# Planetary Nebula & Globular Cluster Luminosity Functions

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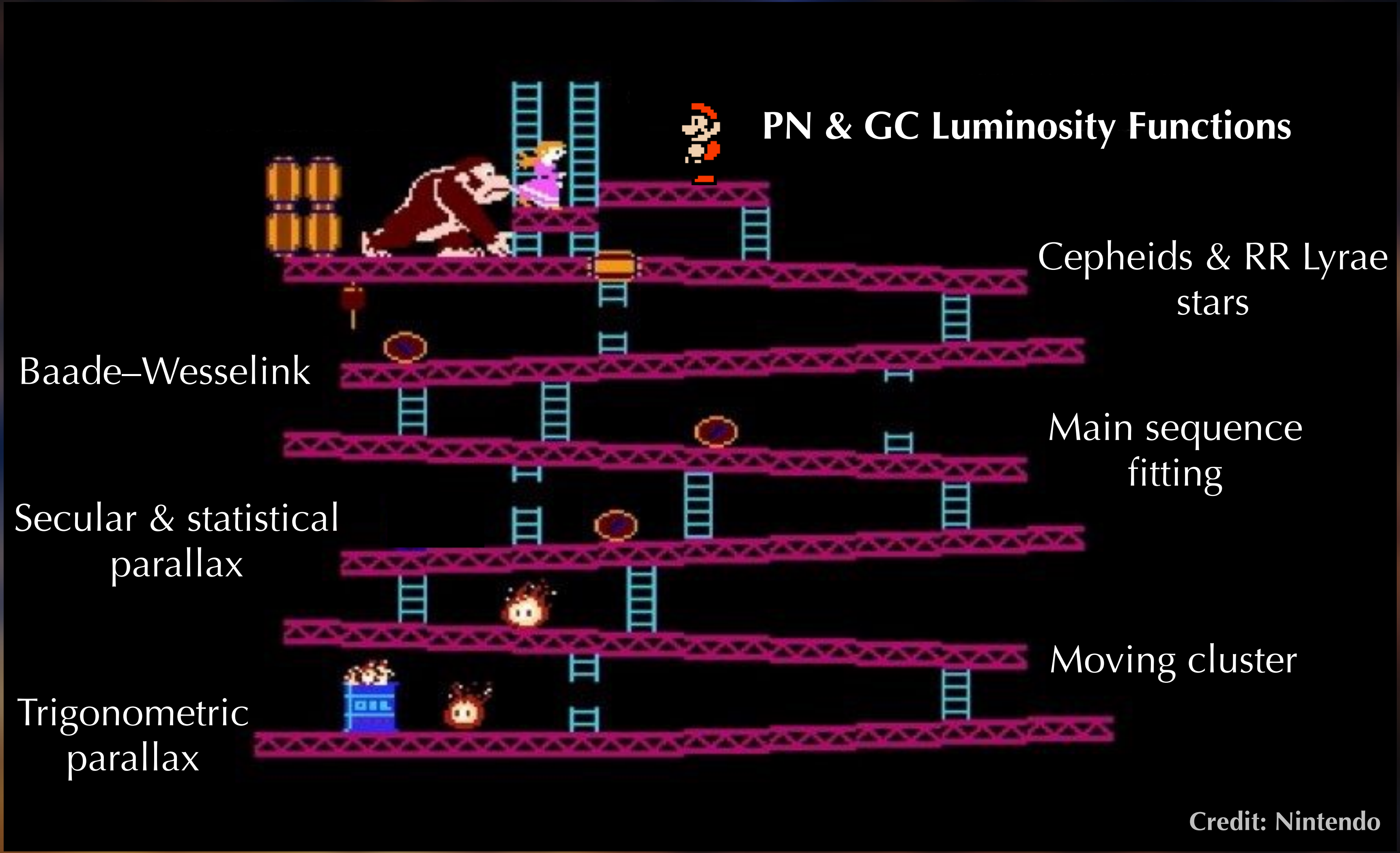
Cosmic Distance Ladder Presentation

Credit: NASA, ESA, CSA, STScI; Alyssa Pagan (STScI)

# The Distance Ladder (so far…)



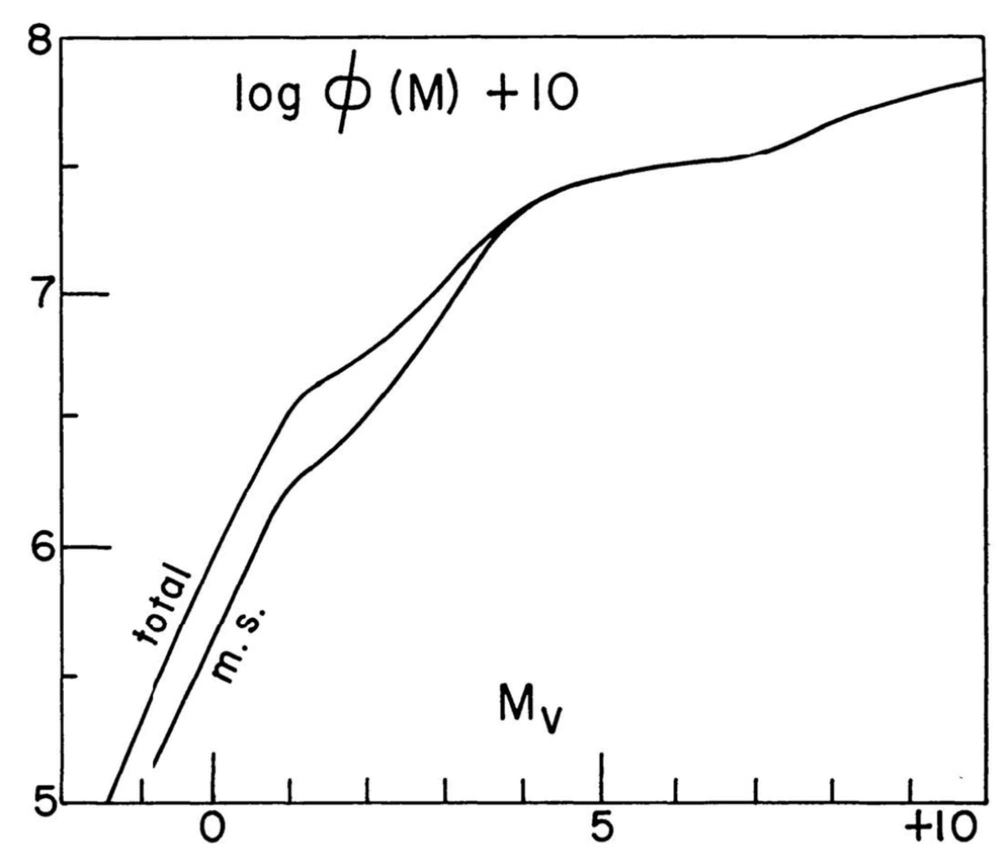

Credit: Nintendo

# Luminosity Functions

- Present number of objects as a function of luminosity

- **Empirical** relations
  - Based on observational data

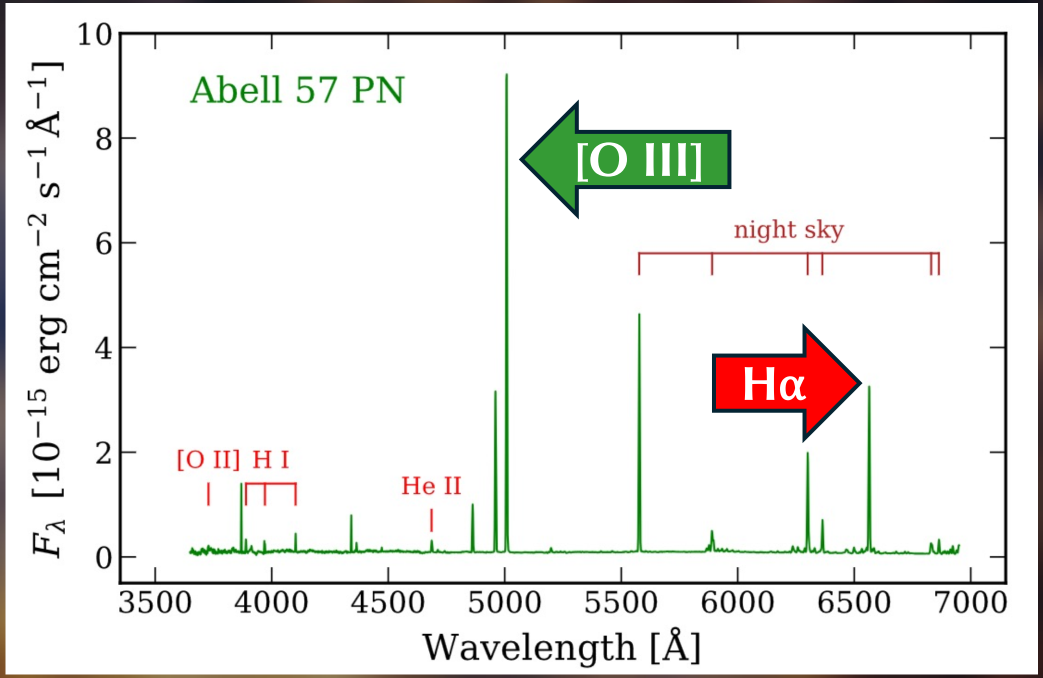
Log number →



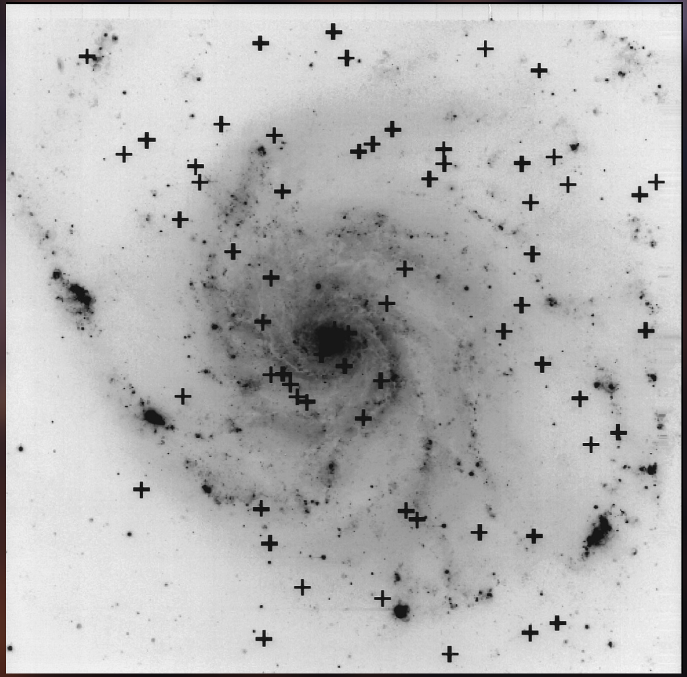

Credit: Saltpeter (1955)

# Planetary Nebula Luminosity Function

- [O III] λ5007 generally the brightest line in PN spectra
  - Used to identify PN through narrow-band photometry



Credit: Bond et al. (2024)

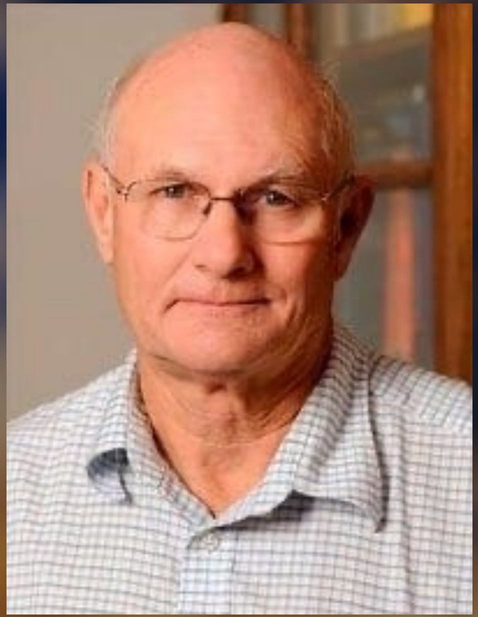

Credit: Feldmeier et al. (1996)

# Planetary Nebula Luminosity Functions

- Evident brightness limit of PNe discovered by Ford et al. in 1978

- First robust calibration carried out by Ciardullo et al. in 1989

Holland Ford

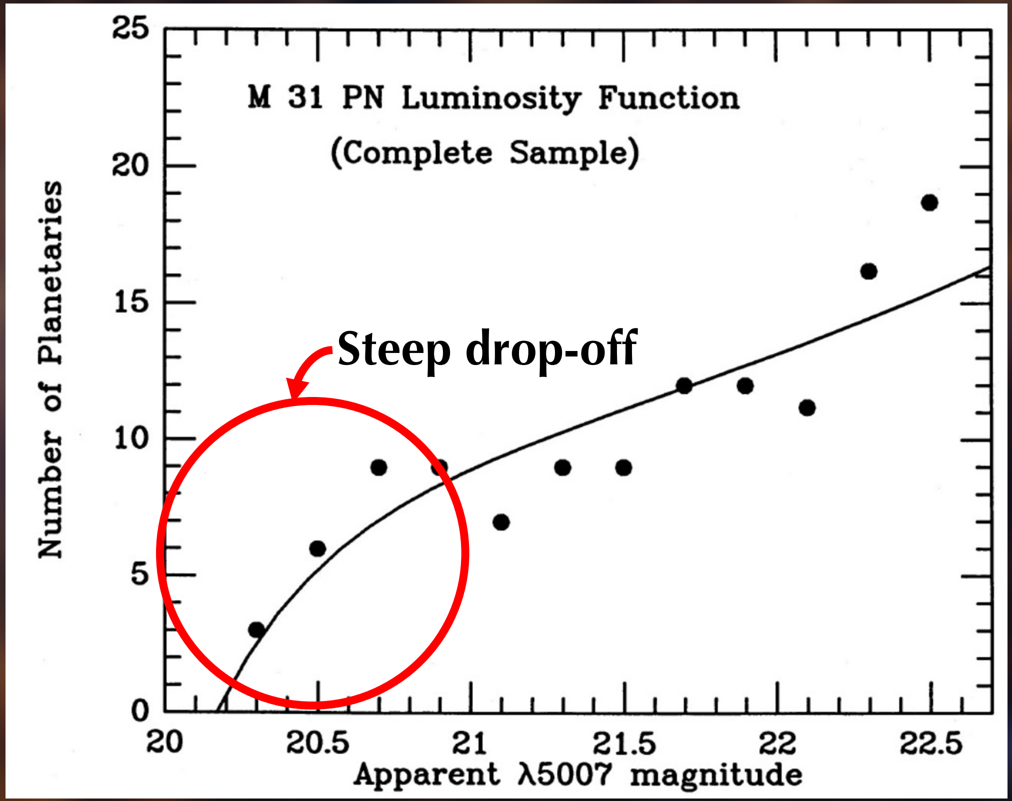


George Jacoby

Robin Ciardullo

# Calibrated PNLF — M 31 et al.

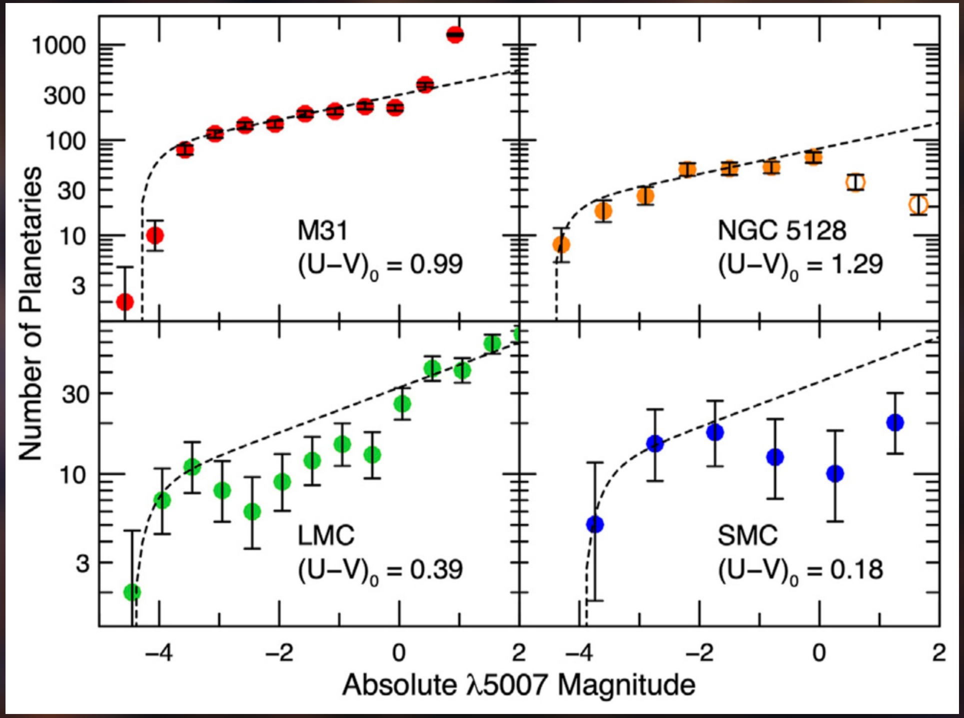
- Ciardullo et al. in 1989 used PNe in **M 31 and companions**
- Calibrated using **Cepheids**
- $N(M) \propto e^{0.307 \cdot M} \left(1 - e^{3(M^{*} - M)}\right)$
- **$M^{*}$ = – 4.53**




Credit: Ciardullo et al. (1989)

# Contemporary PNLF Science

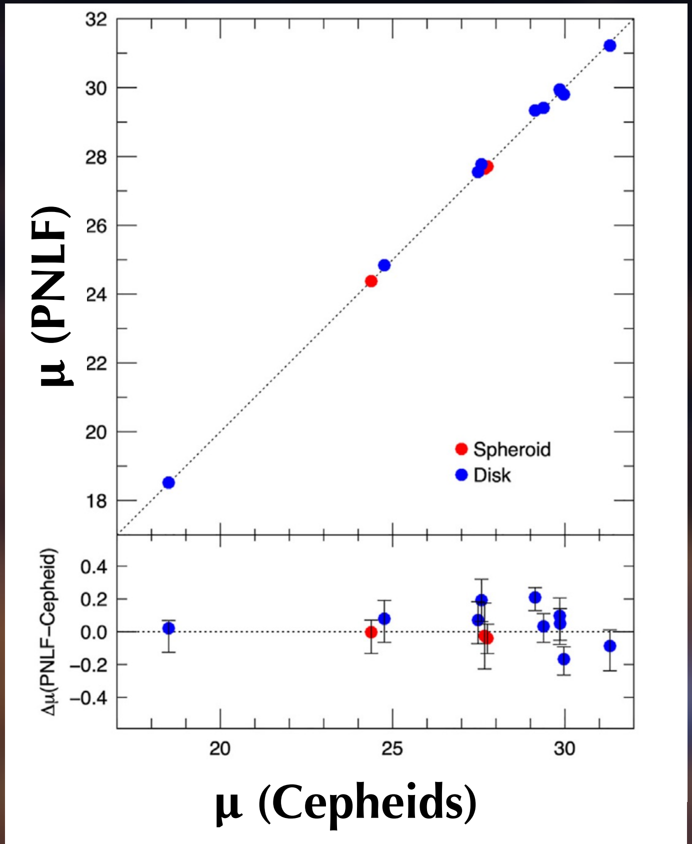
- Integral Field Units + 8–10m-class telescopes reviving PNLF use
- Can go **much** fainter ($m_{\lambda 5007} = 29$!)
- More precise **waveband localization**
- Reaches **40 Mpc** with **10% uncertainty**

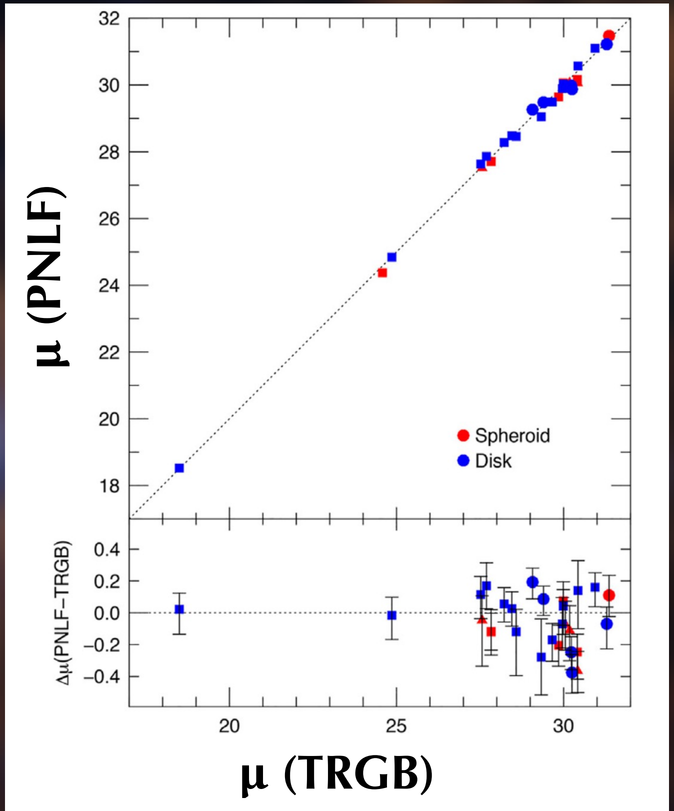



Credit: Ciardullo (2022)

# Pros

# Cons

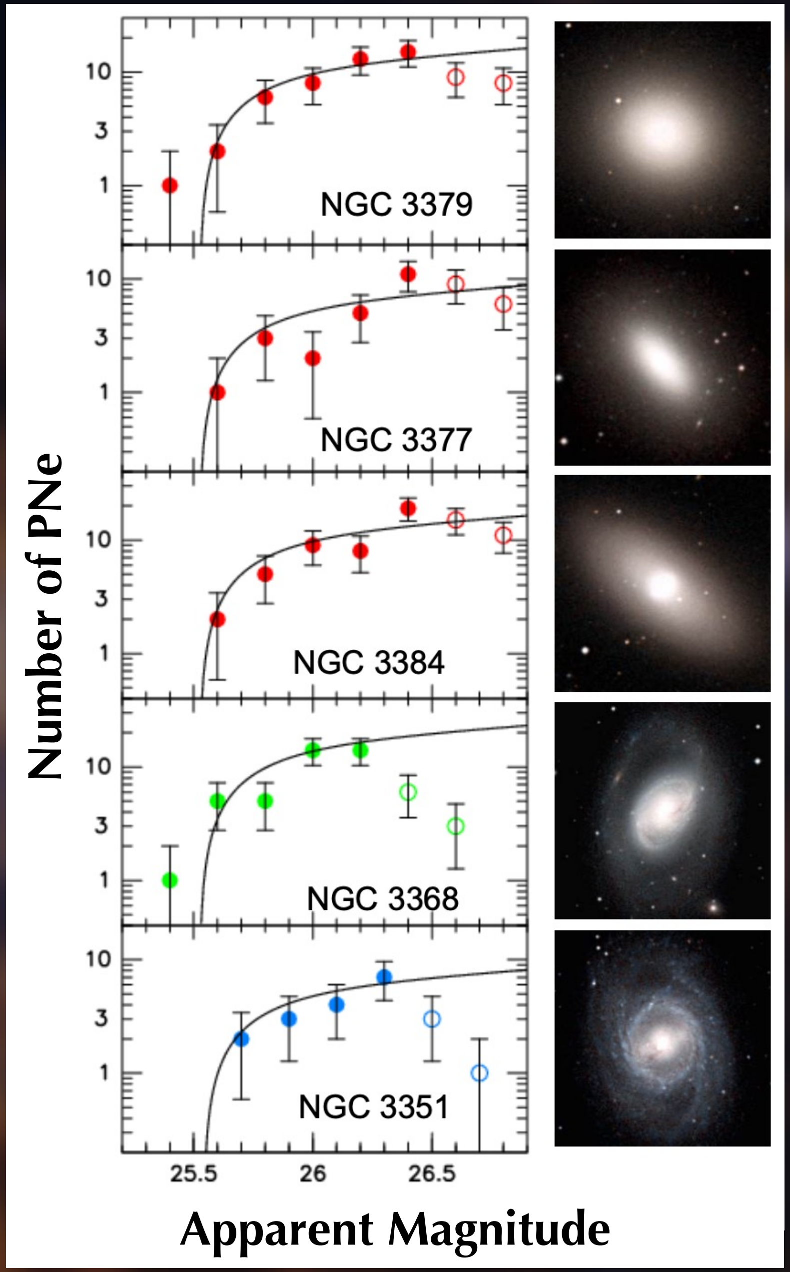

Credit: Ciardullo (2022)

# Pros

# Cons

Independent of galaxy type

Consistent w/ Cepheids & TRGB




Credit: Robin Ciardullo

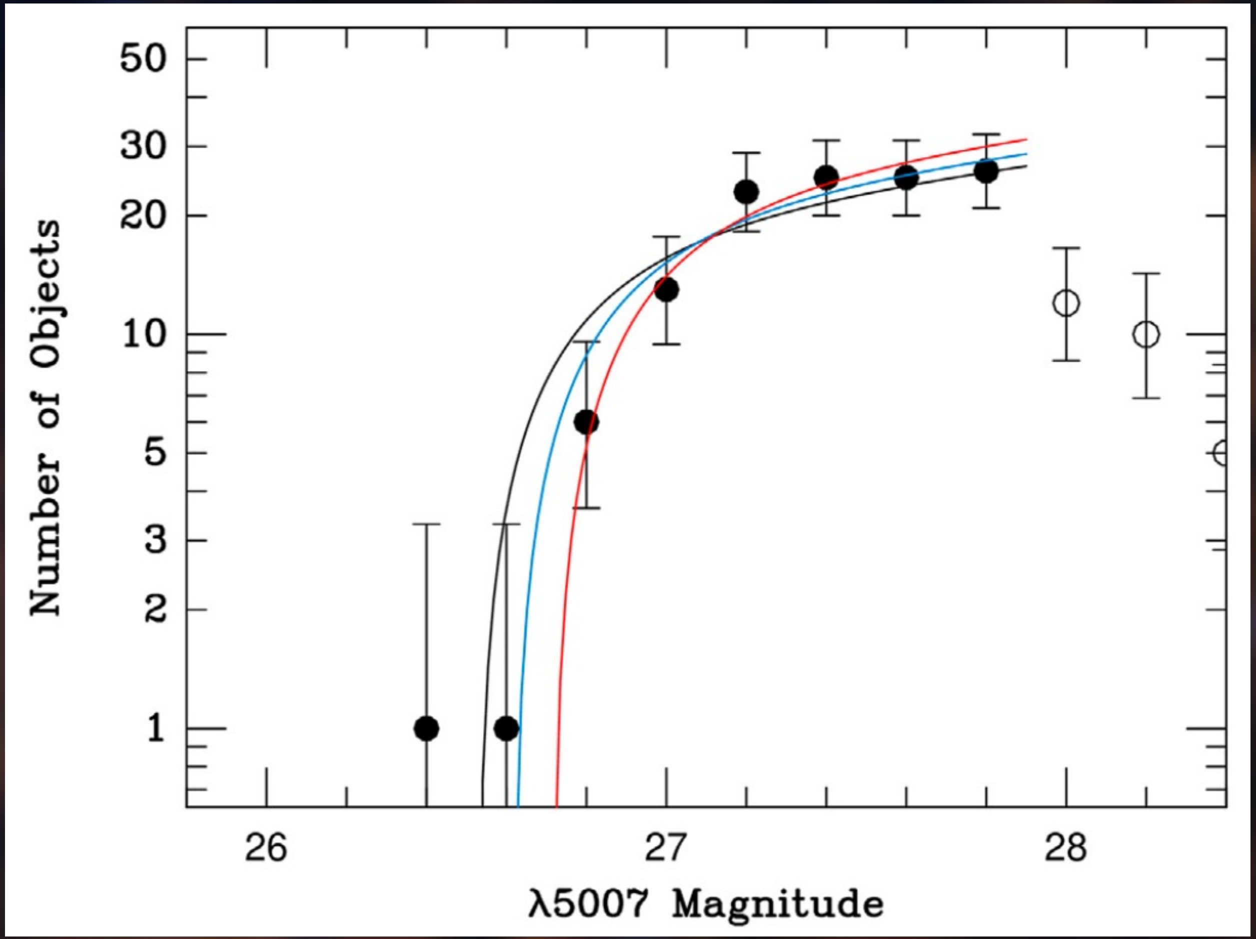
# Pros

# Cons

Independent of galaxy type

Consistent w/ Cepheids & TRGB

Faint-end not well modeled*

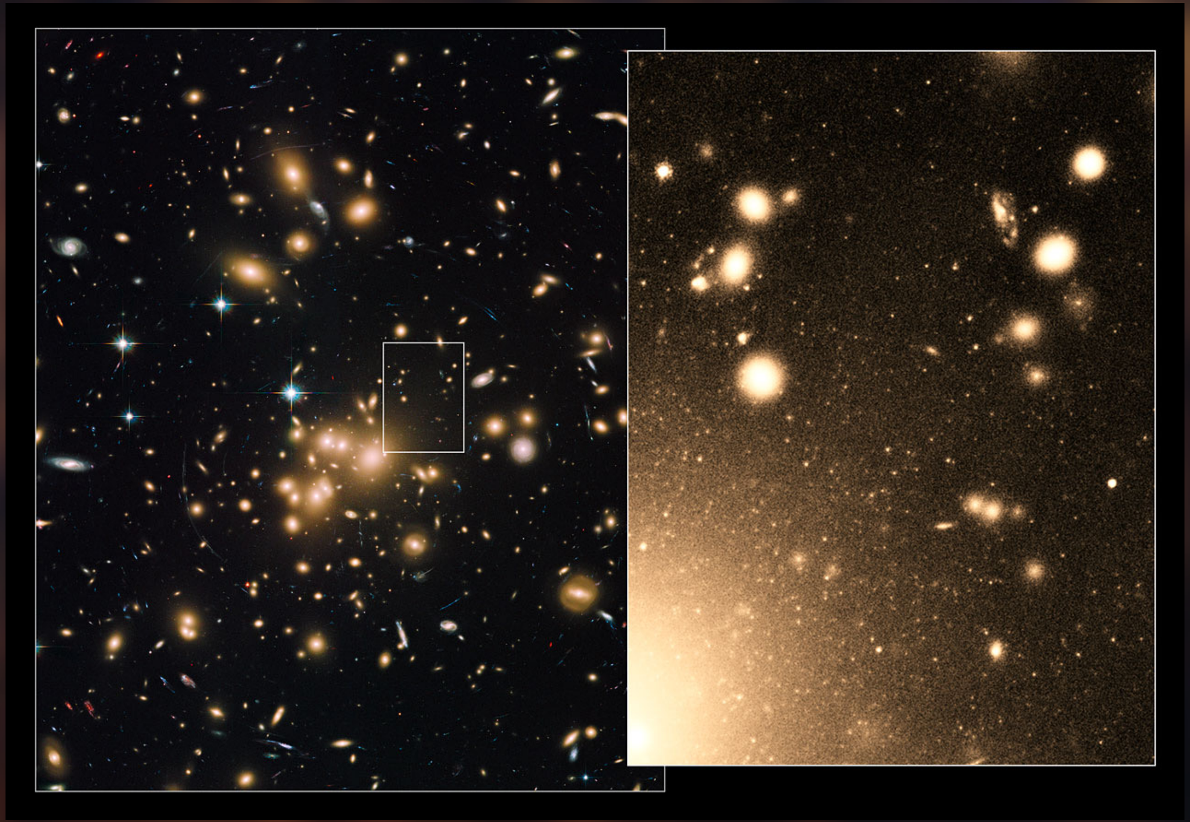



Credit: Ciardullo (2022)

# Globular Cluster Luminosity Function

- Globular clusters look like faint stars in other galaxies (D > 1 Mpc)
  - Easily seen in ellipticals/lenticulars to ~100 Mpc w/ *HST*

Credit: NASA/Hubble



Credit: NASA, ESA, J. Blakeslee & K. Alamo-Martinez/H. Ford

# Globular Cluster Luminosity Function

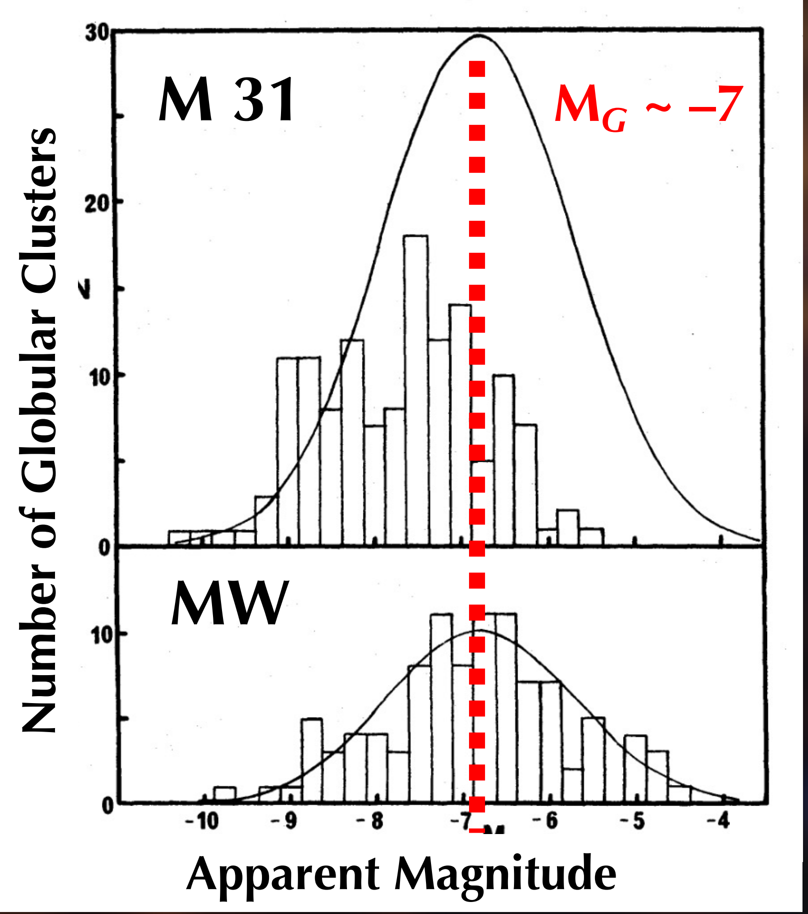
- First discovered by Baum (1955), comparing GCs in M 87 & M 31
- First suggestion of universal "turn-over magnitude" by Hanes (1977)

**William A. Baum**

**David A. Hanes**

# Calibrated GCLF — MW and M 31

- Hanes (1977) noted that MW and M 31 have similar GCLFs
- Both can be modeled as **Gaussians**
  - $\frac{dN}{dm} \sim \exp(\frac{-(m-m_0)^2}{2\sigma^2})$
- Both have similar "**turn-over magnitude**"
  - Calibrated using **RR Lyrae** stars in Galactic GCs
- **$M_V$ = −7.46 ± 0.18**



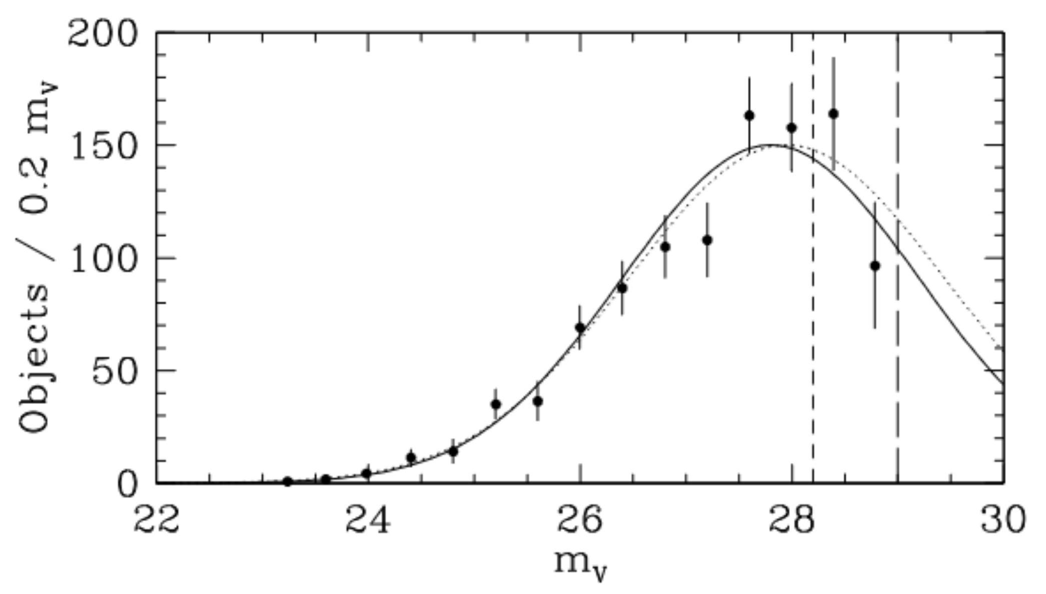

Credit: Hanes (1977)

# Contemporary GCLF Science

- GCLFs fell out of favor in the ’90s
  - Requires **deep** photometry
  - GCLFs **not always Gaussian…**
  - Turn-over magnitudes are **age-dependent**

- *HST* data pushed to 100+ Mpc
  - Coma cluster at 102 Mpc w/ 10% error

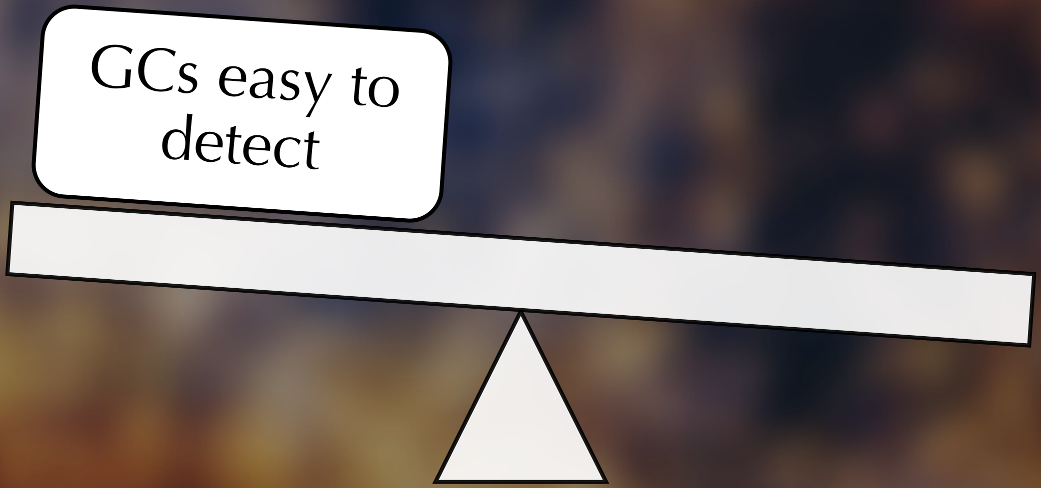
- **Big** systematics!
  - 0.1–0.15 mag less than PNLF-based distance moduli
  - 0.27 mag less than Cepheid-based distance moduli

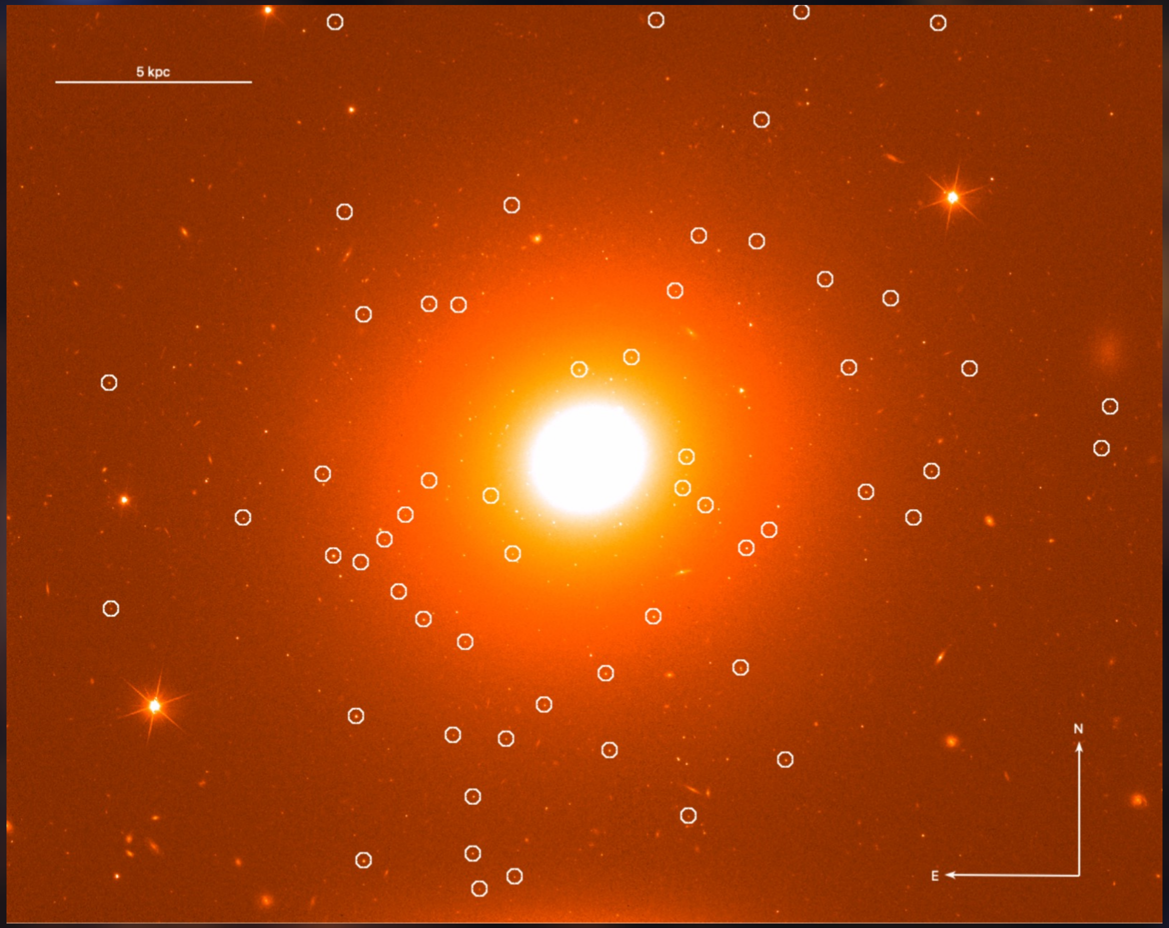



Credit: Kavelaars et al. (2000)

# Pros

# Cons



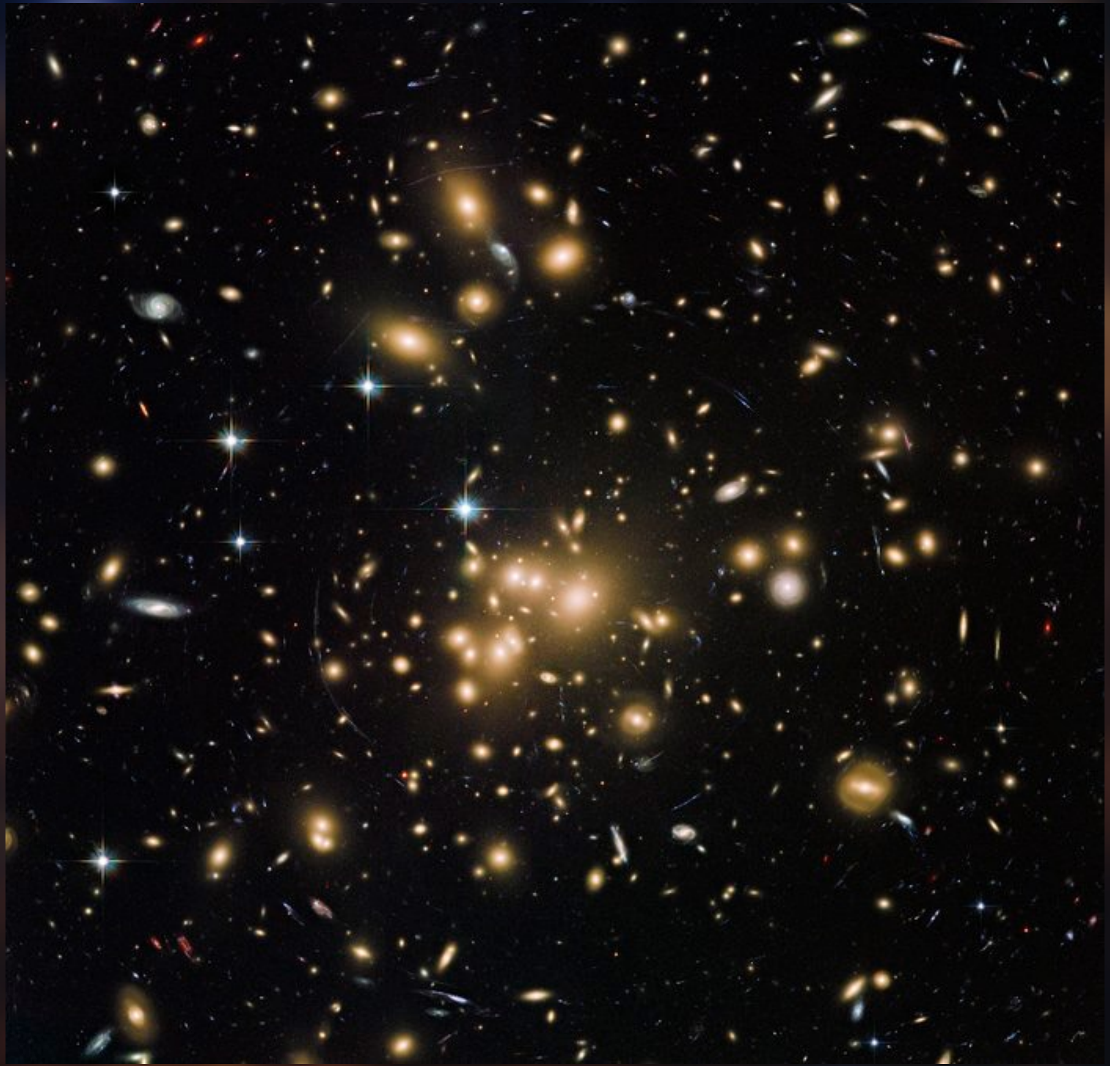

Credit: Euclid Collaboration et al. (2025)

# Pros

# Cons

Can go to ~100 Mpc w/ HST

GCs easy to detect



Credit: NASA, ESA, J. Blakeslee/H. Ford

# Pros

# Cons

Can go to ~100 Mpc w/ HST

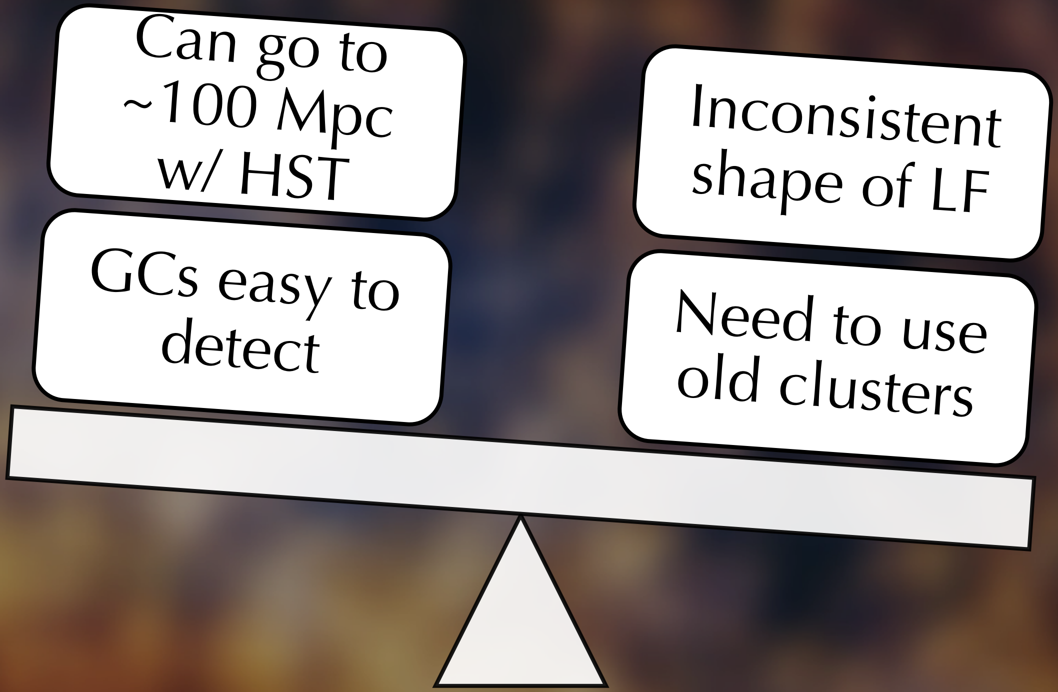
GCs easy to detect

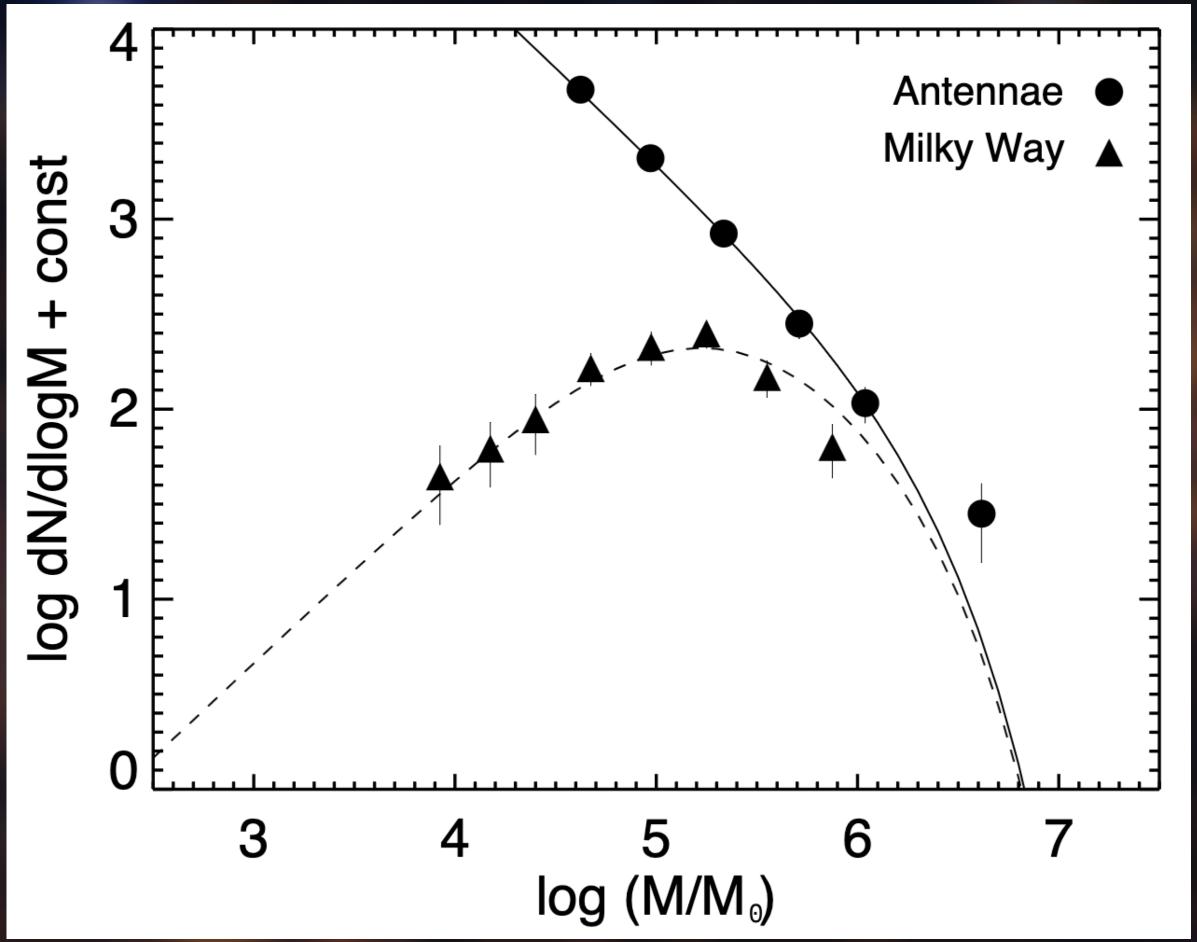
Need to use old clusters

Credit: NASA, The Hubble Heritage Team, STScI, AURA

# Pros

# Cons




Credit: Fall, Chandar, and Whitmore (2009)

**Pros**

- Can go to ~100 Mpc w/ HST
- GCs easy to detect

**Cons**

- Not viable for spirals
- Inconsistent shape of LF
- Need to use old clusters


Credit: Aubrey Graham, Ken Crawford, ESA/Hubble/J. Schmidt & J. Blaekeslee/M. Carollo

# Summary

## Planetary Nebula Lum. Func.

- Back in vogue with IFUs
- Can go to >40 Mpc
- Can use all PNe in any type of galaxy

## Globular Cluster Lum. Func.

- Not really used anymore…
- Can go to >100 Mpc
- Useful for ellipticals and lenticulars