10. VARIABLE STARS AND PROBLEMS OF GENERAL STRUCTURE OF GALAXIES

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The general structure of the galaxies is extremely diverse and can be described by Hubble's classification only in the first approximation. In fact, the differences in the distribution of gas and dust in some galaxies which have been established recently, the evident dissimilarity of the intensity of the radio emission in individual galaxies, as well as other facts, suggest definite differences even among galaxies belonging to the same type according to Hubble. Hubble's classification gives a sufficiently exhaustive description of the diversity of the optical forms of galaxies and unites them in a single sequence, which, in the case of spirals, branches into two parallel sequences (ordinary and barred spirals). The interpretation of Hubble's sequence as an evolutionary one became rather popular. In this case usually either the Eo form is considered as the initial stage (Jeans, Hubble) or, conversely, the irregular galaxies and late spirals are considered as the initial stage with the elliptical galaxies being the late stage of evolution (Shapley and many others).

There is no definite evidence in favour of either of these two opposite hypotheses. Moreover, there is no reliable evidence in favour of the statement that Hubble's sequence is an evolutionary one. In fact, every galaxy observed at present, as well as every other cosmic body or system of such bodies, is the result of various initial conditions and of their evolution under the action both of the internal laws and the inevitable influence of the surrounding medium. There are no reasons to suggest (and such reasons cannot exist) that all the galaxies were formed at the same time in some remote epoch and that the great variety in their properties might be explained by only the differences in their initial conditions. At the same time, there are no solid arguments that the Hubble classification of a galaxy is a simple function of its age.

The problem of the origin of the general structure of galaxies could be solved if we had some means of dividing the influence of the initial conditions from that of conditions created during the process of evolution. It is necessary to search for indicators which permit such a division. Apparently, the variable stars which are so typical for the various galaxies and stellar systems may be among such indicators.

The variable stars may be called *marked stars* since nature itself has made them easily distinguishable from the majority of other stars. Simple methods of investigation permit a fine morphological classification of variable stars. Therefore, it is easy to establish the relationship between the general structure of galaxies and the existence of variable stars of different types or of different morphological properties. We are now beginning to discover the first relationships between the general structure of galaxies and the properties of variable stars. The aim of the present short communication is to recall some facts already known and to invite the astronomers of the whole world to carry out detailed studies of the morphological properties of variable stars in different parts of the complex galaxies similar to our Galaxy, in the large Andromeda nebula, and also in other galaxies.

That long-period Cepheids are typical of the flat component of our galaxy and of other spiral galaxies, and the short-period Cepheids, or RR Lyrae-type stars, of the spherical component of our Galaxy, the elliptical galaxies, and the globular clusters, was known long ago. However, a more detailed investigation showed that long-period Cepheids are found even in the spherical component of our Galaxy. At the same time, the morphological properties of these Cepheids were found to be sharply different from those of the Cepheids belonging to the flat component [1, 2, 3, 4, 5]. Furthermore, long-period Cepheids in globular clusters are similar to the Cepheids in the spherical component of our Galaxy although they possess some individual properties in every globular cluster. A comparison of the morphological properties of the long-period Cepheids in the flat component of our Galaxy with the properties of the Cepheids in the Magellanic Clouds also shows some fine differences between them in spite of the rough similarity which exists. For example, the change from light curves with a clearly outlined hump on the descending branch to light curves in which a hump on the ascending branch is seen, takes place at periods from 9 to 10 days in long-period Cepheids in the flat component of the Galaxy, whereas in the Magellanic Clouds this change occurs in Cepheids with periods from 11 to 12 days. Such small but definite differences are observed in every isolated stellar system. Perhaps these slight differences depend on small variations in the initial conditions during the process of formation of each stellar system. Besides, in such an extremely complicated system as our Galaxy, the long-period Cepheids of even the flat component are heterogeneous and apparently might be divided into several sequences [6]. The same comments also refer to the short-period Cepheids (RR Lyrae stars).

Of extreme importance in the study of the general structure of galaxies is the question of the zero-point of the period-luminosity relation for Cepheids. Indeed, our ideas about the dimensions, densities, and other important characteristics of different galaxies depend upon the correct answer to this question. Fascinated by the similarity of the period-luminosity relation in the most diverse stellar systems, astronomers sometimes assumed that this relation was the same for the whole universe. However, Baade showed convincingly that the long-period Cepheids in the flat component of our Galaxy are at least one and a half stellar magnitudes brighter than the long-period Cepheids in the spherical component [7]. But it would be premature to support Baade's widely shared opinion that all long-period Cepheids are one and a half or even two magnitudes brighter than the magnitudes obtained by H. Shapley. A detailed study of this question shows that there exists a close relationship between the absolute magnitudes of the Cepheids and their morphological properties. As the data at our disposal testify to an extreme diversity of the morphological properties of variable stars of the same type from one stellar system to another and from one part of a complex system to others, it obviously may be stated with certainty that there are numerous zero-points for the period-luminosity relation for the long-period Cepheids [8].

H. Arp's valuable investigation of the long-period Cepheids in globular clusters [9] speaks most convincingly in favour of the plurality of zero points for the period-luminosity relation for the long-period Cepheids. Further, the study by H. Arp confirms the suggestion of a relationship between the morphological properties of the Cepheids and their absolute magnitudes. The study of these relationships will solve the zero-point problem.

The same may also be said about the RR Lyrae stars. Their median absolute magnitude is constant only for a given stellar system, but is not the same for different systems. As is known, W. Baum's remarkable study of the colour-magnitude diagrams of a number of globular star clusters [10] led him to contradictory results. If the same absolute magnitude is assumed for all the RR Lyrae stars, the absolute magnitudes of the stars in the dwarf sequences in these clusters diverge by more than two magnitudes. On the other hand, if these sequences are superimposed, the absolute magnitudes of the RR Lyrae stars will diverge by more than two stellar magnitudes. Such a contradiction is only apparent. W. Baum solves it with the proposition that we do not find in a globular cluster a main sequence typical of that in the solar neighbourhood, but a sub-dwarf sequence which differs for every cluster. It was definitely suggested in 1949 ([2], p. 181) that in the case of globular clusters we are dealing with sub-dwarf sequences. However, we cannot require tens of thousands of sub-dwarfs in various globular clusters to show systematical differences from one cluster to another while for some reason the properties of the RR Lyrae stars are just the same. But, in reality, the RR Lyrae stars in different globular clusters are different in absolute magnitude. It is interesting to notice that the morphological properties of the RR Lyrae stars change appreciably from one cluster to another. Thus, in the case of the globular clusters, the sub-dwarf sequences should not be superimposed; but, equally, we must not expect that the absolute magnitudes of the RR Lyrae stars should be the same in different clusters. The relationship between the absolute magnitudes of the RR Lyrae stars and their morphological properties should be established. The best method of investigating that question would be a study of the RR Lyrae stars in the globular clusters in the galaxy M 31, when they become accessible.

After a comparison of the existence of variable stars in individual galaxies and other stellar systems, it was stated that there is a definite connexion between the general structure of a given stellar system and the existence in it of certain types of variable stars. Thus, long-period Cepheids are typical of late spirals (the flat component of our Galaxy, M 31, M 33, both Magellanic Clouds); in the spherical component of the spiral systems, the short-period Cepheids are typical, and so forth. Novae are very typical of our Galaxy and M 31, but are much less frequent in the developed spirals like M 33 and in developed barred spirals (Magellanic Clouds). In some galaxies, hot, non-stable (variable) super-giants are typical; in others, we find variable super-giants of type F.

Our Galaxy is extremely rich in variable stars of the Mira Ceti type, while the Magellanic Clouds are poor in them. Mira Ceti type variables in the Clouds are sharply different in their morphological properties from stars of that type in our Galaxy. Mira Ceti variables in the flat component of our Galaxy differ decidedly in their morphological properties from stars of the same type in the spherical component of our Galaxy.

The morphological properties of RR Lyrae type stars in the nucleus of our Galaxy are sharply different from the properties of these stars in the solar surroundings [11].

A great number of such examples might be given. They will considerably increase in the future, as soon as such examples reflect the relationships actually existing in nature. There is every reason to suggest that the existence of variable stars of a given type in a stellar system is connected with the age of that system (see also my communication to the Symposium on non-stable stars [12]).

The promising problem which stands before us is to study in detail the morphological properties of variable stars in different galaxies and to define the relationships outlined between them and the general structure of the galaxies. Undoubtedly, a thorough study of these relationships will be a great help in solving the problems of the evolution of galaxies.

REFERENCES

[1] Kukarkin, B. V. *A.J. U.S.S.R.* **24**, 269, 1947.
[2] Kukarkin, B. V. *The Study of the Structure and Evolution of Stellar Systems.* Moscow, 1949.
[3] Kukarkin, B. V. *Erforschung der Struktur und Entwicklung der Sternsysteme.* Berlin, 1954.
[4] Joy, A. *Ap. J.* **110**, 105, 1949.
[5] Kukarkin, B. V. and Kulikovsky, P. G. *Variable Stars*, **8**, 1, 1951.
[6] Eggen, O. *Ap. J.* **113**, 367, 1951.
[7] Baade, W. *Trans. I.A.U.* **8**, 397, 1954.
[8] Kukarkin, B. V. *A.C. U.S.S.R.* no. 155, 1955.
[9] Arp, H. C. *A.J.* **60**, 1, 1955.
[10] Baum, W. A. *A.J.* **59**, 422, 1954.
[11] Gaposchkin, S. *Variable Stars*, **10**, no. 6, 337, 1956.
[12] Kukarkin, B. V. *Non-Stable Stars* (I.A.U. Symposium no. 3, paper 15, 1955), Cambridge, 1957.

Discussion

Baade: Dr Hubble neither stated nor believed that his classification was an evolutionary scheme. It was simply as a manner of speaking that the E-nebulae were called early. Its interpretation as an evolutionary scheme was a complete misunderstanding.

Secondly, I think the paper by Arp has shown that we do not have a unique period-luminosity relation among the population II Cepheids. Although the data are not sufficient yet to show clearly what this means, there is every evidence that there is really a mixture among the stars we call population II Cepheids. In that mixture we can recognize the RV Tau stars already, but we need more observations. Dr Arp is continuing to get data for more globular clusters, which may clear up this point.

The situation of the zero point of the period-luminosity diagram is not too bad. Both classical and cluster-type variables appear in the Magellanic Clouds at the proper apparent magnitudes. Also, all apparent magnitudes which we can observe in the Andromeda nebula seem to be correct, or at least in agreement with, those in our own system.

Kukarkin: I trust that I have never criticized Hubble for giving an evolutionary meaning to his sequence, but only others who have interpreted his work in that way such as, for instance, Jeans.

At least one point is clearly established: there exist two different zero points for the Cepheids. The one for those which belong to the flat component of our Galaxy is 1·5 magnitudes brighter than that for the spherical component. I agree with Dr Baade that the zero point problems should be stated as problems; they should be investigated; they are not yet solved.