CONTINUOUS FORMATION AND RATES OF DEVELOPMENT OF STARS IN STELLAR ASSOCIATIONS

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Observational data on the distribution of O~B1 stars around the nuclei of stellar associations, represented by the law (1), have been analyzed. It is demonstrated that the deviation of this law from formula (3), which holds for continuous formation and expansion of subsystems around the nuclei of stellar associations, with increasing distance from the nuclei is mainly due to the process of star aging. The influence of an existing radial gradient of the expansion rate on the law of distribution of star density in associations is evaluated.

The aging of O~B1 stars with increasing distance from the nuclei and with time has been studied and the period of half-aging of O~B1 stars, defined as the time interval necessary for the aging of half of all the stars of the classes in question, has been estimated. These estimates fall in the range $5 \times 10^6 - 2 \times 10^7$ years.

It is concluded from the observed regular decrease in star density with increasing distance from the nuclei, which refutes the role of successive fragmentation of prestellar bodies, that stars are formed in extremely small volumes around the nuclei and, finally, that in the first approximation the observed distribution of O~B1 stars around nuclei is satisfactorily represented by an exponential law of star aging, as might be expected in the case of a statistical type of aging process. This is interpreted as the result of the great variety of the physical characteristics of newly forming stars.

The continuing formation of stars of flat and intermediate subsystems of the Galaxy in stellar associations can now be considered established [1, 2]. As a result of the expansion and subsequent decay of associations the stars formed in them later enter the general galactic field. New evidence in support of the concept of the expansion and decay of stellar associations was presented by the author in [3].

This article deals with certain problems involved in the formation and development of O~B1 stars on the basis of observational data on the distribution of these stars in stellar associations.

1. Distribution of stars around nuclei. Depending on temporal changes in the intensity of star formation from the beginning of the star-forming process, at each moment of the life of an association there should be a definite distribution of stars around the nuclei generating them. The law of star distribution around the nuclei of present stellar associations will therefore serve as a source of information on the intensity of star formation in the Galaxy at different periods of the lifetime of the associations and on the rates of development of the stars in these systems.

Since O associations have now been quite well studied, it is convenient to consider this problem with reference to these systems. However, the presence of several nuclei in some O associations complicates the expected distribution of stars in the volumes of these associations. This fact, together with the infrequency of OB stars, the most characteristic members of O associations, makes it quite difficult to determine the law of star distribution around the nuclei of any individual association. The problem is simplified considerably when all the known O associations are considered together.

In a recent study [4] the author used data from [5, 6] to determine the law of distribution of O~B1 stars around the nucleus of a synthetic "association" formed by superposing the O~B1 subsystems around the nuclei of all known O associations.

It was found that the distribution of partial density $d(r)$ of stars of spectral classes O~B1 around the nucleus of the synthetic "association" can be represented in the first approximation by a law $\sim r^{-3}$, but more precisely by a "hyperbolic" law of the form

$$ (\lg d)^2 = (2 \lg r - a)^2 - b^2, $$

where $r$ is the distance from the nucleus, expressed in kiloparsecs, and $a$ and $b$ are constants.

Values of the constants $a$ and $b$ for O~B0.5 and O~B1 stars, determined from the observed distribution of these stars in the synthetic "association" [4], are given in Table 1.

2. Continuous star formation. The observed continuous monotonically decreasing distribution of star density around the nucleus of the synthetic "association" must apparently be regarded as the result of continuous star formation in the Galaxy, or more precisely, in its circumsolar volume for which law (1) was found, with an almost constant mean intensity, at least during the lifetime of present stellar associations. In other words, we assume that the intensity of star forma-
tion in the observed volume of the Galaxy during the last tens of millions of years has remained almost constant for the entire group of O associations, although the process of star formation may not have had a continuous character in all associations. This assumption, therefore, is correct only when applied to the entire group of O associations considered, as a statistical set.

It should be noted that such an explanation of the observed distribution of O-B1 stars around the nuclei of associations will hold only if the concept of the expansion and decay of these systems is correct.

However, if this concept is rejected, the observed picture of the distribution of O-B1 stars in the synthetic "association" can be considered as the result of superposing surrounding subsystems with radii as great as 400–600 parsecs and with partial densities of O-B1 stars decreasing toward the periphery.

Since, in fact, the expansion and subsequent decay of stellar associations is now scarcely in doubt [3] and since there is no evidence in support of the existence of subsystems of O-B1 stars possessing the dimensions described above and at the same time dynamically stable (otherwise they would differ in no way from real associations), the assumption of the continuous formation of stars in the circumsolar volume during the last tens of millions of years of the lifetime of the Galaxy, probably with an almost constant intensity, must be regarded as sound.

It is easy to confirm that the converse is also correct. In other words, if we use as a point of departure the concept of star formation in the group of all observed O associations, we inevitably find that there is a continuous distribution function for the stars around the nucleus of the synthetic "association" which decreases with distance.

In fact, if the Galaxy is considered stationary during the period of decay of one association, the stream of stars from the center of the synthetic "association" must satisfy the steady-state condition:

\[ d(r) r^2 V = \text{const}, \]

where \( V \) is the velocity of withdrawal of the stars from the nuclei.

If the constancy of \( V \) in the synthetic "association" is also assumed, on the basis of (2) we obtain the following law for the total density distribution around the nuclei:

\[ d(r) \sim r^{-2}, \]

which holds for a set of stars of all spectral classes generated by the nuclei.

On the other hand, if it is assumed that the star-forming process has already ceased in the Galaxy, it will be necessary to expect a minimum of this function in the immediate neighborhood of the nuclei. Note that the assumption made above concerning the constancy of \( V \) is not essential to the continuity of the distribution law.

3. Aging of stars and gradient of their velocities of escape from the nuclei. When the study is limited to stars of certain classes, the observed law of distribution of partial star density around the nuclei of associations must be different from the steady-state law (3) owing to the differential influence on star density of the process of star aging with withdrawal from the nucleus. This influence, of course, is manifested in a change in the spectral composition of the stars in the stream due to transition to later spectral classes.

Obviously, the phenomenon of the aging of stars with withdrawal from parent nuclei, especially in the case of O-B1 stars, must lead to the impoverishment of the star stream, that is, to a steeper drop in partial star density with increasing distance than that predicted by the law \( \sim r^{-2} \). This important fact makes it possible to judge the rates of development of OB stars in associations on the basis of the deviation of the observed law of distribution of partial star density in the synthetic "association" from the predicted law for the steady-state case.

However, the process of star aging is not the only factor leading to an increasing deviation of the observed law of distribution of partial star density with increasing distance from the nucleus from the predicted distribution for the steady-state.

There are other factors acting in this same direction. For example, among the nuclei of stellar associations there may be relatively stable systems (multiple stars and star clusters) which do not decay immediately, in terms of the cosmic time scale. For this reason, in the immediate vicinity of the nucleus of the synthetic "association" the star density should first decrease somewhat more slowly and then more rapidly than predicted by the law \( \sim r^{-2} \). Unfortunately, at the present time, the influence of this factor on the star density distribution law in the neighborhood of nuclei is not amenable to even approximate evaluation. However, it can be assumed to be small. This is indicated by the fact that the ob-

* Preliminary results of an investigation based on the approximate law \( d(r) \sim r^{-2} \) were published in [7].