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ARMAGH OBSERVATORY & PLANETARIUM
EXPLORING THE COSMOS SINCE 1790

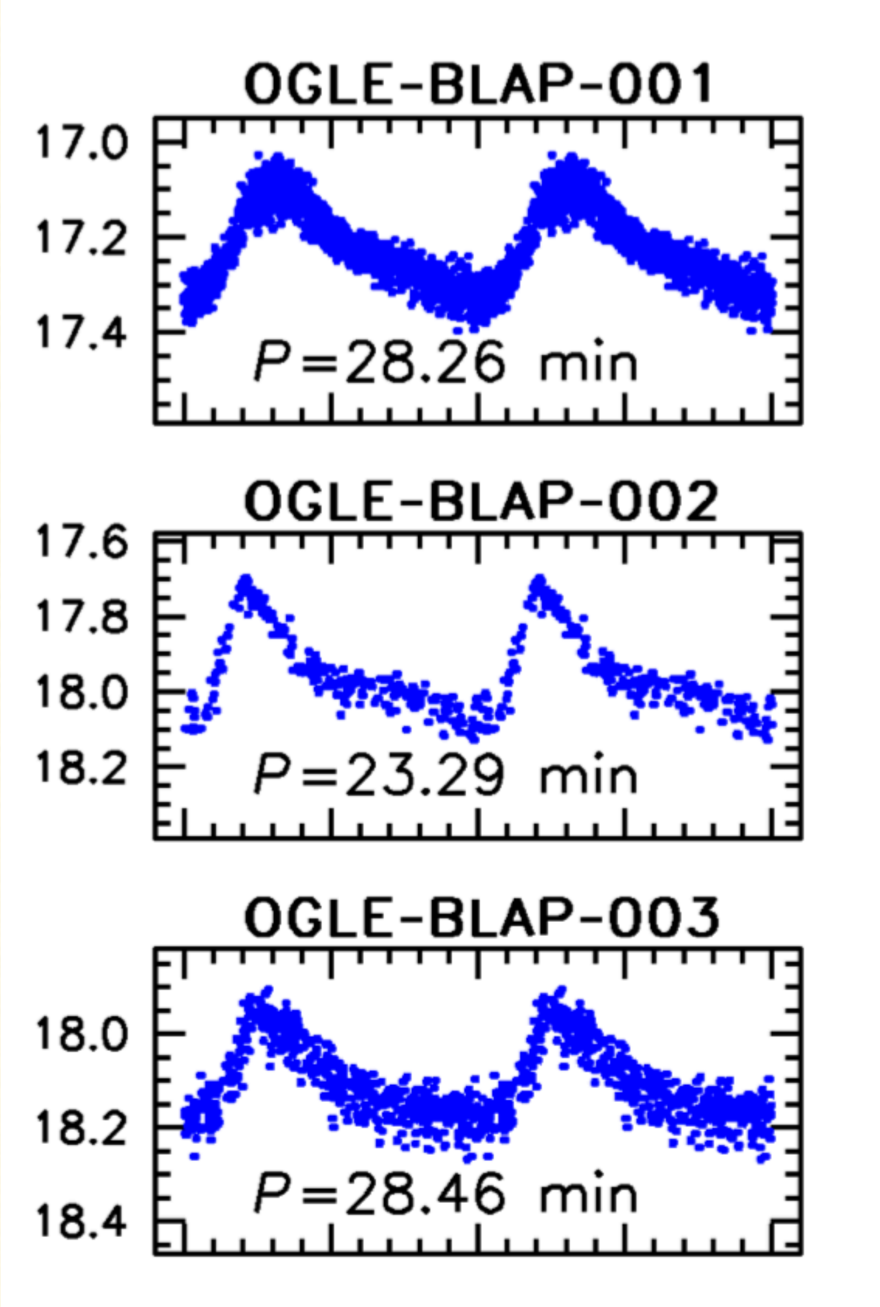
Post-common envelope binary stars: Radiative Levitation and Blue Large-Amplitude Pulsators

Conor Byrne & Simon Jeffery

Armagh Observatory & Planetarium / Trinity College Dublin

6 September 2018

BLUE LARGE-AMPLITUDE PULSATORS (BLAPS)



Pietrukowicz et al., Nature Astronomy (2017)

- Large amplitude pulsators found in the OGLE survey
- Initially classified as δ Sct star
- Brightness variations of 0.2-0.4 mag on timescales of 20-40 mins.
- Spectroscopic follow-up

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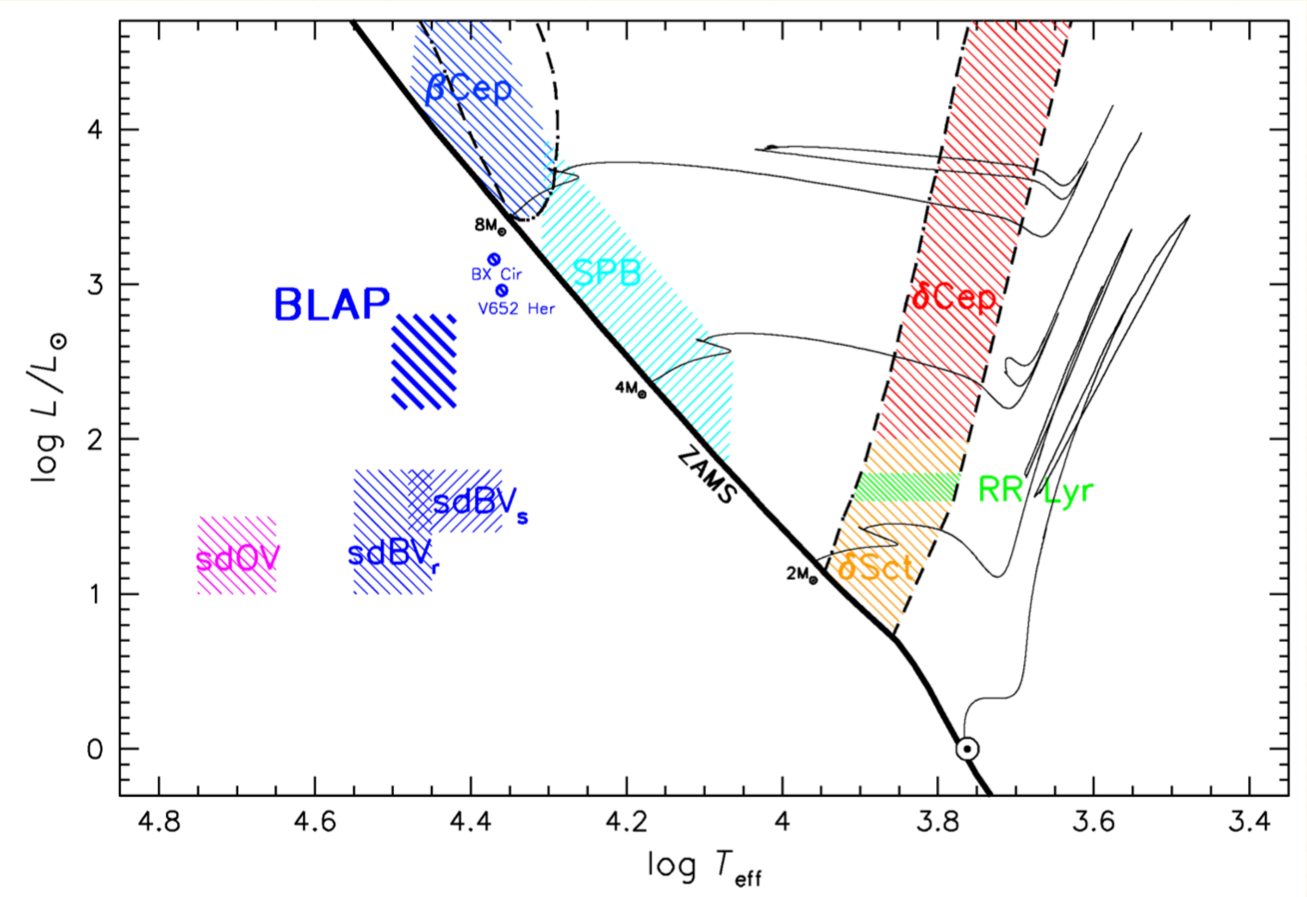
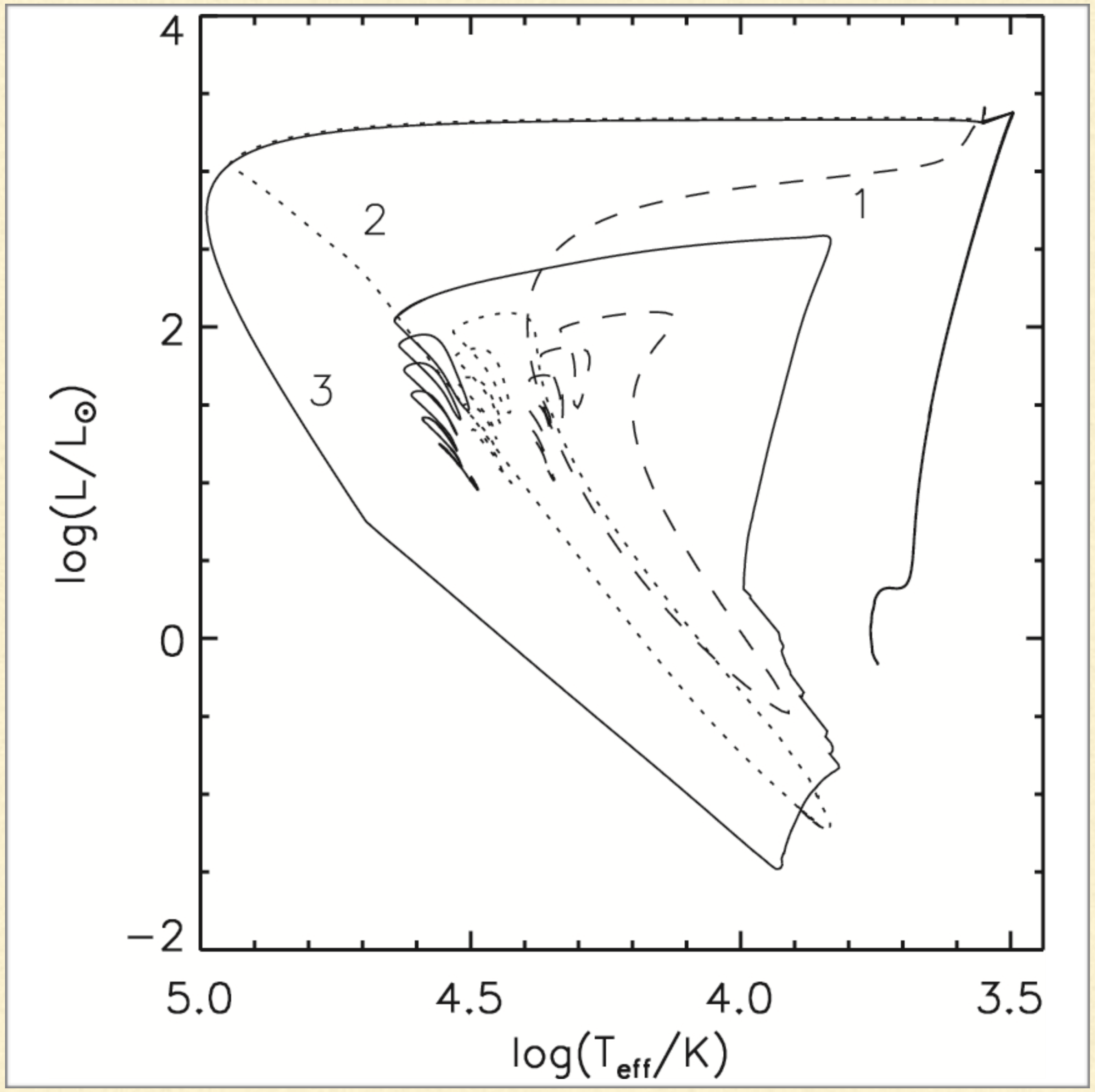


- Discovered that the object was much hotter, T_{eff} ~30,000 K
- Surface gravity lower than sdO/B but higher than MS stars.
- N_{He}/N_H of about 0.28 for the prototype object
- Romero et al. (2018) suggest these may be low mass pre-WDs

Pietrukowicz et al., Nature Astronomy (2017)

PREVIOUS WORK ON SDBS



Byrne et al., MNRAS (2018)

- Subdwarf B stars - products of binary evolution (recall talks of Charpinet, van Grootel, Zong)
- Used MESA (Paxton et al, 2011, 2013, 2015, 2018) to model the evolution of stars from RGB to the EHB having undergone common envelope ejection (CEE)
- Using a high mass loss rate to replicate the effects of CEE.

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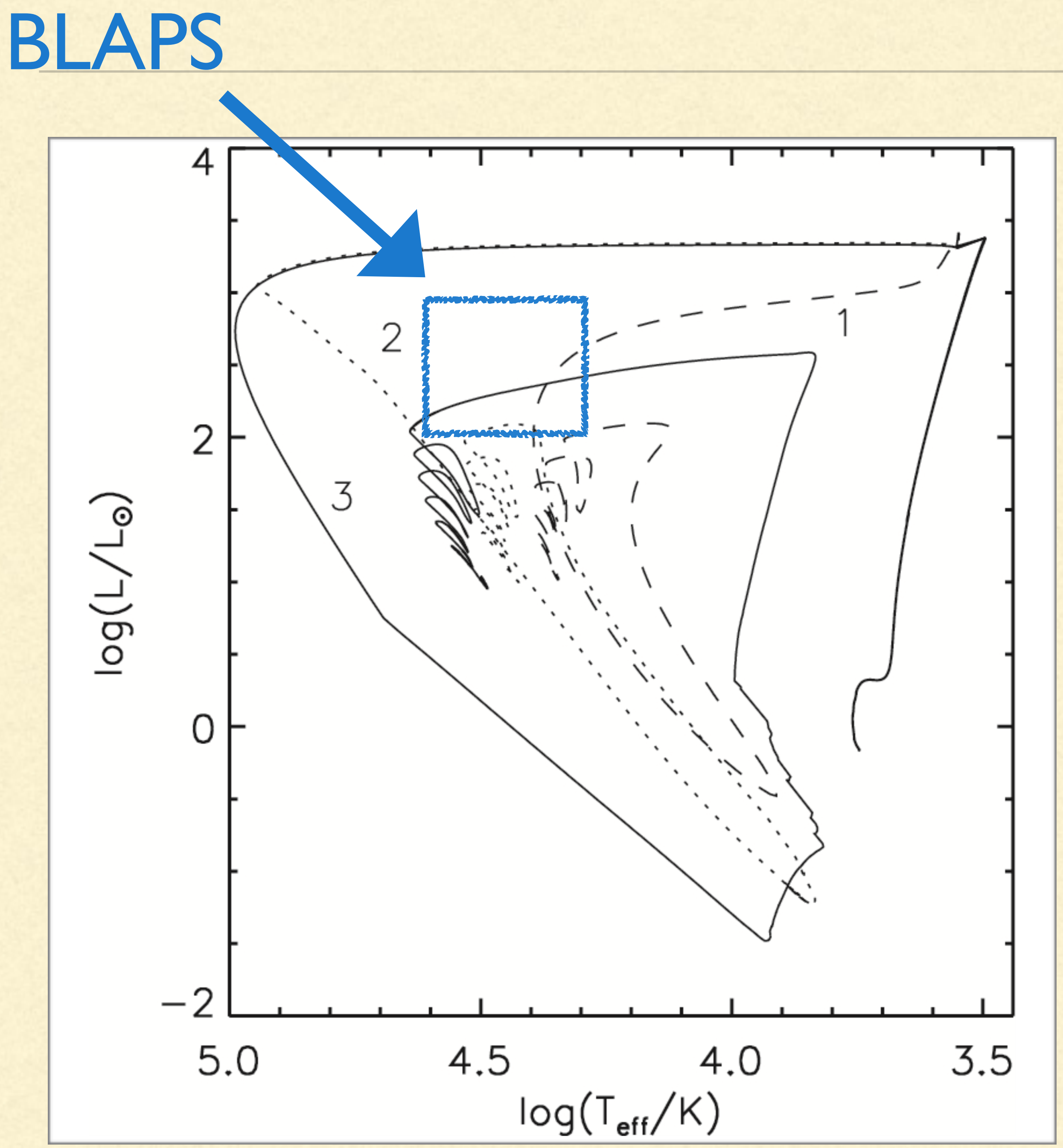

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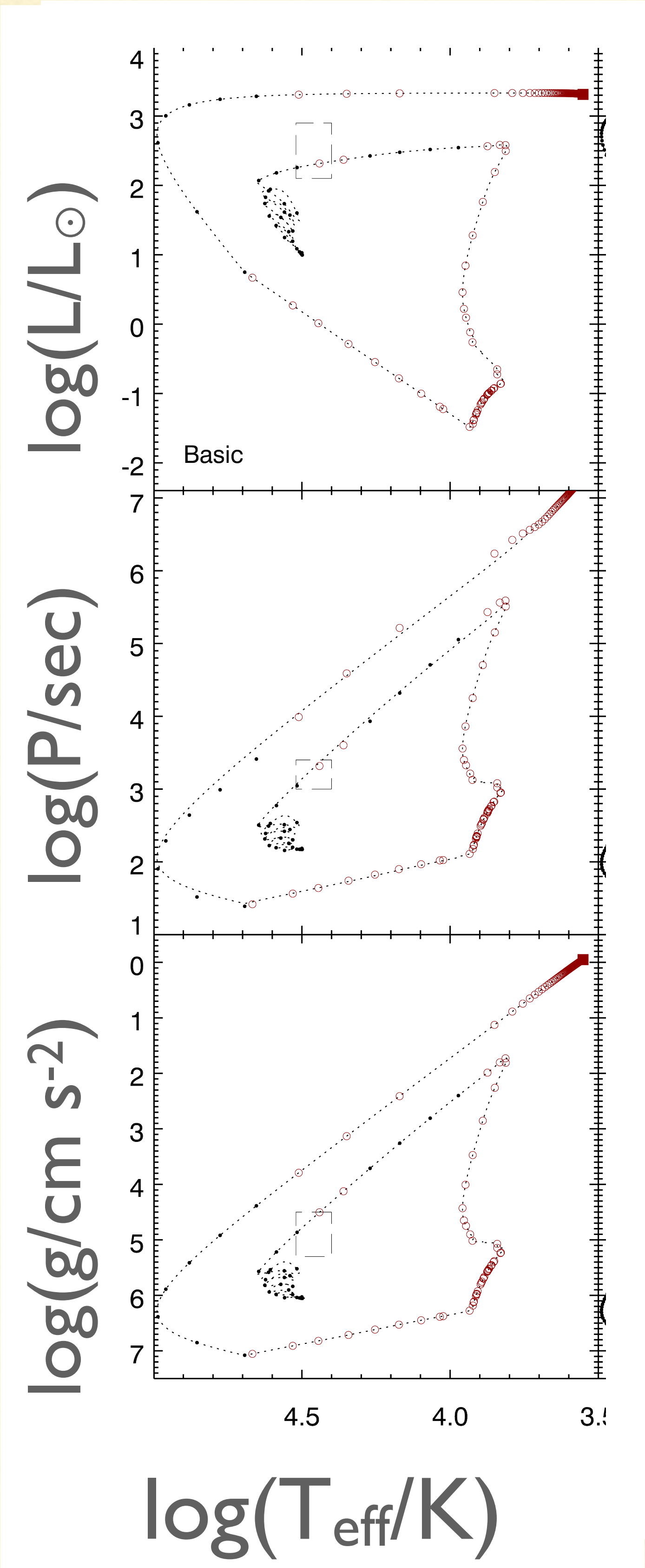
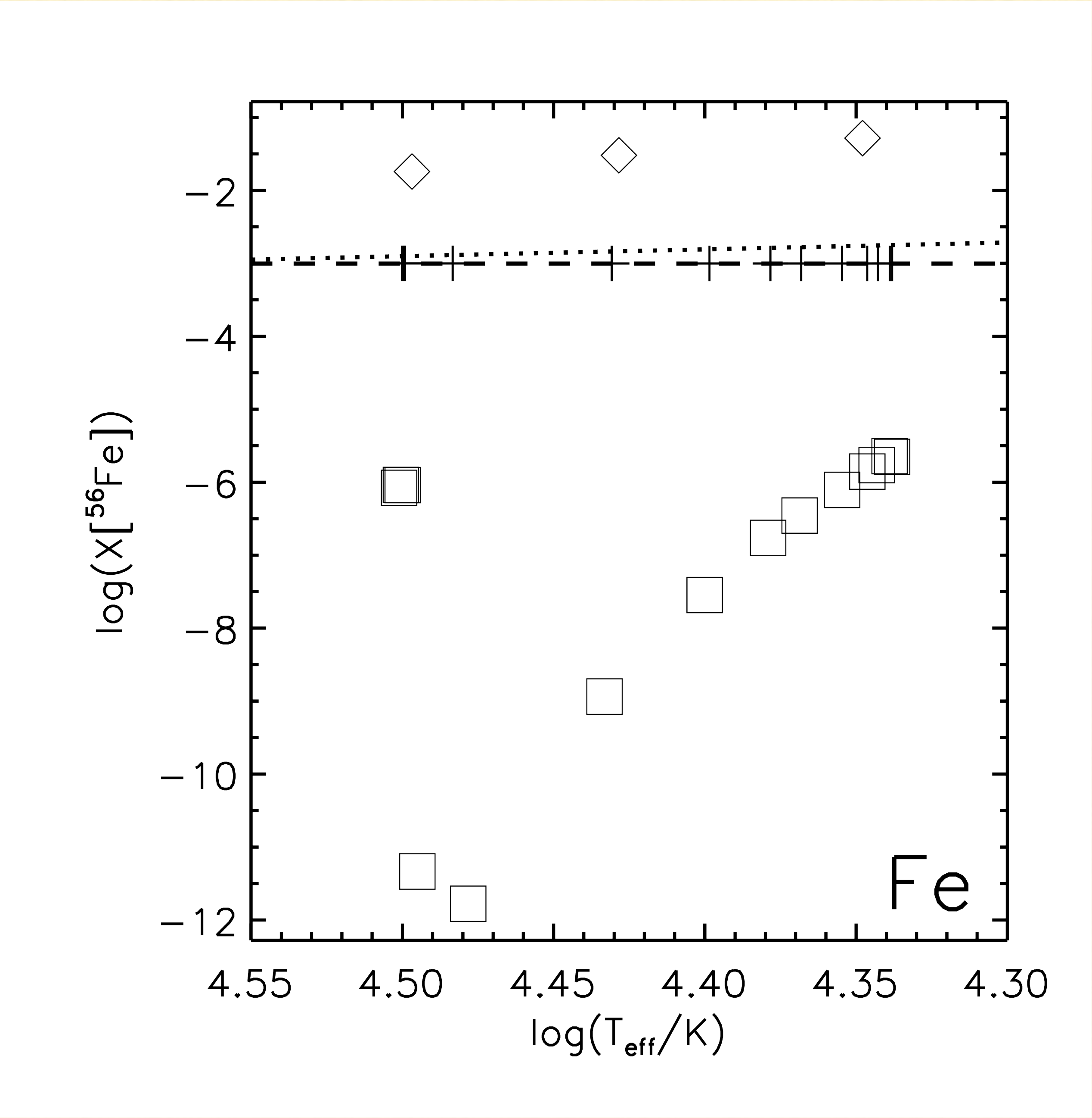


PULSATION ANALYSIS: 0.46 M⊙ POST-CEE OBJECT

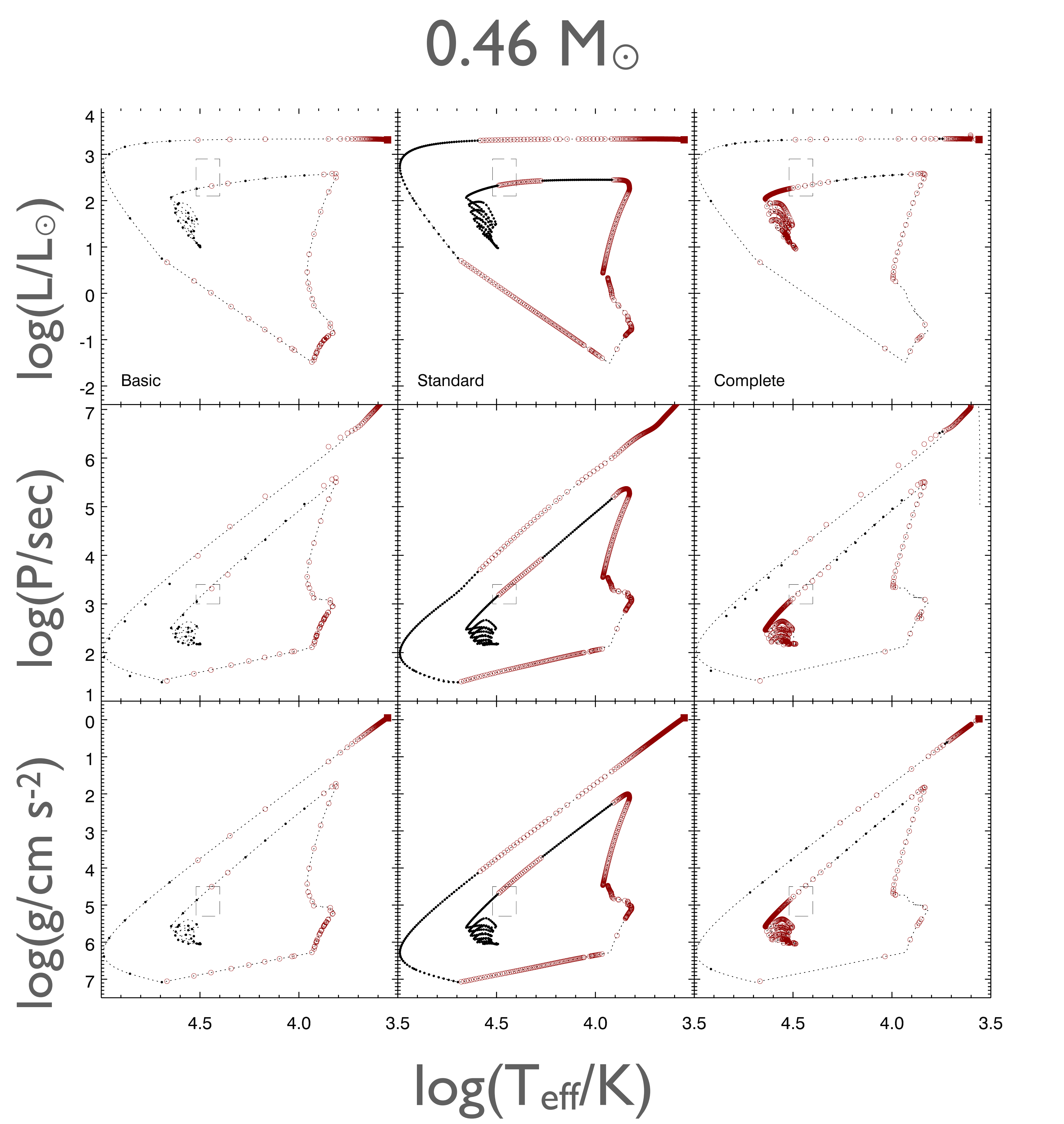
- Using GYRE (Townsend & Teitler 2013) to analyse the MESA models.
- Focus on ℓ = 0 modes owing to high amplitudes
- Instability determined by the sign of complex component of the eigenfrequency from the non-adiabatic solutions.
- For a 0.46 M⊙ star, no pulsations found on horizontal branch

ATOMIC DIFFUSION



Byrne et al., MNRAS (2018)

- <u>Basic</u>
    - No diffusion
- <u>Standard</u>
    - Gravitational settling
    - Thermal diffusion
    - Concentration diffusion
- <u>Complete</u>
    - 'Standard' + Radiative Levitation
    - OP monochromatic data
    - Takes a bit(!) longer to compute

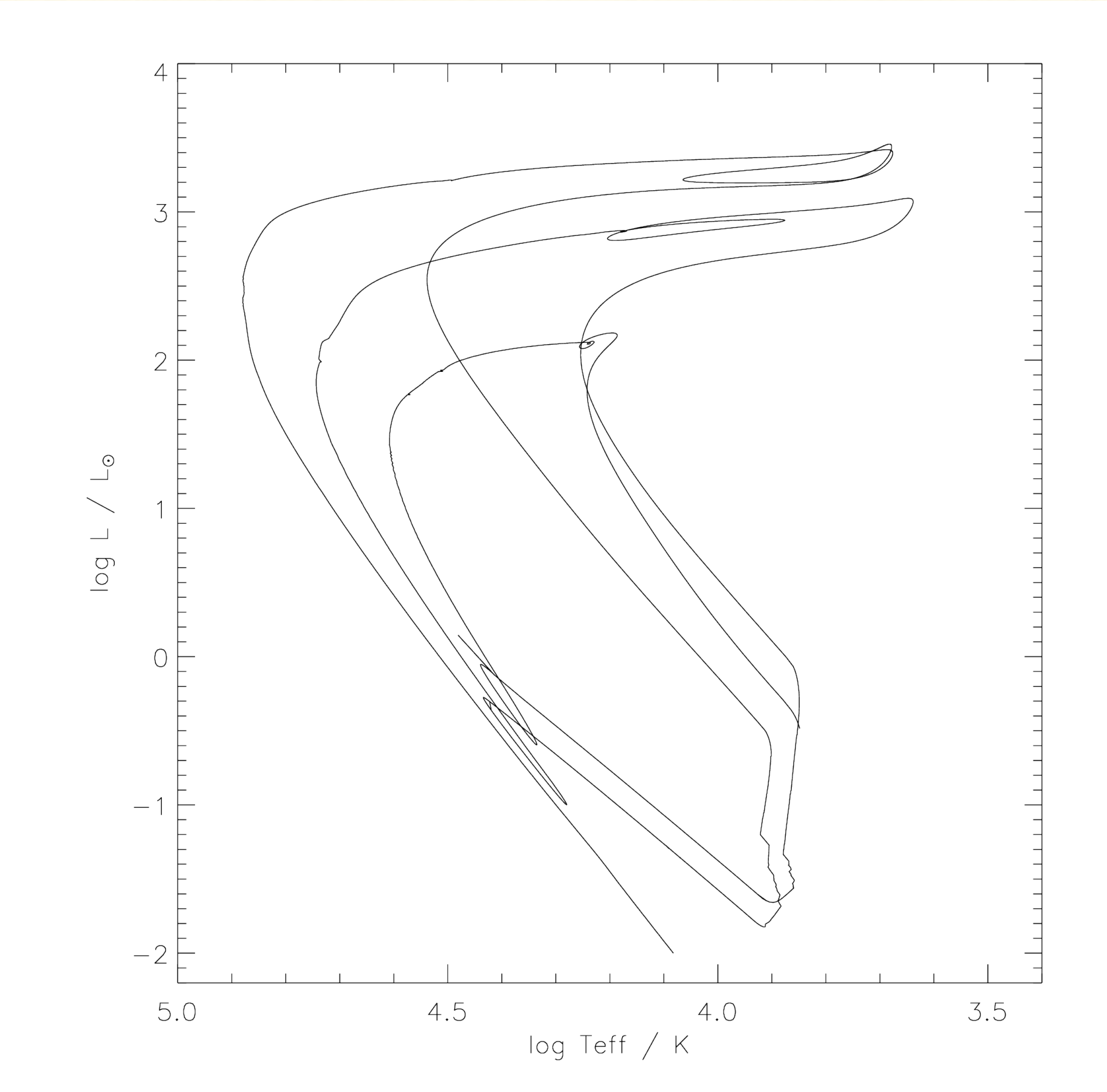


EFFECTS OF DIFFUSION

- Diffusion leads to more instability
- Radiative levitation leads to pulsations on the horizontal branch, as expected
- Pulsations in BLAP region, crossing in about 15,000 yrs

Byrne & Jeffery, MNRAS, submitted

WHAT ABOUT LOWER MASS RGB OBJECTS?



- Analysis of Pietrukowicz et al. (2017) suggested that a ~0.3 M☉ shell-burning stars could be BLAPs, and was explored by Romero et al. (2018)
- Effects of radiative levitation not modelled
- Implement CE ejection in an object with a smaller He core (0.31 M☉), in the same way as for EHB models

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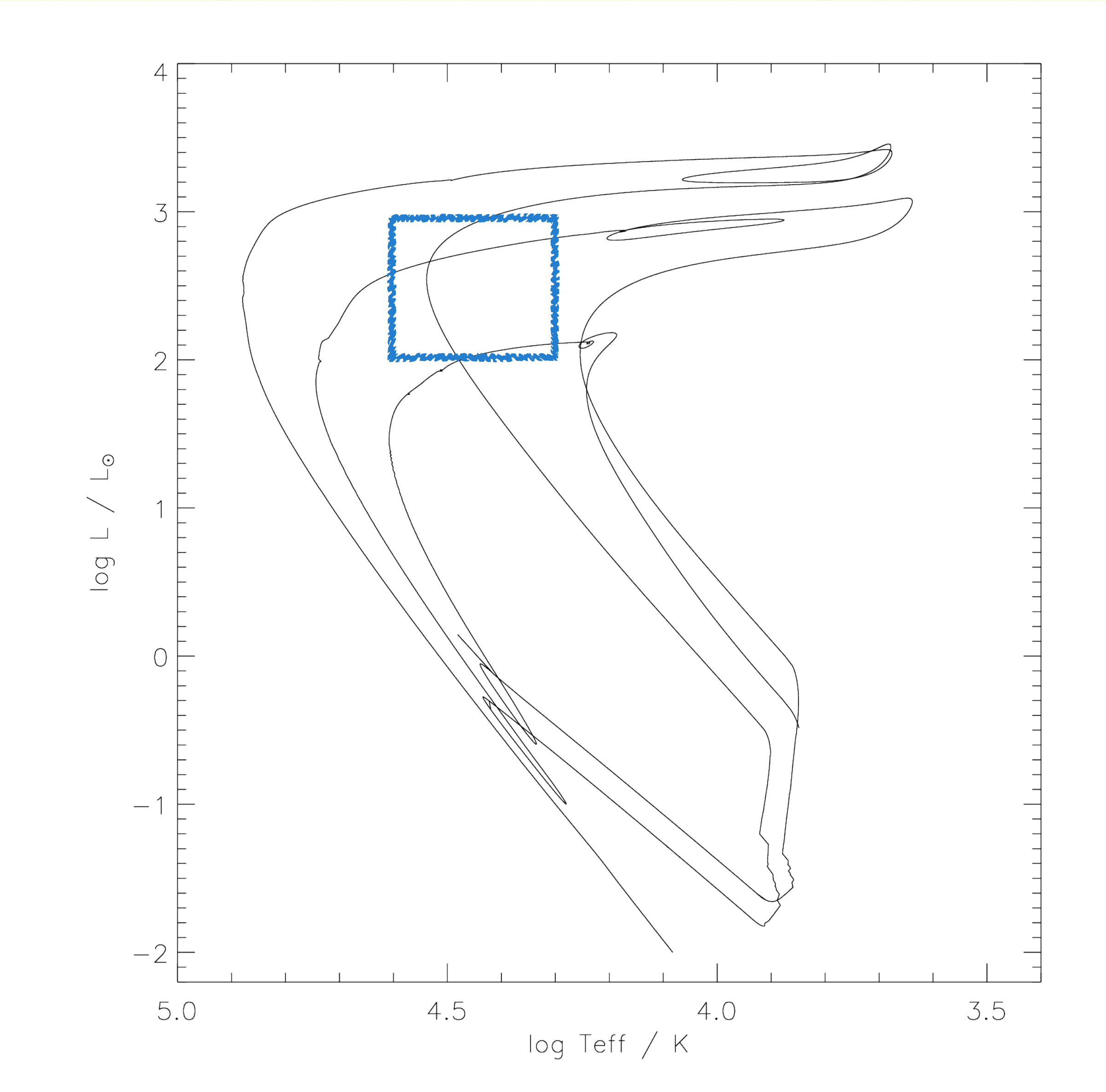

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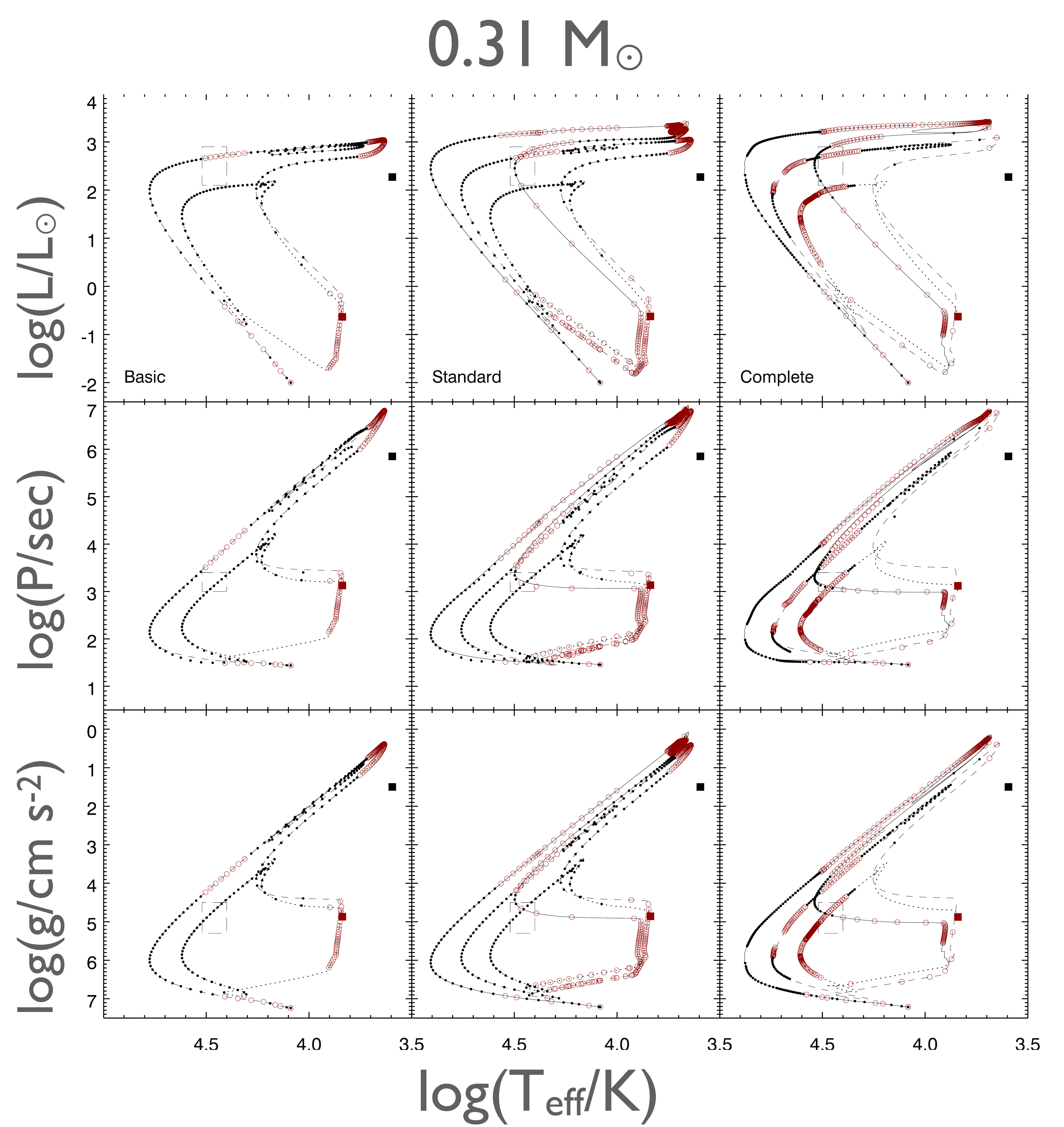
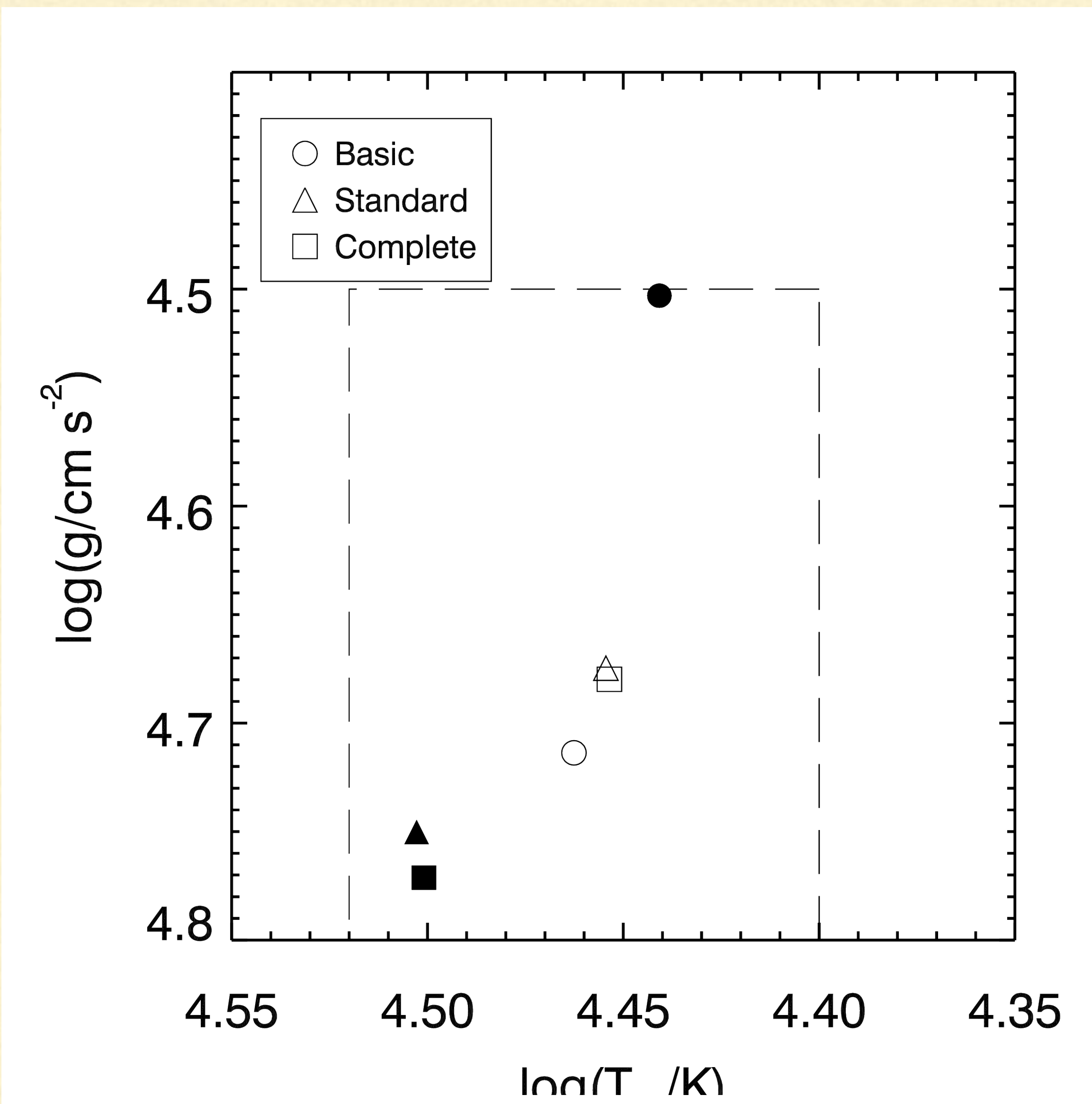


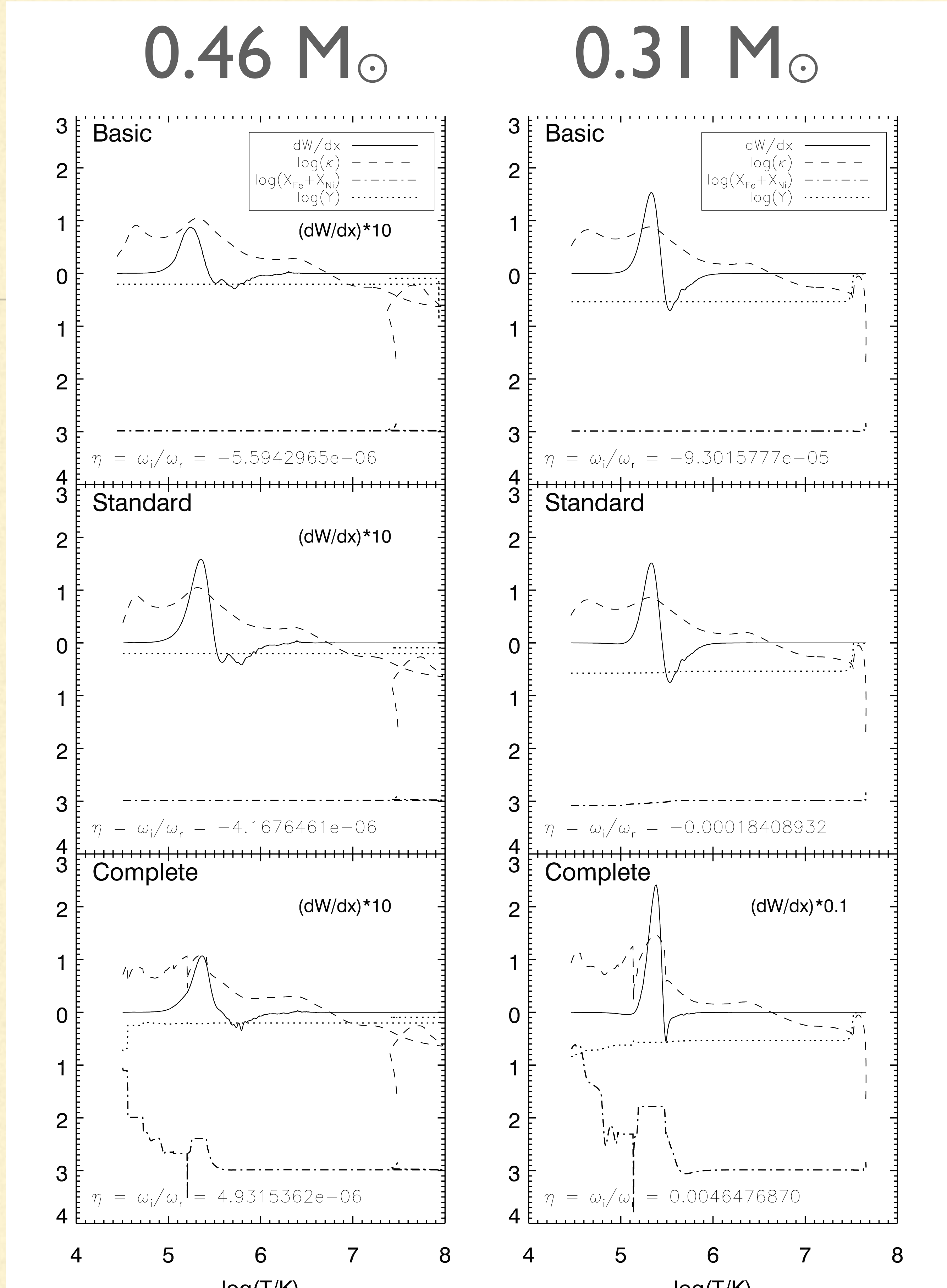
- Impact of radiative levitation clear
- Pulsations in the region of interest!
- Periods comparable to BLAPs!
- Crosses region in ~8×10^5 yrs (longer than 0.46 M⊙)

Byrne & Jeffery, MNRAS, submitted

DRIVING MECHANISM



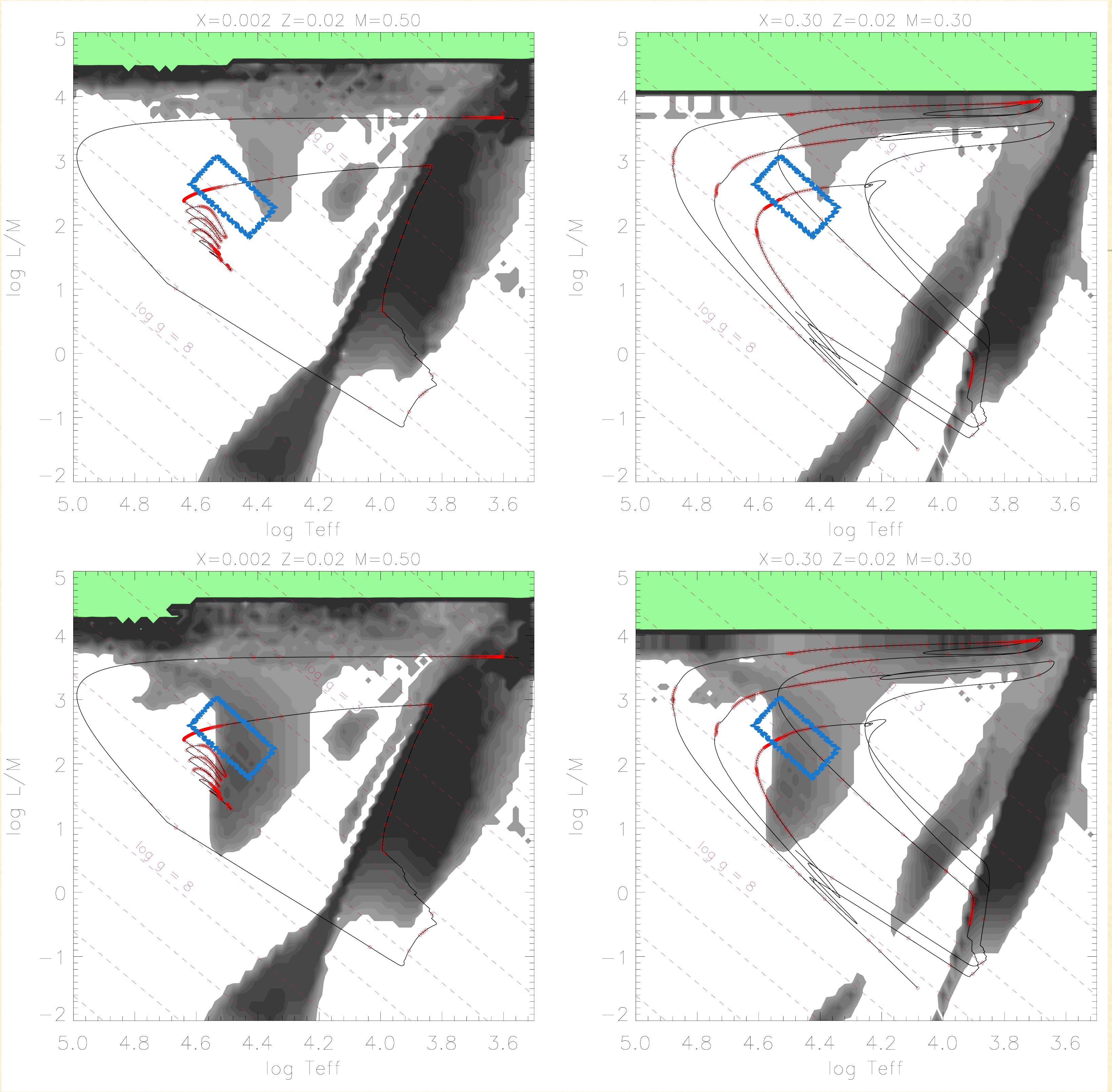
- Selected some specific models for further investigation
- Chose models with gravities and temperatures comparable to those reported for BLAPs
  - 0.46 $M_\odot$ = filled symbols
  - 0.31 $M_\odot$ = open symbols



DRIVING MECHANISM

- Driving zone corresponds to the iron opacity peak at temperatures of ~ $2{\times}10^5$ K
- Opacity peak less pronounced when levitation is neglected.

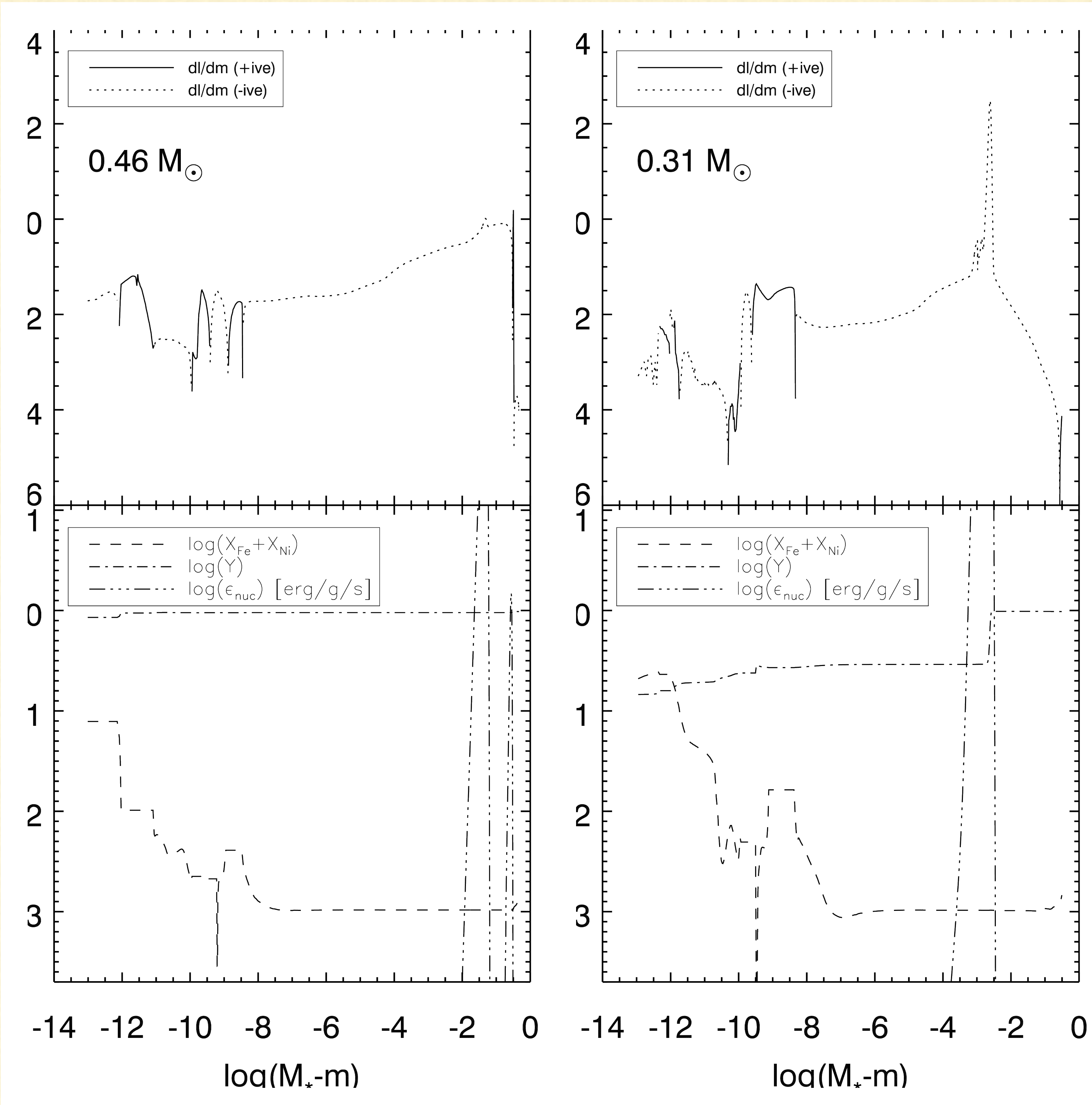
INSTABILITY REGIONS



- The unstable stars generally fall into the instability regions determined by Jeffery & Saio (2016)
- Blue edge seems to extend slightly further

Figure adapted from Jeffery & Saio (2016)

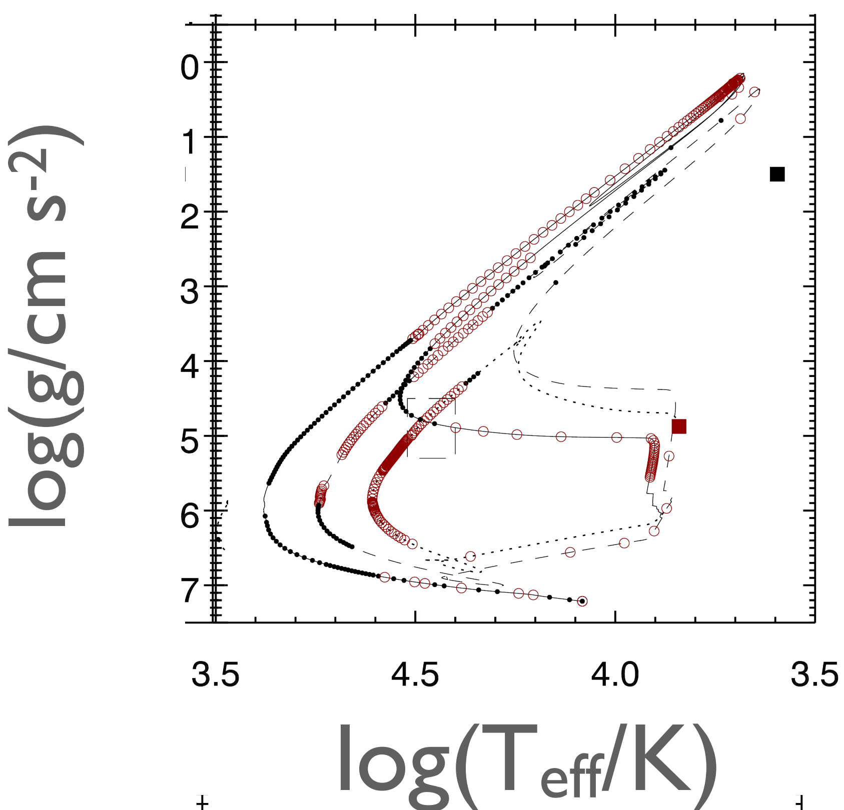
EFFECTS OF THERMAL IMBALANCE

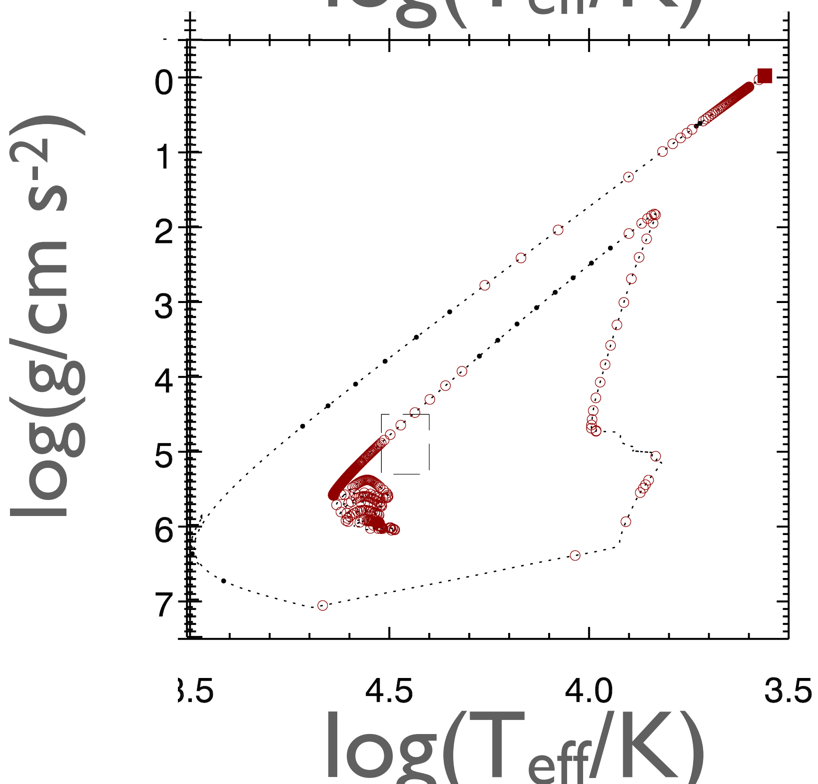


$$\frac{dl}{dm} = \epsilon - T\frac{dS}{dt}$$

- Envelope is not static or homogeneous
- Overall contraction, however heat gets trapped in the ionisation zone
- Aizenman & Cox (1975) found that contraction can act to destabilise the star

REMAINING PUZZLES





- What about the rate of period change?
- OGLE data indicates both positive and negative values
- Post-CEE models here are contracting
  - ➡ negative period change

CONCLUSIONS

- Post-common envelope objects show considerable resemblance to BLAPs
- Radiative levitation plays an important role
- 0.31 $M_{\odot}$ give best agreement with the observations
- Origin of BLAPs with positive period changes remains unclear
- **Thanks for listening!**

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Thank You!

–Questions?