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Very high resolution profiles of 6196 Å and 6614 Å diffuse interstellar bands*

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Abstract. We present a careful analysis of very high resolution (R = 220 000) profiles of two well correlated diffuse interstellar bands (DIBs): 6196 and 6614 Å observed along 7 lines of sight free of the Doppler splitting in interstellar atomic lines. The high signal–to–noise ratio (S/N) of the spectra (∼600–1000) allows us to draw definite conclusion that the ratio of equivalent widths of the two DIBs is not always exactly the same, i.e. they do not seem to originate at the same carrier. The DIB profiles vary from object to object but the variations are different for every DIB. The width of 6196 DIB may change by up to 1.5 times lowest value while that of 6614 remains almost constant. The broadening of 6196 is not caused by the Doppler splitting, absent in atomic interstellar lines. Possibly this fact reflects a strong dependence of the carrier excitation pattern on small variations of physical parameters. The variations of substructure strength ratios inside the 6614 DIB profile, evident in our spectra, are apparently caused by a mechanism different from that which broadens DIB 6196.

Key words. ISM: clouds – ISM: molecules

1. Introduction

The identification of diffuse interstellar bands (DIBs) remains an open problem since the discovery of the first two such features (Heger 1922). Soon after their interstellar origin had been established (Merrill 1934) the hypothesis of their molecular origin was formulated (McKellar 1941). Currently the most often presented hypotheses connect these puzzling spectral structures with different kinds of complicated interstellar molecules, usually some carbon–bearing species (for a review see Fulara & Krełowski 2000). This motivates a search for fine structure which should be detectable if the features originate in the proposed species.

Any attempt to identify some of the DIBs must involve an analysis of their profiles, especially their rotational contours which are likely to be specific to any of the considered species. Also their rest wavelengths should be known with a reasonable precision. These requirements lead to using high resolution spectra acquired with a high S/N ratio. Rest wavelengths can be determined using radial velocities measured in profiles of interstellar atomic lines recorded in spectra of the same targets. It is, however, not proved that the diffuse band carriers have the same spatial distribution and motion as the atoms and diatomic molecules observed along the same lines of sight (Krełowski & Greenberg 1999). The cases where ALL the above mentioned features share the same radial velocity seem to be most certain as sources of velocity reference frames. However, the fact that the procedure of averaging spectra of differently reddened stars, shifted to the same rest velocity frame, gives precise DIB profiles with some fine structure inside, suggests strongly that the DIB carriers share the spatial distribution with interstellar atomic gas, at least in most cases (Krełowski & Schmidt 1997).

The recently discovered DIBs are always very weak (Galazutdinov et al. 2000a). Also the substructures inside the profiles of strong DIBs are very narrow and shallow (Sarre et al. 1995). The task to distinguish these weak features from weak stellar lines or telluric contaminations makes it necessary to observe stars characterized by different rotation velocities. Rapid rotation ($v \sin i$) makes stellar lines broad (weak ones – invisible) while the profiles of interstellar features remain intact.

DIB profile analyses are, however, possible only when spectra of individual clouds are considered. Any heavily

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* Based on data collected at the ESO 3.6 m telescope operated on La Silla Observatory, Chile.

Table 1. The list of observed stars. Columns headings represent: HD – HD number; SpL – spectral and luminosity class; E_{B-V} – reddening; $v \sin i$ – rotational velocity; 5780 – equivalent width (*EW*) of DIB 5780; 5797 – *EW* of DIB 5797; *CH* – *EW* of *CH* (4300.321 Å) line; *CN* – *EW* of *CN* (3874.6 Å) line; 6196 – *EW* of DIB 6196; 6614 – *EW* of DIB 6614; dw_{6196} and dw_{6614} are full widths of features in (km s^{-1}) on half of maximum depth (*FWHM*). All *EW* measurements are in mÅ.

HD	SpL	E_{B-V}	$v \sin i$	5780	5797	*CH*	*CN*	6196	6614	dw_{6196}	dw_{6614}
144217	B0.5V	0.17	130	161 ± 4	15.3 ± 0.5	2.1 ± 0.2	0 ± 10	12.1 ± 0.7	50.8 ± 2.0	21.0	42.0
144470	B1V	0.18	142	183 ± 5	24.0 ± 2.0	n/a	n/a	12.0 ± 0.6	57.8 ± 1.6	18.0	41.5
145502	B2IV	0.20	199	178 ± 4	34.0 ± 2.0	5.2 ± 0.3	n/a	15.8 ± 0.8	57.8 ± 2.0	20.0	41.5
147165	B1III	0.30	53	243 ± 2	26.0 ± 3.0	2.9 ± 0.3	0 ± 0.2	15.1 ± 0.6	60.2 ± 1.2	20.0	43.5
149757	O9V	0.29	379	70 ± 1	31.0 ± 1.0	18.0 ± 0.6	7 ± 0.2	10.6 ± 0.5	45.3 ± 1.3	23.5	42.0
179406	B3V	0.31	150	148 ± 3	71.0 ± 1.0	16.0 ± 1.0	12 ± 1	19.8 ± 0.7	96.8 ± 2.2	16.0	40.0
184915	B0.5III	0.22	259	158 ± 3	23.6 ± 0.4	5.0 ± 0.5	0 ± 10	16.4 ± 1.0	76.4 ± 1.6	16.0	43.0

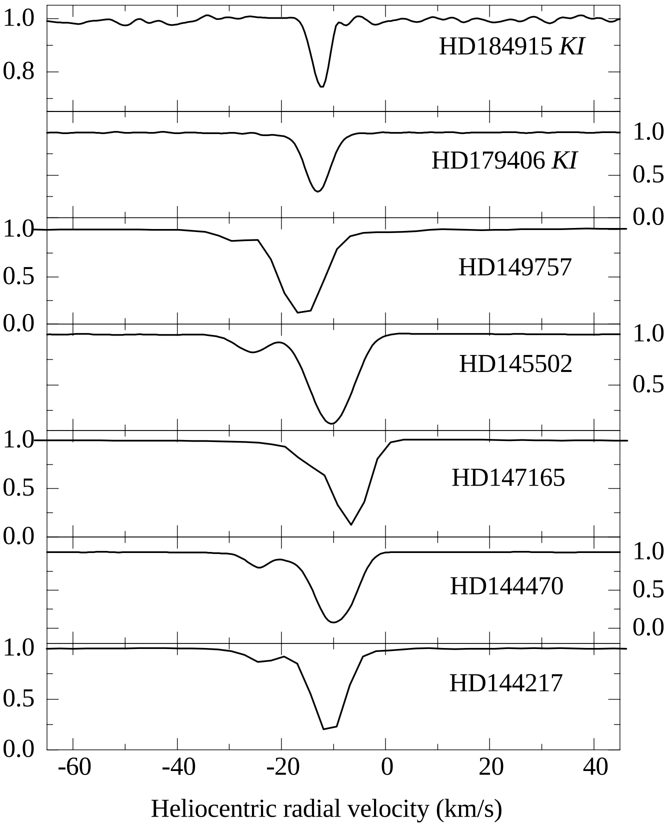

Fig. 1. Figure demonstrates the lack of Doppler splitting in atomic interstellar lines in the spectra of the programme stars. Most spectra are from McDonald observatory (R = 60 000) and show the NaI D$_1$ line, which is typically broad, because of saturation effects. The two upper spectra (R = 80 000) with KI (7699 Å) line (not saturated) are observed with the aid of the coudé-echelle spectrometer (Musaev et al. 1999) of Terskol observatory (Russia).

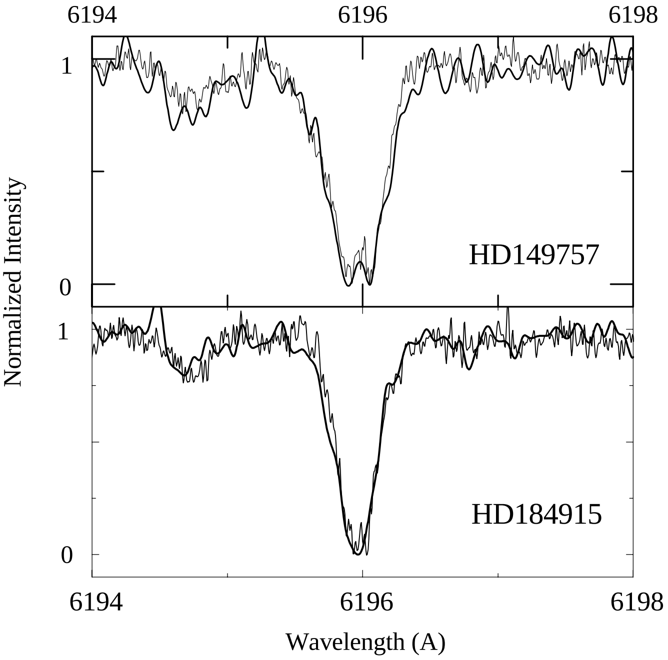

Fig. 2. DIB 6196 profiles of spectra with different resolution; the features are normalized to their central depths. Thick lines correspond to R = 60 000 (McDonald) and thin lines to R = 220 000 (ESO). Note the variability of profiles from star to star confirmed even with lower resolution. The distance between DIB components, seen in the HD 149757 spectrum, is ~6.0 km s^{-1}.

reddened star is observed through several clouds along the line of sight. Their optical properties are very likely to be different as demonstrated many years ago (Westerlund & Krełowski 1988; Krełowski & Westerlund 1988) and an interstellar spectrum, observed towards any heavily reddened object, is very likely an ill–defined average of spectra of all these clouds. With a sufficiently high number of such clouds along a line of sight the observed spectra tend to converge to the same average. Moreover, lines of sight towards heavily reddened stars usually intersect clouds differing in radial velocities (as has been convincingly shown in the case of HD 183143 by Herbig & Soderblom 1982) and thus possible rotational contours of interstellar features cannot resemble those obtained in laboratories. It seems important to check whether variable intensity ratios (like those discovered by Krełowski & Westerlund 1988) are accompanied by some variations of DIB profile shapes.

A set of DIBs, proposed to be the spectrum of a single species, should be characterized by constant strength ratios of the features originating in this species. These ratios should remain the same even towards heavily

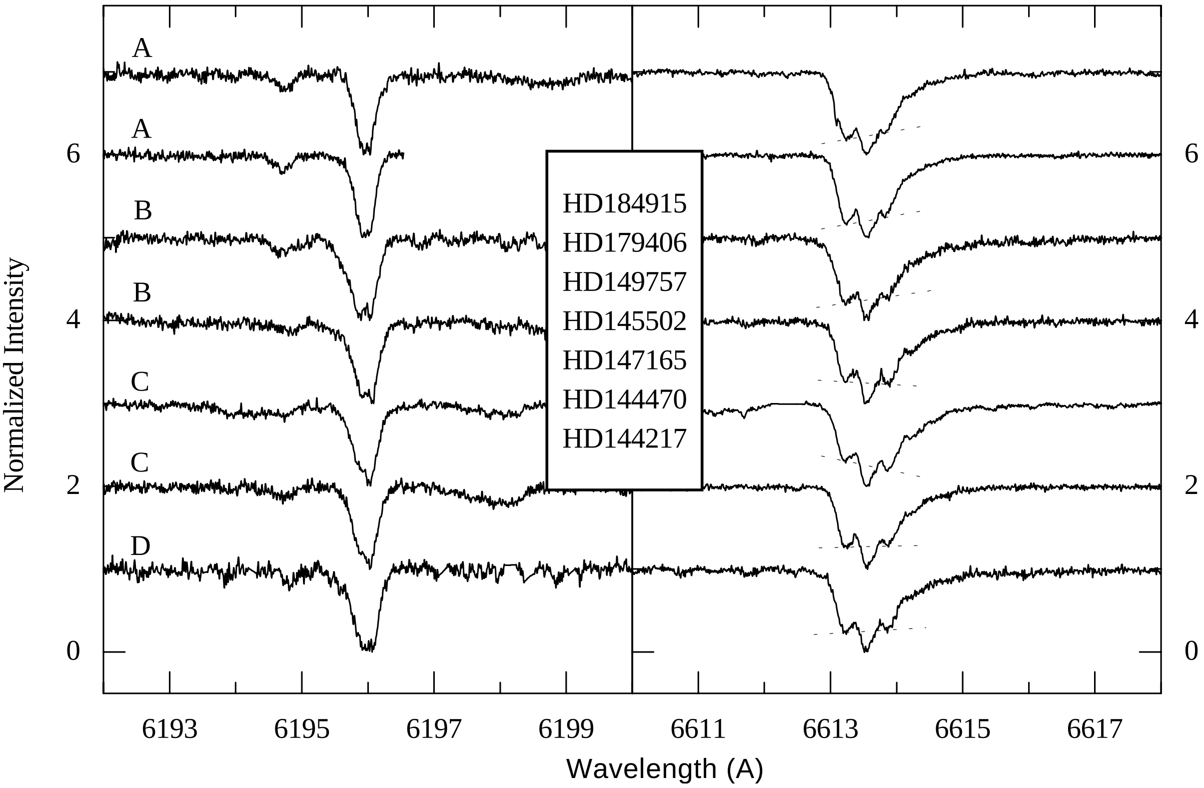

Fig. 3. Profiles of DIBs 6196 (left) and 6614 (right) acquired in ESO spectra with a resolution $R = 220\,000$; the features are normalized to their central depths. Note the variations of profile widths (6196) and their substructure patterns (6614) from star to star. We marked the stars with similar DIB 6196 Å profiles with the same A, B, C or D letters.

reddened stars. We selected the two strong DIBs (6196 and 6614 Å) which correlate very tightly (Moutou et al. 1999), much better than any other pair of strong DIBs. It should be checked whether the shapes of their profiles vary in unison from one line of sight to another and whether their strength ratio is always constant. It was already demonstrated convincingly that the profile of 6614 DIB contains at least three substructures (Kerr et al. 1996) forming very likely a rotational contour of some molecular band. The result was confirmed by Walker et al. (2000) who discussed also the possibility of creation of the observed substructures by isotopic shifts caused by the presence of ^{13}C atoms in big, carbon bearing interstellar molecules (Webster 1996).

The aim of the present paper is to analyze the profiles of the two well–correlated DIBs observed, using a very high resolution, in the spectra of several bright stars i.e. the targets being likely obscured by only a single cloud each. The profiles of the atomic interstellar lines, observed in the spectra of our targets, are free of any observable Doppler splitting (Fig. 1). The main question is how far the behaviour of DIB profiles mimics that of their intensities and thus how far a hypothesis, relating the two DIBs as possibly originated in a single species is correct.

2. The observational data

The main observational material has been collected at ESO with the aid of the CES (Coude Echelle Spectrograph) fed by the fiber link with the Cassegrain focus of the 3.6 m telescope, at La Silla Observatory. All the stars have been observed with the highest resolving power, $R = 220\,000$, using the Very Long Camera. The instrument is equipped with an image slicer which splits the starlight into a dozen well–illuminated slices. The detector is an EEV 2K×4K CCD (pixel size 15×15 μm) with 80% quantum efficiency in the domain of interest.

The objects for this project were chosen from the existing sample of McDonald spectra (Krełowski & Sneden 1993) which includes the NaI D_1 and D_2 lines. Some of the spectra have been acquired using the high resolution (80 000) echelle spectrometer fed with the 2 m telescope of the Terskol Observatory (Northern Caucasia) – in this case the KI line at ∼7700 Å was observed. The chosen targets are listed in Table 1 where HD numbers, spectral types, luminosity classes, colour excesses and rotational velocities are given. We also added some other interstellar data such as intensities of the 5780 and 5797 Å major DIBs (measured in McDonald spectra) and known molecular features (Krełowski et al. 1999). The targets were selected using the profiles of atomic interstellar lines i.e. they do not show Doppler splitting (Fig. 1). Such a choice of targets makes it possible not only to measure intensities of the chosen bands but also to analyze their profiles. Our targets are reasonably bright stars. This was essential as high resolution makes the achievement of high S/N quite difficult.

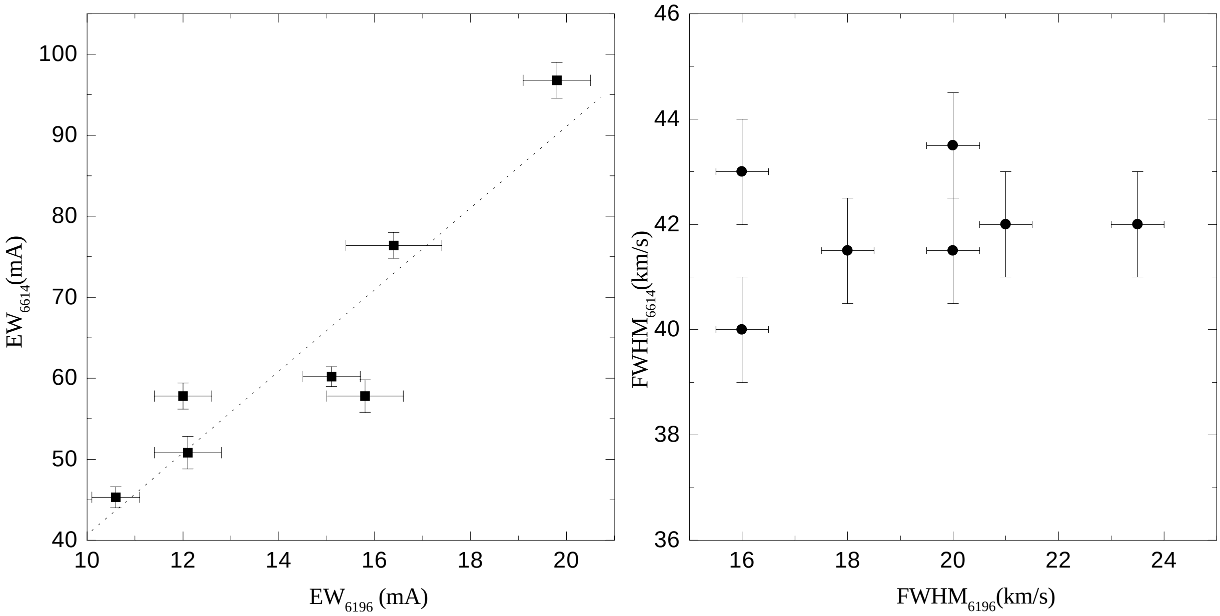

Fig. 4. Left panel: correlation between the equivalent widths of λ6196 and λ6614 DIBs measured in the ESO spectra. Right panel: the relationship between the *FWHM*'s of DIBs 6196 and 6614 (radial velocity scale). The adopted uncertainties of the measurements are 1 and 2 $\mathrm{km\,s^{-1}}$ for 6196 and 6614 respectively. It can been seen that there are large variations in the widths of the λ6196 DIB and that the widths of the λ6614 DIB are practically constant.

The ESO spectra have been recorded with a very high signal–to–noise ratio, in some cases exceeding 1 000. Such a high quality is necessary to allow an analysis of very weak substructure patterns inside the observed DIB profiles. The spectra have been divided by telluric line divisors (HD 143018, HD 149438, HD 120307, HD 205637) to make sure that no telluric contaminations is present inside the considered profiles.

Our reduction of the spectra was made using the DECH code (Galazutdinov 1992). This program allows a flat-field division, bias/background subtraction, one–dimensional spectrum extraction from the 2–dimensional images, correction for the diffuse light, spectrum addition, excision of cosmic ray features, etc. The DECH code also allows location of a fiducial continuum, measurements of the line equivalent widths, line positions and shifts, etc.

The selected objects differ significantly in the strength ratio of the major DIBs: 5780 and 5797 (see Table 1). The ratio is very high towards HD 144217 and HD 147165, a bit lower towards HD 144470, HD 145502 and HD 184915 and extremely low towards HD 149757 and HD 179406. Thus our selection of lines of sight involves environments that are clearly different: they are characterized by different major DIB intensity ratios as well as by different relative (to E_{B-V}) intensities of CH and CN molecular features (Table 1).

3. Results

The extracted DIB profiles are shown in Fig. 3. Both panels, presenting the observed profiles of λ6196 and λ6614, cover equally broad ranges (in Å) to allow a direct comparison of the profile widths. The clearly seen substructure pattern inside the 6614 DIB is well known since the Sarre et al. (1995) publication. The other band has never been observed with a similar resolution until now. Only Krełowski & Schmidt (1997) suggested some asymmetry in its profile.

The variable pattern of substructures inside the λ6614 DIB profile, suggested by Krełowski & Schmidt (1997), is well–seen in Fig. 3. In some of the spectra the substructure in the red wing of the λ6614 DIB is much more evident than in others. The profile shape varies from target to target in both features but the variations do not happen in unison with those of the 5780/5797 strength ratio. The spectra of HD 184915 and HD 179406 provide an evident example. The strength ratio of the λ5780 and λ5797 DIBs is evidently different in their spectra. However, the normalized profiles of λ6196 and λ6614 DIBs are identical in their spectra. It is important to note that the profile variations, observed in our high resolution ESO spectra, closely resemble those, suggested by the much lower resolution McDonald data (Fig. 2). The similarity of results acquired with two different instruments, prove beyond a doubt that the observed, different profiles i.e. of different width from target to target as well as of different substructure pattern are not of instrumental origin.

The 6196 profile shows also a substructure pattern. Its variations do not follow those of the 5780/5797 ratio either. The band is very narrow and almost featureless towards HD 179406 and HD 184915 while toward HD 149757, HD 145502, HD 147165 and HD 144470 it is evidently broader (Table 1) and splits into some substructures in the bottom. Apparently the width of the λ6196 feature is strongly variable while that of λ6614 remains practically constant (Figs. 4 and 5). The variations of the

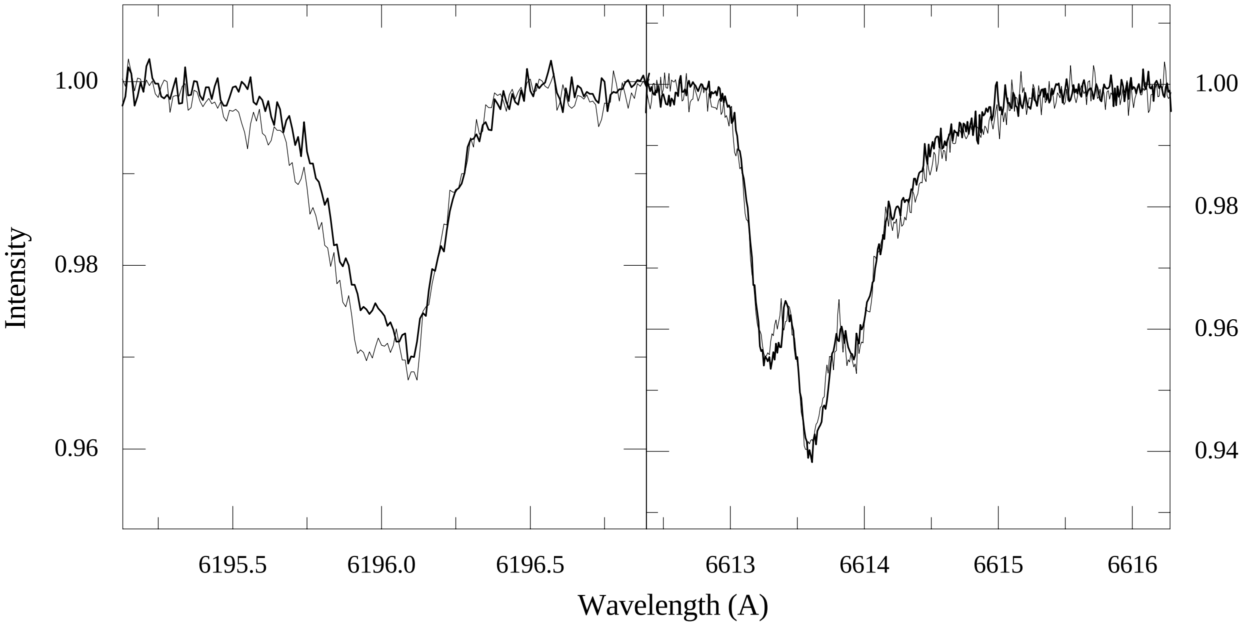

Fig. 5. Comparison of DIB 6196 and DIB 6614 profiles in spectra of HD 145502 (thin line) and HD 144470 (thick line). Note the similarity of the 6614 profiles and evident variations of width and substructure pattern of the 6196 feature.

substructure pattern inside the two profiles are not related either. The lack of any relation between shape variations of the chosen DIBs creates doubts as to whether they are of the same origin.

The relation between the equivalent widths of the two DIBs is presented in left panel of Fig. 4. The plot confirms the very tight correlation already demonstrated by Moutou et al. (1999), but the scatter exceeds the range of observational uncertainties in our high resolution, high S/N ratio spectra. The reliability of this result is shown in Fig. 5 where we demonstrate that while the 6614 profiles are practically identical in the spectra of HD 145502 and HD 144470, those of 6196 differ both in width and shape. The difference is very small and cannot be found in spectra of lower S/N ratio and resolution but the ESO data are sufficiently precise to show it beyond a doubt. The fact that the width of 6196 can change while that of 6614 remains the same is also illustrated in the right panel of Fig. 4. The range of possible 6196 width variations is up to 50% of the smallest value. At the same time the observed variations of the 6614 width hardly exceed the observational uncertainties. Apparently different mechanisms create the observed variations in the profiles of the two DIBs.

The above analysis shows that only spectra of moderately reddened stars, observed through single interstellar clouds, can be used to verify the hypothesis that a proposed set of DIBs can be of common origin. In such a case one should expect a constant strength ratio and related variations of profile shapes. It is a necessary step towards identification. Very high S/N ratio is crucial because interstellar features, observed in such objects, are relatively weak.

4. Profile fitting procedure

The first description of the profiles of strong diffuse bands was given by Herbig (1975). The analysis, based on photographically recorded spectra, demonstrated that their profiles are usually not just single Gaussians. Westerlund & Krełowski (1988) were the first to use a solid state detector to record high resolution spectra of reddened stars. Their description of DIB profiles clearly suggests that a substructure pattern may be expected inside the profiles of certain DIBs especially λ5797. These substructures have been approximated with single Gaussians. When summed these give the observed DIB profiles.

Figure 6 shows a similar approach, i.e. it represents our attempt to find the best fits of the observed profiles using Gaussian components (Table 2). The method used for determining the pattern of components can be described as follows:

1. a selection of the minimal number of obvious components (usually 3 in the case of DIB 6614, and 2 in the case of DIB 6196);
2. calculation of the best fit (using the least squares method) and of the residuals, representing the differences between all points of the achieved fit and the observed profile. All the parameters of the Gaussians (amplitude, position and full width at half maximum) were left free;
3. addition of one more component if the plot of residuals indicates a systematic local discrepancy, then repetition of step 2;
4. repetition of steps 2 and 3 until the plot of the residuals converge to a small scatter around a horizontal line (see Fig. 6).

We tried also to fit λ6614 DIB using fixed (with equal *FWHM*) and/or equally spaced components. Such fits do not reproduce the observed profiles as precisely as those described above. The plots of residuals always show some systematic discrepancies which suggest additional features inside the investigated profiles.

5. Discussion

The high resolution and high signal–to–noise spectra acquired with the ESO instruments leave no doubt that the profiles of the two well–correlated diffuse interstellar bands, λ6196 and λ6614 Å vary from object to object and that these variations are not caused by the Doppler effect. The observed changes involve a broadening in the case of 6196 and variations of the substructure pattern (the relative intensities of the substructures) in the case of 6614.

The fact that similar variations of DIB profiles can be observed in the ESO spectra as well as in the lower resolution McDonald and Terskol stuff leaves no doubt that DIB profile variations are not of instrumental origin. The existing sample does not give a possibility to divide the observed cases into several categories and this can be a very difficult problem also in a future as only a few stars shine through individual interstellar clouds of a substantial optical depth.

There are at least two mechanisms that could explain the variations of DIB profiles: (i) the variation of the rotational temperature of the carrier species, and (ii) the shift and intensity variation of isotopic components. The latter only depends on the relative content of ^{13}C atoms in the interstellar molecules and thus it leaves the width of profile unchanged.

The energy spacing between the central and blue-ward components of λ6614 DIB is 0.78 cm^{-1}. The spacing between the central and the red-ward component is less precisely the same (Table 2). The latter may be due to possible blending with a separate feature centered near 6614.3 Å. Interpreting this spacing in the framework of a rotational sequence, as is often the case in recent studies of DIB profiles (Schulz et al. 2000), would lead to a molecular constant B of 0.39 cm^{-1}.

The intensities of the two considered DIBs are remarkably well–correlated in the interstellar medium in comparison with any other pair of strong DIBs (Moutou et al. 1999). We explain this by assuming that the two species are probably linked by a tight chemical relationship, which induces a similar behaviour of their abundances and, hence a close relation between their spectral features.

It is very likely that the observed profile variations, especially those seen in the 6196 profile, are caused by different rotational temperatures of the molecules carrying the observed features (see e.g. Fulara & Krełowski 2000). The variable substructure pattern, observed in the bottom of 6614, is possibly of another origin. In this case the hypothesis of carbon isotope shift (Webster 1996) cannot be excluded as the isotope shift depends only on the relative content of ^{13}C atoms in the interstellar molecules and thus it leaves profile width unchanged, or, more precisely, all the proposed components should be of the same width. In fact no explanation of the behaviour of any DIB profile can be ruled out before the feature is reliably identified.

It is clear that those components which allow really good fits to the observed profiles are neither of the same widths nor of the same intensity ratios. This fact creates doubts whether the Webster hypothesis is correct even in the case of the 6614 DIB.

The analysis published by Walker et al. (2000) assumes constant widths of all components observed towards the same target. Leaving this parameter free we obtain components which vary from object to object in our $R = 220\,000$ and $S/N = 1000$ spectra. Moreover, some of the proposed components, especially the one centered around $\sim$6614.3 Å, do not seem to appear in certain spectra, e.g. HD 179406 (Fig. 6). This may be due to a blending of two interstellar features of different origin. This can make any fit (like that of Fig. 6) uncertain and physically meaningless as the components can be of very different width and the presence of one of the blended features (of another origin) may strongly influence the profile of the other one. In Fig. 6 we show also the residuals of the obtained fits. It is evident that the found sets of Gaussian curves fit the observed profiles very well and thus any other fitting technique can hardly improve it. Before the carrier of the λ6614 DIB is identified it is very difficult to say definitely whether the observed feature is a single one or a blend.

The same can be said about the simulations similar to those proposed by Kerr et al. (1996). They can allow us to calculate certain parameters of possible carriers only if the 6614 DIB is a single feature, free of any blending. A satisfying hypothesis must account for the observed variable ratios of the 6614 substructures and the presence or absence of some of them.

The structure of the 6196 DIB profile is significantly different to that of 6614. In most of cases we can distinguish one dominating Gaussian curve and a very weak one. Sometimes a good fit requires more weak Gaussian profiles, especially while this particular DIB is very broad (see Figs. 2, 5). This broadening, which is characteristic for 6196 but not for 6614, is much more likely caused by e.g. temperature variations than by the isotopic shift as the simplest possible fit (Fig. 6) does not contain components of comparable strength, equidistantly separated in wavelength and/or energy range. The fact that the profiles of the two, very well–correlated DIBs, behave differently is a strong argument against their common origin.

Table 1 lists the typical problems which emerge when we try to relate any two different interstellar features. We selected our targets, based on the classification of interstellar clouds proposed by Krełowski & Sneden (1995). Table 1 contains both so called σ and ζ type objects. This is confirmed by the variable strength ratios of the two major DIBs: 5780 and 5797. However, with the same ratio of the major DIBs and the same E_{B-V}'s of HD 149757 and HD 179406, the DIB intensities are two times stronger in the latter than in the former. The 6614 profile shape is

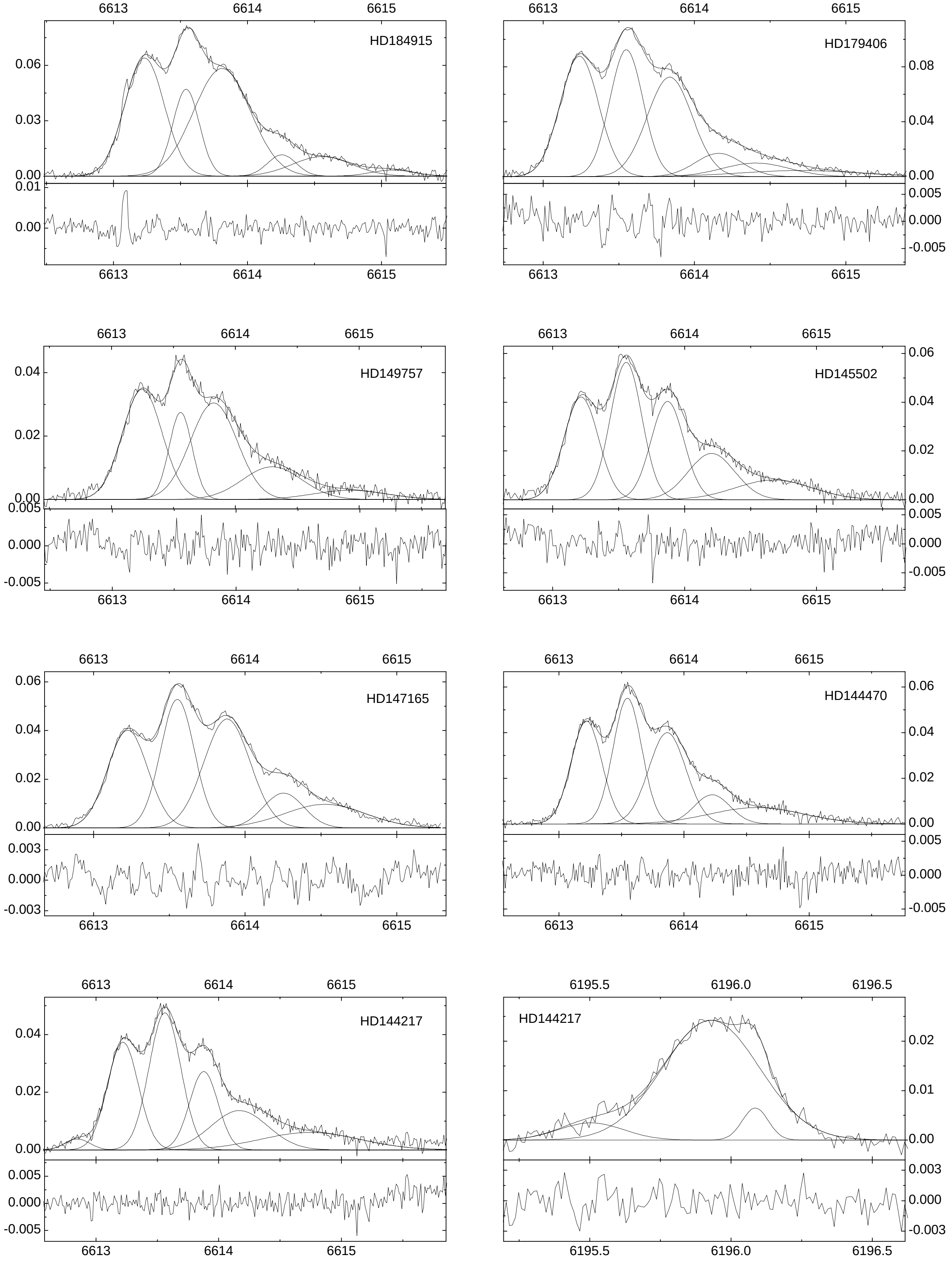

Fig. 6. The observed profiles of DIBs fitted with multiple Gaussian components. Each figure shows the residual plot in the bottom. All DIB profiles are shifted to the rest wavelength (Galazutdinov et al. 2000a) scale.

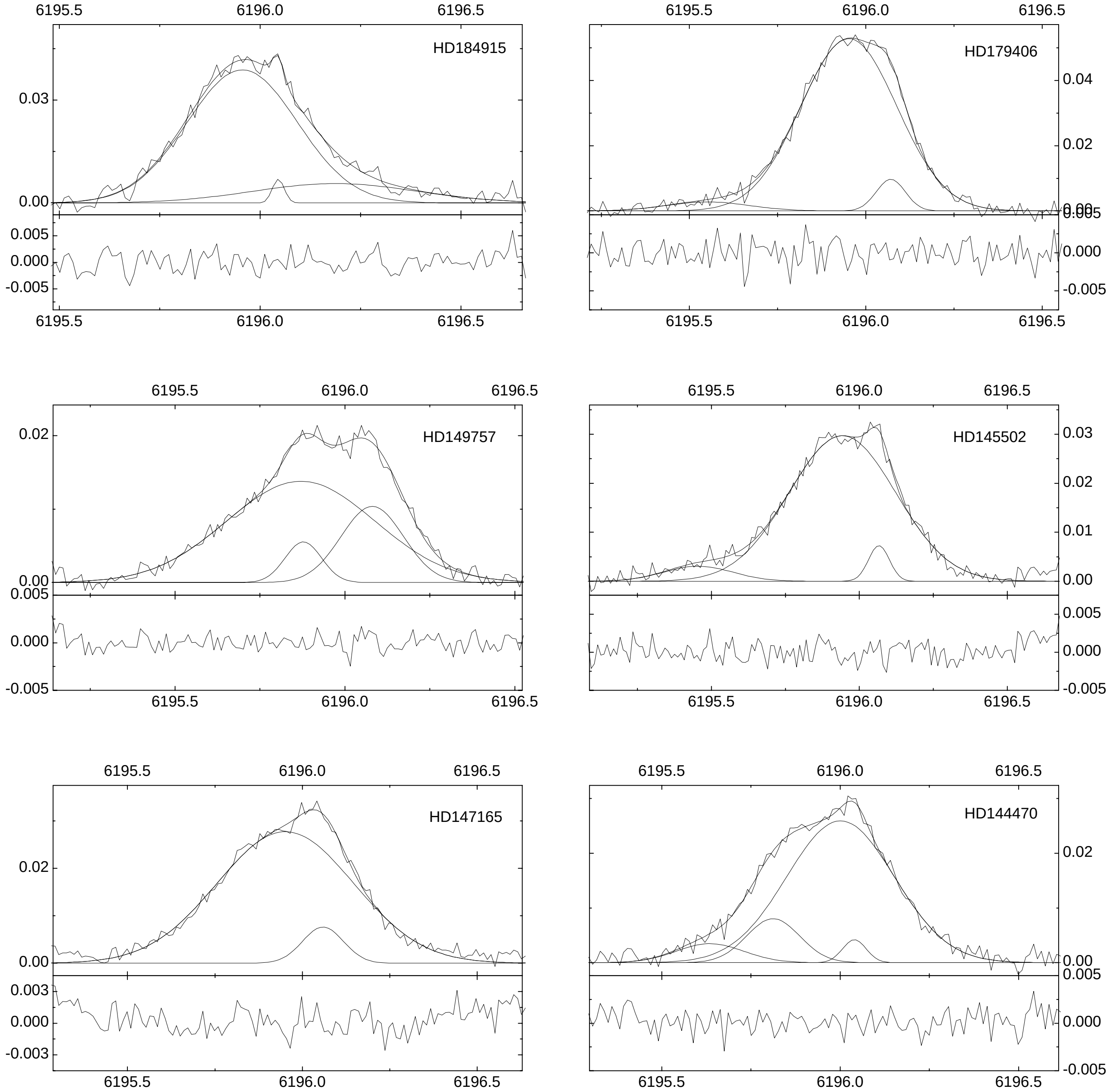

Fig. 6. continued.

very similar in both targets while that of 6196 is evidently broader when the band is weaker (in HD 149757). The intensities of *CH* molecular features are practically the same in both targets. The only spectral structure, other than any DIB, which behaves like the diffuse bands is the *CN* feature. Unfortunately existing spectra, containing a measurable *CN* feature are very scarce and thus we can only suggest that an extensive survey of this molecule seems of importance for it could likely be a result of photofragmentation of a DIB carrier or a building block for one.

At the moment we cannot identify any of the observed DIBs. Nevertheless, some linear species, based on a carbon skeleton, remain to be the most likely carriers of narrow DIBs which typically show some substructures inside their profiles. This hypothesis gets some support from laboratory vs. observational profile comparisons (Motylewski et al. 2000) as well as from theoretical calculations which allow to reproduce the observed profiles reasonably well (Schulz et al. 2000).

The recent gas phase laboratory spectra of other proposed DIB carriers – polycyclic aromatic hydrocarbons (PAHs) (Romanini et al. 1999; Bréchignac & Pino 1999) proved that their spectral features are broad (up to 20 Å *FWHM*) and thus they are not likely to produce the great majority of known DIBs which are an order of magnitude narrower. Also fulleranes are not very likely to be carriers of many DIBs – most probably they can only carry a few interstellar features (Galazutdinov et al. 2000b).

Let us mention also the additional difficulty which appears when trying to identify any of the DIBs.

Table 2. The parameters of the fitted Gaussians.

Star	Peak 1	Peak 2	Peak 3	Peak 4	Peak 5	Peak 6
HD184915			DIB6614			
Amplitude	0.06402	0.04709	0.0583	0.01156	0.01067	0.00335
Position(A)	6612.68938	6612.99974	6613.26793	6613.71484	6614.01531	6614.54282
FWHM (A)	0.14729	0.09853	0.21163	0.10743	0.22124	0.16035
E.W. (mA)	23.64	11.63	30.93	3.11	5.92	1.35
			DIB6196			
Amplitude	0.03882	0.00698	0.00565			
Position(A)	6195.44888	6195.53849	6195.68013			
FWHM (A)	0.13729	0.01483	0.20322			
E.W. (mA)	13.36	0.26	2.88			
HD179406			DIB6614			
Amplitude	0.08772	0.09241	0.07246	0.01698	0.00988	0.00448
Position(A)	6612.77336	6613.08363	6613.37017	6613.69334	6613.93864	6614.23275
FWHM (A)	0.12686	0.10942	0.14876	0.15357	0.22171	0.39634
E.W. (mA)	27.9	25.35	27.02	6.54	5.49	4.43
			DIB6196			
Amplitude	0.00277	0.05285	0.00972			
Position(A)	6195.12962	6195.52938	6195.64833			
FWHM (A)	0.11662	0.13634	0.04106			
E.W. (mA)	0.81	18.06	1.00			
HD149757			DIB6614			
Amplitude	0.03481	0.02753	0.03047	0.01035	0.00292	
Position(A)	6613.13379	6613.44274	6613.71043	6614.18271	6614.80943	
FWHM (A)	0.15985	0.09224	0.18933	0.23926	0.29536	
E.W. (mA)	13.95	6.37	14.46	6.21	2.16	
			DIB6196			
Amplitude	0.0138	0.00555	0.01039			
Position(A)	6195.77057	6195.77803	6195.98068			
FWHM (A)	0.21828	0.05332	0.09161			
E.W. (mA)	7.55	0.74	2.39			
HD145502			DIB6614			
Amplitude	0.04214	0.05638	0.04034	0.01899	0.00811	
Position(A)	6613.27306	6613.61381	6613.9273	6614.26098	6614.73176	
FWHM (A)	0.12969	0.11905	0.12403	0.17673	0.28873	
E.W. (mA)	13.7	16.83	12.54	8.41	5.87	
			DIB6196			
Amplitude	0.00307	0.0297	0.00727			
Position(A)	6195.51903	6196.0062	6196.12972			
FWHM (A)	0.11663	0.18092	0.03516			
E.W. (mA)	0.90	13.47	0.64			
HD147165			DIB6614			
Amplitude	0.04014	0.05281	0.04475	0.01432	0.00969	
Position(A)	6613.33868	6613.66607	6613.9934	6614.36561	6614.63886	
FWHM (A)	0.13273	0.11095	0.15222	0.13262	0.26736	
E.W. (mA)	13.35	14.69	17.08	4.76	6.48	
			DIB6196			
Amplitude	0.02774	0.00764				
Position(A)	6196.08661	6196.19415				
FWHM (A)	0.19563	0.05831				
E.W. (mA)	13.6	1.12				
HD144470			DIB6614			
Amplitude	0.04512	0.05515	0.04001	0.01278	0.00716	
Position(A)	6613.2861	6613.61375	6613.93252	6614.29106	6614.64919	
FWHM (A)	0.1223	0.1145	0.1483	0.14327	0.37621	
E.W. (mA)	13.83	15.83	14.87	4.59	6.76	
			DIB6196			
Amplitude	0.00347	0.00805	0.02592	0.0042		
Position(A)	6195.72435	6195.90162	6196.09053	6196.12944		
FWHM (A)	0.09408	0.07437	0.15074	0.0332		
E.W. (mA)	0.82	1.5	9.8	0.35		
HD144217			DIB6614			
Amplitude	0.00379	0.03734	0.04753	0.02717	0.01362	0.00605
Position(A)	6612.90244	6613.274	6613.61602	6613.93274	6614.22343	6614.79996
FWHM (A)	0.10058	0.12557	0.12869	0.11545	0.23142	0.40398
E.W. (mA)	0.96	11.75	15.33	7.86	7.9	6.13
			DIB6196			
Amplitude	0.00347	0.02422	0.00652			
Position(A)	6195.56494	6195.99015	6196.14664			
FWHM (A)	0.11539	0.17112	0.04571			
E.W. (mA)	1.00	10.39	0.75			

The variations in the profiles, which are shown above, make a comparison between laboratory and astrophysical spectra much more difficult. An observed profile can be broader or narrower than its laboratory counterpart; also a possible substructure pattern may not match that from a laboratory. A solution of this very long standing unsolved problem requires both extensive programs of laboratory investigations as well as reasonably large samples of high class astrophysical spectra.

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