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ON A NEW CLUSTER OF NEBULAE IN PISCES

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A. *Introduction.*—Clusters of nebulae represent the largest aggregations of matter known. It may be expected that an investigation of their distribution in space, of their composition and physical properties will throw new light on such problems as the determination of nebular masses,[1] on the red shift of light from nebulae and on the evolution of stars and nebulae as well as the evolution of the universe as a whole. For these reasons it was thought desirable to undertake a more concentrated study of clusters of nebulae than hitherto attempted. The first step of this program consists in securing more complete data on the number and the distribution of groups of nebulae containing two, three or more members up to clusters of many hundred nebulae. The new 18-inch Schmidt telescope of the California Institute of Technology promises to be an ideal instrument for the investigation of groupings of nebulae brighter than the sixteenth magnitude.

B. *The 18-inch Schmidt Telescope.*—This instrument was built in the shops of the Institute under the direction of Dr. John A. Anderson. Some of its characteristic features are: effective aperture 18 inches, focal ratio $F/2$, diameter of field actually used is about 9.5 degrees; this field is free of coma and astigmatism to its very edge. The limiting magnitude for stellar images lies close to $m = 17.5$ and is reached with exposures of about forty minutes.

The first photographs with the new telescopes were taken on Sept. 5, 1936. During the following two months I obtained over one hundred photographs with exposures of ten to thirty minutes covering about one-fifth of the entire sky. Since then the weather has been mostly bad and it will not be possible to check the results obtained in the first fast survey until the fall of 1937. The results described in the following should therefore be regarded as preliminary. These results are presented here for two reasons. In the first place they illustrate the kind of work which may be done with a Schmidt camera of the type described. Secondly they outline a part of the proposed program on clusters of nebulae.

C. *Distribution of Nebulae in the New Cluster.*—Several new concentrations of nebulae were spotted in the first survey with the Schmidt camera. A large swarm of nebulae in Pisces promises to be of particular interest. In contradistinction to most of the clusters previously described[2] the extension of the new cluster is very great and its boundary surface is characterized by extreme diameters whose ratio is about of the order 1:5. In figure 1 the dots indicate nebulae which can easily be spotted on ten minute exposures. The faintest among them have an apparent magnitude of about $m = 16$. The greatest concentrations of nebulae occur in the groups C_1, C_2, C_3 and C_4. No nebulae are plotted in the region R because no good picture was available. The nebulae brighter than $m = 13$ are marked with their N. G. C. numbers 598, 404, 670 and 672.

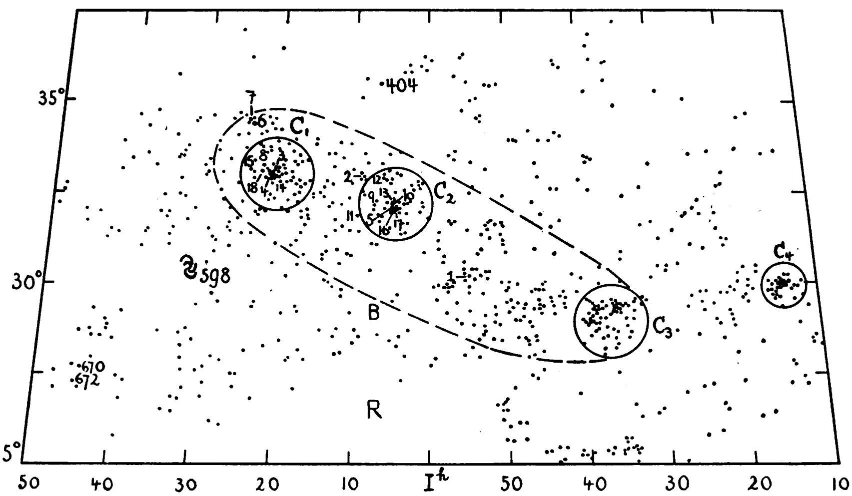

FIGURE 1

Positions in the figure are for the year 1950. No effort, however, has been made to plot the position of every nebula accurately.

According to Hubble's counts the average number N_m of nebulae per square degree near the galactic pole whose brightness is greater than m is given by [3]

$$\log_{10} N = 0.6\, m - 9.1. \qquad (1)$$

However, the actual number of nebulae observed is smaller because of the interference of obscuring matter. At the galactic latitude β a correction for partial obscuration must be added, so that the number of nebulae observed is N_β.

$$\log N_\beta = \log N + 0.15\,(1 - \operatorname{cosec} \beta). \qquad (2)$$

Since for the new cluster approximately $\beta = -30°$, we obtain for the limiting magnitude $m = 16$ the number $N_\beta = 2.2$ nebulae per square degree in this region. This is just about the number of nebulae which can readily be recognized on my ten minute exposures in the normal field. Inside the tentative boundary line B of the cluster (Fig. 1) the count rises to as high as $N_\beta = 30$.

The total number of nebulae brighter than $m = 16$ which belong to the cluster is of the order $N = 120$.

D. *Approximate Magnitudes of the Brightest Nebulae in the Cluster.*—Unfortunately extra focal images of the present Schmidt telescope are not very suitable for the comparison of nebular magnitudes with magnitudes of standard stars. Because of zones in the optical system, the extrafocal images are not sufficiently uniform. I found, however, that by appropriately timed guiding imitating the motion of a Schraffier-Kassette, the extrafocal images may be smeared over square areas in such a manner that over a wide field these squares show uniform blackening. Since the calibrated stars of the Mt. Wilson selected area No. 45 can be photographed on the same film with a major part of the neighboring Pisces cluster I was able to secure fair preliminary magnitudes for the eighteen brightest nebulae of this cluster. I am greatly indebted to Dr. F. H. Seares of the Mt. Wilson Observatory for the use of his tables of standard stars and his magnificent marked photographs of selected areas which enabled me to tie speedily nebular magnitudes to the magnitudes of standard stars. The photographic magnitudes of the eighteen brightest nebulae, marked 1, 2,... 18 in figure 1 are as follows.

TABLE 1

NO.	N. G. C.	m_p	NO.	N. G. C.	m_p
1	315	13.2	10	380	13.95
2	410	13.3	11	420	14.05
3	499	13.5	12	392	14.05
4	507	13.55	13	379	14.10
5	383	13.55	14	494	14.20
6	529	13.60	15	528	14.20
7	536	13.60	16	385	14.20
8	513	13.70	17	384	14.20
9	403	13.80	18	517	14.25

The N. G. C. numbers of the marked nebulae are given in the second column. The greatest concentrations of nebulae occur inside of the circles marked C_1, C_2, C_3. Whether or not all of these groups, as well as perhaps an additional group C_4, really form one giant system of nebulae can only be decided by further investigations.

From Hubble's counts of more distant nebulae it follows that the obscuration all over the new cluster is approximately uniform and amounts to a loss of about 0.25 magnitudes relative to the galactic pole. If we reduce our magnitudes to the pole we must therefore add $\Delta m = -0.25$ to the value of m given in table 1.

E. *Distance of the New Cluster.*—According to Hubble[3] the fifth brightest nebula of a cluster on the average has an absolute magnitude $M_5 = -16.4$. In our list the fifth brightest nebula is of the apparent magnitude $m_5 = 13.6$. In order to determine the distance we must correct this magnitude for total obscuration. The reduction to the galactic pole requires $\Delta m = -0.25$. In addition 0.25 magnitudes are lost because of obscuration at the pole, so that $m_5 = 13.6 - 0.5 = 13.1$. The distance p in parsecs of the new cluster therefore follows from

$$\log_{10} p = 1 + (m - M)/5 = 6.9. \qquad (3)$$

$$p = 7.94 \times 10^6 \text{ parsecs} = 25.8 \times 10^6 \text{ light-years}. \qquad (4)$$

Since the long axis of the cluster extends over more than ten degrees, the actual extension must be greater than four million light-years whereas the shortest axis is of the order of one million light-years.

It should further be noted that the western end of the cluster (Andromeda end) seems to lie at a greater distance than the eastern Pisces end since there is a decrease in brightness of the cluster nebulae going from east to west. The long axis of the cluster therefore may form with the line of sight an angle considerably different from a right angle.

F. *Apparent Velocities of Recession of Nebulae in the New Cluster.*—Hubble[3] gives the following relation for the apparent velocity of recession v of a cluster in terms of the magnitude m_5 of its fifth brightest nebula.

$$\log v = 0.2\, m_5 + 1.025. \qquad (5)$$

In our case, with $m_5 = 13.1$, we should expect

$$v = 4400 \text{ km./sec.} \qquad (6)$$

This value refers to the presumably nearer eastern end of the cluster.

Mr. M. L. Humason of the Mt. Wilson Observatory has kindly consented to measure the red shifts of some of the more prominent nebulae in the new cluster. But so far weather conditions have been most unfavorable. Some data, however, are already available from previous measurements which roughly check the conclusions drawn in this paper.

Hubble and Humason had already previously recognized some groupings of nebulae in Pisces and Andromeda.[2,4] Most conspicuous among these groups is what they designate as the *Pisces group*, with the coördinates R. A. $1^h\ 3.5^m$, Decl. $+ 32°$, 1930. In figure 1 the circle C_2 encloses this group. Hubble and Humason[2] are of the opinion that "this is not a cluster, but a group of some 25 elliptical nebulae which stands out from the approximately uniform background of field nebulae." Since the 100-inch plates cover less than one square degree it is readily understandable that these plates do not directly reveal the fact that the Pisces group may be part of a large cluster covering perhaps more than 15 square degrees. The value of powerful wide angle telescopes such as the new Schmidt camera for investigations of nearby clusters of nebulae becomes thus apparent.

Hubble and Humason[2] give as the average v of four nebulae in the Pisces group

$$v = 4630 \text{ km./sec.} \tag{7}$$

with a range of 500 km./sec. between the individual values. This constitutes a fair check of the previous result (6).

Humason[4] gives additional apparent velocities for nebulae in the group enclosed by the circle C_4.

	R. A. (1950)	Decl.	v
Group C_4	$0^h\ 15.9^m$	29°50′	6560 km./sec.

Whether or not this group has any mechanical relation to the Pisces cluster must be determined by further observations.

G. *Concluding Remarks.*—Assuming that the range in brightness in clusters of nebulae is about five magnitudes, the total number of nebulae in the Pisces cluster may be estimated as between 300 and 400. As already mentioned the most interesting feature of this new cluster is its large extension and its asymmetrical flat shape which suggests that the cluster as a whole is rotating. It will be of interest to test this point. Among the already known clusters the new cluster has perhaps its closest analogue in the clustering in Centaurus described by H. Shapley.[6] The analysis of these two clusters also suggests that the well-known Virgo cluster may not be confined to the relatively small region ascribed to it ordinarily. The concentration of nebulae in Virgo plus the northern and southern extensions of this concentration into Canes Venatici, Ursa Major and Hydra, respectively, may form an extended cluster of the type described in this paper.

On finishing this study I ran into a preliminary notice by C. W. Tombaugh and C. O. Lampland[7] who announce the discovery, with the 13-inch Lawrence Lowell telescope of Flagstaff, of a considerable number of clusters of nebulae ranging from 20 to 90 members. These findings confirm the impression gained in my first fast survey with the Schmidt camera, namely, that our knowledge of the clustering of nebulae will be greatly enriched by the use of powerful wide angle telescopes.

My sincere thanks are due to the observatory council of the California Institute of Technology for the use of the new Schmidt camera as well as for the provision of all the necessary working and living facilities at the new observatory site on Mt. Palomar. I am also greatly indebted to

Dr. W. Baade who has given much of his time to teach me some elements of practical astronomy.

[1] F. Zwicky, *Helv. Phys. Acta*, **6,** 124 (1933).
[2] E. Hubble and M. L. Humason, *Astrophys. Jour.*, **74,** 43 (1931).
[3] E. Hubble, *The Realm of Nebulae,* Yale University Press, 1936.
[4] M. L. Humason, *Astrophys. Jour.*, **74,** 35 (1931).
[5] M. L. Humason, *Ibid.*, **83,** 10 (1936).
[6] H. Shapley, *Harv. Bulletin* No. **874,** 9 (1930) and No. **903** (1936).
[7] C. W. Tombaugh and C. O. Lampland, *Publ. Am. Astr. Soc.*, **8,** 256 (1936).

*ELECTROKINETICS. XIX. INTERFACIAL ENERGY AND THE MOLECULAR STRUCTURE OF ORGANIC COMPOUNDS. V. THE ELECTRIC MOMENT OF Al_2O_3: BENZENE-NITROBENZENE INTERFACE**

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Martin and Gortner[1] and Jensen and Gortner[2] have shown that an intimate relationship exists between the structure of organic molecules in a liquid and the electrokinetic potential which exists at the interface between a solid and that liquid. The greater the polarity or the dipole moment of the liquid, the greater is the potential which develops. Since benzene possesses no permanent dipole moment, no potential develops at the solid-liquid interface. On the other hand, benzene derivatives in which some radical has been substituted for a hydrogen all show orientation and give rise to an electrokinetic potential. The potential developed by nitrobenzene is of large magnitude.[1] Accordingly it seemed of interest to study the behavior of a mixed liquid system containing both polar and non-polar molecules.

The streaming potential technique was used and the sample of Al_2O_3 for the diaphragm was from the same lot employed by Jensen and Gortner in their earlier studies. The large resistances encountered were measured using a quadrant electrometer as a null instrument. We were unable to find a complete series of concentration: dielectric constant values for the system benzene–nitrobenzene. Accordingly the data are recorded only as $\frac{H\kappa\eta}{P}$ where H = e. m. f. developed by streaming a liquid of viscosity η through the diaphragm under hydrostatic pressure P and κ is the specific conductivity of the liquid in the pores of the diaphragm.