

STUDIES IN GALACTIC STRUCTURE. I. A PRELIMINARY DETERMINATION OF THE SPACE DISTRIBUTION OF THE BLUE GIANTS

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ABSTRACT

Distances of a preliminary list of high-luminosity stars of classes O–A have been determined spectroscopically. A total of twenty-seven separate large-scale clusterings, or aggregates, are catalogued.

Seven of the aggregates, located between galactic longitudes 311° and 346° , define part of a spiral arm located between the sun and the galactic center, at a distance from the sun of around 1400 psc. This confirms the tentative identification of an inner arm announced earlier by Morgan, Sharpless, and Osterbrock.

The arm in which the sun is located appears to branch into two; this is in qualitative agreement with the 21-cm H observations of Oort, van de Hulst, and Muller.

A catalogue of some probable members of the aggregates is included.

The present paper is the first of a series dealing with certain investigations of galactic structure being carried out at the Yerkes and Washburn Observatories. A preliminary

TABLE 1
DATA ON AGGREGATES

No.	Name	l (Degrees)	b (Degrees)	r (Kpc)	Associated Feature
1.....	I Sco	311	0	1.4	NGC 6231
2.....	II Sco	315–321	+11 to +22	0.21	σ Sco
3.....	I Sgr	333.7	–2.7	1.3	M 8
4.....	II Sgr	334.9	–1.7	1.4	M 20
5.....	III Sgr	338.9–340.4	–2.0 to –2.9	2.3	Small Sgr cloud
6.....	IV Sgr	341.2	–0.5	1.7	NGC 6561
7.....	I Ser	344.6	–0.7	2.3	M 16
8.....	II Ser	346.1	+0.2	2.0	NGC 6604
9.....	I Vul	28	–1	1.8	NGC 6823
10.....	I Cyg	40.2	+1.4	2.3	NGC 6871
11.....	II Cyg	42–45	+2 to –1	1.5	P Cyg
12.....	III Cyg	44.6	–0.2	2.0	M 29
13.....	IV Cyg	49–52	–7 to –9	1.0	σ Cyg
14.....	I Lac	64–66	–16 to –19	0.46	10 Lac
15.....	I Cep	60–72	+1 to +9	0.72	ν Cep
16.....	II Cep	66–76	–1 to –3	3.6	
17.....	III Cep	77.6	+2.6	0.96	
18.....	I Cas	82.8–84.0	–0.4 to +0.7	2.5	6 Cas
19.....	II Cas	87.2	–0.3	2.2	
20.....	III Cas	89.5–91.5	+0.5 to +2.5	2.5	
21.....	I Per	100–104	–2 to –4.5	2.3	Double cluster in Per
22.....	I Cam	108–119	–2.5 to +4	0.9	
23.....	II Per	124–131	–12 to –17	0.36	ζ Per
24.....	I Aur	137–145	–1.5 to +2	1.15	χ Aur
25.....	I Gem	155–158	+0.5 to +5.5	1.5	3 Gem
26.....	I Ori	166–182	–12 to –24	0.5	ϵ Ori
27.....	I Mon	174–177	–1.5 to +1.5	1.4	NGC 2244

TABLE 2
SOME PROBABLE MEMBERS OF THE AGGREGATES

Star	MK	Aggregate	Star	MK	Aggregate
151804.....	O8f	1	190429 (ft.).....	O9.5 Ib p	10
152003.....	B0 I	1	190864.....	O6	10
152076.....	B0 IV, V	1	190918.....	O9.5 I+WR	10
152147.....	B0 I	1	190919.....	B1 Ib	10
152218.....	O9 IV, V	1	+35°3955.....	B1 Ib	10
152233.....	O6	1	+35°3956.....	B0.5 V	10
152234.....	B0.5 I	1	227634.....	B0 II-III	10
152235.....	B1 I	1	190967.....	B1 Ib-II	10
152247.....	O9	1	227696.....	B0.5 IV:	10
152248.....	O8	1	227704.....	B0 III	10
152249.....	O9 I	1	192422.....	B0.5 Ib	11
152314.....	O9 IV, V	1	192639.....	O8f	11
152408.....	O8fp	1	193183.....	B1.5 Ib	11
152424.....	O9 I	1	193237.....	Bp	11
π Sco.....	B1 V	2	228841.....	O6.5	11
δ Sco.....	B0 V	2	193443.....	O9 III	11
β Sco (br.).....	B0.5 V	2	193514.....	O7f	11
ω^1 Sco.....	B1 V	2	193595.....	O7	11
σ Sco.....	B1 III	2	193682.....	O5	11
τ Sco.....	B0 V	2	193855.....	B2 III	11
164794.....	O5	3	229059.....	B1.5 Ia p	11
164816.....	B0 V	3	194153.....	B1 Iab	11
164906.....	B1 IV: pe	3	229221.....	B0: I: pe	12
165052.....	O7	3	229227.....	B0 II	12
164402.....	B0 Ib	4	229234.....	O9.5 III	12
164492.....	O8	4	229238.....	B0.5 Ib	12
164514.....	A5 Ia	4	229239.....	B1 Iab	12
164637.....	B0.5 III	4	201795.....	B1 V	13
164833.....	B0 III	4	201819.....	B1 Vp	13
166628.....	B3 Ia	5	202349.....	B0.5 V	13
166965.....	B3 II	5	σ Cyg.....	B9 Iab	13
167224.....	B3 II	5	8 Lac (br.).....	B1 Ve	14
167287.....	B1 Ib	5	10 Lac.....	O9 V	14
167336.....	B0 II	5	12 Lac.....	B2 III	14
167659.....	O8	5	198895.....	B1 V	15
167771.....	O8	5	200857.....	B3 III	15
168021.....	B0 Ib	5	202214.....	B0 V	15
166286.....	B1 II	6	203025.....	B2 III	15
166287.....	B0.5 III	6	203374.....	B0 IV pe	15
166304.....	B1 V	6	204116.....	B1 Ve	15
166540.....	B0.5 IV	6	204827.....	B0 V	15
168075.....	O7	7	205139.....	B1 II	15
168076.....	O5	7	9 Cep.....	B2 Ib	15
168137.....	O8 V	7	206267.....	O6	15
168504.....	O8	7	206773.....	B0 V: pe	15
-12°4970.....	B0.5 Ia	8	207198.....	O9 II	15
-11°4586.....	O8 (I?)	8	ν Cep.....	A2 Ia	15
-12°4982.....	B0 II	8	207538.....	B0 V	15
167971.....	O8f	8	208218.....	B1 III:	15
168112.....	O5	8	208392.....	B1 IV:	15
186841.....	B1 Ia	9	13 Cep.....	B8 Ib	15
186745-6.....	B8 Ia	9	208905.....	B1 Vp?	15
+23°3745.....	B0.5 Ib	9	209339.....	B0 IV	15
+23°3759.....	B0 II	9	14 Cep.....	O9 V	15
+22°3782.....	O6	9	209744.....	B1 V	15
+23°3761.....	B0 II:	9	235673.....	O7	16
190429 (br.).....	O5f	10			

TABLE 2—Continued

Star	MK	Aggregate	Star	MK	Aggregate
209678.....	B2 I	16	14302.....	B1 II-III	21
209900.....	A0 Ib-II	16	14322.....	B8 Ib	21
210809.....	O9 Ib	16	14433.....	A1 Ia	21
+53°2827.....	B2 III:	16	14489.....	A2 Ia	21
+53°2833.....	B1 III	16	14535.....	A1 Ia	21
+54°2726.....	B1 II	16	14542.....	B8 Ia	21
235781.....	B6 Ib	16	14818.....	B2 Ia	21
235783.....	B1 Ib	16	14956.....	B2 Ia	21
211853.....	B0: I: +WR	16	15316.....	A3 Iab	21
+53°2843.....	O8	16	15497.....	B6 Ia	21
235813.....	B0 III	16	15571.....	B1 II:	21
212455.....	B5 Iab	16	19820.....	O9 IV	22
235825.....	O9 V	16	21291.....	B9 Ia	22
+54°2764.....	B1 Ib	16	21389.....	A0 Ia	22
213470-1.....	A3 Ia	16	22253.....	B0.5 III	22
214419.....	O7+WR	16	23675.....	B0.5 III	22
215835.....	O6 nn	16	23800.....	B1 IV	22
+55°2840.....	O7	16	24431.....	O9 IV-V	22
216927.....	B9 Ia	16	24432.....	B3 II	22
216532.....	O8	17	21856.....	B1 V	23
216658.....	B0 V	17	40 Per.....	B0.5 V	23
216711.....	B1 V	17	o Per.....	B1 III	23
217035.....	B0 V	17	24131.....	B1 V	23
217061.....	B1 V	17	ζ Per.....	B1 Ib	23
217086.....	O7	17	24534.....	O pev	23
+61°2509.....	B0.5 Ib	18	ξ Per.....	O7	23
+60°2615.....	B0.5 Ib	18	34656.....	O7	24
+61°2526.....	B2 Ib	18	34921.....	B0 IV: pe	24
+61°2529.....	B1 Ib	18	35345.....	B1 Vpe	24
6 Cas.....	A3 Ia+	18	35600.....	B9 Ib	24
+61°2550.....	B0 IV	18	35633.....	B0.5 IV	24
+61°2559.....	O9 V	18	35653.....	B0.5 V	24
223987.....	B1.5 Iab	18	35921.....	O9.5 III	24
224055.....	B3 Ia	18	χ Aur.....	B5 Iab	24
1383.....	B1 II	19	χ ² Ori.....	B2 Ia	25
1544.....	B0 III:	19	3 Gem.....	B2.5 Ib	25
+61°39.....	B0.5 IV	19	42088.....	O6	25
1743.....	B0 III	19	42379.....	B1 II	25
1810.....	B0 IV	19	42400.....	B5 II	25
2451.....	B0.5 IV	19	9 Gem.....	B3 Iab	25
3940.....	A1 Ia	20	43753.....	B0.5 III	25
4694.....	B3 Ia	20	43818.....	B0 II	25
4717.....	A0 Ib	20	46056.....	O8	27
4841.....	B5 Ia	20	46106.....	B0.5 V	27
5551.....	B1.5 Ib	20	46149.....	O8	27
5689.....	O7	20	46150.....	O6	27
12953.....	A1 Ia	21	46202.....	O9 V	27
13267.....	B5 Ia	21	46223.....	O5	27
13476.....	A3 Iab	21	13 Mon.....	A0 Ib	27
13744.....	A0 Iab	21	46485.....	O8	27
13745.....	B0 III	21	46573.....	O7	27
13841.....	B2 Ib	21	46711.....	B3 II	27
13854.....	B1 Iab	21	46847.....	B0 III: p	27
13866.....	B2 Ib	21	46966.....	O8	27
14134.....	B3 Ia	21	47129.....	O8	27
14143.....	B2 Ia	21	47240.....	B1 Ib	27

discussion of the arrangement in space of the high-luminosity stars of classes O–A, as carried out at the Yerkes Observatory, is given here; later papers in the series will include a catalogue of distances of the early-type stars of high luminosity and an investigation of the blue giants and $H\ II$ regions now being observed in South Africa by Code.

The program of spectroscopic absolute magnitudes and color indices of the O, B, and A stars of high luminosity has now reached a point at which certain conclusions on galactic structure are apparent. Details of the observing procedure and a general catalogue of the stars will be given later.

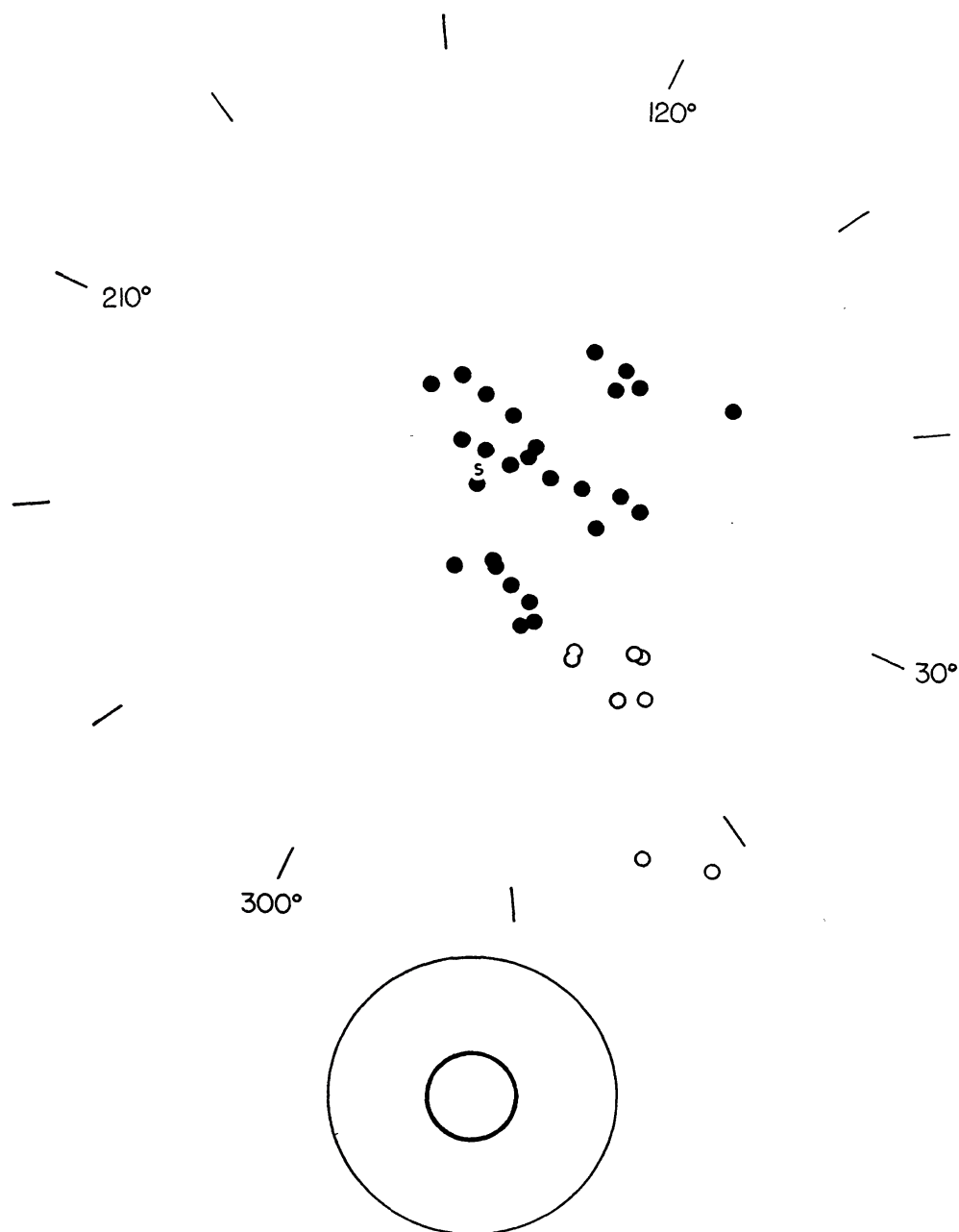


FIG. 1.—Space distribution of aggregates (*solid circles*). Eight distant stars (*open circles*) are also plotted. Oort's value of 9 kpc for the distance to the galactic center has been adopted. The longitude index lines are 500 psc long.

The stars included in the present discussion are those whose spectral types and luminosity classes (on the Yerkes revised *Atlas* system) are as follows: (1) all stars of classes O5–B1, inclusive; (2) classes B2 Ia–A5 Ia, B2 Ib–A5 Ib, B2 II–B5 II, and B2 III–B3 III. The visual absolute magnitude of the lower limit of this group is in the neighborhood of -3.0 .

The majority of these stars fall into well-defined clusterings, or aggregates. It is possible at this time to give preliminary distances for a total of twenty-seven aggregates. A number of these are already well known; in addition, there are some which are probably new.

The locations and distances of the aggregates are given in Table 1. The first column gives a running serial number; the second denotes the aggregate by a roman numeral and the constellation abbreviation; the third and fourth give the galactic co-ordinates; the fifth lists the distance in kiloparsecs; and the sixth identifies an associated cluster or bright star, if either exists.

TABLE 3
SOME DISTANT STARS BETWEEN $l = 347^\circ$ AND $l = 5^\circ$

Star	l (Degrees)	b (Degrees)	MK	r (Kpc)	Star	l (Degrees)	b (Degrees)	MK	r (Kpc)
170716.....	347.4	-2.7	B0.5 Ib	6.0	173438.....	355.9	-2.3	B0.5 Ia	3.8
173783.....	351.9	-4.9	O9 I	3:	-0°3584....	0.5	-2.3	O8	4:
172275.....	352.7	-2.1	O6	2.9:	177812.....	5.2	-3.2	B1 Ib	3.4
173987.....	354.6	-3.8	B0.5 Iab	6.6	178129.....	5.5	-3.4	B3 Ia	3.5

Table 2 lists some probable members of the various aggregates, with the exception of I Ori: for this, the recent paper of Sharpless¹ should be consulted. The third column identifies the aggregates by means of the numbers in Table 1.

The positions of the aggregates are plotted in Figure 1. The small s identifies the position of the sun; the distance of the sun from the galactic center has been taken to be 9 kpc, from the determination of Oort.² The inner circle at the galactic center corresponds to the galactic nuclear region shown in the infrared observations by Stebbins and Whitford;³ the outer circle, representing a region of lower intensity, was plotted from wide-angle photographs by Sharpless and Osterbrock.

The two outer arms are shown well, and, in addition, a third well-marked arm segment can be seen; the latter is located some 1400 psc from the sun in the direction of the galactic center. Eight very distant stars are listed in Table 3 and are plotted in Figure 1; their distances are, of course, less accurately known than are those for the aggregates.

The aggregates III Cep, I Cam, I Aur, I Gem, and I Mon appear to form a branch to the arm in which the sun is located. The observations of Oort, van de Hulst, and Muller² indicate a similar branching.

The present observations confirm and extend the conclusions reached earlier⁴ by Morgan, Sharpless, and Osterbrock.

The data for I Sco are (in part) from a paper by Brownlee and Cox, now in press. We are indebted to Dr. Stewart Sharpless for a series of spectrograms obtained at the McDonald Observatory in July, 1952. Part of the spectral classification was carried out by Mrs. Irene Hansen Osterbrock.

¹ *Ap. J.*, **116**, 251, 1952.

² *Koninkl. Nederl. Akad. Wetenschappen, Amsterdam*, Vol. **61**, No. 8, 1952.

³ *Ap. J.*, **106**, 235, 1947.

⁴ *A.J.*, **57**, 3, 1952.