

Cepheids and RR Lyraes

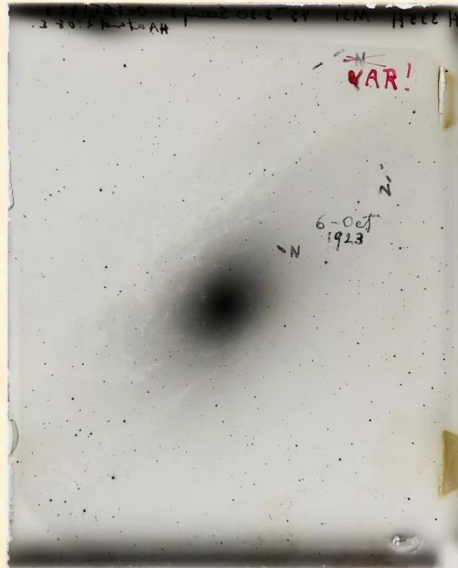
Madeline Davis

Cepheids and RR Lyraes

- Pulsating Stars
- History
- Leavitt's Law
- Pulsation Mechanism
- Sources of error
- Modern work



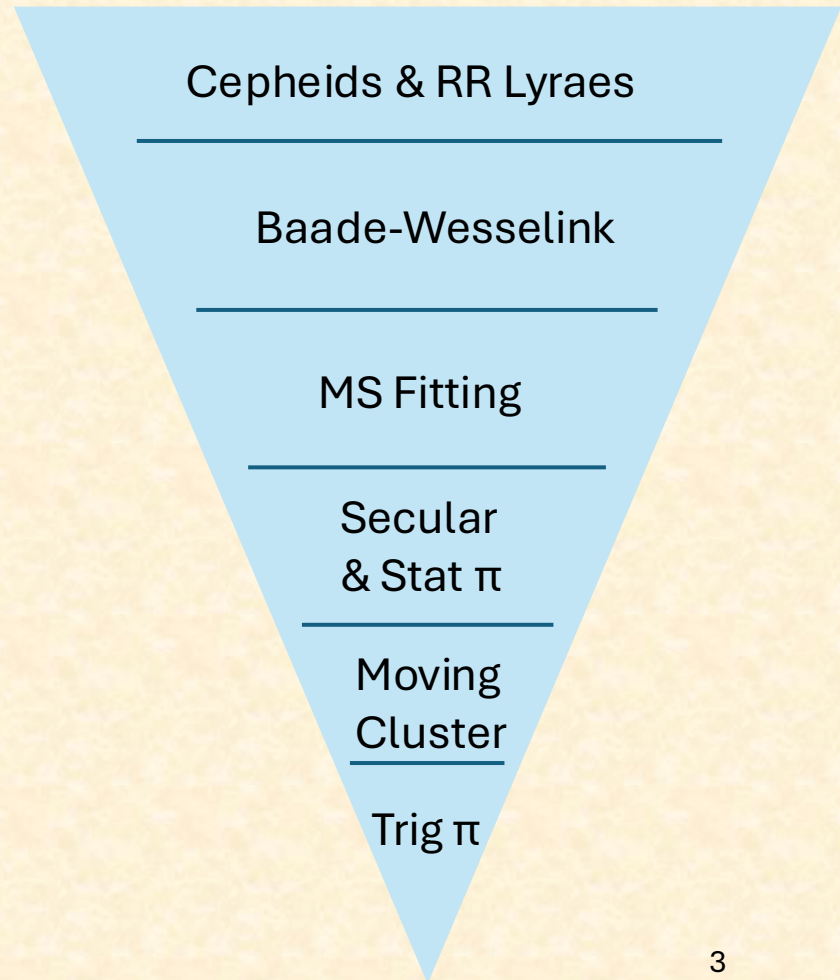
Harvard College Observatory



Hubble's
“Var!”,
first
Cepheid
in M31

The Basics

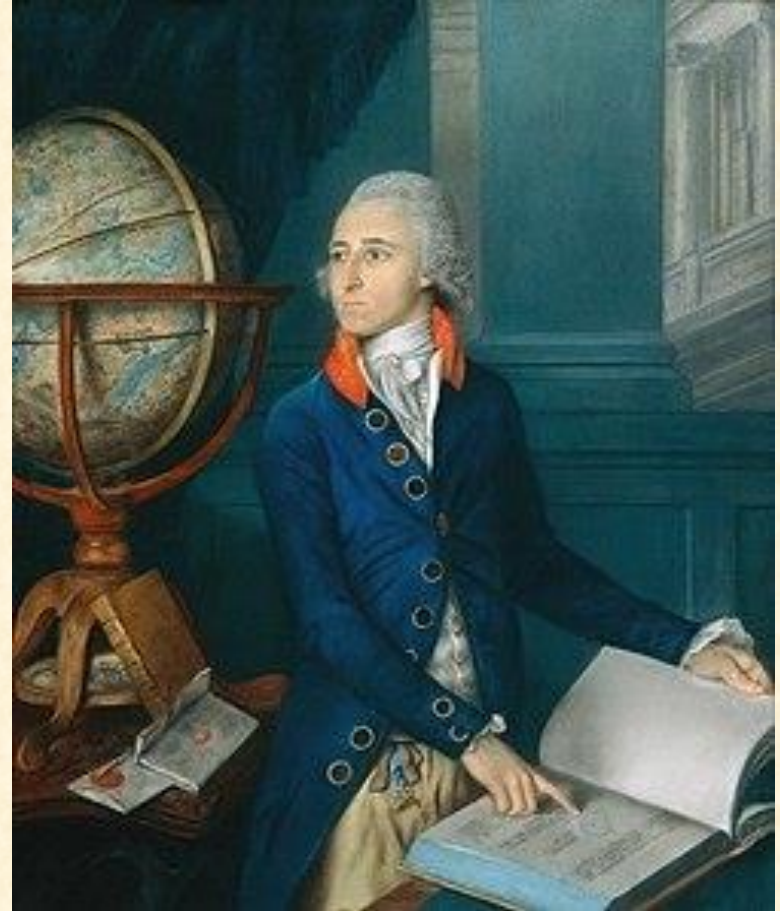
- Pulsating variable stars
 - Strong correlation between Period and Luminosity
1. Measure period and apparent magnitude
 2. Use PL relationship to get Luminosity
 3. Calculate absolute magnitude
 4. Relate m and M : calculate distance with distance modulus formula



1784: Cepheids Discovered



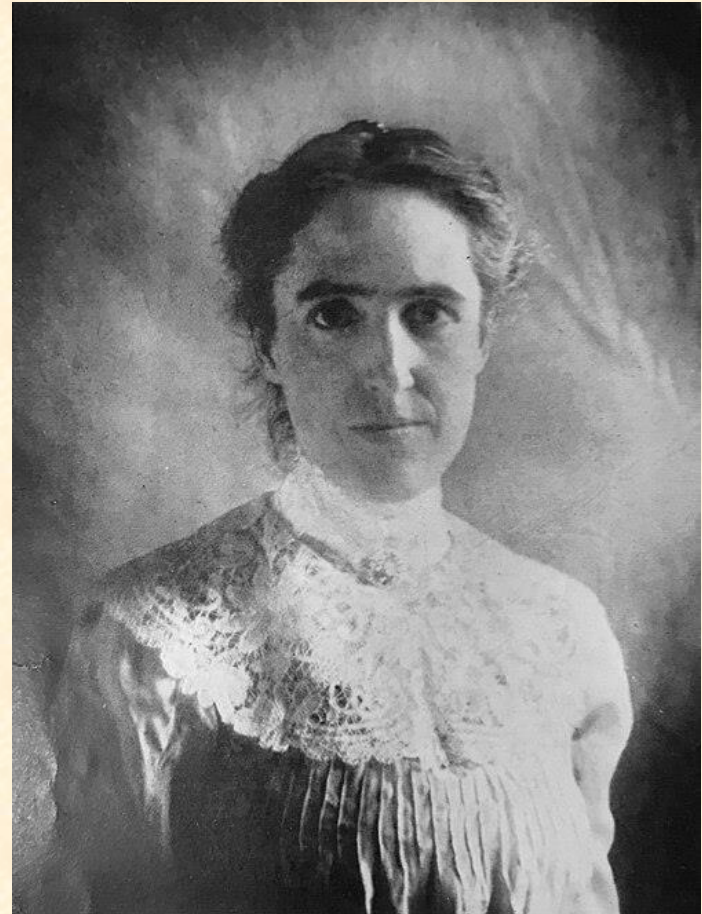
Eta Aquilae discovered by Edward Pigott, English astronomer



δ Cepheid discovered by John Goodricke, English astronomer

Henrietta Leavitt - Cepheids

- Worked as volunteer assistant to computer at Harvard College Observatory (HCO)
- Hired by Edward Charles Pickering
- Early 1900s: Studied photographic plates of the SMC and LMC
- Identified 1,777 variable stars



1868 - 1921

Leavitt's Law - Cepheids

AKA: Period-Luminosity Relationship for Cepheids

- 1912 paper, characterized the period-luminosity relationship of 25 cepheid variables in the SMC
- By assuming all stars in SMC at the same distance and finding this relationship, she established Cepheid's as the first standard candle

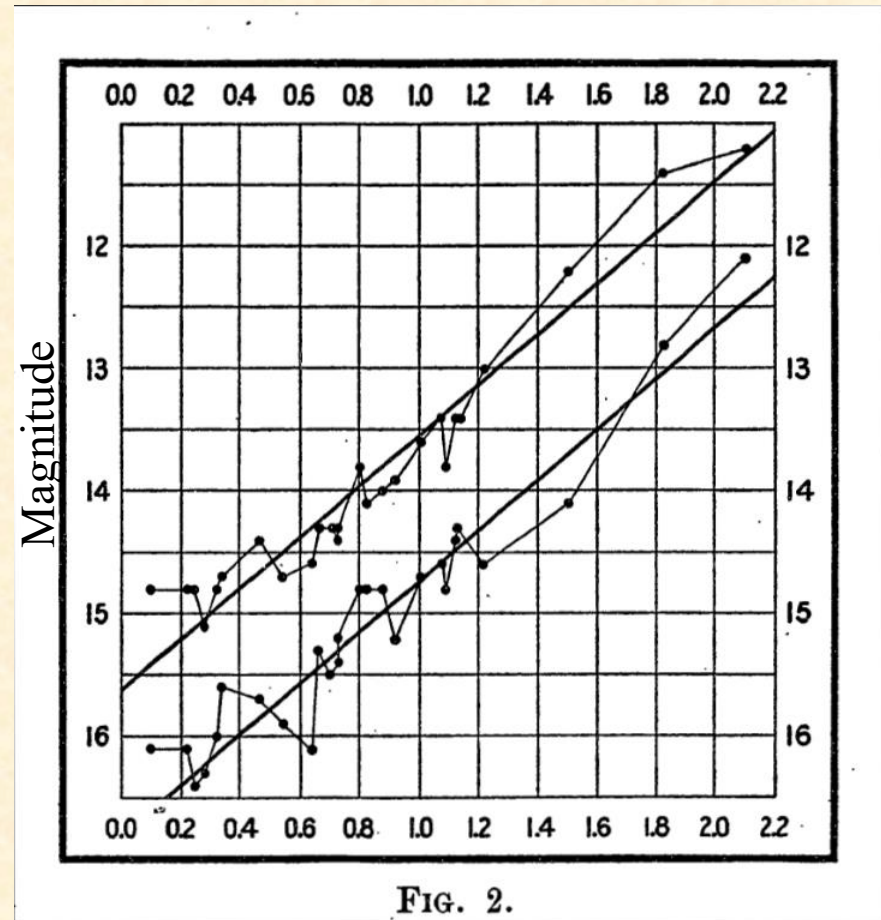


FIG. 2.

Log(P) in days

Williamina Fleming – RR Lyraes

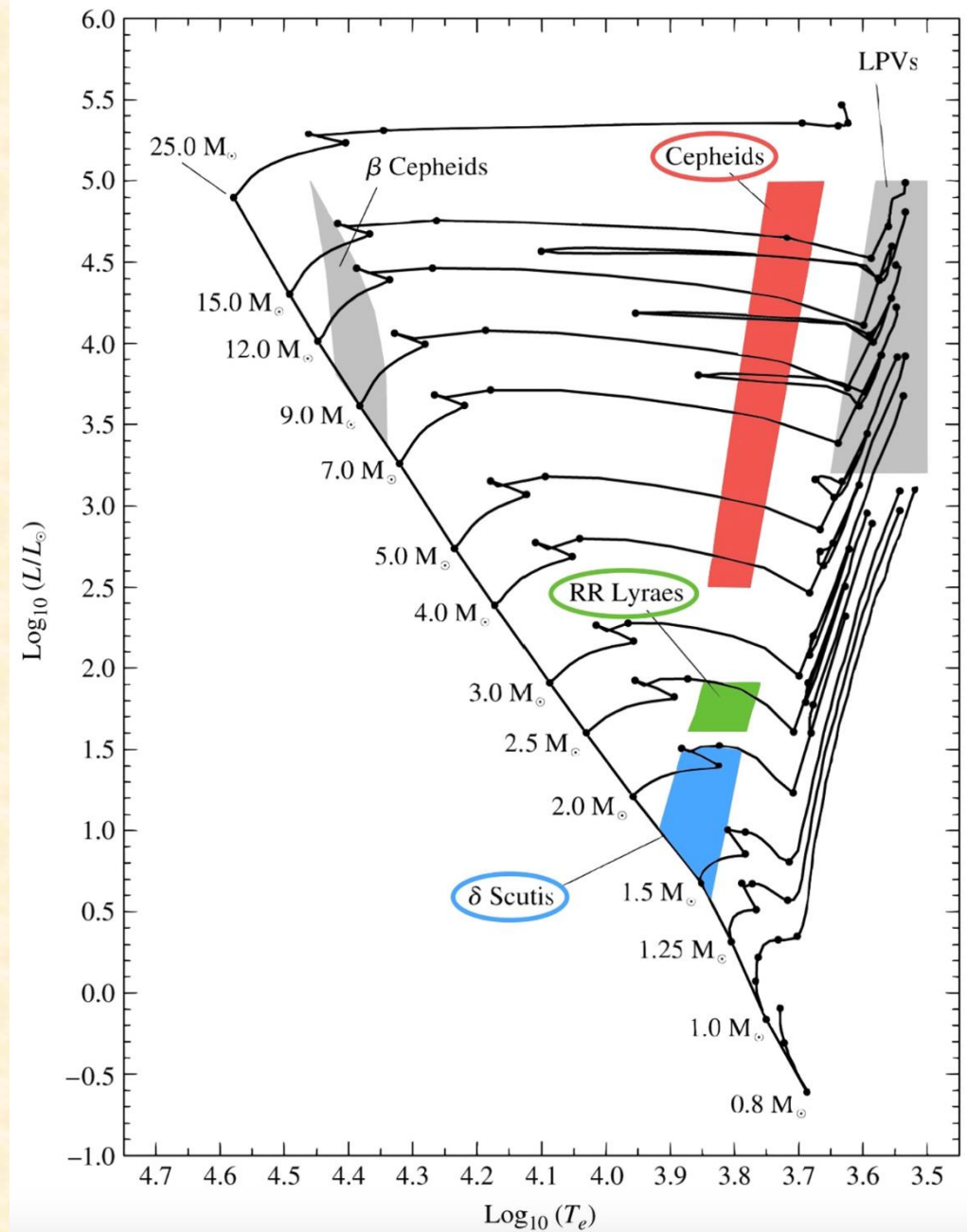
- HCO computer and manager under Edward Charles Pickering
- Late 1890s: Discovered RR-Lyrae's brightness variation via photographic plate.
- Noted these variables had periods similar to those seen in clusters
- Over next 60 years, they became crucial in determining distances to globular clusters in the halo



1857 - 1911

Cepheids and RR Lyraes

- Classical radial pulsators
- Occupy instability strip
- Core He fusion
- κ -Mechanism drives pulsations



κ -Mechanism

- Partially Ionized Zone (PIZ) layers
 - H \rightarrow H⁺ - outermost
 - He \rightarrow He⁺
 - He⁺ \rightarrow He⁺⁺ - innermost
1. Heating/compression of He⁺ \rightarrow He⁺⁺ layer increases – e⁻ opacity goes up
 2. Heat cannot effectively radiate away
 3. Star's atmosphere expands
 4. Atmosphere cools and opacity decreases
 5. Energy from core can radiate away; star must shrink to reestablish hydrostatic equilibrium

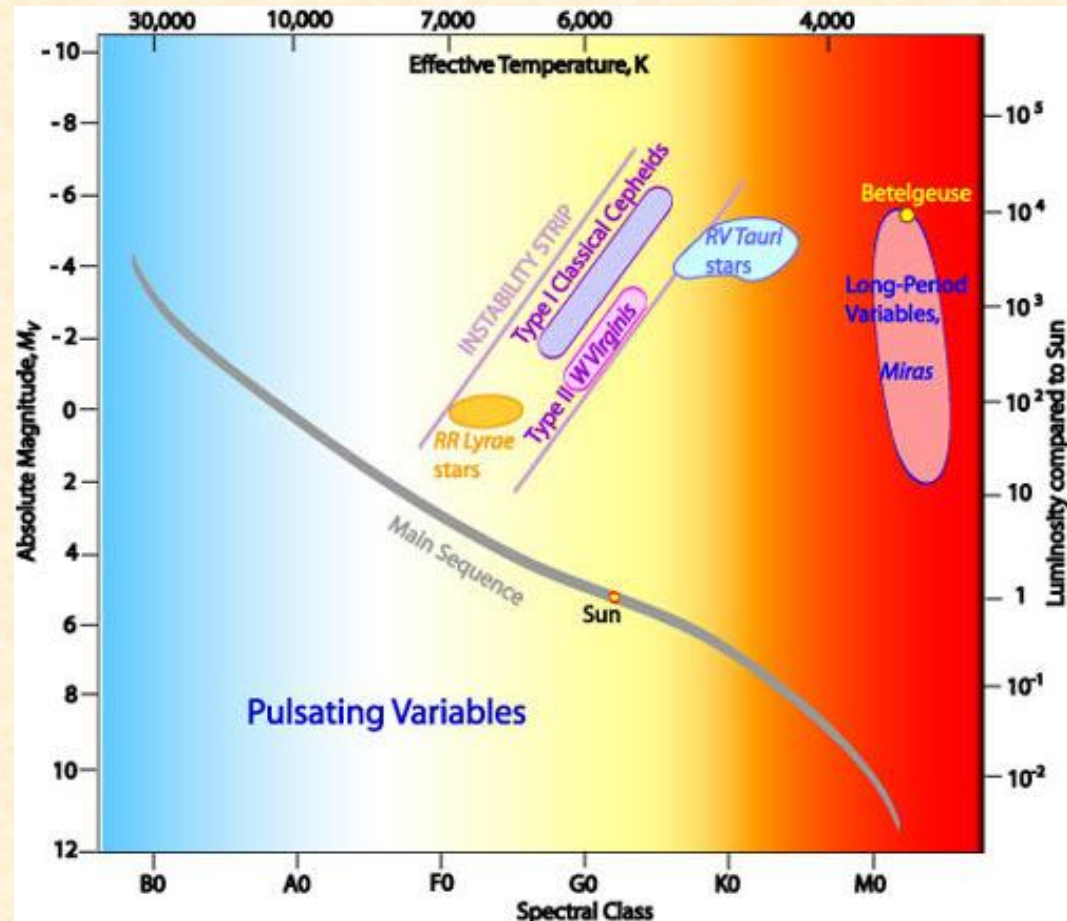
Cepheid Variables

Classical Cepheids

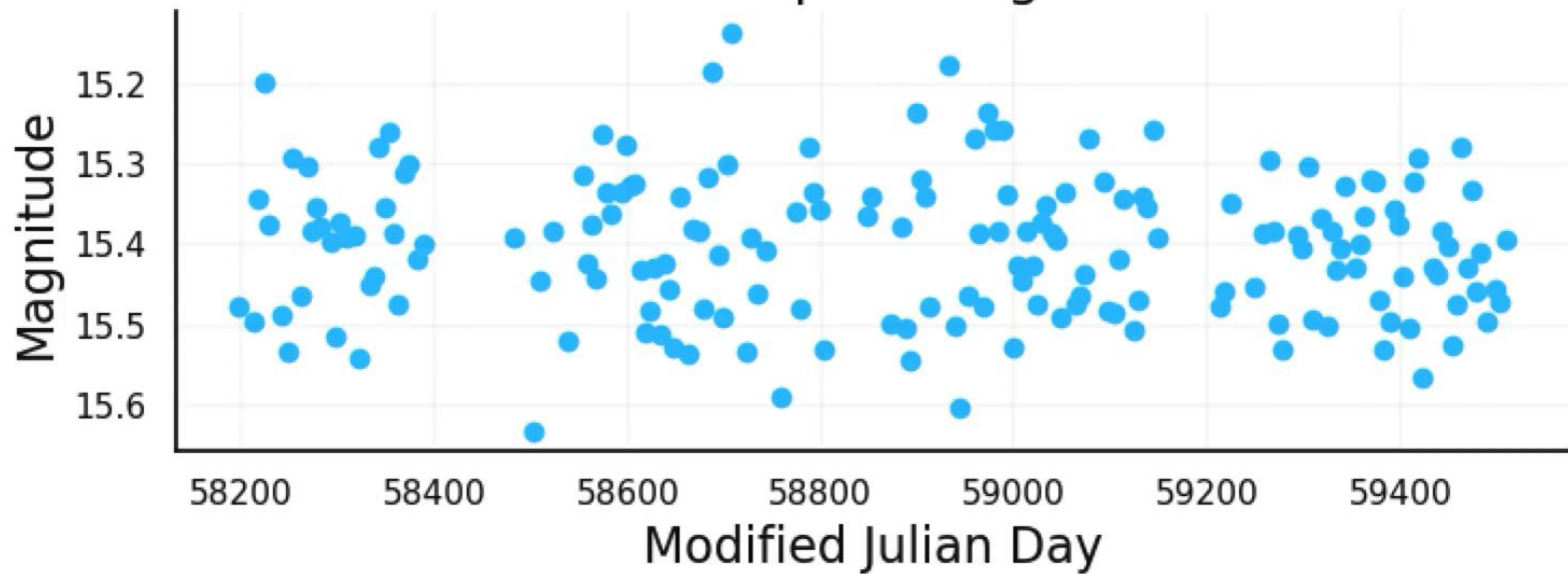
- Prototype: δ Cephei
- Strong PL relationship
- $M \geq 5M_{\text{Sun}}$

Population II Cepheids

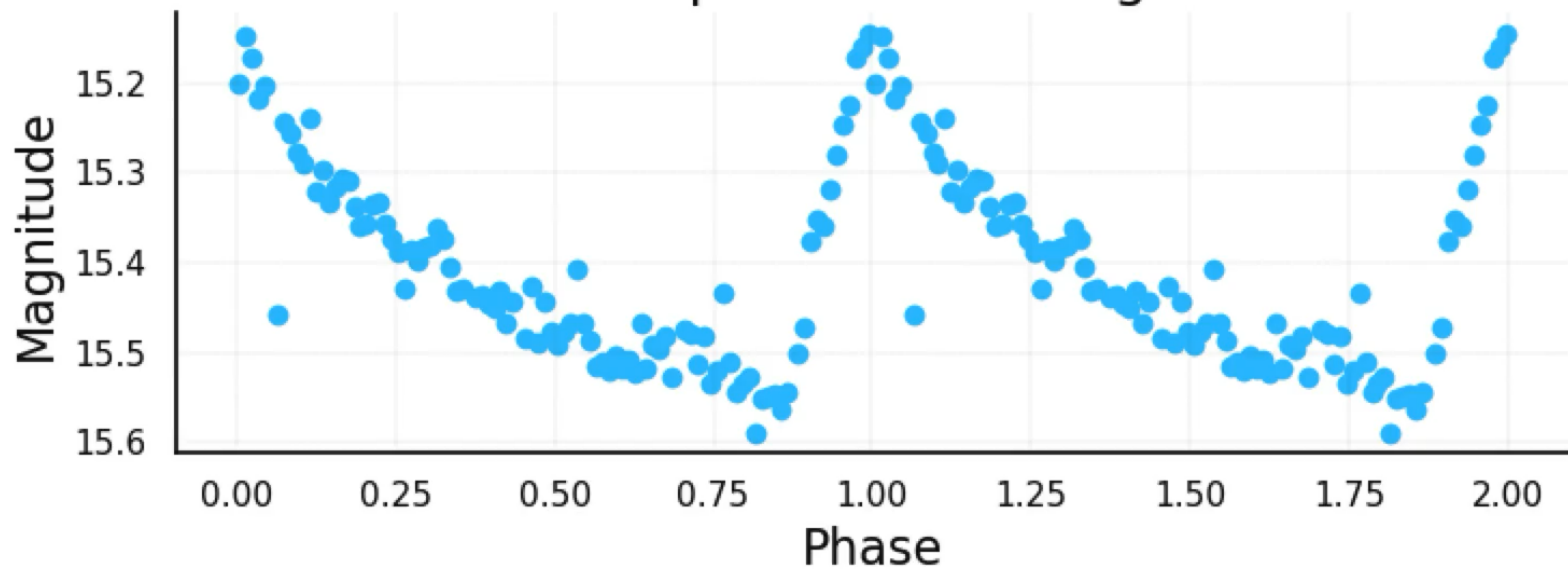
- Prototype: W Virginis
- Weak PL relationship
- Low-mass, low metallicity, halo stars
- $0.5 \leq M_{\text{sun}} \leq 0.85$



Classical Cepheid Light Curve



Classical Cepheid Phased Light Curve



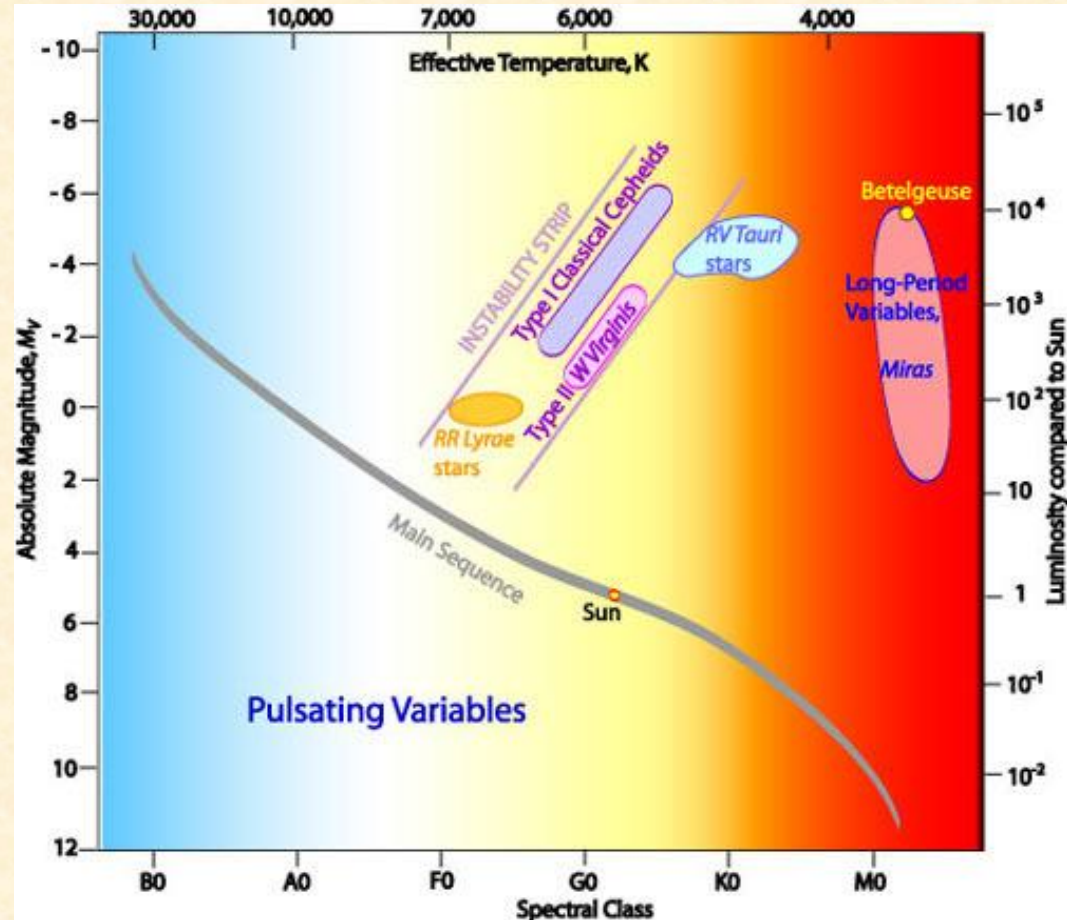
RR Lyraes

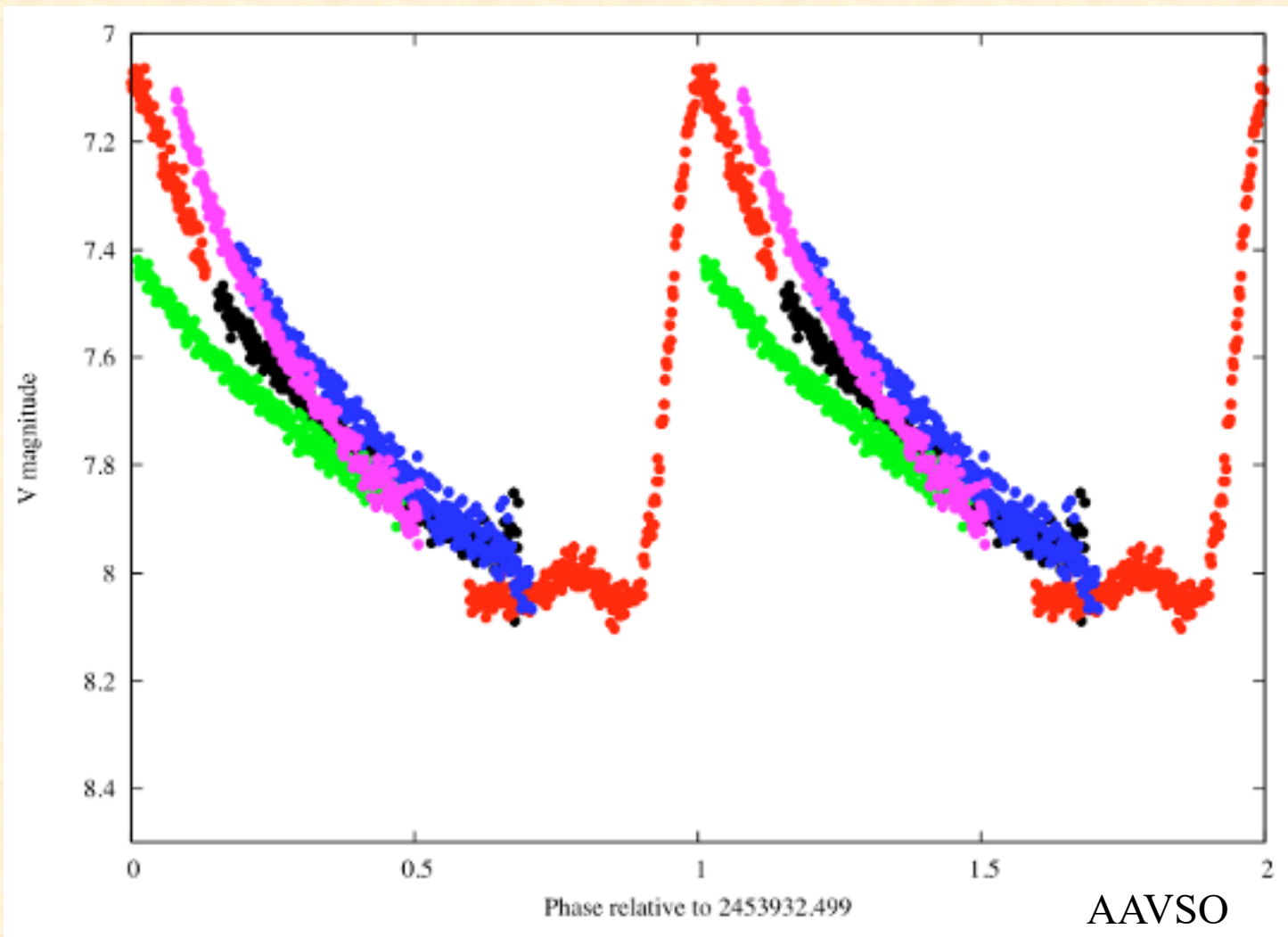
- Horizontal Branch stars
- Population II
- > 80% of variable stars in globular clusters
- Progenitor Mass $0.8M_{\text{Sun}}$

Sub-types:

RR_{ab} , RR_c , RR_d

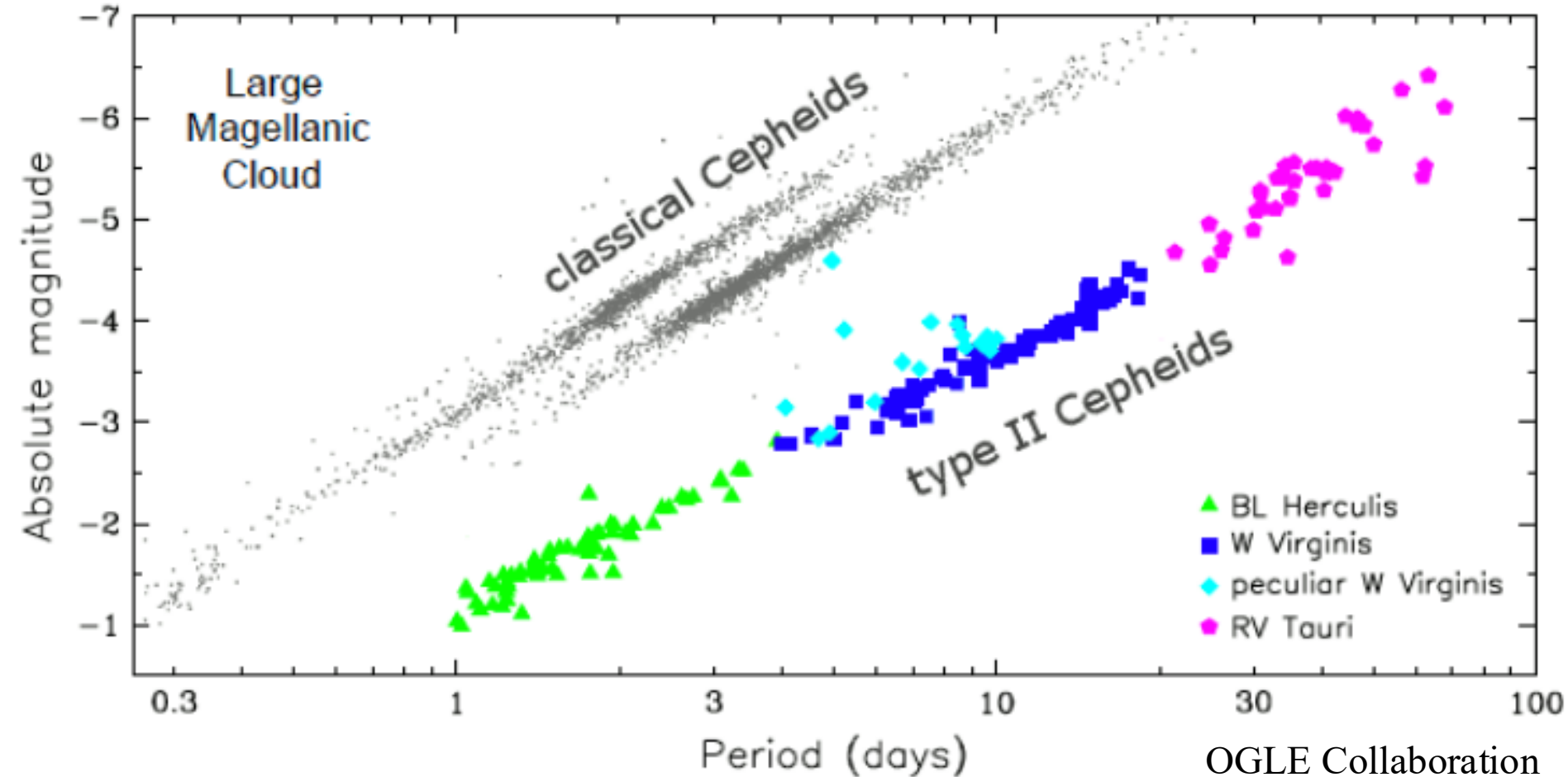
- Slightly different pulsation "modes"
- Different light curve features





RR Lyrae in different modes during different cycles, plotted in different colors
 RRa: Fundamental Mode, star pulses as one
 RRc: First-Overtone Mode, inner and outer layers of stellar envelope move in opposite directions
 RRd: Combination of these two

P-L relation for Cepheids

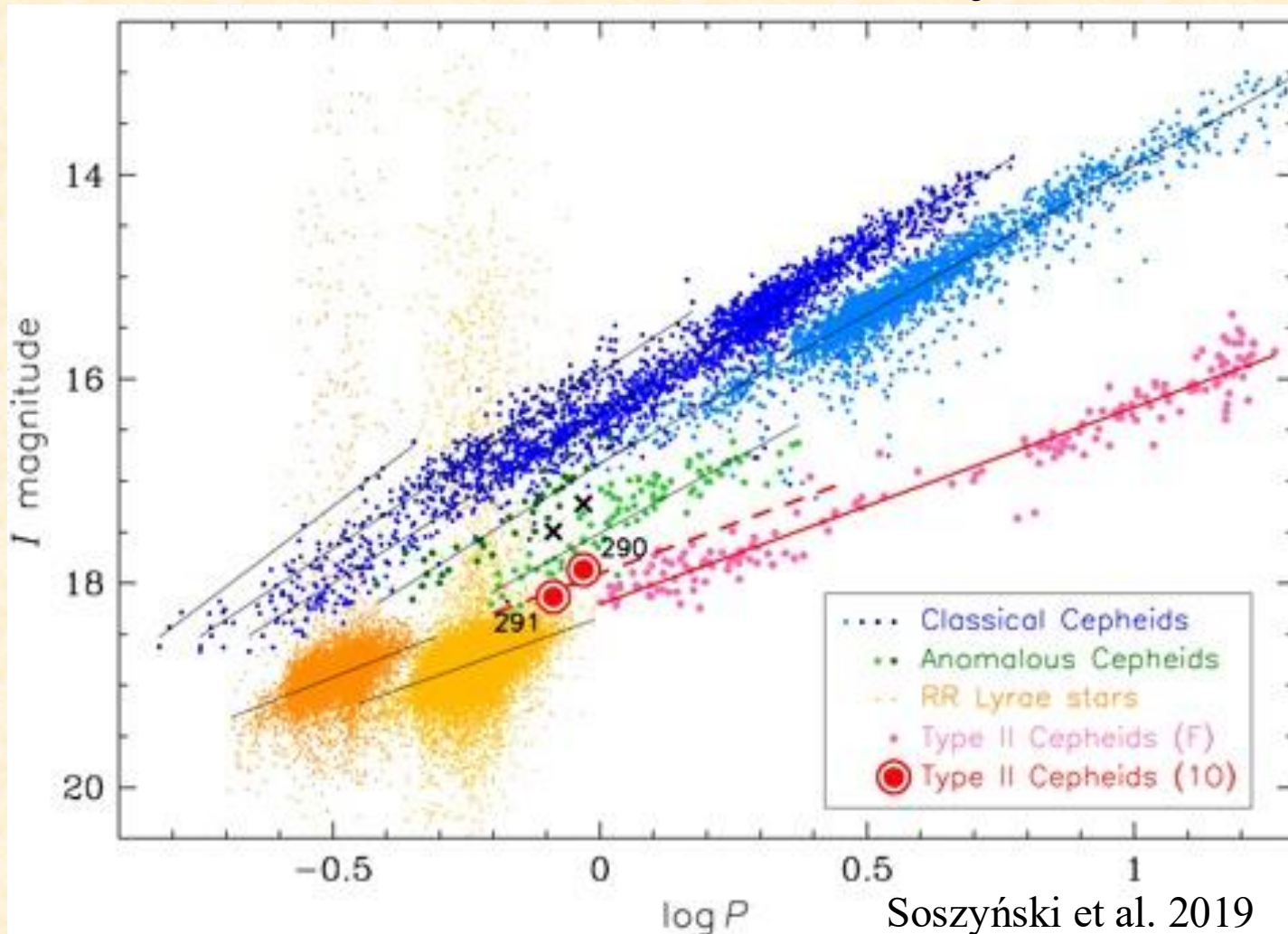


Galactic Cepheids: $M_V = -2.43 \log (P/\text{day}) - 1.62$

Type II Cepheids in LMC: $M = -2.77 \log (P/\text{day}) - 1.29$

Well defined in H-band

P-L relation for RR Lyraes

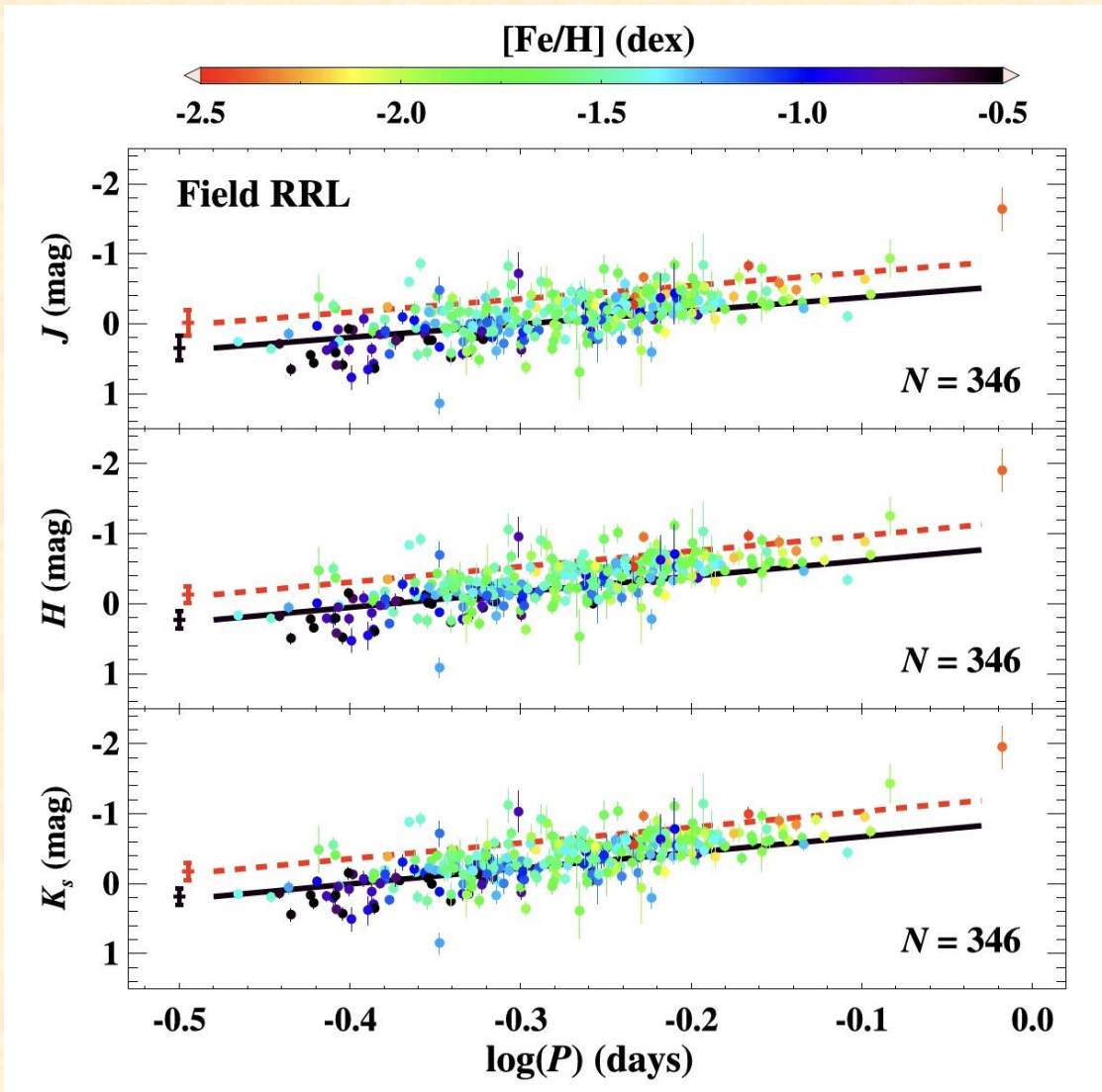


OGLE I and V band LMC radial pulsators

P-L relation for RR Lyraes

MW RR Lyraes in J, H,
and K bands

Red and black lines are
theoretical PIZ
relationships for $[\text{Fe}/\text{H}]$
 $= -2.5$ and -0.5



Cepheids

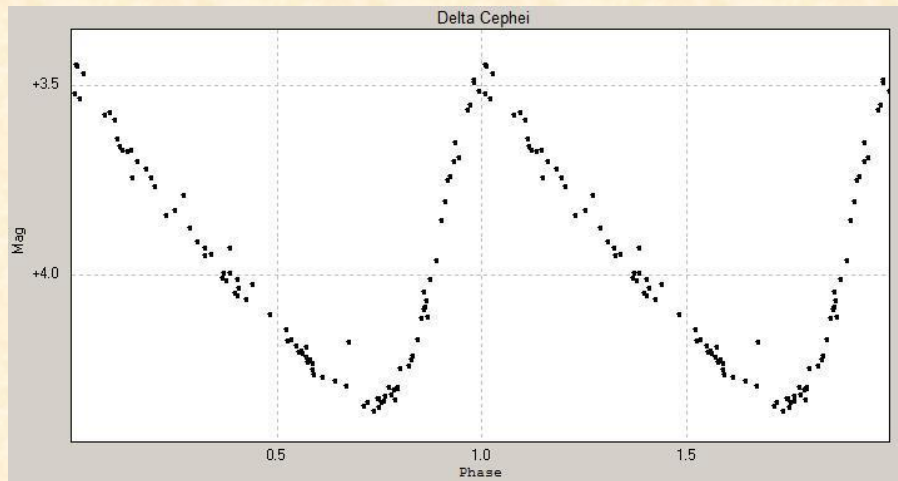
Few days \leq Period \leq 100 days

$-6 \leq M_V \leq -2$

$0.5 \leq \Delta M_V \leq 2$

Up to 30-40 Mpc in optical

Up to 70 Mpc in infrared



δ Cephei phase folded LC

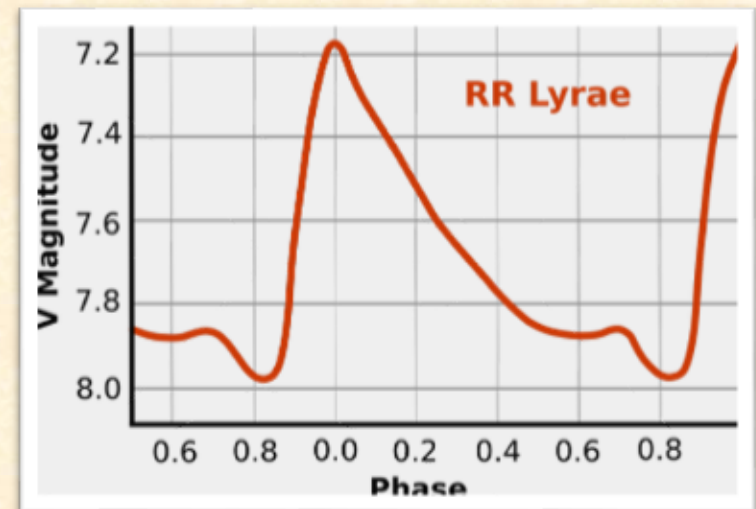
RR Lyraes

Few hours \leq Period \leq 1 day

$M_V \sim 0.6$

$0.3 \leq \Delta M_V \leq 2$

Up to 300 kpc



RR Lyrae phase folded LC

Minutiae & Sources of Error

Cepheids

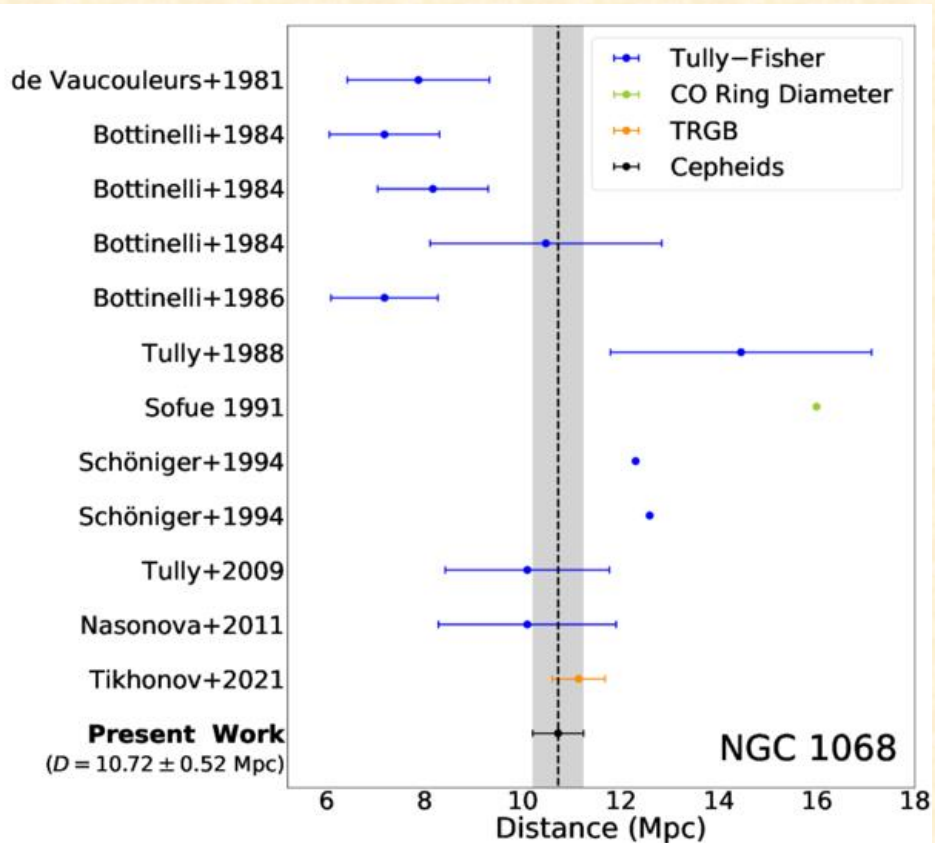
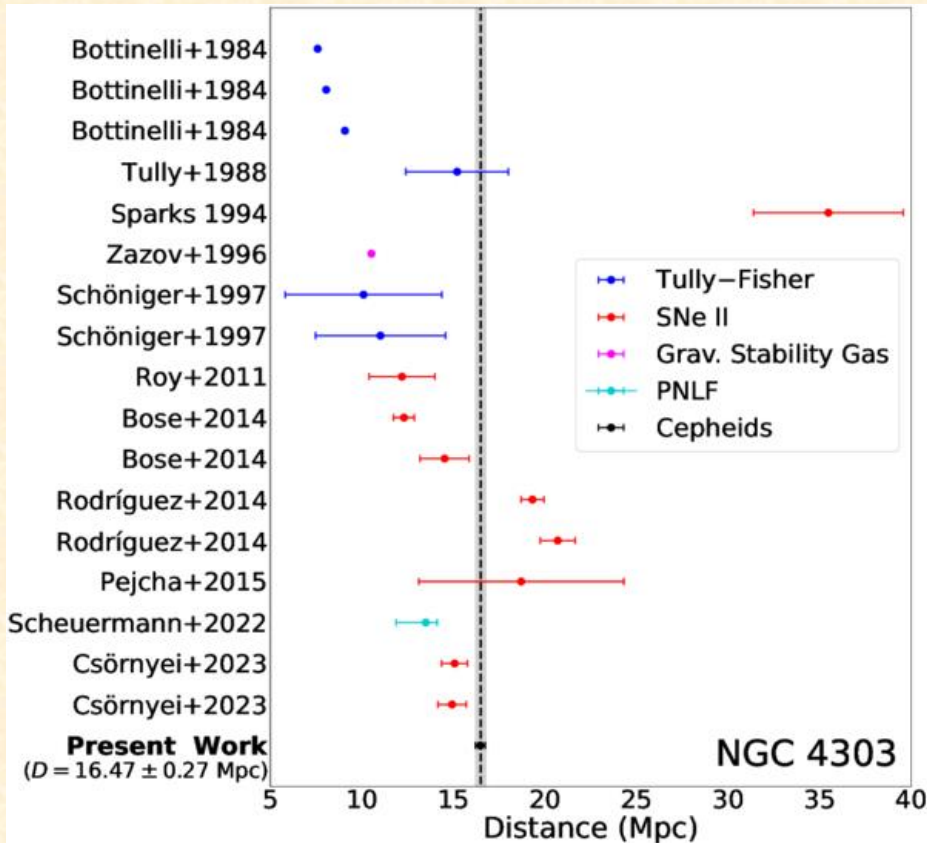
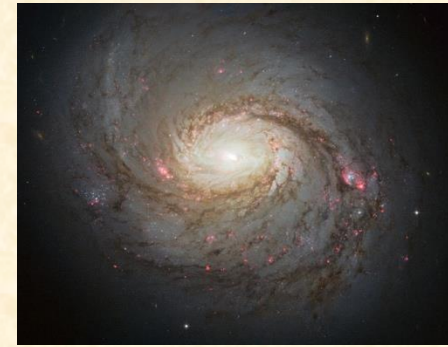
- PL relationship equation is dependent upon photometric band observed.
- PL equation changes with metallicity
- Really a Period-Luminosity-Color relation
- Reddening plays a large role: ISM, IGM, stellar winds

RR-Lyrae

- Pop II RR Lyraes well studied, not other metal populations
- Really a Period-Luminosity-Metallicity relation
- There are Pop I RR Lyraes with high metallicities
 - Experienced high rate of mass loss to become RR Lyraes
- Can change subtype/mode; light curves inconsistent over time



Modern Astronomy



Questions?

