

# Classical pulsators: contrast between pulsation modes

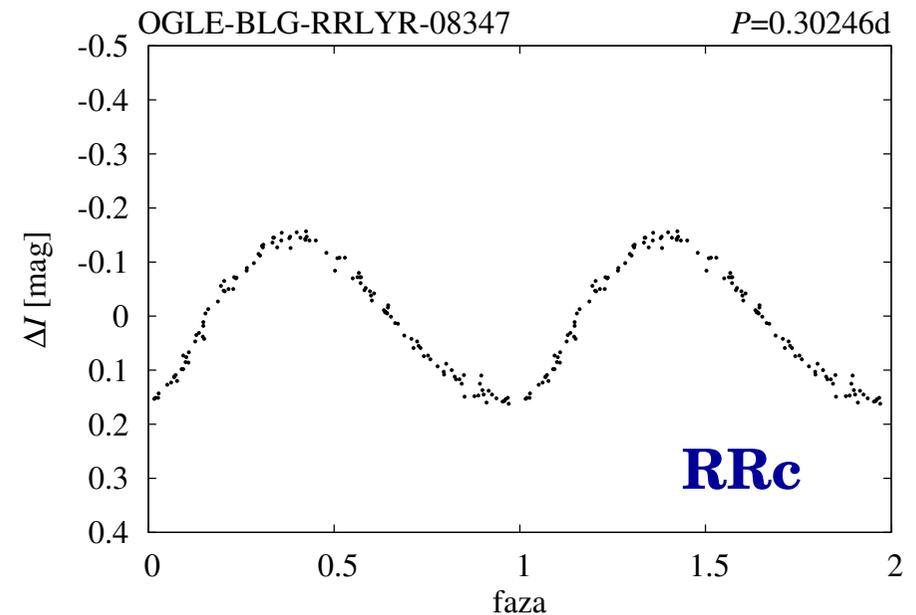
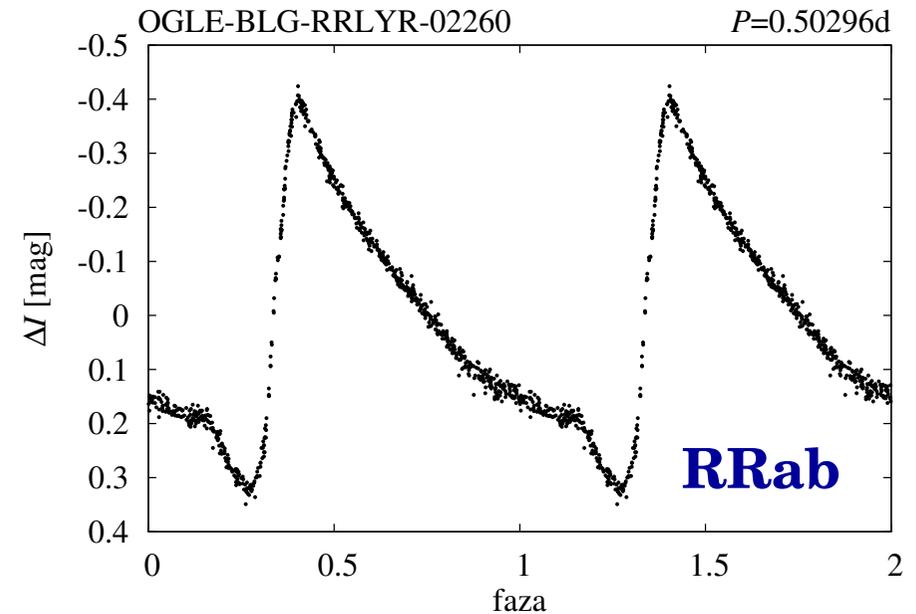
Radek Smolec

Nicolaus Copernicus Astronomical Center, Warsaw



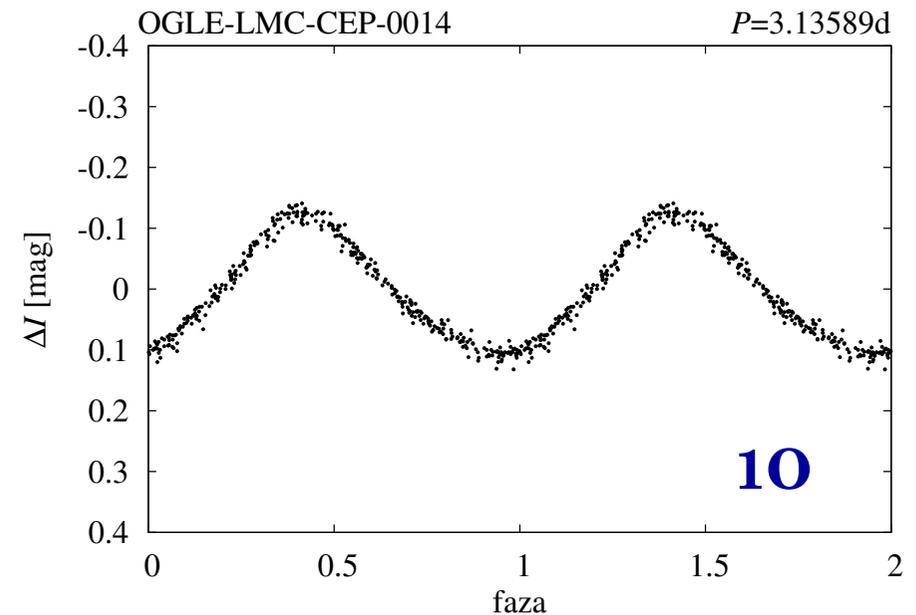
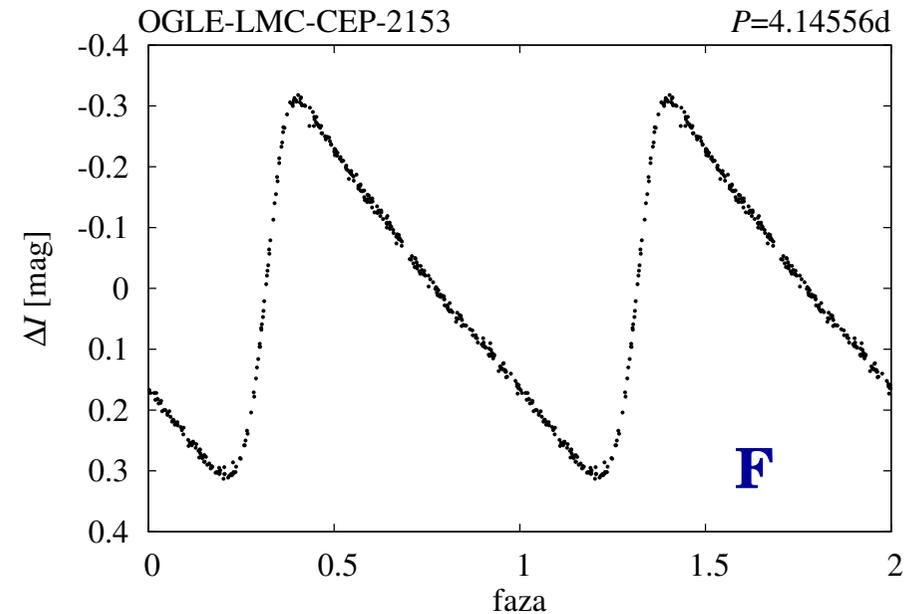
## Cepheids & RR Lyrae stars

- ▶ **RR Lyrae stars** – old, Population II stars, low metallicities, masses in the  $0.5 - 0.7 M_{\odot}$  range
- ▶  $P \sim 0.3 - 1$  d; F mode (RRab) 1O mode (RRc), F+1O (RRd)
- ▶ **classical Cepheids** – young, Population I stars, metal rich and massive  $M > 3 M_{\odot}$
- ▶  $P \sim 1 - 100$  d; F, 1O, F+1O, 1O+2O
- ▶ **type II Cepheids** – similar to, but brighter than RR Lyr stars
- ▶ BL Her ( $P \sim 1 - 4$  d), W Vir ( $P \sim 4 - 20$  d), RV Tau ( $P \gtrsim 20$  d)



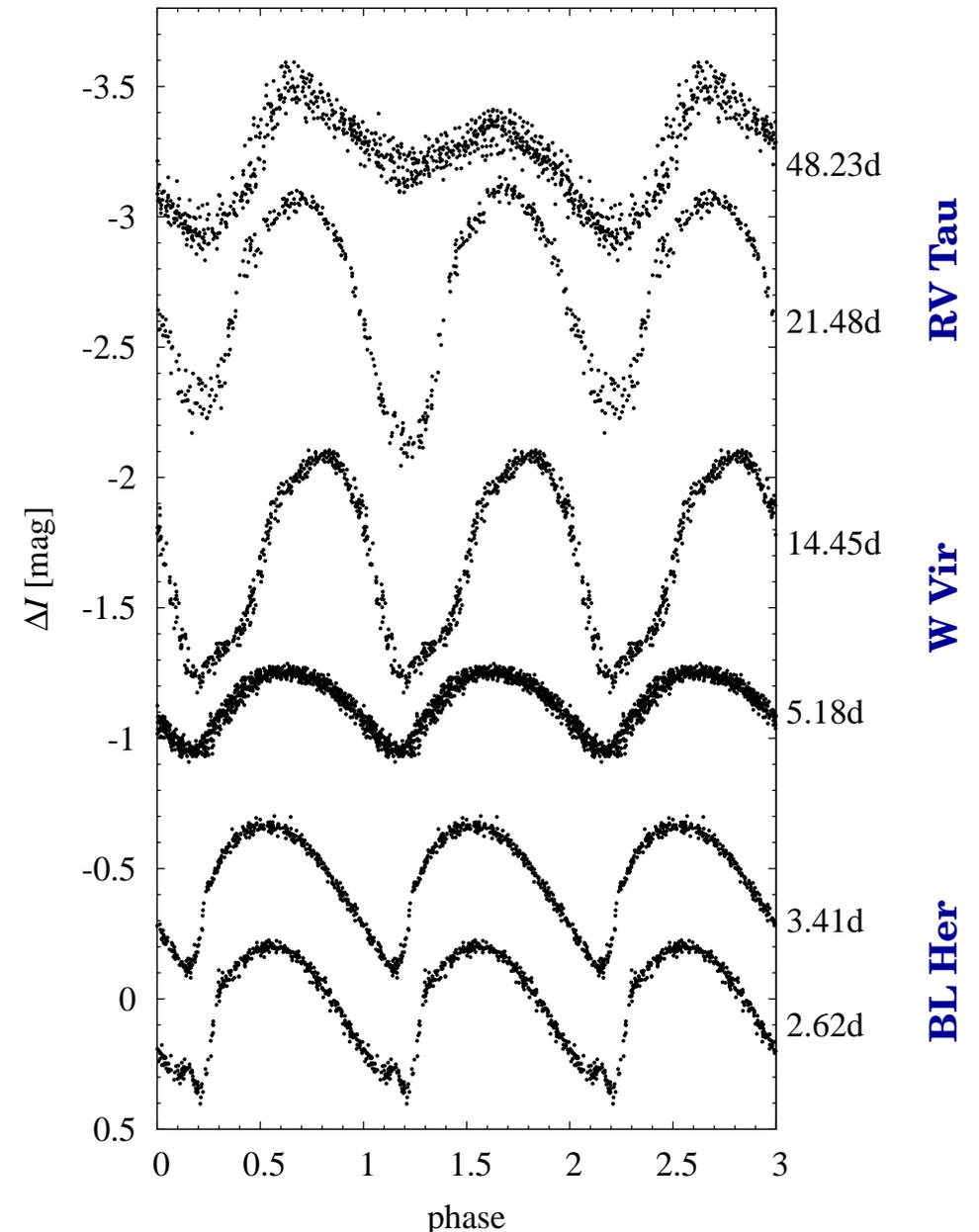
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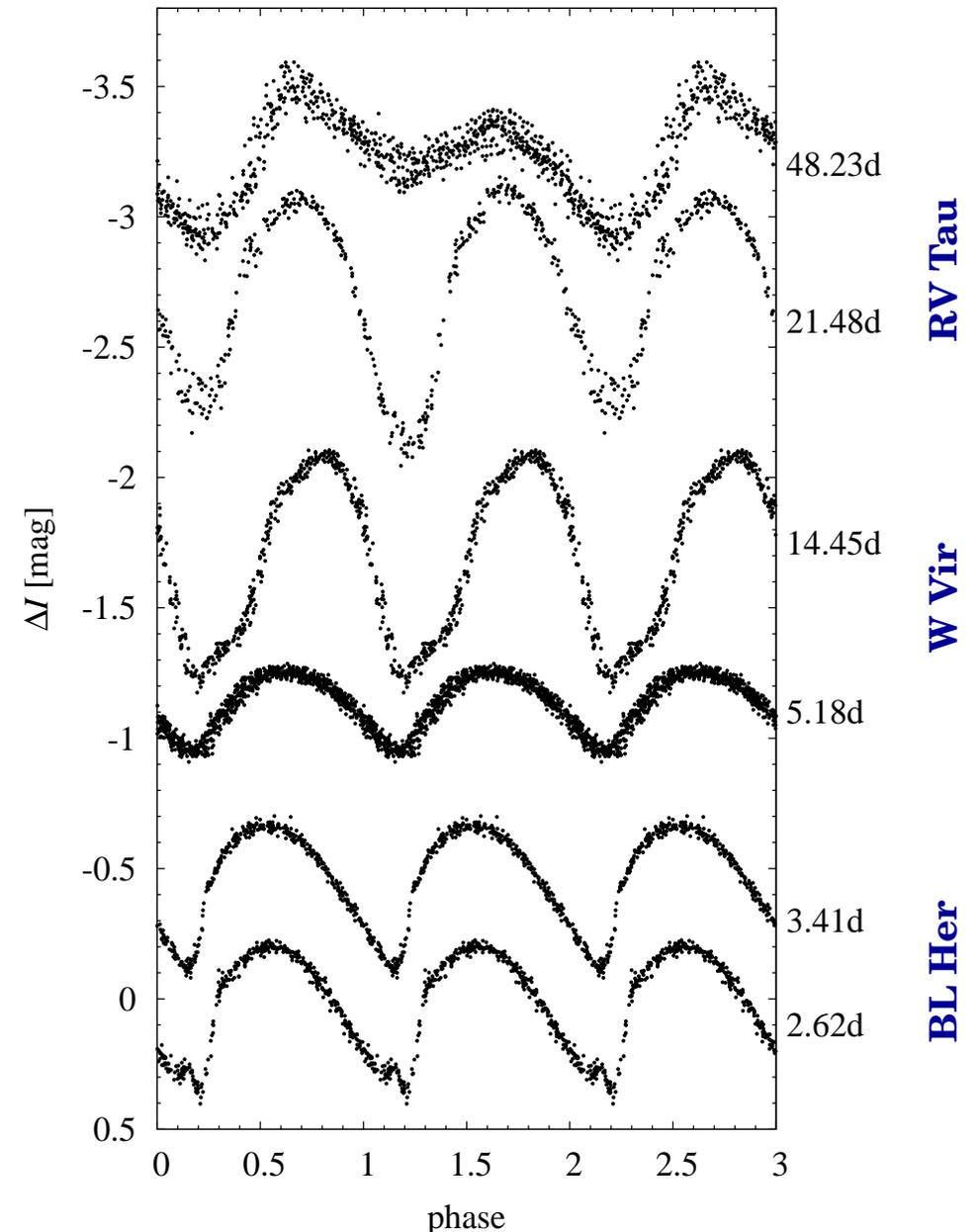
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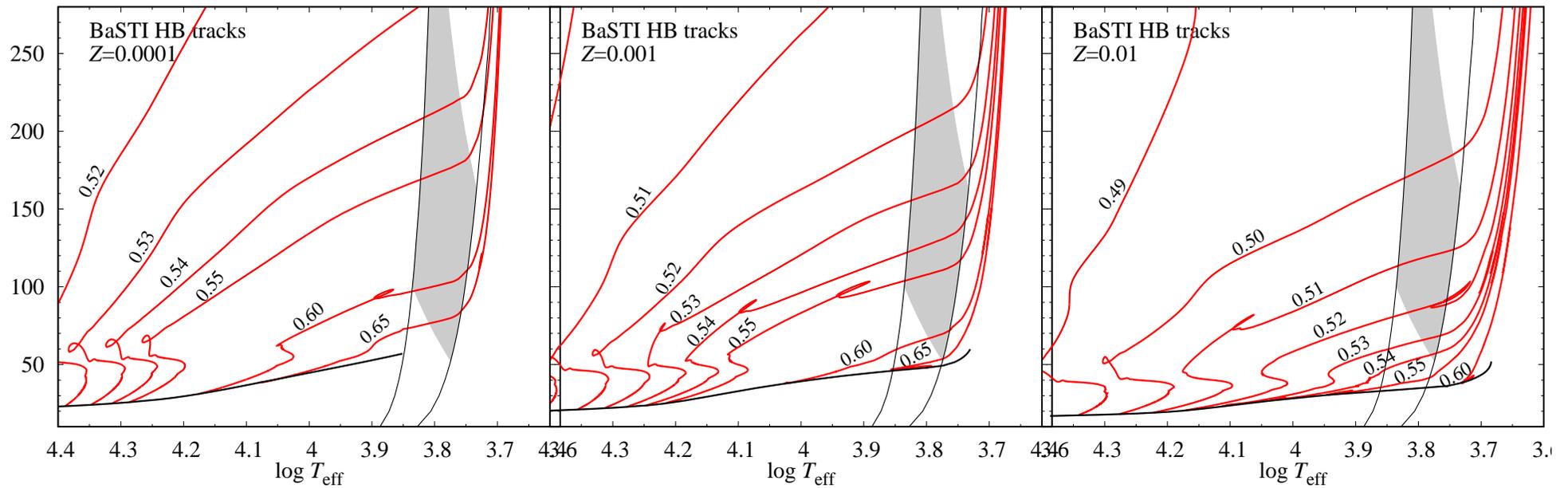


## Extreme contrast between pulsation modes: type II Cepheids

- ★ Till recently, all known type II Cepheids were fundamental mode pulsators. 10 stars and double-mode pulsators were not known.



## RR Lyrae and type II Cepheids – evolutionary picture

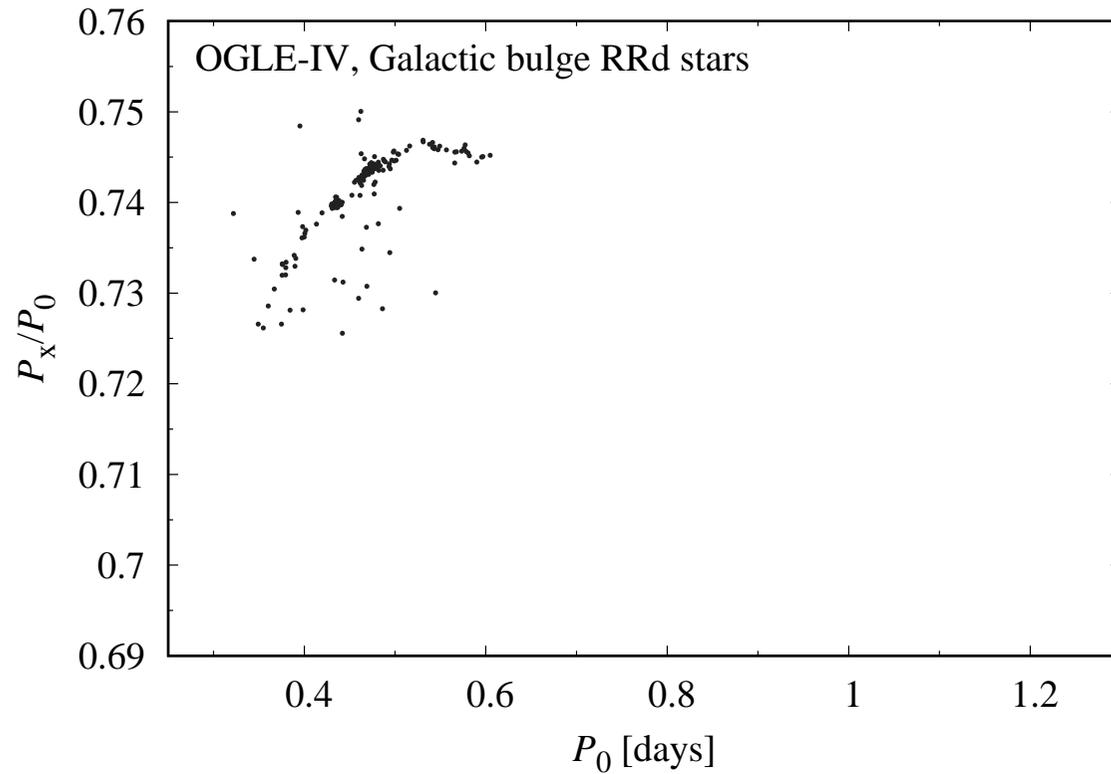


- ▶ Evolutionary scenarios: quite certain for BL Her stars, more unclear for W Virs
- ▶ Borderlines between different groups of pulsators are conventional. For RR Lyr and BL Her the commonly adopted borderline is at  $P_F = 1$  d.

Smolec et al. (2012), *MNRAS*



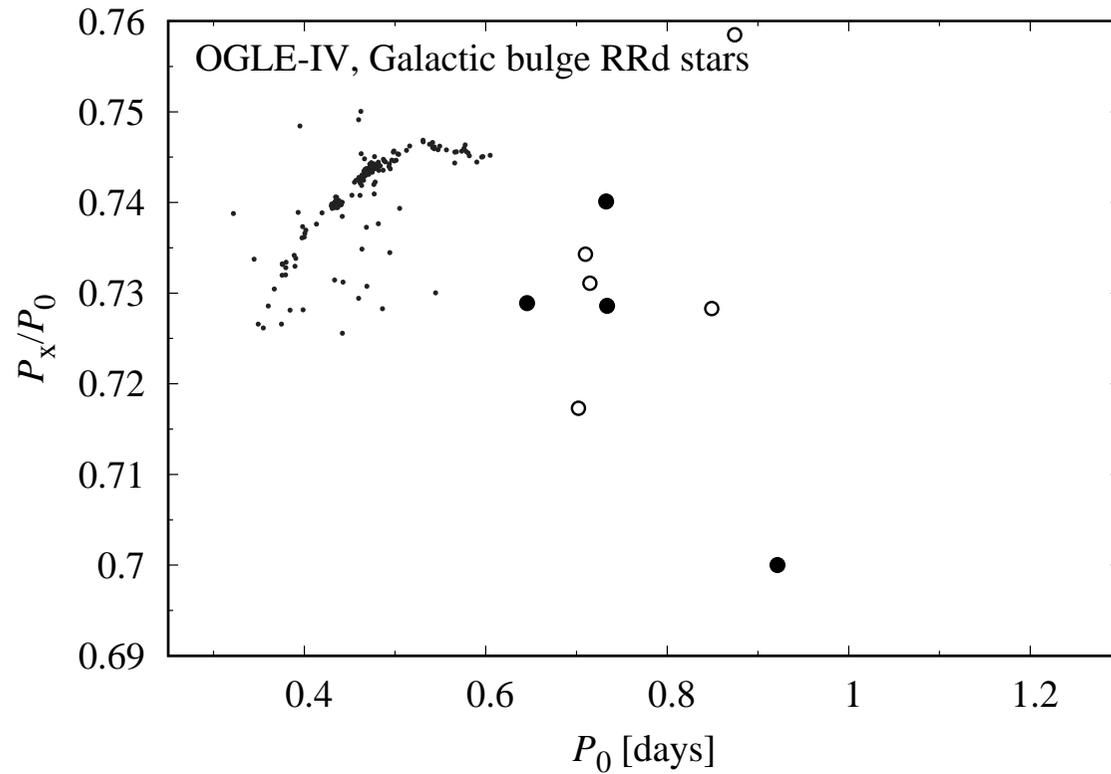
## First double-mode F+10 BL Her stars



► Galactic bulge RRd stars



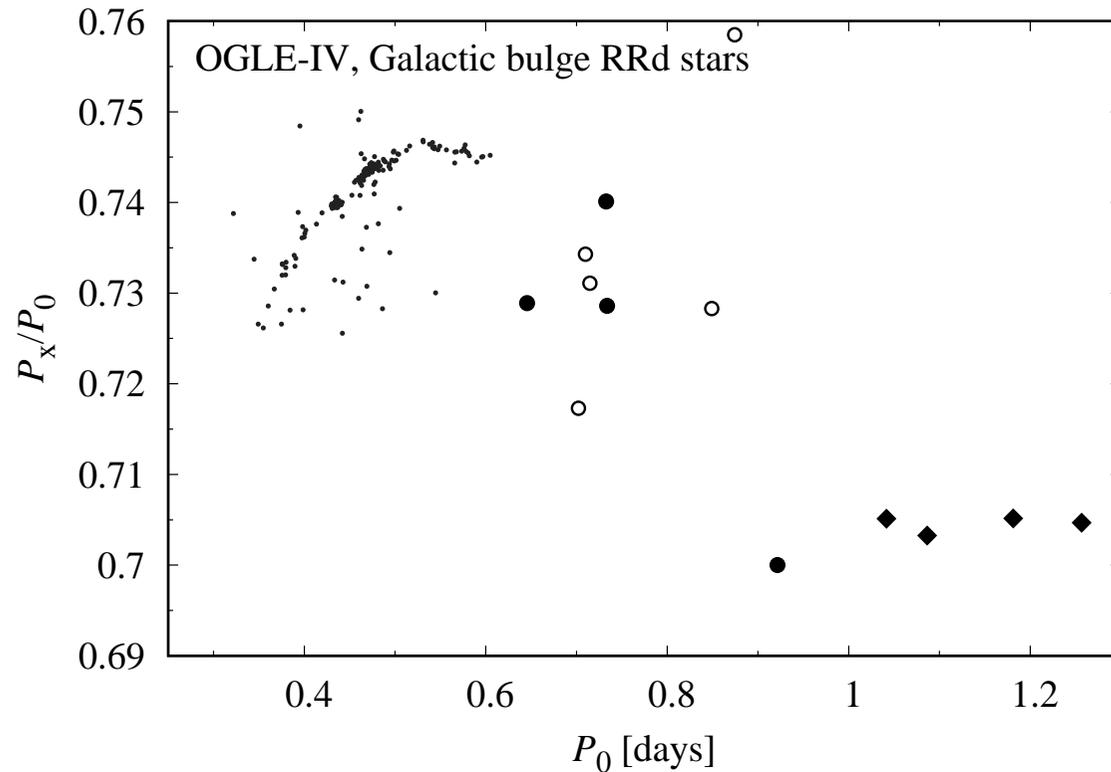
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- ▶ Galactic bulge RRd stars
- ▶ extreme RRd stars (Smolec et al. 2016)



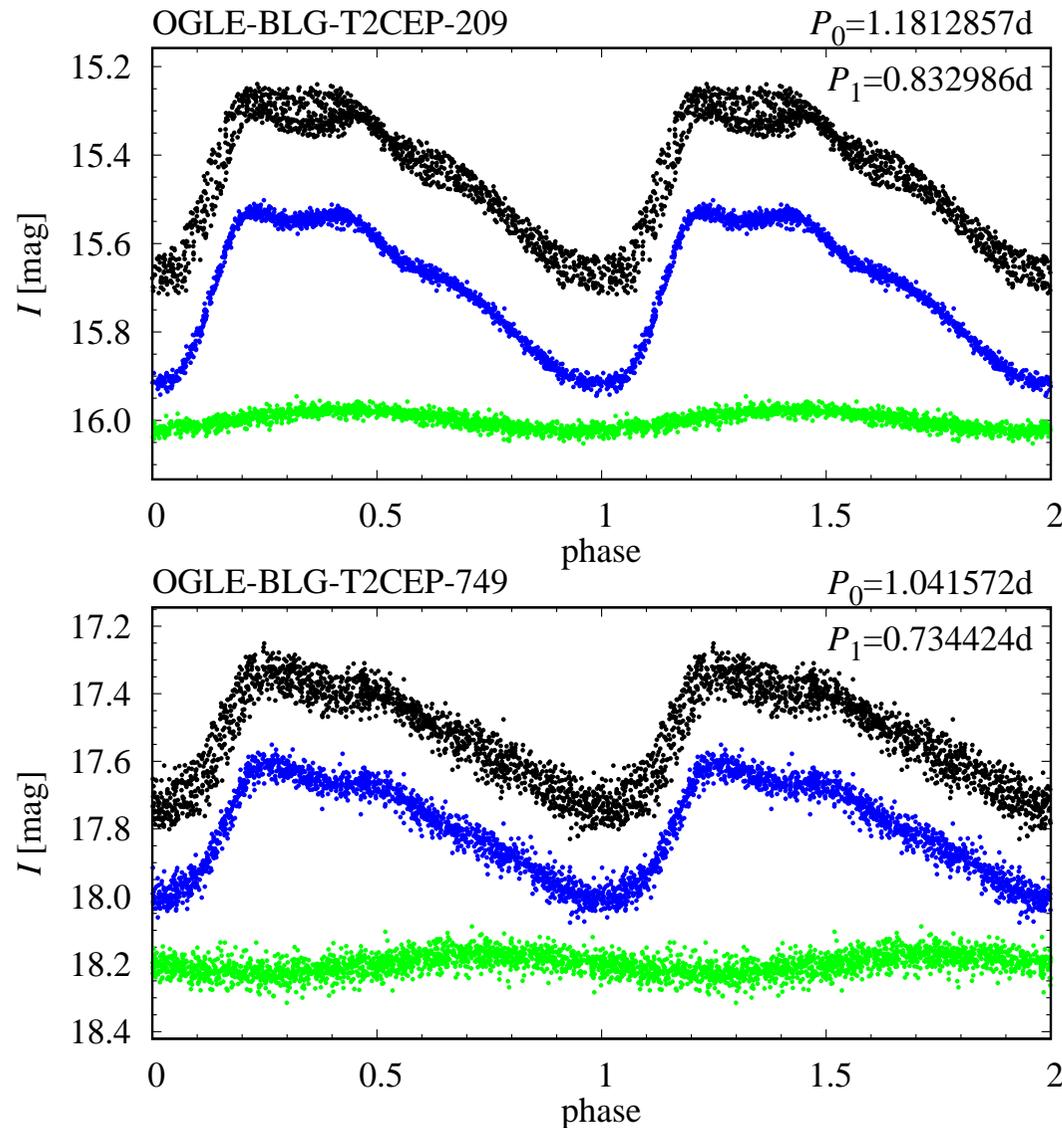
## First double-mode F+10 BL Her stars



- ▶ Galactic bulge RRd stars
- ▶ extreme RRd stars (Smolec et al. 2016)
- ▶ first four F+10 BL Her stars (Smolec et al. 2018; Udalski et al. 2019)



## First double-mode F+10 BL Her stars



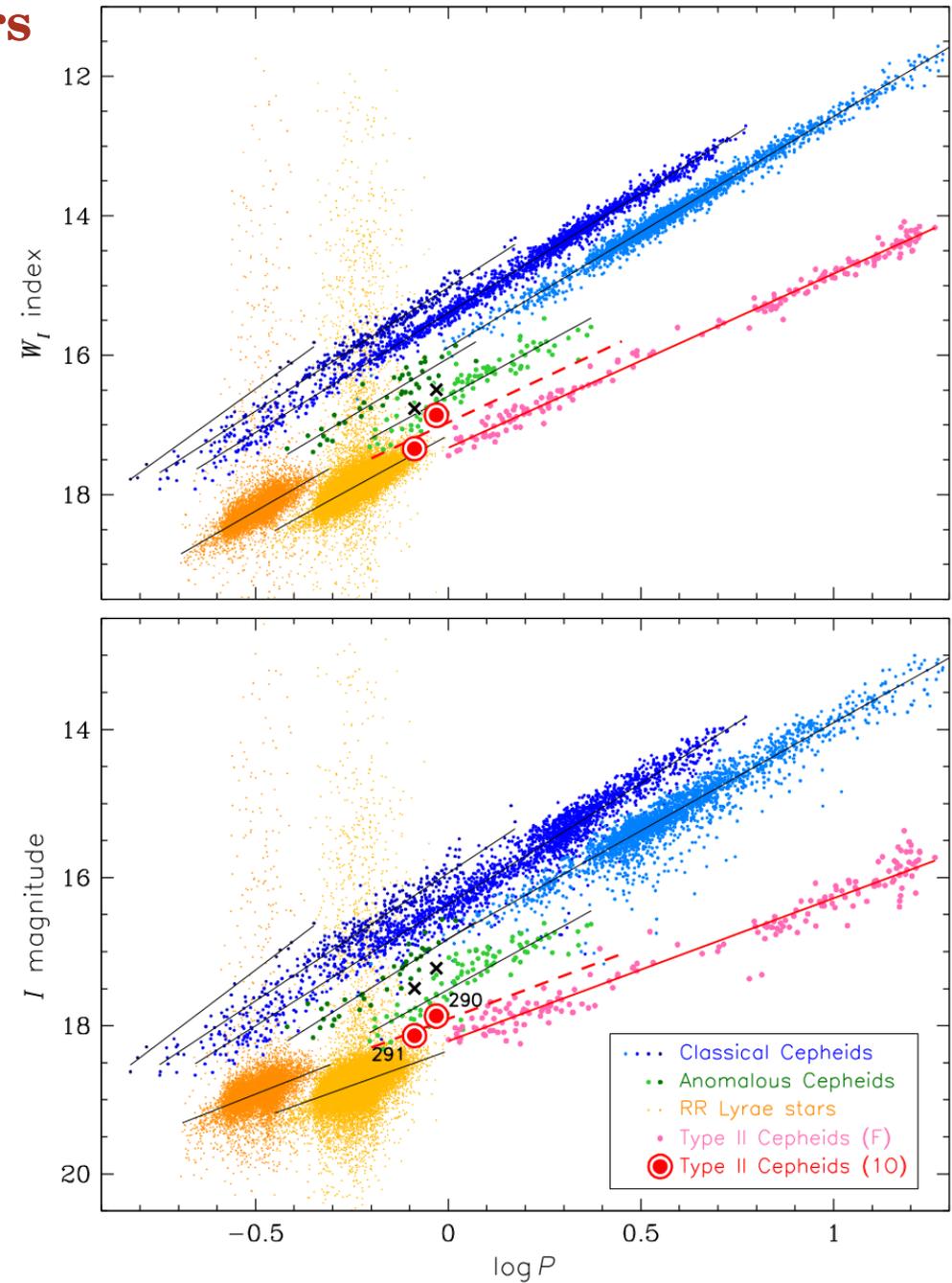
- ▶ fundamental mode dominates
- ▶ 10 is of much lower amplitude may be described with single sine wave
- ▶ light curve morphology is quite similar to extreme RRd stars
- ★ Double-mode stars provide **motivation to look for single-mode 10 stars**
  - ▶ major problem: light curves of 10 pulsators are not too specific

Smolec et al. (2018), *MNRAS*



## First single-mode 10 BL Her stars

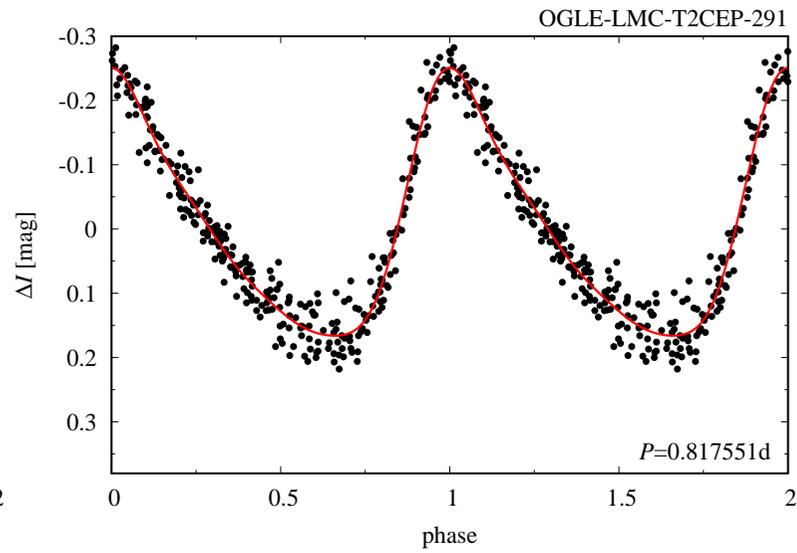
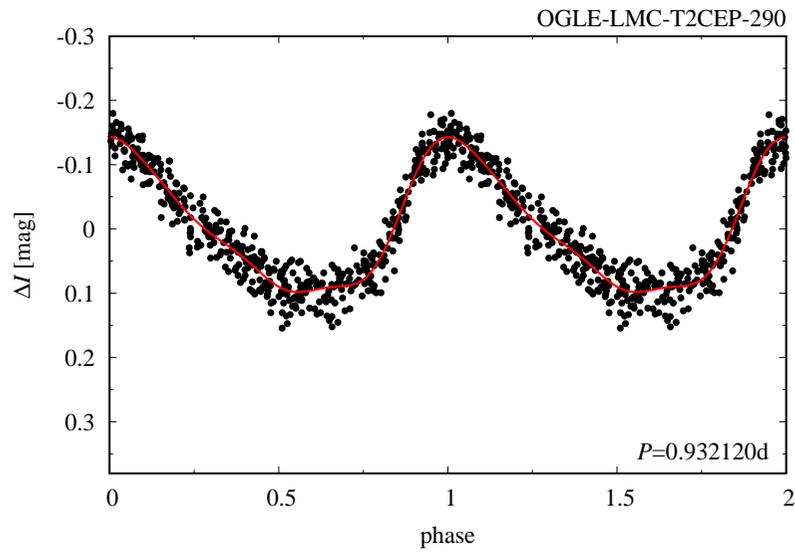
- ▶ search based on  $P - L$  relations
- ▶ two candidates detected in th LMC



Soszyński et al. (2019), *ApJ*



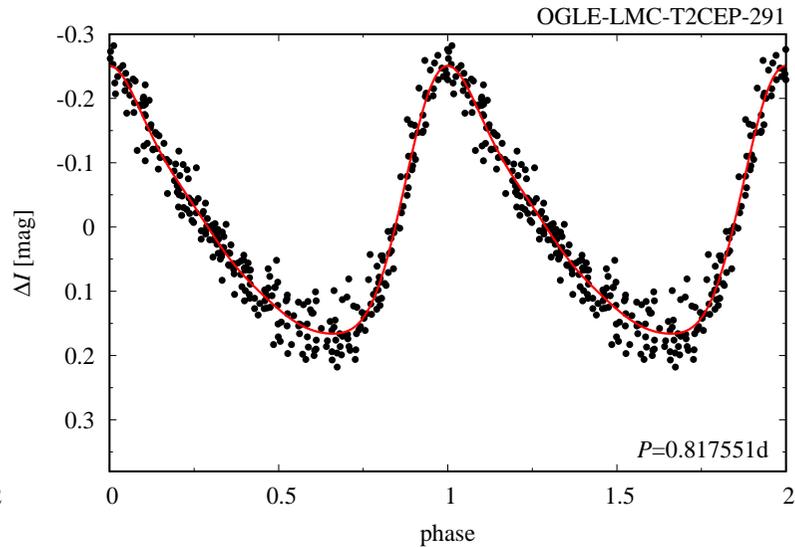
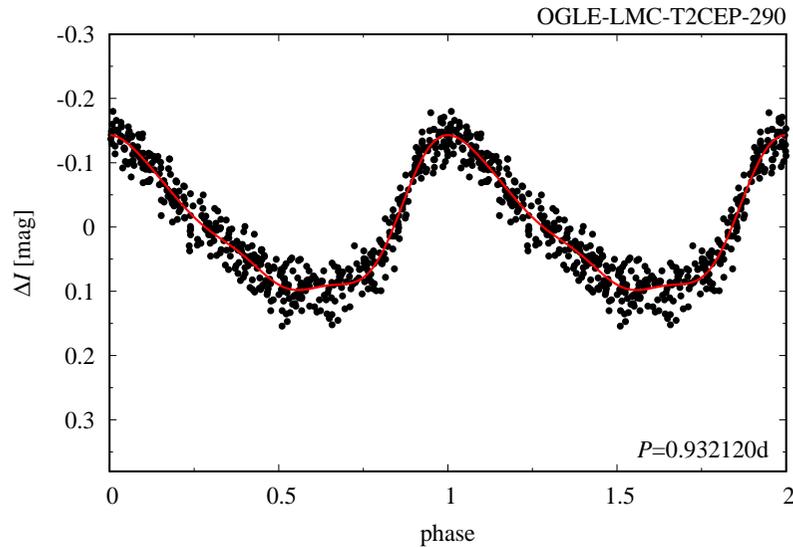
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Soszyński et al. (2019), *ApJ*

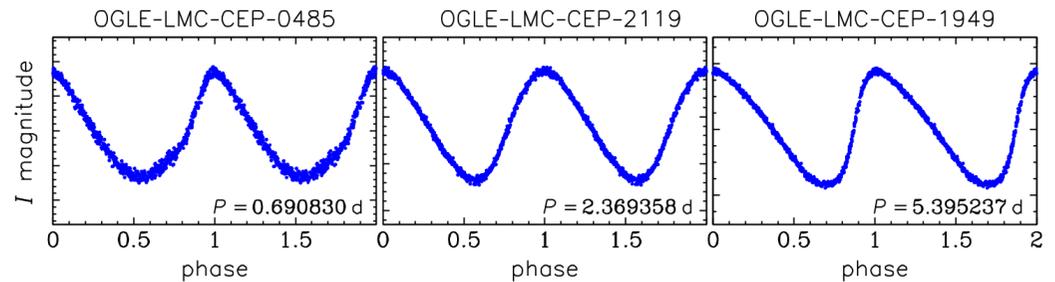


# First single-mode 10 BL Her stars

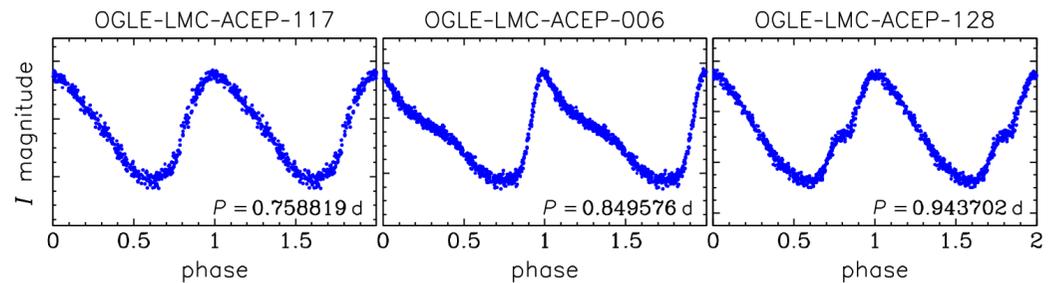


► quite similar to other 10 pulsators

Classical Cepheids (first-overtone mode)



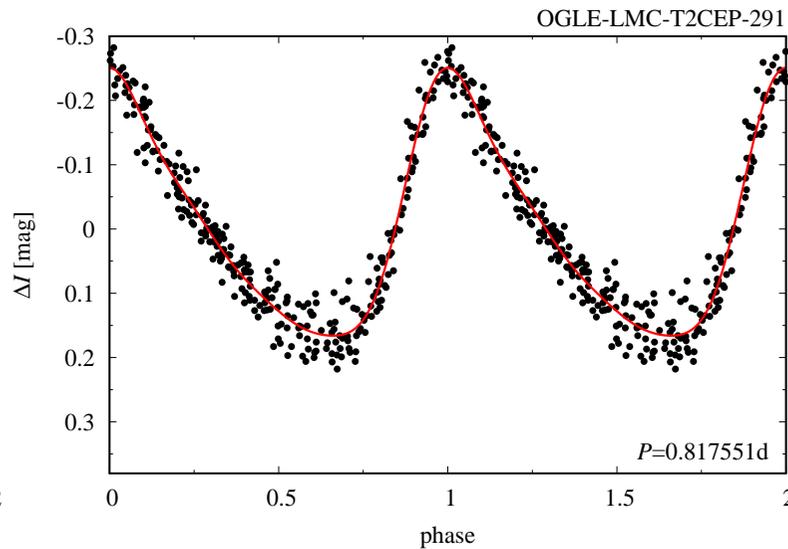
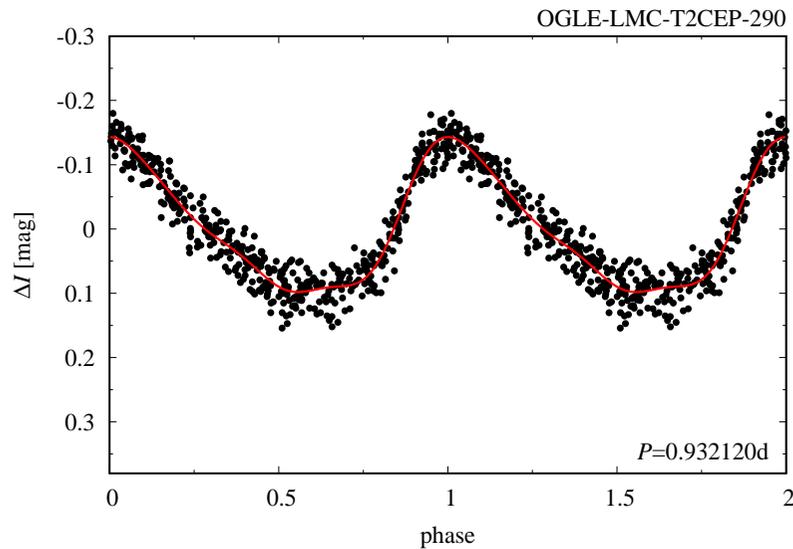
Anomalous Cepheids (first-overtone mode)



Soszyński et al. (2019), *ApJ*

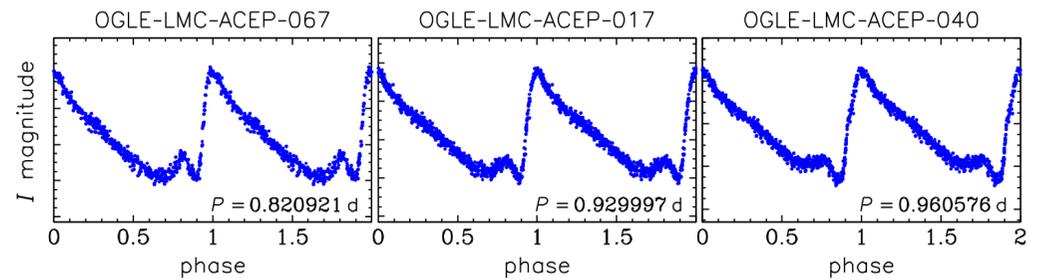


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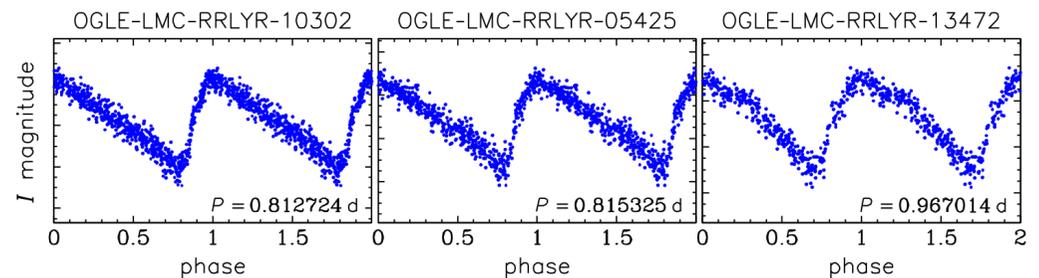


- ▶ quite similar to other 10 pulsators
- ▶ and not to F mode pulsators
- ▶ this is further quantified with Fourier decomposition parameters

Anomalous Cepheids (fundamental mode)



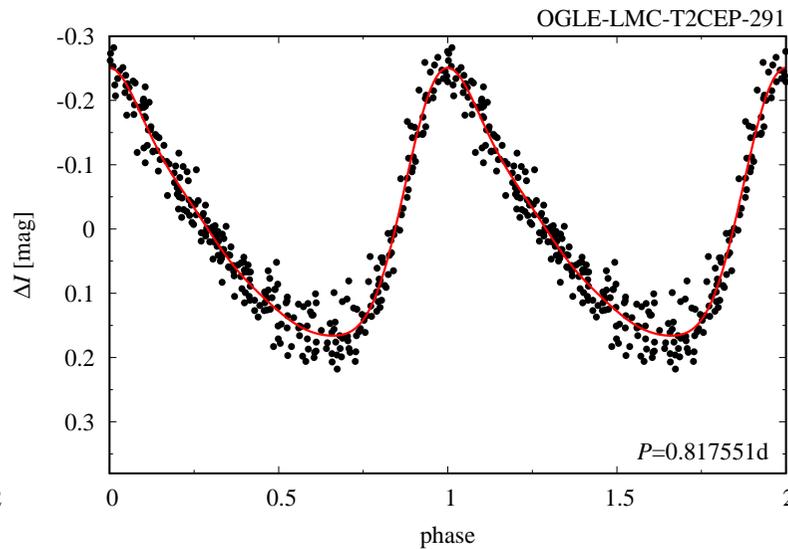
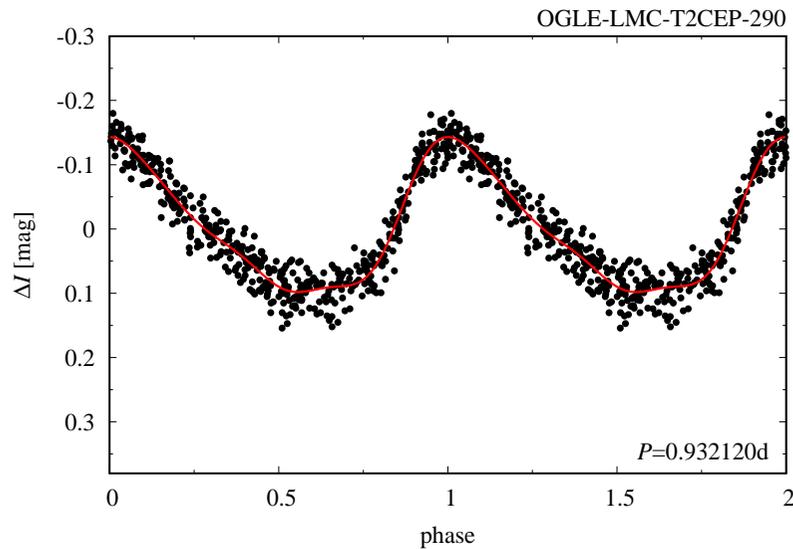
RR Lyrae (RRab) stars



Soszyński et al. (2019), *ApJ*



## First single-mode 10 BL Her stars

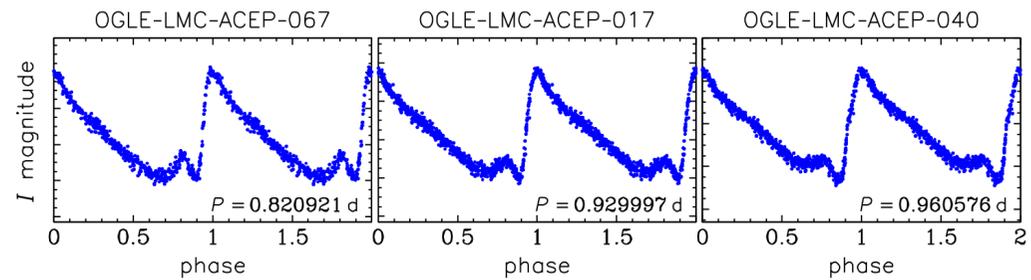


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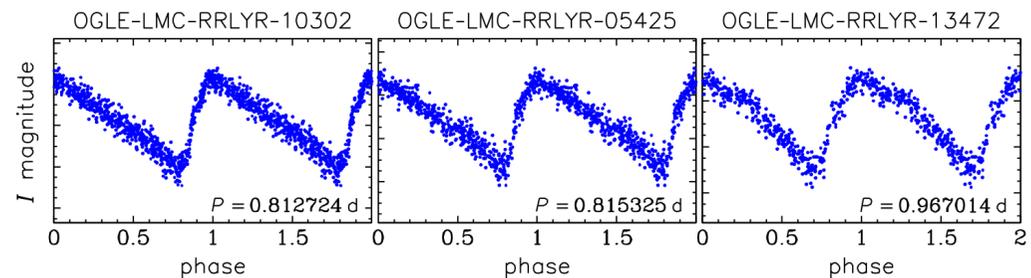
★ **Lets model!**

Soszyński et al. (2019), *ApJ*

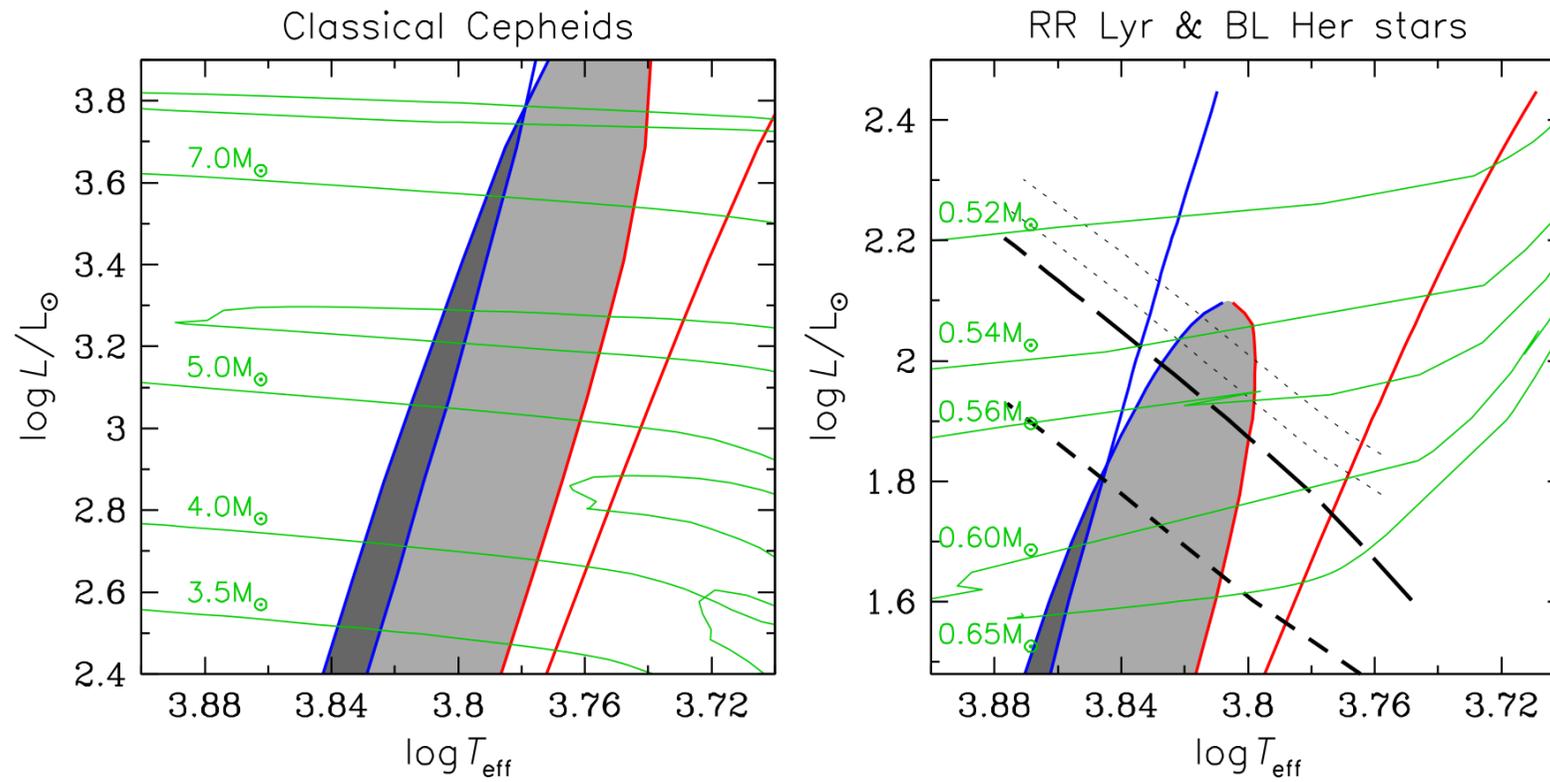
Anomalous Cepheids (fundamental mode)



RR Lyrae (RRab) stars



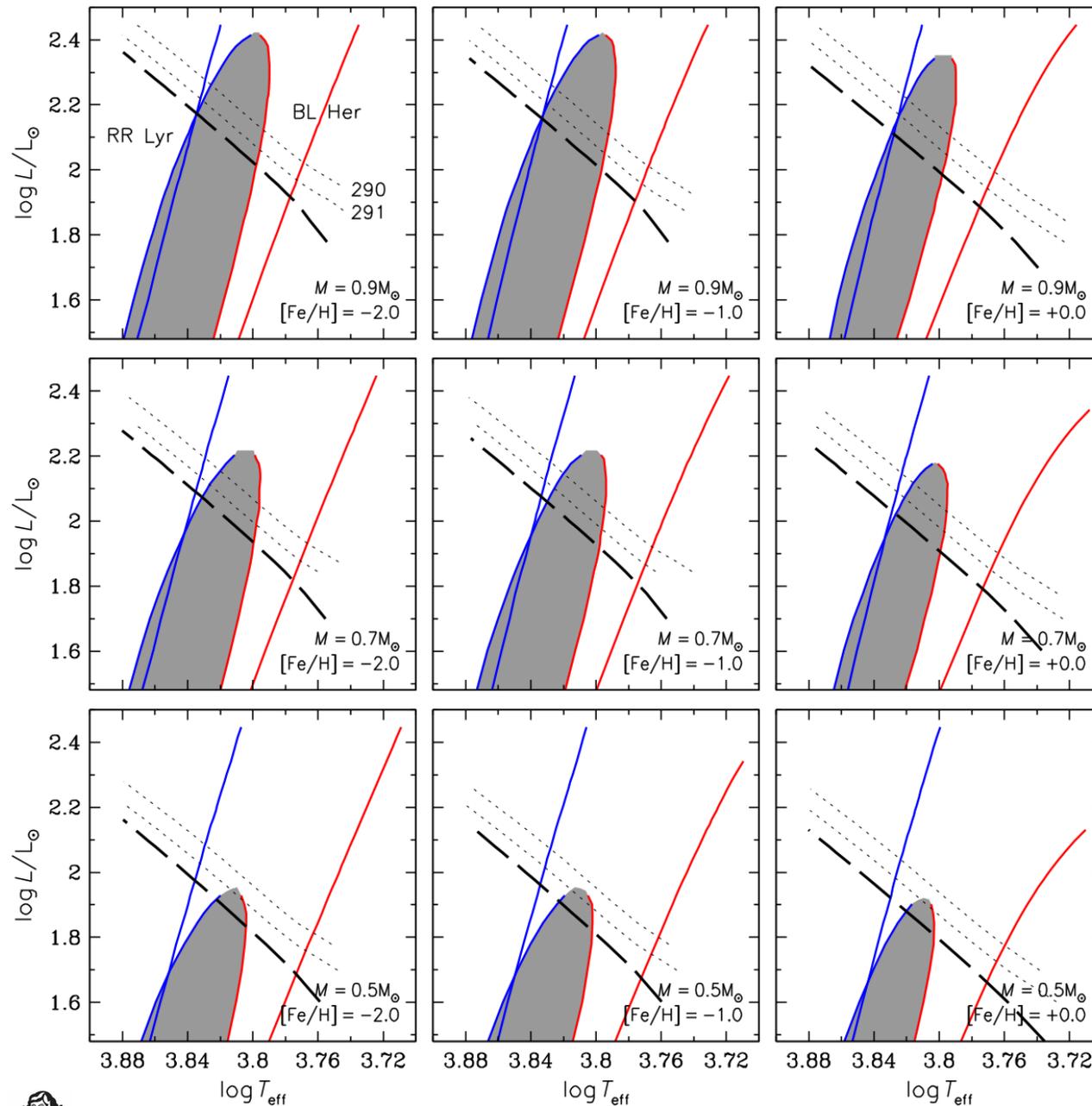
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Soszyński et al. (2019), *ApJ*



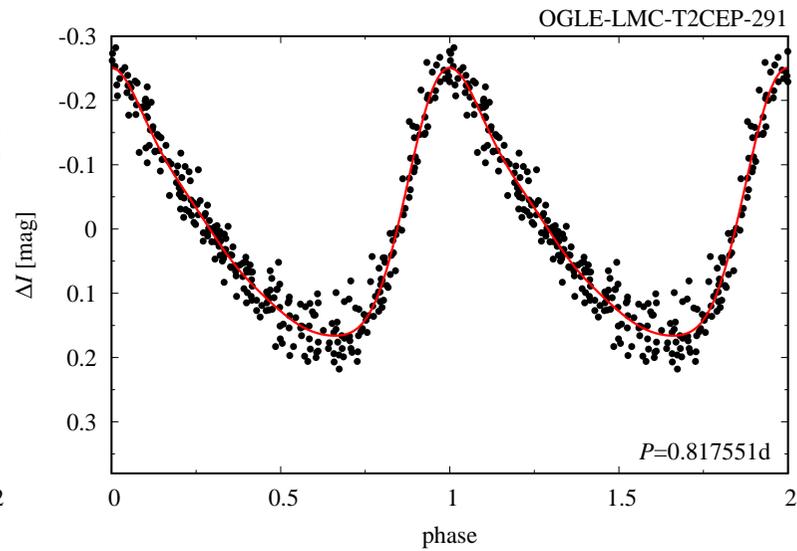
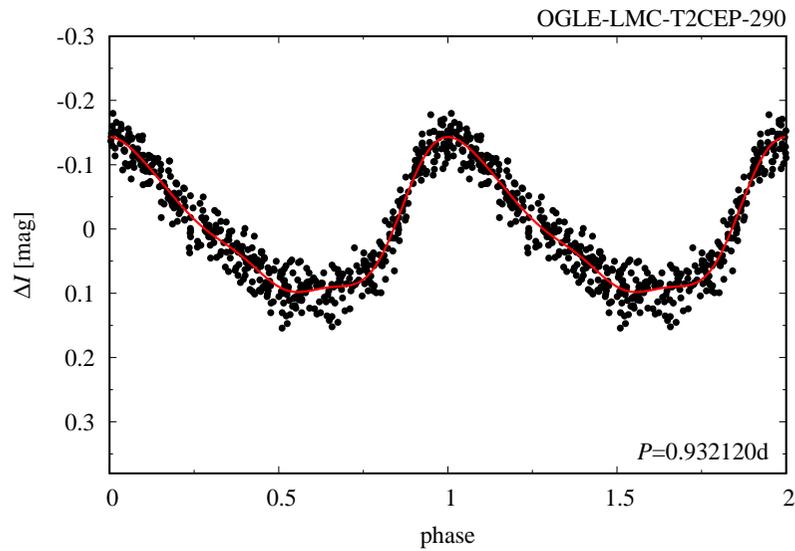
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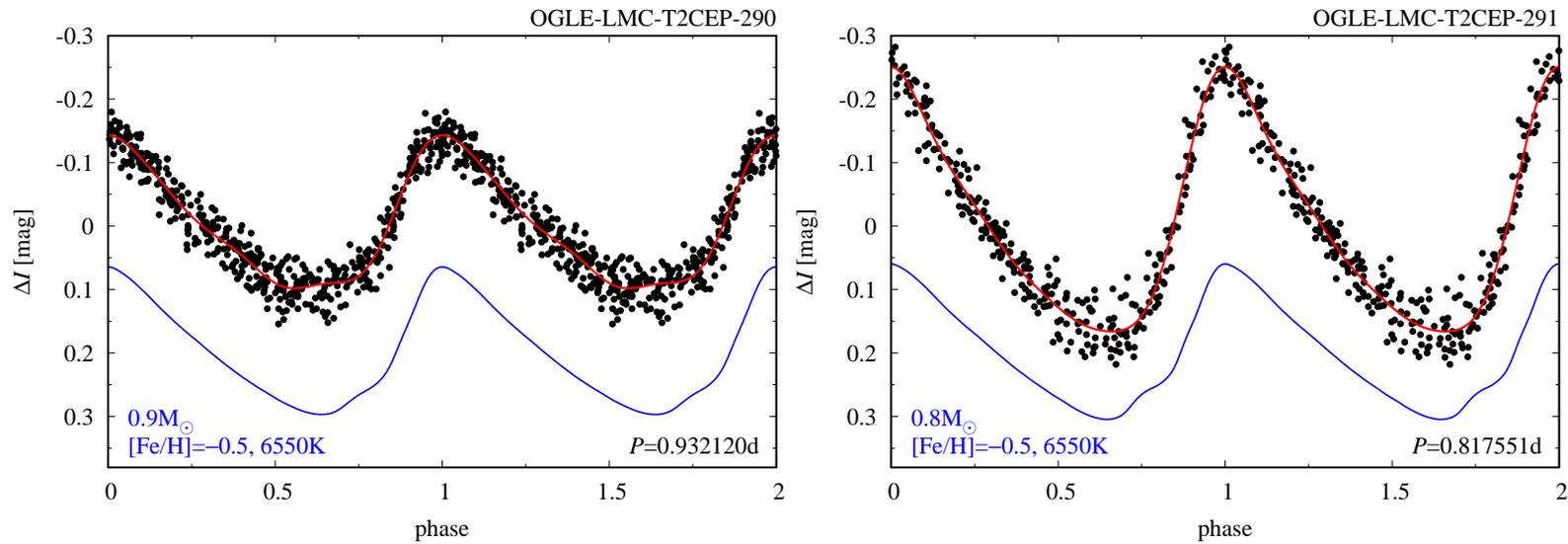
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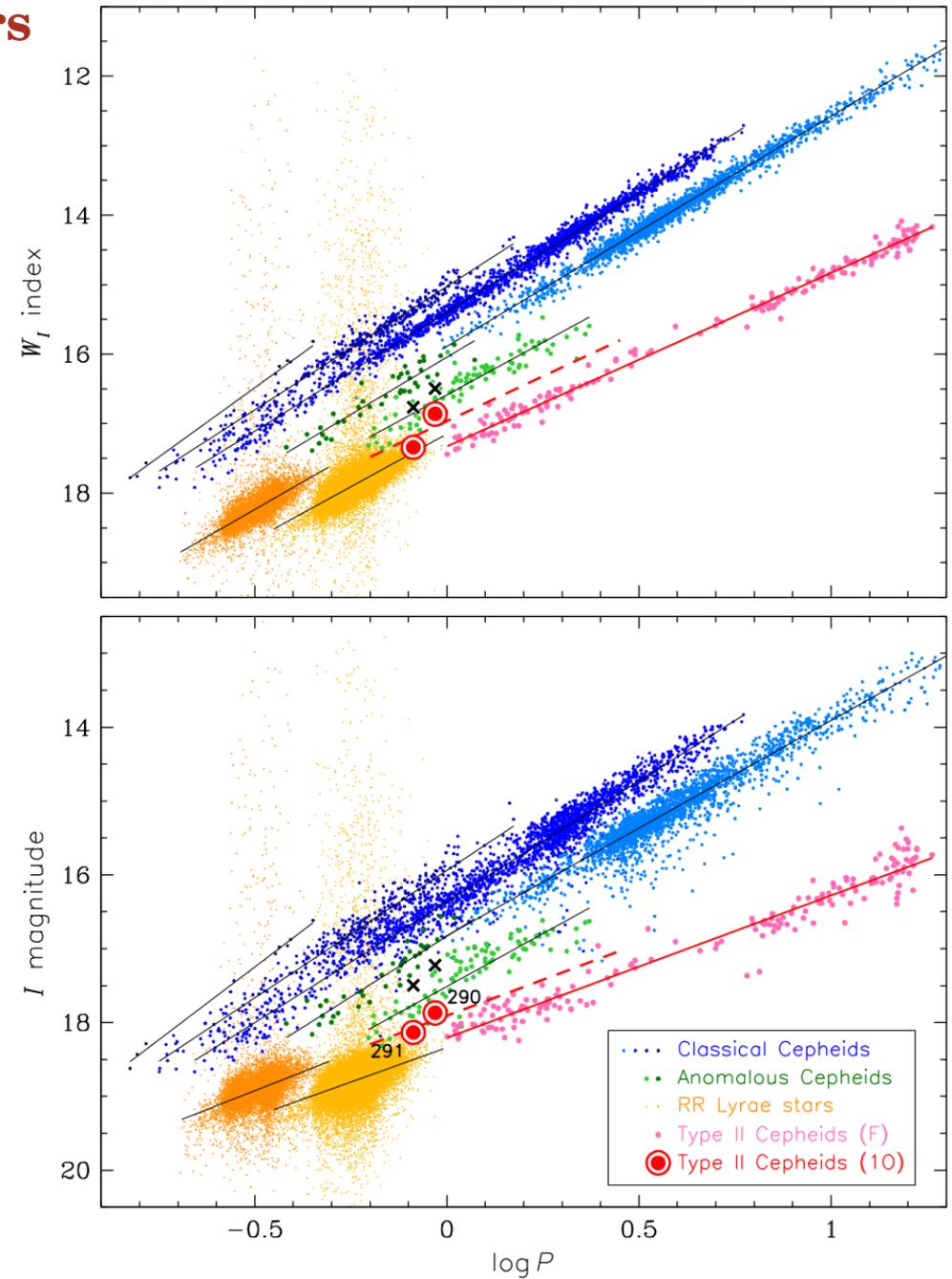
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