N.G.C. 6822, A REMOTE STELLAR SYSTEM[1]

By EDWIN HUBBLE

ABSTRACT

A study of N.G.C. 6822.—The object is a very faint cluster of stars and nebulae, about $20' \times 10'$, resembling the Magellanic Clouds. Detailed investigations confirm the similarity and show that it extends to many structural features of these systems. Familiar relations such as those connecting periods and luminosities of Cepheids, luminosities of brightest stars involved in diffuse nebulae, and frequencies of the most luminous stars in the systems are consistent when applied to N.G.C. 6822, the first object definitely assigned to a region outside the galactic system.

Variable stars.—Eleven of the fifteen variables found in the cluster are Cepheids. A system of photographic magnitudes has been established from comparisons with the two nearest Selected Areas; and periods, light-curves, and magnitudes have been determined for the Cepheids. The periods range from 12 to 64 days and the magnitudes at maximum, from 17.45 to 19.05. The period-luminosity relation is conspicuous, and a comparison with Shapley's general curve in *Harvard Circular*, No. 280, indicates a distance for N.G.C. 6822 of 214,000 parsecs. $m-M=21.65$.

Nebulae.—Five diffuse nebulae are involved in the cluster. The four brightest show emission spectra similar to those of the diffuse galactic nebulae. A radial velocity of +25 km/sec., uncorrected for solar motion, has been derived from one slit spectrogram of the brightest nebula. The mean diameter of the diffuse nebulae, about 40 parsecs, is comparable with those of the largest nebulae in other systems. In addition to the diffuse nebulae, several small objects are present which are probably non-galactic nebulae whose images are superposed on that of the cluster.

Star counts.—The distribution of apparent photographic magnitudes has been determined down to 19.4, corresponding to absolute magnitude −2.25. The brightest stars in the system are of absolute magnitude about −5.8. When a mean color-index of +1.35 is assigned to the cluster stars, their frequencies are very similar to those of the absolute visual magnitudes in the vicinity of the sun.

Luminosity and space density.—The surface brightness of the central core is about 22.1 photographic magnitudes per square second of arc. This value leads to a total absolute magnitude of −12.0 for the core, or −12.7 for the entire system, and to a space density of about 6.1 absolute magnitudes per cubic parsec for the core, or 8.8 for the entire system.

Cepheid criterion of distance.—Since the Cepheid criterion appears to function normally in N.G.C. 6822, its value as a means of exploring extragalactic space is considerably enhanced.

Influence of instruments on observations of nebulae.—A summary of the early observations of N.G.C. 6822 illustrates the confusion which may arise from disregarding the limitations of various types of instrument and emphasizes the caution required in discussing observations of nebulae.

N.G.C. 6822 is a faint irregular cluster of stars with several small nebulae involved. The position for 1925 is $\alpha = 19^h 40.7^m$, $\delta = -15^\circ$, galactic latitude -20°. The general appearance is shown on Plate XIV, enlarged from an exposure of three hours and a half with the 100-inch reflector. The total area covered by the cluster is about $20' \times 10'$, but the most conspicuous feature is a core about $8' \times 3'$ in

[1] *Contributions from the Mount Wilson Observatory*, No. 304.

which the star images are densely crowded. The photographs show a striking resemblance to the Magellanic Clouds, and detailed investigations have abundantly confirmed this first impression. Cepheid variables, diffuse nebulae, dimensions, density, and distribution of stellar luminosities agree in defining the system as a curiously faithful copy of the clouds, but removed to a vastly greater distance. N.G.C. 6822 lies far outside the limits of the galactic system, even as outlined by the globular clusters, and hence may serve as a stepping-stone for speculations concerning the habitants of space beyond.

EARLY OBSERVATIONS

The early observations are confused, as is usual for faint complex objects. In the case of N.G.C. 6822 the confusion is clearly the result of disregarding the limitations of the various instruments employed. A short history will justify this statement and emphasize the caution required in discussing observations of nebulae. Barnard discovered[1] the object, apparently with his own 5-inch refractor. He described it as very faint and stated that some time later, when he determined its position with a 6-inch equatorial, it was seen with difficulty. The next year, however, he examined it with the 6-inch and a comet eyepiece. It was fairly conspicuous, large and round, about 10′ or 15′ in diameter, rather dense and even in its light. Barnard remarked:

> It certainly seems much larger and much denser than last year and I certainly think it has increased in density and size since that time. . . . . If it had always been as large and bright as now, I cannot conceive how it could have been missed by observers when examining G.C. 4510 (the bright planetary N.G.C. 6818, which is about 40′ north preceding). Probably this is a variable nebula.[2]

The comet eyepiece accounts for these discrepancies. The 5-inch, it seems, was not equipped with this accessory, nor would one be used in determining positions with the 6-inch. So large and faint a cluster is best seen with a low power and a wide field. It will not stand magnification. At Mount Wilson, for instance, N.G.C. 6822 is fairly conspicuous in a short 4-inch finder with a low-power eyepiece, but is barely discernible at the primary focus of the 100-

[1] *The Sidereal Messenger*, **3**, 254, 1884. [2] *Ibid.*, **5**, 31, 1886.

inch. The latter, however, shows the small bright details which are invisible in the finder. This factor is apparent in the later observations.

Barnard's remarks obviously refer to the cluster as a whole and furnish the description in the *N.G.C.*—"vF, L, E, dif." During the next year, 1887, the region was examined[1] with the 26-inch refractor at the Leander McCormick Observatory. The relatively high magnification and restricted field conspired to render the cluster inconspicuous. It was missed entirely by the observer. The two brightest of the small involved nebulae, however, were seen and measured. Curiously enough, they were both attributed to Barnard and the discrepancy with the *N.G.C.* description was overlooked. When the *First Index Catalogue* was compiled, the brighter of these two objects was assumed to be N.G.C. 6822, although the description in the *N.G.C.* was not amended, and the fainter object was listed as a new nebula, "I.C. 1308, eF, eS, lE, gbM, 6822 p 12^s." H. A. Howe,[2] with a 20-inch refractor, found only the brighter of these two small nebulae and remarked that N.G.C. 6822 was "very small" instead of "large" as described by Barnard. Bigourdan[3] with a 12-inch could see neither of the small nebulae, nor, of course, the cluster. His instrument was in the blind zone, too large for the cluster and too small for the involved nebulae.

The first photographs were made in 1906 and 1907 by Wolf[4] at Heidelberg with the 16-inch Bruce camera and the 28.5-inch Walz reflector. He identified the two small nebulae as N.G.C. 6822 and I.C. 1308, and announced the cluster, Barnard's original discovery, as a new object which was duly listed in the *Second Index Catalogue* as "I.C. 4895, group of neb., 25′ diam." Wolf described the cluster as an exceptionally dense *Nebelfleckhaufen*, or cluster of small nebulae, similar to those more open clusters to whose study he has contributed so largely. This remarkable interpretation existed for fifteen years unchallenged and apparently unnoticed.

Finally in 1922, Perrine[5] published a fair description from a plate made with the 30-inch reflector at Córdoba. He properly identified

[1] *Publications of the Leander McCormick Observatory*, **1**, Part 6.

[2] *Monthly Notices*, **60**, 137, 1900.

[3] *Observations des Nebuleuses*, **5**.

[4] *Astronomische Nachrichten*, **176**, 109, 1907.

[5] *Monthly Notices*, **82**, 489, 1922.

the entire system as Barnard's nebula, N.G.C. 6822, and described it as a cluster of stars and nebulosity resembling the Magellanic Clouds.

Meanwhile, the object had been photographed at Mount Wilson with the 10-inch camera, and the anomalous character of its image[1] had led to its being placed on the program for further study with the large reflectors. In July, 1921, Duncan[1] obtained two plates with the 100-inch reflector, on which the resemblance to the Magellanic Clouds was very striking. Detailed investigation was undertaken in July, 1923. The object was followed carefully through the two seasons of 1923 and 1924, and some plates are available for the seasons of 1921 and 1925. More than fifty direct exposures and several spectrograms have been made with the large reflectors.

CEPHEID VARIABLES

A survey of the plates with a blink-comparator has led to the discovery of fifteen variable stars within the area covered by the system. These are marked on Plate XV, and are identified by Arabic numerals. No variables have been found on the plates outside the limits of the cluster, hence those within the limits must be considered as actual members of the system. Eleven of the variables are clearly Cepheids, and a few of the remaining four may ultimately prove to be of the same type. Periods, normal curves, and photographic magnitudes have been determined for the Cepheids, the periods ranging from 12 to 64 days and the magnitudes, at maximum, from 17.45 to 19.05. The familiar period-luminosity relation is conspicuously present and the curve is parallel to Shapley's general curve expressing the corresponding relation among previously known Cepheids. The displacement in magnitudes between these two curves leads to a value of $m-M=21.65$, corresponding to a distance of 214,000 parsecs.

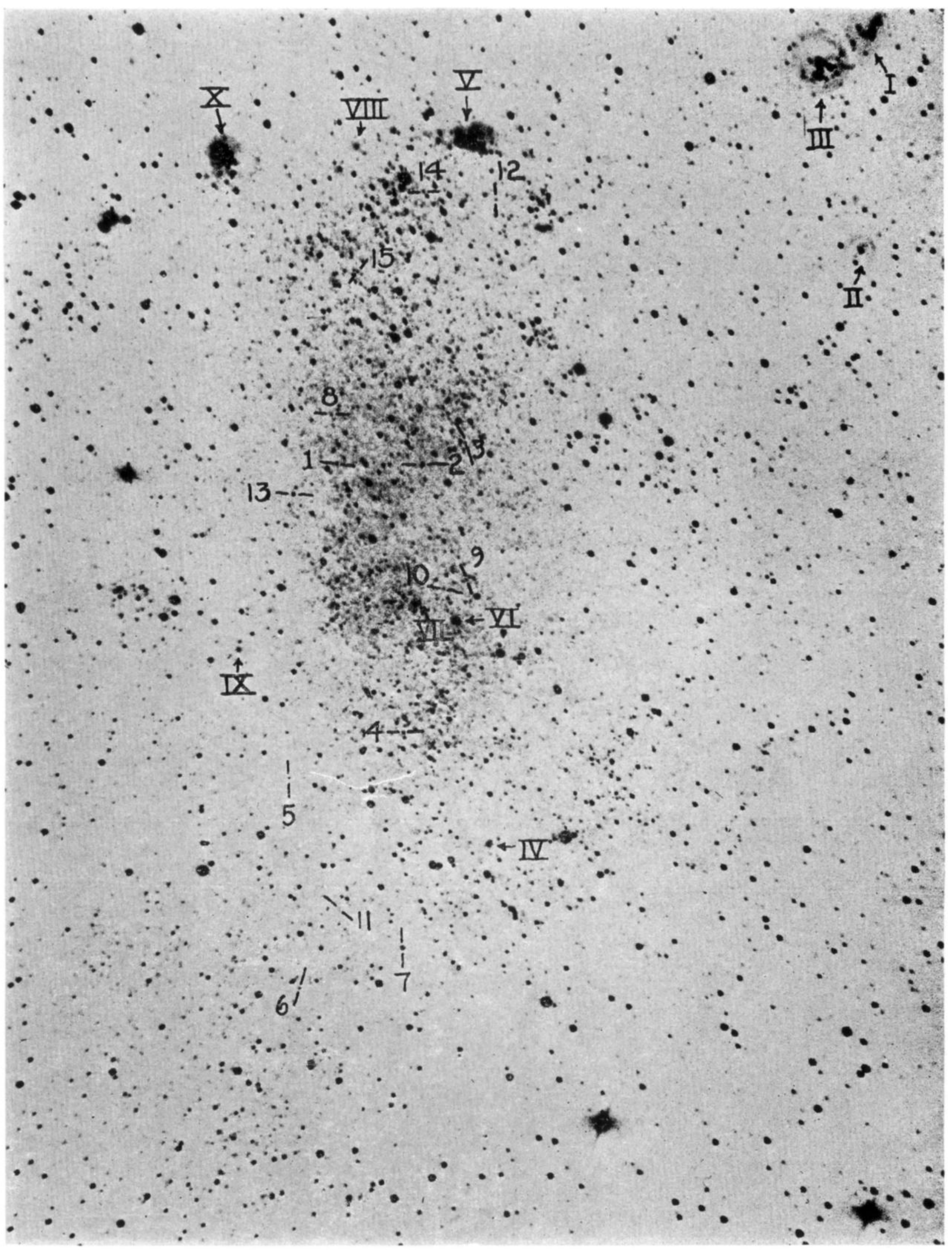
The system of magnitudes is based on nine Seed 30 plates taken with the 100-inch reflector. The zero-point and scale were determined from four 30-minute comparisons with the neighboring Selected Area 136 and two 20-minute comparisons with Selected

[1] *Mt. Wilson Contr.*, No. 256; *Astrophysical Journal*, **57**, 137, 1923. The plates are mentioned earlier in the *Mt. Wilson Annual Report for 1921.*

PLATE XV

N

E



W

N.G.C. 6822

Negative print of Plate XIV. Variable stars are designated by Arabic figures; nebulae involved in or superposed on the cluster by Roman numerals.

Area 135. The plates were centered on three regions of the cluster—the center and points 3′ north and south, respectively—in order to reduce the effect of the distance correction. These comparisons gave magnitudes comparable with those of the Selected Areas down to the limits of the Mount Wilson measures[1] of the latter, about 18.0, and by a legitimate extrapolation, to a fraction of a magnitude fainter. The system was extended by means of three longer exposures, two of one hour each, and one of three hours and a half.

The internal agreement of the measures is very satisfactory down to about 19.1. Average deviations of individual plates from the mean are less than 0.1 mag. and the maximum range for an individual star on all the plates is 0.4 mag. Extrapolations beyond 18.0 depend upon the reliability of the faintest magnitude and a half of the scales in the two Selected Areas. If these are free from systematic errors, as is hoped, the extrapolation can be trusted for at least a magnitude. Distance corrections have never been thoroughly investigated for the field of the 100-inch, but the present measures were confined to the immediate vicinity of the optical axis, and approximate values of the corrections were derived from the measures themselves.

There is, however, a troublesome source of systematic error which has not been eliminated. Under ordinary observing conditions, long exposures at low altitudes with the 100-inch give images of appreciable dimensions. This is due to atmospheric refraction and changing seeing, focus, and figure. The result is that the faintest images are irregular and vary in density rather than in size. Above a certain limiting magnitude the effect is inappreciable, but as measures are carried down to fainter stars, the photometry of approximately point sources merges into photometry of surfaces. When the measuring is done with an ordinary scale-plate, the resulting magnitudes for the fainter stars become increasingly too bright. In the present measures, this effect becomes noticeable beyond about 19.1. Magnitudes fainter than this are increasingly unreliable, while those brighter are probably correct within 0.2.

A series of comparison stars was established for each variable in

[1] These measures on the international scale are unpublished but were available through the kindness of Mr. Seares.

TABLE I

PHOTOGRAPHIC MAGNITUDES OF VARIABLE STARS IN N.G.C. 6822

J.D.†	Q	Cepheid Variables											Other Variables			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2875.44	P	18.85	18.5	......	......	18.85	......	18.2	......	18.8	......	......	18.65	18.1	18.5	18.85
2876.46	G	18.9	18.6	19.0	18.95	18.95	19.1	18.15	18.8	18.8	18.95	19.15	18.65	18.2	18.5	18.75
3611.50	E	18.2	18.3	19.0	18.35	18.9	18.75	17.45	18.85	19.2	19.3	19.2	18.85	18.2	18.75	18.75
3616.50	G	18.1	18.4	18.3	18.75	19.05	19.05	17.55	18.85	19.1	19.2	19.15	18.8	18.1	18.8	18.85
3619.53	E	18.4	18.6	18.45	19.0	19.15	19.25	17.55	18.95	18.85	19.25	19.3	19.05	18.2	18.8	18.7
3619.55	G	18.4	18.6	18.55	18.95	19.15	19.2*	17.65	18.95	18.85	19.2	19.3	19.0	18.25	18.75	18.65
3638.37	P	18.85	18.0	18.95	19.0	18.95	19.1	18.0	......	......	......	......	18.8	17.9	18.85	......
3638.51	F	18.75	18.0	19.05	19.0	19.05	19.1	18.0	19.0	......	19.1	19.0	18.85	17.95	18.75	18.85
3639.40	F	18.85	17.9	19.0*	19.15	18.9	19.2	18.05	18.85	18.9	19.2	19.05	18.75	17.95	18.7	18.85
3640.48	P	18.6	18.0	18.9*	......	19.0	......	18.05	......	......	......	19.15	18.7	17.9	18.8	18.85
3641.50	E	18.55	18.05	19.0	18.95	18.9	19.15	18.15	18.6	19.1	19.2	19.2	18.85	17.85	18.8	18.85
3647.35	F	18.05	18.1	18.4	18.6	19.15	18.45	18.1	19.0	19.1	19.3	19.2	18.7	17.75	18.9	18.7
3678.38	G	18.1	17.85	18.45	18.95	19.05	19.15	17.5	18.95	19.3	19.2	19.1	18.75	17.9	18.7	18.75
3697.31	F	19.0	18.6	19.0*	18.7	19.05	19.1	18.05	19.0	19.1	19.2*	19.3	18.75	18.1	18.7	18.75
3698.33	G	19.05	18.65	19.05	18.45	18.95	19.2	17.9	18.95	19.1	19.3	19.0	18.8	18.05	18.75	18.7
3969.52	G	19.0	18.9	18.5	18.9*	19.0	18.75	18.1	18.8	19.2	19.0	19.15	18.2	18.1	18.7	18.45
3971.51	F	18.9	18.8	18.5	18.9	18.9	18.9	18.15	18.7	18.75	18.85	19.15	18.3	18.1	18.8	18.4
3972.51	P	18.9	......	......	......	19.0	19.1	18.1	......	......	......	19.15	......	18.2	18.75	18.4
3990.45	G	18.8	18.3	19.05	18.85	19.1	18.75	17.8	18.9	19.0	18.8	19.2	18.05	18.3	18.4	18.45
3994.45	F	18.9	18.4	18.35	18.6	19.1	19.05	17.55	18.65	19.2	19.1	19.05	18.15	18.1	18.7	18.4
3995.45	G	19.0	18.45	18.4	18.75	19.15	19.1	17.65	18.75	19.05	18.9	19.2	18.2	18.1	18.65	18.5
3996.40	E	18.9	18.7	18.4	18.8	19.15	19.2	17.5	18.65	18.95	19.0	19.3	18.1	18.1	18.5	18.5
3997.40	G	19.0	18.5	18.4	18.9	18.95	19.1	17.55	18.85	19.1	19.1	19.3	18.2	18.2	18.6	18.4
3998.44	E	18.9	18.6	18.4	18.85	18.8	19.2	17.55	18.85	19.3	18.95	19.25	18.1	18.1	18.6	18.45
4002.37	E	19.05	18.7	18.65	19.0	19.15	19.25	17.65	18.9	19.15	18.95	19.35	18.0	17.95	18.4	18.45
4003.37	G	19.0	18.9	18.8	18.9	19.15	19.25	17.65	18.85	19.0	18.9	19.05	18.1	17.9	18.6	18.4
4004.37	E	18.9	19.0	18.7	18.95	19.1	19.1	17.6	19.0	18.8	18.8	19.05	18.05	18.05	18.5	18.5

4024.34........	P	19.05	18.25	18.4	18.9	19.0	19.2	17.9	19.0	18.9	18.85	.....	18.2	17.8	18.55	18.45
4025.34........	F	19.0	18.3	18.45	18.8	18.95	19.1	18.0	19.0	18.8	18.8	19.15	18.25	17.75	18.5	18.5
4026.40........	P	18.85	18.4	18.5	18.75	18.85	18.55	17.9	18.85	18.9	19.1	19.05	18.35	17.75	18.7	18.4
4031.33........	E	19.0	18.7	18.8	18.85	19.15	18.8	18.05	18.85	19.3	18.9	19.25	18.25	17.8	18.5	18.4
4032.33........	G	18.95	18.8	18.7	18.9	19.05	18.8	17.95	18.85	19.1	18.9	19.25	18.25	17.8	18.6	18.5
4049.35........	P	18.45	18.2	18.9*	18.8	.....	18.55	18.1	.....	.....	.....	.....	18.4	17.95	18.5	18.5
4050.35........	F	18.6	17.9	19.1	18.9	19.1	18.7	18.1	18.8	19.2	18.9	19.2	18.4	18.0	18.55	18.5
4054.32........	P	18.65	18.1	18.4	19.1	18.75	19.05	17.95	18.8	19.0	19.0	19.15	18.2	17.95	18.55	18.55
4056.32........	G	18.75	18.15	18.3	18.95	18.95	19.0	17.75	18.6	18.85	18.8	19.2	18.2	17.9	18.6	18.4
4057.32........	F	18.8	18.1	18.55	18.9	19.05	19.2	17.65	18.8	18.8	18.8	.....	18.3	17.9	18.6	18.5
4058.32........	E	18.8	18.4	18.45	19.05	19.1	19.1	17.5	18.65	18.8	18.85	19.1§	18.35	18.0	18.55	18.45
4059.32........	F	18.9	18.4	18.6	18.8	19.1	19.1*	17.5	18.8	18.85	19.0	.....	18.3	18.05	18.6	18.55
4085.30........	P	19.0	18.1	18.3	18.85	19.0	19.2	17.85	18.8	19.1	18.8	19.3	18.3	18.3	18.5	18.5
4090.30........	P	19.0	17.9	19.0	18.95	.....	18.6	17.9	.....	18.8	18.8	.....	18.2	18.25	18.5	18.6
4298.6.........	F	18.7	18.7	19.0	19.1	19.15	19.2	18.1	.....	19.2	19.3	.....	18.8	18.1	18.5	18.7
4319.6.........	G	18.3	18.0	18.4	18.9	18.85	19.15	17.55	19.0	19.3	.....	.....	18.9	18.2	18.6	18.8

* Limiting magnitude of the plate; variable invisible.
† Figures in this column are to be added to 2,420,000.0. The decimals represent Pacific mean time.
§ Discordant observation.

the manner described above, with successive steps averaging about 0.2 mag. These furnished easy and accurate means of following the variables. The data for the latter from the separate plates are collected in Table I. The first column gives the Julian Day repre-

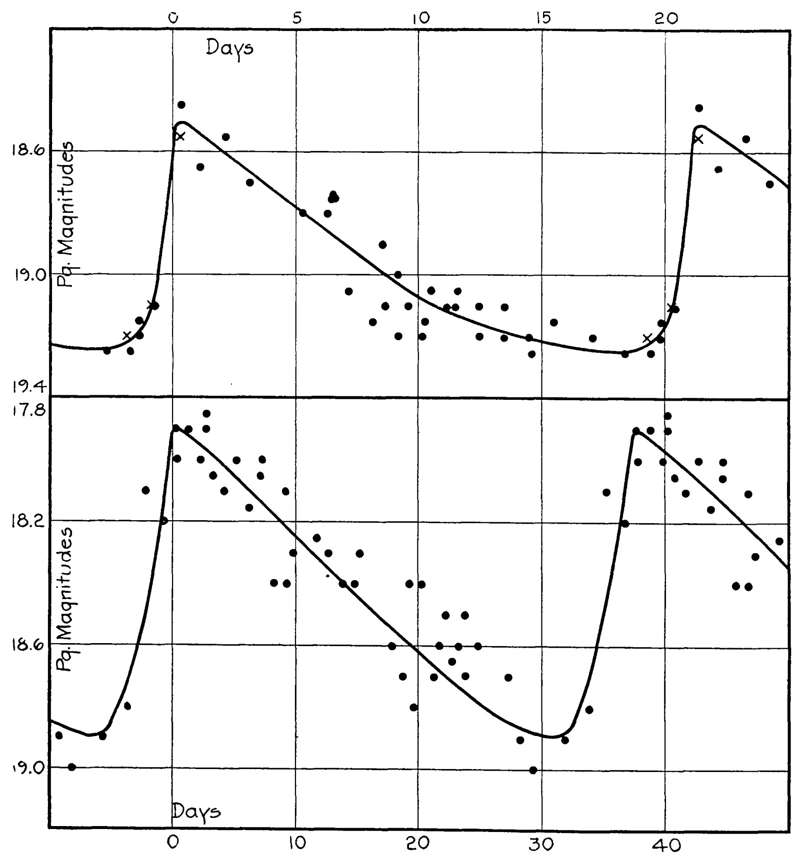


FIG. 1.—Light curves for two Cepheids in N.G.C. 6822. Upper curve, variable No. 6. Period 21.06 days; range 18.5–19.25. Lower curve, variable No. 2. Period 37.45 days; range 17.9–18.9. The three crosses on the rising slope of the upper curve represent observations on successive days and illustrate the rapid brightening of the variables.

senting Pacific mean time; the second, the quality of the plates, the letters "E," "G," "F," "P" and "vP" having their usual significance of "excellent," "good," "fair," "poor," and "very poor"; the remaining columns give the photographic magnitudes of the variables, which are designated by the numbers used on Plate XV. The exposures were usually from 60 to 75 minutes on Seed 30 plates.

The elements of the light-curves derived from these data for the eleven Cepheids are given in Table II. The small amplitudes found for the fainter stars are probably due, in part at least, to the systematic error previously mentioned. In order to emphasize their Cepheid characteristics two of the light-curves are illustrated in Figure 1. The other curves can easily be constructed from the data in Tables I and II.

The period-luminosity relation is shown in Figure 2, in which the logarithms of the periods in days are plotted against the photographic magnitudes at maxima. This departure from the customary

TABLE II

NORMAL CURVES FOR CEPHEIDS

Var. No.	Epoch J.D.	Period in Days	log *P*	Max.	Min.
7	2423994.0	64.0	1.806	17.45	18.15
2	4050.0	37.45	1.574	17.9	18.9
1	3678.0	30.55	1.485	18.1	19.0
3	3994.0	29.2	1.47	18.35	19.1
6	3647.0	21.06	1.325	18.5	19.25
8	3972.0	20.72	1.315	18.6	19.0
4	3992.0	17.31	1.238	18.5	19.1
9	3971.0	16.86	1.225	18.75	19.25
10*	....	16.5±	1.22±	18.8	19.2
5	3699.0	13.87	1.142	18.8	19.2
11	4003.0	11.77	1.071	19.05	19.35

* Observations uncertain but Cepheid characteristics are pronounced. Rejection would not affect the period-luminosity curve appreciably.

Magnitudes fainter than 19.0 are probably systematically too bright, the effect increasing with the numerical value of the magnitudes.

usage of median magnitudes is required by the uncertainties in the fainter magnitudes, including most of those at minima. The full-line curve is the linear relation

$$m(\text{max.}) = 21.401 - 2.193 \log P ,$$

derived by a least-squares solution. The residuals are of the order of accuracy of the measures, averaging ±0.06 mag., with a maximum value of 0.20. This dispersion is surprisingly small and, in a measure, justifies the use of maximum rather than of median magnitudes. Furthermore, it excludes the possibility that the apparent magnitudes of the Cepheids might be sensibly affected by local absorption in the system.

The determination of the distance of N.G.C. 6822 is based on

Shapley's latest revision[1] of the photographic period-luminosity curve. The form of this curve depends on more than a hundred Cepheids in the small Magellanic Cloud and should be definitive except in the region of very long periods. The zero-point[2] was derived from galactic Cepheids of intermediate periods.

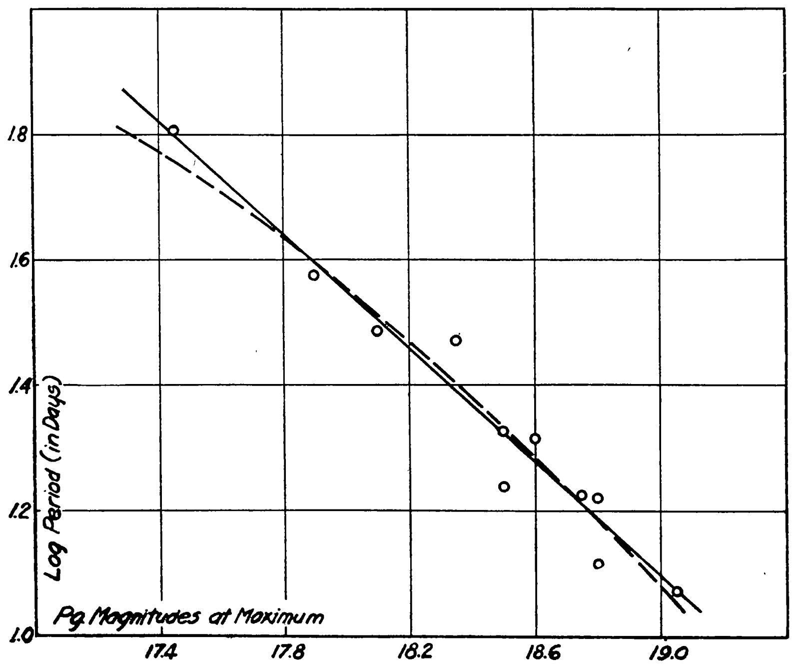


FIG. 2.—Period-luminosity relation among Cepheids in N.G.C. 6822. The continuous line represents the correlation curve, $m(\text{max}) = 21.40 - 2.19 \log P$. The broken curve indicates the corresponding portion of Shapley's general period-luminosity curve reduced to the scale of photographic magnitudes.

In Figure 2, Shapley's curve is represented by the dotted-line curve adjusted to fit the data for N.G.C. 6822 by shifting it along the magnitude axis. The uncorrected modulus is

$$m\ (\text{max.}) - M\ (\text{median}) = 21.26 \pm 0.02.$$

The maximum residual is 0.20 mag., and the mean ± 0.11 mag.

[1] *Harvard Circular*, No. 280.

[2] Recent results by Strömberg for the solar motion referred to the galactic Cepheids indicate the possibility of a substantial correction to the zero-point (*Mt. Wilson Contr.*, No. 293; *Astrophysical Journal*, **61**, 363, 1925). But until the question can be discussed in a definitive manner it seems best to use Shapley's value, with a full realization, however, of the possible necessity of a subsequent revision of all distances derived from the Cepheid criterion.

Since Shapley's curve is based on median magnitudes, the value of the modulus must be increased by half the mean range of the Cepheids in N.G.C. 6822. This quantity is somewhat uncertain, owing to the systematic error affecting the fainter magnitudes at minimum. The mean for all the Cepheids as listed in Table II is 0.67 mag., while for those brighter than 19.1 at minimum, the mean is 0.73 mag. Even this latter value appears to be low, judged by the apparent systematic decrease in range with decreasing luminosity and the ranges of Cepheids in other systems.[1] A value around 0.8 mag. would probably be nearer the truth. That actually used was 0.78 mag. The resulting values of the modulus and the distance are

$$m-M=21.65$$

$$\pi=0''.00000468$$

$$\text{Distance}=214{,}000 \text{ parsecs}$$

$$=700{,}000 \text{ light-years}$$

On the assumption of the universal validity of the period-luminosity relation, the principal source of uncertainty in this result arises from that affecting the zero-point of Shapley's general relation. In addition there is the uncertainty in the extrapolated magnitude scales for the Cepheids in N.G.C. 6822. This is difficult to estimate, but probably does not exceed 0.2 mag. The error arising from accidental sources is insignificant, probably less than 0.05 mag. in the modulus, or 2.5 per cent in the distance.

As for the general validity of the period-luminosity relation, this formula has hitherto led invariably to estimates of distances which are consistent with other characteristics of the systems to which it has been applied. In the case of N.G.C. 6822 such a relation certainly exists, and, within the limits of observational error, its form, as shown by Figure 1, is the same as that observed elsewhere. The only questionable feature is the zero-point, and even here

[1] A frequency curve for ranges of galactic Cepheids, based on data derived from Shapley (*Mt. Wilson Contr.*, No. 153; *Astrophysical Journal*, **48**, 279, 1918; and from the table compiled by the Committee on Variable Stars of the Astronomische Gesellschaft, *Vierteljahrsschrift der A. G.*, **59**, 298, 1924), shows a well-marked maximum at 0.8 mag. The data, however, are not homogeneous and, for the most part, are visual. Moreover, the relation between period and range has never been satisfactorily investigated.

corroborative evidence is not lacking. This is presented in detail later, but reference may be made at this point to Shapley's estimate of the distance of N.G.C. 6822.

He boldly assumed an analogy with the Magellanic Clouds, and, comparing angular dimensions, size, and luminosity of the diffuse nebulae, and estimated magnitudes of the brightest stars involved, arrived at a distance "on the order of a million light-years." This figure is comparable with that derived from the Cepheids and represents a brilliant application of the general principle of the uniformity of nature.

VARIABLES OTHER THAN CEPHEIDS

For completeness, the observational data for the four other variables found in the system have been included in Table I. Concerning three of them, nothing is known beyond the fact that they vary through small ranges and apparently in an irregular manner. The remaining variable (No. 12) ranges from about 18.1 to 18.9 or more. In July, 1922, it was moderately faint; in 1923, July to October, it was faint and slowly rising; in 1924, July to November, it was bright and may have passed through a maximum about the beginning of August; in 1925, June to July, it was again faint. The period, if such exists, must be longer than five months.

NEBULAE INVOLVED IN N.G.C. 6822

The only individual objects, other than the variables, which can be definitely identified as members of the system are five diffuse nebulae and the stars with which they are associated. Several other minute nebulous images lie within the limits of the cluster, which may be small, unresolved globular clusters belonging to the system, or, more probably, non-galactic nebulae whose images are superposed on N.G.C. 6822. The diffuse nebulae and the more conspicuous of the supposedly non-galactic nebulae are listed in Table III, under the Roman numerals by which they are designated on Plate XV. The second and third columns give the co-ordinates in millimeters measured from the upper right (north preceding) corner of Plate XV, and the remaining columns the class, diffuse or non-galactic; the general character of the spectrum when known, *E* denoting emission and *C*, continuous; and short descriptions with angular dimensions as measured on the three-and-a-half-hour exposure with the 100-inch reflector. The linear dimensions are given by the relation 1″ = 1.04 parsecs or 3.4 light-years. Number V is the object which Wolf and others identified as N.G.C. 6822, and Number X, that catalogued as I.C. 1308.

TABLE III

NEBULAE INVOLVED IN OR SUPERPOSED ON N.G.C. 6822

Nebula	Co-ordinates*		Class	Spectrum	Description
	Horizontal	Vertical			
	mm	mm			
I	8.0	2.5	Dif.	E	32″×48″ several stars involved
II	9.5	27.5	Dif.	....	20″ diam. Incomplete ring around star
III	14.0	6.0	Dif.	E	52″ diam. Ring around several stars
IV	52.5	95.5	N.-G.	....	5″ diam. Round, star 2″ n.p. center
V	55.0	15.0	Dif.	E	20″×32″ cometic. Stars involved
VI	56.0	70.0	N.-G.	C	8″ diam. Round
VII	60.5	67.5	N.-G.	C	8″ diam. Round
VIII	67.0	15.5	N.-G.	....	6″ diam. Round
IX	81.0	73.0	N.-G.	....	5″ diam. Round
X	83.0	16.0	Dif.	E	22″ diam. Ring around star, fainter extensions to 30″ s.p. star

* Co-ordinates are measured from the upper right (north preceding) corner of Plate XV.

DIFFUSE NEBULAE

The spectral characteristics of several of the nebulae were obtained from slitless spectrograms made at the primary focus of the 60-inch reflector with two prisms and an *f* 1.9 lens of 3-inch focus. Number V, the brightest of all the nebulae, registered eight definite images with others suspected. The wave-lengths and relative intensities are N_1 (10), N_2 (3), $H\beta$ (5), λ 4471 (1), $H\gamma$ (4), $H\delta$ (2), $H\epsilon$ (1), λ 3727 (1). Number X, the next brightest, registered five images which, with relative intensities, are N_1 (10), N_2 (3), $H\beta$ (5), $H\gamma$ (3), $H\delta$ (1). Numbers I and III registered one faint image each, probably the combination of N_1, N_2 and $H\beta$. The relative intensities of the characteristic lines N_1, N_2 and $H\beta$ in Numbers V and X are those of the diffuse nebulae in the galactic system and in the Magellanic Clouds.

The mean diameter of the five diffuse nebulae is about 37″, or 41 parsecs, which is comparable with the dimensions of the great loop of nebulosity in the constellation of Orion. The largest nebula, Number III, is a ring about 60 parsecs in diameter. This equals the diameter of N.G.C. 604 in Messier 33 and is of the order of size of the largest known diffuse nebula—N.G.C. 2070 in the large Magellanic Cloud—for which Shapley[1] gives a diameter of 80 parsecs.

A single slit spectrogram of Number V has been obtained under difficult observing conditions, using one prism and a 3-inch camera at the Cassegrain focus of the 100-inch. An exposure on August 16, 1923, registered faint images of N_1 and N_2. Independent measures by Dr. Sanford and the writer gave velocities, uncorrected for solar motion, of +16 and +34 km/sec., respectively. The mean, +25 km/sec., not only gives the order of velocity of nebula Number V but also, judged from the small peculiar motions of diffuse nebulae in general, represents the order of the motion of N.G.C. 6822 as a whole.

The emission character of the diffuse nebulae indicates that the spectral types of the brightest stars involved are very probably B0 or earlier.[2] Such stars are highly luminous, and it is not surprising to find them among the brightest contained in the cluster. Their faint apparent magnitudes combined with the considerable galactic latitude are strong evidence of their association with the extra-galactic system. Their presence alone would indicate an enormous distance for N.G.C. 6822.

The photographic magnitudes of the brightest stars involved in the individual nebulae are listed below. The measures required a very uncertain distance correction, and the resulting values may be more accurately described as estimates.

Number	Apparent	Absolute
I.	18.0	−3.65
II.	18.0	−3.65
III.	16.9	−4.75
IV.	16.8	−4.85
V.	16.8	−4.85

[1] *Harvard Bulletin*, No. 816.

[2] *Mt. Wilson Contr.*, No. 241; *Astrophysical Journal*, **56**, 162, 1922.

The absolute magnitudes as computed from the modulus $m-M=21.65$, derived from the Cepheids, are comparable with those of the brightest B0- and O-type stars in the galactic system. The large range among the latter, and the effects of selection on those in N.G.C. 6822, prevent the use of the data as an accurate criterion, but the comparison confirms the general order of the distance derived from the Cepheids, with evidence of an independent nature. This very materially supports the assumption that the period-luminosity relation functions normally in extra-galactic space.

NON-GALACTIC NEBULAE

The objects in Table III which are classed as "N.G." (non-galactic) are small, round, blurry images whose diameters are functions of the exposure times. The two brightest (Nos. VI and VII) have registered faint continuous streaks on the slitless spectrograms, with no evidence of emission. A dozen or more small non-galactic nebulae are scattered over the reflector field outside the limits of N.G.C. 6822, and it is reasonable to expect that some may be found within the limits, especially as this is the region of best definition. Since, however, normal globular clusters are found in the Magellanic Clouds, there is a possibility that some of the objects in Table III may be the central regions of such clusters actually involved in N.G.C. 6822.

Shapley's[1] value for the average absolute photographic magnitude of globular clusters is about -8.2 ± 0.6. At the distance of N.G.C. 6822, $m-M=21.65$, the apparent photographic magnitude for such a cluster as a whole would be about 13.5 or possibly 14.0 for the denser central portion. The brightest of the objects in N.G.C. 6822, however, is certainly fainter than 16.0, and the mean of the five listed in Table III is considerably more than a magnitude fainter than this. The discrepancy between them and normal globular clusters is almost conclusive.

Shapley reports seven globular clusters in the large Magellanic Cloud,[2] with apparent photographic magnitudes ranging from 7.2 to 12.0, the mean being 9.2. At the distance of N.G.C. 6822, these

[1] *Mt. Wilson Contr.*, No. 152; *Astrophysical Journal*, **48**, 154, 1918.

[2] *Harvard Circular*, No. 271.

values would be increased about four magnitudes. Hence only the faintest, whose real nature is doubtful,[1] would be comparable with even the brightest of the objects in N.G.C. 6822.

The angular diameters of the clusters in the large cloud range from 1′.1 to 2′.6 with a mean value of 1′.8. At the distance of N.G.C. 6822, these quantities would be 11″ to 25″ with a mean of 17″. A glance at Table III shows the diameters of the objects in N.G.C. 6822 ranging from 5″ to 8″ with a mean of about 6″.4. Here again the discrepancy is almost impossibly large.

If a normal globular cluster were associated with N.G.C. 6822, the mean apparent photographic magnitude[2] of the twenty-five brightest stars would be about 20.2. In view of the dense crowding, the unresolved background, and the low observing altitude, it is improbable that such a cluster could be resolved by the 100-inch reflector. The discrepancies in size and brightness between normal globular clusters and the objects photographed with N.G.C. 6822, however, are sufficient to differentiate them, and the latter must be considered as ordinary small non-galactic nebulae whose images are superposed on that of N.G.C. 6822.

DISTRIBUTION OF STELLAR LUMINOSITIES IN N.G.C. 6822

A preliminary attempt has been made to determine the distribution of the brighter absolute photographic magnitudes in N.G.C. 6822 by counting the stars within successive limits of apparent photographic magnitude over the central region, including the core. The area investigated is about 8′ in declination and 4′ in right ascension; more accurately it contains 33.75 square minutes of arc, and, to the limit of the counts, is estimated to cover about one-half of the stars in the entire system. This limit was set at 19.4 and approximate corrections for the systematic error affecting the fainter stars have been derived from minimum magnitudes of the Cepheids, the slope of the period-luminosity curve, and extrapolations of the luminosity function itself. These corrections have little weight, but they are confined to a single interval in which stars were counted and cannot seriously affect the final results.

[1] *Harvard Circular*, No. 271.

[2] *Mt. Wilson Contr.*, No. 152; *Astrophysical Journal*, **48**, 154, 1918.

The counts were made on the blink-comparator carrying a scale-plate on one side and a plate of N.G.C. 6822, covered by a reseau, on the other. The scale was calibrated from the series of comparison stars established for the variables, and the field stars were eliminated by means of the new distribution tables for different photographic magnitudes and galactic latitudes recently published by Seares and van Rhijn.[1]

TABLE IV

LUMINOSITY FUNCTION FOR THE BRIGHTER STARS IN N.G.C. 6822

Pg. Mag.	Stars Counted	Normal No.	N.G.C. 6822		Kapteyn*		
		Gal. Lat. −20°	$\phi(m)$	log $\phi(m)$	$\phi(M)$	log $\phi(M)$	M (vis.)
19.4−19.1......	394	13.5	380.5	2.580	379	2.579	−3.75
19.1−18.8......	230	11.6	218.4	2.339	219	2.340	4.05
18.8−18.5......	134	9.8	124.2	2.094	124	2.093	4.35
18.5−18.2......	78	8.3	69.7	1.843	69.2	1.840	4.65
18.2−17.9......	27	7.0	20.0	1.301	38.2	1.582	4.95
17.9−17.6......	25	5.9	19.1	1.281	20.7	1.317	5.25
17.6−17.3......	16	4.9	11.1	1.045	11.1	1.045	5.55
17.3−17.0......	11	4.1	6.9	0.84	5.9	0.77	5.85
17.0−16.7......	9	3.3	5.7	.76	3.1	.49	6.15
16.7−16.4......	9	2.7	6.3	.80	1.6	0.20	6.45
16.4−16.1......	5	2.2	2.8	.45	0.8	9.89	6.75
16.1−15.8......	5	1.8	3.2	0.51	.4	9.59	7.05
15.8−15.5......	0	1.4	− 1.4	....	0.2	9.29	−7.35
15.5−15.2......	1	1.1	− 0.1	....	....	....	....
15.2−14.9......	0	0.9	− .9	....	....	....	....
14.9−14.6......	1	.7	− .3	....	....	....	....
14.6−14.3......	0	0.6	− 0.6	....	....	....	....

* The last three columns give the numbers of stars (visual magnitudes) in a volume of 5.22×10^8 cubic parsecs, in which the distribution is in accordance with Kapteyn's luminosity function for stars in the vicinity of the sun. A comparison with the distribution of stars in N.G.C. 6822 indicates a mean color-index for the latter stars of +1.35 mag.

Results of the counts are given in Table IV. The first three columns represent the number of stars counted in the corresponding intervals of apparent magnitude and the normal number for an equal area in the galactic latitude of the cluster. The fourth and fifth columns give the numbers of stars, $\phi(m)$, with their logarithms, which can be attributed to the cluster. For the brightest stars the results are of low weight because of the small area involved. The remaining columns will be explained later.

The upper limit for the stars in N.G.C. 6822 is about 15.8,

[1] *Proceedings of the National Academy of Sciences*, **11**, 358, 1925.

corresponding to the absolute photographic magnitude −5.85. This appears to be quite normal for the great isolated systems. The brightest star known in the local cluster is −5.5 (β Orionis).[1] The limit for the small Magellanic Cloud[2] has been placed between −4 and −7; for the large cloud,[3] it is brighter than −8; for the globular clusters,[4] fainter than −4.

The smoothness of the luminosity function for N.G.C. 6822 invites a comparison with the corresponding function in the neighborhood of the sun. The latter has been derived by Kapteyn[5] from data based on visual magnitudes. Little is known concerning the distribution of color among the very luminous stars but, as a first approximation, the mean color-index may be assumed to be constant over the short range of magnitudes involved in the present counts. Successive numerical values of the color-index were tried, the two functions being shifted into approximate coincidence by adjusting the volume coefficient[6] for Kapteyn's function.

By this method of trial and error, the best fit was obtained with a mean color-index of +1.35 mag., and a volume coefficient of 5.22×10^8 cubic parsecs. The small range of the counts restricts the sensitiveness of the method, but on the assumption that the functions are comparable, the probable error of the color-index, assumed to be constant, is of the order of 0.3 mag. The numbers of stars, $\phi(M)$, and their logarithms, as calculated from Kapteyn's function with the foregoing assumptions, are listed in the sixth and seventh columns of Table IV. The eighth column gives the median absolute visual magnitudes of the stars in the two preceding columns. These magnitudes, corrected by +1.35, represent the photographic magnitudes of the stars counted in N.G.C. 6822, using the modulus $m-M=21.65$.

Figure 3 represents the two functions in a graphical form. The

[1] *Mt. Wilson Contr.*, No. 147; *Astrophysical Journal*, **47**, 280, 1918.

[2] *Harvard Circular*, No. 260. [3] *Ibid.*, No. 271.

[4] *Proceedings National Academy of Sciences*, **6**, 293, 1920.

[5] *Mt. Wilson Contr.*, No. 229; *Astrophysical Journal*, **55**, 242, 1922.

[6] The volume coefficient represents the space throughout which stars must be distributed according to Kapteyn's function in order that the number of stars in a given interval of absolute magnitude may equal the number actually counted in the cluster.

full broken line represents the counts in N.G.C. 6822; and the dotted curve, Kapteyn's luminosity function. The agreement, especially in the upper and more reliable portions, is remarkably close; but the comparison involves several assumptions and can scarcely be

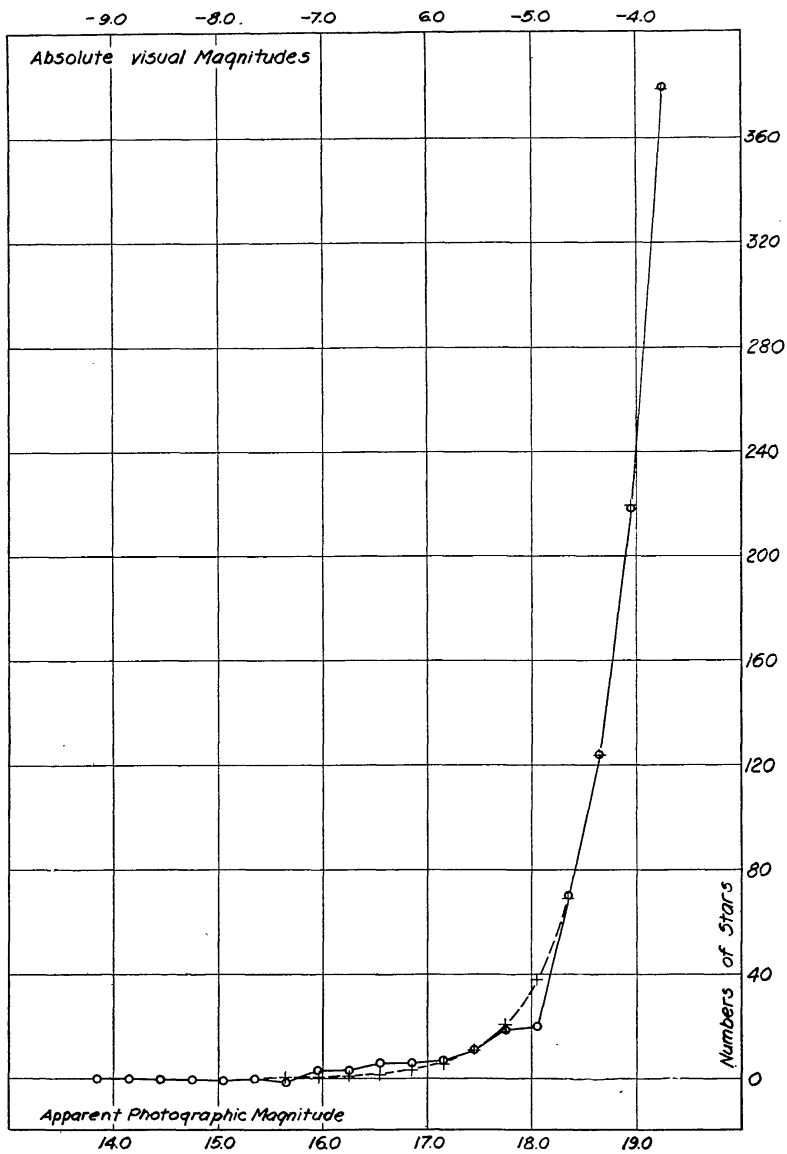


FIG. 3.—Comparison of the luminosity function for N.G.C. 6822 (circles) with Kapteyn's luminosity function (crosses) for stars in the vicinity of the sun. The best fit has been obtained by using a mean color-index of +1.35 mag. for the cluster stars and a volume coefficient of 5.22×10^8 cubic parsecs for Kapteyn's function.

considered as definitive. There is, however, a general similarity between the two functions, and the value of the color-index, judged by the incomplete data available for other systems, seems to be quite reasonable.

The color-index, indeed, appears to confirm the order of the absolute magnitudes assigned to the cluster stars and, consequently, the zero-point of Shapley's general period-luminosity curve for the Cepheids. If the distance assigned the cluster were too great, the color-index as derived from the counts would be too small, and vice versa. An error of 50 per cent in the distance corresponds to an error of about 0.9 mag. in the color-index. There seems to be no reason for supposing that the color-index actually determined from the present data is in error by this amount.

TOTAL MAGNITUDE OF N.G.C. 6822

An approximation to the total photographic magnitude of N.G.C. 6822 has been obtained from short exposures with the 10-inch astrographic camera. The scale of these plates (1 mm $=3'$) is so small that the cluster is unresolved and presents an amorphous surface. The brightest portion is the central core, which just registers in an exposure of 30 minutes on a Seed 30 plate. The corresponding surface brightness can be calculated from the value of 18.8 ± 0.3 photographic magnitudes per square second of arc, which Seares[1] has derived for the limiting surface brightness registering in an exposure of 1 minute on a Seed 30 plate at the Newtonian focus of a reflector with a focal ratio of 1 to 5. For an exposure of 30 minutes the limiting surface brightness will be[2]

$$S.B.=18.8+2.0 \log 30=21.8$$

This can be reduced to the system for a camera of focal ratio 1:4.5 by applying a correction[3] of $+0.3$, so that the final value is

$$S.B.=22.1 \text{ per sq. sec. arc.}$$

[1] *Mt. Wilson Contr.*, No. 191; *Astrophysical Journal*, **52**, 162, 1920.

[2] The coefficient of log exposure time is 2.5 p, where p, the exponent in Schwarzschild's expression for the reciprocity law, is given the usual value of 0.8.

[3] This correction has been applied habitually in deriving surface brightness from limiting exposures with the 10-inch. For an example see *Mt. Wilson Contr.*, No. 250; *Astrophysical Journal*, **56**, 400, 1922.

The area covered by the central core is about $8' \times 3'$, hence the total apparent magnitude is

$$m = 22.1 - 2.5 \log (8 \times 3 \times 3600) = 9.7 .$$

It is estimated that the core contributes about one-half the total luminosity of the nebula, hence the total apparent magnitude of the entire system is about 9.0. The corresponding absolute photographic magnitude is -12.7. The absolute visual magnitude is probably of the order of -13.7.

These quantities furnish an indication as to the space density. As a first approximation, the core can be considered as an ellipsoid whose maximum and minimum diameters are those of the projected image and whose third diameter, in the line of sight, is the mean of the other two. Since the linear scale is $1'' = 1.04$ parsecs, the diameters of the hypothetical ellipsoid are about $500 \times 190 \times 340$ parsecs. The volume is 1.7×10^7 cubic parsecs. The absolute photographic magnitude is $9.7 - 21.65 = -11.95$, hence the density is $2.5 \log (1.7 \times 10^7) - 11.95 = 6.1$ absolute photographic magnitudes per cubic parsec. By a similar computation the mean density of the entire system is found to be about 8.8. This is comparable with the density in the neighborhood of the sun,[1] when reasonable assumptions as to color-indices are introduced. The density of the core alone, however, appears to be from twenty to thirty times that near the sun.

A comparison of the total magnitude of the core, derived from the surface brightness, with that derived from the integration of the luminosity function, extrapolated beyond the limits of the star counts previously discussed, furnishes an independent check on the assumption that the latter is comparable with Kapteyn's function for the stars in the vicinity of the sun. The direct comparison of the two luminosity functions was restricted to some three magnitudes at the extreme bright ends of the curves. The excellent agreement over this small region suggests that the two functions are comparable throughout their entire range. In this case, the total luminosity of the portion of the cluster represented by the counts can be computed by integrating Kapteyn's function over a space equal to the

[1] The space density near the sun is about 8.16 absolute visual magnitudes per cubic parsecs. Seares, *Mt. Wilson Contr.*, No. 191, *Astrophysical Journal*, **52**, 162, 1920.

volume coefficient, 5.22×10^8 cubic parsecs, derived in the restricted comparison. The total luminosity per cubic parsec, from Kapteyn's function, is 8.16 in absolute visual magnitudes.[1] The total magnitude of the cluster is, therefore,

$$2.5 \log (5.22\times10^8)-8.15=-13.64 .$$

The core of N.G.C. 6822 covers an area about 25 per cent less than that over which the counts were made, but, as it is much denser than the rest of the cluster, the correction for reducing the volume coefficient to correspond to the core alone can be taken as half this amount. The total magnitude for the core alone is then about −13.5.

This visual luminosity is to be compared with the photographic absolute magnitude, −12.0, derived from the surface brightness and the angular area. The difference of 1.5 mag. represents the combined effect of the mean color-index of the core, errors in the various quantities involved, and any real difference there may be between the two luminosity functions themselves. A large part of the discrepancy can safely be attributed to color-index alone. The comparison of the luminosity functions indicated a mean color-index of +1.35 for the brighter stars. This value would probably require some reduction for the fainter stars, but the integrated effect of the factor cannot be accurately stated. The probable error in the surface brightness alone is of the order of ±0.4 mag., and errors from other sources, although smaller, would add materially to the total.

The discrepancy in the two results, when the color-index is considered, appears to be within the probable errors of the determinations. Nothing remains which can be attributed with certainty to differences in the luminosity functions. As far as one can determine, the stars in N.G.C. 6822 appear to be the same sort of objects, distributed in much the same fashion, as those in the vicinity of the sun.

COMPARISONS OF N.G.C. 6822 WITH THE MAGELLANIC CLOUDS

Comparisons between N.G.C. 6822 and the Magellanic Clouds are of special interest and significance because the distances of all three objects are based primarily on the Cepheid criterion. The

[1] Seares, *Mt. Wilson Contr.*, No. 191; *Astrophysical Journal*, **52**, 162, 1920.

appearance of the photographic images is remarkably alike. Shapley[1] has previously noted that "the dominating feature in both [the clouds] is an elongated patch of densely crowded stars similar to N.G.C. 6822." In the present paper, this feature is termed the core. Other points of similarity, which have already been discussed, are

TABLE V

COMPARISON OF N.G.C. 6822 WITH THE MAGELLANIC CLOUDS

	Magellanic Clouds		N.G.C. 6822
	Large	Small	
Angular dimensions:			
Total	7°.2×7°.2*	3°.6×3°.6†	20′×10′
Core	3°.6×1°.2	1°.8×0°.9	8′×3′
Apparent luminosity:			
Total	1.2	2.0‡	9.0
Core	1.9	2.7	9.7
Surface brightness:			
Core	21.0	21.0	22.1
Distance	34,500*	31,600†	214,000
Linear dimensions:			
Total	4300§	2000†	1250×625
Core	2150×715	1100×500†	500×190
Volume:			
Total	4.2×10^{10}	4.2×10^{9}	3.8×10^{8}
Core	9.2×10^{8}	2.3×10^{8}	1.7×10^{7}
Absolute luminosity:			
Total	−16.5§	−15.5	−12.7
Core	−15.8	−14.8	−12.0
Mean density:			
Total	10.0	8.5	8.8
Core	6.6	6.1	6.1

* *H.C.O. Circular*, No. 268. † *H.C.O. Circular*, No. 255. ‡ *H.C.O. Circular*, No. 260.
§ *H.C.O. Bulletin*, No. 816.
Luminosities are expressed in photographic magnitudes; surface brightness, in magnitudes per square second of arc; distances, linear dimensions, and volumes, in parsecs and cubic parsecs; densities, in absolute magnitudes per cubic parsec.

the presence of Cepheid variables and of diffuse nebulae, and the magnitudes and the luminosity function of the brightest stars.

A more detailed comparison of dimensions, densities, and total luminosities is given in Table V, both for the cores and for the entire systems. Many of the data depend upon mere estimates which cannot claim any high accuracy, but even the orders of magnitude of the quantities are useful as a first approximation. Distances, dimensions, and luminosities for the two clouds, when given, have

[1] *Harvard Bulletin*, No. 795.

been taken from Shapley's papers.[1] The angular dimensions of the core of the larger cloud have been measured on the Franklin-Adams chart; the cores of both the clouds have been assumed to contribute one-half the total luminosity of the systems; the true figures of the two clouds are assumed to be globular, since their images are approximately circular; the figures of N.G.C. 6822 and of the cores of all three objects are assumed to be ellipsoids whose maximum and minimum diameters are those of the projected images and whose third diameters are the means of the other two. This last assumption is quite arbitrary, but can serve as a basis for comparison.

CONCLUSION

The present investigation identifies N.G.C. 6822 as an isolated system of stars and nebulae of the same type as the Magellanic Clouds, although somewhat smaller and much more distant. A consistent structure is thus reared on the foundation of the Cepheid criterion, in which the dimensions, luminosities, and densities, both of the system as a whole and of its separate members, are of orders of magnitude which are thoroughly familiar. The distance is the only quantity of a new order.

The principle of the uniformity of nature thus seems to rule undisturbed in this remote region of space. This principle is the fundamental assumption in all extrapolations beyond the limits of known and observable data, and speculations which follow its guide are legitimate until they become self-contradictory. It is therefore a matter of considerable importance that familiar relations are found to be consistent when applied to the first system definitely assigned to the regions outside the galactic system.

Of especial importance is the conclusion that the Cepheid criterion functions normally at this great distance. Cepheid variables have recently been found in the two largest of the spiral nebulae, and the period-luminosity relation places them at distances even more remote than N.G.C. 6822. This criterion seems to offer the means of exploring extra-galactic space; N.G.C. 6822 furnishes a critical test of its value for so ambitious an undertaking and the results are definitely in its favor.

[1] *Harvard Bulletin*, No. 816; *Harvard Circulars*, Nos. 255, 260, 268.

ADDENDUM

A pair of Cramer Iso plates, exposed through a visual color filter at the primary focus of the 100-inch, have recently been obtained of N.G.C. 6822. The exposures were one and three hours, respectively. It has not yet been possible to calibrate accurately the plates, but preliminary comparisons have been made with short, unfiltered exposures obtained at the same time.

Cepheids 1, 2, 3, 4, and 5 were identified and gave indications of moderately large color-indices. The non-Cepheid variables appear to have larger color-indices; 12, 13, and 14 being estimated as red. The diffuse nebulae are clearly blue, and the stars associated with them have color-indices as small as, or smaller than, any others seen on the plates. The colors of the non-galactic nebulae were estimated to fall between those of the Cepheid and the non-Cepheid variables.

The general order of these results probably will not be materially changed when accurate measures are possible. They are thoroughly consistent with the conclusions reached in the previous discussion and furnish additional support to the view that the stars in N.G.C. 6822 are comparable with those in other systems.

MOUNT WILSON OBSERVATORY
September 1925

PLATE XIV

N

E

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N.G.C. 6822

Photographed at the 42-foot focus of the 100-inch Hooker telescope on July 10, 1923. Exposure 3^h30^m on a Seed 30 plate. Enlargement 2.5 times original negative.