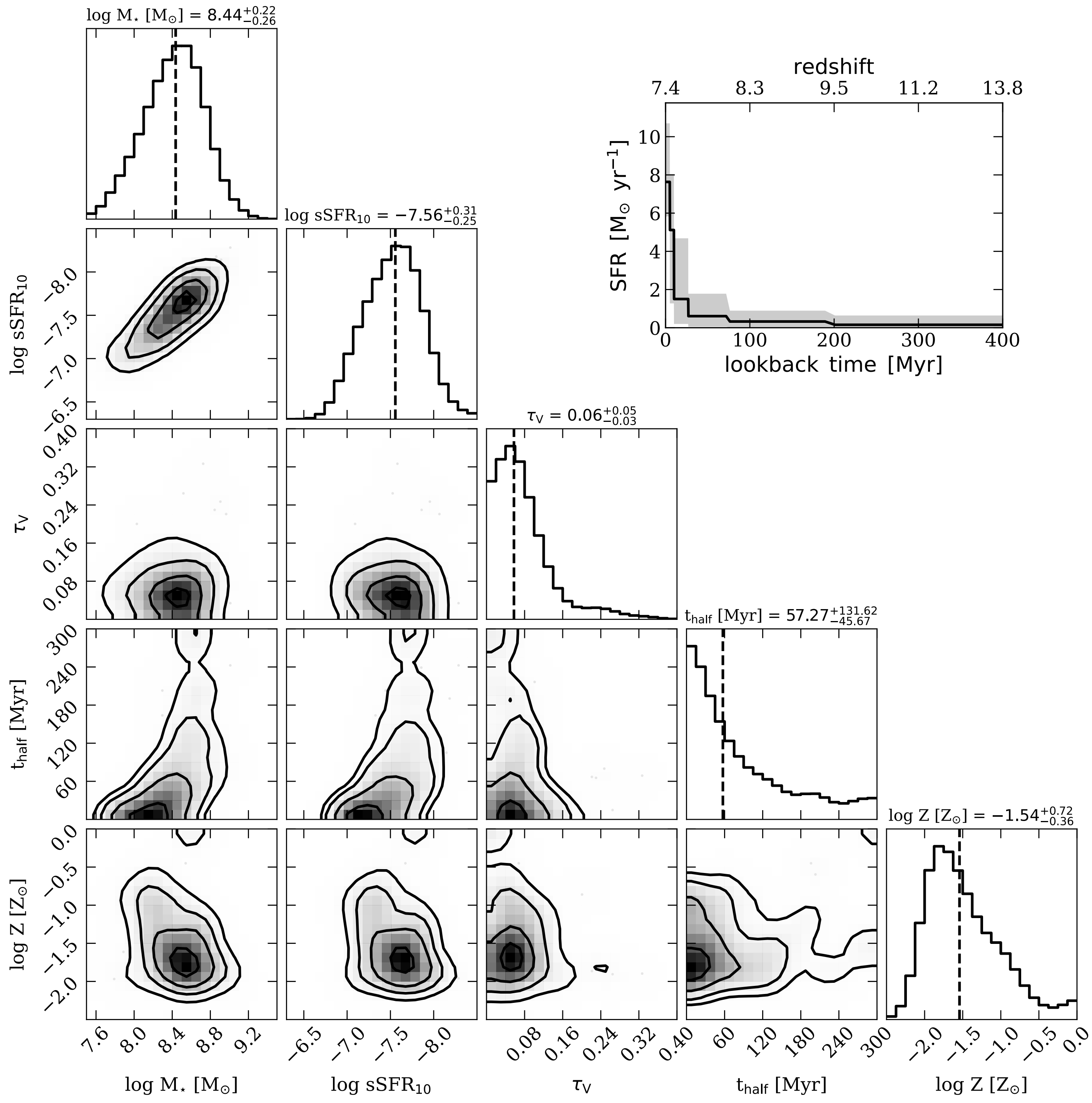
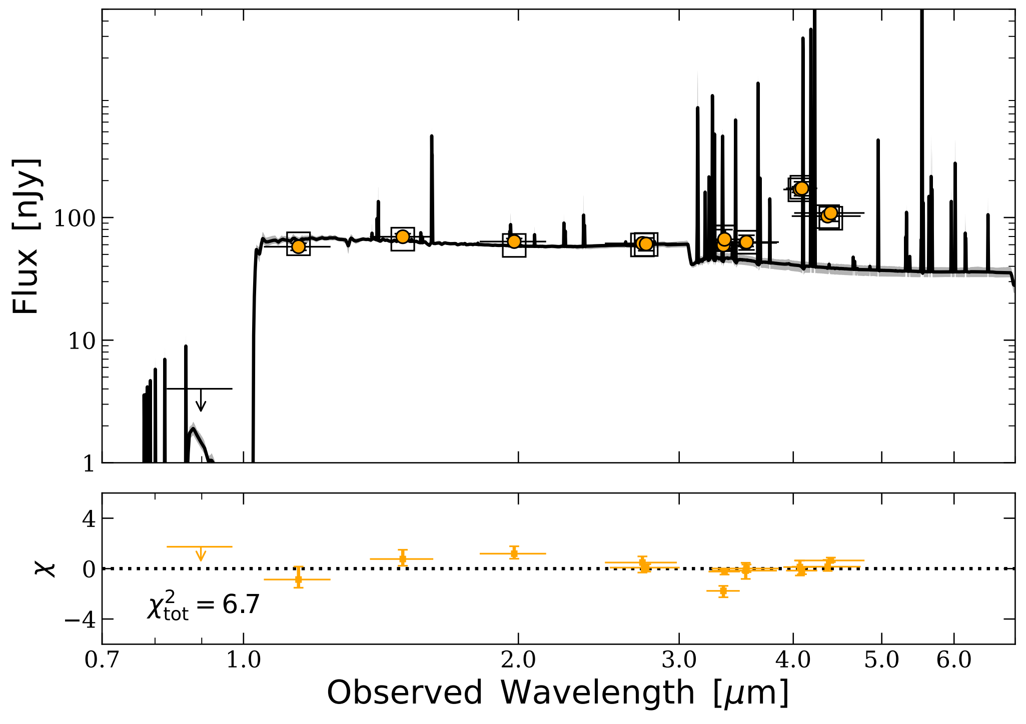


Combined fit



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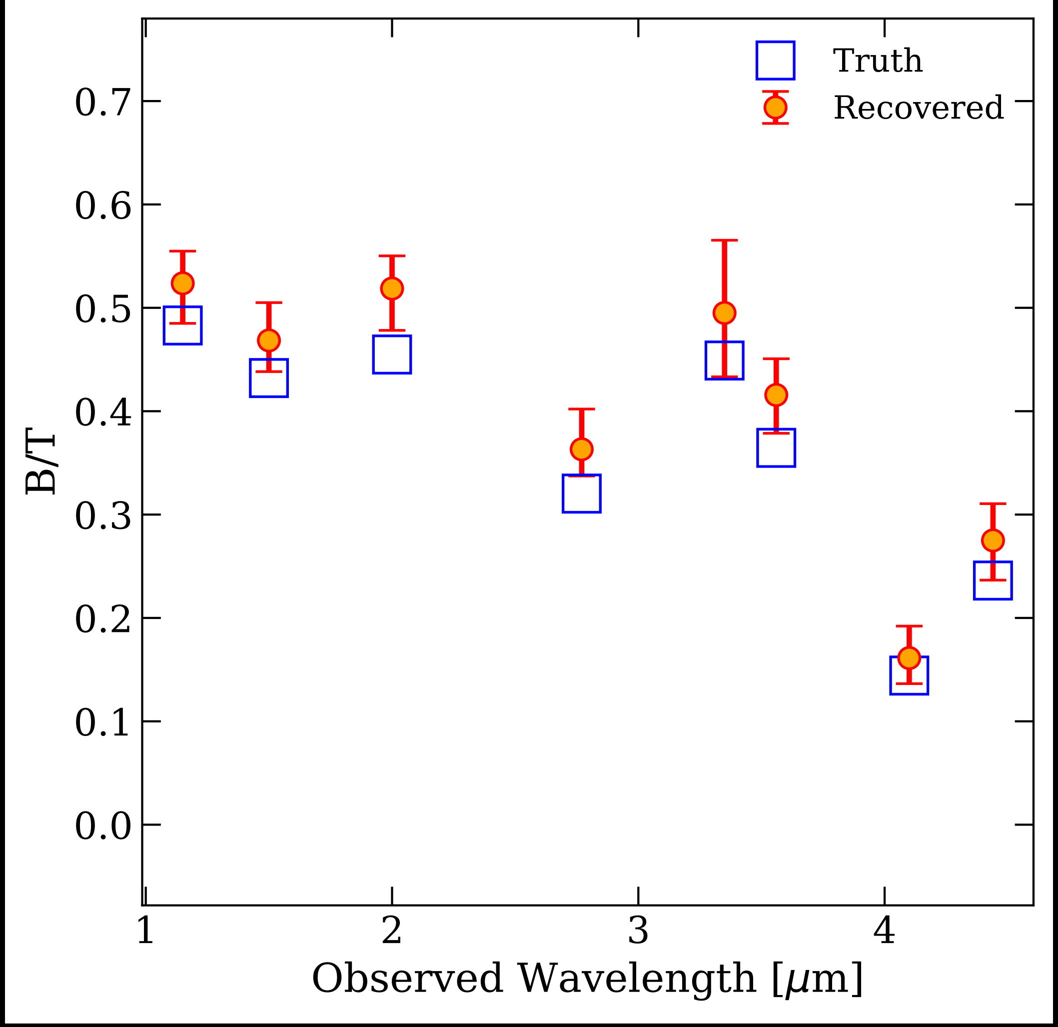
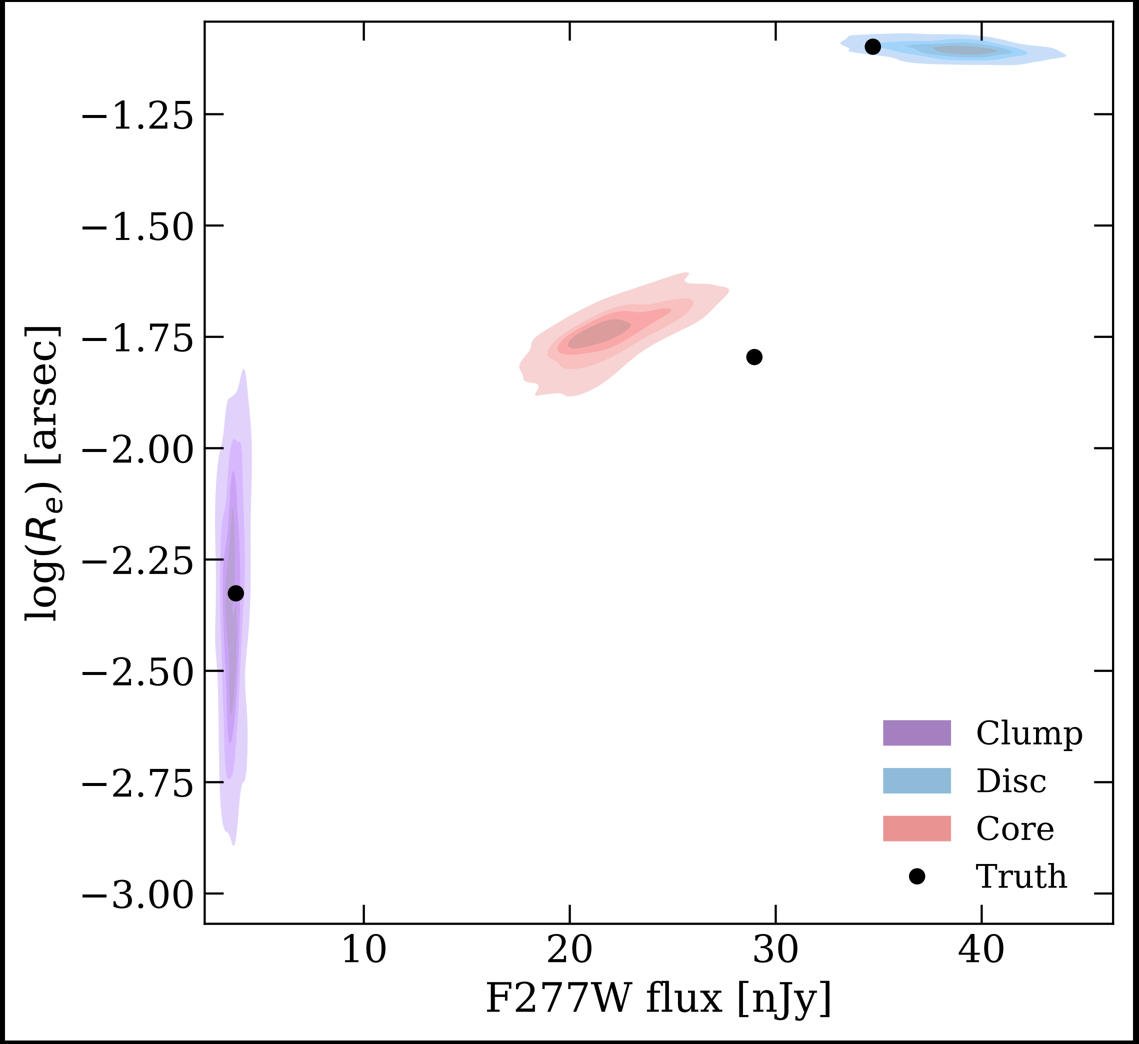
PSF approximations





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