Diffuse Interstellar Bands and Their Families

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Abstract.
Diffuse interstellar bands (DIBs) still await an explanation. 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. Analyzing high resolution optical spectra of reddened stars we try to find out spectroscopic families for two prominent DIBs, at 5780 and 5797 angstroms. Among the DIBs, observed in the spectral range from 5590 to 6830 angstroms, we have found 8 candidates to belong to 5780 spectroscopic family and the other 12 DIBs candidating to family of 5797 structure.

1. Introduction
The DIBs are absorption features which are generated in the interstellar medium by still unidentified set of carriers. They are found in the visual and near infrared spectra, between 4000 and 13500 angstroms. The discovery of the first DIBs in stellar spectra dates back to the pioneering years of stellar spectroscopy. The original report on the discovery of two spectral features, centered near 5780 and 5797 angstroms, in spectra of some spectroscopic binaries was published in 1922 by Heger. The extended review paper presenting DIB problematics was published by Herbig (1995).
To date more than 300 DIBs are detected and the number is still increasing (see e.g. Galazutdinov at all., 2000). None of them has been identified! The identification of the carriers of DIBs is one of the most difficult challenges for spectroscopists. The solution of the mystery of the carriers of DIBs is expected from interdisciplinary spectroscopic collaboration between molecular physicists, molecular chemists and astronomers.

2. DIBs’ observing strategy
To detect DIBs in stellar spectra we need:
(i) relatively bright star of an early spectral type (because in optical spectra of such stars we have relatively smooth continuum with only few strong stellar lines, and therefore DIBs are not lost in the ”forest” of stellar lines),
(ii) transparent interstellar diffuse cloud(s) in line of sight causing reddening of the target star,

(iii) rather big telescope and spectrograph of a very good quality, to give spectra of sufficiently high resolution and of high signal to noise ratio.

To be sure that one has to deal with DIB, and not e.g. with any weak stellar line, the spectroscopic binaries are usually in use. When one compares few spectra of spectroscopic binary (e.g. spectra registered in subsequent nights), one can notice that some lines changed their positions (stellar lines) contrary to the other ones which are always at the same place.

3. Observing constraints on DIBs’ problem

The most recent high-quality observational data and the parallel theoretical studies allow us to define some constraints on the DIBs’ problem:

(i) the presence of DIBs is related to the colour excess, in the sense that the lack of reddening implies the absence of the DIBs; but the DIBs’ intensity along one line of sight is only loosely correlated to the value of the reddening in that direction,

(ii) the DIBs’ intensity is not strongly correlated with the 2200 angstroms extinction bump: dust and carriers of DIBs, although coexisting in the interstellar medium, have an independent history,

(iii) the line profile of the DIBs seem to be quite stable,

(iv) the DIBs seem to be generated not by a single agent but by several carriers; they can therefore be grouped into families, the members of which show well-defined intensity ratios (e.g., 5780 and 5797 DIBs have different carriers because the ratio of their intensities may substantially vary from one line of sight to the other).

All known DIBs form very inhomogeneous sample. Some of them are relatively strong, contrary to the others which are extremely weak. There are DIBs which are narrow, with widths of about 1 angstrom (e.g. 5797), but there are also very broad DIBs, with widths of about 20 angstroms (e.g. 4430).

4. The problem of carriers

Carriers of DIBs, which are still not found, are probably large interstellar molecules in gas or solid phase. Some authors argue that Polycyclic Aromatic Hydrocarbons, carbon chains or fullerenes may be carriers of some DIBs. There are however more exotic expectations which involve even extremely large organic molecules which would be responsible for spreading of life in the universe.

5. Spectroscopic families of DIBs

It is expected that a progress will be possible, and some carriers will be closer to be identified, when all known DIBs are divided into spectroscopic families in such a way that only one carrier is responsible for all bands belonging to a given family. The dividing of such kind is to do only by analysis of astronomical spectra.
Few years ago we published a few promising methods to isolate spectroscopic families of DIBs (Wszolek & Godlowski, 2003). One of proposed methods is a direct visual investigating of the figures with arranged spectrograms of different stars. Using this method one can easily find DIB candidates which tend to be members of the same spectroscopic family.

6. Looking for spectroscopic relatives of 5780 and 5797 DIBs

Among all known DIBs, two lines are special. These are 5780 and 5797 DIBs. They are the first two DIBs discovered by Heger about 85 years ago. They are positioned very close one to the other in the spectra. Both lines are relatively strong and narrow. The intensities of these bands are quite good correlated when few dozens of lines of sight is taken into account, but there are few examples showing that intensity ratio for these bands can change itself very much when going from one target star to another (Krelowski & Westerlund, 1988). That means that 5780 and 5797 do not belong to the same spectroscopic family. These DIBs may play a role of the "heads" of their own spectroscopic families of DIBs. It is interesting to find spectroscopic "relatives" for each of these two bands, and this was a subject of our last investigation.

We used spectra registered in 1993 in McDonald Observatory (2.08 m telescope, echelle spectrograph) by Professor Jacek Krelowski. They cover spectral range from 5590 to 6830 angstroms, in which almost 200 of known DIBs are present.

Looking for spectral "relatives" of 5780 band we used spectra of three stars (HD): 23180, 166937 and 206165. We arranged spectra of the stars in such a way that intensity of DIB 5780 was rising as one followed from one spectrum to the other. In such arranging, intensities of these bands which belong to 5780 spectroscopic family should exactly follow the change of intensity of 5780. Visual comparison of arranged spectrograms, taken for all rows of spectra, allowed us to indicate some member candidates to 5780 spectroscopic family. The most promising candidates are DIBs positioned at 5776, 5795, 6108, 6162, 6697, 6793, 6795 and 6827 angstroms.

The similar analysis but using three other stars, was carried out for DIB at 5797 angstroms. This time, target stars were chosen in such a way that they all give almost equal intensities of 5780 band while the intensity of 5797 is changing very much. These stars are (HD): 147165, 206267 and 207198. DIBs which tend to follow intensity change of 5797 line, and therefore they candidate to 5797 spectroscopic family are these positioned at: 5719, 5766, 5769, 5773, 5793, 5819, 5829, 5850, 6090, 6439, 6449 and 6492 angstroms. The best candidates are bands at 5793, 5829 and 5850 angstroms.

Further investigation, based on better data samples and involving other spectral ranges, is necessary to confirm above candidates and to complete spectroscopic families of 5780 and 5797 DIBs. Also, looking for the further "head" bands, like 5780 and 5797 ones, is an important line of investigation and it is in progress.
7. Conclusion

The problem of DIBs’ carriers, due to its very interdisciplinary character, is a very promising subject for open minded young scientists. Although it is difficult to be solved fast, researcher who investigates DIBs has many occasions to feel a thrill of discovery.

References

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