N91-14900

The Detection of a Broad Interstellar Extinction Feature near 1700Å

David J. Carnochan
Department of Physics & Astronomy
University College London, Gower Street, London WC1E 6BT

Abstract

A statistical examination of 126 extinction curves has revealed the presence of a second broad absorption feature similar in nature to the 2200Å feature. The feature is centred on wavelength 1706Å, has a full-half-width of 350Å and a mean central height of 0.21 magnitudes. The strength of the feature increases with E(B-V) supporting an interstellar origin, and on average it is 18 times weaker than the 2200Å feature.

Extinction curves between 1350 and 2550Å have been produced for 126 normal stars based on data from the S2/68 Ultraviolet Sky Survey in a manner similar to that described by Carnochan (1986a). Following Fitzpatrick & Massa (1988) each curve is initially fitted with the analytic approximation,

$$A(\lambda)/E(B-V) \simeq a_0 + a_1 x + a_2(x-6.0)^2 + b_1 L_1(\lambda) \quad (1)$$

where $L_1(\lambda)$ is the Lorentz profile,

$$L_1(\lambda) = d_1^2/\{(x-x_1)^2 + d_1^2\} \quad (2)$$

$x = 1/\lambda$ in microns; a_0, a_1 represent the intercept and slope of the linear extinction continuum; a_2 (which is zero for $x < 6.0$) is a curvature term representing the far uv rise; $b_1 L_1(\lambda)$ is the 2200Å feature with central wavelength x_1 ($\sim 4.6\mu^{-1}$), half-half-width d_1 ($\sim 0.50\mu^{-1}$) and central height b_1 (~ 3.7 mag). The best fit is found using least squares analysis and all six parameters are allowed to vary including the position, x_1, and half-half-width, d_1, of the 2200Å feature. A quantitative measure for the goodness of the fit is obtained by calculating χ_1^2.

The procedure is illustrated in Figure 1(a) where the extinction curve for ζ Oph (HD 129757, O9V, E(B-V)=0.33) is shown together with the the best fit, the three extinction components, and the residuals. It is clear from the residuals that there

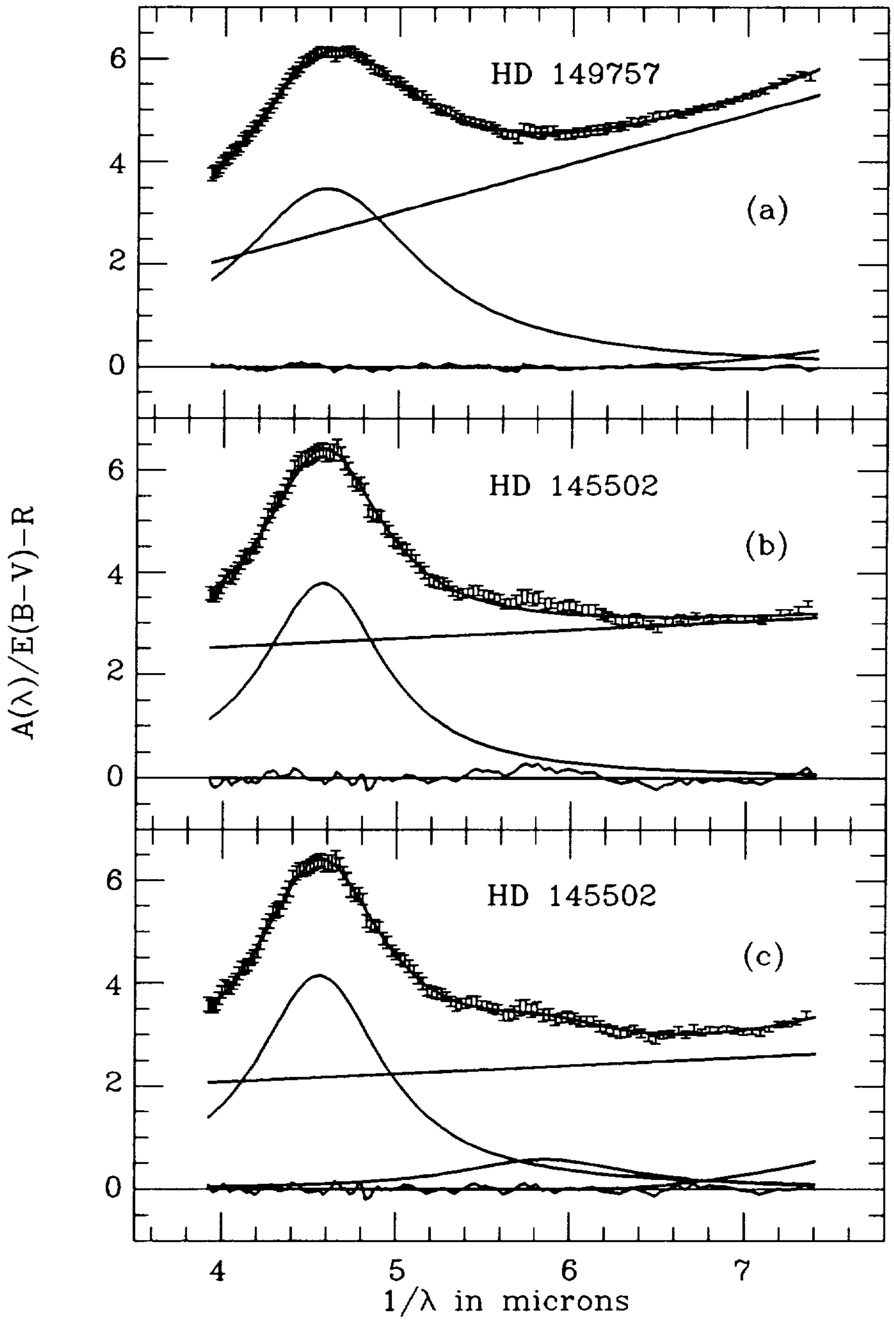

Figure 1: (a) The extinction curve for ζ Oph, HD 149757. Also plotted are the best fit, the three extinction components and the residual extinction. (b) The extinction curve for HD 145502. Note the poorness of the fit between 5.4 and 6.8 μ^{-1}. (c) The revised extinction curve for HD 145502. The best fit uses four components including a contribution from the 1700Å feature. Compare with (b).

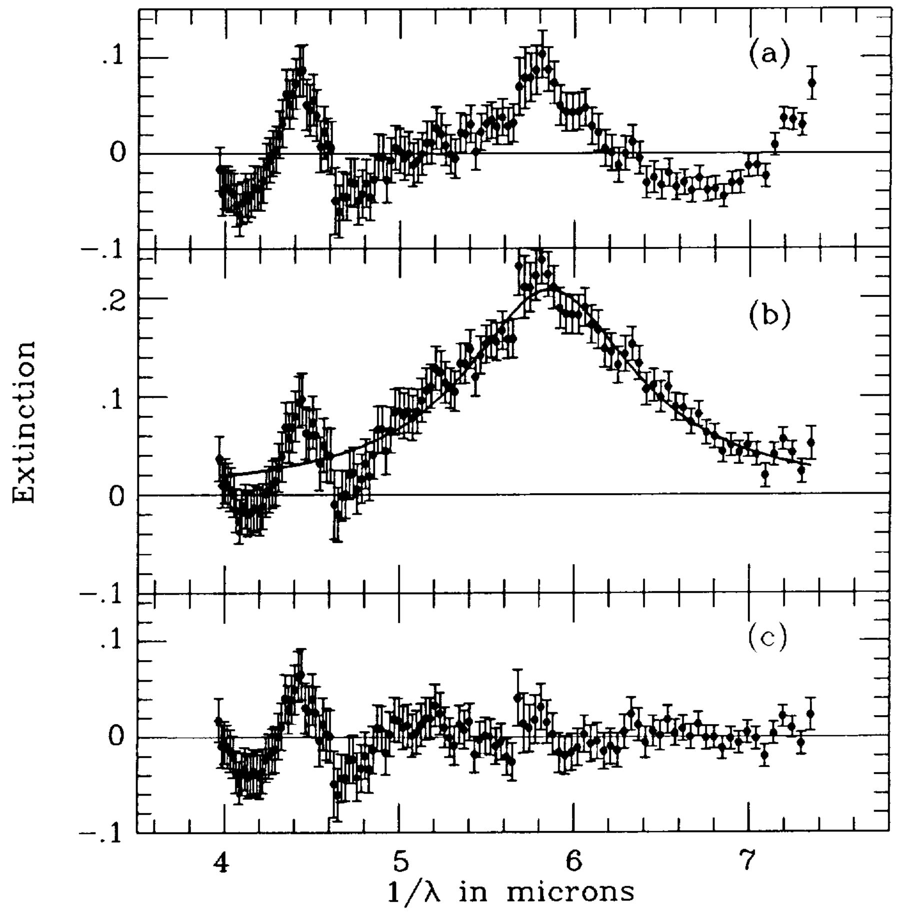

Figure 2: (a) The weighted mean residual extinction averaged over all 126 extinction curves. (b) The profile of the 1700Å feature (including the residuals) averaged over all 126 extinction curves. The best fit Lorentz profile is also shown. (c) The revised mean residual extinction averaged over all 126 extinction curves. This is the same as (b) with the Lorentz 1700Å feature removed.

is no evidence in this star for any additional extinction features. However many stars cannot be fitted quite so well and Figure 1(b) shows the extinction curve for HD 145502 (B2IV, E(B-V)=0.27). It is apparent from the residuals that there are regions where the extinction is either systematically high (around 5.8 μ^{-1}) or systematically low (around 6.5 μ^{-1}), and in this star the long wavelength side of the 2200Å feature does not fit particularly well either.

The weighted mean residuals for all 126 extinction curves are shown in Figure 2(a) and it is now very clear that there is additional structure in the extinction curve that is not accounted for by the three components of equation 1. The ripple between 4 and 5 μ^{-1} is probably associated with the 2200Å feature and indicates that 2200Å is not quite symmetrical, departing slightly from the Lorentz profile

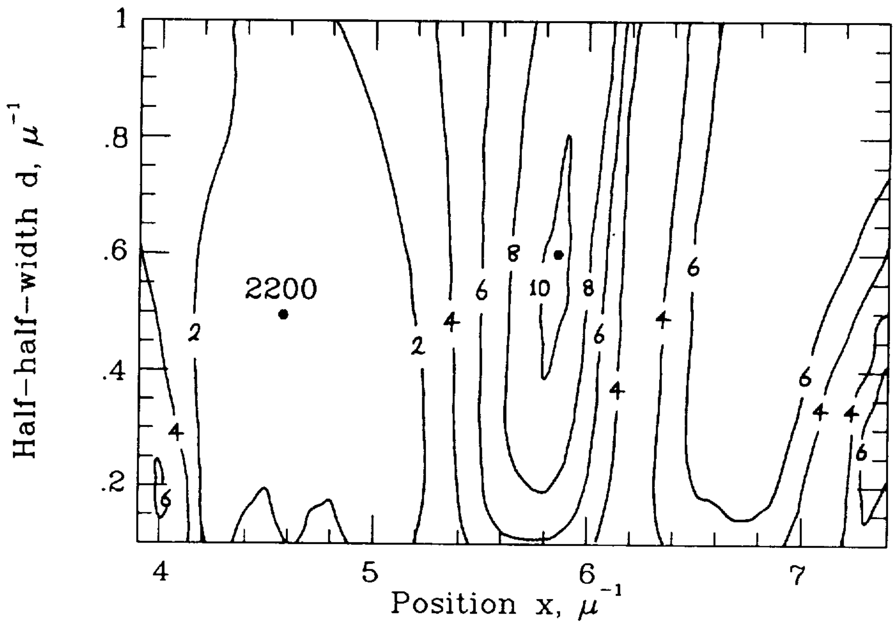

Figure 3: The contour plot of the % improvement in the fit obtained by introducing a feature at wavelength x μ^{-1} and half-half-width d μ^{-1}. The contours are drawn at 2% intervals and the peak of just over 10% occurs at x=5.86, d=0.6 μ^{-1}.

assumed here. If the background is set at about -0.05 then the remainder of the residuals (ignoring the far-uv rise beyond 7 μ^{-1}) can be interpreted as an additional broad absorption feature centred near 5.8 μ^{-1}.

To investigate the possible existence of other features a second Lorentz term was added to equation 1,

$$A(\lambda)/E(B-V) \simeq a_0 + a_1 x + a_2(x-6.0)^2 + b_1 L_1(\lambda) + b_2 L_2(\lambda) \qquad (3)$$

where

$$L_2(\lambda) = d_2^2/\{(x-x_2)^2 + d_2^2\} \qquad (4)$$

The additional feature was assumed to occur at chosen values of position, x_2, and half-half-width, d_2, and a second value for the goodness of fit, χ_2^2, calculated. The percentage improvement in the fit obtained by adding the second feature is simply,

$$(\chi_1^2 - \chi_2^2)/\chi_1^2 \times 100 \qquad (5)$$

A grid search was undertaken for a second feature between $3.9 < x_2 < 7.4$ and $0.1 < d_2 < 1.0$. Figure 3 is the resulting contour map of the improvement in χ^2, meaned over all 126 extinction curves, with contours drawn every 2%. It is clear from this contour map that a 10% improvement can be achieved by postulating the existence of a second absorption feature at 1706Å ($5.86\mu^{-1}$) with a half-half-width of 175Å ($0.60\mu^{-1}$). Statistically the addition of the extra term in equation 3

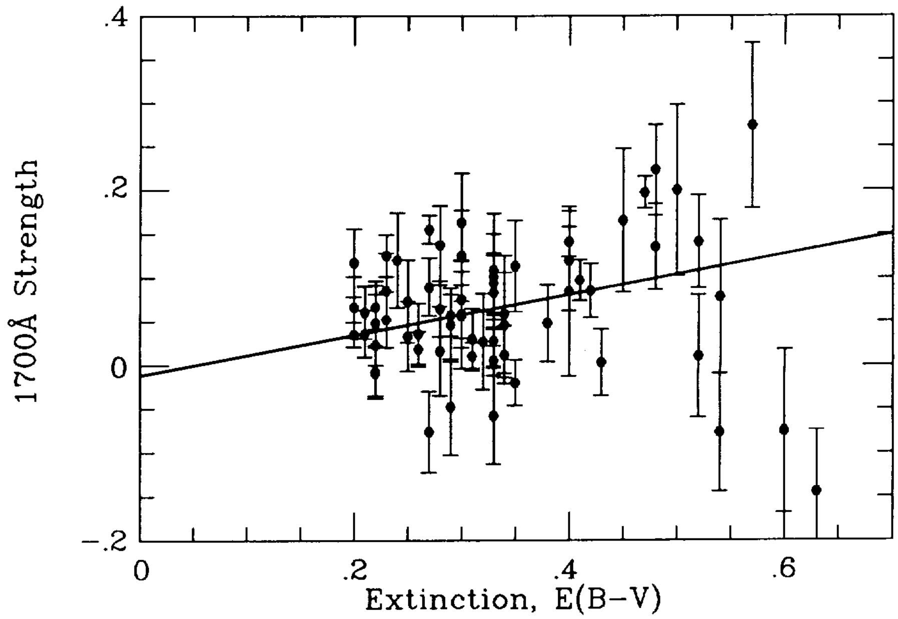

Figure 4: The observed strength of the 1700Å feature plotted against the extinction, E(B-V). The least squares line is also shown which supports an interstellar origin for the 1700Å feature.

should randomly improve χ^2 by about 1%. The actual 10% improvement gives a better than 95% confidence that the 1700Å feature is real. The profile of the feature, $b_2 L_2(\lambda)$, can be checked by inverting equation 3 and Figure 2(b) shows the mean profile averaged over all 126 extinction curves. The mean central height of the 1700Å feature is 0.21 magnitudes which makes it 18 times weaker than the 2200Å feature. The new mean residuals are simply obtained by removing the 1700Å feature from Figure 2(b) and they are shown in Figure 2(c). A comparison of Figures 2(a) and 2(c) demonstrates that the addition of the 1700Å feature makes a considerable improvement to the residuals although the 'ripple' near 2200Å is still present. Figure 1(c) shows the new fit for HD 145502 which again shows considerable improvement over Figure 1(b).

At this point all we have shown is that a significant improvement in fitting the extinction curve can be made by the addition of a 1700Å feature. The most critical task is to demonstrate that such a feature has an interstellar origin. This is quite difficult to accomplish as the feature is weak with relatively large error bars and because it is not observed in all reddened stars (e.g. absent in ζ Oph). The best evidence is to show that its strength, b_2 E(B-V), increases with extinction, E(B-V), and Figure 4 shows the data for 66 stars having mean extinction curve errors smaller than 0.4 magnitudes. Although the scatter is considerable, the best straight line passes very close to the origin and has a positive slope both of which give strong support to an interstellar origin for the 1700Å feature,

$$b_2 \times E(B-V) = -0.009(\pm 0.010) + 0.221(\pm 0.018)E(B-V) \tag{6}$$

The mean values of the nine parameters now used to describe the extinction curve are,

$$\begin{array}{lll} a_0 = 2.825 \pm 0.303, & x_1 = 4.575 \pm 0.011, & x_2 = 5.86 \\ a_1 = 0.650 \pm 0.055, & d_1 = 0.495 \pm 0.032, & d_2 = 0.60 \\ a_2 = 0.143 \pm 0.102, & b_1 = 3.765 \pm 0.139, & b_2 = 0.210 \pm 0.133 \end{array}$$

The normalised strength of the 1700Å feature, b_2, varies from star to star and no significant correlations are found with any of the other extinction parameters, supporting the idea of a distinct feature.

As for an explanation of the 1700Å feature, none is immediately forthcoming. However features near 1600Å have been mentioned in three cases. (1) Gilra (1972) has suggested that if silicate grains produce part of the uv extinction then there ought to be a silicate feature near 1600Å. (2) MacLean et. al. (1982) in associating the 2200Å feature with MgO expected a weaker feature near 1600Å. (3) In explaining the 2200Å feature by charge transfer absorption Carnochan (1986b, 1988) has predicted a second charge transfer feature, similar in width to 2200Å and about 30 times weaker in the neighbourhood of 1600Å.

Considerable information is available on the variations and correlations of the nine extinction parameters listed above. These essentially confirm the findings of Carnochan (1986a) and Fitzpatrick & Massa (1986, 1988). A much fuller account of this work will be submitted shortly for publication in Monthly Notices of the Royal Astronomical Society. Finally one interesting coincidence between the 1700Å and 2200Å features is that, within the errors, they have the same value of $\Delta\lambda/\lambda$.

References

Carnochan, D.J. 1986a, M.N.R.A.S. **219**, 903.

Carnochan, D.J. 1986b, *New Insights in Astrophysics*, ESA **SP-263**, 593.

Carnochan, D.J. 1988, M.N.R.A.S. **231**, 455.

Fitzpatrick, E.L. & Massa, D. 1986, Ap.J., **307**, 286.

Fitzpatrick, E.L. & Massa, D. 1988, Ap.J., **328**, 734.

Gilra, D.P. 1972, *Scientific Results from OAO-2*, NASA **SP-310**, 295.

MacLean, S., Duley, W.W. and Millar, T.J. 1982, Ap.J., **256**, L61.