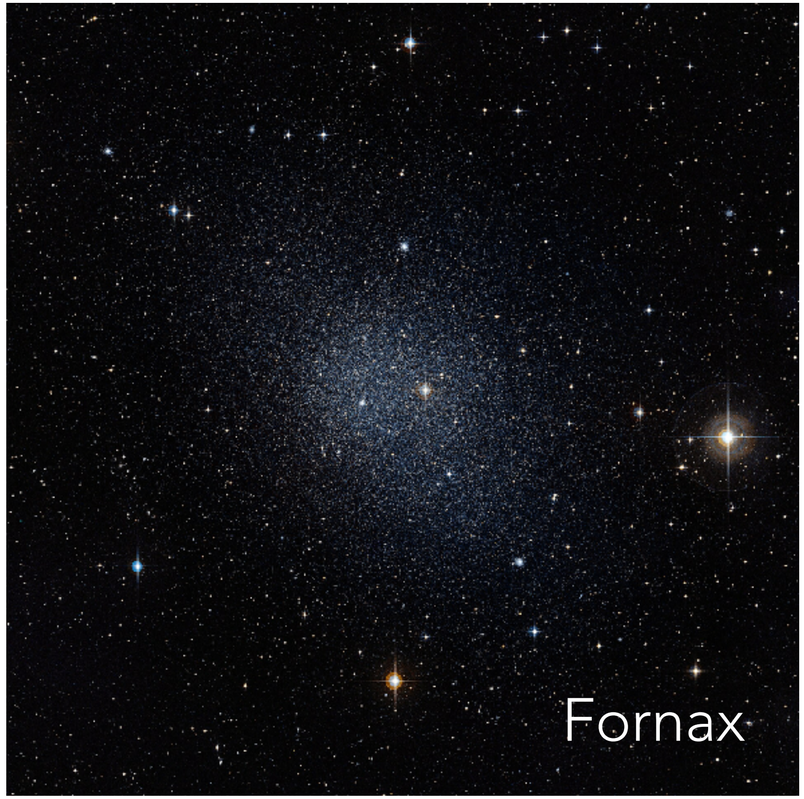
How to characterize semi-resolved dwarf galaxies in Roman

Jiaxuan Li 李嘉轩 (Princeton)

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

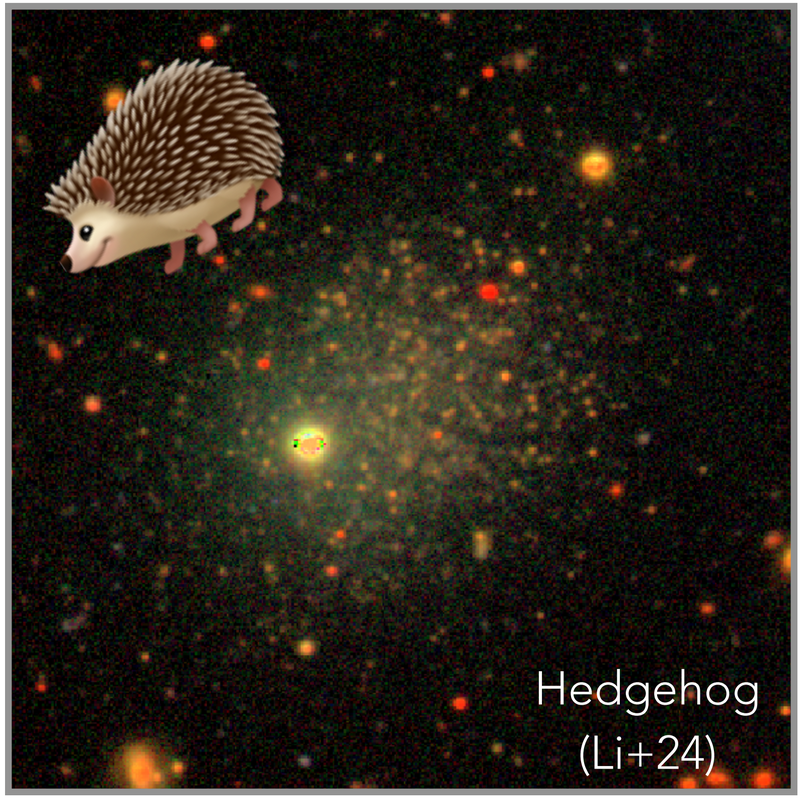
Roman Near-field Science Workshop
Aug 14, 2025

Resolved



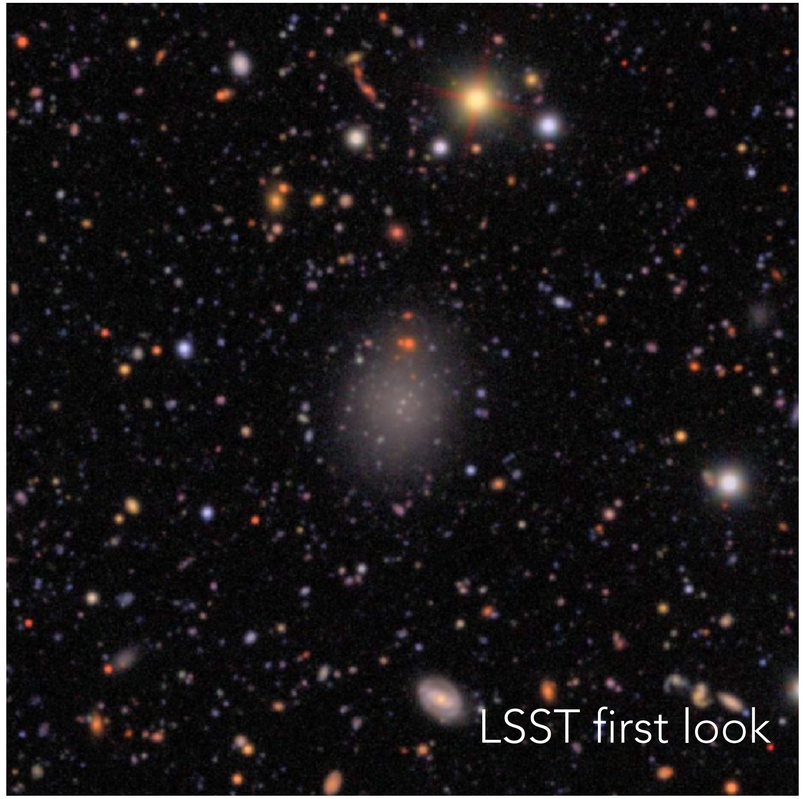
Bell, Williams, McQuinn++

Semi-Resolved



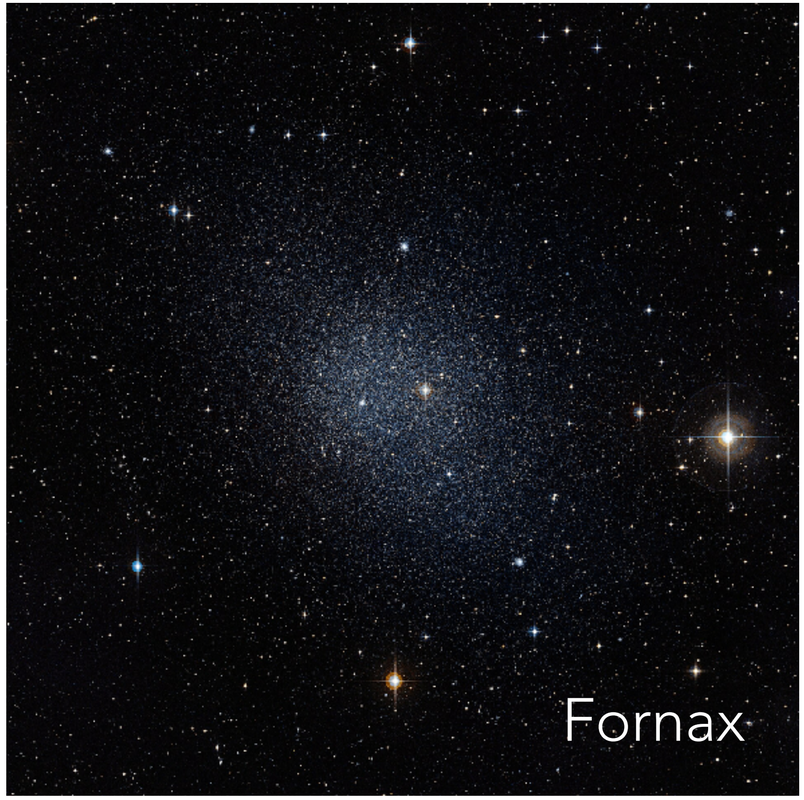
Carlsten, Greene, Danieli, Li ++
Sand, Mutlu-Pakdil,
Jones ++ (SEAMLESS)

Unresolved

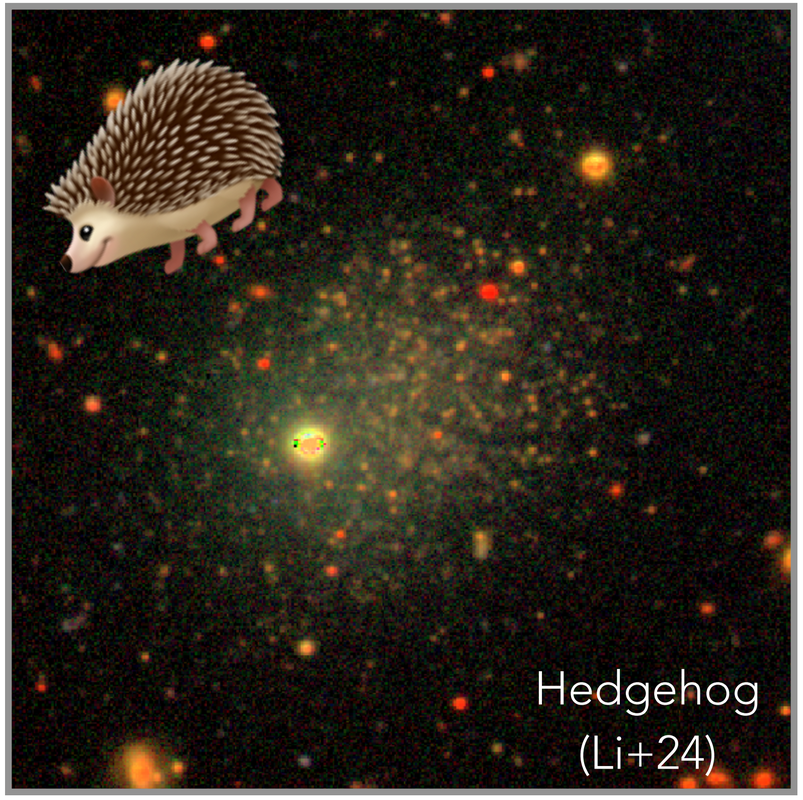


Romanowsky++
Greco+18 (HSC data)
SMUDGES (Zaritsky++)

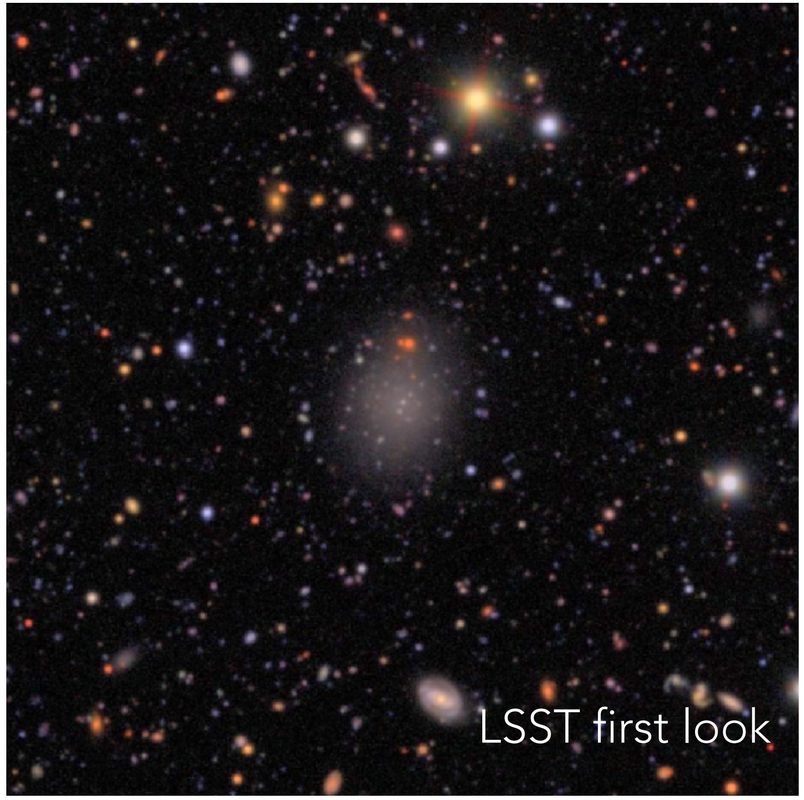
Resolved



Semi-Resolved



Unresolved



Burcin will find all of these in Roman

Distance is needed!

ΛCDM tensions with dwarf galaxies

Sales et al. (2022)

No tension	Uncertain	Weak tension	Strong tension
Missing satellites	M_*–M_{halo} relation	Too big to fail	Diversity of rotation curves
	Core–cusp	Diversity of dwarf sizes	Satellite planes
		Quiescent fractions	

Free distance

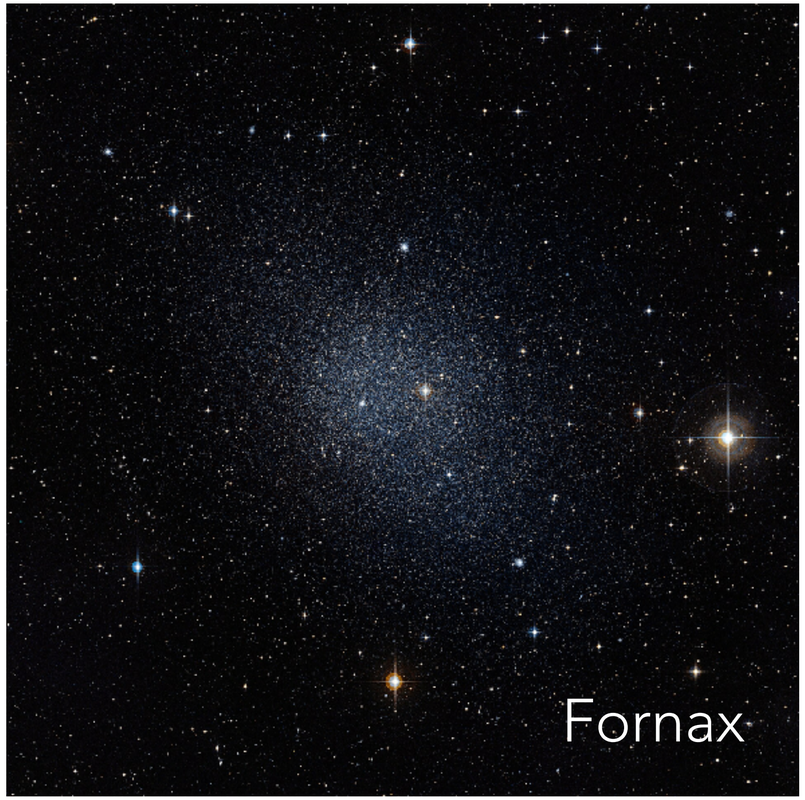
from matched filtering

??

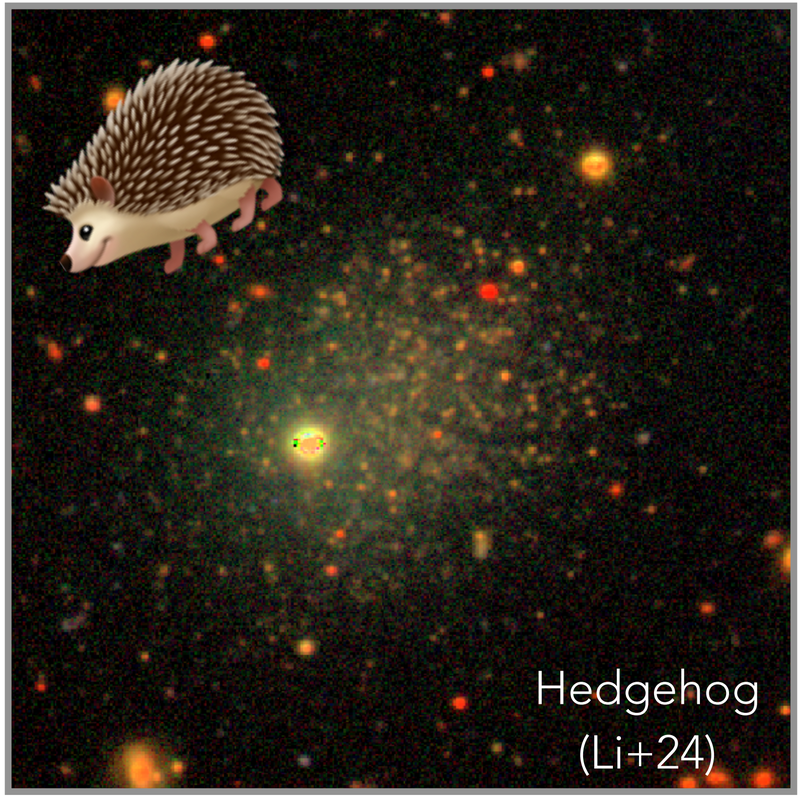
Redshift

Group member

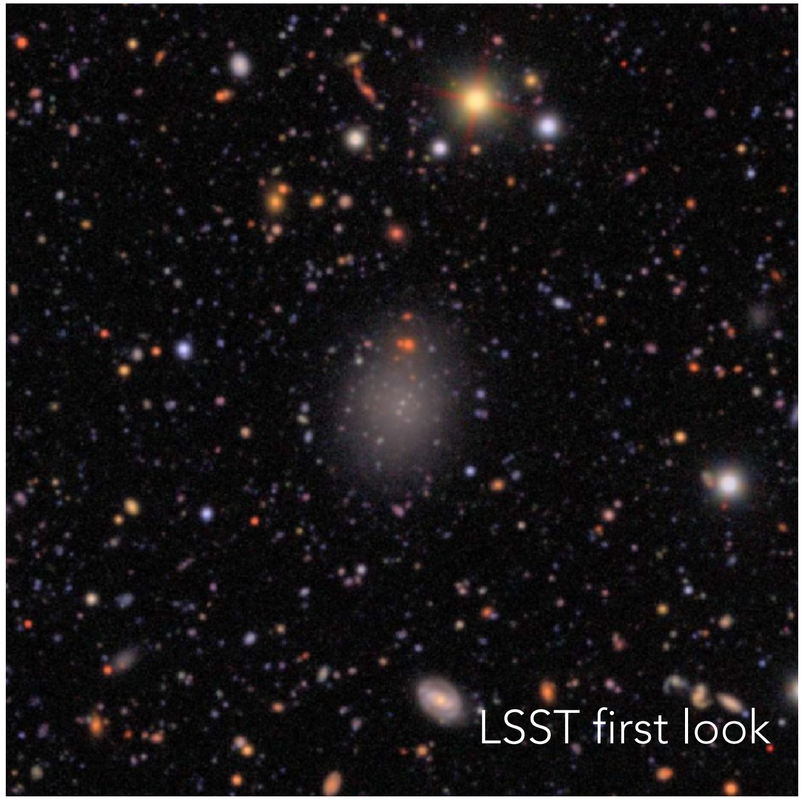
Resolved



Semi-Resolved



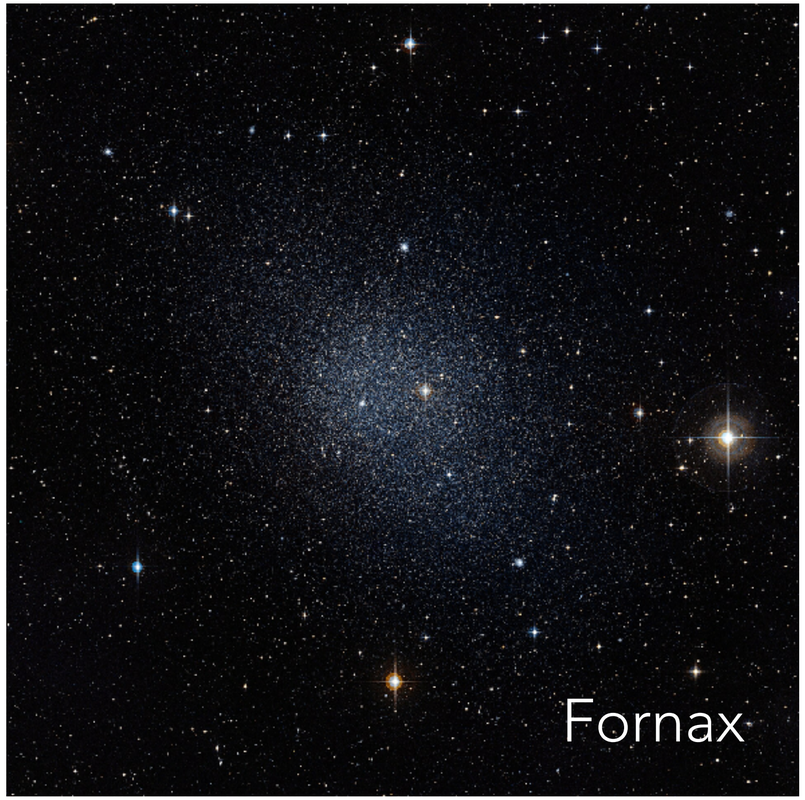
Unresolved



Free distance

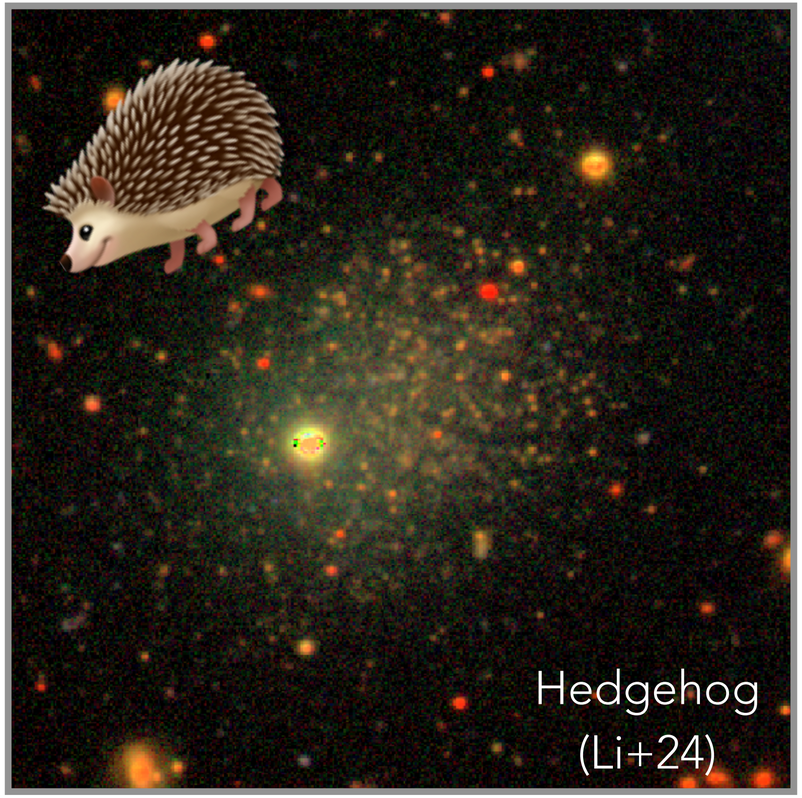
from matched filtering

Resolved



Surface Brightness Fluctuation

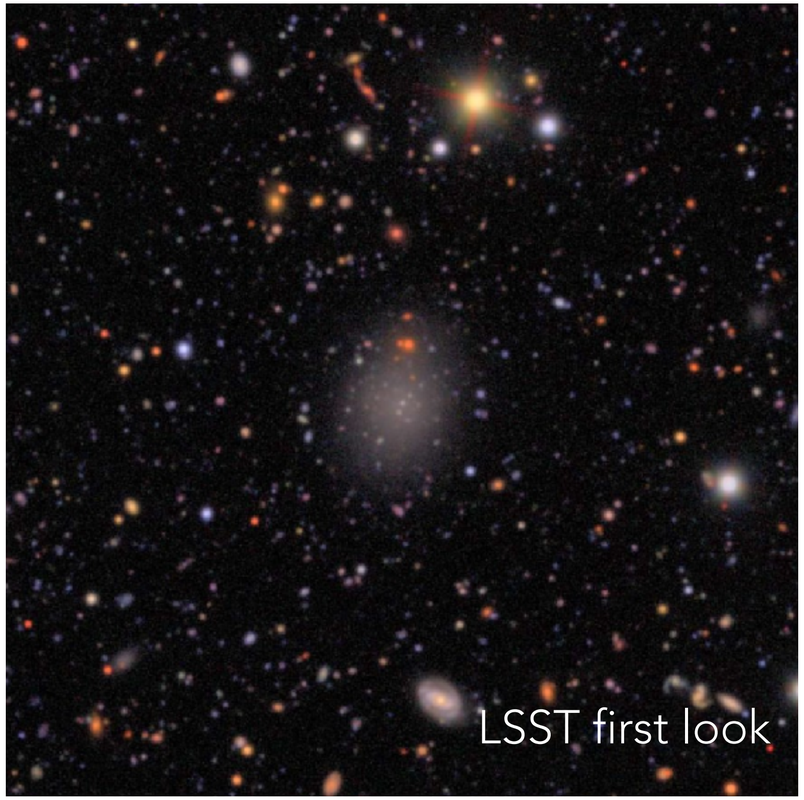
Semi-Resolved



Redshift

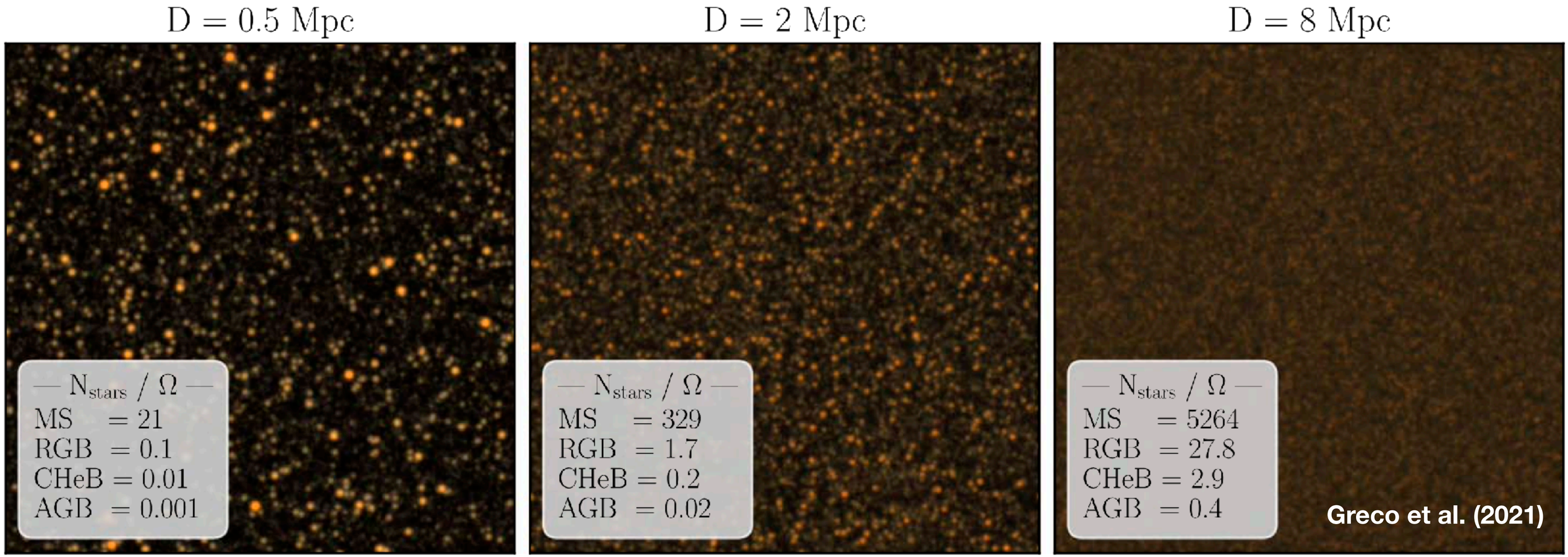
Group member

Unresolved

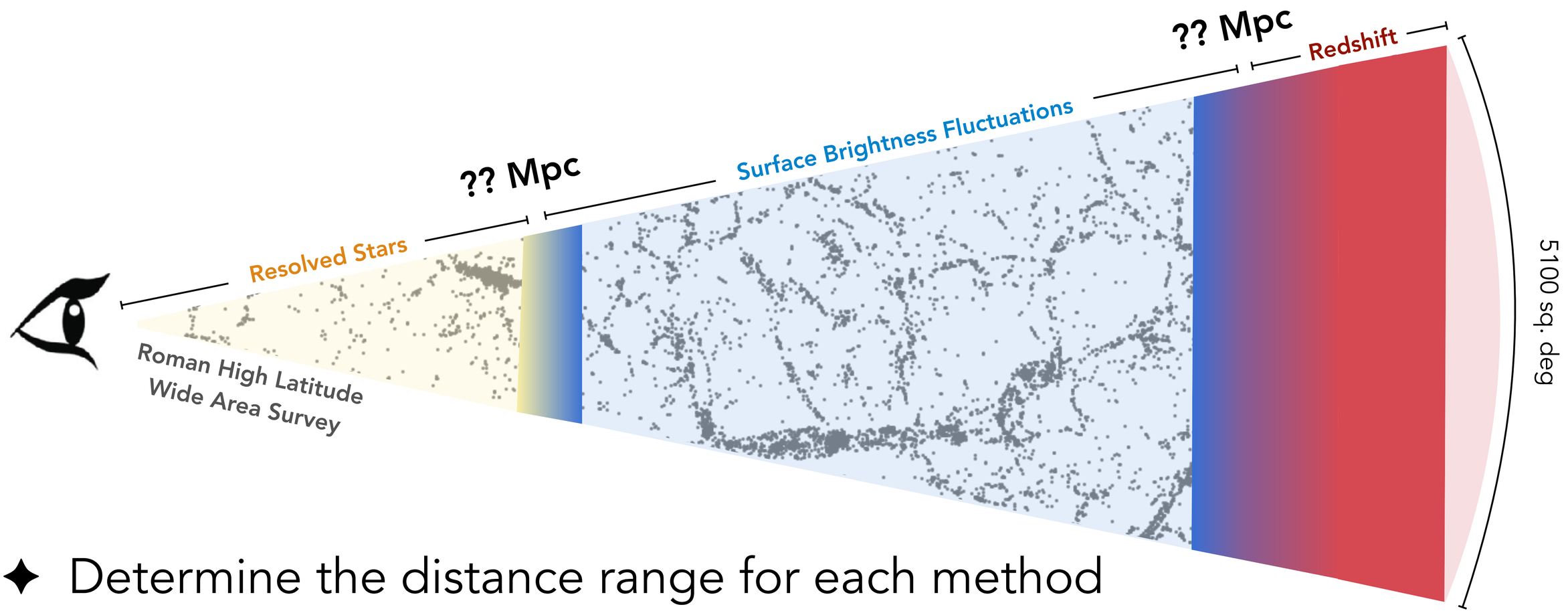


SBF: Pixel-to-pixel variation contains distance information

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



- 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 (logM*<5)

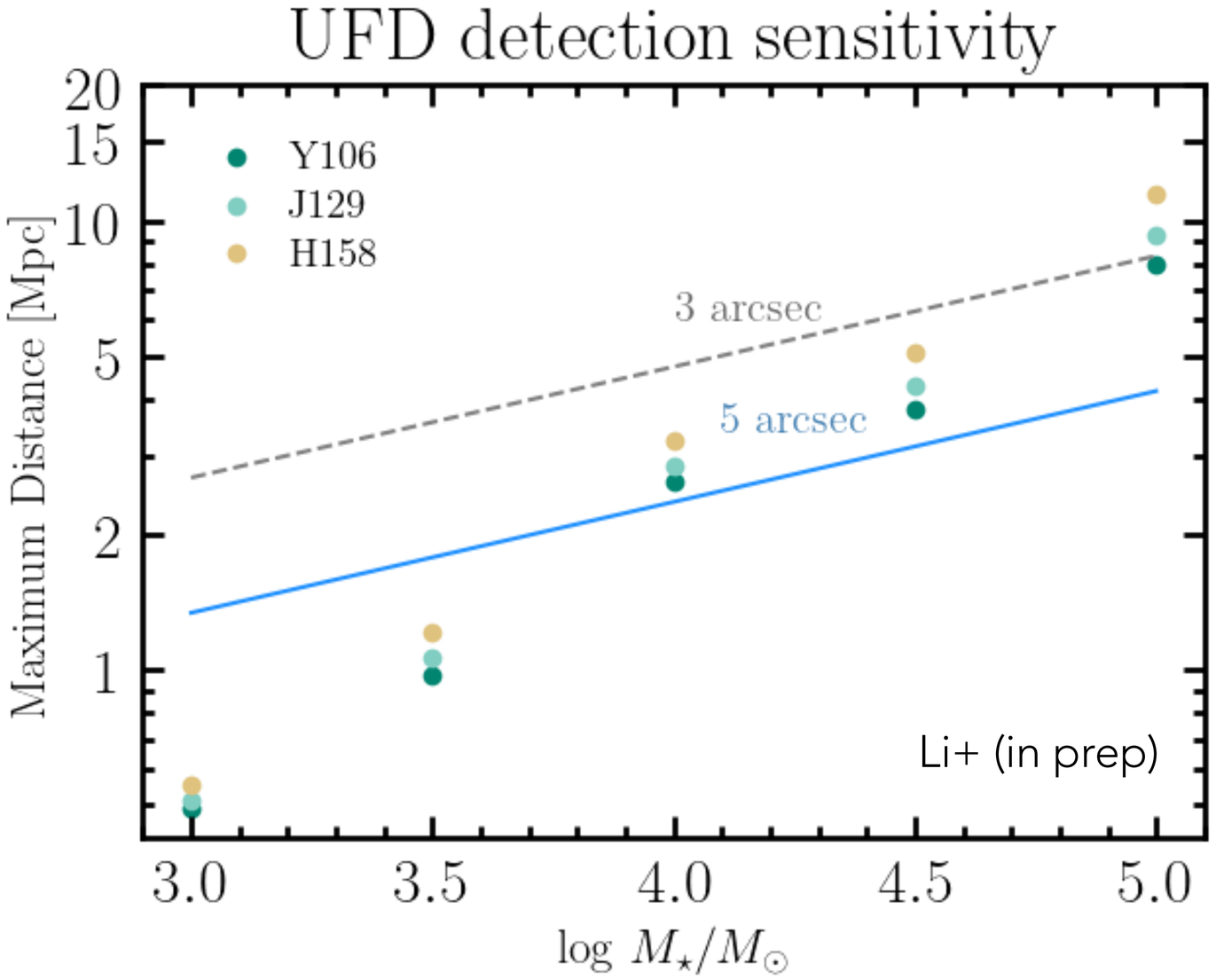
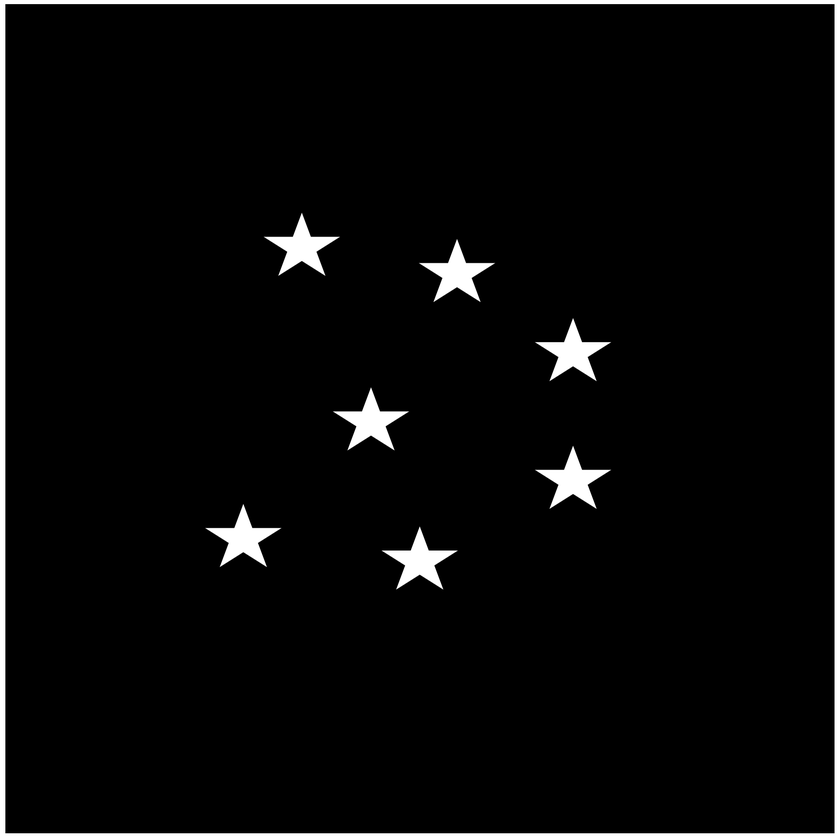


Image simulation is needed



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

Classical dwarfs

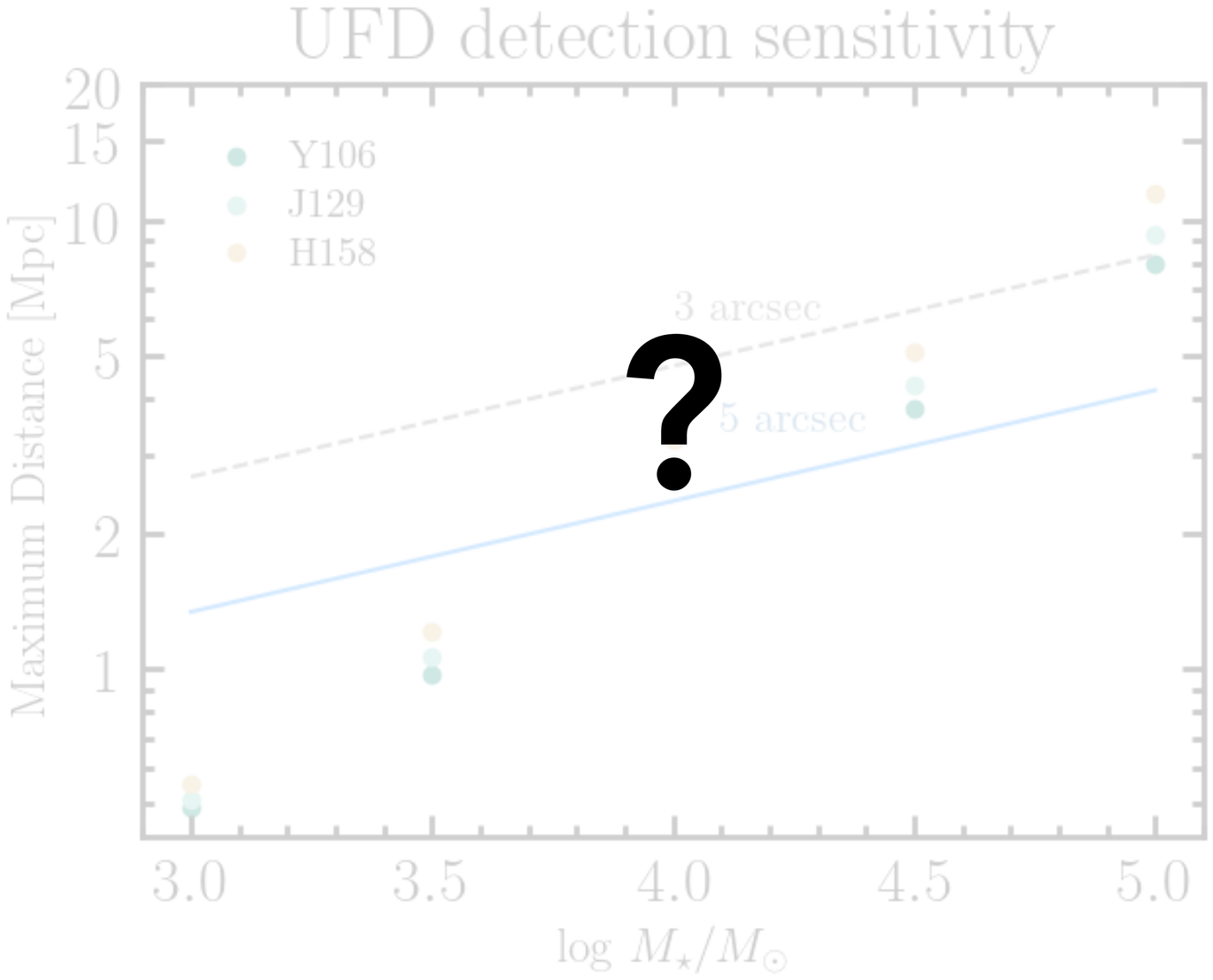
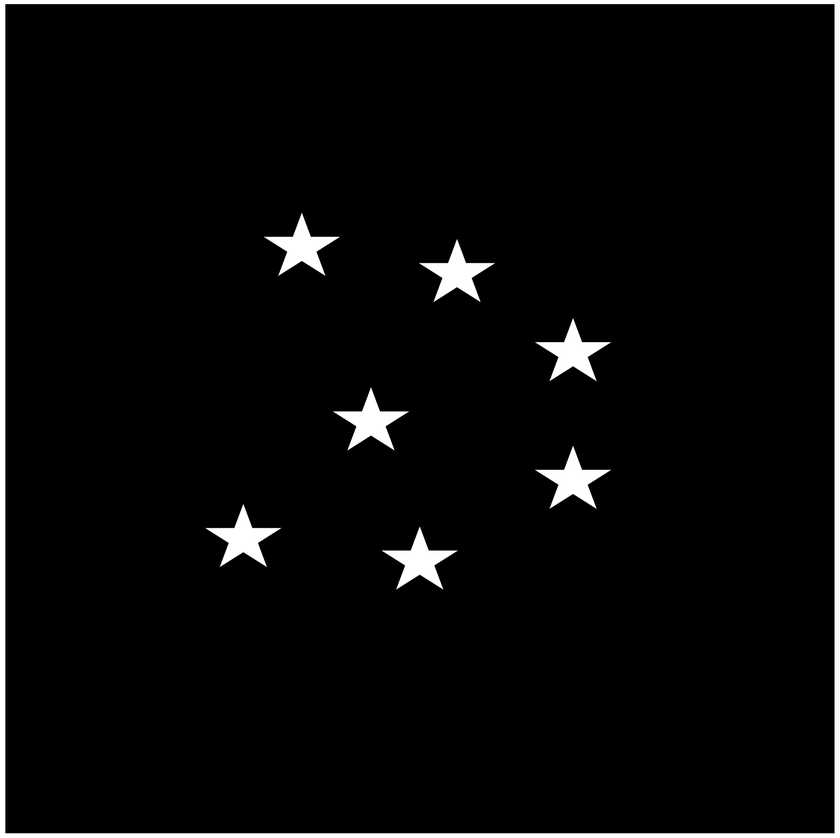


Image simulation is <u>definitely</u> needed



Roman semi-resolved galaxy simulator

Also see Deepthi Prabhu's work

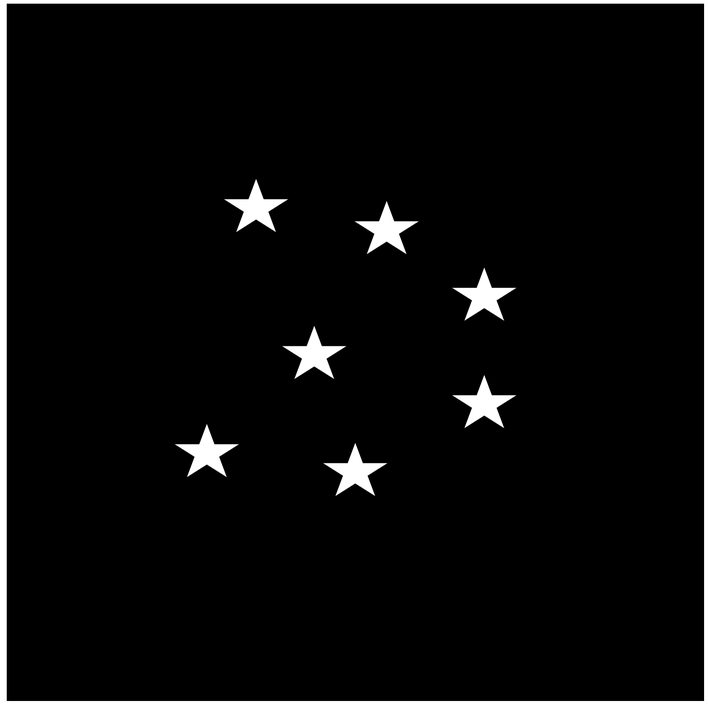
Dwarf galaxy itself

Background Galaxies

Foreground Stars

Roman-I-sim

STIPS



RoSESim: Roman semi-resolved galaxy simulator

Artpop

Sample stars from stellar population (Greco & Danieli 23)

Background Galaxies

Drawn from mock galaxy catalogs or simulations

Foreground Stars

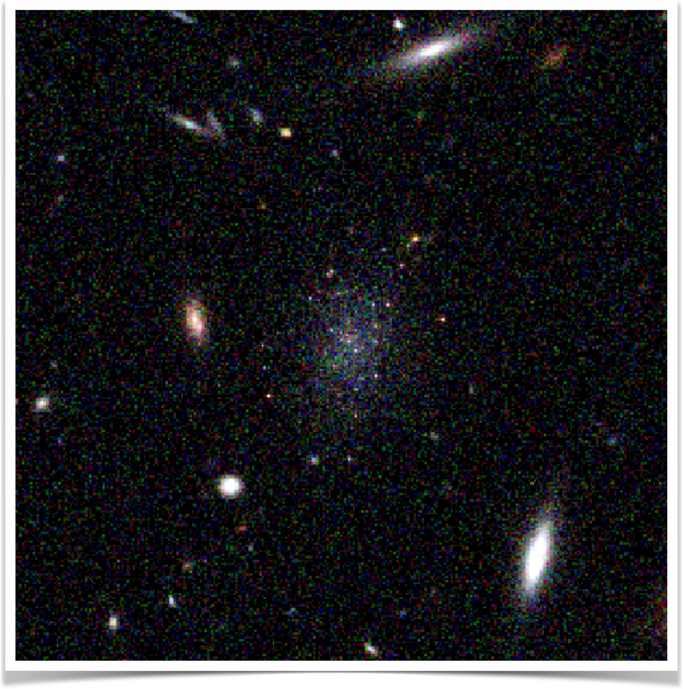
Drawn from Gaia

Roman-I-sim

Exptime, N_exp, RA, Dec

Dither pattern (future)

10^6 solar mass at 25 Mpc



HLWAS depth F106+F129+F158

https://github.com/AstroJacobLi/Rosesim

Foreground and Background

- Foreground stars: taken from Gaia (see Romanisim examples)
- Only to ~21 mag
- MW star simulator TRILEGAL

Semi-Analytic Forecasts for Roman

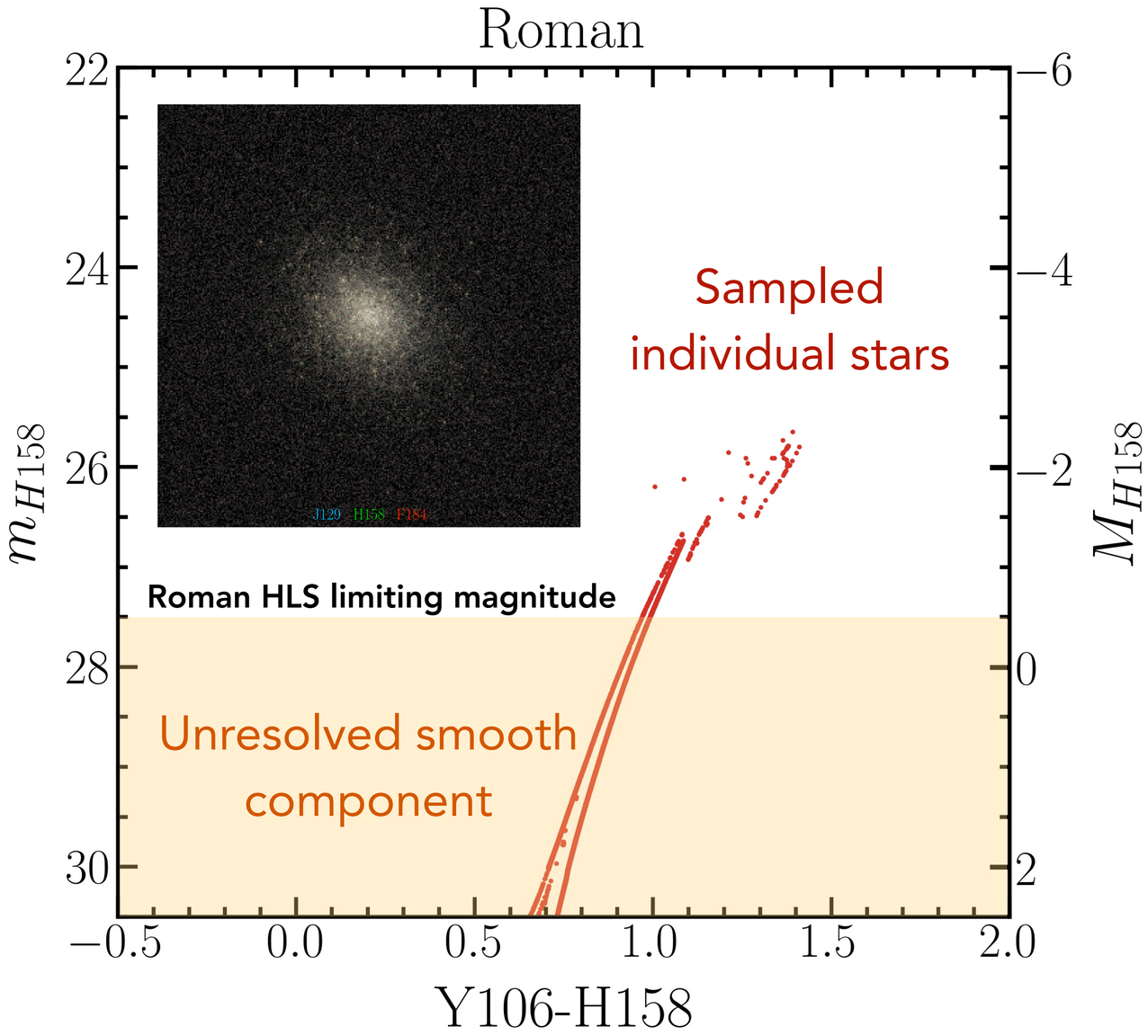
- Background galaxies: either from real catalogs (e.g., COSMOS, CANDELS) or from mock catalogs (e.g., CosmoDC2 for LSST-DESC; Yung+23 for Roman); or using simulated images (Troxel+23)
- We tried JADES Extragalactic Ultra-deep Artificial Realization (JAGUAR, Williams+18)
  - Made for JADES, 10 realizations 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


1′
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

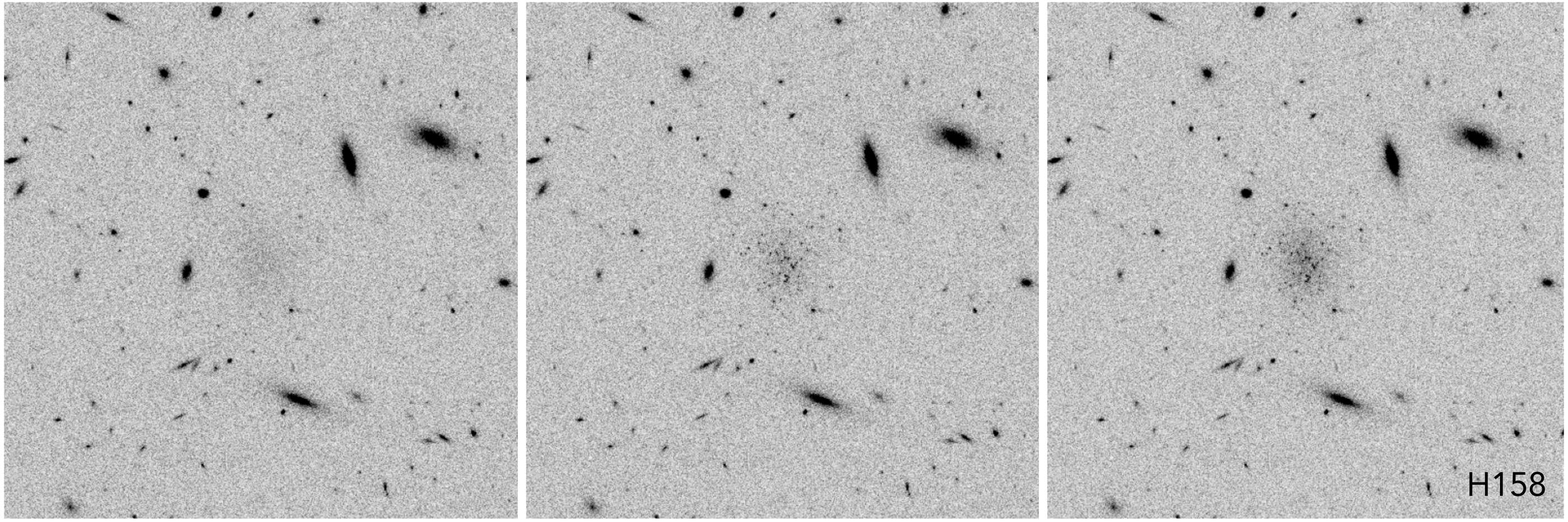


Semi-Resolved Dwarf

Unresolved smooth component

Sampled individual stars

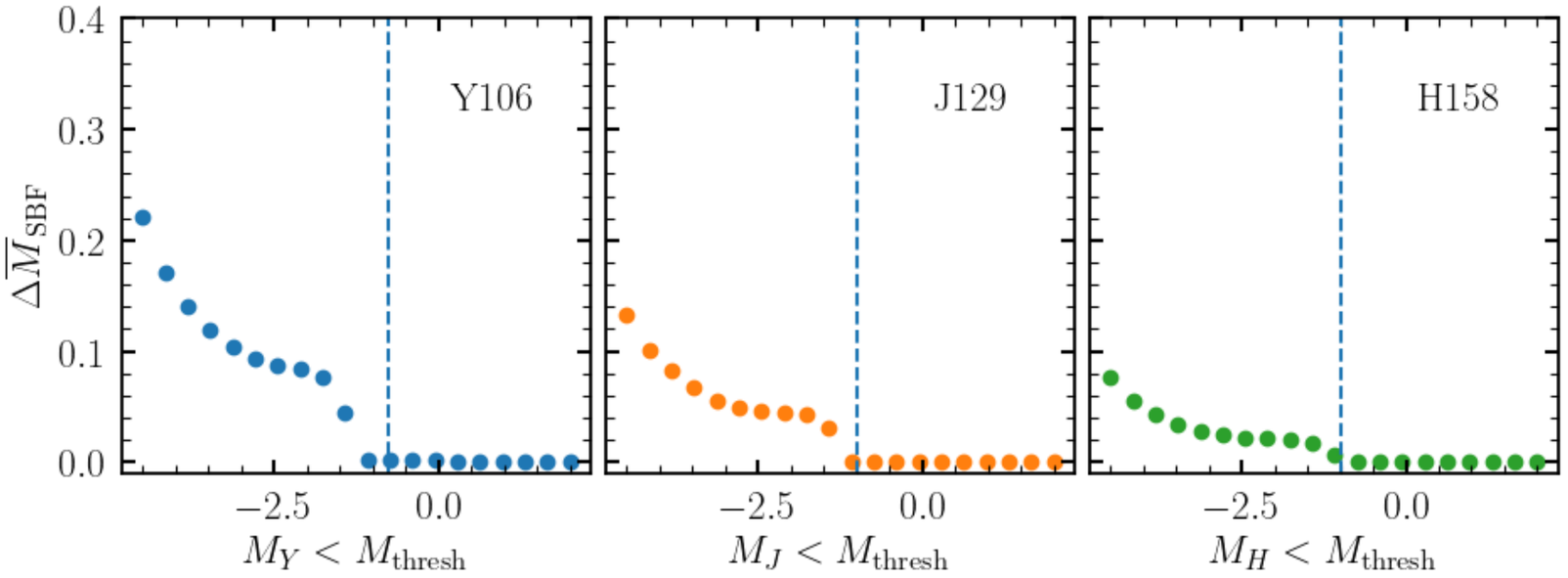
Together



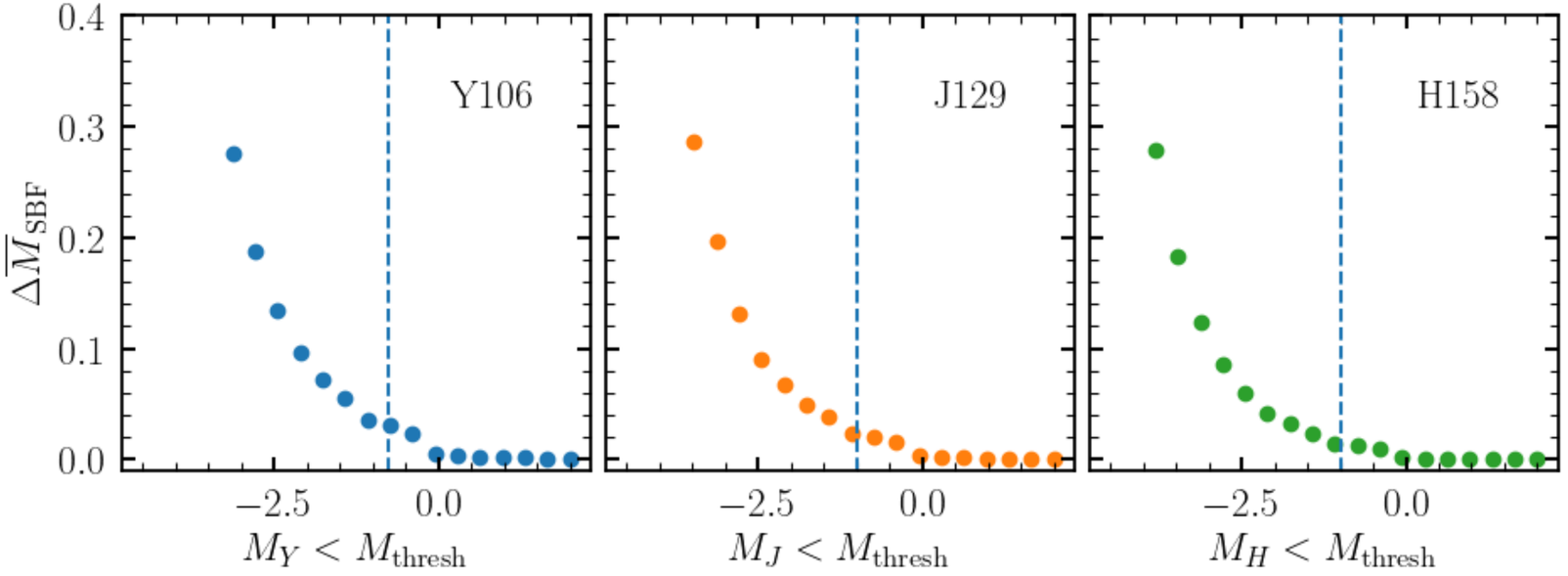
Star sampling threshold

M_abs = -1 is safe

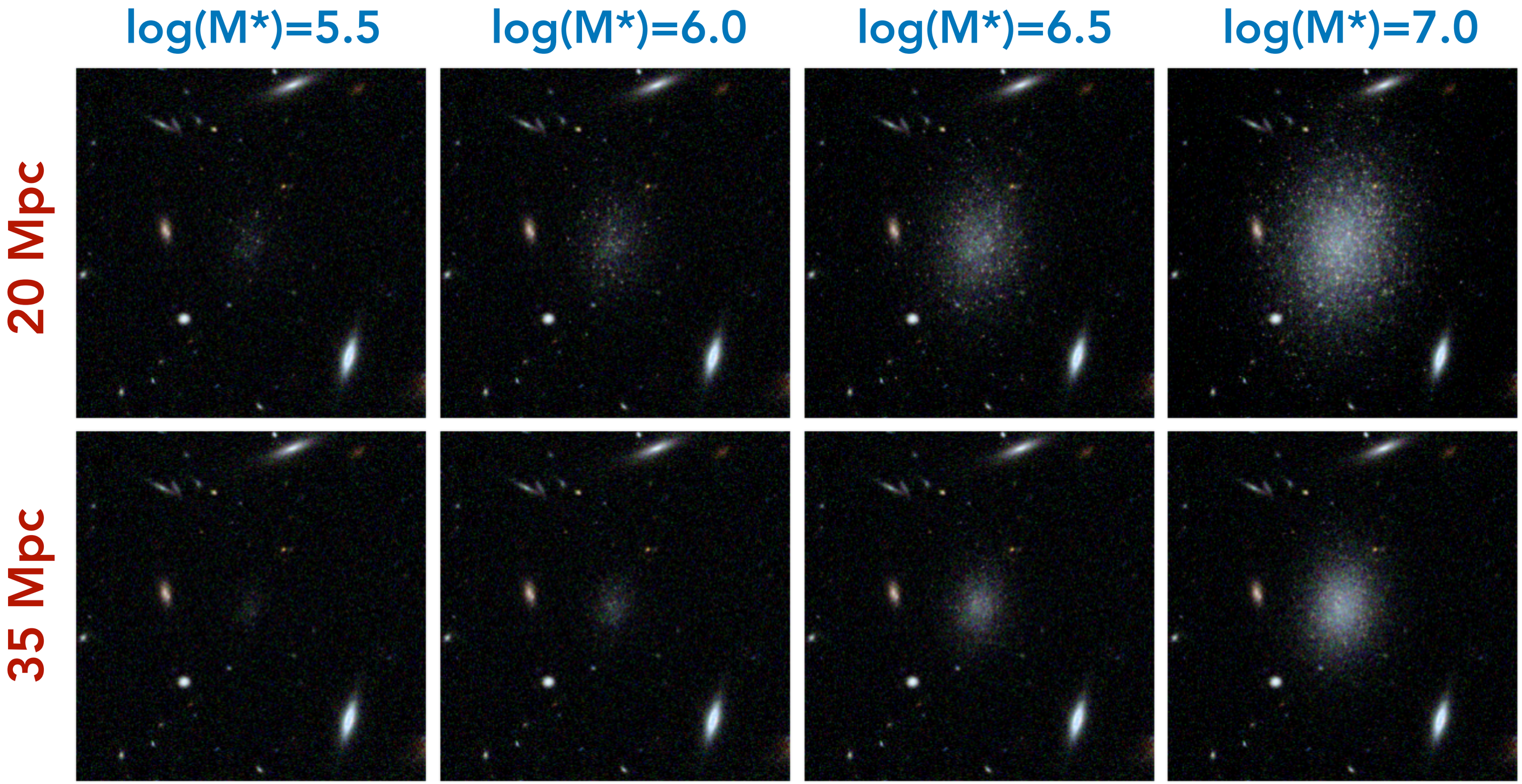
$$\bar{F}_{\mathrm{SBF}} = \frac{\sum_i \overline{N}_i L_i^2}{\sum_i \overline{N}_i L_i}$$



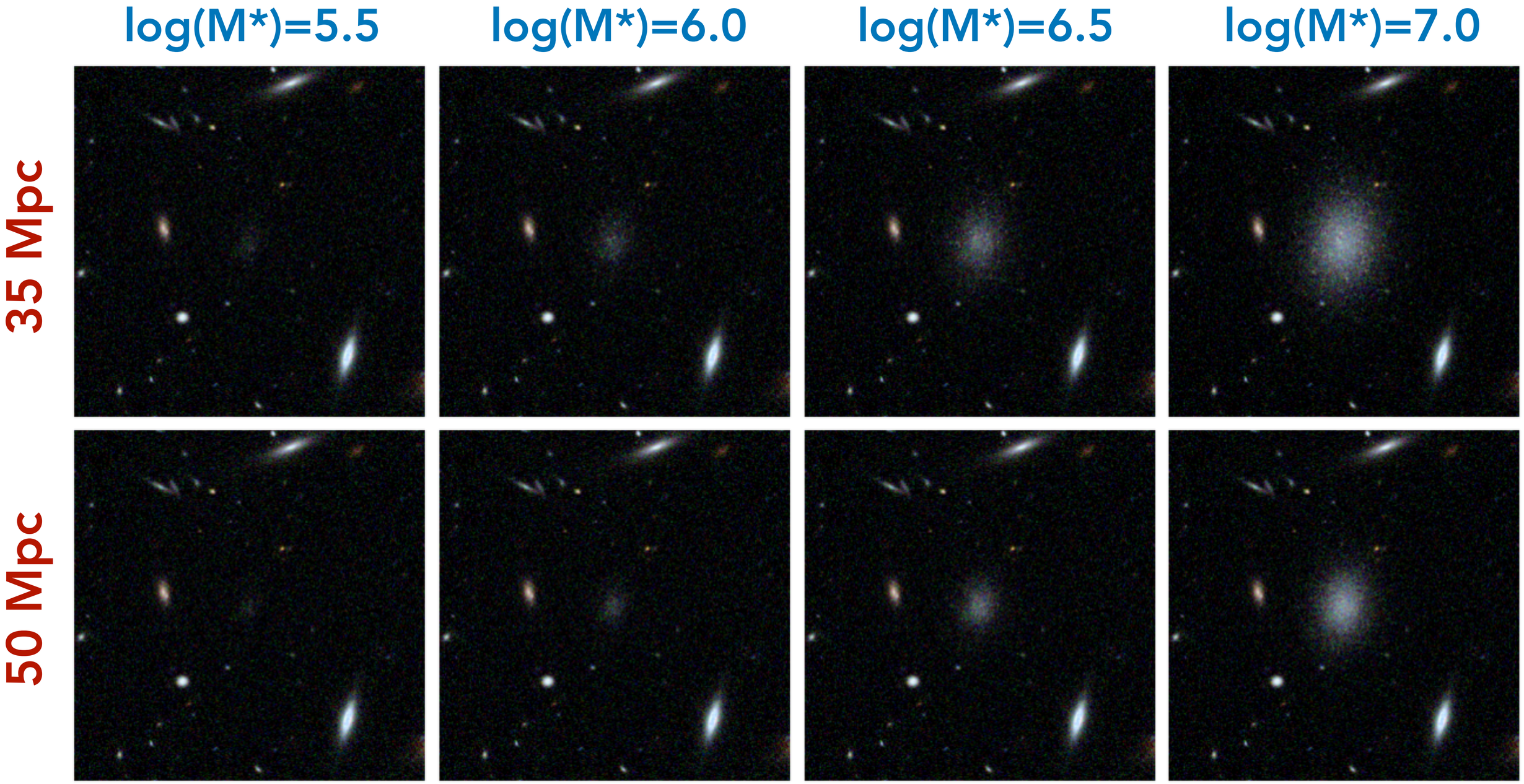
0.4 Gyr, [Fe/H]=-1.5



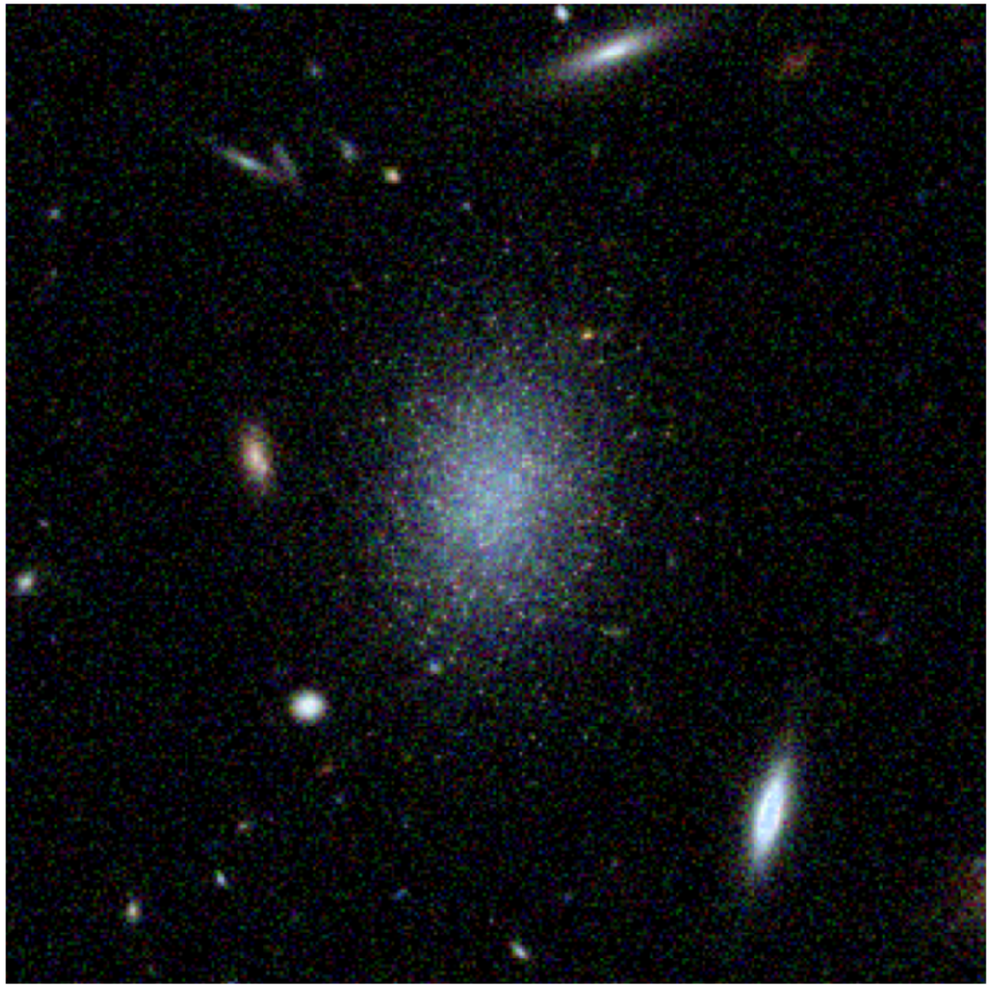
4 Gyr, [Fe/H]=-1.5



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

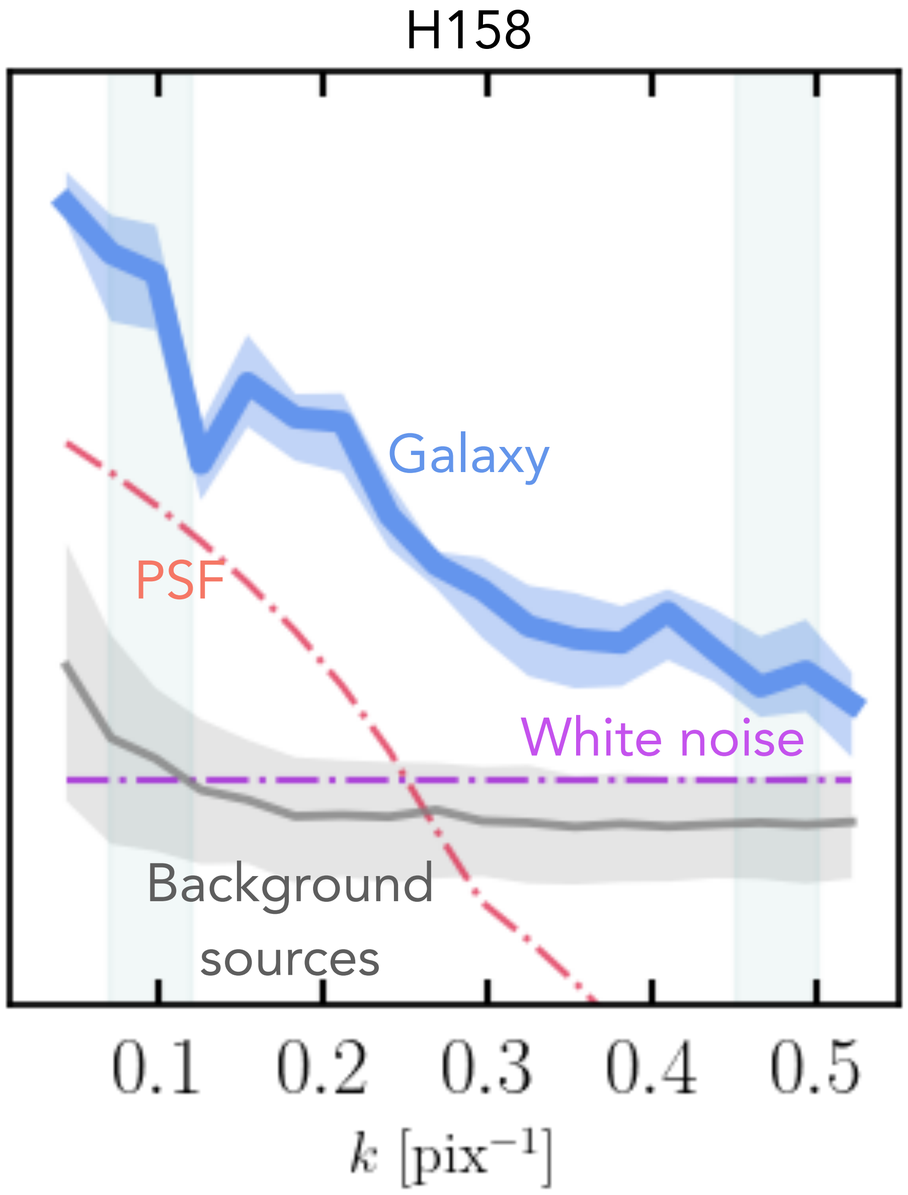

log(M*)=5.5
log(M*)=6.0
log(M*)=6.5
log(M*)=7.0
35 Mpc
50 Mpc
All are SSPs with 1 Gyr, [Fe/H]=-1.5

SBF measurements



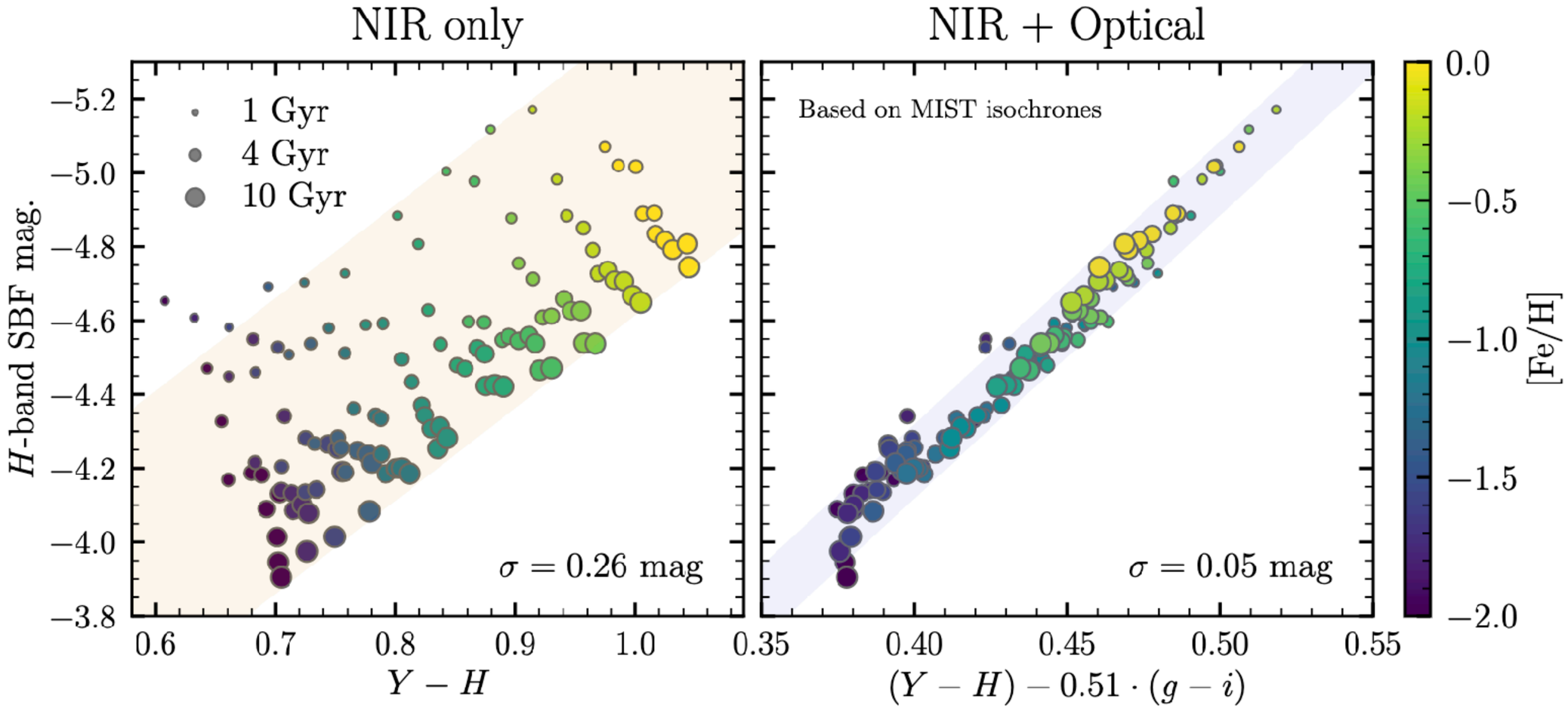
log(M*)=7.0, D=35 Mpc

Age = 0.4 Gyr, [Fe/H]=-1.5



SBF challenge 1: calibration in NIR

Li+ (in prep)



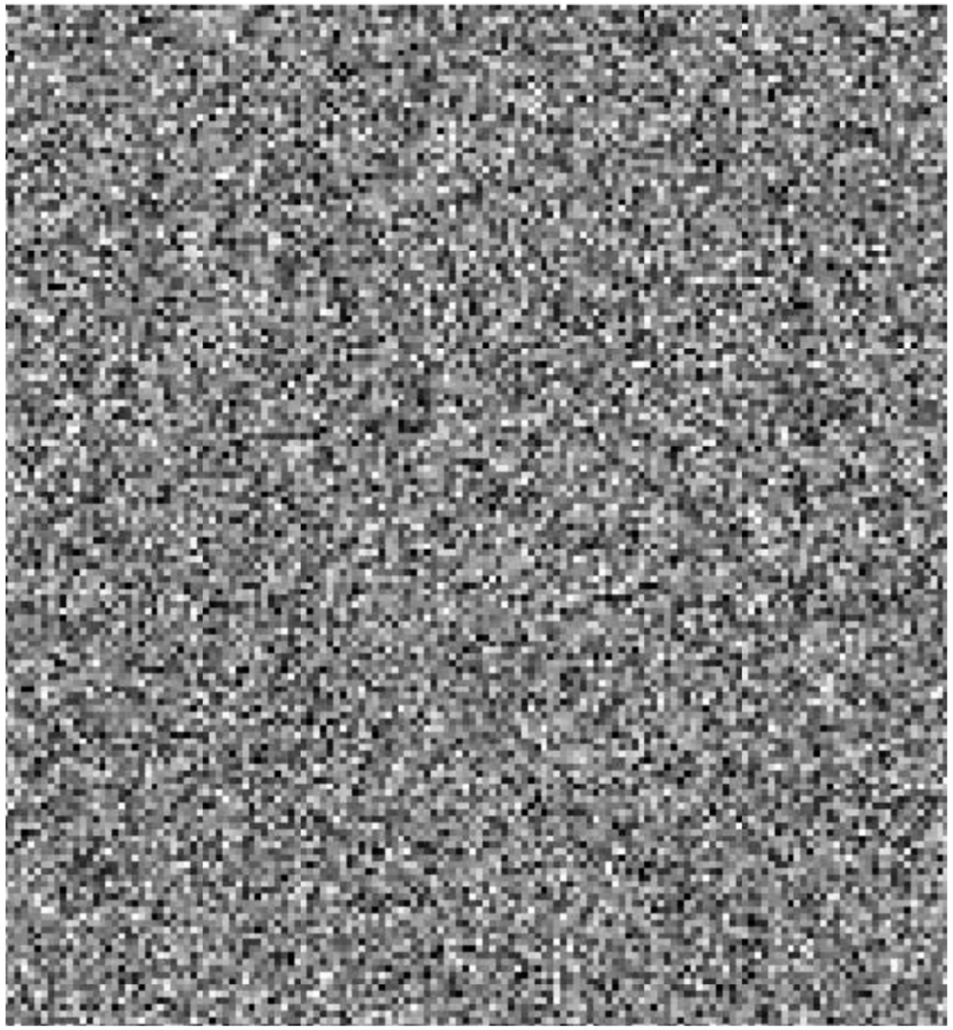
20% uncertainty

3% uncertainty

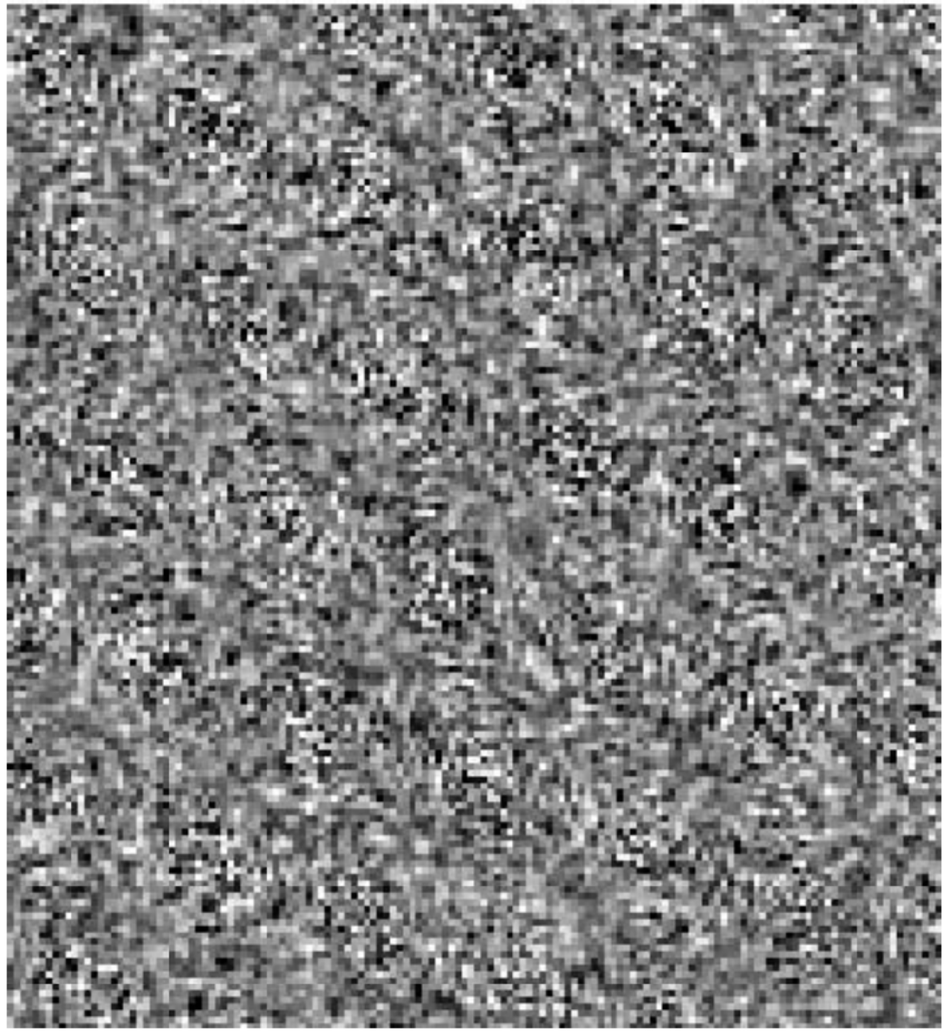
We will calibrate this using JWST archival imaging data

SBF challenge 2: correlated noise

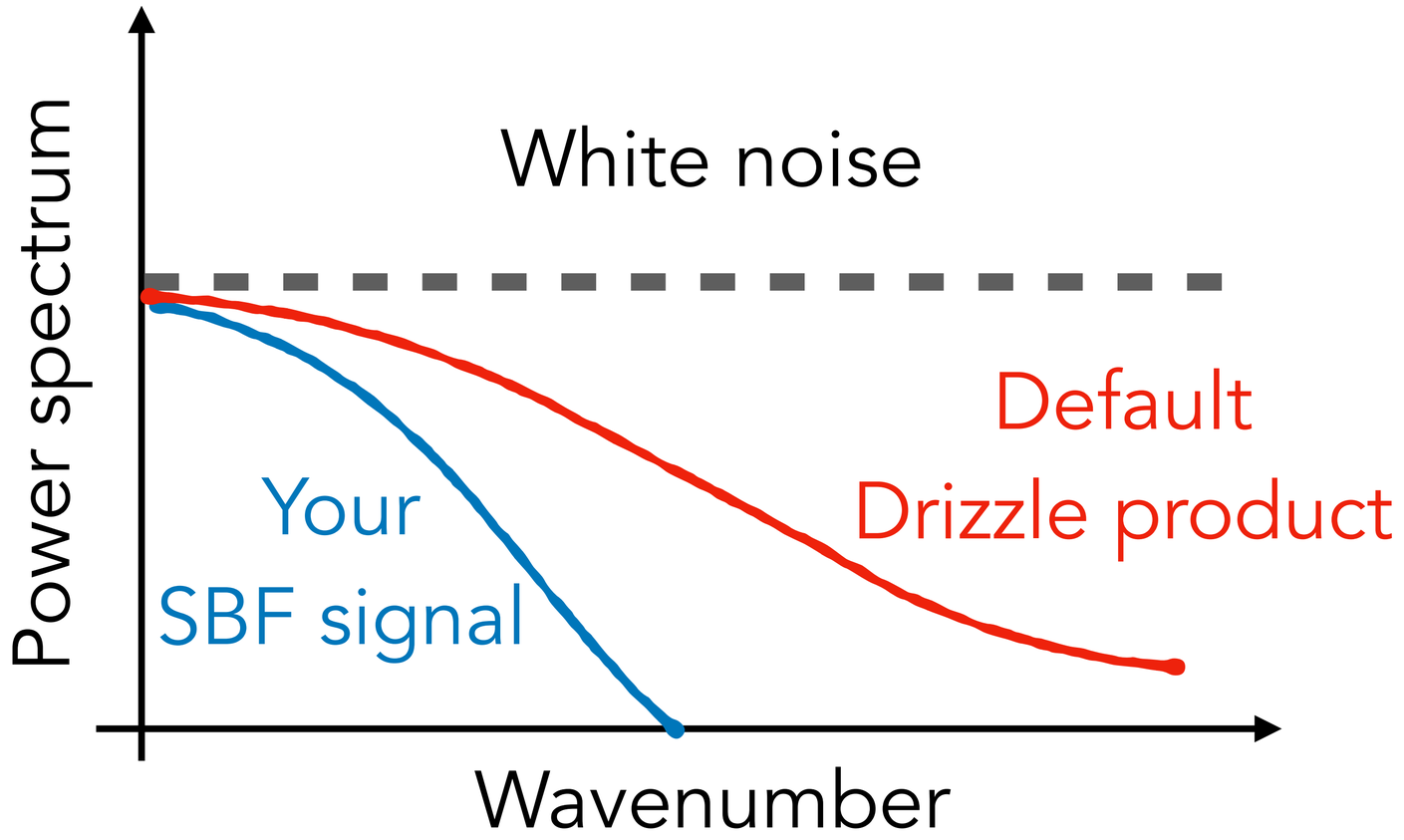
White noise



Default Drizzle product

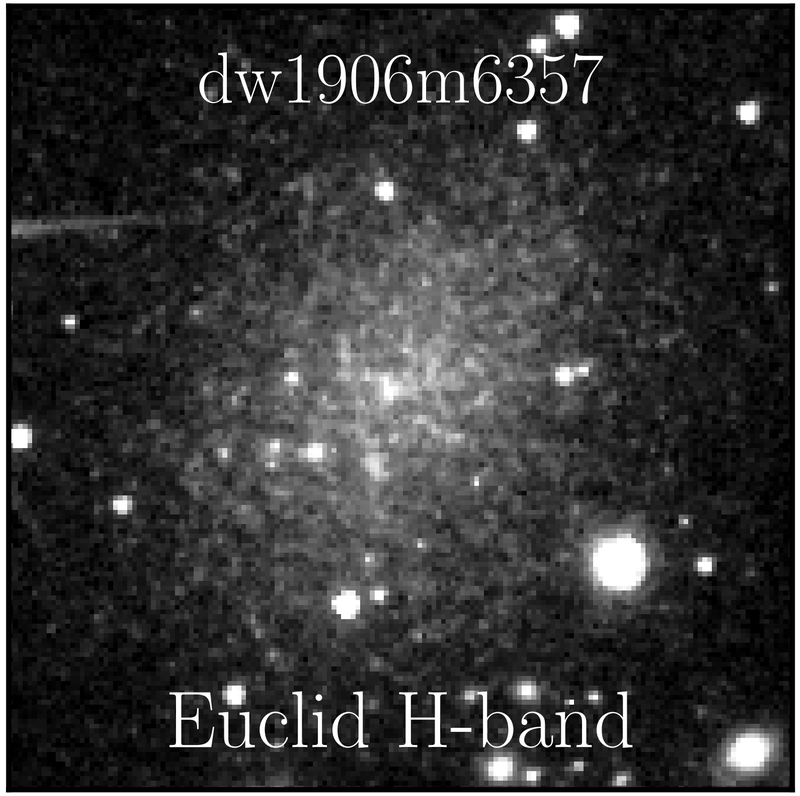


SBF challenge 2: correlated noise

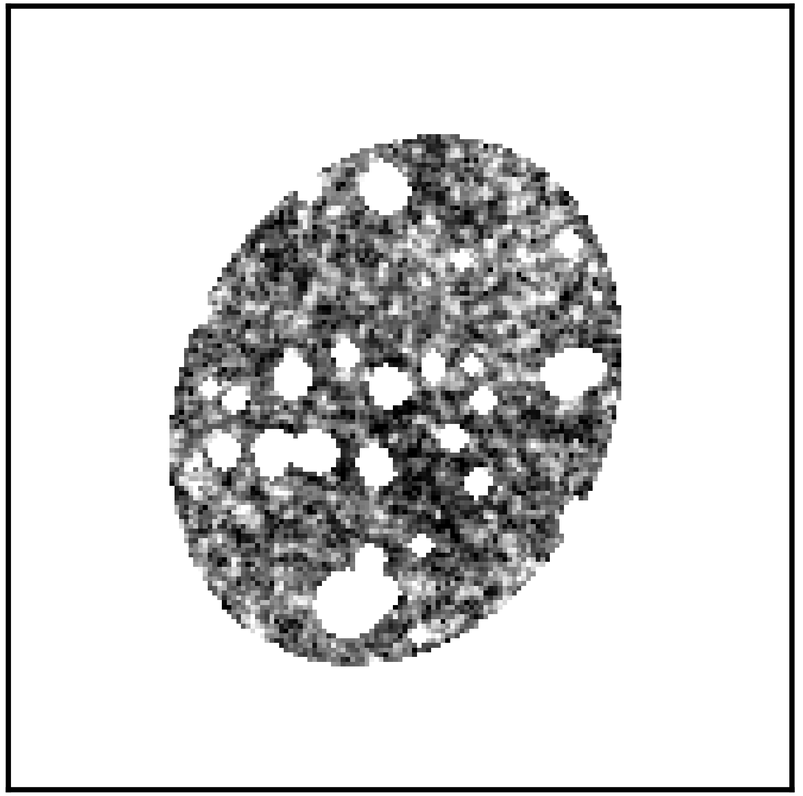


SBF challenge 2: correlated noise

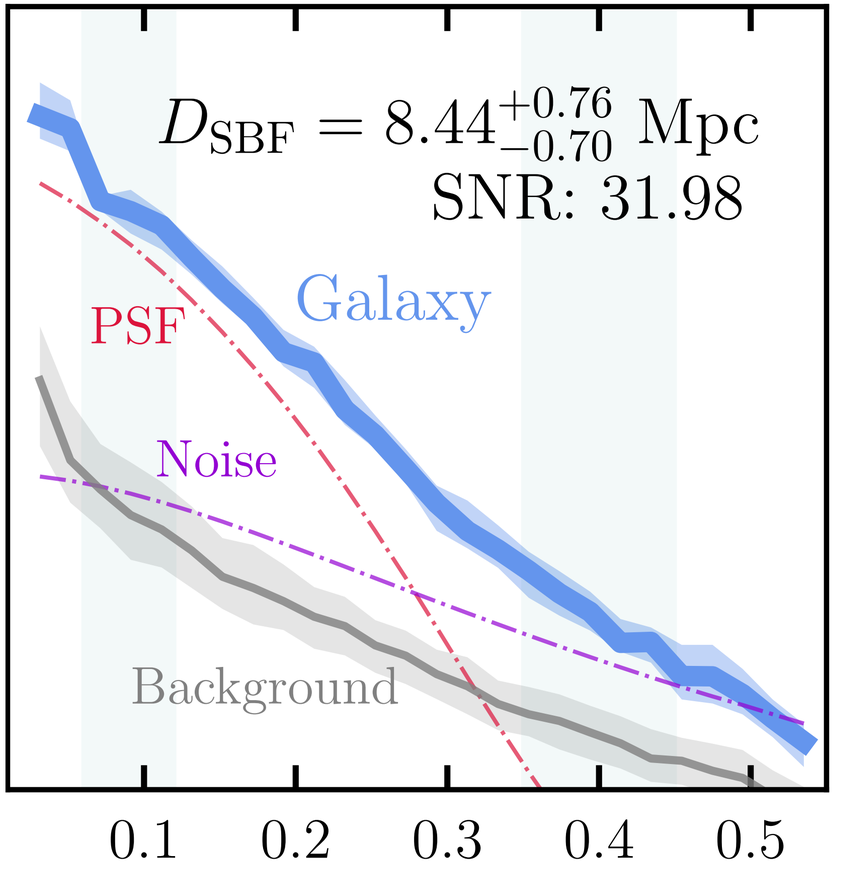
(a) Image



(b) Residual



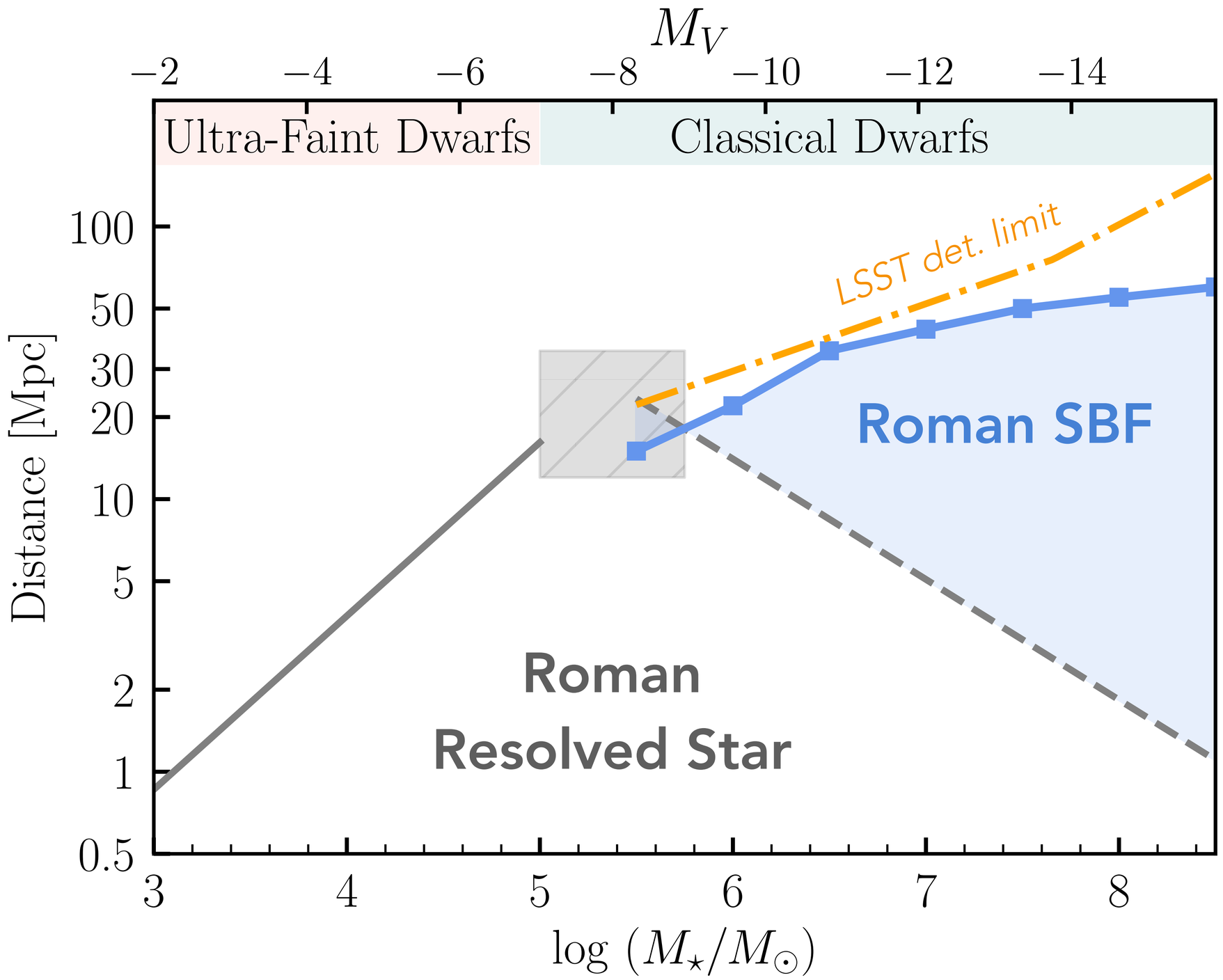
(c) Power Spectrum



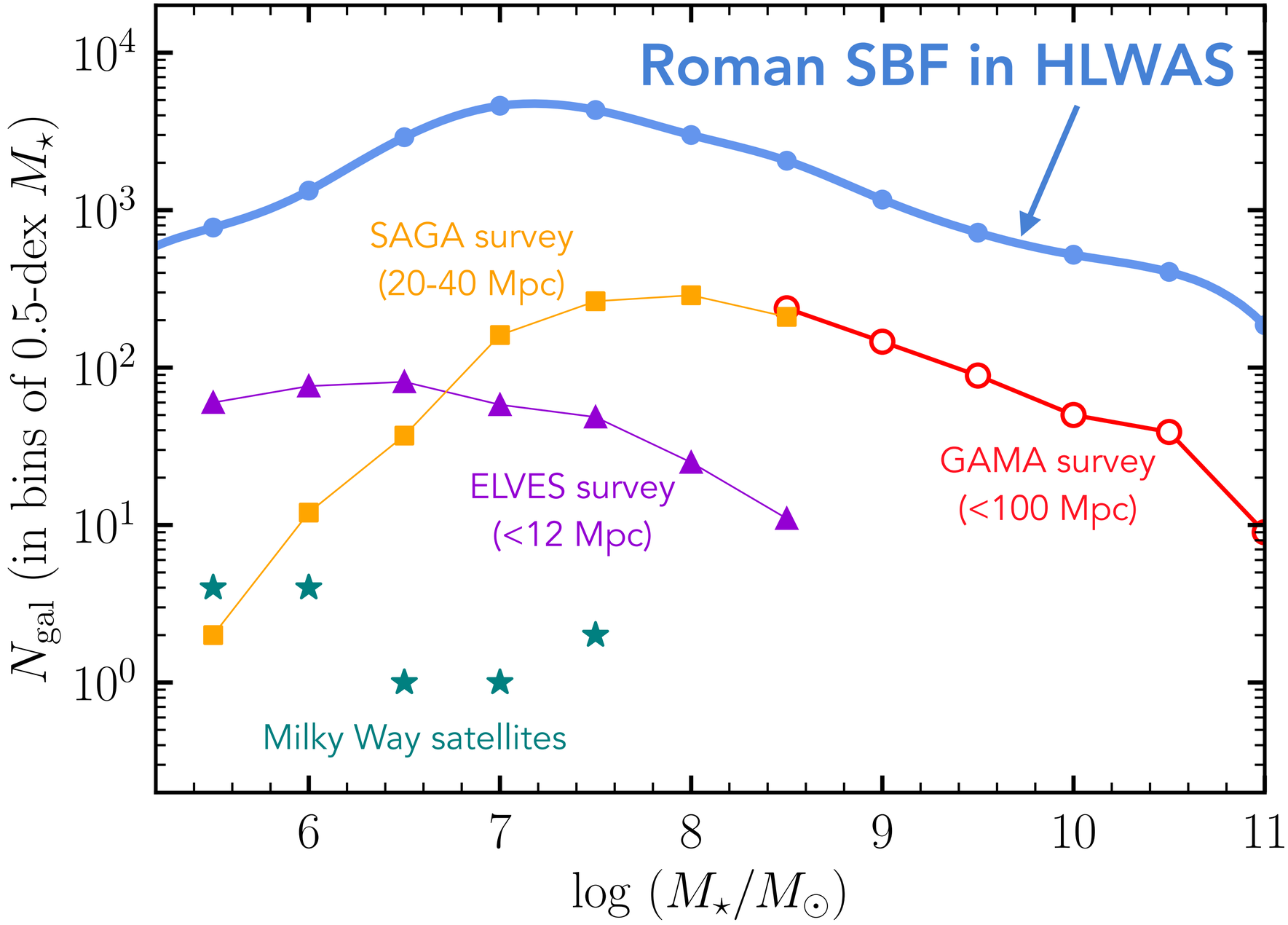
Better coadding technique (IMCOM?)

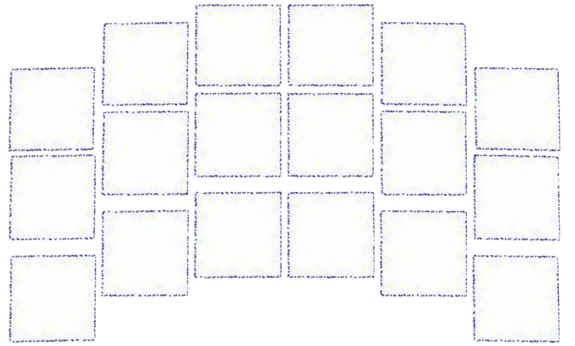
Preliminary!!

Li+ (in prep)



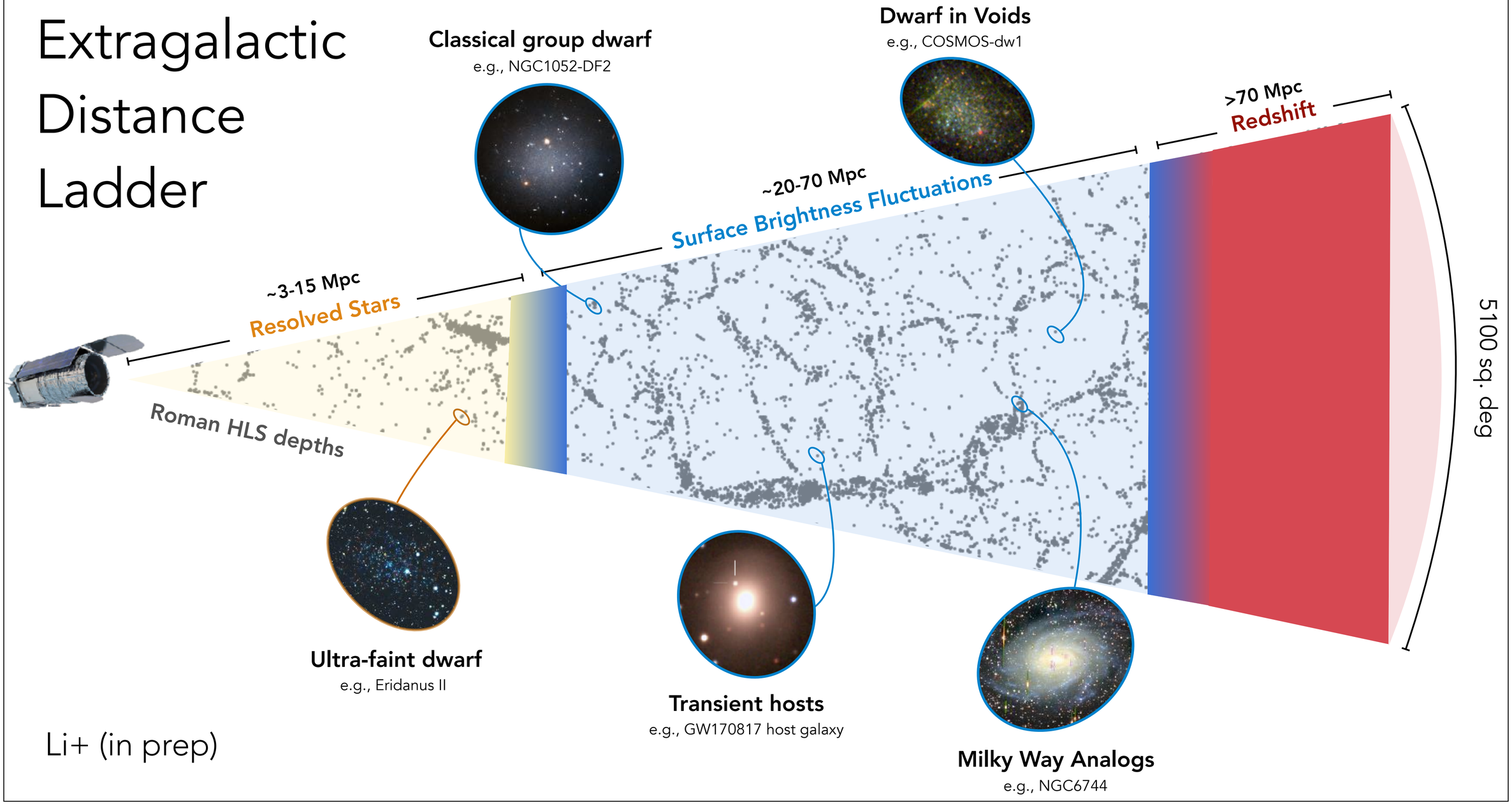
Preliminary!! Li+ (in prep)





~1 SBF-able galaxy per pointing

Extragalactic Distance Ladder



Li+ (in prep)

More Use Cases of Rosesim

UFD beyond LG

D=2 Mpc

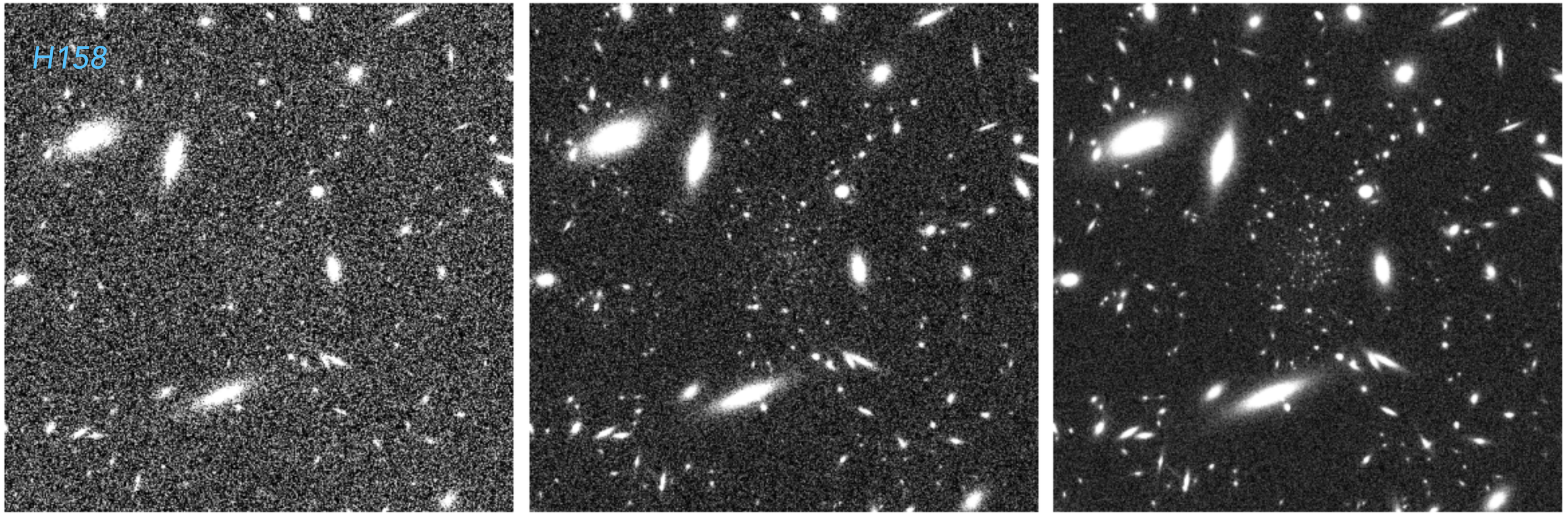
$M_\star = 10^{5.5}\ M_\odot$

Deeper observations for UFDs beyond LG

Standard HLWAS

Intermediate pointing
(4x exposure time)

Deep pointing
(16x exposure time)

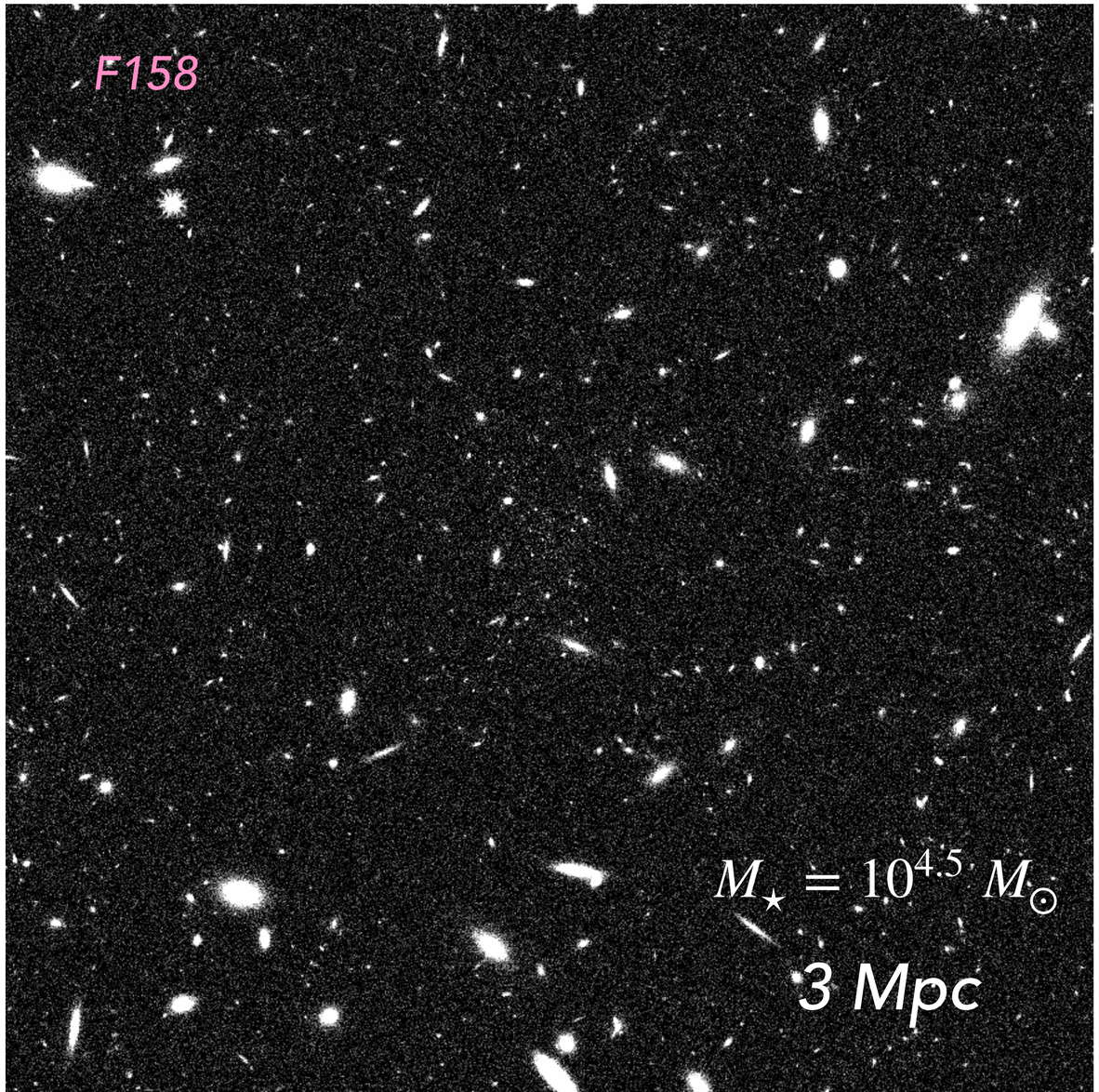


$M_\star = 10^4\ M_\odot$

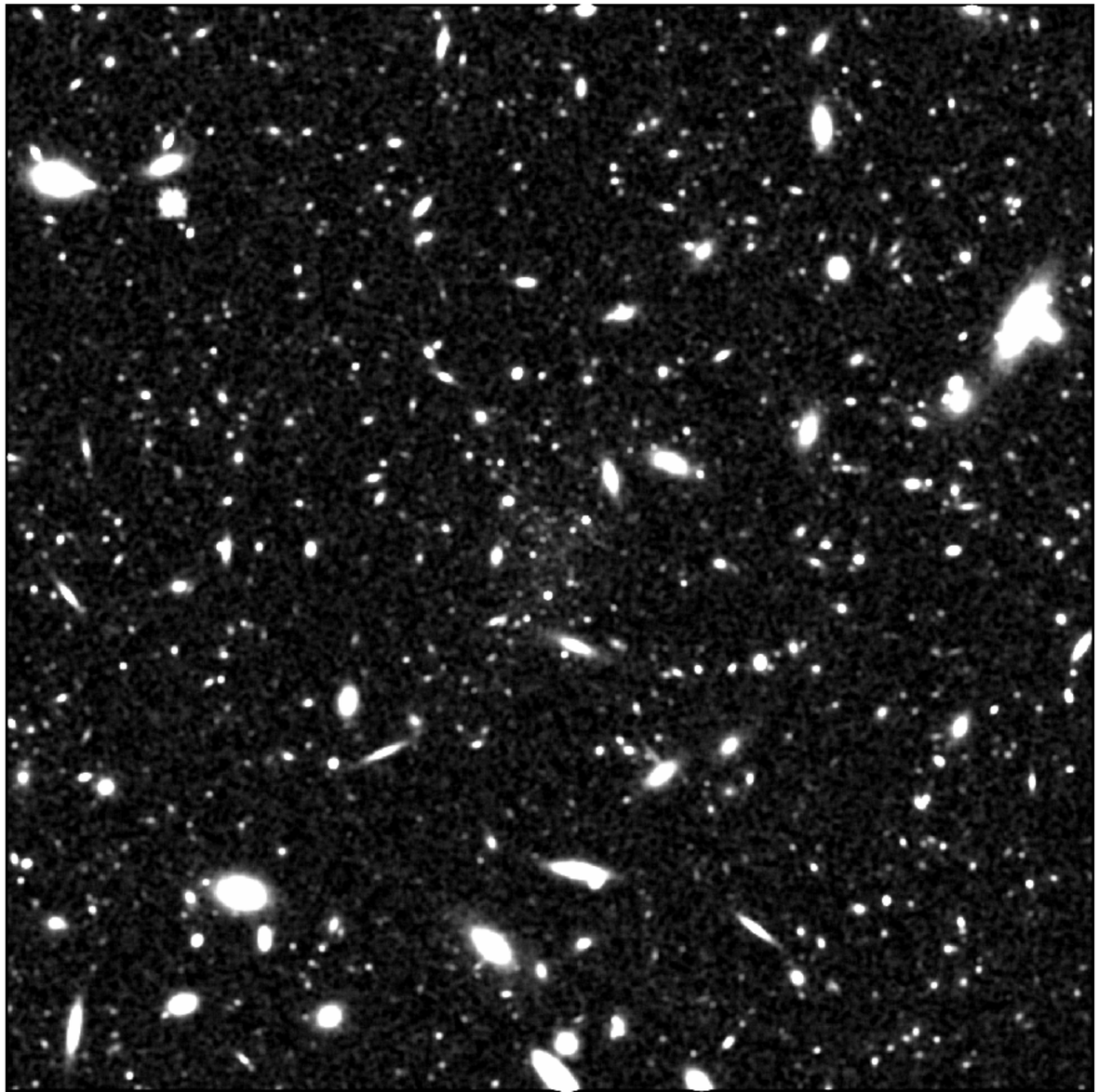
D=5 Mpc

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.)

Jiaxuan Li
(Princeton)