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DIFFERENTIAL INTERSTELLAR POLARIZATION IN THE REGION OF 6284 Å FOR HD 183143

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ABSTRACT

Differential polarization measurements in the region of the diffuse feature at 6284 Å in the spectrum of HD 183143 are described. The observations were made using a television detector and a Polaroid filter. No systematic change through the diffuse feature was observed, and an upper limit of ± 0.4 percent is placed on the variation of polarization in the spectral region.

Subject headings: interstellar matter — polarization — stars, individual

I. INTRODUCTION

There is considerable interest in establishing whether the diffuse interstellar features arise from absorption by the interstellar grains or some gaseous interstellar component. Van de Hulst (1949) pointed out in an early discussion of interstellar grain composition that the diffuse features do not show the very asymmetrical profiles one would expect if they arose through absorption within the grains.

It is generally accepted that optical interstellar polarization is caused by partial alignment of grains which are either elongated or have nonisotropic optical properties. If the diffuse features are considered to be a spectral region of enhanced extinction by the grains, one might expect an accompanying increase in the polarization. Greenberg and Hong (1974) has suggested that a polarization inflection centered on the feature might be observed. In either case one might expect the size of the effect to be of the order of the product of the strength of the diffuse interstellar feature and the value of the interstellar polarization (see, for example, the discussion by Martin and Angel 1974).

Several attempts have been made to measure the variation of the polarization in the region of the λ4430 diffuse interstellar band (Walker 1963; Wampler 1966; Wickramasinghe and Nandy 1971; Kelly 1971; A'Hearn 1972; Martin and Angel 1974; Kemp and Wolstencroft 1974). Martin and Angel (1974) have also looked at the polarization in the region of the λ5780 feature. The conclusions of the various authors are, unfortunately, conflicting.

We have observed the strongest of the known diffuse features at λ6284 for differential polarization, and an upper limit has been established by the results.

II. OBSERVATIONS

The λ6284 feature has a V-shaped profile and is only some 8 Å full width at half its central depth and is contaminated by the band structure of the telluric α-band of oxygen. A spectrograph is almost essential to adequately resolve the line. We have used the 96-inch (2.4 m) camera in the coudé mosaic grating spectrograph attached to the 122-cm telescope of the Dominion Astrophysical Observatory. The detector was a refrigerated image Isocon television camera (S-20 photocathode). The characteristics of the camera and the associated data acquisition system have been described in detail by Walker *et al.* (1972). A spectrum is integrated on the target of the camera within the linear range of the target storage (i.e., up to an approximate signal-to-noise ratio of 20) and then read out once at a standard frame rate. The spectrum is digitized at 840 points and stored on magnetic tape. Spectra are accumulated to improve the signal-to-noise ratio. The spectra had a resolution of some 2.5 Å. A number of frames of dark current were taken after each series of observations.

A piece of high-quality Polaroid mounted between two optical flats was used as the analyzer. It was placed in the telescope beam immediately before the first coudé flat mirror. This position eliminated the depolarizing effect of the train of coudé mirrors. The combined coudé mirror system transmission is strongly polarization sensitive and this is a function of both declination and hour angle. Consequently no useful absolute polarization measurements can be made with the system; only differential variations of the type discussed here can be attempted. After some 16–20 spectra of HD 183143 has been taken with the Polaroid in one orientation, it was rotated to the orthogonal position and further spectra accumulated. The two orientations used were parallel and perpendicular to the linear continuum polarization in HD 183143 which is at a position angle of 0° (Serkowski 1974). The use of only one pair of orthogonal Polaroid positions prevents us from determining any possible dependence of the differential polarization on position angle; indeed, we would obtain a null result if the differential polarization were at a position angle of 45°. However, if it is assumed that the same grains are responsible for both the enhanced extinction at λ6284 and the nearby continuum polarization, it follows that the position angles of the differential

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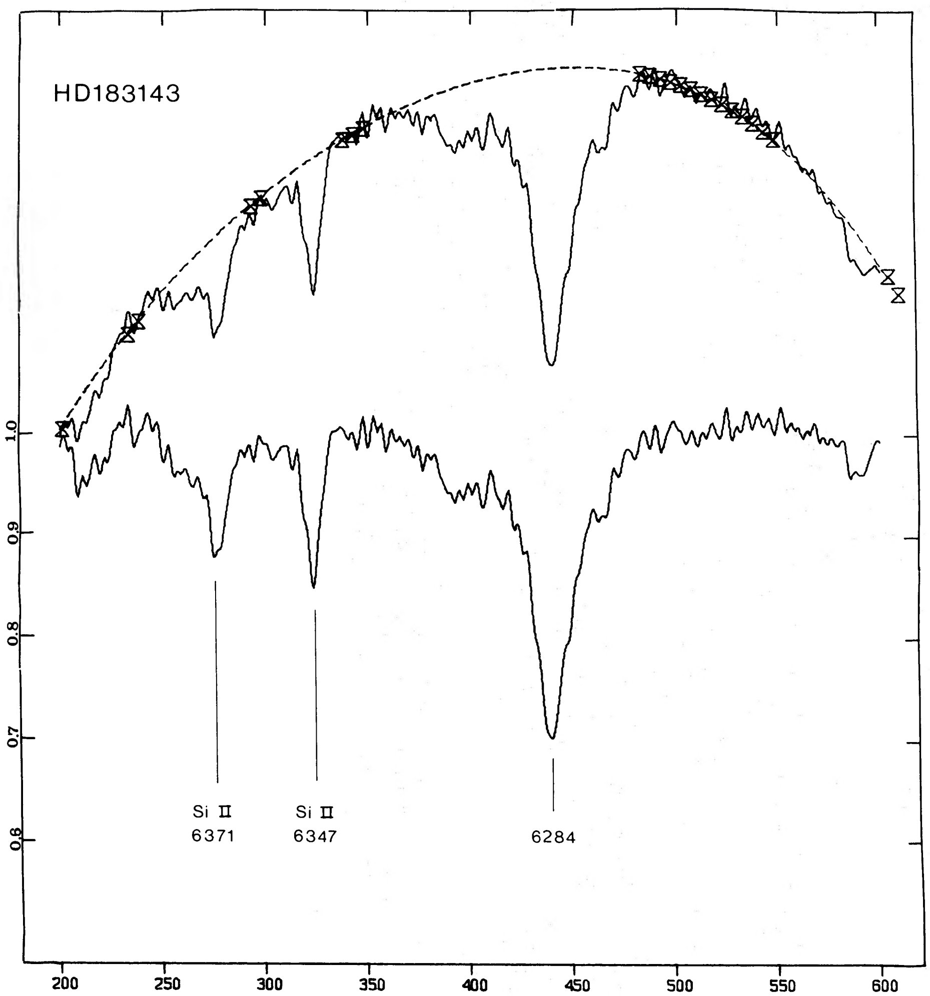

FIG. 1a

FIG. 1.—(*a*) Rectification for HD 183143. A low-order polynomial indicated by the dashed line has been fitted through the marked points. The resulting rectified spectrum is shown below. The left-hand scale indicates the relative intensity. The abscissa is labeled with sample points, the central 400 points of the data being illustrated. (*b*) Rectification for α Cygni as in (*a*). The α-band of O_2 is responsible for the depression in the center of the data.

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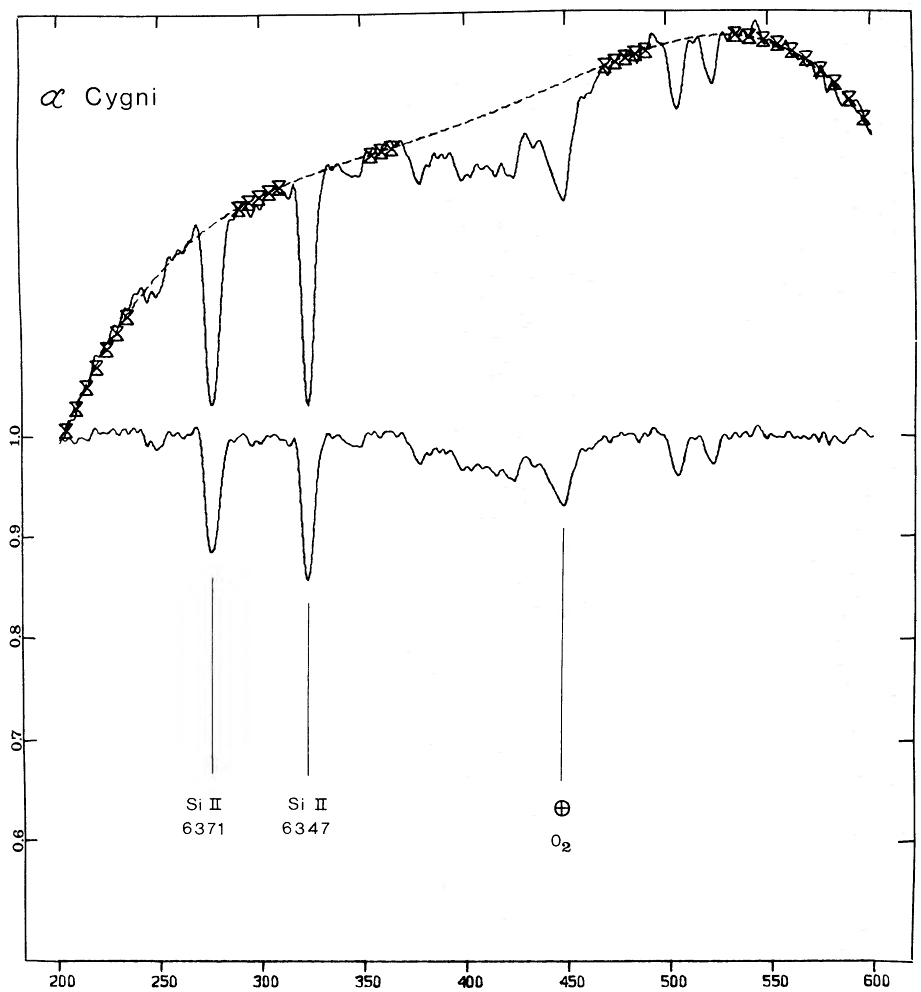

FIG. 1b

FIG. 1.—*Continued*

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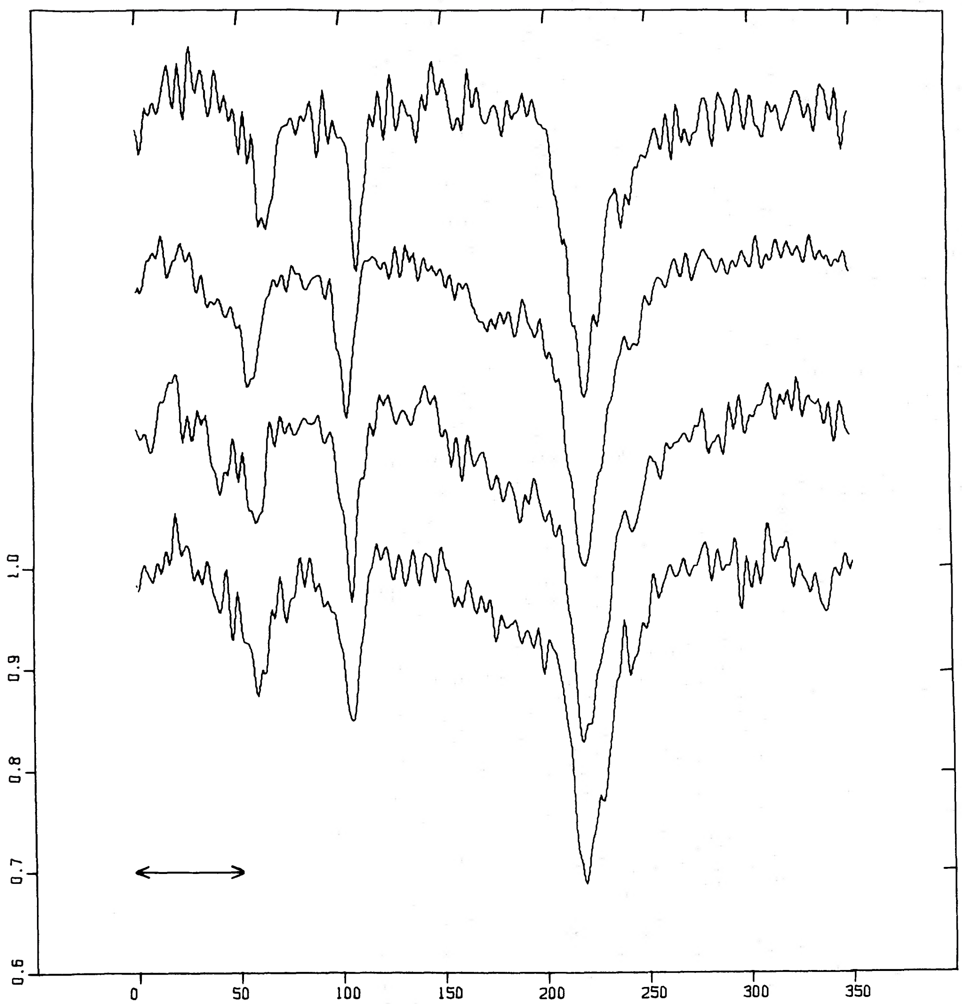

FIG. 2*a*

FIG. 2.—The four nights of data on HD 183143 taken with the polaroid transmission axis oriented in (*a*) the east-west and (*b*) the north-south directions.

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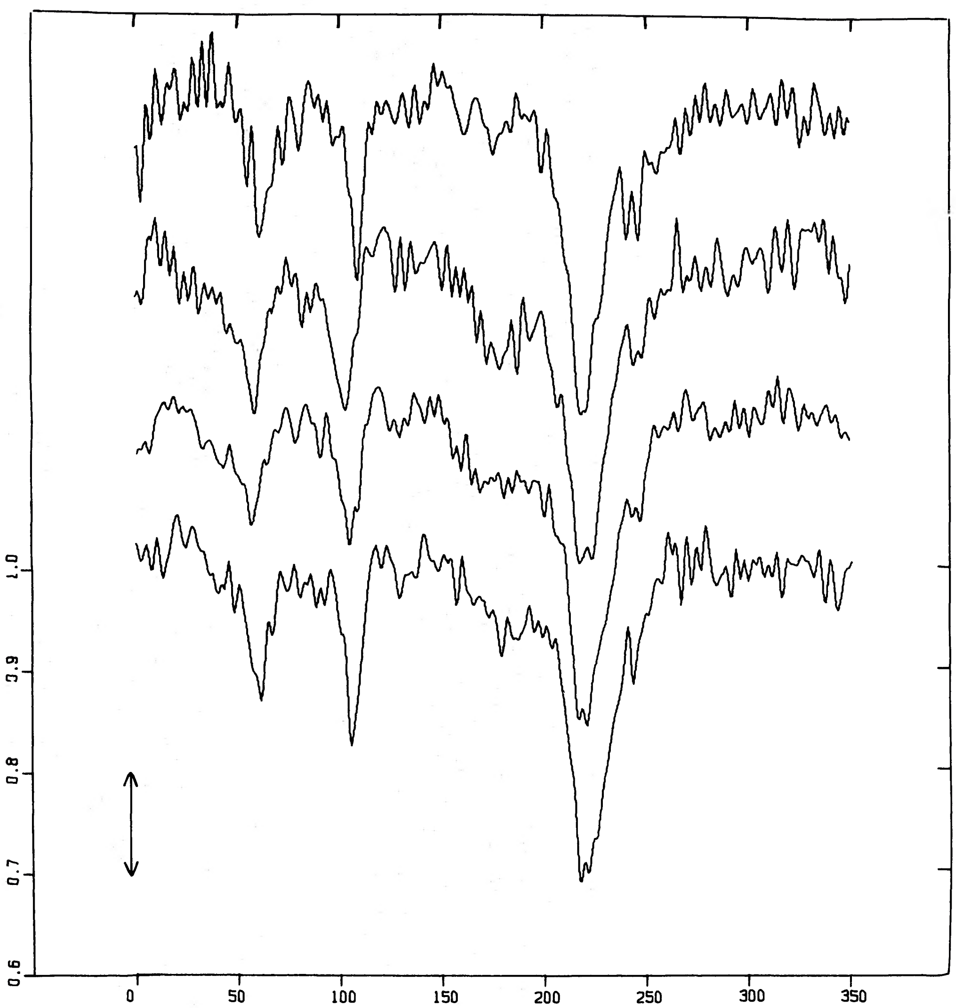

FIG. 2b

FIG. 2.—*Continued*

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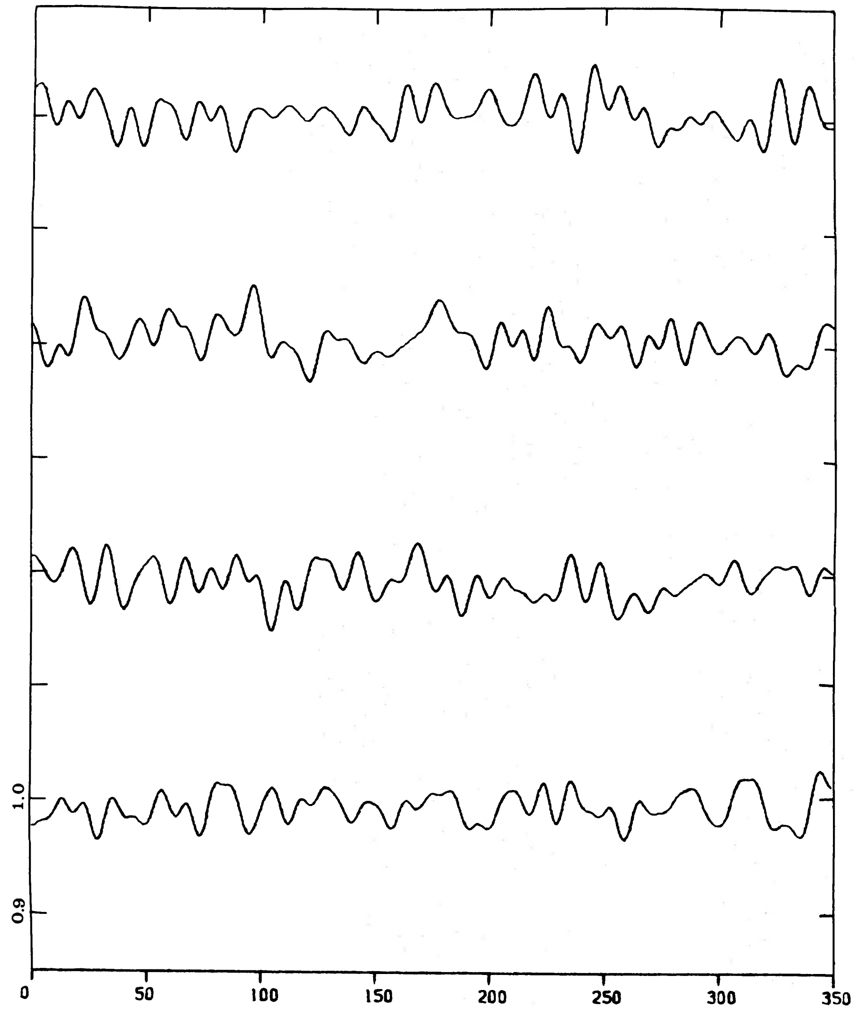

FIG. 3.—The ratios obtained by dividing the data shown in Fig. 2 in the sense of (*a*)/(*b*). A low pass filter with a cutoff at 20 percent of the Nyquist frequency has been applied to these data.

and continuum polarization should be the same. Our observations are adequate to check that assumption.

Spectra of α Cyg were also taken at both polaroid settings to act as a control. The polarization experiment was carried out on four different nights during the summer 1972.

III. RESULTS AND DISCUSSION

After subtracting the appropriate dark level from each set of spectra, the first step in the reduction is to rectify the data by removing the instrumental response. This is illustrated in Figure 1, which shows the central portion of one uncorrected observation for each of HD 183143 and α Cyg taken on the same night with the same Polaroid orientation. The continuum has been defined as shown by fitting a low-order polynomial through representatiive points selected away from obvious spectral features. The same points were used for both polarizations. The complete set of rectified spectra for HD 183143 is shown in Figure 2. The next step is to obtain ratios of the intensity observed in the two orientations of the polaroid. The Isocon is known to suffer from raster instability, leading to spurious displacements in the line positions, so some care must be taken to properly align the spectra before dividing. The two sharp Si II lines visible in Figure 1 longward of 6284 Å were used for this purpose. The ratios for each night are shown in Figure 3. A low pass filter with a cutoff at 20 percent of the Nyquist frequency has been applied to these ratios in order to suppress meaningless high-frequency noise. There is clearly no systematic structure observed in these ratios, which have a formal standard deviation of typically 2 percent. As a check on possible structure in the telluric α-band of O_2, the data on α Cyg were reduced in the same way. No obvious structure was apparent.

Our final result is obtained by combining the data taken on all four nights. In Figure 4 the mean ratio,

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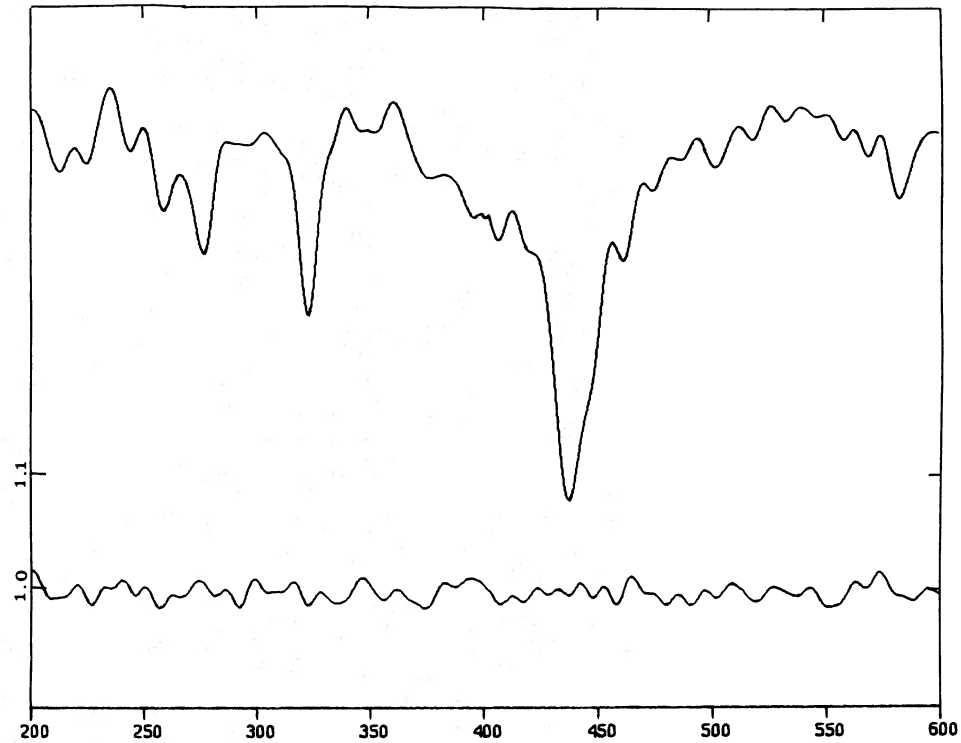

FIG. 4.—The mean ratio obtained by combining the four nights' data is shown under a representative spectrum of HD 183143. Both data sets have been filtered to 20 percent of the Nyquist frequency.

filtered to 20 percent of the Nyquist frequency, is shown together with a representative spectrum also filtered to 20 percent. The mean ratio does not show any systematic structure within the 6284 Å feature exceeding the formal standard deviation of 0.7 percent for the entire data.

If we write the polarization as $p(\lambda) = \bar{p} + \Delta p(\lambda)$, then our rectification technique removes $\bar{p}$ as well as the instrumental response function. The resulting ratio in Figure 4 gives a direct measure of the quantity $\Delta p(\lambda)$ which we expect to be different from zero only in the region of the 6284 Å feature.

If it is assumed that the same interstellar grains are responsible for the extinction, continuum polarization, and the diffuse feature, then, according to Martin and Angel (1974), the change in polarization across a diffuse line, $\Delta p(\lambda)$, is predicted to be

$$\frac{\Delta p(\lambda)}{\bar{p}} = \frac{f \Delta \tau(\lambda)}{\bar{\tau}}, \qquad (1)$$

where $\bar{p}$ is the mean polarization of the local continuum and $\Delta\tau(\lambda)$ is the change in optical depth from the real mean optical depth $\bar{\tau}$. The quantity f is somewhat model-dependent, but a value of 1.4 is suitable for comparison purposes. From the data given by Serkowski (1974), we calculate $\bar{p}(6284) = 6.0$ percent for HD 183143. Similarly, from the value of $\bar{\tau}(5780) -$ 3.6 (Martin and Angel, 1974), we obtain $\bar{\tau}(6284) = 3.3$ using the usual $1/\lambda$ extinction law. From our data, we estimate that the center of the 6284 Å feature, $\Delta\tau_c = 0.39$. Consequently, we might expect a maximum change Δp_c of ~ 0.9 percent. The overall deviation should follow the line profile. The calculations by Greenberg and Hong (1974) for the 4430 Å feature predict polarization changes of a similar order through the diffuse feature, although it appears that the shape of the deviation is rather strongly dependent on the size of the grains and the degree of randomness in their alignment.

From our data we may put a limit on the change in polarization through the central region of the 6284 Å band of

$$|\Delta p| \leq 0.4 \text{ percent}.$$

The accuracy of our observations does not permit us to draw any firm conclusions as to whether or not the interstellar grains responsible for the continuum extinction and polarization are also responsible for the 6284 Å feature. The lack of noticeable broad-band structure through the line is, however, an additional point to consider. In Figure 5, the differential polarization in the region of the 6284 Å feature is shown on a greatly expanded scale in order to compare in detail the observed result with that predicted by equation (1). We conclude that the polarization structure through the 6284 Å feature is certainly no stronger than the predicted effect.

Accurate photometric observations by A'Hearn

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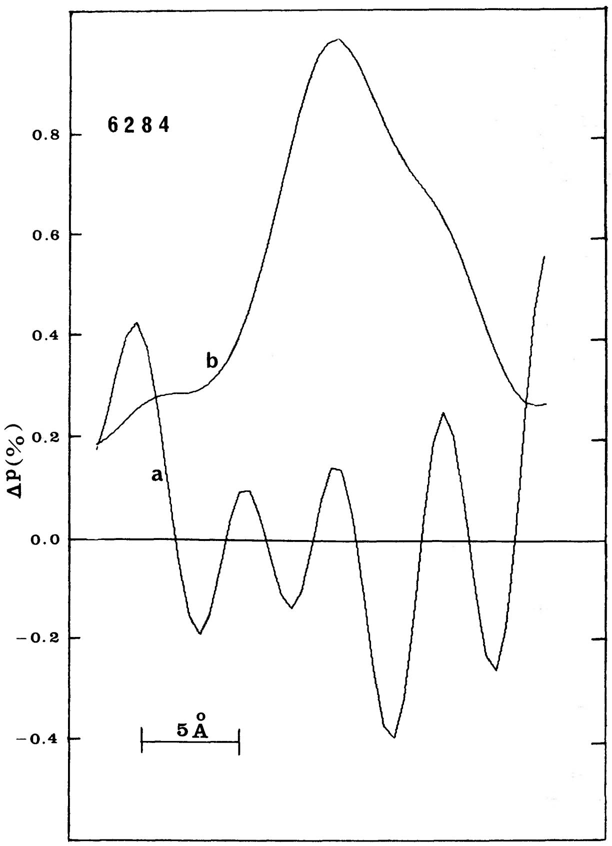

FIG. 5.—The observed differential polarization is indicated by the curve labeled *a*. The curve labeled *b* is the $\Delta p(\lambda)$ predicted by equation (1) of the text and is determined by the observed extinction $\Delta\tau(\lambda)$ through the 6284 band.

(1972) failed to detect any polarization structure through the 4430 Å band in HD 183143. These results were confirmed by Martin and Angel (1974) who also obtained a null result for the 5780 Å feature. The most straightforward interpretation is that the grains are not the source of these particular diffuse features. Our observations at 6284 Å tend to support this conclusion. Recently Wolstencroft and Kemp (1974) have reported the discovery of polarization structure across the 4430 Å band in the three stars HD 21389, HD 39970, and ζ Oph. The magnitude of the effect is consistent with equation (1), but the wavelength dependence is in better agreement with calculations by Greenberg, and Hong (1974). Their result, however, appears to contradict the negative results for both the 4430 and 6284 Å features in HD 21389 reported by Martin and Angel (1974) in a proof note. Also of interest is the report by Gammelgaard and Rudkjøbing (1973) of a net differential polarization effect at the 6180 Å interstellar feature.

The situation thus remains unclear. It seems possible to reconcile the conflicting results obtained for different interstellar features simply by recognizing that such features need not share a common origin. It would be more difficult to explain differing results for the same feature observed in the spectra of different stars. Further observations are obviously required to unequivocally demonstrate such effects. In view of equation (1), the 6284 Å feature is perhaps the most suitable feature for observations since it should show the greatest modulation in Δp.

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