WHY GALAXIES CARE ABOUT AGB STARS II:
SHINING EXAMPLES AND COMMON INHABITANTS
ASP Conference Series, Vol. 445
Kerschbaum, Lebzelter, and Wing, eds.

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

E. Moravveji,[1] E. F. Guinan,[2] and Y. Sobouti[1]

[1]*Department of Physics, Institute for Advanced Studies in Basic Sciences (IASBS), Zanjan, Iran*

[2]*Department of Astronomy, Villanova University, Villanova PA, USA*

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 like 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 star with a mass of ~ 2.5 $M_\odot$ and age of ~ 1.2 Gyr.

1. Mining the 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 a nearby visual binary system. The fainter secondary companion of the system (4.″7 distant) is a 5$^{\rm th}$ mag (F2 V+G5 III) 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). The 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 disagreement 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 a young massive supergiant SN II progenitor, while at the low mass range ($M < 5\ M_\odot$), the star would be an Asymptotic Giant Branch (AGB) star located near the upper tip of the AGB.

2. Isochronal Masses of the Members of the α Her Triple Star System.

For α^2 Her B (F2 V), 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. 2011) are $1.65 \pm 0.10\ M_\odot$ and $\tau = 1.2$ Gyr. For α^2 Her A (G5 III), $T_{\rm eff} = 4900 \pm 100$ 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.

3. 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 the Johnson V filter where our light curve has a higher duty cycle (Moravveji et al. 2010), we deduce $R_{\rm seismic} = 355 \pm 58$ R$_\odot$. Weiner et al. (2003) estimate that the radii of cool M giant and 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 determinations. 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$_\odot$.

4. 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 uncertainties given). Combined with the radius $R_{\rm NIR}$, this indicates a mass of $M = 6.9 \pm 2.4$ M$_\odot$ which 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.

5. 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 later, more evolved M-type semi-regularly pulsating stars.

Acknowledgments. EM is very grateful for the travel grant and accommodation support received from the conference organizers and IASBS (Iran) to participate in this conference. EG also wishes to acknowledge the NSF/RUI grant AST-1009903.

References

Christensen-Dalsgaard, J., Kjeldsen, H., & Mattei, J. A. 2001, ApJ, 562, L141
Deutsch, A. J. 1956, ApJ, 123, 210
El Eid, M. F. 1994, A&A, 285, 915
Harris, M. J., & Lambert, D. L. 1984, ApJ, 285, 674
Kallinger, T., Weiss, W. W., De Ridder, J., et al. 2009, in the Eighth Pacific Rim Conference on Stellar Astrophysics, edited by S. Soonthornthum, S. Komonjinda, K. S. Cheng & K. C. Leung, ASP Conf. Ser., vol. 404, p. 307
Marigo, P., Girardi, L., Bressan, A., et al. 2008, A&A, 482, 883
Moravveji, E., Guinan, E. F., Wasatonic, R., Sobouti, Y., & Nasiri, S. 2010, Ap&SS, 328, 113
Paxton, B., Bildsten, L., Dotter, A., et al. 2011, ApJS, 192:3
Reimers, D. 1977, A&A, 61, 217
Thiering, I., & Reimers, D. 1993, A&A, 274, 838
Weiner, J., Hale, D. D. S., & Townes, C. H. 2003, ApJ, 589, 976
Woolf, N. J. 1963, The Observatory, 83, 260