INTRODUCTION

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1. The great majority of galaxies have a density-maximum somewhere near to their centre of inertia. This *region of maximum* density it is convenient to call *the central part* of the given galaxy.

Sometimes in the astronomical literature this *central part* is referred to as the *nucleus* of the galaxy. It is strongly desirable to avoid such ambiguity since it is not this maximum density region with very indefinite borders which we are going to discuss at this study week.

In some nearer galaxies, for example in M 31, M 32, M 33, we see that there is a starlike, or almost starlike, image superposed on this region of maximal density. In many distant galaxies the limits of angular resolution do not allow us to see similar starlike formation. They appear lost in the bright background of the central part. However, in some distant galaxies this superimposed starlike formation has sufficient luminosity to be observed even in the cases when the angular resolution of photographs are moderate ($1'' - 3''$). This is for example the case in Seyfert galaxies. Similar, but less prominent, starlike formation we observe in the photographic images of many other (mostly spiral) galaxies. It is much more convenient to apply the term "nucleus" just to these formations, since they have shown us a number of exceptionally interesting phenomena, the discovery of which affected the whole outlook of modern extragalactic astronomy.

2. The spectroscopic study of the more prominent nuclei shows that there are processes within the nuclei which differ from phenomena taking place in the other parts of galaxies. We are going to speak about these processes a little later. Let us mention here only some of them: the violent motions of gaseous clouds, considerable excess of radiation in the ultra-violet, relatively rapid changes of brightness, expulsion of jets and of condensations.

The presence of one or of several of these processes is described by the word *activity* of the nuclei. Now there are cases when no starlike discrete image is seen at the center of a galaxy, but there are clear signs of the nuclear activity. It is natural to suppose that in such cases a nucleus exists in the galaxy, but its total luminosity in the visible light is so low that its image is not visible owing to the presence of the bright background of the ordinary stellar population. The higher resolution can show us in such cases the presence of the small nucleus.

Nevertheless no sign of a nucleus has been found in some of the *nearest* galaxies. Examples: S M C and the Sculptor System. We can only speculate on the possible presence of the nuclei in the past history of these systems or on the possibility to find now the remnants of what at some time was the nucleus of a galaxy of such type.

At the same time all existing data make it almost certain that all spiral galaxies as well as all ellipticals of high and intermediate luminosity have nuclei of different prominence. Putting it in another way, we can say that almost all galaxies of high and intermediate luminosity have nuclei, but it is possible that a large proportion of dwarf galaxies are deprived of nuclei.

Of course we do not know exactly where lies the boundary between the galaxies with and without a nucleus. Perhaps there is no clearcut border and the difference is only in the luminosity and significance of nuclei of different galaxies. In any case here is a problem for study which is very difficult.

3. It is widely known that there is a great measure of similarity between quasars or QSRSs and active galactic nuclei. It is known also that parallel to QSRSs, which are comparatively rare objects, we observe optical QSOs. According to Dr SANDAGE and his collaborators the number of QSOs of *a given apparent magnitude* is more than a hundred times larger than the number of quasars of the same apparent magnitude.

The ratio is much higher when we take the corresponding spatial *concentrations* (densities) of the same objects. We know that quasars have optical (photographic) luminosities between —24 and —26 absolute. The QSOs have apparently a somewhat larger dispersion of luminosities and their mean luminosity must be of the order of —23. This makes it very probable that the spatial density of QSOs is more than one thousand times higher than that of quasars. This means that the optical QSOs are in some respects much more important than quasars. We can formulate the situation in the following way:

The QSOs have considerable dispersion of luminosities. The most luminous of them are emitting also intense radio-frequency radiation and are known as Quasars.

Such a large population of QSOs in the universe is an evidence against their short life time. It seems to me that the assumption that QSOs live in the average a time shorter than 10^9 years is connected with many difficulties. However, if we consider the state of quasars as a special active phase in the evolution of QSOs then it is possible to suppose that the total duration of such phase is much shorter (of the order of 10^7 years - 10^8 years, but hardly less).

For a QSO or a quasar of high luminosity ($M_M = -25$) such a long lifetime means that the total amount of energy emitted in the form of electromagnetic radiation including the strong infrared radiation must be of the order of 10^{63} ergs, which quantity is equivalent to about $5 \cdot 10^{8}$ $M_{\odot}$. It is true that we can suppose that the lifetime of very *high luminosity QSOs* is shorter than 10^{9} years, but even in the case of objects with $M_{M} = -22.5$ the problem of the energy sources seems very difficult.

4. One of the most important things to be done in the studies of active nuclei and of QSOs is to find the connection between the different forms of activity.

It is true that the study of radio-galaxies has opened the way to discovery of the phenomena we are now discussing, but it is now clear that the radio-sources form only a small part both of galaxies with active nuclei and of QSOs. In any case this is the case when we speak about strong radio-sources. It is quite possible that all active nuclei emit something in radio-frequencies, but apparently we are not able to detect such weak sources.

Much more widespread among nuclei of galaxies is the activity in the form of presence of ultraviolet excess radiation of non-thermal and *non-stellar origin* and the presence of emission lines. Since in almost all cases the strong emission lines originate by mean of fluorescence processes similar to that in gaseous nebulae of our own galaxy it is possible to concentrate our attention on the continuous emission in the ultraviolet. In the case of QSOs, owing to very large redshifts the presence of ultraviolet excess is quite clear. However, for the majority of galaxies the total radiation of the nucleus (both absolutely and apparently) is weak and only a small part of galaxies shows an ultraviolet excess coming from the nucleus. A careful search of galaxies with bright ultraviolet continuum covering several thousands of square degrees has been made at Burakan Observatory. As a result it has been found that about 2% of galaxies in the interval of apparent magnitudes 13.5 and 17.5 have comparatively bright ultraviolet continuum. About 400 of such "ultraviolet" galaxies have been already found by

MARKARJAN and three lists comprising 300 galaxies with u.v. excess are already published. About one hundred galaxies of these lists were already observed by different observers (KHATCHIKJAN, WEEDMAN, SARGENT, ARAKELJAN, DIBAJ, ESIPOV) and it is now clear that not less than 80% of MARKARJAN's galaxies have strong emission lines. Thus the observations support the idea that the strong emission lines are strongly correlated wtih u.v. excess.

Now there is every reason to believe that the excess observed in the near-ultraviolet of these galaxies expands to the far-ultraviolet, as in the case of QSOs and that there exists a maximum of spectral distribution when we consider the intensities in wavelength scale [I (λ)]. Let us connect this fact with the observations of galaxies made by orbiting astronomical observations launched by American astronomers. They have indicated that some normal galaxies (for example M 31) show an increase of intensity to the far ultraviolet, which suggests a maximum of intensity beyond 2000Å. Apparently we may guess that the nuclear region of every galaxy is a source of non-thermal and non-stellar radiation, which has its maximum in the far ultraviolet. What we observe from the earth's surface is only a relatively faint wing of this radiation. In the cases when the excess is *large* (as in the case of Seyfert or of some N galaxies) *we can* distinguish this wing. However, in the majority of cases the u.v. excess is faint and its near-ultraviolet wing is still fainter and we cannot detect it.

If this extrapolation is valid, we may suppose that all nuclei emit this kind of u.v. radiation, but in galaxies with active nuclei such emission is much more intense. It seems therefore that the observation of radiation of nuclei in the far ultraviolet is becoming very important for understanding the activity of nuclei.

All these questions are connected with the problem of low-level activity of the nuclei of normal galaxies. But even in normal galaxies we have apparently from time to time violent events. The Dutch astronomers have shown recently from

21 cm observations that there are outward motions of some isolated clouds diverted from the nucleus of our Galaxy at a considerable angle to the plane of galaxies.

As regards the source of ultraviolet radiation there is no doubt that this continuum usually comes from a source of small diameter (less than 10^{17} cm) and very characteristic irregular variations are evidence in favour of this. How can we explain these variations? If the mechanism of radiation is of synchrotron nature, then probably the variations of radiation intensity are caused by variation in the flow of particles which are ejected from a central body which has a still smaller volume.

The infrared emission represents another form of activity of some nuclei, however a very important form. There are evidences that dust is present in the nuclei some of the galaxies of Markarjan, but it is not the real cause of infrared emission.

5. Another form of the nuclear activity is the ejection of gaseous clouds. In the case of less active nuclei we have apparently steady outflow of matter from the nucleus. We have some possibilities to estimate the loss of mass by active nuclei.

In the case of NGC 4151 ANDERSON and KRAFT (*Ap. J. 158*, 859, 1969) have calculated that the loss of mass is somewhere between 10 and 1000 $M_\odot$ per year. If we suppose the duration of the Seyfert phase to be $5 \cdot 10^7$ years and take the lower value for the loss per year, we obtain the total loss of the order of $5 \cdot 10^8\ M_\odot$. Thus the activity must be connected with great changes in the state of the nucleus.

Another example is NGC 1275. Apparently the giant filamentary gaseous structure which we observe in this galaxy has a mass of the order of several times $10^8\ M_\odot$.

Thus the outflow of gas from nuclei, either in the form of clouds or of shells, indicates essential evolutionary changes in the masses of nuclei. At the same time we must suppose that in the initial stage of evolution the mass of the active nucleus forms a considerable part of the mass of the whole galaxy.

We can only guess about the further history of the gases.

Where the motions are extremely violent (more than 1000 km/sec) the galaxy loses these gases. In the case of low velocity of outflow from the nucleus the gases can form some system of clouds around the nucleus.

Perhaps the constant escape of mass from such galaxies as NGC 4151 and Markarjan 9 is the cause of the extreme faintness of the envelope surrounding the nuclei of these galaxies.

As you know, the Seyfert galaxies were defined as a class of objects in which the permitted lines have much larger width than the forbidden lines (especially N_1 and N_2). However, it is necessary to say that, if the emission line spectra of Seyfert galaxies are to be explained as the radiation of many gaseous clouds expelled from the nucleus, then the spectral property just mentioned means only that a considerable part of the emission line radiation comes from clouds of small masses. The expanding cloud of small mass can give an appreciable amount of radiation only when it is dense, since the luminosity is proportional to M^2/V.

But at high density and small volume it cannot radiate the forbidden lines. When however, owing to the expansion, the density diminishes, the total radiation is too faint to be observable. Thus in such clouds we do not see any forbidden lines. The opposite is true for the clouds of high masses. When we have only clouds of large mass then we shall observe for a considerable length of time both the permitted and forbidden lines. Now everything depends on the velocity of expansion of these large clouds. If they have low velocity of escape, they produce narrow forbidden lines. If their expansion velocity is high we must observe wide forbidden lines. Now it is important that *there is a group of galaxies which show both the permitted and forbidden lines equally widened.* Examples are Markarjan 3, 6 and 39. But this is exactly opposite to what we have in the case of Seyfert type spectra. At the same time the physical causes are the same. Only the values of the masses of the clouds are different. Thus many other galaxies have active nuclei of the same kind as the nuclei of Seyfert galaxies.

Sometimes one speaks of the spiral structure of Seyfert galaxies. It seems to me that this property is not essential to them. More important from the point of view of morphology is the prominence of the nucleus. We can notice that many galaxies with Seyfert spectra are similar in their structure to N galaxies introduced by Professor MORGAN. Therefore it seems that it is more appropriate to discuss their morphology in connection with morphological properties exhibited by N galaxies. Professor MORGAN has some important new ideas on this matter and I hope that he will tell us more on this matter later. But in this connection I would like to dwell only on one point which has been emphasised by MARKARJAN and ARAKELJAN recently.

In his survey of uv galaxies MARKARJAN has divided all uv objects in two classes. First, s-galaxies which are strongly concentrated objects of spheroidal form, which have a spectral distribution like QSOs, and the second the d-objects which have diffuse borders, where the emission lines are radiated from a large volume of corresponding galaxies.

The redshifts of 42 CS objects (concentrated, spheroidal) are known at this stage, but only for 25 objects have the photoelectric measurements been made. Therefore only for them we can determine more or less reliable absolute magnitudes.

For the mean absolute magnitude and colour of CSOs MARKARJAN and ARAKELJAN give $M_B = -19.2$, $B-V = +0.57$, $U-B = -0.28$ compared with mean values which have been obtained from published data on N galaxies $M_B = -21$, $B-V = +0.9$, $U-B = -0.27$.

The s-galaxies of MARKARJAN, though generally much nearer to us than N galaxies, as a rule were not observed as radio sources.

Therefore we can say that the CSOs of MARKARJAN form together with N galaxies one major class of objects. The optically most luminous of these objects often are radio galaxies.

[1] I - *Ambartsumian* - p. 8

The number of CSOs in a given volume is several hundred times larger than the number of N galaxies.

We have the same situation in the case of QSOs and QSRs, and D – E galaxies and corresponding radio sources.

6. *Radio-frequency emission.* Here we have one of the most important problems. We understand that a strong radio-frequency emission is always connected with the activity of nuclei. But the type of connection between the activity of nuclei and of radio-frequency emission must be different in different cases.

Apparently in the case of Quasars and of N galaxies the connection is a direct one since the optical radiation in these cases is the radiation coming from the nucleus. However, in the case of D or E radio galaxies, in which in many cases the radio emission comes from the clouds of relativistic gas situated outside the galaxy and the optical luminosity is caused by the light of the stellar population, the connection is indirect and the explanation is to be found in the deep connection between the nucleus and the stellar population of the whole galaxy. Every theory which explains the activity of the nuclei and the origin of radio galaxies must explain also these simple facts.

Another important question is connected with the process of formation of clouds of relativistic electrons. The models supposing that the clouds were ejected directly from the nucleus meet some difficulties. It is much easier to suppose that the clouds have been formed by coherent bodies ejected from the nucleus. In this case we must assume that each of these ejected bodies behaves as an active centre, radiating the relativistic electrons. Here is a challenge for theoreticians.

7. *Dense bodies ejected from nuclei.* On several occasions I had the opportunity to speak on jets originating in the nuclei of some giant galaxies. The galaxy NGC 4486 is only one example. The jets in NGC 3561 and IC 1182 are similar in form but consist mainly of classical gas. The condensations

in these jets have bright ultraviolet excess and emission lines. In this respect they behave like compact galaxies with active nuclei. There are some other condensations of this type, which differ from these examples only by absence of the jet which connects the condensation with the nucleus of the primary galaxies. Some of them show spectra similar to that of condensation in the jets of the above mentioned galaxies.

It is possible to argue that we have no direct evidence that these objects (condensations) are of the same nature as active nuclei of galaxies. But it seems that such an argument is not very strong. If we observe a star, which has the same spectral properties as the Sun, we easily assume that such a star is a body of the same kind as the Sun.

Therefore we must consider it very probable that these small blue objects have at least some (if not all) properties of active nuclei of galaxies.

From what we know about the activity of nuclei one thing is clear, that the nucleus can develop around itself a gaseous envelope. In the case of our Galaxy we are almost certain that the interstellar gas enriches itself by the flow coming from the nucleus of the Galaxy. Therefore it is quite natural that we observe in these condensations the emission lines.

Thus we reach the idea of fragmentation of nuclei and formation of new galaxies.

8. In order to explain the inconsistently large masses of galaxies, which we obtain by applying the virial theorem to clusters and groups of galaxies, the suggestion was made that the clusters of galaxies originate by means of successive fragmentation of some initial body and that the corresponding clusters and groups are systems of positive energy. During 15 years that elapsed after this suggestion several attempts have been made to introduce into the clusters some hypothetical quantities of matter (for example neutral hydrogen). However, these attempts were not very successful. Therefore, the sug-

gestion remains as it was put forward originally. I have nothing to add to the original arguments except the fact that both fragmentation concept and idea on the activity of nuclei were closely connected and now, when the second concept is confirmed by direct observation, it is the time to discuss the fragmentation concept very carefully.

But if we ascribe to the activity of nuclei some kind of universality I think we must admit that each galaxy builds around its nucleus owing to the activity of the latter.

In this case the formation of globular clusters and generally of the type II population is one of the kinds of nuclear activity. The same we can suppose on the origin of spiral arms.

I would like to emphasise here that now the risk connected with such a hypothesis is much less than when we had no idea about the energetics of nuclei. Really the kinetic energy of motion of all stars in a galactic system is of the order of 10^{59} ergs, while we know already sometimes energies by one or two orders of magnitude higher are released from the nuclei.

9. Of course, what we observe is only a number of external manifestations of the activity of some massive bodies which lie hidden in the very centrum of the nucleus. The long duration of active processes in nuclei make it quite clear that no processes of collapse or accretion can explain such a continuous activity.

At the present stage we know almost nothing about these central bodies. The only thing which is certain is that they are capable of producing very large amounts of energy both in the form of discrete portions and of continuous flow.

These bodies are apparently unstable, they change their physical state easily, but at the same time persist during a very long time. They eject sometimes great masses of the order of $10^8\ M_\odot$ but after such ejection continue their activity perhaps in a less pronounced way. These central bodies of nuclei of galaxies and of QSOs represent a challenge to theoreticians.

10. As usually happens in astronomy when great new discoveries are made, the theoreticians try to give the explanation of new facts almost immediately. However this time we deal with very complex phenomena. It is even difficult to understand what is going on in the external parts of a nucleus which are transparent and open to our observations. Therefore, some patience is necessary.

At this stage we shall try to undestand better the external manifestation of the activity of nuclei and to obtain a correct general picture of the processes under consideration. Only then will come the second stage when the theoreticians will give the explanation of the deep processes and of the physics of energy generation.

To make the first stage shorter we must put the emphasis on the observations and on the systematization of the results of observations.

The systematization and classification of objects is as important as the classification of relations we discover between different facts and forms of activity.

Nature is endlessly more complicated and diverse than it seems to us, who until recently had no information on these wonderful processes. Let us study them with patience and base our conclusions mainly on the observational data.

DISCUSSION

Chairman: D. J. K. O'CONNELL

MORGAN

I should like to second the remark of Prof. AMBARTSUMIAN concerning the need to select a single point of view — a criterion of classification with the greatest prospect of significance. Then the preliminary classification should be carried through without being diverted by other spectacular phenomena.

LOW

I would like to make a comment about the strength of the ultraviolet continunm. In trying to make models of the infrared phenomenon the problem is to suppress the ultraviolet. There is no difficulty in building a model of the infrared phenomenon phenomenon the problem is to suppress the ultraviolet. There is difficult to make the IR without producing more high energy radiation than is observed.

OSTERBROCK

In connection with the ultraviolet continuum observations of galaxies, I should like to say that I discussed them specifically before this meeting with my colleagues at the University of Wisconsin, who made the Orbiting Astronomical Observatory measurements. Their first material on M 31 seemed to show a very strong ultraviolet excess. However, the data at that time were not completely reduced. It now seems that the *UV* excess is not quite as large as it first appeared. On the other hand, the data continue to show a *UV* excess for the center of M 31, in the sense that between 3000Å and 2000Å there is considerably more radiation than from main-sequence type stars with the same spectral type or *B-V* colour index. The complete reduction in absolute energy units is not yet complete.

OORT

Prof. AMBARTSUMIAN spoke about the possibility of making a whole galaxy from a nucleus by eruption. There is one great difficulty, which is to get angular momentum. Angular momentum is such a characteristic thing everywhere in the universe, especially for spiral galaxies, that to me this forms a very great difficulty.

AMBARTSUMIAN

On the angular momentum which Prof. OORT mentioned: of course, I also keep this problem always in my mind. However, I think that there are many possibilities to explain the angular momentum now observed. Let us consider, for simplicity, how we can have an apparent violation of the law of conservation of momentum. If we have a nucleus from which two jets of equal mass and velocity are being ejected in opposite directions, in this case the nucleus will not change its velocity. But if one of the jets consists of material which, for some reason, will remain long in the condensed form, and the material of the second jet will easily disperse after some time, we shall have only one remaining jet and we shall have an *apparent* violation of the momentum law.

For example, in the case where a nucleus is drawn out into a jet which gives a dense visible condensation, we would expect that the nucleus itself would receive an impulse in the opposite direction. But there may be a diffuse undetected ejection in the opposite direction which carries away this impulse. So it is possible to imagine cases where there is an apparent violation of

[1] I - *Ambartsumian* - p. 14

angular momentum but where there is some unknown compensation. The observations of ARP suggest something of this kind.

OORT

But not angular momentum?

AMBARTSUMIAN

It is easy to build an example of the same type, leading to the apparent violation of angular momentum. I agree that what I have said is not a real explanation. The situation is dark but there are many possibilities.

OORT

I agree that often quite unexpectedly things which we cannot imagine have turned up.

E. M. BURBIDGE

I worried a lot about this angular momentum problem also, because in some ordinary spiral galaxies when one measures the rotation in the outer parts one finds that a lot of the angular momentum resides in the outer part. I wondered if outflow from the nucleus might not be combined with the acquisition of material from outside the galaxies; perhaps the infall of the material coming in an asymmetrical way, or with a small effective rotation far out, could provide angular momentum.

OORT

It would need a lot of matter, the velocities of which would have to be beautifully oriented.

HOYLE

I think here one has to distinguish between the spiral galaxies and the elliptical galaxies. Take the spirals first, where we can be fairly sure that angular momentum is involved. To make a system with angular momentum by a process of ejection, a material with essentially zero total angular momentum, it is necessary for separation to occur, with a part of the material retained to form the galaxy and a part being expelled to infinity. Then there is conservation of angular momentum, with a plus for what stays and a minus for what goes away, making a zero total.

[1] I - *Ambartsumian* - p. 16

II.

OBSERVATIONS AND THEIR INTERPRETATION