CORRELATIONS BETWEEN THE λ2200 FEATURE, THE DIFFUSE λ4430 BAND AND E_{B-V}

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ABSTRACT

The λ2200 extinction feature has been measured from ANS observations of 30 stars. For each star, the depth of the λ2200 feature is compared to E_{B-V} and the equivalent width of the diffuse band λ4430.

A good correlation appears out to E_{B-V} = 1.13. The various mechanisms for producing the diffuse and λ2200 features are discussed, and a discriminatory test is put forward based on observations of the Magellanic Clouds.

INTRODUCTION

Both the λ2200 extinction feature and the diffuse interstellar lines have defied identification. Comparisons of the relative strengths of the two bands may help to identify or distinguish the interstellar carrier responsible for the features. Past correlations of the diffuse bands with the λ2200 feature have been made by Wu (1972), Nandy et al. (1975), Nandy and Thompson (1975), and Schmidt (1978).

The present study makes use of the high sensitivity of ANS for good photometry of faint (i.e. high E_{B-V}) stars, and of the homogeneous set of photoelectric observations of λ4430 given by Gammelgaard (1975). Both the λ4430 diffuse band and the λ2200 feature pose similar problems of measurement. Due to the large half-width of the λ2200 feature, the continuum is difficult to define and so, therefore, is the equivalent width.

Differences in the definitions of satellite systems create problems in comparing the λ2200 widths quoted by other authors, e.g. Nandy and Thompson (1975), Savage (1975). Similarly, λ4430 and other diffuse features have extended wings and are superimposed on stellar features, so that there are differences in measurement between authors. The 30 stars presented here were all chosen from Gammelgaard's (1975) list.

B. H. Andrew (ed.), Interstellar Molecules, 389–394.

(Some of these stars were chosen by Gammelgaard for measurement of the 6180 diffuse band.)

OBSERVATIONS AND REDUCTION

The ANS photometric system is described in detail by Van Duinen et al. (1975). Basically it is a 5 channel photometer with wavelengths centered at λ1550, λ1800, λ2200, λ2500, and λ3300. The counts in each channel were inspected for overflow, and the dark current was subtracted. In many cases, data for individual objects was available for several orbits, so a mean value was taken. The counts were converted to flux following the procedures outlined in internal notes (Wesselius 1975, and Aalders 1975). The fluxes were normalized to λ3300. Each program star was divided by the normalized flux of a star closely matching the program star in spectral type and luminosity class. These stars were taken from Wu (1975) and corrected for interstellar extinction. The depth of the λ2200 (D_{2200}) was derived from the resulting data using the formula $D_{2200} = m_{2200} - (m_{2500} + m_{1800})/2$. Errors in D_{2200} arise from slight spectral and luminosity-class mismatches between program stars and standard stars. Errors in the photometry were also taken into account and are represented in most cases by error bars in Figs. 1 and 2. The 30 stars are listed in Table 1 with D_{2200} and J_c, which is a parameter related to A_c (4430) given in Gammelgaard (1975). J_c is independent of spectral type.

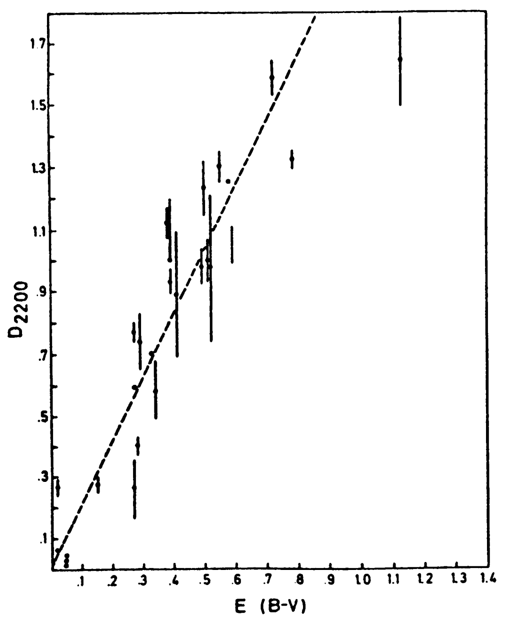

Fig. 1: A plot of D_{2200}, the strength of the λ2200 feature, against E_{B-V}.

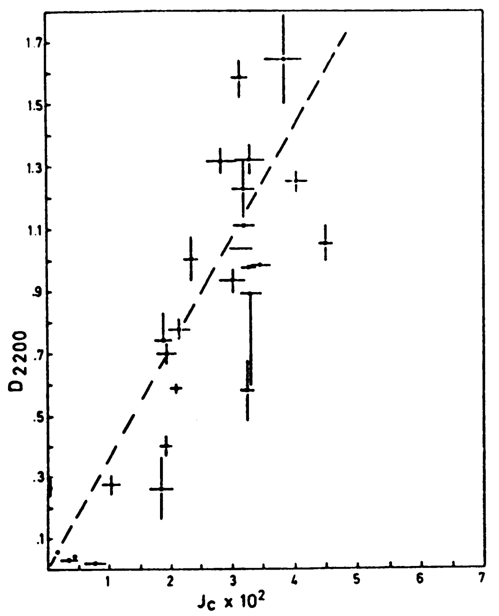

Fig. 2: A plot of D_{2200}, the strength of the λ2200 feature, against J_c(4430), the strength of the diffuse band λ4430.

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TABLE 1

HD	SpT	V	$E_{(B-V)}$	D_{2200}	Jc	kpc
39970	AOIa	6.02	.38	1.124	321	2.5
42088	06	7.55	.39	.926	303	2.4
44965	B3II	7.82	.49	.978	342	1.5
46149	08	7.61	.5	1.226	320	1.8
46769	B8Ib	5.79	.02	.265	2	1.8
47240	B1Ib	6.15	.33	.704	196	1.5
48099	06	6.38	.27	.774	214	1.6
53138	B3Ia	3.04	.05	.021	73	.9
53244	B8II	4.1	-.05	-.045	-44	.4
60308	B2Iab	8.2	.59	1.054	449	3.5
64760	B1Ib	4.24	-.04	.065	26	.9
68450	BOII	6.43	.27	.593	212	1.6
75211	08V	7.5	.72	1.582	314	1.3
83183	B5II	4.08	.15	.275	103	.4
86440	B5II	3.53	.05	.029	34	.4
87737	AOIb	3.48	-.03	-.030	-72	.6
91316	B1Ib	3.85	.05	.039	48	.8
93843	06.5V	7.34	.34	.582	324	2.5
97319	09.5Ib	8.5	.52	.975	333	3.9
97966	07.5V	8.8	.41	.887	333	3.8
102878	A2Ia	5.69	.27	.256	185	3.0
106068	B9Ia	5.92	.29	.742	189	2.7
109867	BO.5Iab	6.24	.28	.402	180	2.1
111775	AOII	6.32	.02	.058	14	.7
115842	BO.5Iab	6.02	.51	1.023	233	1.4
153919	06f	6.55	.58	1.246	406	1.2
154368	09.5Iab	6.11	.78	1.322	287	1.0
165052	07V	6.86	.39	1.032	314	1.7
167838	B5Ia	6.73	.55	1.324	329	2.6
169454	B1Ia	6.61	1.13	1.638	384	1.9

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DISCUSSION

The values of D_{2200} plotted against E_{B-V} are shown in Fig. 1, and D_{2200} against J_c (4430) in Fig. 2. In both figures the dotted line is a weighted least squares fit (LSF) which has been forced through zero. If the fit had not been forced through zero, the lines would have passed through small positive values of J_c and E_{B-V} for zero values of D_{2200}. Both Herbig (1975) and Smith et al. (1976) claimed that the diffuse bands had a finite strength at E_{B-V} = 0.0 that has been attributed to the diffuse bands' originating in clouds of low column density. However Somerville (1979) points out that many of the anomalously strong λ4430 features reported are due to measurements at low spectral resolution that are contaminated by numerous weak stellar features; higher resolution measurements would result in better correlations passing through the origin. Blades and Somerville (1977) illustrate the effect for ρ Leo.

The correlation of D_{2200} vs. E_{B-V} appears linear and quite tight up to E_{B-V}= 0.9. The star showing poor correlation is HD 169454 (B1Ia, E_{B-V} = 1.13, d = 1.0 kpc), which is close to M8. Some nebulosity is included in the satellite diaphragm, resulting in the dilution of the λ2200 feature (Gilra 1979). Correction for this effect would bring HD 169454 on to the LSF line.

The scatter of observations from the LSF in Fig. 2 (D_{2200} vs. J_c) is predictably larger due to errors in measuring both D_{2200} and J_c. Deviations in the plot of m_{2100}-V index against Q [(U-B) - S(B-V)] were noted by Malaise et al. (1974) at values of E_{B-V} = 0.6. Malaise et al. attributed them to a two-component reddening, one component being responsible for the λ2200 feature and the other giving rise to a pure reddening with no absorption at 2200 Å. Malaise et al. also demonstrated the problems of defining the continuum in the UV and the effects that stellar lines can have on the effective equivalent width of λ2200.

The scatter of individual stars from the linear fit in Fig. 2 is large, but there seems to be a weakening at high J_c (4430) of the relationship between D_{2200} and J_c (4430). However this weakening is not convincingly demonstrated because of the large error bars; high resolution observations of both λ2200 and λ4430 are needed to define the relationship better.

Despite the large amount of work in the field, the carrier or carriers for these features have not been identified. The most convincing explanation for the λ2200 feature has been given by Gilra (1972), who attributes it to small graphite particles. These particles may also produce the visible reddening, but are an unlikely cause of the high extinction at wavelengths shorter than 2200 Å. It has not been established if the carrier of the λ2200 feature also produces the visible diffuse bands, or if the diffuse band carriers are simply well mixed with the dust responsible for the visible reddening. As early as 1939, Swings and Ohman proposed that small molecules could cause the diffuse

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features. Following the observations at mm wavelengths of large molecules, Danks and Lambert (1975, 1976) pointed out that relatively small polyatomic molecules of 7 to 14 atoms could be excited to produce diffuse bands such as λ5780 and λ5797, although it would need a larger molecule to produce λ4430.

Duley (1977) suggests MgO and CaO as possible carriers for the diffuse lines. Millar and Duley (1979) show that λ2200 decreases in strength in a cloud as carbon depletion increases, contrary to what is expected if depletion is due to the forming of grains by carbon. Alternatively Rudkjobing (1978) points out that autoionization of O^- could also produce the diffuse features.

Large organic molecules have been proposed to explain the λ2200 feature by Wickramasinghe et al. (1977); more specifically, $C_8H_6N_2$ has been proposed by Hoyle and Wickramasinghe (1977).

The range and type of suggested carriers is large, and a discriminatory test is needed. Abundances in the Large and Small Magellanic Clouds may offer a solution. Although the reddening is relatively small, for instance in the 30 Doradus region (Borgman and Danks 1977), the λ2200 feature has been measured (Borgman et al. 1975) and is weaker than expected compared to E_{B-V}. Abundances have been determined from measurements of HII regions in the Clouds (Dufour and Harlow 1977, Peimbert and Peimbert 1976, Pagel 1978), and some elements, notably N, O, Ne, Ar, are found to be underabundant with respect to Orion. If the carrier of λ2200 or the diffuse bands is dependent on one of these atoms we may see this dependency reflected in the strength of either λ2200 or λ4430. However, an accurate relationship between λ2200 vs. λ4430 is first needed for the Galaxy. Initial steps have been taken by Nandy and Morgan (1978), who observed λ2200 with the IUE at high resolution in two stars in the LMC, and by Blades and Madore (1979) and Danks (1979) who detected λ4430 in several stars in the LMC. If the deficiency reported by Borgman et al. (1975) proves to be correct for individual stars, it may be possible to determine whether λ2200 and λ4430 have the same carrier and which elements are responsible.

Many of the proposed carriers are based on carbon, and it is important, therefore, to determine the abundance of C as accurately as possible. With the introduction of unintensified reticons, Dennefeld (private communication) has been able to measure the red carbon line in supernova remnants. The carbon abundances from these observations are essential in identifying the carrier.

Finally, there appears to be no substitute for observations of high resolution and high signal-to-noise ratio for a range of E_{B-V} and in particular for high E_{B-V}.

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