A STUDY OF THE INTERSTELLAR DIFFUSE ABSORPTION FEATURES

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Abstract. At a resolution of 0.17 Å, the profile of λλ 5780, 5797 were found to be asymmetric and steeper to the blue. The FWHM of λ 5780 and λ 5797 are respectively 2.7 Å and 1.1 Å. There is also a broad, shallow feature shortward of λ 5780. Equivalent widths of λλ 5780, 5797 were measured at a resolution of 0.26 Å, and they present a very tight correlation. Therefore, it is highly likely that these two diffuse lines have a common origin. The correlation between the equivalent width of λ 5780, $EW(\lambda\ 5780)$, and $E(B-V)$ is good for normal field stars. But there is a systematic weakening of λ 5780 in the spectra of Be stars, and the reverse is true for stars in the Scorpius-Ophiucus region. Excluding Be stars, a least square fit gives $EW(\lambda\ 5780) = 0.75\ E(B-V)$ Å mag.$^{-1}$. From the profiles and structures of the diffuse features, and the correlations with various parameters of the interstellar medium, it is suggested that: (1) the diffuse band λ 4430 may be produced by the preionization of H^- and, (2) λλ 5780, 5797 may be due to the pure electronic transitions of the impurity centers in solid grains.

Here I wish to report a recent study of the interstellar diffuse absorption features λλ 4430, 5780, 5797. Earlier work concerning the diffuse features was discussed by Wilson (1964), Johnson (1967), and Herbig (1967). Photoelectric measurements for the central absorption depth of λ 4430 were made by Stoeckly and Dressler (1964) and Wampler (1966). Equivalent widths of λλ 5780, 5797 were obtained for 66 early type stars by the author with a high dispersion echelle spectrograph. The results of the study are summarized here and a more detailed discussion will be published elsewhere.

The profiles and structures of λλ 5780, 5797 are shown in Figure 1 for the heavily reddened supergiant HD 183143. At a resolution of 0.17 Å, the profiles are asymmetric with the steeper side in the blue. There is also a broad, shallow feature shortward

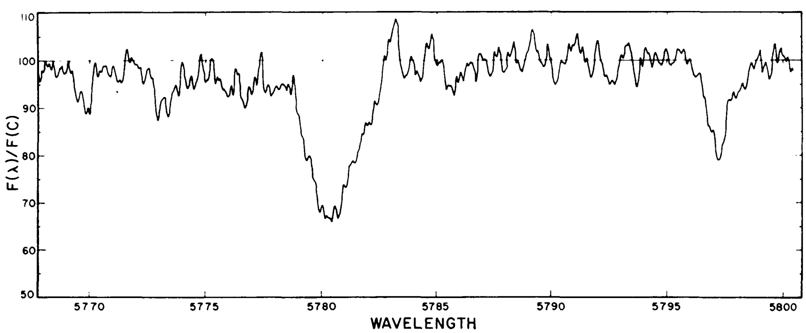

Fig. 1. The profile of λλ 5780, 5797 for HD 183143 at a resolution of 0.17 Å. The continuum is obtained by least square fitting a 3rd order polynomial. Note that the profiles are asymmetric and steeper to the blue, and there is a broad shallow absorption feature shortward of λ 5780.

Greenberg and Van de Hulst (eds.), Interstellar Dust and Related Topics, 91–95.

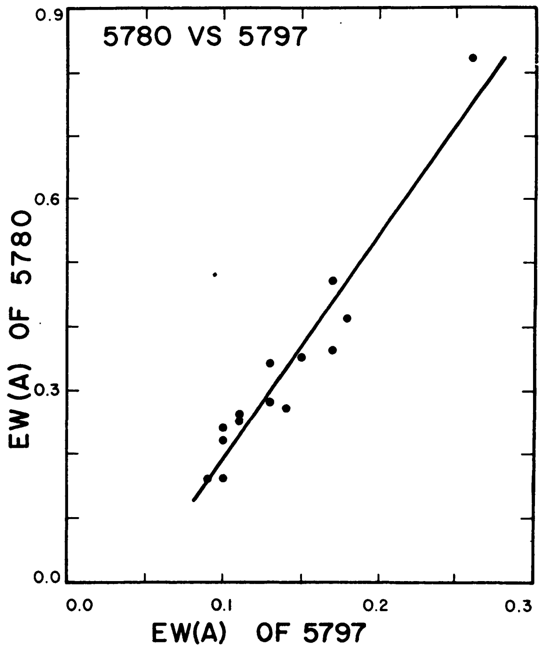

Fig. 2. Correlation between the equivalent widths of λ 5780 and λ 5797.

of λ 5780. If there is also such a broad feature associated with λ 5797, it is not expected to be detectable in the spectrum of HD 183143. The FWHM of λ 5780 and λ 5797 are respectively 2.7 Å and 1.1 Å. Equivalent widths were measured at a resolution of 0.26 Å. As shown in Figure 2, the correlation between the two diffuse lines is tight, indicating that they are very likely carried by the same agent. Henceforth, λ 5797 will be omitted from further discussion. Figure 3 shows the correlation between the equivalent width of λ 5780 and $E(B\text{-}V)$. The Be stars and the close binary system Omicron Per show the systematic weakening of λ 5780 in their spectra, whereas the stars in the Scorpius-Ophiucus region show λ 5780 to be slightly stronger than other field stars with the same $E(B\text{-}V)$. Excluding the Be stars, a first order polynomial least-square fitted to the correlation gives

$$EW(\lambda 5780) = 0.75\, E(B-V)\, \text{Å mag.}^{-1} \tag{1}$$

where $EW(\lambda\, 5780)$ is the equivalent width of λ 5780. Since λ 5780 is not saturated and correlates well with $E(B\text{-}V)$, for normal stars, Equation (1) should give a good estimate of the $E(B\text{-}V)$ excess produced by interstellar grains.

This investigation further proposes that λλ 5780, 5797 are produced by the pure electronic transitions of the impurity centers in solid grains. Pure electronic transitions can give rise to very sharp optical lines with FWHM ranging from less than 1 Å to a few angstroms and sometimes maybe even broader (Rebane, 1970). Therefore the FWHM of λ 5780 (2.7 Å) and λ 5797 (1.1 Å) are well within the FWHM range of

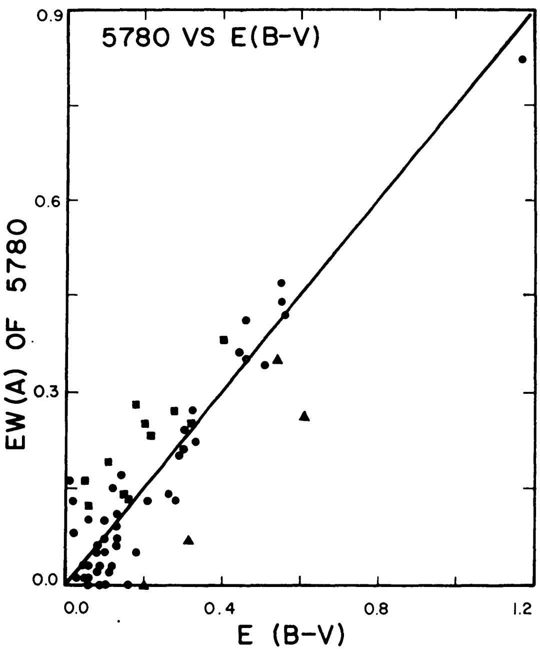

Fig. 3. Correlation between the equivalent width of λ 5780 and $E(B-V)$. λ 5780 is relatively weak in the spectra of Be stars and the close binary system Omicron Per. λ 5780 is systematically stronger for Scorpius-Ophiucus stars. ● fields stars, ▲ Be stars, ■ Sco-Oph stars.

the pure electronic transitions. In the bulk solid, the pure electronic lines are predicted to have a Voight profile (Rebane, 1970). But a symmetric spectral feature in the bulk material will become asymmetric in the extinction spectra of small grains, with the degree of asymmetry depending on the size of the grains (Van de Hulst, 1957, Greenberg, 1968, 1971). Calculations by Wickramasinghe and Nandy (1970) with the observed central wavelength and width as input parameters show that the asymmetric absorption profiles are steeper to the blue. As shown by Figure 1, the profiles of λλ 5780, 5797 are indeed asymmetric and steeper to the blue. This pure electronic transition model can also explain the broad shallow absorption feature shortward of λ 5780. Associated with each parent pure electronic transition, there are weak absorption sidebands shortward of the parent line (e.g. see Yen *et al.*, 1964). As for the systematic weakening of λ 5780 in the spectra of Be stars (Figure 3), it is possible that circumstellar grains are efficient in visual extinction but not carriers of λ 5780 or that circumstellar grains being freshly formed, have not accumulated appreciable concentration of impurity centers, whereas interstellar grains have been subjected to bombardment by cosmic rays and high energy photons for long periods of time, thus contain appreciable concentration of lattice defects.

Rudkjøbing (1969a, b; 1970) and Ingemann-Hilberg and Rudkjøbing (1970), by extrapolating the wavenumbers of resonance lines along isoelectronic sequences and also quantum mechanical calculations, found that the diffuse bands λλ 4430, 4760, 4890, 6180 might be produced by preionization of H^-; and the diffuse lines $\lambda\lambda$ 5780, 5797 might be produced by preionization of O^-. A theoretical investigation of preionization has been carried out by Fano (1961). Preionization processes give rise to asymmetric absorption profiles with the steeper side associated with an apparent emission wing, and an apparent absorption wing associated with the side which drops more slowly to the band center. If λ 5780 were due to preionization process, then the broad, shallow feature to its blue corresponds to the apparent absorption wing and should not be associated with the steeper side of the absorption profile. This suggests that preionization is not responsible for λ 5780. As for the diffuse bands, the observation of Wilson (1958) gives the profiles of $\lambda\lambda$ 4430, 4760, 4890, 6180. These profiles agree qualitatively with preionization profiles. Besides this qualitative agreement of profiles, there are other evidences suggesting that λ 4430 may be produced by the preionization of H^-: (1) central absorption depth of λ 4430 correlates significantly better with the column density of interstellar neutral hydrogen than with $E(B\text{-}V)$ and the 2200 Å ultraviolet extinction bump, (2) λ 4430 is systematically weaker for stars behind dust clouds (Wampler, 1966). It is possible that in dust clouds H_2 formation is more efficient and H density decreases, and this leads to the decrease of H^- concentration, (3) two close members of NGC 7762, both are O7 stars with the same $E(B\text{-}V)$, but the one with stronger CN absorption has weaker λ 4430. This is consistent with the above argument, because if λ 4430 does originate from H^-, one will expect the region which is more efficient for molecular formation to give rise to weaker λ 4430. This model has its difficulties: (1) H^- has to be formed at high enough rate to satisfy the high destruction rate (Wilson, 1964), (2) observed λ 4430 profile changes from star to star as reported by Wampler (1966) and Brück *et al.* (1969), and (3) polarization changes in the λ 4430 spectral region as reported by Nandy and Seddon (1970). However, the most recent observations by A'Hearn (1972) showed that the feature is unpolarized.

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