ANNALS OF THE OBSERVATORY OF LUND. NO 6

A STUDY OF DOUBLE AND MULTIPLE GALAXIES

TOGETHER WITH INQUIRIES INTO SOME GENERAL METAGALACTIC PROBLEMS

WITH AN APPENDIX CONTAINING A CATALOGUE OF 827 DOUBLE AND MULTIPLE GALAXIES

BY

ERIK HOLMBERG

PUBLISHED BY THE OBSERVATORY

LUND, SWEDEN

1937

UPPSALA 1937
ALMQVIST & WIKSELLS BOKTRYCKERI-A.-B.
37522

PREFACE

Our knowledge of the metagalactic system and its constituents has made astonishingly rapid progress during the last two decades. Through the skilful and admirable work of many of the leading astronomers and the extensive collection of data in the course of daily routine-work at several observatories the problems connected with the objects formerly, very inadequately, termed "white nebulae" have been solved to a great extent and new problems have presented themselves.

Since many years it can be positively said that there is no longer any doubt that these objects are vast stellar systems, situated at immense distances as compared with the distances formerly assumed, and as compared with the distances *en vogue* in earlier astronomical work. Thus we have reached the third system in CHARLIER's infinite world, the system of the galaxies, or the metagalactic system as it has been named by LUNDMARK.

Although the fundamental properties of this system and its constituents have been investigated in several respects, there still remain a good many questions to be solved. It is the purpose of the present paper to discuss some general problems concerning the anagalactic objects. Especially it is our intention to study the double and multiple galaxies and the possibilities of obtaining information about the galaxies in general from inquiries into this special class of objects.

The present investigations were started at the Lund Observatory and have been carried out there as well as at the Heidelberg Observatory, Königstuhl (Germany) during the last two years. During the months of September—December 1935, and during March and September 1936 I have had the opportunity of staying at the Observatory of Heidelberg for the collection of the material for the present investigation.

It is my agreeable duty and a great pleasure to me to express my best and sincere thanks to Dr. KNUT LUNDMARK, Director of the Lund University Observatory, who suggested the subject of the present investigation to me. Through his inspiring instruction and through the great interest that he has always taken in my investigations, the carrying out of the work has been greatly facilitated. Dr. LUNDMARK, who has earlier made several investigations into double galaxies, has kindly placed at my disposal a card catalogue containing some 150 objects.

To Professor Dr. HEINRICH VOGT, Director of the Badische Sternwarte zu Heidelberg, Königstuhl, I am very much indebted. Through his kind admission I have had access to the wonderful collection of plates taken with the Bruce refractor by the late Dr. MAX WOLF, Dr. KARL REINMUTH and other members on the staff. By the aid of these plates the collection of all the data which are to be found in the present catalogue has been made feasible. Further I should wish to express my gratitude for the special arrangements at the Heidelberg Observatory which were made for my part and also for the very great kindness which was always shown to me at this institute.

It is a pleasant duty to tender my best thanks to Dr. Karl Reinmuth for a great deal of good advice and assistance in the management and the study of the plates. Through his skilful aid and good practical arrangements my work at Heidelberg was facilitated to a great extent.

To Professor Walter Gyllenberg and to the other members on the staff of the Observatory of Lund I wish to express my thanks for valuable discussions and friendly criticisms.

In conclusion I wish to mention with much gratitude the councils of Kungl. Fysiografiska Sällskapet i Lund and of Längmanska Kulturfonden, which have contributed to the performance of the statistical and numerical work through their pecuniary support. In this connection I also wish to express my thanks to I. G. Farbenindustrie Aktiengesellschaft (Agfa), Berlin, and their representatives in Stockholm for the friendly donation of photographical material, through which it has been possible to obtain the reproductions of the Bruce plates which are given at the end of this paper.

Lund Observatory, September 1937.

ERIK HOLMBERG.

CHAPTER I

INTRODUCTORY REMARKS

1. In the present paper an account will be given of the search for double and multiple galaxies with the aid of the great plate material of the Heidelberg Observatory. The general qualities of these peculiar objects will be discussed, and some problems concerning galaxies in general will also be taken up for discussion. Before entering upon these questions some introductory remarks, however, will be given.

The size and structure of the great system of galaxies, the metagalactic system, have been the subject of many different investigations in the course of time. Even at an early stage it could be shown that the apparent distribution of the anagalactic objects is by no means a uniform one. Non-uniformity seems to be more generally prevalent in the Metagalaxy than uniformity. Here we do not think of the decreasing number of objects in low galactic latitudes, which is very probably a result of a general absorption in our own galaxy. Nor do we think exclusively of the non-uniformities which are the result of the great number of metagalactic clusters. Even in high galactic latitudes and in the general field between the clusters great irregularities are to be found.

These remarkable facts were pointed out already by Sir WILLIAM HERSCHEL in 1811 and they have later on been closely discussed by KNUT LUNDMARK, HARLOW SHAPLEY and others. Among the great number of studies of this problem that have been made in the course of time I only wish to mention the investigation by B. J. BOK[1], who examined the distribution of galaxies from a mathematical point of view to see in how far it deviates from an accidental one. BOK concludes that the tendency towards clustering is probably one of the chief characteristics in the metagalactic system.

Here the question may be raised whether the above deviations are the result of the occurrence of unevenly distributed dark nebulae in our own galaxy or perhaps in the space outside of it. K. LUNDMARK and P. J. MELOTTE[2] have made a scrutiny of the Franklin-Adams Plates in regard to the existence of dark nebulae. It is found that these dark nebulae are present even in high galactic latitudes and LUNDMARK states that the spirals seem to avoid the regions where these nebulae are prevalent. In this connection H. SHAPLEY[3] made an investigation using Harvard plates and he suggested that the dark nebulae in high galactic latitudes might be a consequence of deviations in the distribution of the stars. Later on SHAPLEY[4] investigated the connection between the numbers of stars and of galaxies in the same fields. There was no correlation to be found between the variations in the numbers of the two classes of objects. SHAPLEY concluded that if the irregularities in the distribution of the galaxies are due to obscuring matter, this must be external to our own system. This, how-

[1] Harvard Bull 895 (1934). [2] Upsala Medd 30 (1927). [3] Harvard Bull 844 (1927). [4] Harvard Bull 890 (1932).

ever, seems rather improbable. Several different investigations have been made into this problem and it is found that a general absorption in the metagalactic space probably must have a comparatively small value. We beg to refer to Chapter VIII of the present paper where this absorption problem is discussed in connection with some investigations into the spatial arrangement of the galaxies.

Thus we must very likely accept the clustering tendencies in the metagalactic system as a reality. In these circumstances it is not surprising that there should exist a great number of double and multiple galaxies which are physically connected. We can very well imagine that there is an unbroken line of transition from double systems to the small groups and from these to the still greater metagalactic clusters containing several hundreds of components. At the end of the series we may perhaps place the metagalactic clouds.

2. In the course of time a great many double galaxies have been recorded. Sometimes it has been pointed out that these pairs may be physical systems. For a long time the double galaxies were, however, considered as mere curiosities and no attempts were made to make use of them for the derivation of absolute qualities of the galaxies.

It is not my intention to enter into a historical account of the developement of our conception and knowledge concerning the double galaxies. On the other hand, it seems justified to make a digression here and briefly mention the ideas of Sir William Herschel as to double and multiple nebulae. In his remarkable paper of 1811 Herschel[1] discusses the double nature of altogether 139 objects, which according to him may be called double nebulae. Some of these objects form very narrow systems, and Herschel states that on account of "their great resemblance in size, in faintness, in nucleus, and in their nebulous appearance" it must be evident that their nebulosity originally belonged to one common stock. Herschel thought that he had found objects which were in the process of splitting. In this way many of them had already separated into two or more components. Herschel urges that all these nebulae are really double. "Then if we would enter into some kind of examination how they came to be arranged into their binary order, we cannot have recourse to a promiscuous scattering, which by a calculation of chances can never account for such a peculiar distribution of them." In a figure Herschel gives some drawings of double nebulae of various appearances. Although it would be of great interest to compare in detail the objects of Herschel with those of mine, I can refrain from that work, because during the preparations for the Lund General Catalogue of Nebulae such a comparison has already been started.

K. Lundmark[2] in several papers discusses the origin of the double and multiple galaxies. The frequency of captures between the components of the metagalactic system is found to be very great, one every 3500 years. Thus we ought to have a great many physical double systems. These will then act as condensation nuclei attracting new members. In this manner the systems will grow larger and larger and the possibilities for the formation of groups and clusters are given. In this connection Lundmark also discusses the small "nebulae", accompanying large objects and found by H. D. Curtis in the course of his work on galaxies. Lundmark draws the conclusion that these small objects are certainly no satellites. They are ordinary galaxies and the result of the clustering tendencies in the metagalactic space.

3. In this place I should wish to mention some of the most prominent and well known of the double and multiple galaxies. As a system with at least three components we have our own galaxy and the two Ma-

[1] Phil Trans, 1811, p. 269. Also Scientific Papers, Vol II, p. 459 (1912).

[2] Upsala Medd 30 (1927) and Lund Circ 9 (1934).

gellanic Clouds. Further the great spiral in Andromeda and its two elliptical components form a very well known triplet. In this case the physical connection between the components has been proved through the agreement of radial velocities.

In the Publications of the Lick Observatory, Volume VIII (1908) we find many beautiful reproductions of double and multiple galaxies. There may be found the double systems NGC 3226, 3227 (Plate 24), NGC 4485, 4490 (Plate 36), the multiple system with NGC 4565 as principal component (Plate 40), the double systems NGC 4627, 4631 (Plate 41), NGC 4712, 4725 (Plate 42), NGC 5194, 5195 (Plate 47), NGC 5857, 5859 (Plate 50), and at last the great group of NGC-objects with NGC 7331 at the centre (Plate 67). All these systems, except NGC 5857, 5859, are to be found in the present catalogue and many of them can also be seen on the plates at the end of this paper.

Our list of the more conspicuous objects is, however, not yet finished. Without striving for completeness we further want to mention the very narrow systems NGC 4567, 4568[1] and NGC 4647, 4649. These systems are two of the brightest pairs in Virgo. Concerning the last one H. SHAPLEY[2] has shown that the components have so large diameters that they are perhaps mere nuclei of a larger system. The same thing is perhaps true as regards the pair NGC 5216, 5218, where P. C. KEENAN[3] has found a faint band of connecting matter between the components.

Finally I should wish to call attention to the beautiful group NGC 7317—7320, first described by M. STEPHAN[4] at Marseilles in 1877 and later investigated by H. SHAPLEY and K. LUNDMARK. While the former pointed out that there are in fact five objects shown on modern photographs, the latter discovered on Mount Wilson plates a sixth object, a very faint Magellanic cloud. Whereas SHAPLEY[5] names the group the Quintet of Stephan, LUNDMARK names it the Septet of Stephan, because he also includes a nearby spiral into the group. It seems clear that we here have the nucleus of a metagalactic cluster.

4. KNUT LUNDMARK was the first to recognize the great importance of the double galaxies and to make use of them in obtaining the absolute characteristics of the anagalactic objects. In several papers[6] he calls attention to these problems. Thus LUNDMARK has investigated about 8000 NGC-objects and has found about 200 double and multiple systems. Furthermore he has made a search for these objects on the Franklin-Adams Plates, on Crossley plates and on plates taken with the great instruments at Mt Wilson.

Concerning the absolute characteristics of the anagalactic objects LUNDMARK has pointed out that from the double galaxies we can, among other things, obtain the differences in absolute magnitudes and in absolute dimensions. From these we can derive the dispersions in the corresponding quantities, and through processes of integration, or rather interpolation, numerical expressions for several different connections can be derived. Thus the double galaxies are of very great importance for the derivation of absolute quantities and interrelations within the metagalactic system.

---

[1] See Handbuch der Astrophysik, Band V: 2, p. 864 (1933). [2] Harvard Bull 895 (1934). [3] ApJ 81, p. 355 (1935).
[4] MN 37, p. 334 (1877). [5] See e. g. Harvard Bull 878 (1930).
[6] Upsala Medd 8 (1926), Upsala Medd 16 = VJS 61, p. 254 (1926), Upsala Medd 30 (1927) and Upsala Medd 41 = VJS 63, p. 350 (1928).

CHAPTER II

DOUBLE AND MULTIPLE GALAXIES AS PHYSICAL SYSTEMS

5. A very important question is, of course, how to define a double or a multiple galaxy. The definition should be so formulated that optical systems are excluded as far as possible while as many physical systems as possible are included. Sometimes the physical connection between two neighbouring galaxies can be clearly proved. Some faint bands of connecting matter are perhaps to be found between the two objects, or the radial velocities can be shown to have the same value. These cases, however, are rather the exception than the rule. In general, we thus need some sort of working definition.

The simplest and most natural thing to use in the selecting of physical systems is of course the apparent distance between the components. Thus K. LUNDMARK[1] has considered as double galaxies objects for which this distance is equal to, or smaller than, the apparent diameter of the largest of the components. As an extension of this definition it is also possible to take account of the distance between the components along the line of sight. This distance is to some extent indicated by the differences in the apparent magnitudes and dimensions of the two galaxies. As, however, the dispersions in the absolute magnitudes and dimensions among the galaxies are comparatively large, in most cases this extension will be of no value. In the present investigation we have thus preferred to use a slightly modified form of the above definition. As a double galaxy will here be considered a system in which the apparent distance, ϑ, between its components is equal to, or smaller than, twice the sum of the largest apparent diameters, a_1 and a_2. Thus:

$$\frac{\vartheta}{a_1 + a_2} \leq 2. \tag{1}$$

In a multiple system the condition shall be valid for anyone of the components taken together with one of the others.

This definition has proved to be very practical. Without being too rigorous it excludes, as will be shown below, practically all optical systems. It should be mentioned that in some cases components have been included even though the distances to the next ones are too large according to the definition. These objects are generally more conspicuous ones. They will not, however, be included in the general statistical investigations.

Concerning the above definition some remarks may be made. In one case the definition has not been exactly employed. The great galaxy in Andromeda, NGC 224, has been assumed to have only the two well known elliptical components. In the area within twice the largest diameter several faint galaxies are, however, to be found. In the present catalogue a double galaxy is, for instance, given within this area. In this case we have thus made use of the above-mentioned extension of the definition of a double or multiple system. Further, attention should be called to the systematic errors in the measured diameters of the small objects. It is a well known fact that small galaxies, in a higher degree than large ones, come out too small on the plate. This will cause systematic variations in the above definition which are dependent on the distance of the object. However,

[1] Upsala Medd 30 (1927).

it will be shown below that the most frequent value of the quantity $\frac{\vartheta}{a_1 + a_2}$ is smaller than the unit and thus these variations will be of no great significance.

Concerning the definition of double galaxies it shall frankly be admitted that there might be sources of error which in exceptional cases make a decision as to the double nature of the object on the basis of its structural properties difficult, nay, in very exceptional cases, impossible. One of these sources will arise on the ground that there may be a few galaxies having double nuclei. Suppose now that we photograph a very distant galaxy having two nuclei: then we might classify the object as a double. This source of error is not of high importance, not only because of the few cases of double nuclei but also because double nuclei may be the result of the capture of an outside object and its gradual approach to the capturing nucleus.

Another source of error which should be mentioned in this connection is the effect of an absorption within the objects, which might be so queerly distributed that it gives a false impression of a double system. Dr. K. LUNDMARK has communicated to me that, in his lecture[1] at the first symposion for astrophysics at Paris in July 1937, Dr. B. LINDBLAD suggested that e. g. the double object NGC 1888, 1889[2] is not a double system but a single system exhibiting an unusually strong absorption effect. Without entering here upon a discussion as to the justification of that suggestion it will be admitted that it might be a very interesting illustration of an unusual source of error. From my experience it seems that it can safely be stated that the above-mentioned effects, no doubt, are so scarce that they are of no statistical consequence.

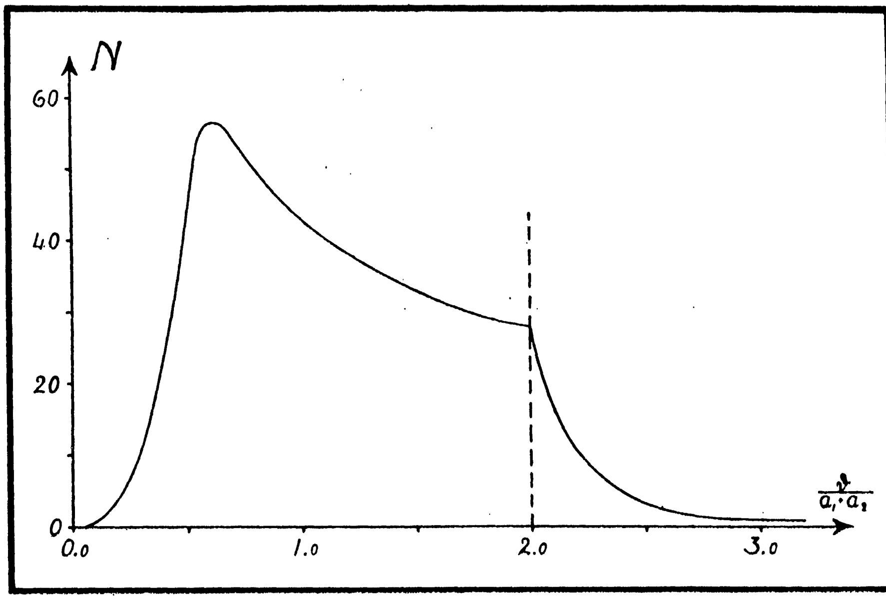


Fig. 1.

Distribution of the relative apparent distances between the components of double systems.

Here may also be the place for some attention to be given to the gravitational lens effects as produced by galaxies. F. ZWICKY[3] points out that anagalactic objects offer a much better opportunity than stars for the observation of deflections of light. Thus some of the massive and concentrated galaxies may be expected to deflect light that passes near the edge of them by as much as half a minute of arc. Since, however, the deviations are of importance chiefly when dealing with optical systems, we need not discuss them in detail here.

The distribution of the values of the quantity $\frac{\vartheta}{a_1 + a_2}$ for the 695 double systems in the present catalogue is shown in Fig. 1. The class breadth has been given the value of 0.1. It appears that the distribution curve

[1] Not yet published. [2] Not included in the present catalogue. [3] The Physical Review, Vol 51, p. 290 (1937).

attains its maximum value when the abscissa reaches the value of 0.6 units. The small frequencies to the left of the said point indicate an under-representation of the material here. This can easily be explained through the fact that one component is more or less completely hidden behind the other. In the appearance of the curve to the right we have a general proof of the existence of physical systems. If the systems consisted mainly of optical pairs, the frequencies would become larger when the value of the abscissa was approaching the value of 2.0.

6. It is of course of great importance especially with respect to the statistical investigations in the following chapters to obtain some information concerning the number of optical systems which might be contained in the material here presented. With the help of certain statistical computations an estimation of this number is possible. If, in this connection, we assume the galaxies to be distributed at random in the sky, we can use a derivation according to G. Pólya.[1] If $(n+1)$ points are scattered arbitrarily over a sphere, and if one of the points, P, is selected as origin, then the probability that the nearest one of the remaining n points is situated within the distances ϑ and $(\vartheta + d\vartheta)$ from P can be expressed as follows:

$$W_{\vartheta,(\vartheta+d\vartheta)} = -d(\cos^{2n} {}^1/_2\,\vartheta). \tag{2}$$

If the average value of this distance is indicated by $\bar{\vartheta}$ we get:

$$\bar{\vartheta} = -\int_0^{\pi} \vartheta \cdot d(\cos^{2n} {}^1/_2\,\vartheta) \simeq \sqrt{\frac{\pi}{n}}. \tag{3}$$

The last expression is obtained from Wallis' formula for π, and thus the assumption has been made that n is a large number.

As the angle ϑ has a very small value, and the number n in the present case has a very large one, the computation of successive values of the expression $\cos^{2n} {}^1/_2\,\vartheta$ has been made by means of the following transformations:

$$ln(\cos^{2n} x) = ln(1-\sin^2 x)^n \simeq n \cdot ln(1-x^2) = n\left(-\frac{x^2}{1}-\frac{x^4}{2}-\cdots\right) \simeq -n \cdot x^2. \tag{4}$$

Here ln designs the natural logarithm.

We will put the value of n at 60000. At the North Galactic Pole this corresponds to a limiting magnitude of $15^m.7$, if we make use of the density curve III in Fig. 24 (Chapter VIII) where the space density of the galaxies is illustrated. The limiting magnitudes of the plates will be discussed in the next chapter and there it will be shown that for stars these magnitudes are in general situated between $15^m.0$ and $17^m.5$. Concerning galaxies we must assume a brighter[2] limiting magnitude, and thus the above value of $15^m.7$ may be considered justified. The assumed value of n may be regarded as a maximum value, especially when we take the great absorption of light in low galactic latitudes into consideration. As, however, the number of optical systems increases with n, it may be more appropriate to assume too large than too small a value.

The right curve in Fig. 2 corresponds to the values of the probability $W_{\vartheta,(\vartheta+d\vartheta)}$ as computed according

[1] AN 208, p. 175 (1919).

[2] In the present paper the terms bright magnitude and faint magnitude will be used in order to avoid every misunderstanding.

to the rules given above. The left curve represents the distribution of all the apparent distances between the components of the double systems in the present catalogue. The upper part of the last curve falls beyond the frame of the figure. The two distribution curves are reduced to a class breadth of five minutes of arc, and the areas within the two curves correspond to the values 0.78 and 0.22 respectively. In a following chapter[1] it will be shown that in the direction of the North Galactic Pole 22 % of all galaxies on an average are members of double or multiple systems.

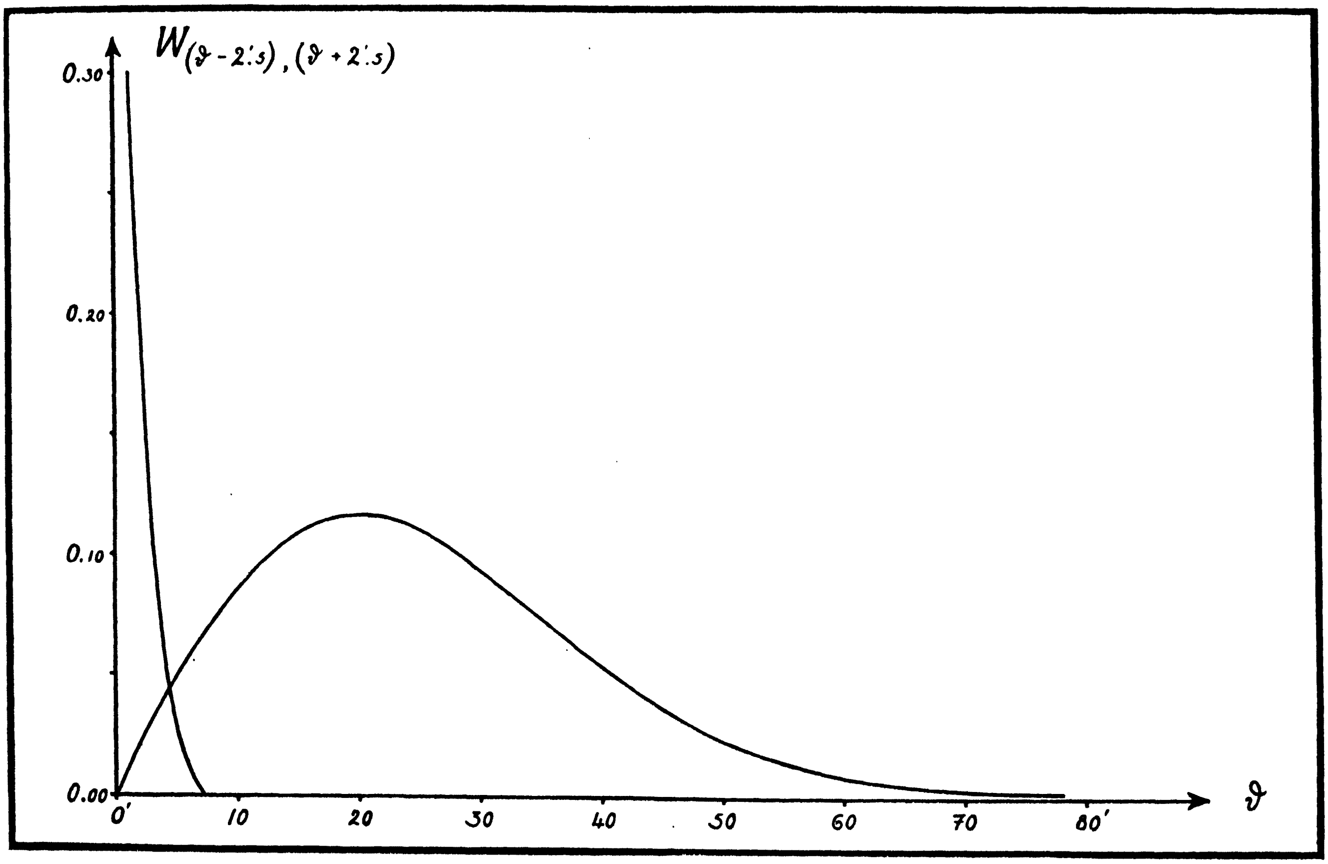


Fig. 2.
The distributions of the apparent distances between the components of physical pairs (left curve) and between isolated galaxies (right curve).

The area that is common to the two curves can be assumed to indicate the maximum value of the number of galaxies of the present catalogue which are the result of the existence of optical systems. This number amounts to 13 % of the number of individuals in the left distribution. In reality, the relative number of optical systems ought to be much smaller. The optical pairs must be more frequent, when the apparent distance between the components is large. Concerning the double galaxies given in the present catalogue, however, both of the components are, in this case, generally large and bright, and on account of this similarity the number of optical systems may be assumed to be greatly reduced. Also it has been pointed out that the number n has been given

[1] See Chapter VIII.

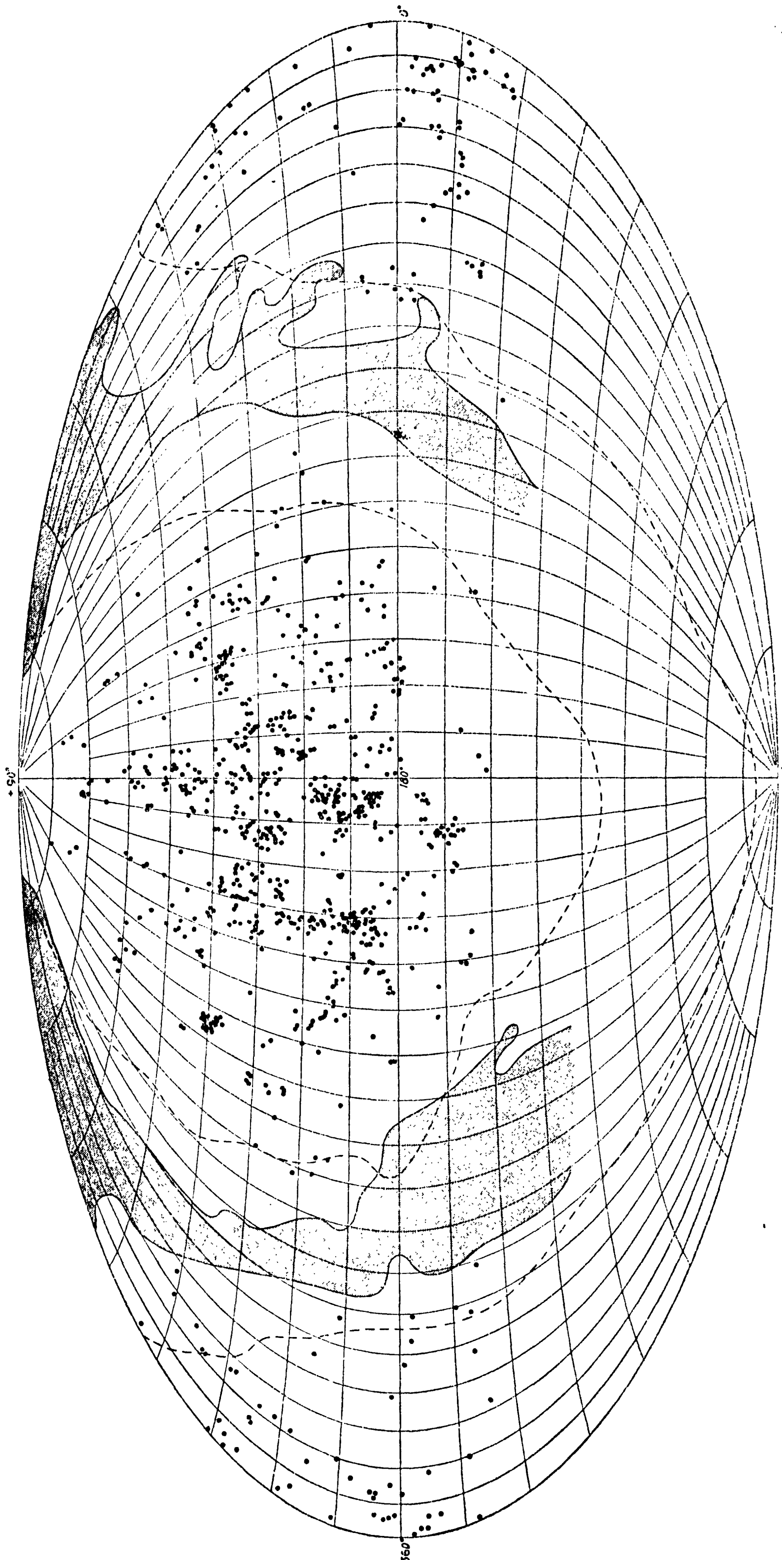


Fig. 3.
Apparent distribution of double and multiple galaxies.

a maximum value. Thus one seems to be justified in assuming that the relative number of optical systems in the present catalogue only amounts to some few per cent. Here we also wish to refer to Chapter VIII of the present paper, where the number of optical systems has been discussed in connection with some investigations into the spatial arrangement of the double galaxies. There similar results have been obtained as above.

7. Here may be the appropriate place for giving a table of distribution showing how, in the present material, the number of systems, N, changes with the number of components, n. From Table 1 it clearly appears how rapidly the number N decreases when n grows larger. The total number of double or multiple systems in the present catalogue amounts to 827.

Table 1.

The number of systems (N) as a function of the number of components (n).

n	N
2	695
3	96
4	22
5	6
6	2
7	4
8	1
9	0
10	1
	Total 827

In this connection the distribution in the sky of the double and multiple systems will also be examined, although the plates and their distribution will not be discussed until next chapter. In Fig. 3 the equator system is reproduced in AITOFF's well known equal area projection. Every dot denotes a double or multiple object in the present catalogue. The dark areas are E. P. HUBBLE's[1] "zone of avoidance" and the dotted lines indicate the boundaries of the apparent Milky Way. These have been drawn with the help of the Milky Way chart by K. LUNDMARK, which was kindly placed at my disposal by him. There are no objects to be found neither in the south declinations nor in the Milky Way zones. The grouping of the objects in high galactic latitudes is very prominent. These effects will be further discussed later on. The similar distribution[2] of LUNDMARK's double galaxies should, however, be noticed.

CHAPTER III

PLATE MATERIAL USED FOR THE PRESENT INVESTIGATION

8. The present work, as far as the search for double and multiple galaxies is concerned, was performed at the Observatory of Heidelberg, Königstuhl. The great collection of Bruce plates offers excellent material for an investigation of this kind. Before entering upon a discussion of these plates we will give a short account of the instrument used.

The Bruce telescope, which is equipped with two photographical tubes, has been in use since the year 1900. The aperture of the photographical objectives amounts to 40 cm. The focal distance is 202 cm and thus one minute of arc corresponds to 0.59 mm on the plate. For a more detailed description of the instrument the reader is referred to the reports of MAX WOLF.[3]

[1] Mt Wilson Contr 485 = ApJ 79, p. 8 (1934). [2] Upsala Medd 30, p. 82 (1927).
[3] VJS 35, p. 121 (1900) and VJS 36, p. 106 (1901).

The work of observation performed at the Heidelberg Observatory has had for its principal object the study of anagalactic objects and asteroids. The plates, the number of which amounts to about six thousand, cover the greater part of the northern sky. As to the southern sky the plates go down to a negative declination of about twenty degrees. Here it may be remarked that the latitude of the observatory amounts to 49°25′ north of the equator. The area covered by each plate is 6×8 square degrees, and the exposure time, which normally amounts to 160 minutes, generally exceeds two hours. The carrying out of these extensive observations has chiefly been the work of Max Wolf and Karl Reinmuth. For some further details concerning the plate material I should wish to refer to Reinmuth[1], 'Die Herschel-Nebel'.

9. From the above-mentioned extensive material those plates have been selected which are most suitable for a general search for double and multiple galaxies. It has been our intention to cover the sky as completely as possible with plates of a faint limiting magnitude and showing a good definition. We have also tried to secure the greatest possible homogeneity for the material as regards these two qualities. The plates selected in this way amount to a number of 602. Their distribution in the sky may be seen on the charts given in figures 36—41 at the end of this paper. In the preparation of these charts the need of guidance for future photographic work concerning double and multiple galaxies has been borne in mind. In several areas the covering of the sky is so good that it can be regarded as complete. There are, however, also areas where conditions are not so favourable, as for instance in the north polar regions. In Table 2 a summary is given, and there the relative size of the covered areas in the various declination intervals is shown.

Table 2.

The size of the areas covered by the plates used.

Decl.	Covered area	Decl.	Covered area
−20° — −10°	56%	+40° — +50°	79%
−10 — 0	86	+50 — +60	61
0 — +10	93	+60 — +70	48
+10 — +20	93	+70 — +80	49
+20 — +30	92	+80 — +90	5
+30 — +40	89	0 — +90	81

For each plate the limiting magnitude at the centre of the plate has been determined by counting the total number of stars in one square degree. The method here used will be described in detail in Chapter V where the determination of the magnitudes of the galaxies is discussed. Fig. 4 (full curve) shows the distribution of these limiting magnitudes for all of the 602 plates. The class breadth is two tenths of a magnitude class, and the curve is reduced to a number of individuals that equals unity. From the figure it will be seen how practically all the values of m_l are situated between $15^m.0$ and $17^m.5$. The great positive excess of the distribution is noticeable. The average value of the limiting magnitudes is found to be $16^m.3$ and the dispersion around this value amounts to $0^m.62$. Of course, there exists a certain mean error in the determined magnitude values. This error causes the distribution curve to fall down. Since in this case the mean error is probably small, we

[1] Heidelberg Veröff, Band 9 (1926).

have not corrected the distribution for these effects, nor have we corrected the individual values for the systematic errors which are connected with them. In the following investigations a somewhat approximate value of the limiting magnitude will be quite sufficient.

In this connection it is of a certain interest to determine in what way the limiting magnitude depends on the distance from the centre of the plate. This has been investigated on fifteen plates selected in such a way that they form a representative collection. Star counts have been performed from the centre and outwards in four directions parallel to the edges of the plate. By taking the average values of these four series of counts,

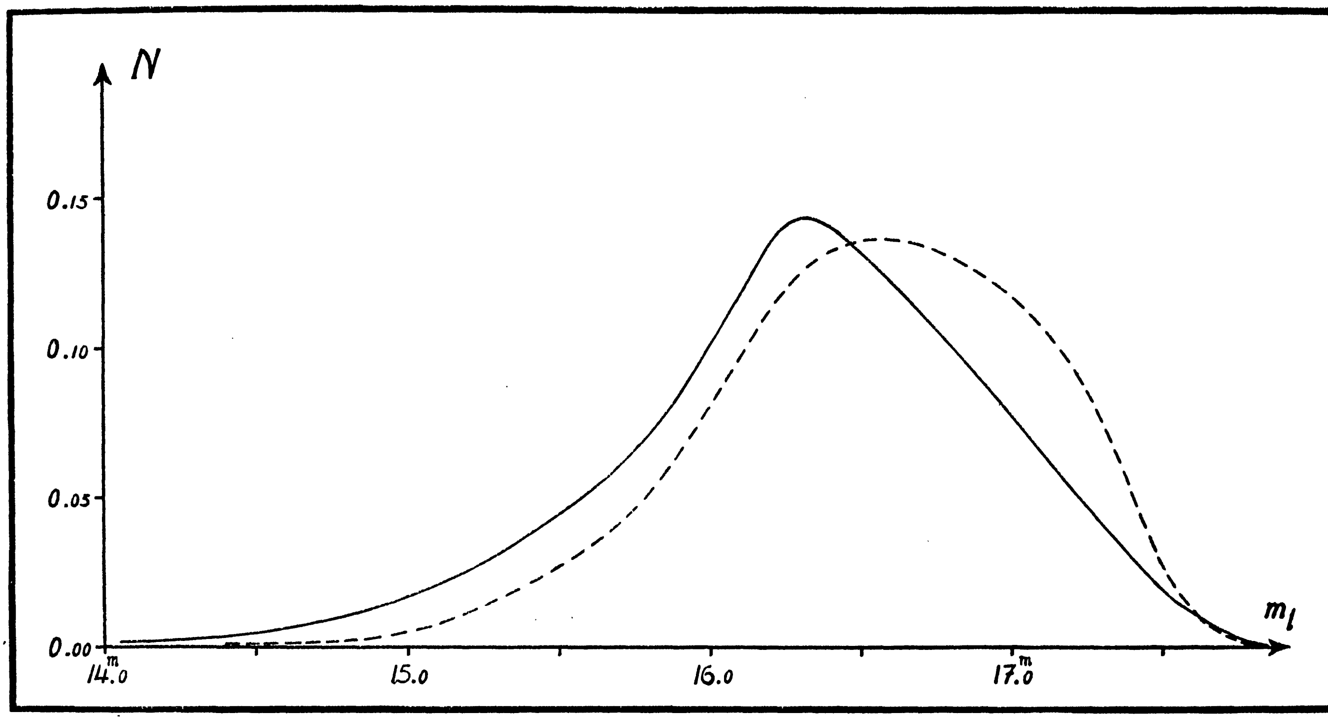


Fig. 4.

The distributions of the limiting magnitudes at the centres of the plates (full curve) and at the places where the double or multiple galaxies are situated (dotted curve).

the limiting magnitudes have been obtained at distances from the centre of the plate corresponding to 0, 1, 2, 3 and 4 degrees. These magnitude values have then been represented by a smoothed curve.

It appears that the fifteen plates agree very well, and thus an average curve will be computed. The limiting magnitude at the distance d degrees from the centre of the plate will be denoted by $(m_l)_d$ and the value of $(m_l)_o$ that is obtained from the smoothed curve will be denoted by $\overline{(m_l)}_o$. For the fifteen plates taken together the average values of $\left((m_l)_d - \overline{(m_l)}_o\right)$ can thus be formed. These average values are represented by the dots in Fig. 5. A smoothed curve has been drawn, and for the sake of completeness some vertical lines have been added, the total lengths of which are equivalent to twice the corresponding dispersions.

In the following investigations the curve of Fig. 5 is used for the derivation of the limiting magnitude at the point on the plate where the double or multiple galaxy is situated. The value of this magnitude is given

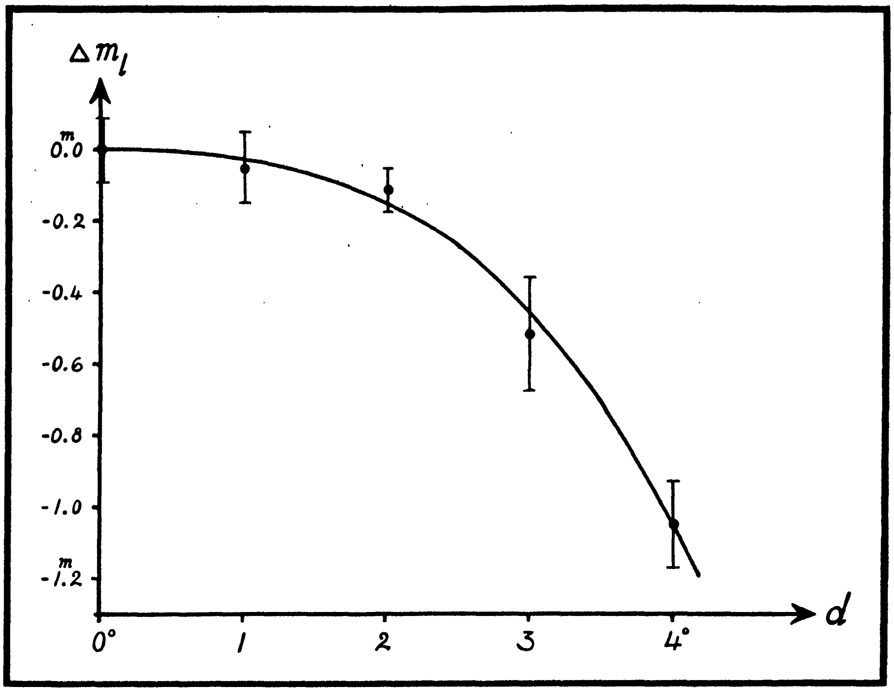


Fig. 5.

Dependence of the limiting magnitude on the distance from the centre of the plate.

for every object in the present catalogue. As it will be of some interest to see how these values are distributed, this is shown in Fig. 4 (dotted curve). A comparison with the distribution corresponding to the centres of the plates (full curve) is here easily made. A remarkable but not at all unexpected feature is the displacement of the dotted curve to the right. The more numerous occurrence of galaxies on good plates is thus clearly shown.

The above limiting magnitudes which have been determined by star counts are, strictly speaking, valid only for stars. As for galaxies, the limiting magnitude generally has a brighter value. In addition to this there is the difficulty of identifying very faint anagalactic objects. In Fig. 6 the distribution of the quantities $(m_l - m)$ for all galaxies in the present catalogue is shown. Here m_l denotes the limiting magnitude of the plate at the situation of the object and m is the corrected magnitude[1] of the galaxy. It appears that the values of the quantity $(m_l - m)$ is generally not smaller than one magnitude. Thus in practice the limiting magnitude for galaxies is approximately one magnitude class brighter than for stars.

10. It is, of course, of great importance to try and determine how large a part of the plate can be used with advantage for an investigation of the present kind. In general all the double and multiple galaxies which are to be found on a plate are included. In the statistical investigations undertaken in the following chapters it may, however, be advisable to exclude objects which are at large distances from the centre of the plate in order to make the material more homogeneous. The influence of the distance from the centre of the plate on the limiting magnitude has been discussed above. For the sake of completeness we should here like to demonstrate how the number of objects pro unit area of the plate decreases when the said distance grows larger. Thus also the poor image definition near the edge of the plate is taken into consideration.

In Fig.7 the galaxies are divided into two groups corresponding to bright and faint values of the corrected apparent magnitude. The full curves show the number of galaxies to be found on all the plates within a certain distance, d, from the centre. In the dotted curves an illustration is given of how matters would be, if all areas on the plates were of the same quality as the central areas. When the distance from the centre of the plate is smaller than three degrees, these curves are straight lines. As regards the brighter galaxies the deviations

[1] See Chapter V.

between the two curves are small, and are perhaps partly to be explained through the fact that the plates cover each other and that the objects have in some cases been measured only on the best plate. As to the faint galaxies, however, all objects on a plate have always been included. In this case the curves deviate from each other in a high degree.

For the above reason it has been considered appropriate to define as an effective plate area the circular area that has a diameter equal to the breadth of the plate. Thus only objects within a distance of three degrees from the centre of the plate have been included in the statistical investigations in the following chapters. It may be remarked that this distance is given for every object in the present catalogue. By calculating the solid angle, ω, that corresponds to the effective areas of all the plates the following value is obtained:

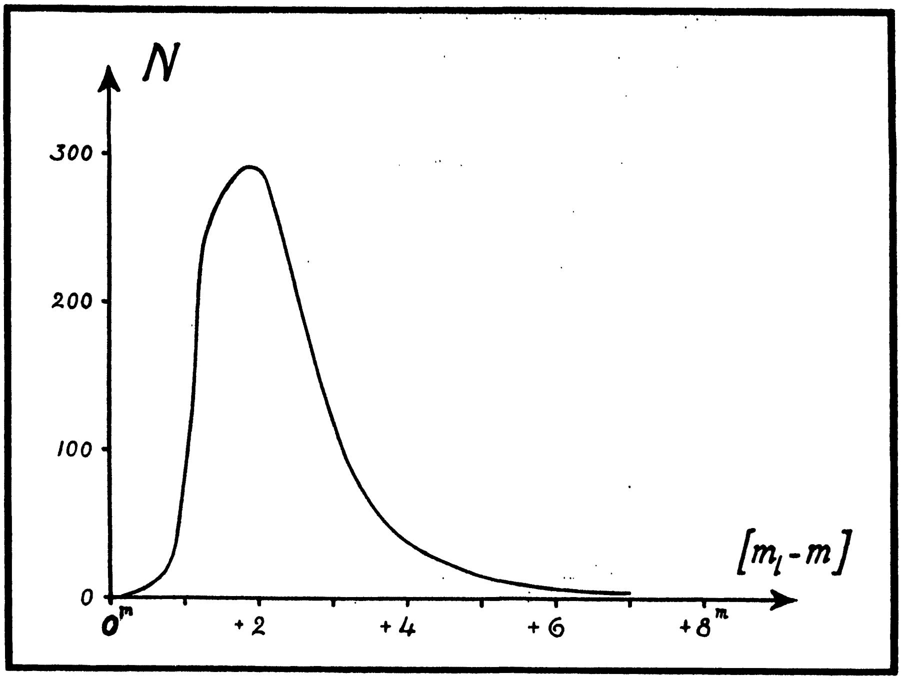


Fig. 6.
Distribution of the differences between the limiting magnitude of the plate and the magnitude of the galaxy.

$$\omega = 0.35 \cdot 4\pi = 4.40.$$

Thus about one third of the sky has been covered by these reduced plate areas.

CHAPTER IV

EXAMINATION OF THE PLATES

11. All the data included in the present catalogue have been collected from the plate material discussed in the preceding chapter. In the present chapter we will describe how the plates have been examined and how the apparent properties of the objects have been measured or estimated. The accuracy of the determined values will also be discussed to some extent here.

The search for double and multiple galaxies on the plates has been performed by means of a small eyepiece having a magnifying power of approximately five times. The field of sight has amounted to half a square degree. All the double and multiple systems thus found on a plate have generally been measured, and a great deal of the plate material has been examined once more in order to secure completeness. Since the plates as

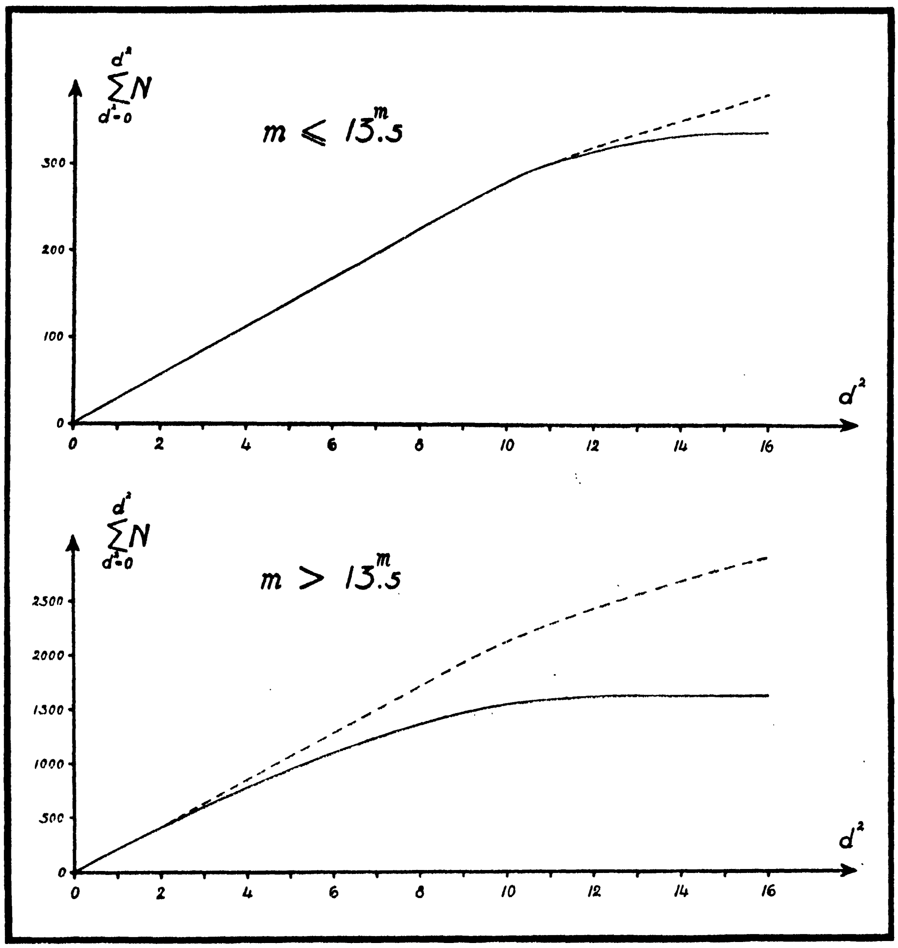


Fig. 7.

Number of objects at different distances from the centre of the plates.

a rule cover parts of each other[1], many objects have been measured twice, and both of these measurings have been included in the catalogue.

When due consideration is given to the way in which the faintest objects discernible on a photographic plate are photographically "built up", it is quite clear that it will enter as a source of error that faint stars may be mistaken for faint galaxies. From the experience obtained from the objects occurring on more than one plate it can be concluded that it is very unlikely that many of the galaxies included in the present catalogue should

[1] See the charts given at the end of this paper.

in future work prove to be stars. Further, I have had the privilege to discuss uncertain cases with Dr. K. REINMUTH and to use not only his wide experience but also his manuscript notes and catalogue.[1] Altogether, it seems justified to conclude that the source of error in question cannot have any statistical importance in connection with the topics under discussion in this paper.

12. The positions have in general been determined through connections to near-by BD-stars. The relative rectangular co-ordinates from the star to one of the components, generally the brightest one, have been measured by means of a small measuring stick divided into minutes of arc. The nearest star has always been used in order to secure accurate values, and the distances have been estimated in half minutes of arc. The positions of the stars have been taken from the AG-catalogues, except in a few cases, where the star was faint and the BD-catalogue had to be used. All the positions thus obtained have been reduced to the equinox 1900.0. It is clear that the co-ordinates do not claim higher accuracy than has been considered necessary for identification purposes.

Using the above principal component as origin, the relative co-ordinates of the other components have been determined by measuring the radius vector and the position angle. As the components are generally situated very close to each other, the distances have in this case been estimated in tenths of a minute of arc. The position angles have been determined by using a revolving eyepiece equipped with a reticle and a graduated circle. These co-ordinates have then been transformed into rectangular ones, and in this way the values of $\Delta\alpha \cos\delta$ and of $\Delta\delta$ have been obtained for each component.

It would be of some interest to see how accurate the positions determined in such a way are. It was pointed out above that several objects were measured on two different plates. In the present catalogue 47 systems of that kind are to be found. The following mean errors have been deduced from the differences which are to be found in the above cases:

$$\varepsilon(\delta) = \varepsilon(\alpha \cos\delta) = 0'.6$$

$$\varepsilon(\Delta\delta) = \varepsilon(\Delta\alpha \cos\delta) = 0'.15.$$

Here δ and α denote the declination and the right ascension of the principal component, while $\Delta\delta$ and $\Delta\alpha$ are the relative co-ordinates within the system under consideration.

13. For each one of the galaxies the apparent total magnitude and the apparent dimensions have been estimated and measured. In the cases where well defined nuclei are to be found, the relative brightnesses and dimensions of these have also been determined. The methods used here will be accounted for in the following chapters, and in these the errors in the measurements will also be discussed.

14. The position angle of the largest diameter of a galaxy has been determined by means of the revolving eyepiece. In the catalogue this angle has been denoted by φ. For an examination of these values we can use K. REINMUTH'S[1] catalogue, 'Die Herschel-Nebel', which has many objects in common with the present catalogue. In Fig. 8, where the straight line is inclined forty-five degrees, the relation between the two sets of values is illustrated. The agreement is very good. Eleven values have, however, been excluded on account of considerable discrepancy. As to some of these values, REINMUTH has pointed out their doubtfulness, and in

[1] Heidelberg Veröff, Band 9 (1926).

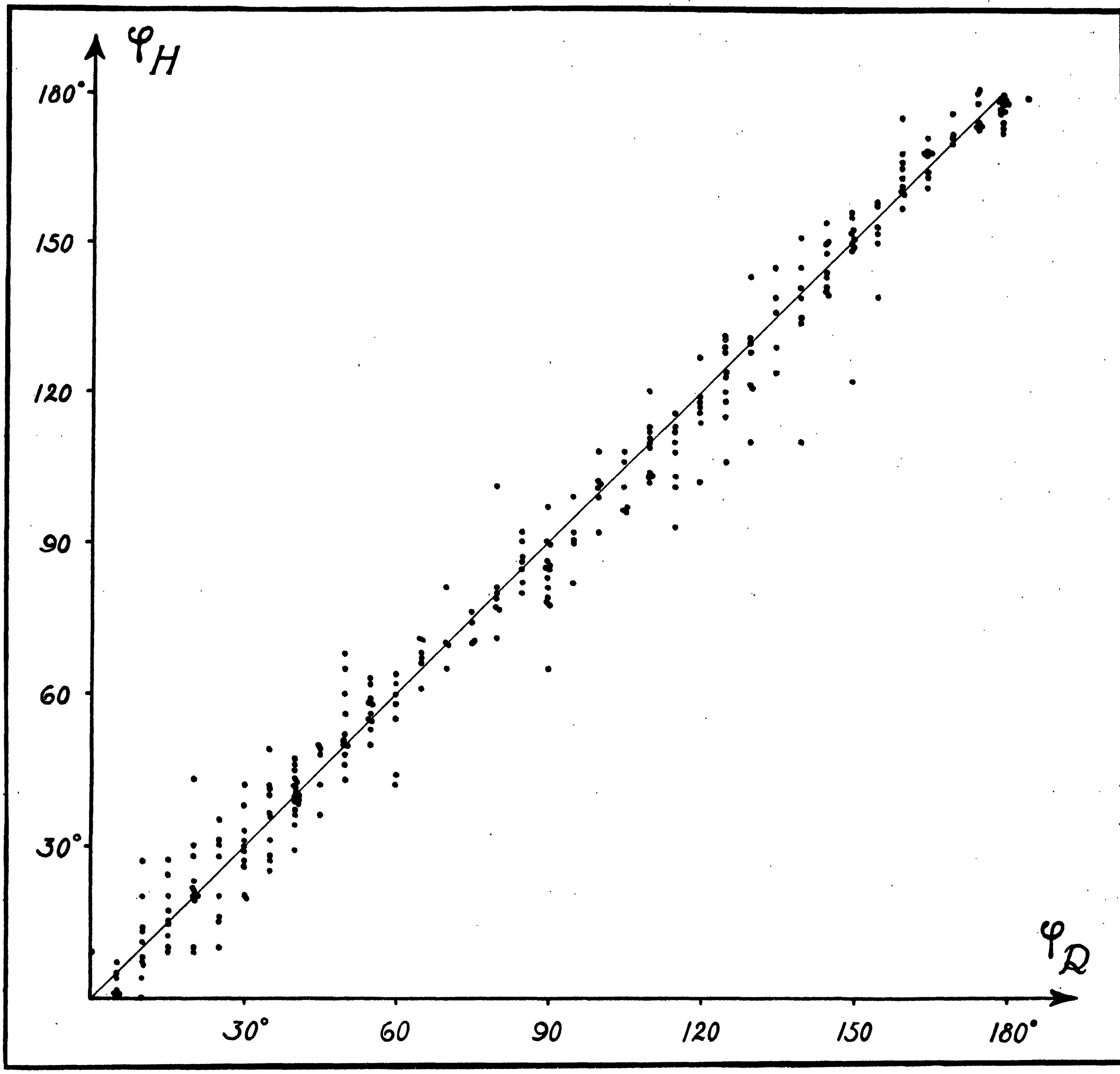


Fig. 8.

Relation between the position angles as measured by REINMUTH and by HOLMBERG.

the other cases the conceptions of the two observers of the apparent appearance of the galaxy may be different. The following values of the coefficient of correlation, r, and of the mean error, $\varepsilon(\varphi)$, have been obtained:

$$r = +0.988 \pm 0.001 \qquad \varepsilon(\varphi) = 5^\circ.9.$$

In the determination of the mean error the assumption has been made that the error has the same value in both catalogues. Thus is has been found that the position angle can be determined very accurately. By means of the objects in the present catalogue that have been measured on two different plates, similar results have been obtained.

15. The type of a galaxy has been determined according to M. WOLF's classification. This system is very detailed, and it gives a very good description of an object by using all the small letters *a*—*w*. The system has been used by REINMUTH in his great catalogue, 'Die Herschel-Nebel', mentioned above, and in this catalogue there is to be found a photographic description of the various types. In order to make comparisons with this catalogue possible, it has been considered appropriate to use WOLF's classification here.

Some remarks concerning the classification should be given. The types *d* and *e* have been characterized by WOLF as consisting of round objects. Since, however, a small ellipticity is very common, somewhat elongated objects have also been included in these classes in the present catalogue. In the cases where it has been possible to distinguish the direction (right or left handed) of the arms of the objects, it has as usual been denoted by S or Ƨ. A further discussion of the types and of their distribution will be found in Chapter IX, where some conclusions regarding the stability of the classification will also be drawn.

16. The concentration of light towards the centre has been estimated for each galaxy. Several different definitions of this concentration have been used by KNUT LUNDMARK, HARLOW SHAPLEY and others. Thus LUNDMARK[1] has made use of the increase of the surface magnitude towards the centre of the object. In this connection it is of interest to make a comparison with the definition used by P. COLLINDER[2] for open clusters. The concentration has been defined by him in a similar way to that used by the present writer.

In this paper the concentration of light towards the centre of the galaxy has been defined in the following way. The relative size of the surface at the centre of the object, which represents half the total light is indicated by p. The value of $1/p$ can then be considered as a measure of the concentration. If this value is diminished by two units the concentration c thus is defined in the following way:

$$c = 1/p - 2. \tag{5}$$

In practice the concentration has been estimated in integral numbers. It has, however, proved convenient to introduce the intermediate step $+0.5$, because this value occurs very frequently.

Concerning the types *d* and h_0, where the surface brightness is about the same at different points, the value of the concentration becomes 0, while the type *b* (planetary nebula) can have a concentration value equal to -1. For the other types the concentration generally has positive values. For objects in which well defined nuclei are to be found large concentration values can be obtained. Here the estimations are considerably simplified through the circumstance that the nucleus often contains about half the total light. On the whole, the use of the definition suggested above has proved to be very convenient.

---

[1] Lund Circ 3 (1931). [2] Lund Ann 2 (1931).

CHAPTER V

APPARENT MAGNITUDES OF THE GALAXIES

17. A very important question is how to determine the apparent total magnitudes of anagalactic objects in a correct and easy way. Especially for an investigation into the spatial arrangement within the metagalactic system accurate values of the apparent magnitudes are necessary.

Some problems, however, arise in this connection. The galaxies are surface objects and thus the difficulties which are always connected with the photometry of objects of this kind appear here, too. The irregularities in the shapes of the galaxies and the different degrees of condensation naturally enough will influence the measured magnitudes.

A further complication is added to the problem in this special case. The image of a certain galaxy on the plate is generally comparatively bright at the centre, but the surface brightness decreases outwards. The diameter of an object in a high degree depends on the limiting magnitude and the quality of the plate, especially in the case of faint objects. As regards very remote and hence on an average faint and small galaxies probably only the nuclei are to be seen on the plate. These effects may exercise an influence also on the determination of the magnitudes. If the total brightness of an object is summed up from the centre and outwards, a rapidly decreasing series is generally obtained. The convergence is not, however, always so large that the outer parts of the object can simply be neglected. Thus in the case of faint galaxies it is necessary to apply several corrections to the measured magnitudes.

Many methods have been suggested and also to some extent used for the determination of magnitudes of anagalactic objects. The luminosities should be given in the international system of photometric magnitudes, and the problem is then in general to photograph a set of standard stars and a galaxy in such a way that the images will be as comparable as possible.

E. P. HUBBLE[1] has obtained the magnitudes of fifteen elliptical galaxies by integrating intensity curves of these objects made with a self-registering microphotometer. Because of the great labour involved, this method cannot be extensively used.

A moving-plate camera[2] offers a photometrically very exact method of determining magnitudes of galaxies. If the objects are spread over an area several times wider than the maximum diameter, all irregularities are effectually smoothed out. P. C. KEENAN[3], who has discussed this procedure, points out that two serious difficulties are, however, to be taken into consideration. Thus the exposure times are considerably lengthened, and further the presence of numerous foreground stars close to the galaxy may hinder the employment of these large images.

In the same paper KEENAN gives an account of the determination of magnitudes by comparing images of galaxies with images of stars, all taken out of focus. By using this procedure it is possible to obtain images of about the same size for both classes of objects. KEENAN has found that this method gives satisfactory results.

---

[1] Mt Wilson Contr 398 = ApJ 71, p. 231 (1930).

[2] See a description by W. H. CHRISTIE, Mt Wilson Contr 476 = ApJ 78, p. 313 (1933).

[3] ApJ 82, p. 62 (1935).

For the vast majority of anagalactic objects the above methods cannot be used. As for the very great number of faint galaxies, comparisons with the standard stars must be made on plates taken in focus. Thus the large Harvard survey[1] of more than seventy thousand galaxies is carried out in this way. In this survey the magnitudes of bright objects have also been determined by comparisons of in-focus images of stars and galaxies. Small scale plates have, however, been used in this case in order to produce the smallest possible diameters of the galaxies. The investigations of C. K. SEYFERT[2], A. E. WHITFORD[3] and P. C. KEENAN[4] have proved that these magnitude values are free from any appreciable systematic errors.

18. In the present investigation the galaxies have been directly compared with neighbouring stars and galaxies on the plate. A small eyepiece of about five times magnifying power has been used for the comparisons. Three methods have generally been combined for the estimation of the magnitude of an object. First, the galaxy can be compared with one star only of about the same brightness. This involves a summing up of the different parts of the galaxy, which requires great experience in the observer, especially in dealing with large and bright objects. More reliable values may be obtained by using stars for this integration. Every part of the galaxy is thus compared with a star of about the same intensity of blackening, and the magnitudes of these stars are then summed up. Finally, the galaxies which are to be found on the same plate can be compared with one another. The distances from the centre of the plate ought to be the same in these cases.

19. On Dr. LUNDMARK's suggestion the apparent magnitudes of the comparison stars have been determined by star counts. P. J. VAN RHIJN[5] and F. H. SEARES[6] with collaborators have, by using principally the Selected Areas, computed tables where the star numbers can be obtained as a function of limiting magnitude, galactic latitude and longitude. By using these tables it is possible to find the photographic magnitude of any star by counting the number of stars per square degree brighter than and equal to the selected one. For a more detailed account of the method used we beg to refer to KNUT LUNDMARK's[7] article in Handbuch der Astrophysik.

The above method for deriving apparent magnitudes was probably first used by A. VAN MAANEN.[8] In this way he determined the magnitudes of certain objects, e. g. planetary nuclei, included in his parallax programs. Later on the method has become generally used through the works of KNUT LUNDMARK, HARLOW SHAPLEY and others. In an extensive paper C. K. SEYFERT[9] has determined the magnitudes of more than seven thousand faint galaxies by establishing magnitude sequences by star counts.

In the above paper SEYFERT makes an investigation of the errors arising in stellar magnitudes determined by star counts. The estimated magnitudes are compared with the values obtained through a comparison with the stars in a Selected Area. The mean error of the estimated values was only $0\overset{m}{.}14$. No systematic deviations could be found.

In the present investigation we have used a diagram constructed by Dr. LUNDMARK, who has been kind enough to place it at our disposal. In Fig. 9 this diagram is reproduced. The galactic latitude is to be found as abscissa, and the apparent photographic magnitude as ordinate. The various curved lines correspond to different numbers of stars per square degree. The diagram thus is a variation of Fig. 2 in the Contributions from the Mount Wilson Observatory, No 301.

[1] Harvard Ann 88, No 1 (1930), Harvard Ann 88, No 2 (1932), Harvard Ann 88, No 3 (1933) and Harvard Ann 88, No 5 (1935).
[2] Harvard Circ 403 (1935). [3] Mt Wilson Contr 543 = ApJ 83, p. 424 (1936). [4] ApJ 85, p. 325 (1937).
[5] Groningen Publ 43 (1929). [6] Mt Wilson Contr 301 = ApJ 62, p. 320 (1925) and Mt Wilson Contr 346 = ApJ 67, p. 24 (1928).
[7] Loc. cit., Band VII, p. 486 (1936). [8] See e. g. Mt Wilson Contr 182 (1919).
[9] The paper is not yet published. A copy has kindly been placed at the disposal of Dr. LUNDMARK.

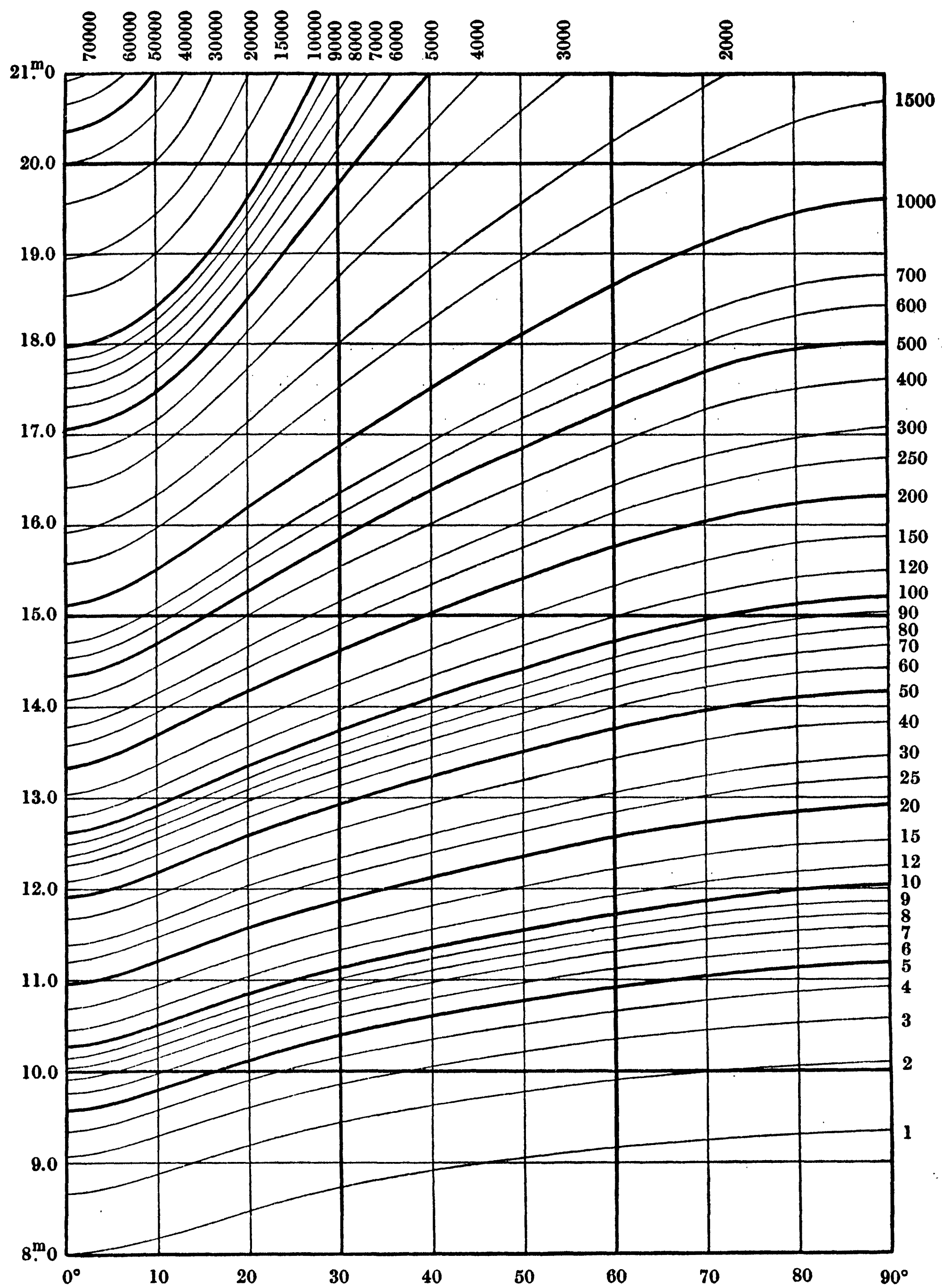


Fig. 9.

Diagram for the determination of apparent magnitudes from star counts.

Concerning this diagram some remarks ought to be made. In reality the curves give the average value of the number of the stars, $F(m)$, that are brighter than or equal to the magnitude m. When using the diagram we assume that the magnitude m is the average value that corresponds to a given value of the number $F(m)$. A further approximation is introduced by neglecting the influence of galactic longitude and the deviations between the northern and southern galactic hemispheres.

Between the observed values of the number $F(m)$ and the adopted mean values certain deviations are thus to be found. These may be treated as accidental ones, and they will contribute to the mean error in the final magnitude values. An illustration of the deviations is given in Fig. 1 in the Contributions mentioned above. An approximate investigation has shown that in high galactic latitudes the deviations will cause errors in the final magnitude values at most amounting to four or five tenths of a magnitude.

20. In this way the apparent photographic magnitudes of the objects in the present catalogue have been determined. As it may be tacitly assumed that errors of different kinds exist in the estimated values, comparisons with magnitude values determined in other ways are of great interest. Concerning the objects brighter than $13^{m}.0$ the catalogue of H. SHAPLEY and A. AMES[1] can be used. As to the fainter objects, corrections will be computed from the material itself by means of the objects which have been measured on two different plates. For compurisons we can in this case make use of the great catalogue of Miss AMES[2], which contains objects in the Coma-Virgo group and is complete down to a magnitude fainter than $17^{m}.0$. It has, however, been pointed out above that these faint magnitudes are probably systematically too faint, because, in this case, only the central part of the galaxy is shown on the plate. Concerning the fainter objects it has thus been considered more appropriate to try to derive corrections from the material at hand.

Of the galaxies of the present catalogue a number of 160 is to be found in the above catalogue of SHAPLEY and AMES. As the magnitudes given in the latter catalogue seem to be free from any noticeable systematic errors, and the mean error is small, the deviations between the two sets of magnitude values must for the greater part be ascribed to the present catalogue. The differences, $(m_H - m_{Sh}) = \Delta$, may be assumed to depend on the quality of the plate used and on the apparent appearance of the object. The galactic longitude and latitude may also have some influence.

In practice the following arguments have proved to be of importance in dealing with the errors in the estimated magnitudes:

A. The distance of the object from the centre of the plate ($= d$).

B. The difference between the limiting magnitude of the plate at the situation of the object ($= m_l$) and the true magnitude of the object.

C. The true magnitude of the object.

The following formula has been applied:

$$\overset{1}{\Delta} = c_1 + c_2 \cdot \overset{2}{d^2} + c_3 \cdot \overset{3}{(m_l - m_{Sh})} + c_4 \cdot \overset{4}{m_{Sh}}. \tag{6}$$

Here every variable has been denoted by a number. The magnitude values of SHAPLEY-AMES have been used to represent the true values. The following values, with mean errors, of the ordinary coefficients of correlation, r, and of the corresponding partial coefficients, R, have been obtained:

[1] Harvard Ann 88, No 2 (1932). [2] Harvard Ann 88, No 1 (1930).

$$r_{12} = -0.160 \pm 0.077 \qquad R_{12} = -0.164 \pm 0.078$$
$$r_{13} = -0.020 \pm 0.079 \qquad R_{13} = -0.047 \pm 0.080$$
$$r_{14} = +0.064 \pm 0.079 \qquad R_{14} = +0.086 \pm 0.079.$$

All the connections prove to be linear. The correlations, especially the second one, have small values, but as similar values are obtained below in the examination of objects measured on two different plates, the results are probably real.

Thus an object is estimated too bright, when the distance from the centre of the plate is large. This can be explained through the corresponding spreading out of the object. Concerning the other two correlations, they suggest that faint galaxies are underestimated in comparison with bright ones.

By using the general formulae of multiple correlation[1] the following expression is obtained of the average value of the difference Δ that corresponds to different values of the above arguments:

$$\bar{\Delta} = -1.32 - 0.027\, d^2 - 0.062\,(m_l - m_{Sh}) + 0.144 \cdot m_{Sh}. \tag{7}$$

Here the distance d is measured in degrees. If the value m_{Sh} is exchanged for $(m_H - \bar{\Delta})$, the following value of the average correction, which should be added to the estimated magnitude m_H, is obtained:

$$\text{corr} = +0.02\, d^2 + 0.05\,(m_l - m_H) - 0.12\,(m_H - 9.0). \tag{8}$$

The corrected magnitudes have been examined for errors depending on the diameter of the object and on the galactic longitude and latitude. With regard to the apparent dimensions, no real dependence is to be found. Only a few of the smallest objects have been estimated too faint. Similarly, the galactic co-ordinates seem to have no appreciable influence.

In Fig. 10 a comparison is made between the corrected magnitudes of the present catalogue and the Harvard magnitudes. Here also faint objects are included. They will be discussed later. Concerning the brighter galaxies no systematic deviations between the two sets of magnitude values are to be found. In a few cases only the differences are greater than one magnitude. Here it may be remarked that such large differences can be partly explained through a divergent conception of the extent of the object. The estimation of the faint outer parts of a galaxy may change with the observer, the quality of the plate, and the focal distance of the instrument used.

In the cases where the Harvard magnitude is equal to $12^m_.8 - 13^m_.0$ the deviations are somewhat larger. Possibly this is due to the fact that we are here approaching the limiting magnitude of the catalogue of SHAPLEY-AMES. If the above values are excluded, we get a dispersion in the remaining differences equal to $0^m_.49$. From the investigations of SEYFERT and KEENAN mentioned above it appears that a mean error of about $0^m_.2$ is probably to be found in the magnitudes of SHAPLEY-AMES. On account of the above considerations regarding the faint outer parts of a galaxy this is perhaps a minimum value. We thus get the following value for the mean error in the brighter corrected magnitudes of the present catalogue:

$$\varepsilon\,(m_{corr}) \leq 0^m_.45.$$

---

[1] See Lund Medd I, No 66 (1915).

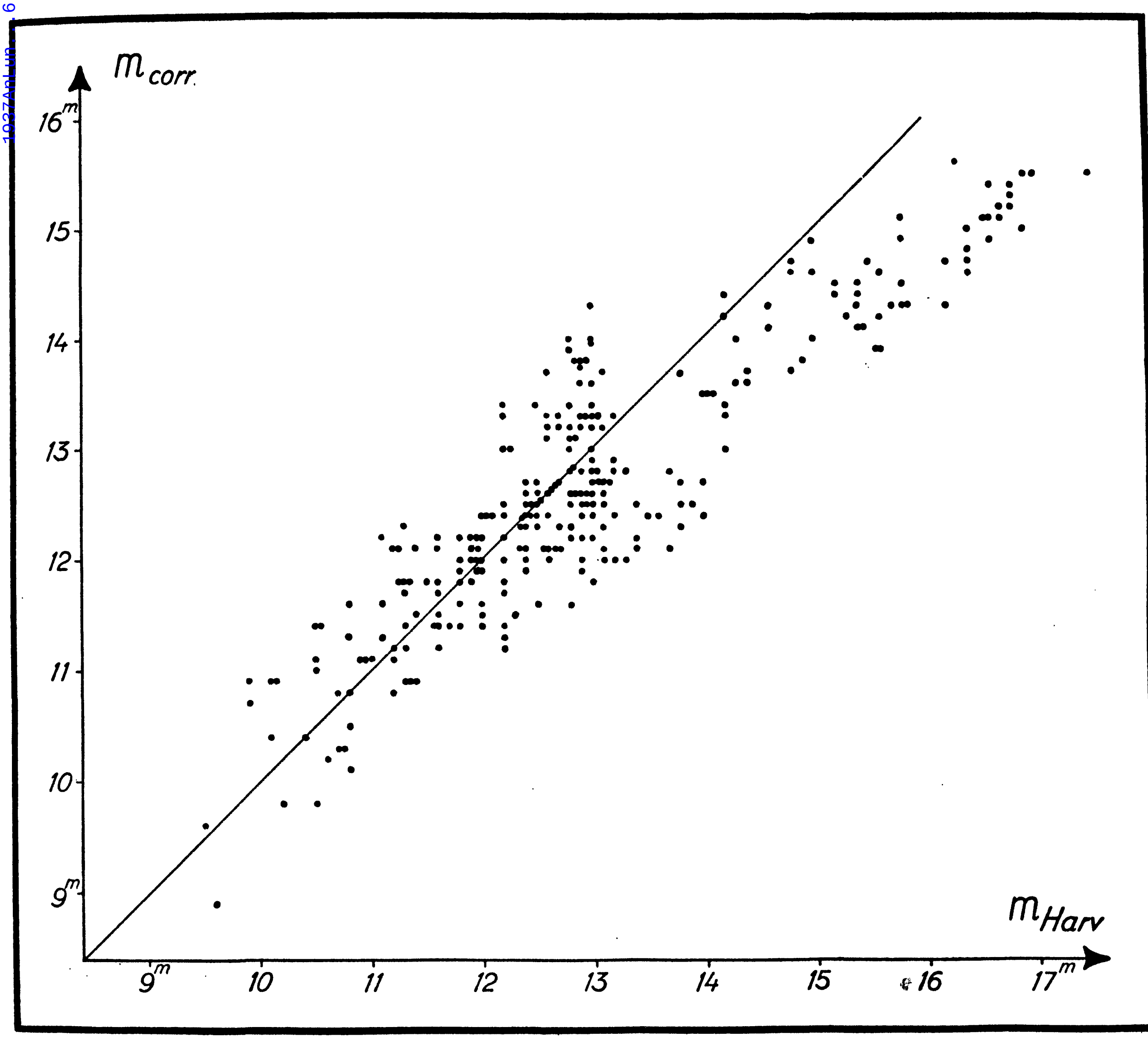


Fig. 10.

Relation between the corrected magnitudes of the present catalogue and the Harvard magnitudes.

21. Most of the objects in the present catalogue are fainter than $13^{m}_{.}0$. In this case an attempt has been made to derive corrections from the material itself. All the 102 galaxies which have been estimated on two different plates have been used for the application of the following formulae.

If an object has been measured on two different plates, these may be arbitrarily denoted by *a* and *b*. The corresponding values of the errors in the estimated magnitudes are denoted by Δ_a and Δ_b, the corresponding values of an argument by x_a and x_b. The following arrangement may be used:

1	2
Δ_a	Δ_b
3	4
x_a	x_b

We assume that the arguments x_a and x_b have known values, and we want to find the regression of Δ on x, i. e. the coefficient of correlation $r_{13}(= r_{24})$ and the dispersion $\sigma_1 (= \sigma_2)$. The problem is indeterminate, unless certain assumptions are made.

From the known differences $(\Delta_a - \Delta_b) = (1-2)$ and $(x_a - x_b) = (3-4)$ the following connections can be obtained:

(9) $$r_{(1-2),\,(3-4)} \cdot \sigma_{(1-2)} \cdot \sigma_{(3-4)} = 2\,\sigma_1\,\sigma_3\,(r_{13} - r_{14})$$

(10) $$\sigma_{(1-2)} = \sqrt{2}\,\sigma_1 \sqrt{1 - r_{12}}.$$

These equations contain the four unknown quantities r_{12}, r_{13}, r_{14} and σ_1. If we assume that the partial coefficient of correlation R_{14} $(= R_{23})$ is zero, which must in this case be considered as a fair approximation, another equation is obtained[1]:

(11) $$\begin{vmatrix} 1 & r_{13} & r_{14} \\ r_{12} & r_{14} & r_{13} \\ r_{14} & r_{34} & 1 \end{vmatrix} = 0.$$

As a fourth equation we may use the value of σ_1 derived above. Thus:

(12) $$\sigma_1 = 0^{\rm m}.4.$$

In this way a sufficient number of equations has been obtained and the value of r_{13} can be computed.

As arguments, x, the quantities d^2 and $(m_l - m)$ will be used. The distance, in degrees, from the centre of the plate is still denoted by d, and the difference $(m_l - m)$ corresponds to the true magnitude of an object measured from the limiting magnitude of the plate, at the situation of the object, as zero-point. Thus the estimated magnitude $m_{\rm H}$ is not used in the formulae. It should of course be remarked that we do not know the quantity $(m_l - m)$. For the deriving of the corresponding moments we can, however, make use of the moments of the known quantity $(m_l - m_{\rm H}) = (m_l - m - \Delta)$. The procedure discussed here may perhaps seem somewhat complicated, but in practice the computations can be rapidly carried out by means of successive approximations.

In the computation of the numerical values the material has been divided into two classes according to the estimated magnitude ($m_{\rm H} \leq 13^{\rm m}5$ and $m_{\rm H} > 13^{\rm m}5$). The number of individuals in the two groups is about the same. For the sake of brevity the error in the estimated magnitude may be denoted by index 1 and the arguments d^2 and $(m_l - m)$ by index 2 and 3 resp. The numerical results are then as follows:

---

[1] See Lund Medd I, No 66 (1915).

A. $m_H \leq 13^m5$:

$r_{12} = -0.29$ $R_{12} = -0.42$

$r_{13} = -0.33$ $R_{13} = -0.45$

B. $m_H > 13^m5$:

$r_{12} = -0.12$ $R_{12} = -0.20$

$r_{13} = -0.30$ $R_{13} = -0.34$.

Especially concerning bright objects it thus appears that the distance from the centre of the plate will influence the estimated values. Further, it is evident that faint objects are estimated too faint. The same effects have thus been found here as by the above comparison with the magnitudes of SHAPLEY-AMES.

As regards the corrections the following expressions are obtained:

$$(13)\quad \begin{aligned} m_H \leq 13^m5 &: \text{corr} = +0.03 \cdot d^2 + 0.17\,(m_l - m_H) + \text{const} \\ m_H > 13^m5 &: \text{corr} = +0.02 \cdot d^2 + 0.17\,(m_l - m_H) + \text{const.} \end{aligned}$$

Here the estimated value m_H has been introduced in the same manner as in formula (8).

The very great similarity between the coefficients in formulae (8) and (13) is remarkable. As final correction formulae the following two have thus been adopted:

$$(14)\quad \begin{aligned} m_H \leq 13^m0 &: \text{corr} = +0.02 \cdot d^2 + 0.05\,(m_l - m_H) - 0.12\,(m_H - 9.0) \\ m_H > 13^m0 &: \text{corr} = +0.02 \cdot d^2 + 0.17\,(m_l - m_H) - 0.91. \end{aligned}$$

The constant -0.91 has been obtained by assuming the two formulae to give the same corrections for $m_H = 13^m0$ and $m_l = 16^m6$. The latter value agrees with the corresponding average value.

22. Concerning the faint objects which have not been compared with the catalogue of SHAPLEY-AMES another correction is to be applied. The mean error causes a falling down of the distribution curve of the magnitudes, and thus systematic errors are introduced into the magnitude values. In accordance with the investigations of A. S. EDDINGTON[1] and of C. V. L. CHARLIER[2] the average correction can be expressed in the following form:

$$(15)\quad \text{corr} = \varepsilon^2 \cdot \frac{d\left(ln.\,N(m)\right)}{dm}.$$

Here ε is the mean error and $N(m)$ is the observed distribution function of the magnitudes. The natural logarithm is denoted by ln.

As the corrections are dependent on the square of the mean error, it is important to obtain a correct value of this. In this particular case a value of 0^m3 has been assumed. This may perhaps be too small a value, but it has been considered more appropriate to assume a value too small than one too large in order to avoid overcorrection. The corrections thus obtained will be found in Table 3.

Table 3.

Statistical corrections to the estimated magnitudes.

m_H	corr
$15.^m4 - 16.^m0$	$-0.^m1$
$16.1 - 16.5$	-0.2
$16.6 - 17.0$	-0.3
$17.1 -$	-0.4

23. As it will be of some interest to see how the double-measured

[1] Stellar movements, p. 172 (1914). [2] Lund Medd I, No 68 (1915).

objects agree with one another, this has been illustrated in Fig. 11. The corrected magnitude values have been arbitrarily denoted by m_1 and m_2. The coefficient of correlation has a very high value:

$$r = +\,0.956 \pm 0.009.$$

It may be remarked that the two estimations of the magnitude of an object have always been made independent of one another. In fact, it was generally not possible to decide until the final reduction whether a galaxy had been measured on two different plates or no.

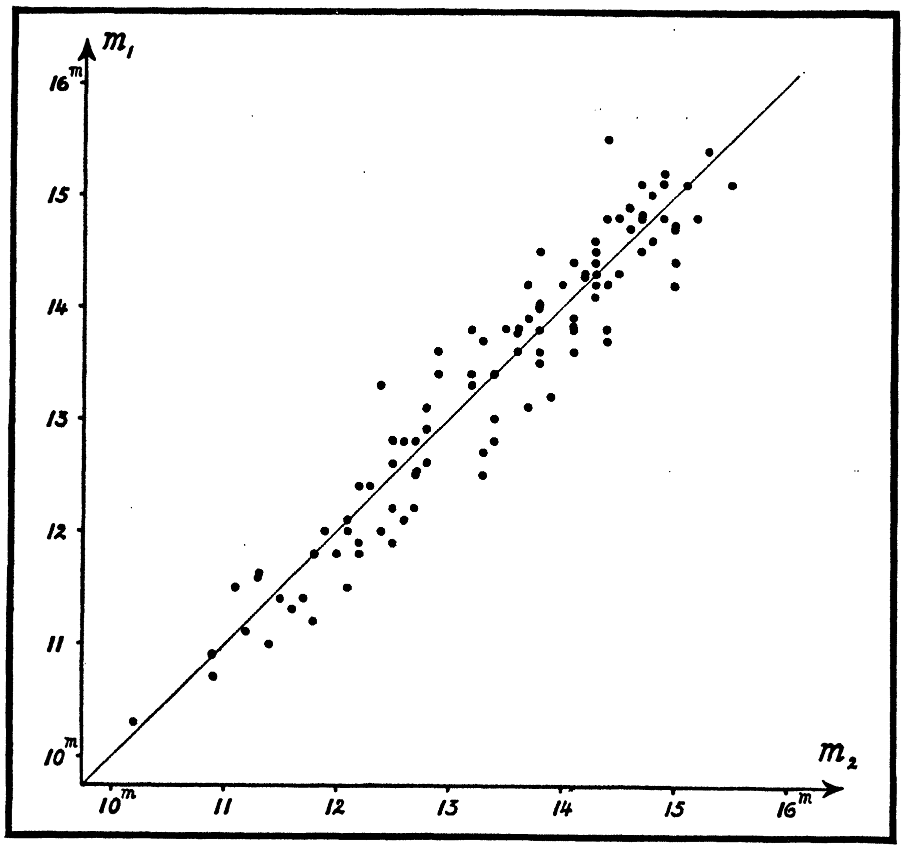


Fig. 11.
Relation between the magnitude values estimated on two different plates.

From the dispersion in the differences found above the following value of the mean error in one single estimation is obtained:

$$\varepsilon' = 0\overset{m}{.}26.$$

This error may be termed the internal mean error, and it must be smaller than the total or external one. For it can be assumed that if an object is estimated on several different plates, the errors in the estimated values are nevertheless correlated with one another, since the observer and the procedure used are the same, and the plates are taken with the same instrument under similar conditions.

24. In Fig. 10 which has already been discussed above as far as the bright objects are concerned we can see how the faint corrected magnitudes agree with the values given by Miss AMES[1] for objects in the Coma-Virgo group. The systematic deviations found in the figure are exclusively due to the corrections applied to the estimated values. If the estimated magnitudes had not been corrected, they would have been in good

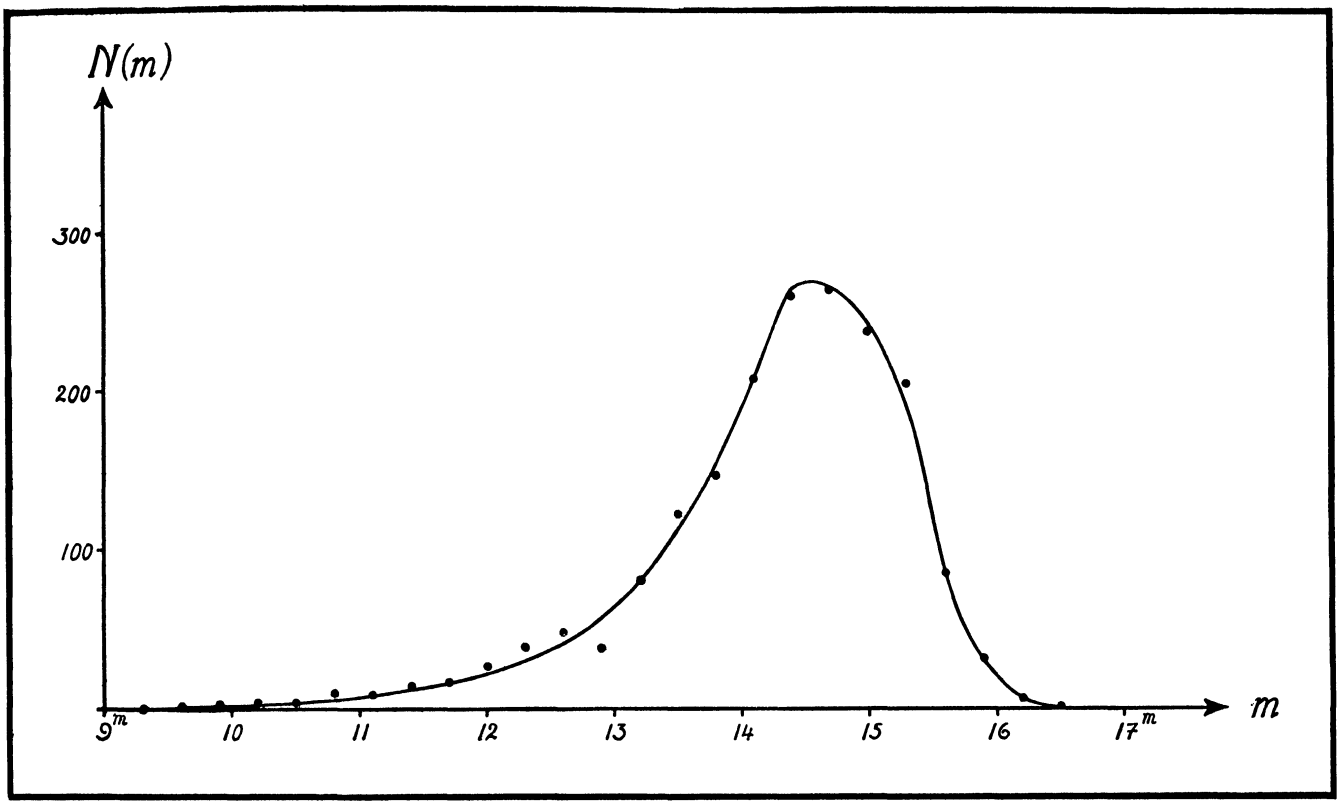


Fig. 12.
Distribution of all the magnitude values of the present catalogue.

agreement with the values of Miss AMES. Through the application of the corrections an attempt has been made to derive the real total magnitudes of the galaxies. The accidental errors in the faint magnitude values seem to be somewhat smaller than for the bright magnitudes.

The systematic deviations between the two sets of magnitudes at most amount to about one magnitude. Here it may be of some interest to refer to Fig. 19 (Chapter VII) where the relative brightness of the nuclei of galaxies of different types is illustrated. Concerning the spirals the figure shows, in agreement with extensive unpublished observations by K. LUNDMARK, that the nuclei are generally one or two magnitudes fainter than the objects themselves.

[1] Harvard Ann 88, No 1 (1930).

5—37522.

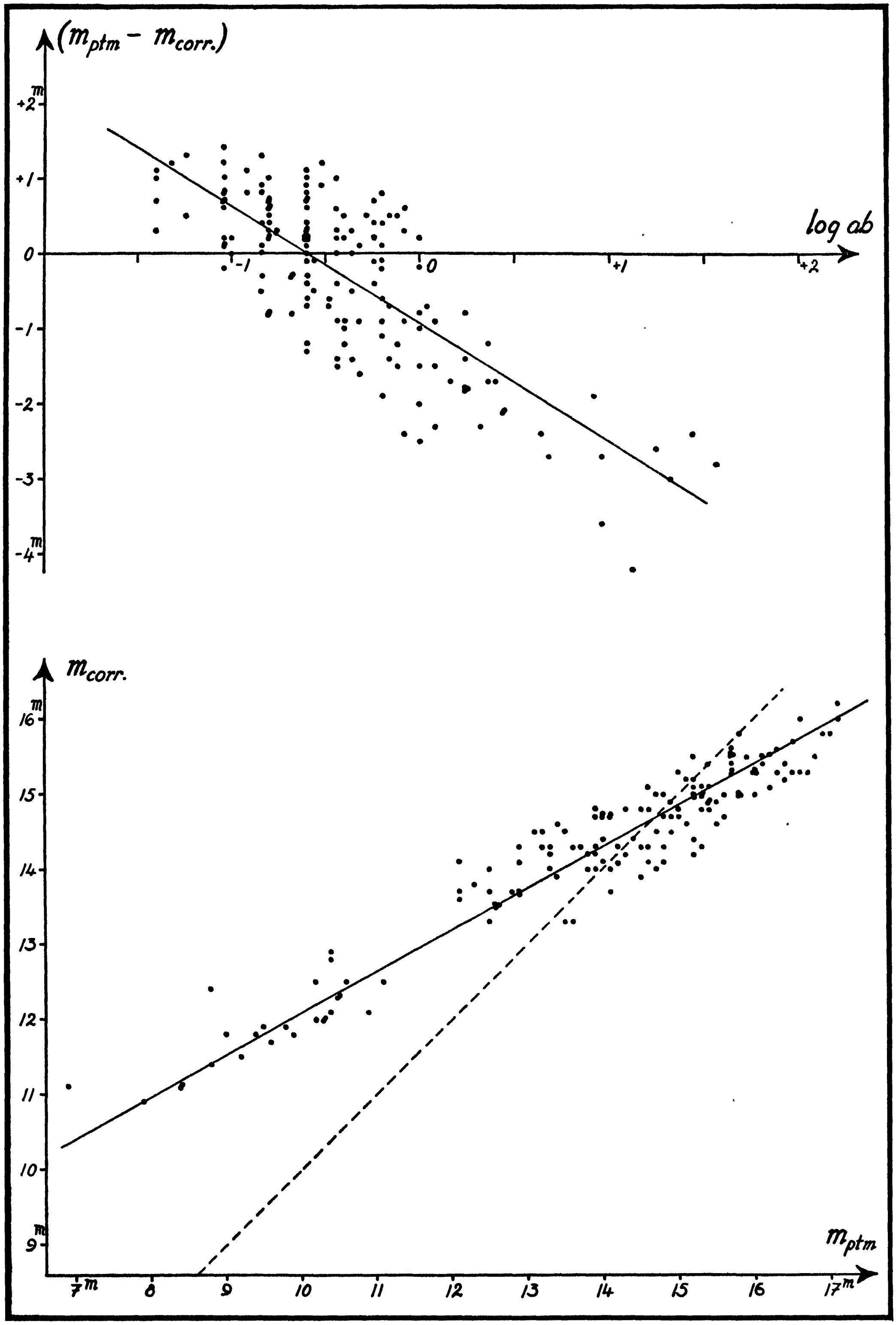


Fig. 13.
Systematic deviations of the photometric magnitudes.

25. In Fig. 12 the distribution of all the corrected magnitudes included in the present catalogue is given. Even in this figure it is indicated that the material should be complete down to a limiting magnitude of about $14^{m}5$. This will be discussed more in detail in a following chapter in connection with some investigations into the spatial arrangement of double and multiple galaxies.

26. Of the objects in the present catalogue a number of 155 have been measured in the Zeiss thermoelectric photometer of the Heidelberg Observatory. A catalogue of these values is to be found at the end of this paper.[1] The standard stellar magnitudes have been taken from the Selected Areas. Since the large scale Bruce plates are used, the bright galaxies have large diameters on the plate. It is a well known fact[2] that a comparison with stars in this case will cause large systematic errors in the measured magnitude values. The present measurements are intended as a small contribution to the nature of these systematic effects concerning the Bruce plates.

The Selected Areas as well as the galaxies measured are generally situated near the centres of the plates. If the distances from the centre are not equal, the corrections to be applied to the measured magnitudes have been given the same values as the differences between the corresponding limiting magnitudes of the plate. These have been determined by star counts. The procedure is perhaps not quite correct, but as the corrections always have small values, it may in this case be permissible.

In Fig. 13 the systematic deviations of these magnitudes, m_{ptm}, and their dependence on the apparent size and brightness of the objects can be seen. Here the corrected estimated magnitude value is denoted by m_{corr}, and the large and small diameter, in minutes of arc, of an object are denoted by a and b.

The two connections which are illustrated in the figure are of a linear nature. If the quantity $(m_{ptm} - m_{corr})$ is denoted by index 1, m_{corr} by index 2 and log ab by index 3 the following numerical values, with mean errors, of the coefficients of correlation can be given:

$$r_{12} = +0.829 \pm 0.025 \qquad R_{12} = +0.525 \pm 0.059$$

$$r_{13} = -0.788 \pm 0.030 \qquad R_{13} = -0.350 \pm 0.071.$$

The straight lines in the figure give the regressions of $(m_{ptm} - m_{corr})$ and m_{corr} on log ab and m_{ptm} resp.

The systematic deviations of the measured magnitudes thus depend on the size and the brightness of the objects. If we correct for these effects, and if the mean error of the corrected estimated magnitude is put equal to $0^{m}4$, we get the following value of the mean error of the corrected photometric magnitude:

$$\varepsilon(m_{ptm}) = 0^{m}46.$$

As may be expected, also large deviations of an accidental nature thus are to be found in the photometric magnitudes.

[1] See Appendix I. [2] Cf. P. C. Keenan, ApJ 82, p. 62 (1935).

CHAPTER VI

APPARENT DIMENSIONS OF THE GALAXIES

27. The measuring of the apparent dimensions of the galaxies has been performed in two directions generally perpendicular to another and corresponding to the largest and the smallest diameter. In some cases—as for instance type v in WOLF's classification—the directions are not at right angles to one another. A measuring stick divided into minutes of arc has been used, and in the present catalogue the diameter values are given in tenths of minutes of arc.

The extensive and very accurate catalogue of K. REINMUTH[1] can be used for an examination of the accuracy of the diameter values. Of the galaxies included in the present catalogue, 531 are to be found in the catalogue of REINMUTH. The comparison as regards the major diameter, a, is illustrated in Fig. 14. Twenty-two points, however, fall outside the frame of the figure. No appreciable systematic deviations are to be found between the values of the two catalogues. The following values of the coefficient of correlation, r, and of the mean error, $\varepsilon(a)$, in an individual diameter value are obtained:

$$r = +0.957 \pm 0.004 \qquad\qquad \varepsilon(a) = 0'.4.$$

The value of the error $\varepsilon(a)$ is computed on the assumption that it is the same in the two catalogues. The very high value of the coefficient of correlation indicates that the two sets of diameter values are in excellent agreement with one another.

The mean error is, of course, to some extent dependent on the size of the diameter. Concerning very small objects the mean error also seems to be small. The deviations in the diameter values must only for a small part be considered as ordinary measuring errors. They mainly depend on the different appearence of the objects on different plates. In the two above catalogues the objects have, however, sometimes been measured on the same plates.

28. As regards anagalactic objects, only the central parts are generally to be seen on the plate. The relative size of the visible part may depend on the type of the object and on the quality of the plate, including the limiting magnitude. On account of instrumental effects, the influences of bad seeing and the effects produced by possible metagalactic absorption, the measurable diameter will also be dependent on the distance of the object.

This is valid also for bright galaxies. Thus E. P. HUBBLE[2] by determining the distribution of light in fifteen elliptical objects has found a very marked dependence of the diameter on the exposure time. Further H. SHAPLEY[3] has examined a number of bright objects including the great galaxy in Andromeda, and he has shown that the diameters can be highly increased by using more accurate methods. Similar investigations have been made by J. STEBBINS and A. E. WHITFORD.[4]

As regards faint objects, it has been pointed out several times that only the central parts, perhaps only

[1] Heidelberg Veröff, Band 9 (1926).
[2] Mt Wilson Contr 398 = ApJ 71, p. 231 (1930).
[3] Harvard Bull 895 (1934) and Harvard Ann 88, No 4 (1934).
[4] Mt Wilson Comm 113 = Wash Nat Ac Proc 20, p. 93 (1934).

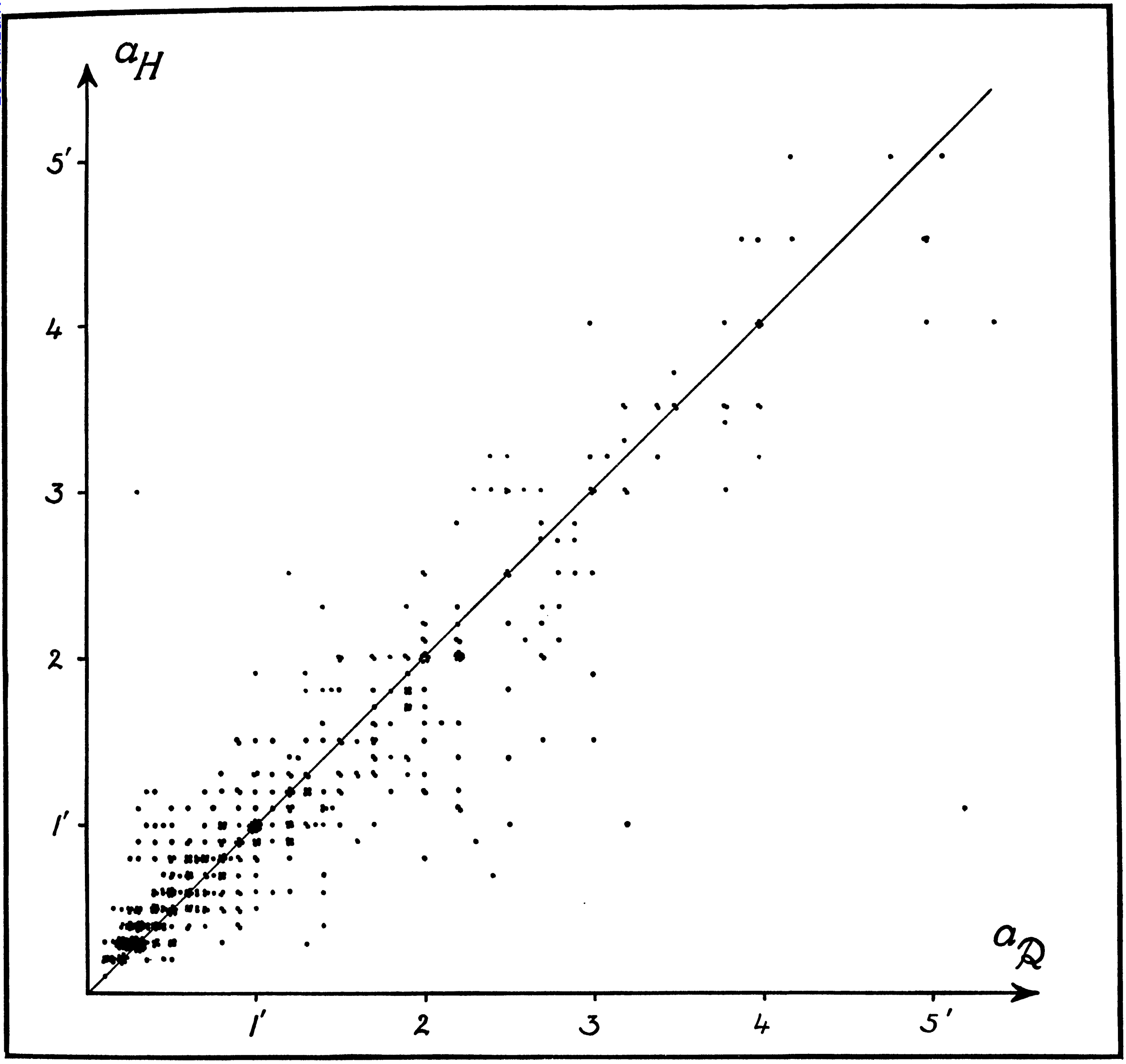


Fig. 14.
Relation between REINMUTH's and HOLMBERG's diameter values.

the nuclei, are to be seen on the plate. Thus K. LUNDMARK[1] states that when photographing a faint galaxy with intense central parts we generally only get a round image corresponding to the concentrated nuclear parts. LUNDMARK draws the conclusion that we do not know the real apparent dimensions of small galaxies.

[1] Upsala Medd 30 (1927).

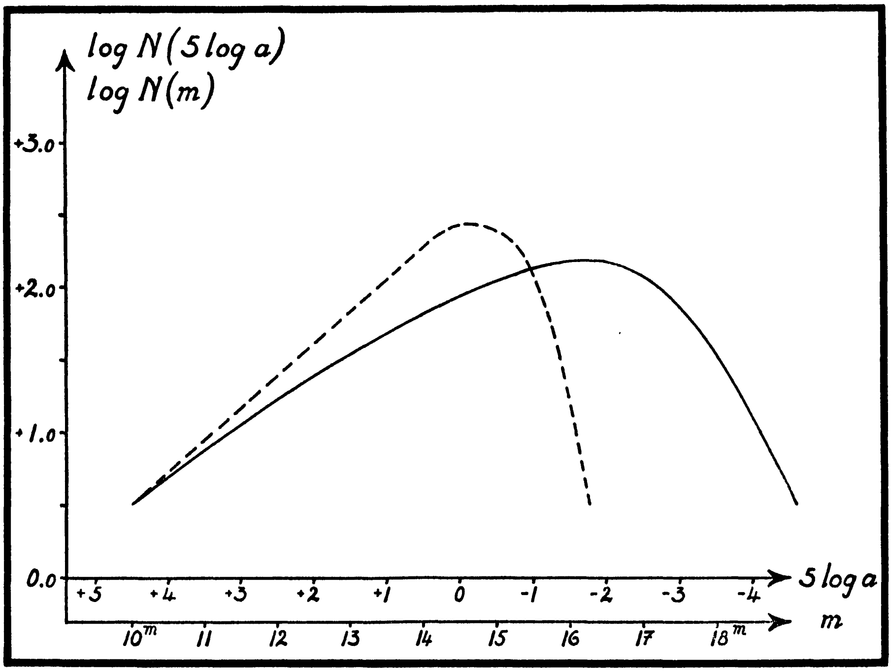


Fig. 15.
The distributions of the quantities 5 log *a* (full curve) and *m* (dotted curve).

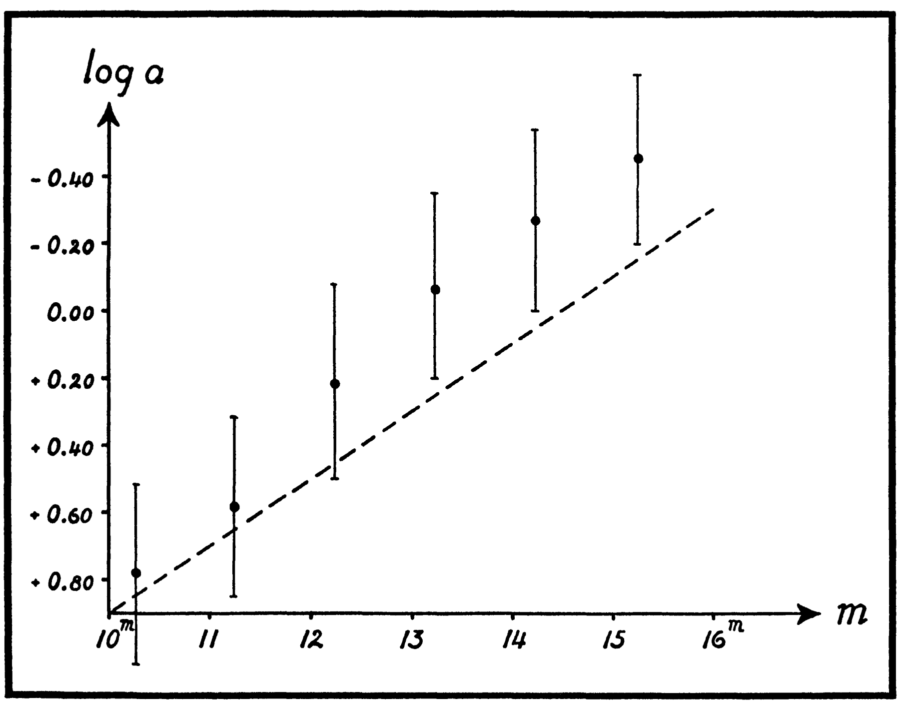


Fig. 16.
Relation between apparent dimensions and apparent magnitudes.

In the present material the systematic effects in the apparent dimensions of the objects are clearly brought out. In Fig. 15 (full curve) the distribution is given of the values 5 log a for all the objects in the present catalogue. The dotted curve corresponds to the distribution of the corrected estimated magnitudes for the same objects. The number of individuals is denoted by $N(5 \log a)$ and $N(m)$ respectively, and the horizontal axes of co-ordinates have been displaced in such a way that the two curves coincide with regard to the bright objects. If we neglect the influences of the dispersions in the absolute dimensions and in the absolute magnitudes, the two curves ought properly to coincide completely. The large displacement of the full curve to the right indicates that large systematic errors are to be found in the small diameter values. If we accept the observed diameters of the brightest objects as standards we can obtain the following average relation from the figure:

$$\overline{(m + 5 \log a)} = +14.5.$$

The correlation between the values of log a and the corrected magnitudes may also be of interest. In Fig. 16, the dots correspond to the observed average values of log a in different magnitude classes. The total length of the vertical lines corresponds to twice the dispersion around the mean values. If no systematic errors were to be found in the diameter values, the connection would approximately follow the dotted line which corresponds to the relation between the apparent magnitude and the apparent diameter that was given above. Thus the figure shows that the small diameter values are systematically too small in comparison with the large values.

The difference $\Delta \log a$ between the objects in the same double or multiple system is of great importance for the computation of the dispersion in the absolute dimensions. If the true angular diameter is denoted by a', we can obtain the following average connection by means of the relations given in Fig 16:

$$\overline{\Delta \log a'} = 0.8 \cdot \overline{\Delta \log a}.$$

In this way the influence of the systematic errors can be approximately neutralized.

The systematic errors in the observed apparent diameters may be assumed to depend on the same arguments as in the case of the apparent magnitudes. Since, however, the errors in the diameter values are very large and to a high degree depend on the type of object, no attempt has been made to compute any corrections here. In the sequel it will be shown that the dispersion in the absolute dimensions is very large. Thus the diameters are in any case of small importance as distance indicators.

CHAPTER VII

ABSOLUTE MAGNITUDES AND DIMENSIONS OF ANAGALACTIC OBJECTS

29. The determination of the absolute magnitudes and the absolute dimensions of anagalactic objects is of very great importance especially for investigations into the spatial arrangement of the metagalactic system. Several methods have been outlined and used in order to determine the individual values of these absolute properties and their statistical distributions. In this chapter we will discuss the results that can be obtained from metagalactic clusters and from individual anagalactic objects. Further, it will be shown that double and multiple galaxies are of great importance for the solution of these problems.

The observed properties of metagalactic clusters can be used to determine the distributions of the absolute luminosities and dimensions of the galaxies. In general, it can be assumed that the components of such a cluster are situated at practically the same distance from us. Thus the distribution of the apparent magnitudes will agree, with regard to its form, with the distribution of the corresponding absolute magnitudes. The same is true for the logarithms of the diameters. As, however, the apparent diameters of these generally small and faint objects are affected with considerable systematic errors[1], the distribution does not interest us so much in this case.

A great many clusters exist in which the number of components amounts to several hundred. The Virgo cluster (centre at $\alpha = 12^h 25^m$, $\delta = +12\overset{\circ}{.}5$, 1930) and the Coma cluster (centre at $\alpha = 12^h 55\overset{m}{.}5$, $\delta = +28°20'$, 1930)

[1] See Chapter VI

are those best investigated of these agglomerations. The former has been the subject of thorough investigations at the Harvard Observatory.[1] The Coma cluster was discovered by M. WOLF[2] and has been investigated at Harvard[3] and at Mount Wilson.[4]

When investigating the distributions of the apparent magnitudes for the above clusters we find that the distribution curves agree very well with normal error curves. In any case, the material is not extensive enough to enable us to obtain reliable values of the skewness and the excess of the distribution. Concerning the dispersion in the magnitudes the following values and mean errors have been derived:

Virgo cluster: $\sigma_M = 0^{\mathrm{M}}.94 \pm 0^{\mathrm{M}}.08$ (from Harvard Circ 294)

Coma cluster: $\sigma_M = 1^{\mathrm{M}}.15 \pm 0^{\mathrm{M}}.05$ (from Mt Wilson Contr 427)

$\sigma_M = 0^{\mathrm{M}}.94 \pm 0^{\mathrm{M}}.03$ (from Harvard Bull 896).

The value obtained from the Virgo cluster may be regarded as somewhat preliminary as being founded only upon the brighter part of the magnitude distribution curve.

Thus we obtain a dispersion in the absolute magnitudes of the cluster components which is very close to one magnitude. Assuming the clusters to contain a representative selection of galaxies we can assume the above result to be valid for galaxies in general. Further on in this chapter we will discuss this selection effect in as far as it concerns double anagalactic objects, and it will be shown that the dispersion ought to remain approximately constant even when a certain selection effect is considered. Supposing this to be valid for clusters too, the dispersion values obtained above can be assumed to possess a general signification.

30. With regard to individual anagalactic objects, absolute magnitudes and dimensions can be obtained only for those galaxies to which the distances have been determined in some way. It is possible to use as distance indicators all resolved objects to be found within the galaxies, the absolute properties of which are known from investigations of our own galaxy. In the first place we have to consider cepheids and novae and the brightest resolved stars. Cepheids were discovered in spirals by E. P. HUBBLE in 1925, while two novae were found in the Andromeda galaxy by G. W. RITCHEY already in 1912. Resolved stars were first used by K. LUNDMARK as distance indicators in 1920. The latter method has proved to be of very great importance, since in most cases a beginning resolution into separate stars can be found for the bright galaxies. Cepheids and novae have been discovered only in a few of the brightest objects. They are, however, of general importance in the calibrating of the distance scales. For a further discussion we beg to refer to LUNDMARK[5], 'Studies of anagalactic nebulae'.

As early as 1927 LUNDMARK[6] determined the absolute magnitudes and dimensions of 29 anagalactic objects. The brightest resolved stars were used in deriving the distances. For these stars an average absolute magnitude of $-7^{\mathrm{M}}.0$ was assumed. The following average values and dispersions, with mean errors, were obtained:

$$\overline{M} = -15^{\mathrm{M}}.8 \pm 0^{\mathrm{M}}.2 \qquad \overline{\log A} = +3.35 \pm 0.08$$
$$\sigma_M = 1^{\mathrm{M}}.23 \pm 0^{\mathrm{M}}.16 \qquad \sigma_{\log A} = 0.43 \pm 0.06.$$

Here M and A indicate the absolute photographic magnitude and the absolute major diameter, in parsecs, respectively.

[1] Harvard Circ 294 (1926) and Harvard Ann 88, No 1 (1930).
[2] AN 155, p. 127 (1901).
[3] Harvard Ann 88, No 1 (1930) and Harvard Bull 896 (1934).
[4] Mt Wilson Contr 427 = ApJ 74, p. 43 (1931).
[5] Upsala Medd 30 (1927).
[6] Upsala Medd 22 (1927).

The average values given above must be corrected because of a statistical effect of selection so as to become representative for anagalactic objects in general. It must be assumed that the above twenty-nine galaxies have been selected in such a way that absolutely bright objects and objects with large absolute dimensions are too numerously represented. Yet it should be mentioned that some elliptical objects are included. However, it is difficult to determine any corrections in this case, as the material is comparatively small. Similarly, the dispersions must be corrected for these effects of selection.

In the same paper LUNDMARK calls attention to the results which he has obtained by using double anagalactic objects. From these a dispersion in the absolute magnitudes of $1^{M}_{.}06$ has been deduced.

In several publications E. P. HUBBLE has made use of the resolved stars to determine the absolute properties and the distances of anagalactic objects. His last and most extensive investigation was published in 1936.[1] From 145 galaxies HUBBLE obtained the following values:

$$\overline{M} = -14^{M}_{.}07 \qquad \sigma_M = 0^{M}_{.}94 .$$

This mean value is considered by HUBBLE to represent the average absolute photographic magnitude of the galaxies in a given volume of space. It should, however, be pointed out that elliptical objects are completely lacking in the material. This is also valid for spirals of an early type (type *Sa* and generally type *Sb*, too). Thus the values given above cannot be accepted as fully representative of galaxies in general.

For the brightest resolved stars HUBBLE assumes an average absolute magnitude of $-6^{M}_{.}12$. This value proves to be to some extent correlated with the absolute magnitude of the galaxy and with the type. The above values of $\overline{M}$ and σ_M are corrected for these connections. The Andromeda galaxy is, however, excluded. If we include this object we get a somewhat brighter value of the average absolute magnitude, and the dispersion can be rounded off to one magnitude. Regarding the individual values of the absolute magnitude, these approximately have a normal distribution.

In a subsequent paper[2] HUBBLE makes use of the residuals in the relation between the radial velocities and the apparent magnitudes of the galaxies for the determination of the distribution of the absolute magnitudes. A normal error curve with about the same dispersion as in the preceding paper is obtained.

HUBBLE has not discussed the absolute dimensions of the objects mentioned above. These, too, as possessing a great interest have been computed here on the basis of the values given by HUBBLE and with the use of the apparent diameter values which are to be found in REINMUTH'S[3] catalogue, 'Die Herschel-Nebel'. For some few of the objects the diameter values must, however, be compiled from other sources. In this way the apparent dimensions of all galaxies, with the exception of four, have been obtained. When computing the distribution of the diameters, twenty objects belonging to the Virgo cluster have been excluded in order to make the material more homogeneous, while the Andromeda galaxy has been included. It appears that a practically normal distribution is obtained of the logarithms of the absolute major diameters. The following numerical values are deduced:

$$\overline{\log A} = +3.17 \pm 0.03 \qquad \sigma_{\log A} = 0.34 \pm 0.02 .$$

Here A denotes the largest diameter in parsecs.

[1] Mt Wilson Contr 548 = ApJ 84, p. 158 (1936). [2] Mt Wilson Contr 549 = ApJ 84, p. 270 (1936).
[3] Heidelberg Veröff, Band 9 (1926).

The values obtained for the absolute magnitudes of the galaxies are independent of absorption within our own galaxy while the absolute diameters are dependent on such an effect. Further, in the apparent diameters, there are perhaps small systematic errors of such a nature that small objects are measured too small. In the above computation no corrections have been applied for these effects. The value given of the dispersion thus ought to be considered a maximum value.

31. In Fig. 17 the values of M and $\log A$ for the above 121 objects have been dotted. The spirals, mainly belonging to the type *Sc*, have been denoted by full circles, while the irregular objects have been denoted by

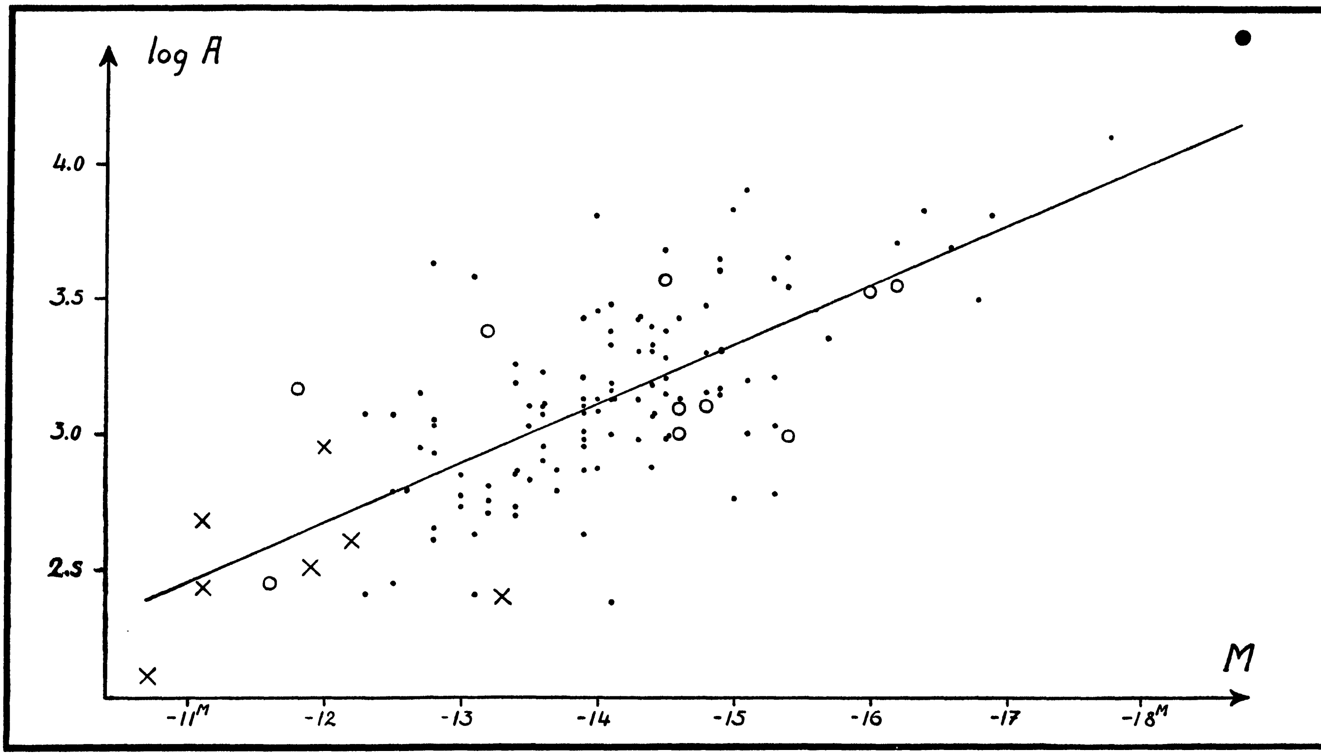


Fig. 17.
Correlation between absolute magnitudes and absolute dimensions of the galaxies.

open circles. There is a high correlation to be found between the two sets of absolute properties and the relation seems to be a linear one. Concerning the line of symmetry which has been drawn in the figure, and the coefficient of correlation, the following numerical values have been obtained:

$$M = -4.6 \log A + 0.3$$

$$r = -0.638 \pm 0.054.$$

As it would be of considerable interest to see where our own galaxy is to be placed in the figure, this has been denoted by the large dot in the upper right-hand corner. The largest diameter of the Galaxy has been assumed to have the generally adopted value of thirty thousand parsecs. Concerning the absolute photographic luminosity an investigation by W. GYLLENBERG[1] has been used, where a value of $-18^{M}.8$ is suggested. Thus it appears that the Galaxy agrees very well with the relation found above. If we take the circumstance into consideration that the outer parts of the other galaxies cannot generally be recorded, the diameter value assumed here is perhaps too large. If we assume a smaller value, this will cause a still better agreement with the line of symmetry given in the figure.

It has already been pointed out that no elliptical objects are to be found in HUBBLE's catalogue. As it would be of great interest to see where the elliptical galaxies are situated in the above Fig. 17, we have tried to obtain some data by the aid of the present catalogue. All elliptical galaxies that form a double or multiple system together with one of HUBBLE's galaxies have been selected. In order to eliminate optical systems as completely as possible the rule has been applied that the double or multiple system shall be a narrow one. Further only those galaxies have been selected from the present catalogue whose elliptical character can be considered as probable. Here the Heidelberg and Harvard catalogues are useful for comparisons. No large number of elliptical galaxies can be obtained that correspond to the above conditions. In Table 4 the seven objects selected are given. In the three columns are to be found the number in the present catalogue, the NGC-number and the type value given in the present catalogue. By assuming the elliptical objects to be situated at the same distances as the corresponding objects in HUBBLE's catalogue we now can derive their absolute properties. The apparent magnitudes and diameters have been taken from the present catalogue. The above elliptical galaxies have been marked in Fig. 17 by crosses.

Table 4.

Elliptical galaxies.

No	NGC	Type
17 b	221	e
17 c	205	g
175 b	3193	e
301 b	3950	d
716 b	—	$d-h_0$
729 b	—	$d-h_0$
729 c	—	$d-h_0$

It appears from the figure that the elliptical objects show very good agreement with the correlation previously found between the absolute magnitude and the absolute dimension of the galaxies. The number of objects is not large, it is true, but all the objects are crowded together in the lower left-hand corner of the figure. Thus we may draw the conclusion that the above correlation has a real meaning and that it is valid for all types of galaxies. Similar results are obtained below in connection with some investigations of double and multiple galaxies. An attempt is also made there to explain the relation in question by means of absorption effects within the galaxies.

Table 5.

Average absolute magnitudes and dimensions for different types of galaxies.

Type	$\bar{M} \pm \varepsilon(\bar{M})$	$\overline{\log A} \pm \varepsilon(\overline{\log A})$	N
Ell.	$-11^{M}.7 \pm 0^{M}.3$	$+2.52 \pm 0.10$	7
Spir. . . .	-14.1 ± 0.1	$+3.16 \pm 0.03$	111
Irr.	-14.3 ± 0.5	$+3.21 \pm 0.09$	10

In Fig. 17 a sequence is indicated from elliptical objects to spirals and to irregular objects. In Table 5 some numerical values are given. The average absolute luminosity increases from one group to another, and in the same manner the absolute dimensions become larger. The elliptical galaxies differ considerably from the other types of objects. The differences between the spirals and the irregular objects are, however, very small. It will be shown below that double and multiple systems offer an excellent means for the determination of relative absolute magnitudes and dimensions for different types of galaxies.

[1] Lund Medd II, No 87 (1937).

32. After these discussions concerning the results to be obtained from metagalactic clusters and from individual anagalactic objects, we will pass on to some investigations into the material given in the present catalogue. Double and multiple galaxies are of great importance for the determination of the absolute qualities of anagalactic objects. K. LUNDMARK[1] in several papers has discussed the methods to be used in connection with preliminary investigations into double galaxies.

Double and multiple objects, however, represent a selected material and they are perhaps not to be compared with isolated galaxies. Systematic deviations may exist between the two classes of objects as regards absolute magnitudes and absolute dimensions. Before entering upon inquiries into the absolute qualities of double galaxies, we will try to take these selection effects into consideration.

According to some investigations in Chapter XII of this paper double and multiple galaxies are very probably formed by captures. By starting from some assumptions we are able to use the formulae of statistical mechanics to compute the number of "collisions", or encounters, that takes place in the metagalactic system within a given unit of space and time. The number of "collisions" depends on the diameter of the objects. Large diameter values correspond to a large number of "collisions", and the reverse. A double system can, however, be formed only when the encounter becomes a capture. At this place we will assume that the probability for the transformation of a "collision" into a capture is independent of the diameter value. Since large diameter values very probably correspond to large mass values the assumption may be justified. Anyhow, we have to make some assumptions in order to be able to discuss the problems that are taken into consideration.

The two components, arbitrarily selected, of a double system will be denoted by index 1 and index 2. If, in a given volume of space, the correlation function of $ln\ A_1$ $(= x_1)$ and $ln\ A_2$ $(= x_2)$ is denoted[2] by $\psi(x_1 x_2)$, and if, for galaxies in general, the distribution function of $ln\ A$ is denoted by $\varphi(x)$, the following approximate relation[3] between these two functions can be derived:

$$\psi(x_1 x_2)\, dx_1\, dx_2 \simeq f \cdot A_1 A_2 \cdot \varphi(x_1) \cdot \varphi(x_2)\, dx_1\, dx_2 \simeq \text{const} \cdot (A_1 A_2)^n \cdot \varphi(x_1) \cdot \varphi(x_2)\, dx_1\, dx_2 . \quad (16)$$

In the above equation the factor f is proportional to the time interval that corresponds to the formation of the double systems, and to an average value of those relative space velocities that correspond to the absolute diameters A_1 and A_2. The geometric mean of the diameters A_1 and A_2 has been made use of instead of the arithmetical mean in order to facilitate the following computations. The formula presupposes a large number of single galaxies in proportion to the number of double systems.

The middle term in the above equation has been transformed into the expression to the right. The value of the constant and of the exponent n thus depends on the factor f. Of course, we have now introduced some further approximations, but as the problem considered can be solved only by making several assumptions, the relation obtained here may be used as a starting-point.

The value of the exponent n in the above equation is highly dependent on the question whether an equipartition of energy exists among the anagalactic objects or not. If there is an equipartition, the exponent probably has a small numerical value, since large values of the diameters A_1 and A_2 probably correspond to large mass values and consequently to small values of the factor f, and the reverse. If no equipartition of energy

[1] Upsala Medd 8 (1926), Upsala Medd 16 = VJS 61, p. 254 (1926), Upsala Medd 30 (1927), Upsala Medd 41 = VJS 63, p. 350 (1928). [2] In the present paper *ln* always means the natural logarithm. [3] Cf. Chapter XII (formula (81)).

exists, the factor f for a given interval of time has a constant value, and the exponent n approximately gets the value of $+1$.

We do not know very much about the relation between mass and velocity in the metagalactic space Several suggestions have been made. Thus K. LUNDMARK[1] discusses the dependence of the velocity on the mass of an object, but no definite results have been reached. S. SMITH[2] investigates the radial velocities determined for the members of the Virgo cluster. In this special case no equipartition of energy is suggested. It may, however, be remarked that in such a cluster somewhat different conditions are probably to be found than in the general field of galaxies.

In accordance with the above discussion the following formula will thus be adopted:

$$\psi(x_1 x_2)\, dx_1\, dx_2 = \text{const} \cdot e^{n x_1 + n x_2} \cdot \varphi(x_1) \cdot \varphi(x_2)\, dx_1\, dx_2 . \tag{17}$$

Further the frequency function $\varphi(x)$ is assumed to correspond to a normal distribution with a dispersion equal to σ:

$$\varphi(x)\, dx = \frac{dx}{\sigma \sqrt{2\pi}} \cdot e^{-\frac{(x-\bar{x})^2}{2\sigma^2}} . \tag{18}$$

If the moments referring to the function $\psi(x_1 x_2)$ are computed, the following results are obtained:

$$\begin{aligned} \bar{x}_1 &= \bar{x}_2 = \bar{x} + n\sigma^2 \\ \sigma_{x_1} &= \sigma_{x_2} = \sigma \\ r_{x_1 x_2} &= 0 . \end{aligned} \tag{19}$$

According to these derivations the correlation between $ln\ A_1$ and $ln\ A_2$ for double objects should be equal to 0, and the dispersion in these quantities should agree with the corresponding dispersion for single galaxies. The average value of the diameters is, however, larger (if $n > 0$) than the value corresponding to single galaxies.

The above deductions refer to the absolute diameters of the anagalactic objects. As these are highly correlated with the corresponding absolute magnitudes, it may be assumed that the above formulae are approximately valid for the magnitudes, too. Thus, in the formulae $ln\ A$ is to be replaced by M. The constant n, in this case denoted by n', of course obtains a different value.

Concerning the expressions (19), we may at once use them for application on observational facts. In HUBBLE's material discussed above all the galaxies have here been selected that in any way form part of double or multiple systems. For the purpose of this selection not only the present catalogue but also REINMUTH's[3] catalogue 'Die Herschel-Nebel' has been consulted. REINMUTH has generally pointed out in special notes whether faint objects are to be found close to a galaxy given in his catalogue. In this way the areas of the sky not represented in the present catalogue have also been included. Altogether, 47 out of the 121 galaxies[4] prove to be components of double or multiple systems. In the computing of average values and dispersions the results given in Table 6 have been obtained.

[1] Lund Medd I, No 119 = PASP 42, p. 23 (1930).
[2] Mt Wilson Contr 532 = ApJ 83, p. 23 (1936).
[3] Heidelberg Veröff, Band 9 (1926).
[4] The Virgo cluster has not been included.

Table 6.

How the components of double and multiple systems deviate from galaxies in general.

Objects	$\overline{M}$	σ_M	$\overline{\log A}$	$\sigma_{\log A}$	N
All galaxies	$-14^{\mathrm{M}}.07 \pm 0^{\mathrm{M}}.09$	$1^{\mathrm{M}}.04 \pm 0^{\mathrm{M}}.07$	$+3.17 \pm 0.03$	0.34 ± 0.02	121
Components in systems . .	-14.38 ± 0.15	1.02 ± 0.11	$+3.28 \pm 0.05$	0.36 ± 0.04	47

From the table it appears that the dispersion in M and $\log A$ is of about the same size for the two groups. On the other hand, the selected group has an average absolute magnitude and an average absolute diameter brighter or larger respectively than galaxies in general. If σ_M is put $= 1^{\mathrm{M}}.0$ and $\sigma_{\log A} = 0.30$[1] the following values are obtained for n and n':

$$n = +0.53 \pm 0.17$$
$$n' = -0.31 \pm 0.12.$$

The numerical value obtained for n suggests that an equipartition of energy is partly to be found within the metagalactic system. On account of the approximations introduced above no definite conclusions can, however, be drawn.

Concerning the components of double and multiple systems the distribution functions of $\log A$ $\left(= \varphi' (\log A)\right)$ and of $M \left(= f'(M)\right)$ can then approximately be written in the following way:

$$\varphi'(\log A) = h \cdot \varphi(\log A) \tag{20}$$
$$f'(M) = k \cdot f(M).$$

Here $\varphi(\log A)$ and $f(M)$ denote the corresponding distribution functions of the absolute dimensions and the absolute magnitudes for anagalactic objects in general. The two factors of selection h and k get the following approximate values:

$$h = \mathrm{const} \cdot e^{+1.2 \log A} \tag{21}$$
$$k = \mathrm{const} \cdot e^{-0.31 M}.$$

33. After these discussions of the effects of selection to be found in double and multiple galaxies the present catalogue will be used for deriving some characteristics of the distributions of the absolute magnitudes and the absolute dimensions.

The difference between the apparent magnitudes of the two components in a double system is equal to the corresponding difference between the absolute magnitudes:

$$\Delta m = \Delta M = M_1 - M_2. \tag{22}$$

The following expression is valid for the corresponding dispersions:

$$\sigma^2_{\Delta m} = \sigma^2_{\Delta M} = 2\sigma^2_M(1 - r_{M_1 M_2}). \tag{23}$$

Here $r_{M_1 M_2}$ denotes the coefficient of correlation between the absolute magnitudes of the components. In this way the dispersion of the apparent magnitude differences can be transformed into the dispersion of the absolute magnitudes.

[1] These values have later on been adopted as final ones.

From the double and multiple systems of the present catalogue the following numerical value of the dispersion in the magnitude differences is obtained:

$$\sigma_{\Delta m} = 1^{\text{m}}.11 \pm 0^{\text{m}}.03.$$

This dispersion has been computed in the following manner. If a system contains n components, a total number of $(n-1)+(n-2)+ \ldots\ldots + 1$ differences Δm can be formed, whereas only $(n-1)$ differences are to be considered as independent. In the final determination of $\sigma^2_{\Delta m}$ every one of the differences has obtained a weight equal to the ratio of the number of independent differences to the total number of differences. Further, the dispersion $\sigma_{\Delta m}$ has been corrected for the influence of the mean error in the magnitude differences. From comparisons between different m-values, estimated for the same object but on different plates, the mean error in a determination of Δm has been found to possess a value of about three tenths of a magnitude.

If the material contains a great number of optical pairs, these will make the computed value of $\sigma_{\Delta m}$ somewhat too large. Assuming p fractions of the double systems to be optical pairs, we may, instead of the above formula (23), use the following expression:

(24)
$$\sigma^2_{\Delta m} = 2\,\sigma^2_M (1 - r_{M_1 M_2}) + 50\,p \cdot \sigma^2_{\log \varrho}.$$

Here ϱ denotes the distance to the individual systems. As the fraction p probably amounts to only a few per cent, and as $\sigma_{\log \varrho}$ might have a value of 0.1 à 0.2, the error introduced here obtains a small value and it may be neglected.

The dispersion $\sigma_{\Delta m}$ must be corrected for a certain effect of selection. Concerning double and multiple systems with faint components, only the brightest of these are to be found on the plate on account of its limiting magnitude. Thus, the computed dispersion in the magnitude differences becomes systematically too small. For the derivation of some corrections the two components, arbitrarily selected, of a double system may be denoted by index 1 and 2. If the limiting magnitude, in regard to galaxies, of the plate is denoted by m_l, and if $(m_l - m_1)$ is put equal to d, the following expression of the dispersion ${}_d\sigma_{\Delta m}$ corresponding to a given value of d is obtained:

(25)
$$ {}_d\sigma^2_{\Delta m} = \frac{\int\limits_{M_1=-\infty}^{+\infty} \int\limits_{M_2=-\infty}^{M_1+d} (M_1 - M_2)^2 \cdot \varphi (M_1 M_2)\, dM_1\, dM_2}{\int\limits_{M_1=-\infty}^{+\infty} \int\limits_{M_2=-\infty}^{M_1+d} \varphi (M_1 M_2)\, dM_1\, dM_2}.$$

Here $\varphi(M_1 M_2)$ is the correlation function of the absolute magnitudes M_1 and M_2. The correction factor f, by which the value of $\sigma_{\Delta m}$ computed above is to be multiplied, gets the following value:

(26)
$$f^2 = \frac{{}_\infty\sigma^2_{\Delta m}}{\overline{({}_d\sigma^2_{\Delta m})}}.$$

The mean value of the denominator corresponds to all observed values of the difference d.

We will make a numerical computation of the integral expression contained in the above formula (25) using the observed distribution[1] of the differences d. The following assumptions will be made:

[1] See Fig. 6.

a) The absolute magnitudes M_1 and M_2 are not correlated.

b) M_1 and M_2 have normal distributions with a dispersion of $1^{\mathrm{M}}.0$.

In this way we obtain the following result:

$$f = 1.23.$$

The dispersion in the magnitude differences now reaches the following corrected value:

$$\sigma_{\Delta m} = f \cdot 1^{\mathrm{m}}.11 = 1^{\mathrm{m}}.37.$$

As regards the dispersion in the absolute magnitudes we obtain the following final expression:

$$\sigma_M = \frac{0^{\mathrm{M}}.97}{\sqrt{1 - r_{M_1 M_2}}}. \tag{27}$$

According to the investigations above, it seems probable that the coefficient of correlation, $r_{M_1 M_2}$, has a small numerical value. If $r_{M_1 M_2}$ is given the value of 0 then:

$$\sigma_M = 0^{\mathrm{M}}.97.$$

Thus a dispersion value has been obtained which is in close agreement with the values previously discussed. Since double and multiple systems seem to contain galaxies of widely different types[1] the value obtained above may be regarded as fairly representative.

Summing up the above discussions concerning the dispersion in the absolute magnitudes of the galaxies, we may conclude that the results obtained from clusters, from individual galaxies, and from double and multiple systems point at a dispersion value so close to one magnitude that it seems justified to round off the value used to exactly one magnitude.

34. By using double and multiple galaxies, it is also possible to obtain a value of the dispersion in the logarithms of the absolute diameters. If the apparent and the absolute major diameter are denoted by a and A resp., we obtain the following expression:

$$\sigma^2_{\Delta \log a} = \sigma^2_{\Delta \log A} = 2 \cdot \sigma^2_{\log A}\left(1 - r_{\log A_1 \log A_2}\right). \tag{28}$$

From the double and multiple objects the following value of the dispersion $\sigma_{\Delta \log a}$, corrected for the corresponding mean error, is obtained:

$$\sigma_{\Delta \log a} = 0.40 \pm 0.01.$$

In this case, too, it is necessary to correct the dispersion for a certain selection in the material. Assuming a *limiting diameter* amounting to $0'.25$ and using a value for the dispersion $\sigma_{\log A}$ of 0.30, we may, in complete accordance with the procedure discussed above, compute a correction factor f. In that case we find:

$$f = 1.25.$$

Thus we here get a value of this factor f which agrees very closely with the value found above.

When the diameters are discussed, it is further necessary to correct for certain systematic errors. It is

[1] See Chapter IX.

a well known fact that the measurable dimensions of small galaxies appear too small, because the external fainter parts of the objects vanish. These effects have been discussed in Chapter VI of the present paper. In that chapter the following average relation was derived:

$$\overline{\varDelta \log a'} = 0.8 \cdot \overline{\varDelta \log a}.$$

Here a' denotes the real angular major diameter and a the observed one.

In accordance with the above average relation the dispersion of $\varDelta \log a$ may be multiplied by the factor 0.8. This is perhaps not quite correct, but it is probably the simplest way to get rid of the large systematic errors existing in the apparent diameter values. The following final expression is thus obtained:

(29)
$$\sigma_{\log A} = \frac{0.28}{\sqrt{1 - r_{\log A_1 \log A_2}}}.$$

If the coefficient of correlation is given the value of 0, we get:

$$\sigma_{\log A} = 0.28.$$

From the above discussions concerning the dispersion in the logarithms of the absolute diameters it may be concluded that the value of 0.30 seems to be the most probable one. On account of the errors involved in the observed diameters this value is, however, not so reliable as the corresponding dispersion value obtained for the magnitudes.

35. We will now make some investigations into the relative luminosities and dimensions of galaxies of different types. Double and multiple objects offer excellent opportunities for a comparison between galaxies of different kinds. K. Lundmark[1] has previously pointed out the results to be obtained by using these objects. Among other things he has found that the elliptical galaxies are on an average 8—10 times smaller than the spirals.

Concerning the results obtained in the present investigation we may at once refer to Table 7. The material of the present catalogue has been divided into three groups. The first class contains objects where no spiral structure appears, namely the types d, e, f, g, h and h_0 in Wolf's scheme. Some of these objects are, however, probably spirals, though the spiral structure does not appear on account of poor resolution.

Table 7.

Distributions of absolute luminosities and dimensions for galaxies of different types.

Type	$\overline{\varDelta M}$	$\sigma_{\varDelta M}$	σ_M	$\overline{\varDelta \log A}$	$\sigma_{\varDelta \log A}$	$\sigma_{\log A}$	N
d, e, f, g, h, h_0	—	—	$0^M.63$	—	—	0.26	362
v	$-1^M.01$	$0^M.73$	0.46	+0.42	0.29	0.17	28
r, s, u, w	−2.19	1.21	1.06	+0.71	0.39	0.38	38

The second group contains spirals of an early type, namely type v, and the third group more advanced spirals of the types r, s, u, w. In the following columns $\varDelta M$ and $\varDelta \log A$ denote the absolute magnitude and the logarithm

[1] Upsala Medd 16 = VJS 61, p. 254 (1926).

of the absolute major diameter, both measured in relation to the elliptical components of the same double or multiple system. The last column of the table contains the number of the objects in every class. It appears from the table that the average absolute magnitude becomes brighter from one group to another, and that the values of the diameters become larger. The different values of σ_M and of $\sigma_{\log A}$ are computed from the corresponding values of $\sigma_{\Delta M}$ and $\sigma_{\Delta \log A}$, and from the values of σ_M and $\sigma_{\log A}$ obtained for the elliptical objects. These latter dispersion values have been computed in the same manner as was used above. They have not, however, been

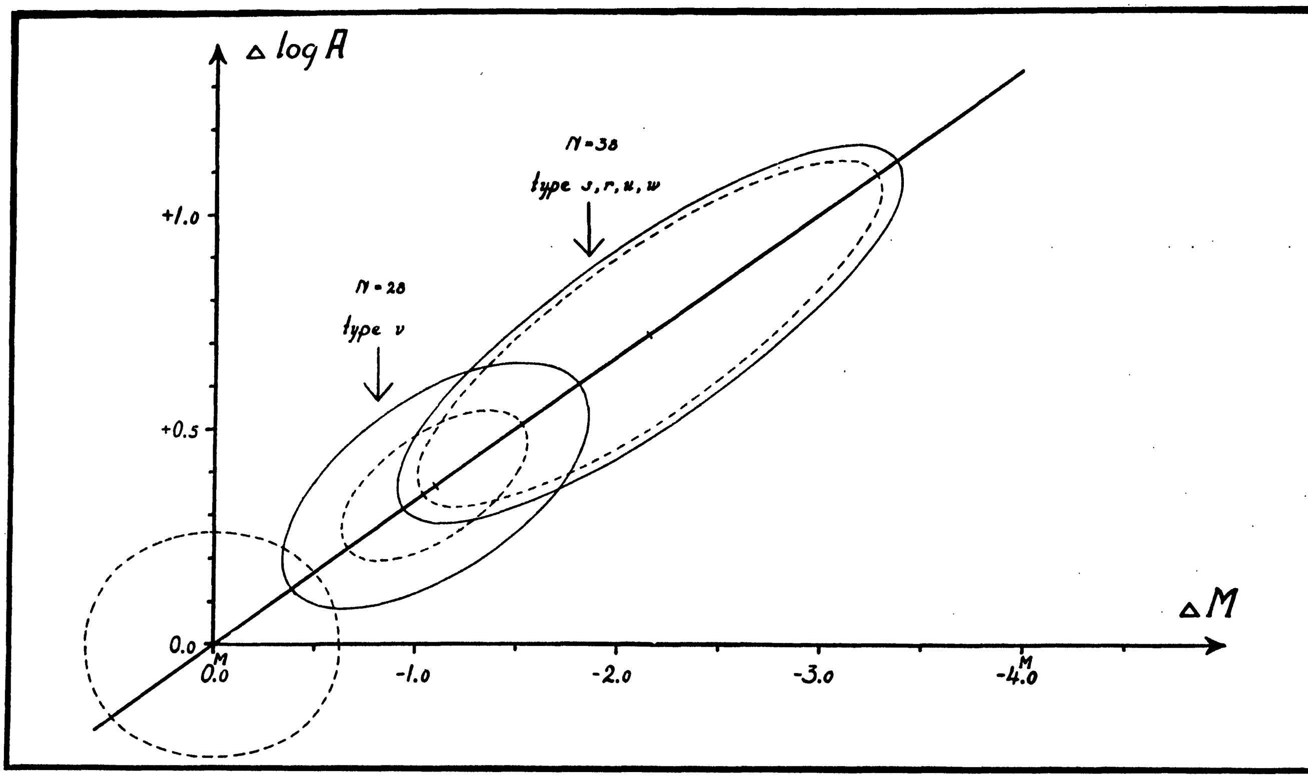


Fig. 18.

Differences between elliptical galaxies and spirals concerning the absolute magnitudes and the absolute dimensions.

corrected for the effects of selection and systematic errors discussed above, because in this case the corrections would become small and unreliable on account of the small dispersion values and the small number of individuals.

The above table has been illustrated in Fig. 18. The individual values of ΔM and of $\Delta \log A$ are highly correlated with one another. The following expression for the coefficient of correlation and for the line of symmetry has been derived:

$$r = -0.777 \pm 0.049$$
$$\Delta M = -3.0 \Delta \log A .$$

In the figure the full line corresponds to the line of symmetry. The full ellipses correspond to the dispersions $\sigma_{\Delta M}$ and $\sigma_{\Delta \log A}$, while the dotted ellipses correspond to the values of σ_M and $\sigma_{\log A}$. Half the major axis and half the minor axis are equal to the dispersions in the respective directions. The dotted ellipse round the origin refers to the elliptical objects. From this figure, which agrees well with Fig. 17 corresponding to Hubble's objects, we thus find a well-marked sequence from elliptical objects over early spirals to late spirals.

Here it should be of some interest to refer to the results obtained in Chapter X of the present paper, where the absorption effects within anagalactic objects are discussed. If an object is expanding, the observed total magnitude probably becomes brighter, because the influence of the absorbing matter within the object is dimin-

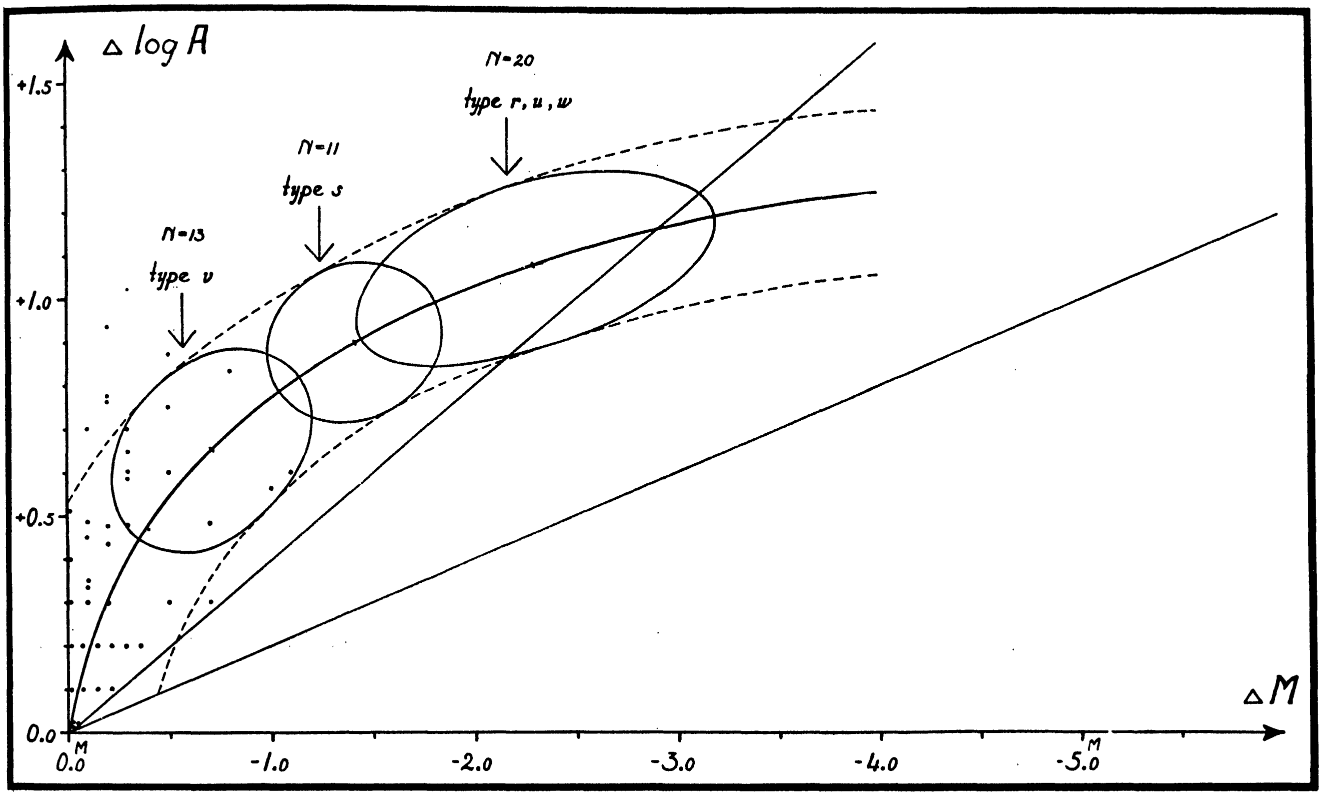


Fig. 19.

Differences between the galaxies and their nuclei concerning the absolute magnitudes and the absolute dimensions.

ishing. The relation here found between M and log A may thus very well be an absorption effect. The value of the absolute magnitude corrected for absorption may in this way be approximately the same for the different types of galaxies. Consequently the different absolute dimensions would constitute the only real distinction between the various types. This is of course of very great importance for all theories concerning the development of the galaxies.

36. In this connection it would also be of some interest to take into consideration the luminosities and dimensions of the nuclei of the objects. A catalogue of the apparent magnitudes and dimensions of the nuclei is found at the end of this paper.[1] In Fig. 19 the elliptical objects used in the above figure are replaced by the

[1] See Appendix II.

nuclei of the respective objects as zero-points in the ΔM- and $\Delta \log A$-scales. The elliptical objects without nuclei thus are to be placed in the origin, while the dots correspond to those elliptical objects in which nuclei are to be found. Concerning the spirals it has been possible to isolate the *s*-type. We thus obtain the following sequence of galaxies: elliptical objects without marked nuclei, elliptical objects with nuclei, spirals of type *v*, spirals of type *s*, spirals of the types *r*, *u*, *w* and finally irregular objects without nuclei.

In the area between the two straight lines drawn in the figure the nucleus must disappear, since the surface magnitude of the nucleus here equals the average surface magnitude of the whole object. The two lines have been obtained in the following manner. If we denote the major and minor diameters of a galaxy by A and B and the diameter of the generally circular nucleus by A', the disappearance of the nucleus corresponds to the following formula:

(30) $$\Delta M = -2.5 \log \frac{A\,B}{(A')^2}\cdot$$

The two straight lines found in the figure correspond to the two extreme cases where $B = A$ and $B = A'$ resp.

Thus it is evident that we obtain a very marked sequence of different types of anagalactic objects by using the nuclei of the objects. Furthermore this sequence agrees very well with the one we obtain by investigating the absolute magnitudes and the absolute dimensions of the galaxies.

CHAPTER VIII

SPATIAL ARRANGEMENT WITHIN THE NEARER METAGALAXY

37. In this chapter we will investigate the arrangement in space of galaxies in general and of double and multiple systems. The average distributions of these two groups of objects and their relation to each other will be discussed. Earlier in this paper we have called attention to the clustering tendencies within the metagalactic system, and it has been pointed out that irregularities and groupings are very common phenomena. Here, however, we do not propose to take these particular effects into consideration.

The distribution in space of the anagalactic objects has already been the subject of several important investigations. Thus all galaxies brighter than $13^{\mathrm{m}}0$ are included in the survey made by H. Shapley and A. Ames.[1] The distributions of the apparent magnitudes here obtained suggest a uniform density of the objects in space. A comprehensive survey of all objects down to a limiting magnitude of about $17^{\mathrm{m}}5$ is in progress at the Harvard Observatory. Concerning some selected regions[2] important results have already been obtained. The extensive investigation by E. P. Hubble[3] comprises objects down to a limiting magnitude of about $20^{\mathrm{m}}0$. A uniform distribution in depth of the objects is there suggested. For other investigations into the distribution of the galaxies we may refer to the above-mentioned paper by Hubble.

[1] Harvard Ann 88, No 2 (1932).

[2] See Harvard Ann 88, No 1 (1930), Harvard Ann 88, No 3 (1933), Harvard Bull 894 (1934), and Harvard Ann 88, No 5 (1935).

[3] Mt Wilson Contr 485 = ApJ 79, p. 8 (1934).

In the present investigation the apparent magnitude of an object will be used as a distance indicator. No account will be taken of the apparent diameter. The observed diameter values, especially the small ones, are subject to large systematic errors, and in addition to this the dispersion in the absolute dimensions is very large. In Chapter VII it was shown that the dispersion in the absolute magnitudes of the galaxies has a value of about one magnitude, while the dispersion in the corresponding quantity $5 \log A$[1] amounts to about 1.5. Systematic errors may of course also be assumed to exist in the apparent magnitude values. In the case of bright galaxies, however, they probably have a very small value. For the rest it may be pointed out that the estimated magnitudes given in the present catalogue have been corrected for the most important systematic errors.

38. All distance determinations on a photometric basis are subject to influence from the existence of obscuring matter in the space between the object and the observer. In the present case several absorption effects must be taken into consideration. Some of these effects will be discussed in greater detail in Chapter X of the present paper. In this connection a few notes will be given.

First the general absorption within our own galaxy must be taken into consideration. This absorption has a small and comparatively constant value in high galactic latitudes, but increases rapidly as we approach the Milky Way. In the determination of the space distribution unreliable results are thus obtained if galaxies in different galactic latitudes are taken together. In the present investigation only objects in the vicinity of the galactic poles $(|b| > 60°)$ have been included. In this way the disturbing effects produced by the galactic absorption can mostly be eliminated.

Our knowledge as regards the existence of obscuring matter in the metagalactic space is comparatively limited. Using the surface magnitudes of the anagalactic objects C. Wirtz[2] and K. Lundmark[3] obtained very small values for this absorption. Very great difficulties are, however, encountered in investigations of this kind, and the results obtained are perhaps not to be considered definitive. Further, H. Shapley and A. Ames[4], on the basis of a study of galaxies in the Coma-Virgo region, concluded that in this direction the space seems to be effectively transparent. The apparent magnitudes of the galaxies were compared by them with the angular diameters. The relation between the apparent dimensions and the absorption effects, which is of very great importance in this connection, was, however, not discussed. With regard to the above investigations we have considered it most appropriate not to take into consideration any metagalactic absorption effects.

The existence of absorbing matter within the galaxies themselves will cause spirals seen edgewise to be fainter than those situated at right angles to the line of sight. In Chapter X of the present paper it will be shown that these orientation effects will cause an additional dispersion in the absolute magnitudes of $0^{\mathrm{M}}.16$. As this value is small in comparison with the total dispersion, this absorption effect will also be neglected here.

39. The problem of determining the distribution in space of a class of objects by means of the distribution of the apparent magnitudes has been much discussed in works on stellar statistics, and many different solutions have been proposed. The following equation, known as the fundamental equation of stellar statistics, has been the general point of departure:

$$N(m) = \omega \int_{0}^{+\infty} D(r)\, \varphi(M) \cdot r^2\, dr. \tag{31}$$

[1] A is the absolute major diameter of the galaxy. [2] Lund Medd II, No 29 (1923) and AN 222, p. 33 (1924).
[3] Upsala Medd 1 = MN 85, p. 865 (1925) and Lund Medd I, No 125 (1930). [4] Harvard Bull 864 (1929).

Here $N(m)$ and $\varphi(M)$ denote the frequency functions of the apparent magnitudes, m, and the absolute magnitudes, M, resp. The number of objects per space unit at the distance r, or the density function, is denoted by $D(r)$. Further ω denotes the solid angle which is taken into consideration. This relation was first given (without $D(r)$) by H. GYLDÉN[1] in 1872, and was later on extensively used by H. SEELIGER in his investigations of the stellar system.

We have, in fact, already made some assumptions concerning the above equation. In the first place it has been assumed that the distribution of the absolute magnitudes is independent of the distance. This cannot, *a priori*, be considered correct, but the assumption must be made in order not to make the problem too complicated. Further, it has been assumed that the conditions are identical for all parts of the solid angle ω. By giving this angle a small enough value we may, however, consider this assumption justified.

In order to obtain the density function, $D(r)$, from the above equation, we must know the other two functions $N(m)$ and $\varphi(M)$. The luminosity function $\varphi(M)$ was discussed in the preceding chapter. It was pointed out that a normal error curve fits the distribution very well. The dispersion in the absolute magnitudes amounts to about one magnitude. We have not yet, however, obtained any definite results concerning the average value of the absolute magnitudes of the galaxies. If we consider the photographic magnitudes, the average value is probably situated between $-14^{\mathrm{M}}.0$ and $-15^{\mathrm{M}}.0$. In the following derivations it has been considered most appropriate to keep the mean value $\overline{M}$ as a parameter. It should be remarked that the galactic absorption effects in the direction of the galactic poles are included in this mean value.

The solution of the fundamental equation will here be made chiefly in accordance with the procedure proposed by K. G. MALMQUIST.[2] We will start from the following equation:

$$(32) \qquad m = 5\log r + M - 5 = 5\log r + \overline{M} + \delta - 5.$$

Thus we have divided the absolute magnitude M into two parts, the average value $\overline{M}$ and the quantity δ. If this deviation from the mean value is considered as an accidental one having a normal distribution, it can be treated in the same manner as an accidental error. The dispersion in the absolute magnitudes is thus compared to a mean error. In accordance with some formulae, given below, the distribution of the apparent magnitudes can then be corrected in such a way that the distribution of the quantity $(5\log r + \overline{M} - 5)$ is obtained. All the details of this distribution cannot, of course, be reconstructed. In this connection, however, only the smoothed curve is required.

The above equation can be written in the following form:

$$(33) \qquad 5\log r + \overline{M} - 5 = r' = m - \delta_m.$$

Here δ_m denotes the value of δ that corresponds to a given apparent magnitude m. Thus the correlation between the apparent and the absolute magnitude is taken into consideration. Further the quantity r' has been introduced into the above equation. For the sake of brevity it will in the following pages be named the *reduced distance*.

Concerning the moments of the deviation δ_m the following expressions can be derived:

---

[1] Cf. K. LUNDMARK, Pop Astr 30, p. 624 (1922).
[2] Lund Medd I, No 100 (1922).

(34)
$$
\begin{aligned}
\nu'_1 &= -\sigma_\delta^2 \cdot D\left(ln\, N(m)\right) \\
\nu_2 &= \sigma_\delta^2 + \sigma_\delta^4 \cdot D^2\left(ln\, N(m)\right) \\
\nu_3 &= -\sigma_\delta^6 \cdot D^3\left(ln\, N(m)\right) \\
\nu_4 &= \sigma_\delta^8 \cdot D^4\left(ln\, N(m)\right) + 3\left(\nu_2\right)^2.
\end{aligned}
$$

Here ν_n denotes the relative moment of the nth order about the mean ν'_1, while σ_δ is the dispersion in the deviations δ, i. e. the dispersion in the absolute magnitudes. Further $N(m)$ denotes the frequency function of the apparent magnitudes and D^n the derivative of the nth order. The natural logarithm is denoted by *ln*.

The distribution of the reduced distances r' can thus be obtained from the distribution of the apparent magnitudes by applying the "corrections" $-\delta_m$. In practice, the procedure is easily performed. Every magnitude class is corrected by the average value $-\bar{\delta}_m\left(= -\nu'_1\right)$, and the corrected magnitudes are then spread out in a normal distribution with a dispersion equal to the value of $\sigma_{\delta_m}\left(=\sqrt{\nu_2}\right)$. The skewness and the excess of the distribution of δ_m are thus neglected. This may, however, generally be considered as a fair approximation.

The distribution of the distances can sometimes be written in the following form:

(35)
$$\psi(r')\,dr' = e^{c_1 r' + c_2} \cdot dr'.$$

This equation is valid for instance if the density function is independent of the distance. In this case the constant c_1 gets the value $+1.38$, while the constant c_2 depends on the average absolute magnitude assumed.

If we start from formula (35) and assume the absolute magnitudes to have a normal distribution, the fundamental equation can be solved in a very simple manner. In this case we get:

(36)
$$N(m) = \int_{-\infty}^{+\infty} \frac{d\delta}{\sigma_\delta \sqrt{2\pi}} \cdot e^{-\frac{\delta^2}{2\sigma_\delta^2}} \cdot e^{c_1 r' + c_2} = e^{c_1 m + c_2 + \frac{c_1^2 \sigma_\delta^2}{2}}.$$

The two curves $ln\, \psi(r')$ and $ln\, N(m)$ thus are straight lines parallel with one another. The distance between the two lines along the m-axis, or the r'-axis, has the following value:

(37)
$$r' - m = +\frac{c_1 \sigma_\delta^2}{2} = +\frac{\sigma_\delta^2}{2} \cdot D\left(ln\, N(m)\right).$$

This is exactly half the average correction $-\bar{\delta}_m\left(= -\nu'_1\right)$ that was discussed above.

40. After these discussions concerning the methods to be used, we will make some investigations into the spatial arrangement of the galaxies. Our chief aim has been to study the distribution of the double and multiple systems to be found in the present catalogue. In order to make comparisons possible, we will, however, begin with an investigation of galaxies in general. The material most suitable to be used here is that found in the catalogue by H. Shapley and A. Ames[1] which comprises all galaxies brighter than $13^m\!.0$.

It has already been pointed out that only objects in high galactic latitudes will be taken into consideration. In Table 8 are given the distributions of the apparent magnitudes in the Harvard catalogue mentioned above. Within 30° from the North Galactic Pole, 359 galaxies are to be found, while only 92 are situated within the

[1] Harvard Ann 88, No 2 (1932).

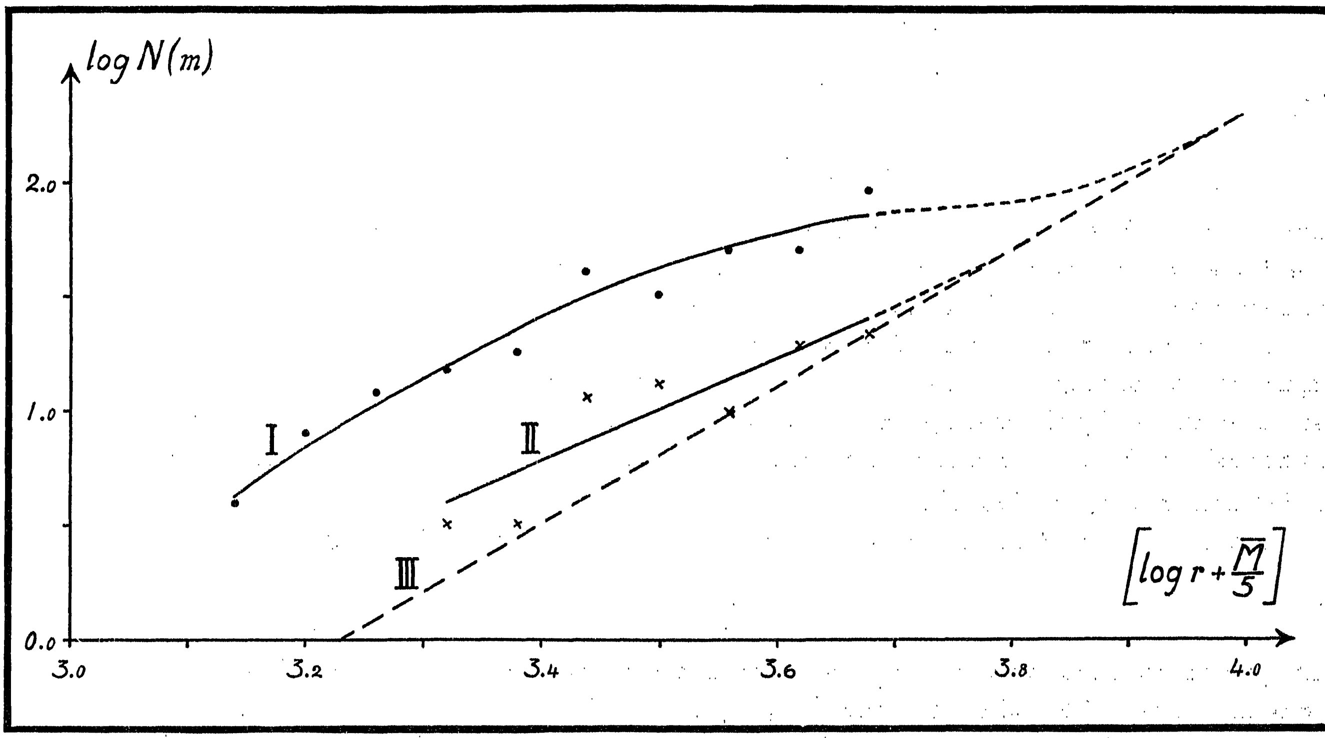


Fig. 20.
Apparent magnitude distributions in the catalogue of SHAPLEY-AMES.

Table 8.

Apparent magnitude distributions in the catalogue by Shapley-Ames.

m	$N(m)$ $b > +60°$	$N(m)$ $b < -60°$
$8^m.9$ — $9^m.1$	2	0
9. 2 — 9. 4	0	0
9. 5 — 9. 7	1	1
9. 8 — 10. 0	1	0
10. 1 — 10. 3	4	0
10. 4 — 10. 6	8	1
10. 7 — 10. 9	12	1
11. 0 — 11. 2	15	3
11. 3 — 11. 5	18	3
11. 6 — 11. 8	40	11
11. 9 — 12. 1	32	13
12. 2 — 12. 4	50	10
12. 5 — 12. 7	51	19
12. 8 — 13. 0	94	22
13. 1 — 13. 3	31	8
Total	359	92

same area of the south hemisphere. In Fig. 20 these distributions have been illustrated. The full curve I refers to the north galactic hemisphere, and the full curve II to the south hemisphere. The dots and the crosses correspond to the individual values. The dotted line III given in the figure will be discussed below.

In the above figure the apparent magnitude has been replaced by $\left(\log r + \frac{\overline{M}}{5}\right)$. This quantity is related in a simple manner to the reduced distance r', which was introduced above:

$$\log r + \frac{\overline{M}}{5} = \frac{r'}{5} + 1. \tag{38}$$

The simple method (formula (37)) discussed above has been used for the transformation of the apparent magnitude m into the reduced distance. The two curves in the figure have thus been considered straight lines. Since the average values of the derivatives $D(ln\, N(m))$ for both curves amount to about $+1.0$, the "correction" to be applied to the magnitudes assumes the value $+0^m.5$.

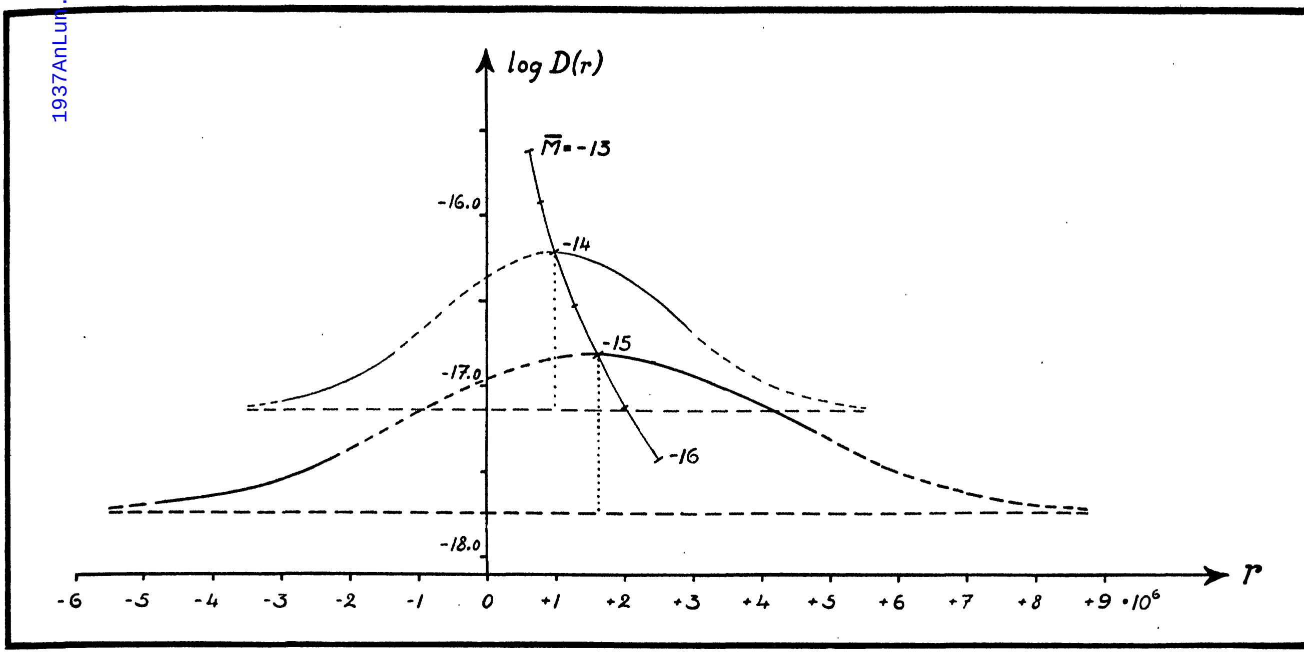


Fig. 21.

Density function for galaxies in general.

Before proceeding further we must call attention to some special effects. The problem is how to treat the groupings and clusters to be found within the areas considered, especially the great Virgo cluster. According to K. LUNDMARK[1] the formation of metagalactic clusters is a gradual process, and the components were once situated in the space outside the cluster. In the distribution chart given in the SHAPLEY-AMES catalogue there is indeed an indication that the areas outside the Virgo cluster are underrepresented as regards the number of galaxies. Since we are here trying to find the average space distribution, and since correct principles of exclusion cannot probably be found, all objects are included in the present investigations. The influence of the Virgo cluster on curve I of Fig. 20 has, however, been investigated here. The general form of the curve is not changed by excluding the cluster members, and the results to be obtained below are still valid.

In Fig. 21, the different values obtained of the density function are illustrated. The distance axis is assumed to be directed towards the North Galactic Pole, and one parsec has been used as unit. The full curves correspond to the full curves in Fig. 20, and the horizontal dotted lines to line III in the same figure. The dependence of the density function on the average absolute magnitude $\overline{M}$ has also been illustrated.

The full curves of Fig. 21, together with the dotted curves, form a very nice normal error curve. Of course, the piece of dotted curve to the right is not, perhaps, quite correctly drawn. The extrapolation here made is founded on the symmetry only, and later on we will show that a different form of the curve must perhaps be considered. Anyhow, the existence of a large metagalactic cloud is suggested. Our own galaxy is situated somewhat apart from the centre of it. The density at the centre may be about eight times the density outside the cloud.

[1] Lund Circ 9 (1934).

The existence of such a cloud has been suggested several times. Thus H. SHAPLEY[1] and E. P. HUBBLE[2] have pointed out that there is an indication not only in the radial velocities but also in the frequency of the apparent magnitudes that the brightest neighbouring galaxies form a local group. This group may constitute the central part of the cloud found above. Further A. DOSE[3] and J. H. OORT[4] have called attention to the fact that the peculiar radial velocities of the galaxies increase with the distance. OORT states that we are possibly situated inside an agglomeration of galaxies, and that it is not unlikely that the peculiar velocities within such a system are smaller than those of galaxies outside it. OORT points out that we can feel the influence of such a cloud down to the 12th or 13th visual magnitude. This is in a good agreement with the results obtained here.

In this connection it should be remarked that the above local cloud is no exceptional case at all in the metagalactic space. Not taking the large number of metagalactic clusters into consideration, we wish to call attention to the large cloud of galaxies found by H. SHAPLEY[5] in his work on the general survey of faint galaxies. In an area between the galactic longitudes 215° and 245° and latitudes — 38° and — 59° there is to be found a sudden increase of the number of galaxies for photographic magnitudes between $15^{m}.5$ and $17^{m}.0$. Here SHAPLEY assumes the existence of a metagalactic cloud at a distance of about $22 \cdot 10^{6}$ parsecs.

41. Before entering upon an investigation of the space distribution of double and multiple galaxies we will to some extent discuss the properties of the metagalactic cloud found above. For this purpose we will at once introduce the rectangular co-ordinates x, y and z. The x-axis may be directed towards the North Galactic Pole. In the following[6] it will be shown that this pole is situated close to the metagalactic equator that results from the investigations of the apparent distribution of the galaxies and of the orientation of the orbital planes of double galaxies. Thus, the x-axis is situated approximately in this metagalactic plane. The z-axis may be directed towards the north metagalactic pole. We now assume that the density function $D(x, y, z)$ can be written in the following way:

$$D(x,y,z)\,dx\,dy\,dz = \frac{N\,dx\,dy\,dz}{\sigma_x\,\sigma_y\,\sigma_z\,(2\pi)^{3/2}} \cdot e^{-\frac{(x-\bar{x})^2}{2\sigma_x^2}-\frac{y^2}{2\sigma_y^2}-\frac{z^2}{2\sigma_z^2}} + D_0\,dx\,dy\,dz. \tag{39}$$

Here D_0 corresponds to the average density outside the cloud. The density function $D(x, y, z)$ has thus been expressed as the sum of a normal distribution and a constant term. According to the formula the centre of the normal distribution shall be situated on the x-axis. Of course we do not know whether the distribution is a normal one or if the centre is to be placed exactly on the x-axis. As, however, we are only trying to get some general results, the above assumptions may be the simplest ones to start from.

If we assume the average absolute magnitude $\bar{M}$ to have the value $-15^{M}.0$, the following numerical values can be obtained from Fig. 21:

$$\bar{x} = +1.6 \cdot 10^{6} \text{ parsecs}$$
$$\sigma_x = 2.1 \cdot 10^{6} \text{ parsecs}$$
$$D_0 = 1.9 \cdot 10^{-18} \text{ parsec}^{-3}.$$

Here we nave put x equal to the distance r given in the figure. As this distance refers to all parts of the solid angle considered, a small approximation is thus introduced.

---

[1] Harvard Repr 61 = Wash Nat Ac Proc 15, p. 565 (1929).
[2] Mt Wilson Contr 548 = ApJ 84, p. 158 (1936).
[3] AN 229, p. 157 (1927).
[4] BAN 6, p. 155 (1931).
[5] Harvard Repr 115 = Wash Nat Ac Proc 21, p. 587 (1935).
[6] See Chapter XI.

If we assume that the three dispersions σ_x, σ_y and σ_z have identical values, we get the following number of objects:

$$N = 2200.$$

The "background" density D_0 causes that within the corresponding volume (a sphere with the radius equal to $3\sigma_x = 3\sigma_y = 3\sigma_z$) we get a number of objects amounting to about 2000. In this manner the total number of galaxies within the cloud should amount to about four thousand. It must be remarked that this result entirely depends on the assumption which was made above concerning the dispersions. It will appear below that the dispersion σ_y is probably smaller than σ_x. Thus the above number may be a maximum number.

In investigating the general absorption within the Galaxy[1] we have started from the apparent distribution of the galaxies along the metagalactic equator. If we start from the expression given in formula (39) we are able to determine how this distribution ought to be if in all galactic latitudes only a small constant absorption corresponding to the galactic poles is taken into consideration. As a limiting distance we assume the distance that corresponds to an apparent magnitude of $13^m\!.0$ at the galactic poles.

The following polar co-ordinates are introduced:

$$\begin{aligned} x &= \varrho \cos B \cos L \\ y &= \varrho \cos B \sin L \\ z &= \varrho \sin B. \end{aligned} \tag{40}$$

Here B is the metagalactic latitude and L the longitude, apart from a constant. In the following computations the average value $\bar{x}$ will be denoted by b and the limiting distance by ϱ'. The dispersions σ_x, σ_y and σ_z are provisionally put equal to 1. If we further introduce a constant C, the following expression is obtained for the correlation function of L and B:

$$\psi(L,B)\,dL\,dB = C\cdot e^{-\frac{b^2}{2}}\cdot \cos B\,dL\,dB\int_0^{\varrho'} d\varrho\cdot\varrho^2\cdot e^{-\frac{1}{2}\left(\varrho^2-2b\varrho\cos L\cos B\right)} + D_0\cos B\,dL\,dB\int_0^{\varrho'} d\varrho\cdot\varrho^2. \tag{41}$$

By solving the above equation numerically and by putting the latitude $B = 0$ we obtain the distribution curve of the longitude L that is given as the dotted curve V in Fig. 32 (Chapter X). Curve III given in this figure has been obtained from the apparent distribution of the galaxies by making certain assumptions concerning the general absorption within the Galaxy. The deviations between the forms of these two curves may be caused by the above assumption concerning the dispersions. If the dispersion σ_y is given a smaller value than the dispersion σ_x, the agreement between the two curves will be better. Thus the local metagalactic cloud may have a flattened or perhaps an elongated shape.

42. We are now going to investigate the spatial arrangement of the double and multiple systems given in the present catalogue. In this case too, we will use the apparent magnitude as a distance indicator. Here the question arises whether the average apparent magnitude of the components within every system should not be used in deriving the distance instead of the individual values of the components. Since, however, we are searching only for the average spatial distribution, the individual magnitude values will be used. In order to

[1] See Chapter X.

Table 9.

Apparent magnitude distribution of objects in the present catalogue.

m	N_1	N_2	N_3
$8^m.9$ — $9^m.1$	1	1	0.6
9.2 — 9.4	0	0	0.0
9.5 — 9.7	0	0	(−0.2)
9.8 — 10.0	2	2	1.8
10.1 — 10.3	2	2	1.6
10.4 — 10.6	2	2	1.3
10.7 — 10.9	6	6	5
11.0 — 11.2	5	5	4
11.3 — 11.5	8	8	7
11.6 — 11.8	5	5	4
11.9 — 12.1	10	10	9
12.2 — 12.4	17	17	16
12.5 — 12.7	18	18	17
12.8 — 13.0	12	13	13
13.1 — 13.3	25	27	27
13.4 — 13.6	34	39	39
13.7 — 13.9	50	59	59
14.0 — 14.2	81	97	97
14.3 — 14.5	105	130	130
14.6 — 14.8	95	131	131
14.9 — 15.1	95	137	137
15.2 — 15.4	108	164	164
15.5 — 15.7	42	68	68
15.8 — 16.0	25	41	41
16.1 — 16.3	4	7	7
16.4 — 16.6	1	2	2
Total	753	991	982

make comparisons with galaxies in general possible it is also of importance to use the same procedure as before. In the preceding chapter it has been pointed out that, on an average, double and multiple galaxies have a larger absolute luminosity than galaxies in general. Since, however, the difference is small, we do not propose to take this effect into consideration.

Of the objects in the present catalogue, however, a certain number are to be excluded. In the first place, we will take only the areas in high galactic latitudes into consideration. Thus the galactic latitude must be larger than + 60°. In the present catalogue the areas situated around the South Galactic Pole are not represented. Further, all components situated too far from the other ones belonging to the same double or multiple system are excluded. Thus the following condition previously discussed[1] should be valid:

$$\frac{\vartheta}{a_1 + a_2} \leq 2.$$

Finally all objects situated at greater distances than three degrees from the centre of the plate used are excluded. Thus only the effective plate areas[2] are used. A computation has shown that these reduced areas cover 79 % of the polar calotte considered. In Table 9 all objects are to be found that correspond to the above conditions. The frequencies are denoted by N_1. In the left column of the table the corrected estimated magnitude is given.

These frequencies, N_1, must be corrected in some respects. First, the limiting magnitude of the plate will cause positive corrections to be added to the frequencies corresponding to faint magnitude values. If, for instance, in a double system one of the components, arbitrarily selected, has a magnitude equal to the limiting magnitude of the plate, the probability that the other component is also to be found on the plate amounts to $^1/_2$. In every second case the first component will not be included, although it is to be found on the plate, since the double nature of the object is not apparent. If a certain galaxy (apparent magnitude = m, absolute magnitude = M) really has a component, the probability w for this component to be brighter than the limiting magnitude, $m + \Delta$, can be written in the following form:

$$w = \int_{-\infty}^{+\infty} dM\, \varphi(M) \cdot Q(M + \Delta). \tag{42}$$

Here $\varphi(M)$ denotes the frequency function of the absolute magnitudes of the galaxies. Further the following relations are valid:

[1] See Chapter II. [2] See Chapter III.

$$\int_{-\infty}^{+\infty} dM\,\varphi(M) = 1 \qquad\qquad Q(M) = \int_{-\infty}^{M} dM\,\varphi(M).$$

Thus we assume the absolute magnitudes of the two components not to be correlated.

Assuming the absolute magnitudes to be normally distributed with a dispersion of $1^{M}.0$ we are able to compute the above probability w as a function of the magnitude difference $\Delta = (m_l - m)$. In Table 10 this relation is given. In the computation of the frequencies every galaxy should be given a weight of $1/w$. The frequencies thus corrected are given in Table 9 as N_2.

Table 10.

The weights 1/w to be applied to the frequencies.

$(m_l - m)$	$1/w$
$0^{m}.0$	2,0
0. 1	1,9
0. 2	1,8
0. 3	1,7
0. 4	1,6
0. 5	1,6
0. 6	1,5
0. 7	1,4
0. 9	1,4
1. 0	1,3
1. 2	1,3
1. 3	1,2
1. 6	1,2
1. 7	1,1
2. 3	1,1
2. 4	1,0

The frequency numbers that correspond to bright objects are small, and a correction depending on the existence of optical systems may here be of some importance. In accordance with some derivations previously made[1] the probability, $W_{0,\vartheta}$, that a certain galaxy has an optical component within a distance ϑ can be expressed in the following way:

$$W_{0,\vartheta} = \int_0^{\vartheta} W_{\vartheta,(\vartheta+d\vartheta)} = -\int_0^{\vartheta} d\left(\cos^{2n}\vartheta/_2\right) = 1 - \cos^{2n}\vartheta/_2. \tag{43}$$

Here n denotes the total number of objects spread out over the sky. In accordance with the definition of a double galaxy used in the present paper the value of ϑ may be put equal to $2(a+0'.5)$. Here a denotes the apparent major diameter of the bright galaxy in question, and the value $0'.5$ corresponds approximately to the diameter of the component, which is generally a comparatively faint object. In comparison with the value of a, the latter value is, however, small and consequently of no great importance.

Table 11.

Average diameter values in different magnitude classes.

m	$\bar{a}$
$9^{m}.0$ — $9^{m}.9$	7'.6
10. 0 — 10. 9	8. 1
11. 0 — 11. 9	4. 0
12. 0 — 12. 9	1. 9

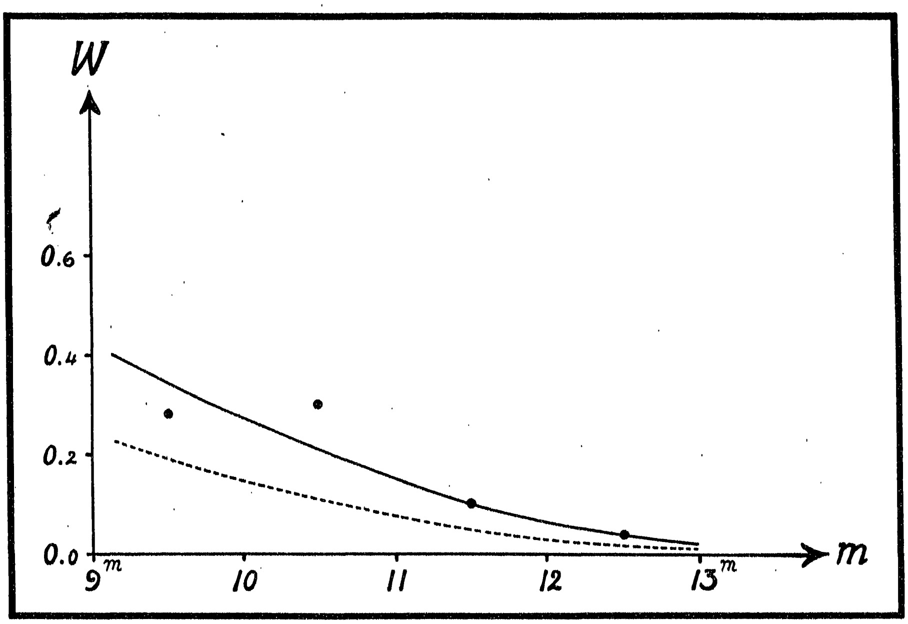


Fig. 22.

Probability for the existence of an optical pair.

[1] See Chapter II.

By using the average diameters $\bar{a}$ that correspond to different magnitude classes we are able to compute the probability, W, for the existence of an optical system, as a function of the apparent magnitude of the brightest component. Of course this procedure can be used only for the bright magnitude classes. On the other hand, the corrections required are of importance in these classes, only. In Table 11 the average diameter values computed by means of the present material have been given for different magnitude classes. Fig. 22 illustrates the final connection between the probability W and the apparent magnitude. Here the dots represent the individual values obtained by means of Table 11 and formula (43), and the full curve represents the smoothed relation. This curve is founded on the same value of the number n as was used in Chapter II of the present paper. There the optical systems were discussed from another point of view, and it was considered appropriate to give the number n the value of 60000. It was, however, pointed out that this value must be regarded as a maximum value. In the present case we should prefer not to use too large a value so as to avoid an overcorrection of the class frequencies given in Table 9. The dotted curve in Fig. 22 corresponds to a value of n equal to 30000, and this curve will be used in the present case. If, for instance, we use the density curve III in Fig. 24, which will be discussed below, we shall find, that the number of galaxies brighter than $14^{\mathrm{m}}_{\cdot}6$ approximately amounts to the value assumed above.

Now the frequencies given in Table 9 can be corrected for the presence of optical systems. Thus every frequency is to be diminished by the probability W multiplied with the total number of galaxies contained in the magnitude class considered. This total number can be obtained from Table 8. In this manner the frequencies N_2 given in Table 9 are transformed into the final frequencies N_3. It should be remarked that only 0.9 per cent of the total number of galaxies are excluded by this procedure.

By means of the definitive frequencies N_3 we can arrive at certain conclusions concerning the completeness of the present material. As regards the apparent magnitudes the catalogue seems to be complete down to about $14^{\mathrm{m}}_{\cdot}5$. The corrected distribution of the apparent magnitudes is to be seen in Fig. 23. Here the quantity $\left(\log r + \frac{\overline{M}}{5}\right)$ has been introduced as abscissa in the same manner as in Fig. 20. The part of the curve that corresponds to $m > 13^{\mathrm{m}}_{\cdot}0$ can be considered a straight line, and the "correction" to be applied to the apparent magnitudes in order to obtain the reduced distances gets the value of $+\,0^{\mathrm{m}}_{\cdot}7$. Concerning the part of the distribution curve that corresponds to the bright magnitudes ($m \leq 13^{\mathrm{m}}_{\cdot}0$) a "correction" of $+\,0^{\mathrm{m}}_{\cdot}3$ has been used. This manner of dividing the distribution into two parts before applying the corrections is, of course, not quite correct, but the errors involved are sure to be small.

The corresponding density function is given in Fig. 24 in the full curve I. This curve corresponds to an average absolute magnitude of the galaxies of $-\,15^{\mathrm{M}}_{\cdot}0$. The full curves II correspond to the density curves given in Fig. 21, hence they are valid for galaxies in general.

The deviations between the two density curves I and II are of very great interest. Further on in this paper[1] the formation of double and multiple galaxies will be discussed. By means of some theoretical derivations based on the principles of statistical mechanics we will obtain a relation between the density function of double and multiple galaxies and the same function of galaxies in general. It will be shown that this theoretical relation agrees very well with the observational facts given here.

However, according to these theoretical deductions, we obtain, in Fig. 24, the dotted curve III as a con-

[1] See Chapter XII.

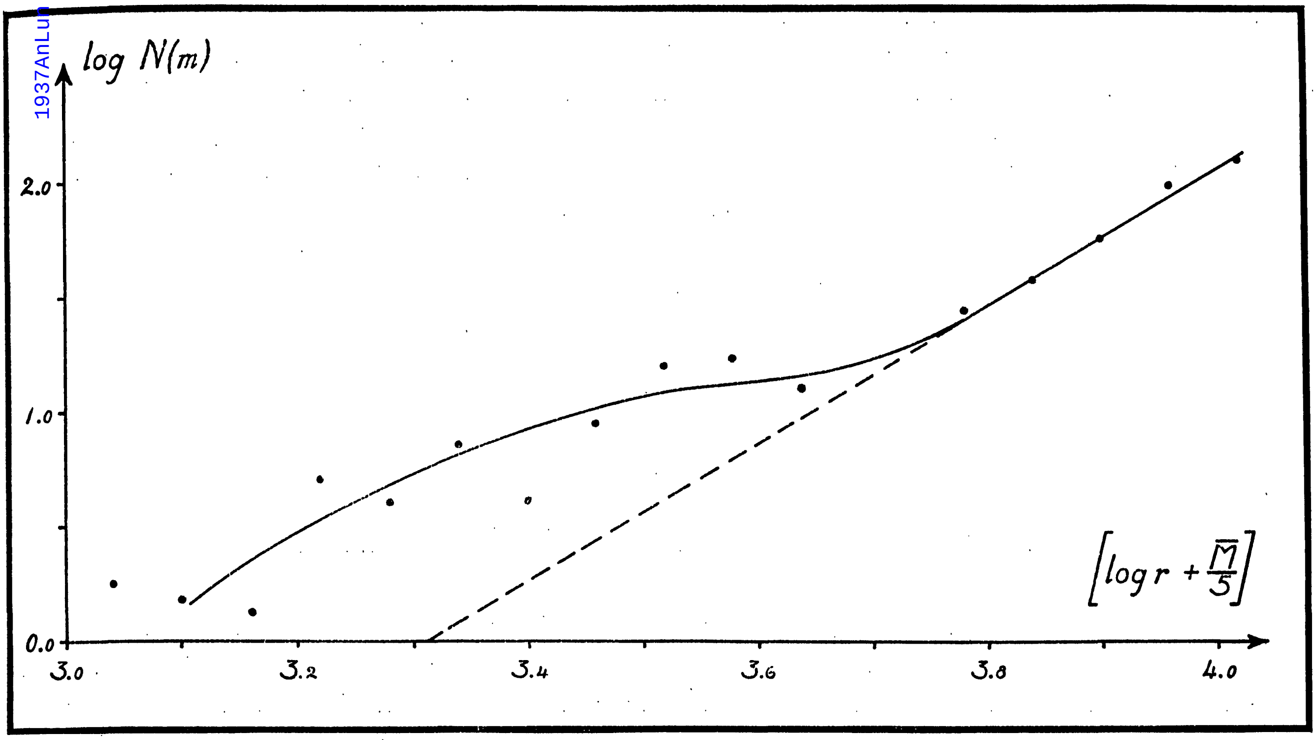


Fig. 23.

Apparent magnitude distribution in the present catalogue.

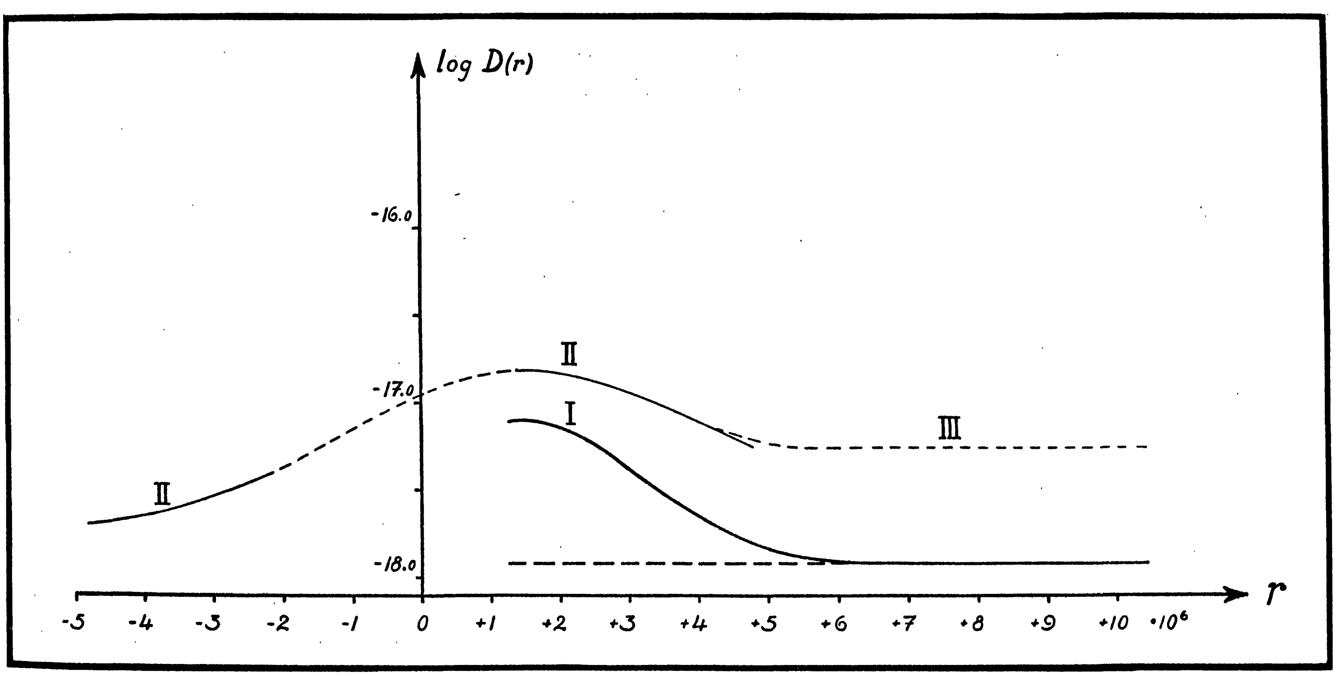


Fig. 24.

Density function for double and multiple galaxies.

tinuation of curve II. This implies that we have here a larger number of galaxies than has been assumed above in the discussion of the local metagalactic cloud. Before we can obtain any reliable results in this respect we must, however, await the accumulation of accurate observational data. Anyhow, the space distribution of double and multiple galaxies indicates the existence of a local cloud, where the maximum density is to be found at about the same place as it is for galaxies in general. Concerning bright galaxies we can draw the conclusion from Fig. 24 that every second galaxy is a component of a double or multiple system. As regards faint objects the relative number of single galaxies increases. If we start from density curve III we find that 22 per cent of all galaxies fainter than $13^{m}.0$ are members of double or multiple systems.

CHAPTER IX

TYPES AND FORMS OF THE GALAXIES

43. In the present chapter some investigations will be made into the classification of anagalactic objects. The dependence of the apparent types on the distances of the objects and on the quality of the plates used will be discussed. Some remarks will be made concerning the relation between the apparent and the absolute appearance of a galaxy, and further some attempts will be made to solve the problem of the absolute forms and the orientation in space of the anagalactic objects.

The planetary nebulae and the galaxies have been divided by MAX WOLF into 23 different types according to their apparent structure or appearance. In a previous chapter[1] we have given an account of the use made of this system of classification in the present catalogue. It was also pointed out that in the extensive catalogue by KARL REINMUTH[2], 'Die Herschel-Nebel', WOLF's classification has been exclusively used. We will here make some comparisons between the above two catalogues, and it will be shown that even by using this simple method we are able to draw some important conclusions regarding the stability of the classifications. It has been pointed out already that the two catalogues are generally based on plates taken with the same instrument.

It may be remarked that investigations of this kind have been made earlier. Thus K. LUNDMARK[3] has made a comparison between the classification made by him on Crossley plates and the classification made by REINMUTH in the above catalogue. LUNDMARK states that the comparison diagram resembles a RUSSELL diagram, for on the Crossley plates the spiral structure is often more plainly shown than is the case on the Heidelberg plates. Further, H. SHAPLEY and A. AMES[4] have compared HUBBLE's and CURTIS' classification with REINMUTH's.

In Table 12 the objects common to REINMUTH's catalogue and to the present one are compared as regards the type values. The arrangement is the same as in an ordinary correlation table, and further explanations of the notations are perhaps not necessary. The total number of objects amounts to 359.

A large number of galaxies are not included in the table. In the first place all those objects have been omitted from the present catalogue that are situated at distances of more than three degrees from the centre

[1] See Chapter IV. [2] Heidelberg Veröff, Band 9 (1926). [3] Upsala Medd 30 (1927). [4] Harvard Ann 88, No 2 (1932).

Table 12.

A comparison between Reinmuth's and Holmberg's classification.

Holmberg \ Reinmuth	d	d−h$_o$	h$_o$	e−h$_o$	e	f	g	h−h$_o$	h	i, k	o	p	q	r	s	t	u	v	w	Total
d	3		1		48	34	12							1					1	100
d−h$_o$			1		4	1	3		3						2			2		16
h$_o$			4				2		4		1	1	4	1	3					20
e−h$_o$					3	1	3													7
e					7	45	19		1										1	73
f						4	7											1	4	16
g					2	1	30		1					4	7	1		2	3	51
h−h$_o$									4											4
h					1	2	3		15					1	3			2		27
i, k														1						1
o											1									1
p												4								4
q													2							2
r														9					4	13
s															9	1				10
t																				
u																				
v																		6		6
w																			8	8
Total	3		6		65	88	79		28		2	5	6	17	24	2		13	21	359

of the plate used for their classification. Thus only the reduced plate areas have been taken into consideration. Further, those objects in the two catalogues have been excluded, the type values of which are given with a note of interrogation, or where the classification has been denoted by two letters not corresponding to the denotations used in the table. In this way 127 galaxies have been excluded.

In the above table several large deviations occur, and these are distributed in such a way that the general appearance of the table recalls that of a Russell diagram. Reinmuth's type values are generally more advanced than those given in the present catalogue. Such deviations are to be expected, since Reinmuth's catalogue is intended to give as good a description as possible of the galaxies considered, while the present catalogue has the character of a general survey. In the former case those plates that are most suitable for the objects in question have been selected, whereas in the present investigation the leading principle has been to cover the sky with plates as completely as possible.

We can thus draw the general conclusion that the type observed is dependent on the limiting magnitude and the quality of the plate used. As, however, all those objects of the present catalogue have been excluded that are situated at distances from the centre of the plate of more than three degrees, and since the quality of the images within the remaining central area is generally good, the limiting magnitude of the plate may have the greatest influence on the apparent type of an object.

9—37522.

The influence of the limiting magnitude of the plate can, however, very well be compared with a distance effect. On account of instrumental effects and the influences of bad seeing and of possible metagalactic absorption the measurable dimensions and the surface blackening of an object appearing on the plate will be dependent on its distance. Consequently, by means of the table, we can probably draw the conclusion that if a galaxy of an advanced type, e. g. $q, r \cdots w$, is placed at a greater distance, the apparent type will change into a simpler one, as for instance f, g, h and h_0. The transformation may be due to a fading away of the outer parts of the galaxy, where the surface brightness is faint, and to a confusion of the structural details within the object. The former procedure, however, seems to be the most important one. Thus the transformation of type v into types h, g, f and $d - h_0$, which is illustrated in the table, must imply a fading away of the faint spiral arms. The transformation of types e, f and g into type d can also be used as an illustration of this effect. With regard to the confusion of the structural details it should be noted that, according to M. WOLF[1], galaxies of type f are, in reality, nearly always spirals.

44. Some other effects may also be investigated here as an illustration of the above discussions. First, there is a very marked dependence of the types of the galaxies on their apparent magnitudes and apparent diameters. This effect is a very well known one, and we beg to refer to K. LUNDMARK[2], 'Studies of anagalactic nebulae'. Further, the concentration and the ratio of apparent major and minor axis are highly correlated with the distance of the object. These connections, as regards the objects of the present catalogue, have been illustrated in Tables 13 and 14. The corrected estimated magnitude has been used as a distance indicator. The material has been divided into magnitude classes with a class breadth amounting to $0^m.5$. In the columns of the tables only the class centres are given. In the faint magnitude classes the crowding of the concentration value zero and of round objects is very striking. This probably implies that only the nuclei of these remote objects appear on the plate.

From an investigation of REINMUTH's catalogue mentioned above LUNDMARK[2] has obtained similar results concerning the ratio of the diameters. He draws the conclusion from this that these small, round objects are mere nuclei of larger systems, and he points out that all small objects should be excluded in statistical works on the orientation in space of the galaxies.

45. From the above discussions it is clear that, just like the apparent magnitude and the apparent diameter, the apparent type is dependent on the distance of the galaxy and on the limiting magnitude of the plate used. Several other effects are, however, to be taken into consideration too. Thus the apparent type may depend on the inclination of the object towards the line of sight and on the focal length of the instrument used. The different effects to be taken into account may as a first approximation be summed up into the following equation:

$$\tau = f(F, S, \beta, r, d, m_l). \tag{44}$$

Here the following denotations are used:

τ = the apparent type
$\left.\begin{array}{l} F = \text{the absolute form} \\ S = \text{the absolute structure} \end{array}\right\} = \text{the absolute type } T$
β = the inclination of the object towards the line of sight

[1] Heidelberg Veröff, Band 8, No 11 (1928). [2] Upsala Medd 30 (1927).

Table 13.

Dependence of concentration on apparent magnitude.

c \ m	9^m5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16^m5
0				1		4	13	17	67	109	202	269	169	32	2
0.5				1	5	4	10	20	37	70	95	76	26	2	
1	1		1	1	3	11	16	20	41	66	71	37	17		
2				1	3	6	6	3	8	11	13	6			
3		1	1		1	2		2	6	7	6	3		1	
4			2	1		2	5	3	1	7	3	2		1	
5					1	1	2	1	4	5	1	1			
6		1	1	1				1	2	5	1				
7					1					1					
8			1	2		2	2		2	1	1				
9						2				1					
10				3	2	1	1		1		1				
11							1	1	1						
12															
13							1	1		1	1				
14															
15															
16															
17															
18				2	1	1			2						

Table 14.

Dependence of the ratio of apparent major and minor axis on apparent magnitude.

b/a \ m	9^m5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16^m5
0.00–0.10			1		1	2	1	1							
0.11–0.20				2	2	4	8	9	16	21	12	6	4	2	
0.21–0.30				4	3	4	4	12	16	28	30	25	3		
0.31–0.40		1		1	1	3	5	8	25	33	27	24	17	5	1
0.41–0.50		2	1	1	6	4	9	8	11	26	43	42	11	3	
0.51–0.60				2	2	2	3	3	12	17	23	10	7	1	
0.61–0.70					2	5	10	5	14	19	26	20	12		
0.71–0.80	1		1	3		3	3	1	11	20	20	13	6	1	
0.81–0.90							4	1	3	2	2	1		1	
0.91–1.00			3	1	2	9	10	21	66	119	215	250	153	23	1

r = the distance of the object
d = the focal length of the instrument used
m_l = the limiting magnitude of the plate.

Thus the apparent type must be considered as a rather complicated function of the absolute type introduced above.

In the present paper we will make some investigations into the equation given above. Thus the absolute form and the inclination of the spirals towards the line of sight will be discussed in the present chapter. In the next chapter the absorption phenomena within anagalactic objects will be investigated, and in this way the absolute structure has also been taken into consideration to a certain degree.

46. The orientation in space of the galaxies in relation to the line of sight has earlier been the subject of some investigations. Thus J. H. REYNOLDS[1] has discussed the orientation of the planes of the spirals. The results obtained suggest that there is an excess of spirals seen edgewise. Later on E. ÖPIK[2] has tried to explain this excess by pointing out that the spirals, if seen edgewise, have a greater surface magnitude than if observed at great angles. On account of this too large a number of objects with small inclinations to the line of sight will be found in any given material. Further, E. P. HUBBLE[3] has made an investigation of the absolute forms of elliptical galaxies. Assuming a random orientation in space of the objects he was able to derive the distribution of the actual ellipticities.

Here it may also be remarked that some investigations have been made into the problem whether, on an average, the spiral planes are parallel to a certain fundamental plane or not. Thus H. KNOX SHAW[4], B. MEYERMANN[5], C. C. L. GREGORY[6] and K. LUNDMARK[7] have discussed this problem. No definite results have been obtained. In the following pages we do not propose to take effects of this kind into consideration. In any case the deviations from a random distribution of the inclinations towards the line of sight must be small, if all areas of the sky are taken together.

Above we have denoted the inclination of an object by β. This is the angle between the principal plane of the galaxy and the line of sight, or the latitude of our galaxy for an observer situated at the centre of the object in question. By making some assumptions concerning the absolute form of the anagalactic objects we are able to compute this inclination by means of the observed ratio of apparent major and minor diameter. In the following discussions only spirals will be taken into consideration, and in this case an oblate spheroid may be the simplest model to start from.

If the axes of this spheroid are denoted by A and kA ($k < 1$), and if the observed major and minor diameters of the galaxy are denoted by a and b respectively, we can derive the following simple relation:

(45) $$\sin^2\beta = \frac{\left(\frac{b}{a}\right)^2 - k^2}{1 - k^2}.$$

Thus we here obtain a relation between the inclination and the observed ratio b/a by introducing the absolute flattening k. It may be remarked that, in the paper mentioned above, HUBBLE has given an equation of the same significance.

[1] MN 81, p. 129 (1920) and MN 82, p. 510 (1922). [2] Obs 46, p. 51 (1923).
[3] Mt Wilson Contr 324 = ApJ 64, p. 321 (1926). [4] MN 69, p. 72 (1908). [5] AN 219, p. 131 (1923).
[6] MN 84, p. 456 (1924). [7] Upsala Medd 30 (1927).

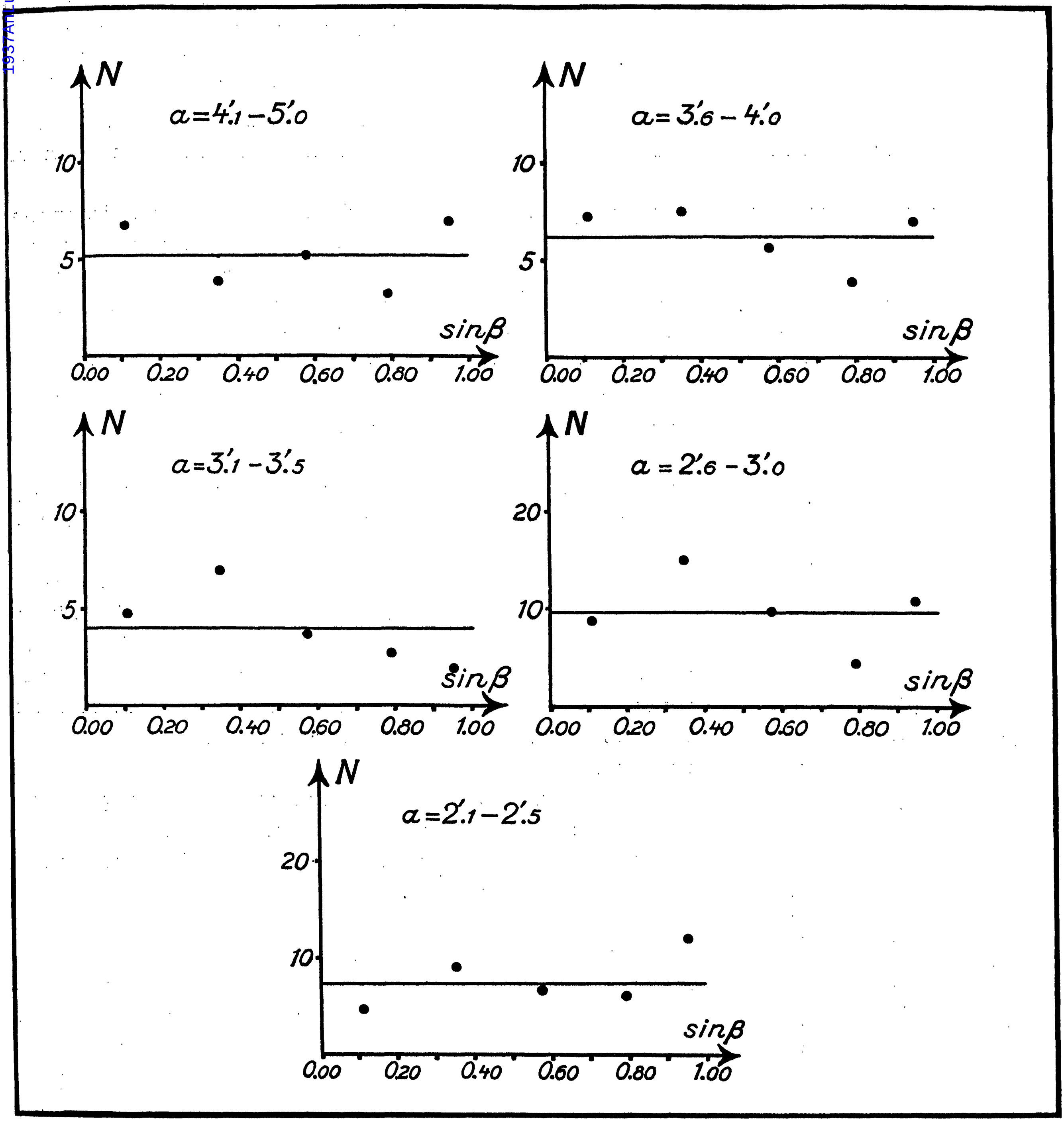


Fig. 25.

Orientation in space of the spirals.

We are going to use below the formula (45), and by assuming the spirals to have a random orientation as regards the inclination towards the line of sight we will try to get an average value of the flattening k. In this connection it is, of course, of very great importance that the observed diameter ratio b/a is free from systematic errors. The errors must not be dependent on the inclination. Since spirals, if seen edgewise, have a brighter surface magnitude than objects at right angles to the line of sight, such dependence is, however, to be expected. In order to eliminate this error we will exclusively use apparent bright and large objects in this investigation.

In order that the above assumption regarding a random orientation should be justified, it is of very great importance that the material used is homogeneous. The galaxies must not be selected according to such apparent properties as are correlated with the inclination of the objects. Thus the apparent magnitude must not be used. In the following chapter it will be shown that the observed magnitude of an object is dependent on the inclination in such a way that an edgewise orientation corresponds to a fainter apparent brightness.

In the present investigation it has been considered most appropriate to select the spirals according to their apparent major diameters. Only apparently large objects have been taken into consideration and thus it can be expected that the systematic errors in the observed diameter values are small and that the selected objects represent a homogeneous material.

The material used here has been taken from the Harvard survey[1] of bright galaxies. The diameter values given in this catalogue have been compiled from various sources, it is true, yet the values given for the large spirals may be comparatively accurate. The results obtained appear in Fig. 25. Here the spirals have been divided into five different classes according to the major diameter a. The values of the inclination β have been computed on the assumption that the absolute flattening k equals 0.20. In this computation Table 15 has been used. The class frequencies N have been reduced to a class breadth, $\Delta \sin \beta$, equal to 0.10.

Table 15.

Relation between diameter ratio and inclination.

b/a	$\sin \beta$	β
0.20	0.00	0°
0.25	0.15	9
0.30	0.23	13
0.35	0.29	17
0.40	0.35	21
0.45	0.41	24
0.50	0.47	28
0.55	0.52	32
0.60	0.58	35
0.65	0.63	39
0.70	0.68	43
0.75	0.74	48
0.80	0.79	52
0.85	0.84	57
0.90	0.90	64
0.95	0.95	71
1.00	1.00	90

If the average value assumed of the absolute flattening is correct and if we assume a random orientation of the spiral planes, the class frequencies will be independent of the value of $\sin \beta$. This seems actually to be the case. Of course, many deviations from the straight horizontal lines drawn in the figure are to be found. Thus the number of objects that corresponds to $\sin \beta = 0.35$ is generally too large. This depends on the diameter ratio $b/a = 1/3$, which is too numerously represented in the material. In the same manner many objects with a diameter ratio equal to 0.8 and 0.9 have probably been classified as round ones.

If we do not take the above small deviations depending on observational errors into consideration, we may thus conclude that a random distribution of the spiral planes is obtained if we assume the spirals to have the form of an oblate spheroid, where the ratio of major and minor axis equals 0.20.

[1] Harvard Ann 88, No 2 (1932).

CHAPTER X

THE EXISTENCE OF DARK MATTER IN THE GALAXIES

47. In the present chapter we are going to take into consideration the general absorption effects to be found within the anagalactic spirals and within our own galactic system. The knowledge of these effects is of very great importance in the determination of the absolute properties of the galaxies and in the discussions of their arrangement in space.

In our own stellar system the occurrence of non-luminous occulting matter has been the subject of a great number of investigations. Especially the general absorption produced by the dark matter has in many respects been discussed. For the solution of the problems considered here it may be of importance to compare the Galaxy with the anagalactic spirals. By using these objects we are able to study the absorption phenomena from other points of view.

M. Wolf[1] was probably the first to suggest that there is an analogy between the dark nebulae to be found in the Milky Way structure and the dark markings in the anagalactic spirals. In an extensive paper H. D. Curtis[2] has discussed the apparent distribution of the dark matter within anagalactic objects. Many reproductions are given in this paper, showing the absorption effects produced by the occulting material. The occurrence of dark bands in edgewise spirals seems to be a very common phenomenon. In some cases the dark matter is probably distributed in rings lying in the principal plane of the spirals.

In several papers K. Lundmark[3] has called attention to the occurrence of dark nebulae in anagalactic objects. It has been shown that these nebulae have probably the same absolute dimensions as the corresponding objects in the galactic system. Thus the absorption effects within the spirals can be compared with the corresponding galactic absorption effects.

Several other investigations have been made into the absorption effects considered here. Some of them will be discussed below. The results obtained indicate that the Galaxy and the anagalactic spirals can very well be compared, not only regarding the distribution of light within them, but also regarding the distribution of dark matter.

48. We will first take the absorption phenomena within the anagalactic spirals into consideration. The dark material in the spirals proves its existence not only in the structural appearance of the objects but also in other observational facts. Thus the dark matter will cause the spirals, if seen edgewise, to be fainter than those situated at great angles to the line of sight. Further, the absorption phenomena will be dependent on the absolute dimensions of the objects if we assume the galaxies to be expanding or contracting. The above effects and some other problems, too, will to some extent be discussed in the following pages.

In order to make the above problems solvable we must start from certain assumptions concerning the distribution of bright and dark matter within the spirals. As regards the distribution of light, a normal frequency function may be the simplest expression to start from:

$$\varphi(x, y, z)\, dx\, dy\, dz = \frac{dx\, dy\, dz}{\sigma_1\, \sigma_2\, \sigma_3\, (2\,\pi)^{3/2}} \cdot e^{-\frac{x^2}{2\sigma_1^2} - \frac{y^2}{2\sigma_2^2} - \frac{z^2}{2\sigma_3^2}}. \tag{46}$$

[1] AN 190, p. 229 (1912). [2] Lick Publ XIII, Part II (1918). [3] See e. g. PASP 33, p. 324 (1921) and Upsala Medd 12 (1926).

Here x, y and z are the rectangular co-ordinates measured from the centre of the object, and the xy-plane is assumed to coincide with the principal plane of the spiral. The dispersions in x, y and z are denoted by σ_1, σ_2 and σ_3 respectively. The total light of the object has been put equal to unity.

Regarding the above assumption, some remarks will be given. In the preceding chapter it was shown that the shape of a spiral can be represented by an oblate spheroid. This observational fact can be represented by the formula (46) by putting the dispersion σ_1 equal to σ_2. Many times small and bright nuclei are to be found in the spirals. These nuclei cannot, of course, be represented by the above simple formula. The relative brightness of the central parts of a spiral is, however, generally in good agreement with a normal distribution of the light. Thus, according to formula (46), about four ninths of the total light is to be found within a central ellipse with axes equal to $2\,\sigma_1$ and $2\,\sigma_2$, if the object is observed from a distant point on the z-axis. Very frequently this is approximately in accordance with observed facts. If we assume that in a given spiral the outermost parts that can be recorded are situated at a distance from the centre of 2.5 times the corresponding dispersion, we shall in the above case obtain a value of the concentration of light[1] equal to about 4. If we investigate the spirals found in the present catalogue, we find an average value of the observed concentrations amounting to 3.9. It is, however, to be remarked that the absorption effects are included in these concentration values.

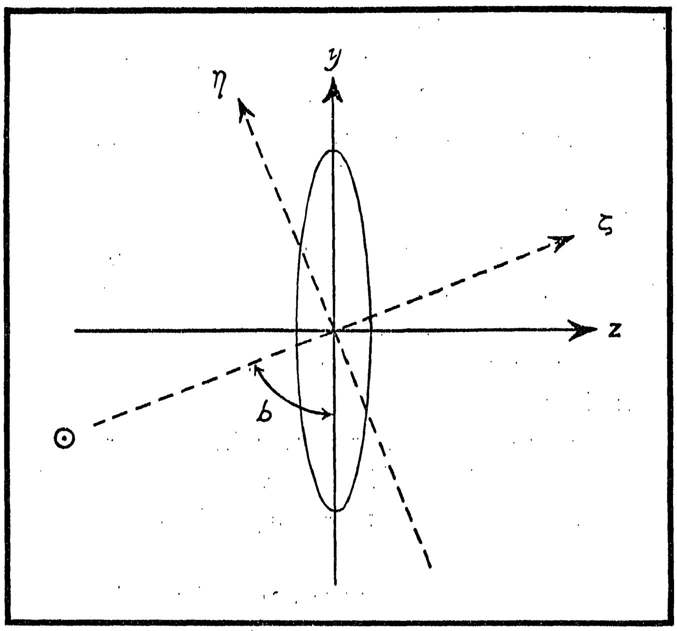


Fig. 26.
The co-ordinate systems introduced.

The distribution function of the absorbing matter will be denoted by $\psi\,(x,\, y,\, z)$. Here x, y and z are the same rectangular co-ordinates as the ones used above. The function $\psi\,(x,\, y,\, z)$ represents the optical density at the point x, y, z. This density is defined as the relative loss of light per unit of length for light passing the point in question.

At this point we need another system of co-ordinates ξ, η, ς. In accordance with Fig. 26 the negative ς-axis is directed towards the sun, while the ξ-axis is assumed to coincide with the x-axis. Thus the x-axis must be situated in the celestial plane, and this can be attained, if we assume the spiral to have the shape of an oblate spheroid ($\sigma_1 = \sigma_2$). The angle between the ς-axis and the y-axis is denoted by b. It is the latitude of the sun for an observer situated at the centre of the system in question.

Now the function $\psi\,(x,\, y,\, z)$ may be replaced by the function $f\,(\xi,\, \eta,\, \varsigma)$:

$$\psi\,(x, y, z) \rightarrow f\,(\xi, \eta, \varsigma). \tag{47}$$

[1] See Chapter IV.

Before entering upon further discussions of the above functions, we will draw some general conclusions regarding the influences of the absorbing matter.

49. A quantity of light $\varphi(x', y', z')\, dx\, dy\, dz$ emitted from an element of volume $dz\, dy\, dz$ situated at point x', y', z' (corresponding to ξ', η', ς') will be considered. On its way to the observer, the light has reached the point x, y, z (corresponding to $\xi = \xi', \eta = \eta', \varsigma$), and by absorption the original quantity has been reduced to $\varphi_\varsigma(x', y', z')\, dx\, dy\, dz$. In the passage through an absorbing layer $d\varsigma$ at this point the following absorption takes place:

$$d\left(\varphi_\varsigma(x', y', z')\, dx\, dy\, dz\right) = f(\xi, \eta, \varsigma)\, d\varsigma \cdot \varphi_\varsigma(x', y', z')\, dx\, dy\, dz. \tag{48}$$

By integrating this expression from $\varsigma = -\infty$ to $\varsigma = \varsigma'$ we obtain:

$$ln\left(\varphi_{-\infty}(x', y', z')\, dx\, dy\, dz\right) = ln\left(\varphi(x', y', z')\, dz\, dy\, dz\right) - \int_{-\infty}^{\varsigma'} f(\xi, \eta, \varsigma)\, d\varsigma. \tag{49}$$

Here ln denotes the natural logarithm. If we want the above loss of light expressed in magnitude classes, the following relation can be derived:

$$dm = 1.09 \int_{-\infty}^{\varsigma'} f(\xi, \eta, \varsigma)\, d\varsigma. \tag{50}$$

Starting from the expression given above, we are able to derive the absorption effects which appear to an observer situated at the centre of the system in question and observing objects outside it. For the absorption Δm as regards the observed magnitudes of these outside objects we find the following expression:

$$\Delta m = 1.09 \int_{-\infty}^{0} f(0, 0, \varsigma)\, d\varsigma. \tag{51}$$

Further the total brightness of the above system, if observed from a distant point on the negative ς-axis, can be related to its real brightness (absorption not considered) by means of the following integral equation:

$$\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \varphi_{-\infty}(x, y, z)\, dx\, dy\, dz = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \varphi(x, y, z)\, dx\, dy\, dz \cdot e^{-\int_{-\infty}^{\varsigma} f(\xi, \eta, \varsigma)\, d\varsigma}. \tag{52}$$

50. We will now pass on to discuss the form to be adopted for the distribution function $\psi(x, y, z)$. In general we do not know very much about the distribution of the dark matter in the spirals. There are, however, some observational facts to be mentioned in addition to those given at the beginning of this chapter. Thus W. E. Bernheimer[1] has investigated the occurrence and distribution of dark matter in the great spiral M 33. Altogether more than four hundred objects, which are presumably absorbing nebulae, have been studied. Several indications are here given that the general distribution of dark and bright matter is similar in nature. Further, we will call attention to the results which can be obtained from our own galactic system. Here the dark matter seems to be concentrated towards the principal plane in about the same way as the stars themselves.

[1] Kungl. Fysiografiska Sällskapets i Lund Förhandlingar I, No 5 (1931).

10—37522.

In anagalactic spirals seen edgewise, there generally appears a band of dark matter. Here we have a possibility of determining the relative thickness of the absorbing layer. Sometimes, however, the occulting matter is probably concentrated in rings lying in the principal plane of the object. Of course, these rings may cause different absorption effects from those produced by an evenly distributed absorbing layer. Here we do not intend to take these peculiar effects into consideration. In order to make possible a simple treatment of the absorption problems we may, for the above rings, introduce the term *effective thickness*, i. e. the thickness of an absorbing layer having the same general absorption effects on the total brightness of the object as the rings.

Following the above discussions we will try to start from a normal distribution of the absorbing matter:

$$\psi(x, y, z)\, dx\, dy\, dz = \frac{r\, dx\, dy\, dz}{k_1 \sigma_1 k_2 \sigma_2 k_3 \sigma_3 (2\pi)^{3/2}} \cdot e^{-\frac{x^2}{2k_1^2\sigma_1^2} - \frac{y^2}{2k_2^2\sigma_2^2} - \frac{z^2}{2k_3^2\sigma_3^2}}. \tag{53}$$

Here the dispersions are denoted by $k_1 \sigma_1$, $k_2 \sigma_2$ and $k_3 \sigma_3$. In general, we may assume the constants k_1, k_2 and k_3 to be smaller than unity. A constant, r, proportional to the optical density at the centre of the system, has been introduced.

In order to transform the above function into the function $f(\xi, \eta, \varsigma)$, the following denotations will be employed:

$$\begin{aligned} p &= \frac{\cos^2 b}{2k_2^2\sigma_2^2} + \frac{\sin^2 b}{2k_3^2\sigma_3^3} \\ q &= \frac{\sin b \cos b}{2k_2^2\sigma_2^2} - \frac{\sin b \cos b}{2k_3^2\sigma_3^2} \\ s &= \frac{\sin^2 b}{2k_2^2\sigma_2^2} + \frac{\cos^2 b}{2k_3^2\sigma_3^2}. \end{aligned} \tag{54}$$

If we start from formula (53), the function $f(\xi, \eta, \varsigma)$ can now be expressed in the following way:

$$f(\xi, \eta, \varsigma) = \frac{r}{k_1 \sigma_1 k_2 \sigma_2 k_3 \sigma_3 (2\pi)^{3/2}} \cdot e^{-\frac{\xi^2}{2k_1^2\sigma_1^2} - \eta^2\left(s - \frac{q^2}{p}\right) - p\left(\varsigma + \eta\frac{q}{p}\right)^2}. \tag{55}$$

By introducing the above formula (55) into formula (51), the following value of the absorption Δm is obtained:

$$\Delta m = \frac{0.061\, r}{\sqrt{p}\, k_1 \sigma_1 k_2 \sigma_2 k_3 \sigma_3}. \tag{56}$$

If we introduce formula (55) into formula (52), the observed total brightness of the galaxy obtains the following value:

$$\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \varphi_{-\infty}(x, y, z)\, dx\, dy\, dz = \tag{57}$$

$$= \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \frac{dx\, dy\, dz}{\sigma_1 \sigma_2 \sigma_3 (2\pi)^{3/2}} \cdot e^{-\frac{x^2}{2\sigma_1^2} - \frac{y^2}{2\sigma_2^2} - \frac{z^2}{2\sigma_3^2} - \frac{\frac{r}{\sqrt{2p}} Q\left(\sqrt{2p}\left(\varsigma + \eta \cdot \frac{q}{p}\right)\right)}{k_1 \sigma_1 k_2 \sigma_2 k_3 \sigma_3 2\pi} \cdot e^{-\frac{\xi^2}{2k_1^2\sigma_1^2} - \eta^2\left(s - \frac{q^2}{p}\right)}}.$$

In the above equation the function $Q(u)$ has been introduced:

$$Q(u) = \int_{-\infty}^{u} \frac{du}{\sqrt{2\pi}} \cdot e^{-\frac{u^2}{2}}. \tag{58}$$

The above formula (57) expresses the relation to be found between the observed total brightness of an object and its inclination towards the line of sight. The integrals given there cannot, however, be exactly solved. Because of the great labour involved, a numerical evaluation will not be performed here. By means of some simplifying assumptions regarding the distribution of the absorbing matter, the expressions will, however, become more suitable for numerical computations.

51. In the preceding chapter it was shown that the exterior form of a spiral can very well be represented by an oblate spheroid. The largest diameter is on an average about five times larger than the smallest. The study of edgewise spirals suggests that the absorbing layer is flattened in a higher degree than the system itself. In any case we may assume as a fair approximation that the absorbing matter is spread out in such a flattened disk that the thickness of the layer can be considered to be about the same everywhere. In this way we arrive at the following distribution function:

$$\psi(z)\,dz = \frac{r\,dz}{k_3\,\sigma_3\sqrt{2\pi}} \cdot e^{-\frac{z^2}{2k_3^2\,\sigma_3^2}}. \tag{59}$$

Here the same denotations have been used as in formula (53). Of course, the constant r now assumes a different numerical value.

As for edgewise spirals, the above formula cannot be used for the derivation of the dependence of the observed total brightness on the absorption effects. For, according to the formula, the absorbing layer has an infinite extension in the xy-plane. Thus we must not consider too small inclinations towards the line of sight.

Now formula (56) gets the following appearance:

$$\Delta m = \frac{0.543\,r}{\sin b} = \frac{C(90°)}{\sin b}. \tag{60}$$

Thus the total absorption that influences an observer situated in the principal plane of the system in question adopts the value of $0.543\,r = C(90°)$, when the latitude b is equal to 90°. In other latitudes the absorption is inversely proportional to the value of $\sin b$. The total optical thickness of the absorbing layer amounts to $2\,C(90°)$.

We get the following expression for the total brightness of the system if observed from a distant point on the negative z-axis:

$$\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \varphi_{-\infty}(x,y,z)\,dx\,dy\,dz = \int_{-\infty}^{+\infty} \frac{dz}{\sigma_3\cdot\sqrt{2\pi}} \cdot e^{-\frac{z^2}{2\sigma_3^2} - \frac{r}{\sin b}\cdot Q\left(\frac{z}{k_3\,\sigma_3}\right)}. \tag{61}$$

The function $Q\left(\frac{z}{k_3\,\sigma_3}\right)$ used here is defined in formula (58).

Formula (61) expresses the relation to be found between the observed total brightness of the object and the inclination b towards the line of sight. The integral expression given to the right of the sign of equality cannot be exactly solved, but a numerical evaluation can in this case very well be performed. The Q-function has been tabulated by C. V. L. CHARLIER[1]. In Fig. 27 the solutions have been illustrated and there four curves have been computed, corresponding to different values of the relative thickness k_3 of the absorbing layer. The quantity $\frac{\sin b}{C\,(90°)}$ has been selected as abscissa, while the ordinate Δm_{tot} corresponds to the total loss of light, expressed in magnitudes, caused by the absorption effects within the spiral.

From the figure it thus appears that the observed total magnitude is highly dependent on the orientation of the principal plane of the object.

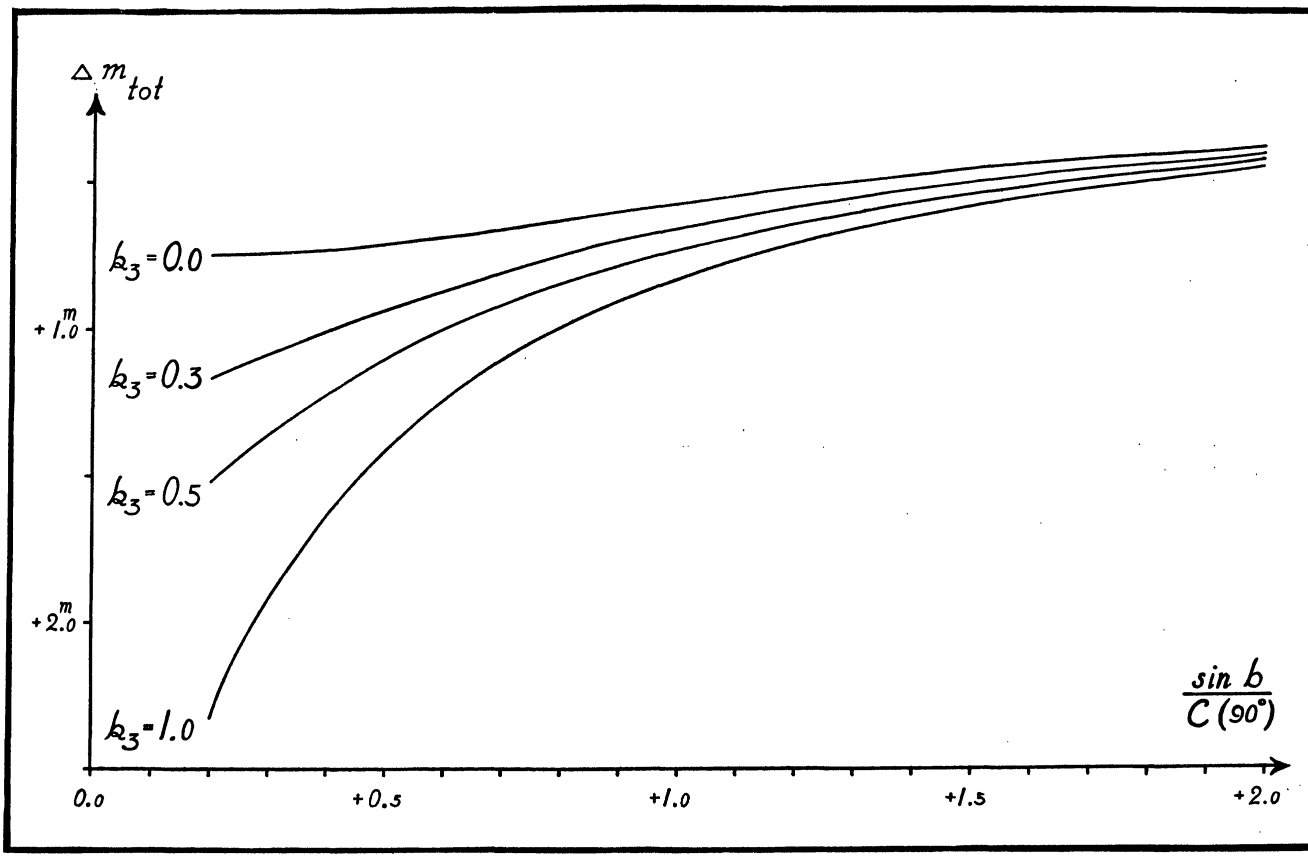


Fig. 27.

Dependence of the observed total magnitude of a spiral on the inclination towards the line of sight.

As the inclination towards the line of sight gets smaller, the observed brightness of the object becomes fainter. If the relative thickness of the absorbing layer has a very small value (in the figure one curve has been drawn corresponding to $k_3 = 0.0$) the absorption Δm_{tot} can at most amount to 0^m75. As the absorbing layer gets thicker, the absorption obtains larger values even if the optical thickness $C\,(90°)$ is unchanged.

52. We will now pass on to investigate how the theoretical relations illustrated in Fig. 27 correspond to

[1] Lund Medd II, No 4 (1906).

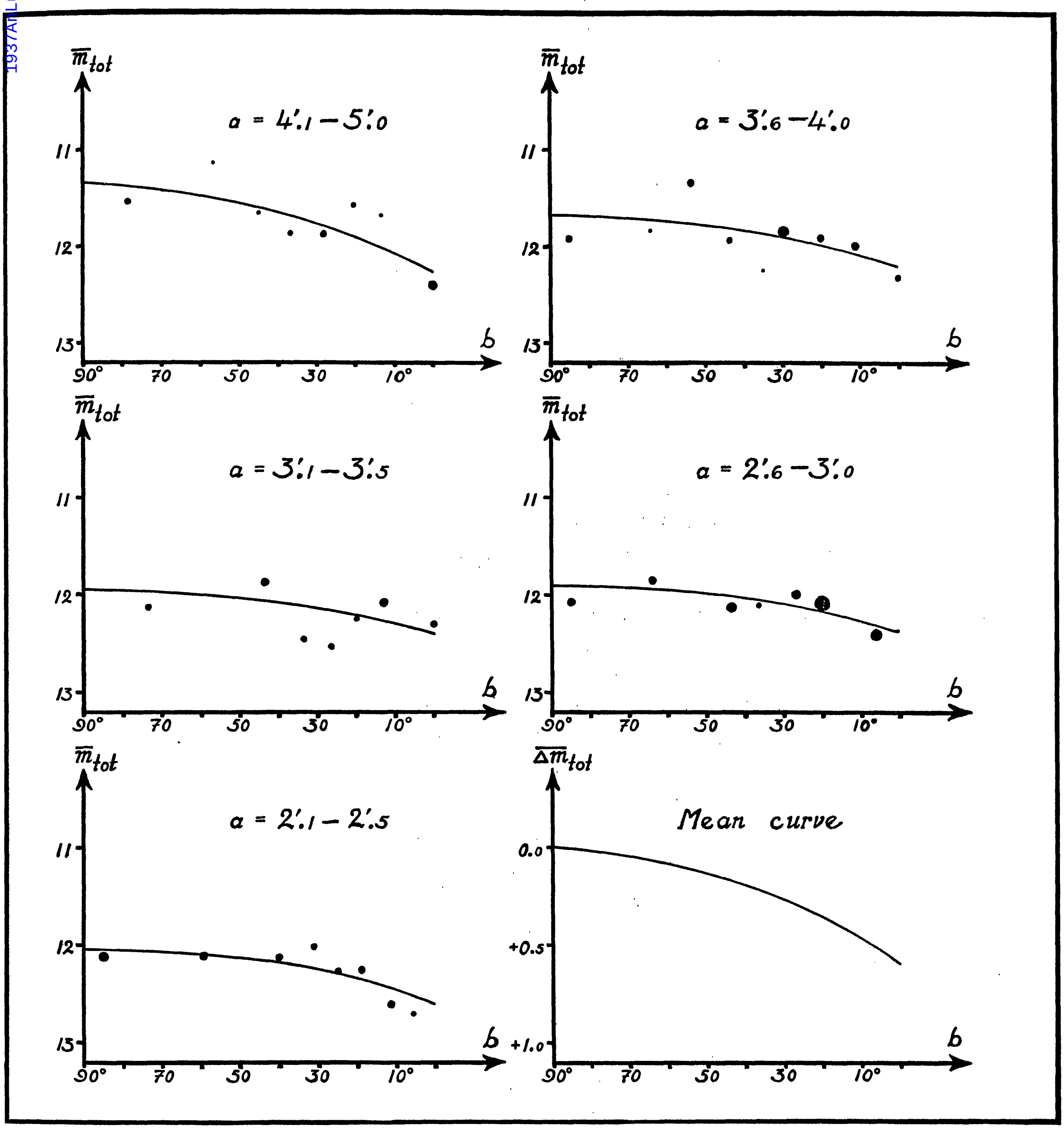


Fig. 28.

Relation between the average apparent magnitude of spirals and the inclination towards the line of sight.

observed facts. The catalogue by H. SHAPLEY and A. AMES[1], comprising all galaxies down to $13^{m}_{.}0$, gives us excellent material to start from. The magnitude values there given are probably very accurate. All large spirals found in this catalogue have been selected, and a division into classes has been made according to the major diameters. This division is illustrated in Fig. 28. The same diameter classes have been used as in the preceding chapter. There the orientation in space of the spiral planes was investigated, and it was shown that within the classes in question the inclinations of the planes towards the line of sight are very probably distributed at random. Thus the objects within the different diameter classes here used probably represent a homogeneous material.

The inclination b of the spiral plane towards the line of sight has been computed from the ratio of major and minor diameter by means of Table 15.[2] The average apparent total magnitude has then been derived within different intervals of this inclination. The results obtained appear in the figure. The areas of the full circles correspond to the number of objects.

There is a conspicuous relation between the average magnitude values and the inclination. On an average, edgewise spirals are fainter than those situated at right angles to the line of sight. This is valid for objects with small diameters too, although, in this case, the observed dimensions are probably systematically too small in comparison with those of large spirals. The mean curve given in the figure is derived from all the five classes. Thus, on an average, the total magnitude becomes $0^{m}_{.}6$ fainter as the inclination b changes from 90° to 0°.

Similar effects of orientation in the apparent magnitudes of the galaxies have been found by E. P. HUBBLE.[3] Using the visual magnitudes as observed by J. HOLETSCHEK and as revised by J. HOPMANN, he obtains an average variation in the total magnitude of about one magnitude, when the inclination of the object changes from 0° to 90°.

The observed values obtained above may now be compared with the theoretical ones. In Fig. 27 above, the theoretical connection between the absorption Δm_{tot}, the optical thickness $C(90°)$, and the inclination b has been illustrated. It was pointed out above that these theoretical derivations cannot be used for small values of the inclination b. Consequently we are not going to consider the values of b that are situated between 0° and 10°. From the observed mean curve in Fig. 28 we obtain a variation in the absorption $\overline{\Delta m_{\text{tot}}}$ equal to $+\,0^{m}_{.}46$ when b changes from 90° to 10°. If we accept this value and if we use Fig. 27, we are able to derive an average relation between the relative thickness k_3 of the absorbing layer and the absorption $C(90°)$.

This average relation is illustrated in Fig. 29. According to this figure, k_3 obtains the value of zero when the optical thickness $C(90°)$ amounts to about $0^{m}_{.}3$. For larger or smaller values of $C(90°)$, the relative thickness k_3 increases. Thus it appears that k_3 is highly dependent on the value of $C(90°)$. By means of edgewise spirals some indications regarding the real value of k_3 can be obtained. It seems safe to conclude that the dark bands appearing in these objects generally have a thickness amounting to about one third of the total thickness of the object. Not leaving out of consideration that these dark bands perhaps cannot give us very reliable values of the constant k_3, we may nevertheless try to use the above value. If k_3 is given the value of $^1/_3$ we can obtain, from the average curve given in Fig. 29, an optical thickness $C(90°) = 0^{m}_{.}15$ and $C(90°) = 1^{m}_{.}4$. It may be remarked that the values of $C(90°)$, which have been obtained for our own galactic system by means of different methods, are generally situated between the two values here given.

53. The above relation between the total magnitude of an object and the absorption effects will influence

---

[1] Harvard Ann 88, No 2 (1932). [2] In this table the inclination is denoted by β.
[3] Mt Wilson Contr 324 = ApJ 64, p. 321 (1926).

the distribution of the corresponding absolute magnitudes. If the observed absolute magnitude is denoted by $\overline{M}$ and the corresponding dispersion by σ_M, the following resolutions can be made:

(62)
$$\overline{M} = \overline{M}_0 + \overline{\Delta M_C} + \overline{\Delta M_b}$$
$$\sigma_M^2 = \sigma_0^2 + \sigma_C^2 + \sigma_b^2.$$

Here M_0 denotes the value of the absolute magnitude, if no absorption is considered, while ΔM_C and ΔM_b are the absorption values depending on the distribution of the dark matter within the system (the inclination $b = 90°$), and on the inclination b. Concerning the dispersions, the indices have the corresponding signification.

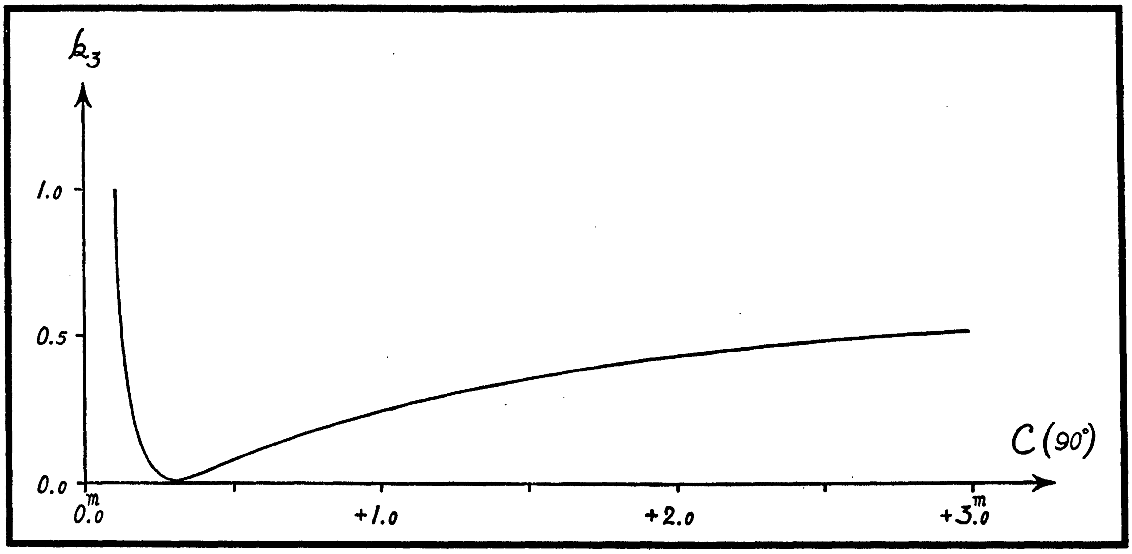


Fig. 29.

Average relation between the relative thickness of the absorbing layer and the corresponding optical thickness.

If we use the mean curve given in Fig. 28, the following numerical values, valid for a given volume of space, are obtained:

$$\overline{\Delta M_b} = +0.^{M}28 \qquad \sigma_b = 0.^{M}16.$$

Thus the different inclinations of the spirals towards the line of sight will produce an additional dispersion in the absolute magnitudes of the objects amounting to $0.^{M}16$. The values of $\overline{\Delta M_C}$ and of σ_C cannot be determined.

54. Fig. 27 above can be used for an investigation into the problem as to how the absorption effects change, if the object is expanding or contracting. The abscissa given in this figure can be transformed in the following way:

(63)
$$\log\left(\frac{\sin b}{C(90°)}\right) = \text{const} + \log \sin b + 2 \log A.$$

This formula implies that the optical density of the absorbing matter at a given point within the system is inversely proportional to the volume of the object. In this way $C\,(90°)$ becomes proportional to A^{-2}, where A is the absolute major diameter. If the present value of the diameter A is put equal to unity, the quantity log A

in the above formula can be replaced by the deviation $\varDelta \log A$, and the constant term of the formula will adopt the value of $-\log C'(90°)$. Here $C'(90°)$ means the present value of half the optical thickness of the absorbing layer.

By means of the above transformations Fig. 30 is obtained. Here $\varDelta \log A$ has been introduced as abscissa. In reality, the curves correspond to an abscissa $\varDelta \log A + \frac{1}{2}\log\left(\frac{\sin b}{4\,C'(90°)}\right)$. However, if b is put equal to 90° and if $C'(90°)$ amounts to $0^{m}.25$[1], the constant term vanishes. The different curves in the figure correspond

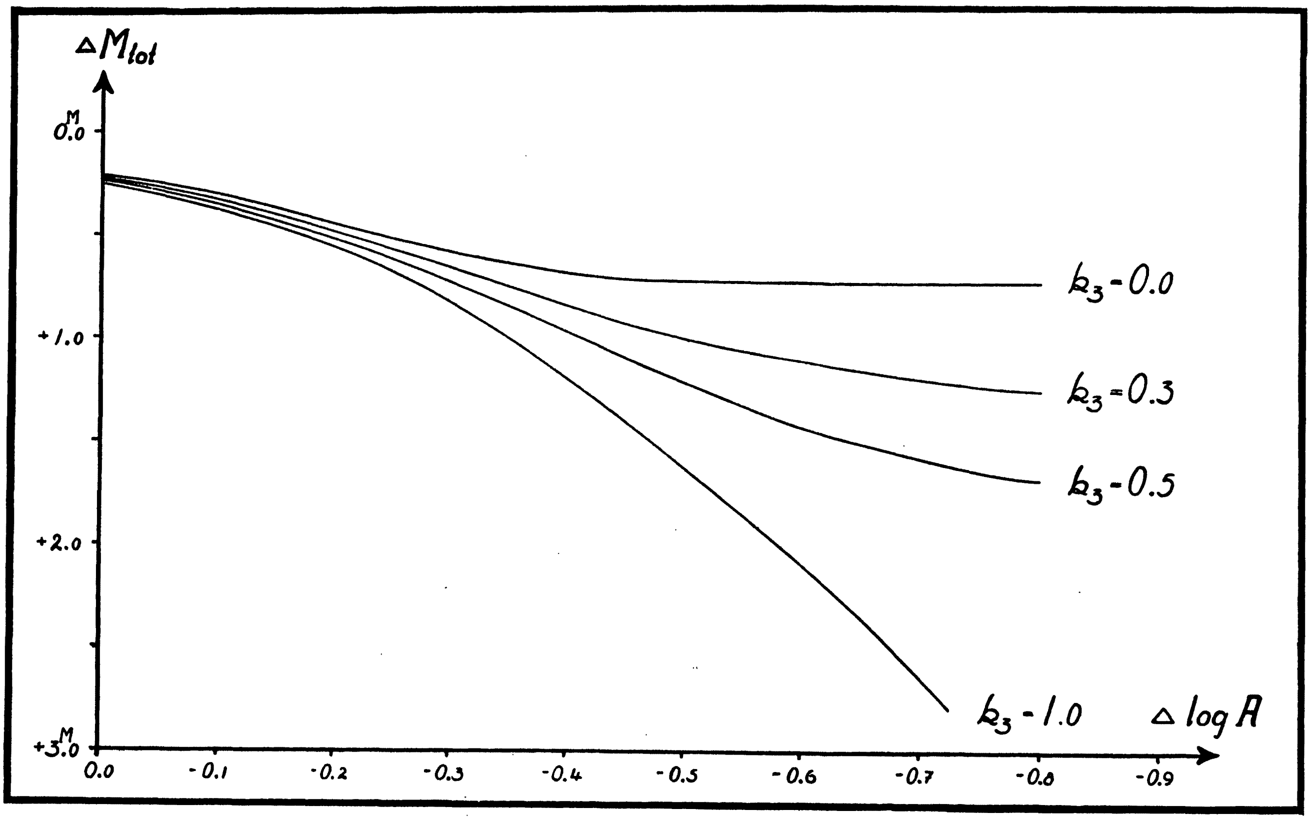


Fig. 30.

Dependence of the observed total magnitude on the absolute dimensions.

to different values of the relative thickness k_3 of the absorbing layer within the object. According to these curves the absolute luminosity of a galaxy will depend on its absolute dimensions, if we assume the dimensions to be changing on account of an expansion or contraction. A large value of the absolute size will correspond to small absorption effects and consequently to a large absolute luminosity. In this way the above curves, especially those given for large values of k_3, enable us to explain the relation between the absolute magnitudes and dimensions of the galaxies derived in Chapter VII of the present paper as an effect of absorption.

[1] This value agrees with the value found by E. P. Hubble for the Galaxy. Cf. Mt Wilson Contr 485 = ApJ 79, p. 8 (1934).

55. At this place it may be remarked that K. Lundmark[1] has determined the proportions of dark and bright matter for five spirals by using their spectroscopically determined rotation velocities. In a table the following ratio f has been given:

$$f = \frac{\text{Dark + Bright matter}}{\text{Bright matter}}.$$

The values of f change between 100 : 1 and 6 : 1. In the computation of the bright matter Lundmark has, however, not considered the absorption effects within the spirals. Here we will make an attempt to take these effects into consideration.

The following denotations will be introduced:

m_d = the total mass of dark matter.
m_b = the total mass of bright matter.
m'_b = the mass that corresponds to the observed light.

In this way we get:

$$f = \frac{m_b + m_d}{m'_b} = \frac{m_b}{m'_b}(1 + k). \tag{64}$$

Here k is the ratio of the total dark matter to the total bright matter. If we put the ratio m_b/m'_b equal to the corresponding ratio of light, and if the absorption concerning the total magnitude of the object is denoted by ΔM, we get the following relation:

$$\Delta M = 2.5 \log \frac{m_b}{m'_b} = 2.5 \log f - 2.5 \log (1 + k). \tag{65}$$

Thus the observed ratio f can be resolved into the absorption effect ΔM and the true ratio k.

In individual cases the above absorption effect ΔM cannot be determined. Concerning the five spirals mentioned above, there is an indication of a correlation between the quantity $\left(\Delta M + 2.5 \log (1 + k)\right)$ and the types of the objects. In Fig. 31 an illustration is given of this. The types of the spirals have been referred to the system of E. P. Hubble[2]. In one case the agreement is not good. This value is, however, considered by Lundmark a doubtful one. The Galaxy, which is also included in Lundmark's table, has been introduced in the figure (open circle) as a spiral of type *Sc*.

Of course the number of individuals is too small for reliable values to be derived of the correlation suggested above. It may, however, be supposed that the absorption effect ΔM becomes smaller, when the type of the spiral becomes more advanced. In this way the large variations to be found in Lundmark's ratios can perhaps be explained as an absorption effect. The true ratio k, of the dark mass to the bright mass, can thus very well be comparatively constant. If, for the type *Sc*, the absorption ΔM is assumed to be zero the ratio k gets a value of 6 or 7.

56. After the above discussions concerning the existence of absorbing matter within the anagalactic spirals, we will take our own galactic system into consideration. The general absorption effects appearing here will influence the observed apparent properties of all objects situated outside the system. Thus every investigation into this problem will be of great importance. In the present paper we do not intend to take up these

[1] Lund Medd I, No 125 = VJS 65, p. 275 (1930). [2] Cf. Mt Wilson Contr 324 = ApJ 64, p. 321 (1926).

11—37522.

absorption effects for general discussion. Only some results to be obtained from the apparent distribution of the anagalactic objects will be discussed.

Several important investigations based on the apparent distribution of the galaxies have already been carried out. Thus P. VAN DE KAMP[1] discusses the material obtained from the Harvard survey[2] of bright galaxies and from E. A. FATH's[3] study of plates of Selected Areas with the 60-inch reflector at Mount Wilson. An optical thickness of the galactic absorbing layer of 0.8 and 1.4 photographic magnitudes respectively is here obtained. Later on E. P. HUBBLE[4] investigated the distribution of about 44000 galaxies on plates with the 100-inch and 60-inch reflectors at Mount Wilson. The absorbing layer was found to have a thickness of $0^{m}.5$. Here we do not intend to give a detailed account of the investigations that have been made into the problem in question. For further information we beg to refer to the papers mentioned above.

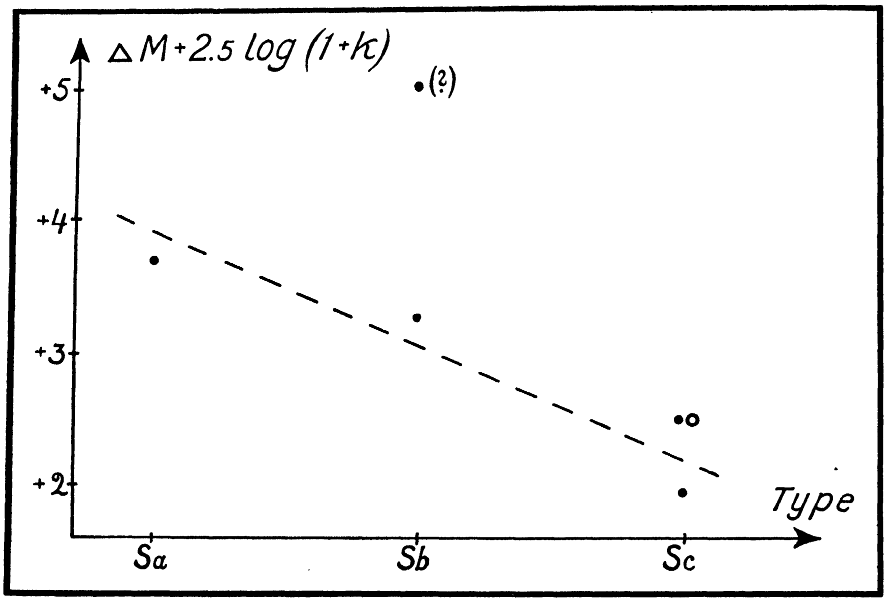


Fig. 31.

The observed ratio of bright matter to dark matter for spirals of different types.

57. In the following investigation we are making use of the material given in the catalogue by H. SHAPLEY and A. AMES.[2] Thus the same objects are used as in the above investigation by VAN DE KAMP. As, however, certain new points of view are taken into account here, a renewed discussion may be justified.

If, in a given solid angle, the density function of the galaxies can be expressed in accordance with formula (35) in Chapter VIII, the number of objects $F(m)$ that are brighter than or equal to the apparent magnitude m can be expressed in the following way:

(66) $$\log F(m) = f m + \text{const.}$$

If the density function within the solid angle considered is constant, the factor f gets the value of $+0.6$. If we consider two different magnitude values m_1 and m_2 the following relation is obtained:

(67) $$m_1 - m_2 = \frac{\log F(m_1) - \log F(m_2)}{f}.$$

Thus the magnitude difference can be obtained from the corresponding difference between the numbers of the galaxies, if the value of the factor f is known.

[1] AJ 42, p. 97 (1932). [2] Harvard Ann 88, No 2 (1932). [3] AJ 28, p. 75 (1914).
[4] Mt Wilson Contr 485 = ApJ 79, p. 8 (1934).

If the density function is the same in different solid angles, the above formula can be used for an investigation into the galactic absorption effects. We may at once take the above Harvard catalogue into consideration. Here the observed limiting magnitude is $13^{m}.0$. If in a solid angle situated at the galactic longitude l and latitude b, the total galactic absorption, in photographic magnitudes, is denoted by $C(l, b)$, the real limiting magnitude gets the value $13^{m}.0 - C(l, b)$. If we omit the influence of the galactic longitude, the following relation is obtained between the absorption effects at the latitudes b_1 and b_2 and the corresponding numbers of galaxies:

$$C(b_1) - C(b_2) = \frac{\log F\big(13.0 - C(b_2)\big) - \log F\big(13.0 - C(b_1)\big)}{f}. \tag{68}$$

In order to justify the above assumption concerning the density function only some selected areas of the sky will be considered. Through investigations made by KNUT LUNDMARK[1] it has been shown that the anagalactic objects are concentrated towards a great circle on the sky, the metagalactic equator. Thus the density function is dependent on the metagalactic latitude. In order to eliminate these effects we will here consider only objects situated between $+20°$ and $-20°$ metagalactic latitude. Since the metagalactic equator intersects the galactic equator at approximately right angles, the dependence of the absorption $C(b)$ on the latitude b can very well be investigated.

As regards the above areas, the distribution of the objects in the Harvard catalogue is given in Table 16. Here L denotes the metagalactic longitude. The metagalactic co-ordinates are based on LUNDMARK's pole ($\alpha = 323°$, $\delta = +66°.5$), and they have been computed by means of a table kindly placed at my disposal by Dr. LUNDMARK.[2] The average numerical value of the galactic latitude has been computed for every class in Table 16.

The above distribution is illustrated in Fig. 32. Here the groups situated at the same galactic latitudes have been taken together in pairs. The metagalactic equator is intersected by the galactic equator at the metagalactic longitudes $L = 41°$ and $L = 221°$. The latter point corresponds to a galactic longitude of 343°. There are some indications that in this direction, which approximately corresponds to the centre of the Galaxy, the absorption effects are somewhat larger than in the opposite direction. Through the above combination of pairs, these effects have been smoothed out. The full curves I and II, which represent the observed frequencies, have been determined graphically. A least squares solution cannot be made, since several class frequencies are equal to zero, and the function $\log F(m)$ thus gets the value of $-\infty$.

Table 16.

Distribution of the objects in the Harvard survey.

L	N	$\overline{\lvert b \rvert}$
0°.0 — 9°.9	2	38°.0
10.0 — 19.9	9	28.8
20.0 — 29.9	0	—
30.0 — 39.9	0	—
40.0 — 49.9	0	—
50.0 — 59.9	1	14.0
60.0 — 69.9	0	—
70.0 — 79.9	3	33.7
80.0 — 89.9	12	43.0
90.0 — 99.9	18	51.1
100.0 — 109.9	41	59.7
110.0 — 119.9	34	66.4
120.0 — 129.9	49	76.6
130.0 — 139.9	138	72.8
140.0 — 149.9	23	63.6
150.0 — 159.9	7	62.0
160.0 — 169.9	25	53.7
170.0 — 179.9	20	44.8
180.0 — 189.9	5	34.6
190.0 — 199.9	1	31.0
200.0 — 209.9	1	20.0
210.0 — 219.9	0	—
220.0 — 229.9	0	—
230.0 — 239.9	0	—
240.0 — 249.9	3	19.7
250.0 — 259.9	5	35.4
260.0 — 269.9	3	45.0
270.0 — 279.9	8	52.6
280.0 — 289.9	20	62.6
290.0 — 299.9	6	67.3
300.0 — 309.9	9	77.6
310.0 — 319.9	19	73.4
320.0 — 329.9	13	67.8
330.0 — 339.9	14	62.2
340.0 — 349.9	29	54.2
350.0 — 359.9	16	48.1
Total	534	

[1] Not yet published. Compare Chapter XI of the present paper.

[2] A diagram for the determination of the metagalactic co-ordinates is given at the end of the present paper (Fig. 35).

The absorption effects will now be discussed. We will try to start from the following simple relation, which in investigations of the present kind has been a generally adopted starting-point. It may be remarked that above, in investigating the absorption effects in the anagalactic spirals, we arrived at the same relation.

(69) $$C(b) = \frac{C(90°)}{\sin b}.$$

Provisionally, the sign of the galactic latitude will not be considered. By means of this relation curves I and II can be transformed into one curve, which gives the distribution corresponding to no absorption. Before this transformation can be made we must, however, know the value of the quantity $f \cdot C$ (90°), or the very value that we are searching for. According to the discussion given below, the following value seems in this case to be the most probable:

(70) $$f \cdot C(90°) = +\, 0\overset{m}{.}6.$$

In this manner the dotted curve III given in the figure is obtained.

A study of the form and appearance of the final curve, corresponding to no absorption, is the only way to decide whether the assumptions (69) and (70) made above are justified. Of course, we do not know, *a priori*, the real form of this curve. We are, however, able to decide whether the form obtained is a probable one or not. Curve III, which has a continuous run, corresponds to constant class frequencies in the south galactic hemisphere, while the number of objects increases towards the North Galactic Pole. Thus the distribution of the objects along the metagalactic equator attains a maximum in the north hemisphere. This distribution has been discussed in a preceding chapter[1] in connection with an investigation into the spatial arrangement of the galaxies. There curve V, corresponding to the absorption at the galactic poles, was obtained, and the relation between this curve and curve III was discussed. By summing up the different facts, we come to the conclusion that curve III probably has a real significance. Thus we may adopt this curve as a representation of the conditions corresponding to no absorption.

The sun is situated north of the galactic principal plane, and it can be assumed that this will influence the absorption effects. In Fig. 32 the dotted piece of curve IV illustrates how large a displacement is obtained, if the quantity $f \cdot C\,(+\,90°)$ changes from the value $+\,0\overset{m}{.}6$ to the value $+\,0\overset{m}{.}5$. If the factor f equals $+\,0.6$, this corresponds to the small difference of $0\overset{m}{.}17$ between the absorption values $C\,(+\,90°)$ and $C\,(-90°)$. Curve IV cannot be combined with the right part of curve III. Thus it can be concluded that in the present material no appreciable difference between the two galactic hemispheres can be found.

In order to make a complete solution of the absorption problem possible, the average value of the factor f must be known. If the density in space of the galaxies is constant within the solid angle considered, the factor f gets the value of $+\,0.6$, and from formula (70) we get the absorption value $C\,(90°) = 1\overset{m}{.}0$. In Chapter VIII, where the spatial arrangement of the galaxies was investigated, it has, however, been shown that within the nearer Metagalaxy the density decreases when the distance becomes larger. From Fig. 20 an average value of $+\,0.45$ is obtained for the factor f. Thus the total general absorption in the direction of the galactic poles gets the value of 1.3 photographic magnitudes. This absorption value is a very large one, and thus the results obtained here do not agree well with the investigations by van de Kamp and Hubble mentioned above.

[1] See Chapter VIII.

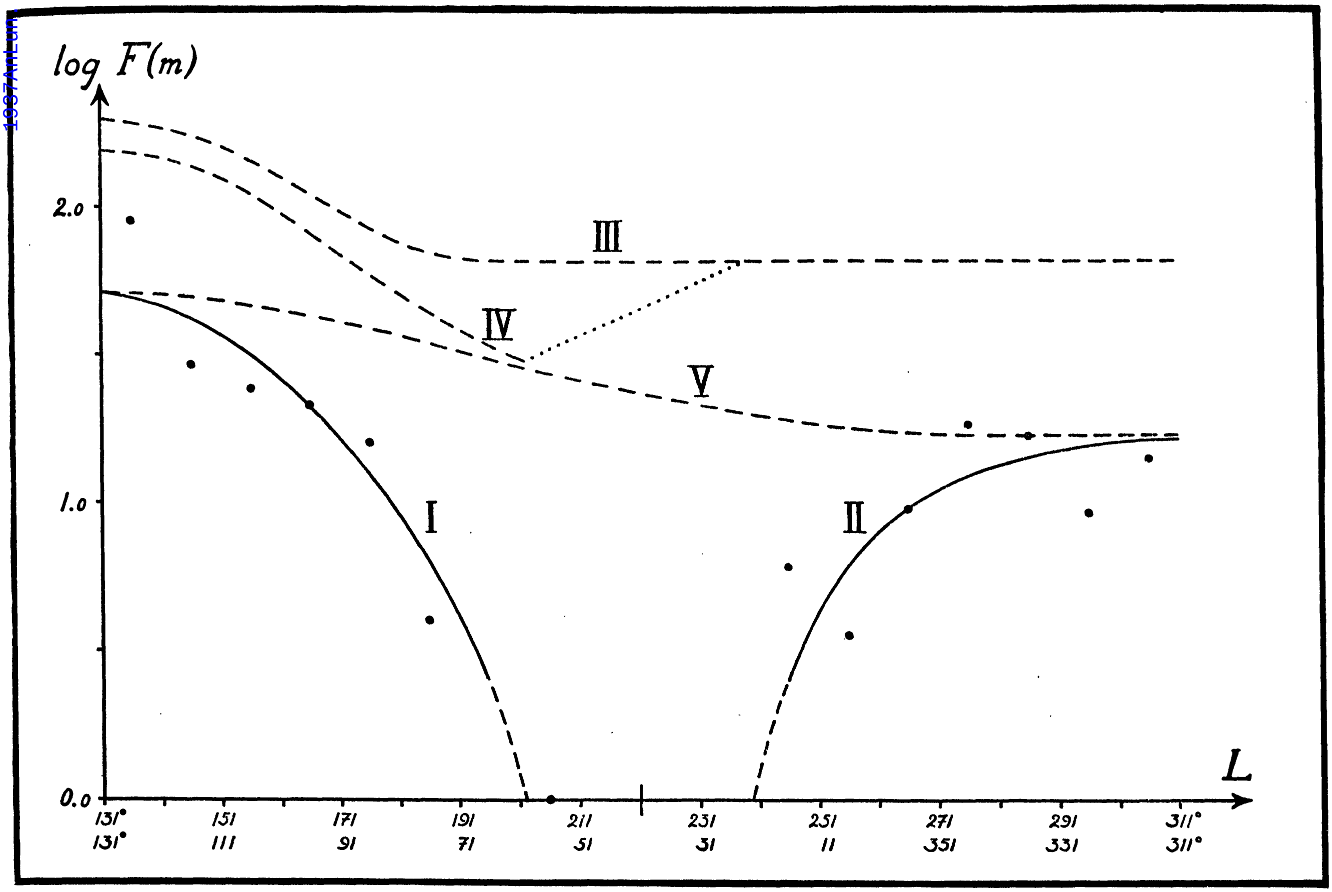


Fig. 32.

Galactic absorption phenomena along the metagalactic equator.

In all investigations of the galactic absorption effects that start from the apparent distribution of the anagalactic objects, certain assumptions must be made concerning the distribution in space of the galaxies. In the above discussions only some selected areas of the sky have been considered in order to make these assumptions as simple as possible. This procedure, however, involves one disadvantage. The number of objects becomes highly reduced, and the accidental groupings of the galaxies will influence the results in a high degree. Here we may refer to results obtained by H. SHAPLEY[1] in an investigation of the apparent distribution of galaxies on Harvard plates. Although the plates have a very faint limiting magnitude, the deviations in the numbers of galaxies from field to field are very great. SHAPLEY states that perhaps no conclusion should be drawn concerning the dependence of the apparent density of the galaxies on the galactic latitude.

In conclusion we ought to mention another source of error that may be of great importance. The galaxies situated in low galactic latitudes are subject to great galactic absorption effects. Consequently their apparent surface brightness is highly reduced, and the faint outer parts of the objects will not appear on the photo-

[1] Harvard Repr 90 = Wash Nat Ac Proc 19, p. 389 (1933).

graphic plate. Hence the observed magnitudes of these objects may be systematically too faint, and consequently not directly comparable with the magnitudes of the objects situated in high latitudes. In Chapter V of this paper some effects of this nature were discussed. It was shown[1] that, when the Harvard magnitudes change from $13^{m}.0$ to $16^{m}.0$, the corrected magnitudes given in the present catalogue change from about $13^{m}.0$ to about $15^{m}.0$. If in this case too, we assume that the true variation in the magnitude values for different galactic latitudes amounts to only two thirds of the observed variation, the absorption values obtained above are to be multiplied with the factor $^2/_3$. In this way we obtain a value of half the optical thickness, C (90°), amounting to 0.8 à 0.9 photographic magnitudes. It may, however, be pointed out that it is difficult to find reliable values of the above corrections. Thus, the value of $^2/_3$ assumed above should not be considered a definite one.

CHAPTER XI

ORIENTATION AND ABSOLUTE DIMENSIONS OF THE ORBITS OF DOUBLE GALAXIES

58. In this chapter some investigations will be made into the orientation of the orbital planes of double galaxies. We must assume that, in analogy with binary stars, the two components of a double anagalactic system move in elliptical or circular orbits around the centre of gravity of the system. Starting from the apparent distances between the components, or the apparent orbital radii, we will try to determine the distribution, or the ellipsoid, of the corresponding absolute distances, which will be called the absolute orbital radii. By the aid of this distribution the orientation and the absolute dimensions of the orbits will be discussed.

The double galaxies form a part of the large cosmical unit, which by KNUT LUNDMARK has been called the metagalactic system. The existence of such a system was already suggested in 1908 by C. V. L. CHARLIER[2] who discussed how an infinite world may be built up by means of systems of different orders. LUNDMARK[3] has discussed the properties of this metagalactic system in several papers. Among other things he has proved that the galaxies are concentrated towards a great circle on the sky, the metagalactic equator. In this we have an indication that the system of galaxies has a flattened shape. Of course, the investigations are complicated by the large absorption effects produced by the dark matter within our own galactic system. It may also be mentioned that we can probably not reach the boundaries of the large system of galaxies. In fact it is an open question whether the observed system is merely a gigantic cluster within a much larger system or not. This, however, does not influence the investigations to be made here. Until further evidence is forthcoming we may consider the observed metagalactic system as a limited unit.

Using all available material LUNDMARK has been able to determine the situation of the poles of the metagalactic system. The methods employed by him are similar to those used for the determination of the galactic poles. By the extreme courtesy of Dr. LUNDMARK, some preliminary values can be given here. They appear in Table 17.

[1] Cf. Fig. 10. [2] Lund Medd I, No 38 (1908). Compare also Lund Medd I, No 98 (1922).
[3] Upsala Medd 30 (1927), Lund Circ 9 (1934) and unpublished papers.

Table 17.

The poles of the metagalactic system according to Knut Lundmark.

Material	Northern pole l	Northern pole b	Number of objects
Shapley-Ames's survey (Harvard Ann 88, No 2)	73°	+11°	1249
All NGC-objects (known clusters and gaseous and planetary nebulae excluded)	104	+15	7527
All NGC- and IC-objects (known clusters and gaseous and planetary nebulae excluded)	116	+ 5	12308
Metagalactic clusters	101	+21	325
Hubble's material (Mt Wilson Contr 485)	89	+45	44000:
Mayall's material (Lick Bull 458)	96	+39	15000:

The poles given in the above table are generally situated not far from the Milky Way, and thus the metagalactic equator passes near the galactic poles. The poles obtained from HUBBLE's and MAYALL's surveys deviate to some extent from the other ones. These deviations can possibly be explained through the fact that these surveys also contain very faint galaxies. At the end of this paper (Fig. 35) a diagram is given for the determination of metagalactic co-ordinates. This diagram is founded on the first pole given in the table. The SHAPLEY-AMES survey probably furnishes the most homogeneous material representing the whole sky.

If the large system of galaxies has a very flattened shape, we may very well assume that, on an average, the orbital planes of double galaxies are parallel to the metagalactic plane. In this case, then, the individual galaxies must move approximately parallel to the principal plane of the metagalactic system and, since the double galaxies are very probably formed through captures[1], a parallelism of the above kind may be the result. The flattening of the distribution, or the ellipsoid, of the absolute orbital radii must, however, be related to the flattening of the metagalactic system. If this latter becomes smaller, the former distribution will probably change rapidly into a globular one, and the parallelism in question disappears. We do not know much about the flattening of the metagalactic system. The results obtained in the present investigation will, however, give some indications concerning this problem.

Some investigations have been made earlier into problems similar to those considered here. Thus the orientation of the spiral planes has been discussed by H. KNOX SHAW[2], B. MEYERMANN[3], C. C. L. GREGORY[4] and K. LUNDMARK.[5] No definite results have, however, been obtained. Several papers have been published on the orbital planes of visual binary stars. Thus J. M. POOR[6] discusses the orientation of these planes. The results obtained by him show that the planes are not parallel to the galactic plane. On the whole they are situated at right angles to the direction of vertex. The material available has now grown considerably, and some new determinations are being worked out at the Lund Observatory.

[1] Cf. Chapter XII. [2] MN 69, p. 72 (1908). [3] AN 219, p. 131 (1923). [4] MN 84, p. 456 (1924).
[5] Upsala Medd 30 (1927). [6] AJ 28, p. 145 (1914).

59. After these introductory remarks we will pass on to the determination of the distribution of the absolute orbital radii. This radius is the absolute distance in space between the two galaxies in the double system, and it will be divided into the three components X, Y and Z. One of the galaxies, arbitrarily selected, may be considered as origin. The components X and Y may provisionally be assumed to be situated in the celestial plane. Then, the following relations are valid between the above absolute components and the apparent ones, x and y, that have been observed:

$$x = \frac{1}{r} \cdot X \qquad\qquad (71)$$

$$y = \frac{1}{r} \cdot Y.$$

Here r denotes the distance to the system, and the x-axis and the X-axis have been assumed to correspond to one another and, in the same way, the y-axis and the Y-axis.

The problem of determining the distribution of the absolute components X, Y and Z by means of the observed distributions of x and y is principally identical with the problem of determining the space velocity distribution for stars by means of the observed peculiar motions. Thus the absolute orbital radius is compared with the absolute space velocity. Before entering upon further details, we will, however, discuss the material to be used in the present investigation.

Not only the double objects in the present catalogue but also some multiple systems have been included in the following computations. Concerning multiple objects the rule has been observed that one of the components shall be prevalent in regard to brightness. We have considered $1^{m}.2$ as the minimum value of the magnitude difference between this component and the next one. The orbital radii have then been measured between the bright component and the faint ones, which can be assumed to move around the bright galaxy approximately independent of one another. The number of multiple systems included in this way is, however, small.

All systems, where the following condition is not fulfilled, have been omitted:

$$\frac{\vartheta}{a_1 + a_2} \leq 2.$$

This condition has been discussed in Chapter II, and it implies that the apparent distance between the components must not be larger than twice the sum of the corresponding major diameters.

Another selection has been made with regard to the apparent magnitude of the objects. All galaxies brighter than $13^{m}.0$ have been omitted. The magnitude values given in the present catalogue have been used for this selection. Concerning these bright galaxies the apparent distances x and y generally have very large values, and they exercise too large an influence upon the corresponding distributions. This exclusion is also justified with a view to possibly occurring optical systems. These must be more frequent in the bright magnitude classes. By the latter exclusion, which is the most important one, 20 % of the number of systems is omitted.

The number of the remaining apparent orbital radii amounts to 570. The distributions of the apparent distances x and y can now be computed. The sky is divided into 48 squares $A_1 - A_2$, $B_1 - B_{10}$, $C_1 - C_{12}$, $D_1 - D_{12}$, $E_1 - E_{10}$, $F_1 - F_2$ according to C. V. L. Charlier.[1] In this case the squares have been referred to the equatorial system, and the quantities x and y have been taken equal to $\Delta\alpha \cos\delta$ and $\Delta\delta$ respectively. These co-ordinate differences are given in the catalogue.

[1] Cf. The motion and the distribution of the stars, Berkeley, California (1926).

Table 18.

The moments of the apparent orbital radii.

Square	N	ν_{200}	ν_{020}	ν_{110}
A 1	3			
2	7	2.45	1.76	−0.69
B 1	4			
2	1			
3	0			
4	16	1.48	1.09	−0.49
5	47	1.94	0.93	−0.13
6	63	2.05	1.73	+0.14
7	36	0.90	1.76	+0.26
8	6	1.49	0.66	+0.23
9	0			
10	4			
C 1	13	1.31	1.31	+0.34
2	0			
3	5			
4	5			
5	21	1.12	1.03	+0.16
6	60	1.50	1.04	+0.02
Total	291			

Square	N	ν_{200}	ν_{020}	ν_{110}
C 7	79	1.35	1.37	−0.02
8	78	1.31	0.91	−0.18
9	11	1.80	0.34	0.00
10	1			
11	3			
12	18	3.75	1.02	+0.38
D 1	24	1.82	1.26	+0.33
2	8	3.94	3.67	−1.14
3	8	0.64	0.32	−0.05
4	1			
5	2			
6	6	0.99	0.89	+0.32
7	21	1.31	3.08	+0.05
8	7	2.19	3.44	+0.08
9	0			
10	0			
11	5			
12	7	1.71	1.96	−0.21
Total	279			

Within each square the following moments have been computed:

$$\nu_{200} = \overline{x^2}$$
(72)
$$\nu_{020} = \overline{y^2}$$
$$\nu_{110} = \overline{xy}.$$

It should be remarked that, according to the definitions, $\bar{x} = \bar{y} = 0$. The numerical results are given in Table 18. Here N denotes the number of orbital radii, and for the moments one minute of arc has been used as unit. The moments are not given for those squares, where the number N is equal to or smaller than five.

Now the moments of the distribution of X, Y and Z can be computed. The moment $(\overline{X^i\, Y^j\, Z^k})$ will be denoted by N_{ijk}. We assume that the co-ordinate system X, Y, Z is defined in such a way that the X-axis points towards the vernal equinox, and that the XY-plane coincides with the equator plane. Then, according to CHARLIER, the following transformations can be made:

12—37522.

$$
\begin{aligned}
\nu_{200} \cdot \frac{k}{\vartheta_2} &= \gamma_{11}^2 \cdot N_{200} + \gamma_{21}^2 \cdot N_{020} + \gamma_{31}^2 \cdot N_{002} + 2\,\gamma_{21}\gamma_{31} \cdot N_{011} + 2\,\gamma_{31}\gamma_{11} \cdot N_{101} + 2\,\gamma_{11}\gamma_{21} \cdot N_{110} \\
\nu_{020} \cdot \frac{k}{\vartheta_2} &= \gamma_{12}^2 \cdot N_{200} + \gamma_{22}^2 \cdot N_{020} + \gamma_{32}^2 \cdot N_{002} + 2\,\gamma_{22}\gamma_{32} \cdot N_{011} + 2\,\gamma_{32}\gamma_{12} \cdot N_{101} + 2\,\gamma_{12}\gamma_{22} \cdot N_{110} \\
\nu_{110} \cdot \frac{k}{\vartheta_2} &= \gamma_{11}\gamma_{12} \cdot N_{200} + \gamma_{21}\gamma_{22} \cdot N_{020} + \gamma_{31}\gamma_{32} \cdot N_{002} + (\gamma_{31}\gamma_{22} + \gamma_{21}\gamma_{32}) \cdot N_{011} + (\gamma_{31}\gamma_{12} + \gamma_{11}\gamma_{32}) \cdot N_{101} + \\
&\quad + (\gamma_{11}\gamma_{22} + \gamma_{21}\gamma_{12}) \cdot N_{110}.
\end{aligned}
\tag{73}
$$

In the above equations a reduction factor k has been introduced, corresponding to a transformation of the observed moments from minutes of arc into radians. The mean value $\overline{\left(\frac{1}{r^2}\right)}$, where r is the distance of the objects, has been denoted by ϑ_2. The quantities γ_{ij} are the direction cosines for the different squares. They have been tabulated by CHARLIER for the centres of the squares, and in this investigation we have used these values, although the objects are not always symmetrically distributed within the areas. The small errors caused by this will be of no importance.

Now the moments N_{ijk} can be derived by means of a least squares solution. From the different areas we obtain 60 equations of the types given in formula (73). Every equation is given a weight inversely proportional to the square of the mean error of the left member. In this way the following numerical values, with mean errors, are obtained:

$$
\begin{aligned}
N_{200} \cdot \frac{\vartheta_2}{k} &= +\,1.46 \pm 0.25 \qquad & N_{011} \cdot \frac{\vartheta_2}{k} &= -\,0.04 \pm 0.09 \\
N_{020} \cdot \frac{\vartheta_2}{k} &= +\,1.40 \pm 0.14 \qquad & N_{101} \cdot \frac{\vartheta_2}{k} &= +\,0.02 \pm 0.13 \\
N_{002} \cdot \frac{\vartheta_2}{k} &= +\,0.76 \pm 0.10 \qquad & N_{110} \cdot \frac{\vartheta_2}{k} &= +\,0.14 \pm 0.13.
\end{aligned}
\tag{74}
$$

The co-ordinate system will now be turned in such a way that the correlation moments disappear. The dispersions σ_1, σ_2 and σ_3 along the new axes can, in accordance with well known transformations, be obtained by solving the following equation of the third degree:

$$
0 = f(t) = \begin{vmatrix} +\,1.46 - t, & +\,0.14, & +\,0.02 \\ +\,0.14, & +\,1.40 - t, & -\,0.04 \\ +\,0.02, & -\,0.04, & +\,0.76 - t \end{vmatrix}.
\tag{75}
$$

Thus we obtain the following final dispersion values, with mean errors. The equatorial co-ordinates of the corresponding axes are denoted by α and δ.

$$
\begin{aligned}
\sigma_1 &= (1.25 \pm 0.10) \cdot \sqrt{k/\vartheta_2} \qquad & \alpha_1 &= 220^\circ \qquad & \delta_1 &= +\ \ 1^\circ \\
\sigma_2 &= (1.14 \pm 0.06) \cdot \sqrt{k/\vartheta_2} \qquad & \alpha_2 &= 309^\circ \qquad & \delta_2 &= +\ \ 5^\circ \\
\sigma_3 &= (0.87 \pm 0.06) \cdot \sqrt{k/\vartheta_2} \qquad & \alpha_3 &= \ \ 27^\circ \qquad & \delta_3 &= +\,84^\circ.
\end{aligned}
\tag{76}
$$

Since the turning of the system of co-ordinates has been comparatively small, the above mean errors have been directly computed from the mean errors of the corresponding moments N_{ijk}.

In this way we find that the distribution of the absolute orbital radii has an ellipsoidal form. The smallest axis is directed towards the following point:

$$\text{(77)} \qquad \begin{cases} \alpha = \ 27^\circ \\ \delta = +\ 84^\circ \end{cases} \qquad \begin{cases} l = \ 92^\circ \\ b = +\ 22^\circ . \end{cases}$$

Here l and b denote the galactic co-ordinates. The difference between the smallest dispersion and any one of the other two is larger than three times the corresponding mean errors. Thus the flattening of the distribution very probably is not caused by accidentality.

60. The pole obtained above is in excellent agreement with the poles determined by LUNDMARK for the metagalactic system. These poles have previously been given in Table 17. Thus we arrive at the very probable conclusion that, on an average, the orbital planes of double galaxies are parallel to the metagalactic plane. In accordance with the introductory discussions given above, the results obtained here indicate that the large system of galaxies is a relatively oblate one. In any case, we are able to explain the parallelism found above by starting from this assumption.

The galactic latitude of the above pole is somewhat larger than the latitudes of the poles obtained by LUNDMARK. Such a deviation can easily be explained. The apparent distribution of the galaxies in the sky is much influenced by the galactic absorption effects in low latitudes. On account of this the corresponding poles are perhaps displaced in the direction of the Milky Way.

The dispersion σ_1 comes out somewhat larger than the dispersion σ_2. The difference is not larger than the corresponding mean error, and thus it is not necessarily a real effect. Two other explanations can, however, be advanced. The axis corresponding to the largest dispersion value points approximately towards the large clusterings of galaxies in the north galactic hemisphere. The gravitational effects produced by these objects may cause an elongation of the orbits in this direction. The third way of explaining the elongation will be discussed below.

Concerning the oblate distribution of the orbital radii, some systematic errors, which perhaps will influence the results, must be taken into consideration. In formula (76) the dispersion values have been expressed with the quantity $\sqrt{k/\vartheta_2}$ as a unit. It may be that the average value ϑ_2 is not the same for the three dispersions. The value of σ_3 is mainly obtained from those double systems that are situated at small declinations, since the corresponding axis points approximately towards the North Celestial Pole. Concerning the dispersions σ_1 and σ_2, the double systems situated at large declinations will influence the values too.

In a given solid angle the average value ϑ_2 is dependent on the limiting magnitude of the plates used and on the general galactic absorption. These two things, together with the absolute brightness of the galaxies, determine how far we reach into space. If a general absorption is to be found in the metagalactic space, we will assume that it has the same value everywhere.

If we assume the density function of the galaxies to have the same form everywhere within the solid angles considered, the values of ϑ_2 that correspond to different solid angles can be compared by means of the above limiting distances. In Chapter VIII, where the spatial arrangement of the galaxies was investigated, it was shown that, in the direction of the North Galactic Pole, the density function of the double galaxies is probably constant unless the nearest space is considered. In the other directions we do not know the density function. In order to make possible an investigation of the systematic effects considered here we will, however, also assume a constant value of the density function in these latter directions. It ought to be pointed out that most of the double and multiple objects given in the present catalogue are situated in the north galactic hemisphere.

Now we will refer to Table 19, where some numerical values are given. In four different declination intervals the total number of double and multiple systems (N), the average numerical value of the galactic latitude ($\overline{|b|}$), and the average limiting magnitude of the plates used ($\overline{m_l}$) have been computed. The declination intervals correspond to CHARLIER's squares. Within the two most important intervals $\delta = 0° — + 30°$ and $\delta = + 30° — + 67°$ the average values of the latitude and of the limiting magnitude are practically identical. Thus the average limiting distance, and according to the above assumption the quantity ϑ_2, too, must have about the same values within these two groups. In the two other areas small deviations occur. They probably have no great influence, since the number N here is small. In the interval $\delta = - 30° — 0°$, the deviations of $\overline{|b|}$ and $\overline{m_l}$ are, in fact, such that they will give the dispersion σ_3 a value that is too large.

Table 19.

Average galactic latitude of the objects and average limiting magnitude of the plates.

δ	N	$\overline{\vert b \vert}$	$\overline{m_l}$
−30° — 0°	129	52.°9	16.m2
0 — +30	411	59. 7	16. 6
+30 — +67	275	59. 6	16. 6
+67 — +90	12	43. 3	16. 6

Thus we cannot explain the difference between the dispersion σ_3 and the dispersions σ_1 and σ_2 by assuming variations in the average value ϑ_2. The difference between the two dispersions σ_1 and σ_2 can, however, be explained in this way. The axis 1 has a numerically larger galactic latitude ($b = + 51°$) than the axis 2 ($b = - 23°$). Consequently the dispersion σ_1 is more dependent than the dispersion σ_2 on the objects situated in low galactic latitudes, and the corresponding value of ϑ_2 then becomes larger.

In the present investigation systematic errors of another kind will also occur. If the two components of a double system are situated very close together, it is generally very difficult to decide whether the system is a double one or not. Small values of the apparent distances x and y thus are underrepresented in the material. This clearly appears when we investigate the distribution of all the numerical values of x and y. This distribution is given in Fig. 33. The different class frequencies have been smoothed by a curve, which fairly well agrees with a normal error curve.

The class frequency corresponding to the values of x or y equal to $0'.0 — 0'.2$ is too small. This will cause the dispersion of the distribution to assume too large a value. The observed dispersion amounts to $1'.22 \pm 0'.03$. If, in the above class, the observed frequency is replaced by the frequency given by the smoothed curve, the dispersion gets the value $1'.18 \pm 0'.02$.

Thus the above systematic effects will influence the final dispersions σ_1, σ_2 and σ_3 in such a way that somewhat too large values are obtained. The errors introduced are, however, very small, and they may be neglected.

61. The three final dispersions σ_1, σ_2 and σ_3 have been expressed with the quantity $\sqrt{k/\vartheta_2}$ as a unit. Here k is a constant and ϑ_2 denotes the average value $\overline{\left(\frac{1}{r^2}\right)}$. If the value of ϑ_2 can be found, the three dispersions can be given in absolute units.

If, in the solid angle ω, the density function is denoted by $D(r)$, ϑ_2 can be expressed in the following way:

$$(78) \qquad \vartheta_2 = \frac{\int_{r_1}^{r_2} \frac{1}{r^2} \cdot \omega r^2 D(r)\, dr}{\int_{r_1}^{r_2} \omega r^2 D(r)\, dr}.$$

Here r_1 and r_2 denote the distances between which the objects in question are situated. If we assume that the density function has a constant value, the following expression is obtained:

$$(79) \qquad \vartheta_2 = 3 \frac{r_2 - r_1}{r_2^3 - r_1^3}.$$

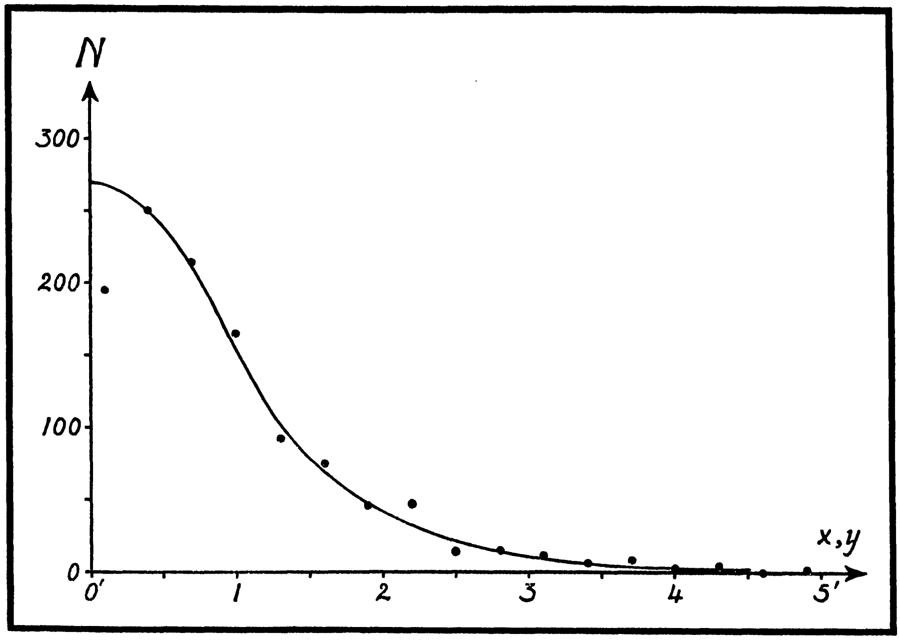


Fig. 33.
Distribution of the apparent distances x and y.

Now we will try to determine the distances r_1 and r_2 by means of the corresponding apparent magnitudes m_1 and m_2. The material given in the present catalogue seems to be complete down to the apparent magnitude $14^m_.5$. It is, of course, difficult to find an "effective" limiting magnitude corresponding to the material used in the present investigation. It seems, however, justified to assume a value of $15^m_.0$. We beg to refer to Table 9 (Chapter VIII), where the distribution of the magnitudes is given. Thus we have:

$$m_1 = 12^m_.95$$

$$m_2 = 15^m_.0.$$

The average values of the distances r_1 and r_2 can now be determined by means of the same procedure that was used in determining the spatial arrangement of the galaxies. We beg to refer to Fig. 23 (Chapter VIII), where the transformation of the apparent magnitude into the distance is illustrated.

Now the absolute values of the dispersions can be given. Two sets of values are computed, corresponding to an average absolute magnitude of the galaxies equal to $-14^M_.0$ and to $-15^M_.0$ respectively. In these values the galactic absorption effects are, however, to be included.

$\overline{M} = -14^M_.0$:		$\overline{M} = -15^M_.0$:	
$\sigma_1 =$	$2.2 \cdot 10^3$ parsecs	$\sigma_1 =$	$3.5 \cdot 10^3$ parsecs
$\sigma_2 =$	$2.0 \cdot 10^3$	$\sigma_2 =$	$3.2 \cdot 10^3$
$\sigma_3 =$	$1.5 \cdot 10^3$	$\sigma_3 =$	$2.4 \cdot 10^3$.

The absolute distance in space between the components of a double galaxy will now be denoted by r' and the corresponding dispersion by $\sigma_{r'}$. The dispersion can be expressed in the following way:

$$\sigma_{r'}^2 = \sigma_1^2 + \sigma_2^2 + \sigma_3^2. \tag{80}$$

In Fig. 34 (left curve) the distribution of r', expressed in parsecs, has been given in the form of a normal error

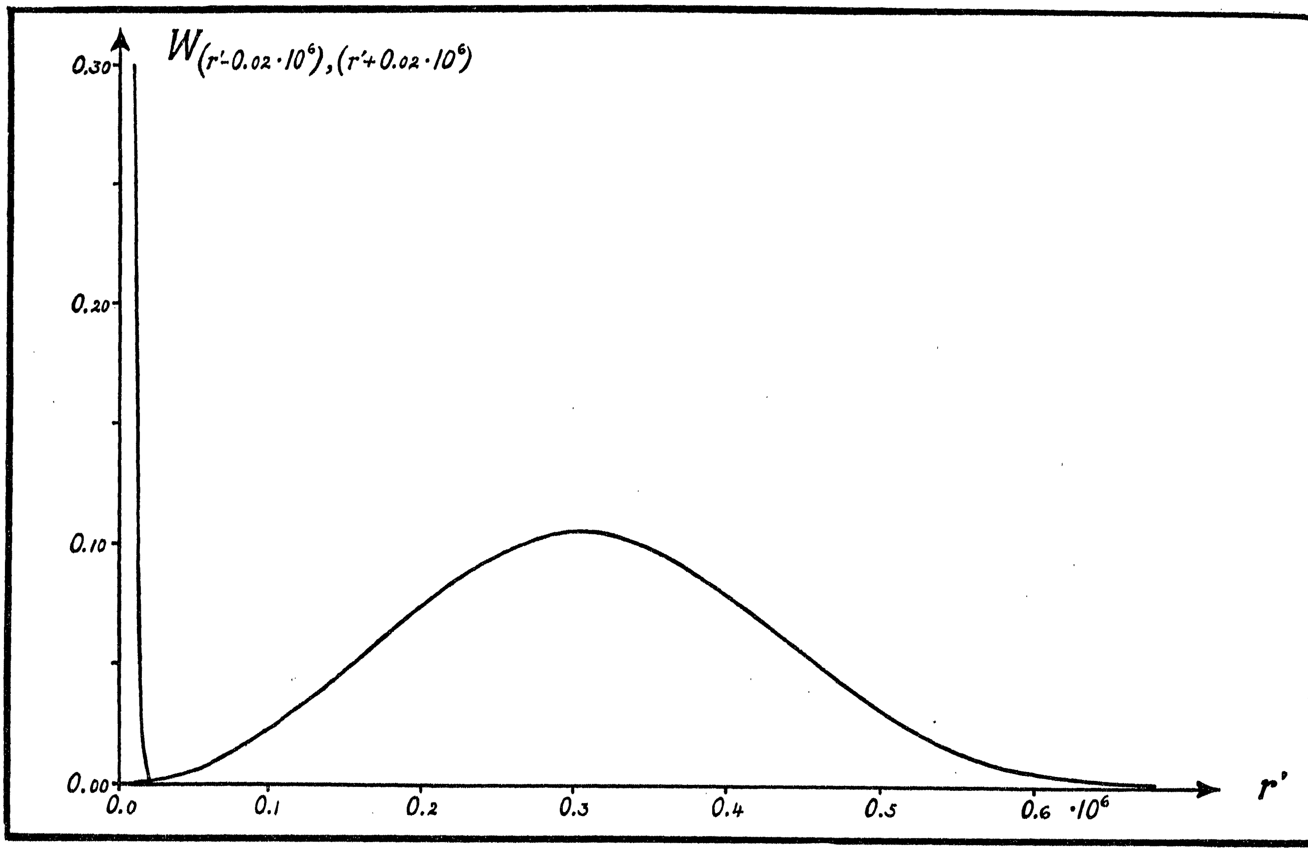


Fig. 34.

The distributions of the absolute distances between the components of physical pairs (left curve) and between isolated galaxies (right curve).

curve. The upper part of the curve falls, however, outside the frame of the figure. The dispersion $\sigma_{r'}$ has been given the value of $5.3 \cdot 10^3$ parsecs, which corresponds to $\overline{M} = -15.^{M}0$. The class breadth amounts to $40 \cdot 10^3$ parsecs.

The right curve in the figure is valid for single galaxies. The quantity r' in this case means the absolute distance from a given galaxy to the nearest one in space. In accordance with the results obtained in the investigations of the spatial arrangement of the galaxies[1], the left curve in the figure has been reduced to a number of individuals equal to 0.22, while the right curve corresponds to the number 0.78. Thus the figure given here corresponds to Fig. 2 (Chapter II), where the distributions of the corresponding apparent distances are given.

[1] See Chapter VIII.

The probability $W_{(r' - 0.02 \cdot 10^6), (r' + 0.02 \cdot 10^6)}$ that the nearest galaxy will be situated within the distances $(r' - 0.02 \cdot 10^6)$ and $(r' + 0.02 \cdot 10^6)$ parsecs has been computed in accordance with the derivations given by G. PÓLYA.[1] This implies that the space distribution of the galaxies is considered as an accidental one. The average value of the space density must be known. From Fig. 24 (curve III) an approximate value of $5.5 \cdot 10^{-18}$ galaxies per cubic parsec is obtained, and this value is used here.

Several important conclusions can be drawn from the above figure. Thus it is evident that the double and multiple galaxies form a very distinct group. The area that is common to the two curves given in the figure is exceedingly small. The average distance between the components of a double system amounts to about 4000 parsecs. The average distance from a certain single galaxy to the nearest one in space is nearly a hundred times as large. According to the figure this average distance amounts to 310000 parsecs.

CHAPTER XII

FORMATION OF DOUBLE GALAXIES—ESTABLISHMENT OF A METAGALACTIC TIME-SCALE

62. The problem how to explain the formation of double and multiple galaxies is of very great importance for our conception of the great system of galaxies, the metagalactic system, and of the processes taking place in it. Two possibilities are given *a priori*. The double objects may be formed from single galaxies by means of some processes of splitting. On the other hand, captures may be a common phenomenon among the constituents of the metagalactic system. In the present chapter it will be shown that the latter procedure is probably for the most part, or entirely, responsible for the formation of double and multiple galaxies. Further, it will be discussed how the frequencies of these captures may be used as a basis for establishing a metagalactic time-scale.

In the great similarity between single galaxies and components of double and multiple systems we have strong evidence that these two classes of objects are of the same nature. Earlier in this paper[2] we discussed the types, according to WOLF's classification, of the galaxies given in this catalogue. It was shown that among the double and multiple objects the same types are to be found as those characteristic of galaxies in general. Further, it was shown[3] that double and multiple galaxies agree very well with single objects as regards the average values and the dispersions of the absolute luminosities and of the absolute dimensions. It was even indicated that the former objects represent a somewhat larger absolute luminosity and larger dimensions than the latter. The above observational facts thus suggest that the galaxies, whether they form part of double or multiple systems or not, are comparable as regards apparent and absolute properties.

From the above discussion it seems very reasonable to assume that the double and multiple galaxies are formed by captures. Some further evidence will be given below. It will be shown that the relation between the observed density function of double objects and the same function of galaxies in general is in very good

[1] AN 208, p. 175 (1919). [2] See Chapter IX. [3] See Chapter VII.

agreement with some theoretical expressions derived on the basis of the assumption that double objects are formed by captures. Thus, the capture theory seems to be able to explain everything that has been observed concerning the double galaxies. Of course, we should not leave out of account that under certain circumstances a galaxy may split into two or more separate parts. These cases seem, however, to be of very little statistical importance.

63. As early as 1922 C. V. L. CHARLIER[1] made some investigations into the number of encounters taking place within the system of galaxies. Using a formula of C. MAXWELL based on the principles of statistical mechanics he computed the frequency of "collisions" between galaxies. It was found that approximately one "collision" takes place per 1000 years. CHARLIER states that this is an unexpectedly high number, but he points out that on photographic plates he has found many examples of two galaxies being about to enter upon such "collisions". We may assume that the latter objects represent objects of the same kind as are here called double galaxies. CHARLIER does not seem to have drawn the conclusion that the encounters will cause the formation of double galaxies. Rather he means that the two objects become intermingled with each other and are transformed into a spiral conglomeration.

Later on K. LUNDMARK[2] discusses in detail the capture effects to be found within the metagalactic system. The total number of encounters, or "collisions", is found to be approximately one per 3500 years. From this LUNDMARK draws the conclusion that we ought to have a great many physically connected double galaxies. Further, he points out that when two galaxies have formed a physical system, they will then act as a condensation nucleus attracting new members. In this manner the large clusters of galaxies may be successively built up. According to LUNDMARK, a metagalactic time-scale may be based on a study of metagalactic clusters. It is found that the formation of some of the clusters should correspond to an interval of time at most amounting to 10^9 years.

64. Now we will take the material given in the present catalogue into consideration. Earlier in this paper[3] the density function of double and multiple galaxies was investigated. It was shown that the distribution in space of these objects is related in a certain manner to the distribution of galaxies in general. Both the distributions correspond to a local metagalactic cloud. Double galaxies give, however, a smaller and more condensated cloud than galaxies in general. We beg to refer to Fig. 24, where the numerical values of the density functions have been illustrated. By starting from the assumption that double galaxies are formed by captures we will try to explain the above deviations.

In accordance with the investigations by CHARLIER and LUNDMARK mentioned above, the following formula, first given by C. MAXWELL and later on discussed by CHARLIER[4], may be used as a simple starting-point:

$$N = \sqrt{2}\,\pi\, d^2 n^2\, \overline{W}. \tag{81}$$

Here N denotes the number of collisions per unit of space and time for spherical bodies moving with the average peculiar space velocity $\overline{W}$. The diameter of the bodies equals d, and n means the density, or the number of bodies per unit of space. The formula is founded on the principles of statistical mechanics, and we have assumed the motions of the bodies to have a random distribution.

According to formula (81) the number of encounters is proportional to the square of the number of bodies

---

[1] Lund Medd I, No 98 (1922). [2] Upsala Medd 30 (1927) and Lund Circ 9 (1934). [3] See Chapter VIII.
[4] Lund Medd II, No 16 (1917).

in a unit of space. Thus, the frequency of encounters is highly dependent on the density function of the objects. If the formula is to be applied to the system of galaxies, the question arises how to treat a possible expansion of the universe. The systematic red shifts observed in the spectra of anagalactic objects indicate large velocities of recession. If this expansion is a real effect, the total number of objects in a unit of space will be dependent on time, and in the same manner the number of encounters. Thus, such an expansion will in a very high degree influence the results to be obtained in the present investigation. In order to eliminate these large uncertain effects and in order to simplify the following derivations, we will in this connection consider the systematic red shifts in the spectra of the galaxies as an apparent effect. Thus we adopt a system of galaxies that agrees with CHARLIER's theory of an infinite universe.

In order to make formula (81) more suitable for the present purpose we may introduce some new denotations. The total number of systems, at the time t, in a unit of space situated at the distance r and within a certain solid angle will be denoted by $S(t, r)$. As a system we will here consider a single, a double or a multiple galaxy. The total number of collisions, or rather encounters, that have taken place within the same unit of space before the epoch t will be denoted by $E(t, r)$. In this manner the above formula can be transformed into the following one:

(82) $$E'_{(t)}(t,r)\,dt = f_{t,r}\bigl(S(t,r)\bigr)^2\,dt.$$

Here $f_{t,r}$ is a factor depending on the values of the absolute diameters and of the absolute space velocities to be found within the unit of space in question at the time t. A small approximation is introduced, since we have assigned to double and multiple objects the same possibilities of encounters as to single galaxies. As, however, the former objects must have somewhat smaller space velocities, and since they are comparatively few in number in comparison with single galaxies, the errors introduced are certain to be small.

We will now define an epoch t_0 representing the moment when the formation of double galaxies started:

(83) $$E(t_0, r) = 0.$$

Provisionally we may assume that such an epoch has a real meaning. Anyhow, we will use the quantity t_0 as a parameter in the following computations.

We now arrive at the following relation:

(84) $$S(t,r) = S(t_0,r) - E(t,r).$$

This formula implies that every encounter passes into a capture. In individual cases, it is of course very difficult, or perhaps impossible, to decide whether an encounter leads to a capture or no. These effects will to some extent be discussed below. Here we should only like to point out that the above condition may be fulfilled by giving the factor $f_{t,r}$ a small enough value.

By means of the above transformations we arrive at the following integral equation:

(85) $$\int_{t_0}^{t_1} \frac{E'_{(t)}(t,r)\,dt}{\bigl(S(t_0,r) - E(t,r)\bigr)^2} = \int_{t_0}^{t_1} f_{t,r}\,dt.$$

In this equation the present moment is denoted by t_1. If we assume the factor $f_{t,r}$ to be independent of time, which implies that the conditions, as regards the diameters and the peculiar space velocities of the galaxies, have remained unchanged during the interval of time in question, we are able to solve the above equation:

$$\frac{1}{S(t_0, r) - E(t_1, r)} - \frac{1}{S(t_0, r)} = f_{t_1, r}\,(t_1 - t_0). \tag{86}$$

The above formula expresses the relation between the interval of time $(t_1 - t_0)$, during which the double and multiple galaxies have been formed, and the two density functions $S(t_0, r)$ and $E(t_1, r)$. However, we must not forget that several assumptions were made above. Among other things we have assumed that the peculiar motions of the galaxies are not directed but have an accidental distribution. Of course, this may be subject to criticism. Clusters and groupings are very common phenomena within the metagalactic space, and the formation of these agglomerations will influence the space velocities of the galaxies in a high degree. On the other hand, it may be pointed out that, according to K. LUNDMARK[1], the metagalactic clusters are formed gradually through processes of condensation. Thus, the age of these clusters may have a small value in comparison with the total age of the metagalactic system.

With regard to the assumptions made in the above derivations we should like to introduce the conception *effective age of the metagalactic system* to represent the interval of time $(t_1 - t_0)$ that is defined in formula (86). This effective age thus corresponds to the interval of time during which the total number of double and multiple galaxies has been formed, if we assume the motions of the galaxies to have an accidental distribution and if the general conditions within the metagalactic system have remained unchanged during the time in question.

We may now use the material given in the present catalogue for the application of formula (86). The two functions $S(t_0, r)$ and $E(t_1, r)$ can be expressed as follows:

$$\begin{aligned} S(t_0, r) &= D_1(r) + 2\,D_2(r) + 3\,D_3(r) + \cdots = D(r) \\ E(t_1, r) &= D_2(r) + 2\,D_3(r) + 3\,D_4(r) + \cdots \cong 1/2\left(2\,D_2(r) + 3\,D_3(r) + \cdots\right). \end{aligned} \tag{87}$$

Here $D_n(r)$ denotes the observed density function as regards multiple systems with n components, i. e. the present number of these systems per unit of space. The ordinary density function is denoted by $D(r)$. The approximation introduced in the second expression is of no great importance, since the number of triple systems is small in comparison with the number of double systems. The number of systems with more than three components is still smaller. In Chapter VIII of this paper the functions $D(r)$ and $\left(2\,D_2(r) + 3\,D_3(r) + \cdots\right)$ have been determined. Some illustrations were given in Fig. 24. Thus, it is possible for us to obtain some numerical values of the functions $S(t_0, r)$ and $E(t_1, r)$.

In Table 20 the resulting values of the quantity $f_{t_1, r}\,(t_1 - t_0)$ have been given. In the first column we have the distance, expressed in parsecs, towards the North Galactic Pole. This distance, r, is the same as that given in Fig. 24. It is very remarkable that the values given in the second column are practically the same, although, according to Fig. 24, the values of the density functions change considerably within the same distance interval. Thus, the density functions become 2.5 and 4.5 times smaller resp., when the distance changes from $1.5 \,.\, 10^6$ to $4.5 \,.\, 10^6$ parsecs. If the value of the factor $f_{t_1, r}$ can be considered as constant within the distance interval in question, the values of the above table give strong support to the correctness of the assumptions hitherto

[1] Lund Circ 9 (1934).

made. Since the distance interval is comparatively small it seems justified to assign a constant value to the factor $f_{t_1, r}$. This question will, however, be somewhat discussed below.

Before proceeding further we will once more go back to Fig. 24. In this figure the full curve I gives the density function of double and multiple galaxies while the full curve II corresponds to the observed density function of galaxies in general. Since the latter curve was obtained by means of the SHAPLEY-AMES survey, it only corresponds to galaxies brighter than $13^m.0$. By means of curve I and by means of the assumption that the average value of the factor $f_{t_1, r}$ given in Table 20 is valid also for larger distances, we obtain the dotted curve III as a continuation of curve II. When further observational data become accessible, it will be possible to decide whether the extrapolated piece of curve has a real meaning or no.

Table 20.

Numerical values of the quantity $f_{t_1, r}\,(t_1 - t_0)$.

r	$f_{t_1, r}\,(t_1 - t_0)$
$1.5 \cdot 10^6$	$2.3 \cdot 10^{16}$
$2.5 \cdot 10^6$	$2.2 \cdot 10^{16}$
$3.5 \cdot 10^6$	$2.0 \cdot 10^{16}$
$4.5 \cdot 10^6$	$2.5 \cdot 10^{16}$
Mean value $2.25 \cdot 10^{16}$	

65. In order to obtain a numerical value of the *effective age*, $(t_1 - t_0)$, of the metagalactic system, we must try to determine an average value of the factor $f_{t_1, r}$. This quantity may be expressed in the following way:

$$f_{t_1, r} = \sqrt{2}\,\pi\,P^2\,\overline{W}. \tag{88}$$

In this expression the diameter of the objects has been replaced by the absolute distance P. This distance may be defined in such a way that, on an average, an encounter results in a capture only when the two objects pass one another closer than the distance P. Of course, this distance depends on the type of the objects and on their space velocities. Yet it may be possible to determine an average value. Properly, we ought to distinguish between the real distance between the components at the closest approach, and the corresponding distance that is obtained if the gravitational forces between the two objects are neglected. The latter distance should be used in the above formula. In this case the difference between these two distances is, however, small. The denotation $\overline{W}$, used in the above formula, still refers to the average peculiar space velocity of the galaxies.

We may first take the average space velocity into consideration. This velocity can be determined by means of the observed radial motions of the galaxies. The peculiar radial velocities are obtained from the spectral shifts corrected for the systematic red shift depending on the distance. In a recently published paper E. P. HUBBLE[1] made a detailed investigation of the peculiar radial motions of the galaxies. It was found that the dispersion among these velocities amounts to about 200 km/sec. This value is, however, valid only for galaxies in the general field. As regards members of the Virgo cluster, HUBBLE points out that we may perhaps assume a value three times as large. This is very remarkable, since we should expect these objects to have smaller peculiar motions. If we assume the peculiar velocities to be distributed at random, the above value of 200 km/sec corresponds to an average space velocity of 320 km/sec.

In this connection it may be remarked that there are some indications that the peculiar radial velocities of the galaxies are dependent on the distance. Thus, J. H. OORT[2] pointed out that the velocities seem to be somewhat larger for galaxies fainter than the 12th or 13th visual magnitude. He suggested that this could be explained by assuming the existence of a large, local cloud of galaxies. The members of this cloud might have smaller peculiar velocities than the outside galaxies. Here we will not take possible deviations of the above

[1] Mt Wilson Contr 549 = ApJ 84, p. 270 (1936). [2] BAN 6, p. 155 (1931).

kind into consideration, since, in the present investigation, only galaxies brighter than the 13th photographic magnitude are included.

At this place we may also devote some attention to the question of the equipartition of energy within the system of galaxies. If an equipartition exists, the velocity of an object will depend on its mass. This problem was discussed in Chapter VII of this paper in connection with some other statistical investigations into double galaxies. It was found that, at the present moment, no definite answer could be given to the question whether an equipartition has taken place or no. Anyhow, we may assume that, originally, the velocities of the objects were independent of their masses.

We will now pass on to a discussion of the value to be assumed of the distance P. The investigation of the absolute dimensions of the orbits of double galaxies[1] showed that the average distance between the components of a double system amounts to about 4000 parsecs. If we start from this value it is possible to determine the approximate size of the distance P. Since P means the distance between the components at the moment when the capture takes place, and since the orbits of double galaxies must be assumed to be more or less elongated, the value of P must be smaller than 4000 parsecs. If we assume that the eccentricity of the orbits on an average amounts to $^1/_2$, it seems justified to adopt a value of 2000 parsecs to represent an approximate value of the distance P. If the diameter of the galaxies amounts to 2000 parsecs, every encounter that takes place according to the above definition will cause the objects to come into contact with one another.

66. Up till now we have not taken into consideration the effects that cause an encounter to become a capture. If the galaxies behave like rigid bodies no capture can take place. Each of the two objects will describe a hyperbolic orbit about the centre of gravity of the two. The eccentricity of this orbit will depend on the masses and the velocities of the objects and on the closeness of the approach. However, we must assume that large disturbing tidal forces are active between the galaxies at the moment of closest approach. These tidal phenomena may cause the hyperbolic orbit to change into an elliptic one. As our knowledge of the masses of the galaxies and of the distribution of matter within them is very small, it is difficult to decide whether a certain encounter will pass into a capture or no.

In Table 21 some values are given of the total angle of deflection[2] of either orbit caused by the encounter,

Table 21.

Total angle of deflection of either orbit corresponding to different values of masses and of relative space velocities.

ΔW \ $\mathfrak{M}$	$10^8 \odot$	$5 \cdot 10^8$	10^9	$5 \cdot 10^9$	10^{10}	$5 \cdot 10^{10}$	10^{11}	$5 \cdot 10^{11}$
100 km/sec	4°.9	24°	46°	130°	154°	175°	177°	179°
200	1.2	6.1	12	56	94	159	169	178
300	0.6	2.7	5.5	27	51	134	156	175
400	0.3	1.5	3.1	15	30	107	139	171
500	0.2	1.0	2.0	9.8	19	81	120	167
600	0.1	0.7	1.4	6.8	14	62	100	161

[1] See Chapter XI. [2] These values have been computed by means of some formulae given by J. H. Jeans, Astronomy and Cosmogony, Cambridge (1928).

if we assume the two galaxies to behave like rigid bodies. These values have been computed for different values of the mass, $\mathfrak{M}$, of the galaxies and for different values of the relative space velocity, ΔW. It has been assumed that the masses of the two galaxies have the same size, and that the smallest distance (if gravitation is neglected) between the objects amounts to 2000 parsecs, or the same value that was assumed above for the quantity P. From the table it immediately appears how large deflections can be obtained. The value of the deflection mainly depends on the masses of the galaxies. If the mass value is not too small, a deflection angle of ninety degrees, or more, is easily obtainable. Thus it is not surprising that the additional tidal forces should effect a capture.

Concerning the mass values given in the table some remarks may be given. Our knowledge as regards average masses of the anagalactic objects is comparatively small. It is, however, possible to give some approximate values. The mass of our own galaxy can be determined by means of the observed galactic rotation effects. Thus, B. LINDBLAD[1] has derived a value of $1.6 \cdot 10^{11} \odot$. In a recently published paper, L. BERMAN[2] investigated the galactic rotation from the data of the planetary nebulae and found a value of $2.3 \cdot 10^{11} \odot$. For other galaxies the mass values can be determined by means of the observed radial velocities. Thus K. LUNDMARK[3] has made use of some determinations of spectroscopic rotation. For four galaxies an average mass value of about $10^{11} \odot$ was obtained. The individual values range, however, from $1.8 \cdot 10^{9} \odot$ to $7.6 \cdot 10^{11} \odot$. Further S. SMITH[4] used the observed radial velocities to determine the masses of the members of the Virgo cluster and found an average value of $2 \cdot 10^{11} \odot$. By means of the mass-luminosity relation, E. P. HUBBLE[5] has obtained a mean mass of the galaxies amounting to about $10^{9} \odot$. This value is founded on an average absolute magnitude of $-14^{M}.5$. By taking the large absorption effects[6] within the galaxies into consideration and by assuming a brighter absolute magnitude it seems, however, possible to increase this value considerably.

At this point it may be remarked that it is possible to derive an average mass value by means of the double galaxies given in the present catalogue. Concerning some of the double systems, radial velocities have been measured for both components. Assuming the two galaxies to move in elliptic or circular orbits around the centre of gravity we are in this case able to determine an average mass value. In Table 22 some numerical values are given. Here No denotes the number of the present catalogue and V means the radial velocity as determined by M. L. HUMASON and S. SMITH[7] at Mt Wilson. Only such systems as are given in the present

Table 22.

Radial velocities of double and multiple galaxies.

No	NGC	V	V'
17 a	224	− 220 km/sec	
b	221	− 185	35 km/sec
c	205	− 300	80
212 a	3379	+ 810	
b	3384	+ 850	20
246 a	3627	+ 650	
b	3623	+ 800	75
397 a	4382	+ 500	
b	4394	+ 850	175
413 a	4472	+ 850	
c	4467	+ 1600	375
526 a	5194	+ 270	
b	5195	+ 300	15
719 a	5982	+ 2900	
b	5985	+ 2600	150
			$\overline{V'}$ = 116 km/sec

[1] Handbuch der Astrophysik, Band V: 2, p. 1068 (1933). [2] Lick Bull 486 (1937). [3] Upsala Medd 40 (1928).
[4] Mt Wilson Contr 532 = ApJ 83, p. 23 (1936). [5] Mt Wilson Contr 485 = ApJ 79, p. 8 (1934). [6] Cf. Chapter X.
[7] Cf. Handbuch der Astrophysik, Band VII, p. 553 (1936). The values given for NGC 5194, 5195 have, however, been determined by V. M. SLIPHER. Cf. Pop Astr 30, p. 9 (1922).

catalogue are included in the table. It is true that it is possible to increase the material by including other systems. However, these systems do not in general fulfil the definition of a double galaxy used in the present paper, and thus we have preferred not to take them into consideration here. Some of the double galaxies given in Table 22 form in fact part of multiple systems. The objects given in the table are, however, always the two brightest components and we may assume that their masses are large in comparison with the masses of the other components. Thus, the disturbances produced by the faint components will be neglected, and we have only to solve a problem of two bodies. As regards system No 413, it seems probable that component c is brighter than component b, especially when we take the magnitude values obtained in the Harvard surveys into consideration. Concerning the Andromeda galaxy, we may assume that the elliptical components move around the principal object approximately independently of one another.

In the last column of the above table the numerical value of the radial velocity V', measured relative to the centre of gravity of the system, is given. In the computation of this velocity it has been assumed that the masses of the components of the double galaxy have the same value. As regards system No 17 we have, however, assumed that the centre of gravity is situated within the principal component, the Andromeda galaxy. It appears that the average value of the above velocity amounts to 116 km/sec.

Between the velocity V' and the orbital velocity, v, of the components of the double galaxy the following average relation is valid:

(89)
$$\overline{V'} = \bar{v} \cdot \overline{\cos\varphi}\ \overline{\cos\psi}.$$

In this equation φ is the angle between the orbital radius and the line of intersection between the orbital and the celestial plane. The angle between the line of sight and the normal of the orbital plane amounts to $(90°-\psi)$. If we assume a random distribution the average values of these angles can be expressed as follows:

(90)
$$\overline{\cos\varphi} = \frac{\int_0^{\pi/2} \cos\varphi\, d\varphi}{\int_0^{\pi/2} d\varphi} = \frac{2}{\pi} \qquad \overline{\cos\psi} = \frac{\int_0^{\pi/2} \cos^2\psi\, d\psi}{\int_0^{\pi/2} \cos\psi\, d\psi} = \frac{\pi}{4}.$$

By starting from the average value of the orbital velocity obtained above we are now able to derive an average mass value. In Chapter XI it was found that the average distance between the components of double galaxies amounts to about 4000 parsecs. If the orbits are assumed to be circular we now arrive at the following value:

$$\text{Average mass of the galaxies} = 1.0 \cdot 10^{11} \odot.$$

By means of the double galaxies we have thus obtained a mass value that is in very good agreement with the values earlier derived. Of course the above value may be affected with some uncertainty because of the assumptions made. The material is still too small to permit a thorough statistical investigation. It may, however, be pointed out that in the present state of our knowledge of radial velocities and internal motions of the galaxies every attempt to determine the masses of these objects must be based on certain assumptions.

67. After this digression on the masses of the galaxies, we will pass on to the final determination of the interval of time (t_1—t_0) that was termed the effective age of the metagalactic system. If we give P the value of 2000 parsecs, and if the average peculiar space velocity is given the value of 320 km/sec, we obtain the following numerical value:

$$\textit{Effective age of the metagalactic system} = 4 \cdot 10^{12} \textit{ years.}$$

It may be pointed out that the mean value given in Table 20 and the relation given in formula (88) have been used for the derivation of the above value.

Thus, we have obtained a numerical expression of the interval of time that corresponds to the formation of the total number of double galaxies, if certain conditions, discussed above, are assumed to obtain. It must, however, be pointed out that the numerical values used in the above formulae and derivations cannot be considered definitive, and that uncertainties in these values will cause errors in the final time-scale. The values given in Table 20 imply an average absolute (photographic) magnitude of the galaxies of $-15^{M}.0$, since the density functions have been computed by starting from this value. If the average absolute magnitude is changed by half a magnitude, the above values of the density functions are to be multiplied or divided by the factor 2.00. On the other hand, the absolute distance P is, in this case, to be changed by a factor 1.26. In this manner the interval of time (t_1—t_0) will be changed by a factor 2.52. Further, the interval of time is inversely proportional to the value assumed of the average space velocity of the galaxies.

For these reasons the final value of $4 \cdot 10^{12}$ years may be affected with some uncertainty. It is a matter of course that no very exact determination of the effective age of the system of galaxies can be made in the present state of our knowledge of the internal conditions within this system. We may, however, conclude that the value obtained is probably of the true order of size, and we hope that it can be used as a basis for further investigations into the metagalactic time-scale.

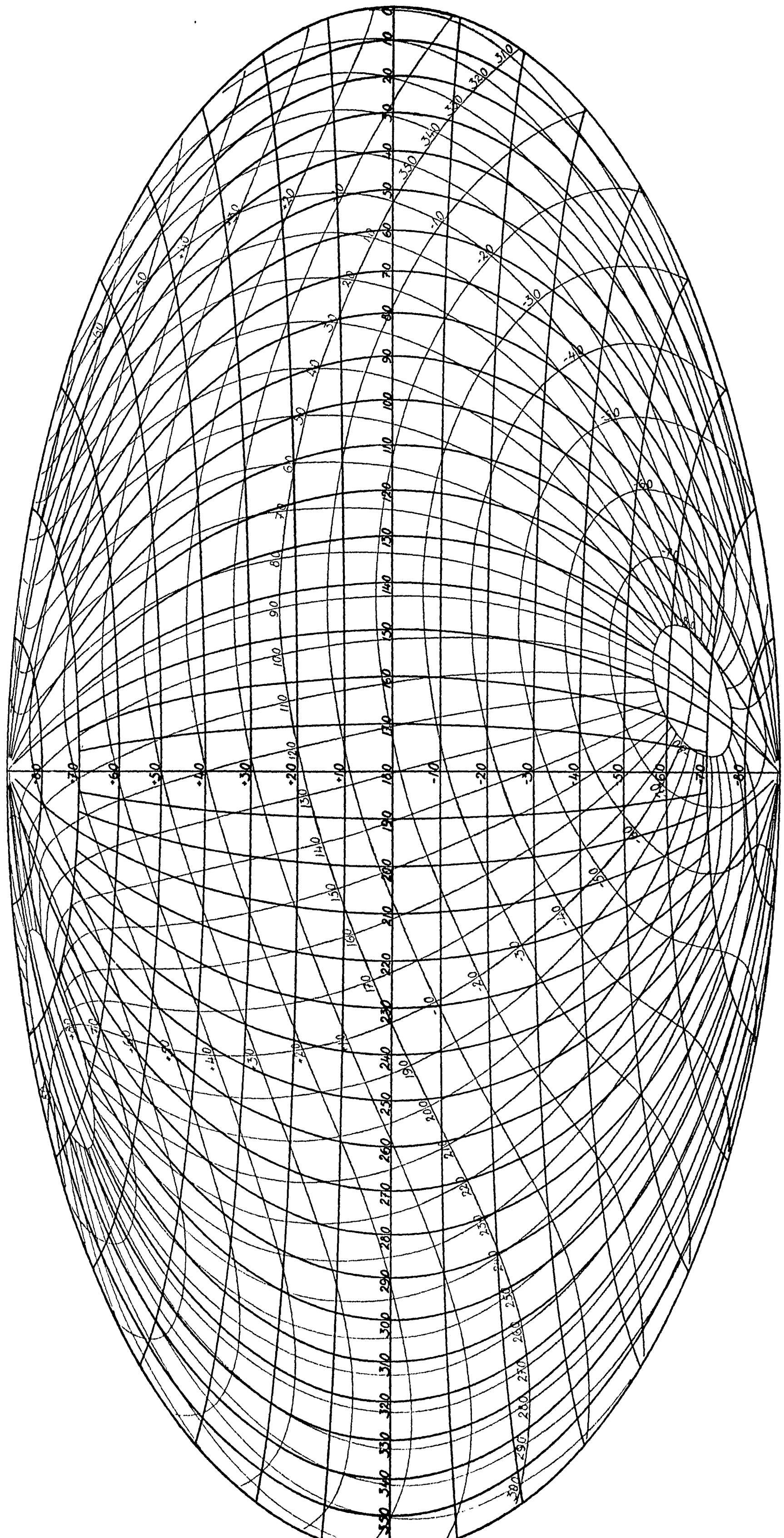


Fig. 35.

Diagram for the transformation of equatorial co-ordinates (black curves) into metagalactic co-ordinates (red curves). The metagalactic co-ordinates are based on LUNDMARK's pole ($\alpha = 323°$, $\delta = +66°.5$).

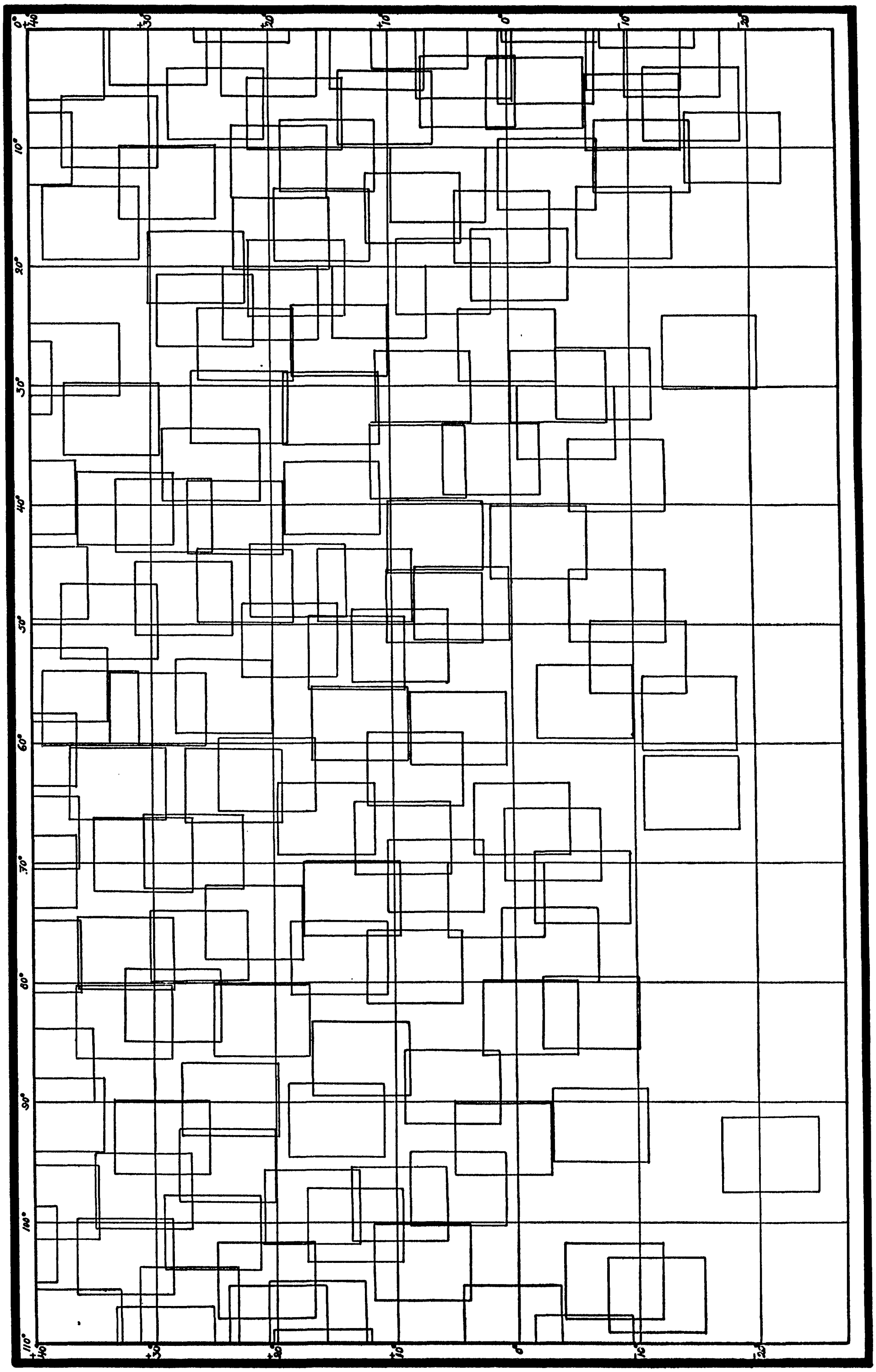


Fig. 36.

Equatorial distribution of the plates used for the present investigation.

14—37522.

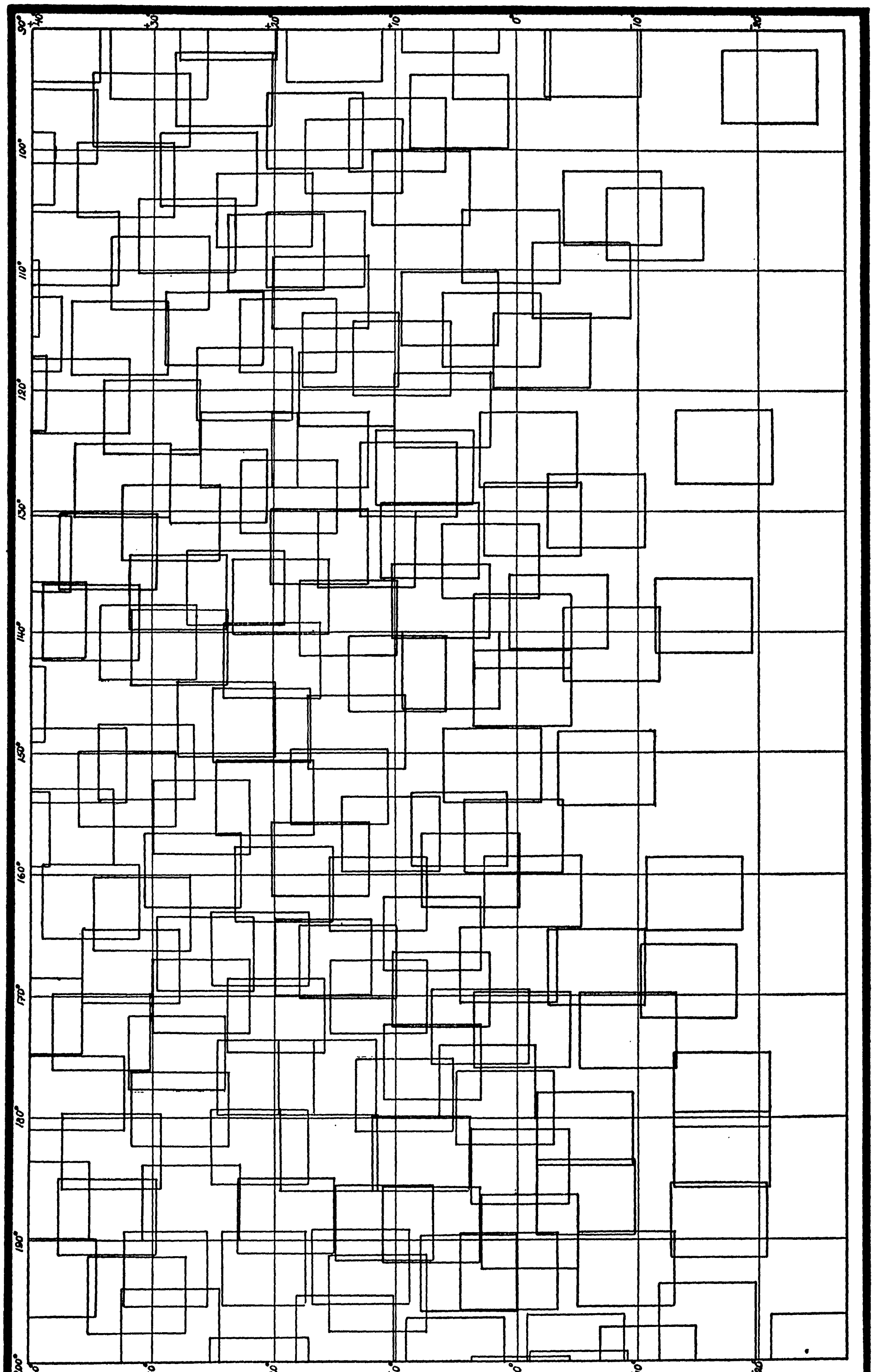


Fig. 37.

Equatorial distribution of the plates used for the present investigation.

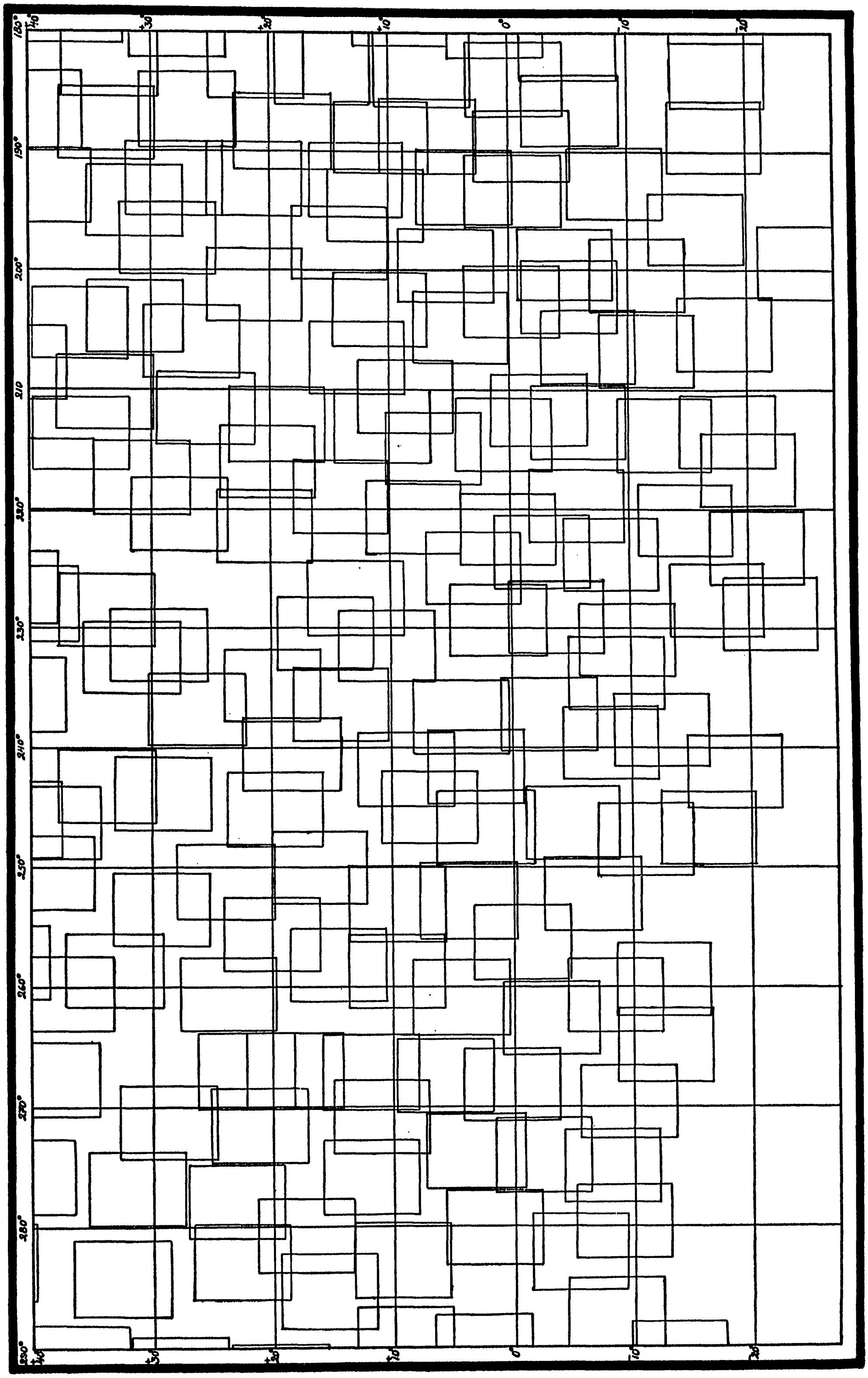


Fig. 38.

Equatorial distribution of the plates used for the present investigation.

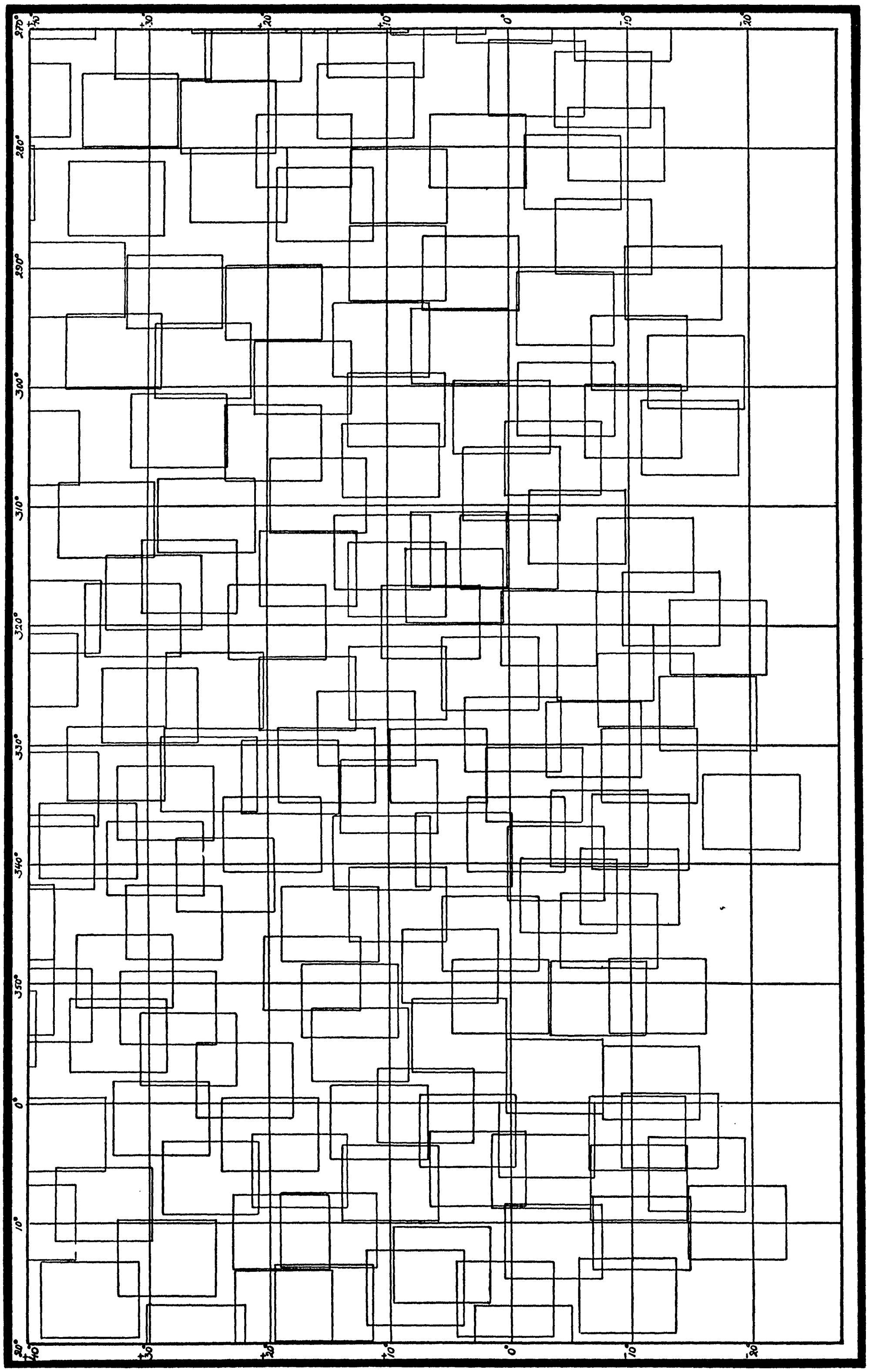


Fig. 39.

Equatorial distribution of the plates used for the present investigation.

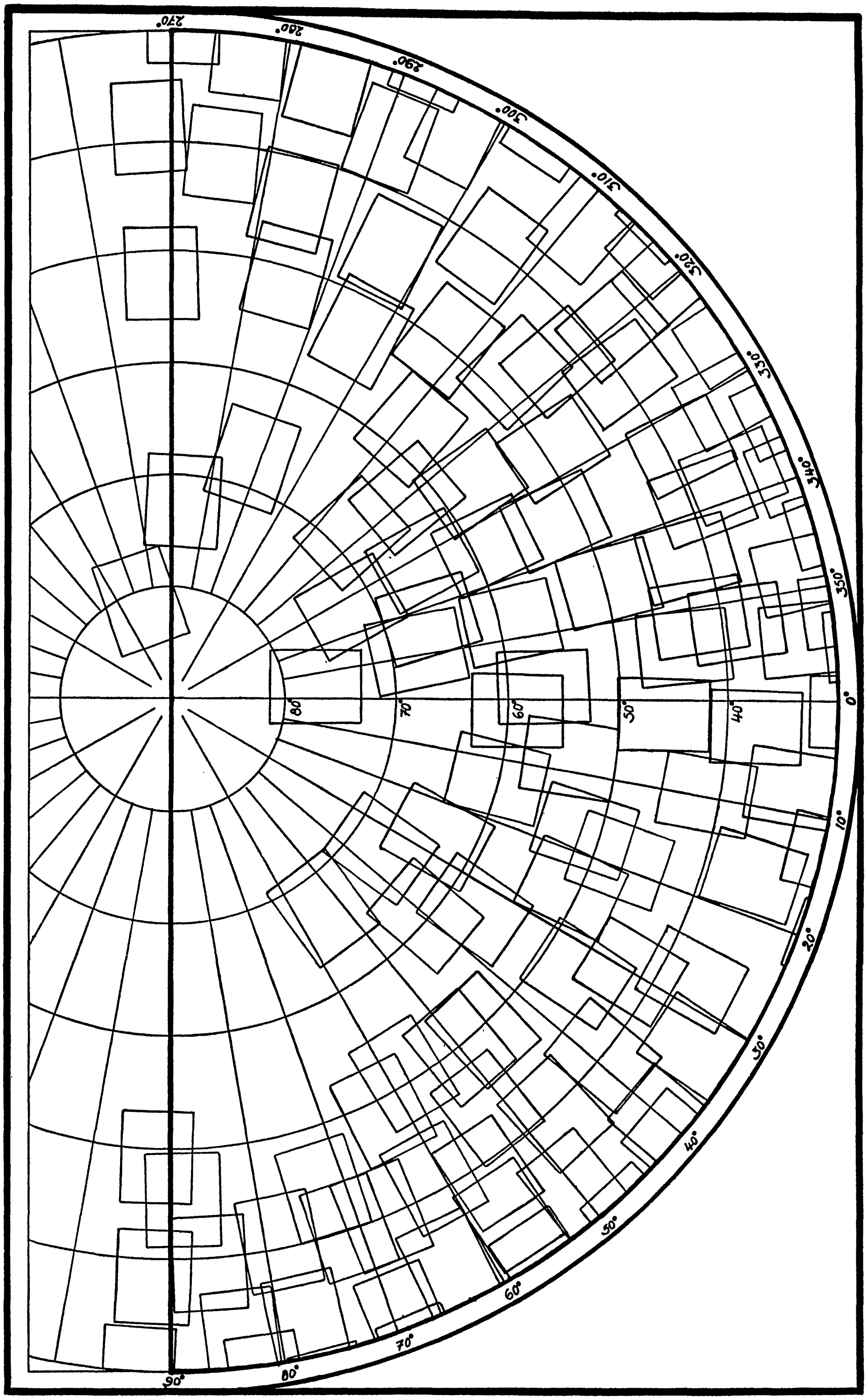


Fig. 40.
Equatorial distribution of the plates used for the present investigation.

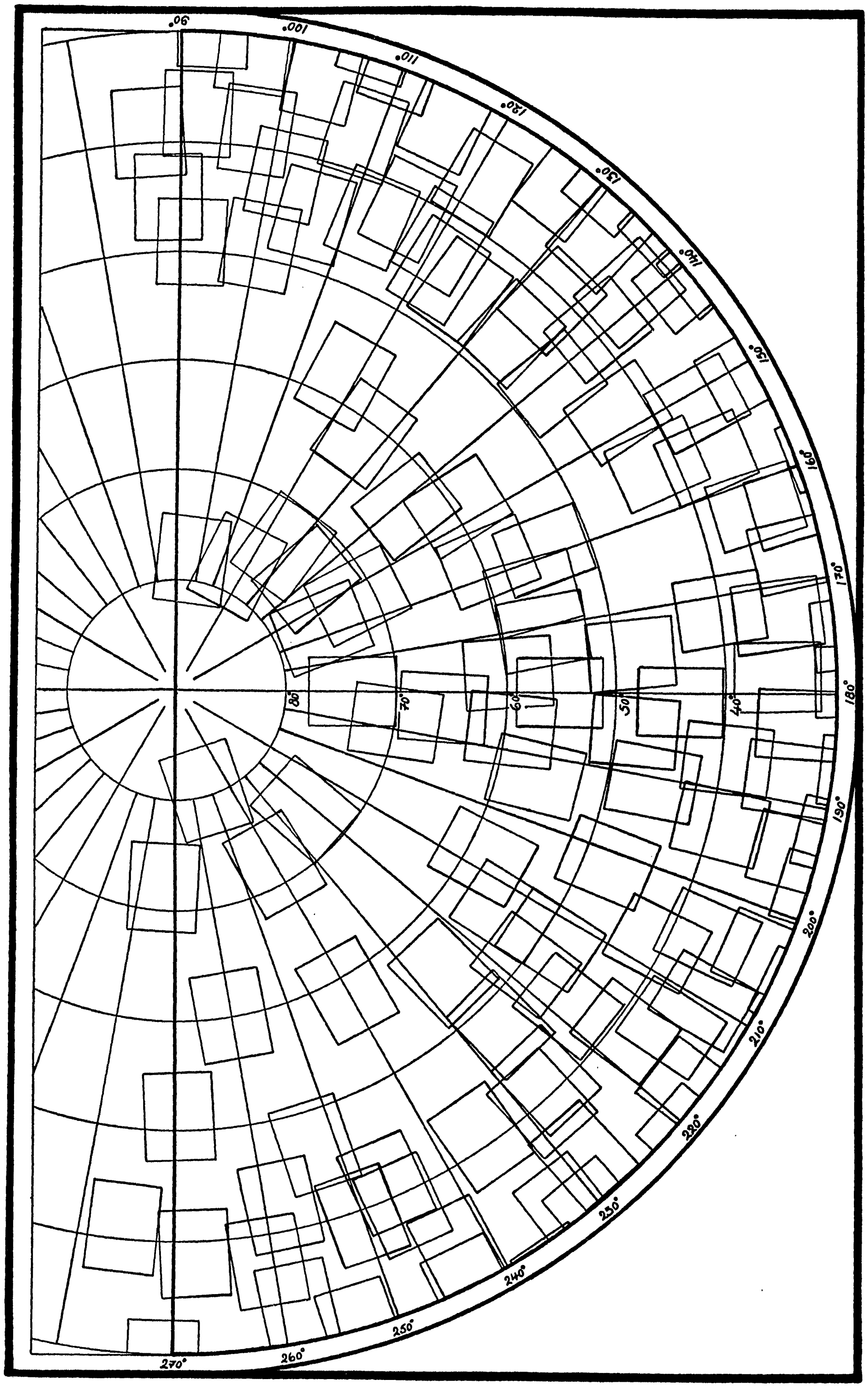


Fig. 41.

Equatorial distribution of the plates used for the present investigation.

APPENDIX I

LIST OF MAGNITUDES MEASURED IN PHOTOMETER

In the following list are included all the 155 galaxies which have been measured in the Zeiss thermo-electric photometer of the Heidelberg Observatory. The numbers (No) refer to the catalogue of double and multiple galaxies. The photometric magnitudes given here are discussed in Chapter V of the present paper.

No	*m*	No	*m*	No	*m*	No	*m*	No	*m*
5 a	$14^{m}.9$	123′ b	$15^{m}.3$	276 b	$14^{m}.7$	339 c	$12^{m}.9$	398 a	$13^{m}.9$
b	15.6	125 a	15.4	277 a	16.0	346 b	12.8	403 a	8.4
22 a	14.6	b	16.6	b	15.4	348 b	13.7	b	8.4
b	16.3	128 a	13.4	279 a	15.8	353 b	11.1	c	9.6
26′ a	13.5	130 a	12.1	b	16.4	c	12.5	d	10.4
b	13.6	b	12.3	280 a	15.3	d	14.0	e	10.5
29 a	15.3	c	15.4	b	16.3	360 b	13.8	f	10.5
b	15.6	d	15.7	283 a	16.0	c	14.3	g	14.2
30 a	14.7	132 a	15.1	b	16.1	361 a	13.3	h	15.9
b	14.8	b	15.8	308 a	14.1	b	16.5	405 a	15.5
33 a	15.4	211 a	14.0	b	13.2	364 a	14.0	b	13.1
b	15.8	b	16.4	c	13.5	b	16.6	c	13.3
52 a	15.3	c	16.7	d	15.0	376 a	9.9	408 a	12.7
b	16.5	214 a	16.2	312 a	12.8	b	10.2	b	10.4
54 a	14.4	b	14.1	b	14.6	381 a	12.6	c	12.1
b	14.1	c	14.6	316 a	15.5	b	13.0	409 a	9.4
c	15.0	216 a	14.5	b	17.1	385 a	10.3	b	9.5
65 a	14.5	b	16.0	318 a	12.9	b	15.7	411 a	9.8
b	15.2	220 a	14.3	b	13.1	387 b	10.9	b	10.6
104 a	12.6	b	16.0	319 a	16.8	c	13.8	492 a	13.2
b	15.4	240 a	9.2	b	16.9	d	13.9	b	13.9
106 a	13.9	b	10.2	322 a	14.5	e	15.0	493 a	15.2
b	15.2	c	12.5	b	16.2	f	14.9	500 a	14.6
113 a	12.9	246′ a	7.9	329 a	15.5	g	14 9	b	15.8
b	14.8	b	8.8	b	15.5	391 a	10.3	501 a	15.2
114 a	13.3	c	9.0	332 a	15.2	b	10.4	b	17.0
b	15.7	252 a	12.9	b	15.7	395 a	15.3	507 a	15.2
115 a	14.1	b	14.8	336 a	15.1	b	14.0	b	17.1
b	15.7	271 a	13.9	b	15.7	c	16.1	508 a	15.7
122 a	14.2	b	14.7	339 a	13.4	397′ a	6.9	510 a	12.6
b	14.8	276 a	12.5	b	12.1	b	8.8	511′ a	13.6

APPENDIX II

CATALOGUE OF NUCLEAR MAGNITUDES AND DIMENSIONS

In the following list are included all galaxies having well marked nuclei. The numbers (No) refer to the catalogue of double and multiple galaxies. The major and the minor diameter of the nucleus are denoted by a and b resp. They are given in *tenths of minutes of arc.* The apparent magnitude of the nucleus is denoted by m_n and the apparent total magnitude of the galaxy by m_t. The difference between these two magnitude values has been estimated for all objects given in the present list. The total number of objects is 236.

No	$a \times b$	$m_n - m_t$	No	$a \times b$	$m_n - m_t$	No	$a \times b$	$m_n - m_t$	No	$a \times b$	$m_n - m_t$
9 b	1×1	+0^{m}6	108 a	3×2	+0^{m}3	215 b	6×3	+0^{m}5	285 a	2×2	+1^{m}3
11 b	1.5×1.5	0.5	112′ a	4×4	0.8	218 c	5×4	0.3	285 b	3×3	0.2
17 a	140×90	1.2	114 a	3×3	0.6	220 a	4×3	0.1	287 a	1.5×1.5	1.0
17 c	16×11	0.8	115 a	3×3	0.0	224 a	4×4	2.2	288 a	1×1	1.4
21 a	3×3	0.7	123′ a	3×3	0.5	226 a	3×3	0.2	289 b	1.5×1.5	0.3
22 a	4×2	0.3	124 b	5×5	2.3	240 a	6×5	0.1	293 a	3×3	1.5
23 b	3×3	0.1	130 b	4×4	0.8	240 b	4×4	0.0	294 a	2×2	0.5
28 a	4×3	0.1	143 c	5×5	0.1	240′ a	8×8	0.2	300 a	4×4	1.5
29 b	3×3	0.1	144 a	7×4	1.2	240′ b	7×7	0.1	305 a	5×4	1.0
31 a	4×4	0.0	147 a	6×6	0.4	241 a	3×3	1.4	308 b	5×3	0.7
34 a	3×2	1.3	158 a	5×5	0.3	241 b	1×1	2.2	308 c	4×4	0.4
44 b	2×2	0.2	173 a	5×5	0.1	243 a	1.5×1.5	0.0	310 a	4×4	0.0
45 b	6×6	0.1	173 b	5×5	0.5	243 b	1×1	1.2	310 b	3×3	0.0
46 a	11×2	1.3	175 a	10×8	0.2	246 a	5×5	2.3	312 a	4×4	0.5
59 b	2×2	0.1	184 a	2×2	0.8	246 b	6×6	1.7	315 a	2×2	0.0
77 a	2×2	0.1	187 a	2×2	0.7	246′ a	5×5	1.3	318 a	4×3	0.3
86 b	3×3	0.4	187 b	1.5×1.5	1.1	246′ b	5×5	1.0	320 a	10×8	0.2
89 a	3×3	0.2	202 b	3×3	0.0	247 a	4×4	1.4	323 a	3×3	0.7
90 a	3×3	1.2	204 a	4×2	0.7	257 c	3×2	0.7	329 a	1×1	0.2
90 b	3×3	0.3	211 a	2×2	1.2	257 d	3×2	0.8	333 a	4×4	0.2
94 a	6×6	0.7	212 a	7×7	0.1	258 c	1.5×1.5	0.8	335 a	3×3	0.2
96 a	5×2	1.5	212 b	7×7	0.0	259 a	5×5	1.0	337 a	4×4	0.4
97 b	2×2	0.1	212 c	6×3	1.5	270 a	5×3	1.4	340 a	5×5	1.2
99 a	3×3	0.7	212′ a	10×10	0.1	271 b	3×3	0.6	342 a	4×4	2.3
101 a	4×4	1.8	212′ b	10×10	0.1	272 a	4×4	1.2	345 a	5×5	0.6
106 a	3×3	0.3	215 a	3×3	1.5	272 b	1×1	2.2	345 b	2×2	1.0

No	$a \times b$	$m_n - m_t$	No	$a \times b$	$m_n - m_t$	No	$a \times b$	$m_n - m_t$	No	$a \times b$	$m_n - m_t$
345' a	6×6	$+1^{\rm m}.2$	406 a	9×9	$+0^{\rm m}.7$	478 b	5×5	$+0^{\rm m}.0$	623 a	2×2	$+0^{\rm m}.0$
348 a	3×3	3.9	406' a	5×3	1.6	478' a	4×4	0.8	626 a	3×3	0.5
353 a	15×5	1.2	409 a	19×8	0.5	478' b	3×3	1.0	630 a	5×5	0.3
355 a	1×1	0.8	409' a	10×10	0.2	483 b	2×2	0.2	633 b	2×2	0.6
355 b	1×1	0.7	410 b	1.5×1.5	0.1	488 a	3×3	0.0	638 b	2×2	0.7
356 b	2×2	0.0	411 a	9×9	0.1	490 a	3×3	0.5	638' b	3×3	1.0
359 a	4×4	1.0	411 b	3×3	1.5	500 a	2×2	1.2	639 a	4×4	0.3
359 c	2×2	0.6	411' a	10×10	0.0	501 a	1.5×1.5	1.2	645 a	2×2	1.2
361 a	2×2	1.3	413 a	7×7	0.5	510 a	5×3	0.2	656 a	3×3	1.0
363 a	5×5	3.0	413' a	9×9	0.3	511 a	3×3	0.1	676 a	1×1	2.0
368 a	2×2	1.7	414 a	9×9	1.5	511 b	4×4	0.8	677 a	2×2	2.4
368 b	3×2	0.7	415 a	9×3	1.5	511' b	3×3	0.5	685 a	8×4	1.0
368 c	3×2	0.5	417 a	2×2	0.1	513 a	2×2	1.8	688 a	4×4	0.2
368 d	2×2	0.3	418 a	2×2	3.3	515 a	1.5×1.5	1.8	694 a	3×3	1.0
369 a	10×10	0.0	418' a	5×2	1.6	516 a	1.5×1.5	0.7	697 b	2×2	0.1
375 a	3×3	0.7	420 a	2×2	3.6	523 b	2×2	1.0	703 b	2×2	1.3
377 a	2×2	4.0	420' a	3×3	3.8	526 a	6×6	1.3	704 a	9×2	2.2
379 a	4×4	3.1	422 a	5×4	0.1	526 b	2×2	0.6	716 a	4×4	1.1
379 b	2×2	1.5	423 a	10×10	1.4	528 a	1.5×1.5	0.1	719 b	3×3	2.6
381 a	3×3	1.5	426 a	25×12	0.7	535 a	3×3	1.4	724 a	2×2	0.1
382 a	2×2	1.0	427 a	2×2	4.4	541 a	2×2	1.8	729 a	3×3	2.1
385 a	5×5	0.9	427 b	2×2	3.8	549 a	2×2	0.8	738 a	2×2	1.4
387 a	6×6	2.0	429 a	4×4	0.1	555 c	2×2	1.6	755 a	2×2	0.5
388 a	3×3	0.9	430 d	2×2	0.2	561 a	2×2	0.5	795 a	13×5	0.5
391 a	6×6	0.3	436 a	2×2	1.3	567 a	3×3	0.1	795 c	2×2	0.3
391 b	6×6	0.2	438 a	10×6	0.7	569 a	2×2	1.0	796 a	4×4	0.6
391' a	6×6	0.2	441 a	4×4	0.3	574 a	2×2	1.6	797 a	2×2	1.7
391' b	5×5	0.0	442 b	4×4	0.3	576 a	4×4	0.6	802 b	2×2	0.0
395 b	3×3	0.5	448 a	9×9	0.7	585 a	3×3	3.1	804 a	3×3	0.5
396 a	2×2	0.3	448 b	3×3	2.1	585 b	4×3	0.1	805 b	3×2	0.2
397 a	6×6	0.5	448' a	8×8	0.2	595 a	3×3	0.1	805' b	3×3	0.7
397 b	3×3	0.1	448' b	3×3	1.7	600 a	2×2	1.5	816 a	3×3	1.3
397' a	11×11	0.3	453 a	5×2	1.6	600 b	2×2	0.4	817 a	1.5×1.5	2.1
397' b	10×10	0.1	453' a	6×6	1.4	604 b	3×3	0.4	820 c	3×3	1.7
402 a	2×2	0.4	455 a	2×2	1.2	604' a	5×5	0.6	820' a	3×3	1.2
403 a	7×7	0.3	466 a	1.5×1.5	0.7	606 a	2×2	1.8	822 b	1.5×1.5	0.9
403 b	8×8	0.2	468 a	4×4	2.4	607 a	3×3	0.4	824 a	4×4	0.1
403 c	10×6	0.2	471 b	3×3	0.1	613 a	1.5×1.5	0.5			
403 e	6×6	0.1	472 a	10×3	1.5	620 a	2×2	1.0			
403 f	3×3	1.2	478 a	4×4	2.1	621 a	2×2	1.1			

APPENDIX III

CATALOGUE OF DOUBLE AND MULTIPLE GALAXIES

The following catalogue contains all data of double and multiple galaxies that have been collected by means of the Bruce plate material of the Heidelberg Observatory. The number of double and multiple systems amounts to 827 and the total number of galaxies is 1854. The distribution of the objects is discussed in Chapter II of this paper. As regards the values given in the different columns of the catalogue the following explanations may be given:

Column 1 contains the number of the present catalogue. An asterisk denotes that a reproduction of the object is to be found on the plates at the end of this paper. If an object has been measured on two different plates both measurements are included in the catalogue. The denotations *a*, *b*, ... refer to the components within the same double or multiple system. The components generally are arranged after decreasing apparent brightness. Sometimes, however, the component situated at the centre of the system has been denoted by *a*.

Column 2 gives the NGC-number. For the identification of these numbers the catalogue by K. Reinmuth[1], 'Die Herschel-Nebel', has been used.

Column 3, 4 give right ascension and declination, reduced to the equinox 1900.0, for the component *a* in every system. The co-ordinates do not claim higher accuracy than is necessary for identification purposes. The errors in the co-ordinate values are discussed in Chapter IV.

Column 5, 6 give the relative co-ordinates $\Delta\alpha \cos\delta$ and $\Delta\delta$ within every system. Component *a* is used as origin. *The values are given in tenths of a minute of arc.*

Column 7, 8 give galactic co-ordinates of component *a*. The determination of these has been performed by means of the table by J. Ohlsson.[2]

Column 9, 10 give metagalactic co-ordinates of component *a*. They have been determined by means of a diagram (Fig. 35) given in this paper.

Column 11 gives the type of the galaxies according to M. Wolf's classification.[3] In the cases where it has been possible to distinguish the direction (right or left handed) of the arms of the spirals, it has as usual been denoted by S or Ƨ.

Column 12 gives apparent major and minor diameter of the galaxies. *The values are given in tenths of a minute of arc.*

---

[1] Heidelberg Veröff, Band 9 (1926). [2] Lund Ann 3 (1932). [3] Cf. Heidelberg Veröff, Band 9 (1926) and Chapter IV of this paper.

Column 13 gives the position angle of the major diameter. This angle is reckoned as usual from the north through the east.

Column 14 gives the concentration of light within the galaxies. This concentration is defined in Chapter IV of this paper.

Column 15 gives the estimated total photographic magnitude. The values have been corrected by means of some formulae given in Chapter V.

Column 16 contains the corresponding magnitude value as given in the Harvard catalogues.[1]

Column 17, 18 refer to the plates used. The limiting magnitude of the plate at the situation of the object is denoted by m_l, and the distance, in degrees, of the object from the centre of the plate is denoted by d.

---

[1] Harvard Ann 88, No 1 (1930) and Harvard Ann 88, No 2 (1932).

No	NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
1 a		0^h $1^m.5$	$+4°$ $34'$			72°	−56°	310°	+21°	d	5×5		0	$14^m.0$		$16^m.0$	2°.6
b				−14	−2					d	2×2		0	14.8			
2 a	1	0 2.1	+27 9			80	−34	320	+44	e	3×3		1	14.3		16.8	1.5
b	2			+3	−18					d—h_0	6×3	108°	0.5	14.6			
3 a	9	0 3.7	+23 16			79	−38	318	+40	d—h_0	9×4	155	0.5	13.8		16.1	3.0
b	8			−22	+13					d	4×4		0	14.9			
4 a		0 5.0	−5 16			67	−65	310	+12	d	6×6		0.5	13.8		16.3	2.3
b				+11	−5					d	2×2		0	15.2			
5 a		0 12.0	−14 3			64	−75	310	+4	d	8×8		0.5	14.5		16.2	1.0
b				+26	+14					d	6×6		0	15.0			
6 a	68	0 13.1	+29 31			83	−32	324	+45	d	3×3		0	14.6		16.6	2.7
b	71			+11	−4					d	3×3		0	14.8			
c	70			+9	+5					d	3×3		0	14.9			
d	72			+22	−19					d	3×3		0	15.0			
e				−13	−9					d	3×3		0	15.3			
f	69			+5	−19					d	3×3		0	15.3			
g	67			−8	−5					d	3×3		0	15.5			
7 a		0 13.8	−10 56			69	−72	311	+7	e	4×4		1	14.2		16.0	2.2
b				−2	+10					d	5×4	173	0	14.4			
8 a		0 14.5	+29 23			83	−32	324	+44	e	4×4		1	14.4		16.5	2.9
b				+12	+1					d	4×4		0	15.3			
9 a	100	0 18.8	+15 56			82	−46	319	+33	h_0	25×6	54	0.5	13.8		16.4	1.8
b				+22	+27					f	7×7		1	14.9			
10 a		0 25.1	−11 39			77	−73	314	+5	d—h_0	11×6	170	0	13.1		16.4	1.4
b				−30	−3					d	5×5		0	14.8			
11 a		0 26.2	+7 55			84	−54	319	+23	h_0	18×6	16	0.5	13.5		15.9	1.9
b				−13	+5					f	5×5		4	14.0			
12 a		0 27.9	−17 20			75	−79	313	−1	d	12×12		0.5	12.2		15.0	2.9
b				−11	−1					d	7×7		0	14.4			
13 a	191	0 33.9	−9 33			85	−71	316	+7	e	9×9		1	14.2		16.2	2.9
b				+3	−7					e	6×6		1	14.2			
14 a		0 35.9	−14 20			86	−76	315	+2	d—h_0	6×3	174	0	14.3		16.4	3.2
b				−13	+13					d—h_0	5×2	109	0	15.1			
15 a		0 36.8	−9 51			87	−72	317	+7	d—h_0	8×5	151	0	13.7		16.4	2.1
b				−7	+12					d	4×4		0	14.6			
16 a		0 36.8	−10 3			87	−72	317	+6	d—h_0	8×3	168	0	15.1		16.5	2.0
b				−3	−6					d—h_0	8×3	72	0	15.2			
17* a	224	0 37.3	+40 43			89	−22	337	+54	s S	2°.4×0°.6	40:	23:	—	5^m:	16.9	0.2
b	221			0	−240					e	27×20	163	1	9.6	9.5		
c	205			−263	+246					g	110×50	171	23	10.1	10.8		
18 a		0 39.8	−18 47			90	−81	315	−3	d—h_0	8×3	113	0.5	13.4		15.4	0.9
b				−10	−3					h_0	10×2	133	0	13.4			
19 a		0 40.0	−17 3			90	−79	316	−1	d—h_0	8×3	29	0	13.6		15.4	0.9
b				+16	−9					d	4×3	31	0	14.4			
20 a		0 40.7	−9 53			90	−72	318	+7	d	5×5		0	13.6		16.5	1.5
b				−10	−6					d—h_0	4×2	4	0	15.3			
21 a		0 42.7	−10 23			92	−72	318	+5	h	20×4	19	5	14.2		16.6	0.8
b				+1	−40					h_0	17×4	79	0.5	14.2			
22 a	259	0 42.9	−3 19			92	−65	320	+12	h	18×3	135	4	14.1		16.6	1.1
b				−36	−10					d	4×4		0.5	15.3			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha\cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a\times b$	φ	c	m	m_{Harv}	m_l	d
23	a		$0^h 43^m 0$	$+27^\circ\ 8'$			91°	−35°	330°	+40°	h_0	5×1	2°	0	$15^m 7$		$16^m 1$	$2^\circ 5$
	b	252			−53	−34					g	12×6	96	8	14.1			
	c	260			+24	+9					d	6×6		0.5	14.5			
	d	258			−26	−13					d	3×2	2	0	15.0			
	e				+15	+20					d	2×2		0	15.2			
24	a		0 45.2	−18 51			97	−81	316	−3	d	5×5		0	12.9		15.3	1.6
	b				−5	−14					d−h_0	11×4	170	0	13.3			
25	a		0 45.9	+40 11			91	−22	340	+53	d	10×10		0.5	13.5		16.8	1.6
	b				−1	+12					d	4×4		0.5	14.9			
26	a	275	0 46.0	−7 37			94	−69	319	+8	d	9×9		0.5	12.5	$13^m 0$	15.8	3.7
	b	274			−6	+5					e	9×9		1	12.7	13.0		
26′	a	275	0 46.0	−7 37			94	−69	319	+8	d	10×10		0.5	13.3	13.0	15.6	3.9
	b	274			−7	+6					e	9×9		1	13.3	13.0		
27	a	309	0 51.7	−10 27			99	−72	319	+5	wS	20×18	80	0.5	12.6	12.5	16.4	2.1
	b				−40	−12					d	3×2	174	0	15.0			
28	a	315	0 52.4	+29 49			93	−32	334	+42	g	11×6	41	5	13.5		16.3	1.4
	b	316			+9	+2					d	2×2		0.5	14.9			
	c	313			−7	+8					d	1×1		0.5	15.1			
29	a		0 52.5	−5 33			98	−67	321	+9	d	6×6		0.5	14.3		16.4	2.3
	b				+18	+33					h	10×3	102	2	14.7			
30	a	327	0 52.9	−5 40			98	−67	321	+9	d−h_0	10×6	0	0.5	14.0		16.3	2.5
	b	329			+14	+35					d−h_0	13×6	21	0.5	14.3			
31	a		0 54.3	−5 21			99	−67	321	+9	h	15×4	169	2	14.7		16.3	2.5
	b				+6	+6					d	5×5		0.5	15.0			
32	a		0 55.1	−11 37			103	−73	320	+4	d−h_0	10×6	160	0	14.2		16.2	2.9
	b				+9	+3					d	3×3		0	14.9			
33	a		0 55.5	−2 14			99	−64	323	+12	d	10×7	178	0	14.9		16.3	2.6
	b				−12	+9					d	9×7	50	0.5	15.0			
34	a		0 56.0	+30 59			94	−31	337	+42	k	25×8	11	1	13.9		16.1	2.6
	b				0	−19					d−h_0	4×2	127	0	15.2			
35	a		0 58.7	+25 17			95	−37	333	+38	d	6×5	17	0	14.4		15.7	3.5
	b				−5	−10					e	4×3	89	1	14.6			
36	a	392	1 2.8	+32 36			95	−29	339	+43	d	3×3		0	13.9		15.0	2.5
	b	394			+5	+9					d	3×3		0	14.2			
37	a		1 7.4	−4 40			108	−66	324	+9	d	4×4		0	14.3		15.7	2.7
	b				+8	+4					d−h_0	9×5	170	0	14.2			
	c				0	−9					d−h_0	9×5	137	0	14.4			
	d				−30	+3					d−h_0	8×4	25	0	14.4			
38	a		1 10.8	+19 14			100	−42	334	+31	d	4×4		0.5	14.6		16.2	0.9
	b				−7	−7					d	2×2		0	15.2			
39	a	469	1 14.4	+14 20			102	−47	333	+27	d	3×3		0	14.4		15.7	2.3
	b				0	−10					d	2×2		0	14.8			
40	a	476	1 15.0	+15 30			102	−46	334	+28	d	4×3	155	0	14.6		15.7	2.1
	b				0	−6					h_0	10×3	79	0	15.2			
41	a		1 18.2	−7 10			115	−67	326	+6	d	7×7		0	14.2		15.9	1.3
	b				−25	+3					d−h_0	7×4	178	0	14.2			
	c				+26	+17					d	3×3		0	14.6			
	d				+43	+30					d	2×2		0	14.7			
	e				−49	−33					d	6×6		0	14.8			
42	a	545	1 20.9	−1 52			112	−62	329	+10	e	5×5		3	13.7		15.7	2.2
	b	547			+5	−4					e	5×5		3	13.8			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
43	a		1^h21^m2	−6° 37′			117°	−67°	327°	+6°	h_0	27×5	24°	0	13^m1		16^m0	$1^\circ2$
	b				−4	−3					d	3×3		0	14.9			
44	a	564	1 22.7	−2 24			113	−62	329	+9	e	4×4		1	13.9		15.8	1.6
	b				−6	+3					h	10×2	112	5	14.5			
45	a	586	1 26.6	−7 24			120	−68	328	+5	d−h_0	10×6	145	0	13.7		15.6	2.8
	b	584			−42	+15					g	14×8	50	2	11.2	11^m6		
	c				+27	−26					d−h_0	6×3	17	0	14.4			
46*	a	672	1 42.2	+26 56			106	−33	345	+35	s	60×17	70	2	12.1	11.9	15.9	2.2
	b				−51	−61					d−h_0	35×15	132	0.5	13.0			
47	a	701	1 46.1	−10 13			133	−66	331	0	d−h_0	13×7	36	0.5	12.7	12.7	15.6	3.3
	b				−17	−28					d−h_0	6×3	97	0	14.2			
48	a		1 46.5	+35 21			105	−25	351	+42	d	2×2		0	14.6		16.1	1.6
	b				+2	+1					d	1.5×1.5		0	14.8			
49	a	708	1 46.9	+35 39			105	−25	351	+42	d	6×4	160	0.5	14.0		16.2	1.2
	b	704			−17	−16					d	4×3	176	0	14.0			
	c	703			−14	+12					d	3×3		0	14.2			
	d	705			−9	−5					d	3×2	113	0	14.3			
	e	700			−29	−23					d	3×3		0	14.8			
50	a		1 49.6	−10 18			135	−66	332	−1	d	5×5		0	14.2		15.8	3.0
	b*				+29	+9					d	6×6		0	14.6			
	c				+9	−3					d	4×4		0	14.7			
	d				−3	+4					d−h_0	5×2	114	0	14.8			
51	a		1 50.9	+10 27			136	−48	341	+20	d	9×9		0.5	13.8		15.8	3.0
	b				+4	+10					d	3×3		0	14.8			
52	a		1 52.8	−1 9			126	−58	336	+9	d	3×2	108	0.5	14.8		16.2	2.2
	b				−4	+2					h_0	5×1	5	0.5	15.3			
53	a		1 54.9	−7 34			134	−63	335	+2	d−h_0	5×3	160	0	14.3		16.2	0.0
	b				−7	+18					d−h_0	5×2	152	0.5	14.3			
54	a	799	1 57.1	−0 34			127	−57	338	+9	d	5×5		0.5	14.4		16.0	2.9
	b	800			−1	−19					d	9×7	3	0	14.0			
	c				+8	+1					d	4×4		0.5	14.8			
55	a		1 57.2	−6 33			134	−62	335	+3	d−h_0	8×4	168	0	14.3		16.2	1.2
	b				−4	−11					d−h_0	5×3	132	0	14.6			
56	a		2 4.0	−7 32			138	−61	337	+2	e	8×8		1	13.5		15.7	3.0
	b				−8	+21					d	5×5		0.5	14.4			
57	a		2 4.5	−7 27			138	−61	337	+2	d−h_0	8×3	140	0	13.5		16.0	2.4
	b				+22	+30					d−h_0	10×6	92	0	13.7			
57′	a		2 4.5	−7 27			138	−61	337	+2	d	7×5	128	0	13.8		15.7	3.0
	b				+21	+29					d−h_0	10×4	96	0.5	14.4			
58	a	945	2 23.7	−10 59			150	−60	340	−4	d−h_0	18×10	8	0	12.9		15.3	2.4
	b	948			+19	+16					d	12×9	43	0	13.7			
59	a		2 24.2	−11 17			150	−60	340	−5	d	4×4		0	14.0		15.2	2.6
	b				+2	−6					h	8×2	46	1	14.0			
MC 29253 – 60	a		2 25.3	+38 37			111	−19	4	+40	d	3×2	0	0	14.6		16.0	2.1
	b				−10	−4					d−h_0	4×2	169	0	14.8			
MC 29253 – 61	a		2 29.2	+37 3			113	−21	3	+39	d	8×8		0.5	13.8		16.0	2.4
	b				−3	+8					d	5×5		0	14.3			
	c				+13	+20					d	5×5		0	14.3			
62	a	1010	2 32.8	−11 28			154	−59	342	−5	d	6×6		0	13.6		15.2	2.5
	b	1011			+10	+12					d	3×3		0.5	14.1			
	c				+37	+11					d	3×3		0	14.5			

No	NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a\times b$	φ	c	m	m_{Harv}	m_l	d
63 a		$2^h 44^m.0$	$+7° 41'$			134°	−43°	352°	+12°	e	7×7		1	$13^m.0$		$14^m.9$	2°.5
b				−25	−3					d	4×4		0	13.3			
64 a	1154	2 53.3	−10 46			158	−55	348	−7	d	6×6		0	13.8		15.6	0.4
b	1155			+14	+9					e	4×4		1	14.0			
65 a	1196	2 58.8	−12 28			161	−54	347	−9	d−h$_0$	8×3	91°	0	13.9		15.4	2.3
b	1195			−8	+23					d	6×4	8	0	14.2			
66 a		3 2.1	−9 55			159	−52	349	−6	d	6×4	43	0	13.7		15.3	2.7
b				+34	−29					d−h$_0$	10×4	12	0.5	14.0			
67 a		3 6.0	−11 8			161	−52	349	−8	d−h$_0$	11×4	89	0.5	13.5		15.5	3.0
b				+4	+23					d−h$_0$	8×3	17	0	13.8			
68 a	1241	3 6.4	−9 18			158	−51	350	−6	e−h$_0$	12×7	110	1	13.6	$13^m.0$	15.8	1.5
b	1243			+27	−14					d	4×4		0	13.7			
c	1242			+11	+13					d	5×5		0	14.1			
69 a		3 20.3	−6 35			158	−46	355	−5	h$_0$	12×4	139	0	13.5		15.5	3.0
b				−12	+29					d	10×8	170	0	13.5			
70 a	1417	3 37.0	−5 1			160	−42	359	−5	d	13×10	0	0.5	13.3	12.9	14.8	3.9
b	1418			+48	−15					d−h$_0$	13×8	20	0.5	13.9			
71 a		4 5.6	−15 33			176	−41	2	−18	d−h$_0$	8×5	11	0	14.4		16.2	2.5
b				+6	−8					d	4×4		0	14.9			
72 a		4 9.4	−12 57			174	−39	4	−15	d	3×3		0	14.5		16.4	2.0
b				+8	−6					d	2×2		0	15.3			
73 a		4 10.4	−13 36			175	−39	4	−16	d	2×2		0	15.0		16.4	1.3
b				+7	+4					d	2×2		0	15.4			
74 a		4 17.8	−16 8			179	−39	4	−19	d	3×3		0	14.8		16.4	1.9
b				−5	−9					d	3×3		0	15.3			
75 a	1561	4 18.6	−16 2			179	−39	5	−19	d	3×3		0	14.7		16.4	1.9
b				−10	+1					d	2×2		0	15.0			
76 a	1587	4 25.4	+0 26			162	−30	12	−5	d	4×4		0.5	13.3		16.0	0.7
b	1588			+10	+2					d	3×3		0.5	14.3			
77 a	1622	4 31.5	−3 24			167	−30	12	−10	h	10×2	42	2	14.0		15.9	0.2
b				−14	−4					d	3×3		0	14.9			
78 a		4 34.4	+6 51			158	−24	17	0	d	6×6		0	14.2		15.9	2.7
b				−6	+8					d	4×4		0	14.9			
79 a	1633	4 34.7	+7 9			157	−24	17	0	d	8×6	31	0	13.9		15.9	2.5
b	1634			+2	−8					e	3×3		1	14.3			
79′ a	1633	4 34.8	+7 9			157	−24	17	0	d	8×8		0.5	14.1		15.7	2.6
b	1634			+2	−8					e	5×5		1	14.2			
80 a		4 44.5	+0 5			165	−25	17	−7	d	3×3		0.5	13.4		16.1	2.6
b				+5	−1					e	3×3		1	14.0			
81 a	1670	4 44.7	−2 56			168	−27	16	−10	d	5×5		0.5	13.9		15.1	2.9
b				+2	−9					d	5×5		0.5	13.9			
82 a		4 45.3	+5 50			160	−22	19	−2	e−h$_0$	10×5	102	2	14.2		16.0	1.0
b				−11	+2					d	3×3		0.5	14.6			
83 a	1719	4 54.4	−0 24			167	−24	19	−8	d	3×2	108	0.5	14.0		16.2	2.1
b	1717			−2	−1					e	2×2		1	14.1			
84 a	1740	4 56.9	−3 27			170	−24	18	−12	d	5×5		0	13.9		15.1	3.0
b	1742			+10	+1					d	2×2		0.5	14.3			
85 a		6 12.1	−21 21			196	−16	31	−35	d−h$_0$	4×2	166	0.5	13.9		15.5	1.1
b				−4	−1					d−h$_0$	4×2	163	0	14.1			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a\times b$	φ	c	m	m_{Harv}	m_l	d
86	a	2342	7h 3m.4	+20° 48′			164°	+15°	56°	+ 2°	r S(?)	13×10	55°	1	14m.0		16m.8	1°.2
	b	2341			−16	−21					f	5×5		2	14.6			
87	a		7 21.4	+19 51			166	+18	59	0	e	9×6	0	1	14.4		16.5	1.6
	b				+ 4	− 9					e	6×6		1	14.8			
88	a	2461	7 48.6	+56 56			128	+32	73	+34	d	4×4		0	14.1		15.5	0.2
	b	2462			+ 7	+ 9					d	4×4		0	14.6			
89	a	2481	7 51.3	+24 2			165	+26	67	+ 3	h	8×3	9	2	13.8		16.3	1.6
	b	2480			− 7	+ 7					h₀	8×2	156	0.5	14.9			
90	a	2487	7 52.3	+25 25			164	+27	68	+ 4	g	18×10	47:	6	13.9		16.1	2.6
	b	2486			−58	+ 7					g	15×10	80:	13	14.6			
91	a	2493	7 53.5	+40 6			148	+31	71	+18	e	6×5	36	1	13.5		16.5	3.2
	b	2495			+19	+ 7					d	3×3		0	14.9			
92	a	2507	7 55.9	+15 59			174	+24	66	− 6	e−h₀	19×7	42	2	13.2		15.4	2.7
	b				+ 4	+21					d	4×4		0.5	14.6			
93	a		8 2.8	+41 53			146	+33	73	+20	d−h₀	5×2	152	0	14.9		17.0	1.1
	b				+ 5	− 4					d	2×2		0	15.1			
94	a	2535	8 5.2	+25 30			165	+29	70	+ 4	v S	25×7	29	3	13.0		15.9	3.1
	b	2536			+ 7	−16					e	5×5		1	14.3			
95	a	2555	8 12.8	+ 1 3			190	+21	68	−21	e	7×7		1	14.4		16.0	2.8
	b				− 6	+ 4					d	3×3		0	14.6			
	c				− 2	+ 5					d	3×3		0	14.8			
96	a	2604	8 27.2	+29 52			162	+36	76	+ 8	g	19×12	132	1	12.7		16.3	2.7
	b				+31	−24					d	8×8		0	14.6			
97	a		8 31.9	+43 54			144	+39	78	+21	h−h₀	14×4	33	1	14.3		16.7	2.9
	b				− 4	+25					h	9×2	141	1	14.6			
98	a	2667	8 42.7	+19 23			175	+35	78	− 4	e	3×2	65	1	14.7		16.7	1.9
	b				+ 7	+16					d−h₀	5×3	40	0	15.0			
	c				−17	+10					d	3×2	22	0	15.7			
99	a	2672	8 43.6	+19 26			176	+36	78	− 4	f	6×6		3	13.2	12m.6	16.6	2.2
	b	2673			+ 6	− 1					d	4×4		0	14.5			
100	a		8 46.3	+42 48			146	+41	81	+20	d	5×5		0	13.3		15.6	2.6
	b				−17	− 5					d−h₀	5×2	99	0	14.4			
101	a		8 48.2	+33 4			159	+40	81	+10	w S	20×17	65	1	13.9		16.3	1.5
	b				+17	−28					d	5×4	26	0	14.6			
102	a		8 49.4	+42 39			146	+42	82	+20	d	7×5	1	0	14.1		16.2	2.1
	b				−28	+ 2					d	5×5		0.5	14.6			
103	a	2704	8 50.3	+39 46			150	+42	82	+16	e−f	9×9		3	13.8		16.4	0.8
	b				−19	− 4					d	3×3		0	15.2			
104	a	2716	8 52.4	+ 3 29			194	+31	79	−19	e	8×8		1	13.5		15.7	2.9
	b				−17	− 6					d	3×3		0	14.8			
105	a	2719	8 54.0	+36 7			155	+42	83	+13	o	10×3	128	1	14.0		16.0	2.8
	b				0	− 4					d−h₀	6×3	122	0	14.5			
106	a	2729	8 56.2	+ 4 6			194	+32	81	−19	h	8×3	3	2	14.0		16.1	2.3
	b				+ 4	− 1					d	3×3		0	14.4			
107	a		8 56.2	+44 54			143	+43	83	+22	d−h₀	10×6	5	0	13.3		15.9	1.1
	b				−24	+14					d−h₀	5×3	20	0	14.1			
108	a		8 56.8	+26 20			168	+41	82	+ 3	h	8×2	97	2	13.4		16.2	1.8
	b				+ 8	+ 3					d	2×2		0.5	14.9			
109	a		9 1.0	+37 37			153	+43	84	+14	d	6×6		0	13.7		15.3	3.0
	b				−14	−32					d	3×2	179	0.5	14.4			
	c				+ 3	−10					d	3×2	129	0	14.5			

No	NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
110 a		$9^h\ 2^m.3$	+36° 3′			156°	+44°	84°	+12°	e	4×4		1	$14^m.8$		$16^m.0$	2°.8
b				− 7	+11					d	4×4		0.5	14.8			
111* a	2770	9 3.5	+33 32			159	+44	84	+10	q	32×7	140°	0.5	11.7		16.3	1.8
b				−31	+ 9					d−h₀	5×2	7	0	15.3			
c				−30	− 3					d	5×5		0	15.0			
112 a	2778	9 6.2	+35 26			156	+44	84	+12	e	5×5		2	13.8		16.3	1.8
b	2779			+ 9	+16					d	5×4	171	0	15.0			
112′ a	2778	9 6.2	+35 26			156	+44	84	+12	f	9×9		3	13.5		15.9	3.1
b	2779			+ 9	+17					d	6×6		0.5	14.8			
113 a	2783	9 7.6	+30 26			164	+44	84	+ 7	e	5×4	164	1	13.7		16.1	2.7
b				−14	+ 4					h₀	16×4	78	0	15.0			
114 a		9 9.9	+12 18			187	+38	85	−12	h	13×3	84	3	14.2		16.5	2.0
b				− 6	−13					d−h₀	5×2	12	0	15.5			
115 a	2796	9 10.7	+31 21			163	+45	85	+ 8	g	8×4	81	1	14.7		16.3	2.0
b				+ 9	− 3					d	3×3		0	15.5			
116 a		9 10.8	+27 46			167	+44	85	+ 4	d−h₀	6×3	41	0	14.0		16.2	1.9
b				+ 6	+ 7					d	3×3		0	14.9			
117 a	2798	9 10.9	+42 25			147	+46	86	+19	e	6×6		2	13.2	$12^m.9$	15.3	2.8
b	2799			+17	− 5					d−h₀	9×5	131	0.5	14.1			
118 a		9 11.3	+ 7 41			192	+37	84	−16	d	9×6	147	0.5	13.9		16.5	2.0
b				−11	−20					e	3×3		1	14.7			
119 a		9 11.3	+27 46			167	+44	86	+ 4	d	3×3		0.5	14.7		16.2	1.9
b				+ 3	+ 5					d	2×2		0	14.8			
120 a		9 12.4	+34 59			157	+46	86	+12	h₀	13×3	157	0	14.1		16.4	0.4
b				− 3	− 6					h₀	7×2	175	0	15.1			
121 a		9 13.6	+ 6 18			194	+36	85	−17	d	5×5		0	14.4		16.5	1.6
b				+16	− 1					d	4×4		0	15.1			
122 a		9 13.7	−16 4			215	+24	85	−40	d	3×3		0.5	14.1		16.3	0.3
b				− 3	0					d	3×3		0.5	14.1			
123 a	2832	9 13.7	+34 10			159	+46	86	+11	e	4×4		2	13.8	12.9	16.4	0.7
b	2830			−13	− 7					h₀	9×3	101	0	14.2			
c	2831			− 4	− 3					d	3×3		0.5	14.4			
123′ a	2832	9 13.7	+34 11			159	+46	86	+11	e−f	6×6		4	13.8	12.9	15.7	3.5
b	2830			−12	− 8					h₀	15×5	109	0	15.0			
c	2831			− 4	− 3					d	3×3		0.5	15.0			
124* a	2820	9 13.7	+64 40			116	+41	88	+41	h₀	30×4	60	1	13.2		17.0	1.8
b	2805			−91	−97					w S	45×45		1	12.0			
c	2814			−39	− 6					d−h₀	8×3	178	0	13.6			
d				−17	−13					d	4×4		0	14.9			
125 a		9 15.0	+28 35			166	+45	86	+ 5	d−h₀	8×5	40	0.5	14.9		16.6	2.0
b				+16	+16					d	3×2	147	0	15.3			
126 a		9 15.0	+62 27			120	+42	88	+39	d	6×4	1	0	14.8		17.0	1.6
b				+ 7	0					h₀	3×1	0	0	15.9			
127 a		9 15.4	− 7 27			208	+29	85	−31	d	6×6		0.5	13.4		15.4	1.9
b				+11	+ 1					h₀	7×2	3	0	14.2			
128 a	2848	9 15.4	−16 6			215	+24	85	−39	d−h₀	7×4	82	0	13.9	12.8	16.3	0.7
b				+ 7	+ 8					d	3×3		0	14.8			
c	2847			+ 1	+ 9					d−h₀	4×2	138	0	14.8			
129 a		9 16.7	+65 54			115	+41	88	+42	d−h₀	7×3	71	0	14.8		16.8	2.5
b				− 2	− 3					d	3×3		0.5	14.9			

16—37522.

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
130*	a	2872	9h 20m.3	+11° 51′			188°	+41°	87°	−12°	e	6×6		2	13m.6		16m.5	2°.0
	b	2875			+13	− 5					h	25×5	39°	4	13.8			
	c	2871			− 8	+ 7					d	2×2		0	15.1			
	d	2873			+15	+13					d	5×5		0	15.3			
131	a		9 22.2	+12 44			188	+41	88	−11	d−h$_o$	7×3	70	0	14.4		16.5	1.6
	b				−24	−13					d−h$_o$	5×2	150	0	15.2			
132	a		9 23.7	+25 59			171	+47	88	+ 2	d	4×4		0	14.6		16.6	1.9
	b				− 4	+ 7					d	3×3		0.5	15.0			
133	a	2894	9 24.2	+ 8 9			194	+40	88	−16	e	4×4		1	14.0		15.8	2.5
	b				− 4	0					d	4×4		0	14.8			
134	a	2930	9 31.9	+23 39			175	+48	90	0	e	6×6		1	13.9		15.9	3.0
	b	2929			− 5	−27					h$_o$	12×4	149	0	13.3			
	c	2931			+13	+24					d	7×7		0	13.7			
135	a	2936	9 32.6	+ 3 13			201	+39	90	−21	h$_o$	9×3	110	0	14.4		16.5	2.0
	b	2937			+ 2	− 9					e	2×2		3	14.8			
136	a	2943	9 33.0	+17 29			184	+45	90	− 7	d	7×6	129	0.5	13.5		15.7	3.3
	b	2941			−22	+ 8					d	7×5	131	0	14.5			
137	a		9 34.3	+ 6 54			197	+42	90	−17	h$_o$	8×2	86	0	14.3		16.5	1.8
	b				−18	−23					e	3×2	83	1	14.7			
	c				+13	−14					e	3×3		1	15.1			
138	a		9 34.5	+48 5			138	+49	90	+23	d−h$_o$	10×4	16	0	13.7		15.9	2.9
	b				+ 7	− 7					h$_o$	6×2	137	0	14.5			
139	a		9 36.9	+41 33			147	+50	91	+18	e	10×10		1	13.3		16.2	1.0
	b				+20	− 7					d	2×2		0	15.1			
140	a		9 37.7	+42 53			145	+50	91	+19	d	3×3		0.5	14.3		16.2	0.4
	b				+16	− 1					d	3×3		0.5	15.2			
141	a		9 37.7	+43 8			145	+50	91	+19	h$_o$	10×3	65	1	13.3		16.2	0.7
	b				− 8	−10					d−h$_o$	4×2	84	0	14.8			
142	a		9 40.8	+42 59			145	+51	92	+19	d−h$_o$	5×3	45	0	14.0		16.2	0.7
	b				− 4	−24					d	3×3		0	15.2			
143	a		9 41.2	+ 3 32			201	+41	93	−20	h$_o$	20×5	66	0	13.7		16.3	2.5
	b				− 2	−17					d−h$_o$	10×4	118	0	13.9			
	c				−58	+44					g−h	10×5	132	2	14.3			
144	a	2998	9 42.4	+44 34			143	+51	92	+20	k	20×9	60	4	12.3	12m.8	16.0	2.1
	b	3008			+92	+18					e	5×4	90	1	13.9			
	c	3005			+57	+33					h$_o$	8×2	139	0	14.2			
	d	3006			+63	−33					h$_o$	8×1.5	81	0.5	14.4			
	e	3000			+13	+30					d−h$_o$	4×1.5	39	0	14.7			
145	a		9 42.5	+20 46			180	+49	92	− 3	h$_o$	6×2	9	0	14.7		16.8	1.0
	b				+12	+ 4					d	2×2		0	15.1			
146	a	3010	9 44.2	+44 47			142	+51	93	+20	d	4×3	9	0	14.1		15.9	2.5
	b	3009			−39	−14					d	8×8		0	13.3			
	c				+ 3	+ 5					d	4×4		0	14.1			
	d				+12	+11					d	5×5		0.5	14.3			
147*	a	3020	9 44.7	+13 17			191	+46	93	−10	o	32×10	96	6	13.1		16.0	2.2
	b	3024			+51	−30					h$_o$	15×3	124	0.5	13.7			
	c	3016			−40	−72					e−g	12×5	71	3	13.9			
	d	3019			+ 2	−40					d	9×9		0.5	14.7			
148	a		9 47.5	+19 54			182	+50	93	− 4	d	3×3		0	14.5		16.7	1.4
	b				− 4	+ 7					d	3×3		0	15.3			
149	a		9 48.7	+23 45			176	+51	94	0	d−h$_o$	18×8	90	0.5	13.1		16.1	0.9
	b				+ 6	−18					d	5×5		0	14.4			

No.		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
150	a		$9^h 49^m.2$	+41° 36′			147°	+53°	94°	+17°	d	8×8		0.5	$14^m.3$		$16^m.0$	2°.2
	b				+ 1	−17					d	3×3		0.5	15.1			
151	a		9 50.9	+20 58			181	+51	94	− 3	d−h₀	4×2	21°	0.5	14.8		16.8	1.2
	b				+ 3	− 4					d	3×3		0	14.8			
	c				−18	+ 8					d−h₀	4×2	112	0.5	15.1			
	d				−14	+38					d	4×4		0	15.1			
	e				− 9	+26					d−h₀	4×2	65	0	15.4			
	f				+ 4	+ 6					d	2×2		0	15.4			
152	a		9 51.5	+36 34			155	+54	94	+12	h₀	12×4	129	0	14.5		16.7	2.2
	b				− 5	+15					e	4×4		1	14.2			
	c				−24	+ 9					d	5×5		0	14.3			
	d				+20	+ 2					h₀	12×3	41	0	14.9			
153	a		9 52.1	+36 37			155	+54	94	+12	d−h₀	6×3	132	0	14.5		16.7	2.2
	b				+22	+ 7					d−h₀	5×2	20	0.5	15.3			
154	a		9 52.2	+37 48			153	+54	94	+14	h₀	23×5	37	0	12.6		16.5	2.9
	b				−33	−18					d	6×6		0	15.1			
	c				−56	+21					d	6×6		0	15.2			
155	a		9 53.6	+18 18			185	+51	96	− 5	d	9×6	103	0	13.9		16.1	3.5
	b				+12	+ 2					d−h₀	10×5	100	0	14.9			
156	a	3079	9 55.1	+56 10			124	+50	94	+32	h₀	45×10	167	0	11.8	$11^m.9$	15.0	3.7
	b	3073			−93	−45					d	8×8		0	13.5			
157	a		9 55.2	+37 55			153	+54	95	+14	d−h₀	8×5	10	0	15.0		16.6	2.6
	b				+ 7	+ 1					d−h₀	8×3	2	0	15.6			
158	a		9 55.7	+37 44			153	+54	95	+14	v S	10×5	3	1	14.1		16.7	2.4
	b				+ 5	+ 9					d	4×4		0.5	15.2			
159	a		9 55.8	+36 59			155	+55	95	+13	d−h₀	11×4	54	0	14.7		16.8	1.8
	b				+ 1	+10					d	4×4		0	15.4			
160	a	3099	9 56.8	+33 11			162	+55	95	+10	e	6×6		1	14.5		16.5	2.8
	b				−14	+ 5					d	5×5		0	14.9			
161	a		9 57.7	+37 56			153	+55	95	+14	e	5×5		1	14.2		16.7	2.4
	b				−11	+ 8					e	4×4		1	14.6			
162	a		9 58.7	+37 34			153	+55	96	+14	e	4×4		1	14.3		16.8	2.0
	b				−17	− 8					d−h₀	5×3	56	0.5	15.2			
163	a		9 58.9	+37 50			153	+55	96	+15	d−h₀	8×5	116	0.5	13.8		16.7	2.2
	b				− 9	+ 1					d	3×3		0.5	15.1			
164	a		10 1.0	+37 46			153	+55	96	+15	d−h₀	6×3	131	0	15.0		16.8	2.0
	b				−10	−19					d−h₀	6×3	70	0	15.2			
165	a		10 2.5	+38 20			153	+56	97	+15	d	6×6		0	14.7		16.6	2.6
	b				+10	− 3					d	7×7		0	15.3			
166	a		10 2.8	+ 0 47			209	+44	98	−23	d	5×5		0	14.3		16.5	0.9
	b				0	+ 7					d	2×1.5	10	0	15.7			
167	a		10 5.3	+ 2 43			207	+45	99	−20	d	6×6		0.5	14.7		16.5	1.1
	b				− 8	−26					d	6×6		0	14.8			
168	a		10 6.5	+38 36			151	+57	97	+15	d−h₀	9×4	96	0	15.2		16.5	3.0
	b				0	+ 6					d	7×7		0	15.6			
169	a		10 7.2	+35 46			156	+57	97	+12	d	3×3		0.5	14.1		16.9	1.0
	b				+ 2	+19					d−h₀	5×2	77	0.5	14.6			
	c				−14	+10					d	3×3		0	15.7			
170	a		10 7.5	+39 9			151	+57	98	+16	e	9×9		1	14.3		16.0	3.4
	b				− 5	+25					d	9×9		0	14.9			

No	NGC	α_{1900}	δ_{1900}	$\Delta\alpha\cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a\times b$	φ	c	m	m_{Harv}	m_l	d
171 a		$10^h\ 8^m.0$	$+3°20'$			208°	+46°	99°	−20°	d	6×6		0.5	$14^m.5$		$16^m.4$	$2°.0$
b				+26	−3					d	3×3		0	15.3			
172 a	3161	10 8.1	+39 11			151	+57	98	+16	e	8×8		1	14.3		16.0	3.4
b	3163			+16	−3					d	9×9		0.5	13.3			
c	3159			−13	−2					e	10×10		1	14.0			
173 a	3166	10 8.6	+3 55			207	+47	99	−19	g	11×8	101°	4	12.2	$11^m.6$	16.2	2.6
b	3169			+75	+29					g	30×15	49	20	12.2	11.9		
c	3165			−36	−32					d	10×7	161	0.5	14.2			
174 a		10 11.2	+5 21			206	+48	100	−18	d	3×3		0	13.6		16.6	2.8
b				−10	−12					d	8×6	170	0	15.4			
175 a	{3189 3190	10 12.6	+22 20			182	+56	99	−2	h	35×8	118	3	12.4	12.1	15.3	4.2
b	3193			+46	+39					e	10×10		1	12.6	12.6		
176 a		10 13.1	+7 33			203	+50	101	−16	d	8×6	130	0	13.7		15.6	3.6
b				−12	−7					d−h_0	6×3	59	0	14.9			
177 a	3183	10 13.2	+74 41			102	+40	95	+52	h_0	14×4	131	0	13.5		16.7	1.9
b				−15	−26					d	3×3		0	15.3			
178 a		10 14.0	+77 23			100	+38	94	+53	d	5×5		0	14.6		16.7	1.5
b				+7	+8					d	2×2		0	15.4			
179 a	3205	10 14.8	+43 28			143	+58	98	+20	d	5×5		0	13.8		15.8	1.4
b	3207			+17	+10					e	3×3		1	13.8			
180 a		10 15.5	+38 48			150	+58	98	+16	d	7×5	168	0	14.3		16.6	2.0
b				+8	+9					h_0	7×2	170	0	14.6			
181 a		10 16.3	+39 2			150	+58	99	+16	d	3×3		0	14.7		16.5	2.1
b				+1	−4					d	3×3		0	14.7			
182 a	3214	10 16.4	+57 33			120	+51	98	+34	d−h_0	10×4	83	0	14.0		15.7	2.6
b	3220			+51	−6					h_0	15×3	85	0	14.0			
183 a		10 16.7	+37 7			154	+59	99	+14	d	10×10		0.5	14.1		16.4	3.2
b				−21	−12					d−h_0	8×4	159	0.5	14.3			
184 a		10 16.7	+39 5			150	+58	99	+16	f	7×7		1	14.3		16.5	2.1
b				−16	+10					d−h_0	10×4	141	0	14.7			
185 a		10 17.6	+53 38			126	+54	98	+30	d	4×4		0	13.5		15.7	2.3
b				0	−5					d	4×4		0	13.8			
186 a		10 17.7	+38 8			152	+59	99	+15	e	8×6	125	1	14.2		16.6	1.3
b				+18	+2					d	7×5	32	0	14.4			
187 a	3227	10 18.0	+20 23			186	+57	101	−3	g	23×15	150	28	13.0	12.2	15.6	1.0
b	3226			−9	+21					f	6×6		4	13.4	12.8		
188 a		10 18.1	+10 26			201	+52	102	−13	d	6×4	137	0	15.1		16.4	1.1
b				+3	−4					d	4×4		0	15.5			
189 a		10 19.6	−0 23			214	+46	103	−24	d	5×4	120	0	14.1		16.5	1.8
b				−14	+7					e−h_0	5×3	150	1	14.4			
c				+18	−8					e	3×3		1	14.7			
190 a		10 19.6	+10 6			202	+53	102	−13	d	6×4	23	0	14.2		16.4	0.7
b				−1	−16					d	3×3		0	15.1			
191 a		10 20.4	+14 14			196	+55	102	−9	d	7×7		0.5	13.7		15.8	2.1
b				+6	+8					d	5×5		0.5	14.1			
192 a		10 20.5	+14 53			194	+55	102	−8	h_0	20×4	161	1	13.1		15.8	2.2
b				0	−23					d	3×3		0	14.1			
193 a		10 22.3	+1 46			213	+48	103	−22	e	2×2		1	14.4		16.5	1.5
b				−1	−6					d	3×3		0.5	14.8			
c				−13	−9					d−h_0	4×2	113	0.5	14.8			

No	NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
193′ a		$10^h 22^m.3$	+1° 45′			213°	+48°	103°	−22°	e	6×4	72°	1	$14^m.3$		$16^m.7$	2°.6
b				0	−5					e	6×4	150	1	14.7			
c				−12	−3					e−h_0	5×3	83	1	14.9			
194 a		10 23.7	+2 56			212	+49	104	−20	d	2×2		0	15.5		16.9	1.5
b				+3	−7					d−h_0	5×3	156	0	15.7			
195 a	3251	10 23.7	+26 36			175	+60	101	+3	h−h_0	30×4	56	1	13.1		16.5	0.8
b				+15	−18					d	3×3		0	14.7			
196 a		10 23.8	+36 42			155	+60	101	+14	e	5×4	0	1	13.8		16.7	0.6
b				+1	−15					d	5×4	93	0	14.1			
197 a		10 24.4	+36 53			154	+60	101	+14	d	5×5		0	14.8		16.7	0.5
b				−8	0					h_0	11×2	179	0	15.2			
198 a		10 26.8	−2 11			218	+46	105	−25	d−h_0	7×3	139	0	14.6		16.3	2.7
b				+5	−6					d	6×5	10	0	14.6			
199 a		10 27.1	−0 59			217	+47	105	−24	d−h_0	6×3	42	0	14.1		16.5	1.7
b				+11	−37					d−h_0	6×3	153	0.5	14.4			
c				−10	−5					d	2×2		0	15.1			
d				−3	−51					d−h_0	5×2	71	0	15.1			
200 a		10 27.4	+16 23			194	+57	103	−7	d	9×9		0.5	13.6		16.5	1.6
b				−1	−9					d	2×2		0	15.0			
201 a		10 29.4	+11 42			201	+55	104	−11	h_0	23×4	154	0	13.2		16.2	2.1
b				+2	+15					d	3×3		0	15.2			
c				−22	0					d	3×3		0	15.2			
202 a	3294	10 30.5	+37 50			151	+61	102	+14	r	30×12	119	1	11.4	$11^m.6$	16.6	1.7
b	3291			−19	−44					g	10×5	100	8	13.7			
203 a		10 31.0	+14 14			198	+57	105	−9	h_0	13×3	2	0.5	13.3		16.4	2.4
b				−5	+10					d	4×4		0.5	15.2			
204 a		10 31.1	+38 33			150	+61	102	+15	k	10×4	72	1	14.3		16.5	2.2
b				−5	+5					d	4×4		0	15.1			
205 a		10 34.1	+24 22			181	+62	104	+2	d	10×10		0	13.7		15.9	3.3
b				+24	+4					h_0	10×3	121	0	14.7			
206 a		10 34.3	+0 8			218	+49	107	−22	d−h_0	8×3	101	0.5	13.6		16.4	2.2
b				−32	−13					d−h_0	8×5	17	0.5	13.8			
207 a		10 34.4	+24 38			179	+62	105	+2	e	10×8	74	1	13.2		16.0	3.2
b				+17	+10					d	4×4		0	14.4			
208 a		10 36.5	+14 25			199	+58	106	+2	d	4×4		0	15.2		16.4	2.3
b				+12	+1					d	3×3		0	15.4			
209 a		10 36.7	+18 47			191	+60	106	−4	d	3×3		0.5	14.2		16.4	2.3
b				−8	+1					d	2×2		0	14.8			
210 a	3340	10 37.2	+0 9			218	+49	108	−22	e	10×7	168	1	12.5		16.2	3.0
b	3339			−21	+4					d	2×2		0.5	14.8			
211 a		10 38.8	−0 46			219	+49	108	−23	g	7×4	14	2	14.1		16.4	1.5
b				−10	+4					d	3×3		0	15.2			
c				−26	−15					d	3×3		0	15.3			
212* a	3379	10 42.6	+13 7			203	+59	108	−9	f	20×20		10	11.3	10.8	16.4	2.1
b	3384			+67	+31					f−h	35×18	43	18	11.4	11.3		
c	3389			+97	−30					i−v 2	20×12	102	3	12.0	12.6		
212′ a	3379	10 42.6	+13 7			203	+59	108	−9	f	20×20		10	11.6	10.8	15.6	4.0
b	3384			+70	+30					f−h	40×12	50	13	11.7	11.3		
c	3389			+94	−33					d−h_0	22×12	103	0.5	12.1	12.6		

No	NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
213 a		$10^h 43^m 6$	+30° 21′			168°	+65°	106°	+ 8°	d	3×3		0	$14^m 8$		$16^m 4$	1°9
b				− 7	− 6					d	3×3		0	15.5			
c				− 8	0					d	3×2	28°	0	15.7			
214 a		10 44.0	− 0 9			220	+51	110	−22	d	5×5		0	15.1		16.4	1.3
b				− 9	+18					e	8×7	31	1	13.7			
c				+42	+ 1					e	6×6		2	14.3			
215* a	3395	10 44.3	+33 31			160	+65	106	+12	v S	13×8	31:	2	12.1	$12^m 4$	16.1	3.0
b	3396			+11	+ 4					h	15×5	92	4	13.1	12.8		
216 a		10 44.8	+ 0 51			219	+51	110	−21	e	5×5		1	14.3		16.3	2.3
b				0	+20					d	4×4		0	15.3			
217 a	3406	10 45.6	+51 33			124	+58	104	+29	d	5×5		0	13.4		15.3	3.3
b	3410			+16	−10					d−h_0	8×5	40	0	14.2			
218 a	3424	10 46.2	+33 26			160	+65	107	+11	h_0	15×5	112	0	13.1		16.1	2.8
b	3430			+54	+31					r	32×12	38	1	12.3	12.4		
c	3413			−51	−85					h	15×6	173	6	13.5			
219 a		10 46.4	+71 15			103	+44	99	+48	e	6×6		2	13.7		15.3	3.0
b				0	− 9					d	5×5		0	14.2			
220 a		10 47.0	− 0 2			221	+51	110	−22	k	12×4	60:	3	14.2		16.4	1.6
b				+12	+17					d	3×3		0.5	15.0			
221* a	3455	10 49.1	+17 50			196	+63	109	− 4	d	12×10	63	0.5	12.6	13.1	15.9	2.4
b	3454			− 3	+38					h_0	23×4	113	0	13.4			
221′ a	3455	10 49.1	+17 49			196	+63	109	− 4	d	15×10	53	0.5	12.5	13.1	15.7	4.4
b	3454			− 3	+37					d−h_0	20×8	121	0.5	12.9			
222 a		10 57.5	+31 57			164	+67	108	+10	d	4×3	11	0	15.0		17.1	2.5
b				+13	−16					d	3×3		0	15.4			
c				+ 3	− 3					h_0	10×2	28	0	16.0			
223 a		10 57.6	+32 32			162	+67	108	+10	d	4×4		0.5	15.0		17.1	2.5
b				+ 4	+ 1					d	4×4		0	15.1			
224* a	3507	10 58.1	+18 41			196	+65	111	− 4	w S	30×20	110	5	12.5		16.8	2.6
b	3501			−91	−91					h_0	35×5	28	1	13.5			
225 a		10 59.5	+ 4 50			219	+57	113	−16	d	7×5	145	0	14.1		16.2	2.0
b				+10	+ 1					e	4×4		1	14.6			
226 a		11 1.5	+23 33			186	+67	110	+ 2	f	8×8		5	14.2		16.2	2.0
b				+19	− 7					d−h_0	6×3	153	0	14.8			
226′ a		11 1.5	+23 33			186	+67	110	+ 2	e	6×6		1	14.0		16.8	2.6
b				+18	− 6					d−h_0	9×5	4	0.5	14.4			
227 a		11 2.8	+24 30			183	+68	110	+ 3	d−h_0	5×3	168	0	14.8		16.3	1.1
b				− 2	+ 8					d	6×6		0.5	14.9			
228 a		11 3.6	+23 28			186	+68	111	+ 2	d	6×6		0.5	14.2		16.2	1.9
b				+ 6	+ 2					d	3×3		1	15.3			
229 a	3534	11 3.6	+27 9			177	+69	110	+ 5	d−h_0	14×5	82	0	14.1		16.2	2.0
b				+ 4	− 9					d	4×4		0	14.5			
A1768 230 a		11 4.4	+22 18			190	+68	112	0	e	5×5		1	14.5		17.0	1.4
b				− 3	−15					d	3×3		0	15.5			
230′ a		11 4.4	+22 18			190	+68	112	0	d	6×6		0.5	13.8		15.9	3.0
b				−10	−13					d	4×4		0.5	14.4			
231 a		11 4.5	+24 48			183	+58	111	+ 3	d	6×6		0.5	13.6		16.3	0.6
b				+ 7	− 4					v S(?)	12×4	78	0.5	13.6			
231′ a		11 4.4	+24 50			183	+68	111	+ 3	e	6×5	0	1	13.8		16.5	3.1
b				+ 8	− 4					h_0	13×3	62	0.5	14.1			

No	NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
232 a		$11^h\ 5^m.2$	$+5°22'$			221°	+58°	114°	−16°	d−h_0	7×4	76°	0.5	$13^m.7$		$16^m.0$	2°.6
b				−2	−7					d−h_0	5×3	19	0	14.7			
233 a		11 5.6	+19 44			195	+67	112	−2	h_0	10×3	81	0	14.5		17.0	1.5
b				+16	+6					d	3×3		0.5	15.4			
234 a	} 3563	11 6.0	+27 31			176	+69	111	+5	d	2×2		0	14.5		16.1	2.2
b				−4	−1					d	2×2		0	14.6			
235 a		11 7.0	+31 56			163	+70	111	+10	e	6×6		1	14.7		17.4	0.3
b				+11	+4					d	5×5		0	15.9			
236 a		11 8.1	+5 45			221	+59	115	−16	d	11×9	38	0.5	13.5		15.8	3.1
b				−5	−12					d	3×3		0.5	14.3			
237 a		11 9.8	+30 5			169	+70	112	+8	e	5×5		1	14.6		17.3	2.0
b				+19	−1					e	2×2		1	15.3			
c				+18	−5					d	2×2		0	15.8			
238 a		11 10.2	+30 4			169	+70	112	+8	d	5×5		0	15.9		17.3	2.0
b				−11	+13					d	4×3	162	0	16.1			
239 a		11 10.9	+10 42			215	+63	115	−10	d−h_0	11×5	43	0.5	14.4		17.0	2.2
b				+8	−2					d	3×2	117	0	15.2			
240 a	3607	11 11.5	+18 35			200	+68	114	−3	g	18×12	121	10	11.5	$11^m.4$	15.8	2.9
b	3608			+7	+60					g	13×9	108	8	12.5	12.5		
c	3605			−19	−22					e	6×4	42	1	13.7	13.1		
240′ a	3607	11 11.7	+18 36			200	+68	114	−3	f	15×15		4	12.1	11.4	16.5	3.3
b	3608			+8	+59					h	15×7	104	2	12.7	12.5		
241 a	3609	11 12.5	+27 11			178	+71	113	+5	g	11×9	65	1	13.3		16.8	2.2
b	3612			+55	−3					g	8×5	163	0.5	14.2			
c				0	+20					d	3×3		0	15.2			
242 a		11 12.7	+32 33			161	+70	112	+11	d−h_0	5×2	49	0	14.4		17.4	0.9
b				−29	+13					d−h_0	6×3	110	0	14.3			
c				0	−7					h_0	5×1	89	0	15.4			
243 a		11 12.8	+30 57			166	+71	112	+9	f	3×3		4	15.0		17.4	1.2
b				+4	−7					f	6×6		1	14.7			
c				+4	+2					d	2×2		0	15.4			
244 a		11 12.9	+28 49			172	+71	113	+7	d	9×9		0.5	14.4		16.8	3.3
b				+3	−22					d	9×9		0.5	14.5			
244′ a		11 12.7	+28 49			172	+71	113	+7	d	8×8		0	14.1		15.3	4.0
b				+3	−22					d	6×6		0	14.3			
245 a		11 13.1	+25 52			181	+70	113	+5	h_0	12×2	11	0.5	14.0		17.0	1.2
b				+7	+7					d	2×2		0	15.4			
246* a	3627	11 15.0	+13 32			212	+66	115	−8	rS	85×35	0	8	10.7	9.9	17.0	2.3
b	3623			−198	+57					s	75×20	171	10	11.0	10.5		
c	3628			0	+360					p	150×20	101	4	11.2	11.3		
246′ a	3627	11 15.0	+13 33			212	+66	115	−8	rS	70×30	158	23	10.9	9.9	15.8	2.9
b	3623			−199	+57					s	85×20	170	18	11.4	10.5		
c	3628			−6	+360					p	150×25	104	8	11.8	11.3		
247 a	3629	11 15.2	+27 32			177	+71	114	+6	g	20×13	20	1	12.6	12.9	15.9	3.0
b				+14	+32					d	4×4		0	14.8			
248 a		11 15.3	+31 47			164	+71	113	+10	h_0	18×2	94	0.5	14.0		17.4	1.2
b				+36	+44					d−h_0	4×2	152	0.5	14.2			
249 a	3651	11 17.1	+24 51			186	+71	114	+3	e−h_0	5×3	174	1	14.3		17.0	0.4
b	3653			+9	−12					e	4×3	78	1	14.5			
c				−29	0					d−h_0	5×3	25	0	14.7			

	No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
A 20107 IC 2776 =	250	a		11h 17m.4	+13° 53′			212°	+66°	116°	− 7°	d−h₀	5×3	170°	0.5	14m.5		17m.0	2°.2
IC 2779 =		b				+11	+10					d	4×4		0	15.2			
	251	a		11 17.7	+35 3			155	+71	112	+14	d	5×5		0.5	14.5		16.3	2.8
		b				+18	− 6					d−h₀	6×3	168	0	14.7			
	252	a	3667	11 19.2	−13 18			242	+45	122	−34	e	4×4		1	13.7		16.0	1.6
		b				+11	+ 1					d	3×3		0	14.7			
	253	a		11 20.2	+32 48			161	+72	114	+11	d	4×3	110	0	15.0		17.2	2.3
		b				+14	+34					d−h₀	8×3	19	0	14.7			
		c				+ 2	−16					d	5×5		0	14.7			
		d				−39	− 9					d	6×6		0.5	15.0			
		e				−35	+42					d	4×4		0	15.4			
		f				−32	+ 6					d	5×5		0	15.5			
A15983	254	a		11 20.3	+23 22			190	+71	115	+ 3	d	6×6		0	13.4		16.9	2.0
		b				+12	+ 9					d	3×3		0	15.1			
	255	a		11 22.2	+36 37			147	+71	113	+16	h₀	10×2	61	0.5	14.1		16.4	2.6
		b				− 2	+ 7					d	4×4		0	14.3			
	256	a		11 22.9	+59 8			108	+56	108	+37	e	4×4		1	13.1		15.9	2.8
		b				+ 4	+ 1					d	4×4		0	13.3			
	257	a		11 23.5	+ 9 39			222	+64	118	−12	e	6×6		1	13.1		17.0	2.4
		b				+59	+10					e	4×3	160	1	13.9			
		c				−64	+27					g	11×6	50	9	14.0			
		d				+69	−65					i	12×4	10	5	14.2			
		e				−21	+ 3					h₀	15×3	161	0.5	14.2			
		f				−66	−24					d−h₀	5×3	112	0.5	14.4			
		g				+52	− 4					d	4×3	74	0.5	15.2			
A15983	258	a	3697	11 23.6	+21 20			198	+71	116	+ 1	h₀	30×8	87	0.5	13.1		16.2	1.5
		b				+20	−28					e	7×7		1	14.4			
		c				+25	−35					f	5×5		3	14.4			
	259	a	3705	11 25.0	+ 9 50			222	+65	119	−11	s	40×13	118	10	12.0	12m.2	17.0	2.4
		b				+52	+69					h₀	6×2	118	0	15.2			
		c				−59	−46					d	4×4		0	15.4			
	260	a	3720	11 27.2	+ 1 21			234	+58	121	−19	d	3×3		0	13.4	13.0	15.5	2.1
		b	3719			−22	+ 9					d−h₀	15×6	35	0.5	13.8			
	260′	a	3720	11 27.2	+ 1 21			234	+58	121	−19	e	4×4		1	13.2	13.0	16.5	2.3
		b	3719			−21	+ 9					e	15×10	31	2	13.6			
	261	a		11 28.0	+46 25			123	+67	112	+25	d	4×4		0	15.0		16.6	2.9
		b				+16	− 4					d	4×4		0	15.0			
	262	a		11 28.1	+33 9			158	+74	116	+12	v S	16×2	18	0.5	14.2		16.6	1.7
		b				−20	−17					d−h₀	4×2	169	0	15.2			
		c				+11	+ 2					d	3×3		0	15.3			
same as Heidelberg	263	a		11 28.1	+49 47			117	+64	112	+28	d	8×8		0.5	13.9		16.7	2.6
#12, [illegible] 13		b				−20	+27					d	4×4		0	14.8			
	264	a		11 28.2	+34 52			151	+73	115	+14	d	4×3	82	0	14.3		16.7	0.5
		b				−15	−13					d	3×3		0	15.3			
		c				− 7	− 2					d	3×3		0	15.6			
	265	a		11 28.4	+33 11			158	+74	116	+12	d	3×3		0	14.3		16.6	1.7
		b				− 2	+ 2					d	3×3		0	14.5			
	266	a	3737	11 30.0	+55 31			110	+59	110	+34	d	3×3		0.5	14.0		16.1	1.9
		b				− 6	−10					d	3×3		0	14.8			
	267	a		11 30.2	+33 52			154	+74	116	+13	h₀	10×3	141	0	14.1		16.7	0.9
		b				−19	− 4					d	3×3		0	15.6			

No	NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
268 a		11h 31m.8	+39° 49′			135°	+72°	114°	+18°	d	6×6		0	13m.8		16m.9	1°.3
b				0	+ 9					h_0	7×2	50°	0	14.0			
269 a		11 32.0	+ 3 24			234	+61	121	−17	e	8×8		1	14.1		16.7	0.7
b				− 8	+ 4					d	6×6		0	14.3			
270* a	3769	11 32.3	+48 28			118	+65	112	+27	v.2	27×5	150	5	12.3	12m5	16.9	1.4
b				+10	− 6					d−h_0	5×2	106	0	14.1			
271 a	3784	11 34.2	+26 52			180	+75	117	+ 6	e−h_0	9×4	130	1	14.3		17.2	1.4
b	3785			+ 8	− 5					h	11×5	20	6	14.5			
272* a	3788	11 34.5	+32 29			158	+75	116	+12	h	17×4	173	2	12.6		16.5	2.4
b	3786			− 4	−15					g	12×7	64	2	13.2			
c	3793			+46	−10					e	2×2		1	15.5			
273 a	3801	11 35.0	+18 17			210	+72	119	− 1	e−h_0	11×5	115	1	13.4		16.0	2.7
b	3802			+ 4	+23					h_0	12×3	92	0	13.8			
273′ a	3801	11 35.1	+18 17			210	+72	119	− 1	e	10×8	126	1	13.4		16.2	3.1
b	3802			+ 5	+23					e	9×6	84	1	14.1			
274 a		11 35.8	+ 2 19			237	+60	123	−18	d	4×4		0	14.9		16.3	2.5
b				+ 7	+ 1					d	4×4		0	15.0			
275 a		11 36.4	+16 32			214	+71	120	− 4	h_0	10×3	19	0.5	13.9		15.7	2.4
b				+29	+ 5					d	7×7		0.5	13.6			
c				−10	0					d	4×4		0.5	14.7			
276 a	3815	11 36.4	+25 21			187	+75	118	+ 6	e−h_0	15×5	66	1	14.0		16.9	3.0
b	3814			−29	+ 3					e−h_0	5×3	160	1	15.0			
277 a		11 36.4	+26 26			182	+76	118	+ 7	e	3×3		1	15.3		17.2	1.9
b				− 1	+ 5					e−h_0	5×2	128	1	15.4			
278 a		11 36.8	+32 34			158	+75	117	+12	d−h_0	8×3	118	0	14.1		16.4	2.5
b				− 2	− 7					d	2×2		0	15.4			
279 a		11 36.9	+26 32			182	+76	118	+ 6	h−h_0	6×2	21	1	15.0		17.2	1.9
b				+ 5	− 2					e	2×2		1	15.4			
280 a		11 37.0	+26 35			182	+76	118	+ 6	e	4×4		2	15.0		17.2	1.9
b				+ 9	−12					d	2×2		0	15.6			
281 a		11 37.2	+18 53			209	+73	119	− 1	h_0	15×4	159	0.5	13.2		16.5	2.3
b				+13	−15					d	3×2	160	0	15.3			
282 a		11 38.4	+ 3 57			236	+62	123	−16	d	6×4	10	0.5	14.3		16.3	2.5
b				+ 8	+17					d	3×3		0	15.0			
283 a		11 38.7	+26 44			182	+76	118	+ 7	d	6×4	138	0	15.3		17.2	1.9
b				− 3	+13					d	5×5		0	15.4			
284 a		11 39.1	+20 47			205	+74	120	+ 1	e	6×6		1	14.5		16.7	1.0
b				− 2	− 5					e	4×4		1	14.7			
285 a	3860	11 39.6	+20 21			206	+74	120	0	g−h	12×5	41	2	13.9		16.7	1.0
b				− 4	−14					h	13×3	168	4	14.8			
286 a	3863	11 39.9	+ 9 1			230	+66	122	−11	h_0	22×4	70	1	14.0		16.1	2.0
b				−22	+ 9					d	3×3		0	15.3			
287 a	3861	11 39.9	+20 32			206	+74	120	0	f	7×7		5	14.1		16.7	0.9
b				+ 7	− 4					h_0	7×2	120	0	14.8			
288 a	3867	11 40.3	+19 57			207	+74	120	0	g−h	11×4	176	3	14.1		16.7	1.1
b	3864			−33	− 6					e	6×6		1	15.2			
289 a	3873	11 40.6	+20 20			206	+74	120	0	e	3×3		1	14.1		16.7	0.8
b	3875			+ 8	− 4					g−h	12×3	90	10	14.5			
290 a		11 40.8	+21 0			204	+75	120	+ 1	d	4×4		0.5	14.6		16.7	0.6
b				+ 1	− 6					d	3×2	128	0	15.2			

17—37522.

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
291	a		11^{h}41^{m}0	−18° 16′			251°	+42°	129°	−37°	d−h_0	9×4	177°	0	14^{m}6		16^{m}0	2°2
	b				0	−13					d	5×5		0	15.2			
292	a		11 42.8	+38 0			136	+74	116	+17	e	2×2		1	14.7		17.0	2.1
	b				+ 5	+ 6					d−h_0	3×1.5	175	0	14.9			
293	a	3893	11 43.4	+49 17			114	+66	113	+28	w S	35×21	179	6	11.1	11^{m}0	17.0	1.1
	b	3896			+33	−20					e	5×5		1	13.9			
294	a	3894	11 43.4	+59 59			103	+57	110	+39	g	9×5	20	3	13.3		16.3	0.3
	b	3895			+17	+12					d	6×6		0.5	14.0			
295	a	3907	11 44.4	− 0 32			243	+59	126	−20	e	4×4		1	14.1		16.2	2.8
	b				−17	+ 1					h_0	12×4	73	0.5	14.2			
296	a	3913	11 45.1	+55 54			106	+60	112	+35	d	5×5		0.5	14.0		15.8	1.3
	b				−11	+13					d	4×4		0	14.8			
297	a		11 45.2	+51 5			111	+65	114	+30	e	5×5		1	14.5		16.6	2.9
	b				− 6	+ 8					d−h_0	5×3	161	0	15.0			
	c				− 2	− 4					e	3×3		1	15.0			
298	a		11 45.6	+46 22			117	+69	115	+26	h_0	13×3	73	0	13.9		16.8	2.1
	b				− 3	+ 3					d	3×2	1	0	15.0			
299	a		11 46.5	+49 2			113	+67	115	+28	d	4×4		0	15.1		17.0	1.2
	b				0	− 7					d	2×2		0	15.7			
300	a	3930	11 46.6	+38 34			133	+75	117	+18	g	30×20	20	0.5	12.7		17.2	1.2
	b				+33	+ 5					d	2×2		0	14.9			
301	a	3949	11 48.5	+48 25			112	+67	115	+28	g	22×11	127	0.5	11.5	11.6	16.9	1.3
	b	3950			− 2	+16					d	2×2		0	15.7			
302	a		11 50.2	+33 41			150	+78	119	+14	e−g	8×3	80	1	14.8		16.9	2.3
	b				−13	+13					h_0	8×2	155	0	15.1			
303	a		11 50.4	+46 47			115	+69	116	+27	d	4×4		0	14.8		16.8	2.2
	b				+ 3	+ 2					d−h_0	4×2	74	0	15.0			
304	a	3972	11 50.5	+55 52			104	+61	113	+35	h_0	35×7	116	0.5	12.7		15.9	1.0
	b	3977			+30	+45					d	4×4		0	14.0			
305	a	3976	11 50.8	+ 7 18			238	+66	126	−13	s	40×9	53	4	12.5	12.4	17.4	1.7
	b				+15	−45					d	4×3	141	0	15.3			
306	a	3978	11 50.9	+61 5			101	+56	112	+40	d	6×6		0.5	13.2		16.2	1.4
	b	3975			−20	+ 3					d	5×5		0	15.2			
307	a		11 51.4	−19 0			255	+42	133	−37	d−h_0	10×5	33	0	14.2		15.9	2.6
	b				+ 4	+ 6					d	5×5		0	14.5			
308*	a	3993	11 52.5	+25 48			190	+79	122	+ 5	h_0	16×4	136	1	14.7		17.4	1.9
	b	3997			+23	+19					v S	16×4	93	8	14.3			
	c	3987			−40	−29					h	25×4	58	4	14.5			
	d	3989			−27	− 5					d	5×4	123	0	15.3			
309	a	3995	11 52.6	+32 51			151	+79	120	+13	v	20×7	36	1	13.3	12.9	16.7	3.0
	b	3994			−17	−11					e	5×4	13	1	13.7			
	c	3991			−32	+25					h_0	13×3	27	0	14.1			
310	a	3998	11 52.7	+56 1			104	+61	114	+36	g	10×7	139	8	11.8	11.6	15.9	1.1
	b	3990			−30	+ 1					g	6×3	41	2	13.3			
311	a		11 52.8	+36 58			135	+76	119	+17	d	6×6		0	13.9		17.0	2.3
	b				+ 4	− 5					e	3×3		1	14.9			
312	a	4004	11 53.0	+28 24			175	+79	121	+ 8	v S	20×4	20	3	13.7		17.5	0.9
	b				−31	− 7					e	3×3		1	14.8			
313	a	I.C. 749	11 53.4	+43 18			119	+72	118	+24	d (w?)	15×15		0	12.4	13.2	15.9	1.3
	b	IC 750			+35	− 6					h−h_0	8×2	41	0.5	12.9	13.0		

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha\cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a\times b$	φ	c	m	m_{Harv}	m_l	d
314	a	4010	$11^h 53^m.4$	+47° 48′			112°	+68°	117°	+27°	h_0	34×4	61°	0	$12^m.5$		$16^m.8$	2°.1
	b	4001			−53	+ 44					e	3×3		1	15.0			
315	a		11 54.1	+35 8			141	+78	120	+15	h	8×2	138	3	14.8		17.1	0.9
	b				+ 4	+ 11					d−h_0	5×2	140	0.5	15.1			
316	a		11 54.5	+27 7			183	+80	122	+ 7	e	9×9		1	14.9		17.5	0.5
	b				+10	− 6					d	5×5		0.5	16.2			
317	a		11 56.0	+ 0 40			247	+61	128	−17	d	5×5		0.5	14.8		16.2	3.0
	b				− 5	+ 8					d	5×5		0.5	14.9			
318	a		11 57.2	+30 24			164	+80	122	+11	k	17×4	68	3	14.3		17.1	2.8
	b				−42	− 9					e	7×6	8	2	14.5			
319	a		11 57.4	+29 4			171	+81	122	+10	d−h_0	5×3	0	0	15.5		17.4	1.5
	b				0	− 11					d	2×2		0	15.8			
320	a	4045	11 57.6	+ 2 31			246	+63	128	−16	f (t?)	25×25		11	13.1	$12^m.8$	16.2	3.0
	b				0	− 16					d	5×5		0	14.8			
321	a		11 57.6	+39 39			124	+75	119	+19	d	6×6		0	14.3		17.1	1.3
	b				+ 1	+ 10					d−h_0	6×3	143	0	15.1			
322	a		11 59.1	+15 4			231	+74	125	− 4	d	5×4	17	0	14.8		17.1	3.0
	b				+ 2	+ 7					d	4×4		0.5	15.5			
323	a		11 59.6	+31 45			156	+81	122	+12	f	7×7		3	14.1		16.1	3.1
	b				+ 4	− 11					d	6×6		0	14.8			
	c				+ 5	+ 9					d−h_0	8×4	148	0	14.9			
324	a		12 0.1	+11 11			239	+71	126	− 7	d−h_0	11×5	30	0	15.6	16.3	16.9	3.3
	b	4082			− 3	+ 19					d	8×8		0.5	14.5	15.4		
	c	4083			+ 6	− 18					d−h_0	11×7	34	0.5	14.6	15.6		
325	a		12 0.2	+18 26			224	+77	125	− 1	d	11×8	150	0.5	13.7		15.9	3.1
	b				− 1	+ 21					d−h_0	8×4	86	0	14.0			
326*	a	4088	12 0.4	+51 6			105	+66	117	+31	v S	50×15	52	0	11.1	11.2	16.1	3.1
	b	4085			−18	−114					h_0	22×3	76	0.5	12.8	12.8		
326′	a	4088	12 0.4	+51 6			105	+66	117	+31	v S	50×15	43	0.5	11.2	11.2	15.9	4.1
	b	4085			−10	−113					h_0	21×6	72	0.5	12.6	12.8		
327	a		12 0.6	+ 9 33			241	+69	127	+ 1	d−h_0	8×5	68	0.5	14.5		17.2	2.6
	b				−16	− 2					d−h_0	6×3	147	0.5	15.2			
328	a		12 0.7	+31 39			156	+81	122	+12	d	5×5		0	14.9		16.2	3.0
	b				− 1	− 12					d	6×4	52	0	14.9			
329	a		12 1.0	+28 47			172	+81	123	+ 9	g	7×2	102	1	14.6		17.4	1.9
	b				+ 1	+ 11					h_0	7×2	9	1	14.7			
330	a		12 1.1	+ 8 25			242	+68	127	−10	d	6×6		0	15.5		17.2	2.7
	b				− 7	− 1					d−h_0	5×3	178	0	15.5			
331	a		12 1.1	+33 27			145	+80	122	+14	d	4×4		0	15.3		16.4	2.2
	b				− 5	− 1					d	4×4		0	15.4			
332	a		12 1.8	+25 33			194	+81	124	+ 7	d−h_0	5×3	38	0.5	15.1		17.2	2.6
	b				+ 7	− 4					d−h_0	5×3	123	0.5	15.3			
333	a	4111	12 1.9	+43 38			114	+73	119	+24	h	35×4	149	7	11.4	11.6	16.0	0.3
	b	4109			−20	− 44					d	5×5		0	13.6			
334	a	4117	12 2.6	+43 41			113	+73	119	+24	g	6×4	4	0.5	13.4		16.0	0.5
	b	4118			+14	− 8					d	4×4		0	14.9			
335*	a	4125	12 3.0	+65 44			96	+52	111	+45	g	18×8	79	13	12.3	11.3	16.0	1.9
	b	4121			−11	− 36					d	3×3		0	14.1			
336	a		12 3.2	+12 51			238	+72	127	− 6	d	8×8		0.5	15.2	16.8	16.9	3.3
	b				+ 5	− 4					d	5×5		0.5	15.5	16.9		

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
337	a	4128	12h 3m.6	+69° 20′			95°	+49°	109°	+48°	h	20×4	71°	6	13m.6	12m.9	16m.7	2°.5
	b				−16	+12					d	2×2		0	15.4			
338	a		12 3.8	+42 18			115	+74	120	+22	d	8×8		0.5	13.4		15.9	1.6
	b				−17	−14					d	2×2		0	14.7			
339	a	4132	12 3.9	+29 49			165	+81	123	+10	e−g	8×5	10	2	14.6		17.1	2.9
	b	4134			+21	−45					h−h_0	16×3	149	2	13.7			
	c	4131			−33	+33					e	6×6		3	14.3			
340	a		12 4.4	+26 47			186	+82	124	+8	g	18×12	80	2	14.4		17.3	2.4
	b				−18	−9					e	5×5		1	15.0			
341	a		12 4.6	+37 1			128	+78	121	+17	d	6×6		0	14.4		16.7	2.9
	b				+21	−17					d−h_0	8×4	175	0.5	14.7			
342	a	4145	12 5.1	+40 27			118	+76	120	+21	w S	50×35	97	1	11.8	12.2	16.0	2.9
	b				+101	−82					d−h_0	8×4	94	0.5	14.4			
343	a		12 5.4	+59 21			98	+58	114	+39	d	6×6		0	13.5		15.3	2.2
	b				−10	−12					d	4×4		0	13.6			
	c				−5	−6					d	3×3		0	13.7			
344	a		12 5.5	+18 26			229	+78	126	0	d	4×4		0	14.3		16.1	2.7
	b				+10	+11					d−h_0	5×3	170	0	14.3			
345*	a	4151	12 5.5	+39 58			118	+76	121	+20	s(?)	30×15	110	18	12.1	11.2	16.0	2.8
	b	4156			+35	+41					g	10×4	79	2	14.2			
345′	a	4151	12 5.4	+39 58			118	+76	121	+20	g	28×20	129	13	12.1	11.2	16.8	2.9
	b	4156			+30	+44					d−h_0	10×6	85	0.5	13.7			
	c				+88	+5					d	9×9		0	14.6			
346	a	4173	12 7.1	+29 47			164	+82	124	+10	h_0	35×8	134	1	13.5		16.7	3.6
	b	4175			+24	−23					d−h_0	13×6	130	1	14.0			
347	a	4187	12 8.4	+51 17			102	+66	118	+32	e	3×3		1	14.4		16.3	2.7
	b				−1	+10					d	2×2		0	15.3			
348	a	4192	12 8.7	+15 27			238	+75	128	−3	s	70×20	150	1	10.9	11.4	17.5	0.6
	b				+47	−105					d	5×5		0.5	14.3			
	c				−53	−79					d	4×4		0	15.1			
349	a		12 8.7	+57 42			99	+60	115	+37	d−h_0	13×8	32	0	13.2		15.2	2.6
	b				+16	−9					d	5×5		0	13.9			
350	a		12 9.0	+35 35			129	+80	123	+16	d−h_0	10×4	71	0	14.9		16.5	2.0
	b				+20	+7					d	2×2		0	15.4			
351	a		12 9.6	+13 53			242	+74	128	−5	e	6×4	162	1	14.7	16.2	17.4	1.6
	b				+13	+2					d	4×4		0	15.4	16.8		
352	a		12 10.5	+51 54			101	+65	118	+33	h_0	12×3	41	0.5	13.6		16.1	3.2
	b				−28	+11					d−h_0	5×3	29	0	14.8			
353*	a	4216	12 10.8	+13 43			243	+74	128	−5	h (s?)	75×9	9	8	10.9	11.3	17.4	1.7
	b	4206			−91	−79					h−h_0	45×4	178	1	12.5	13.9		
	c	4222			+71	+97					h_0	25×4	55	0	13.3	14.2		
	d				−101	+18					e	6×4	84	1	14.4	15.4		
354	a	4217	12 10.8	+47 39			104	+70	119	+28	p	45×10	48	1	12.0	11.9	16.5	1.3
	b	4226			+63	−37					g−h_0	8×2	120	0.5	13.6			
355	a	4227	12 11.5	+34 5			133	+82	124	+15	g	8×3	77	13	14.1		16.6	0.5
	b	4229			+11	+24					g	5×2	156	3	14.7			
356	a	4231	12 11.9	+48 3			103	+69	119	+28	d	4×4		0	13.8		16.6	0.9
	b	4232			0	−11					g	7×3	157	1	14.0			
357	a	4236	12 12.0	+70 2			94	+48	109	+49	r S	150×40	161	0.5	10.9	11.3	16.9	1.5
	b				+42	+79					d	4×4		0	15.1			
358	a	4234	12 12.1	+4 15			253	+65	131	−14	d	10×10		0.5	12.4	13.0	16.0	2.9
	b				−18	−5					d	3×3		0	14.8			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_t	d
359	a	4235	$12^h 12^m.1$	+ 7° 45′			251°	+68°	130°	−11°	h	40×4	49°	8	$12^m.2$	$12^m.8$	$16^m.4$	0°.6
	b	4246			+122	0					e−h₀	18×9	78	1	12.7	14.0		
	c	4247			+120	+51					g	10×4	0	3	14.0	15.0		
360	a		12 12.4	+12 57			245	+74	129	− 6	h₀	25×5	27	0.5	14.3	15.4	17.2	2.5
	b				− 64	+40					h₀	20×3	173	1	14.2	15.3		
	c				− 71	−60					e−h₀	5×3	56	1	14.8			
361	a		12 12.7	+18 0			236	+78	128	0	g	12×9	170	1	14.0		17.2	2.7
	b				− 13	+21					d	5×5		0	15.7			
362	a		12 13.2	+44 44			106	+72	120	+26	e	5×5		1	13.4		15.7	2.6
	b				− 18	+ 3					d	3×3		0	14.4			
363*	a	4258	12 14.0	+47 52			102	+69	120	+29	r S	100×40	152	6	9.8	10.2	16.6	0.9
	b	4248			−117	+62					h₀	14×3	102	0	13.2			
364	a		12 14.4	+17 48			239	+78	128	− 1	e	10×7	146	1	14.7		17.2	2.5
	b				− 13	+ 6					d	4×4		0	16.0			
365	a	4269	12 14.7	+ 6 35			253	+68	131	−12	e	2×2		1	13.6	14.3	16.4	0.7
	b				− 9	− 6					d−h₀	4×2	24	0.5	14.2	15.6		
366	a	4271	12 14.7	+57 17			97	+61	116	+37	d	6×4	179	0	13.4		15.3	2.4
	b				0	+ 5					d	4×4		0	13.5			
367	a		12 14.8	+36 5			122	+80	124	+17	h₀	14×4	18	0.5	14.8		16.3	2.5
	b				− 23	+ 2					d	4×4		0	15.1			
	c				− 23	0					d	4×4		0	15.1			
368*	a	4273	12 14.9	+ 5 54			253	+67	131	−12	g	17×8	7	5	12.2	12.2	16.3	1.3
	b	4281			+ 64	+27					g	14×4	85	8	12.5	12.2		
	c	4270			− 18	+74					g	12×3	106	5	13.2	12.8		
	d	4268			− 22	−37					h	10×2	40	5	13.7	13.8		
	e	4259			− 86	+17					e	3×3		1	13.8	14.9		
	f	4277			+ 20	− 1					d	4×4		0	13.9	15.6		
	g				− 49	+32					d	3×3		0	14.5	15.8		
369	a	4278	12 15.2	+29 50			157	+84	126	+11	f	20×20		5	11.7	11.6	15.6	3.9
	b	4283			+ 31	+20					d	9×9		0.5	12.8	12.8		
370	a		12 15.6	− 6 25			259	+56	135	−24	h₀	15×4	138	1	15.0		16.8	2.6
	b				− 34	+25					d	5×5		0.5	15.3			
371	a	4288	12 15.7	+46 51			102	+70	120	+28	v S	10×7	179	0.5	13.3		16.5	2.0
	b				+ 4	−22					d	3×3		0	15.0			
372	a		12 15.9	+28 32			173	+85	126	+10	d	7×7		0.5	14.7		16.6	2.9
	b				+ 2	− 6					d	6×6		0.5	14.7			
373	a	4290	12 16.0	+58 39			96	+59	116	+39	d	12×8	25	0	13.3	12.7	15.5	1.2
	b	4284			− 47	− 2					d−h₀	8×4	83	0	14.0			
374	a		12 16.1	+40 26			110	+77	123	+22	d	4×4		0.5	14.1		16.4	1.1
	b				+ 6	+15					e	4×4		1	14.2			
	c				− 1	+20					e	4×4		1	14.2			
375	a	4292	12 16.2	+ 5 9			255	+66	132	−13	g	10×4	1	2	13.7	14.4	16.2	2.1
	b				0	+22					d	4×4		0.5	14.9	16.6		
376*	a	4294	12 16.3	+12 4			250	+73	130	− 6	h₀−v	30×28	152	2	11.8	13.0	16.8	3.5
	b	4299			+ 58	− 3					d	13×13		0.5	12.0	13.1		
377*	a	4298	12 16.4	+15 10			246	+76	129	− 3	r S	32×13	124	3	11.6	12.5	17.4	1.3
	b	4302			+ 23	− 5					h₀	50×6	178	1	12.0	13.2		
378	a		12 16.5	+ 5 20			255	+66	132	−13	d	3×3		0.5	14.2		16.3	2.0
	b				+ 3	− 1					d	4×4		0	14.3			
379	a	4303	12 16.8	+ 5 2			255	+66	132	−13	w S	35×35		4	10.4	10.4	16.2	2.3
	b				+ 81	+57					f	11×11		1	13.5	14.0		

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
380	a	4307	$12^h 17^m.0$	+9° 36′			252°	+71°	131°	−8°	h_0 − i	30×6	19°	1	$12^m.2$	$13^m.0$	$16^m.1$	2°.7
	b				+4	−32					d	7×7		0	14.6	16.4		
381	a	4305	12 17.0	+13 18			249	+74	130	−5	h (r?)	17×9	30	3	13.5	14.0	17.2	2.5
	b	4306			+1	+29					e	8×8		1	14.0	14.3		
382	a	4309	12 17.1	+7 42			253	+69	132	−10	g	10×4	76	3	13.6	14.4	16.4	1.2
	b				+6	+15					d	3×3		0.5	15.3			
383	a		12 17.1	+51 37			99	+66	119	+33	d	7×7		0.5	14.0		16.2	2.9
	b				−9	−12					d	2×2		0	15.2			
384	a		12 17.4	−4 6			259	+58	135	−21	h_0	21×5	105	1	13.4		16.9	2.3
	b				+7	+5					d	3×3		0	14.9			
385	a	4313	12 17.6	+12 22			250	+73	131	−6	h	32×7	139	2	12.0	13.3	16.9	3.3
	b				+7	+42					e	5×5		1	15.6			
386	a		12 17.8	+7 14			255	+68	132	−11	h_0	10×3	50	0.5	14.1	15.4	16.4	1.2
	b				−36	−4					h_0	18×4	37	0.5	14.5	15.2		
387	a	4321	12 17.9	+16 24			245	+77	129	−2	w S	60×60		3	10.5	10.8	17.4	1.9
	b	4312			−56	−171					h_0	37×6	171	1	12.1	13.7		
	c				−187	−54					e	10×10		1	14.0			
	d				+63	+3					d	5×5		0	14.2			
	e				−85	−57					d	5×5		0	14.7			
	f				+17	+51					d	5×5		0	14.7			
	g				−146	−114					d	6×6		0	14.9			
388	a	4324	12 18.0	+5 49			256	+67	132	−12	g	9×4	50	2	12.5	12.5	16.3	1.9
	b				−5	−10					d	2×2		0	14.9			
389	a	4336	12 18.1	+20 0			237	+81	128	+2	d	10×9	158	0.5	12.4	14.0	16.0	2.8
	b				+7	+16					d	6×4	27	0	14.8			
390	a	4344	12 18.6	+18 7			242	+79	129	0	d	12×8	65	0.5	13.5	14.1	15.4	4.0
	b				−23	−11					d	5×5		0	15.0			
391	a	4350	12 18.9	+17 17			245	+78	129	−1	h	23×6	27	2	12.0	12.0	17.2	2.6
	b	4340			−56	+16					g	25×17	101	13	12.8	13.0		
391′	a	4350	12 18.9	+17 16			245	+78	129	−1	h	17×6	29	2	11.9	12.0	16.4	3.3
	b	4340			−57	+20					f	20×20		28	12.7	13.0		
392	a		12 19.1	+7 10			256	+68	132	−11	e	5×5		1	13.4	14.2	16.3	1.6
	b				0	+5					d	2×2		0	15.0			
393	a	4360	12 19.2	+9 50			254	+71	132	−8	e	6×6		1	13.0	14.2	15.9	3.2
	b				−17	−17					d	4×4		0	14.1	15.4		
394	a		12 19.7	+5 31			257	+67	133	−12	d	3×3		0.5	14.8		16.2	2.3
	b				+8	−4					d	2×2		0	14.8			
395	a		12 20.1	+16 41			247	+78	130	−1	d	4×4		0	15.1	16.7	17.2	2.5
	b				+28	+3					g	8×4	3	1	14.7	15.5		
	c				−4	−17					d	4×4		0	15.5	17.0		
396	a		12 20.3	−6 41			261	+55	137	−24	h	7×2	168	3	14.5		17.0	1.6
	b				+9	+1					d	3×3		0	15.7			
397*	a	4382	12 20.4	+18 45			242	+80	129	+1	g	45×20	15	34	11.5	10.5	16.7	2.5
	b	4394			+74	+12					h	19×4	143	11	13.3	12.2		
397′	a	4382	12 20.3	+18 45			242	+80	129	+1	g	45×30	10	13	11.1	10.5	16.5	4.0
	b	4394			+75	+16					f	30×30		10	12.4	12.2		
398	a		12 20.6	+16 23			247	+77	130	−1	d	6×6		0	14.8	16.4	17.3	2.4
	b				−1	+12					d	7×7		0	15.5	17.5		
399	a		12 20.8	+46 37			101	+71	122	+27	d	3×3		0	14.8		16.4	2.4
	b				−7	+2					d	2×2		0	15.0			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
400	a	4396	$12^h 20^m.9$	+16° 14′			249°	+77°	130°	− 2°	h	30×6	127°	0.5	$12^m.4$	$13^m.6$	$16^m.2$	3°.6
	b				− 62	− 1					d	8×8		0	15.1			
401	a		12 20.9	+46 27			101	+72	122	+27	d	6×6		0	14.3		16.3	2.7
	b				+ 26	− 9					d−h_0	8×3	9	0	14.4			
402	a	4403	12 21.0	− 7 8			262	+55	137	−24	h	9×2	27	4	13.9		17.0	1.9
	b	4404			+ 9	+ 4					e	5×5		1	14.1			
403	a	4406	12 21.0	+13 28			253	+74	131	− 4	g	35×25	140:	18	11.1	10.9	17.1	3.0
	b	4374			−168	− 42					g	25×20	140:	10	11.1	10.9		
	c	4388			− 60	−173					h−v	40×7	85	5	11.7	12.2		
	d	4402			− 14	+ 99					h_0	35×7	86	0	12.1	13.4		
	e	4425			+154	−125					h	30×6	23	4	12.3	13.1		
	f	4413			+ 58	−202					g	15×12	44	2	12.3	13.8		
	g				+ 93	+143					d−h_0	11×5	170	0	14.3	16.2		
	h				+ 27	+102					d	4×4		0	15.5			
404	a	I 3330	12 21.0	+31 24			138	+85	126	+13	d	6×5	95	0	13.7		16.2	3.0
	b				+ 13	+ 2					d	5×5		0.5	14.8			
405	a		12 22.1	+16 33			250	+78	130	− 1	d−h_0	8×3	89	0	15.2	16.7	17.1	2.9
	b				− 3	− 50					h_0	25×7	80	1	13.9	15.6		
	c				+ 9	+ 27					d−h_0	8×5	162	0.5	14.3	15.7		
406	a	4430	12 22.3	+ 6 49			258	+68	133	−11	f	22×22		4	12.2	13.4	16.2	2.4
	b	4432			+ 20	− 19					d	6×6		0.5	14.3	15.8		
406′	a	4430	12 22.4	+ 6 49			258	+68	133	−11	g	30×23	47	2	12.5	13.4	16.7	2.8
	b	4432			+ 17	− 17					d	6×4	177	0.5	14.3	15.8		
407	a	4433	12 22.5	− 7 44			262	+54	138	−24	h_0	12×4	5	1	12.0	12.9	16.9	2.3
	b	4428			− 27	+ 68					h_0	13×4	74	1	12.1	13.1		
408	a	4436	12 22.6	+12 50			254	+74	131	− 5	d	10×10		0.5	14.2	14.2	16.9	3.3
	b	4440			+ 32	− 14					e	10×10		1	12.9	13.2		
	c	4431			− 35	− 18					d	11×9	9	0.5	14.1	14.6		
408′	a	4436	12 22.6	+12 53			254	+74	131	− 5	d	9×9		0.5	14.4	14.2	16.3	3.4
	b	4440			+ 31	− 14					e	10×10		1	12.8	13.2		
	c	4431			− 37	− 16					d	9×9		0.5	14.3	14.6		
409	a	4438	12 22.6	+13 32			253	+75	131	− 4	r−s	90×30	16	48	11.8	11.9	17.0	3.2
	b	4435			− 15	+ 41					d	9×9		0.5	11.9	11.8		
409′	a	4438	12 22.7	+13 35			253	+75	131	− 4	h	23×10	25	2	12.2	11.9	16.0	4.0
	b	4435			− 14	+ 44					e	10×10		1	12.2	11.8		
410	a		12 22.9	+ 6 16			259	+68	133	−12	h_0	15×3	125	0.5	13.9		16.1	2.7
	b				− 7	− 3					h	10×2	117	5	14.8			
411*	a	4461	12 23.9	+13 43			255	+75	131	− 3	h	30×9	15	3	11.9	12.4	16.8	3.4
	b	4458			− 14	+ 34					f	8×8		1	12.5	13.8		
411′	a	4461	12 24.0	+13 45			255	+75	131	− 3	h	22×10	10	2	12.5	12.4	16.0	3.9
	b	4458			− 15	+ 36					d	10×10		0.5	12.7	13.8		
412	a	4466	12 24.4	+ 8 15			259	+70	133	− 9	d−h_0	10×4	101	0.5	13.7	14.8	16.3	3.5
	b				+ 5	+ 20					d	4×4		0	15.1			
413	a	4472	12 24.7	+ 8 34			258	+70	133	− 9	g	40×30	168	23	10.9	10.1	16.8	2.6
	b	4471			− 14	− 54					d	2×2		0	14.8			
	c	4467			− 42	− 6					d	4×3	74	0	14.9	15.0		
	d	4465			− 58	+ 15					d	3×3		0	15.1	15.8		
413′	a	4472	12 24.7	+ 8 34			258	+70	133	− 9	g	40×30	163	18	10.9	10.1	16.5	3.1
	b	4471			− 24	− 52					e	3×3		1	14.7			
	c	4467			− 41	− 6					d	6×4	0	0	14.6	15.0		
	d	4465			− 58	+ 15					d	6×6		0.5	14.9	15.8		

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
414*	a	4490	$12^h 25^m.7$	+42° 11′			101°	+76°	124°	+24°	v S	45×22	102°	3	$9^m.8$	$10^m.5$	$16^m.0$	2°.8
	b	4485			− 11	+ 33					e—$h_\circ$	11×7	179	1	11.9	12.9		
415	a	}4496	12 26.6	+ 4 30			261	+66	134	−13	g	40×25	45	2	12.4	}12.0	16.6	3.2
	b				+ 4	− 8					d	8×6	117	0.5	13.4			
416	a	4508	12 27.8	+ 6 21			262	+68	134	−11	d	7×6	150	0.5	15.0	16.9	17.0	1.6
	b				+ 1	− 7					d—$h_\circ$	4×1.5	4	0	16.4			
417	a	4518	12 28.1	+ 8 24			261	+70	133	− 9	h	5×2	130	1	14.7	14.8	17.0	1.7
	b				− 3	− 11					d	3×3		0	15.4	16.6		
417′	a	4518	12 28.1	+ 8 24			261	+70	133	− 9	d	5×5		0.5	14.6	14.8	16.6	2.8
	b				− 4	− 10					d	4×4		0	15.3	16.6		
418	a	4519	12 28.4	+ 9 13			261	+71	133	− 8	g	25×20	151	2	12.1	12.6	16.9	2.0
	b				− 14	+ 23					d	4×4		0	15.1	16.6		
418′	a	4519	12 28.4	+ 9 12			261	+71	133	− 8	r	30×20	145	2	12.6	12.6	16.9	2.3
	b				− 16	+ 23					d—$h_\circ$	5×3	28	0.5	15.1	16.6		
419	a	4534	12 29.2	+36 4			104	+82	126	+17	e	9×9		1	12.8		17.5	2.3
	b				+ 6	− 4					e	3×3		1	15.0			
420	a	4535	12 29.3	+ 8 45			262	+70	134	− 8	r S	60×40	12:	1	11.6	11.1	17.0	1.8
	b				− 16	+ 45					d—$h_\circ$	6×3	177	0.5	14.7	16.4		
420′	a	4535	12 29.3	+ 8 45			262	+70	134	− 8	r S	70×40	11	1	11.3	11.1	16.8	2.3
	b				− 17	+ 47					d	4×4		0	15.0	16.4		
421	a	4540	12 29.8	+16 7			258	+78	132	− 1	e—$h_\circ$	12×7	58	2	12.4	12.9	16.6	2.8
	b				+ 12	+ 9					e	4×4		1	14.4			
422	a	4550	12 30.5	+12 47			260	+74	133	− 5	h	28×4	174	4	12.7	12.7	16.8	2.2
	b	4551			+ 23	+ 35					e	7×7		1	12.8	13.3		
423	a	4559	12 30.9	+28 31			165	+88	129	+11	r S	100×35	145	10	10.8	10.7	16.7	2.6
	b				+133	− 57					d	7×5	110	0.5	14.7			
	c				+132	−123					d	5×5		0.5	14.9			
	d				− 11	− 18					d	5×5		0.5	15.5			
424	a		12 31.1	+ 8 5			264	+70	134	− 9	d	7×7		0.5	15.2		16.6	2.8
	b				+ 9	− 3					d	3×3		0	15.3			
425	a		12 31.2	+17 11			260	+79	132	0	d—$h_\circ$	8×3	95	0	15.5		16.9	1.7
	b				0	+ 5					$h_\circ$	6×1.5	90	0	15.7			
426*	a	4565	12 31.4	+26 32			217	+87	129	+ 9	o	150×14	134	6	10.3	10.7	16.9	1.5
	b				−100	− 84					$h_\circ$	20×6	52	1	13.9			
	c				− 98	+139					d	6×4	132	0	14.3			
	d				− 95	+179					d—$h_\circ$	6×3	140	0	15.3			
427*	a	4568	12 31.5	+11 48			263	+73	134	− 5	g	35×10	26	2	11.3	12.2	17.0	1.2
	b	4567			− 5	+ 12					g	20×10	77	0.5	11.5	12.3		
428	a		12 32.0	+ 7 29			264	+69	135	− 9	d—$h_\circ$	11×4	59	0.5	14.3		17.1	0.4
	b				− 5	+ 7					d	4×4		0.5	14.5			
429	a	4578	12 32.5	+10 7			264	+72	134	− 7	g	20×15	39	18	13.4	12.5	17.0	0.8
	b				− 32	− 13					d	4×4		0	15.4			
430	a		12 33.1	+34 35			104	+83	128	+17	$h_\circ$—q	18×3	123	0	14.2		17.7	0.7
	b				+ 12	+ 2					e	3×3		1	15.3			
	c				− 9	0					d	3×2	169	0	15.7			
	d				0	− 20					h	10×2	103	3	16.0			
431	a		12 33.2	+ 8 22			265	+70	134	− 8	d—$h_\circ$	5×3	33	0	15.0		16.6	2.8
	b				− 9	− 6					d	4×4		0	15.2			
432	a		12 33.2	+70 36			91	+48	112	+50	d	3×3		0	15.5		17.0	0.4
	b				− 3	− 8					d	3×3		0	15.5			

No	NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_t	d
433 a		$12^h 33^m.9$	+45° 13′			94°	+73°	124°	+27°	d	3×3		0	$15^m.2$		$16^m.7$	1°.3
b				− 6	+ 7					d	3×3		0	15.3			
c				−12	− 2					d	3×3		0	15.3			
434 a		12 34.5	+71 58			91	+46	110	+52	d	6×6		0	14.6		16.9	1.7
b				−16	− 8					d	3×3		0	15.4			
435 a		12 34.6	+17 8			263	+79	133	0	d	4×4		0	15.6		16.9	2.0
b				+ 3	− 3					d	3×3		0	15.4			
c				− 4	− 1					d	2×2		0	15.4			
436* a	4606	12 35.9	+12 28			266	+74	134	− 4	g	13×5	40°	2	12.4	$13^m.5$	16.9	1.8
b	4607			+37	−14					h_0	28×3	1	0	12.7	14.5:		
437 a		12 36.1	−12 4			268	+50	143	−28	d−h_0	14×7	45	0.5	13.5		16.0	0.9
b				+10	−30					d	6×4	137	0	14.4			
438 a	4618	12 36.6	+41 45			93	+76	126	+24	w	28×22	30	5	11.8	11.5	15.4	3.9
b	4625			+31	+74					e	12×12		2	12.7			
439 a	4615	12 36.7	+26 37			248	+88	131	+ 9	v S	18×5	112	0.5	13.8		16.6	2.8
b	4614			−15	−20					e	5×4	175	1	14.6			
c	4613			−21	+ 9					d	5×4	160	0.5	15.2			
439′ a	4615	12 36.7	+26 38			248	+88	131	+ 9	v S	18×4	126	0.5	13.2		17.1	2.8
b	4614			−14	−17					e	4×4		1	14.3			
c	4613			−19	+11					e	3×3		1	14.9			
440 a		12 37.1	− 5 14			269	+57	140	−21	d	5×5		0.5	14.3		16.7	3.0
b				+ 6	+ 9					e	6×6		1	14.3			
441 a	4628	12 37.3	− 6 25			269	+56	141	−22	v S(?)	11×4	43	2	13.4		16.6	3.1
b	4626			+ 2	−44					d−h_0	11×4	34	0.5	13.4			
442* a	4631	12 37.3	+33 6			97	+85	129	+17	q	145×15	85	1	8.9	9.6	17.7	1.2
b	4627			−15	+21					g	15×8	28	8	13.3			
443 a		12 37.3	+72 22			90	+46	110	+53	h_0	9×3	129	0	14.3		16.8	2.1
b				− 1	−25					e−h_0	6×3	170	1	14.3			
444 a		12 37.5	+11 8			267	+73	135	− 5	d	4×4		0	15.1		17.0	1.0
b				0	+ 3					d	3×3		0	15.6			
445 a	4634	12 37.7	+14 51			268	+77	134	− 2	d−h_0	23×8	152	0	12.8	13.7	15.5	3.4
b				−12	+35					h_0	21×7	33	0	13.5			
446 a	4640	12 37.9	+12 50			268	+75	135	− 3	d−h_0	10×5	73	0	14.4	15.2	16.8	2.3
b				+10	− 1					h_0	6×2	81	0	15.6			
447 a	4644	12 38.1	+55 43			91	+62	121	+37	g−h_0	10×3	49	0.5	13.6		16.4	1.6
b				+16	0					d−h_0	5×2	131	0	14.3			
448* a	4649	12 38.6	+12 6			268	+74	135	− 4	f	27×27		4	10.3	10.6	16.9	1.8
b	4647			−20	+19					f	16×16		2	11.4	12.0		
448′ a	4649	12 38.6	+12 7			268	+74	135	− 4	f	22×22		8	10.2	10.6	15.8	2.8
b	4647			−20	+19					f	20×20		2	11.5	12.0		
449 a		12 39.0	+44 39			91	+74	126	+27	e	3×3		1	15.3		16.7	1.6
b				− 1	− 4					d	3×3		0	15.3			
450 a		12 39.2	+23 6			267	+85	133	+ 7	d	6×6		0	14.8		16.7	2.6
b				+10	− 2					h_0	6×2	27	0	15.4			
451 a		12 39.3	+ 4 57			270	+67	138	−11	d	4×4		0.5	14.5		16.8	2.7
b				− 6	− 1					d	4×4		0	14.6			
452 a		12 39.3	+55 28			90	+63	122	+37	e	4×4		1	13.9		16.4	1.6
b				+ 2	+ 7					d−h_0	4×2	20	0	14.7			
453* a	4666	12 40.0	+ 0 6			270	+62	139	−16	g−h	40×9	39	3	11.8	11.3	15.8	1.3
b	4668			+61	−46					d	10×8	7	0	12.6	13.0		

18—37522.

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha\cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a\times b$	φ	c	m	m_{Harv}	m_l	d
453'	a	4666	12h 40m.0	+ 0° 5'			270°	+62°	139°	−16°	h	45×7	41°	7	11m.8	11m.3	16m.5	2°.9
	b	4668			+ 61	− 46					e—h_0	11×6	1	1	12.8	13.0		
454	a		12 40.1	+56 43			90	+61	121	+38	d—h_0	5×2	125	0	13.9		16.5	1.0
	b				− 3	+ 6					d	3×3		0	15.1			
455	a		12 40.8	+35 38			90	+82	129	+18	g	10×4	81	2	14.3		17.5	2.4
	b				− 14	+ 25					d	4×4		0	15.0			
456	a		12 40.8	+66 39			90	+51	116	+46	d—h_0	10×5	108	0	14.6		16.1	3.8
	b				− 12	+ 4					d—h_0	9×5	23	0	14.9			
457	a		12 41.0	−10 27			270	+52	144	−26	d	4×3	10	0	14.9		16.5	2.5
	b				− 2	− 3					d	3×3		0	15.3			
458	a		12 41.3	+45 45			89	+73	126	+28	v S	11×3	131	0.5	14.6		16.8	0.5
	b				+ 5	+ 6					d	2×2		0	15.3			
459	a	}4676	12 41.4	+31 14			85	+87	131	+15	e—h_0	8×5	43	1	14.4		17.2	3.1
	b				− 4	+ 7					d—h_0	8×5	4	0	14.7			
460	a	4693	12 42.6	+71 43			90	+46	112	+52	h_0	21×6	28	0	12.8		16.9	1.8
	b				− 28	+ 8					d	4×4		0	15.4			
461	a	4688	12 42.7	+ 4 53			272	+67	138	−11	r S	20×15	129	1	13.0	13.0	16.8	2.4
	b				+ 33	+ 59					d	7×5	69	0	14.4			
462	a		12 42.9	− 9 38			271	+52	144	−25	d—h_0	9×4	143	0.5	14.3		16.7	1.7
	b				− 11	+ 5					d	7×7		0.5	14.9			
463	a	4708	12 44.5	−10 33			272	+52	145	−26	e—h_0	5×3	68	1	13.9		16.7	1.9
	b				− 4	− 2					d	2×2		0	14.5			
464	a		12 44.8	+10 48			273	+73	138	− 5	d	10×10		0	14.7		15.9	2.5
	b				− 20	− 21					d	10×10		0	14.7			
465	a		12 44.8	+32 37			79	+84	131	+16	d	8×6	10	0	14.7		17.3	2.9
	b				− 5	− 8					d—h_0	6×3	32	0	15.9			
466	a	4716	12 45.4	− 8 55			272	+53	144	−24	g	11×4	30	7	13.8		16.8	1.1
	b				+ 2	− 36					h_0	15×3	159	0.5	14.5			
467	a		12 45.6	+ 2 1			273	+64	140	−14	h_0	14×2	175	0	14.3		16.8	2.3
	b				− 36	+ 24					h_0	6×2	95	0	15.4			
468*	a	4725	12 45.6	+26 3			303	+88	133	+ 9	r S	100×50	39	8	10.8	10.8	17.4	2.0
	b	4712			−118	− 21					d—h_0	20×10	165	0.5	12.2	12.9		
	c	4747			+176	+164					g—h	35×7	31	2	12.3	12.7		
469	a	4728	12 45.6	+27 59			359	+89	133	+12	e	3×3		1	14.7		17.5	0.3
	b				+ 21	− 6					d—h_0	7×3	34	0	14.6			
	c				+ 19	+ 31					h_0	6×2	74	0	15.1			
470	a	4727	12 45.7	−13 47			272	+48	146	−28	e—h_0	13×8	140	1	12.7		15.7	2.7
	b	4724			− 10	0					e	5×5		1	13.7			
471	a	4722	12 45.8	−12 42			272	+49	146	−27	d	10×10		0.5	13.6		16.0	3.7
	b	4723			+ 2	− 18					h	15×3	90	2	14.1			
472	a	4731	12 45.8	− 5 51			273	+56	143	−21	r S	70×35	82	3	11.2	12.2	16.2	3.3
	b				+ 33	−103					e	9×9		1	12.9			
473	a	4733	12 46.1	+11 28			275	+73	137	− 4	d	6×6		0.5	13.0		15.9	2.9
	b				− 9	0					d	3×3		0	14.7			
474	a	4745	12 46.6	+27 58			359	+89	133	+11	e	4×4		1	14.7		17.5	0.1
	b				− 10	+ 14					d	3×2	20	0	15.4			
475	a		12 46.8	+13 1			276	+75	137	− 3	d	4×4		0	14.7		15.9	3.0
	b				− 4	+ 7					d	3×3		0	14.8			
476	a		12 47.3	− 9 13			273	+53	145	−24	h_0	20×5	69	0	13.8		16.8	0.6
	b				+ 22	− 13					e	3×3		1	13.9			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
477	a	4759	12h 47m9	− 8° 39′			273°	+53°	145°	−23°	e	4×4		1	13m6		16m8	0°6
	b	4761			+10	+ 4					d	3×3		0.5	14.2			
478*	a	4762	12 47.9	+11 47			277	+74	138	− 4	h	45×4	29°	2	11.8	11m8	16.2	1.2
	b	4754			−97	+49					g	30×15	15	28	12.4	12.0		
478′	a	4762	12 47.9	+11 46			277	+74	138	− 4	h	40×4	30	6	12.0	11.8	16.0	2.5
	b	4754			−96	+51					f	7×7		2	12.2	12.0		
479	a		12 48.1	+32 58			72	+85	132	+17	d	7×7		0.5	15.3		17.4	2.0
	b				+ 2	+ 7					d	3×3		0	16.1			
480	a		12 48.4	−11 28			273	+51	146	−26	d	8×8		0	14.1		16.6	2.4
	b				+ 8	−23					h₀	8×2	170	0.5	15.0			
481	a		12 48.4	+25 4			303	+86	134	+ 8	d	8×8		0.5	12.4		17.1	3.0
	b				+ 3	+16					d	4×4		0.5	15.4			
482	a	4780	12 48.9	− 8 5			273	+54	145	−23	d	11×11		0.5	13.2		16.8	1.0
	b				− 5	−19					d	4×3	3	0	14.9			
483	a	4781	12 49.2	− 9 59			273	+52	146	−25	r—s	32×18	117	2	11.4	11.7	16.8	0.9
	b	4784			+34	−46					h	12×2	103	6	14.2			
484	a		12 49.2	+30 9			46	+87	133	+14	g—h₀	15×3	73	1	14.1		17.3	2.2
	b				−32	−11					d	4×3	171	0	14.2			
485	a	4782	12 49.4	−12 2			273	+50	147	−26	e	5×5		1	12.8	12.9:	16.4	2.9
	b	4783			+ 1	+ 7					e	4×4		1	13.2	12.7:		
486	a	4809	12 49.8	+ 3 12			276	+65	141	−13	h₀	20×6	68	1	13.1		17.0	0.8
	b	4810			+ 1	− 8					e	6×4	166	1	13.2			
486′	a	4809	12 49.8	+ 3 11			276	+65	141	−13	d—h₀	13×5	67	1	13.7		16.6	2.6
	b	4810			+ 1	− 8					d—h₀	8×4	163	1	13.9			
487	a	I 3892	12 50.4	+39 45			81	+78	130	+23	d	9×9		0.5	14.9		17.2	1.0
	b	I 3895			− 7	+11					e—h₀	6×3	0	1	15.2			
488	a	4807	12 50.5	+28 4			2	+88	134	+12	h	11×3	175	4	14.3		17.5	0.7
	b				+ 3	+15					d	3×3		0	15.0			
489	a		12 50.9	+34 13			71	+83	132	+17	d	4×4		0	15.8		17.4	2.0
	b				+ 1	− 5					d	3×3		0	15.8			
	c				+13	+11					d	3×3		0	15.8			
490	a	4819	12 51.6	+27 32			350	+87	134	+11	g	10×4	145	4	14.0		17.5	1.0
	b	4821			+ 3	−18					d	2×2		0.5	14.5			
491	a		12 52.6	+23 23			302	+83	135	+ 8	e	2×2		1	14.1		17.4	1.6
	b				+ 5	+ 4					e	2×2		1	14.5			
492	a	}4841	12 52.7	+29 1			21	+87	134	+13	e	5×5		1	14.5		17.1	3.0
	b				+ 6	+ 4					e	4×4		1	14.7			
493	a		12 52.9	+33 5			62	+83	133	+17	e—h₀	11×4	28	1	15.2		17.4	1.5
	b				+ 8	− 5					d	3×3		0	15.8			
494	a		12 53.1	+28 2			1	+87	135	+12	d	4×4		0.5	14.5		17.4	1.3
	b				−16	0					d	4×4		0	14.9			
495	a	4849	12 53.4	+26 56			341	+87	135	+11	e	3×3		1	14.4		17.4	1.8
	b	I 838			+ 2	+19					d	7×7		0.5	14.9			
496	a	I 4003	12 55.0	+39 21			75	+78	131	+23	e	3×3		1	15.2		17.2	0.8
	b	I 4004			+ 7	− 3					e	2×2		1	15.5			
497	a	4880	12 55.2	+13 1			284	+75	139	− 2	d	10×7	175	0.5	12.7	13.1	16.2	3.1
	b				− 7	+16					d	4×4		0	15.5			
498	a	}4893	12 55.3	+37 44			72	+80	132	+21	d	3×3		0	15.2		17.1	1.4
	b				0	− 4					d	3×3		0	15.5			
	c				− 5	+ 4					d	3×3		0	15.9			

No	NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
499 a	4911	12h 56m.0	+28° 21′			7°	+86°	135°	+13°	e	6×6		1	13m.2		17m.4	2°.0
b				− 4	− 4					d	3×3		0	14.9			
500 a		12 56.9	+29 35			25	+86	135	+14	h	14×3	85°	3	15.1		17.2	2.5
b				+ 2	−29					d−h_0	5×3	20	0	15.8			
501 a		12 57.6	+33 25			56	+82	134	+17	h	12×3	98	2	15.0		17.4	1.5
b				+13	+16					d	6×5	166	0.5	15.8			
502 a	} 4933	12 58.7	−10 58			277	+51	148	−25	e	7×5	46	2	13.4	} 12m.8	16.4	2.9
b				− 6	− 5					e	4×4		1	14.1			
503 a		12 58.9	+26 38			343	+85	136	+10	d	7×5	167	0.5	14.3		17.1	2.9
b				+11	+19					d−h_0	11×4	31	0.5	15.1			
503′ a		12 59.0	+26 38			343	+85	136	+10	d−h_0	6×3	150	0	14.5		17.1	3.0
b				+11	+17					d	4×3	34	0.5	15.5			
504 a		12 59.4	+26 40			344	+85	136	+11	d	3×3		0.5	15.5		17.1	2.9
b				+ 6	− 2					d−h_0	5×3	99	0	15.7			
505 a	4948	12 59.7	− 7 25			279	+55	148	−21	d−h_0	13×5	146	0.5	12.9		16.4	3.0
b				+ 6	− 8					d	5×5		0.5	14.6			
506 a		12 59.9	− 7 37			278	+54	148	−21	d−h_0	12×5	4	0.5	13.2		16.4	3.0
b				+11	−31					h_0	17×5	45	0	15.0			
507 a		13 0.7	+33 26			53	+83	134	+17	d−h_0	10×4	72	0	15.0		17.4	1.7
b				− 3	+18					g	6×2	98	3	16.0			
508 a		13 1.3	+30 44			32	+85	135	+15	h_0	9×2	173	0.5	15.4		17.4	1.8
b				− 3	+ 6					d	2×2		0	16.0			
509 a		13 5.0	+26 6			342	+83	137	+10	e	6×5	138	1	14.2		16.8	3.4
b				+ 6	− 9					d	4×4		0.5	15.1			
510 a	5000	13 5.1	+29 27			16	+84	136	+14	i	15×8	22	5	13.5		16.9	3.3
b				+ 9	− 3					e	7×7		1	15.6			
511 a	5004	13 6.3	+30 11			21	+84	136	+15	h	10×3	177	4	14.2		17.4	2.0
b				0	−37					v(?)	9×4	3	1	14.5			
c				−32	+44					d	6×4	4	0.5	14.2			
511′ a	5004	13 6.3	+30 11			21	+84	136	+15	e	5×5		1	14.3		17.1	3.0
b				+ 1	−36					h	12×5	165	3	14.7			
512 a		13 8.7	+16 32			301	+77	141	+ 2	h	13×3	40	0	14.2		16.5	2.2
b				+20	−19					d	3×3		0	15.1			
513 a	5032	13 8.7	+28 19			4	+84	137	+13	g	10×8	11	1	13.7		17.5	0.3
b				− 3	−24					d	4×4		0	14.9			
514 a	5079	13 14.4	−12 10			283	+49	152	−25	d	15×10	42	0.5	12.7		16.1	2.1
b	5077			−17	+25					e	5×5		1	13.0	12.2		
c	5076			−19	−26					d	4×4		0	14.0			
d	5077			−17	+22					d	3×3		0	14.3			
515 a	5088	13 15.1	−12 3			283	+49	153	−25	g	16×5	179	2	13.3	13.2	16.2	2.0
b				−33	−16					e	3×3		1	14.5			
516 a	5146	13 21.4	−11 48			285	+49	154	−24	f	7×7		5	13.7		16.3	1.2
b				+ 3	− 8					d	3×2	85	0	14.5			
517 a		13 22.1	− 2 3			290	+58	150	−14	d	8×8		0	14.5		16.3	0.9
b				+11	−26					d	4×4		0	14.8			
518 a		13 23.6	+29 12			10	+80	140	+15	d−h_0	8×4	178	0	14.5		17.1	3.0
b				+ 2	+14					d	3×3		0	15.1			
519 a	5166	13 23.6	+32 33			28	+79	139	+18	h−h_0	20×4	67	1	13.7		17.1	2.9
b				+41	+24					d	6×6		0	14.5			
520 a		13 23.8	+12 8			305	+71	146	− 1	d	4×4		0.5	14.8		17.0	2.3
b				− 4	− 8					d−h_0	4×2	43	0.5	14.9			

No	NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
521 a	5176	13h 24m.5	+12° 18′			305°	+71°	146°	−1°	d	6×6		0.5	14m.5		17m.0	2°.3
b	5177			−2	+9					d	7×5	127°	0	14.5			
522 a		13 24.6	+12 8			305	+71	147	−1	d	7×7		0.5	14.5		17.0	2.1
b				+11	+7					d	5×5		0.5	15.2			
523 a	5184	13 25.1	−1 9			292	+59	151	−13	e	18×12	143	1	13.3		16.2	1.7
b	5183			−14	−35					g	13×3	112	5	13.6			
524 a		13 25.2	+33 52			35	+79	139	+20	d−h_0	6×3	103	0	15.0		16.6	3.3
b				−4	−9					d	5×3	170	0	15.0			
525 a		13 25.3	−8 4			289	+52	154	−19	h_0	11×2	141	0	14.5		15.9	2.9
b				−10	−11					h_0	10×2	88	0	15.0			
526* a	5194	13 25.6	+47 43			68	+68	134	+32	w S	80×60	20	1	10.4	10m.1	16.0	0.2
b	5195			+10	+43					g	21×15	10	2	12.2	11.1		
527 a		13 28.6	+33 40			33	+78	139	+20	d	5×4	30	0	14.3		16.8	3.0
b				+15	−26					d−h_0	6×3	151	0.5	14.7			
527′ a		13 28.6	+33 40			33	+78	139	+20	d	7×5	40	0	14.2		17.0	3.1
b				+15	−25					d−h_0	8×4	160	0.5	15.0			
528 a		13 28.7	+35 3			37	+78	139	+21	h	8×1.5	91	2	15.2		17.1	2.0
b				−27	+9					h_0	9×2	152	0.5	15.3			
529 a		13 30.7	+3 31			299	+63	150	−8	e	6×6		1	13.8		16.7	2.0
b				−14	+2					d	3×3		0	15.3			
530 a		13 33.0	+29 19			10	+78	142	+16	d	5×5		0	15.0		17.4	1.7
b				−4	−6					d−h_0	11×4	8	0	16.1			
531 a		13 33.9	+26 36			356	+78	143	+14	d−h_0	8×3	35	0.5	14.7		16.8	1.8
b				−14	+12					d	3×3		0	15.3			
532 a	5257	13 34.8	+1 21			298	+60	152	−10	d	6×6		0	12.9		16.4	2.9
b	5258			+12	−4					d−h_0	11×5	30	0.5	13.3			
533 a	5259	13 34.8	+31 30			20	+78	142	+18	d	3×3		0	15.1		17.5	0.6
b				−5	+2					d	2×2		0	15.9			
534 a		13 36.8	+23 45			344	+77	144	+11	d−h_0	8×4	86	0	14.4		16.5	2.8
b				−9	+3					d	4×4		0	14.9			
535 a	5273	13 37.7	+36 10			37	+75	140	+22	f	18×18		11	12.6	12.9	17.2	0.2
b	5276			+29	−19					h_0	6×2	160	0	14.3			
536 a		13 38.1	+30 21			15	+77	143	+17	h_0	10×2	64	0	15.4		17.5	0.9
b				−11	+7					d−h_0	5×2	120	0	15.5			
537 a		13 38.6	+27 58			3	+77	144	+15	d	6×5	17	0	13.0		16.8	1.8
b				+6	−8					d	3×2	30	0	15.1			
538 a		13 39.8	+30 24			14	+77	143	+17	h_0	6×2	151	0	15.8		17.5	1.1
b				−2	−15					d−h_0	4×2	40	0	15.8			
c				−7	+9					d	2×2		0	15.9			
539 a		13 40.1	+25 57			355	+76	145	+14	d	3×2	40	0	14.6		16.9	0.3
b				+6	+7					d	4×4		0	15.0			
540 a		13 40.4	−5 29			296	+54	157	−16	d−h_0	7×3	8	0.5	13.6		15.6	2.5
b				−6	0					d	3×3		0.5	13.6			
c				+4	+7					d−h_0	5×2	23	0.5	13.9			
541 a		13 42.6	+34 22			29	+75	142	+22	v S(?)	10×10		1	13.6		17.0	2.1
b				−13	+8					h_0	13×2	86	0	14.0			
541′ a		13 42.6	+34 22			29	+75	142	+22	d	10×8	30	0.5	13.6		16.5	3.9
b				−13	+8					d−h_0	11×4	81	0	13.8			
542 a	5303	13 43.3	+38 48			41	+73	141	+25	e	7×5	90	1	12.5		16.8	2.9
b				+2	−29					d−h_0	6×3	112	0	14.7			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
543	a		$13^h 43^m.6$	+25° 38′			354°	+76°	145°	+13°	d	2×2		0.5	$14^m.7$		$16^m.9$	0°.8
	b				+ 4	+ 7					d—h$_0$	4×2	70°	0	14.8			
544	a		13 43.7	+26 11			356	+76	145	+15	d	5×5		0	15.0		16.9	0.5
	b				— 1	— 4					d	2×2		0	15.3			
545	a		13 44.8	+35 45			34	+74	142	+23	h$_0$	18×3	120	1	13.5		17.1	1.8
	b				+43	— 2					d	5×5		0	14.2			
	c				0	+24					e	3×3		1	14.6			
	d				— 6	+17					d	4×4		0.5	14.9			
546	a		13 45.9	+25 29			354	+75	146	+14	d	2×2		0	14.7		16.9	1.2
	b				0	— 9					e	2×2		1	14.8			
547	a		13 46.1	+25 41			354	+75	146	+14	h$_0$	8×2	140	0	14.4		16.9	1.2
	b				— 4	+ 5					d	2×2		0	14.8			
548	a	5318	13 46.2	+34 12			27	+75	143	+22	e	4×3	179	1	13.8		16.9	2.7
	b				— 5	+18					d	4×4		0	14.8			
548′	a	5318	13 46.2	+34 12			27	+75	143	+22	d	9×9		0.5	13.6		16.4	4.1
	b				— 5	+18					h$_0$	6×2	163	0	15.2			
549	a		13 46.6	+14 35			322	+70	150	+ 3	v S(?)	10×5	106	1	13.6		16.8	1.9
	b				+ 5	+11					d	6×6		0	15.4			
550	a	5325	13 46.6	+38 47			41	+73	142	+26	d	10×10		0.5	14.1		16.7	3.2
	b				— 3	—21					d	6×6		0	14.6			
551	a		13 47.5	+14 4			322	+69	150	+ 2	d	9×6	24	0	13.7		16.8	1.4
	b				—11	— 2					d—h$_0$	6×3	80	0	15.6			
A20095 552	a		13 47.7	+ 2 45			306	+60	154	— 7	h$_0$	15×3	142	0	14.3		16.4	2.8
	b				+28	— 1					h$_0$	9×2	153	0	14.8			
553	a		13 47.7	+31 58			19	+75	144	+20	d	6×6		0.5	14.4		17.1	3.0
	b				+16	0					d	2×2		0	15.5			
554	a	5351	13 49.1	+38 25			41	+72	142	+26	d—h$_0$	28×10	96	0.5	12.6	$13^m.0$	16.6	3.3
	b	5349			—30	—21					d—h$_0$	9×5	93	0	14.4			
555	a	5354	13 49.2	+40 48			47	+71	141	+28	e	4×4		1	13.6		16.4	1.5
	b	5353			0	—12					e—g	8×3	148	1	12.6	12.4		
	c	5350			—11	+38					r	17×10	20	1	13.8	12.9		
	d	5355			+37	+22					d	3×3		0.5	14.8			
556	a		13 50.6	+25 33			355	+74	147	+14	e	5×5		1	14.2		16.7	2.2
	b				— 2	—20					d	5×5		0	14.4			
557	a	5364	13 51.1	+ 5 31			310	+62	154	— 5	w	55×35	33	2	11.4	11.8	16.1	4.0
	b	5360			—89	—22					d—h$_0$	20×8	81	0	13.2			
558	a		13 51.7	+30 35			13	+74	145	+19	d	5×5		0.5	15.0		16.6	3.2
	b				— 4	— 9					d	5×5		0.5	15.0			
559	a		13 52.7	+24 46			353	+73	148	+14	h$_0$	13×4	29	0	13.9		16.5	3.0
	b				—15	+ 7					d	5×5		0	14.8			
A20095 560	a		13 52.8	+ 7 53			314	+64	154	— 2	e	7×7		1	13.4		17.0	2.0
	b				+12	+10					d—h$_0$	5×3	39	0	14.8			
	c				+21	+23					d	7×7		0	14.5			
	d				+32	+ 2					d—h$_0$	8×4	80	0	15.2			
561	a	5389	13 52.8	+60 14			75	+56	130	+45	g—h	17×3	0	10	13.3		16.1	1.5
	b	5379			—42	— 4					h$_0$	10×3	58	0	14.3			
562	a		13 54.0	+ 7 45			314	+63	154	— 2	d—h$_0$	10×4	140	0	14.1		17.0	1.9
	b				+ 4	—14					d	3×2	149	0	15.5			
563	a	5395	13 54.3	+37 55			38	+72	143	+26	d—h$_0$	21×11	1	0	12.5	13.0	16.0	3.1
	b	5394			— 7	+19					d	7×7		0.5	13.6			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
564	a		13h 54m.4	+ 6° 1'			312°	+62°	155°	− 4°	h_0	12×3	113°	0.5	14m.3		16m.7	3°.0
	b				+12	+12					e	3×2	173	1	14.5			
565	a	5403	13 55.5	+38 41			39	+71	143	+26	d−h_0	12×5	129	0	14.2		16.3	2.3
	b				+11	+15					d	3×3		0	14.6			
566	a		13 55.7	+14 19			326	+68	152	+ 4	d−h_0	5×3	158	0	14.3		16.6	2.7
	b				− 2	+ 9					d	5×5		0.5	14.9			
567	a	5422	13 57.2	+55 39			68	+59	134	+42	h	15×3	158	6	14.0	13m.0	16.5	2.0
	b				+10	+20					d	3×3		0	15.0			
568	a	5421	13 57.3	+34 19			25	+72	145	+23	v S	9×2	160	2	14.5		17.1	1.1
	b				+ 2	− 4					d	2×2		0	14.9			
	c				− 3	− 5					e	1.5×1.5		1	14.9			
569	a	5430	13 57.5	+59 49			73	+55	131	+45	g	9×3	154	1	14.0	12.8	16.1	1.6
	b				+ 3	− 3					d	2×2		0.5	15.0			
570	a		13 57.8	+15 18			328	+68	152	+ 5	h_0	30×6	20	0	13.3		16.1	3.7
	b				−13	−38					d	9×9		0	14.2			
571	a		13 57.9	+ 9 49			319	+64	155	0	e	4×4		1	14.5		17.0	1.3
	b				−17	+ 3					e	4×4		1	15.3			
	c				+16	+ 6					d	5×4	78	0	15.6			
572	a		13 57.9	+32 56			21	+73	146	+22	e	4×3	159	1	14.3		17.1	0.4
	b				− 9	0					d	2×2		0	15.2			
573	a	5427	13 58.2	− 5 33			302	+52	161	−14	w	20×19	88	1	11.6	12.0	16.5	3.6
	b	5426			− 3	−26					v S	21×14	27	1	12.5	12.8		
574	a	5433	13 58.2	+33 0			21	+73	146	+22	h	14×3	1	1	13.3		17.1	0.3
	b				+16	+23					d	3×3		0	15.3			
575	a	5434	13 58.5	+ 9 56			319	+64	155	0	e	11×11		1	13.6		17.0	1.4
	b				+10	+12					d−h_0	10×4	75	0.5	14.0			
575'	a	5434	13 58.5	+ 9 56			319	+64	155	0	d	10×10		0.5	12.9		17.0	2.7
	b				+10	+12					h−h_0	13×4	70	1	13.8			
576	a	5440	13 58.6	+35 15			28	+72	145	+24	g−h	20×5	50	6	13.9		17.0	2.0
	b	5441			+24	−44					d	6×6		0.5	14.9			
577	a		13 58.7	+11 52			322	+66	154	+ 2	d−h_0	8×5	173	0.5	14.1		16.9	2.9
	b				− 1	+ 7					d−h_0	8×5	133	0.5	14.1			
578	a	5443	13 58.8	+56 19			69	+59	133	+43	g−h	15×4	46	1	13.7		16.4	2.1
	b				+ 8	+16					d	2×2		0	15.0			
579	a		13 59.8	+33 47			24	+72	146	+22	e	3×3		1	14.3		17.1	0.6
	b				+20	+ 9					h_0	8×2	50	0	14.8			
580	a		14 0.1	+29 41			10	+72	147	+19	d	6×6		0	14.4		16.3	3.6
	b				− 4	−17					d−h_0	7×3	168	0	15.1			
581	a		14 0.7	+ 9 24			319	+63	155	0	d	8×8		0.5	14.7		17.1	2.3
	b				+ 3	+20					e	2×2		1	15.0			
582	a	5463	14 0.9	+ 9 53			320	+64	155	+ 1	e	5×4	45	1	14.1		17.1	1.2
	b				+ 5	+ 5					d	3×3		0	15.5			
583	a		14 1.2	+13 16			326	+66	154	+ 4	e	5×5		1	14.1		16.8	3.2
	b				+ 8	− 3					d	3×3		0.5	15.5			
584	a		14 1.3	+ 9 50			320	+64	155	+ 1	e−h_0	6×3	45	2	13.9		17.1	2.1
	b				+ 5	+ 5					d	5×5		0	15.4			
585	a	5468	14 1.4	− 4 58			304	+52	161	−13	w S	21×18	82	0.5	12.4	12.4	17.1	2.5
	b	5472			+54	− 5					h	10×3	41	1	14.6			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
585′	a	5468	$14^h 1^m.4$	− 4° 59′			304°	+52°	161°	−13°	w 8	25×25		1	12^m3	12^m4	17^m0	2°7
	b	5472			+50	− 3					h_0	10×3	38°	1	14.8			
	c	5465			−19	−33					e	4×4		1	14.8			
	d	5467			−14	−18					e	4×4		1	15.0			
	e				−32	−51					d−h_0	8×5	155	0.5	15.4			
586	a		14 2.1	+10 56			322	+64	155	+ 2	d	5×4	24	0.5	14.5		17.2	1.8
	b				+ 5	+16					d	3×3		0.5	15.5			
587	a		14 2.7	+11 13			322	+64	155	+ 3	d	5×5		0.5	15.6		17.2	1.7
	b				+ 8	− 9					d	4×4		0.5	15.7			
588	a	5480	14 2.7	+51 11			62	+62	138	+38	e	12×9	14	1	12.1	12.6	16.4	3.2
	b	5481			+31	− 1					e	6×6		1	13.2			
589	a		14 3.2	+ 6 18			316	+60	157	− 3	e	3×2	158	1	14.4		16.9	2.4
	b				− 8	+ 1					d	2×2		0	15.1			
590	a		14 3.5	+ 6 8			316	+60	157	− 3	d	6×6		0.5	14.8		16.8	2.6
	b				− 6	+17					d−h_0	6×3	0	0.5	15.1			
591	a		14 3.5	+ 7 32			318	+61	156	− 2	d	9×9		0.5	13.4		16.7	3.3
	b				+10	− 5					d	3×3		0.5	15.4			
592	a		14 4.2	+24 41			354	+71	150	+14	e	3×3		1	15.3		17.0	1.0
	b				+ 6	−14					d	4×4		0	15.5			
593	a		14 4.6	+24 38			353	+71	150	+14	e	3×3		1	15.2		17.0	1.0
	b				− 1	+ 6					d−h_0	4×1.5	32	0	15.7			
594	a		14 4.9	+ 8 33			320	+62	157	− 1	e−h_0	6×3	71	1	14.1		17.1	2.3
	b				− 9	−17					d−h_0	5×2	161	0	15.3			
595	a	5490	14 5.1	+18 1			338	+68	153	+ 8	g	6×4	7	2	14.1		17.1	2.1
	b				+17	+ 3					d−h_0	4×2	87	0	15.1			
596	a		14 5.4	+18 50			340	+68	153	+ 9	h−h_0	21×3	40	1	13.9		17.2	1.6
	b				+13	− 1					d	1.5×1.5		0	15.4			
597	a	5491	14 5.9	+ 6 51			318	+61	158	− 2	e	8×6	71	1	13.7		16.9	2.2
	b				+ 1	+ 5					d	3×3		0	15.1			
	c				− 8	− 6					e	2×2		1	15.4			
598	a		14 6.4	+25 58			359	+71	150	+15	d	7×7		0.5	14.4		17.0	0.4
	b				+12	+15					d	3×3		0	14.9			
599	a		14 6.9	+20 24			343	+69	152	+11	d	6×6		0	15.8		17.2	1.4
	b				+ 8	+ 4					h_0	6×2	152	0	15.9			
600	a		14 7.3	+ 9 8			322	+62	157	0	g	16×10	3	0.5	14.2		17.2	1.7
	b				+44	− 8					h	10×2	116	4	14.7			
	c				+31	−22					d	3×3		0	15.4			
601	a	5504	14 7.5	+16 19			334	+66	154	+ 7	e	11×11		1	12.9		16.6	3.4
	b				− 8	+17					d	5×5		0.5	14.1			
	c				0	+21					h_0	10×3	50	0.5	14.4			
602	a		14 7.6	+18 46			339	+68	153	+ 9	d−h_0	8×3	28	0.5	14.2		17.3	1.2
	b				−17	+ 7					d	3×3		0	14.7			
603	a		14 7.7	+34 41			25	+70	147	+24	d	3×3		0	13.6		15.6	1.9
	b				+ 1	+ 3					d	2×2		0	13.9			
604*	a	5506	14 8.1	− 2 44			308	+53	162	−10	h_0	21×4	92	0.5	13.3		17.3	0.2
	b	5507			+13	+37					g	10×4	56	4	13.9			
604′	a	5506	14 8.1	− 2 44			308	+53	162	−10	h	21×5	89	1	13.2		17.0	3.0
	b	5507			+12	+37					e	6×6		1	13.7			
605	a		14 8.1	+10 23			324	+63	157	+ 2	d	5×5		0	14.5		17.3	0.3
	b				− 3	− 5					d	1.5×1.5		0	15.5			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha\cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_t	d
606	a	5511	14h 8m.2	+ 9° 5′			322°	+62°	158°	0°	f	8×8		0.5	14m.1		17m.2	1°.7
	b				− 7	− 7					d−h$_o$	4×2	164°	0.5	14.8			
607	a	5513	14 8.4	+20 54			346	+69	153	+12	g	9×4	111	3	13.9		17.2	1.5
	b				−10	−10					d	2×1.5	3	0.5	15.2			
608	a		14 8.5	+ 9 27			322	+62	158	+ 1	h$_o$	10×3	160	0	14.2		17.3	1.2
	b				−12	−10					d	5×5		0.5	15.4			
609	a		14 8.5	+46 10			52	+65	142	+34	d	4×4		0	14.2		16.6	2.6
	b				+ 5	+ 1					d	3×3		0	14.3			
610	a		14 8.8	+ 8 42			321	+62	158	0	e	3×2	170	1	14.7		16.9	2.1
	b				+ 2	+ 1					e	2×2		1	14.7			
	c				−10	+ 2					d−h$_o$	4×2	171	0	15.4			
611	a		14 8.8	+12 40			327	+64	156	+ 4	d−h$_o$	5×2	91	0	15.4		17.2	2.0
	b				− 9	0					d	2×2		0	15.4			
612	a		14 8.8	+16 36			335	+67	155	+ 7	d	5×5		0	14.5		16.9	3.0
	b				− 8	+ 3					d	3×2	0	0	15.2			
613	a		14 9.4	+11 3			325	+63	157	+ 3	h	5×1.5	9	1	15.2		17.3	0.3
	b				+18	− 1					d	5×5		0	15.5			
614	a		14 9.5	+16 5			335	+66	155	+ 6	h−h$_o$	18×6	12	2	13.5		16.5	3.6
	b				+35	− 7					d−h$_o$	5×3	130	0.5	14.5			
615	a		14 10.1	− 3 54			308	+51	163	−11	d−h$_o$	12×5	6	0.5	14.1		17.3	1.1
	b				− 6	−18					d	4×4		0.5	15.7			
616	a		14 10.2	+ 5 18			317	+59	159	− 3	d	10×7	26	0	13.5		16.4	2.3
	b				− 1	+23					d−h$_o$	13×5	6	0	14.3			
617	a		14 10.4	+16 12			335	+66	155	+ 7	d−h$_o$	12×5	137	0.5	13.8		16.6	3.4
	b				− 6	−22					d	8×6	33	0	14.5			
618	a		14 10.5	+35 12			26	+70	147	+24	d	3×3		0	13.7		15.7	1.1
	b				−10	+12					d−h$_o$	6×3	172	0	13.8			
619	a		14 10.6	+17 21			338	+67	154	+ 8	d	2×2		0	15.3		17.1	2.3
	b				0	+ 6					d−h$_o$	2×1	14	0	15.6			
620	a	5528	14 11.4	+ 8 46			323	+61	158	0	g	10×4	38	3	14.5		17.2	2.0
	b				− 3	+ 8					d	1.5×1.5		0	15.4			
621	a		14 11.6	+23 29			353	+69	152	+14	f	9×9		0.5	14.7		16.8	2.3
	b				+16	−12					h$_o$	3×1	156	0	15.4			
622	a	5532	14 12.0	+11 17			327	+63	157	+ 3	e	8×8		2	13.4		16.1	3.9
	b				+ 1	− 6					e	3×3		1	15.0			
623	a	5534	14 12.3	− 6 57			306	+49	165	−14	h	7×2	80	2	14.3	13m.0	17.3	1.5
	b				+ 5	0					d−h$_o$	5×3	21	0	14.9			
624	a		14 12.4	+22 54			352	+69	153	+14	d−h$_o$	5×3	21	0	14.9		16.3	3.2
	b				− 7	+ 4					d	3×3		0	15.0			
625	a		14 12.5	+ 5 2			318	+58	160	− 3	d−h$_o$	9×5	140	0	14.0		16.5	2.0
	b				+ 7	+11					h$_o$	12×4	75	0	14.9			
626	a		14 13.5	+11 40			328	+63	158	+ 4	g	9×4	1	2	14.8		17.2	1.5
	b				−11	+13					d	4×4		0.5	15.1			
627	a		14 14.0	+13 27			331	+64	157	+ 5	d	4×4		0	15.2		16.9	3.0
	b				− 5	+ 6					d	3×3		0	15.4			
628	a		14 14.2	+25 24			359	+69	152	+16	h$_o$	12×2	54	0.5	14.4		16.9	1.9
	b				+31	+ 3					d	3×3		0	15.4			
	c				−12	−11					d	3×3		0	15.4			
629	a		14 14.7	+26 45			1	+69	152	+17	e	4×4		1	14.0		16.8	2.3
	b				+11	+ 4					d	3×3		0	15.0			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
630	a	5566	14h 15m3	+ 4° 24′			318°	+57°	160°	− 3°	g	17×10	10°	9	12m1	11m9	16m4	2°1
	b	5560			−41	+35					d−h₀	11×4	103	0	13.0			
	c	5569			+30	+31					d	7×7		0	14.7			
631	a		14 15.3	+10 15			326	+61	158	+ 3	d	3×3		0.5	15.4		17.2	1.5
	b				− 1	− 4					d	3×2	10	0	15.4			
632	a	5576	14 16.0	+ 3 44			317	+56	161	− 5	e	6×6		1	12.0	11.9	16.2	2.8
	b	5574			−19	−20					g	9×4	62	1	13.2	13.1		
633	a		14 16.2	+22 24			350	+68	154	+13	h₀	25×7	120	0.5	13.0		16.9	3.0
	b				−30	−47					h	7×2	140	2	15.0			
	c				+ 2	−13					e	3×3		1	15.3			
634	a		14 16.3	+18 9			341	+66	156	+ 9	d	4×4		0.5	15.4		17.2	1.8
	b				+ 3	+ 6					d	3×3		0	15.7			
635	a		14 16.8	+30 27			13	+69	151	+21	d−h₀	5×3	125	0.5	14.1		17.2	2.2
	b				0	−10					h₀	6×2	0	0	15.5			
636	a		14 17.5	+17 51			341	+65	156	+10	d−h₀	5×3	50	0	14.4		17.1	2.2
	b				− 2	+ 6					d	5×5		0.5	15.4			
637	a		14 17.6	+ 9 44			327	+61	159	+ 2	d	6×6		0	15.3		17.1	2.2
	b				+20	− 3					d	4×3	99	0	15.4			
638	a	5595	14 18.8	−16 16			301	+40	170	−22	d−h₀	20×8	51	1	12.0	12.4	15.4	3.1
	b	5597			+34	−25					g	16×5	59	2	13.7	12.6		
638′	a	5595	14 18.8	−16 16			301	+40	170	−22	d−h₀	11×6	51	0.5	12.4	12.4	15.8	3.2
	b	5597			+34	−24					g	18×9	60:	1	13.3	12.6		
639	a	5599	14 18.9	+ 7 2			323	+59	160	− 1	h	14×4	168	3	13.7		16.6	0.7
	b				−16	+19					d	3×3		0	15.2			
	c				−14	+14					d	3×3		0	15.4			
640	a		14 19.1	+21 8			348	+66	155	+13	d	3×2	147	0	15.2		17.1	2.3
	b				+ 1	+ 2					d	3×3		0	15.3			
641	a	5603	14 19.1	+40 51			39	+66	146	+30	e	8×8		1	13.9		16.7	2.9
	b				−10	+27					d	11×8	160	0	14.4			
642	a		14 20.1	+19 19			344	+66	156	+11	d	3×3		0	15.2		17.2	2.0
	b				− 8	− 4					d	3×3		0	15.2			
643	a		14 21.3	+39 59			36	+66	147	+29	h₀	50×4	73	0.5	13.0		17.0	2.0
	b				+25	+31					d	4×4		0.5	15.1			
644	a		14 21.6	+30 55			14	+68	151	+21	e	2×2		1	14.8		17.4	1.1
	b				+ 3	+ 1					e	1.5×1.5		1	15.1			
645	a	5619	14 22.2	+ 5 15			321	+57	162	− 3	s	25×10	17	1	13.4		16.5	1.4
	b				+36	+12					e	3×3		1	14.3			
	c				+29	−15					d	3×3		0	15.3			
646	a		14 22.7	+31 58			17	+68	151	+22	h₀	14×3	41	0.5	13.6		17.3	1.4
	b				− 2	+ 5					d	3×3		0	15.8			
647	a		14 23.0	+36 22			28	+67	148	+27	d−h₀	10×5	48	0.5	14.0		16.8	2.6
	b				+ 5	+11					d	4×3	171	0.5	14.8			
648	a		14 23.1	+30 24			12	+67	152	+21	d	8×8		0.5	14.4		17.4	1.0
	b				−13	+ 9					d	4×4		0	15.7			
649	a	5630	14 23.7	+41 42			39	+65	146	+31	h₀	12×4	99	0.5	12.7		15.8	3.1
	b				+ 3	−16					d	3×3		0	14.0			
650	a		14 24.2	+ 8 17			326	+58	161	+ 1	d	5×5		0	14.0		16.4	2.4
	b				+ 4	+ 7					d	4×4		0	14.7			
651	a	5639	14 24.3	+30 52			14	+67	152	+22	d	12×8	109	0	12.4		17.4	0.4
	b				+23	− 4					d	4×4		0	15.5			

MC 29962 –
N.S. " –

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
652	a		$14^h 24^m.4$	+29° 25′			10°	+67°	153°	+21°	e	3×3		1	$14^m.8$		$17^m.3$	1°.6
	b				+11	+ 2					d	3×3		0	15.7			
653	a	5638	14 24.6	+ 3 42			320	+56	163	− 3	e	8×8		1	12.4	$12^m.6$	16.2	3.0
	b	5636			− 3	+20					d	12×9	39°	0	13.8			
654	a	5649	14 25.7	+14 28			337	+62	159	+ 7	d	9×9		0	13.6		16.1	2.3
	b	5648			− 7	+ 7					d	3×3		0	14.4			
655	a		14 25.7	+23 30			355	+66	156	+15	d	12×9	69	0	13.6		16.3	3.1
	b				−21	−23					e	3×3		1	14.0			
	c				−10	0					d	6×6		0	14.8			
656	a	5652	14 26.0	+ 6 26			324	+57	162	− 1	g	12×5	106	3	13.2		16.5	1.9
	b	5650			−20	+ 2					d	1.5×1.5		0	14.8			
657	a		14 26.2	+33 23			20	+67	151	+24	e	4×4		1	15.4		17.1	2.5
	b				+ 2	− 8					d	4×4		0	15.5			
658	a	5661	14 26.9	+ 6 42			325	+57	162	0	d−h_0	9×4	10	0.5	13.1		16.4	2.1
	b				− 5	− 3					d	3×3		0.5	14.9			
659	a		14 27.7	+29 24			10	+66	153	+21	d	4×4		0	15.1		17.3	1.5
	b				+11	+ 3					d	3×3		0	15.9			
660	a		14 27.9	+36 45			28	+66	150	+27	d−h_0	10×5	26	0.5	14.4		17.0	2.0
	b				− 9	− 2					h_0	15×4	111	0.5	14.9			
661	a		14 29.8	+40 31			36	+64	148	+31	d	9×6	119	0.5	13.9		17.0	1.9
	b				+ 4	+ 8					e	6×4	39	1	14.1			
662	a		14 30.2	+31 24			15	+66	153	+23	d−h_0	6×3	0	0	14.5		17.4	1.0
	b				+ 5	+ 3					d	2×2		0	15.2			
663	a	5682	14 31.1	+49 7			53	+60	144	+38	h_0	10×3	121	0	13.7		16.3	1.0
	b	5683			+12	− 5					d	3×3		0	14.2			
664	a		14 33.2	+ 9 46			332	+57	162	+ 3	d	3×3		0.5	14.3		17.1	2.0
	b				+ 2	+ 3					d	2×2		0.5	14.7			
665	a	5709	14 34.5	+30 52			14	+65	154	+23	v S	16×5	95	0.5	12.8		17.3	1.7
	b	5706			−17	+13					d−h_0	3×1.5	4	0	15.1			
665′	a	5709	14 34.5	+30 52			14	+65	154	+23	h_0	18×5	106	0.5	13.4		16.7	3.5
	b	5706			−17	+14					d	7×7		0	14.7			
666	a		14 35.9	+15 5			341	+60	161	+ 8	d−h_0	7×3	38	0.5	14.3		16.3	1.1
	b				0	+10					d	3×3		0	14.4			
667	a	5730	14 36.1	+43 11			40	+62	148	+34	h_0	20×3	80	0	13.7		16.3	0.9
	b	5731			+30	+25					h_0	9×3	120	1	13.9			
668	a		14 37.5	+ 9 25			332	+56	164	+ 3	d−h_0	5×2	154	0.5	14.6		17.2	1.2
	b				−11	0					h_0	8×2	100	0	14.8			
669	a		14 37.8	−15 31			307	+38	174	−20	d	9×9		0	12.2		16.7	1.3
	b				− 3	+ 8					d	3×3		0	14.5			
670	a		14 38.0	+ 5 19			326	+54	165	− 1	d−h_0	20×7	162	0	12.5		16.8	2.9
	b				+24	+ 2					d	5×5		0	15.0			
671	a		14 38.1	+ 5 27			327	+54	165	0	d	4×4		0	14.6		16.8	2.8
	b				− 8	− 9					d−h_0	5×3	167	0	14.6			
672	a		14 40.9	+17 44			346	+60	161	+11	d	4×4		0	13.5		16.2	3.0
	b				−11	− 2					d−h_0	3×1.5	92	0	14.9			
673	a		14 41.1	+73 4			79	+42	121	+57	d−h_0	4×2	71	0.5	14.8		16.4	1.7
	b				+ 3	−16					d−h_0	5×2	86	0	15.2			
674	a	5754	14 41.3	+39 11			32	+63	152	+31	d	10×10		0.5	13.7		16.8	2.6
	b	5755			+ 7	+30					e	8×8		1	14.2			
	c	5752			−11	− 2					d	4×4		0.5	14.8			
	d	5753			− 3	+46					d−h_0	8×3	174	0.5	15.3			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
675	a		$14^h 41^m.5$	+28° 57′			9°	+64°	157°	+22°	d	5×5		0	$14^m.5$		$17^m.3$	1°.4
	b				+ 8	+ 6					d	5×5		0	15.8			
676	a	5756	14 42.0	−14 26			308	+38	174	−18	g	18×9	40°	1	12.7	$13^m.1$	16.8	0.8
	b				+15	+13					d—h_0	13×5	12	0.5	15.1			
677	a		14 42.0	−13 18			310	+39	174	−17	g	20×10	10	0.5	12.6		16.7	1.9
	b				+ 9	−26					d	4×4		0	14.5			
	c				+10	−20					d	4×4		0.5	14.6			
678	a		14 43.6	− 3 18			319	+47	170	− 8	d	12×8	37	0	13.5		15.9	2.7
	b				+ 6	−11					d	6×6		0	14.3			
679	a		14 43.7	+ 7 14			330	+54	166	+ 2	d	8×8		0.5	14.4		17.1	1.7
	b				−11	+10					d	3×2	169	0	15.0			
680	a		14 46.0	+10 31			335	+56	165	+ 5	e	5×5		1	13.9		16.8	3.0
	b				− 4	+ 8					d—h_0	9×4	143	0	15.0			
681	a		14 46.1	+47 48			47	+59	148	+38	d	6×4	160	0	13.7		16.1	2.7
	b				+19	+13					d	3×3		0.5	14.1			
682	a		14 46.5	+ 7 13			331	+54	166	+ 3	d—h_0	7×4	162	0	14.3		17.0	2.2
	b				− 6	+ 4					d	4×4		0	14.9			
683	a		14 46.9	+43 9			39	+60	150	+35	h_0	9×3	151	0.5	13.6		16.1	2.3
	b				+ 7	+18					d	4×4		0.5	14.4			
684	a		14 48.0	+ 3 45			327	+51	168	− 1	d	8×8		0	12.9		16.6	3.2
	b				− 5	−20					d	7×7		0.5	13.6			
685	a	5775	14 48.9	+ 3 57			328	+51	168	− 1	h	35×8	150	2	12.1	12.4	16.6	3.1
	b	5774			−38	+25					e	10×10		1	13.5			
686	a		14 54.8	+13 37			342	+55	166	+ 9	e—h_0	12×6	25	1	14.8		16.2	2.5
	b				− 3	+ 9					d	7×5	60	0	15.0			
687	a	5821	14 56.0	+54 20			56	+54	144	+45	d	5×5		0	14.3		16.2	1.1
	b				+ 8	−10					d—h_0	5×3	21	0	14.5			
688	a	5813	14 56.1	+ 2 6			327	+48	171	− 2	g	23×10	140	18	13.4	12.2	17.1	1.1
	b	5814			+26	−40					e	3×3		1	14.7			
689	a		14 57.5	+48 45			47	+56	149	+41	h_0	17×3	60	0	13.7		16.4	1.0
	b				−17	− 1					d	2×2		0	14.4			
690	a	5828	14 57.5	+50 23			51	+56	148	+42	d	6×6		0	13.5		16.2	2.4
	b				− 1	− 7					d	5×5		0	14.5			
691	a		14 58.2	+48 43			47	+57	149	+41	h_0	18×3	139	0	13.2		16.4	0.8
	b				+ 1	−31					d—h_0	4×2	168	0	15.0			
692	a		14 58.3	+11 36			340	+54	167	+ 7	d	4×4		0	14.7		16.4	2.0
	b				+ 6	− 1					d	3×3		0	15.1			
693	a		15 1.2	+13 8			343	+54	167	+ 9	e	4×4		1	15.1		16.5	0.9
	b				+ 3	− 9					e	4×4		1	15.3			
694	a	5846	15 1.4	+ 1 59			328	+48	172	− 2	f	11×11		9	12.1	11.6	17.1	0.6
	b				0	− 7					e	2×2		1	14.3			
695	a		15 2.0	+13 4			343	+54	167	+ 9	d	9×9		0.5	14.1		16.5	0.7
	b				+ 1	−19					d	3×3		0	15.6			
696	a		15 2.0	+46 57			44	+57	151	+39	h_0	8×2	159	0	13.8		16.4	1.1
	b				−12	+14					d	2×2		0	15.1			
697	a	5851	15 2.2	+13 14			343	+53	167	+ 9	d—h_0	11×6	48	0.5	14.3		16.5	0.7
	b	5852			+ 8	− 7					g	10×5	102	2	14.3			
	c				−17	− 5					d—h_0	5×3	172	0	15.4			
698	a		15 2.9	− 8 40			318	+40	177	−11	d	7×5	49	0	13.5		15.9	2.7
	b				+12	− 5					d	3×3		0	14.3			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
699	a	5865	15h 4m6	+ 0° 53′			328°	+46°	173°	− 2°	e	5×5		1	12m6		16m9	2°1
	b	5869			+10	−17					e	3×3		1	13.9			
	c				−18	+ 6					d	5×3	106°	0	14.3			
700	a		15 6.4	+ 2 9			330	+47	173	− 1	d	4×4		0	14.8		17.0	1.6
	b				+ 2	+11					d	4×4		0	15.3			
701	a	5895	15 10.1	+42 23			36	+56	155	+36	d−h₀	11×5	176	0	14.9		16.4	2.8
	b	5893			−18	−22					d	8×6	36	0	13.6			
	c	5896			+10	+12					d−h₀	8×4	28	0	14.4			
702	a	5900	15 11.5	+42 35			36	+56	155	+36	h₀	18×6	128	0	13.6		16.4	3.0
	b	5901			− 6	+11					d	4×4		0	15.2			
703	a	5912	15 13.1	+75 45			79	+38	119	+60	d	3×3		0.5	13.8		16.4	1.9
	b	5909			− 9	− 2					g	10×3	37	1	14.0			
	c				−14	+24					d	2×2		0	14.3			
704	a	{5906 5907	15 13.2	+56 42			58	+51	146	+48	o−h₀	120×11	153	1	11.6	11m8	16.0	2.2
	b				−97	+71					d	5×5		0	14.3			
705	a		15 13.4	+14 12			347	+52	169	+11	d	4×4		0.5	14.7		16.7	2.5
	b				+11	+10					d−h₀	3×1.5	139	0.5	14.9			
706	a	5914	15 15.1	+42 14			34	+56	157	+36	d	4×4		0.5	14.1		16.4	2.9
	b				+ 3	+16					d	5×5		0	14.9			
707	a	5923	15 17.7	+42 5			34	+55	157	+37	d	13×13		0.5	13.6		16.4	3.0
	b	5922			− 7	−35					d	5×5		0	15.2			
708	a		15 18.7	+13 5			346	+50	171	+10	e	3×3		1	13.6		16.6	2.8
	b				− 7	−14					d	2×2		0	14.9			
709	a		15 20.3	+13 48			347	+50	171	+12	d	2×2		0	14.8		16.9	1.9
	b				+11	+ 2					d	3×2	30	0	15.2			
710	a	5930	15 22.6	+42 2			34	+54	158	+37	e	6×6		1	13.6		16.1	3.5
	b	5929			− 3	− 4					e	5×5		1	14.1			
711	a		15 28.0	− 8 21			324	+35	183	− 7	d−h₀	11×4	77	0	13.5		16.8	2.0
	b				+30	−20					h₀	9×3	10	0	14.3			
712	a		15 28.0	+10 48			345	+47	175	+ 9	h₀	6×2	132	0	14.8		16.6	0.3
	b				0	− 4					h₀	5×1.5	79	0	14.7			
713	a	5951	15 29.0	+15 20			351	+49	173	+14	h₀	17×4	179	0	13.1		16.9	1.8
	b				+15	−12					d−h₀	4×2	174	0	15.1			
714	a	5954	15 29.9	+15 32			352	+50	173	+14	d−h₀	9×4	174	0.5	13.1		16.9	2.0
	b	5953			− 7	− 4					e	3×3		1	13.2			
715	a		15 31.2	+31 13			15	+53	166	+28	e−h₀	8×4	95	1	13.6		17.1	2.4
	b				+ 5	−37					h₀	12×3	48	0	14.9			
	c				+16	+ 3					d	6×6		0	15.0			
716	a	5962	15 31.9	+16 56			354	+49	173	+15	g	18×10	103	10	12.4	12.5	16.7	2.7
	b				+ 5	−14					d−h₀	5×2	19	0	14.9			
717	a		15 34.1	+12 24			348	+46	175	+12	d−h₀	8×5	169	0	14.0		15.6	3.0
	b				− 2	− 7					d	6×6		0	14.2			
718	a	5975	15 35.8	+21 50			1	+50	172	+20	d	5×4	177	0.5	14.5		17.0	1.9
	b				− 3	+14					d	4×4		0	15.2			
719	a	5982	15 36.6	+59 41			60	+46	147	+53	e	5×5		1	12.4	12.5	16.0	2.9
	b	5985			+75	−17					s	40×20	24	0.5	11.4	12.2		
	c	5981			−63	+23					h₀	22×4	144	0	12.5			
720	a	5980	15 36.8	+16 6			353	+48	174	+15	h₀	19×5	21	0.5	12.9		15.8	2.3
	b				−16	− 3					d−h₀	6×3	9	0	14.5			

No	NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
721 a	5996	15h 42m.5	+18° 12′			357°	+47°	175°	+17°	v S	13×6	172°	1	12m.5		16m.9	2°.1
b	5994			−13	− 9					d	2×2		0	15.1			
722 a		15 44.0	+ 5 31			341	+41	180	+ 6	h_o	7×1.5	116	0	15.0		17.1	1.0
b				+ 6	− 9					d−h_o	3×1.5	8	0	15.2			
723 a		15 44.6	+18 48			358	+47	175	+18	d	6×4	13	0	14.6		17.0	2.0
b				−12	−12					d	1.5×1.5		0	15.3			
724 a		15 45.2	+18 50			358	+47	175	+19	h	6×2	158	1	14.6		16.9	2.1
b				+10	−11					d	3×2	163	0	15.4			
725 a		15 45.6	+21 6			1	+47	174	+20	d	4×4		0	14.0		16.9	2.2
b				+ 5	0					d	5×5		0	14.3			
726 a	6008	15 48.5	+21 25			2	+47	174	+21	d	11×8	80	0	13.6		16.7	3.0
b				+28	−16					d	6×6		0	14.4			
727 a	6068	16 0.7	+79 15			80	+35	116	+75	r S	9×5	173	1	13.3		16.2	1.9
b				−20	− 4					e—h_o	5×3	171	1	14.1			
728 a		16 2.0	+20 3			2	+43	178	+22	d	10×7	30	0	13.5		16.8	2.0
b				− 8	− 8					d	5×5		0	14.4			
729 a	6070	16 4.8	+ 0 59			340	+34	187	+ 4	g	30×14	55	0.5	12.1	12m.7	17.0	2.1
b				+26	+34					d−h_o	9×4	1	0	14.9			
c				+33	+44					d−h_o	5×3	28	0	14.9			
730 a		16 5.1	+ 1 20			341	+34	187	+ 5	d−h_o	4×2	4	0	15.1		17.1	1.8
b				− 5	− 3					d	3×3		0	15.4			
731 a	6073	16 5.7	+16 57			358	+41	180	+20	d−h_o	11×5	114	0	13.5		16.8	1.8
b				+ 8	+ 9					d	3×3		0	15.0			
732 a		16 8.7	+57 45			55	+43	155	+54	d	7×7		0	13.8		16.3	1.8
b	6088			− 3	+ 3					d	2×2		0	14.1			
733 a		16 9.4	+37 32			26	+45	171	+37	d	5×5		0	15.0		17.2	1.6
b				+16	+ 9					d−h_o	5×3	129	0	15.5			
734 a		16 10.3	+60 49			58	+42	151	+56	d−h_o	4×2	171	0	14.0		16.1	2.6
b				− 4	+ 2					d	3×2	140	0	14.1			
735 a	6096	16 10.6	+26 48			12	+44	177	+28	d	4×4		0	14.9		17.3	2.7
b				+ 8	− 4					d−h_o	4×1.5	1	0	15.3			
736 a		16 12.4	+38 10			27	+45	171	+38	d	4×4		0	15.4		17.3	0.9
b				+ 3	+11					d	4×4		0	16.1			
737 a	6117	16 15.7	+37 19			26	+44	173	+38	d	7×7		0	14.3		17.3	0.8
b				+ 8	−16					d	3×2	176	0	15.7			
c				0	−19					d−h_o	4×2	134	0	15.8			
d				+ 1	− 7					d	3×3		0	16.3			
738 a		16 15.8	+59 34			56	+42	154	+56	h	13×2	136	1	13.1		16.2	2.3
b				− 3	+39					d	4×3	29	0	13.9			
c				+ 9	− 1					d	3×2	169	0	14.1			
739 a	6120	16 16.3	+38 0			27	+44	172	+39	d	4×4		0	14.1		17.3	0.2
b				− 3	− 2					d	3×3		0	15.8			
740 a		16 17.6	+40 10			30	+44	171	+41	d	4×4		0	14.3		17.1	2.1
b				−19	−34					d−h_o	6×3	42	0	15.1			
c				−20	− 5					d	6×4	130	0	15.3			
741 a	6129	16 18.2	+38 13			27	+44	173	+40	d	3×3		0	14.7		17.3	0.2
b				−19	+ 7					d	3×3		0	15.7			
c				−14	+ 5					d	2×2		0	15.8			
742 a	6131	16 18.3	+39 11			29	+44	172	+40	d	10×7	172	0.5	12.8		17.3	1.1
b				+16	−11					d	3×3		0	14.8			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
742′	a	6131	16h 18m.4	+39° 10′			29°	+44°	172°	+40°	d	11×8	149°	0	12m5		16m7	2°2
	b				+17	−10					d−h₀	8×3	39	0	14.5			
743	a		16 18.6	+27 32			13	+42	179	+29	d	3×3		0	15.3		17.3	2.5
	b				+ 1	− 5					d	2×2		0	15.5			
744	a	6137	16 19.5	+38 10			27	+43	173	+40	d	4×3	168	0.5	13.9		17.3	0.5
	b				− 6	+17					d	4×4		0.5	15.2			
745	a		16 19.8	+40 7			30	+44	172	+41	d	10×10		0.5	13.5		16.9	1.2
	b				0	−21					d−h₀	4×2	177	0	15.4			
746	a		16 20.6	+41 9			31	+44	171	+42	d	3×3		0	15.0		16.9	0.2
	b				+ 9	+ 2					d	2×2		0	15.1			
747	a	6145	16 21.7	+41 11			31	+44	171	+42	d	4×4		0.5	14.6		16.9	0.0
	b				+ 6	−11					d	3×3		0	14.7			
748	a	6150	16 22.5	+40 42			31	+43	172	+42	e	4×4		1	14.7		16.9	2.9
	b				−10	− 9					d	3×3		0	15.2			
749	a	6158	16 24.2	+39 37			30	+43	173	+41	e	3×3		1	14.7		17.1	2.1
	b				0	+ 8					d	2×2		0	15.8			
	c				+ 3	− 4					d−h₀	4×2	20	0	15.6			
750	a		16 24.4	+40 30			30	+43	173	+42	h₀	7×2	76	0	14.9		16.9	0.8
	b				− 5	− 2					d	2×2		0	15.4			
751	a	6166	16 25.2	+39 47			30	+43	173	+42	d−h₀	5×3	62	0.5	13.6		17.1	2.3
	b				−14	−19					e	3×3		1	14.9			
	c				+28	+ 6					d	2×2		0	15.0			
	d				−29	+10					e	3×3		1	15.1			
	e				+ 2	−20					e	3×3		1	15.3			
752	a		16 25.2	+40 20			31	+43	173	+42	d	4×4		0.5	14.3		16.9	1.0
	b				+ 6	+ 1					d	3×3		0	14.8			
	c				+ 1	− 4					d	2×2		0	15.2			
753	a	6173	16 26.4	+41 2			31	+43	173	+43	e	4×4		1	14.2		16.9	0.9
	b	6174			+13	− 5					d	3×3		0	15.1			
754	a		16 27.5	+40 3			30	+42	173	+43	d	3×3		0	14.7		16.8	1.5
	b				− 4	+ 7					d	2×2		0.5	14.7			
755	a		16 40.2	+61 31			58	+39	155	+59	h	14×2	145	5	14.2		16.7	1.5
	b				−16	−23					d	3×3		0.5	15.5			
756	a		16 46.1	+62 21			59	+38	154	+61	d	4×4		0	14.4		16.5	2.6
	b				− 1	+ 3					d	3×3		0.5	14.9			
757	a		16 46.6	+45 38			37	+39	174	+48	d	2×2		0.5	15.2		17.0	1.6
	b				− 4	− 2					d	2×2		0	15.5			
758	a		16 46.9	+46 53			39	+39	174	+49	d	1.5×1.5		0	15.4		17.1	0.5
	b				+ 3	− 3					d	1.5×1.5		0	15.7			
759	a		16 48.1	+23 28			10	+35	188	+29	d	3×3		0	15.1		17.0	1.2
	b				−10	+ 4					d	3×3		0	15.2			
760	a		16 48.5	+30 53			19	+37	184	+36	d−h₀	5×2	99	0.5	14.9		17.0	1.9
	b				+16	+ 6					d−h₀	4×2	170	0	15.2			
761	a		16 49.1	+30 40			19	+36	184	+36	h₀	6×2	135	0	14.7		17.0	1.6
	b				+ 4	+ 2					d−h₀	3×1.5	76	0	15.4			
762	a		16 50.7	+12 3			358	+30	193	+19	d	8×8		0	12.2		14.6	2.5
	b				−16	− 7					d−h₀	4×2	173	0	12.3			
763	a	6264	16 53.3	+28 1			16	+35	186	+34	d−h₀	6×3	20	0	14.8		17.0	1.3
	b				+ 4	0					d	1.5×1.5		0	15.6			
764	a	6267	16 54.0	+23 10			11	+33	189	+29	d	10×10		0	12.7		16.8	2.4
	b				− 1	− 6					d	5×5		0	15.7			

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a\times b$	φ	c	m	m_{Harv}	m_l	d
765	a	6278	16h 56m.6	+23° 10′			11°	+33°	189°	+29°	e	5×5		1	13m.6		16m.6	3°.0
	b	6276			−13	+20					d	3×3		0.5	14.7			
	c	6277			− 4	+18					d	2×2		0.5	15.5			
766	a		16 59.4	+31 47			21	+34	185	+37	d	3×3		0.5	14.7		16.7	2.9
	b				− 2	+ 3					d	3×3		0.5	14.8			
767	a		17 1.4	+30 33			20	+34	187	+36	d	5×5		0.5	14.8		16.9	2.2
	b				− 2	+13					d	2×2		0	15.0			
768	a		17 5.6	+37 10			28	+34	184	+42	d	3×3		0	13.8		15.3	2.8
	b				0	− 3					h₀	9×2	92°	0	14.3			
769	a	6307	17 6.5	+60 53			57	+34	159	+61	e−h₀	7×3	116	1	13.2		15.3	1.8
	b	6306			− 5	−13					d	3×3		0	14.0			
770	a		17 20.4	+25 4			15	+28	194	+34	d	10×10		0.5	14.5		17.6	2.0
	b				+40	− 1					h₀	10×3	166	0.5	14.6			
771	a		17 45.7	+14 19			6	+18	206	+26	d−h₀	10×6	127	0	13.9		16.4	2.4
	b				0	+10					d−h₀	6×3	69	0	14.7			
772	a	6468	17 46.3	+17 30			10	+20	204	+28	d	2×2		0	14.0		16.1	1.0
	b	6467			− 3	− 4					d	2×2		0.5	14.5			
773	a		17 56.5	+28 47			22	+22	202	+40	h₀	6×2	35	0.5	14.2		17.2	1.4
	b				− 6	+ 7					d	3×3		0	15.3			
774	a	6555	18 3.3	+17 35			12	+16	208	+30	d	11×11		0.5	12.4		15.5	3.2
	b				+ 2	+18					d−h₀	5×3	105	0	13.9			
775	a		18 8.3	+21 24			16	+17	208	+35	e	5×5		1	13.9		16.0	1.0
	b				− 4	− 5					d	3×3		0	14.1			
776	a		19 22.9	−14 55			351	−16	238	+ 5	d	3×3		0.5	13.5		16.1	0.8
	b				0	− 6					d	2×2		0	13.5			
	c				− 9	+ 6					d	3×3		0	14.7			
777	a		20 0.5	−10 44			359	−23	246	+12	d	6×6		0.5	14.2		16.6	2.3
	b				− 4	+11					d	6×6		0	14.6			
778	a		20 11.5	−13 22			358	−26	249	+ 8	f	6×6		0.5	12.2		15.6	2.1
	b				− 2	+10					e	3×3		1	13.1			
779	a		20 14.2	+11 14			21	−15	247	+34	h₀	10×2	107	0	14.5		16.6	3.0
	b				−23	− 9					d	6×6		0.5	14.7			
780	a		20 27.1	− 2 35			11	−25	252	+20	d	7×7		0	14.3		17.2	1.5
	b				− 1	+ 9					d	3×3		0.5	15.0			
781	a	6926	20 27.8	− 2 22			11	−25	252	+20	d−h₀	13×8	173	0	12.2		17.2	1.9
	b	6929			+40	− 4					d	3×3		0	13.8			
781′	a	6926	20 27.8	− 2 22			11	−25	252	+20	d−h₀	14×8	175	0	12.7		17.2	2.7
	b	6929			+40	− 5					d	4×4		0	14.4			
782	a		20 50.9	−14 10			2	−35	259	+ 9	d−h₀	6×3	151	0	14.5		16.3	3.0
	b				− 4	+ 7					d	4×4		0	14.6			
783	a		20 52.0	− 0 36			16	−29	258	+23	h₀	8×2	110	0	14.4		16.6	0.6
	b				+16	−15					h₀	8×2	150	0.5	14.5			
784	a		20 59.7	+15 41			32	−21	261	+40	d	3×3		0	14.8		16.9	1.0
	b				+ 4	− 1					d	3×3		0	15.1			
785	a		21 26.6	+ 2 1			25	−35	268	+26	d	6×6		0	14.2		16.6	2.0
	b				− 8	− 4					d	4×4		0	15.0			
n.s. MC 27412 786	a		21 38.3	+40 54			57	− 9	272	+64	d	5×5		0	12.3		15.2	1.5
	b				− 8	− 4					d	2×2		0	13.5			
787	a		21 48.9	−16 55			6	−49	274	+ 6	h₀	9×3	144	0	13.6		16.1	1.3
	b				− 6	+ 8					d	2×2		0	14.4			

No	NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
788 a	7223	22h 5m.9	+40° 31′			61°	−13°	285°	+63°	d	10×10		0	12m.9		17m.0	2°.6
b				− 5	+ 6					d	5×5		0	14.6			
789 a	7242	22 11.2	+36 48			59	−17	286	+60	e	5×5		1	13.7		17.2	1.3
b				+ 4	+ 3					d	3×3		0	14.9			
790 a	}7253	22 14.8	+28 53			56	−23	287	+52	h_0	20×5	103°	0.5	13.2		17.3	0.5
b				+ 6	− 8					h_0	16×4	59	0	13.5			
791 a		22 18.2	+29 16			56	−24	288	+52	e	6×6		1	14.8		17.3	0.8
b				+ 2	+ 5					e	3×3		1	15.6			
792 a	7320	22 31.5	+33 25			61	−22	293	+56	d−h_0	20×7	141	0.5	13.6		16.5	1.6
b	7319			+ 1	+18					d−h_0	5×3	150	0	14.6			
c	7318			−11	+12					e	2×2		1	14.8			
d	7317			−26	− 4					d	2×2		0	14.8			
793 a		22 31.7	+21 7			54	−32	289	+44	d	9×9		0.5	13.3		16.4	3.0
b				− 8	− 9					d	4×4		0	15.2			
794 a	7323	22 32.0	+18 37			53	−34	289	+41	d	7×7		0.5	13.3		16.3	1.5
b	7324			+18	+ 3					d	2×2		0	14.5			
795 a	7331	22 32.5	+33 53			62	−21	293	+56	s S	75×20	170	18	10.8	11m.2	16.6	1.1
b	7337			+46	−26					d	2×2		0	14.4			
c	7335			+32	+19					h	10×3	60	1	14.5			
d	7338			+57	0					d	2×2		0	14.5			
e	7340			+83	− 1					e	2×2		1	14.8			
f	7325			−34	−29					d	2×2		0	14.8			
g	7327			−21	+24					d−h_0	6×3	103	0	14.9			
h	7326			−26	+ 4					d−h_0	2×1	161	0	15.3			
i	7333			+15	+13					d	1×1		0	15.3			
j	7336			+36	+40					d	2×2		0	15.4			
796 a	7332	22 32.6	+23 16			56	−30	290	+46	h	21×4	160	4	13.1	12.6	16.7	1.9
b	7339			+52	− 7					h_0	20×3	90	0.5	13.6			
797 a	7371	22 40.8	−11 32			24	−58	287	+11	f	12×12		0.5	13.8	12.9	16.4	2.1
b				− 6	− 8					d−h_0	5×2	88	0	15.0			
798 a	7374	22 41.0	+10 21			48	−42	289	+33	d	7×7		0.5	14.2		16.3	1.0
b				− 4	+ 9					d	3×3		0.5	14.6			
799 a		22 44.9	− 4 56			35	−54	288	+18	d	5×5		0	14.9		17.0	1.5
b				+ 2	+ 9					d	3×3		0	15.1			
800 a	7435	22 53.2	+25 36			62	−31	299	+47	d	3×3		0	14.1		16.3	2.3
b	7436			+ 6	+ 7					e	3×3		1	14.2			
c	7433			−10	− 2					d	2×2		0	15.3			
801 a		22 56.6	+24 38			62	−32	298	+46	d	12×12		0	13.3		16.1	2.9
b				−21	+12					d	5×5		0	14.2			
802 a	7463	22 56.9	+15 27			57	−40	296	+37	h_0	9×3	86	0.5	13.2		16.8	1.1
b	7465			+22	+ 9					h	6×2	168	1	13.4			
c	7464			+ 5	− 5					d	3×3		0.5	13.8			
803 a	7469	22 58.3	+ 8 21			52	−46	294	+30	d−h_0	7×3	122	0	14.0	13.0	16.6	1.3
b				− 7	−11					d	3×3		0	14.7			
804 a	7480	23 0.2	+ 2 1			47	−52	294	+23	g	12×4	120	2	14.8		17.0	1.1
b				−31	− 6					d	6×6		0	15.5			
805* a	7541	23 9.6	+ 3 59			52	−51	297	+25	p S	25×7	99	0.5	11.6	12.8	16.5	1.0
b	7537			−20	−23					h	13×2	80	4	13.1			
805′ a	7541	23 9.7	+ 3 59			52	−51	297	+25	h_0	30×8	97	0.5	11.3	12.8	16.6	2.9
b	7537			−22	−22					g	11×4	69	2	12.8			

20—37522.

No		NGC	α_{1900}	δ_{1900}	$\Delta\alpha \cos\delta$	$\Delta\delta$	l	b	L	B	Type	$a \times b$	φ	c	m	m_{Harv}	m_l	d
806	a		23h 10m.6	− 0° 8′			49°	−55°	296°	+21°	d	7×6	20°	0	14m.0		16m.8	2°.2
	b				−10	+13					d	3×3		0	14.7			
807	a		23 12.2	+ 5 6			54	−51	297	+26	d	3×3		0	13.9		16.5	0.3
	b				+ 3	−10					d	2×2		0	14.6			
808	a		23 16.8	+ 4 28			55	−52	298	+25	d−h$_o$	8×4	173	0	13.7		16.4	1.6
	b				+13	+19					h$_o$	8×2	110	0.5	13.8			
809	a		23 28.9	+29 31			72	−30	310	+49	d−h$_o$	11×7	131	0	12.6		16.8	1.2
	b				−24	−14					d	5×5		0	14.6			
810	a	7714	23 31.1	+ 1 36			58	−56	301	+21	e	5×5		1	13.4		16.1	2.9
	b	7715			+20	+ 1					h	15×3	70	0.5	14.3			
811	a		23 32.3	+ 4 22			61	−54	302	+23	d−h$_o$	6×3	10	0.5	14.5		16.5	1.0
	b				− 3	−15					d−h$_o$	4×2	8	0	15.3			
812	a	7721	23 33.7	− 7 4			50	−64	301	+13	h$_o$−s	33×11	20	0.5	12.7	12m.4	16.4	2.6
	b				−16	−12					h$_o$	15×2	167	0	15.0			
813	a	7732	23 36.4	+ 3 10			61	−55	303	+22	h$_o$	14×3	90	0.5	13.9		16.5	1.0
	b	7731			−12	+ 9					e	3×3		2	14.7			
814	a		23 36.9	− 4 46			54	−62	302	+15	d−h$_o$	11×7	44	0	13.7		16.3	2.8
	b				−23	+10					d	4×3	100	0	14.4			
815	a		23 38.1	+18 6			70	−42	309	+37	d	3×3		0	14.5		16.2	2.1
	b				+ 1	+ 3					d	3×2	23	0	14.8			
816	a	7753	23 42.0	+28 55			75	−31	314	+47	g	30×16	65	1	12.6		16.6	2.1
	b				−13	−15					e	4×4		1	13.6			
817	a	7757	23 43.6	+ 3 37			65	−55	305	+21	f	20×20		0.5	13.2		16.4	2.0
	b	7756			−37	−22					h$_o$	4×1	10	0	15.1			
818	a	7768	23 45.8	+26 35			76	−34	314	+44	e	3×3		1	14.5		16.7	1.7
	b	7767			−24	−28					h−h$_o$	7×2	141	0.5	14.7			
	c	7765			−15	+10					d	4×4		0.5	14.9			
	d	7766			− 6	−14					d	3×2	47	0	15.0			
819	a		23 46.2	+42 59			80	−18	322	+61	d−h$_o$	6×3	58	0	15.0		17.0	2.0
	b				− 5	− 3					d	2×2		0	15.3			
820	a	7771	23 46.3	+19 33			73	−41	310	+38	h−h$_o$	14×3	70	1	13.0		16.4	1.1
	b	7770			− 5	− 9					d	3×3		0	13.8			
	c	7769			−51	+20					f	8×8		1	12.5	12.9		
820′	a	7771	23 46.3	+19 33			73	−41	310	+38	g−h	13×3	71	1	13.4		16.1	2.8
	b	7770			− 6	− 9					d	3×3		0	14.1			
821	a	7774	23 47.1	+10 55			70	−49	308	+29	e	4×4		1	14.5		16.3	1.6
	b				+ 4	0					d	3×3		0	14.8			
822	a		23 51.6	− 3 12			63	−62	306	+15	d	6×6		0	14.4		16.6	1.3
	b				−19	−17					h	8×1.5	0	1	14.8			
823	a		23 51.7	− 3 54			62	−63	307	+14	d−h$_o$	10×6	127	0	13.5		16.7	1.2
	b				− 1	−21					d−h$_o$	5×3	15	0	14.0			
824	a		23 54.5	−12 1			53	−71	305	+ 7	v S(?)	25×4	125:	6	13.8		15.8	2.8
	b				−13	+15					d−h$_o$	5×3	30	0	14.4			
825	a		23 55.7	+27 51			78	−33	318	+45	d	3×3		0	14.7		16.8	1.6
	b				− 7	0					d	4×4		0.5	15.0			
826	a	7805	23 56.3	+30 52			79	−30	319	+48	e	3×3		1	14.3		16.6	2.6
	b	7806			+ 8	+ 6					e−h$_o$	5×3	176	1	14.5			
827	a		23 58.0	− 2 28			70	−58	308	+15	d	11×11		0	12.8		16.3	3.0
	b				−22	−26					d−h$_o$	5×3	170	0	14.6			

NOTES TO THE PRECEDING CATALOGUE

In the following list some notes are given to the preceding catalogue. For the sake of brevity the following denotations have been introduced:

R = K. Reinmuth's catalogue, Die Herschel-Nebel (Heidelberg Veröff, Band 9 (1926)).

A = A. Ames's catalogue (Harvard Ann 88, No 1 (1930)).

S = H. Shapley's and A. Ames's catalogue (Harvard Ann 88, No 2 (1932)).

6. Comp. *e* is given by *R*.
13. Comp. *b* is given by *R*.
17. The distance from the centre of the plate is measured from the nucleus of comp. *a*.
44. Comp. *b* is given by *R*.
46. Comp. *b* is given by *R*.
68. The value of the position angle of comp. *a* is in bad agreement with the value given by *R*. This may be due to a different conception of the object.
72. The system forms part of a small cluster.
73. The system forms part of a small cluster.
74. The system forms part of a small cluster.
75. The system forms part of a small cluster.
77. Comp. *b* is given by *R*.
94. Position angle of comp. *a* refers to the central nuclear parts.
96. Comp. *b* is given by *R*.
98. Comp. *b* and *c* are given by *R*.
102. Comp. *b* is not well defined on the plate.
105. Comp. *b* is given by *R*.
106. Comp. *b* is given by *R*.
113. Comp. *b* is given by *R*.
115. Comp. *b* is given by *R*.
124. Comp. *d* is given by *R*.
128. Comp. *b* is given by *R*.
133. Comp. *b* is given by *R*.
158. A star may be projected on the nucleus of comp. *a*.
160. Comp. *b* is given by *R*.
173. The nuclei of comp. *a* and *b* are eccentrically situated.
175. According to *R*, NGC 3189 and NGC 3190 form only one object. The magnitude value given by *S* refers to NGC 3190.
182. The two objects are not well defined on the plate.
195. Comp. *b* is given by *R*.
223. The system forms part of a small cluster.
224. Position angle of comp. *a* refers to the central nuclear parts.
229. Comp. *b* is given by *R*.
234. According to *R*, NGC 3563 consists of two objects.
235. The system forms part of a small cluster.
237. The system forms part of a small cluster.
241. Comp. *c* is given by *R*.
246. Position angle of comp. *a* refers to the central nuclear parts.
249. Comp. *c* is given by *R*.
252. Comp. *b* is given by *R*.
253. The system forms part of a small cluster.
258. Comp. *b* and *c* are given by *R*.
266. Comp. *b* is given by *R*.
270. Comp. *b* is given by *R*.
284. The system forms part of a small cluster.
285. The system forms part of a small cluster. Comp. *b* is given by *R*.
287. The system forms part of a small cluster. Comp. *b* is given by *R*.
288. The system forms part of a small cluster.
289. The system forms part of a small cluster.
290. The system forms part of a small cluster.
295. Comp. *b* is given by *R*.
300. Comp. *b* is given by *R*.
305. Comp. *b* is given by *R*.
307. The two components almost form only one object.
308. Position angle of comp. *b* refers to the central nuclear parts.
312. Comp. *b* is given by *R*.
313. According to *S*, comp. *a* and *b* are IC 749 and IC 750 resp.
320. The parts of comp. *a* that are situated outside the nucleus are very faint. Comp. *b* is given by *R*.
324. Comp. *a* is given by *R*.
337. Comp. *b* is given by *R*.

345′. Comp. *c* is given by *R*.

347. Comp. *b* is given by *R*.
353. According to *A*, the apparent magnitude of comp. *a* is $11^{m}_{.}6$.
357. Comp. *b* is given by *R*.
359. According to *A*, the apparent magnitude of comp. *a* is $12^{m}_{.}9$.
365. Comp. *b* is given by *R*.
366. Comp. *b* is given by *R*.
368. According to *A*, the apparent magnitudes of comp. *a*, *b* and *c* are $12^{m}_{.}5$, $12^{m}_{.}4$ and $12^{m}_{.}9$ resp.
376. According to *A*, the apparent magnitudes of comp. *a* and *b* are $12^{m}_{.}8$ and $13^{m}_{.}0$ resp.
377. According to *A*, the apparent magnitudes of comp. *a* and *b* are $12^{m}_{.}5$ and $13^{m}_{.}0$ resp.
379. According to *A*, the apparent magnitude of comp. *a* is $11^{m}_{.}2$.
380. According to *A*, the apparent magnitude of comp. *a* is $12^{m}_{.}9$.
387. According to *A*, the apparent magnitude of comp. *a* is $11^{m}_{.}4$.

388. According to *A*, the apparent magnitude of comp. *a* is $12\overset{m}{.}7$. Comp. *b* is very starlike.
391. According to *A*, the apparent magnitudes of comp. *a* and *b* are $12\overset{m}{.}0$ and $12\overset{m}{.}9$ resp.
397. According to *A*, the apparent magnitudes of comp. *a* and *b* are $10\overset{m}{.}9$ and $12\overset{m}{.}3$ resp.
403. The system forms part of a small cluster. According to *A*, the apparent magnitudes of comp. *a*, *b*, *c* and *e* are $10\overset{m}{.}9$, $10\overset{m}{.}8$, $12\overset{m}{.}4$ and $13\overset{m}{.}1$.
409. The system forms part of a small cluster. According to *A*, the apparent magnitudes of comp. *a* and *b* are $11\overset{m}{.}9$ and $11\overset{m}{.}8$ resp.
411. The system forms part of a small cluster.
413. According to *A*, the apparent magnitude of comp. *a* is $10\overset{m}{.}2$.
415. According to *R*, NGC 4496 consists of two objects.
417. Comp. *b* is given by *R*.
418. According to *A*, the apparent magnitude of comp. *a* is $12\overset{m}{.}8$. Comp. *b* is given by *R*.
419. Comp. *b* is given by *R*.
420. Position angle of comp. *a* refers to the major diameter of the object. For the central nuclear parts the angle amounts to 40°. According to *A*, the apparent magnitude of comp. *a* is $11\overset{m}{.}8$. Comp. *b* is given by *R*.
421. According to *A*, the apparent magnitude of comp. *a* is $12\overset{m}{.}4$. Comp. *b* is given by *R*.
422. According to *A*, the apparent magnitude of comp. *a* is $12\overset{m}{.}8$.
427. According to *A*, the apparent magnitudes of comp. *a* and *b* are $12\overset{m}{.}5$ and $12\overset{m}{.}5$ resp.
429. According to *A*, the apparent magnitude of comp. *a* is $12\overset{m}{.}5$.
438. The two objects are not well defined on the plate.
439. Comp. *a* has no well defined nucleus.
448. According to *A*, the apparent magnitudes of comp. *a* and *b* are $10\overset{m}{.}5$ and $12\overset{m}{.}8$ resp.
459. According to *R*, NGC 4676 consists of two objects.
469. Comp. *b* and *c* are given by *R*.
473. Comp. *b* is very starlike. According to *R*, this object may be a star.
474. Comp. *b* is given by *R*.
485. According to *R*, NGC 4782 is situated south of NGC 4783.
488. Comp. *b* is given by *R*.
492. According to *R*, NGC 4841 consists of two objects.
495. Comp. *b* is given by *R*.
498. According to *R*, NGC 4893 consists of two objects.
499. The system forms part of a small cluster. Comp. *b* is given by *R*.
502. According to *R*, NGC 4933 consists of two objects.
510. Comp. *b* is given by *R*.
511. Comp. *b* and *c* are given by *R*.
514. According to *R*, NGC 5077 consists of two objects.
516. Comp. *b* is given by *R*.
519. Comp. *b* is given by *R*.
533. Comp. *b* is given by *R*.
541. Position angle of comp. *a* refers to the central nuclear parts.
542. Comp. *b* is given by *R*.
548. Comp. *b* is given by *R*.
565. Comp. *b* is given by *R*.
567. Comp. *b* is given by *R*.
568. Comp. *b* is projected on comp. *a*. Comp. *c* is very starlike.
569. Comp. *b* is given by *R*.
578. Comp. *b* is given by *R*.
582. Comp. *b* is given by *R*.
585'. Comp. *e* is given by *R*.
595. Comp. *b* is given by *R*.
597. Comp. *b* and *c* are given by *R*.
621. The parts of comp. *a* that are situated outside the nucleus are very faint.
622. Comp. *b* is given by *R*.
641. Comp. *b* is given by *R*.
645. Comp. *b* and *c* are given by *R*.
658. Comp. *b* is given by *R*.
694. Comp. *b* is given by *R*.
701. Comp. *a* is not well defined on the plate.
703. Comp. *c* is given by *R*.
704. According to *R*, NGC 5906 and NGC 5907 are only one object.
718. Comp. *b* is not well defined on the plate.
721. A star may be projected on comp. *a*. The star is not included in the apparent magnitude.
727. Comp. *b* is given by *R*.
732. Comp. *a* is given by *R*.
739. Comp. *b* is given by *R*.
741. Comp. *b* and *c* are given by *R*.
744. Comp. *b* is given by *R*.
745. The system forms part of a small cluster.
746. The system forms part of a small cluster.
747. The system forms part of a small cluster.
748. Comp. *b* is given by *R*.
749. Comp. *b* and *c* are given by *R*.
750. The system forms part of a small cluster.
752. The system forms part of a small cluster.
753. The system forms part of a small cluster.
762. Comp. *a* is not well defined on the plate.
763. Comp. *b* is given by *R*.
764. Comp. *b* is given by *R*.
774. Comp. *b* is given by *R*.
788. Comp. *b* is given by *R*.
789. Comp. *b* is given by *R*.
790. According to *R*, NGC 7253 consists of two objects.
792. A star may be projected on comp. *a*. The star is not included in the apparent magnitude.
798. Comp. *b* is given by *R*.
805. Comp. *a* (type *p*) is somewhat S-formed.
824. Comp. *a* is not well defined on the plate.

SUMMARY

The present paper contains a study of double and multiple galaxies. The apparent properties of the 827 double and multiple systems given in the present catalogue have been determined by means of the extensive collection of Bruce plates of the Heidelberg Observatory. In connection with the above investigations some general metagalactic problems are discussed.

In *Chapter I* the general clustering tendencies within the metagalactic system are discussed. The existence of double galaxies cannot be explained as a result of absorption effects. There is an unbroken line of transition: double galaxies — multiple galaxies — metagalactic clusters — metagalactic superclusters or clouds.

In *Chapter II* the working definition used in this paper of a double or multiple galaxy is given (formula (1)). The double galaxies selected according to the said definition prove in general to be physical systems. It is thus found that the probable number of optical systems included in the present catalogue should amount to only some few per cent. The apparent distribution of the 827 double and multiple systems is given in Fig. 3.

In *Chapter III* the plate material used for the present investigation is discussed. The limiting magnitudes of the Bruce plates are situated between $15^{m}_{.}0$ and $17^{m}_{.}5$. More than 80 % of the northern hemisphere is covered with plates.

In *Chapter IV* an account is given of the examination of the plates. The concentration of light within the galaxies is defined in formula (5). This definition has proved to be very convenient in practical use.

In *Chapter V* the determination of apparent total magnitudes of the galaxies is discussed. In the present case estimations have been made by means of star counts (a diagram is given in Fig. 9). The mean error in a single determination amounts to about $0^{m}_{.}4$. The dependence of the estimated values on the distance of the object from the centre of the plate and on the limiting magnitude of the plate is investigated. It appears that faint objects are estimated too faint because the outer parts of the objects do not appear on the plate.

In *Chapter VI* the apparent dimensions of the galaxies are discussed. Faint galaxies are generally measured too small and these effects clearly appear in the present material.

In *Chapter VII* the absolute magnitudes and dimensions of anagalactic objects are investigated. From metagalactic clusters, from individual distance determinations and from double and multiple galaxies a dispersion in the absolute magnitudes of about $1^{M}_{.}0$ is obtained. The dispersion in the quantities log A (A being the absolute major diameter) amounts to about 0.30. By means of double and multiple galaxies a very marked sequence of different types of galaxies is obtained: elliptical objects — spirals of type v — spirals of type s — spirals of types r, u, w — irregular objects. It is shown that it is possible to explain the difference in absolute luminosity between these different types as an absorption effect.

In *Chapter VIII* the spatial arrangement within the nearer Metagalaxy is investigated. It is found that galaxies in general and similarly double and multiple objects form a local metagalactic cloud. It is possible

that the number of objects within this cloud amounts to about 4000. Among the bright galaxies every second forms part of a double or multiple system.

In *Chapter IX* the apparent and absolute types of the galaxies are discussed. The apparent type may depend on the absolute type, the inclination of the object towards the line of sight, the distance of the object and the observational conditions. It is found that the inclination of the spirals towards the line of sight has a random distribution and that the form of the spirals can, on an average, be represented by an oblate spheroid, where the ratio of major and minor axis equals 0.20.

In *Chapter X* some investigations into the existence of dark matter within the galaxies are made. By making certain assumptions regarding the distribution of bright and dark matter in the spirals it is found that the observed total magnitude must depend on the inclination of the object towards the line of sight. These theoretical derivations prove to be in good agreement with observed facts (Cf. Fig. 28). It is further shown that the observed total magnitude of an object will depend on its absolute dimensions, if an expansion or contraction is assumed. Thus, it is possible to explain the difference in absolute luminosity between elliptical galaxies and spirals as an absorption effect. The absorption within the Galaxy is investigated by means of the SHAPLEY-AMES catalogue. As regards the optical thickness of the galactic absorbing layer a rather large value is obtained.

In *Chapter XI* it is shown that the orbital planes of double galaxies may, on an average, be parallel to the metagalactic plane established by LUNDMARK in his investigations of the apparent distribution of the galaxies. The average distance between the components of double galaxies amounts to about 4000 parsecs, while the average distance in space between single galaxies may be nearly a hundred times as large.

In *Chapter XII* it is shown that the formation of double galaxies is very probably due to captures. By starting from certain formulae of statistical mechanics it is possible to explain the relation between the observed density function of double galaxies and the same function of galaxies in general. It is found that the formation of the observed number of double objects should correspond to an interval of time of 4.10^{12} years, which interval is here called the effective age of the metagalactic system. From the radial velocities determined for the components of double systems an average mass of the galaxies of about 10^{11} $\odot$ is obtained.

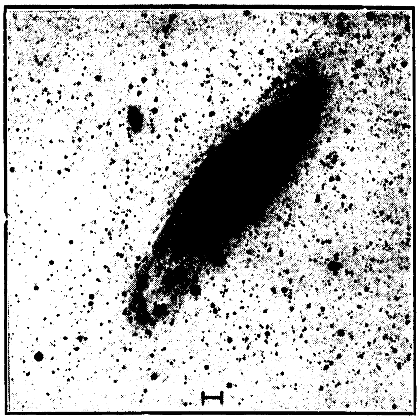
TABLE OF CONTENTS

		Page
Preface		5
Chapter I.	Introductory remarks	7
Chapter II.	Double and multiple galaxies as physical systems	10
Chapter III.	Plate material used for the present investigation	15
Chapter IV.	Examination of the plates	19
Chapter V.	Apparent magnitudes of the galaxies	24
Chapter VI.	Apparent dimensions of the galaxies	36
Chapter VII.	Absolute magnitudes and dimensions of anagalactic objects	39
Chapter VIII.	Spatial arrangement within the nearer Metagalaxy	52
Chapter IX.	Types and forms of the galaxies	64
Chapter X.	The existence of dark matter in the galaxies	71
Chapter XI.	Orientation and absolute dimensions of the orbits of double galaxies	86
Chapter XII.	Formation of double galaxies—Establishment of a metagalactic time-scale	95
Diagram for the determination of metagalactic co-ordinates		104
Equatorial distribution of the plates		105
Appendix I.	List of magnitudes measured in photometer	111
Appendix II.	Catalogue of nuclear magnitudes and dimensions	112
Appendix III.	Catalogue of double and multiple galaxies	114
Notes to the preceding catalogue		155
Summary		157
Plates		161

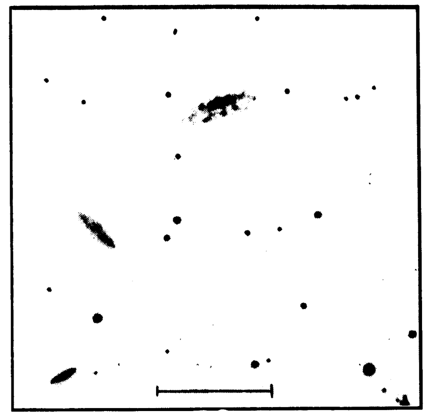
PLATES

The photographs of double and multiple galaxies, reproduced on the accompanying plates are enlargements from the Bruce collection of the Heidelberg Observatory. The enlargements in question have been prepared in the photographic laboratories of the observatories at Heidelberg and Lund. Most of the objects suitable for photographic reproduction have been included, and we have tried to give a representative selection of various types. A careful *retouch*-work has been made in order to bring out in the reproduction as intricate structural details as is possible.

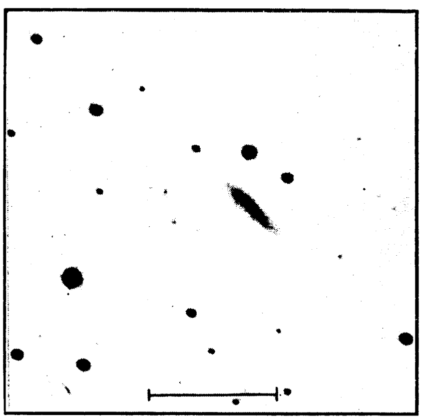
The numbers refer to the numbers in the present catalogue. On the reproductions the right ascension increases from the left side towards the right and the declination increases from the bottom and upwards. In order to show the apparent dimensions of the objects the straight horizontal lines have been drawn. The length of these lines amounts in all cases to five minutes of arc.



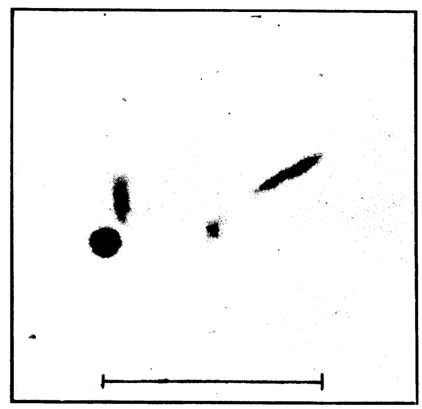
No 17.
(NGC 205, 221, 224)



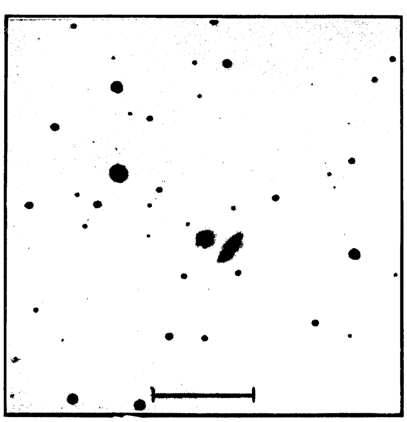
No 46.
(NGC 672)



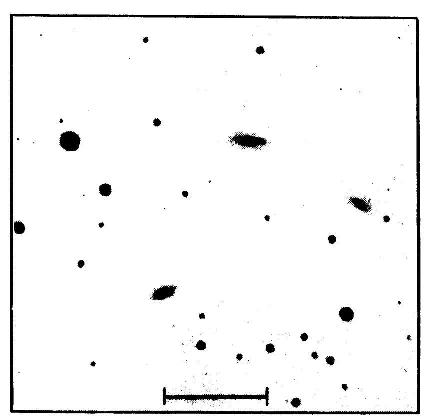
No 111.
(NGC 2770)



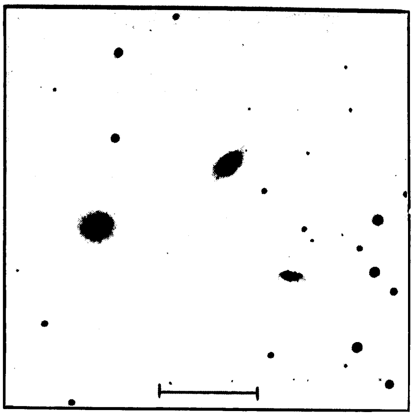
No 124.
(NGC 2814, 20)



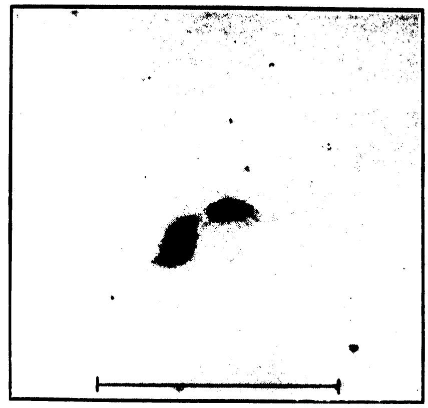
No 130.
(NGC 2871, 72, 73, 75)



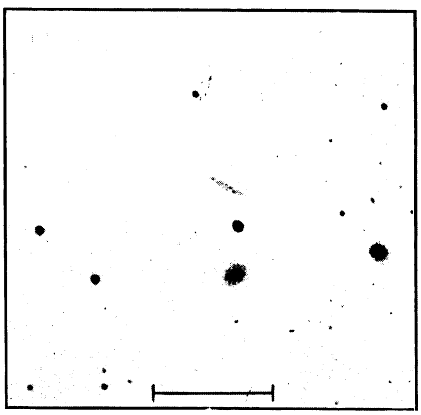
No 147.
(NGC 3016, 19, 20, 24)



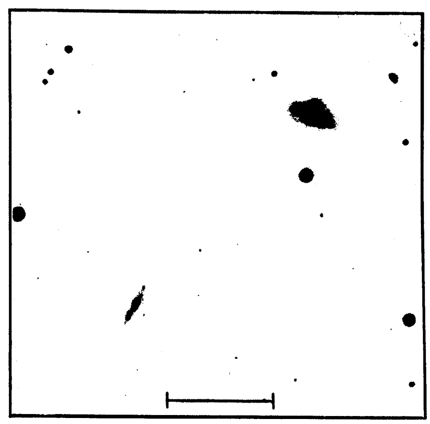
No 212.
(NGC 3379, 84, 89)



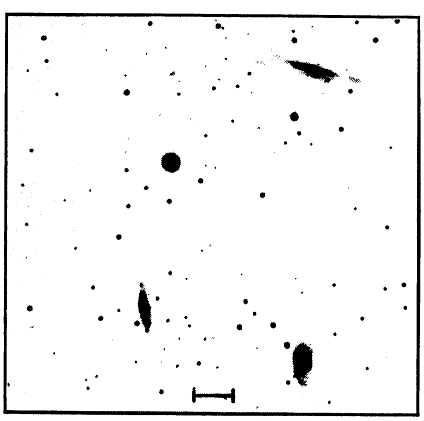
No 215.
(NGC 3395, 96)



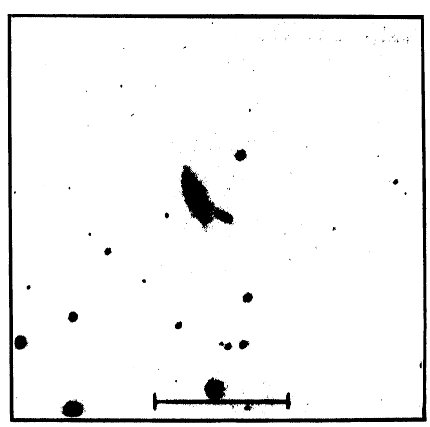
No 221.
(NGC 3454, 55)



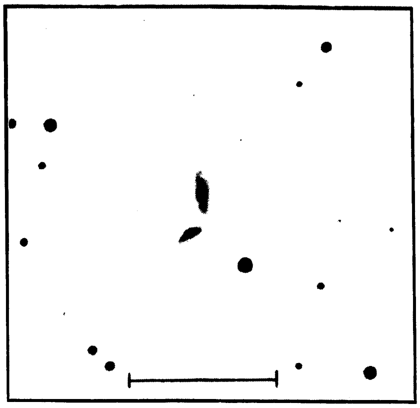
No 224.
(NGC 3501, 07)



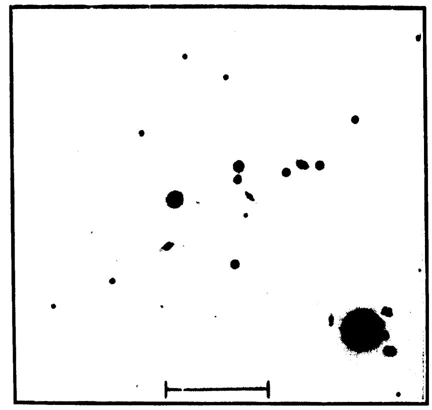
No 246.
(NGC 3623, 27, 28)



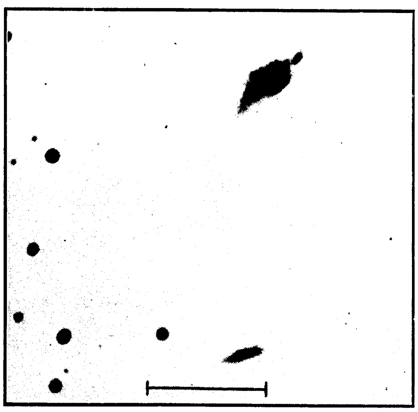
No 270.
(NGC 3769)



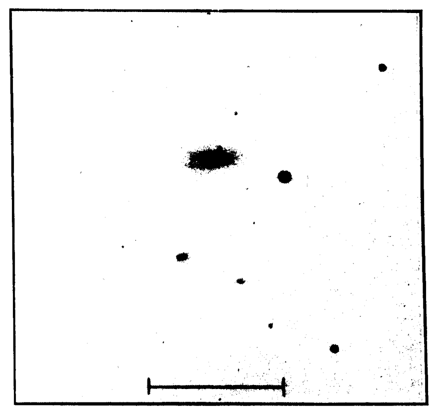
No 272.
(NGC 3786, 88, 93)



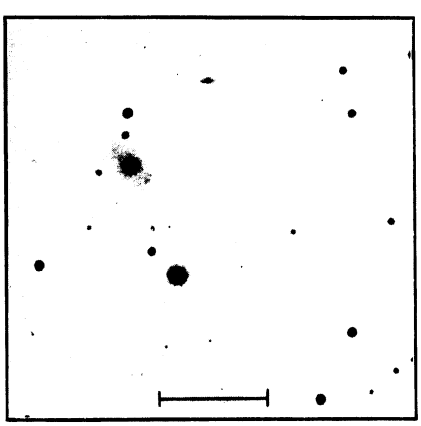
No 308.
(NGC 3987, 89, 93, 97)



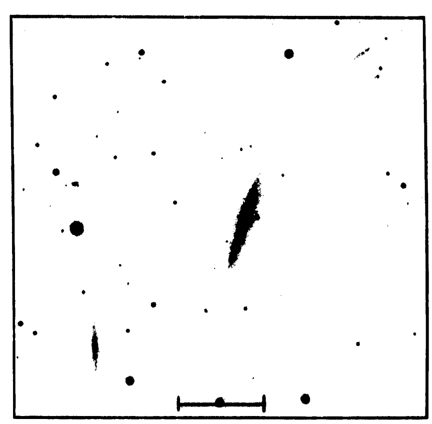
No 326.
(NGC 4085, 88)



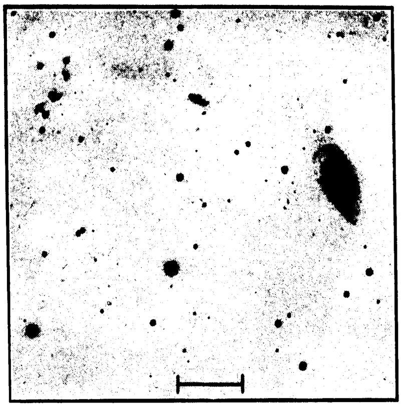
No 335.
(NGC 4121, 25)



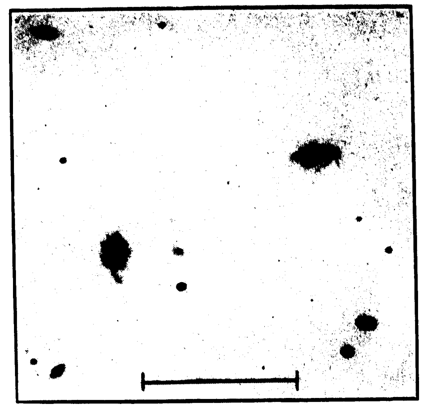
No 345.
(NGC 4151, 56)



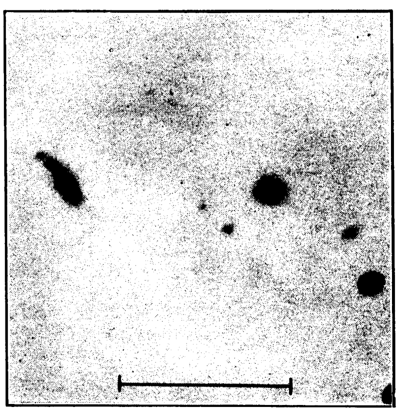
No 353.
(NGC 4206, 16, 22)



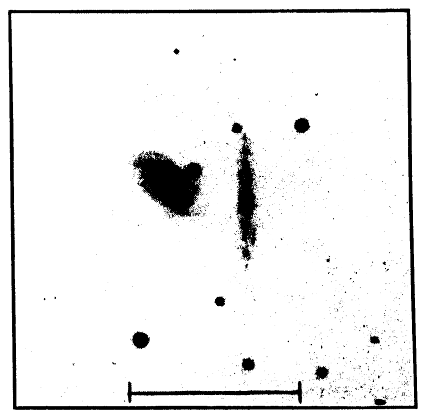
No 363.
(NGC 4248, 58)



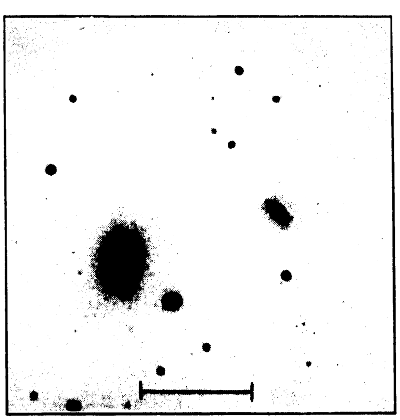
No 368.
(NGC 4268, 70, 73, 77, 81)



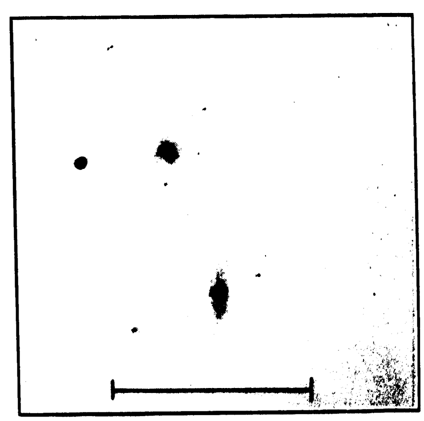
No 376.
(NGC 4294, 99)



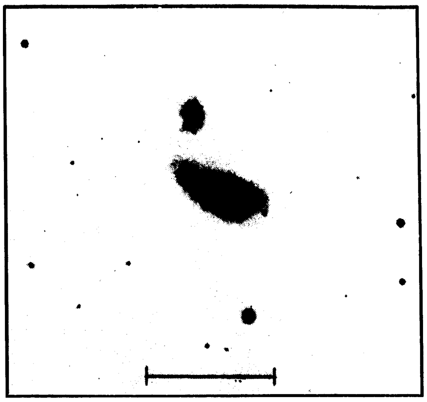
No 377.
(NGC 4298, 4302)



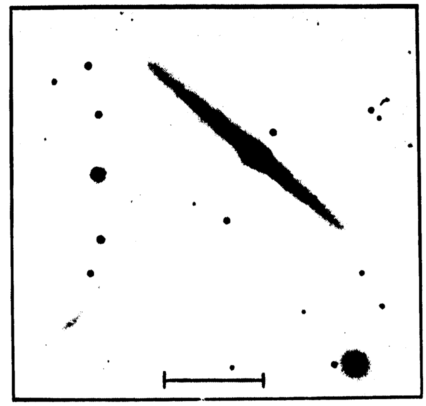
No 397.
(NGC 4382, 94)



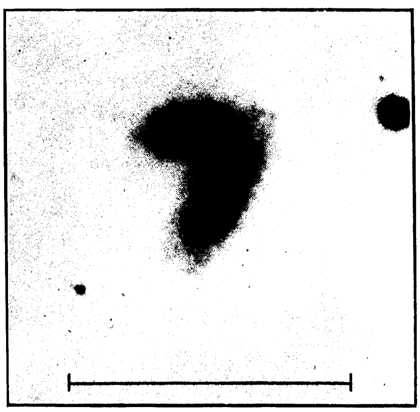
No 411.
(NGC 4458, 61)



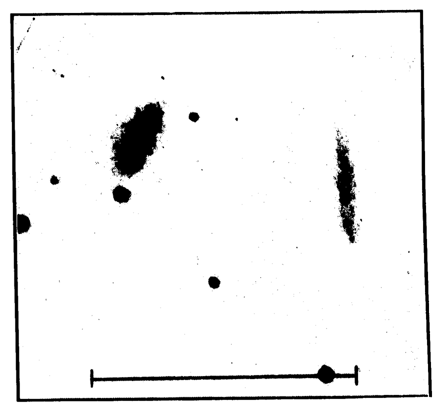
No 414.
(NGC 4485, 90)



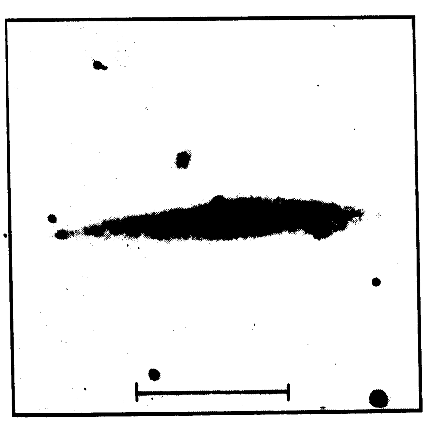
No 426.
(NGC 4565)



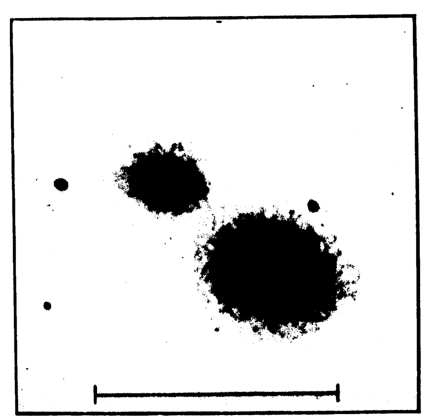
No 427.
(NGC 4567, 68)



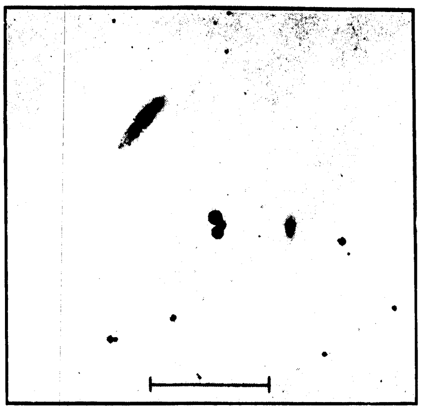
No 436.
(NGC 4606, 07)



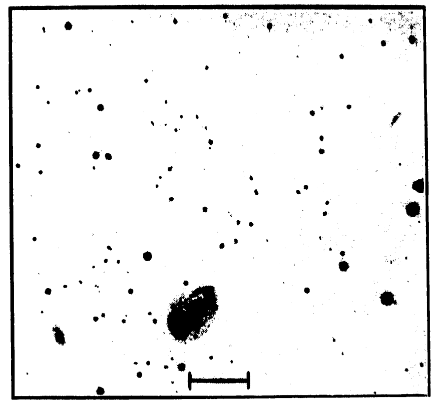
No 442.
(NGC 4627, 31)



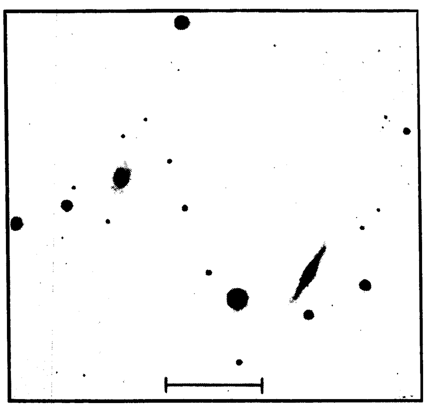
No 448.
(NGC 4647, 49)



No 453.
(NGC 4666, 68)

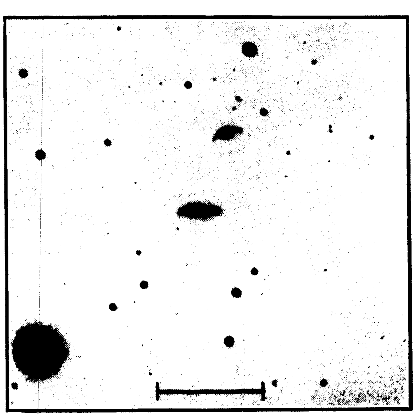


No 468.
(NGC 4712, 25, 47)

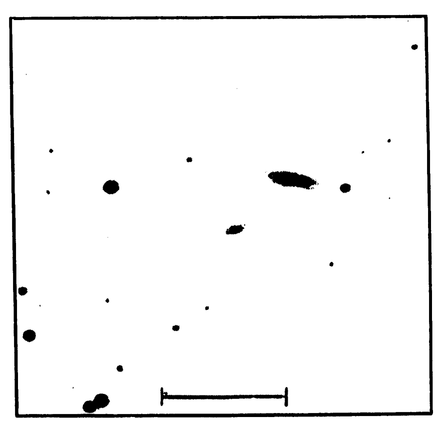


No 478.
(NGC 4754, 62)

No 526.
(NGC 5194, 95)



No 604.
(NGC 5506, 07)



No 805.
(NGC 7537, 41)