

# EXTRAGALACTIC NEBULAE CLOSE TO THE GALACTIC PLANE

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In 1954 Shane and Wirtanen described the density distribution for extragalactic nebulae counted in their Area III, extending from  $\delta = -20^\circ$  to  $+20^\circ$  and from  $\alpha = 12^h$  to  $18^h$ .<sup>1</sup> The results were given in their Figure 2. In this figure are also plotted a number of objects which, on the plates of the 20-inch Carnegie astrograph of the Lick Observatory, appeared very much like extragalactic nebulae, but which were found close to the galactic plane in the so-called zone of avoidance. Similar objects have been picked out by Shane in his Area V, which extends from  $\delta = +20^\circ$  to  $+60^\circ$  and from  $\alpha = 0^h$  to  $6^h$ . An investigation of these nebulae was recently undertaken while I was at the Lick Observatory, since a confirmation of the extragalactic nature of these objects might afford information about the density distribution of the obscuring matter in the Milky Way.

Dr. Shane kindly placed at my disposal his list of suspected nebulae in the zone of avoidance. In Area V near galactic longitude  $120^\circ$ , and including the direction of the galactic anticenter, only nebulae with galactic latitudes between  $\pm 5^\circ$  were picked out for investigation. There were 72 of these nebulae.\* In Area III, near galactic longitude  $345^\circ$ , where there were no nebulae in the  $\pm 5^\circ$  zone, 66 suspected extragalactic nebulae between galactic latitudes  $\pm 15^\circ$  were selected,† omitting those which were known to be planetaries or red stars (cf. Shane and Wirtanen,<sup>1</sup> p. 295). Because of limited observing time not all of the objects could be observed, so a selection was made from the brightest ones and from those whose positions fitted best with the observing program.

Direct photographs of 22 nebulae in each of the Areas III and V were taken with Crossley reflector of the Lick Observatory. Direct photographs of 26 additional nebulae in Area III, and of 38 additional nebulae in Area V, could be found on those copies

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\* Including nebula No. 20 from Table IV.

† Including nebulae Nos. 1, 14, and 21 from Tables I and II.

of the Palomar 48-inch Schmidt plates that were available at the Lick Observatory. But only a few of the investigated objects are sufficiently bright and large to permit a decision concerning their nature by these direct photographs alone.

Plate I is a reproduction of a part of one of the Crossley plates. The two northernmost nebulae are certainly spirals (Nos. 1 and 2 in Table III). Objects whose extragalactic nature could be stated as surely as for these two are listed in Tables I and III. The southernmost nebula in Plate I (No. 12 in Table IV) is also almost certainly a spiral, especially since it is so close to the other two spirals. But its structure cannot clearly be seen. This and similar objects are listed in Tables II and IV. If several nebulae were found in a field of a few square minutes of arc, I regarded this circumstance as support for the identification of the objects as extragalactic, as we may expect to find several extragalactic nebulae together in reasonably transparent regions. Objects for which no decision was possible by direct photography alone were investigated spectroscopically.

TABLE I  
EXTRAGALACTIC NEBULAE IN THE ZONE OF AVOIDANCE  
IN AREA III

No.	$\alpha(1950)$	$\delta(1950)$	$l$	$b$	Evidence
1*	17 <sup>h</sup> 48 <sup>m</sup> 2	+5°31'	358°8	+14°7	<i>Sch, s.n.</i>
2	17 56.7	+7°09'	1°2	+13°2	<i>d, Sch</i>
3	17 57.0	+6°18'	0°3	+12°9	<i>d, Sch, r.s.</i>
4	17 59.4	+6°58'	1°4	+12°3	<i>d, Sch</i>
5	18 01.9	+7°16'	1°8	+12°5	<i>s.n., r.s.</i>
6	18 09.9	+8°47'	4°0	+11°2	<i>Sch, s.n.</i>

\* This object was not mentioned in Shane's list, but was found on the Palomar 48-inch Schmidt plates.

Spectrograms of some relatively bright objects were taken with the nebular spectrograph of the Crossley reflector. Most of the objects are too faint to get good spectrograms in a reasonable exposure time. Only two spectra showed the H and K lines in good definition so that a redshift could be seen definitely and the extragalactic nature of the object could be stated with certainty. If H and K were not well defined but a continuous spectrum was

TABLE II  
NEBULAE IN THE ZONE OF AVOIDANCE IN AREA III THAT ARE  
ALMOST CERTAINLY EXTRAGALACTIC

No.	$\alpha(1950)$	$\delta(1950)$	$l$	$b$	Evidence
7	17 <sup>h</sup> 15 <sup>m</sup> 9	−17°19′	334°2	+ 9°9	<i>d.</i>
8	17 40.0	+ 0°15′	352°8	+14°1	<i>d, s.n.</i>
9	17 42.4	+ 2°32′	355°1	+14°4	<i>s.n., no H<math>\alpha</math></i>
10	17 48.3	+ 6°04′	359°1	+14°8	<i>d, s.n., no em.</i>
11	17 49.8	+ 5°28′	358°7	+14°2	<i>c.s.</i>
12	17 50.7	+ 6°17′	359°6	+14°3	<i>Sch., s.n.</i>
13	17 51.2	− 1°32′	352°5	+10°6	<i>s.n., no H<math>\alpha</math></i>
14*	17 51.8	+ 6°05′	359°5	+14°0	<i>Sch.</i>
15	17 52.0	+ 2°53′	356°6	+12°5	<i>d, Sch, s.n.</i>
16	17 52.6	− 0°02′	354°0	+11°0	<i>d, s.n.</i>
17	17 53.2	+ 6°12′	359°6	+13°6	<i>no H<math>\alpha</math></i>
18	17 57.3	+ 3°58′	358°3	+11°8	<i>s.n., c.s.</i>
19	17 57.5	+ 3°31′	357°3	+11°5	<i>d, Sch.</i>
20	18 01.8	+ 7°02′	1°5	+12°2	<i>d, s.n., c.s.</i>
21*	18 08.0	+ 5°44′	1°1	+10°2	<i>Sch.</i>
22	18 09.7	+ 9°25′	4°6	+11°5	<i>Sch., s.n.</i>
23	18 10.4	+ 6°42′	2°2	+10°2	<i>s.n., c.s.</i>

\* Objects 14 and 21 were not in Shane's list, but were picked out by the author on the 20-inch and the Palomar plates, respectively.

clearly visible, the nebula was listed in Table II or IV. In such cases the object could conceivably be a small reflection nebula or a very distant star cluster.

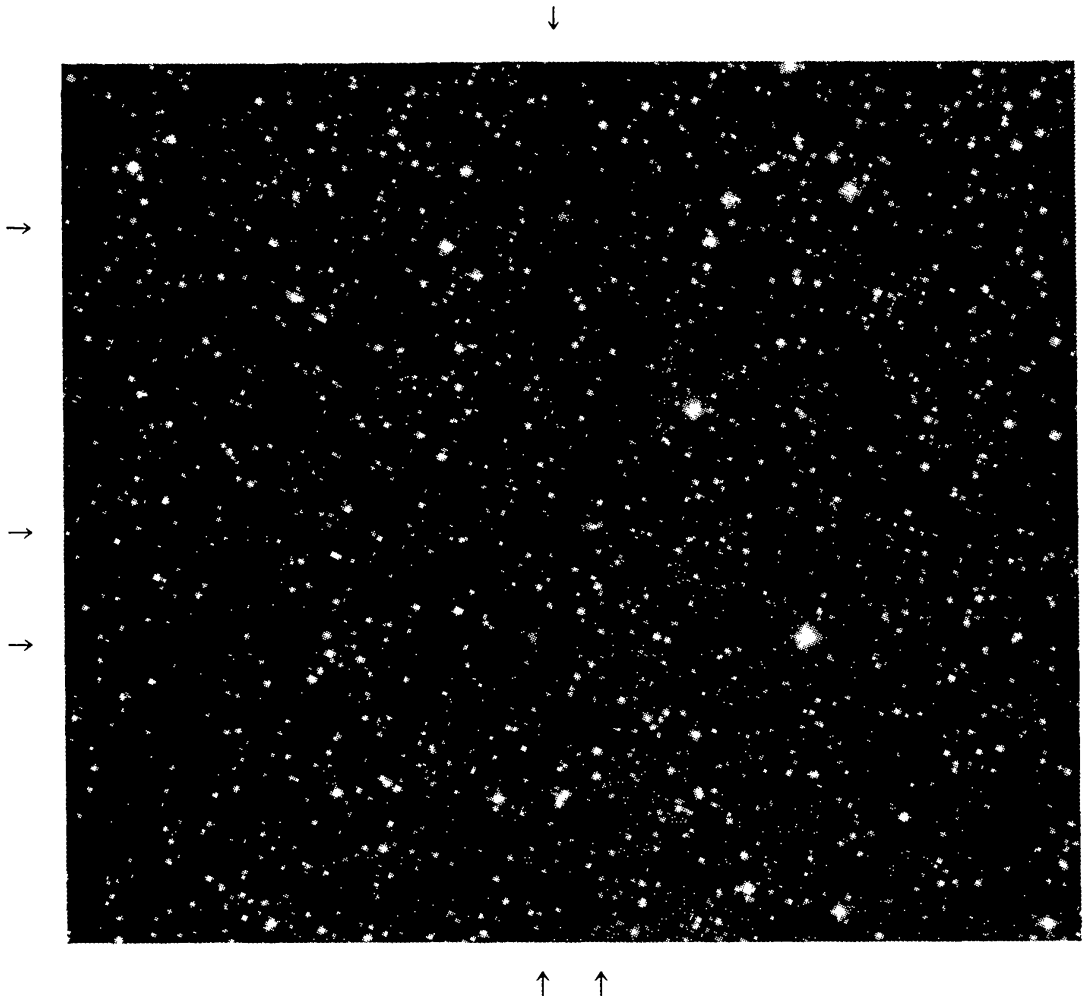
Since most of our objects shown on the Palomar 48-inch Schmidt plates appeared to be red, it was decided to investigate

TABLE III  
EXTRAGALACTIC NEBULAE IN THE ZONE OF AVOIDANCE  
IN AREA V

No.	$\alpha(1950)$	$\delta(1950)$	$l$	$b$	Evidence
1	2 <sup>h</sup> 02 <sup>m</sup> 2	+55°49′	101°1	− 4°7	<i>d, s.n.</i>
2	2 02.3	+55°55′	101°0	− 4°6	<i>d, s.n.</i>
3	3 01.1	+53°58′	109°5	− 3°0	<i>Sch.</i>
4*	4 25.0	+39°31′	129°7	− 5°1	<i>Sch.</i>
5	4 33.5	+43°51′	127°6	− 1°0	<i>Sch., 2 n.</i>
6	4 36.9	+40°12′	130°7	− 2°9	<i>Sch.</i>

\* A small correction to the original, less accurate coordinates brought this object slightly out of the  $\pm 5^\circ$  zone of galactic latitude.

PLATE I



Crossley reflector photograph showing the nebulae Nos. 1 and 2 of Table III and No. 12 of Table IV. The plate was taken August 14, 1955 on a IIa-O emulsion. North is up, east is to the left.

the fainter nebulae with the H $\alpha$  spectrograph constructed and described by Herbig.<sup>2</sup> With this instrument objects with strong H $\alpha$  emission can be picked out easily. If no H $\alpha$  emission could be detected, the objects were also listed in Table II or IV. Again there is a slight possibility that some of these objects might be very distant reflection nebulae or star clusters.

The first five columns of Tables I through IV are self-explanatory. In the last column I have listed the observation from which the conclusion was drawn that the nebula is extragalactic; *d* or *Sch* means that the direct photographs with the Crossley reflector or the Palomar 48-inch Schmidt plates showed spiral structure of the nebula or that the image looked at least like a spiral even when the spiral structure was not resolved. If *d* or *Sch* is not given, the direct photograph showed an approximately elliptical or round, very concentrated nebula. The remark *s.n.* means that in a field of a few square minutes of arc several nebulae could be detected, and *r.s.* indicates that the redshift of H and K could be seen on the spectrogram taken with the nebular spectrograph. If H and K were not well defined but a continuous spectrum was

TABLE IV

NEBULAE IN THE ZONE OF AVOIDANCE IN AREA V THAT ARE  
ALMOST CERTAINLY EXTRAGALACTIC

No.	$\alpha(1950)$	$\delta(1950)$	$l$	$b$	Evidence
7	0 <sup>h</sup> 36 <sup>m</sup> 2	+58°19'	89°1	— 3°9	<i>d, c.s.</i>
8	1 17.3	+57°49'	94°6	— 4°1	<i>s.n., no H<math>\alpha</math></i>
9	1 23.9	+58°14'	95°4	— 3°6	<i>s.n., no H<math>\alpha</math></i>
10	1 54.4	+57°14'	99°6	— 3°8	<i>no H<math>\alpha</math></i>
11	2 00.8	+57°55'	100°2	— 2°8	<i>s.n., no H<math>\alpha</math></i>
12	2 02.4	+55°47'	101°1	— 4°8	<i>d, s.n.</i>
13	2 58.9	+51°50'	110°4	— 4°9	<i>Sch.</i>
14	3 02.2	+54°06'	109°6	— 2°8	<i>Sch., s.n.</i>
15	3 14.8	+51°13'	112°7	— 4°1	<i>Sch.</i>
16	3 23.8	+49°52'	114°7	— 4°5	<i>d, s.n., no H<math>\alpha</math></i>
17	3 33.6	+49°07'	116°4	— 4°2	<i>d, s.n., no H<math>\alpha</math></i>
18	4 00.1	+46°36'	121°3	— 3°4	<i>d, s.n., c.s.</i>
19	4 22.0	+42°39'	127°0	— 3°4	<i>Sch.</i>
20*	4 34.9	+43°58'	128°0	— 0°8	<i>Sch.</i>
21	4 52.0	+43°58'	129°6	+ 1°6	<i>Sch.</i>

\* This object was found on the Palomar 48-inch Schmidt plates.

clearly visible, this is indicated by *c.s.* Objects that were investigated with the  $H\alpha$  spectrograph and did not show any detectable  $H\alpha$  emission are marked *no H $\alpha$* . Lastly, the remark *no em.* means that a spectrogram taken with the nebular spectrograph did not show any emission lines, though it was felt that the exposure time was sufficient to show an emission-line spectrum, while it was too short to show a continuous spectrum.

Table V contains three new planetary nebulae which were found during this survey.

TABLE V  
NEW PLANETARY NEBULAE

No.	$\alpha(1950)$	$\delta(1950)$
1	0 <sup>h</sup> 17 <sup>m</sup> 5	+62°41'
2	0 37.5	+62°35'
3	1 50.4	+56°10'

One object in Area V was identified as a reflection nebula, and one object turned out to be stellar. In Area III one object proved to be stellar, one object is most probably a distant star cluster, and one could not be verified on a Crossley plate but was apparently a defect in the 20-inch astrograph plate. As for all the remaining objects, no decision about their nature has been reached so far.

Altogether, the nature of 52 nebulae in the zone of avoidance in Shane's Areas III and V could be specified: 44 of them are certainly or almost certainly extragalactic nebulae, while 8 of them were found not to be. If we may use this relatively small number of objects for statistical purposes, we may conclude that more than 75 percent of Shane's suspected extragalactic nebulae in the zone of avoidance are indeed galaxies, so that the distribution of these objects as given by Shane and Wirtanen may be expected to be approximately the real distribution.

In Figure 1 I have replotted the distribution in Area V as given by Shane. Only nebulae with  $b$  between  $-5^\circ$  and  $+5^\circ$  have been included. The extragalactic nebulae listed in Table III are marked by filled circles, those listed in Table IV by open circles; those objects whose nature is still unknown are marked

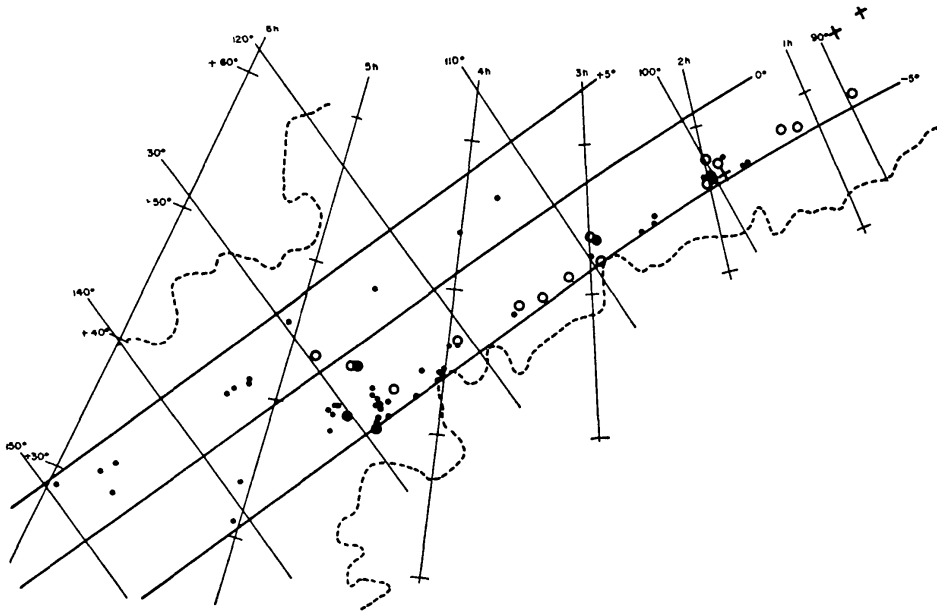


FIG. 1.—The nebulae found in the zone of avoidance in Shane and Wirtanen's Area V. Filled circles represent those nebulae found to be extragalactic, the open circles those which are almost certainly extragalactic, and the dots those whose nature is still unknown. The crosses give the positions of three newly-found planetary nebulae.

by points. The three crosses indicate the three planetary nebulae of Table V. From this figure it is obvious that the obscuring matter in the galactic plane must be extremely thin and full of holes between galactic longitudes  $125^\circ$  and  $130^\circ$ . This is of interest in comparison with the density distribution of neutral hydrogen as investigated by van de Hulst, Muller, and Oort.<sup>3</sup> According to their studies of the 21-cm radiation, we are probably looking through both the Orion and the Perseus spiral arms in this direction. But in spite of this fact their Table 5 shows a relative though not very well pronounced minimum in the amount of hydrogen. In this connection it may be also of interest to mention that Weaver has drawn attention to the scarcity of highly luminous early-type stars in longitudes  $120^\circ$  to  $140^\circ$ ,<sup>4</sup> which probably indicates some kind of a break in the spiral arms not shown so clearly by the 21-cm radiation. A complete comparison between the intensity of the 21-cm radiation and the abundance of extragalactic objects seen near the galactic plane, which may give us some information about the correlation of neutral hydrogen and

interstellar dust, must be postponed until Shane and Wirtanen have completed their counts of extragalactic objects and until the investigation of the 21-cm radiation has been extended to somewhat higher galactic latitudes.

I should like to express my gratitude to Dr. Shane for suggesting this investigation and for many helpful discussions. I am also very much indebted to Dr. N. U. Mayall and Dr. G. H. Herbig for kind advice concerning the observational work.

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<sup>1</sup> C. D. Shane and C. A. Wirtanen, *A.J.*, **59**, 285, 1954.

<sup>2</sup> G. H. Herbig, *J.R.A.S. Canada*, **46**, 222, 1952.

<sup>3</sup> H. C. van de Hulst, C. A. Muller, and J. H. Oort, *B.A.N.*, **12**, 117, 1954 (No. 452).

<sup>4</sup> H. F. Weaver, *A.J.*, **58**, 177, 1953.