Stellar Haloes of galaxies in SDSS Stripe 82: what's out there?

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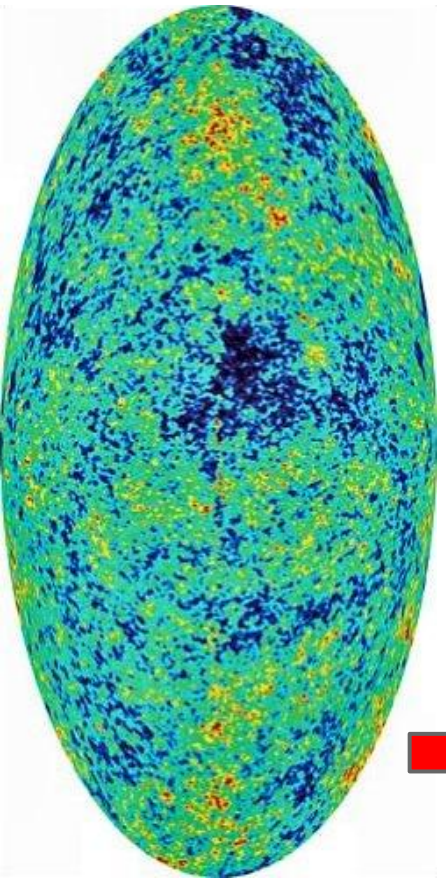
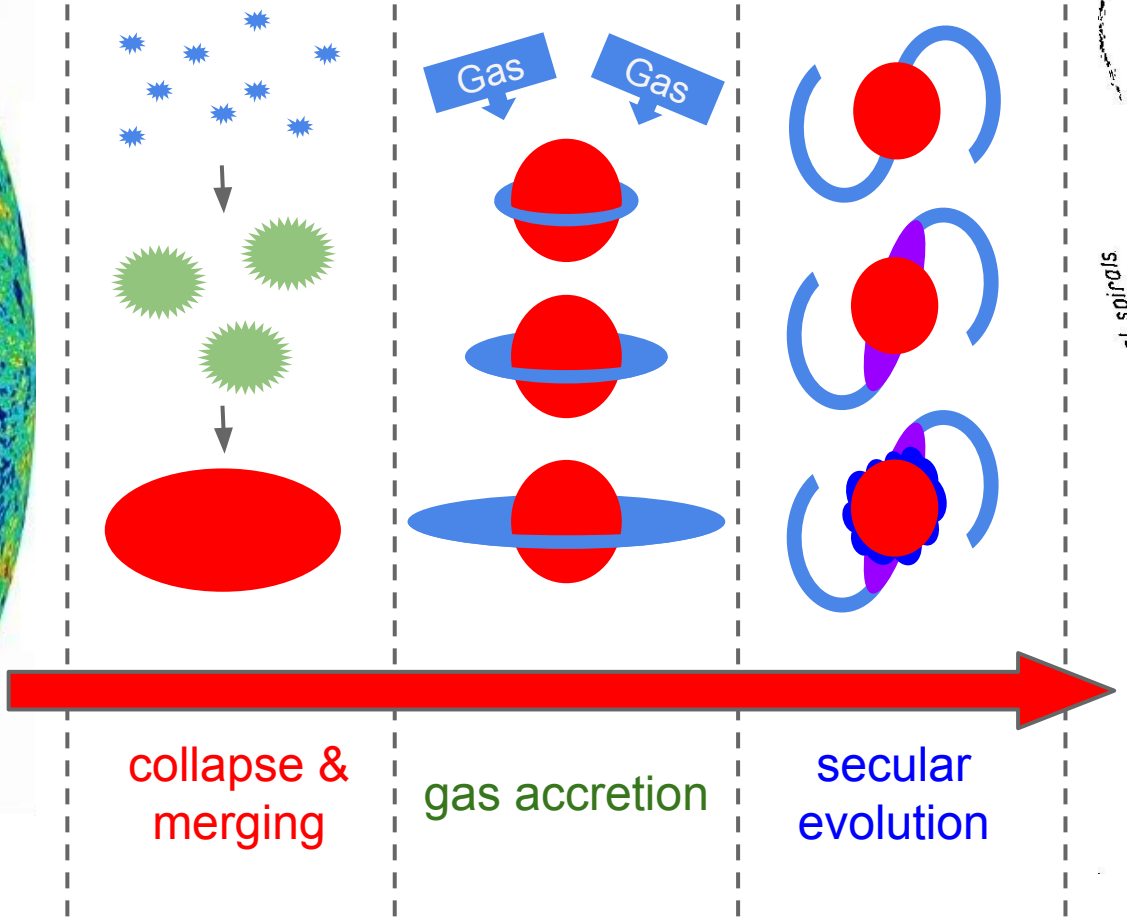
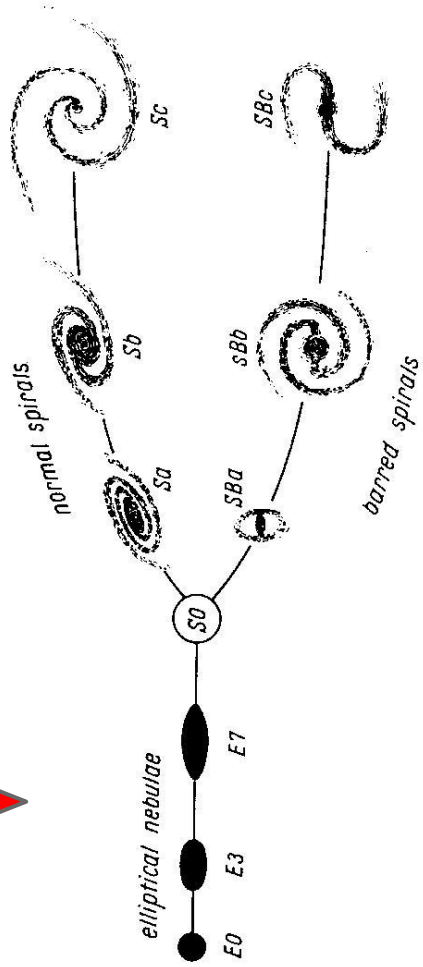
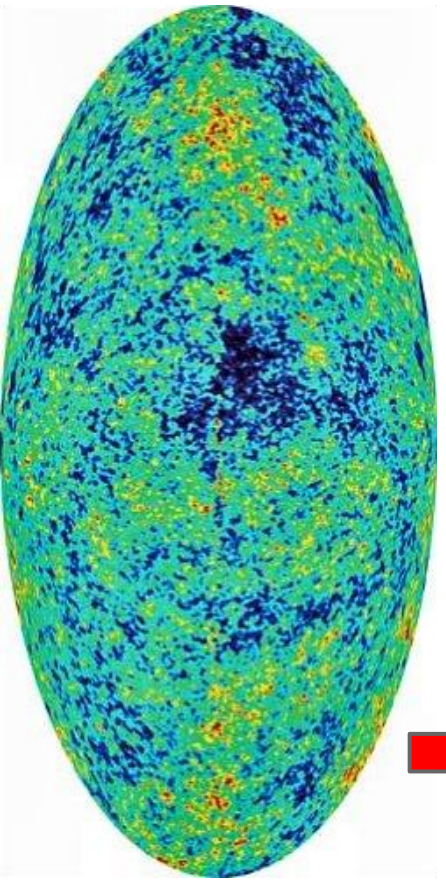
Evolutionary Mechanisms

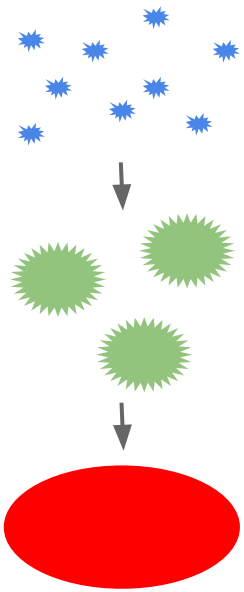






Evolutionary Mechanisms



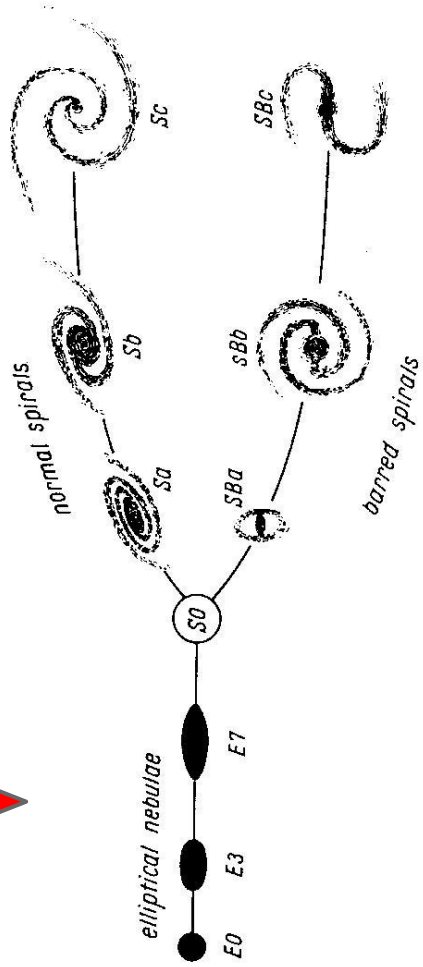


Hierarchical merging → stellar haloes

Eggen, Lynden-Bell & Sandage 1962
Toomre & Toomre 1972
Searle & Zinn 1978
Steinmetz & Muller 1995
Cole et al. 2000
Bekki & Chiba 2001
Samland & Gerhard 2003

Stellar haloes:

- satellites, streams, shells; old diffuse pop.
- ~few% stellar mass (?)
- pressure supported



collapse & merging

gas accretion

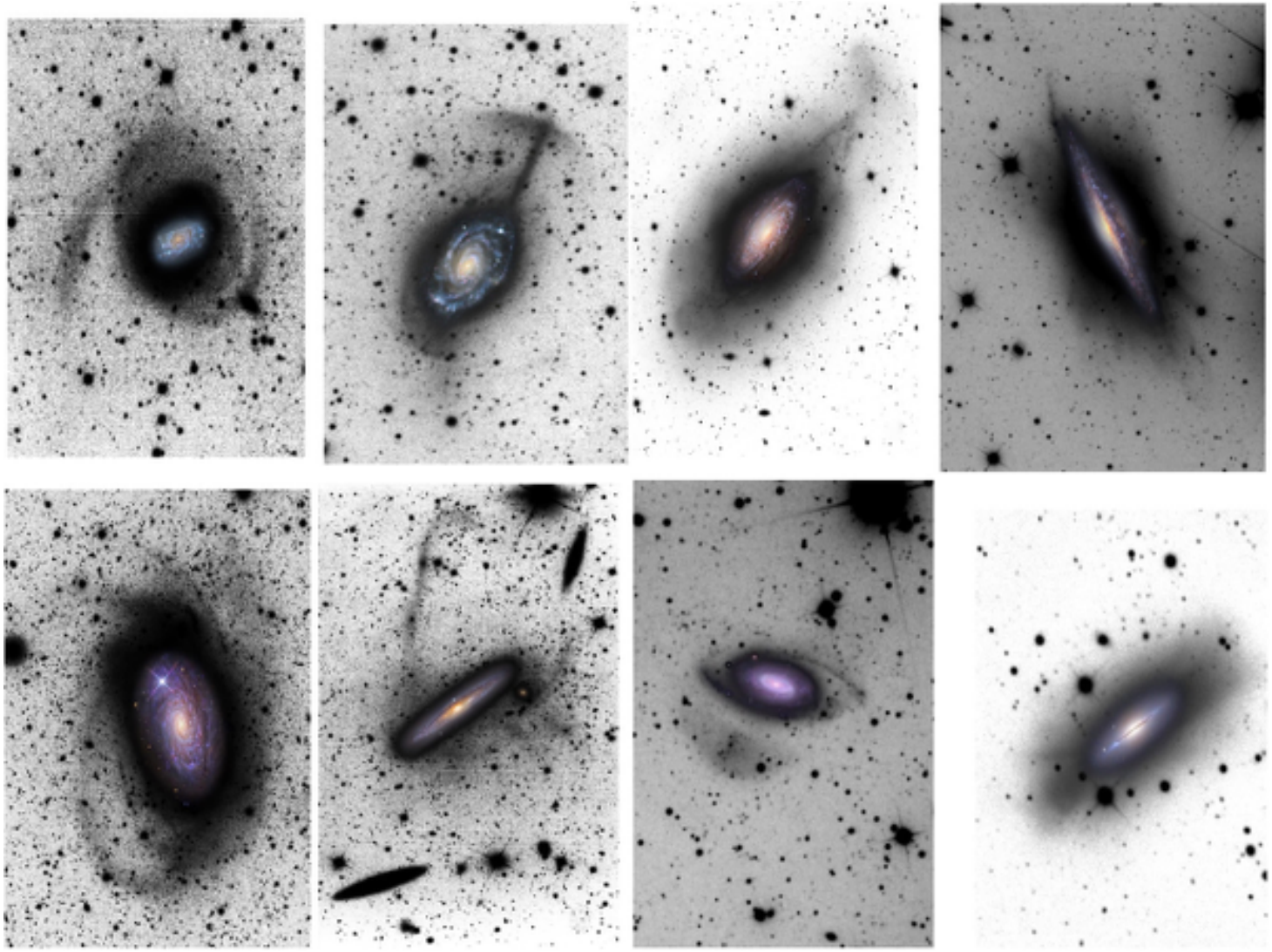
secular evolution

The Star Streams of NGC 5907

R Jay Gabany (Blackbird Observatory), David Martínez-Delgado (IAC) et al.

http://apod.nasa.gov/apod/ap080619.html

Streams, Plumes, Umbrellas, Clouds, Spikes, Haloes...



D. Martínez-Delgado et al. 2010

Why Stellar Haloes?

- Signatures of merging events which have shaped galaxy evolution
- Provide a record of galaxy mass assembly
- Imply a history of feedback, SFR, metal enrichment
- Stellar haloes believed to be ubiquitous and diverse, however:
- Current studies limited to small cosmological volume/low mass (e.g.; Mouhcine, Ibata & Rejkuba 2010; Ibata, Radburn-Smith et al. 2011)

A wide, deep and robust extragalactic survey of extended and diffuse stellar components is required to provide the ultimate test of ΛCDM hierarchical merging scenarios.

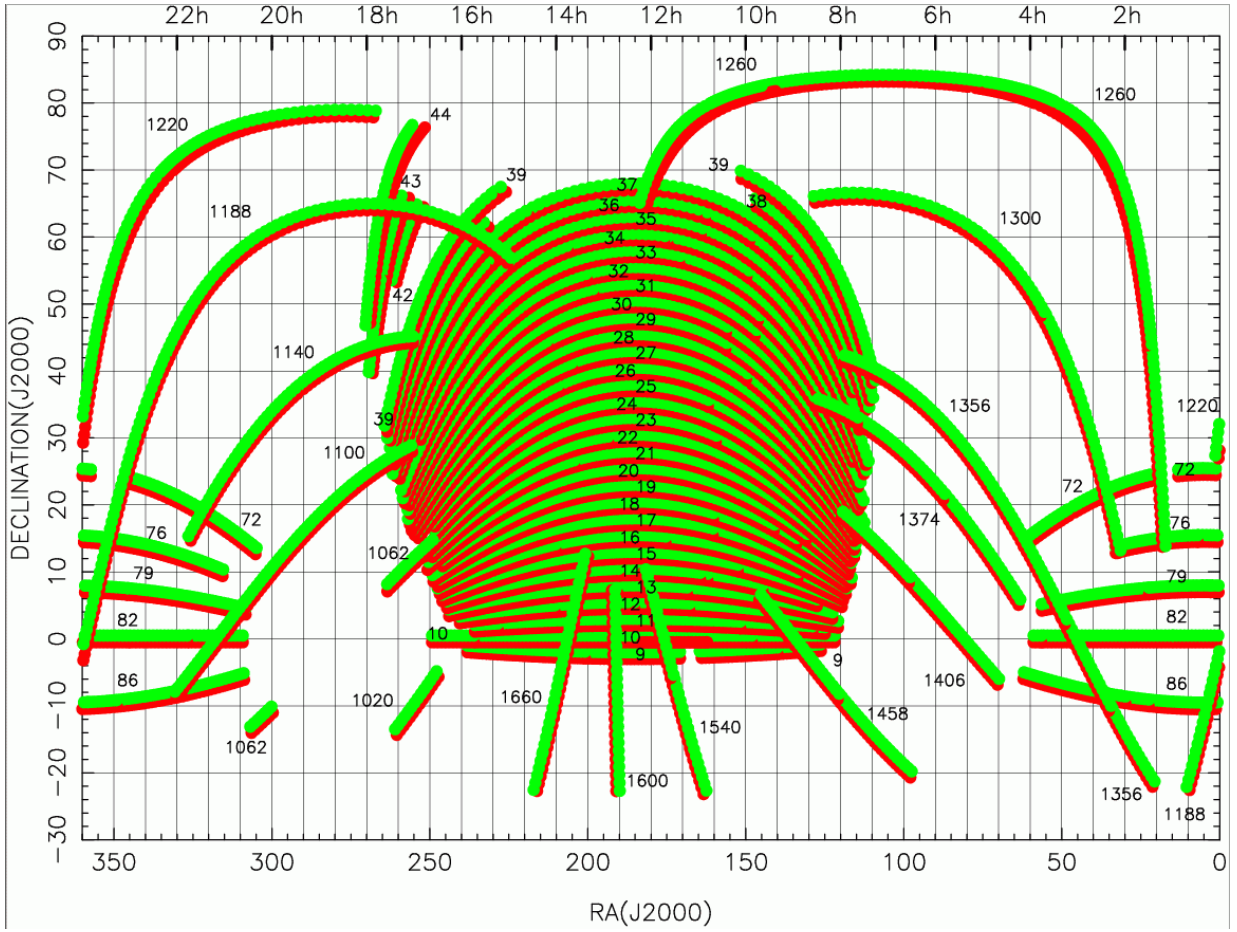
SDSS Stripe 82

SDSS-II Supernova Survey along SDSS Stripe 82

270 deg^2 area

- $-50 < \alpha < 59$
- $-1.25 < \delta < 1.25$

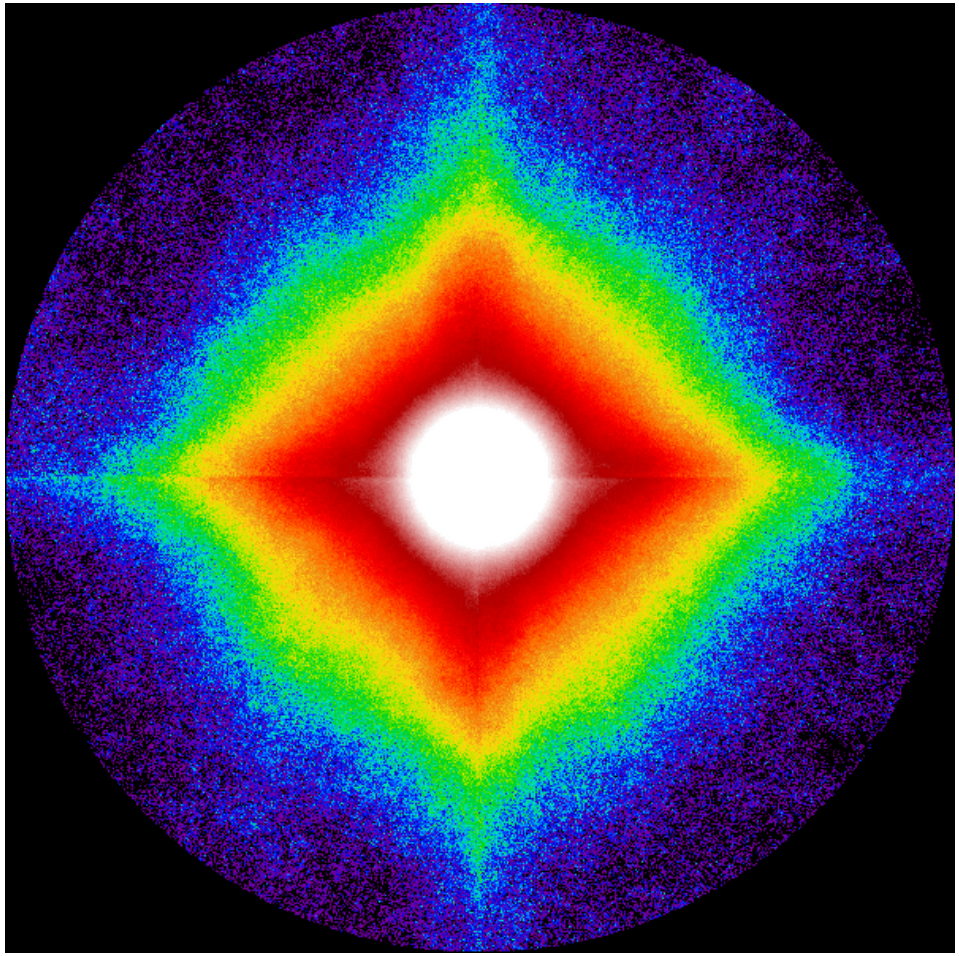
303 runs, avg. 80 exposures per pixel



Sloan Digital Sky Survey

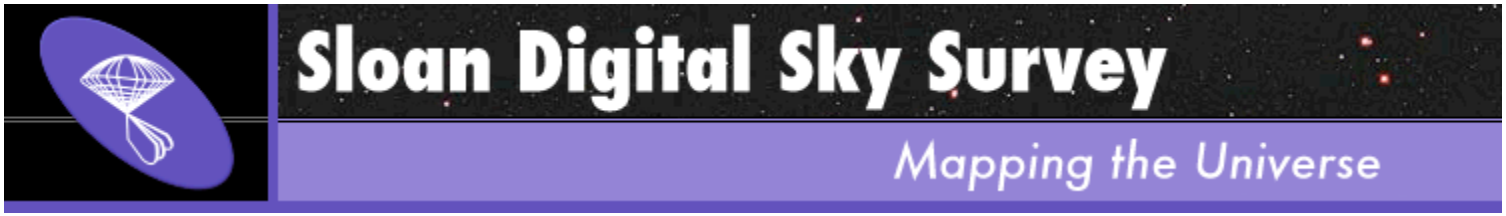
Mapping the Universe

SDSS Stripe 82

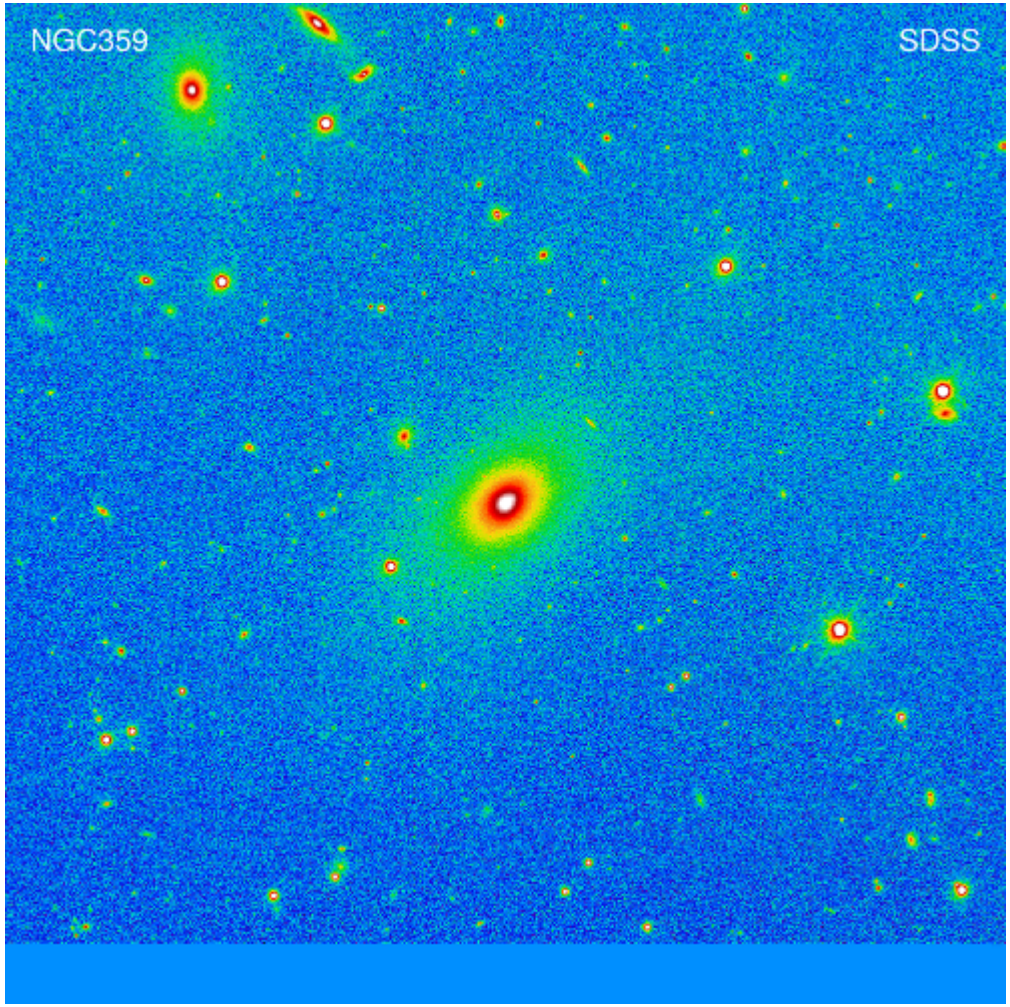


Reprocessed at the IAC:
(Jürgen Fliri, Mauricio Cisternas)

- minimally aggressive sky subtraction
- PSF stacking to produce large (~800''x800'') PSFs
- stack *gri* bands to produce *r-deep* passband



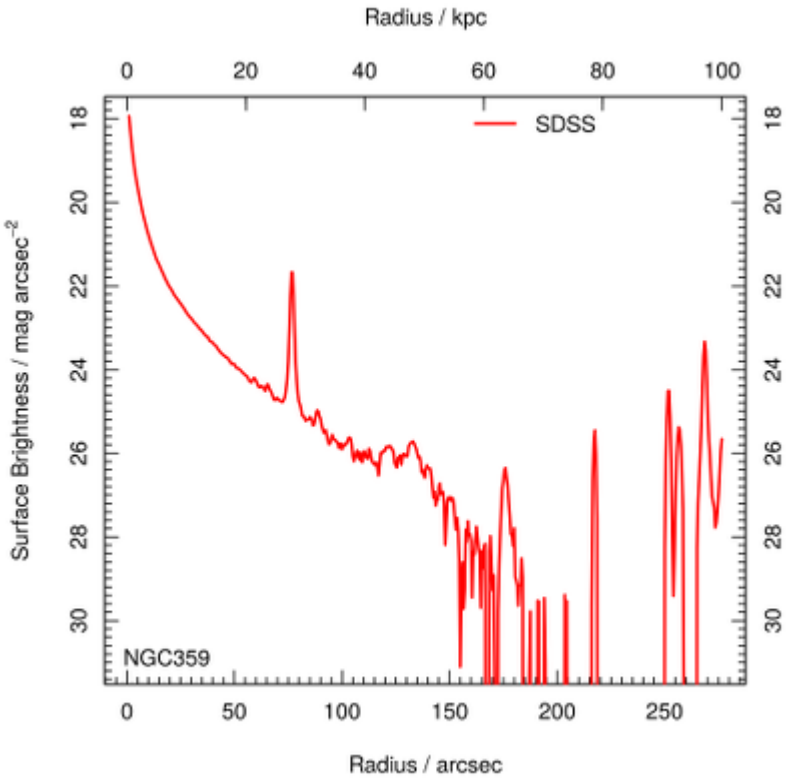
NGC 359



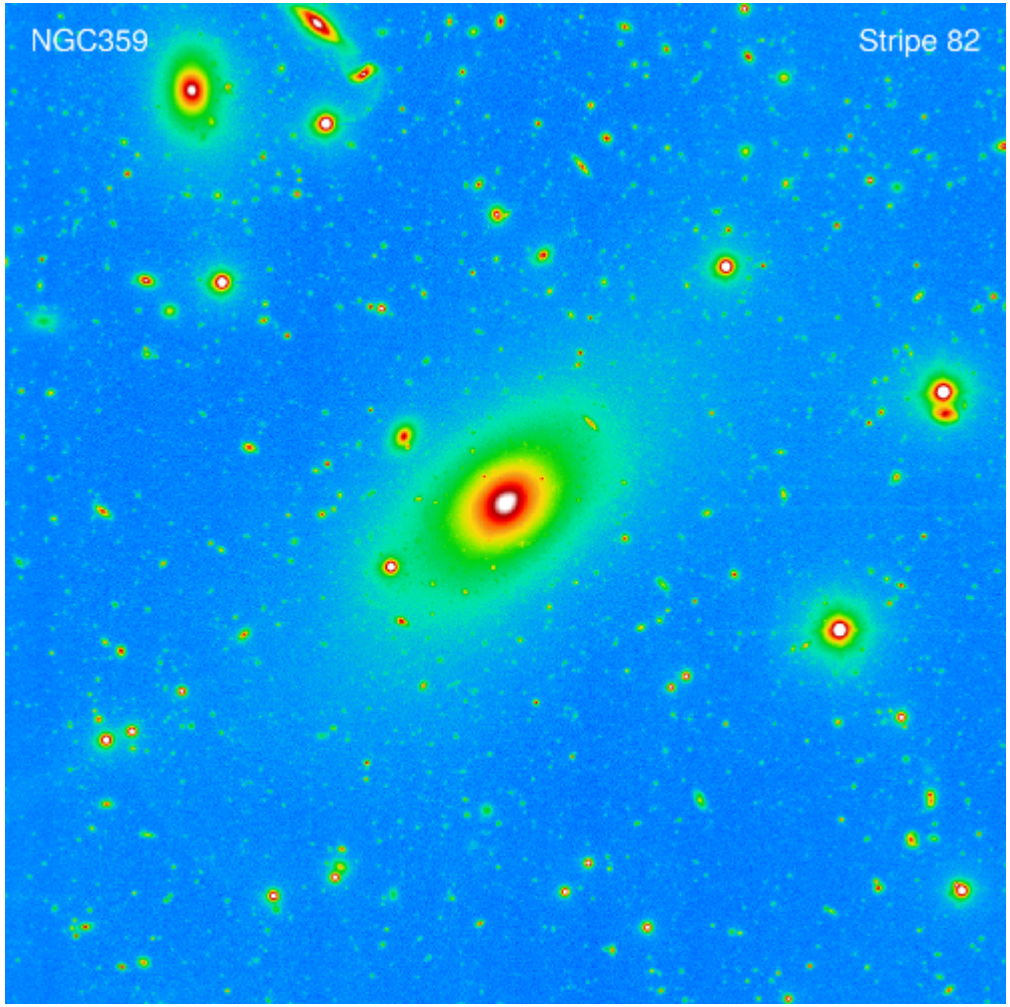
200 kpc x 200 kpc

SDSS DR7 imaging

Smooth early type (?)



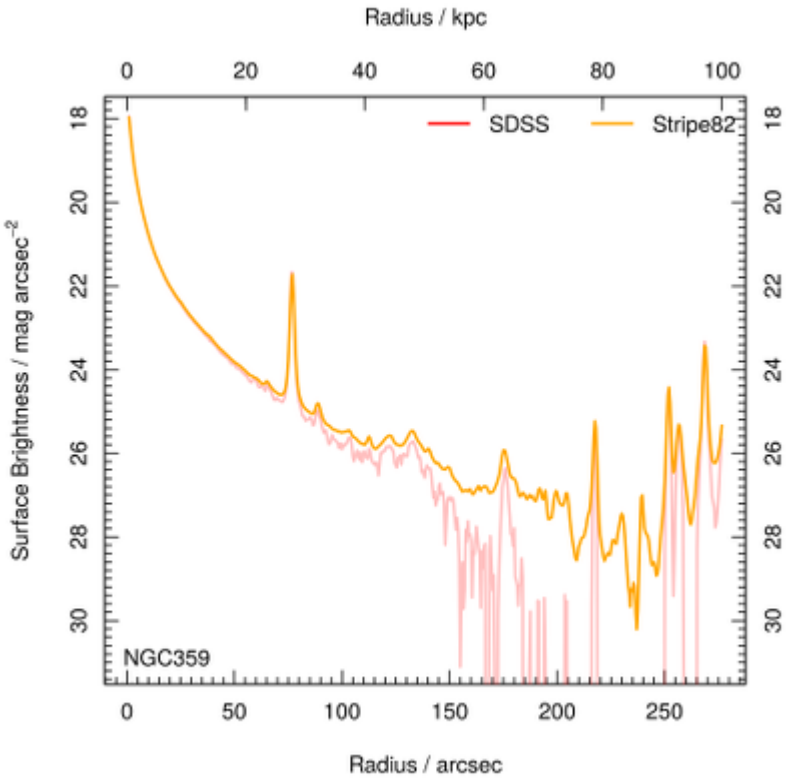
NGC 359



200 kpc x 200 kpc

Stripe 82 imaging

Early type / crowded field

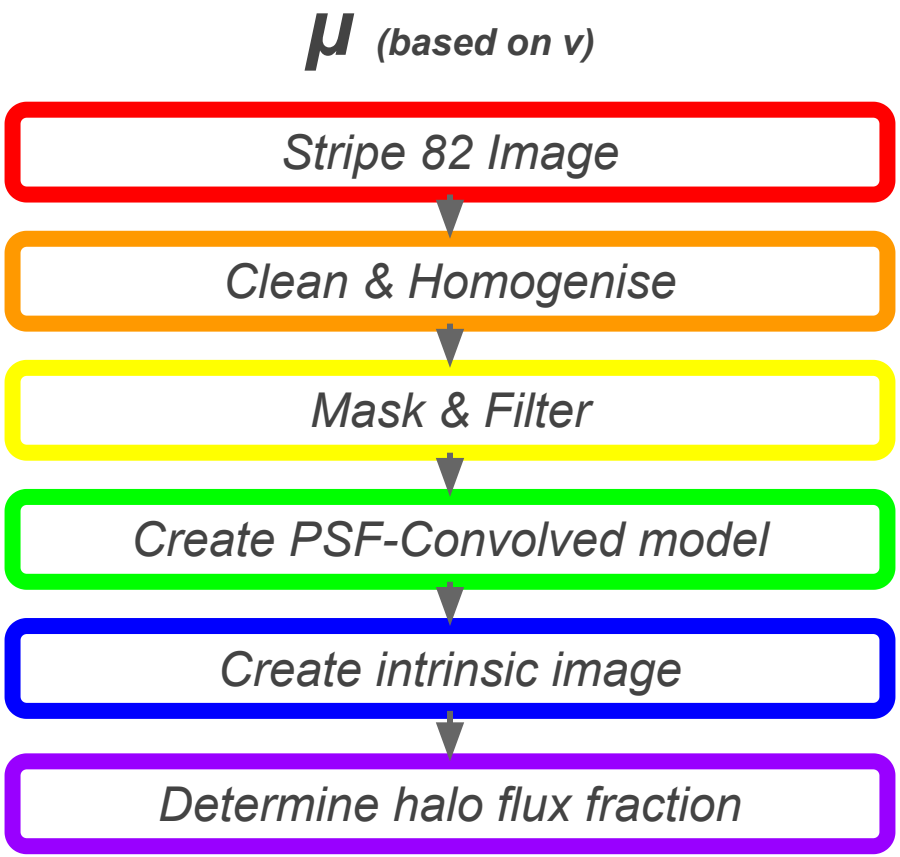


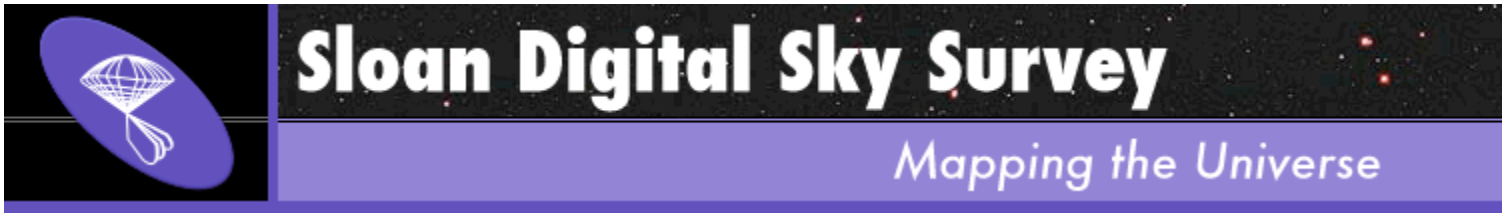
Quantifying the halo fraction

What fraction of the total light/mass of a system lies in the stellar halo?

Need to account for the effects of secondary neighbours and the effects of the PSF.

Desirable to have large-number statistics: automated process.





Clean & Homogenise

Use source extractor for source detection

Secondary flux must be removed, obvious answer is to fit and subtract with GALFIT/IMFIT/etc… -> too slow

Exploit object fitting routine built into Source Extractor [exp, sersic, deV, PSF]

Thanks: *Aldée Charbonnier*

No further sky subtraction

Fit secondary objects, large -> small

(6 levels, PSFEx PSF for each level)

Remove image stripes (homogenise)

6 levels of cleaning:

6: sersic/exp/point source

5: sersic/exp/point source

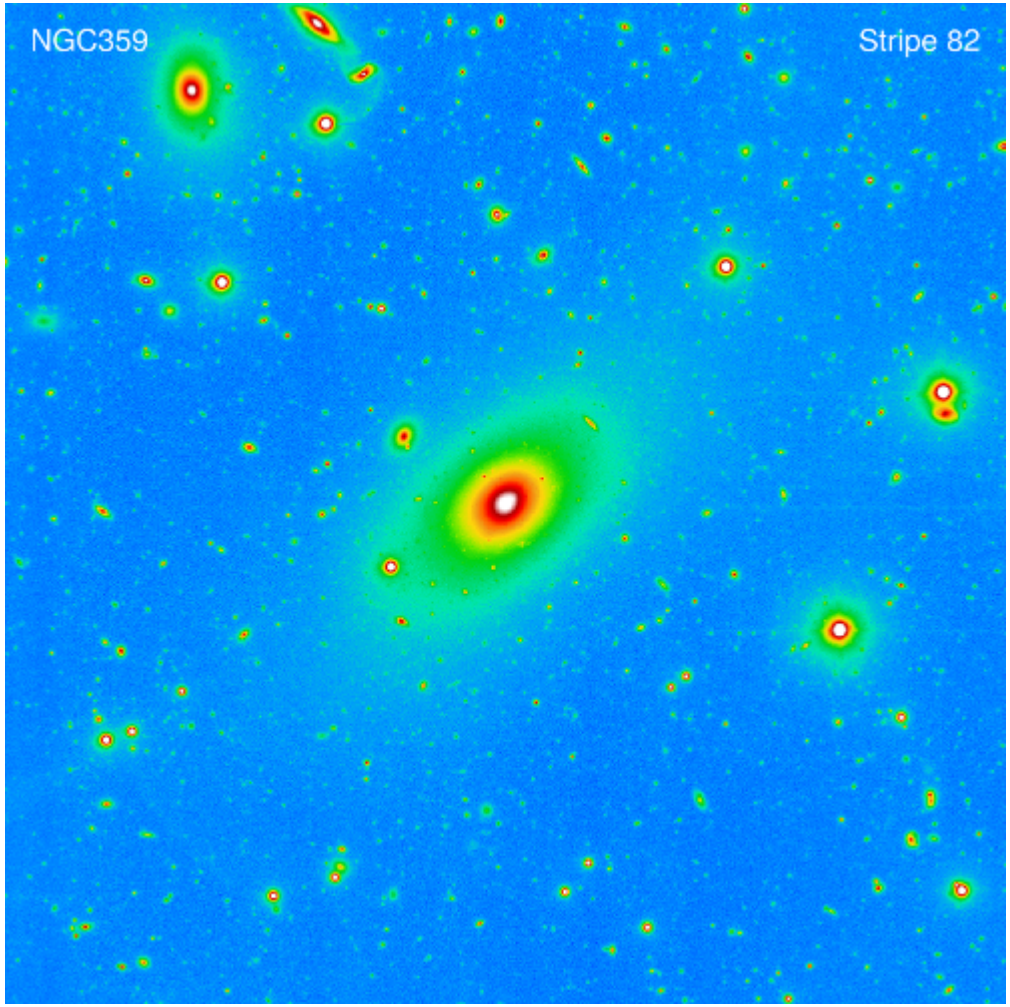
4: sersic

3: sersic

2: exponential

1: point source

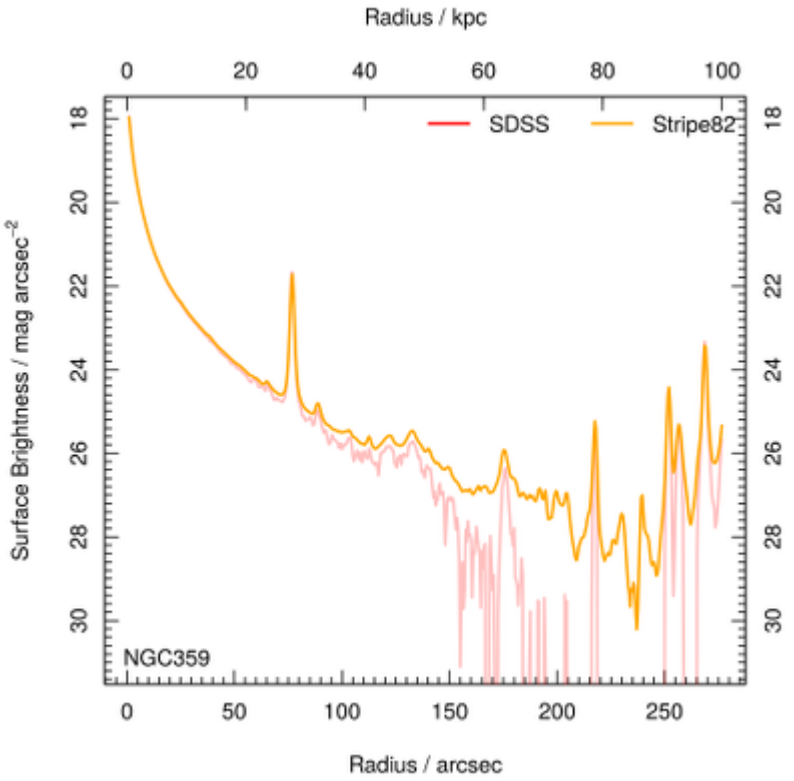
NGC 359



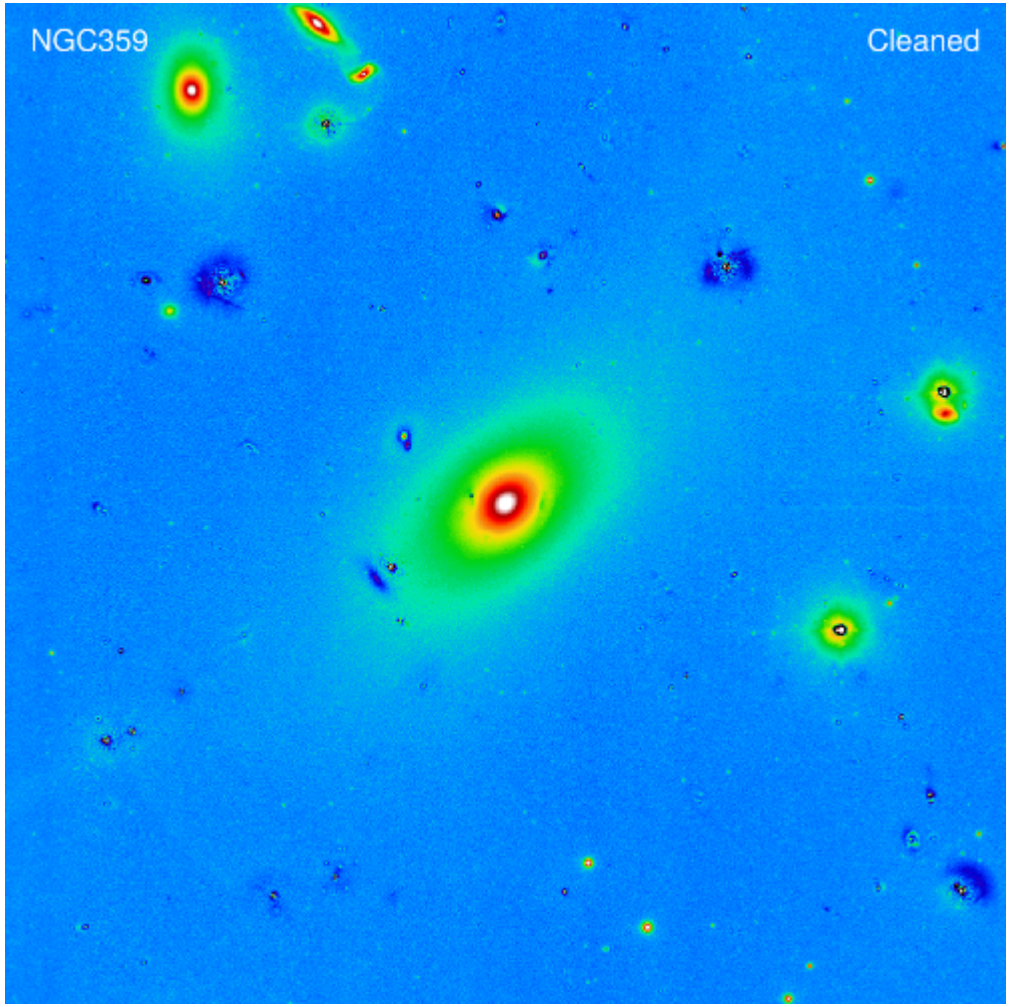
200 kpc x 200 kpc

Stripe 82 imaging

Early type / crowded field



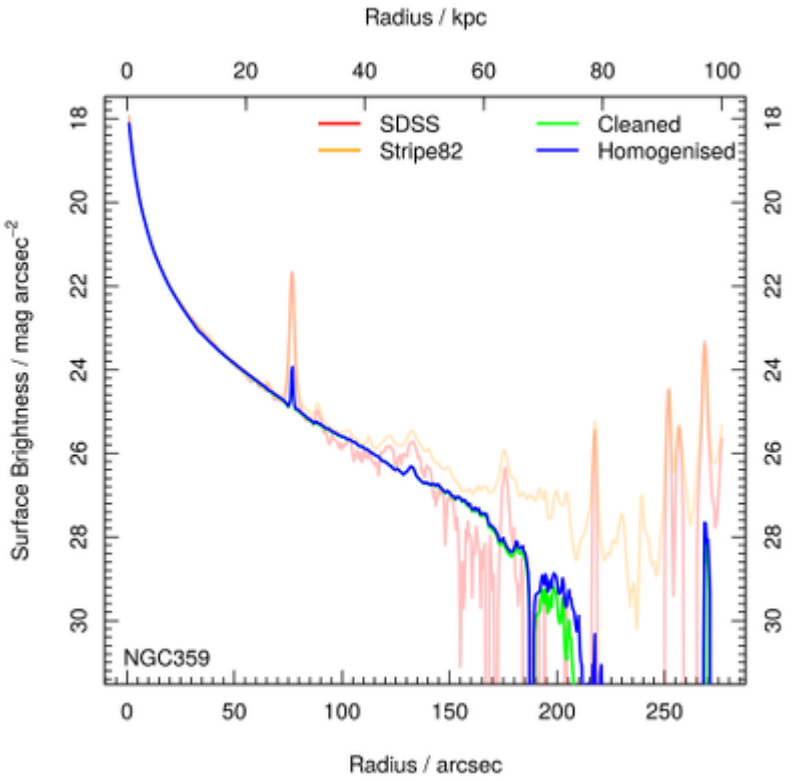
Clean & Homogenise



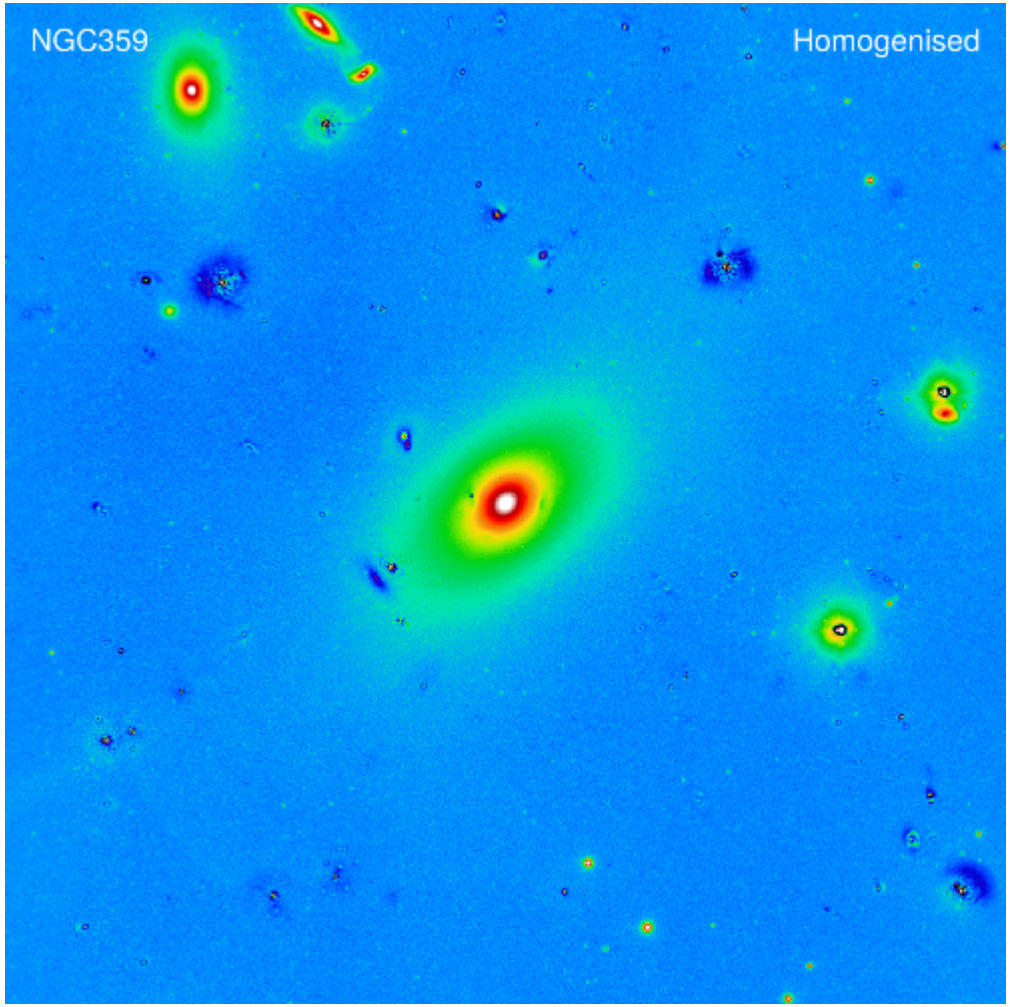
200 kpc x 200 kpc

Stripe 82 cleaned image

Early type / stripy background



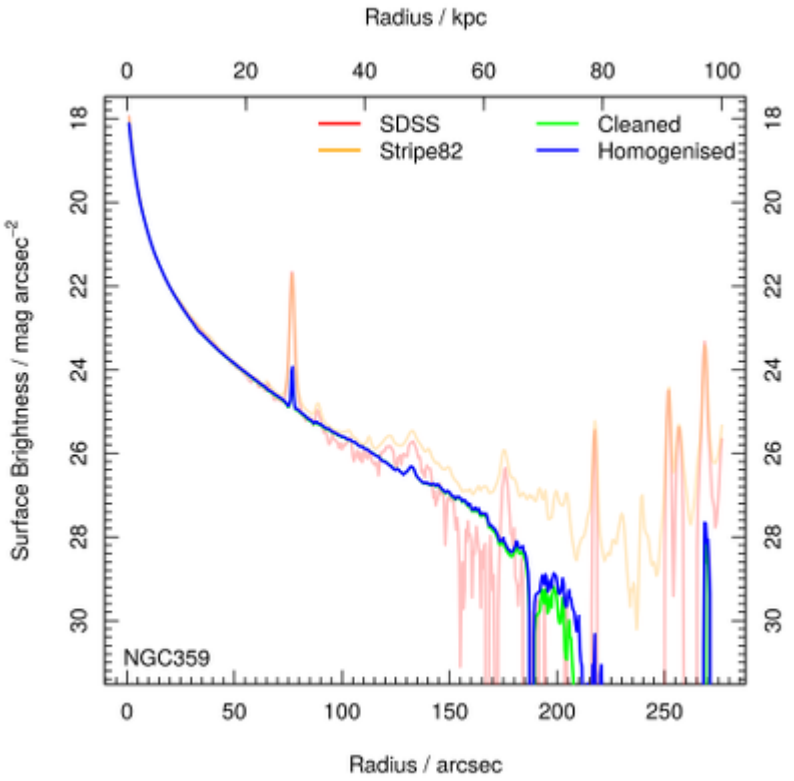
Clean & Homogenise



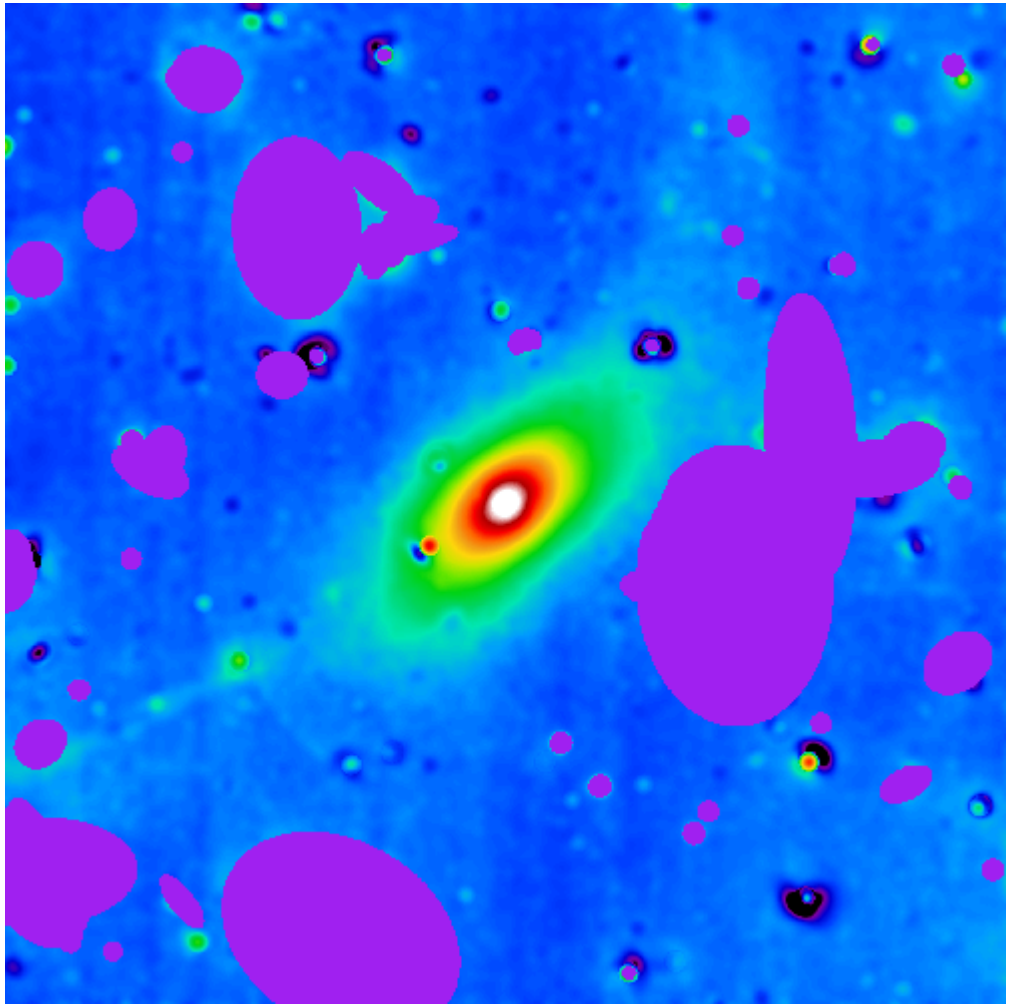
200 kpc x 200 kpc

Stripe 82 homogenised image

Early type with complex halo



Mask & Filter

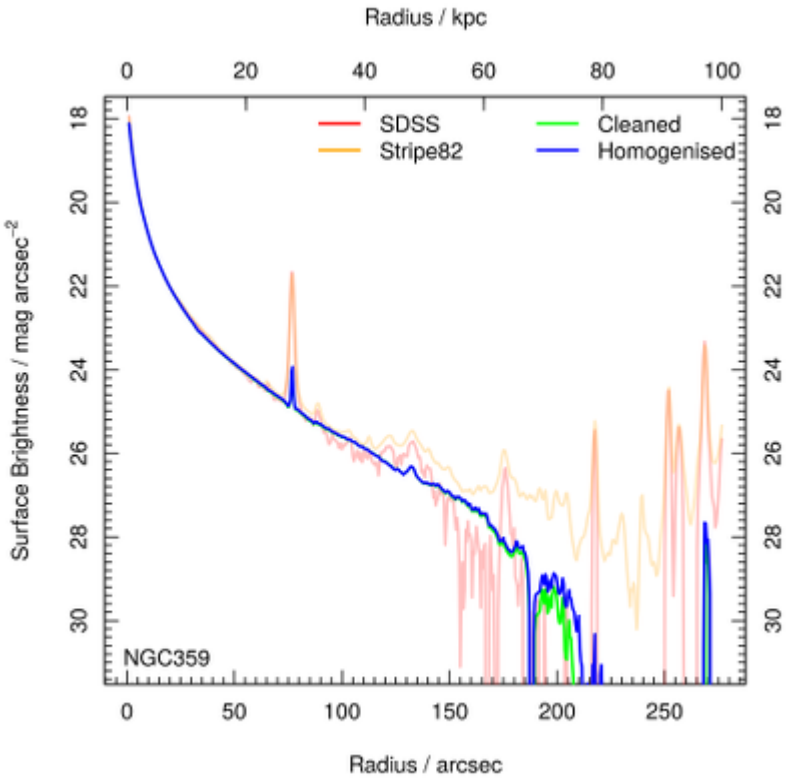


Gaussian filter, FWHM = 25 pixel

300 kpc x **300** kpc

Stripe 82 filtered image

Early type with complex halo



Create PSF-Convolved model

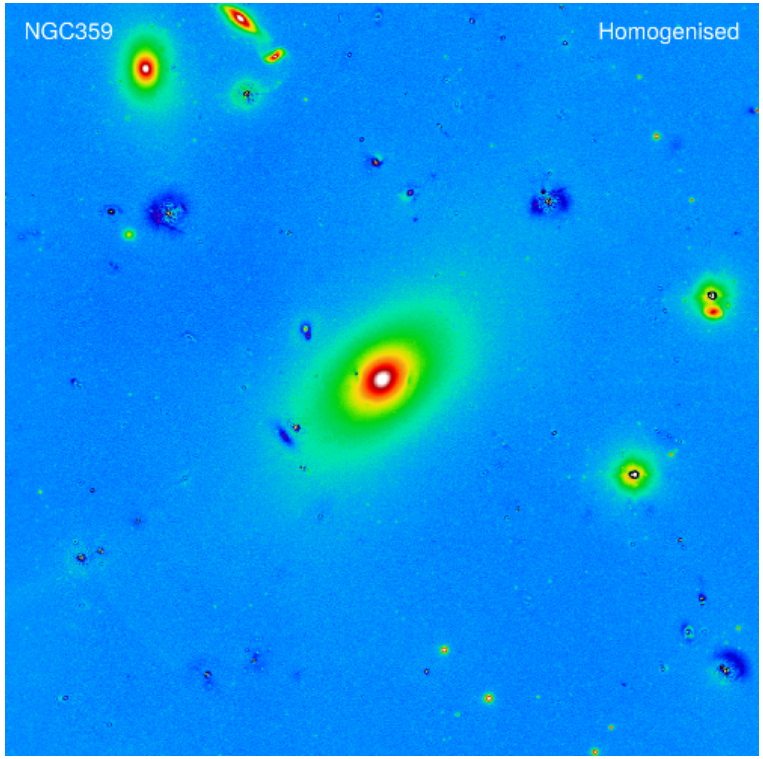
Use GALFIT (Peng+ 2010) and IMFIT (Erwin 2014) to create a robust PSF-Convolved model of the primary galaxy.

GALFIT

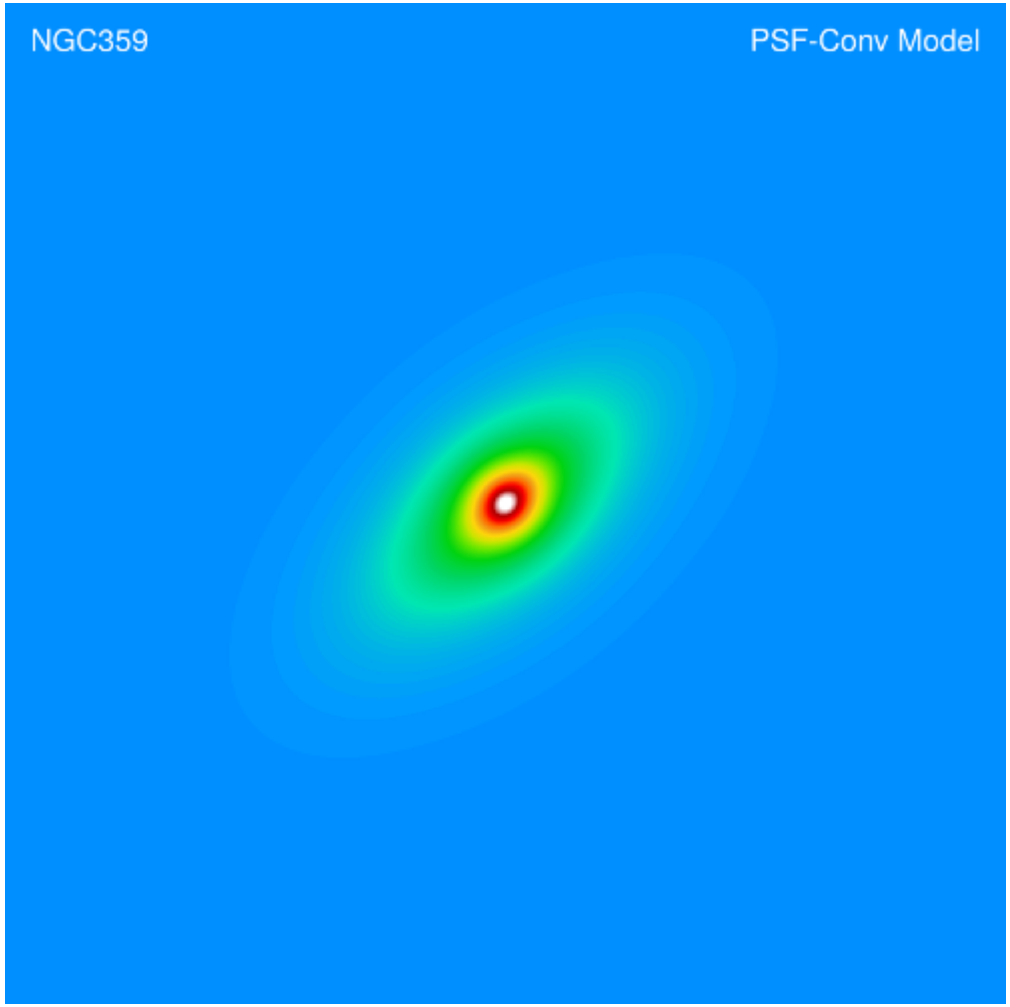
Imfit

GALFIT favoured for ease of use and comparison with other studies.

IMFIT natively fits disk breaks, which remains significant for these data.



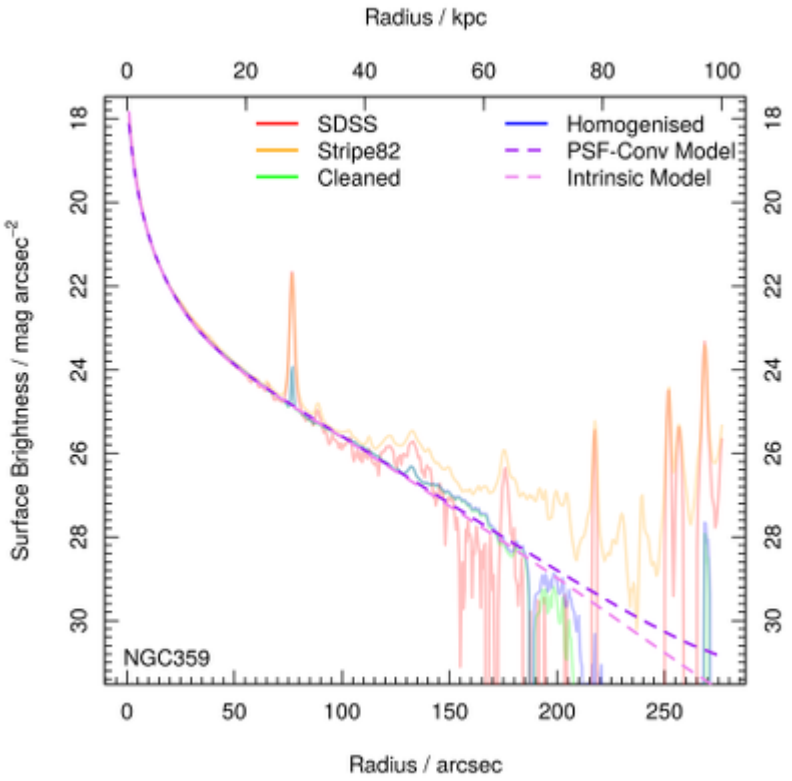
Create PSF-Convolved model



200 kpc x 200 kpc

PSF-Convolved model

3x free Sérsic functions



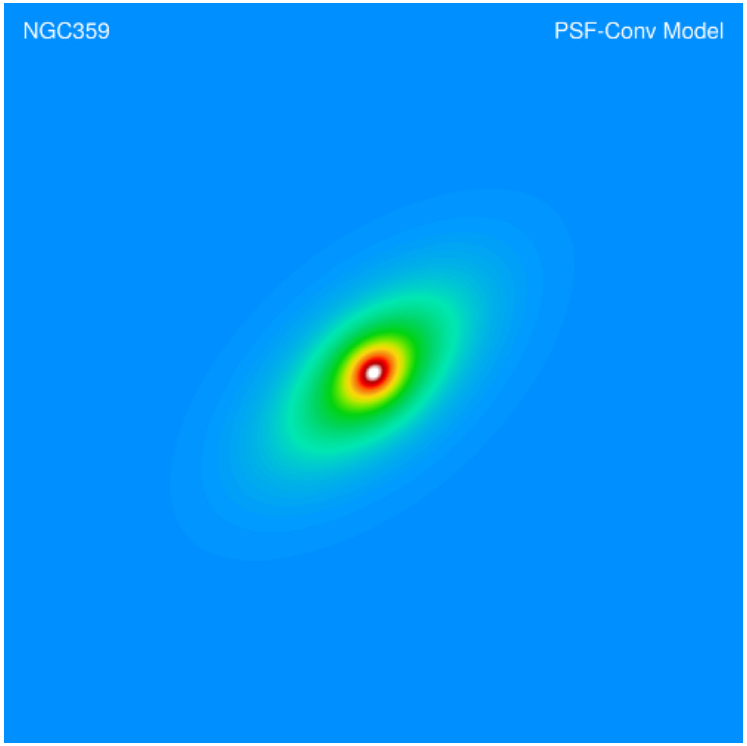
Create intrinsic image

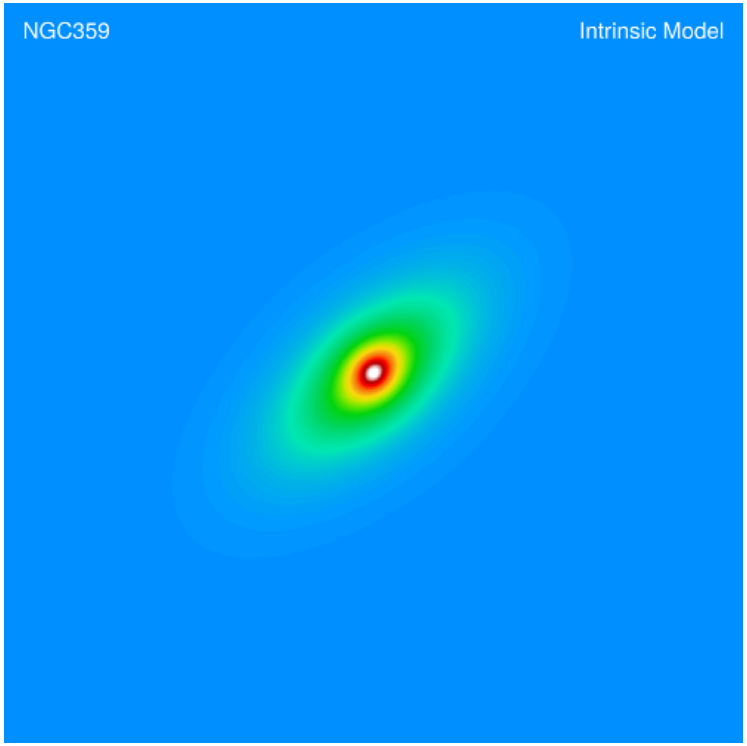
Subtract PSF-Convolved image from data

Add intrinsic model to residual

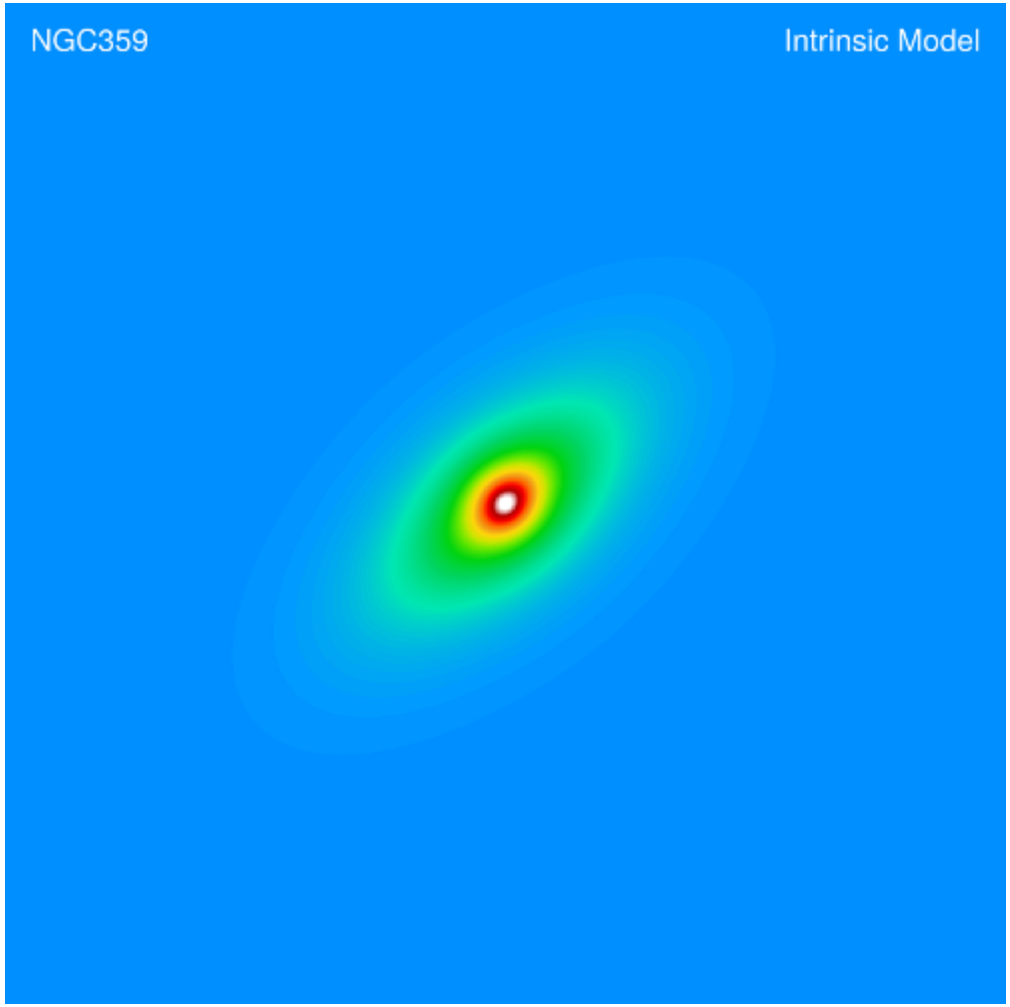
GALFIT

Imfit





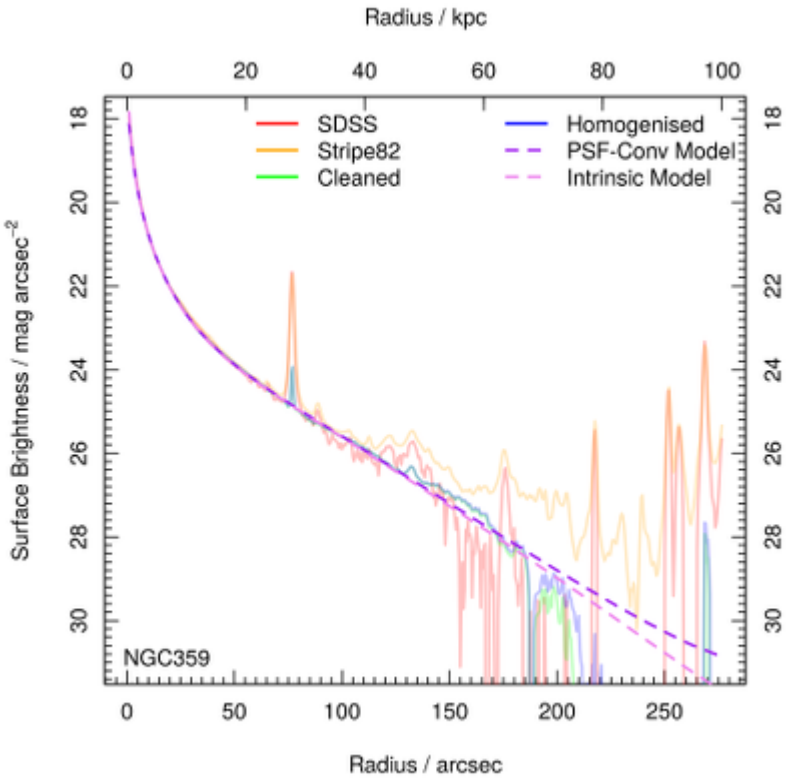
Create intrinsic image



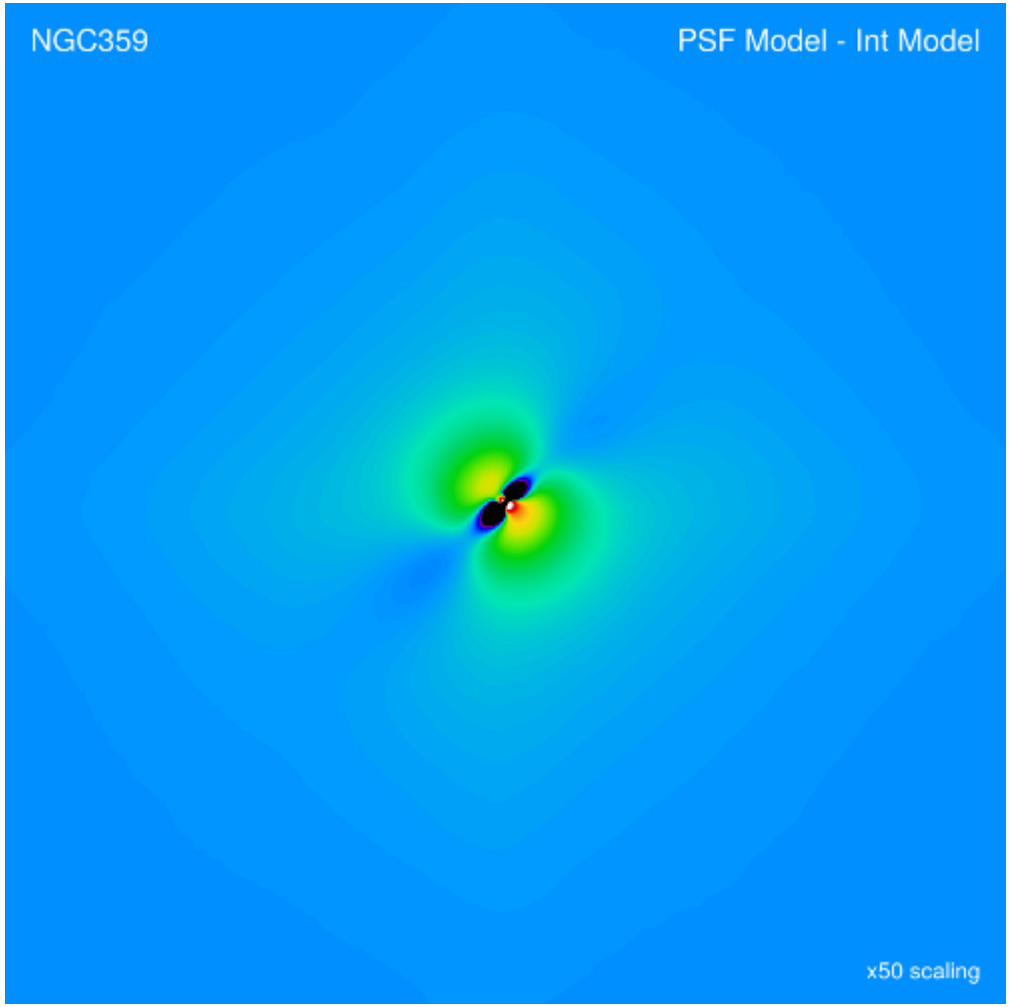
200 kpc x 200 kpc

Intrinsic model

3x free Sérsic functions



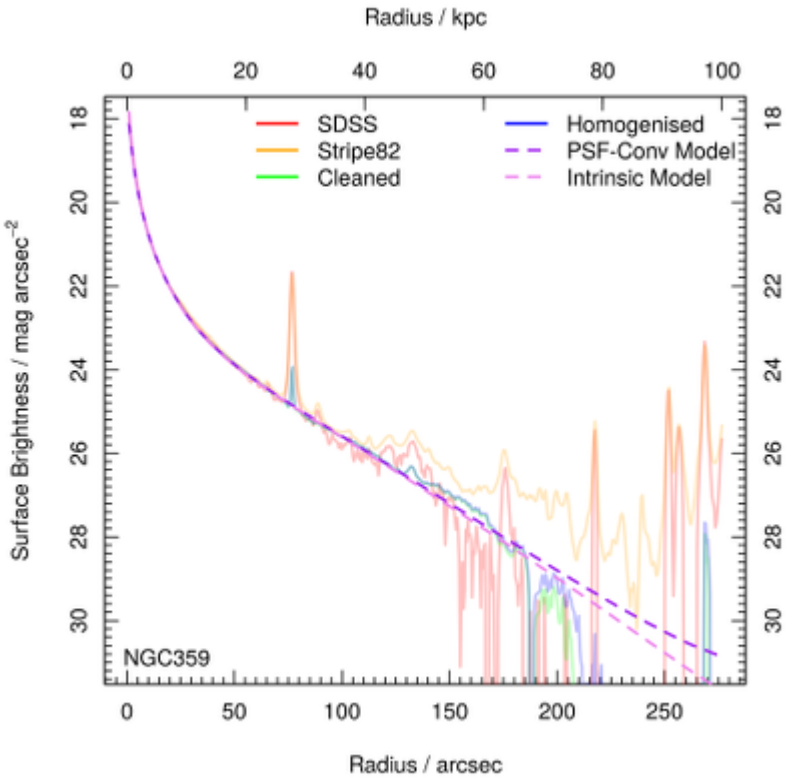
Create intrinsic image



200 kpc x 200 kpc

PSF model - Intrinsic model

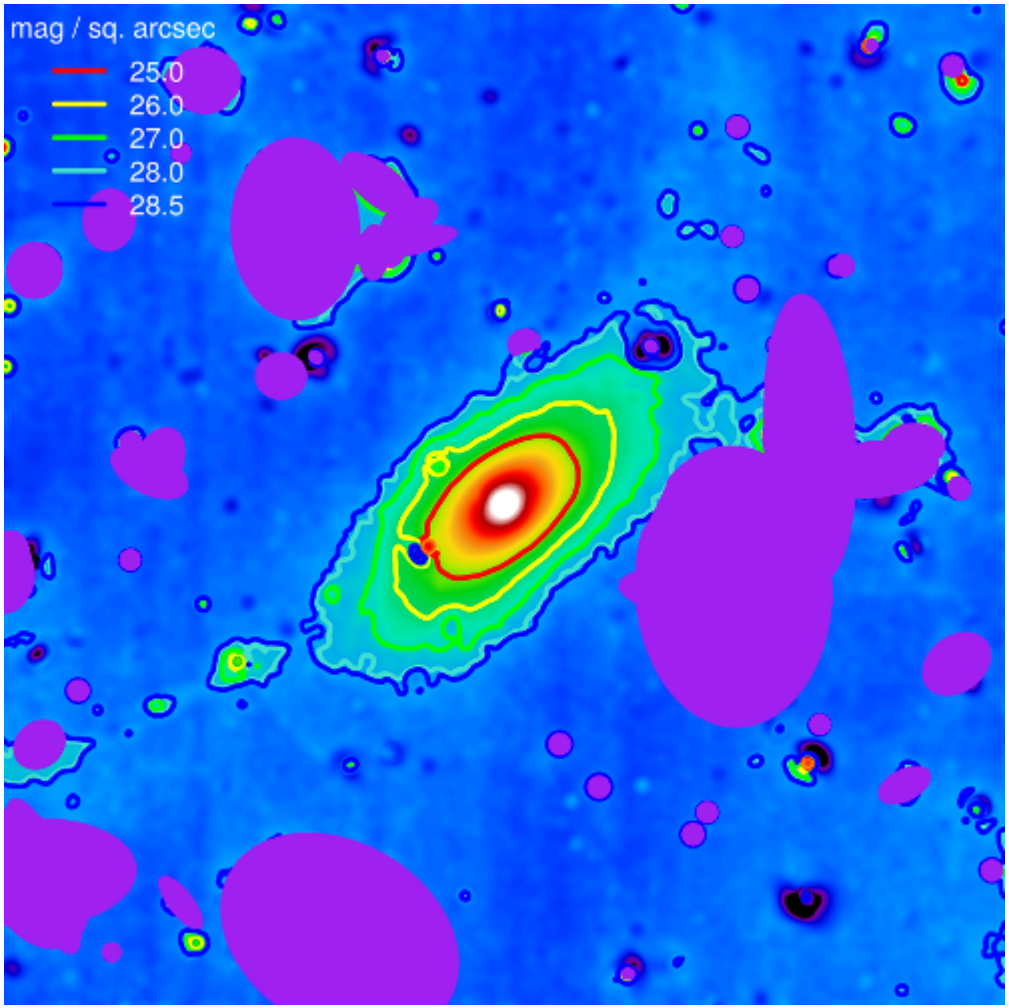
3x free Sérsic functions



Determine halo flux fraction

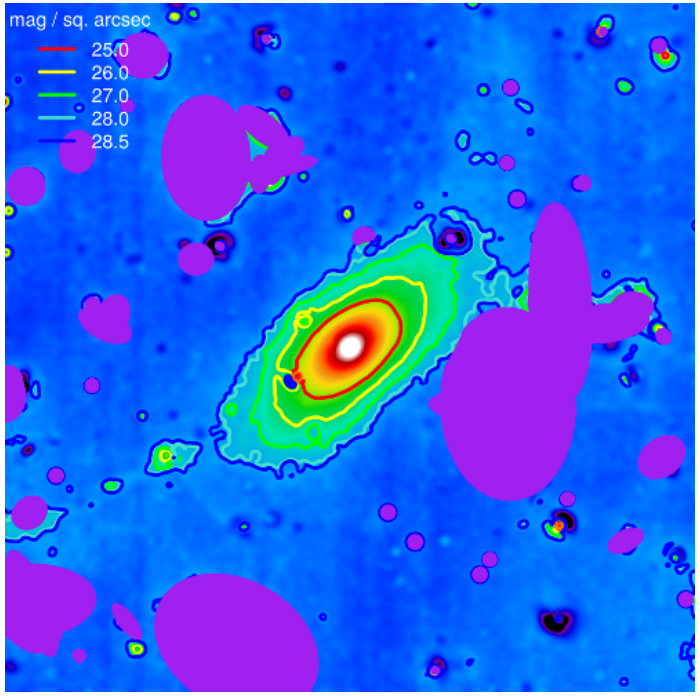
Use filtered image to generate contours of constant surface brightness.

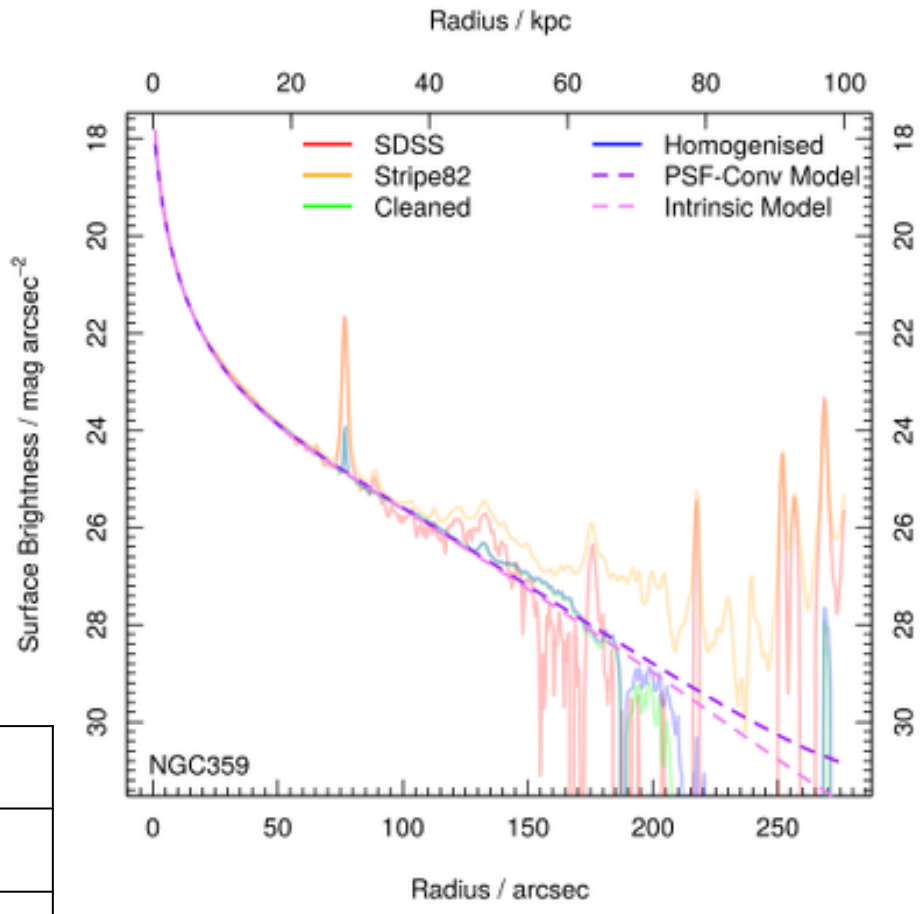
Apply contours to original image and intrinsic image, to quantify the **halo flux fraction** *and* the **effect of the PSF**.



NGC 359: Results

200 kpc x 200 kpc



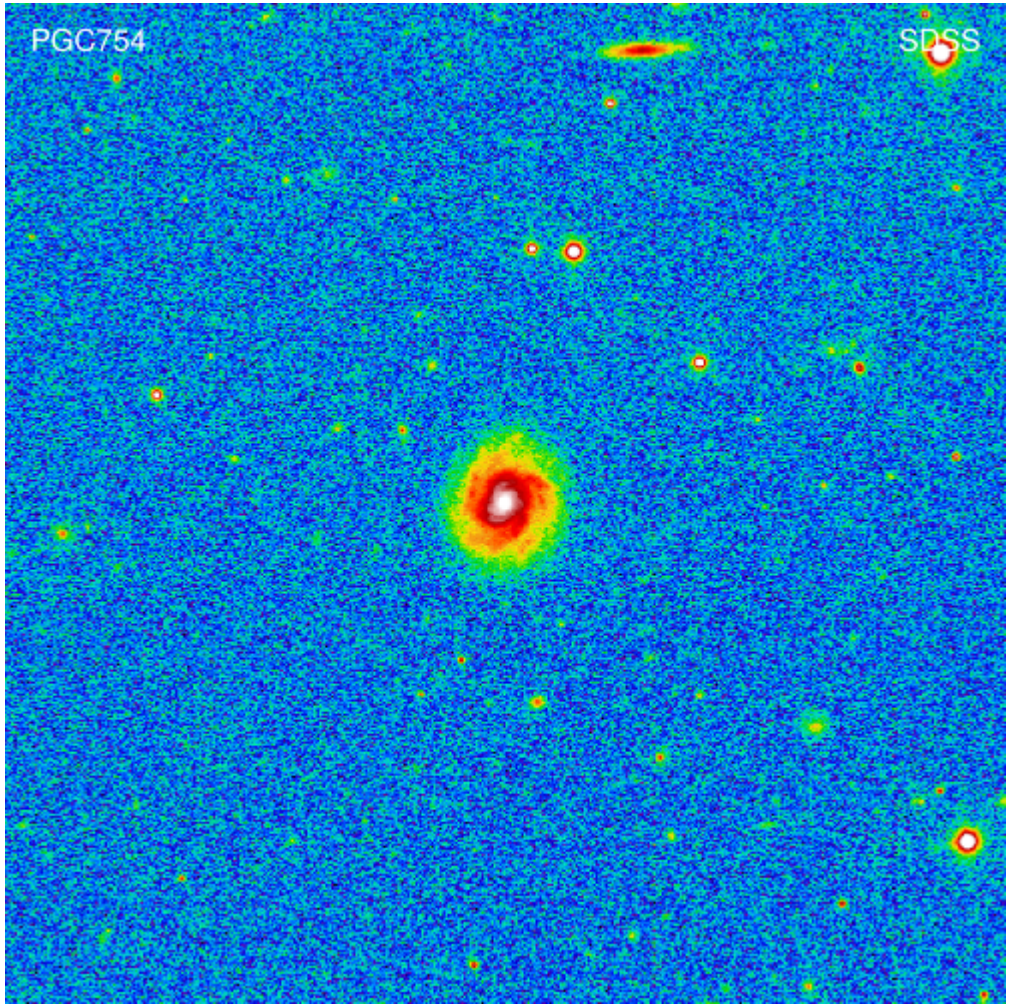


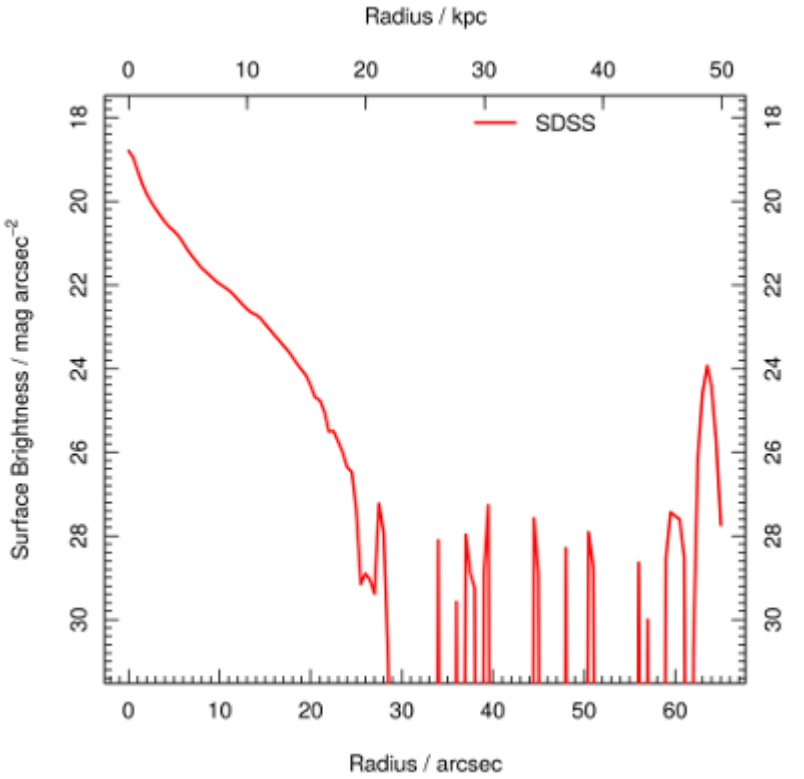
From μ=28.5 to...	μ=25	μ=26	μ=27	μ=28
PSF-Conv	17.04%	7.81%	2.17%	0.20%
Intrinsic	16.54%	7.49%	2.03%	0.17%

For NGC 359, negligible PSF impact

PGC 754: Results

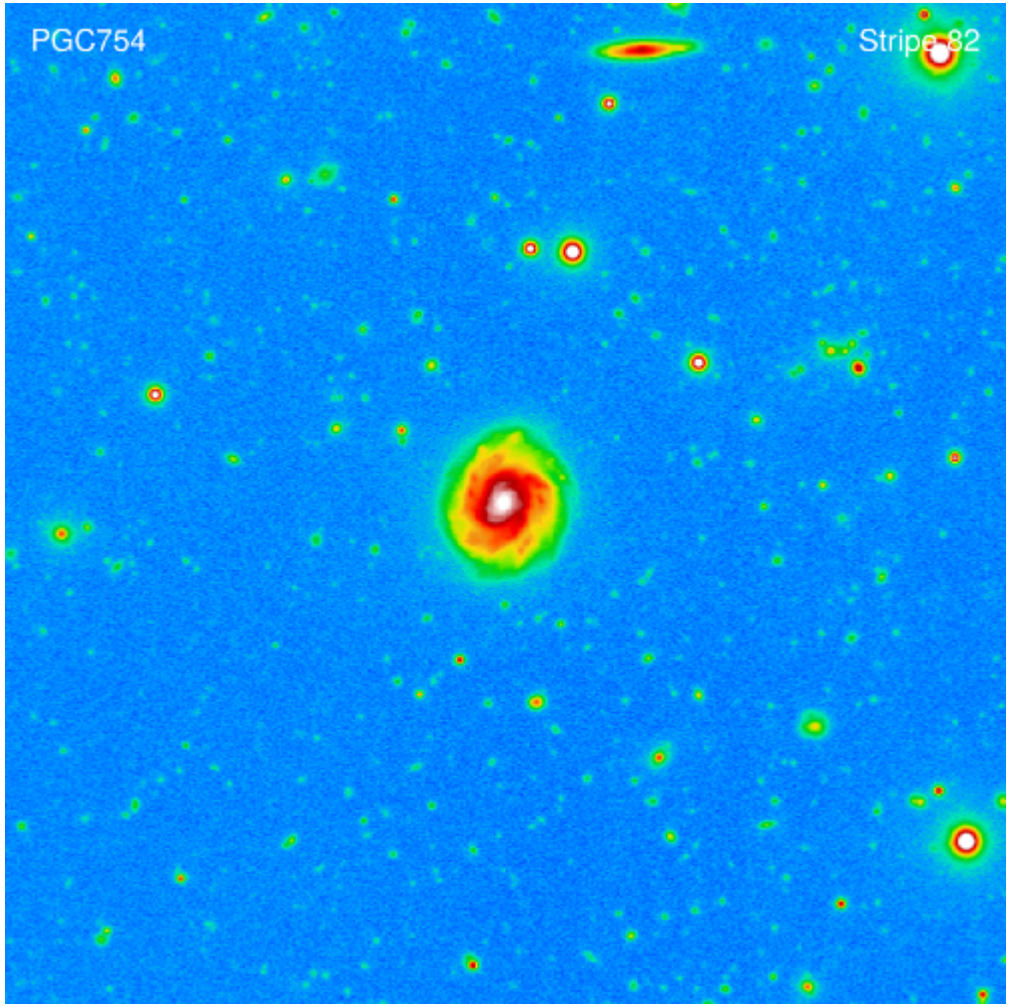
200 kpc x 200 kpc

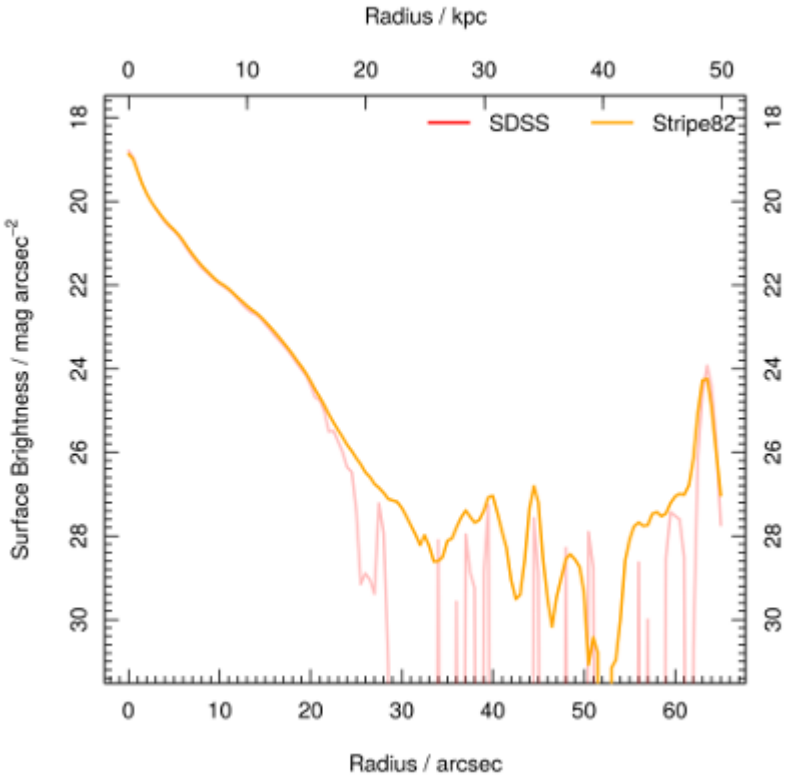




PGC 754: Results

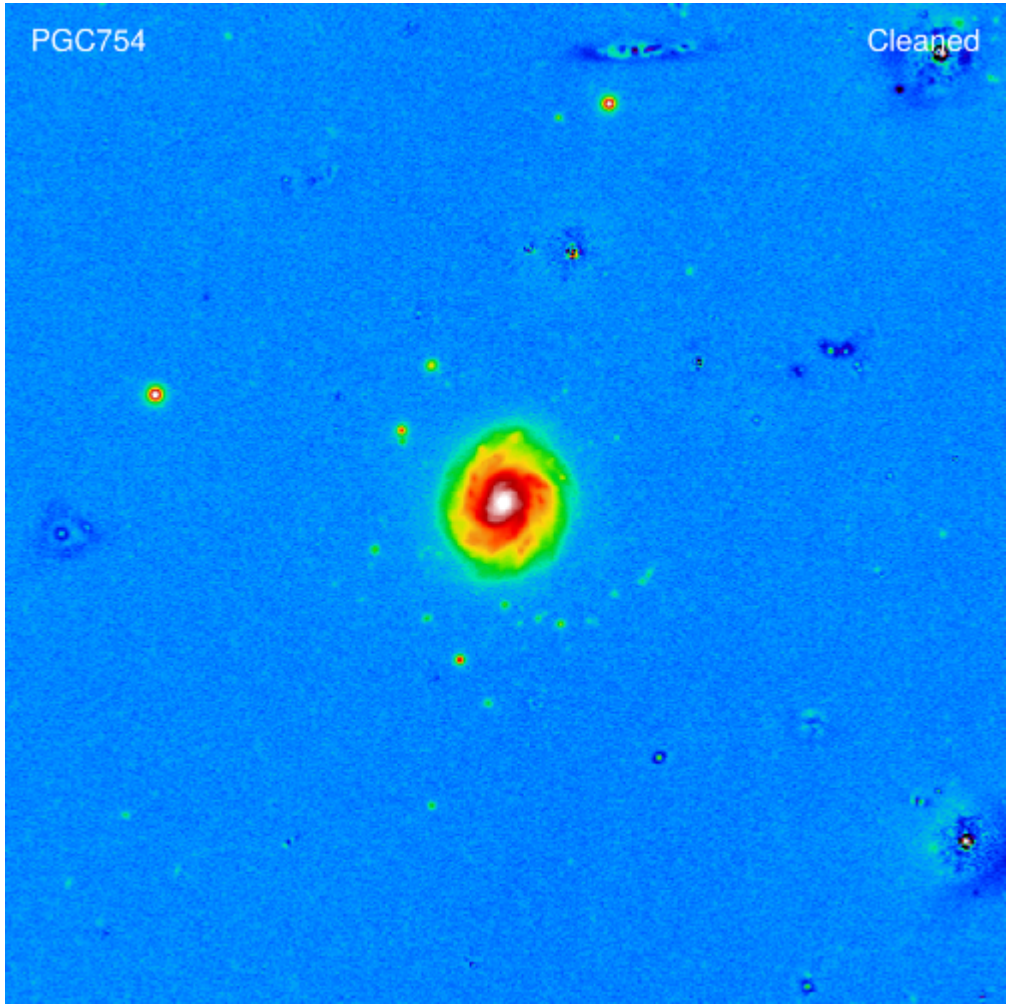
200 kpc x 200 kpc

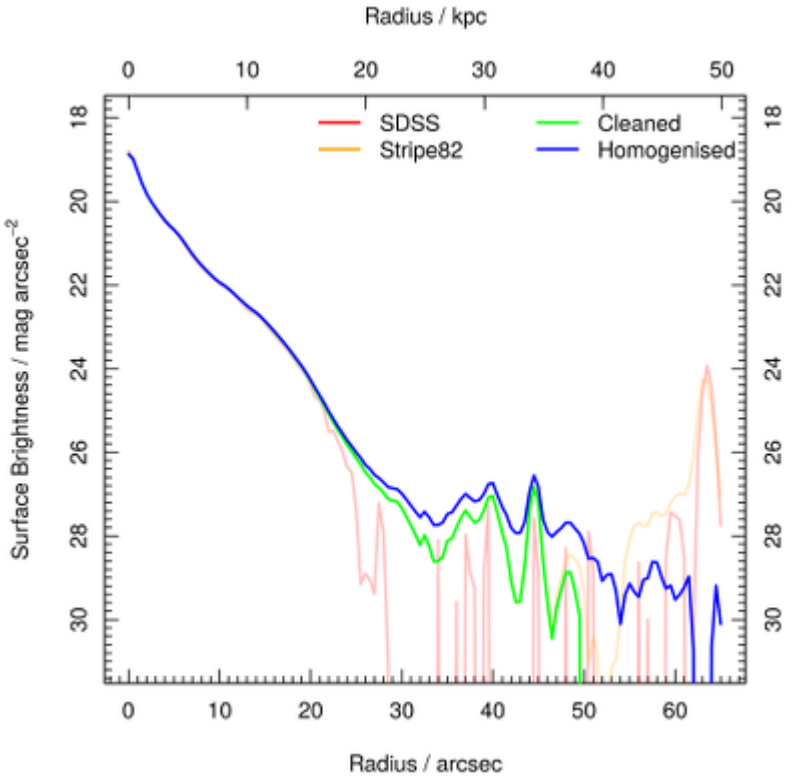




PGC 754: Results

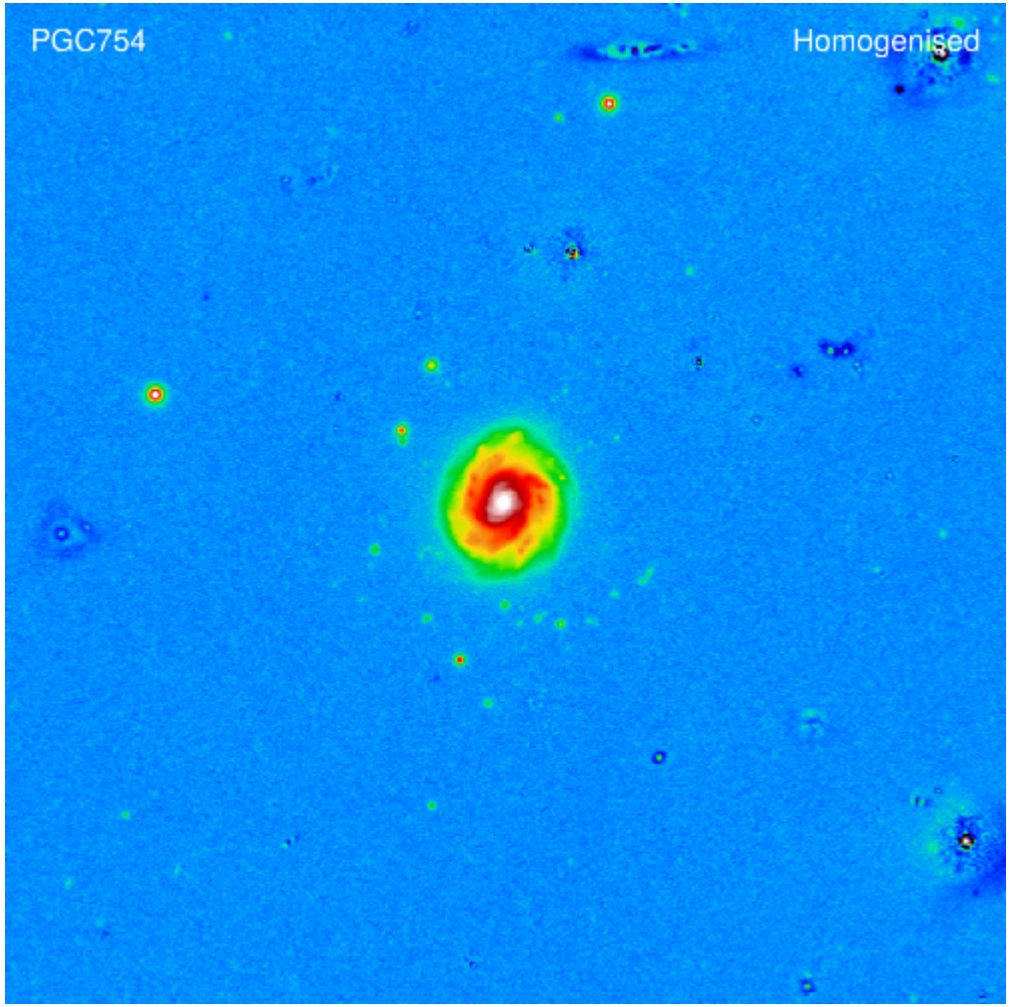
200 kpc x 200 kpc

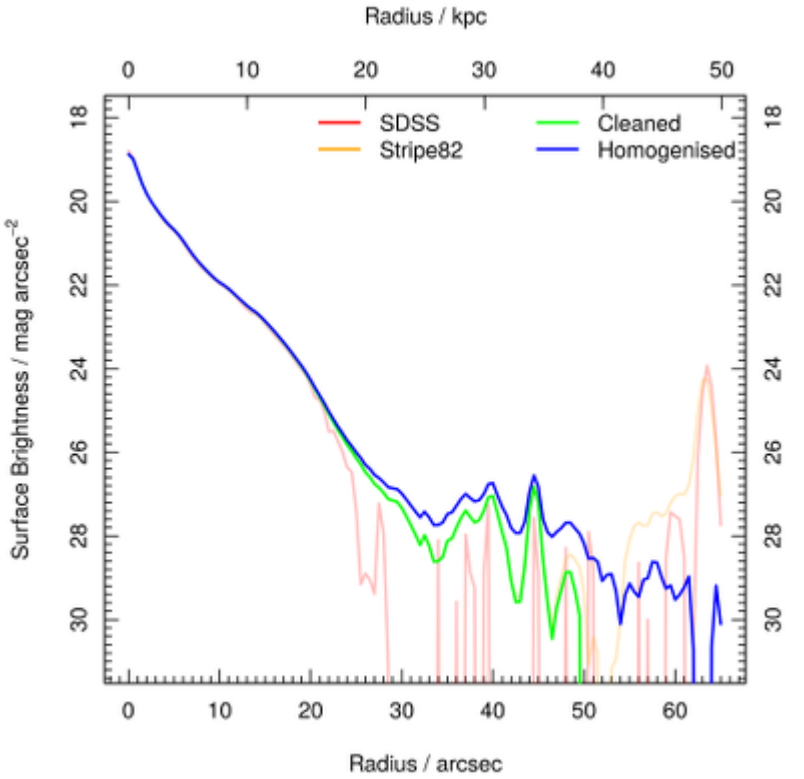




PGC 754: Results

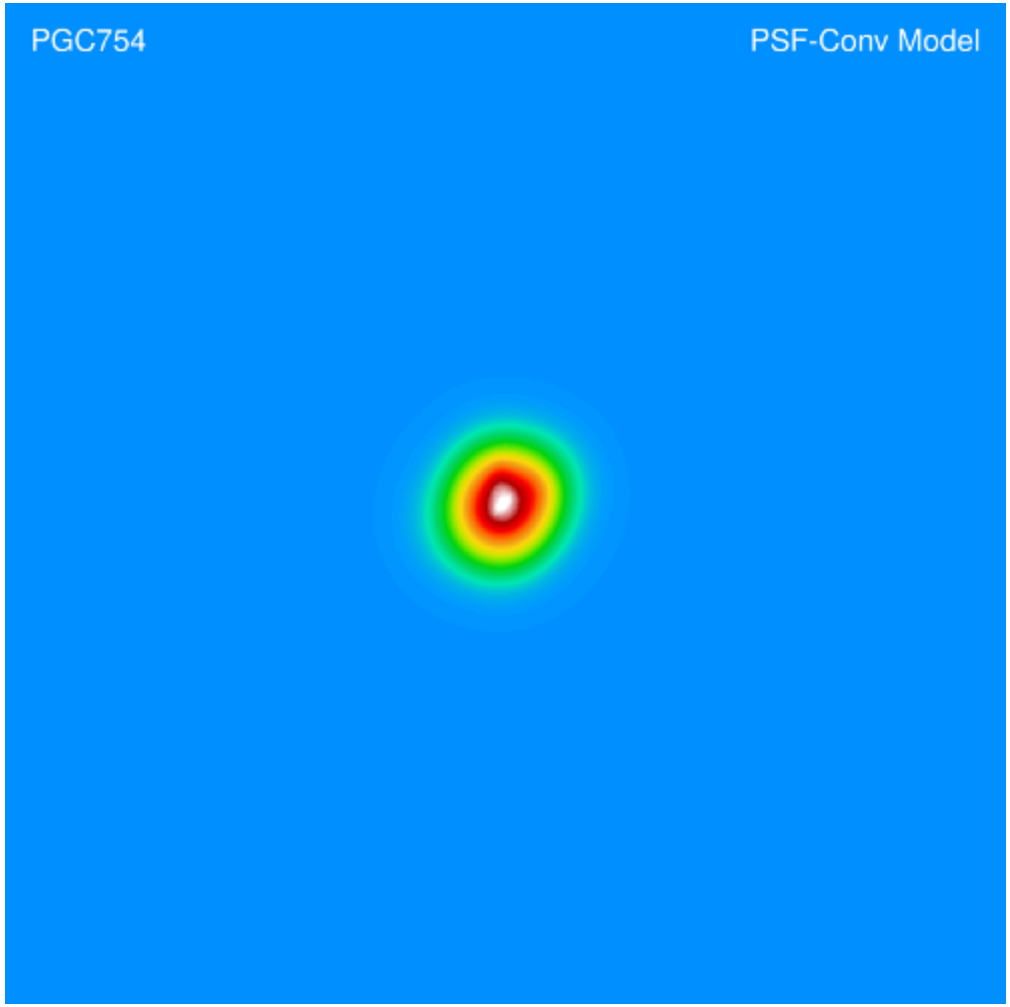
200 kpc x 200 kpc

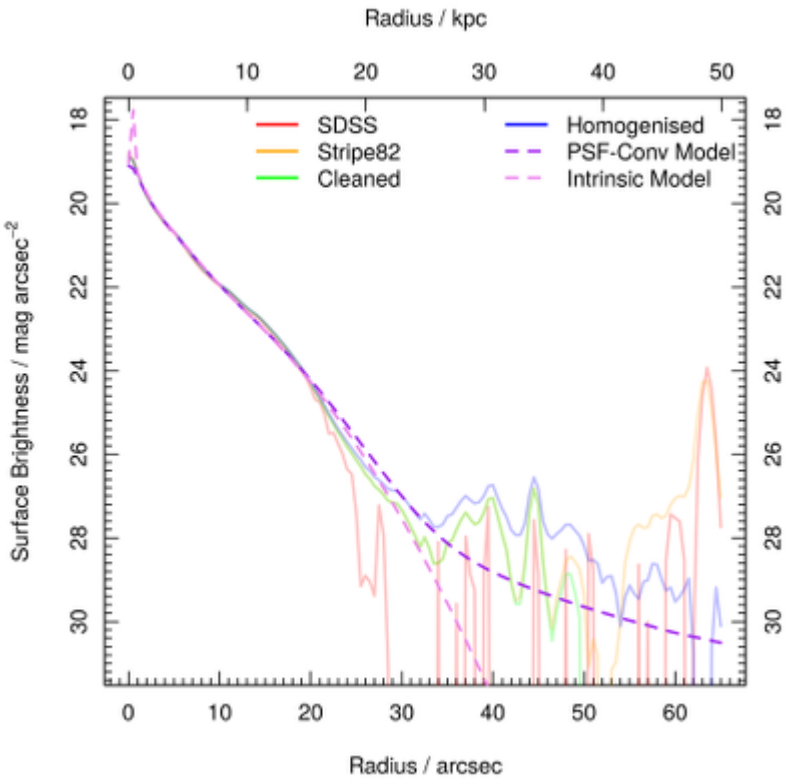




PGC 754: Results

200 kpc x 200 kpc

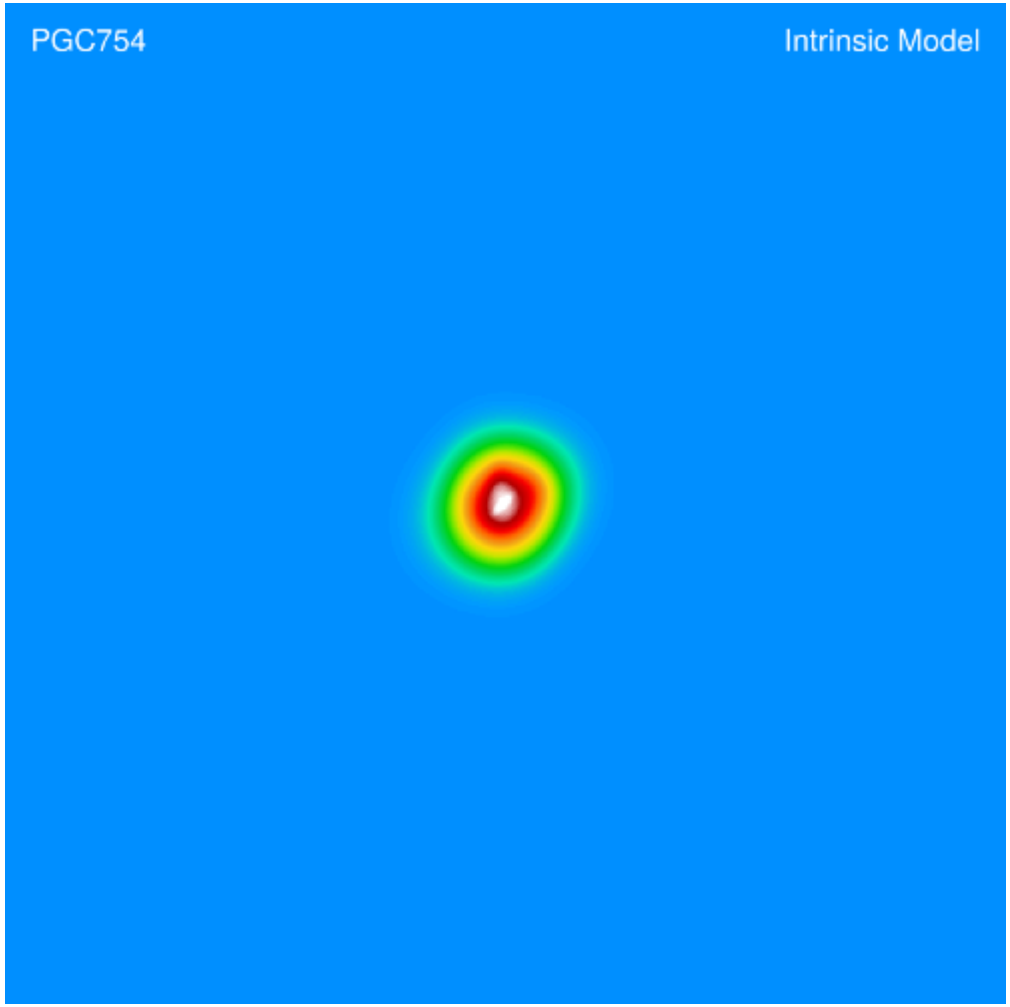


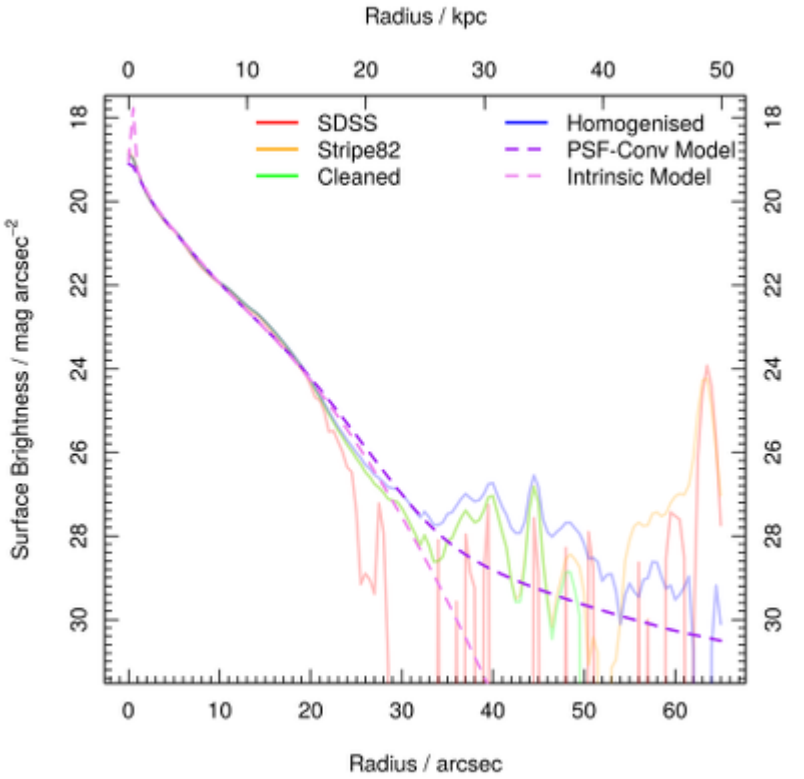


GALFIT: 9x Gaussian

PGC 754: Results

200 kpc x 200 kpc





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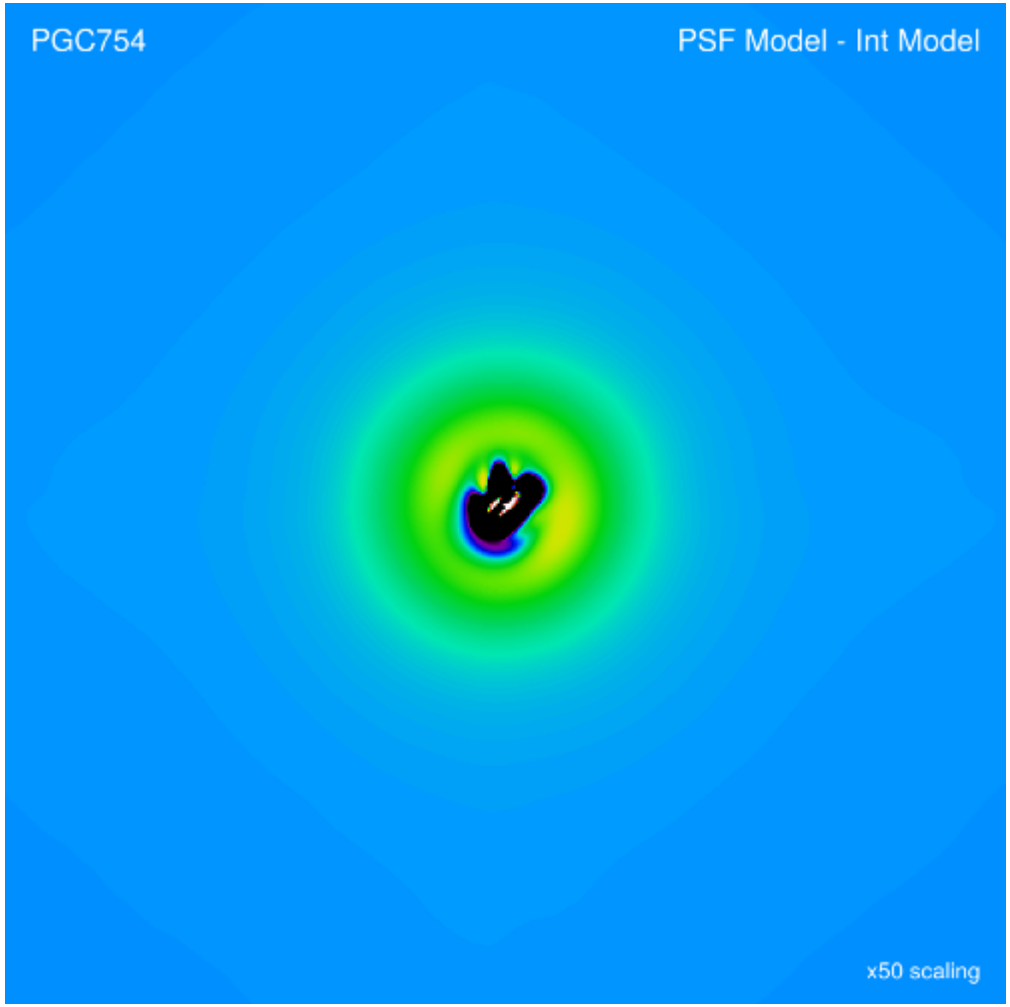
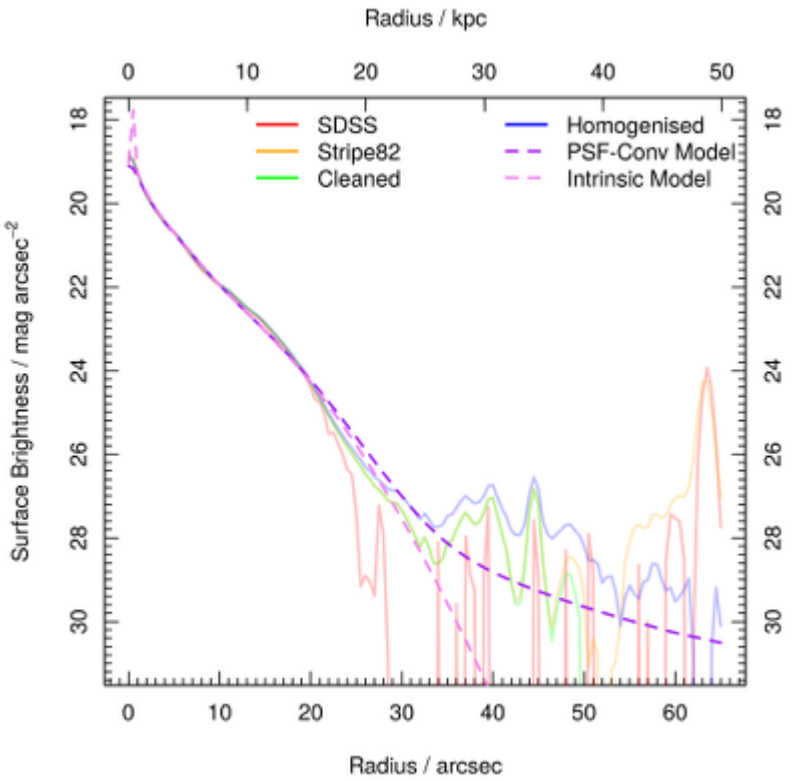
200 kpc x 200 kpc





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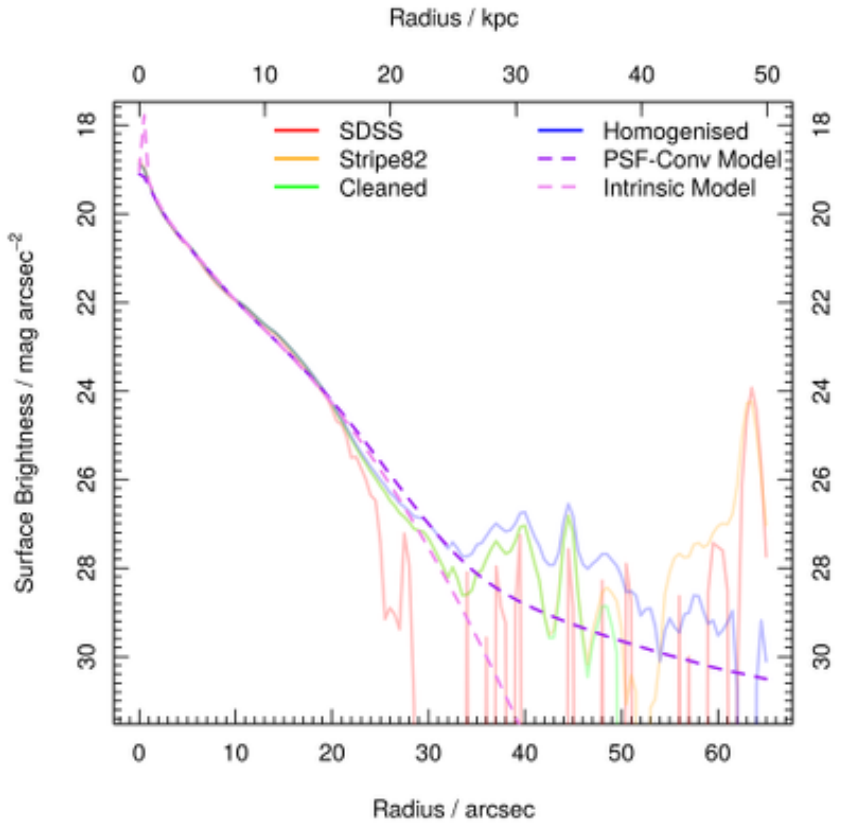
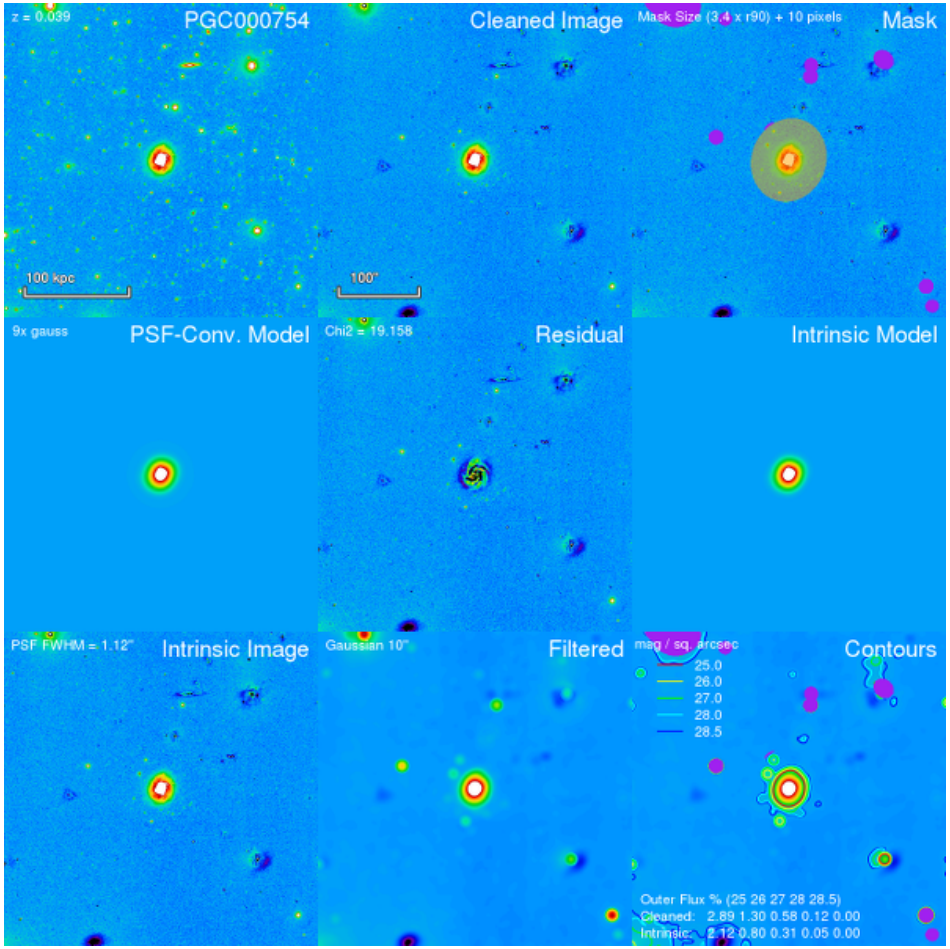
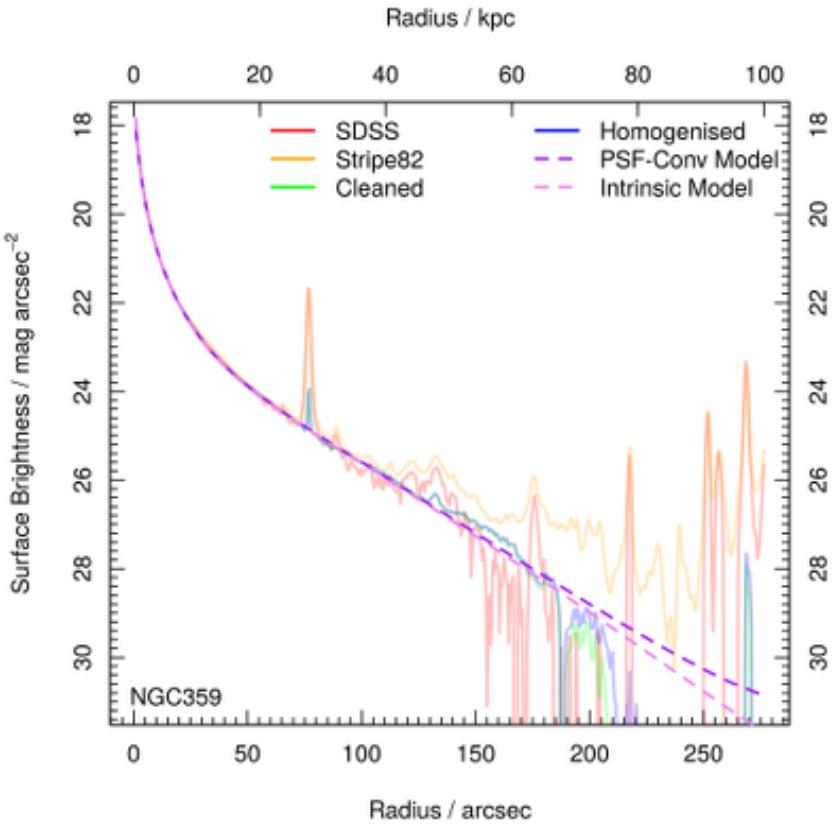


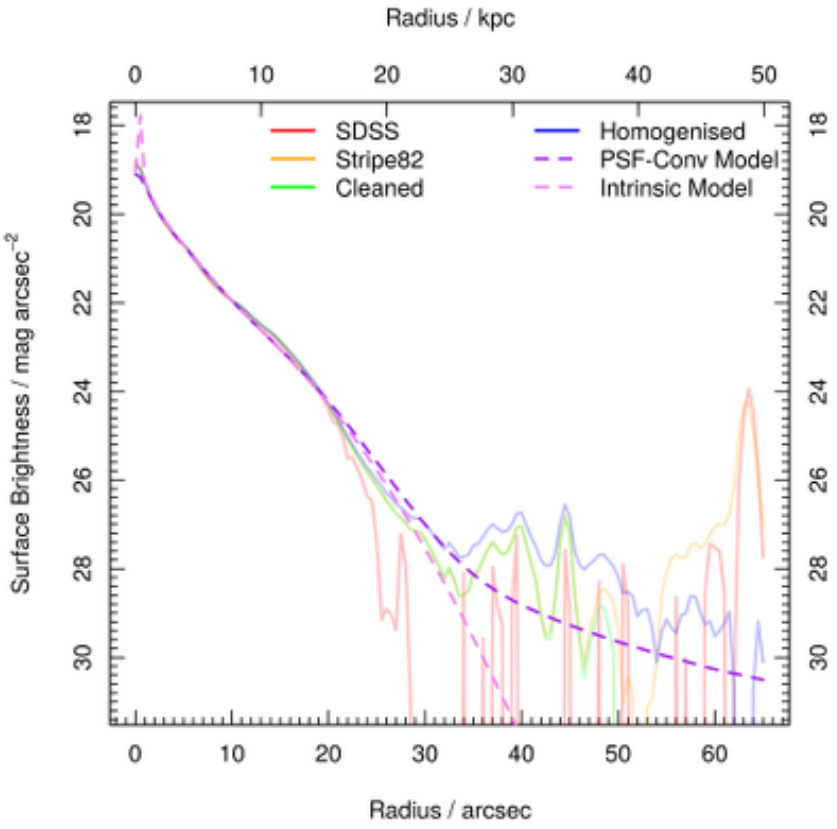


From μ=28.5 to...	μ=25	μ=26	μ=27	μ=28
PSF-Conv	2.89%	1.30%	0.58%	0.12%
Intrinsic	2.12%	0.80%	0.31%	0.05%

For late-type PGC 754, PSF accounts for x1.5/x2 increase in halo flux

Impact of the PSF





Early Type

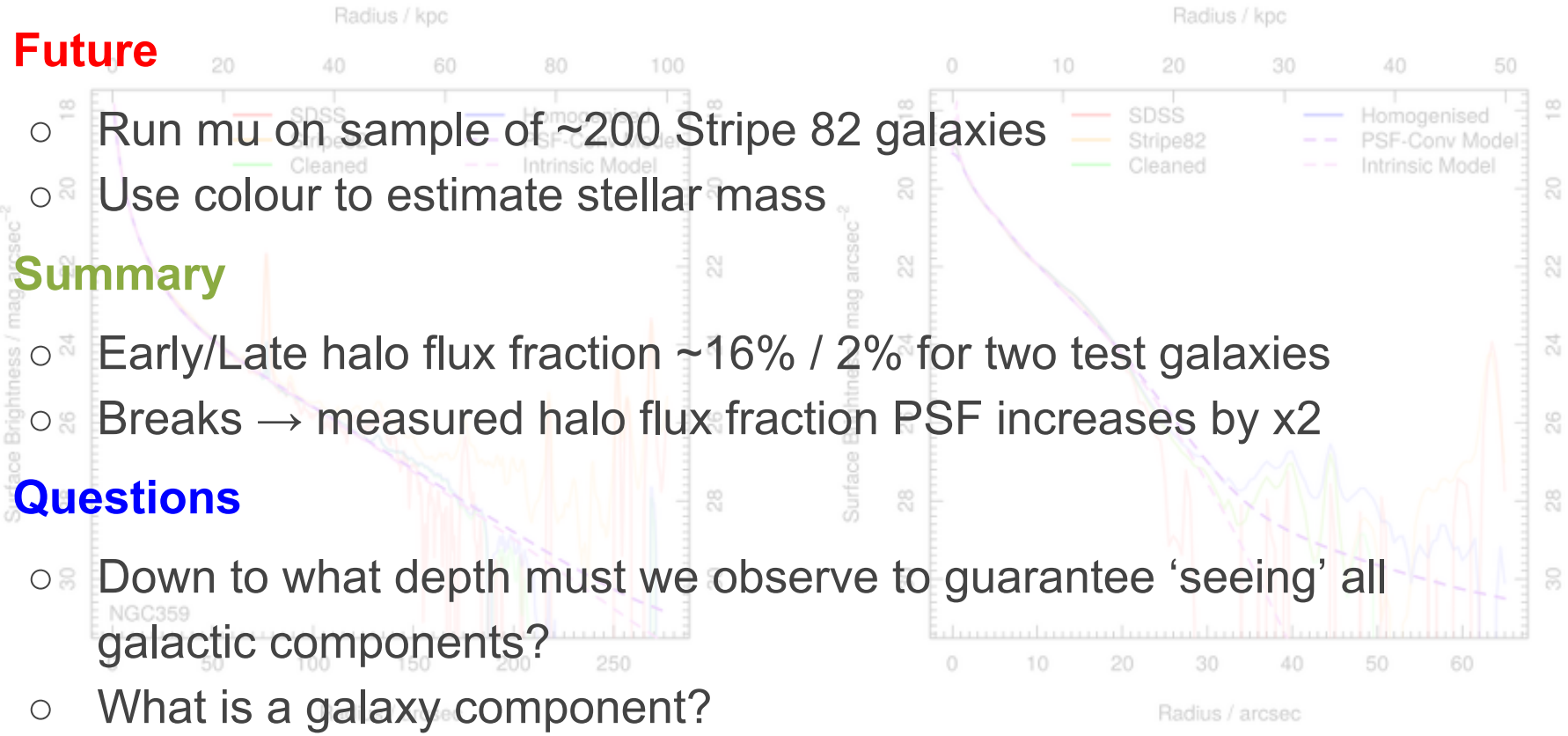
PSF flux ~0%

Breaks or truncations at large radii have substantial effects on the measured stellar halo flux fraction.

Late Type

PSF flux ~50%

Final Thoughts



Future

- Run mu on sample of ~200 Stripe 82 galaxies
- Use colour to estimate stellar mass

Summary

- Early/Late halo flux fraction ~16% / 2% for two test galaxies
- Breaks → measured halo flux fraction PSF increases by x2

Questions

- Down to what depth must we observe to guarantee ‘seeing’ all galactic components?
- What is a galaxy component?
- Do single component galaxies exist?