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THE DISTANCE OF THE ORION NEBULA*

By Robert J. Trumpler

The fainter stars situated in the central part of the *Orion* nebula, in the immediate neighborhood of the Trapezium, form a well-marked cluster quite comparable with other galactic star clusters; for convenience we may call it the Trapezium cluster. This cluster is not well shown on ordinary photographs on account of the great brightness of the nebula in which it is imbedded. It is, however, possible to bring out the fainter stars by eliminating with suitable color filters most of the nebular emission. Plates sensitized with kryptocyanin and a deep-red filter (No. 70 of the catalogue of the Eastman Kodak Company) were used. For this combination, light between wavelengths 7000 and 7600 A.U. is effective, and this region contains only a relatively faint nebular emission at 7300 A.U. due to *O*II. A one-hour exposure was made with the Crossley reflector which reaches about the fifteenth magnitude and shows more stars than have so far been observed in this region; forty-one stars were counted within a circle of 1′ radius drawn around the center of the Trapezium, while a similar circle of 2′ radius contains sixty-two stars. The Trapezium cluster is thus characterized by a strong concentration toward the center, where we have thirteen stars per square minute as compared with two stars per square minute in the surrounding ring.

The distance of the Trapezium cluster was determined by the same methods which the writer[1] has used for galactic star clusters in general; in the first place from apparent magnitudes and spectral types of the stars, in the second place from the apparent angular diameter and classification of the cluster.

Accurate photographic magnitudes for the brighter stars were obtained with a 4-inch Ross lens of 60-inches focal length mounted on the Crocker telescope. Four comparisons with the north polar sequence were made with exposures short enough

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[1] *Lick Obs. Bull.*, 14, 154, 1930.

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to eliminate any effect of the nebula on the intensity of the star images. Seventeen stars, situated within 11′ from the center of the Trapezium, were observed with the one-prism slit spectrograph attached to the 36-inch refractor, using a 12-inch camera for the brighter stars and a 6-inch camera for the fainter ones. On some of these spectrograms the nebular emission lines are superposed on the star spectrum but are not strong enough to disturb the spectral type estimates. In Table I the stars are listed in the order of apparent brightness, and are designated by their numbers in *Bond's Catalogue,*[2] those of the Trapezium being marked by *T*. The photographic magnitudes and spectral types determined by the writer are found in the second and third columns.

TABLE I

PHOTOGRAPHIC MAGNITUDES, SPECTRAL TYPES AND COLOR INDICES OF 17 STARS IN THE TRAPEZIUM CLUSTER

No. Bond	Photographic Magnitude	Spectral Type	$m - M$	Color Index	Color Excess
585	$5^m.13$	B1	$8^m.9$	$-^m.04$	$+^m.26$
628T	5.44	O9	10.1	+.08	+.44
708	6.24	B2s	8.3	−.29	−.03
619T	6.81	B1.5s	9.2	−.03	+.25
640T	6.81	B1.5s	9.2	−.04	+.24
734	6.97	B1.5s	9.4		
624T	7.95	B6n	8.8	+.02	+.16
741	8.17	B6n	9.0		
570	8.31	B3	9.7		
505	8.70	B9n	8.4		
724	9.25	A0n	8.3		
669	9.84	B8	10.1		
746	9.92	A8			
523	9.95	A0	9.0		
479	10.57	A2	8.9		
635	10.59	A2	8.9		
822	10.86*	A0:	10.0		
	Mean		$9^m.1$		$+^m.22$

* Variable?

In Figure 1 the seventeen stars of Table I are plotted according to their apparent photographic magnitudes and their

[2] *Harv. Ann.*, **5**, 1867.

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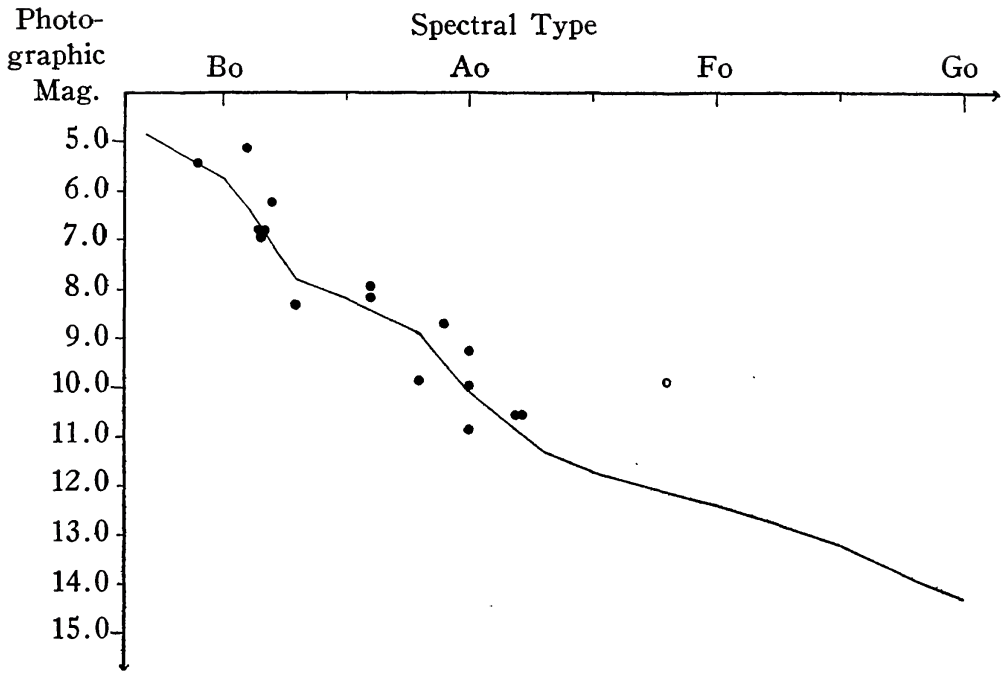


FIG. 1.—Magnitude-spectral class diagram for stars in Orion nebulae. Each star is plotted according to its apparent photographic magnitude and its spectral class. The broken line represents the dwarf branch of the Hertzsprung-Russell diagram so adjusted that the zero point of absolute magnitudes falls at apparent magnitude 9.1.

spectral types. The stars mark plainly the upper part of the main branch of the Hertzsprung-Russell diagram; as we proceed from the brighter to the fainter stars, the spectral types advance from O9 to A2. This distribution is characteristic for galactic star clusters of type 1b.[3] One star of spectral type A8 falls off and is probably a foreground star. The numerous fainter members of the Trapezium cluster for which no spectra are available would be expected to fall along the continuation of the dwarf branch, being F-, G-, and K-type dwarf stars. Observations with color filters indeed show at a glance that they are yellow or reddish in color. Accurate color indices for these stars are now being determined, but the results are not yet completed.

In the fourth column of Table I the mean absolute magnitude M of each spectral class[4] has been subtracted from the

[3] *Publ. A.S.P.*, **37**, 307, 1925. [4] According to *Lick Obs. Bull.*, **14**, 154, 1930.

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apparent photographic magnitude m, the results of the four brightest stars being increased by the empirical corrections discussed in *Lick Observatory Bulletin*, **14**, 155–156.

The individual values of $m - M$ show quite satisfactory agreement, and their mean is 9^m1. If our stars were not affected by any absorption of light this figure would correspond to a distance of 660 parsecs. The general light absorption in low galactic latitudes[5] noted in a study of the distances and diameters of galactic star clusters would have little effect on the *Orion* nebula since the latter lies 17° distant from the galactic circle; but it might be expected that the stars of the Trapezium cluster would be affected by absorption in the nebula itself in which they are involved.

Some light on this question may be gained by a study of color indices. For six of our stars visual photometric magnitudes have been derived at the Harvard Observatory. When these are subtracted from our photographic magnitudes we obtain the color indices in the fifth column of Table I, and a comparison of the color index with the spectral type leads to the color excess of the sixth column. With one exception the color excesses are all positive, and their mean, $+0^m22$, is quite appreciable. To show that this is not the result of any systematic errors in the magnitudes, a comparison was made with the cluster N.G.C. 1981, for which similar data are available. This cluster lies just one degree south of the *Orion* nebula and contains stars of the same spectral types and magnitudes; its mean color excess is —0.09, a small negative value which may be due to a difference in the magnitude scales.

	Color Excess	
Trapezium cluster	$+0^m22$	(6 stars)
N.G.C. 1981	−0.09	(4 stars)
Difference	$+0^m31$	

Here then we have two clusters less than one degree apart and both approximately at the same distance. The photographic as well as the visual magnitudes were each measured by the

[5] See *Publ. A.S.P.*, **42**, 214, 1930.

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same observers, but the stars in the *Orion* nebula are systematically redder by 0^m3 than stars of the same spectral types in N.G.C. 1981, which is free from nebulosity. We must conclude from this that the *Orion* nebula is causing a selective absorption of light, and this conclusion is supported by the marked reddish color of many of the fainter stars involved in it.

If we assume this selective absorption to be caused by light scattering we can estimate that the photographic magnitudes of the Trapezium cluster stars must have been dimmed at least twice the amount of the selective effect; i.e., about 0^m6. With this value of absorption we derive from the magnitudes and spectral types a distance of 500 parsecs. A second determination of the distance of the Trapezium cluster is based on its angular diameter of 15′ and its classification I3p, according to the method developed in *Lick Observatory Bulletin,* **14,** 159, 1930.

It seems highly probable that the Trapezium cluster is physically related to the cluster N.G.C. 1981. In the first place the two clusters are separated by less than one degree, in the second place the magnitudes and spectral types of the stars contained in them are very similar, and in the third place both have the same radial velocity. We may then assume that the distance of the Trapezium cluster is nearly the same as that of N.G.C. 1981, and the latter was redetermined with improved data concerning the magnitudes and spectral types of the stars.

The results of the three methods outlined above are listed in Table II (p. 260). They are in fair agreement and we take their mean as our final result:

Distance of the *Orion* nebula = 540 parsecs or 1800 light-years.

This distance is three times larger than the value of 180 parsecs (600 light-years) adopted in most textbooks;[6] the latter is based on an investigation by Kapteyn,[7] which makes use only of stars widely surrounding the nebula. W. H. Pickering,[8] on the other hand, deduced a distance of 2000 parsecs from the apparent magnitudes and colors of the stars involved in the

[6] E.g., Russell-Dugan-Stewart, *Astronomy,* II, p. 831.
[7] *Mt. Wilson Contr.,* **147,** 1918. [8] *H.C.O. Circ.,* 205, 1917.

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TABLE II

DISTANCE OF TRAPEZIUM CLUSTER

1. Distance computed from magnitudes and spectral types		
a) No light absorption: 660 parsecs		
b) Assuming light absorption of 0m6	500	parsecs
2. Distance computed from classification and angular diameter	690	
3. Distance of N.G.C. 1981		
From magnitudes and spectral types: 400 pars. / From classification and angular diameter: 470 pars.	435	
Mean	540	parsecs

nebula. Estimating the angular diameter of the *Orion* nebula as 50′, our result for the distance leads to the conclusion that the nebula measures at least 8 parsecs or 26 light-years across. Large as these dimensions may appear, they are of the same order as those of galactic star clusters. It is of interest to compare the dimensions of the *Orion* nebula with those of other diffuse galactic nebulae. This has been done in Table III for some of the brighter nebulae which envelop star clusters;

TABLE III

DIMENSIONS OF DIFFUSE GALACTIC NEBULAE

	Distance in Parsecs	Angular Diameter	Linear Diameter	
Orion nebula	540	50′	8	parsecs
Pleiades nebula	150	360	16	
N.G.C. 2237	1340	60	23	
N.G.C. 6514, *Trifid*	980*	23	6.5	
N.G.C. 6523, Messier 8	1090	35 × 55	11 × 17	
N.G.C. 6611, Messier 16	2050	20	12	

* Assuming distance the same as that of the neighboring cluster N.G.C. 6531.

in these cases the distances of the star clusters determined by the writer[9] were adopted for the nebulae, while the angular diameters were measured on Barnard's Milky Way photographs.[10] According to this comparison the *Orion* nebula rates rather among the smaller objects of its class.

[9] *Lick Obs. Bull.*, **14**, 170, 1930.

[10] *Publ. Lick Obs.*, 11, 1913, and *A Photographic Atlas of Selected Regions of the Milky Way*, 1927.

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