SMALL DARK NEBULAE

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ABSTRACT

Attention is drawn to the small, round, dense dark nebulae with diameters varying between 5′ and 10′. We propose that these be named "globules." The region of Messier 8 abounds in globules. Published photographs show at least sixteen of them projected against the bright background of the diffuse nebula. At the derived distance of 1260 parsecs for Messier 8, the diameters of twelve of the sixteen observed globules are between 10,000 and 35,000 A.U. It is noteworthy that there is no evidence for globules in the region of the Orion nebula.

At least twenty of the dark objects in Barnard's lists are true globules. A preference is shown for the regions of Sagittarius and Ophiuchus and for the Scutum Cloud, but some isolated examples of large globules (with diameters of the order of 100,000 A.U.) are found in the anticenter region.

The estimated *minimum* absorptions for the small globules are 2–5 mag. The larger globules are more transparent (1 mag.).

In recent years several authors have drawn attention to the possibility of the formation of stars from condensations in the interstellar medium.[1] It is therefore necessary to survey the evidence for the presence in our galaxy of relatively small dark nebulae, since these probably represent the evolutionary stage just preceding the formation of a star.

In the early days of astronomical photography, Barnard drew attention to the prevalence of small dark objects, and his famous two lists of dark objects in the sky are still our best source in the field.[2] Since Barnard's days there have been published many excellent photographs of bright nebulae and of Milky Way regions, notably the Lick atlas[3] and the Ross-Calvert *Atlas*.[4] The new Schmidt cameras, with their short focal ratios and excellent definition and with scales comparable to those of the standard astrographic cameras, provide new opportunities for the search for, and detection of, small dark nebulae.

In connection with the possible evolutionary process referred to above, we are primarily interested in roundish, small dark nebulae. We shall omit here from consideration the wind-blown wisps of dark nebulosity that are seen in large numbers in many parts of the sky and shall concentrate our attention on the approximately circular or oval dark objects of small size. We shall for convenience refer to these as "globules."

Our search for globules has proceeded along two lines. We have examined with care the best available photographs of some of the well-known diffuse nebulae and listed the globules that can be seen projected against the luminous background. We have, further, examined a representative number of prints of the Milky Way photographs and marked on them the objects which satisfy our definition of a globule.

The first region to be investigated was that of Messier 8, a region for which an excellent photographic print is available in the Lick atlas. To guard against defects, this photograph was compared with other published photographs of this diffuse nebula,

[1] Spitzer, *Ap. J.*, **94**, 232, 1941; Whipple, *Ap. J.*, **104**, 1, 1946.

[2] *Ap. J.*, **49**, 1, 1919, and Barnard's *Photographic Atlas of Selected Regions of the Milky Way* (1927), Introd., p. 18.

[3] Moore, Mayall, and Chappell, *Astronomical Photographs Taken at the Lick Observatory.*

[4] *Atlas of the Northern Milky Way.*

notably a photograph by Duncan[5] and an original print of a plate taken by Struve and Elvey at the prime focus of the 82-inch reflector at McDonald Observatory.[6]

In 1908, Barnard[7] noted that there are "a number of very black, small, sharply defined spots or holes" among the markings of Messier 8. A similar observation was made by Duncan. The Lick photograph reveals the presence of twenty-three potential globules. Of these, sixteen are round and range in diameter from 6″ to 1′, and seven are irregular. The measured diameters of the sixteen true globules are distributed as shown in the accompanying tabulation. The dimensions of the irregular objects range from

Approx. Diam.	No.	Approx. Diam.	No.
0″–10″	1	30″–40″	1
10 –20	8	40 –50	1
20 –30	4	50 –60	1

6″ × 60″ and 12″ × 24″ to 60″ × 84″ and 36″ × 216″. Some of these are of an oval shape, with small dark streamers extending from them.

Since the globules are seen projected against the diffuse nebula, Messier 8, their distances must all be smaller than that of the diffuse nebula. The distance of Messier 8 can be determined with a fair degree of accuracy, since we have, apparently associated with the nebula, the galactic cluster NGC 6530. This region has recently been the subject of a careful study by Wallenquist,[8] who obtains $m - M = 11.00$ as the value for the distance modulus, uncorrected for absorption. This value for the distance modulus agrees well with that of 11.05 for the two stars of spectral class Oe5 and B0, which, according to Hubble,[9] are most likely to be responsible for the emission nebula.

To derive the probable distance, we must first apply a correction for absorption. Four stars in the region are in the list of Stebbins, Huffer, and Whitford,[10] and we find from the observed excesses that the total photographic absorption for $m - M = 11.0$ equals 0.6 mag. The derived distance of Messier 8 is then 1260 parsecs, corrected for absorption.

The globules viewed against Messier 8 are, therefore, at the maximum distance of 1260 parsecs. The *maximum* linear diameters of the globules can, therefore, be computed on the assumption that 1″ = 1260 A.U. We find, then, that the maximum diameters of the globules viewed against Messier 8 range from 7000 to 80,000 A.U., with twelve of the sixteen globules having diameters between 10,000 and 35,000 A.U.

The evidence for other large bright nebulae shows that the population of globules viewed against the luminous background of Messier 8 is unusually large. The Trifid nebula, which is a close neighbor of Messier 8, shows, for example, at the most, only three or four objects that could be called globules, and in other parts of the sky globules seem almost totally absent. The Orion nebula is apparently free from superimposed globules, which is all the more surprising since there is plenty of obscuring matter associated with it. Another instance of a bright nebula without globules is the delicate California nebula in Perseus.

The emission nebula near η Carinae is also rich in globules. The general appearance is very much like that of Messier 8. At least a dozen globules can be recognized on a plate taken with the 60-inch Rockefeller reflector of the Boyden Station.

In our further search for globules, we have examined the dark objects in Barnard's lists.[2] It is not a simple matter to draw the line between true globules and minor condensations in dark lanes or in regions of variable obscuration. From an inspection of the beautiful prints in Barnard's *Atlas* and in the Ross-Calvert *Atlas* we find, however, at least twenty unmistakable globules.

[5] *Ap. J.*, **51**, 5, 1920.

[6] See Bok and Bok, *The Milky Way*, Fig. 65

[7] *A.N.*, **177**, 234, 1908.

[8] *Uppsala Ann.*, Vol. 1, No. 3, 1940.

[9] *Ap. J.*, **56**, 184, 1922.

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

The regions of the star clouds in Sagittarius and Ophiuchus are rich in clearly marked globules. Plate 21 in the Barnard *Atlas* shows numerous objects that stand out against the bright stellar background. Barnard 68, 69, 70, and 255 (in the region near θ Ophiuchi) appear very similar in character to the globules in Messier 8. If one assumes that they are at the distance of the near-by dark nebulae in Ophiuchus, one finds diameters of the order of 30,000 A.U. for some of the best-defined objects. They seem to occur at the rate of one per square degree in the regions where the star density is sufficient to show them by contrast to the background.

A few exceedingly small and distinct globules are seen projected against the Scutum Cloud. It is unlikely that the linear diameter of Barnard 117 or 118 is much in excess of 20,000 A.U. About half-a-dozen globules can be recognized in this section.

The situation in Cygnus and Cepheus is of interest, since in this transition region there are indications for the presence of a few round dark holes, such as Barnard 350. The stellar background is, however, not sufficiently dense in this section to show the globules as clearly as for the Sagittarius-Ophiuchus section. A few globule-like dark spots are seen projected against the North America nebula, but these are more generally hazy and not nearly so distinct as the globules seen projected against Messier 8.

In Perseus, Auriga, and Gemini the stellar background is too thin to permit the detection of many globules. Only the larger objects cover sufficiently large areas to be detectable. Barnard 34 in Auriga, 201 in Perseus, and 227 in Gemini are among the clearest "dark holes" in the anticenter region. Their diameters are large, 10′–20′, which, in all probability, means that the corresponding linear diameters are of the order of 100,000 A.U. or more.

It is not a simple matter to measure the total photographic absorptions produced by the globules. The small ones, seen projected against diffuse nebulae, show no stars shining through them; and the best that we can do is to estimate a *minimum* absorption by comparing the surface brightness in the globule with that in the outer parts of the diffuse nebula. Because of possible overlying bright nebulosities, this represents, at best, a minimum estimate for the absorption, which, for the globules with diameters of 10,000–35,000 A.U., proves to be between 2 and 5 mag.

For some of the larger globules, absorptions can be estimated with greater accuracy, since stars shine through them in considerable numbers. Stoddard[11] has made star counts according to photographic and photovisual magnitudes for four large globules in Barnard's list, Barnard 34, 201, 226, and 227. He finds the average total photographic absorptions to be of the order of 1 mag. Star counts on plates taken with the Harvard Jewett-Schmidt telescope confirm this estimate. It is worth noting that these four objects are all in the anticenter section of the Milky Way and that their minimum diameters are of the order of 100,000 A.U.

The cosmological status of the globules was considered in a paper presented at the Harvard Observatory Centennial Symposium on Interstellar Matter (December, 1946). The globules are interesting objects, which deserve further study by the powerful Schmidt telescopes now being put into operation. Every one of them merits further careful study with the largest available reflecting telescopes. Star counts in blue, red, and infrared light should be supplemented with measurements of surface brightness for the globules and for neighboring "unobscured" areas of comparable size.

[11] *Ap. J.*, **102**, 267, 1945.