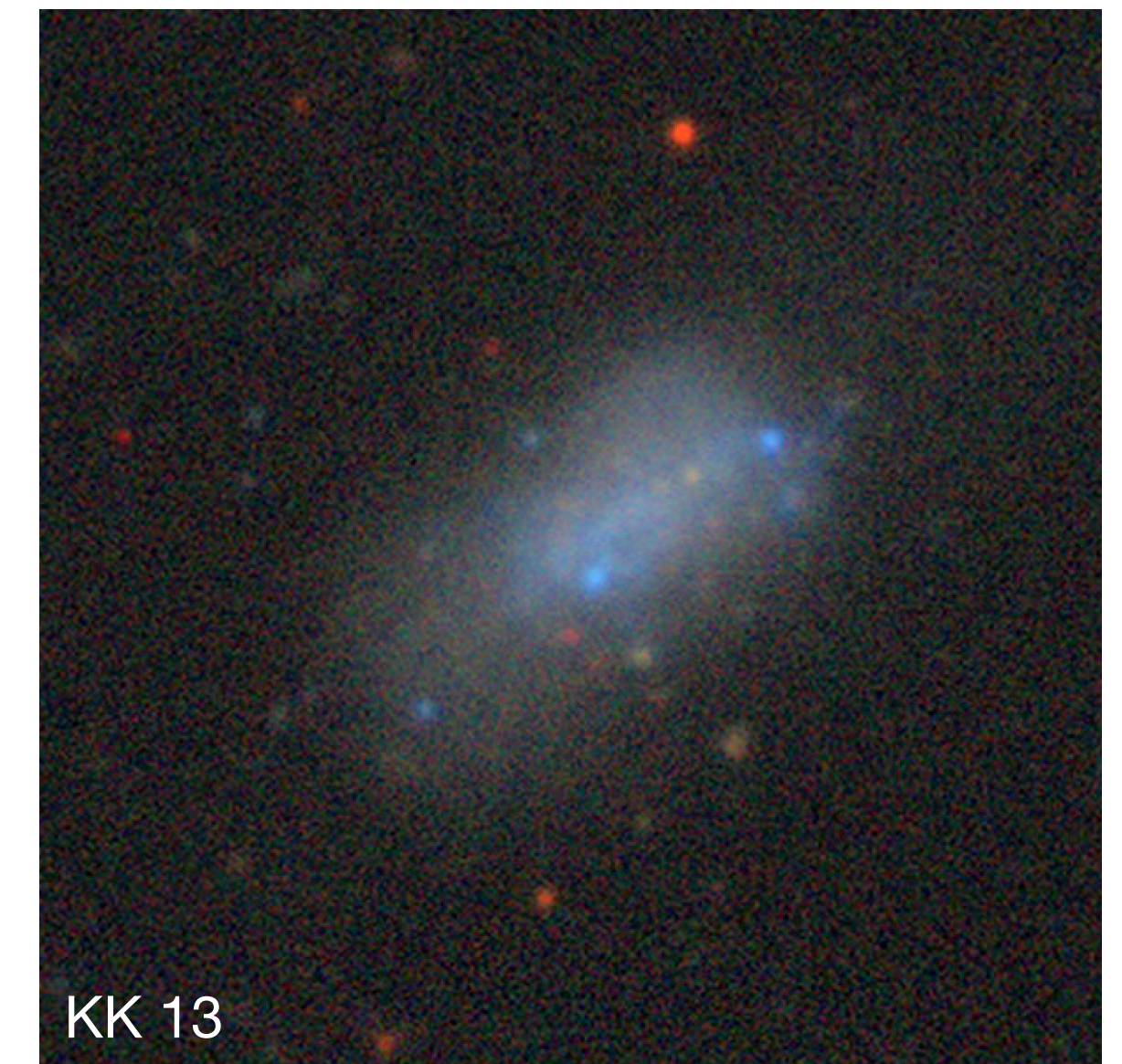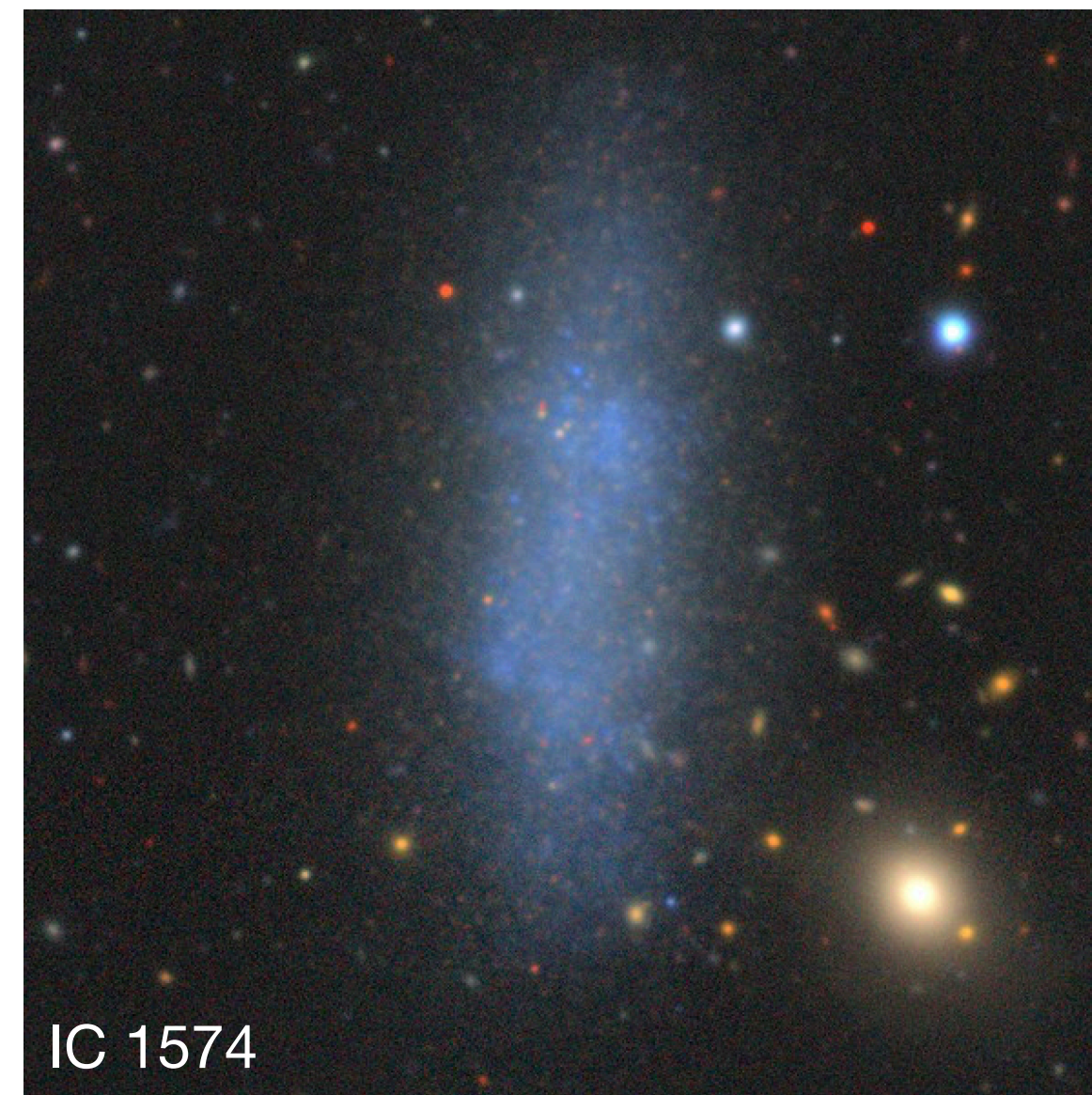# How to Measure Distances to Dwarf Galaxies (ft. ML)
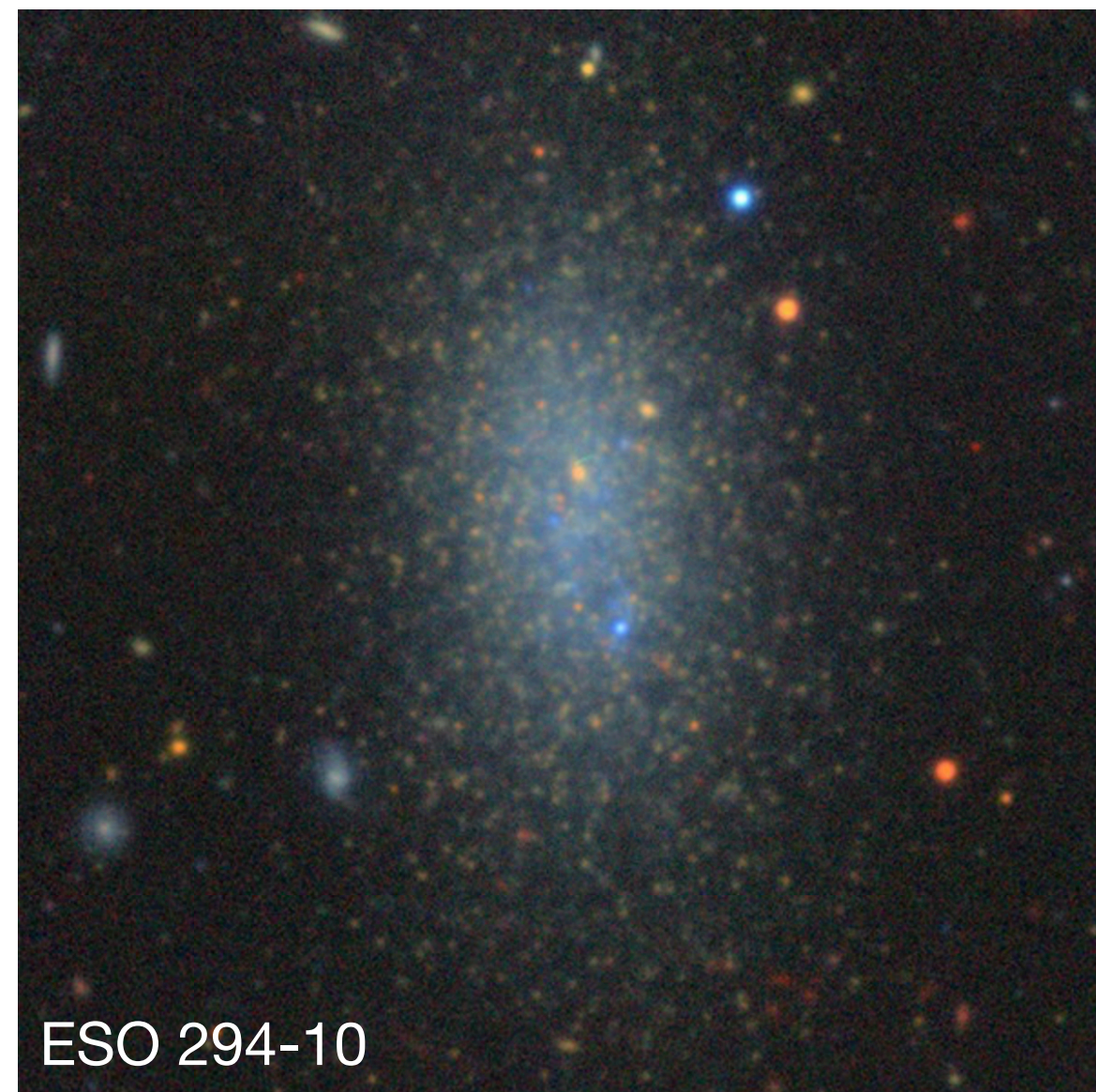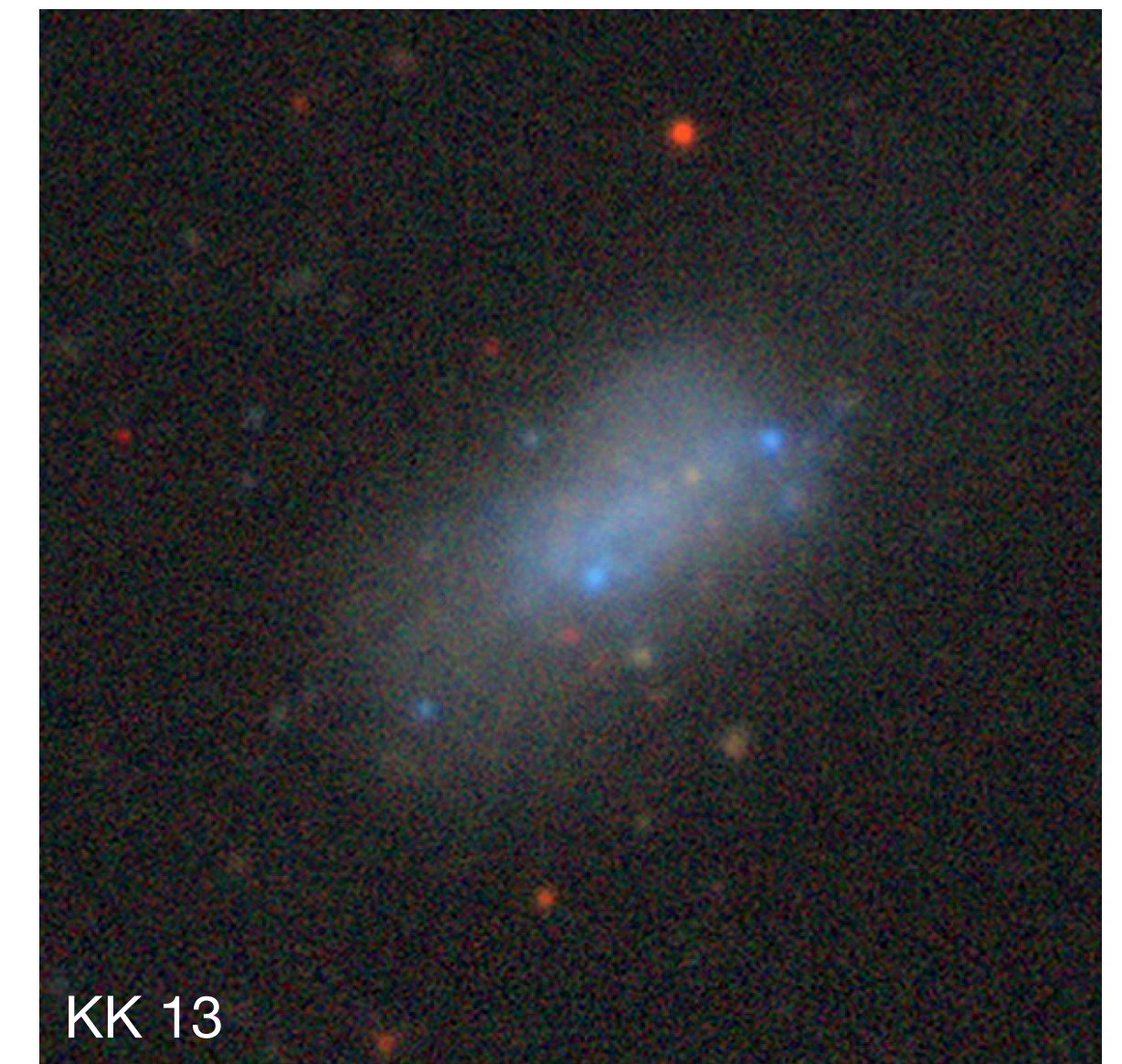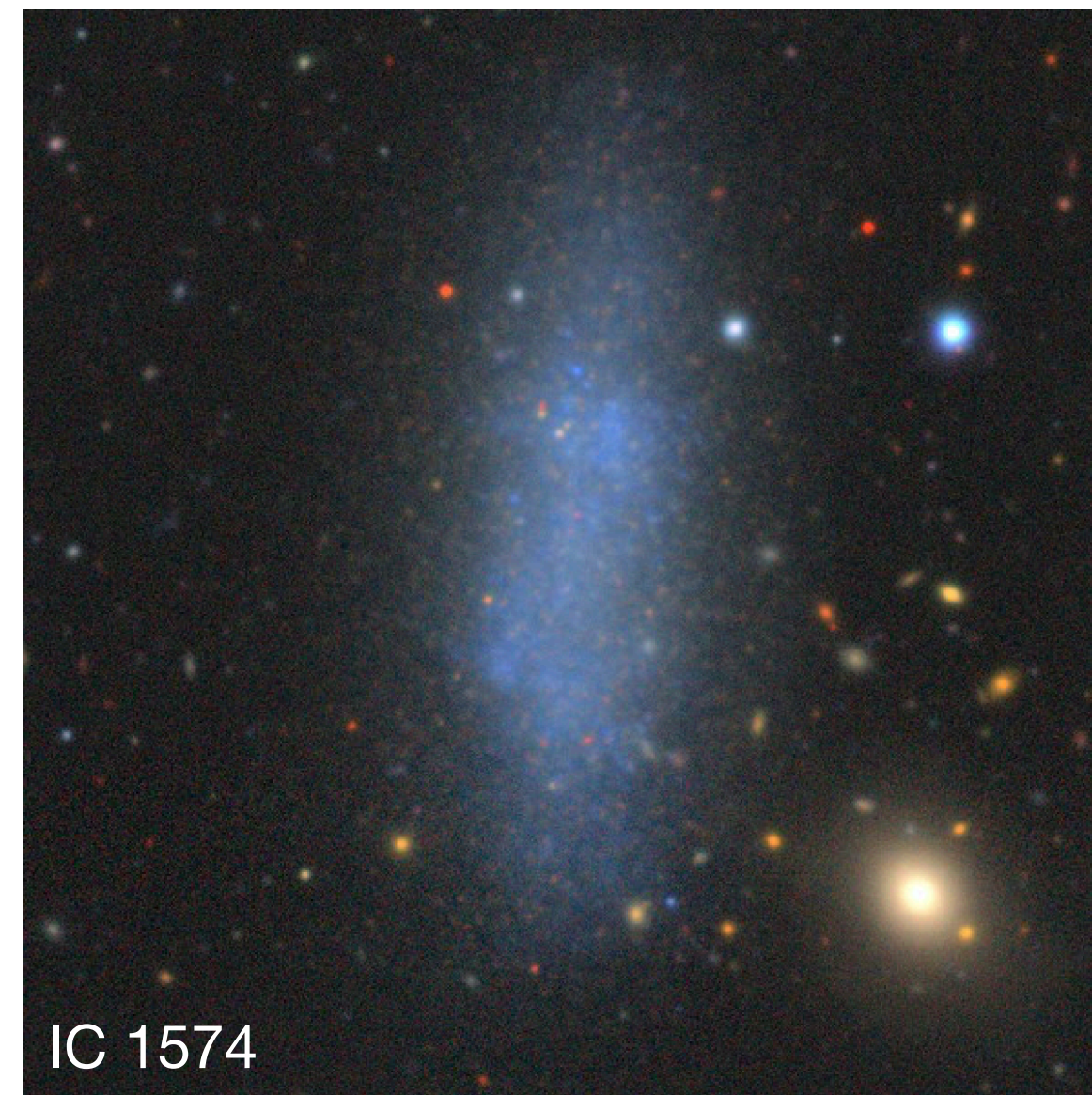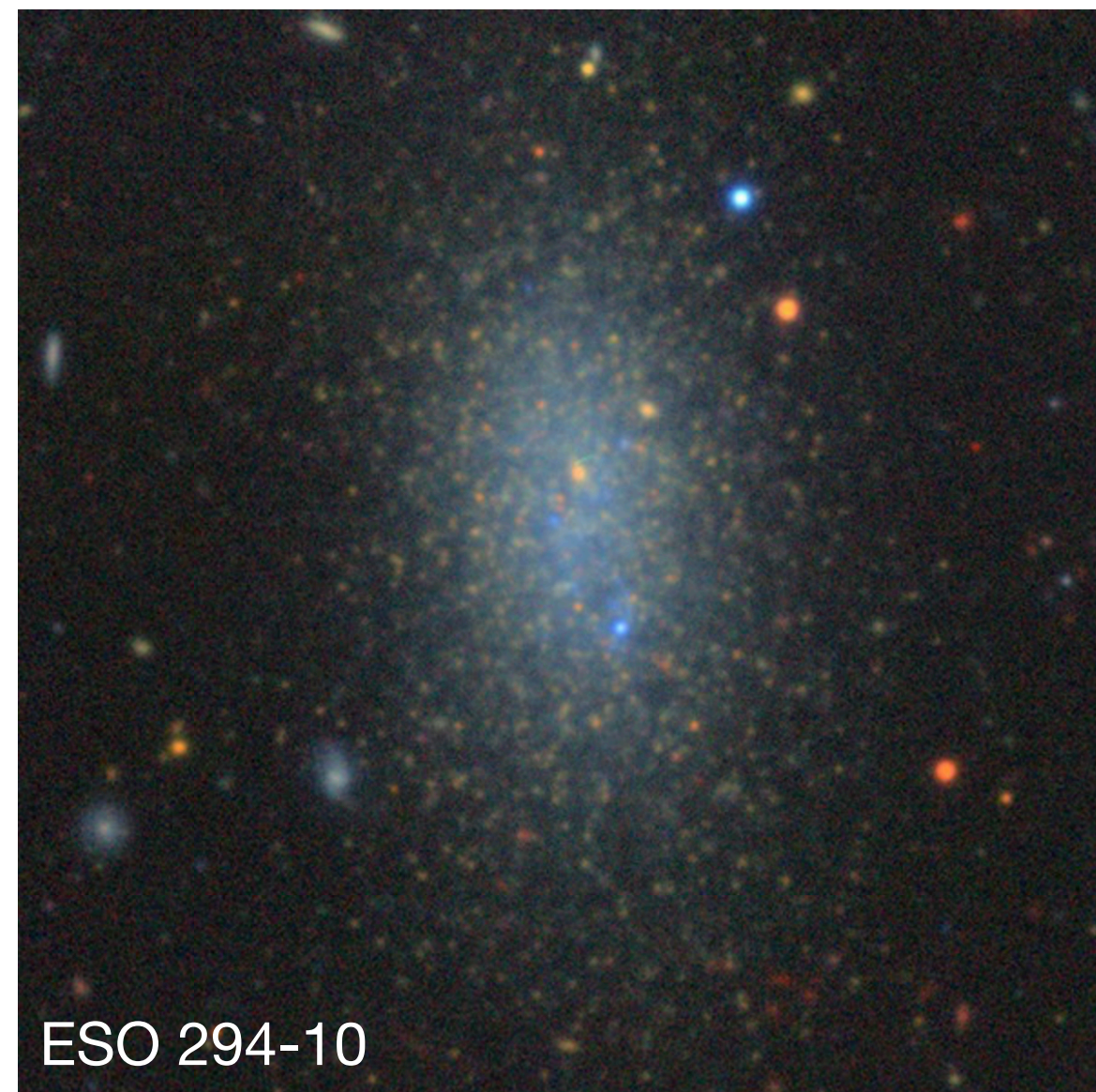
ESO 294-10

IC 1574

KK 13

Tim Miller

Rare Gems in Big Data 2024

Imad Pasha, Ava Polzin and Pieter van Dokkum

Dwarf galaxies ($6 < \log M_*/M_\odot < 8$) are old and dark matter dominated

ESO 294-10

IC 1574

KK 13

Dwarf galaxies are sensitive to ΛCDM (and baryonic physics and selection effects)

See review by Sales, Wetzel and Fattahi (2022)

WHERE ARE THE MISSING GALACTIC SATELLITES?

ANATOLY A. KLYPIN, ANDREY V. KRAVTSOV, AND OCTAVIO VALENZUELA

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FRANCISCO PRADA

Instituto de Astronomia, Apartado Postal 877, 22900 Ensenada, Mexico

submitted to the Astrophysical Journal

THE NATURE OF DARK MATTER

Ben Moore

Department of Astronomy, University of California, Berkeley, CA 94720, USA

Too big to fail? The puzzling darkness of massive Milky Way subhaloes

Michael Boylan-Kolchin,⋆† James S. Bullock and Manoj Kaplinghat

Department of Physics and Astronomy, Center for Cosmology, University of California, 4129 Reines Hall, Irvine, CA 92697, USA

NEAR-FIELD COSMOLOGY

A whirling plane of satellite galaxies around Centaurus A challenges cold dark matter cosmology

Oliver Müller,[1]* Marcel S. Pawlowski,[2] Helmut Jerjen,[3] Federico Lelli[4]

3

Current and new surveys find many dwarfs beyond the local group

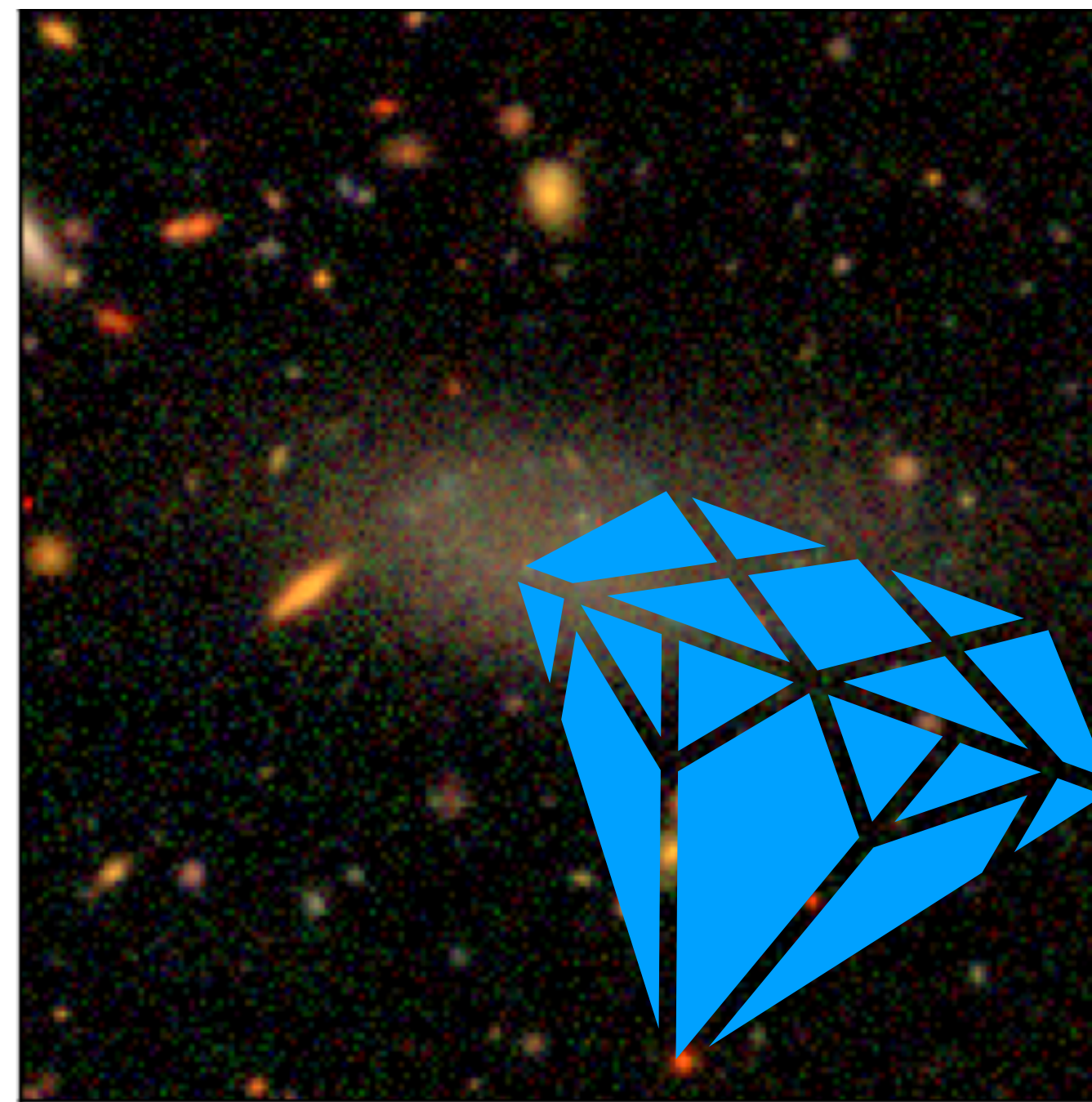Three example galaxies found in HSC-SSP imaging by Greco et al. 2018

See also: Zaritsky et al. 2019, Prole et al. 2019, Carlsten et al. 2019
and Nicolas's posters
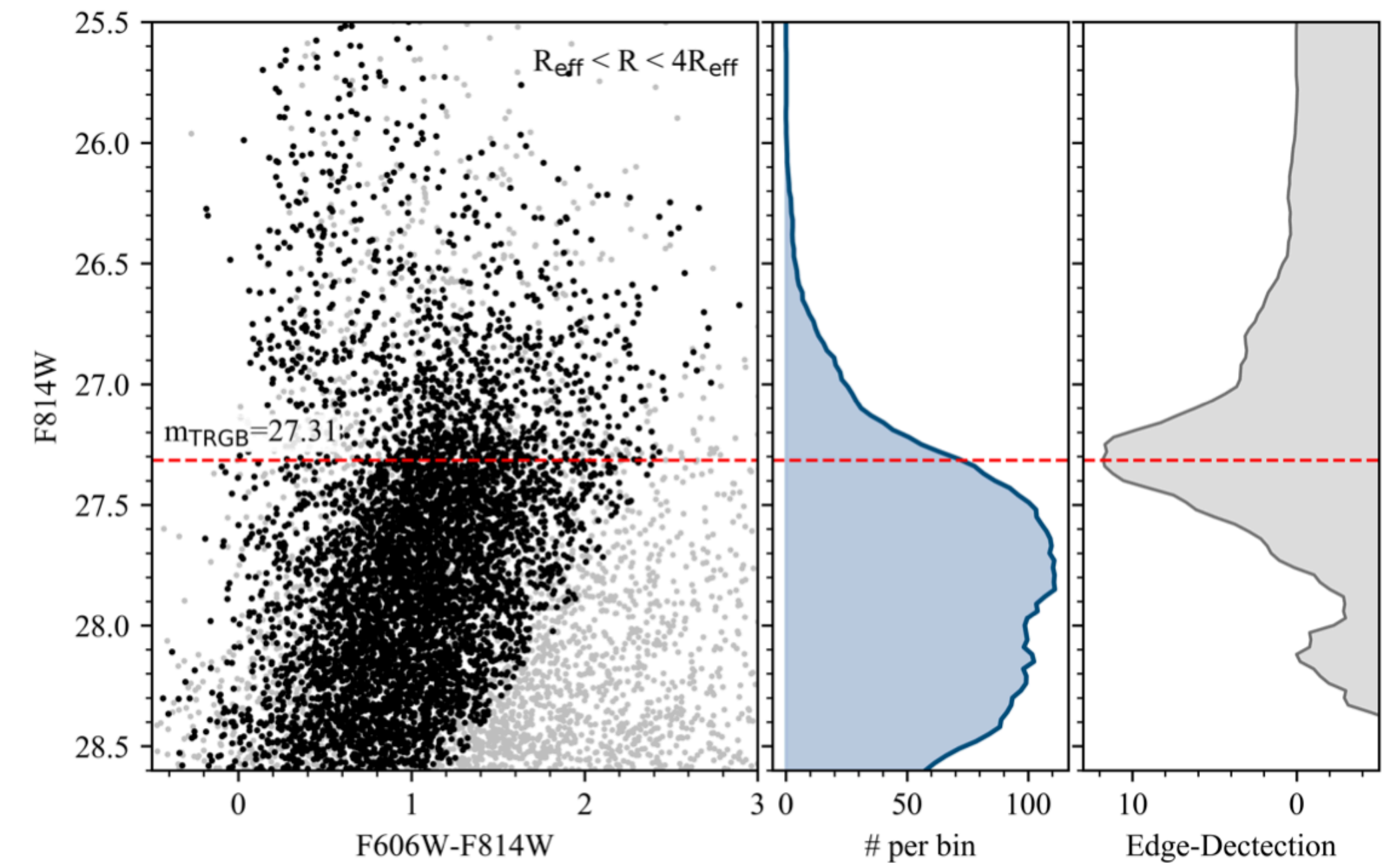
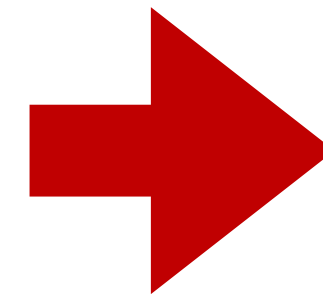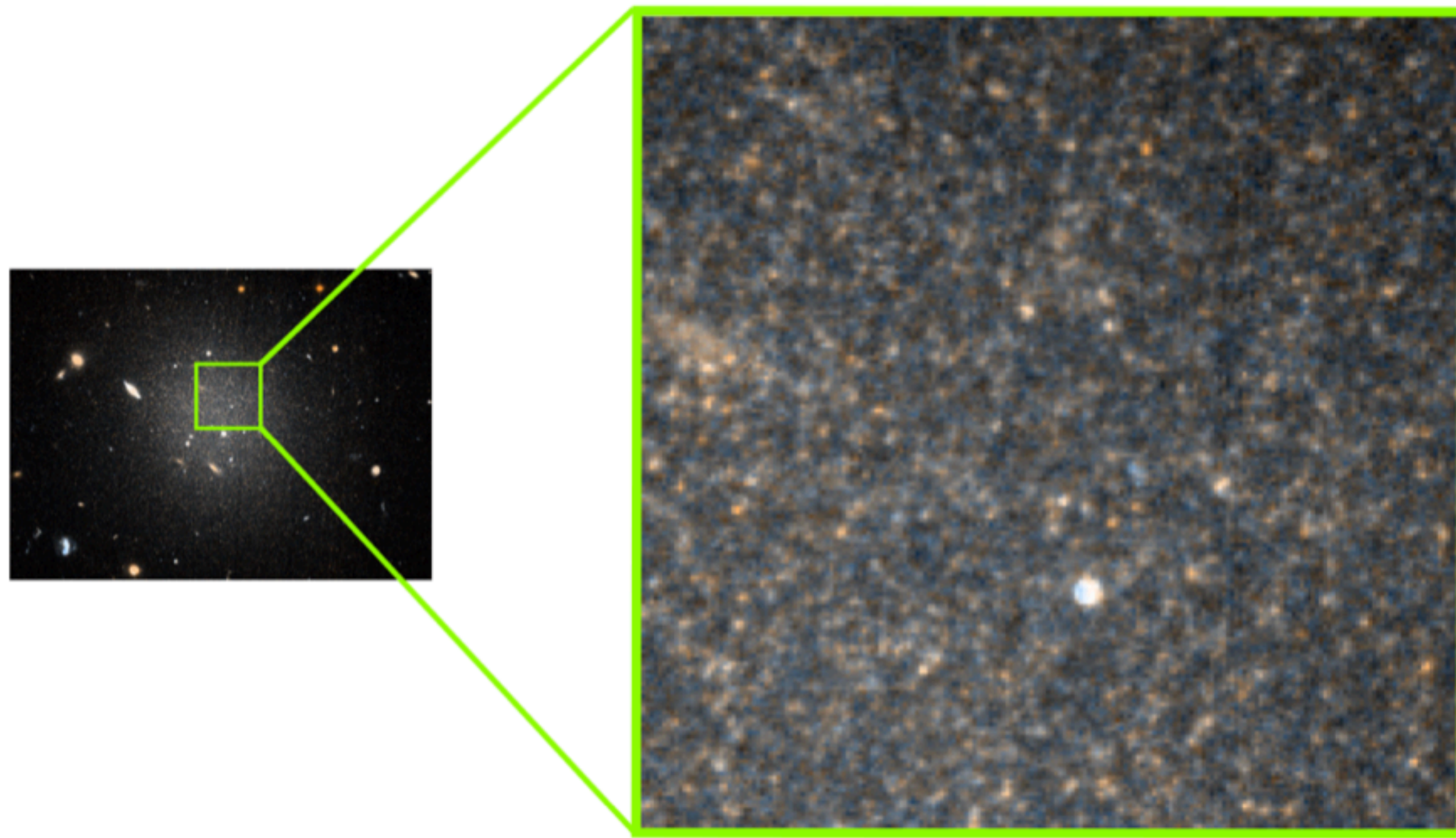# But distance measurements are needed

Three example galaxies found in HSC-SSP imaging by Greco et al. 2018

See also: Zaritsky et al. 2019, Prole et al. 2019, Carlsten et al. 2019

and Nicolas's posters

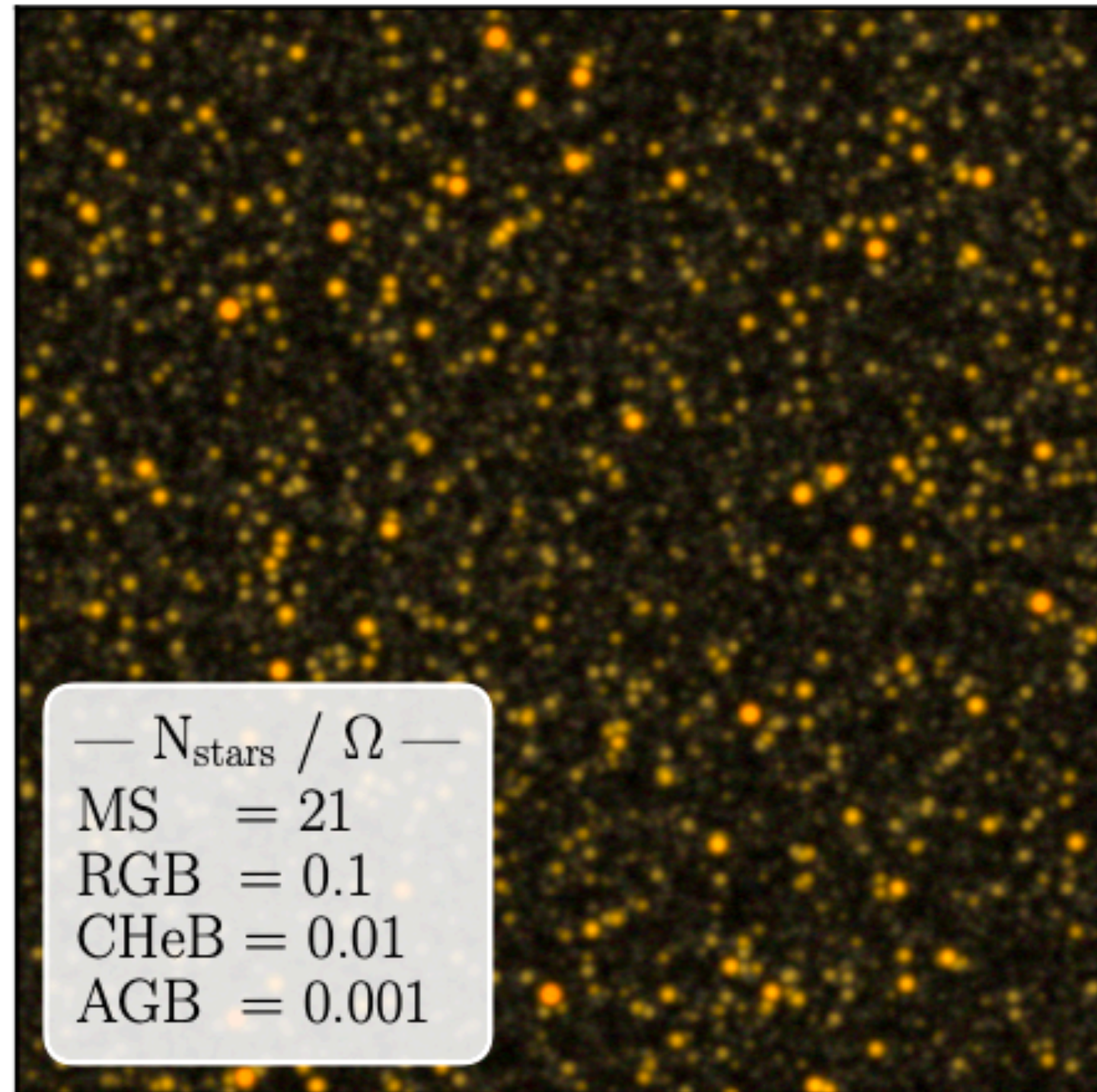# How do you measure distances to dwarf galaxies?

Tip of the red giant branch (TRGB)

Danieli et al (2019)

Surface brightness fluctuations (SBF)

D = 0.5 Mpc

$- N_{stars} / \Omega -$
MS   = 21
RGB = 0.1
CHeB = 0.01
AGB = 0.001

D = 2 Mpc

$- N_{stars} / \Omega -$
MS   = 329
RGB = 1.7
CHeB = 0.2
AGB = 0.02

D = 8 Mpc

$- N_{stars} / \Omega -$
MS   = 5264
RGB = 27.8
CHeB = 2.9
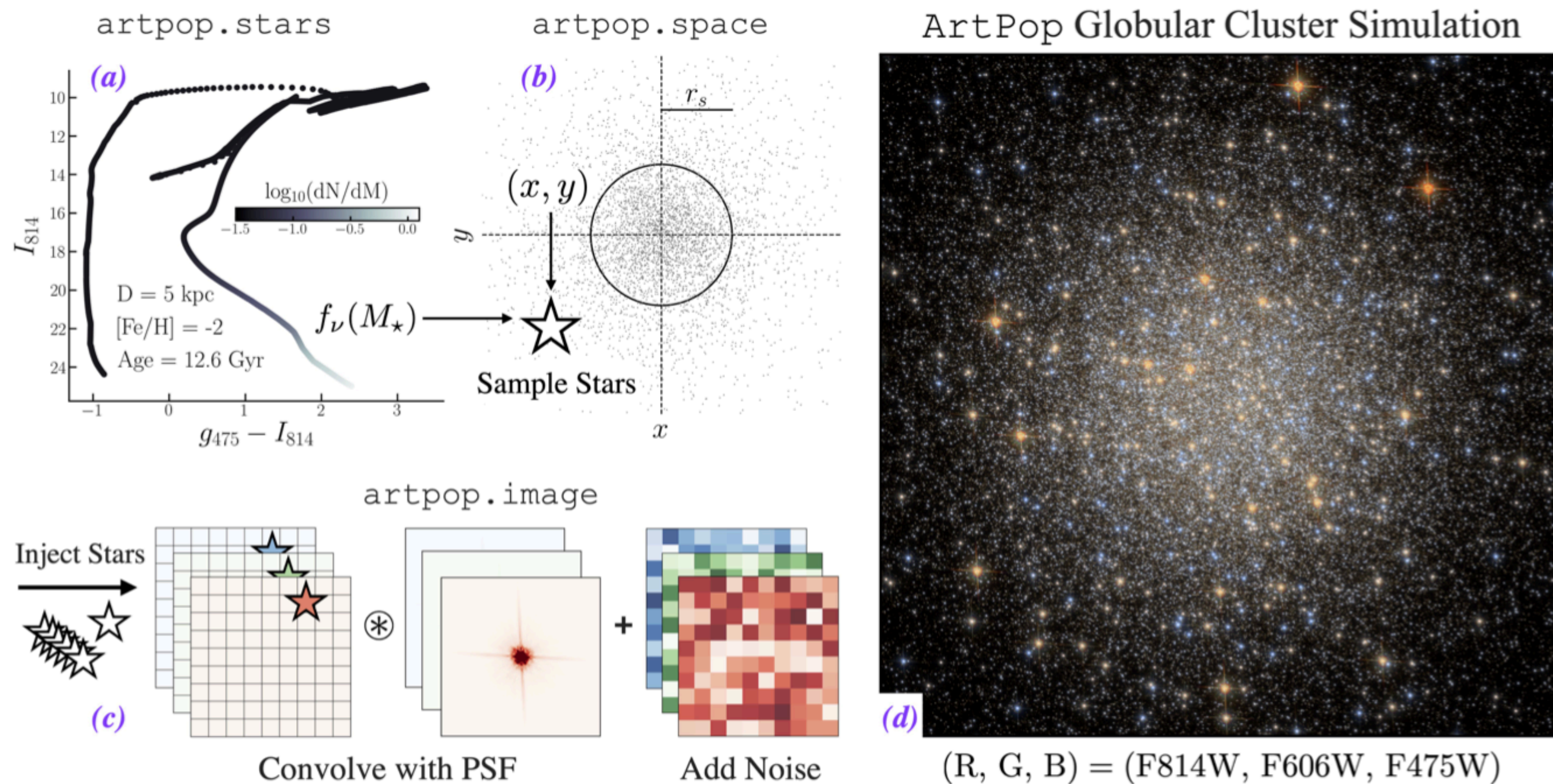AGB = 0.4
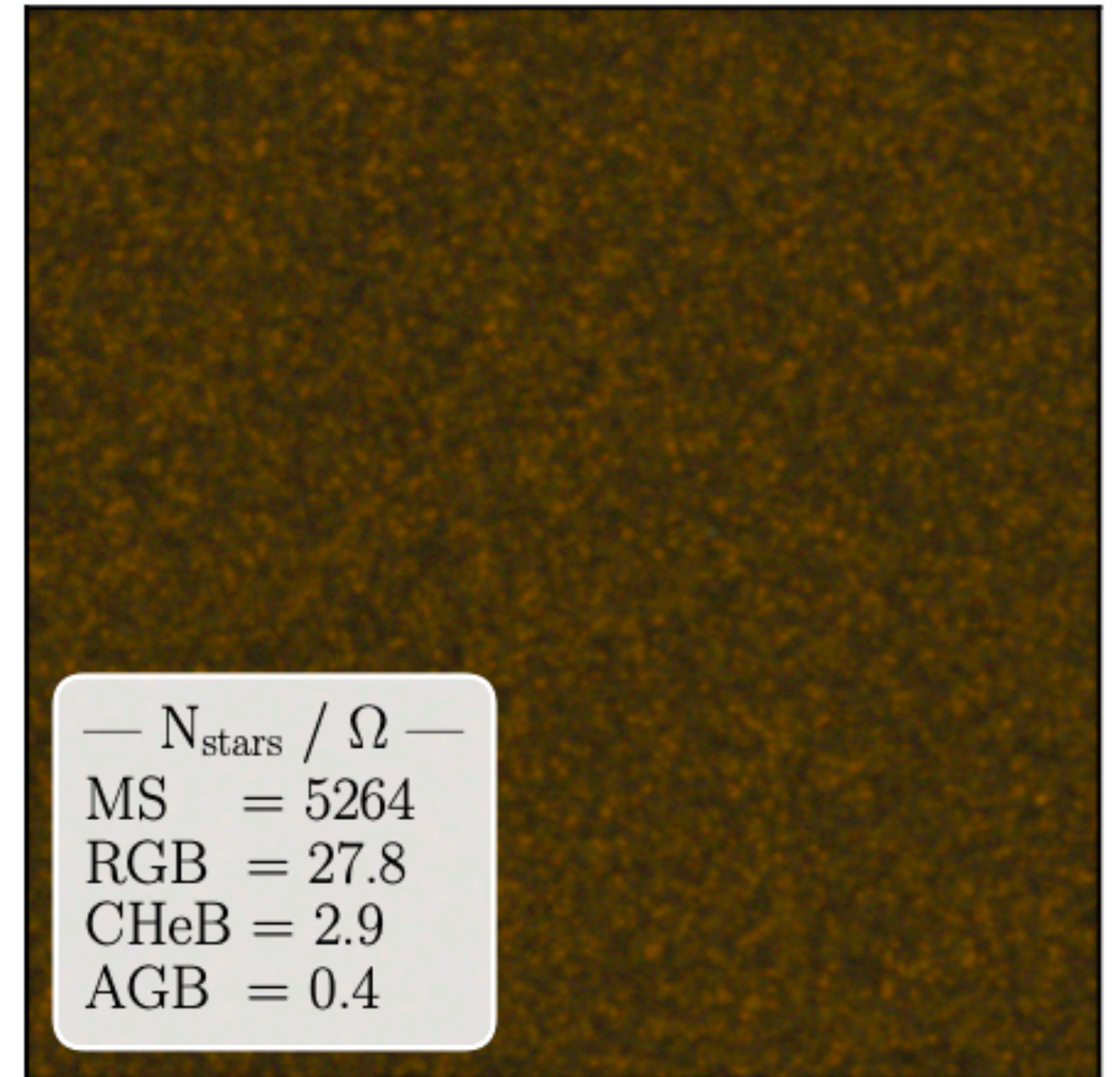
Greco et al. 2021

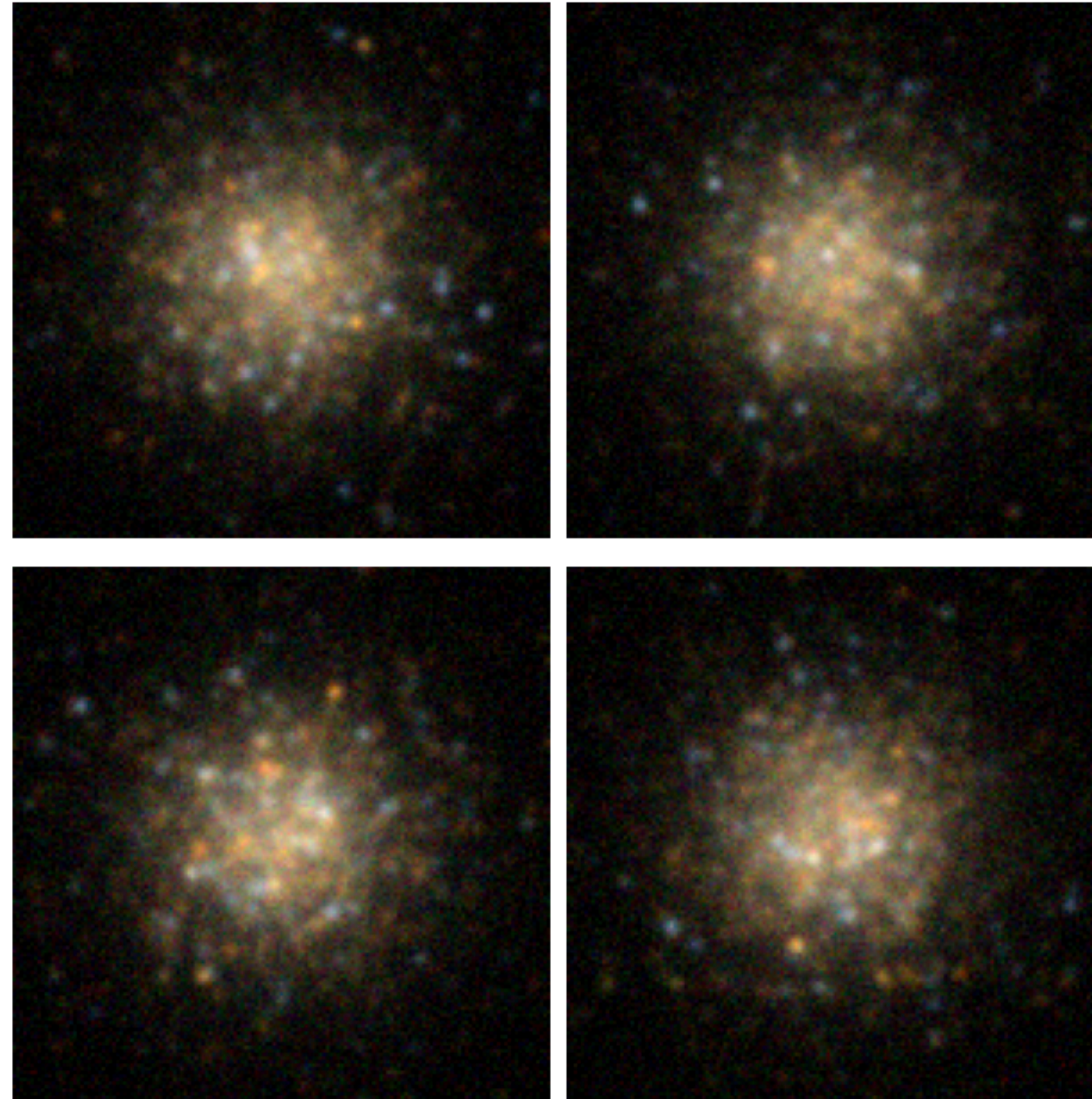# SBF is a standard*izable* candle
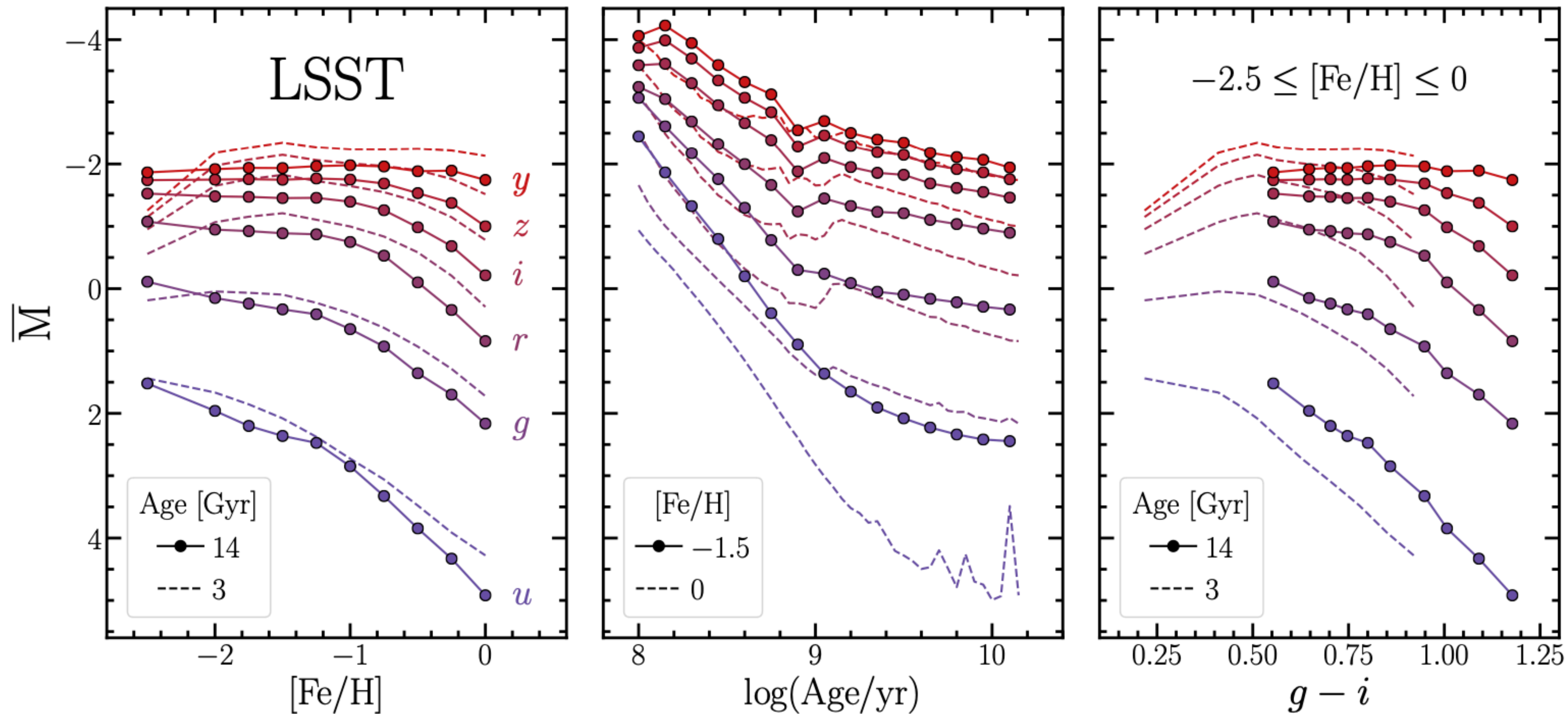
Greco et al. 2021 9

It is possible to forward model images of dwarf galaxies

Artpop - Greco & Danieli (2022)
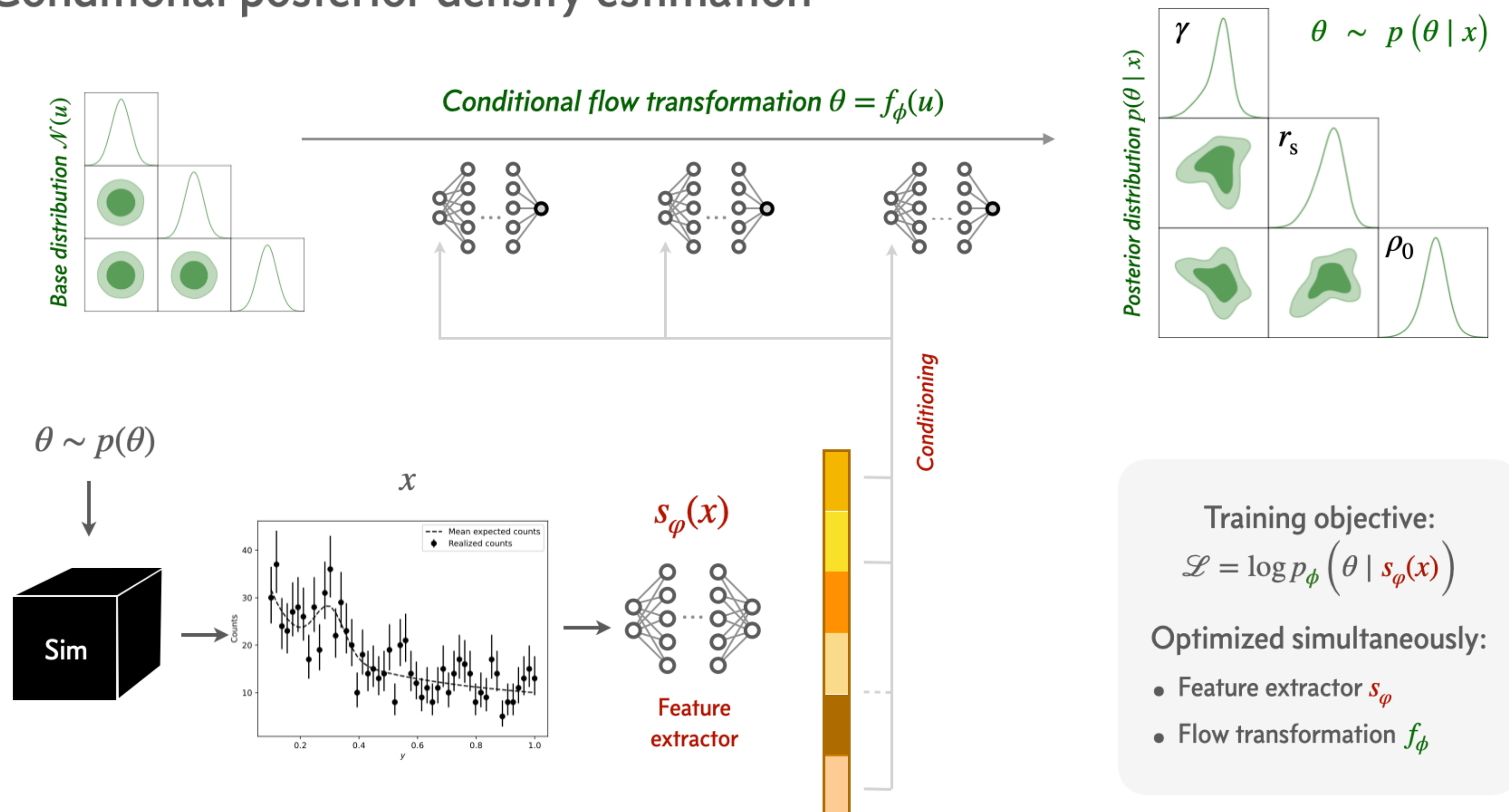
See also: Mutlu-Pakdil et al. (2021) and Cook et al (2019)

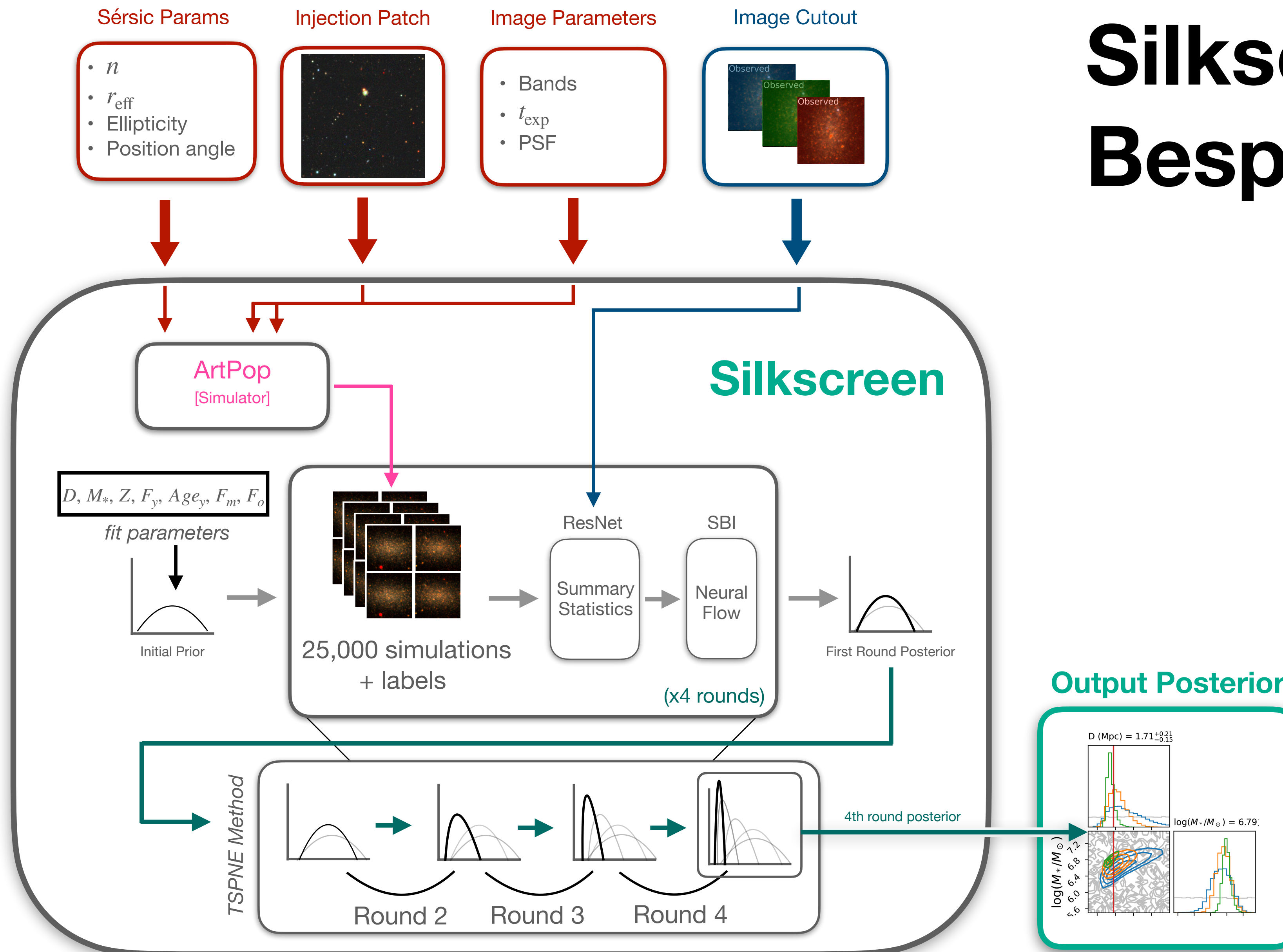# Difficult to perform traditional inference

Simulation based inference - Neural posterior estimation

Conditional posterior density estimation

Base distribution $\mathcal{N}(u)$

Conditional flow transformation $\theta = f_\phi(u)$

Posterior distribution $p(\theta \mid x)$

$\theta \sim p(\theta \mid x)$

γ

r_s

ρ_0

Conditioning

$\theta \sim p(\theta)$

Sim

x

- - - Mean expected counts
- Realized counts

$s_\varphi(x)$

Feature extractor

Training objective:
$$\mathcal{L} = \log p_\phi\left(\theta \mid s_\varphi(x)\right)$$

Optimized simultaneously:
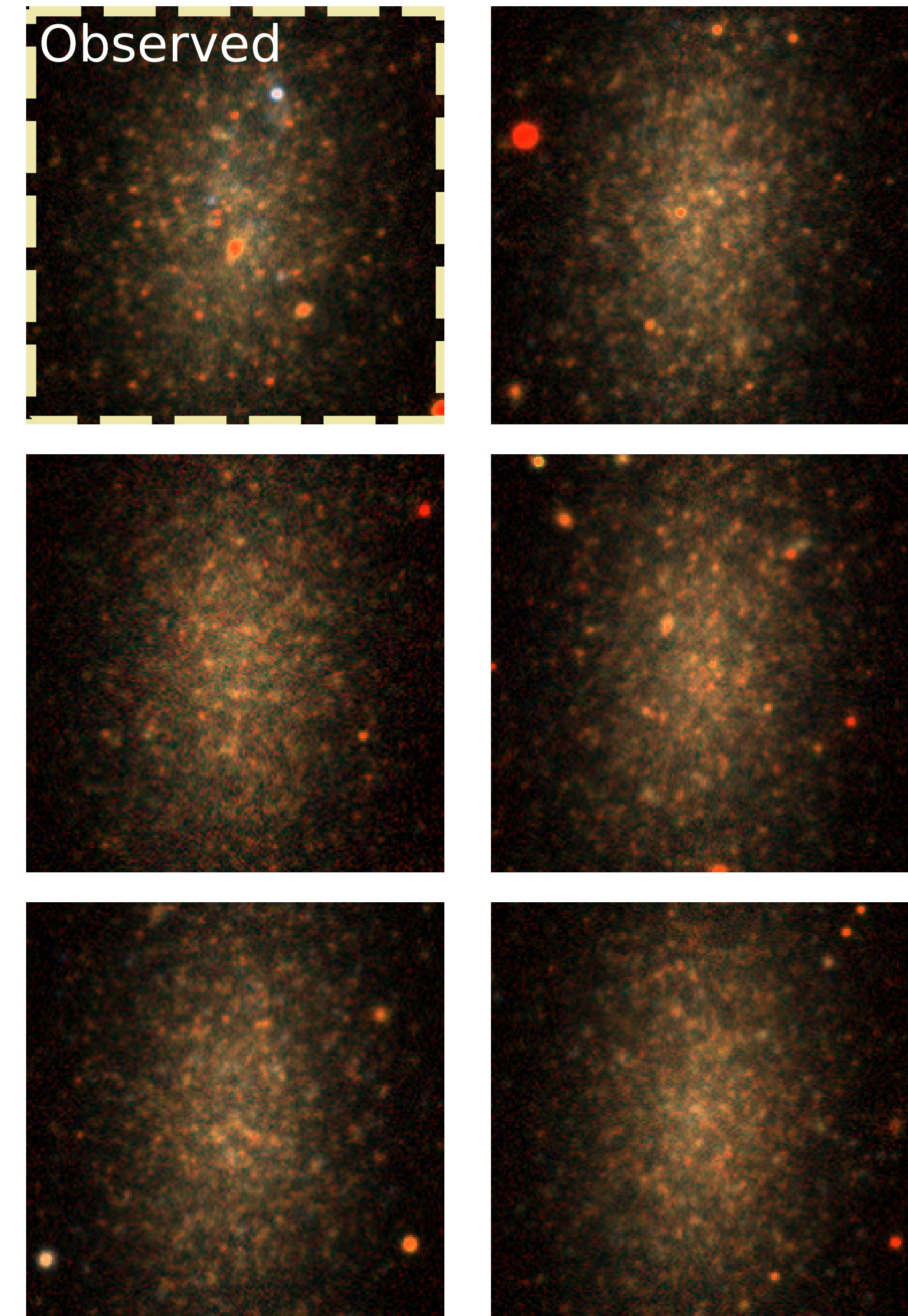- Feature extractor s_φ
- Flow transformation f_ϕ

Credit: Siddharth Mishra-Sharma

12

Silkscreen - Bespoke Pipeline

Sérsic Params
- n
- r_{eff}
- Ellipticity
- Position angle

Injection Patch

Image Parameters
- Bands
- t_{exp}
- PSF

Image Cutout

Observed
Observed
Observed

Silkscreen

ArtPop
[Simulator]

$D, M_*, Z, F_y, Age_y, F_m, F_o$

fit parameters

Initial Prior

25,000 simulations + labels

ResNet
Summary Statistics

SBI
Neural Flow

First Round Posterior

(x4 rounds)

TSPNE Method

Round 2   Round 3   Round 4

4th round posterior

Output Posterior

D (Mpc) = $1.71^{+0.21}_{-0.15}$

$\log(M_*/M_\odot)$ = 6.79

$\log(M_*/M_\odot)$

Applied to ESO 294-10 at 1.99 Mpc

Distance

Stellar mass

Metallicity

Frac. in young pop.

Age of young pop.

Frac. in 1 Gyr pop.
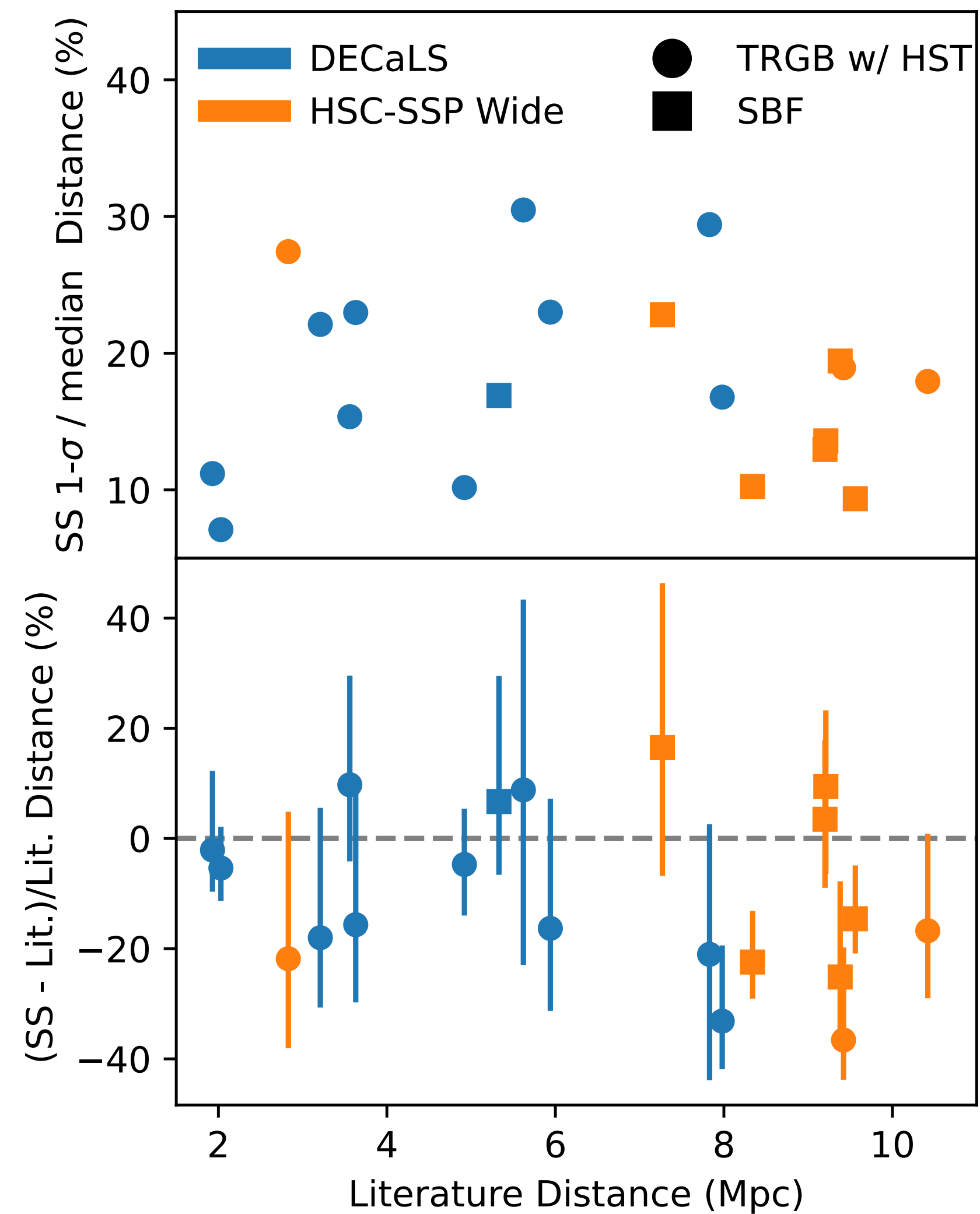
Observed
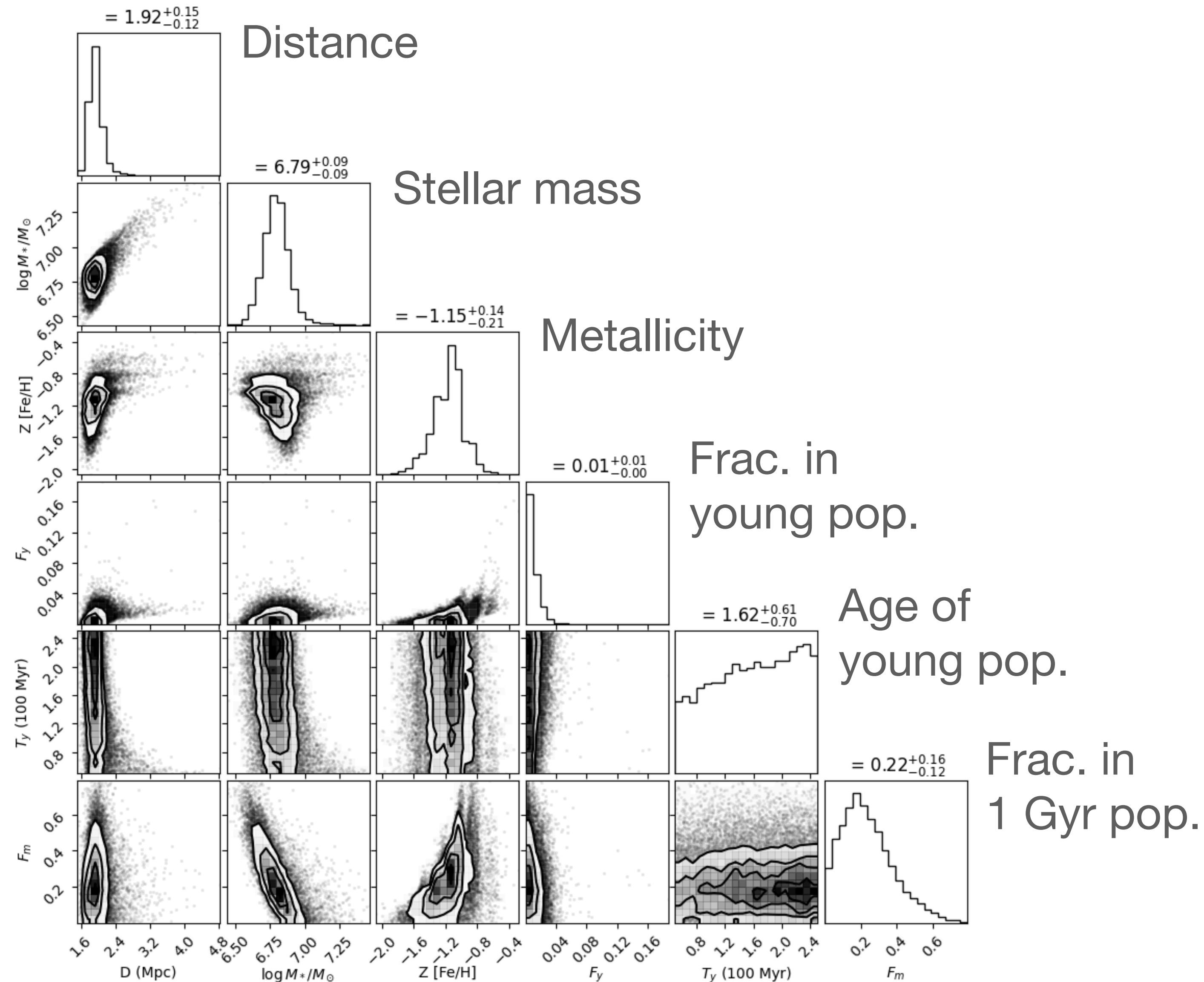
SilkScreen can recover known distances
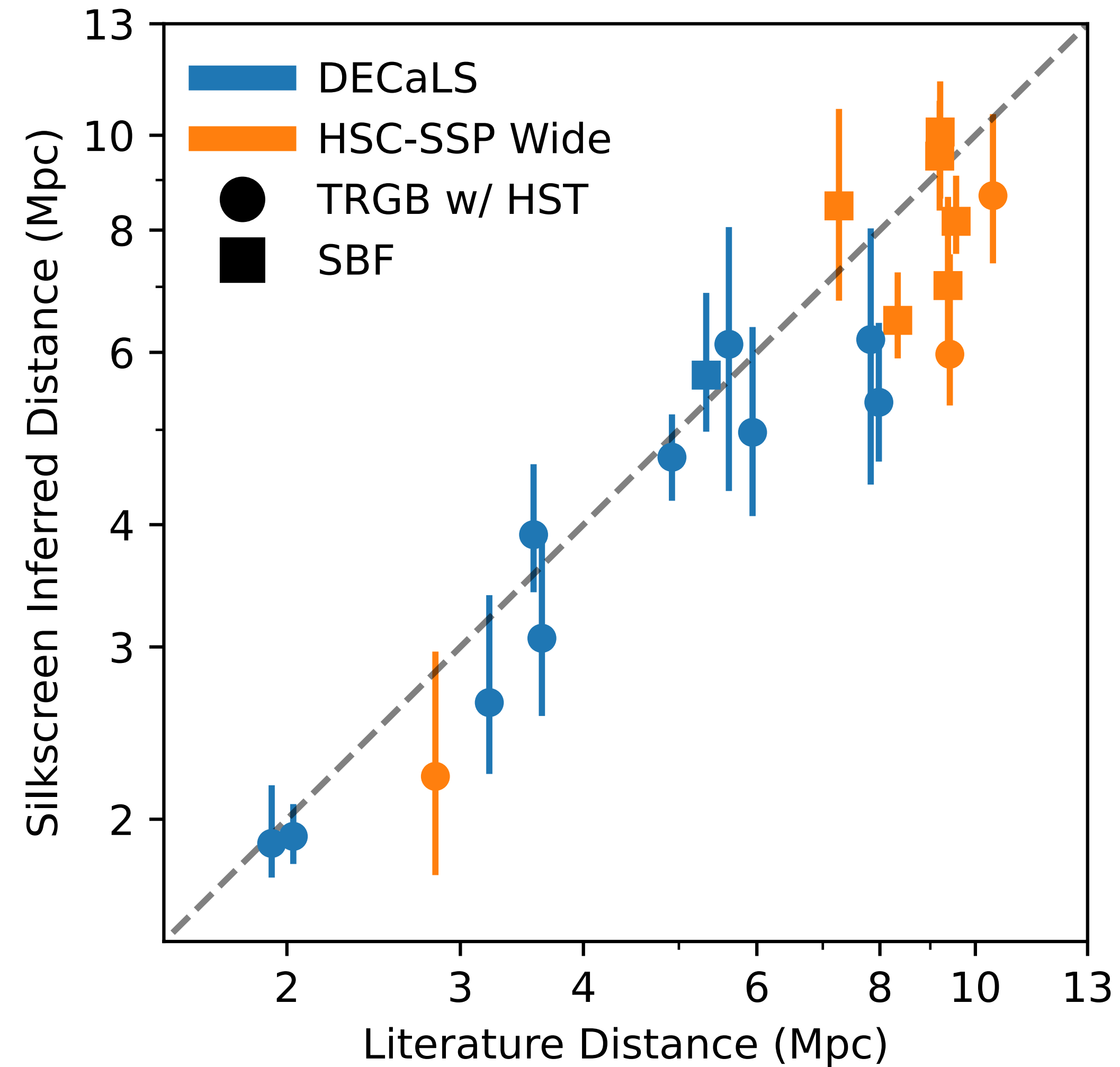
# SilkScreen can recover known distances

Pro's and Con's of Silkscreen

- Marginalize over stellar population parameters
- Utilize full information of images in multiple bands
- Flexibility
  - Any filters or telescope
  - Resolved though unresolved

- Interpretability
- Computational cost of current bespoke pipeline

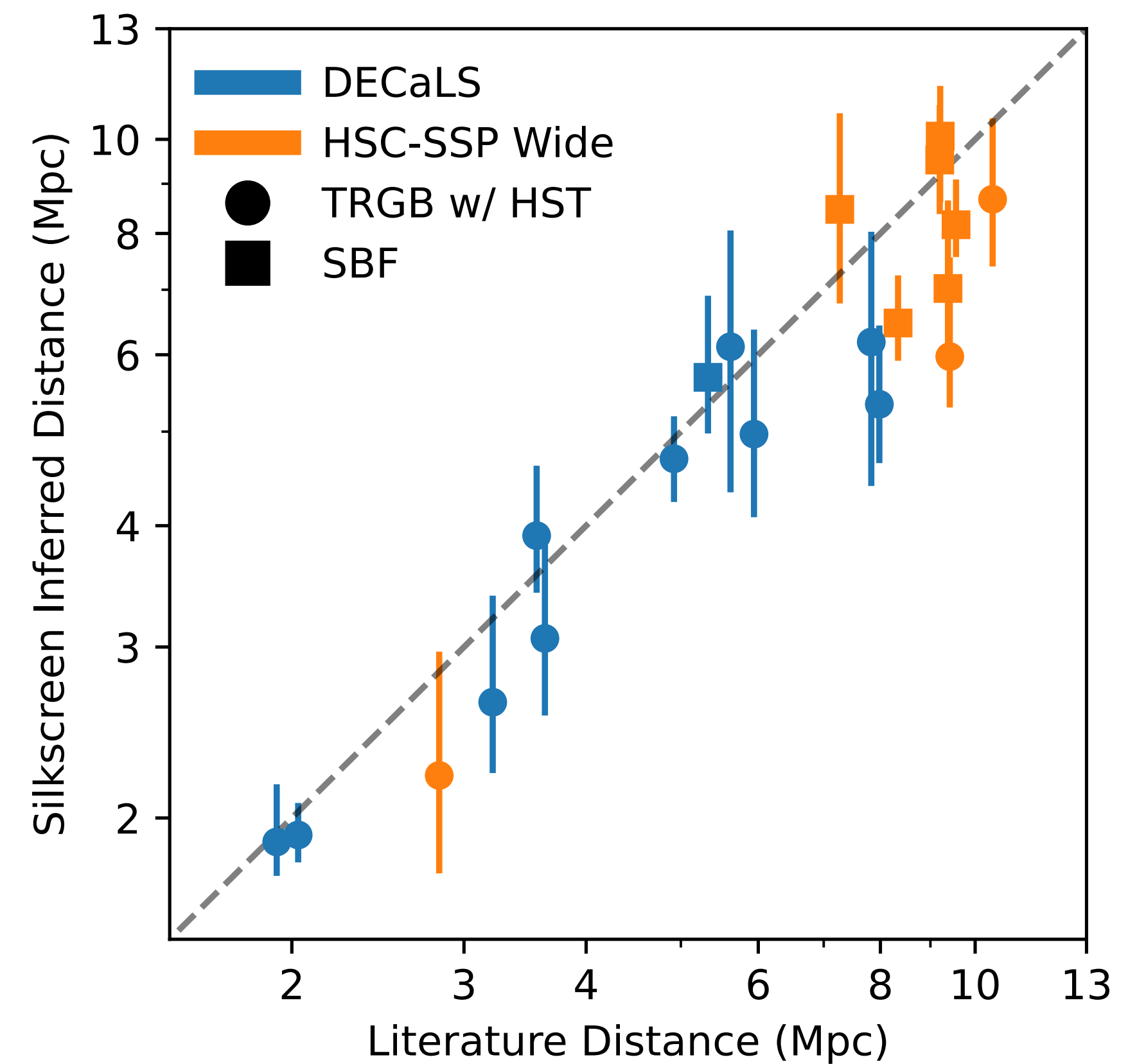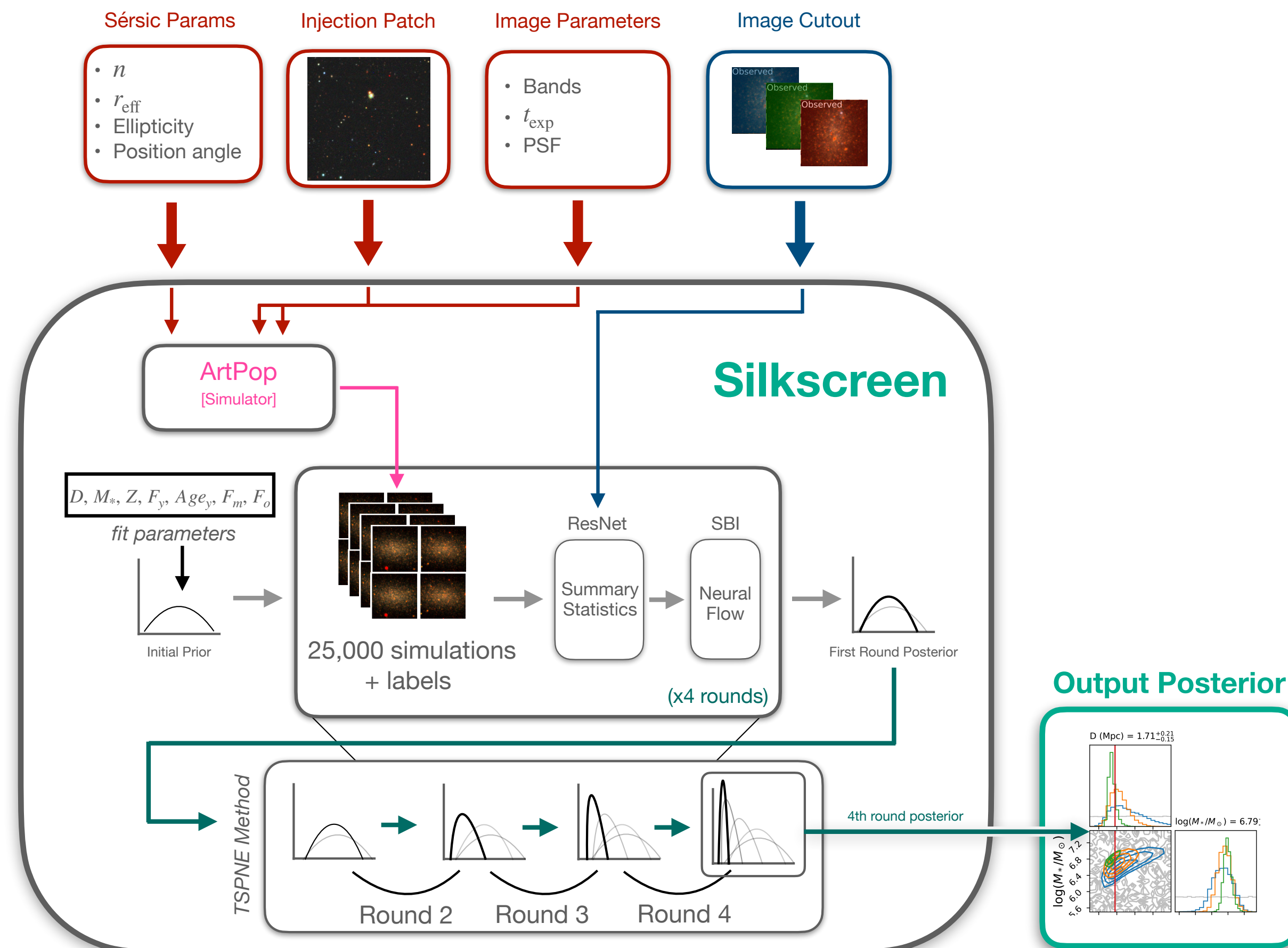# Amortized inference needed for large surveys like LSST

LSST Survey projection
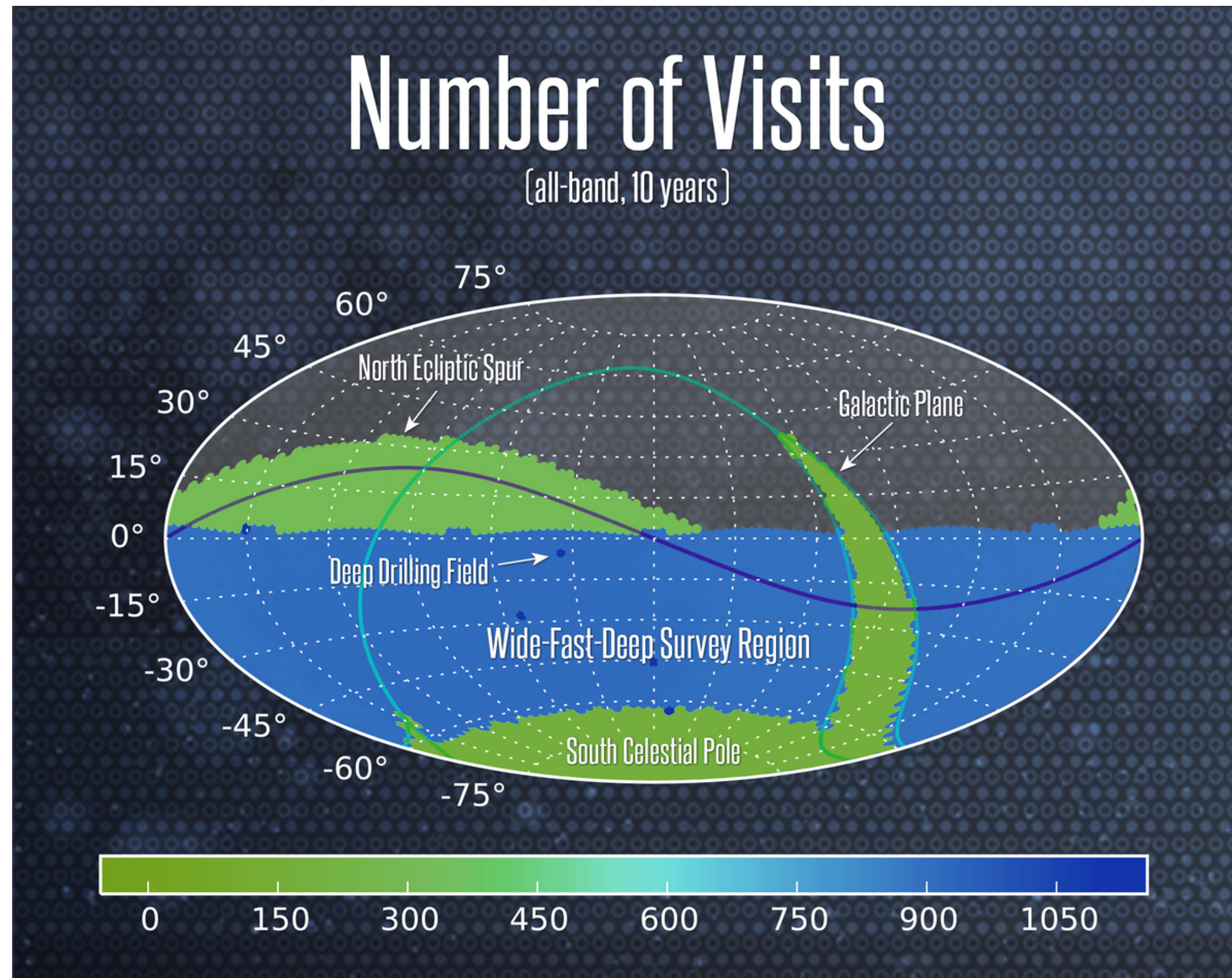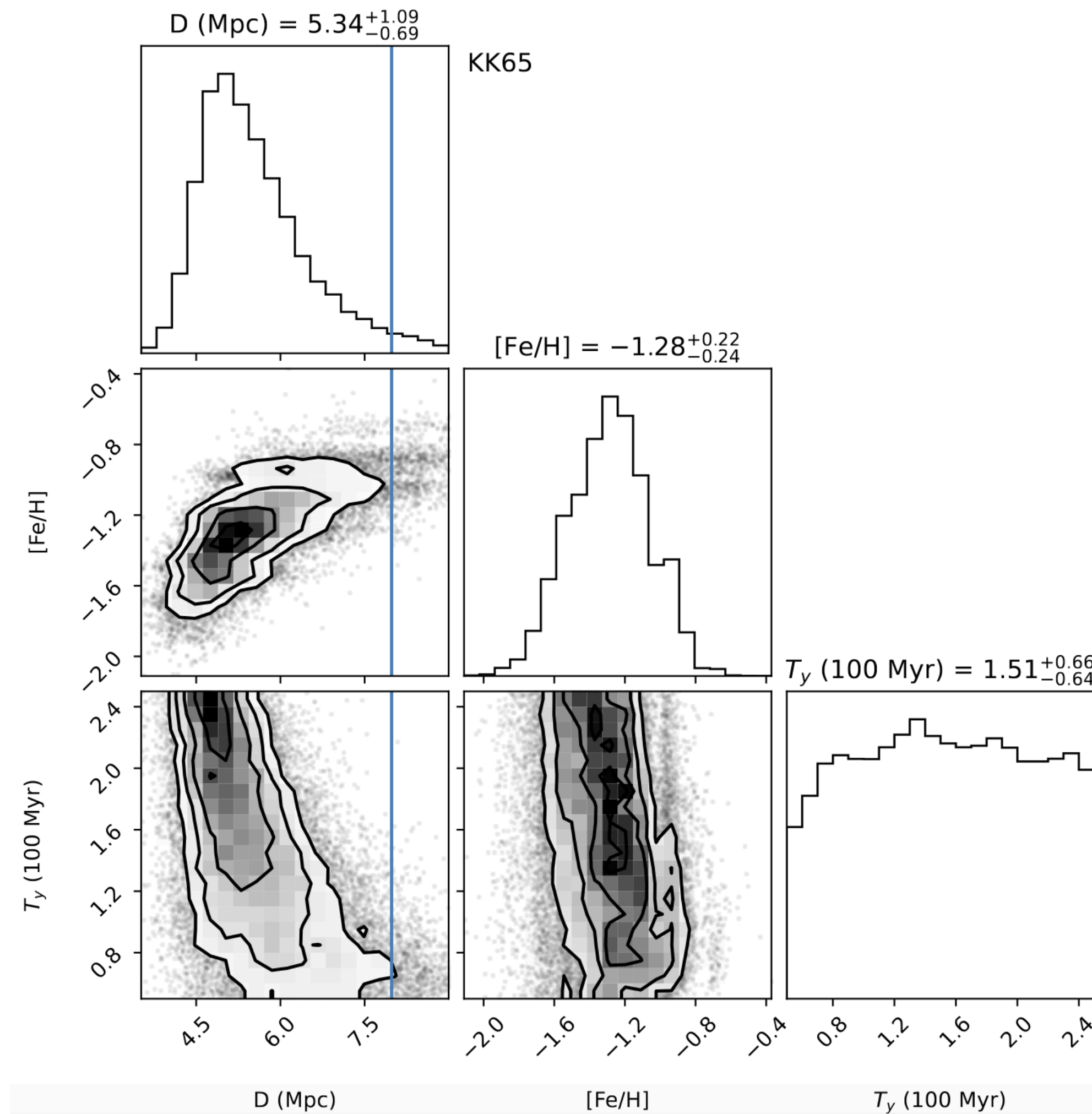
Silkscreen: Inferring distances to dwarf galaxies using SBI

Paper soon!
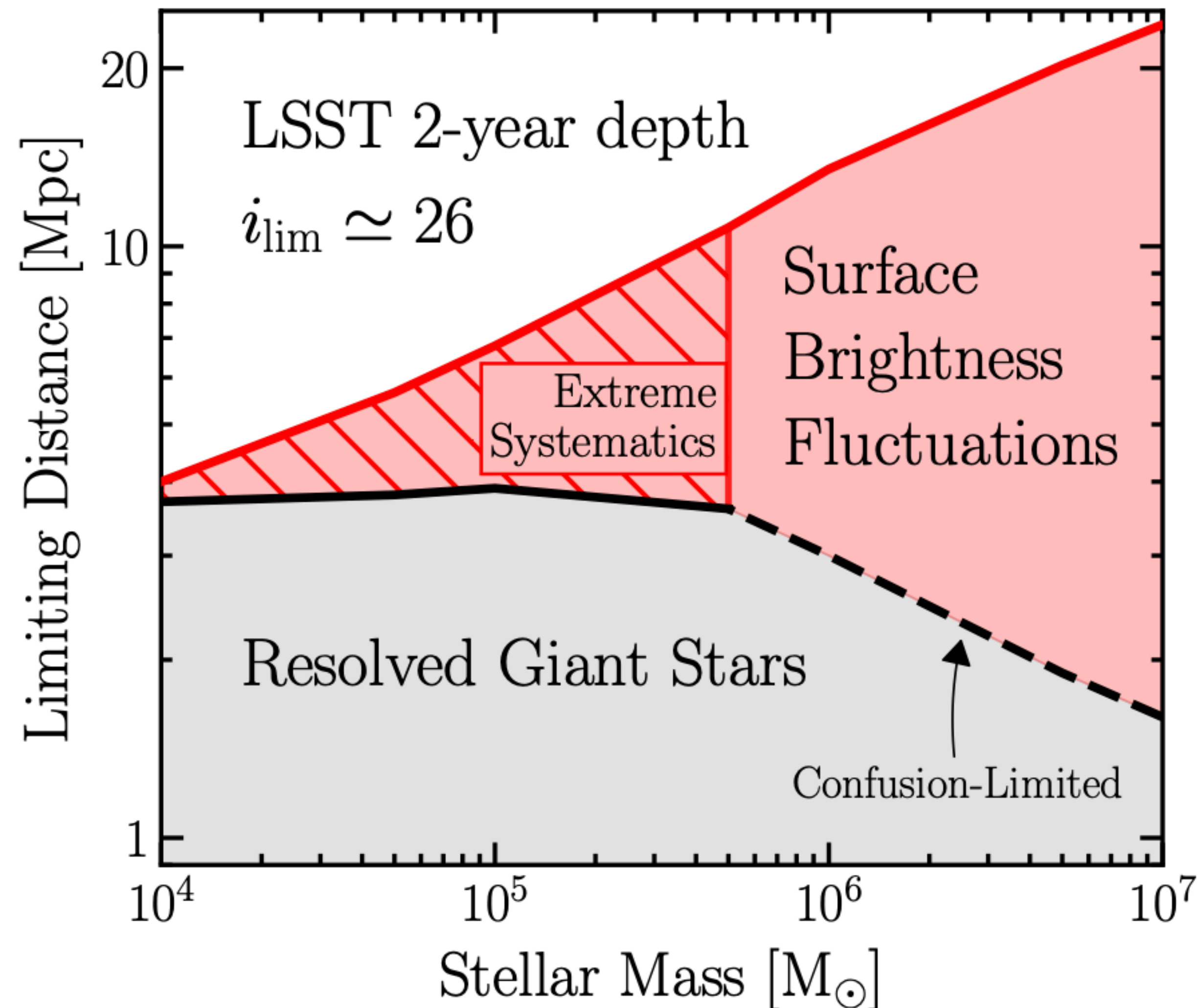## https://github.com/tbmiller-astro/silkscreen

Extra

Some issues with description of the youngest population

Greco et al (2021) projections

Greco et al. (2021) Contribution of different stellar phases to SBF signal