

# How to characterize semi-resolved dwarf galaxies in Roman



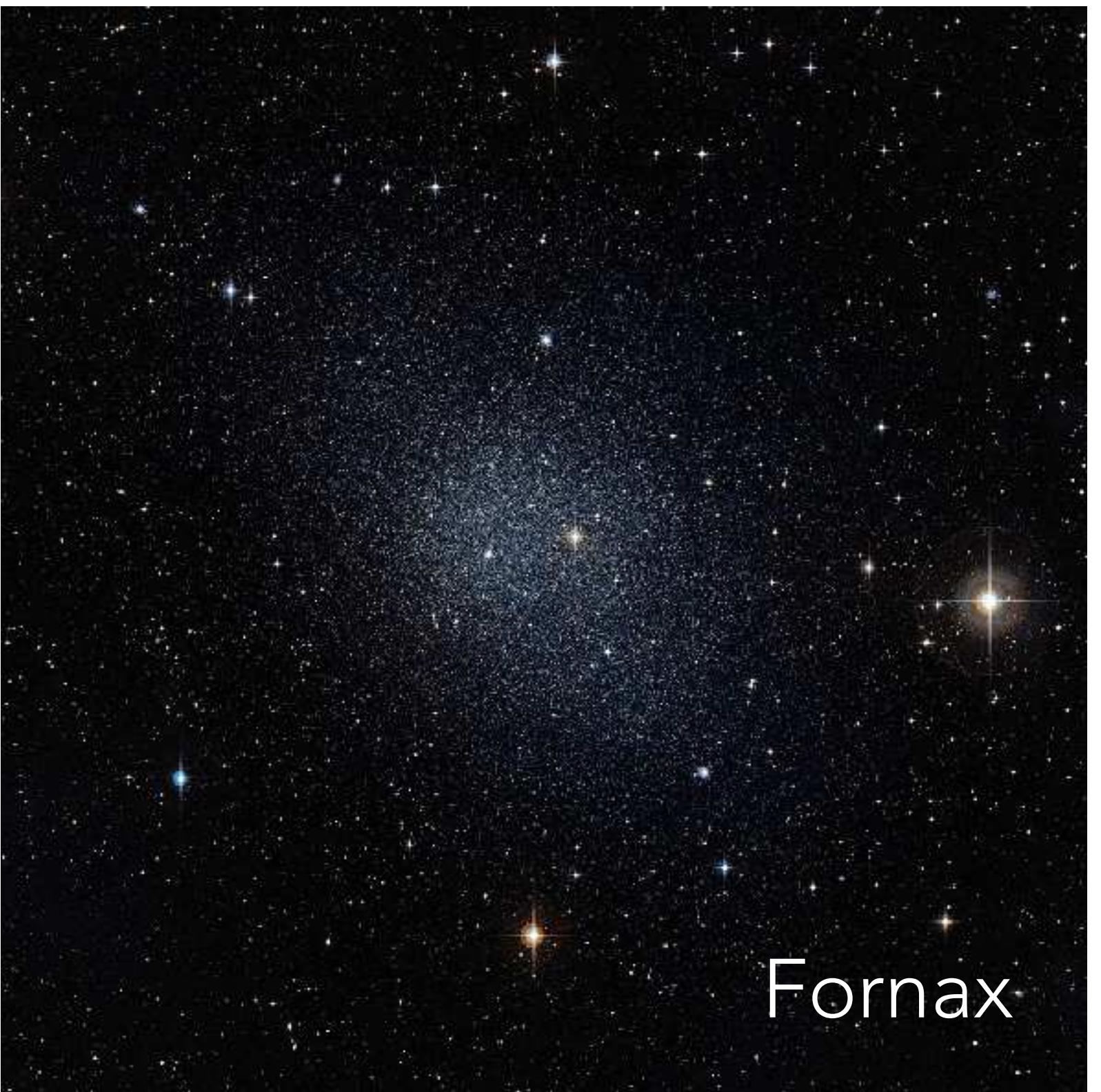
Jiaxuan Li 李嘉轩 (Princeton)

Jenny Greene, Shany Danieli, Scott Carlsten,  
Risa Wechsler, Yao-Yuan Mao, Marla Geha,  
Rachael Beaton, Marcelo Alvarez

Roman Near-field Science Workshop

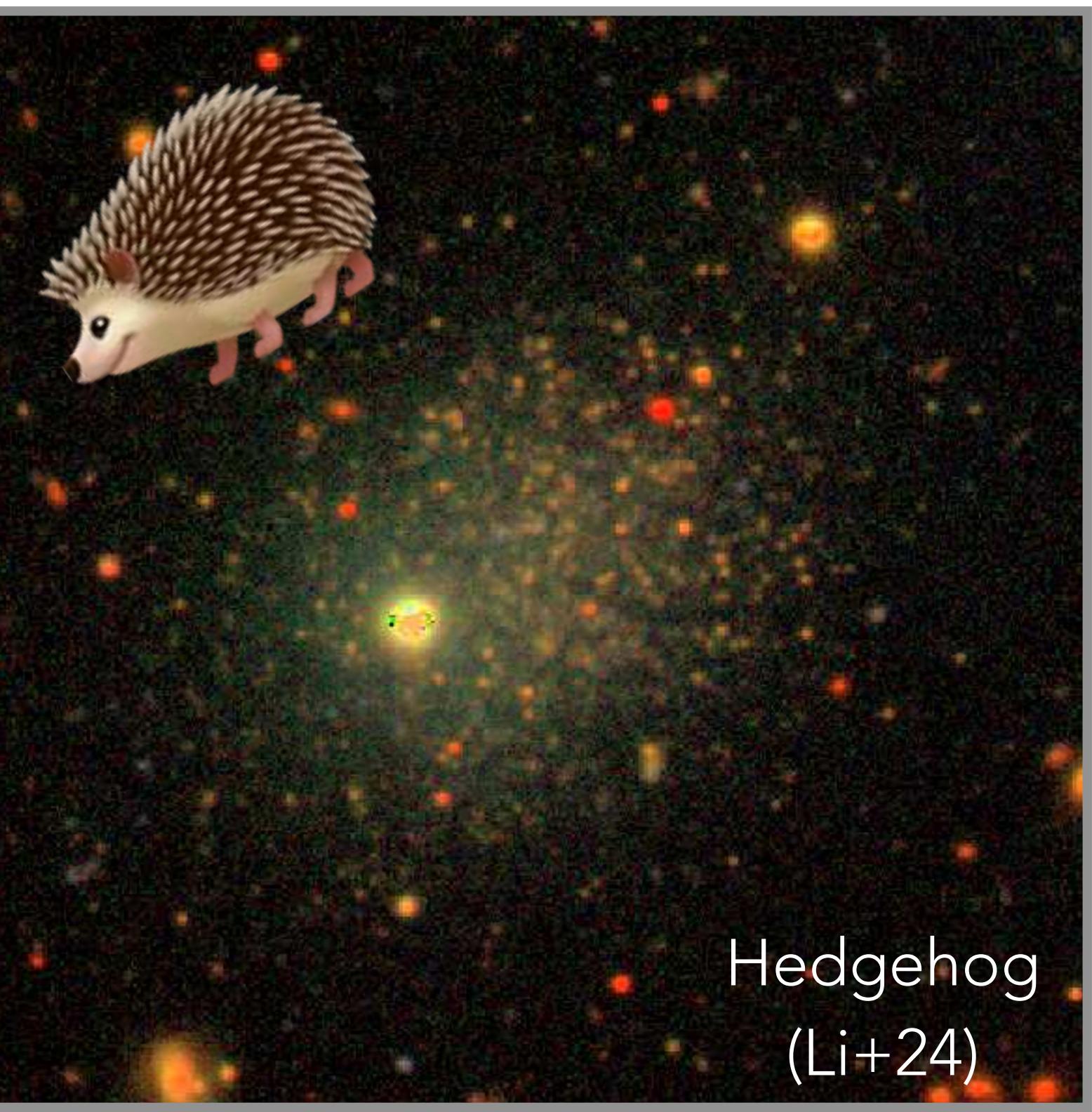
Aug 14, 2025

## Resolved



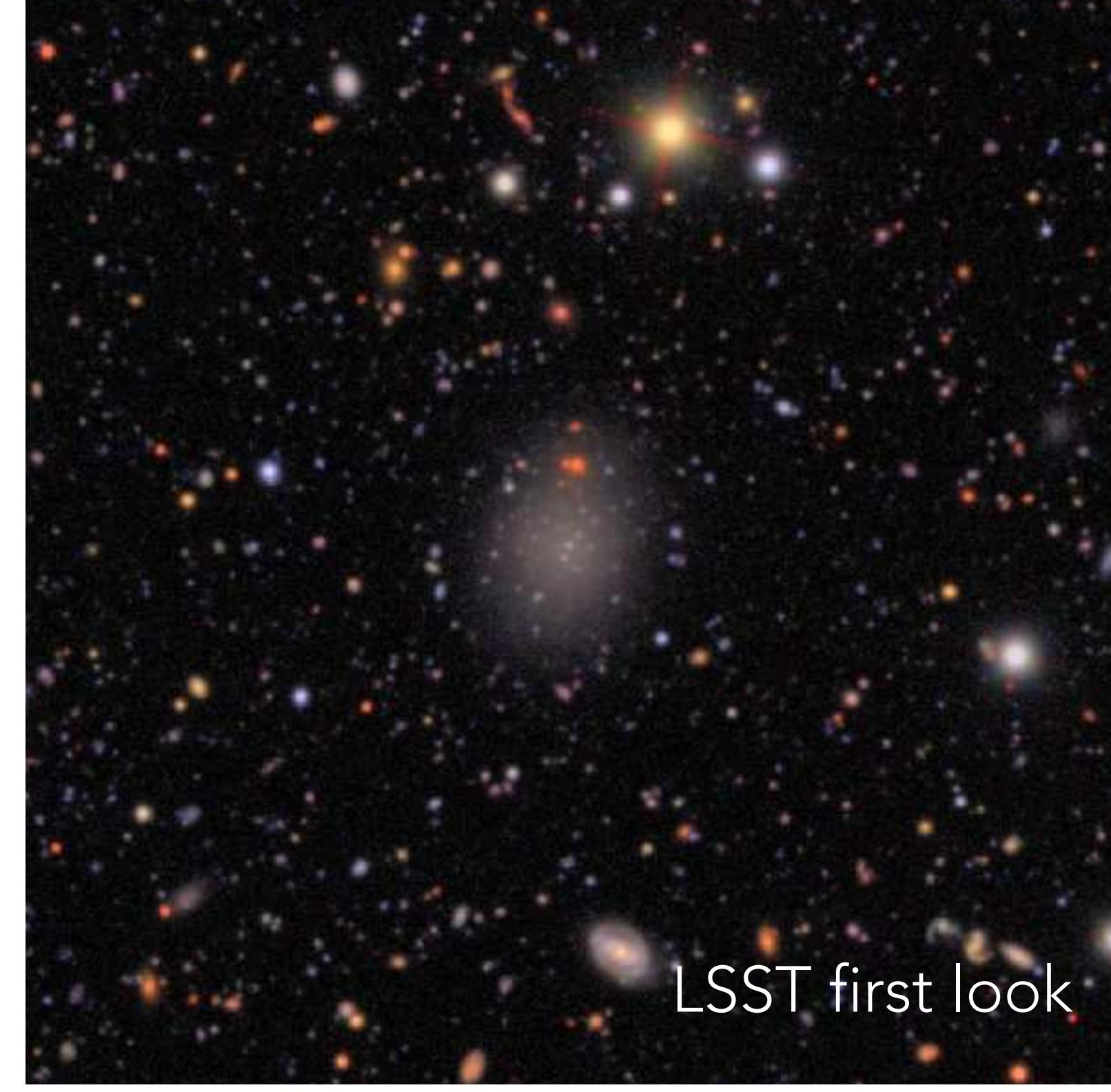
Bell, Williams, McQuinn++

## Semi-Resolved



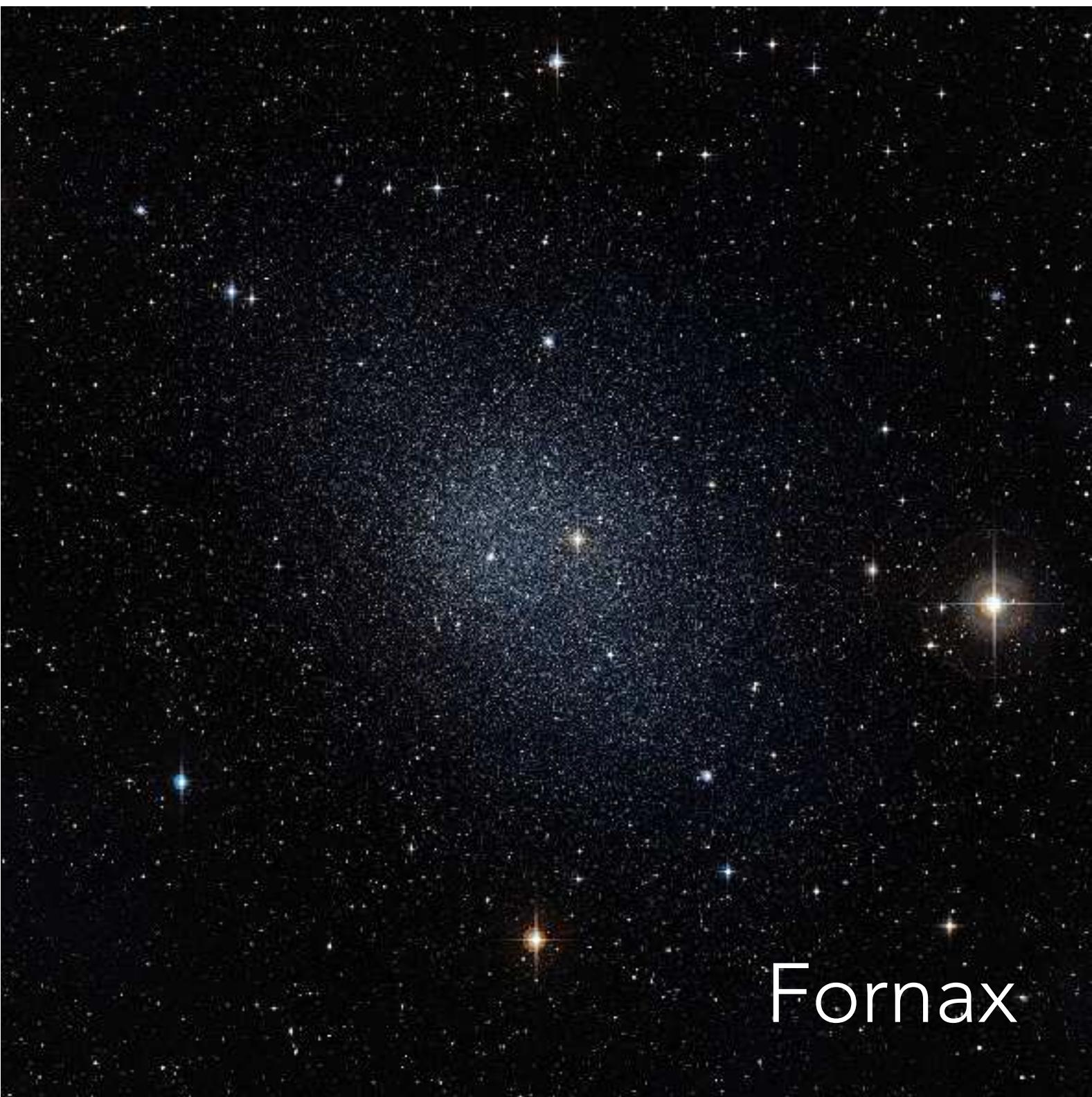
Carlsten, Greene, Danieli, Li ++  
Sand, Mutlu-Pakdil,  
Jones ++ (SEAMLESS)

## Unresolved



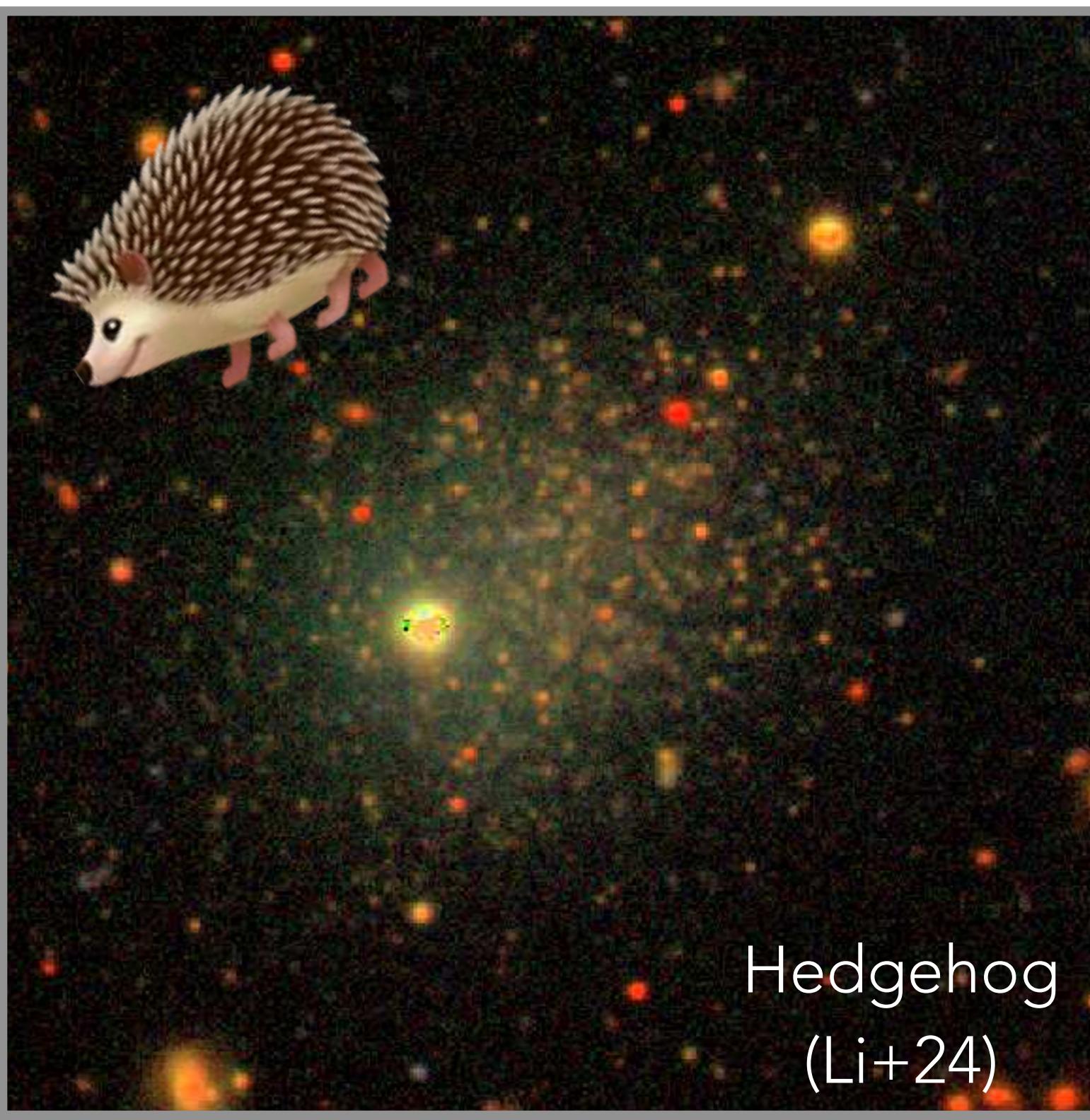
Romanowsky++  
Greco+18 (HSC data)  
SMUDGES (Zaritsky++)

## Resolved



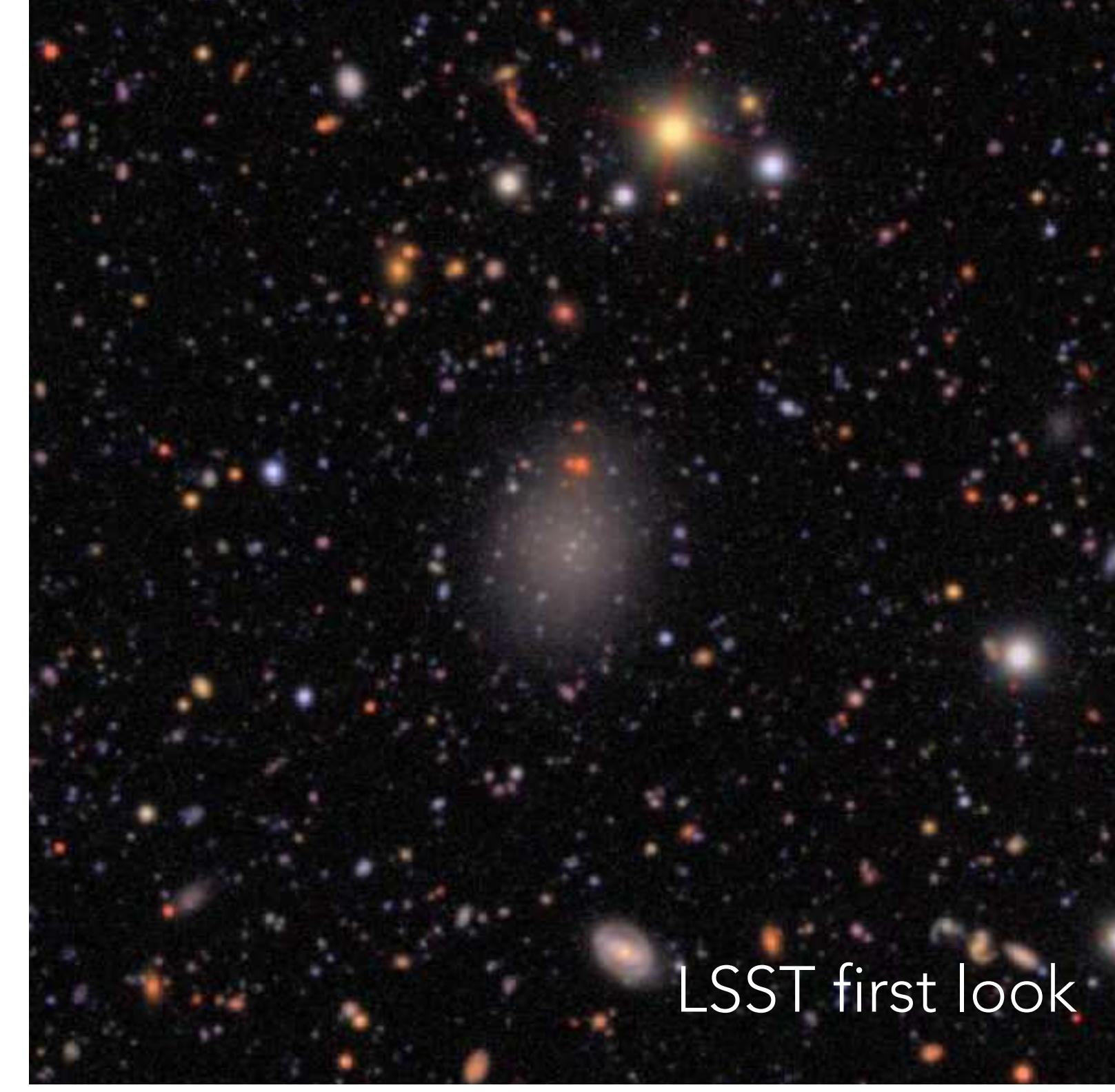
Fornax

## Semi-Resolved

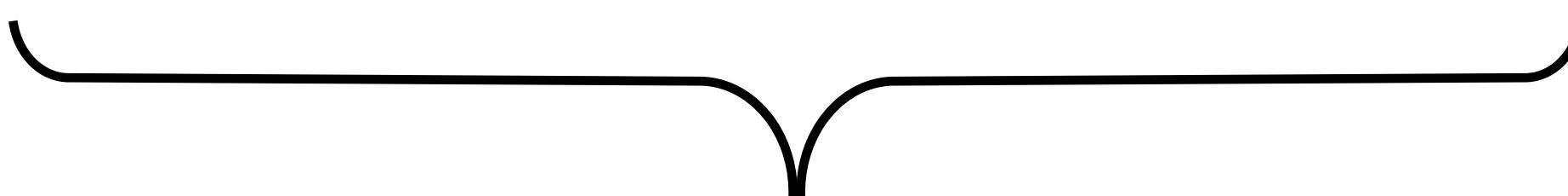


Hedgehog  
(Li+24)

## Unresolved



LSST first look



*Burcin will find all of these in Roman*

Resolved

# Distance is needed!

Unresolved

$\Lambda$ CDM tensions with dwarf galaxies

Sales et al. (2022)

No tension

Uncertain

Weak tension

Strong tension

Missing satellites

$M_*$ – $M_{\text{halo}}$  relation

Too big to fail

Diversity of rotation curves

Core–cusp

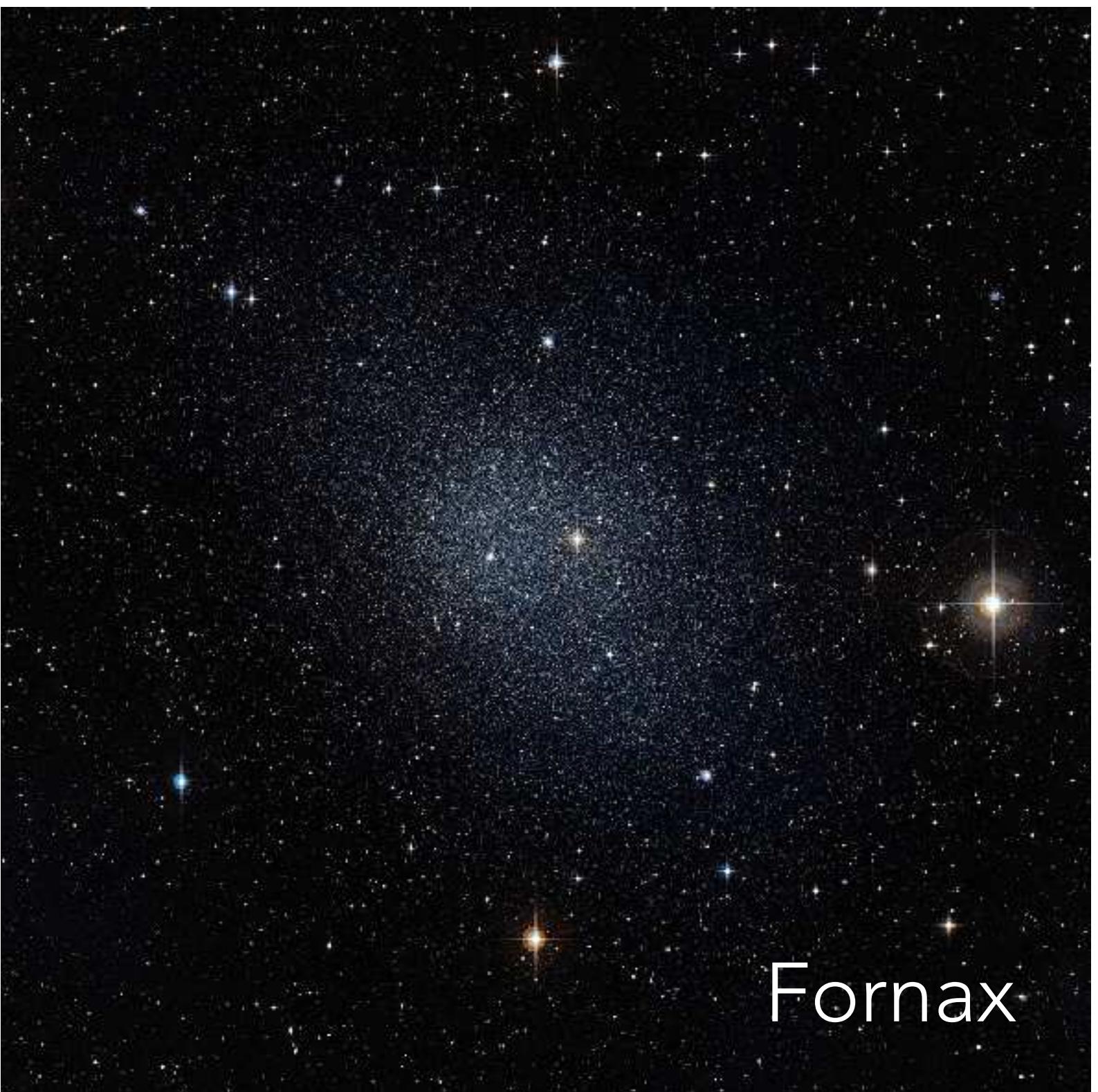
Diversity of dwarf sizes

Satellite planes

Quiescent fractions

Free distance  
from matched filtering

**Resolved**



Fornax

??

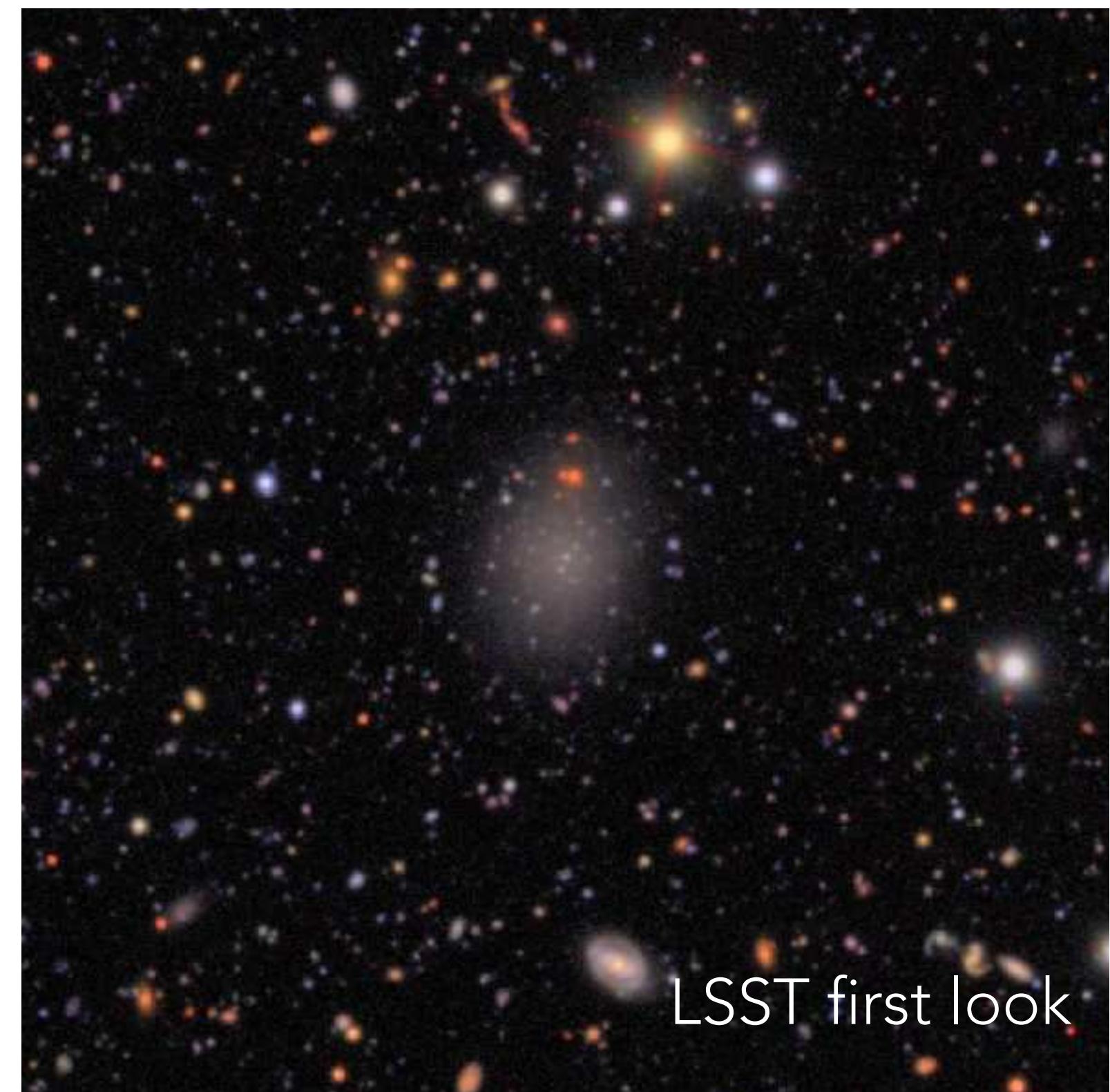
**Semi-Resolved**



Hedgehog  
(Li+24)

Redshift  
Group member

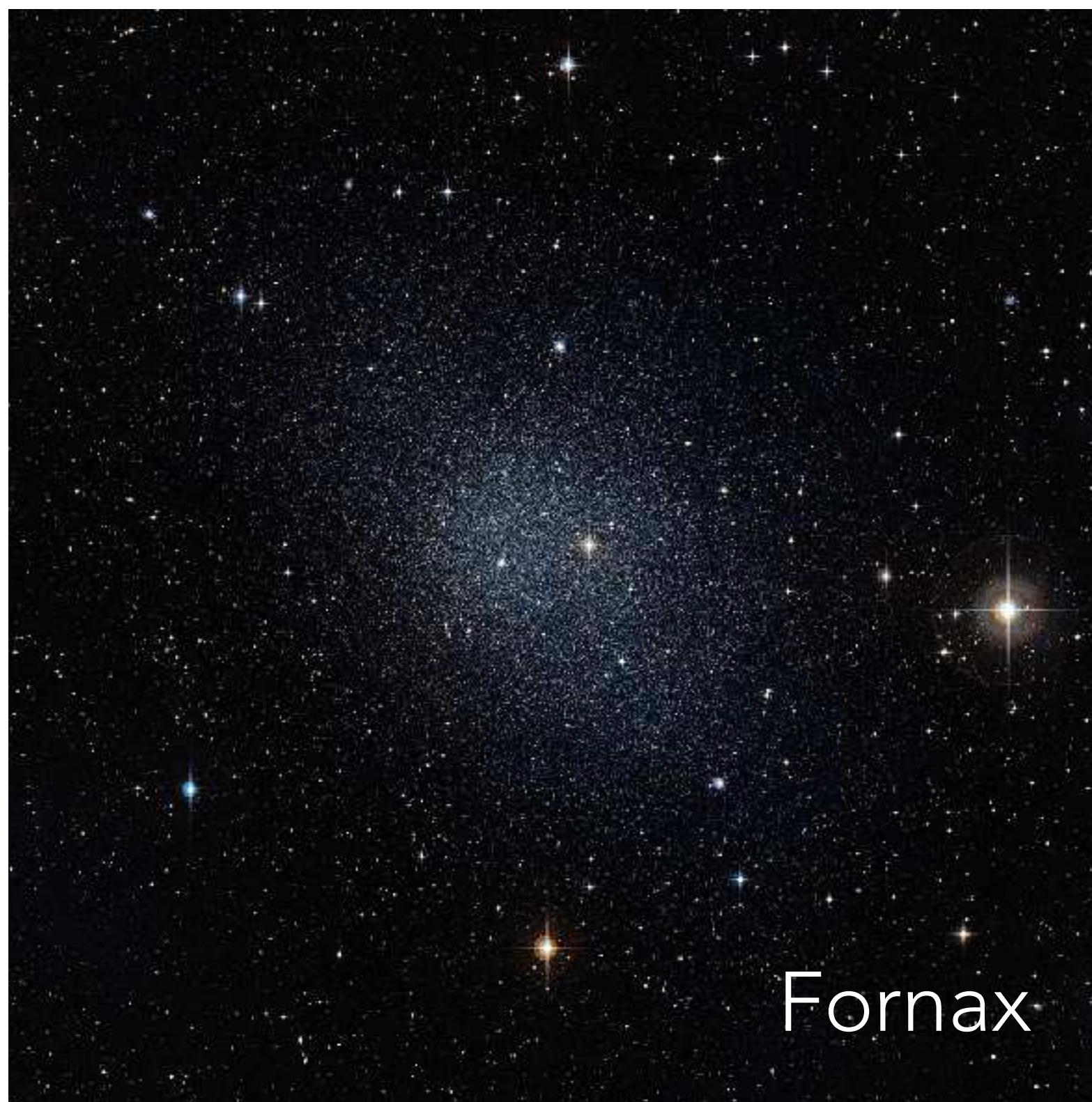
**Unresolved**



LSST first look

Free distance  
from matched filtering

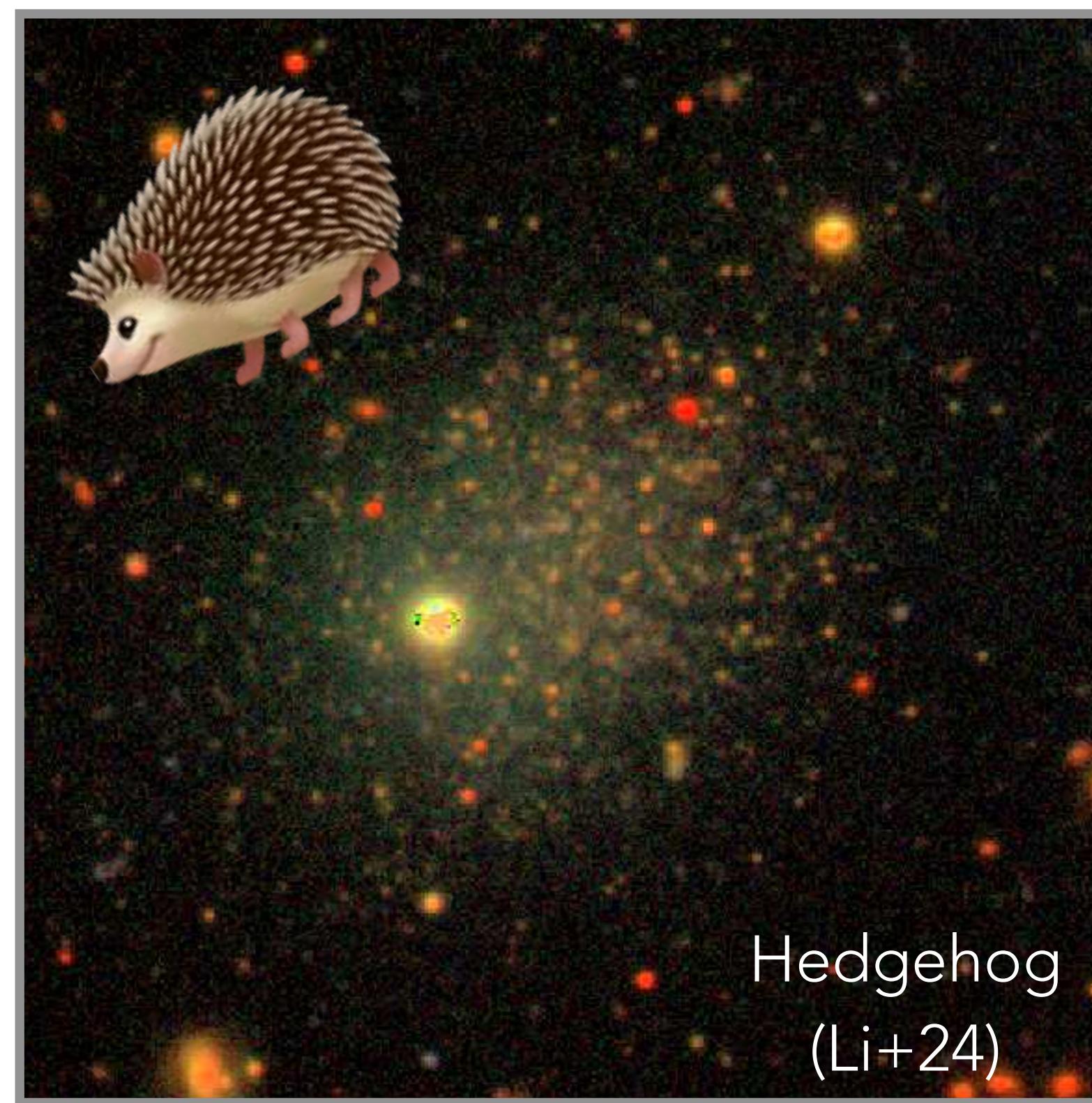
Resolved



Fornax

Surface Brightness  
Fluctuation

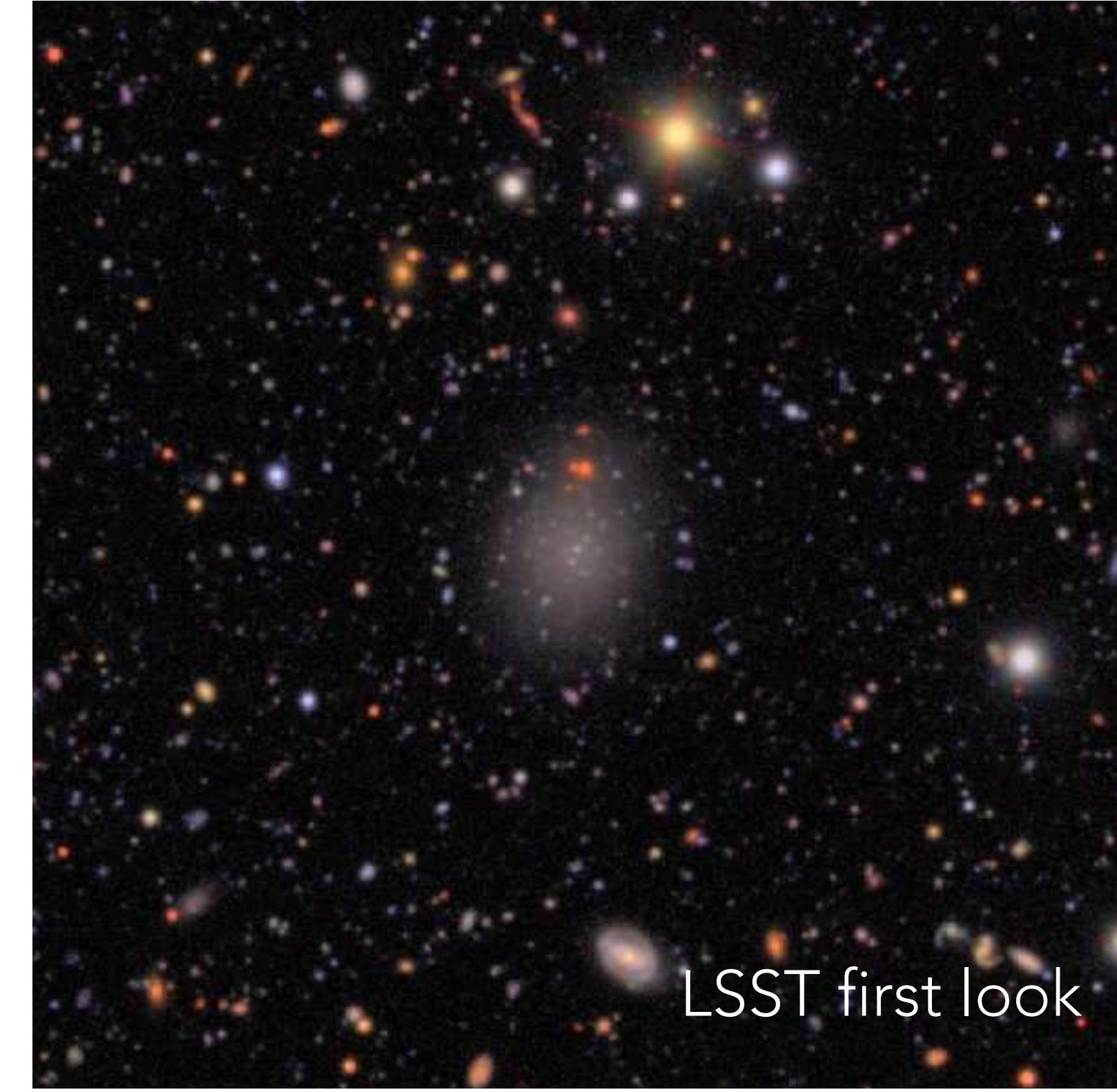
Semi-Resolved



Hedgehog  
(Li+24)

Redshift  
Group member

Unresolved



LSST first look

# SBF: Pixel-to-pixel variation contains distance information

*SBF is an **OLD** technique!! (Tonry & Schneider 1988)*

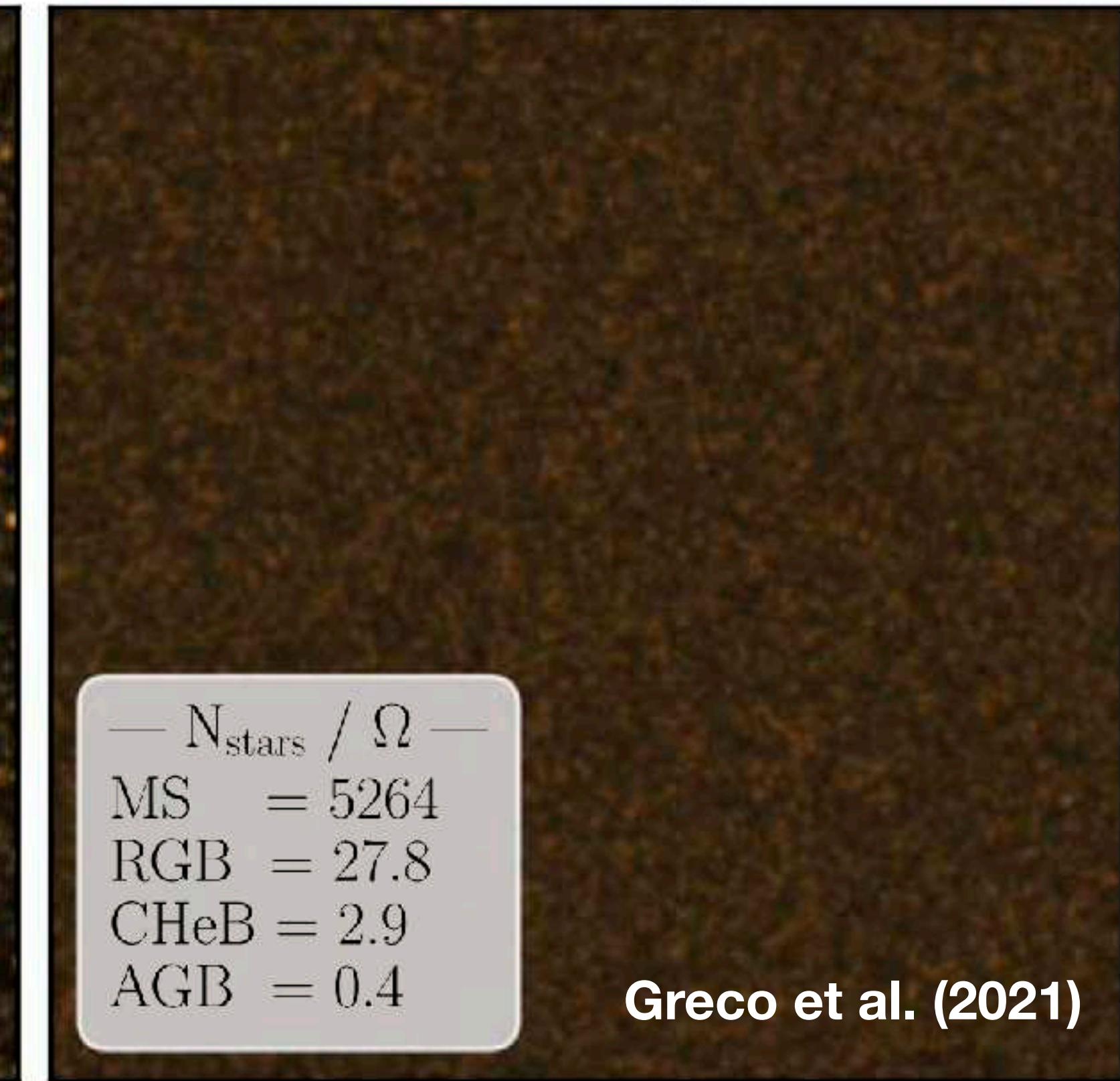
D = 0.5 Mpc



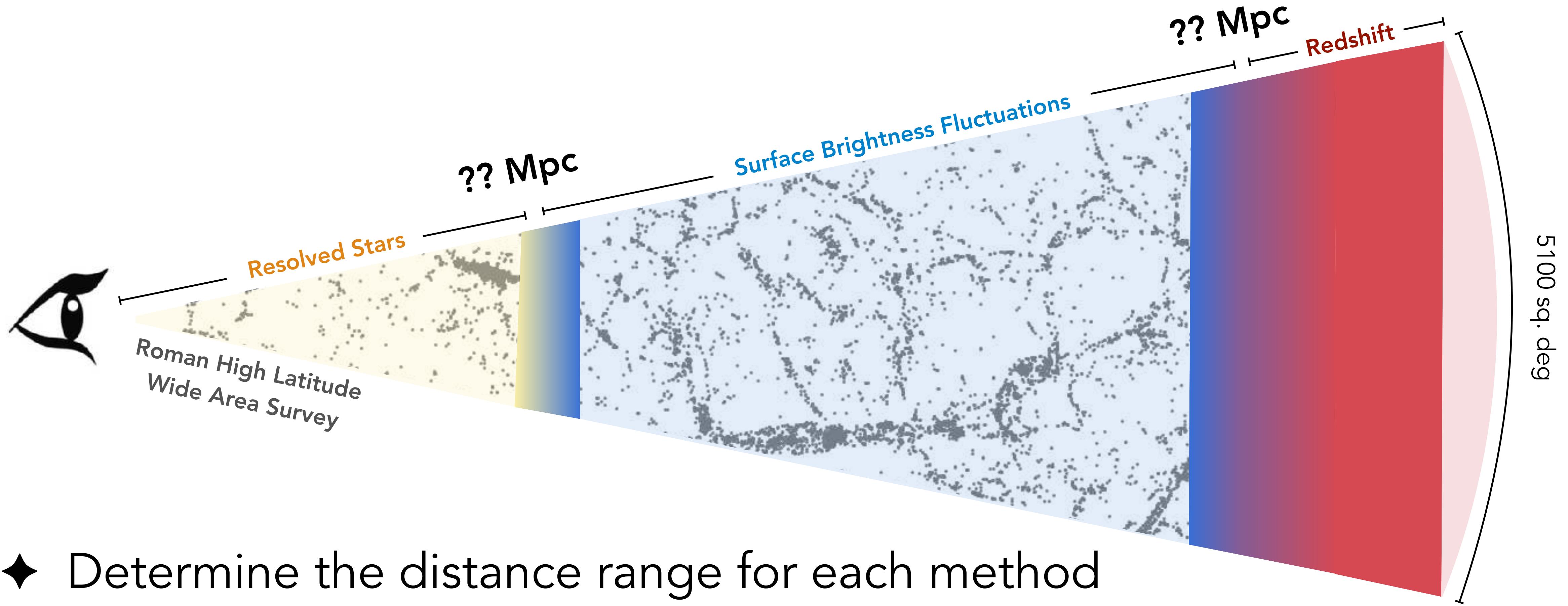
D = 2 Mpc



D = 8 Mpc



- Not biased towards blue dwarfs (compared with spectroscopic surveys)



- ◆ Determine the distance range for each method
- ◆ How does that depend on stellar mass, SFH, etc.?
- ◆ Detection completeness, purity, etc.

# Ultra-Faint Dwarfs ( $\log M^* < 5$ )

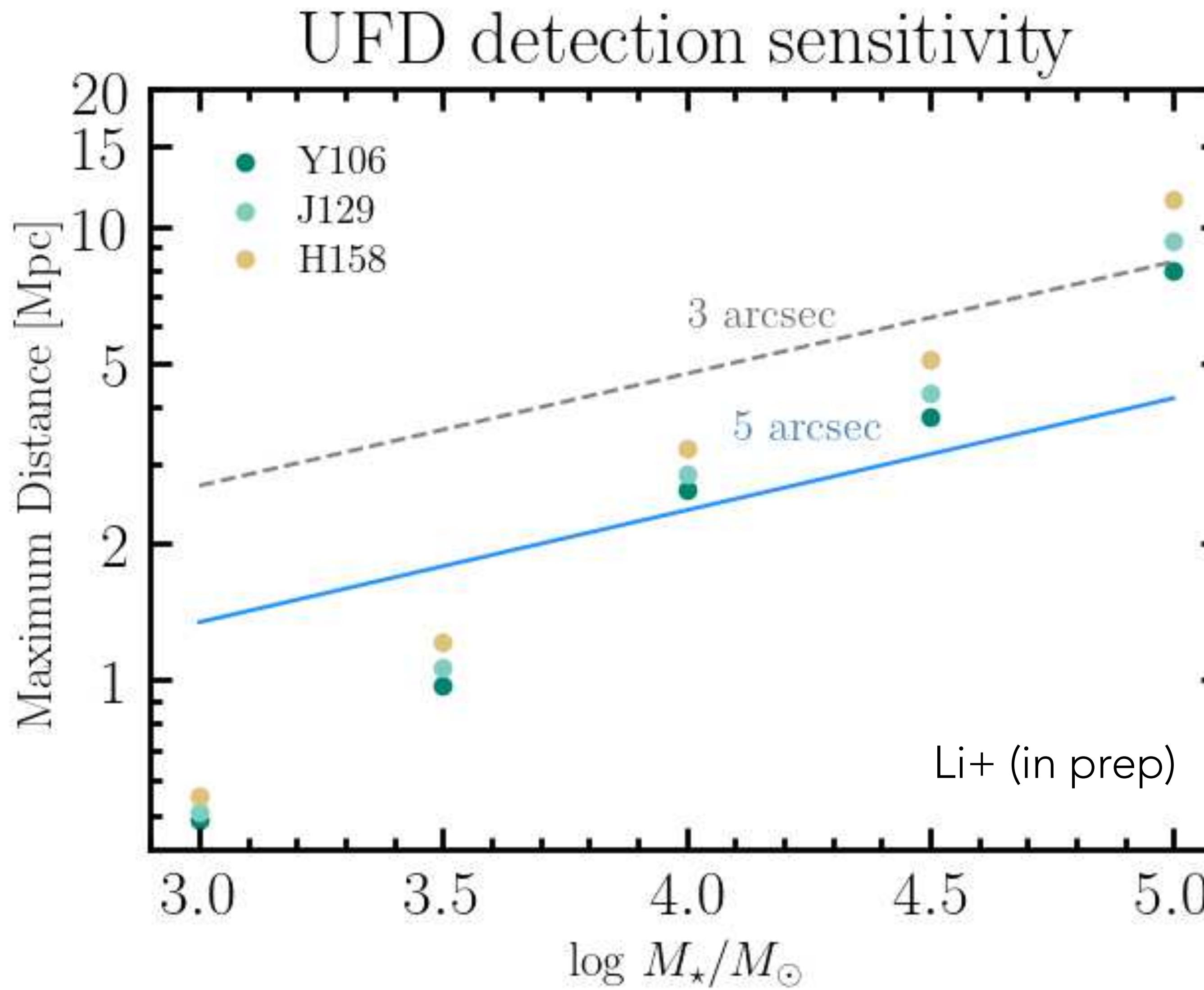
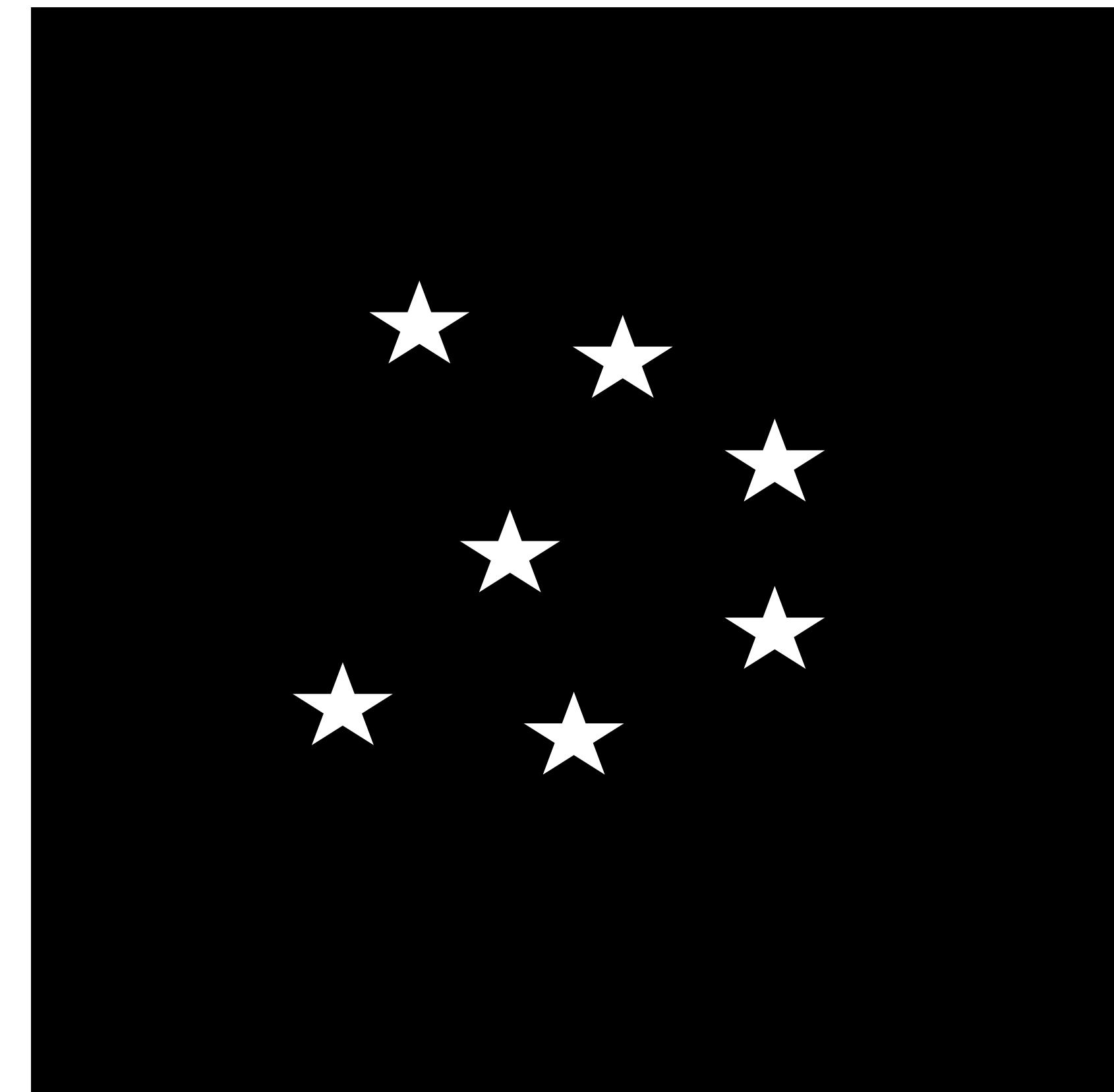


Image simulation is needed



\*Assuming no crowding, 5-sigma detection of the 20th brightest star

# Classical dwarfs

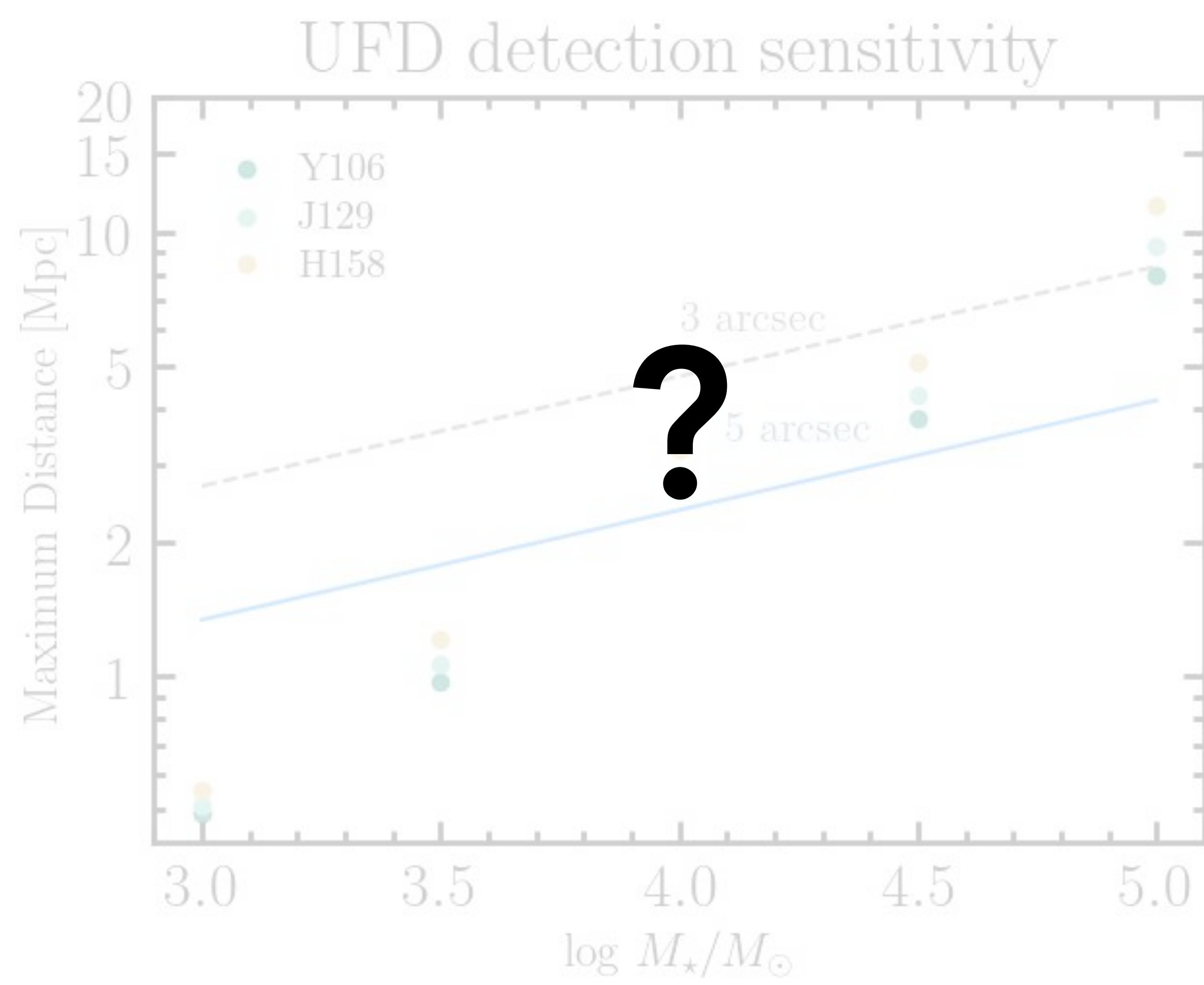
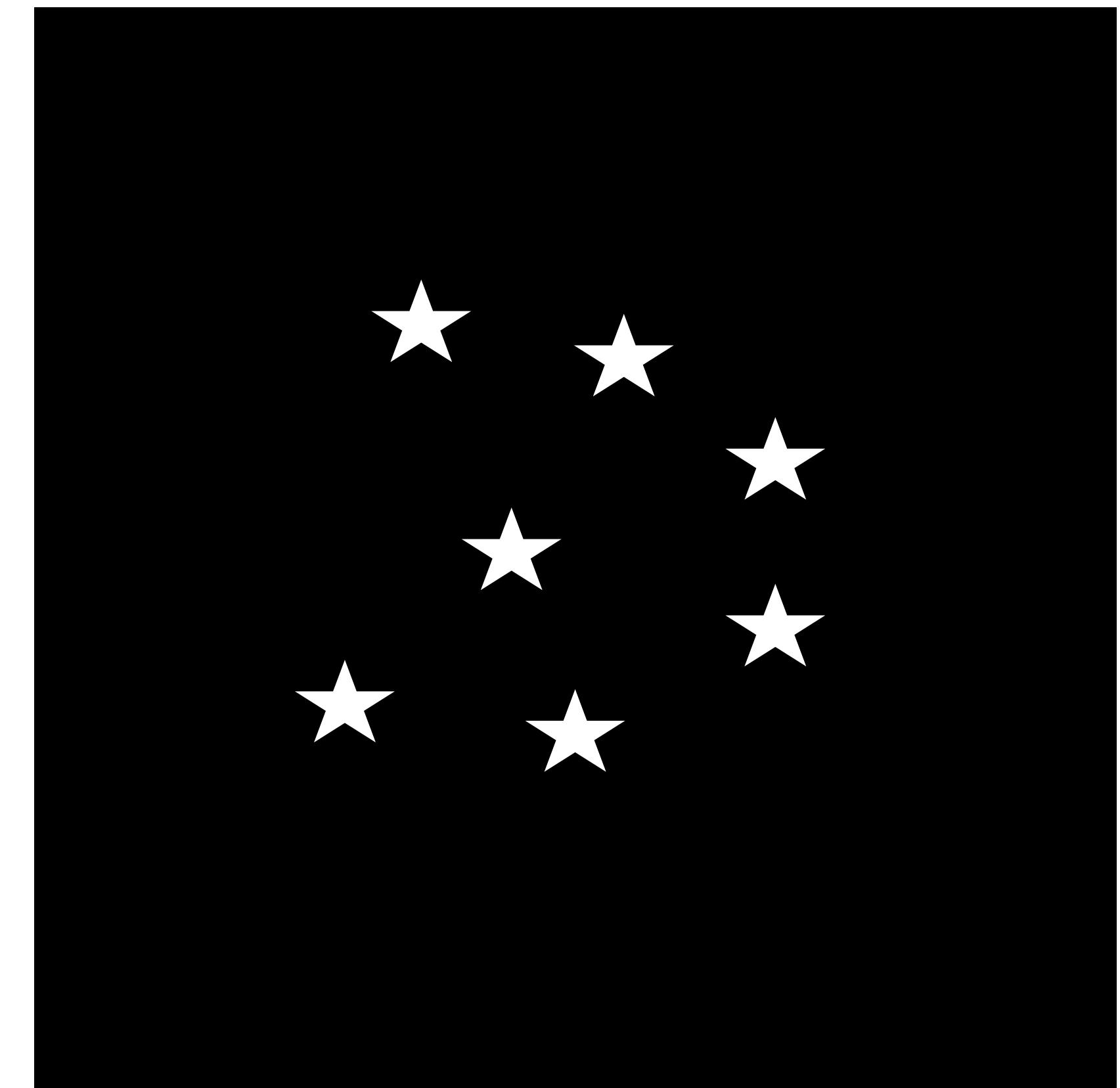
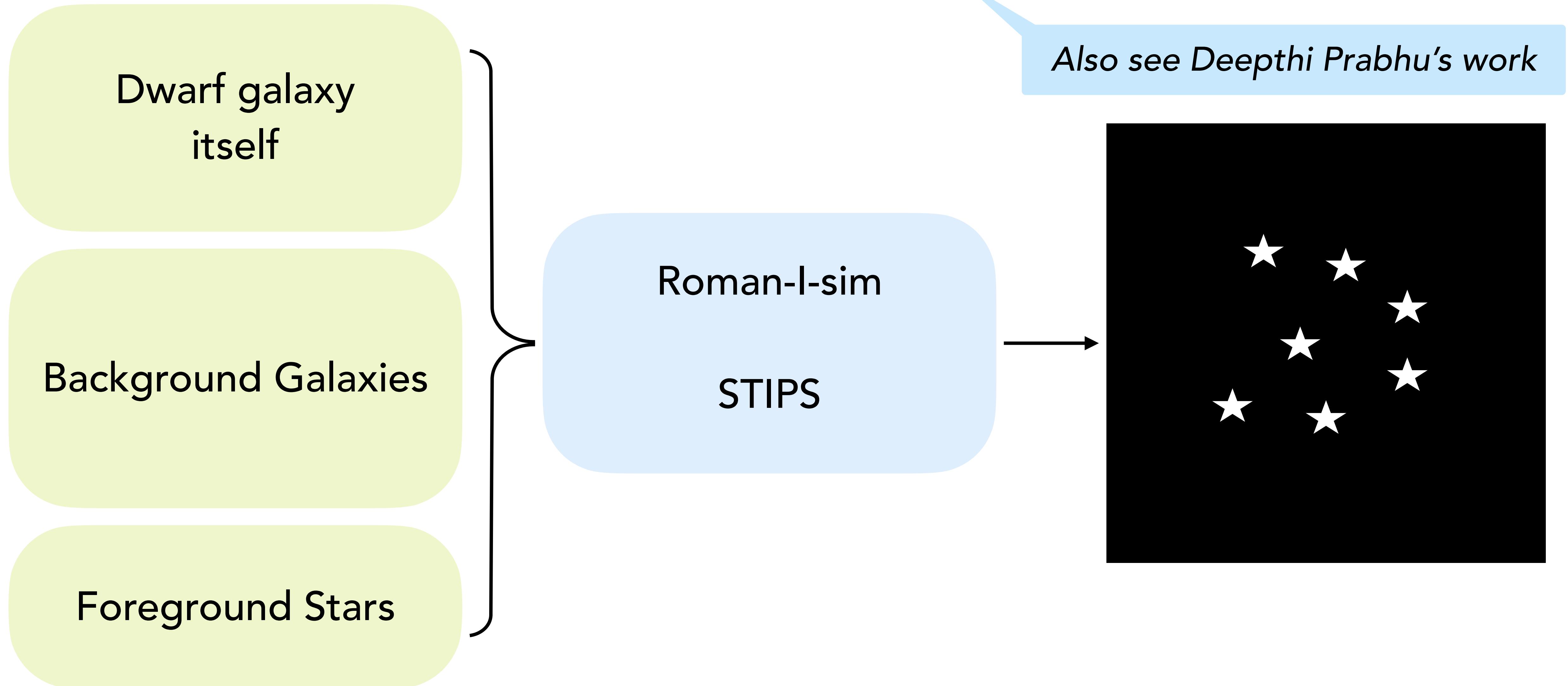


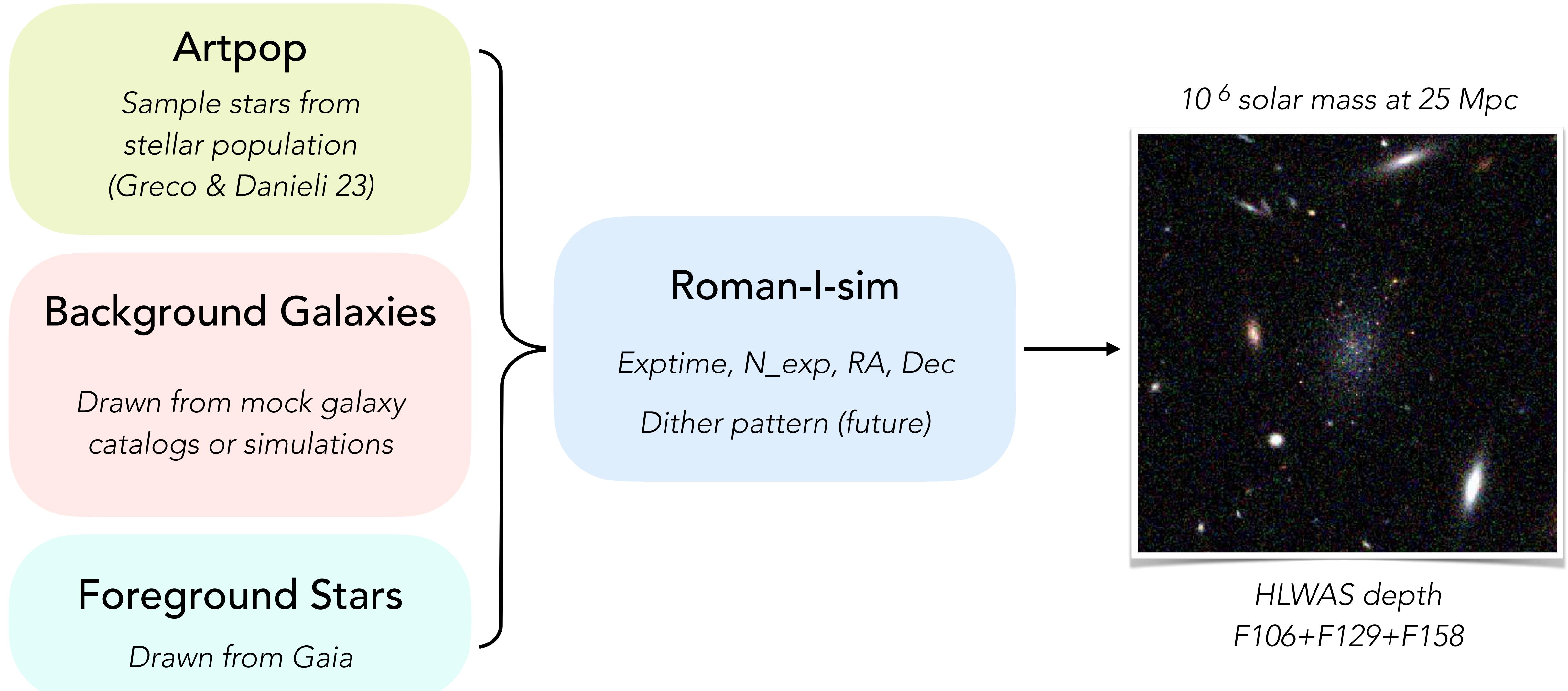
Image simulation is definitely needed



# Roman semi-resolved galaxy simulator



# RoSESim: Roman semi-resolved galaxy simulator



<https://github.com/AstroJacobLi/Rosesim>

# Foreground and Background

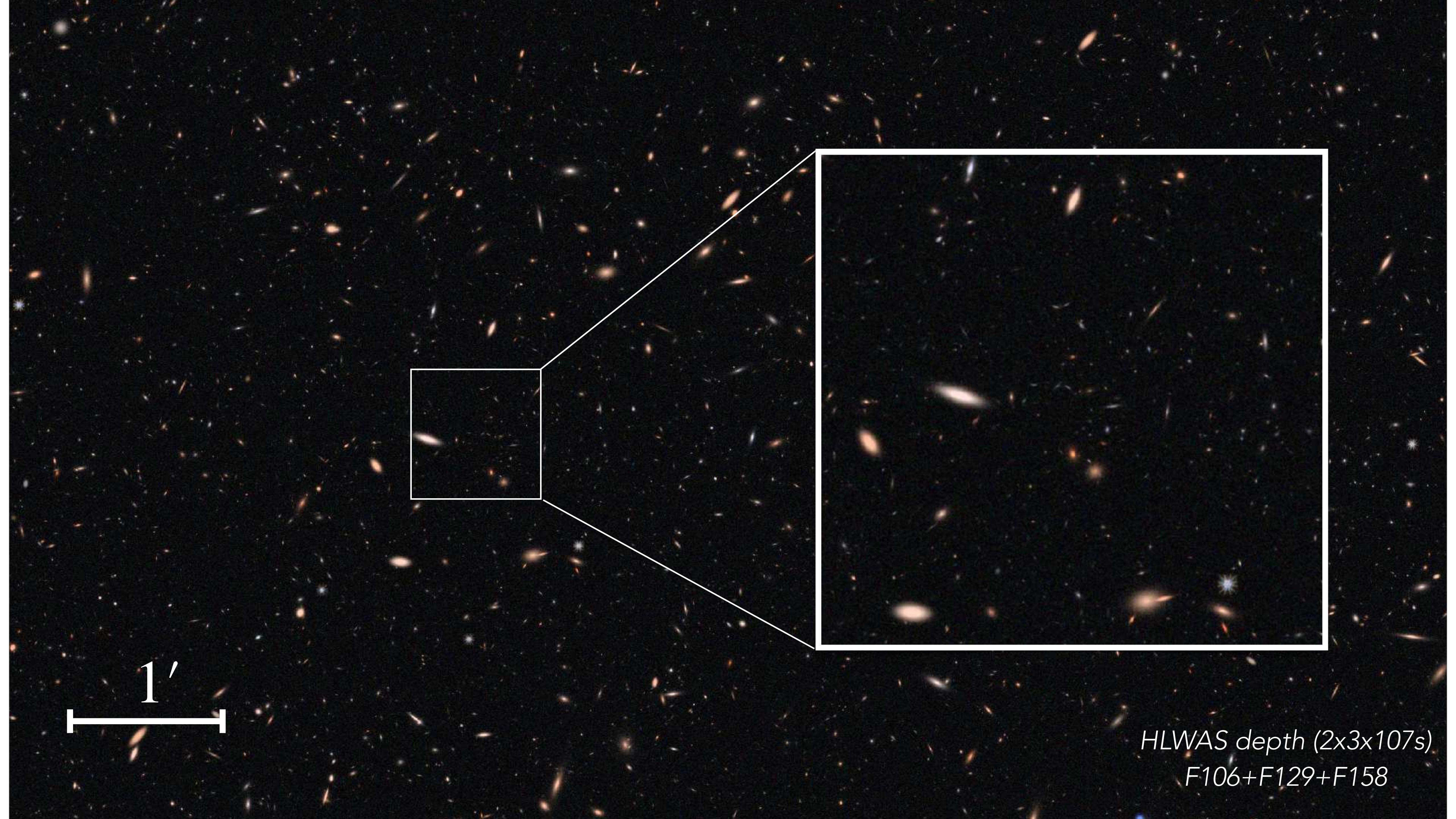
- Foreground stars: taken from Gaia (see [Romanism examples](#))
- Only to  $\sim$ 21 mag
- MW star simulator [TRILEGAL](#)
- Background galaxies: either from real catalogs (e.g., [COSMOS](#), CANDELS) or from mock catalogs (e.g., [CosmoDC2](#) for LSST-DESC; [Yung+23](#) for Roman); or using simulated images ([Troxel+23](#))
- We tried [JADES Extragalactic Ultra-deep Artificial Realization](#) (JAGUAR, Williams+18)
  - ▶ Made for JADES, 10 realizations of 11'x11' sky
  - ▶  $z=0.2-15$ ,  $\log(M^*) = 6 - 12$
  - ▶ Lots of JWST filters, can be easily transformed to Roman filters
  - ▶ Galaxies are modeled with Sersic profiles





1'

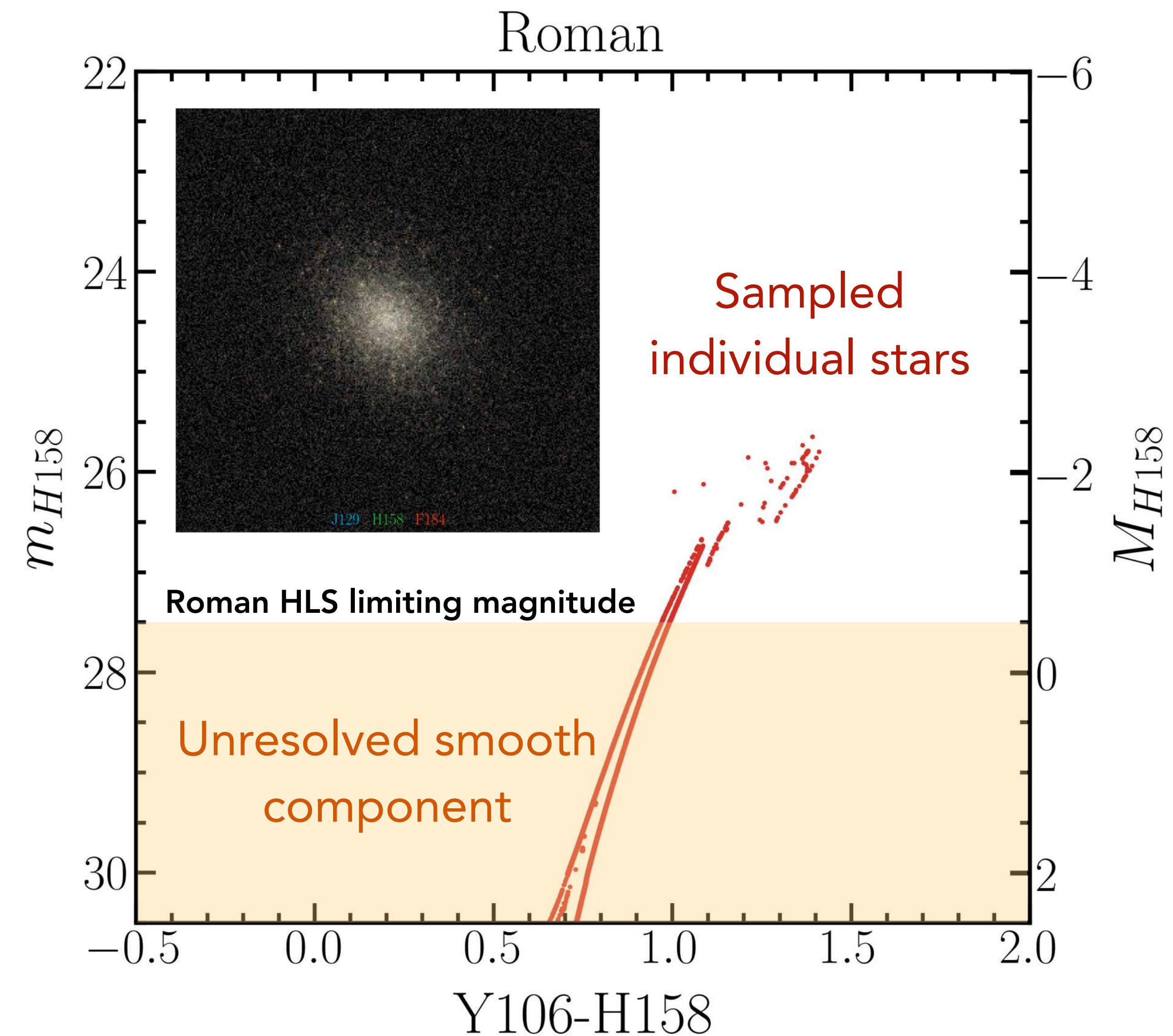
HLWAS depth (2x3x107s)  
F106+F129+F158



*HLWAS depth (2x3x107s)*  
*F106+F129+F158*

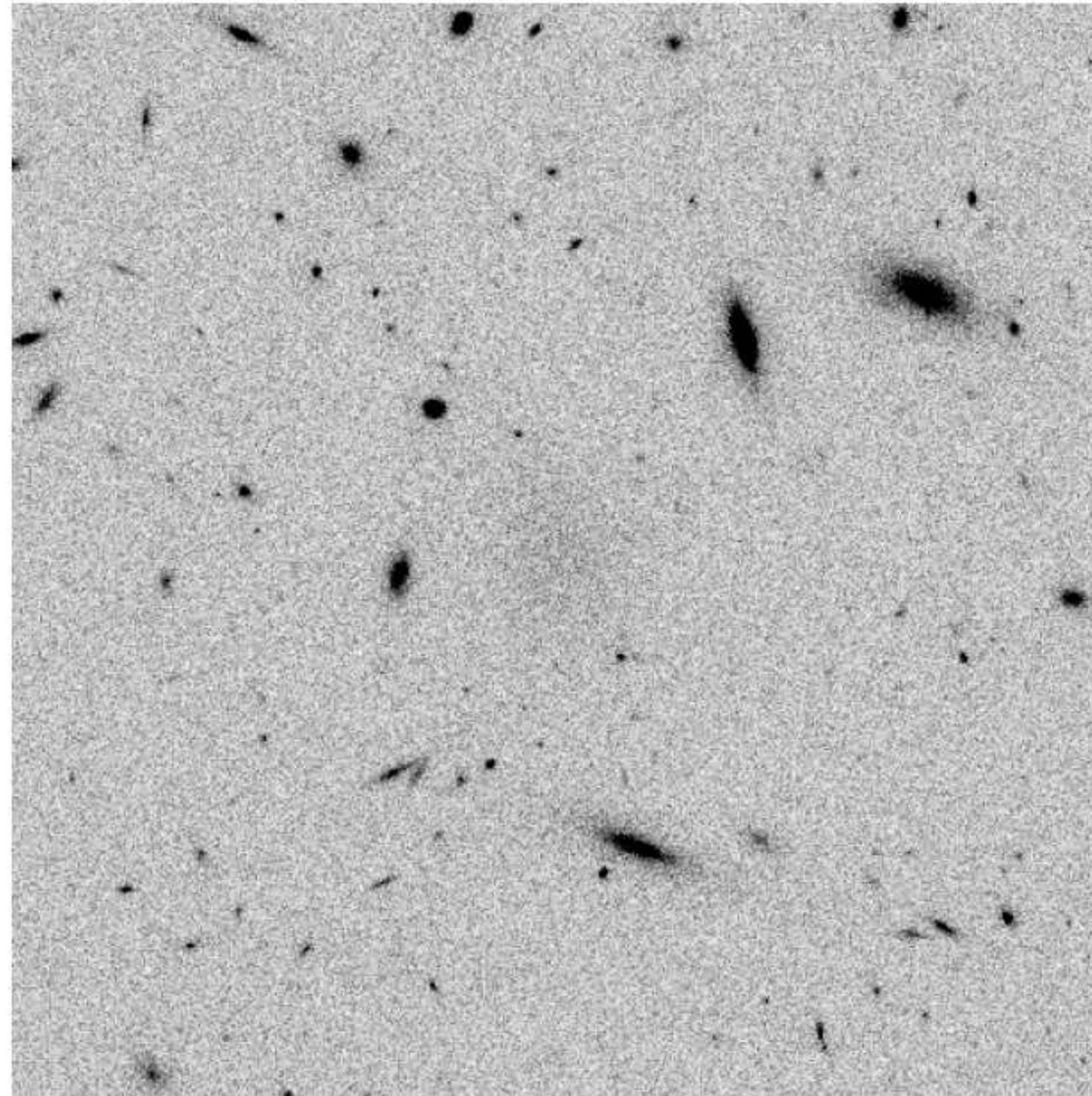
# Semi-Resolved Dwarf

- A semi-resolved dwarf should be decomposed into two parts: resolved and unresolved
- Resolved component dominates SBF
- In **ArtPop**, You can specify a magnitude threshold above which you sample individual stars
- Both resolved stars and smooth component follow a Sersic profile
- Can choose MIST vs PARSEC

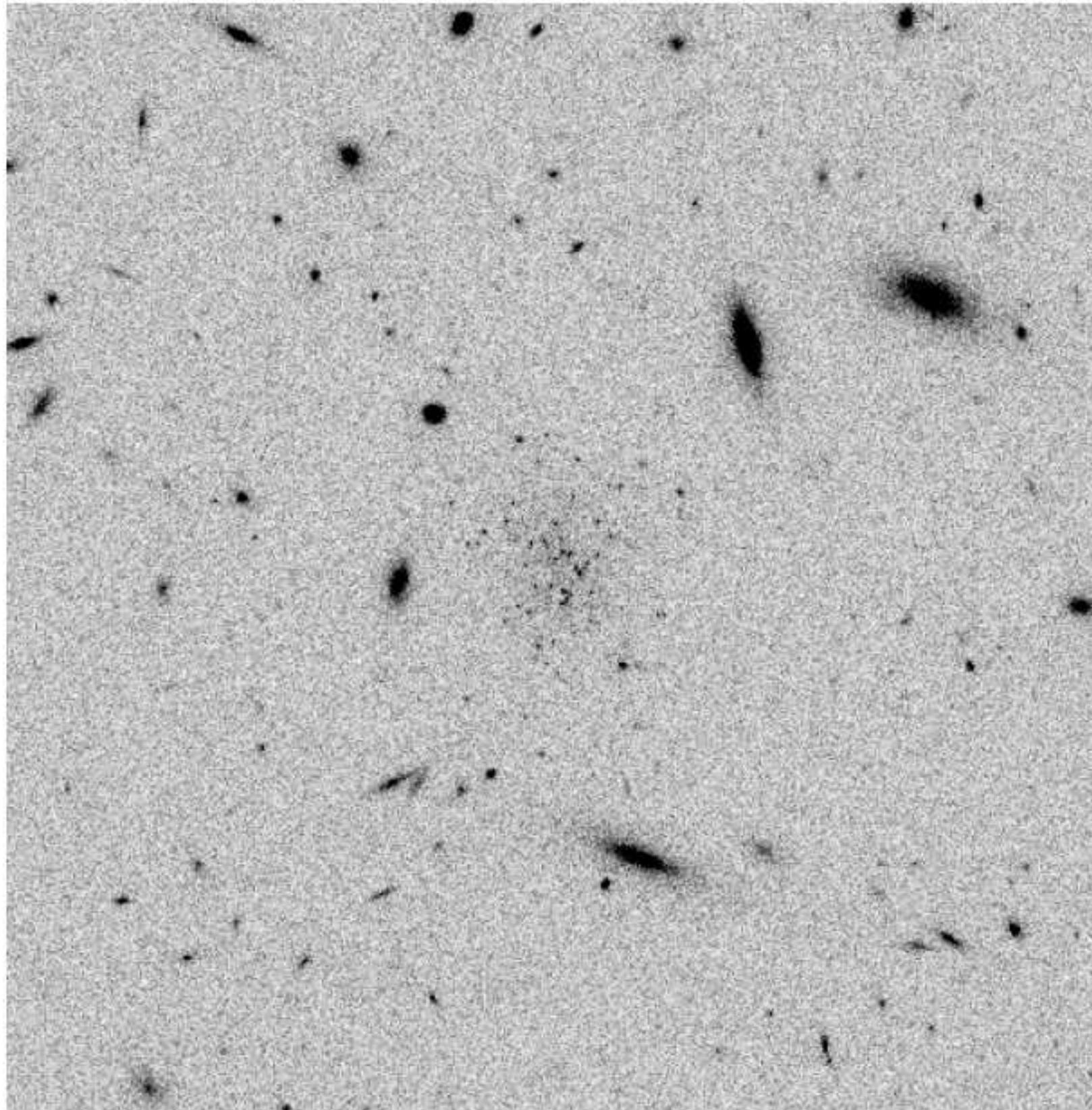


# Semi-Resolved Dwarf

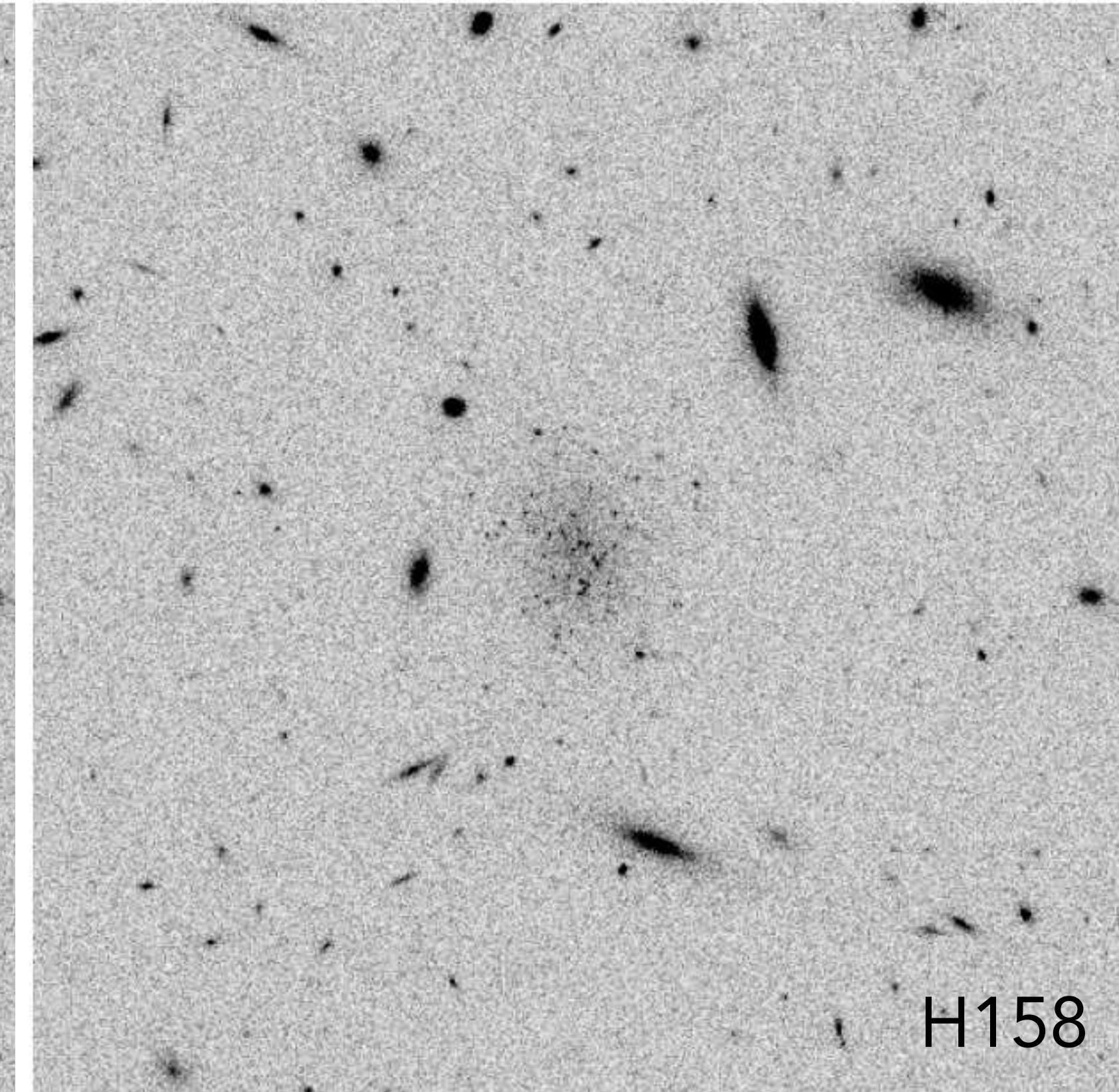
Unresolved smooth component



Sampled individual stars



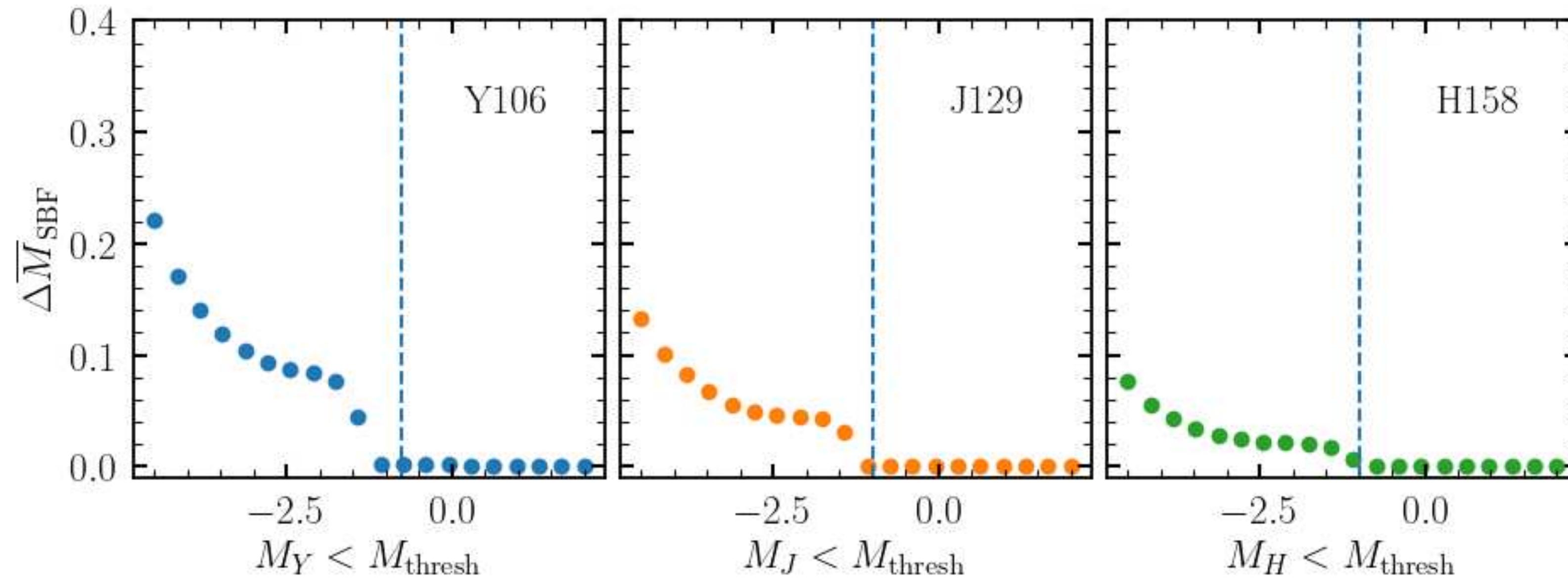
Together



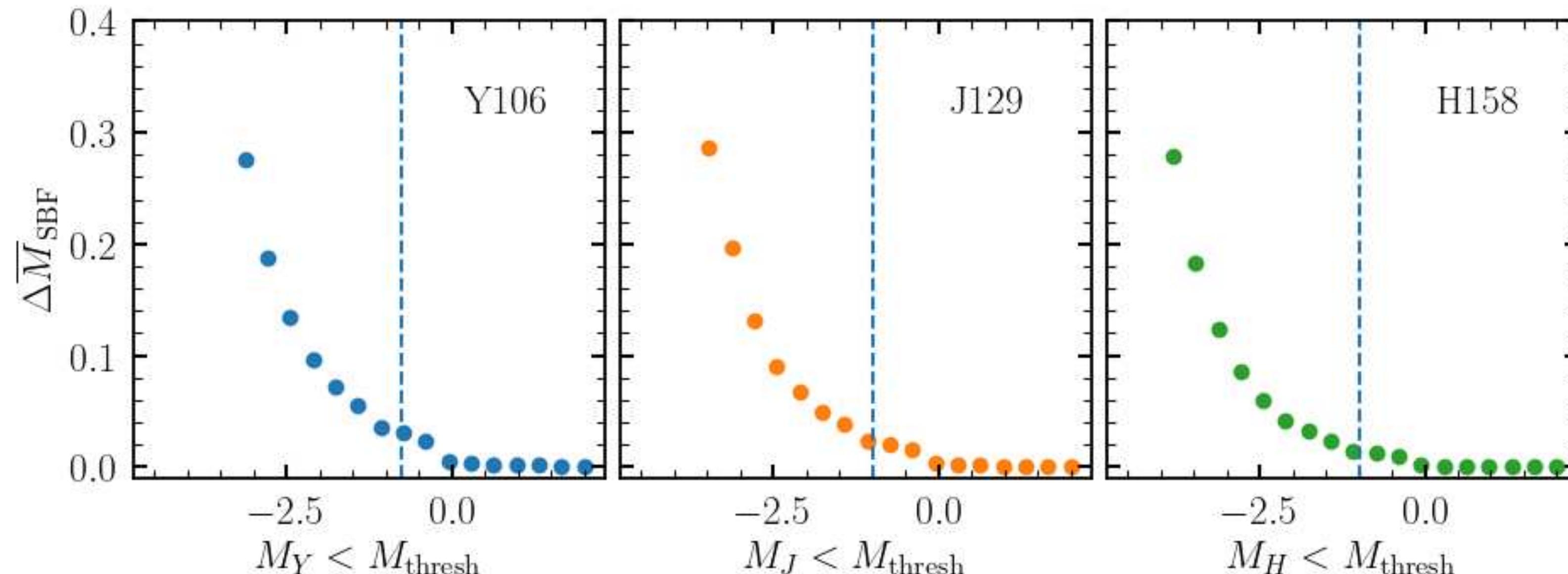
H158

# Star sampling threshold

$M_{\text{abs}} = -1$  is safe



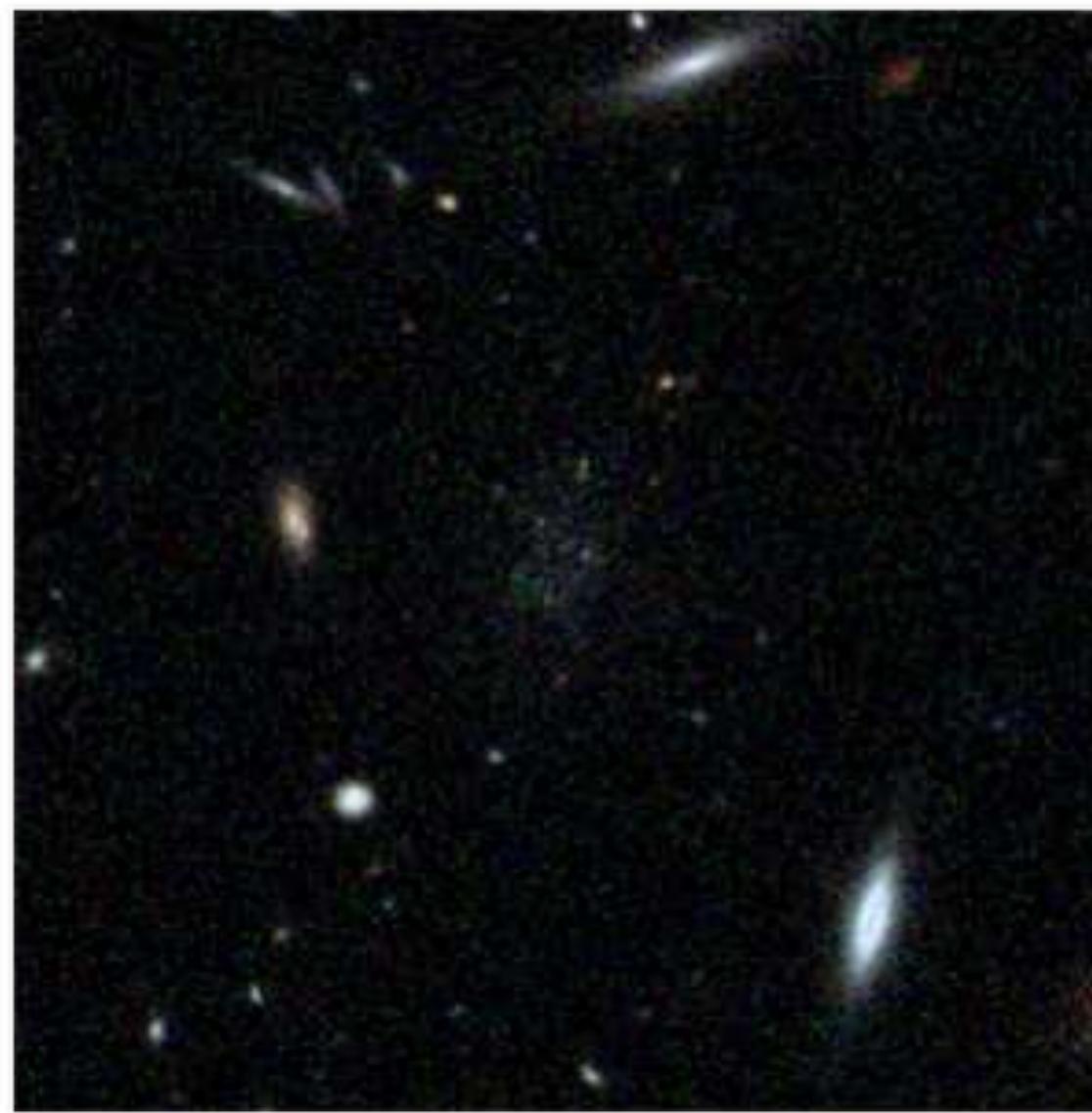
0.4 Gyr, [Fe/H]=-1.5



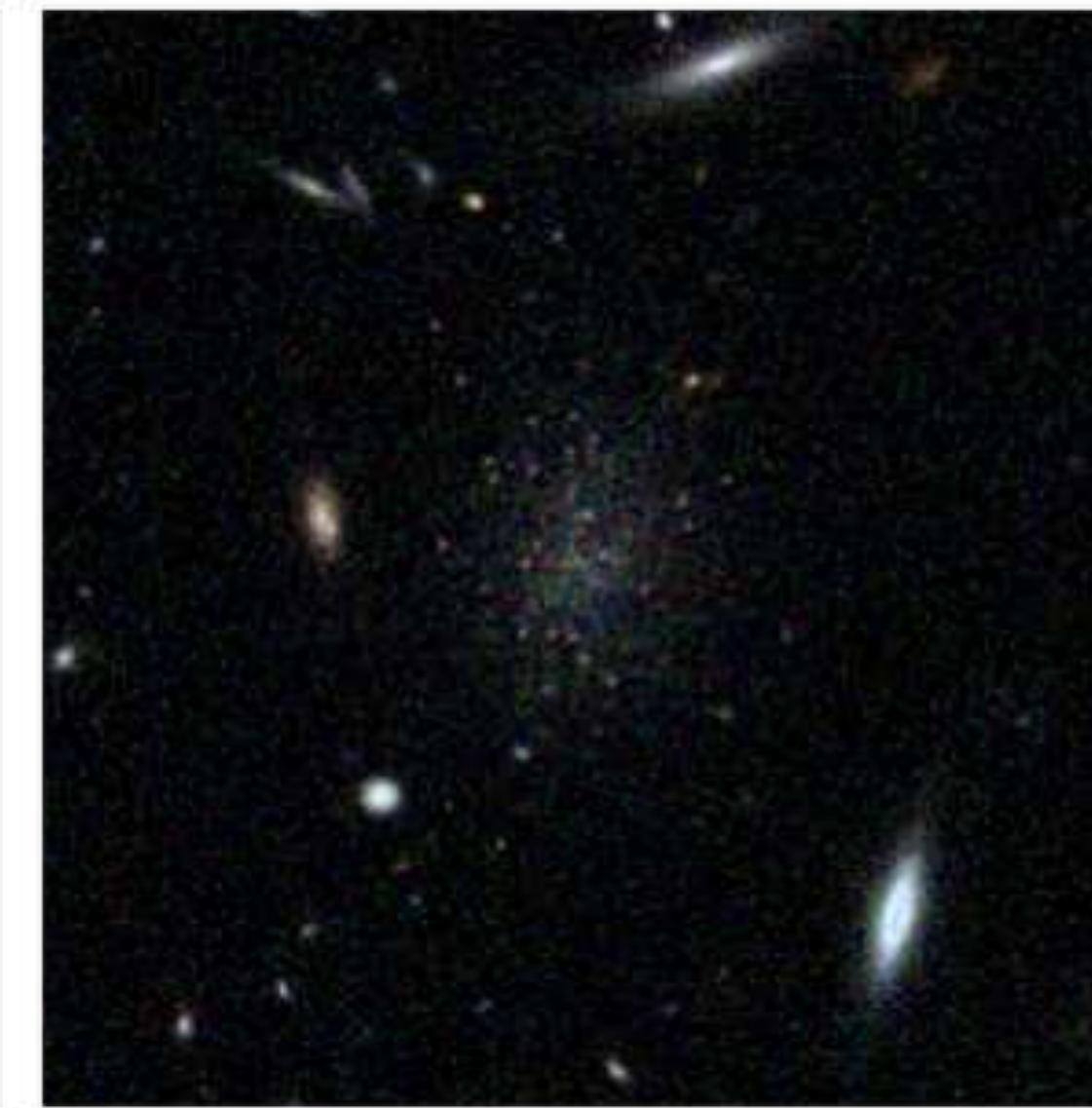
4 Gyr, [Fe/H]=-1.5

$$\bar{F}_{\text{SBF}} = \frac{\sum_i \overline{N}_i L_i^2}{\sum_i \overline{N}_i L_i}$$

20 Mpc



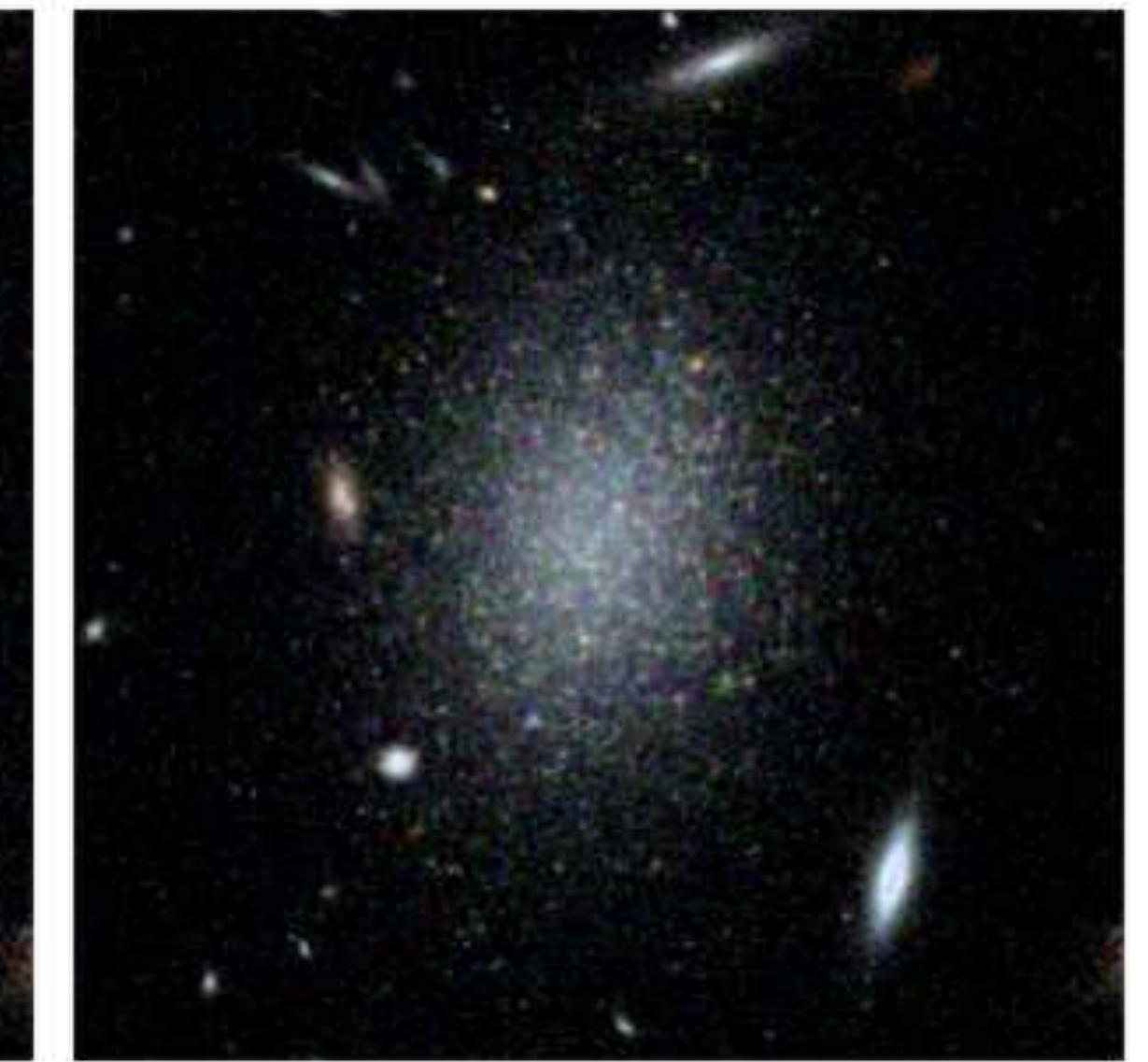
$\log(M^*)=6.0$



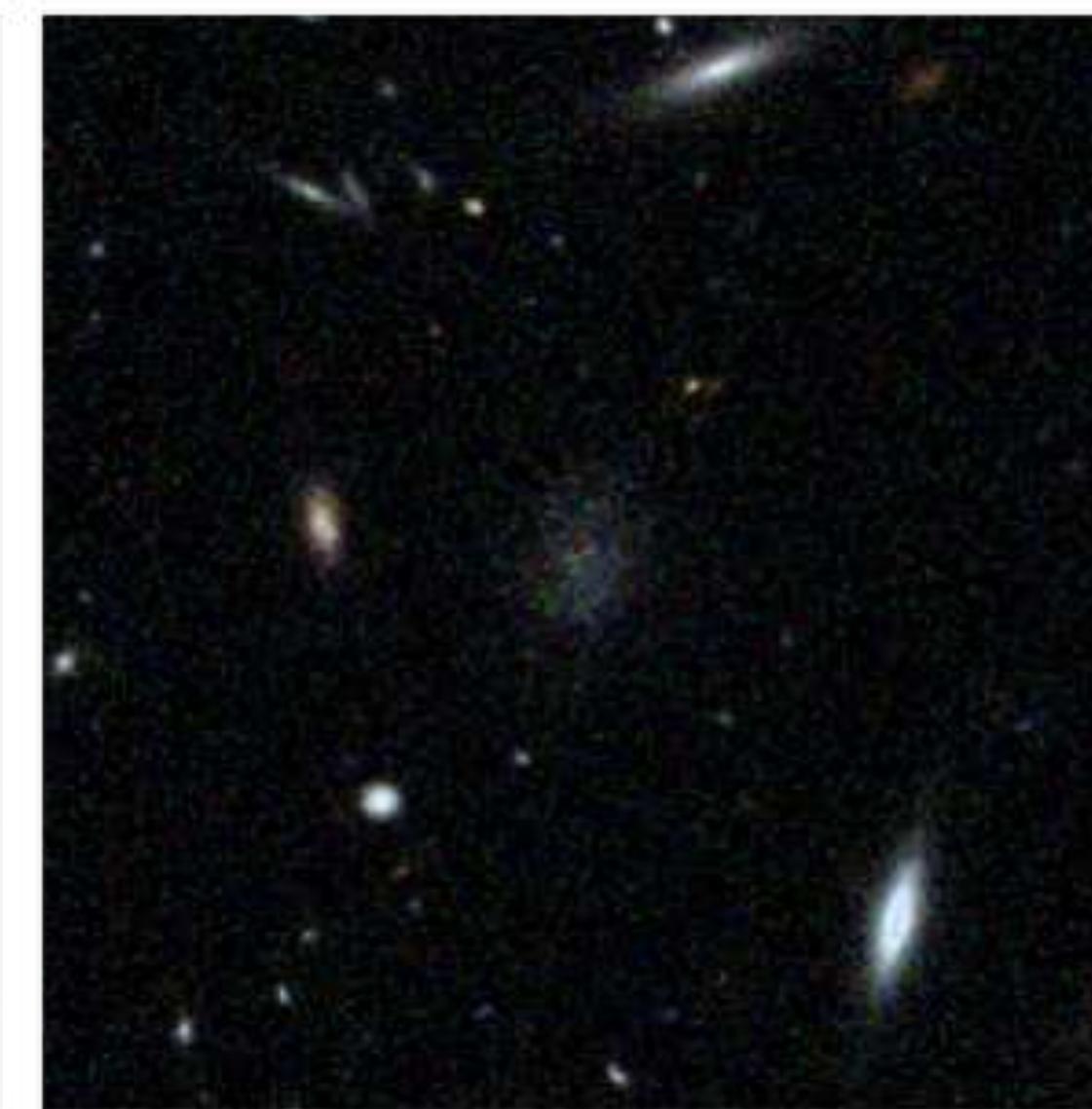
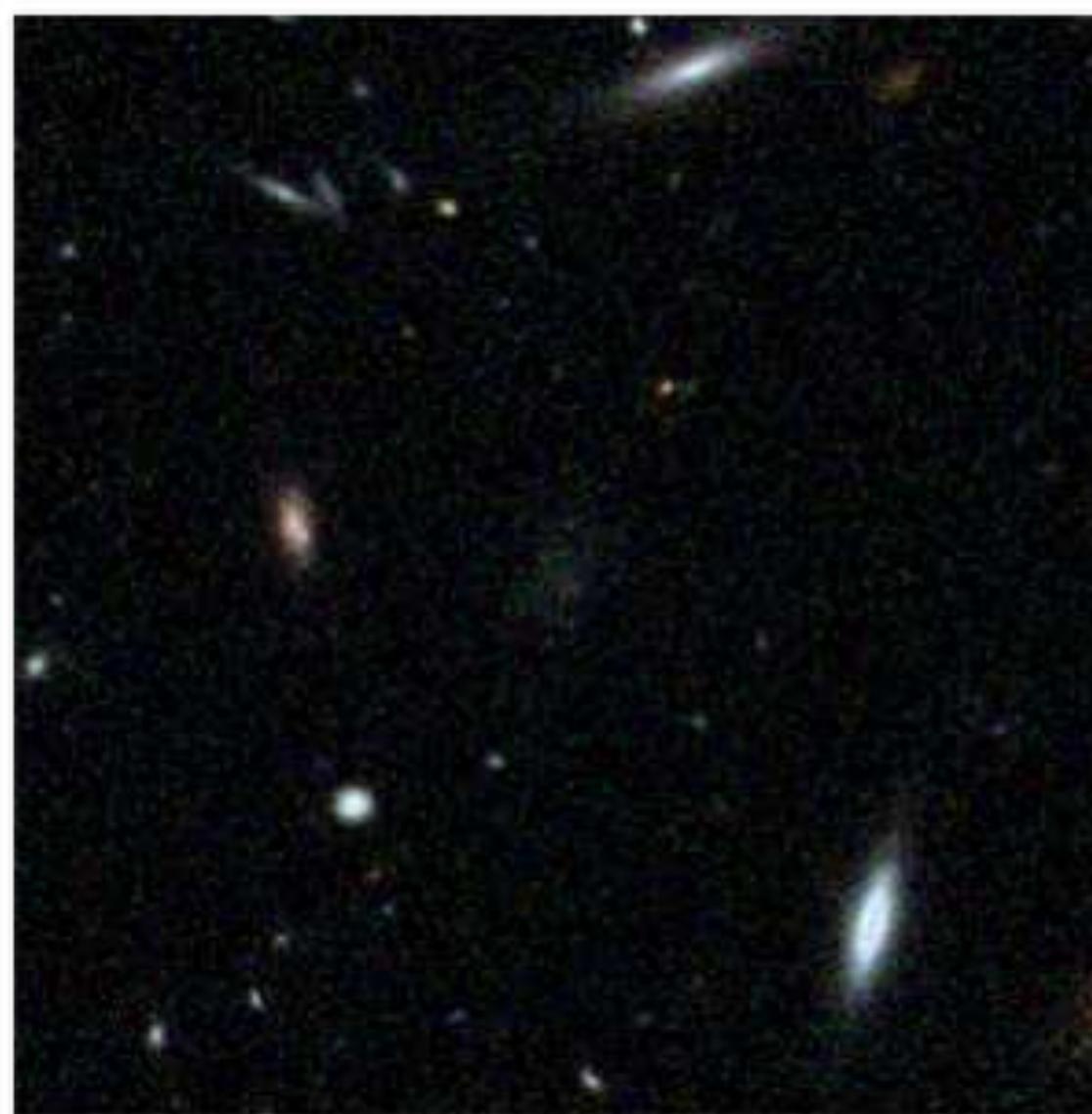
$\log(M^*)=6.5$



$\log(M^*)=7.0$

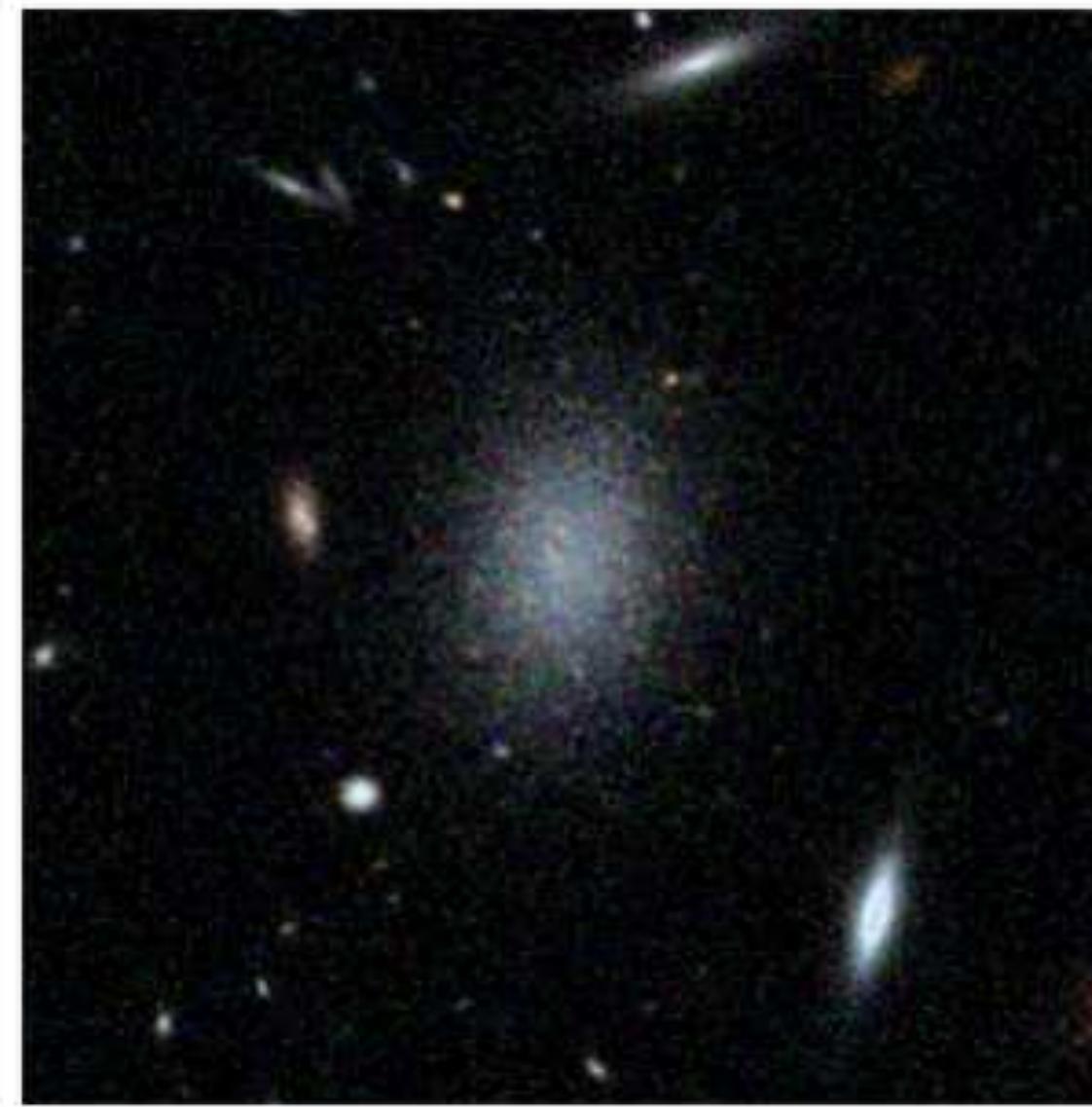
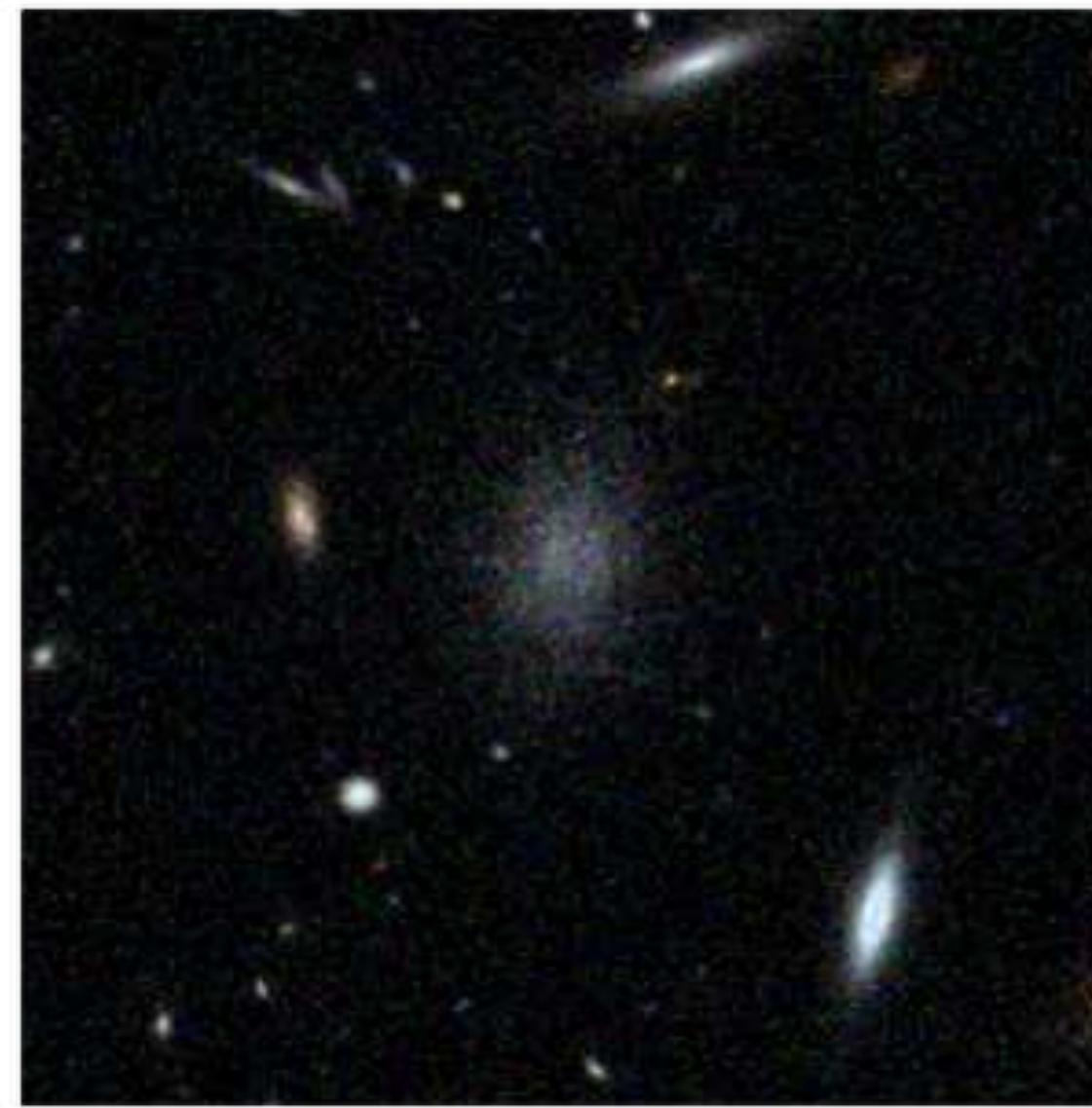
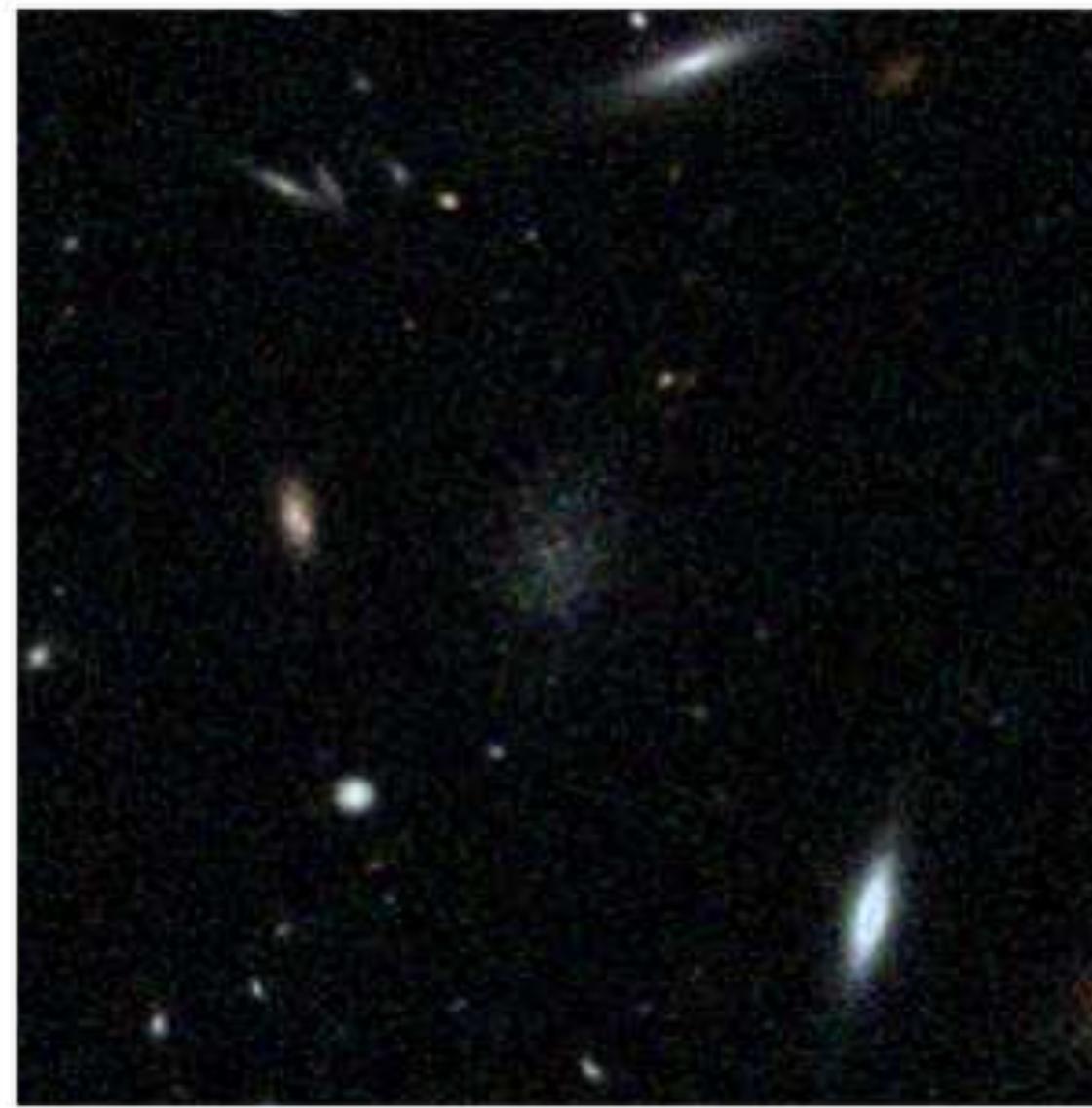
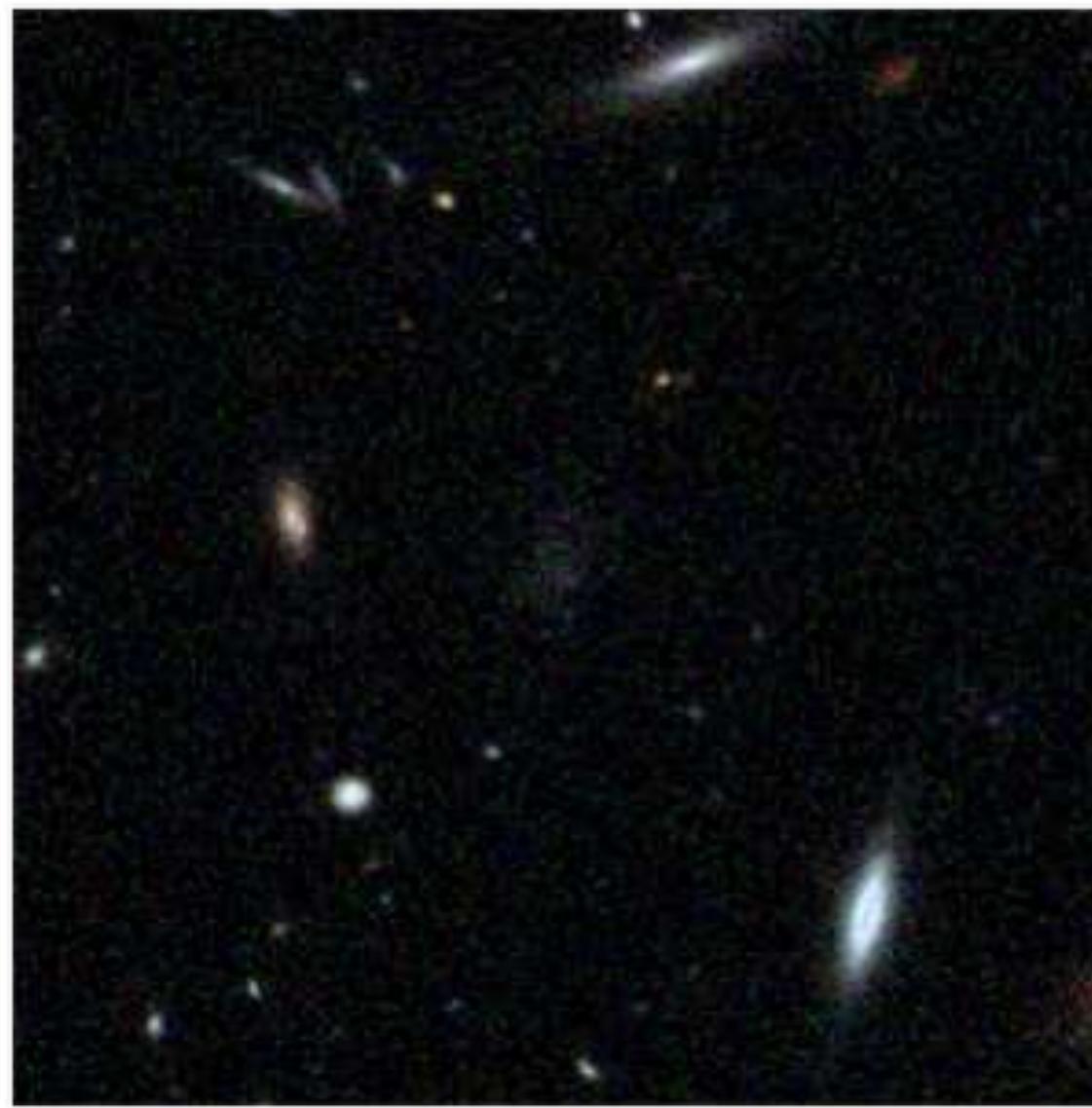


35 Mpc

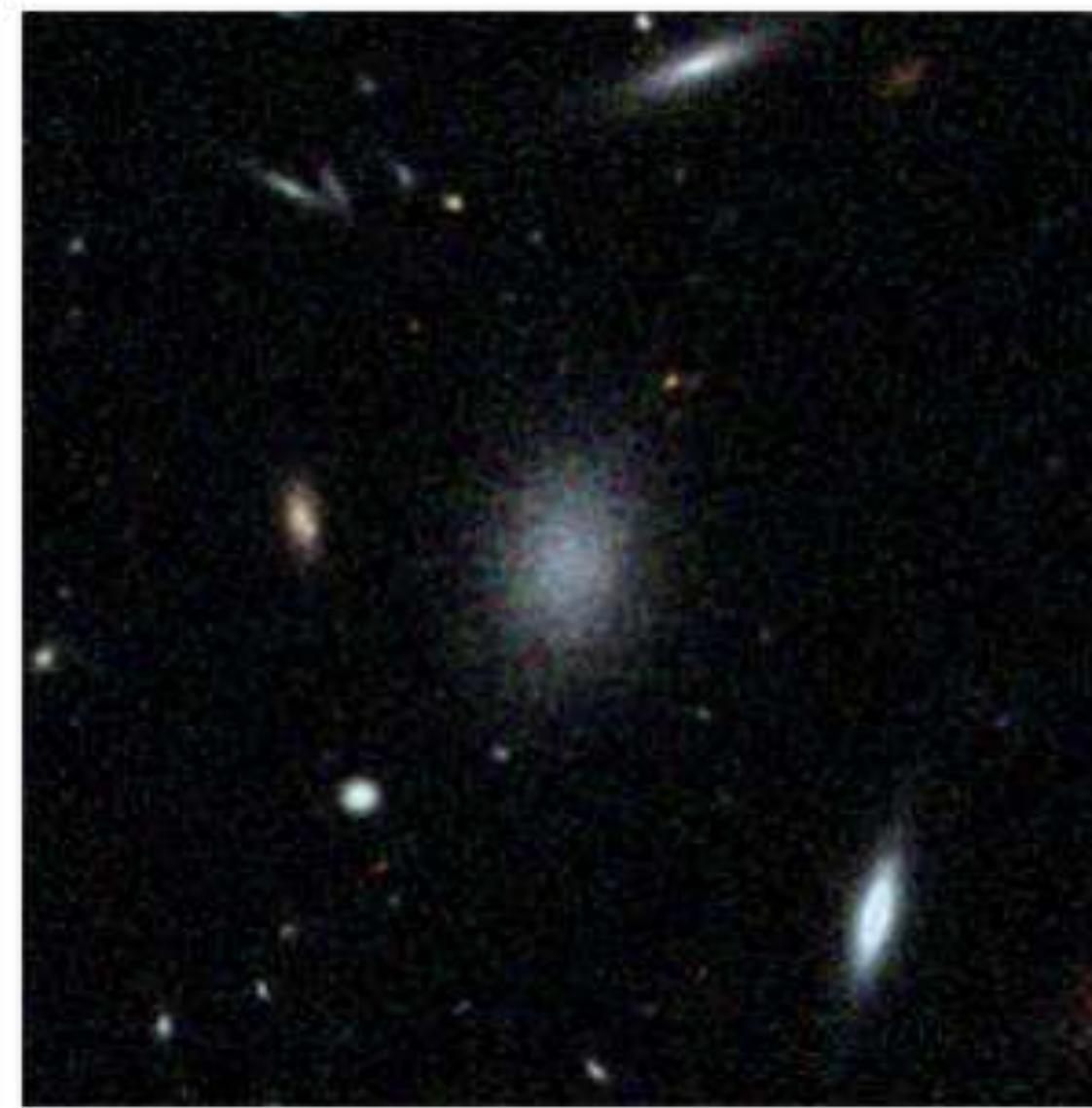
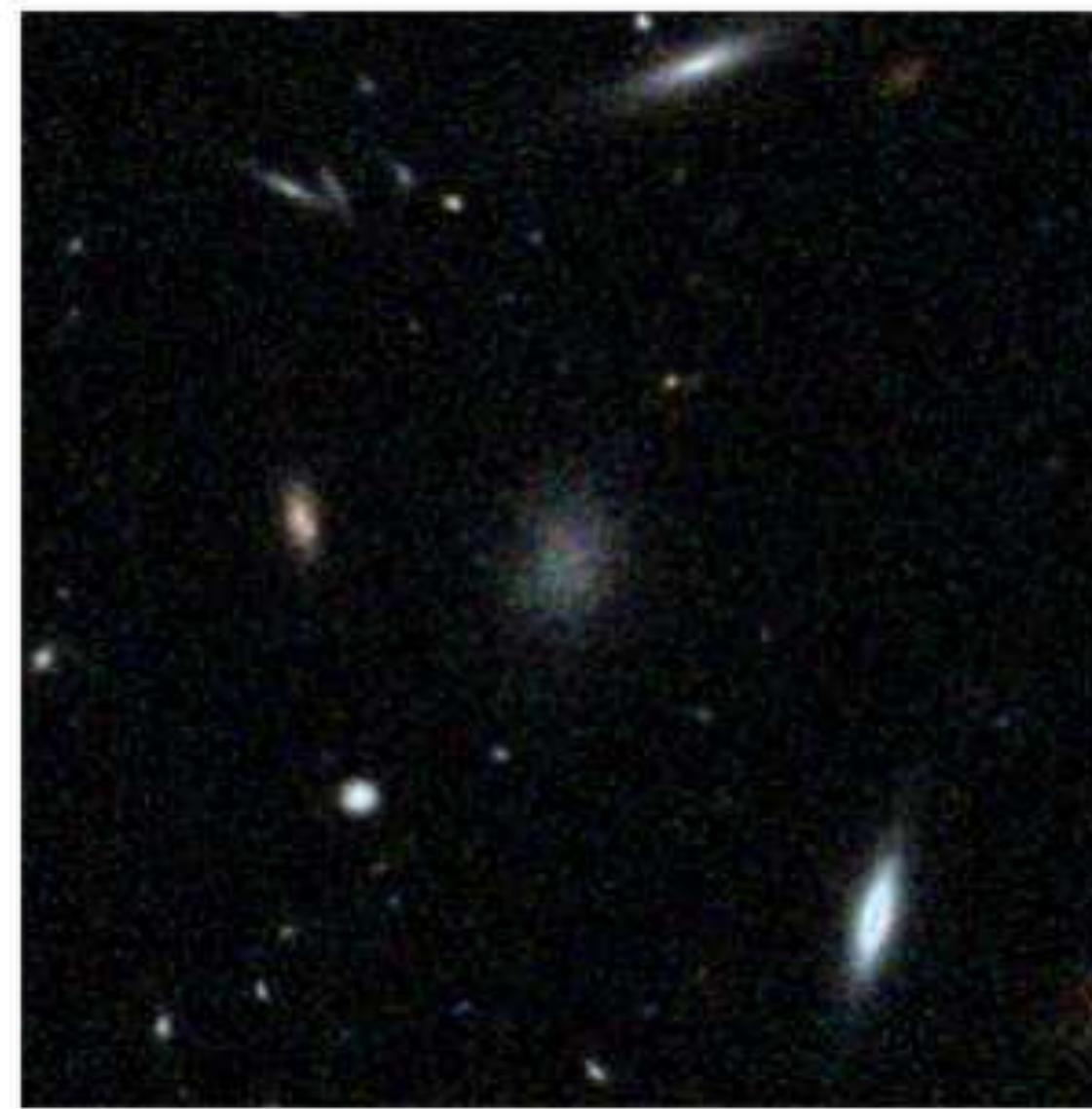
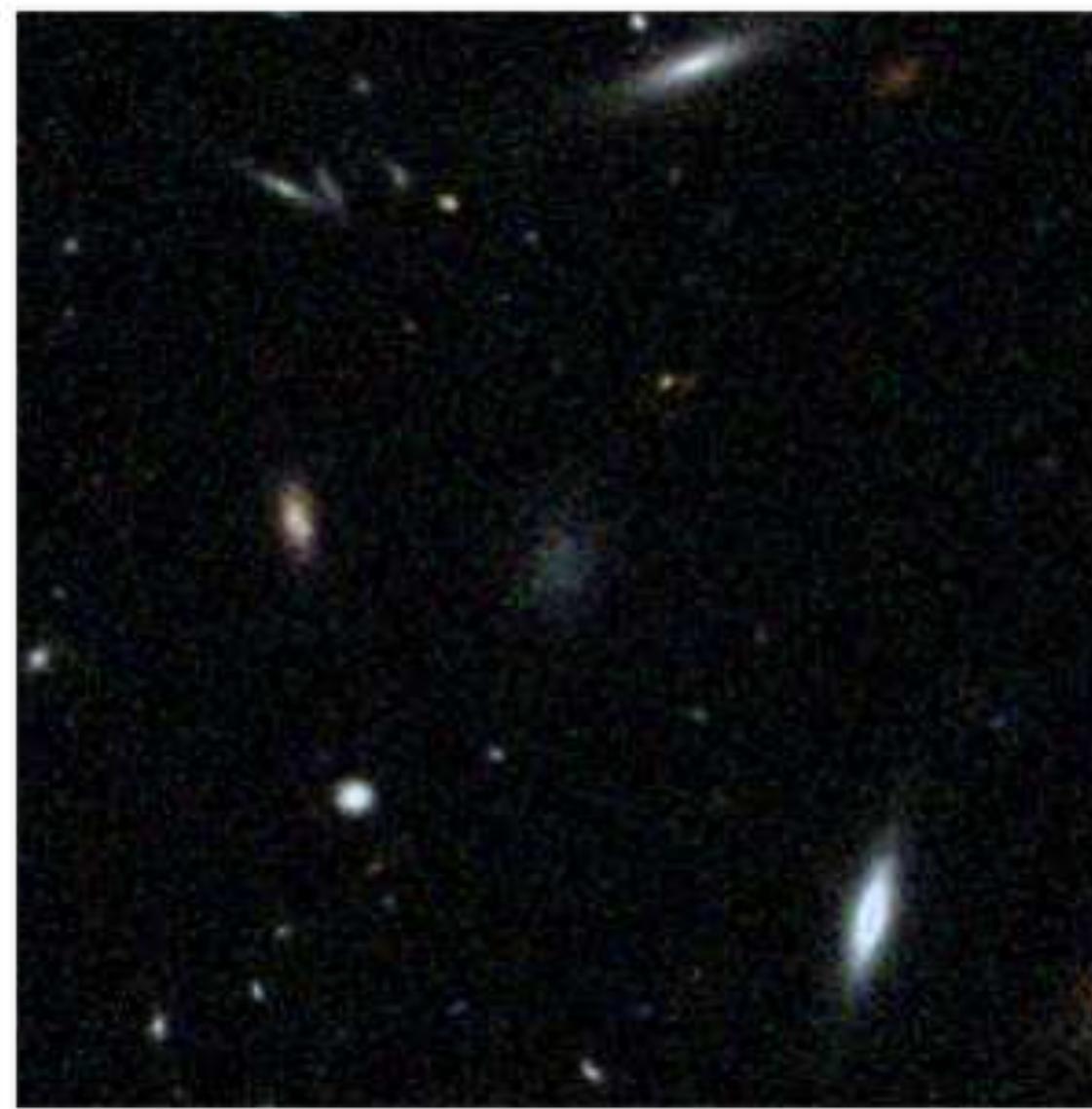
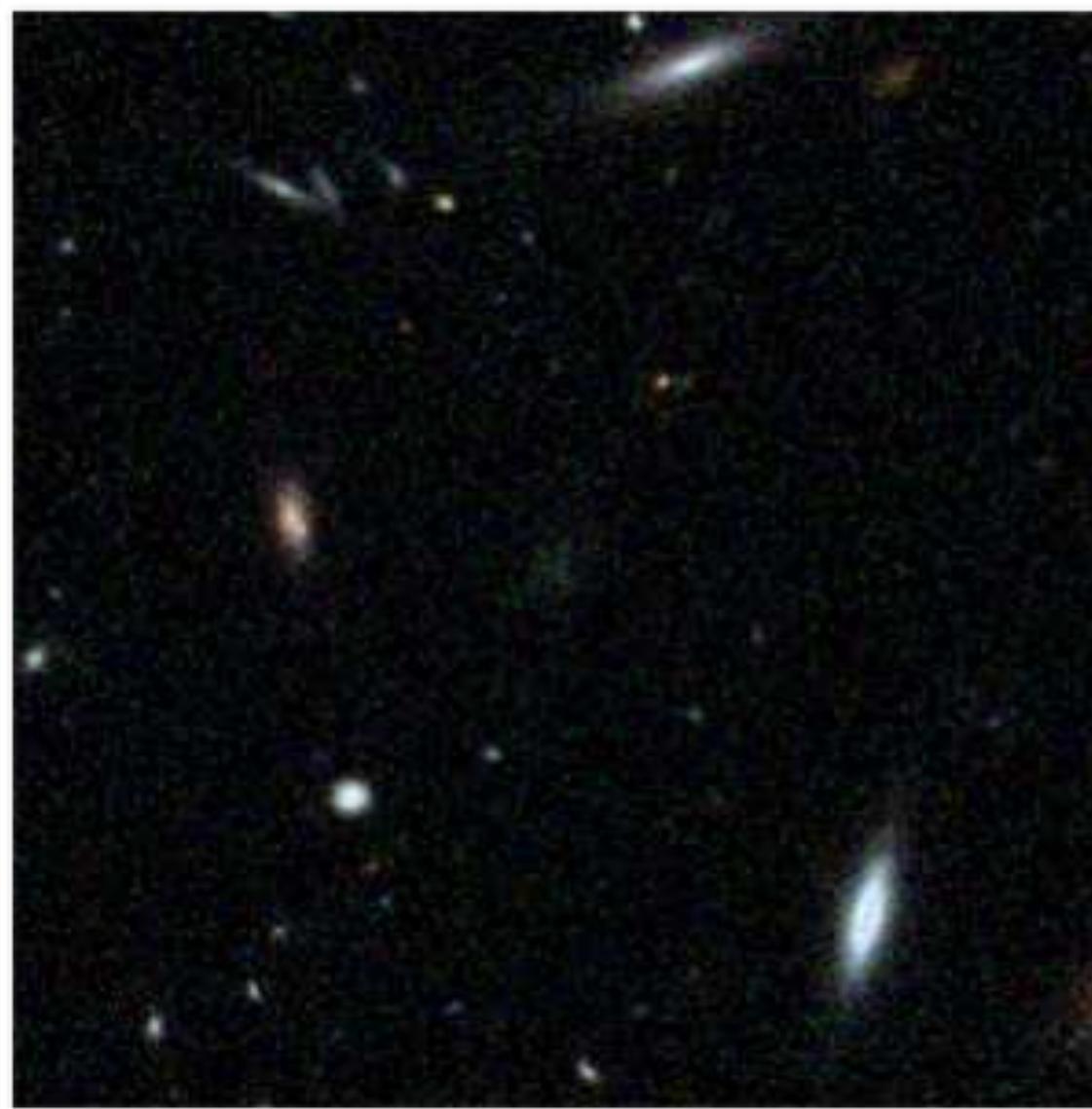


All are SSPs with 1 Gyr,  $[Fe/H]=-1.5$

**35 Mpc**

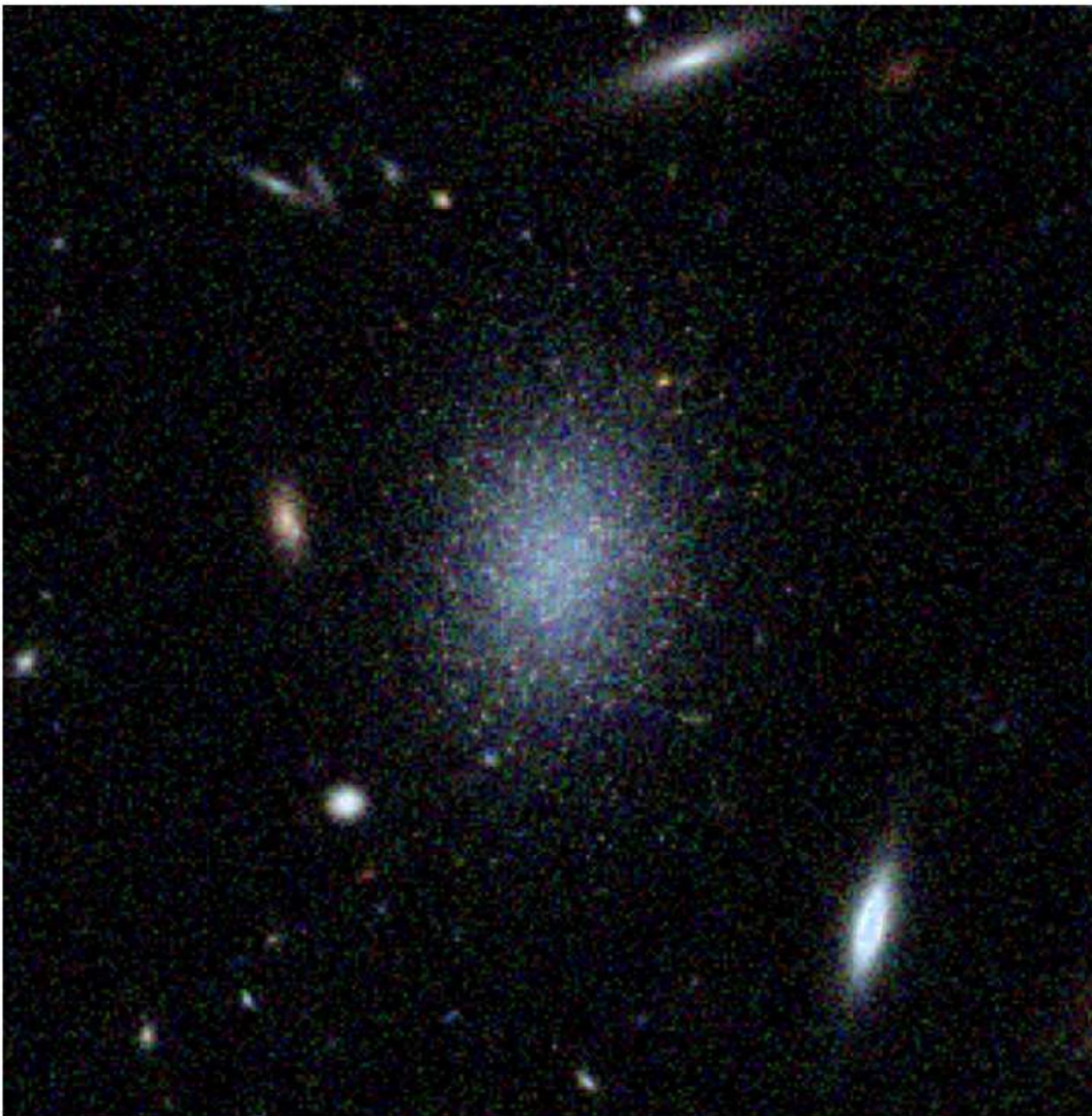


**50 Mpc**

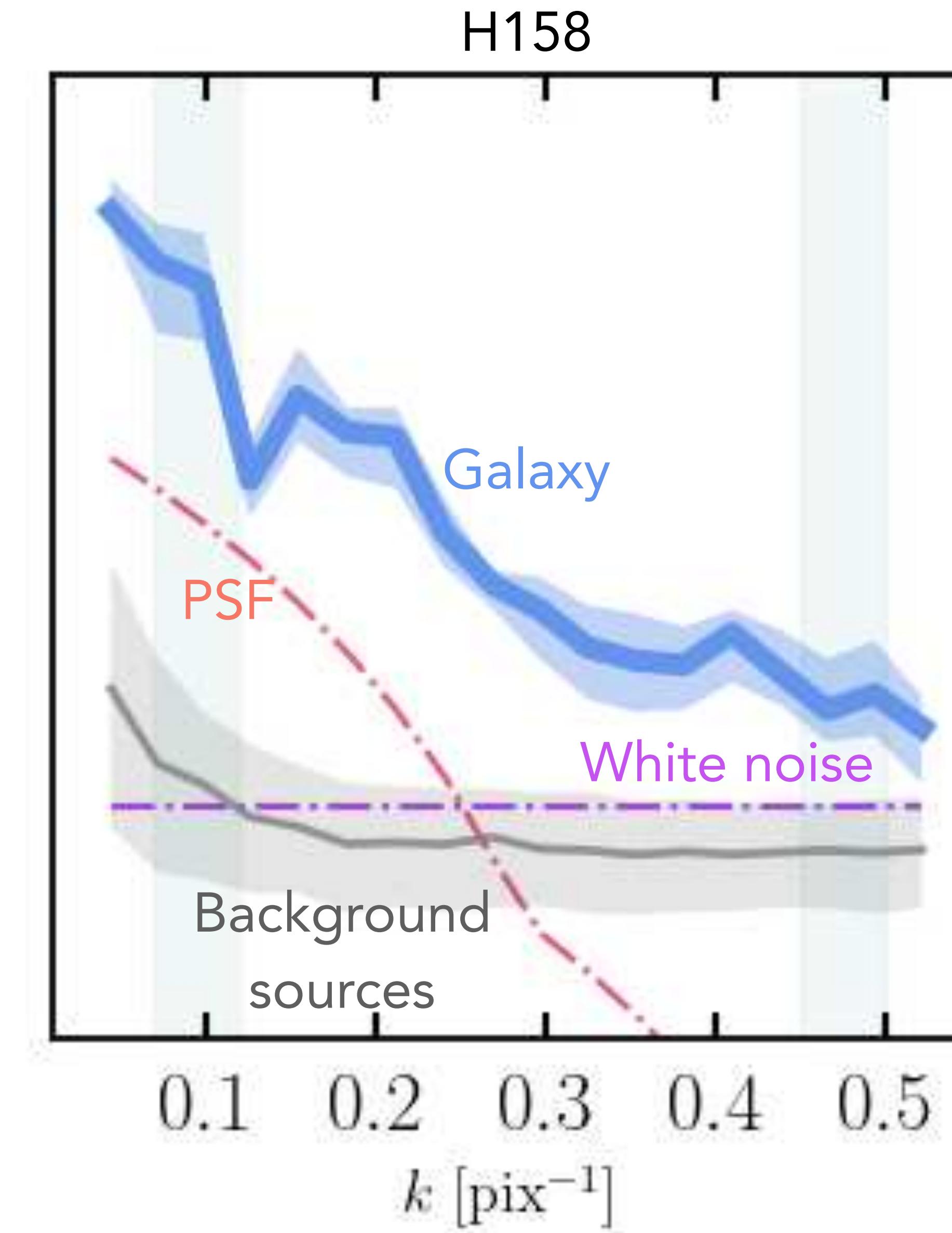


All are SSPs with 1 Gyr, [Fe/H]=-1.5

# SBF measurements

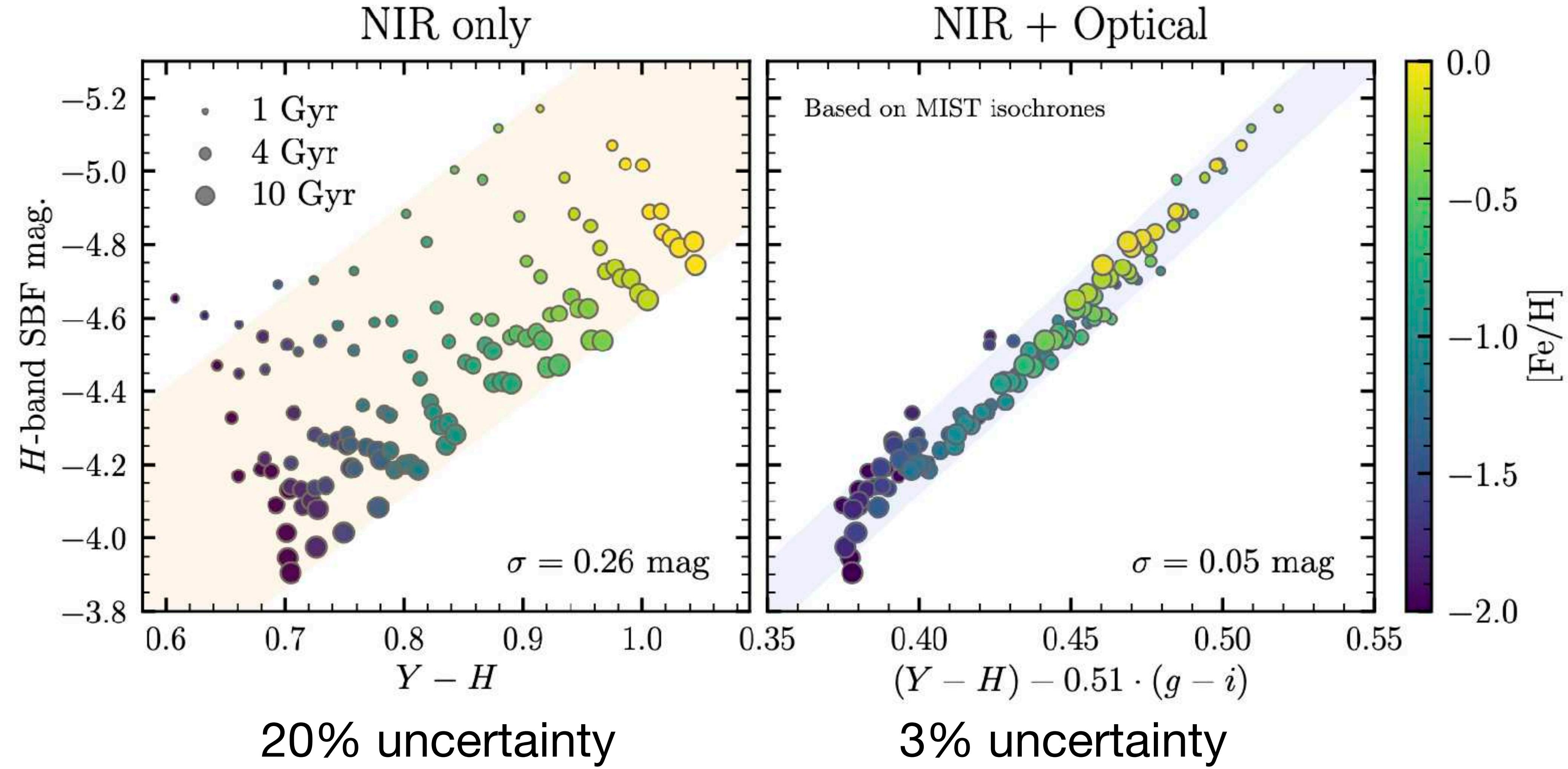


$\log(M^*)=7.0$ ,  $D=35$  Mpc  
Age = 0.4 Gyr,  $[\text{Fe}/\text{H}]=-1.5$



# SBF challenge 1: calibration in NIR

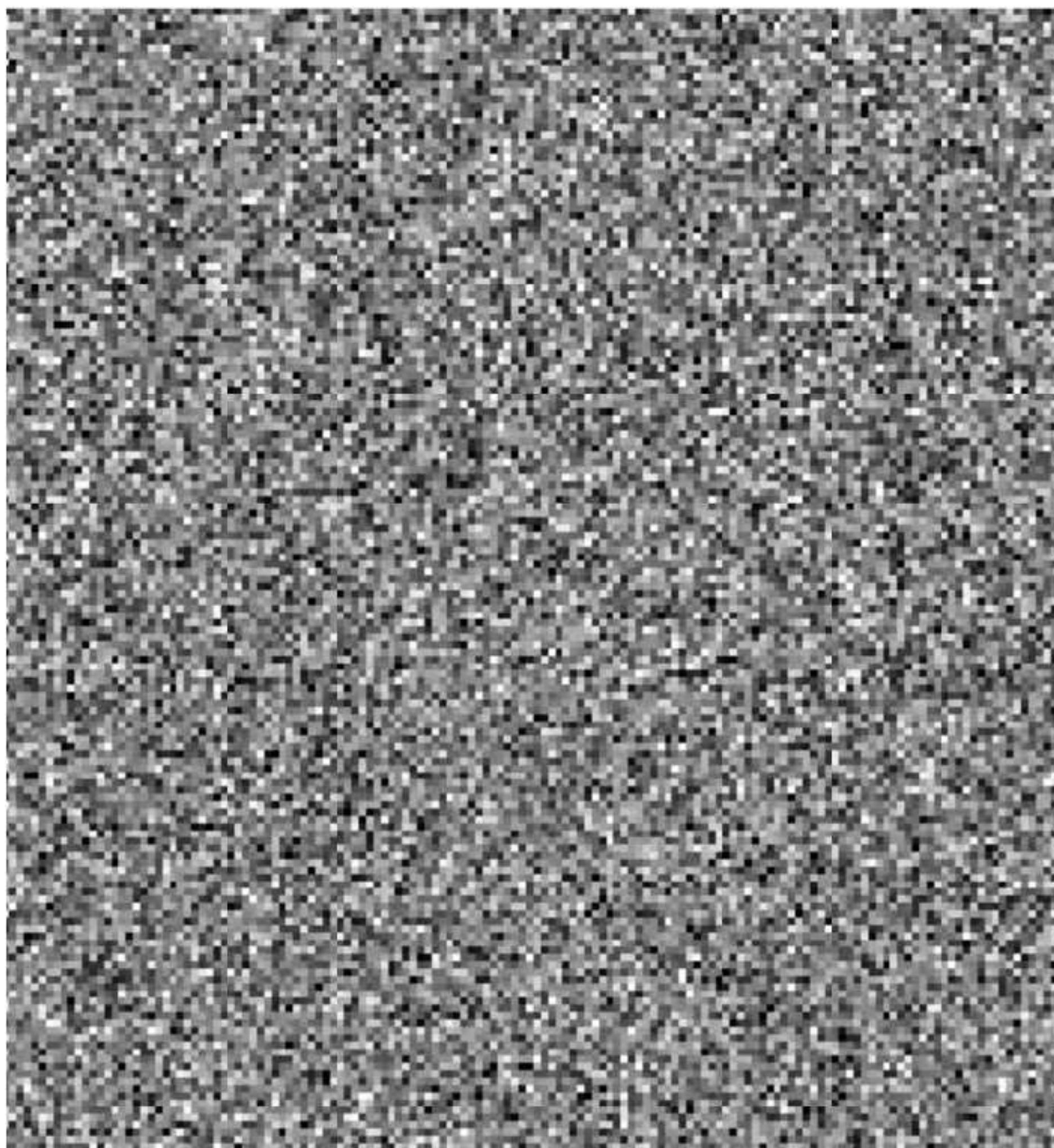
Li+ (in prep)



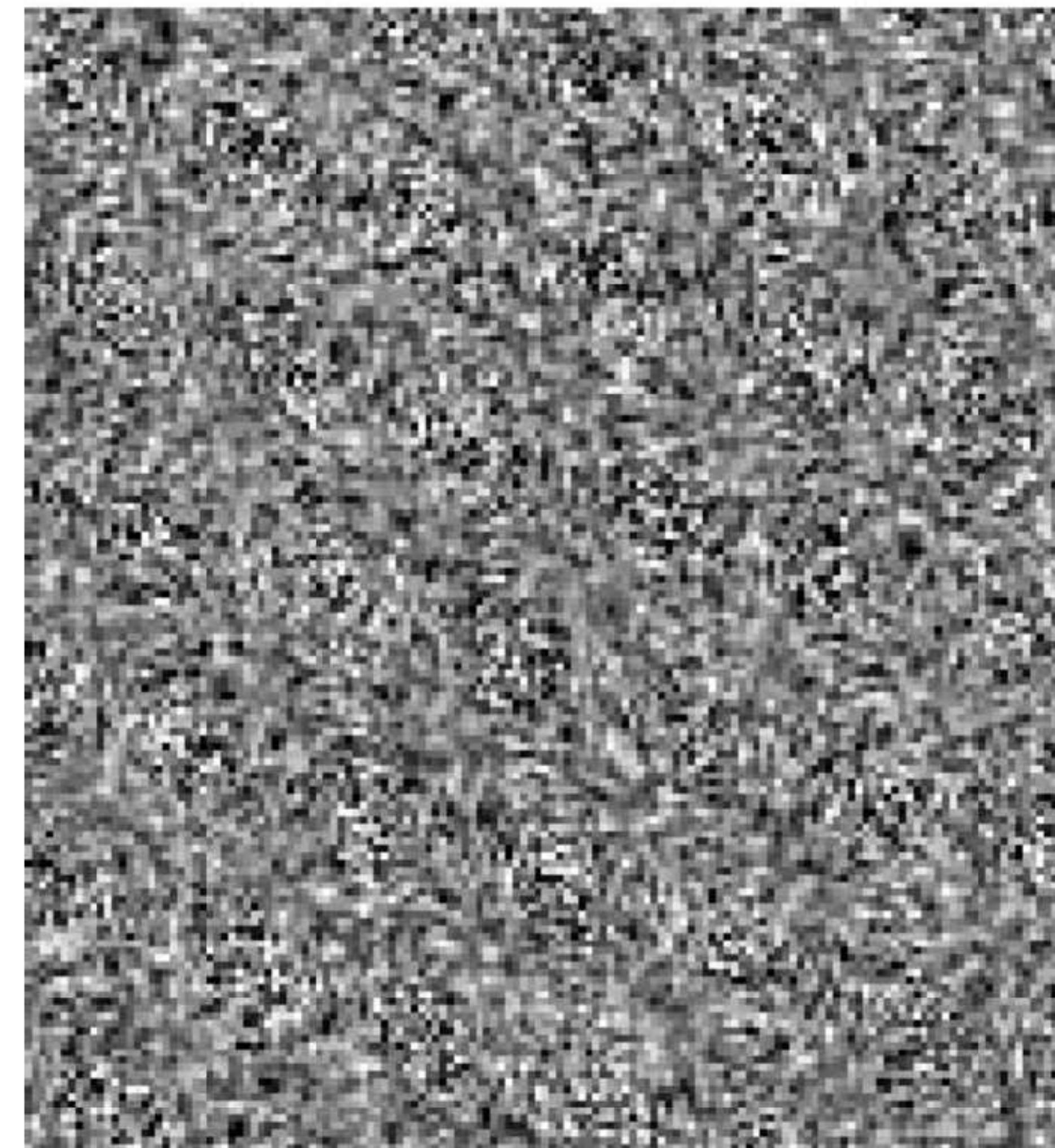
We will calibrate this using JWST archival imaging data

# SBF challenge 2: correlated noise

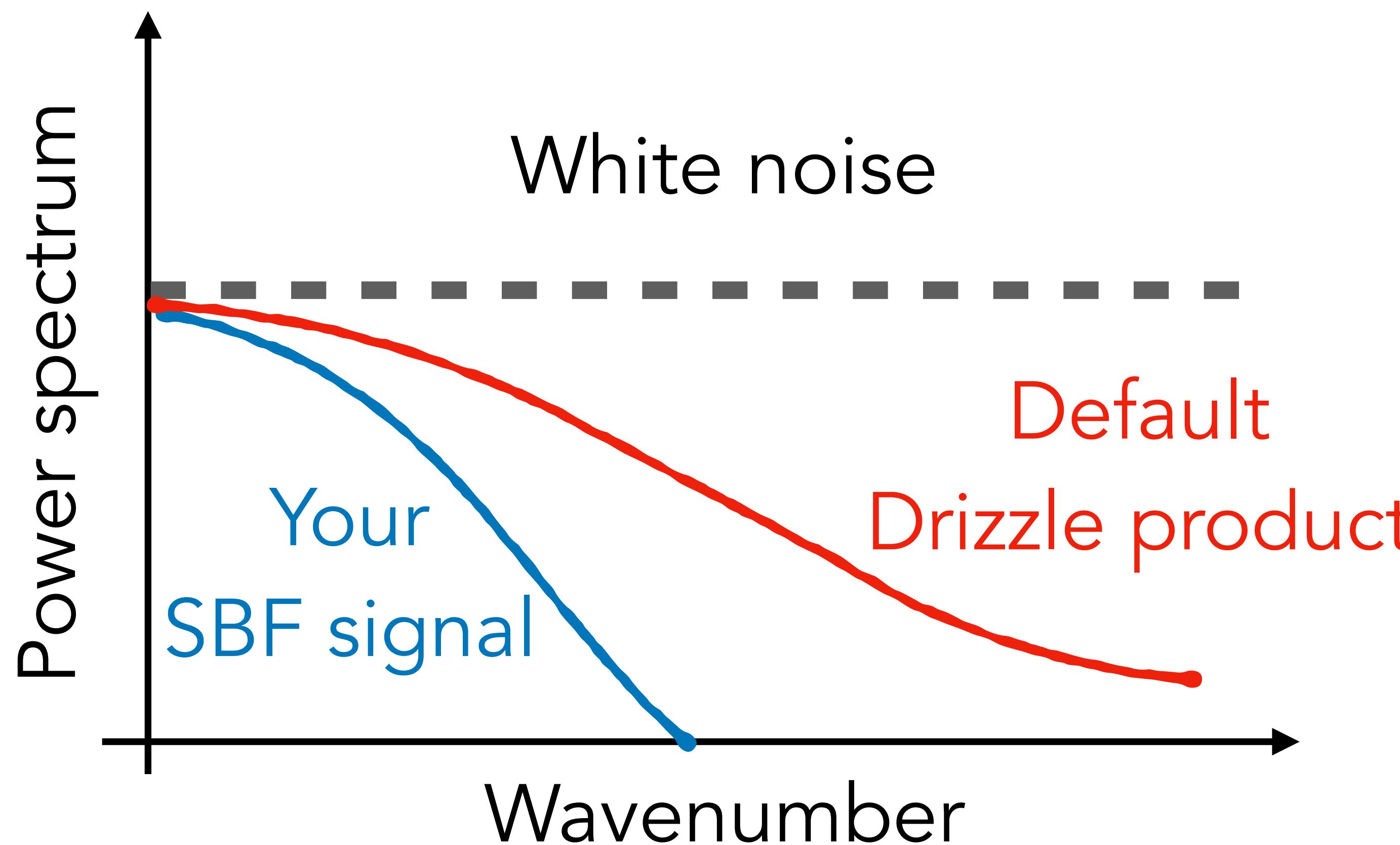
White noise



Default Drizzle product

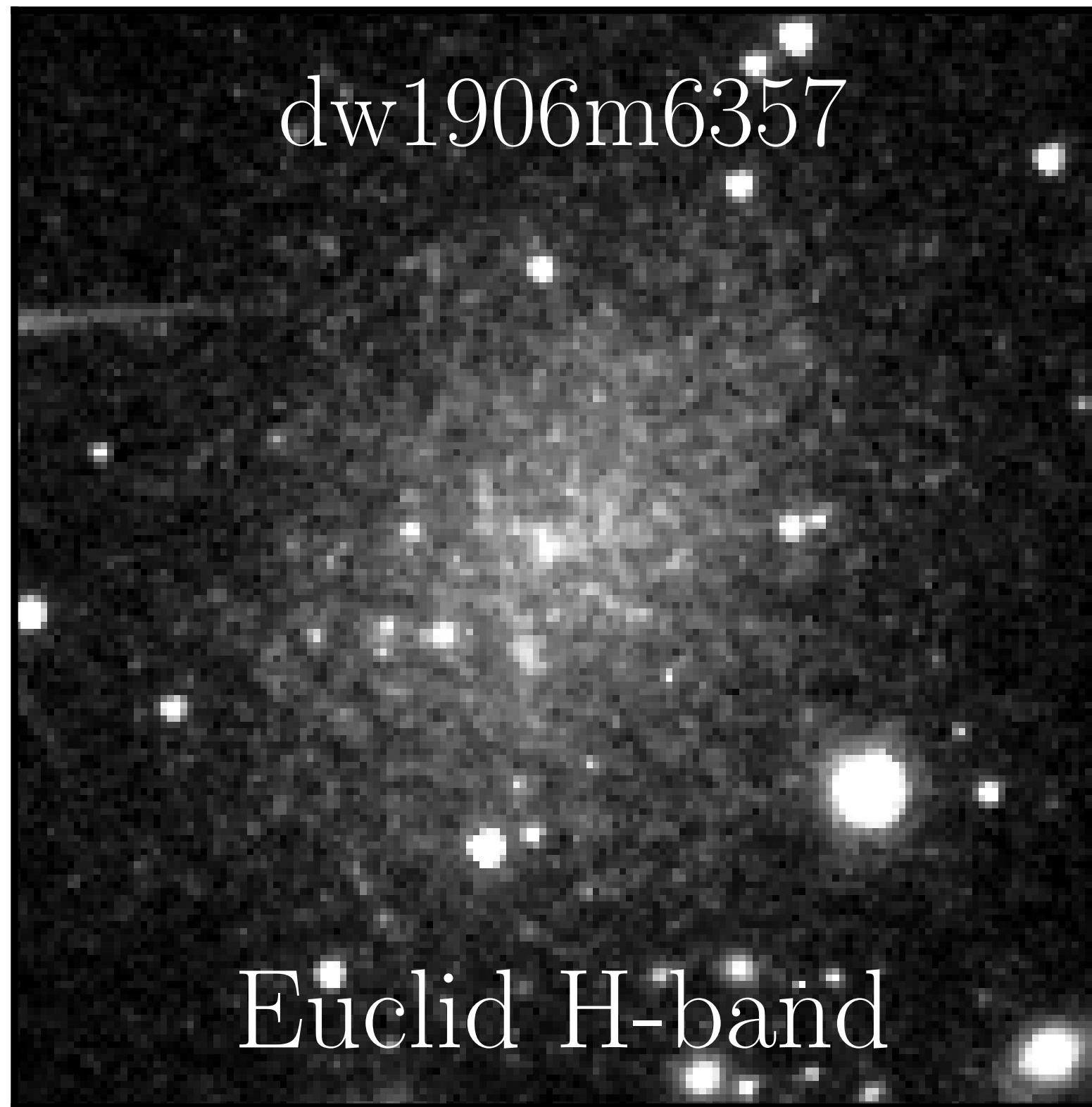


# SBF challenge 2: correlated noise

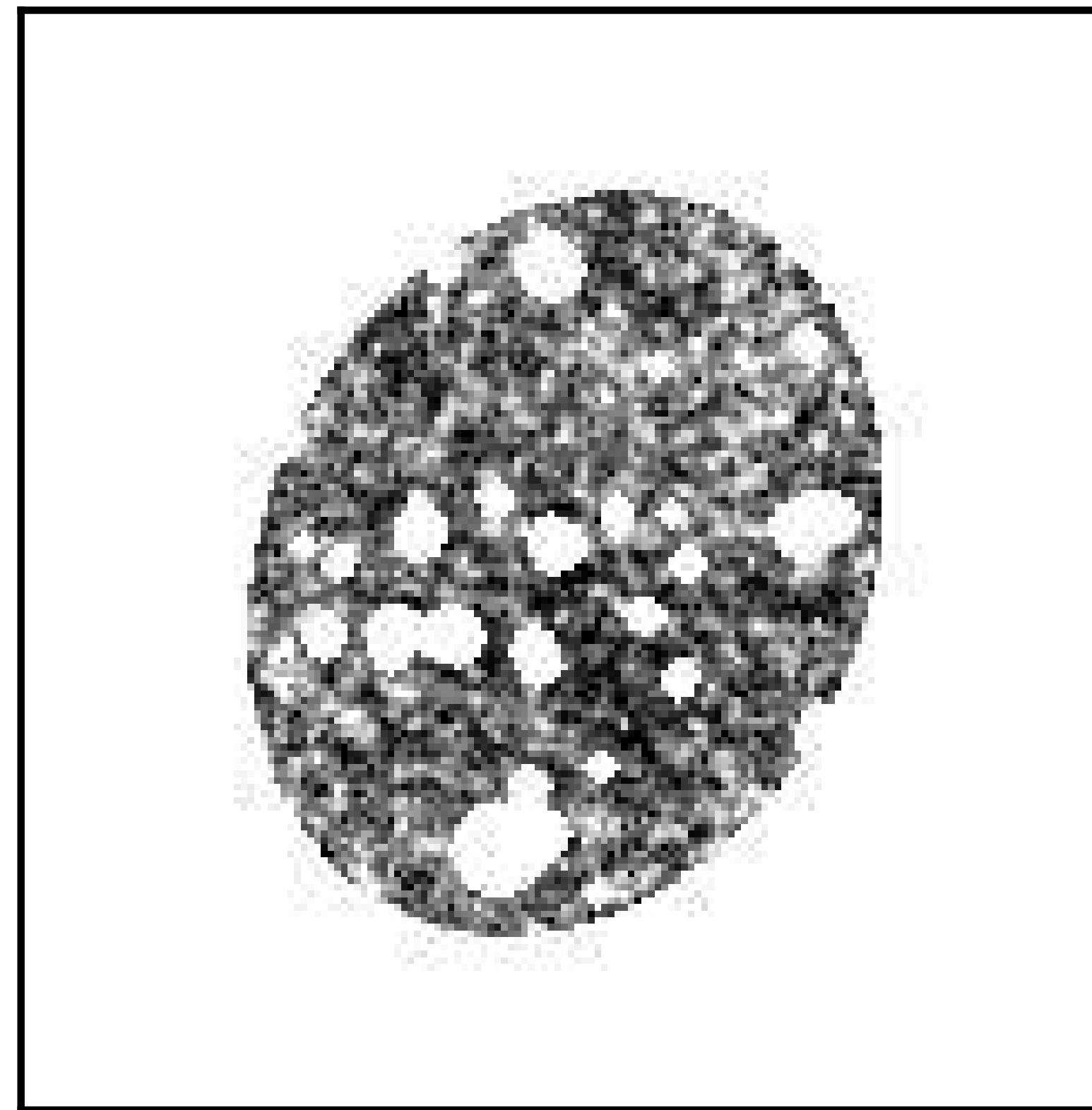


# SBF challenge 2: correlated noise

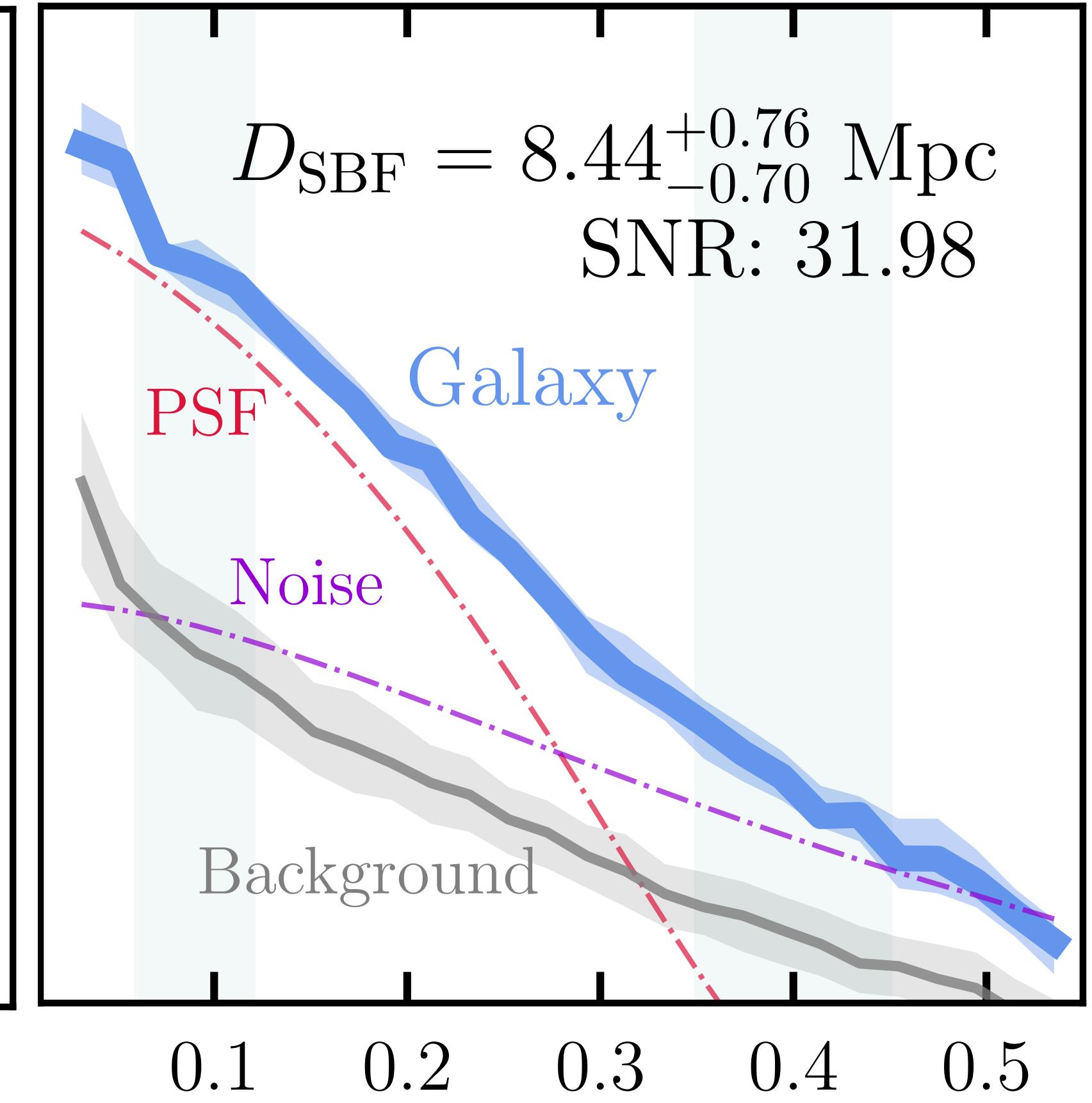
(a) Image



(b) Residual



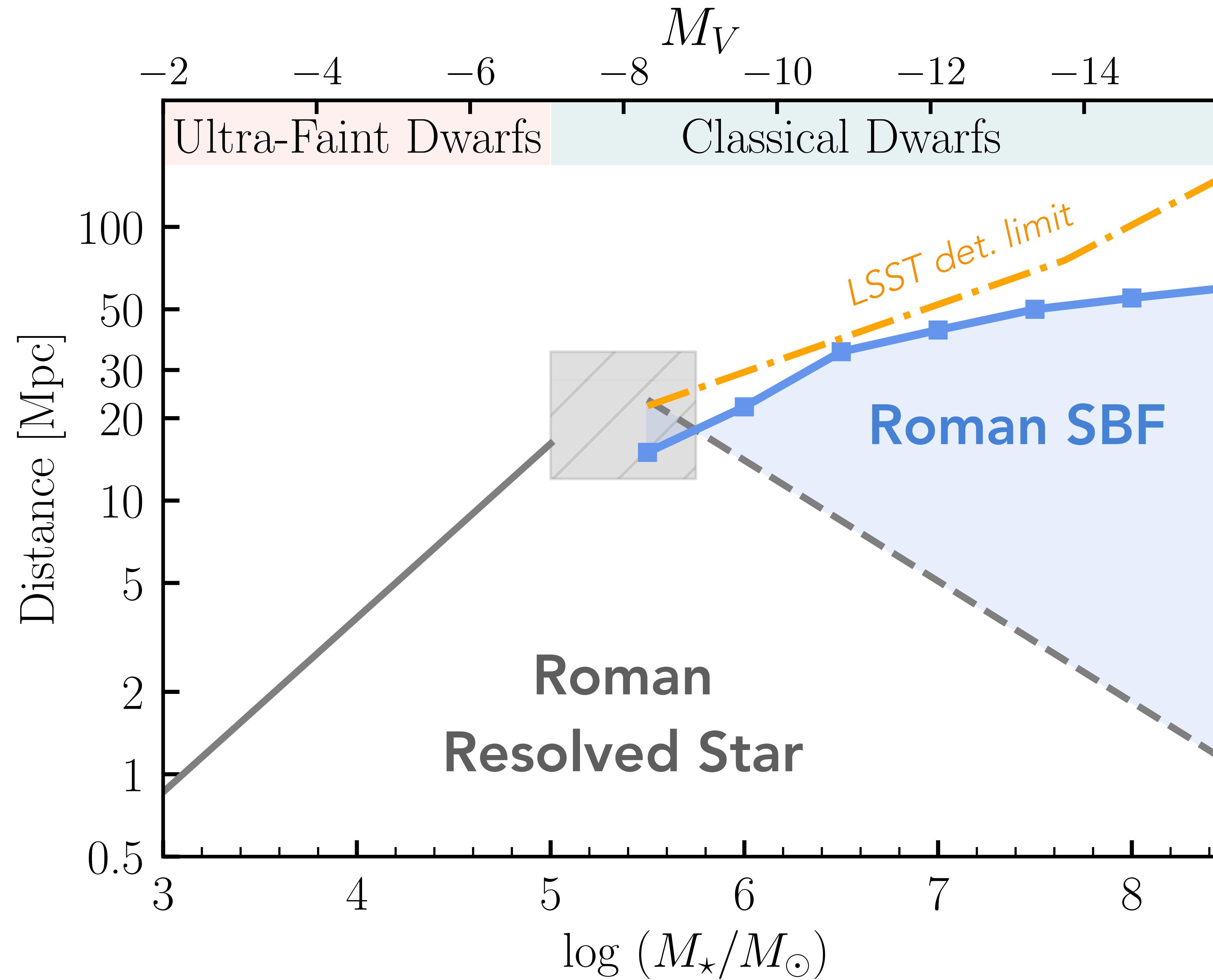
(c) Power Spectrum



Better coadding technique (IMCOM?)

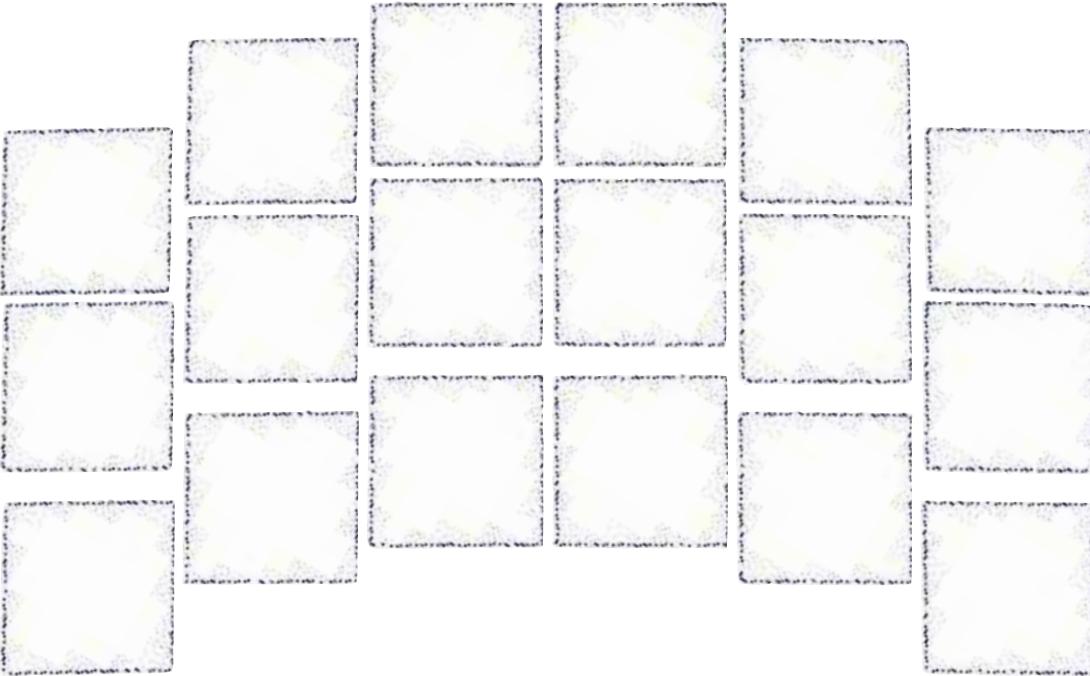
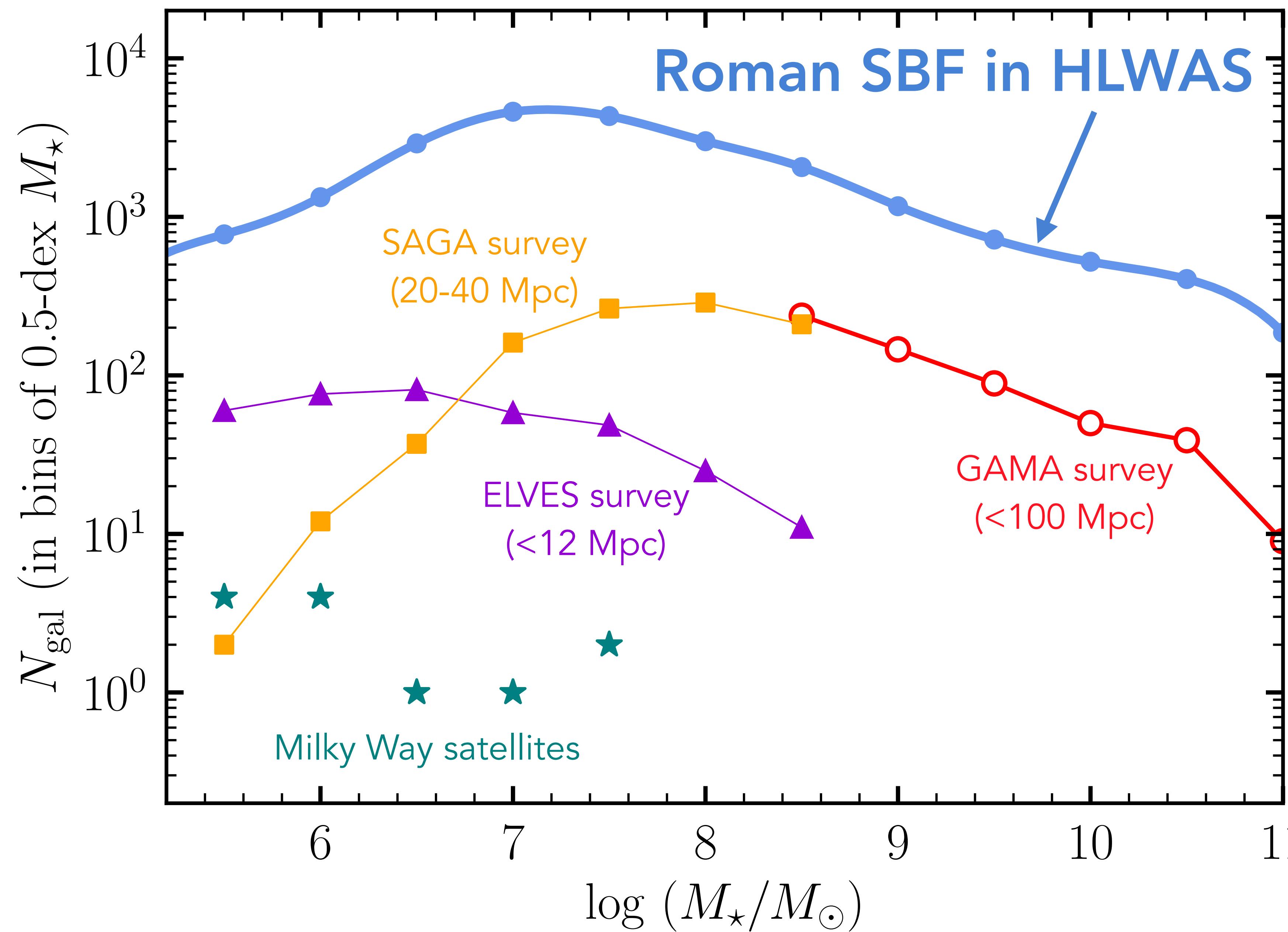
Preliminary!!

Li+ (in prep)



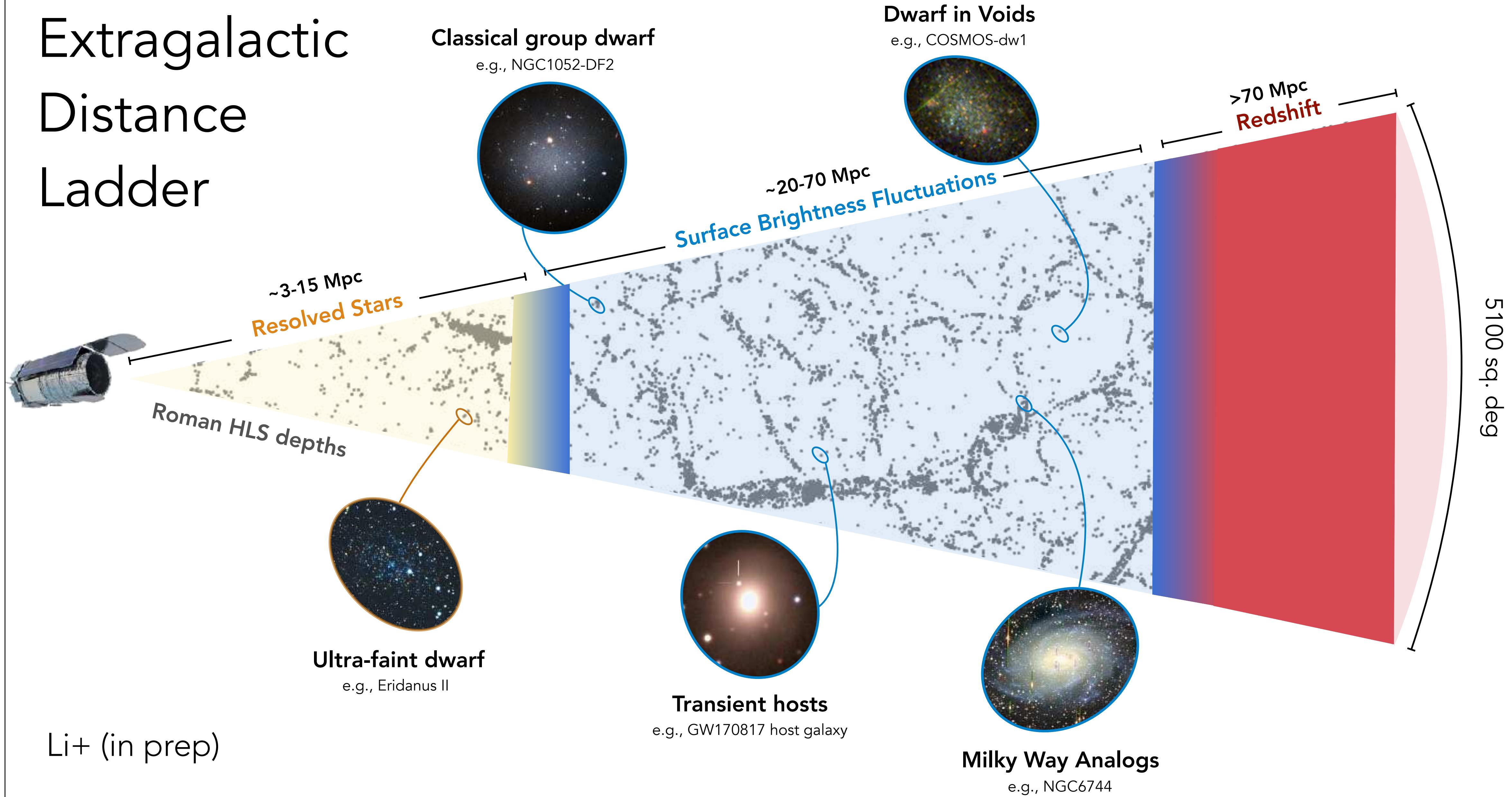
Preliminary!!

Li+ (in prep)



~1 SBF-able  
galaxy per  
pointing

# Extragalactic Distance Ladder



## More Use Cases of RoseSim

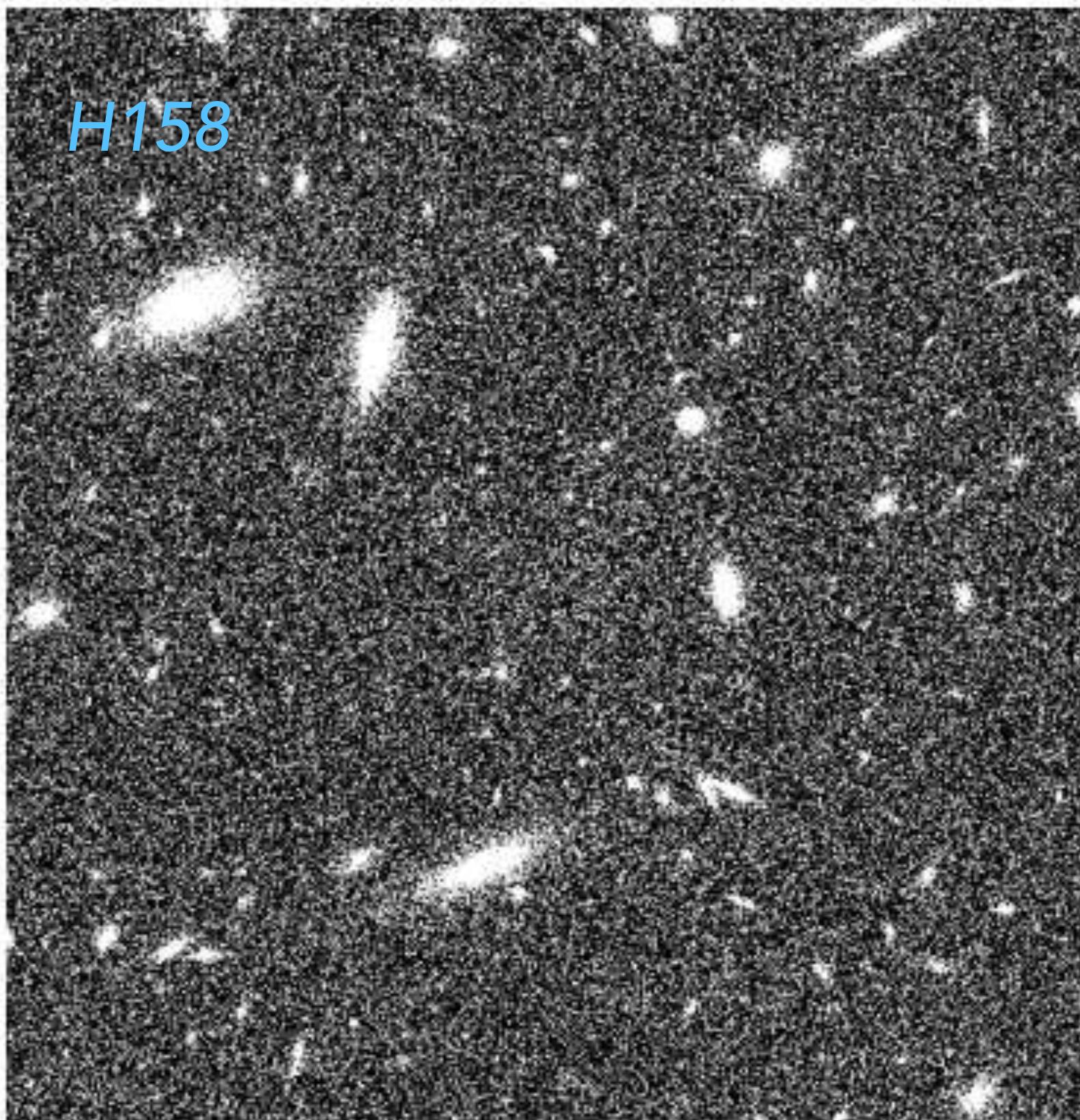
*UFD beyond LG*

$D=2 \text{ Mpc}$

$M_\star = 10^{5.5} M_\odot$

# Deeper observations for UFDs beyond LG

*Standard HLWAS*



*Intermediate pointing  
(4x exposure time)*



*Deep pointing  
(16x exposure time)*

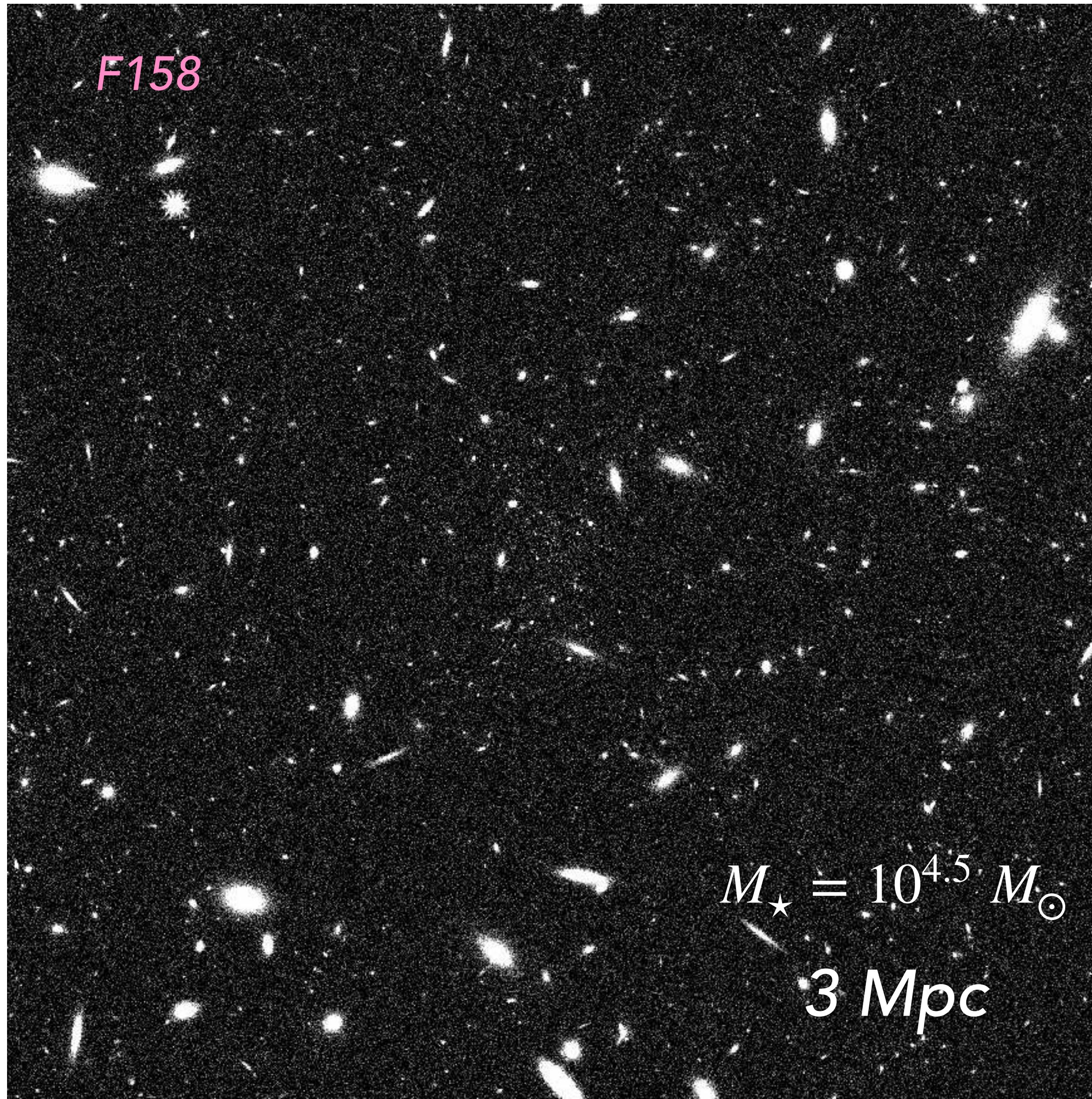


$$M_{\star} = 10^4 M_{\odot}$$

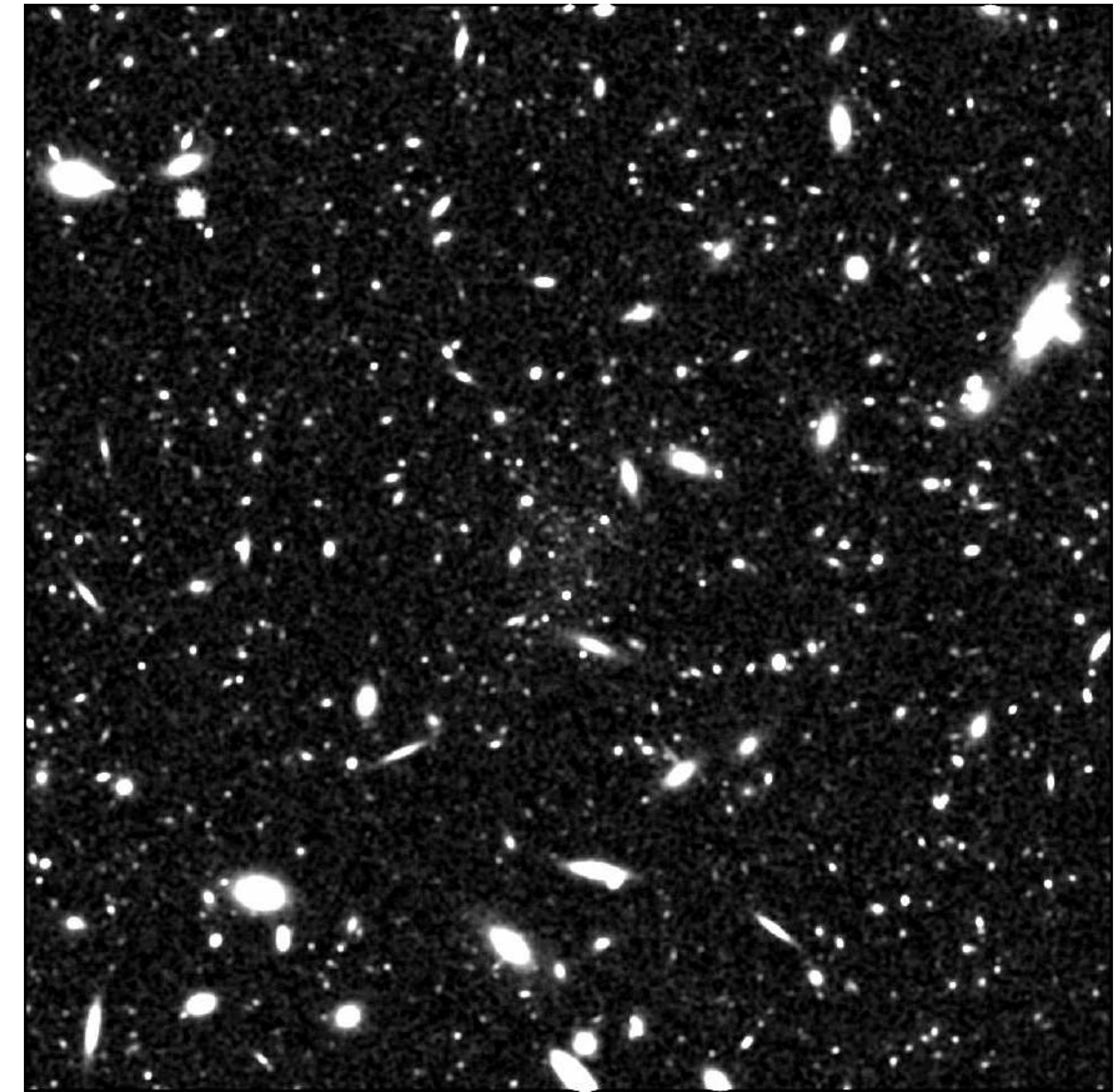
$$D=5 \text{ Mpc}$$

# Integrated light component of UFD

*Before smoothing*



*After smoothing*



# Summary

- Semi-resolved dwarfs are dominant in Roman dwarf world!
- SBF is the most efficient way to get distances
- **Rosesim:** <https://github.com/AstroJacobLi/Rosesim>; you can run image simulation very easily. Let's collaborate!!

```
$ rosesim_gal --obs_ra=150.1049 --obs_dec=2.2741 --distance=5 --age=1.0  
--log_m_star=4 --exptime=642
```

Happy to work with anyone here on:

- Imperfect star injection — direction spike, scattered light, etc.
- Go beyond SSP: more complicated stellar population
- Go beyond simple Sersic — Hydro sims will be helpful!
- Try Different isochrones (MIST, PARSEC, etc.)

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