SEARCH FOR SPECTROSCOPIC FAMILIES AMONG DIFFUSE INTERSTELLAR BANDS

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ABSTRACT. Diffuse interstellar bands (DIBs) await an explanation for many decades. One expects that significant progress in identification of DIBs' carriers 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. Analysing high resolution optical spectra of reddened stars we test a new method to find out the first true spectroscopic families among DIBs.

Keywords: Interstellar medium.

1. Introduction

One of the longest standing problems in astronomy and astrochemistry has been the inability to identify the diffuse interstellar band (DIB) carriers. It is debated whether the DIB carriers arise from the dust, the gas, or the large-molecule component of the interstellar medium (Sarre 2006, Herbig 1995). Furthermore, different strength ratios of major DIBs along different lines of sight, revealed a DIB origin in many carriers.

Any attempt to solve the mystery of DIBs' carriers must involve interdisciplinary collaboration between molecular physicists, chemists and astronomers. One expects that progress in this field will be possible when all known DIBs are divided into families in such a way that only one carrier is responsible for all bands belonging to a given family. The first trial on dividing DIBs into spectroscopic families were presented by Wszołek & Godłowski (2003). The authors noted that formal statistical attitude to DIBs' intensities measurements, without any additional supporting methods, is not sufficient to find out spectroscopic families. They proposed also some alternative methods as more adequate to the problem.

Among all known DIBs we can see only few relatively strong bands and many rather weak ones. With better quality spectra one can expect to find more weak DIBs. It is very probable that DIBs originated by the same carrier have different intensities; in one spectroscopic family we expect to find stronger bands as well as weak (and extremely weak) ones. Discovering new very weak DIBs may be therefore crucial when we want to find complete spectroscopic families among DIBs. Extracting spectroscopic families of DIBs is a task to solve with use of astronomical spectra of the best quality. After extracting any spectroscopic family, its carrier will be to find by the way of laboratory search supported by quantum chemical considerations.

2. Looking for spectroscopic families - new method

We test a new method of extracting spectroscopic families of DIBs. This method may be summarized as follows:

1. We measure equivalent widths (EWs) of all accessible DIBs in the spectra of two different target stars. These stars should be slightly reddened and they should be sufficiently far away one from the other on the sky, to have slightly different chemistry in the corresponding interstellar clouds; this will enable to minimize the so called "noisy correlation" (see Wszołek & Godłowski 2003). We get series of measurements:

EW^1_1 , EW^1_2 , EW^1_3 , ..., EW^1_n
(for the first star, n - number of measured DIBs)

EW^2_1 , EW^2_2 , EW^2_3 , ..., EW^2_n
(for the second star)

2. We count the ratios of kind: $R_i = EW^1_i/EW^2_i$, (where i = 1, ..., n) and we draw the diagram with R_i on vertical axis and i on horizontal one.

3. We look on the diagram for elongated (in horizontal direction) concentrations of points with almost constant R. If the commonly used assumption that intensity ratio for two DIBs originated by the same carrier should be constant (independently on direction to the target star) is valid, all points in such line-shaped concentration on diagram should correspond to DIBs

Table 1: The details concerning observed stars. In rows HD number is followed by spectral type, magnitude, reddening, air mass and the date of observation. First two items are for comparison stars.

HD	Sp	m(v)	E(B-V)	air mass	date
35497	B7 III	1.68	0.00	1.08	13.03.2010
120315	B3 V	1.85	0.02	1.02	23.06.2010
23180	B1 III/B3 V	3.82	0.3	1.25	12.03.2009
				1.7	13.03.2010
24760	B0.5 V/A2 V	2.9/3.9	0.1	1.27	13.03.2010
149757	O9 V	2.56	0.29	1.7	23.06.2010
184915	B0.5 III	4.96	0.22	1.9	23.06.2010
210839	O6 I	5.04	0.54	1.1	23.06.2010

belonging to the same spectroscopic family. Searching one diagram we may expect to find many spectroscopic families (different R).

EW ratios defined above will have much smaller errors than the ratios of type $r^m_{k,i} = EW^m_k/EW^m_i$ (m = 1, ..., n), which were of common use before, since they avoid dividing very big numbers (for strong DIBs) over very small numbers (for weak DIBs). Furthermore, our method needs in principle only spectra for two stars; instead of a few dozens stars needed by other methods.

3. First trials

To test our method we used the echelle spectra taken by spectropolarimeter NARVAL coupled by Telescope of Barnard Lyot (TBL) at Pic du Midi Astronomical Observatory. We got spectra with S/N ratio of about 2000 and with resolution R of 67 000. For given pair of target stars observations were done during the same night to have the same atmospheric conditions. Observations with different air mass helped us to decide which weak absorption lines come from Earth atmosphere and which are extraterrestrial in their origin. To distinguish interstellar lines from weak stellar lines we observed moderately reddened spectroscopic binary (HD23180) during two subsequent nights. We observed also practically non-reddened comparison stars, which were helpful to indicate telluric lines. In Table 1 we summarize the details concerning the observed stars.
To minimize errors for ratio R we limited our measurements only to well confirmed DIBs which were additionally quite good visible in our spectra. Resulting diagrams look like this presented in Figure 1.

4. Final remarks

When watching the Figure 1 we can see that DIBs 4964, 5546 and 5819 tend to belong to the same spectroscopic family with R=EW(o Per)/EW(κ Aql) of about 6. Similarly, DIBs 5766, 5850 and 5595 seem to reprezent the other spectroscopic family, with the ratio R of about 4. However, before qualifying DIBs as the same spectroscopic family members one has to check whether they show the same tendency for different pairs of stars, minimum for two of them. To exploit successfully the presented method we need to use spectra of very high original S/N ratio. Spectra, which are averaged from many single spectrograms taken in different time, may be slightly contaminated by weak telluric lines which are not to be fully removed when using traditional reduction procedures.

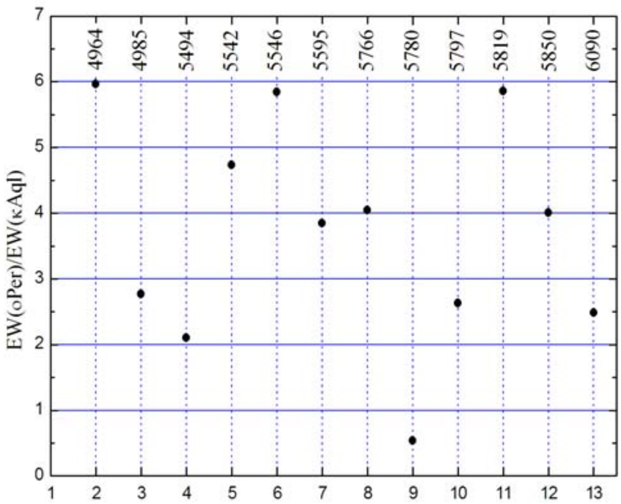

Figure 1: R^i/i diagram for the pair of stars: o Per (HD23180) - κ Aql (HD184915). On the top DIBs' names (in common notation - the profile wavelengths in angstroms) are written. On the botton we have i-numbers describing individual DIBs.

References

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