Virgo WISESize: Investigating Environmental Processes of Galaxies in the Virgo Cluster

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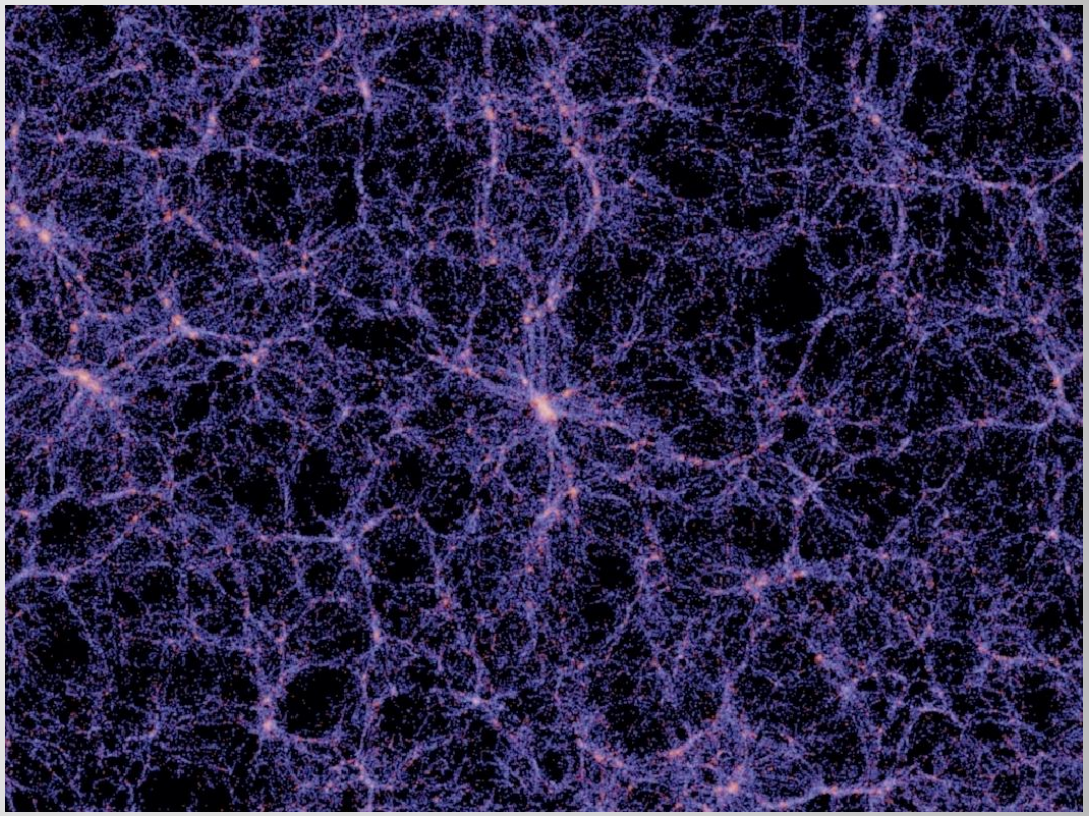
with Gregory Rudnick (KU) and Rose Finn (Siena College)

KU PALOOZA
March 2023

The universe is not homogeneous…

A patchwork of cosmic architecture:

- fields
- filaments
- groups
- clusters
- etc.



V.Springel, Max-Planck Institut für Astrophysik, Garching bei München

…nor is it static!

Low Density (Field)

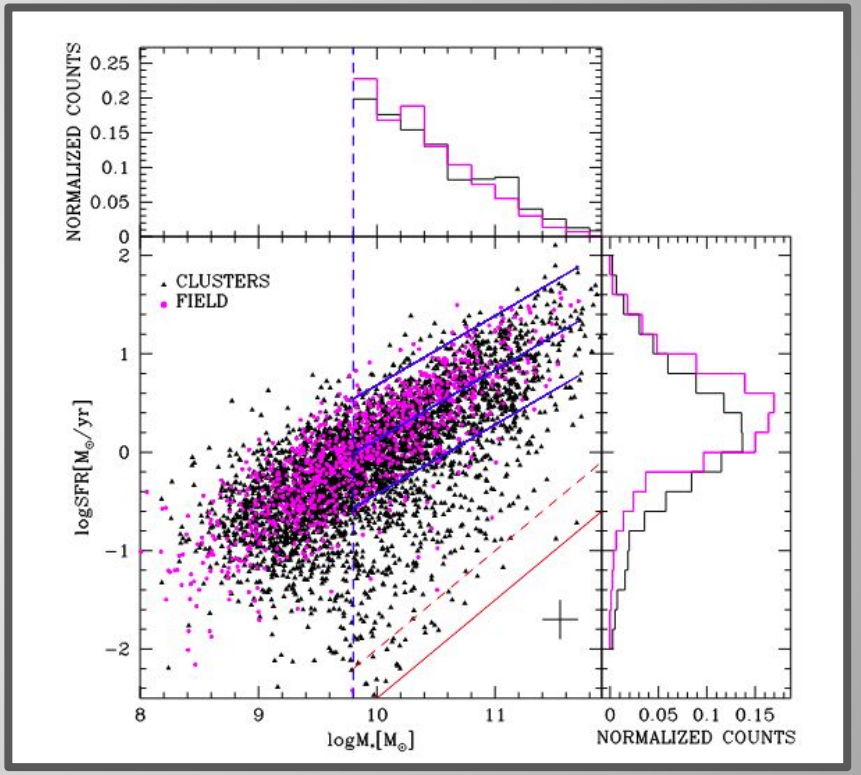
Filaments!

High Density (Cluster)

Images from legacysurvey.org/viewer

Cluster vs. Field

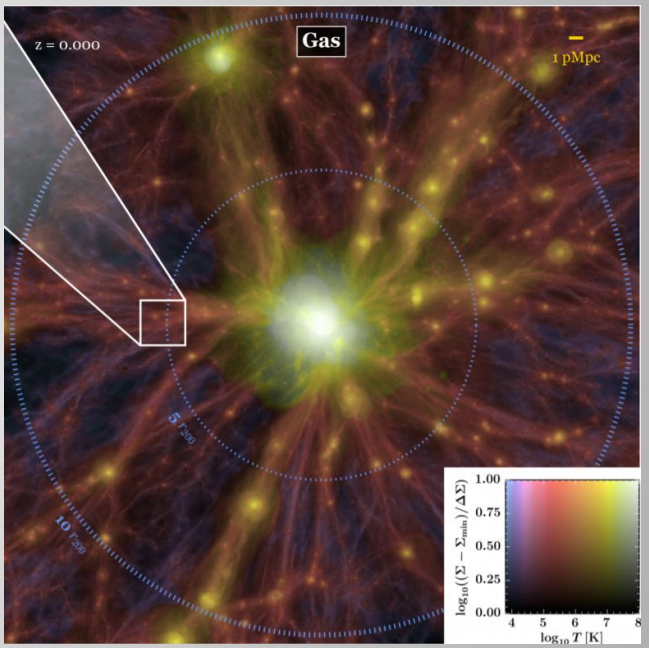
- Galaxy environments affect a galaxy's ability to form stars
- **Cluster galaxies:**
  - lower star formation rates (e.g., Balogh+1998)
  - smaller star-forming disks (e.g., Finn+2018)
  - lower gas contents (e.g., Boselli+2014)
  - earlier-type morphologies (e.g., Dressler+1980)



Paccagnella+16

Filaments: what are they, and what do they want?

- Simplest way to measure galaxy quenching: field vs. cluster and cluster-centric radius.
- But filaments are nontrivial environments that can affect how efficiently a galaxy forms stars!
- We have to include a full range of environments to understand how galaxies evolve. (e.g., Bahé+2012)

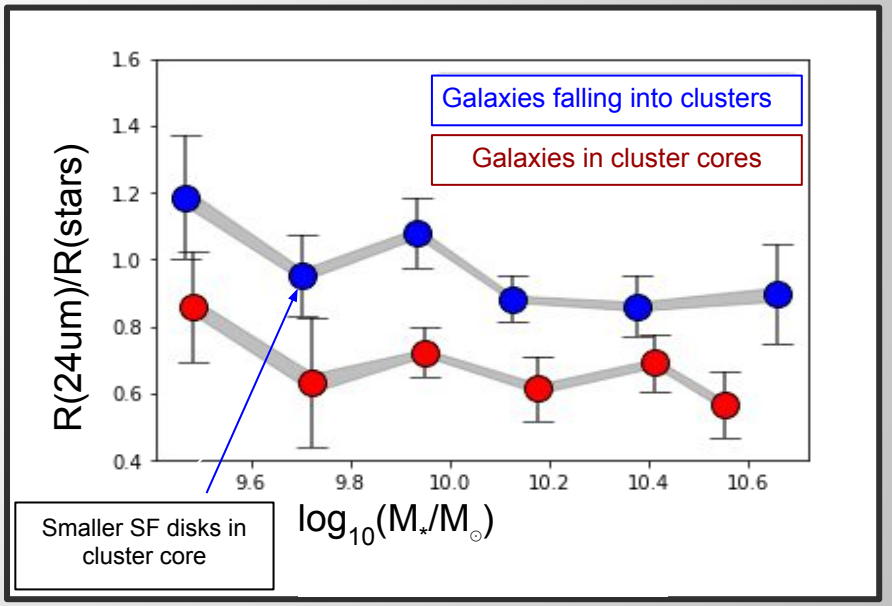


Bahé et al. (2017)

Current objectives:

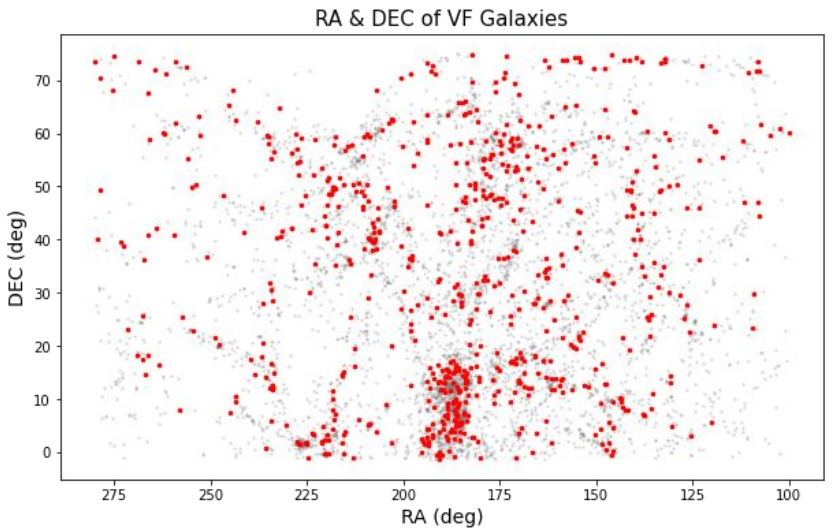
Abell 2670 Cluster; Sheen et al. (2017)

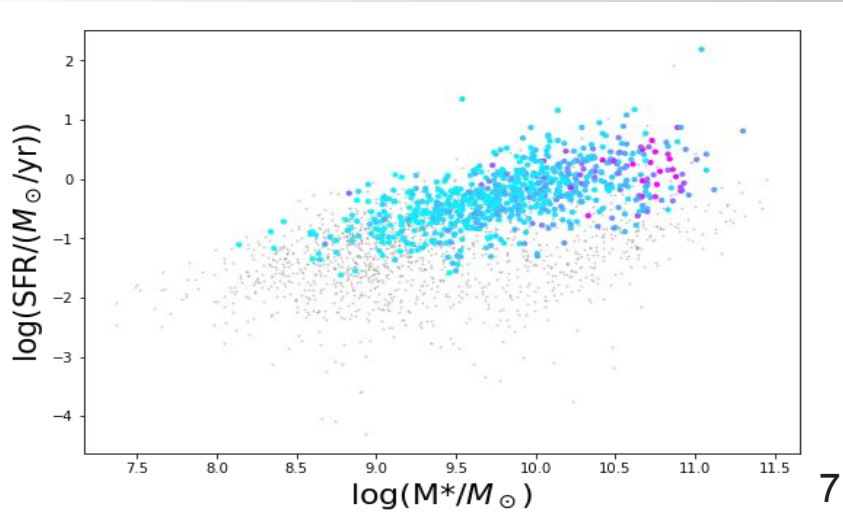
1. Directly observe and compare dust (12-micron) disk to stellar (optical) disk of galaxies
2. Calculate size ratios in order to determine the first sites of environmental quenching, as well as what mechanisms are dominant where (Finn et al. 2018)



Virgo Subsample Selection

- VF sample of 6780 galaxies cut according to 12μm SNR > 10 and late-type morphology to control for trends between disk size, SFR and B/T (Finn+2018)
- 702 galaxies remaining, compare with 224 from Finn+2018
- Most lie along the main sequence





The Modeling Tool

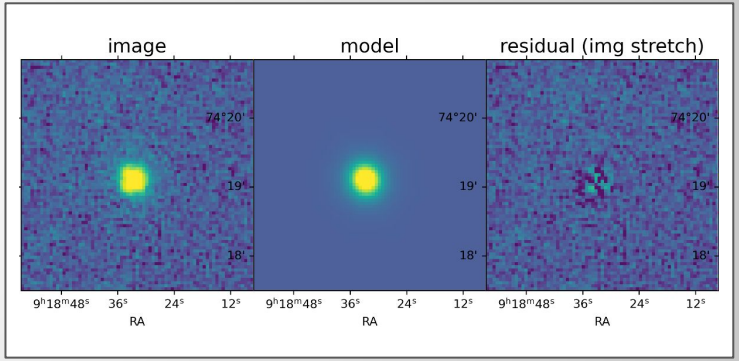
Input image
(2D postage stamp of galaxy)

Sigma/noise image, object mask, bad pixel mask, PSF image

Input parameters
(central x pixel, central y pixel, effective radius, Sersic index, axis ratio (BA), position angle (PA), magnitude)

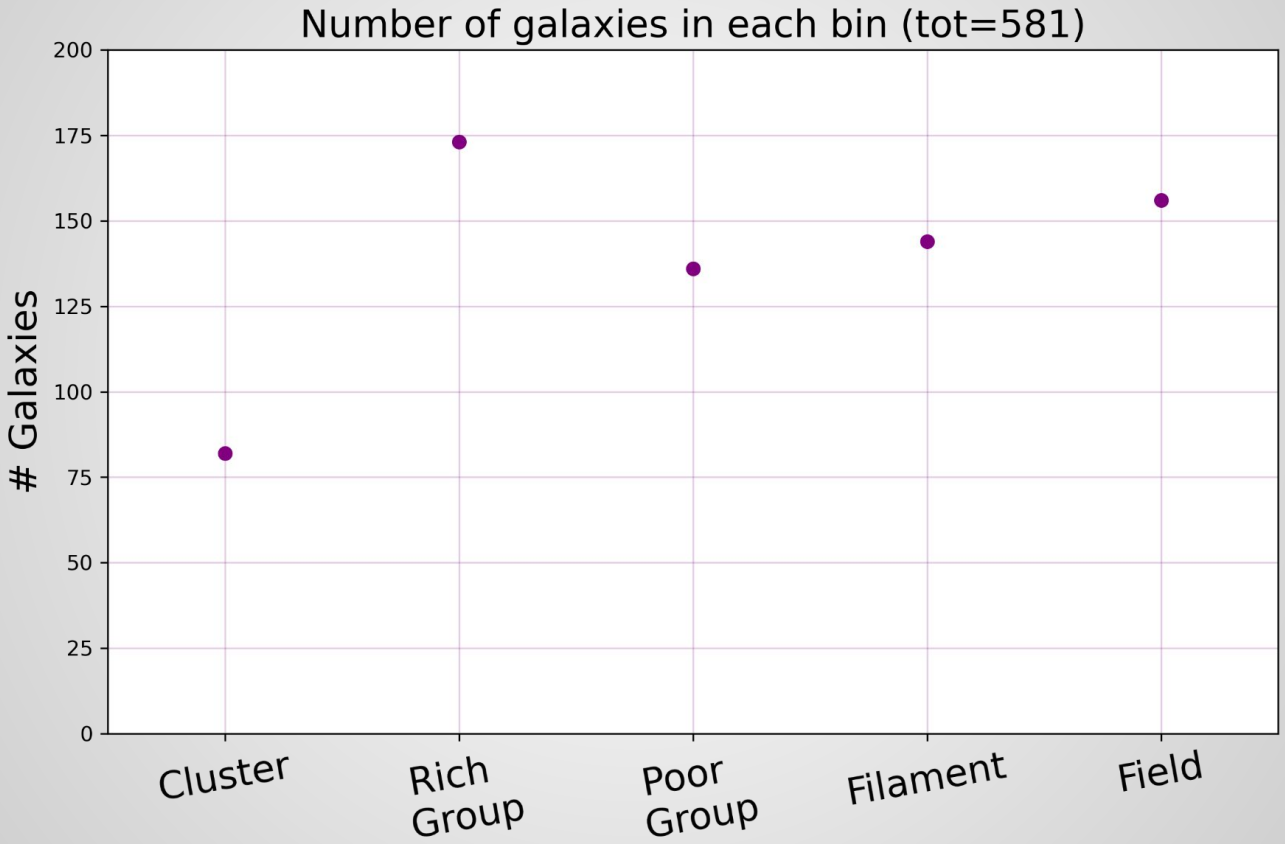
GALFIT

Best-fit parameters with errors, chi-squared

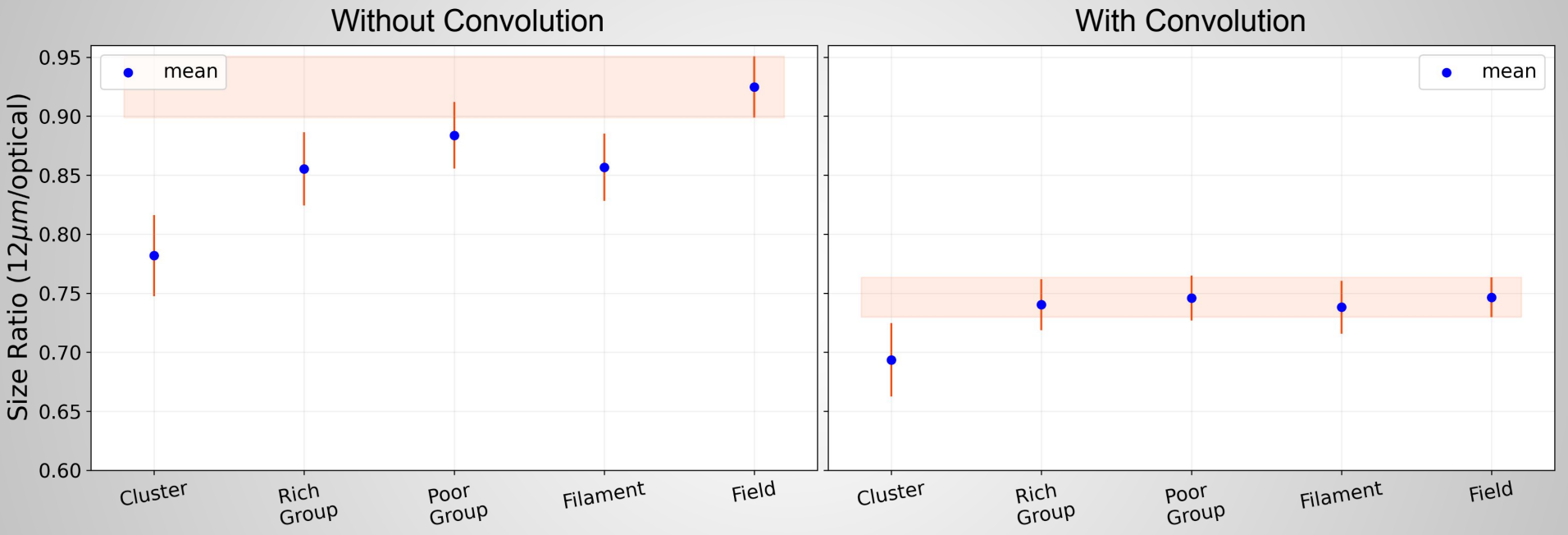


Output mosaic (input image, model, residual)

Data Analysis: Number of Galaxies per Environment

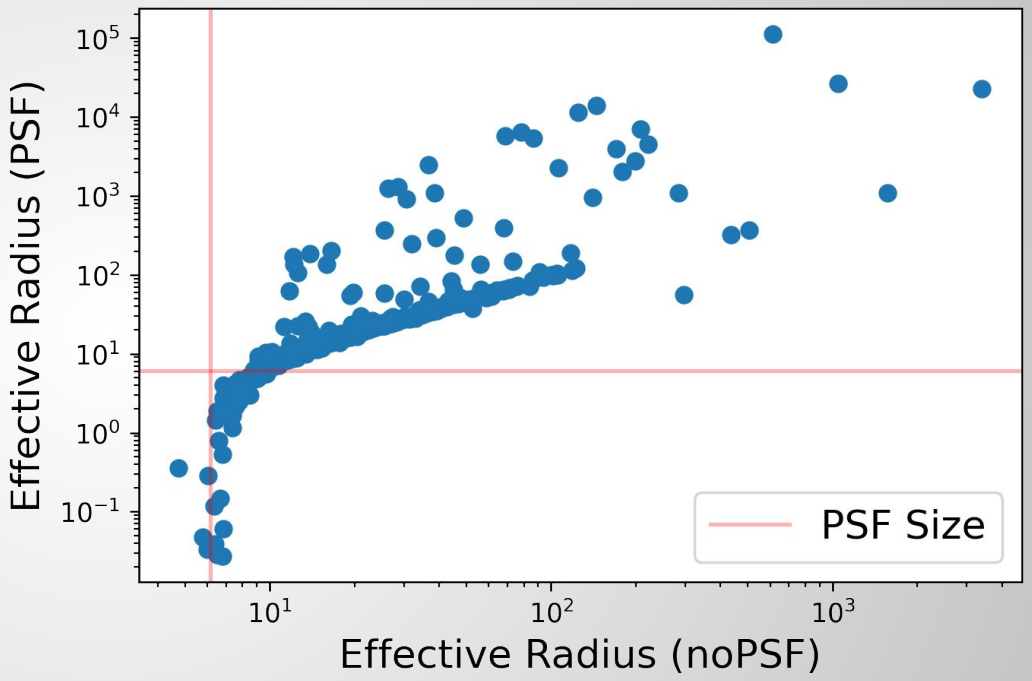


Mean Size Ratio vs. Environment

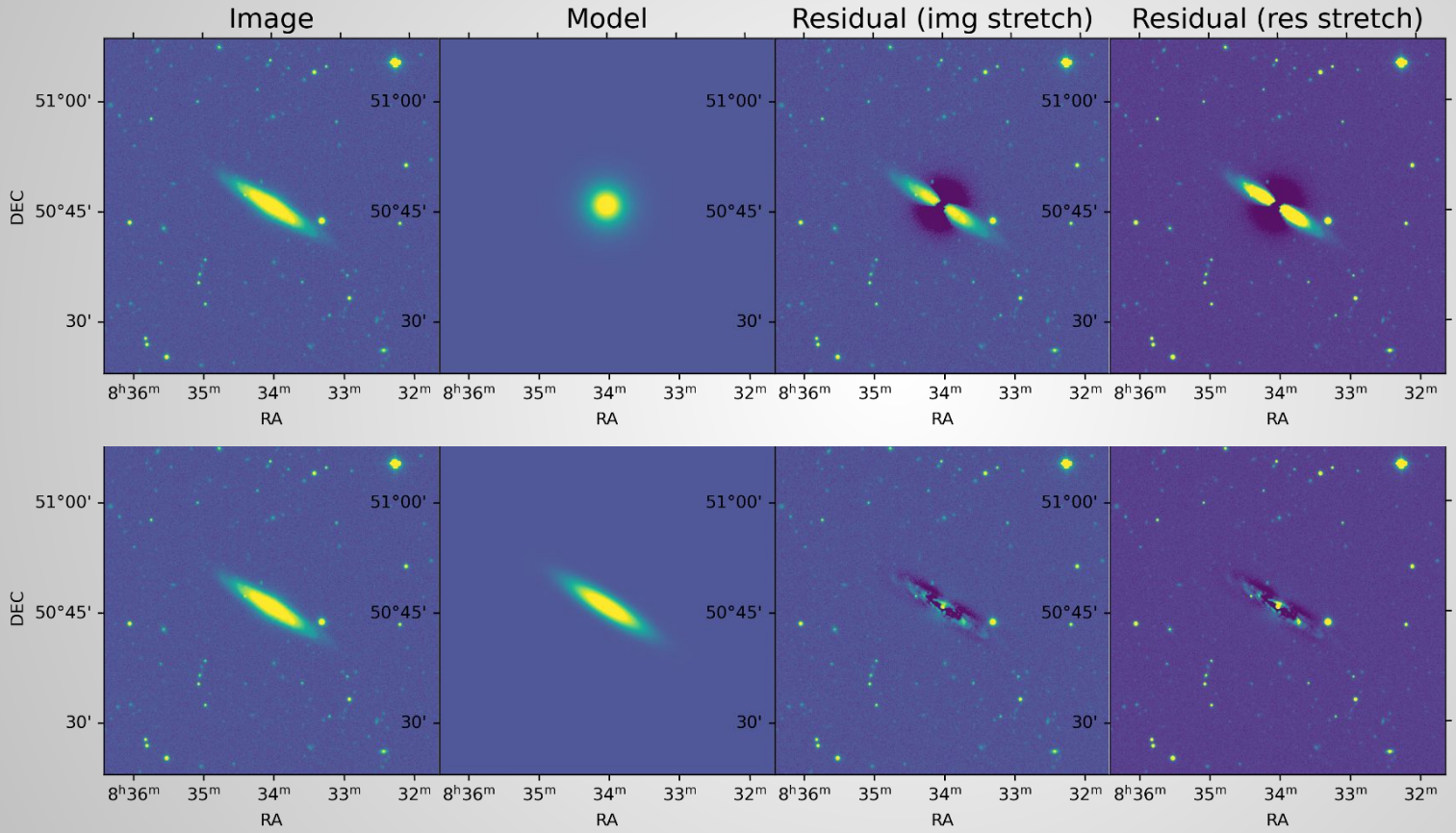


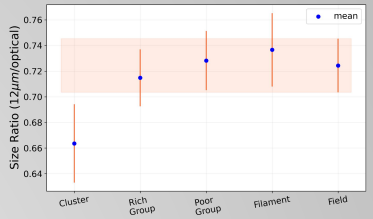
Why the discrepancy?

- Like all telescopes, WISE is not immune to distortion effects
- The PSF is a model of how the point source looks due to these effects
- With convolution, small galaxies become even smaller!



And there is the occasional “oops” galaxy.

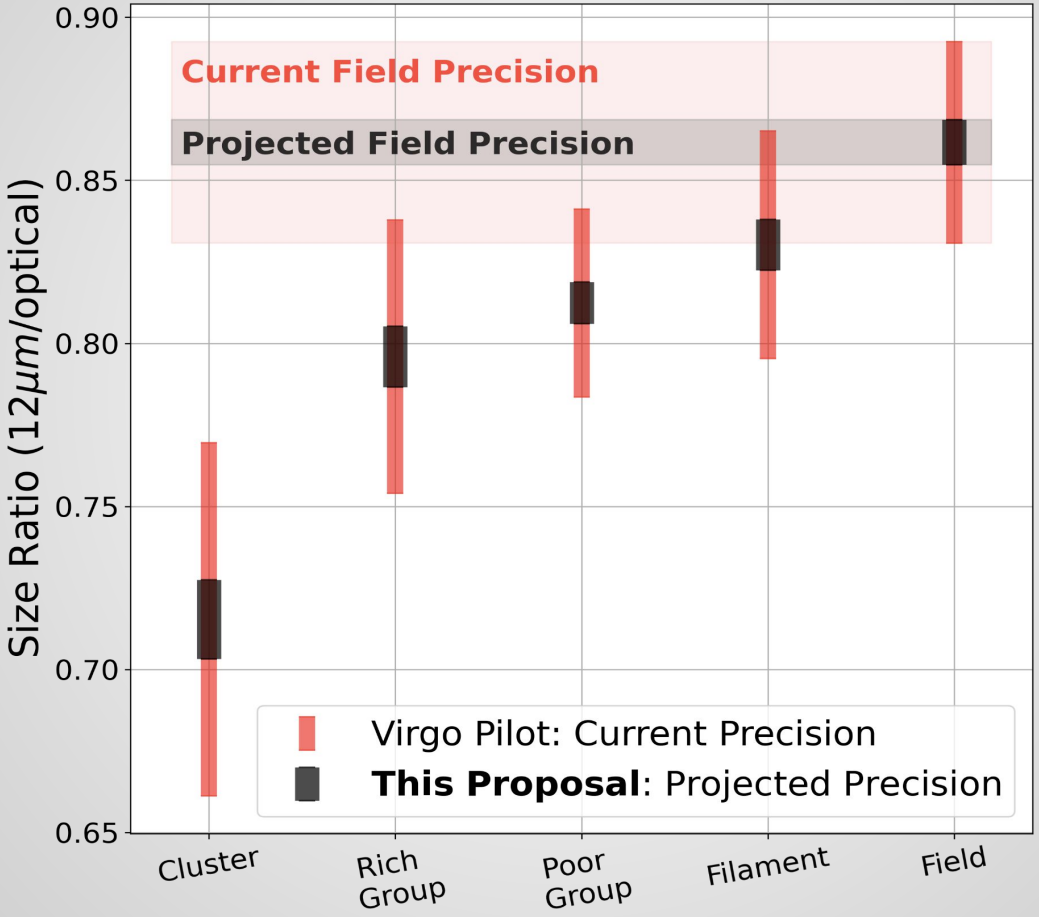




no conv
Re=29.28

conv
Re=65.19

But there is a positive… (no conv, non-parametric optical photometry)



Conger+2022 in Prep

Summary:

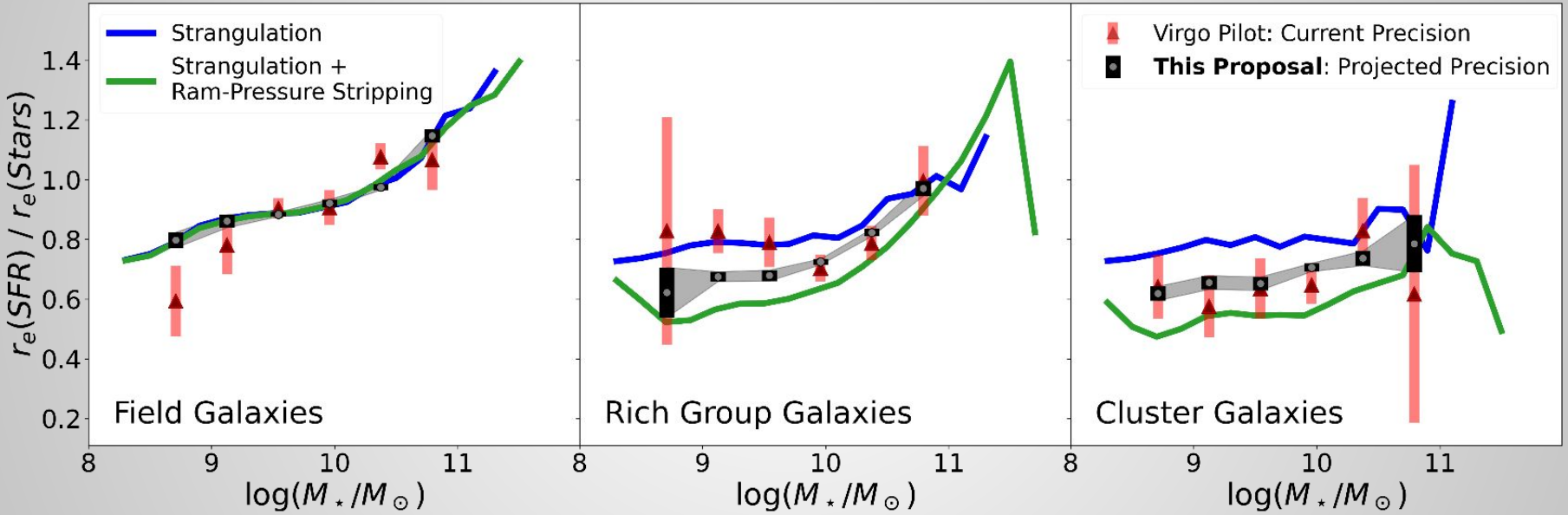
- **Aims:** Directly observe spatial extent of gas and stellar disks of galaxies in the Virgo cluster, namely those in filaments, and compare results to galaxies nearer to the cluster center and in the field

- **Current work:** Used GALFIT to generate 2D models of dust emission in SNR>10, late-type subsample; calculated preliminary size ratios between 12-micron and r-band effective radii

- **Preliminary Results**: Disk size appears to decrease toward denser environments, field-cluster trend relatively robust against different r-band measurement techniques

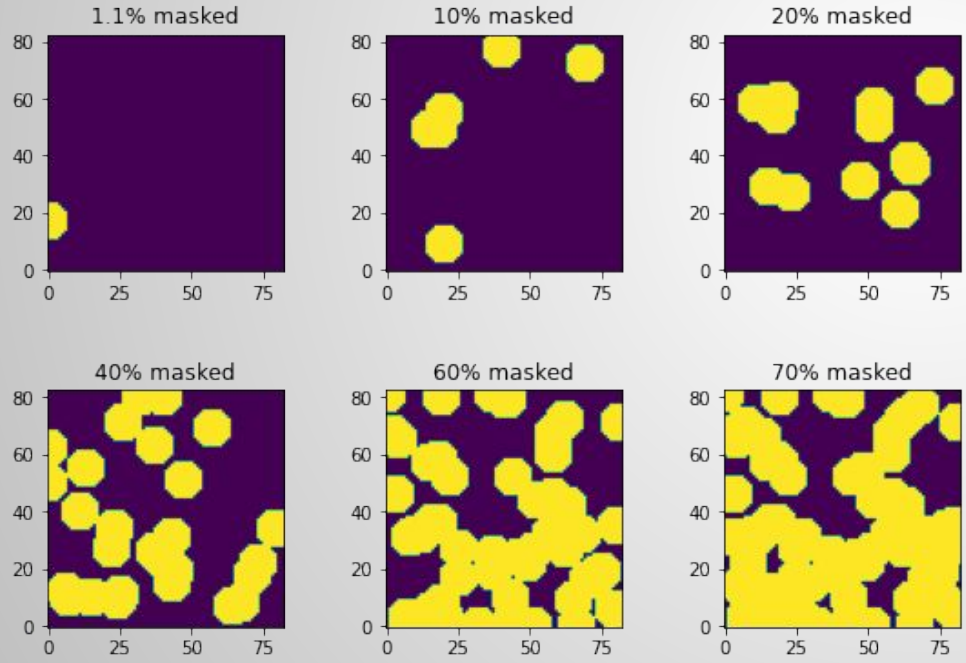
- **Next steps:** Further investigate discrepancies, implement masking

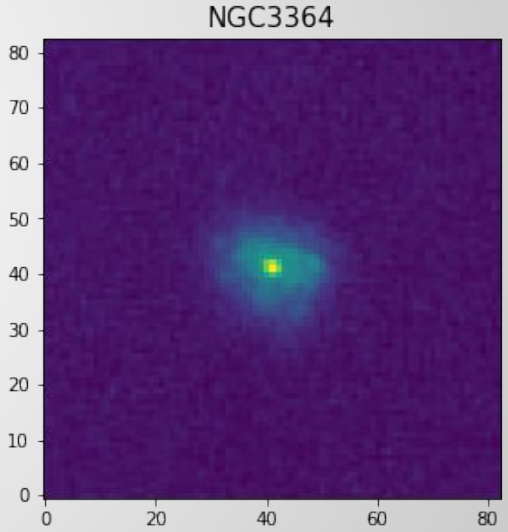
Environment Model Predictions (Xie+2020)



Masking Analysis (all px)

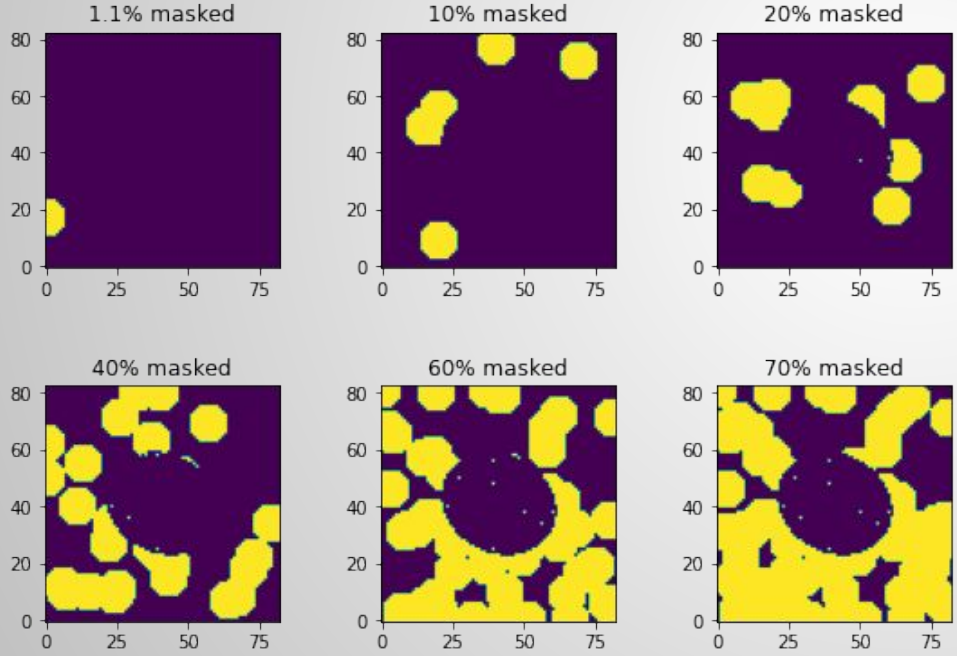
- Testing galfit's sensitivity to the number of unmasked background pixels in a galaxy cutout image

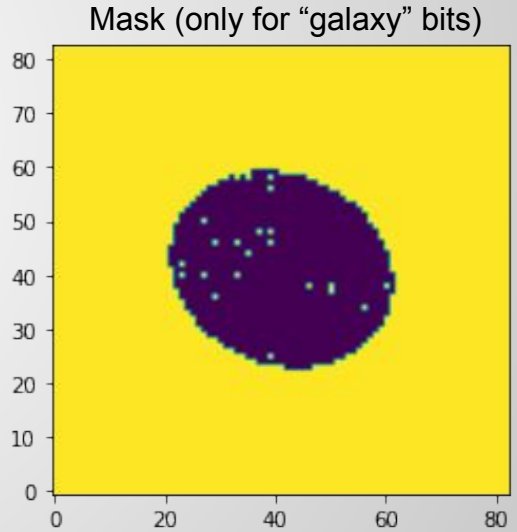




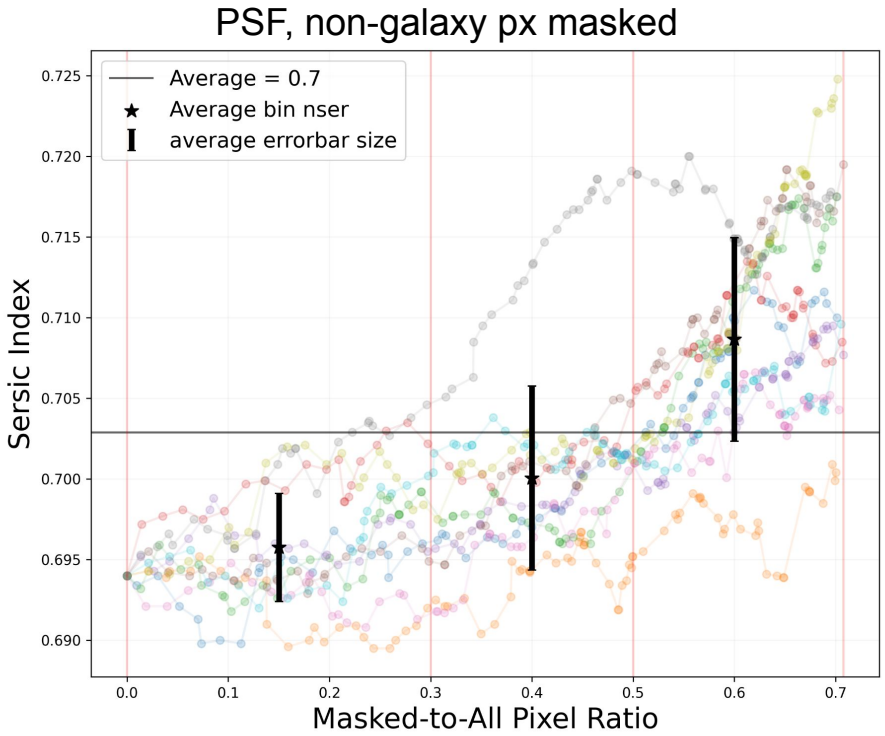
Masking Analysis (non-galaxy px)

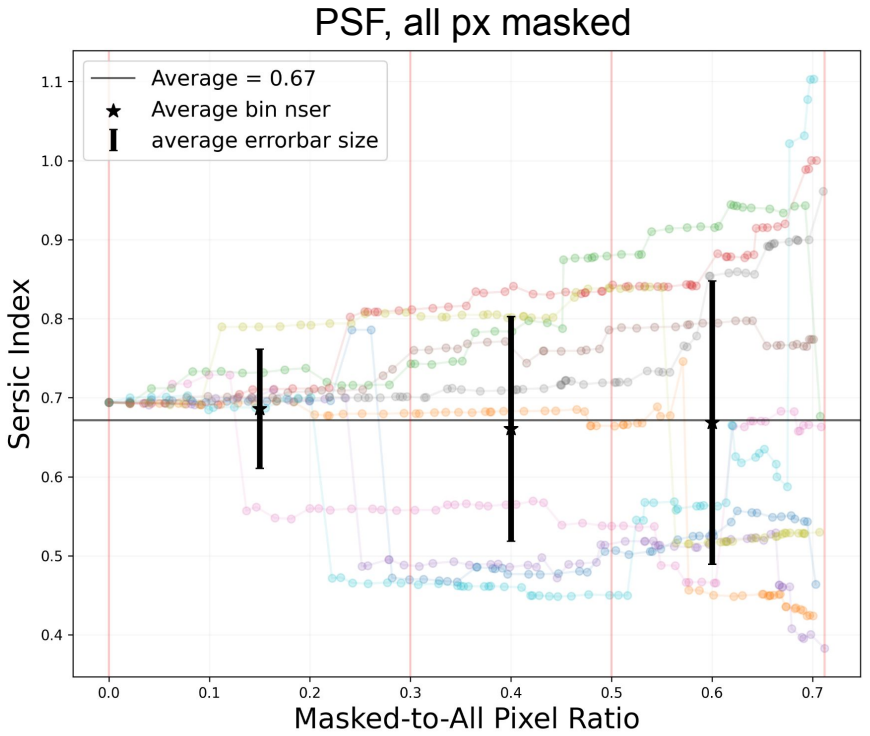
- Testing galfit's sensitivity to the number of unmasked background pixels in a galaxy cutout image



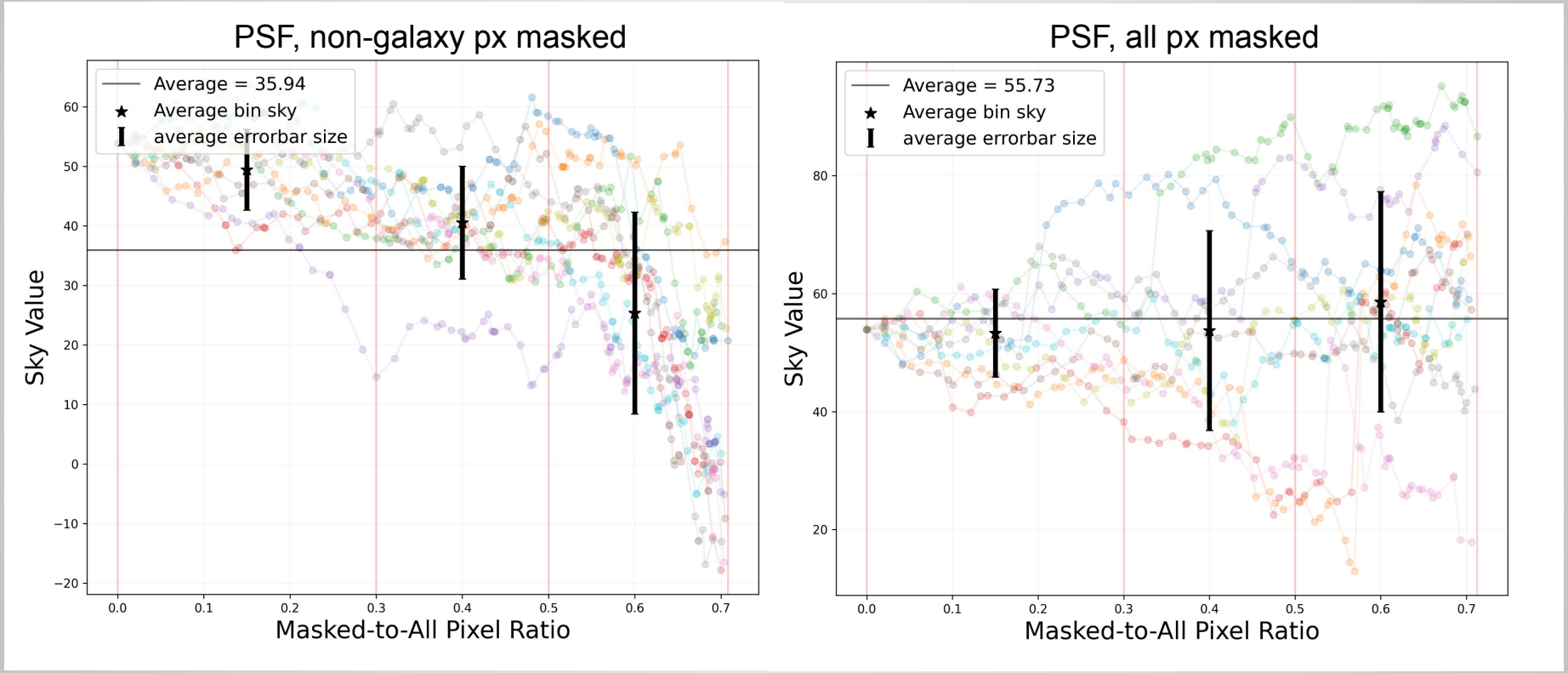


Example: Sersic Index





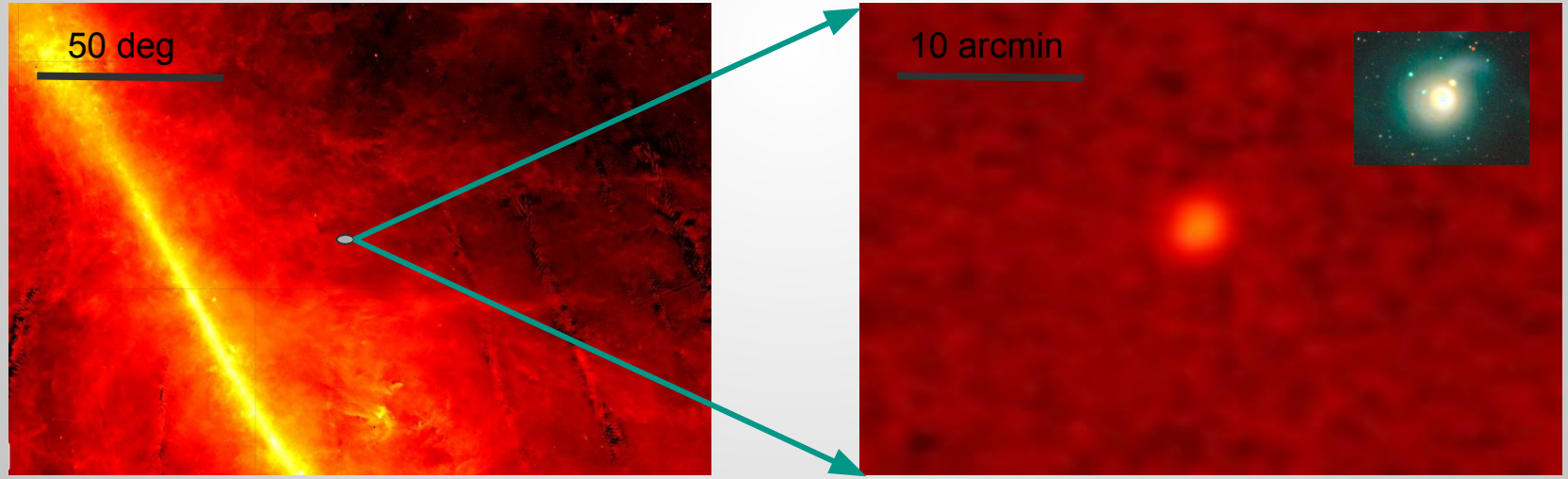
Example: Sky


PSF, non-galaxy px masked
Average = 35.94
Average bin sky
average errorbar size
Sky Value
Masked-to-All Pixel Ratio
PSF, all px masked
Average = 55.73
Average bin sky
average errorbar size
Sky Value
Masked-to-All Pixel Ratio

The Dust.

(1 deg = 60 arcminutes)
WISE resolution = 6 arcsec

-WISE 12μm channel reveals obscured star formation
-Helpful for determining quenching of infalling galaxies into Virgo cluster
-GALFIT as modeling tool



(Legacy Survey Viewer - 12 micron map)

NGC5614

Silly Side Project…

- Sonification of 2D galaxy cutouts
- Draw horizontal rectangle that encloses galaxy; create array of the average value of every vertical strip of pixels within this rectangle
- Assign midi note to every array element. And tah-dah.

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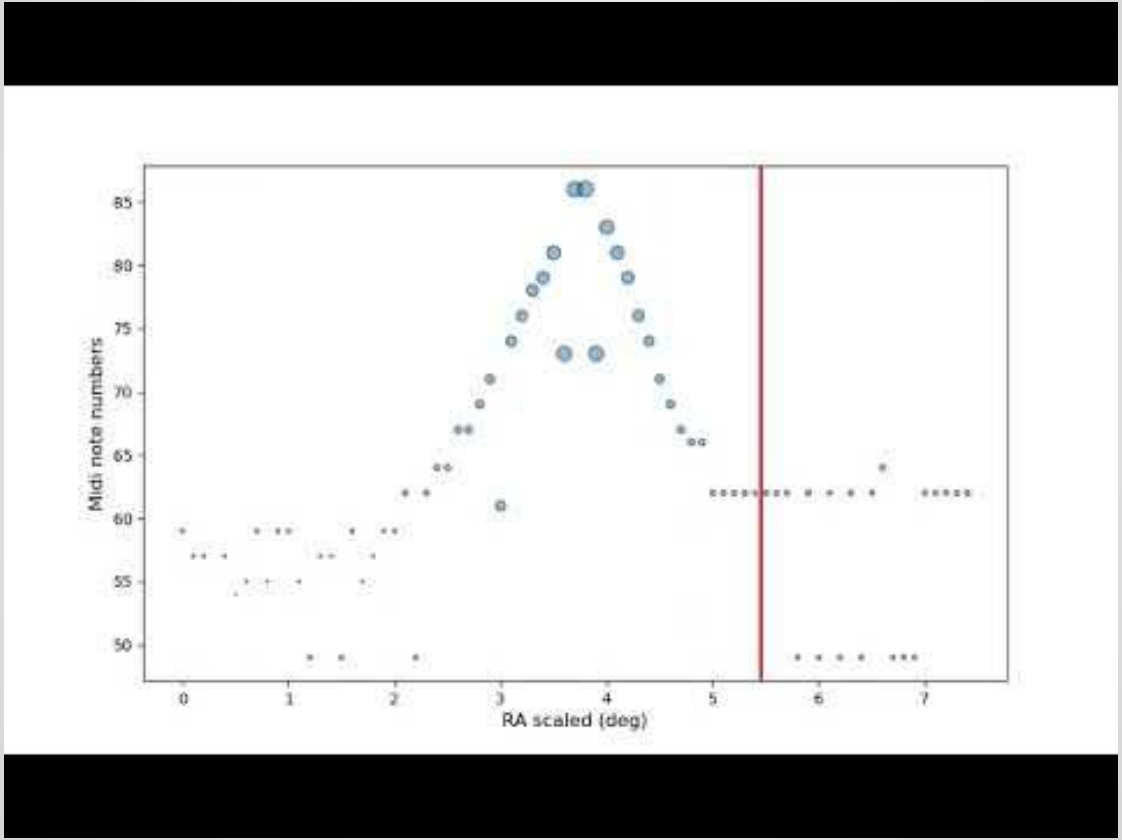
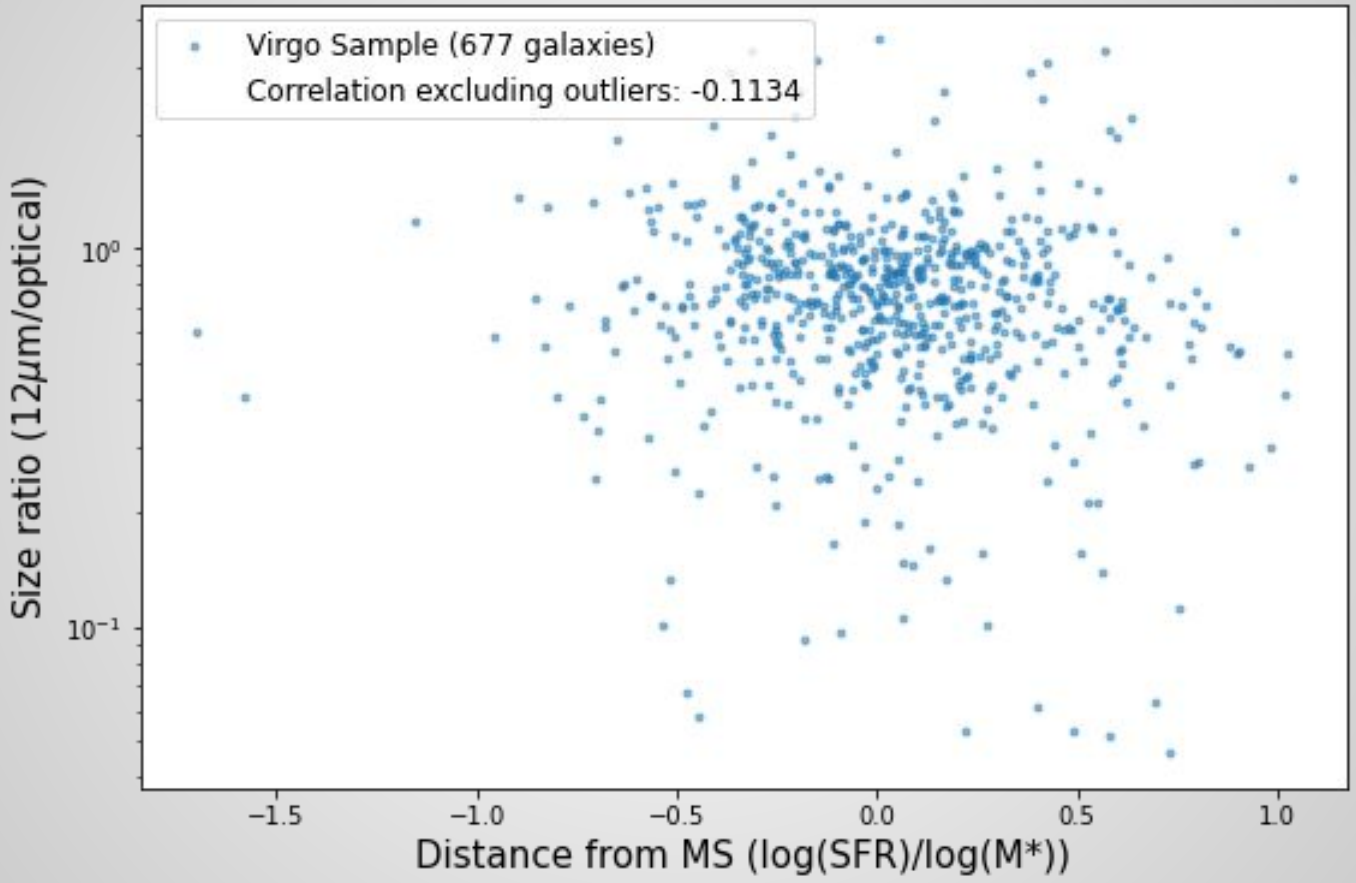
NGC3364 (Midi Notes)



Data Analysis: Main Sequence Offset

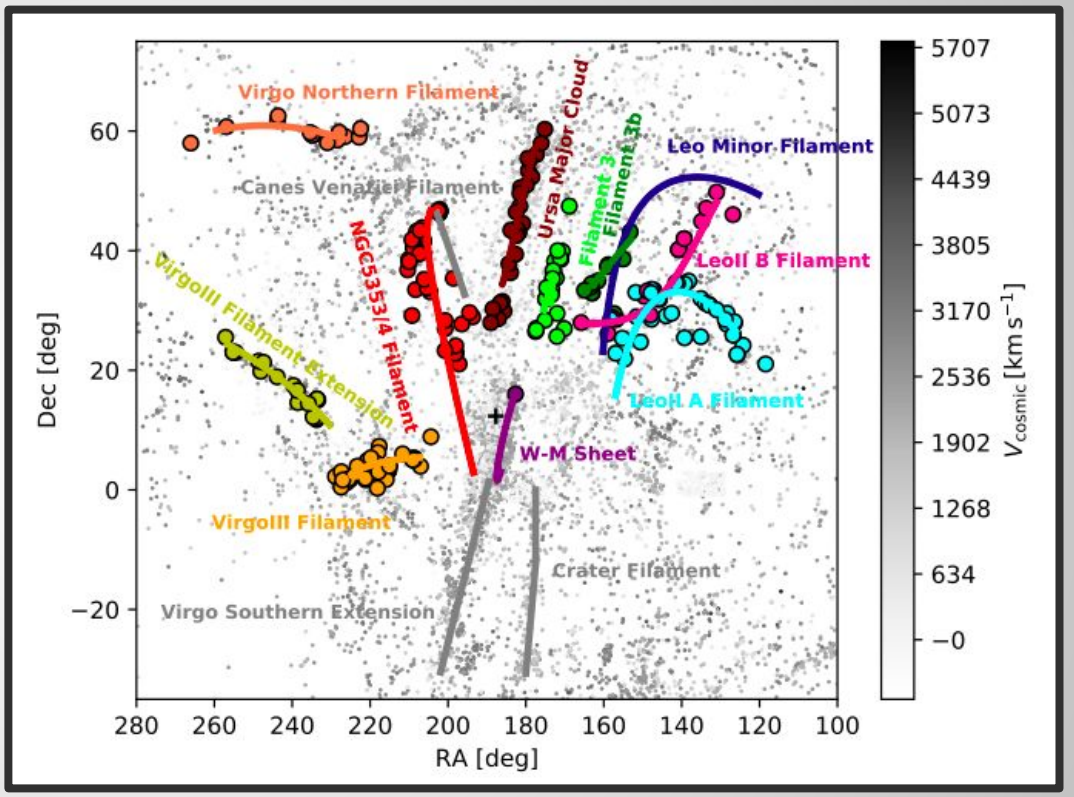


The Data.

Virgo galaxies imaged via the following surveys:

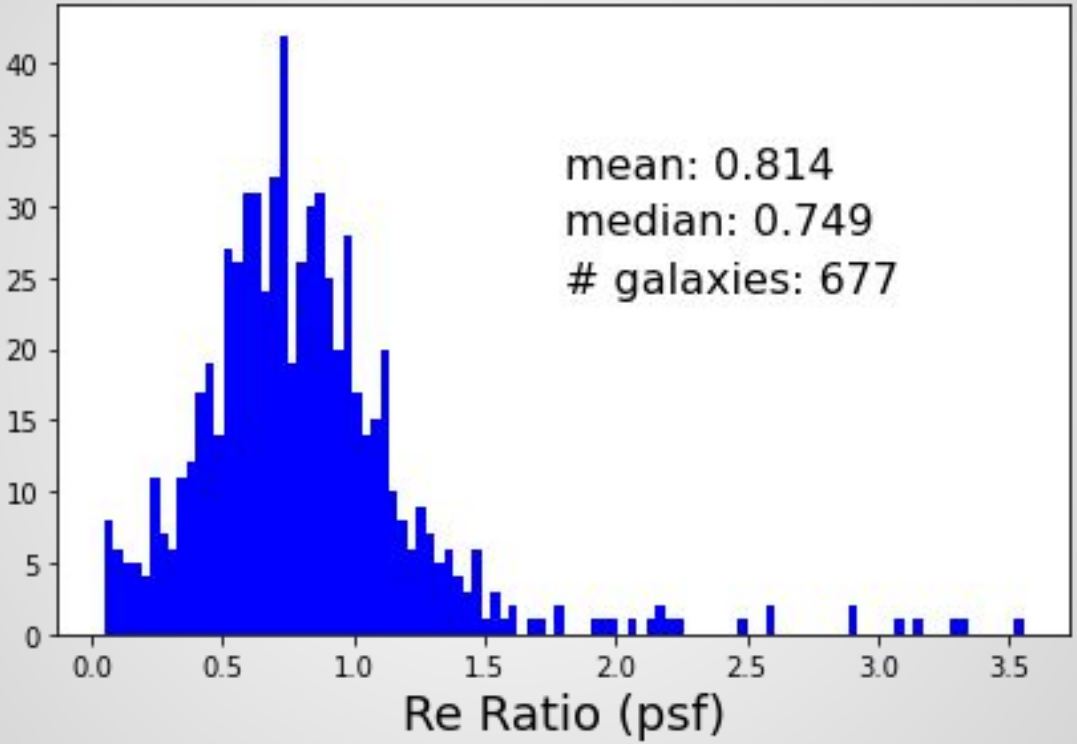
- WISE: Wide-Field Infrared Survey Explorer; gives data in 3.4, 4.6, 12 and 22 μm
- Legacy Survey deep GRZ imaging
- GALEX → UV wavelengths, unobscured SF

(Virgo objects with CO observations only)***



Castignani et al. (2022)

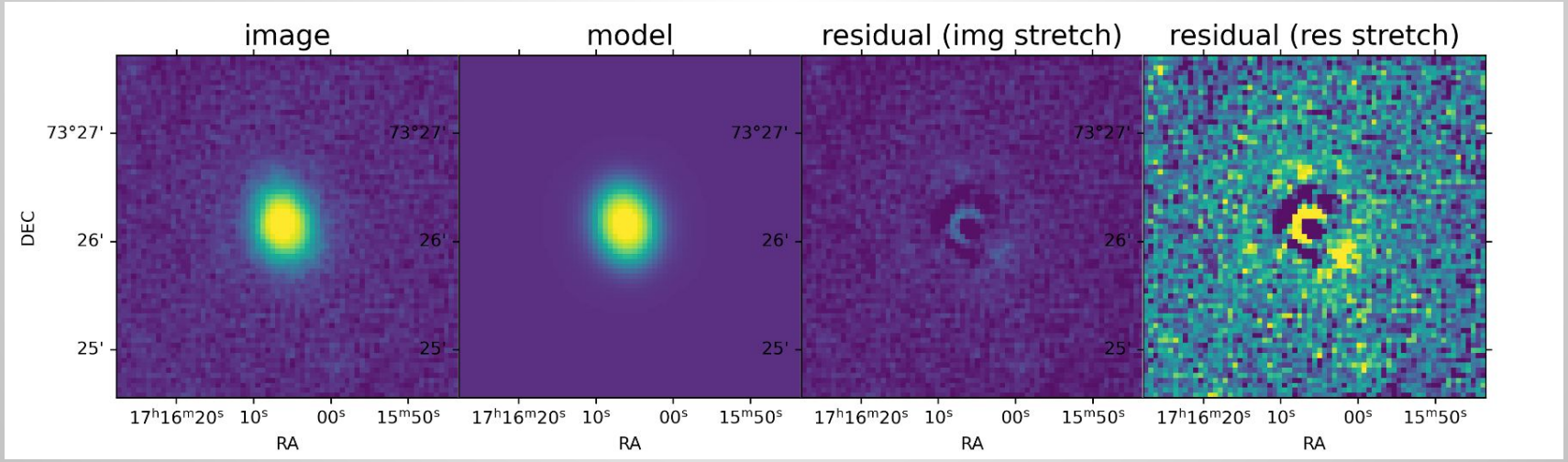
Data Analysis



Mosaic Example!

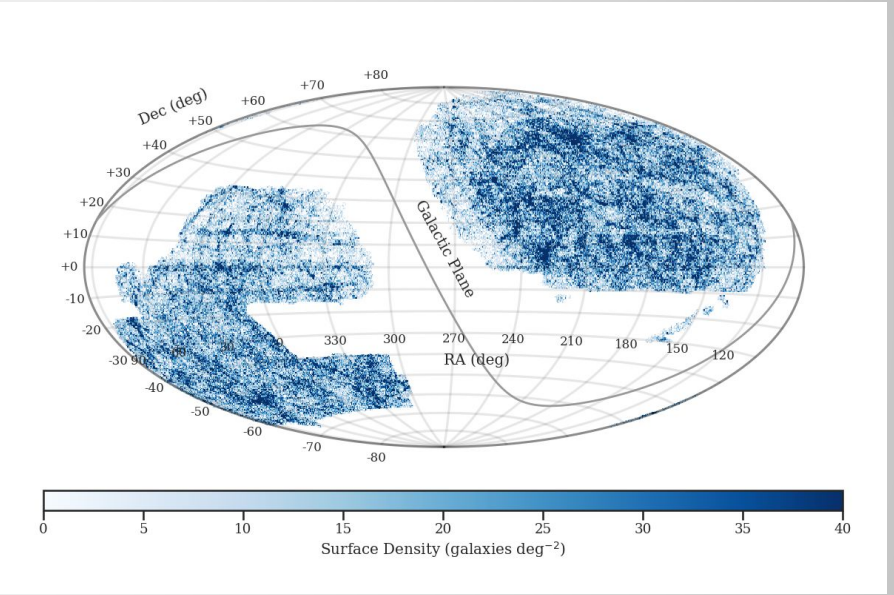
UGC10803

- Model traces input image shape well
- Smooth fit, so does not account for any clumpiness



Siena Galaxy Atlas (SGA-2020)

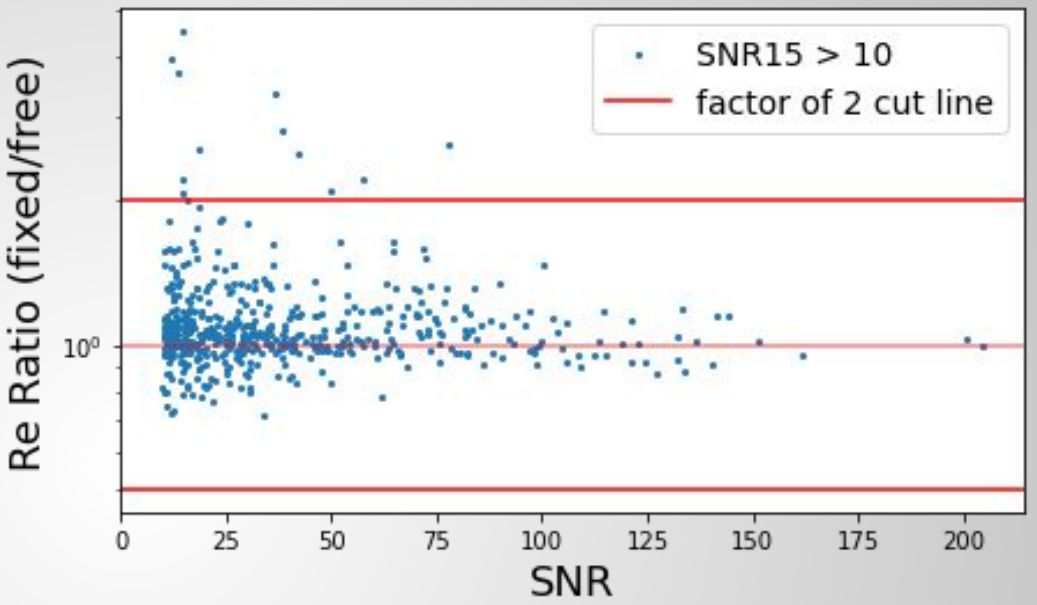
- Catalog of 383,620 galaxies spanning 20,000 square degrees, in grz (optical)
- 99% of vf subsample are in SGA
- Includes optical half-light semi-major axis (R_{50}), can compare to 12-micron Re!



From: https://www.legacysurvey.org/sga/sga2020/

Free v. Fixed PA, B/A

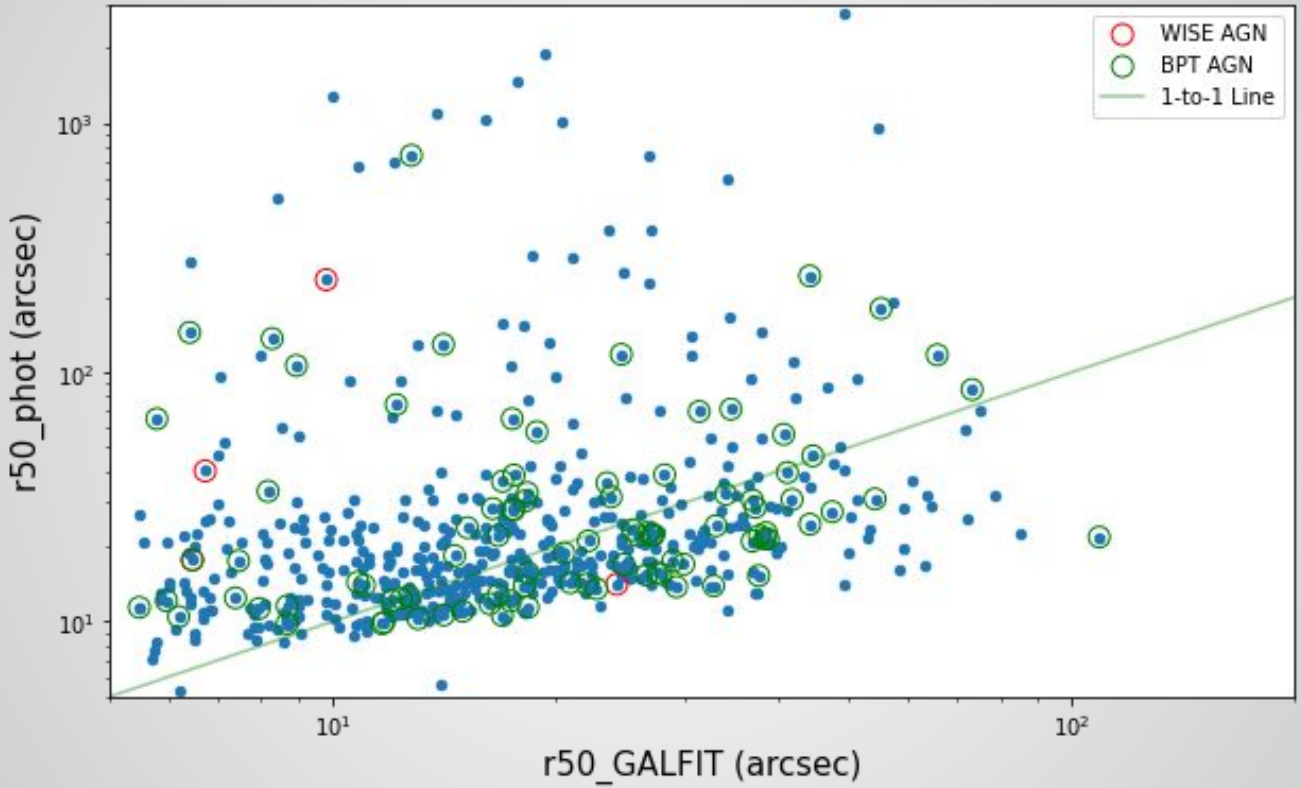
- Re Ratio = Re_fixed/Re_free
- Most galaxies are within the factor of two cut line
- More scatter at lower SNR galaxies, but the amount of scatter is consistent up to SNR=120.




```
Fraction of galaxies above or below with 10<SNR<40:  0.026
Fraction of galaxies above or below with 40<SNR<70:  0.032
Fraction of galaxies above or below with 70<SNR<120:  0.014
```

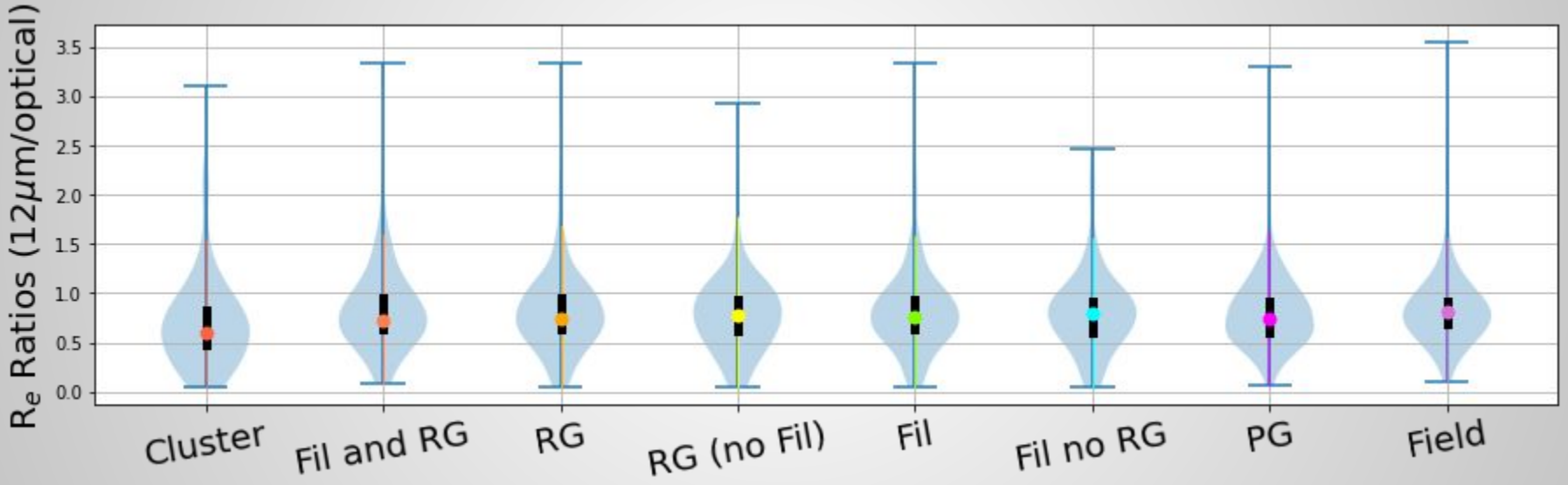
phot-v2 vs. GALFIT w3 r50

phot-v2 vs. GALFIT w3 r50



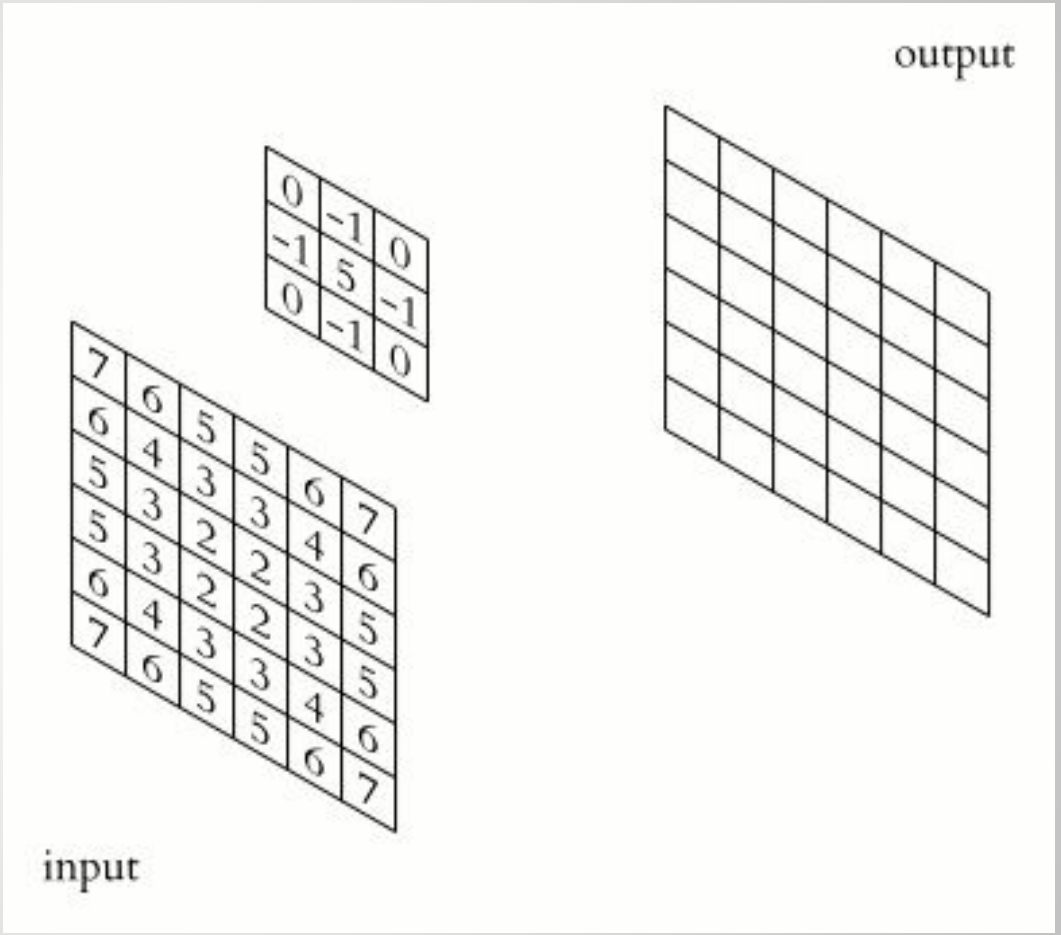
Violin (*Onion*) Plot

(May not be most helpful visualization of the data.)

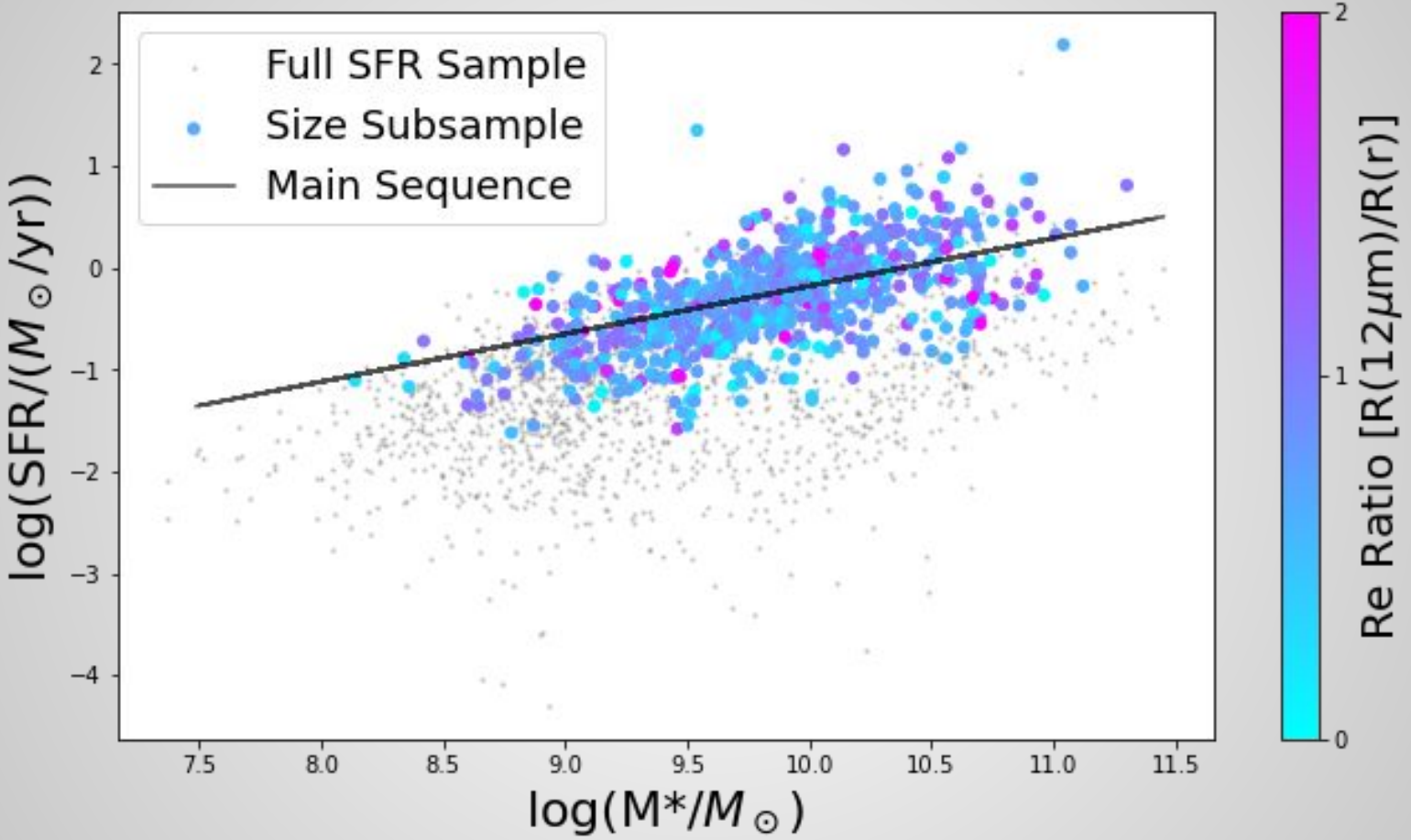


Convolution

- Smooths noisy pixels, sharpens signal pixels
- Uses point spread function input (how a system images a point source)
- Much more computationally expensive

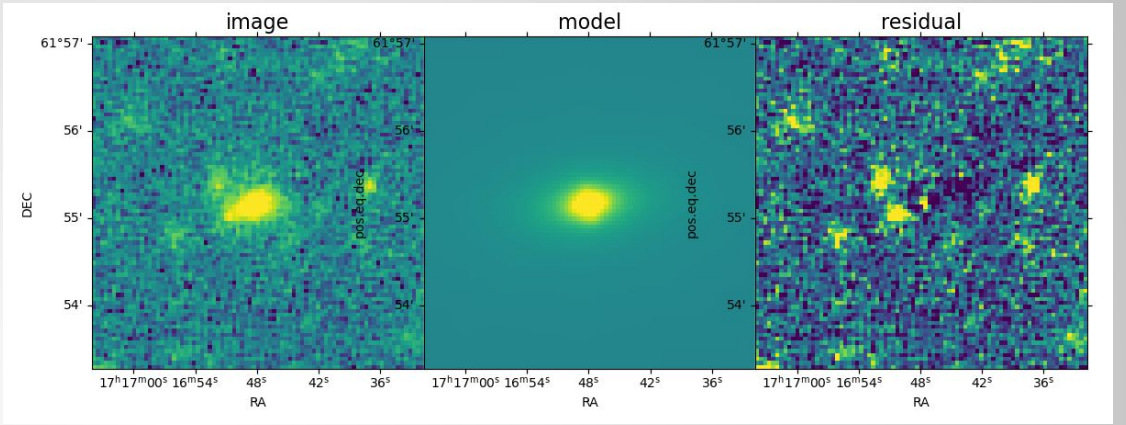


https://commons.wikimedia.org/wiki/File:2D_Convolution_Animation.gif

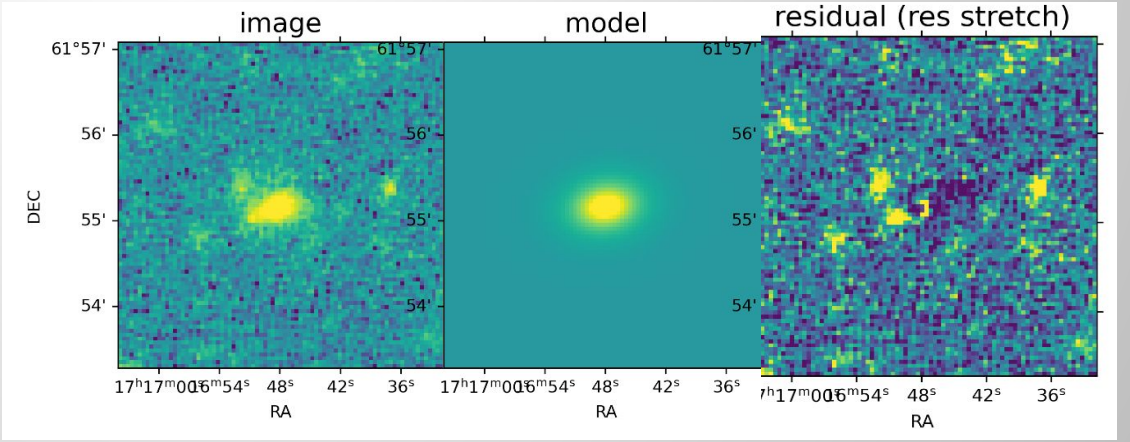

Full SFR Sample
Size Subsample
Main Sequence
log(SFR/($M_\odot$/yr))
log(M*/$M_\odot$)
Re Ratio [R(12μm)/R(r)]
2
1
0
−1
−2
−3
−4
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5

- New, “personalized” PSFs according to nearest coadd ID
- In most instances, the problem of ‘large’ nser is resolved
- Example galaxy: UGC10796

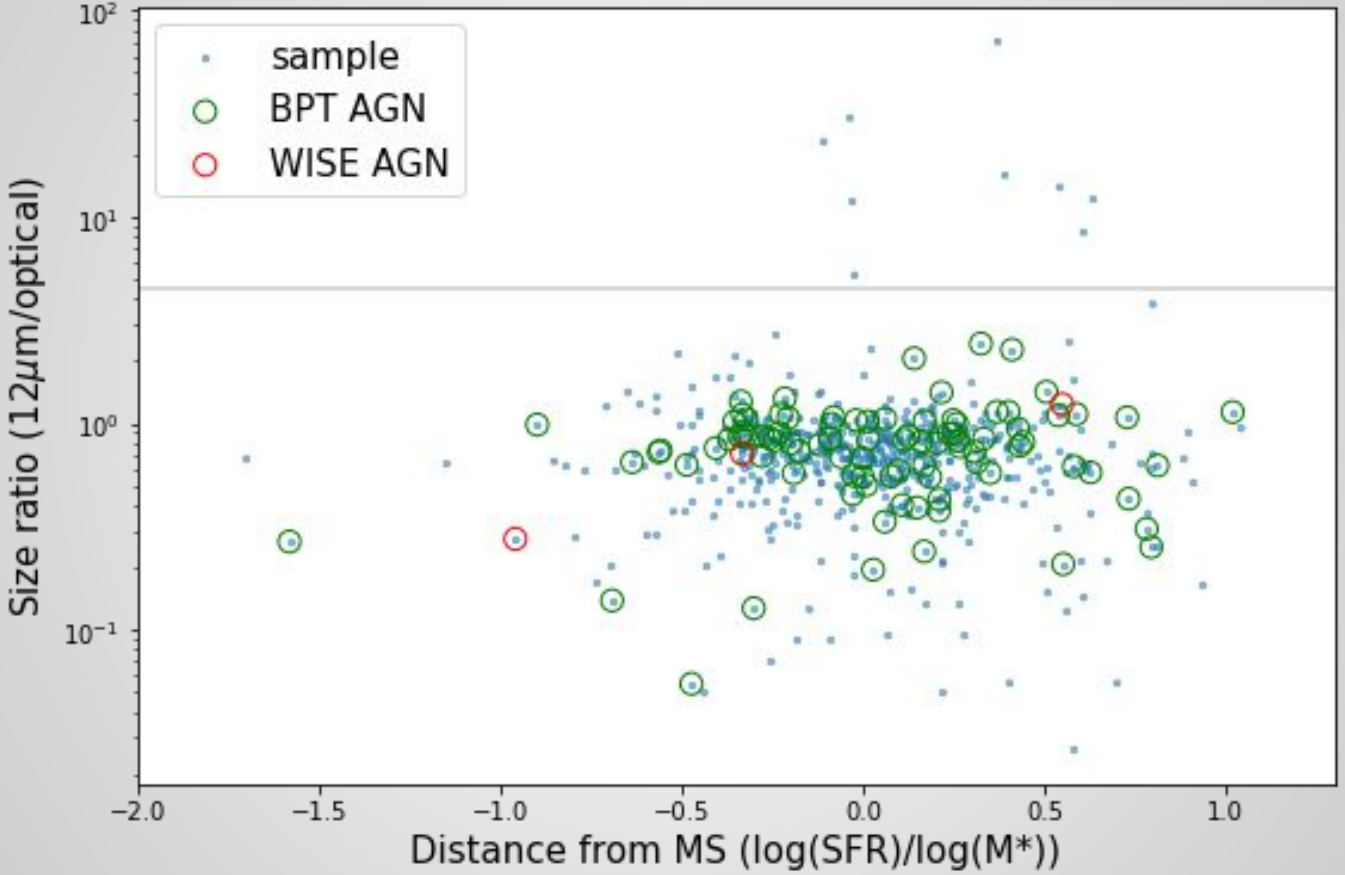
Default PSF (n=9.4975)



Updated PSF (n=1.7015)

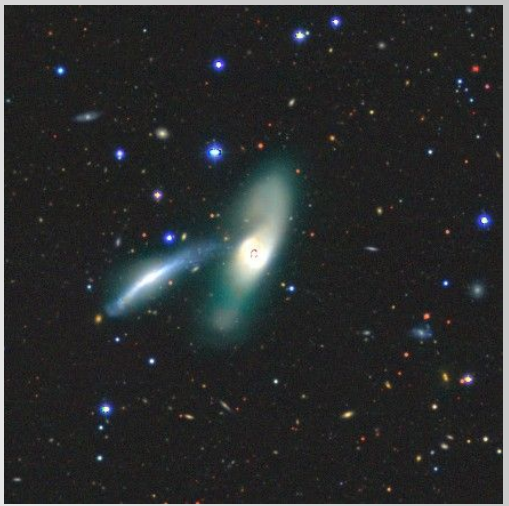


Outliers…

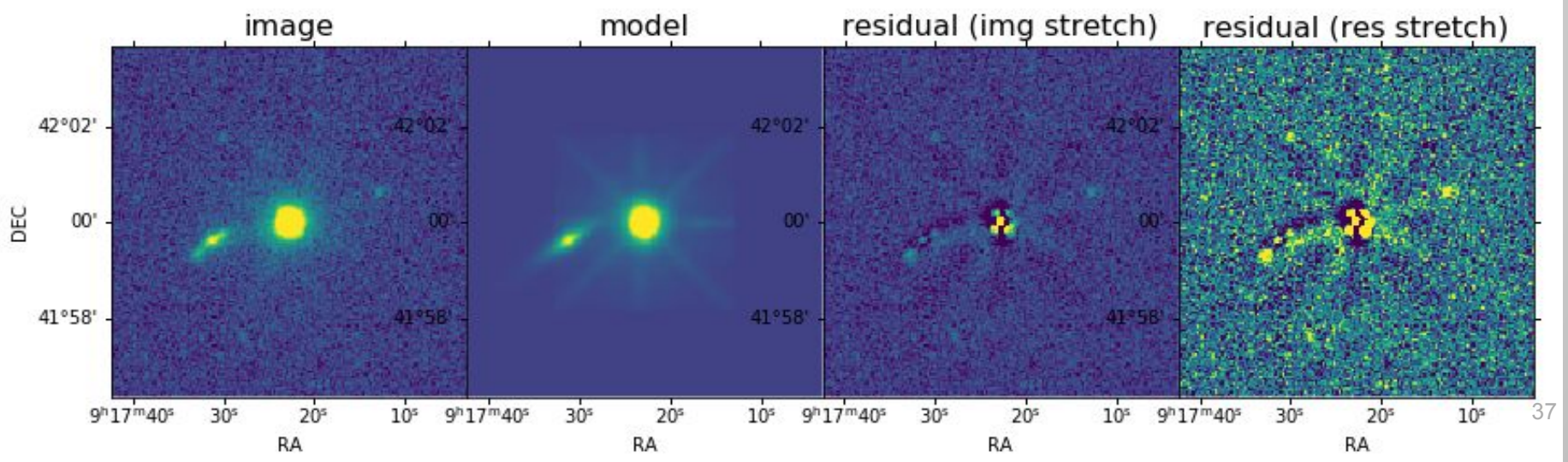

sample
BPT AGN
WISE AGN
Size ratio (12μm/optical)
Distance from MS (log(SFR)/log(M*))
10^{2}
10^{1}
10^{0}
10^{-1}
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0

The Fruits of our GALFIT

Example: NGC2798 (Central Galaxy)



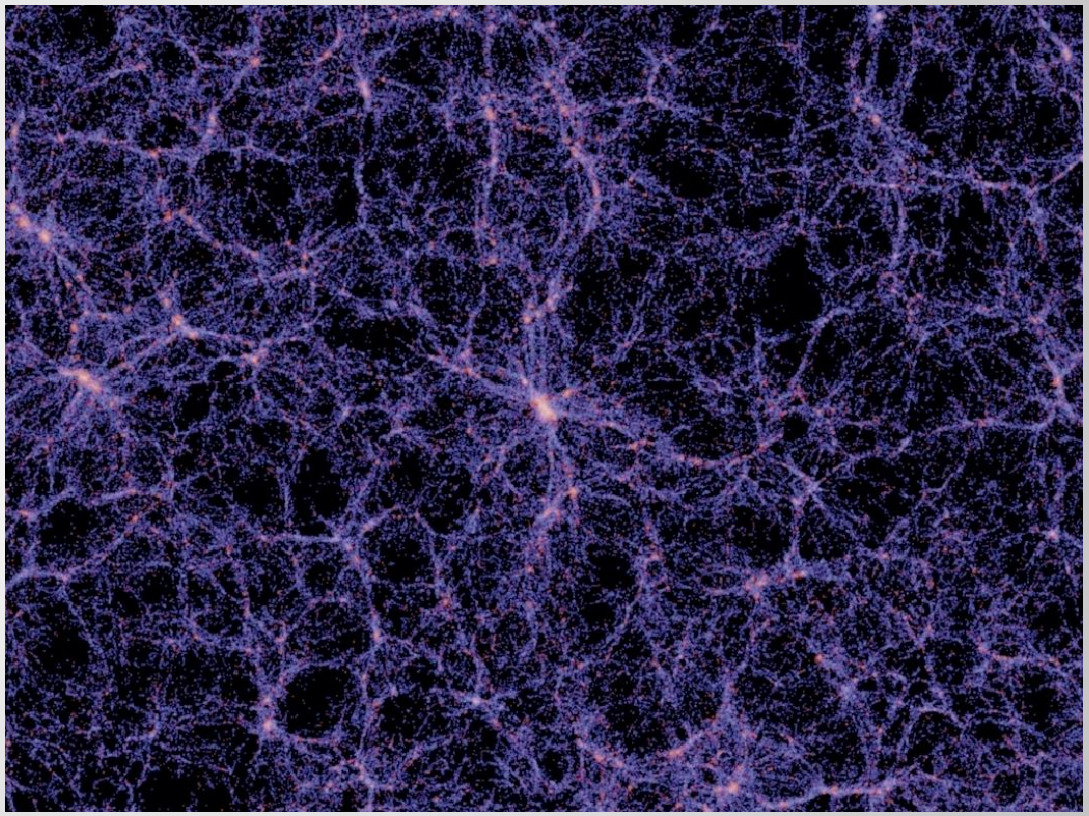
- GALFIT can also model 2+ Sersic objects per cutout
- Input for example: two sets of initial parameters (x,y pixel guesses for each object)
- Output for example: two sets of model parameters!



The universe is not homogeneous…

A patchwork of cosmic architecture:

- fields
- filaments
- groups
- clusters
- etc.



V.Springel, Max-Planck Institut für Astrophysik, Garching bei München

…nor is it static.

Low Density (Field)

?????????

High Density (Cluster)

Images from legacysurvey.org/viewer

…nor is it static.

Low Density (Field)

Filaments!

High Density (Cluster)

Images from legacysurvey.org/viewer