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On the Mass and Evolution Status of the Bright Red AGB Supergiant α^1 Herculis

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Abstract. The mass of the bright M5 supergiant α^1 Herculis has been estimated in a number of studies to range over wide limits of 1.7 to 15 $M_\odot$. Here, we address this wide range of mass assessments by constraining the age, mass and nature of this interesting variable star from three independent approaches: (1) isochronal fitting of the three stars in the α Her multiple star system, (2) extending asteroseismic mass and radius scaling to semi-regular variable stars that include similar to α^1 Her, and (3) directly from assessments of $\log g$ and interferometric radius measures. Our study indicates that α^1 Her is an intermediate-mass AGB with a mass of $\sim 2.5\ M_\odot$ and age of ~ 1.2 Gyr.

1. Mining α^1 Her mass from the literature and data archives

α^1 Herculis (HD 156014; $V \sim +3.5$ mag; $d_{\rm hip} = 110 \pm 16$ pc) is the bright M5 Ib-II member of the nearby visual binary system. The fainter secondary companion of the system (4.7″ distant) is a 5$^{\rm th}$ mag (F2V+G5III) double-line spectroscopic binary (α^2 Her AB). α^1 Her is a semi-regular (SRc) pulsating star with a long secondary period of ~1350 d, and complex multiple shorter periods around 126 d (Moravveji et al. 2010). Interferometric mid-infrared (11 μm) radius (Weiner et al. 2003) of the M-supergiant is $R_{\rm mid\text{-}IR} = 467 \pm 80\ R_\odot$ using the more recent Hipparcos parallax. Deduced from various approaches, there is controversy in the literature concerning the current mass and evolutionary status of α^1 Her. Historically, the estimated masses for the star range from M = 15 $M_\odot$ (Deutsch 1956), ~2.0 $M_\odot$ (Woolf 1963), 1.7 $M_\odot$ (Reimers 1977; Thiering & Reimers 1993), and ~5 to 7 $M_\odot$ (Harris & Lambert 1984; El Eid 1994). At the high mass range α^1 Her would be young massive supergiant SN II progenitor while at the low mass range ($M < 5M_\odot$), the star would be a Asymptotic Giant Branch (AGB) star located near the upper tip of the AGB.

2.1. Isochronal masses of the members of the α Her triple star system

For α^2 Her B (F2V), Thiering & Reimers (1993) report $T_{\rm eff} = 7350 \pm 150$ K and $\log L = 1.02 \pm 0.43\ L_\odot$. The mass and age of this star as derived from MESA evolutionary tracks (Paxton et al. 2010) are $1.65 \pm 0.10\ M_\odot$ and $\tau = 1.2$ Gyr, respectively. Similarly, for α^2 Her A (G5III) we have $T_{\rm eff} = 4900 \pm 100$ K and $\log L = 1.71 \pm 0.39\ L_\odot$, which yields $2.30 \pm 0.20\ M_\odot$. Hence the total mass of the secondary is $3.95 \pm 0.30\ M_\odot$. Assuming that the three stars in the system are coeval, τ is the age of the triple system. Employing this age constraint τ, and the location of α^1 Her in the theoretical H-R diagram, using the CMD 2.2 isochrones (Marigo et al. 2008), results in $M_{\rm iso} \approx 2.2^{+0.6}_{-0.8}\ M_\odot$ for the M5 Ib-II star. However, evolved AGB stars like α^1 Her may have undergone significant mass loss.

2.2. Scaling mass and radius with oscillating red giants

Christensen-Dalsgaard et al. (2001) predict stochastic excitation of pulsation by turbulent convection in semi-regular pulsators; moreover, the oscillation pattern of solar-type pulsating red giants can be scaled with those of the Sun to yield estimates of their masses and radii (see Eqs. 5 and 6 in Kallinger et al. 2009). For α^1 Her with large frequency spacing $\Delta\nu = 2.68 \times 10^{-3}$ cd^{-1} and dominant pulsation frequency $\nu_{\rm max} = 0.080$ cd^{-1} in Johnson V filter where our light curve has higher duty cycle (Moravveji et al. 2010), we deduce $R_{\rm seismic} = 355 \pm 58\ R_\odot$. Weiner et al. (2003) estimate that radii of cool M giant/supergiant stars in mid-IR are ~30% larger than their near-IR (NIR) radius which for α^1 Her gives $R_{\rm NIR} = 359 \pm 62\ R_\odot$. This value is in very good agreement with $R_{\rm seismic}$, indicating the validity of asteroseismic radius determination. Exploiting $R_{\rm NIR}$ which comes from direct observation into Eq. 6 of Kallinger et al. (2009) for asteroseismic mass yields $M_{\rm seismic} = 2.5^{+1.6}_{-1.1}\ M_\odot$.

2.3. Mass of α^1 Her inferred from surface gravity log *g*

Reimers (1977) has published a surface gravity of α^1 Her of $\log g = 0.17$ cm s^{-2} (but with no unvertainties given). In combination with the radius $R_{\rm NIR}$, this indicates a mass of $M = 6.9 \pm 2.4\ M_\odot$. This approach to estimating the mass does not agree well with mass estimates found from the other two approaches discussed above. A modern determination of a spectroscopic surface gravity of α^1 Her is needed to resolve this apparent discrepancy.

3. Summary and Conclusion

Our preliminary results show that α^1 Her can be identified as an intermediate-mass archetypal AGB star with $M \simeq 2.5\ M_\odot$ and age $\sim$ 1.2 Gyr. More interesting is the reasonable agreement between the NIR stellar radius and the similar radius deduced from asteroseismic scaling. This supports the feasibility of extending the asteroseismic results from early G- to late K-type red giants to late, more evolved M-type semi-regularly pulsating stars.

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