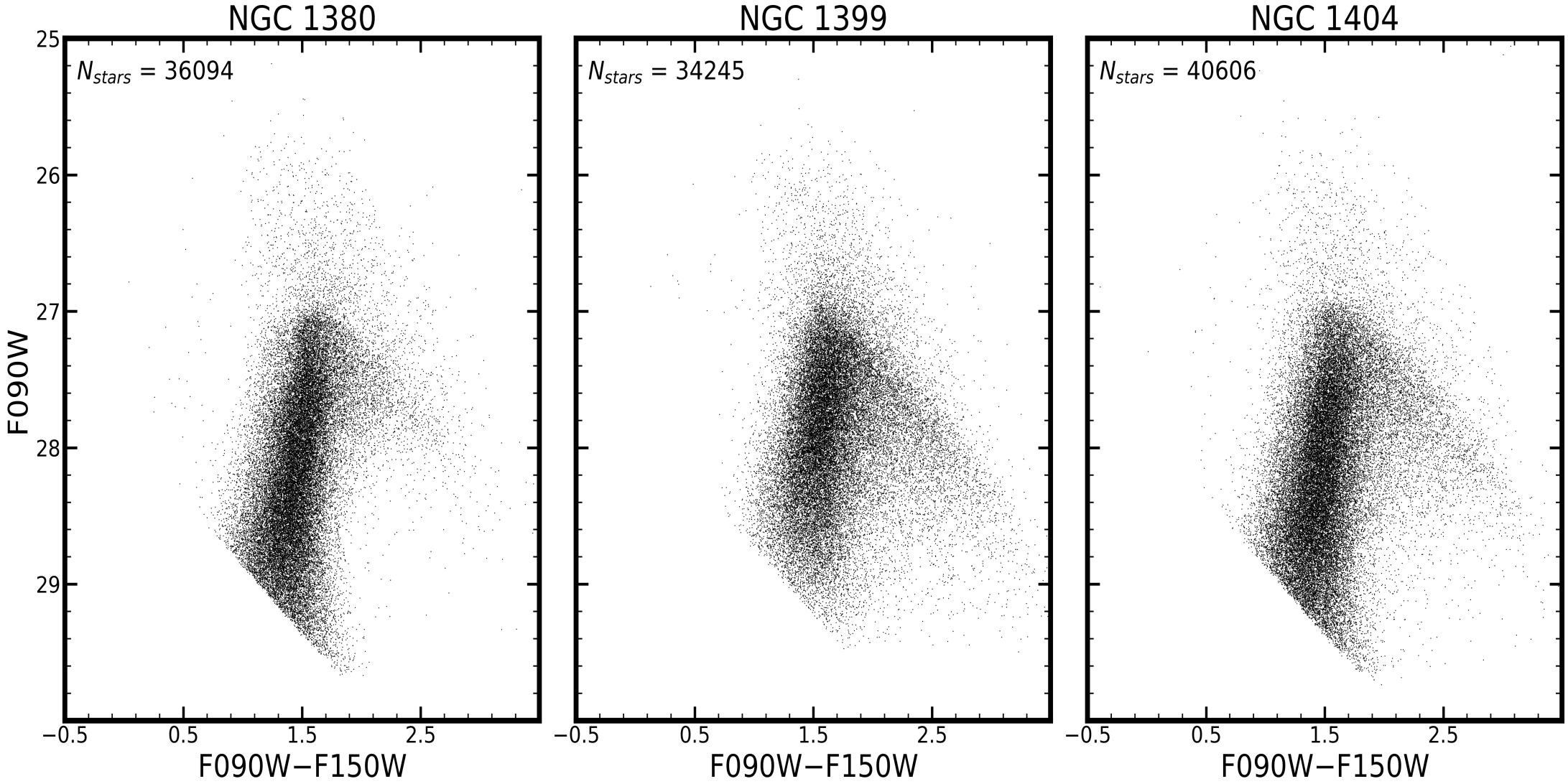
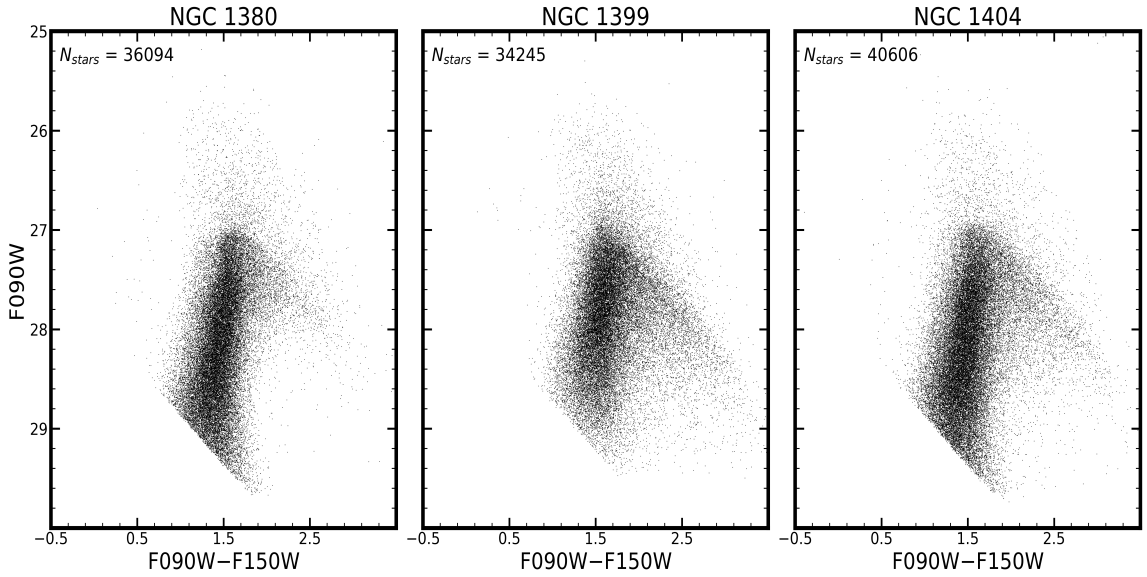
The Pop II Distance Scale with HST & JWST

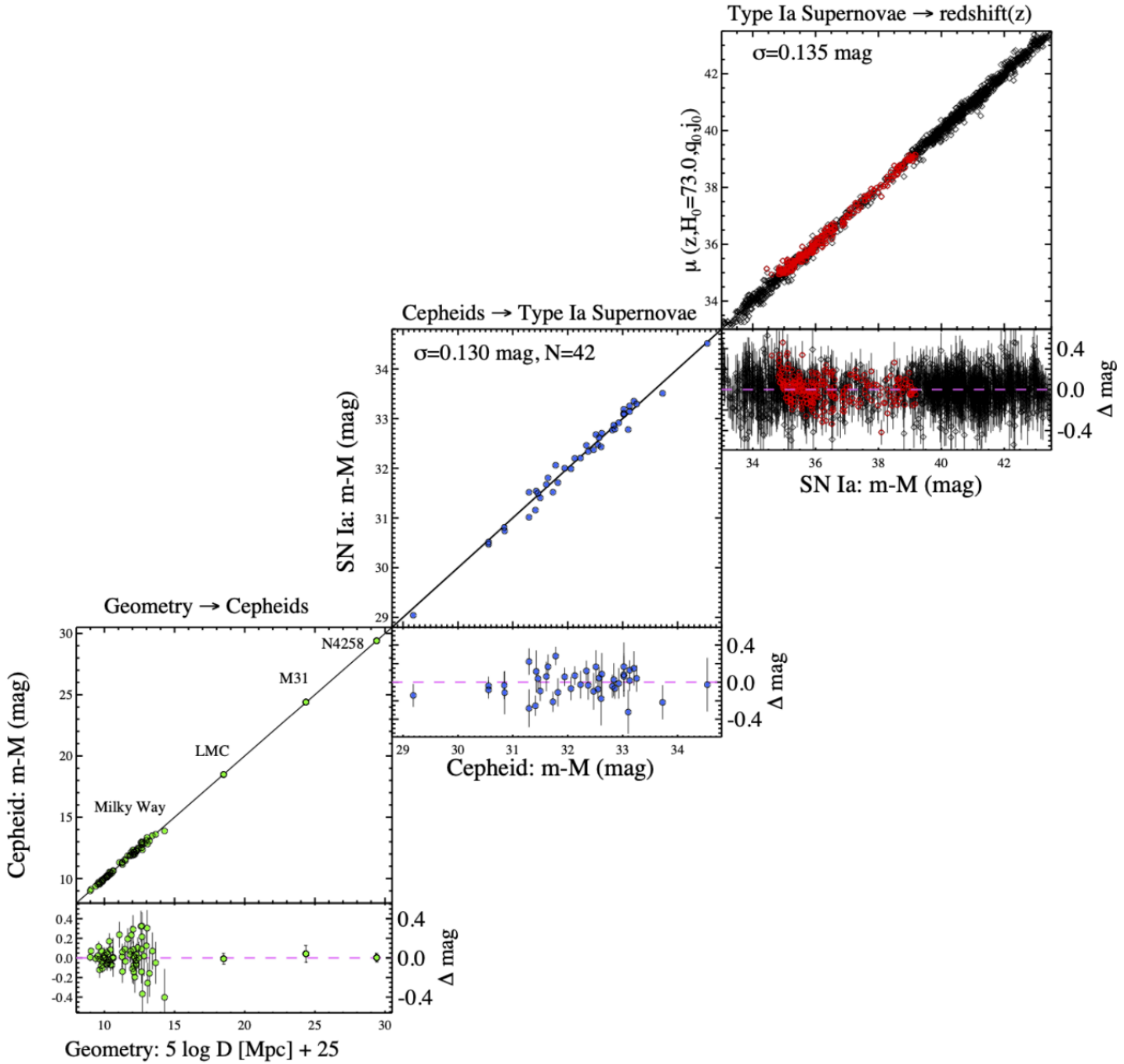


The Pop II Distance Scale with HST & JWST



Deep Anand
John Blakeslee
Michele Cantiello
Joe Jensen
Gabriella Raimondo
Brent Tully

Pop I ladder

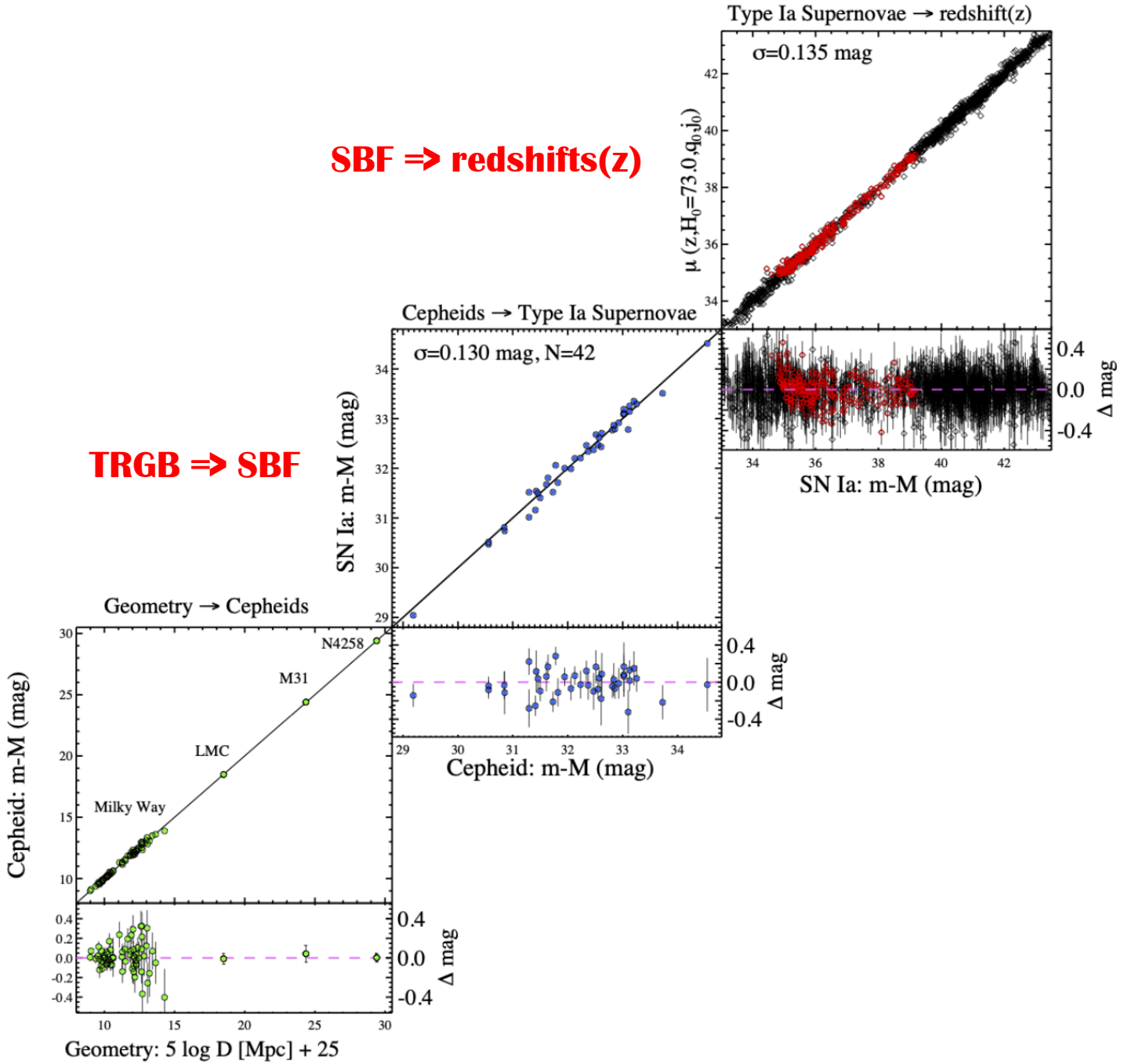

Type Ia Supernovae → redshift(z)
σ=0.135 mag
μ (z,H0=73.0,q0,j0)
Cepheids → Type Ia Supernovae
σ=0.130 mag, N=42
SN Ia: m-M (mag)
Δ mag
Geometry → Cepheids
N4258
M31
LMC
Milky Way
Cepheid: m-M (mag)
Geometry: 5 log D [Mpc] + 25

Pop II ladder

SBF ⇒ redshifts(z)

TRGB ⇒ SBF

Geometry ⇒ TRGB



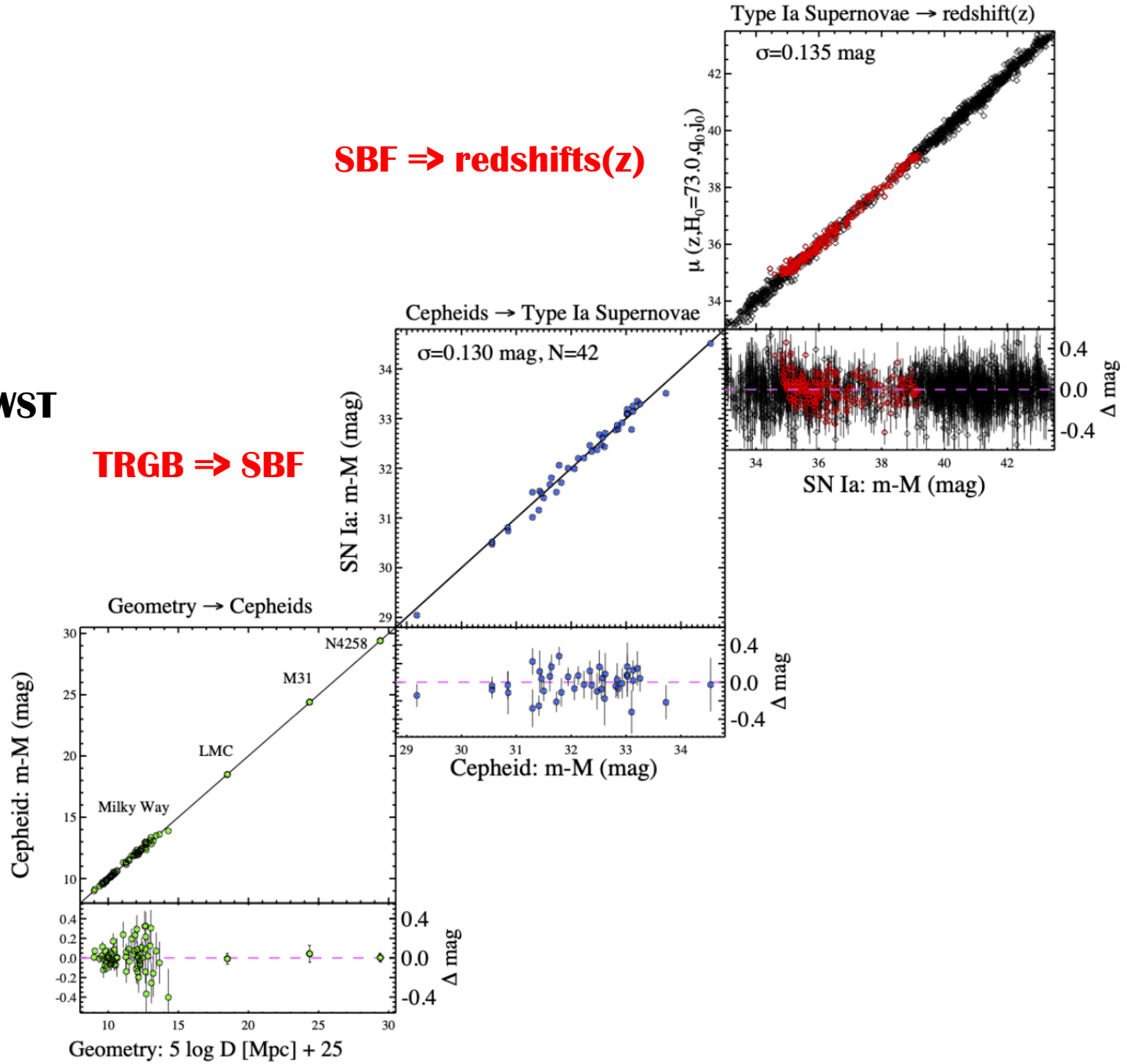
Pop II ladder

- **Entirely independent of Pop I scale**
- **TRGB: F814W w. HST; F090W w. JWST**
- **SBF: F150W w. HST & JWST**

SBF ⇒ redshifts(z)

TRGB ⇒ SBF

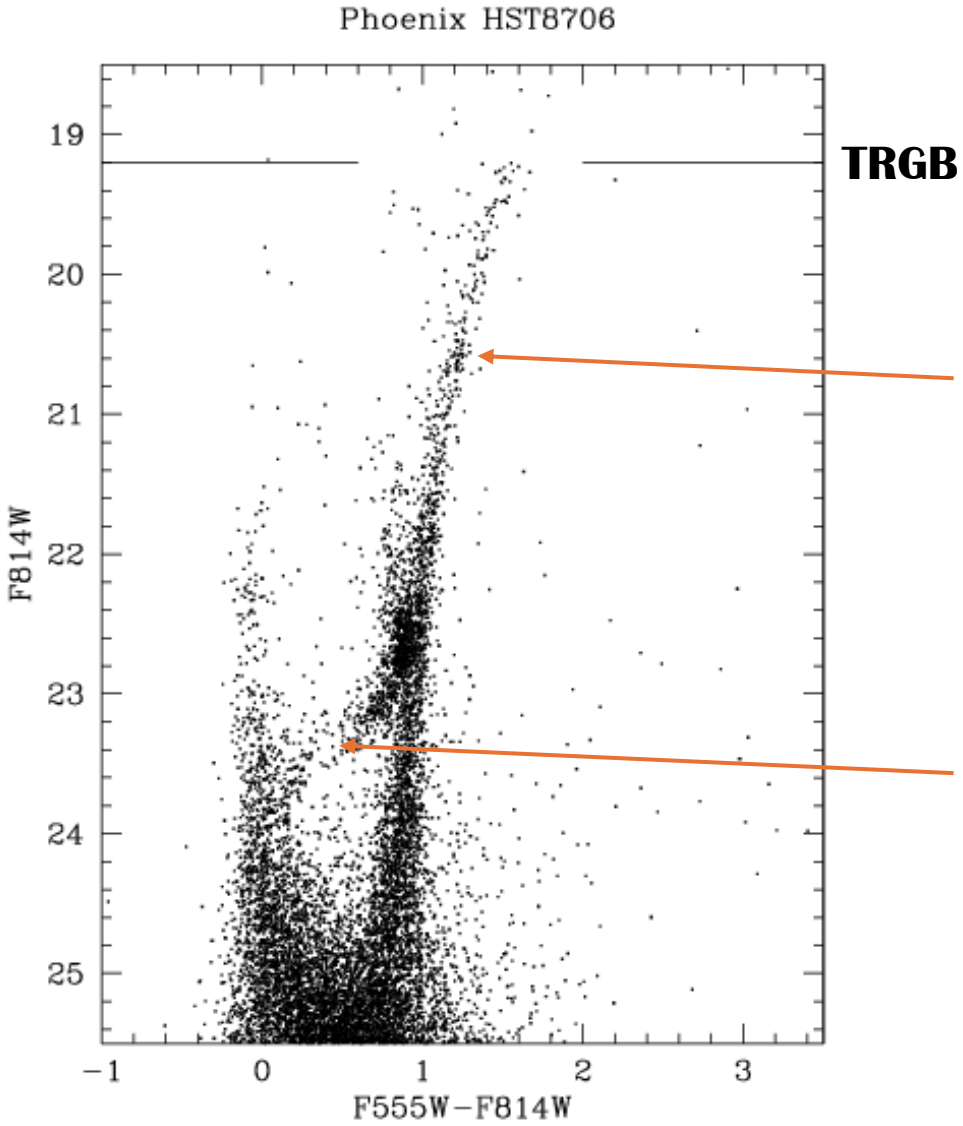
Geometry ⇒ TRGB



TRGB: Tip of the Red Giant Branch

Gaia geometric distances from parallaxes of RGB, HB, RR Lyr stars in Milky Way

All Pop II !!

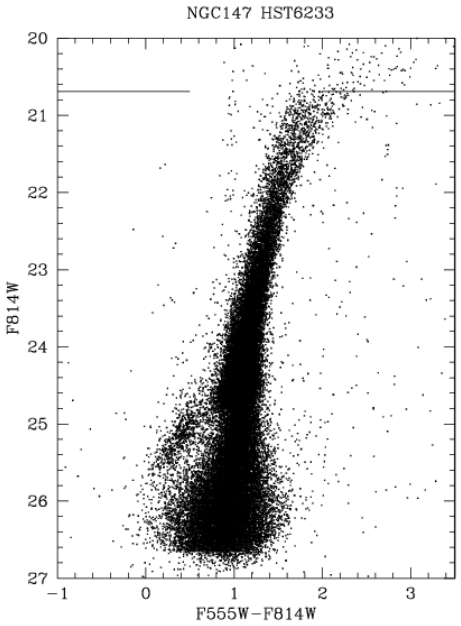


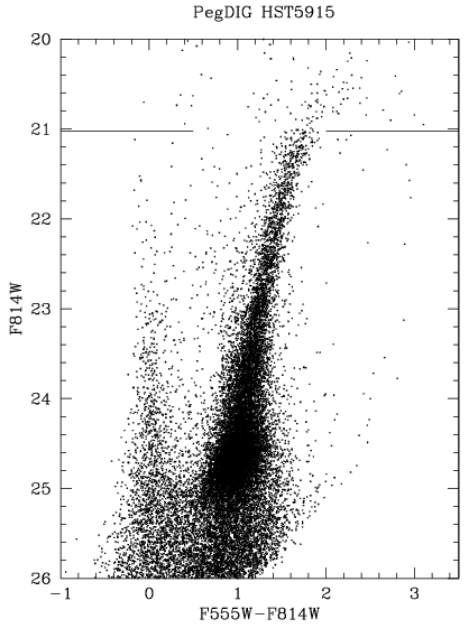
TRGB

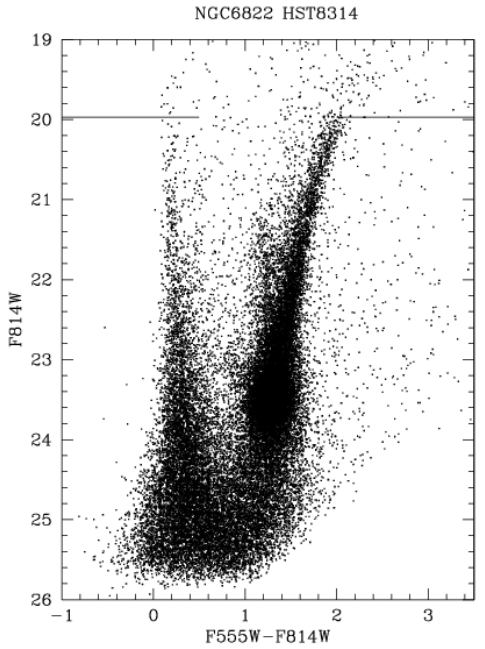
Red Giant Branch

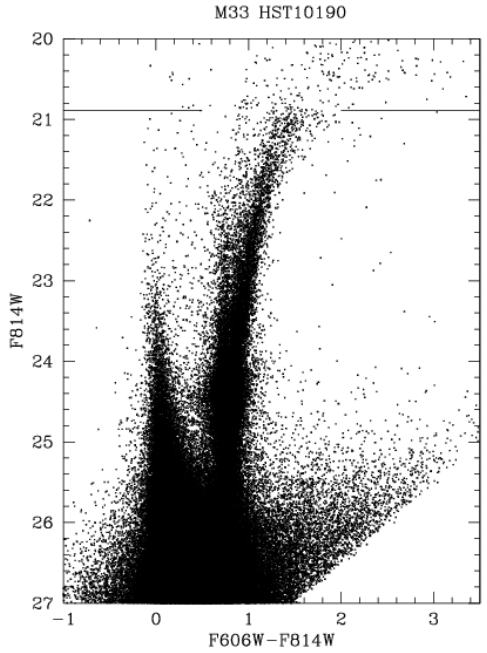
Horizontal Branch
RR Lyrae stars

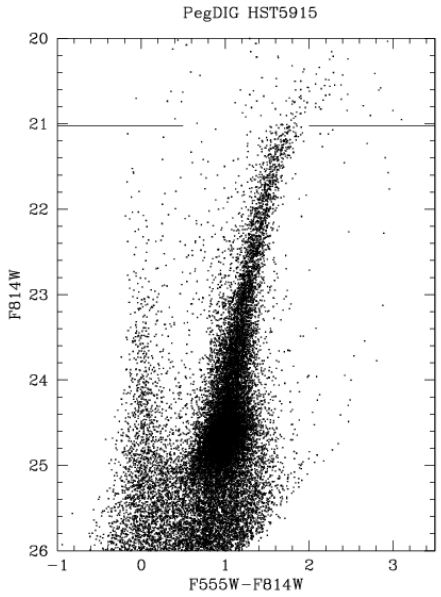
TRGB in the Local Group



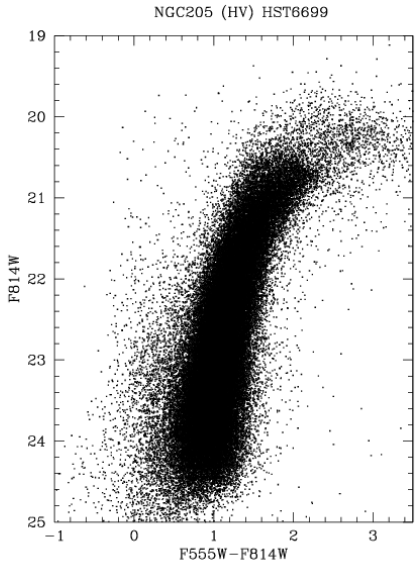


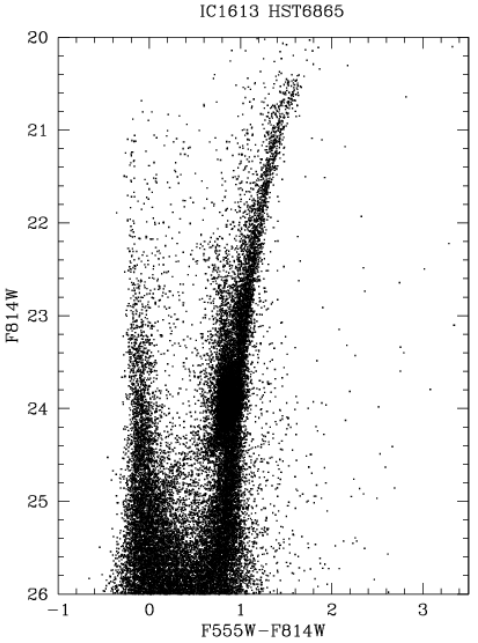






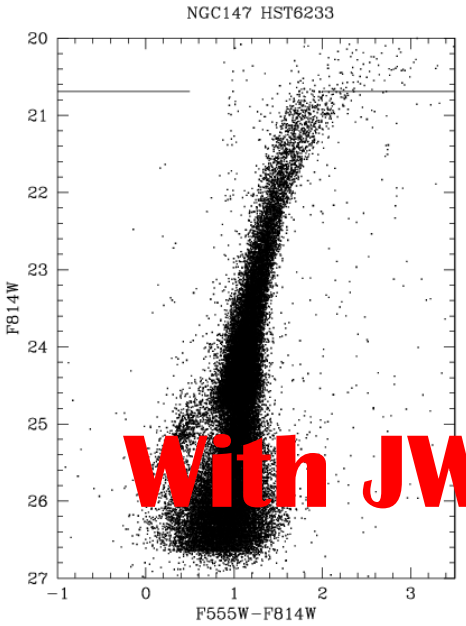
All HST

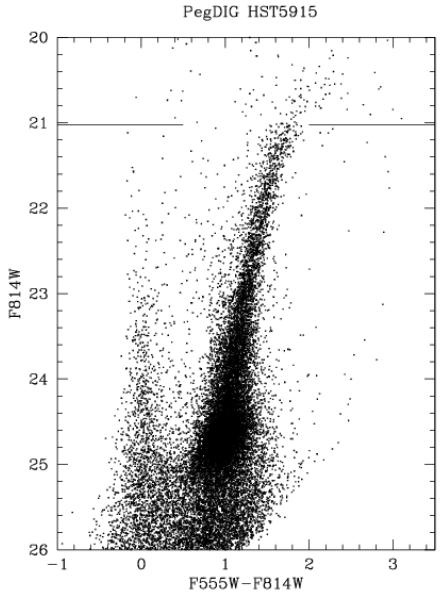


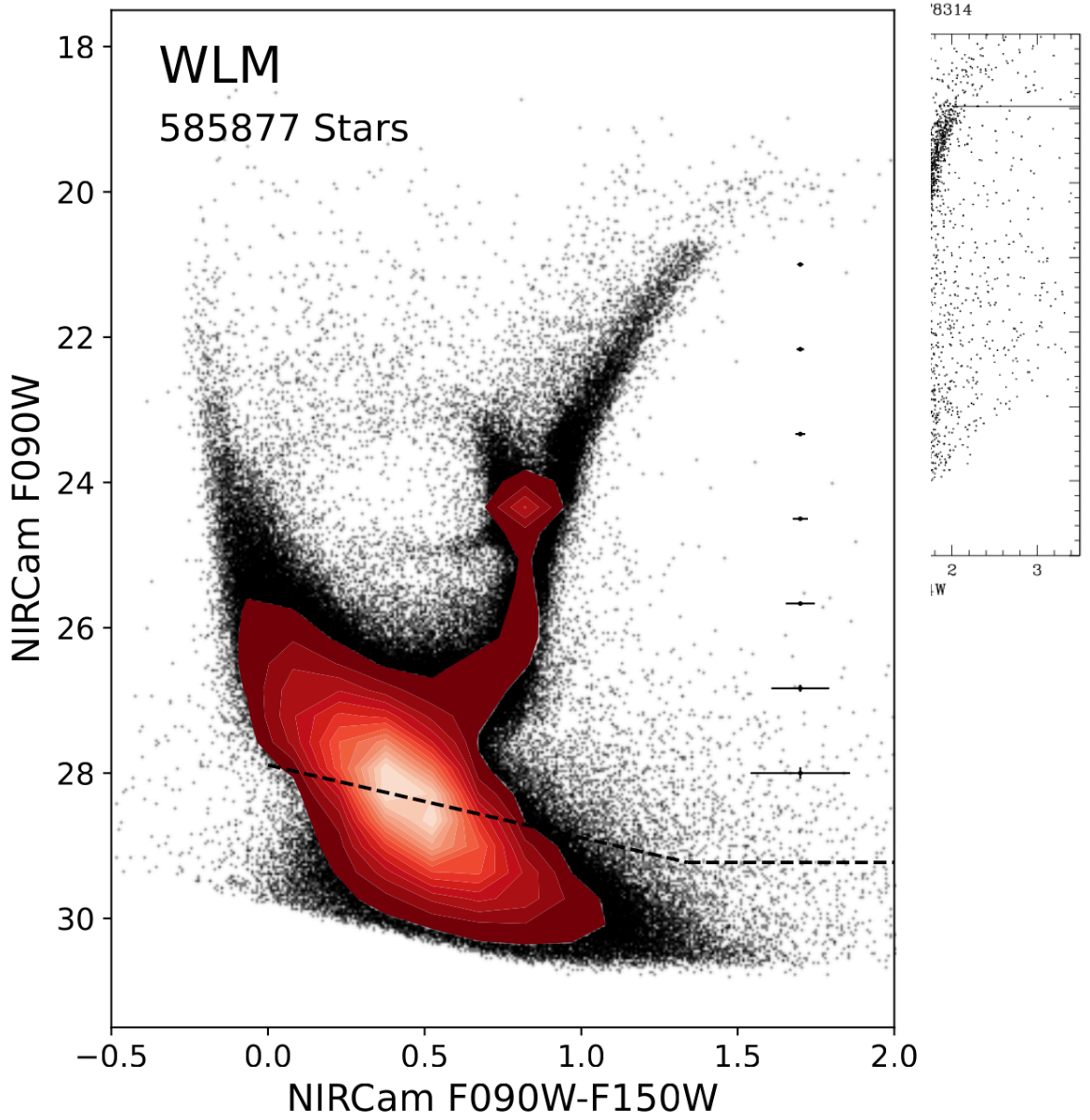


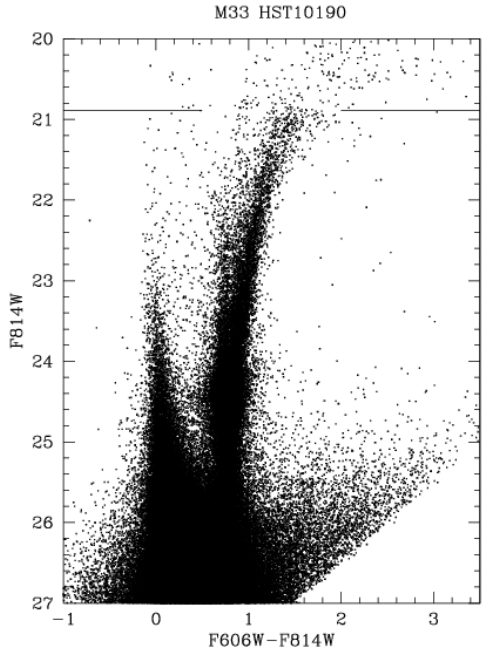
TRGB in the Local Group

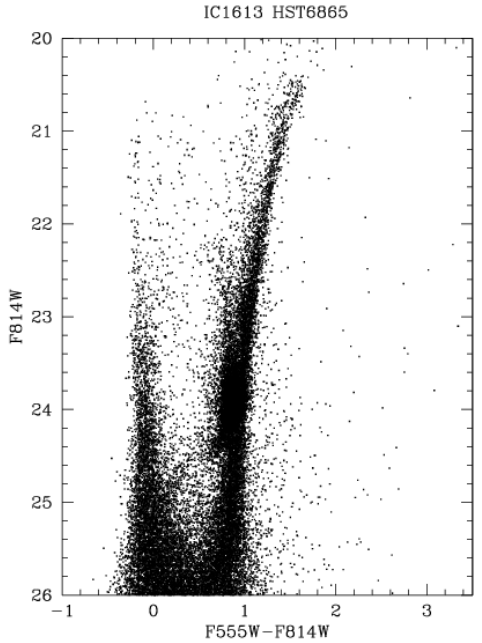
With JWST











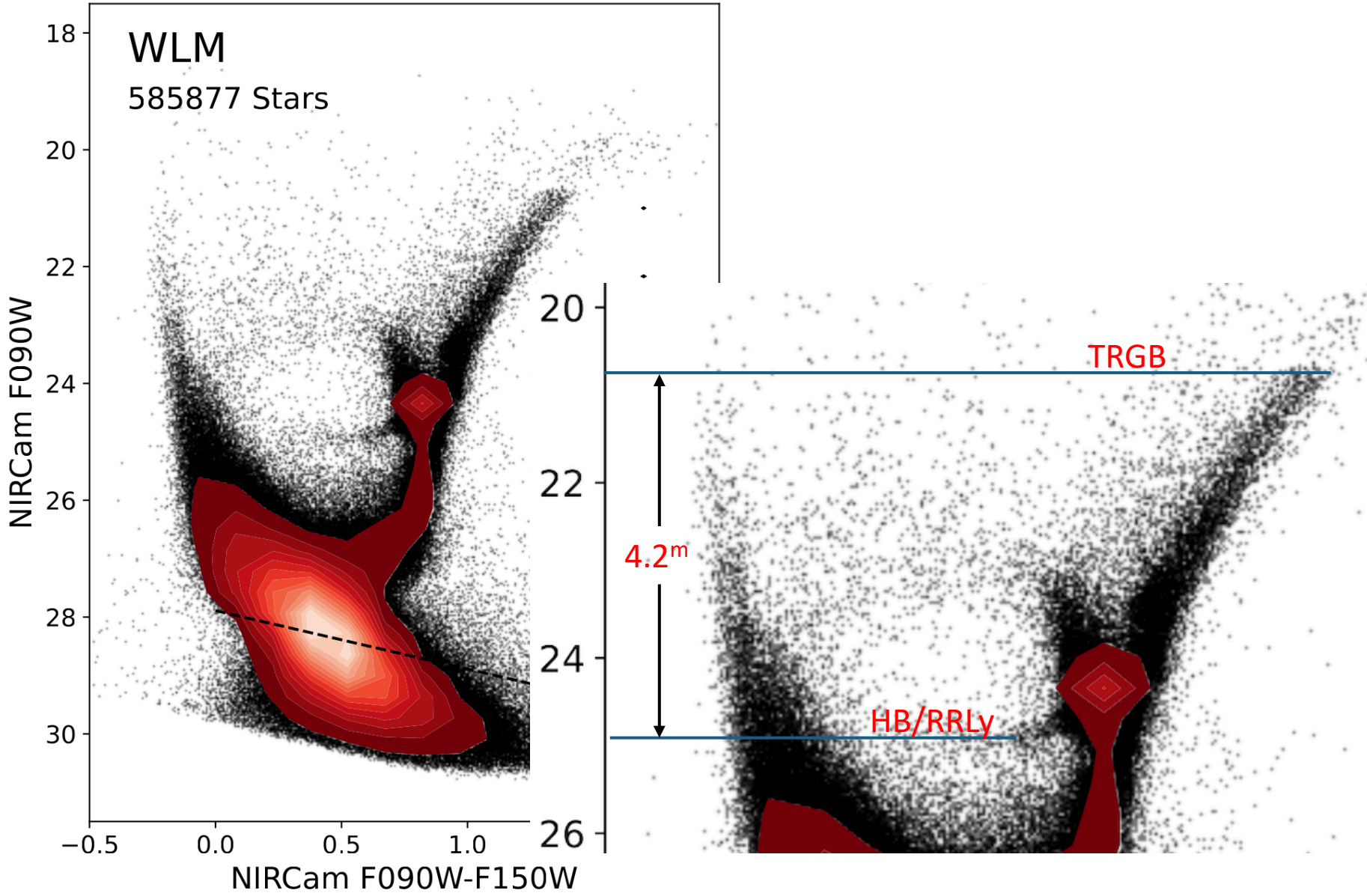
TRGB in the Local Group

With JWST

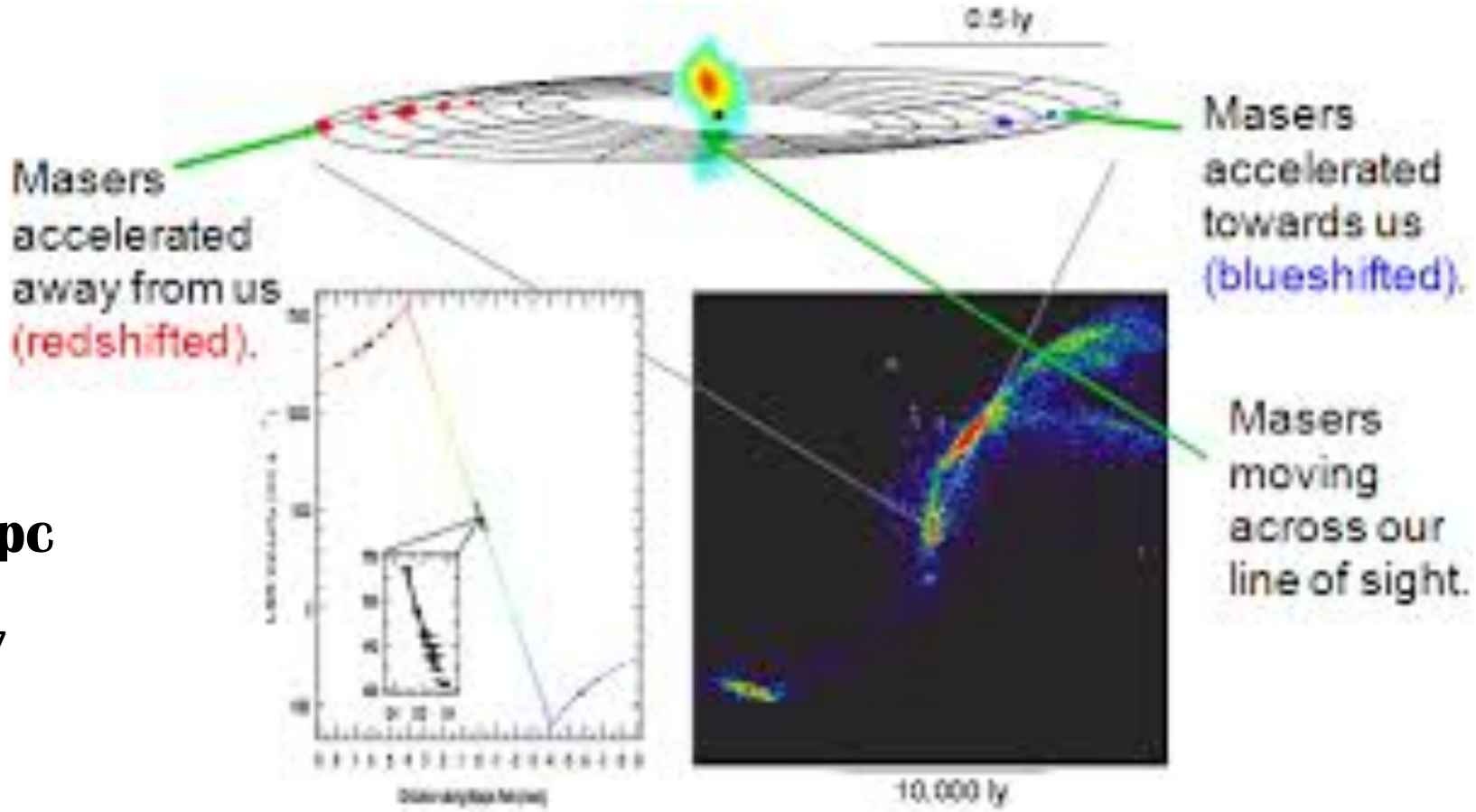
Coming in cycle 3:
JWST-GO-4783 PI: Savino

NGC147
NGC185
NGC205
IC1613
Aquarius
Pegasus
Leo A
Cetus

Also see poster by Max Newman



NGC 4258: Distance Scale Rosetta Stone

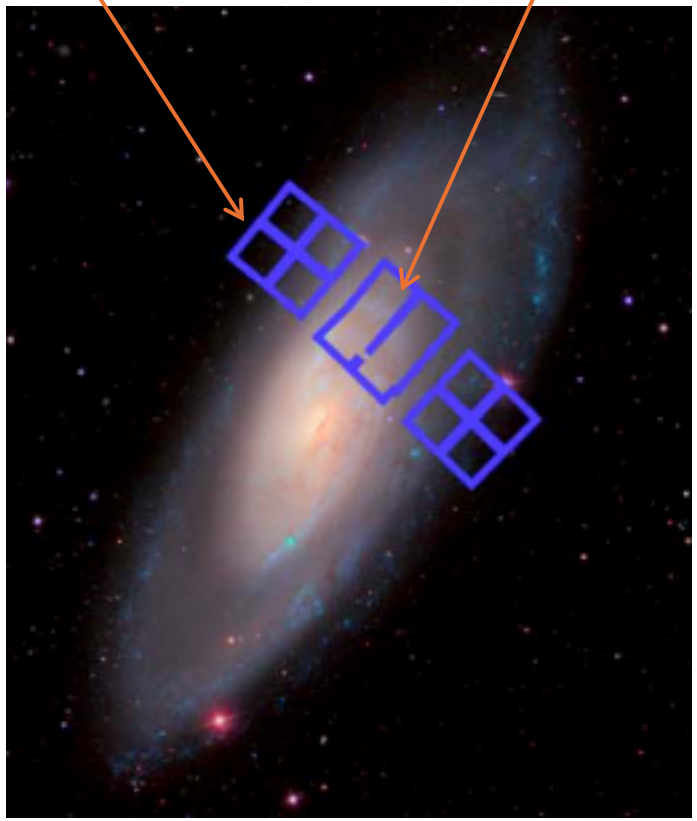


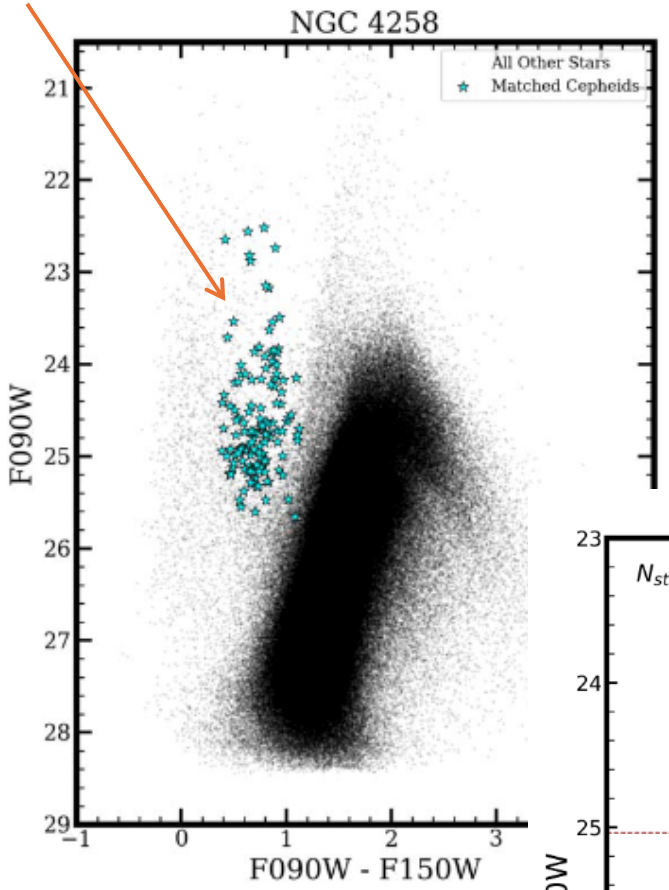
d = 7.576+-.082+-.076 Mpc

Reid, Pesce. Riess 2019, ApJ, 886, L27

TRGB

cepheids

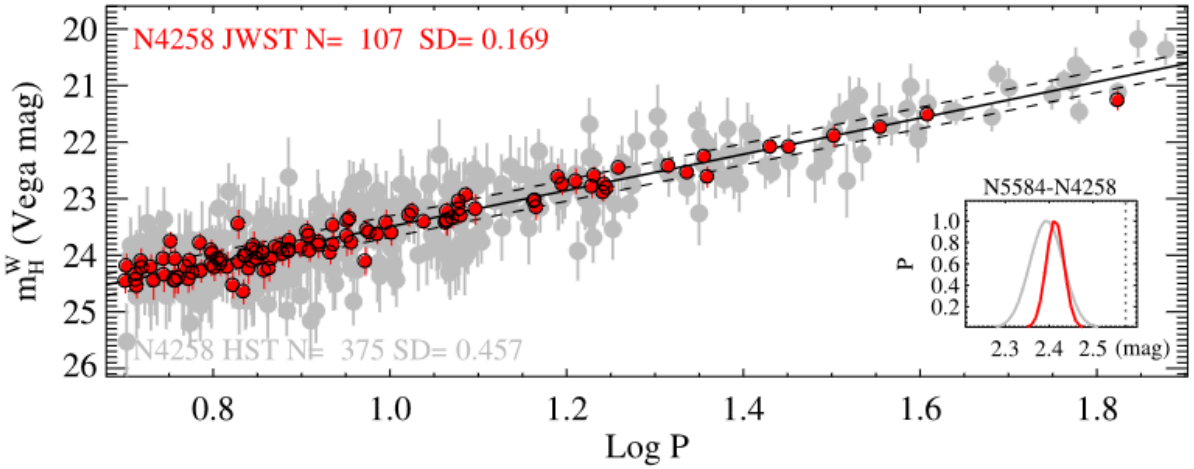


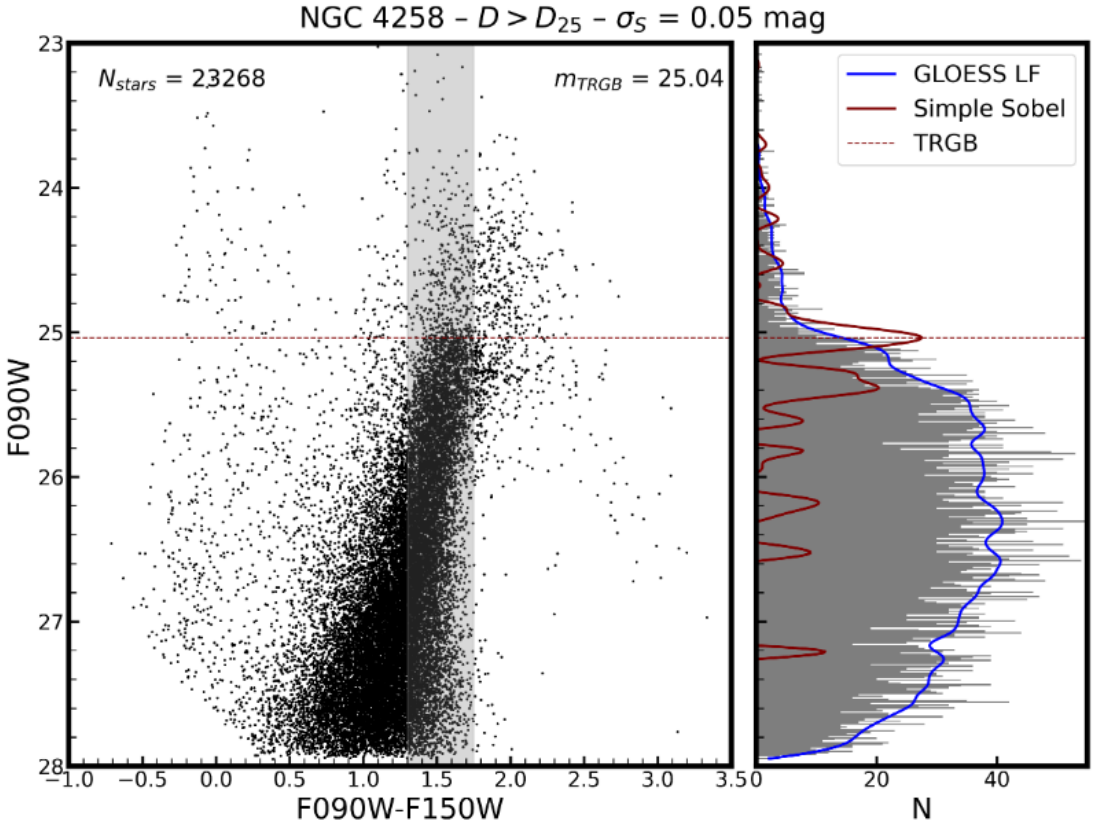


JWST

NGC 4258: Rosetta Stone

d_{maser} = 7.58+-.11 Mpc





JWST

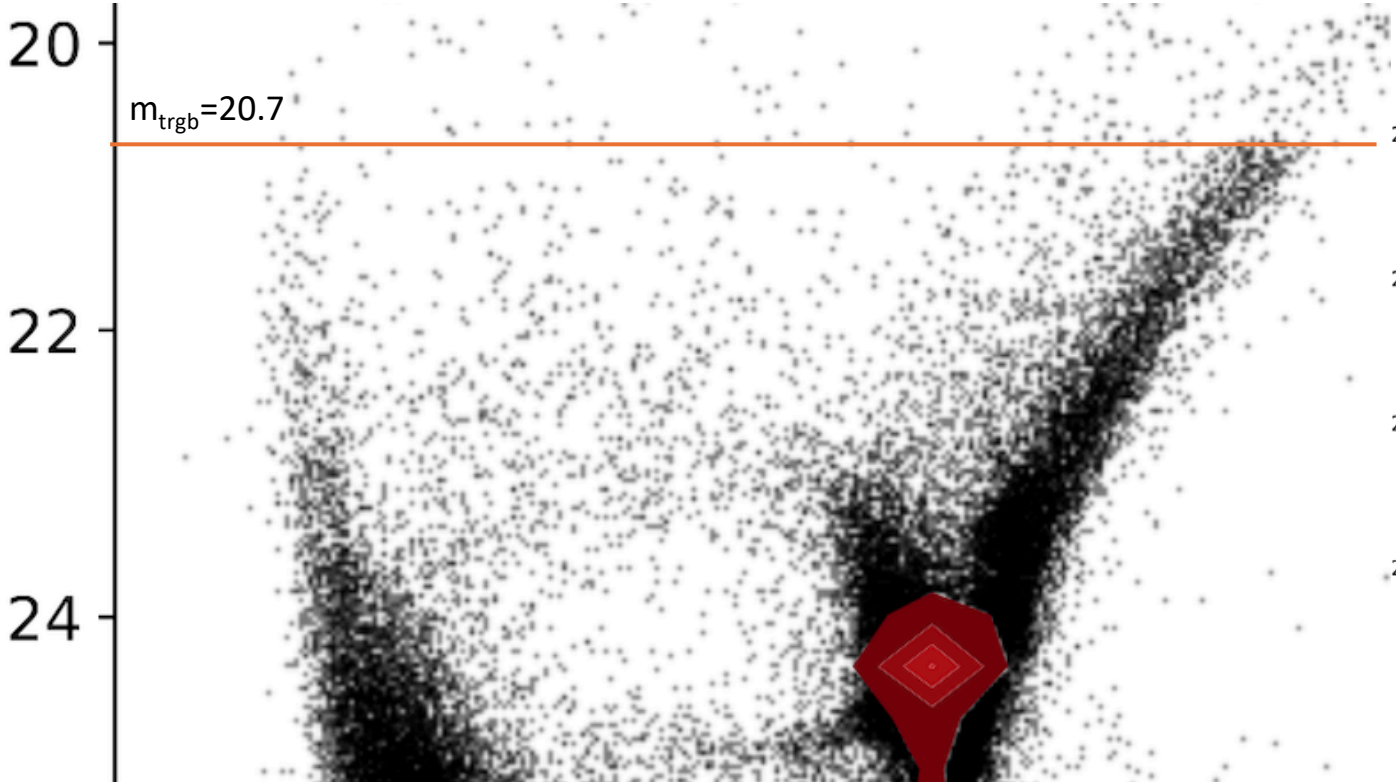
NGC 4258: Rosetta Stone

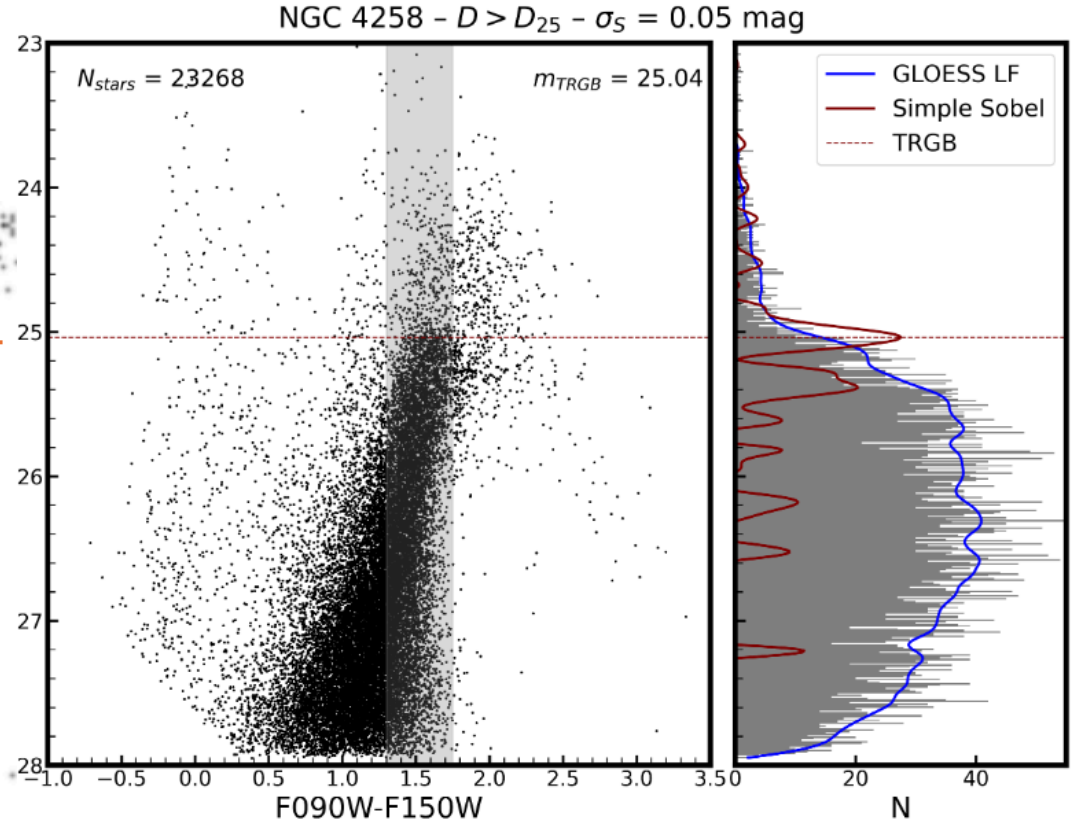
d_{maser} = 7.58+-.11 Mpc

Relative NGC 4258 – WLM distance modulus

$(M_{F090W} - A_{F090W})^{NGC4258} - (M_{F090W} - A_{F090W})^{WLM}$ ~ 4.4 mag

WLM





TRGB calibration via LMC

Anderson, Koblischke, & Eyer 2024, ApJ, 963, L43

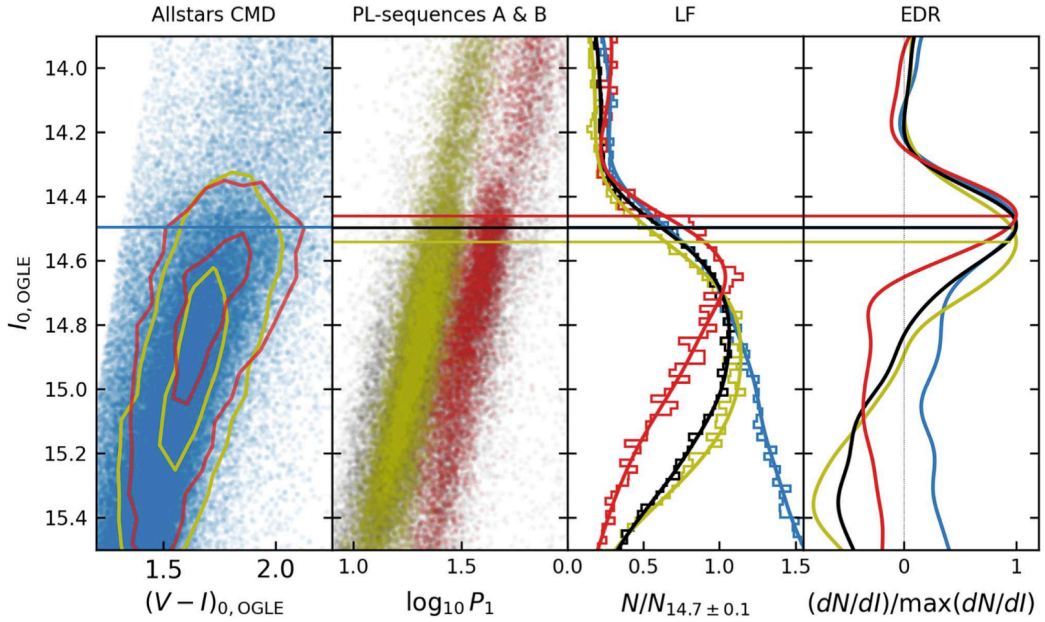
RGB stars near the tip are variable!

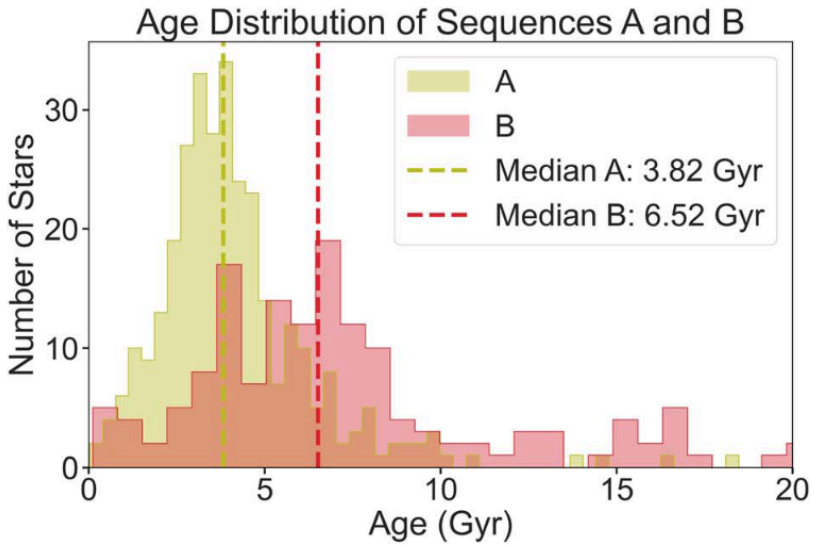
Two PL sequences: A & B

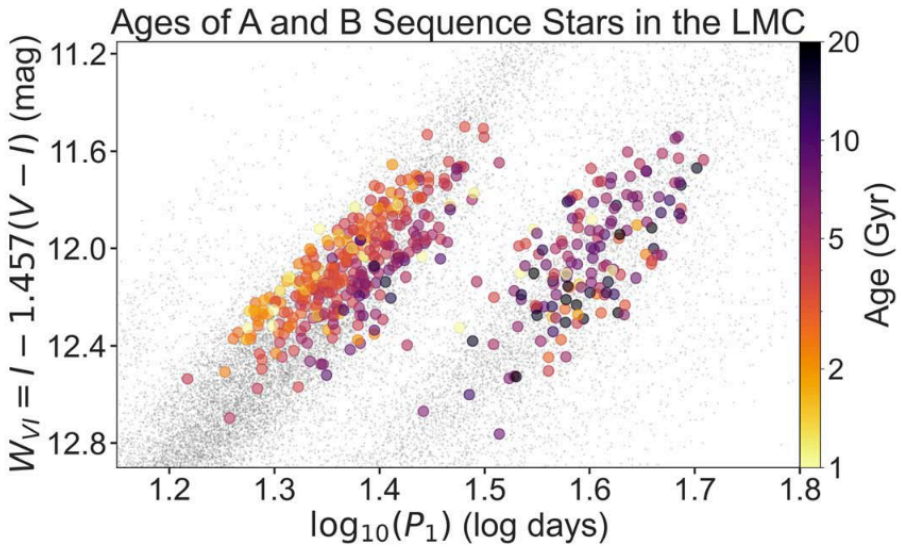
A sequence stars have younger mean than B sequence

B sequence TRGB slightly brighter: $\mathbf{M_{F814W} = -4.025}$

Assumes LMC eclipsing binary distance of 49.59 kpc







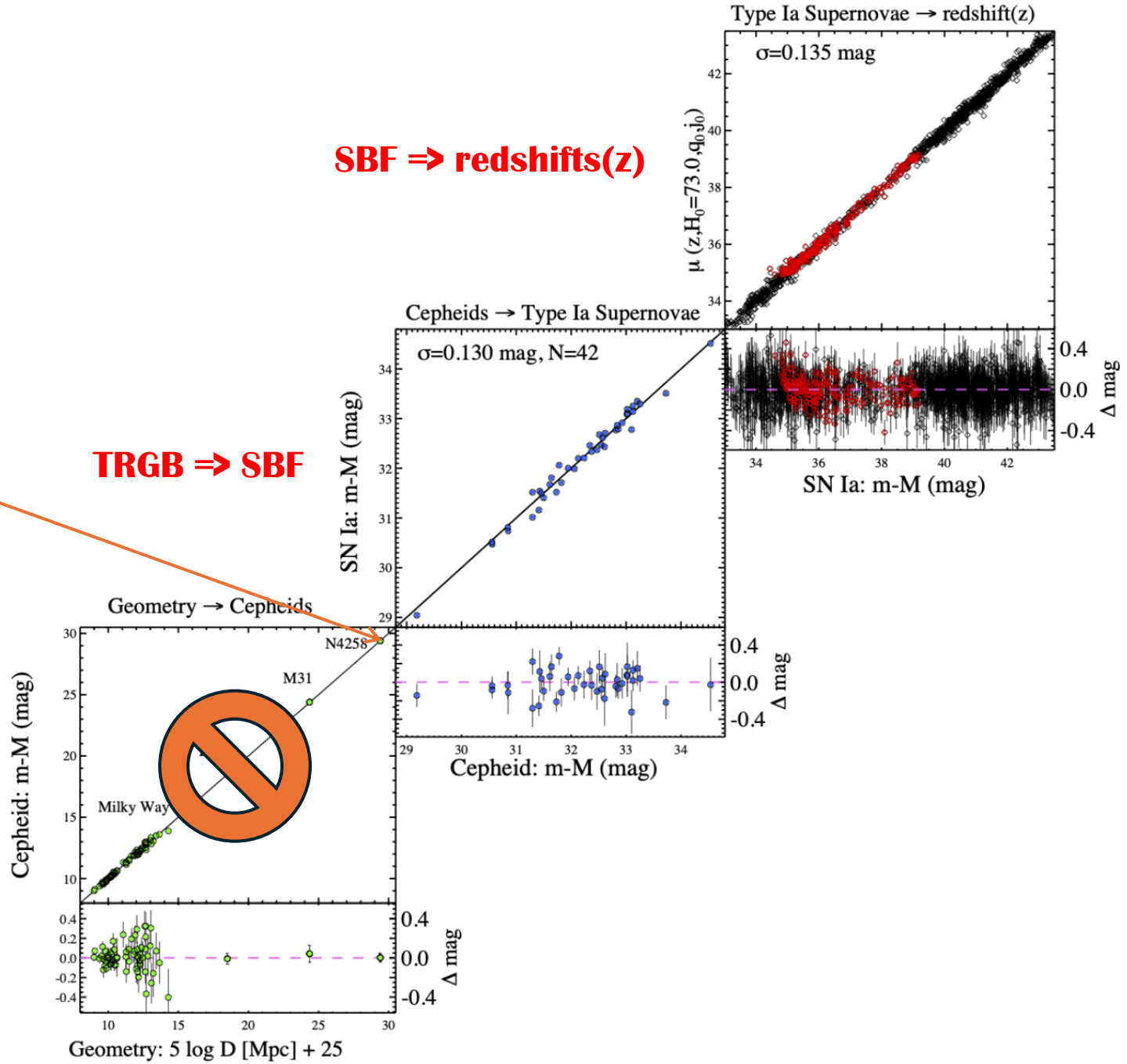
Tentatively!
Distance to NGC 4258 is 7.69 Mpc
1.5% greater than maser distance

NGC 4258:
Rosetta Stone

TRGB ⇒ SBF

SBF ⇒ redshifts(z)

Geometry ⇒ TRGB



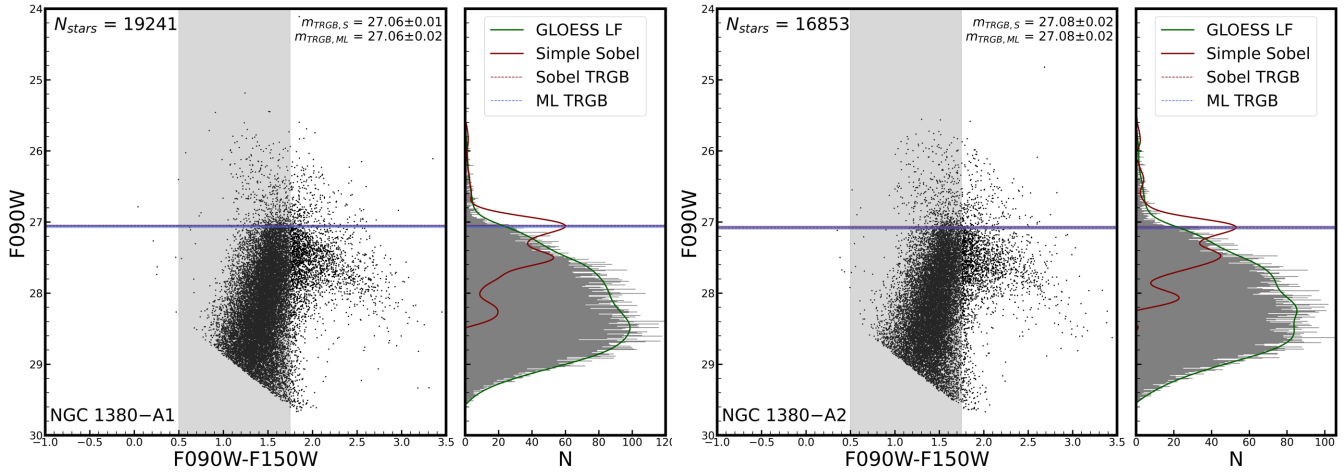
JWST TRGB @ Fornax Cluster

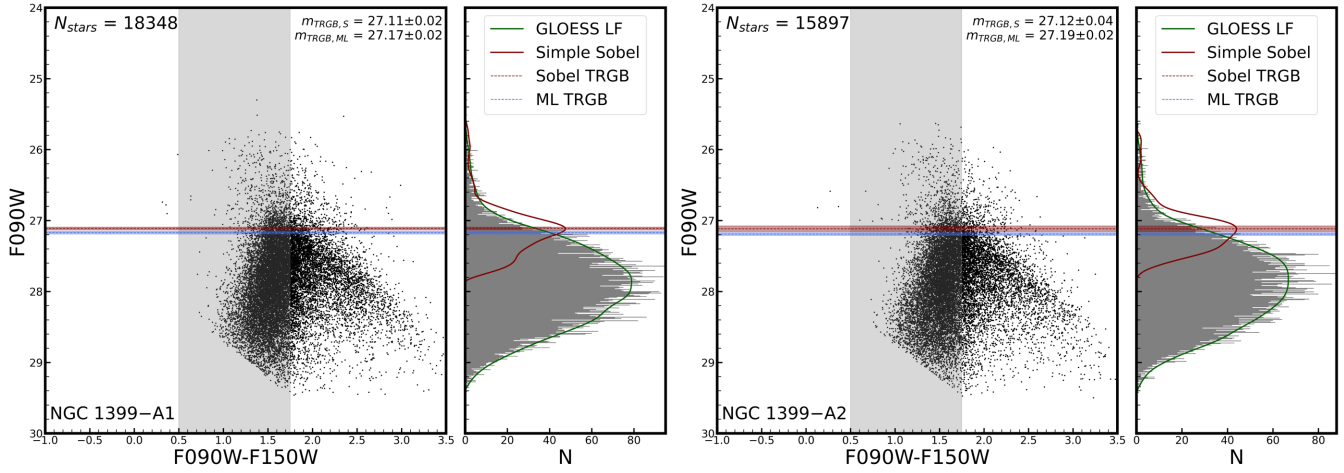
$\langle d \rangle_3$ = 19.3+-.7 Mpc

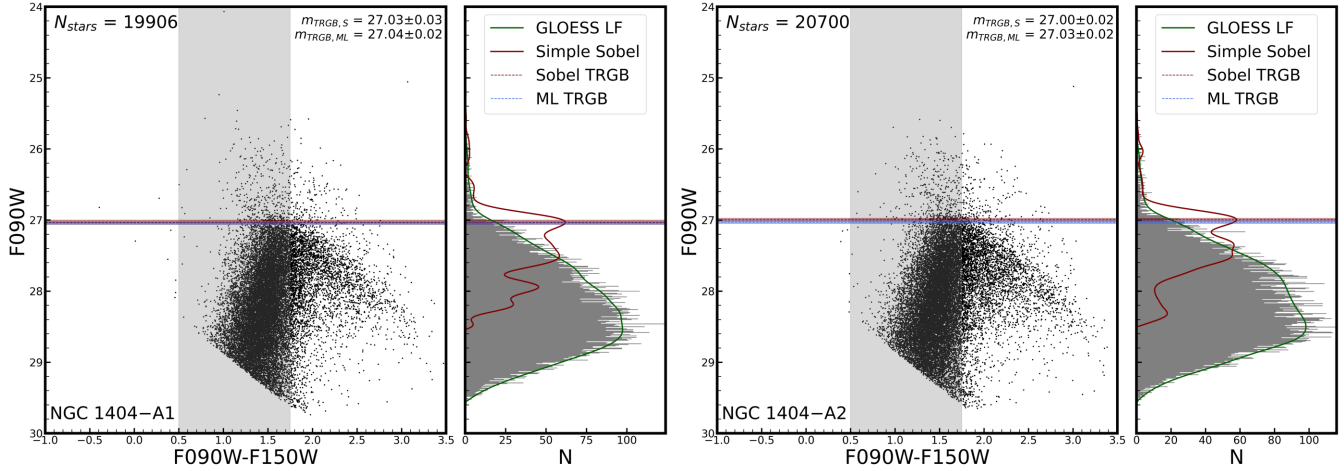
NGC 1380
d = 19.0+-.6 Mpc

NGC 1399
d = 20.1+-.6 Mpc

NGC 1404
d = 18.7+-.6 Mpc

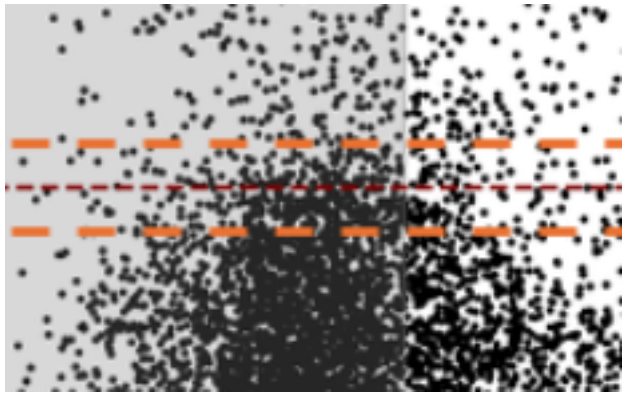


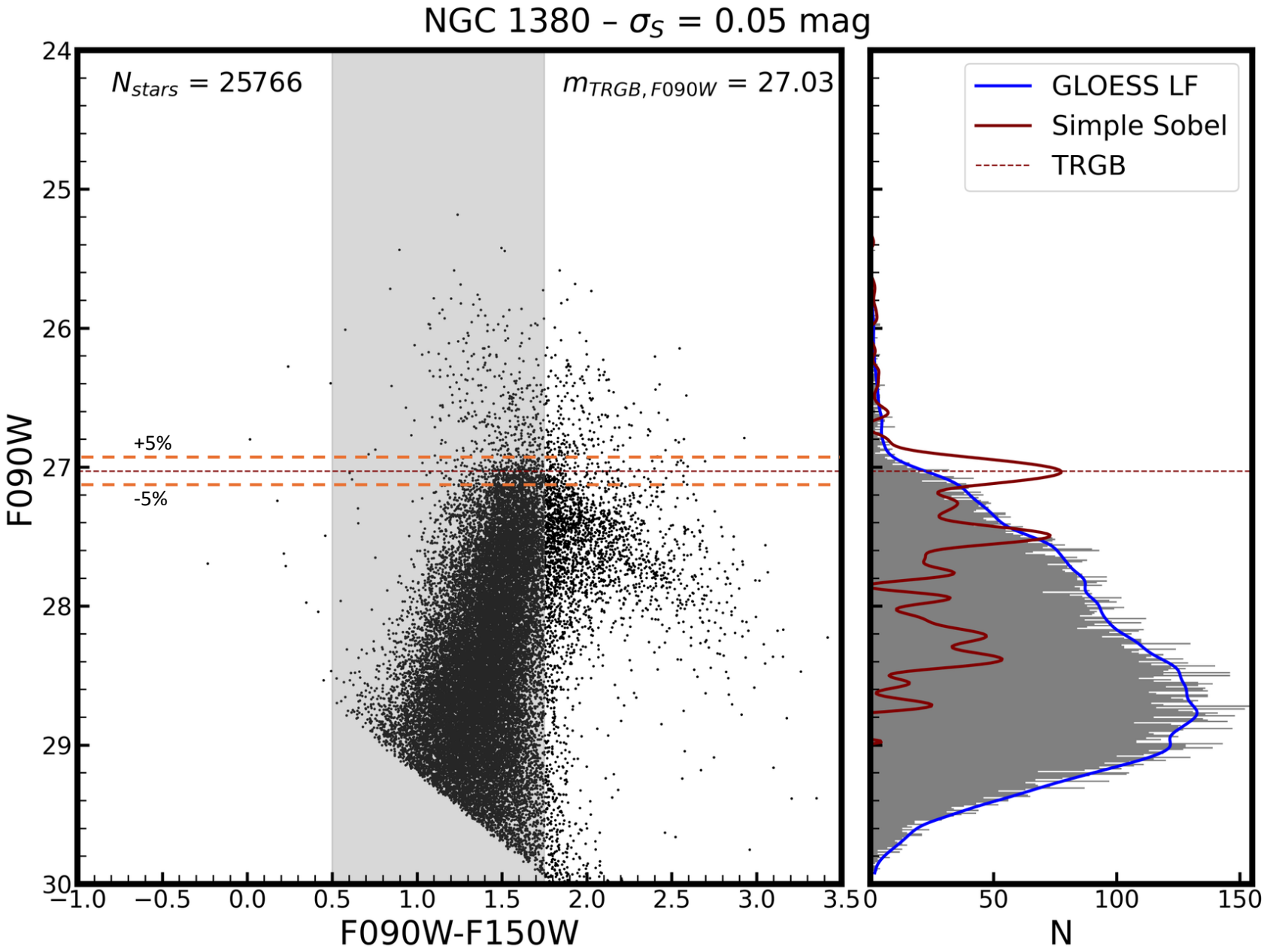




NGC 1380

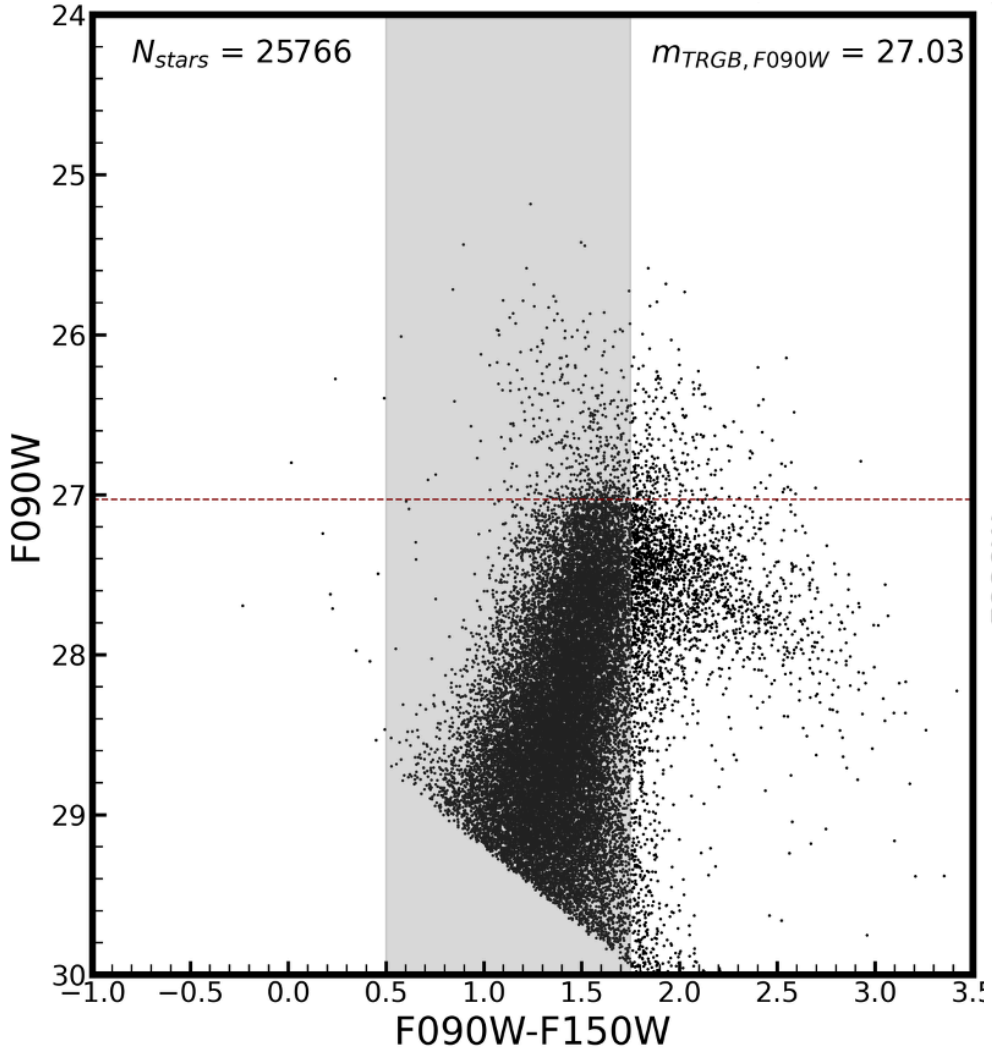
3 hours total in 2 filters with JWST
d = 19 Mpc (Fornax Cluster)



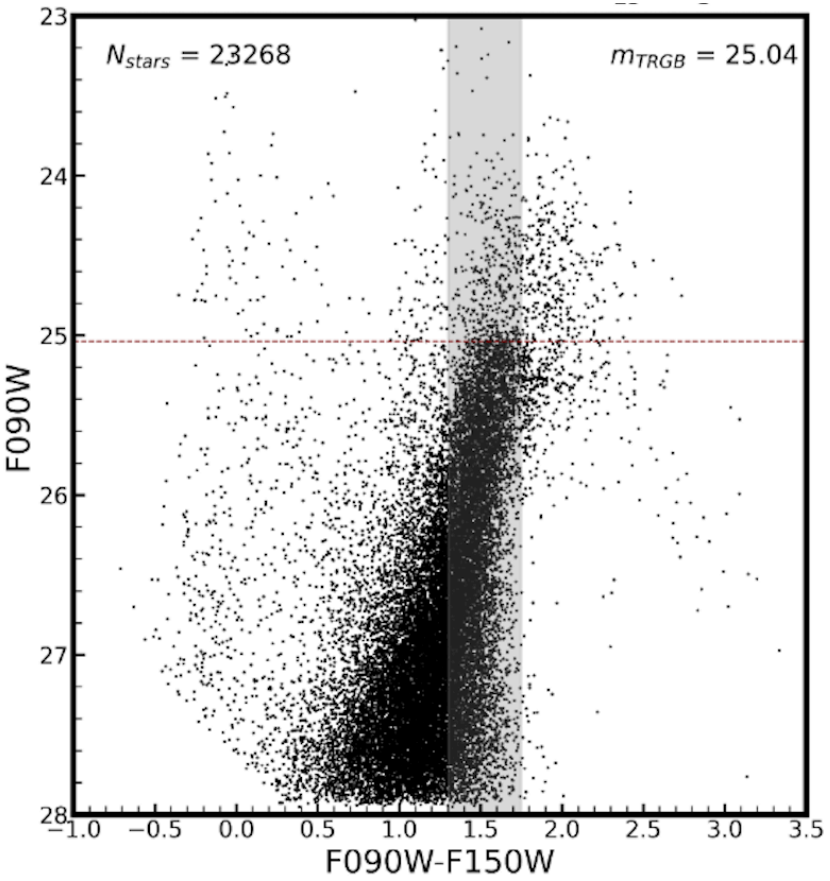


$\Delta\mu$(NGC1380-NGC4258) = 1.99 mag => factor 2.50 in distance

NGC 1380



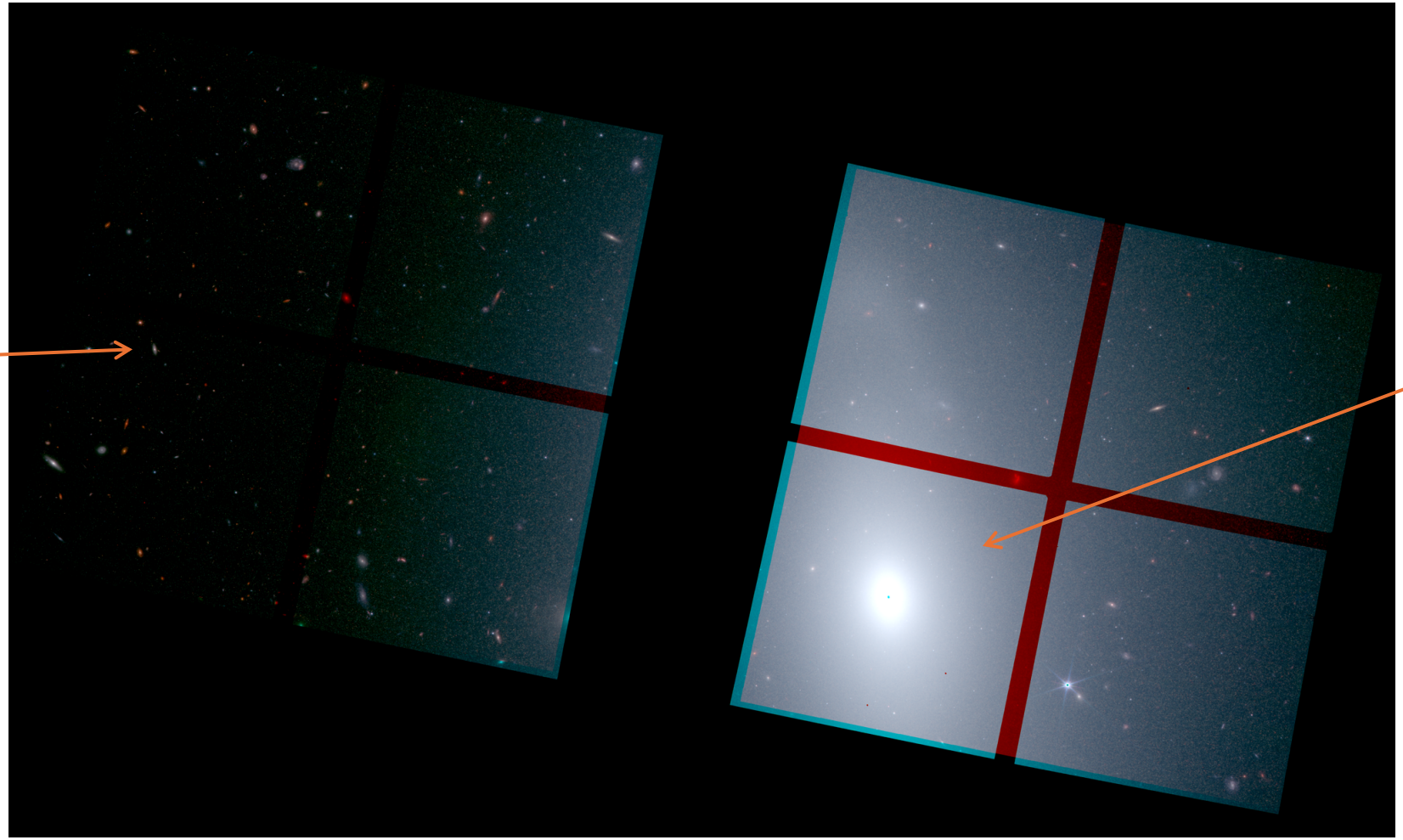
NGC 4258



Tip of the Red Giant Branch

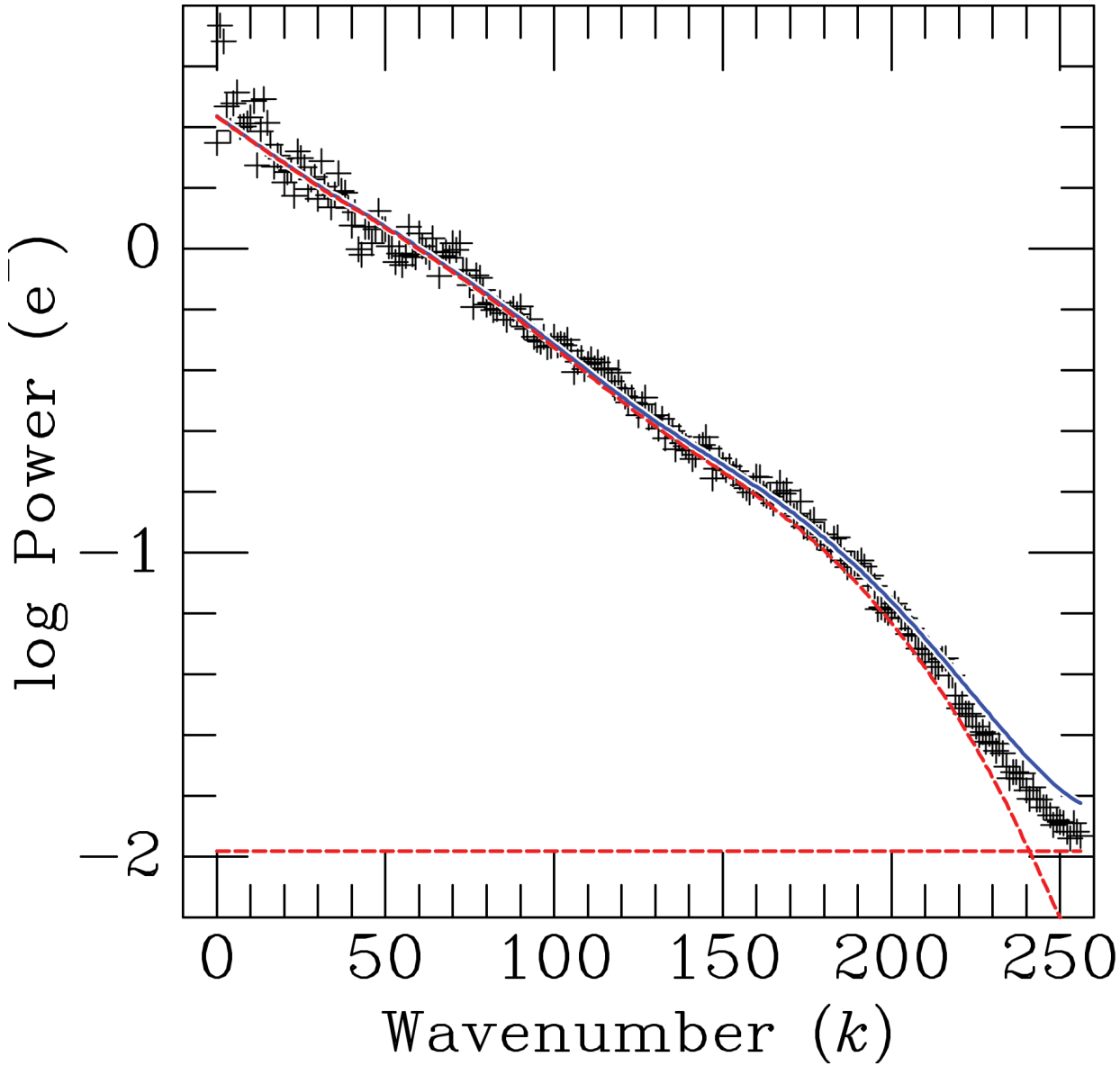
⇒

Surface Brightness Fluctuation



JWST NIRCam observations of NGC 1380

SBF spatial power spectrum for NGC 1399



Probably the highest S/N SBF power spectrum you have ever seen!!

Pop II ladder

JWST-GO-3055

14 E/S0 galaxies @ ~20 Mpc
Split NIRCam fields optimal for TRGB and SBF

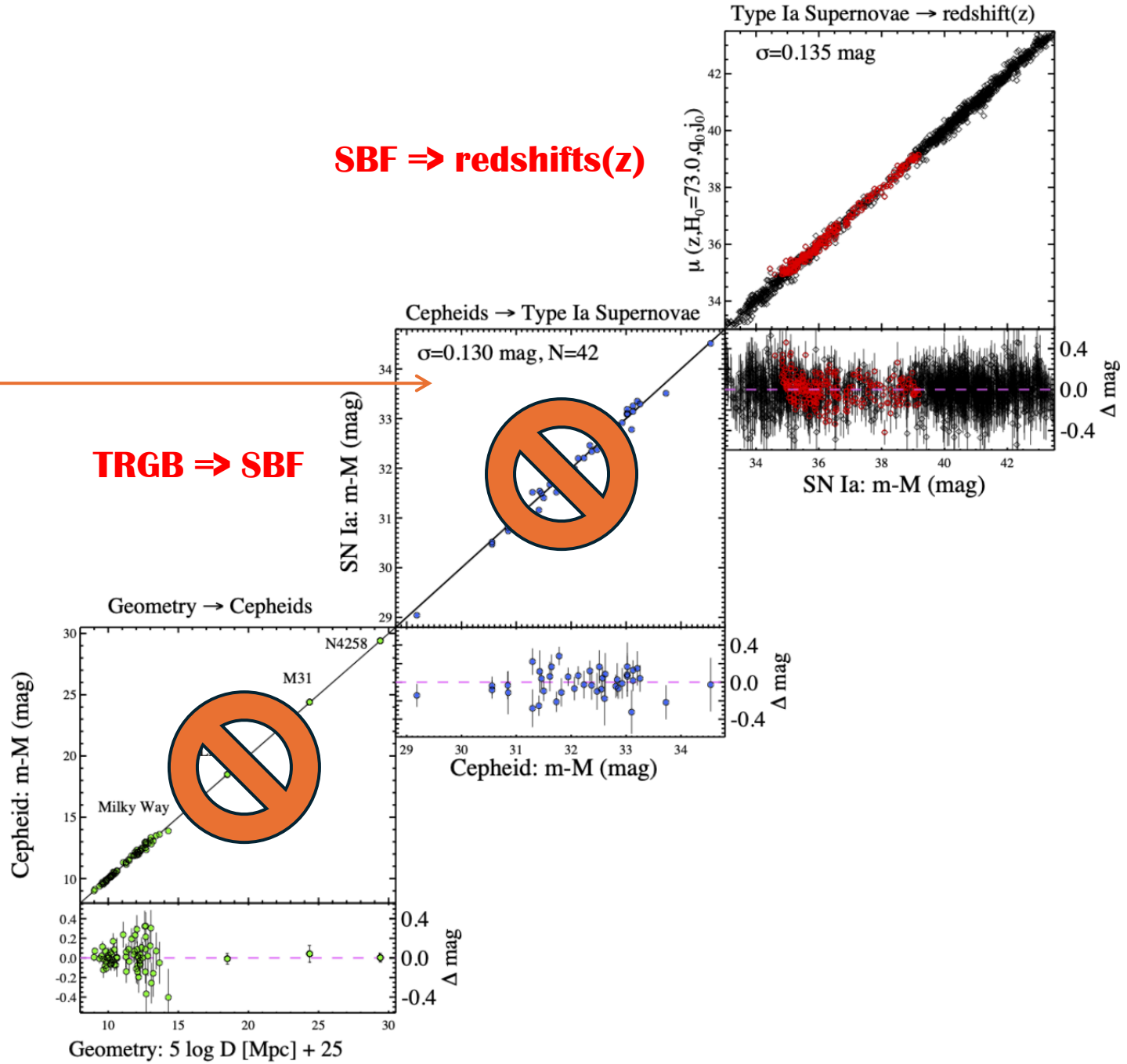
3/14 currently observed
NGC's 1380, 1399, 1404

Remaining 11 observations scheduled

SBF ⇒ redshifts(z)

TRGB ⇒ SBF

Geometry ⇒ TRGB



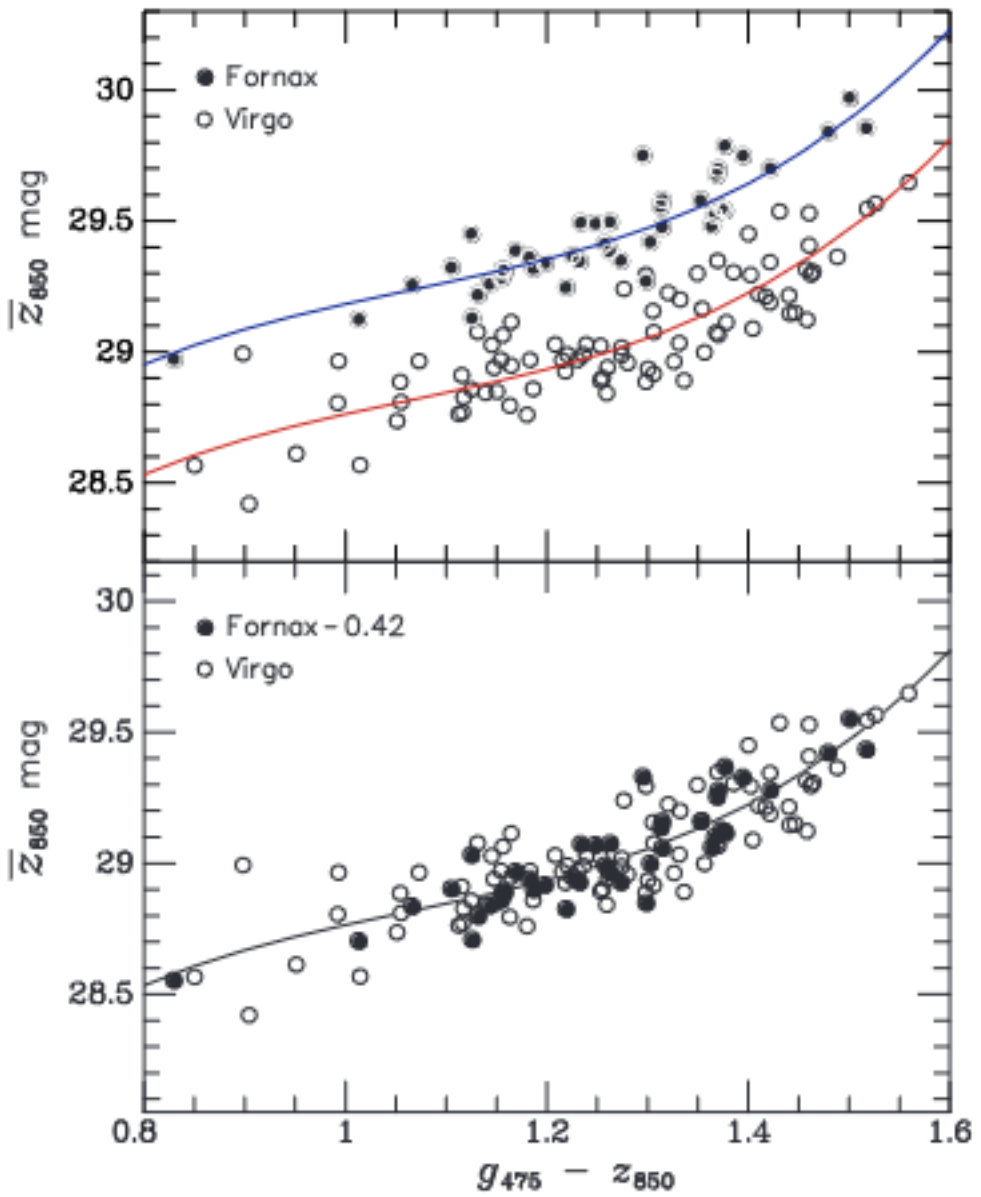
SBF with HST - clusters

Virgo: 85 galaxies
Mei et al. 2007, ApJ, 655, 144

Fornax: 43 galaxies
Blakeslee et al. 2009, ApJ, 694, 556

$d_F/d_V = 1.214+-.017$

$d_{NGC4258} = 7.58$ Mpc
$\Rightarrow d_F = 19.3$ Mpc
$\Rightarrow d_V = 15.9$ Mpc

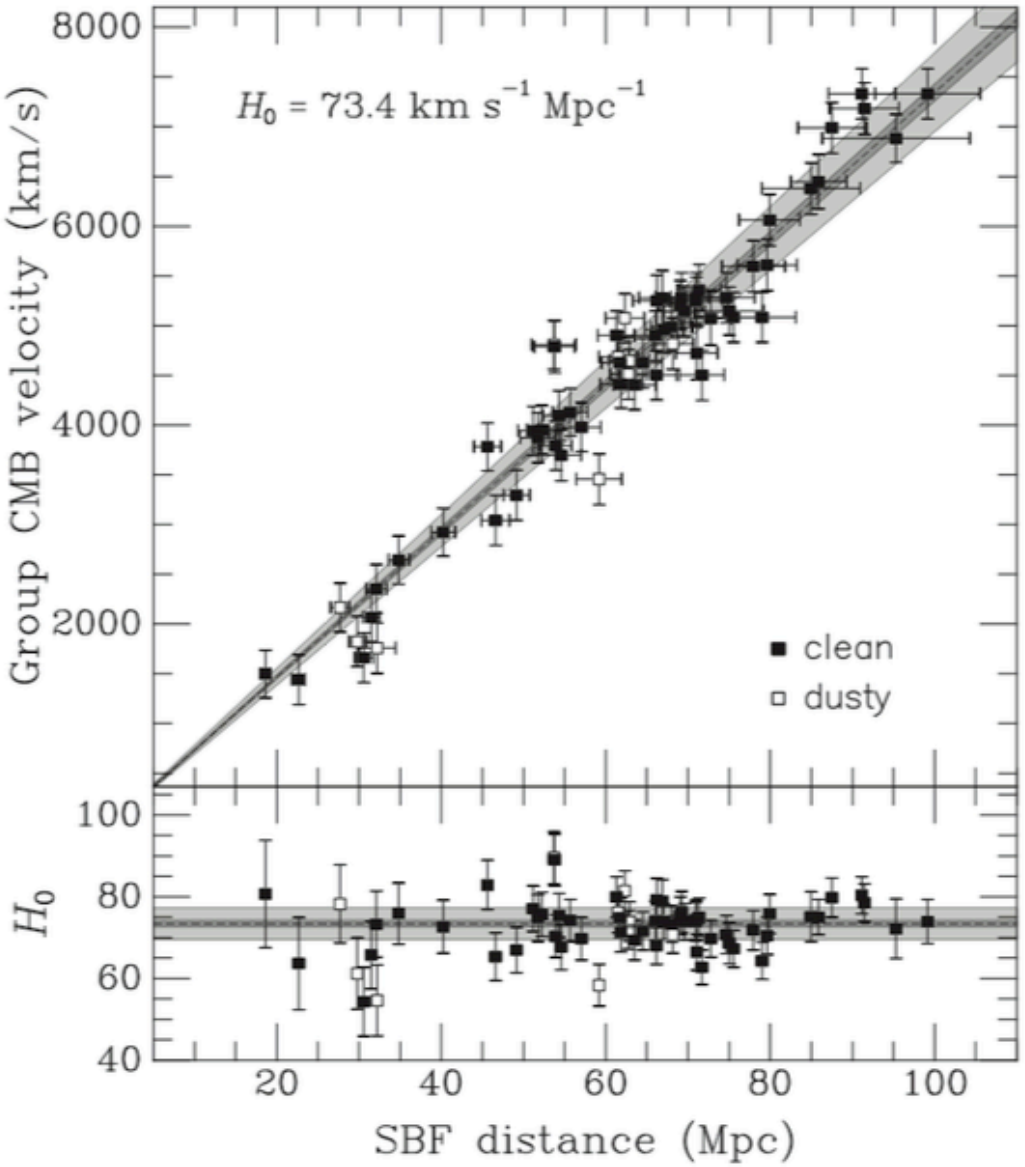


SBF with HST - field

63 galaxies
Jensen et al. 2021, ApJS, 255, 21
Blakeslee et al. 2021, ApJ, 911, 65

Coming soon HST c28
68 galaxies snap-16262

Coming soon HST c31
?? galaxies snap-17436
29 galaxies GO-17446

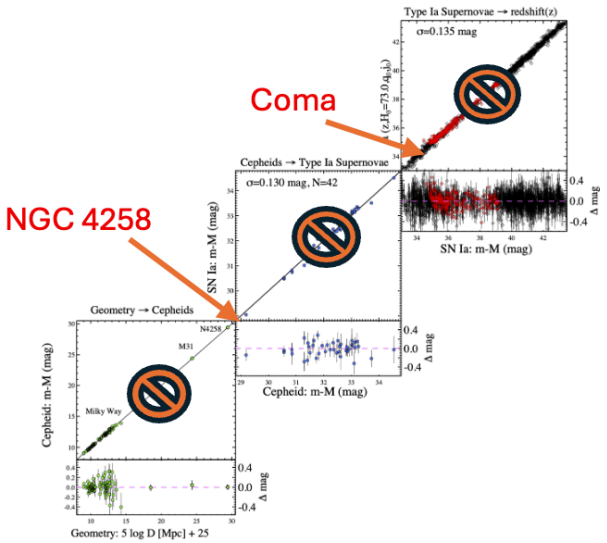


Zero point from Cepheids, NGC 4258, LMC

SBF with JWST – Coma Cluster

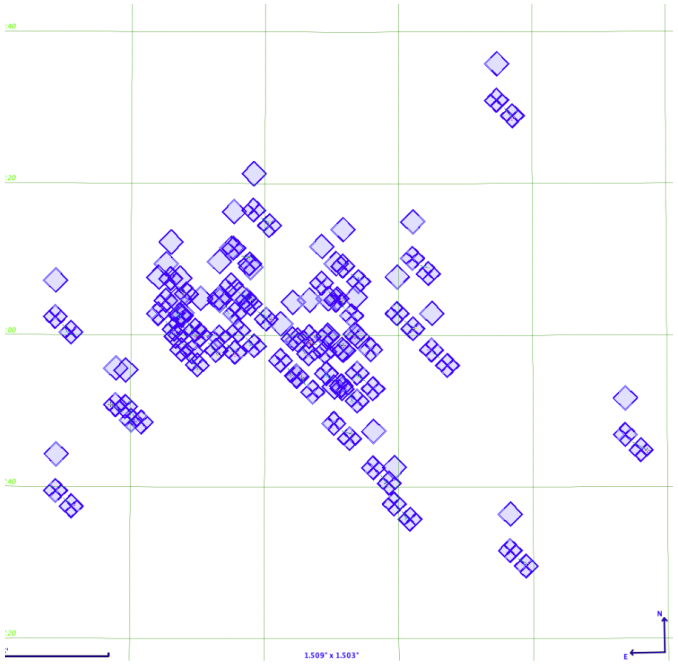
Coma Cluster: ~40 galaxies

Cycle 3: JWST-GO-05989



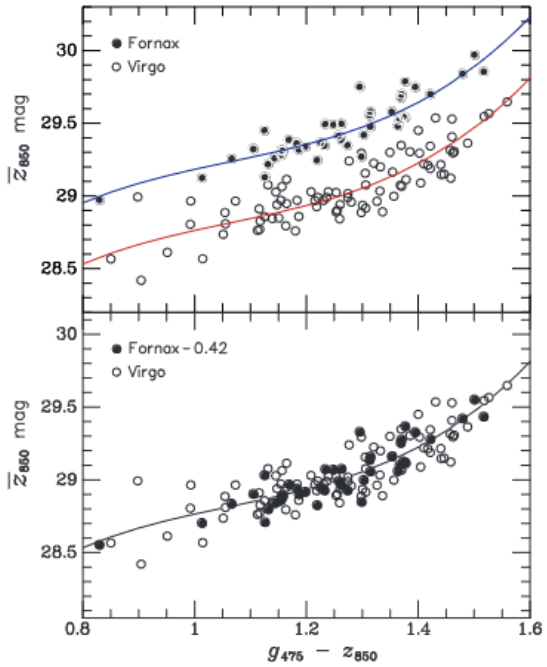
Coma Cluster: a 2nd Rosetta stone
10 SNIa studied in cluster to date

d_c ~ 100 Mpc



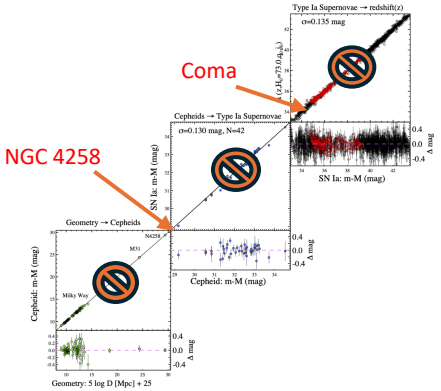
coverage of central 1.5° of Coma Cluster
tentative cycle 3 field orientations

Task: to establish color dependence with JWST F090W



color dependence in HST filter

SBF with JWST



3 steps:

1. Zero-point link through TRGB. Cycle 2 GO-3055
   14 nearby galaxies with NIRCam windows simultaneously optimized for TRGB and SBF

2. Metallicity-age calibration of SBF at JWST bands. Cycle 3 GO-5989
   39 E/S0 galaxies in the Coma Cluster; study SBF scatter with color, all at same distance

3. SBF observations of E/S0 galaxies in the range 0.03 < z < 0.07. Cycle ??
   100+ targets scattered across the sky and in redshift

Advantages of Pop 2 TRGB-SBF over Pop 1 Cepheid-SNIa

7% ⟶ SNIa absolute magnitude variations? Age? Host characteristics?
SNIa observations: multiple teams cover different sectors of sky and distances

5% ⟶ SBF with JWST: uniform coverage of entire sky, all accessible distances, same filters

rms per target

Prediction:

Come back in 3 years and

Gaia => TRGB => SBF

will be the gold standard

for the determination of H_0

Thanks to HST & JWST!