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EVOLUTION OF THE CHEMICAL ELEMENT ABUNDANCES WITH AGE IN OPEN CLUSTERS: THE HYADES, PLEIADES, COMA BERENICES AND M6

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Abstract. We compare the averaged photospheric abundances of A and F stars in open clusters of different ages: M6 ($\sim$ 80 Myr), Pleiades ($\sim$ 100 Myr), Coma Berenices ($\sim$ 450 Myr), and the Hyades ($\sim$ 800 Myr). The variation in the averaged abundances among F stars generally reflects the differences between the initial compositions of the clusters in their various birthplaces. The differences of the averaged chemical composition of A stars may also reveal the effects of radiative difussion for the stars of different ages. We also discuss the methods, resolutions and wavelength coverages of spectra and discrepancies in the derived microturbulent velocities among the various studies to check if these studies are comparable. We also present the pattern of mean abundances and metallicity for the M6 cluster determined by spectral analysis of GIRAFFE spectra acquired with the VLT, Paranal Observatory.

Keywords: Open clusters and associations: individual: Hyades, open clusters and associations: individual: Pleiades, open clusters and associations: individual: Coma Berenices, open clusters and associations: individual: M6

1 Introduction

The detailed chemical abundance analyses of open clusters, carried out over the last few decades, allow us to monitor the changes in abundances of the chemical elements during stellar evolution. Chemical abundance analyses, usually based on the analysis of spectra observed in the optical region, mostly reveal the chemical compositions of the photospheres of stars. For the A type main-sequence stars, these photospheric abundances are thought to be affected by radiative diffusion, and generally do not reflect the initial and bulk chemical composition of these stars. Conversely, the deep convective envelopes of the F type main-sequence stars mix the matter in their outer layers. The derived photospheric abundances should thus reflect their original values at time of stellar formation. In this study, we compare the mean abundances derived from A and F stars in several clusters of different ages.

2 Fundamental Parameters and Spectral Data of the Open Clusters

In order to compare the abundances of open clusters of different ages, we selected the papers of Gebran et al. (2008), Gebran & Monier (2008), Gebran et al. (2010), and Kılıçoğlu et al. (2014) who have analysed the Hyades, Pleiades, Coma Berenices, and M6 open clusters, respectively. The fundamental parameters of the clusters, which were retrieved from the SIMBAD and WEBDA databases, and spectral studies that were mentioned above (with references therein), are given in Table 1. The observational properties of the open clusters from selected studies are collected in Table 2.

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Table 1. Fundamental Parameters of the M6, Hyades, Pleiades, and Coma Berenices Open Clusters

Cluster	l (°)	b (°)	Age (Myr)	Distance (PC)	Reddening	[Fe/H]
M6 (NGC 6405)	356.580	–0.777	80	400	0.144	0.07
Pleiades	166.571	–23.521	100	150	0.03	0.06
Coma Berenices	222.514	-83.4011	450	96	0.013	0.07
Hyades	180.060	-22.34	800	45	0.010	0.05

Table 2. Spectral Data of the M6, Hyades, Pleiades, and Coma Berenices Open Clusters

Cluster	Spectrograph	Wavelength interval (Å)	Res.	S/N	Code	Reference
M6 (NGC 6405)	FLAMES with GIRAFFE	4490–5080 5140–5350 5590–5840	7800 25900 24200	~ 200	ATLAS9[1] SYNSPEC48[2]	Kılıçoğlu et al. (2014)
Pleiades	ELODIE SOPHIE	3850–6811 3820–6930	42000 75000	~ 200	ATLAS9[1] SYNSPEC48[2]	Gebran & Monier (2008)
Coma Berenices	ELODIE	3850–6811	42000	~ 200	ATLAS9[1] SYNSPEC48[2] Takeda's code[3]	Gebran et al. (2008)
Hyades	SOPHIE AURELIE	3820–6930 5000–6200	75000 30000–60000	~ 200	ATLAS9[1] SYNSPEC48[2]	Gebran et al. (2010)

[1]Kurucz (1993), Sbordone et al. (2004), Sbordone (2005), [2]Hubeny & Lanz (1992), [3]Takeda (1995)

3 Microturbulent Velocities

The microturbulent velocities for the four clusters are compared in figure 1. There is no systematic difference between the microturbulent velocities of the clusters. For M6, we noticed that the microturbulence velocities of the stars having temperature between 7500-8500 K are not as large as for the other clusters. The main reason of this difference is that the M6 cluster has only one observed Am star. The relatively lower resolution of the spectra of M6 may also cause these slightly lower derived microturbulent velocities.

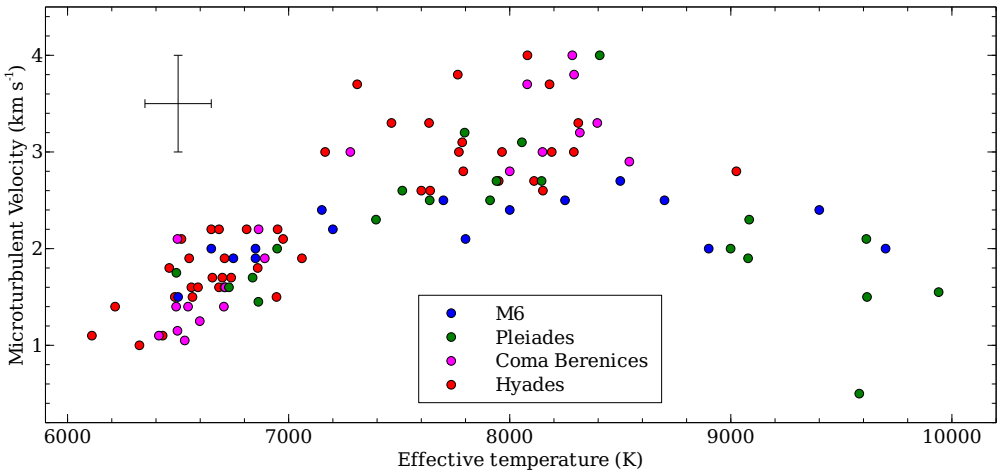

Fig. 1. Microturbulent velocity distribution with effective temperatures

4 Comparisions of the Mean Abundances of the M6, Pleiades, Coma Berenices and Hyades Open Clusters

We compared the mean abundances of A and F type stars in the four open clusters analyzed by Gebran et al. (2008), Gebran & Monier (2008), Gebran et al. (2010), and Kılıçoğlu et al. (2014). These studies use similar methods and spectral data to derive chemical abundances with few exceptions: The resolution of the spectra of the M6 cluster is slightly lower than the other clusters, and AURELIE spectra of the F stars in the Hyades have wavelength coverage of only about 1200 Å. We collected all derived elemental abundances of the chemically normal members, and computed the average of the abundances of the elements seperately for A and F stars, for each cluster.

We found that the M6 and Pleiades clusters, which have similar ages ($\sim$ 100 Myr), also exhibit similar mean abundance patterns except for a few chemical elements. The mean abundance pattern of F stars in the M6 cluster shows that only Mg, Si and Ca elements are slightly less abundant than those of Pleiades. Thus, the initial chemical composition of these two clusters might be similar.

There seems to be large discrepancies between the abundances of A stars of the Pleiades and Coma Berenices (450 Myr) cluster. However, this should not be considered as a real difference, since the study of Gebran et al. (2010) covers mostly Am-type stars. The main abundances of A stars were derived form only three chemically normal A stars which are far from to reflect the overall cluster composition. In contrast, the mean abundance pattern of F stars in Coma Berenices is remarkably similar with those of Pleiades except Ca, Y, and Ba. The main differences between the mean abundances of A stars in the Pleiades and the relatively older Hyades cluster is that the Hyades are significantly enhanched in C, O and Sc.

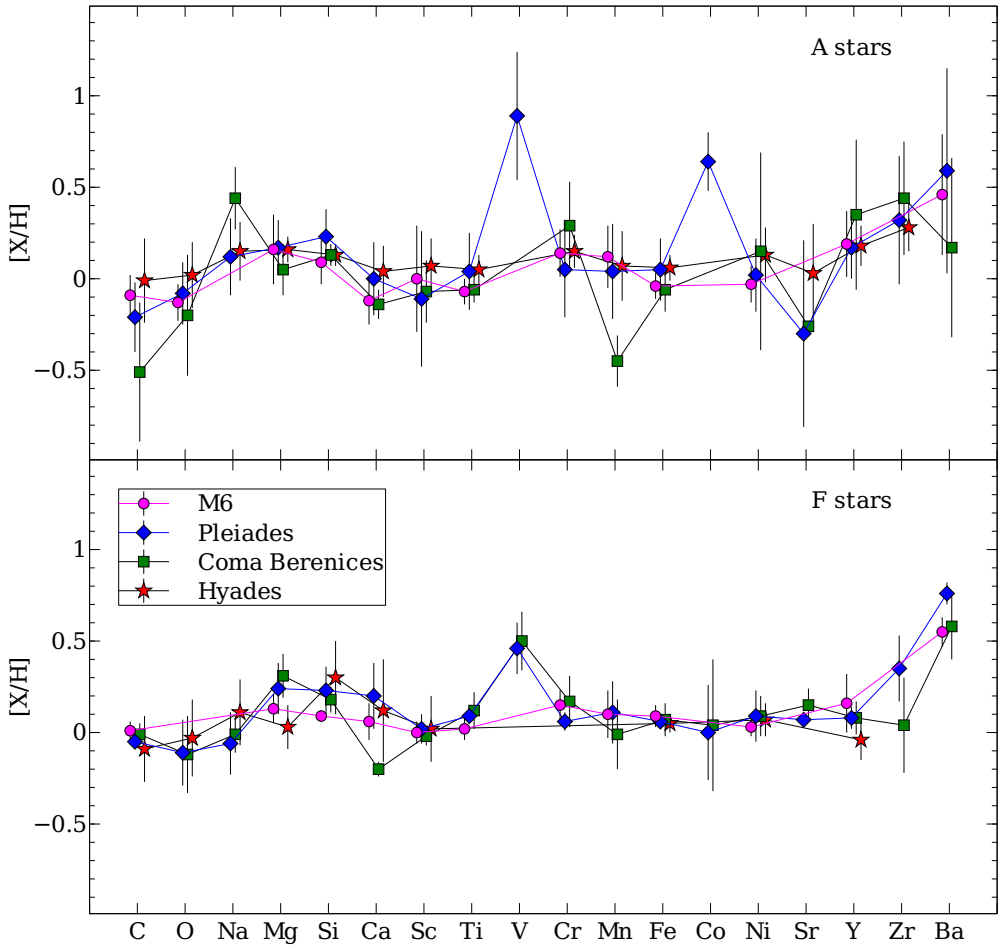

Fig. 2. The mean abundance patterns of the M6, Pleiades, Coma Berenices, and Hyades clusters, for chemically normal A type (upper panel) and F type (lower panel) stars (the bars represent star-to-star variations for corresponding element).

5 Summary and Discussions

If we exclude the mean abundance of Coma Berenices, which contains only three studied chemically normal A stars, the mean abundance pattern of chemically normal A stars in all clusters are found to be very similar. However, the Hyades, which is the oldest cluster in our samples, are slightly enhanced in light elements (C and O) to the other open clusters.

From Sc to Ni, we found that the mean abundance pattern of F stars in all clusters are quite similar. For the other chemical elements, the youngest and the oldest clusters (M6 and Hyades) exhibit a few discrepancies. Mg, Si and Ca are less abundant than other clusters for M6 cluster, while O, Na and Si are slightly enhanced in the Hyades.

In order to perform a better comparison, a study of high resolution spectra of F stars in Hyades, and chemically normal A star in Coma Berenices would be valuable. It is also necessary to ensure the homogeneity of data used to derive abundance pattern of these open clusters. The comparison presented in this paper already shows that the the mean abundance pattern of F type stars for M6, Pleiades, and Hyades clusters are surprisingly similar for many chemical elements.

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