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COMPACT GROUPS OF COMPACT GALAXIES

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КОМПАКТНЫЕ ГРУППЫ КОМПАКТНЫХ ГАЛАКТИК

РЕЗЮМЕ

Отмечена пионерская работа Ф.Цвикки по изучению компактных галактик, указавшего на большую частоту встречаемости компактных галактик в кратных системах и существование их скоплений. Уточнено определение компактности галактик (средняя поверхностная яркость больше 20^m с квадратной секунды, в красных лучах). На картах Паломарского атласа выявлено существование более 250 систем, компактных и состоящих из около десятка галактик, в своем большинстве компактных, часто эллиптических или сферических. Многие из этих систем имеют необычные конфигурации (цепочки, криволинейные структуры с пустотой в центре и т.д.). На примере систем Шахбазян 1 и 1 23, обладающих очень небольшой дисперсией радиальных скоростей, что указывает на крайне низкое значение отношения масса-светимость, показано, что, по крайней мере, часть членов компактных групп различается, по природе, от обычных галактик тех же светимостей.

The study of compact galaxies and their systems indicates the unusual physical nature of these objects, their major significance to physics and the evolution of galaxies.

Zwicky (1971) was the first to appreciate the importance of compact galaxies and conducted their systematic study. He found out the following regular features:

1. Both blue and quite red objects occur among compact galaxies;
2. Frequently compact galaxies are encountered in pairs, triplets, etc.;
3. Clusters of compact galaxies exist; they consist of at least several dozen objects most of which are described as quite red. Blue objects in those clusters occur very seldom. The dimensions of clusters of compact galaxies are comparable to those of usual clusters of galaxies.

The significant investigation of Robinson and Wampler (1973), gave a new impetus to the research of compact galaxies; they showed that cluster Shahbazian 1 discovered in Byurakan (Shahbazian, 1957) is a distant compact cluster of compact galaxies possessing quite unusual properties.

This has led Arp, Burbidge and Jones (1973) to consider it as a unique in characteristic features of clusters of galaxies. In fact, the Palomar Atlas contains no other group of galaxies that might equal or excel the group Shahbazian 1 simultaneously in number of members, in its compactness and the compactness of the members of the group.

However, the group Shahbazian 1 can also be regarded as the extreme representative of a broader class of groups of compact galaxies, groups of compact galaxies which are poorer as to the number of their members or groups richer yet less compact. Such an approach to the problem of the existence of compact groups of compact galaxies proved to be quite fruitful.

Compactness is the principal characteristic of galaxies - members of compact groups under review. Therefore, to distinguish compact galaxies and their groups from the totality of all the galaxies one must be equipped, foremost of all, with definite practical criteria in order to assign the galaxies to the compact type. In other words, one must have a definite criterion of compactness.

Zwicky was quite right in suggesting to conside the high average surface brightness as a criterion of compactness of galaxies. The great value of this quantity in fact characterizes somewhat the "excited" state of the galaxies producing an unusually high surface brightness of compact galaxies.

The experience of studying compact galaxies has led to the conclusion (Ambartsumian et al., 1975), that as a correction for this definition of compactness offered by Zwicky, it is convenient to consider compact those galaxies the average surface brightness of which in the red is higher

than 20^m from the square second of arc.

An examination of the maps of the Palomar Sky Survey has shown that a considerable number of compact groups of compact galaxies exist, made up of a small number (of the order of one dozen) of members. Most of the members of those groups satisfy the specified condition of compactness.

On the other hand, in accordance with the data of de Vaucouleurs' Catalogue (1964) only 1/25 part of all the galaxies possesses the average surface brightness in the red above $20^m/_\square$ i.e. are compact (Ambartsumian et al., 1975). Therefore there are no doubts that the great majority of the observed compact groups of compact galaxies are real physical systems and not the random result of projection. Most galaxies of these groups possess red magnitudes in the interval $17^m.5 - 18^m.5$. Saturation of the images on the maps of the Palomar survey is for them a sufficient condition to be compact, as has been shown (Ambartsumian et al., 1975).

Spectroscopic observations of the group Shahbazian 78 (Ambartsumian et al., 1975;Mirzoyan et al., 1975) have shown that its brightest members are stars, while on the photograph of the group Shahbazian 129 obtained with the 5-m telescope (Ambartsumian et al., 1975) of the Palomar Observatory, all the objects have star-like images. Only the spectroscopic observations of this group enable us to determine its true nature. Those data attest that an insignificant number of groups, consisting of stars or casual groupings of galactic stars and galaxies may occur in the published lists of compact galaxies (Shahbazian, 1975; Shahbazian and Petrosian, 1974; Petrosian, 1974, Baier et al., 1974; Baier and Tiersch, 1975). However, most of those groups are undoubtedly real physical systems, consisting of compact and some non-compact galaxies. Naturally, objects projected on those groups are likely to be included in the lists of the members of compact groups.,(Shahbazian, 1975; Shahbazian and Petrosian, 1974; Petrosian, 1974; Baier et al., 1974; Baier and Tiersch, 1975).

Over 250 systems (Shahbazian, 1975; Shahbazian and Petrosian, 1974; Petrosian, 1974; Baier et al., 1974; Baier and Tiersch, 1975), have so far been included in the lists of compact groups of compact galaxies, compiled by the astronomers of the Byurakan Astrophysical Observatory of the Academy of Sciences and the Central Institute of Astrophysics of the Academy of Sciences of the GDR. Clearly, the total number of compact groups of compact galaxies up to the limit of the Palomar Atlas all over the sky must be considerably larger: of the order of one thousand.

The group Shahbazian 1 (Robinson and Wampler, 1973; Shahbazian, 1957) containing at least 20 galaxies, is a relatively rich group of compact galaxies. The linear diameter of this group is of the order of 200-300 thousand parsecs (Robinson and Wampler, 1973; Ambartsumian et al.,1975). Some of the members of the group are quite compact.

Croups more compact than Shahbazian 1 are met among compact groups of compact galaxies included in the lists, however, most of them are less compact.

Spectroscopic observations of the compact group Shahbazian 1 (Robinson and Wampler,1973) as well as of the brightest galaxies of the compact group Shahbazian 123 (Mirzoyan et al., 1975) testify to a very small dispersion of radial velocities in those systems as compared to other groups of non-compact objects. Although, as the observations of Lynds and Khachikian of the group Shahbazian 4 (Lynds and Khachikian,private) have shown, the small dispersion of radial velocities is not a property characteristic of all compact groups of compact galaxies, yet the presence between those groups of systems with small dispersion of galaxies is a highly important property for this class.

As distinct from the case of great dispersion of radial velocities, when a strong violation of the virial theorem cannot be excluded, such great violation is ruled out in this case. Worded differently, even in case of instability of the system the velocity dispersion cannot be many times less than the virial one., if we have not caught the system right in time of the beginning of the collapse. The latter is, of course, unlikely. Therefore the value of the mass of the system derived from the virial theorem should be taken as close to the reality. This leads to a very low value (of the order of unity and less) of the ratio mass to luminosity - M/L. In this way it turns out that at least several members of the compact groups of compact galaxies differ by their nature from ordinary galaxies of the same luminosities.

Supposing that red compact galaxies consist of a physically homogeneous class of objects, it should be assumed that even in cases when the dispersion of radial velocities in the group is large, for instance in the group Shahbazian 4 (Lynds and Khachikian, private), the ratio M/L is of equally small value. The large dispersion of radial velocities can in this case be accounted for by the violation of the stability of the system.

It is to be noted in connection with the problem under consideration that the data on the rotation of compact galaxies 1 Zw 129 and 11 Zw 70 confirm the small value of the ratio M/L (O'Connel and Kraft, 1972). In particular, for the compact galaxy I Zw 129 this ratio is estimated equal to 0.18 (O'Connel and Kraft, 1972). On the other hand, it is well known that for normal galaxies this ratio is equal to several unities or considerably more. According to the investigation by O'Connell and Kraft (1972), the small value of the ratio M/L and the observed energy distribution in the spectrum of galaxy 1 Zw 129 attest that the initial luminosity function of stars formed in it differed substantially from the corresponding function for the vicinity of the Sun. However, as the observations show (O'Connel and Kraft, 1972), kinematically compact galaxy 1 Zw 129 differs but little from normal galaxies.

It should be noted that compact galaxies included in the lists of compact groups, are often very red objects. For instance, according to Börngen and Kalloglian's determination (1974),most of the compact galaxies in the compact groups Shahbazian 17, 18, 41 and 42 have colour indices B-V well surpassing 1. This is not surprising as during the search for compact groups (Shahbazian,1975;Shahbazian and Petrosian,1974;Petrosian,1974;Baier et.al.,1974;Baier and Tiersch, 1975) particular attention was paid to colour and groups were chosen that consisted mainly of objects red in colour.

However, the existence of blue compact galaxies admits no doubt . From this more general point of view Sargent (1970) believes that compact galaxies, form an extremely unhomogeneous class of objects.

Among the blue compact galaxies are known, for instance, (1 Zw 17 and 11 Zw 40) for which the ratio mass-luminosity is essentially larger than unity (Sargent and Searle, 1970).

Compact galaxies differ sharply as to the relative content of gas. For instance, the mass of ionized hydrogen in the galaxy 1 Zw 129 by an approximate estimation comes to 0.07 of its total mass (O'Connell, Kraft , 1972) while its portion in the galaxies I Zw 17 and II Zw 40 is at least of one order less (Sargent and Searle, 1970).

It cannot be excluded that there is some heterogeneity also among red compact galaxies. The unusually high surface brightness of compact galaxies can be due to both uncommonly low values of the ratio mass-luminosity, M/L. and the unusually high concentration of stars in them. Which of these possibilities is realized in each particular case is a matter for special investigation.

Most compact groups of compact galaxies contain non-compact galaxies in their composition as well. However, it is of interest to note that most of the galaxies, at a definite interval of absolute stellar values, are compact in the clusters of compact galaxies especially in Zwicky's clusters of compact galaxies (Zw Cl 0152 +:3337, Zw Cl 1700.5 +:3322, Zw Cl 0054.6-127, Zw Cl 1710.4 +:6401 (Zwicky F. and Zwicky M., 1971). This means that in the above clusters a considerable number of compact galaxies have luminosities close to each other. As a result of which there is a certain maximum in the luminosity function of these galaxies corresponding to the above interval of absolute magnitudes.

Such a distribution of compact galaxies according to their luminosities indicates that the observed state of a compact galaxy can last for an essential portion of the age of the cluster.

Compact galaxies in compact groups are mostly nearly elliptical or spherical in form. Besides, spiral galaxies also occur, though much less in number. However, bright irregular galaxies are presumably lacking in compact groups (Ambartsumian et al., 1975).

The geometrical configurations of the compact groups themselves are of great interest. As distinct from usual groups and clusters of galaxies, the compact groups do not show, for the most part, noticeable concentration toward the center of the system. Less than 10% of all the known groups show signs of concentration. Moreover, low density of galaxies is observed in the central part of some groups. A considerable part of the compact groups are anomalous in form. Chains or systems of chains are frequently met among compact groups of compact galaxies. Of special interest are groups that are nearly closed curves in shape (with a cavity in the middle). We can describe them as groups of peripherical structure.

Those structures are sometimes extremely unusual. For instance, the structure of the group Shahbazian 65 is so much unusual that it calls for some special interpretation. This is not a group but rather a cluster of compact galaxies in the form of the Greek letter "Ω" with a cavity in the center. The cluster of galaxies Shahbazian 65 is certainly at a distance greater than the group Shahbazian 1 and considerably richer than the latter. If we assume, judging by the visible brightnesses of galaxies, that the radial velocity of the group Shahbazian 65 is close to 50,000 km/sec, we shall obtain about 800 Kpc for its diameter. This is appreciably larger than the diameters of the group Shahbazian I. The group Shahbazian 65 excels the group Shahbazian I in other characteristics too (the number of members, mass, etc.).

Most of the compact groups of compact galaxies seem to be well isolated, however we come across cases one can suspect that the group is a kind of nucleus of a larger system, the peripherical part of which consists of considerably weaker galaxies. Calculations of the number of galaxies in consecutive rings surrounding the systems Shahbazian 31, 41 and 84 on plates obtained in the primary focus of the 4-m telescope of the Kitt Peak National Observatory (Ambartsumian et al., 1975), showed a marked decrease in their density, as the distance from their nuclei increased, which definitely indicates the presence of objects connected with the given compact group, in addition to background galaxies. In the case of the groups Shahbazian 34, 35 and 43 this decrease is less pronounced. Thus one can suspect that, at least in some cases, the compact group of compact galaxies is quite a dense nucleus of a larger extended cluster. This question deserves serious attention.

In this connection it is necessary to mention the interpretation of compact groups of compact galaxies given by J.E.Einasto et al., (1974). They consider them as nuclei of what they call giant hypergalaxies - a class of systems which are quite different from clusters of galaxies.

It should be added that the group Anon (Ambartsumian et al., 1975) seems to be the richest among the studied groups of compact galaxies. Group Anon consists of at least two dozen compact galaxies; it has not as yet been entered in the published lists of compact groups of compact galaxies (Shahbazian,1975; Shahbazian and Petrosian, 1974; Petrosian, 1974; Baier et al., 1974; Baier and Tiersch, 1975).

We should like to note in conclusion that the compact groups of compact galaxies form an interesting class of systems of galaxies, and their detailed study can throw light on the physics and evolution of galaxies.

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DISCUSSION

DEUTSCH: Is it not difficult to define the mean surface brightness of compact objects, since the diffusion of light in the photographical emulsion always enlarges the images?

MIRZOYAN: No, the criterion of the mean surface brightness is indeed very useful for the definition of compactness of galaxies. It is, however, quite another question how to define this parameter on photos taken with different telescopes.

GOUGUENHEIM: You mentioned that the red compact galaxies look like elliptical galaxies; but we find from 21-cm line observations at Nançay that their neutral hydrogen content is quite large. How did you determine the masses?

MIRZOYAN: The main difference we have noticed is that the red compact galaxies in compact groups look more spherical than the classical elliptical galaxies. We estimate the masses by the virial theorem, using the practical absence of dispersion in the radial velocities of the galaxies in the compact groups Shahbazian 1 and 123. We also used the data of O'Connel and Kraft from their study of the rotation of two compact galaxies 1Zw 129 and 11Zw 70.