Abundance determinations for the F dwarfs members of the Hyades from SOPHIE high resolution spectra

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ABSTRACT. The mean chemical composition of open clusters can be derived from the chemical abundance analysis of F type main-sequence stars, as they have convective layers which homogenize the material in their outer layers and thus keep track of the initial composition of the cluster. We present a preliminary abundance analysis of 5 F type members of the Hyades open cluster using the high resolution spectra retrieved from SOPHIE archive. Our aim is to derive the elemental abundances of these stars as well as the mean abundance distribution of the cluster. The analysis was carried out by iteratively adjusting LTE synthetic spectra for several chemical elements: C, O, Na, Mg, Al, Si, S, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Sr, Y, Zr, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd. Each element was found to be marginally/slightly overabundant relative to solar, except for Zn, Ga, Y, and Pr which are solar, and for Sr, Ba, La, Ce, Sm, and Gd which are overabundant. The mean iron abundance of the cluster is found to be [Fe/H] = 0.21 dex.

Introduction

- The deep convective layers of the F type main-sequence stars homogenize the gas in their outer layers. The derived photospheric abundances of these stars should thus reflect their original values at the time when cluster formed and reveal the mean chemical composition of the cluster.
- The Hyades Open Cluster is one of the most important laboratory for stellar astrophysicists due to its brightness and large number of members. The C and Fe abundances have been derived by Friel & Boesgaard (1990) and Boesgaard & Friel (1990) for 14 F-type stars. Thorburn et al. (1993) reported also Li abundance of several F-type members. A detailed abundance analysis of this cluster (including both chemically normal and peculiar stars) was carried out by Varenne & Monier (1999) and, recently by Gebran et al. (2010). For the abundance analysis of F-type stars, Gebran et al. (2010), however, used mono-order AURELIE spectra, which allowed them to derive the abundance for a limited number of elements with a fairly large uncertainty.
- Our aim is to derive the mean chemical abundances for F-type members in Hyades open cluster precisely, using the high resolution and high signal-to-noise echelle SOPHIE spectra which span a much wider wavelength range, from 3900 Å to 6860 Å, than AURELIE spectra did. We selected HD 18404, HD 26345,HD 27534, HD 28736, and HD 28911 to derive their abundances. This study is a part of a long-term ongoing project which includes 25 F-type members of Hyades and we present here our first results.

Atmospheric Parameters

- In order to derive the atmospheric parameters of the five cluster members, we initially used Strömgren's uvbyβ photometry of these stars (Crawford et al. 1966, Crawford & Perry (1966), Eggen 1982, Eggen 1985, Hauck & Mermilliod 1998, Olsen 1994) and Napiwotzki et al. (1995)'s calibration of this photometry in terms of T_e and log *g*. We then compared the observed and the theoretical hydrogen Balmer line profiles (Hβ, Hγ, Hδ) to derive the effective temperature of the stars more accurately (Fig. 1). As the hydrogen Balmer lines are not very sensitive to surface gravity changes at these effective temperatures, the surface gravities were adopted from photometry. The derived effective temperatures from Strömgren photometry and from hydrogen Balmer lines agree with each other. The microturbulent velocity of the stars varies between 1.6 and 2.0 km.s^{-1}. The derived atmospheric parameter and final adopted values are shown in Table 1.

Table 1. The derived atmospheric parameters of the program stars

		HD 18404	HD 26345	HD 27534	HD 28736	HD 28911
T_e(K)	Hβ	6800	6900	6750	6800	6800
	Hγ	6800	6850	6600	6800	6900
	Hδ	6850	6900	6700	6800	6800
	Str. uvbyβ	6917	6866	6665	6833	6767
	Adopted	6850 ± 100	6900 ± 100	6700 ± 100	6800 ± 100	6800 ± 100
Log *g*	Str. uvbyβ	4.25	4.23	4.08	4.17	4.16
	Adopted	4.25 ± 0.05	4.25 ± 0.10	4.10 ± 0.30	4.15 ± 0.10	4.15 ± 0.10

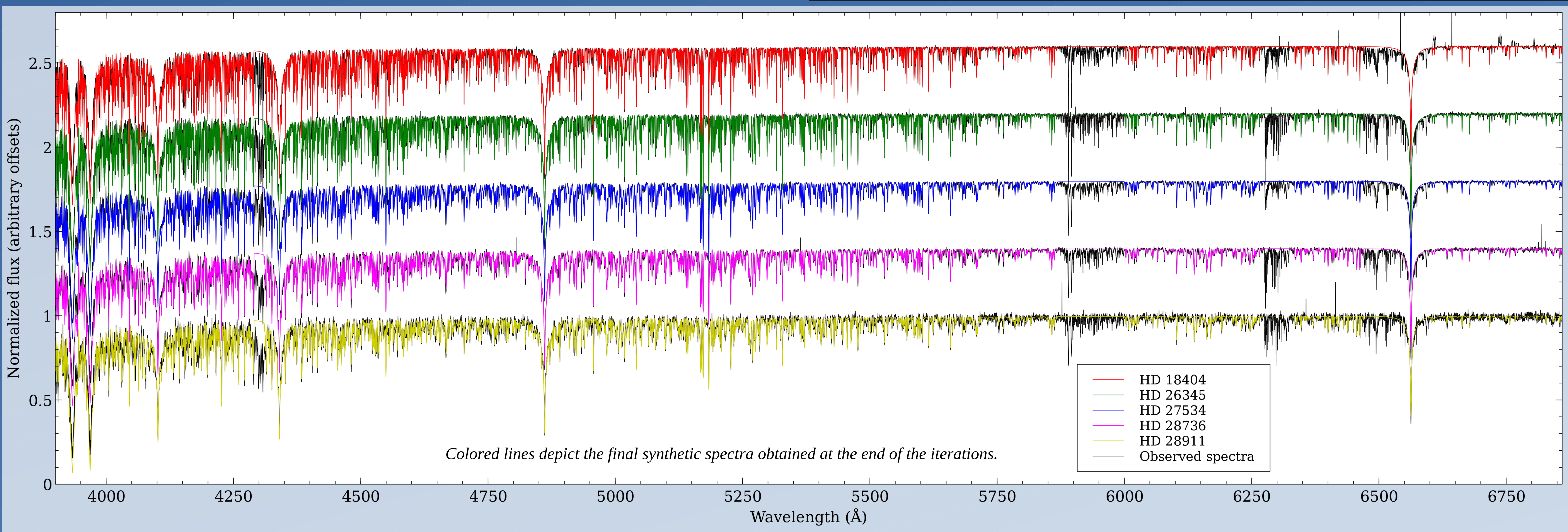

Fig. 1 Comparision of the observed and synthetic spectra (for the derived elemental abundances)

Spectral Data and Abundance Analysis

- The spectra and radial velocities of HD 18404, HD 26345, HD 27534, HD 28736, and HD 28911 were retrieved from the SOPHIE archive. The spectral data spans the wavelengths between 3872 and 6942 Å, with a resolution of about R=75000.
- In the event more than one spectrum was available for a given star, we co-added these spectra to obtain higher signal-to-noise (S/N) ratio. The spectra were then normalised to the local continuum using low-order spline functions.
- Model atmospheres were computed using ATLAS9 (Kurucz 1993, Sbordone et al. 2004, Sbordone 2005) code assuming LTE (Local Thermodynamic Equilibrium) approximation and HE (Hydrostatic Equilibrium).
- The synthetic spectra were computed using SYNSPEC48 (Hubeny & Lanz 1992). We have slightly modified this code to compute the chi-squares between observed and synthetic spectra.
- The linelist of Kurucz (gfhyperall.dat) was used as an initial source of atomic data and then was updated using the NIST (Kramida et al. 2013) and VALD (Piskunov et al. 1995, Ryabchikova et al. 1997, Kupka et al. 1999, Kupka et al. 2000) databases.
- In order to derive the elemental abundances, we iteratively adjusted the synthetic spectra to the observed spectrum for each star. The final outputs of this adjusting process are illustrated in Fig. 1.
- We only analysed the spectral region from 3900 Å to 6860 Å as the spectra are too noisy outside this range. We discarded the following wavelength intervals: 5870-6000, 6270-6330 and 6470-6600 Å because of the telluric lines. We also rejected the 4290-4310 Å interval because we had difficulties to normalise to a local continuum in that region.

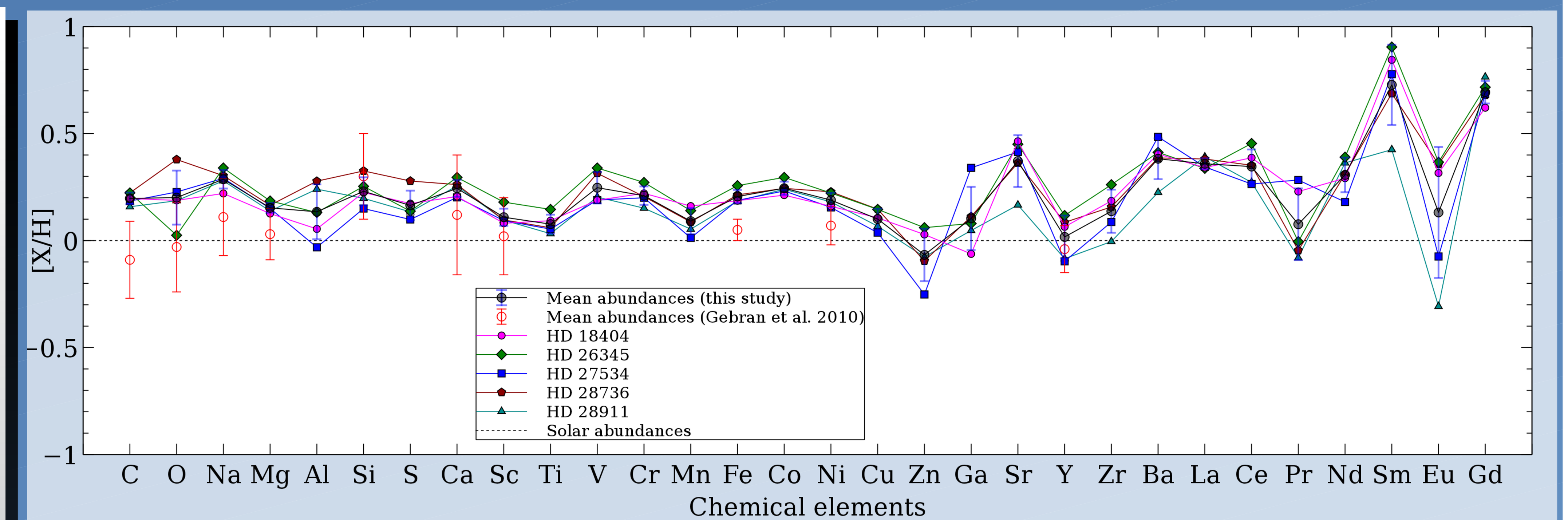

Fig. 2 Derived abundances for the program stars

Results and Discussion

- Fig. 2 displays the derived elemental abundances of 30 chemical elements for each star. To our knowledge, the abundances of many lanthanides (La, Ce, Pr, Nd, Sm, Eu, and Gd) were derived for the first time in this study for the Hyades Open Cluster.
- We found that the abundances of Zn, Ga, Y and Pr are normal, Mg, S, Sc, Ti, Mn, Cu, and Zr are marginally overabundant (~+0.1 dex), while C, O, Na, Si, Ca, V, Cr, Fe, Co, Ni and Nd are slightly overabundant (~+0.25 dex), Sr, Ba, La, Ce, Sm, and Gd is overabundant (~+0.4 dex) relative to solar abundances (Grevese et al. 1999). We did not find significant variations of the abundances from one star to another. The apparent star-to-star abundance variations for O, Ga, and Eu most-likely is caused by the limited number of lines analysed and differences in the rotational velocities between the program stars.
- We compared our derived mean abundances for the F stars in the Hyades with those determined by Gebran et al. (2010) with uncertainties about ±0.20 dex in Fig.2. The mean abundances in these two study are similar in the limit of uncertainties, except for C and Fe. The differences between the two study most-likely arise from the different resolution and wavelength coverage of the two instruments used in the analyses. However, the found C enrichment for these F stars in this study is unexpected. A fine analysis on several high quality C I lines is clearly necessary for a better conclusion.
- The first results presented in this study reveal that the F stars of Hyades cluster are enriched in metals ([Fe/H]=0.21) than previously reported (0.13 by Boesgaard & Friel 1990 and 0.05 by Gebran et al. 2010). Our ongoing project on a large number of F-type members in Hyades will help us to derive a more precise distribution of elemental abundances for the cluster. A differential abundance analysis may also help to eliminate the systematic instrumental errors on derived abundances.

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