

The TRGB as a Cosmological Tool : High 1

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Back to the future of me in 1990

- ▶ **Two big cosmological questions**
I had with **high dream (a seed of High 1?)!**

**How old are galaxies?
(Are there any young galaxies?)**

NGC 1309 (HST)



Leo I, the youngest galaxy in 1993?

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LEO I: THE YOUNGEST MILKY WAY DWARF SPHEROIDAL GALAXY?

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MIGUEL ROTH

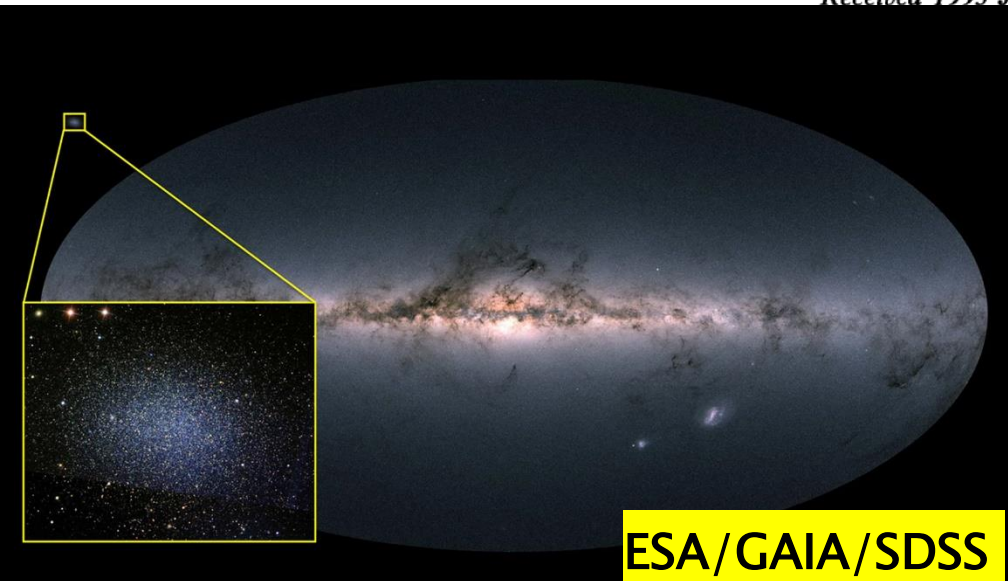
Las Campanas Observatory, The Carnegie Institution of Washington, La Serena, Chile

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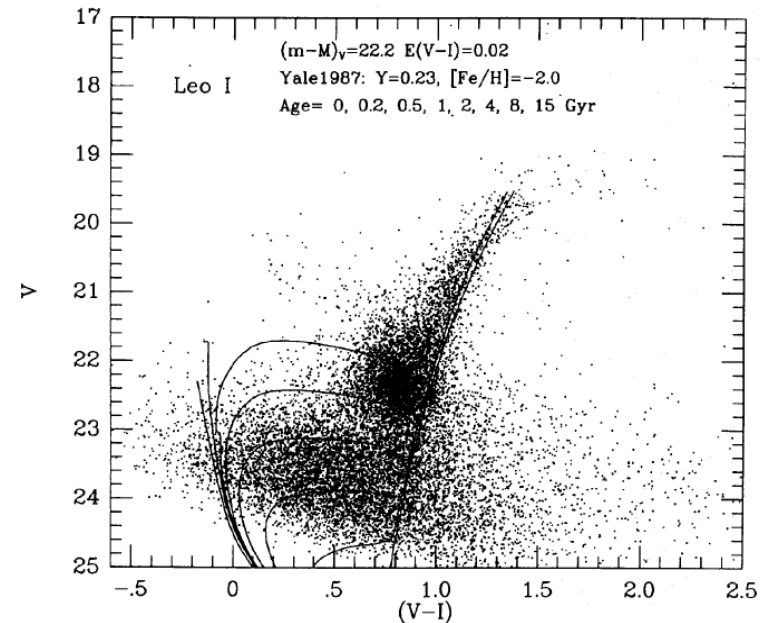
MARIA-TERESA RUIZ

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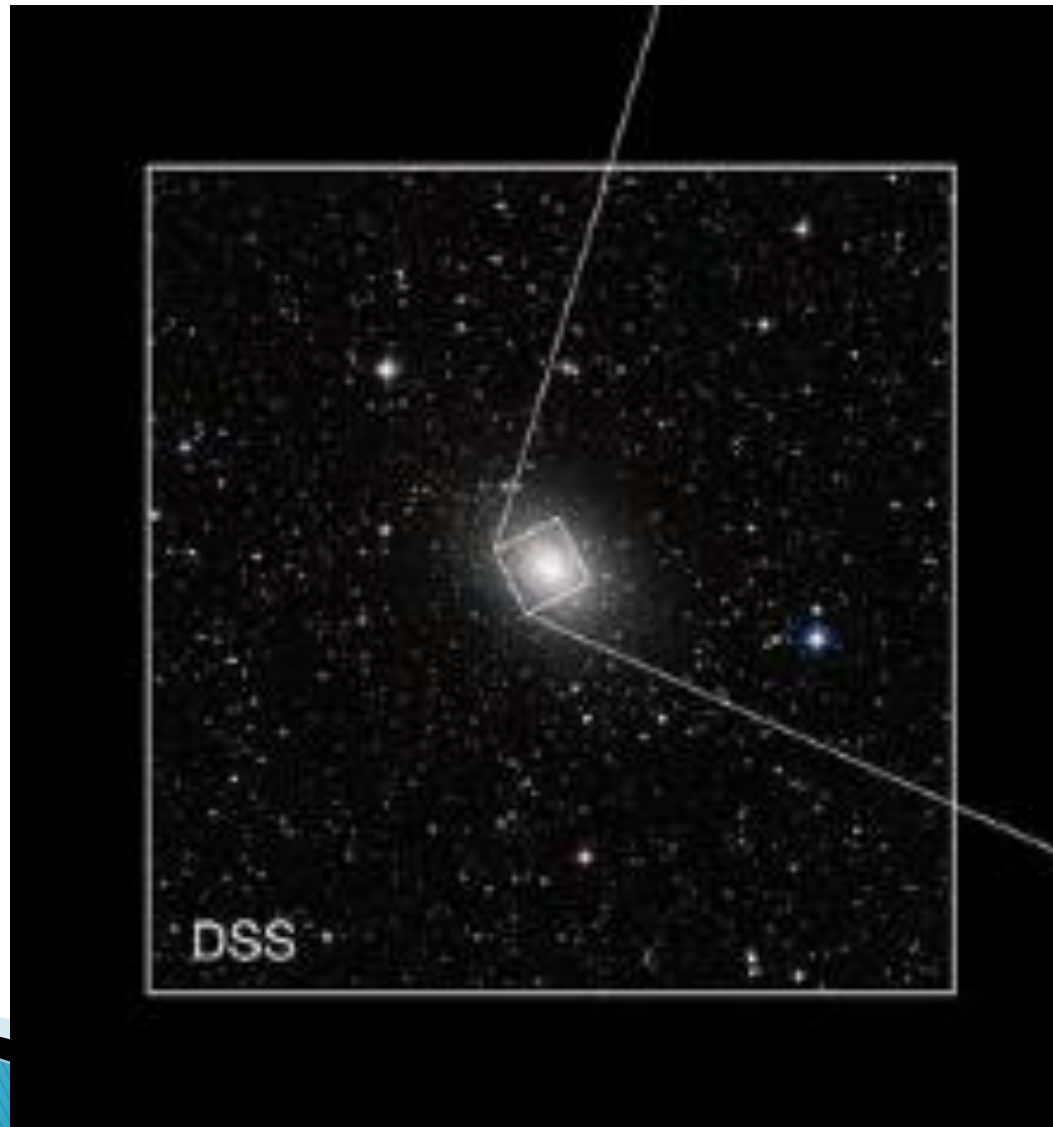
Received 1993 June 11



ESA/GAIA/SDSS



How can I measure the distance to NGC 185, d_E ?



NGC 185, **dE**, hosts both old & young populations (1993 Sep)!

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STELLAR POPULATIONS IN THE DWARF ELLIPTICAL GALAXY NGC 185

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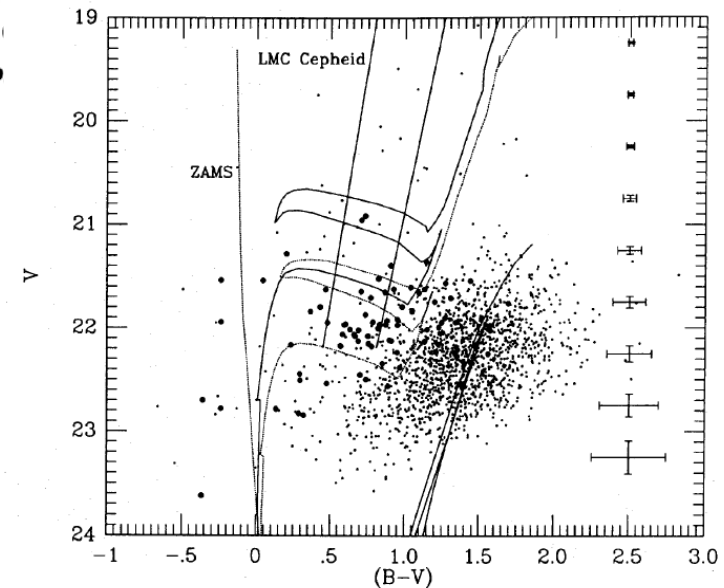
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Electronic mail: I: barry@ipac.caltech.

Received 1993 March 12; revised 1993 Ap

**CFHT BVI with short exposure but excellent seeing,
resolving both young and old stars!**



NGC 3109, Sm IV (Magellanic spiral), the first galaxy I got with the TRGB (May, 1993)!

THE ASTROPHYSICAL JOURNAL, 408:409–415, 1993 May 10
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THE DISTANCE TO NEARBY GALAXY NGC 3109 BASED ON THE TIP OF THE RED GIANT BRANCH

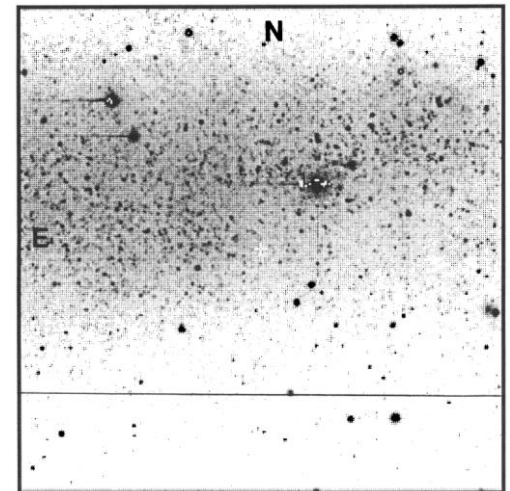
MYUNG GYOON LEE

The observatories of the Carnegie Institution of Washington, 813 Santa Barbara Street, Pasadena, CA 91101

Received 1992 August 17; accepted 1992 November 2

Dec 30/31, 1991

Las Campanas Observatory 2.5m, I-band



Return of the TRGB (an obscure candle) as a Cosmological Tool in 1993 (Nov)!

THE ASTROPHYSICAL JOURNAL, 417:553–559, 1993 November 10

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THE TIP OF THE RED GIANT BRANCH AS A DISTANCE INDICATOR FOR RESOLVED GALAXIES

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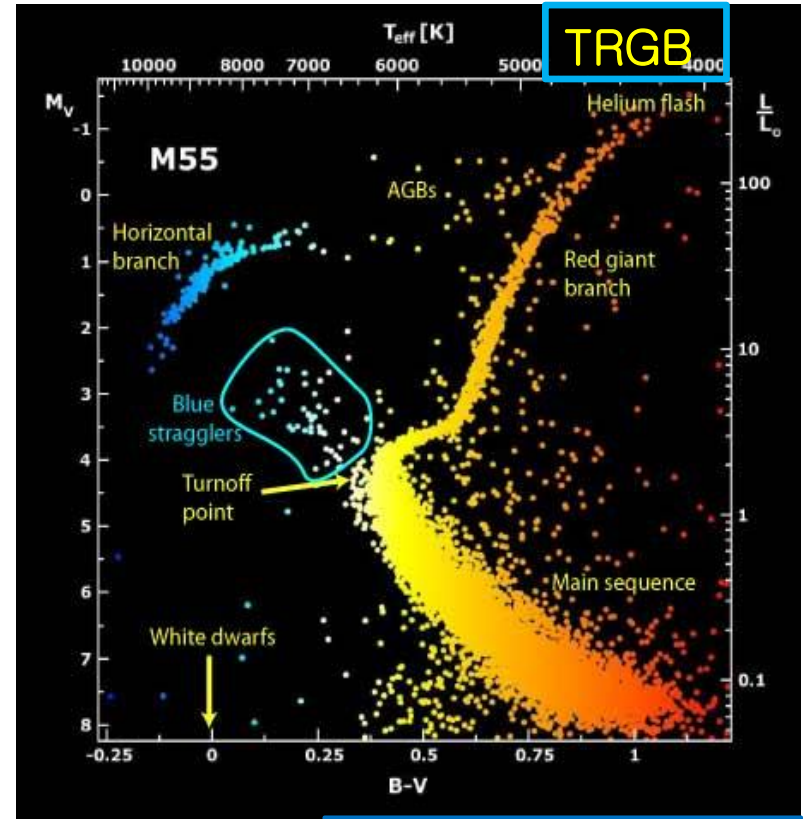
TRGB is an excellent standard candle!

- ▶ The **T**ip of the **R**ed **G**iant **B**ranch (RGB) in CMDs/HRDs
- ▶ Low mass stars at He flash in stellar evolution theory
- ▶ **TRGB magnitude at I-band** is almost constant at $M_I \sim -4.0 \pm 0.1$
(Lee, Freedman & Madore 1993).



Globular cluster M55

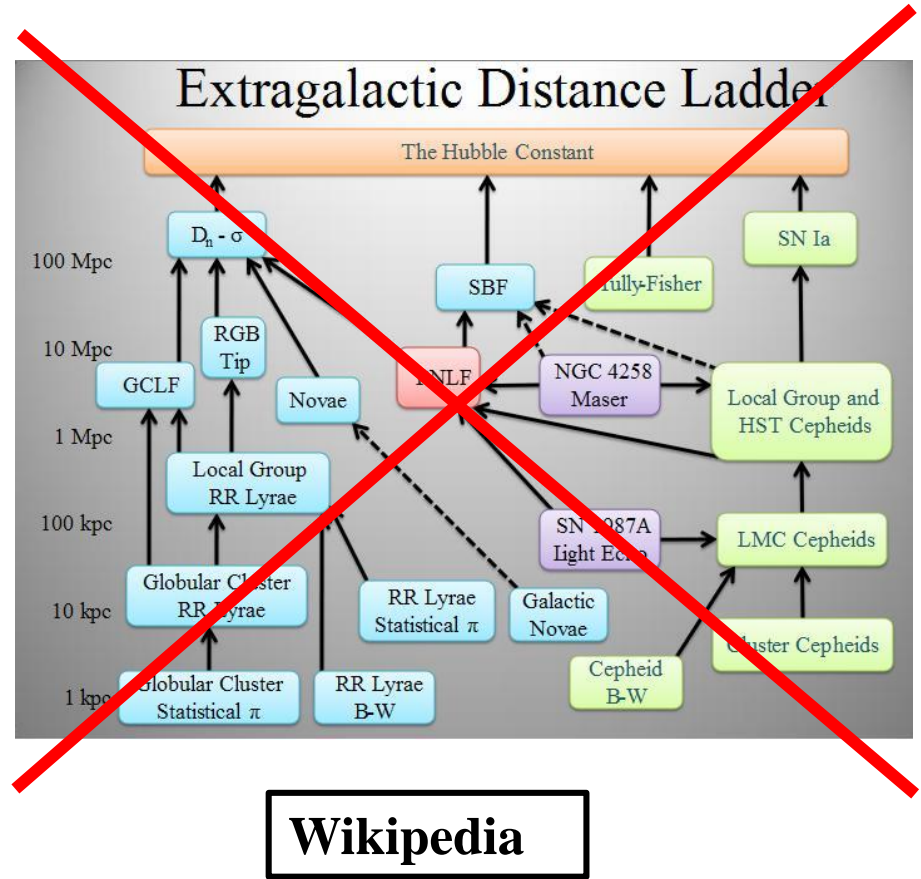
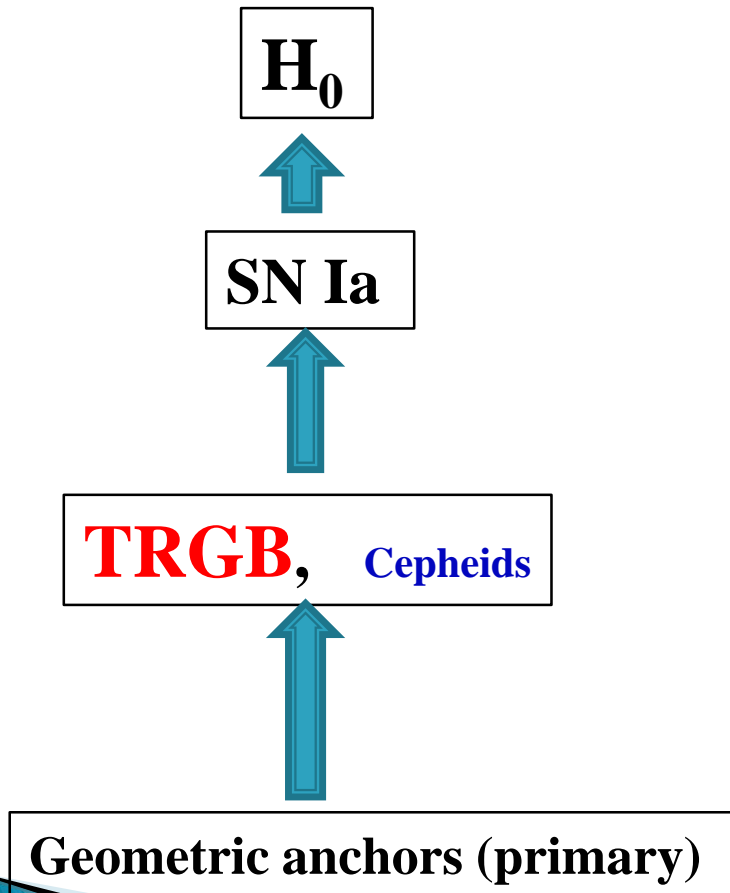
Wikipedia



Mochejska & Kaluzny

Modern ladder for SN cosmology

- Key: calibration of SN Ia & TRGB/Cepheids



Geometric anchors: parallax, DEB, H₂O MASERS

Answer 1:

All local galaxies are very old ($t < 13.8$ Gyr)!

Answer 2:

We can measure distances to all resolved galaxies with TRGB!



TRGB Cosmology

For local universe

- 3D Cosmography
- Cosmic Flow
- Dark Matter Distribution

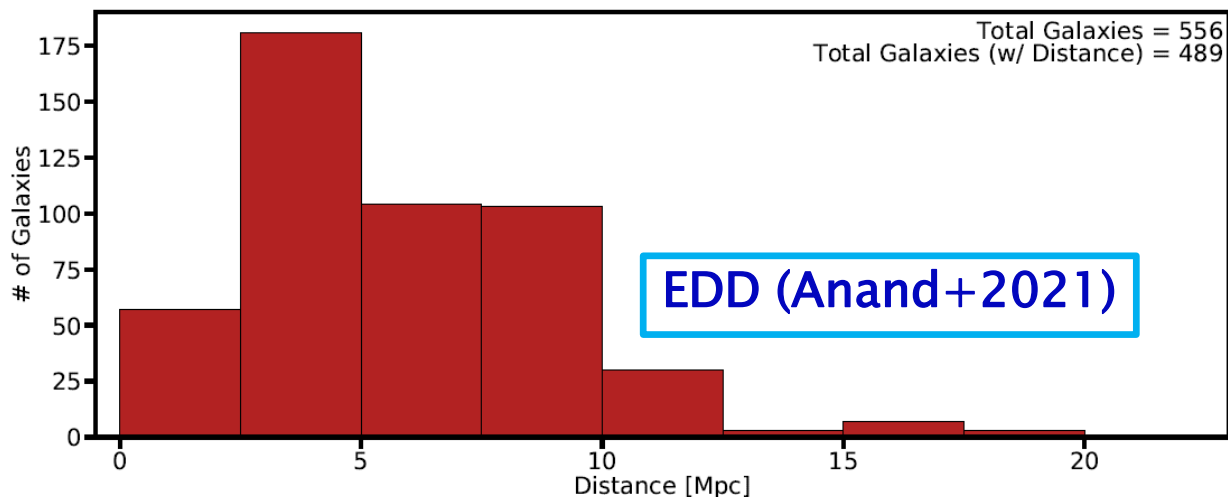
For farther universe

- Calibration of SBF, TF, SN Ia, etc

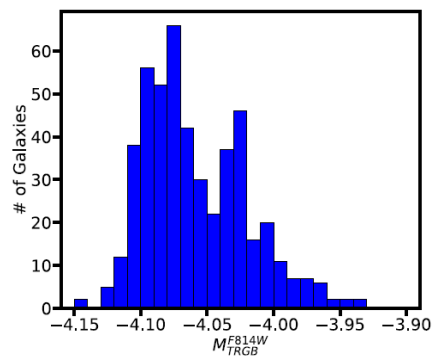
A Golden Era of the TRGB with the HST (1993–Now)

N(galaxies with TRGB distances) ~ 500 (2021)

- Anand+2021: **Extragalactic Distance Database (EDD):**
HST CMD/TRGB Catalog (Anand+2021) ($d < 20$ Mpc)
- Jang & Lee 2017: the most distant galaxies ($d < 31$ Mpc)**



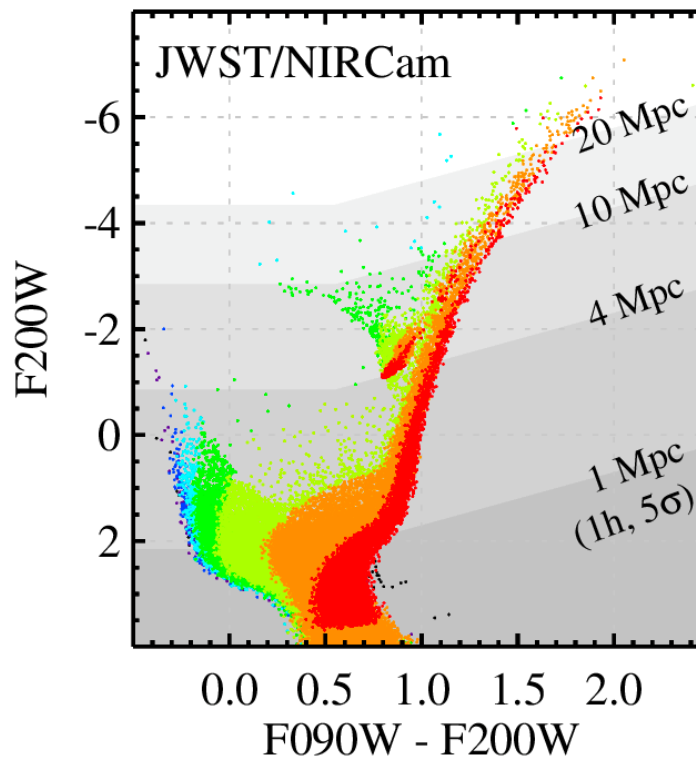
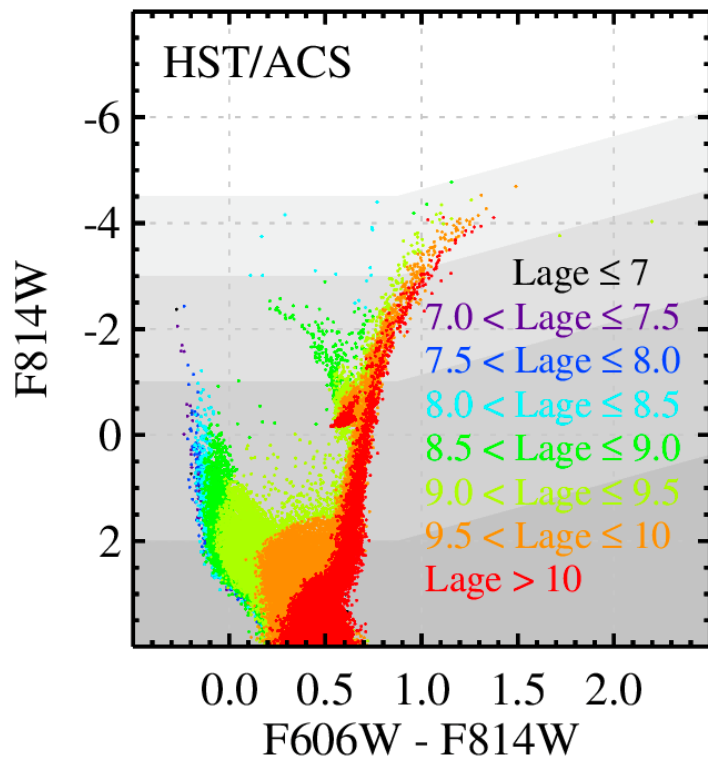
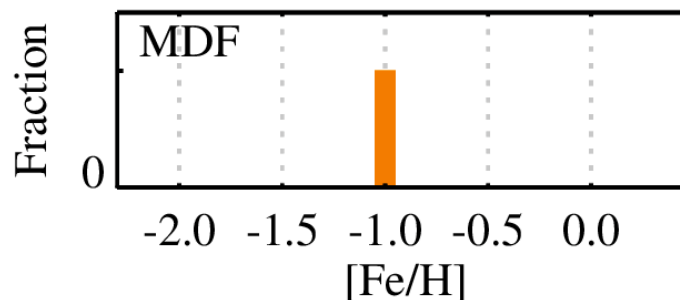
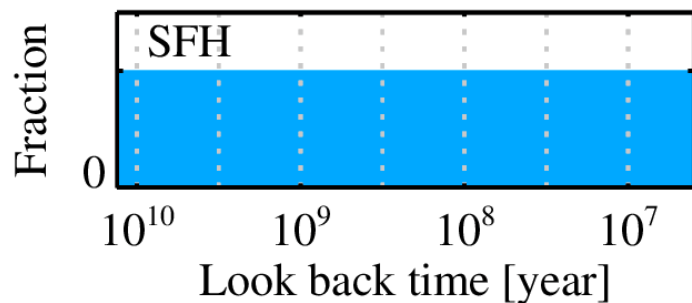
TIPSNU (Jang&Lee 2017)
 $D \leq 31$ Mpc



Future

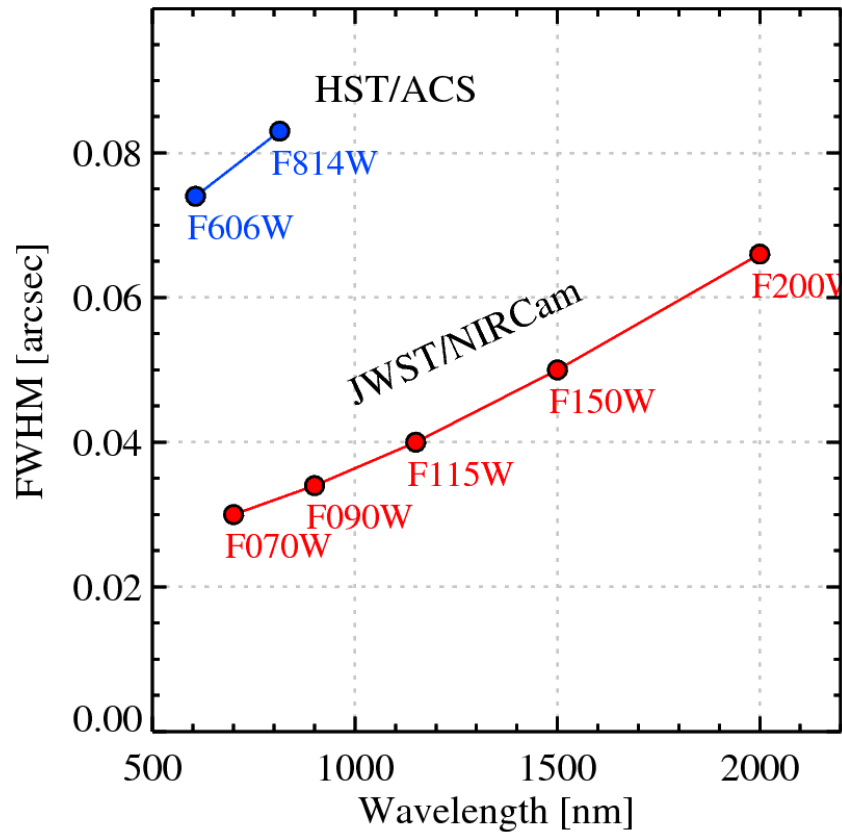
**A Diamond Era of the TRGB
with the JWST (2022–) began!**

HST vs JWST: Simulation CMDs



(Jang2019)

HST vs JWST: Spatial Resolution



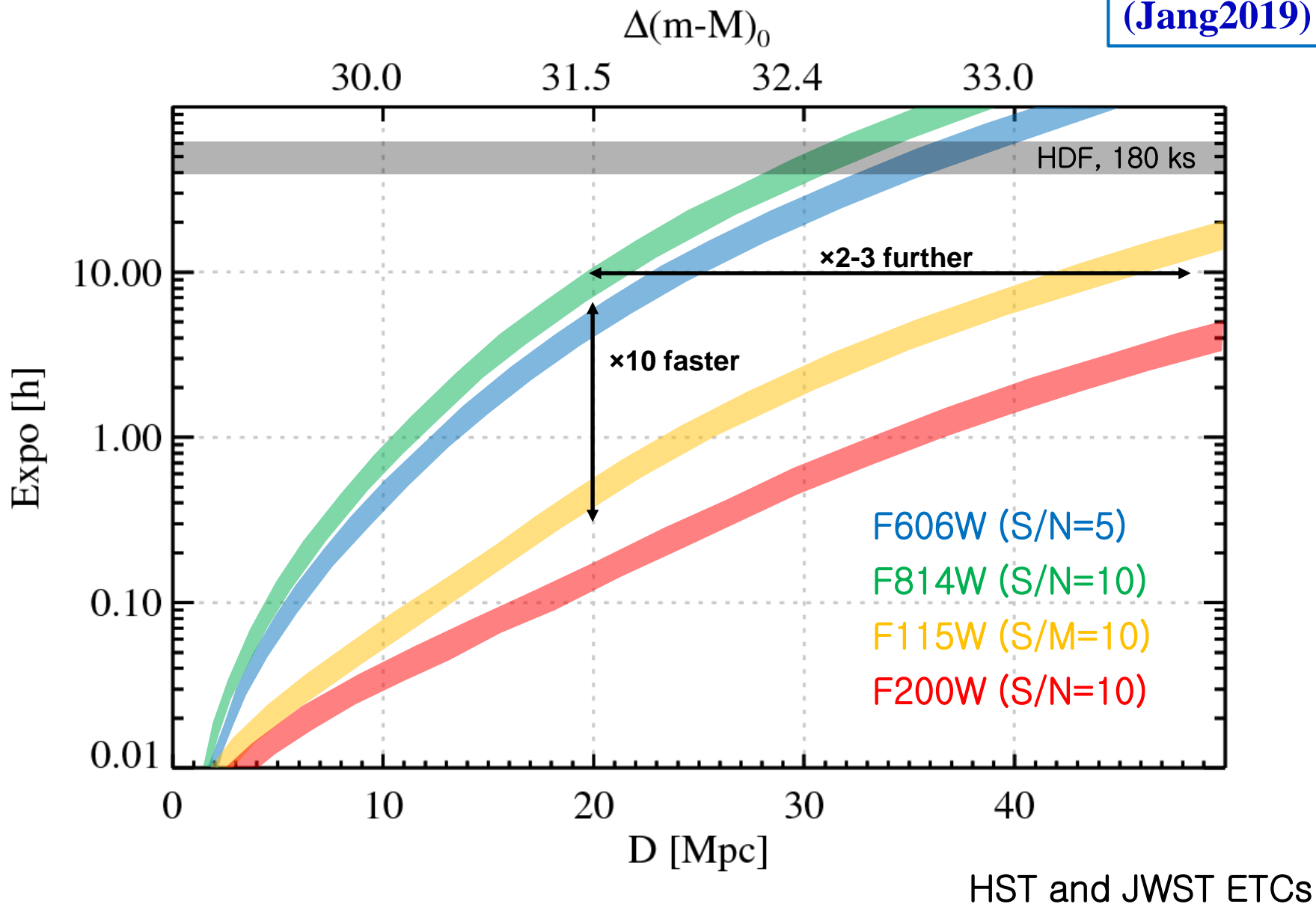
From HST and JWST
PSF simulation tools

(Jang2019)

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

Required exposure times to detect the TRGB

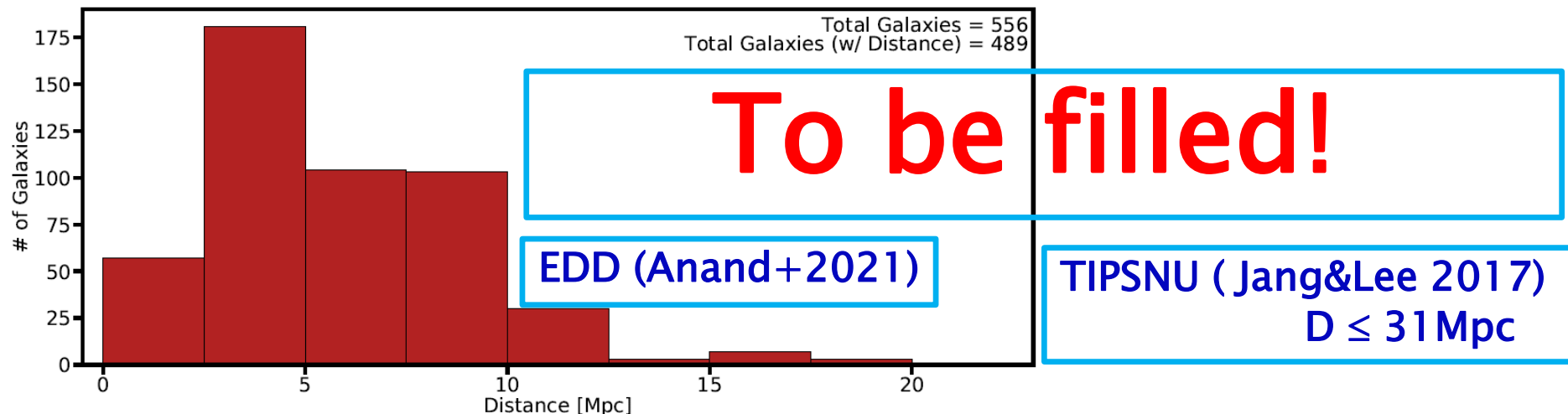
(Jang2019)



The TRGB Survey of the Local Universe!

TRGB survey with JWST!

N will increase from ~ 500 to a few 10^3 ,
filling the universe out to 100 Mpc from 2022!

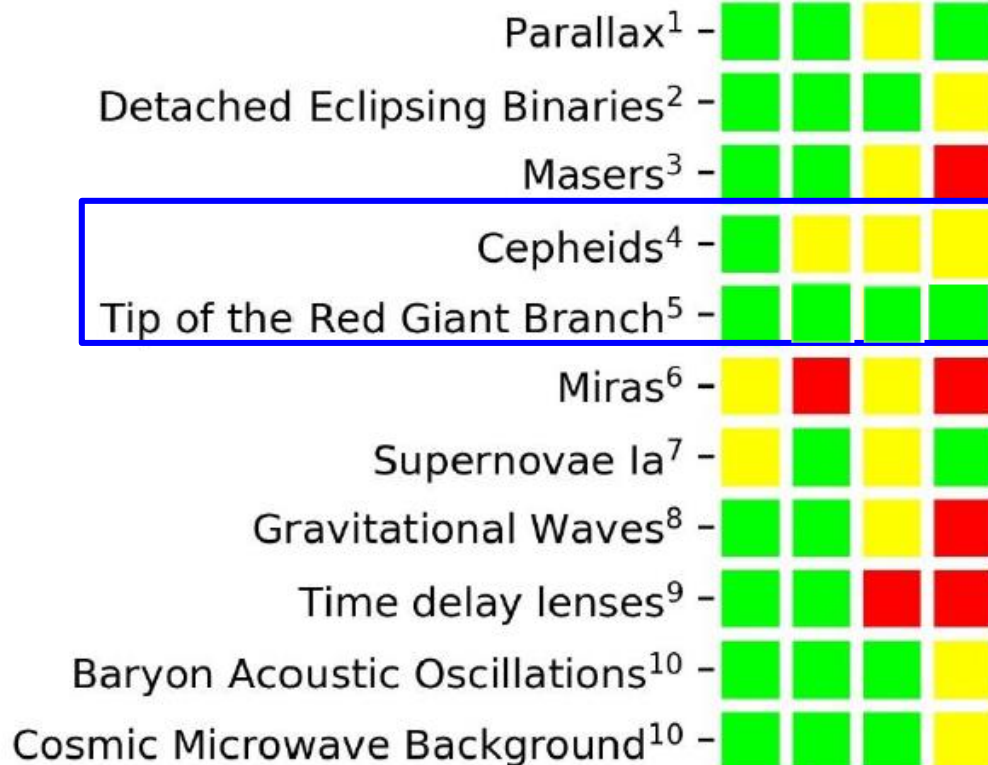
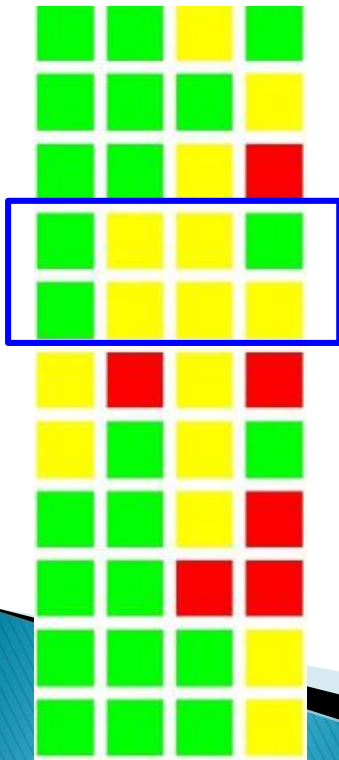


A Revised Traffic Light for the Future

- Cepheids: Late type galaxies only, extinction, metallicity
- TRGB: any type galaxies, little extinction

Astrophysical Modelling^a
 Photometric Reduction^b
 Calibration^c
 Population size^d

Shah+(2021)



Revised
(MGL)!

Summary and Future

- The precision, accuracy, and **versatility** of the TRGB is a critical key to cosmography.
- Another golden era in high resolution imaging began with JWST (post-HST), providing the best time for the TRGB.
- The volume and filling factor of the local universe with TRGB will increase soon.
- Tensions/Puzzles will be resolved or not?
- Let's enjoy High 1!

Thank you!