Characterizing Retired A Stars

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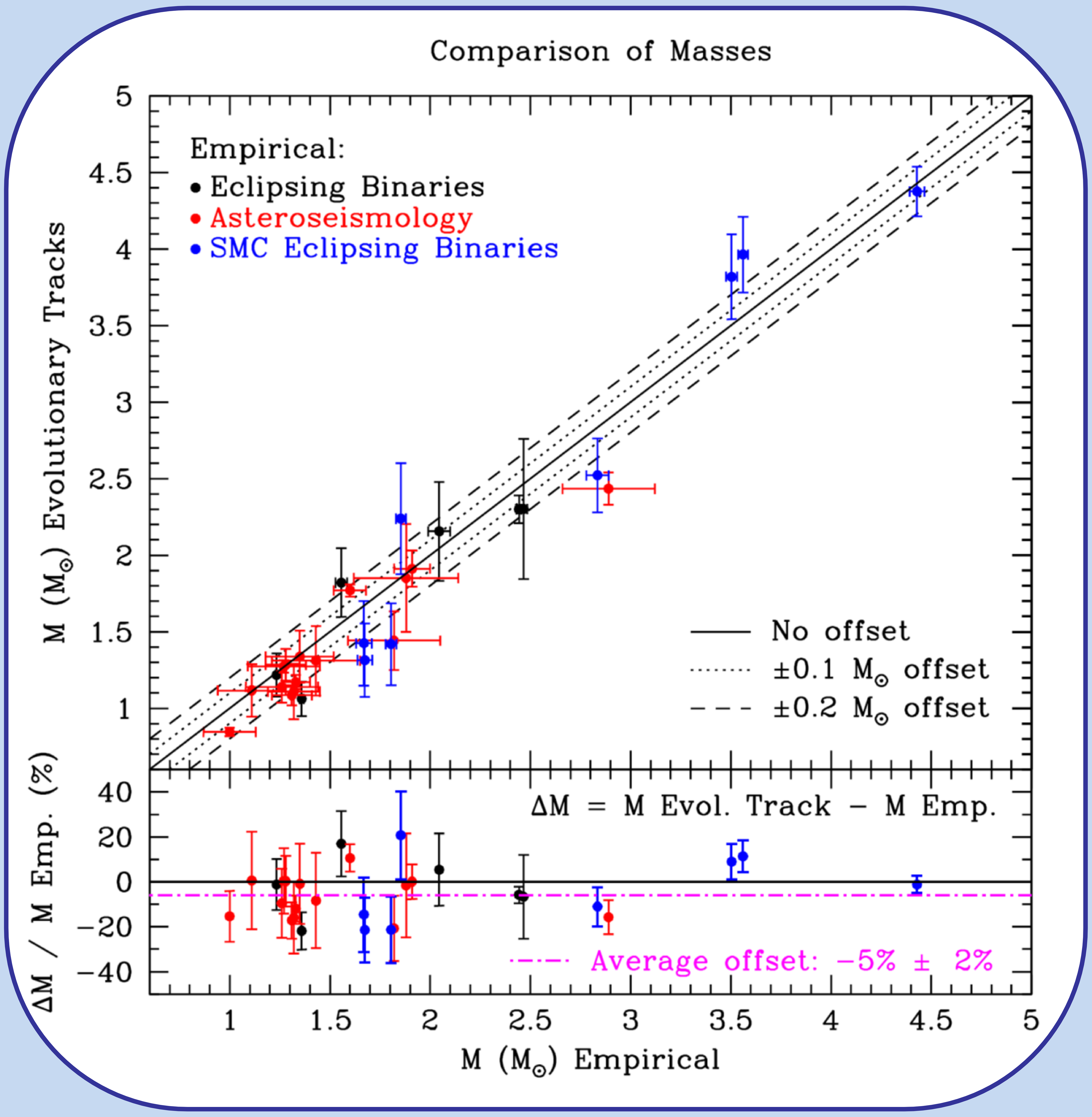
1. Are retired A stars really massive?

Giant planet occurrence is correlated with stellar metallicity and possibly stellar mass, increasing linearly from 0.2 $M_\odot$ to 2.0 $M_\odot$ (e.g., Johnson et al. 2010).

The massive end of the planet-host mass distribution comprises evolved giants and subgiants, representing A stars after they evolve off the main sequence: the so-called "Retired A Stars."

Determination of masses for these isolated target stars relied on stellar evolutionary tracks and could be affected by systematic errors (e.g., Lloyd 2013; Schlaufman & Winn 2013).

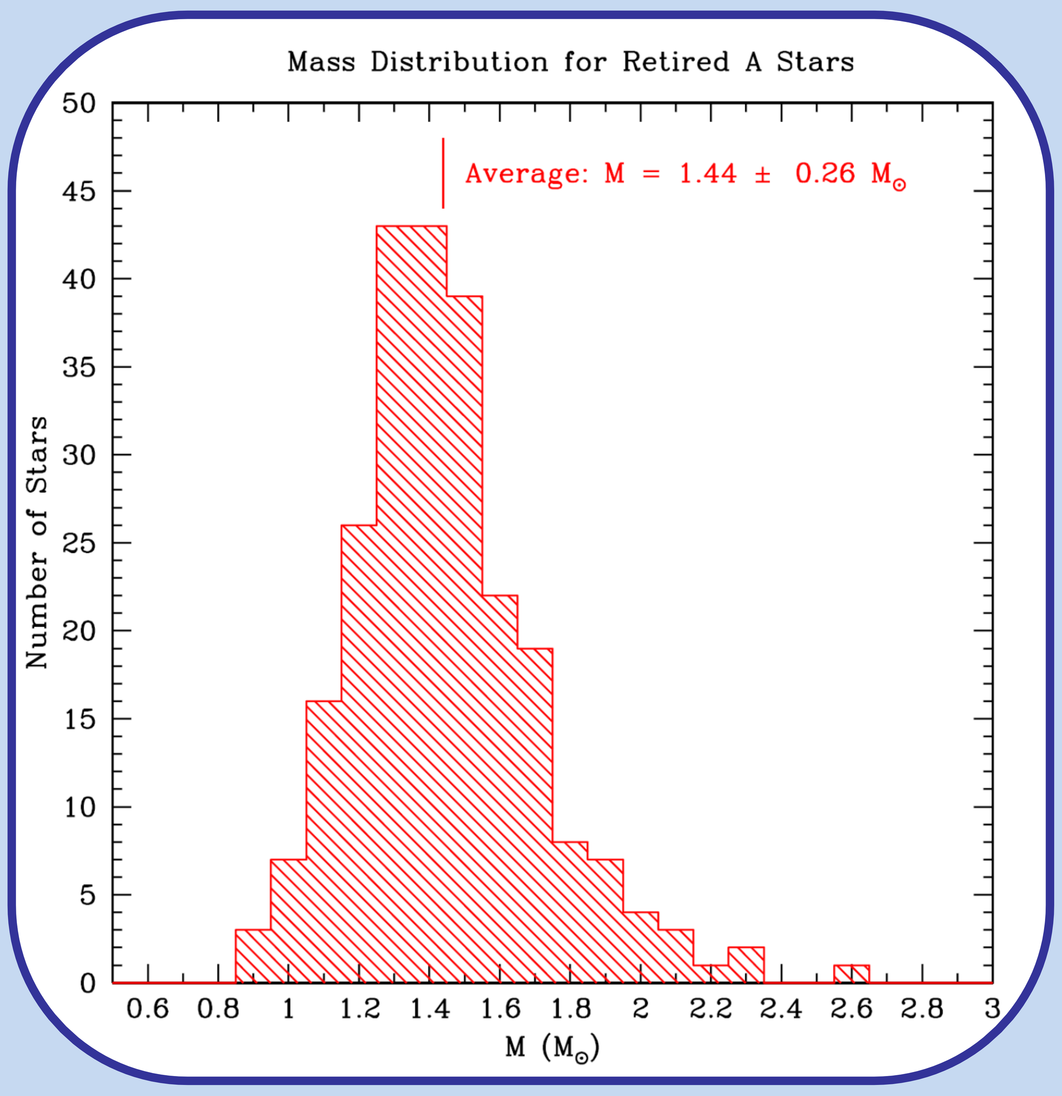
We describe the ongoing effort of the Harvard Exolab group to precisely measure the masses of evolved stars, with implications ranging from understanding the formation and architectures of planetary systems to Galactic stellar population models.



4. New mass distribution for retired A stars

After validating the mass estimates from evolutionary tracks, we performed a spectroscopic analysis of a sample of 244 retired A stars. The details are as follows:

- Keck/HIRES spectra (R=60,000 and S/N>100 per resolution element at ~6700 Å) are available for all stars.
- Atmospheric parameters (T_{eff}, [Fe/H], log g) were derived in LTE using an iterative method based on the excitation and ionization equilibria of Fe I and Fe II lines (e.g., Ghezzi et al. 2010).
- Masses were obtained with PARAM, the spectroscopic T_{eff} and [Fe/H], *Hipparcos* V magnitudes and revised parallaxes (van Leeuwen 2007). Their distribution is shown in the figure below.



2. Test case: HD 185351

The giant HD 185351 was selected as a test case because it is a bright nearby star located within the *Kepler* field.

Its mass was determined from the extensive analysis of Johnson et al. (2014). Colored regions in the figure below show 1σ constraints from the observations: interferometry (Int); spectroscopy (SME); asteroseismology (seism). The small dots show BaSTI evolutionary tracks (Pietrinferni et al. 2004) for [Fe/H] = 0.16 (SME value).

The estimated mass range of ≈1.6 – 2.0 $M_\odot$ is consistent with a retired A star, but definitive conclusions require a larger sample.

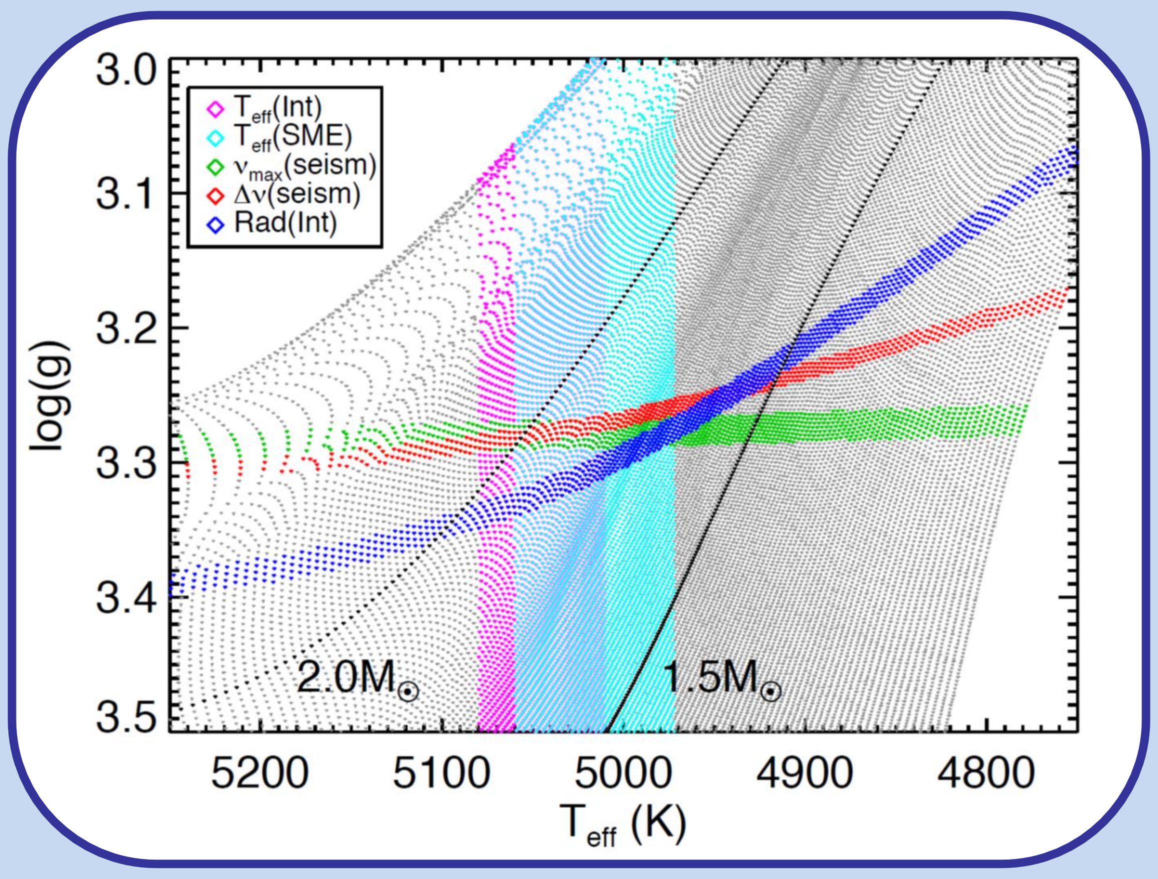


Figure from Johnson et al. (2014)

3. Extending the sample of benchmark stars

We are conducting an extensive literature search for stars with precise empirically measured masses. Our current sample is shown in the above figure and contains 29 stars divided in two categories:

- Eclipsing binaries (14 stars) → Masses from radial velocities, light curves and Kepler laws. Errors ≤ 3%.
- Asteroseismic targets (15 stars) → Masses from scaling relations (weak dependence on spectroscopic T_{eff}).

Their model dependent masses that are being tested were derived with the PARAM web interface. The PARSEC evolutionary tracks (Bressan et al. 2012) and the option for stars with known parallax were adopted.

Models ***underestimate*** empirical masses by 0.07 ± 0.04 $M_\odot$, or roughly 5% ± 2%, showing reasonable agreement in a wide range of stellar masses (1.0 – 4.5 $M_\odot$).

This underestimate of the masses of evolved stars is evidence in direct contradiction to the predictions of Lloyd (2013), who anticipated overestimates of ~50% on average.

The observed correlation between planet occurrence and stellar mass is therefore validated by our test.

5. Conclusions

- Measuring masses using evolutionary tracks does not seem to suffer from significant systematic offsets that would overestimate the masses of evolved stars.
- **Our preliminary results are consistent with a sample of stars dominated by the evolved counterparts of A dwarfs, which supports the results from Johnson et al. (2010, 2013).**
- More benchmark stars are currently being added to the study.

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