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Red Clump stars in *Kepler* open cluster NGC 6819

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Abstract. We measure the large frequency separation, $\Delta\nu$, and the frequency of maximum amplitude, $\nu_{\rm max}$, for 10 Red Clump (RC) single member (SM) stars in the *Kepler* open cluster NGC 6819. We derive luminosities and masses for each individual RC star. A comparison of the observations with an isochrone of Age = 2.5 Gyr, Z = 0.017 with no mass loss using a statistical techniques is made. A fractional mass loss of 5 ± 3 percent is obtained if we assume that no correction to $\Delta\nu$ between RC and red-giant branch (RGB) is necessary. However, models suggest that an effective correction of about 1.9 percent in $\Delta\nu$ is required to obtain the correct mass of RC stars owing to the different internal structures of stars in the two evolutionary stages. In this case we find that the mass loss in the red giant branch is not significantly different from zero. This finding confirms that of [6]. It is clear that the mass estimate obtained by asteroseismology is not sufficient to deduce the mass loss on the red giant branch. However, it is clearly only a few percent at most.

Mass loss at the tip of the RGB

NGC 6819 is an open cluster centered at RA = 19:41:18, Dec = 40:11:12. It is a moderately old cluster (≈ 2.5 Gyr; [1], [2],[4],[7]) with near-solar or slightly super-solar metallicity ([Fe/H]= +0.09 ± 0.03; [3]). A distance modulus of $\mu_0 = V_0 - M_V = 12.36$ mag and a reddening of $E(B-V) = 0.16$ from *BV* photometry and main-sequence fitting was obtained by [7] for this cluster. The objective of the work is to study the mass loss at the tip of the red giant branch (RGB) in this cluster.

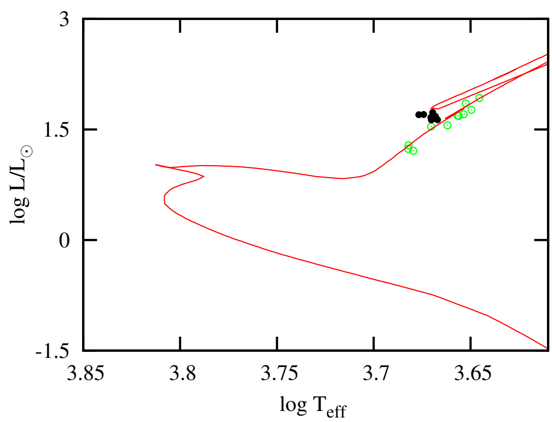

Fig. 1. Theoretical isochrone for log t = 9.4 and Z = 0.17, Y = 0.30 with mass loss rate free parameter η set to 0.0 with Padova code [5]. The filled circles are the RGC stars while the open circles are the RGB stars.

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Table 1. Results of mass-loss in red giants from asteroseismology of RGB and RGC stars using different ages and metallicities for NGC 6819. The fourth column shows mass loss derived directly from asteroseismology while the last column shows the mass loss when a correction of 1.9 % is applied to $\Delta\nu$ for RGC stars as suggested by models [6].

Age (Gyr)	Z	Y	Mass loss (%) without correction	Mass loss (%) with correction
2.5	0.017	0.30	5.0±3.2	-2.7±3.3
2.5	0.020	0.30	4.8±3.0	-2.7±3.2
1.9	0.017	0.30	5.3±3.2	-2.2±3.3

Red giants are expected to lose mass on the RGB, nearly all of it at the tip of the RGB, but the amount of mass loss is a major unsolved problem. Obtaining mass from asteroseismology can in principle contribute to answer this question. Firstly, there are likely to be systematic differences in the way $\nu_{\rm max}$ and $\Delta\nu$ are measured. In particular, there is no precise definition of how $\nu_{\rm max}$ should be measured. Since only the relative mass difference between stars in the RGB and RC branches is required, systematic errors should cancel out.

For each of the stars in Fig.1, we used $\nu_{\rm max}$, $\Delta\nu$ and $T_{\rm eff}$ to obtain log $L/L_{\odot}$ and log $M/M_{\odot}$ as was done by [1]. Since we know the approximate measurement errors in these three quantities, we derive approximate standard deviations σ(M)/M = 0.100, σ(L)/L = 0.200, $\sigma(\rm T_{eff})/T_{eff}$ = 0.038. Because of systematic and random observational errors, the stars in Fig.1 will deviate from the isochrone. We assume that the true values of T = log $\rm T_{eff}$, L = log $L/L_{\odot}$ and M = log $M/M_{\odot}$ are given by points on the theoretical isochrone. The corresponding observed values, t, l and m can be used to define a goodness-of-fit criterion (1)

$$\chi^2 = \sum_{i=1}^{n} \left(\frac{(t_{\rm i} - T)^2}{2\sigma_t^2} + \frac{(l_{\rm i} - L)^2}{2\sigma_l^2} + \frac{(m_{\rm i} - M)^2}{2\sigma_m^2} \right). \tag{1}$$

Thus, χ^2 gives the scaled distance between an observed point (t, l, m) and the true value on the isochrone (T, L, M). For each star on the RGB we found values of T, L and M which minimize χ^2. The average differences between the observed and derived true values of log $L/L_{\odot}$, log $M/M_{\odot}$ and log $\rm T_{eff}$/K for RGB stars can be derived. We assume that the same systematic differences are applicable to stars on the RGC. In this way we obtain masses of RGC stars free of systematic errors. Mass loss is calculated by taking the average value $\Delta M = \sum_{i=1}^{n}(m_i - M_i)$, later expressed as a percentage ratio in Table 1. We applied the method using isochrones computed from the Padova evolution code with no mass loss for a wide range of cluster age and metalicity and determined the difference between the asteroseismic mass and the evolutionary mass of RGC stars in NGC 6819. We find that the asteroseismic masses of RGC stars are 5 percent smaller than the evolutionary mass computed with no mass loss. This result is independent of the chosen cluster age or metallicity as shown in the fourth column of Table 1. We conclude that the mass loss on the red giant branch is, at most, only a few percent - too small to be measured with current asteroseismic techniques. This conclusion supports the same conclusion previously derived by [6].

References

1. Balona, L. A. et al., MNRAS **430**, (2013) 3472
2. Basu, S. et al., ApJ **729**, (2011) L10
3. Bragaglia, A. et al., AJ **121**, (2001) 327
4. Kalirai, J. S. et al., AJ **122**, (2001) 266
5. Marigo P., et al., A&A **482**, (2008) 883
6. Miglio A., et al., MNRAS **419**, (2012) 2077
7. Rosvick J. M., Vandenberg D. A., AJ **115**, (1998) 1516