CNO in the Universe
ASP Conference Series, Vol. 304, 2003
C. Charbonnel, D. Schaerer & G. Meynet, eds.

Abundances and Kinematics of Extremely Metal-Deficient, Carbon-Rich Halo Stars

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Abstract. To study the possible nucleosynthetic backgrounds of extremely metal-deficient, carbon-rich (EMDC) stars, we have conducted high-resolution spectroscopy of 26 candidate objects selected from HK-survey stars with [Fe/H] ≤ -2.0. The aims of the analysis are: (a) to calculate abundances for the targets, including the CNO- and neutron-capture elements; (b) to monitor the radial velocities of the survey targets and another 17 bona fide EMDC stars to search for binarity.

1. Introduction

Extremely metal-deficient ([Fe/H] ≤ -2), carbon-rich (EMDC) stars are Pop. II, field halo objects possessing overabundant carbon. Up to 20−25% of very metal-poor stars exhibit carbon excesses, which grow with decreasing metallicity (Rossi, Beers & Sneden 1999). Since in stars with [Fe/H] > -2.0, carbon traces the iron abundance, the discovery of C-rich stars is surprising at lower metallicity; Galactic chemical evolution models (e.g., Timmes, Woosley & Weaver 1995) do not predict efficient early production of carbon.

A variety of abundance patterns is exhibited by EMDC stars. For example, CS 22892−052 is C-rich and also exhibits an enhanced solar r-process pattern for elements Z $\geq$ 56 (Sneden et al. 1994), whereas some equally carbon-rich stars exhibit no neutron-capture excesses at all (Aoki et al. 2002a). Furthermore, the r-process pattern is at present unique to CS 22892−052 among EMDC stars; all other n-capture-rich EMDC objects exhibit an s-process pattern. In addition, while McClure's (1984) C-rich stars are members of binary systems, several EMDC stars exhibit no variation in their heliocentric radial velocity (e.g., LP 706−7; Norris, Ryan & Beers 1997).

In order to explore the origin of EMDC stars, we have obtained high-resolution spectra of 26 candidate objects from the HK survey (Beers, Preston & Shectman 1992, 1985) and have begun to monitor the radial velocities of another 17 EMDC stars. Thus, we expect to be able to test two theories for the origins of EMDC stars: the self-mixing hypothesis (a possible candidate for some of the

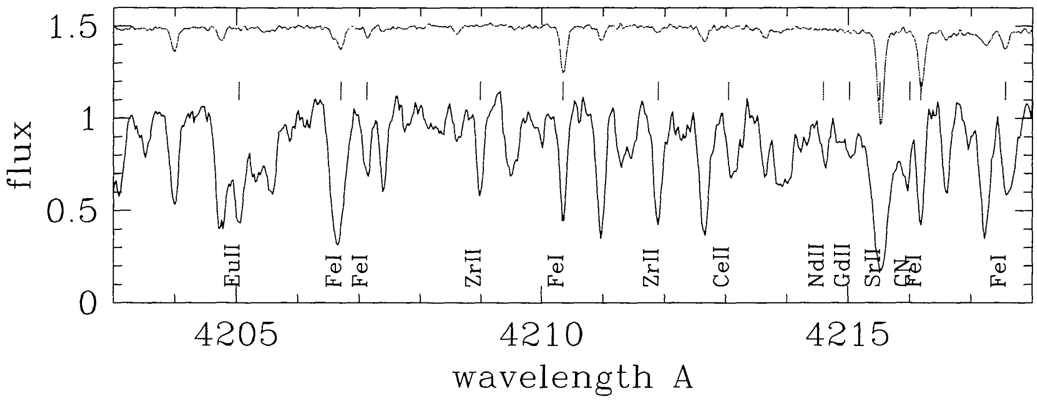

Figure 1. Neutron-capture-rich region $\lambda\lambda = 4203 - 4218$ Å in the spectrum of a candidate EMDC star compared with HD 140283. HD 140283 has been shifted by +0.5.

single objects) and the binary mass-transfer scenario (popular in explaining the halo CH stars).

2. Observations and Results

Over the period August 2001 – July 2002, four observing runs were allocated on the WHT with UES (spectral coverage $\lambda\lambda \simeq 3600 - 5800$ Å), and one on the TNG using SARG ($\lambda\lambda \simeq 3600 - 5140$ Å). For stars for which abundance data were sought, we obtained S/N ~ 40, with $\lambda/\Delta\lambda \simeq 55000$. Lower S/N ($\sim$ 10–15) was obtained for radial velocity measurements only.

Here we report on our August 2001 run. We observed 15 candidate EMDC stars at high S/N and another 10 stars for radial velocities. Thirteen of our targets appear to be genuine EMDC stars from preliminary inspection of their spectra. Figure 1 compares one such spectrum to that of the 'normal' metal-poor star HD 140283. Although abundances have not yet been calculated, it is obvious that some of our program stars exhibit strong n-capture-element lines.

Heliocentric radial velocities (HRV's) were computed by cross-correlation with the spectrum of HD 140283. The velocity of HD 140283 was found by measuring the wavelengths of 357 unblended lines. Table 1 shows the computed HRV's (middle column). SE in Table 1 is the standard error of the procedure computed by adding in quadrature the: (a) variation between matching pairs of absorption lines in the comparison of HD 140283 with the sun; (b) deviation of pairs of spectral orders in the cross-correlation. A preliminary comparison between this work and Ryan, Norris & Beers (1999) on the velocity of HD 140283 shows this star's HRV to be in good agreement with literature values.

Most of our August 2001 EMDC candidates are interesting objects: some exhibit strong excesses of carbon and the n-capture elements and at least two are binaries. One of the two confirmed binaries, CS 29526–110, is rich in s-process elements in addition to carbon (Aoki et al. 2002b). This star is likely to have received its enhanced material from a metal-poor AGB companion which is now extinct.

Table 1. Computed heliocentric radial velocities (HRV) and standard errors (SE), both in kms^{-1}, for the 2001 August targets: HD 140283, 24 candidate EMDC stars and 10 bona fide EMDC stars.

Star	HRV	SE	Star	HRV	SE
HD 140283	−170.93	0.03	CS 29502−092	−67.66	0.06
CS 22898−027	−48.54	0.11	CS 29503−010	−24.59	0.05
CS 22183−015	−68.44	0.12	CS 31070−073	−111.74	0.16
CS 22887−048	−120.54	0.07	CS 22171−009	−31.15	0.15
CS 29512−073	−75.83	0.11	CS 22174−007	−71.38	0.15
BS 17436−058	6.12	0.10	CS 22949−008	−153.25	0.16
BS 16080−175	−253.42	0.09	BS 16090−048	−7.07	0.06
BS 17451−031	−13.95	0.08	HD 24289	151.01	0.05
CS 30306−132	−109.46	0.07	LP 625−44	27.93	0.12
CS 30312−100	−123.92	0.05	CS 30301−015	85.53	0.12
CS 31082−001	138.19	0.08	LP 706−7	79.35	0.15
CS 29526−110	201.70	0.26	CS 31086−024	111.76	0.22
CS 29528−028	58.89	0.33			

Spectra taken during the other four runs will be reduced in the near-future, and HRV's and abundances will be calculated. Thus, we expect to be in a position to test the two popular theories for the origins of this class of objects (self-mixing and binary mass transfer) against our large sample of EMDC stars.

ST and SGR wish to thank the staff of the Observatorio del Roque de los Muchachos (especially the WHT) for their assistance with observations. ST is grateful to Universities UK for an Overseas Research Student Award (ORS/2001031002).

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