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A Census of the Most Luminous Stars. I. The Upper HR Diagram for the Large Magellanic Cloud

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Abstract

Spectral classification and multiwavelength photometry for the most luminous stars in the LMC has greatly increased due to several recent surveys for both the hottest and coolest members. Combining data from these spectroscopic and photometric surveys, we have created catalogs based on their spectral classifications of the different groups: the luminous O and B stars, the A-type supergiants, and the evolved yellow and red supergiants. We derive their stellar parameters based on spectroscopic characteristics, and discuss the problems with extinction in crowded fields and the role of binarity on selected stars. Based on these surveys, we present the upper HR diagram representative of the LMC massive star population greater than 20 $M_{\odot}$.

Unified Astronomy Thesaurus concepts: Massive stars (732); Large Magellanic Cloud (903)

Supporting material: machine-readable tables

1. Introduction

The most luminous and massive stars and the final stages in their evolution are critical for our understanding of supernovae and the subsequent enrichment of the interstellar medium, the formation of neutron stars and black holes, and the "first stars." The upper HR diagram is complicated. Stars with the same luminosity and temperature can have very different mass loss histories and evolutionary states. Mass loss including nonterminal giant eruptions can determine their final fate. The relationships among various groups of evolved and mass losing stars such as luminous blue variables (LBVs), B[e] supergiants, Wolf Rayet stars, and the hypergiants requires an enhanced census of the upper HR diagram. Unfortunately, the initial mass function limits the number of very massive stars, so that studies of individual star clusters yield small samples in only the youngest clusters. In our own galaxy the sample is also incomplete, limited by interstellar extinction and uncertainty in distances over the full extent of the Galactic disk even with the advantages of Gaia.

Alternatively, star-forming galaxies in the Local Group provide more complete samples of luminous star populations with all the stars essentially at the same distance. Recent photometric surveys (Massey 2002; Zaritsky et al. 2004; Evans et al. 2011) and GAIA DR3 (Gaia Collaboration et al. 2023) have established rich photometric database for the Large Magellanic Cloud (LMC). But HR diagrams for the LMC constructed from photometry alone cannot always differentiate foreground stars from members of the LMC and recognize emission line stars. They can also exclude stars with exceptional extinction or other properties. Selecting stars by spectral type combined with multiwavelength photometry ensures more accurate identification and determination of effective temperature and extinction for individual targets. Also, many past surveys have excluded the Tarantula nebula due to extreme crowding and high/uncertain extinction but now the VTFS survey (Evans et al. 2011) addresses many of those limitations so those stars can be included in a full census of the LMC.

In this study, we combine photometric and spectroscopic surveys of the LMC to produce a *spectroscopically*-selected HR diagram of stars more massive than 20 $M_{\odot}$. By relying on spectral identification and focusing on the most luminous stars (brighter than Log($L_{\odot}$) >4.7), significant foreground contamination should be limited in all but the coolest and latest spectral types. In the next two sections we describe the selection of the OBA-type stars, and discuss the yellow supergiants (YSGs) and red supergiants (RSGs). The extinction and luminosity are determined for each star relying on the spectral type and recent calibrations. The effects of strong spectral emission, crowding and binarity are also considered. The HR diagram is presented and discussed in the final section.

2. OBA-type Star Selection

Stars of spectral type A8 and earlier were selected based on the classifications of Ardeberg et al. (1972), Brunet et al. (1975), Walborn (1977), Rousseau et al. (1978), Crampton (1979), Conti et al. (1986), Fitzpatrick (1988), Parker & Garmany (1993), Massey et al. (1995, 2000), and Jaxon et al. (2001). Early large-scale spectral surveys were favored for their accuracy and uniformity. Several of them required careful curation because they are not available in machine-readable form with accurate positions. Additional stars were selected from the VLT-FLAMES Tarantula Survey (Walborn et al. 2014) and by crossmatching Zaritsky et al. (2004)[3] with spectral types in SIMBAD (Wenger et al. 2000).[4] Special classes of hot luminous stars (i.e., luminous blue variables and B[e] supergiants) are *excluded from the catalog*.

Johnson UBV photometry was obtained primarily from Massey (2002), Brunet et al. (1975), Rousseau et al. (1978), Conti et al. (1986), Parker & Garmany (1993), or Evans et al. (2011). In the absence of photometry from those sources Zaritsky et al. (2004) was used (see Appendix). When there

[3] In Appendix we discuss the development of a necessary correction to the *U*-band photometry in the Zaritsky et al. (2004) catalog.
[4] Sources cited by SIMBAD are given in Table 12.

Table 1
Adopted Values by Spectral Type

Sp. Type	$(B-V)_0$	Log($T_{\rm eff}$)	B.C (mags)	Sp. Type	Log($T_{\rm eff}$)	B.C (mags)
	Supergiants (I)				Giants (III)	
O3	−0.33	4.626	−3.87	O3	4.647	−4.03
O4	−0.33	4.607	−3.74	O4	4.628	−3.88
O5	−0.32	4.587	−3.61	O5	4.605	−3.73
O6	−0.31	4.566	−3.46	O6	4.582	−3.57
O7	−0.29	4.544	−3.31	O7	4.557	−3.40
O8	−0.29	4.521	−3.16	O8	4.531	−3.23
O9	−0.28	4.496	−2.99	O9	4.503	−3.04
O9.5	−0.27	4.484	−2.91	O9.5	4.488	−2.94
O9.7	−0.26	4.469	−2.82	O9.7	4.452	−2.73
B0	−0.25	4.454	−2.74	B0	4.418	−2.52
B0.2	−0.23	4.427	−2.58	B0.2	4.386	−2.34
B0.5	−0.21	4.377	−2.29	B0.5	4.356	−2.18
B0.7	−0.20	4.331	−2.05	B0.7	4.328	−2.03
B1	−0.18	4.309	−1.93	B1	4.301	−1.89
B1.5	−0.17	4.287	−1.82	B1.5	4.275	−1.76
B2	−0.16	4.247	−1.62	B2	4.229	−1.53
B2.5	−0.14	4.228	−1.52	B2.5	4.208	−1.41
B3	−0.12	4.209	−1.42	B3	4.188	−1.31
B4	−0.11	4.174	−1.23		————	
B5	−0.08	4.127	−0.96		Dwarfs (V)	
B6	−0.06	4.100	−0.80		————	
B7	−0.05	4.071	−0.64	O3	4.652	−4.05
B8	−0.03	4.040	−0.46	O4	4.632	−3.91
B9	−0.02	4.013	−0.31	O5	4.611	−3.77
B9.5	0.00	3.992	−0.21	O6	4.590	−3.62
A0	0.02	3.978	−0.15	O7	4.567	−3.47
A2	0.05	3.965	−0.10	O8	4.543	−3.03
A5	0.10	3.929	0.00	O9	4.517	−3.13
A8	0.14	3.913	0.02	O9.5	4.504	−3.04
F0	0.16	3.895	0.03	O9.7	4.488	−2.97
F2	0.20	3.874	0.03	B0	4.452	−2.73
F5	0.26	3.845	0.03	B0.2	4.418	−2.52
F8	0.37	3.813	0.01	B0.5	4.386	−2.34
G0	0.55	3.778	−0.04	B0.7	4.356	−2.18
G2	0.63	3.764	−0.07	B1	4.328	−2.03
G5	0.76	3.741	−0.14	B1.5	4.301	−1.89
G8	0.98	3.700	−0.30	B2	4.275	−1.76
K0	1.12	3.663	−0.53			
K5	1.57	3.585	−1.09			
M0	1.61	3.573	−1.31			
M1	1.63	3.568	−1.45			
M2	1.65	3.559	−1.69			
M3	1.67	3.549	−2.01			
M4	1.70	3.538	−2.18			
M5	1.70	3.538	−2.49			

Table 2
Average Extinction of O-Type Stars in LMC Clusters

R.A.J2000	Decl.J2000	Radius (arcmin)	N stars[a]	Avg A_V	Comments
84.64157	−69.11476	3.5	75	1.222	NGC 2070 (Tarantula Nebula)
84.43089	−69.16632	1.5	17	1.366	Extended Tarantula Nebula
84.75127	−69.49901	2.0	14	1.138	NGC 2074
82.70307	−71.06600	3.0	12	0.605	[GKK2003] O236 (open cluster)
80.53637	−67.93357	3.0	23	0.675	LH 47
81.44631	−67.49502	2.5	3	1.171	L54S,L51S, O236
83.09506	−66.46582	2.5	3	0.166	MHK 1041 (star cluster)
83.88639	−66.03622	3.0	6	0.393	NGC 2030
74.17531	−66.48343	2.0	19	0.409	NGC 1761

Note.
[a] Number of O-type stars in cluster with $A_V > 0$, excluding known and suspected binaries.

Table 3
O-type Supergiants

R.A. J2000	decl. J2000	Name	V	(B–V)	(U–B)	Phot Source[a]	Sp Type	Sp Type Source[a]	A_V	A_V Flag[b]	Log($T_{\rm eff}$)	$M_{\rm Bol}$
71.86501	−70.56268	SK -70 1a	13.65	−0.05	−0.90	R78	O9II	C86	0.71	0	4.50	−8.58
72.46671	−67.68750	SK -67 4	13.02	−0.16	−0.98	R78	O9Ib	J01	0.37	0	4.50	−8.84
72.90995	−69.49827	IRSF J04513837-6929542	13.87	−0.14	−1.16	Z04	O3.5O6If	M14	0.58	0	4.62	−9.02
72.94129	−69.34064	2MASS J04514589-6920261	13.34	−0.14	−1.01	Z04	O9.7Ib	SIM	0.37	0	4.47	−8.35
72.94566	−69.31794	CTIO85 23	13.16	0.17	−0.91	Z04	O9.7Ib	SIM	1.33	0	4.47	−9.49

Notes.
[a] See Table 12 for key to abbreviations.
[b] Extinction is: 0 = estimated from spectral type, 1 = average value across LMC, 2 = average value from stars in same region (for O-type stars)
(This table is available in its entirety in machine-readable form.)

Table 4
B-type Supergiants

R.A. J2000	decl. J2000	Name	V	(B–V)	(U–B)	Phot Source[a]	SpType	SpType Source[a]	A_V	A_V Flag[b]	Log($T_{\rm eff}$)	$M_{\rm Bol}$
70.15500	−68.29427	SOI 297	13.92	0.07	−0.46	Z04	B9Ib	SIM	0.28	0	4.01	−5.17
70.67763	−68.35182	ARDB 2	13.60	−0.03	−0.42	R78	B8:I:	S72	0.00	0	4.04	−5.36
71.04928	−69.30209	SOI 447	13.78	0.00	−0.42	A72	B7Ib	SIM	0.16	0	4.07	−5.52
71.11896	−69.67617	SOI 449	13.51	0.06	−0.18	A72	B8Ib	SIM	0.29	0	4.04	−5.74
71.18682	−69.29464	SOI 451	13.98	0.06	−0.46	Z04	B9Ib	SIM	0.27	0	4.01	−5.10

Notes.
[a] See Table 12 for key to abbreviations.
[b] Extinction is: 0 = estimated from spectral type, 1 = average value across LMC, 2 = average value from stars in same region (for O-type stars).
(This table is available in its entirety in machine-readable form.)

Table 5
A-type Supergiants

R.A. J2000	decl. J2000	Name	V	(B–V)	(U–B)	Phot Source[a]	SpType	SpType Source[a]	A_V	A_V Flag[b]	Log($T_{\rm eff}$)	$M_{\rm Bol}$
70.77955	−70.45868	SOI 696	13.09	0.21	⋯	H15	A3I	R78	0.46	0	3.95	−5.93
71.59925	−69.86503	SOI 456	13.80	0.36	14.22	Z04	A5Ib	SIM	0.84	0	3.93	−5.54
71.76841	−68.65186	SOI 299	13.92	0.06	14.12	R78	A7:I	R78	0.22	1	3.92	−4.79
71.80518	−69.69462	SOI 459	13.45	0.13	⋯	H15	A5I	R78	0.09	0	3.93	−5.14
71.88854	−69.24250	HD 268612	12.47	0.23	12.90	A72	A2I	A72	0.58	0	3.96	−6.71

Notes.
[a] See Table 12 for key to abbreviations.
[b] Extinction is: 0 = estimated from spectral type, 1 = average value across LMC, 2 = average value from stars in same region (for O-type stars).
(This table is available in its entirety in machine-readable form.)

was insufficient data or the photometry yielded a nonsensical color excess (likely to occur in crowded fields), other measurements were found in: Ardeberg et al. (1972), Isserstedt (1979), Isserstedt (1982), Fitzpatrick (1988), Parker (1992), Schild & Testor (1992), Parker et al. (1992), Parker (1993), Malumuth & Heap (1994), Oey & Massey (1995), Oey (1996a), Will et al. (1997), Massey et al. (2005), Evans et al. (2006), Bonanos et al. (2009), or De Marchi et al. (2011).

The selection of stars with spectral types OBA was magnitude limited to focus on masses greater than 20 $M_{\odot}$, roughly corresponding to $M_{\rm Bol} < -7.0$. Assuming a distance modulus to the LMC of 18.5 (Wagner-Kaiser et al. 2017) and an average extinction of $A_V \sim 1.0$, this corresponds to O-type stars brighter than V <16.5 (for a B.C. range of ∼−4 to −3), B-type stars brighter than V <15.5 (for B.C. ∼−3 to −1), and A-type stars brighter than V <14.5 (for B.C. ∼−1 to 0).

Table 1 includes the adopted intrinsic colors, $T_{\rm eff}$, and bolometric corrections for spectral types from O3 to M5 based on recent calibrations for O stars from Martins et al. (2005), for B- and A-type supergiants from Flower (1996) and for the cooler stars (Section 3) from Flower (1996) and Levesque et al. (2006). In cases were the star had no luminosity class, it was assigned using the spectral type, photometry, and tables of Humphreys & McElroy (1984).

Absolute visual magnitudes (M_V) were determined in the usual way using E(B–V), $R = 3.2$ and a distance modulus of 18.5 for the LMC. When available, the absolute visual magnitudes published in the VLT-FLAMES Tarantula survey (Evans et al. 2011) were adopted. Extra scrutiny was given to stars with negative E(B–V). OB-type stars with negative color excess occurred predominantly in compact star-forming regions. Negative E(B–V) can be a result of strong emission which is common in early type supergiants. When they could not be otherwise resolved, negative E(B–V) values for OB stars were replaced by the median E(B–V) value from other stars of the same type in the same star-forming region (see Table 2). A-type stars with negative E(B–V) that could not be resolved with better photometry are removed.

An anomalous luminosity is often caused by the influence of a known or undetected binary companion or other unresolved blend. Most work to determine the binary frequency for hot luminous stars has focused on O-type stars. Mason et al. (2009), Barbá et al. (2010) and more recent surveys (see Sana (2017) Table 1) have found that between 50% and 60% of the O-type stars in the Milky Way are binary. A similar binary fraction has been observed for O-type stars in the Tarantula region of the LMC (Sana et al. 2013; Almeida et al. 2017). The binary fraction of B-type stars is lower (20%–40%), especially among supergiants evolved off the main sequence (Dunstall et al. 2015; Banyard et al. 2022; Guo et al. 2022).

Both SIMBAD (Wenger et al. 2000) and Dunstall et al. (2015) were used to identify known and suspected binaries or unresolved blends (Table 6). 30% of the O stars and 8.5% of the B-type stars in our samples are known or suspected binaries or blends. Only one of the A-type stars is a known binary. It is very likely we have not identified all the binaries in our sample. Five stars ([FBM2009] 41, MCPS 085.10302-69.67033, PGMW 3073, SK -69 25, and MCPS 084.86883-69.45283) are flagged as suspected blends for being unrealistically luminous for their spectral types. Since anomalous luminosities can also be a result of foreground contamination, stars were checked for Gaia DR3 parallaxes (Gaia Collaboration et al. 2022) with greater than three sigma significance, proper motions, and radial velocities consistent with LMC membership.

Tables 3, 4, and 5 show the format for the separate catalogs for the O-, B-, and A-type supergiants. The full lists of 635 O-type, 2034 B-type, and 339 A-type supergiants are available

Table 6
OBA-type Known and Suspected Binaries

R.A. J2000	decl. J2000	Name	V	(B–V)	(U–B)	Phot Source[a]	Binary Class[c]	SpType	SpType Source[a]	A_V	A_V Flag[b]	Log($T_{\rm eff}$)	$M_{\rm Bol}$
72.46422	−69.20119	SK -69 9	12.56	−0.15	−0.96	R78	EB	B0:	R78	0.32	0	4.45	−9.00
72.46432	−69.20107	SK -69 9	12.54	−0.13	−0.77	B09	EB	O6.6III	J01	0.52	0	4.57	−9.97
73.08029	−69.34704	OGLE LMC-ECL-1886	14.31	−0.08	−0.72	M02	EB	O9.5V:	SIM	0.59	0	4.50	−7.82
73.25367	−68.02569	BI 12	13.48	−0.18	−1.04	B75	EB	O7.5III	SIM	0.33	0	4.54	−8.67
73.35605	−70.59436	SK -70 10	13.28	−0.15	−0.10	R78	EB	B0III[e]	R12a	0.32	0	4.45	−8.27

Notes.
[a] See Table 12 for key to abbreviations for sources of photometry and spectral types.
[b] 0 = estimated from spectral type, 1 = average value across LMC, 2 = average value from stars in same region (for O-type stars)
[c] Multiplicty types: blend = unresolved blend of more than one star, EB = eclipsing binary, SB = Spectroscopic Binary, HMXB = high mass x-ray binary, and ? = suspected or uncertain.

(This table is available in its entirety in machine-readable form.)

Table 7
Yellow Supergiants

R.A .J2000	decl. J2000	Name	J^b	H^b	$K_s{}^b$	V	(B–V)	Phot Source[a]	SpType	SpType Source[a]	A_V	Log($T_{\rm eff}$)	$M_{\rm Bol}$
72.30833	−68.96992	SOI 465	11.45	11.24	11.16	12.48	0.43	M02	F5 I	R78	0.42	3.85	−6.7
72.73271	−69.43128	HD 268687	9.69	9.45	9.36	10.65	0.47	A72	F6 Ia	A72	0.54	3.83	−8.5
73.08000	−69.07847	HD 268708	10.64	10.48	10.36	11.60	0.35	A72	F0 I	A72	0.61	3.90	−7.6
73.40496	−69.71864	TYC 9165-851-1	11.86	11.72	11.65	12.66	0.27	M02	F2 I	R78	0.22	3.87	−6.2
73.55938	−69.21019	HD 268757 R59	8.02	7.64	7.45	10.09	1.55	A72	G8 0	K76	1.76	3.70	−9.6

Notes.
[a] See Table 12 for key to abbreviations.
[b] From 2MASS point source catalog (Cutri et al. 2003).

(This table is available in its entirety in machine-readable form.)

Table 8
Probable Blended Red Supergiants

R.A. J2000	decl. J2000	Name	J^b	H^b	$K_s{}^b$	V	(B–V)	Phot Source[a]	SpType	SpType Source[a]	Log($T_{\rm eff}$)	Blend Flag[c]
72.54041	−70.06949	RM 1-8	10.27	11.21	10.46	13.89	1.56	M02	M:	R83	3.57	2
73.14858	−70.67853	SP77 32-1	9.71	8.83	8.59	12.95	1.20	M02	M0.5	W81	3.58	1
73.32708	−69.28431	LHA 120-S 70	9.52	8.67	8.36	12.88	1.20	M02	M1	W81	3.57	2
73.37850	−69.29717	WOH S 60	9.32	8.46	8.06	13.00	1.03	M02	M3	H90	3.56	2
73.66067	−69.18817	AP J04543854-6911170	8.54	7.66	7.20	13.19	1.82	M02	M0.5	W81	3.58	1

Notes.
[a] See Table 12 for key to abbreviations.
[b] From 2MASS point source catalog (Cutri et al. 2003).
[c] Binarity/blend was: 1 = confirmed by spectroscopy, 2 = inferred from negative color excess.

(This table is available in its entirety in machine-readable form.)

online. A separate Table 6 is included with the 464 known and suspected OBA-type binaries.

3. YSG and RSG Selection

The selection of the YSGs is outlined in Humphreys et al. (2023). Due to the high foreground contamination in this color range, only YSG with confirmed spectral types F0 to early K and velocities supporting membership in the LMC were selected. Parallaxes and proper motions from the GAIA DR3 catalog (Gaia Collaboration et al. 2022) were used to confirm membership. Spectral types combined with visual and near-infrared photometry were used to derive the visual extinction (A_V) and visual luminosities. Bolometric luminosities were derived from K-band photometry following the method of Neugent et al. (2012) using the color excess derived for each individual star. See Humphreys et al. (2023) for details. Table 7 shows the format for the YSG catalog. The full list of 85 stars are available online.

Systematic surveys to determine the binary fraction of supergiants have focused entirely on the hottest (OB) and coolest (RSG) supergiants. Very little is known about the expected binary fraction for yellow supergiants except what may be inferred from their evolutionary status relative to OB supergiants and RSG. We checked the YSG in our list for blends/binarity using SIMBAD. HV 883 (a spectroscopic binary) is the only YSG in our list with any known binary/blend status.

RSGs with spectral types K5 and later, and luminosity classes I, Ia, and Ib were selected from the merged lists of Neugent et al. (2020) and Massey & Olsen (2003). Two luminous heavily dust obscured RSG identified in Elias et al. (1986) are also included. Like the YSGs, the RSGs are prone to foreground M-giant or M-dwarf contamination. Gaia DR3 (Gaia Collaboration et al. 2022) parallaxes, proper motions, and radial velocities were used to confirm membership in the LMC. Stars were assigned spectral types primarily from Humphreys (1979) and Massey & Olsen (2003). Additional spectral types are from: Cannon (1925), Ardeberg et al. (1972), Hyland et al. (1978), Sanduleak & Philip (1977), Blanco et al. (1980), Westerlund et al. (1981), Rebeirot et al. (1983), Wood et al. (1983), Reid & Mould (1985), Mould & Reid (1987), Lundgren (1988), Reid et al. (1990), Frogel & Blanco (1990), Heydari-Malayeri et al. (1990), and González-Fernández et al. (2015). For ambiguous spectral types (i.e., K5-M3 from Sanduleak & Philip 1977; or M from Rousseau et al. 1978), a mean spectral type or M0 was adopted.

The Johnson BVR photometry is from Massey (2002), Oestreicher et al. (1997), or Zaritsky et al. (2004), and the near-infrared JHK magnitudes are from the 2MASS point source catalog (Cutri et al. 2003). Like the OBA-type stars, the E(B–V) color excess for each star was calculated using intrinsic colors in Table 1. Absolute V magnitude (M_V) was calculated from the color excess using $R = 3.2$ and assuming a distance modulus of 18.5 for the LMC.

Also like the OBA stars, the RSG selection is magnitude limited to focus on masses greater than 20 $M_\odot$ roughly corresponding to $M_{\rm Bol} < -7.0$. Assuming an LMC distance modulus of 18.5, average extinction $A_V \sim 1.0$ and bolometric correction between B.C. ~ -1 to -3 this corresponds to $V < 15.5$. This significantly limits contamination by LMC

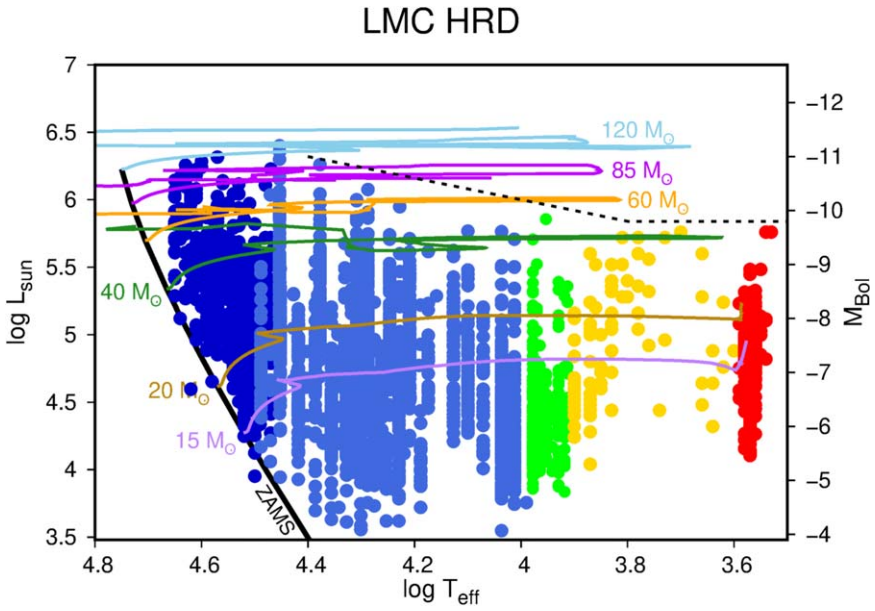

Figure 1. The Hertzsprung–Russell diagram for the most luminous and massive stars in the Large Magellenic Cloud. The Zero Aged Main Sequence (ZAMS) is noted with a solid black line. The Humphreys/Davidson limit (Humphreys & Davidson 1979) is noted with the dashed black line. Stars are colored as follows: O-type = dark blue, B-type = light blue, A-type = green, YSG = yellow, RSG = red. The ZAMS and evolutionary tracks are adopted from Eggenberger et al. (2021) $Z = 0.006$ nonrotating models (LMC is $Z = 0.004$).

Table 9
Red Supergiants

R.A. J2000	decl. J2000	Name	J^b	H^b	$K_s{}^b$	V	(B–V)	Phot Source[a]	SpType	SpType Source[a]	A_V	Log($T_{\rm eff}$)	$M_{\rm Bol}$
72.36154	−68.75167	SP77 22-10	9.42	8.50	8.12	13.30	1.94	M02	M1	W81	0.99	3.57	−7.69
72.45701	−69.92601	RM 1-7	10.09	9.26	8.98	13.54	1.69	M02	M:	R83	0.26	3.57	−6.75
72.74454	−69.23411	SP77 31-5	9.43	8.60	8.36	12.88	1.95	M02	M0	W81	1.09	3.58	−7.54
72.83807	−68.94768	RM 1-14	10.29	9.38	9.09	13.99	1.96	M02	M:	R83	1.12	3.57	−6.74
72.87913	−69.24778	SP77 31-6	9.43	8.55	8.24	13.55	1.94	M02	M0.5	W81	1.02	3.58	−7.64

Notes.
[a] See Table 12 for key to abbreviations.
[b] From 2MASS point source catalog (Cutri et al. 2003).
(This table is available in its entirety in machine-readable form.)

AGB or super-ABG stars. Stars without luminosity class are included if they met the limiting magnitude criteria.

Binary companions to RSG should be bluer than RSG and almost all RSG binaries should have either O or B star companions (Neugent et al. 2018, 2019). Therefore stars with observed colors bluer than the intrinsic colors for an RSG are probably blends. Suspected blends, with negative color excess (E(B–V) < 0) are listed in Table 8 along with binary RSG noted by composite spectral type and/or spectroscopically confirmed by Neugent et al. (2020). The number of RSG in our list which are confirmed or suspected blends (∼20%) is consistent with the estimates of binary frequency by Neugent et al. (2020) and Patrick et al. (2019). Table 8 shows the format for the catalogs of blended RSG. The full list of 61 blended RSG is available online.

Bolometric corrections were computed following the method of Neugent et al. (2012) with differences in how the color excess and effective temperature were determined. Neugent et al. (2012) assumed a constant color excess of E(B–V) = 0.13 for all LMC stars. The average color excess for RSG in our sample is significantly greater (for single RSG, $E(B-V)_{\rm avg} = 0.27$). So we adopted the E(B–V) computed individually for each star from spectral type and intrinsic colors. Neugent et al. (2012) calculated effective temperatures from (J–K) colors. Instead we used effective temperatures derived from the spectral types (Table 1). For two luminous heavily dust obscured RSG identified in Elias et al. (1986; WOH G 64 and IRAS 05346-6949), $T_{\rm eff}$ and $M_{\rm Bol}$ were directly adopted from that publication. Table 9 shows the format for the RSG catalog. The full list 244 RSG is available online.

4. The Upper HR Diagram

The HR diagram for the most luminous and most massive stars in the LMC, from our spectroscopy-based survey and resulting catalogs is shown in Figure 1. The most luminous stars of each type in our catalog are listed in Table 10.

We have not tried to evaluate the completeness of the catalog. Since we relied on spectroscopic surveys to identify the stars, the completeness of those respective surveys will determine the relative completeness of the different classes of stars by spectral type. Instead we show the luminosity functions for the OB-type stars (Figure 2), the two spectroscopic groups that are most likely to be main sequence stars. We set out to produce a catalog of stars in the LMC with masses greater than 20 $M_\odot$ corresponding roughly to Log($L_\odot$) >4.7 and the catalog

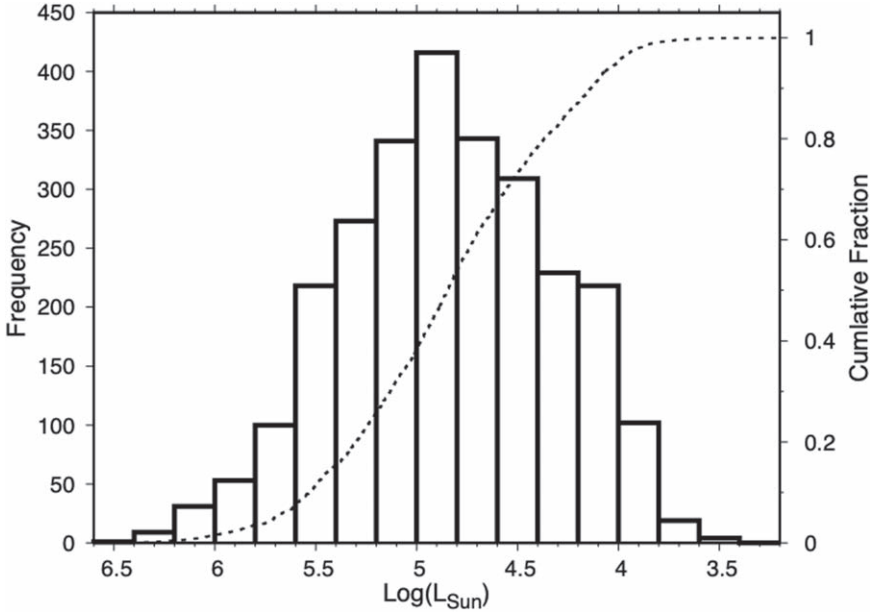

Figure 2. The luminosity distribution for O and B-type stars in the catalog (frequency read off the left axis). The cumulative fraction going toward lower luminosity is read of the right hand axis.

Table 10
Most Luminous LMC Supergiants of Each Spectral Type

Name	SpType	$M_{\rm Bol}$
O-type supergiants (O3-O9) $M_{\rm Bol} \leqslant -10.80$		
2MASS J04542610-6911022	O7V	−10.99
W61 3-20	O5-6V((f))z	−10.91
CPD-69 471	O21f	−10.84
PGMW 3120	O5.5V((f*))	−10.80
Early B-type supergiants (B0-B1) $M_{\rm Bol} \leqslant -11.00$		
HD 37836	B0e	−11.81
HD 269327	B0:	−11.20
HD 268804	OB0	−11.09
Mid B-type supergiants (B2-B5) $M_{\rm Bol} \leqslant -9.40$		
HD 269649	B2.5:	−10.07
HD 269992	B2Ia	−9.55
HD 269997	B3Ia	−9.48
LHA 120-S 46	B2	−9.47
Late B-type supergiants (B6-B9) $M_{\rm Bol} \leqslant -9.40$		
HD 269923	B6I	−9.62
HD 268851	B8	−9.61
HD 32034	B9Iae	−9.47
A-type supergiants (A0-A8) $M_{\rm Bol} \leqslant -9.00$		
HD 33579	A3Ia	−9.84
HD 33579	A3IaO	−9.84
HD 269902	A0I	−9.47
HD 270086	A1Ia0	−9.01
Yellow supergiants (F0-K4) $M_{\rm Bol} \leqslant -9.50$		
HD 268757 R59	G8Ia	−9.6
HD 271182 R92	F8Ia	−9.5
HD 269723	G4Ia	−9.5
HD 269953	G0Ia	−9.5
Red supergiants (K5-M4)$M_{\rm Bol} \leqslant -8.80$		
WOH G 64	M5	−9.60
IRAS 05346-6949	M5	−9.60
[W60] A27	M1Ia	−8.91
SV* HV 888	M4Ia	−8.91
SV* HV 5618	M1I	−8.82

appears to be well populated for masses greater than 15 $M_{\odot}$ and Log($L_{\odot}$) >4.5.

The A-type supergiants, YSGs, and RSGs are all post-main-sequence. Several may even be in a post-RSG state. In a recent paper (Humphreys et al. 2023), we identified six high-luminosity yellow supergiants with circumstellar dust as potential post-red supergiants. Similarly, the two most luminous RSGs are highly obscured dusty stars. The RSGs will be discussed in more detail in a forthcoming paper. This enhanced census of the upper HR diagram in the LMC will also be the reference population for a study of special subsets of evolved massive stars such as LBVs and B[e] supergiants to evaluate their associated populations and evolutionary state.

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Appendix
Supplemental Correction to *U*-band Photometry in Zaritsky Catalog

Zaritsky et al. (2004) identified a systematic difference between their *U*-band photometry and Massey (2002). Massey (2002) is better calibrated. Their photometry is preferred, but it does not cover the full spatial extent of the LMC. Zaritsky et al. (2004) replaced photometry in their catalog with data from Massey (2002) for stars which they identified as common between the two catalogs (flagged 1, 11, or 21 in Zaritsky et al. 2004) and suggested a *U*-band correction for the remaining stars.

A spatial crossmatch with a radius of 0.″5 rejecting matches with $dU_{mag} > 1.0$ mag identified more than 10,000 stars in both Zaritsky et al. (2004) and Massey (2002), which did *not* have their photometry replaced in the Zaritsky et al. (2004) catalog. A plot of those stars revealed a remaining offset between the *U*-band photometry in each catalog *after* applying the Zaritsky et al. (2004) correction. Those data were used to formulate an additional correction (Table 11) Both the Zaritsky et al. (2004) correction and our supplemental correction were applied to the *U*-band photometry of our targets.

Table 12 contains the codes used to reference the photometry and spectroscopy sources.

Table 11
Supplemental Correction to Zaritsky et al. (2004) *U*-band Photometry

Condition	Supplemental Correction
$U < 13$	$du_2 = -0.083\ U + 1.07$
$13 < U < 14.5$	$du_2 = -0.020$
$14.5 < U < 15.2$	$du_2 = -0.038\ U + 0.53$
$U > 15.2$	$du_2 = 0.038\ U - 0.62$

Table 12
Key for Sources of Photometry and Spectral Types

Abbreviation	Citation
A72	Ardeberg et al. (1972)
B09	Bonanos et al. (2009)
B09	Bonanos et al. (2009)
B17	Bagnulo et al. (2017)
B73	Brunet et al. (1973)
B75	Brunet et al. (1975)
B80	Blanco et al. (1980)
B85	Bohm-Vitense et al. (1985)
B99	Bosch et al. (1999)
C01	Cidale et al. (2001)
C09	Chen et al. (2009)
C78	Cowley & Hutchings (1978)
C79	Crampton (1979)
C86	Conti et al. (1986)
C93	Cannon & Pickering (1924)
C98	Caloi & Cassatella (1998)
D05	de Wit et al. (2005)
D11	De Marchi et al. (2011)
D12	Dunstall et al. (2012)
D18	Davies et al. (2018)
D92a	Deharveng & Caplan (1992)
D92b	Deharveng et al. (1992)
E06	Evans et al. (2006)
E10	Evans et al. (2010)
E15a	Evans et al. (2015b)
E15b	Evans et al. (2015a)
E86	Elias et al. (1986)
F09	Fariña et al. (2009)
F60	Feast et al. (1960)
F74	Feast (1974)
F87	Fitzpatrick (1987)
F88	Fitzpatrick (1988)
F90	Frogel & Blanco (1990)
F91	Fitzpatrick (1991)
G11a	Gvaramadze & Gualandris (2011)
G11b	Girard et al. (2011)
G12	Gvaramadze et al. (2012)
G14	Gvaramadze et al. (2014)
G15	González-Fernández et al. (2015)
G87	Garmany & Walborn (1987)
G93	Gochermann et al. (1993)
G94	Garmany et al. (1994)
H00	Høg et al. (2000)
H01	Heydari-Malayeri et al. (2001)
H12	Hénault-Brunet et al. (2012)
H13	Howarth (2013)
H15	Henden et al. (2015)
H74	Humphreys (1974)
H78	Hyland et al. (1978)
H79	Humphreys (1979)
H90	Heydari-Malayeri et al. (1990)
I79	Isserstedt (1979)
I75	Isserstedt (1975)
I82	Isserstedt (1982)
J01	Jaxon et al. (2001)
K12	Kavanagh et al. (2012)
K76	Keenan & McNeil (1976)
L03	Le Borgne et al. (2003)
L88	Lundgren (1988)
M00	Massey et al. (2000)
M02	Massey (2002)
M03	Massey & Olsen (2003)
M05a	Massey et al. (2005)
M05b	Meynadier et al. (2005)
M06	Martayan et al. (2006)
M12	Massey et al. (2012)
M14	Massey et al. (2014)
M15a	Massey et al. (2015)
M15b	McEvoy et al. (2015)
M19	McLeod et al. (2019)
M72	Martin & Rebeirot (1972)
M85	Melnick (1985)
M87	Mould & Reid (1987)
M92	Morgan et al. (1992)
M94	Malumuth & Heap (1994)
M95	Massey et al. (1995)
N12	Neugent et al. (2012)
N18	Neugent et al. (2018)
N19	Neugent et al. (2019)
O95	Oey & Massey (1995)
O96a	Oey (1996a)
O96b	Oey (1996b)
O97	Oestreicher et al. (1997)
P01	Parker et al. (2001)
P12	Paul et al. (2012)
P92a	Parker (1992)

Table 12
(Continued)

Abbreviation	Citation
P92b	Parker et al. (1992)
P93a	Parker & Garmany (1993)
P93b	Parker (1993)
R12a	Reid & Parker (2012)
R12b	Rivero González et al. (2012)
R13	Ridley et al. (2013)
R18	Ramachandran et al. (2018)
R78	Rousseau et al. (1978)
R85	Reid & Mould (1985)
R83	Rebeirot et al. (1983)
R90	Reid et al. (1990)
S11	Shanti Priya et al. (2011)
S12	Selier & Heydari-Malayeri (2012)
S70	Sanduleak (1970)
S72	Sanduleak (1972)
S76	Stock et al. (1976)
S77	Sanduleak & Philip (1977)
S84	Shore & Sanduleak (1984)
S92	Schild & Testor (1992)
S99a	Smith Neubig & Bruhweiler (1999)
S99b	Schmidt-Kaler et al. (1999)
SIM	From SIMBAD with no source[a]
T82	Thompson et al. (1982)
T98	Testor & Niemela (1998)
V18	van Jaarsveld et al. (2018)
VTFS	Evans et al. (2011)
W02a	Walborn et al. (2002a)
W02b	Walborn et al. (2002b)
W10a	Walborn et al. (2010)
W10b	Weidner & Vink (2010)
W14	Walborn et al. (2014)
W77	Walborn (1977)
W81	Westerlund et al. (1981)
W83	Wood et al. (1983)
W97a	Will et al. (1997)
W97b	Walborn & Blades (1997)
Z04	Zaritsky et al. (2004)
Z12	Zacharias et al. (2012)
Z13	Zastrow et al. (2013)
Z86	Zickgraf et al. (1986)

Note.
[a] This is the classification given in SIMBAD which Wenger et al. (2000) identify as either from Houk & Cowley (1975) or Jaschek (1978).

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