OXYGEN, SODIUM AND IRON ABUNDANCES IN THE HYADES

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Abstract
We analyze spectra of a sample of turn-off and main sequence stars in the Hyades cluster with masses in the range 1.2 – 2.1 \( M_\odot \), or effective temperatures between 6000 and 8200 K, to derive oxygen, sodium, and iron abundances. The abundances of the warmer stars are much higher than those of the late F-type dwarfs, which could signal pollution by material from a protoplanetary disk as predicted by Dotter & Chaboyer (2003).

Key words: Convection – stars: abundances – open clusters and associations: individual: Hyades

1. Introduction
Stellar spectroscopy is commonly used to investigate issues far broader than the chemical compositions of particular stars relying on the golden rule that "the surface composition of a main sequence star resembles that of the cloud where it formed". It has been proposed, however, that stellar surface abundances can be significantly altered by pollution due to infalling rocky/icy material as protoplanetary disks leave place to planetary systems (Murray et al. 2001), or interstellar dust is accreted as stars travel through the interstellar medium (Ragot 2001). The added material would dilute quickly in the envelopes of low-mass stars with large convective zones, but enhance significantly the surface composition of warmer stars with radiative envelopes.

2. Observations and analysis
We obtained high-resolution spectra of 36 high-fidelity members of the Hyades with the 2.7m Harlan J. Smith Telescope and the 2dcloud\textsuperscript{e} spectrograph (Tull et al. 1995) at McDonald Observatory. The CCD Tektronix detector was at the B focal station and the observations were carried out with a 1.2 arcsec slit, providing a FWHM resolving power about 60,000. The daylight sky spectrum was recorded through a special port (not the telescope), and two reference bright stars were also observed in the same dates, Sirius A and Vega. Th-Ar spectra were recorded at least once an hour for wavelength calibration. Stellar atmospheric parameters for the Hyades stars were directly adopted from de Bruijne, Hoogerwerf & de Zeeuw (2001), and are shown in Fig. 1.

We calculated LTE line profiles for the selected transitions (Na D lines, Fe II 5315 A, and the O I infrared triplet) and derived abundances and projected rotational velocities by minimizing the \( \chi^2 \) statistics between observed and calculated spectra. Fig. 2 shows the fittings for three stars. Multiple spectra were available for several stars, and were individually analyzed. We found a mean iron abundance for the members with \( T_{\text{eff}} < 6400 \) K of \( [\text{Fe/H}] = +0.12 \pm 0.02 \) (sem). Finally, NLTE corrections were calculated as in Allende Prieto et al. (2003) and used to correct the abundances obtained from the Na doublet and the oxygen infrared triplet.

3. Results
Fig. 3 shows the inferred abundances. The iron abundances are directly obtained from an LTE analysis. The sodium and oxygen abundances derived assuming LTE are shown with open circles, and those corrected to account for departures from LTE with filled circles. Our differential abundances agree well with the literature in that the Hyades are slightly more metal-rich than the Sun by 0.1-0.2 dex, but the Fe, Na, and O abundances of the warm...
members are significantly higher than those of the late-F dwarfs.

The upper panel of Fig. 3 shows that the derived iron abundance is flat for Hyades stars with an $T_{\text{eff}}$ cooler than 6400 K, but increases with with temperature for warmer stars, reaching $\text{[Fe/H]} \sim +0.7$ at $T_{\text{eff}} \sim 7800$ K. Such trend resembles the predictions of Dotter & Chaboyer (2003) for the accretion of 2 M$_\odot$ of iron. Assuming that the infalling material (similar to the solar photosphere and CI-type chondrites in the solar system case) has the same Na/Fe abundance ratio as the parent star, the [Na/H] abundances should closely follow the trend of the Fe abundances. The derived sodium abundances indeed increase monotonically with $T_{\text{eff}}$, but their reach higher values than for iron. The oxygen abundances are lower, as it would be expected for the addition of meteoritic-like material.

Besides accretion of protoplanetary material, several other explanations are possible for the non-uniform abundances found. The most simple scenario would be that the abundances are not real, but only a measurement error (see, e.g., the concerns raised by Landstreet 1998). Even though we have made an effort to derive non-LTE corrections to the abundances from the Na I and O I lines, LTE is still implicit in the calculation of the model atmospheres we employ. Surface inhomogeneities have been recently studied in detail for the F5-type subgiant Procyon using three-dimensional time-dependent hydrodynamical simulations of surface convection, and found to have a very limited impact on the derived iron abundances (Allende Prieto et al. 2002). But again, such studies are yet to be extended to A-type stars.

Other explanations are possible. With shallower convection zones, the photospheres of early F and A-type dwarfs could be more stable than those of G and late-F type stars. A reduced mixing could leave room for other mechanisms to induce vertical variations in the abundances. Effects such as gravitational settling or radiative levitation are in fact known to operate very effectively in B-type horizontal branch stars in globular clusters (Behr 2003). More work is urgently needed in order to understand the observed abundances and their possible impact on the use of stellar photospheric abundances to investigate other astrophysical problems.

**References**


