Updated High-Temperature Opacities for DSEP and their Effect on the Jao Gap Location

Thomas M. Boudreaux[1] & Brian C. Chaboyer[1]

Department of Physics and Astronomy, Dartmouth College, Hanover, NH 03755, USA

Abstract

The Jao Gap (Jao et al. 2018), a 17 percent decrease in stellar density at $M_G \sim 10$ identified in both Gaia DR2 and EDR3 data, presents a new method to probe the interior structure of stars near the fully convective transition mass. The Gap is believed to originate from convective kissing instability wherein asymmetric production of 3He causes the core convective zone of a star to periodically expand and contract and consequently the stars luminosity to vary. Modeling of the Gap has revealed a sensitivity in its magnitude to a populations metallicity and consequently opacity. Thus far, models of the Jao Gap have relied on OPAL high-temperature radiative opacities. However, OPLIB opacities (Colgan et al. 2016) are more up to date. Use of these updated opacities changes the predicted location of the Jao Gap by 0.05 mag as compared to models which use the OPAL opacities.

Updating Opacities

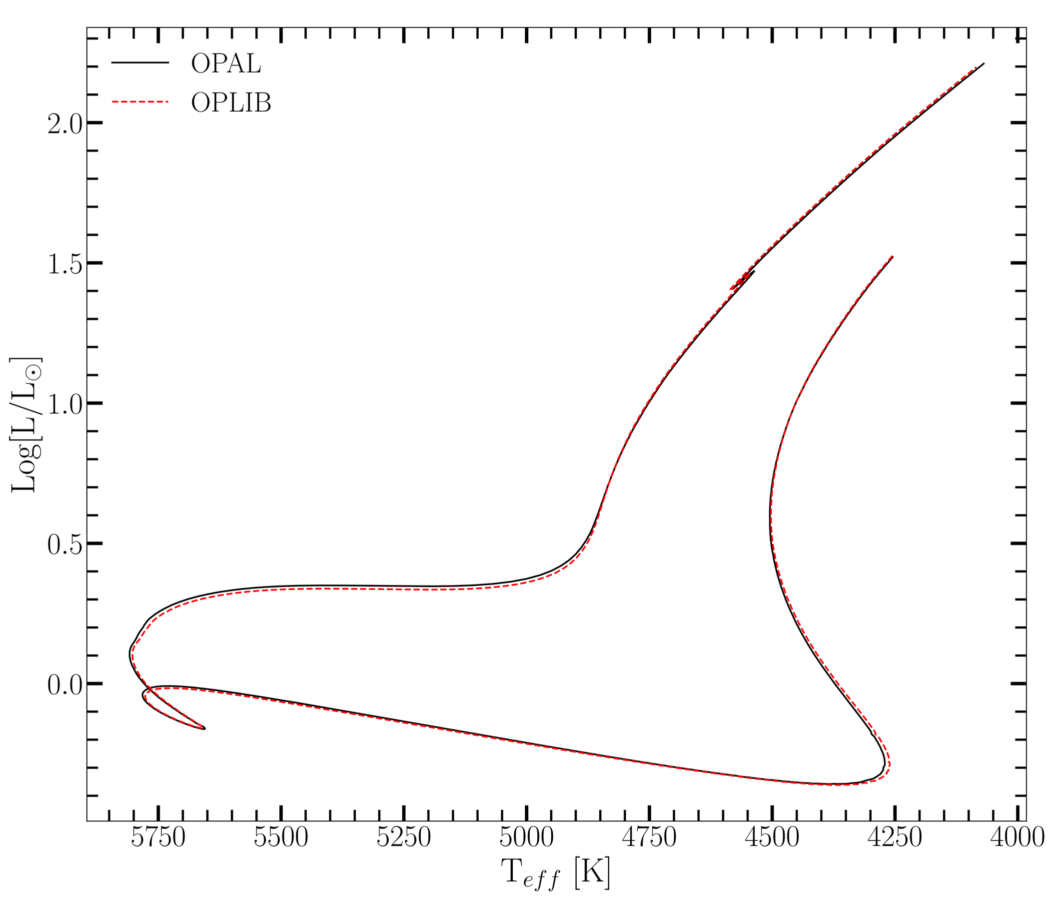

Fig. 1: Solar Calibrated Stellar Models using both OPAL (black) and OPLIB (red) high–temperature opacity tables.

For $\log(R) = -1.5$, OPAL and OPLIB opacities vary up to approximately 2% when $T \geq 10^6$ K. We calibrate a solar model (above) to confirm that variations of this order do not dramatically alter a solar model's evolutionary path.

These small variations may be more impactful for stars at or near the convective transition mass. The interior structure, which is believed to result in the Jao Gap, of such stars is very sensitive to temperature; therefore, small changes in opacity may be more impactful than in higher mass models.

Modeling the Gap

A theoretical explanation for the Jao Gap comes from van Saders & Pinsonneault 2012, who propose that in a star directly above the transition mass, due to asymmetric production and destruction of He^3 during the proton-proton I chain (ppI), periodic luminosity variations can be induced. This is known as convective-kissing instabilitie.

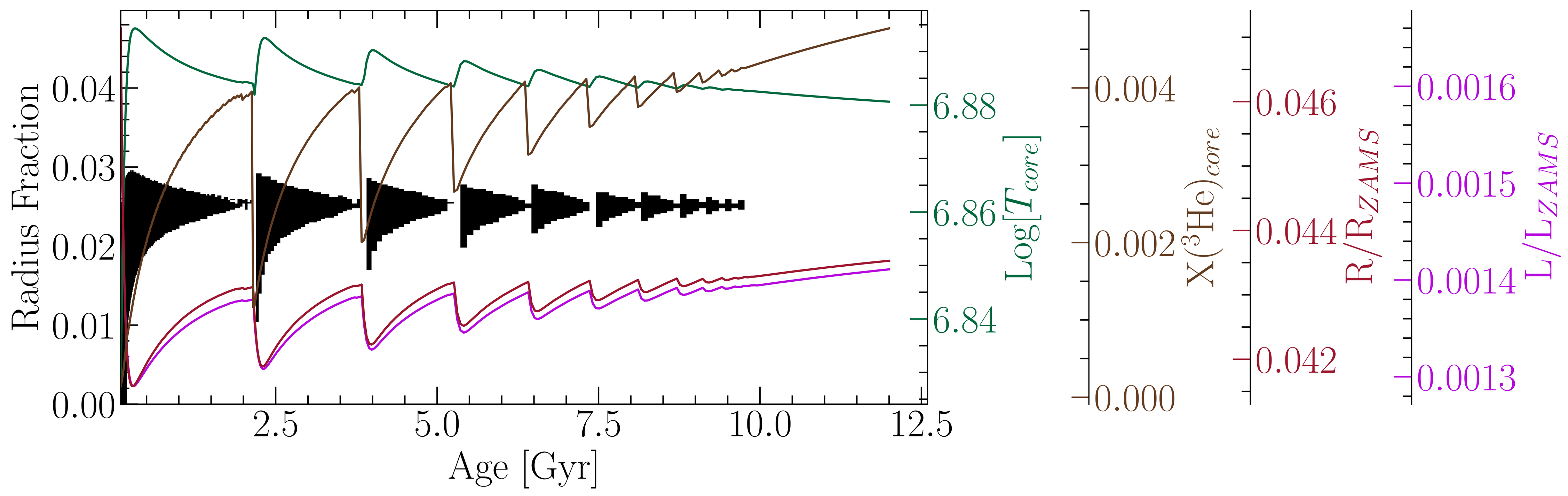

Fig. 2: Internal Evolution of a star experiencing convective kissing instabilities. The shaded region shows the where in the model radiative transport dominates.

We evolve a set of models with very finely spaced masses (dM=0.002 M$_\odot$) using DSEP (Dotter et al. 2008). These models are transformed into Gaia DR2 bolometric magnitudes. Photometric and astrometric uncertainties are introduced into the sampled populations using empirically calibrated relations between Gaia DR2 parameters.

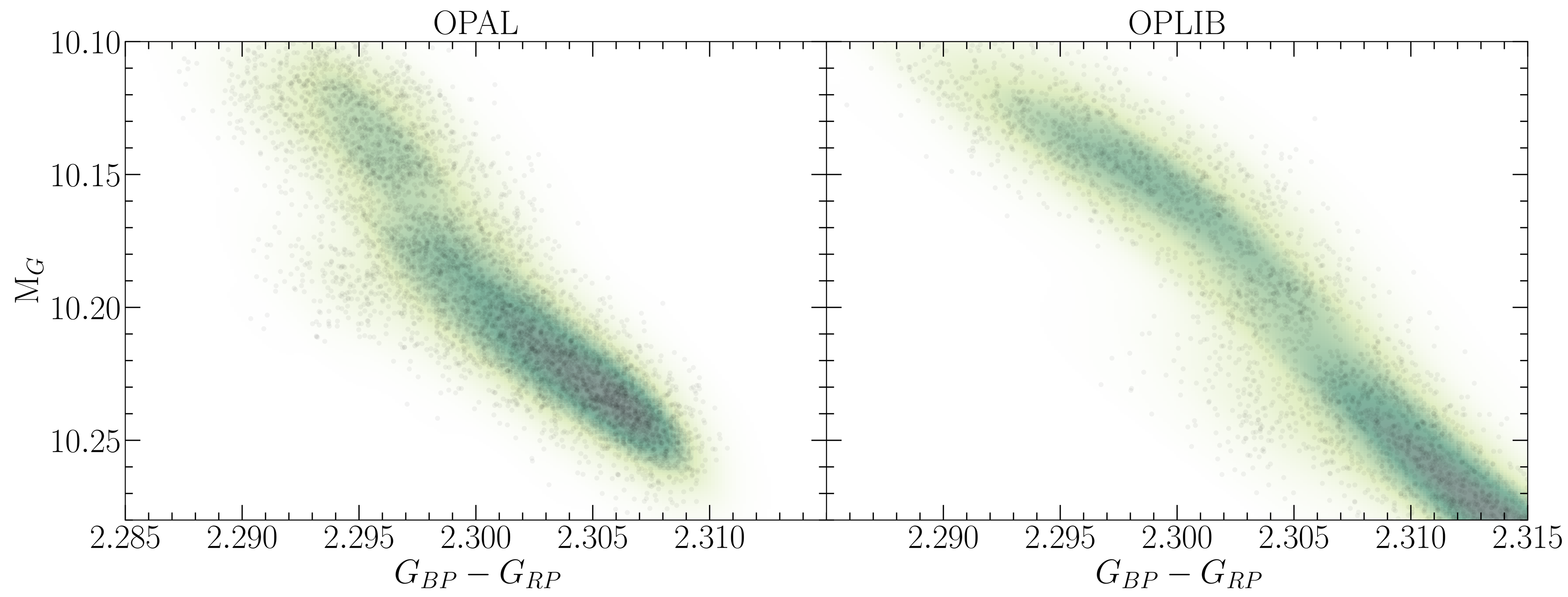

Fig. 3: Population synthethis results derived from models evolved using OPAL high temperature opacity tables and models evolved using OPLIB high temperature opacity tables. A gaussian kernel density estimator is displayed on top of the points. Note how the Jao gap is visible in both but at a different M_G.

Locating the Gap

We locate the Jao Gap using troughs in the number density of points along the magnitude axis. Because that density function tends to be noisy we run a butter low-pass filter over it before selecting all peaks with a prominence greater than 0.1 as potential Jao Gap locations.

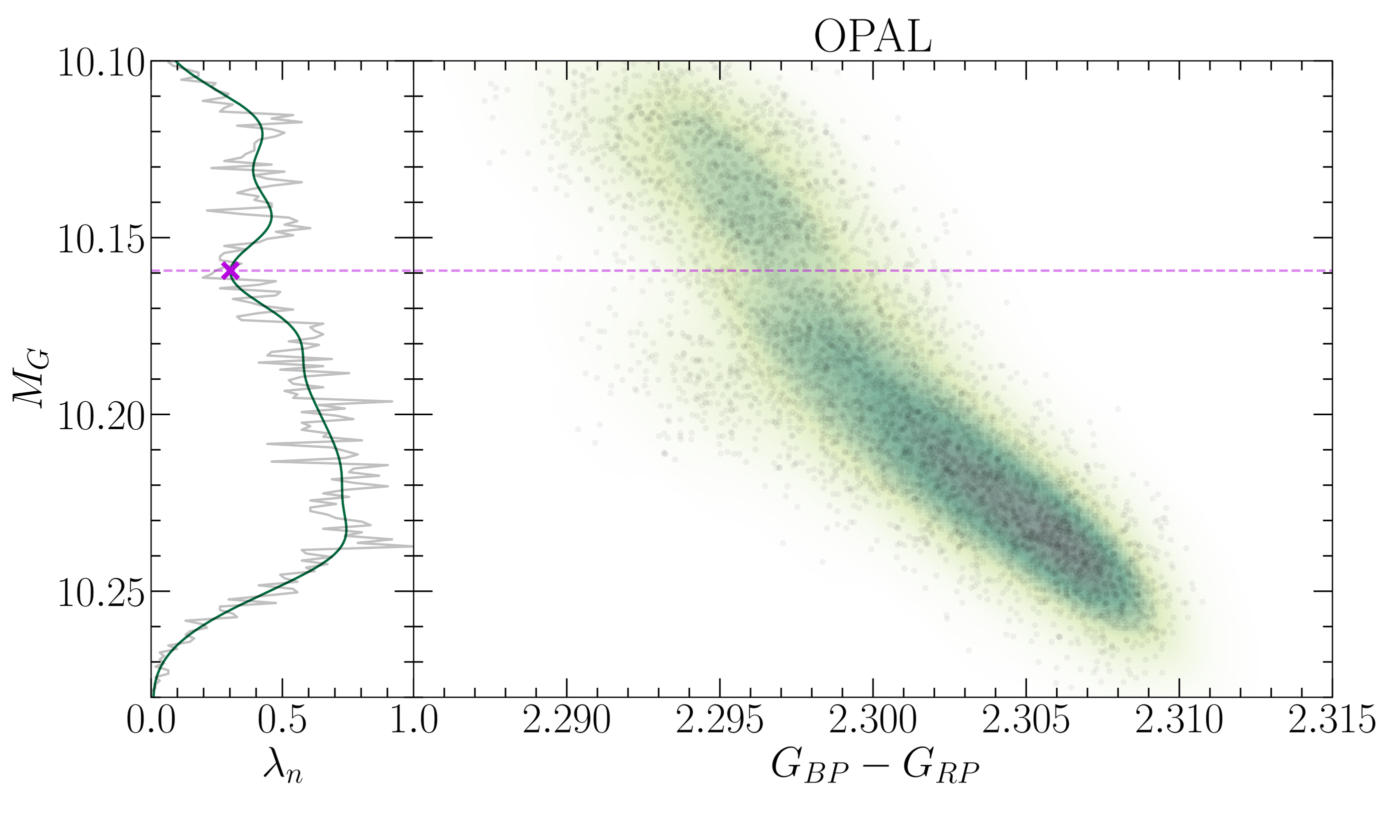

Fig. 4: We locate the Jao Gap when using OPAL opacity tables at $M_G \sim 10.16$ mag

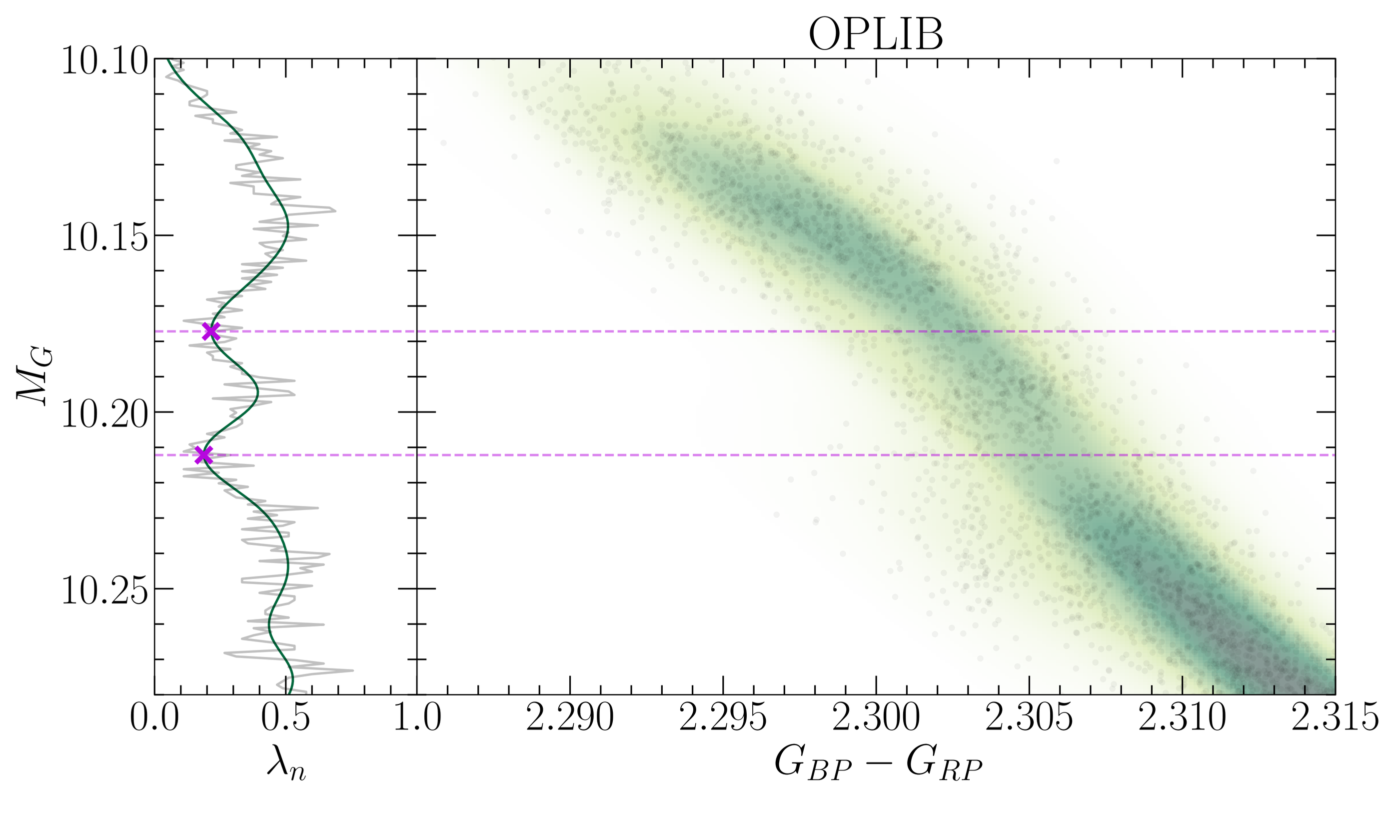

Fig. 5: Both Jao Gap locations are dimmer than OPAL. This is in line with the slightly lower opacity in OPLIB.

peak	M_G	Prominence
OPAL$_1$	10.15933	0.15671
OPLIB$_1$	10.17718	0.17795
OPLIB$_2$	10.21218	0.32097

Tab. 1: Identified Jao Gap Locations

Acknowledgments

We acknowledge the support of an NASA grant (No. 80NSSC18K0634). Additionally, we would like to thank James Colgan for his assistance with the OPLIB opacity tables. We would also like to thank Aaron Dotter and Elisabeth Newton.

References

1. Dotter, A., Chaboyer, B., Jevremovi c, D., et al. 2008, The Astrophysical Journal Supplement Series, 178, 89
2. van Saders, J. L., & Pinsonneault, M. H. 2012, The Astrophysical Journal, 751, 98
3. Jao, W.-C., Henry, T. J., Gies, D. R., & Hambly, N. C. 2018, ApJL, 861, L11,
4. Colgan, J., Kilcrease, D. P., Magee, N. H., et al. 2016, in APS Meeting Abstracts, Vol. 2016, APS Division of Atomic, Molecular and Optical Physics Meeting Abstracts, D1.008

SCAN ME