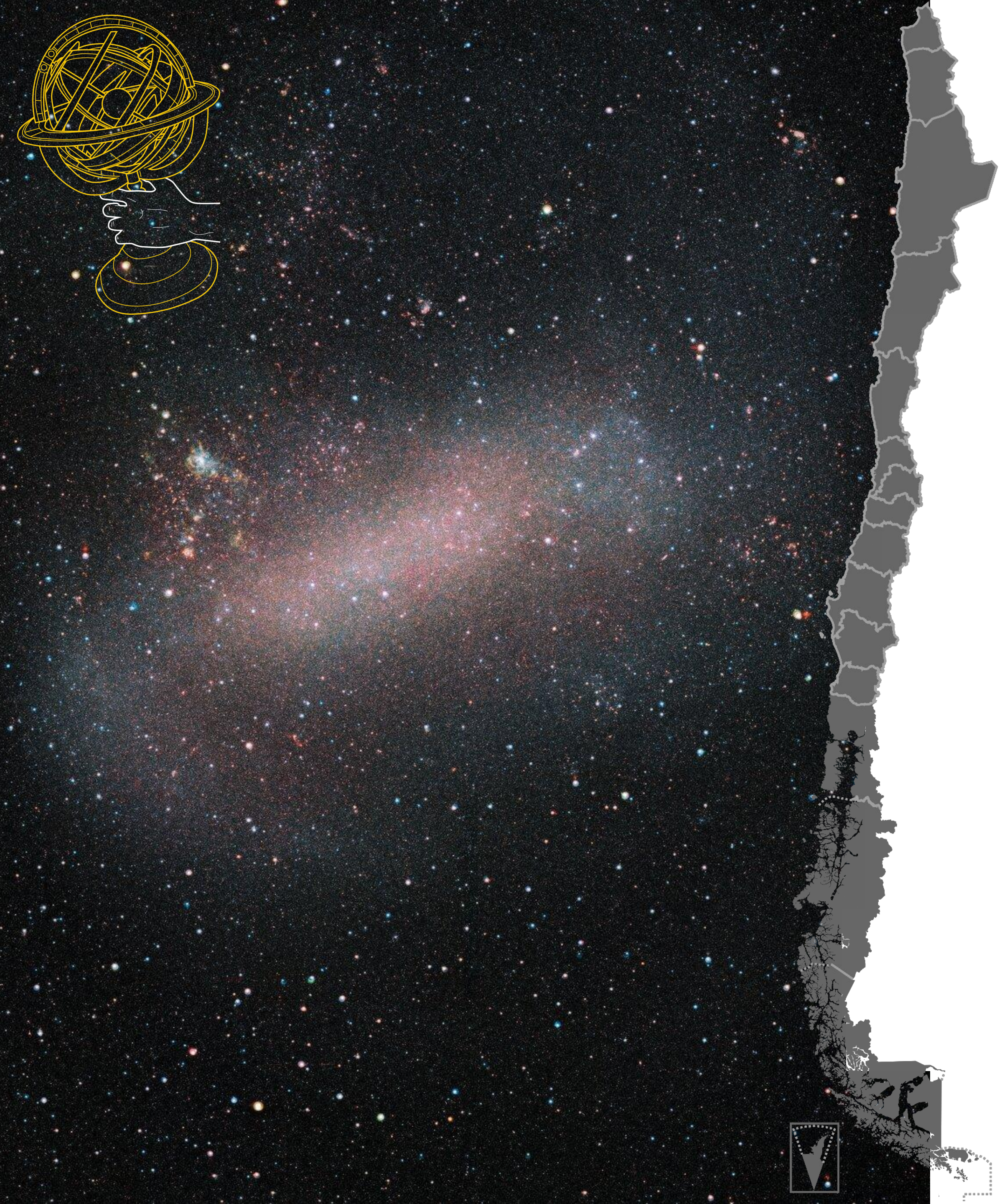
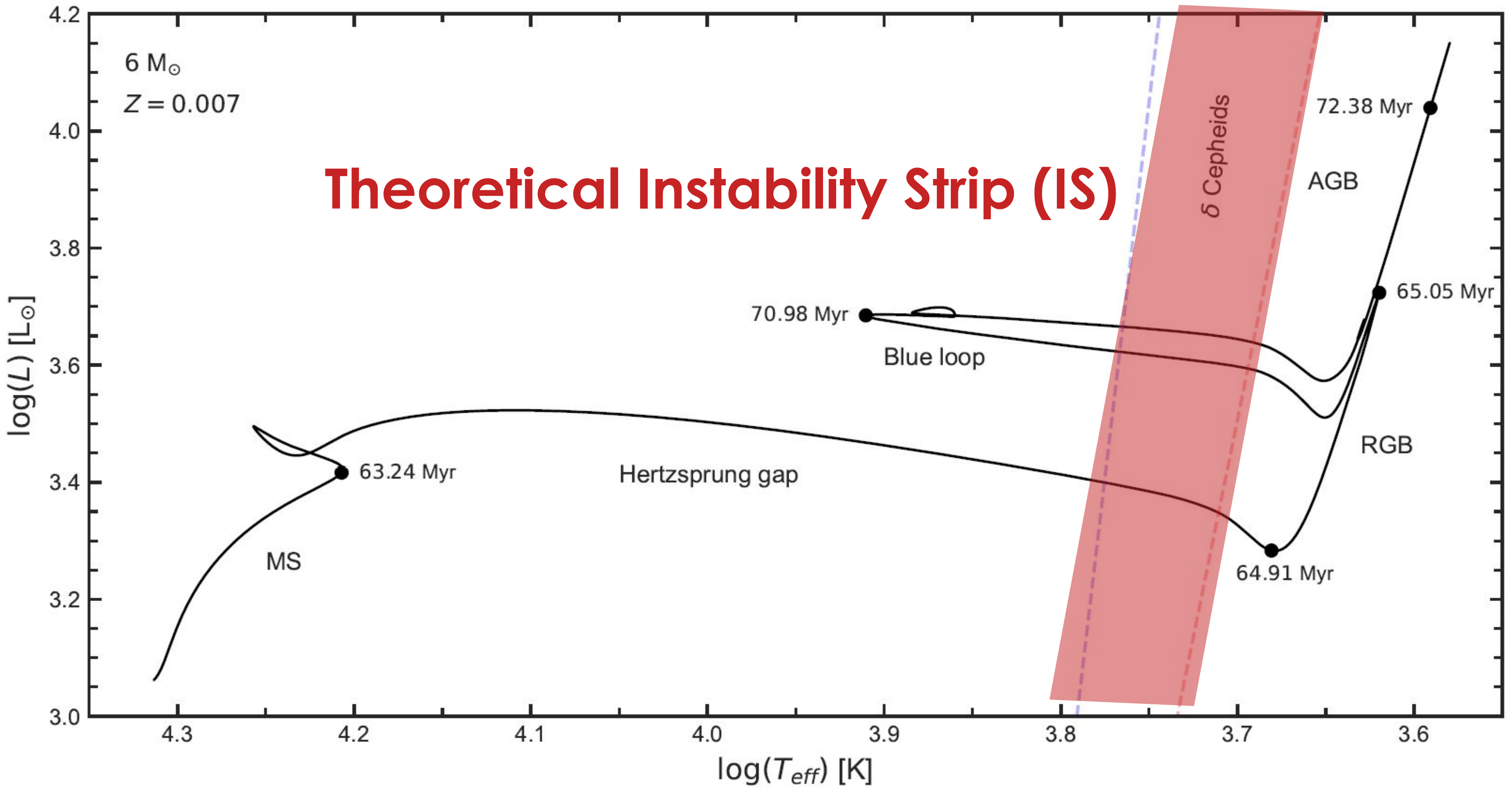


Empirical constraints for the instability strip from the analysis of LMC Cepheids

Felipe Espinoza-Arancibia

Dr. Bogumił Pilecki

CAMK PAN

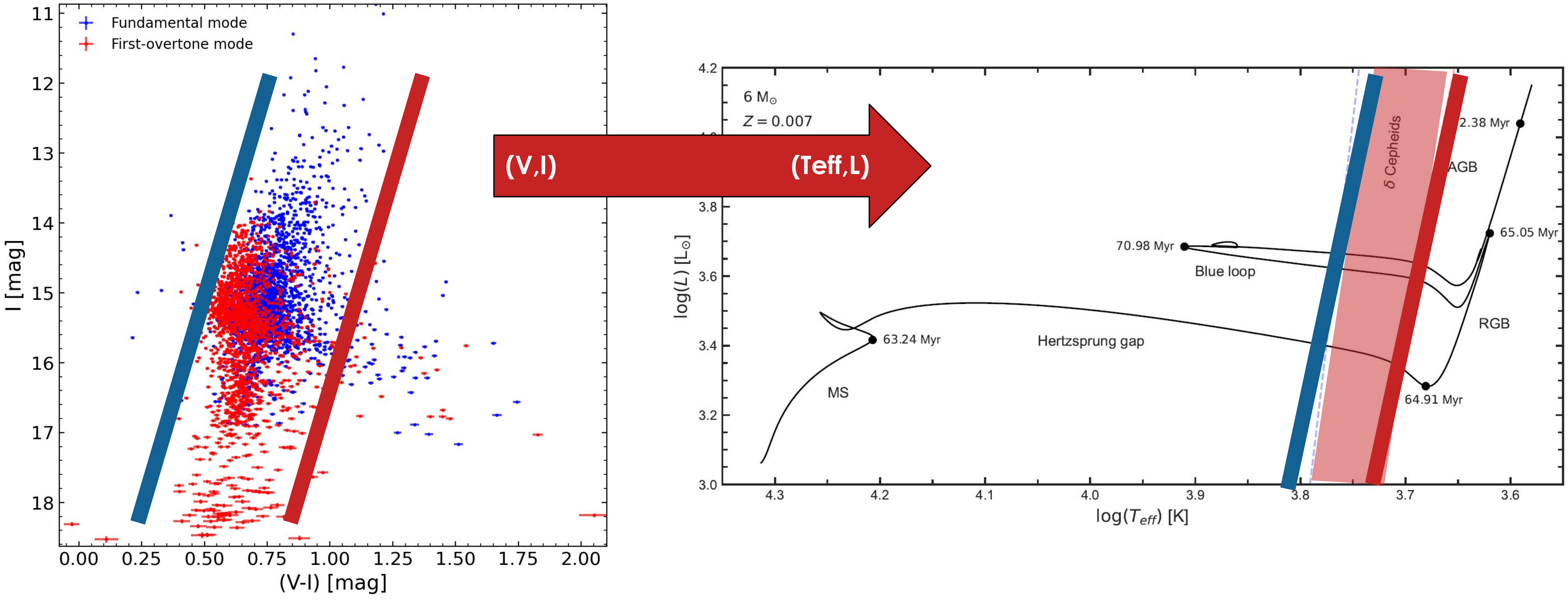


Anderson et al. (2016) → Metallicity and rotation

Paxton et al. (2019) → Different parameters for the convective model

De Somma et al. (2022) → Mass-luminosity relation and convection efficiency

Empirical Instability Strip



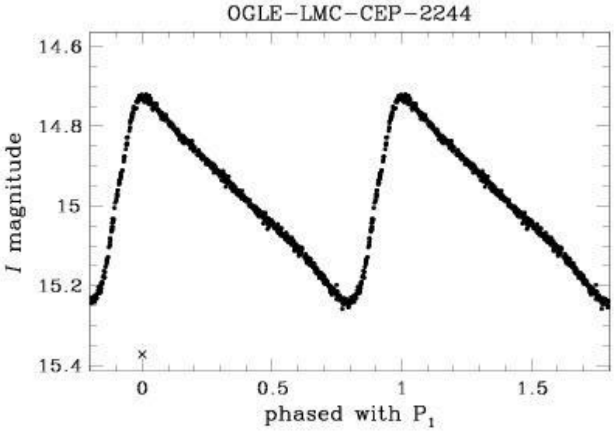
Data

OGLE-IV catalog + OGLE III Shallow Survey

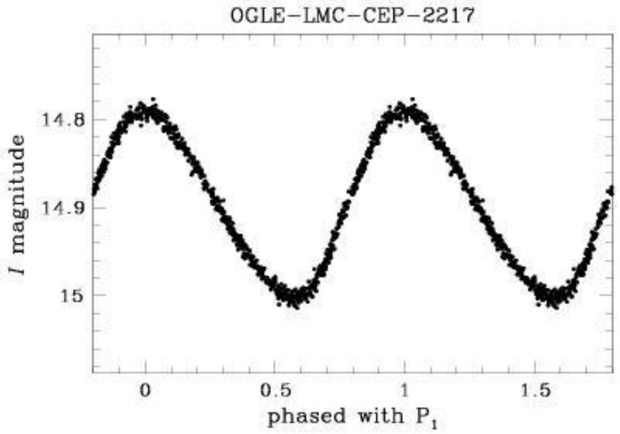
Fundamental (F) and first overtone (1O) mode LMC Cepheids

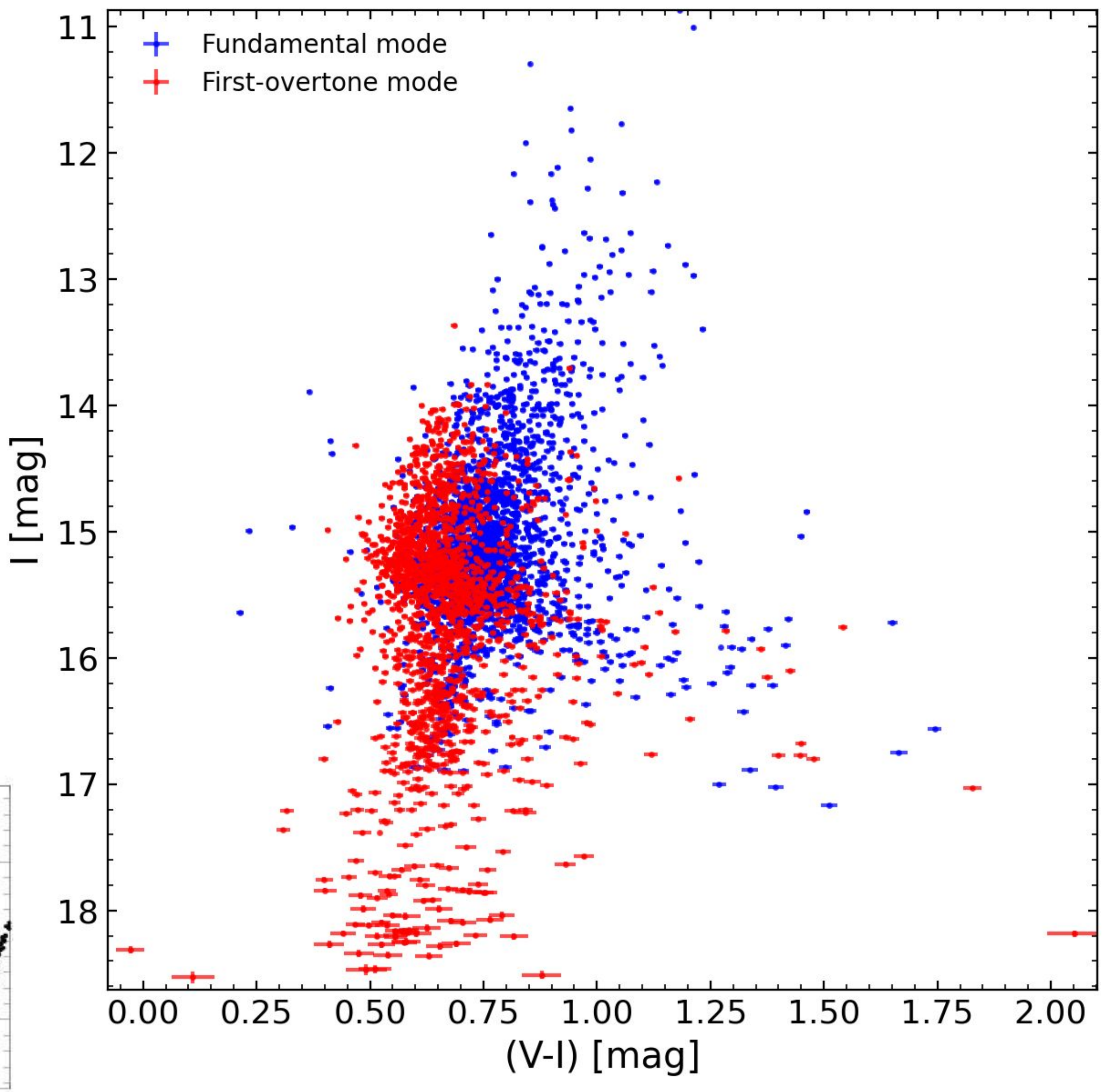
Full sample: **2335** F and **1682** 1O Cepheids

F-mode



1O-mode



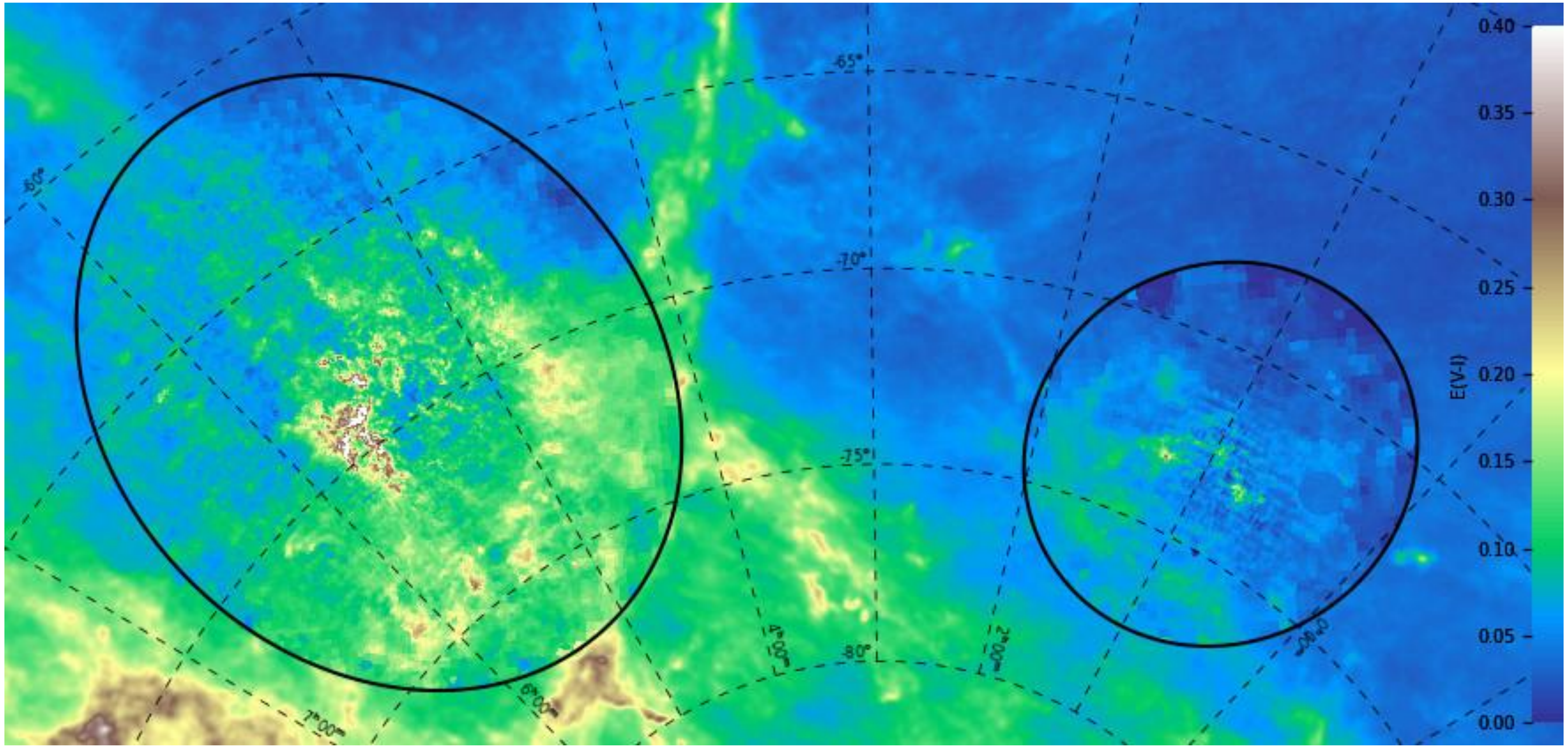


Data

Reddening

High-resolution reddening map **Skowron et al. (2021)**

Based on Red Clump stars from the OGLE-IV survey



Data

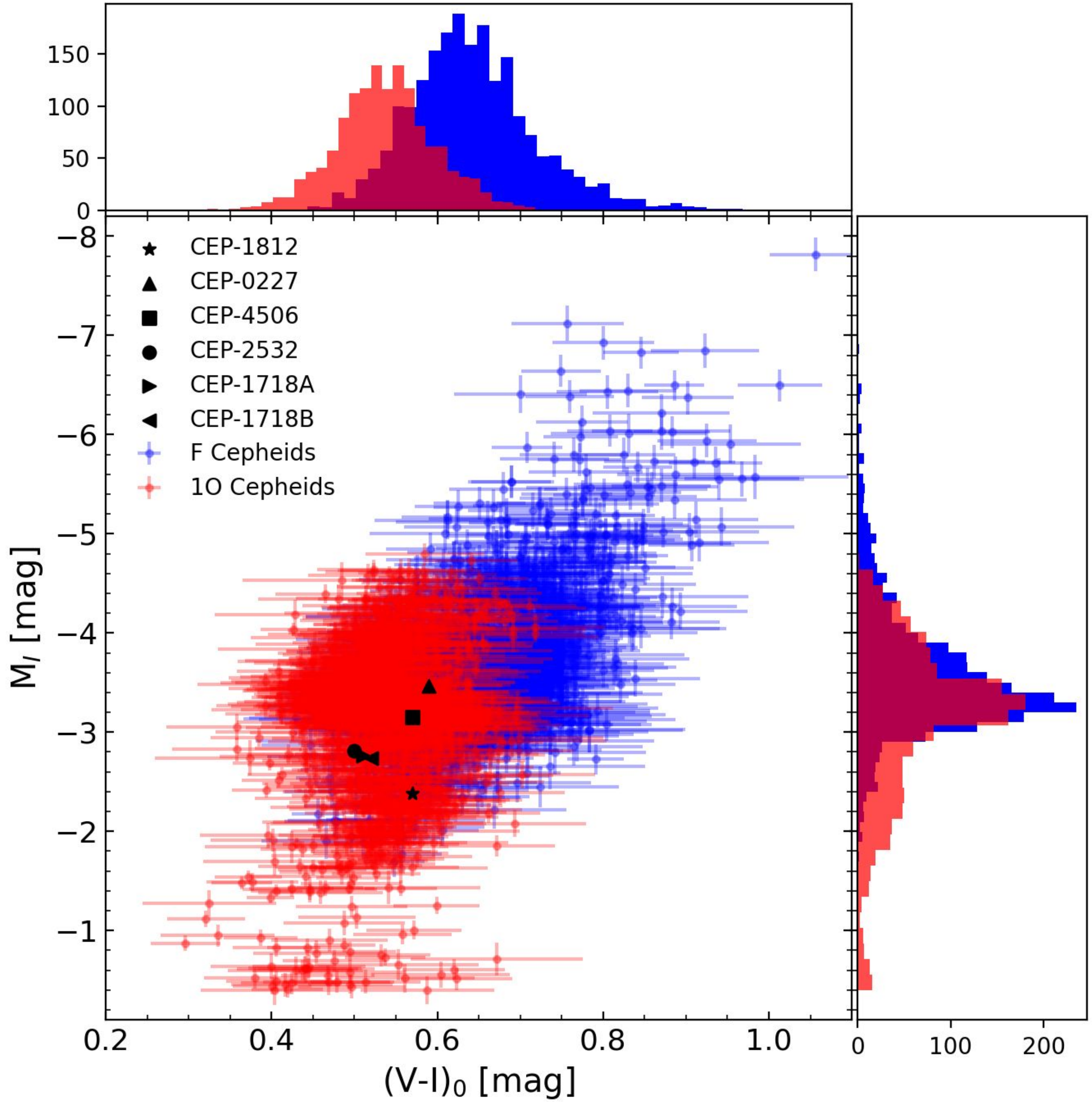
Careful cleaning

Discarding objects that presents remarks in the OGLE catalog, high vertical dispersion in the P-L relation, and high uncertainties in reddening.

Distances

Jacyszyn-Dobrzeniecka et al. (2016).

2058 F and 1387 1O-mode LMC Cepheids



Goal

Intrinsic IS

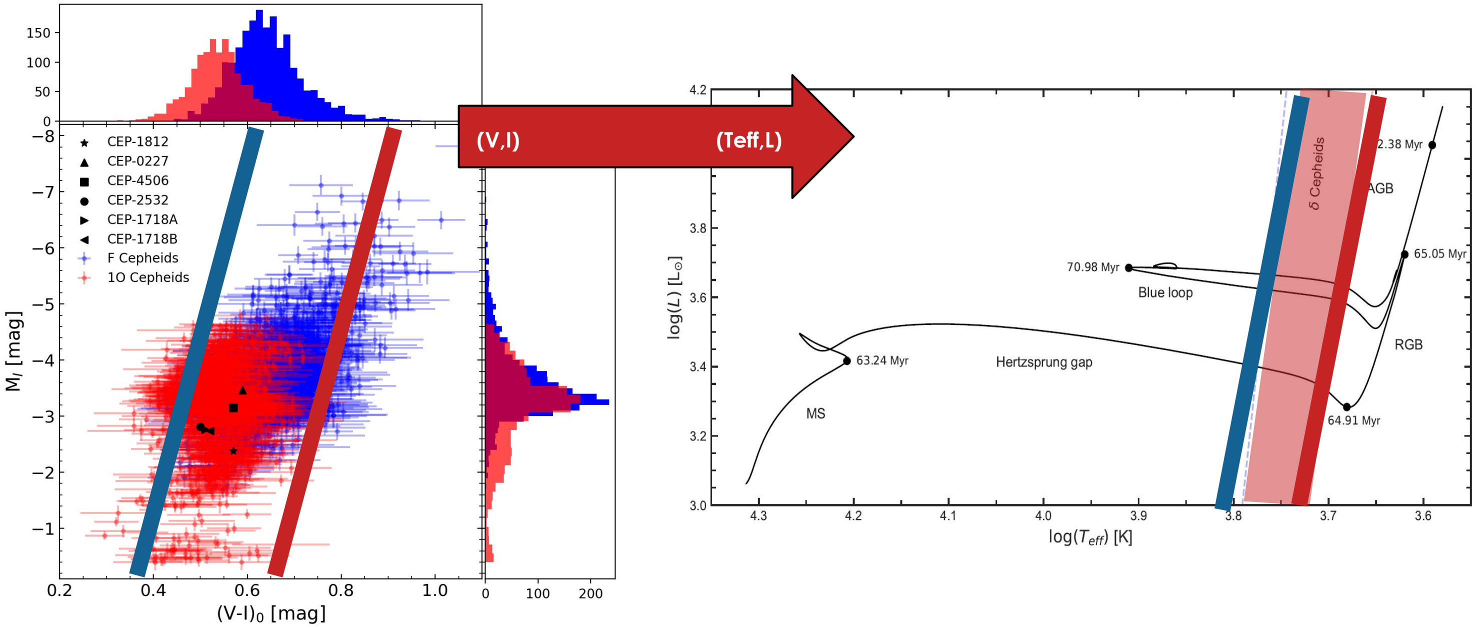
To be able to compare the empirical IS with theoretical models, one has to correct for any effect that could change its intrinsic width:

- ➢ Outliers ✓
- ➢ Uncertainties of photometry ✓

  ~ 0.005 mag

- ➢ **Uncertainties of reddening**

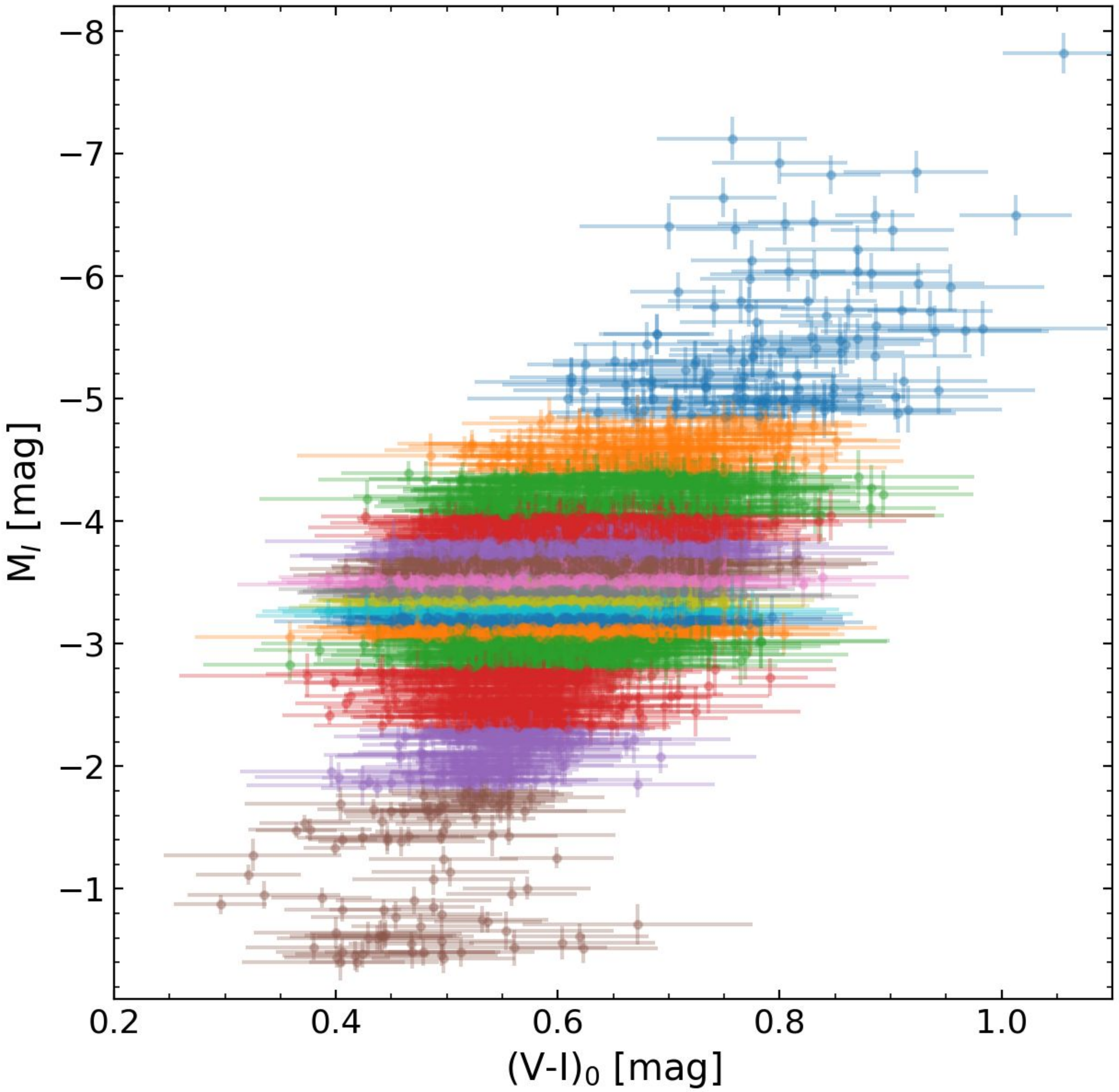
  ~ 0.06 mag



Method

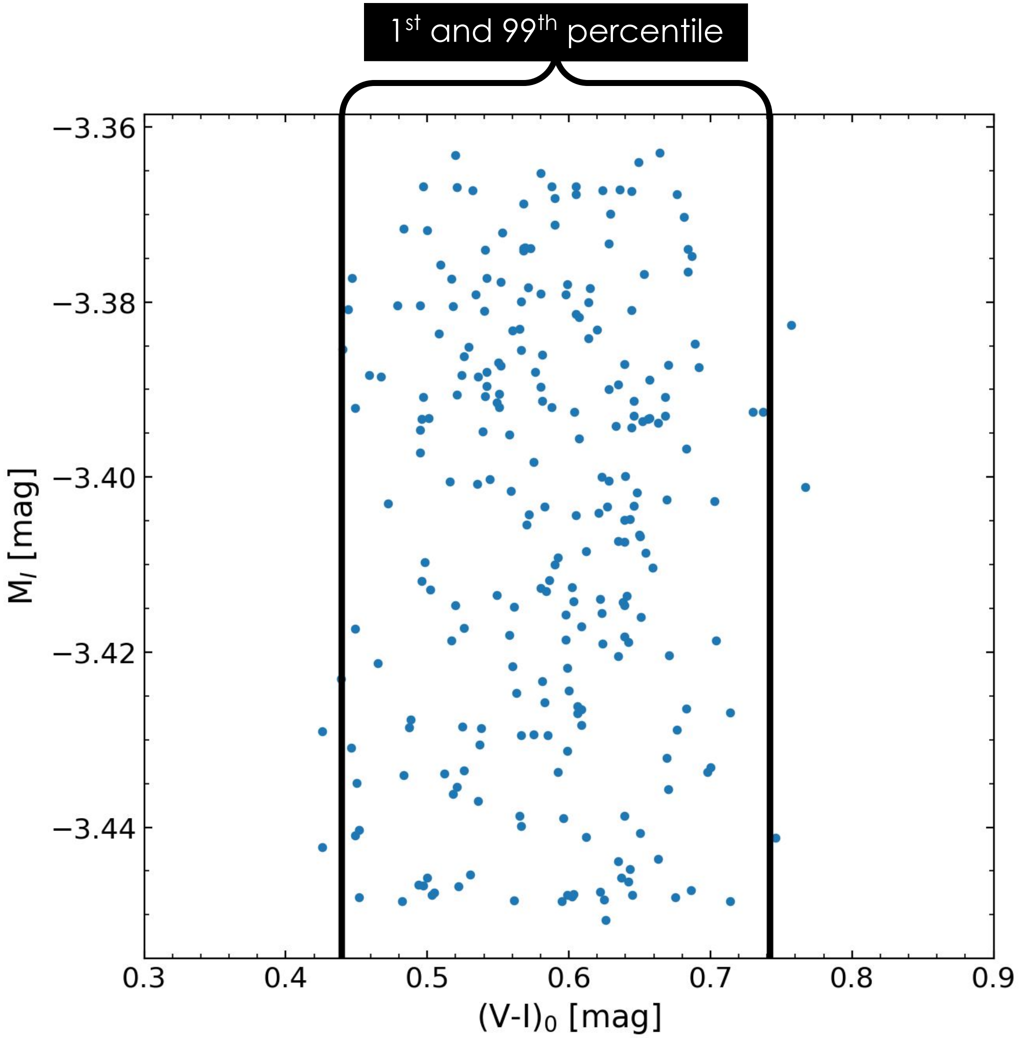
<u>IS boundaries</u>

➢ Each bin contains ~ 200 stars.



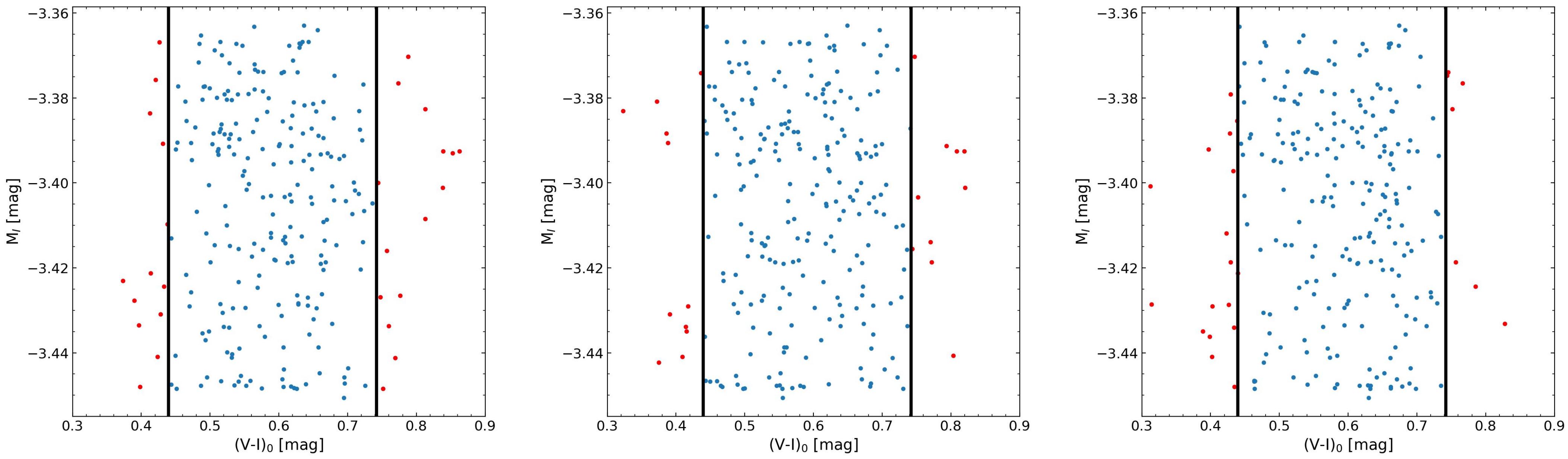
Method

➢ We located the **1st** and **99th percentile** of the intrinsic color distribution



Method

- We then add random Gaussian errors to the intrinsic color of each Cepheid, making the distribution of color wider.

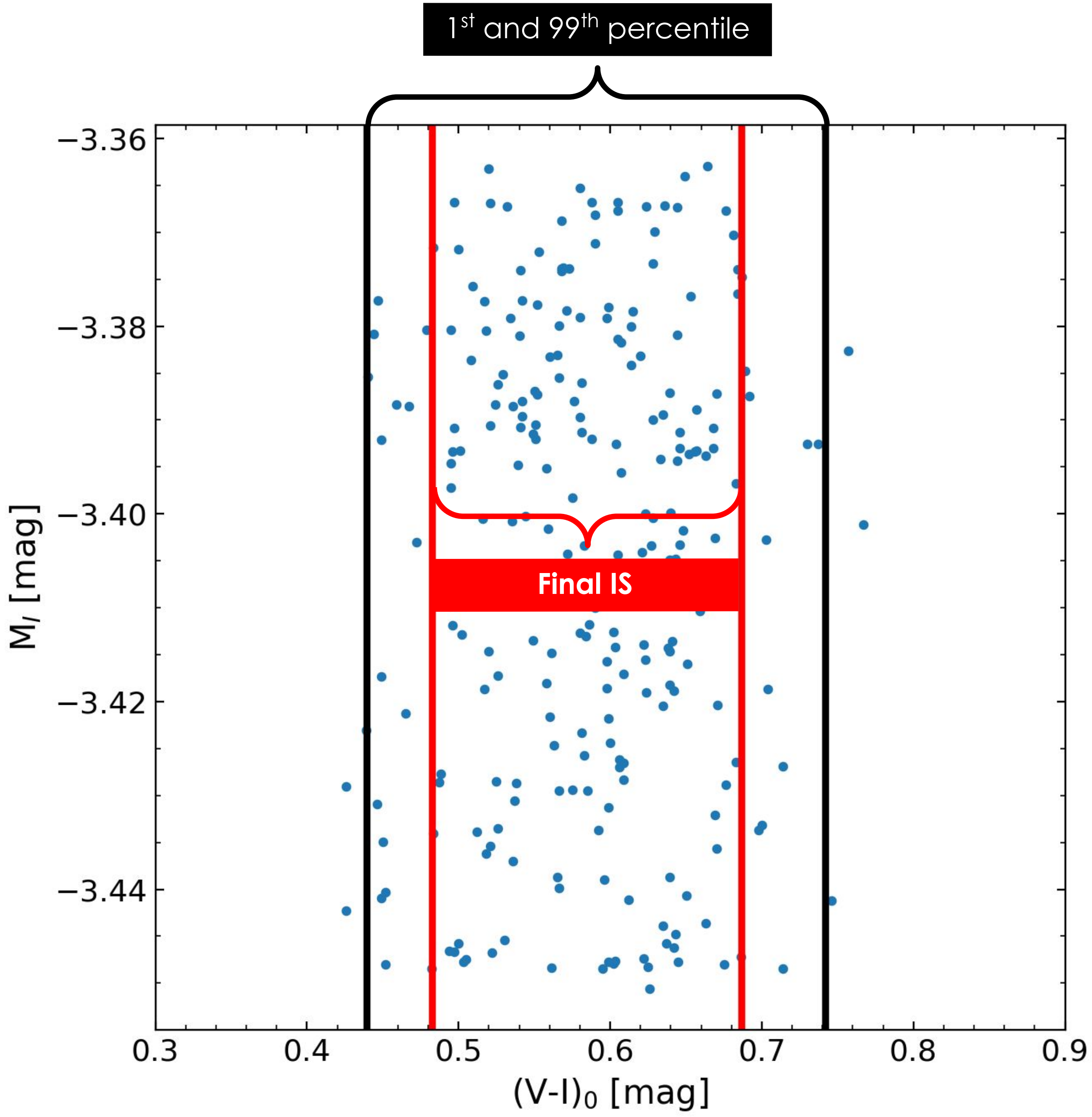


x 10000 times

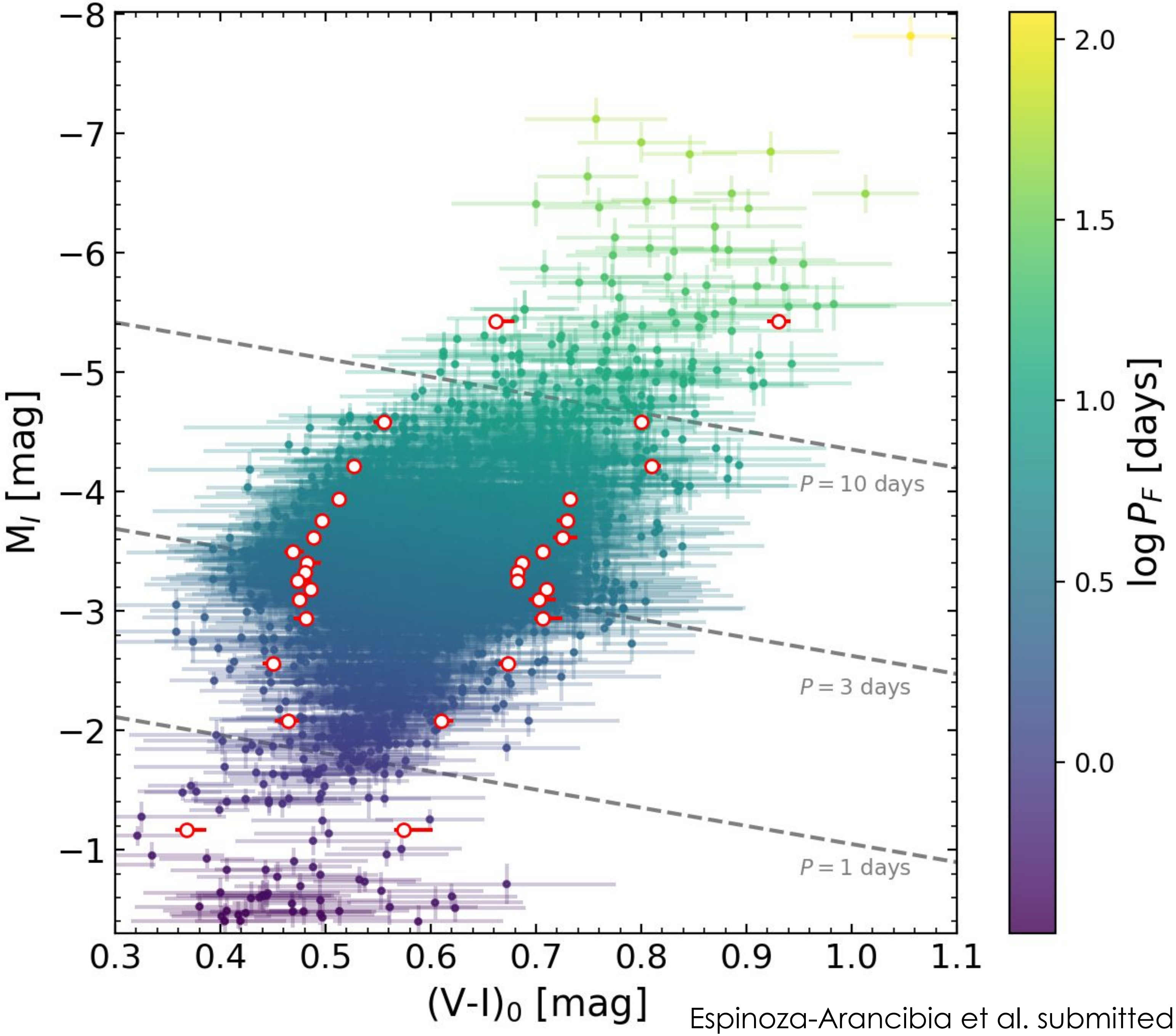
- Subsequently, we count the number of extra stars that after such procedure are located outside the initial edges. After 10000 iterations, we computed the median of the distribution of these numbers, namely n_{blue}, and n_{red}.

Method

➢ The final blue and red IS positions, of each bin, were obtained by moving the initial edges “inside" the IS by n_{blue} and n_{red} stars, respectively.

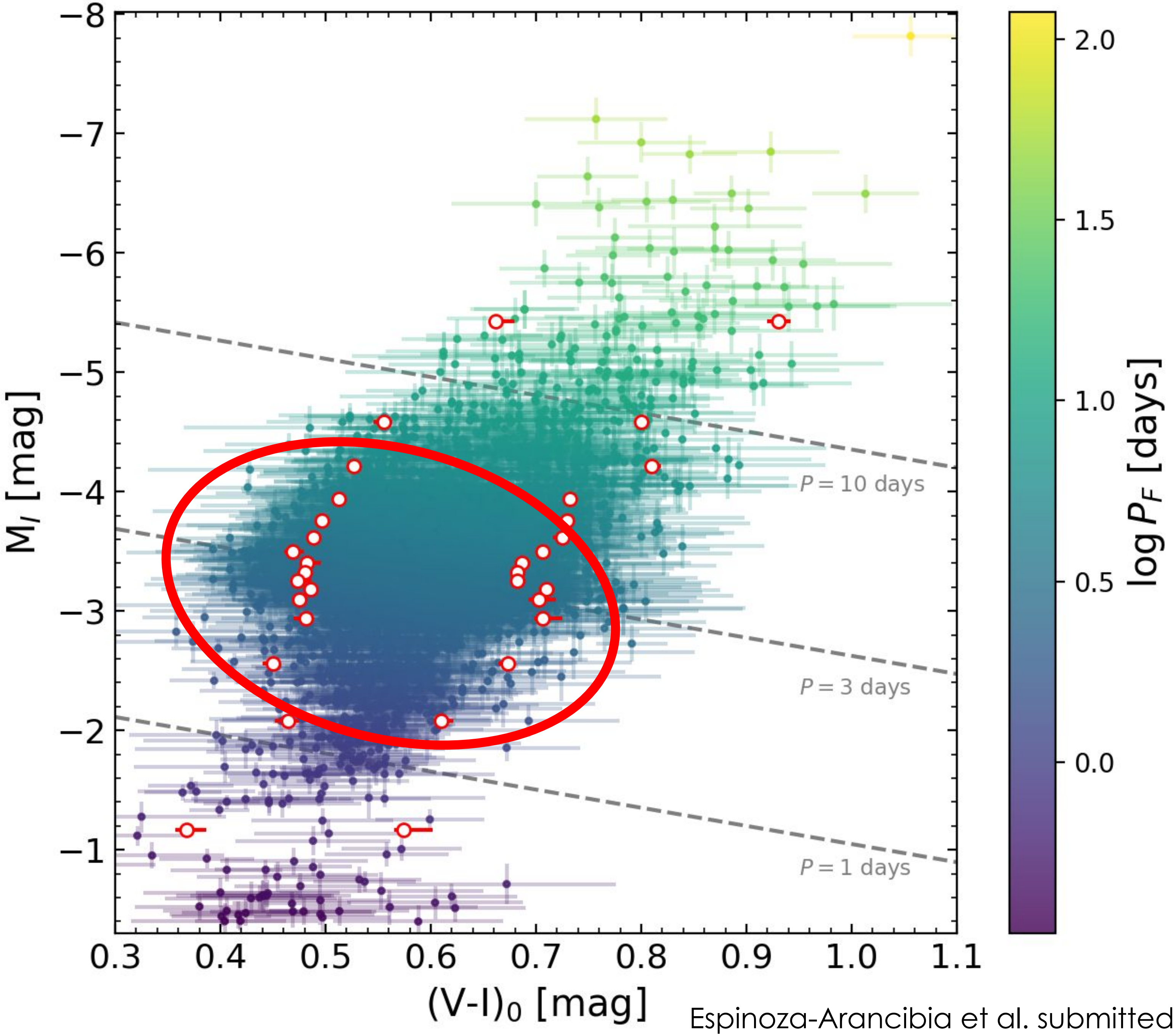


Results



Espinoza-Arancibia et al. submitted

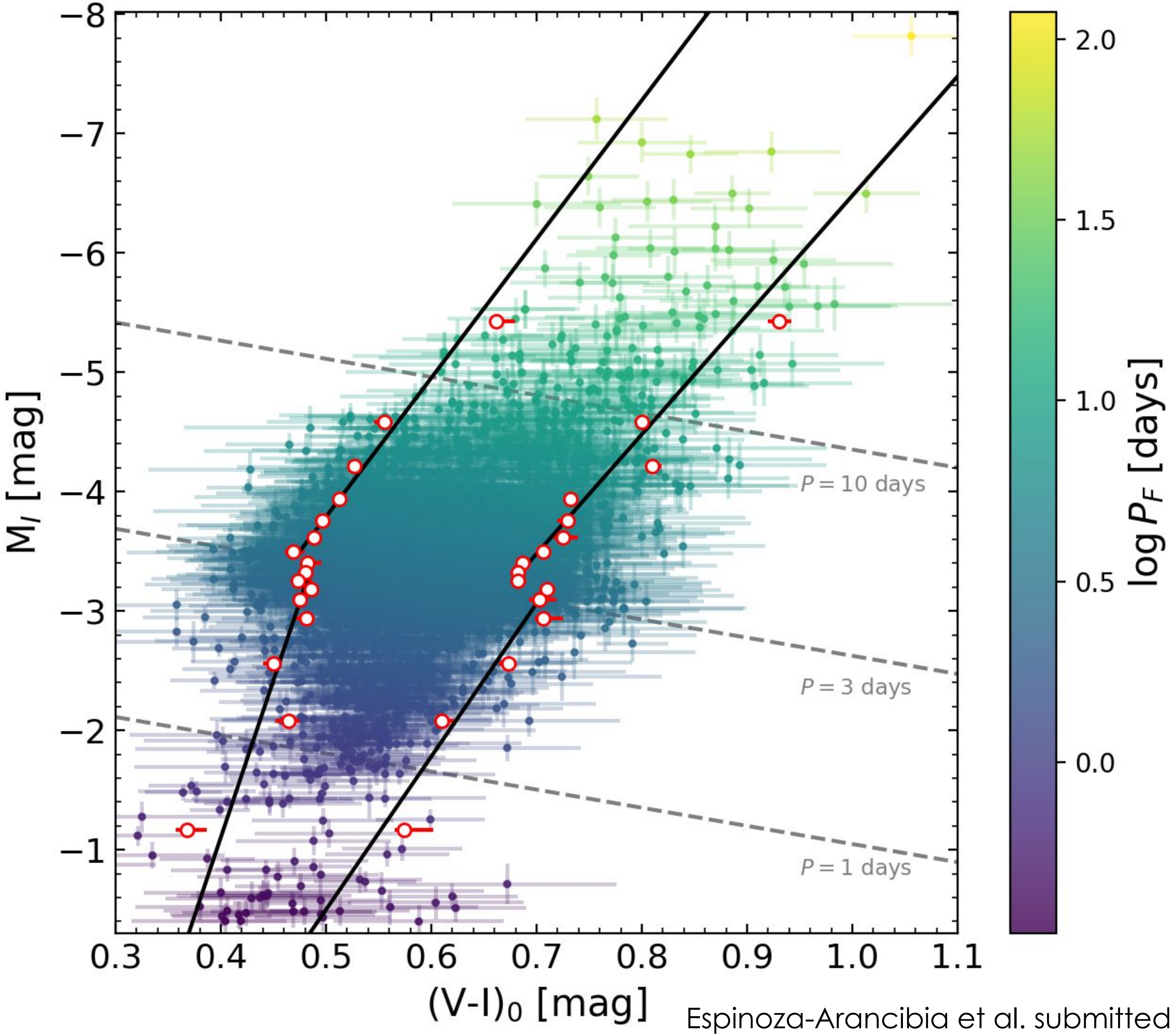
Results



Espinoza-Arancibia et al. submitted

Results

- ➢ Break in the IS positions at P_F ~ 2.5 - 3 days

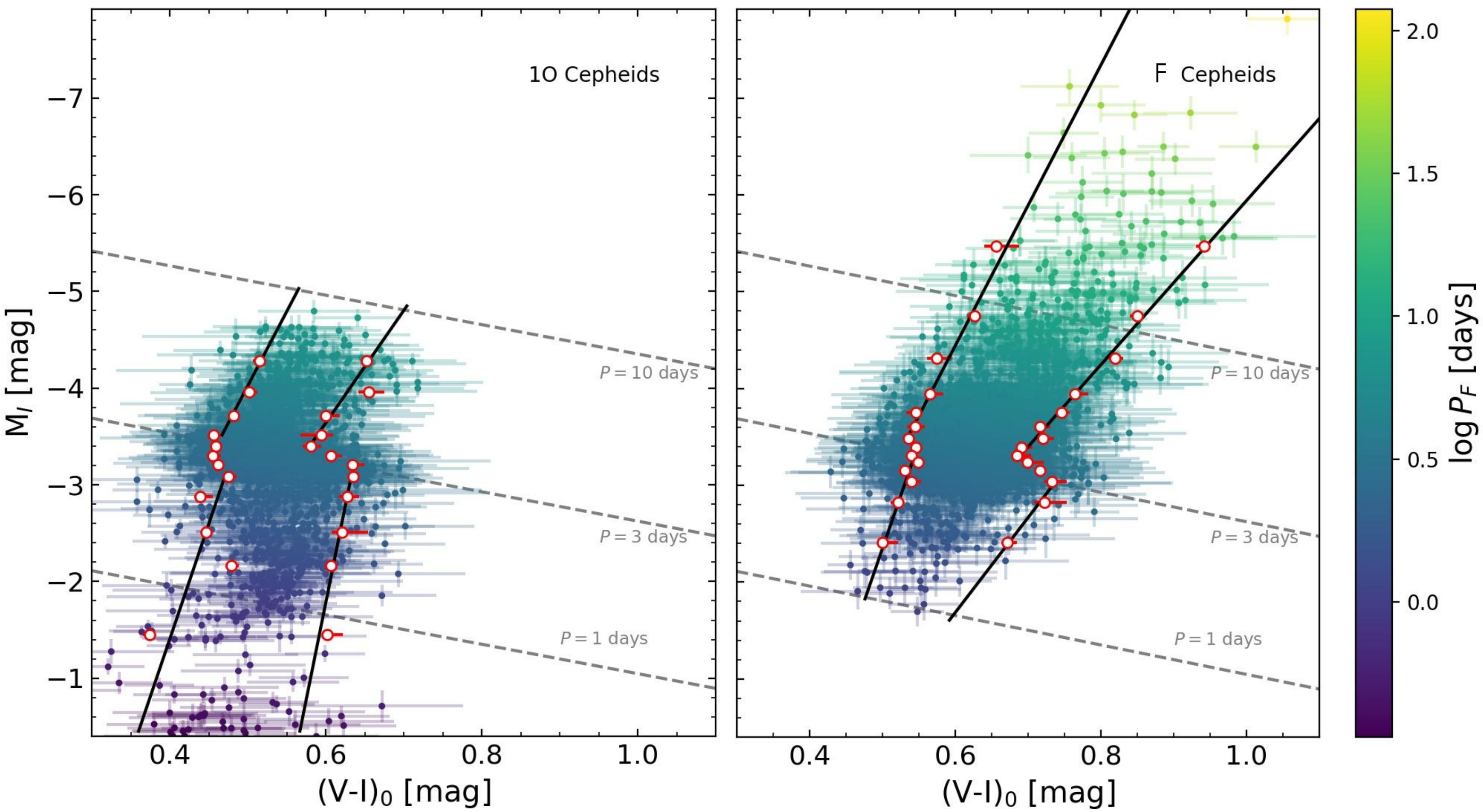


Espinoza-Arancibia et al. submitted

Results

- Break in the IS positions at P_F ~ 2.5 - 3 days

Also present in F and 1O samples



Espinoza-Arancibia et al. submitted

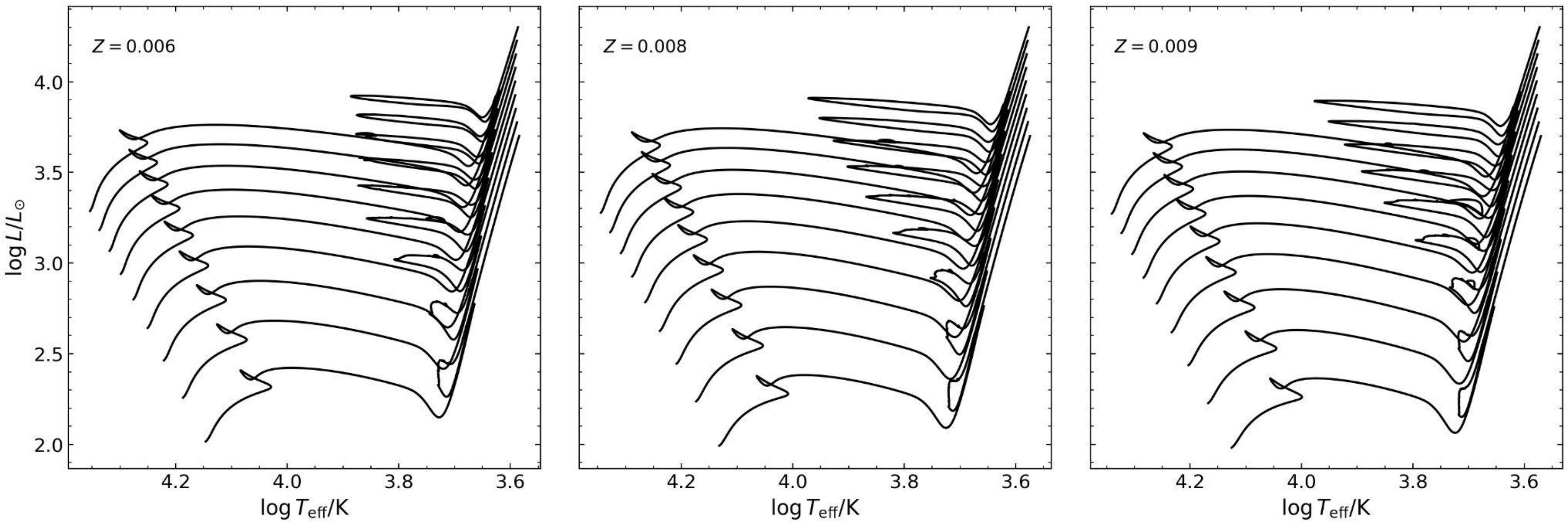
Results

- ➢ Break in the IS positions at $P_F \sim 2.5 - 3$ days

Also present in F and 1O samples

Why?

MESA evolutionary tracks
3 - 7 Solar masses (in steps of 0.1)



Results

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Also present in F and 1O samples

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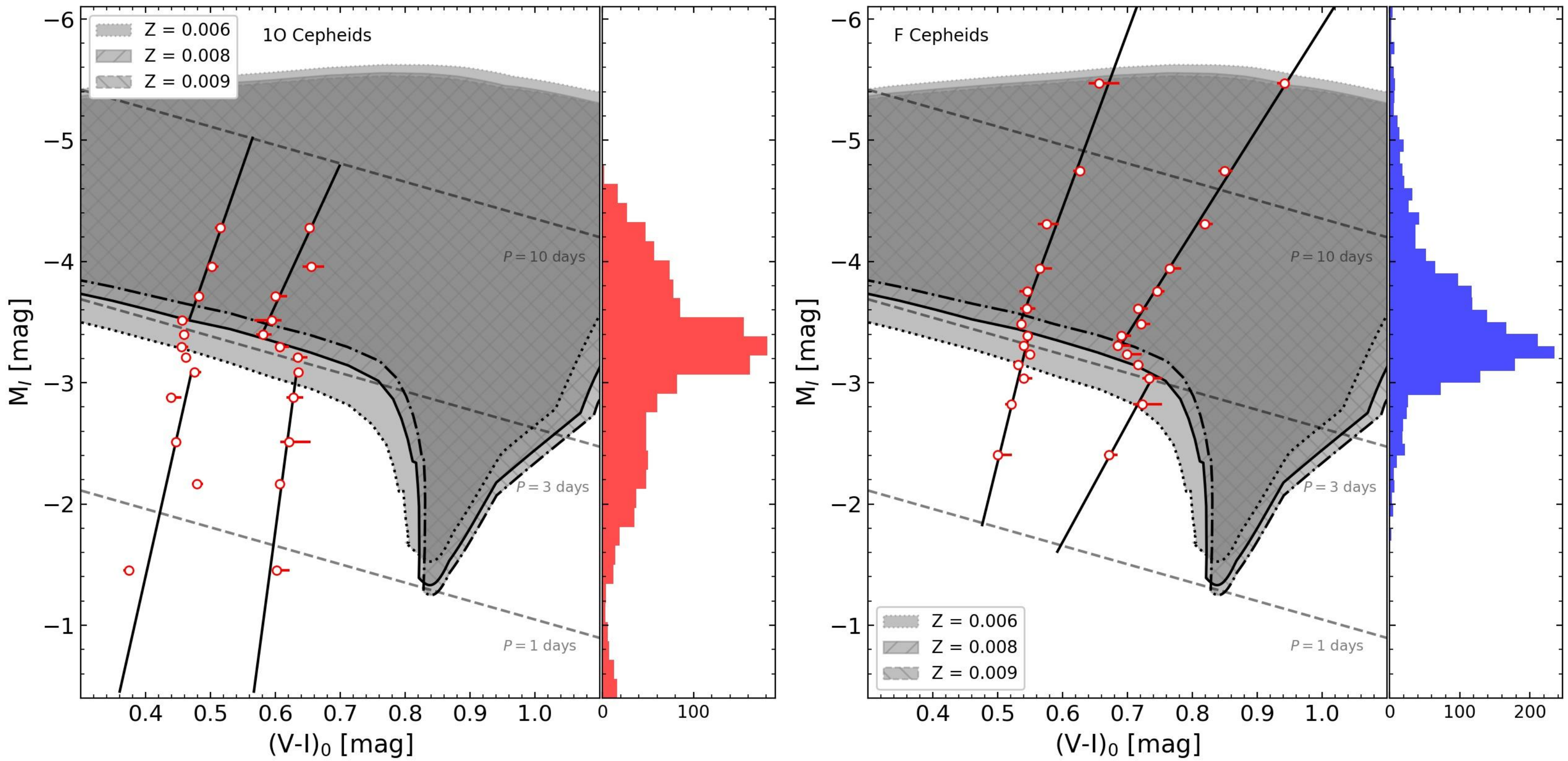


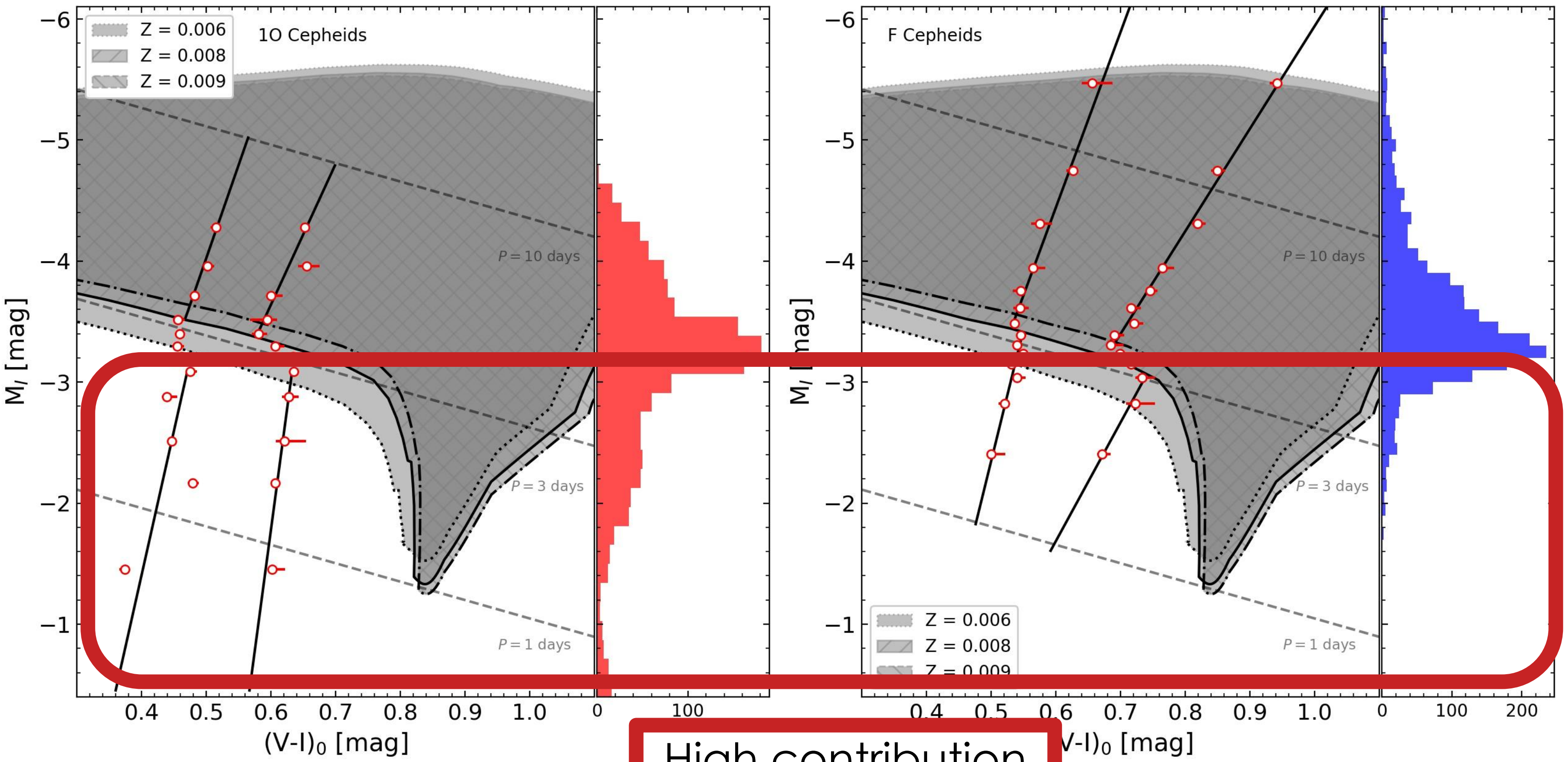
Espinoza-Arancibia et al. submitted

Results

- ➢ Break in the IS positions at $P_F \sim 2.5 - 3$ days

Depopulation of 2nd and 3rd crossing Cepheids in the faint part of the IS.

Blue loops become shorter as the mass and period of Cepheids decreases (Bauer, F. et al. 1999; Ripepi et al. 2022).



High contribution of 1st crossing Cepheids

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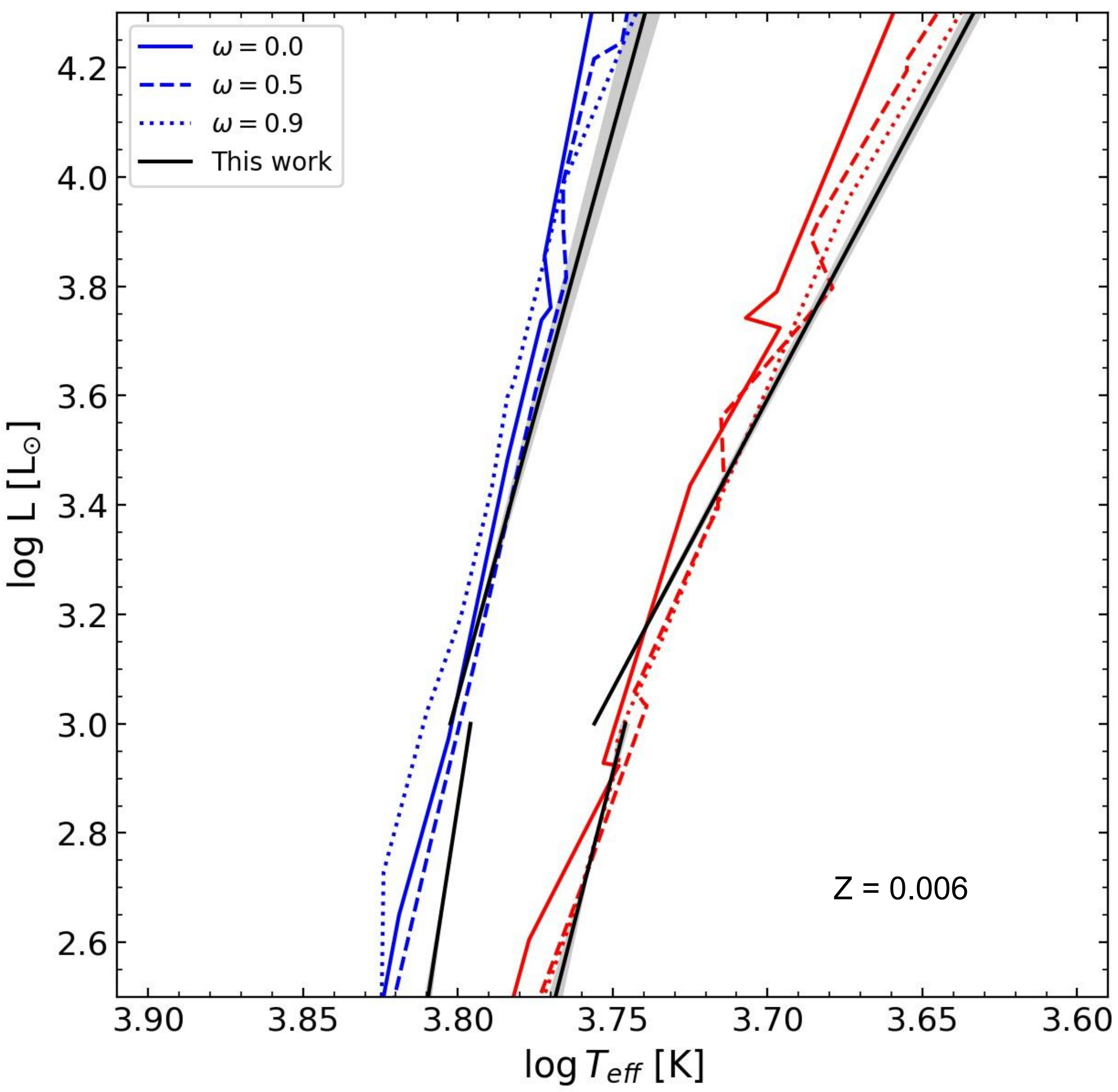
Comparisons

Anderson et al. (2016)

Theoretical IS obtained using Geneva code, as a function of metallicity, and rotation rate.

➢ Their red edges present several shifts to higher temperatures, related to the dependency of the red IS boundary on the crossing number.

➢ Globally their models with high rotation rates describe best our determined edges but the lower part seems to favor those with moderate rotation rates.



Espinoza-Arancibia et al. submitted

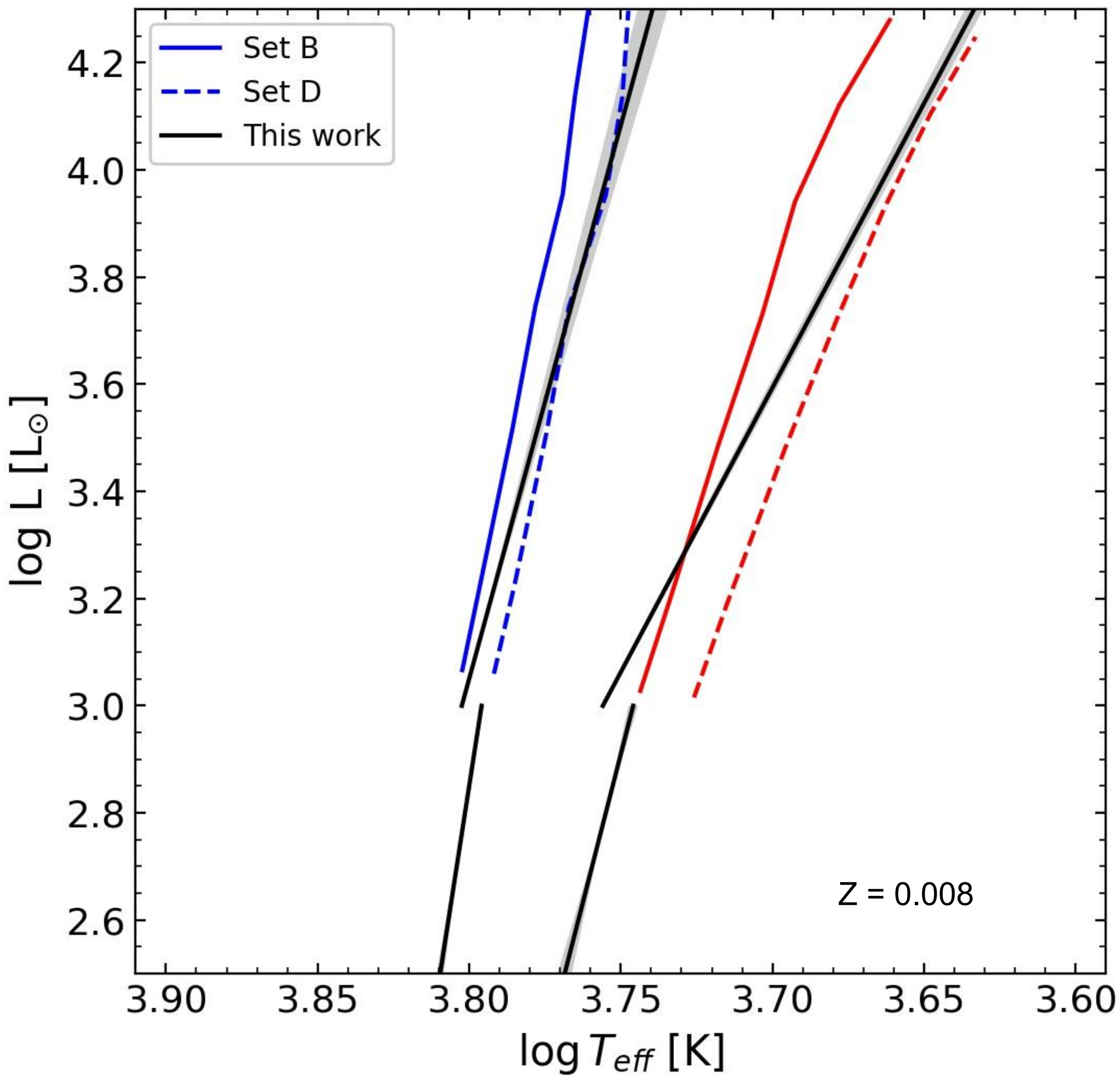
Comparisons

Paxton et al. (2019)

IS obtained *RSP*, a functionality of the *MESA* code to model pulsations. The RSP convective model depends on free parameters.

Set B of free parameters includes radiative cooling effects.
Set D includes turbulent pressure, turbulent flux and radiative cooling.

➢ Our blue edge is in closer agreement with that of set D, while our red edge lies somewhere in between sets B and D.



Espinoza-Arancibia et al. submitted

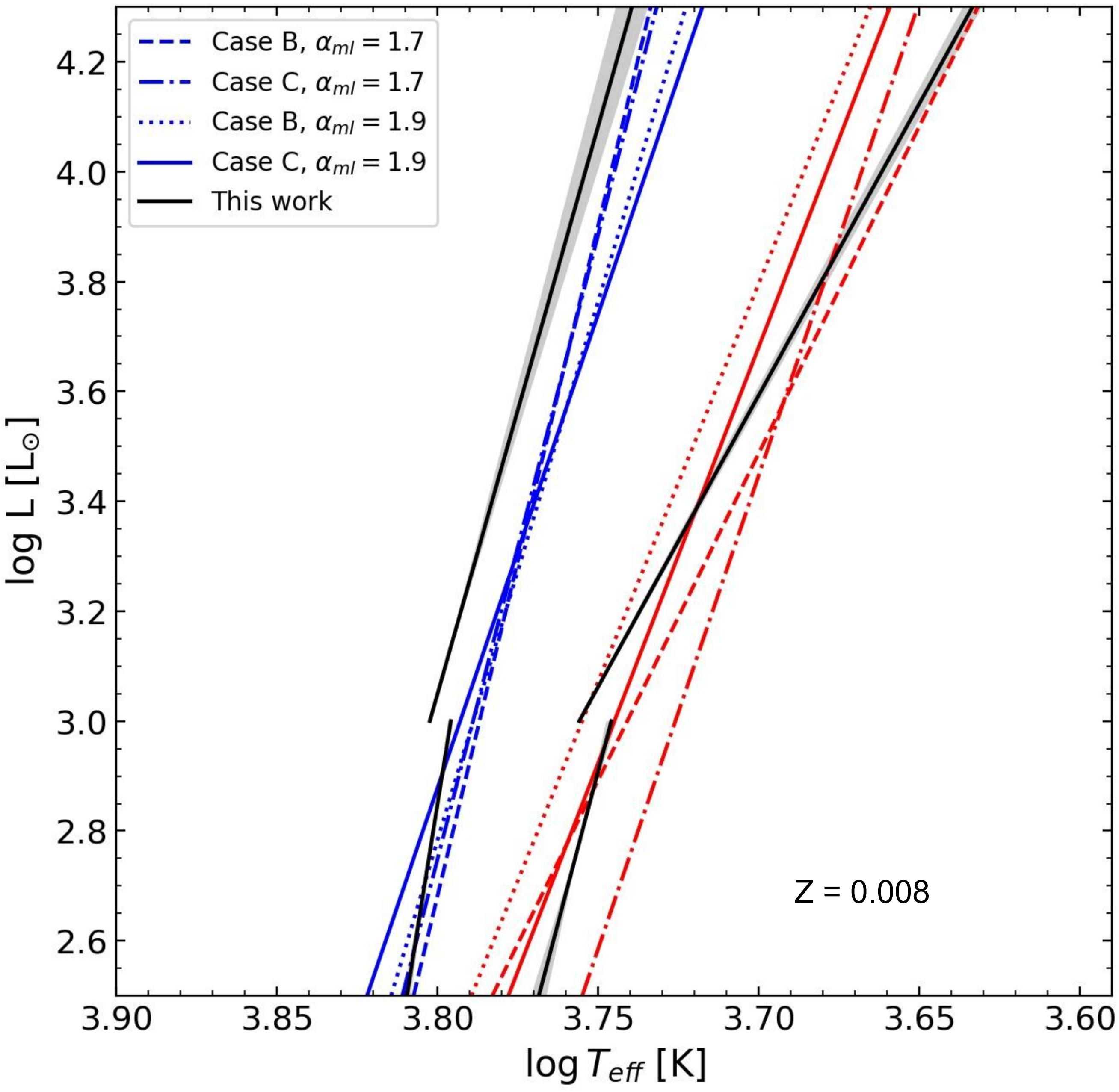
Comparisons

De Somma et al. (2022)

Theoretical IS obtained using BasTI evolutionary tracks, studying the effects of mass-luminosity (ML) relations, and superadiabatic convection efficiency.

ML B and C considers an increase in luminosity over their canonical model by 0.2 and 0.4 dex.

- ➢ Our empirical edges are most consistent with their models for case B and a_{ml}=1.7.
- ➢ Our upper blue edge is systematically hotter.



Espinoza-Arancibia et al. submitted

Conclusions

- ➢ **We developed a method which uses a sample of classical Cepheids from the LMC to obtain an empirical and intrinsic IS. A break in the IS positions was observed at P ~ 2.5 - 3 days.**

- ➢ **Our empirical IS and theoretical models shows that below 4 solar masses blue loops do not cross the IS.**

  Consequently, in this part of the IS, there is a high contribution of first crossing Cepheids.

- ➢ **Theoretical models showed good agreement with our results. Allowing us to point out models with certain physical parameters that would be more likely.**

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Thank you!