THE CONCEPTS ON THE STAR FORMATION PROBLEMS

V.A. Ambartsumian

Byurakan Observatory, Armenia, U.S.S.R.

RESUMEN. Se hace una presentación acerca de los conceptos sobre los procesos de formación de estrellas, que se han desarrollado en el Observatorio de Byurakan durante los últimos 35 años. Estas ideas son, en muchos aspectos, contradictorias con los puntos de vista compartidos por la mayoría de los teóricos que postulan la condensación de estrellas a partir de nebulosas. El rechazo de esta suposición tradicional condujo en su momento (1947-1949) al descubrimiento de procesos de formación de estrellas en asociaciones estelares. En la actualidad, cuando ha resultado claro que la formación de estrellas está acompañada de flujo de materia al espacio, se requieren modelos muy artificiales para reconciliar este hecho con el colapso de materia difusa. En realidad, el flujo de material por parte de estrellas tempranas es una continuación de los procesos de fragmentación y de decrecimiento por el cual las estrellas se forman a partir de cuerpos desconocidos que son mucho más densos. Por consiguiente, el flujo de materia desde las estrellas tiene una significación fundamental para la teoría futura de la formación de estrellas.

ABSTRACT. The concepts on the star formation processes, which have been developed at the Byurakan Observatory during last 35 years are presented. These ideas are in many respects contradictory to the views shared by the majority of theoreticians who postulate the condensation of stars from nebulae. Just the rejection of this traditional assumption has lead in its time (1947-1949) to the discovery of star formation processes in stellar associations. At present, when it became clear that the formation of stars is accompanied with an outflow of matter from them into space, very artificial models for reconciliation of this fact with the concept of the collapse of diffuse matter are needed. In reality the outflows of matter from young stars is a continuation of the processes of fragmentation and decay in the result of which stars are forming from unknown very more dense bodies. Therefore the outflow of matter from stars has fundamental significance for the future theory of star formation.

I. THE CONCEPTS ON THE ORIGIN OF STARS

The development of Astrophysics in the last 60 years has shown that astrophysical observations give us a vast amount of data relating to the stellar evolution and (in the less degree) to the problem of origin of stars. The obtained data permit to make some general conclusions, which are yet far from being final, but which definitely indicate the desirable direction of subsequent investigations and searches. We mean here those view, which have started to develop in the Byurakan Observatory beginning at the end of the forties (Ambarstumian 1947). And though these views have undergo some changes, they have helped us in programming research work of our Observatory. In particular, namely these views permitted us to understand the significance of stellar associations and to develop first ideas on the processes of star formation in them, to predict the events of decay of stellar associations (Ambartsumian 1949), *to discover the phenomenon of activity of galactic nuclei*, to understand the significance of superassociations and of many other events in active galaxies (Ambarstumian 1958). These views stimulated

also the orientation of our research in the field of flare stars Ambartsumian (1954).

1. Some of the evolution processes related to the stars and nebulae may at present be observed almost directly. Though the majority of them are not so fast to happen before our eyes. We, nevertheless, often observe bodies and systems in such sequence of their states that sometimes we succeed to connect these states in some evolutionary chains.

The consideration of those cases which are more obvious showed that there exists a great variety of evolution processes. An example: the structure of the star formation region in the Orion association is not absolutely similar to that of similar regions in the association W 49 or in the complex W 51. The complex connected with the nebula NGC 2244 differs from all of them. Almost literally everywhere we notice differences in states of the systems representing group of stars that have just appeared and diffuse matter outflowing from them and therefore we may conclude on the existance of differences in nature of the evolution processes.

A large work is needed to find general regularity in these various observed examples. It is the most difficult problem in the field under consideration. Meanwhile, large amount of astrophysicists, who consider themselves as theoreticians, probably think that the problem of formation of stars may be solved by one blow, by introducing some witty scheme-hypotheses. At the same time they pay too little attention to the indicated variety of the observed phenomena. We even begin to suspect that the diversity of observed facts, which do not satisfy simple schemes, begins to irritate them.

From our point of view, the future theory of star origin should result from the correct interpretation and generalization of these observational data. This explains the difference in the approach to observational data. For us they form the basis of the solution. The generalization of these data will permit to find those fundamental concepts from which future theory should proceed. For them the observational data are a means of checking their speculative theoretical constructions. We do not deny that some benefit may be obtained in the second approach. But it surprises us a little that in many works devoted to the development of this approach, the idea on the origin of stars from diffuse matter is accepted as something which goes without saying. Meanwhile, in our opinion, the first approach turned out to be much more fruitful and we prefer to devote all our efforts to its development.

2. Observational data permitted to establish that the majority of stars are in a more or less stationary state during many hundreds of millions of years. On the other hand, some stars, in particular, the most massive stars and also nebulae (including diffuse nebulae) undergo fast variations. These objects, at least in that form in which we observe them, either originated recently or they are now in a stage of formation. This especially refers to nebulae.

Continuing to pay attention to the problem of star formation we have, as it follows from what it has been said, to concentrate our attention on the origin and evolution of the nebulae as well. The remarkable fact is that, as observations show, the masses of almost all giant complexes of nebulae increase as the result of intense outflow of matter from massive bodies situated in them. This apparently sheds a light on the mechanism of formation of diffuse nebulae. We are probably close to the solution of the final fate of such complexes. All data are in favor of their instability and, in the end, dispersion in interstellar space.

Thus there is a hope that both the origin and the final fate of large complexes of diffuse nebulae (similar to complex in Orion association) will be understood in the near future. Observations directly indicate that they arise from the matter ejected by massive objects (including young stars as well), and then *disappears as the result of dispersion and decay*. In other words, observations, instead of bringing us direct proofs for the concept on collapse of diffuse matter, provide evidence that just a contrary process plays a dominant role in nature.

3. The study of observational results gives, at the same time, possibility to make some statements on the nature of the star formation process. Most briefly they come to the following:

a. Stars appear by groups in OB associations and T-associations. Each of OB association contains, as a rule, giant complex of diffuse matter most of which is in a form of molecular cloud with a mass of the order of 10^4 $M_\odot$ and more. Star group originating in association is usually immersed in large diffuse molecular cloud. Powerful outflow of matter occurs from the very centre of the star formation region, i.e. from newly forming stars and perhaps from protostars which still exist here. This outflow is by tens of times more intense than that which occurs from already formed OB stars situated outside of molecular cloud.

I would like to formulate this fact in the form of a simple question and answer. Question: from what does the life of star begin? Answer: from very powerful outflow of matter from it which is essentially weakening during about 10^5 years. At the same time an electromagnetic emission starts which is not weakening, but perhaps becomes stronger with time at this stage.

The phase at which powerful outflow occurs lasts, as we said before, not longer than 10^5 years. Meanwhile the process of gravitational contraction should last according to theoretical calculations about 10^6 years or longer. It is quite obvious that the observed phase of powerful outflow is not possible to identify with such phase of contraction theorethically suggested. In connection with this, those theoreticians which proceed from the contraction hypotheses must admit that before the long phase of contraction, almost explosive phase of outflow with consequent expansion of the surrounded nebulosity should exist. In connection with such picture (contraction at first and then expansion) it is possible to say, that for some reason the first, more prolonged phase is observed nowhere and the statement of its existance is based just on preconceived ideas. But the point is not only this. One may ask: where from are the giant molecular clouds (GMC) in stellar associations? Studying the environments of the Sun (within the radius of the order of 2000 pc from us) we see that giant molecular clouds or *complexes* are in overhelming majority *situated in stellar associations* (Blitz and Shu 1980). It means that their lifetime should be of the same order as that of the associations (10^7 years). Then there are only two possibilities; they appear either immediately before the origin of the corresponding association or they are forming inside the association during its life. On should perhaps reject the first suggestion. No one will accept that a GMC may appear in the emptiness from nothing. But the suggestion put forward by some investigators that large number of diffuse nebulosities of small mass may, as the result of some reason, merge into a giant molecular complex is unacceptable. For such process of gathering of nebulae 10^8 years are needed. In other words, we have to observe in the space at least several times more groups of gathering-together-nebulae, than the number of OB-associations. Nothing similar is observed. Thus only the second suggestion is valid, i.e. a GMC arises in stellar association during the process of the evolution of the latter from both the same objects, which give birth to stars and from matter ejected by newly formed stars. One has to suggest that the whole mass of stellar association including GMC as well, originates in the end from very dense unseen bodies.

It is appropiate to note here, that the hypotheses on formation of diffuse nebulae from the matter ejected by massive stars has been put forward yet in the thirties by Prof. Vorontzov-Velliaminov.

b. The supporters of contraction may indicate to a class of diffuse nebulae which at first glance may seem to be contracting objects. Those are Bok's dark globulae. The smallness of velocities of matter in them determined from CO lines (of the order of 1-3 km/s makes the contraction hypotheses very attractive. It is important that such slow motions cannot forbid the collapse. And since the masses of globulae are not large, either massive single stars or small groups of stars of little mass could be formed. Sometime ago such hypotheses seemed acceptable. But detection of cometary nebula within small part of them changed the whole situation example. A cometary nebula discovered in Byurakan which is connected with PV Cephei and is immersed in a dark globulae is the most remarkable case. The presence of the cometary nebula is direct indication of outflow of matter from an already formed star is taking place. Thus here too instead of theoretically suggested scheme of contraction the real process of outflow takes place.

It could be argued that cometary nebula are observed not in all dark globules. But one has to take into account that we can observe a cometary nebula and the exciting star only in those cases when they are situated in the part of the globule turned to us. We cannot see them if they are in the deepest part or in opposite side of the globule. If the optical depth of the globule is more than ten, the cometary nebula could hardly be detected. Thus the majority of globules rather contain such nebulae. It would be very desirable to detect cometary nebula immersed in globules by infrared observations in the 2-3 μm wavelength region.

Thus efforts to detect a process of contraction somewhere in star formation regions were in vain.

c. The stated arguments suggest that concept on simultaneous formation of stars and of diffuse matter from more dense and more massive bodies is more fruitful and close to reality. One should be glad the observing astrophysicists turned to be influenced not exclusively by the hypotheses of contraction of diffuse matter and begin to raise a curtain, which covers the complicated picture of processes accompanying the formation of stars.

It seems to us that proceeding from the idea on the common origin of stars and diffuse matter from unknown massive objects one could outline very promising programs of new observations.

As to the theoretical astrophysics we would like to concentrate the efforts on the physics of matter outflowing from stars. The theory of this question could help to reach a more complete and correct interpretation of all events observed in the field of star formation.

II. THE CONCEPTS ON ORIGIN OF GALAXIES

The fact that formation of groups of stars takes place in the star formation regions and that these groups (for example, the Trapezium Orion type systems) occupy in the beginning a very small volume suggested an idea on the possible evolutionary role of such very dense formations as the *galactic nuclei*.

In the result at Byurakan in the middle of fifties instead of an old idea that the nucleus of each galaxy is simply a region of maximal star population density the idea on activity of galactic nuclei has been put forward, which has been generally accepted later. We would not dwell here on numerous studies of the processes of nuclear activity in various galaxies made in Byurakan. These results are well known. But I would like to note that in Byurakan we came to the correct understanding of the significance of activity of nuclei only after disproving the wrong idea that galaxies were colliding galaxies. And radiogalaxies began to be considered, at first in Byurakan and then everywhere else, as a result of activity of nuclei.

Further development of the idea on activity of galactic nuclei led us, after all, to the suggestion that each galaxy seems to be a sum result of long activity of its nucleus. In other words, the life of a galaxy starts along with the active processes in its nucleus.

We understand that in those years when this suggestion was expressed it could seem too courageous. But after the discovery of quasars it became obvious that the nucleus of a galaxy, at the initial period of its existence, could possess an amount of energy and also a possibility to eject matter quite enough to form many features of the galaxy and perhaps of all galaxy. Now this hypothesis may not be considered as extremely courageous. In reality the current study of Seyfert type galaxies permits one to say that the nucleus gives birth to at least an appreciable part of the interstellar matter contained in it. Therefore now the following question is rather to be discussed: which of features of a given galaxy are the result of nuclear activity and which of them may have some other origin. Of course, the final answer to this question will not be obtained very soon, but the necessity to get observational data for solving it opens interesting ways for the planning of our observational work.

But here too there is a fundamental difference between our views and the views of the majority of theoreticians. When those theoreticians think that the outflow of matter and other signs of nuclear activity are secondary events, and the hypothetical "accretion" of diffuse matter into the nucleus is the primary event, we are inclined to think that *the basic factor is the outflow of matter and emission of energy* from the nucleus which at the beginning was an isolated body and gradually created a galaxy around itself.

I would like to draw attention to the Prof. Oort's recent paper "On the nucleus of our Galaxy". In this review extremely interesting data on the intense outflows from comparatively small mass nucleus of our Galaxy and on mini-spirals situated in the area of size of 2 pc around it are presented. These new data though they relate to comparatively less active nucleus, undoubtly will help to solve the indicated problems. I would like to note that a lot may be expected also from the study of superassociations. The study of superassociations (which are called HII regions as well) commenced in Byurakan and is carried out now at many observatories in the world. The work of Prof. Khachikian and his collaborators on the relation which exist between superassociations and ultraviolet galaxies, extensive lists of which are published by Byurakanian astronomers, are of special importance. It is interesting, in particular, that some of these ultraviolet galaxies are, in essence, isolated superassociations.

REFERENCES

V.A. Ambartsumian. 1947, *Stellar Evolution and Astrophysics*, Erevan (In Armenian and Russian).
V.A. Ambartsumian. 1949, *Sov. Astron.* 26, 3.
V.A. Ambartsumian. 1958, *XI Solvay Conference*, 241.
V.A. Ambartsumian. 1954, *Comm. Byurakan Observatory*, 13, 3.
L. Blitz, and F.H. Shu. 1980, *Ap. J.* 238, 148. See also L. Blitz report "New Observational Evidence Regarding the Lifetime of GMC complexes", given at the Green Bank Workshop on "The Phases of the ISM" (Preprint, 1981).

DISCUSSION

Marraco: You have rejected massive molecular cloud collapse as the origin of stellar formation, inter alia because you cannot tell where the massive clouds came from.
Please tell us where the massive dense matter comes.

Parsamian: The observations show that expansion (outflow) plays a dominant role in nature.

Ferrer: I would like to know if some progress has been made in recent years about the knowledge of the physical properties of pre-stellar matter.

Parsamian: Most important is observational data about molecular clouds in stellar association.

Unidentified: Are there any Soviet astronomers, in addition to Ambartsumian, working on the idea of star formation by expansion of massive prestellar material?

Parsamian: There is a group of physicists at the U. of Erevan with Prof. A. Sahakian.

V.A. Ambartsumian: Byurakan Observatory, Armenia, U.S.S.R.