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ON THE SYSTEM OF DIFFUSE INTERSTELLAR BANDS AT 5844 AND 5850 Å

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ABSTRACT

Two neighboring diffuse interstellar bands (DIBs) at 5844 and 5850 Å are shown to be of different origin. The presence or absence of the 5844 DIB is related to the ratio of the two prominent DIBs at 5780 and 5797 Å as well as to the nature of the ultraviolet extinction curve. The 5844 Å DIB is very sensitive to the extinction, being completely absent in cases where the far-UV extinction is low. This suggests that the carrier is destroyed by photons having energies above 11 or 12 eV. The 5850 Å DIB correlates very well with the well-studied DIB at 5797 Å, suggesting that these two features belong to the same family of DIBs and may be produced by the same carrier.

Subject headings: ISM: molecules — line: identification

1. INTRODUCTION

The diffuse interstellar bands at 5844 and 5850 Å were first reported by Herbig in his review of the unidentified diffuse interstellar bands (DIBs), published in 1975. Both features were clearly seen in the spectrum of the heavily reddened bright star HD 183143. One of them (λ5850) is a fairly strong and sharp feature. In the paper of Josafatsson & Snow (1987) it appears in all reddened spectra. It has been observed also by Krełowski & Walker (1987) and included in the same family of diffuse bands as the strong feature near 5759 Å. The neighboring feature was described as a shallow one; in the paper of Josafatsson & Snow (1987) it appears only in the most heavily reddened stars.

Since the papers of Chlewicki et al. (1986) and Krełowski & Walker (1987), it became clear that there must be multiple carriers for the diffuse bands, or, if a single carrier is involved, it must have distinct physical states having different spectra. The evidence for this came about through the identification of "families" of DIBs, which are groupings having good internal correlation; i.e., within a given family, the bands correlate very well with each other, while the correlation between bands from different groupings is poor. In at least one case, apparent variations in the profile of one of the DIBs were found to be the result of a blend of two DIBs from different families, which therefore had differing strength ratios from one line of sight to another (Porceddu, Benvenuti, & Krełowski 1991).

The number of DIBs has grown dramatically in recent years, primarily through the introduction of electronic detectors capable of recording spectra with very high signal-to-noise ratios. Now over 200 DIBs are known or suspected (Herbig 1975; Sanner, Snell, & Vanden Bout 1978; Herbig & Leka 1991; Jenniskens & Desert 1993), and more structure seems to appear each time a given spectral region is scrutinized carefully (e.g., Krełowski & Sneden 1993). This profusion of features makes it all the more important to clearly identify families of bands that behave in the same way and therefore appear to be formed by the same carrier. Such a division should facilitate the eventual identification of the band carriers—the longest standing unsolved problem in all of spectroscopy.

The goal of the present paper is to explore further the properties of the DIBs at 5844 and 5850 Å, in the hope of identifying clearly the families to which they belong. In the next section we describe our observations, and in the final section we present the results and provide some discussion of their implications.

2. OBSERVATIONS

The spectra described in this paper have been acquired with the Canada-France-Hawaii Telescope (CFHT). The procedure for data acquisition and reduction using this system has already been described by Snow & Seab (1991). The spectra cover the yellow spectral range (5760–5905 Å) with a resolution of 0.14 Å. In this range we observe (in addition to the two diffuse bands under consideration) the two prominent DIBs near 5780 and 5797 Å as well as the interstellar sodium doublet D_1 and D_2. In the spectra of some of our targets we observed also the 4300.3 Å line of CH as well as the 4232.62 Å line of CH^+ and the 4226.92 Å line of Ca I. Unfortunately, the latter features have not been observed in all our targets.

Data reduction was performed at the University of Colorado, where flat fields were divided out, and wavelength cali-

[1] Guest Observer, Canada-France-Hawaii Telescope.

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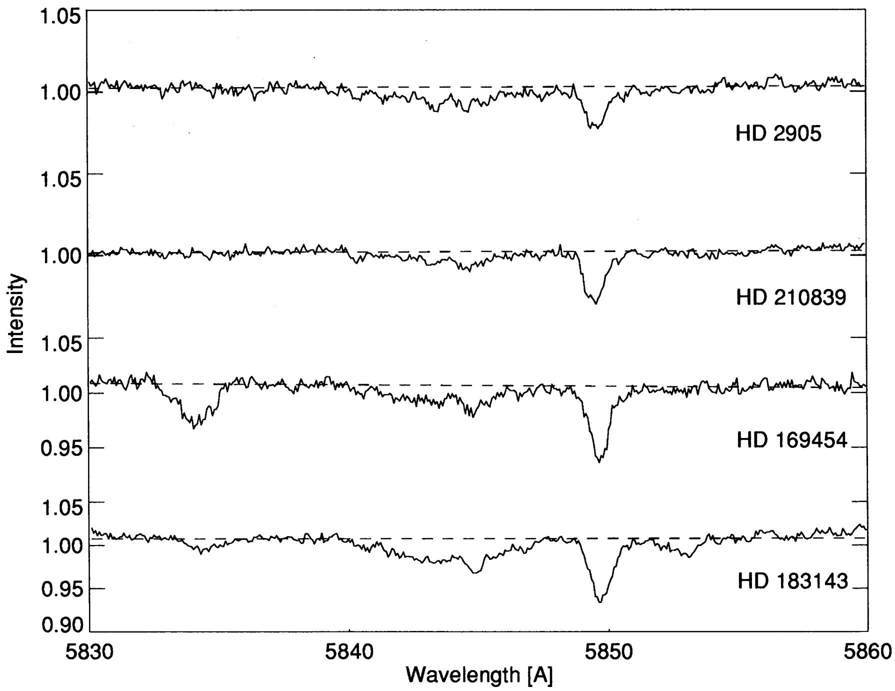

FIG. 1*a*

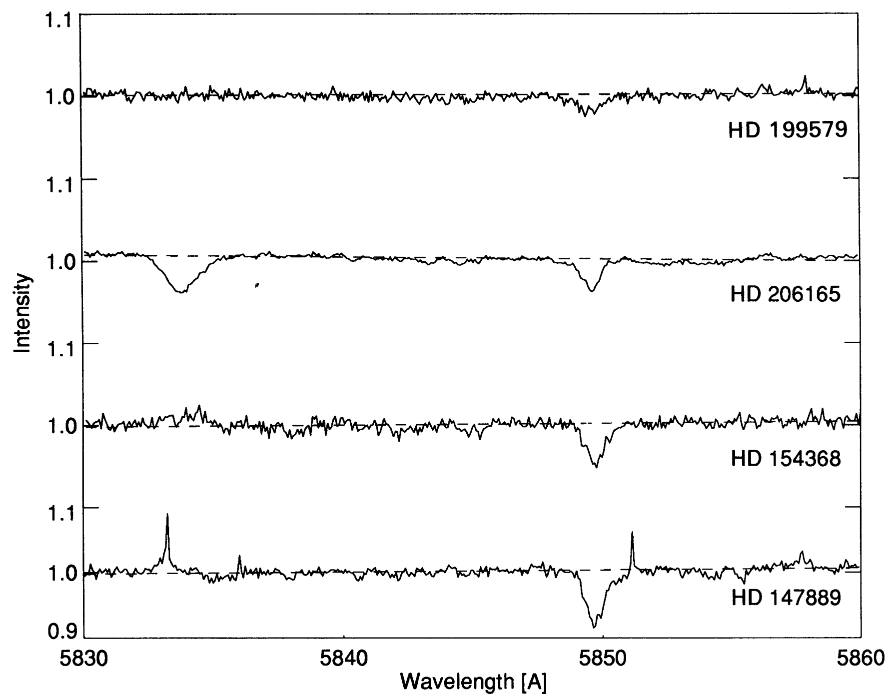

FIG. 1*b*

FIG. 1.—The spectra of target stars covering the 5844 and 5850 diffuse bands. Note the presence of λ5844 in the sample of (*a*) and the absence of this feature in sample (*b*). The effect is not related to the value of E_{B-V}, since both sample groups cover a similar range.

brations were performed, in both cases using calibration lamp spectra obtained at the telescope.

The observed stars are listed in Table 1, which includes their basic parameters. The range of E_{B-V}'s that is covered is quite broad. Our sample includes the prototypical DIB star HD 183143 (Herbig 1975). This spectrum facilitates the identification of the diffuse features in the spectra of our observed stars.

3. RESULTS AND DISCUSSION

Figures 1*a* and 1*b* show the 5844 and 5850 Å region in the spectra of our target stars. In each figure the stars are divided into groups of four, shown separately in panels (*a*) and (*b*); the reason for this grouping will become apparent shortly. The high quality of our spectra (S/N ~ 800) allows for easy identifi-

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1993ApJ...419..692K

TABLE 1

BASIC DATA FOR THE PROGRAM STARS

Star	Spectral Type	V	$B-V$	$U-B$	$R-I$	E_{B-V}
2905.........	B1 Iae	4.16	0.14	−0.80	0.06	0.33
147889......	B2 V	7.92	0.86	−0.15	...	1.07
154368......	O9 Ia	6.13	0.50	−0.53	...	0.78
169454......	B1 Ia	6.61	0.94	−0.18	...	1.13
183143......	B7 Ia	6.87	1.24	0.15	...	1.28
199579......	O6 Ve	5.96	0.05	−0.85	...	0.35
206165......	B2 Ib	4.73	0.30	−0.53	0.18	0.46
210839......	O6 If	5.04	0.25	−0.74	0.15	0.55

cation of the bands. In some of the other heavily reddened stars in our sample we see one, but not both, of the features, as shown in Figure 1*b*. In some cases the 5844 Å band is absent while its neighbor at 5850 Å is quite strong. This suggests the possibility that the two DIBs are of different origin. For comparison, we show the 5780 and 5797 Å DIBs in Figures 2*a* and 2*b*.

In order to quantify our conclusions, we have measured the equivalent widths of the four DIBs that have been observed in all of our target stars; the results are listed in Table 2. these values were then used to construct correlation plots, in the first instance showing each of the four DIBs versus the color excess E_{B-V}; the results are shown in Figure 3.

Examination of Figure 3 suggests that the 5850 Å DIB behaves very similarly to the DIB at 5797 Å, while the 5844 Å feature bears some resemblance to λ5780, though perhaps not as close. The major apparent departure between the 5780 and 5844 Å bands is that the latter is undetected in several cases where λ5780 is present, though possibly weak.

In order to further check these apparent trends, we next plotted correlations between the bands themselves, with results shown in Figure 4. Here we see only one correlation that appears to be strong: the correlation between the 5850 and 5797 Å DIBs. Thus we conclude tentatively that these two bands belong to the same family. We cannot say the same for the 5844 and 5780 Å DIBs, primarily because of the apparent bimodal behavior of λ5844, correlating well with λ5780 when present, but being totally absent in half of the cases.

In earlier work, we found that the contrast in behavior between the bands at 5780 and 5797 Å appeared to be related to the ultraviolet extinction curve, in that stars having steep far-UV extinction rises tend to have 5797 Å features comparable to or stronger than the 5780 Å band, whereas stars having low far-UV extinction tend to have 5780 Å DIBs that are much stronger than the 5797 Å feature (Krełowski et al. 1992). In the same study it was noted that the stars having steep far-UV extinction rises also tend to have high molecular abundances, whereas those having low far-UV extinction tend to have low molecular abundances (this is discussed further by Snow 1992, who has developed a possible scenario to explain the different dust grain properties in the two types of clouds).

TABLE 2

MEASURED EQUIVALENT WIDTHS

Star	$W_\lambda(\lambda5780)$ (mÅ)	$W_\lambda(\lambda5797)$ (mÅ)	$W_\lambda(\lambda5844)$ (mÅ)	$W_\lambda(\lambda5850)$ (mÅ)
HD 2905.........	266.9 ± 3.4	64.9 ± 2.4	28.1 ± 3.4	19.8 ± 1.8
HD 210839......	233.8 ± 3.4	71.4 ± 2.6	32.8 ± 3.0	26.0 ± 1.4
HD 169454......	447.3 ± 7.0	155.3 ± 4.6	50.1 ± 5.4	59.7 ± 3.6
HD 183143......	734.1 ± 8.0	195.4 ± 6.6	123.6 ± 7.6	70.0 ± 6.0
HD 199579......	120.8 ± 5.0	48.1 ± 3.6	0.0 ± 6.4	20.6 ± 3.6
HD 206165......	190.8 ± 3.0	74.1 ± 2.4	0.0 ± 3.6	28.8 ± 1.8
HD 154368......	202.3 ± 7.6	98.2 ± 5.2	0.0 ± 7.8	44.4 ± 4.4
HD 147889......	321.7 ± 9.0	150.5 ± 7.6	0.0 ± 9.8	78.2 ± 5.6

The stars in the present study are evenly divided between those having steep far-UV extinction rises and those having shallow far-UV extinction, and we have grouped them in this way in Figure 1. Those having steep far-UV extinction are shown in Figure 1*a*, while those having normal or shallow UV extinction are presented in Figure 1*b* (the extinction curves have been derived for all the stars using data from the *TD-1* survey; Wegner, Papaj, & Krełowski 1991). In Figure 2 special symbols have been used to distinguish stars having the two types of extinction curves from one another: the diamonds indicate the stars having steep far-UV extinction, while the squares represent the stars having shallow UV extinction.

There is evidently a very strong link between UV extinction curve behavior and the strength of the 5844 Å DIB. The stars we have classified as having low far-UV extinction are, in every case, the same stars in which the 5844 Å DIB is absent. This might suggest that the carrier of this DIB is extremely sensitive to the intensity of the local radiation field, since this is strongly dependent on the nature of the extinction curve (Mathis 1990). If this is a photoionization or photodissociation effect, it suggests further that the ionization potential (or photodissociation energy) corresponds to a far-UV wavelength, in the range between 912 and 1500 Å, where the contrasts between the two types of extinction curves are most significant. Most likely the cutoff energy is closer to the short-wavelength end of this region, where the contrast is most extreme. Thus we can speculate that the carrier of the 5844 Å DIB is destroyed by photons having energies above 11 or 12 eV. We can also conclude that this is not true of the carriers of the other bands under discussion, since none of these disappear completely even for the stars having low far-UV extinction. Thus almost certainly the 5844 Å band is produced by a carrier that is not responsible for the other three bands.

Any possible connection between DIBs and the behavior of simple molecules is less clear, since we do not have observations of CH, CN, and CH^+ for all of our stars. We suspect that the bands (such as λλ5797 and 5850) that are strong when the UV extinction is high will be found to correlate well with the abundances of CN and CH, since it is already established that CN correlates well with steep far-UV extinction (Joseph et al. 1986), and that CH correlates strongly with R_V, the ratio of total to selective extinction (Cardelli 1988), which in turn is closely related to the strength of the far-UV extinction (Cardelli, Clayton, & Mathis 1988, 1989). We will more fully explore the correlations among the DIBs and the diatomic molecules in a later paper.

If all the DIBs are molecular features, then in view of the behavior of the 5780 and 5844 Å DIBs some of the responsible molecules must favor regions having high-UV radiation field intensities. This would suggest species that are ionized, such as ionized PAH molecules (as suggested in several papers: Van der Zwet & Allamandola 1985; Leger & d'Hendecourt 1985; Crawford, Tielens, & Allamandola 1985; Salama & Allamandola 1992a, b), or species that require activation energy for their formation, such as CH^+. On the other hand, the 5797 and 5850 Å band carriers must be able to exist in denser, more sheltered clouds, although we note that apparently *all* DIBs

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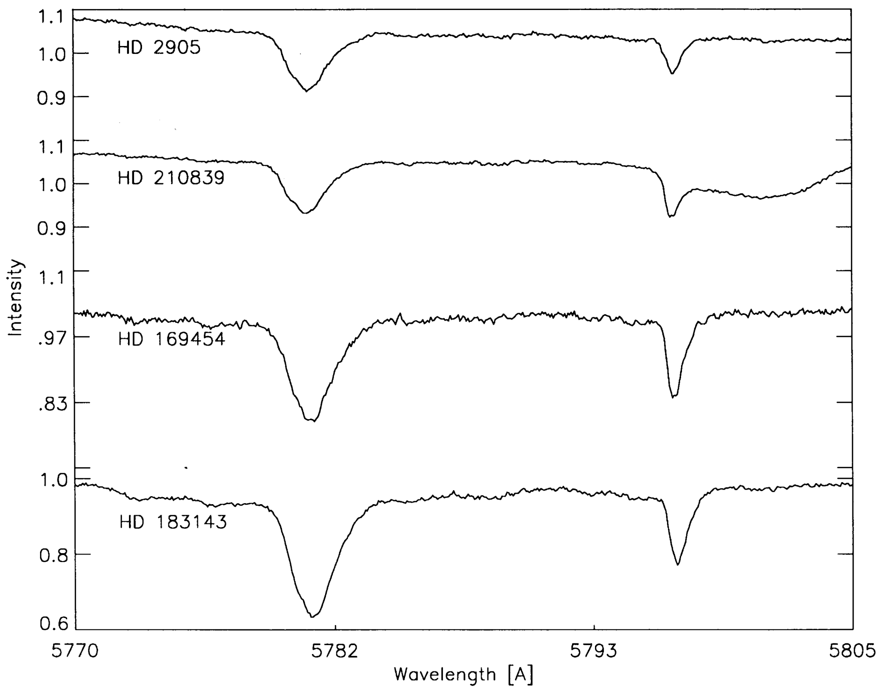

FIG. 2*a*

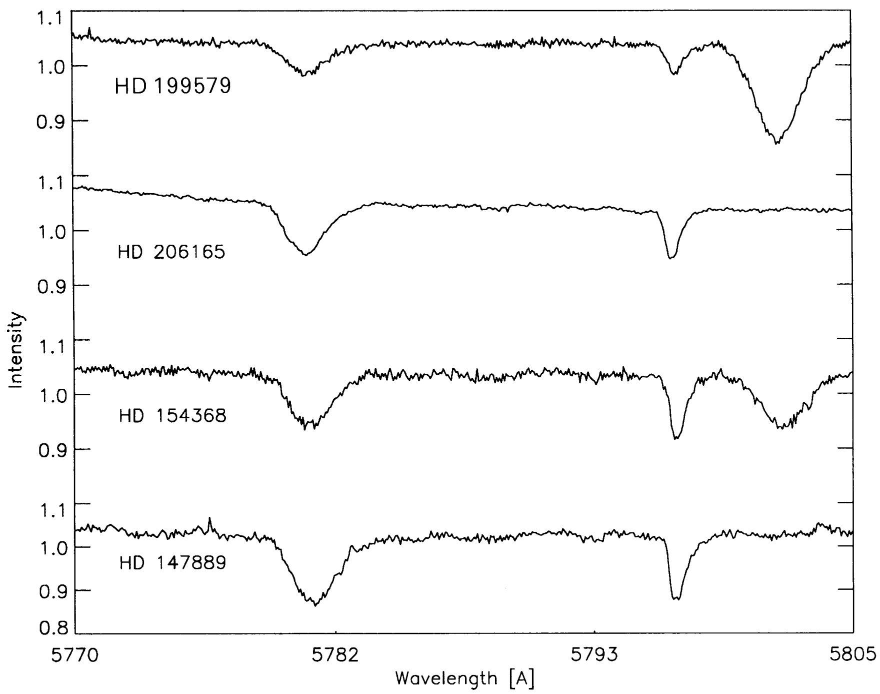

FIG. 2*b*

FIG. 2.—The prominent diffuse bands 5780 and 5797 Å observed in the same samples of stars as in Fig. 1. Note the different ratio of the bands in the two subsamples.

begin to weaken relative to color excess in very dense clouds (Wampler 1966; Snow & Cohen 1974; Herbig 1975). This suggests that all of the DIB carriers require some exposure to UV radiation.

It appears to be very important to collect spectral data for many different components of the absorption spectra of dark interstellar clouds. Almost every set of new high-quality spectra offers something unexpected. To understand the processes associated with the presence, absence, or varying strengths of different absorption features, it is necessary to consider the full spectrum of features that characterize H I clouds. Therefore we are planning to continue our efforts to build a large data set of high-quality spectra of DIBs and possibly related features.

1993ApJ...419..692K

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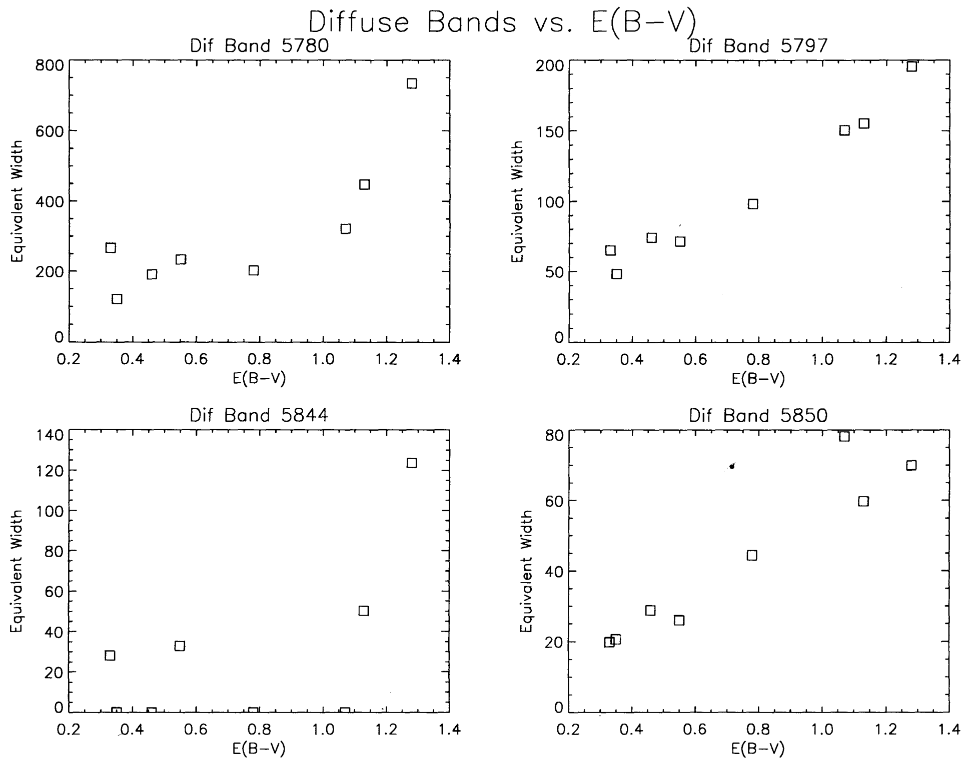

FIG. 3.—Correlation of the DIBs with E_{B-V} for the program stars

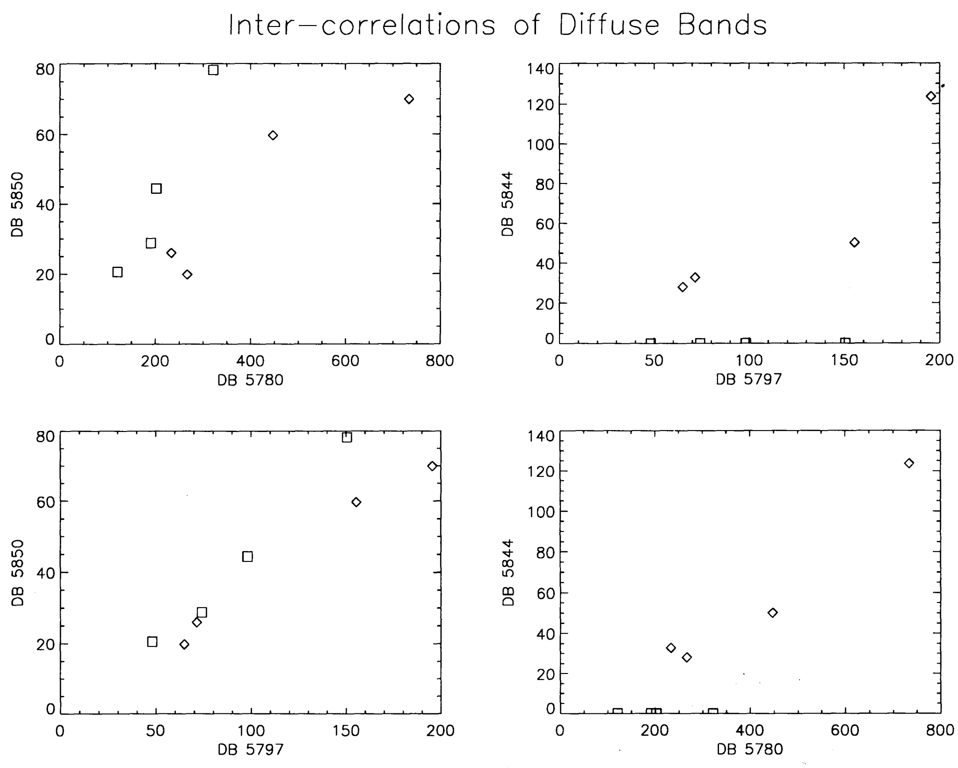

FIG. 4.—Correlations of the DIBs among themselves. Diamonds represent the stars having steep far-UV extinction; squares represent those having low far-UV extinction.

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1993ApJ...419..692K

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