SPECTROSCOPIC FAMILIES OF DIFFUSE INTERSTELLAR BANDS

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In this work we are trying to find spectroscopic 'relatives' for two prominent diffuse interstellar bands (DIBs) 5780 and 5797. We have used two methods; averaging equivalent widths (EWs) and visual investigation of the figures with arranged spectrograms. On the basis of our analysis we suggest some candidates as members of two spectroscopic families with 5780 and 5797 bands as principal structures.
Key words: diffuse interstellar bands, interstellar matter, spectroscopic families.

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I. INTRODUCTION

Diffuse interstellar bands (e.g. Herbig [1]), absorption structures of interstellar origin, still await their explanation. The identification of the carrier(s) of DIBs became one of the most difficult tasks for spectroscopists.

One tries, in general, to solve the mystery of the carrier(s) of DIBs on the field of interdisciplinary spectroscopic collaboration between molecular physicists, molecular chemists and astronomers. One expects that some progress in this field will be possible when all the known DIBs are divided into families in such a way that only one carrier is responsible for all bands belonging to the given family. Such families of bands we call 'spectroscopic' ones, to distinguish them from 'characterological' families isolated by the authors cited below.

First findings of the DIB families were done in the middle eighties. Chlewicki *et. al.* [2] divided strong DIBs into two families; the criteria of segregation were the degree of correlation between reddening E(B-V) of the target star and intensity of the DIB.

Krełowski and Walker [3] selected three families among the known DIBs. Structures belonging to each family were defined as groups of bands whose strengths in different lines of sight are more closely correlated with one another than with other DIBs, and which obey common dependence on reddening.

The trials to divide DIBs into families cited above were very preliminary as far as spectroscopic families are considered. In order to try to identify a carrier of a given family one needs well defined series of spectral bands (with strong bands as well as weak ones) originating from a single substance.

The number of DIBs has grown dramatically in recent years, primarily due to better quality of observational material. More and more weak DIBs (WDIBs) seem to appear every time when a given spectral region is analysed carefully. The aim of this report is to explore further the properties of DIBs in the context of isolating spectroscopic families of these structures.

II. OBSERVATIONAL MATERIAL

All the spectra analysed for the purpose of this work were taken from the archives of professor Jacek Krełowski (Astronomical Centre, Nicolaus Copernicus University, Toruń, Poland). We used the spectra taken with CFHT (described by Snow and Seab [4]) and those acquired at the McDonald Observatory with echelle spectrograph fed with the 2.1m. telescope (Krełowski and Sneden [5]). Relatively high quality of these observational data allowed us to measure the EWs for many strong and weak DIBs.

III. DATA ANALYSIS

The aim of our analysis was to find spectroscopic relatives to strong 5780 and 5797 bands which, as was shown by Krełowski and Westerlund [6], belong to different spectroscopic families (names of DIBs we give here as wavelengths corresponding to the centres of the individual bands, given in angstroms). We have selected spectra covering spectral range from 5750 to 5860 Å for 74 stars and we have measured EWs for 11 WDIBs — 5760, 5763, 5766, 5769, 5773, 5776, 5793, 5795, 5809, 5819 and 5829, as well as for two relatively strong DIBs — 5780 and 5797. Extremely low EWs of WDIBs (in most cases less than 0.01 Å) make their measurements very difficult. Avoiding of large errors of the measured parameters was impossible. In such a case one looks for an adequate method to find any possible correlation between individual WDIBs and chosen strong DIBs.

Statistical correlation not always gives us entirely satisfying results because bands which do not belong to the same spectroscopic family are usually very well mutually correlated in statistical sense. We had to by-pass in some way the problem of such 'noise' correlation. We have used two simple but promising methods described below.

A. The averaging EWs method

To check mutual dependence between WDIBs and 5780 and 5797 bands we have started from the following procedure. We extracted a sample with EW(5797) restricted to a very narrow range of values. From such a sample we separated two subsamples: the first one with relatively low, and the second one with relatively high values of EW(5780).

HD	5780	5797	5760	5763	5766	5769	5773	5776	5793	5795	5809	5819	5829
24912	194	50	2	4	10	3	5	8	2	4	–	–	6
54662	195	49	3	–	9	5	–	6	7	4	3	7	2
147933	200	57	7	8	9	9	8	7	5	5	6	3	7
164402	170	55	3	–	7	2	12	10	–	–	1	2	2
193443	302	56	–	–	13	10	15	10	4	7	–	4	–
mean value in the group	212.2	53.4	3.75	6	9.6	5.8	10	8.2	4.5	5	3.33	4	4.25
148184	96	51	1	3	8	8	–	–	3	2	–	2	5
199579	111	55	2	2	9	6	6	4	5	4	2	–	–
216200	114	47	–	5	–	–	15	–	–	–	3	–	9
218376	108	46	3	4	4	2	4	2	2	2	2	3	1
223128	112	52	4	5	6	1	–	–	6	3	4	12	5
mean value in the group	108.2	50.2	2.5	3.8	6.75	4.25	8.67	3	4	2.75	2.75	5.67	5
very probable corelation with 5780								+		+			

Table 1. Two subsamples of stars chosen in such a way that average EW(5797) is almost constant in both subsamples contrary to EW(5780) which in first subsamples is almost twice as large as in the second one. The names of bands are listed in the first row, whereas names of target stars used are given in the first column of the table. In both subsamples for each band the mean value of measured EWs was counted. The sign ”−” stands for the lack of the data and ”+” indicates interesting examples of correlation (see text).

HD	5780	5797	5760	5763	5766	5769	5773	5776	5793	5795	5809	5819	5829
42087	255	100	5	5	–	7	–	7	7	5	3	–	6
206267	238	105	3	5	15	8	8	6	6	4	3	4	4
207198	252	152	7	9	22	11	12	7	13	6	–	7	12
208501	255	113	4	6	9	5	–	–	7	6	8	11	8
mean value in the group	250	117.5	4.75	6.25	15.33	7.75	10	6.67	8.25	5.25	4.67	7.33	7.5
13267	275	69	6	3	4	–	7	8	6	8	4	9	3
14134	277	77	–	–	16	7	12	15	–	–	5	5	6
14489	274	77	3	5	6	6	8	8	6	–	–	–	3
147165	237	32	–	2	10	–	–	5	2	6	6	2	1
152408	278	43	–	–	–	–	9	4	5	5	3	1	2
166937	277	71	3	5	14	–	–	–	5	9	9	12	7
167263	280	72	–	–	12	10	11	6	–	–	2	2	3
mean value in the group	271.14	63	4	3.75	10.33	7.67	9.4	7.67	4.8	7	4.83	5.17	3.29
very probable corelation with 5797									+			+	+

Table 2. The same as in Table 1 but here the mean EW(5780) is rather stable whereas EW(5797) drops almost twice when going from the first subsample to the second one.

In these sub-samples we calculated mean values of EW(5780), EW(5797) and EWs for WDIBs. Both sub-samples, as well as results of averaging, are exposed in Table 1. WDIBs correlated with 5780 should follow changes in EW(5780), contrary to those which are not correlated.

In a similar way we have extracted a sample of stars with almost constant EW(5780) and separated sub-samples with opposite values of EW(5797), see Table 2. Such a simple procedure allowed us to divide considered WDIBs into three groups; (i) well correlated with 5780 (5776 and 5795), (ii) well correlated with 5797 (5793, 5819 and 5829) and (iii) rather not correlated neither with 5780 nor 5797 (5769, 5773 and 5809). Three other cases (5760, 5763 and 5766) are rather complicated because they seem to be correlated with 5797 as well as with 5780. The main selecting criterion was here a gradient of the average value for WDIBs. If this gradient,

for considered WDIB, is evidently similar to the gradient which is typical for the head band (in our case this gradient is very close to 0.5), we decided to include this WDIB into the family.

B. Investigating the figures with arranged spectrograms

Another way to divide WDIBs into three, above mentioned, groups consists in visual inspection of spectrograms. If we compose sequences of spectrograms in such a way that EW(5780), for example, is constant and EW(5797) gradually increases (Figure 1), we are able, after visual inspection of the picture, indicate WDIBs which follow, and those ones which do not follow, the behaviour of 5797.
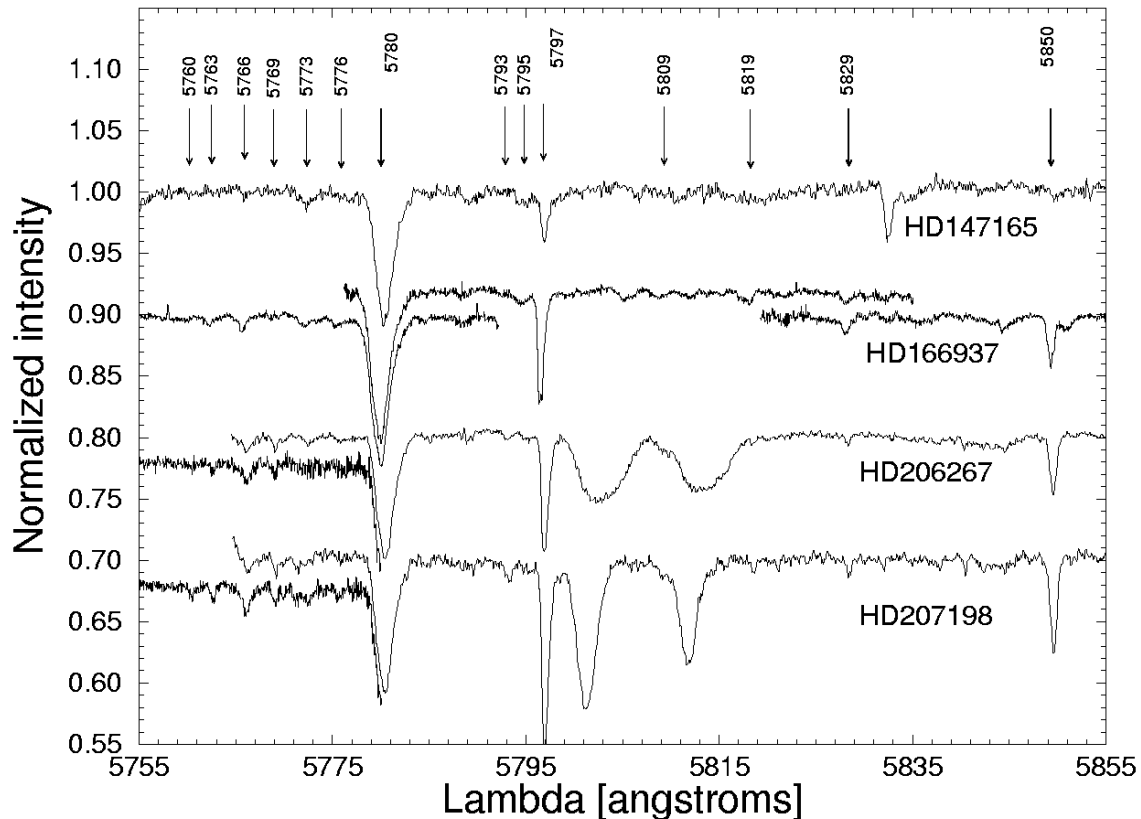

Fig. 1. CFHT (the longest pieces) and McDonald's (shorter, individual orders of echelle spectrograph) spectrograms arranged in such a way that strength of 5797 band gradually increases whereas intensity of 5780 band remains constant.

Figure 2 shows the case of nearly constant EW(5797) and changing EW(5780). Inspection of Figures 1 and 2 does not contradict but confirm results achieved with the earlier described averaging procedure.
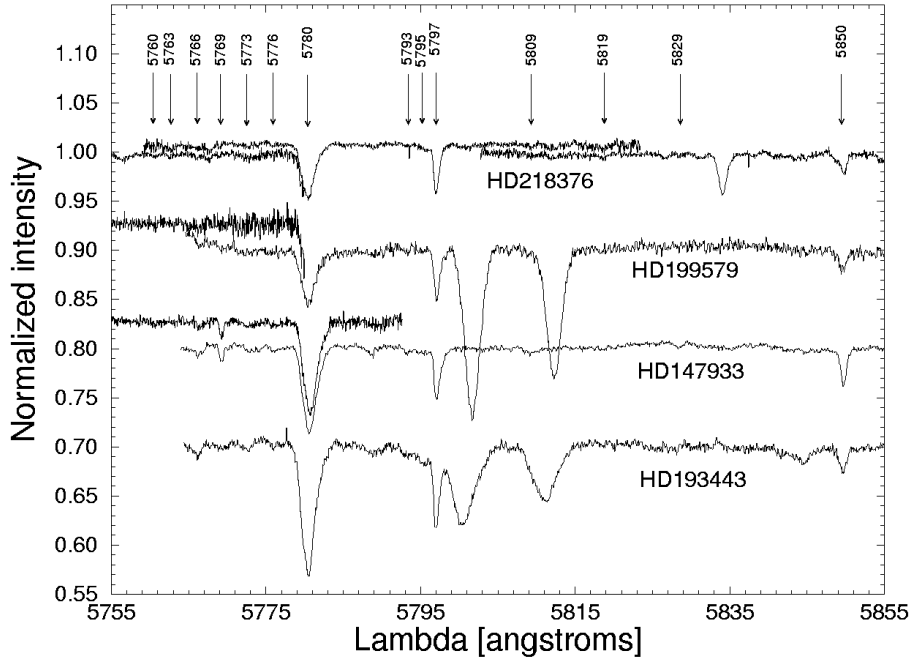
Fig. 2. Similar to Figure 1, but here the roles of 5780 and 5797 bands are exchanged. Intensity of the first band increases whereas the strength of the second one remains constant.

IV. CONCLUSIONS

Methods described in subchapters III.A and III.B are appropriate to extract spectroscopic families of DIBs. Using them we performed very preliminary separation of two presumable (probably not complete yet) spectroscopic families: (i) 5780, 5776 and 5795, and (ii) 5793, 5797, 5819, 5829 and 5850.

One cannot, however, exclude such a possibility that we made wrong indications. In the case of almost constant ratios between column densities of various DIB carriers in interstellar clouds we have a chance of getting results which are quite similar to those when we have to deal with few spectral lines of the same carrier. Further investigations based on better data samples and involving other spectral ranges are necessary to isolate true spectroscopic families of bands.

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СПЕКТРОСКОПІЧНА РОДИНА ДИФУЗНИХ МІЖЗОРЯНИХ СМУГ

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Зроблено спробу знайти спектроскопічні відповідники для двох відомих дифузних міжзоряних смуг (DIBs) 5780 і 5797. Використано два методи усереднення еквівалентних ширин (EWs) і візуальне дослідження фігур з упорядкованими спектрограмами. На основі аналізу запропоновано декілька кандидатів у члени двох спектральних сімейств зі смугами 5780 і 5797 як основні структури.