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

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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 He^3 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 population's 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

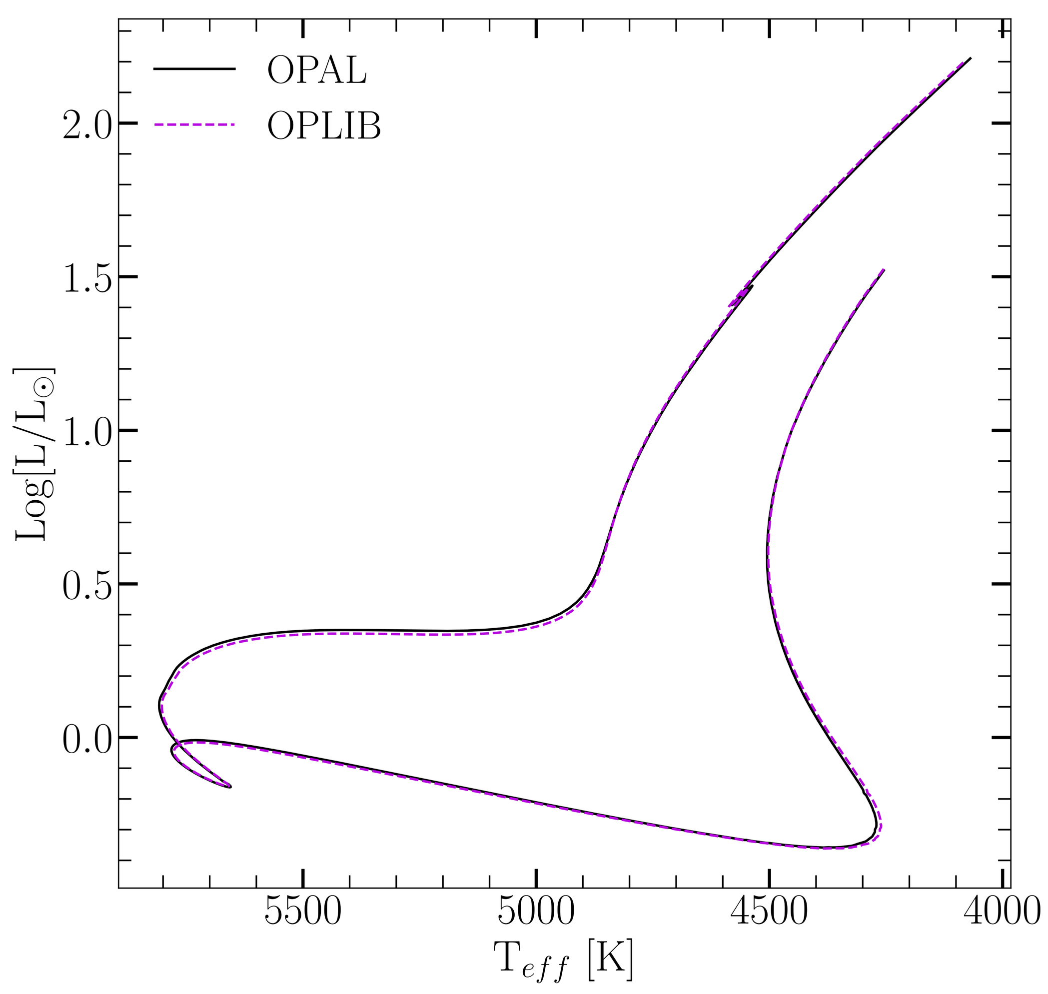

Fig. 1: Solar Calibrated Stellar Models using both OPAL (black) and OPLIB (violet) high–temperature opacity tables.

For much of a stars radius ($\log(R) \approx -1.5$), OPAL and OPLIB opacities vary by up to approximately 2%. 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.

References

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3. Jao, W.-C., Henry, T. J., Gies, D. R., & Hambly, N. C. 2018, ApJL, 861, L11,
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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 instability.

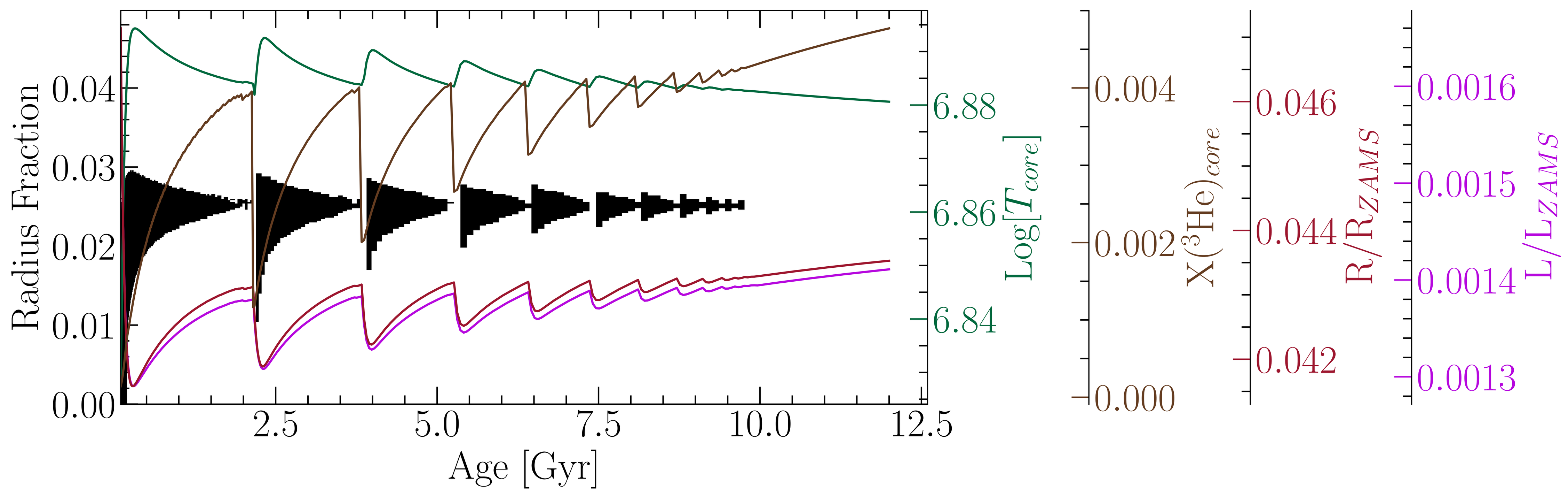

Fig. 2: Internal Evolution of a star experiencing convective kissing instabilities. The shaded region shows the where in the model radiative transport dominates.

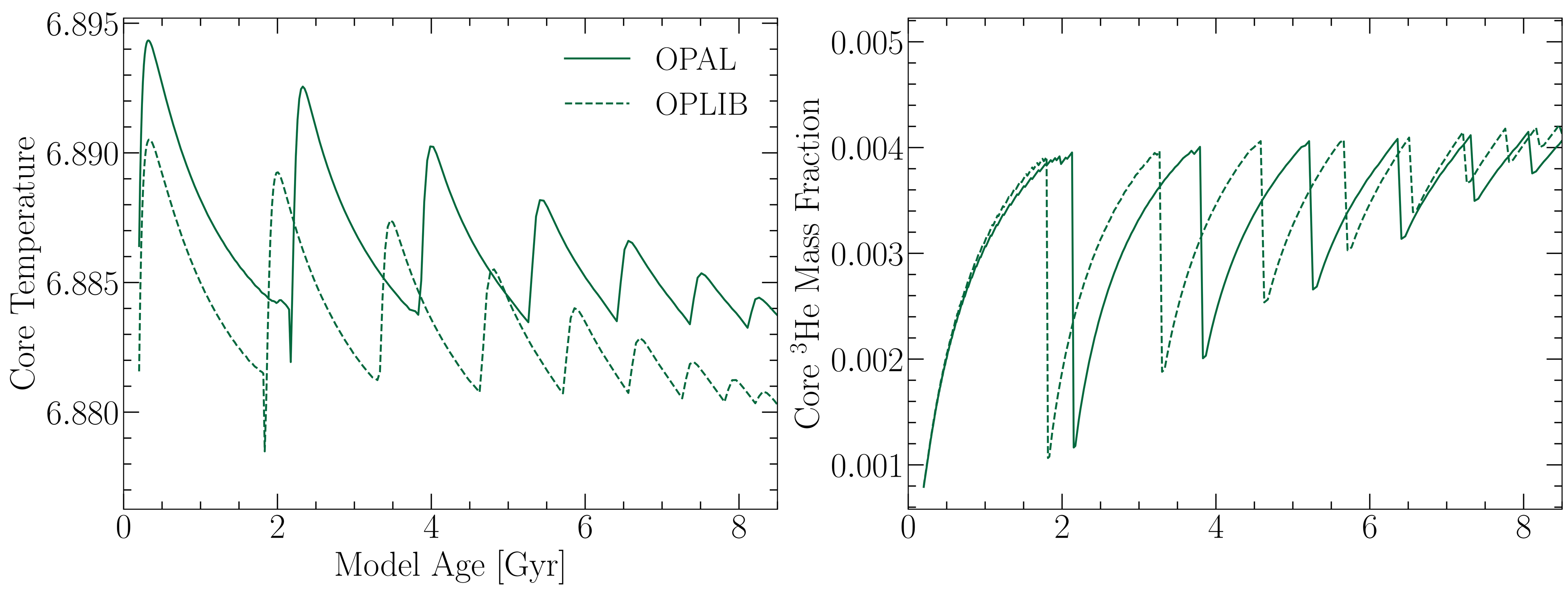

Fig. 3: Interior evolution of OPAL and OPLIB derived models. OPLIB models have both consitently lower core temperatures and shorter lived radiative transition zones.

Locating the Gap

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.

To accurately locate the Jao Gap (at 6 Gyr), we use troughs in the number density of points along the magnitude axis. Because that density function tends to be noisy we use the normalized mean linear density function ($\tilde{\lambda}_n$) from Monte Carlo trials of the population Synthesis code instead of a single density function.

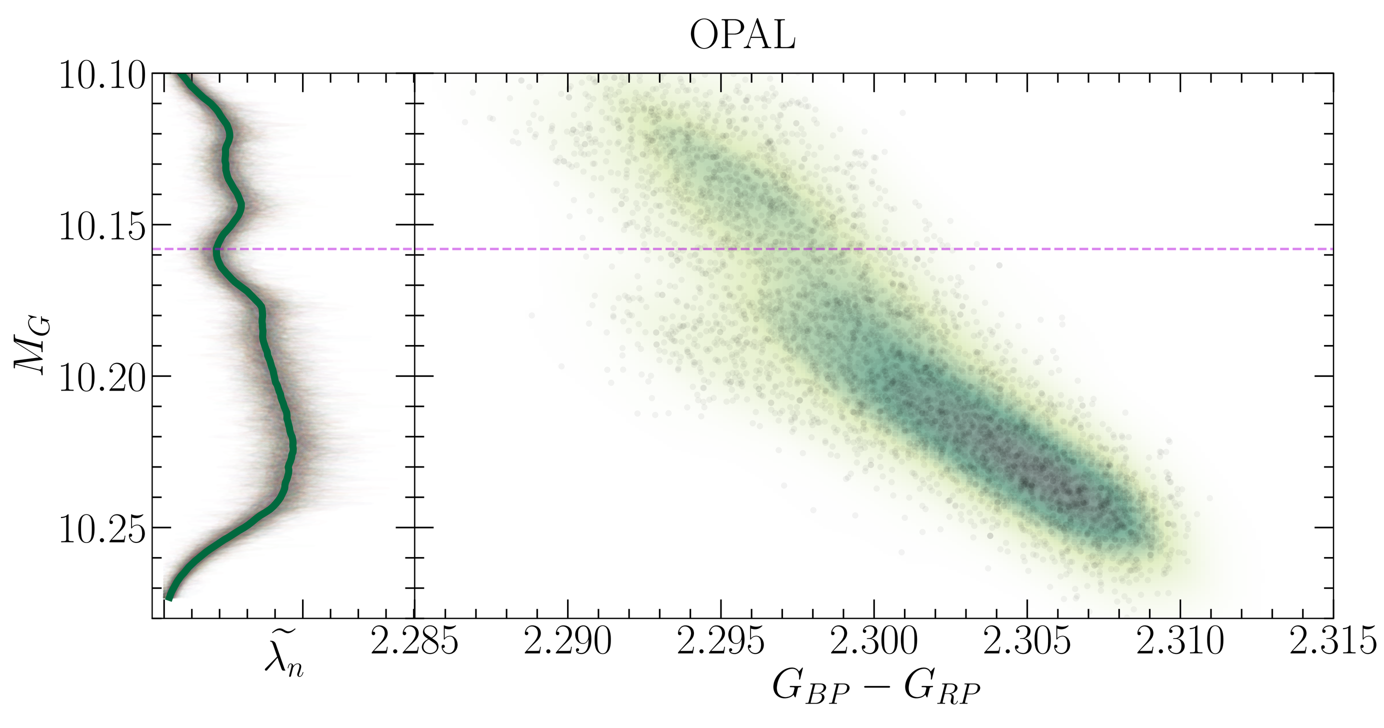

Fig. 4: We locate the Jao Gap when using OPAL opacity tables at $M_G \sim 10.16$ mag

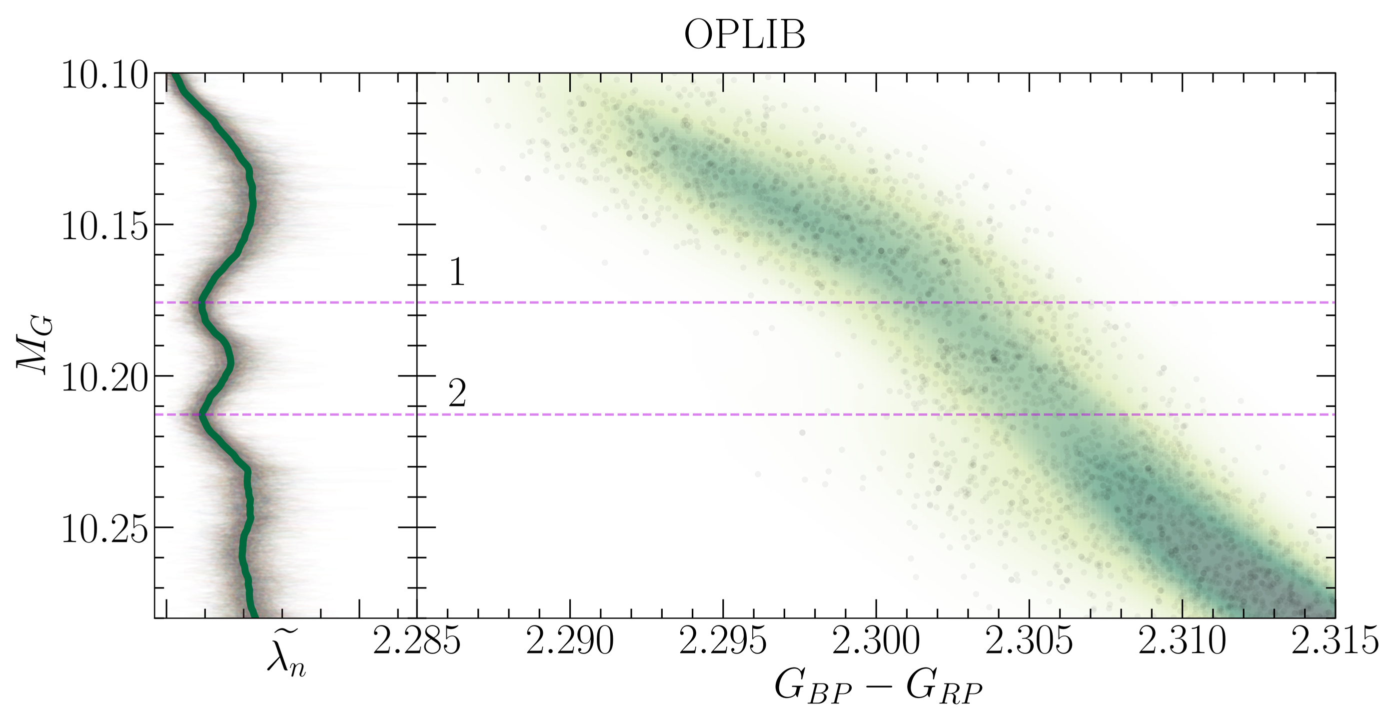

Fig. 5: Both Jao Gap locations are dimmer than OPAL. This is in line with the slightly lower opacities of models derived from OPLIB tables.

peak	M_G	Prominence
OPAL$_1$	10.1593	0.1567
OPLIB$_1$	10.1771	0.1779
OPLIB$_2$	10.2121	0.3209

Tab. 1: Identified Jao Gap Locations

Acknowledgments

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