1982Ap&SS..84..317A

AN OBSERVATIONAL APPROACH TO THE EARLY STAGES OF STELLAR EVOLUTION

V. A. AMBARTSUMIAN and L. V. MIRZOYAN
Byurakan Astrophysical Observatory, Armenia, U.S.S.R.

(Received 19 August, 1981)

Abstract. During the last three decades an observational approach has been applied at the Byurakan Astrophysical Observatory to the problems of the evolution of astronomical bodies and systems. In contradiction to the traditional point of view, assuming that the processes of condensation are dominant in the Universe, this approach makes use of the observed predominance of expansions, ejections, and explosions.

In the past, the observational approach has led to the prediction of an expansion of some stellar associations confirmed later by the analysis of observations. It became clear that the stellar associations are very young systems where the star-formation process is still continuing. The new approach has also led to the concept of the activity of galactic nuclei. The observational approach considers as a phenomenon of primary importance the formation of nebulae as a consequence of the activity of dense bodies (nebulae surrounding the novae, planetary nebulae, supernova remnants, cometary nebulae, and the diffuse nebulae in OB-associations).

The new approach in application to the early stages of stellar evolution is discussed. The T Tauri-stage is considered as a phase following the more dense protostellar state. The flare stars are regarded as the next phase of evolution. The phenomena of fuors (FU Ori-type brightenings) can be considered as an expression of the same tendency (the transformation of dense matter into a rarefied state).

1. Introduction

At present, astronomical literature is full of studies of stellar evolution which stem from the idea of condensation of diffuse matter into stars.

On the other hand, it is already more than 30 years since the idea was developed which could be called the hypothesis of decay and expansion of protostellar matter. However, up to now, this hypothesis has been applied in only a few studies for the interpretation of particular phenomena connected with stellar evolution.

At the same time, the observational astronomy opens before us more and more new facts on the processes of decay (disintegration) and expansion. The existing large discrepancy between theoretical and observational studies on stellar evolution can be explained by just this hypothesis.

The notable fact that some theoreticians (see, for example, Hoyle, 1980) who earlier unconditionally supported the condensation hypothesis, recently began to understand that the decay and expansion processes are important not only for cosmology, but also in phenomena of a more modest scale, are also condition by this circumstance.

The aim of the present paper is a discussion of the whole complex of new observational data from the point of view of the decay and expansion hypothesis and an attempt to show that it is in better accordance with them.

Rejecting, from the very outset, the assumptions predetermining the following

Astrophysics and Space Science **84** (1982) 317–330. 0004–640X/82/0842–0317$02.10.

course of evolution, we consider that it is necessary to take into account the facts which are connected with the observed high-speed stages of the evolution of cosmic matter.

Various observations testify that the high-speed phenomena are usually connected with the life of nebulae, from one side, and with the early stages of stellar evolution, from the other side. Just because of it, in contrast with the traditional point of view, in the first place, we consider the problem of the origin and evolution of nebulae in close connection with stars being in the early stages of their evolution. The comparison of these stages, as it seems to us, testifies much more favourably towards the idea of decay and expansion.

As regards the late stages of stellar evolution, their course is naturally less connected with the processes of the origin of these objects. Just because of that, at least in some degree, they, can be used in the theory of the equilibrium states of stars. The evolutionary factors in these stars, which have already reached equilibrium states, are essential only when one discusses the more finer problems.

Thus, refusing the traditional point of view, we first of all consider the problem of the origin of the nebulae.

2. On the Origin of Diffuse Nebulae

Our Galaxy is made up of stars and nebulae. That the stars are discrete objects and their totality is not a continuous radiating medium, is so trivial a fact that even elementary text-books avoid making special reference to it.

Different is the picture with the nebulae. For instance, during the 1930s, it was assumed that the absorbing matter distributes more or less continuously in the equatorial plane of our Galaxy. However, further observations led to the conclusion that the absorbing medium consists of separate, mostly unilluminated or, more precisely, nearly unilluminated discrete gaseous dusty clouds, producing interstellar absorption. Only some clouds are illuminated, and at times they are even reduced to a state of ionization by stars situated around or within them. The study of the illuminated nebulae indicated that they are, as a rule, irregular in shape. Naturally, the ratio of the linear dimensions of separate clouds to the mean distance between them is by many orders of magnitude greater than the same ratio for stars. Nevertheless, it can be asserted that the nebulae of our Galaxy, like the stars, are discrete and displaying the same individuality and objects.

Under the circumstances it is quite natural to raise the question of the origin of individual nebulae. When considering this problem, it is necessary to take into account that there are different types of nebulae. It can readily be shown that for some types of nebulae the observations give a direct and unambiguous answer to the question of their origin. Thus, one can hardly doubt the fact that small expanding nebulae, observed around Novae several years after their outbursts, arise from stellar explosions as a result of which expanding diffuse envelopes are ejected from the stars into the surrounding space. In the same way, the planetary nebulae form envelopes, also ejected from stars, with the only difference that, in this case, the ejection process goes on at a slow rate, yet the mass of the envelope is a thousand times greater.

Thus we are aware of at least two types of nebulae originating during the transition of the dense matter into a diffuse state.

Much more striking are the data of some radio nebulae. One of them (say, the Crab Nebula) originated, no doubt as a result of the Supernovae outbursts, others resulted from the activity of such seemingly exotic objects as SS 433 (see, for example Clark and Murdin, 1978). These object-radio nebulae (remnants of Supernovae) are of dimensions that often exceed the diameter of diffuse nebulae. Their existence proves that large-sized nebulae can also originate from the dense matter of stars.

More complicated is the problem of the origin of *cometary nebulae.* They usually have a conic shape in the apex of which the star illuminating the nebula is situated. The biconic (or 'bipolar') nebulae are found to have a shape of two fans directed in opposite sides from the central star. In the recent paper of Canto *et al.* (1981), it has been shown that the observed shape of the cometary nebula near R Mon is a result of outflow of matter from the star in opposite directions. It is natural to consider that other biconic shapes must have the same explanation for it is impossible to think that the matter from two opposite regions relative to a star can suddenly gather together simultaneously in these two places and inflow into the star. If it is so, then in the case of simple cones we must also take the same interpretation.

There remains the problem of the origin of both emission and reflection *diffuse* nebulae.

The question of their origin and evolution is much more complicated. The processes go on at a slower rate, whereas the complexity and irregularity of their forms make it difficult to detect the direct signs of *the trend* of the occurring changes. If, in the former cases, we witness directly or nearly directly the origin of the objects, then in the present case we can only make an attempt to establish the evolutionary trend at a given moment and then extrapolate back from the present-day state to the moments of the past.

A considerable part of the *emission* diffuse nebulae forms a constituent element of O-associations. Sometimes the cluster of hot stars is entirely involved in the volumen of the nebulae (for instance, NGC 2244 and the association Mon II). In some cases the emission nebulae contain multiple systems of the Trapezium type, the members of which are massive O-B stars. On the other hand, the so-called stellar wind (a fashionable word that has gained currency of late) takes out of each O-B-member of the association annually a mass of the order of 10^{-5}–10^{-6} $M_{\odot}$. It follows that a nebula with a mass of the order of a hundred and more solar masses can and must be drived from a dozen massive stars over a period of several million years. Therefore, if we failed to observe diffuse nebulae around the compact groups of hot giants, the formulation of a special theory accounting for their absence would be called for.

In addition to the massive stars, we also observe in diffuse nebulae T Tauri-type stars. While the star is in this ste most of the time it ejects matter rather intensively. The amount of matter ejected by each star of the T Tauri-type attains 10^{-5}–10^{-7} $M_{\odot}$ per year. But T Tauri-type stars are available also in reflection nebulae. All this means that it is possible, in this case too, to account for the origin of a considerable part of the nebular mass.

In this connection, also of great interest are the observed cases of the ejection by stars of dust clouds or of a substance, out of which subsequently the dust cloud is formed. The recent discovery of Hackwell *et al.* (1979) adds new evidence to the list of well-known facts concerning the presence (or ejection) of dust clouds around the *clod* stars; it establishes the fact of a sudden appearance (possibly a direct ejection) of a dust cloud from the hot star HD 193793 of the Wolf–Rayet type.

It is essential that the so-called compact H II regions are observed within many dark and reflection nebulae. The investigations of Mezger and his group played a decisive role in their study (see, for example, Mezger and Smith, 1977; Mezger, 1978). The compact H II regions often emit almost no radiation in the visible part of the spectrum, since the light from them is absorbed by the surrounding dusty matter. However, we can observe them through radio radiation, sometimes also in the infra-red rays. Investigations have shown that in the above regions an outflow of ionized matter from hot objects takes place, which reminds one in all respects of ordinary O-B stars. But in these cases the stars are hidden in a dark cloud. It is interesting to note that Herbig–Haro objects and compact H_2O-masers occur in the vicinity of some such regions (see (below). Naturally this gave rise to the assumption in literature that the latter result from the ejection of matter from very young stars which are the centres of compact H II regions.

It should be noted that as early as the beginning of the 1960s Walker (1963) discovered that some T Tauri-type stars displaying, unlike most of the stars of this type, absorption components of emission lines, shifted to the long-wave side (the structure of anti-P Cyg type). In Walker's opinion, an accretion of matter on the star from the surrounding envelope takes place in these stars, named 'YY Ori-type'. This view was later regarded as evidence in favour of the condensation hypothesis. Clearly, the possibility is not excluded, *in some cases*, of the presence of favourable conditions for accretion in the vicinity of the stars. However, the accretion of the matter certainly is not typical of T Tauri-type stars.

Numerous facts can be adduced in favour of the outflow of matter from the T Tauri-type star. Suffice it to mention only the results of two recent investigations. Herbig (1977) studied the spectra of 50 T Tauri-type stars and showed that the 'anti-P Cyg' structure of lines is not observed in any of these stars, including YY Ori. A similar result has been attained quite recently by Schneeberger *et al.* (1979), studying with a high resolution (0.2 Å) the profiles of line Hα in the spectra of 10 T Tauri-type stars. Therefore, we can barely have doubts at present that the outflow of matter from T Tauri-type star is a rule of nature.

The absence or scarcity of 'anti-P Cyg' profiles of spectral lines in the spectra of T Tauri-type stars comes as immediate and decisive evidence countering the assumption of the condensation of matter into stars. In fact, if at certain stages in the evolution of the nebula, an accretion of matter or condensations forming in it occurs, the conditions of its observation are particularly favourable in the cases when condensations have already turned into sources of radiation: in T Tauri-type stars the temperatures had not yet had time to reach too high values.

Thus, it follows from the observations alone that the mass of each diffuse nebula is largely, if not wholly, due to the outflow of matter from denser objects.

However, as we can see, stars ejecting the part of the mass of diffuse nebulae, except those that pass accidentally through their volume, belong to those types which are conventionally regarded as young (O-B stars, T Tauri-type stars). Their age, as well as that of the nebulae, does not exceed 10^7 years (see below). Therefore, the foregoing arguments support the common origin of stars and of gaseous material co-existing during such an interval of time. It is therefore natural to assume that every such complex (nebula plus young stars) is the result of the disintegration of a very massive body (the mass being of the order of several hundreds of solar masses), of one particular protostar.

It is equally natural to regard the remaining part of the mass of the diffuse matter of the nebula (perhaps, the greater part) might be ejected already from the protostar at the time of its disintegration into separate pieces, which are then able to be transformed into stars.

Another possible picture of evolution consists of the assumption that originally the nebula lacked stars, part of the mass of this nebula being later condensations in stars. This concept is rather widespread among theoreticians who, disregarding the above-mentioned observational data on the formation of entire nebulae and at least part of the mass of diffuse nebulae out of denser matter, have constantly been working out models of the condensation of nebulae, presumably observed nowhere.

The only advantage of the second viewpoint is that it is possible to make some simple and clear assumptions about the initial phase nebular matter conforming to the laws of hydrodynamics and the physics of ordinary plasma. Meanwhile no one, so far, has discovered the properties of a protostar. Reference can be made only to its high density and low luminosity. Nevertheless, recent observations, leading to definite conclusions on the mechanism of the formation of a whole set of nebulae and condensations of diffuse matter, indicate that the ground of the supporters of this conception is gradually narrowing.

Despite those divergences in possible interpretations, the facts discussed above concerning the nebulae have made it possible to attain a definite conception on the initial phase of stellar life: it is a rather unstable phase accompanied by quite an obvious outflow of matter – 10^{-5}–10^{-7} $M_\odot$ per year.

3. Stellar Associations and the Early Stages of Stellar Evolution

The discovery and investigation of stellar associations have made it possible to detect certain regularities of the star-formation process in the Galaxy, based exclusively on observational data (Ambartsumian, 1947, 1949, 1954a, 1957a; Ambartsumian and Mirzoyan, 1976).

It was shown (see, for example, Ambartsumian, 1949, 1954a) that the stellar associations are dynamically unstable systems, as a result of which they gradually expand and disintegrate during the whole period of an order of 10^7 years. Some of them are expanding with relatively large linear velocities – of the order of 10 km s^{-1}.

This estimate of the age is hundreds of times less than the age of most stars in the Galaxy (Ambartsumian, 1937); therefore *the stellar associations should be regarded as young formations, while their constituent stars have been formed quite recently.* Consequently the single fact of the existence of stellar associations is evidence of the *stellar formation process that started several billion years ago in the Galaxy, and which is still continuing now.*

The percentage of multiple stars, often exceedingly unstable and disintegrating (systems of the Trapezium type and stellar chains) (Ambartsumian, 1954c), is very high in the composition of stellar associations. This fact indicates the important peculiarity of the process of stellar formation *and within the association itself the stars originate not singly, but in groups.*

The above conclusions on the continuing and group formation of stars in the Galaxy have been confirmed in modern times by various investigations of the stellar associations. Particularly the studies, initiated by Blaauw, of the internal motions of stars in the associations based on their proper motions (Blaauw, 1952, 1964, 1978) corroborated the theoretically-formulated prediction of the expansion of stellar associations, based on the conception of their dynamic instability (see, for example, Ambartsumian, 1949). The radial velocities of the members of the associations provide added proof to this (Mirzoyan, 1961, 1966; Mirzoyan and Mnatsakanian, 1970).

These regularities in the evolution of stellar groups are being successfully used in studying the process of the origin and evolution of stars. For instance, the important facts on the group origin of stars, which had been left out of the sight of the theoreticians prior to the discovery of stellar associations, fostered to a large extent, the study of the early stages in the evolution of stars.

The observational approach proved particularly useful in the study of the early stages of the evolution, when the stars on the Hertzsprung–Russell diagram are situated far from the Main Sequence (see, for example, Mirzoyan, 1976, 1978). In this phase, active dynamic processes go on in the outer layers of stars that have not as yet attained a state of equilibrium. It is in the early stages of evolution that physical instability is the most important property of stars (Ambartsumian and Mirzoyan, 1976).

In the earliest stage of a duration of the order of 10^6 years, this corresponds to the irregular variability of the T Tauri-type met exclusively in T-associations (Ambartsumian, 1954b, 1957b). Irregular variations of the power and composition of the radiation of these objects characterize the stage of the evolution corresponding to the complex process of transformation of a prestellar mass into a star.

The variability of T Tauri objects is quite often accompanied by chromospheric activity which is marked by the appearance of emission lines and ultraviolet continuum emission. There is good reason to believe that this continuum emission is of a nonthermal nature, while its sources originating the emission spectra of stars and bringing about irregular changes in the radiation power, appear from time to time in its outer layers (Ambartsumian, 1954b).

In this stage of evolution other unusual properties are also observed such as the anomalously rich content of lithium. Typical of this stage is also a close genetic relation of stars with diffuse matter (see, for example, Herbig, 1962).

The stage of flare stars lasting for 10^7–10^8 and more years depending on the mass of the star, should be regarded as the next stage in the evolution of dwarf stars.*

The flare activity is the most characteristic feature of the star at this stage of evolution. During the flares, that alternate with longer periods of the quiescent state of the star, the radiation eruptively emitted from the star in several respects resembles the radiation of T Tauri-type stars. On the other hand, during long periods between flares, a quiet radiation is observed. However, even during this time the radiation spectrum also displays some traces of chromospheric activity, provided that we observe with a fairly high spectral resolution.

The physical similarity of the radiation of flare stars and rapid variations of brightness of the T Tauri-type stars (Ambartsumian, 1954b), testifying to the fact that in both cases related processes of radiation take place, different from black-body thermal radiation, at least during the flares, is in itself an indication of the close genetic relation between these two classes of stars. This conclusion has been confirmed by the investigations of Haro and coworkers (Haro, 1957), discovering a large number of flare stars in the Orion association, along with T Tauri-type stars.

This was followed by the discovery of flare stars in a number of comparatively older stellar aggregates lacking T Tauri-type stars (Haro, 1968).

The comparative study of a relatively small number of flare stars in stellar aggregates of different ages by Haro and Chavira (1966), based on their own observations and on those of Rosino *et al.* (see Haro and Chavira, 1966), gave, for the first time, good reason to conclude that that stage of the flare star is an evolutionary phase setting in after the star has gone through the T Tauri-type stage.

This hypothesis received strong support when it had been shown statistically (Ambartsumian, 1969; Ambartsumian *et al.*, 1970) that in a comparatively young stellar aggregate of Pleiades (the age being of the order of 10^7 years) virtually all the dwarf stars, painter than a certain absolute magnitude, must be flare stars.**

Brilliant confirmations of this conclusion came from subsequent observations of the region of the Pleiades aggregate made in the observatories of Tonantzintla (Mexico), Asiago (Italy), Byurakan (U.S.S.R.), and Konkoly (Hungary), thanks to which the

---

* We have dwelt upon certain aspects of the physics and evolution of flare stars at the Bamberg colloquium (Ambartsumian and Mirzoyan, 1971; Mirzoyan, 1977) and at the IAU Symposium 'Variable Stars and Stellar Evolution' (Ambartsumian and Mirzoyan, 1975).

** Acceptance of this statement means a strict definition of what we understand here as flare stars. The matter is that our Sun and probably all similar to it stars undergo flares of small scale. However, during these flares their B-magnitude remains constant within 0.01 stellar magnitude. Speaking on flare stars in the Pleiades we mean on them flares with an amplitude not less than 0.5 magnitude. Such flare stars can be found during photographic observations.

number of known flare stars in this region reached 500, most of which belong to the aggregate itself (see, for example, Mirzoyan *et al.*, 1977; Chavushian, 1979).

A considerable number of flare stars were discovered in other stellar aggregates as well (Orion: Haro, 1976; Praesepe: Yankovics, 1975; around NGC 7000 in Cygnus: Tsvetkov, 1976; etc.). The abundance of flare stars in the aggregates has become an observational fact. This meant that the stage of the flare star is a regular stage in the life of the young dwarf star, at least most of them go through that stage.

The observations indicate that the stages of the evolution of T Tauri and flare types mutually overlap. Haro and Chavira (1966) have established that some T Tauri-type stars in the Orion association showed classical flares at the same time, i.e., they possess flare activity.

In this connection, an estimate of the relative number of T Tauri-type stars displaying flare activity in the Orion association was made (Ambartsumian, 1970). It was shown that only about a quarter of T Tauri-type stars in this system are capable of displaying photographic flares (amplitude $0\overset{m}{.}5$). This made it possible to conclude that the stage of the flare star sets in shortly before the break of the T Tauri stage. During a short period the star displays a flare activity along with the T Tauri-type activity.

The Herbig–Haro (Ambartsumian, 1954b; Herbig, 1974) objects and fuors (FU Orion-type objects) (Ambartsumian, 1971) are of great interest in studying the early stages of evolution of the stars.

The similarity of the spectra of Herbig–Haro objects to the spectrum of the nebula, connected with the T Tauri star, and the wonderful changes in object H–H 2 of this class, discovered by Herbig (see, for example, Herbig, 1969), testify to states of extreme instability. The analysis of the observations of these objects has led to the assumption (Ambartsumian, 1954b), made before Herbig's observations, that the above objects present an evolutionary stage preceding the T Tauri-type stage.

The studies of Herbig–Haro objects (see, for example, Gyulbudagian, 1980) confirm this conclusion. In recent years a large number of new Herbig–Haro-type objects have been discovered at the Byurakan Observatory (the so-called Gyulbudagian–Magakian objects; Gyulbudagian and Magakian, 1977). A more detailed investigation of the vicinity of most of those objects has led Rodriguez *et al.* (1980) to the conclusion that compact H_2O-masers and compact H II regions occur at relatively small distances from thses objects. This fact is interpreted as a sign of the presence of massive and hot stars. The analysis of these data has led Rodriguez *et al* (1980), who generally accept the conception of the condensation of stars from nebulae, to the following scheme: along with the outflow of matter, the massive star in discrete episodes ejects relatively dense gaseous concentrations. In the first stage of such a concentration this ejection manifests itself as an H_2O-maser. The life time of such a maser must be of the order of a thousand years. Subsequently, the same concentration, receding somewhat from the star ejecting it, behaves as a Herbig–Haro object. By the reckonings of the above authors, the observational data can be accounted for on the assumption that the masses of the ejected concentrations are of the order of 10^{29} g. However, the possibility of the presence of a dense body with a mass of the order of 10^{31}–10^{32} g in the centre of the concentration, cannot be ruled out. In other words, the above arguments do not in any way contradict the assumption expressed earlier that the Herbig–Haro objects represent one of the earliest phases in the evolution of stars (Ambartsumian, 1954b). Even if this assumption on the presence of dense condensations in H–H objects proves to be erroneous, the scheme suggested by Rodriguez *et al.* (1980) can hardly be interpreted in terms of the condensation hypothesis, especially if we take into account the fact that according to this scheme, the ejection of concentrations from the massive star must recur.

The observations apparently indicate that there are two different kinds of Herbig–Haro objects, whose physical properties correspond to the initial concept of this term and objects whose radiation can be accounted for in the reflection of the light of the continuous sources by condensations in dark nebulae (Gyulbudagian, 1980). Of course, the above-mentioned remark concerns the first of these classes.

Somewhat different is the case with the fuors. The discovery of fuor V1057 Cyg (Welin, 1971), which before the increase of the brightness had a T Tauri-type spectrum (Herbig, 1958), excluded the possibility of explanation fuors in terms of the condensation hypothesis – by rapid collapses, as Herbig assumed (Herbig, 1967) in the case of FU Ori revealing that the phase of the fuor is associated with that of T Tauri (can sometimes interrupt the stage).

The peculiarity of the fuor phase is its short-lived duration (of the order of dozens of hundreds of years). It can be assumed that this phenomenon is of a recurrent nature, as the young star passes the fuor phase several times. In this connection, some features of the similarity of the fuor phenomenon details concerning the processes of stellar flares (Ambartsumian, 1971) merits attention.

The study of the early evolutionary stages of more massive stars (the hot giants), based on observation, for the time being lags behind considerably compared to the investigation of the early evolutionary stages of dwarf stars.*

However, in the case of massive stars, there are two auspicious circumstances. First the existence of O + T associations, like Orion association, attests to the fact that the origin of the giant and the dwarf stars takes place simultaneously in a number of cases. This is also supported by the results of investigations by Ström *et al.* (1972a, b) indicating that the Ae and Be-type stars associated with the nebulae are, apparently, exceedingly young and bright members of recently originated stellar groups. Second, the evolutionary phase of the fuor is similar to the stage of the increasing of the brightness observed in P Cyg and it leads to the formation of an earlier spectrum than that before the increase of the brightness. An object of high luminosity emerges from this increase. The phenomenon of four presumably illustrates the possibility of transitions from dwarf stars to objects with high luminosity, though, at first sight, it seems that such transitions must be in contradiction with the large observed difference of

---

* The early evolutionary phases of dwarf stars with the application of the observational approach are the object of intensive studies also in Tonantzintla Observatory under the direction of Haro. The most important results of this investigation are referred to in our thesis. The researches of Mexican scientists in this field are summed up in Haro's significant work, the first part of which was put to press in 1976 (Haro, 1976).

corresponding masses. All of these arguments give good reason to believe that the observational data relating to the common origin of giant and dwarf stars in stellar associations are important for the understanding of the evolution of high-luminosity stars.

It should also be noted that, in the investigation of the evolution of young giant stars, of great interest are the intense processes of the continuous outflow of matter as well as the ejection of discrete gaseous envelopes observed in young giant stars of P Cyg, Wolf–Rayet, Be, etc. types.

4. Concluding Remarks

The assumption of the condensation of diffuse matter into stars is usually considered as the basis for theoretical research concerning the internal constitution and evolution of stars.

The observed abundance of diffuse matter in those regions of our Galaxy where the process of star formation is currently going on intensely, has always been regarded as substantial evidence in favour of the condensation hypothesis. However, these observational facts only indicate that the young stars and the diffuse nebulae are in some way genetically related.

On the other hand, the condensation hypothesis encounters serious and possibly insurmountable difficulties in the face of observational data (see, for example, Ambartsumian and Mirzoyan, 1976). Some of those facts were dwelt upon at the beginning of this paper. Here are set out the recently obtained results, which remain unaccountable in terms of that hypothesis.

Haro and Chavira (1966) were the first to draw attention to the relatively young stars in the Orion association situated on the Hertzsprung–Russell diagram below the Main Sequence, the development of which to an equilibrium state is not interpretable in terms of the theory of the evolution of stars relying on the hypothesis of gravitational condensation. The attempts of Poveda (1965) and Grasdalen *et al.* (1975) to account for this fact in favour of this hypothesis can hardly be considered as successful (Mirzoyan, 1976).

Observations made by means of space stations, covering the regions of the spectrum, inaccessible to ground observations, have resulted in the discovery of objects of a new type which were unpredicted by existing theories. This implies more or less constant sources of γ-radiation and those X-ray sources which are neither pulsars nor binary systems. Neither class of objects is identified with the sources of optical radiation.

Thus, in matters concerning the existence of objects manifesting various evolutionary stages of cosmic matter, the theory based on the condensation hypothesis is essentially away from observations. At best, it tries to find some explanation of the existence of objects ‘unexpected’ for the theory itself.

It is all the more difficult for this theory to account for the more finer problems of the evolution of celestial bodies and processes accompanying that evolution.

Finally, if we consider the fact that the initial stage of the evolution is the stage presented by the diffuse nebulae, it is natural to pose the question: where do the maternal nebulae come from? For instance, in frames of the condensation hypothesis, it is very hard to conceive some mechanism of the origin of the Great Orion Nebula lying at a rather high galactic latitude.

Particular emphasis should be laid on the fact that the *unstable phenomena directly observed in cosmic formations and their systems almost always are of the nature of explosions, ejections, expansion and disintegration. This indicates that the evolution of cosmic matter, at least in that part of the Universe which has been the object of our observation, is characterized by processes of the diffusion and disintegration of matter* – i.e., by its transition from dense to less dense states.

This observational fact lies at the basis of the hypothesis of dense protostars (see, for example, Ambartsumian, 1953), contrasting with the condensation hypothesis. The hypothesis of protostars was formulated about 30 years ago. It allows the common origin of stars and diffuse matter resulting from the disintegration of massive protostars, assuming at the same time that the additional ejection of diffuse matter continues from stars which are already formed.

Well-known observational data enable us to judge certain properties of hypothetical protostars. Thus, it follows from the expansion of stellar associations that the protostars generating them are small in volume and dimension. It should be assumed that so far their direct observation has been hampered by the low radiation capacity of those formations in the optical region of the spectrum (see, for example, Ambartsumian, 1953).

The data available, relating to the activity of galactic muclei, also allow one to make the assumption that the protostellar matter is in states differing from those in stars and nebulae, and possibly, dissimilar in general to those so far studied by theoretical physics (see, for example, Ambartsumian, 1962).

Indirect evidence supporting the existence of remnants of dense protostellar matter in young stars had been derived by the beginning of the 50s. The analysis of the irregular changes of the brightness and the spectrum of unstable T Tauri-type stars and flare stars has shown (Ambartsumian, 1954b) that, at times, powerful sources of energy, outflowing from the inner regions, become discernible in the outer layers of those stars.

In view of the young age of T Tauri-type stars and flare stars, it can be assumed that this energy is contained in the condensations of protostellar matter still retained in their interior. The outflow of particular condensations and the transition of this matter in the decay process into a diffuse state results in the release of separate (discrete) portions of interstellar energy. Such portions bring about the observed unusual changes in the radiation of these stars (Ambartsumian, 1954b). We should like to emphasize however that such a concept of the nature of stellar explosions is but a hypothesis requiring confirmation.

Recently this concept has been applied in according for the engimatic phenomenon of fuors (FU Ori-type brightenings) (Ambartsumian, 1971). This interpretation is based on the assumption that before the sharp increase of the brightness of fuor in the region immediately surrounding it, sources have been present releasing most of their energy in the form of the kinetic energy of corpuscular radiation. An increase of the brightness of fuor is due to the ejection of the gaseous envelope by the star. These sources are included inside the envelope in the course of time. The envelope transforms the energy of corpuscular radiation of such sources into optical energy, as a result of which almost all of the particle flux energy changes into optical radiation accounting for the increase of the optical luminosity of the stars. This interpretation is substantiated by the observed appearance of lines markedly shifted to the ultraviolet in the spectra of fuors. These lines are indicative of the outflow of matter from the star.

Although the concept of the outcome into outer layers of unstable stars (or even into the surrounding space) of the fragments of protostellar matter containing discrete portions of interstellar energy, has not yet been universally acknowledged, it has already allowed the prediction of a number of interesting phenomena, such as the occurrence of two classes of flares 'fast' and 'slow' with differerent physical properties (Ambartsumian, 1954b, 1971).

A sceptical attitude to the hypothesis of protostars from the very onset of its formulation was also partly due to the fact that science was unaware of the large cosmic masses with high densities. However, the picture has recently undergone a radical change. Many facts concerning the unstable phenomena in the world of stars and galaxies indirectly point to the existence of such bodies.

In particular, the conclusion of the trend of the evolution of cosmic matter, determined by transitions from dense to less dense states, is corroborated by data relating to the activity of galactic nuclei (see, for example, Ambartsumian, 1958).

The possibility of the existence of large superdense cosmic masses is also substantiated theoretically (Ambartsumian and Sahakian, 1960a, b; Sahakian, 1972): in principle, a confirmation has been made of the possible existence in nature of equilibrium configurations of cosmic masses with the matter density exceeding that of the atomic nuclei.

The above formulated results on the evolution of stars, derived from observational data, would be, in our opinion, considerably greater in number and better grounded if this approach were also applied as extensively as the 'classical' approach based on the idea of the formation of stars by means of the condensation of diffuse matter.

In conclusion, we should like to note that an ignorance of the exact *laws of behaviour of the matter of massive protostars* is a stumbling block in the solution of problems concerning the formation of stars from dense protostars. Even such a comparatively simple matter as the problem of the behaviour of a piece of superdense matter in the vacuum, after it disengages itself in some way from the volume of the star (for example, from a neutron star), proves to be quite complicated and involves a number of uncertainties.

References

Ambartsumian, V. A.: 1937, *Astron. Zh.* **14,** 207.

Ambartsumian, V. A.: 1947, *Stellar Evolution and Astrophysics*, Acad, Sci. Armenian SSR, Yerevan.

Ambartsumian, V. A.: 1949, *Astron. Zh.* **26,** 3.

Ambartsumian, V. A.: 1953, *Compt. Rend. Acad. Sci. Armenian SSR* **16,** 97.

Ambartsumian, V. A.: 1954a, in P. Th. Oosterhoff (ed.), *Transactions IAU*, Vol. 8, University Press, Cambridge, p. 665.

Ambartsumian, V. A.: 1954b, *Contr. Byurakan Obs. 13* = 1955, *Astron. Popular* (*Mexico*) **2,** 27.

Ambartsumian, V. A.: 1954c, *Contr. Byurakan Obs.* **15.**

Ambartsumian, V. A.: 1957a, *Vestnik Acad. Sci. USSR* **11,** 45.

Ambartsumian, V. A.: 1957b, in G. H. Herbig (ed.), 'Non-Stable Stars', *IAU Symp.* **3,** 177.

Ambartsumian, V. A.: 1958, *La structure et l'evolution de l'Univers*, Editions Stoops, Bruxelles, p. 241.

Ambartsumian, V. A.: 1962, *Voprosy Kosmogonii* **8,** 3.

Ambartsumian, V. A.: 1969, *Stars, Nebulae, Galaxies*, Byurakan Symposium, Acad. Sci. Armenian SSR, Yerevan, p. 283.

Ambartsumian, V. A.: 1970, *Astrofizika* **6,** 31.

Ambartsumian, V. A.: 1971, *Astrofizika* **7,** 557.

Ambartsumian, V. A. and Mirzoyan, L. V.: 1971, in 'New Directions and New Frontiers in the Variable Star Research', *IAU Colloq.* **15,** 98.

Ambartsumian, V. A. and Mirzoyan, L. V.: 1975, in V. Sherwood and L. Plaut (eds.), 'Variable Stars and Stellar Evolution', *IAU Symp.* **67,** 3.

Ambartsumian, V. A. and Mirzoyan, L. V.: 1976, in V. A. Ambartsumian (ed.), *Probleme der Modernen Kosmogonie*, Birkhäuser Verlag, Basel, Stuttgart, Chapters I and II.

Ambartsumian, V. A. and Sahakian, G. S.: 1960a, *Astron. Zh.* **37,** 193.

Ambartsumian, V. A. and Sahakian, G. S.: 1960b, *Voprosy Kosmogonii* **9,** 3.

Ambartsumian, V. A., Mirzoyan, L. V., Parsamian, E. S., Chavushian, H. S., and Erastova, L. K.: 1970, *Astrofizika* **6,** 3.

Blaauw, A.: 1952, *Bull. Astron. Inst. Netherlands* **12,** 405.

Blaauw, A.: 1964, *Ann. Rev. Astron. Astrophys.* **2,** 213.

Blaauw, A.: 1978, in L. V. Mirzoyan (ed.), *Problems of Physics and Evolution of the Universe*, Acad. Sci. Armenian SSR, Yerevan, p. 101.

Cantó, J., Rodríguez, L. F., Barral, J. F., and Carral, P.: 1981, *Astrophys. J.* **244,** 102.

Chavushian, H. S.: 1979, *A Study of Flare Stars in the Pleiades Aggregate Region*, Byurakan Astrophys. Obs.

Clark, D. H. and Murdin, P.: 1978, *Nature* **276,** 44.

Grasdalen, G., Gehrz, R. D., Joyce, R., Knacke, R. F., Strom, S. E., and Strom, K. M.: 1975, *Astron. J.* **80,** 177.

Gyulbudagian, A. L.: 1980, in L. V. Mirzoyan (ed.), *Flare Stars, Fuors and Herbig–Haro Objects*, Acad. Sci. Armenian SSR, Yerevan, p. 247.

Gyulbudagian, A. L. and Magakian, T. Y.: 1977, *Compt. Rend. Acad. Sci. Armenian* SSR **64,** 104.

Hackwell, J. A., Gehrz, R. D., and Grasdalen, G. L.: 1979, *Astrophys. J.* **234,** 133.

Haro, G.: 1957, in G. H. Herbig (ed.), 'Non-Stable Stars', *IAU Symp.* **3,** 26.

Haro, G.: 1968, in B. M. Middlehurst and L. H. Aller (eds.), *Stars and Stellar Systems*, Vol. 7, University Press, Chicago, p. 141.

Haro, G.: 1976, *Bol. Inst. Tonantzintla* **2,** 3.

Haro, G. and Chavira, E.: 1966, in A. Beer and K. Aa. Strand (eds.), *Vistas Astron.* **8,** Pergamon Press, London, p. 89.

Herbig, G. H.: 1958, *Astrophys. J.* **128,** 259.

Herbig, G. H.: 1962, *Adv. Astron. Astrophys.* **1,** 47.

Herbig, G. H.: 1967, *Scientific Am.* **217,** No. 2, 30.

Herbig, G. H.: 1969, in L. Detre (ed.), 'Non-Periodic Phenomena in Variable Stars', *IAU Colloq.* **4,** 75.

Herbig, G. H.: 1974, *Lick Obs. Bull.*, No. 658.

Herbig, G. H.: 1977, *Astrophys. J.* **214,** 747.

Hoyle, F.: 1980, *Steady-State Cosmology Revisited*, University College, Cardiff.

Mezger, P. G. and Smith, L. F.: 1977, in T. de Jong and A. Maeder (eds.), 'Star Formation', *IAU Symp.* **75,** 133.

Mezger, P. G.: 1978, *Astron. Astrophys.* **70,** 565.

Mirzoyan, L. V.: 1961, *Contr. Byurakan Obs.* **29,** 81.

Mirzoyan, L. V.: 1966, in J.-C. Pecker (ed.), *Transactions IAU* **13B,** Academic Press, London, New York, p. 419.

Mirzoyan, L. V.: 1976, in E. K. Kharadze (ed.), *Stars and Galaxies From Observational Points of View*, Proc. III European Astronomical Meeting, Acad. Sci. Georgian SSR, Tbilisi, p. 121.

Mirzoyan, L. V.: 1977, in R. Kippenhahn, J. Rahe, and W. Strohmeier (eds.), 'The Interaction of Variable Stars with Their Environment', *IAU Colloq.* **42,** 126.

Mirzoyan, L. V.: 1978, in L. V. Mirzoyan (ed.), *Problems of Physics and Evolution of the Universe*, Acad. Sci. Armenian SSR, Yerevan, p. 209.

Mirzoyan, L. V. and Mnatsakanian, M. A.: 1970, *Astrofizika* **6,** 411.

Mirzoyan, L. V., Chavushian, H. S., Erastova, L. K., Ohanian, G. B., Melikian, N. D., Natsvlishvili, R. Sh., and Tsvetkov, M. K.: 1977, *Astrofizika* **13,** 205.

Poveda, A.: 1965, *Bol. Obs. Tonantzintla* **4,** 15.

Rodriguez, L. F., Moran, J. M., Ho, P. T. P., and Gottlieb, E. W.: 1980, *Astrophys. J.* **235,** 845.

Sahakian, G. S.: 1972, *Equilibrium Configurations of Degenerate Gas Masses*, Nauka, Moscow.

Schneeberger, T. J., Worden, S. P., and Wilkerson, M. S.: 1979, *Astrophys. J. Suppl.* **41,** 369.

Strom, K. M., Strom, S. E., Breger, M., Brooke, A. L., Yost, J., Grasdalen, G., and Carrasco, L.: 1972a, *Astrophys. J.* **173,** L65.

Strom, S. E., Strom, K. M., Yost, J., Carrasco, L., and Grasdalen, G.: 1972b, *Astrophys. J.* **173,** 353.

Tsvetkov, M. K.: 1976, *A Study of Non-Stable Stars in the NGC 7000 and IC 5068–70 Nebulae Region in the Cygnus*, Yerevan University.

Walker, M. F.: 1963, *Astron. J.* **68,** 298.

Welin, G.: 1971, *Astron. Astrophys.* **12,** 312.

Yankovics, I.: 1965, *Flare Activity of Red Dwarf Stars in the Praesepe Cluster Region*, Yerevan University.