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## A SPECTRAL CLASSIFICATION OF GALAXIES\*

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### I. INTRODUCTION

There is at least one advantage in a classification of galaxies based on their spectra: the absorption and emission features, despite their composite nature, contain significant information bearing on the stellar populations of the systems. Such a classification, however, should be regarded as complementary to the classical Hubble sequence based on form and degree of resolution. The reason is that the spectral characteristics considered here seem to correlate rather well with the appearance of spiral structure and central concentration, which are two properties of galaxies that show progressive changes in Hubble's scheme. Thus the classification proposed here will incorporate additional information that did not, in general, enter into Hubble's assignments of nebular types.

The procedure of classification was very simple: accurate estimates of spectral type (and of luminosity class, when possible) were made for a number of the brightest galaxies. Special attention was given to the wavelength region used and to the particular parts of the galaxies to which the spectra referred. The observational material consists of spectrograms obtained principally by Humason at the Mount Wilson and Palomar Observatories and by Mayall at the Lick Observatory.<sup>1</sup> For some objects new plates were taken with the nebular spectrograph of the 36-inch Crossley

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reflector, and with the Cassegrain spectrograph of the 82-inch McDonald reflector.

## II. GENERAL CHARACTERISTICS OF THE SPECTRA OF GALAXIES

In the case of spectroscopically composite systems such as galaxies it is to be expected that the spectral types deduced will depend upon the wavelength region observed; if a mixture of early- and late-type stars is present, the integrated spectral type will tend to become progressively earlier on passing toward regions of shorter wavelength. Moreover, the features observed in any one spectral region may indicate a considerable range in type for the contributing stars. We shall first review briefly some aspects of the spectral classification system of Humason.<sup>2</sup>

### *Humason's Spectral Classification System*

For galaxies having absorption-line spectra, Humason estimated spectral types by comparison with standard spectrograms of M 32 (NGC 221), for which Adams, Joy, and Humason had determined a type of dG3; the dwarf designation resulted from the relative intensities of luminosity-sensitive pairs of lines. It was noted, however, that the hydrogen lines indicated an earlier type, while Ca I  $\lambda$  4227 and the G band indicated a later.

The range in spectral type for the galaxies observed by Humason is from A5 to G8 in his most recent discussion.<sup>1</sup> He found a loose but definite correlation between these types and Hubble's nebular classifications. On the average, the earliest spectral types are associated with Sc and SBc systems; at the other extreme, the latest spectral types are associated, in general, with elliptical systems. But the spectrum-form relationship shows a large scatter; in particular, the Sc or SBc systems show a range in Humason's spectral types from A5 to G5—that is, over almost the whole spectral range found for all kinds of galaxies observed.

It should be emphasized that these determinations of spectral type generally represent data obtained as by-products of the principal program for which the plates were taken: the determination of redshifts. In addition, the best spectrograms obtainable in earlier years do not compare favorably with those taken at the present time.

*Criteria for a Spectroscopic Classification of Galaxies*

With the great improvements made in recent years in instrumentation and photographic emulsions, it now seems worth while to attempt a more precise spectroscopic classification of the integrated spectra of galaxies. This classification system has the following four properties :

1. It refers in general to two principal parts of a galaxy : (a) The system as a whole when there is little or no central concentration, and (b) the nuclear region when it dominates the system. In the first case, if there is any appreciable variation over the system, the spectral type corresponds to a weighted-mean sample of the main contributors to the total light.

2. A narrow interval in wavelength is used to obtain the spectral classification ; in the present investigation it is that between  $\lambda$  3850 and  $\lambda$  4100. For a complete description of the composite spectrum of a galaxy, a spectral classification should be made for as many different wavelength regions as possible. In particular, classifications in the green, yellow, and red regions would add a great deal to the information obtainable from the blue-violet region. The crucial point, however, is that only similar spectral regions should be used when comparing spectroscopically the relative importance of stellar populations in different galaxies ; a violet-region spectral type of one system should not be compared with a green-region type of another. Also, probably only similar parts of different systems should be compared.

3. An approach that is fundamentally two-dimensional is used for the spectral classification, and, as far as practicable, the Yerkes MK system was utilized. Some generalities concerning the classification of composite systems have already been outlined in connection with the spectral classification of globular clusters.<sup>3</sup>

4. An attempt is made to interpret the spectral class–wavelength relationships with artificial or hypothetical H-R diagrams.

## III. THE SPECTRUM OF THE ANDROMEDA NEBULA (M 31)

We shall now present a description of the spectrum of M 31 with regard to the four properties just enumerated. This description supplements and amplifies an earlier summary by Morgan.<sup>3</sup>

*The Spectrum of the Nuclear Region*

Spectrograms were obtained by G. H. Herbig and Morgan in the autumn of 1955 with the 36-inch Crossley reflector of the Lick Observatory; the two-prism nebular spectrograph was used, together with Kodak plates of I-N emulsion, which were hypersensitized in ammonia. The slit was centered on the nuclear region and the nucleus was trailed during the exposure to give a uniformly widened spectrum. A number of exposures of varying duration were made in order to obtain a record of the whole spectral interval  $\lambda\lambda$  3700–8000 with optimum density; the dispersion is 430 Å/mm at H $\gamma$ . A series of plates of standard stars in the MK system also was obtained, under nearly identical spectroscopic conditions. This material made possible a comparison of the nuclear region of M 31 with MK standard stars over the full range of wavelength from the ultraviolet to the infrared.

Although the dispersion is very low, certain unique conclusions may be drawn; these are as follows: (a) The principal contributors to the luminosity of the inner, brightest region of M 31 in the spectral interval  $\lambda\lambda$  3880–4300 are “cyanogen giants”—that is, stars in the general category gG8 to gK3. (b) The principal contributors in the neighborhood of  $\lambda$  4600 are probably K4 to K5 giants. (c) Bands of TiO are present in the red and infrared regions. The luminosities of the M-type stars responsible for these bands have not yet been observationally determined, but it seems highly probable that they are normal giants. Certain luminosity criteria described by Öhman<sup>4</sup> should settle this point when observations with higher dispersion in the red region have been obtained. (d) In spectral regions below  $\lambda$  3900 there is evidence for the presence of an appreciable number of stars of types G0 to G5. Their presence is suggested by a softening in the contrast of the K-type absorptions in the ultraviolet. It is very improbable, however, that a considerable proportion of stars of spectral types earlier than F8 is present; in particular, no indication of hydrogen absorption lines in the ultraviolet has been observed. The spectrum of the inner region of M 31 is illustrated in Plate I.

*A Hypothetical H-R Diagram for the Inner Region*

It is now possible to infer a luminosity-spectrum array that

would give an integrated spectrum similar to the one observed for the nuclear region of the Andromeda Nebula. This is illustrated by the vertical lines in Figure 1, where the areas covered

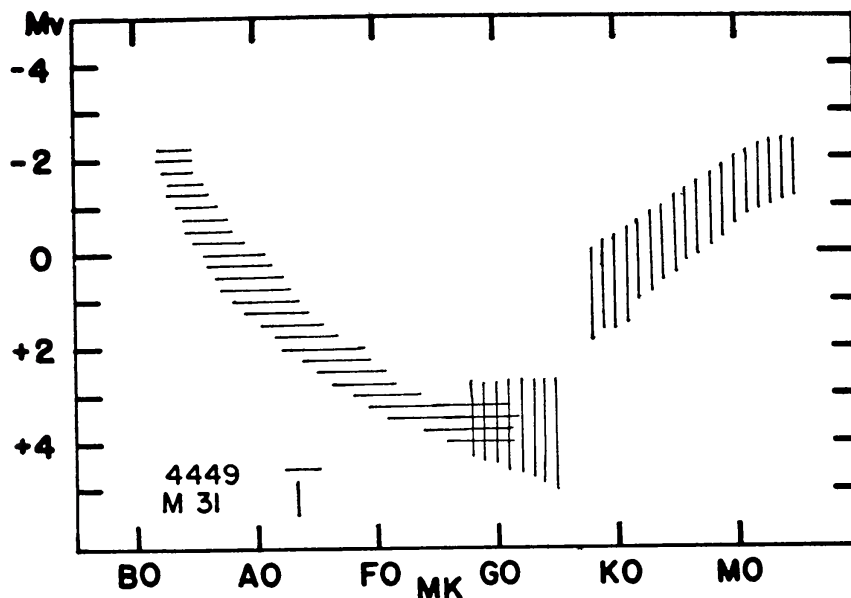


FIG. 1.—Hypothetical H-R diagram for the principal contributors to the light of the inner part of M 31 (vertical lines) and of NGC 4449 (horizontal lines). The plot for NGC 4449 is less complete than that for M 31, since spectra in the yellow and red regions were not available.

by these lines give the approximate loci of the principal contributors to the integrated light.

The question naturally arises as to how nearly unique this interpretation of the composite spectrum of M 31 may be. Although no certain answer can be given on the basis of the scanty M 31 data, the information available on the H-R diagrams and color-magnitude arrays for the older open clusters leads us to conclude that the hypothetical H-R diagram illustrated is approximately correct—as far as the principal contributors to the luminosity are concerned.

It is important to emphasize that the absence in Figure 1 of main-sequence dwarf stars of types G8 to M does not imply that such stars may not be plentiful in the inner part of M 31. In order to have an approximately equal effect in the integrated light, there would have to be of the order of 100 times as many G8 to K2 dwarfs as giants, and thus the relative number of K dwarfs to

giants probably is less than 100 to 1. Any ratio smaller than about 50 to 1, however, would be consistent with the appearance of the integrated spectrum. Since the ratio of G8 to K3 dwarfs to giants is of the order of 40 to 1 in the neighborhood of the sun, it appears that a similar ratio is possible for the nuclear region of M 31. This conclusion emphasizes the fact that the principal contributors to the luminosity and to the mass of the inner part of M 31 may be entirely different in nature. Nevertheless, the existence of large numbers of K dwarfs in the system cannot yet be said to have been demonstrated.

We summarize this section as follows : The principal sources of luminosity for the inner part of the Andromeda Nebula are (a) giant stars of spectral types G8 to early M, and (b) an appreciable number of F8 to G5 stars. There is no evidence for the presence of A or early F stars in sufficient numbers to affect the integrated spectrum to an observable degree.

#### *The Spectrum of the Main Body*

The angular dimensions of the Andromeda Nebula are so great that spectroscopic observations usually refer only to the brightest inner part in the neighborhood of the nucleus. In order to investigate the spectrum over a larger region it is convenient to have an image-forming telescope of short focal length.

Such an instrument was constructed a number of years ago at the Lick Observatory by Horace W. Babcock, who employed a short-focus six-inch mirror that had the same focal ratio of 5.8 as the Crossley reflector.<sup>5</sup> The nebular spectrograph was then used in conjunction with this small reflector to obtain slit spectrograms that cover a far greater angular extent of M 31 than is possible with larger telescopes. We consider it most fortunate that these small-scale spectrograms taken by Babcock were available for the investigation of the integrated spectral type of those parts of the main body of M 31 that are situated at some distance from the nuclear region.

A careful comparison of these spectrograms with those of the nuclear region itself fails to disclose any marked differences, as far as the spectral types in the violet and blue regions are concerned. It seems justifiable, therefore, to draw the tentative con-

clusion that the populations of the nuclear region, and of the smooth, featureless disk that extends out from the nucleus, are similar.

There is one further spectral characteristic that seems to be of interest: the giants that compose the principal source of luminosity in M 31 are “normal” giants; they are not the weak-lined variety observed in some globular clusters.

#### *A Comparison of the Spectra of M 31 and M 33*

The Crossley spectrograms of M 33 obtained by Mayall and Aller<sup>6</sup> reveal an entirely different distribution of stellar population in the H-R diagram; the ultraviolet region—in both the nucleus and the surrounding area—shows conspicuously in absorption the Balmer lines of hydrogen; the cyanogen absorptions, which are well marked in the spectrum of M 31, are not observed. The spectral type in the range  $\lambda\lambda$  3800–4100 is F, at  $\lambda$  4340 it is G0, and thus the spectral type changes rapidly with wavelength. Since spectrograms in the green, yellow, and red regions were not available, it was not possible to construct a hypothetical H-R diagram with the same confidence as in the case of M 31. This is an important future spectroscopic task, especially since independent information on the stellar content of M 33 may be anticipated from current work by A. R. Sandage at the Mount Wilson and Palomar Observatories.<sup>7</sup>

In spite of the present incomplete data, there can be little doubt that the percentage of A- and F-type stars is far higher in the main body of M 33 than in that of the Andromeda Nebula. We therefore emphasize the points that differences in the physical appearances of M 31 and M 33 are reflected in their integrated spectra, and that there is no large, bright amorphous central bulge in M 33.

#### IV. SPECTRA OF IRREGULAR GALAXIES LIKE THE LARGE MAGELLANIC CLOUD

The irregular galaxy NGC 4449 has often been considered the northern hemisphere counterpart of the Large Magellanic Cloud. Little symmetry of structure is visible, and the most striking features are apparently large gaseous emission regions, which bear some resemblance to the H II regions in the Galaxy and in the Andromeda Nebula. Crossley spectrograms show that the system

is, in fact, either immersed in a gaseous stratum, or is composed of numerous unresolved H II regions in which the Balmer emission lines originate. In addition, the chief nebular [O III] lines are well marked, and the emission spectrum resembles that to be expected from a gigantic H II region. The absorption spectrum is also of great interest: the Balmer lines are strong in the ultraviolet, the spectral type in the range  $\lambda\lambda$  3850–4100 is around A7, and at  $\lambda$  4340 the spectral type is middle F.

It may be seen, therefore, that the three systems NGC 4449, M 33, and M 31 possess widely differing spectral and physical characteristics. The irregular galaxy NGC 4449 has a spectrum suggestive mainly of spiral-arm population, M 33 is intermediate in structural symmetry and spectrum, while M 31 is a well-developed Sb spiral having a pronounced central bulge that contains a relatively great number of CN giants.

A hypothetical H-R diagram for NGC 4449 also is illustrated in Figure 1 by the horizontal lines. A comparison with M 31 shows how different the stellar population may be in these two galaxies—as far as the contribution to the luminosity is concerned. Moreover, there may be a significant similarity between these two arrays and those for galactic clusters in the solar neighborhood that are considered to be of greatly different ages. Thus the hypothetical diagram for NGC 4449 appears to correspond to that for a young galactic cluster, while that for M 31 resembles the kind expected for an old cluster, whether galactic or globular. Despite its interest, we do not pursue this line of reasoning further at the present time, because of the fragmentary nature of the observations of spectra of galaxies.

#### V. A SPECTRAL CLASSIFICATION OF GALAXIES

We now give a general outline of a classification of some of the brighter galaxies based on their integrated spectra. The investigation depends upon the rich spectroscopic and general photographic material of the Mount Wilson–Palomar and Lick Observatories. The Mount Wilson–Palomar spectrograms were obtained mainly by Humason, with a certain number by Hubble and Minkowski; the direct photographs were taken with the 200-inch, 100-inch, and 60-inch reflectors at Mount Wilson–Palomar,

principally by Hubble, Humason, and Sandage. We wish to express our deep indebtedness for the opportunity to make use of this material.

The Lick spectrograms were taken principally by Mayall with the 36-inch Crossley reflector; the direct photographs were taken with the same instrument by a large number of observers over the past 50 years.

A number of galaxies could not be considered because the spectrograms were not of a type suitable for classification; others were omitted because the spectral lines were too faint to permit accurate classification. The remainder were classified and divided into groups according to spectral type. In all cases the spectral type refers to the principal contributors to the integrated light of the galaxy concerned.

### *The A-systems*

The spectral types in the region  $\lambda\lambda$  3850–4100 are of class A, and hence we shall refer to them as “A-systems”; they are listed in Table I.

TABLE I

A-SYSTEMS

| NGC  | Hubble |
|------|--------|
| 672  | SBc    |
| 1518 | Scp    |
| 3319 | SBc    |
| 3389 | Sc     |
| 4449 | Irr    |
| 4559 | Sc     |
| 4631 | Sc     |

These seven galaxies are of three kinds in Hubble’s classification: Irr, SBc, and Sc. They seem to have similar stellar populations, and the principal contributors to the total light in the violet region are main-sequence stars of type A. This classification appears to be unique, for the observed broad hydrogen absorption lines could not be produced by a mixture of B- and F-type stars. The spectral type for all of these systems is around F8 at  $\lambda$  4340; therefore the degree of compositeness is considerable.

*The AF-Systems*

The seven galaxies listed in Table II have spectral types in the range F0 to F2 in the spectral region  $\lambda\lambda$  3850–4100; at  $\lambda$  4340 their types are near F8. All of them are spirals of Hubble's nebular type Sc, characterized by a very low central concentration of light.

TABLE II  
AF-SYSTEMS

| NGC  | Hubble |
|------|--------|
| 925  | Sc     |
| 2903 | Sc     |
| 2976 | Sc     |
| 3556 | Sc     |
| 4088 | Sc     |
| 4244 | Sc     |
| 4713 | Sc     |

*The F-Systems*

The four systems listed in Table III have spectral types slightly later than those in Table II, and thus they are designated F-systems. Two of these are the well-known galaxies M 33 and M 51, which are spirals that have a central luminosity concentration of an intermediate nature.

TABLE III  
F-SYSTEMS

| NGC         | Hubble |
|-------------|--------|
| 598 (M 33)  | Sc     |
| 3628        | Sb     |
| 3810        | Sc     |
| 5194 (M 51) | Sc     |

*The FG-Systems*

Table IV lists six galaxies whose spectra are of a somewhat later type than those in the F group, and so they are designated FG-systems.

In this group the central concentration of light tends to contribute a larger percentage of the total luminosity. Two of the

TABLE IV

## FG-SYSTEMS

| NGC         | Hubble |
|-------------|--------|
| 4666        | Sc     |
| 5005        | Sb     |
| 5055 (M 63) | Sb     |
| 5633        | Sb     |
| 6574        | Sb     |
| 7331        | Sb     |

galaxies, however, NGC 5633 and NGC 6574, are small and the direct-exposure evidence does not indicate definitely whether they are, in fact, similar to the larger systems.

*The K-Systems*

This is the most numerous group of all and comprises 23 galaxies having a great diversity in appearance. Their spectra, however, indicate that the principal contribution to the total luminosity in the blue-violet region is probably from K-type giant stars. The K-systems are listed in Table V, and they all have one property in common: the major part of the luminosity originates in a brilliant, amorphous central region.

TABLE V

## K-SYSTEMS

| NGC         | Hubble | NGC         | Hubble | NGC         | Hubble |
|-------------|--------|-------------|--------|-------------|--------|
| 224 (M 31)  | Sb     | 4111        | S0     | 4649 (M 60) | E2     |
| 1398        | SBb    | 4216        | Sb     | 4699        | Sb     |
| 2841        | Sb     | 4260        | SBa    | 4762        | Sa     |
| 2950        | SB0    | 4486 (M 87) | E0     | 5308        | S0     |
| 3031 (M 81) | Sb     | 4565        | Sb     | 5363        | Irr    |
| 3115        | E7     | 4594        | Sb     | 5473        | SB0    |
| 3990        | S0     | 4636        | E0     | 5850        | SBb    |
| 3998        | S0     | 4643        | SB0    |             |        |

The forms of the K-systems fall into several well-defined groups: (1) the great Sb and Sa spiral systems; (2) barred spirals of strong central concentration of light; (3) the giant elliptical systems; (4) "dustless" systems similar in figure to the Sa-Sb spirals; (5) nondescript systems.

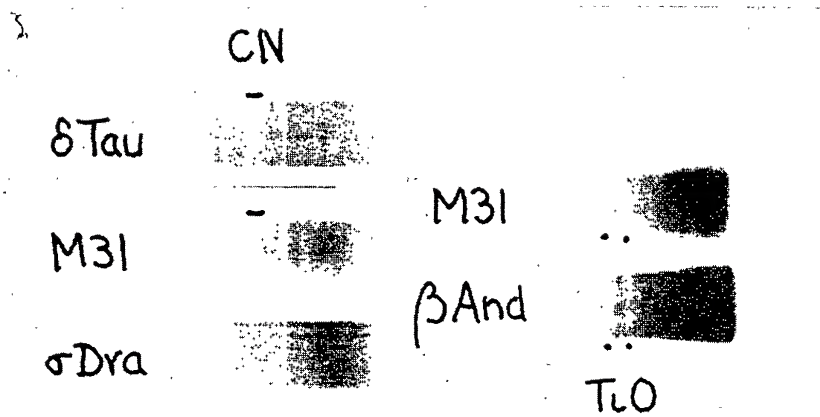
## VI. THE RELATIONSHIP BETWEEN FORM AND SPECTRUM

Plate II illustrates the marked differences in form and spectra, while Plates III to VII show direct photographs of representative galaxies in three spectroscopic categories: the A-, F-, and K-systems. It can be seen that, although a considerable diversity in form exists for systems of the same spectral class, there is a definite basic similarity between form and spectrum. The A-systems illustrated in Plate III have the common characteristic of a minor central concentration of light, the F-systems have a greater central concentration, and the K-systems have the greatest central concentration of all. In the case of the last named, the greatest contribution to the total luminosity is due to a large, amorphous central bulge that is absent in both the A- and F-systems, and which is first observed in the FG group. The central concentration of light in such F-systems as M 33 and M 51 is due principally to stars of earlier type than is the case in the K-systems; the structural appearance of the central region in the F-systems is also different from that in the K-systems.

## VII. A POSSIBLE LUMINOSITY EFFECT IN THE SPECTRA OF THE K-SYSTEMS

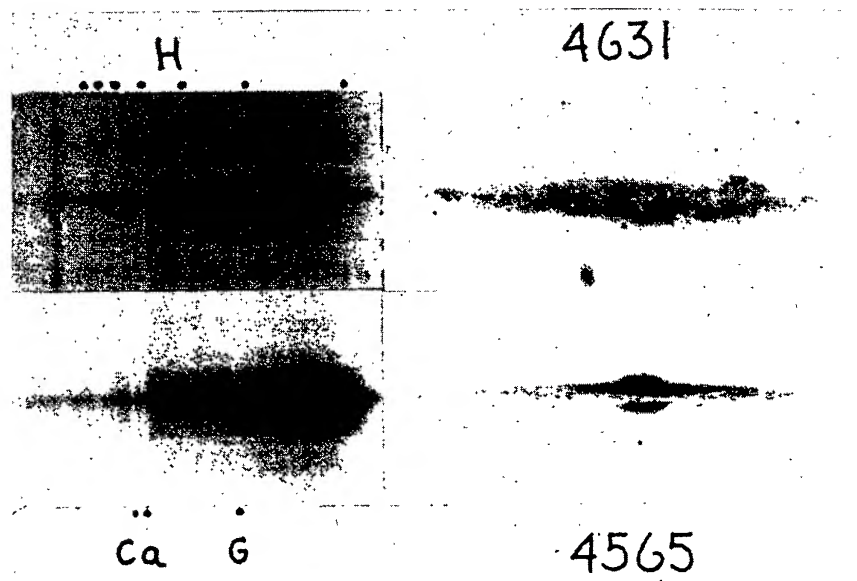
A series of 150 Å/mm spectrograms of bright K-systems, observed with the Cassegrain spectrograph of the 82-inch McDonald reflector, shows an effect that may prove to be useful in the derivation of spectroscopic parallaxes for extragalactic nebulae. A well-marked relationship was found between the width of the spectral lines and the apparent brightness of certain members of the Virgo cluster of galaxies. The giant elliptical galaxies NGC 4486 (M 87) and NGC 4649 (M 60) have spectral lines considerably broader than those in M 31 and M 81. For progressively fainter Virgo cluster ellipticals the spectral lines tend to become narrower, as if there were a line width–absolute magnitude effect for the brighter members. This effect may also be present in the giant Sb spirals, for NGC 4594 also has spectral lines considerably broader than those in M 31 and M 81. When the distance modulus of the Virgo cluster becomes known with some precision, the high-luminosity members of this rich cloud of galaxies may serve to calibrate a line width–absolute magnitude relationship. This may then be used for the estimation of spectroscopic parallaxes of more

## PLATE I



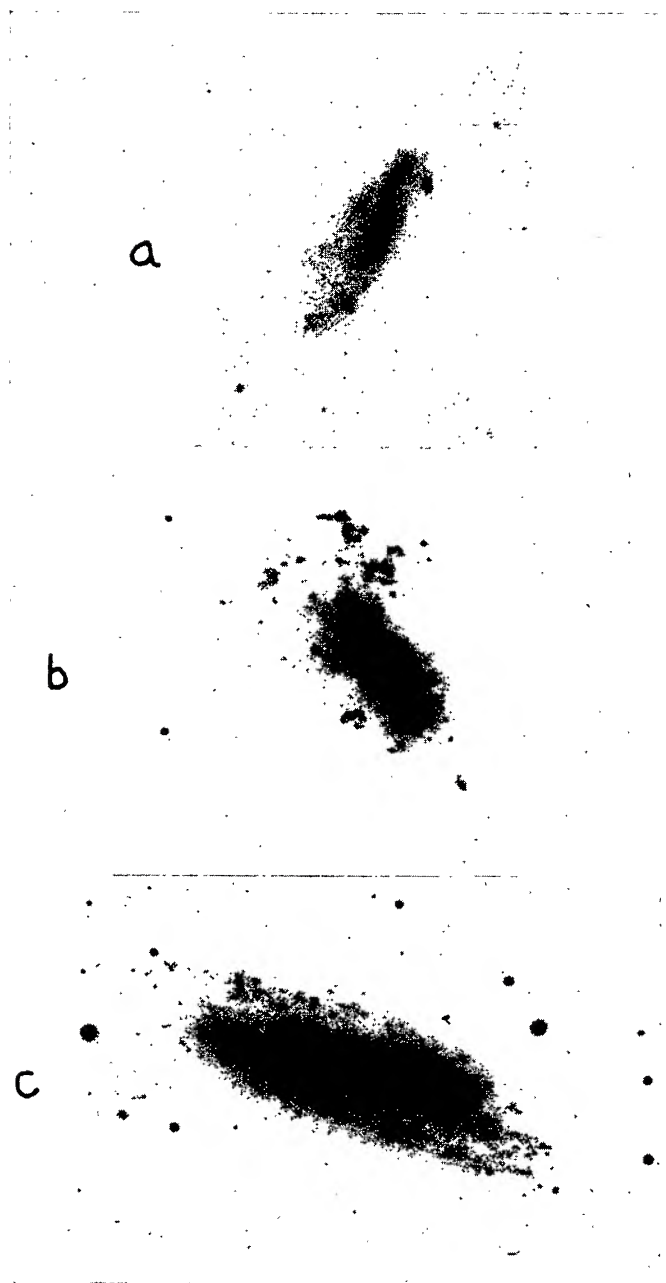
Spectra of the central region of M 31 and of comparison stars in the blue (*left*) and red (*right*). The MK spectral type of  $\delta$  Tauri is K0 III and of  $\sigma$  Draconis K0 V. The conspicuous CN absorption near  $\lambda$  4200 shows both in the giant star and in M 31; the same spectral region in the dwarf is quite different. The MK spectral type of  $\beta$  Andromedae is M0 III, and the TiO absorptions near  $\lambda$  5900 and  $\lambda$  6200 show both in the M giant and in M 31. Crossley reflector spectrograms with Kodak 33 emulsion were used for  $\sigma$  Draconis, and Kodak I-N hypersensitized for the others.

## PLATE II



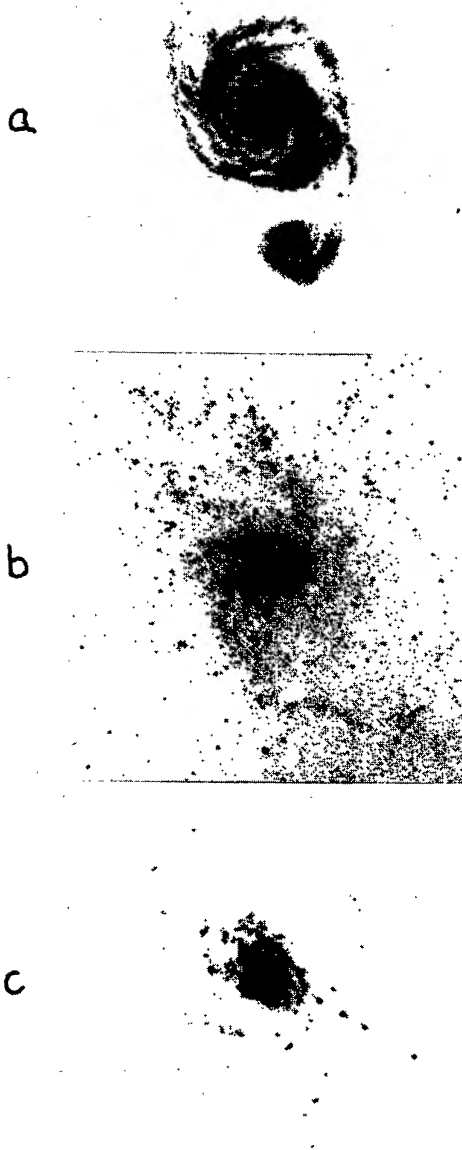
Spectra (Lick) and direct photographs (Mount Wilson-Palomar) of an "A-system," NGC 4631, and a "K-system," NGC 4565. The spectra, taken with the slit on the major axis of each galaxy, appear significantly different. In the ultraviolet that of NGC 4631 shows strong  $\lambda 3727$  [O II] emission and Balmer hydrogen absorption, and that of NGC 4565 shows blends of arc metallic lines. Irregular systems like NGC 4631 usually have an early-type spectrum, while systems like NGC 4565 with a pronounced, central amorphous bulge generally show a K-type spectrum having giant characteristics. These differences strongly suggest different stellar populations, or H-R diagrams, for the principal contributors to the luminosity.

## PLATE III



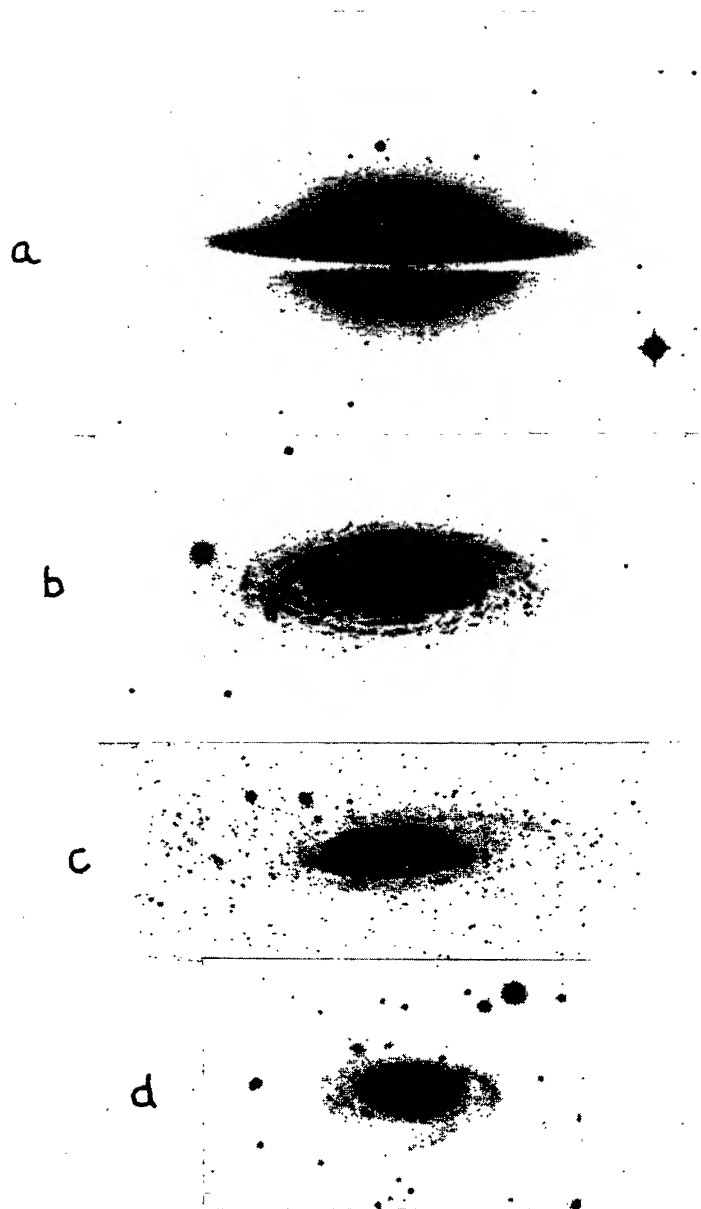
Three A-systems: (*a*), NGC 1518; (*b*), NGC 4449; and (*c*), NGC 672, in which the main part of the light probably comes from A-type stars. There is no bright, amorphous bulge in any of these galaxies, nor any pronounced central concentration of light or well-developed spiral structure. The reproductions are from Mount Wilson–Palomar negatives.

## PLATE IV



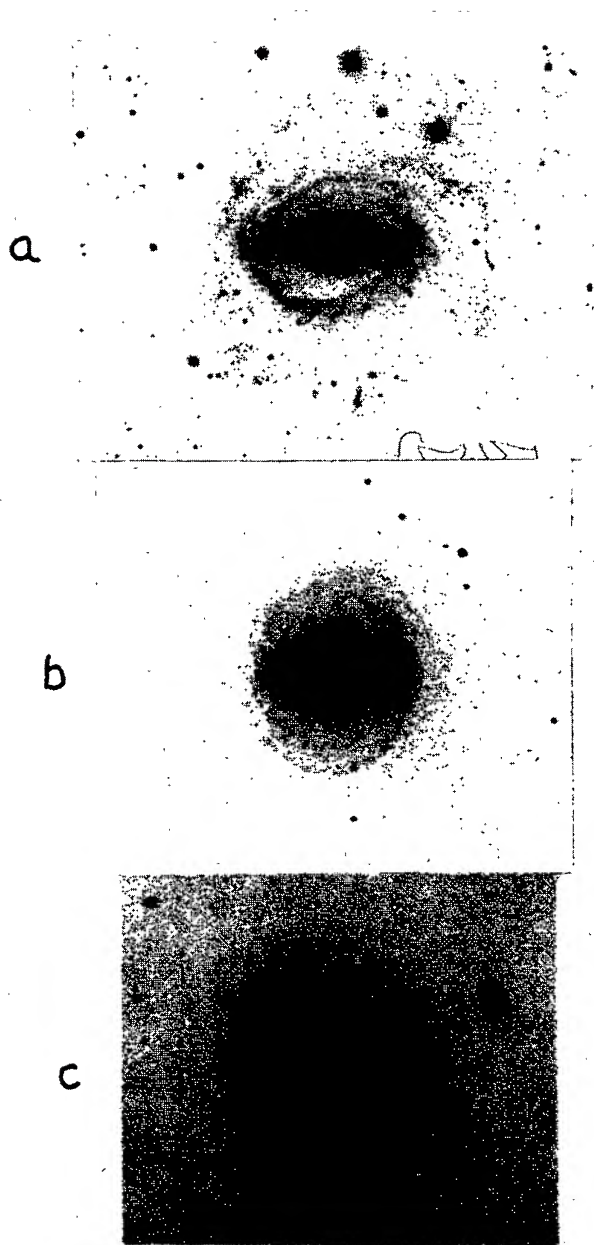
Three F-systems: (a), NGC 5194 (M 51); (b), NGC 598 (M 33); and (c), NGC 3810, which are intermediate in general appearance between those of classes A and K. The nuclear regions are appreciably more condensed than those in A-systems, but still much less so than in K-systems. In the range  $\lambda\lambda$  3900–4400 their spectra are of F type. The reproductions of M 51 and NGC 3810 are from Mount Wilson–Palomar negatives, that of M 33 from a Yerkes 40-inch refractor plate taken with a Meinel reducing camera.

## PLATE V



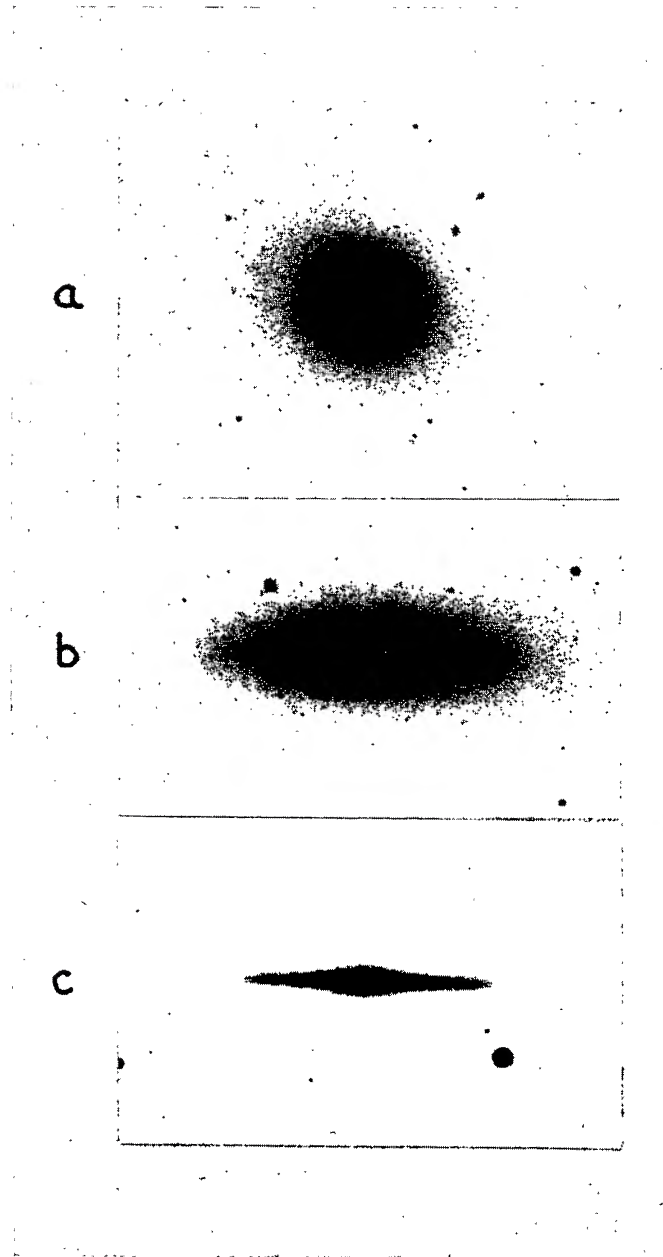
Four normal spiral K-systems: (*a*), NGC 4594; (*b*), NGC 2841; (*c*), NGC 224 (M 31); and (*d*), NGC 3031 (M 81), which have the common property of large, amorphous nuclear regions in which most of the light originates. The light from these central bulges comes largely from yellow and red giant stars of spectral types from gG8 to gM. The reproductions of NGC 2841 and NGC 4594 are from Mount Wilson–Palomar plates, those of M 31 and M 81 from Lick negatives taken with an  $f/7$  Ross camera of 35 inches focal length.

## PLATE VI



Three barred spiral K-systems: (a), NGC 5850; (b), NGC 1398; and (c), NGC 4643, which have large, bright, and amorphous central bulges, and for which the spectral types are K in the blue-violet region. The reproductions are from Mount Wilson-Palomar plates.

## PLATE VII



Three “dustless” K-systems: (*a*), NGC 4486 (M 87); (*b*), NGC 3115; and (*c*), NGC 4762, which are examples of galaxies that do not show evidence of dust lanes or spiral arms. M 87 is representative of the giant elliptical galaxies whose spectra are of type gK, as for the central parts of the spirals in Plate V. The spectral lines in the highest luminosity ellipticals also are abnormally broad, even more than in the nuclear region of M 31. In general form and appearance, NGC 4762 resembles an Sb galaxy without spiral structure outlined by dust. The reproductions are from Mount Wilson–Palomar plates.

distant galaxies, provided their spectra can be obtained with a dispersion high enough to show the true line width.

#### VIII. CONCLUSION

The preceding discussion of the spectral class-form relationship seems to apply to approximately 80 percent of the brighter extragalactic systems; if those in the highest luminosity category are considered, the percentage is probably greater. Among well-known systems, the most striking exception is probably NGC 205—one of the fainter companions of the Andromeda Nebula. In spite of its amorphous elliptical structure, its spectral type is considerably earlier than in the K-systems; the principal contributors to the integrated light in the photographic region are probably F-type stars. It is of considerably lower luminosity, however, than the giant ellipticals and spirals, and Baade has pointed out the presence of several dust clouds and a number of blue stars.<sup>8</sup> Also, Baum and Schwarzschild found the anomaly that nebular patches near NGC 205 and near M 31 have the same color, despite a presumed membership in two different stellar populations.<sup>9</sup>

This investigation was begun while one of us (W.W.M.) was an Alexander F. Morrison Research Associate at the Lick Observatory, and was continued while he was Visiting Professor at the California Institute of Technology. He wishes to make grateful acknowledgment for facilities and plate material made available by Directors I. S. Bowen of the Mount Wilson and Palomar Observatories and C. D. Shane of the Lick Observatory. He is also indebted to Dr. G. H. Herbig for help in obtaining Crossley spectrograms of M 31, and to Drs. W. Baade and A. R. Sandage for discussions on the subject of classification of galaxies. The research was supported in part by a grant (to W.W.M.) by the Office of Naval Research.

<sup>1</sup> M. L. Humason, N. U. Mayall, and A. R. Sandage, *A.J.*, **61**, 97, 1956.

<sup>2</sup> M. L. Humason, *Ap. J.*, **83**, 18, 1936.

<sup>3</sup> W. W. Morgan, *Pub. A.S.P.*, **68**, 509, 1956.

<sup>4</sup> Y. Öhman, *Ap. J.*, **80**, 171, 1934.

<sup>5</sup> H. W. Babcock, *Lick Obs. Bull.*, **19**, 41, 1939 (No. 498).

<sup>6</sup> N. U. Mayall and L. H. Aller, *Ap. J.*, **95**, 5, 1942.

<sup>7</sup> Reported by I. S. Bowen, *A.J.*, **61**, 339, 1956.

<sup>8</sup> W. Baade, *Pub. Michigan Obs.*, **10**, 10, 1951.

<sup>9</sup> W. A. Baum and M. Schwarzschild, *A.J.*, **60**, 247, 1955.