

A Classification of Globular Clusters. — Notwithstanding a general similarity of globular clusters in size, form, content, and absolute brightness, some deviations from the average have been frequently noted in the course of past studies. Clusters such as Messier 19 and ω Centauri are conspicuously elongated; Messier 62 is strikingly non-symmetrical; N.G.C. 4147 is deficient in giant stars; and for nearly one third of the globular systems the brighter stars are so loosely arranged that from an ordinary examination, photographic or visual, we might place them with the galactic clusters and exclude them from their true class.

It was proposed some years ago (Mt. W. Contr. 161, 7, 1918) that N.G.C. 7492 might be taken as a type of a rather distinct subdivision, called the loose globular cluster, which would include among others Messier 4, Messier 72, N.G.C. 288, N.G.C. 3201, N.G.C. 5466, and I.C. 4499. That such systems are of the globular class is made certain by long exposure photographs which bring out the thousands of faint stars that are never present in even the richest of galactic clusters, and their identity is also often indicated by their high galactic latitude and by the discovery in several of them (M 4, 72, N.G.C. 3201) of many cluster type Cepheid variables.

A detailed examination of the globular clusters on good Bruce photographs, which are available in the Harvard collection for practically all the ninety-five systems now listed as globular, shows that many intermediate forms exist between the loosest and most concentrated clusters. Instead of classing the clusters, therefore, in the two or three broad and obvious categories, we arrange them in finer subdivisions, in a series of grades on the basis of central concentration.

Detailed star counts may or may not agree with our classification. The numerical concentration will certainly depend upon the magnitudes of the stars included in the counts, and because of crowding and Eberhard effect will always be of doubtful value except for the brightest stars. On the other hand, our estimated concentrations are slightly influenced by the quality of the plates and the total brightness and angular diameters of the clusters; but we believe that these factors are not of such consequence that they detract appreciably from the value of the classification.

For the accompanying tabulation, all of the ninety five globular clusters have been classified twice by two observers. Class I represents the highest concentration toward the center, and Class XII the least.

Asterisks with the N.G.C. numbers mark the clusters (usually bright) which have been chosen as representative of their respective classes. The objects marked with daggers are the eight whose identification as globular clusters is yet considered questionable (H.B. 848). The uncertainty of their classification and that of a few others is indicated by colons.

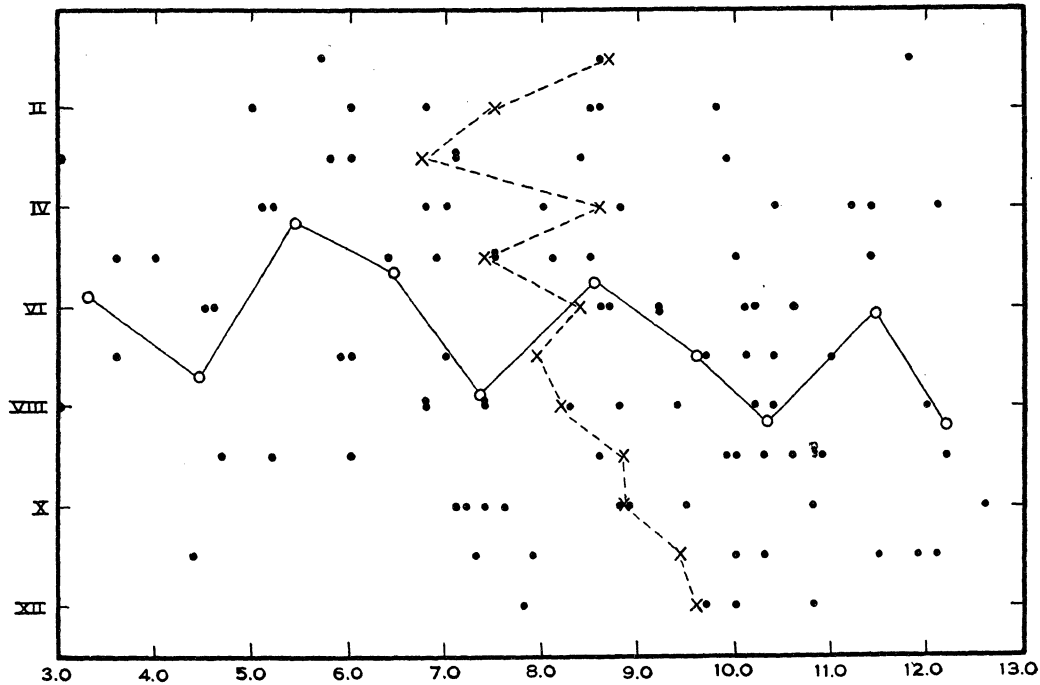
For the following clusters, superposed stars have interfered somewhat with

CLASSIFICATION OF GLOBULAR CLUSTERS

N.G.C.	Messier	Class	N.G.C.	Messier	Class	N.G.C.	Messier	Class
*104		III	5986		VII	6453		IV
*288		X	6093	80	II	6496		XII
362		III	6101		X	6517		IV
1261		II	6121	4	IX	†6535		XI:
†1651		VIII:	6139		II	†6539		X:
1783		VII	6144		XI	6541		III
1806		VI	6171		X	6553		XI
1831		V	6205	13	V	6569		VIII
1846		VIII	*6218		IX	6584		VIII
1851		II	6229		VII:	6624		VI
*1866		IV	6235		X	6626	28	IV
1904	79	V	6254	10	VII	6637	69	V
1978		VI	6266	62	IV	6638		VI
2298		VI	6273	19	VIII	6652		VI:
2419		VII	6284		IX:	*6656	22	VII
*2808		I	6287		VII	6681	70	V
3201		X	6293		IV	†6712		IX:
4147		IX	6304		VI	6715	54	III
4372		XII	6316		III	6723		VII
4590	68	X	6333	9	VIII	*6752		VI
4833		VIII	6341	92	IV	†6760		IX:
5024	53	V	6342		IV	6779	56	X
5139		VIII	†6352		XI:	*6809	55	XI
5272	3	VI	6356		II	6864	75	I
5286		V	6362		X	6934		VIII
5466		XII	6366		XI	6981	72	IX
5634		IV	6388		III	7006		I
I.C. 4499		XI	6397		IX	7078	15	IV
5897		XI	*6402	14	VIII	*7089	2	II
5904	5	V	†6426		IX:	*7099	30	V
5927		VIII	6440		V	*7492		XII
†5946		IX:	6441		III			

the assignment of a class: N.G.C. 4147, 6284, 6453, 6553, 6569, 6624. In some of these cases it is difficult on the scale of the photographs used in the classification to distinguish between a high central concentration and a superposed star.

The bright cluster ω Centauri is peculiar in what appears to be a remarkable uniformity in the magnitudes of the brightest stars. The following clusters somewhat resemble ω Centauri in this respect: N.G.C. 5272, 5927, 6273, 6656. These



The scatter diagram of classes of globular clusters (ordinates) and integrated photographic magnitudes. Circles and crosses indicate means.

clusters also resemble each other in their moderate concentration (Classes VI-VIII), and two of them, ω Centauri and Messier 3, are the richest of all in variables.

It should be noted, however, that the clusters rich in variable stars are scattered throughout all classes. A satisfactory statistical consideration of class with respect to frequency of variables must await the completion a few years hence of the survey for variability.

The present classification of globular clusters is really a study of apparent concentration. It is of interest, therefore, to examine the relation of class to in-

tegrated photographic magnitude as given by us in Harvard Bulletin 848. The accompanying figure shows the distribution of magnitude among the classes.

The mean magnitude for each class and the number of clusters are as follows:

Class	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Magnitude	8.70	7.45	6.76	8.60	7.39	8.41	7.96	8.21	8.84	8.88	9.42	9.58
Number	3	6	7	10	10	9	8	11	10	9	8	4

The mean magnitudes are plotted as crosses in the diagram; and the average class for each interval of one magnitude is plotted as a circle.

For Classes I to VI the mean galactic longitude is 265° , and the mean galactic latitude is $\pm 23^\circ$; for Classes VII to XII the means are 263° and $\pm 21^\circ$. The mean latitude with regard to sign is $-3^\circ.4$ for the more concentrated clusters (Classes I to VI), and is $+3^\circ.0$ for the less concentrated. These computations on galactic position do not include the five globular clusters that appear definitely to belong to the Large Magellanic Cloud.

Summary. The globular clusters are placed in twelve approximately equal classes on the basis of apparent concentration of stars to the center. There are only a few peculiarities not covered by the simple classification. The ellipticity of clusters is not involved in the classes, it being, in general, very slight and apparently more a matter of the present orientation than a structural characteristic; moreover, new measures of cluster forms will be published in the near future. The various classes are widely spread in apparent brightness and diameter and do not depend on the integrated magnitude, except for a slight tendency of the least condensed clusters in the mean to be faint. In apparent galactic distribution the classes are thoroughly mixed.

The classes of globular clusters are probably an indication of developmental age. They should prove useful in studies of diameter, variable stars, luminosity curves, and the deeper problems of the origin and life history of stellar clusters.

Harlow Shapley
Helen B. Sawyer