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Collinder 261: Abundances in an Old Disk Cluster

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Abstract

We present an analysis of high-dispersion echelle spectra of four giants in the 8 Gyr open cluster Collinder 261. Abundances were determined relative to the disk giant Arcturus. Cr 261 is found to be very slightly metal-deficient, with mean [Fe/H] = -0.22 ± 0.05 (m.e.). Oxygen abundances, determined from the forbidden [OI] lines show roughly solar or slightly depleted abundance ratios. The α-elements Mg, Ca, Si, and Ti also show scaled solar abundance ratios, with suggestions that the Si abundance is slightly enhanced. The odd-Z elements Na and Al are significantly enhanced relative to scaled solar abundances. The abundance results for Cr 261 are compared to those from high-dispersion studies of other old open clusters in the literature, which overall show similar behavior. None of the abundance ratios show trends with overall cluster [Fe/H] or with cluster age.

1.1 Introduction

The open clusters of the Milky Way serve as excellent probes of the structure and evolution of the Galactic disk. They have been used to trace abundance gradients and to look for evolution in gradients and mean abundances over time. Most of this work has been done with photometrically determined metallicities, or abundances from low resolution spectroscopy. There have been relatively few detailed abundance analyses for open clusters that allow a look at their nucleosynthetic history, and a comparison, for example, with the field or other cluster populations.

We have begun a study of abundances in red giants in the oldest of the open clusters from high resolution data, to refine the Fe abundances and to provide determinations of the light elements, in particular of oxygen and the α-elements. Here we present the results for 4 giants observed in Cr 261, the oldest of the southern open clusters known. It is a rich cluster located at l = 302^o and b = -5.6^o, 7.5 kpc from the Galactic center and 325 pc below the plane. Age estimates for Cr 261 range from 7 to 10 Gyr (Janes & Phelps 1994; Gozzoli et al. 1996).

1.2 Analysis

Data were taken with the CTIO 4-meter echelle and reduced following standard procedures with IRAF. Equivalent widths were measured using the interactive routines in IRAF. The abundance analysis was done with MOOG (Sneden 1973), using MARCS model atmospheres.

Preliminary stellar parameters T_{eff} and log g were obtained from BV and VI photometry

Table 1.1. *Parameters for Cr 261 stars*

Star	T_{eff}	log g	v_t	[Fe/H]
Cr261 1045	4400	1.5	1.2	-0.16 ± 0.03
Cr261 1080	4490	2.2	1.2	-0.11 ± 0.04
Cr261 1871	4000	0.7	1.5	-0.31 ± 0.04
Cr261 2105	4300	1.5	1.5	-0.32 ± 0.03

Table 1.2. *Mean Cluster Abundances for Cr 261*

Element	[X/H]	σ	[X/Fe]	σ
Fe I	–0.22	0.11		
Fe II	–0.21	0.10		
Na I	+0.26	0.19	+0.48	0.22
Mg I	–0.15	0.05	+0.07	0.12
Al I	+0.09	0.24	+0.31	0.22
Si I	+0.00	0.05	+0.22	0.09
Ca I	–0.26	0.17	–0.04	0.10
Ti I	–0.31	0.20	–0.07	0.09
Ti II	–0.30	0.13	–0.06	0.01
Cr I	–0.43	0.16	–0.19	0.13
Ni I	–0.20	0.10	+0.02	0.04
O I	–0.4	0.1	–0.2	0.1

(Phelps et al. 1994; Gozzoli et al. 1996); these were revised based on the spectroscopic analysis. T_{eff}, log g, and microturbulent velocity were adjusted to remove dependences on excitation potential, equivalent width, and ionization state. Final adopted values for the four Cr 261 stars are given in Table 1.1 (identifications are from Phelps et al. 1994).

The abundance analysis was done by reference to Arcturus, adopting the atmospheric parameters and abundances from Peterson et al. (1993). Initial line lists were adopted from Fulbright (2000) and Balachandran (private comm). Lines were measured from the Arcturus atlas (Hinkle et al. 2000), and gf-values were adjusted to yield the Peterson et al. abundances. Oxygen abundances were determined from spectral synthesis of the [OI] lines 6300A and 6360A.

1.3 Results

Abundances of Fe, Na, Al, the α-elements Mg, Si, Ca, and Ti, and several heavier elements were determined for each of the Cr 261 giants. Average cluster values and the rms standard deviations are given in Table 1.2.

We find the average cluster iron abundance of [Fe/H] = -0.22 ± 0.05 (error in the mean), a value similar to that found from the low resolution spectroscopy of Friel et al. (2002). We find excellent agreement in the determinations of oxygen among the four Cr 261 stars, with

Table 1.3. *Abundances in Old Open Clusters*

Cluster	R_{gc}	Age	[Fe/H]	[O/Fe]	[α/Fe]	[Mg/Fe]	[Na/Fe]	[Al/Fe]	# Stars
NGC 2360[1]	9.3	1	+0.07	−0.1	0.03	0.0	+0.10	....	4
NGC 2112[2]	9.2	2	−0.1	0.0	−0.05	+0.06	+0.08	+0.29	2
NGC 2420[3]	10.6	2	−0.47	....	+0.06	....	....	....	4
NGC 6819[4]	8.2	3	+0.09	....	0.00	−0.12	+0.47	−0.07	3
To 2[2]	13.1	3	−0.4	−0.2	+0.06	+0.13	−0.25	+0.17	3
M 67[5]	9.1	4	−0.03	0.0	+0.07	+0.10	+0.19	+0.14	9
Melotte 66[6]	10.2	4	−0.38	+0.3	+0.08	+0.04	+0.12	+0.25	2
NGC 2243[6]	10.7	5	−0.48	+0.03	+0.08	+0.02	+0.08	+0.08	2
Cr 261[7]	7.5	8	−0.2	−0.2	+0.04	+0.07	+0.48	+0.31	4
NGC 6791[8]	8.1	9	+0.4	0.0	+0.1	+0.2	+0.4	0.0	1
Arcturus[9]	....	....	−0.5	+0.4	+0.4	+0.4	+0.3	+0.4	1
Disk Field[10]	....	....	−0.2	0.0	0.0	+0.1	0.0	+0.05	...

[1]Hamdani et al. 2000, A&A, 360, 509; [2]Brown et al. 1996, AJ, 112, 1551; [3]Smith & Suntzeff 1987, AJ, 92, 359; [4]Bragaglia et al. 2001, AJ, 121, 327; [5]Tautvaisiene et al. 2000, A&A, 360, 499; [6]Gratton & Contarini 1994, A&A, 283, 911; [7]This study; [8]Peterson & Green 1998, ApJ, L502, 39; [9]Peterson et al. 1993, ApJ, 404, 333; [10]Edvardsson et al. 1993, A&A, 275, 101

values close to the solar ratio or slightly depleted, at [O/Fe] = −0.1 to −0.2. Although the four giants span a significant range in evolutionary state, they appear to share a common abundance unaffected by mixing processes.

The α-elements, on average, show scaled solar abundances, with [α/Fe] = $+0.03 \pm 0.06$ (m.e.). Only Si shows any evidence of being slightly enhanced.

Sodium and aluminum, on the other hand, show significant enhancement over the solar ratios, with cluster averages of [Na/Fe] = $+0.48 \pm 0.22$ and [Al/Fe] = $+0.31 \pm 0.22$. They also show a higher degree of star-to-star scatter which is expected to some extent through the sensitivity of these lines to errors in the atmospheric parameters, the relatively few lines of Na and Al measured, and the difficulty of measuring some of the more blended Al lines. Both elements are also susceptible to non-LTE effects, though those are expected to be small for stars of this metallicity and temperature (Gratton et al. 1999).

1.4 Discussion

These results for Cr 261 are generally consistent with those for other old open clusters. In Table 1.3, we have collected the results of abundance determinations in the literature for open clusters with ages greater than about 1 Gyr, as well as those for Arcturus and the field stars of Edvardsson et al. (1993). The sample of old open clusters with abundance analyses from high resolution data is limited, and one must always be cautious in interpreting results combined from many different studies. It is nevertheless interesting to begin to look at dependences among the cluster population, particularly by comparison to the field stars, for suggestions in differences in nucleosynthetic history.

Figures 1 and 2 show that although these clusters cover a range of 9 Gyr in age and almost 1 dex in [Fe/H] they show quite uniform behavior in abundance ratios. Figure 1 plots the

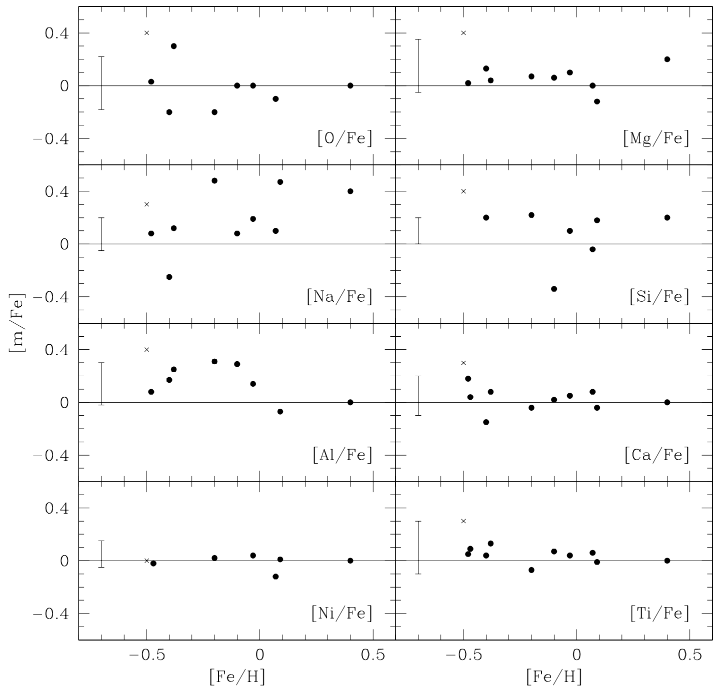

Fig. 1.1. Filled circles are mean open cluster values from Table 1.3; Arcturus is indicated with an 'x'; vertical line denotes the range of abundances of field stars from Edvardsson et al. 1993.

mean cluster abundance ratios in O, Na, Al, Ni, and the α-elements against mean cluster [Fe/H]. Similarly, Figure 2 shows the behavior of [O/Fe], [α/Fe], [Na/Fe], and [Al/Fe] with cluster age and galactocentric radius.

The open clusters show roughly scaled solar or slightly lower ratios of [O/Fe]. Even the oldest clusters NGC 6791 and Cr 261, at 8 to 9 Gyr, do not display the signature of oxygen enrichment due to the early production by massive stars, and must have formed from material that had been enriched by the products of the longer-lived Type Ia supernovae. Consistent with this, they show remarkably constant, scaled solar abundance ratios of the α-elements.

However, the enhancement in Na and Al seen in Cr 261 is also found in other open clusters. Both NGC 6791 and NGC 6819 show high [Na/Fe], with values of +0.4 to +0.5. Several other clusters show more modestly enhanced [Al/Fe] values. These values for Na are in excess of the range exhibited among the field stars of samples like Edvardsson et al. (1993), or Feltzing & Gustafsson (1998) and Chen et al (2000) and suggest that additional sources of Na and perhaps Al contributed to the ISM in the regions where these clusters were formed. The complexity of possible nucleosynthetic sites for Na and Al over the range of ages and distances sampled by these clusters, in combination with the uncertainty introduced by possible non-LTE effects, suggests that we wait for a larger sample of cluster abundances before drawing any conclusions about the behavior of Na and Al.

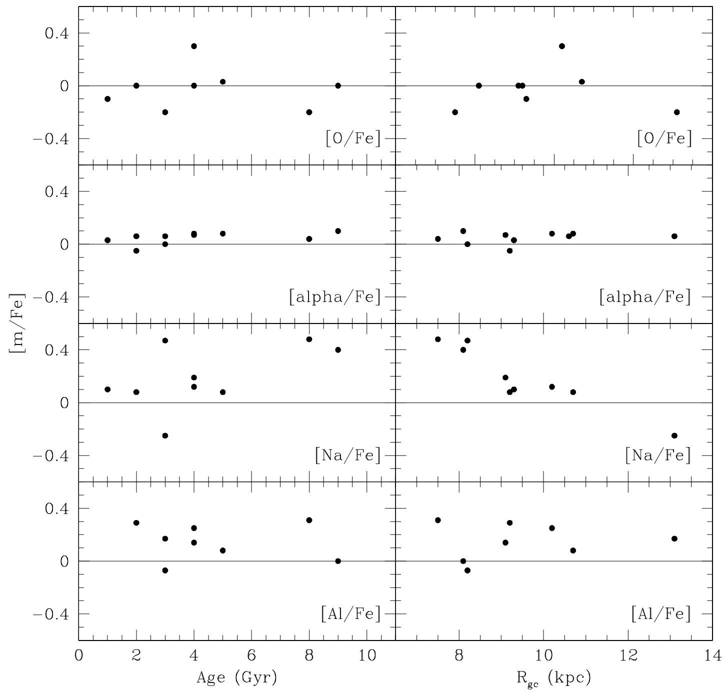

Fig. 1.2. Filled circles are mean open cluster values from Table 1.3.

1.5 Acknowledgements

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