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Are DY Persei Stars Cooler Cousins of R Coronae Borealis Stars?

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Abstract

In this paper we present, for the first time, the study of low resolution *H*- and *K*-band spectra of 7 DY Per type and suspect stars, as well as DY Persei itself. We also observed *H*- and *K*-band spectra of 3 R Coronae Borealis (RCB) stars, 1 hydrogen-deficient carbon (HdC) star, and 14 cool carbon stars, including normal giants as comparisons. High $^{12}C/^{13}C$ and low $^{16}O/^{18}O$ ratios are characteristic features of majority RCBs and HdCs. We have estimated $^{16}O/^{18}O$ ratios of the program stars from the relative strengths of the $^{12}C^{16}O$ and $^{12}C^{18}O$ molecular bands observed in *K*-band. Our preliminary analysis suggests that a quartet of the DY Per suspects, along with DY Persei itself, seem to show isotopic ratio strength consistent with that of RCB/HdC stars, whereas two of them do not show significant ^{13}C and ^{18}O in their atmospheres. Our analysis provides further indications that DY Per type stars could be related to the RCB/HdC class of stars.

Key words: infrared: stars – stars: carbon – stars: evolution – stars: variables: general – supergiants

1. Introduction

R Coronae Borealis (RCB) stars are low mass, hydrogen deficient carbon-rich yellow supergiants associated with very late stages of stellar evolution. These are characterized by their unusual light variability, showing a rapid aperiodic light dimming of several magnitudes in the optical with a slow return to their maximum light, and exhibit IR excess (Payne-Gaposchkin & Gaposchkin 1938; Clayton 1996).

Six hydrogen deficient carbon stars (HdCs) are known. They are spectroscopically similar to RCBs, but most of them do not exhibit light declines or show IR excess (Warner 1967; Clayton 2012), the exception being HD 175893, which shows IR excess (Tisserand 2012).

DY Persei and DY Persei type (DY Per type) stars are, however, a peculiar class of cooler carbon stars showing also dramatic but slower light declines than RCBs and with more symmetric rise in time. Some IR excess (Alksnis 1994; Alcock et al. 2001) is also observed for these stars, with somewhat warmer circumstellar shells than RCBs (Tisserand et al. 2009). DY Per type star candidates are the stars having similar light curves and positions in the *J–H* and *H–K* diagram, like DY Per type stars found so far, but without any spectroscopic observations or confirmations. We introduce here the term "DY Per suspect," that is, carbon stars showing spectroscopic features similar to DY Per type stars but whose light curve has not shown characteristic symmetrical decline events but rather large photometric variations that could also be due to dust obscuration.

The effective temperatures of DY Per type stars appear to be at the cooler end of the known RCB stars (Keenan & Barnbaum 1997). DY Per type stars may be hydrogen deficient due to the absence of hydrogen Balmer lines in their spectra; nevertheless, the status of hydrogen deficiency is not yet clear due to their cooler effective temperatures and absence of flux in the *G* band of CH at 4300 Å region (Keenan & Barnbaum 1997; Začs et al. 2007; Yakovina et al. 2009). Until now, in addition to DY Persei itself, only seven Galactic DY Per type stars are known (Tisserand et al. 2008, 2013; Miller et al. 2012). Alcock et al. (2001) and Tisserand et al. (2004, 2009) reported around 27 Magellanic DY Per type stars and candidates, with more possible suspects given by Soszyński et al. (2009) through their OGLE-III light curves. Due to the small number of known DY Per type stars and candidates, it is a challenge to characterize these stars and investigate any possible connection with the RCBs. We therefore also introduced DY Per suspect stars in our study.

Two scenarios have been proposed to explain the evolutionary origin of an RCB star: first, the double-degenerate merger (DD) scenario involving the merger of an He and a C–O white dwarf (Webbink 1984; Saio & Jeffery 2002; Pandey et al. 2006), and second, the final helium shell flash (FF) scenario (Iben et al. 1983) involving a single star evolving into planetary nebular (PN) phase or post asymptotic giant branch (post-AGB) phase contracting toward the white dwarf sequence. The ignition of the helium shell in a post-AGB star (say, a cooling white dwarf) results in what is known as a late or very late thermal pulse (Herwig 2001) that ingests the thin hydrogen-rich outer layer, making the star hydrogen deficient, and the star expands to supergiant dimensions (Fujimoto 1977; Renzini 1979).

Based on the fluorine (Pandey et al. 2008), ^{13}C (Hema et al. 2012), and ^{18}O (Clayton et al. 2005, 2007; García-Hernández et al. 2009, 2010) abundances in RCB and HdC stars, a consensus is now emerging for the DD scenario; however, a small fraction of these may be produced by the FF scenario (Clayton et al. 2011).

Along with hydrogen deficiency, the main spectral characteristics of RCBs and HdCs that distinguish them from normal AGB and post-AGB stars are the presence of very high amounts of ^{18}O and weak or no presence of ^{13}C in their atmospheres. Using the NIR, *K*-band spectra of these stars, Clayton et al. (2005, 2007) and García-Hernández et al. (2009, 2010) found that the isotopic ratios of $^{16}O/^{18}O$, derived from the relative strengths of the observed $^{12}C^{16}O$ and $^{12}C^{18}O$ molecular bands, range from 0.3 to 20. Note that the typical value of $^{16}O/^{18}O \sim 500$ in the solar neighborhood and 200–600 in the Galactic interstellar medium (Geiss et al. 2002). Also, the $^{12}C/^{13}C$ ratio for several RCBs and all HdCs are significantly higher than the CN-equilibrium value of

Table 1
Log of Observations of RCB and HdC Stars as Well as DY Persei and the DY Per Affiliated Stars

Star Name (SIMBAD)	Date of Observation	K-mag.[a] (SIMBAD)	S/N (2.29 μ)	Star Type
HD 137613	2016 Apr 16	5.25	70	HdC
Z UMi	2016 May 01	7.3	55	RCrB
SV Sge	2016 Nov 18	5.9	110	RCrB
ES Aql	2016 Nov 18	7.9	105	RCrB
DY Persei	2014 Oct 04, 2016 Jan 16, 17, Nov 06	4.4	105	DY Per prototype
ASAS J065113+0222.1	2016 Jan 16, 17, 2017 Feb 23	4.9	80	DY Per type star[b]
ASAS J040907–0914.2 (EV Eri)	2016 Jan 16, 17 2016 Nov 06, 2017 Feb 23	3.6	95	DY Per suspect[c]
ASAS J052114+0721.3 (V1368 Ori)	2016 Jan 16, Nov 06, 2017 Feb 23	2.19	110	DY Per suspect[c]
ASAS J045331+2246.5	2014 Oct 04, 2016 Jan 16, 17	2.84	80	DY Per suspect[c]
ASAS J054635+2538.1 (CGCS 1049)	2016 Jan 16, 17, Mar 18	4.3	90	DY Per suspect[c]
ASAS J053302+1808.0 (IRAS 05301+1805)	2016 Jan 16, 17	5.6	90	DY Per suspect[c]
ASAS J191909–1554.4 (V1942 Sgr)	2016 Jul 01	1.06	105	DY Per type star[b]

Notes.
[a] Reported from the Two Micron All Sky Survey Point Source Catalog (Cutri et al. 2003).
[b] Miller et al. (2012).
[c] Tisserand et al. (2013).

3.4 (Alcock et al. 2001; Hema et al. 2012). Thus the low values of $^{16}O/^{18}O$ and high values of $^{12}C/^{13}C$ in both HdCs and RCBs make it obvious that these two classes of carbon-rich and hydrogen poor stars are indeed closely related.

On the contrary, the possible evolutionary connection of DY Per type stars with RCBs/HdCs or with normal carbon-rich AGBs needs to be explored. Začs et al. (2007) reported the high resolution spectrum of the DY Persei showing significant hydrogen deficiency with high $^{12}C/^{13}C$ ratio like most RCBs. It is to be noted that the low resolution spectra of DY Per type variables in the Magellanic clouds show significant enhancement of ^{13}C from the isotopic Swan bands at about 4700 Å, but the ^{13}CN band at 6250 Å is not seen (Alcock et al. 2001; Tisserand et al. 2009). Also, the enhancement of ^{13}C in the atmospheres of Magellanic DY Per type stars is reported for only 9 cases out of 27 (Alcock et al. 2001; Tisserand et al. 2004, 2009). Hence there seems to exist a mixed $^{12}C/^{13}C$ isotopic ratio in Magellanic DY Per type stars.

In this paper we search for the contributing spectral features involving ^{18}O and ^{13}C in the low resolution H- and K-band NIR spectra of the observed DY Per type stars and DY Per suspects. Note that our DY Per suspects are the cool carbon stars taken from Table 5 of Tisserand et al. (2013), which they rejected as RCB candidates due to enhanced ^{13}C in their spectra and no clear rapid decline events in their light curves. However, we selected these stars based on their similarity with DY Per type stars, as given in the description by Tisserand et al. (2013) in their text, verbatim, “Their light curves show variations up to 2 mag, but with no clear signs of a fast decline. Because they all present large photometric oscillations of $\sim$0.8 mag amplitude and their spectra do not show clear signs of presence of hydrogen, they should be considered as DY Per star candidates.”

Table 2
Log of Observations of Normal Cool Giants Selected from Jorissen et al. (1992) and Tanaka et al. (2007)

Star Name (SIMBAD)	Date of Observation	K-mag. (SIMBAD)	S/N (2.29 μ)	Star Type
Arcturus	2016 May 01	−2.9	85	K
HD 156074	2014 Oct 14	5.28	125	R
HD 112127	2016 Jan 17, Mar 18	4.17	170	R
BD+06 2063	2016 Apr 16	4.1	205	S
HR 337	2016 Jan 17	−1.85	120	M
HD 64332	2016 Apr 16	2.3	185	S
HD 123821	2016 Mar 18	6.3	110	R
HR 3639	2016 Apr 16	−1.7	130	S
HD 58521	2016 Mar 18	−0.44	140	S
HD 76846	2016 Jan 17, Mar 18	6.6	130	R
V455 Pup	2016 Jan 17, Apr 16, 2017 Feb 23	5.27	80	C
TU Gem	2016 Mar 18	0.78	85	N
Y CVn	2016 Apr 16	−0.81	80	J
RY Dra	2016 Apr 16	0.19	75	J

The objective is to explore possible connections between DY Per type stars and DY Per suspects with classical carbon stars or with RCBs/HdCs. Our observations, analysis, and results are discussed in the following sections.

2. Observations and Reductions

H- and K-band spectra of our target stars were obtained from the TIFR Near Infrared Spectrometer and Imager (TIRSPEC; Ninan et al. 2014), mounted on the Himalayan *Chandra* Telescope (HCT) in Hanle, Ladakh, India. The log of observations is given in Table 1 for the RCB and HdC stars,

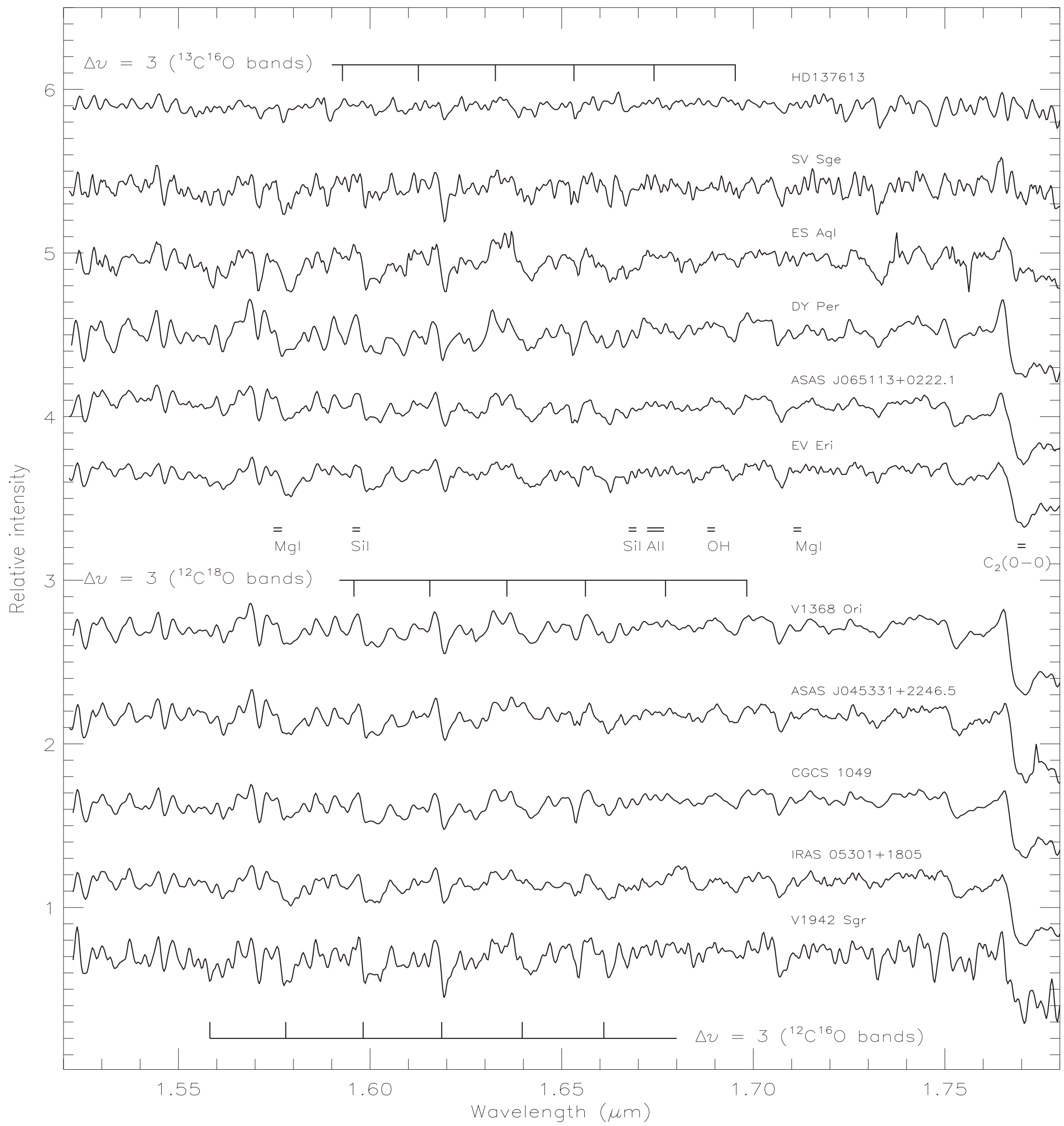

Figure 1. 1.52–1.78 μm spectra of RCBs, HdCs, DY Persei, and DY Per affiliated stars. The band head positions of $^{12}C^{16}O$, $^{12}C^{18}O$, and $^{13}C^{16}O$ and other key features are marked. The stars are ordered according to their increasing effective temperature (approximate) from the bottom to the top.

as well as all the DY Per affiliated stars, and in Table 2 for the normal and cool carbon stars.

Spectra were recorded in cross-dispersal mode in two dithered positions, with multiple exposures in each position having an average exposure time of 100 s for each frame. The frames were combined to improve the signal-to-noise ratio (S/N; see Tables 1 and 2). The recorded spectra in the *H*-band appear noisier than the *K*-band due to lower photon counts. For stars fainter than *K*-magnitude 6, frames of 500 s exposure were taken and combined to improve the S/N. After each set of star exposures, three continuum lamp spectra and an argon lamp spectrum were obtained. For removing the telluric lines from the star's spectrum, rapidly rotating O/B type dwarfs (telluric standards) were observed during each observing run in the direction of the program stars.

The slit setting mode S3 with a slit width of 1.″97 was available. For this slit setting, the average resolving power at the *H*- and *K*-central wavelength is about ∼900, as measured from the FWHM of the clean emission lines of the comparison lamp spectrum.

The data obtained are made available after dark and cosmic ray corrections. The Image Reduction and Analysis Facility (IRAF) software package was used to reduce these recorded spectra. The dithered frames of the recorded spectra were combined to correct for background emission lines using the ABBA dithering technique. A master flat was made by combining the continuum lamp spectra. The object frames were flat corrected using standard IRAF tasks. One-dimensional (1D) spectrum was then extracted and wavelength calibrated using the argon lamp spectrum. The wavelength-calibrated star's spectrum is then divided by a telluric standard's spectrum, to remove the telluric absorption lines, using the task TELLURIC in IRAF.

All seven DY Per affiliated stars (two DY Per type stars and five DY Per suspects) we observed were taken from the catalog of stars presented by Tisserand et al. (2013) and Miller et al. (2012). Our selection was limited by the location of the

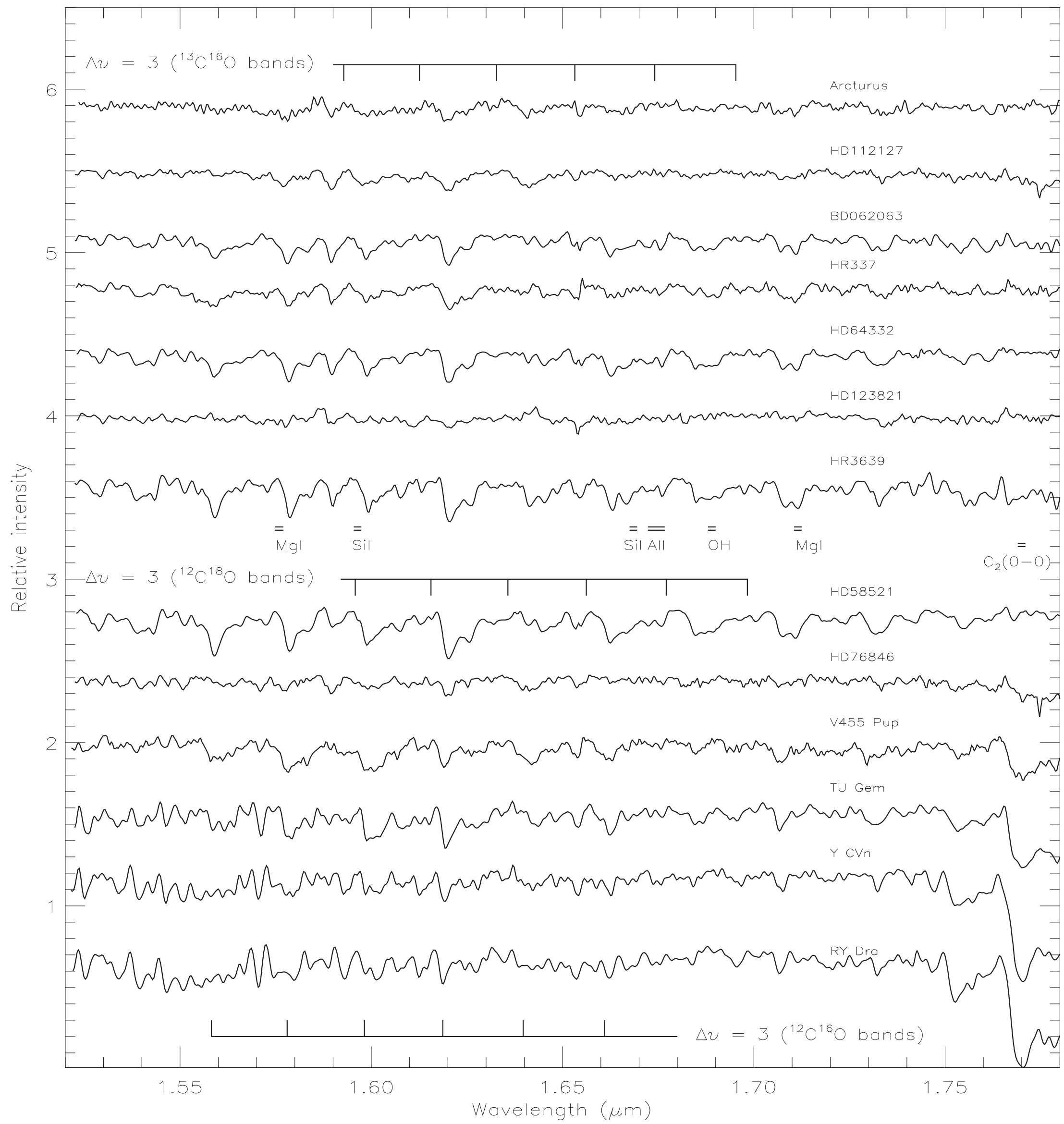

Figure 2. 1.52–1.78 μm spectra of normal giants/supergiants of different spectral type ranging from K giants on the top to cool N type carbon stars at the bottom. The band head positions of $^{12}C^{16}O$, $^{12}C^{18}O$, and $^{13}C^{16}O$ and other key features are marked.

observatory, HCT, where we could observe only the stars north of the $-25°$ declination. Three cool RCBs, Z UMi, SV Sge, and ES Aql, and one HdC star HD 137613 were also observed. Except for Z UMi, the other two RCBs were observed at about their maximum light, as verified from the AAVSO database (www.aavso.org). Z UMi was in a recovery phase ($\Delta V \sim 3$), and so the observed spectrum is particularly noisy. We have also observed a variety of normal giants/supergiants covering the effective temperature range of the program stars. The normal giants/supergiants were taken from Jorissen et al. (1992) and Tanaka et al. (2007), spanning K giants through N- and J-type cool carbon stars. These stars, along with the HdC/RCBs, were observed to compare and confirm the presence/absence of $^{13}C^{16}O$ and $^{12}C^{18}O$ features in DY Per type stars, and DY Per suspects.

3. CO Bands and Overview of the Spectra

The band head wavelengths of $^{12}C^{16}O$ are available in literature for both the *H*- and *K*-band region. We have calculated the wavelengths of $^{13}C^{16}O$ and $^{12}C^{18}O$ by using the standard formula for the isotopic shift from Herzberg (1950), and the ground state constants of $^{12}C^{16}O$ are taken from Mantz et al. (1975). We have verified our calculated band head wavelengths of $^{13}C^{16}O$ and $^{12}C^{18}O$ for the first overtone transition with those given by Clayton et al. (2005) and, hence, applied the same procedure to calculate the second overtone band head wavelengths of $^{13}C^{16}O$ and $^{12}C^{18}O$.

Figures 1 and 2 show the *H*-band (1.52–1.78 μm region) spectra of our program stars and the comparison stars (normal giants/supergiants), respectively; the second overtone features of $^{12}C^{16}O$, $^{12}C^{18}O$, and $^{13}C^{16}O$, including the C_2 Balik-Ramsay system (0–0), are marked with other key features. *H*-band spectra of HD 156704 (normal K giant) and Z UMi (RCB) were very noisy and, hence, not shown. The *K*-band (2.25−2.42 μm region) spectra of the program stars and the comparison stars are shown in Figures 3 and 4, respectively; the first overtone band heads of $^{12}C^{16}O$, $^{12}C^{18}O$, and $^{13}C^{16}O$ are indicated. The spectra shown in Figures 1–4 are normalized

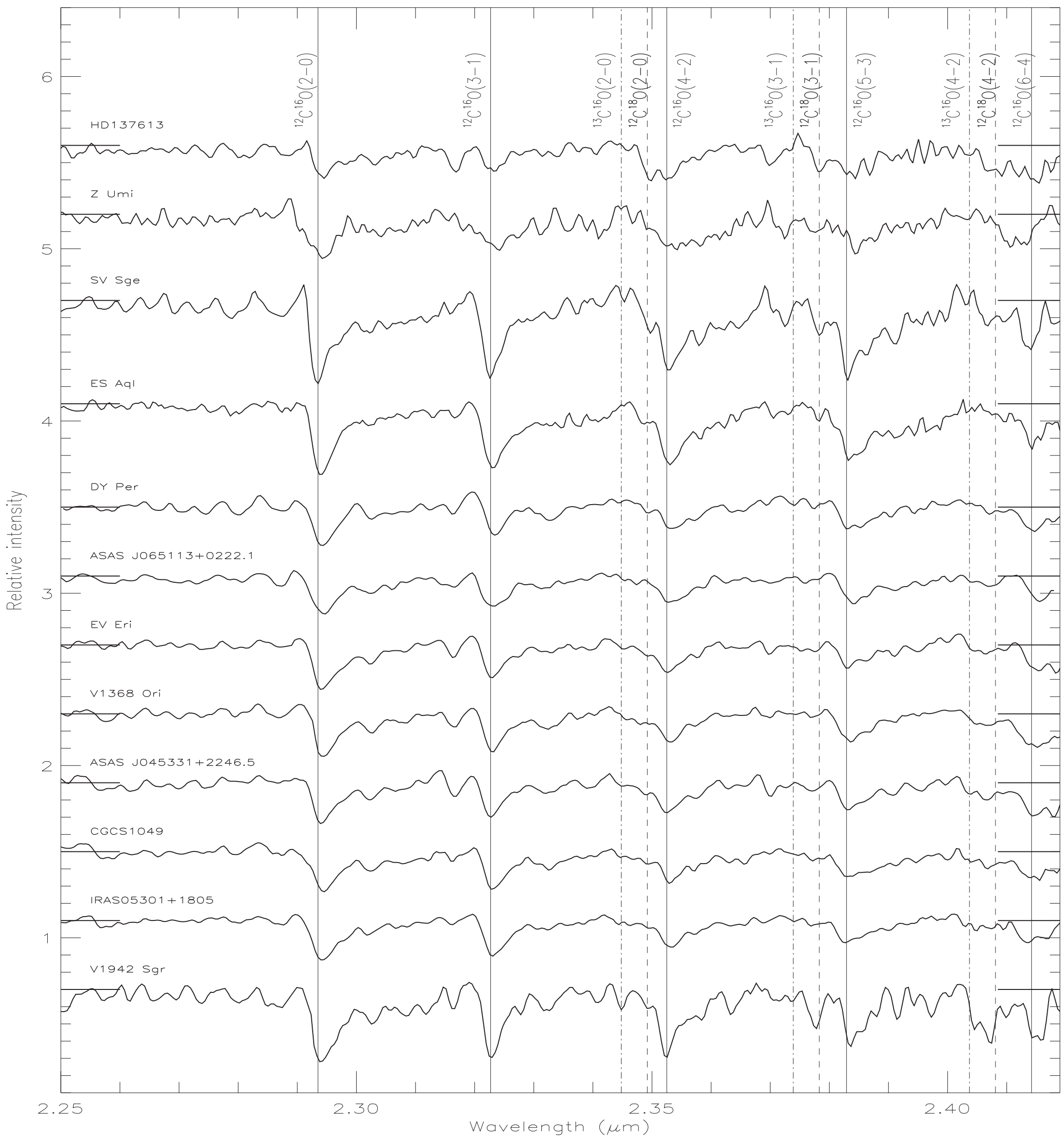

Figure 3. 2.25–2.42 μm spectra of RCBs, HdC, DY Persei, and DY Per affiliated stars, with wavelengths of $^{12}C^{16}O$, $^{12}C^{18}O$, and $^{13}C^{16}O$ indicated by vertical lines. The stars are ordered according to their increasing effective temperatures (approximate) from the bottom to the top. The position of the mean continuum for each spectrum is indicated by the line marked.

to the continuum and are aligned to lab wavelengths of $^{12}C^{16}O$ band heads.

4. Preliminary Results and Discussion

The observed stars show strong first overtone bands of $^{12}C^{16}O$ in the *K*-band region (see Figures 3 and 4). As reported by Clayton et al. (2007), prominent first overtone bands of $^{12}C^{18}O$ are seen with no detection of $^{13}C^{16}O$ in the two cool RCBs, SV Sge, and ES Aql, and in the HdC star HD 137613 (see Figure 3); Z UMi spectrum is particularly noisy but suggests the presence of $^{12}C^{18}O$ bands. As expected, a close inspection of the *K*-band spectra of the observed normal cool giants clearly shows the presence of $^{13}C^{16}O$ bands, including the prominent $^{12}C^{16}O$ bands with no detection of $^{12}C^{18}O$ bands (see Figure 4). We have used these HdC/RCBs' and cool giants' spectra as comparisons to look for the detection of $^{12}C^{18}O$ and $^{13}C^{16}O$ bands in the observed spectra of DY Persei, DY Per type stars, and DY Per suspects.

Among the DY Persei and seven DY Per affiliated stars, we find a suggestion of $^{12}C^{18}O$ bands with no clear detection of $^{13}C^{16}O$ bands in five of these stars: DY Persei, EV Eri, V1368 Ori, ASAS J045331+2246.5, and CGCS 1049 (see Figure 3). In Figure 3, spectra of two stars, ASAS J065113+0222.1 and IRAS 05301+1805, do not show any suggestion of $^{12}C^{18}O$ and $^{13}C^{16}O$ bands within the detection limit. In the case of V1942 Sgr's spectrum (see Figure 3), numerous features are observed, and we could not confirm the presence or absence of both $^{12}C^{18}O$ and $^{13}C^{16}O$ bands.

Based on the observed *K*-band spectra of HdC/RCBs, DY Persei, and DY Per affiliated stars, an attempt is made to estimate $^{16}O/^{18}O$ values by measuring the absorption depths of $^{12}C^{16}O$ and $^{12}C^{18}O$ band heads using 2−0 as well as 3−1 bands. This exercise is more difficult for the DY Per type stars since spectra of cool stars are full of absorption features and the blending of these features with the identified $^{12}C^{18}O$ band heads (in such low resolution spectra) is surely a possibility.

Table 3
Absorption Depths of First Overtone CO Band Heads and the Estimated $^{16}O/^{18}O$ and $^{12}C/^{13}C$ Ratios of RCBs, HdC, and DY Per Affiliate Stars

Star Name	Star Type	$^{12}C^{16}O$		$^{12}C^{18}O$		$^{16}O/^{18}O$	$^{12}C/^{13}C$
		2–0	3–1	2–0	3–1		
HD 137613	HdC	0.174	0.127	0.2	0.148	∼0.86 ± 0.02	>15
SV Sge	RCB	0.46	0.45	0.225	0.22	⩾2.05 ± 0.01	>45
ES Aql	RCB	0.373	0.362	0.093	0.088	⩾4 ± 0.1	>37
DY Persei	DY Persei	0.24	0.19	0.06	0.045	⩾4 ± 0.2	>24
ASAS J045331+2246.5	DY Per suspect	0.25	0.22	0.052	0.045	⩾5 ± 0.2	>19
V1368 Ori	DY Per suspect	0.275	0.25	0.05	0.045	⩾5.5 ± 0.1	>25
EV Eri	DY Per suspect	0.29	0.22	0.04	0.03	⩾7.5 ± 0.2	>20
CGCS 1049	DY Per suspect	0.25	0.23	0.025	0.024	⩾10 ± 0.5	>19
IRAS 05301+1805	DY Per suspect	0.24	0.23	…	…	…	>19
ASAS J065113+0222.1	DY Per type star	0.22	0.20	…	…	…	>15

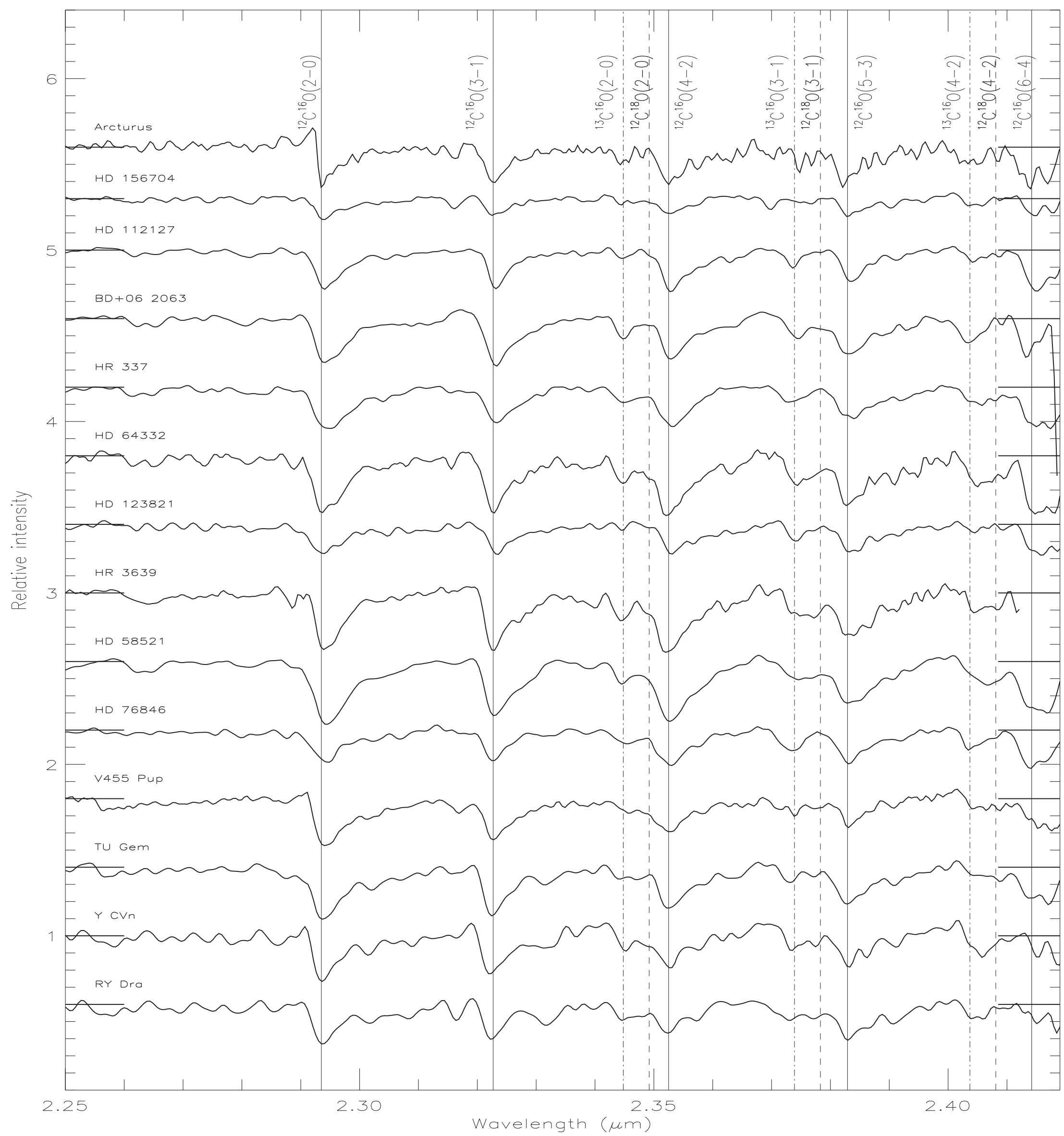

Figure 4. 2.25–2.42 μm spectra of normal giants of different spectral type, ranging from K giants at the top to cool N type carbon stars at the bottom. As in Figure 3, wavelengths of $^{12}C^{16}O$, $^{12}C^{18}O$, and $^{13}C^{16}O$ are indicated by vertical lines. The position of the mean continuum for each spectrum is indicated by the line marked.

Yet with the exact wavelength matches we could confirm the presence of $^{12}C^{18}O$ bands. As these bands are not completely resolved and the bands from the more abundant isotopic species are possibly saturated, the estimated $^{16}O/^{18}O$ values are the lower limits in most cases (see Table 3). Using synthetic spectra for the analysis is avoided, as it is extremely difficult to

Table 4
Absorption Depths of First Overtone CO Band Heads and the Estimated $^{12}C/^{13}C$ Ratios of Normal and Cool Carbon Giants

Star Name	$^{12}C^{16}O$		$^{13}C^{16}O$		$^{12}C/^{13}C$
	2–0	3–1	2–0	3–1	
Arcturus	0.228	0.205	0.098	0.095	>2.25 ± 0.2
HD 156704	0.125	0.11	0.04	0.032	>3.25 ± 0.2
HD 112127	0.215	0.225	0.060	0.08	>3.2 ± 0.4
BD+062063	0.255	0.268	0.126	0.125	>2.05 ± 0.1
HR 337	0.24	0.21	0.089	0.087	>2.55 ± 0.2
HD 64332	0.33	0.332	0.158	0.165	>2.05 ± 0.1
HD 123821	0.167	0.186	0.052	0.083	>2.75 ± 0.5
HR 3639	0.33	0.331	0.16	0.145	>2.15 ± 0.2
HD 58521	0.365	0.322	0.13	0.102	>3 ± 0.2
HD 76846	0.184	0.186	0.088	0.101	>1.9 ± 0.2
V455 Pup	0.266	0.243	0.066	0.07	>3.75 ± 0.3
TU Gem	0.312	0.293	0.068	0.075	>4.2 ± 0.3
Y CVn	0.262	0.2512	0.1632	0.16	>1.6 ± 0.2
RY Dra	0.215	0.213	0.123	0.118	>1.75 ± 0.1

identify all the contributing features from the observed low resolution spectra.

As all the DY Per affiliate stars observed here were reported to show a strong presence of ^{13}C in their respective discovery papers (Miller et al. 2012; Tisserand et al. 2013), we expected enhanced $^{13}C^{16}O$ depths in the *K*-band spectra. We have estimated $^{12}C/^{13}C$ ratios from the *K*-band absorption depths of $^{12}C^{16}O$ and $^{13}C^{16}O$ band heads. Since the observed depth at $^{13}C^{16}O$ band heads is more or less comparable with the noise levels of the observed spectra, we conclude that there is no clear suggestion of $^{13}C^{16}O$ in their spectra within the detection limit. However, we have estimated the lower limits of the $^{12}C/^{13}C$ ratios measured from the *K*-band spectra of these stars, as given in Table 3. The depth at the $^{13}C^{16}O$ 2−0 band head region is used due to the better signal than other regions. We find that our estimated lower limit on $^{12}C/^{13}C$ for DY Persei is in line with the range of values (20–50) obtained by Keenan and Barnbaum (1997).

We have also estimated the $^{12}C/^{13}C$ ratios for the observed normal and the cool carbon giants (see Table 4) for comparison. These very low lower limits on $^{12}C/^{13}C$ ratios measured for these carbon giants clearly show enhanced ^{13}C in contrast to the DY Per affiliates. The $^{12}C/^{13}C$ ratios are expected to be more than the estimated lower limits for the normal and cool carbon giants.

In the *H*-band region, the observed spectra do show the second overtone bands of $^{12}C^{16}O$, but most of these are affected by noise. The strength of $^{12}C^{16}O$ features in the *H*-band is much weaker compared to that in the *K*-band. Thus detection of $^{12}C^{18}O$ and $^{13}C^{16}O$ in the *H*-band spectra is extremely difficult due to noise issues. For example, Figures 1 and 2 show the atomic features as well as the wavelength positions of $^{12}C^{18}O$ and $^{13}C^{16}O$ band heads.

5. Conclusions

Our analysis shows the presence of strong $^{12}C^{18}O$ band heads in RCB and HdC stars. The HdC star, HD 137613, and the two RCB stars, SV Sge and ES Aql, are common with Clayton et al. (2007). Our $^{16}O/^{18}O$ estimates for these three stars are in fair agreement with the values given in column (4) of Clayton et al. (2007), Table 2.

For DY Persei and the relatively cooler DY Per affiliated stars, our conclusions are less clear; however, there seems to be an indication of ^{18}O in the atmosphere of DY Persei and four DY Per suspects and no ^{13}C (within the detection limit), which is the main isotopic signature of RCB/HdC stars. In the case of the DY Per type star, V1942 Sgr, numerous features are observed, and we could not confirm the presence or absence of both $^{12}C^{18}O$ and $^{13}C^{16}O$ bands. Note that the *K*-band spectra of all the normal carbon stars, with similar S/N spectra of DY Per affiliates, having similar effective temperatures, show prominent $^{13}C^{16}O$ bands. On the contrary, one DY Per type star ASAS J065113+0222.1, and one DY Per suspect IRAS 05301 +1805 show little or no presence of both ^{18}O and ^{13}C in their atmosphere.

So whether DY Per type stars are the cooler cousins of RCBs or just a counterpart of normal carbon-rich AGBs suffering ejection events can be better explored through the analyses of high resolution *H*- and *K*-band spectra. Our preliminary analysis suggests that a quartet of suspects along with DY Persei itself show prominent $^{12}C^{18}O$ bands and no $^{13}C^{16}O$ bands, which is in sharp contrast to the normal carbon stars and much similar to RCBs, and builds up a strong case to dig deeper into the high resolution spectra of these stars to find their evolutionary origins.

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