1966AJ.....71..922V

Luminosity Classifications of Dwarf Galaxies

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(Received 26 July 1966)

Luminosity classifications are given for 243 dwarf galaxies with diameters $\phi > 1'.0$ and located north of $\delta = -33°$. The distribution of these dwarfs over the sky is seen to be similar to that of the nearer giant galaxies. The space density of dwarf galaxies is approximately 0.1 galaxy/Mpc^3.

Attention is drawn to the striking difference between the luminosity functions of spiral and irregular galaxies. Giant spirals outnumber giant irregulars but dwarf irregulars are more numerous than are dwarf spirals. Barred spirals are found to be more frequent among dwarfs than they are among giant and supergiant spirals.

I. INTRODUCTION

SOME years ago Dr. H. C. Arp asked me to prepare a list of the most interesting objects in a catalogue of dwarf galaxies (van den Bergh 1959) for him. The objects so selected were intended for more detailed study with the 200-in. telescope. As a by-product of this investigation all objects in the 1959 catalogue of dwarf galaxies were classified on the DDO luminosity classification system (van den Bergh 1960a,b,c). Most of the galaxies in the original catalogue were found to be dwarfs of luminosity classes IV–V and V. A few peculiar objects and subgiant galaxies of luminosity class IV were, however, found to have been included in the original catalogue.

Some objects have been classified V without the prefix S or Ir. The mean magnitude of such galaxies is probably even fainter than that of the S V and Ir V dwarfs.

II. OBSERVATIONAL DATA

Table I lists all dwarf galaxies north of $\delta = -23°$ with diameters larger than 1.0 min of arc, which were found on the prints of the Palomar Sky Survey. An asterisk refers to a remark at the end of the table. (References to NGC and IC numbers are given in the 1959 catalogue.) The diameter of each galaxy in millimeters on the blue print of the Sky Survey (1 mm = 67″) is given in the fourth column of the table. The fifth column lists the degree of resolution on the blue prints on the following scale: − unresolved, ± incipient resolution, + clearly resolved, and ++ resolved stars only. Table II lists newly discovered dwarf galaxies with declinations in the range $-33° < \delta < -23°$. The only difference between Tables I and II is that the latter table gives 1875 rather than 1855 coordinates. Because of strong atmospheric absorption of blue light at large zenith distances the luminosity classification of galaxies

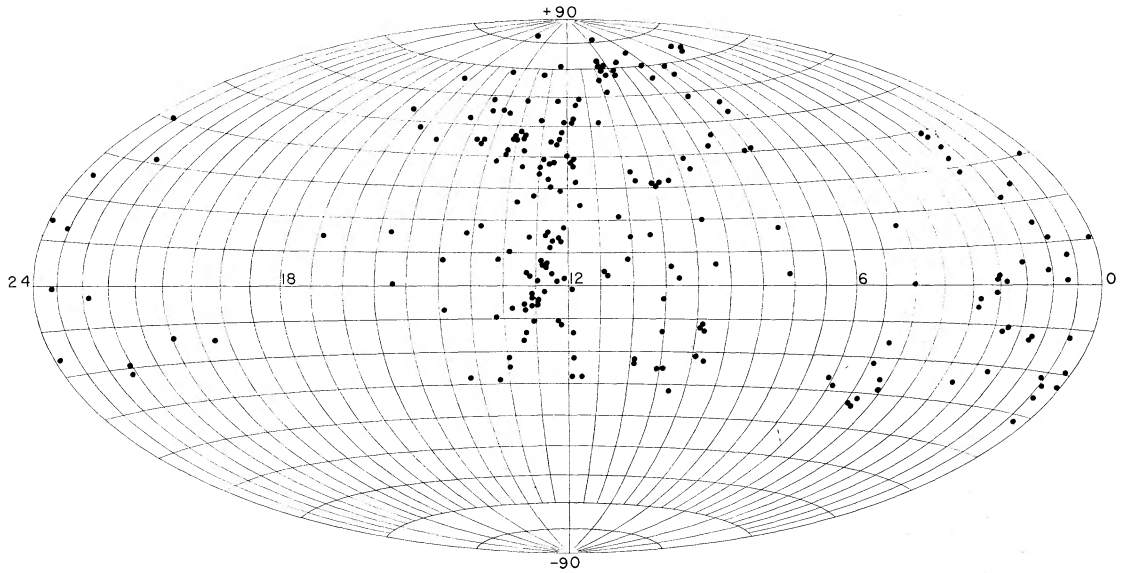

FIG. 1. Equal area projection in equatorial coordinates of all dwarf galaxies with $\phi > 1'.0$ which are north of $\delta = -33°$. The figure shows the 'zone of avoidance' and clusterings of dwarfs associated with the M81, Canes Venatici, Ursa Major, and Virgo clusters.

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TABLE I. Catalogue of dwarf galaxies.

No.	α(1855)	δ(1855)	ϕ	res	DDO type
1	0^h11^m	−19°50′	1.0	±	S V
2	0 12	+10 05	1.0	+	S V
3	0 25	+47 40	6.0	−	dE
4	0 26	+30 40	1.0	±	S V:
5	0 39	−12 20	1.5	±	S(B) V
6	0 43	−21 50	1.0	±	Ir V
7	0 54	+06 50	1.0	±	S(B) V
8	0 57	+01 20	15.0	+	Ir V
9	1 02	+48 50	1.5	±	?
10	1 14	+11 40	1.5	±	S(B) IV–V:
11	1 22	+25 05	1.5	+	S(B) V:
12	1 27	+03 40	1.5	−	S V:
13	1 32	+15 10	1.5	−	Ir V
14	1 41	−13 10	1.5	+	S IV–V
15	1 42	−13 30	1.0	−	V
16*	1 44	+17 25	1.5	−	
17	1 55	+21 15	1.5	+	Ir V or pec
18	2 03	+06 05	1.0	?	Ir V
19	2 16	+35 20	1.5	±	S V:
20	2 19	−10 30	2.0	+	S(B) IV–V:
21	2 19	−22 05	1.5	−	S V
22	2 24	+38 00	1.0	−	V
23	2 24	−11 25	1.0	±	IV–V
24	2 25	+39 50	1.5	±	Ir IV–V or Ir V
25	2 25	+32 50	2.0	+	Ir V
26	2 26	+29 05	1.0	−	Ir V
27	2 33	+00 40	1.0	−	Ir V
28	2 40	+03 15	3.0	−	V
29	2 42	+01 30	3.0	±	V
30	2 44	−01 45	1.5	±	S(B) V
31	3 07	−03 20	1.5	+	Ir V:
32	3 07	−05 20	1.0	+	Ir V
33	4 29	+74 40	1.0	±	SB IV–V or SB V
34	4 41	00 00	1.0	−	V
35	4 55	+16 10	1.0	±	V:
36	5 01	−16 30	1.0	±	SB IV–V
37	5 13	−21 45	1.5	±	V?
38	5 16	+73 35	1.0	±	Ir V
39	5 36	+75 15	2.0	−	V
40	6 53	+56 40	1.0	±	S(B) V
41	6 58	+53 40	1.0	±	Ir V:
42	7 13	+69 30	5.0	+	S IV–V or Ir IV–V
43	7 18	+41 05	1.0	±	Ir IV–V or Ir V
44	7 20	+67 10	1.5	−	V
45	7 28	+03 05	2.0	−	Ir V
46	7 31	+40 25	1.0	−	V
47	7 34	+17 05	3.0	−	Ir V?
48	7 47	+58 25	1.5	−	S(B) IV–V:
49	8 01	+46 55	1.0	−	Ir IV–V:
50	8 04	+71 10	6.5	+	Ir IV–V
51	8 08	+74 55	1.0	±	SB IV–V:
52	8 19	+42 20	1.0	−	V
53	8 21	+66 40	1.0	+	Ir V
54	9 00	+06 30	1.5	−	S V
55	9 03	+36 05	1.0	±	IV–V or V
56	9 03	−22 25	1.0	−	V
57	9 04	−14 25	1.0	±	Ir V
58	9 05	+20 00	1.0	+	Ir V
59	9 06	+39 50	1.0	±	S(B) V
60	9 13	−11 35	1.0	+	Ir V
61	9 14	−12 00	1.0	−	Ir V
62	9 15	−21 50	2.0	−	V?
63	9 28	+71 50	2.5	±	Ir V
64	9 42	+32 10	1.5	±	Ir IV–V:
65	9 44	+02 05	1.0	±	Ir V
66	9^h46^m	+69°45′	1.5	±	Ir V
67	9 48	+81 00	1.5	+	S IV
68	9 48	+29 30	2.0	−	pec
69	9 51	+31 25	3.5	+	Ir V
70	9 52	+06 00	3.0	+	Ir IV–V
71	9 55	+67 15	1.0	−	V
72	10 00	+30 15	1.0	−	S V:
73	10 01	+30 50	1.0	±	Ir V
74	10 01	+13 00	8.5	+	dE
75	10 04	−04 00	4.0	+	Ir V
76	10 04	−13 05	1.5	±	Ir V:
77	10 13	+71 40	2.0	+	SB IV–V
78	10 16	+68 20	1.0	−	V
79	10 17	+15 30	1.0	±	SB IV–V
80	10 19	+70 45	2.0	+	S(B) V
81	10 19	+69 10	11.5	+	S IV–V
82	10 20	+71 20	1.5	±	S V:
83	10 28	+32 15	1.0	±	Ir V
84	10 34	+35 15	4.0	+	Ir V
85	10 34	−22 40	1.0	−	Ir V
86	10 35	+61 05	1.5	±	Ir V
87	10 40	+66 15	1.0	−	V
88	10 40	+14 50	1.0	±	V
89	10 43	+20 25	1.0	±	pec
90	10 45	+08 25	1.0	±	V
91	10 58	+20 35	1.0	−	Ir V
92	11 05	+54 20	1.0	±	S IV–V
93	11 06	+22 55	5.0	±	Spheroidal
94	11 13	+03 20	2.0	+	Ir V
95	11 17	+04 10	1.5	+	S(B) IV–V:
96	11 36	+59 55	1.0	±	S V
97	11 42	+24 40	1.0	−	Ir V
98	11 43	+57 15	1.0	+	S(B) IV–V:
99*	11 43	+39 40	3.5	±	Ir IV–V or Ir V
100	11 45	+52 55	1.0	−	SB IV–V
101	11 48	+32 20	1.0	−	V
102	11 50	+51 40	1.0	−	S(B) V
103	11 51	−13 45	1.0	+	?
104	11 51	−13 55	1.0	±	V:
105	11 51	+38 50	2.5	±	Ir V
106	11 51	−21 40	2.0	−	Ir V
107	11 52	+38 40	1.5	±	S(B) IV:
108	11 57	−00 44	1.0	±	Ir V
109	12 00	+40 35	1.0	−	Ir V
110	12 04	+02 50	1.0	−	V
111	12 04	+51 05	1.0	−	Ir V
112	12 04	+18 50	1.0	±	Ir IV–V
113	12 07	+37 00	1.0	−	?
114	12 07	+13 35	1.0	±	Ir IV–V:
115	12 08	+14 20	1.0	−	Ir IV–V or Ir V
116	12 09	−10 40	1.5	±	Ir V
117	12 10	+29 35	1.0	±	Ir V
118	12 10	−10 50	1.0	±	Ir V
119	12 13	+47 10	1.5	+	S(B) IV?
120	12 14	+46 40	1.0	+	Ir IV–V
121	12 15	+01 15	1.0	+	Ir V
122	12 19	+71 10	1.5	±	S V
123	12 19	+59 05	2.0	+	IV–V
124	12 20	+13 55	1.0	−	Ir IV–V
125	12 20	+44 15	3.0	±	Ir IV–V
126	12 20	+38 00	2.0	±	Ir V
127	12 21	+38 00	1.0	−	V
128	12 22	+03 35	1.5	±	V pec
129	12 22	+44 00	2.0	+	Ir V
130	12 22	+12 15	1.0	−	V

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TABLE I (*continued*)

No.	α(1855)	δ(1855)	ϕ	res	DDO type
131	12^h24^m	+30°30′	1.0	±	Ir V
132	12 25	+13 35	1.0	−	Spheroidal ?
133	12 26	+32 25	3.0	±	Ir V
134	12 26	−01 50	1.0	±	Ir V
135	12 27	+16 00	1.5	+	S: V:
136	12 28	+16 00	1.0	±	Ir V
137	12 28	+07 05	1.0	−	V
138	12 29	+07 25	1.0	+	S IV–V or S V
139	12 30	+07 55	1.0	+	Ir V
140	12 32	+08 45	1.0	+	Ir IV–V:
141	12 35	+39 15	2.0	±	Ir IV–V
142	12 37	−04 55	2.0	±	S IV–V or S V
143	12 37	+35 10	2.0	±	Ir V
144	12 37	+01 15	1.0	±	V
145	12 38	+12 50	1.0	−	dE ?
146	12 38	−05 20	2.5	±	V
147	12 40	+37 15	1.0	−	V
148	12 41	−04 30	1.5	−	V
149	12 42	−03 15	1.0	±	Ir V
150	12 42	+51 55	1.5	+	S IV–V or S V
151	12 43	−10 05	3.5	+	IV–V
152	12 45	−05 30	1.0	±	Ir V
153	12 46	−11 20	1.5	±	?
154	12 47	+27 55	3.0	+	Ir IV–V
155*	12 51	+15 00	1.0	+	Ir V
156	12 50	+03 30	1.0	±	Ir V
157	12 51	+15 40	1.0	−	S IV:
158	12 51	+03 35	1.0	±	SB IV–V
159	12 53	−14 55	1.5	−	V
160	12 54	−03 55	1.0	±	Ir ?
161	12 55	−16 40	6.5	+	pec
162	12 58	−07 25	1.0	+	S(B) IV–V
163	12 58	−07 10	1.0	±	SB V
164	12 59	−16 45	1.0	±	V
165	13 01	+68 30	2.5	±	Ir IV–V
166	13 06	+37 05	1.5	+	Ir IV–V
167	13 07	+47 05	1.0	+	Ir V
168	13 08	+46 40	3.0	+	Ir IV–V
169	13 09	+48 15	3.0	±	Ir IV–V or Ir V
170	13 09	+26 10	1.0	−	V
171	13 11	−07 40	1.0	+	Ir V:
172	13 12	+42 45	1.5	±	SB IV–V
173	13 14	+10 30	1.5	±	S(B) IV–V:
174	13 19	−21 30	1.0	±	Ir V
175	13 20	+58 35	1.5	±	V
176	13^h24^m	+46°05′	1.5	±	S(B) IV–V
177	13 30	+46 55	1.0	+	SB V
178	13 30	+46 40	1.0	±	S V
179	13 30	+08 25	2.0	+	IV–V
180	13 31	−09 05	1.0	+	S IV–V:
181	13 34	+41 25	1.5	±	Ir IV–V or Ir V
182	13 36	+40 20	1.0	−	Ir V
183	13 45	+38 45	2.0	−	Ir IV–V
184	13 48	+18 30	2.0	−	V
185	13 49	+54 35	2.5	+	Ir IV–V
186	14 00	+55 10	1.0	+	Ir IV–V
187	14 09	+23 40	1.0	±	pec
188	14 09	+17 15	1.0	±	V
189	14 17	+46 05	1.0	±	Ir V
190	14 19	+45 10	1.0	±	Ir IV or Ir IV–V
191	14 20	+56 55	1.5	±	S(B) V
192	14 24	+45 05	1.0	±	SB V
193	14 30	+59 10	1.0	+	S(B) V
194	14 31	+57 50	1.0	−	V
195	14 31	−08 00	2.0	±	Ir V
196	14 38	+08 30	1.0	−	Ir V
197	14 42	−09 30	2.0	+	pec
198	14 57	+53 15	1.0	±	Ir IV–V
199	15 07	+67 50	20.0	++	Spheroidal
200	15 32	+44 40	1.0	±	S V
201	15 35	+00 55	1.0	±	Ir IV–V
202	15 45	+16 45	2.0	±	Ir V
203	15 55	+82 15	1.0	±	SB IV–V
204	16 12	+47 25	1.5	+	IV–V
205	16 16	+64 15	1.0	±	IV–V:
206	16 51	+53 20	1.0	±	S(B) V
207	17 13	+14 35	1.0	−	S(B) V:
208	17 18	+58 05	8.0	++	Spheroidal
209	19 37	−15 10	12.5	+	Ir IV–V
210	20 39	−13 25	1.5	±	V
211	22 02	−19 35	1.0	−	V:
212	22 09	−21 55	1.5	+	Ir IV–V:
213	22 27	+32 05	1.5	±	S V
214	22 29	−03 40	2.0	+	S IV–V
215	22 32	−05 30	1.0	±	?
216	23 21	+13 55	4.0	±	Ir V
217	23 23	+40 10	2.5	±	S V:
218	23 28	+17 25	1.0	±	pec
219	23 30	−00 30	1.5	±	S V:
220	23 42	+25 25	1.0	±	IV–V or V
221	23 54	−16 15	11.0	+	Ir IV–V
222	23 56	+14 30	1.5	±	S V

REMARKS
DDO 16 probably distant interacting galaxies.
DDO 99 corrected coordinates.
DDO 155 corrected coordinates.

in Table II are probably somewhat less accurate than are those in Table I.

III. DISCUSSION

Unfortunately very few of the galaxies in Tables I and II have known apparent magnitudes so that the luminosity classifications cannot be used to determine individual distances. Some conclusions about the spatial distribution of dwarf galaxies may, however, be derived from their apparent distribution on the sky, which is plotted in Fig. 1. The figure shows that the large-scale distribution of dwarf galaxies is quite similar to that of the brighter galaxies in the Shapley–Ames (1932) catalogue. Figure 1 shows a significant clumping of galaxies associated with the M81 cluster near $\alpha = 9^h50^m$, $\delta = +69°$. Other clusterings coincide with the Canes Venatici cluster ($\alpha = 12^h50^m$, $\delta = +41°$) the Ursa Major cloud ($\alpha = 12^h00^m$, $\delta = +50°$) and the Virgo cluster ($\alpha = 12^h25^m$, $\delta = +13°$). The Virgo cluster is, however,

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TABLE II. Dwarf galaxies with $-33° < \delta < -23°$.

No.	α(1875)	δ(1875)	ϕ	res	DDO type
223*	00^h08^m	−23°50′	7.0	+	S IV–V
224	00 28	−31 30	1.5	+	S IV–V:
225*	00 30	−26 00	3.0	±	S IV–V or S V
226*	00 37	−23 00	1.0	±	Ir IV–V
227	02 58	−25 45	1.0	−	S V
228	04 44	−29 25	2.0	+	S V
229	04 48	−25 30	2.5	±	S(B) IV–V
230	05 06	−31 45	1.5	±	S IV–V:
231*	05 07	−33 05	2.5	−	Ir V
232*	05 15	−32 15	1.5	−	S(B) V
233	05 56	−29 00	1.0	−	SB: V
234	06 10	−26 30	1.5	−	V
235*	09 40	−31 15	1.0	±	Ir IV–V
236*	09 57	−25 30	12.0	+	Ir IV–V
237	10 05	−25 15	1.0	±	V
238	10 30	−24 05	2.5	+	S IV–V:
239	11 42	−27 35	1.5	−	S V
240	11 58	−27 25	1.0	−	Ir V
241	13 17	−24 00	1.0	−	S V:
242*	13 35	−29 15	1.5	±	Ir IV–V
243*	14 13	−28 40	2.0	−	S(B) IV–V:

REMARKS

DDO 223 = NGC 45.
DDO 225 = IC 1558.
DDO 226 = IC 1574.
DDO 231 See Sher (1963).
DDO 232 = NGC 1879.
DDO 235 Near NGC 2997. Many very small dwarf galaxies in same region.
DDO 236 = NGC 3109.
DDO 242 = NGC 5264.
DDO 243 = NGC 5556.

much less prominently outlined by dwarf galaxies than it is by the giants contained in the Shapley–Ames catalogue. This is due to the fact that most of the dwarfs in the Virgo cluster have apparent diameters smaller than 1 min of arc. Due to selection by apparent diameter the nearer clusters appear more prominently than do those at greater distances. A detailed comparison of the distribution of dwarf and giant galaxies on the sky suggests that most of the dwarfs in the catalogue are located at distances ($H = 100$ km/sec/Mpc) less than or equal to 10 Mpc. If one *assumes* that the data in Tables I and II are complete to 10 Mpc at intermediate and high galactic latitudes one finds that the space density of dwarfs is approximately 0.1 galaxies/Mpc^3. It should, of course, be emphasized that this number is quite uncertain. Nevertheless it is of interest to note that the number density of dwarf galaxies appears to be comparable to that of giant galaxies (Oort 1958; Kiang 1961; van den Bergh 1961).

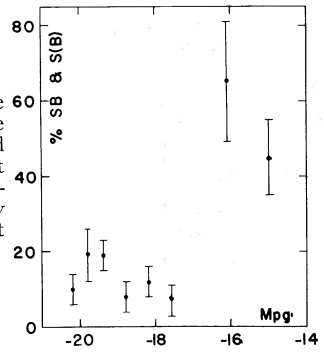

FIG. 3. Absolute magnitude dependence of the percentage of all spirals which are barred spirals. The figure shows that barred spirals are more frequent among dwarfs than they are among giant and supergiant galaxies.

Table III gives the observed numbers of pure spirals, barred spirals [SB and S(B)] and irregular galaxies of different luminosity classes. Since spirals, barred spirals, and irregulars of any one luminosity class have the same absolute magnitude their relative numbers are independent of selection effects. For galaxies of luminosity classes I through IV the data were taken from van den Bergh (1960c) and unpublished luminosity classifications of the Shapley–Ames galaxies with $-33° < \delta < -23°$. The data on dwarf galaxies of luminosity classes IV–V and V were taken from Tables I and II.

The data in Table III, which are plotted in Fig. 2, show that irregular galaxies are absent among supergiants, rare among the giants, but dominant among the dwarfs. Possibly this result indicates that late-type galaxies of high luminosity are, in the mean, formed with more angular momentum per unit mass than are faint galaxies of late types.

Figure 3 shows the percentage of all spirals which are of types SB or S(B). The data, which were taken from Table III, show that barred spirals are far more common among dwarf spirals than they are among giants. A secondary maximum in the relative frequency

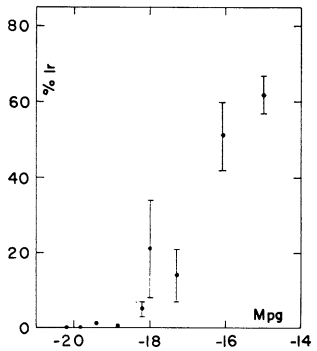

FIG. 2. The figure shows the percentage of all galaxies with luminosity classifications which are irregular. Spirals are seen to dominate the bright end of the luminosity function whereas most very faint galaxies are observed to be irregular.

TABLE III. Relative frequency of spiral, barred spiral, and irregular galaxies.

DDO class	$\langle M_{pg} \rangle$	Spiral	Barred spiral	Irregular
I	−20.2	56	15	0
I–II	−19.8	34	8	0
II	−19.4	112	24	1
II–III	−18.8	59	5	0
III	−18.2	66	9	4
III–IV	−18.0:	8	3	3
IV	−17.3:	26	4	5
IV–V	−16.1:	9	17	27
V	−15::	22	18	64

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of barred spirals may be indicated near $M_{pg}=-19.5$. The statistics, however, are not yet sufficient to establish its reality.

Dwarf galaxies in clusters have been studied by Reaves (1956, 1962) and by Hodge (1959, 1960). Within clusters dwarf galaxies may occur as free cluster members or as satellites of giant galaxies. In the Local Group NGC 6822 and IC 1613 are probably free whereas the Magellanic Clouds are almost certainly satellites of the Galaxy. It is not yet clear if all the Sculptor type systems which are known in the Local Group (Hodge 1966) are satellites of the Galaxy or members of the Local Group as a whole. No Sculptor type systems are known to be associated with the Andromeda Nebula. At the distance of M31 such objects would, however, be difficult to detect. Only the Fornax system would be observable as a compact grouping of 4 globular clusters.

Inspection of the Palomar Sky Survey prints strongly suggests that dwarf galaxies are more frequently associated with supergiants of types Sb and Sc than they are with fainter galaxies of the same types. Detailed study of the Sky Survey prints suggests, but does not prove, that giant ellipticals do not have late type dwarf companions.

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