Revised Ages for the Alpha Persei and Pleiades Clusters

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Abstract. We derive ages for the Alpha Persei and Pleiades clusters of 77 Myr and 119 Myr, respectively, using lithium abundances and K-band photometry of very low-mass members. These ages are older than the canonical ages of 50 Myr and 70 Myr obtained from isochrone fitting of the upper main sequence.

1. Introduction

The ages of clusters are usually estimated from isochrone fitting to the more massive members. In the case of young open clusters, this method has two problems: (a) there are few massive stars that have evolved away from the main sequence; (b) the ages of the massive stars depend on mass loss, convective overshooting, and rotation. A full model of stellar evolution taking into account all those effects does not exist yet. Magazzù, Martín, & Rebolo (1993) proposed to use observations of lithium in very low-mass stars as a tool to study their age and mass. A derivation of such a lithium test was used by Basri, Marcy, & Graham (1996) to estimate an age for the Pleiades cluster of 115 Myr, based on the detection of lithium in a very low-mass cluster member. Martín et al. (1998, 2000) and Stauffer, Schultz, & Kirkpatrick (1998) provided additional lithium observations of Pleiades very low-mass members. Basri & Martín (1999a) and Stauffer et al. (1999) provided lithium data for very low-mass members of the Alpha Persei open cluster. In this paper we revisit the ages of Alpha Persei and the Pleiades using K-band data to estimate the luminosity of the objects (previous work used I-band data), and synthetic spectra to estimate the lithium abundances. We obtain new age estimates that confirm the known trend for older ages than those estimated from upper main sequence isochrone fitting.

2. Analysis

Unresolved binaries make objects appear brighter than they really are because of the combined light of two components. For equal brightness components, the magnitude decreases by 0.75 mag. Basri & Martín (1999b) found one double-lined spectroscopic binary in the Pleiades with a mass ratio $\geq$0.8. It is possible than many other unresolved binaries exist among the very low-mass population of the Pleiades and other clusters. The effect of unresolved binaries on the age
Figure 1. Lithium isoabundance curves from the Lyon group (Baraffe et al. 1998). Each curve represents a constant amount of lithium left over after depletion from the initial value. Line code (from left to right): solid is 90%, dot and short dash is 50%, dot and long dash is 10%, short dash and long dash is 1%, and dashed is 0.1%. Absolute $K$-band magnitudes of very low-mass cluster members are marked with horizontal lines. The Li I equivalent width given in the literature is given at the end of each line.

derived from the lithium abundance is to make the cluster appear younger. To minimize this effect we chose to derive the age from the faintest cluster member for which lithium has not been detected. Brighter cluster members for which lithium has been detected are binary candidates.

Previous estimates of the cluster ages from very low-mass members have used $I$-band photometry. This may be problematic due to variability, such as that reported by Martín & Zapatero Osorio (1997), Terndrup et al. (1999), and
Bailer-Jones & Mundt (2001). In late M-type stars it is likely that the variability is due to magnetic cool spots, and that the amplitude of variability decreases for longer wavelength, although this has never been checked. Additionally, synthetic spectra are not able to reproduce well the $I$-band region because of the presence of TiO and FeH bands, plus the effects of dust condensation for the latest M types. We prefer the $K$-band filter because synthetic models are able to reproduce better the spectrum around 2.1 microns than the spectrum around 0.8 microns. We believe that the $K$-band magnitudes provide a more reliable comparison with theoretical models. The difference in ages obtained using the $I$-band and $K$-band photometry are up to 10 Myr.

Using synthetic spectra, we find that the lithium equivalent width is not very sensitive to effective temperature in the range 3200 K to 2600 K. A cosmic lithium abundance of $\log N(\text{Li}) = 3.1$ (in the customary scale of $\log N(\text{H}) = 12$) gives an equivalent width of 0.61 Å for $T_{\text{eff}} = 3200$ K and 0.64 Å for $T_{\text{eff}} = 2600$ K. We also estimate that at $\log N(\text{Li}) = 1.0$ (about two orders of magnitude of lithium depletion), the Li I resonance features becomes blended with the surrounding TiO lines and cannot be detected. Stronger lithium lines have been reported by Rebolo et al. (1996) and Stauffer et al. (1998). Such line strengths are not well understood using model atmospheres without dust condensation.

3. Results

Our results for the Alpha Persei open cluster are shown in Figure 1. The lithium depletion boundary age is obtained from the faintest cluster member with no lithium detection. We infer a lithium depletion of two orders of magnitude from synthetic spectra. The age derived for Alpha Per and the Pleiades is 77 Myr and 119 Myr, respectively.

References


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