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DIFFUSE INTERSTELLAR BANDS TOWARD HD 62542

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ABSTRACT

Diffuse interstellar bands (DIBs) have been detected for the first time along the peculiar translucent line of sight toward HD 62542, which passes through a diffuse cloud core. Although only a small fraction (18 out of more than 300) of generally weak DIB features have been shown to correlate with C_2 and C_3 (the "C_2 DIBs"), it is predominantly these DIBs that are observed toward HD 62542. The typically strong DIBs $\lambda\lambda$5780 and 5797 are detected but are significantly weaker than toward other lines of sight with similar reddening. Other commonly observed DIBs (such as $\lambda\lambda$4430, 6270, and 6284) remain noticeably absent. These observations further support the suggestion that the line of sight toward HD 62542 crosses only the core of a diffuse cloud and show that the correlation between the C_2 DIBs and small carbon chains is maintained in environments with very large fractions of molecular hydrogen, $f_{H_2} > 0.8$. A comparison of CH, CN, C_2, and C_3 column densities and C_2 DIB strengths toward HD 62542, HD 204827, and HD 172028 suggests that the line of sight toward HD 204827 passes through a diffuse cloud core similar to that seen toward HD 62542, as well as what might be referred to as a diffuse cloud envelope. This indicates that the bare core toward HD 62542 may not have significantly different relative chemical abundances from other diffuse cloud cores and that the C_2 DIBs may serve as a diagnostic of such cores.

Subject headings: astrochemistry — ISM: lines and bands — ISM: molecules

1. INTRODUCTION

A great deal of the fascination with the diffuse interstellar bands (DIBs) arises from their ubiquity toward lightly reddened sight lines and from the challenge of identifying their molecular carriers (for recent reviews see Herbig 1995; Tielens & Snow 1995; Snow 2001). Much like the total column densities of the interstellar molecules C_2, C_3, CN, and CH, the strengths [i.e., equivalent widths, W_λ(DIB)] of individual DIBs generally increase with extinction, yet can be highly variable among sight lines with the same color excess, $E(B-V)$. This indicates that the strengths of these features relative to one another are sensitive to some varying physical condition(s) in the diffuse interstellar medium (ISM) in addition to simply the total amount of material along the line of sight. Since DIBs are observed in nearly all diffuse clouds, an understanding of the mechanisms that determine the relative line strengths of the DIBs may turn the enigmatic DIBs into a widely applicable probe of diffuse ISM properties.

Correlations between the strengths of individual DIBs have been used to identify features that respond similarly to differences in the diffuse cloud environment (see reviews above and references therein). The fundamental idea is that any group of features arising from a particular carrier or set of chemically related carriers must maintain the same relative intensities in all lines of sight with the same temperature, density, and radiation field. While variations in the molecular excitation among sight lines may cause the measured correlation coefficients between bands arising from the same carrier to be poorer than expected from observational uncertainties, identifying such correlating subsets of DIBs nonetheless provides a valuable spectroscopic constraint on the identity of the carrier(s).

There have been a few successful measurements of the correlation between DIB strengths and the column densities of identified species. Herbig (1993) showed that W_λ(5780) depends strongly on the total column density of atomic hydrogen, N(H I). A moderate correlation has been shown between CH and the ratio $W_\lambda(5797)/W_\lambda(5780)$ (Krełowski et al. 1999). Recently, an extensive DIB survey at Apache Point Observatory (APO) has shown that a group of 18 relatively weak DIBs, the "C_2 DIBs," correlate with C_2 (Thorburn et al. 2003), which in turn correlates with C_3 (Oka et al. 2003; Ádámkovics et al. 2003). These results show that the physical environment that favors small carbon chains also favors some DIB carriers, while the environments that are unfavorable to carbon chains are equally inhospitable to these DIB carriers.

In diffuse clouds the H I concentration falls toward the center of the cloud because of the increasing density and corresponding conversion of H I to H_2, as well as the self-shielding of H_2 against photodissociation. Likewise, one would expect λ5780 to become weaker toward the center of a diffuse cloud, so that lines of sight probing the denser regions of diffuse clouds will have weaker λ5780 for a given color excess. This was first emphasized by Snow & Cohen (1974) and has been studied more thoroughly for $\lambda\lambda$5780, 5797, 5850, 6196, 6203, 6269, and 6284 in the Taurus clouds (Adamson et al. 1991, 1994). The propensity for increased DIB carrier concentration in the outer regions of diffuse clouds, sometimes called the "skin" phenomenon, is the opposite of the modeled behavior for small carbon species such as C_2, CH, and CN (van Dishoeck & Black 1986), which increase in concentration toward the center of clouds.

The line of sight toward HD 62542 offers a unique opportunity to study the molecular abundances in the dense ($n \sim 500$ cm^{-3}; Gredel et al. 1993) central region of a diffuse cloud. The diffuse cloud toward this star has apparently been stripped of the lower density outer layer(s) by stellar winds and radiation pressure (Cardelli et al. 1990). These lower density outer layers have been called a skin; however, this terminology implies a region of material that is thinner than the core. We use the term "envelope" here to describe the outer layers of a diffuse cloud, so as to

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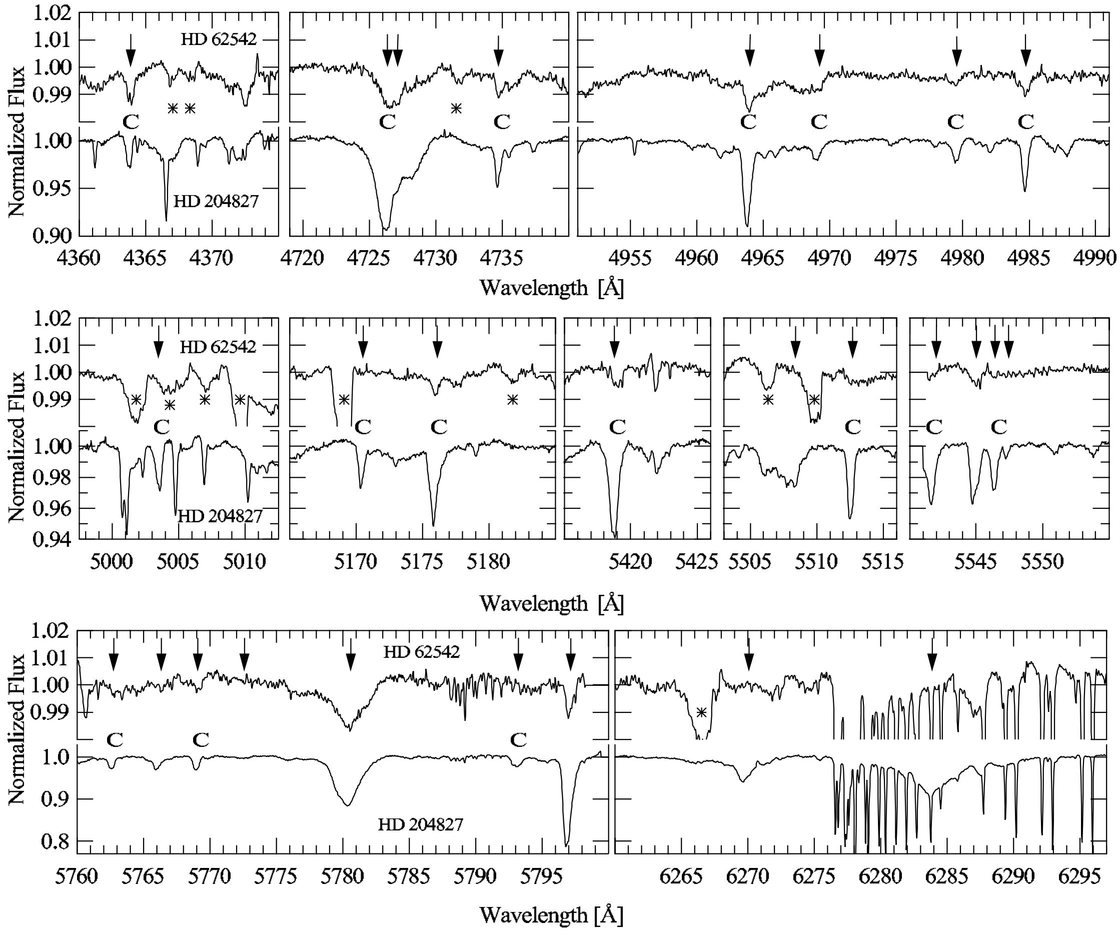

Fig. 1.—Detections of diffuse bands toward HD 62542 along with spectra of HD 204827 for comparison. Arrows indicate the locations of DIBs, with the C_2 DIBs highlighted with C's, and stellar lines in HD 62542 identified by asterisks. Note that the vertical scales are different for the two stars.

not imply anything about the relative length scales of these two regions. Evidence for the missing envelope toward HD 62542 includes the unexpectedly high molecular abundances for a line of sight with only 1 mag of visual extinction (Cardelli et al. 1990), the extreme far-UV extinction (Cardelli & Savage 1988), and recent observations showing that the DIBs are unusually weak in this sight line (Snow et al. 2002). Further intriguing characteristics of the cloud toward HD 62542 include the very small column density of CH^+ (Cardelli et al. 1990; Gredel et al. 1993) and the unusually high ratio of $N(C_3)/N(C_2)$ (Ádámkovics et al. 2003).

One would expect that unlike the generally strong DIBs (e.g., $\lambda\lambda$5780, 5797, and 6284), those features that correlate with carbon chain molecules (Thorburn et al. 2003) would be located predominantly in the central regions of diffuse clouds (diffuse cloud "cores"), where the C_2 concentration is expected to be high. The C_2 DIBs should therefore be stronger in sight lines with diffuse cloud cores. Here we use the high-sensitivity (signal-to-noise ratio [S/N] $\sim 700-1000$) spectrum of HD 62542 obtained during our measurements of C_3 (Ádámkovics et al. 2003) to test this assumption, while searching for the unusually weak DIBs in this sight line. We report here the detection toward HD 62542 of 10 of the 18 DIBs that correlate with C_2 and C_3, as well as the DIBs $\lambda\lambda$4727, 5494, 5544, 5780, and 5797.

2. OBSERVATIONS

Observations were performed using the High Resolution Echelle Spectrometer (HIRES; Vogt et al. 1994) on the 10 m Keck I telescope atop Mauna Kea on 2002 December 14, as detailed in Ádámkovics et al. (2003). Briefly, spectra in the 3985–6420 Å range were recorded with a resolving power $R \sim 67,000$ and have a dispersion ranging from $d = 0.0287$ Å pixel^{-1} at 4050 Å to $d = 0.0431$ Å pixel^{-1} at 6265 Å. The data were reduced using standard procedures in the echelle package in NOAO's Image Reduction and Analysis Facility (IRAF).

Calibration and target exposures were first bias-corrected and combined, then target images were flat-fielded and echelle apertures were extracted. Continuum fitting was performed for each order by fitting a fourth-order polynomial to the entire extracted aperture blaze. Data points on an absorption feature that constituted greater than 3 σ deviations below the continuum fit were excluded, and then a new continuum fit was performed. This procedure was iterated 40 times to select against absorption features before obtaining the continuum fit that was used to normalize the observed spectra.

To prevent misidentification of stellar lines as ISM features, we compared the spectrum of HD 62542 (stellar type B5 V) with the spectra of three very lightly reddened stars HD 26326, HD 16219, and HD 212120 (types B4 V, B5 V, and B6 V, respectively) from the APO DIB survey (D. G. York 2004, private communication). Strong stellar features in the unreddened stars were velocity shifted to match the stellar transitions in HD 62542. Weak features in the spectra of the unreddened stars that matched features in the spectra of HD 62542 were then identified as stellar lines. Because the S/N of each unreddened reference

TABLE 1
Measurements of HD 62542, HD 204827, and HD 172028

Parameter	HD 62542	HD 204827	HD 172028[a]	HD 204827[b] (no "core")
Type	B5 V	B0 V	B2 V	...
V	8.04	7.94	7.83	...
$E(B-V)$	0.35	1.11	0.79	0.76
A_V	0.99	2.62	2.20	1.62
C_2 DIB Equivalent Widths (mÅ)				
4363.81	5.5 ± 1	15 ± 1	9.3 ± 1[c]	9.5 ± 1.4
4727.06	Blend	Blend	Blend	...
4734.79	5 ± 0.5	17.8 ± 1	12.3 ± 0.8	12.8 ± 1.1
4963.99	6 ± 1	50.2 ± 2	50 ± 1	44.2 ± 2.2
4969.24	3.7 ± 1.5	11.8 ± 2	14.5 ± 1[c]	8.1 ± 2.5
4979.64	2.6 ± 0.5	14.7 ± 1	11.5 ± 1[c]	12.1 ± 1.1
4984.84	5.6 ± 0.5	30.8 ± 1	26 ± 1	25.2 ± 1.1
5003.58	<2	16.9 ± 1	6.5 ± 1.5[c]	15.9 ± 2.2
5170.57	<2	11.3 ± 1	14 ± 1[c]	10.3 ± 2.2
5176.09	3.7 ± 0.5	32.4 ± 1	23 ± 2	28.8 ± 1.1
5418.82	4.5 ± 0.5	52.6 ± 2	46 ± 2[c]	48.1 ± 1.6
5512.75	<2	24.0 ± 1	26 ± 1	23.0 ± 2.2
5542.02	<2	25.3 ± 2	18 ± 1.5[c]	24.3 ± 2.8
5546.48	<2	17.2 ± 1	13 ± 1[c]	16.2 ± 2.2
5762.67	<2	18.3 ± 2	...	17.3 ± 2.8
5769.05	3.3 ± 1	17.6 ± 1	17 ± 1.5	14.3 ± 1.4
5793.24	<2	22.4 ± 2	...	21.4 ± 2.8
Other DIB Equivalent Widths (mÅ)				
4727.06	Blend	Blend	Blend	...
5494.19	5.4 ± 1	22.9 ± 1	22 ± 1[c]	17.5 ± 1.4
5545.11	4.1 ± 1	25.8 ± 1	26 ± 1	21.7 ± 1.4
5766.25	<2	28 ± 1	23 ± 2[c]	27.0 ± 2.2
5780.69	52.8 ± 4	266 ± 5	256 ± 8	213 ± 6
5797.20	8.5 ± 1	158 ± 4	217 ± 5	150 ± 4
6270.06	<2	80 ± 3	45 ± 5	79.0 ± 3.6
6283.89	<8	518 ± 60	450 ± 60	514 ± 61
Column Densities (10^{12} cm^{-2})				
$N(C_2)$	80 ± 20[d]	440 ± 29[e]	290 ± 26	360 ± 35
$N(C_3)$	10.5 ± 0.5[f]	11.5 ± 0.8[f]	3.6 ± 0.6[g]	1.0 ± 1.0
$N(CH)$	38 ± 2[h]	80 ± 10[e]	53 ± 6	42 ± 10
$N(CN)$	41.7 ± 14.7[h]	55 ± 5[e]	28 ± 5	13 ± 15
$N(CH^+)$	<1.9	>33.6	24 ± 2.2	>31.7

[a] All values for HD 172028 from Thorburn et al. (2003) unless otherwise noted.
[b] Shown in this column are the DIB equivalent widths and molecular column densities measured toward HD 62542, representing a central core, subtracted from the same quantities measured toward HD 204827.
[c] APO DIB survey (D. G. York 2004, private communication).
[d] Gredel et al. (1993).
[e] Thorburn et al. (2003).
[f] Ádámkovics et al. (2003).
[g] Oka et al. (2003).
[h] Cardelli et al. (1990).

star exceeded that of HD 62542, we are confident that even weak stellar features, which could contaminate the DIB spectrum, were accounted for.

3. RESULTS

Figure 1 shows the spectrum of HD 62542 in the regions in which DIBs have been detected, along with the spectrum of HD 204827 for comparison. HD 204827 has the largest observed column densities of C_2 and C_3 (Ádámkovics et al. 2003) and is used as the model target toward which the C_2 DIB features are strongest (Thorburn et al. 2003). Equivalent widths are measured by numerical integration and are reported in Table 1 with 1 σ errors and 2 σ upper limits.

We have performed a preliminary comparison of the DIB line profiles between transitions toward HD 62542 and HD 204827. For relatively narrow and strong unblended DIBs such as $\lambda\lambda$4364, 4735, and 5176 we used a Gaussian fit to compare the FWHM of features toward both stars. Within our uncertainties there is no significant difference between DIB widths toward these two stars.

A qualitative inspection of the other DIB features also shows similarities between the two targets. The blended DIBs near

4726 Å have different relative intensities toward HD 62542 and HD 204827; however, both stars show a shoulder toward the red of these features, which is perhaps another DIB. There are many weak ISM features surrounding the four C_2 DIBs centered near 4975 Å in the spectra of HD 204827. Tantalizingly, these same features may be buried just beneath the noise in the spectrum of HD 62542. Other features such as $\lambda\lambda$4734, 4979, 5545, and 5766 are too weak toward HD 62542 for reliable measurements of the FWHM; however, they are not inconsistent with the line widths toward HD 204827. The widths of the broad λ5780 DIB, which are poorly fit by Gaussian profiles, are also in agreement toward both stars.

A search for other molecular transitions (which have not been previously reported in these sight lines) yielded a detection of the strong 4232 Å line of CH^+ toward HD 204827, which is likely saturated, as well as a tentative detection (complicated by narrow stellar line contamination) of the same line toward HD 62542. Therefore, we report a lower limit for $N(CH^+)$ toward HD 204827 and an upper limit toward HD 62542.

4. DISCUSSION

4.1. C_2 *DIBs and Diffuse Cloud Envelopes*

The implications of the weakness of the generally strong DIBs $\lambda\lambda$5780, 5797, 6270, and 6284 in HD 62542 have already been articulated by Snow et al. (2002). In short, the weakness of these DIBs is consistent with the idea that most DIB carriers exist in the outer envelope of diffuse clouds, which in this sight line has been stripped away by stellar winds and radiation pressure. We further emphasize their results by placing upper limits on $\lambda\lambda$6270 and 6284 that are factors of 6 and 15, respectively, lower than previously reported. It is clear that the conditions that favor the presence of the carriers of $\lambda\lambda$6270 and 6284 in most diffuse clouds do not exist toward HD 62542.

Studies comparing W_λ(DIB) against $E(B-V)$ (Sonnentrucker et al. 1997) and H I/(H I + H_2) (Cami et al. 1997) have suggested that the carriers of λ5797 and λ5780 have different ionization potentials, explaining their different strengths toward various sight lines with differing radiation environments. Both works indicate that λ5797 has a lower ionization potential than λ5780. Along these lines, it may be possible to interpret the weakness of these two DIBs toward HD 62542 as due to a weak radiation field that may be not be sufficient (for example) to ionize neutral species, producing the ions that could be responsible for these DIBs. We note that $W_\lambda(5797)/W_\lambda(5780)$ is uncommonly small toward HD 62542. Although it may seem that the weakness of DIBs—in particular λ5797—toward HD 62542 could be due to the weak UV radiation field and steep extinction curve, the sight line toward HD 204827 has a similar extinction curve with much stronger DIBs and a more typical ratio of $W_\lambda(5797)/W_\lambda(5780)$.

Our detection of predominantly those DIBs that correlate with carbon chain molecules remains consistent with the picture of a missing envelope, and these results further support the grouping of the C_2 DIBs together as features arising from a set of closely chemically related carriers. Our measurements suggest a differentiation of the chemical environment in which the C_2 DIB carriers exist from that in which other DIB carriers exist. Whereas DIB carriers had previously been thought to exist in the envelope of diffuse clouds, the present results suggest that some of the C_2 DIB carriers can survive in the central higher density regions. However, these results do not rule out the presence of these carriers in lower density regions as well.

In order to compare column densities of molecules or DIB line strengths among sight lines through different diffuse clouds—which may or may not have different physical environments—a necessary consideration is the normalization for total diffuse cloud material along the line of sight. A very good measure of the total material along the line of sight is the total column density of hydrogen $N(\text{H I} + \text{H}_2) \equiv N(\text{H I}) + 2N(\text{H}_2)$; however, direct measurements of hydrogen column densities are not always available. Bohlin et al. (1978) have shown that for lightly reddened stars, where $E(B-V) < 0.6$, the ratio of neutral hydrogen to color excess is constant,

$$\left\langle \frac{N(\text{H I} + \text{H}_2)}{E(B-V)} \right\rangle = 5.8 \times 10^{21} \text{ atoms cm}^{-2} \text{ mag}^{-1}.$$

This result has been confirmed and extended to more heavily reddened stars up to $E(B-V) = 1.04$ (Rachford et al. 2002). Here we use $E(B-V)$ as a measure of the total hydrogen—and thereby the total amount of diffuse cloud material—along the line of sight.

Comparison with HD 204827 shows that, per unit $E(B-V)$, the C_2 DIBs are in general a factor of a few stronger toward HD 204827 than HD 62542. The DIBs $\lambda\lambda$4364, 4734, and 4969 are exceptions, where the $W_\lambda(\text{DIB})/E(B-V)$ ratio is nearly the same in both stars. The broad velocity dispersion of C_3 (Ádámkovics et al. 2003) and multiple velocity components of CH^+ toward HD 204827 both indicate absorption in multiple diffuse clouds, in contrast with the HD 62542 line of sight. If the line of sight toward HD 62542 is an environment like the central core of a cloud, the line of sight toward HD 204827 could cross both the envelope *and* the "core" material for multiple clouds.

Since C_2 correlates with C_2 DIBs, it is not surprising that $N(C_2)/E(B-V)$ is greater in HD 204827 by nearly a factor of 2, as well; however, this contrasts with the column densities of CH, CN, and C_3, which per unit $E(B-V)$ are higher toward HD 62542. This is discussed further below and raises the possibility that $W_\lambda(C_2\ \text{DIB})/E(B-V)$ is smaller toward HD 62542 because C_2, and likewise the C_2 DIBs carriers, have reacted to form other species (e.g., CN and C_3).

4.2. *Molecular Column Densities*

Molecular hydrogen should dominate the core of diffuse clouds, because the increased density of gas and dust facilitates H_2 production while also shielding against photodissociation. The fraction of all hydrogen that is in molecular form,

$$f_{\text{H}_2} = \frac{2N(\text{H}_2)}{2N(\text{H}_2) + N(\text{H I})},$$

may therefore be a useful diagnostic of the presence of diffuse cloud cores. It has been shown by UV measurements of $N(H_2)$ that f_{H_2} correlates moderately well with properties of translucent sight lines that are characteristic of cores, such as low kinetic temperature and large column densities of CN (Rachford et al. 2002). A limitation of these measurements is that sight lines with $A_V > 2$ do not have enough UV flux for measurement of $N(H_2)$, and it is also difficult to get a precise measure of $N(H_2)$ toward sight lines with steep UV extinction curves such as HD 62542. It is also unclear how much the amount of H I–rich diffuse material can vary among clouds with similar cores. One would expect that a sight line that was stripped of its outer diffuse material such as HD 62542 would have a very high f_{H_2}. Rachford et al. (2002) estimated $f_{H_2} = 0.60 \pm 0.28$ toward HD 62542, which within the observational uncertainty can range from moderately low to exceptionally high for a translucent sight line. However, the observed correlations among molecular species

TABLE 2
Hydrogen Abundances

Parameter	HD 62542	HD 204827	HD 172028	Note
Column Densities (10^{20} cm^{-2})				
$N(H_2)_{obs}$	$6.46^{+4.02}_{-2.48}$	...	...	1
$N(H_2)_{CH}$	8.89 ± 0.55	18.7 ± 2.4	12.4 ± 1.5	2
$N(\text{H I})_{5780}$	3.57 ± 0.29	18.0 ± 0.7	17.3 ± 0.8	3
N_H	21.4 ± 2.20	55.4 ± 7.5	42.1 ± 5.3	4
$N_{H,E(B-V)}$	20.3 ± 1.22	64.4 ± 3.9	45.8 ± 2.8	5
Molecular Fraction				
f_{H_2}	0.83 ± 0.10	0.68 ± 0.13	0.59 ± 0.10	6
$f_{H_2,E(B-V)}$	0.88 ± 0.08	0.58 ± 0.08	0.54 ± 0.07	7

Notes.—(1) *FUSE* observations (Rachford et al. 2002). (2) $N(H_2)_{CH} = 2.34 \times 10^7 N(\text{CH})$. (3) $N(\text{H I})_{5780} = 6.77 \times 10^{18} W_\lambda(5780)$. (4) $N_H = 2N(H_2)_{CH} + N(\text{H I})_{5780}$. (5) $N_{H,E(B-V)} = 5.8 \times 10^{21} E(B-V)$. (6) Calculated using $N(H_2)_{CH}$ and $N(\text{H I})_{5780}$. (7) Calculated using $N(H_2)_{CH}$ and $N_{H,E(B-V)}$.

allow for an independent determination of hydrogen column densities.

Since $W_\lambda(5780)$ correlates with $N(\text{H I})$ (Herbig 1993), as does $N(H_2)$ with $N(\text{CH})$ (Federman 1982; Federman et al. 1984; Cardelli & Wallerstein 1986; Rachford et al. 2002), f_{H_2} can be estimated using molecular proxies. The APO DIB survey has produced a large sample of very high S/N optical observations, and along with the systematic DIB measurements these observations provide the column densities of a handful of molecular species, such as CH and C_2 (Thorburn et al. 2003). An extensive database has been compiled of the APO measurements and the results in the literature for species such as $N(\text{H I})$ and $N(H_2)$, which are predominantly from Diplas & Savage (1994) and Rachford et al. (2002), respectively. We use the relationship between $W_\lambda(5780)$ and $N(\text{H I})$ measured for 60 diffuse sight lines in the APO database (D. G. York et al. 2005, in preparation),

$$\left\langle \frac{N(\text{H I})}{W_\lambda(5780)} \right\rangle = 6.77 \pm 0.21 \times 10^{18}\ \text{cm}^{-2}\ \text{mÅ}^{-1},$$

to estimate $N(\text{H I})$ toward HD 62542 (Table 2). This relationship is consistent with the data presented in Herbig (1993), where $\langle N(\text{H I})/W_\lambda(5780)\rangle = (11.5 \pm 8.3) \times 10^{18}$ cm^{-2} mÅ^{-1}. Our analysis of the data from Herbig (1993) has a larger uncertainty than the APO scaling law, because the Herbig (1993) data are from a smaller sample of measurements, which were compiled from various observations, at lower S/N. We should note that Herbig (1993) only presents a power-law analysis of these data and does not make a linear regression analysis, as we have done. Using a similar scaling law and the database, we can infer $N(H_2)$ from $N(\text{CH})$ using the observed relationship (D. G. York et al. 2005, in preparation),

$$\left\langle \frac{N(H_2)}{N(\text{CH})} \right\rangle = 2.34 \pm 0.08 \times 10^7,$$

yielding a very high $f_{H_2} = 0.83 \pm 0.10$ toward HD 62542. The linear relationship between $N(\text{CH})$ and $N(H_2)$ that is used here also agrees with previous observations reported by Federman et al. (1984), although ours has an order of magnitude smaller uncertainty. The molecular fraction reported here for HD 62542 is higher than $f_{H_2} = 0.60 \pm 0.28$ reported by Rachford et al. (2002) and discussed by Snow et al. (2002). This result is consistent with the H I–rich outer layer(s) of the diffuse cloud having been stripped away from a core that is predominantly H_2. The results of multiple methods of calculating hydrogen column densities from observations of $N(\text{CH})$, $W_\lambda(5780)$, and $E(B-V)$ and their corresponding uncertainties are shown in Table 2. In the case of HD 62542 the correlations among molecular species allow for a more precise determination of f_{H_2} than do the UV observations.

The above analysis can also be performed for stars that are too faint in the UV for H_2 and H I measurements, such as HD 204827 (Table 2). In this case, we determine $f_{H_2} = 0.58 \pm 0.08$ toward HD 204827. This value is higher than that for typical diffuse clouds and suggests that HD 204827 may also have a core rich in H_2. We examine this possibility further in § 4.3 using C_2 DIB strengths and comparison with the line of sight toward HD 172028.

Cardelli et al. (1990) have shown that HD 62542 and HD 204827 have remarkably similar FUV extinction curves, the main difference being a weaker 2200 Å bump toward HD 62542. Both have exceptionally steep FUV extinction when compared to typical diffuse clouds such as those toward ζ Per. If, as Cardelli et al. (1990) suggest, the high column densities of CH and CN in HD 62542 were due to the decreased photodissociation rates of these molecules from the attenuated flux shortward of ~3000 Å, then similar column densities per unit color excess might be expected toward HD 204827. However, the measurements in Table 1 show that this is not the case; while $E(B-V)$ and A_V are larger toward HD 204827 than toward HD 62542 by factors of 3.2 and 2.6, $N(\text{CN})$ and $N(C_3)$ ratios in the two stars are nearly the same, and $N(\text{CH})$ is larger in HD 204827 by a factor of only 2.1. This, and the order of magnitude difference in $N(\text{CH}^+)$, indicate that the chemistry in these sight lines cannot be explained by the shape of the extinction curves alone. Perhaps it is important that the color excess toward HD 204827 arises from multiple clouds.

4.3. *Diffuse Cloud Cores*

Since many observations are consistent with the diffuse cloud toward HD 62542 having been stripped of its outer envelope, the question arises as to whether the material along this sight line is analogous to the cores that may exist in diffuse clouds that have not lost their envelopes or whether the exposure of the central core has significantly altered molecular abundances. To examine this question we have subtracted the DIB line strengths and molecular column densities observed toward HD 62542 from the same quantities measured toward HD 204827; in the absence of chemical alteration of HD 62542 material due to exposure, the calculated difference should then be representative of a diffuse cloud without a core.

The calculated value for a cloud without a core can be compared with measurements of HD 172028 from the Apache Point DIB survey (Thorburn et al. 2003). This sight line was selected simply because the $E(B-V)$ toward HD 172028 (used here to infer the total material along the line of sight) is close to the difference in $E(B-V)$ between HD 204827 and HD 62542 and because measurements of molecular column densities and C_2 DIB strengths are also available. Table 1 shows that the strengths of the DIBs and molecular column densities toward our hypothetical "diffuse cloud without a core" are similar to those in HD 172028. The agreement becomes slightly better in many cases when taking into account the somewhat larger $E(B-V)$ toward HD 172028.

It is striking that eight of the 16 C_2 DIBs for which we can measure the line strength (λ4726 is a blend and λ6729 is out of the range of our spectra) agree within 1 σ uncertainty toward HD 172028 and the hypothetical cloud. The agreements for $\lambda\lambda$4364, 4735, 4980, and 4985 are particularly good and may indicate a more significant relationship among these DIBs. Within this method of analysis, and with this small sample of three stars, the C_2 DIBs show better agreement than the identified molecular carriers. However, the agreement in this single case should not be overstated, since the line of sight toward HD 204827 has a complicated velocity profile for atomic features, implying multiple clouds, which are not necessarily equivalent to a single diffuse cloud with a single dense core.

There is less C_2 and more C_3 toward HD 172028 than toward our fabricated cloud, which would be consistent with the destruction of C_2 and formation of C_3 toward HD 62542. Conversely, the cloud toward HD 172028 may have a "corelike" component indicated by the lower than expected $N(C_2)$ and higher than expected $N(C_3)$, N(CH), and N(CN). Overall, however, the general agreement in molecular column densities and DIB strengths suggests that the sight line toward HD 62542 may be similar to the environment found in the center of other diffuse clouds. Clearly this type of analysis will need to be extended to a large sample of stars before conclusions about the differences in diffuse clouds and their cores can be confirmed.

5. CONCLUSIONS

We have reported here the detection of 10 of the 18 C_2 DIBs, as well as $\lambda\lambda$4727, 5494, 5544, 5780, and 5797 toward HD 62542. Other generally strong DIBs such as $\lambda\lambda$4430, 6270, and 6284 are not detected in this line of sight. The observation of the C_2 DIBs toward HD 62542, despite the lack of other strong DIBs in the same sight line, suggests that the carriers of the C_2 DIBs are chemically distinct from the carriers of the generally strong DIBs. For example, the C_2 DIB carriers may occupy denser regions of diffuse clouds than do other DIB carriers, or perhaps they respond to the interstellar radiation field in a significantly different way. Using known correlations, measurements of $W_\lambda(5780)$ along with N(CH) have allowed for a more precise measurement of the large f_{H_2} toward HD 62542 and the first measurement of f_{H_2} toward the UV-faint HD 204827. Taken together, these results support the conventional wisdom that the carriers of generally strong DIBs exist in the outside envelope of diffuse clouds and demonstrate that most C_2 DIB carriers are abundant in regions of high molecular fraction near the central core of a cloud.

Our interpretation of the clouds along the observed lines of sight as a bare core (HD 62542), a cloud with a core and diffuse material (HD 204827), and a cloud with only diffuse material (HD 172028) is supported by the observed C_2 DIB line strengths toward this small sample of targets. A similar comparison of molecular column densities also supports this interpretation, but not as well as the C_2 DIBs. Although this example of combinations of diffuse clouds works well in the small sample of three stars presented here, a broader analysis of line strengths, molecular column densities, and physical properties toward a large sample of stars must be performed to validate this method and its applicability to diffuse clouds in general. While these results do not identify a carrier of the DIBs, they provide the important clue that the presence of H_2 does not destroy the carriers of the C_2 DIBs.

Higher S/N observations of the C_2 DIBs toward HD 62542, in particular measurement of the "quartet" of lines near 4980 Å, should be performed in order to compare what may prove to be resolvable molecular structure, which could lead to identification of the DIB carrier. While it is possible that the same transitions are observed toward HD 204827, the multiple components of the velocity profile in this sight line complicate identification of what could be molecular structure. It will be useful to apply the method of analysis presented here for measuring f_{H_2} to a larger sample of stars toward which $W_\lambda(5780)$ and N(CH) are known, in order to find other targets that warrant extremely deep integrations in the search for weak DIB molecular structure. The spectral regions near C_2 DIBs may be particularly lucrative locations for these searches.

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