

Abstract

We present a characterization method based on spectral cross-correlation to obtain the physical parameters of the controversial object ESO442-SC04. The spectra data used was obtained with GMOS at Gemini-South telescope including 17 stars in the central region of the object and 6 standard-stars. FXCOR was used to obtain a self-consistent set radial velocities for the standard-stars in an iterative process. These values were used to calculate radial velocities for the science-spectra, by averaging the values found from each standard-star. Next spectral types, effective temperature, surface gravity and metallicities parameters were determined using task FXCOR, with a proper configuration, to correlate cluster spectra with ELODIE spectral library to select the best correlation matches using the Tonry and Davis Ratio (TDR). The results suggests that ESO442-SC04 is not bound and do not constitute a physical system.

Data

The Gemini Multi-Object Spectrograph (GMOS) (Gemini-South) was used to collect spectra of 36 selected stars on a $5' \times 5'$ region centered in ESO442-SC4. Radial velocity and metallicity standard stars were also observed using GMOS on longslit mode.

The science object ESO442-SC4 was integrated over 3 exposures of 600s giving signal-to-noise ratios (S/N) in the range 5 – 50 for the selected stars. The observed standard stars achieved S/N about 25. Figure 1 shows the cluster image from DSS2 I band.

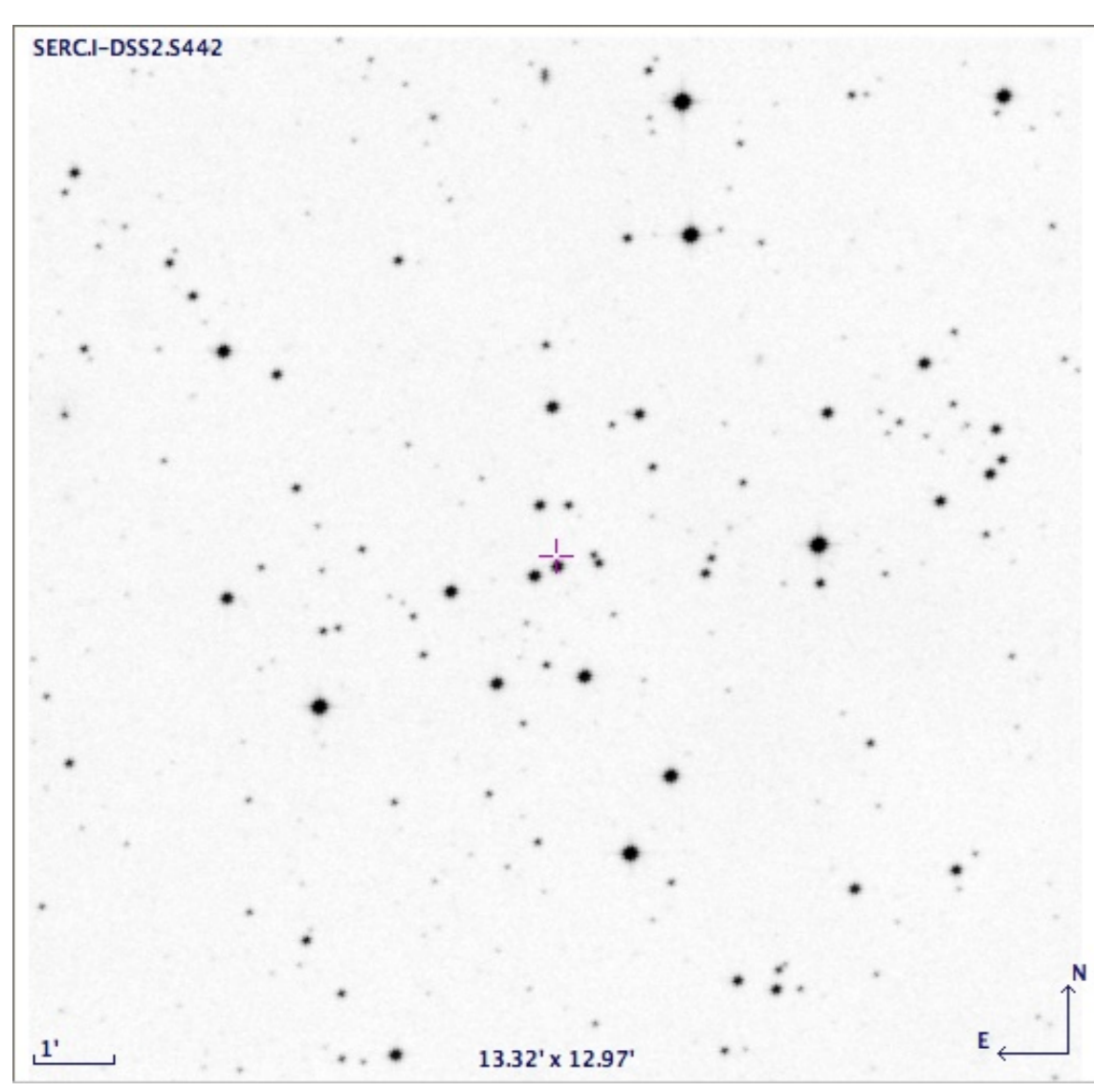


Figure 1 : ESO442-SC04 image from DSS2 I band.

Table 1 lists the observed standard stars and their properties as found in Nordström et al. (2004) (effective temperatures, radial velocities and metallicities) and SIMBAD (spectral types).

Object	ST	V_r (km/s)	[Fe/H] (± 0.12)	T_{eff} (± 110) (K)
HD104471	G0V	-7.2 ± 0.1	0.00	5984
HD104982	G2V	10.5 ± 0.1	-0.40	5610
HD105004	F8IV	121.6 ± 0.3	-0.79	5821
HD107122	F1V	16.2 ± 3.3	-0.42	6576
HD111433	F3IV	4.0 ± 0.6	0.25	6471
CD-289374	—	30.4 ± 0.2	-1.18	4830

The collected spectra cover the spectral range 3875 – 5300 with resolution $R = 3945$ ($\Delta\lambda = 1.2 \text{ \AA}$) and dispersion of 0.4713 \AA/pixel . Grating *B1200_G5321* was used with 0.5 arcsec slit width.

Data reduction was carried out using IRAF standard routines from the GEMINI package. At the end of the reduction process 17 out of the 36 collected spectra were found to be usable, the others being discarded for presenting high levels of noise ($S/N < 5$).

ELODIE Stellar Spectral Library

ELODIE.3.1 stellar spectral library (Prugniel & Soubiran, 2001) was extensively used in this work for determination of spectral types and dereddening of the science spectra.

The library includes 1962 spectra of 1388 stars obtained with the ELODIE spectrograph at the Observatoire de Haute-Provence 193 cm telescope in the wavelength range 3892 – 6800 providing a large coverage of stellar atmospheric parameters T_{eff} , $\log g$ and [Fe/H]. The library is available at two resolutions: $R = 42000$ and $R = 10000$, only the latter one being used in this work.

Radial velocity determination

Standard stars

Radial velocities were determined by cross-correlation using the FXCOR task. As a first step the task was applied on the standard stars set using the values given by table 1 as a first guess to stars radial velocity. A self-consistent set of solutions was then obtained by making corrections to the velocities and redoing the correlation in order to find consistent values for the whole set.

Table 2 shows the results of the employed correlations and the averaged radial velocities obtained.

Table 2: Calculated radial velocities for the standard stars. Boldfaced values represent the velocities adopted for each template in the correlation.

star/template	HD104471	HD104982	HD105004	HD107122	HD111433	CD-289374
HD104471	-126.3 ± 11.5	-7.5 ± 5.2	118.0 ± 15.1	16.7 ± 25.9	-24.6 ± 11.4	30.4 ± 5.7
HD104982	-127.5 ± 5.2	-8.7 ± 5.7	114.0 ± 13.4	9.4 ± 24.7	-28.8 ± 13.0	32.9 ± 11.2
HD105004	-122.7 ± 15.8	-1.1 ± 13.4	121.6 ± 0.3	19.6 ± 27.9	-20.6 ± 18.0	37.5 ± 16.6
HD107122	-126.8 ± 25.9	-1.9 ± 24.7	118.2 ± 27.9	16.2 ± 3.3	-24.6 ± 18.4	36.0 ± 28.9
HD111433	-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
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

The velocities found for the standard stars HD107122, HD105004 and CD-289374 agree with the values presented in table 1.

Based on this result, we have found velocities for standard stars HD104471, HD104982 and HD111433, consistent with the relative velocities found from the correlation with HD107122, HD105004 and CD-289374. Indeed HD104471 is a confirmed binary system with similar mass components and HD104982 and HD111433 show a significant Doppler deviation from previous literature measurements.

Science stars

Next, with the heliocentric velocities previously determined for the standard stars, FXCOR was run on the 17 science spectra using the 6 standard stars spectra as templates.

The radial velocities found from each template were averaged and the dispersion calculated for all science spectra. Table 4 shows the used spectra, their corresponding S/N and the radial velocities obtained.

Cross-correlation with spectral library

Spectral type, effective temperature, surface gravity and metallicity parameters were determined by matching each star's spectrum against ELODIE.3.1 stellar spectral library.

As a first step we used ELODIE's lower resolution spectra ($R = 10000$) as templates to the standard stars spectra on task FXCOR in order to determine, through the sharpness of the correlation function peak (TDR, Tonry & Davis, 1979), the most similar templates to each standard star.

Figure 2 show the three best matching spectra found by correlation for the standard-star HD 111443 and for one of our science-spectra. Their spectral types and TDR correlation parameter are also shown.

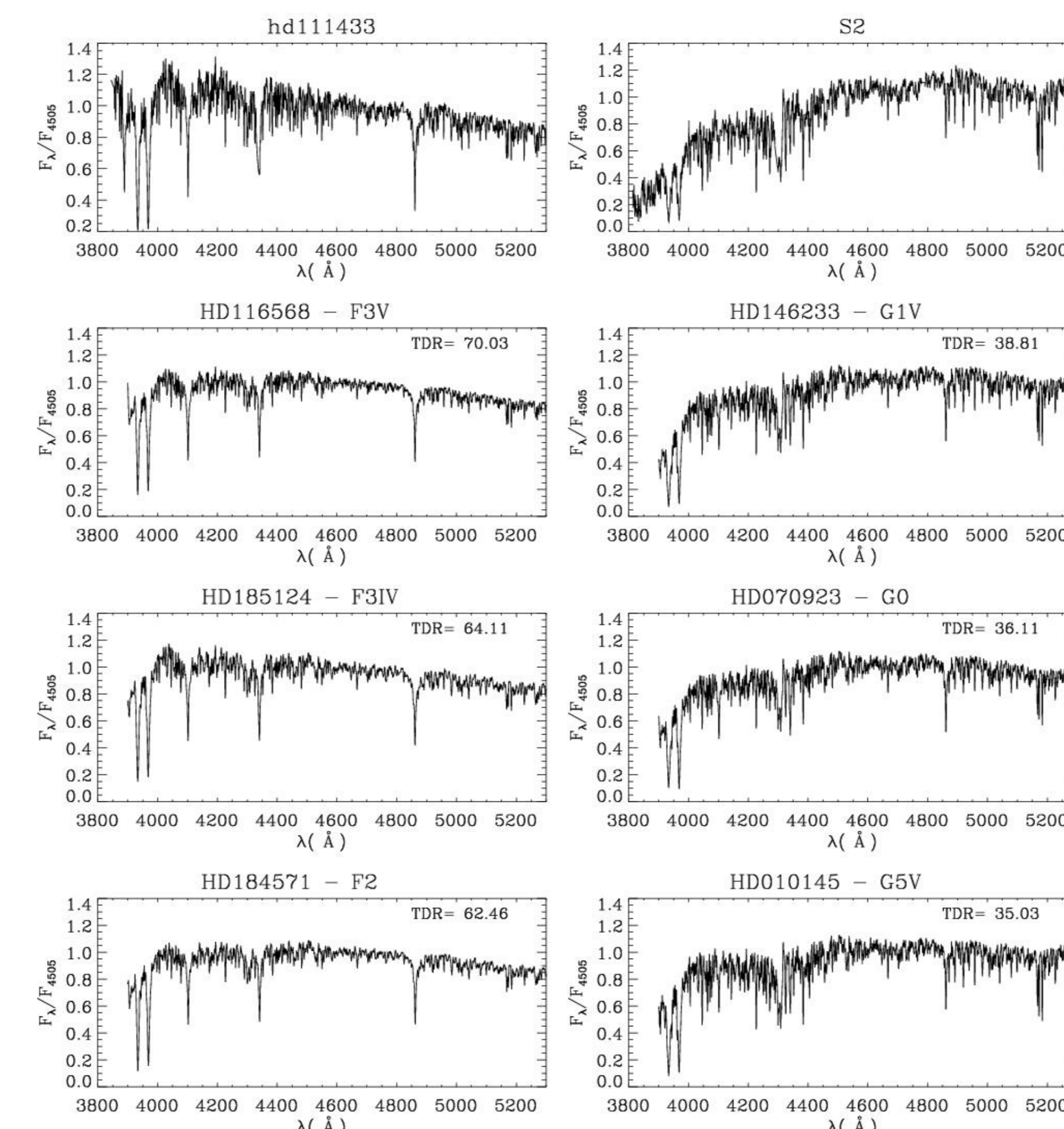


Figure 2 : Best correlation templates for standard-star HD 111443 and science spectra S2. Name of the object and TDR value are shown.

The spectral types were determined by collecting the ten most similar templates and summing over the TDR correlation value of each template with the same spectral type. The one with the highest TDR sum, was adopted as the final spectral type of the spectrum. Table 3 shows the determined spectral types for standard stars and their spectral types as provided by SIMBAD (table 1).

Table 3: Comparison of determined Spectral Types for standard stars.

	HD104471	HD104982	HD105004	HD107122	HD111433	CD-289374
Determined	G0	G2V	F5V	F3V	F3V	G0
SIMBAD	G0V	G2V	F8IV	F1V	F3IV	—

It can be seen that the spectral types determined by the adopted method are uncertain by up to 3 spectral subclasses.

Effective temperatures, surface gravity and metallicity parameters were calculated as the averaged value of these parameters listed for the chosen templates, weighted by the TDR correlation value of each template. The uncertainties adopted correspond to the weighted standard deviation of the weighted mean. Figure 3 shows the relation between the determined temperatures and metallicity and the literature parameters shown on Table 1.

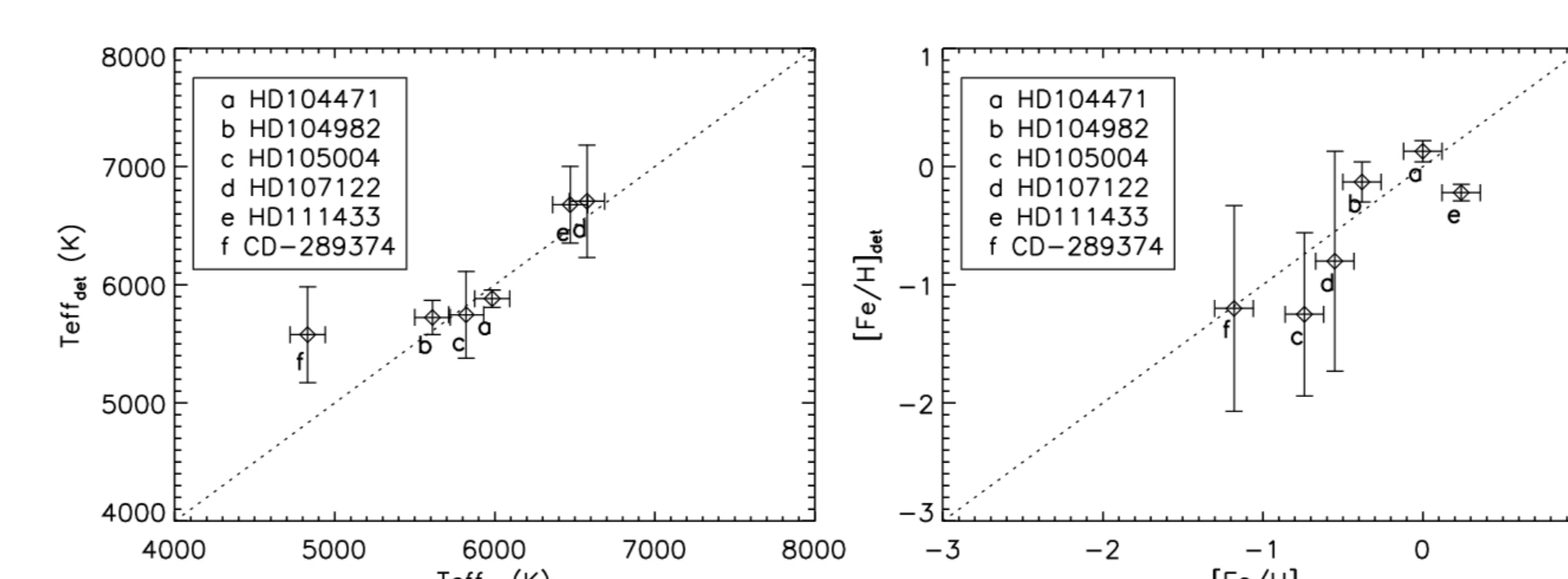


Figure 3 : Relation between determined effective temperatures (left) and metallicities (right) and the literature values for those parameters for the standard-stars.

Considering the uncertainties involved, the determined parameters show good agreement with the literature values. Guided by this result we used the same method to determine the spectral type, effective temperature, surface gravity and metallicity parameters of our science spectra, as shown in table 4.

Results

By means of cross-correlation with ELODIE's spectral library we were able to determine heliocentric radial velocities, spectral types, effective temperatures, surface gravity and metallicities for 17 stars in the inner region of stellar object ESO442SC4. These results are summarized in table 4.

Table 4: Radial velocity, spectral type, effective temperature, surface gravity and metallicity determined parameters for the science spectra.

Spectrum	S/N	V_r (σ_{V_r}) (km/s)	Sp. Type	T_{eff} ($\sigma_{T_{eff}}$) (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)

In order to analyze in detail the data in Table 4 we cross-referenced our objects with data from the 2MASS catalog (Skrutskie, et. al, 2006) to create a spatial diagram showing the positions of the stars in the sky. The relative position of the stars, along with the information on Table 4, should make clear if the stars belong to physical group. Additionally a color-magnitude diagram (CMD) was built using the J and $J-K$ 2MASS bands to show if evolutionary sequences can be recognized, suggesting the existence of an open cluster. The objects in those diagrams are labeled according their internal identification and coded with colors representing groups with a range of radial velocities. Such diagrams are shown in Figure 4.

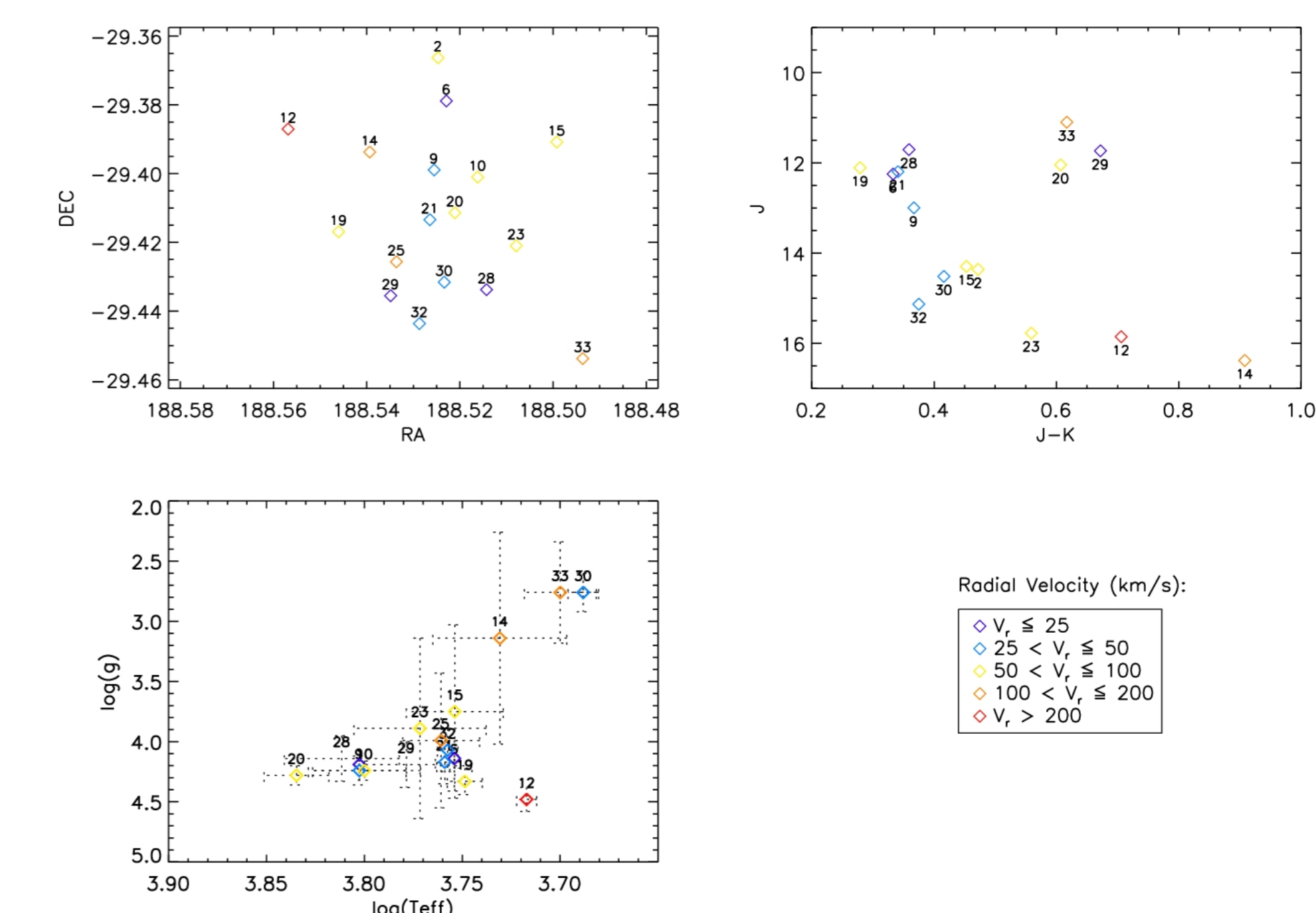


Figure 4 : Positional chart (top left), color-magnitude diagram (top right) and surface gravity-temperature diagram (bottom left) for the studied spectra. Stars are labeled by their internal identification shown in Table 4 and color-coded according to their radial velocities (bottom right legend).

Although the stars distribution on the CMD's suggests that they follow evolutionary sequences typical of old clusters, the radial velocity data, alongside the spectral types and metallicities points otherwise. Radial velocity data in table 4 suggests that few, if any, of the studied stars are physically bound. The values obtained show dispersion greater than 50 km/s. Also metallicities and spectral types obtained allow us to exclude at least 5 stars with very low metal content or early spectral types, not expected in old, dispersing clusters. Although further studies on the metallicity and reddening of the spectra are still in progress, the data strongly points out that ESO442SC4 is not a physical system.

Conclusion

We devised a method that determined, by means of a spectral cross-correlation technique, the radial velocity, spectral type, effective temperature, surface gravity and metallicity for stars in the central region of ESO442SC04. With these results, our method was able to discern the real nature of this controversial object as being an asterism. We have shown that superficial analysis of open clusters, based solely on color-magnitude diagrams, and density profiles could characterize the object ESO442SC04 erroneously, as an old open dispersing cluster.

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References

- Bica, E., Santiago, B. X., Dutra, C. M., Dottori, H., de Oliveira, M. R., & Pavani, D. 2001, A&A, 366, 827
- Nordström, B., et al. 2004, A&A, 418, 989
- Prugniel, P., & Soubiran, C. 2001, A&A, 369, 1048
- Skrutskie M.F., et. al. 2006, AJ, 131, 1163.
- Seaton, M. J. 1979, MNRAS, 187, 73P
- Tonry, J., & Davis, M. 1979, AJ, 84, 1511