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CH stars at High Galactic Latitudes

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ABSTRACT

Carbon-rich stars of population II, such as CH stars, can provide direct information on the role of low to intermediate-mass stars of the halo on the early Galactic evolution. Thus an accurate knowledge of CH stellar population is a critical requirement for building up scenarios for early Galactic chemical evolution. In the present work we report on several CH stars identified in a sample of Faint High Latitude Carbon stars from Hamburg survey and discuss their medium resolution spectra covering a wavelength range 4000 - 6800 Å . Estimation of the depths of bands (1,0) $^{12}C^{12}C$ $\lambda4737$ and (1,0) $^{12}C^{13}C$ $\lambda4744$ in these stars indicate isotopic ratio $^{12}C/^{13}C \sim 3$, except for a few exceptions; these ratios are consistent with existing theories of CH stars evolution. The stars of Hamburg survey, a total of 403 objects were reported to be carbon star candidates with strong C_2 and CN molecular bands. In the first phase of observation, we have acquired spectra of ninety one objects. Inspection of the objects spectra show fifty one objects with C_2 molecular bands in their spectra of which thirteen stars have low flux below about 4300 Å . Twenty five objects show weak or moderate CH and CN bands , twelve objects show weak but detectable CH bands in their spectra and there are three objects which do not show any molecular bands due to C_2, CN or CH in their spectra. Objects with C_2 molecular bands and with good signals bluewards of 4300 Å which show prominent CH bands in their spectra are potential candidate CH stars. Thirty five such candidates are found in the present sample of ninty one objects observed so far. The set of CH stars identified could be the targets of subsequent observation at high resolution for a detail and comprehensive analysis for understanding their role in early Galactic chemical evolution.

Key words: stars: CH stars - variable: carbon - stars: spectral characteristics - stars: AGB - stars: population II

1 INTRODUCTION

Knowledge of stellar population offers a fossil record of formation and evolution of galaxies and thus provide strong constraints on the scenarios of the Galaxy formation and evolution. Carbon stars, for instance, were thought to be giants without exceptions and sought as tracers of the outer halo. Recent surveys on stellar populations have led to the discovery of different types of stars, numerous metal-poor stars, carbon and carbon-related objects etc. (Beers et al. 1992, Totten and Irwin 1998, Beers 1999). One of the results of these efforts is the great discovery that the fraction of carbon-rich stars increases with decreasing metallicity (Rossi, Beers and Sneden 1999). Extensive analysis of many carbon-enhanced metal-poor stars at high resolution (Norris et al. 1997a, 1997b, 2002, Bonifacio et al. 1998, Hill et al. 2000, Aoki et al. 2002b) have revealed many more intriguing results; however, the specific trend of increase in carbon-enhanced stars with decreasing metallicity still remains unexplained. Also, the production mechanisms of carbon in these stars still remain unknown. There are different types of carbon-enhanced stars; (i) stars showing carbon enhancement with *s*-process element enhancement, (ii) carbon enhancement with *r*-process element enhancement and (iii) carbon enhancement with normal *n*-capture element abundances. There is yet another type of very metal-poor stars with strong *s*-process enhancement but only slightly carbon-enhanced ([C/Fe] = +0.2; Hill et al. 2002). Certainly a single well defined production mechanism is unlikely to lead to such a diversity in abundances. To shed light on the production mechanisms of carbon-excess resulting in different types of carbon-enhanced stars and to understand the nucleosynthesis of *s*-process, and *r*-process elements at low metallicity it is desirable to conduct analysis of as many different types of C-enhanced stars as possible.

Christlieb et al. (2001) reported a sample of 403 Faint

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High Latitude Carbon (FHLC) stars identified by means of line indices - i.e. ratios of the mean photographic densities in the carbon molecular absorption features and the continuum band passes, which were the basis for the Hamburg catalog of high Galactic latitude carbon stars. The identification was primarily based on the presence of strong C_2 and CN molecular bands shortward of 5200 Å; it did not consider CH bands. At high galactic latitudes, although the surface density of FHLC stars is low, different kinds of carbon stars are known to populate the region (Green et al. 1994). One kind is the normal asymptotic giant-branch (AGB) stars, carbon-enriched by dredge-up during post-main-sequence phase which are found among the N-type carbon stars. Another kind is the FHLC stars showing significant proper motions and having luminosities of main- sequence dwarf called dwarf carbon stars (dCs). A third kind of FHLC stars is the so-called CH-giant stars, similar to the metal-poor carbon stars found in Globular clusters and some in dwarf spheroidal (d Sph) galaxies (Harding 1962). Among these, at high galactic latitudes warm carbon stars possibly some C-R stars are also likely to be present. The sample of stars offerred by Christlieb et al. (2001) being high latitude objects, with smaller initial mass and possible lower metallicity is likely to contain a mixture of these objects. Different kinds of objects have different astrophysical implications and hence it is important to distinguish them from one another, although in certain cases it is not easy to do so. For example, dCs are difficult to distinguish from C-giants as they exhibit remarkable similarity in their spectra with those of C-giants. They are however distinguishable through their relatively high proper motion and apparently anomalous JHK infrared colours (Green et al. 1992).

Interpretation of chemical compositions of the intermediate-mass stars formed from the interstellar matter is not straight forward as the interstellar matter is already affected by the ejecta of many generations of more massive stars. In comparison, the halo red giant stars offer more direct information on the role of intermediate-mass stars of the halo. Thus, existance of CH stellar component has important astrophysical implications for Galactic chemical evolution. The processes responsible for carbon excess in these stars to a large extent are responsible for the origin and evolution of carbon, nitrogen and heavy elements in the early Galaxy. Furthermore, isotopic ratios of $^{12}C/^{13}C$ in C and C-related stars provide useful probes of nucleosynthesis processes and their location leading to carbon excess in these stars. To determine these ratios useful candidates are those with strong isotopic carbon bands in their spectra; CH stars provide an useful set of candidates.

Determination of the chemical compositions as well as carbon isotopic ratios $^{12}C/^{13}C$ would require high resolution spectroscopy. But before this, a target list of CH stars needs to be generated and this can be done from spectral analysis of stars using even low resolution spectroscopy. Prompted by this we have undertaken to identify the CH as well as other types of stellar objects in the sample of FHLC stars of Christlieb et al. using low resolution spectroscopy. These identifications and the low resolution spectroscopic analysis of the candidate CH stars is the main theme of this paper.

Observations and data reductions are described in section 2. In section 3 we briefly discuss different types of C stars and their spectral characteristics. JHK photometry of the stars is briefly described in section 4. Description of the program stars spectra and results are drawn in section 5. Section 6 contains a brief discussion on the atmospheres of candidate CH stars. Concluding remarks are presented in section 7.

2 OBSERVATION AND DATA REDUCTION

The stars listed in Table 1 (51 stars) and Table 2 (40 stars) have been observed with 2-m Himalayan Chandra Telescope (HCT) at the Indian Astronomical Observatory (IAO), Mt. Saraswati, Digpa-ratsa Ri, Hanle during June 2003 - May 2004. Spectra of a number of carbon stars such as HD 182040, HD 26, HD 5223, HD 209621, Z PSc, V460 Cyg and RV Sct are also taken for comparison. A spectrum of C-R star HD 156074 taken from Barnbaum et al.'s (1996) atlas is also used for comparison. The spectrograph used is the Himalayan Faint Object Spectrograph Camera (HFOSC). HFOSC is an optical imager cum a spectrograph for conducting low and medium resolution grism spectroscopy (http://www.iiap.ernet.in/iao/iao.html). The grism and the camera combination used for observation provided a spectral resolution of $\sim 1330(\lambda/\delta\lambda)$; the observed bandpass ran from about 3800 to 6800 Å .

Observations of Th-Ar hollow cathod lamp taken immediately before and after the stellar exposures provided the wavelength calibration. The CCD data were reduced using the IRAF software spectroscopic reduction packages. For each object two spectra were taken each of 15 minutes exposures, the two spectra were combined to increase the signal-to-noise ratio. 2MASS JHK measurements for the stars in Table 1 are also listed. These measurements are available on-line at http://irsa.ipac.caltech.edu/ . In Table 2, the objects observed on 2nd and 3rd March, 2004 are acquired using OMR spectrograph at the cassegrain focus of the 2.3 m Vainu Bappu Telescope (VBT) at Kavalur. With a 600 lmm^{-1} grating, we get a dispersion of 2.6 Å per pixel. The spectra of these objects cover a wavelength range 4000 - 6100 Å, at a resolution of ~ 1000.

3 TYPES OF C STARS AND THEIR SPECTRAL CHARACTERISTICS

Carbon stars are classified into different spectral types based on their characteristic spectral properties. We briefly discuss here the main characteristics essential for our purpose. More detail discussion on this can be found in literature including Wallerstein (1998) and references therein. Among the carbon stars, the C-N stars have lower temperatures and stronger molecular bands than those of C-R stars. C-N stars exhibit very strong depression of light in the violet part of the spectrum. They are used as tracers of an intermediate age population in extragalactic objects. The C-R stars as well as CH stars have warmer temperatures and blue/violet light is accessible to observation and atmospheric analysis. C-N stars are easily detected in infrared surveys from their characteristic infrared colours. The majority of C-N stars show ratios of $^{12}C/^{13}C$ more than 30, ranging nearly to 100 while in C-R stars this ratio ranges from 4 to 9. The strength/weakness of CH band in C-rich stars provides a measure of the degree of hydrogen deficiency in carbon stars.

The characteristic behaviour of *s*-process elements in C-stars can also be used as an useful indicator of spectral type. The s-process element abundances are nearly solar in C-R stars (Dominy 1984); whereas most of the carbon and carbon related stars show significantly enhanced abundances of the s-process elements relative to iron (Lambert et al. 1986, Green and Margon 1994).

CH stars are characterised by strong G-band of CH in their spectra. These stars are not a homogeneous group of stars. They consist of two populations, the most metal-poor ones have a spherical distribution and the ones slightly richer in metals are characterised by a flattened ellipsoidal distribution (Zinn 1985). These stars form a group of warm stars of equivalent spectral types G and K giants, but show weak metallic lines. The ratio of the local density of CH stars is as high as 30% of metal-poor giants (Hartwick & Cowley 1985); and being the most populous type of halo carbon stars known, are important objects for our understanding of galactic chemical evolution, the evolution of low mass stars and nucleosynthesis in metal poor stars.

Most of the CH stars are known to be high velocity objects. 'CH-like' stars, where CH are less dominant have low space velocities Yamashita (1975). At low resolution to make a distinction between CH and C-R stars is difficult as many C-R stars also show quite strong CH band. In such cases secondary P-branch head near 4342 Å is used as a more useful indicator. Another important feature is the strength of Ca I at 4226 Å which in case of CH stars is weakened by the overlying faint bands of the CH band systems. In C-R star this feature is quite strong. These spectral characteristics allow for an identification of CH and C-R stars even at low resolution. Enhanced lines of s-process elements, weaker Fe group elements as well as various strengths of C_2 bands are some other distingushing spectral features of CH stars. However, at low dispersion the narrow lines are difficult to estimate and essentially do not provide with a strong clue to distinguish C-R stars from CH stars. Although CH and C-R stars have similar range of temperatures the distribution of CH stars place most of them in the Galactic halo, their large radial velocities , typically $\sim$ 200km s^{-1} are indicative of their being halo objects (McClure 1983, 1984).

The objects observed from Hanle are classified considering these spectral characteristics. In the following we discuss the medium resolution spectra of the objects listed in Table 1 with their photometric data.

4 JHK PHOTOMETRY

Infrared colours made from JHK photometry provide a supplementary diagnostics for stellar classification. Figure 1 is a two colour JHK diagram where J-H versus H-K colours of HE stars listed in Table 1 are plotted. The HE stars 2MASS JHK measurements are available on-line at http://iras.ipac.caltech.edu/.

The two boxes superimposed in the figure representing the location of CH stars (thick line solid box) and the C-N stars (thin line solid box) illustrate the loci of the separate carbon-star types and are taken from Totten et al. (2000). In this figure, the CH stars classified by us (following our discussions in the subsequent sections), plotted with open circles fall well within the CH box, except the three outliers HE 1429-0551, HE 2218+0127 and HE 0457-1805. These three stars are represented by solid circles. The spectral characteristics of these stars led us to classify them as CH stars. Their spectra do not show any peculiarities from which their location in the J-H, H-K plane seems obvious. A difference between the spectra of the first two stars lies in molecular C_2 bands in the spectral region 5700 - 6800 Å . In this region HE 1429-0551 does not show molecular C_2 bands (or could be marginally detected) whereas HE 2218+0127 shows molecular C_2 bands as strongly (or marginally stronger) as they are seen in CH star HD 5223. Ba II feature at 6496 Å is weak in HE 1429-0551. In HE 2218+0127, this feature appears to be of equal depth to its counterpart in HD 5223. HE 2218+0127 seems to be the warmest among the candidate CH stars (Table 3). HE 0457-1805, another CH star outside the CH box resembling HD 26, a known CH star, shows stronger CN molecular band around 4215 Å and slightly stronger features due to Ba II at 6496 Å and Na I D. H_α feature is marginally weaker but G-band of CH appears almost of equal strength. There are ten stars in the present sample which show spectral characteristics of C-N stars, they are represented by solid triangles. Four of them fall well within the C-N box, three of them just outside the C-N box and the rest two fall within the CH box. Stars HE 2319-1534 and HE 1008-0636 at the redder edge of the C-N box show H_α and H_β in emission whereas HE 2331-1329, HE 0915-0327 and HE 1254-1130 with lower H-K values do not show H_α and H_β features in their spectra. HE 1501-1500, HE 1228-0402 and HE 1107-2005 (inside the CH box) do not have flux below 4500 Å . CN molecular bands are weaker in HE 1228-0402 than their counterparts in other C-N stars. This is not the case with HE 1501-1500. H_α and H_β features are not detectable in these two stars. At present it remains to be understood why these two stars occupy a location among the CH stars in the J-H, H-K plane.

5 RESULTS

5.1 Spectral characteristics of the program stars

The spectra are examined in terms of the following spectral characteristics.
1. The strength (band depth) of CH band around 4300 Å .
2. Prominance of Secondary P-branch head near 4342 Å .
3. Strength/weakness of Ca I feature at 4226 Å .
4. Isotopic band depths of C_2 and CN, in particular the Swan bands of $^{12}C^{13}C$ and $^{13}C^{13}C$ near 4700 Å .
5. Strength of other C_2 bands in the 6000 -6200 Å region.
6. ^{13}CN band near 6360 Å and other CN bands across the wavelength range.
7. Strength of s-process element such as Ba II features at 4554 Å and 6496 Å .

To establish the membership of a star in a particular group we have conducted a differential analysis of the program stars spectra with the spectra of carbon stars available in the low resolution spectral atlas of carbon stars of Barnbaum et al. (1996). We have also acquired spectra for some of the objects from this Atlas and used them for comparison of spectra at the same resolution.

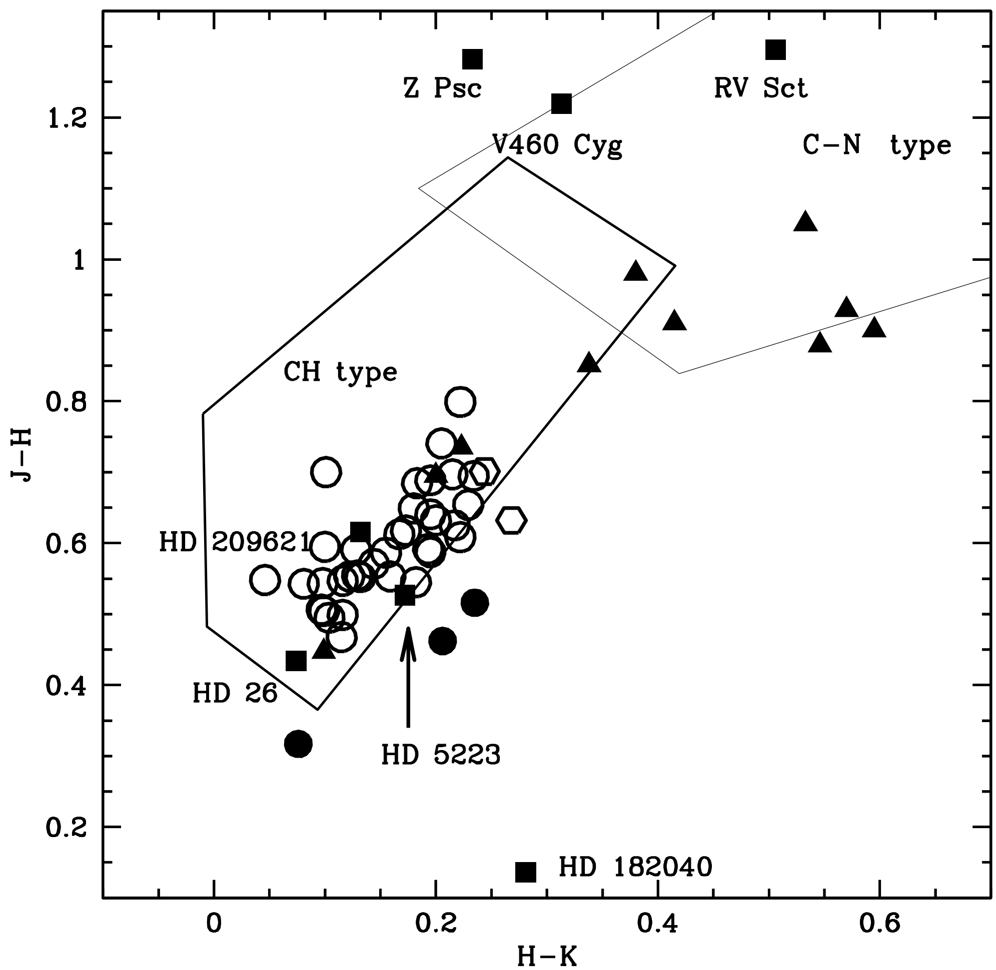

Figure 1. A two colour J-H versus H-K diagram of the stars listed in Table 1. The candidate CH stars are represented by open circles except the three outliers represented by solid circles. C-N stars are represented by solid triangles and C-R stars by open hexagon. The two boxes superimposed in the figure illustrate the loci of separate carbon-star types and are taken from Totten et al. (2000). The location of the comparison stars are labeled and maked with solid squares.

5.2 Candidate CH stars: Description of the spectra

At low resolution the spectra of C-R and CH stars look very similar and this makes distinction between them a difficult task. The differences are made apparent by making a comparison between spectra of known C-R and CH stars. Application of this comparison to the program stars helped in an easy identification of their spectral class. In figures 2 and 3 we show a comparison of the spectra of a pair of C-R stars HD 156074 and HD 76846 and a pair of CH stars HD209621 and HD 5223. Although we have considered here four stars, the comparison is generally true for any C-R and CH stars.

A comparison of known C-R and CH stars spectra

(i) Wavelength region 4000 - 5400 Å (Figure 2):
G-band of CH is strong in all the spectra, almost of equal strength. However, the secondary P-branch head around 4343 Å is distinctly seen in the CH stars spectra. In C-R stars spectra this feature is merged with contributions from molecular bands.

In C-R stars the Ca I at 4226 Å line depth is almost equal to the CN band depth at 4215 Å whereas in CH stars spectra this line is marginally noticed. CN band around 4215 Å is much deeper in C-R stars than in the CH stars.

Narrow atomic lines are blended with contributions from molecular bands and hence their real strength could not be estimated at this resolution. In the above wavelength range H_β and Ba II at 4554 Å are the two features clearly noticeable in the CH stars. In C-R star this region is a complex combination of atomic and molecular lines. There is no obvious distinction in the isotopic bands around 4700 Å in C-R and CH stars. C_2 molecular bands around 5165 Å and 5635 Å are two prominent features in this region.

(ii) Wavelength region 5400 -6800 Å (Figure 3)
C_2 molecular bands around 5635 Å is the most prominent feature in this region. This region too is a complex mixture of atomic and molecular lines. A blended feature of Na I D_1

Table 1: HE stars with prominent C_2 molecular bands

Star No.	RA(2000)[a]	DEC(2000)[a]	l	b	B_J^a	V^a	B-V[a]	U-B[a]	J	H	K	Dt of Obs
HE 0002+0053	00 05 25.0	+01 10 04	99.71	-59.61	14.5	13.3	1.72	1.25	11.018	10.386	10.118	06.11.04
HE 0017+0055	00 20 21.6	+01 12 07	106.90	-60.70	12.6				9.309	8.693	8.498	15.11.03
HE 0038-0024	00 40 48.2	-00 08 05	117.09	-62.89	15.4	14.4	1.86	1.67	12.433	11.768	11.573	06.11.04
HE 0043-2433	00 45 43.9	-24 16 48	98.33	-86.88	13.8	13.1	1.04	1.00	11.064	10.493	10.365	07.11.04
HE 0110-0406	01 12 37.1	-03 50 30	136.11	-66.17	13.4				10.523	9.988	9.866	17.9.03
HE 0111-1346	01 13 46.5	-13 30 49	145.01	-75.42	13.3				10.684	10.155	10.039	07.11.04
HE 0151-0341	01 53 43.3	-03 27 14	157.78	-62.04	14.6	13.4	1.27	0.87	11.847	11.364	11.248	07.11.04
HE 0207-0211	02 10 12.0	-01 57 39	163.12	-58.55	15.5	14.0	2.16	2.13	11.505	10.605	10.010	07.11.04
HE 0308-1612	03 10 27.1	-16 00 41	201.12	-55.96	12.5				10.027	9.475	9.331	17.9.03
HE 0310+0059	03 12 56.9	+01 11 10	178.95	-45.73	12.6				9.871	9.296	9.196	17.9.03
HE 0314-0143	03 17 22.2	-01 32 37	182.98	-46.69	12.7				8.993	8.222	8.000	17.9.03
HE 0319-0215	03 21 46.3	-02 04 34	184.58	-46.17	14.6	13.6	1.43	1.01	11.785	11.218	11.063	16.9.03
HE 0322-1504	03 24 40.1	-14 54 24	201.90	-52.39	15.0	13.8	1.63	1.24	12.105	11.533	11.340	06.11.04
HE 0429+0232	04 31 53.7	+02 39 01	192.72	-29.17	14.2	13.3	1.35	1.08	11.088	10.520	10.325	07.11.04
HE 0457-1805	04 59 43.6	-18 01 11	217.85	-32.51	12.1	11.2	1.25	1.20	8.937	8.421	8.186	07.11.04
HE 0507-1653	05 09 16.5	-16 50 05	217.54	-29.96	15.6	12.4	1.06	0.68	10.883	10.430	10.315	06.11.04
HE 0518-2322	05 20 35.5	-23 19 14	225.62	-29.74	13.7				11.151	10.672	10.568	15.11.03
HE 0915-0327	09 18 08.2	-03 39 57	235.26	+30.09	14.5	12.9	2.29	2.12	9.968	8.989	8.609	10.4.04
HE 0932-0341	09 35 10.2	-03 54 33	238.38	+33.41	14.8	13.9	1.23	1.02	12.295	11.807	11.708	06.11.04
HE 1008-0636	10 10 37.0	-06 51 13	248.12	+38.35	14.5	12.9	2.28	2.11	9.952	9.073	8.527	29.3.04
HE 1027-2501	10 29 29.5	-25 17 16	266.68	+27.42	13.9	12.7	1.73	1.51				30.3.04
HE 1056-1855	10 59 12.2	-19 11 08	269.48	+36.29	13.6				10.784	10.249	10.090	20.12.04
HE 1104-0957	11 07 19.4	-10 13 16	265.35	+44.92	14.7				8.262	7.561	7.317	20.12.04
HE 1107-2105	11 09 59.6	-21 22 01	273.53	+35.65	14.3	12.1	3.11	2.44	8.279	7.229	6.696	30.3.04
HE 1125-1357	11 27 43.0	-14 13 32	274.20	+43.93	15.2	14.1	1.41	1.40	11.730	11.057	10.842	12.4.04
HE 1145-0002	11 47 59.8	-00 19 19	271.30	+58.60	13.5	13.6	1.48	1.49	10.911	10.240	10.006	11.4.04
HE 1204-0600	12 07 11.6	-06 17 06	283.56	+54.91	14.9	14.0	1.36	1.45	11.517	10.898	10.703	11.4.04
HE 1211-0435	12 14 12.0	-04 52 26	285.83	+56.76	15.0	14.2	1.08	0.90	12.492	11.962	11.916	12.4.04
HE 1228-0402	12 30 50.6	-04 18 59	293.16	+58.16	16.3	15.1	1.68	1.92	12.805	12.070	11.847	11.4.04
HE 1254-1130	12 56 57.0	-11 46 19	305.08	+51.08	16.1	14.5	2.13	2.37	10.731	9.821	9.406	30.3.04
HE 1259-2601	13 01 52.4	-26 17 16	305.84	+36.52	13.9	12.8	1.77	1.56				03.3.04
HE 1304-2046	13 06 50.1	-21 02 10	307.75	+41.69	15.2	14.3	1.32	1.36	11.978	11.386	11.219	30.3.04
HE 1305+0132	13 08 17.8	+01 16 49	312.52	+63.84	13.8	12.8	1.35	1.25	10.621	9.994	9.814	28.3.04
HE 1418+0150	14 21 01.2	+01 37 18	346.80	+56.66	14.2				9.988	9.356	9.127	10.4.04
HE 1425-2052	14 28 39.5	-21 06 05	331.40	+36.64	13.6	12.7	1.27	1.29	10.043	9.446	9.273	28.3.04
HE 1429-0551	14 32 31.3	-06 05 00	343.02	+48.76	13.5				10.734	10.272	10.066	05.9.03
HE 1446-0112	14 49 02.2	-01 25 24	352.42	+49.80	14.5	13.5	1.38	1.39	10.983	10.379	10.162	06.9.03
HE 1501-1500	15 04 26.3	-15 12 00	344.28	+36.78	16.5	15.3	1.65	1.61	12.725	12.030	11.830	10.4.04
HE 1523-1155	15 26 41.0	-12 05 43	351.87	+35.63	14.2	13.4	1.14	0.70	11.372	10.846	10.748	29.3.04
HE 1524-0210	15 26 56.9	-02 20 45	0.98	+42.35	14.4	13.3	1.53	1.25	11.740	11.079	10.896	06.9.03
HE 1528-0409	15 30 54.3	-04 19 40	359.87	+40.30	15.8	15.0	1.10	0.78	12.945	12.455	12.358	29.3.04
HE 2144-1832	21 46 54.7	-18 18 15	34.65	-46.78	12.6				8.768	8.180	7.958	16.9.03
HE 2145-1715	21 48 44.5	-17 01 03	36.63	-46.73	14.2	13.2	1.39	1.18	11.032	10.356	10.255	17.9.03
HE 2207-0930	22 09 57.5	-09 16 06	50.27	-47.96	14.4	13.1	1.82	1.40	10.527	9.812	9.607	16.9.03
HE 2207-1746	22 10 37.5	-17 31 38	38.87	-51.77	11.8				9.115	8.579	8.450	06.9.03
HE 2218+0127	22 21 26.1	+01 42 20	65.46	-43.80	14.6	14.0	0.80	0.31	11.826	11.509	11.433	16.9.03
HE 2221-0453	22 24 25.7	-04 38 02	59.04	-48.38	14.7	13.7	1.36	1.11	11.524	10.997	10.815	17.9.03
HE 2239-0610	22 41 53.1	-05 54 22	61.61	-52.61	14.1	13.1	1.34	1.59	13.830	13.296	13.164	07.11.04
HE 2319-1534	23 22 11.1	-15 18 16	58.09	-66.14	15.3	13.8	2.09	2.16	10.866	9.937	9.367	17.9.03
HE 2331-1329	23 33 44.5	-13 12 34	66.55	-67.12	16.2	14.5	2.29	2.19	11.841	10.990	10.652	06.11.04
HE 2339-0837	23 41 59.9	-08 21 19	78.51	-65.05	14.9	14.0	1.32	0.62	12.632	12.107	12.026	06.11.04

[a] From Christlieb et al. (2001)

and Na I D_2 in C-R stars is sharper with two distinct dips. In CH stars this feature is shallower and the individual contribututions of Na I D_1 and Na I D_2 are not distinguishable. H_α feature appears as a distinct feature in CH stars; in C-R stars this feature seems to be contaminated by molecular contributions. Ba II feature at 6496 Å is also blended with contributions from CN bands around 6500 Å; in CH stars this blending is not so severe. CN molecular bands, although present are in general weaker in CH stars than in C-R stars.

The main features of the above comparison are used to identify the spectral type (CH or C-R) of the program stars. A small number of C-N stars were easily identified from their distinct spectral properties. In figure 4 we present the spectra of the comparison stars in the wavelength region 4000 -6800 Å . In figure 5 we show one example of HE stars cor-

Table 2: HE stars without prominent C_2 bands

Star No.	RA(2000)[a]	DEC(2000)[a]	l	b	B[a]	V[a]	B-V[a]	U-B[a]	Bands noticed	Dt of Obs
HE 0201-0327	02 03 49.0	-03 13 05	161.94	-60.49	14.1	13.4	1.02	0.95	CH, CN	07.11.04
HE 0333-1819	03 35 18.8	-18 09 54	208.37	-51.32	12.6				CH, CN	16.9.03
HE 0359-0141	04 02 21.2	-01 33 05	192.03	-37.64	14.5	13.4	1.26	1.08	CH, CN	15.11.03
HE 0408-1733	04 11 06.0	-17 25 40	211.87	-43.11	13.1	12.2	1.28	1.26	CH, CN	17.9.03
HE 0417-0513	04 19 46.8	-05 06 17	198.66	-35.82	14.6	13.7	1.31	1.21	CH, CN	15.11.03
HE 0419+0124	04 21 40.4	+01 31 46	192.17	-31.92	15.7	13.0	1.44	1.37	CH, CN	07.11.04
HE 0443-1847	04 46 10.9	-18 41 40	217.23	-35.75	13.1	12.9	1.27	1.21	CH, CN	16.9.03
HE 0458-1754	05 00 34.5	-17 50 21	217.73	-32.26	13.5	12.7	1.18	1.09	CH, CN	02.3.04
HE 0508-1604	05 10 47.0	-16 00 40	216.82	-29.31	12.8	12.1	1.04	1.15	CH, CN,	20.12.04
HE 0518-1751	05 20 28.4	-17 48 43	219.71	-27.84	13.5	12.8	1.05	1.22	CH, CN	07.11.04
HE 0519-2053	05 21 54.4	-20 50 36	223.06	-28.62	13.6	13.7	1.18	1.14	CH, CN	15.11.03
HE 0536-4257	05 37 40.4	-42 55 39	248.71	-31.11	13.8	12.7	1.44	1.41		03.3.04
HE 0541-5327	05 42 14.3	-53 26 31	261.05	-31.59	13.6					03.3.04
HE 0549-4354	05 50 34.3	-43 53 24	250.28	-28.98	13.7	12.8	1.31	1.18	CH	03.3.04
HE 0900-0038	09 02 50.5	-00 50 20	230.15	+28.43	14.2	13.3	1.27	1.19	CH, CN	29.3.04
HE 0916-0037	09 18 47.6	-00 50 35	232.63	+31.79	13.7	12.8	1.24	1.02	CH	03.3.04
HE 0918+0136	09 21 26.1	+01 23 28	230.81	+33.55	14.0	13.1	1.30	1.21	CH	03.3.04
HE 0919+0200	09 22 13.0	+01 47 56	230.52	+33.93	13.5	12.6	1.31	1.20	CH	03.3.04
HE 0930-0018	09 33 24.7	-00 31 46	234.74	+35.01	14.2	14.7	1.43	1.45	CH	02.3.04
HE 0935-0145	09 37 59.0	-01 58 36	236.99	+35.12	13.8	12.9	1.16	1.07	CH	02.3.04
HE 0939-0725	09 42 11.9	-07 39 06	243.19	+32.50	14.0	13.1	1.20	1.13	CH, CN,	20.12.04
HE 1042-2659	10 44 24.2	-27 15 30	271.05	+27.64	14.7	12.6			CH	03.3.04
HE 1117-2304	11 19 42.8	-23 21 07	277.08	+34.87	13.3				CH, CN	11.4.04
HE 1119-3229	11 22 21.9	-32 46 19	282.08	+26.47	14.0	13.1	1.18	1.25	CH	03.3.04
HE 1227-3103	12 30 34.5	-31 19 54	297.72	+31.33	14.3	13.3	1.39	1.54		02.3.04
HE 1304-3020	13 07 24.2	-30 36 36	306.99	+32.14	13.5	12.7	1.17	1.06	CH	02.3.04
HE 1356-2752	13 59 25.0	-28 06 59	320.71	+32.40	13.3				CH	03.3.04
HE 1455-1413	14 57 51.6	-14 25 10	343.27	+38.36	13.1				CH	03.3.04
HE 1500-1101	15 03 40.9	-11 13 09	347.25	+40.01	13.8	12.9	1.28	1.24	CH	29.3.04
HE 1514-0207	15 16 38.9	-02 18 33	358.67	+44.29	13.6				CH, CN	05.9.03
HE 1521-0522	15 24 12.2	-05 32 52	357.20	+40.70	14.7	13.8	1.24	1.11	CH, CN	11.4.04
HE 1527-0412	15 29 42.3	-04 22 22	369.56	+40.49	13.8	12.9	1.21	1.19	CH, CN	05.9.03
HE 2115-0522	21 18 11.8	-05 10 07	46.39	-34.80	17.4	14.3	1.22	1.15	CH, CN	07.11.04
HE 2121-0313	21 23 46.2	-03 00 51	49.51	-34.90	14.9	13.9	1.35	1.47	CH, CN	05.9.03
HE 2124-0408	21 27 06.8	-03 55 22	49.09	-36.09	14.8	13.9	1.26	1.15	CH, CN	17.9.03
HE 2138-1616	21 41 16.6	-16 02 40	36.95	-44.70	14.7	13.9	1.01	0.91	CH, CN	16.9.03
HE 2141-1441	21 44 25.7	-14 27 33	39.43	-44.77	14.3	13.5	1.13	1.03	CH, CN	16.9.03
HE 2145-0141	21 47 48.3	-01 27 50	55.23	-39.10	13.4	12.6	1.10	1.02	CH, CN	16.9.03
HE 2224-0330	22 26 47.9	-03 14 58	61.23	-48.01	14.3	13.5	1.08	0.94	CH, CN	16.9.03
HE 2352-1906	23 54 49.0	-18 49 31	62.50	-74.57	12.9				CH, CN	16.9.03

[a] From Christlieb et al. (2001)

responding to each comparison star's spectrum in figure 4, in the sequence top to bottom. In the following we present the spectral description of the individual star.

HE 2145-1715, HE 0518-2322, HE 0457-1805, HE 0043-2433, HE 1056-1855

The spectra of these objects closely resemble the spectrum of HD 26, a known CH star. CH bands around λ4300 are of almost equal strength in the spectra of these stars. Ca I 4226 Å line is very weak, 4271 Fe I line is barely detectable. Strength of G-band of CH, prominent secondary P-branch head around 4342 Å and a weak Ca I feature at 4226 Å show that these stars could be CH stars.

C_2 molecular bands around 4730 Å , 5165 Å and 5635 Å are much deeper in HE 2145-1715 than their counterparts in HD 26. H_β features are of equal strength. Ba II line around 4545 Å is marginally weaker in the spectrum of HE 2145-1715 whereas Ba II feature at 6496 Å and H_α are of equal strength. The effective temperature of HD 26 is $\sim$ 4880 K, and [Fe/H]=-0.5 (Aoki & Tsuji 1997). A marginally weaker NaI D feature than in HD 26 spectrum and the deeper C_2 bands in HE 2145-1715 perhaps is an indication of slightly lower metallicity and lower temperature for HE 2145-1715 than HD 26. This statement however can be asscertained only from high resolution spectral analysis.

In HE 0518-2322, CN molecular band depth matches well with that of HD 26. Na I D appears weakly in emission, Ba II at 6496 Å and H_α features are marginally stronger. H_α feature has an weak emission at the absorption core. HE 0043-2433 has a stronger CN band around 4215 Å but H_α, H_β and Ba II at 6496 Å appear with almost similar strength to those in HD 26. Na I D feature appears weakly in absorption in this star. In HE 0457-1805, Na I D is stronger than in HD 26 but H_α, H_β and Ba II at 6496 Å appear with almost similar strength. In HE 1056-1855, H_α and H_β are marginally weaker but Ba II at 6496 Å appear with almost equal strength as in HD 26.

HE 0310+0059, HE2239-0610, HE 0932-0341, HE 0429+0232

These four stars spectra resemble the spectrum of HD 26 to a large extent. G-band of CH around 4300 Å is of similar strength to that in HD 26 but the secondary P-branch head around 4342 Å is not seen prominently as it is seen in CH stars. Further, in contrast to HD 26, these stars spectra exhibit strong Ca I feature at 4226 Å in their spectra. These stars do not seem to be potential candidate CH stars. In HE 0310+0059, lines appear much sharper than in HD 26 and especially Na I D feature is seen as a much stronger feature in absorption. In HE 0429+0232, this feature is marginally weaker than in HD 26. In HE 2239-0610 and HE 0932-0341 Na I D features appear in weak emission. CN bands are stronger in HE 0310+0059 but C_2 bands are of similar strength. H_α, H_β, and Ba II feature at 6496 Å appear in these stars almost with equal strength as in HD 26.

HE 0110-0406, HE 0308-1612, HE 0314-0143, HE 1125-1357, HE 1211-0435, HE 1225-2052, HE 1446-0112, HE 1524-0210, HE 1528-0409, HE 2144-1832, HE 2207-1746

The spectra of these stars closely resemble the spectrum of HD 209621 except for some marginal differences in the molecular band depths. The star HD 209621 is a known CH giant with effective temperature ∼ 4700 K and metallicity -0.9 (Wallerstein 1969, Aoki & Tsuji 1997).

Except for HE 1446-0112 and HE 1524-0210 the CN band depth around λ4215 are weaker in the program stars spectra than in the spectrum of HD 209621. Ca I at 4226 Å is not detectable in the spectra of HE 1446-0112, HE 1127-1357, and HE 1211-0435, but appears weakly in the rest of the stars spectra. In the first three stars although Ca I feature at 4226 Å is seen with its depth almost half the depth of CN band around 4215 Å it should be noted that in these three stars CN band itself is much weaker than its counterpart in HD 209621 and in C-R stars. CH band at λ4300 in the spectra of the program stars are equal or stronger than in the spectrum of HD 209621 except for HE 2207-1746, HE 0308-1612 and HE 0110-0406 where this features are slightly weaker. In these stars CN band around 4215 Å is also weak, much weaker than in C-R stars. Secondary P-branch head around 4342 Å is seen prominently in all the cases. We assign the membership of these stars to the CH group. Molecular band heads of C_2 around λ4700 is of equal strength in HE 1446-0112, HE 1524-0210 and HE 1127-1357; in the rest of the stars spectra this band is slightly weaker than in HD 209621. C_2 band depth around λ5165 and λ5635 are almost of equal strength except for stars HE 2207-1746, HE 1211-0435, HE 0308-1612, and HE 0110-0406. Ba II feature at 4554 Å is detectable and of similar strength; however H_β feature is weaker in HE 1524-0210 and HE 1528-0409. Except in HE 1446-0112 and HE 1528-0409 where NaI D feature appears slightly weaker, in the rest of the stars spectra this feature is of similar strength with that of NaI D feature in HD 209621. Ba II feature at 6496 Å which is distinctly seen in HD 209621 appears blended with CN molecular band in HE 1446-0112. In HE 1125-1357, HE 1528-0409 and HE 1211-0435 this feature appears slightly weaker than in HD 209621 and in the rest they seem to be of equal strength. Hα profile is of equal strength in all the stars except in HE 0314-0143 where this feature is slightly weaker. In figure 6, we show as an example a comparison of spectra of three objects in the wavelength region 4125 - 5400 Å with the spectrum of HD 209621.

HE 1429-0551, HE 1523-1155, HE 2218+0127, HE 2221-0453, HE 1204-0600, HE 1418+0150, HE 2207-0930, HE 1145-0002, HE 0111-1346, HE 0151-0341, HE 0507-1653, HE 0038-0024, HE 0322-1504, HE 2339-0837

With marginal differences in the molecular band depths these stars spectra closely resemble the spectrum of HD 5223, a well known CH giant with effective temperature ∼ 4500 K, and metallicity -1.3 (Aoki & Tsuji 1997).

The CN band depth around λ4215 in the HE stars spectra are very similar to the CN band depth in the spectrum of HD 5223 except in HE 1145-0002 where this feature is weaker and does not show a sharp clear band head. G-band of CH around λ4300 in the spectra of the program stars resemble greatly to their counterparts in HD 5223. Ca I at 4226 Å is seen in the spectra of HE 2218+0127, HE 1204-0600 and HE 2207-0930 but not as prominently as they are seen in C-R stars. Moreover, the line depth of this feature is quite shallow compared to the CN molecular band depth around 4215 Å . We note, in C-R stars these two features appear almost with equal depth and CN band depth is deeper in C-R stars than in CH stars.

The Ca I feature is seen marginally also in the rest of the stars spectra. Fe I at 4271.6 Å although weak could be marginally detected in all the spectra. Prominance of secondary P-branch head near 4342 Å , strong G-band of CH and weak or marginally detectable Ca I feature at 4226 Å allow these stars to be placed in CH group. The dominance of CH is shown not only by the marked band depths, but also by the weakness of Ca I at 4226 Å and distortion of metallic lines between 4200 and 4300 Å . In figure 7, we show a comparison of three spectra in the wavelength region 4000 - 5400 Å with the spectrum of HD 5223.

Isotopic bands of Swan system around λ4700 appear to be of equal strength in HE 1204-0600 and HE 2218+0127 with their counterpart in HD 5223. These bands are slighly deeper in HE 2207-0930, HE 1145-0002 and HE 2221-0453 and marginally swallower in HE 1429-0551 and HE 1523-1155. C_2 bands around λ5165 and λ5635 greatly resemble those in the spectrum of HD 5223, except for stars HE 2207-0930 and HE 1145-0002 where these bands are slightly deeper. As in the case of HD 5223, Ba II feature at 4554 Å is distinctly seen in the program stars spectra. However in HE 1429-0551, HE 1523-1155 and HE 2218+0127 this feature is marginally weaker, and in the rest the feature is of similar strength. H_β feature appears in all the spectra with similar strength as in HD 5223. Except in HE 1429-0551, HE 1523-1155, and HE 2121-0453, NaI D feature appears slightly stronger as compared to this feature in HD 5223. Ba II feature at 6496 Å appears weaker in HE 1429-0551, HE 1523-1155 and HE 2218-0127 than in HD 5223, this feature appears blended with contributions from CN molecular bands in HE 1204-0600, HE 2207-0930 and HE 1145-0002. Hα profile is of equal strength in HE 1429-0551, HE 1523-1155, HE 2218-0127, and HE 2221-0453; this feature appears slightly weaker in HE 1204-0600, HE 2207-0930 and HE 1145-0002 and blended with contributions from molecular bands. The spectra of HE 1204-0600, HE 2207-0930 and HE 1145-0002 resemble closely the spectrum of HD 5223 in the wavelength region 4000 - 5800Å ; they show marginally stronger CN bands in the wavelength region 5700 - 6800 Å .

The spectra of HE 0111-1346 and HE 0322-1502 show a very good match with the spectrum of HD 5223, with similar depths in molecular bands and also line depths of Hα, H_β and Ba II at 6496 Å appear with similar strength. In HE 0322-1502 Na I D appears weakly in emission.

In HE 0151-0341, G-band of CH around 4300 Å and CN band around 4215 Å have similar strength but C_2 bands are marginally weaker than in HD 5223. Hα and H_β are of equal strength but Na I D and Ba II at 6496 Å are much weaker than in HD 5223. HE 0507-1653 has marginally weaker bands and also Na I D feature is slightly weaker than in HD 5223; Hα, H_β and Ba II at 6496 Å appear with similar strength. The spectra of HE 0038-0024 and HE 2339-0837 show marginally stronger CN band around 4215 Å and G-band of CH around 4300 Å but exhibit slightly weaker C_2 molecular bands. Na I D feature appears in weak emission, Hα, is of similar strength but Ba II at 6496 Å appear in equal strength in HE 0038-0024 which is marginally weaker in HE 2339-0837.

HE 1305+0132, HE 1027-2501, HE 1304-2046, HE 0017+055, HE 0319-0215

The spectra of these stars also show spectral characteristics of CH stars. The spectra exhibit strong G-band of CH. Secondary P-branch head of CH near 4342 Å is distinctly seen as usually seen in CH stars spectra. Ca I feature at 4226 Å is weak or undetectable in their spectra. We place these stars in CH group. Ba II at 4554 Å , Sr II around 4606 Å and H_β are seen in their spectra. Strong molecular bands include C_2 Swan bands around 4700 Å and C_2 bands around 5165 Å and 5635 Å . Ba II feature around 6496 Å is blended with contributions from CN bands. CN bands around 5730 Å and 6300 Å are detected. Na I D features appear very similar as seen in most of the CH stars except in HE 0319-0215, where this feature appears in weak emission.

5.3 Candidate C-N stars: Description of the spectra

HE 2319-1534, HE 1008-0636, HE 2331-1329, HE 0207-0211, HE 1107-2105

The spectra of these stars show a close resemblance with the spectrum of C-N star Z Psc with similar strengths of CN and C_2 bands in them seen across the wavelength regions. In figure 8, we show as an example, a comparison of spectra for three objects in the wavelength region 5500 - 6800 Å with the spectrum of Z Psc. The spectra of HE 2319-1534, HE 1008-0636 and HE 1107-2105 have low flux below about 4500 Å . In HE 1008-0636 the SiC_2 bands around 4800 - 5000 Å are seen. These red-degraded features are not seen in the other four and Z Psc. Na I D feature is much deeper in HE 1008-0636 than in HE 2319-1534. In the spectrum of HE 2331-1329, Ca I feature at 4226 Å is much weaker than in Z PSc. G-band of CH around 4300 Å and C_2 molecular bands are of similar strength but CN bands are much weaker in HE 2331-1329 than their counterparts in Z PSc. Na I D, H_α and H_β are marginally detectable in this star. In HE 0207-0211 CN bands are much weaker than in Z PSc but C_2 bands are in good match; Na I D feature is weak and barely detectable. In HE 0207-0211 and HE 1107-2105 H_α and H_β appear in emissionr; these two features are also seen strongly in emission in the spectra of HE 2319-1534 and HE 1008-0636 are indicative of a possible strong chromospheric activity or shock-waves of the type associated with Mira variables.

HE 1228-0402, HE 0915-0327, HE 1254-1130, HE 1501-1500, HE 1259-2601

The specta of these stars show very low flux below about 4500 Å . Their spectra mostly resemble the spectra of C-N star with prominent CN and C_2 bands seen across the wavelength regions. The spectrum of C-N star V460 Cyg compares closest to the spectra of these stars. Na I D feature is weaker in their spectra as compared to their counterparts in V460 Cyg. We place these stars in C-N group. In V460 Cyg the molecular bands of C_2 as well as CN are much deeper than in Z Psc.

HE 0002+0053, HE 1104-0957

The spectra of these two objects greatly resemble the spectrum of C-R star RV Sct. C_2 bands in the spectrum of HE 0002+0053 match closely with those in RV Sct but CN bands are much weaker. In HE 1104-0957 molecular bands due to both CN and C_2 are much weaker than those in RV Sct. In both the stars, H_α and H_β are weakly seen in absorption. Na I D is marginally detectable but weaker than in RV Sct. but G-band of CH around 4300 Å is marginally stronger in these stars. Ca I feature around 4226 Å which appears weakly in the spectrum of RV Sct is missing in the spectra of these two stars. ^{13}C isotopic band around 4700Å is absent in these two stars. CN band around 5200 and 5700 Å distinctly seen in RV Sct is marginally detected in HE 0002-0053 but not seen in HE 1104-0957.

6 ATMOSPHERES OF CH STARS

6.1 Effective temperature

Preliminary estimates of the effective temperatures of the candidate CH stars are determined by using temperature calibrations derived by Alonso et al. (1996). These calibrations were derived by using a large number of lower main sequence stars and subgiants, whose temperatures were measured by infrared flux method, and holds within a temperature and metallicity range 4000 ≤ T_{eff} ≤ 7000 K and -2.5 ≤ [Fe/H] ≤ 0 . This calibration relates T_{eff} with Stromgren indices as well as [Fe/H] and colours (V-B), (V-K), (J-H) and (J-K). By considering the uncertainties arising from different sources such as uncertainties in the Stromgren photometry, reddening and the calibration of the absolute flux in the infrared, Alonso et al. (1996) estimated an uncertainty of ∼ 90 K in T_{eff} determination. The broad band B-V colour is often used for the determination of T_{eff}, however B-V colour of a giant star depends not only on T_{eff} but also on metallicity of the star and the molecular carbon absorption features, due to the effect of CH molecular absorption in the B band. For this reason, we have not used the empirical T_{eff} scale for the B-V colour indices. Since there is a negligible difference between the 2MASS infrared photometric

Table 3: Estimated effective temperatures (T_{eff}) of the candidate CH stars

Star Names	$T_{eff}-$ (J-K)	$T_{eff}-$ (J-H)	$T_{eff}-$ (V-K)	$^{12}C/^{13}C$
HE 0017+0055	3919.1	4124.4	-	1.3
HE 0038-0024	3783.8	3929.2	4306.2	1.9
HE 0043-2433	4263.8	4271.3	4379.3	-
HE 0110-0406	4405.6	4444.0	-	2.1
HE 0111-1346	4449.5	4481.0	-	2.5
HE 0151-0341	4619.2	4696.5	4912.7	1.7
HE 0308-1612	4274.8	4369.2	-	2.8
HE 0314-0143	3454.4	3561.6	-	76.8
HE 0319-0215	4188.9	4314.8	4480.4	4.7
HE 0322-1504	4054.8	4293.7	4614.6	2.2
HE 0457-1805	4097.6	4513.4	4165.5	-
HE 0507-1653	4740.2	4846.3	4983.1	6.7
HE 0518-2322	4680.9	4689.1	-	-
HE 1027-2501	-	-	-	1.8
HE 1056-1855	4280.5	4427.3	–	-
HE 1145-0002	3665.5	3905.5	3691.2	1.4
HE 1125-1357	3708.6	3897.9	3910.2	3.7
HE 1204-0600	3910.0	4102.6	3881.6	1.7
HE 1211-0435	4710.3	4476.0	4732.4	3.7
HE 1304-2046	4073.0	4200.9	4061.1	1.7
HE 1305+0132	3931.4	4061.2	4131.2	1.4
HE 1425-2052	4038.5	4179.1	3824.0	1.7
HE 1418+0150	3781.1	4042.8	-	1.5
HE 1429-0551	4367.4	4800.0	-	1.9
HE 1446-0112	3891.9	4160.2	3854.9	1.8
HE 1523-1155	4524.2	4491.1	4380.8	2.5
HE 1524-0210	3826.9	3942.1	4611.2	2.3
HE 1528-0409	4666.7	4662.4	4388.4	2.4
HE 2144-1832	3922.2	4226.4	-	2.1
HE 2145-1715	4019.1	3862.1	4214.1	2.2
HE 2207-0930	3628.5	3751.7	3736.5	1.4
HE 2207-1746	4378.8	4448.4	-	3.2
HE 2218+0127	5544.6	5631.3	-	4.2
HE 2221-0453	4231.7	4487.1	4163.8	12.6
HE 2339-0837	4592.6	4499.1	5104.5	2.3
HD 26				5.9
HD 209621				8.8
HD 5223				6.1

system and the photometry data measured on TCS system used by Alonso et al. (1998) in deriving the T_{eff} scales; we have used the empirical T_{eff} scales with 2MASS photometric data. We have further assumed that the effects of reddening on the measured colours are negligible. In estimating the T_{eff} from T_{eff} - (J-H) and T_{eff} - (V-K) relations we had to adopt a value for metallicity of the star as the metallicity of these stars are not known. We assumed the metallicity of the stars to be same as their closest comparison star. This assumption has definitely affected the accuracy of the T_{eff} measurements. Estimated effective temperatures are listed in Table 3.

For a reliable determination of metallicity, effective temperatures and chemical compositions of these stars, observation at high resolution is necessary. High resolution spectra will also enable us for an accurate measurement of $^{12}C/^{13}C$ ratios.

6.2 Isotopic ratio $^{12}C/^{13}C$ from molecular band depths

Carbon isotopic ratio $^{12}C/^{13}C$ provides an important probe of stellar evolution but low resoltuion of the spectra does not allow a meaningful estimation of this ratio.

We have estimated the ratio of the molecular band depths using the bands of (1,0) $^{12}C^{12}C$ $\lambda4737$ and (1,0) $^{12}C^{13}C$ $\lambda4744$. For a majority of the sample stars, we find from the depths of molecular bands the ratio $^{12}C/^{13}C \sim 3$, with an exception of three stars for which this ratio is 7, 13 and 77 respectively. The ratios are presented in Table 3. This ratio measured on the spectra of the welknown CH stars HD 26, HD 5223 and HD 209621 are respectively 5.9 , 6.1 and 8.8 . Tsuji et al. (1991) had suggested two kinds of CH stars; one with very high $^{12}C/^{13}C$ ratio and the other with the values less than about 10. Our estimated ratios of $^{12}C/^{13}C$ are consistent with this.

Several explanations on the significance of the range of values of $^{12}C/^{13}C$ ratios are put forward in terms of the stars evolutionary scenarios. One explanation for a lower value of

$^{12}C/^{13}C$ ratio is that, generally, the $^{12}C/^{13}C$ ratio and total carbon abundances decrease due to the convection which dredges up the products of internal CNO cycle to stellar atmosphere as ascending RGB. If it reaches AGB stage, fresh ^{12}C may be supplied from the internal He burning layer to stellar surface leading to an increase of $^{12}C/^{13}C$ ratio again. Since the abundance anomalies observed in CH giants are believed to have originated by the transfer of mass from a now extinct AGB companion, the CH giant's atmosphere should be enhanced in triple α products from the AGB star's interior- primarily ^{12}C. This explanation is in favour of stars which give high $^{12}C/^{13}C$ ratios. The low carbon isotope ratios imply that the material transferred from the now unseen companion has been mixed into the CN burning region of the CH star or constitutes a minor fraction of the envelope mass of the CH star, thus giving isotope ratios typical of stars on their first ascent of the giant branch.

7 CONCLUDING REMARKS

Large samples of high latitude carbon stars such as one reported by Christlieb et al. allows a search for different kinds of carbon stars; the present work is a step in this direction. The sample of carbon star candidates offered by Christlieb et al. being high latutude objects, smaller initial masses and possible lower metallicity, it is likely that a reasonable fraction of it could be CH stars. Indentification of several CH stars and description of their spectra are the main results of this paper. Another effort is known to be underway to make a medium-resolution spectroscopic study of the complete sample of stars from Christlieb et al. 2001 (Marsteller et al. 2003, Beers et al. 2003). From the sample list we have acquired spectra for ninety one stars in the first phase of observation. Out of these, fifty one objects were found to exhibit strong C_2 molecular bands in their spectrs of which thirteen stars have low flux below about 4300 Å . Twenty five objects show weak or moderate CH and CN bands, twelve objects show weak but detectable CH bands in their spectra and there are three objects which do not show any molecular bands due to C_2, CN or CH in their spectra. As an example, in figure 9 we show three spectra: a spectrum of HE 0443-1847 which exhibits very weak molecular bands due to CN around 4215 Å and a weak G-band of CH around 4300 Å (but no C_2 molecular bands); a spectrum of HE 0930-0018 which show a weak signature of G-band of CH around 4300 Å and a spectrum of HE 1227-3103 which do not show any molecular bands due to C_2, CN or CH in its spectrum.

Although spectroscopically, appearance of strong C_2 molecular bands is an obvious indication of a star being a carbon star, the conventional defination of a carbon star is a star with C/O $\geq$ 1 (Wallerstein et al. 1997). Hence if one adopts this conventional definition non appearance of any C_2 molecular bands will not necessarily disqualify a star from being a carbon star as this does not exclude the condition C/O $\geq$ 1; which at our resolution of the spectra is not derivable.

Westerlund et al. (1995) defined dwarf carbon stars as having J-H $\leq$ 0.75, H-K $\geq$ 0.25 mag. None of the stars occupies a region defined by these limits in J-H, H-K plane. With respect to J-H, H-K colours there is a clear separation between the C-N type stars and dwarf carbon-star populations; there are CH stars with J-H $\leq$ 0.75 but their H-K values are less than the lower limit of 0.25 mag set for dwarf carbon stars. We find that the sample of stars under investigation is comprised mostly of CH stars and a small number of C-N and C-R stars.

We have derived the effective temperatures of the candidate CH stars from correlations of Alonso et al. (1996) making use of (J-K), (J-H) and (V-K) colour indices. They vary over a wide range of temperature with an average of $\pm$ 240 K. These temperature estimates provide a preliminary temperature check for the program stars and can be used as starting values in deriving atmospheric parameters from high resolution spectra using model atmospheres. For majority of the sample stars, we find carbon isotopic ratio $^{12}C/^{13}C \sim 3$ with an exception of three stars HE 0507-1653, HE 2221-0453 and HE 0314-0143 for which this ratio is 7, 13 and 77 respectively. It was suggested by Tsuji et al. (1991) that there could be two kinds of CH stars, one with very high $^{12}C/^{13}C$ ratio and the other with values $\sim$ 10. Our $^{12}C/^{13}C$ estimates are consistent with this. This range of ratios is the same as found for the population II giants and globular cluster giant stars (Vanture 1992). Different evolutionary scenarios are held responsible for the two groups of CH stars, one with high and the other with low $^{12}C/^{13}C$ ratios.

From radial velocity survey CH stars are known to be binaries. For the moderately metal-poor classical CH stars ([Fe/H] $\sim$ -1.5), a scenario for abundance anomalies and the origin of carbon was proposed in which the carbon-enhanced star is a member of a wide binary system that accreted material from a former primary, during the asymptotic giant branch (AGB) phase of the latter, as described by McClure & Woodsworth (1990). In such a scenario CH stars with large $^{12}C/^{13}C$ ratios indicates that their atmosphere is enhanced in triple α products. The process of convection dredges up the products of internal CNO cycle to the stellar atmospheres as ascending RGB and this leads to a decrease of or a small value of $^{12}C/^{13}C$ ratio and a small total carbon abundance; on reaching the AGB stage $^{12}C/^{13}C$ ratio increases again due to the receipt of fresh ^{12}C supplied from the internal helium burning layer to the stellar surface. According to the models of McClure (1983, 1984) and McClure & Woodsworth (1990) the CH binaries have orbital characteristics consistent with the presence of a white dwarf companion, these stars have conserved the products of carbon rich primary and survived untill the present in the Galactic halo.

However, in case of a few carbon-enhanced, metal-poor stars (subgiants) monitoring of radial velocity over a period of eight years did not reveal radial velocity variations greater than 0.4 km s^{-1} which is against the mass transfer scenario for these stars (Norris et al. 1997a, Aoki et al. 2000, Preston and Sneden 2001). Furthermore, it is expected that the star we observe today should display an enrichment of *s*-process elements, produced by the former primary in its AGB phase, while the carbon-enhanced metal-poor star CS 22957-027 (Norris et al. 1997b, Bonifacio et al. 1998), as well as the stars reported by Aoki et al. 2000 do not exhibit this behaviour. The carbon-enhanced metal-poor stars that do show *s*-process enrichment provide strong observational constraints for theoretical models of the structure, evolution and nucleosynthesis of early-epoch AGB stars and permit studies of the *s*-process operating at very low metallicities. It was shown by Goriely & Siess (2001) that even at the absence of iron seeds efficient production of *s*-process elements can take place at zero metallicity provided protons are mixed into carbon-rich layers producing ^{13}C, which acts as a strong neutron source via ^{13}C(α ,n)^{16}O. The recent discovery of carbon-enhanced metal-poor stars with strong overabundances of Pb support these predictions (Aoki et al. 2000, Van Eck et al. 2001). Thus CH stars being the most prominent of the few types of heavy element stars that exist in both the field of the Galaxy and globular clusters are an important class of objects which can provide some of the very few direct observational tests to stellar evolution theory.

While in the present work, the spectra of the stars listed in table 1, are discussed the analysis and description of the spectra of the stars listed in table 2 will be discussed in a subsequent work.

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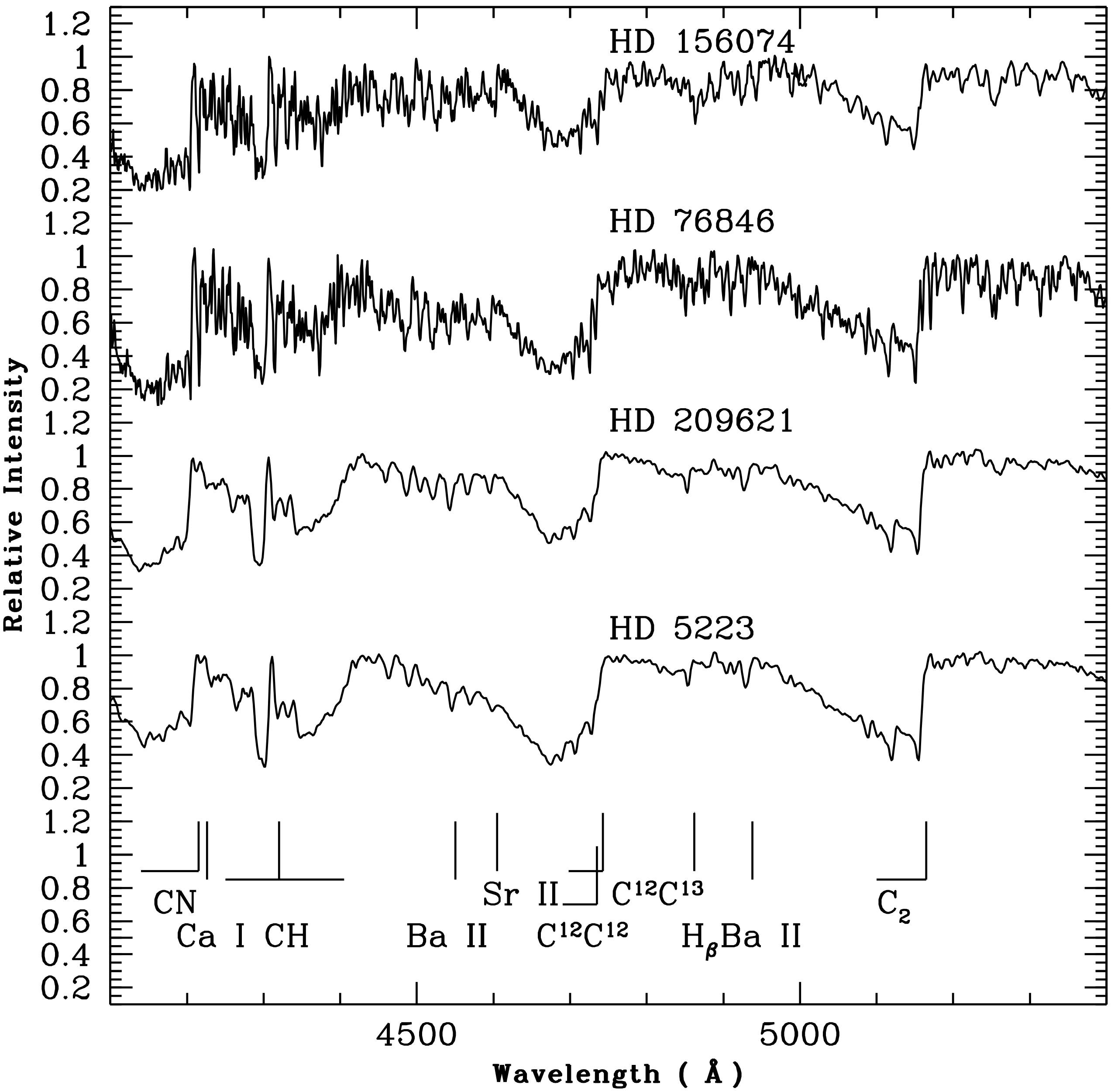

Figure 2. A comparison of the spectra of a pair of C-R stars HD 156074 and HD 76846 and a pair of CH stars HD 5223 and HD 209621 in the wavelength region 4100-5400 Å. The most prominent features noticeable are marked on the figure.

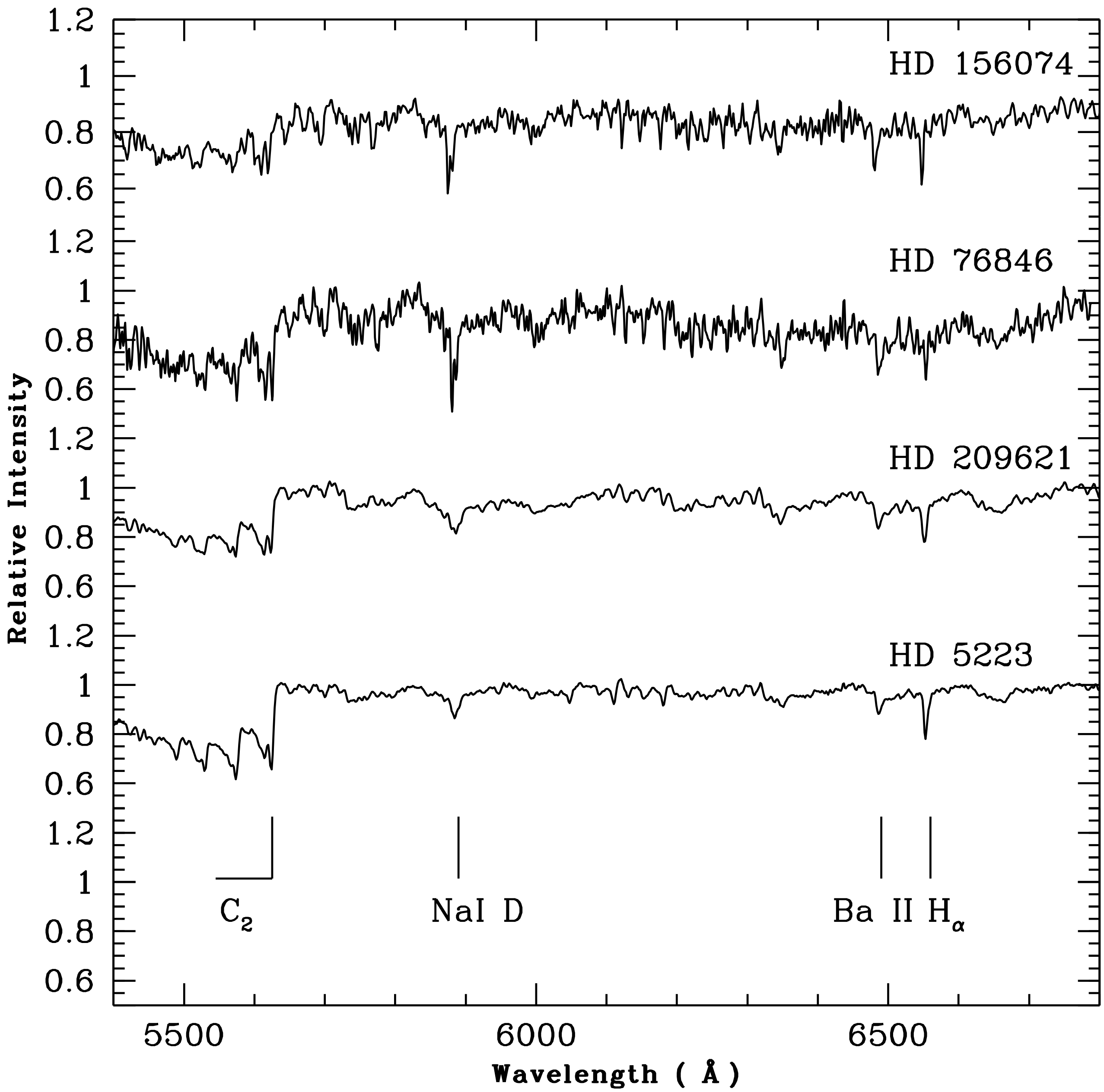

Figure 3. Same as figure 2 but for the wavelength region 5400-6800 Å . The prominent features of Na I D, Ba II at 6496 Å H_α and C_2 molecular bands around 5635 Å are indicated.

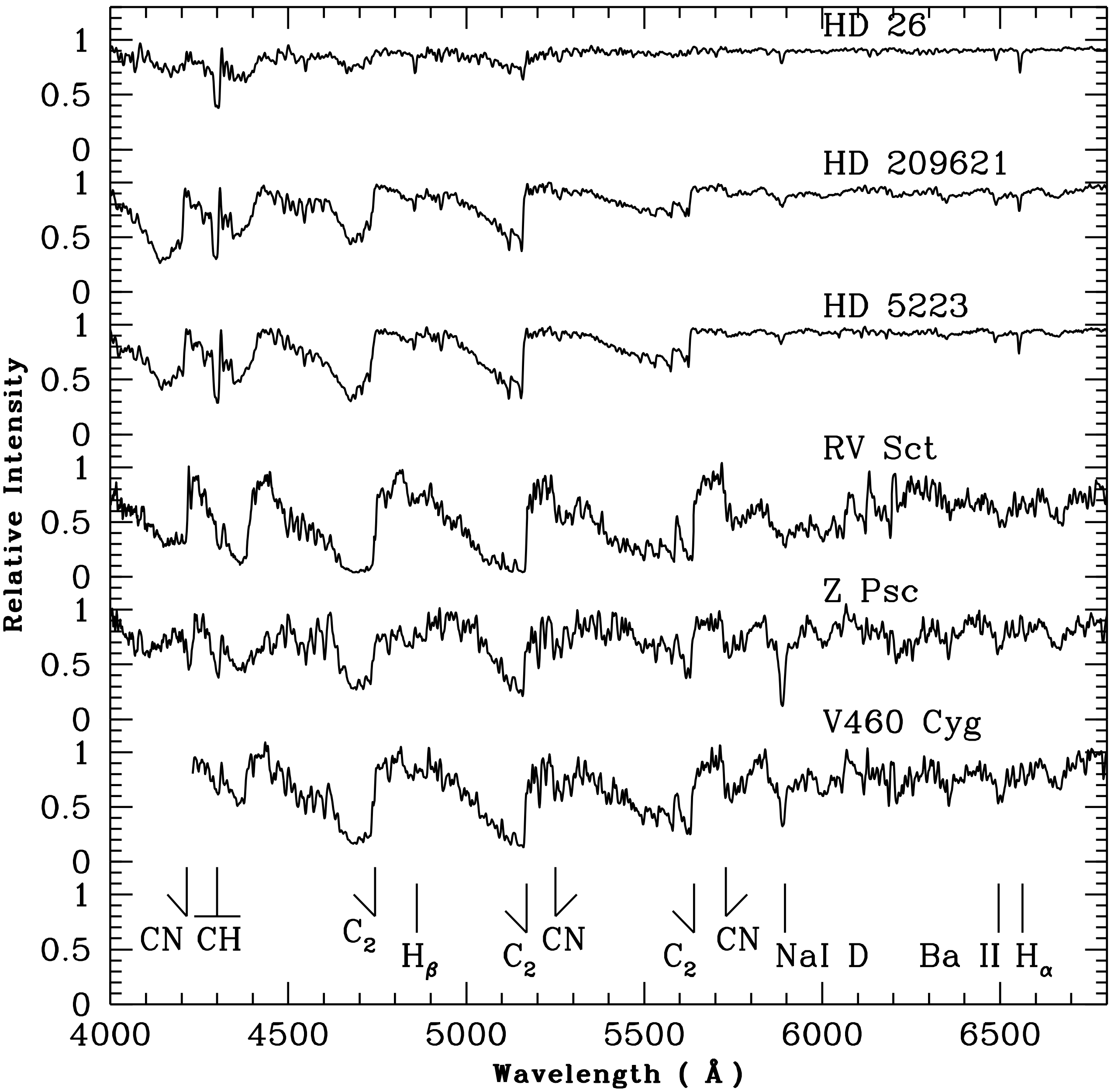

Figure 4. The spectra of the comparison stars in the wavelength region 4000-6800 Å .

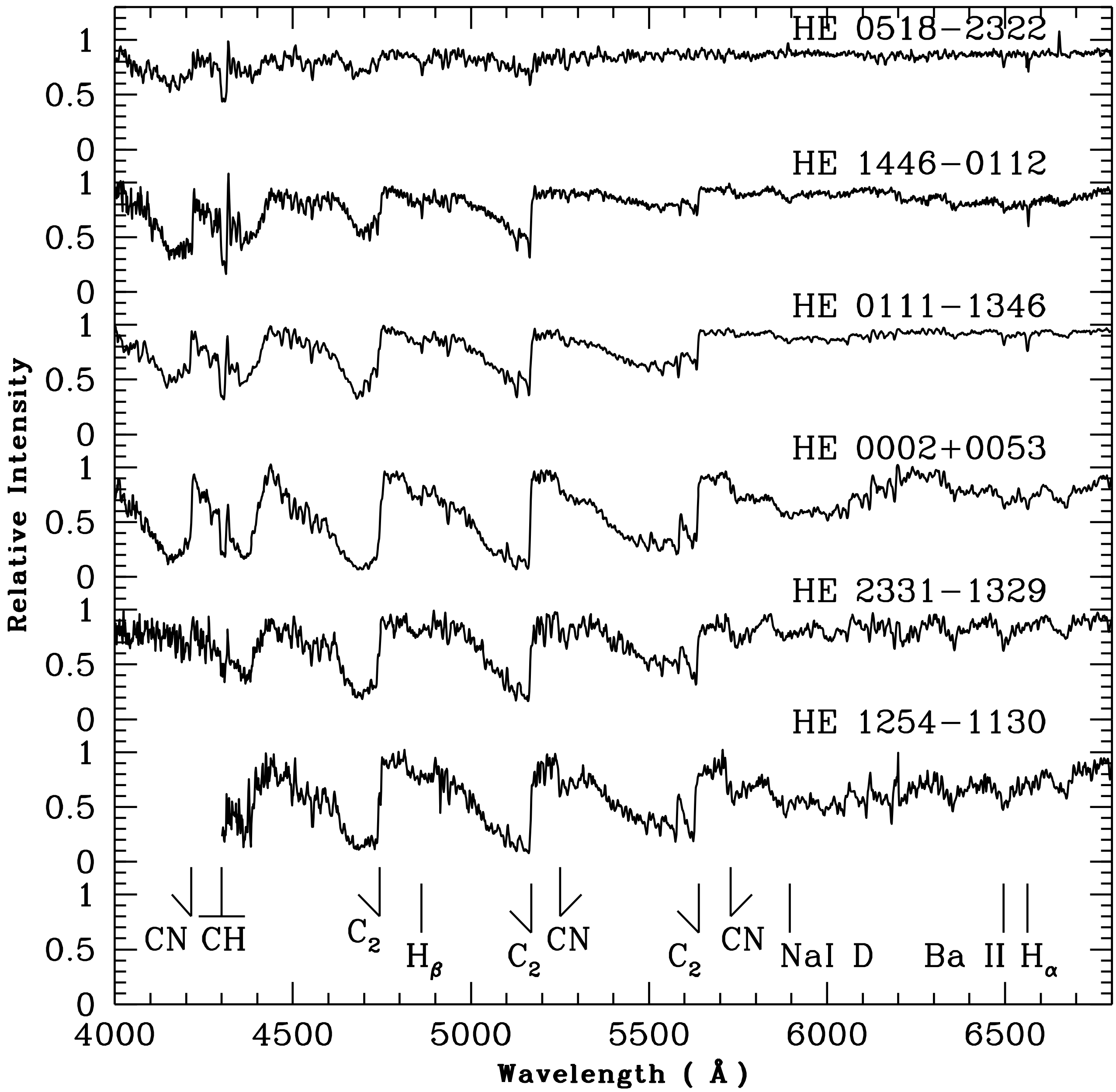

Figure 5. The figure shows one example from the HE stars corresponding to the comparison stars presented in figure 4, in the top to bottom sequence, in the wavelength region 4000-6800 Å . The locations of some prominent features seen in the spectra are marked on the figure. HE 1254-1130 has low flux below about 4400 Å . Ba II at 6496 Å and H_α seen in the top three stars spectra are not detectable in the lower three stars spectra. Except for the Na I D feature which is barely detectable in the spectra of HE 2331-1329 and HE 1254-1130, these two stars spectra resemble closely to their comparison stars spectra of Z Psc and V460 Cyg respectively.

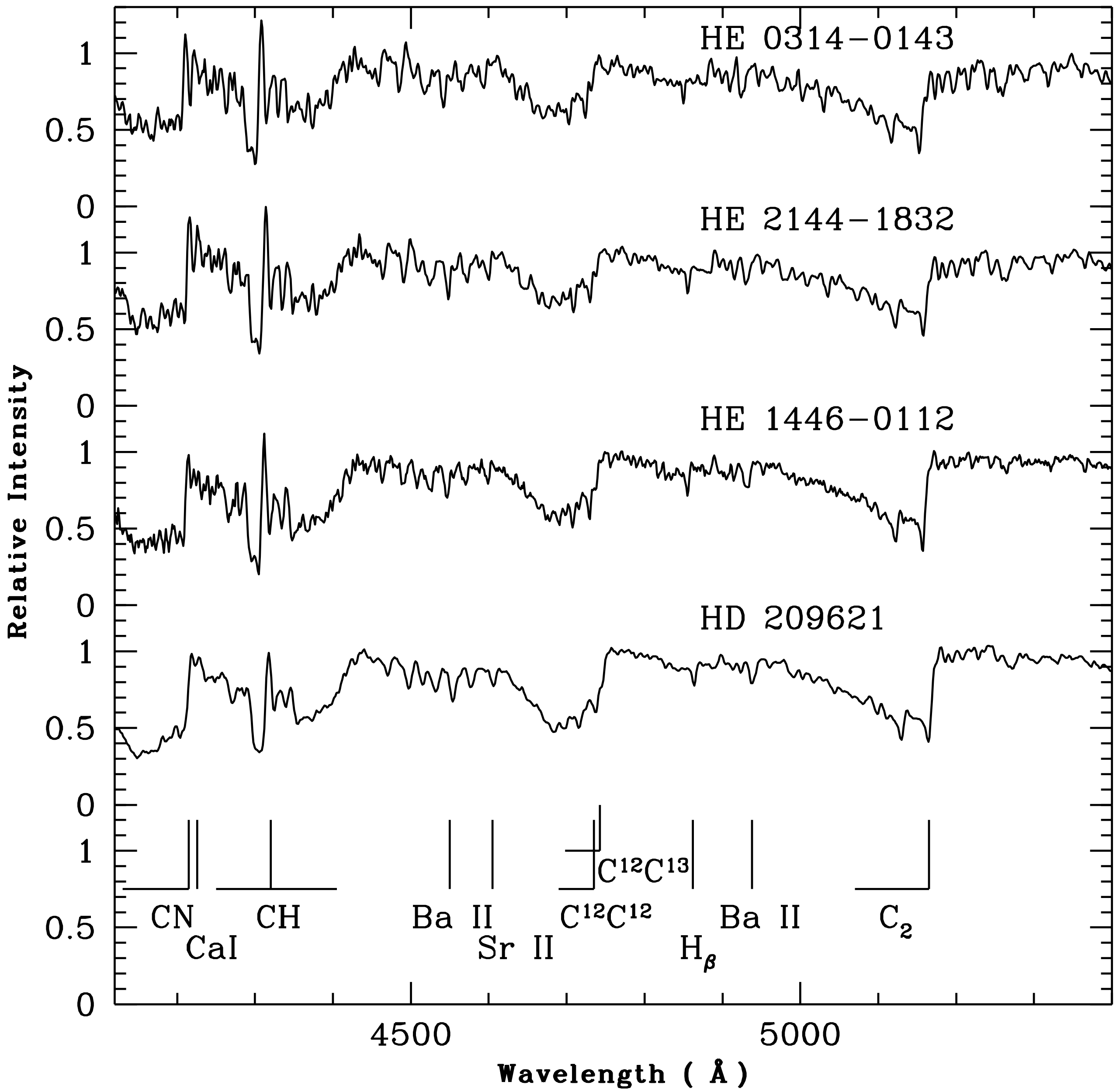

Figure 6. The figure shows a comparison of three HE stars spectra in the wavelength region 4120 - 5400 Å with the comparison star's spectrum of HD 209621. Prominent features seen in the spectra are marked on the figure.

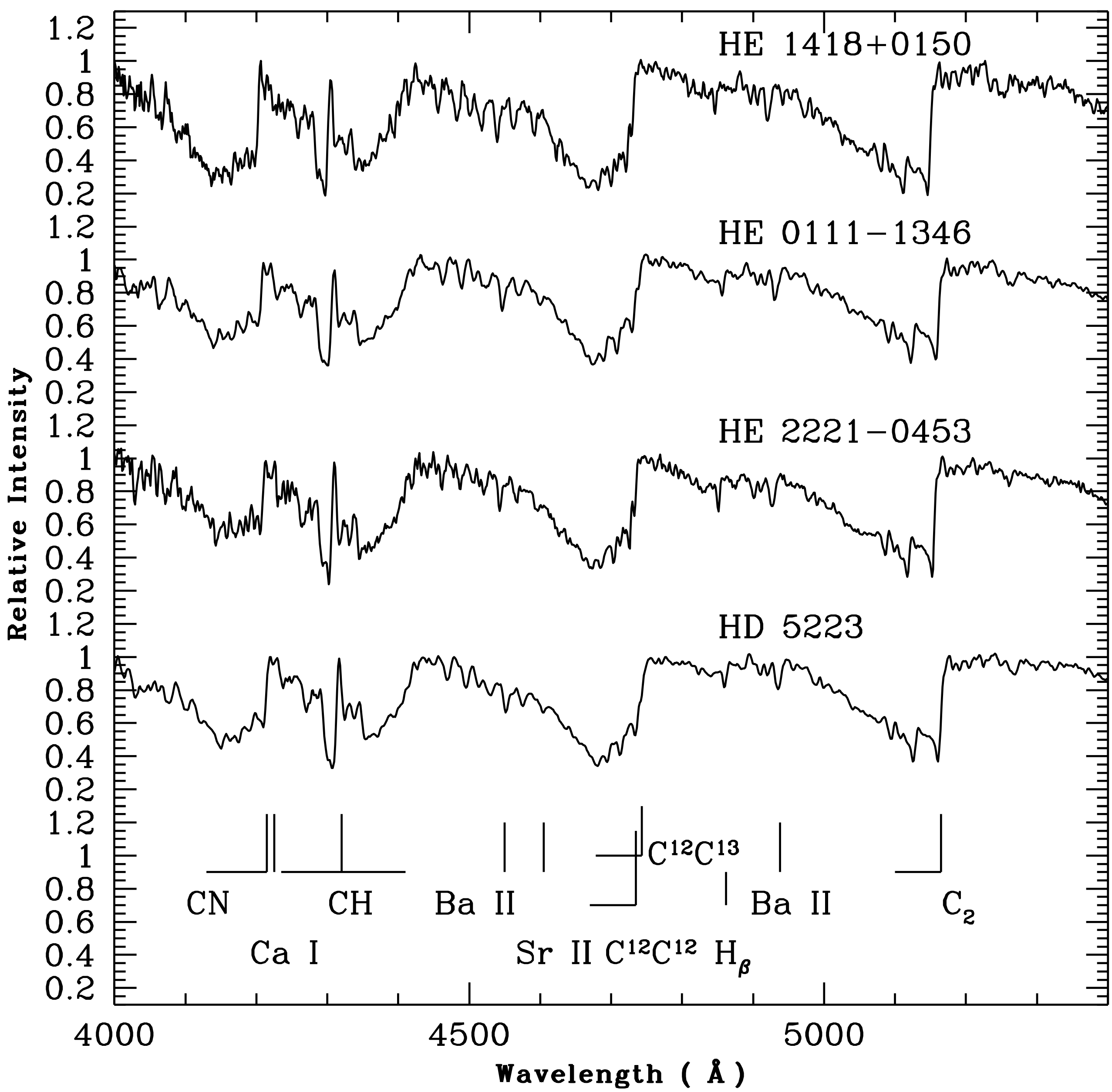

Figure 7. The figure shows a comparison of three HE stars spectra in the wavelength region 4000 - 5400 Å with the comparison star's spectrum of HD 5223. Some of the prominent features seen in the spectra are marked on the figure.

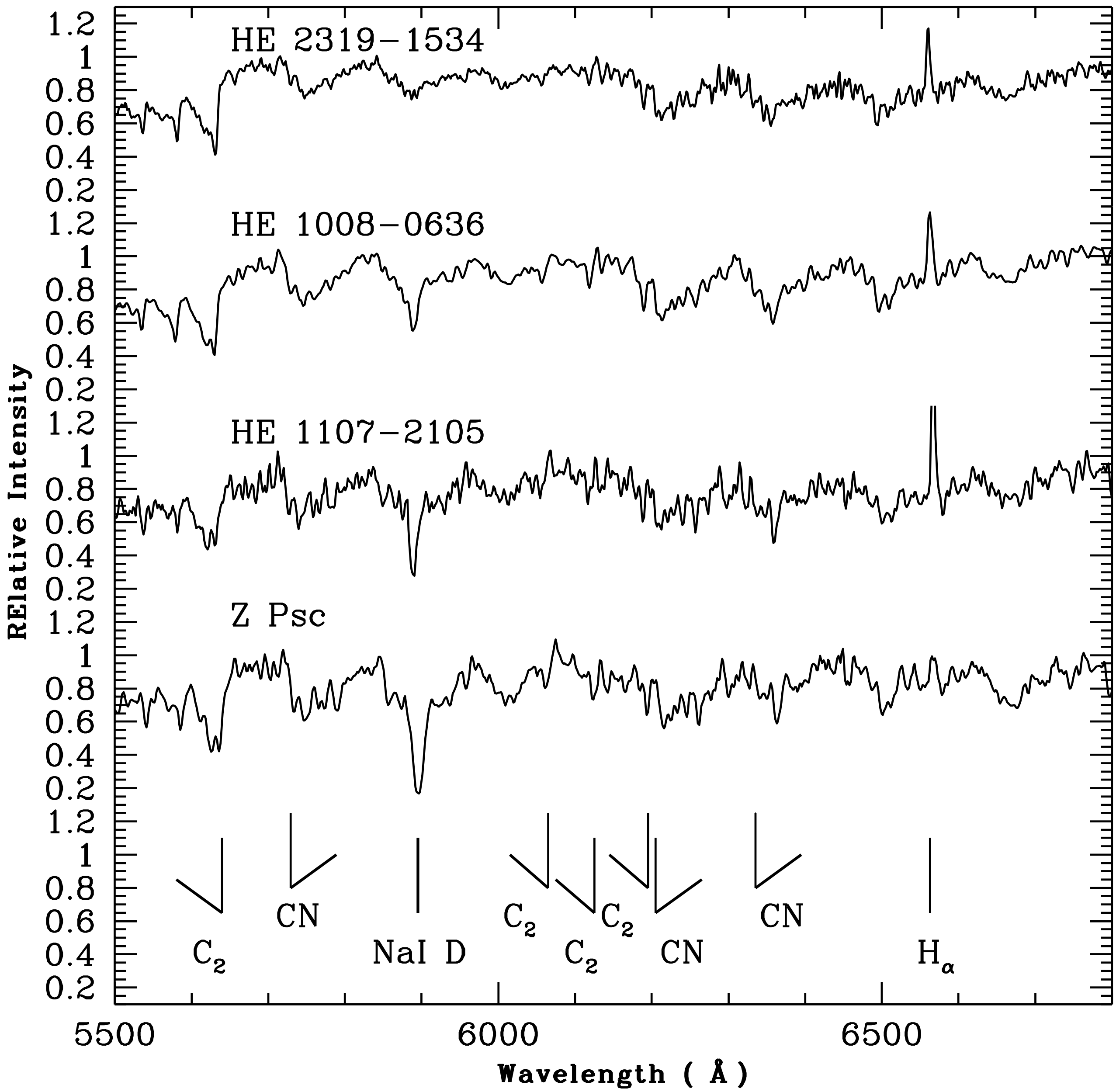

Figure 8. A comparison of the spectra of the candidate C-N stars HE 2319-1534, HE 1008-0636 and HE 1107-2105 with the spectrum of Z Psc in the wavelength region 5500 Å to 6800 Å. The bandheads of the prominent molecular bands, NaI D and H_α are marked on the figure. H_α is seen strongly in emission in the HE stars spectra.

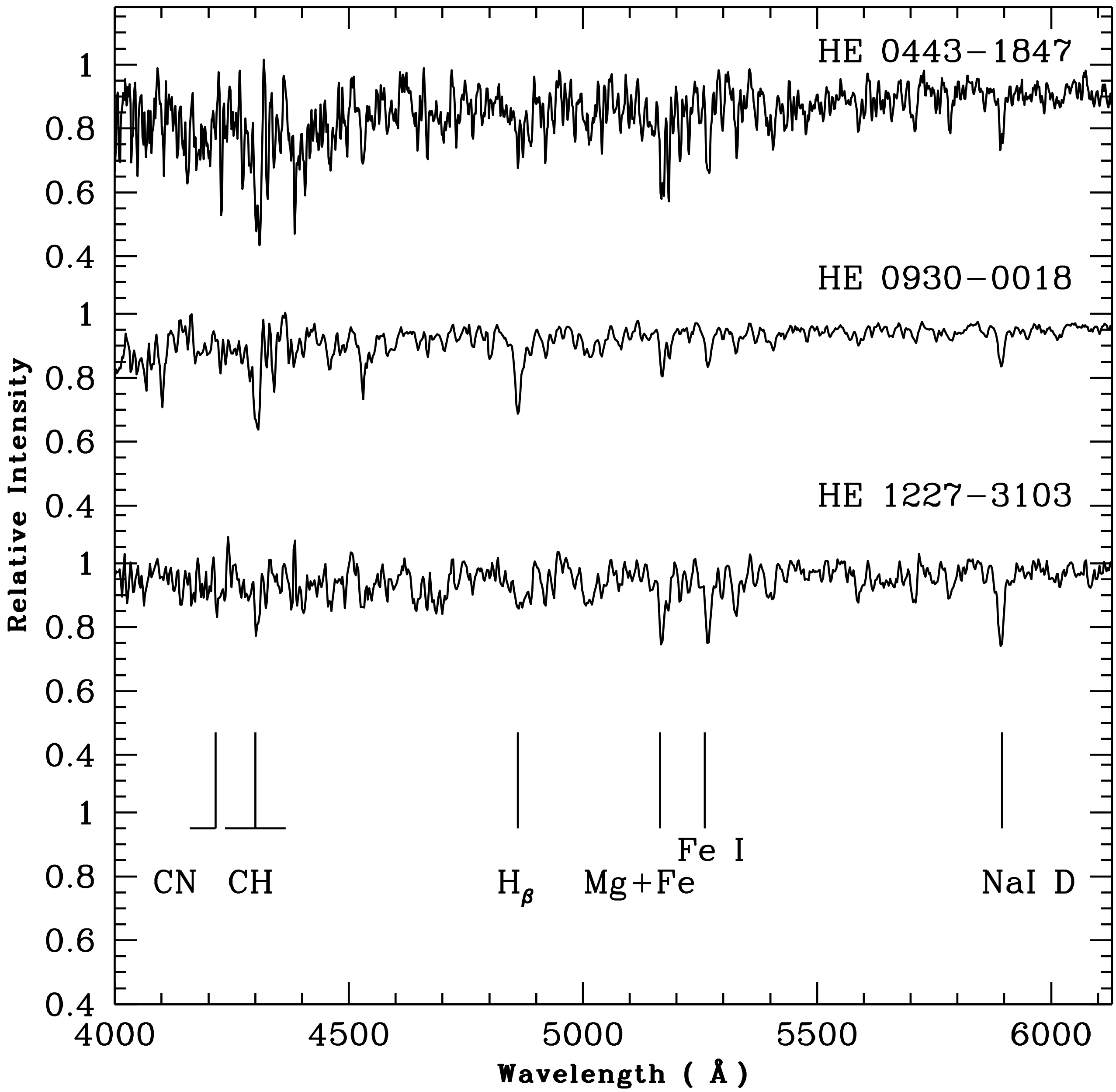

Figure 9. This figure demonstrates three examples of HE stars in the wavelength range 4000 - 6130 Å . The spectrum of HE 0443-1847 which exhibits very weak molecular bands due to CN around 4215 Å and a weak G-band of CH around 4300 Å (but no C_2 molecular bands); the spectrum of HE 0930-0018 which show a weak signature of G-band of CH around 4300 Å and the spectrum of HE 1227-3103 which does not show presence of any molecular bands due to C_2, CN or CH in its spectrum.