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Massive luminous early type stars in the LMC

I. The reddening of individual stars and the LMC reddening law

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Abstract. In order to construct a comprehensive HRD of early type stars in the Large Magellanic Cloud (LMC) in the first step the reddenings of individual stars and the LMC reddening law have been investigated. 1942 LMC member stars with good *UBV*photometries from the Bochum photometry data base have been first corrected individually for galactic foreground reddening. From stars with good spectral classification the slope of the LMC internal reddening line $\left(\frac{E_{U-B}}{E_{B-V}}\right)$was calculated for each spectral subclass between O3 and A4. A remarkable difference to the galactic reddening law was found. The slope of the reddening line first decreases for stars from O3 to B0, and then increases rapidly between B0 and B3 from ∼0.7 to ∼1.1. For later type stars it remains higher than for early type stars. This effect has important consequences for all extinction corrections. We checked this using different methods. Because no evidence for systematically wrong classifications was found, the differences in the reddening slopes must be caused by the ISM of the LMC itself. Four possible causes are considered.

Key words. ISM: dust, extinction – ISM: structure – stars:early type – galaxies: Magellanic Clouds – astronomical data bases: miscellaneous

1. Introduction – Stellar evolution in the Large Magellanic Cloud

The Large Magellanic Cloud (LMC) offers a unique opportunity to study the structure of stellar systems and the course of stellar evolution. Due to the small distance one can get information on both, extended regions and single objects. Not only luminous objects can be observed, but also giants and early type main sequence stars. In contrast to our Galaxy, where most of the stars are hidden behind the dust of the galactic disk or the galactic center, the LMC allows us to observe a nearly statistically complete ensemble of individual stars. This allows us better studies of the internal structure of the LMC and its ISM, and gives a comprehensive data base to calculate a Hertzsprung-Russell Diagram (HRD) of the LMC.

Since the early sixties several authors have constructed HRD's of the LMC. The so far most complete HRD was given by Fitzpatrick & Garmany (1990). However, their results did not match very well with the theoretical models. In addition, during the last ten years stellar evolution theories have been extended to take into account effects like mass loss, rotation, overshooting, and semiconvection. Due to the lower metallicity of the LMC (e.g. Maeder 1991) these effects cause evolutionary tracks in the LMC different from those predicted before.

To construct the HRD of the LMC one has to study several questions in detail, focussed on the special conditions of the LMC:

- the galactic foreground and the LMC internal interstellar extinction;
- the spectral type and luminosity relations for the LMC, and
- the effective temperatures and bolometric corrections.

For all questions differences to our Galaxy are expected due to different metallicities.

This paper is the first of a series on early type stars in the LMC. Further papers will deal with the determination of spectral types and intrinsic colors, absolute magnitudes, effective temperatures and bolometric corrections, and the Hertzsprung-Russell Diagram of the LMC.

2. Galactic and internal LMC extinction

The light from objects in the Large Magellanic Cloud (LMC) is influenced by both internal LMC extinction, and the galactic foreground extinction caused by dust inside our own Galaxy.

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Due to different evolutionary histories and different metallicities of both galaxies the interstellar dust obviously might be different. Therefore the reddening effects mainly caused by dust might be different too.

These differences are well known in the ultraviolet. But they have been neglected in the Visible so far. To correct measurements of objects in the LMC for interstellar extinction it is necessary to derive the galactic foreground extinction and the internal LMC extinction separately.

2.1. The galactic foreground extinction

The reddening law in our Galaxy is well known. Schmidt-Kaler (1982) found for the slope of the redening line

$$\left(\frac{E_{U-B}}{E_{B-V}}\right)_{\rm gal} = \begin{cases} 0.65 - 0.05\,(U-B)_0 + 0.05\,E_{B-V} \\ \qquad\qquad \text{for} \quad (U-B)_0 < 0 \\ 0.64 + 0.26\,(B-V)_0 + 0.05\,E_{B-V} \\ \qquad\qquad \text{for} \quad (B-V)_0 > 0 \end{cases} \tag{1}$$

and for the relation between visual absorption and E_{B-V}.

$$R = \frac{A_V}{E_{B-V}} = 3.30 + 0.28\,(B\text{–}V)_0 + 0.04\,E_{B-V}. \tag{2}$$

These values have been confirmed by Oestreicher et al. (1995) for the direction towards the LMC.

The galactic foreground extinction in the direction of the Magellanic Clouds has been examined since the 1960s. However, only little is known. Due to low numbers of observed stars only mean E_{B-V} values could be determined. Up to 1991 only a mean value of $\overline{E_{B-V}} = 0\overset{\rm m}{.}07 \pm 0\overset{\rm m}{.}02$ was used (see Table 1 in Oestreicher et al. 1995). Because of this lack of data most authors who dealt with objects in the Magellanic Clouds adopted uniform foreground reddening.

Gochermann et al. (1989), however, realized already in 1987 that the galactic foreground reddening is not constant even on small scales. The area on the sky covered by the LMC is about $10° \times 8°$. Assuming a typical scale height of the galactic dust of 110 pc (Parenago 1945) a typical area in the galactic foreground of about 10×12 pc^2 is influencing the light from LMC objects. There is no evidence that the dust distribution is homogeneous in such a large area.

From Walraven photometry of 41 foreground stars around SN 1987 A Gochermann et al. (1989) found that the reddening can differ significantly on scales as small as $10'$. From IR satellite measurements Schwering & Israel (1991) found variations of the galactic foreground reddening towards the LMC from $0\overset{\rm m}{.}06$ to $0\overset{\rm m}{.}17$ on scales smaller than $9'$.

From *UBV* photometry of 1409 galactic foreground stars, all located outside the galactic disc and therefore suffering the full amount of dust extinction, Oestreicher et al. (1995) calculated a galactic foreground reddening map with a resolution of $10'$. It shows strong variations of the foreground reddening E_{B-V} from $0\overset{\rm m}{.}00$ to $0\overset{\rm m}{.}15$. The mean reddening is found to be $0\overset{\rm m}{.}06 \pm 0\overset{\rm m}{.}02$. This map can be used to derive the individual galactic foreground extinction for objects in the LMC.

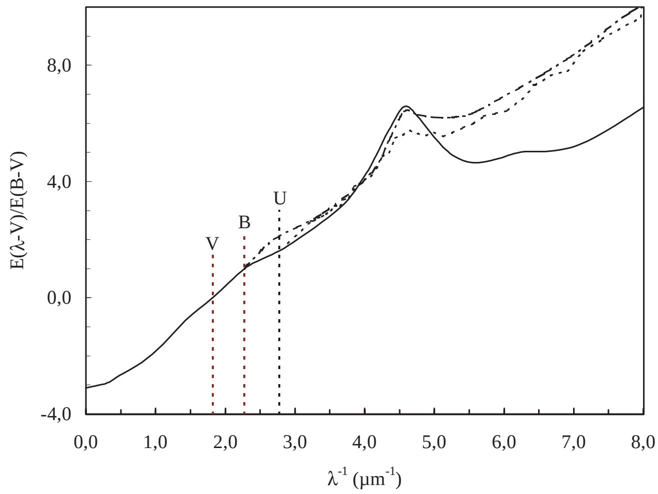

Fig. 1. Extinction curves for the LMC (Koornneef & Code 1981: dashed-dotted line, Nandy 1981: dashed line) and for our Galaxy (Savage & Mathis 1979: solid line). The central wavelengths of the Johnson *UBV* band are indicated. Differences in the extinction curves occur already in the *U* band.

2.2. The LMC extinction law

The extinction law depends on the nature and the composition of the interstellar dust grains. Therefore the laws are different for special regions in our Galaxy, e.g. star forming regions like the Orion nebulae, and for different galaxies like the Magellanic Clouds or our own Galaxy. Strong differences exist in the UV due to various composition of silicates and carbon particles. Several authors have investigated these extinction curves (Savage & Mathis 1979; Nandy et al. 1981; Koornneef & Code 1981; Prévot et al. 1984; Bouchet et al. 1985; Misselt et al. 1999; Sauvage & Vigroux 1991).

Because the differences are much stronger in the UV most of the authors assumed the optical extinction curve to be identical with the galactic curve. Figure 1 shows clearly that there are differences already in the *U* band. From the extinction curve given by Savage & Mathis (1979) and Koornneef & Code (1981) we estimated the slope of the reddening line for our Galaxy and for the LMC:

$$\left(\frac{E_{U-B}}{E_{B-V}}\right)_{\rm gal} = 0.64; \quad \left(\frac{E_{U-B}}{E_{B-V}}\right)_{\rm LMC} = 1.10. \tag{3}$$

The galactic value matches well with the one given in Eq. (1). Although the value for the LMC is noticeably higher no examination of the slope of the LMC reddening has been made so far.

3. The Bochum LMC photometry data base

Broad-band photometry allows us to observe a lot of individual stars with high accuracy. CCD images give a great number of stars but within small fields of view. In contrast to this photoelectric photometry allows us to observe stars in different areas of the LMC within the available time. Under good conditions the limit of *UBV* photometry with small telescopes ($\lesssim$1 m) is about $14^{\rm m} \ldots 15^{\rm m}$. Adopting a distance modulus of the LMC

Table 1. Number of observation nights.

period	telescope	available nights	photometric number	%
1990/91	Bochum 61 cm	23	13	57
	ESO 50 cm	16	9	56
	Las Campanas	7	2	29
1991/92	Bochum 61 cm	96	54	56
	ESO 50 cm	16	8	50
1992/93	Bochum 61 cm	68	42	62
	ESO 1 m	6	4	67
1993/94	Bochum 61 cm	64	28	44
	ESO 50 cm	13	6	46
	ESO 1 m	6	3	50
total		315	169	54

of $(m_V - M_V) = 18\overset{\mathrm{m}}{.}45 \pm 0\overset{\mathrm{m}}{.}08$ (Schmidt-Kaler & Oestreicher 1998) this yields an absolute magnitude limit of $M \approx -4^{\mathrm{M}}$. Therefore almost all supergiants, O and B giants and O type main sequence stars are observable. This gives at least a comprehensive statistical ensemble of early type stars in the LMC.

The systematic separation of stars in the direction of the Magellanic Clouds into member stars and galactic foreground stars has been initiated by Fehrenbach & Duflot (1970). These first lists were supplemented by numerous authors (Ardeberg et al. 1972; Fehrenbach & Duflot 1973, 1974, 1981, 1982; Brunet et al. 1973, 1975; Isserstedt 1975a, 1979, 1982; Rousseau et al. 1978) with additional stars and photometric measurements. However, there are problems in combining these data:

- Due to overlapping objective prism spectra in crowded regions of the LMC, and due to selection effects of the observations, this data base is incomplete;
- There are only a few cross-references for stars in the different catalogues;
- There are many stars which have never been observed individually to get photometries, spectral types, luminosities etc. Isserstedt (1975a, 1979) only has tried to get a complete photometric data sample. He observed nearly 800 supergiants in the LMC with the Bochum 61 cm telescope at La Silla;
- Photometries in the Rousseau catalogue (1978) have in part been calculated from various measurements of different authors by simply taking the arithmetic mean even if the data differed by up to $0\overset{\mathrm{m}}{.}30$;
- A number of variable stars have been included and no check for multiple systems could be done;
- Classifaction errors are included.

Therefore, a new digital data base of LMC member stars and galactic foreground stars has been built up at the Ruhr-Universität Bochum (Gochermann et al. 1992; Gochermann 1994). The data base contains both published data and new observations. We were careful about separating uncertainties like variable stars, peculiar objects, stars embedded in nebulae, or multiple systems using as many information sources as we could find.

Table 2. Stars in the data base with *UBV* photometry.

total number of stars		V	%	$(B{-}V)$	%	$(U{-}B)$	%
		proportion with … photometry					
3260	foreground	2149	65.9	2125	65.2	2101	64.4
7131	member	4576	64.2	4322	60.6	2509	35.2
334	uncertain	260	77.8	252	75.5	65	19.5

For nearly all individual stars for which single channel photometries can be collected using a small telescope, new *UBV* photometries have been obtained. Between 1990 and 1994 a total of 315 nights mainly on La Silla were available. Table 1 gives the number of nights at the various telescopes and the photometric conditions.

The observations and the reduction procedures were described by Gochermann et al. (1993). We were careful about homogeneous procedures for the different photometric systems at the various telescopes, and because of the variation of the atmospheric extinction at least due to the Pinatubo volcano eruption in June 1991 (Grothues & Gochermann 1992). Atmospheric extinction has been derived every night, and the second order extinction coefficients have been measured at least once for each period.

New measurements have been collected for 3126 individual stars: 1989 galactic foreground stars, 1077 LMC member stars, and 60 stars with uncertain membership. About 66% have been measured at least two or three times. All new photometries have been published by Gochermann et al. (1993), Grothues et al. (1996), and Schmidt-Kaler et al. (1999).

Combining these new observations with the published data a total number of 10 725 stars with *UBV* photometries is included in the Bochum data base. Table 2 gives the number of stars divided into the number of *UBV* photometries. Two thirds of all galactic foreground stars have good quality photometries even in the U band. Due to the lower brightness of the LMC stars U photometry has been collected for only 35% of the member stars. Nevertheless, in the end good quality *UBV* photometry exists for more than 2500 LMC stars, which is about two times more than before. At least 60% of the LMC member stars have good B and V data.

To be sure of having a representative sample of *UBV* photometries the ratio of observed stars to known stars per spectral type class is a good measure. Table 3 gives these ratios. It is clearly seen that the deficiency in the number of observed member stars comes from missing measurements of the late type stars. In the range O to G between 78 and 95% of the stars with spectral classification have been observed. The lower ratio for the O stars is due to missing observations of O stars located in associations where it is difficult to collect good photometric measurements with a single channel diaphragm photometer. Because most of the B, A, and F stars are taken from catalogues which aimed to list all stars, the data base is probably representative. The great number of stars with spectral type “others” consists of 887 C type stars, measured by Reid et al. (1990),

Table 3. Number of LMC member stars with spectral type and *UBV* photometry.

	spectraltype								without	
	O	B	A	F	G	K	M	others	SpType	total
number	347	1327	623	62	20	124	1776	991	1861	7131
with *UBV*	272	1265	545	59	19	63	15	82	189	2509
prop. %	78	95	87	90	95	50	1	8	10	35

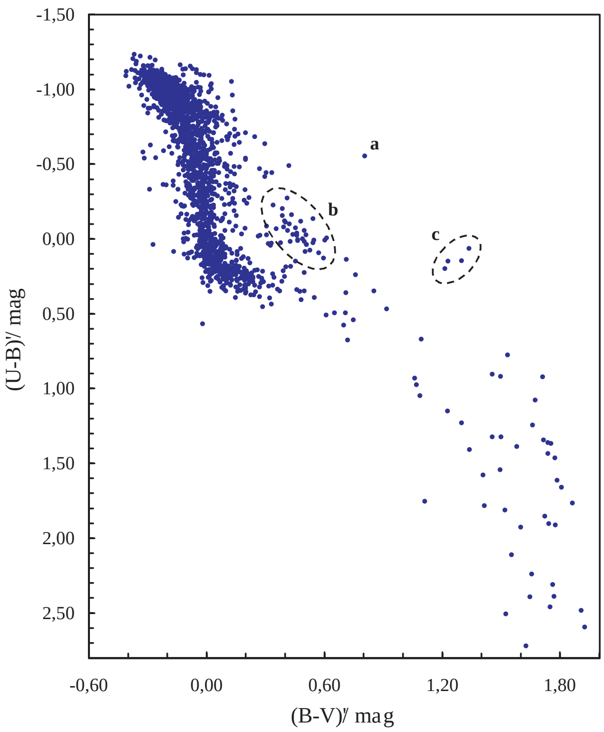

Fig. 2. Two-color diagram of LMC member stars corrected for galactic foreground reddening. For remarks to star a and groups b and c see text.

73 WN stars, 19 WC stars, and 12 others like neb., pec., PN, and SC.

The completeness limit of the data has been found by Schmidt-Kaler et al. (1999) to be $12\overset{\mathrm{m}}{.}8 \pm 0\overset{\mathrm{m}}{.}2$. Assuming a mean visual absorption of $A_V = 0\overset{\mathrm{m}}{.}70 \pm 0\overset{\mathrm{m}}{.}06$ (Oestreicher & Schmidt-Kaler 1996) this yields an unreddened limit of completeness of $12\overset{\mathrm{m}}{.}1 \pm 0\overset{\mathrm{m}}{.}2$ corresponding to an absolute magnitude of $M_V = -6\overset{\mathrm{m}}{.}3$.

4. The determination of $\left(\frac{E_{U-B}}{E_{B-V}}\right)_{\mathrm{LMC}}$

4.1. Correction for galactic foreground extinction

As a first step all *UBV* photometries in the Bochum data base have been corrected individually for the galactic foreground reddening by taking the E_{B-V} value from the map given by Oestreicher et al. (1995). The visual absorption was calculated using Eq. (2).

Figure 2 shows the two-color diagram of 1942 LMC member stars after correction for galactic foreground extinction. Apart from the late-type stars in the lower right-hand corner, three groups of stars are conspicuous. Star a is Stock's (1976) star no. 594, classified as B9 Iab, with $V = 13\overset{\mathrm{m}}{.}308$, $(B-V) = 0\overset{\mathrm{m}}{.}877$, and $(U-B) = -0\overset{\mathrm{m}}{.}495$ (corrected for galactic foreground extinction: $V' = 13\overset{\mathrm{m}}{.}061$, $(B-V)' = 0\overset{\mathrm{m}}{.}807$, $(U-B)' = -0\overset{\mathrm{m}}{.}555$). No information about any peculiarity has been found. The stars in group b are late-type stars mainly given by Stock, they are not a group associated in space. Stars in group c are late-type stars (K-M) and one unknown star measured in the neighborhood to FD 421.

Table 4. Classification errors found by Lennon (1997) and Venn (1999).

spectral type	No.	Δ subclasses		
B0–B1	18	0.48	±	0.84
B2	13	0.54	±	1.28
B3–B4	9	0.28	±	1.18
B4–B7	8	1.13	±	2.46
B8–A0	5	0.80	±	1.10
weighted mean		0.55	±	0.21

4.2. The shift in the two-color-diagram due to extinction

The reddening of the starlight by interstellar extinction causes a shift in the two-color diagram downwards in $(U-B)$ and to the right in $(B-V)$. The slope of this reddening line is given by $\left(\frac{E_{U-B}}{E_{B-V}}\right)$. How can one measure this slope without knowing the amount of reddening of the light?

Assuming the same intrinsic color for stars of the same spectral type, stars with more or less interstellar reddening may scatter around their line of reddening with the slope $\left(\frac{E_{U-B}}{E_{B-V}}\right)$. Fortunately, a sufficient number of stars with good spectral classification (including a luminosity classification) has been measured (see Table 5). Although we considered new good spectral classifications available (e.g. Massey et al. 1995; Jaxon et al. 2001), existing uncertainties in the spectral classification enlarge the scattering. Moreover, Lennon (1997) and Venn (1999) found systematic classification errors of the order of +0.5 subclass for stars between B0 and B4, and +1.0 subclass for stars from B5 to A0. From their data for 64 LMC B-stars the differences listed in Table 4 are obtained. Venn noted a similar effect for A stars in the SMC. However, stars of a given spectral type should suffer the same type of reddening. Figure 3 shows the LMC reddening scattering for 92 B2 stars.

For most of the spectral subclasses more than 20 stars with good spectral classification were available. If the number of

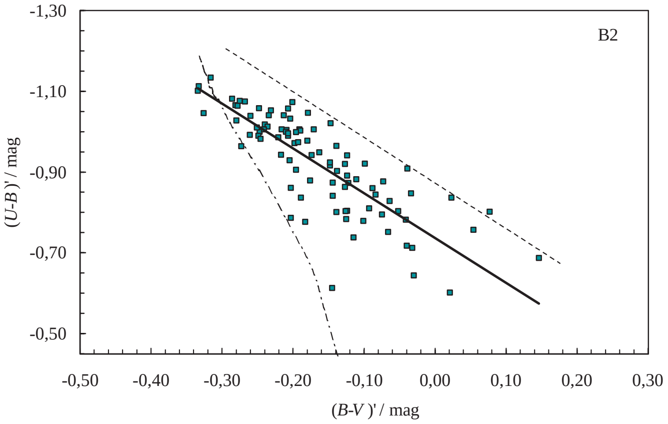

Fig. 3. Two-color diagram of 92 B2 stars in the LMC, corrected for galactic foreground reddening. The dashed-dotted line represents the intrinsic colors found by Gochermann (2000, see Paper II) for luminosity class ≈V, the solid line is a linear fit to the data representing the reddening line. The dashed line gives the upper ledge of the data.

Table 5. Slope m of the reddening line as a function of spectral type.

spectral type	number	$m = \frac{E_{U-B}}{E_{B-V}}$
O3–O5	12	0.971 ± 0.158
O6–O7.5	30	0.702 ± 0.063
O8–O8.5	27	0.648 ± 0.080
O9–O9.7	45	0.586 ± 0.087
B0	15	0.731 ± 0.096
B0.5–B0.8	90	0.833 ± 0.084
B1	132	0.763 ± 0.077
B1.5	61	0.984 ± 0.119
B2	92	1.017 ± 0.082
B2.5	13	1.253 ± 0.190
B3	65	1.116 ± 0.140
B4	19	1.106 ± 0.291
B5	38	1.506 ± 0.188
B6	32	1.117 ± 0.194
B8	27	1.451 ± 0.427
B9	119	1.426 ± 0.229
A0	165	1.016 ± 0.241
A1	24	1.197 ± 0.392
A2	95	1.176 ± 0.213
A3	44	1.205 ± 0.321
A4	20	1.266 ± 0.374

stars per bin was low we combined a few subclasses to get better statistics. Only stars with positions inside the galactic foreground reddening map have been taken. Table 5 gives the slope m for all stars from O3 to A4. For later spectral types the numbers of observed stars with good classification are too low.

5. The reddening law in the LMC

The slope of the reddening line as a function of the spectral type is shown in Fig. 4. A remarkable difference to the galactic reddening law is seen. The slope of the reddening line first

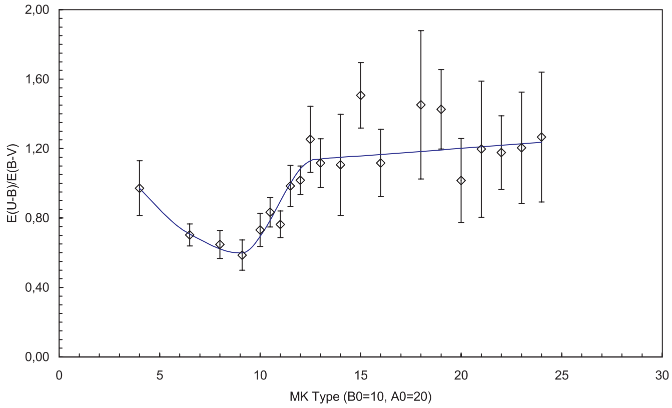

Fig. 4. The slope of the reddening line from stars with good spectral classification from O3 to A4.

Table 6. Slope of the upper ledge from reddened stars.

SpTyp	m
O3–O7	0.99
O8	0.90
O9	0.86
B0	0.68
B1	0.92
B1.5, B1–2	0.89
B2	1.00
B2.5	1.11

decreases for stars from O3 to B0, and increases then rapidly between B0 and B3 from ∼0.7 to ∼1.1. For later type stars it remains higher than for early type stars. We checked this unexpected effect in different ways.

5.1. Check for the fitting routine

Koornneef & Code derived the LMC extinction law given in Fig. 1 from 10 early-type stars (3 B0-0.5 (Ia), 4 B1 (Ia), 2 B1.5 Ia, and 1 B2 Ia). In the UV they used IUE spectra to derive $A(\lambda)/E_{B-V}$, in the Visible they derived $\left(\frac{E_{U-B}}{E_{B-V}}\right)$ only from the old Rousseau photometries but with the LMC intrinsic colors of Isserstedt (1975b). No evidence is found for variations in the reddening slope. However, the mean value of 1.08 ± 0.24 indicates a higher value than the galactic one.

For ≈B2/B3 we found $m = 1.14$ which matches closely the value of $m = 1.10$ estimated from the extinction curves in Sect. 2.2.

Another proceedure to estimate the reddening slope – or at least to test it – is to measure the upper ledge of the scattered data. In Fig. 3 this upper limit is indicated too (dashed line). We found the same trend (see Table 6): higher values for early O stars, decreasing a little to B0, and then increasing again.

5.2. Check for local variations

We derived the reddening slope from the total ensemble of LMC stars distributed over the whole LMC. To check if

Table 7. Mean reddenings for O and B0/B1 stars in two OB associations.

Association	Spectral types	$\overline{(U–B)}$	$\overline{(B–V)}$	$\overline{(U–B)_0}$	$\overline{(B–V)_0}$	$\overline{E_{U-B}}$	$\overline{E_{B-V}}$	$\frac{E_{U-B}}{E_{B-V}}$
LH 9:	O3–O9 V	–1.036	–1.154	–0.208	–0.325	0.118	0.117	0.992
	B0–B1 V	–0.961	–1.002	–0.184	–0.279	0.041	0.095	0.432
LH 10:	O3–O9 V	–0.968	–1.154	–0.117	–0.325	0.118	0.117	0.992
	B0–B1 V	–0.930	–1.002	–0.105	–0.279	0.072	0.174	0.414

Table 8. Slope m of the reddening line as a function of spectral type for 85 stars in or around LMC-2.

spectral type	number	$m = \frac{E_{U-B}}{E_{B-V}}$
O3–O6.5	6	0.696 ± 0.319
O3–O9.5	11	0.512 ± 0.123
O8–O9.5	5	0.413 ± 0.163
B0–B0.5	15	0.924 ± 0.186
B1	9	0.889 ± 0.129
B1.5	13	1.042 ± 0.348
B2–B2.5	9	0.924 ± 0.260
B3–B5	6	1.112 ± 0.221
B6–B8	7	1.401 ± 0.806

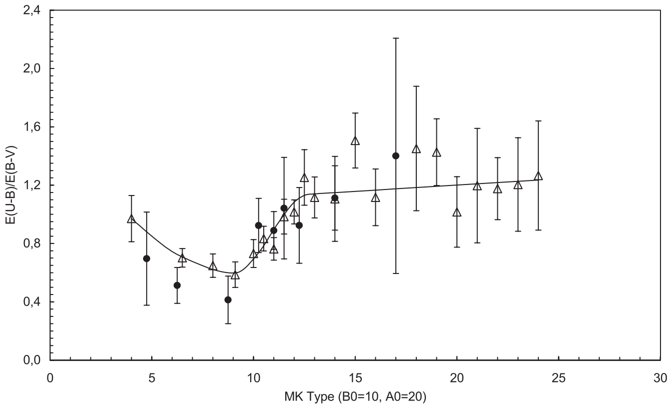

Fig. 5. The slope of the reddening line from all stars (△, see Fig. 4) and from stars around LMC-2 (●).

variations in the reddening law are correlated with the location of stars in the LMC we calculated the reddening lines for three different areas.

We checked the decreasing effect between O3 and B0 stars using CCD photometries of two OB associations given by Parker et al. (1992). From the arithmetic means of the observed $(U–B)$ and $(B–V)$ and the intrinsic colors given by Gochermann (2000) we calculated mean reddenings and reddening slopes (see Table 7). It is clearly seen that the reddening slope is higher for O3-O9 stars than for B0-B1 stars.

Misselt et al. (1999) found very significant differences in the 2175 Å bump strength in the UV extinction law from stars in or around the supergiant shell LMC-2 on the south-east side of 30 Dor. Unfortunately they rejected all stars with $\left(\frac{E_{U-B}}{E_{B-V}}\right) > 1.03$. From our database we selected 85 stars between O3 and B8 with good *UBV* photometry in an area of $\Delta\alpha \approx 20^{\rm m}$ and $\Delta\delta \approx 1°$ around LMC-2. The number of stars per spectral class is rather poor but sufficient to derive the reddening slope for some subclasses. Table 8 gives the results.

Due to the low number of stars per spectral class the errors are larger, but the increasing effect is clearly visible again. Figure 5 shows that the slope of the reddening line follows the same trend as in Fig. 4. No evidence for local variations of the reddening law could be detected in our data.

5.3. Effects of binarity on the reddening line

We carefully rejected all stars from our data sample showing any evidence for binarity. Nevertheless, one cannot exclude that close binaries or multiple systems have been measured together in the diaphragm of the photometer. The measured color index then is a mixture of two energy distributions. The representative point of such an energy distribution in the *UBV* diagram will not necessarily be aligned with the position of a star having a MK classification. This effect has been discussed by Golay (1974).

A binary or multiple system consisting of stars of the same or similar spectral types does not change the colors even if the stars are of different magnitudes. But how do colors change when the intensities of an early and a late type star are mixed?

A typical star of our data sample is a B1 star with $V = 13\overset{\rm m}{.}0$, with $\overline{A_V} = 0\overset{\rm m}{.}62$ (corresponding to the measured $\overline{E_{B-V}} = 0\overset{\rm m}{.}193$ and $\overline{E_{U-B}} = 0\overset{\rm m}{.}175$). The absolute magnitude of this star is approximately $M_V = -6\overset{\rm m}{.}1$, typically a Iab supergiant. Using the intrinsic colors of Gochermann (2000) the U and B magnitudes should be $U = 12\overset{\rm m}{.}05$ and $B = 12\overset{\rm m}{.}92$. The influence on the colors by measuring a K0 companion can be estimated as follows. Adopting a minimum V difference of $\Delta V = 2\overset{\rm m}{.}5$, corresponding to a factor of 10 in luminosity, the absolute magnitude is $M_V = -3\overset{\rm m}{.}6$ (K0 Ib). The differences in the blue magnitudes are greater, $\Delta B = 3\overset{\rm m}{.}89$, $\Delta U = 5\overset{\rm m}{.}91$, due to the redder energy distribution. Measuring this star together with the B1 Iab star the colors should change as follows: $\Delta(U–B) = 0\overset{\rm m}{.}03$ and $\Delta(B–V) = 0\overset{\rm m}{.}07$. Therefore the reddening line will be changed by $\Delta(U–B)/\Delta(B–V) = 0.43$. The reddening line will be less steep. It is easy to see that the influence of an earlier type star like B9 or A0 will not change the reddening line sensibly. To explain the lower $\left(\frac{E_{U-B}}{E_{B-V}}\right)$ values for stars earlier than B3 one had to assume a very red companion for each star, which is very unlikely.

5.4. Possible causes for the reddening differences

From our data we found that the reddening law for early-type stars differs from that for later types with a strong increase between B0 and B3 stars. This effect has important consequences for all extinction corrections.

But *why* is $\left(\frac{E_{U-B}}{E_{B-V}}\right)$lower for the early type stars and why does it increase so much? Is the effect real?

The slope of the reddening line differs with the spectral type also in our Galaxy. This has already been found by Schmidt-Kaler (1961) and Golay (1974). The reddening depends on the colors of the objects when measured with broad-band photometric systems. But these variations are rather small.

In principle there are two possible explanations for the strong effect found in the LMC: the interstellar matter surrounding the early type stars is different from the "normal" ISM, or the classifications of the early type stars are systematically wrong.

We found no evidence for systematically wrong classifications, except those small ones found by Lennon (1997) and Venn (1999). Therefore the differences in the reddening slopes must be caused by the ISM of the LMC itself. Four cases seem possible:

1. The material is different from the normal ISM in the LMC because most of the very early type stars are located in star forming regions;
2. The material has been originally the same, but has been changed due to the strong energy input by the hottest stars;
3. The surrounding ISM has been enriched by material from the stars themselves by strong stellar winds and mass loss;
4. The surrounding ISM has been blown away by the strong stellar winds.

From our *UBV* data alone we cannot decide which case is dominant. Detailed further investigations of the interstellar medium around early type LMC stars and the influence of the hottest stars on the surrounding ISM are necessary.

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