The Abundances of Na, Mg, & Al in the Hyades: Giants, Dwarfs, and Mixing

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Introduction:
As intermediate-mass stars (2.9 M☉) evolve off the main sequence and start He core burning, their radiative outer layers become convective, and the stars experience the first dredge-up, a mixing of nuclear processed material from the core convective regions to the surface. Spectroscopic analyses of the surface abundances of these giants are used as critical tests of stellar evolution models and our understanding of core nuclear processes, stellar structure, and stellar evolution. Star clusters are particularly useful for such studies, because they provide a homogeneous stellar sample in which the initial stellar surface compositions—given by the cluster dwarfs—are compared to post-dredge surface compositions—given by the cluster giants. Here we present our abundance analysis of 4 dwarfs (~1 M☉) and 3 giants (~2.3 M☉) in the Hyades open cluster, a metal-rich open cluster ([Fe/H = 0.15] of intermediate age (525 Myr).

Stellar Model: 2.5 M☉ and Hyades Metallicity

Stellar Structure:
Stellar structure is shown as a function of time for our model of a 2.5 M☉ star with an initial Hyades-like composition. Time is given on a logarithmic scale as the difference between total elapsed time (t_e = 7.9 × 10⁷ yr) and time t from t = 0. Convective regions are gray, and radiative regions are white. The first dredge-up occurs at about 500 Myr, when core He burning commences, and processed material from the core is mixed to the surface. Notice that at subsequent times no additional mixing between the core and surface is predicted. The Clemson-American University of Beirut stellar evolution code is fully described in The, El Eid, & Meyer (2000).

Model-Surface Abundances:
Surface abundances as a function of time from our stellar evolution model. The 12C/13C ratio is expected to drop from an initial value of 90 to a post dredge-up value of ~24, in agreement with other predictions (e.g., Charbonnel 1994). The abundance of 16O experiences a negligible drop (~3%), while that of 12C decreases by ~56% (~0.20 dex) and that of 23Na increases by ~41% (~0.15 dex). No change in the surface abundances of 24Mg and 27Al are expected.

References:
Schuler, Hatzes, King, Küster, & The 2006, AJ, 131, 1057

High-Res Spectroscopy: Hyades Dwarfs & Giants

Sample high-Resolution, high-S/N spectra of a Hyades dwarf (left; HD 19793) and giant (right; γ Tau) obtained with the Harlan J. Smith 2.7-m telescope and the '2dcoude' cross-dispersed echelle spectrometer at The McDonald Observatory. The spectra are characterized by a resolving power of R ~ 60,000 and a typical S/N of 200. Some of the lines used to determine the Na, Mg, and Al abundances are marked with arrows. Abundances have been derived via an equivalent width analysis, using the LTE stellar line analysis package MOOG (Sneden 1973) and Kurucz model atmospheres.

Conclusions:
1. Observed 12C/13C ratios and 16O abundances in the Hyades Dwarfs and Giants agree well with the predictions from our evolutionary model (Schuler et al. 2006).
2. 23Na, 24Mg, and 27Al abundances are 0.25-0.50 dex higher in the Hyades Giants than the dwarfs, counter to model predictions and possibly suggesting NLTE effects and/or non-standard mixing are at work.
3. NLTE studies of metal-rich stars are scarce or nonexistent, making it difficult to draw firm conclusions about the 23Na, 24Mg, and 27Al abundances in the Hyades. Detailed NLTE analyses of Na, Mg, and Al in metal-rich stars—particularly for the Hyades—are needed before this issue can be resolved conclusively.