

of large spots and with concomitant long-duration Type IV radiation at radio frequencies. For other important  $H\alpha$  flares, especially those far from spots (e.g., 1959 July 14<sup>d</sup>14<sup>h</sup>45<sup>m</sup>), excellent  $\lambda$ -sweep records have been secured, but give no evidence for the occurrence of "loops." Therefore, according to our records to date, the complex systems of loop-type prominences represent an even rarer solar phenomenon than do "important"  $H\alpha$  flares.

<sup>1</sup> McMath, R. R., O. C. Mohler, and H. W. Dodson, these PROCEEDINGS, 46, 165 (1960).

<sup>2</sup> McMath, R. R., and E. Pettit, *Astrophys. J.*, 85, 279 (1937) and 88, 244 (1938).

<sup>3</sup> Sawyer, H. E., and J. Brodie, *Publs. Observatory Univ. Mich.*, 7, 79 (1938).

<sup>4</sup> Ellison, M. A., S. M. P. McKenna, and J. H. Reid, *Observatory*, 80, 149 (1960).

## THE CLASSIFICATION OF CLUSTERS OF GALAXIES

BY W. W. MORGAN

YERKES OBSERVATORY, UNIVERSITY OF CHICAGO

*Read before the Academy, April 26, 1961*

1. The recent publication of the catalogue of clusters of galaxies by George O. Abell<sup>1</sup> is a landmark in extragalactic astronomy; for the first time it is now possible to investigate satisfactorily the general characteristics of rich clusters of galaxies as a class. The present paper gives an application to clusters of galaxies of the system of classification of individual galaxies developed by the writer<sup>2</sup> on the negatives of the National Geographic Society-Palomar Observatory Sky Survey. The introductory parts of this investigation were carried out during periods as a Guest Investigator of the Mount Wilson-Palomar Observatories; the remainder is based on plates obtained with the Yerkes 40-inch refractor, combined with a Meinel reducing camera; the Yerkes plates were taken by Mr. Robert F. Garrison.

The revised classification of the forms of galaxies is a modification of that of Hubble; in effect, one of Hubble's criteria (degree of central concentration of luminosity) has been used exclusively: the resulting classification can be considered a very coarse one; but it does have a physical significance, since it is correlated rather well with spectroscopic evidence concerning the stellar population of the individual galaxies. In particular, two extreme kinds of galaxies can be cleanly separated: (1) galaxies whose light comes principally from hot, blue stars; and (2) galaxies whose light comes principally from yellow giant stars. In addition to these two extremes, galaxies of an intermediate population, consisting of mixtures of (1) and (2) can also be recognized by their form class in the new system of classification.

In class (1) occur a number of highly irregular galaxies and spirals with little central concentration of luminosity; in class (2) are the giant ellipticals, spirals with pronounced nuclei, and certain other galaxies having a high concentration of luminosity in their central regions: in general, the progression in average stellar population from hot stars to the cooler yellow giants changes smoothly with increasing contribution to the total luminosity of the inner regions of each galaxy.

2. Now, when this system of form classification is applied to multiple galaxies and clusters of galaxies, certain common characteristics of the latter emerge. In order to investigate these characteristics further, the rich clusters of galaxies in Abell's nearest groups (distance groups 0 and 1), located north of the equator, were photographed with the 40-inch Yerkes refractor. Since the field of the latter with the Meinel reducing camera is about 20', the observations apply principally to the nuclear part of each cluster; but each of the 20 clusters in the distance groups observed was examined on the Sky Survey prints to find whether any systematic difference between the galaxies in the inner and outer parts of each clusters existed. No marked differences were found; and it can be taken that the galaxies located in the nuclear region of each cluster are a fairly good index of the nature of the cluster as a whole. For the purposes of the present investigation, this rough comparison is sufficient; but a similar, more precise comparison on the original negatives of the Sky Survey would still be of importance.

3. The conclusions from the reclassification of the visually brightest members of the nearest of Abell's distance groups can be summarized as follows:

(a) All of the clusters in the group observed have, for their visually brightest members, galaxies of the centrally-condensed type.

(b) The clusters can be divided into two categories according to the types of galaxies encountered one to two magnitudes below the brightest members: (i) those containing appreciable numbers of galaxies of minor central concentration of light; and (ii) those containing few or none of the latter.

(c) In terms of the correspondences found between form and stellar population, conclusion (a) can be recast as follows: The brightest members of all of the rich clusters in the observed volume tend to have stellar populations of the "evolved" type—yellow giant stars. This would suggest that at some time in the past the physical condition of these rich clusters would have been systematically different from what we observe at the present time.

The question now arises as to how representative of the total observable volume of space the restricted volume appropriate to the present observations can be considered to be. Since no clusters in the observed volume have a richness greater than class 2 on Abell's scale, it has to be concluded that observation of a larger volume, including a number of the richest clusters, would be necessary before the sample can be considered a representative one.

The writer is indebted to Dr. I. S. Bowen and the research committee of the Mount Wilson-Palomar Observatories for permission to use the original negatives of the National Geographic Society-Palomar Observatory Sky Survey. He is also indebted to Dr. W. A. Hiltner and to the latter's contract with the Air Force (Galactic Field Study) for making possible the obtaining of the Yerkes photographs of clusters of galaxies.

The present investigation was supported in part by a contract with the Office of Naval Research.

<sup>1</sup> Abell, George O., *Ap. J.*, Supplement No. 31, 211 (1958).

<sup>2</sup> Morgan, W. W., *Pub. A.S.P.*, 70, 364 (1958), and *Pub. A.S.P.*, 71, 394 (1959).