ON THE GROUP FORMATION OF STARS IN STELLAR ASSOCIATIONS

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The discovery and study of stellar associations by Ambartsumian (1947, 1954 a) proved two fundamental points regarding the star formation process, e.g., Mirzoyan, 1976. One of them is that the formation process still continues in the present evolution of the Galaxy, and this thesis is not disputed now. According to the second, stars form as physical groups of multiple stars and star clusters, which become stellar associations during the initial phases of their evolution.

This paper deals with observational data accumulated since the discovery of stellar associations, proving the common origin of the components of stellar systems. The first evidence in its favor was derived from statistics of double stars, before the discovery of stellar associations.

It has been shown (Ambartsumian, 1937), that a double star can form as a result of a two-star encounter, or the close encounter of three independent stars during their motions. A double star system can also split as a result of a close encounter with a third star, and a statistical equilibrium between the formation and decay processes of pairs must be established in time. The available observational data testify to the absence of such a so-called dissociative equilibrium, between the processes of formation and decay of pairs due to close stellar encounters. The observed portion of wide pairs among single stars in the Galaxy is some ten million times less than the portion expected for the dissociative equilibrium. It means that at the present time, the number of wide pair decays in the Galaxy is some ten million times larger than the number of formations due to capture by the close passing of triple stars. It is therefore impossible to explain the formation of all double stars in the Galaxy by the stellar encounter theory.

On the other hand, large values of the angular momentum of double stars relative to their center of gravity, and the absence of strong differences between close and wide pairs, testify against their

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formation due to the division of separate stars (Ambartsumian, 1956).

Based on the above mentioned observational facts, Ambartsumian (1947, 1956) concluded that the components of double stars have a common origin.

The formation of multiple stars and clusters by captures is no less difficult to explain. It is feasible then, that the components of a physical system, independent of their number, are formed in common; that is, the stars originate in groups. Also, the results of morphological studies of stellar associations and clusters, strongly confirm this idea of a common origin, since among recently formed young stars (as are the members of stellar associations) a very high portion of double and multiple stars was observed.

In O-associations for example, there are many visual double stars, close pairs and spectroscopic binaries. We can say in this respect, that the Wolf-Rayet stars which usually occur in O-associations, show the same characteristics. According to statistical evidence (Mirzoan, 1949), almost all of them are double, but because of the selective nature of the observations, duplicity was found for only a few of them. This conclusion, obtained in 1949, was recently confirmed (Brutian, 1981) based on new observational data.

In both O-and T-associations, the abundance of multiple stars is very high, especially of dynamically unstable, multiple systems and stellar chains. All these facts indicate that stars are formed in groups.

From this point of view, the existence of Trapezium-type multiple stars in associations, is of particular significance. Ambartsumian (1954 b) was the first to pay attention to the fact that the motions in the systems having a space configuration resembling the famous Orion-Trapezium (Trapezium-type systems+)), must differ sharply from the motions in the "ordinary"-type systems, establishing their dynamical instability. He showed that the lifetime of the Trapezium-type systems as such, (keeping the Trapezium-type configuration) must be around 2×10^6 years if the total energy of the system is negative, and 5×10^5 years and even less if the total energy is positive.

Statistics on the configuration of multiple stars (Ambartsumian, 1954 b), show that among the real Trapezium-type systems in the Galaxy, those systems prevail in which the main (brightest) members are of spectral types O-B2. It is thus concluded that the real Trapezium-type

+) All multiple systems in which at least three members share mutual distances in the same order of magnitude belong to the Trapezium-type systems (Ambartsumian, 1954 b), independent of the total number of their members.

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systems consist almost exclusively of young stars (Ambartsumian, 1954 b). This is confirmed in Table 1, taken from the paper by Salukvadze (1978), and given here with an additional two columns.

TABLE 1

Statistics of Multiple Stars According to the Index Catalogue of Visual Double Stars

Spectrum of the main member	Total number of multiple stars	Number of observed Trapezia	Estimation of the number of Pseudo Trapezia	Probable number of Real Trapezia	Relative number of Trapezia (%)
O-B2	59	39	5	34	58
B3-B5-B	72	23	6	17	24
B8-B9	1118	25	11	14	12
A	394	60	35	25	6
F	309	41	28	13	4
G	224	33	20	13	6
K	153	37	14	23	15
M	11	8	1	7	64
Unknown spectrum	526	146	47	99	19

Table 1 gives in consecutive columns: the spectrum of the main member of systems, the total number of such multiple stars, the number of multiple stars having a configuration of the Trapezium-type, the estimated number of Pseudo-Trapezia (the multiple systems observed as Trapezia due to projection of the ordinary-type multiple systems on the sky), the probable number of real Trapezia and the relative number of real Trapezia (in per cent) among all multiple stars with the main members having the same spectral type. Estimates of the number of Pseudo-Trapezia presented in Table 1 have been derived from the probability of such phenomenon for triplets and quartets with P = 0.09 as defined by Ambartsumian (1954 b).

Table 1 shows that in fact there are no real Trapezium-type systems among multiple systems in which the main members belong to the spectral classes A, F, G; only a few systems are observed in which the main members are of spectral type B8-B9 and K. This is even more obvious if one takes a slightly higher value than 0.09 (Ambartsumian, 1954 b) for the probability of Pseudo-Trapezia.

Table 1 also shows that the relative number of real Trapezia is very large among multiple systems containing O-B2 type stars. Sharpless (1954) reached the same conclusion after evaluating data on the multiple systems of Trapezium-type in emission nebulae, showing that there is a strong tendency in the brightest components to have spectral classes earlier than O9.

It is an important observational fact that the real Trapezium-type systems, in the overwhelming majority of cases, are found among the multiple systems containing young O-B stars. This fact testifies that the life-time of these systems is really rather short, at least shorter than the ages of the above mentioned stars. One must therefore assume that after this short span, the Trapezia either disintegrate completely or lose some of their members and form stable systems of the ordinary type with less members than earlier.

In Table 1 the high proportion of Trapezium-type systems among multiple stars whose main components belong to the spectral class M is shown. This fact is probably due to the tendency of cool supergiant variables of spectral class M to be members of O-associations (Ambartsumian, 1953 a). However, the total number of multiple stars for this spectral class is too small for serious statistical conclusions.

The fact that Table 1 shows only a small portion of Trapezia whose main members are of other spectral classes can be understood if one takes into account that recently originated young systems could also be among them.

An original evidence in favor of the youth of the Trapezium-type systems comes from the true distribution of triple star configurations derived by Agekian (1954) from their apparent distribution according to Aitken's Catalogue of Double Stars. It shows that the portion of non-stable (Trapezium-type) systems, is greatest for spectral classes O and B. In this regard, it must be noticed that a considerable number of Trapezium-type multiple systems in T-associations has been found and studied recently by Salukvadze (1980 a, b).

Further, the results obtained by Allen and Poveda (1974) on the dynamical evolution of the Trapezium systems, in spite of the author's opinion, are in perfect agreement with Ambartsumian's (1954 b) estimations of the life-time of these systems. Indeed, studying the problem for 30 sextets of the Trapezium-type with different parameters of structure and negative total energy by means of a computer, they found that the probability of keeping their configuration during 10^6 years is equal to 2/3. This means (Mirzoyan and Mnatsakanian, 1975), that already during 2×10^6 years, more than half of all studied Trapezium systems must lose their characteristic configuration. In other words, the life-time of the Trapezium systems having negative total energy is in fact 2×10^6 years.

The origin of associations themselves, which are dynamically unstable and due to this are still in expansion (see, for example, Mirzoyan 1976, 1981) and the presence of Trapezium-type multiple systems in associations, is a confirmation of the findings on group formation of stars. Thus, the results of the morphological study of O-associations by Markarian (1950, 1951) used for the new classification of open star clusters are of great interest.

It is well known that multiplicity is a wide-spread phenomenon among galactic field stars as well. However, multiple star systems in the general galactic field are almost without exception, of an ordinary type, that is they are dynamically stable.

Thus, according to observational data, the general galactic field is rich in multiple stars of an ordinary type, which are dynamically stable, and stellar associations are rich also in Trapezium-type multiple stars, which are dynamicall unstable.

This phenomenon - the abundance of stable multiple systems in the general galactic field and the abundance of non-stable multiple systems in stellar associations - has a natural explanation. The stars are being formed in stellar associations in groups, which are dynamically stable and, especially, dynamically unstable (Trapezium-type systems). The dynamically stable multiple systems are decaying extremely slowly, only as a result of the interaction of the stars in the systems during their close passing; on the other hand, the unstable systems are decaying completely or in part more rapidly than the associations themselves. As a consequence, the general field in the Galaxy enriches itself by dynamically stable multiple systems and practically no unstable multiple systems remain in this field.

We did not discuss here the problem of the nature of protostellar matter, but note that the idea of group formation of stars, which was strongly confirmed by the results of morphological studies of stellar associations, can be better explained in the frame of a high-density "protostar" hypothesis (Ambartsumian, 1953 b).

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Comments by J. Dommanget following L.V. Mirzoyan's paper:

In connection with the idea of Prof. V.A. Ambartsumian that in stellar associations stars are formed in groups, I would like to mention that from visual binary orbit considerations, it appears that stars in the surroundings of the Sun also seem to have been formed in groups. Such groups seem to occupy volumes of the order of ten to twenty parsecs. This clearly appears from a first study we made in 1967 on the distribution of the orbital poles of some 70 binaries of which the orbital ascending nodes are well defined from radial velocity observations. All binaries nearer than approximately 10 parsec. show some similarity in their orbital plane orientation, while the orientation for more distant systems appears clearly different.

A new list of binaries for which the orbital poles are well defined is presently being prepared. It probably will contain some 140 systems. From a first look at this material, the above mentioned phenomenon seems to be confirmed.

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