# In Here: Dwarf Galaxies in the OutThere Survey

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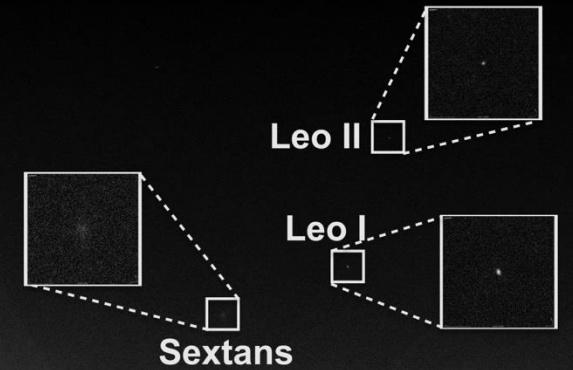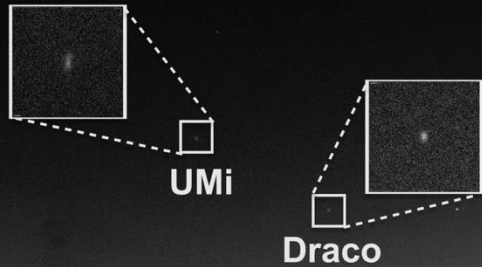
With Ivelina Momcheva, Raphael Erik Hviding,

 Jiaxuan Li, Erik Tollerud, Yang Cheng,
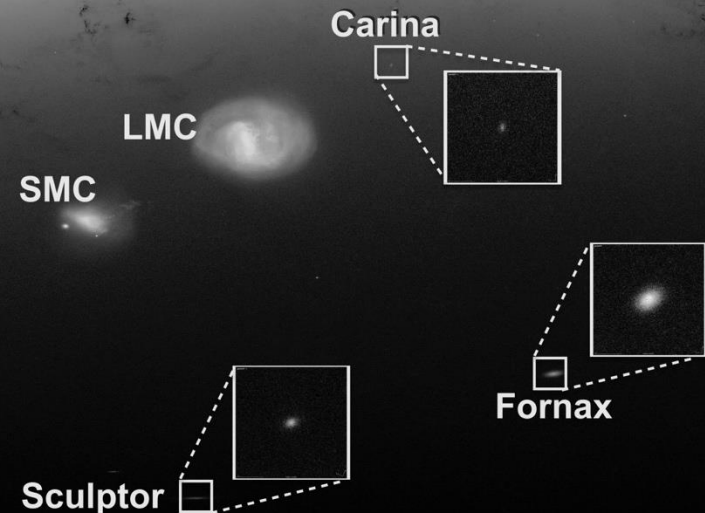
Morgan Fouesneau, Aarya Patil

MPIA Galaxy Coffee
Sep 4th, 2025

# Dwarf Galaxies



Small galaxies contain just few billion stars with $M_* < 10^9 M_\odot$

- Tracers of early galaxy formation and evolution
- Key Lab to test different dark matter models

*CREDIT: ESA/Gaia/DPAC*

# OutThere    JWST/NIRISS Pure-Parallel Survey

**PI: Karl Glazebrook**

| JWST/NIRISS 1000 arcmin² pure parallel spectroscopic survey (Table 1) | |
|---|---|
| 20,000 z>1 continuum spectra K<24 1.4–2.2μm | 3000 massive galaxies at z>1.5 |
| 60,000 spectroscopic redshifts | 250 massive quiescent galaxies at z>3 |
| 20 Coma clusters ancestors at z>2 identified in 3D | 2000 spatially resolved z~2 emission line images in multiple lines |
| 2000 reionization analog galaxies at z~3 | z>10 bright sources. Unknown populations. |

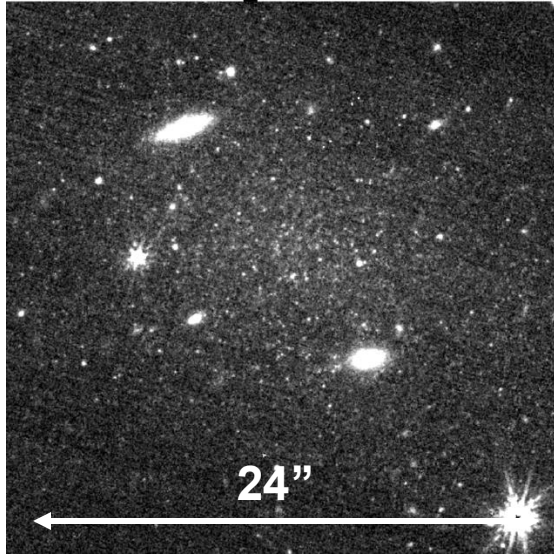**Unexpected Discoveries**

**Nearby Dwarf Galaxies**

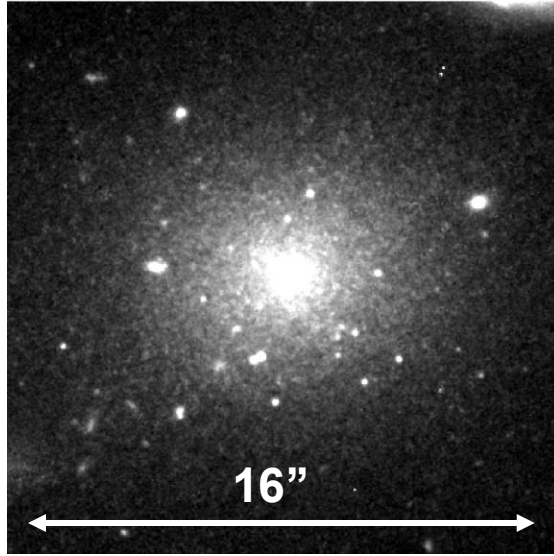# OutThere   JWST/NIRISS Pure-Parallel Survey
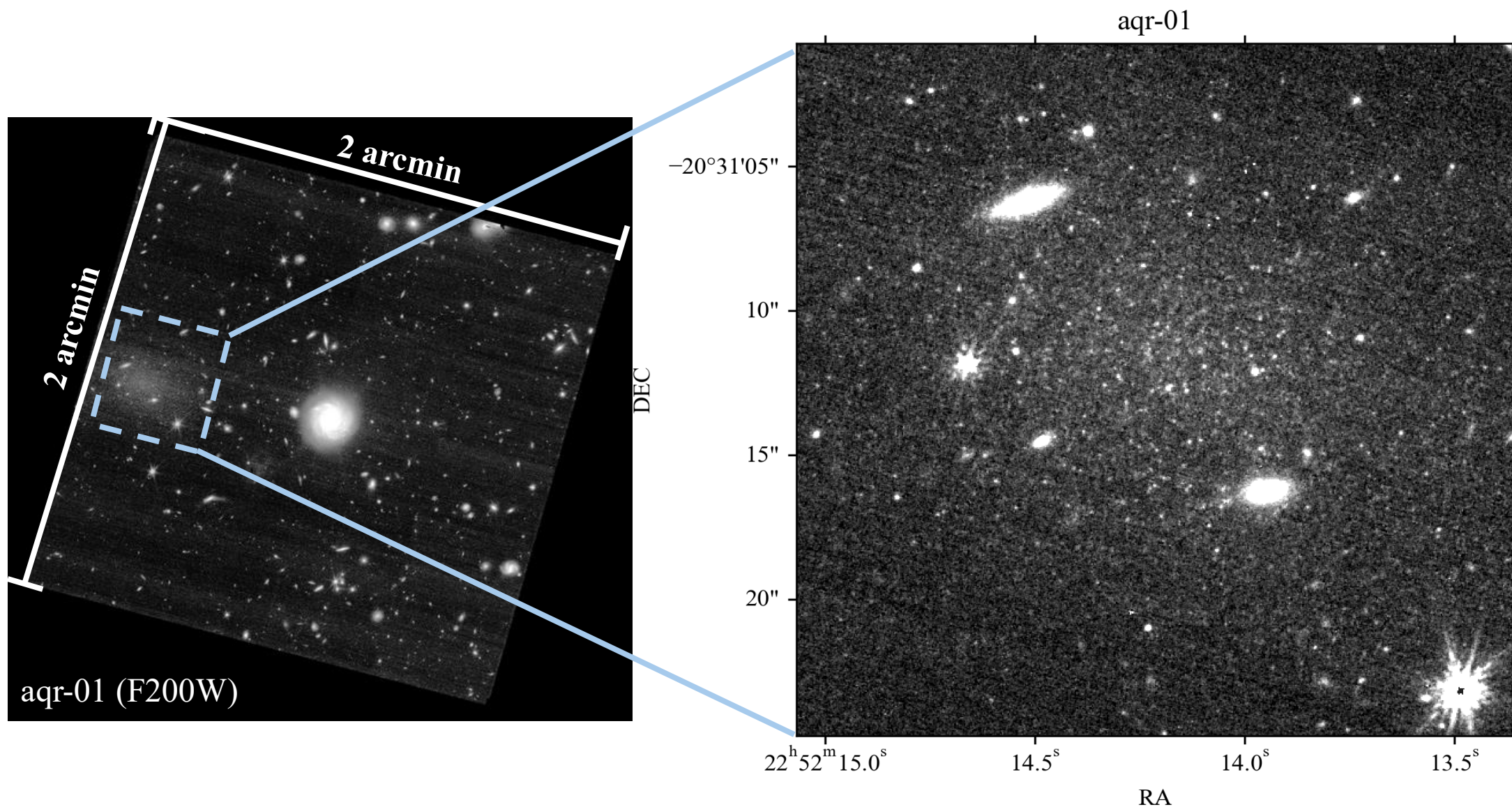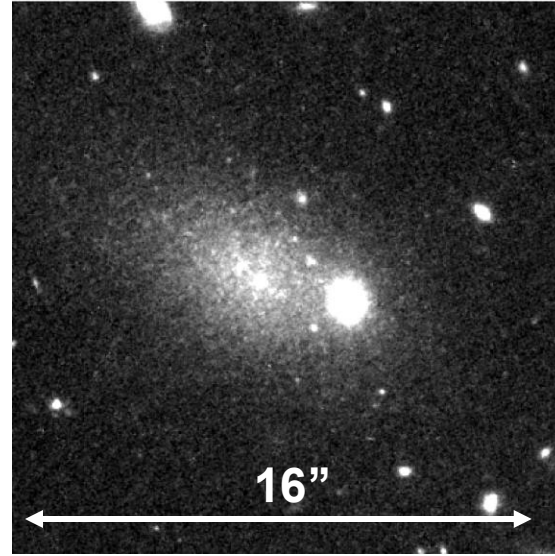
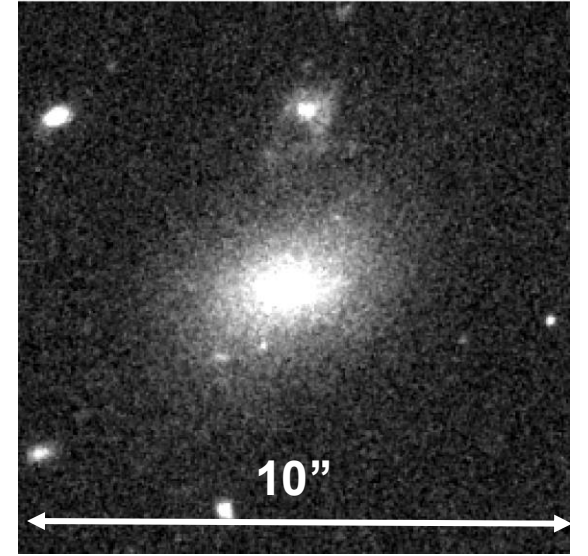# Dwarf Galaxies in OutThere Survey
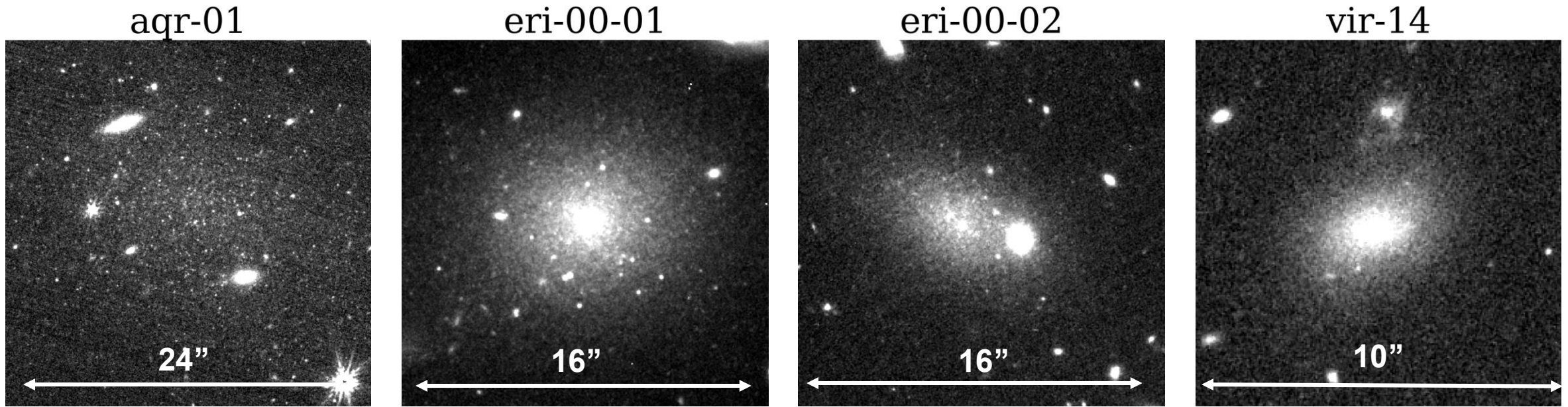
aqr-01      eri-00-01      eri-00-02      vir-14

24"      16"      16"      10"

# Dwarf Galaxies in OutThere Survey

aqr-01      eri-00-01      eri-00-02      vir-14
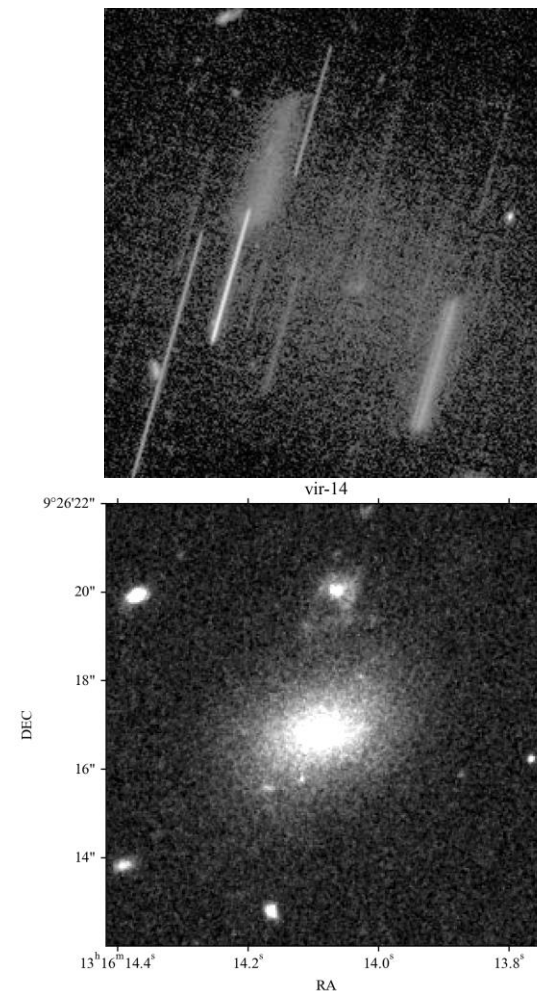


24"       16"       16"       10"

## Goal of project

- **Determine the distances of the four discovered dwarf galaxies.**
- **Determine their masses and place them in a cosmological context.**
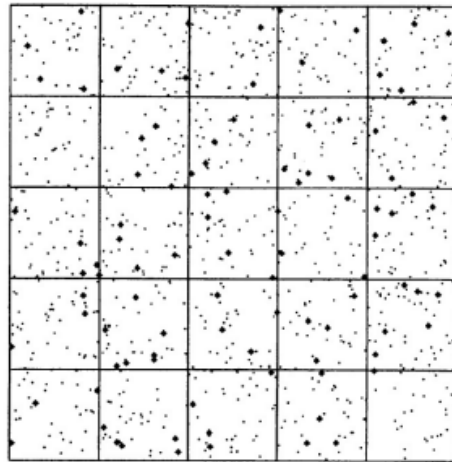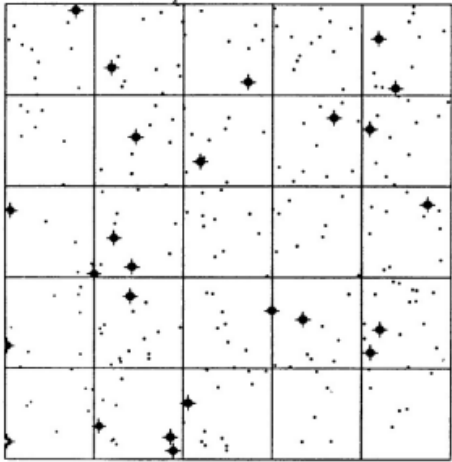
# Distance Measurement Methods

❌ Spectrum: Hard to determine wavelength for extended galaxies

❌ Resolved Stars: TRGB, variable stars

❌ CMD: only have F200W, without color
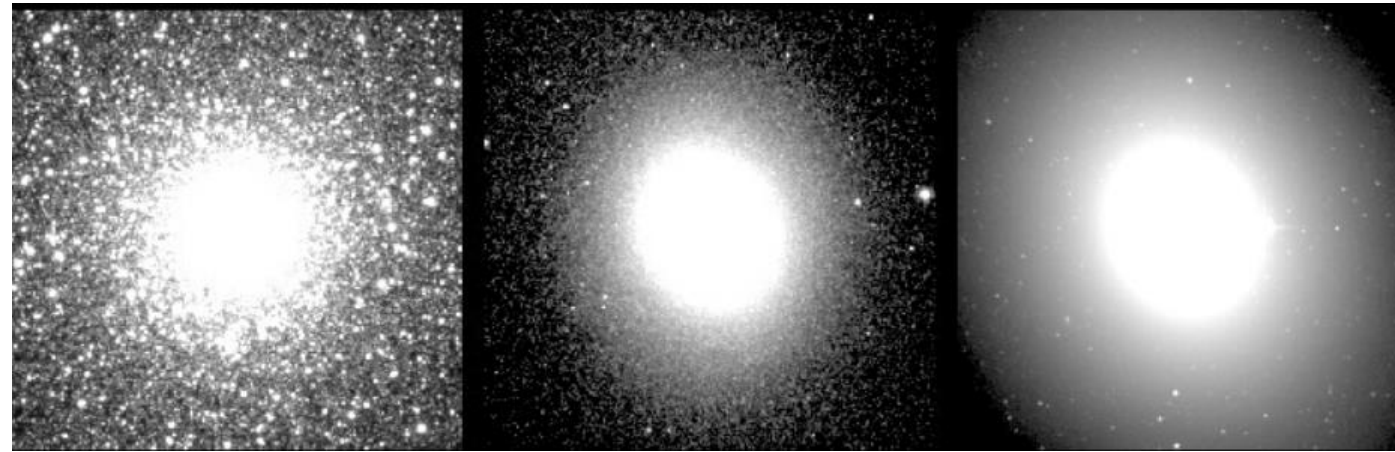
✅ Surface Brightness Fluctuation (SBF)

# Surface Brightness Fluctuation (SBF)

*Tonry & Schneider (1988)*

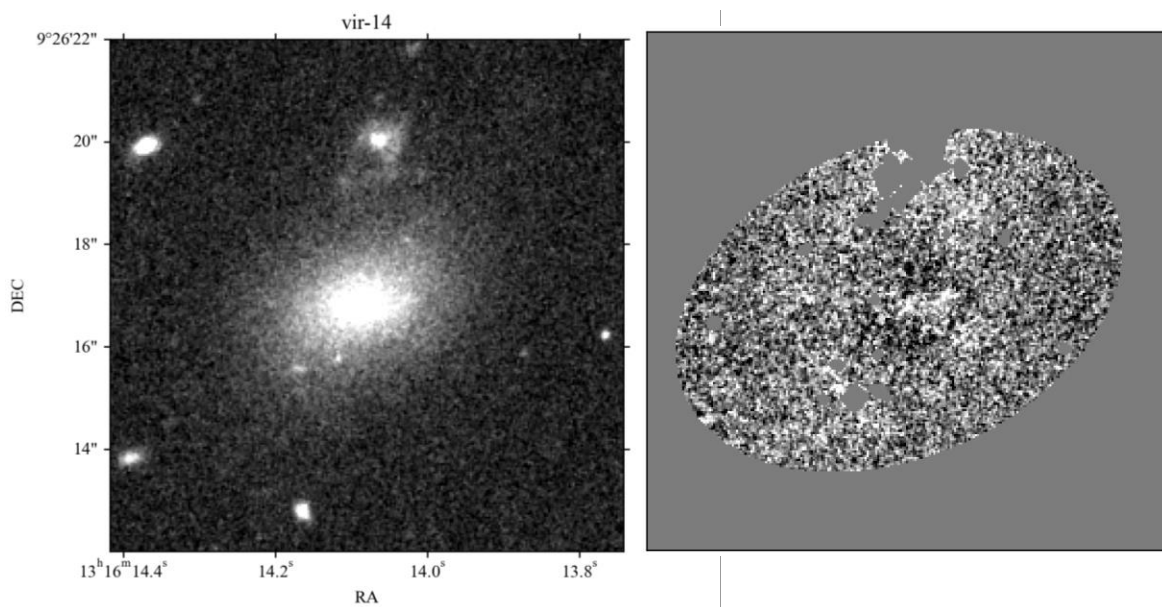## Distance range: 10-100Mpc



Jacoby et al., 1992, PASP 104, 599

close

SBF $\propto 1/d^2$

far

# Surface Brightness Fluctuation (SBF)
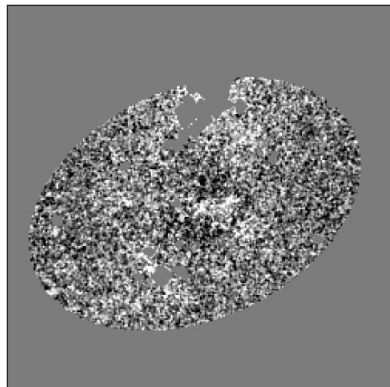


Data – non-SBF variance
(smooth galaxy profile, background, nearby objects)

Residual

Image Space
= SBF + Noise

Fourier Space
= **SBF signal** × [PSF * Mask] + Noise

# Surface Brightness Fluctuation (SBF)



Data – non-SBF variance
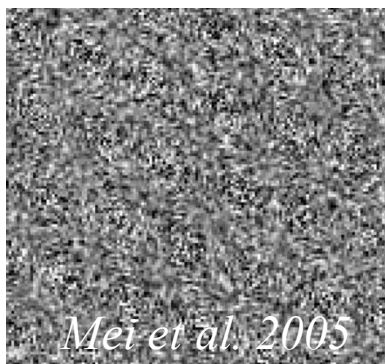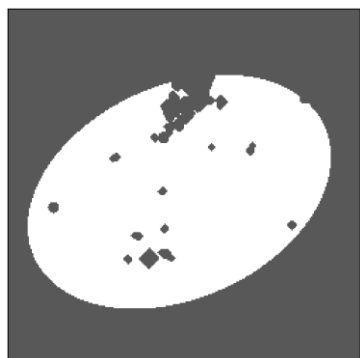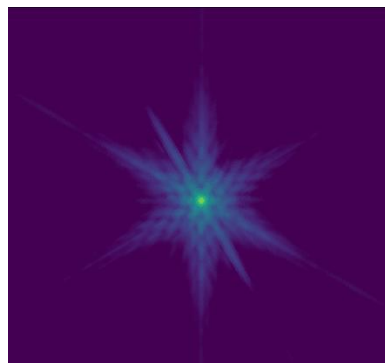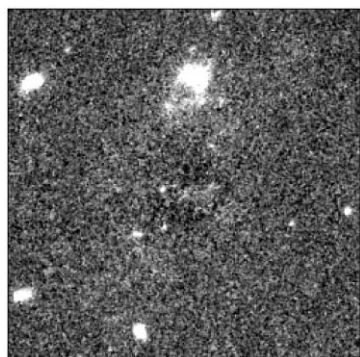(smooth galaxy profile, background, nearby objects)

## Residual

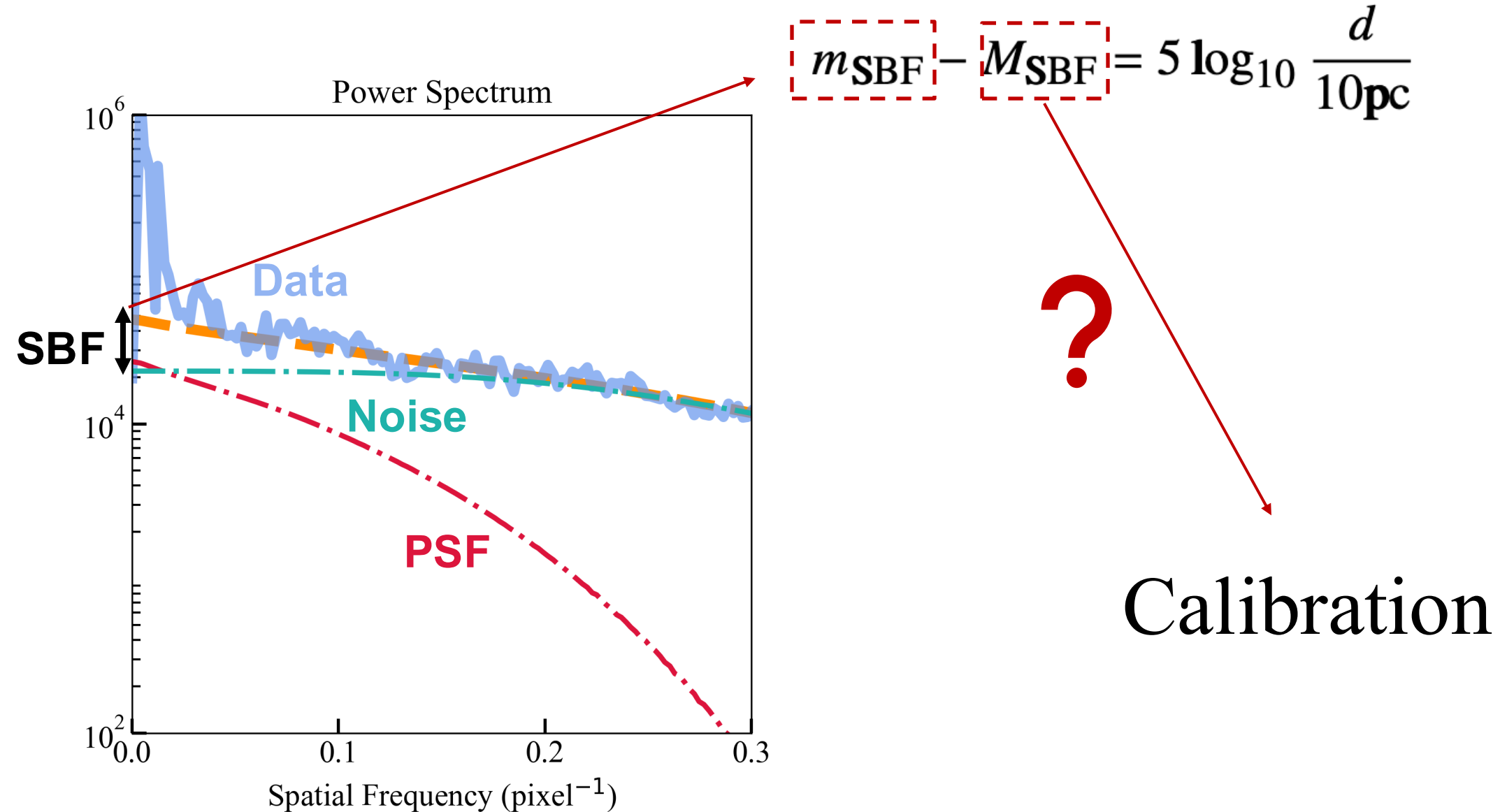Image Space

= SBF + Noise

Fourier Space

= **SBF signal** × [PSF * Mask] + Noise

*Mei et al. 2005*

# Surface Brightness Fluctuation (SBF)



Data – non-SBF variance
(smooth galaxy profile, background, nearby objects)
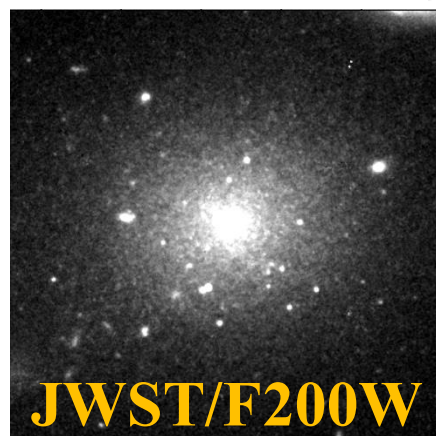
## Residual

Image Space

= SBF + Noise

Fourier Space

= **SBF signal** × [PSF * Mask] + Noise

# Surface Brightness Fluctuation (SBF)



$$m_{\text{SBF}} - M_{\text{SBF}} = 5\log_{10}\frac{d}{10\text{pc}}$$

?

Calibration

# Calibration

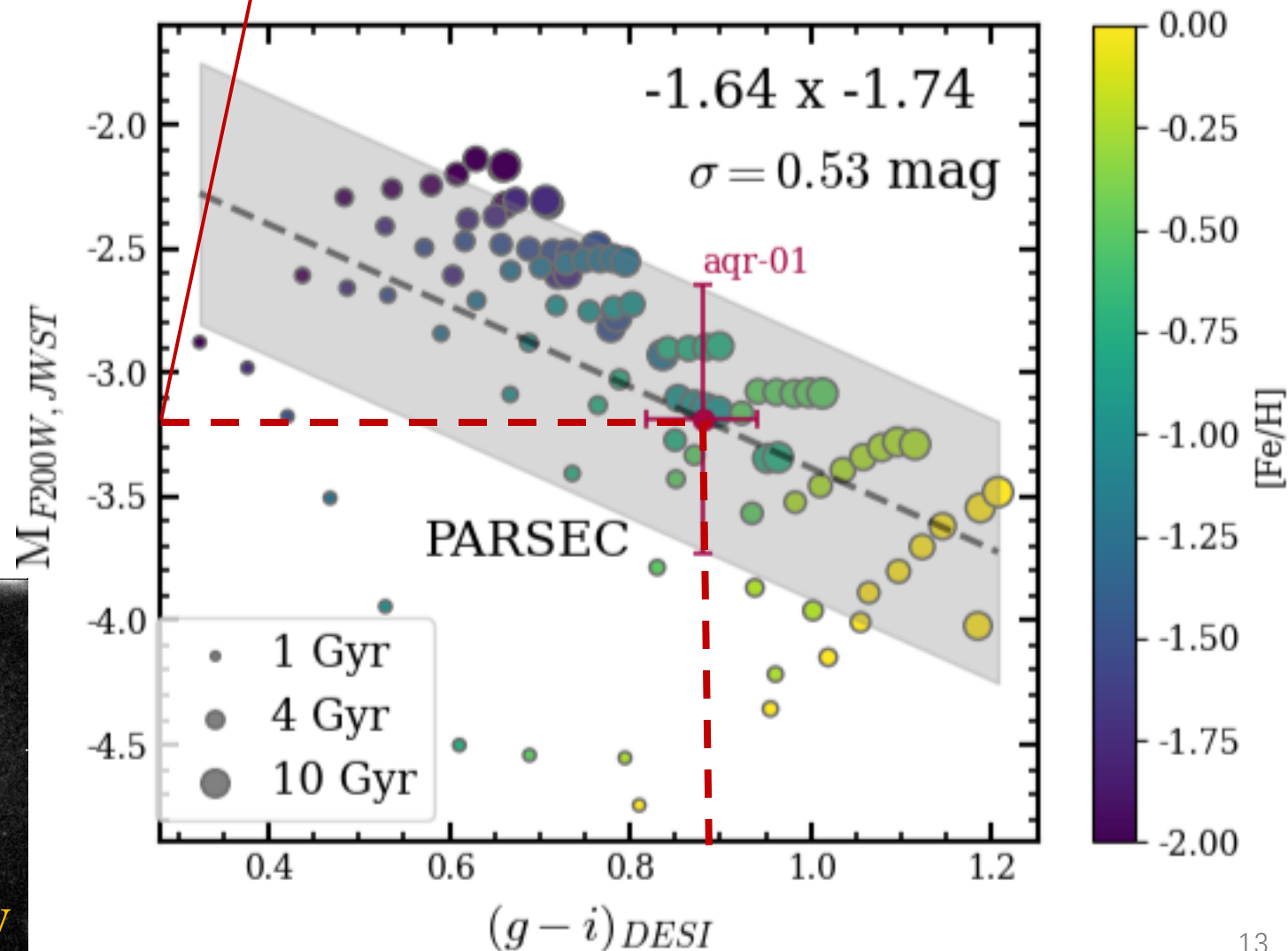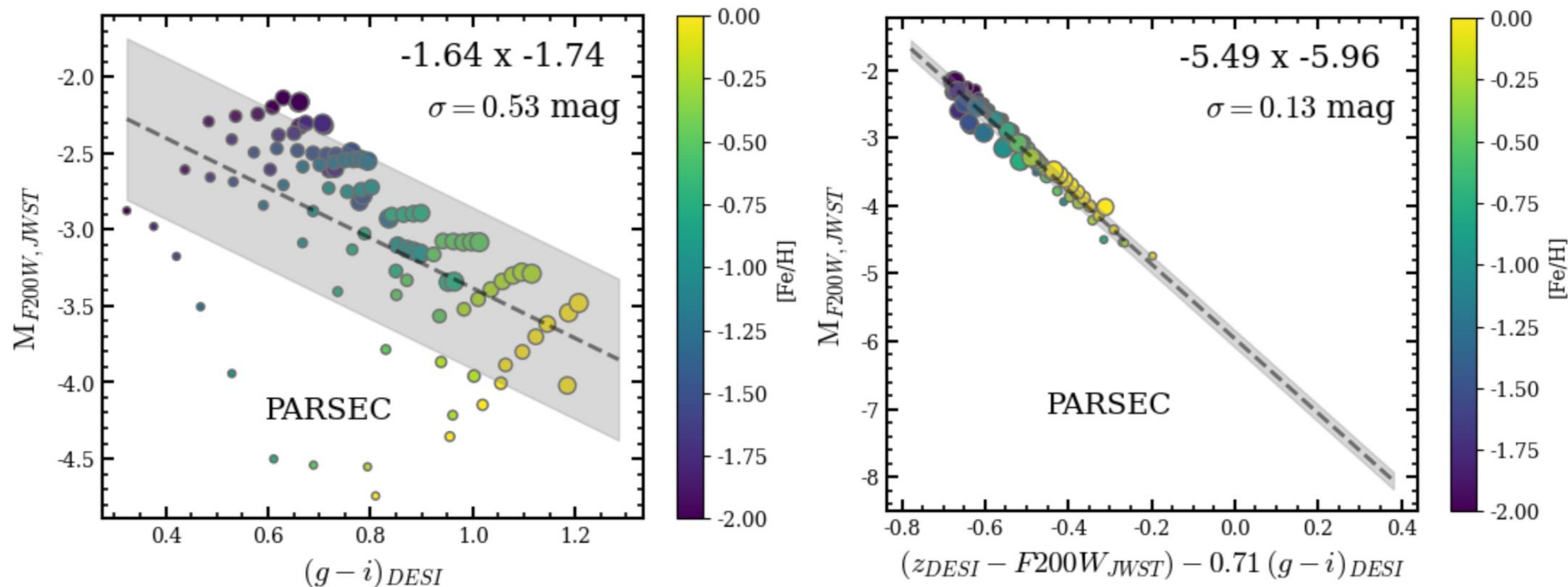$$m_{\mathrm{SBF}} - \boxed{M_{\mathrm{SBF}}} = 5\log_{10}\frac{d}{10\mathbf{pc}}$$

- $M_{SBF}$ varies with metallicities & ages

- No calibration in JWST F200W.

- Stellar population synthesis Model
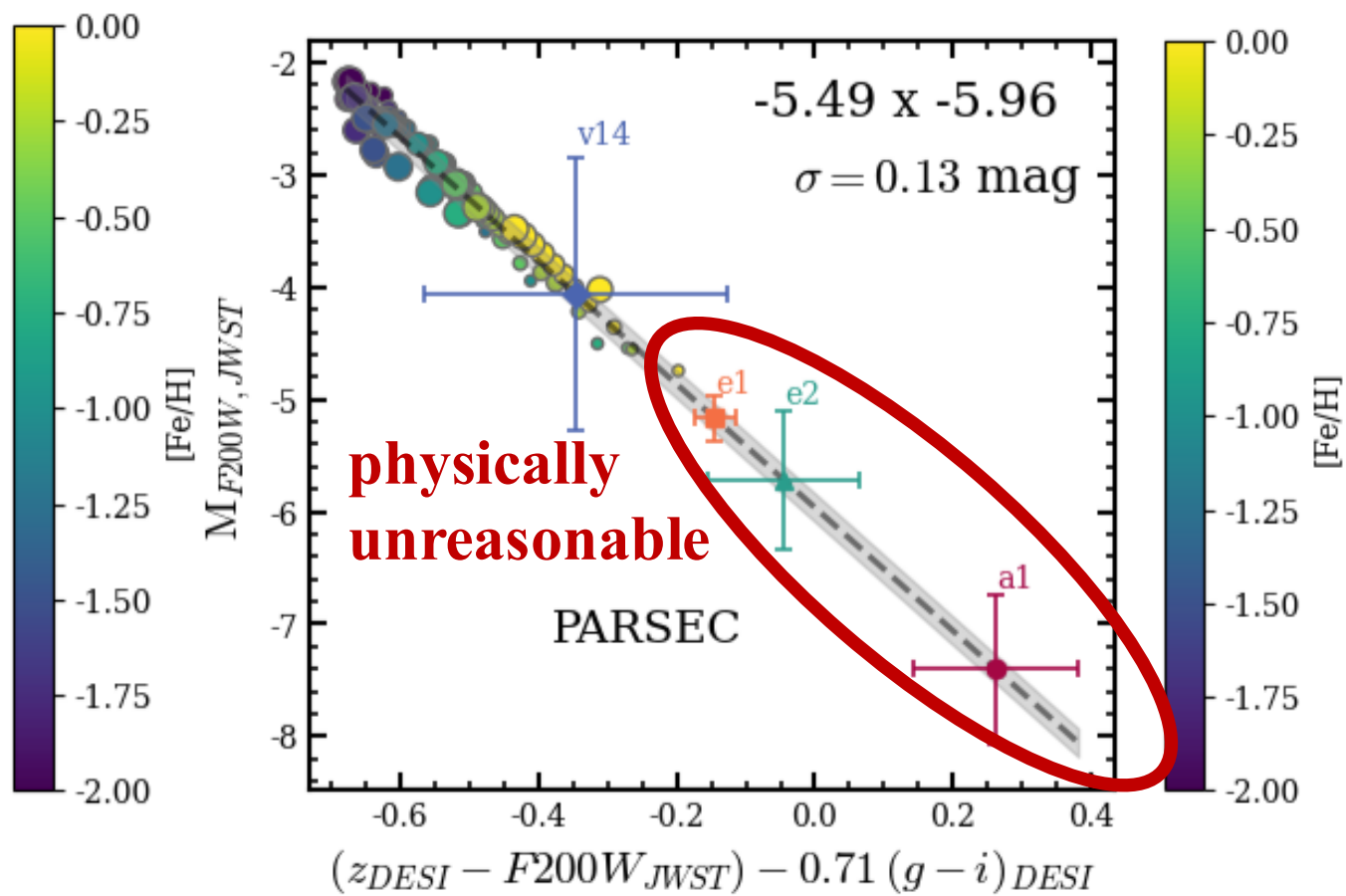


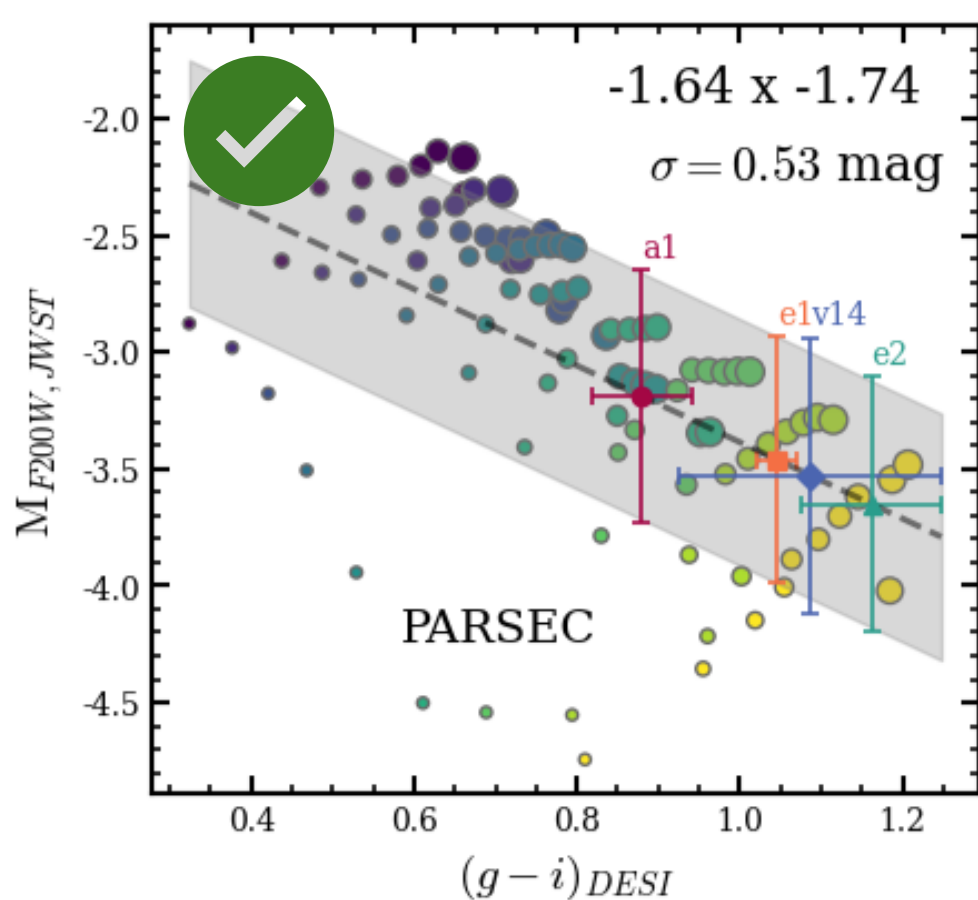**DESI Legacy Survey/g,i,z**

**JWST/F200W**

# Calibration

# Calibration

ZP / Photometry issue...

# Distance

| Galaxy | $(g-i)_{DESI}$ |
|--------|----------------|
| aqr-01 | $47.22^{+13.19}_{-10.29}$ |
| eri-00-01 | $82.37^{+22.95}_{-17.35}$ |
| eri-00-02 | $82.72^{+23.89}_{-18.33}$ |
| vir-14 | $239.22^{+73.03}_{-55.20}$ |
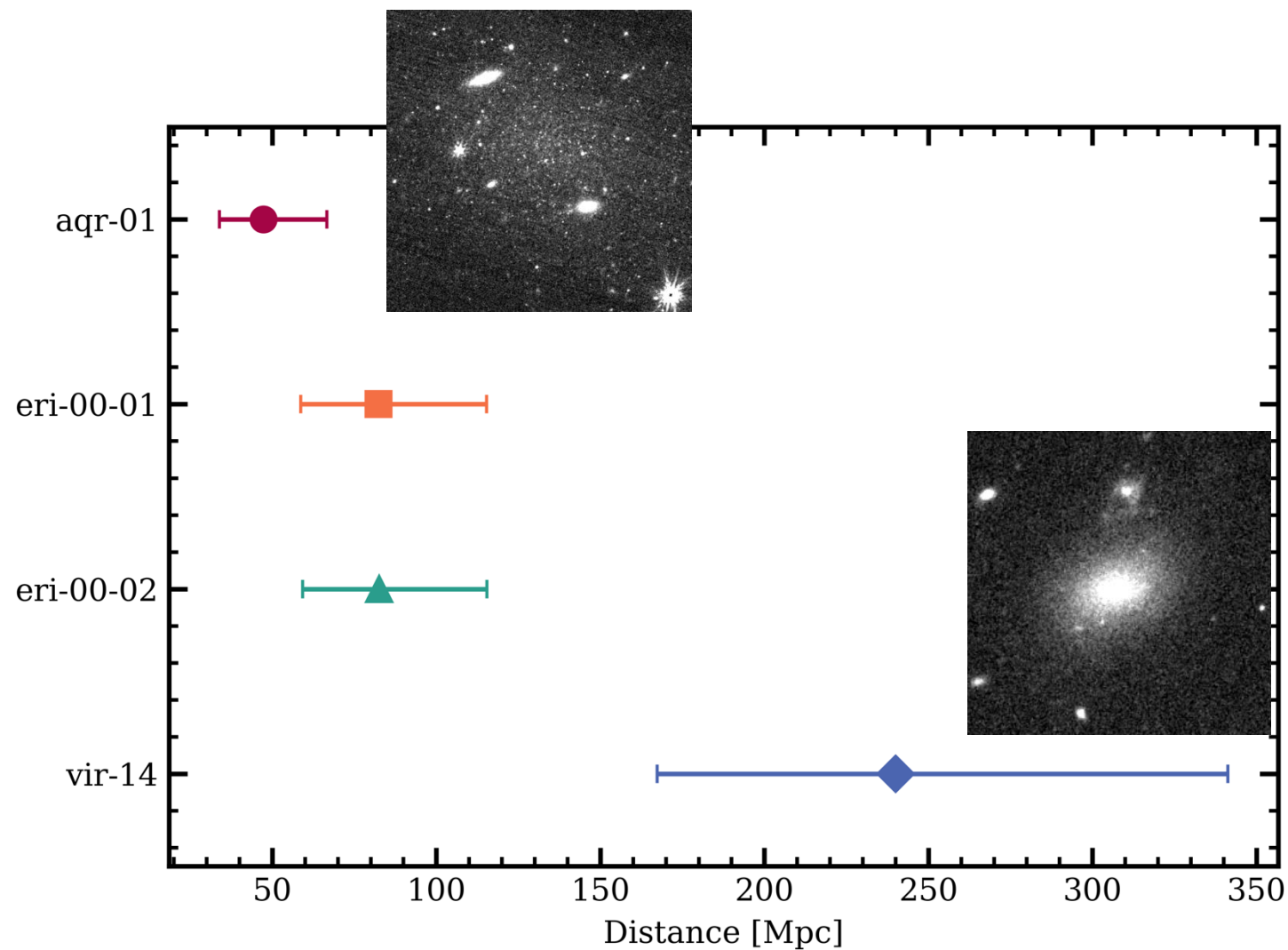
# Future Work

- ☐ Check Distance results
- ☐ Determine masses and place them in a cosmological context
- ☐ Resolved Stellar Populations & Extra Distance constraint
- ☐ Spectroscopy of Star-Forming region
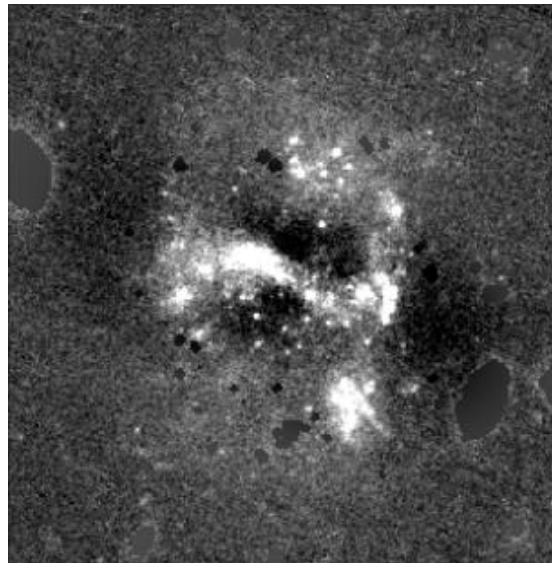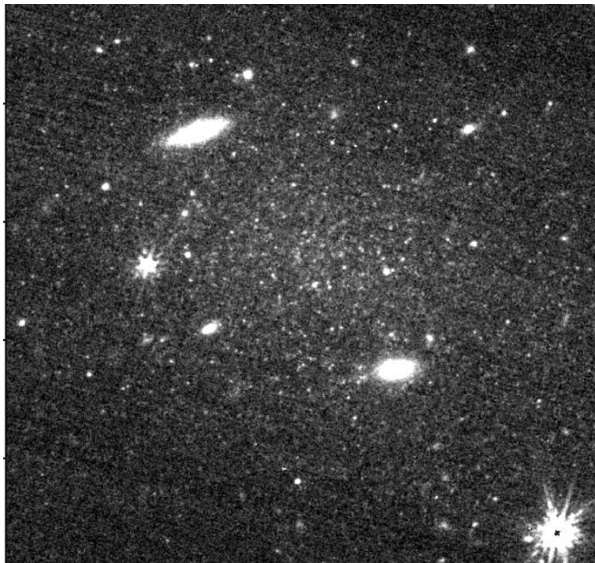
# Summary

- ✓ Identified 4 dwarf galaxies in the OutThere Survey

- ✓ Measured distances using SBF for all dwarf galaxies

- ✓ Distances range from 40–200 Mpc
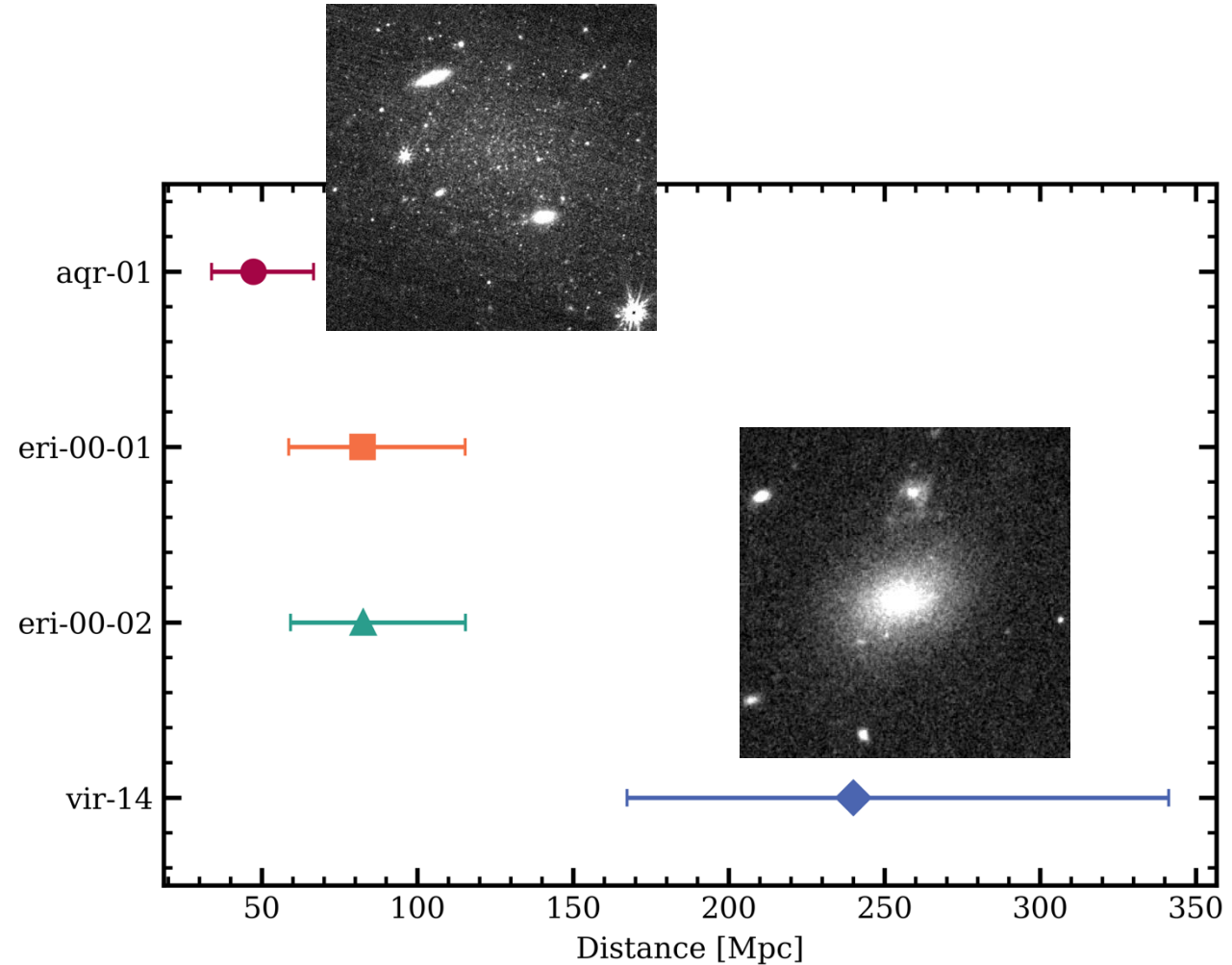
# SBF

## 1.1 SBF what?

The idea…

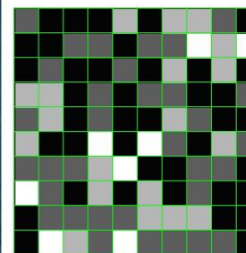… in practice

M32 @ 0.75 Mpc

N7768 @ 100 Mpc

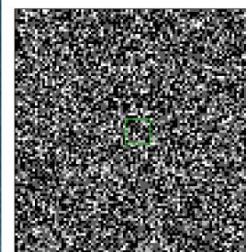$$\overline{M} \overset{\text{def}}{=} M_{SBF}$$
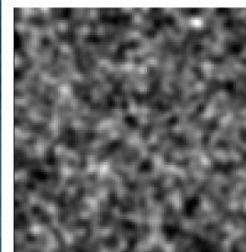
(courtesy J. Tonry)

| | Nearby Galaxy | | Same Galaxy Three times the distance |
|---|---|---|---|
| | $\overline{f}$ | Star flux | $\overline{f}/9$ |
| | n | Star density | 9n |

Galaxy star field

Surface Brightness

$n\overline{f}$       $n\overline{f}$

What the CCD sees

Rms fluctuation
(inversely prop. to distance)

$\sqrt{n}\,\overline{f}$      $\sqrt{9n}\,\overline{f}/9$

$$= \frac{1}{3}\sqrt{n}\,\overline{f}$$

More CCD pixels

Variance divided by Mean
(Star flux)

$\overline{f} = \frac{(rms)^2}{mean}$     $\overline{f}/9 = \frac{(rms)^2}{mean}$

Blurred by atmosphere