IV. INSTABILITY IN THE REGULAR VARIABLES OF LATER TYPE

https://doi.org/10.1017/S0074180900018696 Published online by Cambridge University Press

15. VARIABLE STARS AND PROBLEMS OF STELLAR FORMATION

B. V. KUKARKIN
Sternberg Astronomical Institute, Moscow, U.S.S.R.

The possibility of discovering phenomenologically similar objects either located in different stellar systems, or in totally different (according to their origin and age) parts of some complex stellar system (as, for instance, our Galaxy) is of extreme importance. The detection of such objects permits us to confirm that, in spite of different initial conditions and evolutionary paths, stars of quite different origin pass in the course of their evolution through the same stages.

Variable stars are such phenomenologically similar objects. They might be called 'marked stars', since it is rather easy to recognize and distinguish them from other stars because of the specific properties of their variability. Mira Ceti type stars are particularly interesting and promising. The large variations of their brightness make their discovery and study extremely simple. Of prime importance is the fact that Mira Ceti type stars are found in most different parts of the Galaxy (in the flat, spherical, and intermediate components) and in isolated systems of various types (as, for example, in globular clusters and the Magellanic Clouds). The stars contained in various galaxies, or in different parts of our Galaxy, are doubtlessly of quite different origin.

The preliminary analysis of the morphological properties of Mira Ceti type stars in different systems and in different components of our Galaxy led to the decisive conclusion that these properties are extremely diverse [1]. Thus, in the Magellanic Clouds the periods of all the Mira Ceti stars exceed 540 days, whereas in globular clusters the periods are less than 310 days. The light curves of the Mira Ceti stars belonging to the flat component of our Galaxy are asymmetrical and have a clearly expressed hump on the ascending branch, while the light curves of stars in the spherical component are symmetrical and only some of them show a slight wave on the ascending branch. Many more examples of this kind might be given.

Similar stages of stellar evolution are observed in different stellar systems and in various parts of complex stellar systems. For every system (or for parts of a complex stellar system) the Mira Ceti stars (as well as variable stars of other types) show slight morphological differences.

The Mira Ceti stars are bolometrically among the brightest stars. The

absolute bolometric magnitude of the Mira Ceti stars exceeds -3, reaching even -7 or -8 for some members. This suggests that the Mira Ceti stars represent quite massive and, therefore, quite young stars.

The Mira Ceti stars show well-known and extensively studied spectroscopic anomalies. Among these anomalies the emission spectrum is the most striking. The intensity of the photospheric radiation which determines the absorption spectrum of the Mira Ceti stars (a temperature of the order of 2500° K. is representative) can by no means produce the emission spectrum. The emission spectrum can be caused, as was convincingly shown by G. A. Shajn [2], only by strong short-wave radiation, the intensity of which must exceed the short-wave radiation of the photosphere by many orders of magnitude. Thus, we meet here with short-wave continuous emission, similar to the continuous emission of other, obviously young stars. The cosmogonical significance of the properties of these latter objects has been discussed by V. A. Ambartsumian [3].

P. Merrill [4] has recently discovered in the spectra of some Mira Ceti variables intense lines of technetium. This discovery suggests that Tc originates directly in the outer layers of the Mira Ceti stars and that, consequently, element formation is going on in these layers. Either in the Mira Ceti stars there are conditions particularly favourable for element formation, or the Mira Ceti stars themselves are very young and still in 'the making'. The latter supposition seems to be the most probable.

The apparent distribution of Mira Ceti stars on the celestial sphere is characterized by the existence of real groups and clusters. These visible groups are the reflexion of the actual spatial clustering. The peculiar tendency to form spatial nests is a typical feature of Mira Ceti stars located in the galactic plane and of those located in high galactic latitudes. Taking into account the velocity dispersion of the Mira Ceti stars, it may be shown that the observed groups cannot be of a long duration. This suggests, in its turn, the youth of the Mira Ceti stars.

The above facts testify that the process of star formation is going on not only in the spiral arms of galaxies, but also in stellar systems that many authors are inclined to consider 'quite old' and deprived of their powers of star formation.

Numerous proofs have been obtained during recent years which show that in different stellar systems and in various parts of complex stellar systems, like our Galaxy and M31, variables of the same type possess their own specific morphological properties. Special studies have been devoted to that problem [5, 6, 7, 8].*

* See also Prof. Kukarkin's communication to the I.A.U. Symposium on the Large-Scale Structure of Galaxies, held in Dublin in September, 1955.

These facts suggest that in different parts of the Universe matter passes through phenomenologically similar, but not quite the same, evolutionary stages. If variable stars show slight differences, but are generally quite similar, this may be interpreted as a difference of initial conditions that existed in the stellar system, or in some parts of a complex stellar system. Furthermore, the existence of variable stars of the same type in extremely different stellar systems allows one to believe that the evolution of these systems passes through similar stages: i.e. that their ages are equal.

Variable stars of certain types are apparently young. Thus, the numerous RW Aurigae, or T Tauri, stars form unstable associations and are connected with dark and comet-shaped nebulae [3, 10, 13]. It is evident that in this case we see young stars of recent origin. Semi-regular and irregular super-giant variables also form associations [9, 11].

Important arguments have been put forward in favour of the youth of carbon stars [12] as well. There are reasons to believe that the Mira Ceti stars are also of recent origin [1].

There are no reasons to believe that any variable stars of other types are particularly young. Thus, cepheids do not form associations and are not connected with them. The long-period cepheids are more or less uniformly distributed in the galactic plane, in the nearest spiral systems, and in the Magellanic Clouds. There are no reasons to think that novae, nova-like variables, and red semi-regular variables (not super-giants) are particularly youthful objects.

The existence of both extremely young and older variables permits one to compare their presence with the peculiarities of some stellar systems and their parts. Evidently young stars are met both in spiral arms of the Galaxy and in its spherical component, both in the spiral stellar systems and also in globular clusters and elliptical stellar systems. This permits one to state that the process of star formation is going on not only in the flat, but also in the spherical component of our Galaxy, and in the spiral and the elliptical galaxies.

At the same time in some stellar systems young stars are found, whereas they do not occur in other systems of similar types. It may be concluded that the process of formation of the stellar systems themselves is still going on and that both young and old stars are met in them. If the presence of variables of definite types is actually an extremely certain criterion of the youth of a given stellar system and of the process of stellar formation going on in it, the necessity for a study of the peculiarities of the population in many such systems becomes quite apparent.

The colour-magnitude diagram permits one to characterize the population of a stellar system rather fully and objectively. It is well known that this diagram has a quite different character for the flat and spherical components of our Galaxy. But we also know that the process of stellar formation is going on in both the first and the second components. The above-mentioned sharp difference is, consequently, caused by the dissimilarity of the initial conditions in the formation of stars in these two components.

When studying the peculiarities of the colour-magnitude diagrams for various stellar systems in the same component (for example, for different globular or open clusters), we discover, along with a general likeness, an extreme dissimilarity in their details (as, for example, in passing from one globular cluster to another). Such a dissimilarity is usually connected with the presence or absence of variable stars of different types. For example, the colour-magnitude diagrams for globular clusters that are rich in variables of the RR Lyrae type, differ in detail from such diagrams for clusters containing few RR Lyrae stars. This difference is due mainly to the age and not to the initial conditions. The youth of a star cluster in a galaxy is manifested in the peculiarities of the colour-magnitude diagram, and also in the presence of variable stars of definite types.

From the remarkable study of variable stars in the galactic nucleus by W. Baade and S. Gaposchkin [14] it may be concluded that the lifetime of the RR Lyrae stars cannot be long. Their morphological properties are sharply expressed and entirely different from RR Lyrae stars in the solar neighbourhood. At the same time, owing to the extremely large eccentricities of their orbits they should have attained the solar neighbourhood. Their lifetime is probably much less than the period of one galactic rotation. Thus, this is additional proof that within the nucleus of the Galaxy and on its periphery, stars of different origin enter into a similar stage of evolution.

Further investigations of variable stars contained in different stellar systems are required. It is necessary to compare the presence of variables of different types with the peculiarities of the populations in these stellar systems. We are apparently approaching the solution of the main and most difficult problem of stellar cosmogony—that of a separation of the influence of the initial conditions from the properties acquired in the process of evolution. If we remember the simplicity of the methods of investigation and of the precise classification of variable stars, the course that we should follow and along which our efforts should be directed in the near future becomes quite clear and evident.

REFERENCES

[1] B. V. Kukarkin, *A.J. U.S.S.R.* **31**, 489 (1954).
[2] G. A. Shajn, *Comptes rendus de l'Acad. d. Sci. de l'U.R.S.S., série phys.* **9**, 161 (1945).
[3] V. A. Ambartsumian, *Comm. Burakan Obs.* No. 13 (1954).
[4] P. W. Merrill, *Ap.J.* **116**, 21 (1952).
[5] B. V. Kukarkin, *The Study of the Structure and Evolution of Stellar Systems*, Moscow, 1949.
[6] B. V. Kukarkin, *Erforschung d. Struktur und Entwicklung der Sternsysteme*, Berlin, 1954.
[7] B. V. Kukarkin and P. G. Kulikovsky, *Variable Stars*, **8**, 1 (1951).
[8] A. H. Joy, *Ap.J.* **110**, 105 (1949).
[9] B. V. Kukarkin, *Progress of Astronomical Sciences*, **4**, 183 (1948).
[10] P. N. Kholopov, *Problems of Cosmogony*, v. **1**, p. 195, Moscow, 1952.
[11] V. A. Ambartsumian, *Comptes rendus de l'Acad. d. Sci. de l'Arménie*, **16**, No. 3 (1953).
[12] J. J. Ikaunieks, *Variable Stars*, **8**, 393 (1952).
[13] P. P. Parenago, *Publ. Sternberg Astronomical Inst.*, **25** (1954).
[14] S. Gaposchkin, *Variable Stars*, **10**, No. 6 (1956).