The Ultraviolet Reddening Law in the 30 Doradus Complex

Borgman, J.

Published in:
Astronomy & astrophysics

Publication date:
1978

Citation for published version (APA):
Borgman, J. (1978). The Ultraviolet Reddening Law in the 30 Doradus Complex. *Astronomy & astrophysics*, *69*(2), 245-251. http://articles.adsabs.harvard.edu/full/1978A%26A....69..245B

1978A&A....69..245B

Astron. Astrophys. 69, 245—251 (1978)

ASTRONOMY
AND
ASTROPHYSICS

The Ultraviolet Reddening Law in the 30 Doradus Complex

J. Borgman

Kapteyn Sterrenwacht, University of Groningen, Mensingheweg 20, Roden, The Netherlands

Received January 23, 1978

Summary. The question of the near-absence of the 2200 Å interstellar feature in the 30 Doradus area is re-examined. It is found that an explanation of the data which adopts the average galactic extinction law cannot be ruled out. This alternative explanation is based on a number of reasonable assumptions with respect to the stellar population and the geometry of the associations in relation to the dust.

Key words: Large Magellanic Cloud — interstellar extinction — ultraviolet — intrinsic colours — absolute magnitudes

1. Introduction

In a paper on early ANS results Borgman et al. (1975) have concluded that the 2200 Å interstellar feature is almost absent in the direction of 30 Doradus. Koornneef (1976, 1978), when analyzing a much more complete data set, comes to the same conclusion. Borgman and Danks (1977) and Borgman et al. (1978) discussed *uvby* surface photometry and confirmed the earlier assumption that O and early B type stars form the photometrically dominant population, as well in the visible as in the ultraviolet. However, it appeared desirable to further investigate the effects of early type supergiants on the ultraviolet photometry. In the present paper an attempt is made to derive the ultraviolet intrinsic colours and absolute magnitudes of luminous early type stars (Sect. 2); the consequences for the interpretation of ANS surface photometry in the 30 Doradus complex are discussed in Section 3.

2. ANS Intrinsic Colours and Absolute Magnitudes

The ANS photometric system is described by Wesselius et al. (1978, in preparation). The five channels are centred at 1550 Å, 1800 Å, 2200 Å, 2500 Å and 3300 Å. The magnitude system is related to the absolute calibration (F_λ in erg cm^{-2} s^{-1} Å^{-1}) by a single formula

$$m_\lambda = -2.5 \log F_\lambda - 21.10. \quad (1)$$

It should be noted that this definition does not conform to the usual convention that any colour index of an A0V star is zero. As a consequence of the rather long dead time of the photon counters the number of bright blue stars observed by ANS is somewhat limited. This makes it desirable, for the purpose of deriving intrinsic colours, to add data on bright stars from other sources to the available ANS photometry in order to obtain satisfactory coverage of early spectral types and supergiants. A rich source of easily transformable data is the TD-1 catalogue (Jamar et al., 1976) which gives flux densities in 20 Å intervals between 1350 Å and 2540 Å. Mean flux densities $F_{\lambda,\mathrm{TD}}$ within the ANS channels centred at 1550 Å, 1800 Å, 2200 Å and 2500 Å, weighted with the ANS response functions, were transformed to magnitudes $m_{\lambda,\mathrm{TD}}$, using relation (1). The following transformations were found, each based on at least 25 stars:

$$\begin{aligned} m_{15,\mathrm{ANS}} &= m_{15,\mathrm{TD}} + 0.073\ (\pm 0.007 \text{ s.e.}) \\ m_{18,\mathrm{ANS}} &= m_{18,\mathrm{TD}} - 0.023\ (\pm 0.005 \text{ s.e.}) \\ m_{22,\mathrm{ANS}} &= m_{22,\mathrm{TD}} - 0.073\ (\pm 0.007 \text{ s.e.}) \\ m_{25,\mathrm{ANS}} &= m_{25,\mathrm{TD}} - 0.055\ (\pm 0.005 \text{ s.e.}) \end{aligned} \quad (2)$$

No colour terms could be established. The constant terms in (2) represent magnitude differences of the absolute calibrations of the ANS and TD-1 photometers; the agreement is better than 7% (cf. Beeckmans, 1977).

Similarly, the 3300 Å ANS data have been supplemented by using data from Borgman (1961) and OAO magnitudes from Code and Meade (1976). The relevant transformations, based on 11 and 28 stars, resp., are

$$m_{33,\mathrm{ANS}} = m_{33,B} - 1.680\ (\pm 0.007 \text{ s.e.}) \quad (3)$$

$$m_{33,\mathrm{ANS}} = m_{33,\mathrm{OAO}} + 0.084\ (\pm 0.014 \text{ s.e.}) \quad (4)$$

The constant term in (3) refers to the difference in zero point between the two magnitude systems. The constant term in (4) expresses a difference between the 3300 Å absolute calibration of ANS and OAO of 8%.

Dereddening was done by a procedure which assumes that a mean extinction law is valid and that the reddening is characterized by the excess extinction at 2200 Å. This excess extinction is defined by

$$\sigma = 0.34m_{18} + 0.66m_{25} - m_{22}. \tag{5}$$

The coefficients 0.34 and 0.66 have been determined by adjusting p in

$$\sigma = p \cdot m_{18} + (1 - p)m_{25} - m_{22} \tag{6}$$

in such a way that σ becomes independent from (black body) temperatures in the range 9000–40,000 K. The black body model is sufficiently accurate (cf. Fig. 3) for small reddening corrections. Figure 1 shows the σ, E_{B-V} diagram for 26 main sequence O and B type stars ($E_{B-V} \leqq 0.05$) and 43 O and B type supergiants. The reddening line of the preliminary ANS extinction law (Pottasch et al., 1976, Table 2) appears to fit the data quite well, in fact better than the TD-1 extinction law as derived by Nandy et al. (1975). The better fit of the ANS extinction law is remarkable since the data on reddened stars in Figure 1 lean heavily on the TD-1 catalogue.

From the ANS extinction law it is found that $\Delta\sigma = 2.39$ for $\Delta E_{B-V} = 1.00$. Furthermore, it can be shown that $\sigma = 0.17$ for $E_{B-V} = 0$ by studying the σ, E_{B-V} relation near $E_{B-V} = 0$. The colour excesses which follow from the ANS extinction law are then

$$\begin{aligned} E_{15-18} &= -0.05\,(\sigma - 0.17) \\ E_{18-22} &= 0.89\,(\sigma - 0.17) \\ E_{22-25} &= -1.06\,(\sigma - 0.17) \\ E_{25-33} &= -0.89\,(\sigma - 0.17). \end{aligned} \tag{7}$$

The following data have been used to establish the intrinsic colour matrix of Table 1.

A. Main sequence intrinsic colours of spectral types B2–B9 have been taken from a preliminary table, to appear in its final version in Wesselius et al. (1978).

B. Main sequence star data earlier than B2 have been derived from Wesselius et al. (1978), supplemented by 19 bright stars from the TD-1 catalogue.

C. Data on supergiants in the ANS file have kindly been made available by Dr. P. R. Wesselius; in addition, data on 29 supergiants were taken from the TD-1 catalogue. Because of the small number of supergiants within one spectral class the luminosity classes Ia, Iab and Ib have been lumped together and the data have been smoothed; low weight has been given to stars with $E_{B-V} > 0.30$. The scatter of the intrinsic colours for supergiants of spectral type later than B2 is quite large.

It should be emphasized that the intrinsic colour data of Table 1 are preliminary insofar data set A is not yet

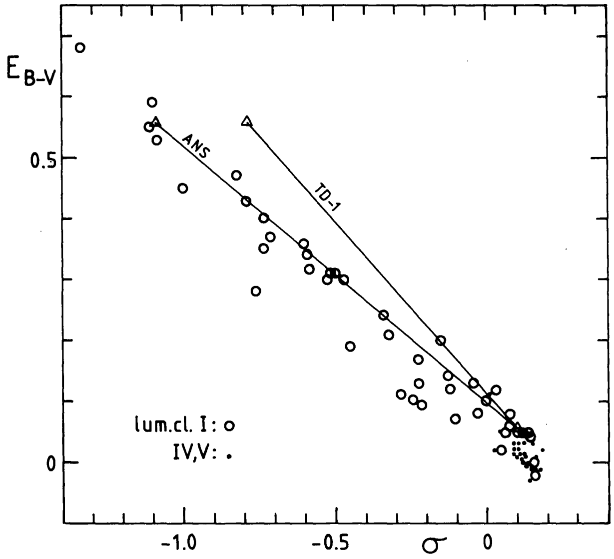

Fig. 1. E_{B-V} plotted against σ. The two reddening lines are the reddening trajectories of 15 Mon ($\Delta E_{B-V} = 0.5$, triangles) for the ANS extinction law and the TD-1 extinction law (Nandy et al., 1975)

Table 1. Intrinsic colours in the ANS photometric system

	$(m_{15} - m_{18})_0$		$(m_{18} - m_{22})_0$		$(m_{22} - m_{25})_0$		$(m_{25} - m_{33})_0$	
MK	I	V	I	V	I	V	I	V
O7	−0.22	−0.22	−0.47	−0.47	−0.50	−0.50	−1.11	−1.11
O8	−0.18	−0.22	−0.40	−0.47	−0.44	−0.50	−1.08	−1.11
O9	−0.14	−0.21	−0.34	−0.46	−0.40	−0.49	−1.00	−1.10
B0	−0.05	−0.25	−0.26	−0.45	−0.36	−0.47	−0.92	−1.06
B1	−0.02	−0.25	−0.14	−0.42	−0.32	−0.45	−0.82	−0.95
B2	−0.04	−0.23	0.00	−0.39	−0.29	−0.42	−0.69	−0.82
B3	−0.05	−0.26	0.03	−0.38	−0.28	−0.40	−0.55	−0.69
B5	−0.11:	−0.25	−0.02:	−0.33	−0.26:	−0.37	−0.32:	−0.55
B8	−0.08:	−0.17	−0.06:	−0.28	−0.26:	−0.32	−0.02:	−0.39
B9	−0.03:	−0.12	−0.06:	−0.25	−0.26:	−0.30	0.06:	−0.31

: a colon means that the entry is largely based on interpolation or that the scatter is unusually large available in its final form. However, changes are expected to be small and will not affect the conclusions of the discussion in Section 3 on the 30 Doradus extinction.

The approach to use σ for an estimate of the ultraviolet colour excesses rather than E_{B-V} was inspired by the consideration that σ is defined in the ultraviolet and requires a constant shape of the extinction law over a more limited spectral region. An attempt to use E_{B-V} gave comparable mean intrinsic colours but showed increased scatter.

The intrinsic colours of the early B-type supergiants resemble those of later B-type main sequence stars for wavelengths shorter than 2500 Å, e.g. a B0I star has approximately the same colour indices as a B8V star. The effect of luminosity on the intrinsic colours, as illustrated in Table 1, is in agreement with similar findings of Nandy et al. (1976).

The absolute ANS magnitudes of Table 2 have been derived in the following way. Using the colour excess ratio $E_{m_{33}-V}/E_{B-V} = 2.03$ (Pottasch et al., 1976) and colour excesses E_{B-V} (from $B-V$ and spectral type) intrinsic colours $(m_{33}-V)_0$ were calculated. Adding the absolute visual magnitudes M_V (Blaauw, 1963) yields the absolute magnitudes M_{33}. The other ultraviolet absolute magnitudes in Table 2 have been derived from M_{33} and the intrinsic colours of Table 1.

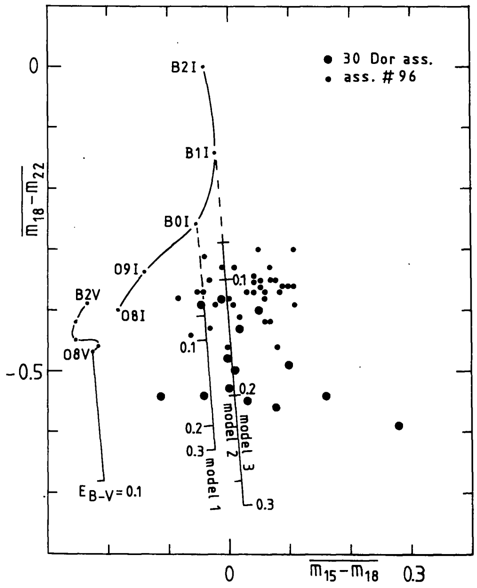

Fig. 2. $\overline{m_{18}-m_{22}}$ against $\overline{m_{15}-m_{18}}$ for the two best observed associations in the 30 Doradus area. The intrinsic colours of O8-B2 stars have been taken from Table 1. The reddening line of an O8V star is the galactic reddening law. The reddening lines of a B0I and a B1I star are calculated according to the models of Table 4 by varying the extinction depths. The markings along these reddening lines correspond to the predicted surface photometry colour excesses $\overline{E_{B-V}}$ and include $E_{B-V} = 0.07$ of galactic foreground extinction (broken line)

3. The Ultraviolet Reddening Law in the 30 Doradus Complex

Figures 2, 3 and 4 are colour-colour diagrams of the surface photometry of Koornneef (1977) for the brightest ANS measurements (Koornneef's "m_{15}" $\leqq -3$, which is equivalent to $m_{15} \leqq 8.97$ in the ANS photometric system) in the 30 Doradus association, centred on NGC 2070 and the large association no. 96 (Lucke, 1974; approximately 22′ south and 6′ west of NGC 2070).

In each of the three colour-colour diagrams the unreddened main sequence and supergiant sequence from O8 to B2 have been plotted on the basis of the data of Table 1. The galactic extinction law vectors are indicated for spectral type O8V. In addition, reddening lines of B0I and B1I have been drawn; these reddening lines will be discussed later. For the time being we discuss the reddening of colour indices $\overline{c_i}$ as observed from surface photometry in terms of the colour excess $\overline{E_{B-V}}$ of a sheet of extinction material in front of the stars.

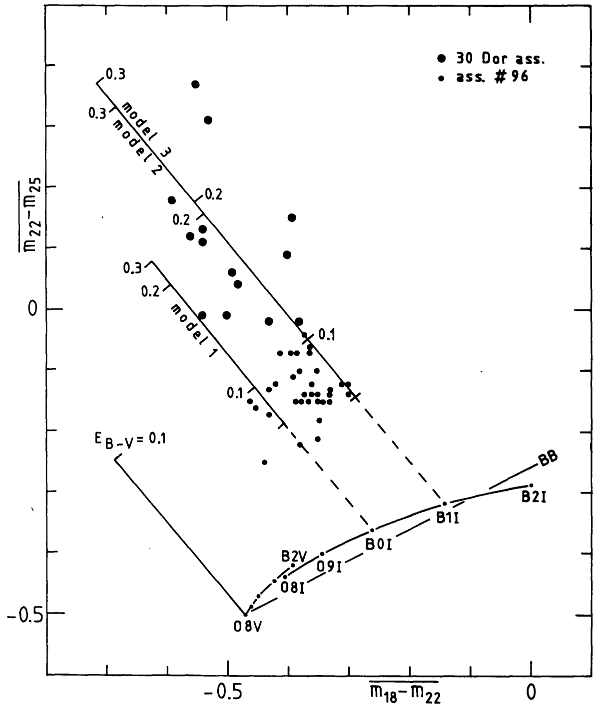

Fig. 3. $\overline{m_{22}-m_{25}}$ against $\overline{m_{18}-m_{22}}$. The straight line labelled BB is the direction of the black body trajectory. For further explanation see caption of Figure 2

In all diagrams the reddening of the 30 Doradus association is larger than for association no. 96; however, the reddening in terms of E_{B-V} is larger for $\overline{m_{25}-m_{33}}$ than for the shorter wavelength colours. This can be explained qualitatively as a geometrical effect; for a cluster embedded in a dust cloud one may expect to see deeper in the cloud at 3300 Å than at the shorter wave-

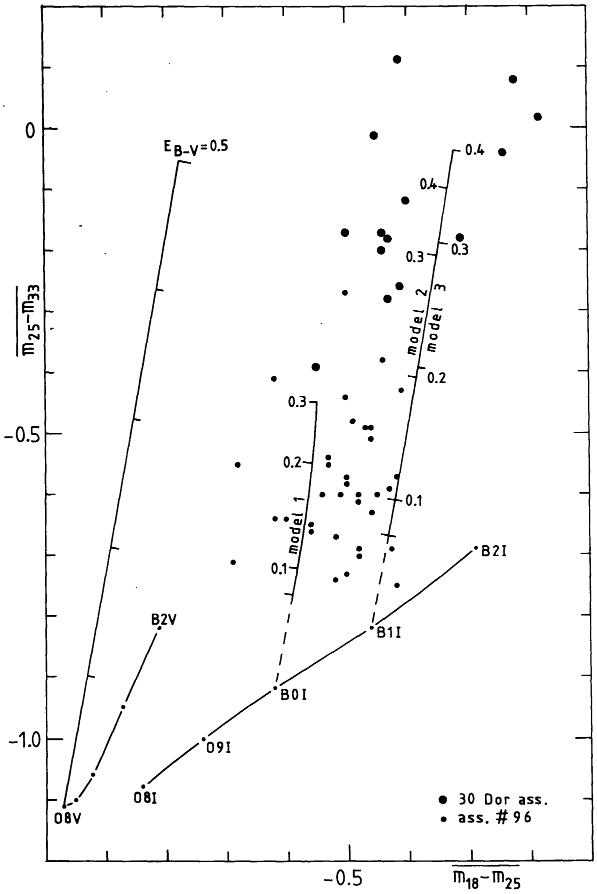

Fig. 4. $\overline{m_{25}-m_{33}}$ against $\overline{m_{18}-m_{25}}$; for further explanation see caption of Figure 2

lengths. An inspection of the three colour-colour diagrams learns that the position of the association colours could be interpreted as a stellar population of B0–B1 supergiants, reddened by $E_{B-V} < 0.4$ of "galactic type" reddening (cf. reddening vectors of O8V). The scatter of $m_{15} - m_{18}$ in Figure 2 is considerable and may point to a variation of the degree of upturn of the extinction towards shorter wavelengths. Since the conclusions of this paper are hinging largely on the interpretation of colours at the red side of 1800 Å we will avoid complicating the analysis using m_{15} but rather concentrate the discussion of brightness on m_{18}. In the following we will make a more quantitative investigation of the hypothesis that the observed colours and magnitudes in the 30 Doradus complex are due to a stellar population dominated by early type supergiants and reddened by the same reddening law as in our galaxy. We will use Sandage and Tammann's (1971) distance modulus $(m - M)_0 = 18.6$.

An average unreddened supergiant with $M_V = -6.2$ (Blaauw, 1963) has a visual magnitude $V = 12.4$, which is just about the limiting magnitude of Sanduleak's (1969) catalogue. As the supergiants in the 30 Doradus complex are all reddened (Isserstedt, 1975) one must expect that Sanduleak has only identified the brighter and less reddened supergiants. In association no. 96 he has, within the limit of the $m_{15} = 8.97$ contour, identified 16 luminous early type stars.[1] As an alternative approach we may try to count the number of stars brighter than the nominal absolute magnitude $M_V = -5.7$ of early type supergiants of luminosity class Ib (Blaauw, 1963). From Lucke's (1974) photometry of association no. 96 we find a minimum of 33 stars brighter than this limit, adopting a minimum reddening $E_{B-V} = 0.1$. Likewise, from Westerlund's (1966) data on the 30 Doradus association a minimum of 52 such stars can be identified, adopting a minimum reddening $E_{B-V} = 0.3$. These numbers are considerable and they suggest that at the spatial resolution of ANS a continuum of early type supergiants should be observed with some concentrations like ANS grid point no. 6475 (which is the brightest spot of association no. 96 and also contains the brightest supergiant HDE 269859 of the association) and grid point no. 6593 (which is the centre of the 30 Doradus association).

A more "refined" tentative population model, based on the photometry of Westerlund (1966) and Lucke (1974) has been constructed in the following way. All stars brighter than $M_V = -5.7$ are supposed to be B0 supergiants. Fainter stars are classified as main sequence stars of spectral type O7–B0 on the basis of the assigned M_V; M_V is calculated from V and the adopted E_{B-V}. The total stellar brightness in V and m_{18} of the two associations has thus been calculated down to $V = 15$, using $(m_{18} - V)_0$ colours as follow from Table 2 and Blaauw (1963).

The data are summarized in Table 3, together with data from other sources. Both association no. 96 and the 30 Doradus association have visual surface brightnesses which exceed the integrated stellar brightness by 1.6 and 1.4 mag, resp. These numbers can be reduced to 0.8 and 0.2 mag, resp., taking into account the contribution of stars fainter than $V = 15$ ($M_V = -3.9$ and $M_V = -4.5$, resp.) which should be there according to the initial luminosity function (Sandage, 1955). The remaining margins between integrated visual stellar brightness and the surface photometry brightness are comfortably small, considering the possibilities to explain a brightness excess as due to stars not being measured because of crowding and the contribution of nebular light. The agreement between integrated stellar brightness and the surface photometry brightness at 1800 Å, after correction for the contribution of faint stars is quite satisfactory.

---

[1] Including the very luminous HDE 269859, $V = 10.63$, $B - V = -0.06$, classified as B0Ia by Ardeberg et al. (1972); the star has been measured with ANS at position no. 6475 (Koornneef, 1977) but even in the case of this bright object a straightforward analysis is not possible as there are several nearby luminous stars which may have been in the ANS diaphragm of 2.5′ × 2.5′

Table 2. Absolute luminosities in the ANS photometric system

	M_{15}		M_{18}		M_{22}		M_{25}		M_{33}	
Spec.	I	V	I	V	I	V	I	V	I	V
O7	—	−9.5	—	−9.3	—	−8.8	—	−8.3	—	−7.2
O8	−10.1	−9.2	−9.9	−9.0	−9.5	−8.5	−9.1	−8.0	−8.0	−6.9
O9	−9.8	−8.8	−9.7	−8.6	−9.4	−8.1	−9.0	−7.6	−7.9	−6.5
B0	−9.5	−8.5	−9.4	−8.3	−9.1	−7.8	−8.7	−7.3	−7.9	−6.2
B1	−9.2	−7.4	−9.2	−7.2	−9.1	−6.8	−8.8	−6.3	−7.9	−5.3
B2	−9.0	−6.0	−9.0	−5.8	−9.0	−5.4	−8.7	−4.9	−8.0	−4.0
B3	−8.8	−5.0	−8.8	−4.8	−8.8	−4.4	−8.5	−4.0	−8.0	−3.2
B5	−8.2	−3.7	−8.1	−3.5	−8.1	−3.2	−7.8	−2.8	−7.5	−2.1
B8	−7.5	−1.8	−7.4	−1.6	−7.3	−1.4	−7.0	−1.0	−7.0	−0.5
B9	−7.2	−0.7	−7.2	−0.6	−7.1	−0.4	−6.8	0.0	−6.7	+0.4

Table 3. Total brightness budget (magnitudes)

	Observed		Dereddened[1]	
	Ass. 96	30 Dor	Ass. 96	30 Dor
[2]Visual brightness, from stars $V < 15.0$	8.3	7.9	8.0	7.0
[3]same, including fainter stars	7.5	6.7	7.2	5.8
[4]same, from surface photometry	6.7	6.5	6.4	5.6
[5]1800 Å brightness, from stars $V < 15.0$	5.0	6.2	4.2	3.9
[6]same, including fainter stars	4.6	5.5	3.8	3.2
[7]same, from surface photometry	4.9	5.5	4.1	3.2
[8]same, from supergiant component	5.8	6.5	5.0	4.2
$\overline{m_{18} - V}$, from surface photometry	−1.8	−1.0	−2.3	−2.4

[1] Extinction corrections for ass. 96: $\overline{E_{B-V}} = 0.1$, $A_V = 0.3$ and $A_{18} = 0.8$; for 30 Dor ass.: $\overline{E_{B-V}} = 0.3$, $A_V = 0.9$ and $A_{18} = 2.3$

[2] Based on Westerlund (1963)

[3] Same, and initial luminosity function

[4] Based on Danks (1977) and Danks and Hartsuiker (1978)

[5] Based on Westerlund's data, the tentative population model and $(m_{18} - V)_0$ colours

[6] Same, and initial luminosity function

[7] Based on Koornneef (1977)

[8] All stars brighter than $M_V = -5.7$

40% of the surface photometry brightness at 1800 Å can be assigned to the supergiant component of our tentative population model.

The analysis illustrated by Table 3 assumes that the stars are obscured by a sheet of extinction material in front of the associations. This is certainly the case for that fraction of the extinction, corresponding to a colour excess $E_{B-V} = 0.07$, which is the foreground extinction in our Galaxy (Sandage and Tammann, 1971; Feast et al., 1960; Lucke, 1974). For the remainder of the extinction it is realistic to assume that the extinction is in the LMC and that the supergiants in the 30 Doradus complex are actually embedded in the dust (Isserstedt, 1975). In such a geometry the simple approach of Table 3 requires some modification. We will compare the observations with three models (Table 4), each based on a star cluster embedded in a homogeneous slab of dust and with different degrees of concentration of the cluster. The cluster contains, in each case, 20 supergiants; for model 1 these are B0 supergiants, for models 2 and 3 we have taken B1 supergiants in order to improve the separation of the reddening lines in the illustrations. The three models in Table 4 are calculated for an extinction depth $E_{B-V} = 1.00$. The calculations have been repeated for smaller extinction depths and the resulting reddening lines have been drawn in Figures 2, 3 and 4. The markings on the reddening lines correspond to $\overline{E_{B-V}}$ (including $E_{B-V} = 0.07$ of foreground reddening, broken line) as would be observed from surface photometry. Model 1, representative for a loose association, has saturated ultraviolet colours for extinction depths $E_{B-V} > 0.5$; stars with $E_{B-V} > 0.5$ make no significant contribution to the surface photometry. Even $\overline{E_{B-V}}$ saturates at the low value 0.3. Larger values of $\overline{E_{B-V}}$ can be achieved with con-

Table 4. Integrated photometric properties of 20 supergiants at $m - M = 18.6$

Model	m_{15}	m_{18}	m_{22}	m_{25}	m_{33}	B	V	$\overline{E_{B-V}}$	$\overline{\Delta\sigma/E_{B-V}}$	$\overline{m_{18}-V}$
1	7.78	7.81	8.29	8.38	8.99	10.27	10.27	0.24	−1.13	−2.46
2	8.95	8.94	9.58	9.30	9.50	10.67	10.52	0.37	−1.54	−1.58
3	9.31	9.29	10.09	9.62	9.68	10.79	10.59	0.42	−1.79	−1.30
Ext. law	7.77	7.65	9.78	7.26	5.14	4.10	3.10	1.00	−2.39	—

The construction of the models is as follows:

1. 20 B01 stars in a homogeneous slab of dust, causing $E_{B-V} = 0.05, 0.10, 0.15, \ldots, 0.95$ and 1.00, resp.
2. The same homogeneous slab of dust with a total depth $E_{B-V} = 1.00$; the stars now show a linear increase and decrease of space density in the intervals $0 < E_{B-V} < 0.5$ and $0.5 < E_{B-V} < 1.0$, resp.
3. Same as model 2, but now the concentration of stars towards $E_{B-V} = 0.5$ is stronger, following a power law (exponent 2)

centrated star clusters as can be concluded from the data in Table 4. We will now compare the surface photometry of the 30 Doradus association and association no. 96 with the three models.

30 Doradus Association. This is a strongly concentrated cluster which should be compared with model 2 or 3. Approximately half the 1800 Å flux comes from the centre observed at ANS position no. 6593. The reddening from Figure 3, $\overline{E_{B-V}} < 0.27$, is smaller than the observed value 0.37 (Borgman et al., 1978). The agreement is satisfactory, taking into account that the observed value is an upper limit since it includes intrinsic reddening due to stars which are still on their way to the main sequence; also, red stars become noticeable in V. The rather red colour indices $\overline{m_{25} - m_{33}}$ are partly due to Balmer continuum emission in the 3300 Å channel (cf. Israël and Koornneef, 1978). The observed value $\overline{m_{18} - V} = -1.0$ calls for somewhat more extinction or a somewhat stronger cluster concentration than adopted for model 3.

Association No. 96. This loose group of stars may resemble model 1. The observed $\overline{m_{25} - m_{33}}$ colours (Fig. 4), the observed $\overline{m_{18} - V} = -1.8$ (Table 3), the excess visual brightness of 0.8 mag. (Table 3) from surface photometry over the integrated stellar brightness and the apparent colour excess $\overline{E_{B-V}} > 0.3$ (Borgman et al., 1978) all point to a stellar component of red stars which have no photometric significance in the ultraviolet. Consequently, we restrict the discussion to Figure 3; the low value of $\overline{E_{B-V}}$ points to an extinction depth $E_{B-V} \cong 0.2$, not in contradiction with Lucke's (1974) value $E_{B-V} = 0.18$ for the association as a whole.

4. Conclusion

The hypothesis that the ultraviolet surface photometry of the 30 Doradus area can be explained by a stellar population dominated by early type supergiants and embedded in dust which follows the galactic extinction law cannot be ruled out. We have demonstrated that the number of stars in the 30 Doradus area which are candidates for an early type supergiant classification is considerable. The geometry of a star cluster embedded in dust tends to saturate the ultraviolet colours to small apparent colour excesses, causing an apparent lowering of the 2200 Å interstellar feature.

This conclusion does not support earlier suggestions of an anomalous reddening law in the 30 Doradus area, characterized by the near-absence of the 2200 Å interstellar extinction feature (Borgman et al., 1975; Koornneef, 1976 and 1978). However, the earlier work did not take into account the intrinsic reddening of the ultraviolet intrinsic colours due to the presence of early type supergiants; also, the apparent extinction of an association embedded in a dust cloud was not discussed in the previous work.

More data on individual stars are needed in order to clarify the confusing and multi-interpretable picture presented by the surface photometry. Such additional data include colour-magnitude diagrams in a photometric system which avoids the nebular lines and going as faint as $V = 18$. Of prime importance are slit spectra of the stars down to $V = 15$ for the purpose of classification. Such spectra should also identify the O-stars; a considerable number of O-stars or other efficient ionizers are required to excite the H II region in the 30 Doradus association.

Acknowledgement. I am indebted to Drs. R. J. van Duinen and P. R. Wesselius for permission to use their unpublished data for the compilation of Table 2. Comments on a first draft of this paper were received from Drs. Andriesse, Gilra, Pottasch, Wesselius, van Albada and van Duinen. Constructive criticism by Dr. Koornneef led to a cautious formulation of the conclusion.

References

Ardeberg, A., Maurice, E., Brunet, J.P., Prévot, L.: 1972, *Astron. Astrophys. Suppl.* **6**, 249
Beeckmans, F.: 1977, *Astron. Astrophys.* **60**, 1

Blaauw, A.: 1963, The calibration of luminosity criteria, in Basic Astronomical Data, p. 383, ed. K. Aa. Strand, Univ. of Chicago Press, Chicago
Borgman, J.: 1961, *Bull. Astron. Inst. Neth.* **15**, 255
Borgman, J., Danks, A. C.: 1977, *Astron. Astrophys.* **54**, 41
Borgman, J., Danks, A. C., Hartsuiker, J. W.: 1978, *Astron. Astrophys.* in press
Borgman, J., van Duinen, R. J., Koornneef, J.: 1975, *Astron. Astrophys.* **40**, 461
Code, A. D., Meade, M. R.: 1976, Wisconsin Astrophys. Report No. 30
Danks, A. C.: 1977, *Astron. Astrophys. Suppl.* **30**, 89
Danks, A. C., Hartsuiker, J. W.: 1978, *Astron. Astrophys. Suppl.*, in press
Feast, M. W., Thackeray, A. D., Wesselink, A. J.: 1960, *Monthly Notices Roy. Astron. Soc.* **121**, 337
Israël, F. P., Koornneef, J.: 1978, in preparation
Isserstedt, J.: 1975, *Astron. Astrophys.* **41**, 21
Jamar, C., Macau-Hercot, D., Monfils, A., Thompson, G. I., Houziaux, L., Wilson, R.: 1976, ESA SR-27
Koornneef, J.: 1976, Ph.D. Thesis, Groningen
Koornneef, J.: 1977, *Astron. Astrophys. Suppl.* **29**, 117
Koornneef, J.: 1978, *Astron. Astrophys.*, submitted
Lucke, P. B.: 1974, *Astrophys. J. Suppl.* **28**, 73
Nandy, K., Thompson, G. I., Jamar, C., Monfils, A., Wilson, R.: 1975, *Astron. Astrophys.* **44**, 195
Nandy, K., Thompson, G. I., Jamar, C., Monfils, A., Wilson, R.: 1976, *Astron. Astrophys.* **51**, 63
Pottasch, S. R., Wesselius, P. R., van Duinen, R. J.: 1976, *Astron. Astrophys.* **47**, 443
Sandage, A. R.: 1955, *Astrophys. J.* **125**, 422
Sandage, A., Tammann, G. A.: 1971, *Astrophys. J.* **167**, 293
Sanduleak, N.: 1969, Cerro Tololo Inter-American Obs. Contr. No. 89
Wesselius, P. R., van Duinen, R. J., Aalders, J. W. G., Kester, D., Wu, C. C.: 1978, in preparation
Westerlund, B. E.: 1966, Multicolour photometry at Mt. Stromlo Observatory, in *Spectral Classification and Multicolour Photometry*, IAU *Symp.* **24**, p. 353,. eds K. Lodén, L. O. Lodén and U. Sinnerstad, Academic Press, London