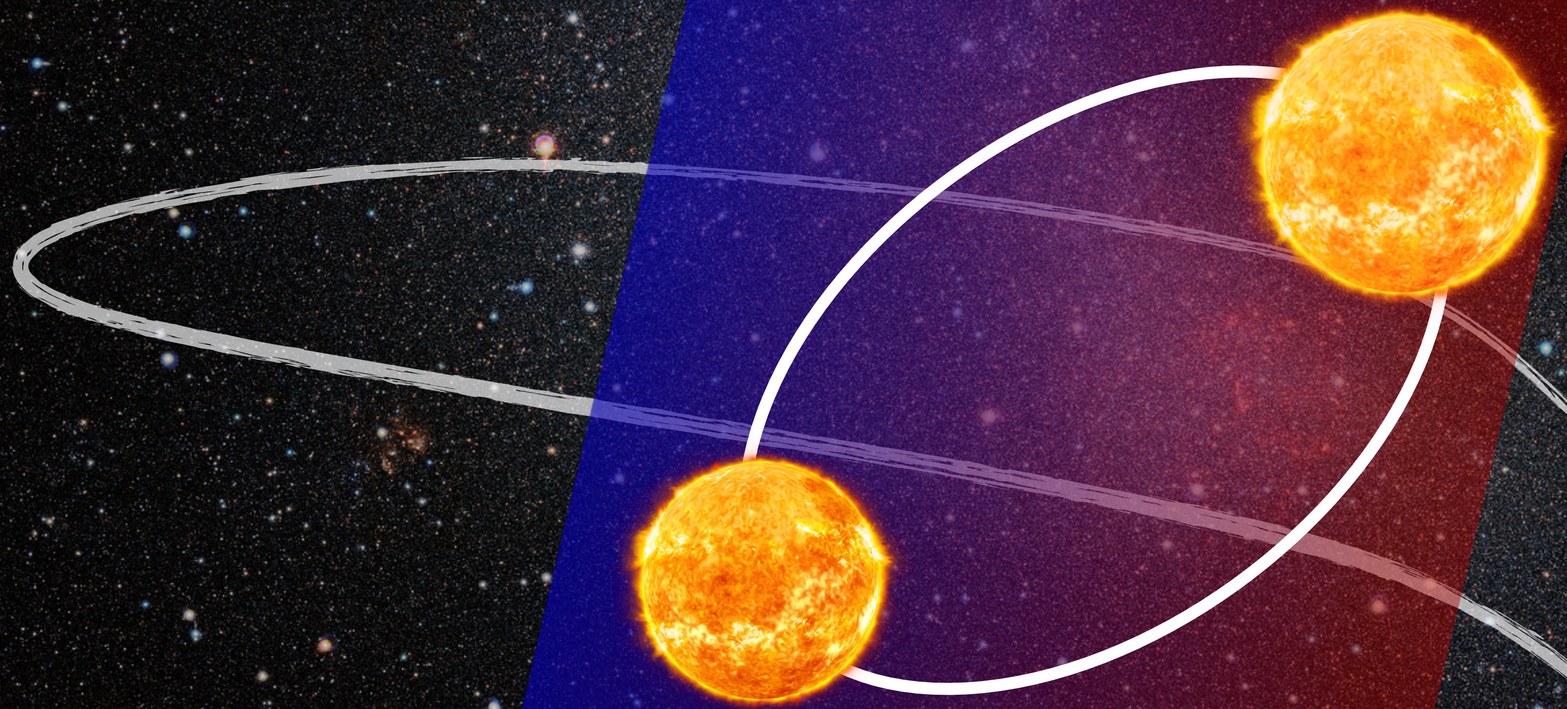
FELIPE ESPINOZA ARANCIBIA
SUPERVISOR: BOGUMIŁ PILECKI

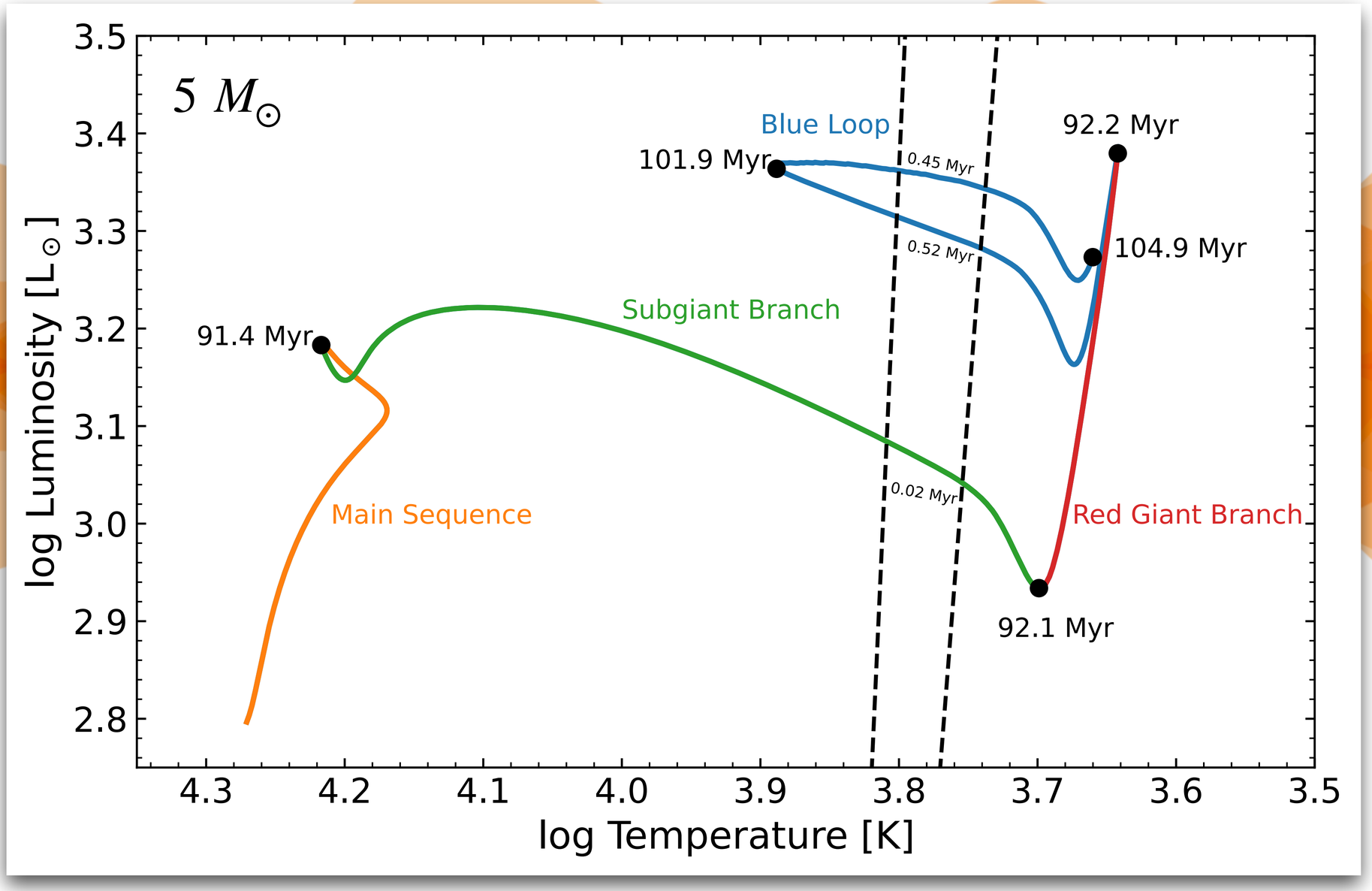
YOUNG ASTRONOMERS MEET

MODELING CLASSICAL CEPHEIDS IN BINARY SYSTEMS



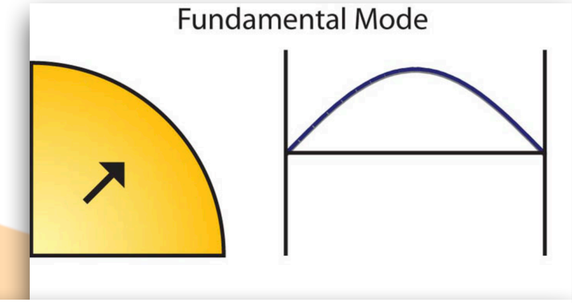
NATIONAL SCIENCE CENTRE
POLAND

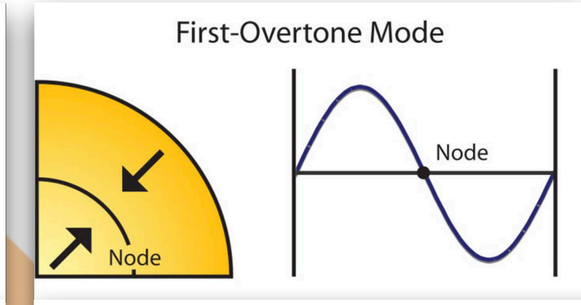
INTERMEDIATE-MASS STARS $\sim 2 - 13\,M_\odot$

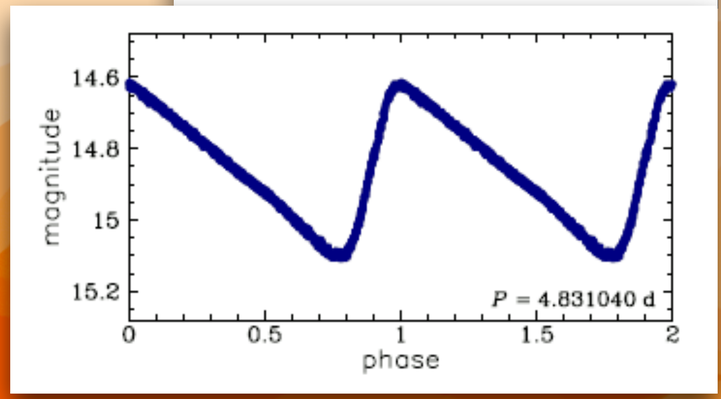


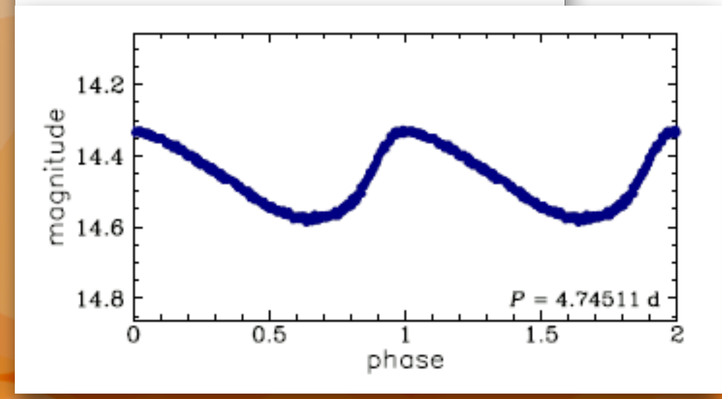
CLASSICAL CEPHEIDS

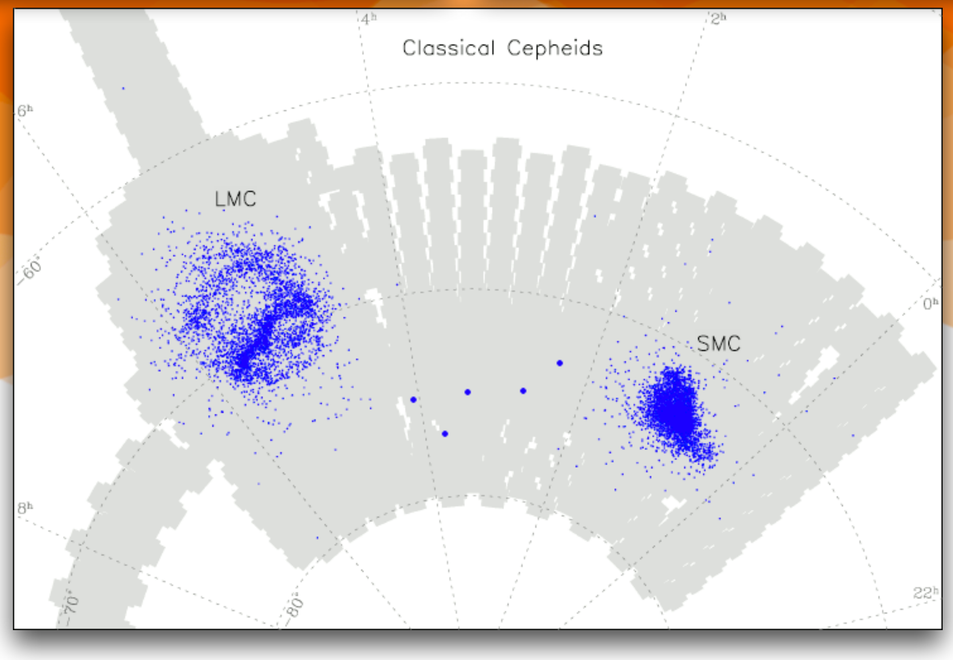
- Mostly radial pulsators.
- Pulsation periods ranging from about 1 to 200 days.
- Around 10 000 Cepheids in the Magellanic Clouds











OGLE Project

CLASSICAL CEPHEIDS

- In 1912, Henrietta Leavitt discovered that the pulsation period of Cepheids depends on their brightness.

Physically:

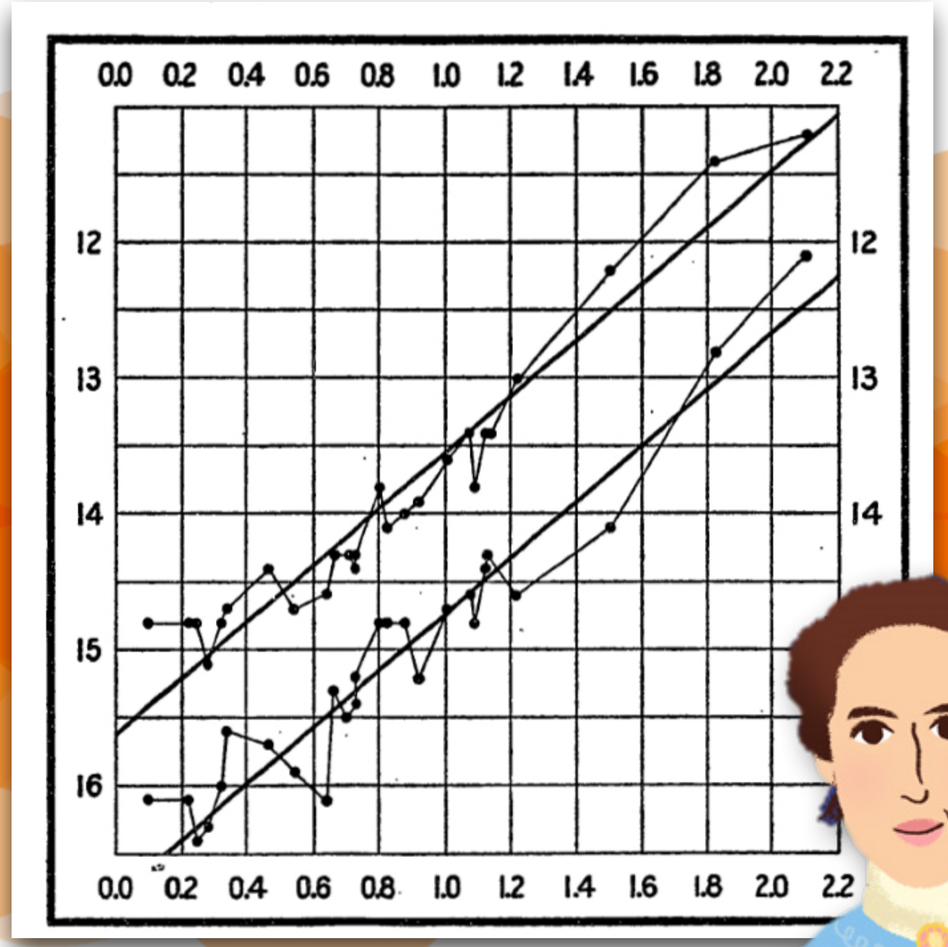
$$L = 4\pi R^2 T_{eff}^4 .$$

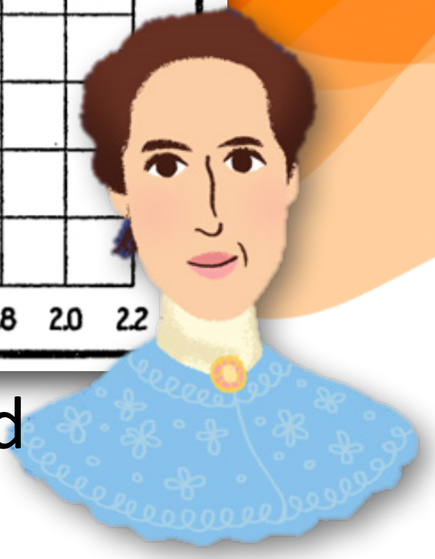
In more astronomical-friendly units:

$$M_{bol} = -5 \log R - 10 \log T_{eff} + C .$$

$$P\sqrt{\rho} = Q$$

$$T_{eff} \propto \text{color index}$$





CLASSICAL CEPHEIDS

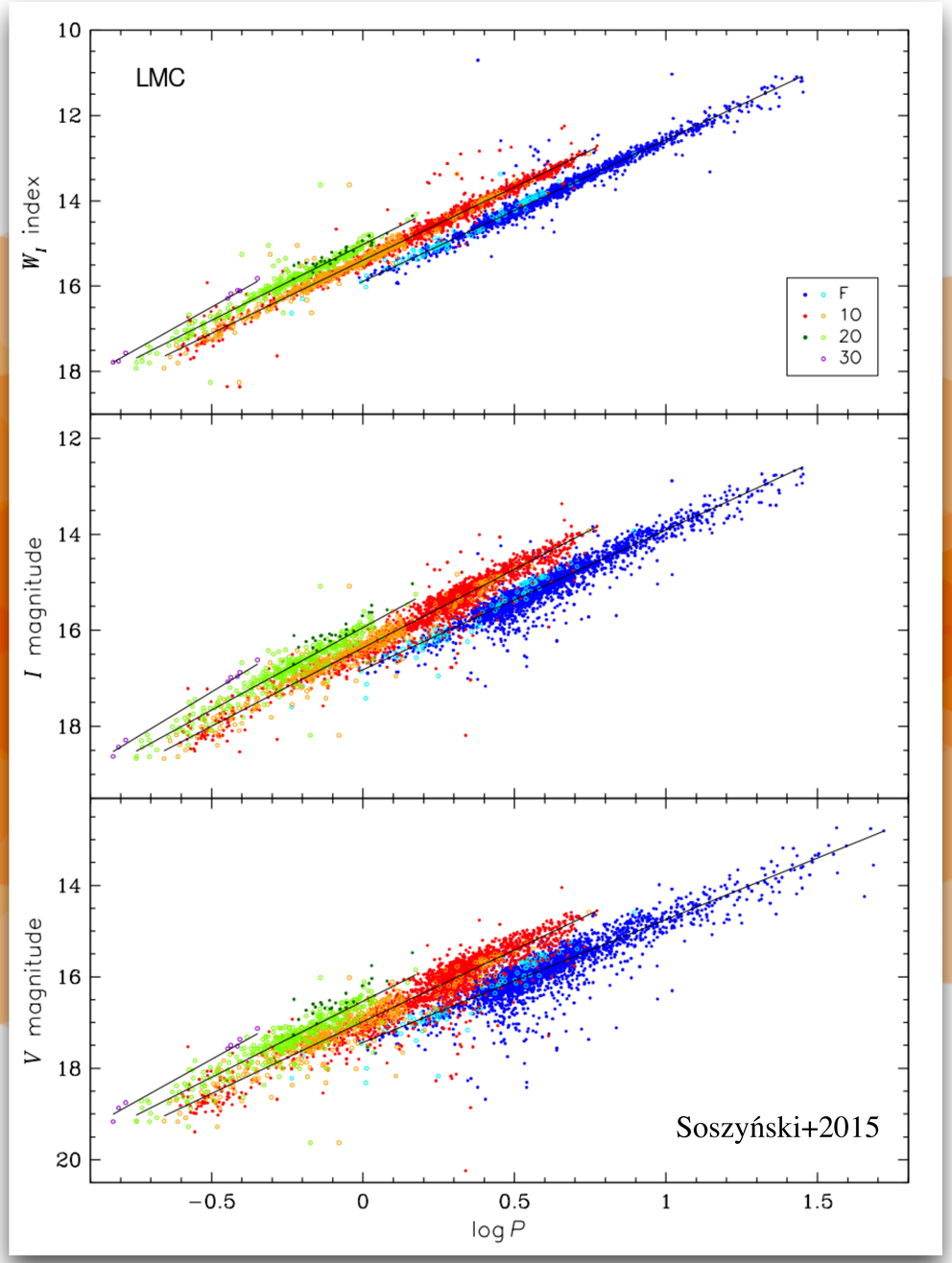
- In 1912, Henrietta Leavitt discovered that the pulsation period of Cepheids depends on their brightness (P-L relation).

Physically:

$$L = 4\pi R^2 T_{eff}^4 .$$

In more astronomical-friendly units:

$$M_V = \alpha \log P + \beta (B-V)_0 + \gamma .$$



CLASSICAL CEPHEIDS

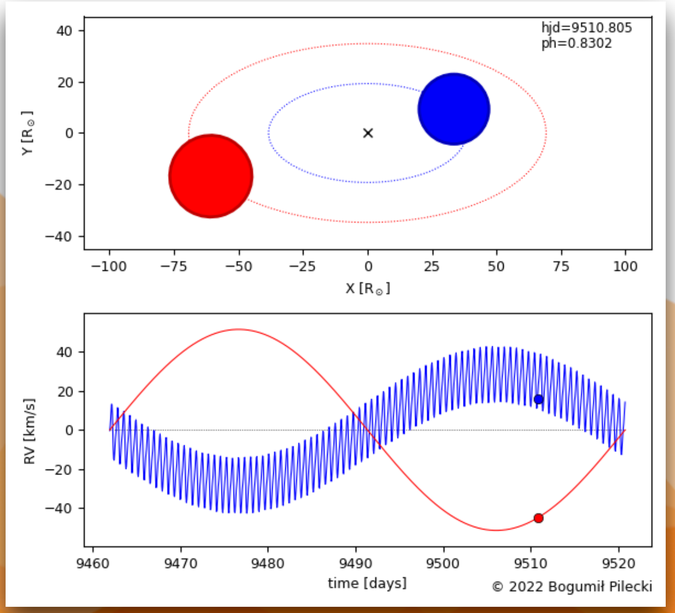
There are still open questions…

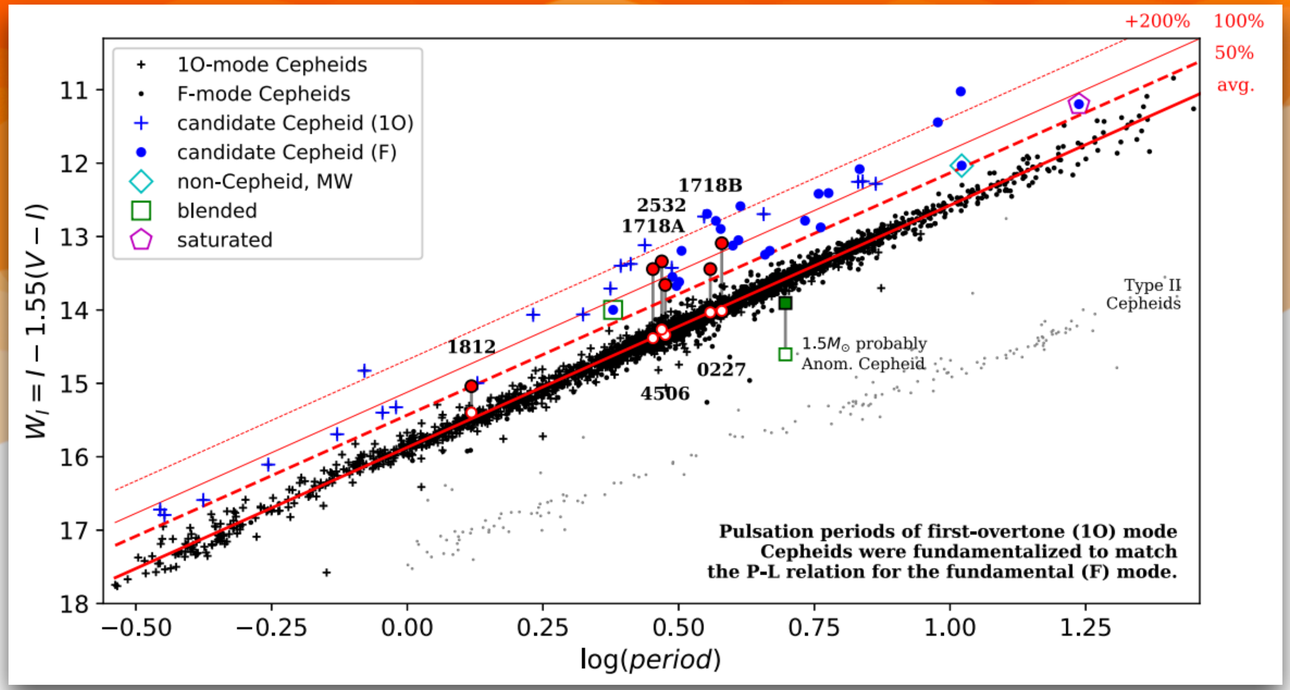
- Mass-luminosity relation is poorly constrained .
- Metallicity dependence of the P-L relation.
- Blue loops are very sensitive to input physics.
- Binary interactions.

CEPHEIDS IN BINARY SYSTEMS

- 80% in binaries (Kervella+2019)
- 5 Eclipsing binaries with very precise physical parameters (Pilecki+2018)

Masses between 3.6 - 5 $M_\odot$





CEPHEIDS IN BINARY SYSTEMS

From Bogumił's talk…

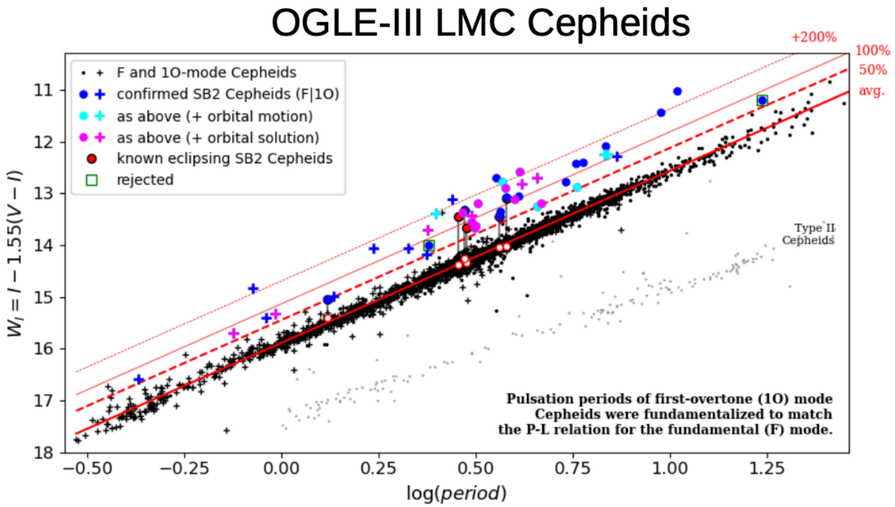
Cepheids with giant companions

current status of the project

- **~64 Cepheids in SB2 systems** in the LMC, SMC, and MW
- **~40** with **orbital motion**
- **~30** with preliminary **orbital solution**
- **15** with **final solution** (P < 1000 d)

Other results:

- **9** new systems composed of **two Cepheids**
- **Interesting objects!**



Pilecki+2025 (updated)

DOUBLE BINARY CEPHEIDS

The q-PED method (Espinoza+2025)

- q (mass ratio)
- Pulsation models
- Evolutionary models
- Distance

OGLE ID	Modes	P_1 [days]	P_1^F [days]	P_2 [days]	P_2^F [days]	P_2^F/P_1^F
BLG-CEP-067	1O + 1O	2.610721	3.827	1.692381	2.444	0.639
GD-CEP-0291	F + F	3.667693	3.668	3.398977	3.399	0.927
LMC-CEP-0571	F + 1O	3.079937	3.080	2.100885	3.057	0.992
LMC-CEP-0835	F + F	4.562781	4.563	2.750956	2.751	0.603
LMC-CEP-1718	1O + 1O	2.480909	3.649	1.963683	2.869	0.786
SMC-CEP-1526	F + F	1.804311	1.804	1.290234	1.290	0.715
SMC-CEP-2699	1O + F	2.562225	3.772	2.117341	2.117	0.561
SMC-CEP-2893	F + F	1.321549	1.322	1.135859	1.136	0.860
SMC-CEP-3115	F + F	1.251945	1.252	1.159784	1.160	0.926
SMC-CEP-3674	F + 1O	2.896089	2.896	1.827785	2.665	0.920

DOUBLE BINARY CEPHEIDS

$$M_V = \alpha \log P + \beta (B - V)_0 + \gamma .$$

Example: LMC-CEP-0835

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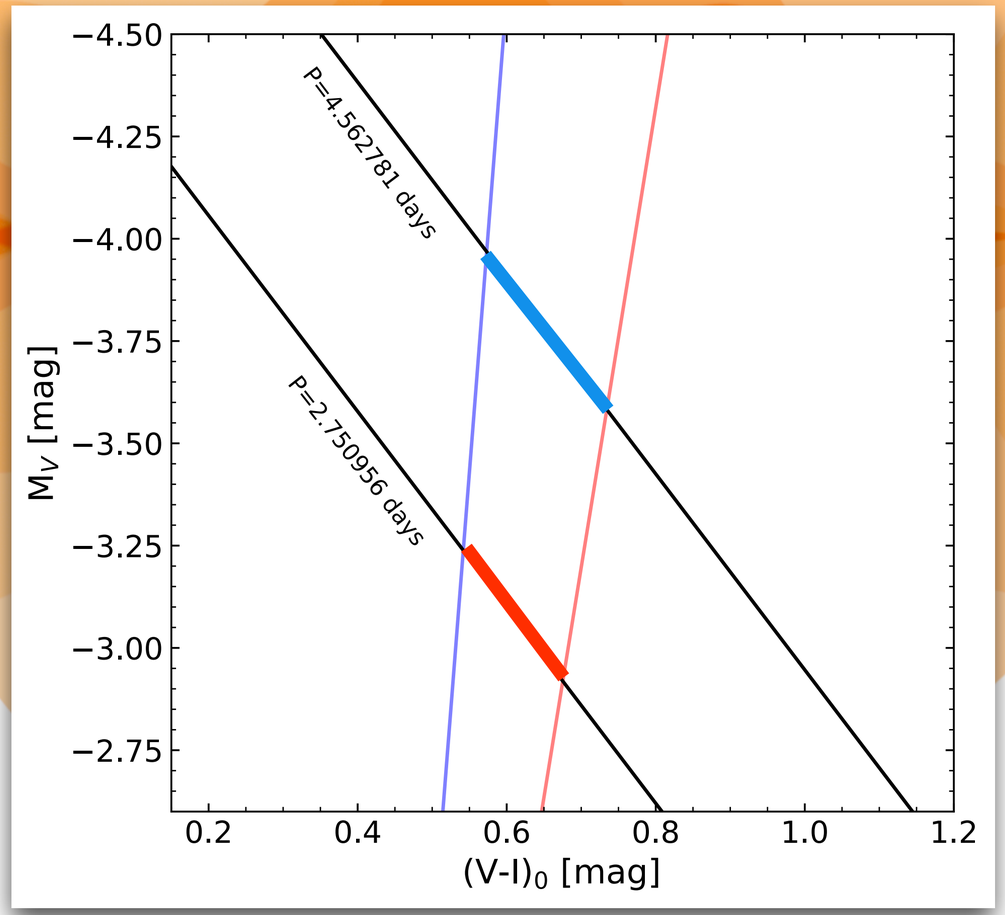

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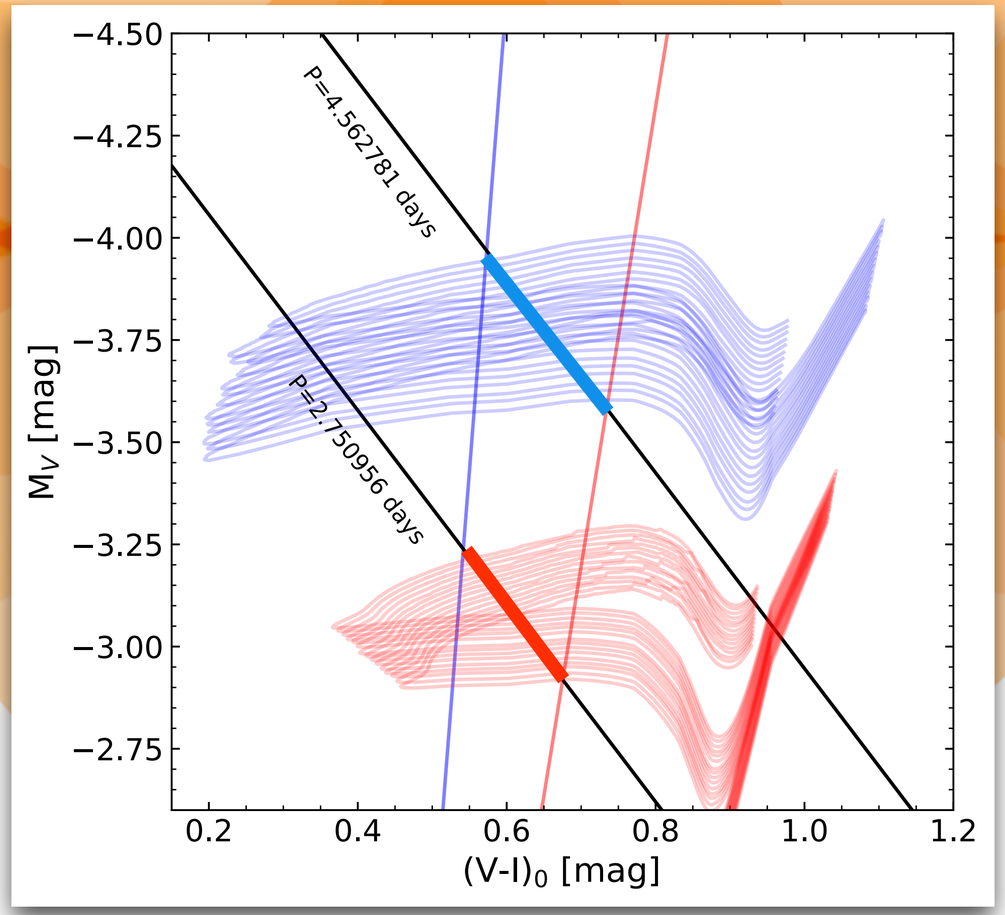

MESA + RSP

Paxton+(2019)

DOUBLE BINARY CEPHEIDS

$$M_V = \alpha \log P + \beta (B-V)_0 + \gamma\,.$$

Example: LMC-CEP-0835

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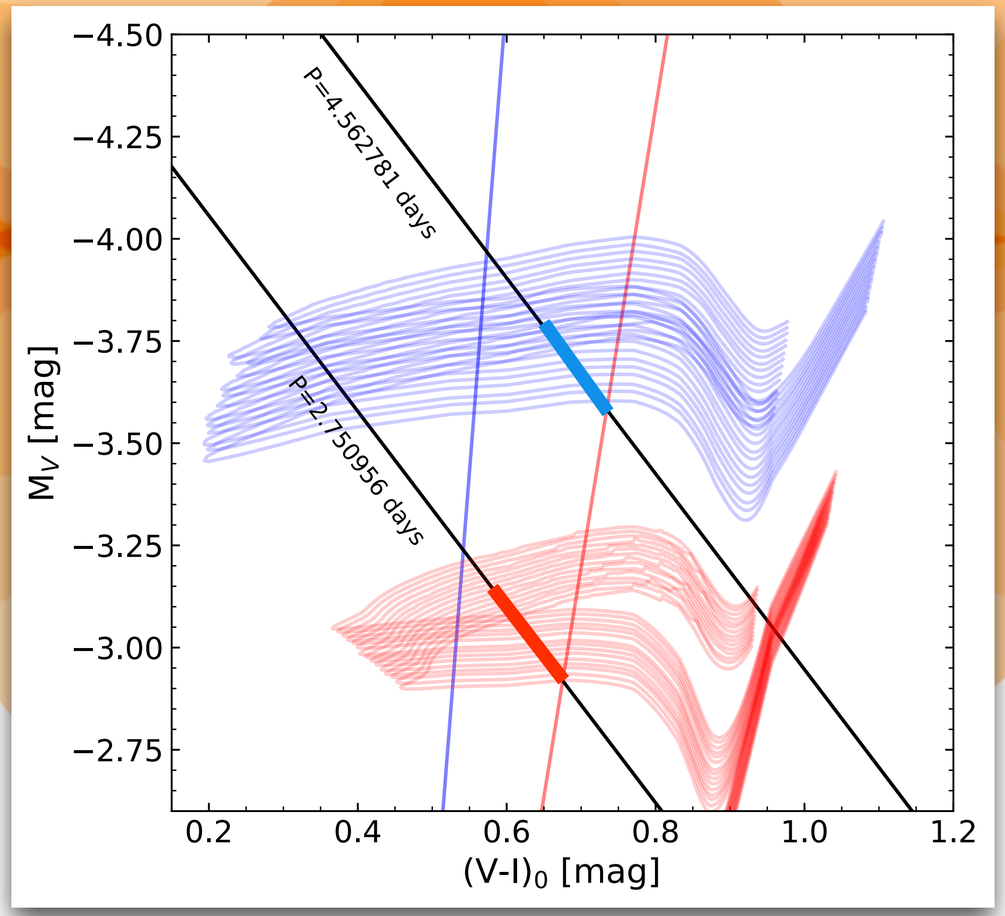
$M_1 = 4.13 \pm 0.04\ M_\odot$

$M_2 = 3.62 \pm 0.07\ M_\odot$



Distance to the LMC (Pietrzyński+2019):

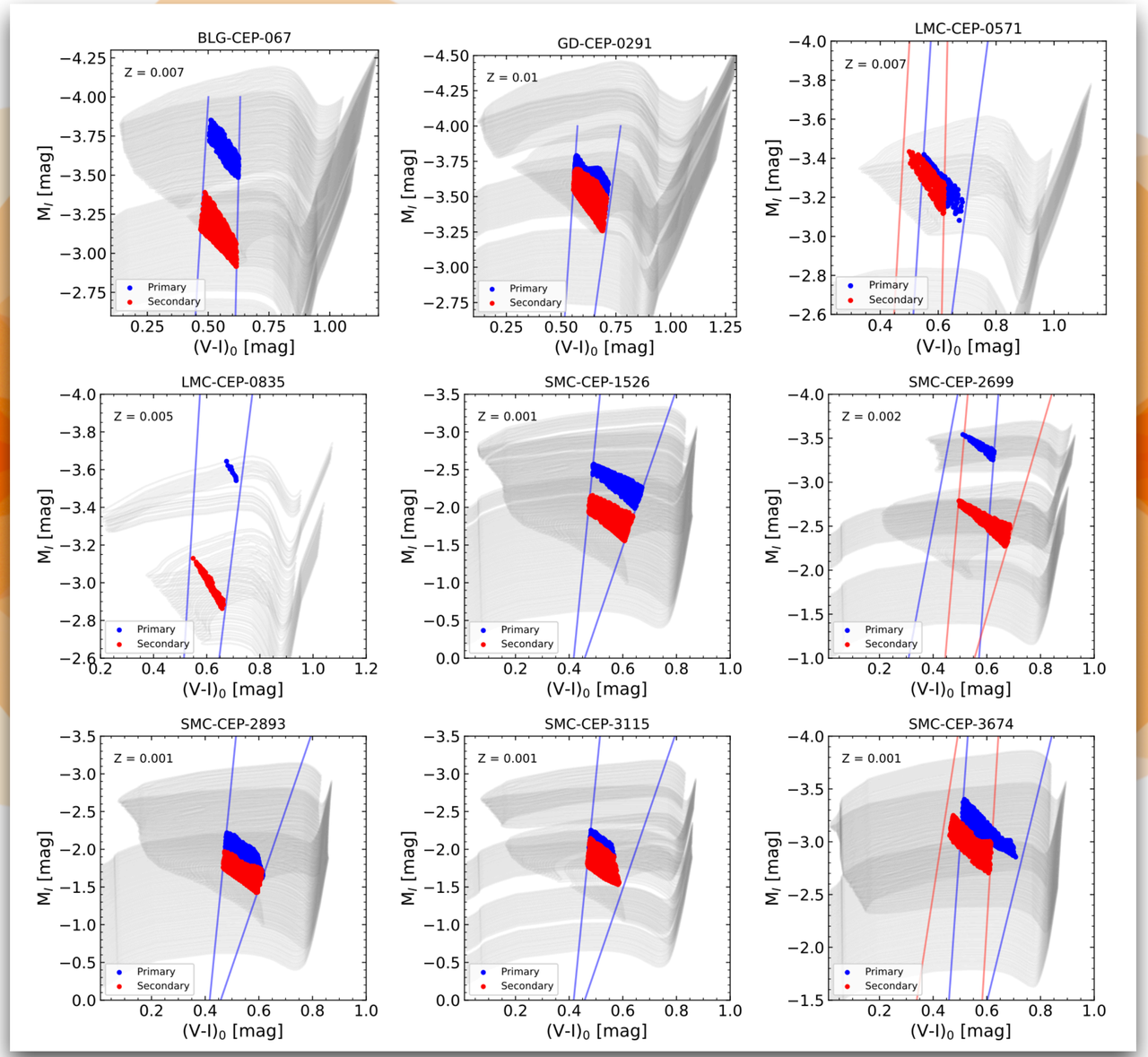
49.59 ± 0.63 kpc

$(m-M)_0 = 18.477 \pm 0.030$

MESA + RSP

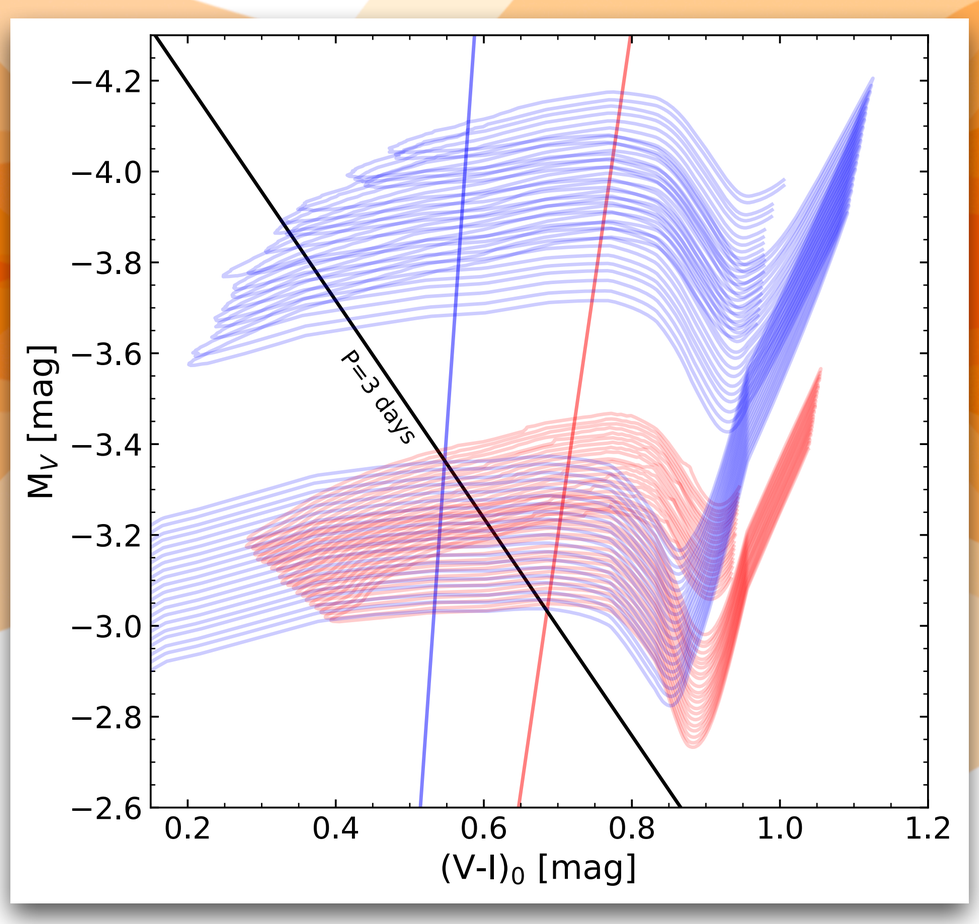
Paxton+(2019)

DOUBLE BINARY CEPHEIDS



DOUBLE BINARY CEPHEIDS

Multiple solutions are possible…



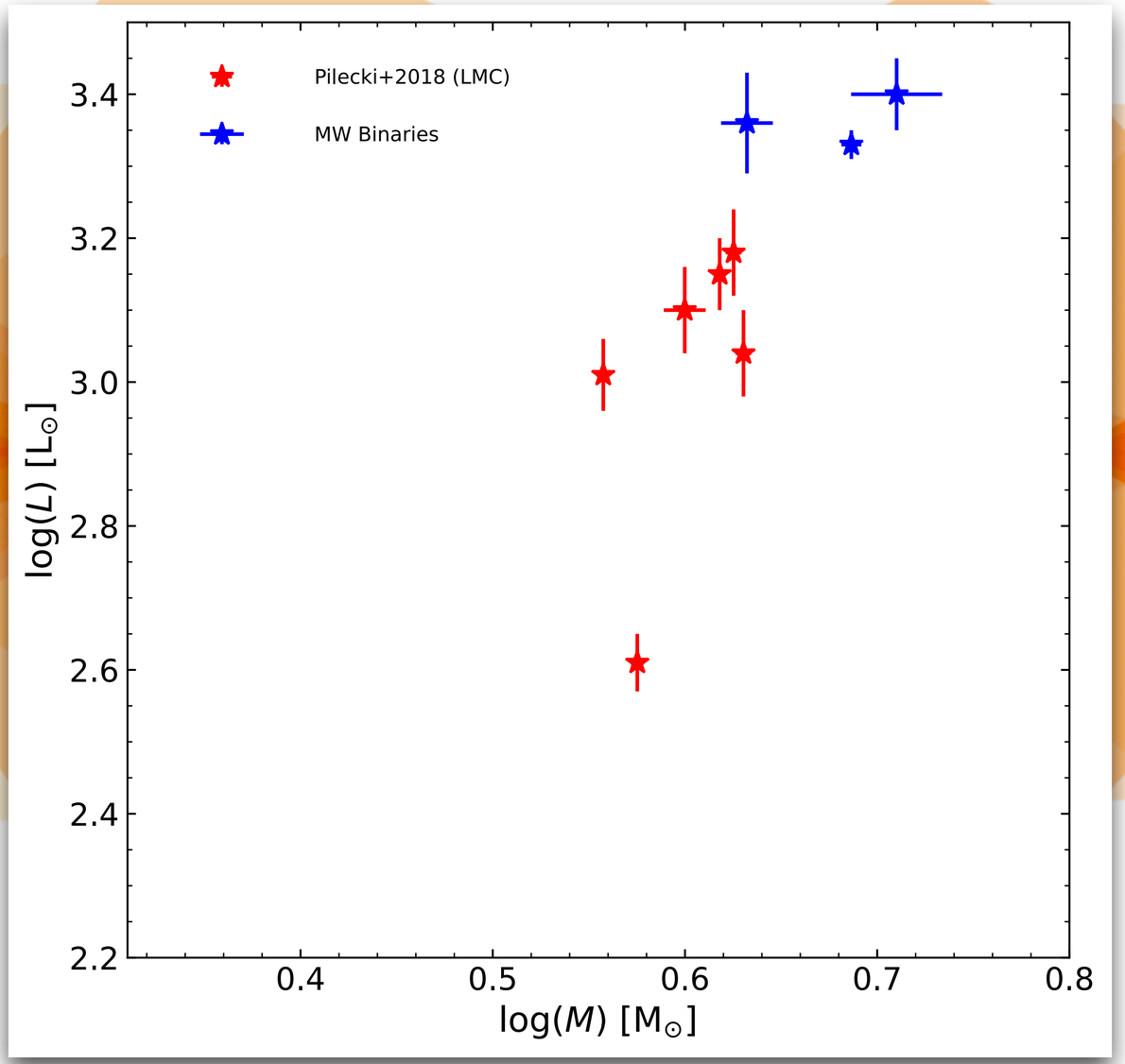
$4.4 - 4.8\ M_\odot$

$3.8 - 4.0\ M_\odot$

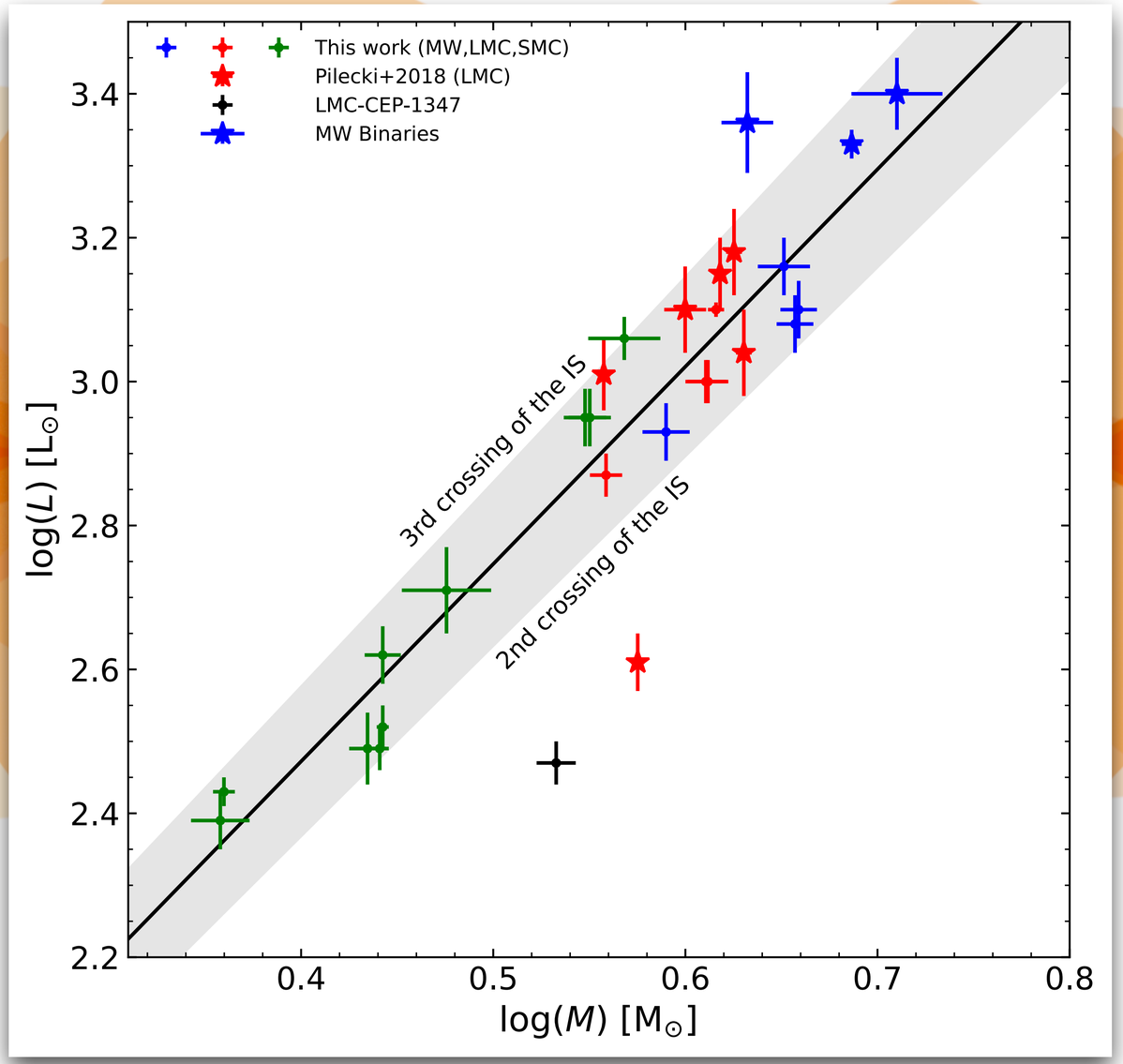
Mass-ratio of the system will change.

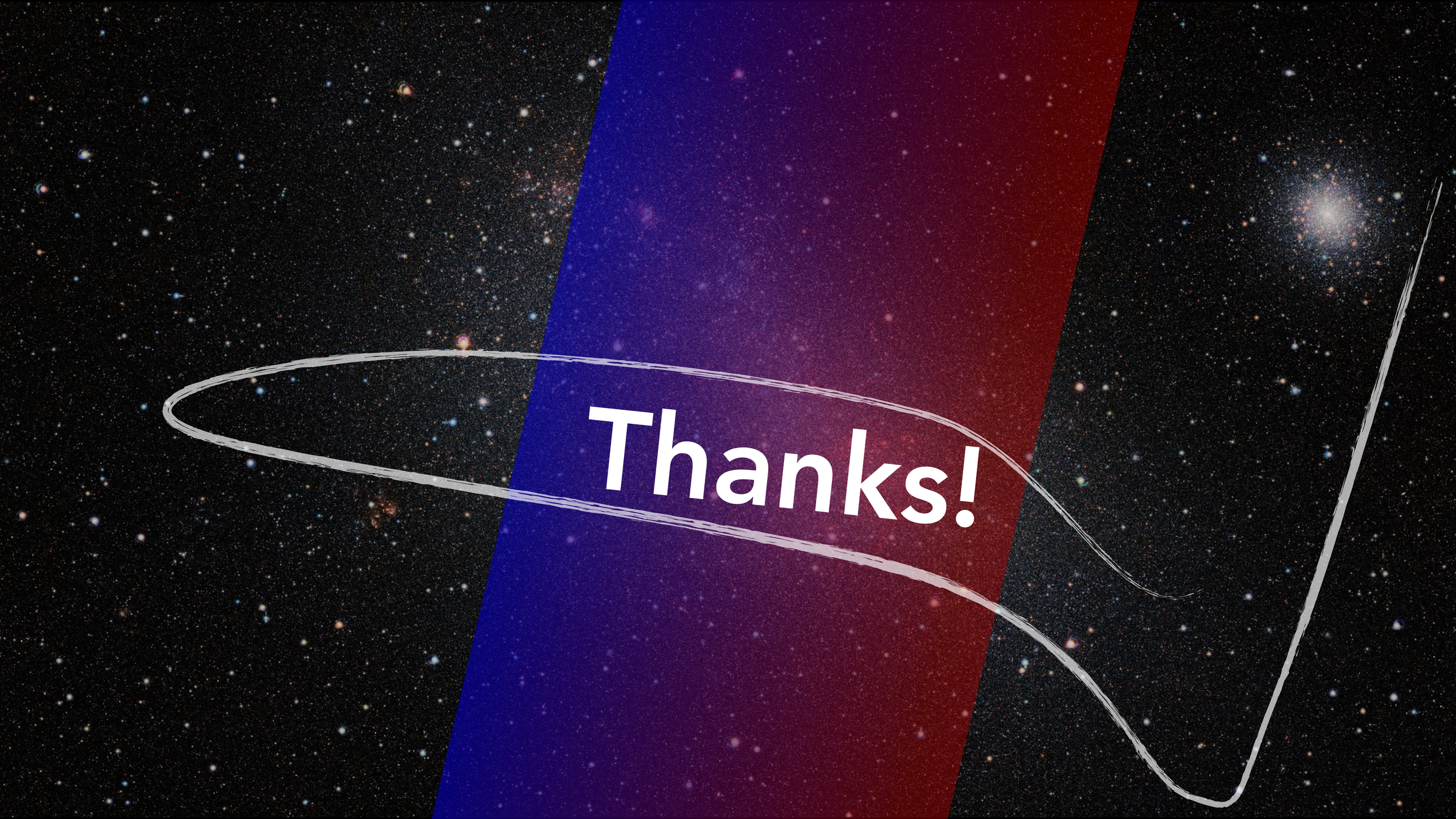
Therefore, an empirical mass-ratio is essential to select the correct solution

DOUBLE BINARY CEPHEIDS



DOUBLE BINARY CEPHEIDS




Thanks!