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Variations in UV extinction in galactic associations and perpendicular to the galactic plane

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Summary. For about 1200 O-B4 stars observed by ANS, normalized UV extinction parameters, $E(\text{bump})/E(B-V)$ and $E(1550-1800)/E(B-V)$, have been calculated together with the distance from the galactic plane, z. A slight correlation of UV extinction parameters with $|z|$ appears: at high $|z|$ low values of $E(\text{bump})/E(B-V)$ and high values of $E(1550-1800)/E(B-V)$ are more frequent. Shock waves and/or radiation fields may be responsible for this effect. The same parameters have been studied in 30 OB associations. Association-to-association variations of UV extinction are confirmed, which are not well correlated with galactic longitude. The open cluster Tr 37 is found to exhibit an exceptional behaviour.

Key words: clusters: open, and associations–galaxies: structure–interstellar medium: dust–extinction–UV radiation

1. Introduction

In the last decade the determination of the relationship between interstellar extinction and location of target stars in the galactic disk has become an important point in studies of the behaviour of interstellar matter (Nandy et al., 1976). Several authors (Morales et al., 1980a; Meyer and Savage, 1981; Kester, 1981) reported region-to-region variations of extinction in the ultraviolet. It has been found that toward different lines of sight, the UV extinction parameters differ significantly (Massa et al., 1983; Massa and Fitzpatrick, 1986). From several investigations it follows that the UV extinction does not seem to be well correlated with galactic longitude. Nothing is known yet on the UV extinction distribution perpendicular to the galactic plane.

Young OB associations are the probable places of massive star formation. From a theoretical point of view, shock waves and strong radiation fields can be expected to occur in such regions, leading in turn to the processes of grain destruction. Some studies of the local UV extinction within OB associations have already been published (Morales et al., 1980b; Kiszkurno et al., 1984). In the present paper the problem is reexamined using another criterion defined by Massa et al. (1983) for the strength of the 2200 A bump, which is now taken as $E(\text{bump}) = E(2200-V) - 0.35E(1800-V) - 0.65E(2500-V)$. We also expect that the relative number of small particles responsible for the UV extinction may change toward higher $|z|$ (the distance from the galactic plane). Since the lifetime of grains may be a function of $|z|$ as well as the frequency of shocks, one may expect that the processes of grain destruction are a function of $|z|$.

In this paper, after a short description of the method (Part II), we use the ANS catalog of far-UV extinction (Savage et al., 1985) to reexamine the extinction in OB associations and also as a function of $|z|$ (Part III). Part IV contains a short discussion and the conclusions.

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2. Data base and methods

In the present study we limit ourselves to stars of spectral type earlier than B4 since they are known to yield a better determination of the extinction, especially in the far-UV. Our data base is the catalog of Savage et al. (1985) from which we extract the values of the strength of the 2200 A bump, $E(\text{bump})$, and the slope of the extinction curve at the shortest wavelengths observed, $E(1550-1800)$ (hereafter $E(15-18)$). For the study of extinction in associations, we select the early-type stars listed in the catalog of clusters and associations of Humphreys (1978); double and variable stars have been excluded. For each star, we obtain the normalized values $E(\text{bump})/E(B-V)$ and $E(15-18)/E(B-V)$. Their average values and r.m.s. star-to-star deviations for each of 30 OB associations are listed in Table 1, together with some values derived from Morales et al. (1980b), who obtained extinction curves for 5 associations. Based on distances given in Savage et al. (1985) and galactic latitudes, we calculate for each star earlier than B4 the distance $|z|$ from the galactic plane. Groups with approximately equal number of stars (around 100) were sorted according to $|z|$, thus defining bins in $|z|$. For each bin mean values of $E(\text{bump})/E(B-V)$ and $E(15-18)/E(B-V)$ were calculated together with their r.m.s. deviation.

3. Results

Figure 1 shows how the mean values of $E(\text{bump})/E(B-V)$ and $E(15-18)/E(B-V)$ for each association vary with galactic longi-

Table 1. UV extinction parameters for 30 OB associations

Association	l^{II}	$\|z\|$(pc)	Number of stars	$E(15-18)/E(B-V)$	σ	$E(\text{bump})/E(B-V)$	σ
Cas OB7	123°	43.8	6	0.39	±0.04	2.20	±0.04
Cas OB4	120	2.5	7	0.43	0.07	2.15	0.09
Cas OB6	136	38.2	4	0.27	0.05	2.55	0.06
Per OB1	134	159.7	26	0.51	0.03	2.32	0.08
Cam OB1	143	34.9	4	0.42	0.09	2.23	0.09
Aur OB1	173	34.6	5	0.37	0.12	2.59	0.09
Aur OB2	173	5.5	4	0.19	0.04	2.43	0.11
Ori OB1	201	163.2	3	1.0	0.76	1.83	1.02
Gem OB1	189	26.3	8	0.54	0.11	2.07	0.15
Mon OB2	207	25.1	5	0.30	0.08	2.42	0.07
CMa OB1	224	34.5	4	0.34	0.18	2.31	0.12
NGC 2439	246	334.9	3	0.51	0.11	1.95	0.18
Vela OB1	266	20.6	13	0.37	0.09	1.90	0.15
Cru OB1	294	41.9	3	0.28	0.08	1.93	0.11
Ara OB1a	338	0.0	6	0.34	0.15	2.29	0.10
Sco OB1	343	33.3	13	0.33	0.05	2.17	0.07
Sco OB2	350	50.0	15	0.04	0.08	2.14	0.22
Sgr OB5	359	65.9	4	0.26	0.05	2.47	0.11
Sgr OB1	9	16.6	11	−0.03	0.08	2.25	0.05
Ser OB1	17	0.0	2	0.26	0.12	2.10	0.10
Sct OB2	23	8.7	6	0.48	0.07	1.92	0.06
Cyg OB1	76	31.8	9	0.47	0.16	2.35	0.19
Cyg OB3	73	91.9	6	0.46	0.07	2.04	0.05
Cyg OB8	78	159.7	5	0.30	0.14	2.18	0.10
Cyg OB9	78	31.5	3	0.10	0.04	2.22	0.08
Cyg OB7	90	29.0	5	0.32	0.10	2.12	0.21
Cep OB1	103	121.1	20	0.51	0.04	2.27	0.04
Cep OB2	103	86.8	7	0.47	0.14	1.98	0.10
Cep OB3	111	56.2	4	0.13	0.06	2.34	0.12
Cas OB5	116	43.8	11	0.40	0.06	2.16	0.10
Associations from Morales et al., 1980b							
I Lac	97	135.0	21	0.29	0.06	2.23	0.23
I Cep	103	62.7	31	0.28	0.01	1.95	0.09
Cas-Tau	120	~40	19	0.37	0.02	2.91	0.19
II Per	159	105.2	28	−0.09	0.03	2.54	0.17
Sco-Cen	350	~38	19	−0.17	0.03	2.52	0.41

tude. From Table 1 and Fig. 1 it is clear that real association-to-association variations in the UV extinction exist, but that there is no systematic longitude effect, except perhaps a sinusoidal variation in $E(\text{bump})/E(B-V)$.

Let us now turn to star-to-star variations inside a given association. Figs. 2, 3 and 4 give individual values of $E(\text{bump})/E(B-V)$ and $E(15-18)/E(B-V)$ for stars of the associations Sco OB2, Cep OB2 and Tr 37 respectively, as a function of $E(B-V)$. The variations are often much larger than the measurement errors and are most probably real. While the behaviour of Cep OB2 is rather typical of that of most associations (not presented here), that of the open cluster Tr 37 which is embedded in this association is peculiar, indicating the presence of anomalous dust as already discussed by Clayton and Fitzpatrick (1987). Note the very narrow range of extinctions $E(B-V)$ in this cluster and the possible inverse correlation between the normalized bump strength and $E(B-V)$, which appears to be unique. Probably shock waves play an important role in grain processing in this cluster.

We tried to see whether such a behaviour is also exhibited by other young clusters like the Pleiades or the Hyades. However, these clusters contain only later-type stars: B8 to A9. The values of $E(\text{bump})/E(B-V)$ and $E(15-18)/E(B-V)$ exhibit large variations but we doubt their reality since all three quantities $E(\text{bump})$, $E(15-18)$ and $E(B-V)$ are small and very poorly determined, especially for stars of these late types. Thus the behaviour of Tr 37 is unique up to now.

We now turn to the behaviour of extinction perpendicular to the galactic plane. The mean values of $E(\text{bump})/E(B-V)$ and $E(15-18)/E(B-V)$ for about 1200 OB stars (Spt ≥ B4) are

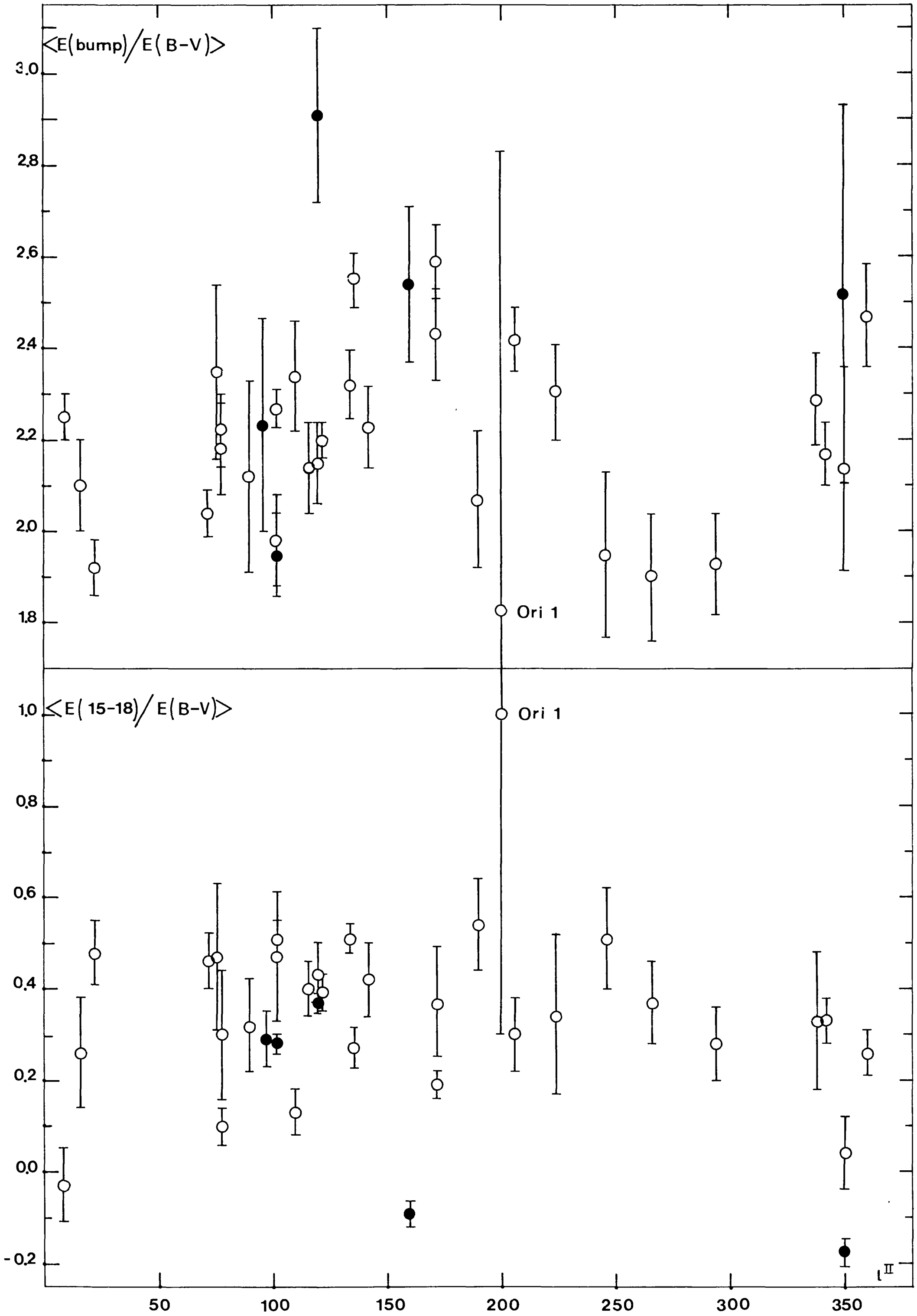

Fig. 1. Mean values of E(bump)/$E(B-V)$ and $E(15-18)/E(B-V)$ for O-B4 stars observed by ANS belonging to 30 OB associations, plotted against galactic longitude. Open circles correspond to values from Table 1, full circles correspond to data from Morales et al. (1980b). Bars indicate r.m.s. deviation from the mean values

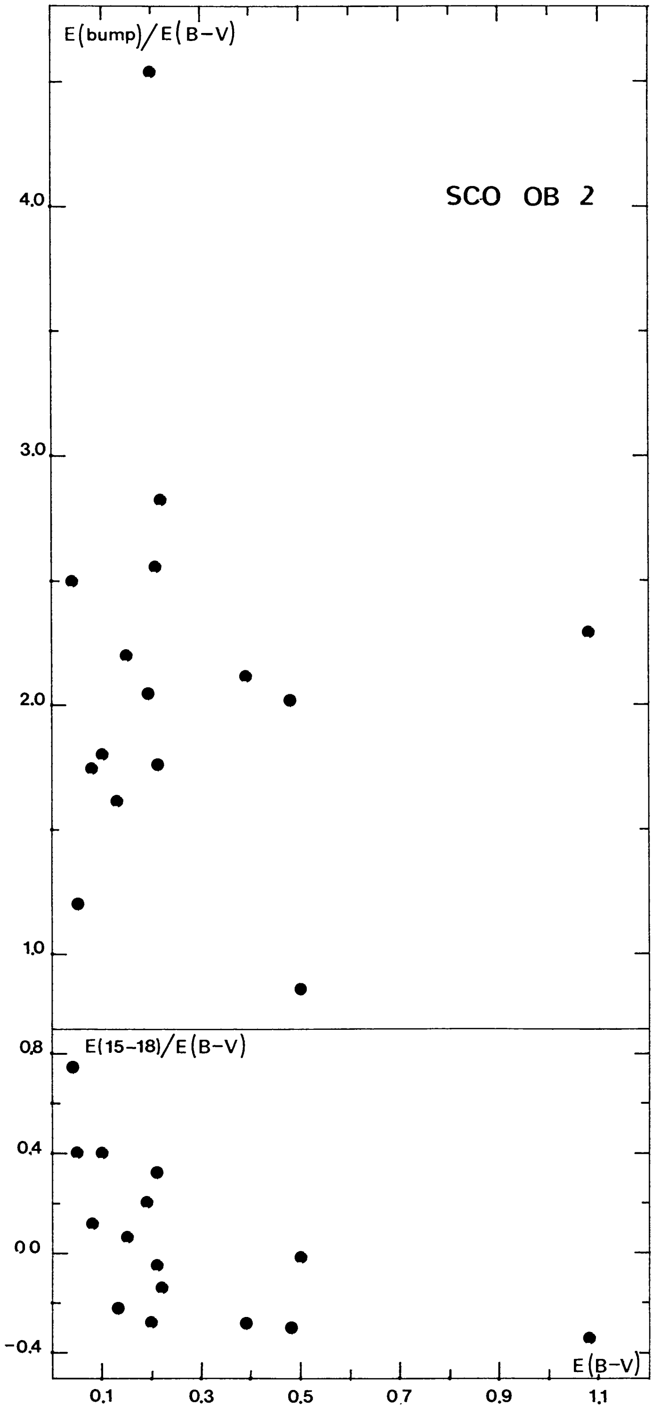

Fig. 2. Example of a diagram of E(bump)$E(B-V)$ and $E(15-18)E(B-V)$ versus $E(B-V)$ for the association Sco OB2

plotted against the distance from the galactic plane, $|z|$, in Fig. 6. For comparison, we plot in Fig. 5 the same thing for the associations, but the statistical value of this plot is smaller than that of Fig. 6. It appears that at higher $|z|$ low values of $E(\mathrm{bump})/E(B-V)$ and high values of $E(15-18)/E(B-V)$ are more frequent. A least-squares analysis of the data gives the following regressions:

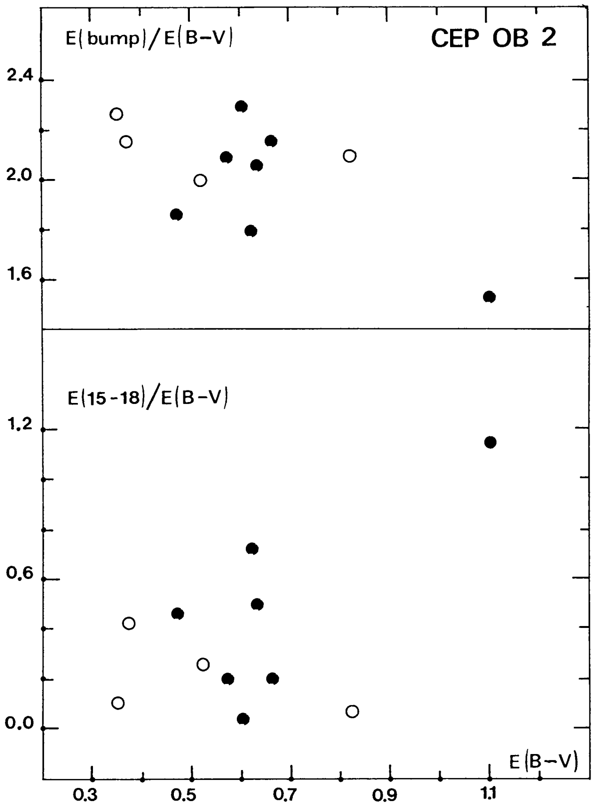

Fig. 3. The same as in Fig. 2, for outermost stars belonging to Cep OB2. Open circles denote double or variable stars excluded from calculations

$$E(\mathrm{bump})/E(B-V) = (2.11 \pm 0.04) - (0.07 \pm 0.02)(|z|/100\,\mathrm{pc})$$
$$E(15-18)/E(B-V) = (0.32 \pm 0.04) + (0.11 \pm 0.02)(|z|/100\,\mathrm{pc})$$

The effects appear to be significant at the 3–5σ level.

4. Discussion and conclusions

The nature of interstellar dust is still very poorly understood. The origin of the particles responsible for the 2200 A extinction bump is unclear. They are often considered as small grains of graphite but this is far from certain. Recently, Leene and Cox (1987) have shown that the carriers of the bump are very sensitive to the strength of the radiation field, the bump getting weaker when the radiation field gets stronger. This suggests that the carriers do not survive strong radiation fields. Our finding of a (somewhat marginal) decrease of the bump strength with increasing distance to the galactic plane may mean that the lifetime of the particles responsible for the bump is longer at higher $|z|$: this allows a higher average degree of destruction by the radiation field, which is rather uniform in the Galaxy except in places of star formation. Variations in the bump strength in associations may correspond to differences in the degree of exposition of the corresponding particles to strong local radiation fields produced by the young, massive stars.

The slope of the far-UV extinction curve, $E(15-18)$, is linked to the size distribution of the small-grain component of interstellar dust. More precisely, as shown e.g. by Joseph et al. (1986) higher values of the extinction at the shortest UV wavelengths

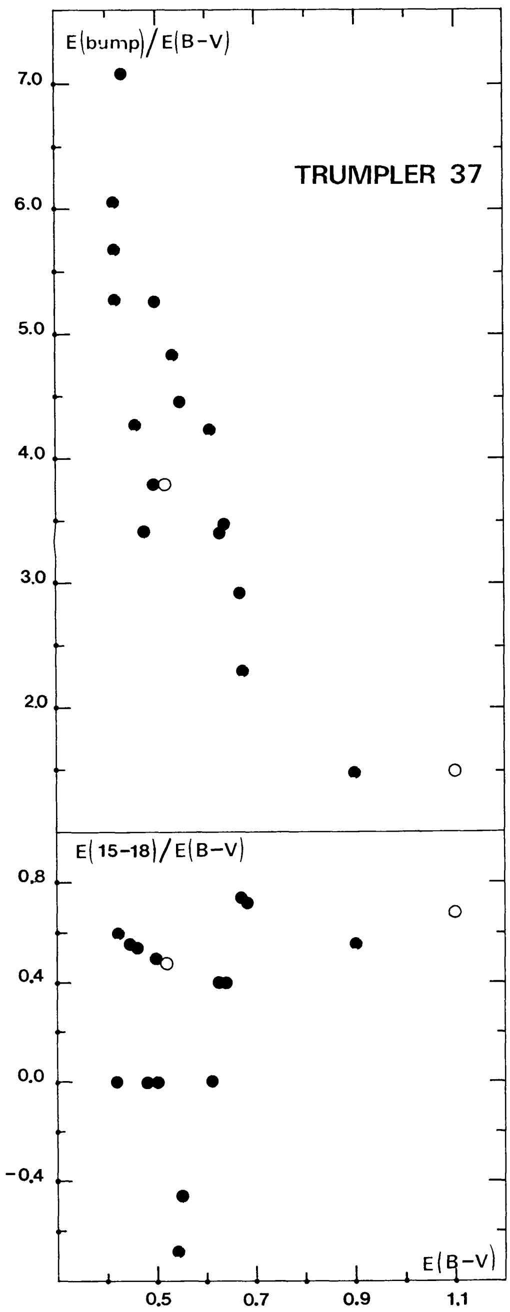

Fig. 4. The same as in Fig. 2, for the open cluster Trumpler 37 (data from Clayton and Fitzpatrick, 1987). This cluster is believed to be the core of the association Cep OB2. Same symbols as in Fig. 3

(here 1550 A) correspond to a higher proportion of smaller grains; this is expected to increase $E(15-18)/E(B-V)$. A higher proportion of small grains can be due either to selective destruction of big grains or to growth of the smallest grains via accretion (Joseph et al., 1986). The first mechanism appears to us more probable to explain our finding of an increase of $E(15-18)/E(B-V)$ at higher $|z|$. Presumably the big grains are more efficiently destroyed by shock waves (Seab and Shull, 1985) at large distances from the galactic plane. Shock waves easily travel high above the galactic plane as shown e.g. by the presence of large H I "bubbles" far above the plane. If the grain lifetime is long enough, they may destroy more efficiently the large grains at high $|z|$. In OB associations, the broad variations in $E(15-18)/E(B-V)$ may be linked to local variations in the exposition to shocks created by the explosion of supernovae in these associations. It thus appear possible to explain at least qualitatively the behaviour of far-UV extinction in OB associations and as a function of distance to the galactic plane. However, the latter effect should be confirmed by more accurate observations of extinction in front of high-z stars using the IUE satellite.

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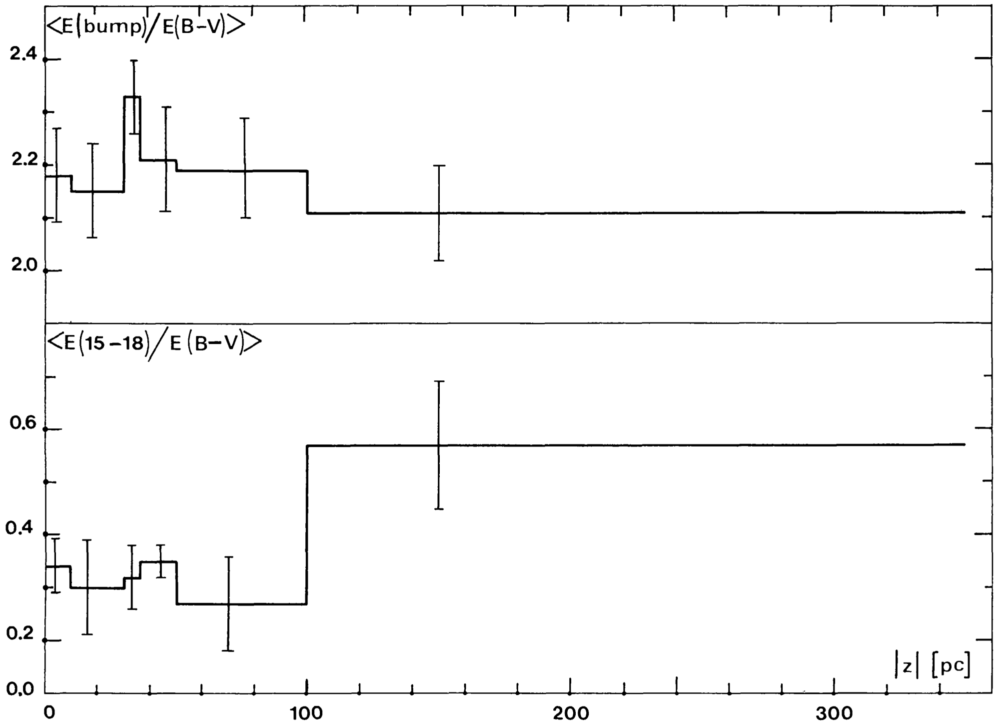

Fig. 5. Variations of mean values of E(bump)/$E(B-V)$ (top) and E(15–18)/$E(B-V)$ (bottom) with the distance from the galactic plane, $|z|$, for 30 OB associations (5 associations per bin). Bars indicate r.m.s. deviation from the mean values

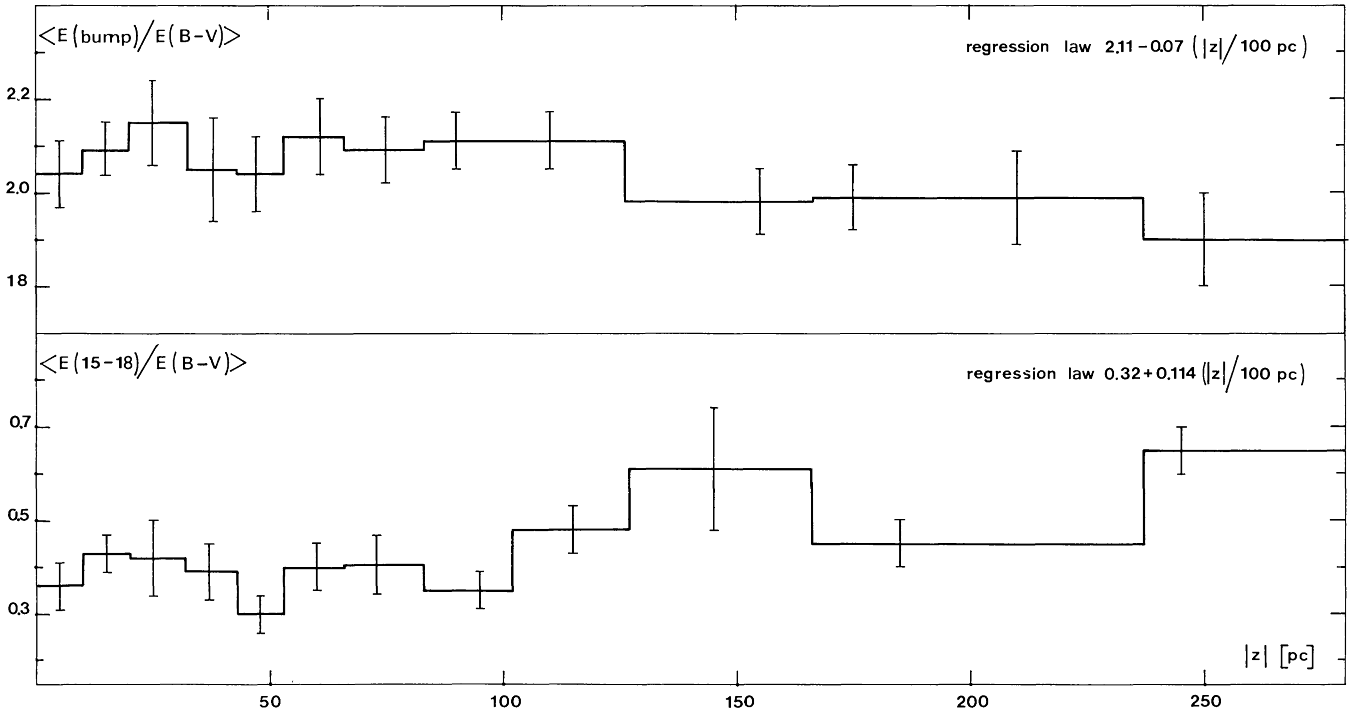

Fig. 6. The same as in Fig. 5, for about 1200 O-B4 stars observed by ANS (data from Savage et al., 1985) (100 stars per bin). Bars indicate r.m.s. deviation from the mean values