THE NEAREST *H* II REGIONS

STEWART SHARPLESS AND DONALD OSTERBROCK*
Yerkes Observatory
Received August 23, 1951

ABSTRACT

Distances and linear dimensions are given for hydrogen emission regions visible on plates taken in the *Hα* region with the Greenstein-Henyey wide-angle camera. Two new large *H* II regions were found surrounding the stars λ Orionis and ζ Ophiuchi and having apparent diameters of about 7° and 10°, respectively.

A survey in *Hα* of the brightest hydrogen emission regions has recently been made with the Greenstein-Henyey wide-angle camera.[1] A Corning 2403 filter was used with Eastman 103*a*-F plates. This combination isolates a spectral band about 300 A wide, centered approximately on *Hα*. The night-sky lines at λ 6300 and λ 6363 are cut out by the filter, and exposures up to 2 hours can be made without objectionable sky background. Comparison exposures were made with no filter on Eastman 103*a*-F plates.

Emission regions were found by comparing the *Hα* and panchromatic photographs, both in a blink microscope and on prints. Many of these regions have been previously detected with the nebular spectrograph[2] at the McDonald Observatory.

For each emission region appearing on the plates an attempt was made to identify the exciting stars. The criteria for this identification were early spectral type (O-B0) and apparent association with the nebulosity. In some cases the excitation is due to a single star, while in others it is due to an entire cluster. Spectral types and luminosity classes for most of these stars were kindly furnished by W. W. Morgan. Spectroscopic parallaxes were computed and then corrected for interstellar absorption by means of the colors of Stebbins, Huffer, and Whitford.[3] The angular sizes of the emission regions were measured from the plates, and their linear dimensions then computed.

Table 1 lists the emission regions, their designations in the catalogue of Struve and Elvey,[2] their galactic co-ordinates, the adopted distance moduli corrected for interstellar absorption, and the measured angular sizes of the emission regions and their computed linear dimensions.

Photographs of the Milky Way from Sagittarius to Cepheus and from Cepheus to Canis Major in *Hα* are reproduced in Figures 2 and 3. In Figures 1 and 4 the emission objects are identified according to their numbers in Table 1. Aside from the discrete emission regions listed here, it appears from the photographs that the Milky Way from Sagittarius to Cygnus is considerably brighter in the spectral interval observed than from Cepheus to Canis Major. This enhancement is relatively greater on the *Hα* plate than on the panchromatic comparison plate, and thus is probably due, at least in part, to a general *Hα* illumination, consisting of a great number of overlapping emission regions.

Two new large *H* II regions were recorded in this survey and are shown in detail in Figure 5. They are excited by the stars ζ Ophiuchi and λ Orionis, respectively. The λ Orionis *H* II region is about 7° in diameter, while the ζ Ophiuchi region is about 10° in length. The lower part of the λ Orionis nebulosity appears on a photograph by H. A.

* Atomic Energy Commission Pre-doctoral Fellow in Astrophysics.

[1] O. Struve, *Sky and Telescope*, **10**, 215, 1951.

[2] O. Struve, C. T. Elvey, and W. Linke, *Contr. McDonald Obs.*, No. 9, 1939.

[3] *Ap. J.*, **91**, 20, 1940.

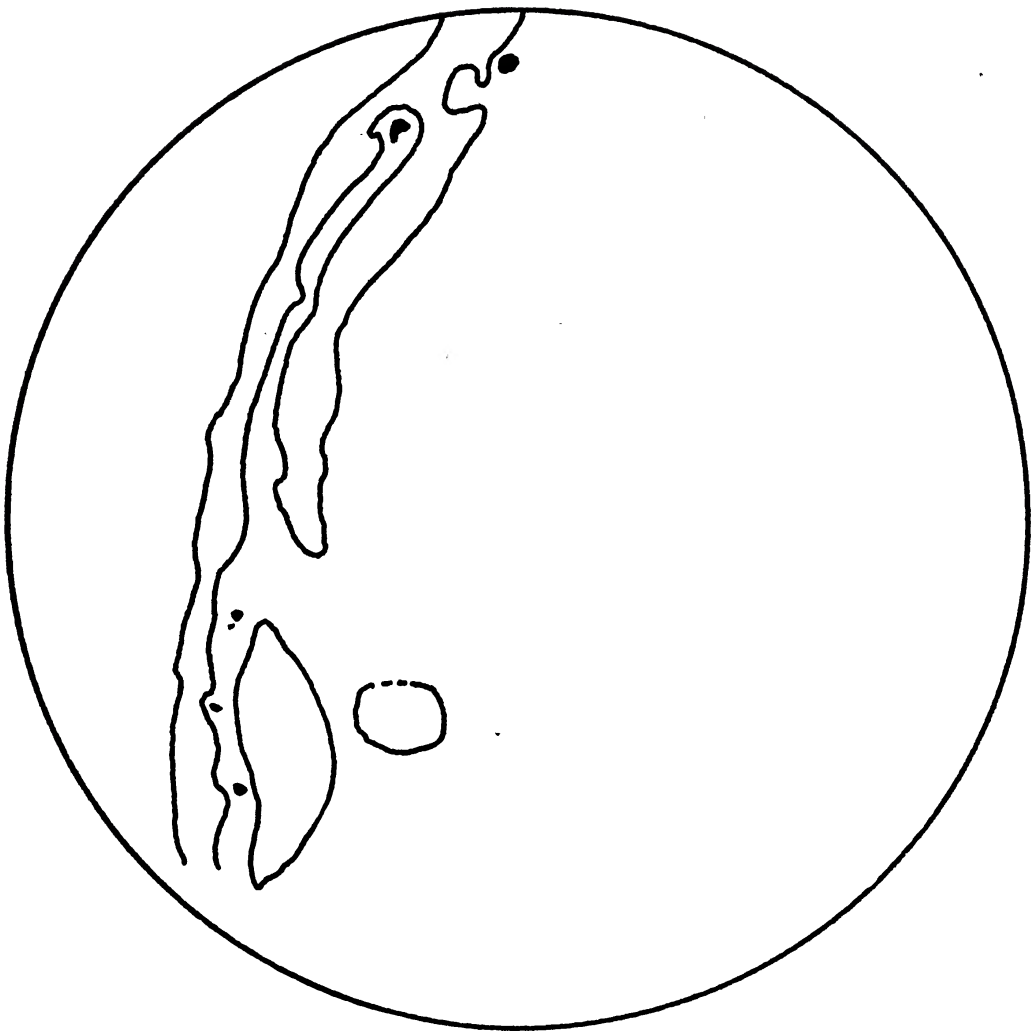

FIG. 1.—The location of the emission regions appearing in Figure 2. Numbers *10* through *16*, except *15*, lie along the Milky Way from top to bottom.

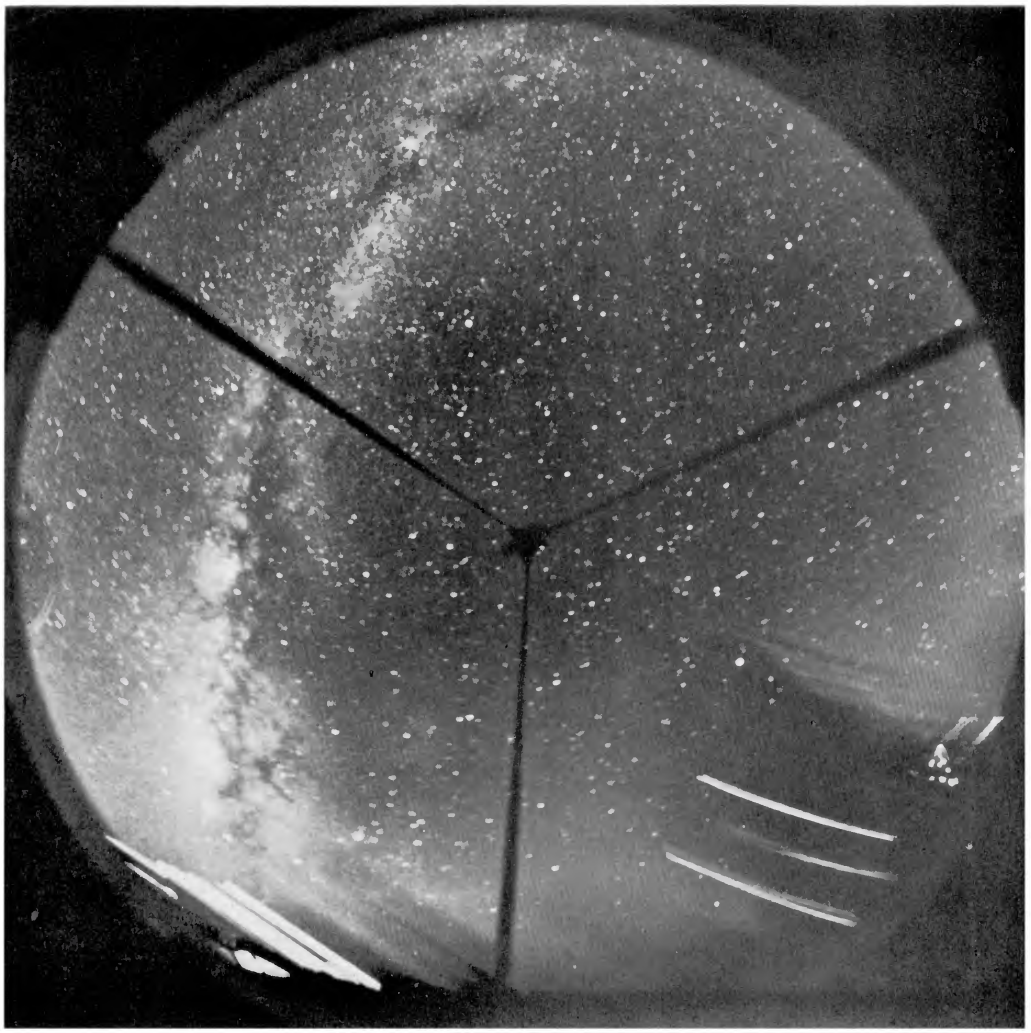

FIG. 2.—The Milky Way from Sagittarius to Cepheus in *Hα*. Exposure, 2 hours on Eastman 103*a*-F emulsion, Corning 2403 filter. The bright lines at the bottom are due to trailed horizon lights.

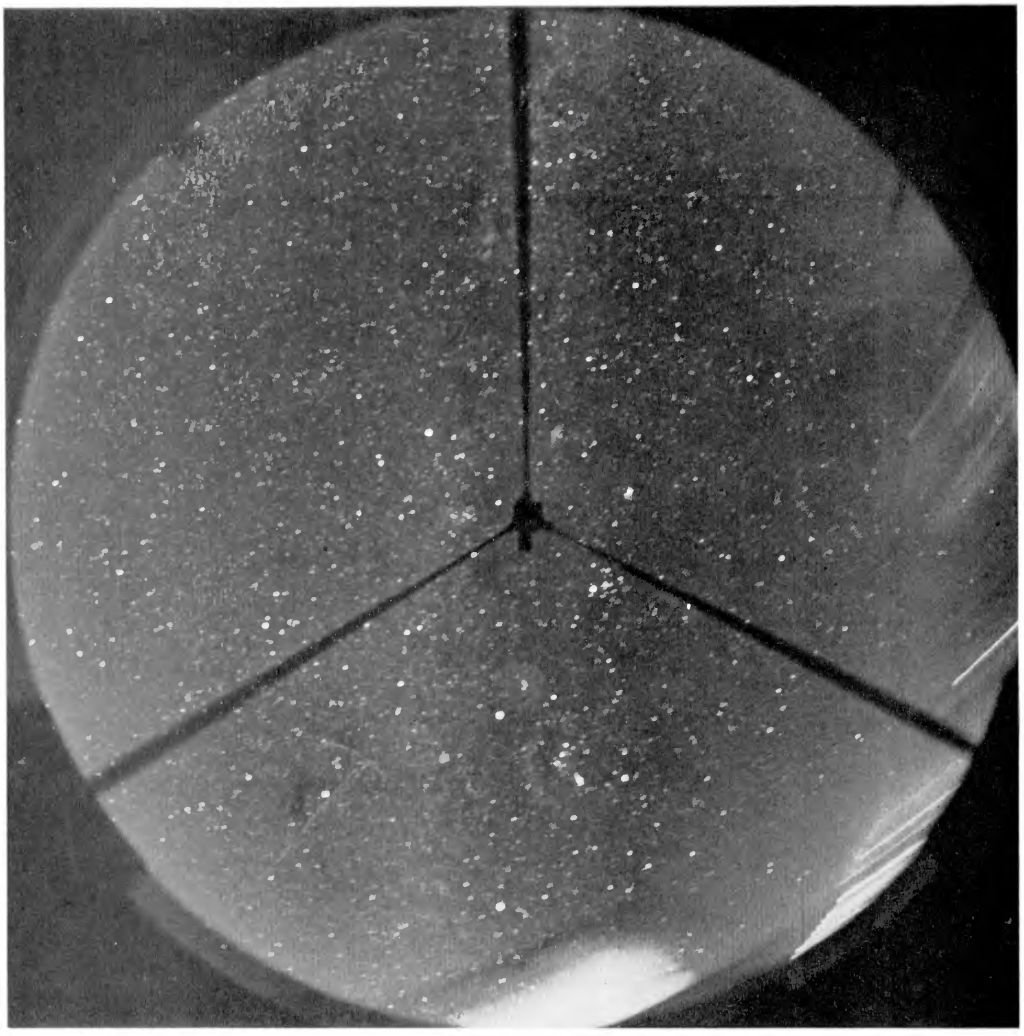

FIG. 3.—The Milky Way from Cepheus to Canis Major in *Hα*. Exposure, 2 hours on Eastman 103*a*-F emulsion, Corning 2403 filter.

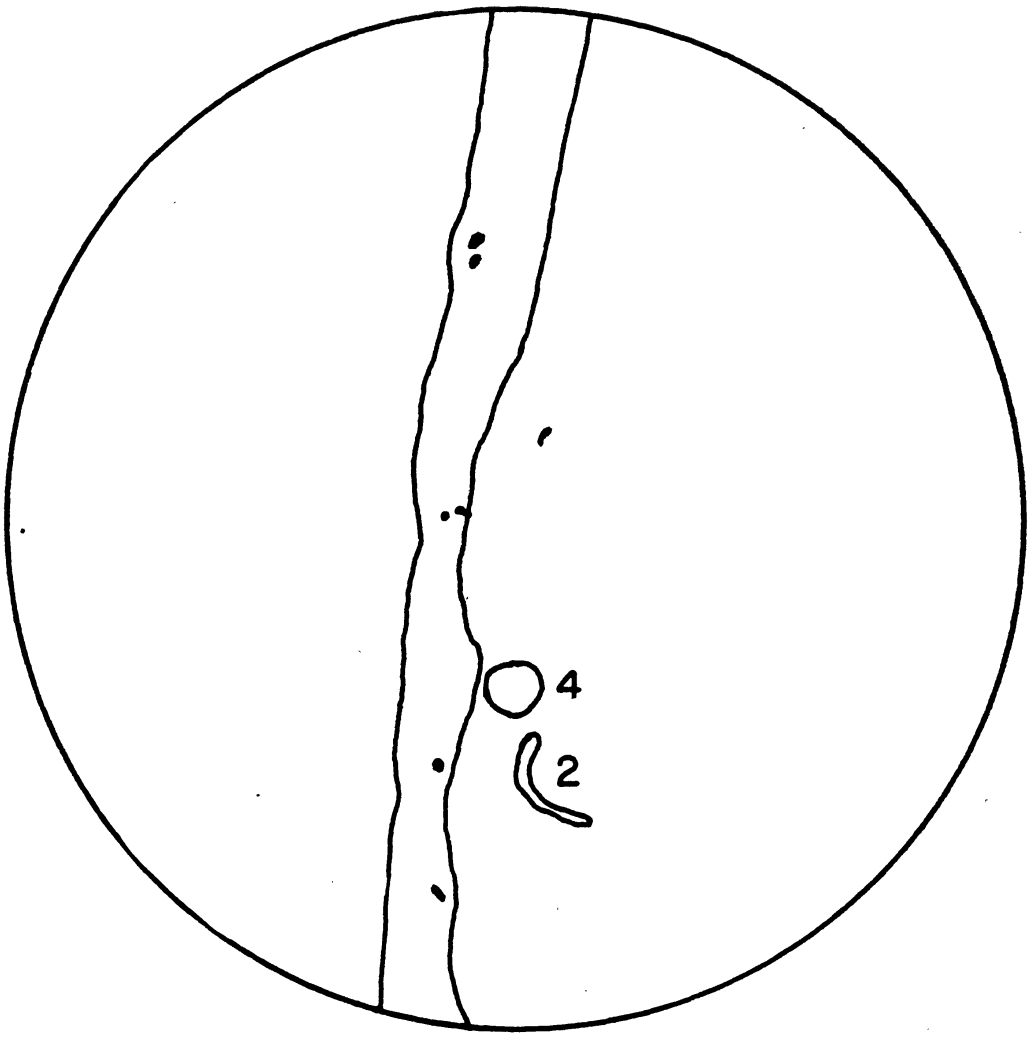

FIG. 4.—The location of the emission regions appearing in Figure 3. Numbers *1* through *9*, except *4* and *2*, lie along the Milky Way from bottom to top.

Lower.[4] The fact that they both appear at intermediate galactic latitude is probably a selection effect, since similar regions near the galactic circle would be lost in the general illumination of the Milky Way. These two emission regions seem to resemble most closely the idealized *H* II regions investigated by Strömgren,[5] since they appear homogeneous and approximately spherical about the exciting star. The apparent irregularities in the ζ Ophiuchi nebulosity are due to foreground obscuring material which can be traced on the blue-sensitive photographs of this region taken by Ross.[6] Knowing the diameters of these regions and the spectral types of the exciting stars, one can use Strömgren's tables[5] to obtain an estimate of the density of hydrogen. The quantity tabu-

TABLE 1

HYDROGEN EMISSION REGIONS

	Object	McD.	*l*	*b*	$m_0 - M$	Angular Dimension	Linear Dimension (Parsecs)	Remarks
1...	IC 2177	45	192°	+ 1°	10.2	2°.5×1°.3	48×25	
2...	Orion Loop	41	177	−18	8.0	12×7.2	84×50	Barnard's Great Curved Nebula
3...	NGC 2244	55	173	+ 1	10.0	1.2	21	12 Mon Cluster
4...	λ Ori	4	162	−10	8.9	6.8	71	
5...	IC 410	.....	141	− 1	12.7:	0.6	37	
6...	IC 405	.....	140	− 1	8.6	1.4	13	Excited by AE Aur
7...	NGC 1499	5	127	−13	7.4	2.4×0.8	13×4	Excited by ξ Per
8...	BD+59°522	29	105	+ 1	11.5*	1.8×0.8	63×28	
9...	NGC 1027	27	103	+ 1		2.1×1.6	73×56	
10...	IC 1396	22	67	+ 3	9.5	2.8	39	Excited by HD 206267
11...	NGC 7000	.....	53	− 1	9.8	2.1	33	North America Nebula; excited by HD 199579
12...	NGC 6604	.....	346	0	10.7	1.2	29	
13...	NGC 6611	.....	345	− 1	12.6:	0.7	40	M 16
14...	NGC 6523	.....	334	− 3	10.3	1.0×0.5	20×10	M 8
15...	ζ Oph	.....	334	+23	5.8	9.6	24	
16...	IC 4628	69	323	− 1	9.4	2.5	33	Excited by HD 159176

* Assumed to be at the same distance.

lated by Strömgren is $s_0 \times N_H^{2/3}$, where s_0 is the radius of the emission region and N_H is the number of hydrogen atoms or ions per cubic centimeter. The results of the computations are given in Table 2. The computed values of N_H are tabulated under the two assumptions: A, that the hydrogen is uniformly distributed, and B, that the hydrogen is nonuniformly distributed but with 5 per cent of the volume occupied by small clouds. These results agree fairly well with other determinations[5, 7] of the density of hydrogen in interstellar space.

It should be noted that HD 199579 has been taken to be the exciting star in the case of the North America Nebula, rather than α Cygni, as has been previously assumed. The former is a sixth-magnitude O6 star near the densest part of the nebulosity. Assuming that HD 199579 is the exciting star, one finds a density of hydrogen of 15 ions/cc and an emission measure,[5] which is proportional to the surface brightness, of about 8000. For the faintest nebulosities, around λ Orionis and ζ Ophiuchi, the emission measures are

[4] *Ap. J.*, **89**, 137, 1939.

[5] *Ap. J.*, **89**, 526, 1939; **108**, 242, 1948.

[6] Unpublished photographs in Yerkes plate collection.

[7] R. Minkowski, *Pub. A.S.P.*, **61**, 151, 1949.

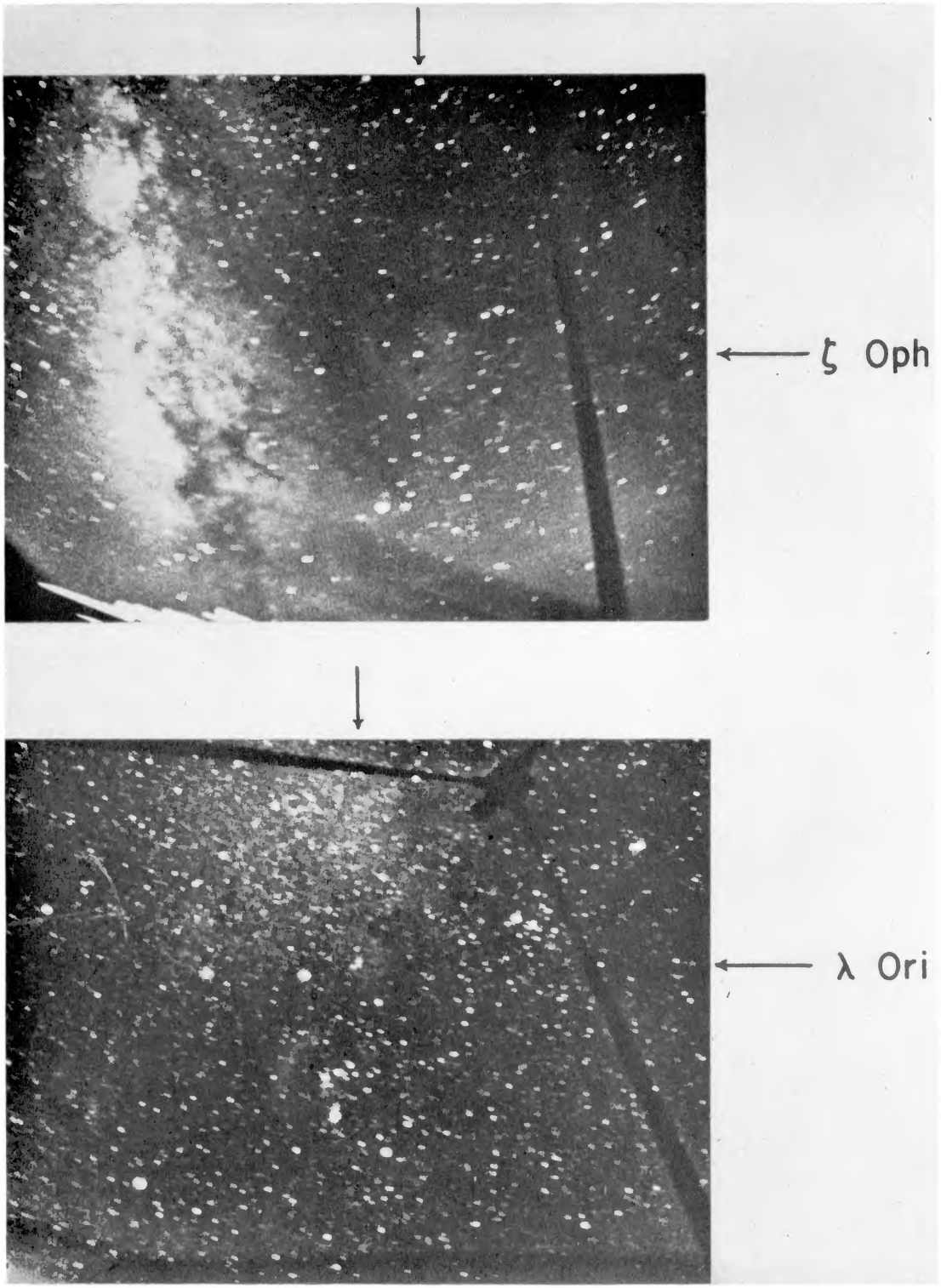

FIG. 5.—Enlargements of the regions of the ζ Ophiuchi nebulosity (*upper*) and the λ Orionis nebulosity (*lower*). These reproductions have been copied to higher contrast.

about 500. The assumption of α Cygni as the exciting star, however, leads to a density of 0.3 ions/cc and an emission measure of 3, which would make the nebula too faint to be observed.

TABLE 2

DENSITY OF HYDROGEN

OBJECT	SPECTRUM*	DIAMETER (PARSECS)	$s_0 \times N_H^{2/3}$	N_H (CM^{-3})	
				A	B
λ Ori.....	O8	71	66	2.5	11
ζ Oph.....	O9.5 V	24	36	5.2	24

* W. W. Morgan, unpublished.

The emission regions listed in Table 1 seem to be identical in nature with those in the Andromeda nebula studied by Baade and Mayall.[8] Their sizes are, on the average, the same, and they are associated in both cases with high-luminosity objects of population I.

We are indebted to W. W. Morgan for his advice regarding this investigation.

[8] *Problems of Cosmical Aerodynamics* (Dayton, Ohio: Central Air Documents Office), p. 185.