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STUDIES ON STAR CLUSTERS
A NEW SMALL CLUSTER NEAR NGC 2175 AND SOME REMARKS ON THE LATTER

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SUMARIO

Un cúmulo estelar pequeño se ha descubierto en la cercanía del cúmulo nebuloso NGC 2175. Una nebulosidad brillante envuelve a este cúmulo, al cual hemos llamado NGC 2175s. En placas de larga exposición la región HII de NGC 2175 se extiende hasta cubrir al pequeño cúmulo.

Se ha hecho fotometría en UBV de la región de los dos cúmulos mencionados. Doce estrellas en NGC 2175s observadas fotoeléctricamente han servido de calibración para obtener las magnitudes fotográficas. Los diagramas color-magnitud y color-color están dados para ambos cúmulos. El enrojecimiento de NGC 2175s es de 0.70 magnitudes y el de NGC 2175 es 0.20-0.30.

Las distancias de los cúmulos se ha estimado basándose en los datos de la estrella más brillante de cada uno de ellos. De estas distancias resulta que la proximidad de los cúmulos es probablemente un efecto de proyección pues las distancias encontradas de NGC 2175s y NGC 2175 son respectivamente 3500 y 1950 pcs.

Se han efectuado conteos de estrellas usando una rejilla polar, centrada en los cúmulos. Las estrellas de NGC 2175 parecen estar repartidas en forma circular. Los resultados de los conteos muestran que la región central carece de estrellas. Si este resultado es físicamente significativo se podrá concluir que las estrellas de NGC 2175 están repartidas en forma de una cáscara esférica. Se encuentra también que el número de las estrellas pertenecientes a los cúmulos NGC 2175s y NGC 2175 son 14 y 65 y sus radios 3.6 pcs y 8.1 pcs respectivamente.

ABSTRACT

A small cluster was discovered in the vicinity of the nebulous cluster NGC 2175. A bright patch of nebulosity encircles the small cluster which we designate as NGC 2175s. On long exposure plates the HII region of NGC 2175 has such extension that it overruns the small cluster.

UBV photometry is done of the stars in the region of the two clusters. Twelve stars in NGC 2175s observed photoelectrically have served as standards to obtain the photographic magnitudes. The diagrams color-magnitude and color-color are given for both clusters. The reddening of NGC 2175s is 0.70 magnitudes while that of NGC 2175 is 0.20-0.30.

The distances of the clusters are determined based on the data of the brightest stars in each cluster. These determinations show that the proximity of the two objects is a projection effect as the distances found for NGC 2175s and NGC 2175 are 3500 and 1950 pcs respectively.

Starcounts are made using a polar réseau centered on the clusters. The stars in NGC 2175 seem to be arranged in circular form. The results of the starcounts show that the central region is almost devoid of stars. If this result is physically significant one should conclude that the stars in NGC 2175 are distributed as in a spherical shell. It is also found that the number of stars belonging to the clusters NGC 2175s and NGC 2175 are 14 and 65 whithin a radius of 3.6 pcs and 8.1 pcs respectively.

I. Introduction

The New General Catalogue describes NGC 2175 as an "8th magnitude star in nebulosity". Mention of this object prior to 1931 is made as a galactic nebula. At present it is recognized as an HII region of which the exciting star is HD 42088 of spectral type 06 and V = 7.56. That a star cluster is associated with the nebula was first pointed out by Collinder (1931). An extensive study of photographic and photovisual magnitudes of the stars in this region down to mpg = 16 was done by Kirillova (1958).

On plates taken with the Schmidt Telescope of Tonantzintla Observatory a small compact stellar group was noted, very close and to the northwest of NGC 2175. This paper deals with this small cluster which is referred to hereafter as NGC 2175s (where s stands for small); it falls outside the region studied by Kirillova. The 1950 coordinates of the two objects are taken to be as those of the brightest star in each cluster – NGC 2175 (+20.1284: $6^h\,6^m\,41.4^s$; + 20°30'.2) and NGC 2175s (+20.1293: $6^h\,7^m\,53.8^s$; + 20°37'.4).

On red prints of the Palomar sky survey the small cluster lies well within the confines of the H II region. This peculiarity is apparent also in figure 1 which is an enlargement of a Schmidt plate of the region taken in blue light. A cursory comparison of the plates taken in Hα and in blue light shows clearly that the nebulosity around the small cluster, compared to that around NGC 2175, is not a strong H II region.

Radio isophotes (equal brightness temperature contours) of NGC 2175 (w 13) at 1410 MHz are given by Terzian (1965). A more recent study of the kind by Kaigu and Morimoto (1969) at

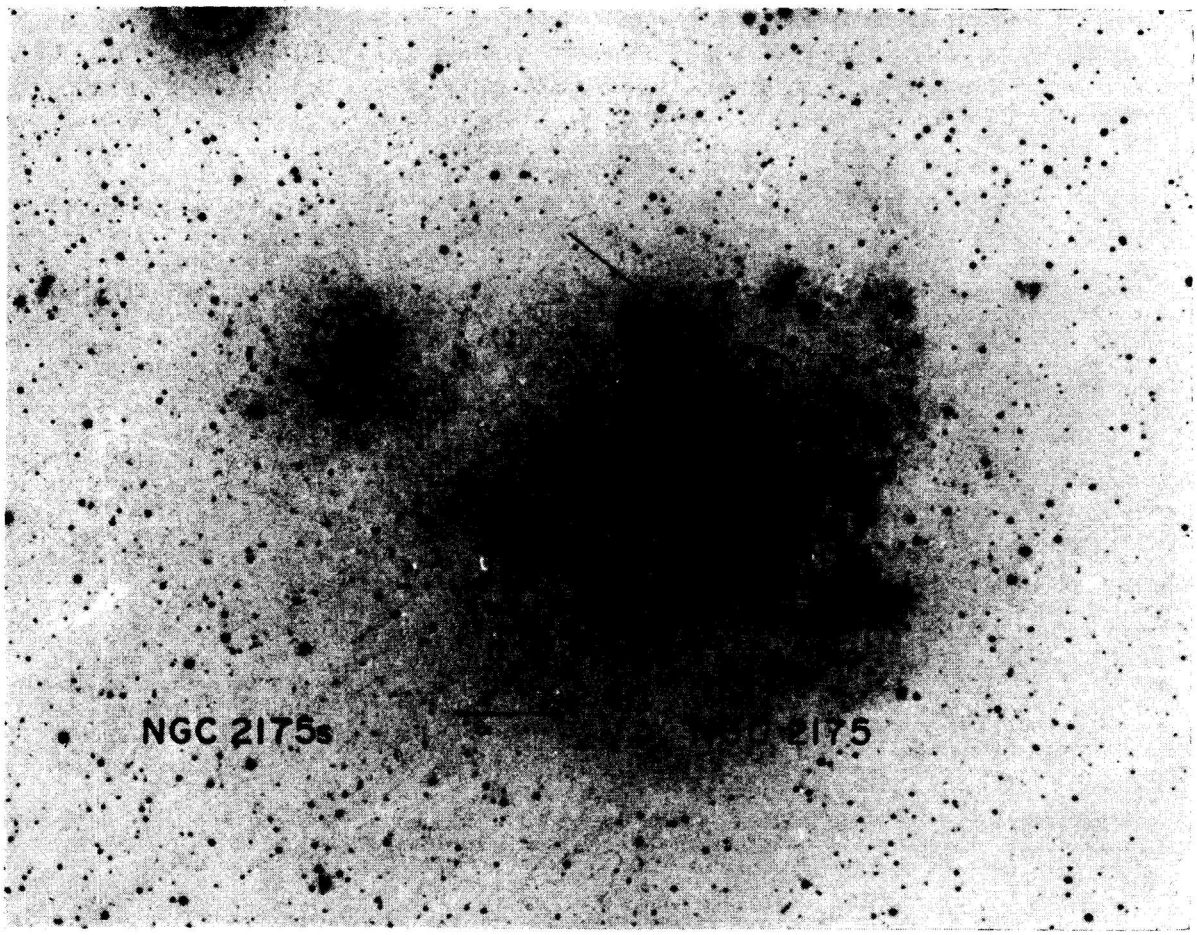

Figure 1.—*Enlargement of a 103a0 plate taken with the Schmidt Telescope at Tonantzintla Observatory showing NGC 2175s and NGC 2175. The innermost circle of the polar réseau used for the starcounts is marked at both clusters. The scale of the print is 1 mm = 17".4.*

a frequency of 4170 MHz agrees in its general features with that of Terzian's. Both of these studies show that NGC 2175s lies within the closed isophotes and that the presence of this grouping in no way affects the rather smooth contours. This may be due to the circumstance that the small cluster is not a strong source of excitation, and that the source is much smaller than the beam width.

It is suggested by Markarian that NGC 2175 is a part of the association Gem I (Markarian 1952), a suggestion borne out in subsequent investigations. Whether NGC 2175s belongs to the same association will be known only after its distance is estimated.

We have performed photometry in the UBV of the stars in NGC 2175s as well as of a fairly large number of stars in NGC 2175 itself although not exhaustively, since this investigation was directed towards the small cluster in particular. Starcounts were also made in both clusters so as to determine the number of stars belonging to each cluster and their extent.

II. The observations

Ample photographic material on the region of NGC 2175 was obtained with the Schmidt telescope of Tonantzintla Observatory (1): only the very best plates were selected for photometry. These plates with their specifications are listed in Table 1 of which the details are self explanatory.

Twelve stars in the region of NGC 2175s were chosen as standards for the calibration of the photographic plates. These stars were then observed photoelectrically in the *UBV* system in the fall of 1966 and 1967, with the 40-inch reflector at the Tonantzintla Observatory and in 1968 with the

(1) I am indebted to Mr. E. Chavira for taking the plates.
(2) I am also indebted to Dr. H. L. Johnson for the observing facilities offered at the Catalina Station.

5-foot reflector of the Catalina Station of the University of Arizona (2). Figure 2 is a chart where all the stars observed in *UBV*-photoelectrically o ıphotographically– are identified by numbers. The mean of the photoelectric observations and their probable errors wherever possible appear in Table 2.

TABLE 1

Plates Used for Photographic Photometry

Plate Number	*Coordinates of Center (1950)*	*Spectral Region*	*Exposure*
AC 6847	$6^h\ 5^m\ +10°\ 30'$	*V*	3 min
6848	,,	*V*	9 min
6849	,,	*V*	27 min
4156	,,	*B*	1 min
4154	,,	*B*	9 min
6850	,,	*U*	9 min
6151	,,	*U*	18 min

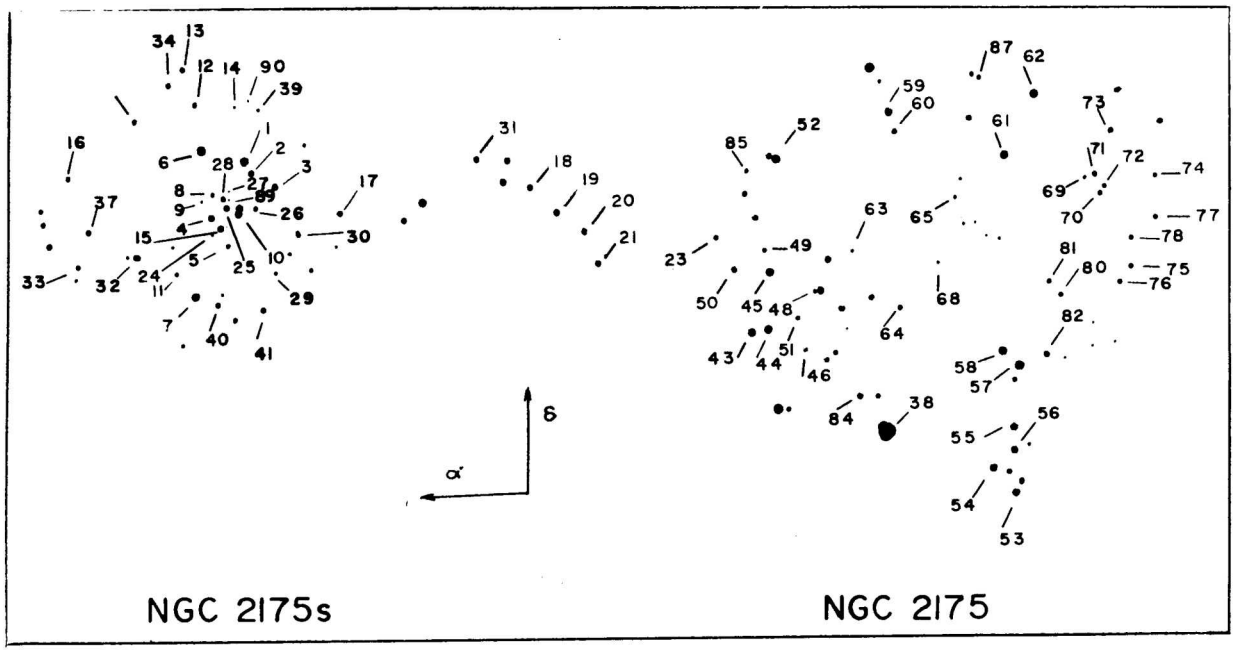

Figure 2.—*Identification chart for the region studied.*

The plates listed in Table 1 were measured on an Eichner astrophotometer of the University of Mexico, mainly by Miss Teresa Gomez. The calibrations were based on the photoelectric magnitudes given in Table 2. The limiting magnitude is set by the photoelectric standards and the measurements are complete to 15.0 magnitude.

Several plates were measured twice and in one case three times. Such repeated measurements provided a check on the combined behavior of astrophotometer and measurer. The probable errors of the means are comparable to those obtained of the mean magnitudes from different plates (measured once) with the same emulsion and filter combination. Therefore the unweighed mean values over all the measurements were taken, be these on the same plate or on different plates. The adopted *V* magnitudes as well as the *B*–*V* and *U*–*B* colors are listed in Table 3.

The first column gives the number of the star as it appears on the identification chart. The second, third and fourth columns are self explanatory. In the fifth column the probable membership to cluster NGC 2175 and NGC 2175s is designated by p and s respectively; the designation n indicates that the star is probably not a member of the clusters. (This scheme for the designation of membership is also employed in Table 2).

TABLE 2

Photoelectric Standards in the Region of NGC 2175s

Star	*V*	*B−V*	*U−B*	*Probable Member of*
1	10.95 ±0.00	+0.41 ±.02	−0.03 ±.02	s
2	12.80 ±0.01	+ .41	− .38	s
3	12.80 ±0.02	+ .44 ±.01	− .22 ±.01	s
4	11.01	+ .53	− .26	s
5	13.15 ±0.01	+ .45 ±.01	− .31 ±.01	s
6	13.29 ±0.00	+1.36 ±.02	+ .78	s?
7	9.21	+ .07	− .26	n
8	13.35 ±0.06	+ .61 ±.03	− .07 ±.01	s
9	14.54 ±0.01	+ .75	− .19	s
11	14.46 ±0.00	+ .85 ±.04	+ .11 ±.03	n
12	14.18	+ .77	+ .45	n
14	15.45	+ .39	+ .56	n
15	12.90	+ .58	− .11	s
16	13.01	+1.37	+1.54	n
17	13.64	+ .64	+ .56	n

TABLE 3

Magnitudes and Colors Obtained Photographically in the Region of NGC 2175 and NGC 2175 s.

Star	*V*	*B−V*	*U−V*	*Probable Members*
18	15.18	−0.39		n
19	14.04	+ .74		p
20	13.73	+ .69	−0.04	p
21	13.58	+ .43	+ .05	p
23	15.50	+ .80		p
25	11.50	+ .37	+ .01	s
26	14.65	+ .76		s
27	15.26	+ .41		s
28	13.94	+ .45	+ .07	s
29	13.72	+ .55	− .17	n
30	14.61	+ .75		n
31	13.18	+1.36		n
32	13.03	+ .54	− .25	n
33	12.87	+ .53	− .49	n
34	14.27	+ .40		n
37	13.03	+ .03	+1.20	n
39	14.59	+ .87		n
40	12.95	+ .56	− .09	n
41	12.65	− .56	− .06	n
43	10.77	+ .27	+ .11	p
44	10.83	+ .45	+ .04	p
45	10.72	+ .50	+ .11	p
46	13.86	+ .54	+ .10	p
48	13.83	+1.12		n
49	13.07	+ .42	− .08	p

TABLE 3 (cont.)

Star	*V*	*B–V*	*U–V*	*Probable Members*
50	12.96	+1.33	+ .61	p
51	13.31	+ .69	+ .75	n
52	9.93	+ .24		p
53	10.69	+1.79	+ .89	s
54	12.60	+ .40	+ .10	p
55	11.56	+ .30	+ .07	p
56	12.83	+ .54	− .03	p
57	11.37	+ .66	+ .24	p
58	13.18	+ .41	.05	p
59	11.71	− .01		n
60	12.97	+ .89	+ .16	n
61	11.56	+ .55	+ .06	p
62	11.68	+ .36	+ .20	p
63	14.81	+ .32		p
64	14.45	+ .36		p
65	14.77	+ .48		n
68	14.45	+ .51		p
69	14.73	+1.00		p
70	14.72	+ .54		p
71	14.79	+ .35		p
73	14.12	+ .48	+ .02	p
74	12.89	+ .66	+ .07	p
75	14.60	+ .40		p
76	12.69	+ .50	− .01	p
77	12.54	+ .30	− .01	p
78	13.26	+ .32	− .11	p
80	13.88	+ .25		n
81	14.75	+ .71		p
82	13.87	+ .33	− .27	n
84	14.42	+ .52		p
85	14.74	+ .28		p
87	13.79	+1.10		n
89	14.52	+ .36		s
90	15.11	+ .44		n

TABLE 4

Probable Errors of the Adopted Magnitudes Determined Photographically

Magnitude Interval / *Spectral Region*	10-11	11-12	12-13	13-14	14-15	15-16
V	0.02	0.03	0.02	0.03	0.05	0.06
B	——	0.04	0.07	0.04	0.05	0.07
U	——	0.02	0.02	0.03	0.03	——

Stars 10b and 10f which form a very close pair —with a separation of around 6″— are the brightest stars in NGC 2175s and certainly members of it, have defied determination of magnitude both photoelectrically and photographically by the usual methods. Therefore estimates are based on the diameter of the images. These measurements performed several times have finally yielded the V and the $U-B$ as follows: for 10b, $V = 10^{m}25$ $B-V = 0^{m}45$ and for 10f, $V = 10^{m}95$ and $B-V = 0^{m}55$. It is these data that are used in the diagrams.

The probable errors of the magnitudes of Table 3 are not given individually. Instead the average probable error for intervals of one magnitude, in U, B and B separately, are given in Table 4.

Comparison is made between Kirillova's B magnitudes (Kirillova 1958) and ours, based on 24 stars which are common to both lists. Kirillova admits that her magnitudes are not on the international scale. As a result of this comparison one finds that for B magnitudes fainter than 12.0, Kirillova's photographic magnitudes are systematically fainter than ours.

III. Color - Magnitude and Color-Color diagrams

With the data given in Table 2 and 3 color-magnitude and color-color diagrams are constructed. The V *vs* $(B-V)$ diagram for all measured stars in the region of NGC 2175s appears in figure 3, while figure 4 gives the color-magnitude diagram for stars in a smaller region around the cluster, marked by the small circle in figure 1.

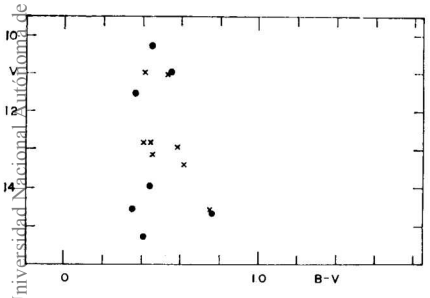

Figure 3.—*NGC 2175s all stars.*

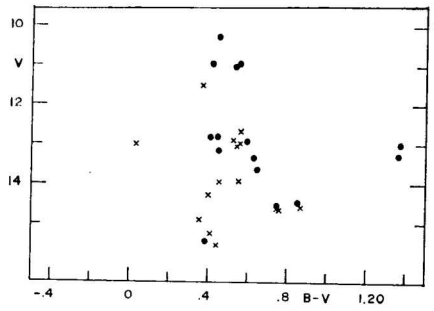

Figure 4.—*NGC 2175s stars within the region marked by a circle.*

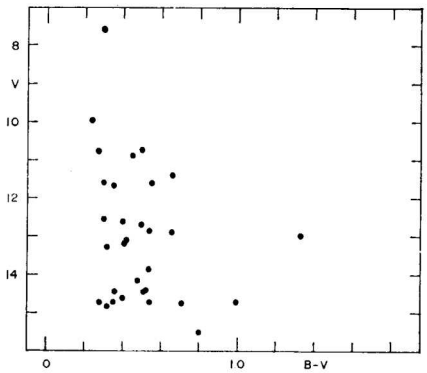

Figure 5.—*NGC 2175 all stars.*

Figures 3, 4, 5.—*Color-magnitude diagrams of the clusters. Stars with photoelectric magnitudes and colors are marked by crosses. Points stand for stars with photographic data.*

A main sequence is clearly manifested in either of the two diagrams but better still by the stars within the small circle. It will be shown later, by starcounts, that indeed the small cluster does not extend beyond the limiting circle.

The color-magnitude diagram for the stars in NGC 2175 proper, given in figure 5 shows a considerable scatter but still it appears quite acceptable as a galactic cluster C.M. diagram. Next, a smaller region is selected, around the star HD 42088 which lies in the sector marked on the chart. The color-magnitude diagram, not reproduced here, of the stars lying in this region marked in figure 1, shows much less scatter.

The color-color diagram, that is $(U-B)$ *vs* $(B-V)$, for NGC 2175s and NGC 2175, is given in figures 6 and 7 respectively. Due partly to the small number of stars in the small cluster it is difficult to reach a definite conclusion as to the amount of reddening suffered by this cluster. A color-excess as large as 0.70 magnitude or as small as 0.20 magnitude may not be incompatible with the color-color diagram of figure 6. On the other hand the $(U-B)$ *vs* $(B-V)$ diagram of NGC 2175 with a larger number of points and less scatter is compatible with a color-excess of around 0.20-0.25 magnitudes.

The color excess of HD 42088 (06), the brightest star in NGC 2175 and the source of the excitation of the H II region, has been investigated previously by others. The value obtained by Stebbins, Huffer and Whitford (1940) gives $E(B-V) = 0^{m}39$. More recently Hardie *et al* (1960) obtain $E(B-V) = 0^{m}37$ while Hiltner's Catalogue on polarization measurements of stars (Hiltner 1956) gives a value of $E(B-V) = 0^{m}39$. In the present discussion we have not obtained photoelectric UBV magnitudes of the star HD 42088. Its V magnitude and colors entered in the diagrams are those of Hardie *et al*. If one restricts the cluster NGC 2175 to the immediate vicinity of the

06 star, specifically to those stars that lie within the sector mentioned earlier one obtains the color-color diagram of figure 8, which might possibly be compatible with a reddening of 0.30-0.40 magnitudes. But we shall adopt here what appears to be more plausible from our data, that the reddening of NGC 2175 and NGC 2175s is 0.20 and 0.70 magnitude respectively. Whether the reddening of NGC 2175s is entirely interstellar or that a part of it is circumcluster remains to be seen.

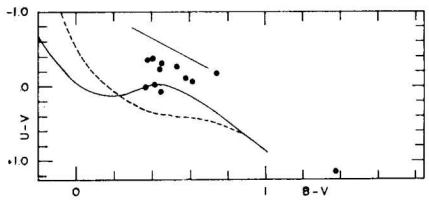

Figure 6.—*NGC 2175s.*

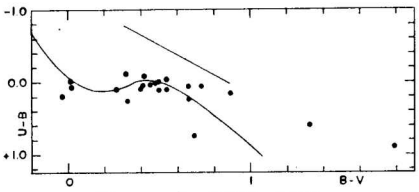

Figure 7.—*NGC 2175.*

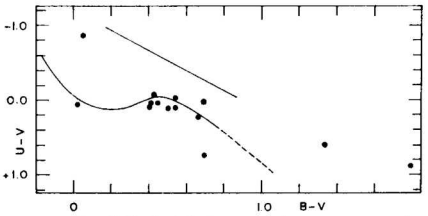

Figure 8.—*NGC 2175 stars in sector only.*

Figures 6, 7 and 8: (U—B) *vs* (B—V) *diagrams for stars in the clusters. Abscissae and ordinates are in magnitudes; the full line is the unreddened* (U—B) *vs* (B—V) *relation for main-sequence stars, the dashed line is that for supergiants, the straight line is the reddening line.*

IV. The distance of the clusters

The color-magnitude diagrams obtained in this work do not go faint enough, so that distances of the cluster cannot be determined based on these diagrams. However an estimate of the distance of particularly NGC 2175s will be attempted below.

Spectra were obtained in February of this year of the very close pair marked 10b and 10f in figure 2 (b and f stand for bright and faint respectively) with the new spectrograph attached to the 40-inch reflector, at Tonantzintla Observatory at a dispersion of 250Å per millimeter. Due to the proximity of stars the spectra could not be widened sufficiently to enable an unambiguous determination of spectral type and absolute luminosity. However both 10b and 10f belong to the natural group OB as defined by Morgan (1951). Star 10b may provisionally be classified as B2III. It is hoped to continue the spectral study of this region during the next observing season.

The absolute magnitude of a B2III star is around -4^m8 according to a recent study of the absolute magnitude calibration, (Weaver and Ebert, 1964). On the other hand a reddening of 0^m7 would give an interstellar extinction of the order of 2^m1 (for R = 3). The distance of the cluster NGC 2175s would then be 3500 pcs. This is probably a lower limit of the distance as the reddening adopted is an upper limit.

Taking again the calibration of absolute magnitudes cited above the distance of NGC 2175 may be estimated assuming that it is the same as that of the 06 star HD 42088 for a total absorption of 0.6 magnitude ($E(B-V) = 0^m2$; R = 3) and $M = -5^m1$ we obtain 2500 parsecs as the distance of NGC 2175. For an absorption of 1.2 magnitudes (based on the highest value of reddening mentioned earlier), the distance will be 1950 pcs. Hardie *et al* (Hardie, Seyfert and Gulledge, 1960) give 1660 parsecs as the distance of the Gem I association, which presumably includes NGC 2175; however they also suggest that the radial extension of the association is quite large, so that the distances determined here for HD 42088 may not be incompatible with their distance of Gem I.

With these tentative values of the distances it is more likely that the proximity of NGC 2175 and NGC 2175s is indeed a projection effect. In the direction of these clusters (l = 156°) the line of sight traverses the spiral arms nearly orthogonally. We are thus probably looking at two consecutive spiral arms where the large and small clusters are respectively located.

V. Starcounts around the clusters

A polar réseau, with concentric circles and radial lines, was placed over the clusters and stars to the plate limit were counted in each cell of the réseau. All starcounts were made by J. Peña. Averages were then obtained for each ring and for each section of ring in four quadrants. The unit of surface for the density is that of the innermost circle (region 1) of radius 1.2 millimeters (marked around NGC 2175s in fig. 2) which corresponds to 1.8 minutes of arc on our Schmidt plates. The plates used and some data on the starcounts are given in Table 5.

The location of the réseau for each one of the clusters is given in the chart where only the innermost réseau circle is marked. It is to be noticed that unlike previous convention the brightest star in NGC 2175, HD 42088, is not taken as the center of the cluster. A cursory inspection of a long exposure photograph in, say, blue light reveals that the stars involved in nebulosity —a circums-

tance that attests their physical relationship with the nebula NGC 2175– are roughly arranged in circular outline. The circles of the réseau were therefore placed in such fashion that this circular arrangement of the stars would fall in the same ring.

TABLE 5

The Starcounts on the Clusters

Plate	*Exposure*	*Spectral region*	*Field*	*No. of stars in cluster*	*Average number of stars of background per 10.17 sq. minutes or arc*	*Limiting magnitude of the counts*
AC 6269	2 min	*V*	NGC 2175s	7	3.2	14.50
AC 6269	2 min	*V*	NGC 2175	54	3.0	14.50
AC 6849	27 min	*V*	NGC 2175s	15	9.5	16.50
AC 6849	27 min	*V*	NGC 2175	65	8.6	16.50

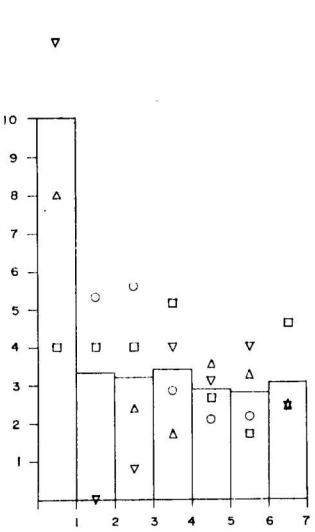

Figure 9.–*NGC 2175s on plate AC 6269.*

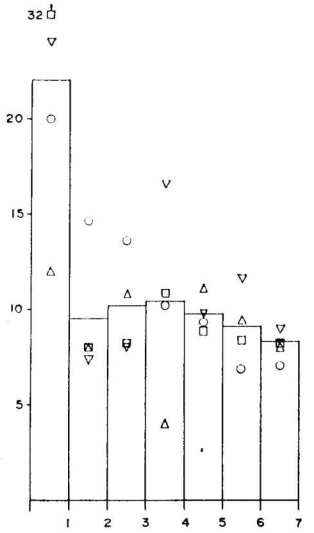

Figure 10.–*NGC 2175s on plate AC 6849.*

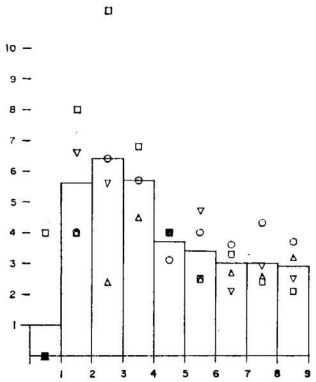

Figure 11.–*NGC 2175 on plate AC 6269.*

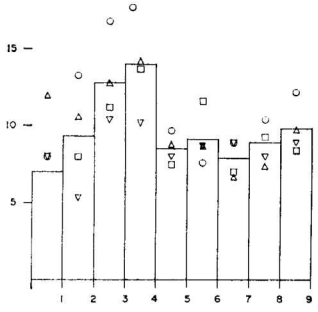

Figure 12.–*NGC 2175 on plate AC 6849.*

Figures 9, 10, 11, and 12: *Histograms giving results of starcounts made around the clusters. Abscissae are the radii of the polar réseau and ordinates the number density of stars; the unit area is that of the innermost réseau circle with radius of 1'.8.*

The results of the starcounts are presented by histograms –in Figures 9, 10, 11, 12– where the run of the star density in the central circular region (with diameter 3'.6 minutes of arc on our Schmidt plates) and in concentric rings is given. In addition, the density in four quadrants for each annular region also appears on the histograms. The variation of the density in the individual quadrants warrants the validity of the following conclusions reached from the histograms. Thus:

1.–The small cluster lies entirely within the first circle of the réseau. The number of stars belonging to the cluster is 15 (see figure 10). The range of absolute magnitude is not less than 5 magnitudes. Starcounts on the shorter exposure (figure 9), down to magnitude 14.5 give 7 as the probable number of members.

2.–As regards NGC 2175 figures 11 and 12 show that the major concentration occurs in regions 2, 3 and 4. Outside these the average density remains reasonably constant within what appear to be the statistical fluctuations. It may be interesting to note that the star density at the very center, within 1.8 minutes of arc is much lower than the average background. The concentration in the regions 2, 3 and 4 can also be traced in the four quadrants. The total number of stars within these three regions (the background eliminate) is 65 and this is taken to be the membership of the cluster.

The central empty region may well be the result of a statistical fluctuation. But if the central "void" is physically significant it follows that the cluster has no central condensation and that the stars are distributed in a spherical shell. In such a case the average density of the central region should have been at least of the order of magnitude of the background density. It is however much less than that, and this circumstance may lead one to suspect that the central empty part undergoes heavy absorption. No *UBV* colors are available for the few faint stars that fall in the region to enable a check on this point.

And finally, diameters of the clusters can be estimated using the distances determined above. For NGC 2175 it is 8.1 pcs assuming an apparent diameter of 14'.4 and a distance of 1950 pcs. For NGC 2175s it is 3.6 pcs for an apparent diameter of 3'.7 and a distance of 3500 pcs.

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