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The distribution of stars in three regions in the northeastern part of the Large Magellanic Cloud*

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Abstract. B,V-CCD photometry has been obtained for stars in two fields in the NE part of the Large Magellanic Cloud (LMC) and photographic photometry, and a calibrating CCD sequence, for a third field. The colour-magnitude diagrams (CMDs) and luminosity functions (LFs) for main sequence (MS) and red giant (RG) stars in the fields are established. The red giant clumps (RGCs) are found to be bimodal and to contain stars from one old population, $\geq$ 10 Gyr, and one younger, $\geq$ 0.3–4 Gyr old. Analyses of published data for a number of LMC fields reveal similar compositions of their RGCs. These epochs of star formation are common to most of the studied LMC fields; only those in or close to now active star-forming regions contain a considerably younger population. Comparisons with recent HST results for main-sequence stars permit the identification of star formation events $\sim$ 1 and 2 Gyr ago.

The data are used to estimate the masses of Population II and the intermediate-age Population I to ~ 2 and $7.5 \times 10^8 \mathrm{M}_\odot$, respectively, meaning that the burst(s) of star formation which occurred between 4 and 0.3 Gyr ago were about 3 to 4 times as productive as the original star production in the LMC.

Key words: Hertzsprung-Russel(HR) diagram – stars: luminosity function, mass function – galaxies: evolution – Magellanic Clouds – galaxies: stellar content

1. Introduction

Stellar distribution studies to relatively faint magnitudes (V > $21^{\rm m}$) have now been carried out for a number of small fields in the LMC (see Westerlund et al. 1995 and Vallenari et al. 1996b for references). Hubble Space Telescope (HST) results to V > $26^{\rm m}$ are beginning to appear (cf. Elson et al. 1997, Gallagher et al. 1996, Holtzman et al. 1997, Stappers et al. 1997). As a result the discussion of the star formation history of the LMC has intensified appreciably. It was early suggested (Westerlund 1964) that a global burst of star formation was responsible for the appearance of the Extreme Population I in the LMC. Several investigations have since indicated that major bursts may have played a fundamental role also in the earlier star production, and the bursts have been ascribed to interactions between the SMC, the LMC and possibly our Galaxy (cf. Westerlund 1997 for references). Claims have been made that pronounced differences exist between some fields, indicating that enhanced star formation may have occurred at different epochs in different parts of the LMC (Bertelli et al. 1992, Vallenari et al. 1996a,b).

Gallagher et al. (1996), Holtzman et al. (1997), and Stappers et al. (1997) have analyzed the same field, near NGC1866, as also studied by Bertelli et al. (1992) in a less deep investigation. The latter suggested that the star formation rate was quite low during the 70% of the lifetime of the LMC, and that a major event, about (3–4) Gyr ago triggered a substantial increase in the star formation rate throughout the entire LMC which persisted for several Gyrs and even up to the present epoch in some of its parts.The three HST investigations listed indicate (i) that a pronounced peak in star formation occurred about 2 Gyr ago (Gallagher et al.), (ii) that star formation was roughly constant for 10 Gyr, then increased by a factor of three for the past 2 Gyr (Holtzman et al.), and (iii) that a unique increase in star formation occurred about 3 Gyr ago, but otherwise a steady star formation rather than a history dominated by bursts (Stappers et al.). In their HST study of a separate field Elson et al. found evidence for an intense star formation event a few Gyr ago, probably responsible for the formation of the LMC disc, but also for another burst about one Gyr ago. The latter may correspond to the formation of the LMC Bar. About 5% of the stars in this field have an age of $\sim$ 12 Gyr.

Also the distribution of planetary nebulae (PN) in the HR-diagram implies that the rate of star formation in the LMC has not been uniform over time (Dopita 1993). The faintest PN are assigned ages of about 15 Gyr. Concentration of more massive PN near 1.5 and 2.5 $\mathrm{M}_\odot$ imply that bursts of star formation occurred about 3–4 Gyr ago and within the last 0.3 Gyr.

It is highly desirable to obtain further analyses of the composition of the field population in the LMC by extending the studies to new regions. If age differences are found between the various regions, the reason for their existence will have to be determined with a particular view at the possible effects of interactions between the LMC, the Small Magellanic Cloud (SMC) and the Galaxy.

* Based on Observations carried out at the European Southern Observatory, La Silla, Chile

Table 1. Data for the fields

Field	RA 1950	Decl	size	Distance from LMC centre
6,-67 (CCD)	$5^h57^m\!.5$	$-67°08'\!.8$	8.5	$\sim 4°$
6,-67 (pg)			19.2	
6.5,-68 (pg)	$6^h26^m\!.3$	$-68°49'\!.2$	49	$\sim 7°$
N2204 (CCD)	$5^h31^m\!.5$	$-67°18'\!.0$	8.9	$2\overset{\circ}{.}5$

Note: Sizes are in arcmin^2

Several years ago we began a study of the distribution of stars in two fields in the northeastern part of the LMC (Table 1) rather far from its centre. The fields were chosen in regions free from signs of recent star formation. Deep photographic plates were secured. Calibration problems arose, however, and the investigation was temporarily shelved. More recently, we have obtained CCD photometry for calibration of one of the fields and CCD photometry of the other and therefore deemed it possible to complete the investigation. We have also added a field in the southern part of Constellation III, showing recent star formation. Here, we present the results of the analysis of their CMDs and LFs and a comparison of the derived LFs with data available in the literature.

2. Observations and reductions

Photographic plates in B and V were obtained in 1980 of two fields, 6,-67 and 6.5,-68, in the LMC with the aid of the prime focus camera on the 3.6 m telescope at ESO, La Silla. Photoelectric UBV sequences to about $V = 16\overset{m}{.}5$ were established (by BW) in the two fields for zero-point calibrations. CCD photometry was carried out of a third field, N2004, near NGC2004. The positions and sizes of the fields are given in Table 1; the sizes of the pg fields were chosen from the estimated stellar density so that a sufficient material for reliable luminosity functions should be available.

The plates, three in each colour, were measured (by EK) with the aid of the Iris photometer at Uppsala Observatory. The extension of the calibration to faint magnitudes had been planned to be done with the aid of the Racine-wedge technique (Racine 1969). However, it was soon realised that the Racine 'reduction value' was not constant even within one plate but varied with the magnitude. Deep calibrating sequences had to be obtained for the completion of the investigation. For the field 6.5,-68 a sequence was established for us by G. Alcaino and W. Liller with the aid of CCD photometry with the Danish 1.5 m telescope on La Silla. For the field 6,-67 deep CCD frames were secured (by KL). As their quality was high, we decided to base our analysis of that region primarily on them. The analysis of the frames has been done following the ESO MIDAS and Romafot routines.

For the third field, N2004, near the cluster NGC2004, CCD photometry was obtained (by BP). The zero-point has been determined with the aid of stars observed by Sagar et al. (1991a) in a study of the cluster itself. It should be noted that in an investigation of NGC2004 by Balona and Jerzykiewicz (1993) severe discrepancies in the zero-point of V are noted: -0.182, and magnitude dependent, to Bencivenni et al. (1991), +0.099 to Elson (1991) and -0.036 to Sagar et al. (1991b). The discrepancies in B$-$V are smaller: -0.070, +0.037 and +0.038, respectively. The differences are ascribed to problems encountered in the calibration of CCD frames. It is necessary to bear the possibility of rather large zero-point discrepancies in mind when using CCD data from various sources, in particular if the zero-points have been transferred from a standard field or scattered standard stars to the field under investigation.

The photographic photometry of the 6,-67 field has been used for estimating the quality of the photographic LFs as compared with those based on CCD photometry, so that a proper interpretation of the results for field 6.5,-68 could be achieved. The comparison shows that the photographic photometry agrees well with the CCD photometry for $M_V < 1\overset{m}{.}5$ (See the Appendix).

The accuracy of the photographic photometry is estimated to $0\overset{m}{.}1$ in one measurement in B and V. For the CCD frames, only one is available in each colour, the accuracy is estimated to $0\overset{m}{.}03$.

Catalogues containing the CCD photometry of fields 6,-67 and NGC2004 and the photographic photometry of field 6.5, -68 are are available on request as well as the calibrating sequences.

3. The colour-magnitude diagrams

A colour excess E_{B-V} of $0\overset{m}{.}08$ has been used to derive $(B\text{-}V)_0$ for the stars in fields 6,-67 and 6.5,-68. It is a mean value frequently used in areas of the LMC where there is no reason to suspect an excessive amount of dust; i.e. where no pronounced star formation or absorption features are observed (cf. Westerlund et al. 1995). In the field N2004 we have assumed a reddening of $E_{B-V} = 0\overset{m}{.}15$. Lower values are found in the literature for the cluster itself. Lee (1991) gives $E_{B-V} = 0.08\pm0.03$, Balona (1993) 0.028 ± 0.005, Caloi & Cassatella (1995) $0\overset{m}{.}09$. However, the reddening determinations are still rather uncertain, and, as we feel that the reddening in the LMC is frequently underestimated, we have preferred our higher value. We use $(m\text{-}M)_0 = 18\overset{m}{.}5$ as the distance modulus of the LMC (Westerlund 1997).

The colour-magnitude diagrams of the fields are presented in Fig. 1a–c. The ZAMS (Schmidt-Kaler 1982), the Yale (Green et al. 1987) isochrones for 7 and 10 Gyr, Z = 0.001, Y = 0.30, the VandenBerg (1985) isochrones for 0.3, 0.5, 1, 2 and 3 Gyr, all with Z = 0.010, and the Bertelli et al. (1990) isochrone for 0.1 Gyr, Z= 0.02, η = 3.5, are drawn.

Comparisons of the main sequence (MS) luminosity functions (LF) of the 6,-67 and N2004 fields with HST data indicate that our data are reliable for discussions for stars with $M_V \leq 2$ (see Fig. 6).

Our fields contain a number of galactic foreground stars as well as a number of background galaxies. Using the results of Stryker (1984) and Ardeberg et al. (1985) we conclude that field 6,-67 is likely to contain about 40 stars and 70 galaxies brighter than $V = 23^m$. The same will hold for the N2004 field. Most of

Table 2. The distribution of stars (per arcmin^2) in the 6,-67 (CCD) field. Corrections for incompleteness are applied.

	$(B-V)_0$								
	− 0.4	− 0.2	0.0	0.2	0.4	0.6	0.8	1.0	1.4
	− 0.2	0.0	0.2	0.4	0.6	0.8	1.0	1.4	
M_V									
− 4.5								0.05	
− 4.0							0.05		
− 3.5					0.10				
− 3.0									0.05
− 2.5					0.05				
− 2.0				0.05	0.05	0.05		0.21	0.1
− 1.5								0.21	0.05
− 1.0	0.05	0.10			0.10	0.05	0.10	0.31	
− 0.5*		0.38				0.44	0.44	0.38	
0.0		0.67	0.22			0.83	2.00	0.33	0.11
0.5		0.86	0.34	0.23	0.11	1.03	1.66	0.11	0.29
1.0	0.12	1.70	1.39	0.73	0	0.42	0.73	0.06	0.12
1.5	0.13	1.86	3.34	1.67	0.32	0.96	0.32	0.13	0.06
2.0	0.22	0.80	4.70	4.70	1.23	1.08	0.94	0.22	0.36
2.5	0.09	0.69	5.37	8.75	4.51	0.78	0.87	0.35	0.17
3.0	0.11	1.02	4.75	10.97	9.27	3.28	1.02	0.79	0.11
(3.5		1.04	4.16	6.07	10.05	4.33	2.25	1.91	)

Table 3. The distribution of stars (per arcmin^2) in the N2004(CCD) field. Corrections for incompleteness are applied.

	$(B-V)_0$								
	− 0.4	− 0.2	0.0	0.2	0.4	0.6	0.8	1.0	1.4
	− 0.2	0.0	0.2	0.4	0.6	0.8	1.0	1.4	
M_V									
− 6.5									0.11
− 6.0	0.11								0.22
− 5.5	0.22	0.11						0.11	
− 5.0		0.11			0.11				
− 4.5		0.11	0.11						
− 4.0	0.9	0.22							
− 3.5	0.56	0.22						0.11	
− 3.0	1.01	0.11						0.11	
− 2.5	2.13				0.11		0.11	0.11	0.34
− 2.0	1.01	0.11		0.11	0.22			0.11	0.11
− 1.5	3.26	0.11	0.11			0.22	0.11	0.22	
− 1.0	3.43	1.07	0.23		0.36	0.12	0.63	0.47	
− 0.5*	4.99	2.74	0.25	0.37	0.37	0.88	0.49		
0.0	3.44	5.02	1.19	0.27	1.06	4.63	1.06	0.27	0.13
0.5	2.88	10.4	2.16		0.72	2.88	1.73	0.15	0.15
1.0	2.03	13.7	6.55	1.88		0.93	0.47	0.16	0.31
1.5	1.73	12.6	13.0	4.15	2.25	1.55	0.7	0.35	
2.0	2.40	10.2	15.9	12.0	2.81	2.20	1.2	0.40	
2.5	1.53	5.36	15.1	13.3	5.88	1.79	0.51	0.26	
3.0	1.49	2.62	5.99	3.74	0.57		0.57		

Note: Two stars, at $M_V \sim -7.5$,$(B-V)_0 \sim 0.0$, are left out.

these objects are fainter than V = 21^m.The faint foreground stars will have colours redder than $(B-V)_0$ = 1$^m_.$0. In the field 6.5, -68 we expect about 2.5 as many interlopers due to the larger field. However, our survey of that field reaches only to M_V = 1$^m_.$75, i.e. V = 20$^m_.$5, so that little contribution by interlopers is to be expected.

Table 4. The distribution of stars (per arcmin^2) in the 6,-67 (pg) field. Corrections for incompleteness have been applied

	$(B-V)_0$								
	−0.4	−0.2	0.0	0.2	0.4	0.6	0.8	1.0	1.4
	−0.2	0.0	0.2	0.4	0.6	0.8	1.0	1.4	
M_V									
−3.5						0.12		0.12	
−3.0						0.12	0.12	0.12	
−2.5					0.12				0.23
−2.0				0.12	0.12		0.12	0.47	
−1.5			0.12			0.23		0.23	
−1.0		0.12	0.12				0.12	0.47	
−0.5*		0.24				0.24	0.49	0.74	
0.0	0.25	0.38				1.63	2.02	0.25	0.25
0.5	0.38	0.51	0.38	0.13	0.13	1.15	1.78	0.13	
1.0	0.14	1.62	0.80	1.22		1.08	1.08		
1.5	0.15	0.15	4.20	5.64	3.62	1.88	0.15	0.43	
2.0	0.49	0.97	2.44	5.21	3.96	0.17		0.32	

Most of the stars in the colour range $0^m_.3 < (B\text{-}V)_0 < 0^m_.8$ with, apparently, $M_V < -1^m_.0$, i.e. are probably galactic stars. There are 33 such stars in the 6.5,-68 field, 7 in the 6,-67(CCD) and 7 in the N2004 field. Considering the sizes of the fields we conclude that the numbers agree well.

The CMDs show that the 6,-67 and N2004 fields contain a population aged about 0.3–0.5 Gyr but the latter also an appreciably younger population. Both fields have a population aged 1–3 Gyr. The CMD of the N2004 field shows a well defined link between the MS and the red-giant branch (RGB) at about the 1 Gyr isochrone (Fig. 1b). A similar feature may be identified at about the 2 Gyr isochrone but must be considered more uncertain. Also the CMD of the 6,-67 field shows these features but weaker. Recent HST investigations (cf. Gallagher et al. 1996,

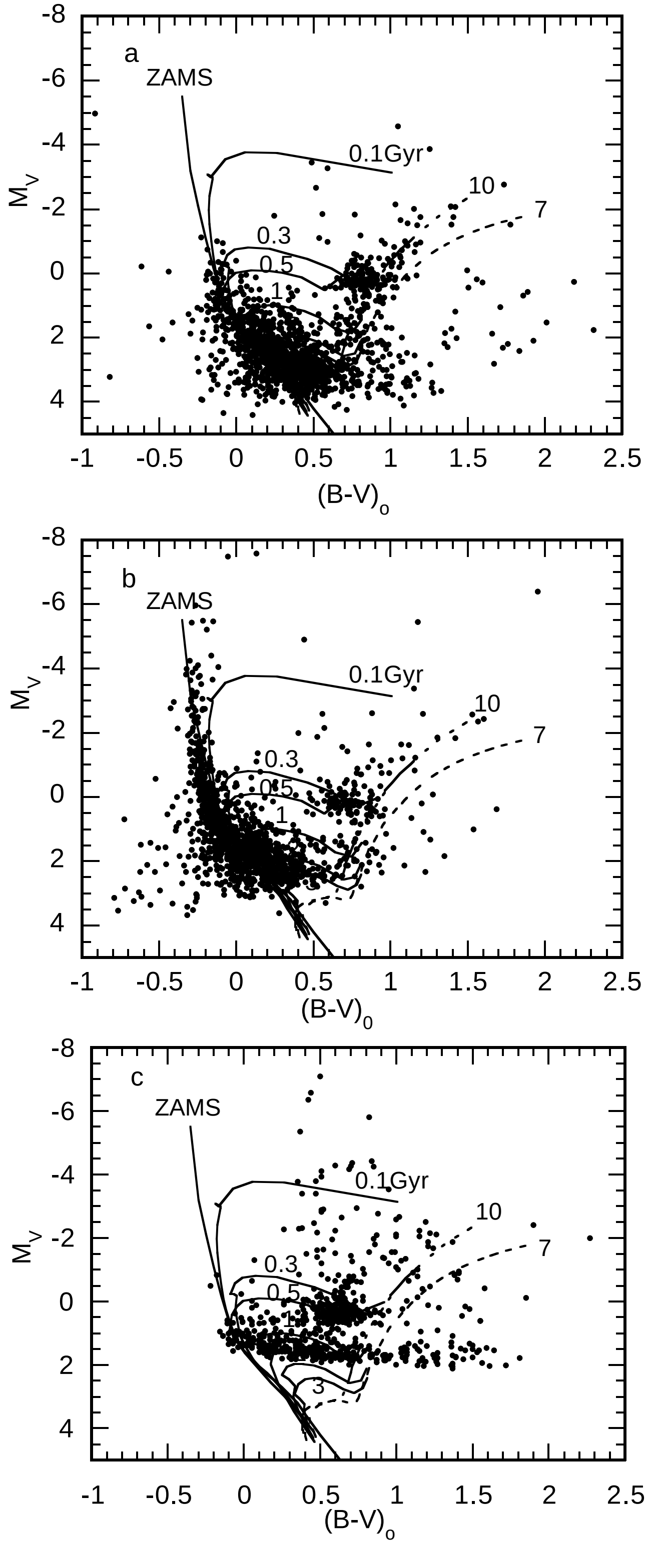

Fig. 1a–c. CM diagrams for **a** the 6,-67 field; **b** the N2004 field and **c** the 6.5,-68 field. The ZAMS, and isochrones for 0.1, 0.3, 0.5,1, 2, 3, 7 and 10 Gyr (see text) are drawn.

Holtzman et al. 1997) find evidence for periods of enhanced star formation at about 2 Gyr ago from similar features, and Elson et al. (1997) find two peaks in their $(V-I)_0$ histograms corresponding to populations of these ages. The 6.5,-68 field has no pronounced young population; there are few MS stars above the 0.5 Gyr isochrone. The sharp cutoff of its MS at about M_V =1.5 and its slope towards the red is caused by the V plates being less deep than the B plates. The distribution of stars is otherwise what may be expected in a LMC field with its position.

A comparison of the N2004 field CMD with that of the NGC2004 cluster shows great similarities (See e.g. Bencivenni et al. 1991, Fig. 5). The ages of the youngest field stars may therefore be taken as about 6 Myr and their zero-age masses as $\sim 20\ M_\odot$.

The turnoff points on the MSs in the 6,-67; N2004 and 6.5,-68 fields are $M_V \sim 0\overset{\rm m}{.}5$, $M_V \sim -4\overset{\rm m}{.}0$ and $M_V \sim 1\overset{\rm m}{.}25$, corresponding to lower ages of 0.3 (Z=0.008), 0.008 (Z = 0.02), and 3.5 (Z=0.001) Gyr, respectively (Bertelli et al.1994). In the CMD of the field 6.5,-68 there are a few blue stars at about $M_V \sim -0\overset{\rm m}{.}75$. They appear more likely to be blue stragglers than MS stars defining the dominating blue field population. If we disregard the stellar sequence identified by the stars with $M_V < -2^{\rm m}$ in the N2004 field a turnoff point corresponding to that in the 6,-67 field may be suggested (see page 389).

Red stars are defined here, in concordance with definitions frequently applied in the literature, as having $(B-V)_0 > 0\overset{\rm m}{.}6$. We have accepted this definition in order to be able to compare our fields with others observed in the LMC.[1] The part of the LF of the RG stars more luminous than the red-giant clumps (RGCs) may then receive some contribution of relatively blue stars; it is strong only in the case of the 6.5,-68 field. Irregularities which may be due to this are evident, e.g. in Fig. 3. The interpretations have to be done with this in mind. The Yale 10 Gyr isochrone follows the RGBs rather well and indicates the existence of a population of about that age. Assuming that the most luminous stars on the red giant branch are AGB stars, the Bertelli et al. (1994) tables, with Z = 0.001, indicate ages of $\sim$10–15 Gyr.

The centres of the RGCs are given in Table 9. In field 6,-67 the area occupied by RGC stars is $0.55 < (B-V)_0 < 0.9$, $-0.3 < M_V < 0.75$, in field N2004 $0.55 < (B-V)_0 < 0.95$, $-0.5 < M_V < 0.95$, and in field 6.5,-68 $0.55 < (B-V)_0 < 0.9$, $-0.3 < M_V < 0.75$.

The populations in our fields are compared with those in other LMC fields below.

Tables 2 and 3 give the counts, reduced to stars per arcmin^2, in the 6,-67 and N2004 fields based on the CCD photometry. Corrections for incompleteness have been applied. They have been determined with the aid of the artificial-star technique available in the ESO MIDAS documentation. An '*' indicates the magnitude from which corrections have been applied. For the 6,-67 and 6.5,-68 fields with photographic photometry (Tables 4 and 5) give the corresponding counts. The 6,-67pg field is larger than the 6,-67 CCD field, but the photometry does not reach as faint. The same corrections for incompleteness have

[1] In some cases the sloping lines drawn to separate blue and red stars in the CDs have to be taken into account; see page 392.

Table 5. The distribution of stars (per arcmin^2) in the 6.5,-68 (pg) field. Corrections for incompleteness have been applied.

	$(B-V)_0$							
	− 0.2	0.0	0.2	0.4	0.6	0.8	1.0	1.4
	0.0	0.2	0.4	0.6	0.8	1.0	1.4	
M_V								
− 6.5				0.06				
− 6.0						0.02		
− 5.5			0.02					
− 5.0								
− 4.5				0.02	0.04	0.02		
− 4.0			0.02	0.06	0.02	0.02		
− 3.5			0.02	0.02				
− 3.0				0.04	0.02	0.02		
− 2.5			0.04	0.02	0.02	0.02	0.06	0.02
− 2.0				0.02		0.12	0.10	0.02
− 1.5		0.02		0.12	0.04	0.10	0.08	0.02
− 1.0	0.02		0.04	0.04	0.10	0.04	0.10	0.04
− 0.5*		0.04		0.08	0.33		0.09	0.02
0.0	0.02	0.06	0.15	0.65	0.69	0.02	0.11	0.06
0.5	0.15	0.22	0.20	0.86	1.48	0.24	0.04	0.04
1.0	0.38	0.54	0.47	0.36	0.11		0.07	
1.5	0.22	0.99	0.94	1.19	0.70	0.36	0.51	0.12

Note: Stars with 0.21 <(B-V)$_0$, $M_V < -4.75$ are not likely members of the LMC.

Table 6. Luminosity function for the 6,-67 field

			lg A(M)		
M_V	MS	Φ	RG	RG(LW55)	M3
− 4.5			− 1.3		
− 4.0			− 1.3		
− 3.5					
− 3 7			− 1.3		
− 2.5					
− 2			− 0.44		− 0.84
− 1.5		− 0.89	− 0.59	− 0.18	− 0.64
− 1.0	− 0.82	− 0.59	− 0.34		− 0.46
− 0.5	− 0.42	− 0.28	0.10	− 0.18	− 0.31
0.0	− 0.05	− 0.01	0.51	0.04	− 0.18
0.5	0.08	0.25	0.43	0.84	0.58
1.0	0.49	0.51	0.06	0.25	0.03
1.5	0.72	0.75	0.11	0.19	0.14
2.0	1.01	0.96	0.31	0.35	0.29
2.5	1.17	1.16	0.22	0.13	0.51
3.0	1.20	1.33	0.63	0.46	0.75
3.5	1.05	1.48	0.82	0.42	

Column 3 gives the general LF normalized to the MS over $-1.0 < M_V < 2.5$. The stellar distribution in M3 is normalized to that in LW55 (see Westerlund et al. 1995, p.52)

Table 7. Luminosity function for the N2004 field

			log A(M)			
M_V	MS	RG	Ψ	Φ	Ψ_1	MS$-\Psi_1$
−6.5		−0.96				
−6.0	−0.96	− 0.66				
− 5.5	− 0.48	− 0.96	− 0.479	−1.010	−0.913	
− 5.0	− 0.96		− 0.080	− 0.613	−0.514	
− 4.5	− 0.66		0.156		− 0.278	
− 4.0	0.05		0.332	− 0.201	− 0.102	
− 3.5	− 0.11	− 0.96	0.466	− 1.321	− 0.032	
− 3.0	0.05	− 0.96	0.607	− 1.008	0.173	
− 2.5	0.33	− 0.25	0.728	− 0.691	0.294	
− 2.0	0.05	− 0.66	0.818	− 0.385	0.384	
− 1.5	0.54	− 0.26	0.907	− 0.084	0.473	−0.292
− 1.0	0.67	0.09	0.988	0.212	0.554	0.061
− 0.5	0.90	0.14	1.059	0.514	0.625	0.575
0.0	0.98	0.78	1.128	0.789	0.694	0.673
0.5	1.19	0.66	1.189	1.049	0.755	0.989
1.0	1.35	0.15	1.244	1.309	0.810	1.200
1.5	1.44	0.35	1.296	1.544	0.862	1.300
2.0	1.61	0.53	1.343	1.758	0.909	1.510
2.5	1.55	0.36	1.387	1.955	0.953	1.420
3.0	1.14	− 0.24	1.430	2.127	0.996	0.594

been used for the two pg fields as for the the 6,-67 field with CCD data.

4. The luminosity functions

Stars are counted as MS stars in the ranges -0.40 – $(B-V)_0$ – 0.00 for M_V¡-1.75; -0.40 – $(B-V)_0$ – 0.20 for -1.75 ¡ M_V < 1.75; and -0.40 – $(B-V)_0$ – 0.40 for $M_V > 1.7$ for the CCD data. For the photographic data a width in $(B-V)_0$ of -0.40 – 0.40 has been accepted for $M_V > -1.75$.

Stars with $M_V > 1.75$ and 0.40 < (B-V)$_0$ < 0.60 fall in between the MS and RG stars. They may belong to the population aged 2 – 4 Gyr or be part of the MS of a younger population.

As mentioned above stars with (B-V)$_0$ > $0.^m6$ are considered as red giants. However, stars with (B-V)$_0$ > $1.^m0$ and with $M_V > 0.^m25$ are assumed to be red dwarfs belonging to our Galaxy (cf. Mateo et al. 1990) and, consequently, not included in the counts.

4.1. The main-sequence luminosity functions

The luminosity functions for the MS and RG stars in the three fields are given in Tables 6, 7, and 8 and shown in Fig. 2a and b.

The population of the N2004 field differs markedly from those of the other fields. (We disregard in this comparison the range of the LF with $M_V > 2$ where the lack of stars may be due to extreme crowding, making the star counts far from complete.) Columns Ψ and Φ in Table 7 give the initial and general Salpeter LFs (Sandage 1957) normalized to the N2004 MS over $-3.5 < M_V < 2$. Evidently no good fit can be obtained between the observed total N2004 MS population and either Ψ or Φ. There is clear evidence of a very young population; the MS reaches $M_V = -5.5$. We identify it by normalizing Ψ to the N2004 MS over $-5.5 < M_V < -1.5$. The result is given in column Ψ_1, Table 7. By subtracting this population from the total, a more ”average-aged” one remains. It is given in column MS$-\Psi_1$ and shown in Fig. 2a as 2004C . The LF Ψ_1 represents the population formed in this region in the most recent burst of star formation.

Table 8. Luminosity functions for the 6,-67(pg) and 6.5,-68 fields

			lg A(M)			
M_V	MS(6)	Φ	MS(6.5)	Φ	RG(6)	RG(6.5)
−3.5					−0.62	
−3.0					−0.44	−1.40
−2.5					−0.64	−0.92
−2.0					−0.23	−0.62
−1.5	−0.92	−1.05	−1.7	−1.30	−0.34	−0.62
−1.0	−0.62	−0.74	−1.22	−1.05	−0.23	−0.55
−0.5	−0.62	−0.46	−1.4	−0.72	0.17	−0.36
0.0	−0.20	−0.17	−0.64	−0.46	0.62	−0.06
0.5	0.10	0.09	−0.23	−0.18	0.47	0.24
1.0	0.19	0.34	0.14	0.07	0.33	−0.96
1.5	0.65	0.58	0.33	0.30	0.31:	0.03
2.0	0.96		0.79			

Note: The Φ is normalized to MS(6,-67) over $-1 < M_V < 1.5$, and to MS(6.5,-68) over $-1.5 < M_V < 1.5$..

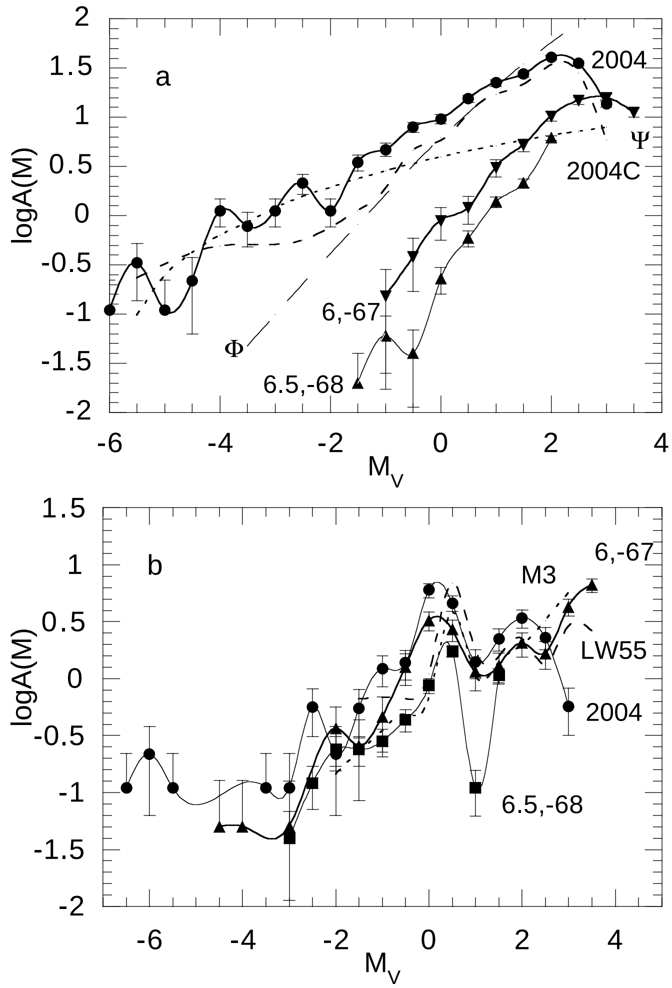

Fig. 2a and b. Differential LFs of the stars in the fields N2004, 6,-67, and 6.5,-68: **a** MS stars. Drawn are also the LFs of the LW55 field and of the "average-aged" population in the N2004 field, 2004C. **b** RG stars. Shown is also the distribution of the stars in the globular cluster M3. Error bars show Poisson sampling errors.

The luminosity functions for the stars in the photographically observed fields are given in Table 8. Columns 2 and 4 give the MSs of the 6,-67 and 6.5,-68 fields, respectively, and columns 3 and 5 the corresponding normalized general LFs. Columns 6 and 7 present the LFs of the red giant stars in the two fields.

The LF of the "average-aged" MS stars in the N2004 field has the same slope for $-1 < M_V < 2$ as that of the MS in 6,-67 (Fig. 2a) and in SL196 and the other average-aged regions studied by Westerlund et al. (1995). This indicates that the evolution of the dominating population has been rather similar over much of the LMC. Also the 6.5,-68 field may have a similar population. Only the LF of the LW55 field, in the SW part of the LMC, shows a steeper slope. Westerlund et al. (1995) noted that agreement with the ϕ function could be reached also for this field by bringing the evolved red giants with $M_V \leq 1\overset{m}{.}75$ and $0\overset{m}{.}41 \leq (B-V)_0 \leq 0\overset{m}{.}80$ back to the main sequence. The main difference between this field and the others is that no (burst of) star formation has occurred to replace the evolved stars in the former.

4.2. The red-giant luminosity functions

Fig. 2b compares the red-giant LFs of the present fields with that observed in the LW55 field and in the galactic globular cluster M3 (cf. Westerlund et al. 1995). The stellar distribution in the 6.5,-68 field does not reach deep enough to permit the identification of a subgiant branch. The scatter of its red giant stars (see Fig. 1c) makes it also difficult to identify a RG branch (RGB). The 6,-67 and N2004 fields contain RGB stars as well as subgiant stars. Their RGBs are most likely composed of Population II stars and younger, more massive objects. In the N2004 field in particular, the younger population(s) may dominate this branch. The slope of their subgiant branches (Fig. 2b) are similar to that of M3. The N2004 subgiant branch is cut off at $M_V \sim 2$, surprisingly early, but probably due to the crowding effect discussed above.

The RGC stars in the LW55 field, with M_V = 0.5±0.25, may be either HB stars or stars aged 2–4 Gyr. In order separate the generations we normalize the M3 LF, representing the oldest generation, to the LW55 subgiant branch. (The same technique will be applied to all other fields, using mostly the range $1 \leq M_V \leq 2$.) The normalized M3 LF is then subtracted from the LF of the RG stars of the field leaving the Population I objects.

The result for the LW55 field is that 2.6 horizontal branch (HB) stars per arcmin^2 and 4.3 RGC stars of younger age exist (Table 13).

The 6,-67 and N2004 fields contain also well defined RGCs which are much wider in M_V than the RGC in the LW55 field and appear to be bimodal (Fig. 2b. This may be seen also in the extents of the RGCs along the M_V axis in the CD diagrams. An analysis of their RGCs, similar to that for the LW55 field, shows two generations of stars: (i) an old one, age $\sim$ 7–10 Gyr; and (ii) an intermediate-aged one, age 0.3–4 Gyr. In the 6,-67 field there are 2.4 stars/arcmin^2 of the oldest type, and 2.8 of

Table 9. The RGCs in the present fields

Field	M_V	σ	$(B-V)_0$	σ	N	$(B-V)_{0,old}$	d_{B-R}
6,-67	0.19	0.34	0.85	0.11	15.2	0.81	0.14
N2004	0.19	0.31	0.74	0.10	9.9	0.74	0.15
6.5,-68	0.31	0.24	0.66	0.08	3.0	0.65	0.24

Note: The numbers, N, are per arcmin^2.

0.3-4 Gyr. In the N2004 field we find 3.6 stars/arcmin^2 of the oldest type, and 5.9 of 0.3-4 Gyr (See Table 12). There are no intermediate-aged subgiants in either field, but a few RGs, more luminous than $M_V = -2.5$ may exist.

Table 9 shows that the mean $(B-V)_0$ of the RGCs of the three fields differ appreciably, being reddest in the 6,-67 field, bluest in the 6.5,-68 field. The latter effect is hardly due to photometric errors. Eleven stars in the CCD sequence fall in the RGC region; they give a mean $(B-V)_0$ of 0.68, σ = 0.079. Possibly, only the oldest (part of the old) generation is present is this outer part of the LMC.

Hatzidimitriou (1991) has found that, for populations older than ∼2 Gyr, the colour difference between the median colour of the RGC and the colour of the RGB at the level of the HB is a good age indicator with the difference increasing with age. This indicator is insensitive to metal abundance for a wide range of metallicities. The stellar populations in our fields 6,-67 and N2004 are, however, dominated by appreciably younger stars. This is shown by the mean M_V of the RGCs (Table 9) and also seen in Fig. 2b. Only in the field 6.5,-68 the older stars may dominate. In order to obtain an age estimate by this calibrator we determine the median colour of the oldest RGC stars by using the stars in the M_V-range 0.5± 0.25. The results are given in Table 9, column 7. For the application of the Hatzidimitriou calibration (1991,Fig. 2) we need $(B-R)_0$ and calculate it as $(B-R)_0 = 1.6(B-V)_0 + 0.16$ (derived from Johnson et al. 1966) at the required level. The differences, d_{B-R}, are given in Table 9, column 8. The average ages of the oldest stars in the 6,-67, N2004 and 6.5,-68 fields are then determined to 4, 5 and 11 Gyr, respectively. The uncertainty in these values is considerable, due to the difficulty in defining the RGB accurately.

Application of the Mateo and Hodge (1985) relation between M_V and $(B-V)_{0,g}$, as displayed in their Fig. 7, gives mean ages of ∼0.4 Gyr for the Population I red stars in fields 6,-67 and N2004. This is about the same age as derived above with the aid of isochrones for the average-aged populations in the two fields.

5. Comparison of the stellar distribution in the present fields with those in other LMC fields

As mentioned in the Introduction several studies of the stellar distribution in LMC fields are now available. We compare here our present results with others; the fields concerned are listed in Table 10. Our data, with intervals in M_V of 0.5 mag, are presented in Fig. 2a and b; those from counts in six other fields, using 0.4 mag, in Fig. 5 and Fig. 3 for MS and RG stars, respectively. The observed structures are, evidently, independent of the magnitude intervals chosen.

Table 10. LMC fields used in comparing LFs

Field	RA	Decl	Distance	Reference
LMC-30	$4^h59\overset{m}{.}6$	$-68\overset{\circ}{.}3$	2°W	Vallenari et al. 96b
LMC-45	$5^h25\overset{m}{.}5$	$-67\overset{\circ}{.}3$	2°NNE	Vallenari et al. 96b
LMC-56	$5^h44\overset{m}{.}2$	$-72\overset{\circ}{.}1$	3°SE	Vallenari et al. 96a
LMC-61	$5^h53\overset{m}{.}2$	$-68\overset{\circ}{.}2$	3°NE	Vallenari et al. 96b
LMC-69	$6^h05\overset{m}{.}4$	$-68\overset{\circ}{.}1$	4°NE	Vallenari et al. 96a
NGC1783	$4^h58\overset{m}{.}1$	$-66\overset{\circ}{.}0$	$4\overset{\circ}{.}5$ NW	Bertelli et al. 92
NGC1866	$5^h13\overset{m}{.}4$	$-65\overset{\circ}{.}5$	$4\overset{\circ}{.}4$ N	Bertelli et al. 92
NGC2155	$5^h58\overset{m}{.}1$	$-65\overset{\circ}{.}5$	$5\overset{\circ}{.}5$ NE	Bertelli et al. 92
SL196	$5^h03\overset{m}{.}8$	$-65\overset{\circ}{.}8$	$4\overset{\circ}{.}4$ NW	Westerlund et al. 95
NW reg.	$5^h02\overset{m}{.}5$	$-65\overset{\circ}{.}8$	$4\overset{\circ}{.}4$ NW	Westerlund et al. 95
LW55	$4^h45\overset{m}{.}6$	$-73\overset{\circ}{.}4$	$4\overset{\circ}{.}7$ SW	Westerlund et al. 95

Note: The values for the 'NW region' are mean values of four fields (See Westerlund et al. 1995). The photometric zero-points are determined by photoelectric standards in the 'NGC fields'; in the other cases they are based on CCD transfers.

Before constructing Fig. 5 and Fig. 3 we have applied certain corrections to some published data. They are based on a comparison of of the LFs of the RG populations in the fields listed in Table 10 and those shown in Fig. 2b. Many similarities between the fields exist as well as appreciable differences. Their subgiant branches do all run virtually parallel to that of M3. Thus, as there are Population II stars in all the fields, HB peaks might exist in their luminosity functions. In the case of the fields N2004 and 6,-67 (see Fig. 2b) there is a clear increase in stellar numbers at M_V = 0.5 mag, corresponding to the M3 peak. This indicates a Population II contribution in the fields.

In the LFs of the RG stars in all the other fields with bimodal RGCs, the positions of the RGCs differ widely.This may be caused (i) by what may be called astrophysical reasons, (ii) by zero-point differences in the photometry, or (iii) by the applied reddening corrections.

In case (i) the positions of the fields along the lines-of-sight, i.e.differences in distances, may have some effect. However, it appears unlikely that a sufficiently strong difference can be found that way. Evolutionary effects are likely to contribute to the composition of the RGCs, but the Population II peak ought to be identifiable independent of the shape of the more luminous side.

(ii) If zero-point differences in the photometry are responsible for the discrepancies they have to be of the order of 0.2–0.5 mag. Even if some differences certainly exist, we consider it rather unlikely that they will exceed 0.2 mag (cf. page 386).

(iii) The amount of reddening in the various parts of the LMC is rather unknown. Reddening corrections may therefore frequently be erroneous and thus cause discrepancies. We have assumed that the RGC of the N2004 field is correctly positioned (Fig. 4d) and shifted the RGCs of all other fields to that position. This is achieved by increasing E_{B-V} with 0.07–0.15 mag in most other fields, and the A_V correspondingly. Support for differences in the reddening may be found in the $(B-V)_0$ values of the RGCs (Table 11). However, the widths of the clumps in

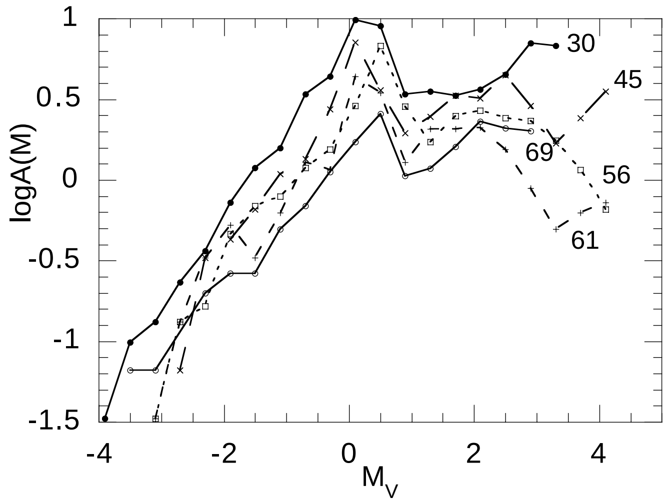

Fig. 3. A comparison of the differential LFs of the RG stars. Completeness factors have been applied to the star counts and the M_Vs have been corrected as discussed in the text.

Table 11. The RGC in the fields. Reddening corrections (see text) have been applied

Field	M_V	$(B-V)_0$	N	Field	M_V	$(B-V)_0$	N
N2004	0.19	0.74	9.9	N1783	0.30	0.75	7.9
LMC-30	0.25	0.75	18.8	N1866	0.30	0.80	6.5
LMC-45	0.10	0.68	13.5	N2155	0.55	0.85	4.6
LMC-61	0.20	0.73	7.9	LW55	0.50	0.90	8.3
LMC-56	0.50	0.75	12.4	NW	0.25	0.80	9.7
LMC-69	0.50	0.72	4.3				

$(B-V)_0$, and, consequently, of their mean values are determined by their stellar compositions: either HB stars or more massive stars will dominate, causing different centroids.

In order to make the RGC peaks of the bimodal fields coincide with that of N2004 (see Fig. 3) we have applied the following corrections in M_V: to LMC30, 45, 61 -0.5; to LMC56, 69 -0.3; and to N2155, N2004, 6,-67, NW field, LW55 0.0. In the case of the fields with one-peaked RGCs, LMC-56, LMC-69 and N2155, their peaks are shifted to $M_V = 0.5$ and agree thus in position with that of M3.

5.1. The red-giant luminosity functions

As noted above the subgiant branches in all the fields run virtually parallel to that of M3, for $1 < M_V < 2$. Also the RGBs are reasonably similar. Some contribution of more luminous red stars is evident in the N2004 field and may be suspected in some of the other fields. The only pronounced differences are seen in the RGCs as just discussed. They indicate that the age compositions of the fields may differ appreciably.

The total number of RGC stars in the fields under discussion are given in Table 11. Four of the fields, LMC-30, LMC-45, LMC-56 and the NW field, are as rich as or richer in RGC stars than our field N2004. The fields LMC-69 and N2155 have very few stars. The N2155 field is far from the centre of the LMC, in opposite direction to the LW55 field. The latter field is relatively rich in Population II stars (cf. Westerlund et al. 1995). The remaining fields, including N2004, show similar numbers, averaging 8.4 $\pm$ 0.5 stars/arcmin^2.

As noted above there are significant differences between the RGCs of the fields as regards their extent in M_V. A bimodal RGC structure is seen in the fields N2004, 6,-67 (Fig. 2b), LMC-30 and LMC 61 (Fig. 3), the NW region (see Westerlund et al. 1995), and probably also in LMC-45, though it may be hidden by the richness of its red Population I. Only the RGC of the LW55 field is as narrow as that of M3, but richer, and covers over one magnitude in M_V. The RGCs of the fields, LMC-56, LMC-69 and N2155 (see below) show pronounced peaks of M3-type. They extend, however, over a larger range in magnitude towards higher luminosities, indicating a contribution of Population I stars.

Under the assumption that the secondary, or only, RGC peak, at about $M_V = 0.5$, coincides in position with the M3 HB peak the Population I RG stars may be separated from the Population II stars as done above in the case of our fields .

The elimination of the oldest population with the aid of the M3 LF is illustrated in Fig. 4a–f for our fields. Most of the other fields show similar distributions with more or less the same widths of the remaining RGCs. The overall decline in faint red stars at about $M_V = 2$ is most likely due to the incompleteness of the material at that magnitude. The outlying fields LW55, LMC-69 and N2155 have peaks remaining at $M_V = 0.5$. They contain few if any Population I objects. The fields near or in star-forming regions (LMC-30, LMC-45, the NW field and N2004) show pronounced luminous extensions of the RGCs towards higher luminosities (Fig. 3). They may be related to the blue extension discussed by Mateo and Hodge (1987) for the LMC cluster LW79 but may equally well be luminous evolved stars.

On the low-luminosity side of the RGC the effects of " the sloping-line separation of red stars" can be seen (see page 388): at V = 21: stars with $(B-V)_0 > 0.8$ are counted as red in the LMC-30 field, whereas in the LMC-45 field this occurs for $(B-V)_0 > 0.5$ (see Vallenari et al.1996b). Possibly for this reason LMC-45 shows a comparatively large surplus of faint red stars. In our fields the borderline goes at $(B-V)_0 = 0.6$.

The RGC stars remaining after subtraction of the Population II contribution (NII) (see page 389) are those $\sim$ 0.5 mag more luminous (NI), 0.3–4 Gyr old. Their numbers and given in Table 12 together with the RG stars in the interval $-2.5 < M_V < -0.5$. All the fields, except N2155, have 2.4–3.6 Population II stars/arcmin^2. The intermediate-age population is richest in the central regions, with LMC-30 appreciably richer than the others. Population I red giants are scarce in all fields except LMC-30 and LMC-45.

There is an indication of a subgiant branch in some of the fields even after subtraction of the M3 population-type. This supports the existence of a 2–4 Gyr old population in those fields, i.e. in LMC-30, LMC-45, and possibly LMC-61. In all

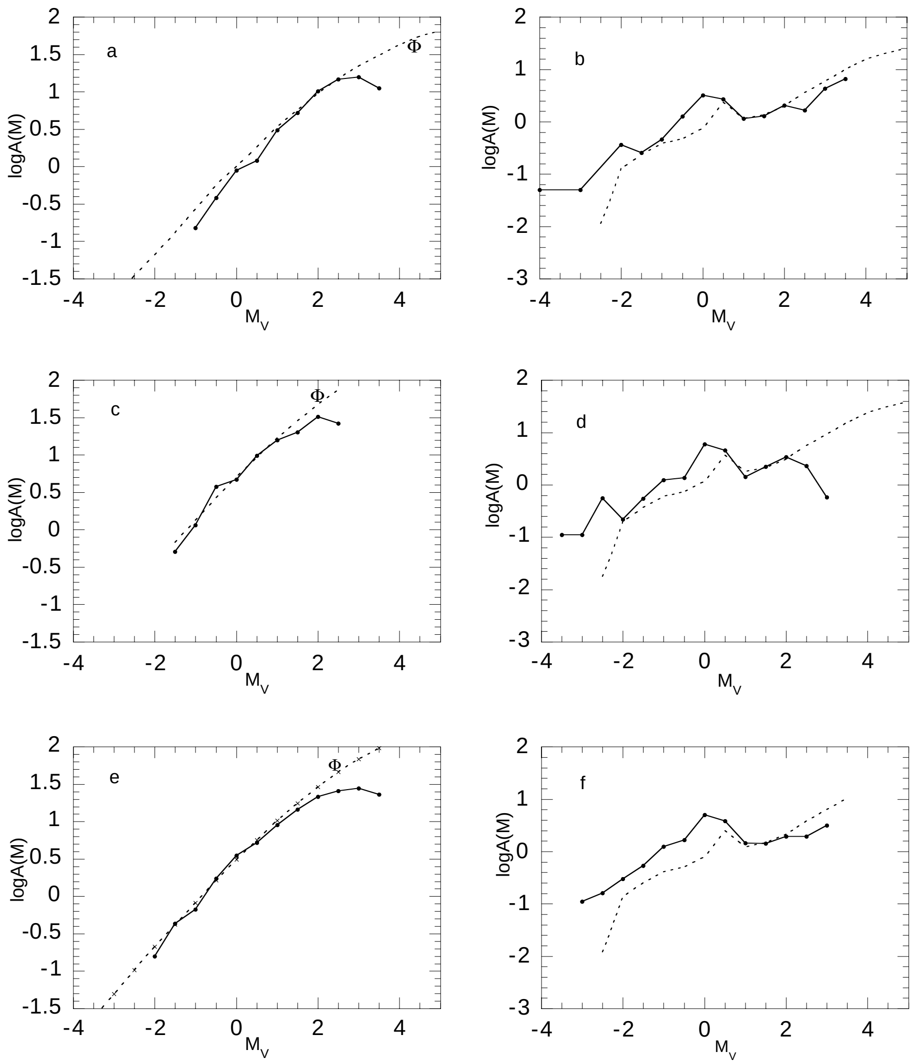

Fig. 4a–f. The luminosity functions of MS and RG stars in fields 6,-67 (**a**, **b**), N2004 (**c**, **d**) and NW (**e**, **f**). The GLF (Φ) is normalized to the MS LFs (**a**, **c**, **e**) and the M3LF (dashed) to the RG LFs (**b**, **d**, **f**); see the text.

Table 12. The numbers, N/arcmin^2, of the oldest (II), 0.3-4 Gyr old (I) and RG stars in the fields

Field	N(II)	N(I)	N(RG)	Field	N(II)	N(I)	N(RG)
LMC-30	3.5	14.2	9.2	6,-67	2.4	2.8	1.1
LMC-45	3.6	6.0	4.1	LMC-56	3.7	4.8	2.2
N2004	3.6	5.9	1.5	LMC-69	2.5	1.0	1.3
NW field	2.5	5.3	2.6	N2155	1.1	2.3	1.0
LMC-61	2.9	4.0	2.2	LW55	2.6	4.6	0.5

Note: Columns N(RG) give the number of Population I red giants with $-2.5 < M_V < -0.5$.

Table 13. The numbers, N/arcmin^2, of the oldest red giant stars as read from the normalized M3-population curves for $-2.5 < M_V < 3.5$ in the fields under comparison

Field	N	Field	N	Field	N
LMC-30	38.8	LMC-61	32.3	LMC-69	27.4
LMC-45	39.8	6,-67	28.3	LW55	31.8
N2004	44.2	NW field	30.2	N2155	24.4
LMC-56	41.0				
Mean:	41.0		30.3		27.9
σ	2.3		2.0		3.7

the others the red stars remaining after subtraction o the M3-type population will be younger than 1 Gyr.

It is interesting to compare these data with those in Table 14 where the numbers of MS stars at M_V = 1 are given. This is at about the magnitude where the 0.3 Gyr isochrone leaves the ZAMS so that these stars may eventually reach the RGC region in the HR diagram. Stars being initially more massive have to a great extent already left the MS.

We determine the number of Population II stars in the fields with the aid of the normalized M3 distribution curves independently for each field. The result (Table 13) shows a rather reasonable distribution over the LMC: The centrally situated fields (d$\leq 2\overset{\circ}{.}5$), column 1 in Table 13, have $\sim$ 40 stars/arcmin^2, those further out $\sim$30 or less.

5.2. The main-sequence luminosity functions

There are no significant features to use in a comparison of the LFs of the various fields so that the discrepancies caused by the reddening effects and seen between the RG luminosity functions are difficult to detect. The richness of the fields is the dominating separating factor. A decrease in M_V of about 0.2–0.5 mag has, however, noticeable effects on the internal positions of the MS LFs (cf. Fig. 5).

The stellar MS luminosity functions have the same slopes in nearly all the fields for $M_V > -2^m$; for the N2004 field this is true when the youngest population has been subtracted (Fig. 2a and Fig. 5). An appreciably steeper slope is seen in the LW55 field, the only field in this sample far out in the SW part of the LMC. Not plotted are the NGC1866 and 1783 fields; their LFs fall between those of NGC1787 and LMC-30 (See Fig. 14a in Westerlund et al. 1995). The LF of LMC-30 (Fig. 5) is also very similar to that of the LS196 field. The LFs of the other fields, shown in Fig. 5, agree in shape and position particularly well for $M_V > 0\overset{m}{.}5$. This is from about the luminosity of the RGCs. Differences seen at higher luminosities may be related to the positions of the fields in the LMC.

A further measure of the MS populations in the field is obtained by counting the number of stars at $M_V = 1^m \pm 0.25$ (Table 14). The MS population is richest in the LMC-30 field with those of N2004 (youngest population subtracted) and N1787 following. The numbers decrease from 16.4 stars/arcmin^2 in LMC-30 to 0.2 in the LW55 field. The richness of a field does not depend on its distance from the LMC centre, only, but also on its evolutionary history. The first four fields in the Table show an excess of luminous stars .They are all in or close to regions with evidence of recent bursts of star formation; the difference between the N1787 and SL196 fields is caused by the former being closer to such a region. LMC-45 is at the western border of the star forming region SGS LMC-4, N2004 is on its southern part.

5.3. Further discussion of field star luminosity functions

The assumptions applied in Salpeter's work (1955) on the initial and general luminosity functions are (a) the rate of formation of stars in the solar neighbourhood has been uniform since the beginning of the Galaxy, and (b) all stars leave the main sequence after a certain characteristic time when about 7 per cent of the hydrogen has been changed into helium. This time varies with mass and luminosity. In the LMC (a) does most likely not apply: A series of bursts of star formation has led to the formation of a number of more or less well defined generations. Each generation will have had its ILF develop into a GLF following the assumption in (b). There will be certain periods when no new stellar generations are formed; consequently the aging generation will lose stars without replacement. Thus, when the most recent ($\leq$0.01 Gyr) and the oldest ($\geq$7 Gyr) are identified and subtracted from the total population of a field, there remains an average-aged population ($\simeq$ 0.3–4 Gyr). It is tempting to attempt to identify in the latter also the generations younger and older than about 1.5 Gyr,but we refrain from it. There are problems already in identifying a population aged $\simeq$ 2–4 Gyr in the CM diagrams. The low numbers of Population I subgiant stars speaks against the existence of a strong component of that age in the LMC..

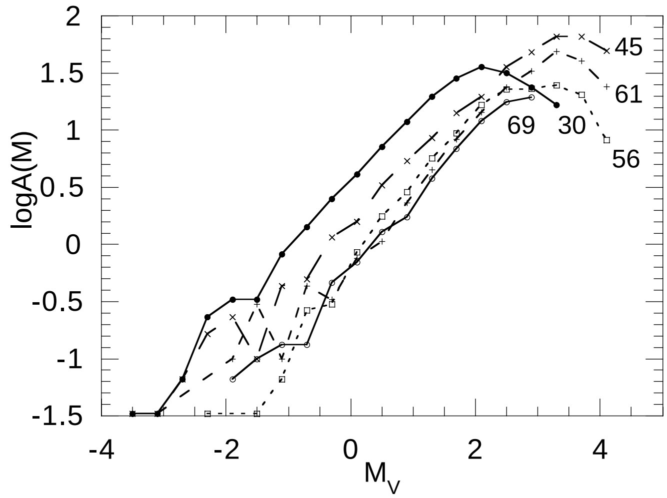

Fig. 5. A comparison of the differential LFs of the MS stars in the fields identified in the figure. The M_Vs are calculated using colour excesses and distances as given in the literature and completeness factors have been applied to the star counts.

In the N2004 field the a very young generation is easily identified (see page 389). It is still young enough to be identified with the ILF; its most luminous stars are still on or very near the ZAMS. Its subtraction from the total MS population leaves an average-aged population very similar to that in the LS196 field (Westerlund et al. 1995).

The LFs of our field N2004, with the youngest generation subtracted, and 6,-67 are compared in Fig. 6 with recent HST results. The difference in logA(M) between the two investigations of the NGC1866 field is probably caused by the reduction of the numbers of stars read in the Holtzman et al. LF diagram to stars per arcmin^2; we have assumed that the field is about 5 arcmin^2 as given by Gallagher et al.(1996) and this may not be accurate enough.

All the LFs except that of the N2004 field run parallel from about $M_V = -1$ over the range of reliability ascribed to the various fields and follow the shape of the GLF well. The numbers of MS stars at M_V = 1 are 5.9 and 6.8 per arcmin^2 in the Stappers et al. and Elson et al. fields, respectively. A comparison with the data in Table 14 shows that both fields, the NGC1866 field, at $4\overset{\circ}{.}4$ N of the LMC centre and the Elson field at $5^h36\overset{m}{.}6, -69°25\overset{\prime}{.}6, \sim 1\overset{\circ}{.}5$ SE of it, have about the number of stars to be expected considering their positions. Towards the SE the numbers seem to fall off more rapidly than towards the North.

6. The masses of Populations I and II in the LMC

We have used the structures of the RGCs to determine the composition of the red population in the fields. By assuming that

Table 14. Number of MS stars per arcmin^2 at $M_V = 1\overset{m}{.}0$ in the LMC fields

Field	N	D	Field	N	D	Field	N	D
N2004corr	15.8	2.5NE	LMC-45	7.4	2NE	LMC-69	2.4	4NE
LMC-30	16.4	2W	LMC-56	4.0	3SE	N2155	1.6	5.5 NE
N1787	10.0	4.4NW	LMC-61	3.2	3NE	6.5,-68	1.4	7NE
SL196	8.0	4.4NW	6,-67	3.0	4NE	LW55	0.2	4.7SW

Note: D = distance from the centre of the LMC in degrees. Corrections for bandwidths have been applied (to ±0.25)

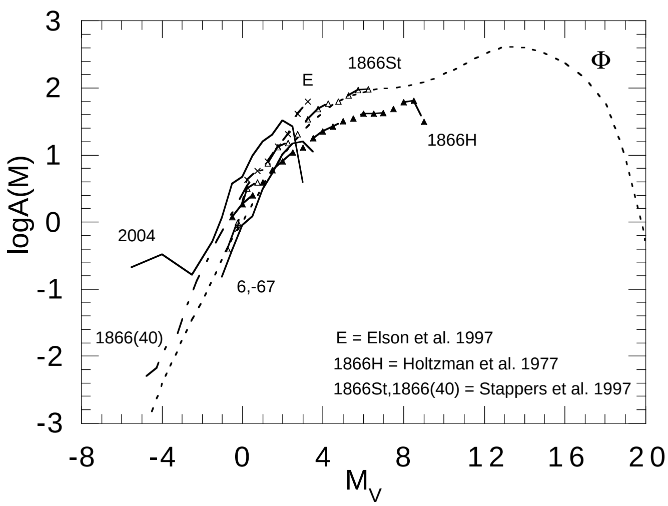

Fig. 6. A comparison of the differential LFs of the MS stars in the fields identified in the figure. "2004" represents here the N2004 population with the youngest population subtracted. The GLF (Φ) is normalized to the 6,-67 LF (see text).

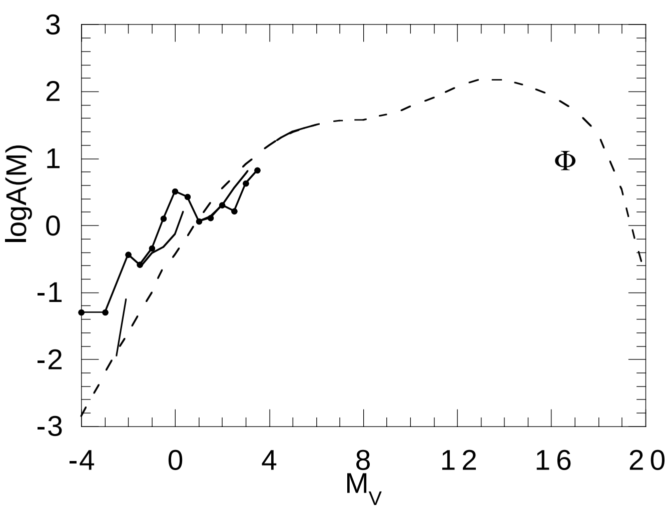

Fig. 7. The numbers of stars of Population II in the 6,-67 field after extrapolation as described in the text.

the M3 luminosity curve represents the differential distribution of Population II stars over the range $-2.5 <$M$_V$ < 6, i.e. that the number of HB stars is proportional to those in the subgiant branch independent of their colour, we have identified that population in all the fields. Subtracting it from the red field population leaves a Population I component, the age of which is 0.3 Gyr and older. We have also, following Sandage (1957) extended the normalized M3 curve with the aid of the GLF, reaching $M_V = 19$.

We use the field 6,-67 as most representative of our fields of the general LMC population, undisturbed by recent star formation. The resulting curve is shown in Fig. 7. Integrating under the curve gives the total number of stars in the one arcmin^2 area. Similarly, we use the GLF, normalized to the MS LF of the field, to determine the number of stars in its intermediate-age population (See Fig. 6). These estimates may be turned into estimates of the total masses of the two Populations. For the Population II we take the masses from Green et al. (1987, 10 Gyr, Z=0.001, Y = 0.30) for $M_V \leq 8$ and from Schmidt-Kaler (1982) for $8.5 \leq M_V \leq 19$. The result is 403 $M_\odot$/arcmin^2. In this field the number of Population II stars is about 3/4 of that in the inner regions, ∼50 deg^2. (See above). The total Population II mass in the LMC, assuming a total area of 100 deg^2, is then $1.7\times10^8 M_\odot$. Adding still fainter objects and white dwarfs will increase this mass by ∼ 25 %. This mass, 2.1×10^8, may be compared with the "halo" mass of $3.8\times10^8 M_\odot$ derived by Frogel (1984) from the RR Lyrae stars.

The mass of the Population I stars in the 6,-67 field is determined from the normalized GLF curve, using masses from Vandenberg (1985) (0,3 Gyr, 0,0169). The mass is 1131 $M_\odot$ per arcmin^2. The 6,-67 field may also for this population represent a more peripheral population; there are two to five times as many Population I stars in the inner fields (Table 14). A conservative estimate of the total mass may then be $3 \times 1131 \times 50 \times 3600\ M_\odot \simeq 6\times10^8 M_\odot$ or, with a correction similar to that for Population II, $7.5\times10^8 M_\odot$. This is about three times the mass of the Population II stars.

7. Conclusions

Most of the fields of the LMC discussed here have similar compositions. All of them have main-sequence luminosity functions with the same slope; the slope agrees well with that of the standard GLF[2].The ages of the populations involved are 0.3 Gyr and older. Star formation events at ∼ 1 and 2 Gyr ago are seen in several fields, including the present ones. Extreme Population I appears in the N2004 field and may be traced also in the LMC-30, LMC-45 and LMC-61 fields. As shown in a previous paper the LW55 field has a much steeper MS LF than the others with that of the NGC2155 field approaching it in steepness.The

[2] In certain fields agreement with the GLF is achieved after application of corrections for extreme populations as discussed above

Table A1. Comparison of CCD and pg data for the 6,−67 field. ($\Delta(B-V)_0$ = CCD − pg; numbers of stars per arcmin^2)

	$\Delta(B-V)_0$								
	−0.4 −0.2	−0.2 0.0	0.0 0.2	0.2 0.4	0.4 0.6	0.6 0.8	0.8 1.0	1.0 1.2	1.4
M_V									
−4.5							0.05		
−4.0							0.05		
−3.5					0.10	−0.12		−0.12	
−3.0						−0.12	−0.12	−0.12	0.05
−2.5					−0.07				−0.23
−2.0				−0.07	−0.07	0.05	−0.12	−0.27	0.10
−1.5			−0.12			−0.23		−0.03	0.05
−1.0	0.05	−0.02	−0.12		0.10	0.05		−0.17	
−0.5		0.14				0.20	−0.05	−0.36	
0.0	−0.25	0.29	0.22			−0.80	−0.02	0.08	−0.14
0.5	−0.38	0.35	−0.04	0.10	−0.02	−0.02	−0.12	−0.02	0.29
1.0	−0.02	0.08	0.59	−0.49		−0.66	−0.35	0.06	0.12
1.5	−0.02	1.71	−0.86	−3.97	−3.3	−0.92	0.17	−0.3	0.06
2.0	−0.27	−0.17	2.26	−0.51	2.73	0.91	0.94	−0.10	0.36

former field shows a pronounced lack of Population I stars. Its stellar density at $M_V = 1^m$ is a factor of 7 less than in the outlying fields on the NE side and about 80 times less than in the N2004 field even after subtraction of the youngest population in the latter. The age of its dominating population is $\geq$ 1.4 Gyr.

We have used the bimodal nature of the RGCs to identify the Population I and II components. Assuming that the stellar luminosity function of the galactic globular cluster M3 describes the differential distribution of the LMC Population II, we have derived the Population II mass in the 6,-67 field, and, thereupon the total mass of that Population in the LMC. In a similar way, using the normalized general luminosity function, we have determined the mass of the intermediate-age Population I in the LMC. The result is 2 and $7.5\times10^8 M_\odot$, respectively, meaning that the bursts of star formation which occurred between $\sim$4 Gyr and $\sim$0.3 Gyr ago were nearly four times as productive as the initial star formation.

It is important to underline the fact that reddening corrections play an important role in interpreting the data.

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Appendix A: comparison of the CCD and pg results for the 6,−67 field

A comparison of the results drawn from a small CCD field and a larger pg field is of some interest as it may reveal effects due to the sizes of the fields as well as the photometrically higher accuracy of the CCD observations.

Table A1 presents the difference in number of stars per colour interval for the covered range in M_V. Generally, the differences are small. As the scatter in both coordinates is larger in the pg data, larger intervals in magnitude and colour will diminish the deviations appreciably. We derive this in determining the luminosity functions for the MS and RG stars, separately. The results are shown in Fig. A1. For the pg data Poisson sampling

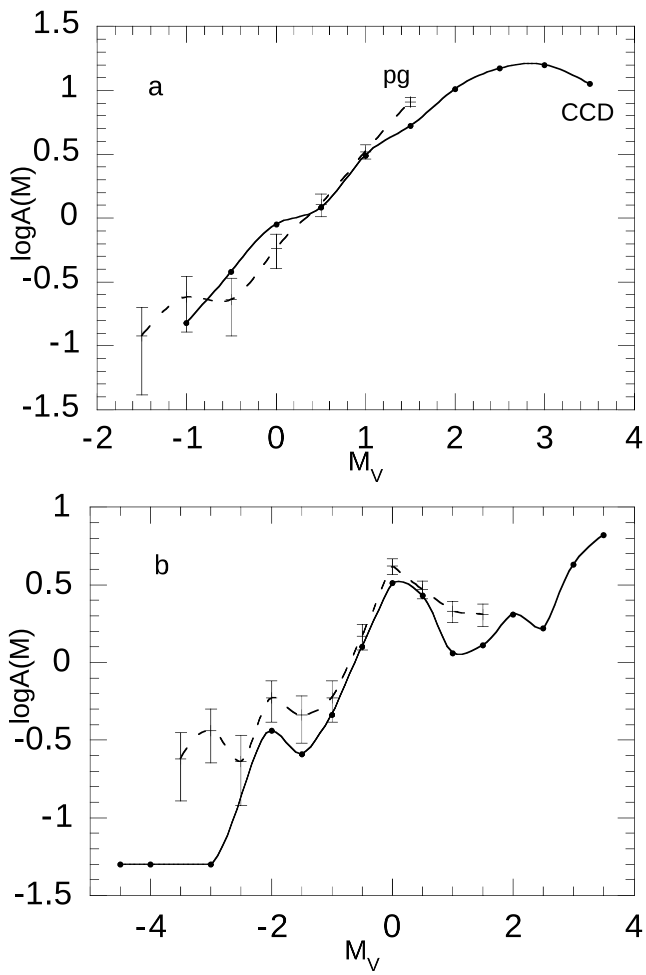

Fig. A1a and b. Comparison of the LFs derived from CCD (fulldrawn) and pg (dashed) observations in the 6,−67 field. **a** MS stars, **b** RG stars.

error bars are given. The curves agree sufficiently well for pg data to be acceptable over the ranges plotted in the figure.

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