Star clusters: basic galactic building blocks
Proceedings IAU Symposium No. 266, 2009
R. de Grijs & J. R. D. Lépine, eds.

doi:10.1017/S1743921309991694

Open cluster characterization via cross-correlation with a spectral library†

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Abstract. We present a characterization method based on spectral cross-correlation to obtain the physical parameters of the controversial stellar aggregate ESO442–SC04. The data used was obtained with GMOS at the *Gemini South* telescope, and includes spectra of 17 stars in the central region of the object and 6 standard stars. FXCOR was used iteratively to obtain self-consistent radial velocities for the standard stars and average radial velocities for the science spectra. Spectral types, effective temperatures, surface gravities and metallicities were determined using FXCOR to correlate cluster spectra with the ELODIE spectral library and select the best correlation matches using the Tonry & Davis ratio. Analysis of the results suggests that the stars in ESO442–SC04 are not bound and, therefore, they do not constitute a physical system.

Keywords. open clusters and associations: general, open clusters and associations: individual (ESO 442–SC04)

1. Introduction

Open clusters are destroyed over time by the action of external forces (Galactic tidal field, collisions with molecular clouds) and as a consequence of their own dynamical and stellar evolution. Studies on the subject indicate that most open clusters dissolve in 0.5–2.5 Gyr (Portegies Zwart *et al.* 2001) and that finding clusters in a state of dissolution should be common. However, distinguishing such objects from a random overdensity of field stars is a difficult task, and many authors have been developing techniques to study and properly classify them (e.g., Pavani & Bica 2007).

ESO442–SC04 was identified by Bica *et al.* (2001) as a possible open cluster remnant, but was later classified by Carraro *et al.* (2005) as an asterism. We have applied an iterative method to characterize this object and derive the physical parameters of its stars.

2. Data

The Gemini Multi-Object Spectrograph (GMOS, *Gemini South*) was used to collect spectra of 36 selected stars in a $5' \times 5'$ region centered on ESO442–SC04, and 6 standard stars from Nordström *et al.* (2004). The collected spectra cover the spectral range $3875\,\text{Å} - 5300\,\text{Å}$ at a resolution of $R \approx 4000$ and signal-to-noise ratios (S/N) in the range $5 - 50$. Table 1 lists the observed standard stars and their properties (from the literature).

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† The full poster (in pdf format) is available at
`http://www.astro.iag.usp.br/~iaus266/Posters/pMaia.pdf`.

Table 1. Literature data for the standard stars.

Object	Type	v_r (km s−1)	[Fe/H](±0.12)	$T_{\rm eff}$ (± 110) (K)
HD 104471	G0V	−7.2 ± 0.1	0.00	5984
HD 104982	G2V	10.5 ± 0.1	−0.40	5610
HD 105004	F8VI	121.6 ± 0.3	−0.79	5821
HD 107122	F1V	16.2 ± 3.3	−0.42	6576
HD 111433	F3IV	4.0 ± 0.6	+0.25	6471
CD−289374	...	30.4 ± 0.2	−1.18	4830

We adopted the ELODIE.3.1 stellar spectral library (Prugniel & Soubiran 2001) as template spectra for the cross-correlation technique to determine the physical parameters of the targets. The library includes 1962 spectra of 1388 stars, providing a broad coverage of the stellar atmospheric parameters $T_{\rm eff}$, log g and [Fe/H].

3. Radial-velocity determination

Initially, the FXCOR task was applied to the standard-star spectra, using the values given in Table 1 as a first guess of their radial velocities. A self-consistent set of solutions was then obtained by correcting the velocities and redoing the correlation to find consistent values for the full set. Table 2 shows the results of the correlations and the average radial velocities obtained.

Table 2. Calculated radial velocities for the standard stars. Bold-faced values represent the velocities adopted for each template in the correlation.

star/template	HD 104471	HD 104982	HD 105004	HD 107122	HD 111433	CD −289374
HD 104471	**−126.3±11.5**	−7.5±5.2	118.0±15.1	16.7±25.9	−24.6±11.4	30.4±5.7
HD 104982	−127.5±5.2	**−8.7±5.7**	114.0±13.4	9.4 ±24.7	−28.8±13.0	32.9±11.2
HD 105004	−122.7±15.8	−1.1±13.4	**121.6±0.3**	19.6±27.9	−20.6±18.0	37.5±16.6
HD 107122	−126.8±25.9	−1.9±24.7	118.2±27.9	**16.2±3.3**	−24.6±18.4	36.0±28.9
HD 111433	−126.3±11.5	−4.5±13.0	117.6±18.0	16.2±18.4	**−24.6±11.4**	33.7±17.8
CD −289374	−128.8±11.2	−8.7±5.2	114.5±16.6	10.6±3.3	−27.9±17.8	**30.4±0.2**
$\overline{V_r}$	−126.4±6.1	−5.4±5.4	117.3±7.0	14.8±9.5	−25.2±6.3	33.5±6.6

Next, FXCOR was run on the science spectra using the six standard-star spectra as templates. The radial velocities found for each template were averaged and the dispersion calculated for all science spectra. Table 4 shows the spectra used, their corresponding S/N and the radial velocities obtained.

4. Cross-correlation with spectral library

We used ELODIE spectral library templates for the standard stars and FXCOR to determine, through the sharpness of the correlation-function peak (Tonry & Davis ratio: TDR; Tonry & Davis 1979), the most similar templates for each star. Figure 1 shows the two best-matching spectra (found from correlation) for both the standard star HD 111443 and one of our science spectra. Their spectral types and TDR correlation parameters are also shown.

Spectral types were determined by collecting the ten most similar templates and summing over the TDR values of those with the same spectral type. The template with the highest TDR sum was adopted as the closest spectral type. Table 3 shows the resulting spectral types for the standard stars, compared with the relevant values from SIMBAD.

Effective temperatures, surface gravities and metallicities were calculated as the average values listed for the chosen templates, weighted by the TDR correlation value of each template. The adopted uncertainties correspond to the weighted standard deviation of

Table 3. Comparison of spectral types for standard stars.

	HD 104471	HD 104982	HD 105004	HD 107122	HD 111433	CD −289374
Determined	G0	G2V	F5V	F3V	F3V	G0
SIMBAD	G0V	G2V	F8IV	F1V	F3IV	—

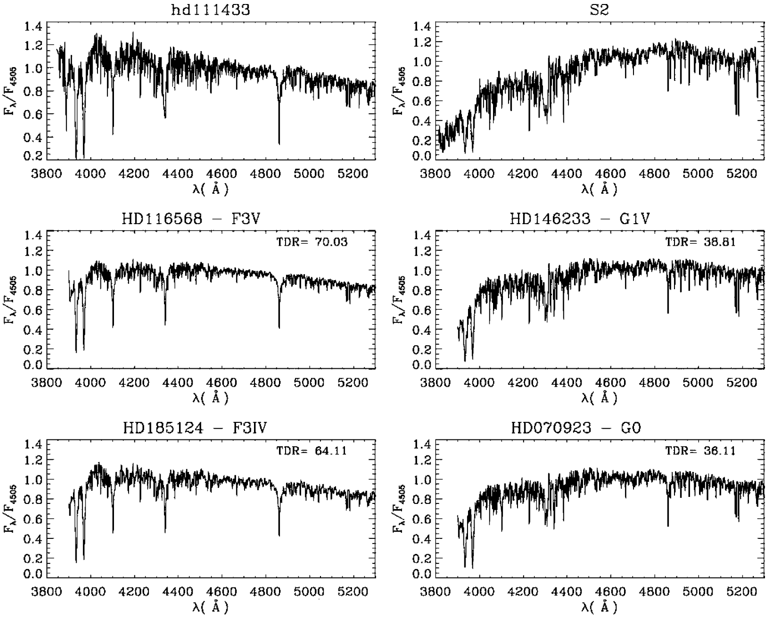

Figure 1. Best correlation templates for standard star HD 111443 *(left)* and science spectrum S2 *(right)*. The name of the template and TDR value are shown.

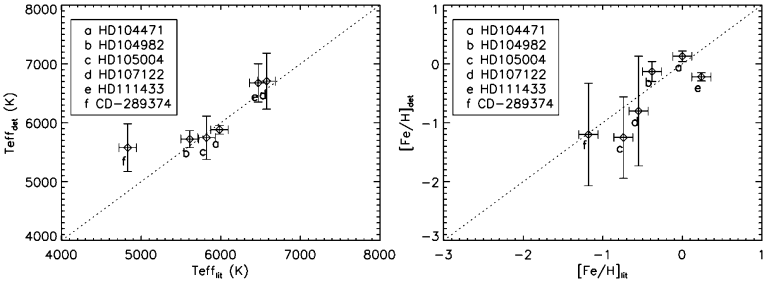

Figure 2. Comparison between our and literature parameters for the standard stars. Effective temperatures *(left)* and metallicities *(right)*.

the derived average. Figure 2 shows the relation between the effective temperatures and metallicities thus determined and the literature parameters.

We used the same method to determine the spectral types, effective temperatures, surface gravities and metallicities of our science spectra, as shown in Table 4.

5. Results

By employing cross-correlation techniques and using the ELODIE spectral library, we were able to determine heliocentric radial velocities, spectral types, effective temperatures, surface gravities and metallicities for 17 stars in the inner region of ESO442–SC04. These results are summarized in Table 4.

Table 4. Radial velocities, spectral types, effective temperatures, surface gravities and metallicities determined for the science spectra.

Spectrum	S/N	$\overline{v_r}$ (σ_{v_r}) (km s^{-1})	Sp. Type	$T_{\rm eff}$ ($\sigma_{T_{\rm eff}}$) (K)	log(g) ($\sigma_{\log(g)}$)	[Fe/H] ($\sigma_{[Fe/H]}$)
S2	15	75.8 (7.2)	G5V	5676 (117)	4.20 (0.21)	−0.01 (0.09)
S6	40	9.5 (5.2)	F5V	6347 (348)	4.24 (0.12)	−0.59 (0.27)
S9	20	25.1 (4.7)	F5V	6309 (416)	4.24 (0.08)	−0.52 (0.29)
S10	10	93.6 (10.3)	K2V	5213 (61)	4.48 (0.10)	−0.03 (0.14)
S12	20	227.2 (12.7)	G0	5380 (424)	3.14 (0.88)	−1.60 (0.66)
S14	25	110.0 (10.9)	G0	5673 (324)	3.75 (0.72)	−1.79 (0.57)
S15	30	78.5 (7.5)	G5V	5606 (115)	4.33 (0.11)	+0.02 (0.08)
S19	50	68.0 (8.2)	F3V	6834 (261)	4.28 (0.08)	−0.41 (0.29)
S20	25	74.4 (6.9)	G2V	5740 (63)	4.17 (0.18)	+0.03 (0.13)
S21	30	31.3 (5.6)	F7IV	5910 (460)	3.89 (0.75)	−0.99 (0.81)
S23	35	95.5 (8.5)	G0V	5765 (261)	3.99 (0.56)	−0.92 (0.67)
S25	6	145.9 (17.1)	F2IV	6480 (439)	4.14 (0.19)	−0.19 (0.16)
S28	30	15.0 (5.4)	F8V	6005 (306)	4.19 (0.19)	−0.57 (0.26)
S29	22	10.7 (7.1)	G8III	4877 (87)	2.76 (0.16)	−0.03 (0.15)
S30	12	40.0 (6.6)	G0III	5721 (69)	4.07 (0.18)	+0.16 (0.07)
S32	10	47.0 (6.7)	G8III	5011 (212)	2.76 (0.42)	−0.03 (0.13)
S33	12	142.4 (12.9)	G8V	5633 (117)	4.31 (0.18)	−0.01 (0.06)

2MASS data was used to construct a colour–magnitude and a spatial diagram showing the relative positions of the stars on the sky, along with the radial velocities, surface gravities and effective temperatures obtained for the targets. The objects diagrams are labelled according to their internal identification and coded with colors representing groups including a range of radial velocities: see Figure 3.

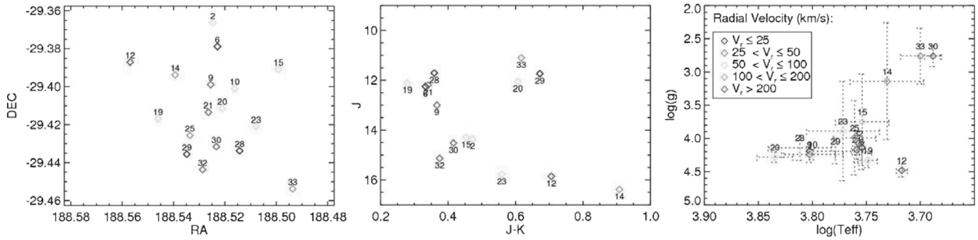

Figure 3. Positional chart *(left)*, color–magnitude diagram *(middle)* and surface gravity–temperature diagram *(right)* for the spectra. Stars are labeled by their internal identification shown in Table 4 and color-coded according to their radial velocities *(right legend)*.

6. Conclusion

We devised a spectral cross-correlation method to determine kinematic and astrophysical parameters for stars in the central region of ESO442–SC04. The radial velocities and metallicities exhibit dispersions greater than 50 km s^{-1} and 0.6 dex, respectively, suggesting that few, if any, of the stars are physically bound. Although their distribution in the CMD (Figure 3) suggests that they follow evolutionary sequences typical of old clusters, our results suggest that ESO442–SC04 does not constitute a physical system.

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