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The Galactic Distribution of the Wolf-Rayet Stars

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All known galactic Wolf-Rayet stars are presented in a catalogue that is considered complete for those lying within about 2 kpc of the sun. Regions of concentration in the projected density distribution are interpreted as spiral arm features. In this manner the Cygnus-Carina arm, the Sagittarius arm, the Vela spur, and the Perseus region are indicated. However, no Wolf-Rayet stars appear in the direction of the Orion spur. In fact, the entire quadrant of the galactic plane, centered on the galactic anticenter is devoid of Wolf-Rayet stars, although OB-type stars are present in this part of the galactic plane.

The WC and WN stars show no significant differences in their projected distribution.

Lists of known and suspected binaries and observational desiderata are presented.

I. INTRODUCTION

THE arms of a spiral galaxy are defined optically by high-luminosity early-type stars. Stellar groups containing such stars, i.e., associations and galactic clusters, have been employed to map out the optical arms of our galaxy. Such a mapping requires the coordinates and the distances of the stars or groups as necessary data which now cover a distance of about 3 kpc. Although systematic and random errors may still exist in the determination of the distances, the emerging picture shows the regions in the galactic plane where the greatest concentration of such stars and groups appear.

Wolf-Rayet stars, because of their high luminosity or frequent membership in binaries containing early supergiant stars, are an excellent class of spiral tracers. Since the Wolf-Rayet stars are members of at least some associations and galactic clusters, they have been used indirectly in the delineation of spiral arms. As a class, they have not been used as spiral tracers; their absolute magnitudes and true colors are not known with sufficient accuracy. However, they do represent a class of stars which have been *completely* discovered out to about 2 kpc (assuming $M_{pg}=-3.5$). In addition, many have also been discovered at greater distances. This completeness results from the ready detection of these stars on objective prism surveys. Furthermore, their strongly exhibited emission lines allow the limiting magnitudes in such surveys to go fainter for the WR stars than for absorption-type spectra.

Lacking individual distances for the Wolf-Rayet stars, a spatial map of their distribution cannot be constructed. However, their surface distribution contains significant information. We may reasonably assume that regions of high concentration of WR stars represent directions in which our line of sight goes along a spiral arm or "spur."

II. CATALOGUE OF WOLF-RAYET STARS

To outline the surface distribution of WR stars a catalogue has been prepared listing all galactic Wolf-Rayet stars whose discovery has been reported in the literature or privately reported to me. This catalogue is presented in Table I. Known nuclei of planetary nebulae have been omitted from the list. Stars suspected of having Wolf-Rayet characteristics have been included. The catalogue is proposed to serve as a basis for statistical discussions and as a finding list for observers. No attempt has been made to present a complete bibliography for each star. Later independent discoveries reported in the literature have not been listed in the references which are given only as a guide for the tabular material, especially for the spectral types where minor differences in the literature often exist. Every attempt was made to credit original discoverers in the references, except in the cases of those stars listed in the *Henry Draper Catalogue.*

The following information is offered: Column 1: A running catalogue number. An asterisk in this column refers to a note at the end. Column 2: HD, CD, or BD number. Columns 3 and 4: The 1900 coordinates. Columns 5 and 6: The IAU galactic coordinates. Column 7: The spectral type; the source is indicated in the reference column. Columns 8 and 9: Photographic and visual magnitudes. Many of the magnitudes are from the *Henry Draper Catalogue* or from Payne (1930), others are often estimates made by the discoverer. Magnitudes to two decimal places are on the *UBV* system. Column 10: References to discovery, spectral type, and magnitude. No entry has been made for those stars which were found in the Draper survey and for which no further information is available.

III. SPIRAL ARMS

The galactic distribution of the stars in Table I is illustrated in Fig. 1, where IAU galactic coordinates are used. Clustering of the Wolf-Rayet stars at certain longitudes is clearly visible. This clustering is also illustrated in Fig. 2, which is a histogram showing the distribution of the stars in 10° longitude intervals. Major peaks are found in Fig. 2 at $l^{II}\approx 75°$, 290°, and 350°, while less prominent peaks occur at $l^{II}\approx 20°$, 110°, and 240°.

The major peaks lie in directions where spiral arms have previously been delineated. The minor peaks can also be associated with spurs or extensions of optical arms. An exception to these identifications is the Orion spur described by Bok (1959) and by Johnson *et al.* (1961). No Wolf-Rayet stars are found in this direction. In fact, a striking feature in Figs. 1 and 2 is the complete absence of WR stars in that quadrant of the galactic plane centered on the anticenter. This unusual feature in the distribution of WR stars has been noted by Vorontsov-Velyaminov (1953) and Roberts (1958) and is also displayed on the plot of the distribution of WR and O-type stars published by Plaskett (1924) as well as on a similar plot published by Payne (1930). Although the discovery of 48 Wolf-Rayet stars since 1930 does not represent the result of a systematic survey of the entire sky, this region continued void of WR stars.

The spiral indicating properties of the Wolf-Rayet stars allow us to draw certain conclusions about galactic structure in the general direction of the "zone of avoidance." That a complete spiral arm does not exist beyond the Cygnus-Carina arm has already been noted in the literature (e.g., Bok 1959; Johnson *et al.* 1961). The total absence of Wolf-Rayet stars in the direction in which such an arm would lie ($l^{II}=145°$ to $225°$) supports the view that no significant stellar arm exists in this direction. However, OB stars are found in this general direction, and their number would indicate that the Wolf-Rayet stars are unusually deficient in the anticenter direction. Figure 3(a) shows the distribution in longitude of OB stars to $m_{pg}=11$ in the region $l^{II}=12°$ to $232°$ (Nassau and Morgan 1951). These longitude limits define a sector cutting through the Cygnus-Carina arm; many of these OB stars lie within this arm. Figure 3(b) shows the distribution of the Wolf-Rayet stars in the same longitude region. Except for the "zone of avoidance" there is a qualitative agreement in the distribution of the WR stars and OB stars. Differences in detail between the two distributions are to be expected because of differences in distance limits in the Wolf-Rayet and OB surveys.

TABLE I. Catalogue of Wolf-Rayet stars.

No.[a]	HD	R.A. (1900)	Dec. (1900)	l^{II}	b^{II}	Sp. Type	m_{pg}	m_v	Ref.[b]
1*	4004	$0^h37^m.5$	+64°14′	122°.1	+1°.9	WN6	10.55	10.18	1, 2
2*	6327	0 59.2	+59 53	124.6	−2.4	WC7	10.1		3
3*	9974	1 32.4	+57 39	129.2	−4.1	WN5	10.71	10.69	1,2
4	16523	2 33.9	+56 18	137.6	−3.0	WC6	10.0	10.0	1
5	17638	2 44.8	+56 31	138.9	−2.2	WC6	10.2	10.2	4
6*	50896	6 50.0	−23 48	234.8	−10.1	WN5	6.9	6.6	5
7	56925	7 13.9	−13 03	227.8	−0.1	WN7	12.1	11.0	6
8*		7 39.2	−29 04	244.6	−2.8	WR			7
9	62910	7 41.1	−31 41	247.1	−3.8	WN6p	9.7	10.0	8
10	63099	7 42.0	−34 05	249.3	−4.8	WC6 +O7:I	10.8	11.3	8
11	65865	7 55.7	−28 28	246.0	+0.6	WNp	10.1	11.4	8
12*	68273	8 06.5	−47 03	262.8	−7.7	WC7 +O7:	2.2	2.2	8
13	CD−45°4482	8 41.4	−45 37	265.2	−2.0	WN8		10.0	9, 10
14*		8 45.4	−45 43	265.7	−1.5	WR			7
15		8 46.4	−44 48	265.1	−0.8	WC6			9, 10
16	76536	8 51.6	−47 13	267.6	−1.6	WC7	8.8	9.0	8
17	79573	9 09.8	−49 42	271.4	−1.1	WC6	11.0	10.9	8
18*		9 50.0	−54 24	279.1	−0.4	WR			7
19	86161	9 51.6	−57 15	281.1	−2.6	WN8	8.3	8.3	8
20*	88500	10 07.2	−60 09	284.4	−3.7	WC7+	10.1	10.3	8
21*	89358	10 13.5	−57 25	283.6	−1.0	Oa	11.1		
22*		10 18.0	−57 36	284.2	−0.8	WR			7
23	90657	10 22.9	−58 08	285.0	−0.9	WNp	9.8	10.1	8
24	91421	10 28.2	−57 43	285.4	−0.2	WN5	9.1	9.3	11
25	92740	10 37.4	−59 09	287.2	−0.8	WN7	6.3	6.5	12
26*	92809	10 37.8	−58 15	286.8	0.0	WC6	9.1	9.0	8
27*	93128	10 40.1	−59 02	287.4	−0.6	Oc	8.5	7.1	13
28	93131	10 40.1	−59 36	287.7	−1.1	WN7	6.3	6.7	8
29	93162	10 40.3	−59 12	287.5	−0.7	WN7 +O7	8.8	8.4	8
30	94305	10 47.9	−61 46	289.5	−2.6	Oa	12.0		
31	94546	10 49.7	−58 59	288.5	0.0	WN6p +B0n::	10.6	10.9	8
32*		10 54.7	−60 39	289.8	−1.2	WR			7
33*	95435	10 55.8	−57 17	288.5	+1.9	Oa	11.5		
34*	96548	11 02.3	−64 58	292.3	−4.8	WN8	8.2	7.8	12
35*		11 04.4	−60 11	290.7	−0.3	WR			7
36	97152	11 05.8	−60 26	290.9	−0.5	WC6 +B0V:	7.9	8.1	8
37*		11 10.3	−60 46	291.6	−0.6	WR			7
38	97950	11 10.8	−60 43	291.6	−0.5	WN5 +O	9.2	8.8	14
39		11 12.5	−58 53	291.2	+1.3	WR			15
40	104994	12 00.2	−61 29	297.6	+0.4	WN4p	10.1	10.4	8
41*		12 06.0	−61 56	298.3	0.0	WR			7

TABLE I (*continued*)

No.[a]	HD	R.A. (1900)	Dec. (1900)	l^{II}	b^{II}	Sp. Type	m_{pg}	m_v	Ref.[b]
42		$12^h37^m.9$	$-62°32'$	$302°.1$	$-0°.2$	WN5	11.5		17, 18
43*	113904	13 01.7	−64 46	304.7	−2.5	WC6 +O9.5I	5.4	5.6	8
44		13 11.5	−61 54	306.0	+0.3	WC6	12.6		18, 19
45		13 11.9	−61 57	306.0	+0.2	WC7	14.7		18
46	115473	13 12.2	−57 37	306.5	+4.5	WC6	9.0	9.3	8
47	117297	13 24.2	−61 34	307.5	+0.4	WC7	10.9	11.2	8
48		13 25.8	−64 30	307.3	−2.5	Oa	12.6		19
49	117688	13 26.8	−61 48	307.8	+0.2	WN6	10.9	11.2	8
50	119078	13 35.9	−66 54	307.9	−5.0	WC7	9.4	9.7	8
51		13 41.8	−65 12	308.8	−3.5	Ob	13.0		19
52	121194	13 48.8	−60 40	310.6	+0.8	Oa	11.0		16
53		14 05.3	−64 58	311.3	−3.9	WR			15
54	134877	15 07.1	−59 28	320.1	−1.8	WR			15
55		15 07.7	−58 40	320.6	−1.2	WR			15
56	136488	15 15.8	−62 19	319.5	−4.8	WC8	9.1	9.4	8
57	137603	15 21.8	−58 14	322.3	−1.8	WNp	10.4	10.7	8
58	143414	15 55.0	−62 24	323.1	−7.6	WN6	9.2	9.5	8
59*		16 13.3	−36 24	342.9	+9.6	WR			7
60	147419	16 16.8	−51 18	332.8	−1.5	WN5	10.5	11.6	8
61*		16 19.5	−51 12	333.2	−1.7	WR			7
62*		16 33.9	−47 49	337.3	−1.1	WR			7
63		16 45.1	−25 49	355.5	+11.6	WR			15
64	151932	16 45.3	−41 41	343.2	−1.4	WN7	6.4	6.6	12
65*	152270	16 47.3	−41 40	343.5	+1.2	WC7 +O8	7.2	6.7	8
66		16 55.3	−45 50	341.1	−2.6	WC8			7
67*		17 03.6	−46 28	341.5	−4.1	WR			7
68	156327	17 11.8	−34 18	352.2	+1.8	WC7 +B0V:	10.0	9.4	8
69	156385	17 12.1	−45 32	343.2	−4.8	WC7p	7.5	7.2	8
70		17 12.2	−33 57	352.6	+2.0	WR			53
71	157451	17 18.2	−43 24	345.5	−4.4	WC8	10.2	11.6	8
72	157504	17 18.5	−34 06	353.2	+0.8	WC6		11.8	8
73	158860	17 26.5	−33 33	354.6	−0.2	WN5+	11.1	11.1	8
74*		17 29.7	−33 22	355.1	−0.7	WR			7
75	320102	17 30.3	−33 58	354.7	−1.1	WR			15
76*		17 30.6	−33 24	355.2	−0.9	WR	12.7		54
77*		17 35.6	−32 30	356.5	−1.3	WR	13.8		54
78*	163758	17 52.7	−36 00	355.4	−6.1	Oe	7.1	7.3	
79	164270	17 55.2	−32 43	358.5	−4.9	WC8	8.6	8.8	12
80		17 56.0	−23 38	6.4	−0.5	WC8			10
81*		17 56.7	−18 05	11.3	+2.1	WR			7
82*		17 58.9	−21 12	8.9	+0.1	WC7	13.27	12.02	20
83	165688	18 02.1	−19 25	10.8	+0.4	WN5	9.7	9.8	8
84	165763	18 02.5	−21 16	9.2	−0.6	WC6	7.7	7.8	12
85*	168206	18 13.5	−11 40	18.9	+1.8	WC7 +B0:	9.86	9.14	8
86*	169010	18 17.5	−13 46	17.5	−0.1	WC6	12.99	12.02	20
87		18 19.8	−14 42	17.0	−1.0	WR			21
88		18 25.7	−6 41	24.7	+1.5	WR			21
89*		18 36.0	−4 33	27.8	+0.2	WN7	12.99	11.94	20, 22
90*		18 39.2	−3 54	28.7	−0.2	WC7+	13.34	11.94	20, 23
91*	177230	18 58.7	−4 28	30.5	−4.8	WN8	11.1	11.1	24
92*		19 12.8	−11 16	26.0	−11.0	WR			23
93		19 24.0	+19 23	54.5	+1.0	WR			21
94*	186943	19 42.2	+28 01	64.0	+1.7	WN5	10.50	10.23	25
95*	187282	19 44.1	+17 57	55.6	−3.8	WN5	11.0	10.51	12
96		19 44.3	+30 12	66.2	+2.4	WC	13.4		26
97		19 56.4	+32 59	69.9	+1.7	WR			21
98	190002	19 57.8	+32 18	69.5	+1.1	WC7	11.1	11.1	3
99*	190918	20 02.2	+35 31	72.7	+2.1	WN5 +O9.5III	7.0	7.0	27
100	191765	20 06.5	+35 53	73.4	+1.6	WN6		8.0	12
101*	192103	20 08.1	+35 54	73.6	+1.3	WC7	8.11	8.06	2, 12
102	192163	20 08.4	+38 03	75.5	+2.4	WN6	7.5	7.4	12
103*	192641	20 10.8	+36 21	74.3	+1.1	WC6	8.20	7.93	2, 27
104*	193077	20 13.3	+37 07	75.2	+1.1	WN5	8.0	8.1	27
105*	228766	20 13.8	+37 00	75.2	+1.0	WN7	9.79	9.14	28
106*	193576	20 15.8	+38 25	76.6	+1.4	WN5 +B1:		8.0 var	29

TABLE I (*continued*)

No.[a]	HD	R.A. (1900)	Dec. (1900)	l^{II}	b^{II}	Sp. Type	m_{pg}	m_v	Ref.[b]
107*	193793	$20^h17^m.1$	+43°32′	80°.9	+4°.2	WC6 +O6	6.8	6.8	30
108*	193928	20 17.8	+36 36	75.3	+0.1	WN5+	10.60	9.78	25
109	195177	20 24.7	+38 17	77.5	0.0	WC			3
110		20 28.5	+40 55	80.0	+0.9	WC6	15.5		31
111*		20 28.5	+40 28	79.7	+0.7	WN7	14.0		31
112	BD+40°4243	20 32.3	+41 00	80.6	+0.4	WC6	15.5		31
113*	197406	20 38.4	+52 14	90.1	+6.5	WN5	10.87	10.30	23, 32
114*		22 06.1	+57 13	102.6	+1.4	WN5	12.5 var		33, 34
115	211564	22 12.9	+55 07	102.2	−0.9	WN5	11.1		12
116*	211853	22 15.0	+55 37	102.8	−0.6	WN6 +B0:I:	9.42	9.02	25, 35
117	213049	22 23.7	+55 46	103.9	−1.2	WC6	11.0		3
118*	214419	22 32.9	+56 23	105.3	−1.3	WN6 +O7	9.4: var		36, 37
119*		22 56.1	+60 24	109.8	+0.9	WN8	11.5		33, 38
120*	219460	23 10.8	+59 55	111.3	−0.2	WN5	10.51	9.89	39
121		23 28.2	+61 28	113.8	+0.5	WN6:		9.5:	40
122*		23 38.7	+61 23	115.0	+0.1	WR	11.9		23, 41
123		23 39.2	+61 14	115.0	0.0	WN8:		9.5	40

[a] The following notes are indicated by an asterisk in the first column. The number of the note is the same as the number in column 1.

1. HD 4004. $B-V=+0.37$, $U-B=-0.27$, reference 2.
2. HD 6327. Same as Bergedorf Spectral-Durchmusterung, Field 8, No. 533. Spectral type Ob, $m_{pg}=11.7$.
3. HD 9974. $B-V=+0.02$, $U-B=-0.86$, reference 2. May be O6+WR, reference 35. Possible spectroscopic binary, reference 39.
6. HD 50896. Possible spectroscopic binary or spectrum variable, reference 5.
8. Henize (reference 7) tentatively classifies this star as a WR type on the basis of a perceptibly widened H_α emission line.
12. HD 68273. γ_2 Vel. Probably light variable, reference 42.
14. See remark, star No. 8.
18. See remark, star No. 8.
20. HD 88500. Variable magnitude, reference 42.
21. HD 89358. CPD mag. =10.
22. See remark, star No. 8.
26. HD 92809. Variable magnitude, reference 42.
27. HD 93128. Visual magnitude is for HD 93128 plus HD 93129.
32. See remark, star No. 8.
33. HD 95435. Suspected light variations, reference 42.
34. HD 96548. Variable magnitude, reference 42.
35. See remark, star No. 8.
37. See remark, star No. 8.
41. See remark, star No. 8.
43. HD 113904. ϑ Mus. B0I: companion, reference 35.
59. See remark, star No. 8.
61. See remark, star No. 8.
62. See remark, star No. 8.
65. HD 152270. Spectroscopic binary, reference 43.
67. See remark, star No. 8.
74. See remark, star No. 8.
76. Henize (reference 7) classifies star as WR.
77. Henize (reference 7) classifies star as WR.
78. HD 163758. Spectral classification O5w−WIII sk, reference 44.
81. See remark, star No. 8.
82. $B-V=+1.25$, $U-B=+0.31$, reference 20.
85. HD 168206. CV Ser. Eclipsing and spectroscopic binary, reference 52. $B-V=+0.72$, $U-B=-0.26$, reference 2.
86. HD 169010. $B-V=+0.97$, $U-B=+0.54$, reference 20.
89. $B-V=+1.05$, $U-B=+0.11$, reference 20. There is some question as to whether this is a planetary nebula; see reference 22.
90. MH_α 345–32. $B-V=+1.40$, $U-B=+0.36$, reference 20.
91. HD 177230. Spectroscopic binary, reference 24.
92. MH_α 319–34. Reference 23 states that Minkowski has found this star to be of type W. From an examination of case objective prism plates, Stephenson (reference 49) feels that this object is a planetary nebula.
94. HD 186943. $B-V=+0.27$, $U-B=-0.64$, reference 2. Spectroscopic binary, reference 47.
95. HD 187282. $V=10.51$, reference 2.
99. HD 190918. ADS 13374 (A). Spectroscopic binary, reference 48.
101. HD 192103. $B-V=+0.05$, $U-B=-0.41$, reference 2. Variable by about $0^m.2$, reference 42.
103. HD 192641. $B-V=+0.27$, $U-B=-0.45$, reference 2. Variable magnitude, reference 42.
104. HD 193077. ADS 13641 (A). Small variations in magnitude, reference 42.
105. HD 228766. $B-V=+0.65$, $U-B=-0.37$, reference 2. Spectroscopic binary, reference 28.
106. HD 193576. V444 Cygni. Spectroscopic and eclipsing binary, references 29 and 45.
107. HD 193793. Spectroscopic binary, reference 30.
108. HD 193928. $B-V=+0.82$, $U-B=+0.07$, reference 2. Spectroscopic binary, reference 47.
111. Spectroscopic binary, reference 46. MH_α 328–53.
113. HD 197406. $B-V=+0.57$, $U-B=-0.45$, reference 2. Spectroscopic binary, reference 24.
114. CX Cep. Eclipsing and spectroscopic binary, reference 34.
116. HD 211853. $B-V=+0.40$, $U-B=-0.55$, reference 2. Spectroscopic binary, reference 47. Small light variation, reference 42.
118. HD 214419. CQ Cep. Eclipsing and spectroscopic binary, references 36, 37.
119. AC +60°38562.
120. HD 219460. $B-V=+0.62$, $U-B=-0.28$, reference 2. Visual binary, brighter companion (1″ separation) is a B star, reference 39.
122. MH_α 217–9. Spectrum variable, reference 50.

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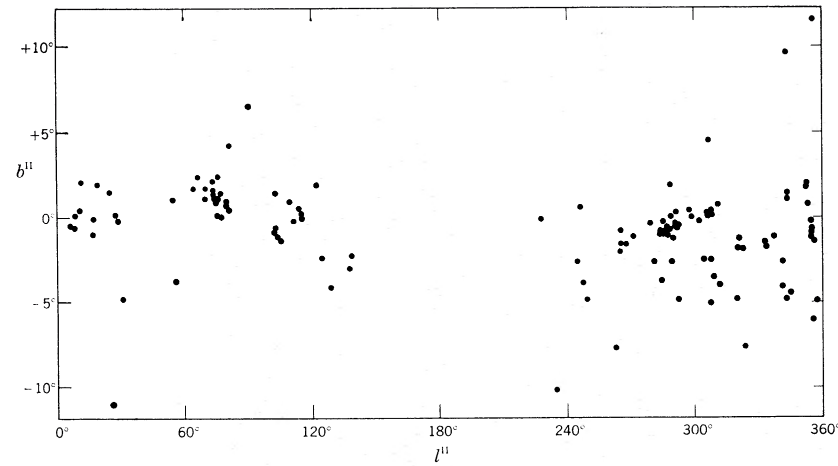

FIG. 1. The galactic distribution of Wolf-Rayet stars listed in Table I.

We may estimate the number of Wolf-Rayet stars to be expected in the direction of the anticenter from the ratio of WR stars to OB stars in a region where relatively large numbers of both types are present. For these calculations a 120° zone from $l^{II}=12°$ to 132° was chosen. Such a procedure assumes that over a large enough region of space the ratio is constant. This assumption obviously does not hold for the anticenter direction. Thus, the size of the *expected* number of Wolf-Rayet stars in the anticenter direction may allow us to choose between (a) statistical fluctuations or (b) a physically significant deficiency of Wolf-Rayet stars. For the 85° interval from $l^{II}=137°$ to 222° we would expect 17 WR stars if we use Wolf-Rayet stars in the comparison zone of all magnitudes. If we restrict the Wolf-Rayet comparison to $m_{pg}\leqslant 11.5$, we would expect 11 WR stars to occur in the above 85° longitude zone. Taking $n^{\frac{1}{2}}$ as a measure of statistical fluctuations, we would expect at least seven Wolf-Rayet stars. Although this number is relatively small, we may reasonably conclude that the absence of Wolf-Rayet stars in that quadrant of the galactic plane centered on the anticenter is not due to statistical fluctuations in their distribution. It thus seems likely that for some unknown physical reason, Wolf-Rayet stars are formed less frequently in this particular region of a spiral arm.

The Wolf-Rayet stars in the southern hemisphere are found to be not only more numerous, but also to lie systematically below the galactic plane, as can be seen in Fig. 1. Table II presents the average galactic latitude for the stars in the two hemispheres and also illustrates these characteristics. In this table, the average latitudes are given for all the known Wolf-Rayet stars, for those brighter than $m_{pg}=11.5$, and for the two sequences, WC and WN. No significant differences appear in any of these groupings for a given hemisphere.

The distribution in distance may be estimated by plotting, in the l, b plane, the numbers of stars to different limiting magnitudes. Interpreting apparent magnitudes as a direct (but unknown) distance measure assumes (a) that the dispersion in the absolute magnitude of Wolf-Rayet stars is small and (b) that obscuring matter is uniformly distributed in space. Both of these assumptions are doubtless poor approximations to the true situation and we can only hope, at present, to obtain the roughest picture of the spatial distribution of the WR stars from their apparent magnitudes.

With these precautions in mind we illustrate in Fig. 4 the numbers of WR stars in intervals of $\Delta l=40°$ and $\Delta b=2°$ and to different limiting magnitudes. The faintest magnitude limit, $m_{pg}\leqslant 11.5$, very likely represents the completeness limit for the Wolf-Rayet stars

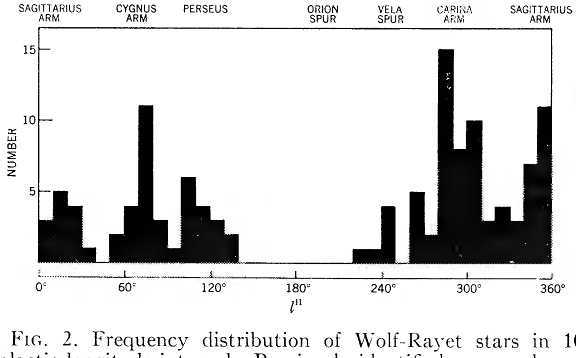

FIG. 2. Frequency distribution of Wolf-Rayet stars in 10° galactic longitude intervals. Previously identified arms and spurs are noted at the top of the figure.

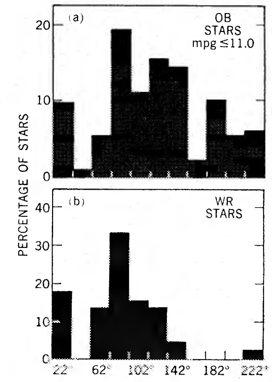

FIG. 3. (a) Frequency distribution of OB stars at different galactic longitudes. (b) Frequency distribution of Wolf-Rayet stars at corresponding longitudes.

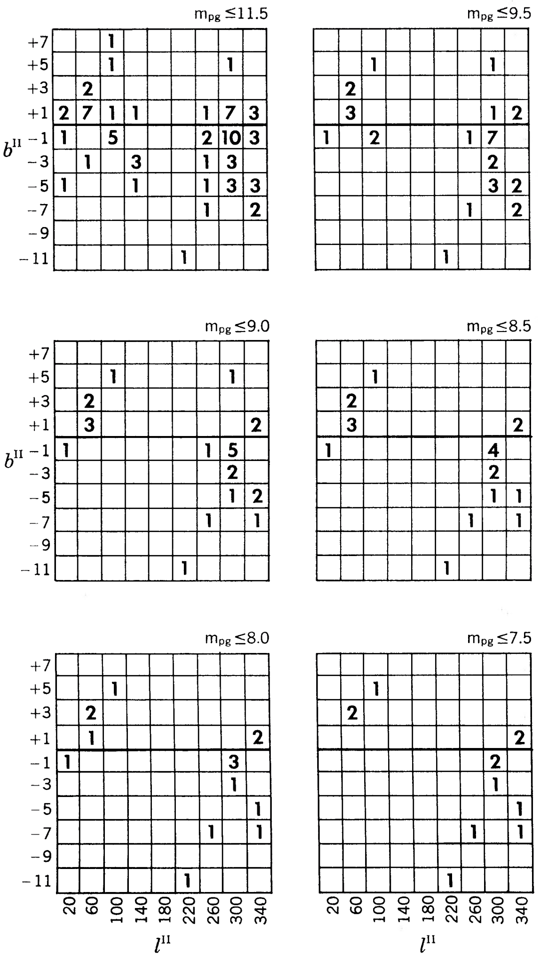

FIG. 4. Frequency distribution in galactic coordinates of Wolf-Rayet stars to different limiting magnitudes. Regions of high concentration may be compared with galactic arms and spurs in Fig. 2.

listed in Table I. Two regions of high density stand out, the Cygnus region, a bit north of the galactic plane; and the Carina region, a bit south of the galactic plane.

TABLE II. Average galactic latitudes for Wolf-Rayet stars.

	l^{II} = 0°–139°.9		220°–359°.9	
	⟨b^{II}⟩	No.	⟨b^{II}⟩	No.
All WR	+0°.13	49	−1°.23	74
WR with $m_{pg}\leq 11.5$	+0.10	27	−1.83	42
All WN	+0.10	24	−1.68	24
WN with $m_{pg}\leq 11.5$	+0.14	17	−1.66	21
All WC	+0.52	18	−1.57	26
WC with $m_{pg}\leq 11.5$	+0.01	10	−1.81	20

Both areas have been noted for their large numbers of Wolf-Rayet stars. Since the Cygnus region persists over a range of ~3.5 mag., a correspondingly large range in depth over which we view these stars is implied. Although the distribution of the Wolf-Rayet stars along the Cygnus-Carina arm is undoubtedly irregular, they appear along this arm over a total distance of about 4 kpc.

IV. CARBON AND NITROGEN SEQUENCES

The Wolf-Rayet stars have been divided into two subgroups on the basis of their spectral nature: a carbon group and a nitrogen group. These spectral differences have been attributed to differences in excitation conditions and to abundance differences. Regardless of the true explanation for the carbon and nitrogen series, we obviously have a difference in some physical parameter existing in these two groups of stars. It would be important to know if these two subgroups exhibit any differences in their spatial distributions. However, without knowledge as to the distances of the individual Wolf-Rayet stars, we can only detect possible differences in their surface distributions. Since the WC and WN stars may have different absolute magnitudes, surface distributions based on samples of the same limiting apparent magnitude may refer to different volumes of space.

Figure 1 has been redrawn in Fig. 5 for those stars for which definite spectral classification is available. The upper part of this figure displays the galactic distribu-

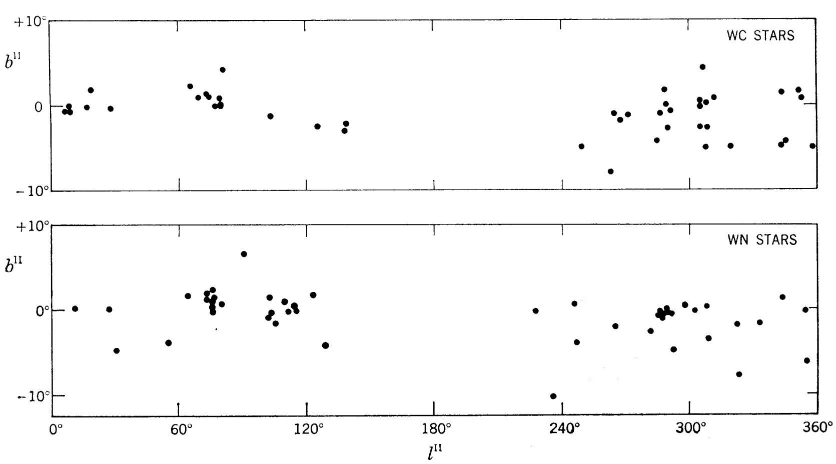

FIG. 5. Galactic distribution of Wolf-Rayet stars according to spectral classes. The upper part exhibits the distribution for the carbon sequence (WC) and the lower part is for the nitrogen sequence (WN).

TABLE III. Wolf-Rayet stars known to be spectroscopic binaries.

Catalogue No.	HD	Spectrum	m_{pg}
10	63099	WC6+O7:I	10.8
12	68273	WC7+O7:	2.2
29	93162	WN7+O7	8.8
31	94546	WN6p+B0n::	10.6
36	97152	WC6+B0V:	7.9
38	97950	WN5+O	9.2
43	113904	WC7+O9.5I	5.4
65	152270	WC7+O8	7.2
68	156327	WC7+B0V:	10.0
85	168206	WC7+B0:	9.9
91	177230	WN8	11.1
94	186943	WN5	10.5
99	190918	WN5+O9.5III	7.0
105	228766	WN7	9.8
106	193576	WN5+B1:	(8.0)
107	193793	WC6+O6	6.8
108	193928	WN5+	10.6
111		WN7	14.0
113	197406	WN5	10.9
114		WN5	12.5
116	211853	WN6+B0:I:	9.4
118	214419	WN6+O7	9.4

tion of the WC stars while the lower part shows the distribution of the WN stars. There are no significant differences in their distributions.

Table II presents the average galactic latitude for WN stars and WC stars in the two hemispheres. No significant difference in galactic latitude exists between the nitrogen- and carbon-type Wolf-Rayet stars.

V. BINARY SYSTEMS

Wolf-Rayet stars frequently occur in binary systems. Table III lists 22 known spectroscopic binaries while Table IV lists 10 stars which may be spectroscopic binaries or have been reported as showing light variations. Table IV also contains a Wolf-Rayet star reported to be a visual binary. Fourteen of the stars in Table III have magnitudes equal to or brighter than 10, this is 36% of all known Wolf-Rayet stars to this magnitude limit.

TABLE IV. Wolf-Rayet stars which may be binary.

Catalogue No.	HD	Spectrum	m_{pg}	Remarks
3	9974	WN5	10.7	Possible spectroscopic binary.
6	50896	WN5	6.9	Possible spectroscopic binary or spectrum variable.
20	88500	WC7+	10.1	Variable magnitude.
26	92809	WC6	9.1	Variable magnitude.
33	95435	Oa	11.5	Suspected light variations.
34	96548	WN8	8.2	Variable magnitude.
101	192103	WC7	8.1	Variable magnitude.
104	193077	WN5	8.0	Variable magnitude, ADS 13641(A).
120	219460	WN5	10.5	Visual binary.
122		WR	11.9	Spectrum variable.

TABLE V. Comparison of HD and IAU classifications for Wolf-Rayet stars.

IAU \ HD	Oa	Ob	Oc
WC	29	2	0
WN	9	10	12

VI. DESIDERATA

Although the total of known Wolf-Rayet stars is relatively small, there is a surprising lack of observational data about many of them including a number of relatively bright stars. A valuable contribution to the study of the Wolf-Rayet stars would include the following information:

(1) Accurate magnitudes and colors on a standard photometric system.

(2) Modern spectral types where needed. A number of the entries in Table I have either an HD spectral type or no spectral type other than WR. To assist in the transformation from the HD system to WN or WC, Table V was prepared from those stars having both classifications.

(3) Radial velocity studies. The absence of radial velocity variation also represents important information in assembling statistics on the duplicity of the Wolf-Rayet stars.

(4) Photometric studies to confirm the reported light variation for some of the Wolf-Rayet stars (see Table IV).

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