On the 100-th anniversary of the birth of Academician V. A. Ambartsumyan

STAR FORMATION AND MOLECULAR CLOUDS

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The hypothesis advanced by V. A. Ambartsumyan according to which stars are formed from prestellar superdense objects—protostars—was an alternative to the hypothesis of the 1950’s (and even now, not much changed) according to which stars are formed by accretion with subsequent collapse (in various modifications). Ambartsumyan’s basic inferences were based on an analysis of the observational data available at that time. This paper presents both Ambartsumyan’s pioneering ideas and some modern hypotheses of star formation. Some results from studies of molecular clouds and star formation regions are also discussed. One of the distinctive features of young stellar objects (YSO) is the outflow of matter from these objects (molecular, in the form of jets, etc.), a phenomenon whose importance for the evolution of stars was noted by Ambartsumyan as long ago as 1937. Radial systems of dark globules are examined, as well as H-H objects associated with star formation regions, cometary nebulae, and close Trapezium-type systems (consisting of YSO). Keywords: stars: formation: molecular clouds: protostars

1. Introduction

Before V. A. Ambartsumyan published his papers on star formation it was widely assumed that stars were all born simultaneously and die simultaneously. Ambartsumyan showed that the process of star formation is a protracted event, which took place in the past, is continuing now, and will occur in the future, in stellar associations and out of protostars:

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"For brevity, we shall say that both stars and nebulae originate from protostars.

We can assume that protostars have a high mass and short radius. Stellar groups develop as the result of the division of protostars into a number of parts. The resulting small masses (on the order of a star’s mass) of prestellar matter are unstable and are rapidly transformed into ordinary matter to form stars. The mass of the protostar which remains outside the stars forms a nebula. During these transformations the energy concentrated previously in the protostar is often converted into kinetic energy of expansion of the nebula and the stellar group” [1].

Ambartsumyan noted [2] that, “The presence of giant gas nebulae, along with stars of early types, in O-associations merits attention. Of course, this is still no proof that the stars in an association originate directly from nebulae. But it does indicate, at least, an evolutionary relationship between stars of early types and gaseous nebulae,” and that [3], "My personal opinion is that future observations will show that stellar associations and expanding nebulae are formed together.

Briefly stated, I suggest that we must renounce the old idea that stars originate from diffuse matter, but, rather, assume that both the diffuse matter and the stars are formed jointly as the result of the breakup of protostars.

2. Molecular clouds

Beginning in the mid-1970's molecular hydrogen became one of the major objects of research on the physics of the interstellar medium. Studies of the distribution of H$_2$ in the galaxy led to the discovery of a new structural element in the disk of our galaxy – the molecular ring – a region of elevated H$_2$ concentration in an annulus with $R = 4 – 8$ kpc. In this ring we also have high concentrations of stellar associations, star-formation regions, HII regions, pulsars, supernova remnants, diffuse γ-radiation sources, and synchrotron radiation sources. The bulk of the H$_2$ is concentrated in giant molecular clouds (temperature 10-100 K, density $\sim$3·10$^2$ cm$^{-3}$, size $>50$ pc) and in molecular complexes (temperature 10-100 K, density $\sim$10$^2$ cm$^{-3}$, size $>100$ pc) [4,5].

It is now known that OB-stars are mainly born in molecular clouds in star-formation regions and that during star formation the molecular clouds are partially or completely destroyed [6]. Recent observations by Japanese astronomers have shown that $\sim$24% of giant molecular clouds contain no stars, $\sim$53% are associated with HII regions, and $\sim$24% are associated both with HII regions and with young star clusters [7].

Inside some giant molecular clouds there are hot nuclei. The hot molecular nuclei are characterized by a gas temperature exceeding 100 K and a rich chemistry, which is observed in molecular lines at submillimeter wavelengths. It is assumed that these hot nuclei are an early evolutionary phase of the formation of high-mass stars, where active outflow takes place from protostars, while ultracompact HII regions have not yet developed [8]. Young stellar objects (YSO) usually consist of a central protostellar object surrounded by a shell and a flat disk. YSO’s are characterized in terms of classes 0, 1, 2, and 3, where the degree of outflow decreases along this sequence [9,10]. The phase with class 0 is of special interest both because many properties of a future star are determined during this phase, and, mainly, because of the powerful outflows which may have a significant effect on the surrounding interstellar medium: they form molecular clouds, may form cavities in them, and may compress dust shells. Observations of this phase