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Revised classification of the SBS carbon star candidates including the discovery of a new emission line dwarf carbon star⋆,⋆⋆,⋆⋆⋆ *(Research Note)*

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ABSTRACT

Context. Faint high-latitude carbon stars are rare objects commonly thought to be distant, luminous giants. For this reason, they are often used to probe the structure of the Galactic halo; however, more accurate investigation of photometric and spectroscopic surveys has revealed an increasing percentage of nearby objects with luminosities of main sequence stars.
Aims. In the General Catalogue of the Second Byurakan Survey (SBS) only ten objects are indicated as carbon star candidates. This work aims at clarifying the nature of these stars.
Methods. We analyzed new optical spectra and photometry and used astronomical databases available on the web.
Results. We verified that two stars are N-type giants already confirmed by other surveys. We found that four candidates are M type stars and confirmed the carbon nature of the remaining four stars; the characteristics of three of them are consistent with an early CH giant type. The fourth candidate, SBS 1310+561 identified with a high proper motion star, is a rare type of dwarf carbon showing emission lines in its optical spectrum. We estimated absolute magnitudes and distances to the dwarf carbon and the three CH stars.
Conclusions. Our limited sample confirmed the increasing evidence that spectroscopy or colour alone are not conclusive luminosity discriminants for CH-type carbon stars.

Key words. surveys – stars: carbon – stars: individual: SBS 1310+561

1. Introduction

The faint high-latitude carbon stars (FHLCs , $R > 13$, $|b| > 30°$) are rare objects. The observed spatial distribution indicates a surface density less than 0.06 deg^{-2} (e.g., Downes et al. 2004 and references therein); for this reason they are seldom the specific target of dedicated photometric or spectroscopic surveys. It is of interest that their colours are very similar to those of the much more numerous QSOs. In surveys searching QSO, FHLCs are a small fraction of contaminants initially flagged as high-redshift QSO candidates and then identified as galactic objects by their spectra showing the characteristic absorption features of C2 Swan bands (e.g., Totten & Irwin 1998; Christlieb et al. 2001; Downes et al. 2004). In this way distant giants in the halo are usually discovered, but a non-negligible fraction has a significant proper motion indicative of a close object having the luminosity of a main sequence star.

The discoveries of red faint stars from the prism surveys conducted at the Byurakan Astrophysical Observatory (BAO) are typical examples of this kind of follow-up. The results obtained by the first spectroscopic survey conducted at BAO have stimulated the need for a deeper survey to reach fainter magnitudes in searching for extragalactic objects with UV excesses and emission lines. The plates of the SBS were obtained at the BAO between 1974 and 1991 with the 1m Schmidt telescope and three objective prisms in the range $7^{\rm h}40^{\rm m} < \alpha < 17^{\rm h}15^{\rm m}$ and $+49° < \delta < +61°$ (Markarian & Stepanian; 1983, Stepanian et al. 1990); follow-up spectroscopic programme with better resolution started soon after and, as a by-product a number of stellar objects were also found, mainly white dwarf (WD) and sdB subdwarfs. In some cases cool stars were also serendipitously discovered, the most important being SBS 1517+5017, showing a peculiar energy distribution. Higher resolution spectra have revealed that the object is a rare type of binary system composed of a quite hot white dwarf and a dwarf carbon star (Liebert et al. 1994). The General Catalogue of the SBS published by Stepanian (2005) is mainly dedicated to extragalactic objects, but it also includes 39 late type star candidates, listed in Table 41. Most of them simply classified as red stars are probably M type stars, and only ten were indicated as possible carbon stars.

In the present paper we clarify the nature of these ten carbon star candidates. We discuss the characteristics of four

⋆ Based on observations made at the 1.52 m telescope of the Bologna Observatory and 1.83 m telescope of the Asiago Observatory.
⋆⋆ Figures 1, 3, and 5 are available in electronic form at http://www.aanda.org
⋆⋆⋆ The spectra (ascii files) are only available at CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/532/A69

new confirmed C-type stars with particular attention to SBS 1310+561, which we discovered to be a dwarf carbon star (dC) showing emission lines in the spectrum, making it the most interesting object of this sample.

2. SIMBAD association

The coordinates of the ten carbon star candidates published in the SBS General Catalogue refer to the equinox 1950, with uncertainties of 1−2 arcmin, making it practically impossible the direct identification of the objects on the Digital Sky Survey maps. We precessed the coordinates then, in order to check their carbon rich nature, we started looking for these stars in the Hamburg Quasar Survey low-resolution spectroscopic database (HQS, Hagen et al. 1995) in a field of 5 arcmin radius around the positions of each SBS object. From closer inspection, we verified that two of them, SBS 0748+540 and SBS 0832+534, were also candidates from other surveys with different names and were already confirmed as N type giants on the basis of spectroscopic or photometric follow-up (Knapik et al. 1999). These two stars have already been included in the General Catalogue of Galactic Carbon Stars (GCGCS, Alksnis et al. 2001). Four of the remaining eight stars are in fact M type stars with erroneous classification as C stars in the SBS General Catalogue. Two of them could be identified with known M type variables, already included in the General Catalogue of Variable Stars (X Uma is a Mira and AY Dra is a semi regular variable star, Samus et al. 2010). We classified the other two objects as M stars with our recent observations as described below. The position of SBS 0854+530 corresponds to a variable star with no previously published spectral classification (Maciejevski et al. 2004). The last M star, SBS 1444+503 is a faint object not associated with known sources.

The remaining four carbon star candidates were not included in GCGCS. Although their HQS spectra showed strong absorption bands, the resolution was not sufficient to derive more detailed information. We clarified their carbon nature and kinematical properties by the use of modern astronomical databases and by our recent dedicated observations described in the following sections.

In Table 1 we give the revised data for all the ten SBS carbon candidates, including the four M and the two known carbon stars.

3. Recent observations

We observed the four C star candidates on 18 and 19 January 2010 with the 1.52 m Cassini telescope of the Bologna Astronomical Observatory equipped with the Bologna Faint Object Spectrometer and Camera BFOSC, and an EEV P129915 CCD detector in the spectroscopic and photometric (B, V, R Johnson bands) modes. We obtained moderate resolution spectra for all the stars in the range 3700−8500 Å (grism #4, dispersion 3.9 Å/pixel). We also obtained spectra in the range 4000−6600 Å (grism #7, dispersion 1.8 Å/pixel) for SBS 0759+533 and SBS 1310+561. We reduced all the data by means of standard IRAF procedures. In Table 2 we present the averages of our photometry (3 values for each band); the corresponding "rms" from the individual values range between 0.05 and 0.09 mag, quite good even though the nights were not excellent for photometric observations. In the last column we report the Galactic colour excess in the direction of the stars according to the extinction maps by Schlegel et al. (1998). We finally obtained a spectrum of our M candidate SBS 0854+530 with the same equipment with grism #4 on 6 February 2011 and a spectrum of SBS 1444+503 on 9 February 2011 with the 1.82 m telescope of the Asiago Astronomical Observatory equipped with the Asiago Faint Object Spectrometer and Camera AFOSC and a TK1024 CCD and grism #4, with a dispersion 4.8 Å/pixel in the range 3900−8500 Å.

Table 1. Revised data for the ten C star candidates of the SBS General Catalogue.

SBS number	Coordinates (GSC2.3) α	δ	sp. class	SIMBAD association	Ref.
0748+540	07 52 04.0	+53 56 54	N	CGCS 1889	[1]
0759+533	08 03 12.4	+53 11 34	CH		
0832+534	08 36 27.6	+53 17 52	N	CGCS 2244	[1]
0837+503	08 40 49.5	+50 08 12	M	X UMa	[2]
0854+530	08 57 44.3	+52 47 28	M9	GSC03805-0109	[3]
1310+561	13 12 42.6	+55 55 54	dC		
1444+503	14 46 36.4	+50 11 28	M4V		
1537+571	15 38 39.3	+57 01 33	M	AY Dra	[2]
1543+555	15 45 22.4	+55 21 33	CH		
1701+555	17 02 05.6	+55 27 13	CH		

Notes. Description of the columns: 1) SBS number according to Stepanian (2005); 2) coordinates in the Guide Star Catalogue (Lasker et al. 2008) of the identified objects; 3) revised spectral classification; 4) other association according to SIMBAD database.

References. [1] Alksnis et al. (2001); [2] Samus et al. (2010); [3] Maciejevski et al. (2004).

Table 2. CCD optical photometry of our confirmed carbon stars.

SBS number	GSC2.3 number	B mag	V mag	R mag	$E(B-V)$ mag
0759+533	N8T4000463	14.15	13.23	12.50	0.034
1310+561	N4BP000199	16.6	14.76	14.00	0.015
1543+555	N4G7000252	16.42	14.83	14.20	0.011
1701+555	N4ID000249	16.24	15.19	14.12	0.016

4. Data analysis

4.1. Spectral classification

The spectra of SBS0854+530 and SBS1444+503 confirm the nature of M type stars. SBS 0854+530 presents features typical for very late giant, very similar to those of the M7.5 giant RX Boo; the most prominent absorptions belong to the TiO bands at 4761, 4954, 5167, 5448, 5862, 6159, 6700, 7055, 7600 Å, and the VO bands of the red system with several bandheads in the range 7334−7472 Å, and 7851−7973 Å, seen only in late type stars. SBS 1444+503 can be classified as an M4 dwarf similar to GJ402 and LHS486. Its most prominent features are: the TiO absorption bands at 4954, 5167, 5448, 6700, 7100, 7600 Å; the Mg b triplet 5167, 5173, 5184 Å; very strong NaD doublet; the CaOH diffuse bands centered at 5550 and 6230 Å; the MgH bands at 4780, 5211 Å; the CaH at 6382, 6908, 6946 Å. We will study these stars in more details in a forthcoming paper dedicated to the other 29 late type star candidates of the General Catalogue of the SBS.

Concerning the four carbon candidates, the raw spectral classification from HQS was confirmed by our new spectra, which allowed determination of the carbon type class, finding very

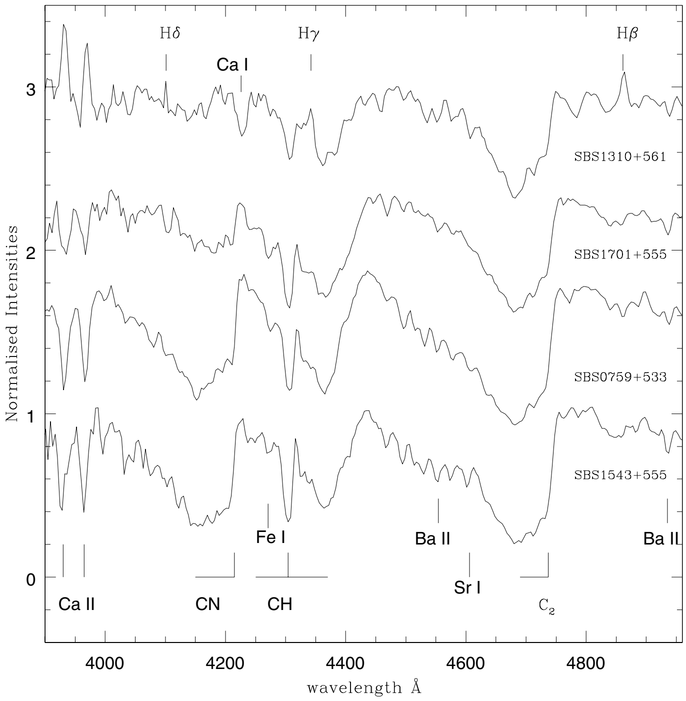

Fig. 2. Spectra of the four carbon stars in the wavelength region 3900−4960 Å, normalized to the continuum and vertically shifted. The most prominent features are indicated.

interesting results in one case. All six low-resolution spectra in the range 3850−7600 Å are presented in Fig. 1, including those of the two M stars. The spectra of the four carbon stars in the wavelength region 3900−4960 Å normalized to the continuum are shown in Fig. 2. To be consistent with the data of SBS 1543+555 and SBS 1701+555 for which we only have grism #4 spectra, and to show the region below 4000 Å, the lower resolution spectra of SBS 1310+561 and of SBS 0759+533 have been plotted in this figure. The better resolved spectra of these two stars are shown in Fig. 3. We classified our stars on the basis of a number of spectroscopic and photometric characteristics. At first glance the spectra could indicate either C−R or CH type stars. Although our spectral resolution does not allow us to derive isotopic ratios, in any case it is sufficient to detect and measure the prominent spectral features defining the carbon type by comparing our targets with those of known standards. In Fig. 2 important lines and molecular bands are indicated with vertical bars. Three stars, SBS 0759+533, SBS 1543+555, and SBS 1701+555, are characterized by a number of absorption features that can be summarized as follows:

– Atomic lines: Ca II K and H; Fe I 4271 Å; Ba II 4935, 4554, 6497 Å. The last two absorptions could have a contribution from close CN lines, but the features are also present in the spectrum of SBS 1701+555 where the CN bands are faint and the strength of the isolated 4935 Å line is similar in the three stars with an equivalent width ≃1.5 Å with respect to the local continuum. The Ca I at 4226 Å is not detectable (marginally visible in the grism #7 spectrum of SBS 0759+533).
– Molecular bands: strong G band of CH , with prominent secondary P branch at 4342 Å ; strong $^{12}C^{12}C$ bands at 4737, 5165, 5635, 6122, 6192 Å ; $^{12}C^{13}C$ bands, if present are faint and not resolved in the grism #4 spectra. The $^{12}C^{13}C$ band head at 4744 Å is marginally detected in the grism #7 spectrum of SBS 0759+533. The CN bands at 4215, 5264, 5746, 6206, 6360 Å are present in the spectra of SBS 0759+533 and SBS 1543+555. In SBS 1701+555, only the band at 4215 Å is strong, other CN bands are barely visible or absent.

Considering the global appearance of the spectra, one can see that with marginal differences in the CN bands SBS 1701+555 matches the spectrum of HD 5223 quite well, which is used as CH standard by Goswami et al. (2010) and classified as C−H 3, C_2 4.5, CH 5 in Barnbaum et al. (1996). The spectra of SBS 0759+533 and SBS 1543+555 are similar to the CH star V Ari, classified as C−H 3.5, C_2 5.5, CH 4.5 in Barnbaum et al. (1996), but also to the late-R star RV Sct (Goswami et al. 2010 and references therein). The close inspection of the spectral lines and the supplementary diagnostics of the infrared colours (see below) have been fundamental in discarding this second hypothesis.

In summary, the spectroscopic and photometric characteristics of SBS 0759+533, SBS 1543+555 and SBS 1701+555 led us to classify these stars as belonging to the CH class, with the differences in the strength of CN bands most probably depending on the chemical composition of the atmospheres of individual stars (see Wallerstein & Kanpp 1998; Lloyd Evans 2010).

The most interesting object is SBS 1310+561, which shows a number of differences with respect to the other stars. The Na D doublet is very strong ($EW = 15.0 \pm 0.5$ Å). Ca I at λ 4226 Å and the molecular band at λ 5211 Å of MgH are present with equivalent widths of 3.5 and 4.1 ± 0.2 Å, respectively. Noticeably, all the Balmer lines are in emission, and the Ca II doublet at λ 3934, 3968 Å is also in emission with $EW = 7.0 \pm 0.4$ Å and 6.0 ± 0.5 Å. These values must be taken with caution given that, owing to the low S/N at the very blue end of the spectrum and the spectral resolution, we could not evaluate the contribution from the absorption components. While not common, emissions are still expected in carbon giants (see for example Totten et al. 2000 and references therein), but in our case there are at least two indications that it is a main sequence object: one is the high proper motion $\mu_\alpha = -118$ mas/y and $\mu_\delta = +28$ mas/y (PPMXL catalogue, Roesner et al. 2010); the other three stars have negligible proper motions in both directions. Another promising good low-luminosity indicator of CH stars is the strength of the two CaH bands at λ 6382 and λ 6750−6950 Å (Margon et al. 2002). From a statistically significant sample of FHLCs, those authors find these features strong only in the cool stars with detected proper motion. We measured an indicative value of the heliocentric radial velocity of the star by using the hydrogen emission lines of the higher resolution spectra. From Gaussian fits of H_α and H_β we found −50 and −30 km s^{-1} with uncertainties of about 20 km s^{-1}.

4.2. Optical and infrared photometry

The optical colours are typical of CH-type stars with the dwarf being the reddest. We can assume that these colours are very close to the intrinsic values because at the Galactic latitudes of our stars, the interstellar reddening is negligible (see Table 2). All the data from our new photometry agree quite well with those of GSC2.3 within the errors, indicating that no major changes occurred between the different epochs of observations. For SBS 0759+533, SBS 1310+561, and SBS 1543+555, there are also photometric data obtained during the Sloan Digital Sky Survey. The first star is saturated. For the other two stars the original photometry, converted to the Johnson bands with the transformation equations by West et al. (2005), yields the following

Table 3. Infrared photometry and colours of the four carbon stars. The last two columns are in the SAAO system.

SBS number	2MASS identification	J mag	H mag	K_s mag	$R-J$ mag	$J-H$ mag	$H-K$ mag
0759+533	J08031240+5311340	10.84	10.27	10.05	1.66	0.66	0.16
1310+561	J13124251+5555546	12.06	11.22	10.80	1.94	0.92	0.36
1543+555	J15452240+5521327	12.57	11.85	11.62	1.63	0.80	0.19
1701+555	J17020556+5527134	12.87	12.34	12.19	1.25	0.60	0.12

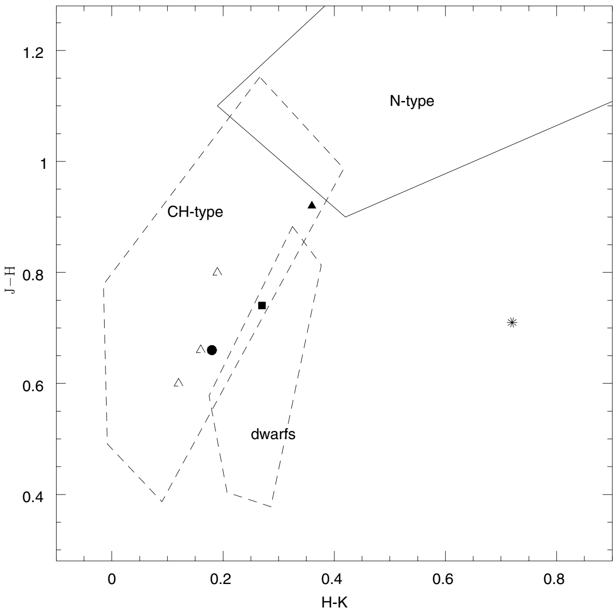

Fig. 4. Near infrared two-colour diagram in the SAAO photometric system; the zones limiting the loci of the different carbon classes are those defined in the Fig. 3 by Totten et al. (2000). Open triangles: the three SBS−CH giants; filled triangle: SBS1310+561; filled square: CLS29; filled circle: PG0824+289; star: SDSS J085853.3+012243.

magnitudes: for SBS 1310+561: B = 16.8, V = 15.0, R = 13.8, and for SBS 1543,+555: B = 16.6, V = 15.2, R = 14.2 mag. Considering our measurement uncertainties and the fact that the SDSS conversions are not calibrated to carbon stars, the agreement is very good.

From the infrared magnitudes published in the Two Micron All Sky Survey (2MASS) catalogue (Skrustkie et al. 2006), we could check the position of our stars in the infrared colour-colour diagrams. In Table 3 we present the 2MASS magnitudes and $R-J$ colour. In the last two columns we report the colours $J-H$, $H-K$ in the SAAO photometric system obtained by transforming the 2MASS magnitudes according to the formulae by Koen et al. (2007). In the infrared two-colour diagram shown in Fig. 4 SBS 0759+533, SBS 1543+555 and SBS 1701+555 are placed inside the region occupied by the large majority of CH-type stars studied by Totten et al. (2000), colours confirming the spectral classification. For these stars the need for a spectroscopic classification originates from there being no obvious distinction in the colours of CH and early C−R stars. We discuss this argument more fully in Sect. 5.

SBS 1310+561 lies on the ill-defined boundary between CH and the dwarf zone. Border-line colours are not unique in the small family of the emission line dC. To our knowledge there are only three confirmed dC stars previously reported showing emission lines: CLS29, identified by Totten et al. (2000), which also lies on the boundary region between CH and dwarfs. PG0824+289 which is placed in the CH domain, has a composite spectrum (Heber et al. 1993); for this star most probably the optically visible white dwarf companion affects the infrared emission of the system. The opposite case is the third star, SDSS J085853.3+012243, which is the reddest object of the sample studied by Downes et al. (2004). The situation is less clear for SBS 0759+533, SBS 1543+555, and SBS 1701+555 when using the 2MASS colours directly and the more general diagrams of Figs. 2 ($R-J$ vs. $J-K_s$) and 3 ($J-H$ vs. $H-K_s$) of Lowrance et al. (2003). But these authors point out that the tracks for giants and dwarfs overplotted in their Fig. 3 were obtained by interpolating the data of Fig. 5 of Bessel & Brett (1988), based on the colours of non-carbon stars. In these plots SBS 1310+561 falls well inside the region defined by known dC stars.

The photometric behaviour of all the four stars has been monitored by the Northern Sky Variability Survey (NSVS, Wozniak et al. 2004) between March 1999 and May 2000. SBS 0759+533 is constant with very little scatter from the mean magnitude. The three other stars show fluctuations of about ±0.4 mag amplitude as shown in Fig. 5. It is worth remembering that the NSVS system has an overall response that is similar to the Red Johnson band, but the values are measured from an unfiltered CCD detector, therefore the zero magnitude strongly depends on the stellar colours. For the considered stellar type the NSVS magnitudes are fainter of about 0.3−0.5 mag with respect to the Johnson filter.

5. Discussion

It is not necessary to repeat here the detailed discussion by Margon et al. (2002) and Downes et al. (2004) on the reliability of the spectroscopic and photometric luminosity discriminants for CH-type stars. It can be sufficient to remember their final comment that at low dispersion "spectra and colours of the disparate classes are frustratingly similar". The same consideration is valid when the various types of carbon stars are considered. While infrared colours of N and late-R giants are separated well from CH and early-R stars, there is no clear distinction between CH and early-R, as noted in Sect. 4.2, and even between N and late-R types. This problem has been discussed in detail by Zamora et al. (2009) who did an accurate photometric and spectroscopic analysis of 17 previously classified R stars. The high resolution spectra and the use of the most recent stellar models allowed these authors to find that 40% of their sample were incorrectly classified, and this result confirms previous doubts about the real relative number of R and CH types among the carbon stars. The importance from the evolutionary point of view has been discussed in depth by Zamora et al. (2009); we refer to that paper for further reading.

We want to remark here that there are also a few minor, but very common, causes of confusion in the colour plots. One is that data from different photometric systems are often put together without taking the necessary transformations into account, increasing in this way the spread of the results. Another is that previous schemes are often strictly adopted without considering that the conditions are never tight, and/or those schemes are based on possibly different photometric systems. In our case, which also deals with an emission line star we paid particular attention to the photometric system used to place our stars in a two-colour diagram. For the limited number of known emission line dwarf carbon, the photometric situation is further confused by the possible presence of a companion, as discussed below.

Even the photometric fluctuations cannot be regarded as conclusive luminosity indicators. Figure 5 presents the light curves of our targets and of CLS29 and PG0824+289, also monitored by the NSVS. The figure shows how the three dC stars are variable in a similar way and with similar amplitude to the two CH variable giants.

5.1. Looking for a companion for SBS 1310+561

It is important to remember that, since according to the evolutionary models no carbon is produced by main sequence hydrogen burning stars, the most reasonable, widely accepted explanation is that dCs belong to evolved binary systems. The presently observed carbon stars are thought to be formed through mass transfer of carbon-enriched material while the initial primary component was ascending the asymptotic giant branch as a C giant (Green 2000 and references therein). De Kool & Green (1995) constructed several models of binary system evolution leading to dC star formation, and their predictions have been confirmed by radial velocity and chemical abundances studies of several targets (Lucatello et al. 2005; Behara et al. 2010). The characteristics of the individual spectra depend on the distance between the components of the binary system and the nature of the collapsed companion.

The prototype G77−61 is a single line spectroscopic binary not showing emission lines, and the companion, invisible in the optical range is a WD with $T_{\rm eff} < 6000$ K (Dearborn et al. 1986).

In SBS 1517+5017 no emissions are visible, but the hot white dwarf contributes to the continuum and to the absorption lines already in the blue spectral region.

CLS29 only shows H_α in emission (Fig. 5 of Totten & Irwin 1998).

For PG 0824+289, the Balmer emission lines have been attributed to the heating of the dC atmosphere by the visible WD.

Except for the emission lines, SBS 1310+561 does not show a composite spectrum. Most probably the visible star has an optically invisible companion, possibly a close WD. This can be suggested by the emission of the Ca II H and K lines which are normally indicators of strong chromospheric activity. This should not be the case for a single dwarf star, but in a binary system a white dwarf companion in close orbit can spin up the M dwarf via tidal locking and thus trigger chromospheric activity on the cool star. In this respect we remember that mass transfer or a similar interaction was suggested as the cause of the luminosity fluctuations for CLS29 and PG0824+289.

Ultraviolet spectra might confirm the presence of a white dwarf companion, hence the binarity of SBS 1310+561. We can compare the photometry only with the SLOAN data for similar stars. The average $u-g$ computed from 65 stars classified "D" in Table 1 of Downes et al. (2004) gives $u-g = 2.7$ mag with $\sigma = 0.6$. For this star $u-g = 2.3$ mag. We finally verified that the Galex archive (Martin et al. 2005) (farUV∼1400−1800, nearUV∼1800−2800 Å) contains data of our targets, of several known dCs and of the FHLC present in the list of Totten el al. (2000). Excluding the dwarfs with composite spectra, most of the stars, including SBS 1543+555, with similar spectral type and similar B magnitudes or brighter than SBS 1310+561 are not detected. Very few, including SBS 0759+533 and SBS 1701+555, have the difference NUV$-B \sim 6.5$ mag. The difference is ∼5.3 mag for the two dCs G77−61 and CLS50. SBS 1310+561 has the smallest difference NUV$-B = 3.7 \pm 0.3$ mag, possibly indicating the presence of a low-luminosity but hot source.

At present we do not have enough information for deeper speculations.There are no other data published for any of these stars in the near or in the far IR, where an emission excess could witness the presence of a residual debris disk from the mass transfer event (see Fazio & Lowrance 2008).

Table 4. Absolute K magnitudes and distances to the three CH giants.

SBS number	M_K mag	d kpc	Δd kpc
0759+533	–4.9	10	1.
1543+555	–5.8	20	2.
1701+555	–4.3	20	2.

5.2. Luminosities and distances

From the data at our disposal, we could estimate approximate values of the distance to our targets. For the dC star SBS 1310+561, we started assuming $+6.1 < MK_{\rm s} < +6.6$ which is the range of the absolute magnitude in the K band for dC stars with known parallaxes (Lowrance et al. 2003 and references therein). With the observed $K_{\rm s} = +10.80$ mag the distance modulus is then $4.2 < {\rm DM} < 4.7$ and the distance $70 < d < 87$ pc.

To compute the absolute visual magnitude we must take into account the variability of the star. We adopted $V = 14.6$ mag, average between our $V = 14.76$ and $V = 14.44$ from GSC2.3 and the two limits for the distance modulus obtained from the K magnitude which is less sensitive to variability. These data yield the absolute visual magnitude $M_V = +10.1 \pm 0.2$, in good agreement with the mean value of the dC stars with measured parallaxes. Finally we can give a crude estimate of the space velocity components and try to put some constraints on the Galactic population membership of SBS 1310+561. For the mean value of the distance $d = 80$ pc, the parallax is $\pi = 12.5$ mas. Combining this value with the kinematical properties of the star yields the space velocity components $(U, V, W) = (-6 \pm 5, -10 \pm 8, -30 \pm 15)$ km s^{-1}, consistent with disk membership (in Galactocentric coordinates: −6, +210, −30 km s^{-1}). The values are corrected for the solar motion (10, 15, 7 km s^{-1}) with respect to the LSR; U is positive in the direction of the Galactic centre. The formulae used are those described by Johnson & Soderblom (1987).

To compute the absolute magnitudes M_K and the distances to the three CH stars, we used the empirical fitting formula:

$$\log(M_K + 9.0) = 1.14 - 0.65(J - K) \tag{1}$$

obtained by Totten et al. (2000) from a selected sample of giants (standard deviation =0.5 mag) and applied to all their faint high-latitude carbon stars. The computed K-band absolute magnitudes in the SAAO system and the derived heliocentric distances are given in Table 4.

Assuming the standard deviation of fitting formula as the main cause of the uncertainty on M_K and therefore on the distance modulus, the uncertainties on the distances are about 10%. In the 2MASS system, the absolute magnitudes would differ by about 0.04 mag.

6. Summary and conclusions

We presented moderate resolution CCD spectra and new photometric data for four SBS candidate C stars. Spectra and colours are consistent with early CH type classification. The most important result is the discovery that SBS 1310+561 belongs to the small group of dwarf carbon stars. In spite of the limited sample, we could verify the increasing evidence that spectroscopy or colours alone are inconclusive as luminosity discriminants for CH−type stars. In fact, only the high proper motion, and possibly the strength of the red CaH bands, lead to the conclusion that SBS 1310+561 is a main sequence star, an extremely rare case of dwarf carbon showing Balmer and Ca II lines in emission. Dealing with a possible close binary system, close-time spaced observations should be performed to shed more light on the object, which shows photometric fluctuations, but the sparse data do not allow speculating too much about a possible light curve and/or periodical spectral variations.

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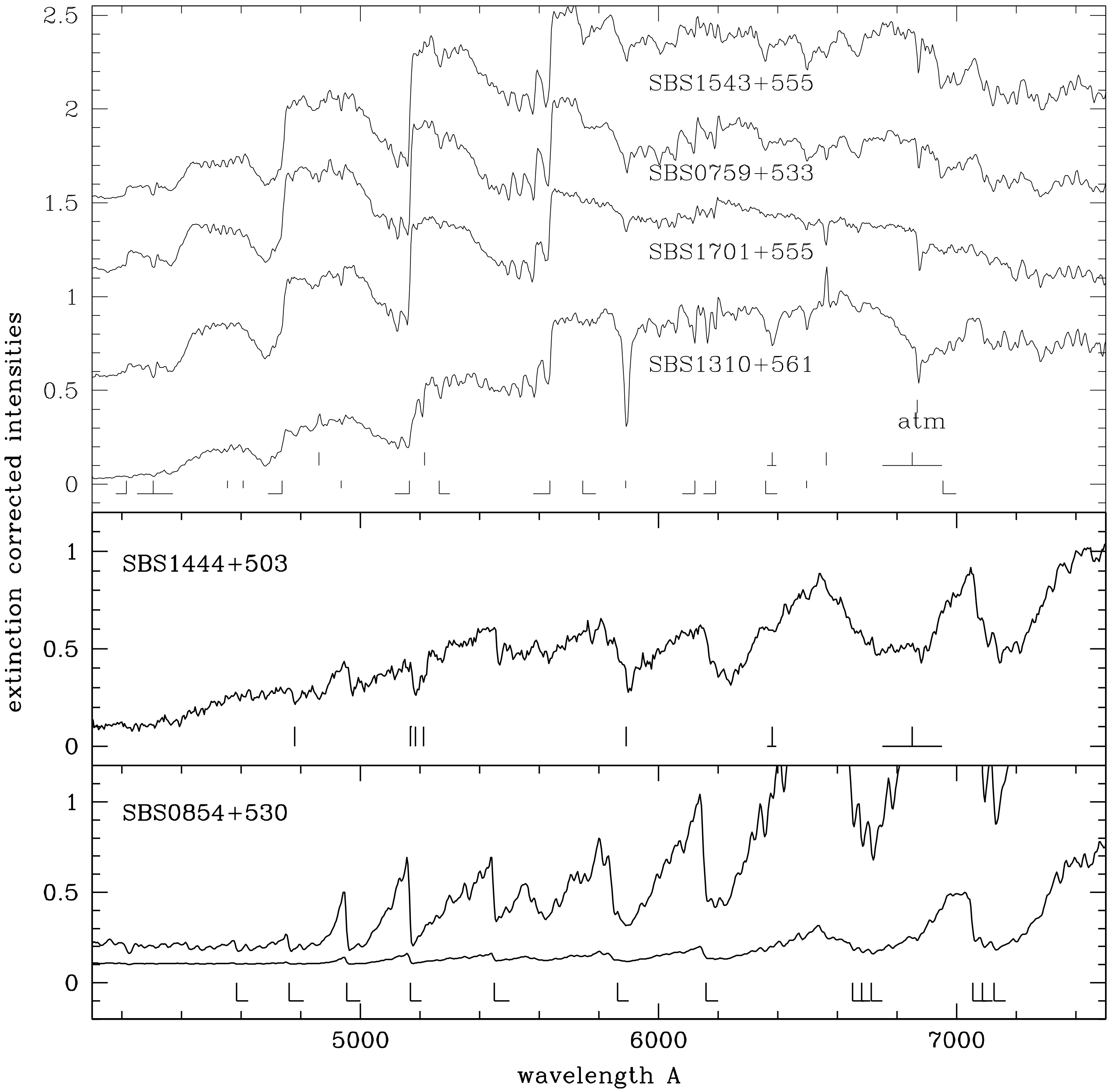

Fig. 1. CCD spectra of the recently classified SBS stars in the range 4100−7500 Å. *Bottom panels*: the two confirmed M stars; bars in the *lowest panel* indicate TiO bands common to both stars and VO bands of the late type; lines prominent in SBS 1444+503 are only reported in the corresponding panel. *Upper panel*: the dwarf carbon and the three CH stars; vertical bars indicate prominent features listed in the text. Bars corresponding to lines of particular interest for SBS 1310+561 are vertically shifted by 0.15 units above the others.

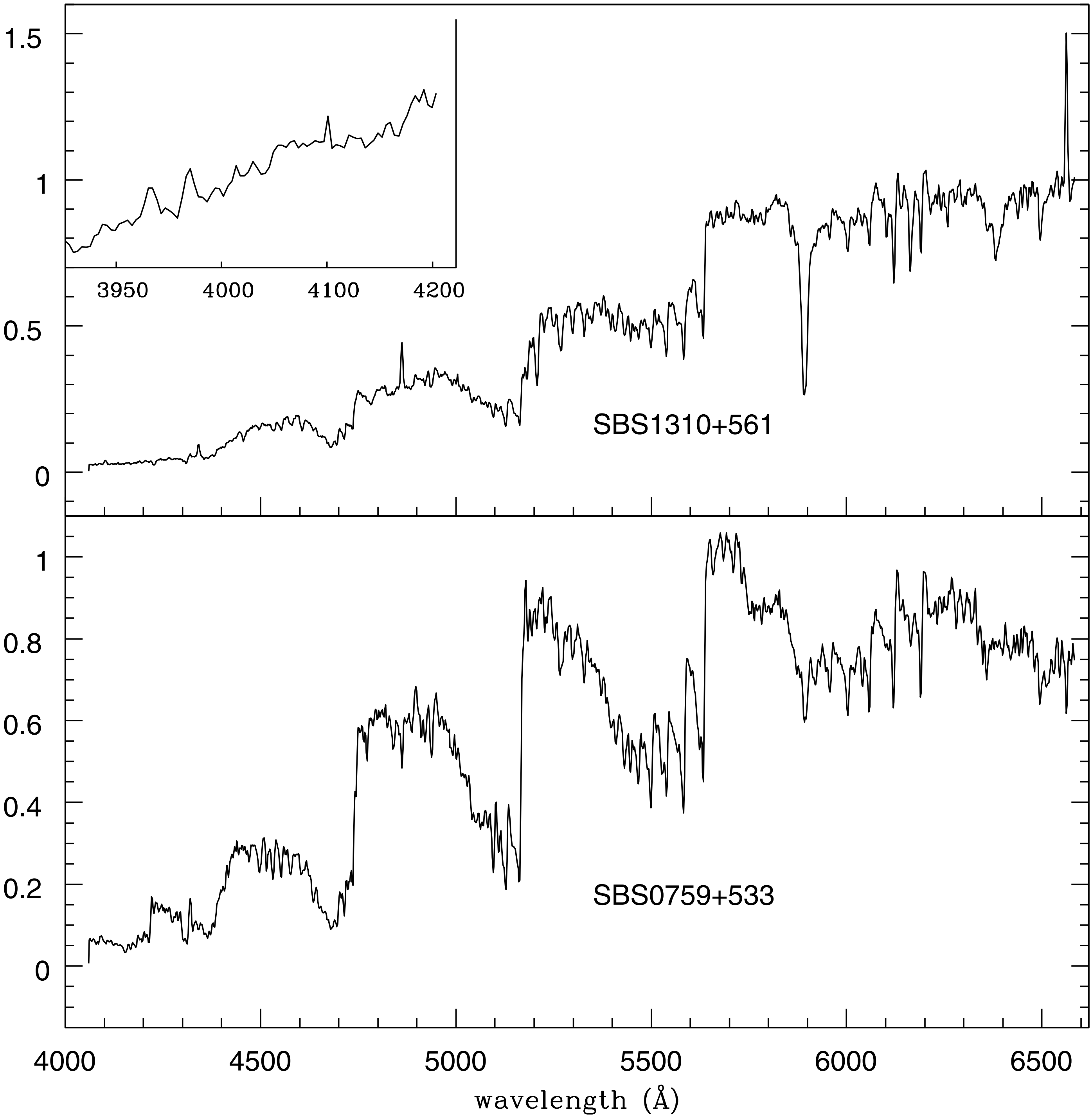

Fig. 3. Medium-resolution spectra of the CH giant SBS 0759+533 and the dC SBS 1310+561. For this star an enlargment of the region 3900−4200 Å from the lower resolution spectrum is plotted to emphasize Hδ and the CaII emissions, which are not covered by the grism #7 spectral range. Ordinates are the same as in Fig. 1.

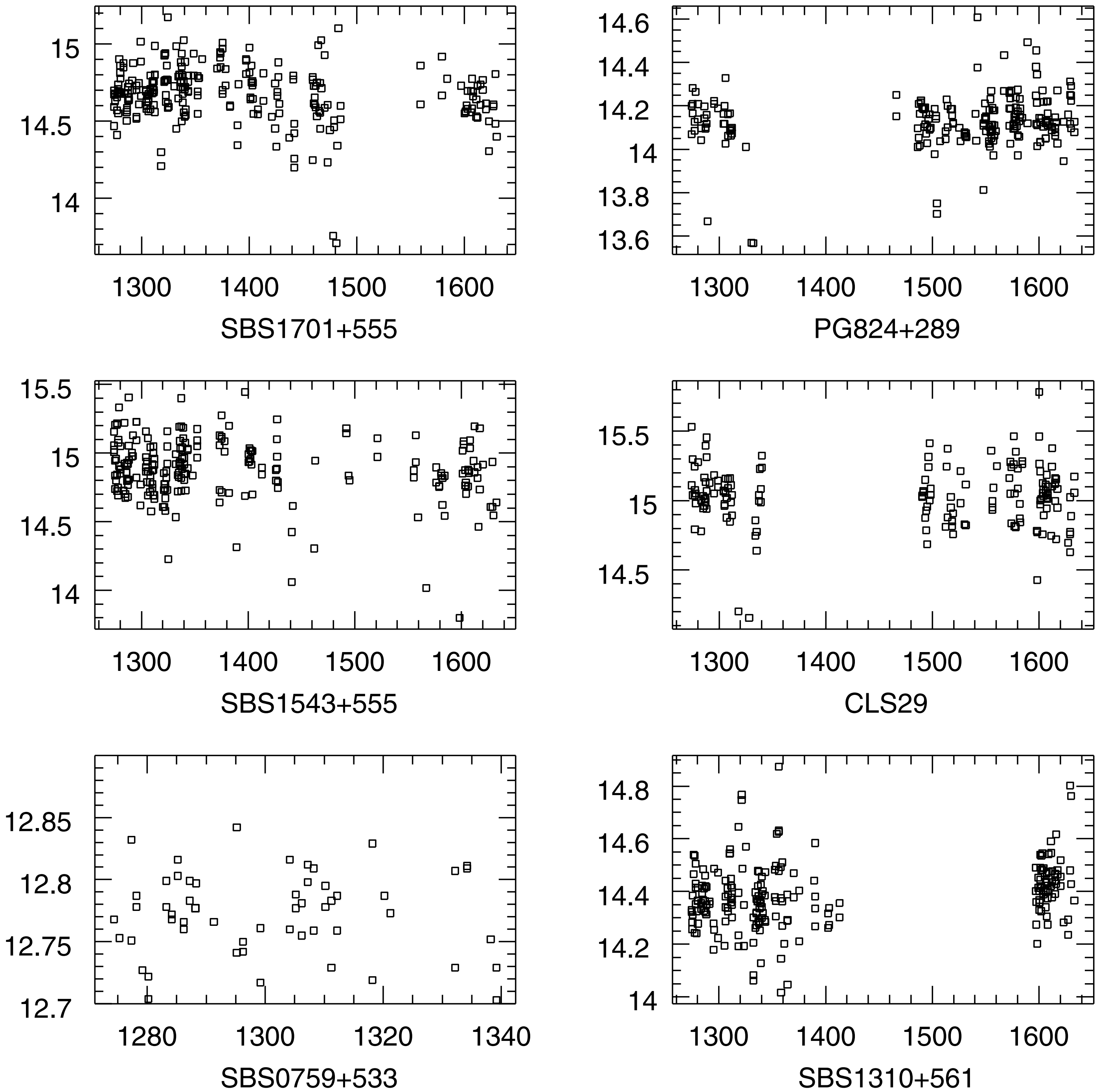

Fig. 5. Light curves of our CH stars plus CLS29 and PG084+289. The dates are MJD-50 000 days; the data are from the NSVS archive. The typical uncertainties are 0.03 mag for SBS 0759+533, and 0.08 mag for SBS 1310+561 and PG824+289. For the other stars the uncertainties are 0.11 mag.