Preliminary Results of Ultraviolet Interstellar Extinction from TD1 Satellite Observations

K. Nandy, G. I. Thompson, C. Jamar, A. Monfils and R. Wilson

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Preliminary results of ultraviolet interstellar extinction from TD1 satellite observations

By K. Nandy, G. I. Thompson
Royal Observatory, Edinburgh

C. Jamar, A. Monfils
Institut d'Astrophysique, Liège, Belgium

and R. Wilson
University College London, Gower Street, London, W.C. 1

The interstellar extinction law in the far ultraviolet has been derived from observations of about 100 stars for three galactic regions in the direction of Cygnus, galactic centre and anticentre. For each region the weighted mean extinction curve has an accuracy of about 6 % and shows no variation for the different directions. The profile of the broad extinction band centred near 2200 Å is derived and shown to be symmetrical. It is concluded that the extinction characteristics will need more than one type of particle for their explanation.

INTRODUCTION

The extensive sky coverage and large number of stars observed by the ultraviolet sky-survey telescope (S2/68) in the TD1 satellite make it ideally suited to the study of interstellar extinction. Since the extinction curve is derived from a comparison of near and distant stars of the same spectral type, then an important source of error arises from any differences in their intrinsic spectra and this can only be reduced by increasing the number of comparison pairs. A major study is in progress to use the very large number of S2/68 observations to derive accurate ultraviolet extinction curves throughout the galactic plane and to investigate any variations that may exist. This paper reports on the current status and presents data based on observations of about 100 OB stars down to V = 7.0*m*.

RESULTS

The experiment has been fully described elsewhere (Boksenberg *et al.* 1973) and gives data in the form of low dispersion spectra which cover the range 1350–2550 Å with a resolution of *ca.* 35 Å together with a broad band (*ca.* 300 Å) measurement centred at 2750 Å.

The galactic distribution of the stars used in the present paper is shown in figure 1, where the reddened stars are depicted by filled circles and the unreddened comparison stars by open circles. They are concentrated in three galactic regions – the direction of the galactic centre (mean $l^{\mathrm{II}} = 0 \pm 30°$), Cygnus (mean $l^{\mathrm{II}} = 70 \pm 30°$), and the anticentre ($l^{\mathrm{II}} = 170 \pm 30°$). Spectral types range from O to B8 and embrace main sequence, giant and supergiant stars. Great care has been taken to select the reddened and comparison stars on the basis of both spectral type and luminosity class since the latter is as important as the former in establishing a spectrum match. This is illustrated by figure 2, where main sequence, giant and supergiant

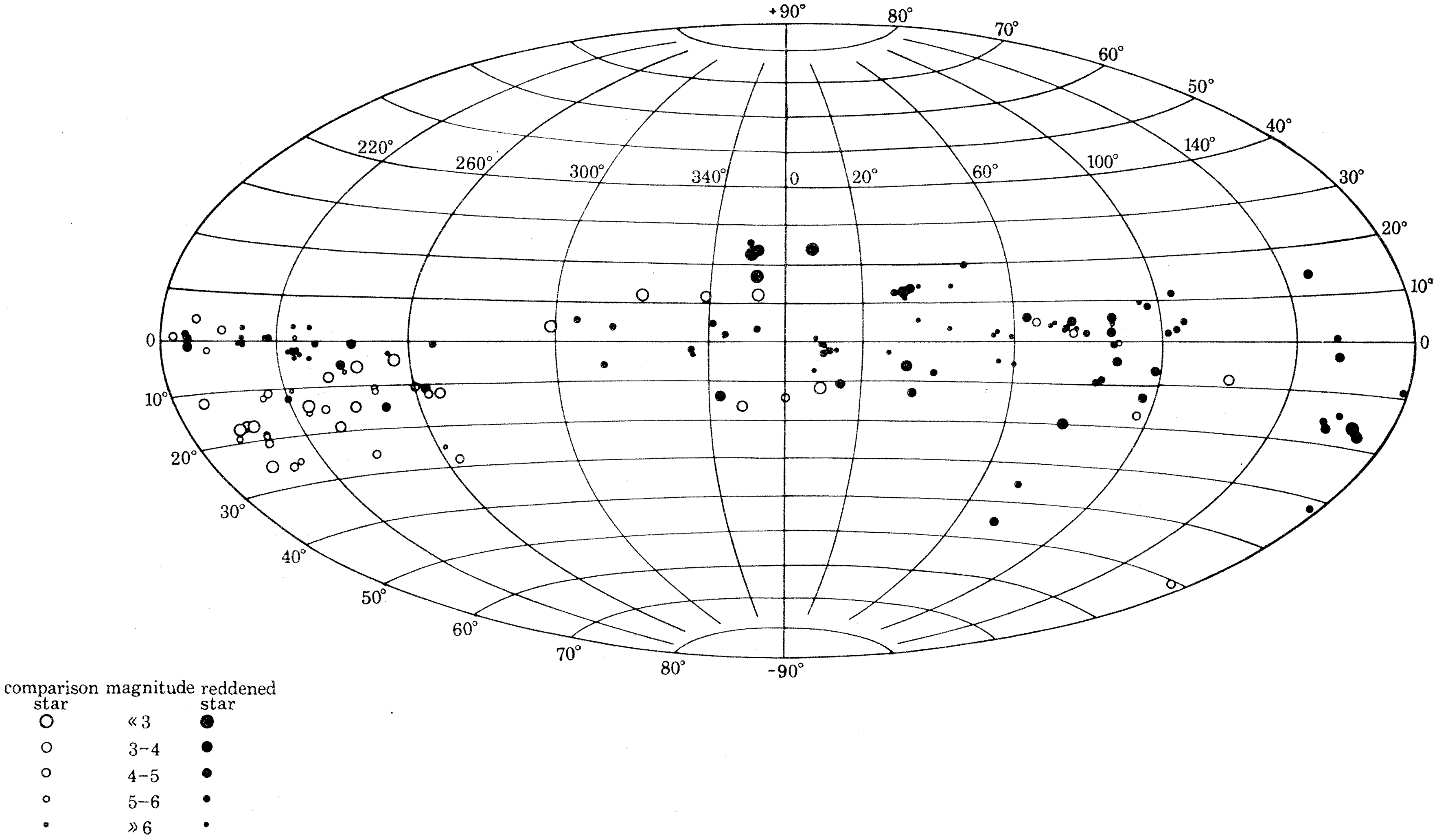

Figure 1. Galactic distribution of stars used for the present analysis of interstellar ultraviolet extinction.

spectra are plotted for unreddened stars of spectral types B0 and B1. The ultraviolet fluxes in higher luminosity classes decrease systematically to shorter wavelengths as compared to the fluxes of main sequence stars of the same spectral type.

Extinction curves, expressed in magnitudes, have been derived for each star pair, and normalized to $\Delta m = 0$ at 2740 Å and $\Delta m = 1$ at 2190 Å. In order to form mean extinction curves, a weight W was assigned to each individual curve, given by

$$W \propto \frac{1}{\sigma^2}\frac{1}{F},$$

where σ^2 is the mean square photometric error, given by

$$\sigma^2 = \frac{1}{N_1}+\frac{1}{N_2},$$

where N_1 and N_2 are the number of recorded counts in the spectra of the reddened and comparison stars, and the normalizing factor F is defined by

$$F = 1/(\Delta m(2190) - \Delta m(2740)).$$

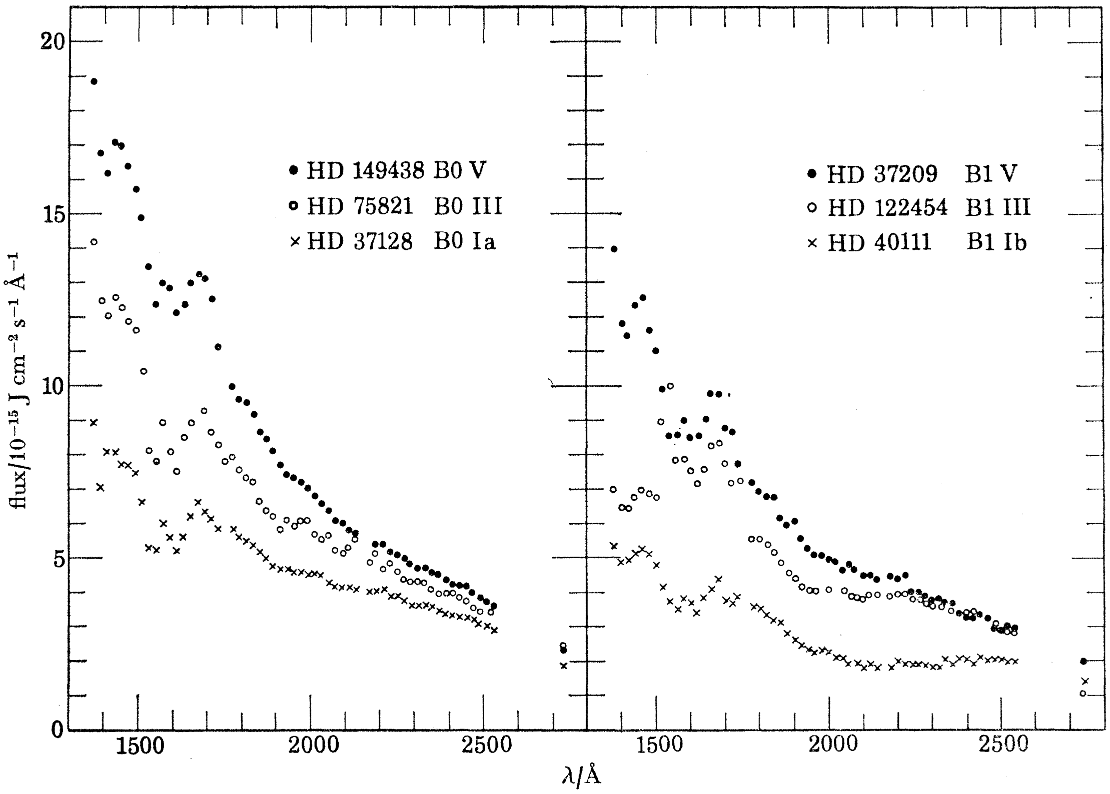

FIGURE 2. Ultraviolet spectra of unreddened stars demonstrating the pronounced luminosity effect.

The weighted mean curves for each of the three galactic regions covered by the present observations are displayed in figure 3. The vertical bars represent the r.m.s. errors and have been derived from the dispersion between individual extinction curves. The numerical values of the error for each mean extinction curve are listed below. It should be noted that the method of normalization to the longer wavelengths introduces an apparent variation of the error with wavelength. The more instructive errors are those for the shorter wavelengths.

Cygnus region: ± 0.02 for $\lambda > 2000$ Å
± 0.06 for $\lambda < 2000$ Å
anticentre region: ± 0.02 for $\lambda > 2000$ Å
± 0.04 for $\lambda < 2000$ Å
galactic centre: ± 0.03 for $\lambda > 2000$ Å
± 0.06 for $\lambda < 2000$ Å

Within these errors of measurement, there is no systematic difference in the extinction curves derived for the three different directions. This would indicate that the considerable variations found by Bless & Savage (1972) are due to mismatch in the stars being compared rather than variations in the interstellar medium. The curves also show a rather neutral extinction law at wavelengths below the extinction maximum at 2200 Å.

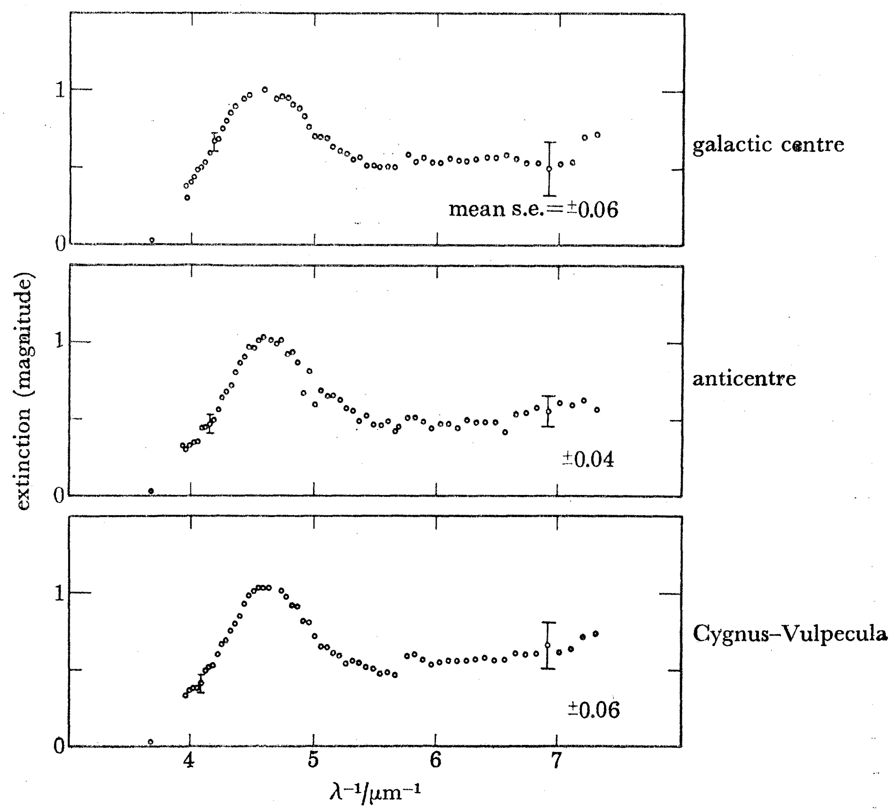

FIGURE 3. Mean ultraviolet extinction curves for three galactic regions.

Since the errors quoted above are derived from the dispersion of individual extinction curves, they will include contributions due to the errors of measurement of each individual curve together with any intrinsic variation between them. The errors of measurement arise from photometric errors and errors due to differences between the intrinsic spectra of the stars being matched, the latter being the greater. Adopting the usually quoted error in MK spectral types of ± 1 subclass, it is possible to estimate the expected error of measurement from all sources and this gives, for each of the mean extinction curves, ± 0.03 for $\lambda < 2000$ Å. Since the derived errors are larger, it is possible that some intrinsic variations in the interstellar extinction law do exist in the ultraviolet.

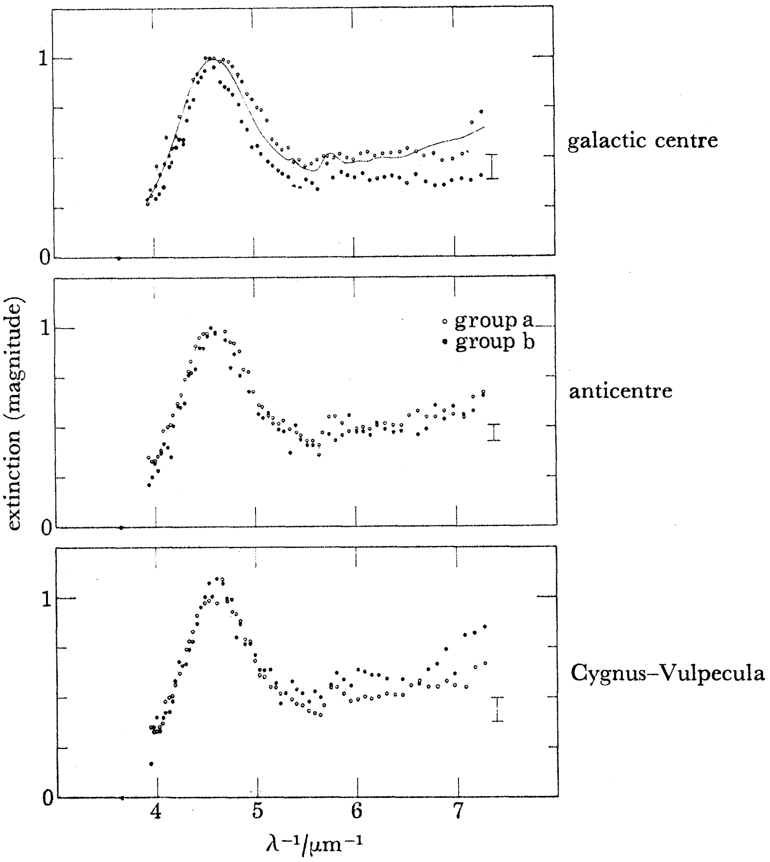

FIGURE 4. Mean ultraviolet extinction curves for near (350 pc – group a) and distant (800 pc – group b) stars in three galactic regions.

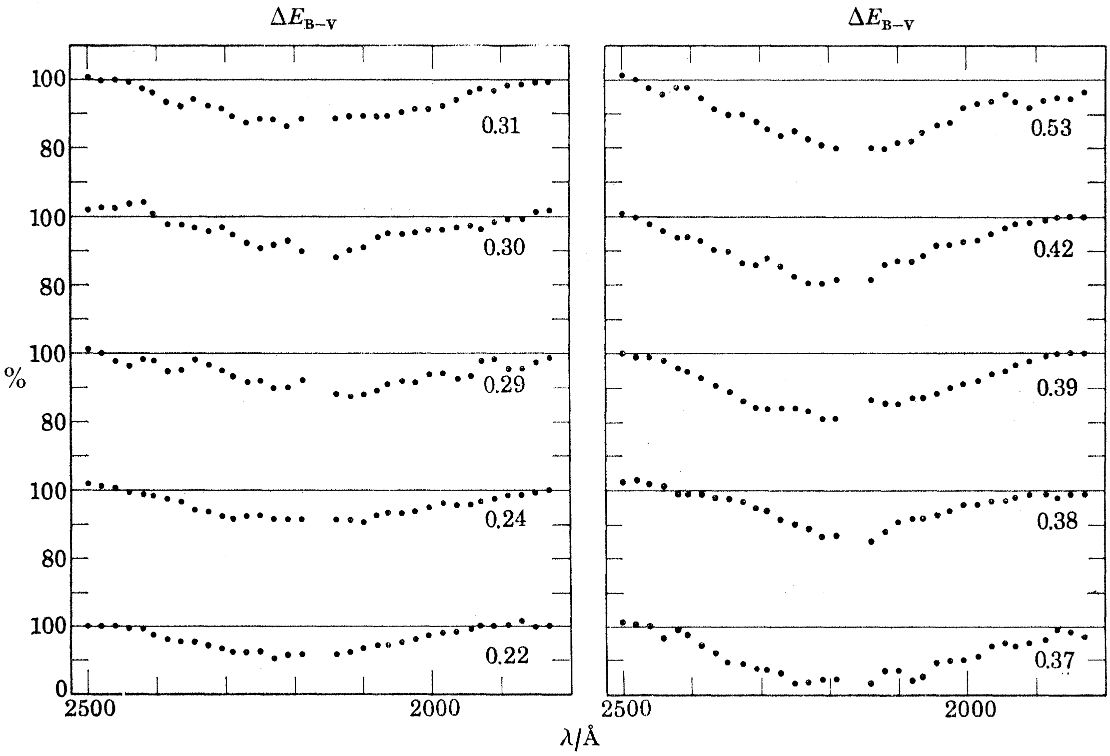

FIGURE 5. Profiles of the interstellar absorption band near 2200 Å in a number of stars of various colour excess.

One possible way in which the extinction law may vary in each region is with distance. To investigate this, the reddened stars in each region were divided into two groups, a and b, each group containing approximately an equal number of stars and having mean distances of 350 ± 50 pc and 800 ± 100 pc respectively. The mean extinction curves for each group and for each region are shown in figure 4. For Cygnus stars the distant group exhibit higher extinction in the ultraviolet than the nearer one, while the reverse is the case for the galactic centre; in the anticentre direction the extinction curves for the two groups are the same. However, the differences shown for Cygnus and the galactic centre just exceed the r.m.s. error and are, therefore, of doubtful significance. Clearly further investigation is required.

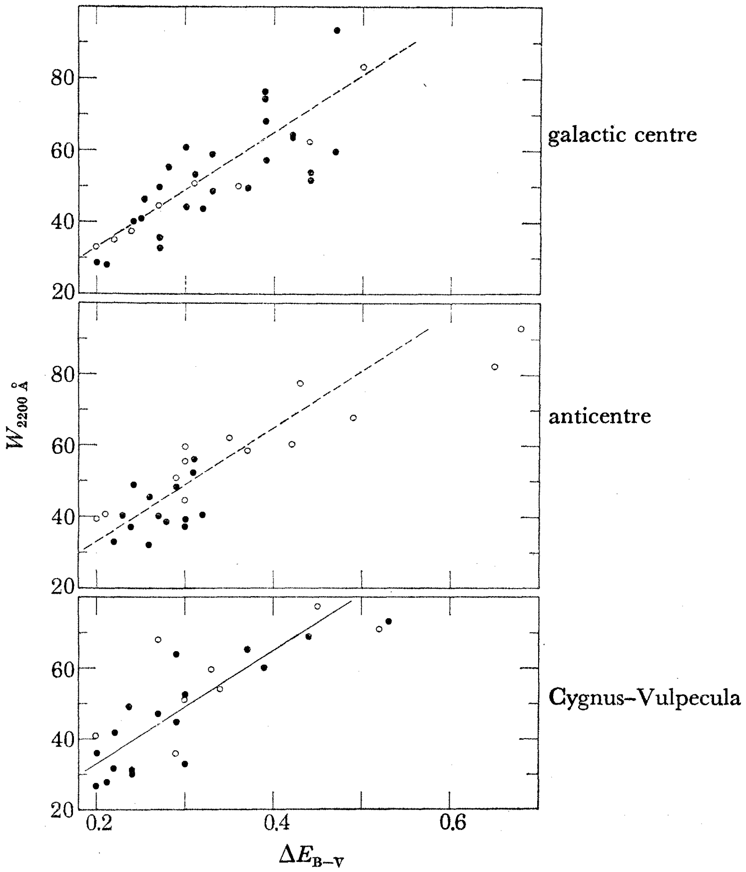

Figure 6. The relation between the equivalent width of the interstellar absorption feature near 2200 Å and colour excess in three galactic regions.

The most pronounced feature in the interstellar extinction curve is the strong maximum near 2200 Å which is produced by absorption (Witt & Lillie 1972). Its study is facilitated by regarding it as an absorption band and separating it from the extinction curve in order to determine its profile. This has been done for each reddened star by interpolation in each individual extinction curve (without normalizing). Figure 5 shows some examples of the profiles derived in order of increasing visual colour excess. They are symmetric with a half-width between 280 and 340 Å, and a centre lying between 2100 and 2200 Å. The symmetrical nature of such a strong absorption band makes it highly unlikely that it is produced by the same particles that cause the general extinction through the visible and ultraviolet ranges. It will probably be more profitable to think in terms of a two-component medium in which the absorption band at 2200 Å (and possibly the others, like 4430 Å, observed in the visible region) is produced by separate small particles.

The relation between the equivalent width of the absorption band and the difference in colour-excess ΔE_{B-V} between the reddened and comparison star is shown in figure 6 separately for the three galactic regions. The line of best fit has the same slope for Cygnus and the galactic centre but in the anticentre direction it may have a slightly reduced slope.

This 2200 Å band is analogous to the 4430 Å absorption band, but is much stronger and wider. The correlation between the equivalent width of the 2200 Å band and the central depth of the 4430 Å band is shown in figure 7.

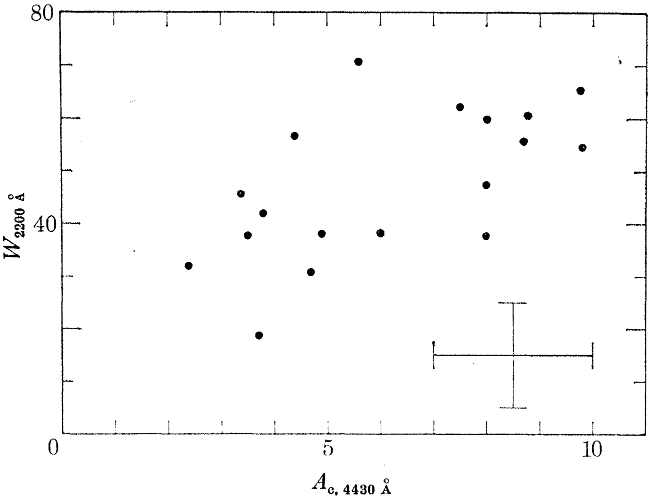

Figure 7. The relation between the strengths of the interstellar absorption bands near 2200 and 4430 Å.

Conclusion

Mean ultraviolet extinction curves have been derived for three galactic regions – the centre, anticentre and Cygnus. These are accurate to ± 6 % but show no variations between the three regions. Beyond 2200 Å, the extinction is not strongly wavelength dependent. The strong absorption band at 2200 Å has a symmetrical profile, and it would seem very likely that the extinction characteristics will need more than a single type of particle, albeit composite, for their explanation.

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