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

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Abstract

The Jao Gap, 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. Here we present updated synthetic population models tracing the Gap location modeled with the Dartmouth stellar evolution code using the OPLIB high-temperature radiative opacities. 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

The OPAL opacity tables are very widely used by current generation stellar evolution programs (in addition to current generation stellar model and isochrone grids). However, they are no longer the most up date or highest presicion elemental opacities. Moreover, the generation mechanism for these tables, a webform, is no longer reliably online. Consequently, it makes sense to transition to more modern opacity tables with a more stable generation mechanism, OPLIB from the T-1 group at Los Alamos.

The most up to date OPLIB tables include monochromatic Rosseland mean opacities for elements hydrogen through zinc over temperatures 0.5eV to 100 keV and for mass densities from approximately 10^{-8} g cm^{-3} up to approximately 10^{4} g cm^{-3} (though the exact mass density range varies as a function of temperature).

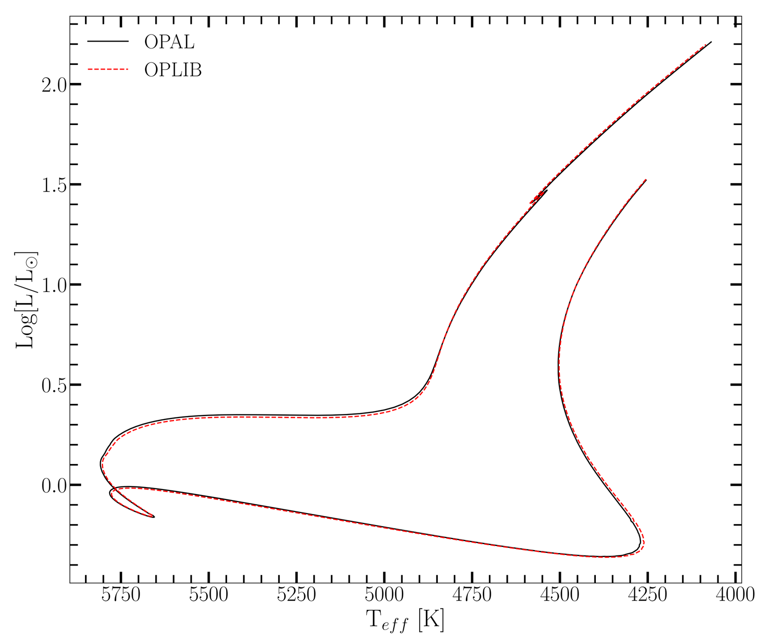

Fig. 1: Solar Calibrated Stellar Models using both OPAL (black) and OPLIB (red) high–temperature opacity tables.

For $\log(R) = -1.5$, OPAL and OPLIB opacities vary up to approximately 2% when $T \geq 10^6$ K. The calibrated solar model above shows that variations of this order are not expected to dramatically alter a stars evolutionary path. However, these small variations may be more impactful for stars at or near the convective transition mass where small changes in κ can result in large changes in T for a constant ∇_{rad}.

Modeling

Acknowledgments

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Modeling the Gap

A theoretical explanation for the Jao Gap comes from [CITE], 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 process is known as convective-kissing instability. Such a star will descend the pre-MS with a radiative core; however, as the star reaches the zero age main sequence (ZAMS) and as the core temperature exceeds 7×10^6 K, enough energy will be produced by the ppI chain that the core becomes convective. At this point the star exists with both a convective core and envelope, in addition to a thin, radiative, layer separating the two. Subsequently, asymmetries in ppI affect the evolution of the star's convective core.

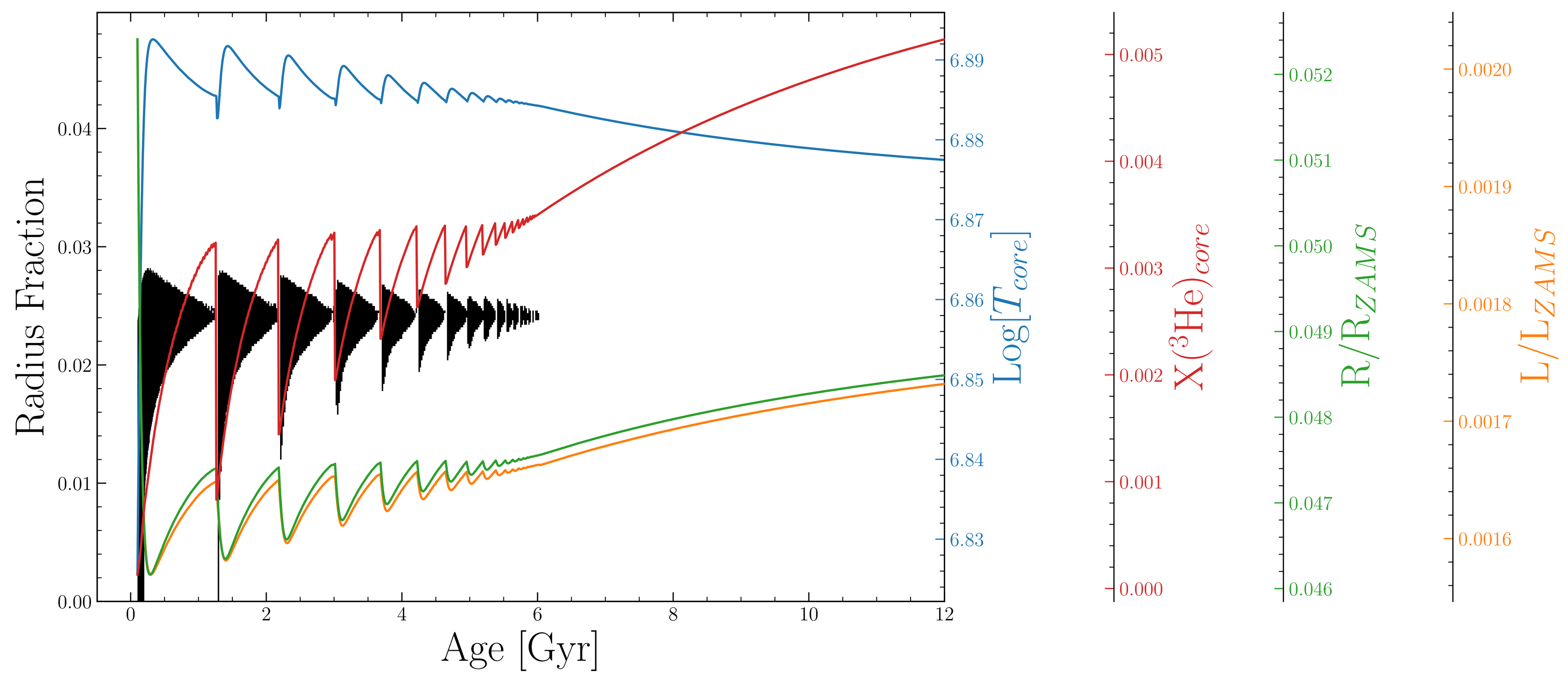

Fig. 2: Internal Evolution of a star experiencing convective kissing instabilities.

We evolve a set of models with very finely spaced masses (between 0.2 and 0.8 M$_\odot$, dM=0.002 M$_\odot$) using the Dartmouth Stellar Evolution Program (DSEP, Dotter et al. 2008)

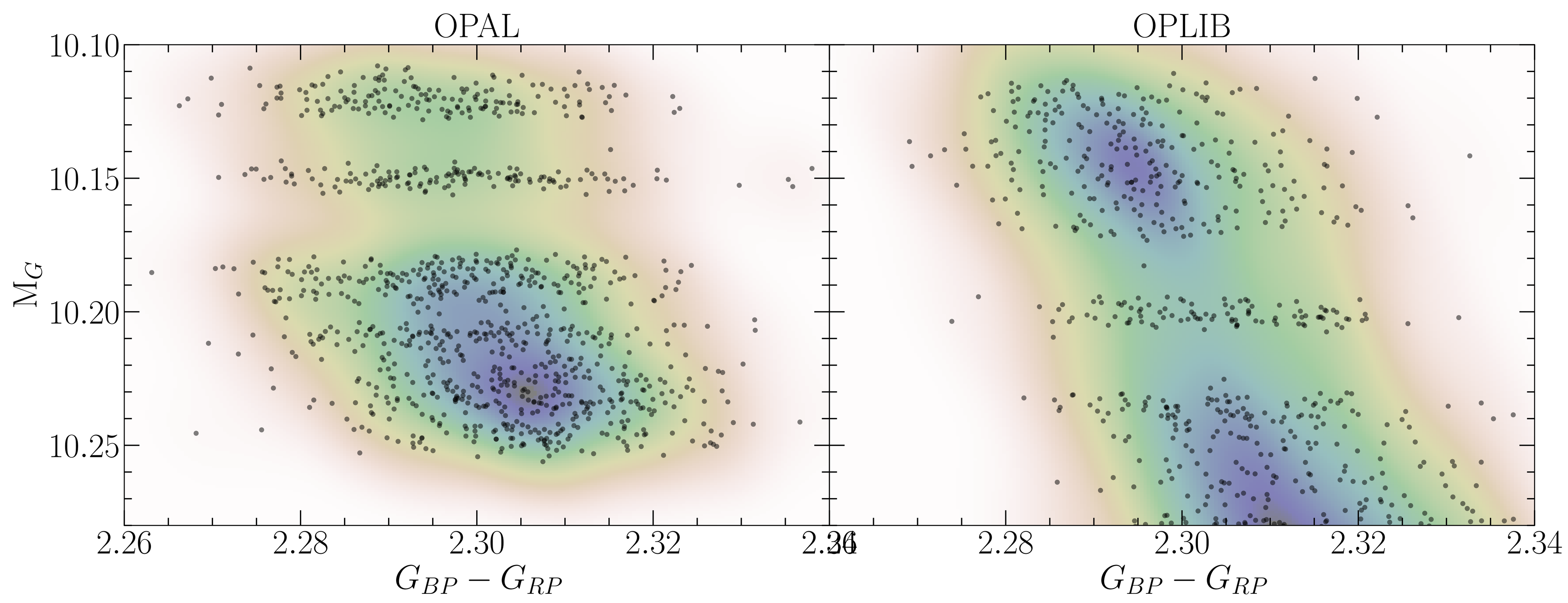

Fig. 3: Jao Gap in population synthetis