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II. THE MOTIONS, DISTRIBUTION AND RATES OF EVOLUTION OF O-B1 STARS IN STELLAR ASSOCIATIONS

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The most typical members of the O-associations, the O-B1 stars, are young objects (**1, 2**). Due to their high luminosities they are observable in a fairly large volume around the Sun.

These two circumstances arouse great interest in O-B1 stars, in connection with problems on the origin and evolution of stars and stellar systems in our Galaxy as well as from the point of view of studying the local motions of stars in the vicinity of the Sun.

In this report we shall try to present a summary of some results of the study of O-B1 stars relating to the programme of the present Joint Discussion. They have been obtained in recent years at the Byurakan Astrophysical Observatory of the Academy of Sciences of the Armenian SSR.

Motions of O-B1 Stars

It has been shown in paper (**3**) that the *K*-term for the subsystem of O-B1 stars decreases nearly regularly with the mean distance from the Sun and becomes negative at considerable distances. A similar dependence has been found between the *K*-term and the mean absolute magnitude of O-B1 stars. It is clear that these two dependences are correlated, since the proportion of high luminosity stars of a given visible magnitude increases with the distance from the Sun. Therefore, to reveal the nature of the *K*-effect it is necessary to elucidate which of those dependences is the basic one.

An investigation based on an analysis of residual (corrected for galactic rotation) radial velocities of O-B0·5 stars (stellar and interstellar) and classical cepheids has led to the conclusion that such correlation between the *K*-term and the mean distance from the Sun is observed in all three cases (**4**). This fact may be considered as evidence in favour of the dynamic nature of the *K*-effect.

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A more detailed discussion has made it possible to interpret the K-effect, in the first approximation, as resulting from non-stationary (radial) motions of stars with respect to the galactic centre in the vicinity of the Sun, in which the latter takes part itself, in accordance with the results of the investigations of F. Kerr (**5**), P. Pismis (**6**), V. Rubin *et al.* (**7**). In particular, the observed run of the K-term is in full qualitative compliance with the model of expansion of the Galaxy for all three subsystems (O–B0·5 stars, classical cepheids and interstellar gas), at least, in the vicinity of the Sun.

Expansion of Stellar Associations

The phenomenon of expansion of stellar associations was predicted by V. A. Ambartsumian (**1**) based on the idea of dynamic instability of these systems. The real expansion, confirming this prediction, was discovered for the first time by A. Blaauw (**8**) for the association Perseus II, and then by B. E. Markarian (**9**) for the association Cepheus II. Further data on real expansion were obtained for some other associations (**10–14**), too.

Although doubts were voiced regarding individual investigations of this series (for example (**15**)), none the less, the reality of expansion in at least some cases may be considered as established.

The author (**16, 17**) has considered the question of the expansion of stellar associations by means of radial velocities of about 350 O-B0·5 stars (**18**) and the data on O-associations (**19, 20**). According to the theory of stellar associations (**1, 2**) a part of the above stars are, at present, members of stellar associations, while the rest have left the stellar associations comparatively recently and have been absorbed by the general galactic stellar field.

Instead of individual associations, in which the scantiness of stellar population and the occurrence, at times, of several nuclei (centres of expansion) appreciably hinder the study of the internal motions of stars, a synthetic 'association' was made the object of study in the above-mentioned papers. This 'association' comprises a superposition of O-B0·5 subsystems around the nuclei of all the known O-associations.

The basic results of these papers (**16, 17**), which are in full agreement with the concept of the expansion of stellar associations, can be formulated as follows:

1. The dispersion of residual radial velocities in the synthetic 'association' increases with the mean distance from the nucleus—the centre of the system;

2. The observed increase of this dispersion is caused by an increase of the mean peculiar space velocity of stars with respect to the centre of the synthetic 'association' with the distance, which in its turn is due to the expansion and the subsequent disintegration of stellar associations;

3. The stars scatter from the nuclei of stellar associations with different velocities, and the great the velocity of expansion the farther from the nucleus they are located at present;

4. The O-B0·5 stars of the general galactic field have originated in the nuclei of stellar associations and occur in the field owing, as a rule, to their large initial velocities of expansion.

Distribution of O-B1 Stars around the Nuclei of Associations

Depending on the variations of the intensity of star formation in the subsystem of O-associations of the Galaxy, a definite distribution of stars around the centre at every moment of the life of the synthetic 'association' should be observed.

From this point of view, the law of stellar density distribution in the synthetic 'association' may serve as a source of information on the intensity of star formation in stellar associations of the Galaxy and on the rates of stellar evolution in these systems.

Based on observational data (**19, 21**) the law of distribution of O-B1 stars around the nucleus of the synthetic 'association' has been derived (**22**). It turned out that the stellar density distribution may be represented in the first approximation by the law $d(r) \sim r^{-3}$ or, more precisely, by the 'hyperbolic' law

$$(\log d)^2 = (2 \log r - a)^2 - b^2, \tag{1}$$

where $d(\mathrm{r})$ is the stellar density and r the distance from the nucleus in kpc, while a and b are constants.

The space stellar density has been determined by Zeipel's method and the numerical solutions of Abell's equation (**23**) have been used.

The law (1) holds good for the derived values of a and b up to distances of 0·4–0·5 kpc from the nucleus of the synthetic 'association'. This is of the order of the mean half-distance between O-associations in the Galaxy, in the vicinity of the Sun.

A similar study, concerning only the association Perseus I, around the double cluster of h and χ Persei containing a fairly large number of O-B1 stars, has led to results which are not in contradiction with the foregoing results (**24**).

Rates of Evolution of O-B1 Stars

In the stationary case with a continuous formation of stars in the expanding associations, the law of stellar density distribution around the nucleus of the synthetic 'association' is to be of the form (**25**):

$$d(r) \sim r^{-2} \tag{2}$$

The deviation of the observed law (1) from this law is obvious. The law (2) corresponds to the asymptote of the hyperbola (1), and this accounts for the choice of the latter.

It is natural to interpret the observed, monotonously decreasing character of the stellar density distribution around the nucleus of the synthetic 'association', described by the law (2), as the result of the continuous formation of stars in the whole complex of the associations of the Galaxy during the lifetime of recently-formed stellar associations.

Since it is difficult to assume that the intensity of star formation in associations has sharply increased during this period, it is to be believed that the deviation of the observed law (1) from that expected in the stationary case, is related to internal processes within these stars.

It has been shown (**25**) that this deviation is due, on the whole, to the phenomenon of star ageing with increasing distance from the parent nuclei.

Indeed, the law (1) relates to the whole stream of stars from the nucleus of the synthetic 'association', while our discussion is confined only to O-B1 stars, that is, to definite spectral classes. That is why star ageing causing a change in the spectral composition of the stream, diminishes the proportion of the earliest types of stars in the stream.

Of other factors leading to the deviation of the observed law (1) from the expected law (2), mention should be made of the existing dependence of the mean velocity of expansion upon the distance from the nucleus (the gradient of the mean velocity), which is a direct consequence of the continuous scattering of stars from the nuclei of stellar associations with different velocities (**16**). The influence of this phenomenon is estimated to be of minor value.

Thus, the increase of the deviation of the observed law (1) of the density distribution of O-B1 stars from the expected law for the stationary case (2) with the distance from the nucleus describes the rate of the evolution—the ageing of the star stream moving away from the nucleus.

The variation of this stream with the distance from the nucleus is expressed by the function

$$f(r) = d(r)\, r^2\, V(r), \tag{3}$$

where $V(r)$ is the mean velocity of expansion at a distance r from the nucleus. With the help of this function one can estimate the rate of evolution of O-B1 stars and their 'mean age', determined as an interval of time necessary for the ageing of one half of all stars of the given class. The estimates of the 'mean age' have been obtained from the values of the ratio of the length of the path at which the stream $f(r)$ is reduced two times the mean velocity.

For O-B1 stars the estimates obtained for the 'mean age' range from $5 \cdot 2 \times 10^6 - 1 \cdot 0 \times 10^7$ years. They depend but little on the gradient of the velocity of expansion (within the possible limits) and show that the average proportion of the ageing stars is almost the same at different distances from the nucleus.

Owing to this circumstance the observed stellar density distribution and the stream $f(r)$ in the synthetic 'association ' are expressed satisfactorily by the exponential law of star ageing which should be expected in the case of the statistical nature of the ageing process.

This fact has been considered as associated with a large variety of physical characteristics of the stars originating in stellar associations. This in its turn is probably due to a variety in the initial conditions of their formation.

Estimates of the 'mean age' of O-B1 stars based upon the agreement of the exponential ageing law with the observed law (3) range over $1 \cdot 1 – 2 \cdot 1 \times 10^7$ years for the groups of O-B1, O-B0·5 and the Perseus I association stars.

Finally, it has been concluded that the majority of stars are formed in stellar associations in negligible volumes around their nuclei. This inference is based on the observed rate of decrease of stellar density within the synthetic 'association' with the distance from the nucleus.

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