

DETECTION OF NEW NEBULÆ BY PHOTOGRAPHY.

THE advantages of a photographic doublet over the ordinary photographic objective for astronomical work have already been pointed out by the writer elsewhere. Not only may a far larger field be covered by each photograph, but a much larger angular aperture may be employed. The greatest advantage is attained in photographing a faintly illuminated surface. If the angular aperture be defined as the linear aperture divided by the focal distance, the amount of energy received on any portion of a sensitive plate exposed to the image of a given surface will be nearly proportional to the square of this quantity. The angular aperture of an ordinary objective seldom exceeds one twelfth, that of a photographic doublet is often greater than one sixth. The latter will therefore accumulate more than four times as much energy as the former. If the time required to produce an image were that required to receive a certain amount of energy, the doublet would photograph a faint object in one fourth part of the time required, under the circumstances above supposed, by an ordinary lens. In reality the difference is greater, since with a given lens the requisite time of exposure is more than doubled when the brightness of the object photographed is reduced by one half. A limit is reached with the most sensitive plates that have been made when applied to astronomy, owing to the light of the background or sky. Long exposures cannot be made in moonlight, or indeed on any night in the vicinity of a large city where electric lights are used. Evidently one of the most important applications of the principles described above is to photographing nebulæ. An attempt has therefore been made to enumerate all the nebulæ photographed in a given portion of the sky, and compare the result with that of existing catalogues. From this we may infer whether it is probable that the number of known nebulæ may be greatly increased by this method. The region selected extended from $5^h 10^m$ to $5^h 50^m$ in right ascension, and from -10° to $+5^\circ$ in declination. The Nebula of Orion is near the centre of this region, and several photographs had already been taken of it at the Harvard College Observatory. The

instrument employed was the Bache telescope, which has a photographic doublet with an aperture of 8 inches and a focal distance of 44 inches. Each plate covers a region ten degrees square, the definition being good in a central circular area about seven degrees in diameter.

The examination of the plates was made by Mrs. M. Fleming, according to the following method. Each plate was laid on a frame inclined at an angle of 45° , and the light of the sky reflected through it by means of a horizontal mirror. Each portion of the plate was then studied with a magnifying glass, and the co-ordinates of every object resembling a nebula were measured. The approximate right ascensions and declinations of these objects were next determined from the configuration of the adjacent stars on the charts of the *Durchmusterung*, which are upon the same scale of two centimetres to a degree. A comparison was next made of all the objects detected upon any of the plates. The results of these two examinations are indicated by the following letters: A denotes that the object was found in the original examination of the plate; B, that, although overlooked at first, it was detected when looked for; C, that on the second examination its confirmation was doubtful; D, that it was not confirmed; and E, that the region was not contained upon the plate. A repetition of the letter A indicates that the object was found independently on different plates; of B, that it was confirmed when its position was known, although in general too faint to be detected independently; C does not confirm, and D indicates that the object may be a defect in the plate; E gives no evidence one way or the other. Four plates were examined in this way. A fifth plate, 2414, was used to check the results of the others. In the following description the first number refers to the series of plates taken with the Bache telescope.

2312. February 6, 1888. Exposure 90^m . Declination -10° to 0° .

2325. February 7, 1888. Exposure 187^m . Declination -10° to 0° . Images elongated owing to the length of the exposure, and bent up at the ends owing to the differential refraction. The back of the plate was covered with shellac and lampblack, to absorb the light reflected from the rear surface of the plate.

2335. February 13, 1888. Exposure 77^m . Back of plate varnished like 2325. Declination -7° to $+3^\circ$.

2414. March 4, 1888. Exposure 78^m . Declination -5° to $+5^\circ$. The clock ran badly during this exposure, so that each star formed two images connected by a trail.

2423. March 6, 1888. Exposure 69^m . Declination -5° to $+5^\circ$.

In the following table, a number for reference is followed by the approximate right ascension and declination for 1855, by the letters indicating the result of the

examinations as described above, and by a final column giving the probable conclusion. The letter κ denotes that the object is a known nebula, occurring in the recent Catalogue of Nebulæ prepared by Dr. J. L. E. Dreyer (Memoirs of the Royal Astronomical Society, XLIX., Part I., page 1). \mathfrak{N} denotes that the object is a nebula, and, as it does not occur in the Catalogue mentioned above, we may infer that it has not previously been detected. \mathfrak{D} denotes that the object is probably a defect in the plate. All doubtful objects were carefully examined a third time, and a direct comparison of the plates generally left little uncertainty. A further description of these objects will be found in the remarks following the table.

TABLE I.
LIST OF NEBULÆ.

No.	R.A. 1855.	Dec. 1855.	Exam.	Res.	No.	R.A. 1855.	Dec. 1855.	Exam.	Res.
	<i>h. m.</i>	$^{\circ}$ /				<i>h. m.</i>	$^{\circ}$ /		
1	5 15.2	+3 24	E E A C	D	15	5 29.5	-6 45	A A C E	N
2	19.0	-8 40	A D E E	D	16	29.6	-6 36	A B C E	N
3	24.3	-0 19	C A C E	D	17	31.5	-7 10	A B E E	N
4	25.1	-4 36	A B C E	N	18	31.6	-6 40	C A C E	D
5	25.3	-8 11	A B E E	N	19	32.9	-1 32	A A C C	N
6	25.8	-0 22	C A C D	D	20	33.6	-1 34	A A A C	N
7	26.0	-0 43	A A A A	N	21	33.8	-2 29	A A A B	N
8	26.0	-1 56	A D D D	D	22	34.3	-2 20	A A A A	K
9	26.3	-0 25	A A A A	N	23	34.5	-1 50	A A A A	K
10	28.0	-4 59	A A A A	K	24	35.7	-2 23	A A B A	N
11	28.0	-6 9	C A C E	K	25	39.3	+0 1	A A A A	K
12	28.2	-5 50	A A A E	K	26	39.6	+0 16	A A A A	K
13	28.5	-3 35	A D D D	D	27	41.3	+0 21	D D D A	D
14	29.4	-0 20	A A A A	N					

REMARKS.

- In Plate 2335, DM. +3° 871, magn. 5.3, is situated a little outside the limits of the photograph. A band of nebulous light, however, extends about 10' south of it. As this nebulosity is not confirmed by Plates 2414 and 2423 it is probably due to a defect.
- Dreyer 1927 has the position, R.A. 5^h 14.4, Dec. -8° 30', and is described as a diffused nebulosity. No such object is visible in the photographs in this position, but on Plate 2312 a straight nebulous line extends from DM. -8° 1119 in R.A. 5^h 19^m.0, Dec. -8° 40', to DM. -8° 1132 in R.A. 5^h 21^m.6, Dec. -8° 50'. It passes through about sixteen faint stars upon this line. Most of these stars are also visible on Plate 2325, but the nebulosity is not perceptible there. Although perhaps a defect in Plate 2312, the resemblance to the nebulous lines found by the MM. Henry in the Pleiades is striking.
- An irregular patch of nebulous light about 8' in diameter, 6' north of δ Orionis and preceding that star 0^m.3. Probably a defect, as it is not confirmed by Plate 2312, 2335, or 2414.
- Very faint nebulosity preceding and a little south of DM. -4° 1162. Not confirmed by Plate 2414.
- Faint nebulosity about 2' in diameter.
- Nebulous patch about 5' in diameter.
- Irregular oval ring having diameters 3' by 5'. The position angle of the larger axis is about 165°.
- Narrow line about 10' long, doubtless a defect of Plate 2312.
- Nebula about 2' in diameter, brightest on following side.
- Nebulosity surrounding ϵ Orionis. Dreyer 1973, 1975, and 1977 are portions of this nebulosity where the condensation of light is sufficient to be visible to the eye. The photo-

- graph gives it an extension of $2^m.0$ in right ascension and of $2'.5$ in declination. As it is connected on the following side by nebulosity with the Great Nebula of Orion, true limits cannot be given in this direction. The photographs of this nebula are nearly equal to the best drawings yet made of the Great Nebula of Orion, both in extent and in the amount of detail shown.
11. A nebulous band extends south preceding from DM. $-6^\circ 1234$ for about $6'$. Plate 2325 shows that the whole of this region is included in No. 12. Dreyer 1980 is near, and perhaps refers to this object.
 12. The Great Nebula in Orion, Dreyer 1976. With the sensitive plates and large aperture of the instrument here employed, the central portion of this nebula is burnt out with an exposure of an hour over a region of about $-1^m.0$ in right ascension and $15'$ in declination. The entire nebulosity extends continuously from about $5^h 26^m.0$ to $5^h 30^m.0$ in right ascension, and from $-4^\circ 40'$ to $-6^\circ 10'$ in declination. It therefore includes Nos. 11 and 12. The bright nebulosity Dreyer 1982, north following the Great Nebula, is connected with it by a nebulosity which photographs so intensely that the details of its structure are not well shown with long exposures.
 13. Defect in Plate 2312.
 14. Faint nebula about $5'$ in diameter.
 15. A large patch of faint nebulosity, probably connected with No. 12. Dreyer 1999 is near here, but the description given is unlike that of this object.
 16. Perhaps this object should have been included with No. 15.
 17. Nebulous band $3'$ wide extending $10'$ north preceding from DM. $-7^\circ 1142$. Probably connected with No. 12 through No. 15.
 18. Nebulous band $3'$ wide extending $5'$ south preceding from DM. $-6^\circ 1275$. Probably a defect in Plate 2325.
 19. Nebulosity surrounding DM. $-1^\circ 1001$.
 20. Well-marked nebulosity surrounding DM. $-1^\circ 1005$. Unlike most nebulous stars, the nebulosity does not fade away towards the edges. It looks rather like an irregular oval nebula on which a star was superposed.
 21. A large nebulosity extending nearly south from ζ *Orionis* for about $60'$. More intense and well marked on the following side, with a semicircular indentation $5'$ in diameter $30'$ south of ζ . All good plates of this region show this object, and it has been used here as a test for some time. Attention was called to it in a letter of March 28, 1887, describing copies of some of these photographs sent to the Astrophotographic Congress of 1887. This object and No. 23 are probably the same as those referred to by Admiral Mouchez in the "Rapport Annual sur l'État de l'Observatoire de Paris pour l'Année 1887."
 22. Dreyer 2023. The nebulosity, which is mainly on the following side, takes the form of several spiral rays.
 23. Dreyer 2024. An irregular nebulosity next following ζ *Orionis*, showing a very marked structure. A greater amount of detail is shown in this nebula than in any of the others of this list except Nos. 10 and 12.
 24. Nebulosity surrounding DM. $-2^\circ 1350$.
 25. Dreyer 2068, or Messier 78, is identical with this object. Dreyer 2064 preceding $0^m.4$ south $5'$, and Dreyer 2067 preceding $0^m.2$ north $2'$, are shown in Plates 2312, 2325, 2335, and perhaps in 2423. They appear to be connected by a nebulous band passing on the preceding side of Dreyer 2068, which does not include it.
 26. Dreyer, 2071.
 27. Defect in Plate 2423.

The total number of clusters and nebulae in this region which are contained in Dreyer's Catalogue is eighteen. Besides those mentioned above are the following:—

1908. Very diffused nebula suspected by Herschel. Suspected in Plates 2312 and 2325; not seen on the other plates.

1924. Not seen on any of the plates. Plate 2423 does not contain this region

1980. Included in No. 12.

1981. Coarse cluster, well shown on all the plates.

1990. Including ϵ *Orionis*. Suspected on 2312, 2325, and 2335; not contained on 2423.

It therefore appears that fourteen of these objects are contained in Dreyer's Catalogue and the photographs. Four in the Catalogue are not photographed. Twelve are detected by the photographs which are probably new. The region covered is about four one-thousandths of the entire sky, and the total number of objects in Dreyer's Catalogue is 7840. If the same proportion held, we might expect to discover four or five thousand such objects by photographing the entire sky. The vicinity of the Nebula of Orion has been so carefully studied by astron-

omers, that a still larger proportion of new objects might be found in other regions. Moreover, the southern sky has been comparatively neglected, and doubtless many faint nebulæ have escaped detection there. As the telescope employed covers so large a field in each photograph, it would not be a large piece of work to cover the entire sky. Only four hundred plates would be required, if there were no losses by overlapping or defective plates.

There is one consideration that may seriously modify this conclusion. The successive improvements in photography have continually increased the limits of the Nebula in Orion. These plates show that it not only includes the sword-handle, ϵ , ι , and θ , but a long nebulosity extends south from ζ , others surround this star, while others both north and south indicate that perhaps the next increase in sensitiveness of our plates will join them all in a vast nebula many degrees in length. Another effect may be due to accident, but appears to be connected with the presence of the Great Nebula. While the region around it is crowded with minute stars, its immediate vicinity is much freer from them, and the same effect is noticeable on the preceding side of No. 21. A similar effect is shown around the large nebulæ enshrouding the Pleiades, which appear to be of the same character.