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Chemical analysis of K giants in the young open cluster NGC 2345

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Abstract. We present elemental abundance results of five giants of the young open cluster NGC 2345. The atmospheric parameters of the studied giants and their chemical abundances were determined using high-resolution optical spectroscopy, obtained with the FEROS spectrograph, attached to 2.2 m telescope at ESO, Chile. In this study, we determine abundances of light elements (Li, C, N, O), light odd-Z elements (Na, Al), α-elements (Mg, Si, Ca, Ti), Fe-group elements (Cr, Fe, Ni), and n-capture elements (Y, Zr, La, Ce, Nd) for each star, where abundances of light species were derived using spectral synthesis technique. By applying isochrones to NGC 2345 photometry, comparing the color-magnitude, as well as information of the elements sensitive to dredge-up events, we suggest that the 5 observed red giants can be red-clump stars. In addition, the metallicity we obtained for the open cluster target is [Fe/H] = −0.33 ± 0.05 and is in good agreement with recent studies on clusters in the Milky Way, although atypical for its galactic latitude (b = −02°31).

Resumo. Apresentamos os resultados das abundâncias elementares de cinco gigantes do jovem aglomerado aberto NGC 2345. Os parâmetros atmosféricos das gigantes estudadas e suas abundâncias químicas foram determinados usando dados de espectroscopia de alta resolução na região ótico, obtida com o espectrógrafo FEROS, anexado ao telescópio de 2.2 m no ESO, Chile. Neste estudo, nós determinamos as abundâncias dos elementos leves (Li, C, N, O), elementos leves de número atômico par (Na, Al), elementos-α (Mg, Si, Ca, Ti), elementos do grupo do ferro (Cr, Fe, Ni) e elementos produzidos na captura de nêutrons (Y, Zr, La, Ce, Nd) para cada estrela, onde a abundância das espécies leves foram derivadas usando a técnica de síntese espectral. Aplicando isócronas à fotometria de NGC 2345, comparando a relação cor-magnitude, bem como a informação dos elementos sensíveis aos eventos de dragagem, nós sugerimos que as cinco gigantes vermelhas observadas podem ser estrelas do red-clump. Ademais, a metalicidade que nós obtivemos para o aglomerado alvo é [Fe/H] = −0.33 ± 0.05 e está em boa concordância com um recente estudo sobre os aglomerados da Via Láctea, apesar de atípica para sua latitude galactica (b = −02°31).

Keywords. Galaxy: open clusters and associations: individual: NGC 2345 – stars: abundances – stars: fundamental parameters

1. Introduction

In stellar open clusters we assume that all the stars are formed in the same interstellar cloud and are generated at the same time, therefore with the same age, at the same distance, and with similar chemical composition, making them excellent objects for the study of stellar and Galactic evolution (Friel 1995; da Silveira et al. 2018). In this context, young open clusters are excellent indicators of spiral structure and are helpful tools to investigation recent star formation in Milky Way, because they are indicators of the variations in the abundance of heavy chemical elements in the Galactic disk (Lada & Lada 2003). Said that we focused the chemical analysis on the young open cluster NGC 2345, located in Canis Majoris, that contains the presence of five K-type red giants, which we dispose of spectra.

2. Methods

Spectroscopy observation was carried out during runs on March 11th, 2016, and have been made using FEROS spectrograph (Fiber-fed Extended Range Optical Spectrograph; Kaufer et al. 1999) at the 2.2 m European Southern Observatory (ESO) Telescope in La Silla, Chile. The exposure time of our spectra were 1 200–2 400 s. The model atmospheres for our giants were employed by interpolation within Kurucz (1993) grid. In this case, it is considered local thermodymamical equilibrium plane-parallel atmospheric models. After that, we implemented the spectral analysis code MOOG (Sneden 1973) for the determination of stellar atmospheric parameters and stellar abundances.

Table 1. Main parameters of NGC 2345.

Parameter	Value	Reference
ℓ	226°58	—
b	−02°31	—
$E(B-V)$	0.616	Dias et al. (2002)
d (kpc)	2.251	Kharchenko et al. (2005)
R_{GC} (kpc)	9.64	This Work
log t (Gyr)	7.9±0.1	This work
$M_{turn-off}$ ($M_{\odot}$)	5.40±0.15	This work
[Fe/H] (dex)	−0.33 ± 0.05	This work

Equivalent width measurements and spectral synthesis techniques were employed to derive the chemical abundances of light elements (Li, C, N, O), light odd-Z elements (Na, Al), α-elements (Mg, Si, Ca, Ti), Fe-group elements (Cr, Fe, Ni), and n-capture elements (Y, Zr, La, Ce, Nd). The lists and procedures are related to other works, e.g., Santrich et al. (2013) and da Silveira et al. (2018). But, exceptionally for Fe I and Fe II, we have adopted the line list by Hekker & Meléndez (2007).

3. Discussion and conclusions

Tab. 1 shows the main parameters adopted and found about the open cluster in question. We implemented the UBV photometry

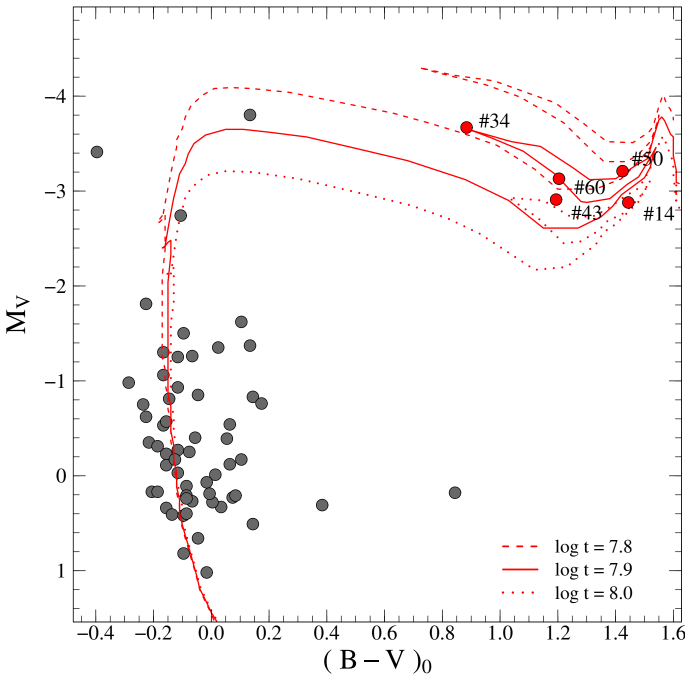

Figure 1. Color-magnitude diagram of NGC 2345 (photometric data taken from Moffat 1974). Our program stars are identified by red circles. We show isochrones (Bertelli et al. 1994) for three different ages: 63.09 Myr (*log t* = 7.8), 79.43 Myr (*log t* = 7.9) and 100 Myr (*log t* = 8.0).

of Moffat (1974), downloading it from the WEBDA database[1]. Once we have done this, we employed the isochrone fitting method to determine the age of NGC 2345 as shown in Fig. 1. We used a color excess of $E(B-V) = 0.616$ (Dias et al. 2002). Finally, was found log $t = 7.90$ for NGC 2345, which is in good agreement with log $t = 7.85$ reported by Dias et al. (2002). In this Figure, we highlight our spectra program in red dots, and stars are marked according to ID provided Moffat (1974).

Another young open cluster is NGC 3114 (Santrich et al. 2013), which analysis was performed with a similar methodology to ours, present log $t = 8.2$ and [Fe/H] = −0.01. Fig. 2 shows the comparison of detailed abundances between the young open clusters NGC 2345 and NGC 3114. The abundance pattern observed for the light elements is typical of giants that have already suffered the first dredge-up (e.g., a decrease of Li[2] and C and an increase of N). This fact can also be inferred by the position of the objects in the color-magnitude diagram, being evolved stars (Fig. 1). Besides, it is also possible to verify the enrichment of Na, according to the values predicted by the standard mixing model by Lagarde et al. (2012). Furthermore, we see more s-process[3] is righer than older open clusters, a fact that is common to young open clusters (Maiorca et al. 2011). This fact is due to the release of neutrons through the $^{13}C(\alpha, n)^{16}O$ reaction which occurs mainly in low-mass AGB stars ($M < 1.5\,M_\odot$). Maiorca et al. (2012) denote the chemistry importance theses low-mass objects in the subsequent formation of stars with enhancement of s-process elements.

From the point of view of iron abundance, NGC 2345 has a low metallicity relative to other young open clusters and even

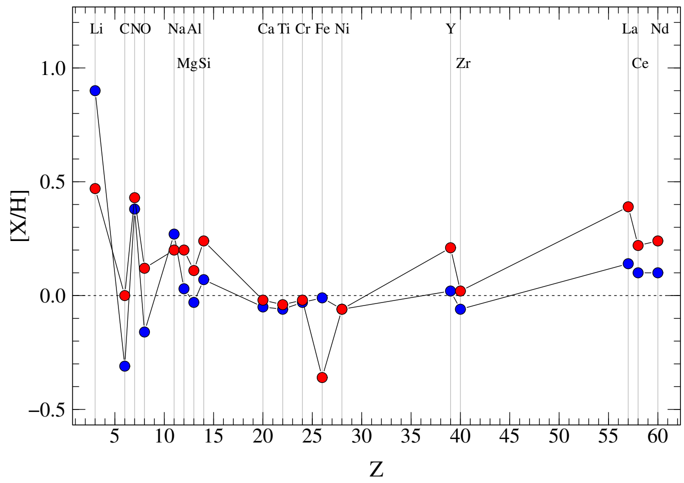

Figure 2. Comparison of detailed chemical abundances between the young open clusters NGC 2345 (red) and NGC 3114 (blue; Santrich et al. 2013).

to the Galactic center. For a projected Galactocentric distance[4] of 9.64 kpc, NGC 2345 is well below to the typical value of [Fe/H] = −0.10.

Another pertinent comparison to be done is based on the result of [Fe/H] = −0.26 found by Reddy et al. (2016) for NGC 2345. However, Reddy and colleagues used another list of lines and only three red giants (#34, #43, #60). It is worth noting that the list of lines adopted by us is appropriate for the study of cold objects since it selected regions were iron lines do not suffer from blending with molecular bands common see in cold giant spectra (Santos et al. 2009).

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References

Bertelli, G., Bressan, A., Chiosi, C., Fagotto, F., Nasi, E. 1994, A&A Supplement Series, 106
da Silveira, M., Pereira, C. B., Drake, N., 2018, MNRAS, 476, 4907
Dias, W., Alessi, B., Moitinho, A., Lépine, J., 2002, A&A, 389, 871
Friel, E., 1995, Annual Review of A&A, 33, 381
Hekker, S., Meléndez, J. 2007, A&A, 475, 1003
Heiter, U., Soubiran, C., Netopil, M., Paunzen, E. 2014, A&A, 561, A93
Lada, C. J., Lada, E. A., 2003, Annual Review of A&A, 41, 57
Lagarde, N., Decressin, T., Charbonnel, C., Eggenberger, P., Ekstrom, S., Palacios, A., 2012, A&A, 543, A108
Kaufer, A., Stahl, O., Tubbesing, S., Nørregaard, P., Avila, G., Francois, P., Pasquini, L., Pizzella A., 1999, The Messenger, 95, 8
Kharchenko, N. V., Piskunov, A. E., Roeser, S., Schilbach, E., Scholz, R.-D., 2005, A&A, 438, 1163–1173
Kurucz R.-L., 1993, Kurucz CD-Rom
Maiorca, E., Randich, S., Busso, M., Magrini, L., Palmerini, S., 2011, ApJ, 736, 120
Maiorca, E., Magrini, L., Busso, M., Randich, S., Palmerini, S., Trippella, O., 2012, ApJ, 747, 53
Moffat, A., 1974, A&A Supplement Series, 16, 33
Reddy, A. B., Lambert, D. L., Giridhar, S. 2016, MNRAS, 463, 4366
Santos, N., Lovis, C., Pace, G., Melendez, J., Naef, D. 2009, A&A, 493, 309
Santrich, O. K., Pereira, C. B., Drake, N. 2013, A&A, 554, A2
Sneden, 1973, Ph.D Thesis. Univ. of Texas

[1] Available on: http://webda.physics.muni.cz/
[2] Lithium abundance is given by: $\log \epsilon(\mathrm{Li}) = \log N_{Li}/N_H + 12.0$
[3] By definition: $[s/Fe] = \frac{1}{5}([Y/Fe]+[Zr/Fe]+[La/Fe]+[Ce/Fe]+[Nd/Fe])$
[4] Obtained by the formula: $R_{GC} = [R_\odot^2 + (d \cos b)^2 - 2 R_\odot d \cos l \cos b]^{\frac{1}{2}}$, for a Galactocentric distance of the Sun of 7.95 kpc