

## BOOK REVIEW

ATLAS OF PECULIAR GALAXIES, by Halton Arp  
California Institute of Technology, Pasadena, 1966

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Many branches of modern astronomy are concerned with classes of objects which are distinguished by the variety of their external forms and states. Such objects include the diffuse nebulae, open clusters, stellar spectra and galaxies. In these cases a very important stage in the investigation is the classification of the objects or phenomena. In developing the classification an important aspect is the compilation of appropriate atlases. Sometimes atlases are published for the clarification, or illustration, of an already formulated classification. In other cases they serve as the initial material for formulating a new classification.

A whole series of astronomical atlases of this type have appeared in the post-war period. Here it suffices to mention the Atlas of Diffuse Nebulae by Shayn and Gaze, the Atlas of Absorption Nebulae by Fesenkov and Rozhkovskii, the Atlas of Open Star Clusters by Markaryan, and the later atlas of open clusters published by Weaver.

The value of such atlases, where the most interesting facts and phenomena are collected, is enormous for everyone who does not regard astronomy solely as the arena for comparison of theoretical models and observational data and who considers the construction of diagrams and models to be only one of the means for generalizing and understanding facts.

The appearance of the Hubble-Sandage atlas of galaxies in 1961 seemingly marked the completion of work on the classification of regular galaxies begun by Hubble in the field of galactic studies. Although the further development of extra-galactic astronomy has pursued a different direction, this atlas nevertheless will retain its importance for a long time in imparting information on a wide range of more or less stationary phenomena in galaxies.

However, the appearance in the 1950's of the Palomar Sky Atlas, which was primarily a reference work, exerted an enormous influence on extra-galactic astronomy. An enormous amount of factual material was made available to astronomers, making it possible for them to judge the forms and distribution of hundreds of thousands or even millions of galaxies. A first examination of this material nevertheless made two facts obvious to everyone:

- a) The Hubble classification of galaxies is only an initial rough classification which does not cover the full variety of the morphological characteristics of galaxies.
- b) Hubble's conclusion that there is an approximately uniform distribution of galaxies in the sky, based on observations with the 100" reflector, was erroneous. Most galaxies exist in clusters or groups.

On the basis of studies of the Palomar Atlas a number of astronomers have drawn conclusions relating to other, more specialized problems of extra-galactic astronomy.

After studying the maps of the Palomar Atlas Vorontsov-Vel'yaminov became convinced that great deviations from the simple and regular forms of the Hubble classification are particularly conspicuous in many close pairs and compact groups of galaxies. It seemed that one galaxy exerted an influence on the structure of others.

Thus introducing the new concept of "interacting galaxies," Vorontsov-Vel'yaminov compiled and published an atlas and a corresponding catalogue which until recently was the only summary of data on anomalous forms of galaxies. After the publication of this catalogue it became obvious that strong deviations from regular forms are by no means infrequent. Vorontsov-Vel'yaminov made the suggestion, which is gaining increasing support, that the reason for these deviations is not gravitational interaction, but other factors.

In the 1950's study of the properties of a number of peculiar galaxies from the maps of the Palomar Atlas, together with an analysis of data on radio galaxies and blue galaxies, served as a point of departure for a group of Byurakan astronomers, on which they based their explanations of the explosive processes in galactic nuclei and of the activity of nuclei in general.

Many of the objects in the Vorontsov-Vel'yaminov catalogue were investigated in detail. However, there was no atlas of large-scale photographs which would give some idea of the entire class of phenomena. This required that a collection of such photographs be obtained using the most powerful telescope available. This work has been done with great dedication and care by Halton Arp, an astronomer at the Palomar Observatory, and has been published in the atlas reviewed here.

The atlas contains 338 photographs of galaxies. Only eight of these were taken with the 48" Palomar Schmidt telescope. The other 330 were obtained using the 200" telescope. These photographs have been reproduced in the atlas with different enlargements. The scales therefore also are different: from 11" to 1:3 per millimeter. The atlas was reproduced by two methods: photographic reproduction (expensive edition) and typographically (inexpensive edition). In writing this review we had available the first of these publications in which the fluorescent screen method was used in obtaining prints, thus making it possible to compress the density scale and thereby reproduce in the paper impression the full range of densities present

on the negative. The quality of almost all the prints is therefore excellent. Details throughout the entire image, except for the innermost parts of the galaxies, is visible on most of the photographs.

The author intended to produce an atlas of peculiar galaxies which would include individual objects as well as "interacting" pairs. In fact, the atlas includes many remarkable individual objects such as the well-known galaxy NGC 2685 with a number of transverse rings around the main elongated body, M 101, having a peculiar, almost star-like condensation on the extension of one of the arms, and the less known, but equally interesting individual objects NGC 3664, NGC 2537, and many others.

However, most of the objects included in the atlas are either double or multiple galaxies (that is, interacting objects), or have within them or near them condensations or formations which make it possible to assume that in one way or another they are related to the category of double galaxies. If it is also remembered that all the double objects included in the atlas are close pairs, it seems natural to assume that the relationship between peculiarity and double structure can be attributed to the fact that the objects are observed in a stage when the formation of one, or even both of the components is occurring. In any case, it is obvious that almost all the objects included in the atlas are unstable and the observed peculiarities should disappear or change their character in a relatively short time, comparable to the time of rotation of the outer parts of the galaxy about the galactic axis, that is, in several hundred million years.

The author of the atlas has clearly recognized that it is difficult at present to provide a unified classification for peculiar galaxies. However, he has made a quite successful attempt to group together similar examples. The following groups are of particularly great interest from this point of view:

1) Spiral galaxies, having a satellite associated with an arm and sometimes situated precisely at the end of the arm (system of the M 51 type). This group includes the photographs numbered 37–101. A study of these photographs indicates without doubt the presence of an important evolutionary pattern: the formation of a galactic satellite is closely associated with the process of formation of the main galaxy. Since the arm must have an age less than the main galaxy to which it belongs, it is clear that in these cases the satellite is a new formation, that is, a very young galaxy. This is, of course, difficult to explain on the basis of condensation of the satellite from intergalactic matter. Instead it agrees better with the hypothesis that the satellite, like the arm, was formed of matter ejected from the nucleus of the main galaxy.

2) Jets, filaments and diffuse formations ejected from the central part of the main galaxy (photographs 149–208). In many cases these jets and filaments contain whole small galaxies. In essence, the group of photographs 102–108, showing surges from elliptical or D Galaxies, also belong to this group. In Particular, this includes the well-known galaxy NGC

3561 (photograph 105) in which the jet emanating from the center contains a blue galaxy.

The role of the nucleus of the main galaxy in the formation of objects of the scale of galaxies of small or moderate luminosity is still more obvious in this group of photographs.

3) A group of close pairs of galaxies in which the components of the pair have a luminosity of the same magnitude and are sometimes morphologically similar (photographs 233–256).

4) Groups and chains of galaxies (photographs 311–332). One of the most surprising systems in this group is the chain shown on photograph 329. This chain, like others pointed out by Markaryan, must be a relatively young formation. In fact, it is easy to confirm the short lifetime of such groupings of galaxies. At the same time, this and other chains contain E and D galaxies. It therefore follows that at least part, if not all of the E and D objects are young.

In addition to the four groups mentioned, there are others of interest which contain, in particular, galaxies having certain irregularities in the structure of the arms or in other details. We have not cited here the group breakdown in the detailed form given by the author. We have mentioned only a few of the principal groups of greatest interest.

In the Arp atlas the material is presented in such a form that some preliminary conclusions on the nature of peculiar galaxies seem inevitable. The most important of these conclusions is that these are systems in a state of vigorous activity and that in each case the nucleus of the corresponding galaxy is the probable center of such activity. In the case of double galaxies, it must be surmised that the appearance of the satellite is also related to the eruptive activity of the nucleus. If this is so, there is some remote analogy between the peculiar galaxies of this atlas under review and radio galaxies. The analogy is that in both classes of objects we are observing the more or less direct results of activity in the nuclei.

Due to the studies of Oort and his associates (in particular, see the communication of Oort at the Byurakan symposium in 1966), we know that the nucleus of our Galaxy also shows considerable activity associated with the ejection of large masses of gas. Therefore, the high cosmogonic activity of nuclei, at least in galaxies of high luminosity, is more likely to be the rule rather than the exception. In this respect peculiar galaxies or radio galaxies stand out only in the sense that the existence of new formations in them is more obvious than in other galaxies due to their non-stable character.

With respect to the sequence of presentation of peculiar galaxies adopted by Arp, and their combination into different groups, the reviewer in studying the various parts of the atlas sometimes felt that he would prefer to assemble the photographs into other groups and subgroups. For example, in the atlas the galaxies M 51 and NGC 3448, which are essentially very similar to one another because they are associated pairs of one Sc galaxy and one Irr II galaxy, actually fell

into completely different groups and were a considerable distance apart in the sequence (their sequence numbers were 85 and 205 respectively). However, when the atlas as a whole is considered, it seems that the system adopted by the author is as good as any.

The use of the atlas is made easy because at the front of the atlas there is a listing of the photographs of the galaxies in two forms: in the sequence of arrangement in the atlas and by increasing right ascensions. Studies devoted to individual galaxies are listed in the bibliography.

The use of the atlas would be still easier if each sheet of photographs (six photographs are present on each sheet) was preceded by a sheet of text containing

data on the galaxies shown in these photographs. This would hardly increase the cost of the publication greatly.

Due to competent preparation and diligent work, Arp has succeeded in producing an atlas of galaxies which will be an irreplaceable aid for everyone involved in the problems of extragalactic astronomy. The atlas is particularly valuable for anyone interested in unusual dynamically unstable processes in galaxies. The author can be congratulated on his successful execution of a major undertaking.

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