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LETTER

Letter to the Editor

Diffuse Interstellar Bands towards BD+63° 1964*

A new reference target

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Abstract. We report the discovery of a remarkable target concerning the Diffuse Interstellar Bands (DIBs), namely BD+63° 1964. The unusual high DIB strengths in this object allow to confirm DIBs that were so far denoted only as "probable", because of their intrinsic weakness in most lines-of-sight. Due to specific line-of-sight conditions, the high reddening and the early spectral type of the star, this object is proposed as a new reference star for DIB measurements. We compared the spectrum of BD+63° 1964 to the spectrum of the well studied star HD183143. Line-of-sight parameters such a far UV extinction and Ca I abundance indicate a denser environment towards BD+63° 1964, which can shield molecules efficiently from far UV radiation above 6 eV. The relative enhancement of narrow DIBs in BD+63° 1964 versus HD183143 is then discussed in the context of neutral fullerene compounds or large PAHs. The relative weakening of broad DIBs indicate carriers with higher photo-ionization potential and different recombination properties.

Key words: ISM: molecules - ISM: dust,extinction - Stars: individual: BD+63° 1964, HD183143; Line: profiles

1. Introduction

The identification of the Diffuse Interstellar Band (DIB) carriers remains an important problem in astronomy. The current number of ∼150 DIBs is still increasing, suggesting that up to 400 DIBs may be present in the interstellar medium. The evolution of the DIB research in the recent years indicates that most DIB carriers would be large C-molecules residing ubiquitously in the interstellar gas. The main proposed species are carbon-chains, polycyclic aromatic hydrocarbons (PAHs) and fullerenes (see Herbig 1995 for a review). Two strong DIBs in the near-infrared have been assigned to C_{60}^+, indicative for the first direct identification of DIBs (Foing & Ehrenfreund 1994, 1997). An assessment of the PAH-DIB proposal is presented by Salama et al. (1996) and suggests to correlate the known DIBs with 150-200 stable PAH ions belonging to the class of smaller PAHs. Recent detections of substructures in the profiles of several narrow DIBs (such as λ5797, λ6613 and λ6379) reveal the gaseous nature of the carrier (Sarre et al. 1995, Ehrenfreund & Foing 1996) and suggest in comparison with model calculations of PAHs and fullerenes that those DIBs originate in large molecules with more than 40 C atoms (Ehrenfreund & Foing 1996).

The DIB strength varies as the total HI column density, which results in a decline of DIB strength with depth in the cloud where the H_2 concentrations rises, the so called "skin-effect" explained by a concentration of DIB carriers in the surface layers of dense clouds (Herbig 1995). Environmental studies of strong DIBs show a significant dependence of the carrier molecules on the local UV radiation field (Jenniskens et al. 1994, Cami et al. 1996). An approach to identify the DIB carriers is therefore to study the complete DIB spectrum in different regions of the interstellar medium. The significant differences in density and UV flux will determine the existence, abundance and ionization stage of the corresponding carrier molecules.

2. New observational results

Observations were obtained on July 24th and November 8th, 1995 - at the Observatoire de Haute Provence (OHP). We used the 1.93 m telescope, equipped with the spectrograph ELODIE, which is a new fiber-fed echelle spectrograph, covering the wavelength range from 3906 to 6811 Å with a resolution of ∼ 42000 (Baranne et al. 1996).

BD+63° 1964 is a B0II star of visual magnitude V* = 8.6 and was observed at sec z = 1.07 resulting in a $S/N > 200$.

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* Based on observations at Observatoire Haute Provence with the spectrograph ELODIE.

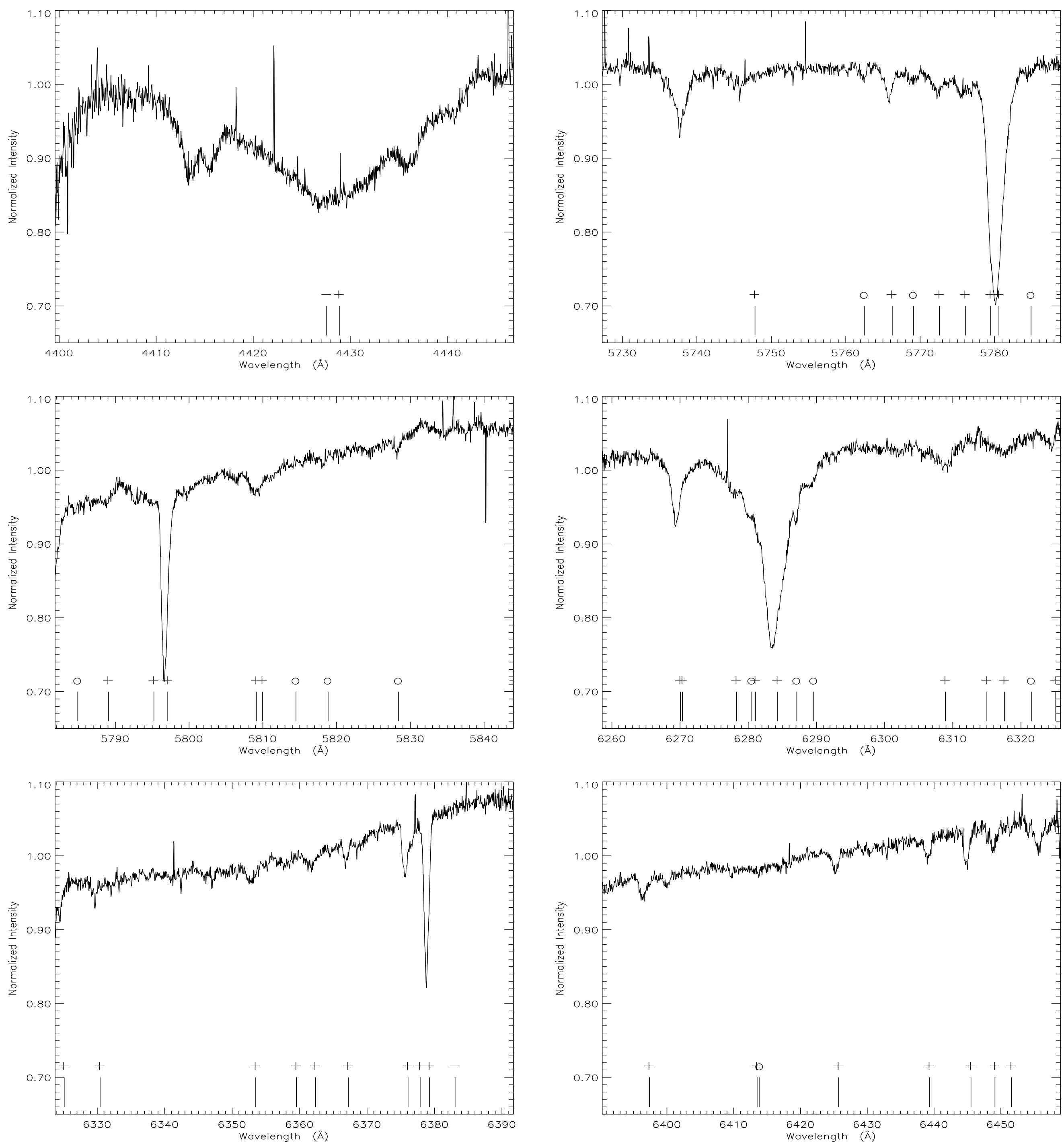

Fig. 1. Several orders of the ELODIE spectrum observed towards BD+63° 1964 with increasing wavelength. The vertical lines at the bottom denote the wavelength where a DIB should be found (according to JD94). Confirmed DIBs are marked with "+". DIBs denoted as "probable" in the previous literature are marked with an "o" in the Figure. Several features that have tentatively been suggested as "probably not" DIBs are marked with "-". DIBs that are very weak are definitely present in this object.

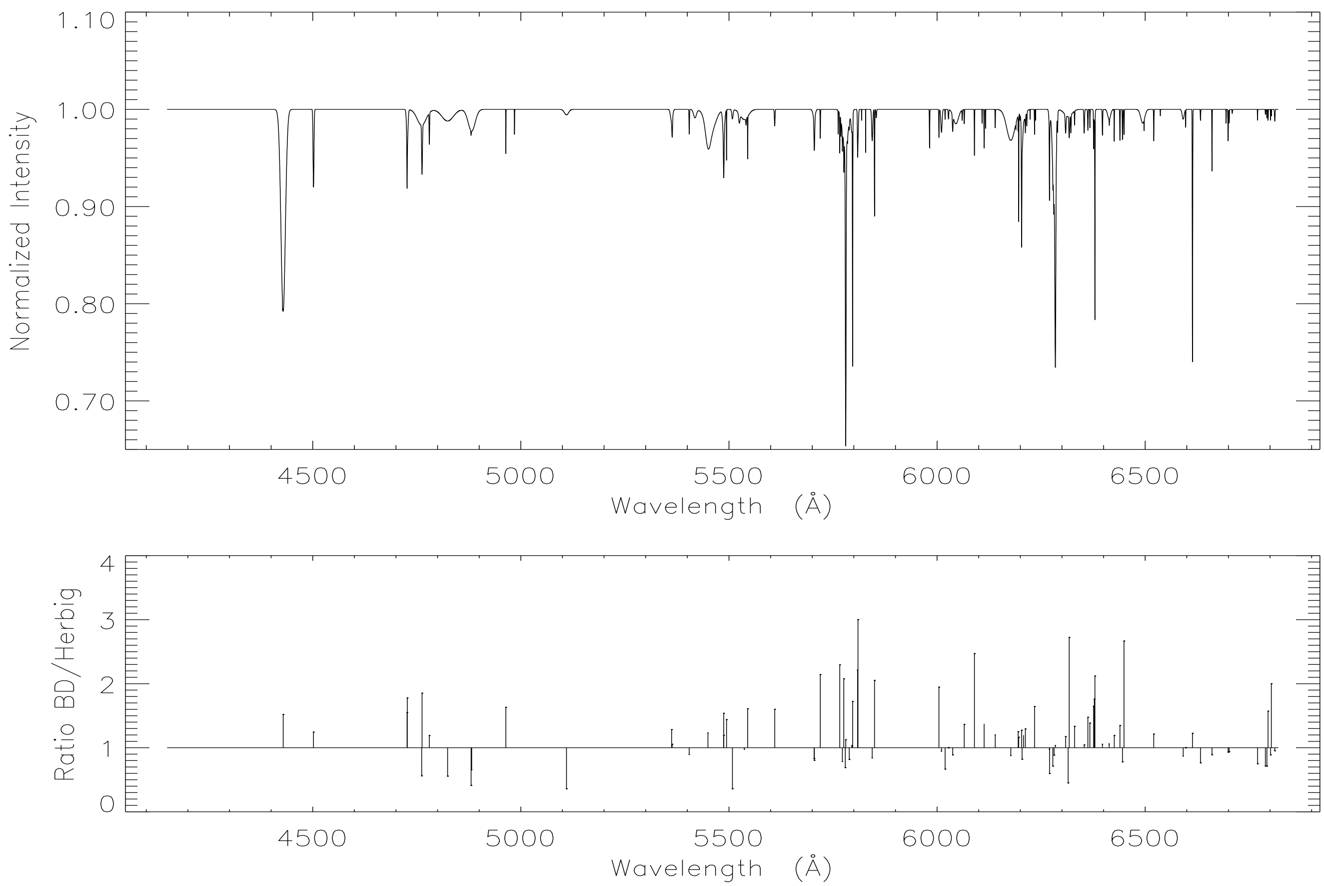

Fig. 2. a) (top) A composite DIB spectrum of BD+63° 1964 between 4100-6800 Å. It is synthesized from measured equivalent widths and widths of more than 120 DIBs in this wavelength range. This object is proposed as future reference target for DIB studies.
b) (bottom) Ratio of DIB equivalent widths of BD 63° 1964 over HD183143 (normalized to unit reddening) showing enhancement of many narrow DIBs and weakening of broad DIBs. Some of the confirmed broad DIBs, which could not be accurately measured because of stellar line blending and positions at edges of echelle orders, are not included in this analysis.

A first inspection of its spectrum revealed that many narrow DIBs are very strong but broad DIBs seem relatively weakened. We can confirm 26 DIBs which were denoted as "probable" by Jenniskens & Desert (1994, thereafter JD94). In Fig. 1 we display several orders of the spectrum towards BD+63° 1964, where important and weak DIBs are detected. A search for new weak DIBs in this object is currently underway.

BD+63° 1964 is a remarkable target for DIB-observations :

- It is a hot star (spectral type B0 II) which mostly eliminates stellar contamination
- The reddening E_{B-V} is 1.01
- The interstellar extinction curve is very similar to the extinction curve of the average interstellar medium (Witt et al. 1984).
- Every single confirmed DIB known to date seems to be present, even DIBs that were so far not certain.

A composite DIB spectrum towards this object is shown in Fig. 2a. In order to investigate possible causes of the abnormal DIB strengths in this line-of-sight, we compared the DIB spectrum to the one of HD183143 (spectral type B7Iae, E_{B-V}=1.28), which is most often used as the DIB reference star with the strongest DIBs. DIB measurements for HD183143 were obtained from our own observations of HD183143 using ELODIE, in order to have a consistent data set and DIB definition. The comparison shows that two third of the DIBs measured between 4000-7000 Å are stronger in BD+63° 1964 than in HD183143. In Fig. 2b we plot the DIB strength ratio according to the wavelength. Selected important DIBs are listed in Table 1.

3. Discussion

3.1. The line-of-sight conditions towards BD+63° 1964

The extinction curve of BD+63° 1964 is very similar to the extinction curve for the "average" interstellar medium (Witt et al. 1989). The extinction in the far UV suggests a denser line-of-sight than diffuse clouds (Cardelli 1988). The Na lines are strongly saturated and the Ca II line at 3968 Å shows two substructures, at -10 and -28 km/s, respectively. The Ca II equivalent widths of 605 mÅ and absorption depth is within 10 % of the value measured for HD183143, which indicates a comparable Ca II column density, even after considering non-linear curve

λDIB (Å)	BD 63° 1964 (mÅ)	HD183143 (mÅ)	ratio
4761	442	786	0.56
4824	416	747	0.56
5537	252	258	0.97
5780	677	602	1.12
5797	260	151	1.72
5849	121	59	2.05
6207	117	140	1.19
6284	1387	1476	1.03
6379	176	83	2.12
6613	316	258	1.22

Table 1. Equivalent widths of several strong DIBs in the line-of-sight towards BD+63° 1964 and towards HD183143 (normalized to reddening 1). Errors range from 5 to 15 %. The DIB strength ratio of BD+63° 1964/HD183143 is given in the last column.

of growth effects. However, the Ca I absorption at 4226 Å has a strength of 24 mÅ (compared to 10 mÅ for HD183143) leading to a column density of 9.5 x 10^{10} cm^{-2}. The 5797/5780 DIB ratio of 0.384 indicates a dense cloud contribution of DIBs, in addition to the classical diffuse cloud DIB spectrum (Krelowski & Sneden 1995). The CH and CH^+ lines have strength of 23 and 45 mÅ (compared to 36 and 51 mÅ for HD183143) leading to column densities N(CH) = 28 x 10^{12} cm^{-2} and N(CH^+) = 51 x 10^{12} cm^{-2}, respectively. Relative enhancement of CH and CH^+ densities are thus 0.82 and 1.1. Most strong DIB carriers are concentrated in the surface layers of dense clouds (Herbig 1995). Therefore observations sampling cloud interiors differ from those crossing mostly cloud edges. Also the correct equilibrium of parameters such as density, gas/dust ratio, electron density and UV field influences the DIB strength. We can summarize that conditions in the line-of sight towards BD+63° 1964 do show enhancement of a majority of narrow DIBs observed between 4000-7000 Å.

3.2. DIB weakening/enhancements towards BD+63° 1964

What is the cause of the enhancements in DIBs strength towards BD+63° 1964 ? The classical DIBs with large width (FWHM - Full Width at Half Maximum) of $\sim$ 10-30 Å (e.g 4761, 4824, 4881 Å etc.) are depleted or at most equal in the line-of-sight towards BD+63° 1964 versus HD183143 (ratios 0.56-1.05). Intermediate DIBs with FWHM of 1.8-3.5 Å have intermediate enhancement ratios of 1.0-1.75.

The strong narrow DIBs with FWHM of 1.1-1.4 Å (e.g. 5797, 6379, 5849) are significantly enhanced with ratios 1.72-2.1. The similar behaviour of these 3 DIBs indicate close properties of the respective carriers in ionization, electron affinities, and stability over a large range of interstellar conditions. Weak narrow DIBs with FWHM of 0.8-1.5 Å show a large range of ratios from 0.7 to 2.5. This suggests a population of large molecules with different ionization/ recombination properties. It is interesting to recall that the measured FWHM (3 cm^{-1}) of this DIB population is reminiscent of the broadening effect of fullerene compounds (Ehrenfreund & Foing 1997).

The Ca I density enhancement (per reddening E_{B-V}) towards BD+63° 1964 versus HD 183143 amounts to 3.1, indicating the presence of one or more dense cloud(s) in the line-of-sight, which shield the DIB carriers from UV photons above 6 eV, the ionization potential of CaI. These local conditions would also lead to the relative enhancement of DIB carriers having a similar ionization potential (IP), such as large neutral PAHs or neutral fullerene compounds (IP of 7eV). Also carrier molecules which are ionized by UV photons less than 6 eV could be favoured. The DIB population with narrow widths and strength enhancement above 1.5 in BD+63° 1964 must differ from the carriers of weakened broad DIBs in terms of photo-ionization potential, recombination properties and chemical production pathways.

4. Conclusion

We observed the star BD+63° 1964 and found that it is a remarkable object to serve as a reference target for future DIB observations. The far UV extinction and the Ca I column density indicate a denser environment for BD+63° 1964 than for HD183143 leading to a weakening of broad DIBs and an enhancement of many narrow DIBs. For those narrow DIBs with enhanced strengths, carrier molecules with an ionisation potential near 6 eV are suggested, reminiscent of large neutral PAHs or fullerene compounds. However, the carriers of the broad DIBs would have very different ionisation potential and recombination properties. Future observations of this target using high spectral resolution to resolve the cloud components and interface can probably shed light on DIB formation. A parameter of great importance in future DIB studies is to resolve the geometry and distribution of clouds in the line-of-sight.

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