

Interstellar extinction toward symbiotic stars

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(Research report, Submitted on 21 May 2020; Accepted on 27 June 2020)

Abstract. Using diffuse interstellar bands (DIBs) at 5780 Å, 5797 Å and 6613 Å, visible in the high resolution spectra, and measuring their equivalent widths, we estimate the interstellar extinction toward seven symbiotic stars. We find $E_{B-V} = 1.28 \pm 0.10$ for AS 289, $E_{B-V} = 1.55 \pm 0.10$ for BI Cru, $E_{B-V} = 0.63 \pm 0.10$ for HD 330036, $E_{B-V} = 0.33 \pm 0.05$ for V2756 Sgr, $E_{B-V} = 0.30 \pm 0.05$ for V2905 Sgr, $E_{B-V} = 1.52 \pm 0.11$ for V417 Cen, $E_{B-V} = 0.81 \pm 0.10$ for PN Sa 3-22. The derived values are in agreement with the extinction through the Galaxy.

Key words: stars: late-type – (stars:) binaries: symbiotic – stars: binaries: symbiotic – ISM: dust, extinction – stars: individual: AS 289, BI Cru, HD 330036, V2756 Sgr, V2905 Sgr, V417 Cen, PN Sa 3-22

1 Introduction

The symbiotic stars are interacting binaries, in which an evolved red-yellow giant or supergiant transfers mass to a hot compact companion, usually a white dwarf (Mikołajewska 2012; Akras et al. 2019). The cool primary can be a normal red giant, yellow giant or a Mira-type asymptotic giant branch star. The two components are embedded in complex surroundings, such as ionized and neutral regions of the wind of the giant, accretion disc, in some cases colliding winds, non-relativistic jets, remnant from nova explosion, dust shell (Sokoloski et al. 2017).

A few diffuse interstellar bands (DIBs) are clearly visible in our spectra of symbiotic stars. Diffuse interstellar bands are over 400 broad spectroscopic absorption features observed in stellar spectra in ultraviolet, visible and infra-red ranges (Sarre 2006, Fan et al. 2019). DIB carriers are believed to be large molecules in gas phase (e.g. Spieler et al. 2017; Elyajouri et al. 2018).

Using high resolution optical spectra of a few symbiotic stars we estimate the interstellar extinction toward them.

2 Observations

The observations have been performed with FEROS at the 2.2m telescope La Silla, European Southern Observatory (ESO). FEROS is a fibre-fed echelle spectrograph, providing a high resolution of $\lambda/\Delta\lambda = 48000$, a wide

wavelength coverage from about 4000 Å to 8900 Å in one exposure and a high throughput (Kaufer et al. 1999). The 39 orders of the echelle spectrum are registered with a 2k×4k EEV CCD. The spectra are reduced using the dedicated FEROS data reduction software implemented in the ESO-MIDAS system. A few examples of the interstellar features in our spectra are given on Fig. 1, Fig. 2, and Fig. 3. The most prominent interstellar features are NaD1 and D2 lines. In Fig. 1 the NaD1 and D2 lines are plotted in the upper panel together with KI7699 line. In the lower panel are plotted the DIB5780 and DIB6613. The comparison between the profiles indicates that a part of the NaD lines has circumstellar origin (not interstellar). Thus, for estimation of the interstellar extinction we will use the DIBs.

3 Interstellar reddening E_{B-V}

There is an apparent general correlation between the DIB strengths and the interstellar extinction (or reddening). To calculate E_{B-V} we measure the equivalent width of a few interstellar features and use the following equations from Puspitarini, Lallement & Chen (2013):

$$E_{B-V} = 2.3W_{5780} + 0.0086, \quad (1)$$

$$E_{B-V} = 6.3W_{5797} + 0.0203, \quad (2)$$

$$E_{B-V} = 5.1W_{6613} + 0.0008. \quad (3)$$

These equations refer to the equivalent width of DIB λ 5780.38, DIB λ 5797.06, and DIB λ 6613.62, respectively. In them W is in Å and E_{B-V} is in magnitudes. DIB 5797 is more tightly correlated with the column density of molecular hydrogen, while DIB 5780 – with that of atomic hydrogen (Weselak 2019). DIB 6613 total column density is proportional to the total column density of Ca II and H I (Sonnentrucker et al. 1999).

For each object we measured equivalent widths of the three DIBs. We also approximated the red giant features in and around DIBs with stellar spectra of similar spectral types taken from the ELODIE archive (Moultaka et al. 2004) and field stars across the Hertzsprung – Russell diagram (Bagnulo et al. 2003).

In Fig. 2, the spectrum of HD 330036 (black solid line) is compared with the bright giant HD 432 (β Cas, F2III). The spectrum of β Cas is broadened to take into account the fast rotation of the cool component of HD 330036. This figure demonstrates how the comparison with a field giant gives the possibility to place the continuum, and to measure more precisely the equivalent widths of DIB5780 and DIB5797, which are used in Eq.1 and Eq.2.

In Fig. 3 the spectrum of AS 289 is plotted together with that of the bright red giant HD 44478 (μ Gem, M3IIIab). This figure illustrates that the subtraction of the red giant spectrum gives us the possibility to estimate accurately the equivalent width of the DIB 6613.

In Table 1 are given: the name of the object, the modified Julian Day (MJD) of the observation as given in the fits file header, and the spectral

type of the cool component. The last column is the upper limit of E_{B-V} , which is the extinction through our Galaxy in the direction of the object, taken from the IRSA: Galactic Reddening and Extinction Calculator in the NASA/IPAC Extragalactic Database (NED), which is operated by the Jet Propulsion Laboratory, California Institute of Technology. This calculator uses Galactic reddening maps to determine the total Galactic line-of-sight reddening and is based on the results by Schlegel, Finkbeiner & Davis (1998) and Schlafly & Finkbeiner (2011).

Our measurements are summarized in Table 2. In this table are given: the name of the object, W_{5780} , W_{5797} , W_{6613} and E_{B-V} calculated for each DIB. The last column is the average value of E_{B-V} .

Table 1. In the table are given: the name of the object, MJD of observations, spectral type of the cool component, the upper limit of the reddening (IRSA values, see Sect. 3).

No:	object	MJD	spec.type	upper limit of E_{B-V}
1	AS 289	53161.3071	M3.5 III	2.44 - 2.84
2	BI Cru	53107.2002	M2/3 III	5.78 - 6.72
3	HD 330036	53107.2882	F5 III	1.06 - 1.23
4	V2756 Sgr	53164.3968	M4 III	0.27 - 0.31
5	V2905 Sgr	53184.0858	M3 III	0.27 - 0.32
6	V417 Cen	53107.2548	F6V-G9Ib	7.63 - 8.87
7	PN Sa 3-22	53402.2405	M4.5 III	0.81 - 0.94

Table 2. Equivalent widths of the DIBs [\AA] and calculated E_{B-V} [magnitudes] of the symbiotic stars. In the table are given: the name of the object, EWs of the DIBs and the calculated E_{B-V} . The last column are our estimations of E_{B-V} , i.e. the mean values.

No:	object	W_{5780} E_{B-V} DIB $\lambda 5780$ [\AA] [mag]	W_{5797} E_{B-V} DIB $\lambda 5797$ [\AA] [mag]	W_{6613} E_{B-V} DIB $\lambda 6613$ [\AA] [mag]	E_{B-V} mean [mag]
1	AS 289	0.576 1.33	—	0.240 1.22	1.28 ± 0.07
2	BI Cru	0.697 1.61	0.250 1.60	0.288 1.47	1.55 ± 0.10
3	HD 330036	0.265 0.62	0.109 0.71	0.110 0.56	0.63 ± 0.10
4	V2756 Sgr	0.141 0.33	—	—	0.33 ± 0.05
5	V2905 Sgr	0.146 0.34	—	0.050 0.26	0.30 ± 0.05
6	V417 Cen	0.674 1.56	0.263 1.68	0.272 1.39	1.52 ± 0.10
7	PN Sa 3-22	0.360 0.84	0.125 0.81	0.154 0.79	0.81 ± 0.10

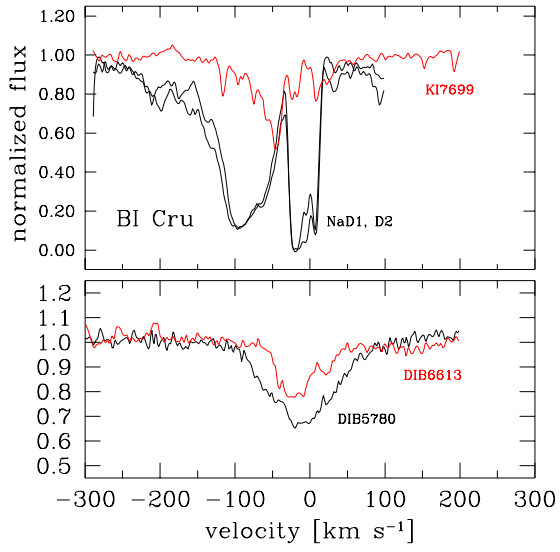


Fig. 1. Interstellar lines in the spectrum of BI Cru - NaD1 and D2 lines, KI7699, DIB 6613, DIB 5780.

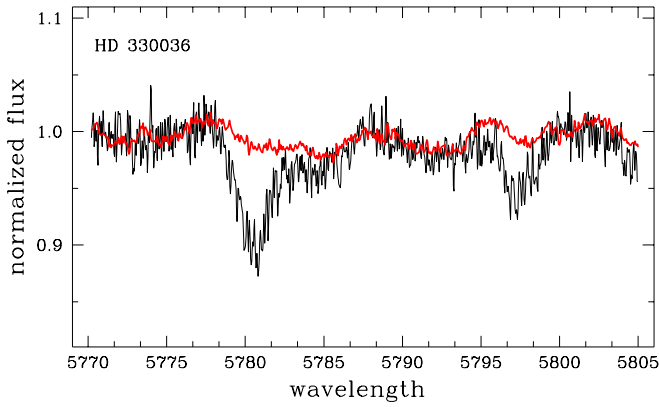


Fig. 2. Spectrum of HD 330036 (black solid line) compared with HD 432 (the spectrum is broadened, red line). The comparison gives the possibility to measure precisely the equivalent widths of DIB5780 and DIB5797.

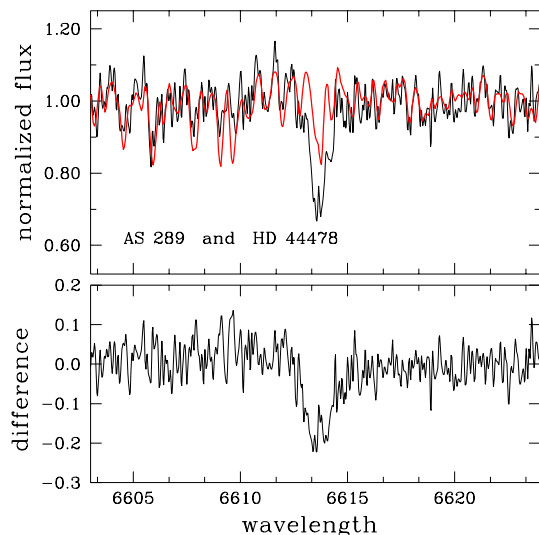


Fig. 3. Spectrum of AS 289 (black solid line) compared with HD 44478 (red line). The lower panel is the difference between them.

4 Objects and results

As a reference point and upper limit of the expected reddening we use E_{B-V} through the Milky Way in the direction of the objects. Because IRSA calculates the extinction through the entire Galaxy, it is an upper limit for objects in our Galaxy. In some cases all the interstellar clouds are in front of the star and it will give a similar result to ours. In other cases (e.g. AS 289, BI Cru and V417 Cen), part of the clouds are behind the object and it leads to a significant difference between our estimation and IRSA values.

AS 289 (V343 Ser): for this object Luna & Costa (2005) give $E_{B-V}=1.18$. Our value $E_{B-V} = 1.28 \pm 0.07$ is similar.

BI Cru (Hen 3-782): for this object Rossi et al. (1988) give $E_{B-V} = 1.5 \pm 0.5$. Our value $E_{B-V} = 1.6 \pm 0.1$ is similar and with better accuracy.

HD330036 (PN Cn 1-1) having three circumbinary dust shells is a demonstration of the complexity of the symbiotic environment (Angeloni et al. 2007). For this object Lutz (1984) estimated $E_{B-V} = 0.28$, Bhatt & Mallik (1986) gave $E_{B-V} = 0.41$. Our value $E_{B-V} = 0.63 \pm 0.10$ is higher, but still consistent with the extinction through the Milky Way.

V2756 Sgr (AS 293): for this object we can measure only DIB5780. The derived extinction $E_{B-V} = 0.33 \pm 0.05$ is consistent with the Galactic reddening and with the value $E_{B-V} = 0.32$ estimated by Luna & Costa (2005).

V2905 Sgr (AS 299): for this object Pereira, Landaberry & da Conceicao (1998) measured $E_{B-V} = 0.72 \pm 0.15$, Luna & Costa (2005) – $E_{B-V} = 0.43$. We compared the spectrum of V2905 Sgr, with that of the red giant 51 Gem, for which SIMBAD gives M4III, a spectral class similar

to that of V2905 Sgr. DIB 5780 and DIB6613 are clearly detectable and correspond to $E_{B-V} = 0.30 \pm 0.05$. We do not detect DIB 5797, its EW is expected to be low ($EW(5797) \leq 0.03 \text{ \AA}$). The reddening through the Galaxy in the direction of V2905 Sgr is $E_{B-V} = 0.27 - 0.32$, which is in agreement with our value $E_{B-V} = 0.30 \pm 0.05$.

V417 Cen (Hen 3-977): for this object Stoyanov et al. (2014) estimated $E_{B-V} = 0.95 \pm 0.10$ based on the non-variable part of KI7699 line. Here, using three DIBs, we obtain a larger and probably more accurate value $E_{B-V} = 1.52 \pm 0.10$.

PN Sa 3-22 (also named in few papers **St 2-22**) is a symbiotic star with high-velocity ($\approx 1700 \text{ km s}^{-1}$) bipolar jets (Tomov et al. 2017). Mikolajewska, Acker & Stenholm (1997) have derived reddening $E_{B-V} = 1.0$ mag. Our value $E_{B-V} = 0.81 \pm 0.1$ is slightly lower and more consistent with the Galactic reddening.

5 Conclusion

We measured the interstellar extinction toward 7 symbiotic stars using the equivalent widths of DIBs visible in our FEROS spectra. Our values are in agreement with the extinction through the Galaxy and are improvement over the previous measurements. They should be useful for modeling.

Acknowledgments: This work is part of the project *KII-06-H28/2* 08.12.2018 "Binary stars with compact object" supported by National Science Fund (Bulgaria). It is based on observations obtained in ESO programmes 073.D-0724A and 074.D-0114. We thank to the anonymous referee for the useful comments.

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