The Effects of Main-Sequence Mass Loss on Surface C/N Abundance Ratios During the Ascent of the First Giant Branch

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The surface C/N abundance ratios of many cluster and field G and K giants following the 1st dredge-up phase are much lower than predicted from standard stellar evolution modeling. The occurrence of substantial mass loss, either during or immediately after the main-sequence phase would both reduce the mass fraction of the unprocessed envelope necessary to contaminate with CN-cycle products, as well as allow CN-processing of a greater amount of core material during the earlier high-mass phase. Willson, Bowen and Struck-Marcell (1987) have proposed that a combination of pulsation and rapid rotation could drive substantial mass loss in main-sequence stars of initial mass 1-3 $M_{\odot}$. We evolved a grid of 16 mass-losing models from the zero-age main sequence through 1st dredge-up. The models have initial masses of 1.25, 1.5, 1.75 and 2.0 $M_{\odot}$, and exponentially decreasing mass-loss rates with e-folding times 0.2, 0.4, 1.0 and 2.0 Gyr; all models evolve toward a final mass of 1.0 $M_{\odot}$. Since the mass-loss epoch is short-lived, most of the models reach 1.0 $M_{\odot}$ rapidly, and follow the evolutionary track of a standard 1 $M_{\odot}$ model redward away from the main sequence and up the 1st giant branch. The convective envelope deepens during 1st dredge-up to homogenize the outer 3/4 of the star's final mass.

The initial ratio of C to N mass fractions for all models is 3.07. The final C/N ratios depend primarily upon initial mass, but also decrease somewhat with increasing mass-loss timescale. Compared to a final C/N ratio of 2.12 for a standard 1 $M_{\odot}$ model without mass loss, the final C/N ratios, averaged for models with different mass-loss timescales, decrease to 2.0, 1.3, 0.65, and 0.32 for initial mass 1.25, 1.5, 1.75, and 2.0 $M_{\odot}$, respectively. These lower values can easily accomodate the observed abundance ratios for low-mass giants. The surface C/N ratios also begin to change at lower luminosities with increasing initial mass, with only a slight dependence upon mass-loss timescale. The average log $L/L_{\odot}$ at which the change commences is 0.48 for the standard 1 $M_{\odot}$ model without mass loss, compared to 0.45, 0.32, 0.26, and 0.18 for initial mass 1.25, 1.5, 1.75, and 2.0 $M_{\odot}$, respectively. Because the mass-loss phase is short-lived, stars with differing initial mass and nearly equal final mass may have nearly equal main-sequence lifetimes, enabling giants with a spread of post dredge-up C/N abundance ratios to be present in the same cluster. Since in the main-sequence mass loss scenario, cluster ages cannot necessarily be determined from main-sequence turnoff mass, the magnitude and onset location of C/N abundance ratio changes in cluster giants ascending the first giant branch may be a useful indicator of their initial mass and mass-loss timescale, and hence the cluster age.