tude by lunar observations, and the accuracy of the work has since been fully confirmed.

The observations for longitude were continued through the months of October, November and December, 1874. During this time over 700 meridional transits of the moon, thirteen occultations of stars, and about 540 zenith distances of the moon's upper and lower limbs, combined with those of well-known stars near the moon, were observed. The first reduction of the observations apparently agreed with the result obtained by Professor Lyman, viz., 10 h. 31 m. 15 s., but after returning to Europe and correcting the tabular right ascension by the contemporary observations made at Washington, Greenwich, Paris, Königsburg, Strasburg and the Cape of Good Hope, Captain Tupman increased the result by about twelve seconds of time. His final result by meridional transits of the moon was 10 h. 31 m. 26.0 s.; by zenith distances, 10 h. 31 m. 27.3 s.; by occultations of stars, 10 h. 31 m. 26.9 s.

The result officially communicated to the Hawaiian Government Survey was 10 h. 31 m. 27.2 s., upon which all the maps since then have been based. It is interesting to note that this value agrees to the tenth of a second with the latest determination of the longitude.

Captain Tupman, however, afterwards weighted the above results according to the number of observers employed on each, giving the occultation result the weight 5, the mean of the first two results the weight 4 and M. Fleuriais' result the weight 1, on which conditions the resulting longitude is 10 h. 31 m. 26.3 s. If he had used the value deduced from Fleuriais' work by the *Astronomische Nachrichten*, his final mean would have been 10 h. 31 m. 26.7 s.

In March, 1875, Captain Tupman made an attempt to connect Honolulu with San Francisco by transportation of chronometers. Accordingly twenty chronometers were carried by H. B. M. S. *Reindeer*, Commander C. V. Anson, from Honolulu to the U. S. Navy Yard, Mare Island, and compared with the local time at both stations. Unfortunately the *Reindeer* was blown out of her course by a northerly gale, which lengthened her voyage seven or eight days, and lowered the temperature in the chronometer boxes as much as 15° F. Hence the resulting determination of the longitude of Honolulu, viz., 10 h. 31 m. 33.2 s. ± 3.0 s. w., had very little value.

Again, in August and September, 1884, an attempt was made by the Hawaiian Government Survey with the cooperation of Professor Davidson and Mr. Morse in San Francisco, to determine the longitude of Honolulu by comparing the chronometers on board the O. S. S. Co. steamer *Mariposa*, with the local time at each end. This was done for two round trips, giving a mean result of 10 h. 31 m. 25.8 s.

In view of all the above facts, the Hawaiian government adopted 10 h. 31 m. 26.0 s. as the most probable value, in rating chronometers and furnishing standard time, but not for mapping, until the recent telegraphic determination made by the U. S. Coast and Geodetic Survey.

JOHN F. HAYFORD.

SCIENTIFIC BOOKS.

A Discussion of Variable Stars in the Cluster ω Centauri. By SOLON I. BAILEY. Annals of the Astronomical Observatory of Harvard College, Vol. 38. 4°. Cambridge, Mass. 1902. Pp. 252; 13 plates.

Among the most interesting discoveries in the subject of variable stars during the last decade belongs the finding of an exceptionally large number of variables in certain globular star clusters. The remarkable fact that in many of these systems a not insignificant proportion of all the stars change their light in a quite regular way, and that among the objects of one and the same system the elements of the light changes, especially the length of period, amplitude of variation and form of light-curve, show certain common characteristics, impels one to the acceptance of a common, or at least similar, cause for the changes of light. To be sure, up to the present time, no entirely satisfactory explanation has been found; but precisely this enigmatical character of the phenomenon, which, without doubt, stands in a certain relation to the stage of development of the cluster concerned, increases the interest in itself, and incites to further research on this new subject.

The credit for the discovery of the many variables in the star clusters belongs to Professor Bailey, who is in charge of the Arequipa Station of the Harvard Astronomical Observatory. This credit is much enhanced from the fact that the discoverer has taken upon himself the enormous task of studying the light changes of this increasing number of variables, and of determining their elements. The first fruit of this undertaking is the present volume, which is especially concerned with the cluster *ω Centauri.* The unwearied industry and great skill which the author, and his colaborer, Miss Leland, have shown in the measurement and study of the rich materials of observation, will call forth special acknowledgment and admiration, and one may well congratulate the Harvard Observatory on a publication which commands a prominent place among the valuable works of this institution.

This work bears eloquent witness also to the high importance which the application of photography has won in the development of astronomy at the present time. In general only by photographic means was the solution of the above problems possible. It is scarcely conceivable that in the densely crowded star clusters any such valuable results could have been obtained by direct estimates of brightness or measures in the telescope. Even the identification of the individual objects would present the greatest difficulties, and the precision of the observations would be injured by the troublesome nearness of the other stars, quite aside from the great expenditure of time which the execution of the work would require. On the other hand, a single photographic plate renders possible the determination of the brightness of all the variables in the cluster. By means of réseaux, by the use of enlargements, and the selection of special portions of the photographs, the discovery of the various variables is notably simplified. The danger of confusion can thus be wholly eliminated, and the first comparison of brightness can be checked by another determination, and improved at will by the independent estimates of another observer.

In the discussion of this comprehensive volume one naturally can not enter into all the details; and in what follows only the most important points in regard to the reduction of the observations and the most weighty conclusions are discussed somewhat carefully.

In the first chapter the author gives, first of all, a brief historical sketch in regard to the discovery of variables in the different clusters. The surprising phenomenon was first observed in the two clusters Messier 3 and Messier 5.* In the first, Pickering, in the year 1889, had discovered a star near the center of the cluster, which he at first regarded as a nova, but which later proved to be an ordinary variable. In the second, Packer, in 1890, found by direct observations the variability of two stars, which was verified at the Harvard Observatory by means of photographic plates. Also in the same year Common made the discovery of several variable stars in this cluster. An examination by Mrs. Fleming and Professor Pickering of photographs made at Arequipa led in August, 1893, to the discovery of two variables in *ω Centauri,* and soon after followed the finding of six variables in 47 *Tucanæ* by Professor Bailey and Mrs. Fleming. In the year 1895, after Pickering and Bailey had succeeded in establishing the variability of 26 stars in *ω Centauri,* a systematic investigation of the densest star clusters was undertaken at the Arequipa Observatory, and this search brought to light a surprisingly large number of variables. A summary of all the objects discovered up to 1898 was given by Pickering in the

Harvard circular No. 33. The same is again published on page 2 of the present volume. In the 23 clusters which had been examined, 19,050 stars were compared, and not less than 509 variables were found. The distribution among the different clusters is very different. In two of them no variable was found, in three, only one; in four, only two; and so on. The two clusters Messier 3 and *ω Centauri* show the greatest number of variables. The first has 132 among 900 stars examined, the second, 128 among 3,000 stars compared; in the first case there is one variable in every seven stars, and in the second case one in every twenty-three.

In the present volume only the cluster *ω Centauri* is discussed, for which more material was available than for the others. In regard to number of stars it is the most striking cluster in the sky, and, on account of the brightness of the individual stars, photographs of it can be obtained with shorter exposures than of the other clusters.

To the naked eye it appears as a hazy star of the fourth magnitude. Its form is elliptical. A count of the number of stars, made in the year 1893, gave for the best photographs, 6,389. The diameter was taken as 35′, but a few variables were found somewhat more distant from the center, and as it appeared probable that these really belonged to the system, the borders of the clusters were thus somewhat extended, even to a diameter of 40′. In regard to the magnitudes of the stars, there is no star brighter than 8 magn., less than 100 stars between 8 magn. and 12 magn., and more than 6,000 between 12 magn. and 14½ magn. A large number of the stars which were counted may perhaps not belong to the system, but are only accidentally projected upon it.

The photographic plates which furnished the basis for the investigation were nearly all made with the thirteen-inch Boyden refractor, which for the photographic rays has a focal length of 191.5 inches. On the original plates, therefore, 1 mm. is equivalent to 42.4″. The images of the fainter stars have a mean diameter of 2″. This quantity, however, varies considerably on different plates. For keeping the position of the stars fixed on the plates no finder was used, but an eye-piece, which was inserted near the plate, in the field of the main telescope itself. A few plates were made with the Bruce 24-inch telescope, and with the 11-inch Draper telescope, which are of less focal length than the 13″. The time of the exposure which was necessary at Arequipa, in order to show the faintest variables when at minimum, was for *ω Centauri* 30 minutes. For the fainter clusters notably longer exposures are necessary: in the case of Messier 5 about 50 minutes, for Messier 3 about 100 minutes, and for others even two hours. In most clusters the central portions are so densely crowded with stars that a detailed study is quite impossible.

The method which was pursued by Bailey in the discovery of variables in clusters was substantially as follows: The particular cluster was divided into a number of parts each of which contained about ten stars. These stars were arranged in a so-called sequence according to their brightness, from the brightest to the faintest. This sequence was then memorized and as large a number as possible of original plates (if possible, at least ten) was tested and compared as to how and to what extent the particular sequence was changed. In this way the whole cluster was examined piece by piece. This labor is extremely tiresome. It demands a rigorous examination of numberless plates under a microscope of considerable power, in order to separate the thickly crowded portions, and extraordinary care not to confuse the different stars with one another. In all cases where the variation is small, or where the period is about twenty-four hours or a fraction thereof, the detection of the variability was difficult. On this account many variables may have remained undiscovered. Especially difficult is found the examination of the central portion, where the star images coalesce, and precise comparisons are impossible. On this account it happens that, especially in the densest clusters, relatively few variables are found near the center. The discovery is also rendered difficult from the fact that the duration of the maximum phase is only a comparatively short part of the whole period (sometimes only one fifth). For, since in the remaining time no noticeable changes occur, the variability is made apparent, in many cases, only by the examination of very many plates.

In order to determine the brightness of the variables in the cluster *ω Centauri,* in the first place, a system of 38 comparison stars was selected, whose brightness ranged between magnitude 9.0 and 14.6, and which lie either within the cluster itself or at least in its immediate neighborhood, in any case not farther from the center than the most distant variables. The mean difference in brightness between two successive sequence stars is about 0.15; for the brighter stars the interval is in general larger, while the fainter stars lie closer together. The method which was employed in the determination of the magnitudes of the comparison stars is that which Pickering has described in Volume 26, Part II. A comparison scale was first made in which by the use of a selected star a line of images was obtained on the same plate by clockwork, and also with exposures of different lengths. The star was first exposed for 810 seconds, then the telescope was moved by a slight amount in right ascension and the star again exposed, this time for 270 seconds. Four other images with exposures of 90, 30, 10, and 3 seconds serve to complete the scale. On the supposition that the photographic effect is proportional to the time of exposure, any two successive images of the six star impression on the plate would differ by about 1.2 magnitudes. That portion of the plate which contained the six images was cut out and, protected by a glass cover, was fastened in a small frame, and could be placed on any other plate. By the help of such a comparison scale the determination of the brightness of the 38 selected comparison stars was made by placing first the brightest of them between the two images of the scale, which seemed to stand next to it in intensity, by which means the difference of the interval was estimated to tenths. The same process was then performed for the second star, and in this way the difference in brightness between the two comparisons was determined in magnitudes. In just the same way the second comparison star was joined to the third, the third to the fourth, and so on, each one with the one following it in brightness. The whole work was not, moreover, carried out by the use of a single scale, but in all four different scales were used, and, moreover, each pair of stars was measured on several plates, for the most part on four. All the measures were independently made by Mrs. Fleming as well as by Miss Leland. In order to arrange all the brightnesses in magnitude, values were taken for the first three, which accorded with the photometric system of the Harvard Observatory, and the magnitudes of the remaining 35 stars were then obtained by the use of the differences found for the single pairs of stars, after the application of an unimportant correction, which was made on the assumption that the first three stars belonged to a different spectrum type from the others. The final magnitudes of the 38 comparison stars are given on page nine, in the last column of Table III.

It is obvious without extended discussion that the whole method of the determination of the brightness of the comparison stars does not permit the attainment of the highest degree of accuracy. Aside from the fact that the ratio between the times of exposure and the brightness of the images is not rigidly exact, as a result of which the different images do not differ from each other by precisely 1.2 magnitudes, the comparisons between two images of the scale is a somewhat uncertain operation. It is, therefore, not to be wondered at that the various columns of determinations show in part very strong systematic differences from one another, not only between the two observers, but also with the same observer on different plates, and especially with the use of different scales. Apparently the appearance of the star images played an important rôle. Also the different scales, on account of dissimilar atmospheric conditions, may give a noticeably different result. Perhaps it would have been better for the precision of the comparisons to have made the steps between successive images of the scale less than 1.2 magnitudes, and yet more desirable would it have been for the formation of the scale to have made use, not of change in the time of exposure, but rather of the cutting down of the objective (which Pickering has already made use of on another occasion), not, however, through the use of circular caps, but by sectors, or to have made use of polarization methods for decreasing the light for the formation of the scale. It is thus only indicated by what method it may be possible to obtain greater accuracy. The Pickering method for the determination of photographic stellar magnitudes in and for itself in the present instance the reviewer regards as thoroughly commendable. It is without doubt preferable to various methods, especially to that of measuring the diameters of the stellar images.

In the second and third chapters are given the measurements of brightness of the variables in the cluster *ω Centauri*. The photographic plates employed for this purpose cover the time from May 15, 1892, to August 16, 1898. In all 128 variables were measured. At first 132 objects were selected as variable, and were designated with the numbers 1–132. But later the four stars Nos. 28, 31, 37 and 93, which appeared not sufficiently sure, were rejected. The extremely wearisome comparisons, which made the greatest demands on the endurance and skill of the observer, were made for the most part by Miss Leland. A smaller number of plates were measured by the author himself, especially for the purpose of determining the provisional periods. The measurements were made in such a manner that the variable was estimated between two comparison stars, one of which was brighter, the other fainter than the variable. The difference in brightness was estimated in grades. The method is thus the same as the well-known Argelander method of comparison by grades, which has proved so effective in direct observations of brightness in the sky. The value of a grade was not far from 0.1 magnitude. Generally only two comparisons were made. Only when the variable appeared equal to one of the comparison stars, two other comparisons were made, one with the fainter and the other with the brighter comparison star. All the observations for each of the 128 variables are given in tabular form on pages 17–124 of the volume. In all there are 15,000 determinations of brightness, and since on the average each determination consists of two comparisons, there are about 30,000 comparisons for bringing the results into form. In the tables are give the individual comparisons in grades, and also the derived magnitudes of the variables, as well as the residuals of the single estimates from the mean, and also the phase, that is, the time between the mean time of the exposure and the preceding computed maximum, and finally the residuals of the observed magnitudes from the mean light curve found for the star in question. When this residual was 0.40 or more the measurement was repeated, and in case the new measurement brought no sure conclusion it was checked still a second or third time, eventually also by another observer.

Most interesting is the fourth chapter, which contains the results of all the observations. In the tabulated grouping of the elements of the light changes are found only 95 examples out of the 128 variables. For 13 variables no periods at all were found, and for 20 objects the results obtained were so doubtful that they are not given in the table itself, but are mentioned only in the remarks which follow the table. In regard to the method of determining the periods, the epochs, the extremes of brightness and the mean curves, no description at all is given in this chapter, and one only finds in the whole volume some brief notes on page 232. The method of computation is, however, so well known in such cases that a detailed description would perhaps be superfluous. The plates made on the successive days, May 3 and May 4, 1898, eight plates on the first, and six on the second date, which cover periods of seven and five hours, respectively, give for nearly all the variables a sufficient indication of the character of the light changes, and render possible in most cases the finding of an approximate value of the period. An improvement on this approximate period can generally be obtained without great difficulty by the use of several groups of plates which in greater number were made on closely associated dates, as, for example, those of 1895, from May 31 to June 30, and of 1897, May 13 to June 17. So by degrees the period can be continually improved, until eventually a use of the widely separated observations is possible, with the use provisionally of a derived light curve, which then gives the final sure value of the period. When this value is once found, and an initial epoch determined, one can at length for each individual measure find the difference in time from the preceding maximum or minimum, arrange the magnitudes according to these differences, unite the several adjacent ones to means and by the help of these normal magnitudes construct graphically the mean light curve.

The light curves obtained by the author for the reasonably sure variables are reproduced in Plates II. to VII. at the end of the volume, and give a glimpse at the peculiarities of the light changes for the individual objects. The scale of these curves is chosen somewhat small. By a somewhat larger representation clearness would have been gained. The residuals of the individual observations from these curves have already been given in the table of observations in Chapter III. Also in Chapter IV., in a special table approximate values are found for the duration of the maximum and the minimum phases, as well as for the increase and the decrease of the light, and for the rate of increase and decrease in magnitudes per hour, and finally the mean residual, that is, the mean of the residuals from the curves without regard to sign. The last value varies between 0.07 and 0.25 magnitude, the mean being 0.128.

In order to obtain an idea as to the certainty with which the elements of the light changes may be derived from the available materials, the writer selected at random several stars, and without knowing beforehand the results obtained by the author, independently determined the elements. The results agreed closely in all cases with those in the present volume. One may, therefore, put full confidence in them. One who has himself carried out such computations and knows thereby how many attempts and approximations must be made before a satisfactory arrangement of all the materials of observation is reached, will at best be able to appreciate what enormous labor is involved in his table of elements.

A glance over this table shows that for nearly all the stars the length of period is only a fractional part of a day. Only 5 stars make an exception, which have periods of 1.35, 14.75, 29.34, 297 and 484 days, respectively. For 26 stars the periods are less than 10 hours; No. 19 has the shortest period, 7.2 hours.

The range of light variation is noticeably different for the different variables. The difference between the maximum and minimum brightness varies between 0.45 and 4.58 magnitudes, and in general also, as with variables not situated in clusters, the longer the period the greater is the amplitude. A range of less than 1 magnitude for the determined difference is found in the case of 56 stars. Where the amplitude is less than 0.6, or perhaps 0.5 magnitude, the determination of the light curve is naturally somewhat uncertain, and one must look upon these objects with some doubt. It ought not to be overlooked, however, that frequently the real changes in brightness will be somewhat greater than those given in the table, since for many stars the brightness changes with great rapidity at maximum, and on this account the photographs, especially when the exposure is very long, do not record the true maximum brightness, but one something less. Especially is the relatively long duration of the exposure, which for these swiftly changing objects may be a considerable part of the whole period, a provoking hindrance to the determination of the genuine light phenomena.

Of great interest is the study of the light curves. These are by no means alike for all the variables in the cluster. They are, however, always of certain types. The author has distinguished three different classes of light curves. The first class, in which 37 stars may be reckoned, is characterized by the fact that the star remains at minimum during half of the period, perhaps with very slight fluctuations. Moreover, the light curve is uniform, the increase of light very rapid and the decrease noticeably slower. The amplitude of the light variations attains in general 1 magnitude and a little more, and the periods lie between 12 and 15 hours. The second class embraces the relatively small number of 19 stars. They differ from the first only in the fact that the long duration of minimum is absent, and that in general the increase is much slower. The decrease continues with ever-lessening rapidity till the beginning of the following increase. In many cases on the descending arm of the curve a 'stillstand' appears to exist. The whole range in brightness is generally less than 1 magnitude, and the periods range between fifteen and twenty hours. In the third class are counted about 34 stars. The peculiarities of these stars are that the durations of increase and decrease are not very different; also, the increase is in general somewhat shorter than the decrease, but in some cases they are equal, and it even happens that the opposite is true. The amplitude of the variation is for the most part not much greater than 0.5 magnitude, and the periods are between eight and ten hours.

As one sees, the three classes are not separated very widely from one another; especially, the second is only a little different from the first, and there are transitions from one to the other, but as a whole the differences of the changes in light, especially between the extreme members of the classes *a* and *c*, are marked. The circumstances by which the variations of light take place among the different members of the cluster, whether due to occultation, rotation or to other causes, must in any case be very different.

In regard to many peculiarities of the light curves of the different stars the remarks at the end of Chapter IV. give information. Notes are also found in regard to the doubtful objects for which no elements are given in the table.

The fifth chapter is devoted to a special study of four variables of the cluster. The author aimed to prove by this special investigation whether noticeably better results could be obtained if the number of comparisons of brightness was increased, and especially if comparison stars, greater in number, and in the immediate vicinity of the variable, were employed. For each of the selected variables a list of comparison stars was chosen, no one of which was more than 2′ distant from it. The variable was then compared with as many of these as possible, and the difference in brightness determined each time in grades. All the new measures were made independently by the author and by Miss Leland. The magnitudes of the new comparison stars were determined on four plates by joining them to the previously chosen fundamental stars, and also in this case by both observers independently.

In addition to these direct determinations, the brightness of the new comparison stars was also found by an indirect method, by which, as is done in visual comparisons of variable stars, by the comparison of the variables with the comparison stars the differences in brightness of these stars in grades were derived; and then by the union of the various differences a scale of grades was formed. The union of the values of the comparison stars, obtained in these two different ways, furnished at length definite values for them, from which the results of both observers were united to form mean values. The differences between the two observers are in general small, although there are indications of systematic differences. The magnitudes of the four variables were derived from the observations simply by the Argelander method, by the help of the scale of grades, first in grades and then in magnitudes.

The result of this somewhat complicated and prolix research was, in the case of three of the selected variables, a complete accordance with the previously derived elements, in which, naturally, as might be expected from the large number of the measures and especially from the greater nearness of the comparison stars, the residuals of the single observations from the light curve resulted somewhat smaller. The case was different with the fourth star, which of all the variables in the cluster has the smallest range of brightness. For this variable, at first, a proof of 0.275 days had been derived, which, indeed, satisfied a large part of the observations. The new investigation gave a distinctly different value, 0.37987, and, moreover, made it probable that the period is not constant, but, within the time which the observations cover, varies between 0.3796 and 0.3801 day. At least with this assumption a noticeably better representation is obtained. Since in the case of this star the changes of brightness are not much greater than the unavoidable errors of measurement, it is not very surprising that the new determination, made with other comparison stars, has led to an entirely different result. The limit is here reached where the precision of the method employed in the determination of the brightness fails, and it appears more than doubtful whether the new result deserves more confidence than the old. It would, indeed, be wiser, where the light fluctuations are so small, not to attempt the determination of the period.

Under the heading, 'Miscellaneous Results,' in the last chapter is discussed a number of questions which are concerned with the precision of the measurements, the distribution of the variables in the cluster, the light curves, etc. Some of these investigations deserve to be taken up briefly.

The distance of the stars from the center of the cluster has a marked effect on the precision of the comparisons. The nearer the variables are to the center, and the more, on this account, the images run together on the photograph, so much more difficult also are the comparisons of brightness. Within a distance of 5′ from the center of the cluster are found 46 variables; for 16 of these, on account of the difficulty of the observations, no period at all could be found, and for the remaining 30 the mean deviation from the corresponding curves is for the whole ± 0.159 magnitude. On the other hand, for 35 variables whose distance from the center lies between 5′ and 10′, the corresponding mean deviation is only ± 0.114 magnitude, and for 30 stars, whose distance is greater than 10′, it is only ± 0.113 magnitude.

When the deviations of the individual observations from the mean light curve attained a value of 0.40 magnitude and greater, the observations were repeated. In certain cases it happened that errors of measurement existed, which were due to errors of identification, probably. Very many large residuals are found, however, in all 287 cases, which are verified by the measurements of the revision. These residuals have their cause, perhaps, in real irregularities of the light curve, perhaps also in defects on the photographic plates. The general quality of the plates has naturally an influence on the precision of the results, and in general the sharpest and best plates give the smallest residuals; while with very experienced observers and with the extremest care the gain is not so important as one might expect beforehand.

Since it is known that in case of comparisons of brightness of two stars in the sky their relative position plays an important rôle, it was of importance to investigate whether in the determinations on photographs the relative position of the two star images might exercise a marked effect. To find the answer to this question one of the variables was compared on several plates with a number of comparison stars, while, by turning the plate under the microscope, the comparison star was placed first on the right and then on the left of the variable, and each time the difference in brightness was estimated in grades. It was thus shown that the influence of the change in position, if it exists at all, is so small that it can be completely ignored.

Of special interest is the investigation concerning the distribution of the variables in the cluster. The author has for this purpose divided the variables into twelve groups, of which the first includes all to a distance of 2′ from the center, the second those whose distance lies between 2′ and 4′, etc. For each group the number of variables per square minute was computed. The following table contains the results for the different groups. Next to them are given the corresponding numbers for the distribution of all the stars of the cluster, which were taken from a previous publication in the *Harvard Annals*. The numbers in the last column, which give how many variables are found in the different groups for each 100 stars, are not noticeably different from one another. It follows, therefore, that in the whole cluster, in a definite area the proportion of variables is about constant, and that in no place occurs a very large number.

Variables.			All Stars.		
Mean Distance of Group.	Number.	Number per Square Minute.	Mean Distance of Group.	Number per Square Minute.	Per Cent.
1′	7	0.556	1.1′	42.8	1.3
3	26	0.690	3.1	32.3	2.1
5	21	0.334	5.2	19.7	1.7
7	17	0.193	7.1	12.3	1.6
9	17	0.150	9.1	6.5	2.3
11	16	0.116	11.1	3.9	3.0
13	9	0.055	13.3	2.8	2.0
15	6	0.032	15.0	2.1	1.5
17	4	0.019	16.7	1.6	1.2
19	4	0.017	18.4	1.1	1.5
21	0	0.000	20.2	0.7	—
23	1	0.003	—	—	—

In regard to the three classes into which the variables were divided, the mean distances of the stars from the center of the cluster of the different groups are 7.7′, 8.1′ and 8.9′. It appears, therefore, that no marked difference is indicated in the distribution, on account of the character of the light changes. The mean maximum brightnesses of the three classes are 12.99, 13.10 and 13.33 magnitudes, and the minimum, 14.11, 13.97 and 13.89 magnitudes. The amplitudes are thus distinctly different. The mean lengths of the periods are 0.58617, 0.75153 and 0.39463.

It is of great value that for the 95 variables whose periods are determined the light curves are given not only graphically in Plates II. to VII., but that the coordinates of the light-curves are given in detail on pages 210 to 222, and in such a way that for each star the period is divided into 24 equal parts, and for each part the corresponding brightness is given. There are also given typical light tables for the three classes, by taking from each class five especially characteristic examples, and taking the mean values for these.

The chapter closes with some remarks concerning the possible causes of the light changes of so many stars in one and the same cluster. The author hesitates to accept widely current hypotheses, and to test them from the available materials of observation. He concludes only that from the complete uniformity of the periods, which is shown in ω *Centauri* for a long time, the variability must be associated with some regularly returning phenomenon, either through regular eclipses by bodies which are in revolution about each other in definite paths, or through the rotation of unequally illuminated or irregularly shaped bodies. The explanation by means of occultations, as with Algol stars, involves great difficulties. For, if one would assume, as at first sight might appear plausible, that the planes of the orbits of the different double star systems of the cluster lie about parallel to each other, and that on that account the light-curves of the different systems should show a certain similarity, the form of the light-curves, nevertheless, speaks against the eclipse theory. In ω *Centauri* are found three different types of light-curves, but in other clusters investigated by the author the first type with the long duration of minimum is so much more common that we may regard this as the characteristic type of variables in star clusters. This type of light-curve is, however, entirely distinct from the Algol type. The eclipse would have to last for a considerable part of the period, and this would hardly be consistent with any orbit system. Also the assumption of an axial rotation with unequally luminous surfaces seems not very probable, when one considers that such a large number of similar variables is concerned. The whole phenomenon is at this time somewhat enigmatical, and we must await the investigation of the occurrences in other clusters before further conclusions are permissible.

In an appendix to the volume are given preparatory studies toward the measurements of all those clusters in which more than one variable has been found. There are given the positions of those objects selected to serve as fundamental stars, and the comparison stars chosen for the comparisons of brightness, and the stars already known to be variable, all the positions being given in seconds of arc, and determined from the center of the particular cluster. In Plates VIII. to XII. are given reproductions from the original plates of fourteen clusters, on which the variables and comparison stars are marked. On these reproductions 1 mm. equals about 10″. Especially interesting are the repeated enlargements of certain portions of some clusters, which are given in the last plate of the volume. These show clearly the change in appearance of the variables on different plates, and give an idea of the certainty with which the comparison with adjacent stars can be made.

From the materials given in the appendix one sees that there still remains a very great amount of labor to be done. We hope that the author will be able to carry out his plan, and to give as clear and exhaustive a discussion of the light changes in the other star clusters, as he has done in the present volume.*

G. Müller.

SCIENTIFIC JOURNALS AND ARTICLES.

The contents of the *American Journal of Science* for November are as follows: 'Mineralogical Notes,' by C. H. Warren; 'Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum' (with plates XVI. and XVII.), by J. L. Wortman; '*Tridenum Virginicum* (L.) Rafin,' a morphological and anatomical study (with figures in the text), by T. Holm; 'Ephemeral Lakes in Arid Regions,' by C. R. Keyes; 'Note on the Identity of Palacheite and Botryogen,' by A. S. Eakle; 'Colloidal Gold: Absorption Phenomena and Allotropy,' by J. C. Blake.

SOCIETIES AND ACADEMIES.

AMERICAN CHEMICAL SOCIETY. NEW YORK SECTION.

The first meeting of the season was held at the Chemists' Club, No. 108 West 55th Street, on Friday evening, October 9.

* Translated from *Vierteljahrsschrift der Astron. Gesellschaft*, 38. Jahrgang, Erstes Heft, 1903.

After a few remarks by the chairman, Professor Miller, outlining the policy of the section for the ensuing year, and requesting members to present papers in abstract as far as possible, so as to have more time for discussion, the following papers were read:

The Volumetric Determination of Zinc: W. J. Waring.

This paper was read by Mr. Stone and discussed by Messrs. Brenneman, Stone, Miller and Danziger. It called attention to the widely differing results which are obtained by different chemists in the determination of zinc by the ferrocyanide titration method, and pointed out the necessity of uniformity in the conditions of standardizing and titrating, so that the composition of the precipitate shall be uniform. The occurrence of cadmium in the ores of the Joplin District in amounts varying from 0.1 to 2 per cent. was shown to interfere with the accuracy of the method, so that the cadmium should be removed, best by aluminum foil, before the titration. A new cadmium ammonium ferrocyanide was also described.

The Reduction of Lead from Litharge in Preliminary Assays and the Advantages of an Oxide Slag: E. H. Miller, E. J. Hall and M. J. Falk.

Professor Miller gave an abstract of an article which will soon appear in the *Transactions* of the American Institute of Mining Engineers. It was shown in making preliminary assays to determine the reducing power of an ore that, not only did the amount of lead reduced vary with the acid or basic character of the slag, but that the amount of lead oxidized by niter varied with the reducing agent present, even under uniform conditions as to charge, time and temperature. This was not anticipated, and explains the difficulty in the old preliminary assays.

The best results were obtained by using a charge of ore 3 grams, litharge 50 grams, soda 10 grams, no silica, no borax glass and no salt cover. With this charge and a temperature of over 900° C. the sulphur is completely oxidized to sulphate and forms an upper layer in the slag (Na_2CO_3 and Na_2SO_4), while the lower layer consists of a readily fusible mixture of oxide of lead, of iron, etc.