The Tip of the Red Giant Branch (TRGB) : current status and future prospects

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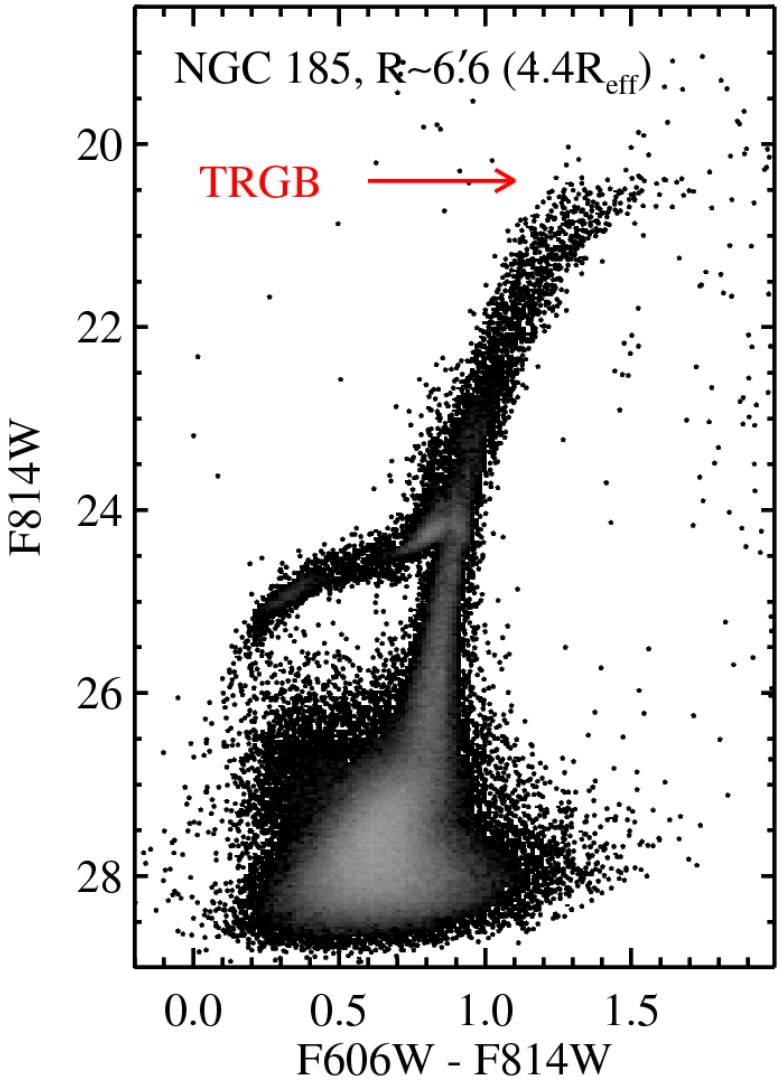
Background: GHOSTS imaging of NGC 891

The Tip of the Red Giant Branch

TRGB is

- ✓ the brightest part of RGB in the CMD of old stellar systems.
- ✓ seen in any types of galaxies older than a few Gyr.
- ✓ comparable to Cepheids in precision (Lee, Freedman, and Madore 1993)
- ✓ now a reliable distance indicator applied to ~300 galaxies (as of Feb 2019, NED).



Contents

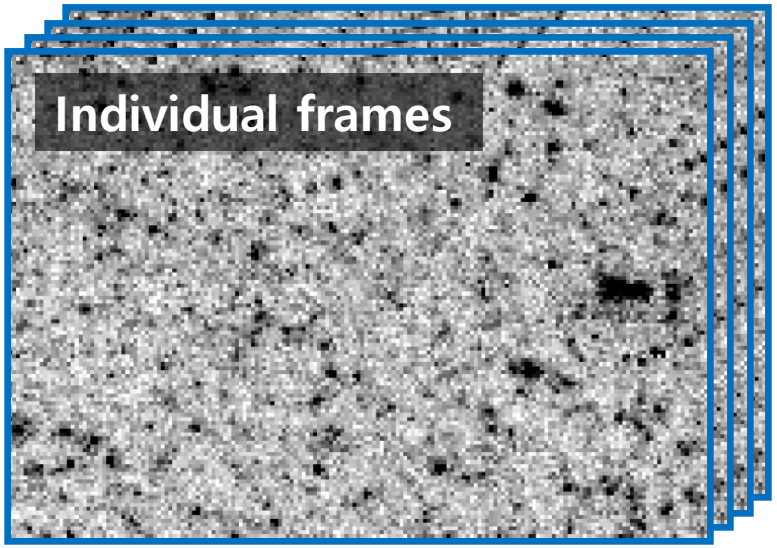
1. Comparison of the TRGB with Cepheids
2. Metallicity and Age Dependence of the TRGB
3. Detecting the TRGB with HST and JWST

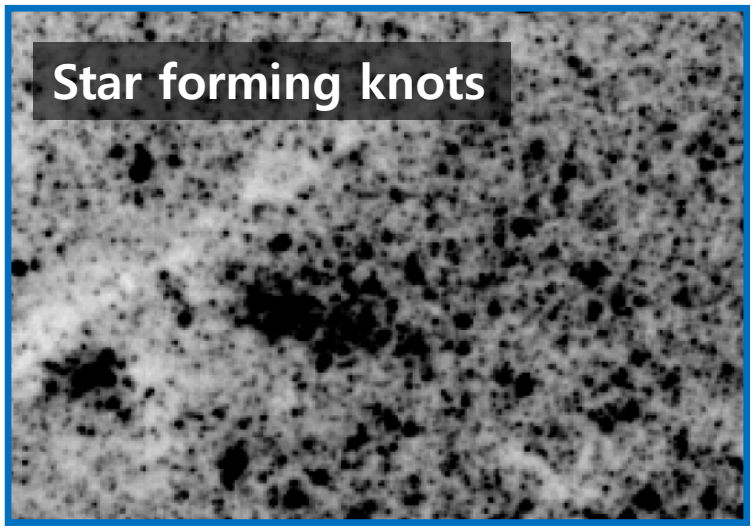
Comparison of the TRGB with Cepheids

TRGB VS Cepheids

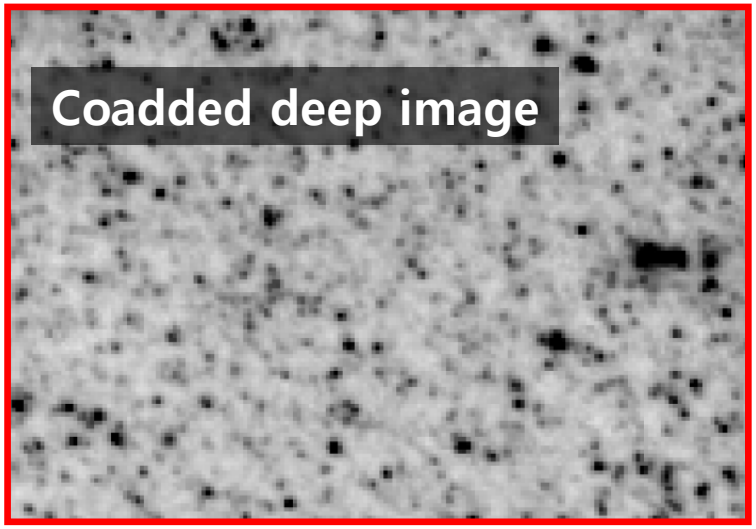
	TRGB	Cepheid
Pros	• no extinction • in any types of galaxies • non variables • low stellar crowding	• bright! ($M_{V,max}$~-6) • up to d ≲ 40 Mpc
Cons	• fainter (M_I~-4.0) • limited to d≲30 Mpc	• metallicity effect (controversial) • Interstellar extinction • only in late-type galaxies • Variable stars

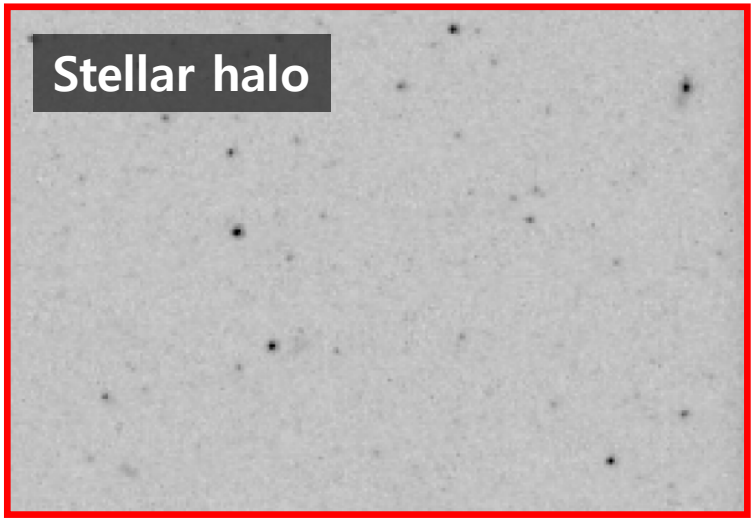
Cepheids



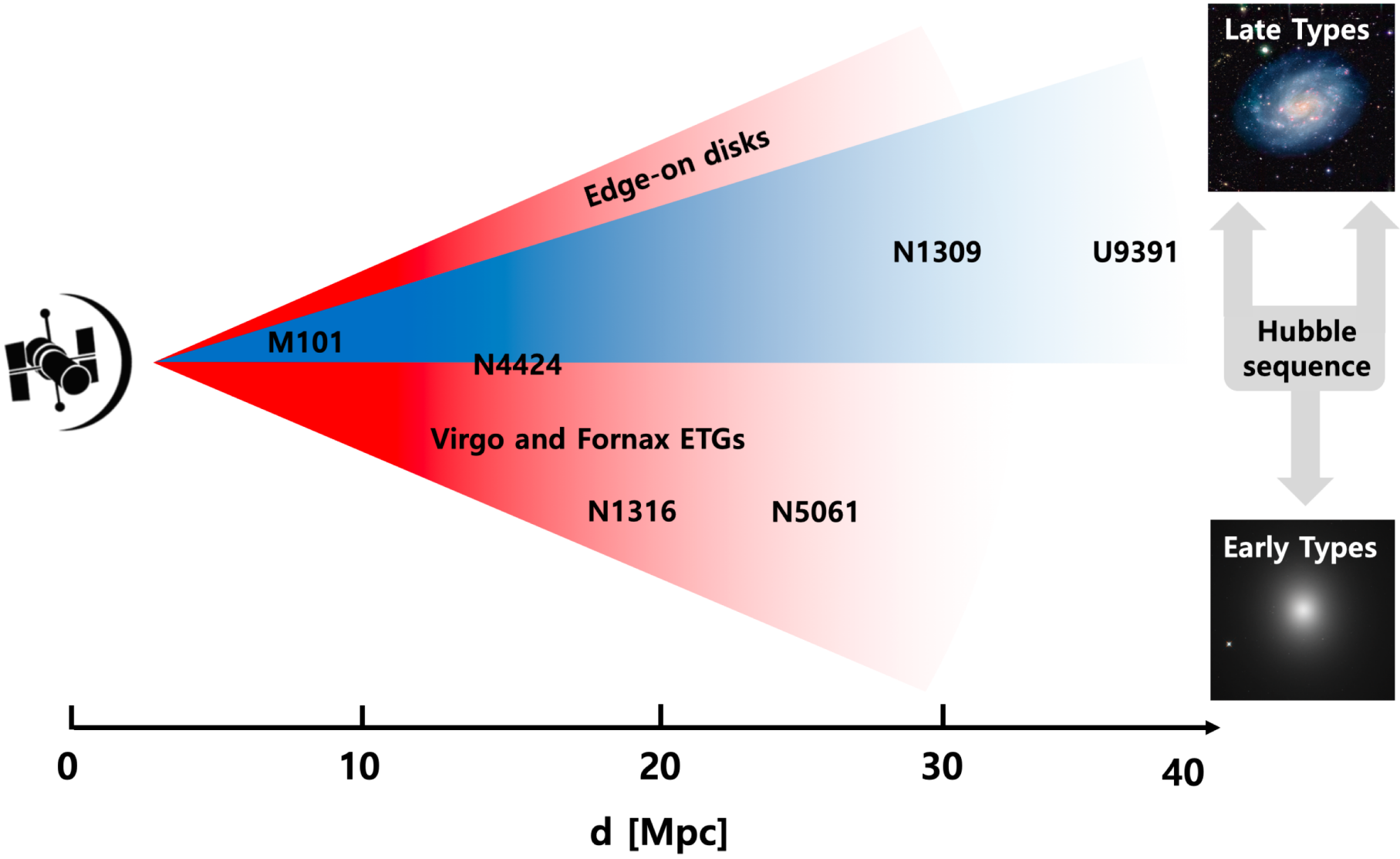


TRGB



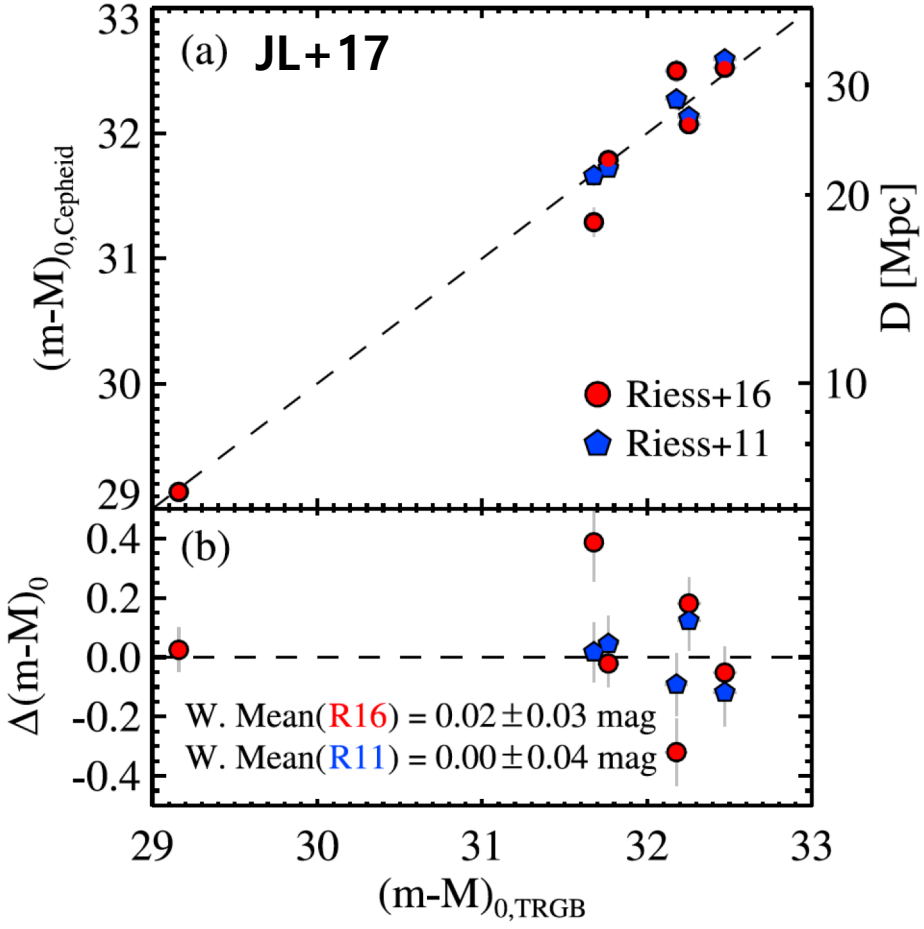


TRGB VS Cepheids



TIPSNU and SH0ES

(Jang&Lee+17) (Riess+16)



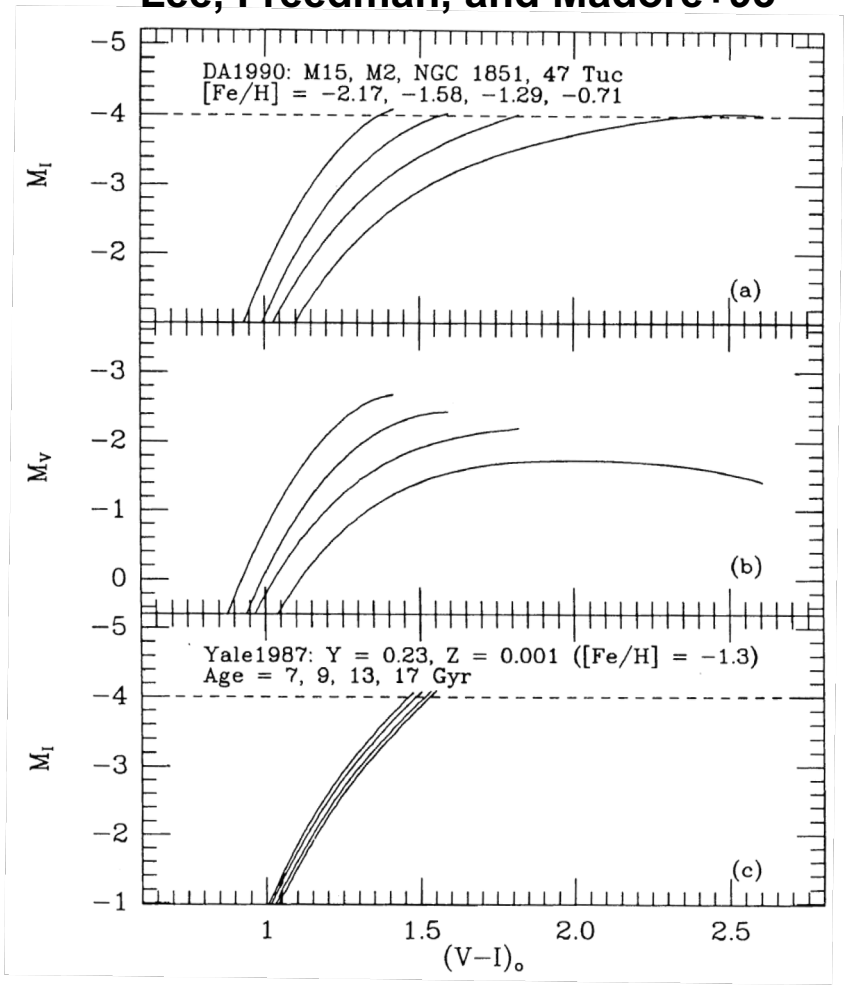
- ✓ JL17 VS R11 (5 SNe)
  : $\Delta(m-M)_0$=0.00±0.04 mag
- ✓ JL17 VS R16 (6 SNe)
  : $\Delta(m-M)_0$=0.02±0.03 mag
- ✓ R11 VS R16 (8 SNe)
  : $\Delta(m-M)_0$=0.02±0.04 mag
- ✓ R11 VS R16 (NGC 4038/39)
  : $\Delta(m-M)_0$=0.45±0.14 mag

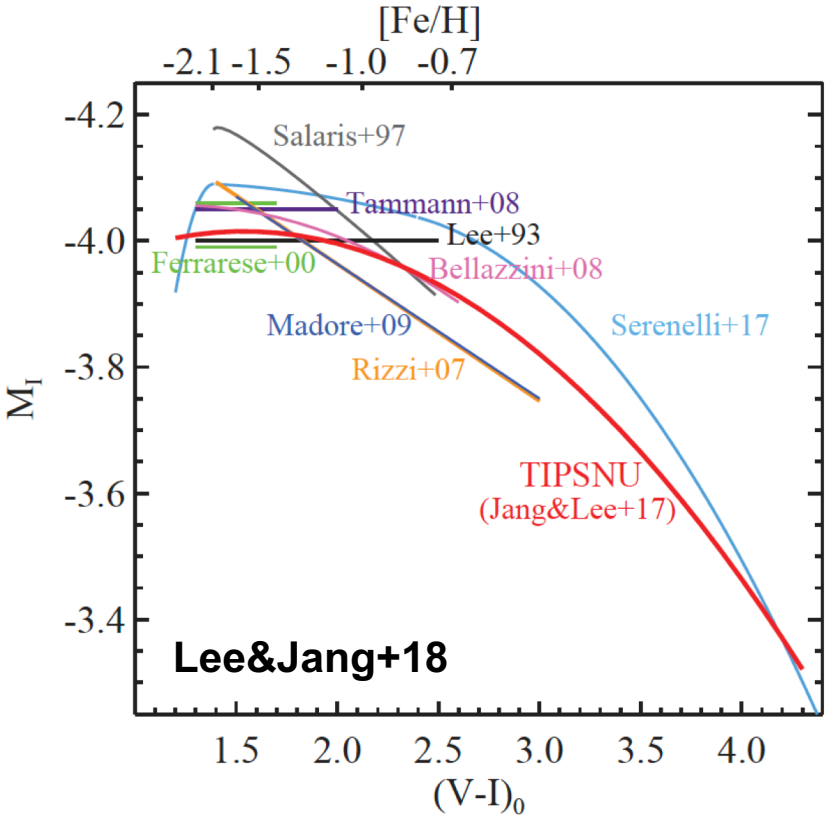
"See Freedman+19 for details"

Metallicity and Age dependence of the TRGB

Color (Metallicity) dependence of the TRGB

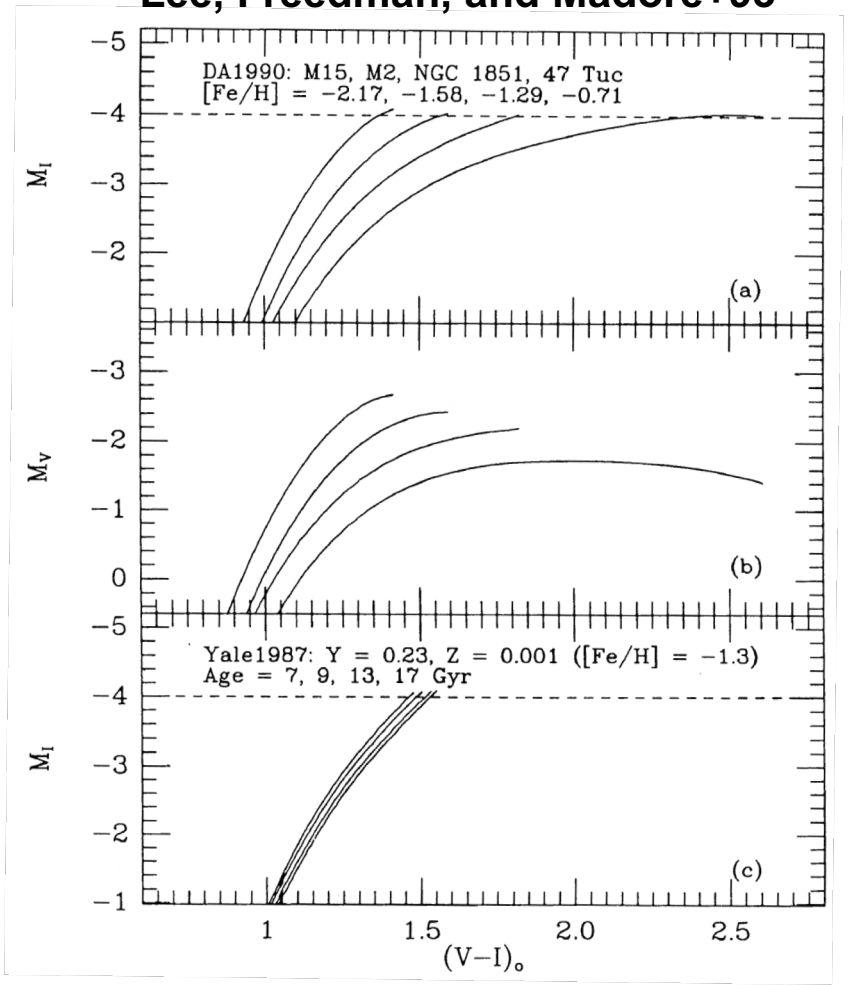
Lee, Freedman, and Madore+93

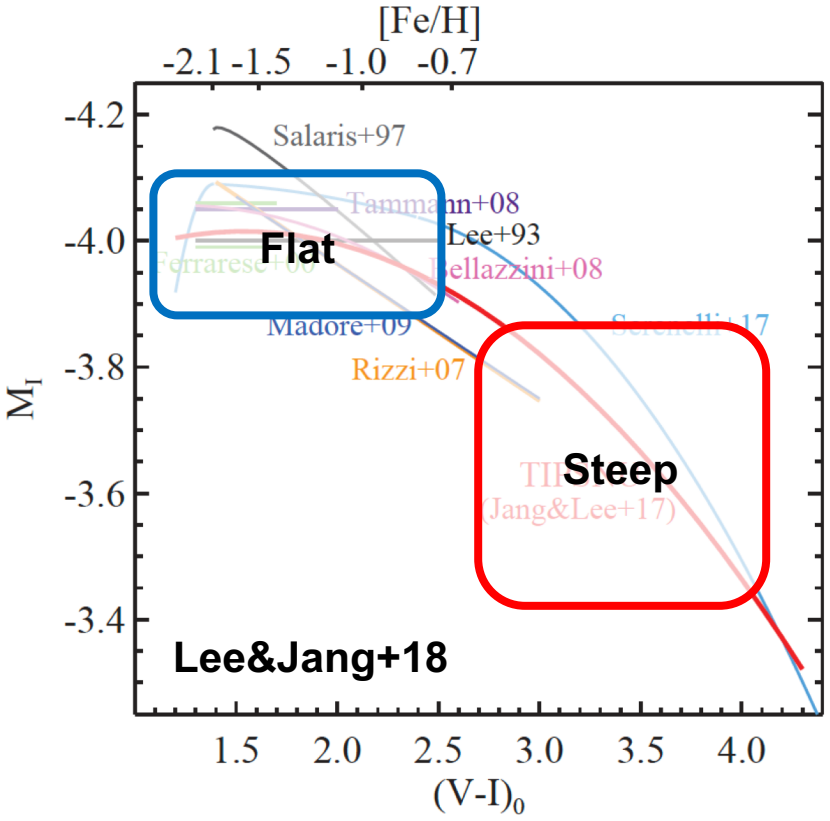




Color (Metallicity) dependence of the TRGB

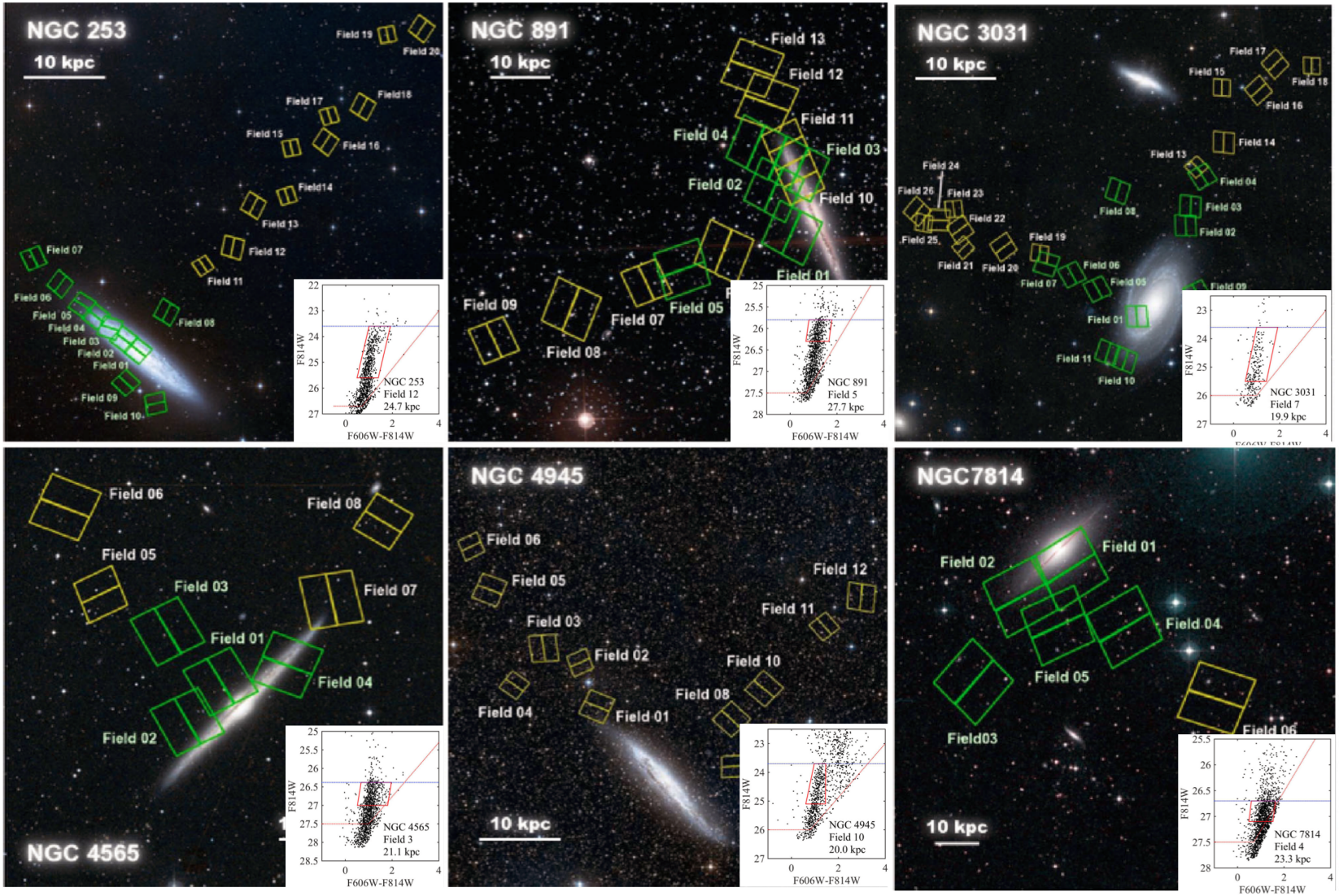
Lee, Freedman, and Madore+93





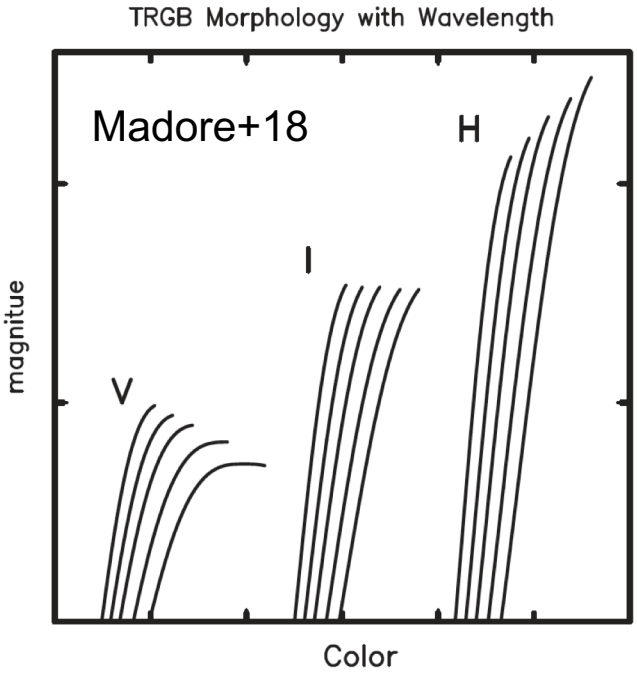
GHOSTS: A Survey of Nearby Disk Galaxies

"halo stars are old and metal poor!"



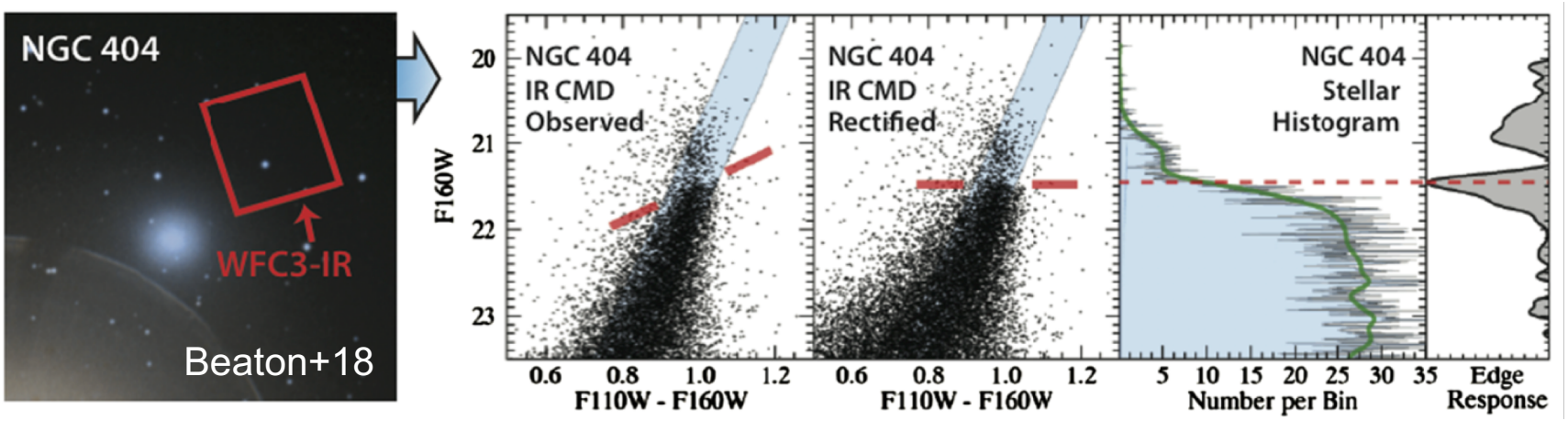
GHOSTS survey, Harmsen+17

TRGB in the near-infrared



Pros
- brighter TRGB luminosity
- lower interstellar extinction

Cons
- color (metallicity) dependent TRGB luminosity
  - color corrected (retified) magnitude required



Age dependence of the TRGB

✓ **Observational tests**

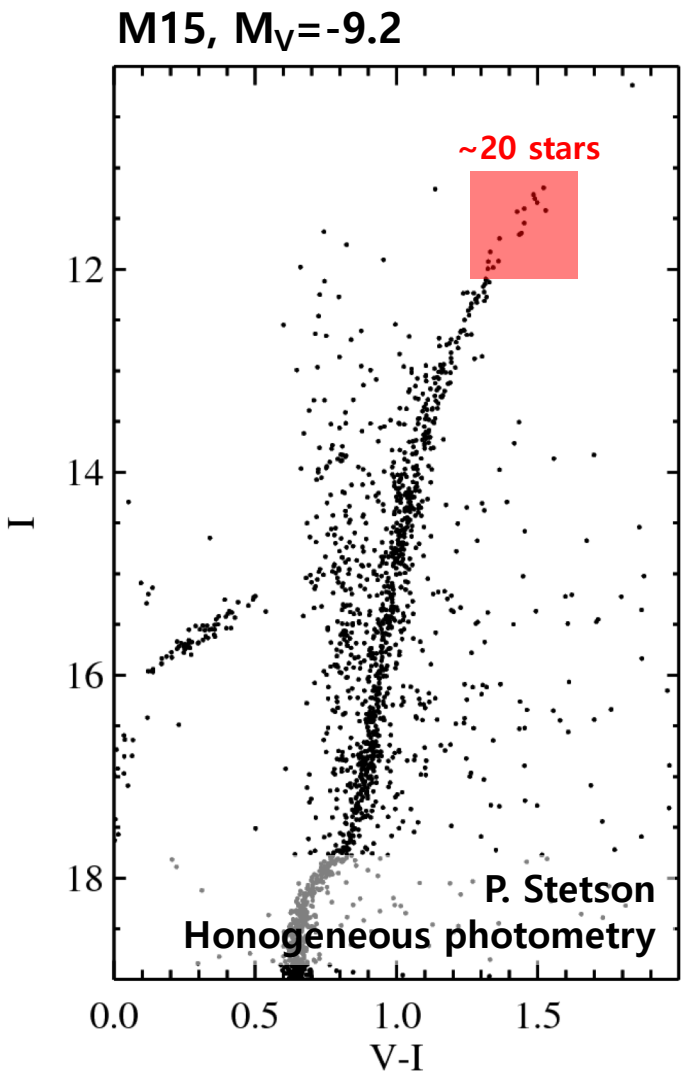
- using old star clusters (1-12 Gyrs).
- Lack of massive star clusters in the MW

✓ **Theoretical predictions**

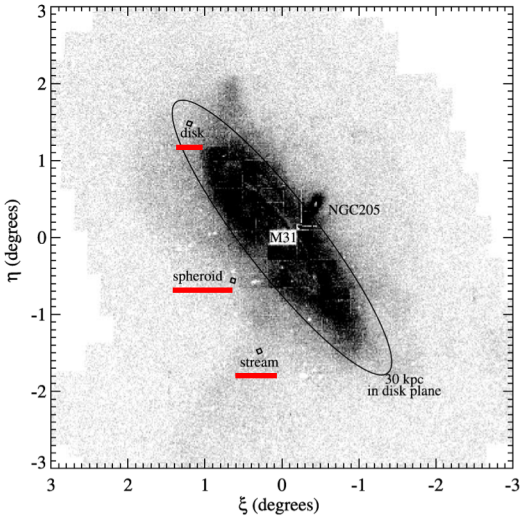
- stellar evolution models

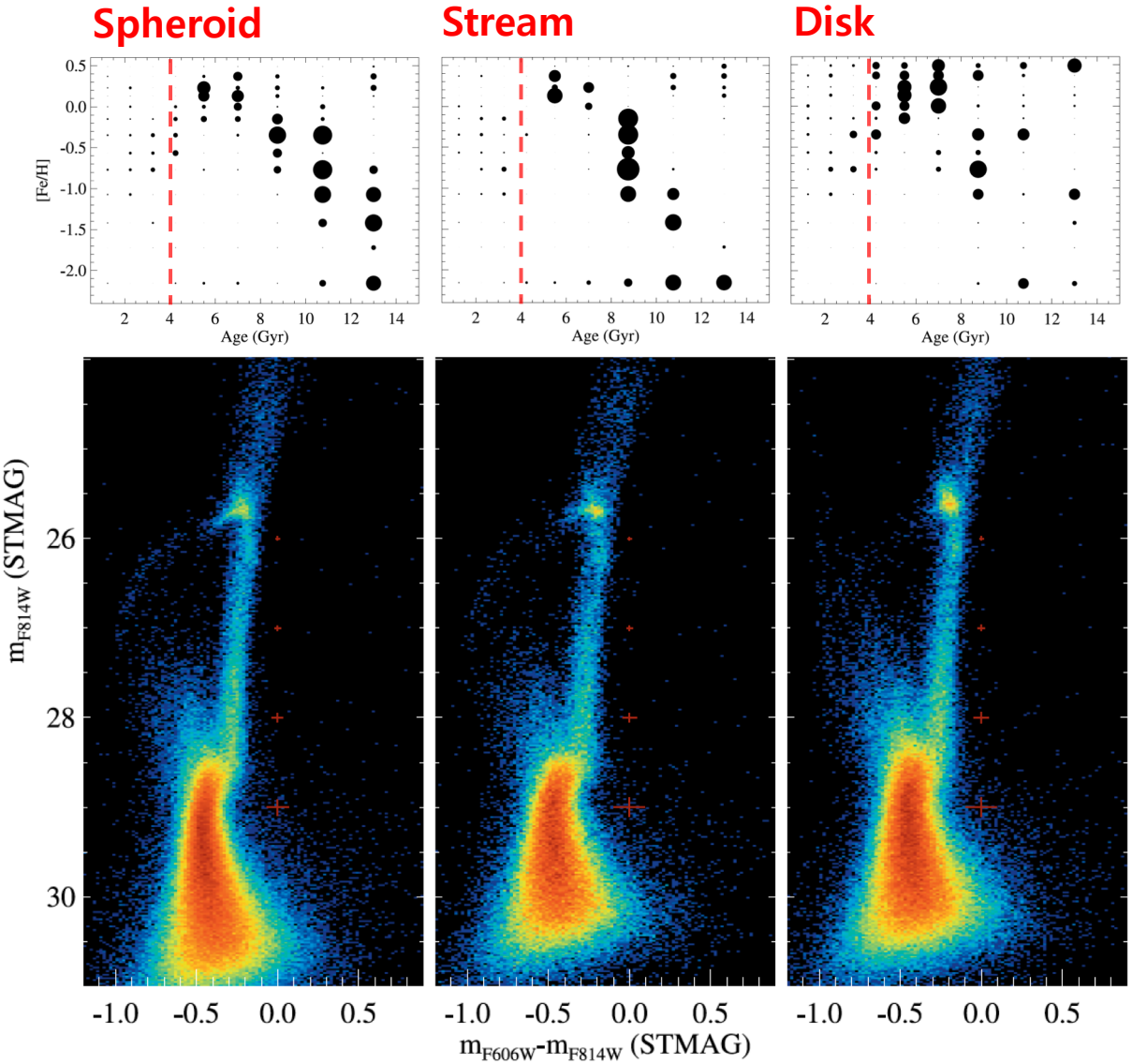
I-band luminosity of the TRGB is stable for old (≳4 Gyr) stellar systems.

Lee+93, Salaris&Casisi+05, Mcquinn+19



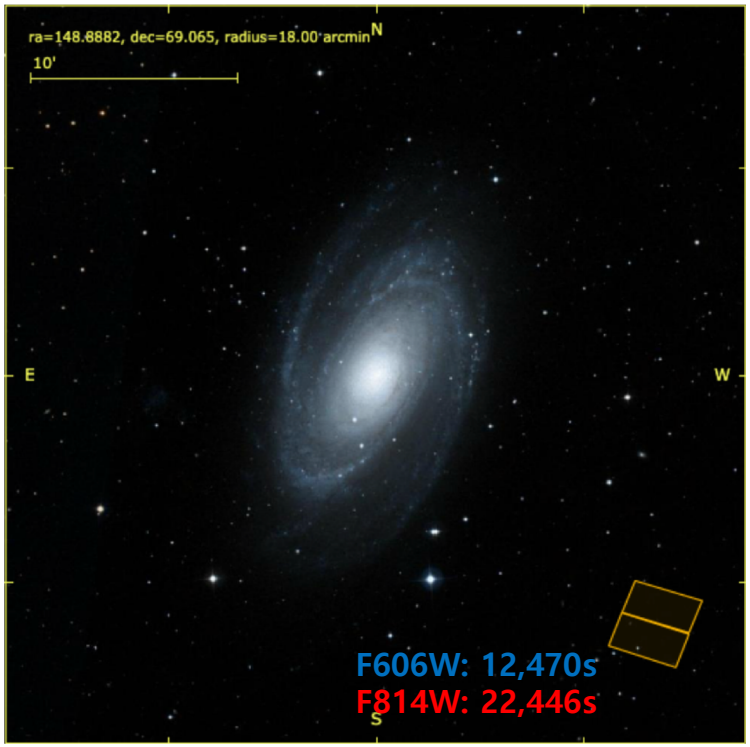
Ages of galaxy outskirts: M31 (Brown+06)

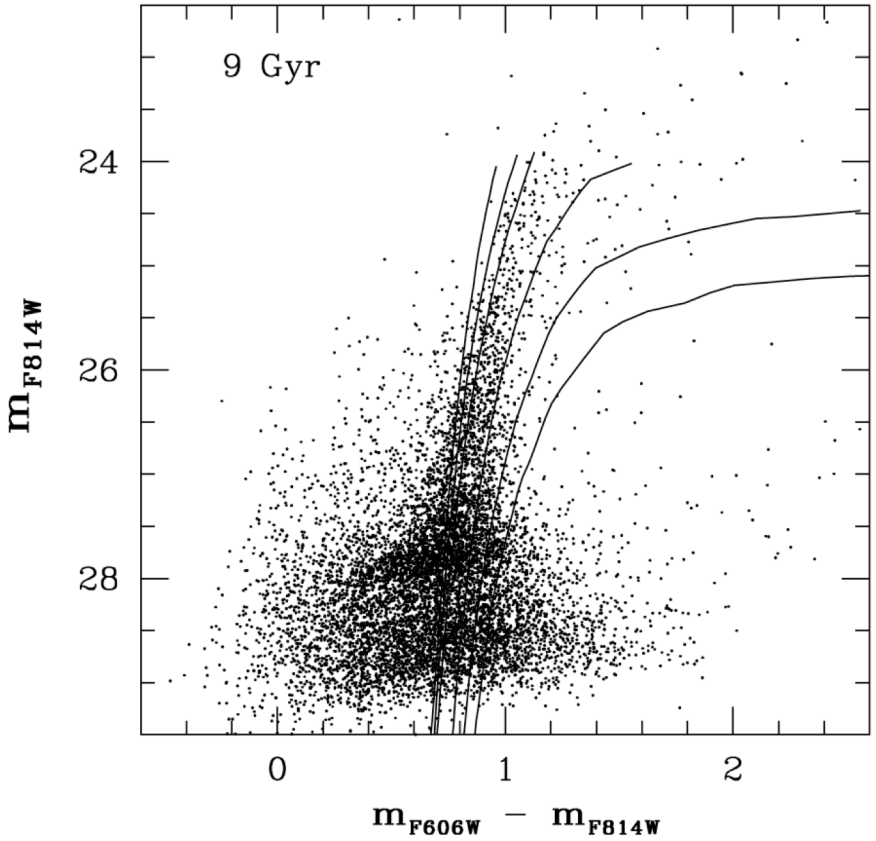




„Each field exhibits an extended SFH with many stars younger than 10 Gyr, but few younger than 4 Gyr."
Brown+06

Ages of galaxy outskirts: M81 (Durrell+10)

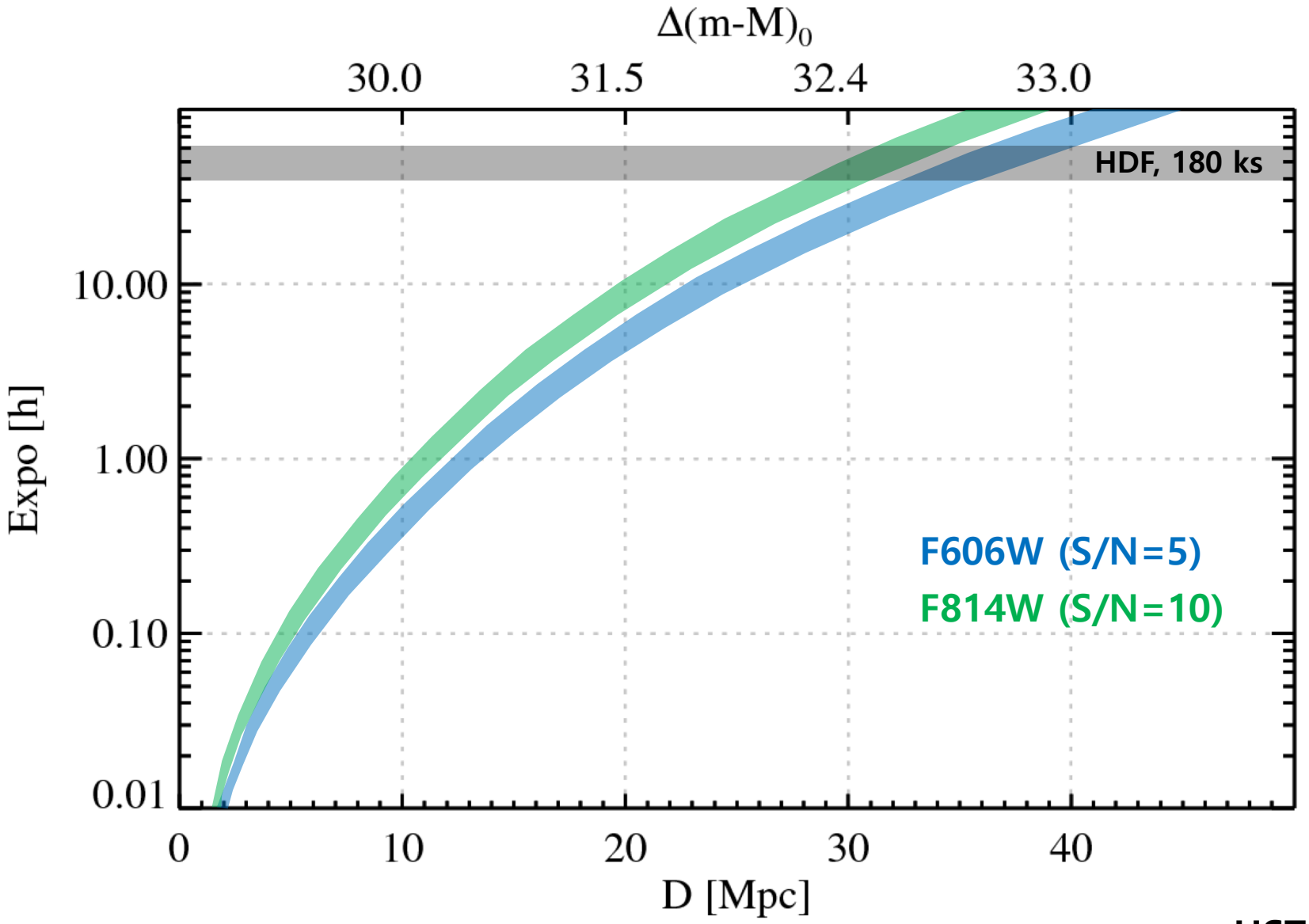




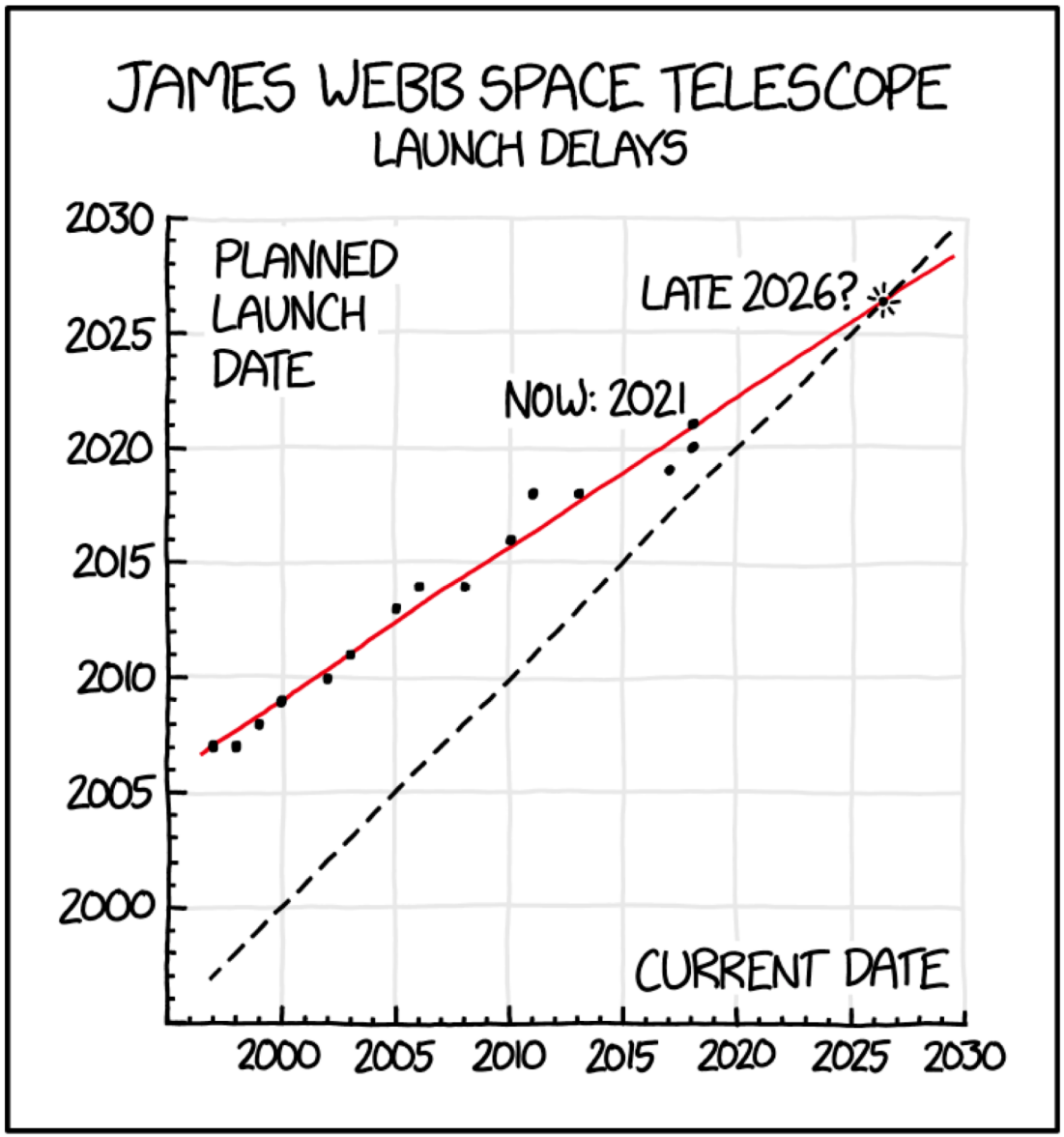
„We derive a mean metallicity of [M/H]=-1.15±0.11 and age of 9±2 Gyr for the dominant population in our field"

Detecting the TRGB with HST and JWST

Required exposure times to detect the TRGB

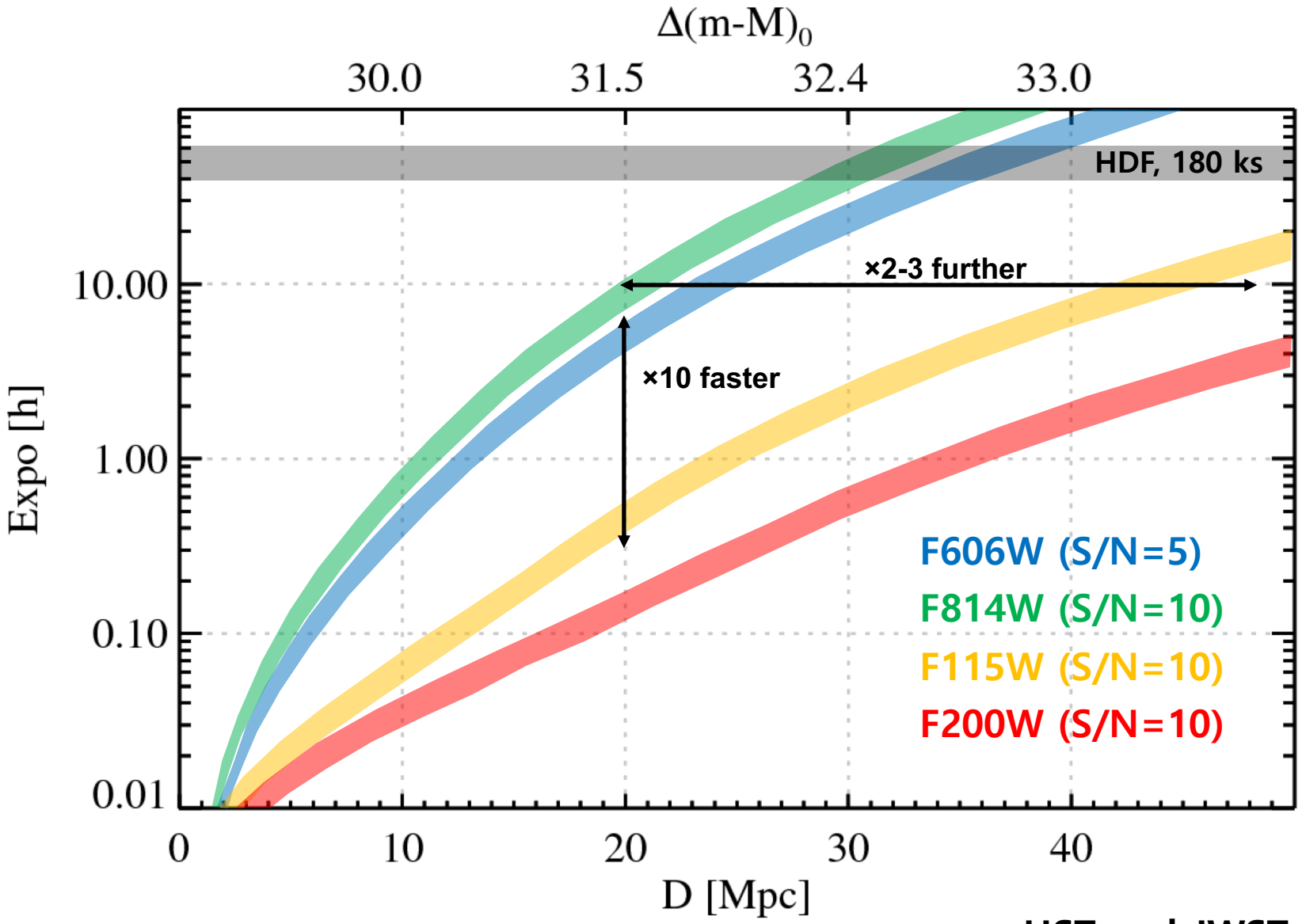


HST ETC

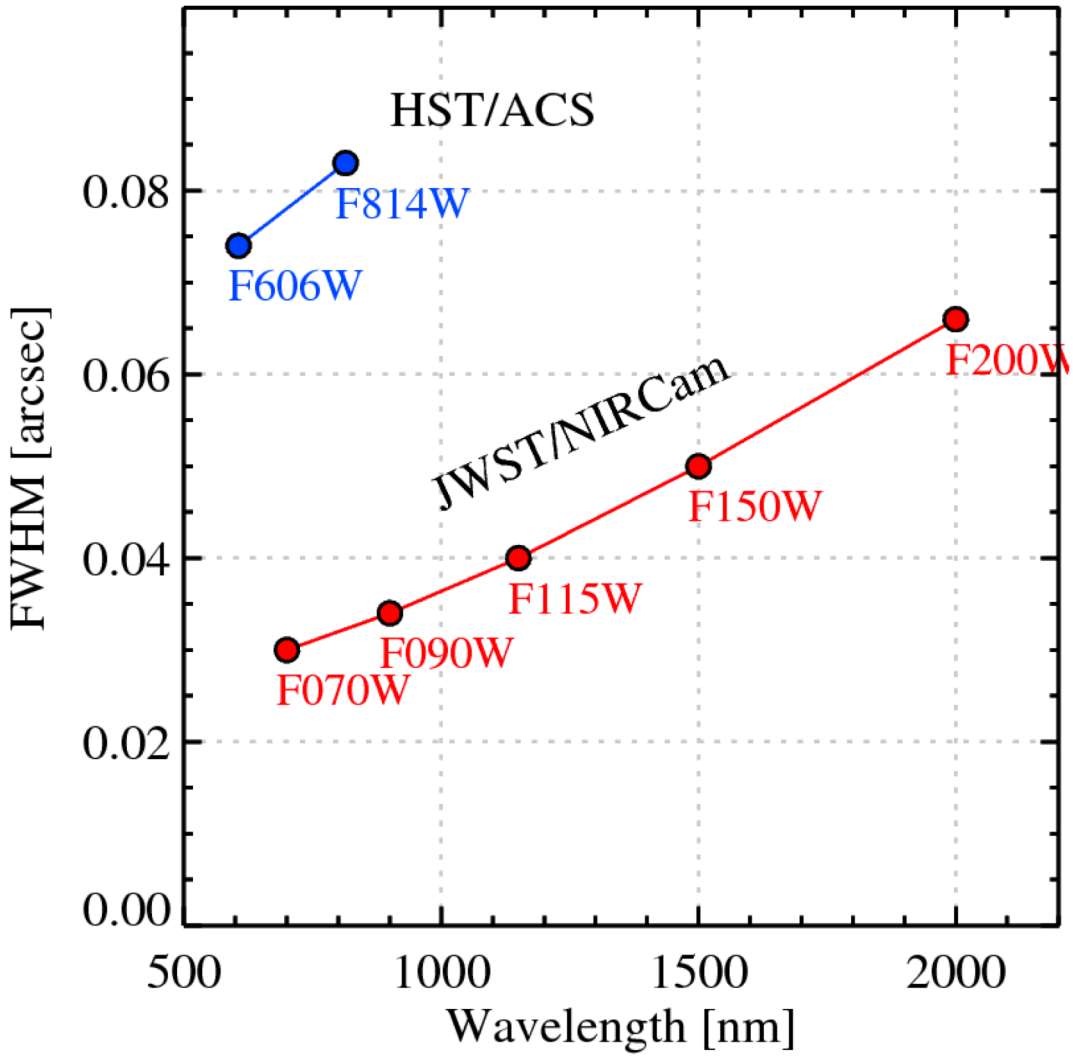


LOOK, AT LEAST THE SLOPE IS LESS THAN ONE.

Required exposure times to detect the TRGB

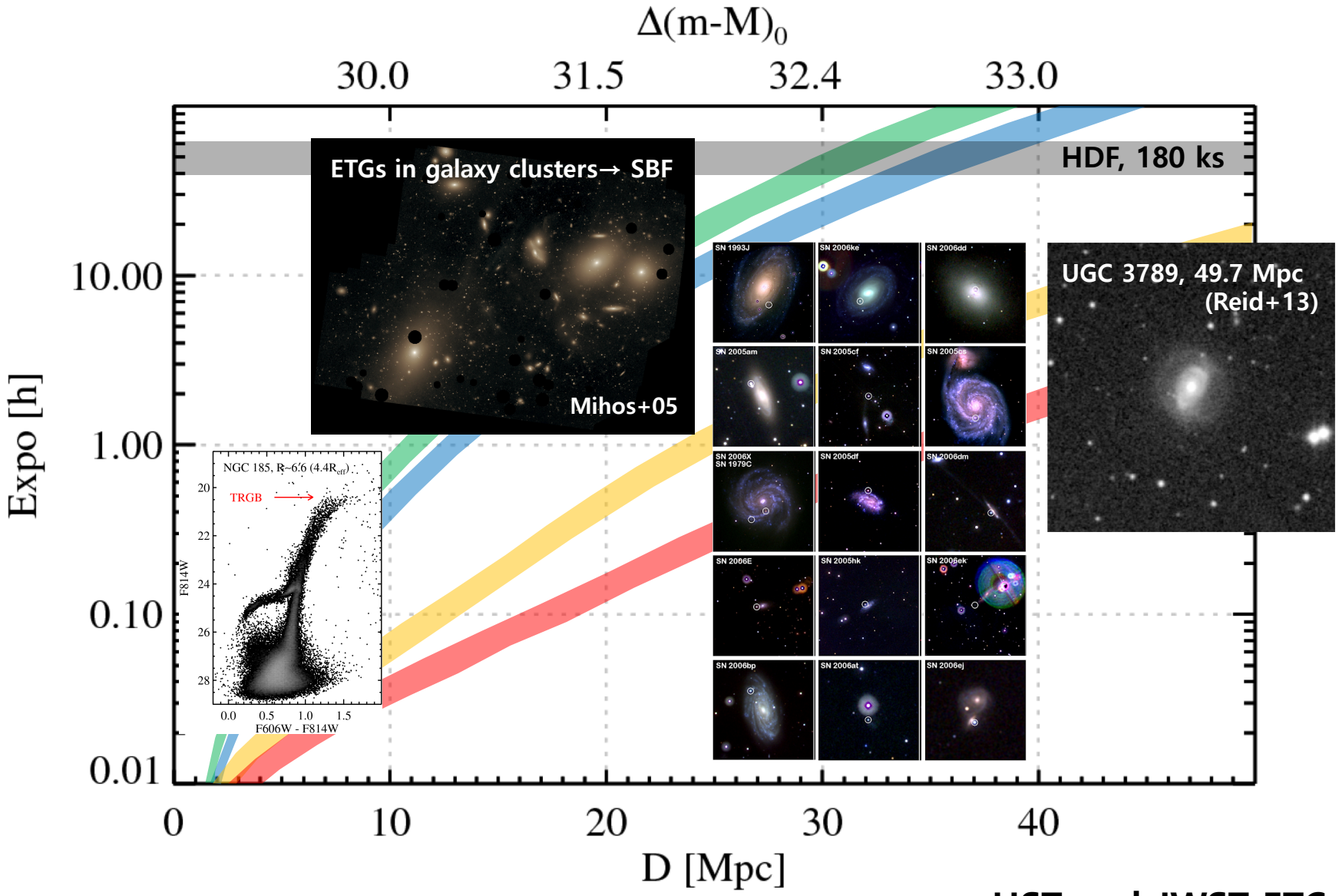


HST and JWST ETCs

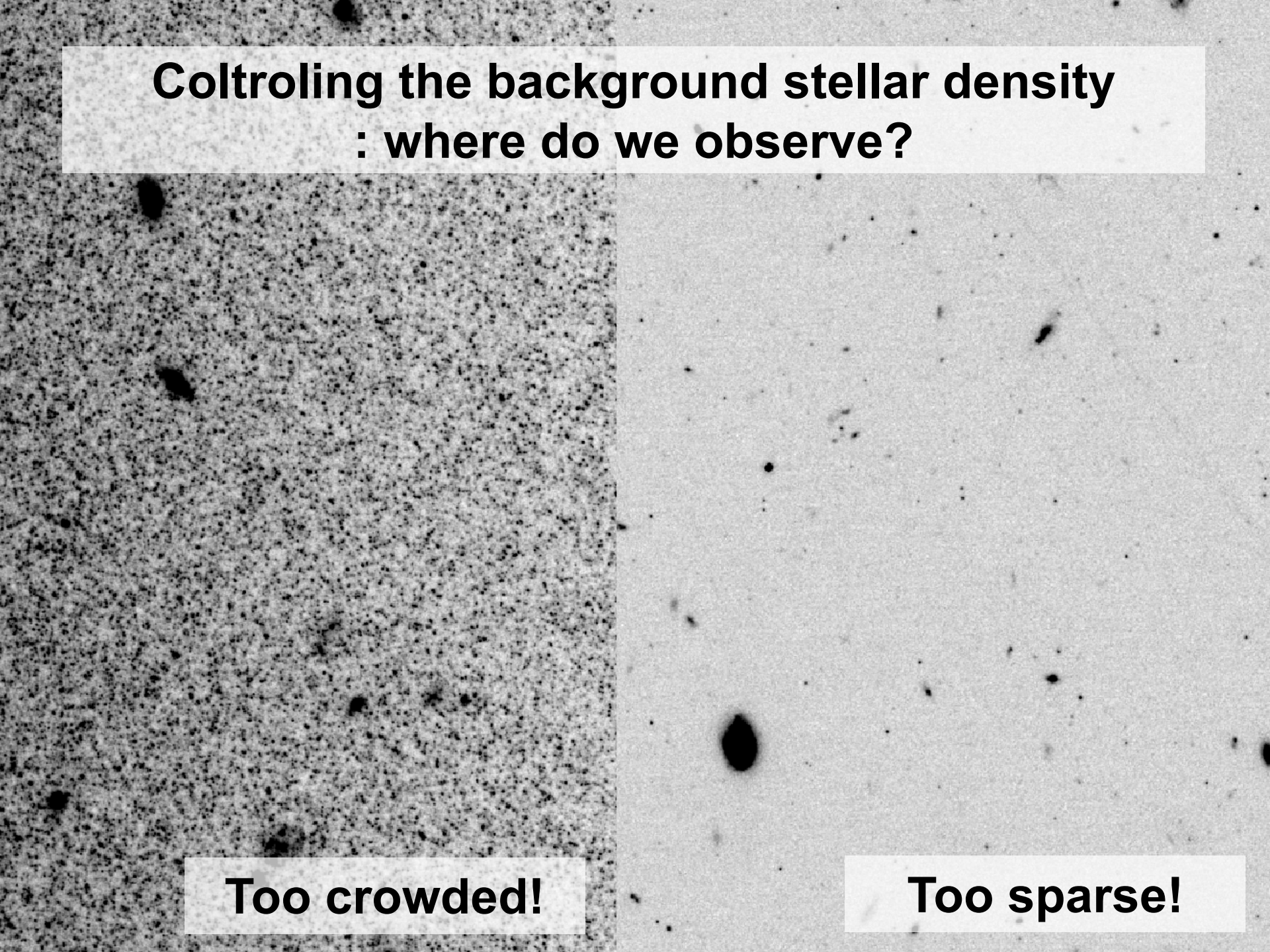


JWST can go ×2 further and will have ×2 higher angular resolution.

Required exposure times to detect the TRGB

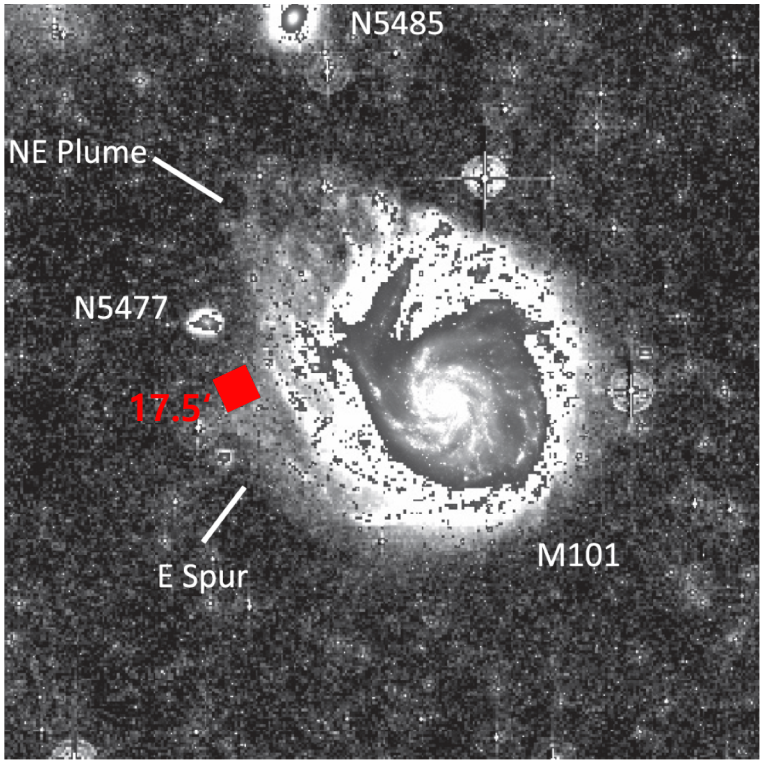


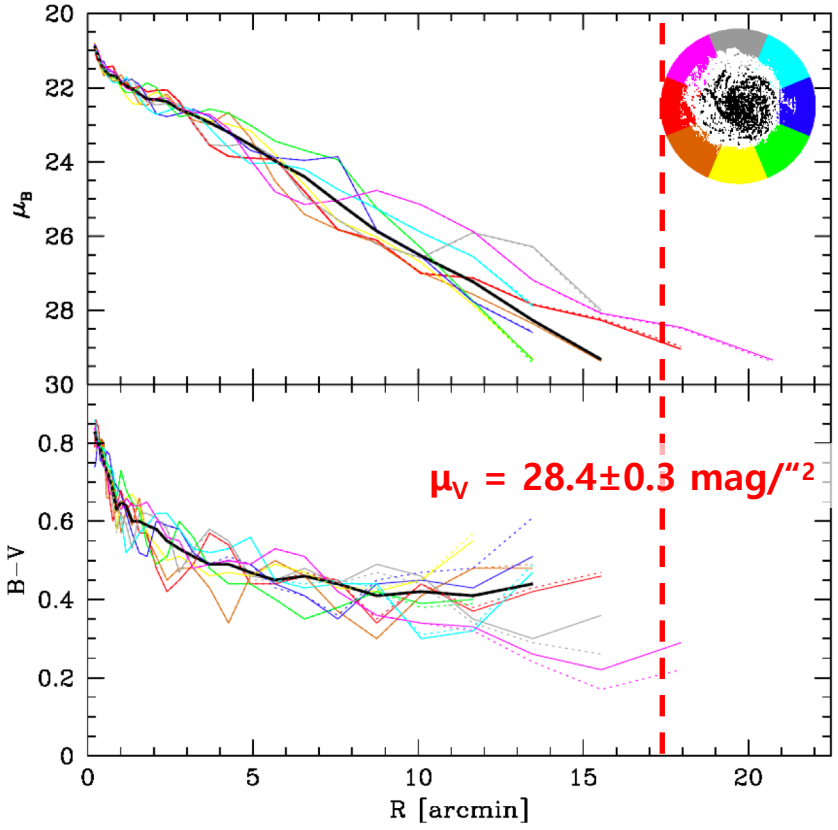
HST and JWST ETCs


Coltroling the background stellar density
: where do we observe?
Too crowded!
Too sparse!

Tests of stellar densities

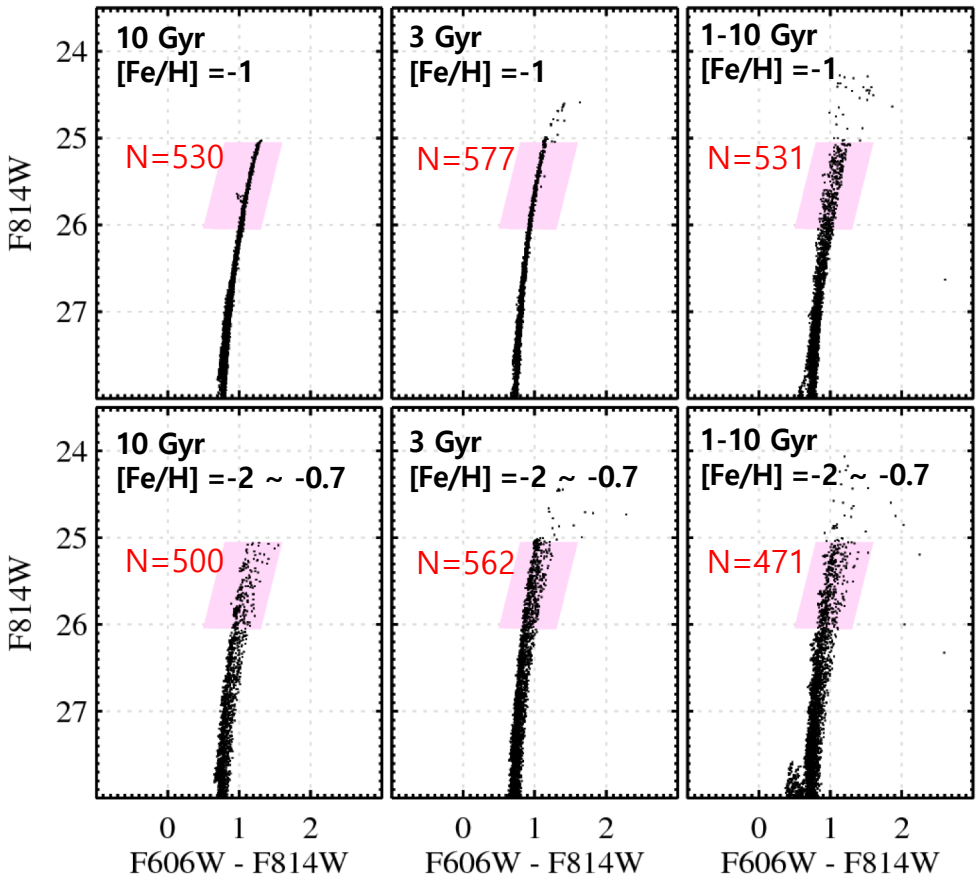
Mihos+13



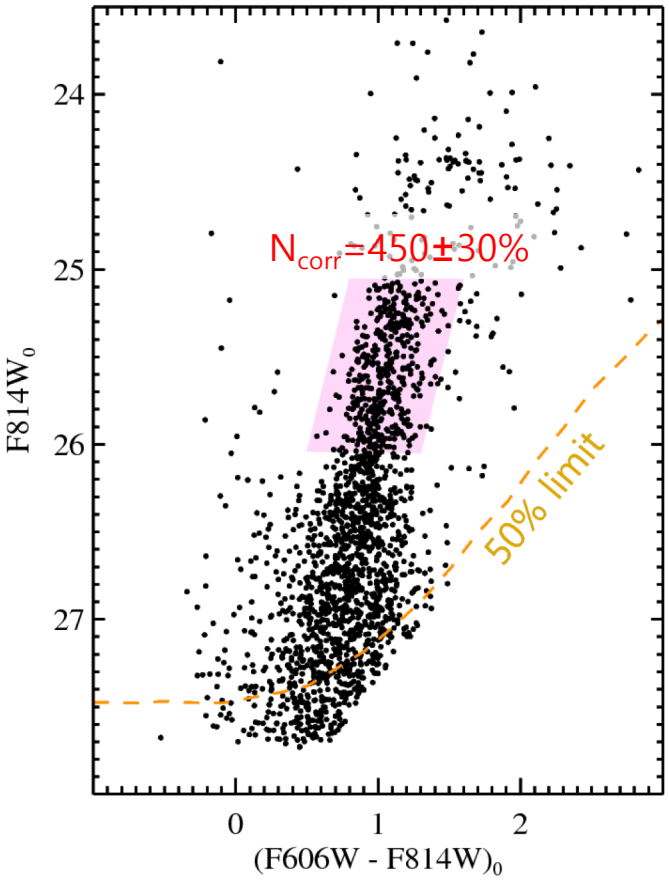


Tests of stellar densities

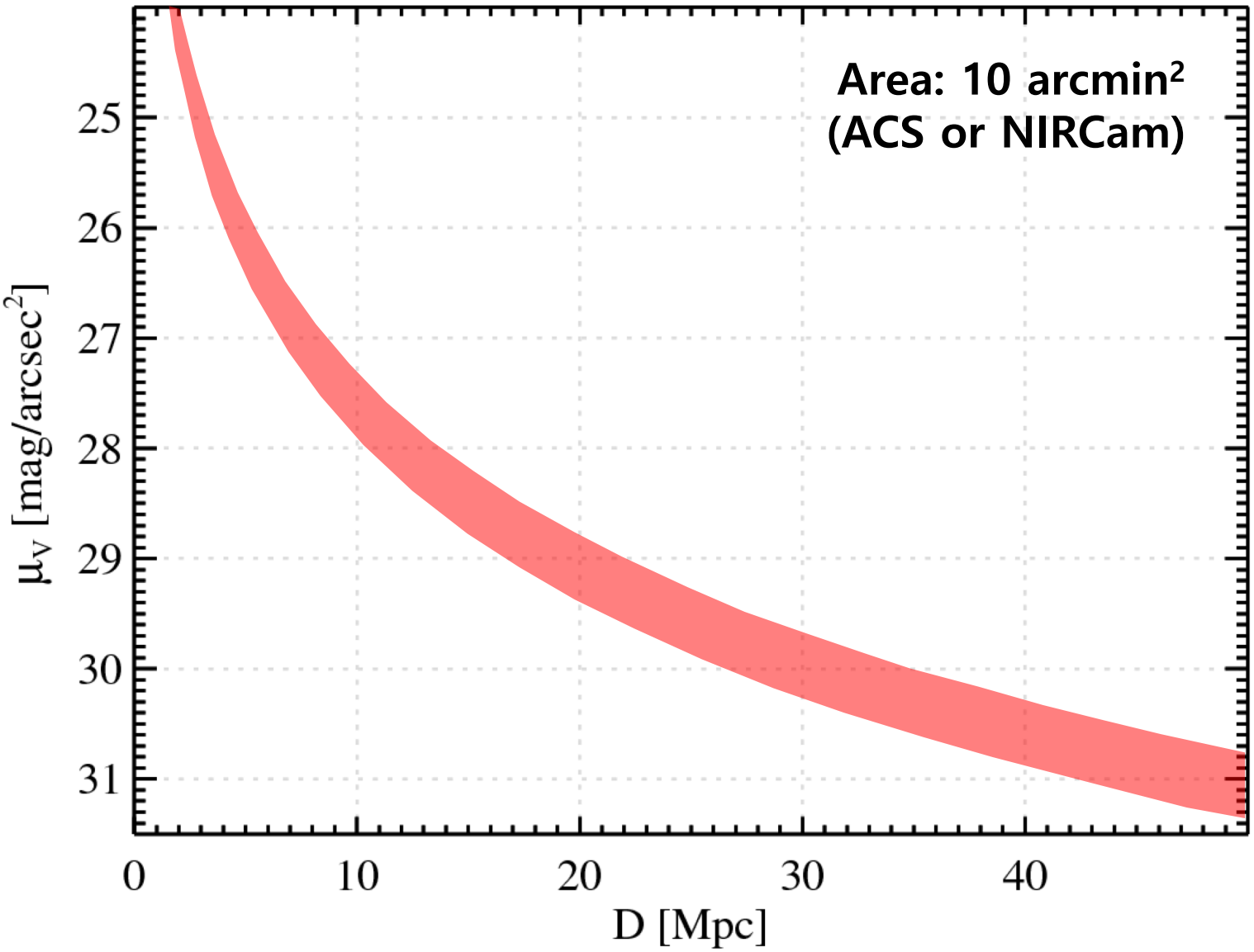
Simulated CMDs, S/N=100



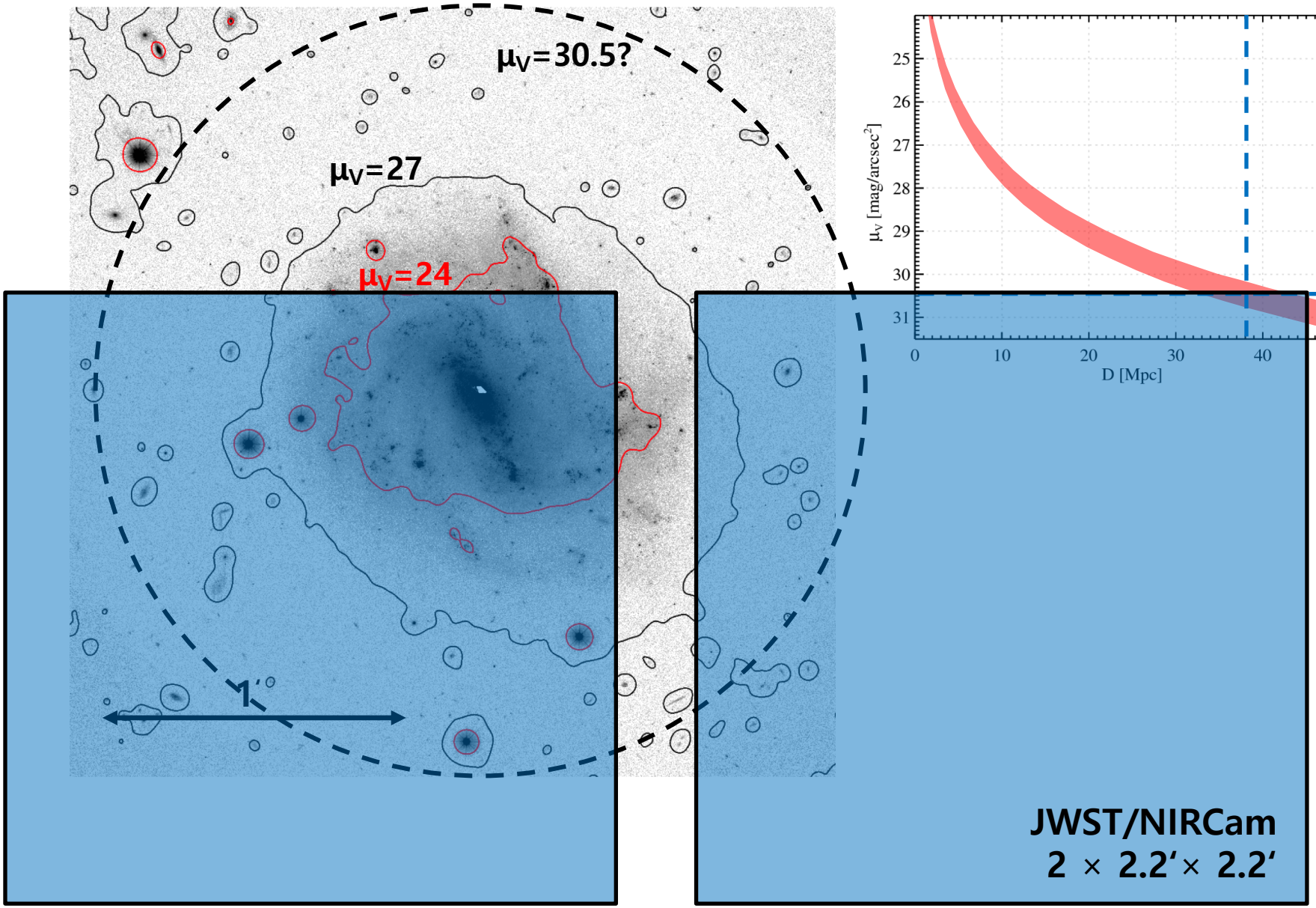
Observed CMD



3000 RGB stars in 1 mag bin below the TRGB



UGC 9391 (SN 2003du), D = 38.4 Mpc (Riess+16)



Summary

1. Comparison of the TRGB with Cepheids
   - Two independent distance estimates are in good agreement within uncertainties, but see Freeeman+19.

2. Metallicity and Age dependence of the TRGB
   - uncertainties can be minized down to ~1% in distance.

3. Detecting the TRGB with HST and JWST
   - HST can detect the TRGB out to ~30 Mpc.
   - JWST can go out to ~50 Mpc, sampling more SNe.

The future of the TRGB method is bright!