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LOW-DISPERSION SPECTRA AND GALACTIC DISTRIBUTION OF VARIOUS INTERESTING STRONG-EMISSION-LINE OBJECTS IN THE SOUTHERN MILKY WAY

N. SANDULEAK* AND C. B. STEPHENSON
Warner and Swasey Observatory, Case Western Reserve University
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ABSTRACT

The entire southern Milky Way has been surveyed for various types of strong-emission-line objects on low-dispersion objective-prism plates taken mostly within a nine-month observing period in 1967–1968. This appears to be the first such comprehensive southern survey to utilize plates covering the entire λλ3300–6800 wavelength range. The spectra of 179 objects (including 20 apparently newly discovered emission-line objects) are classified into various major spectral categories recognizable at low dispersion. These include extreme Be–like objects, Z Andromedae–like stars, suspected very-low-excitation nebulae, peculiar M-type stars, VV Cephei stars, and very-steep-Balmer-decrement objects of unknown type. The galactic-longitude distributions of some of these types are discussed.

Subject headings: combination spectra — emission-line stars — spectral classification

I. INTRODUCTION

With the recent completion of a massive survey (Stephenson and Sanduleak 1971), the entire southern Milky Way contained within the boundaries $l \sim 215°$ and $l \sim 35°$ and b generally less than $\pm 10°$ has now been canvassed with moderately deep, low-dispersion objective-prism plates covering both the photographic and visual spectral regions. A few of the most northerly plates were taken with the Burrell Schmidt telescope of the Warner and Swasey Observatory, but most of the coverage was provided by plates taken (by N. S. in 1967–1968) with the University of Michigan's Curtis Schmidt telescope (essentially a twin of the Burrell telescope) which is now in operation at the Cerro Tololo Inter-American Observatory in Chile.

In scanning these plates, our main goal was the detection and cataloguing of high-luminosity stars, hopefully to serve as tracers of spiral structure in the inner parts of the Galaxy. However, we also systematically noted many other objects of interest, including all those showing emission-line spectra on either the blue-green sensitive (Kodak IIa-O) or the yellow-red sensitive (Kodak 103a-F + GG 14 filter) plates. We have compiled in table 1 a potpourri of some of the more exotic and spectroscopically intriguing varieties of strong-emission-line objects noted during the course of our survey. At our plate scale of about 100″ mm^{-1}, all of these objects display rather sharp emission lines indicating that, if not stellar, they are at least semistellar in apparent size. Most of these show a distinct continuum and clearly must be regarded as emission-line stars. However, since some stellar-like nebulae are probably also included, we will often make use of the term "object" in this discussion.

Although table 1 contains some well-known and well-observed entries, most of these southern-hemisphere objects were known previously only to have bright Hα or

* Visiting Astronomer, Cerro Tololo Inter-American Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

at least had not been studied spectroscopically over the entire λλ3300–6800 wavelength range recorded by our two types of plates. Carlson (1968) has recently discussed intermediate-dispersion slit spectra of some of the brighter stars in table 1, while Herbig (1969) has obtained low-dispersion slit spectra of some of the fainter objects in the direction of the galactic center. Both authors provide excellent illustrations of the spectra of the various types of strong-emission-line objects represented in table 1. In particular, we direct attention to figure 1 of Herbig where the dispersion and resolution are comparable to that obtained on our objective-prism plates taken under the good seeing conditions that normally prevail at Cerro Tololo.

Besides being a source of many new spectral classifications and serving as a finding list for interesting objects, table 1 also provides, as a result of its believed completeness, data that make it possible to study the galactic-longitude distributions of several types of emission-line objects in the southern Milky Way. It appears that 20 of the entries in table 1 have not been previously reported to show emission-line spectra. Since these apparently were not detected in earlier Hα-emission-line surveys reaching a similar limiting magnitude, one might suspect that they have strongly variable hydrogen-line emission.

Recently, one of us (Sanduleak 1970) made a survey of the Large Magellanic Cloud (LMC) using the Curtis Schmidt telescope, the same objective prisms, and plate material essentially identical to that used in the present survey. A number of similar emission-line stars were noted, most of which had been studied and discussed earlier by Smith (1957) and Feast, Thackeray, and Wesselink (1960). It would of course be of great interest to compare the spectral properties of these LMC stars with the galactic strong-emission-line stars in hopes of identifying closely matching counterparts. We intend to make this the subject of a subsequent paper.

II. LOW-DISPERSION SPECTRAL CATEGORIES

Because of the low dispersions used (580 Å mm^{-1} at Hγ; 1000 Å mm^{-1} at Hα) and the general faintness of these objects, only the strongest emission features are usually visible on our plates. Based on these limited spectral characteristics, the strong-emission-line objects under consideration here have been assigned to the various major spectral categories described below.

a) *Extreme Be–like Objects*

These objects, at the time of our observations, had spectra in which the only emission lines visible over the entire λλ3300–6800 range appeared to be those of hydrogen. We know from higher-dispersion studies of some of these objects (e.g., Carlson 1968) that they usually also display emission lines of He I, Fe II, or [Fe II] among others. However, in most cases such lines are nearly an order of magnitude less intense than Hβ and thus are not likely to be detected at low dispersion.

Specifically, the criterion for selection of objects of this type, for inclusion in table 1, was that the hydrogen emission be sufficiently intense to be readily visible at Hγ or beyond at this dispersion. Actually we have included some faint objects, seen near our plate limit, which showed only Hβ emission but which undoubtedly would show emission in the higher Balmer series members if they were brighter or better exposed. All of the brighter objects in this category show a more or less normal decrement in the relative strengths of the hydrogen emission lines.

It is the intensity of the hydrogen emission that distinguishes these objects from the vast majority of early-type emission-line stars in which emission at Hβ or beyond is generally not detectable at this dispersion. However, since it seems reasonable to consider them as extreme examples of the same phenomenon, we have adopted the symbol Be! to designate such objects in column (7) of table 1. Most of these do show

TABLE 1

VARIOUS INTERESTING STRONG-EMISSION-LINE OBJECTS IN THE SOUTHERN MILKY WAY

No. (1)	R.A. (1950) (2)	Decl. (1950) (3)	m_p (4)	m_v (5)	n (6)	Sp. Category (7)	Identifications (8)
*1..........	06h46m19s.7	−07°21′16″	13.5	12.0	3	M2ep+OB?	New
2..........	07 14 57.1	−07 28 52	13.0	12.0	6	Be!	MWC 553
*3..........	17 52.5	−19 25 06	11.5	9.0	3	M3ep+OB?	BD−19°1821, New
*4..........	22 53.0	−03 29 50	12.5	11.0	6	M4ep	BX Mon, AS 150
*5..........	23 26.0	−07 38 04	12.5	12.5	9	M4ep	MWC 560
6..........	29 37.1	−19 21 04	14.0	12.5	4	Be!	PK 234−0°1
*7..........	31 00.5	−11 42 08	13.5	12.5	6	Be!	New
*8..........	08 12 28.2	−41 33 18	13.5	12.5	5	Mep?	RX Pup, HD 69190, HEN 138
9..........	23 26.7	−51 18 46	A	A	5	Z^+	WRA 208
*10..........	47 03.2	−45 53 58	13.0	12.5	4	Be!	WRA 285
*11..........	50 17.2	−46 06 44	A	A	5	VLE?	PK 266−1°1
*12..........	54 53.1	−46 12 21	12.5	12.0	>5	Be!	WRA 310
*13..........	09 20 20.9	−52 21 02	10.0	8.5	?	M5ep+B	WY Vel, HD 81137
*14..........	39 24.7	−49 09 04	A	A	4	VLE?	PK 274+2°1
*15..........	10 02 49.8	−58 25 14	10.0	10.0	6	Be! pec	HD 87643, MWC 198
16..........	08 14.5	−56 47 20	A	12.5	4	Be!	WRA 507
*17..........	09 18.0	−57 33 24	11.0	10.5	7	M3ep+OB	CPD−57°2768
*18..........	13 35.4	−57 36 44	11.5	10.0	6	Be!	CPD−57°2874, WRA 535
*19..........	14 29.8	−55 20 52	10.0	10.0	6	Be!	HD 89249, MWC 200
20..........	17 14.9	−56 56 03	A	A	3!	X	New
21..........	17 48.2	−59 58 24	13.5	A	6	Be!	WRA 543
22..........	19 45.2	−57 50 39	A	12.5	4	Z?	WRA 549
*23..........	21 07.0	−59 22 16	9.5	8.5	5	Be!	HR Car, HD 90177, MWC 202
*24..........	44 00.0	−59 40 56	13.0	11.5	6	Be! pec	WRA 642
*25..........	51 59.3	−60 10 44	11.5	11.0	7	Be! pec	PK 288−0°1, WRA 682
*26..........	53 57.7	−60 07 31	9.5	9.5	10	Be!	GG Car, HD 94878, MWC 215
*27..........	54 10.4	−60 11 10	8.0	8.5	6	Be!	AG Car, HD 94910, MWC 216
*28..........	11 04 19.3	−54 32 19	A	A	3!	X	PK 288+5°1, HEN 573
*29..........	06 27.3	−65 31 02	13.0	A	8	Be! pec	New
30..........	23 16.5	−59 40 02	A	12.5	4	Be!	WRA 807
*31..........	27 00.0	−65 22 45	12.5	12.5	6	Be!	WRA 813
*32..........	29 55.0	−65 08 36	12.5	11.0	7	Z^++M2	SY Mus, HD 100336, WRA 824
*33..........	12 02 28.9	−65 03 59	12.0	12.0	7	Be!	WRA 934
*34..........	19 37.4	−63 00 38	A	12.5	3!	X	PK 299−0°1
*35..........	41 19.2	−61 39 48	9.5	8.0	4	M3ep+OB	CD−61°3575, HEN 814
*36..........	42 48.3	−62 44 09	A	A	3!	X	PK 302−0°1
*37..........	48 01.6	−57 34 28	13.5	12.5	7	Z	WRA 1022
*38..........	48 21.8	−64 43 38	A	12.5	5	Z^-	See remark
*39..........	13 06 52.2	−62 55 32	A	A	3	X	PK 305−0°1
40..........	27 23.2	−57 42 50	A	12.5	4	Z?	WRA 1108
41..........	30 19.6	−63 16 41	A	12.5	3	X	WRA 1119
42..........	31 59.1	−64 30 25	A	12.5	6	Z	WRA 1123
*43..........	14 08 33.3	−51 12 18	A	A	3!	X	PK 315+9°1
44..........	59 15.8	−63 11 10	A	12.5	6	Z^-	New

TABLE 1—*Continued*

No. (1)	R.A. (1950) (2)	Decl. (1950) (3)	m_p (4)	m_v (5)	n (6)	Sp. Category (7)	Identifications (8)
*45	$15^h21^m10^s.4$	−51°39′15″	A	A	5	Z	PK 325+4°2
*46	42 29.9	−66 19 59	13.5	A	6	Z^-	PK 319−9°1, HEN 1092
47	45 00.3	−44 09 50	A	A	4	Z?	WRA 1359
*48	54 10.4	−55 33 14	A	A	3!	VLE?	PK 327−1°2
*49	55 51.0	−41 48 38	13.5	12.0	6	Be!	WRA 1400
*50	16 03 10.7	−52 55 40	11.5	11.0	6	Be! pec	CPD−52°9243, WRA 1416
*51	05 46.0	−41 32 30	A	12.5	6	Mep?	WRA 1423
52	16 44.4	−36 31 03	13.5	12.0	4?	Mep	WRA 1457
*53	17 38.8	−42 16 48	A	12.5	4	Be!	PK 338+5°2, WRA 1461, CSV 2635?
*54	18 18.2	−53 33 52	A	A	3	VLE?	PK 331−2°1
*55	20 16.0	−27 33 17	A	12.0	7	Z^-+M4	WRA 1470
56	23 31.9	−48 32 45	A	A	3!	X	WRA 1484
*57	23 53.0	−53 54 46	A	A	5	VLE?	PK 331−3°1
*58	26 48.3	−45 56 20	A	A	3	VLE?	PK 337+1°1, WRA 1495
*59	30 47.0	−34 59 10	A	A	5	Z	PK 346+8°1
*60	31 23.0	−51 36 14	13.5	12.0	7	Z^-+M2	WRA 1511
*61	32 59.0	−39 45 38	A	A	3	X	PK 342+5°1, WRA 1518
*62	34 51.8	−45 17 43	13.0	12.5	4	Be!	PK 338+1°1, WRA 1520
*63	39 37.5	−45 55 04	A	12.5	3	X	PK 339+0°2
64	43 20.9	−38 31 35	12.5	A	4	Be!	PK 345+4°1
65	47 53.3	−37 12 59	A	A	4	Be!	New
*66	48 15.7	−25 55 25	14.0	A	6	Z	AS 210
*67	49 47.5	−44 47 53	A	A	3	X	PK 341−0°1, WRA 1552
*68	51 29.8	−30 18 16	14.0	12.5	5	Z^+	HK Sco, AS 212
*69	51 40.3	−30 32 30	12.5	11.5	7	Z^-+M?	CL Sco, AS 213
*70	55 33.8	−42 37 37	11.5	10.5	6	Be!	CD−42°11721, MWC 865
71	56 09.1	−32 10 14	A	A	3	X	New
*72	17 03 20.5	−42 32 37	10.0	9.0	4	Be! pec	CD−42°11834, HDE 326823, HEN 1330
*73	03 30.3	−45 20 08	A	A	3	X	New
*74	04 04.0	−34 01 18	13.5	12.0	6	Z^+	V455 Sco, PK 351+3°1, AS 217
*75	05 42	−17 24	13.5	12.0	8	Z^-	HEN 1341
*76	05 47.1	−27 08 44	13.5	12.5	8	Be!	New
77	05 53.2	−23 19 50	14.0	12.0	6	Z+M?	HEN 1342
*78	06 57.7	−32 55 05	A	A	3	X	See remark
*79	08 57.2	−32 34 11	A	A	3!	X	PK 352+3°1, AS 221
80	10 51.4	−38 55 32	14.0	11.0	4	Be!	AS 222
81	10 53.4	−31 16 16	A	A	3!	X	PK 354+4°1, WRA 1647
82	17 15.0	−33 06 49	A	12.5	3!	Mep?	WRA 1680
83	17 30.4	−37 57 00	A	12.0	3!	X	AS 225
*84	20 55.5	−25 56 40	13.5	12.5	6	VLE?	PK 359+5°1
85	21 43.1	−28 03 18	A	A	3	X	PK 358+4°1
86	22 48.5	−29 19 17	A	A	3	X	PK 357+3°2
87	26 20.1	−25 46 45	A	A	3	X	PK 0+4°1
88	26 53.7	−27 57 01	A	A	3	X	PK 358+3°4
89	30 37.3	−21 44 19	A	A	3!	X	PK 4+6°2

TABLE 1—*Continued*

No. (1)	R.A. (1950) (2)	Decl. (1950) (3)	m_p (4)	m_v (5)	n (6)	Sp. Category (7)	Identifications (8)
90	17h31m20s.5	−19°07′23″	14.0	A	7	Z	PK 6+7°1
*91	31 25.0	−22 51 16	A	A	3	VLE?	PK 3+5°1
92	32 10.4	−29 43 27	A	A	3	X	PK 358+1°3
*93	37 03.4	−24 24 07	A	A	3	X	PK 3+3°1
94	37 04.1	−11 55 03	14.0	12.5	6	Z	RT Ser, MWC 265
*95	37 19.7	−47 01 50	11.5	11.5	8	Be!	AE Ara, PK 344−8°1, MWC 591
*96	38 04.8	−36 46 14	14.0	12.0	6	Be! pec	New
97	38 35.8	−22 11 36	A	A	3	X	PK 5+4°2
98	39 46.3	−15 23 03	A	12.5	4	Z?	UU Ser, AS 237
99	39 58.1	−36 37 00	A	A	3	X	WRA 1763
100	41 24.9	−25 19 00	A	A	3!	X	New
101	42 34.0	−25 38 47	A	A	3	X	PK 2+1°1
*102	43 28.3	−33 07 17	A	A	4	VLE?	PK 356−2°2
103	44 41.8	−36 07 16	A	12.5	4	Be!	HEN 1481
*104	45 04.8	−27 59 52	11.5	9.5	8	Be! pec	CD−27°11944, HDE 316285, MWC 272
105	45 57.4	−23 41 58	A	A	3	X	PK 4+2°1
*106	47 31.6	−06 41 39	11.5	10.0	6	M0ep+OB?	RS Oph, HD 162214, MWC 414
*107	47 59.8	−22 18 49	A	A	3!	X	PK 6+2°2, AS 245
108	48 47.2	−29 51 15	A	A	3	X	New
*109	50 02.4	−33 55 20	A	A	3	VLE?	PK 356−3°3
*110	51 06.2	−34 26 28	A	A	3!	X	New
111	53 47.8	−35 15 15	13.5	12.0	6	Z	AS 255
*112	54 15.7	−21 41 10	A	12.5	4	Z^+	PK 7+1°2, V2416 Sgr
*113	54 56.0	−33 47 22	A	A	3	VLE?	PK 357−4°3
114	57 13.9	−17 40 40	A	A	3	X	PK 11+2°1
*115	57 26.1	−29 21 41	A	A	3	VLE?	PK 1−3°1
*116	57 59.4	−26 21 24	12.5	11.5	3	Mep?+B	PK 3−1°1
117	59 07.6	−31 59 14	14.0	12.5	3!	X	New
*118	59 20.8	−23 28 39	A	12.0	3	M3ep	HEN 1560, see remark
*119	18 00 07.2	−32 42 31	12.5	A	5	Be!	PK 358−5°2, AS 269
*120	00 56.5	−21 59 40	A	11.0	3	Mep?	See remark
121	01 19.7	−28 21 48	A	A	6	Be!	PK 2−3°1
122	01 33.1	−27 09 26	A	12.0	5	Be!	New
*123	01 45.5	−21 51 43	13.5	12.0	4	Be! pec	See remark
124	02 16.0	−28 22 20	A	A	5	Be!	PK 2−3°3
125	02 34.8	−24 30 57	A	A	3	X	New
*126	02 35.2	−20 20 52	A	12.5	4	Mep?	AS 270
*127	02 50.3	−26 30 01	A	A	3!	X	PK 4−2°1
*128	02 51.4	−28 17 22	A	A	6	Z^-	PK 2−3°4
*129	03 54.0	−29 36 50	A	12.5	3	Mep?	See remark
*130	04 02.7	−29 41 47	A	A	3	VLE?	PK 1−4°1
*131	04 17.5	−36 06 47	A	12.5	5	Be!	PK 356−7°1, WRA 1840, V615 Sgr?
*132	04 25.8	−25 54 13	13.0	12.0	4	Z^+	HEN 1591, see remark
133	04 40.9	−13 29 16	A	A	3!	X	PK 15+3°1
*134	05 17.9	−24 34 13	A	12.5	3	X	See remark

TABLE 1—*Continued*

No. (1)	R.A. (1950) (2)	Decl. (1950) (3)	m_p (4)	m_v (5)	n (6)	Sp. Category (7)	Identifications (8)
*135..........	18h05m37s.2	−41°13′58″	A	12.5	6	Z^+ + M?	AS 276
*136..........	06 34.6	−33 20 21	13.0	12.5	8	Z	PK 358−6°1, AS 280
*137..........	07 19.5	−28 08 19	A	12.5	4	Be!	PK 3−4°2
*138..........	07 34.6	−27 58 30	A	A	5	Z	PK 3−4°1, AS 281
*139..........	07 51.6	−28 33 22	A	A	3	X	PK 3−4°6
*140..........	08 25.3	−28 23 19	12.5	12.0	4	Be!	PK 3−4°7, AS 283
*141..........	08 53.9	−33 11 27	13.0	12.5	5	Be!	See remark
142..........	09 29.4	−24 50 45	A	A	3	X	PK 6−3°1
*143..........	09 34.7	−11 40 55	13.0	11.0	4	Z^+ + M3	AS 289
*144..........	10 47.3	−42 51 26	A	12.5	6	Z^+	Y CrA, HD 166813, HEN 1632
*145..........	11 22.4	−29 50 18	A	A	4	Z?	PK 2−5°1, AS 293
*146..........	12 11.5	−30 32 53	13.0	12.5	7	Z?	PK 1−6°1
147..........	12 30.8	−21 36 23	14.0	12.0	5	Z? + M?	PK 9−2°1
*148..........	12 36	−00 20	13.0	10.5	5	Z + M5	AS 296
*149..........	12 51.9	−30 52 14	13.0	11.5	7	Z	AS 295
150..........	13 09.4	−27 05 41	12.5	12.5	5	Be!	PK 4−4°2
*151..........	14 10.7	−28 10 57	11.5	11.0	7	Be! pec	AS 299
*152..........	17 05.1	−24 16 24	A	A	5	Be!	PK 7−4°1, AS 301
*153..........	17 12.2	−26 24 06	12.5	A	4	Z	WRA 1864, see remark
*154..........	17 51.3	−26 49 52	13.0	A	7	Z^-	PK 5−5°2, CSV 4026?
*155..........	18 14.3	−31 33 22	12.5	12.0	7	Z^-	AS 302
156..........	18 26.9	−13 02 52	A	12.5	3	X	MWC 922
157..........	18 43.0	−06 03 22	A	A	3	X	PK 24+3°1
*158..........	18 49.4	−27 26 51	12.5	11.0	6	M3ep	V1862 Sgr
159..........	20 10.7	−19 18 39	A	A	3	X	PK 12−2°1
*160..........	20 28.5	−21 54 45	A	A	3!	X	PK 10−3°1, see remark
*161..........	20 34.0	−12 42 27	12.0	9.5	3	M4ep + OB?	FR Sct
*162..........	22 16.7	−28 37 42	11.5	11.5	8	Z^- + M?	AS 304
163..........	23 43.0	−07 15 07	A	11.0	3	X	MWC 930
164..........	25 01.4	−03 51 47	14.0	11.0	4	Be!	MWC 297
165..........	25 46.5	−24 34 00	A	A	3!	X	PK 8−6°1
166..........	26 16.7	−17 29 14	A	A	3	X	New
167..........	28 40.7	−18 17 40	14.0	12.0	5	Be!	New
168..........	30 42.0	−11 09 44	A	A	3	X	PK 21−1°1
*169..........	31 21.5	−17 38 39	13.0	12.5	6	Be! pec	MWC 939
170..........	31 38.4	−00 28 45	A	12.5	3	X	New
*171..........	35 00.7	−22 44 32	A	12.5	5	Z + M5	AS 313, V2601 Sgr
*172..........	39 33.4	−21 20 46	A	A	6	Z^+	PK 12−7°1, AS 316
173..........	40 36.3	−05 08 40	A	A	3	X	AS 319
*174..........	44 58.2	−20 09 12	13.5	12.0	6	Z	MWC 960
*175..........	46 57.4	−26 27 46	10.0	9.5	6	Fe, pec	CD−26°13521, AS 325
*176..........	50 13.5	−24 26 38	13.0	12.0	7	Z + M?	AS 327
*177..........	50 57.0	−19 03 30	11.0	11.0	7	Z + M?	FN Sgr, AS 329
*178..........	19 00 51.6	−17 04 24	14.0	12.5	7	Z^- + M?	AS 337, V919 Sgr
179..........	07 18.6	−02 52 34	13.0	11.0	6	Be!	AS 341

REMARKS ON TABLE 1

1. A faint OB–like continuum appears in the ultraviolet, but no emission lines are seen in the blue-green region.

3. OB–like continuum in the ultraviolet. TiO bands appear veiled. No emission lines in the blue-green region.

4. Listed as symbiotic in Wackerling (1970). In the *General Catalog of Variable Stars* this is listed as a suspected long-period variable with a period of 1374 days!

5. A system of strong absorption features appear just blueward of the lower Balmer members. There is some evidence of variable line emission. TiO bands are strong in both the visual and near-infrared.

7. This should not be confused with MWC 846 which is seen to be about 3′ to the north on our plates.

8. Listed as symbiotic in Wackerling (1970). Our spectrum, obtained 1968 February 26, is much different from that reported by Swings and Struve (1941) in that we do not see λ4686 and λ5007 is very weak relative to Hβ.

10. Spectrum described by Carlson (1968) as probably of P Cygni type.

11. Stellar. Considered a doubtful planetary by Webster (1966), but Henize (1967) suspects the presence of λ6584.

12. Overlapping spectrum prevents a determination of the last resolvable Balmer line, but Henize (1967) reports emission up to Hδ.

13. A well-known VV Cephei star showing exceptionally strong Fe II and [Fe II] emission. The hydrogen emission is apparently absent on our plates.

14. Stellar. A λ5007 line is definitely present.

15. The lower Balmer members show violet absorption borders and the lines go entirely into absorption beyond Hδ. Also present are Fe II emission lines. For additional details see Hiltner, Stephenson, and Sanduleak (1968) and Carlson (1968).

17. The spectrum is not exactly as described by Henize (1952) in that Hγ is slightly stronger than Hβ on 1968 February 27.

18. Spectrum found to be of P Cygni type by Carlson (1968).

19. Numerous weak Fe II emission lines are present in the spectrum according to Hiltner *et al.* (1968) and Carlson (1968).

23. Spectrum is classified as P Cygni type by Carlson (1968), who also finds numerous weak [Fe II] emission lines. We find no evidence of strong He I λ5876 reported by Henize (1952).

24. Our plates show numerous weak emission lines some of which appear to be those of Fe II or [Fe II].

25. This object contains exceptionally strong He I emission lines at λλ3889, 4026, 4471, 4921, 5016, 5876, and 6678. See also Henize (1952).

26. The spectrum of this eclipsing binary is discussed by Carlson (1968). He finds many weak Fe II emission lines.

27. This is the central star of the nebula PK 289−0°1. Strong He I emission is reported by Carlson (1968) but is not in evidence on our plates.

28. Stellar. Definitely not a planetary according to Webster (1966), but no details are given.

29. Weak [Ne III] λ3869 is present and He I λ5876 suspected.

31. The Balmer decrement appears shallow. Our position agrees with Wray (1966), but not with that given by Wackerling (1970).

32. Listed as symbiotic in Wackerling (1970). We suspect [O III] lines at λλ5007, 3760, and O III at λ3444. Also see Henize (1952) and Carlson (1968).

33. Shallow Balmer decrement.

34. Stellar. Webster (1966) found this to be a doubtful planetary.

35. A known VV Cephei star. See Henize (1952) and Carlson (1968).

36. Stellar. Doubtful planetary according to Webster (1966).

37. A λ5007 line suspected.

38. Discovered independently by Weaver (1973). Spectrum contains moderately strong [O III] nebular lines at λλ5007 and 4363 and [Ne III] λ3869.

39. Stellar. Light variability suspected by Allen (1973).

43. Stellar. Coordinates are from Wray (1966).

45. Stellar. Weak λ5007 present.

46. Stellar. Also shown to be definitely not a planetary by Webster (1966), who gives a description of the spectrum.

48. Westerlund and Henize (1967) found a diameter of about 7″, and Henize (1967) reported λ6584 present.

49. Shallow Balmer decrement.

50. Very strong sodium D-lines are seen in accord with the findings of Carlson (1968), who also reports numerous Fe II emission lines.

51. Hγ slightly stronger than Hβ. TiO bands are suspected.

53. Stellar.

54. Stellar. Henize (1967) reports λ6584 present.
55. Coordinates are taken from Wray (1966).
57. Stellar. Henize (1967) reports λ6584 in the spectrum.
58. Stellar. The very strong λ6584 reported by Henize (1967) is seen as a broadening of Hα on our plate.
59. Stellar. The spectrum contains rather strong nebular lines of [O III] at λλ5007, 4363, and of O III at λ3444 as well as [Ne III] λ3869.
60. Listed as symbiotic in Wackerling (1970). A λ5007 line is suspected, but λ4686 is much weaker in our spectrum of 1967 June 12 than in the spectrum obtained by Carlson (1968).
61. Stellar.
62. Stellar. Also classified as a nonplanetary by Webster (1966) but no details are given.
63. Stellar. Doubtful planetary according to Webster (1966).
66. Spectrum shows weak [O III] lines at λλ5007, 4363, and O III at λ3444. Wilde (1965) found evidence of spectrum variations.
67. Stellar. Webster (1966) calls this a doubtful planetary.
68. Listed as symbiotic in Wackerling (1970). A λ5007 line suspected.
69. Listed as symbiotic in Wackerling (1970). Weak nebular lines seen at λλ4363 and 3869. He I λ6678 present.
70. Spectrum is discussed by Carlson (1968). An infrared objective-prism plate shows strong emission of O I λ8446.
72. In agreement with Carlson (1968), we find the hydrogen emission very weak compared to strong He I lines at λλ3889, 4120, 4471, 4713, 5016, and 5876.
73. Besides Hα, the visual region contains a single emission line which we can tentatively identify as [N II] λ5755.
74. Listed as symbiotic in Wackerling (1970). Weak λ5007 present.
75. Weak λ5007 seen. Approximate coordinates are from Wackerling (1970).
76. Shallow Balmer decrement. Some evidence of variability in emission-line strengths.
78. This is object 255 in table 16 of Wray (1966).
79. Definitely not a planetary according to Henize (1967), but no details are given.
84. A λ6584 line reported by Henize (1967).
91. This object has a diameter of about 9″ according to Westerlund and Henize (1967).
93. Stellar. A doubtful planetary according to Webster (1966).
95. The coordinates are from Wray (1966).
96. He I λ5876 is suspected to be present.
102. Henize (1967) found λ6584 in the spectrum.
104. Our plates also show the numerous emission lines of He I and Fe II reported to be present by Carlson (1968).
106. Our spectrum obtained 1965 March 31 differs from that described by Swings and Struve (1941) in that we can see neither He I λ5876 nor He II λ4686.
107. Although details are lacking, Henize (1967) comments that this is definitely not a planetary nebula.
109. A λ6584 line detected by Henize (1967).
110. Note that this is not PK 356−4°1. Our plates show that the Hα is strongly variable.
112. Classified as symbiotic by Herbig (1969).
113. Henize (1967) suspects the presence of λ6584.
115. Strong λ6584 present according to Henize (1967).
116. Stellar. TiO bands are suspected in the visual region while weak hydrogen absorption lines are seen in the blue-green.
118. This is star 64 of Velghe (1957). The coordinates agree closely with the Caltech infrared object IRC−20418.
119. Because of faintness we are unable to verify the G- or K-type absorption spectrum reported by Herbig (1969).
120. This is star 52 of Velghe (1957). TiO bands are suspected in both the visual and near-infrared.
123. This is object 11 in the list of Arhipova and Dokuchaeva (1971). The He I lines at λλ5876 and 6678 appear remarkably strong compared to Hα.
126. Listed as symbiotic in Wackerling (1970).
127. Stellar.
128. Rather strong [O III] lines at λλ5007, 4363, and O III at λ3444.
129. This appears in Herbig (1969) under the name T17 and is classified as probably symbiotic.
130. A λ6584 line seen by Henize (1967).
131. Stellar.
132. This is called T53 in the list of Herbig (1969) and classified as probably symbiotic. Our spectrum of 1967 August 3 shows strong λλ4686 and 4363 but no evidence of the other strong forbidden nebular lines noted by Herbig. Hoffleit (1970) suspects variability in light.
134. This is star 57 in Velghe (1957).

135. The coordinates are those of Wray (1966).
136. Stellar. Hγ appears slightly stronger than Hβ.
137. Stellar. Spectrum described by Herbig (1969).
138. Stellar. Probably symbiotic according to Herbig (1969). Hoffleit (1970) finds no evidence of light variations.
139. Stellar.
140. Stellar. Herbig (1969) describes the spectrum.
141. This appears to be object 384 in table 16 of Wray (1966). Our plates indicate strongly variable Hα emission.
143. The TiO bands are seen on both yellow-red and near-infrared objective-prism plates.
144. The coordinates are from Wray (1966). O III lines appear at λλ3760 and 3444, and He II λ4541 is suspected.
145. Stellar. Definitely variable in light according to Hoffleit (1970), and probably symbiotic according to Herbig (1969).
146. Weak nebular lines appear at λλ5007, 4363, and 3869. He I λ5876 suspected. See also Herbig (1969).
148. Approximate coordinates are from Wackerling (1970) where the star is classified as symbiotic. He I λ6678 is present.
149. This star lies very close to but should not be confused with MWC 288.
151. The spectrum shows moderately strong He I lines at λλ3889, 4471, and 5016. Herbig (1969) suspects TiO bands.
152. Spectrum is described by Herbig (1969).
153. This star is listed as T21 by Herbig (1969) and considered symbiotic. He I λ6678 may be present.
154. Stellar. Weak [O III] lines appear at λ5007 and λ4363.
155. Coordinates are from Wray (1966). Weak λλ5007 and 4959 are seen, and He I λ6678 is present. Probably symbiotic according to Herbig (1969).
158. Hγ slightly stronger than Hβ.
160. This is variable star 52 in the list of Hoffleit (1972).
161. Fe II emission is suspected. See the description of the spectrum provided by Bidelman and Stephenson (1956).
162. A λ5007 line suspected and He I λ5876 present.
169. Fe II and [Fe II] emission lines are conspicuous.
171. Classified as symbiotic by Herbig (1969). TiO bands were detected on a near-infrared objective-prism plate.
172. Herbig (1969) reports an M-type spectrum and considers this a symbiotic star. Light variability suspected by Hoffleit (1970).
174. Probably symbiotic according to Herbig (1969) and possibly variable in light according to Hoffleit (1970). He I λ6678 may be present.
175. The coordinates are taken from Wray (1966). A strong K-line in absorption would lead us to concur in the F-type classification given by Herbig (1969).
176. Coordinates are from Wray (1966). Classified as symbiotic by Herbig (1969).
177. Coordinates are taken from Wackerling (1970). Weak λ5007 present. Spectrum is described by Herbig (1950).
178. Coordinates are from Wackerling (1970). He I λ6678 visible.

a featureless continuum extending into the ultraviolet, indicative of a very early-type star. Only a few show absorption in the higher members of the Balmer series. It is improbable but not impossible that some of the fainter ones may be of later spectral type, although, if any were as late as carbon, M-type, or S-type stars, they would undoubtedly be detected as such on our yellow-red sensitive plates. A number of these objects are known to show P Cygni profiles in their emission lines and it seems likely this is a general characteristic of this category. Such profiles ordinarily cannot be discerned on objective-prism plates of this kind.

As we have noted, most of the Be! objects show a definite continuum and clearly are stars. However, in some cases a continuum is apparently absent, giving the impression that a nebula is seen. Consequently, these were provisionally classified as planetary nebulae in earlier Hα emission-line surveys. Based on the apparent absence of the [O III] lines at λλ5007 and 4959, none of these would be considered to be a planetary within the normally defined range of excitation characteristics. Some of the fainter Be! objects, however, may represent very-low-excitation compact nebulae of

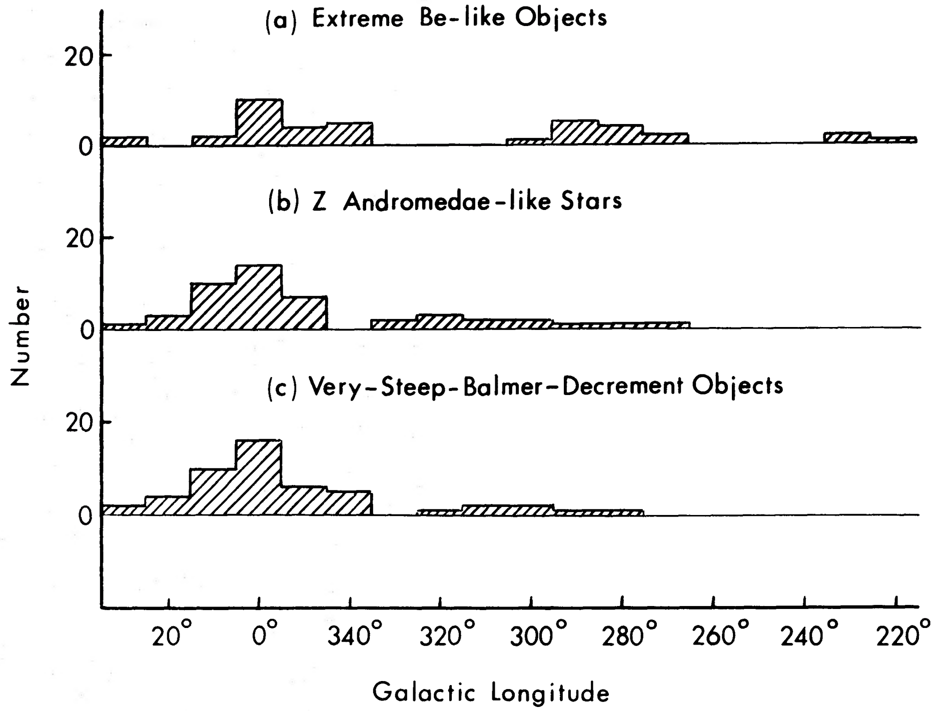

FIG. 1.—Galactic longitude distributions for several types of strong-emission-line objects in table 1.

the type we have recently discussed (Sanduleak and Stephenson 1972). Why this may be so is explained in § II*c* under the category of suspected very-low-excitation nebulae.

The galactic-longitude distribution of the Be! objects is shown in figure 1*a*. In confirmation of our expectation that this group involves or is related to the Population I emission-line stars, we find that the distribution resembles the overall surface distribution of OB stars in our survey, i.e., minima occur in the directions of Puppis (250°) and Circinus (320°) while strong concentrations appear in Carina (270°–295°) and in the direction of Scorpius-Sagittarius (335°–15°).

b) *Peculiar Be-like Objects*

A small number of very interesting objects were noted which, in addition to having very strong hydrogen emission as in the previous category, also contained exceptionally strong emission lines of neutral helium, singly ionized iron, or various other spectral features not frequently encountered on our plates. These are labeled as Be! pec in column (7) of table 1, and the respective peculiarities of the individual objects are noted in the remarks following the table.

c) *Suspected Very-Low-Excitation Nebulae*

In the reference mentioned earlier (Sanduleak and Stephenson 1972) we identified and discussed a group of compact nebulae having very-low-excitation characteristics. These are objects in which the [O III] lines at $\lambda\lambda$5007 and 4959 apparently are either absent or very weak compared to Hβ whereas the [O II] λ3727 doublet is usually quite strong relative to Hβ. However, among the 23 relatively bright nebulae listed in that paper, there were two examples in which the λ3727 feature was comparatively weak relative to Hβ. This prompts us to suspect that strong interstellar absorption might selectively weaken the λ3727 feature relative to Hβ to the extent that only the lower Balmer series members would be visible in some very-low-excitation nebulae seen near our plate limit. This is our reason for stating that possibility that some of the very faint Be! objects in table 1 may ultimately prove to be nebulae of this type.

This possibility is also the basis for our defining a spectral category known as suspected very-low-excitation nebulae abbreviated as VLE? in column (7) of table 1. In this category we place any weak-continuum object which, in addition to strong hydrogen emission, displays forbidden nebular lines. These must show no evidence of higher excitation lines of helium, iron, or other elements. A few objects were assigned to this category because they appeared to have an [O III] λ5007 line that was observed to be weak relative to Hβ on our plates. However, most of the VLE? objects in table 1 were identified from the fact that they are known or suspected to contain the low-excitation nebular line of [N II] at λ6584 according to data provided by Henize (1967). Unfortunately, the presence of this line cannot be reliably established from our own plates because the dispersion is too low to resolve it independently of Hα. The λ3727 doublet is not seen in any of these VLE? objects, but, as we noted earlier, its absence might well be attributed to the existence of strong interstellar absorption.

In addition to noting the presence of forbidden nebular lines, one might also seek to identify nebulae from their resolvable images. As stated at the outset, all objects in table 1 appeared stellar on our plates. This impression is substantiated by the results of Westerlund and Henize (1967) who obtained large-scale direct photographs of 31 members of table 1 which they considered to be possible planetary nebulae. Only two of these are definitely resolved and belong in the VLE? category. Actually one should not expect such apparent-diameter measurements to be a very effective discriminant in the case of very-low-excitation nebulae since they are generally very compact and often indistinguishable from stars. The 29 objects found to have stellar dimensions by Westerlund and Henize are identified in the remarks following table 1 by the appearance of the word "stellar."

In brief, then, the VLE? category consists of objects which we have reason to suspect may be of the same nature as those listed in our earlier paper (Sanduleak and Stephenson 1972).

d) *Z Andromedae–like Stars*

This category contains stars that at the time of our observations showed evidence of having a Z Andromedae–like emission-line spectrum, i.e., a sharp He II λ4686 line in addition to strong hydrogen emission plus weak He I and forbidden nebular lines in many cases. A symbol Z is used to denote this kind of spectrum in column (7) of table 1. These may prove to be symbiotic stars, and indeed nearly one-half of those in this group have been classified as such elsewhere.

Although He II λ4686 emission is also characteristic of Wolf-Rayet stars, the narrowness of the emission lines and the absence of strong carbon and nitrogen emission features in both the photographic and visual spectral regions should serve to exclude W-R stars from this group. The Wolf-Rayet stars detected by our survey have been listed in our catalog of luminous stars (Stephenson and Sanduleak 1971).

Column (7) also conveys data concerning the observed strength of λ4686 relative to Hβ. The symbol Z? indicates that λ4686 was suspected of being present; Z^- signifies that λ4686 was definitely present but much weaker than Hβ; Z means that the two lines had roughly comparable strengths; Z^+ is used when λ4686 is significantly stronger than Hβ. These distinctions should enable subsequent observers to determine if this line ratio is strongly variable as might be expected in symbiotic stars.

In addition to the emission-line spectrum, most of these Z-type stars display a continuum, commonly more apparent at the longest wavelengths. In some of the brighter ones, TiO bands are clearly evident and in such cases we have added the M-type classification, e.g., Z+M4, in column (7) of table 1. In some of the fainter stars where we only suspect the presence of TiO we have added the notation M? in that column. It is of interest to note, as did Herbig (1969), that several of these stars clearly lack TiO bands and thus may be of K type or perhaps even earlier. Some of the stars showed no evidence of a continuum on our survey plates. One might best search for continuua and TiO bands in these very faint stars by using long-exposure, low-dispersion objective-prism plates covering the near-infrared spectrum. Suitably deep infrared plates were available in the Warner and Swasey Observatory's plate collection for only a few of the more northerly stars. Positive results obtained from these additional plates are mentioned in the Remarks to table 1.

Some of the weak-continuum Z-type stars were previously classified as probable planetary nebulae. Such classifications are refuted by the fact that the [O III] λ5007 line is either apparently absent or significantly weaker than Hβ in all cases. If any of these were actually high-excitation nebulae (as required by the presence of λ4686), they would be expected to have λ5007 much stronger than Hβ rather than the reverse.

Although marked variability in light is usually thought to be a salient characteristic of this class of object, very few of these Z-type stars are established variables. Of course, this may be primarily a consequence of their general faintness. However, we note that Hoffleit (1970) studied six of these stars that were first detected spectroscopically by Herbig (1969) and found only one to be conspicuously variable in light and two others that appeared to be nonvariable. Thus it is not certain that this type of spectrum is necessarily associated with strong or regular light variations.

The galactic-longitude distribution is illustrated in figure 1*b*. This shows a relatively smooth increase in number as the direction of the galactic center is approached. The distribution of the Z-type stars thus resembles that of intermediate-age populations such as novae, planetary nebulae, and R CrB variables and seems to confirm the prevailing opinion that the symbiotic stars are of a similar population type.

e) *Peculiar M-Type Emission-Line Stars*

This group is composed of M-type stars having strong hydrogen emission but no evidence of He II λ4686 emission. They appear peculiar in that they show strong Hα and in some cases Hβ emission as well. This is quite different from the typical Mira-type long-period variables in which Hα and Hβ emission is absent on our plates while either Hγ or Hδ is the most prominent Balmer emission line. The essentially normal Balmer decrement in these stars suggests that the emission arises in a very extended atmosphere or circumstellar envelope or in a companion star such as might occur in a symbiotic star. Actually several of these have been classified elsewhere as symbiotic stars, and perhaps the only distinction between this group and what we have called the Z-type stars is that these stars were observed at a phase when the λ4686 line was very weak or absent and the M-type component was predominant. There is no evidence that any of these could be dMe stars in terms of large proper motion, strong sodium D-lines, or other indicators of low luminosity.

f) *Proven and Probable VV Cephei Stars*

Our use of an ultraviolet-transmitting objective prism permits spectral coverage down to a shortward cutoff at about λ3300 in well-exposed images. This makes it rather easy to detect composite stars of the type in which a very late-type component dominates the blue-green spectral region while the continuum and perhaps absorption features of an early-type component are clearly visible in the ultraviolet. During the survey we noted a small number of such composite stars combining M-type with OB- or *B*-type components which also showed evidence of hydrogen and/or iron emission lines. Several of these are well-known VV Cephei stars. Because of the great interest which attaches to this rare type of star, we have included these in table 1.

g) *Very-Steep-Balmer-Decrement Objects*

This category consists of strong-emission-line objects which, on the 103a-F plates, show Hα with a strength comparable to or, in some cases, even exceeding the average Hα intensity characterizing the previously discussed categories of objects. Surprisingly, however, emission lines and usually continuua as well are totally invisible on the matching IIa-O plates. Because the two types of plates were taken on separate nights, generally several days apart, one cannot entirely dismiss the possibility that this absence might result, in some instances, from variable line emission. However, considering that we encountered 50 such examples, the more plausible explanation is that Hβ is exceptionally weak relative to Hα in these objects, much weaker than the usually observed ratio of about three or four to one.

In the absence of any definitive emission features in the blue-green spectral region, the true nature of these objects remains unknown and to emphasize this we have assigned them a symbol X in column (7) of table 1. If this ostensibly very steep Balmer decrement is an intrinsic property, these may well constitute a physically distinct class of objects. However, the very strong concentration of these X-type objects toward the direction of the galactic center, shown in figure 1*c*, suggests that this group may consist primarily of the more distant and highly reddened Be! and symbiotic stars in that direction.

In any event we have evidence that several objects of this type are exceedingly red. Allen (1973) has obtained near-infrared photometric data for a large sample of emission-line objects including numbers 34, 36, 39, 43, and 61 in our table 1. Typically, these have $V - K$ (2.2 μ) color indices of 6–9 mag, as compared to less than 1 mag for most of the brighter, early-type emission-line stars. Allen's data also show that several of these have a large infrared excess of the type usually attributed to reradiation from a circumstellar dust cloud. Whatever their nature, these results and our own observations would indicate that the X-type objects will prove difficult to observe spectroscopically in the conventionally used blue-green portion of the spectrum.

Most of the X-type objects were provisionally classified as planetary nebulae in earlier objective-prism surveys confined to coverage of the Hα region. Primarily because of the failure to detect any trace of [O III] λ5007 in their spectra, we think it highly improbable that any of them will prove to be nebulae within the normally encountered range of excitation types. If interstellar absorption is indeed the mechanism which produces the X-type objects, it is difficult to see how it could effectively obliterate λ5007 relative to Hα since these two lines are intrinsically comparable in strength in most planetaries. More likely, λ5007 is very weak or absent in these objects. This same argument led Webster (1966) to label a number of these same objects as doubtful planetaries and to show that several definitely were not. The nonplanetary nature of at least 13 of the 50 X-type objects is further supported by the fact that they have stellar dimensions according to Westerlund and Henize (1967). From the data available from Henize (1967) we know that 24 of them show no definite evidence of [N II] λ6584. The status of this line in the remaining objects is not known.

IV. CONTENTS OF TABLE 1

An asterisk in column (1) signifies the presence of a remark following the table. Unless otherwise noted in the Remarks, the 1950 coordinates in columns (2) and (3) were derived from measures made on our objective-prism plates and should be reliable to within several seconds of arc.

Column (4) contains direct eye-estimates (to the nearest half-magnitude) of the photographic apparent magnitude of the continuum associated with the emission-line object. If no continuum was observed, we indicate this absence by a letter A. The estimated average limiting magnitude for detection of a continuum on the IIa-O plates (11-minute exposure and spectra widened to 0.20 mm) is $m_p \sim 14.0$. Column (5) gives corresponding data derived from the 103a-F plates (10-minute exposure and 0.15-mm widening) where we estimate $m_v \sim 12.5$ as the average limiting magnitude for detection of a continuum. Since these data are crudely derived, they are intended to give only an approximate idea of the apparent brightness and perhaps color of these objects at the time of our observations.

Column (6) lists the last resolvable Balmer emission line visible on our plates, following the standard convention that $H\alpha = 3$, $H\beta = 4$, etc. This limiting line is obviously a function of the intrinsic strength of the emission, the resolution on the plate, and, perhaps most importantly, the apparent magnitude. Higher dispersion and better exposed spectra will undoubtedly show emission in still higher members of the Balmer series than those listed in column (6). However, we have given these data since they may enable subsequent objective-prism spectroscopists to detect gross changes in the strength of the hydrogen emission in these objects. The objects having the apparently steepest Balmer decrements are indicated in column (6) by the notation 3! which signifies extremely strong $H\alpha$ but no evidence of $H\beta$ in emission. Column (7) gives the general spectral category according to the criteria outlined earlier.

Finally, column (8) contains various names and catalog numbers previously assigned to these objects. The two main sources for these identifications were the comprehensive catalog of early-type emission-line stars compiled by Wackerling (1970) and the *Catalog of Galactic Planetary Nebulae* compiled by Perek and Kohoutek (1967). Objects contained in the latter catalog carry the prefix PK in column (8). Most of the objects which can be found in Wackerling's catalog are identified in column (8) by one of the following designations: MWC or AS (numbers assigned in the various Mount Wilson Observatory $H\alpha$ surveys), WRA (numbers taken from table 15 of Wray 1966), or HEN (unpublished numbers attributed to Henize). A few additional identifications are contained in the remarks. If, to best of our knowledge, the object has not been previously reported to show line emission, the word "new" appears in column (8).

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