THE GALACTIC DISTRIBUTION OF WOLF-RAYET STARS *

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ABSTRACT

On the basis of the most recent compilation of narrow-band photometry and absolute visual magnitudes of Wolf-Rayet stars, and adopting a normal interstellar extinction law in all directions, the galactic distribution of 132 of the 159 known galactic WR stars is presented and discussed.

The spiral structure is found to be more clearly pronounced than in earlier studies. Furthermore we find an indication of two spiral arms at r=4 and 6 kpc. There appears to be an asymmetry of the z-distribution of single stars with respect to galactic longitude.

The location of the WC8.5 and WC9 stars between 4.5 and 9 kpc from the galactic center is discussed in the context of Maeder's red supergiant to WR star scenario.

I. INTRODUCTION

The galactic distribution of Wolf-Rayet stars has been studied in the past two decades by Roberts (1962), Smith (1968c, 1973), Sim (1968), Mikulásek (1969), Stenholm (1975), Moffat and Isserstedt (1980), and Gomez *et al.* (1981). With the appearance of the *Sixth Catalogue of Galactic Wolf-Rayet Stars* by Van der Hucht *et al.* (1981, henceforth HCLS), it became possible to re-examine the photometric distances of the 159 known galactic WR stars (80 WN stars, 71 WC stars, 3 WN+WC stars, 5 not classified). In this paper we give a general view of the WR galactic distribution.

II. DISTANCES

In Table I we present relevant data from HCLS and the resulting photometric distances d and z, from respectively the Sun and the galactic

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*Contributions from the Bosscha Observatory No. 68.

C. W. H. de Loore and A. J. Willis (eds.), Wolf-Rayet Stars: Observations, Physics, Evolution, 27–40.

Table 1. PHOTOMETRIC DISTANCES FOR 132 OF THE 159 GALACTIC WR STARS.

WR	HD or other design.	Sp. type	v	b - v	l^{II}	b^{II}	$(b-v)_o$	E_{b-v}	A_v	v_o	M_v	$v_o - M_v$	d (kpc)	z (pc)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1	4004	WN5	10.54	+0.56	122°08	+1°90	-0.21	0.77	3.16	7.38	-4.6	12.0	2.49	+83
2	6327	WN2	11.43	+0.18	124.65	-2.41	.	.	.	.	.	.	.	
3	9974	WN3+abs	10.79	0.00	129.18	-4.14	-0.21	0.21	0.86	9.93	-4.6	14.5	8.05	-581
4	16523	WC5	10.61	+0.23	137.59	-2.98	-0.23	0.46	1.89	8.72	-4.5	13.2	4.41	-229
5	17638	WC6	11.12	+0.42	138.87	-2.15	-0.22	0.64	2.62	8.50	-4.8	13.3	4.56	-171
6	50896	WN5 (SB1)	6.94	-0.07	234.76	-10.08	-0.21	0.00*	0.00	6.94	-4.6	11.5	2.03	-356
7	56925	WN4	11.74	+0.33	227.75	-0.13	-0.21	0.54	2.21	9.53	-4.1	13.6	5.31	-12
8	62910	WN6+WC4	10.56	+0.43	247.07	-3.79	-0.24	0.67	2.75	7.81	-4.9	12.7	3.47	-230
9	63099	WC5+abs	11.04	+0.76	249.27	-4.84	-0.23	0.99	4.06	6.98	-4.5	11.5	1.98	-167
10	65865	WN4.5	11.08	+0.18	245.98	+0.58	-0.21	0.39	1.60	9.48	-4.3	13.8	5.70	+58
11	68273	WC8+O9I	1.74	-0.32	262.80	-7.69	-0.33	0.01	0.03	1.71	-6.7	8.4	0.48	-64
12	CD-45°4482	WN7	11.06	+0.48	265.20	-1.97	-0.25	0.73	2.99	8.07	-6.5	14.6	8.20	-282
13	Ve6-15	WC6	13.83	+0.82	265.13	-0.77	-0.22	1.04	4.26	9.57	-4.8	14.4	7.47	-100
14	76536	WC6	9.42	+0.15	267.55	-1.64	-0.22	0.37	1.52	7.90	-4.8	12.7	3.47	-99
15	79573	WC6	11.73	+0.75	271.42	-1.08	-0.22	0.97	3.98	7.75	-4.8	12.6	3.24	-61
16	86161	WN8	8.43	+0.25	281.08	-2.55	-0.33	0.58	2.38	6.05	-7.0	13.1	4.08	-181
17	88500	WC5	11.11	+0.04	284.44	-3.69	-0.23	0.27	1.11	10.00	-4.5	14.5	7.95	-512
18	89358	WN5	11.20	+0.54	283.57	-0.97	-0.21	0.75	3.08	8.13	-4.6	12.7	3.51	-59
19	LS3	WC4	13.85	+0.95	283.89	-1.19	-0.22	1.17	4.80	9.05	-2.2	11.3	1.78	-37
20	BS1	WN4.5	14.60	+0.74	284.51	-1.84	-0.21	0.95	3.90	10.71	-4.3	15.0	10.02	-322
21	90657	WN4+O4-6	9.80	+0.30	285.02	-0.90	-0.33	0.63	2.58	7.22	-6.6	13.8	5.80	-91
22	92740	WN7+abs (SB1)	6.44	+0.03	287.17	-0.85	-0.25	0.28	1.15	5.29*	-6.5	11.8	2.28	-34
23	92809	WC6	9.71	+0.04	286.78	-0.03	-0.22	0.26	1.07	8.64	-4.8	13.4	4.88	-3
24	93131	WN7+abs	6.49	-0.06	287.67	-1.08	-0.25	0.19	0.78	5.71	-6.5	12.2	2.77	-52
25	93162	WN7+abs	8.17	+0.29	287.51	-0.71	-0.25	0.54	2.21	5.96	-6.5	12.5	3.10	-38
26	MS1	WN5p	14.64	+0.72	286.68	+0.97	-0.21	0.93	3.81	10.83	-4.6	15.4	12.17	+206
27	LS4	WC6+abs	14.73	+1.03	287.14	+0.12	-0.22	1.25	5.13	9.61	-4.8	14.4	7.60	+16
28	MS2	WN6	12.98	+0.72	287.75	+0.15	-0.25	0.97	3.98	9.00	-4.8	13.8	5.76	+15
29	MS3	WN7	12.65	+0.64	288.59	-1.01	-0.25	0.89	3.65	9.00	-6.5	15.5	12.60	-222
30	94305	WC6+abs	11.73	+0.27	289.44	-2.61	-0.22	0.49	2.01	9.72	-4.8	14.5	8.02	-365
31	94546	WN4+O7	10.69	+0.28	288.50	+0.02	-0.33	0.61	2.50	8.19	-6.6	14.8	9.07	+3
32	MS5	WC5	(14.5)		289.36	+0.02	-0.23	.	.	.	-4.5	.	.	
33	95435	WC5	12.34	+0.20	288.51	+1.90	-0.23	0.43	1.76	10.58	-4.5	15.1	10.36	+344
34	LS5	WN4.5	14.50	+0.76	290.03	-1.39	-0.21	0.97	3.98	10.52	-4.3	14.8	9.22	-224
35	MS6	WN6	13.83	+0.75	289.97	-1.18	-0.25	1.00	4.10	9.73	-4.8	14.5	8.05	-166
36	LS6	WN4	13.57	+0.76	289.48	+0.56	-0.21	0.97	3.98	9.59	-4.1	13.7	5.48	+54
37	MS7	WN3	(15.0)		290.55	-1.05	-0.21	.	.	.	-4.6	.	.	
38	MS8	WC4	(14.0)		290.57	-0.92	-0.22	.	.	.	-2.2	.	.	
39	MS9	WC6	(13.2)		290.63	-0.90	-0.22	.	.	.	-4.8	.	.	
40	96548	WN8	7.85	+0.11	292.31	-4.83	-0.33	0.44	1.80	6.05	-7.	13.1	4.07	-342

Table 1. (Cont'd 1)

WR (1)	HD or other design. (2)	Sp. type (3)	v (4)	b - v (5)	l^{II} (6)	b^{II} (7)	$(b-v)_o$ (8)	E_{b-v} (9)	A_v (10)	v_o (11)	M_v (12)	$v_o - M_v$ (13)	d (kpc) (14)	z (pc) (15)
41	LS7	WC5	(14.0:)		290°.89	-1°.03	-0.23	.	.	.	-4.5	.	.	
42	97152	WC7+O5-7	8.25	-0.06	290.95	-0.49	-0.33	0.27	1.11	7.14	-7.1	14.2	7.06	-60
43	97950	OB+WN	(9.66)	(+0.97)	291.62	-0.52	.	.	.	.	.	.	.	
44	LSS2289	WN4	12.96	+0.37	291.18	+1.26	-0.21	0.58	2.38	10.58	-4.1	14.7	8.64	+190
45	LSS2423	WC6	14.82	+0.85	294.51	-0.60	-0.22	1.07	4.39	10.43	-4.8	15.2	11.13	-117
46	104994	WN3pec	10.96	0.00	297.56	+0.34	-0.21	0.21	0.86	10.10	-4.6	14.7	8.71	+52
47	E311884	WN6+O5	11.09	+0.72	302.07	-0.23	-0.33	1.05	4.31	6.79	-6.6	13.4	4.75	-19
48	113904	WC6+O9.5I	5.69	-0.11	304.67	-2.49	-0.26	0.15	0.62	5.08	-6.5	11.6	2.07	-90
49	LSS2979	WN5	13.87	+0.56	305.27	-2.54	-0.21	0.77	3.16	10.71	-4.6	15.3	11.55	-512
50	LSS3013	WC6+abs	12.49	+0.54	306.00	+0.28	-0.22	0.76	3.12	9.37	-4.8	14.2	6.84	+33
51	LSS3017	WN4	14.76	+1.05	306.04	+0.24	-0.21	1.26	5.17	9.59	-4.1	13.7	5.48	+23
52	115473	WC5	9.98	+0.15	306.50	+4.55	-0.23	0.38	1.56	8.42	-4.5	12.9	3.84	+305
53	117297	WC8	11.06	+0.16	307.53	+0.44	-0.50	0.66	2.71	8.35	-4.8	13.2	4.27	+33
54	LSS3111	WN4	12.99	+0.46	307.27	-2.50	-0.21	0.67	2.75	10.24	-4.1	14.3	7.39	-322
55	117688	WN8	10.87	+0.40	307.80	+0.16	-0.33	0.73	2.99	7.88	-7.	14.9	9.45	+26
56	LS8	WC6	13.97	+0.26	307.53	-1.63	-0.22	0.48	1.97	12.00	-4.8	16.8	22.93	-652
57	119078	WC7	10.11	-0.18	307.89	-5.03	-0.24	0.06	0.25	9.86	-4.8	14.7	8.56	-751
58	LSS3162	WN4	13.08	+0.42	308.82	-3.49	-0.21	0.63	2.58	10.50	-4.1	14.6	8.31	-506
59	LSS3164	WC8.5	13.90	+1.24	309.80	+0.57	-0.50	1.74	7.13	6.77	-4.8	11.6	2.06	+20
60	121194	WC8	13.25	+0.94	310.61	+0.74	-0.50	1.44	5.90	7.35	-4.8	12.2	2.69	+35
61	LSS3208	WN4.5	12.56	+0.28	311.28	-3.91	-0.21	0.49	2.01	10.55	-4.3	14.9	9.34	-637
62	NS2	WN6	(13.1)		314.59	-0.75	-0.25	.	.	.	-4.8	.	.	
63	LSS3289	WN6	12.81	+1.28	317.42	-0.39	-0.25	1.53	6.27	6.54	-4.8	11.3	1.85	-13
64	BS3	WC7	15.08	+0.03:	319.95	+2.82	-0.24	0.27:	.	.	.	.	.	
65	LSS3319	WC9	14.45	+1.35	320.27	-1.20	-0.55	1.90	7.79	6.66	-5.5	12.2	2.70	-57
66	134877	WN8	11.71	+0.73	320.07	-1.83	-0.33	1.06	4.35	7.36	-7.	14.4	7.47	-238
67	LSS3329	WN6	12.21	+0.74	320.55	-1.19	-0.25	0.99	4.06	8.15	-4.8	13.0	3.89	-81
68	BS4	WC7	14.23	+0.97	320.54	-1.88	-0.24	1.21	4.96	9.27	-4.8	14.1	6.51	-214
69	136488	WC9	9.43	+0.14	319.48	-4.82	-0.55	0.69	2.83	6.60	-5.5	12.1	2.63	-221
70	137603	WC8+abs	10.15	+0.91	322.34	-1.81	-0.50	1.41	5.78	4.37	-4.8	9.2	0.68	-22
71	143414	WN6	10.22	+0.06	323.08	-7.61	-0.25	0.31	1.27	8.95	-4.8	13.8	5.62	-744
72	NS1	WC4pec	(14.2)	(+0.2)	341.55	+12.11	(-0.27)	(0.5)	(1.5)	(12.7)	-2.1	14.8	9.30	+1950
73	NS3	WC8.5	(14.5:)		334.89	+3.38	-0.50	.	.	.	-4.8	.	.	
74	BP1	WN7-8	14.01	+1.52	331.88	-0.64	-0.25	1.77	7.26	6.75	-6.5	13.3	4.47	-50
75	147419	WN4	11.42	+0.63	332.84	-1.48	-0.21	0.84	3.44	7.98	-4.1	12.1	2.60	-67
76	LSS3693	WC8.5	15.36:	+0.94:	338.88	+0.62	-0.50	1.44:	5.90:	9.46:	-4.8	14.3:	7.10:	+77:
77	He3-1239	WC8.5	13.16	+0.60	337.26	-1.09	-0.50	1.10	4.51	8.65	-4.8	13.5	4.90	-93
78	151932	WN7	6.61	+0.21	343.22	+1.43	-0.25	0.46	1.89	4.72	-6.5	11.2	1.76	+44
79	152270	WC7+O5-8	6.95	+0.01	343.49	+1.16	-0.33	0.34	1.39	5.56	-6.6	12.2	2.70	+55
80	LSS3871	WC9	14.63	+1.11	340.97	-1.93	-0.55	1.66	6.81	7.82	-5.5	13.3	4.62	-156

Table 1. (Cont'd 2)

WR	HD	Sp. type	v	b - v	l^{II}	b^{II}	$(b-v)_o$	E_{b-v}	A_v	v_o	M_v	$v_o - M_v$	d	z
	or other design.												(kpc)	(pc)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
81	He3-1316	WC9	12.75	+1.14	341°15	-2°60	-0.55	1.69	6.93	5.82	-5.5	11.3	1.84	-83
82	LS11	WN8	12.42	+0.81	341.92	-2.32	-0.33	1.14	4.67	7.75	-7.	14.7	8.90	-360
83	He3-1344	WN6	12.79	+0.65	341.51	-4.11	-0.25	0.90	3.69	9.10	-4.8	13.9	6.03	-432
84	Thé3	WN6	13.55	+1.18	346.98	-0.21	-0.25	1.43	5.86	7.69	-4.8	12.5	3.14	-12
85	LSS3982	WN6	10.60	+0.56	347.43	-0.61	-0.25	0.81	3.32	7.28	-4.8	12.1	2.60	-28
86	156327	WC7+abs	9.73	+0.44	352.25	+1.85	-0.24	0.68	2.79	6.94	-4.8	11.7	2.23	+72
87	LSS4064	WN7	12.59	+1.34	348.69	-0.77	-0.25	1.59	6.52	6.07	-6.5	12.6	3.27	-44
88	Thé1	WC9	13.38	+1.03	352.67	+2.04	-0.55	1.58	6.48	6.90	-5.5	12.4	3.02	+108
89	AS223	WN7	11.53	+1.22	348.72	-0.78	-0.25	1.47	6.03	5.50	-6.5	12.0	2.51	-34
90	156385	WC7	7.45	-0.12	343.16	-4.76	-0.24	0.12	0.49	6.96	-4.8	11.8	2.25	-186
91	StSa1	WR:	(15.0)		348.76	-1.07	.	.	.	.	.	.	.	
92	157451	WC9	10.60	+0.06	345.54	-4.42	-0.55	0.61	2.50	8.10	-5.5	13.6	5.25	-404
93	157504	WC7	11.46	+1.15	353.23	+0.83	-0.24	1.39	5.70	5.76	-4.8	10.6	1.29	+19
94	158860	WN6	12.27	+0.74	354.60	-0.25	-0.25	0.99	4.06	8.21	-4.8	13.0	4.00	-17
95	He3-1434	WC9	14.10	+1.49	355.13	-0.70	-0.55	2.04	8.36	5.74	-5.5	11.2	1.65	-21
96	LSS4265	WC8.5	14.14	+1.01	355.58	-0.43	-0.50	1.51	6.19	7.95	-4.8	12.7	3.55	-27
97	E320102	WN3+abs	11.15	+0.68	354.68	-1.12	-0.21	0.89	3.65	7.50	-4.6	12.1	2.63	-51
98	E318016	WN7+WC7	12.51	+1.08	355.21	-0.87	-0.25	1.33	5.45	7.06	-6.7	13.8	5.64	-86
99	DA2	WN	(16.)		359.85	+1.54	.	.	.	.	.	.	.	
100	E318139	WN6	13.44	+1.17	356.53	-1.26	-0.25	1.42	5.82	7.62	-4.8	12.4	3.05	-67
101	DA3	WC8	(14.9)		357.47	-1.43	-0.25	.	.	.	-6.5	.	.	
102	LSS4368	WC4pec	14.24	+0.44	2.38	+1.41	-0.22	0.66	2.71	11.53	-2.2	13.7	5.58	+137
103	164270	WC9	9.01	+0.03	358.49	-4.89	-0.55	0.58	2.38	6.63	-5.5	12.1	2.67	-228
104	Ve2-45	WC9	13.54	+1.31	6.44	-0.49	-0.55	1.86	7.63	5.91	-5.5	11.4	1.92	-16
105	NS4,Ve2-47	WR:	(13.0:)		6.52	-0.52	.	.	.	.	.	.	.	
106	E313643	WC9	12.36	+0.72	8.90	+0.20	-0.55	1.27	5.21	7.15	-5.5	12.7	3.39	+12
107	DA1	WN7-8	(13.2)		8.29	-0.16	-0.25	.	.	.	-6.5	.	.	
108	E313846	WN9	10.16	+0.68	7.36	-0.85	.	.	.	.	.	.	.	
109	NS5	WR	[14.1]		356.94	-7.19	.	.	.	.	.	.	.	
110	165688	WN6	10.23	+0.71	10.80	+0.39	-0.25	0.96	3.94	6.29	-4.8	11.1	1.66	+11
111	165763	WC5	8.25	-0.07	9.24	-0.61	-0.23	0.16	0.66	7.59	-4.5	12.1	2.62	-28
112	CRL2104	WC8	(17.7)	(+3.0)	12.15	-1.19	(-0.62)	(3.6)	(11.2)	(6.5)	(-4.6)	11.1	1.64	-34
113	168206	WC8+O8-9	9.43	+0.47	18.91	+1.75	-0.33	0.80	3.28	6.15	-5.4	11.5	2.04	+62
114	169010	WC5	12.92	+0.90	17.54	-0.13	-0.23	1.13	4.63	8.29	-4.5	12.8	3.61	-8
115	IC14-19	WN6	12.26	+1.14	16.98	-1.03	-0.25	1.39	5.70	6.56	-4.8	11.4	1.87	-34
116	ST1	WN8	(13.0)		19.16	-0.32	-0.33	.	.	.	-7.	.	.	
117	IC14-22	WC8	14.19	+1.15	24.74	+1.50	-0.50	1.65	6.77	7.43	-4.8	12.2	2.79	+73
118	CRL2179	WC8-9	(20.)	(+5.0)	21.81	-0.21	(-0.62)	(5.6)	(17.4)	(2.6)	(-4.6)	7.2:	0.27:	-1:
119	Thé2	WC9	12.43	+0.64	22.57	-1.92	-0.55	1.19	4.88	7.55	-5.5	13.1	4.08	-137
120	Vy1-3	WN7	12.28	1.03	27.80	+0.29	-0.25	1.28	5.25	7.03	-6.5	13.5	5.09	+26

Table 1. (Cont'd 3)

WR (1)	HD or other design. (2)	Sp. type (3)	v (4)	b - v (5)	l^{II} (6)	b^{II} (7)	$(b-v)_o$ (8)	E_{b-v} (9)	A_v (10)	v_o (11)	M_v (12)	$v_o - M_v$ (13)	d (kpc) (14)	z (pc) (15)
121	AS320	WC9	11.81	+0.68	28°.73	-0°.13	-0.55	1.23	5.04	6.77	-5.5	12.3	2.84	-6
122	NaSt1	WR	[16.]		33.92	+0.26	.	.	.	.	.	.	.	
123	177230	WN8	11.27	+0.47	30.51	-4.75	-0.33	0.80	3.28	7.99	-7.	15.0	9.95	-824
124	209BAC	WN8	(11.08)	(+1.07)	50.20	+3.31	(-0.41)	(1.48)	(4.58)	(6.50)	(-6.8)	13.3	4.58	+264
125	IC14-36	WC5	13.48	+1.35:	54.44	+1.06	-0.23	1.58:	6.48:	7.00:	-4.5	11.5:	2.00:	+37:
126	ST2	WC:	(13.5:)		61.89	+2.11	.	.	.	.	.	.	.	
127	186943	WN4+O9	10.36	+0.21	64.06	+1.73	-0.33	0.54	2.21	8.15	-5.2	13.3	4.67	+141
128	187282	WN4	10.56	+0.02	55.62	-3.79	-0.21	0.23	0.94	9.62	-4.1	13.7	5.54	-366
129	Sey1	WN4	(13.3)		66.16	+2.44	-0.21	.	.	.	-4.1	.	.	
130	LS16	WN8	(12.28)	(+1.40)	68.25	+0.94	(-0.41)	(1.81)	(5.61)	(6.67)	(-6.8)	13.5	4.94	+81
131	IC14-52	WN7+abs	12.30	+2.05:	69.90	+1.71	-0.25	2.30:	9.43:	2.87:	-6.5	9.4:	0.75:	+22:
132	190002	WC6	11.55	+1.13:	69.46	+1.10	-0.22	1.35:	5.54:	6.02:	-4.8	10.8:	1.46:	+28:
133	190918	WN4.5+O9.5Ia	7.48	+0.13	72.65	+2.07	-0.33	0.46	1.89	5.59	-7.1	12.7	3.46	+125
134	191765	WN6	8.31	+0.25	73.45	+1.55	-0.25	0.50	2.05	6.26	-4.8	11.1	1.63	+44
135	192103	WC8	8.51	-0.06	73.65	+1.28	-0.50	0.44	1.80	6.71	-4.8	11.5	2.00	+45
136	192163	WN6 (SB1)	7.73	+0.25	75.48	+2.43	-0.25	0.50	2.05	5.68	-4.8	10.5	1.25	+53
137	192641	WC7+abs	8.18	+0.15	74.33	+1.09	-0.24	0.39	1.60	6.58	-4.8	11.4	1.89	+36
138	193077	WN5+abs	8.21	+0.26	75.24	+1.11	-0.21	0.47	1.93	6.28	-4.6	10.9	1.50	+29
139	193576	WN5+O6	8.27	+0.38	76.60	+1.43	-0.33	0.71	2.91	5.36	-6.2	11.6	2.05	+51
140	193793	WC7+abs	7.19	+0.24	80.93	+4.18	-0.24	0.48	1.97	5.22	-4.8	10.0	1.01	+74
141	193928	WN6 (SB1)	10.15	+0.75	75.33	+0.08	-0.25	1.00	4.10	6.05	-4.8	10.8	1.48	+2
142	ST3	WC5pec	(12.96)	(+1.43)	75.73	+0.33	(-0.28)	(1.71)	(5.31)	(7.65)	-2.2	10.0	1.00	+6
143	195177	WC5	12.32	+1.19	77.50	-0.05	-0.23	1.42	5.82	6.50	-4.5	11.0	1.58	-1
144	HM19-1	WC5	(14.3)		80.04	+0.93	-0.23	.	.	.	-4.5	.	.	
145	AS422	WN+WC	(12.3)		79.69	+0.66	.	.	.	.	.	.	.	
146	HM19-3	WC4	(13.2)		80.57	+0.45	-0.22	.	.	.	-2.2	.	.	
147	MS6	WN7 or Of	(13.8)		79.85	-0.32	-0.25	.	.	.	-6.5	.	.	
148	197406	WN7 (SB1)	10.50	+0.42	90.08	+6.47	-0.25	0.67	2.75	7.75	-6.5	14.2	7.09	+799
149	ST4	WC4	(14.2)		89.53	+0.65	-0.22	.	.	.	-2.2	.	.	
150	ST5	WC6	(13.0:)		96.13	-2.48	-0.22	.	.	.	-4.8	.	.	
151	CX Cep	WN4+O8	12.40:	+0.70:	102.66	+1.39	-0.33	1.03:	4.22:	8.18:	-5.5	13.7:	5.44:	+132:
152	211564	WN3	11.62:	+0.35:	102.23	-0.89	-0.21	0.56:	2.30:	9.32:	-4.6	13.9:	6.09:	-95:
153	211853	WN6+O	9.20	+0.32	102.78	-0.65	-0.33	0.65	2.66	6.53	-5.5	12.0	2.55	-29
154	213049	WC6	11.69	+0.31	103.85	-1.18	-0.22	0.53	2.17	9.52	-4.8	14.3	7.30	-150
155	214419	WN7+O	8.94	+0.33	105.32	-1.29	-0.33	0.66	2.71	6.23	-6.6	12.8	3.69	- 83
156	AC+60°38562	WN8	11.18	+0.88	109.82	+0.92	-0.33	1.21	4.96	6.22	-7.	13.2	4.40	+71
157	219460	WN4.5	10.03	+0.52	111.33	-0.24	-0.21	0.73	2.99	7.04	-4.3	11.3	1.85	-8
158	AS513	WN7	11.49	+0.81	115.03	+0.10	-0.25	1.06	4.35	7.14	-6.5	13.6	5.35	+9
29a		WR+abs	14.0		288.90	-1.38	.	.	.	.	.	.	.	

plane, for 132 WR stars of which sufficient spectroscopic and photometric data are available. Magnitudes are in the narrow-band system of Smith (1968b). The extinction is calculated with $A_V = 4.1\ E_{b-v}$ (Turner and Smith, 1981). Magnitudes between parentheses are in Johnson's UBV system, where $A_V = 3.1\ E_{B-V}$ has been used. Magnitudes between brackets are photographic magnitudes.

So, we have assumed a normal extinction law toward all stars. Another assumption is the validity of the intrinsic parameters in Table XV of HCLS, which are mainly based on the work of Turner and Smith (1981) on WR stars in open clusters. Notably the assumption that stars of the same subclass have similar intrinsic colours, is subject to criticism, since binary studies show that stars of the same subclass may have different masses (Massey, 1981). But this fact may be limited to binary systems. At the other hand, the three Carina Nebula WN7 stars should be at the same distance d=2.7 kpc (Thé *et al.*, 1980), but they are not, according to our statistical approach. This could be caused by anomalous extinction, or by different intrinsic colours of the individual stars (WR22, WR24 and WR25). For statistical purposes, however, we have used the available information in this straightforward manner.

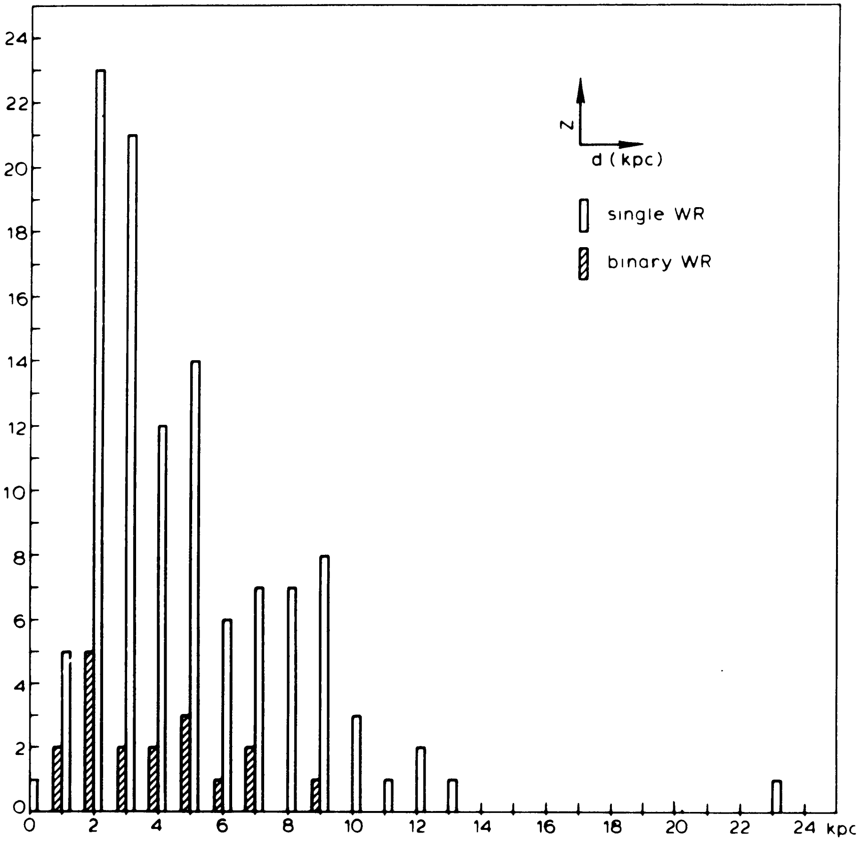

Fig. 1. The occurrence of the WR stars versus their distances from the Sun.

In Figure 1 we present the count of WR stars as a function of heliocentric distance d. Stenholm (1975), considering almost the same number of stars, notes that the galactic WR stars may be completely known out to a distance of 5 kpc, as can be concluded again from our Figure 1. The recent discoveries in the infrared of the CRL-objects WR112 and WR118 (Allen *et al.*, 1977) indicate that more relatively nearby WR (notably WC8-9) stars may be hidden in and behind dust clouds within 5 kpc from the Sun, awaiting discovery by future infrared surveys.

III. THE SPATIAL DISTRIBUTION

In Figure 2 we show the distribution of galactic WR stars projected on the galactic plane using ℓ^{II} and d from Table 1. The spiral structure of this distribution is more clearly pronounced than in earlier studies, which had less data available. We have placed the galactic center at d_O = 10 kpc from the Sun. The Carina arm ($280^{o} < \ell^{II} < 300^{o}$) is most clearly defined, extending to r = 13 kpc from the galactic center, as well as the 8 kpc arm. There is an indication of a spiral arm at r = 6-7 kpc, and another arm at r = 4-5 kpc from the galactic center. The Cygnus arm ($50^{o} < \ell^{II} < 80^{o}$) appears still rather short. The Perseus-Cepheus arm ($100^{o} < \ell^{II} < 120^{o}$) seems also defined by WR stars, extending from r = 11 to 14 kpc from the galactic center.

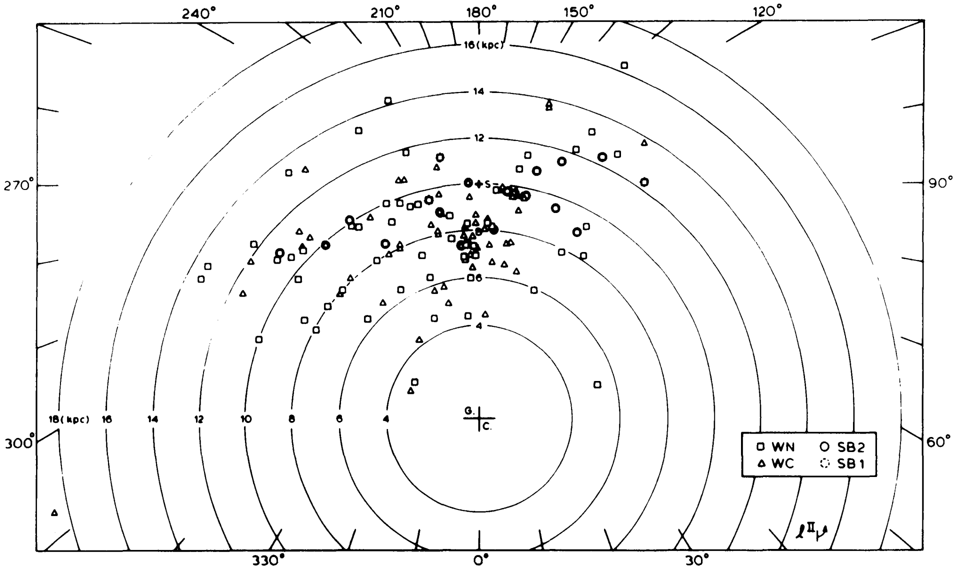

Fig. 2. Distribution of 132 galactic WR stars projected on the plane of the Galaxy. New galactic coordinates are given at the periphery. Distances from the galactic center are marked in kpc. The position of the galactic center is marked + G.S., at 10 kpc from the Sun. The position of the Sun is marked + S.

A clear asymmetry is present in the WR distribution between the left hand and the right hand half of the picture, in spite of extensive objective prism surveys over the whole galactic belt supposed to be complete down to 15^m.

The dearth zone in the anti-galactic-center direction ($140^\circ < \ell^{II} < 225^\circ$), noted in earlier studies, is still present. Although Figure 2 suggests that we should expect WR stars in all directions within r = 14 kpc, the interstellar density distribution and spiral conditions have apparently not been favourable to the formation of WR stars there. This inspite of the presence there of some OB stars (viz. Stenholm, 1975), H II regions (viz., Georgelin *et al.*, 1979) and Cepheids (Efremov *et al.*, 1981). Sparke and Dodd (1978) offer an explanation of this dearth zone in terms of an effect predicted by the density-wave theory of spiral structure. They hypothesize that the n = 2 ultraharmonic resonance disrupts the Perseus arm at the point where it crosses $\ell^{II} = 140^\circ$. The shock-wave in the gas will be weakened in the region past $\ell^{II} = 140^\circ$, and will trigger less star formation. Another dearth zone is present between $30^\circ < \ell^{II} < 50^\circ$ in Aquila. In this direction is an obvious concentration of reddening material (Lucke, 1978; Neckel and Klare, 1980).

IV. THE z-DISTRIBUTION

The distribution of the distances z from the galactic plane has been studied before by Stenholm (1975) and Moffat and Isserstedt (1980). The latter found in a sample of 56 WR stars, on the basis of photometry and classification from Smith (1968a), that the mean absolute distance $\overline{|z|}$ is significantly larger for single stars than for binaries, suggesting that at least some single WR stars may be runaway stars, following the evolutionary scheme of Van den Heuvel (1976). With our sample of 132 WR stars we are able to re-examine this matter.

In Figure 3 we present the (ℓ^{II}, z) distribution, using Table 1. We note the following results, given in Table 2. These values of $\overline{|z|}$ for single WR stars are larger than those found by Moffat and Isserstedt, who found the $\overline{|z|}$ value for the single WR stars to be coincident with that of OB runaway stars, i.e. 130 pc. Our larger $\overline{|z|}$ value for single WR stars, anyhow, is not in contradiction with the hypothesis of Moffat and Isserstedt that at least some single WR stars may be runaway stars.

Table 2. $\overline{|z|}$ of single and binary stars

WR stars		$\overline{|z|}$ (pc) ± σ
WN single:	54 stars	170 ± 202
WC single:	57 stars	163 ± 295
SB1 binaries:	5 stars	249 ± 339
SB2 binaries:	14 stars	72 ± 42

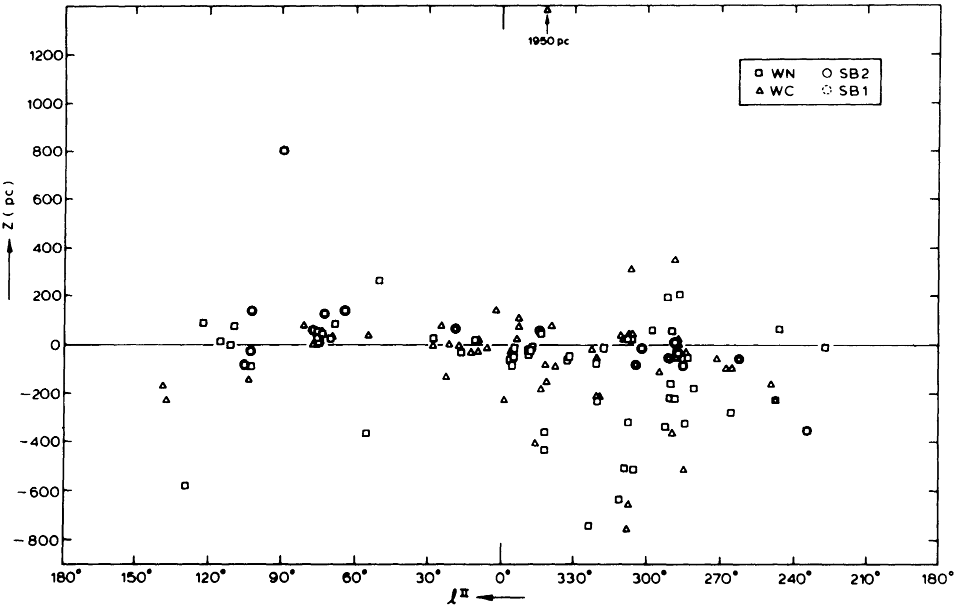

Fig. 3. The distance z from the galactic plane versus the galactic longitude ℓ^{II} *for the WR stars.*

On the contrary, our higher value of $\overline{|z|}$ for single WR stars is in better agreement with the kick-out velocities calculated by Sutantyo and Dermawan (1981) for supernova explosions of WR binaries with masses found by Massey (1981). It should be noted that massive X-ray binaries, which are supposed to follow the same evolutionary scheme of Van den Heuvel (1976) as mentioned before, have only $\overline{|z|}$ = 72 ± 65 pc (Sutantyo, 1981), considerably less than OB runaway stars and single WR stars, but remarkably equal to that of SB2 WR binaries.

The $|z|$ - frequency distribution is given in Figure 4. We note the following division: the stars around the galactic plane with a scale height of z ≈ 75 pc, and scattered stars at various high z-values. The latter group may contain runaway stars. We count 43 WR stars with $|z| \geqslant$ 150 pc, 25 of which are WN stars and 18 of which are WC stars. All subclasses except WC8 and WC8.5 stars are present beyond $|z|$ = 150 pc, including 44% of the known WC9 stars.

The stars in Figure 3 are clearly asymmetrically distributed with respect to the galactic plane in the sense that more stars are found at negative latitudes, (although the binaries are rather symmetrically distributed) and that there exists a concentration of stars at negative latitudes in the fourth quadrant. This may be explained by tidal interaction during the prehistoric passage of the LMC and SMC (Fujimoto and Sofue, 1977).

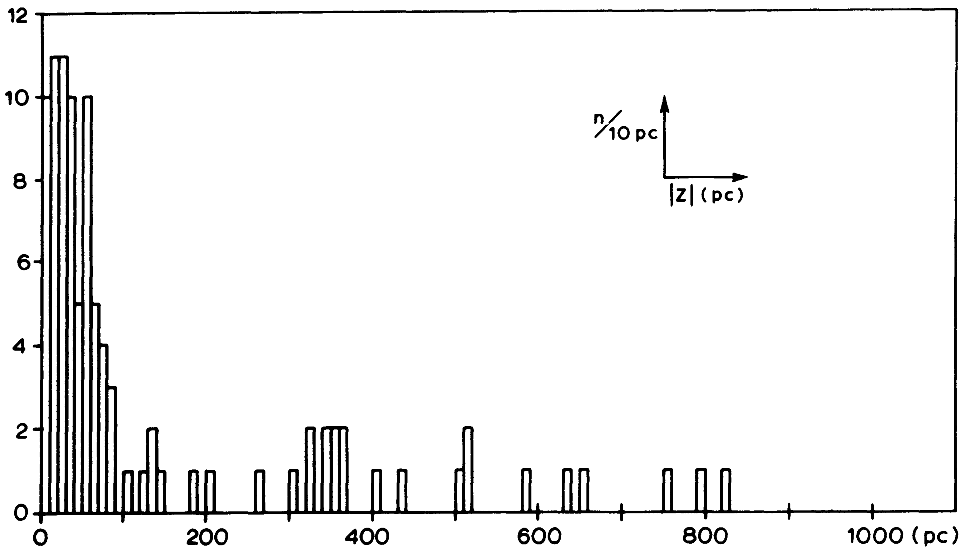

Fig. 4. The |z| - frequency distribution of galactic WR stars.

V. THE DISTRIBUTION OF SUB-CLASSES

The distribution of WR stars over the spectral sub-classes is given in Table XIV of HCLS. In Figure 2, we find more WC stars than WN stars in the inner galactic regions, and vice versa more WN stars than WC stars in the outer galactic regions. For 7 < r < 13 kpc the WN:WC ratio is listed in Table 3.

Table 3. The WN:WC distribution

r(kpc)	WN	WC	$\frac{WC}{WN+WC}$
7-9	17	24	0.6
9-11	22	15	0.4
11-13	10	5	0.3

By considering the sub-classes of the individual stars in Figure 2, we can make the following observations, confirming and elaborating on earlier work by Gomez *et al.* (1981):

- In some cases two or three stars of the same sub-class are found together: three WN5, three WN6 and two WC7 stars in Cygnus; three WN7 and four WC6 stars in Carina; two WC6 stars in Crux; and all WC8, WC8.5 and WC9 stars in the Norma-Scorpius-Sagittarius-Scutum direction. The latter sub-classes are absent in the Magellanic Clouds.

- Other sub-classes present in the inner regions of the Galaxy are all WC types and all WN types, except WN5.
- The distribution of the sub-classes as a function of the galactocentric distance r is given in Figure 5. Of course, this picture may be biased by limited statistics, but for the time being it indicates that
  - . WN4, WN4.5 and WN5 stars are found only beyond r = 7.5 kpc;
  - . WN6, WN7, and WN8 stars are found already at r = 3 kpc and beyond;
  - . WC8, WC8.5 and WC9 stars are found only within r = 10 kpc.

It may be that this distribution of sub-classes with r is related to the metallicity gradient in the Galaxy. The fact that WN5 stars are found only beyond r = 9.5 kpc, and that WC9 stars are found within r = 8.5 kpc may indicate that WN5 stars can not evolve in to WC9 stars.

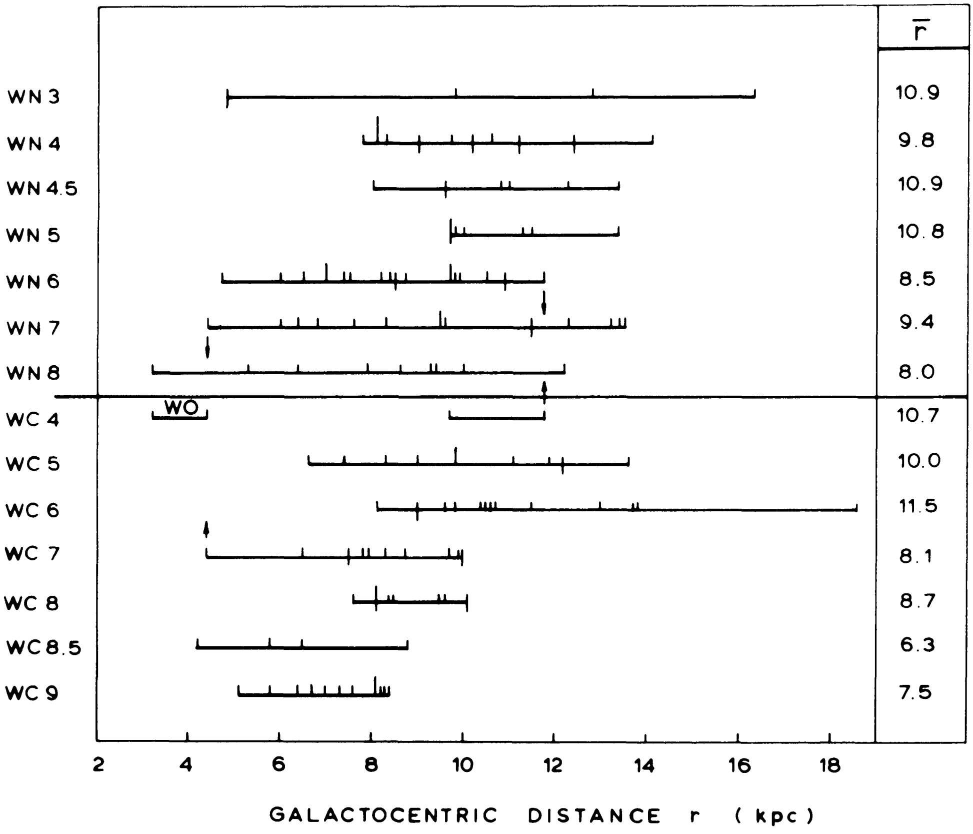

Fig. 5. The WR sub-classes versus their location in galactocentric distances r. Vertical bars above the horizontal bars indicate individual stars. Vertical bars of double or triple length above the horizontal bars indicate two or three stars with the same r. Bars extending below the horizontal bars indicate WR+O binaries. Arrows indicate the two WN + WC objects.

In Table 4 we list the occurrence of the WR sub-classes in open cluster or associations, and in H II regions. The correlations with open clusters or associations is taken from HCLS, and concerns 25 WN stars and 14 WC stars. Of these stars it are notably the WN4.5, WN5, WN7 and WC7 stars which have a preference to be located in young stellar groups. The correlation with H II regions is from Chu (1980, private communication) who found that 101 WR stars (i.e. 64%) are associable with H II regions. Among these are 51 WN stars, 47 WC stars and 3 WN+WC stars. 15 of these H II regions are ring shaped (Chu, 1981; Heckathorn *et al.*, 1981). Table 4 shows that, although almost all sub-classes do occur in H II regions, there is a preference for the later sub-classes.

Table 4. Distribution of WR sub-classes in stellar groups and H II regions.

WR subclass	Total number in Galaxy	Fraction correlated with open clusters or associations	Fraction correlated with H II regions
WN2	1	1.0	0.0
3	5	0.0	0.60
4	13	0.15	0.77
4.5	6	0.50	0.50
5	8	0.50	0.75
6	18	0.33	0.72
7	16	0.44	0.38
8	10	0.10	0.80
9	1	0.0	1.00
Subtotal WN	80	0.31	0.64
WC4	6	0.17	0.67
5	13	0.23	0.69
6	15	0.13	0.67
7	10	0.40	0.80
8	8	0.13	0.38
8.5	6	0.17	0.50
9	12	0.17	0.83
Subtotal WC	71	0.20	0.66
WN + WC	3	1.0	1.0
unclassified WR	5	0.0	0.0
TOTAL	159	0.26	0.64

VI. WR SUB-CLASSES AND EVOLUTION

Gomez *et al.* (1981) suggest evolutionary relationships between certain WR subclasses, because of their location. These are difficult to prove without further knowledge, e.g. of the masses of the individual stars, most of which are not binaries. We discuss here only two sub-classes, the WC8.5 and WC9 stars, which are clearly concentrated in the region toward the galactic center between r = 4.5 and r = 9 kpc, and are all single stars.

Maeder (1981c) discusses eight possible scenarios of O star to WR star evolution and warns against the myth of the uniqueness of any of them. He emphasizes that the relative importance of the various scenarios changes very much with distance from the galactic center, or location in LMC and SMC, and thus with metallicity. One of these eight scenarios, presented first by Maeder *et al.* (1980) and elaborated on by Maeder (1981a,b,c), produces WR stars as post-red supergiants (PRS scenario). Maeder *et al.* (1980) note that the ratio of the number of red supergiants over that of WR stars increases rapidly with galactocentric distance r, while the sum of the number of WR stars plus that of red supergiants over the number of blue supergiants is almost constant with galactocentric distance r. Maeder's PRS scenario is apparently more favourable for WC stars than for WN stars, as can be judged from Table 3.

Within the solar circle we find all the known WC8.5 and WC9 stars. If these stars (all single) are candidates to have followed Maeder's red supergiant to WR scenario, we might want to look for a relic of their past. All WC8.5 and WC9 stars are known to have dust shells around them, located at radii of about 80 AU (viz. Cohen, 1975; Cohen *et al.*, 1975; and Allen *et al.* (1981) for WR 104 (= Ve2-45)). It has never been explained why only these subtypes display dust shells, and the other subtypes do not. Red supergiants are also known to have dust shells, relatively close to these stars. It is conceivable that the dust shells around massive red supergiants may survive while these stars evolve to the WR phase, gradually being expelled to larger dust shell radii. Consequently, the presence of dust shells around WC8.5 and WC9 stars may indicate that Maeder's red supergiant to WR star evolutionary scenario is valid for WC8.5 and WC9 stars.

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