1954AJ.....59..285S

THE DISTRIBUTION OF EXTRAGALACTIC NEBULAE*

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Abstract. Counts of extragalactic nebulae have been made on plates taken with the 20-inch Carnegie astrograph of the Lick Observatory. The area of the sky for which the results are published in the present paper extends in right ascension from 12^h to 18^h and in declination from $-20°$ to $+20°$. The limiting magnitude of about 18.4 has been made as nearly as possible constant over this entire region through the use of uniform procedures and the application of corrections for systematic errors. The principal data are given in a table containing the counted numbers of nebulae in each square degree together with corrections to reduce these numbers to a uniform basis, and the results are portrayed by means of a chart giving contours of equal numbers of nebulae per square degree.

In addition to a very irregular boundary of the zone of avoidance, several more or less detached areas of galactic obscuration are apparent on the chart. In higher latitudes, where the effect of galactic obscuration should be small, the distribution of nebulae is still so far from random as to suggest strongly that clustering is a very general feature of the distribution.

The distribution of surface density of nebulae in Coma-type clusters has been studied in a very preliminary way and is found to be well represented by de Vaucouleurs' empirical formula for the distribution of light in elliptical nebulae. The association of clusters to form larger aggregations or clouds of nebulae seems to be a rather general feature of the distribution.

I. INTRODUCTION

The problem of nebular distribution may be considered from two aspects. One is concerned with the way in which the nebulae are distributed over the surface of the sky, and the other with their distribution in depth. Extensive nebular counts, or surveys, provide the observational material for both investigations but the approach is very different.

A survey in depth requires that nebulae be counted in properly selected sample areas to specific limiting magnitudes that cover as wide a range as possible. Nearly twenty years ago Hubble carried out the principal survey in depth that has been made to date.[1] More recently he has outlined the direction that should be taken in an improved and definitive survey.[2] The requirements are very severe, for the limiting magnitudes must be determined on a highly accurate scale. In order to correct for the larger red shifts, the intensity distribution in the spectra of the nebulae must be known to much shorter wave lengths than those covered by the adopted magnitude system. Since it is not possible to determine the intensity distribution in the far ultraviolet, it is desirable to make the survey in the region of longer wave lengths. Even if proper allowance can be made for the spectral energy distribution, the corrections for the red shift depend on whether or not the shift is due to recessional velocity. It is not at present clear what allowance should be made for the excess reddening of very distant nebulae as observed by Stebbins and Whitford.[3] Observers at the Mount Wilson Palomar Observatories are laying the foundation for what it is hoped will be a definitive survey in depth.[4] When this survey is complete, it will provide essential information not only on a possible large-scale radial density gradient of the universe, but also on the nature of the red shift and on the curvature of space.

A study of the surface distribution of the extragalactic nebulae requires quite a different observational approach. For this purpose the plates should cover a very substantial connected area of the sky, but the counts may be restricted to a single limiting magnitude. This limiting magnitude need not be determined with high precision but it should be constant over the region surveyed. Smaller-scale inhomogeneities can be observed than those revealed by a survey in depth.

Suitable material for a nebular survey over the surface of the sky is provided by a series of 1246 plates taken with the 20-inch Carnegie Astrograph at the Lick Observatory. These plates are the first of two series in a proper motion program originally planned by Wright.[5] It is intended that the second series shall be taken after an interval of some decades. The plates cover the entire sky north of declination $-23°$, with uniform exposures of two hours centered on the meridian. Perhaps their greatest advantage lies in the fact that each plate covers an area 6° square with the plate centers not more than 5° apart in each coordinate. Thus each plate has a generous overlap with at least three and usually with four of its neighbors. Nebulae in the overlaps are most useful in reducing the counts to a common standard.

The number of nebulae photographed to a limiting magnitude of 18.3 or 18.4 is of the order of a million. Nebular counts were started by the authors late in 1947, and in the interest of uni-

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* *Lick Observatory Bulletin*, No. 528. A preliminary report of this work was published in *Proc. Amer. Phil. Soc.* **94**, 13, 1950.

formity, all the plates are now being counted by them. Five of the earlier plates were counted by Mayall. The counts are about 44 per cent complete and are being continued as rapidly as possible.

For purposes of discussion the sky has been divided into nine areas. Areas I to IV inclusive cover 6^h intervals starting at 0^h and lying between $-23°$ and $+20°$. Areas V to VIII cover the same intervals in right ascension from declination $+20°$ to $+60°$. Area IX comprises all of the polar region north of $+60°$. Only the counts in Area III, $\alpha = 12^h$ to 18^h, $\delta = -23°$ to $+20°$, have been completely reduced to date. The results of this discussion form the subject of the present paper.

II. THE PHOTOGRAPHS

The photographic plates are seventeen inches square and cover a field of slightly more than 36 square degrees. They were coated by the Eastman Kodak Research Laboratory with emulsion of type 103a-O. The five emulsions used in Area III were uniform in average sensitivity to a very satisfactory degree, with an extreme range of less than 0.2 mag. in average limiting magnitude, as determined from the nebular counts. Care was taken to maintain uniformity in development and to guard against deterioration of the plates in storage.

The plate centers for the entire program are referred to the equator and equinox of 1950. From $\delta = -20°$ to $\delta = +35°$, the centers are spaced 20^m apart, starting at $\alpha = 0^h$. From $\delta = +40°$ to $\delta = +50°$, the increments are 24^m. North of $\delta = +50°$ the increments are as follows: for $\delta = +55°$, 32^m; $\delta = +60°$, 36^m; $\delta = +65°$, 40^m; $\delta = +70°$, 48^m; $\delta = +75°$, 60^m; $\delta = +80°$, 90^m; $\delta = +85°$, 144^m. All plates are centered accurately with the errors seldom exceeding 1′ in either coordinate. While the usable field on each plate is 6° square, the plate centers are no more than 5° apart, so that except for the southern band of plates, one degree around the edge of each plate is duplicated on adjacent photographs.

Each exposure was started 1^h1^m before the center of the field crossed the meridian. At the end of an hour the exposure was interrupted for 2 minutes. During this interval a one-minute exposure centered on the meridian was taken with the telescope shifted approximately 1′ in right ascension. The telescope was then returned to its original position for the second hour exposure.

A coarse wire grating of $\frac{1}{4}$-inch spacing placed in front of the lens was used throughout. This grating gives first-order images 4 magnitudes fainter than the primary images and separated from them by $0\overset{'}{.}24$. It reduces the limiting magnitude by 0.3 mag. Both the grating images and the short exposures are a slight hindrance in the nebular work, but they are important in an astrometric study of the material when the positions of bright and faint stars are compared.

Occasionally exposures were interrupted by clouds. Some plates of deficient effective exposures were used in the survey if the deficiency did not exceed 20^m. In such cases suitable corrections were applied to the counts.

III. THE COUNTS

The uncorrected nebular counts per square degree for Area III are given in Table I. The numbers are arranged so that north is at the top, east to the left. Plates in each 5° zone of declination are tabulated as separate groups. Above each block of counts representing the 36 square degrees on a plate are certain designations pertaining to that plate. The plate number is given at the upper left. Below this is the initial of the observer who counted the plate, followed by a small letter indicating the emulsion. The right ascension of the plate is given at the upper right and below it is the complete plate factor, F, defined below. Several plate numbers are followed by asterisks, which refer to the notes following the table. The notes list the plates deficient in effective exposure time and those omitted from the solution for the various correction factors because of outstanding discrepancies with their overlapping neighbors.

Although the numbers of nebulae per square degree are tabulated, the original counts were actually recorded in 10′ squares. The counting procedure is in general uniform throughout. The plate is mounted in a frame with a motion in the north-south or y direction. The observing microscope moves in the east-west or x coordinate. Scales reading to 1′ permit the fairly accurate location of the area to be counted. In the focal plane of the microscope there is a square 10′ on a side defined by cross hairs. This is first centered on the northwest 10′ square of the plate, and the number of nebulae in that square is counted and recorded. Counts are made across the plate by 10′ intervals from west to east. Then the plate is moved south by successive 10′ intervals and the process is repeated in the same

TABLE I. AREA III, UNCORRECTED COUNTS OF NEBULAE PER SQUARE DEGREE

δ = -20°

788 $12^h\,00^m$
S b 1.022

35	36	38	27	22	36
68	69	37	49	73	40
51	44	34	49	51	36
31	39	54	67	41	62
21	34	36	53	30	15
29	13	23	28	14	10

1512 $12^h\,20^m$
S h 0.953

56	73	61	41	30	33
41	46	35	37	59	51
31	77	36	24	33	49
42	39	19	25	24	27
31	50	52	47	31	18
39	31	32	29	29	14

469 $12^h\,40^m$
S a 0.822

56	49	50	51	32	50
77	53	43	45	42	60
61	61	54	57	48	66
77	65	50	50	42	59
82	81	72	45	46	57
59	69	54	45	49	51

476* $13^h\,00^m$
S a 0.999

50	53	62	70	146	40
54	72	49	61	70	56
57	63	84	44	40	51
57	72	50	33	51	47
60	74	49	53	40	58
37	57	47	46	60	54

803 $13^h\,20^m$
S b 0.892

50	54	35	74	50	38
33	44	30	39	41	63
48	26	58	20	48	60
39	83	41	33	47	39
43	55	33	56	40	53
45	29	49	45	49	37

1164 $13^h\,40^m$
W e 0.834

34	27	33	30	30	59
30	33	57	48	25	24
63	49	69	67	52	38
35	31	38	33	50	48
22	25	24	25	37	51
35	42	40	31	41	44

1574** $14^h\,00^m$
S h 1.780

17	28	19	14	14	12
20	19	22	22	20	13
25	28	24	29	24	20
18	20	11	30	25	16
16	19	23	27	18	7
16	20	23	28	19	11

789** $14^h\,20^m$
W b 0.415

30	31	48	32	35	33
43	40	51	32	44	44
52	59	50	62	39	46
32	59	47	37	24	33
25	32	25	25	29	37
36	47	29	32	46	33

1590 $14^h\,40^m$
S h 0.978

10	24	21	35	12	5
19	23	36	18	15	27
21	32	21	15	16	21
26	31	20	27	11	15
23	33	38	15	21	16
17	17	19	20	13	7

470 $15^h\,00^m$
Wa 0.825

25	15	5	12	16	21
19	14	13	22	18	21
35	26	16	33	24	29
35	25	20	22	10	31
39	23	22	28	25	31
23	20	19	20	32	40

852* $15^h\,20^m$
Wb 0.885

34	23	24	28	20	25
19	9	9	16	11	15
22	12	10	15	16	8
20	24	17	16	17	21
18	29	17	14	15	21
35	31	30	16	27	27

1254** $15^h\,40^m$
W f 1.522

8	5	17	7	11	13
5	5	13	10	6	14
10	3	9	12	6	10
6	4	5	1	10	5
4	5	9	9	14	22
19	12	13	15	32	37

1604 $16^h\,00^m$
S h 1.047

0	1	4	5	3	10
4	1	6	4	2	4
2	5	6	5	5	5
7	3	8	11	3	4
3	0	7	7	8	4
4	2	9	7	5	2

1208 $16^h\,20^m$
S e 0.879

2	1	2	0	2	2
2	4	2	3	1	3
0	1	0	1	1	3
1	0	0	0	2	1
1	1	1	1	1	5
0	0	0	2	10	0

874 $16^h\,40^m$
S b 1.000

0	2	0	1	1	2
0	0	1	1	2	0
3	1	0	1	6	1
5	3	5	2	1	1
0	1	0	0	1	2
2	1	0	0	0	0

888 $17^h\,00^m$
S b 0.879

0	0	0	1	2	0
1	1	3	6	3	1
0	1	3	3	0	0
1	1	5	2	3	7
0	0	0	2	2	0
0	0	0	1	2	0

529 $17^h\,20^m$
S a 0.914

0	0	0	0	0	0
1	0	0	1	2	1
0	0	0	0	5	1
0	0	0	0	1	0
0	0	0	0	0	0
0	0	0	1	0	0

526 $17^h\,40^m$
S a 0.914

0	0	0	0	0	0
0	1	0	0	2	0
0	1	0	0	0	0
0	0	1	0	0	0
0	0	0	1	1	0
0	0	0	0	1	0

487 $18^h\,00^m$
S a 0.914

0	0	0	0	0	0
0	0	0	1	0	0
0	0	0	0	0	0
0	0	0	0	2	0
0	0	0	0	0	0
0	1	0	0	0	0

δ = -15°

1532 $12^h\,00^m$
S h 0.975

45	39	49	42	54	52
63	66	54	44	45	39
49	45	41	37	77	57
49	39	29	23	49	76
51	52	29	38	48	65
47	36	50	39	28	32

1568** $12^h\,20^m$
S h 1.695

21	24	29	57	27	19
32	44	39	79	44	30
35	26	40	35	27	28
35	24	46	26	23	17
25	30	31	19	14	15
24	37	30	16	15	6

812 $12^h\,40^m$
W b 1.155

72	44	35	37	15	22
41	32	24	27	15	45
139	80	34	27	54	34
165	50	42	49	22	31
48	40	36	45	19	17
47	34	51	46	27	43

774 $13^h\,00^m$
S b 0.844

68	34	51	78	119	76
58	55	91	111	152	58
56	82	66	92	111	169
72	82	85	128	121	193
67	86	143	115	134	51
63	54	64	102	154	33

814 $13^h\,20^m$
S b 0.977

73	66	82	68	56	68
87	62	46	43	55	55
90	40	41	59	54	45
50	53	37	56	63	40
29	47	55	113	48	31
26	29	32	57	55	28

482 $13^h\,40^m$
S a 1.077

56	37	46	59	52	50
52	66	56	42	48	71
63	49	41	47	36	59
49	34	46	34	38	23
25	26	34	37	33	19
27	27	34	23	22	24

1223 $14^h\,00^m$
W f 0.716

49	57	33	54	97	89
53	49	52	29	53	62
38	32	39	36	48	63
35	50	31	25	77	41
28	37	25	32	28	34
26	39	17	31	30	27

1587 $14^h\,20^m$
S h 1.329

28	9	13	13	12	18
14	18	14	13	23	25
17	21	36	20	14	19
14	16	31	30	24	20
17	20	50	44	13	8
6	13	27	13	12	9

1601 $14^h\,40^m$
S h 1.202

14	16	21	23	12	18
18	32	25	18	22	12
31	17	19	17	13	16
30	22	16	19	18	10
16	16	24	37	16	15
13	21	21	18	4	2

475 $15^h\,00^m$
S a 0.788

19	12	22	28	18	22
48	31	31	36	23	51
26	21	22	18	33	27
17	14	9	18	25	39
10	12	7	27	32	8
17	7	12	16	15	15

841 $15^h\,20^m$
S b 1.238

16	20	14	16	11	8
12	18	19	19	12	18
26	18	12	11	21	14
14	11	16	8	11	9
12	14	9	7	15	7
20	12	17	17	12	10

504 $15^h\,40^m$
M a 1.029

9	13	32	18	6	14
13	19	29	21	9	15
18	25	19	32	27	21
45	36	45	25	22	11
26	24	48	49	64	11
13	25	46	26	17	7

483 $16^h\,00^m$
S a 1.401

7	15	13	12	21	12
13	12	18	17	16	10
13	14	19	16	14	17
15	5	9	15	26	19
14	5	10	9	11	10
11	3	10	7	12	18

871 $16^h\,20^m$
S b 1.000

5	3	3	6	4	5
7	5	4	5	1	7
4	1	0	0	3	4
8	4	3	5	7	3
4	3	1	6	6	5
5	5	5	3	3	2

850 $16^h\,40^m$
S b 1.000

9	3	11	8	9	8
7	4	6	9	6	5
3	5	4	4	2	4
4	3	1	7	2	4
8	13	3	5	7	6
5	13	5	6	3	3

891 $17^h\,00^m$
S b 1.000

3	2	1	8	3	9
6	5	2	5	3	1
2	5	1	2	2	4
5	3	0	4	1	0
1	1	1	2	5	4
1	2	1	1	3	1

1615 $17^h\,20^m$
S h 1.047

1	1	1	1	0	0
0	1	0	1	0	1
0	0	0	1	1	0
0	1	0	0	2	1
0	0	1	0	3	1
3	2	0	1	1	1

534 $17^h\,40^m$
S a 0.914

0	0	0	1	0	0
0	0	0	0	2	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	3	0	0	0
0	0	0	0	0	0

505 $18^h\,00^m$
S a 0.914

0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	1	0	0	0
0	0	0	0	0	0

δ = -10°

1529 $12^{h}\,00^{m}$
Sh 0.740

63	89	79	44	60	47
63	59	34	41	49	44
31	32	36	52	58	35
44	37	22	35	41	52
53	37	29	34	51	40
44	40	52	51	57	39

827 $12^{h}\,20^{m}$
Sb 1.144

59	48	57	54	65	33
59	76	56	30	29	43
31	51	37	38	36	24
62	52	58	47	31	34
46	52	34	48	50	30
26	32	41	54	33	18

1145 $12^{h}\,40^{m}$
Se 0.781

42	79	69	84	84	60
85	98	61	93	61	64
125	70	68	52	82	37
81	49	49	126	96	58
88	75	104	72	46	54
109	60	71	71	39	44

453 $13^{h}\,00^{m}$
Wa 0.924

33	55	47	68	51	33
53	45	56	48	49	75
62	36	39	64	69	88
62	42	34	54	52	63
43	40	54	48	60	93
66	31	47	69	108	85

1231 $13^{h}\,20^{m}$
Sf 1.090

38	39	33	30	27	33
70	37	29	44	39	42
56	41	28	32	31	47
60	46	25	26	32	39
67	54	55	34	32	25
53	48	66	55	39	35

463 $13^{h}\,40^{m}$
Sa 0.973

55	57	47	37	31	29
39	44	34	42	55	52
14	42	39	22	37	45
65	64	89	57	65	50
84	67	40	64	58	78
61	32	45	39	45	41

1207 $14^{h}\,00^{m}$
We 0.937

82	84	45	51	53	46
37	89	62	43	29	27
49	71	74	38	31	28
58	40	98	73	44	52
50	70	62	127	85	66
43	45	24	38	81	81

1584 $14^{h}\,20^{m}$
Sh 1.037

22	26	35	14	31	57
40	36	18	43	19	22
31	37	56	65	26	21
21	10	32	28	21	36
19	12	19	16	25	28
36	13	23	21	13	16

828 $14^{h}\,40^{m}$
Sb 1.022

21	37	29	32	27	24
46	49	59	42	56	41
35	32	21	34	30	39
25	20	16	24	18	20
42	26	33	35	22	17
17	24	18	18	7	22

832 $15^{h}\,00^{m}$
Sb 1.273

33	24	12	24	12	16
24	22	18	43	25	36
34	21	28	13	25	26
26	29	22	22	16	21
33	26	29	16	24	27
9	11	17	21	17	13

454 $15^{h}\,20^{m}$
Sa 0.912

12	22	31	49	29	38
32	16	30	65	30	41
22	23	35	46	35	40
28	30	30	55	34	39
18	36	20	30	31	39
20	24	20	21	18	6

498 $15^{h}\,40^{m}$
Ma 1.163

39	41	24	8	8	10
8	42	35	20	26	29
32	34	30	26	40	18
19	18	13	18	25	14
12	14	35	31	25	9
9	19	33	17	14	17

457* $16^{h}\,00^{m}$
Sa 0.652

12	26	22	23	17	34
22	28	41	25	38	23
19	25	14	23	33	30
17	12	11	26	17	26
27	26	16	25	29	19
26	21	27	28	33	22

869 $16^{h}\,20^{m}$
Sb 1.017

14	14	18	29	15	10
23	23	20	26	17	11
25	25	18	15	13	14
23	12	12	16	16	10
24	16	16	11	14	17
16	14	11	11	11	9

878 $16^{h}\,40^{m}$
Sb 1.000

5	13	16	7	4	5
15	9	11	5	12	8
6	6	1	3	4	1
4	2	0	1	7	7
4	1	6	4	4	2
2	7	10	4	2	1

829 $17^{h}\,00^{m}$
Sb 1.000

0	1	1	0	4	5
3	3	11	4	7	6
13	8	2	6	3	2
5	9	5	3	5	0
8	6	3	13	8	0
2	4	1	7	1	4

1623 $17^{h}\,20^{m}$
Wh 1.031

0	2	1	0	0	3
2	1	0	0	0	1
2	0	0	1	0	2
1	0	0	1	0	1
0	0	0	0	0	0
0	1	0	1	0	1

1246 $17^{h}\,40^{m}$
Sf 1.084

1	0	0	0	0	0
0	0	0	1	0	0
0	0	0	0	1	0
0	0	0	0	0	0
0	0	0	0	1	0
1	0	0	0	0	0

499 $18^{h}\,00^{m}$
Sa 0.914

1	1	1	0	0	0
0	1	0	0	0	0
0	0	0	0	0	1
0	0	0	0	0	0
0	1	0	0	0	0
0	0	0	0	0	0

δ = -5°

451* $12^{h}\,00^{m}$
Wa 1.581

32	23	35	27	30	55
33	29	28	32	26	40
31	49	46	26	19	50
94	39	39	27	41	53
55	34	55	48	32	36
25	34	34	14	20	25

834 $12^{h}\,20^{m}$
Sb 1.012

35	46	39	38	45	28
55	41	44	33	65	42
62	43	38	80	77	50
57	50	48	52	55	100
55	42	54	60	119	79
73	52	59	49	63	41

439 $12^{h}\,40^{m}$
Sa 0.848

54	83	65	83	44	39
67	93	58	77	76	71
89	117	96	144	104	68
62	109	106	106	59	69
81	86	92	75	59	48
47	71	71	75	75	50

447 $13^{h}\,00^{m}$
Sa 0.924

53	61	118	69	55	46
65	60	76	119	47	51
61	68	48	97	62	63
35	68	58	62	42	48
45	62	50	58	44	68
33	56	39	68	54	31

1211 $13^{h}\,20^{m}$
We 0.977

49	49	51	41	33	45
43	67	85	56	47	50
43	47	41	50	50	45
35	39	58	37	51	32
39	34	34	39	27	32
32	42	48	29	40	38

1181 $13^{h}\,40^{m}$
We 0.796

56	34	35	44	35	58
37	27	24	22	61	46
34	39	40	53	39	39
56	71	54	58	55	31
43	91	47	46	36	32
49	63	53	47	40	38

1203 $14^{h}\,00^{m}$
We 0.732

53	48	21	63	43	49
61	63	51	52	40	43
66	63	58	51	43	37
77	51	52	44	31	37
72	69	53	62	38	50
111	110	76	82	65	62

849 $14^{h}\,20^{m}$
Sb 1.322

29	38	30	27	36	34
14	43	15	26	20	33
22	13	17	32	21	30
36	26	9	39	24	35
29	31	14	28	16	37
25	23	18	14	33	38

822 $14^{h}\,40^{m}$
Sb 0.804

45	50	59	30	33	31
76	106	55	47	35	36
46	51	25	28	54	19
48	48	46	32	34	24
40	38	56	52	21	29
29	46	40	48	36	30

442 $15^{h}\,00^{m}$
Sa 0.979

23	32	36	24	24	23
33	28	18	40	49	53
38	40	41	34	30	37
41	65	43	32	32	54
38	43	33	39	51	28
36	50	41	52	26	13

474 $15^{h}\,20^{m}$
Sa 0.685

21	28	19	36	30	30
38	34	34	25	28	57
34	30	43	32	30	78
47	43	29	47	30	70
33	38	42	45	50	62
38	39	59	54	52	57

508 $15^{h}\,40^{m}$
Ma 0.846

16	28	42	32	40	30
2	11	17	33	57	24
3	20	42	57	24	19
45	37	30	27	40	28
35	34	37	37	22	23
25	43	31	16	18	13

464 $16^{h}\,00^{m}$
Ma 1.390

12	32	31	15	3	3
16	25	16	7	4	1
12	39	8	15	4	7
18	32	10	9	14	19
15	12	26	14	20	15
0	21	13	18	7	11

872 $16^{h}\,20^{m}$
Sb 1.056

20	18	11	17	15	17
11	15	9	23	7	14
15	14	4	19	11	7
11	4	7	9	5	9
7	10	10	7	7	7
13	15	12	9	9	2

820 $16^{h}\,40^{m}$
Sb 1.583

17	15	10	6	4	11
7	9	7	7	4	8
10	12	8	1	6	10
8	8	3	5	10	3
4	9	1	11	7	4
9	15	5	13	6	5

823 $17^{h}\,00^{m}$
Sb 1.233

3	6	4	12	3	12
3	4	3	5	6	9
2	4	6	5	3	10
6	7	4	6	6	5
4	3	5	4	11	0
2	6	5	4	5	3

839 $17^{h}\,20^{m}$
Sb 1.000

3	3	1	0	1	0
1	2	1	2	0	0
4	0	0	1	1	0
0	1	1	0	1	5
4	0	2	2	2	3
1	1	0	4	4	1

1274 $17^{h}\,40^{m}$
Sf 1.084

1	2	1	4	0	0
0	1	1	1	0	1
0	2	0	0	0	0
0	1	1	0	0	0
0	0	1	0	0	0
0	0	0	0	0	0

509 $18^{h}\,00^{m}$
Sa 0.914

0	0	0	0	0	1
0	0	0	0	0	0
1	0	0	0	0	0
1	0	0	1	0	1
0	1	0	0	0	1
0	0	0	0	0	0

δ = 0°

792 $12^h 00^m$
Sb 0.769

71	82	137	113	84	55
61	72	101	59	78	52
71	84	89	102	85	74
99	78	73	119	120	76
54	66	77	81	88	90
56	49	66	58	59	55

821 $12^h 20^m$
Wb 0.793

74	68	81	50	55	62
55	45	49	67	47	50
88	50	30	49	53	64
42	73	27	56	81	53
96	69	38	61	65	66
63	68	65	64	45	58

441 $12^h 40^m$
Sa 1.053

29	47	71	63	62	49
52	53	125	91	54	53
62	102	121	73	41	73
67	93	92	48	68	39
103	150	100	75	43	44
64	66	51	61	33	26

444 $13^h 00^m$
Sa 1.003

45	52	43	47	58	26
80	53	47	57	44	41
62	47	50	48	40	55
96	70	67	41	47	44
42	70	60	97	79	61
45	66	124	94	48	37

480 $13^h 20^m$
Sa 0.714

84	62	59	47	53	57
108	110	117	74	76	74
80	107	131	82	80	74
91	72	99	172	126	108
121	98	76	87	66	51
59	61	62	57	57	35

1234 $13^h 40^m$
Wf 1.534

60	25	48	59	31	28
32	38	24	24	32	39
30	26	39	28	45	26
21	22	29	41	33	20
27	37	22	36	32	72
35	23	19	21	16	32

1247 $14^h 00^m$
Sf 0.990

43	26	29	28	18	59
74	36	36	43	26	35
69	48	34	28	27	41
82	82	67	23	43	29
41	59	37	41	30	37
29	41	28	55	27	38

793 $14^h 20^m$
Sb 0.820

92	50	64	62	109	56
88	79	74	74	100	80
91	91	61	48	79	68
65	73	75	74	101	97
87	110	63	46	59	36
44	51	45	52	47	25

825 $14^h 40^m$
Sb 1.331

24	27	27	33	36	44
25	22	39	27	37	49
38	38	27	35	38	52
36	42	25	35	55	35
44	40	32	41	61	43
19	30	42	21	23	24

492 $15^h 00^m$
Sa 0.875

63	47	43	59	40	30
97	83	58	55	52	47
74	65	40	49	35	46
46	60	37	30	54	51
40	71	46	44	52	55
20	25	37	27	17	20

445 $15^h 20^m$
Sa 0.956

30	62	55	82	68	46
60	75	62	66	67	67
87	61	34	34	51	48
32	42	26	37	51	31
31	30	21	22	30	18
20	16	14	26	38	26

481 $15^h 40^m$
Ma 1.500

16	20	25	33	40	27
7	12	12	26	14	28
14	38	24	23	7	48
18	39	33	30	29	41
10	7	9	22	15	23
5	20	17	16	24	16

491 $16^h 00^m$
Sa 0.676

36	60	49	60	41	20
51	67	21	24	22	20
71	66	46	47	33	50
44	55	62	52	40	25
57	37	36	30	49	16
31	50	28	15	11	4

1248 $16^h 20^m$
Sf 1.169

16	24	24	17	19	22
15	8	16	24	25	16
27	19	15	32	22	38
27	19	24	12	11	20
27	12	16	21	17	28
19	10	13	20	15	16

876 $16^h 40^m$
Sb 0.733

21	14	12	12	9	15
20	15	6	24	13	11
24	16	10	17	21	19
30	27	33	16	22	27
33	30	40	20	32	34
30	25	23	16	22	29

836 $17^h 00^m$
Sb 0.891

22	26	34	31	23	26
25	20	18	35	36	18
16	9	13	13	14	13
11	6	2	7	6	13
5	8	7	19	41	8
4	8	12	8	5	16

521 $17^h 20^m$
Sa 0.914

2	1	5	6	6	3
2	2	5	0	4	6
0	3	8	7	2	6
2	3	7	14	6	9
3	6	7	18	7	2
2	4	0	2	1	2

1275 $17^h 40^m$
Sf 1.084

2	0	1	2	6	3
3	2	0	1	3	0
1	0	0	6	0	0
0	0	0	0	2	1
2	3	4	1	2	0
1	3	1	0	1	0

514 $18^h 00^m$
Sa 0.914

0	0	3	1	3	0
1	1	1	1	2	1
0	0	0	0	2	2
1	0	1	2	2	1
0	0	1	0	1	1
0	0	0	0	1	0

δ = +5°

758 $12^h 00^m$
Wb 1.066

58	37	42	40	42	76
89	67	43	54	56	74
80	62	44	56	89	100
49	40	94	39	73	85
46	36	40	61	47	60
45	51	94	73	52	36

824* $12^h 20^m$
Sb 1.217

41	63	70	54	50	39
95	84	65	91	63	64
90	66	76	127	121	65
60	41	105	68	93	47
87	72	78	69	93	53
43	48	59	36	38	41

816 $12^h 40^m$
Wb 0.792

63	81	48	45	54	72
83	53	49	118	94	98
88	97	53	62	71	119
106	75	69	93	101	98
72	49	90	104	63	105
53	55	98	83	83	76

467 $13^h 00^m$
Sa 0.814

87	79	101	82	58	51
93	69	97	64	62	64
136	64	75	89	78	84
101	71	103	66	66	105
82	83	96	61	94	53
52	61	51	39	61	27

1232 $13^h 20^m$
Wf 1.229

39	33	25	37	89	27
34	25	47	40	41	55
50	28	35	50	55	76
29	22	24	35	44	52
31	26	34	43	34	41
71	46	37	41	37	39

1236 $13^h 40^m$
Sf 0.911

65	58	65	50	34	53
50	53	47	54	56	28
112	64	40	54	29	40
50	63	84	86	48	36
43	69	80	71	64	40
79	39	65	106	65	49

1216 $14^h 00^m$
Se 1.112

40	55	61	41	56	46
61	88	89	54	68	38
101	76	48	58	68	95
24	34	39	36	54	30
52	39	46	47	48	27
42	18	31	25	18	55

819 $14^h 20^m$
Sb 1.106

45	55	38	41	51	41
48	66	93	75	57	59
96	58	76	73	115	78
85	74	71	57	74	38
79	99	55	37	60	67
58	47	54	63	90	45

835 $14^h 40^m$
Sb 1.021

41	50	48	41	42	54
46	42	35	52	65	54
82	41	28	52	55	60
48	46	69	52	56	61
89	55	77	122	84	87
33	31	36	35	38	48

817 $15^h 00^m$
Sb 0.811

165	126	90	43	27	33
198	115	63	44	67	64
243	108	119	81	95	104
256	96	59	52	47	52
148	123	63	61	70	93
94	59	55	49	54	24

448 $15^h 20^m$
Sa 1.151

48	66	96	90	113	83
47	63	69	85	82	112
63	85	91	114	124	161
78	118	123	213	199	177
55	96	56	111	87	75
31	51	55	68	51	44

815* $15^h 40^m$
Sb 0.734

32	41	75	92	63	77
62	66	50	85	54	72
45	39	68	59	55	91
53	45	69	55	62	86
24	38	48	95	44	61
23	25	41	48	53	34

1182 $16^h 00^m$
Se 0.884

11	19	14	19	18	13
29	41	20	48	65	47
33	35	50	42	26	33
48	33	30	27	33	41
31	55	31	28	26	17
25	40	33	57	29	17

1217 $16^h 20^m$
Se 0.966

25	39	29	19	15	14
24	36	40	27	26	17
27	32	32	27	33	29
25	17	36	16	16	31
23	37	38	24	14	15
19	25	36	19	21	16

1585 $16^h 40^m$
Sh 1.146

12	13	11	23	27	20
10	28	18	18	33	15
12	11	11	19	18	16
28	15	16	17	11	13
20	18	13	16	6	14
12	13	7	9	12	10

1229 $17^h 00^m$
Sf 1.050

7	8	8	12	7	16
12	8	9	11	12	13
15	6	13	7	14	10
11	17	15	7	12	26
14	13	14	16	11	16
11	9	14	13	17	11

1227 $17^h 20^m$
Sf 1.099

8	9	6	7	15	4
15	15	13	12	21	20
10	6	11	7	5	11
3	3	5	7	6	10
5	10	3	3	0	3
4	4	2	6	5	4

842 $17^h 40^m$
Sb 1.060

4	10	9	9	6	10
10	7	5	7	15	18
7	5	10	5	14	6
4	4	8	10	5	2
3	4	3	5	1	2
0	1	4	2	6	5

913 $18^h 00^m$
Sb 1.000

4	2	3	2	2	1
2	6	1	3	1	6
2	2	2	2	2	3
3	4	4	1	0	2
2	0	1	3	4	0
5	1	4	4	3	3

δ = +10°

1149 $12^{h}\,00^{m}$
Se 1.016

60	69	47	42	41	79
65	110	66	51	123	73
71	98	99	93	85	51
75	46	49	48	61	65
51	46	37	37	29	58
68	47	50	39	42	49

1140 $12^{h}\,20^{m}$
Se 0.814

115	130	111	125	89	69
108	129	64	68	63	71
122	108	103	75	78	70
104	153	113	82	71	92
75	136	99	136	102	69
55	73	96	65	62	58

831 $12^{h}\,40^{m}$
Sb 1.118

33	31	80	64	55	57
27	53	61	61	65	72
52	45	69	70	81	80
67	43	70	73	71	89
64	61	79	51	62	44
47	71	51	46	57	35

471 $13^{h}\,00^{m}$
Wa 0.742

92	78	78	69	37	47
114	83	115	59	59	55
63	104	70	56	68	92
101	176	128	101	74	86
106	118	122	89	105	113
63	58	77	69	39	44

1508 $13^{h}\,20^{m}$
Sh 1.092

47	103	48	52	52	43
95	132	92	122	61	59
104	70	52	62	53	50
69	64	39	49	79	54
48	66	76	62	73	45
55	40	30	40	77	38

1238 $13^{h}\,40^{m}$
Wf 1.083

59	59	47	46	32	50
57	51	51	58	57	78
48	34	37	59	64	78
83	63	40	58	45	54
61	59	40	31	53	36
79	70	75	57	40	55

1249 $14^{h}\,00^{m}$
Sf 0.954

97	93	88	69	68	65
85	92	68	47	68	60
49	100	84	75	53	47
60	66	117	71	42	78
76	81	37	60	48	37
54	71	52	34	60	34

1597 $14^{h}\,20^{m}$
Sh 0.882

70	69	42	32	46	50
73	106	61	40	62	86
86	54	31	31	43	29
98	39	59	72	75	52
67	62	39	52	157	91
87	113	56	67	68	67

1592 $14^{h}\,40^{m}$
Sh 1.078

44	55	43	78	52	41
67	154	72	51	31	47
86	94	65	77	74	84
90	95	86	84	89	73
66	52	78	66	63	59
49	45	56	39	34	53

838 $15^{h}\,00^{m}$
Sb 0.912

47	56	48	69	66	51
62	58	72	72	61	64
47	83	82	58	41	75
59	86	93	66	127	59
80	155	130	55	48	47
153	137	71	32	22	31

472 $15^{h}\,20^{m}$
Sa 1.069

27	26	28	34	35	24
31	42	51	34	40	60
57	52	63	43	56	36
46	41	63	42	33	46
51	77	133	120	73	48
53	74	87	95	112	86

1255 $15^{h}\,40^{m}$
Sf 1.069

44	46	16	35	49	25
25	40	48	28	31	27
47	45	41	36	47	46
65	65	50	19	40	27
65	72	91	60	50	40
17	24	43	58	31	47

1235 $16^{h}\,00^{m}$
Sf 1.448

22	33	33	23	34	31
25	27	23	19	42	22
21	17	12	33	16	39
18	16	18	21	27	36
15	30	29	19	12	17
8	10	9	10	8	6

1224 $16^{h}\,20^{m}$
Sf 0.916

36	27	17	29	45	23
46	61	37	47	35	37
38	39	36	56	34	24
31	37	76	47	28	21
38	102	51	26	25	31
24	48	32	26	16	11

1270 $16^{h}\,40^{m}$
Sf 1.024

20	20	19	23	20	23
24	24	38	53	25	30
18	22	17	18	21	14
10	18	26	30	19	19
11	21	21	16	18	23
15	9	12	17	26	13

881 $17^{h}\,00^{m}$
Sb 1.469

8	4	8	9	9	7
2	11	10	9	13	9
6	9	13	11	8	12
8	18	15	10	6	4
6	2	7	8	7	4
4	7	8	7	5	6

524 $17^{h}\,20^{m}$
Sa 1.112

9	6	10	4	6	4
4	15	4	8	4	4
4	9	4	14	12	6
12	6	4	14	14	13
8	14	19	29	20	6
6	8	8	9	17	4

1621 $17^{h}\,40^{m}$
Sh 1.060

4	6	7	6	11	5
6	7	8	9	10	1
6	4	8	8	9	5
4	6	10	17	5	4
1	2	9	6	7	5
7	6	13	10	6	6

915 $18^{h}\,00^{m}$
Sb 1.168

7	6	6	5	10	5
6	6	13	3	6	2
5	7	11	15	2	3
2	12	5	2	2	1
1	5	3	1	5	1
2	0	2	2	5	0

δ = +15°

1132 $12^{h}\,00^{m}$
Se 0.752

73	59	65	56	55	55
79	63	54	61	60	58
120	113	63	85	70	101
157	81	75	56	44	63
150	116	86	96	111	125
77	94	60	55	81	81

1136 $12^{h}\,20^{m}$
Se 0.831

64	75	89	67	56	43
116	68	86	72	78	89
62	57	54	54	62	101
49	46	53	71	98	101
65	75	91	114	101	120
107	205	135	125	92	74

449 $12^{h}\,40^{m}$
Sa 1.106

37	53	47	68	66	40
30	38	56	86	128	58
29	51	33	52	76	39
45	35	41	77	67	49
39	68	50	73	57	52
33	26	64	49	44	54

473 $13^{h}\,00^{m}$
Wa 0.890

67	52	54	43	38	44
63	75	38	50	32	39
85	62	56	55	29	36
101	113	59	36	48	73
78	98	53	53	57	55
53	44	59	50	30	25

1515 $13^{h}\,20^{m}$
Sh 1.012

36	68	62	60	53	46
57	77	46	75	44	58
33	38	53	68	51	45
84	73	120	70	70	57
94	83	111	56	55	57
46	91	46	65	54	43

1240 $13^{h}\,40^{m}$
Wf 1.148

47	56	55	52	42	25
63	56	51	44	43	37
82	46	47	62	43	22
117	61	64	62	53	70
74	50	53	32	47	85
65	66	54	55	50	59

1251 $14^{h}\,00^{m}$
Wf 1.243

29	50	45	44	42	60
52	57	101	63	67	46
52	91	95	98	62	76
60	70	73	61	90	90
43	64	56	65	62	82
52	65	72	41	56	55

847** $14^{h}\,20^{m}$
Sb 1.917

56	78	89	52	40	26
39	96	65	25	28	40
39	60	38	29	30	24
53	47	32	29	28	26
35	46	29	28	28	12
28	23	13	12	14	14

1555 $14^{h}\,40^{m}$
Sh 0.972

126	88	46	87	89	49
136	82	87	60	107	39
72	88	80	99	88	66
59	95	78	107	80	59
62	95	114	108	43	52
60	78	58	84	55	37

496 $15^{h}\,00^{m}$
Sa 0.951

85	68	66	51	64	127
87	85	77	88	89	136
79	50	52	50	43	66
53	62	47	51	38	74
52	53	47	53	42	46
23	42	37	61	67	33

477 $15^{h}\,20^{m}$
Sa 0.815

27	36	28	21	58	71
24	45	46	28	70	67
50	52	46	55	86	73
33	45	35	55	56	48
57	40	53	56	39	51
36	39	39	55	51	29

1617 $15^{h}\,40^{m}$
Sh 1.126

20	34	66	37	22	18
33	42	34	49	32	19
21	34	48	27	23	23
25	37	37	33	32	25
46	25	37	48	28	24
41	40	25	35	43	22

1237 $16^{h}\,00^{m}$
Sf 1.078

53	63	175	53	41	25
30	64	238	105	55	25
50	87	149	97	33	16
64	68	94	42	20	16
29	51	44	30	28	30
32	41	53	40	31	42

1250 $16^{h}\,20^{m}$
Sf 1.004

32	44	47	43	19	42
30	41	35	55	46	36
23	63	46	51	59	44
45	88	98	67	48	63
86	73	66	52	49	37
42	37	31	30	49	34

873** $16^{h}\,40^{m}$
Sb 2.839

12	5	6	3	13	3
8	13	19	7	7	11
4	8	8	18	2	12
12	4	29	9	6	11
11	9	12	21	18	25
15	6	14	9	11	13

856 $17^{h}\,00^{m}$
Wb 0.790

18	9	9	18	22	23
18	19	21	17	20	26
15	14	22	29	15	15
9	24	23	17	17	24
25	28	35	26	25	29
12	14	15	17	11	16

497 $17^{h}\,20^{m}$
Sa 0.808

23	13	18	12	10	16
27	20	21	17	13	19
23	20	14	9	10	14
14	22	28	9	7	7
9	16	18	17	11	12
10	14	16	11	9	10

1273 $17^{h}\,40^{m}$
Sf 1.231

13	23	25	31	15	12
15	18	31	18	10	11
9	24	21	16	15	11
24	23	17	13	27	10
6	14	12	7	16	7
5	11	9	3	7	6

1280 $18^{h}\,00^{m}$
Sf 0.914

2	9	6	9	6	15
6	18	5	4	9	25
8	7	11	9	11	17
13	7	8	14	13	27
15	4	10	13	17	10
6	9	8	9	14	3

						751	$12^h 00^m$					757*	$12^h 20^m$					837	$12^h 40^m$					840	$13^h 00^m$				
						S b	1.182					S b	1.113					Wb	1.017					S b	0.927				
						67	70	97	72	76	77	33	44	55	75	97	46	32	32	33	26	33	30	55	45	35	29	37	31
						66	48	85	98	89	119	53	29	67	55	67	49	25	28	40	42	36	42	61	65	33	37	19	19
δ = +20°						63	42	142	76	36	106	57	42	76	61	63	53	42	43	32	22	44	51	65	70	65	41	51	39
						74	51	59	45	50	50	48	52	43	77	84	53	83	58	35	66	32	48	86	85	116	103	89	52
						55	49	50	54	55	47	39	62	59	34	67	53	67	44	38	127	39	45	71	83	109	87	69	63
						48	42	43	39	41	39	39	59	61	52	51	40	36	40	54	76	63	57	50	47	43	36	38	43
1524	$13^h 20^m$					1566	$13^h 40^m$					1577	$14^h 00^m$					1253*	$14^h 20^m$					1591	$14^h 40^m$				
S h	1.179					S h	0.906					S h	0.964					W f	1.390					S h	0.916				
37	58	69	74	51	52	78	51	51	44	48	28	54	51	42	66	95	62	40	24	35	27	21	27	119	110	118	97	82	63
31	43	61	68	51	46	82	51	48	63	41	24	75	55	54	58	92	53	32	41	36	43	30	44	107	95	54	86	67	66
35	39	36	47	56	33	74	39	66	51	42	43	90	52	41	83	91	54	46	51	47	25	41	56	82	97	91	78	64	76
50	55	52	35	33	66	93	87	68	42	37	39	95	103	57	58	91	75	53	47	51	33	52	79	73	75	107	87	76	77
59	50	56	41	42	44	78	155	135	116	63	70	86	70	54	57	72	70	57	44	35	89	60	63	134	99	56	68	95	52
31	53	57	48	31	34	80	97	96	66	59	38	44	63	76	69	57	60	78	86	103	59	46	39	118	93	42	78	85	57
1571	$15^h 00^m$					1560	$15^h 20^m$					506	$15^h 40^m$					1239	$16^h 00^m$					1262	$16^h 20^m$				
S h	1.200					S h	1.037					S a	0.869					S f	1.075					Wf	0.989				
36	53	39	50	70	61	37	38	31	52	42	32	51	38	53	83	76	62	39	37	39	46	25	37	40	30	39	42	23	52
38	58	86	85	64	60	51	48	55	58	29	31	67	53	42	114	74	59	45	35	47	52	41	56	80	54	50	53	44	54
58	89	80	50	63	48	30	32	72	58	56	55	74	56	40	39	42	23	36	30	71	70	66	64	71	61	60	50	46	42
75	69	41	80	73	55	31	41	70	58	65	75	91	111	38	61	44	49	29	47	64	71	60	53	52	44	41	48	76	38
109	46	36	41	103	90	44	56	40	35	69	96	86	82	52	65	39	38	49	76	151	119	91	38	41	31	38	59	41	42
66	53	39	37	34	80	32	39	32	21	47	67	34	39	60	50	22	19	70	114	192	78	45	30	18	31	39	37	28	55
848	$16^h 40^m$					519	$17^h 00^m$					833	$17^h 20^m$					1272**	$17^h 40^m$					507	$18^h 00^m$				
Wb	1.008					S a	0.865					S b	1.179					S f	2.310					S a	0.940				
41	21	25	30	34	34	36	33	32	36	33	22	19	21	23	18	13	21	9	9	5	8	6	9	9	18	9	10	11	4
27	19	27	15	27	48	10	40	41	19	25	38	15	16	20	23	25	21	7	4	3	7	7	5	35	18	22	10	16	11
32	33	27	27	21	36	24	32	19	30	22	30	31	24	22	19	28	19	8	6	7	6	6	6	7	11	26	14	12	14
35	17	25	33	26	38	30	32	23	22	33	15	18	37	32	21	18	11	7	4	9	8	7	9	3	5	13	14	17	7
39	26	28	22	29	38	20	36	35	30	41	7	34	19	15	21	20	10	10	6	7	9	5	5	16	3	6	10	33	14
44	33	28	10	27	20	17	10	11	16	24	29	19	18	14	10	7	13	10	17	7	11	11	2	8	9	9	8	4	15

west-east direction. The only exception to this procedure was that Mayall counted the strips alternately from west to east and from east to west. There are 1296 separate counts recorded for each plate. The 36 counts in each square degree are combined to give the tabular values.

It is of the greatest importance to maintain a uniform standard for the identification of nebulae. This requirement is particularly difficult since by far the most numerous nebulae lie near the limit of detection. It would be possible to stop the counts somewhat above the limiting magnitude, but this procedure would necessitate estimating whether each nebula fell above or below the standard brightness. Due to the great variety of nebular forms, sizes and surface brightness, this process would be very uncertain. It was accordingly decided to count every nebula that could be identified as such with reasonable probability. It is obvious that the limiting magnitude will not be the same for all nebular types. A fairly bright but small elliptical nebula may fail to be distinguished from a star. On the other hand a large nebula of extremely low surface brightness may escape detection though its total apparent magnitude is well above the normal limit. Thus for certain types of nebulae the limit is no doubt fainter than 18.4 mag. while for others it is brighter than this value. The value 18.4 mag. is an average limit derived from comparing our counts with those of Hubble, and it refers to the scale of magnitudes that he used.

On some plates the number of defects resembling nebulae introduces an exasperating element of uncertainty. Little can be done to avoid errors in identification beyond relying on judgment and experience. To duplicate the plates and the counts would extend the program beyond practical limits.

IV. CORRECTIONS TO THE COUNTS

In order to reduce the data to a reasonably homogeneous system, it is necessary to apply several corrections.

Off-axis correction. Due to vignetting and to some inferiority of the images at considerable distances from the optical axis there is a decrease in the number of nebulae counted with increasing distance from the center of the plate. To correct for this effect, the numbers of nebulae in each of the thirty-six square degrees were added for all the plates in Area III. The counts were again summed for all square degrees at the same distance from the plate center, and a smooth curve was drawn through these sums plotted against the distance. The reciprocals of these ordinates

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are proportional to the off-axis corrections. Finally, the factor of proportionality was chosen so as to make the off-axis correction factor unity at the plate center. This "stacking" process was based on a total count in Area III of 210980 nebulae.

East-west effect. For some unexplained reason fewer nebulae are counted west of a plate center than east of it. This effect was found consistently in the counts by both Shane and Wirtanen and also in Mayall's counts which were made in alternate rows east and west. A number of suggestions to explain this puzzling phenomenon have been offered. To test any one of them adequately would require so large an amount of work that it would delay unduly the main program. It was therefore thought best to postpone an investigation of this effect.

To calculate the east-west correction, the number of nebulae in the overlapping regions of all plates were compared, except in cases where less than 30 nebulae occurred in an overlap. From a study of the plates in Area III, it was found that in a field $2\frac{1}{2}°$ east of a plate center, 1.236 times as many nebulae are recorded as in the same field counted $2\frac{1}{2}°$ west of the center on the overlapping plate. There is no corresponding north-south effect. This result has been checked in Area V from $\alpha = 0^h$ to $\alpha = 6^h$ and from $\delta = +20°$ to $\delta = +60°$. Here the east-west factor is 1.231, and again there is no certain evidence of a north-south effect.

In correcting for the east-west effect, the assumption is made that the logarithm of the correction factor varies linearly across the plate with a value of zero at the center. The factors thus derived were combined with the off-axis corrections to form a table of "field corrections." The nebular count in each square degree was accordingly multiplied by the appropriate tabular number.

TABLE II. FIELD CORRECTION FACTORS

North

	1.10	1.03	1.02	1.06	1.17	1.36
	0.99	0.95	0.98	1.02	1.08	1.22
East	0.94	0.94	0.98	1.02	1.07	1.16
	0.94	0.94	0.98	1.02	1.07	1.16
	0.99	0.95	0.98	1.02	1.08	1.22
	1.10	1.03	1.02	1.06	1.17	1.36

Atmospheric extinction. Corrections were made for atmospheric extinction to reduce the counts to their probable zenith values. This correction is simplified by the circumstance that all exposures were centered on the meridian, and to a sufficient approximation, therefore, the extinction factor depends only on δ. A value for the photographic extinction in the zenith of 0.30 mag., supplied by Kron, was used. The logarithm of the correction factor is accordingly equal to

$$0.60 \times 0.30 (\sec z - 1),$$

where 0.60 is the logarithm of the factor by which the number of nebulae increases per unit of limiting magnitude, on the assumption of a uniform distribution in depth, and z represents the average zenith distance of the region during the exposure. The extinction factor is read from a curve as a function of δ. The factor varies from 1.00 in the zenith to 1.53 at $\delta = -22\overset{\circ}{.}5$.

Effective exposure time. Eight plates were estimated to be deficient in exposure time mostly because of haze or clouds. It was assumed that a factor of three in the exposure time corresponds to a unit change in limiting magnitude. An exposure of 100 minutes, the minimum accepted, requires that the counts be corrected by a factor of 1.26 to reduce them to the standard 120 minute exposure.

Emulsion factor. Five different emulsions were used for the plates in Area III, and as these varied slightly in sensitivity, an appropriate emulsion factor was applied in each case. The emulsion factors and the personal factors were derived together from a least-squares solution, which is discussed in detail in the next section.

Personal factor. All except five of the plates in this area were counted by the authors. Personal factors were applied to reduce Wirtanen's and Mayall's counts to the standard of the senior author. The following method was used in determining this factor and the emulsion factor.

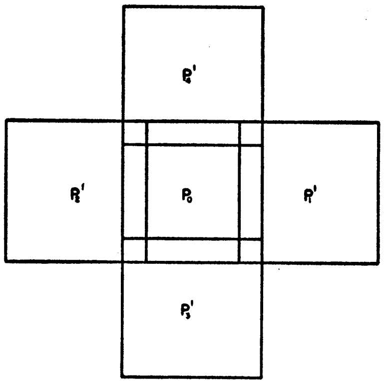

Figure 1. Plate notation.

To explain the notation reference is made to Figure 1, which represents a particular photograph with its four overlapping plates. The overlap regions are the four long rectangles including the corner squares, so that each corner is included twice.

Let

$\nu_m{}^0$ = the true number of nebulae in overlap m to the standard limiting magnitude,

$\nu_m, \nu_m{}'$ = numbers of nebulae counted in m on plates P_0 and $P_m{}'$, respectively,

$\alpha_m = \alpha_m{}'$ = average off-axis correction for region m on P_0 and $P_m{}'$, respectively,

q = east-west factor,

$\beta_m = \beta_m{}'$ = average extinction correction for region m,

$i_0, i_m{}'$ = exposure deficiency factors for P_0 and $P_m{}'$, respectively,

$\epsilon_0, \epsilon_m{}'$ = emulsion factors for P_0 and $P_m{}'$, respectively,

$p_0, p_m{}'$ = personal factors for P_0 and $P_m{}'$, respectively.

$$\rho_m = \frac{\nu_m{}'}{\nu_m}.$$

Then

$$\nu_1 = \frac{\nu_1{}^0}{\alpha_1\beta_1 i_0\epsilon_0 p_0 q},$$

$$\nu_1{}' = \frac{\nu_1{}^0 q}{\alpha_1{}'\beta_1{}' i_1{}'\epsilon_1{}' p_1{}'}.$$

Whence

$$\rho_1 = \frac{i_0\epsilon_0 p_0 q^2}{i_1{}'\epsilon_1{}' p_1{}'},$$

or

$$\log \rho_1 + \log i_1{}' - \log i_0 - \log q^2 = \log \epsilon_0 - \log \epsilon_1{}' + \log p_0 - \log p_1{}'.$$

The corresponding equation for m = 2 has the same form except that q^2 is replaced by $1/q^2$. For m = 3 and m = 4 the q^2 term does not occur. In the solution, however, only equations for m = 1 and m = 3 are used since the observational material in m = 2 and m = 4 appears in m = 1 and m = 3 when $P_2{}'$ and $P_4{}'$ are adopted as P_0. The left-hand members of the equations are known quantities. When we replace ϵ_0 and $\epsilon_m{}'$ by the emulsion factors appropriate to the particular plates, four unknown emulsion factors ϵ_a, ϵ_e, ϵ_f, and ϵ_h appear in the equations. $\epsilon_b = 1$ was adopted as standard so that $\log \epsilon_b = 0$. Similarly the personal factors p_w and p_m corresponding to Wirtanen and Mayall are unknowns, with the factor for Shane taken as standard. The plates counted by Mayall were too few to justify inclusion in the general solutions. After the other constants were determined, p_m was calculated from the 12 equations in which it appeared. In the general solution no equation was included if either ν_m or $\nu_m{}'$ was less than 30.

A least-squares solution was made from the 261 resulting equations. The constants together with their probable errors are included in Table III.

TABLE III. PLATE CONSTANTS

	log	number	
ϵ_a	−0.039 ± .009	0.914	
ϵ_b	0.000	1.000	Standard
ϵ_e	−0.056 ± .014	0.879	
ϵ_f	+0.035 ± .011	1.084	
ϵ_h	+0.020 ± .012	1.047	
p_s	0.000	1.000	Standard
p_w	−0.007 ± .008	0.984	
p_m	+0.103 ± .034	1.268	

The ratio of the extremes of the emulsion factors is 1.234. This value corresponds to the surprisingly small range in limiting magnitude of 0.15 mag. The large value of p_m probably reflects a certain degree of conservatism in Mayall's identification of objects as nebulae.

Accidental errors. The counts on each plate are subject to a further source of error that may be treated as accidental in character. It is the compounded effect of seeing, night-to-night fluctuations in atmospheric transmission, variation of plate sensitivity within a given emulsion, nonuniformity in processing the plates, and irregular changes in the personal counting factors. In addition to these sources of variation, there may be others of a more obscure nature. The best that can be done to determine the "accidental factor" is to adopt a smoothing process based on the overlaps.

Let $f_1, f_m{}'$ = the accidental factors for plates P_0 and $P_m{}'$, respectively. Then for m = 1

$$\nu_1 = \frac{\nu_1{}^0}{\alpha_1\beta_1 i_0\epsilon_0 p_0 q}\,\frac{1}{f},$$

$$\nu_1{}' = \frac{\nu_1{}^0 q}{\alpha_1{}'\beta_1{}' i_1{}'\epsilon_1{}' p_1{}'}\,\frac{1}{f_1{}'},$$

whence

$$f = f_1{}'\rho_1\left[\frac{i_1{}'\epsilon_1{}' p_1{}'}{i_0\epsilon_0 p_0}\,\frac{1}{q^2}\right].$$

Let the factor in brackets be called $g_1{}'$. Expressions for $g_2{}'$, $g_3{}'$, $g_4{}'$ are the same except that $g_2{}'$ has q^2 in the numerator instead of the denominator while in $g_3{}'$ and $g_4{}'$, q^2 is replaced by unity.

We thus have n equations for f of the form

$$f = f_m' \rho_m g_m',$$

where n is normally 4 but may be less if any of the plates P_m' are not used. These equations determine f in terms of f'. In addition we should use the equation $f = 1$ to give appropriate weight to P_0. If we multiply the $n+1$ equations together we get

$$f^{n+1} = \prod_n f_m' \rho_m g_m'.$$

The smoothing process depends on the assumption that $\prod_n f_m' = 1$. Thus

$$f = [\prod_n f_m' \rho_m g_m']^{1/(n+1)}.$$

If the plate P_0 is of such low weight that its accidental factor, f, should be determined solely from its neighbors, we replace the exponent $1/(n+1)$ by $1/n$, i.e., we omit the equation $f = 1$. In Area III there were seven plates that for one reason or another were omitted in calculating the constants and the f's. All but one were strongly deficient in numbers of nebulae as compared with the numbers in their overlaps. In most cases this effect was verified by an examination of the star images. A single plate ($\alpha = 14^h 20^m$, $\delta = -20°$) showed a great excess of nebulae. The reason is not known but it was thought desirable to omit this plate in determining the constants.

No overlap was used in calculating f if ρ_m depended on ν_m or ν_m' less than 30. In and near the zone of avoidance this was the usual situation, so that for many plates, f was taken equal to unity.

A study of the f factors reveals that their logs are distributed about zero in an approximately normal manner with a slight excess of large and small values. The probable departure of $\log f$ from zero is ± 0.055.

Let us designate by F the complete plate factor for P_0. This quantity equals f multiplied by the exposure, emulsion and personal factors.

Thus

$$F = f i_0 \epsilon_0 p.$$

The value of F calculated for each plate is included in Table I.

The reduction of the counts requires first that the field and extinction factors shall be applied for each square degree on a plate, and that these values shall then be multiplied by the appropriate F. After these corrections have been applied to the counts, the material is ready for discussion.

V. THE PROBABLE ERRORS

The comparison of corrected counts in the same square degree on overlapping plates provides material for calculating the probable errors. Only the northwest quarter of Area III was used since it contains sufficient data for a solution, and it is the region of greatest nebular density. The logarithm of the ratio of counts in overlapping regions was formed from 510 comparisons. The resulting probable error in the logarithm of the nebular count per square degree is 0.054 which corresponds to ±12.5 per cent of the number of nebulae. The probable error in the logarithm applies to counts in the more populous area, and it should obviously be larger in areas of low nebular density. The distribution of residuals closely follows a normal error curve. An application of the χ^2 test showed that the probability of a poorer fit than that obtained is 0.40.

The errors arise from several sources, the most important of which appear to be:

1. The plate factors, F, are not determined with complete accuracy because they depend on a smoothing process that reduces but does not eliminate the individual plate errors.
2. The limiting magnitude is not necessarily constant over a given plate but varies with any non-uniformity of emulsion sensitivity and with dark-room processing.
3. Some nebulae may be overlooked in counting while certain plate defects may be recorded as nebulae.
4. In counting near the limit of detectability the observer cannot maintain a uniform standard of identification.

If all the discrepancies among the counts were assigned to variations in emulsion sensitivity alone, they could be accounted for by a probable error in the sensitivity of only 0.09 mag. A variable plate sensitivity cannot, of course, bear the entire responsibility, and its effect may well be equaled or exceeded by one or more of the other sources of error. If this conjecture is correct, the observations indicate a rather remarkable uniformity of emulsion coating over a one-degree border around the large plates.

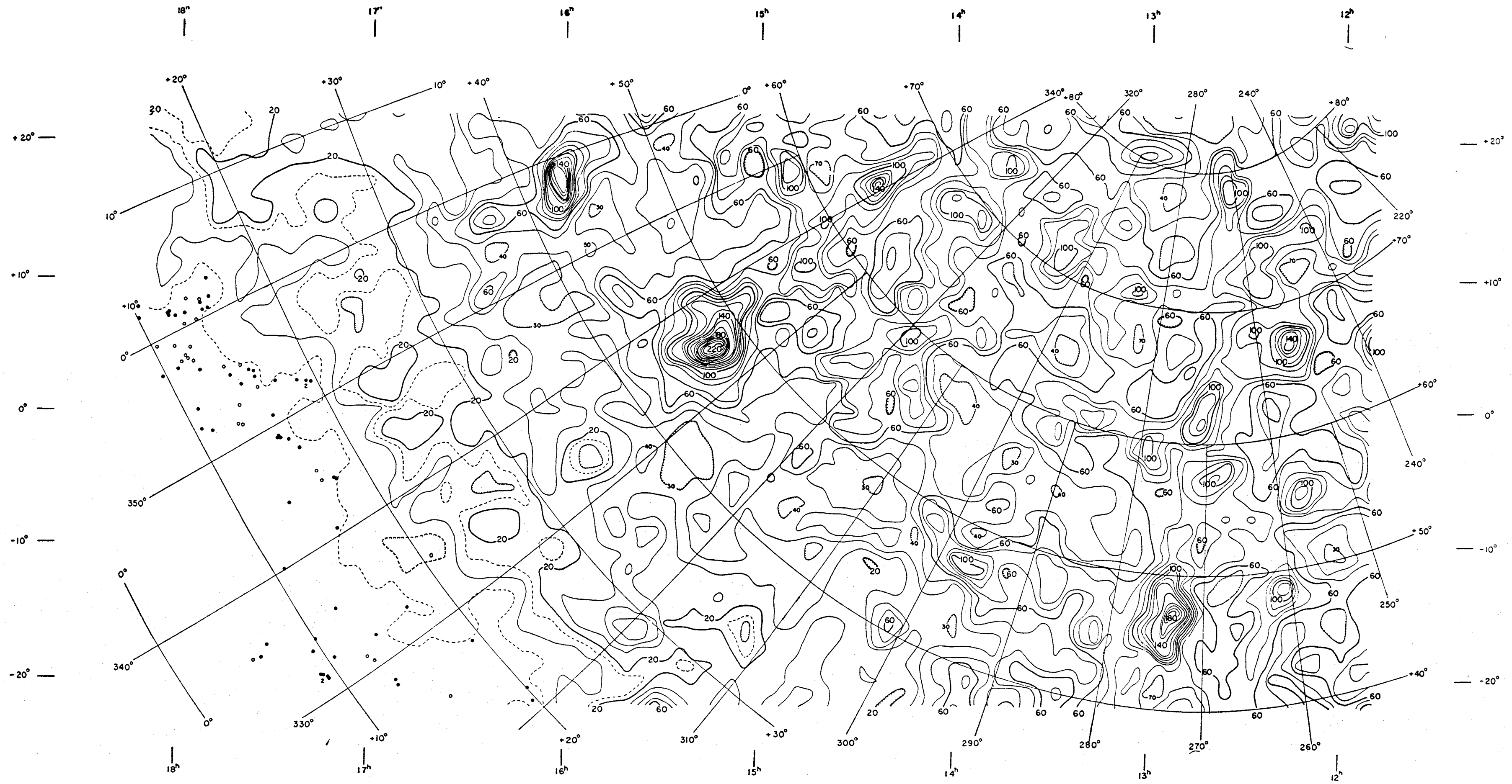

Figure 2. Equal surface density contours for nebulae in Area III, based on smoothed counts by 1° squares.

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VI. THE CONTOUR MAP

The general features of the nebular distribution are probably best portrayed by means of a contour map showing curves of equal surface density. In drawing the contours it is not feasible to use the individual reduced counts by square degrees. For one reason, the variation in numbers of nebulae between adjacent square degrees is so irregular that excessively complicated contours would be required. Moreover, the probable errors of the counts are of such size that in many cases this complicated detail would be misleading. It was therefore decided to form running means of four square degrees and to base the map on these values. Every combination of four square degrees having a common corner was averaged, and the results were entered on a chart at the position of the corner. The contour map, Figure 2, was drawn from these data. The contour interval is ten nebulae per square degree, with the contours 20, 60, 100, 140, etc. drawn in heavy lines. In addition the contours representing 5 and 15 nebulae per square degree are indicated by broken lines. Completely enclosed areas of lower density are shown by hachures on the lowest contours of such areas. The process of smoothing by fours obviously conceals some detail and suppresses the relief to a certain extent. For example, if we consider the three great clouds of nebulae that lie between galactic latitudes $b = +40°$ and $+50°$, the maximum contours are 180, 220, and 160, whereas the most populous square degrees contain 244, 272, and 258 nebulae, respectively. The two strongly deficient areas at galactic longitude $l = 212°$, $b = +34°$ and at $l = 333°$, $b = +35°$ each have minimum contours of 10, whereas the minimum numbers of nebulae are 7 and 2, respectively. The actual relief is thus greater than is indicated by the map.

Individual nebulae on the low density side of the number 5 contour are indicated by small circles. The open circles represent nebulae that have a strong appearance of reality but were observed on only one plate. Nebulae represented by the filled circles were verified on at least one additional plate. Nevertheless the identities of many of these objects are open to question. In one case a Crossley photograph and a spectrogram by Gibson Reaves revealed that an apparent extragalactic object is, in fact, a small planetary resembling the Owl nebula. A second object highly plausible as a nebula proved to be stellar on another Crossley photograph by Reaves. It is probably a carbon star in which the strong blue-green region of the spectrum is sufficiently out of focus on the astrograph plates to give it the appearance of a nebula. The objects thus plotted individually should not be regarded definitely as extragalactic in nature, without further confirmation.

VII. DISTRIBUTION IN LATITUDE

The contour map shows clearly the well known correlation between the number of nebulae and the galactic latitude. From his counts Hubble derived the following expression for this relationship:

$$\text{Log } N_{\text{H}} = 2.115 - 0.15 \csc b,$$

where N_{H} is the number of nebulae and b is the galactic latitude.[6] This equation is appropriate to a uniform layer of absorbing material lying symmetrically about the galactic equator and extending to infinity in all directions parallel to that plane. The irregularities in the distribution of galactic absorbing matter should produce departures from this simple formula, but it serves to delineate the obscuration approximately.

TABLE IV. VARIATION OF NUMBER OF NEBULAE WITH LATITUDE

Long. Interval	No. of Values of N	A	B	$\log N_{\text{H}} - \log N$	No. of Points
240°–260°	10	2.17	−0.29 ± .11 (p.e.)	+0.10	6
260 –280	16	1.78	+0.05 ± .07	+0.05	14
280 –300	20	2.12	−0.29 ± .07	+0.07	41
300 –320	24	2.25	−0.43 ± .03	+0.16	18
320 –340	23	2.42	−0.51 ± .03	+0.13	18
340 –360	23	2.46	−0.55 ± .03	+0.15	15
0 – 20	5	2.46	−0.54 ± .16	+0.52	3

The more complete data now available justify separate solutions, by 20° longitude intervals, of the equation

$$\text{Log } N = A - B \csc b,$$

where N represents the average of the corrected numbers of nebulae per square degree for each plate whose center lies within a given longitude interval. The constants, A and B, were determined by least-squares solutions for seven longitude intervals in Area III. Values of N corresponding to $b < +25^\circ$ and a few values of N in the more conspicuous clouds were omitted from the solution. The results are included in Table IV.

The first four columns are self explanatory. The fifth column contains the means of the difference between the logarithms of Hubble's counts[6] corrected for quality, log N_H, and log N as calculated from A and B. The sixth column lists the number of values of log N_H used in forming these means. It should be noted that the first three values of B are subject to considerable inaccuracy due to the small range of b, and also due to the sensitivity of B to a possible systematic error in the amount of the atmospheric extinction.

For each of the seven longitude intervals, log N was plotted as a function of csc b (Figures 3 to 9). The straight line corresponding to the constants A and B is drawn for each figure. The points used in the solution are indicated by circles. Those that correspond to positions in large clouds of nebulae are represented by dots, and Hubble's values are shown by crosses. One of Hubble's points that coincides with a large cloud is omitted.

It is evident that in Area III the constant B is much larger than that derived by Hubble in the more extensive area covered by his survey. Since Area III includes part of the galactic bulge where the strong absorption persists to a considerable distance from the galactic equator, we would anticipate a larger absolute value of B than the 0.15 Hubble determined. However, the distribution of the points representing his observations in Area III suggests that a solution from them would yield a value of B even larger than ours.

An average value of B suitable for reducing the counts in Area III to a standard galactic absorption at the pole may be calculated from the data in Table IV. For this purpose it is recognized that the variation in B with longitude is for the most part real and does not result from accidental effects. Therefore the best average value is the unweighted mean. Since the corrections would ordinarily be used only in intermediate or higher latitudes, and since Area III does not include the longitude range $l = 0^\circ$–20° in these latitudes, we omit the last value of B in Table IV. The resulting mean is $\bar{B} = -0.34$. In an earlier paper by Neyman, Scott and Shane,[7]

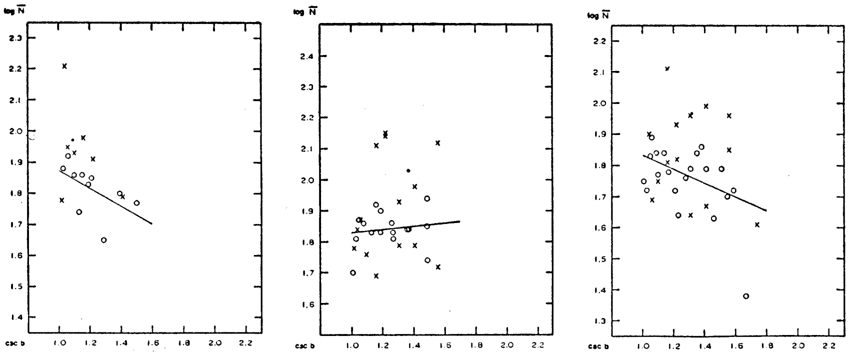

Fig.3 Long. = 240° to 260°   Fig.4 Long. = 260° to 280°   Fig.5 Long. = 280° to 300°

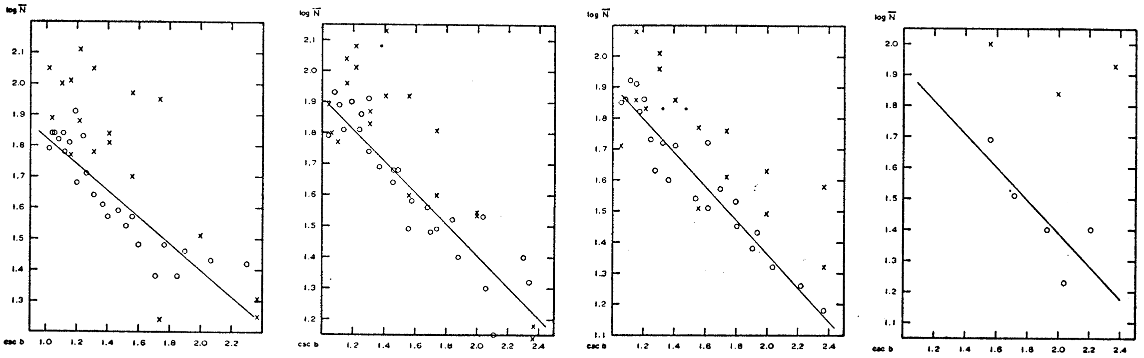

Fig.6 Long. = 300° to 320°   Fig.7 Long. = 320° to 340°   Fig.8 Long. = 340° to 360°   Fig.9. Long. = 0° to 20°

Figures 3–9. Relation between log $\bar{N}$ and csc b for seven different ranges of galactic longitude.

the adopted value of $\bar{B}$ was -0.37, derived by including the last entry in the table.

VIII. LIMITING MAGNITUDE OF THE COUNTS

The limiting magnitude of our counts may be derived from the values of $\log N_{\rm H} - \log N$ for each of the longitude intervals, listed in the fifth column of Table III. The mean of these quantities, weighted according to the number of Hubble regions, is $+0.13$. However, for comparison with our counts, $\log N_{\rm H}$ must be reduced to the area unit of one square degree, and his coma factor must also be applied. When this combined correction of $+0.70$ is included, we find that the logarithm of the ratio of Hubble's counts for limiting magnitude 20.0 to our counts is $+0.83$. If a uniform average density of nebulae in depth is assumed, and if the effect of red shift is neglected, the logarithm of the number of nebulae counted should increase by 0.6 per unit of limiting magnitude. Our limiting magnitude would therefore be 1.4 mag. brighter than Hubble's, or 18.6 mag.

It is more probable that the rate of increase in the log number of nebulae should correspond to Hubble's empirical value 0.501.[1] This value yields a difference in limiting magnitude of 1.64 mag. Thus we suggest for the counts published here an approximate limiting magnitude of 18.4 mag. based on Hubble's scale. Because of uncertainties in the stellar and nebular magnitude scales near the faint end, a substantial revision of this value may be necessary at some future time.

It should again be emphasized that the assignment of a limiting magnitude to the counts does not imply that all types of nebulae are counted to this magnitude. Some nebulae can no doubt be detected beyond the stated limit while others that are somewhat brighter than the limit escape detection. The value 18.4 mag. is merely a general average for all types of nebulae.

IX. IRREGULAR GALACTIC ABSORPTION

The contour map, Figure 2, strongly suggests irregularities in the galactic absorption. Two areas markedly deficient in nebulae occur at $l = 312°$, $b = +34°$ and at $l = 333°$, $b = +35°$. These regions of deficiency probably are due to galactic absorbing clouds. Other somewhat less conspicuous regions with abnormally small numbers of nebulae are readily noted, especially in low latitudes. In several of these regions low star densities indicate that at least some of the absorbing clouds are fairly close to the sun. The behavior of the long continuous contour showing 60 nebulae per square degree is particularly striking. It seems to outline a northward extension of the area of apparent absorption between longitudes 310° and 350°, south of latitude +40°. The extension contains several isolated deficient regions, and it reaches nearly to latitude +70°.

In determining the true nebular distribution, it is important to know whether absorbing clouds can be observed in high latitudes. Table V contains the positions of five deficient regions north of latitude +60° for which the nebular count falls below 40 per square degree. In this connection it should be recalled that the smoothing process applied in constructing the contour map tends to suppress the extremes and therefore the deficiencies are actually greater than are indicated by the map. The third column of Table V gives the three smallest nebular counts in each of the regions listed. Because of accidental errors it would over-emphasize the deficiencies to tabulate merely the smallest count, but the mean of two or three should give a fair idea of the minimum number of nebulae per square degree. If these areas of deficiency do represent galactic absorbing clouds, there are probably other less conspicuous clouds not so readily noted on the contour map. There are three obvious methods of testing the hypothesis that such clouds occur in high latitudes.

TABLE V. DEFICIENT REGIONS

Gal. Long.	Gal. Lat.	3 Smallest Counts		
280°	+83°	20	24	28
281	+78	28	32	34
296	+65	28	32	33
259	+62	23	26	33
330	+62	28	28	30

First, if the hypothesis is correct, nebular deficiencies in any obscured area should tend to persist when the counts are made over a wide range of limiting magnitudes. Hubble's counts are not well adapted for use in conjunction with ours in making this test, because his plates are distributed in a regular pattern over the sky and only rarely fall in strongly deficient areas. Furthermore his actual counts extend to limiting magnitude 20 only at the center of his better 100-inch reflector plates. Before the coma factor is applied, Hubble's counts average only about one magnitude fainter than ours. Thus irregularities in our results should be reflected to a considerable degree in Hubble's counts. Table VI contains the correlation coefficients for a comparison of the $\log N_{\rm H}$ and $\log N$ by zones of galactic latitude. A definite positive correlation obviously exists but the meager data do not admit of any general conclusions as to the presence of irregular absorption in high latitudes. A survey of nebulae to about 15.5 magnitude has recently been undertaken at the Lick Observatory, and at a later time it is hoped to count nebulae on plates in selected regions photographed with the 120-inch reflector. A comparison of counts to the three limiting magnitudes, 15.5, 18.4 and 21 should provide a fairly definitive test of the hypothesis of absorbing clouds in high latitudes.

TABLE VI. CORRELATION WITH HUBBLE'S COUNTS

Latitude	No. of Comparisons	Correlation Coefficient
+80° to +65°	26	+0.46
+60 to +50	32	+0.47
+45 to +40	25	+0.60
+35°	7	+0.16
+30	6	−0.08
+25	6	+0.48

A second test consists of comparing star counts with nebular counts. Any definite, positive correlation that may be found to exist would be evidence of absorption.

Finally, a possible test for absorbing clouds could be based on the colors of nebulae in the deficient areas. A systematic reddening would be strong evidence of absorption. Unfortunately the dispersion of colors among the nebulae is so great that a large number of measures of faint objects would be required. There is considerable doubt if the labor of such a program would be justified by the results.

A number of other methods of uncertain promise in this connection could be suggested, such as a search for the 21 cm radiation of neutral hydrogen in the suspected regions, the strengths of interstellar lines, and measures of the surface brightnesses of nebulae as seen through the suspected absorbing clouds. Among all the methods suggested, however, the first two, based on nebular and star counts respectively, seem to offer the best possibilities.

It is probable that interstellar clouds exist in high latitudes, and their location and measurement, or at least the determination of their statistical properties, is of great importance in a study of the true distribution of the nebulae. The investigations by Neyman, Scott and Shane are based on the simplifying assumption of no irregular absorption in high latitudes.[7] Ambartsumian, on the other hand, derived statistical properties of the interstellar medium from Hubble's nebular counts on the assumption that the irregularities are due to galactic absorption.[8] The actual situation may lie somewhere between these extremes.

X. SOME STATISTICAL PROPERTIES OF THE NEBULAR DISTRIBUTION

The appearance of the contour map, Figure 2, suggests that the nebulae are not distributed at random but tend to congregate in certain areas. So many aggregations stand out prominently that one is tempted to speculate that clustering may be a predominant characteristic of nebular distribution. In considering this possibility we note that nearby clusters are relatively few in number and their members are so widely separated on the sky that they are lost among the far greater number of distant nebulae. The Virgo cluster of bright nebulae is included on the contour map, but it is quite unrecognizable because of its small number of nebulae per square degree. This cluster becomes apparent only when one takes account of apparent magnitudes. Distant clusters, on the other hand, are very numerous and therefore closely spaced on the sky, but only their few brightest members may be visible on our plates. While these nebulae contribute materially to the total counts, their distribution, when studied by square degrees, should to some extent simulate a random distribution. There is in any survey, however, an intermediate range of distance most favorable for the detection of clusters by means of counts. Thus the aggregations so prominent on the map probably are in this range, while a considerable fraction of the structureless background may come from very distant clusters.

A test of the hypothesis that all nebulae belong to clusters was made by Neyman, Scott and Shane.[7] For this purpose the counts in the less obscured region of Area III were analyzed. The analysis depended on certain reasonable assumptions regarding the structure of clusters. The investigation showed that the main statistical properties of the distribution could be represented by the hypothesis of complete clustering. On the other hand, it is quite possible that a different model that includes an appreciable number of random nebulae could be found to represent the observations equally well.

If the nebulae are individually distributed at random we should find (1) that the numbers in neighboring square degrees are uncorrelated, and (2) that they have a Poisson distribution. Neither of these properties is possessed by the observed distribution.

(1) Serial quasi-correlations for the counts by square degrees corresponding to the west half of the contour map, Figure 2, were calculated under the direction of Scott in connection with the paper mentioned above. After correction for observational errors and for the effects of general galactic obscuration, it was found that counts in neighboring square degrees are correlated out to a distance of four to five degrees. Since the data are fully given in the reference they are not included here. These correlations in themselves strongly suggest that some kind of clustering is a prominent feature of nebular distribution.

(2) On the basis of his counts, Hubble showed that the logarithm of the number of nebulae per counted area closely approximates a normal frequency curve with a mean log $N = 1.925$ and a dispersion, $\sigma = 0.18$.[6] Mayall's counts of nebulae on plates taken with the Crossley reflector likewise give an approximately normal distribution in the logarithm, with $\overline{\log N} = 1.785$ and $\sigma = 0.22$.[9] Bok pointed out that the σ derived by Hubble is so greatly in excess of the dispersion to be expected from a random distribution that a strong degree of clustering among the nebulae is indicated.[10] Hubble also suggested a small-scale clustering to explain an apparent observed decrease in σ with increasing average numbers of nebulae in the counted areas.[1]

Table VII contains the results of fitting our counts as well as certain counts by Hubble and Mayall to a normal distribution curve in log N. The first three columns are self-explanatory. The fourth and fifth contain, respectively, the average actual numbers of nebulae counted per standard survey area and the mean of the logarithms of their corrected values. The sixth column gives the observed dispersion. In the seventh column σ_c is the dispersion corrected for errors of observation, based on probable errors in log N for Hubble, Mayall, and Shane and Wirtanen of 0.04, 0.04 and 0.054, respectively. The eighth column, σ_r, gives the dispersion in log N on the assumption of a random distribution. The ratios in the ninth column may be regarded as a measure of the departure from randomness. In view of the contagion in distribution, these numbers should show dependence on the average size of the samples counted in each row, but the range in sample size is not great enough to make the dependence obvious. The last column, P, gives the probability that if the true distribution in log N were normal, the χ^2 test would indicate a poorer fit than was actually found.

In Table VII the Hubble counts and those by Shane and Wirtanen north of latitude +50°, all have values of P that strongly indicate a normal distribution in log N. The Mayall counts in 71 areas are influenced by three plates very deficient in nebulae. If these plates were excluded, a normal distribution would represent the data reasonably well. The Shane and Wirtanen counts between latitudes +40° and +50° are greatly affected by the three large clouds in this region. But even if the areas of these clouds are omitted, the distribution has a strong skewness. The authors' counts between latitudes +30° and +40° are affected by local areas of galactic absorption and yield an excess of small values for log N. When 1/30 of the largest and smallest counts were excluded, however, and the results were fitted to a partial normal curve in which the extremes were omitted, a good fit was obtained. The conclusion one may draw from this material is that, except where the counts are disturbed by unusual conditions, log N is represented very satisfactorily by a normal distribution function.

The values of σ_c/σ_r range from 2.2 to 2.4 except in regions strongly affected by large clouds of nebulae or by irregular galactic absorption. This large departure from unity strengthens the conclusion that nebulae tend to occur in clusters.

TABLE VII. COMPARISON OF OBSERVED AND RANDOM DISPERSIONS IN LOG N

Authority	Lat.	No. of Areas	$\overline{N_c}$	$\overline{\log N}$	σ	σ_c	σ_r	$\frac{\sigma_c}{\sigma_r}$	P
Hubble*	45°	148	50.3	1.898	0.148	0.136	0.062	2.2	0.34
Mayall†	45	71	38.1	1.756	.230	.222	.074	3.0	<.01
S and W	>70	431	63.9	1.806	.154	.132	.054	2.4	.59
S and W	60°–70°	508	68.3	1.837	.148	.125	.053	2.4	.27
S and W	50 –60	656	58.9	1.770	.156	.135	.057	2.4	.69
S and W	40 –50	827	55.9	1.725	.208	.193	.060	3.2	<.01
S and W	30 –40	671	32.1	1.484	.212	.197	.081	2.4	<.01
S and W	30 –40 **	649	32.1	1.490	0.197	0.182	0.081	2.3	0.54

* 1 hr. exposures with the 100-inch telescope.
† 1 hr. exposures with the 36-inch Crossley.
** The largest and smallest counts contributing 1/30 to the total were omitted.

XI. THE CLUSTER DENSITY FUNCTION

There appear to be two extreme structural types among the populous clusters, exemplified by the Virgo and the Coma clusters. The Virgo type is characterized by the absence of a strong central condensation and by lack of symmetry. Such clusters cannot readily be recognized at great distances where they become confused with the general background of nebulae, and therefore not many are known. They may be regarded as "open" clusters of nebulae. The Coma-type cluster is characterized by a strong central condensation and a tendency toward spherical symmetry. Such clusters can be recognized at great distances and are found in large numbers on the photographs. There may well be intermediate types, but at present our knowledge is too fragmentary to discuss their structure.

A considerable number of Coma-type clusters appear on the photographs of Area III. It is therefore worth while to investigate in a very preliminary fashion the manner in which the surface density in such clusters diminishes with distance from the center. Six of the clusters are suitable for such a study. All six are rather small or are somewhat disturbed by proximity to the edges of the plates, or to other clusters, and they therefore could not be investigated individually. The data were combined to form an average cluster whose density gradient could be determined.

The six clusters: For each cluster the center was located by inspection and the central count was recorded. The mean of the counts for the squares adjoining its four sides gave the value at 10′ from the center. This process was continued outward by grouping conveniently increasing numbers of squares located within a sufficiently small range of distance until there was no longer an appreciable decrease in numbers of nebulae. Areas that were obviously disturbed by nearby clusters or groups of nebulae were avoided. A provisionally estimated value of the background was subtracted from the counts for each cluster, the resulting values were plotted against distance from the center, and a smooth curve was drawn to represent the points as well as possible. The curves for all six clusters were characterized by an initial rapid decrease in numbers of nebulae, followed by a very slow approach to zero. To reduce the observations to a common basis, abscissa and ordinate correction factors were derived for each cluster. The abscissa factor was determined by finding the abscissa at which the ordinate fell to one-third of its maximum value as read from the curves. The scale of abscissae was then multiplied by a number to make this "one-third point" the same for all clusters. A single ordinate factor was determined for each cluster to bring all six curves into the best agreement. When the individual observations corrected by these factors were plotted on a single chart, a large scatter was evident. The points were then grouped into eleven means or normal points on which the further discussion is based. The positions of the six clusters together with their coordinate factors are listed in Table VIII.

TABLE VIII. SIX COMA-TYPE CLUSTERS

α_{1950}	δ_{1950}	Abscissa Factor	Ordinate Factor
$12^h 16^m 3$	$+5°35'$	0.84	1.30
12 16.9	−13 05	1.06	1.37
12 39.0	− 4 35	0.90	1.40
14 24.5	+16 55	1.06	0.82
14 50.6	+16 55	1.06	0.64
14 52.6	+18 55	1.17	0.94

TABLE IX. CLUSTER DENSITY FUNCTION

Six Clusters

r	n_r obs	O−C
0.00	14.3*	+1.3*
1.09	4.8	−0.2
1.70	3.3	+0.1
2.35	2.16	−0.08
2.90	2.13	+0.40
3.32	1.33	−0.16
3.87	1.44	+0.22
4.47	1.02	0.00
5.28	0.83	+0.03
6.52	0.61	+0.01
7.97	0.41	−0.03

Coma Cluster

	Plate 303		Plate 1613	
r	n_r obs	O−C	n_r obs	O−C
0.0	30.0*	−23.0*	36.4*	−23.4*
1.0	20.2	+ 2.2	23.4	+ 2.3
1.4	11.5	− 0.9	15.9	+ 1.1
2.1	6.3	− 1.1	6.7	− 2.4
2.8	3.7	− 1.4	3.7	− 2.8
3.1	3.9	− 0.6	5.1	− 0.6
3.8	3.7	+ 0.4	4.5	+ 0.2
4.1	2.6	− 0.4	3.0	− 0.9
4.7	2.2	− 0.2	2.5	− 0.6
5.2	2.5	+ 0.5	3.4	+ 0.7
6.0	1.2	− 0.4	2.3	+ 0.1
6.3	2.7	+ 1.2	2.5	+ 0.5
7.6	1.3	+ 0.2	1.4	− 0.1
7.8	1.3	+ 0.3	1.9	+ 0.5
8.8	0.8	0.0	1.3	+ 0.1
9.7	0.8	+ 0.1	0.9	− 0.1
9.9	0.6	− 0.1	1.0	+ 0.1
10.8	0.6	0.0	0.6	− 0.3
12.3	0.4	0.0	0.9	+ 0.3
12.9	0.4	0.0	0.8	+ 0.2

* For $r = 0$ the observed values are the numbers of nebulae in a 10′ square corrected for background. The computed values are the numbers within a circle of 100 square minutes area.

The average number of background nebulae subtracted from the counts was 1.5 nebulae per 10′ square. This value is certainly too large since it is based on the distance at which the counts were terminated. With the evident slow decrease in numbers of nebular outward from the center a greater distance should be used to establish the true background density. For each cluster several areas, two or more degrees from the center, were located in which there seemed to be little or no effect of nebular aggregations. The background densities derived from these areas gave a mean value of 1.1 nebulae per 10′ square. Each of the eleven normal points was accordingly increased by 0.4. The first and second columns of Table IX give, respectively, distances, r, in units of 10′ from the center of the average cluster, and the corresponding corrected surface densities.

Two plates of the Coma cluster (α 1950 = $12^{h}\,57^{m}.5$; δ 1950 = $+28^{\circ}\,20'$), which lies just off the northern edge of Area III, were investigated separately.

The Coma Cluster, Plate 303. This plate, a two-hour exposure centered on the cluster, was taken without the grating. Figure 10 represents the nebular density distribution by contours whose interval is four nebulae per ten minute square. The contour for two nebulae per ten minute square is shown by the broken line. In drawing the contours the counts were averaged by fours in the usual manner. However, the numbers on the chart give the actual counts. It is apparent that there is a subsidiary concentration of nebulae southwest of the cluster center. This grouping may be a secondary feature of the cluster or it may represent an independent aggregation. The area included in the rectangle outlined by the broken lines was therefore not used in discussing the density function. With this omission the cluster approximates circular symmetry.

The position of the largest count, 31, was adopted as the center of the cluster. The true center probably lies somewhere between counts 31 and 22, but this centering error should appreciably effect only the central count. At 130′ from the center the average number of nebulae per ten minute square reached 1.4 and was no longer decreasing noticeably. This distance seemed to correspond to the average distances at which the counts on the six clusters were terminated. Consequently, as with the 6 clusters, the terminal value was decreased by 0.4 to give a background count of 1.0. The surface density corrected for this background is given in the second column of the lower part of Table IX.

The Coma Cluster, Plate 1613. This plate was taken on the regular program and includes the cluster centered 105′ south and 35′ west of the plate center. Figure 11, the contour representation for this plate, indicates a close similarity to the chart for Plate 303 but with a fainter limiting magnitude. If a Number 6 contour were drawn on Plate 303, it would correspond rather closely to the Number 8 contour on Plate 1613. The

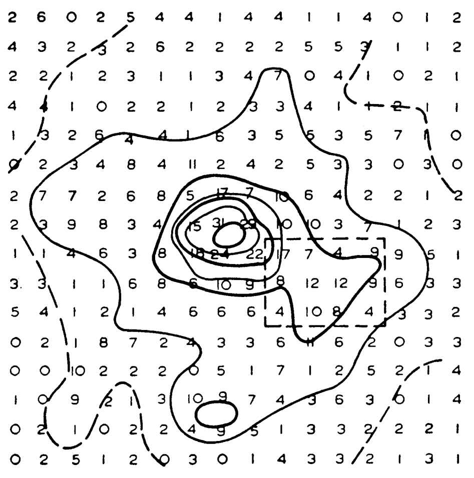

Fig. 10. Plate 303

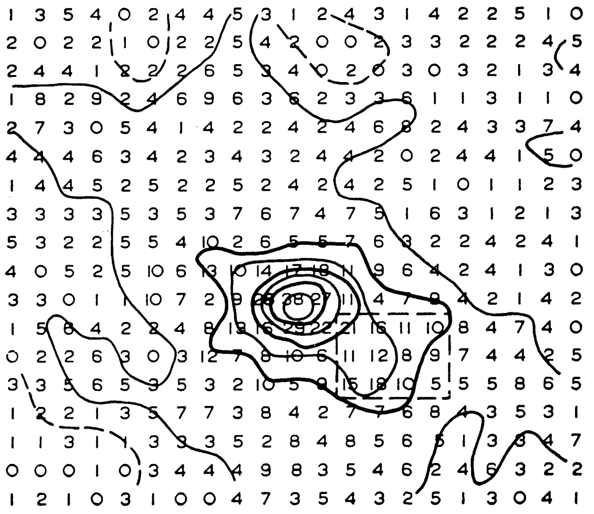

Fig. 11. Plate 1613

Figures 10 and 11. Contour maps of the Coma cluster of nebulae, based on smoothed counts by 10′ squares.

latter plate has a uniformly higher density of nebulae, with 2.2 or 2.3 nebulae per ten minute square at 130′ from the cluster center. Since the cluster was considerably south and west of the plate center, it was possible to find relatively undisturbed areas of background near the north edge of the plate. The average count in these areas was 1.6 nebulae per square degree. Correction for this background density was applied to the counts with the results tabulated in the fourth column of the lower part of Table IX.

Empirical formula of de Vaucouleurs. It has been shown by G. de Vaucouleurs that a formula equivalent to $\log n_r = a(r^{\frac{1}{4}} + b)$ represents with remarkable fidelity the observed distribution of brightness in elliptical nebulae.[11] His value $b = -1$ corresponds to the adoption of a special unit of brightness in his applications. De Vaucouleurs[12] also applied the formula to nebular counts by Zwicky[13] in three clusters of nebulae and obtained an excellent representation. The formula was applied to our observations with the results represented by the O−C columns of Table IX and the constants in Table X. The quantities in Table X not enclosed in parentheses are based on the observational data in Table IX; those in parentheses are derived from n_r diminished throughout by 0.1. This change corresponds to raising the assumed background by 3.6 nebulae per square degree, an amount within the uncertainties of its determination. The column headed r_e gives the distance from the center of each cluster within which half the total number of nebulae should lie, according to the formula. The number within the distance r_e is given in the last column of the table. The total number of nebulae to $r = \infty$ is twice this value for each cluster. The constants in Table X were determined without using the observational data for $r = 0$. Clearly, the equation does not fit at the immediate center of the Coma cluster, but elsewhere the agreement is good.

TABLE X. CONSTANTS FOR DE VAUCOULEURS' FORMULA

	a	b	r_e	Neb. inside r_e
Six Clusters	−1.595	−1.458	19.01	405
	(−1.738)	(−1.426)	(13.48)	(290)
Coma Cl., Plate 303	−1.855	−1.677	10.38	738
	(−1.938)	(−1.652)	(8.71)	(642)
Coma Cl., Plate 1613	−1.745	−1.759	13.25	1153
	(−1.807)	(−1.738)	(11.54)	(972)

The important point to be noted is that the density of nebulae in a Coma-type cluster, and the brightness of an elliptical nebula, decrease outward in much the same manner.

XII. CLOUDS OR MULTIPLE CLUSTERS

In the list of twenty-five clusters of nebulae published by Shapley,[14] he noted the occurrence of two double groups and one triple group. He suggested that these multiple groups were physically connected because of the proximity of the members both in direction and in distance as indicated by their distribution in apparent magnitude.

In Area III there occur three large multiple clusters or clouds of nebulae and several smaller ones. Contour maps of six of these clouds are illustrated in more detail in Figures 12 to 16 than in the main chart, Figure 2. The corrected counts by quarter instead of whole square degrees were smoothed by fours and then contours were drawn through the smoothed points. The contour interval is ten nebulae per square degree. It is apparent that each cloud consists of two or more comparable clusters with subsidiary condensations, except for the cloud at $\alpha = 14^h 25^m$, $\delta = +16.^\circ7$. An examination of the unsmoothed counts for this cloud shows that the ridge extending to the northwest is produced by two secondary aggregations of nebulae whose identities were lost through the smoothing process.

Data for the six clouds are given below. All positions are for 1950. Distances are given on the scale proposed by Baade at the Rome I.A.U. meeting in September 1952.

1\. Figure 12: $\alpha = 12^h 16^m$, $\delta = +4.^\circ8$. In 14.8 square degrees 505 nebulae above a background of 80 nebulae per square degree. Two main centers of condensation at $\alpha = 12^h 15^m$, $\delta = +4.^\circ0$; $\alpha = 12^h 16^m$, $\delta = +5.^\circ5$.

2\. Figure 13: $\alpha = 12^h 54^m$, $\delta = -15.^\circ2$. In an area of 25 square degrees 1388 nebulae above a background of 80. Distance of the southernmost condensation based on magnitude distribution according to Shapley,[14] 58×10^6 parsecs. Three major condensations at $\alpha = 12^h 51^m$, $\delta = -15.^\circ2$; $\alpha = 12^h 55^m$, $\delta = -17.^\circ2$; $\alpha = 12^h 55^m$, $\delta = -13.^\circ2$. Also two minor condensations.

3\. Figure 14: $\alpha = 14^h 25^m$, $\delta = +16.^\circ7$. In 6.5 square degrees 214 nebulae above a background of 88. One major condensation at $\alpha = 14^h 25^m$, $\delta = +16.^\circ7$. Two minor condensations at $\alpha = 14^h 20^m$, $\delta = +17.^\circ8$; $\alpha = 14^h 16^m$, $\delta = +18.^\circ8$.

4\. Figure 14: $\alpha = 14^h 52^m$, $\delta = +17.^\circ9$. In 8.2 square degrees 359 nebulae above a background

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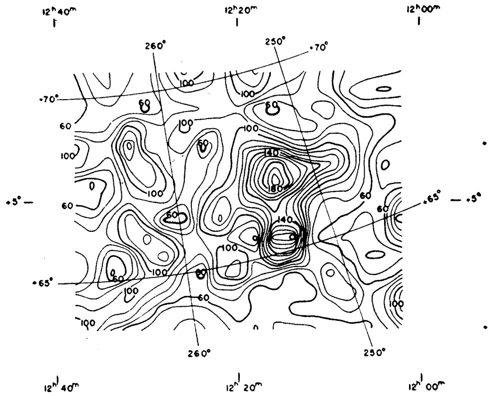

Fig. 12

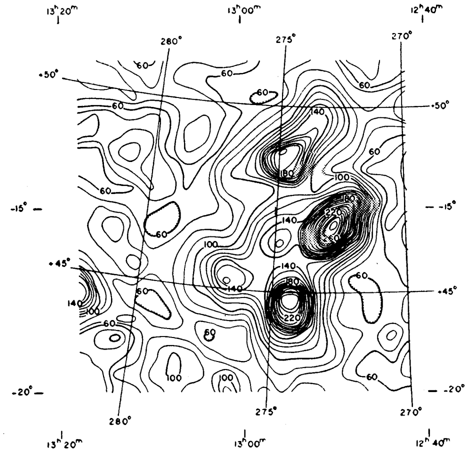

Fig. 13

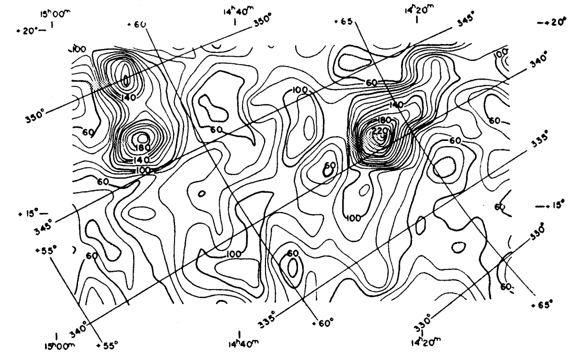

Fig. 14

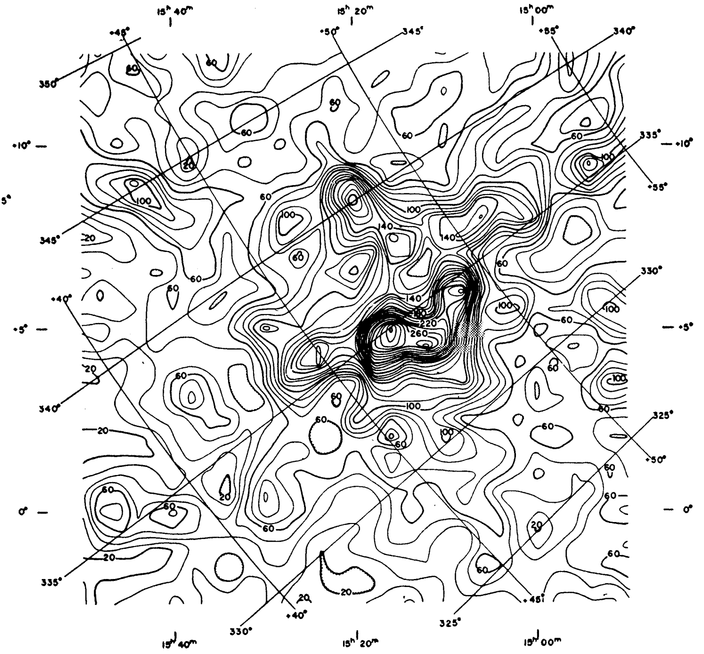

Fig. 15

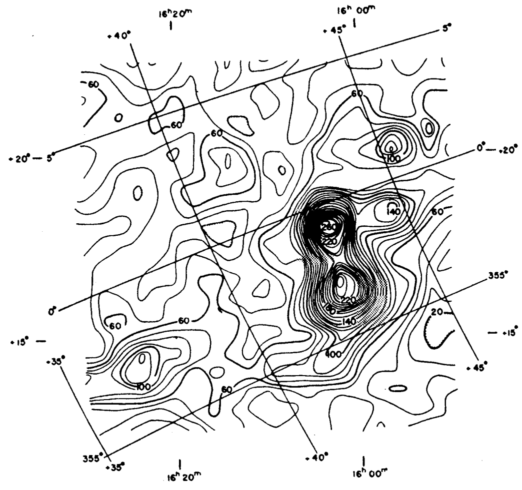

Fig. 16

Figures 12–16. Contour maps of clouds of nebulae, based on smoothed counts by 0.5° squares.

of 88. Two main condensations at $\alpha = 14^{\mathrm{h}}\,51^{\mathrm{m}}$, $\delta = +17^\circ\!.0$; $\alpha = 14^{\mathrm{h}}\,53^{\mathrm{m}}$, $\delta = +18^\circ\!.8$.

5. Figure 15: $\alpha = 15^{\mathrm{h}}\,12^{\mathrm{m}}$, $\delta = +5^\circ\!.2$. In 52 square degrees 2810 nebulae above a background of 68. Three major condensations at $\alpha = 15^{\mathrm{h}}\,09^{\mathrm{m}}$, $\delta = +6^\circ\!.0$; $\alpha = 15^{\mathrm{h}}\,11^{\mathrm{m}}$, $\delta = +4^\circ\!.8$; $\alpha = 15^{\mathrm{h}}\,17^{\mathrm{m}}$, $\delta = +4^\circ\!.5$. Three to five minor centers of condensation. Spectrograms of two nebulae at $\alpha = 15^{\mathrm{h}}\,20^{\mathrm{m}}\!.4$, $\delta = +8^\circ\,47'$ in a minor condensation, kindly obtained by Dr. Mayall to estimate the distance of the cloud, give red shifts +10,500 and +10,400 km/sec; with the corresponding distance 39×10^6 parsecs.

6. Figure 16: $\alpha = 16^{\mathrm{h}}\,02^{\mathrm{m}}$, $\delta = +17^\circ\!.0$. In 20.2