Viktor Ambartsumian's most important scientific achievements

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Abstract

We give a review of the most important scientific achievements of one of the greatest scientists of the XX century, the founder of the modern astrophysics in Armenia, Viktor A. Ambartsumian (1908-1996). He has fundamentally contributed in various fields of astronomy and astrophysics, cosmogony, theoretical physics, mathematics, and philosophy. We list the most important scientific results, including his revolutionary works on origin and evolution of stars and activity of galactic nuclei that turned over the development of astrophysics and gave life to our before unchanged Universe. He was one of the founders of the theory of planetary nebulae, stellar dynamics, protostellar dense matter, as well as he has contributed in other important areas of the theoretical astrophysics. Ambartsumian was also a great organizer of science, important political and public figure. He was the founding Director of the Byurakan Astrophysical Observatory (BAO, 1946-1988), the President of the Armenian Academy of Sciences in 1947-1993, the President of the International Astronomical Union (IAU) in 1961-1964 and the President of the International Council of Scientific Unions (ICSU) in 1968-1972. He was the founder of the theoretical astrophysics in the Soviet Union, the founder of chairs of astrophysics in Leningrad (St. Petersburg) and Yerevan state universities, as well as the journals Communications of BAO and Astrofizika (Astrophysics).

Keywords: *Theoretical Physics – Theoretical Astrophysics – Stellar Dynamics – Stellar Evolution – Planetary Nebulae – Interstellar Medium – Radiative Transfer Theory – Stellar Associations – Active Galactic Nuclei – Superdense Matter.*

1. Introduction

Viktor Ambartsumian (1908-1996) is one of the greatest scientists of the XX century who has fundamentally contributed in various fields of astronomy and astrophysics, cosmogony, theoretical physics, mathematics, and

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philosophy. His revolutionary works on origin and evolution of stars and activity of galactic nuclei turned over the development of astrophysics and gave life to our before unchanged Universe. He is one of the founders of the theory of planetary nebulae, stellar dynamics, protostellar dense matter, as well as he has contributed in other important areas of the theoretical astrophysics. Ambartsumian was also a great organizer of science, important political and public figure. He is the founder of the Astrophysics Departments at Leningrad (St. Petersburg) and Yerevan state universities, Byurakan Astrophysical Observatory (BAO), journals *Communications of BAO* and *Astrofizika (Astrophysics)*, one of the founders of the Armenian Academy of Sciences. Ambartsumian was the founding Director of BAO (1946-1988), the President of the Armenian Academy of Sciences in 1947-1993, the President of the International Astronomical Union (IAU) in 1961-1964 and the President of the International Council of Scientific Unions (ICSU) in 1968-1972.

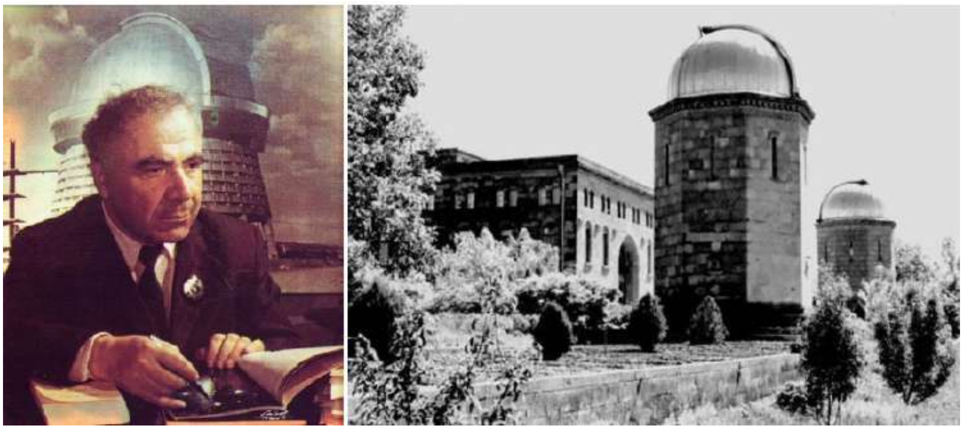

Figure 1: Viktor Ambartsumian (1908-1996) and Byurakan Astrophysical Observatory (BAO), founded by him.

Viktor Amazasp Ambartsumian was born on September 18, 1908, in Tbilisi (Georgia). After the graduation of Leningrad (Saint-Petersburg) University and post-graduate studentship in Pulkovo Observatory, he founded at the University the first Department of Astrophysics in the Soviet Union. In 1943, V.A. Ambartsumian was one of the founding members of the Armenian Academy of Sciences and its Vice-President. Soon, in 1947, he became the President of the Academy, and since 1993 he was its Honorary President.In 1946, Byurakan Astrophysical Observatory (BAO) of the Academy of Sciences of Armenia was founded. Since the first days till 1988 V.A. Ambartsumian was the Director and scientific leader of BAO. And since 1988, he was its Honorary Director. Thanks to Ambartsumian's and his colleagues' works it became one of the known observatories in the world.

Ambartsumian's research works are distinguished in perfection and almost every time opened new directions in astrophysics. His works on physics of gaseous nebulae and radiation transfer theory are classic. They played an important role in this field, in particular, in the theory of multiple light scattering. The invariance principle, formulated in these works for the first time, had a wide application in a number of other fields of the science. Ambartsumian's investigations on the problem of stellar evolution brought in 1947 to revealing of stellar systems of new type, stellar associations. The existence of stellar associations in the Galaxy, dynamically non-stable and disintegrating systems, was the first observational evidence in favour of continuing at present star-formation in it. Ambartsumian put forward a hypothesis about the joint origin of the diffuse matter and stars of dense matter of unknown nature, protostars. Ambartsumian's studies of early stages of evolution of stars and stellar systems are rather significant. It was shown, that in the early stages of the evolution, the instability of the state reveals itself, being the regular phase of the cosmogonic processes. Among these results the conclusions about the existence of stellar systems of positive total energy in the Galaxy, non-thermal nature of ultraviolet stellar radiation of T Tauri type and flare stars, are to be mentioned. New principle results were achieved by V.A. Ambartsumian in study of evolution of galaxies. It was shown for the first time that the central regions of galaxies, their nuclei, play a decisive role in the phenomena of instability, observed in galaxies. Besides the stars and diffuse matter, they must contain dense massive bodies of unknown nature. The activity of galactic nuclei defines their evolution. At present the active galactic nuclei (AGN) are the most intensively studied objects in extragalactic astronomy.

Ambartsumian has carried out some other investigations of great importance in astrophysics as well, such as the study of interstellar absorbing matter in the Galaxy (the idea of its clumpy structure, the theory of fluctuations of light of the Milky Way), works on stellar dynamics (establishing of the basis of new, statistical mechanics of stellar systems), statistical investigations of flare stars, and others. V.A. Ambartsumian has published about 20 books and booklets, more than 200 scientific papers, and numerous popular articles.

Ambartsumian was an outstanding organizer of science, who significantly promoted the international scientific cooperation. In 1948-1955 he was the Vice-President, and in 1961-64, the President of the International Astronomical Union (IAU), in 1968 and 1970 he was twice elected the President of the International Council of Scientific Unions (ICSU). His many-sided activity accepted high estimate. He was awarded governmental prizes, orders and medals of a number of countries (Twice Hero of Socialist Labour in 1968 and 1978, USSR State Prizes in 1946 and 1950, Russian State Prize in 1995, National Hero of Armenia in 1994), gold medals of a number of academies and scientific societies.

He was elected honorary and foreign member of 28 Academies of Sciences, including USA, UK, France, Italy, Netherlands, Belgium, Denmark, Sweden, Greece, Czechoslovakia, India, Argentina, and others, honorary member of scientific societies of many countries, honorary doctor of the Universities of Canberra (Australia), La Plata (Argentina), Warsaw and Torun (Poland), Prague (Czechoslovakia), Liege (Belgium) and Sorbonne (France).

Victor A. Ambartsumian passed away on August 12, 1996 in Byurakan. He will remain forever as one of the most outstanding scientists of the XX century.

Viktor Ambartsumian's scientific achievements are well-known in the scientific community, especially among astronomers and astrophysicists. However, he has left so much legacy that one should try to thoroughly study, analyze and classify all this big material. Once, a small attempt was made by Ambartsumian himself in his memories given in the book "Life Episodes" (Shahbazyan 2001; 2003; however, this is only in Russian and Armenian and the world community still has no access). Ambartsumian recalled that some scientists especially mention some definite results by him from 1930s. Most of these concerned theoretical astrophysics, theory of planetary nebulae, stellar dynamics, etc. On the other hand, later on, many scientists considered the discovery of stellar associations (1947) and the hypothesis on the activity of galactic nuclei (1950s) as Ambartsumian's most important works. The theory of superdense matter (1960s) and the statistics of the flare stars (1968) that resulted in the major conclusion about the flare activity of all dwarf stars are also worth to mention. In 2008 we released a DVD devoted to Ambartsumian's 100th anniversary and we made an effort to sort his major achievements in science (Mickaelian 2008). These results were also published in Harutyunian Mickaelian (2008; 2011). Most detailed description of Ambartsumian's most important scientific results is given in the book "Viktor Ambartsumian: Life and Activities" (Mickaelian 2014).In this review we summarize and analyze Viktor Ambartsumian's most important achievements based on all these previous studies.

2. Most important scientific results

2.1. Astronomy, Astrophysics and Cosmogony

2.1.1. Theory of Planetary Nebulae (PN)

For the first time the **influence of the light pressure on the planetary nebulae dynamics was studied** (1932). Each quantum of light owns a definite amount of energy and linear momentum. The bigger the frequency of the quantum (or shorter the corresponding wavelength), the bigger the momentum carried by them. As there are many hot stars in the center of planetary nebulae, which emit short wavelength photons, a question arises, how this emission may affect the circumstellar gas medium.This problem had a very important subtext. The matter was that the classical cosmogony claims that stars are being formed as a consequence of the condensation of gas and dust, and the joint existence of a star and a nebula could introduce a definite clarification in their evolutionary chain. And it was really obtained that **owing to light pressure the planetary nebulae expand and should gradually dissipate in the space**. It was also shown that **the age of the planetary nebulae could not exceed 100000 years if no continuous outflow existed from the central star**. Thus, for the first time the new evolutionary paradigm on the formation of objects from denser matter was formulated.

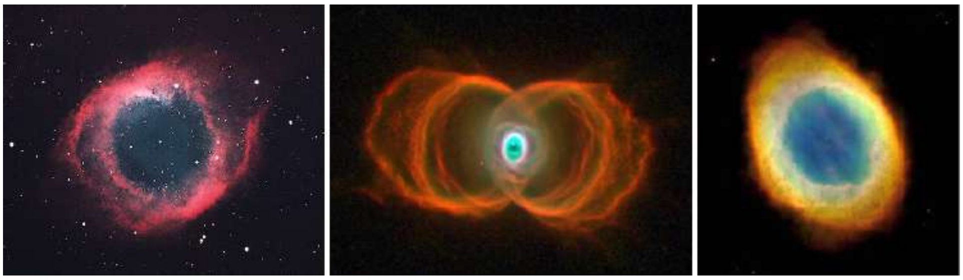

Figure 2

Zanstra's method for determination of the planetary nebulae's central star temperature was modified giving the probabilistic definition of short-wave energetic photons transformation into less energetic ones (1932). It is known that the planetary nebulae radiate due to the transformation of short-wave photons emitted by the hot stars located in their center. It means that the high energy photons emitted from the star, which are not visible to the eye due to their short wavelengths, are being absorbed in the nebula ionizing the gas atoms. Due to this, ions and electrons are being originated in the nebula. Later on, electrons couple with ions and as a result numerous different energy photons form, including those visible to the eye. If a method is being developed allowing calculate the number of the transformed and hence visible photons, the number of those short wavelength photons that originated the visible ones also may be determined. Just due to this it becomes possible to calculate the surface temperature of the star. This definition leads to the determination of radiative equilibrium.

2.1.2. Novae and Supernovae

For the first time **the amount of matter ejecting as a result of Novae and Supernovae explosions was estimated** (together with N.A. Kozyrev, 1933). The phenomena of Novae and especially Supernovae belong to the largest stellar explosions. The first of these names has been formed historically. The matter was that in the sky from time to time people discovered stars that had never been observed before and it seemed as if they were newly born stars.Later on it was understood that they also existed before, however were not visible due to their faintness. They become visible at some moment due to a burst and increase of their brightness dozens of thousands or even million times. And in a few months they return to their previous state. The Supernova phenomenon is much more powerful compared to the ordinary Novae. If the Nova after the explosion returns to its normal state, the Supernovae after the explosion don't return to their former state anymore. For the thrown out matter as a consequence of the explosion **Ambartsumian obtained the presently known values of 0.00001 and 1 solar masses correspondingly for the Novae and Supernovae** phenomena.

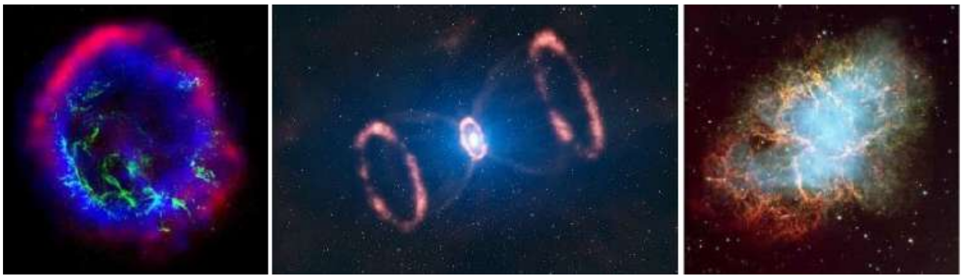

Figure 3

2.1.3. Stellar Dynamics

For the first time **the distribution of stellar spatial (3D) velocities was derived** using only the coordinates and radial velocities. By classical method, the stellar spatial velocities are being determined by their radial and tangential velocities. However, the observations at different directions lead to a variety of errors. Taking into account that the spatial velocities are being given in three components, Ambartsumian applied a completely different method using three other variables for each star; the radial velocity and celestial coordinates. As a matter of fact, a necessity originated to find the required function that depended on three variables by means of a known function also depending on three other variables. This problem was reduced to the numerical inversion of the Radon transformation. Four decades later **the same mathematical scheme was applied for the construction and exploitation of computer tomography**. *"It seems to me quite possible that Ambartsumian's numerical methods might have made significant contributions to that part of medicine had they been applied in 1936"*, – mentioned in 1985 Allan Cormack who won the Nobel Prize in

Physiology and Medicine for creating the tomography.

Figure 4: Viktor Ambartsumian derived the 3D distribution of the stellar velocities and 4 decades later the same mathematical scheme was applied for the construction and exploitation of computer tomography by Godfrey Hounsfield and Allan Cormack who won the Nobel Prize in Physiology and Medicine in 1979.

Using the statistical studies of, so called, wide binaries it was shown for the first time that those did not obey the dissociative equilibrium conditions (1936-1937). The matter is that during the stellar approaches as physically coupled binaries may form so as the existing binaries may disrupt. So, if three physically uncoupled stars approach each other, an energy exchange may happen between them. One of the possible consequences of such exchange is that one of the three stars obtains large energy and leaves and the remaining two, losing some part of their energy, cannot anymore move away and form a binary. The inverse phenomenon may also take place, when a third star approaches a physically coupled binary, transfers part of its energy to them and decouples them from each other and three uncoupled stars form as a consequence. A dissociative equilibrium establishes in a definite time when these two inverse processes equal each other. Ambartsumian showed that such equilibrium has not yet been established and the number of binaries is many times larger than was expected in the case of the equilibrium state. The same studies allowed arriving at a conclusion that the components of binaries had been formed jointly. Moreover, *the observed distribution put an upper limit for the Galaxy age*, which agreed with "the short scale".

Figure 5

The mechanism of star "evaporation" from the open star clusters was revealed (1938). The use of this phenomenon allowed him for the first time find the halftime of the clusters' decay, and was applied to anticipate the gradual decrease of the number of low mass stars in clusters. A new stellar statistical method was developed to consider this problem. For this, it was taken into account that in the stellar system of any type mutually connected by gravitational forces an ongoing energy exchange was taking place between its components. As a consequence, a so-called equilibrium Maxwell distribution of energies is being established. On the other hand, in the case of equilibrium distribution some stars gain such velocities that allow them break away from the gravitational field of the system and irreversibly leave. As a result, the energy equilibrium is being broken and the energy exchange again establishes a new equilibrium state. This process, which is by its sense the same as the water evaporation, gradually depletes the star cluster. And by the way, the low-mass stars leave the cluster the first as in the case of the same energy low-mass stars gain larger velocities. These studies provided a theoretical basis for decreasing the accepted age of the Galaxy for thousand times (the previous estimate, so-called "the long scale" was by James Jeans, 1013 years), making it equal to 10 billion years and for **introducing "the short scale" of the Galaxy age**. Note that this estimate has not changed until nowadays, though with the development of science many new methods have been applied to calculate the age of the Galaxy. It is worth stating that by modern estimates the age of the Universe is 13.8 billion years.

Figure 6: Viktor Ambartsumian and James Jeans (UK), who disputed in 1930s about the age of Our Galaxy

2.1.4. Interstellar Medium (ISM)

The patchy structure of the Milky Way's absorbing dust component was revealed (together with Sh.G. Gordeladze, 1938). Our Galaxy has two components, one having disk-like flat form and spiral arms come out from its nucleus. The stars belonging to this component form in the sky the nebulous strip of the Milky Way. And the whole gas-dust matter of the Galaxy belongs just to this component. Even with the naked eye one can see that the stars in the Milky Way are not distributed equally; in some parts their number is rather small compared to the neighboring regions. This is simply because of the presence of the absorbing matter. Ambartsumian was the first to show that the distribution of the absorbing matter was rather inhomogeneous and in the reality it was formed of individual clouds. The sense of the name "patchy structure" is just the fact that it is consisted of these individual clouds. For the first time, **the mean absorption of corresponding single clouds was estimated to be of the order of 0.2 magnitudes corresponding to some 1.2 times weakening of the light passing through it.**

Figure 7

The **theory of the fluctuations in brightness of the Milky Way** was formulated (1944). In the simplest form it asserts that the probability distribution of fluctuations in the brightness of the Milky Way is invariant to the location of the observer. In the interstellar space the absorbing clouds are concentrated in a rather thin strip around the plane of symmetry of the Galaxy. Definite deviations of the observed distribution of the brightness of the Milky Way have formed in the sky due to the light absorption in them. For the same reason, deviations from the equal distribution of the number of other galaxies are also formed. In other words, for example if in the case of absence of interstellar absorption, the brightness of the Milky Way in the neighboring regions of the sky would not vary much, the presence of the absorbing clouds causes abrupt variations of this brightness. The nature and size of the observed deviations are completely determined by the properties and the number of the interstellar absorbing clouds. **The investigation of the observed deviations by the theory of fluctuations allowed determine the properties of the absorbing clouds.**

2.1.5. Radiative Transfer Theory

The Invariance principle was proposed to solve the radiative transfer problems (1941-1942). The principle in fact has a very simple physical sense and statement. For the first time it was established for the purpose of the formulation of the problem of the reflection of radiation from the semi-infinite medium. It is enough to imagine a radiation scattering and reflecting medium that has only one surface and fills half of the space. An example of such a medium is the ocean for the ordinary light. The radiation penetrates into the depth of the medium and may change its direction in the case of each scattering process and move in the opposite direction or continue moving in the same direction. The problem is to determine the number of the reflected radiation as a result of numerous scattering processes, which in general case depends on different variables, including the direction, wavelength, etc. Very simple physical reasoning that the reflection properties of the semi-infinite medium will not be changed if a very thin layer of the same physical properties is added to the medium boundary gave an excellent basis for creation of a new and strong research method. The mathematical equations describing the problem are much simpler and are being easily solved compared to the previously used so-called transfer equation. After many years Ambartsumian declared *the Invariance Principle* to be one of the most important tools he invented. This principle bears V. Ambartsumian's name and the corresponding function was named V. Ambartsumian's ϕ function.

Figure 8: A humorous drawing by the French astronomer Jean-Claude Pecker showing Ambartsumian's Principle of Invariance

2.1.6. Stellar Evolution

The importance of the stellar associations as dynamically unstable entities was revealed (1947-1949). The stellar associations, which are distinguished by a rather big partial density of similar stars, attracted Ambartsumian's attention still in 1930s. A special interest caused the question how the similar stars had gathered in the same area. Investigating their structural properties, Ambartsumian showed that **they had been formed together and that they could not be older than a few dozen million years**. It meant that the stars belonging to the stellar association also could not be older than that. Taking into account that the prevailing part of the stars of the Galaxy are a few billion years old, **a conclusion was made that these were newly born stars**. Thus it was shown for the first time that **at present the star formation process also continues**. It was the first case when it was shown that in a finite space volume there exist stars of different ages. The other important conclusion was that **the star formation occurs in groups**.

Figure 9

Ambartsumian showed that **the continuous emission observed in the spectra of non-stable stars had nonthermal nature** and put forward an idea about new possible sources of stellar energy, the hypothesis of the superdense protostellar matter (1954). Moreover, later on Ambartsumian concluded that the same source might be responsible for the phenomena taking place in the centres of galaxies, galactic nuclei. Observational evidences, particularly huge amounts of energy emitted from the central parts of galaxies, insist on the existence of powerful sources of energy. At present the most popular explanation for the AGN powerhouse, the Unified Scheme, involves accretion of gas onto a Super Massive Black Hole (SMBH). Thus, Ambartsumian's suggestion that there existed a supermassive dense body in the center of galaxies is now well accepted and SMBH could be one of the possible models of such matter. Though Ambartsumian believed that the source of energy was inner, it is obvious that his idea on the activity of galaxies based on the energy sources hidden in the galactic nuclei is modified to fit known physical theories, which Ambartsumian himself did not find unambiguous.

Theoretical studies of the hypothetical superdense protostellar matter have been done in the frame of the modern knowledge of physics (together with G.S. Sahakyan, 1960-1961). The existence of stellar associations and the possibility of the formation of stellar groups in a small space volume already require the presence of matter of a new type that is by its density comparable to atomic nuclei. The activity of the galactic nuclei and the need of the presence of large masses in them even more increased the necessity of the theoretical justification of the superdense matter. **These researches allowed later increase the Chandrasekhar limit of stellar masses.** However, so far it has not been possible to theoretically prove the possibility of the existence of superdense matter concentrations having masses of galaxies or their nuclei. So far just this prevents the further dissemination of the point of view of the activity of galactic nuclei and the formation of daughter galaxies by decay and ejections from galaxies. Some researchers believe that this obstacle is in fact a consequence of the non-perfect knowledge of the laws of Nature.

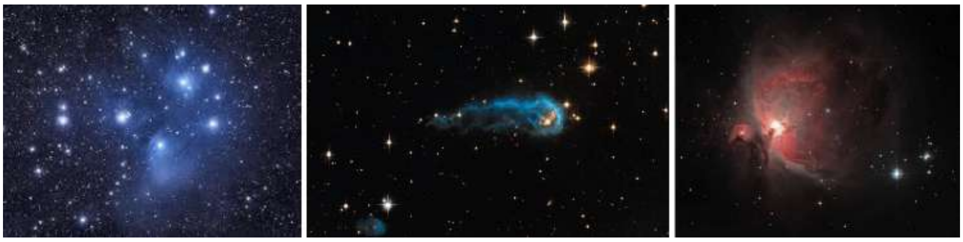

Figure 10

Statistical studies of the flare stars revealed their evolutionary status (1968). In general, on all stars one can find various evidences of activity. Even on the Sun that is considered as a quiet star, giant explosions and bursts take place, though having essentially smaller energy compared to the total energy emitted by the Sun. However, there exists a whole class of dwarf stars, which show flares having emitted energy dozens and hundreds times more than that of the star at quest state. These stars are called flare stars and no stellar inner structure model had predicted such a phenomenon. For this reason for some time these stars were considered as "crazies" of the stellar family that do not obey the general regularities. However, their observational study and statistical investigation showed that the flare activity was a regular phase in the evolutionary path of low-mass and low-luminosity stars. It was proved that **all the stars of the mentioned category inevitably possess flare activity in the early phases of their evolution**. Later on (1978), on the basis of the chronology of discovery (first flares) and confirmation (second flares) of the flare stars, Ambartsumian by a solution of an inverse problem derived the **distribution function of average frequencies of flares in the given stellar system.**

2.1.7. Active Galactic Nuclei (AGN)

The **hypothesis on the activity of galactic nuclei** was proclaimed (1956). Previously it was believed that the nuclei of galaxies were their oldest parts that did not have any participation in the evolution of galaxies. Even there was an opinion that the nucleus was the "grave" of the dead matter. However, the observational facts showed evidence that there were ejection and outflow of matter from the nuclei of galaxies, including some cases when these processes were connected with expenditure of a rather large amount of energy. Moreover, the amount of the ejected matter sometimes can be enough to form a new smaller mass galaxy. This and other similar facts served as a basis for a formation of an unprecedented idea on the activity of galactic nuclei. The various forms of activity have been presented as different manifestations of the same phenomenon of activity. **The evolutionary significance of the activity in the galactic nuclei** was emphasized and further hypothesis was declared on the ejection of new galaxies from the active galactic nuclei.

Figure 11

Since the beginning of 1950s, Ambartsumian carefully analyzed all accumulated data on emission-line galaxies, radio galaxies, blue components around giant galaxies, Haro's blue galaxies, etc. and came to a conclusion that all these different manifestations (various forms of activity) related to the same physical phenomenon, namely activity of the galactic nuclei. It was not straightforward and obvious, as the data were very few and each seemed to have independent explanation. Moreover, blue-UV emission of some nearby galaxies obviously came from their spiral arms and was explained by a large number of hot stars. Thus, a hypothesis on the activity of galactic nuclei was proclaimed by Ambartsumian (1955; 1956). The evolutionary significance of the activity in the galactic nuclei was emphasized and a further hypothesis was suggested on the ejection of new galaxies from the active galactic nuclei. The hypothesis on the superdense protostellar matter was engaged to explain the observational data. According to Ambartsumian, forms of activity could be rather different: emission of gas from the central part of the galaxy having velocities up to several hundreds of km/sec, emission of fluxes of relativistic particles originating high-energy particles (forming radio halos around the nuclei), eruptive outbursts of gas matter, eruptive outbursts of relativistic plasma, outbursts of blue concentrations having absolute luminosity typical of dwarf galaxies, etc. A comparative analysis of all these observational data shows that independent on their apparent differences, all these phenomena have a common physical nature. Ambartsumian came to such conclusion at the very beginning of investigations, however, during many years (1960s-1980s), all types of revealed AGN were regarded as different kinds of objects, probably with different mechanisms of radiation. Moreover, all historical classifications (Seyfert 1 and 2, radio galaxy, QSO, LINER, BL Lac objects, etc.) supported an idea to explain them separately and then (if possible) try to find similarities or links between these classes.

The theoretical study of the numerous observational evidences of various sorts of physical instability in galaxies led Ambartsumian to a fundamental conclusion that in processes of origin and evolution of galaxies, the role of the central small in their sizes condensations, the nuclei of galaxies, is huge. He justified an essentially new understanding that all observational evidences of the instability of galaxies are a consequence of activity of the galactic nuclei. Further on he established that to various degrees of activity of nuclei of galaxies correspond various manifestations by the form and power in structure and radiation of galaxies.

In 1985, Antonucci and Miller published a paper *"Spectropolarimetry and the nature of NGC 1068"* (a classical Seyfert 2 type showing only narrow emission lines). The polarized flux plot revealed the presence of very highly polarized, very broad symmetric Balmer lines and also permitted Fe II closely resembling the flux spectra of Seyfert type I nuclei. This line emission indicated that both polarizations were due to scattering, probably by free electrons which must be cooler than a million K. A model was suggested in which the continuum source and broad line clouds were located inside a thick disk, with electrons above and below the disk scattering continuum and broad-line photons into the line of sight. All of the narrow lines, including the narrow Balmer lines, had similar low polarizations, unrelated to that of the continuum. Further studies strengthened such a geometrical understanding of the difference between the AGN, so that each type (the classification) depended on the observed angle.

Ambartsumian considered the existence of a supermassive dense matter in the center of stars and galaxies that was responsible for their activity and evolution. However, there in fact was no any developed model to describe this hypothesis, beside some attempts to build superdense stellar configurations. Observational evidences, particularly the huge amounts of energy emitted from the central parts of galaxies, insist on existence of a powerful source and until now this puzzle is not yet finally solved. There are in fact two opposite understanding on the phenomena of star formation, cos-

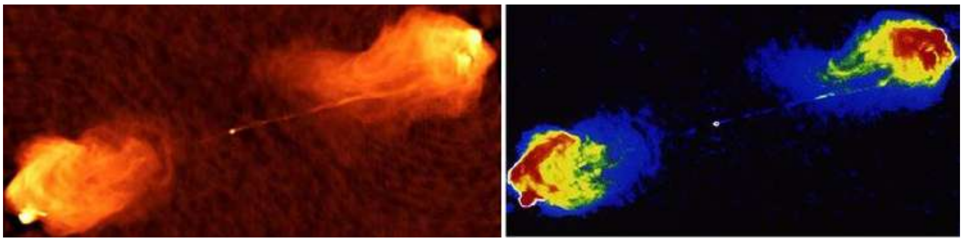

Figure 12

mogony in general, and activity of the galactic nuclei; classic approach and Ambartsumian (or Byurakan) one. It is important to anyway understand, how much these two "opposite" approaches contradict each other and how much they are related.

At present, the most popular explanation for the AGN powerhouse involves accretion of gas onto a Super-Massive, perhaps spinning Black Hole (SMBH). Different regimes of accretion have been invoked to constitute the basis of a unified picture of AGNs. The predictions of the theory are that rotationally supported thin disks would form at lower accretion rates ($M < M_{Edd}$), while supercritical ($M > M_{Edd}$) accretion flows are expected to form thick disks supported by radiation pressure. A very subcritical flow may not be able to cool and, instead of forming a thin disk, it puffs up giving rise to an ion torus supported by gas, rather than radiation, pressure. The formation of the torus is crucial to support the unified model of AGN. Further studies strengthened such an understanding of the AGN energy sources. However, there still are many difficulties and the discovery of new objects with new properties encounter challenges in their explanation in frame of the general scheme. Ambartsumian's theoretical consideration of observational data about the known forms of activity of the galactic nuclei gave serious bases to admit that activity of nuclei was caused not by stars and not by diffuse matter containing in them. They could not explain, at least, such observed forms of nuclear activity, which were connected with allocation of enormous amounts of energy and eruptions of unusually big masses of matter. Hence, it is necessary to consider that in corresponding nuclei there are bodies of at present unknown nature, which contain very big stocks of matter and have huge energy. In other words, it is necessary to consider, that in galactic nuclei physical conditions of matter are extremely unusual and strongly differ from the conditions observed in other parts of the Universe. In particular, in some bodies containing in nuclei of galaxies, the matter density should be extremely high. Only in this case the nuclei can provide the continuous outflow of matter or emissions and eruptions of the big masses from the nuclei, phenomena revealed by observations in some galaxies. These reasons also have formed a basis for working out of new important understanding that the galactic nuclei are sources of huge amounts of matter and energy, which then give rise to formation around them galaxies or systems of galaxies and supply them with energy of the observed non-stationary motions. Ambartsumian showed that the results of studies of non-stationary systems of galaxies and various forms of display of nuclear activity of separate galaxies represent huge scientific interest not only for discovery of the laws of the origin of stars and stellar systems of various scales, but also for detection and research of while unknown states of matter, including the proto-stellar ones. And the results received by Ambartsumian in this area are in a full consent with understanding of the theory of stellar associations already mentioned earlier that matter development in the Galaxy has a certain orientation from denser states to less dense ones. One could believe that the search for such forms and states of matter in the central parts of galaxies led some astrophysicists to find the model of SMBH as such, though not completely explaining many aspects.

There are of course principle differences in the classical and Ambartsumian's approaches to the explanation of AGN energy sources. Ambartsumian believed that the source of energy was inner; it is emitted from the central engine and was directly connected to the nature of the central dense matter. The unified scheme and related accreting SMBH theory attributes the energy to the accretion on SMBH, which is in fact a physical process related to the environment of the central source. But there also are similarities between the classical and Ambartsumian's approaches. Ambartsumian's suggestion that there existed a supermassive dense body in the center of galaxies is now well accepted and SMBH could be one of the possible models of such matter. It is obvious that Ambartsumian's idea on the activity of galaxies based on the energy sources hidden in the central parts of galaxies (nuclei) is modified to fit known physical theories, which Ambartsumian himself didn't find unambiguous.

2.2. Theoretical Physics

In 1930 he published a paper with Dmitri Ivanenko where the **impossibility of the existence of free electrons in the atomic nuclei was proved**. After the formation of the first understanding on the atomic structure, the explanation of the contents of the atomic nucleus was considered as the most important problem. It was known that the nuclei were charged positively and the simplest explanation was that they consisted of protons. However, as the experiments showed, the nuclear mass was bigger than the summarizing mass of the protons corresponding to their charge. To overcome this controversy the author of the atomic structure Ernst Rutherford believed that the nuclei were formed of as many protons as was needed to reach the nuclear mass and the excessive charge was neutralized by the corresponding number of electrons located in the nucleus. Ambartsumian and Ivanenko showed that **only electrically uncharged elementary parti-**

cles of approximately proton mass could exist together with protons in the nuclei. Two years later the English physicist James Chadwick discovered the neutron. Ambartsumian and Ivanenko also put forward an idea that not only the quanta of the electromagnetic field, photons, but also other **particles (including particles having nonzero rest mass) may be born and disappear as a result of their interaction with other particles** (this idea lays in the basis of modern physics of the elementary particles and quantum field theory).

Figure 13: Viktor Ambartsumian, Dmitri Ivanenko and James Chadwick

2.3. Mathematics

For the first time **the problem of finding the form of the differential equation corresponding to the known family of eigenvalues was solved**. This problem is rather hard in its general statement. As an example, one can imagine such a problem. It is known that all atoms have discrete energy levels and spectral lines form due to transitions between them. A question arises; having the set of the spectral lines characterizing an atom, is it possible to find the equation with the line frequencies as its eigenvalues? The problem discussed by Ambartsumian belonged to the same family of problems but was incomparably simpler, though at that time also seemed unsolvable. It related to the frequencies of oscillations of a homogeneous string. It was shown that only the given string could have the given spectrum of frequencies. The paper devoted to the solution of this problem was published in the German Journal of Physics (*ZeitschriftfürPhysik*, 1929). It remained unnoticed for one and half dozen years. *"If an astronomer publishes a paper on a mathematical problem in a physical magazine, he is not to be wondered that nobody has noticed it"*, – was recalling he many years later. However, the paper was found, valued highly by mathematicians and **it initiated a wide direction in mathematics – inverse problems**.

3. Ambartsumian's most important scientific publications

Here we give the papers that contain Ambartsumian's most important scientific results listed above.

W.A. Ambarzumjan – Uber eineFrage der Eigenwerttheorie (On a Problem of the Theory of Eigenvalues) // Zeitschrift fur Physik, Vol. 53, Nos. 9-10, p. 690-695, 1929 (in German)

W.A. Ambarzumjan, D.D. Iwanenko – Eine quantentheoretischeBemerkungzureinheitlichenFeldtheorie (A Quantum-Theoretical Remark on the Uniform Field Theory) // Doklady USSR Acad. Sci., Ser. A, Vol. 3, p. 45-49, 1930 (in German)

W.A. Ambarzumjan, D.D. Iwanenko – Uber eineFolgerung der DiracschenTheorie der Protonen und Elektronen (On a Consequence of the Dirac Theory of Protons and Electrons) // Doklady USSR Acad. Sci., Ser. A, Vol. 6, p. 153-155, 1930 (in German)

V.A. Ambartsoumian, D.D. Ivanenko – Les electrons inobservables et les rayons (The Inobservable Electrons and Rays) // Compterenduhebdomadaire des seances de l'Academie des sciences de Paris, Vol. 190, No. 9, p. 582-584, 1930 (in French)

V.A. Ambartsumian – The Radiative Equilibrium of a Planetary Nebula // Monthly Notices of the Royal Astronomical Society (MNRAS), Vol. 93, No. 1, p. 50-61, 1932 (in English)

V.A. Ambartsumian – On the Temperatures of the Nuclei of Planetary Nebulae // Poulkovo Observatory Circular, No. 4, p. 8-12, 1932 (in English)

W.A. Ambarzumjan, N.A. Kosyrew – Uber die Massen der von den neuenSternenausgestossenenGashullen (On the Masses of Envelopes thrown out by Novae) // Zeitschrift fur Astrophysik, Vol. 7, No. 4, p. 320-325, 1933 (in German)

V.A. Ambartsumian – On the Derivation of the Frequency Function of Space Velocities of the Stars from the Observed Radial Velocities // Monthly Notices of the Royal Astronomical Society (MNRAS), Vol. 96, No. 3, p. 172-179, 1936 (in English)

V.A. Ambartsumian, G.A. Shain – On the Faint White Stars in Low Galactic Latitudes // Soviet Astronomy, Vol. 13, No. 1, p. 1-7, 1936 (in English)

V.A. Ambartsumian – Double Stars and the Cosmogonic Time-Scale // Nature, Vol. 137, No. 3465, p. 537, 1936 (in English)

V.A. Ambartsumian –On the Statistics of Double Stars // Astron. Zh., Vol. 14, No. 3, p. 207-219, 1937 (in Russian)

V.A. Ambartsumian –On the Dynamics of Open Clusters // Trudy LGU; UcheniyeZapiski LGU, Ser. Math. Sciences (Astronomy). Issue 4, No. 22,

p. 19-22, 1938 (in Russian)

V.A. Ambartsumian, Sh.G. Gordeladze – Problem of Diffuse Nebulae and Cosmic Absorption // Bulletin of the Abastumani Astrophysical Observatory, No. 2, p. 37-68, 1938 (in English and Georgian)

V.A. Ambartsumian – The Scattering of Light in a Turbid Medium // Journal of Physics, Vol. 5, No. 1, p. 93, 1941 (in English)

V.A. Ambartsumian – A New Method of Calculation of the Light Scattering in Turbid Medium // Izvestiya Acad. Sci. USSR, Ser. Geograph. and Geophys. Sci., Vol. 3, p. 97-103, 1942 (in Russian)

V.A. Ambartsumian – To the Theory of Fluctuation in the Brightness of the Milky Way // Doklady USSR Acad. Sci., Vol. 44, No. 6, p. 244-247, 1944 (in Russian)

V.A. Ambartsumian –Evolution of Stars and Astrophysics // Acad. Sci. ArmSSR, 39 p., Yerevan, 1948 (in Armenian)

V.A. Ambartsumian – Preliminary Data on O-Associations in the Galaxy // Doklady USSR Acad. Sci., Vol. 68, No. 1, p. 21-22, 1949 (in Russian)

V.A. Ambartsumian – Stellar Associations // Astron. Zh., Vol. 26, No. 1, p. 3-9, 1949 (in Russian)

V.A. Ambartsumian, B.E. Markarian – Stellar Association around P Cygni// Communications of the Byurakan Observatory, No. 2, p. 3-17, 1949 (in Russian)

V.A. Ambartsumian – On the Frequency of the Orion Trapezium type Apparent Multiple Systems // Doklady Acad. Sci. ArmSSR, Vol. 13, No. 4, p. 97-103, 1951 (in Russian)

V.A. Ambartsumian –On the Statistics of Trapezium type Multiple Systems // Doklady Acad. Sci. ArmSSR, Vol. 13, No. 5, p. 129-131, 1951 (in Russian)

V.A. Ambartsumian – The Phenomenon of the Continuous Emission and Sources of Stellar Energy // Communications of Byurakan Observatory, No. 13, p. 1-36, 1954 (in Russian)

V.A. Ambartsumian –On the Nature of Radio Sources // Proc. Fifth conference on Problems of Cosmogony: "Radioastronomy", held on 9-12 Mar 1955. Acad. Sci. USSR), p. 413-416, Moscow), 1956 (in Russian)

V.A. Ambartsumian –On Multiple Galaxies // Izvestiya Acad. Sci. ArmSSR, Ser. Phys.-Math., Nat. and Tech. Sci., Vol. 9, No. 1, p. 23-43, 1956 (in Russian)

V.A. Ambartsumian, G.S. Saakyan – The Degenerate Superdense Gas of Elementary Particles // Astron. Zh., Vol. 37, No. 2, p. 193-209, 1960 (in Russian) // English translation in: Soviet Astronomy, Vol. 4, No. 2, p. 187-201, 1960

V.A. Ambartsumian, G.S. Saakyan –On Equilibrium Configurations of Superdense Degenerate Gas Masses // Astron. Zh., Vol. 38, No. 5, p. 785-797, 1961 (in Russian) // English transaltion in: Soviet Astronomy, Vol. 5, No. 5, p. 601-610, 1962

V.A. Ambartsumian, G.S. Saakyan –Internal Structure of Hyperon Configurations of Stellar Masses // Astron. Zh., Vol. 38, No. 6, p. 1016-1024, 1961 (in Russian) // English transaltion in: Soviet Astronomy, Vol. 5, No. 6, p. 779-784, 1962

V.A. Ambartsumian –On the Statistics of Flare Objects // Proc. symp. "Stars, Nebulae, Galaxies", devoted to the 60th anniversary of academician V.A. Ambartsumian, held in Byurakan, 16-19 Sep 1968. Acad. Sci. ArmSSR), p. 283-292, Yerevan, 1969 (in Russian)

V.A. Ambartsumian –Derivation of the frequency function of stellar flares in a star cluster // Astrofizika, Vol. 14, No. 3, p. 367-381, 1978 (in Russian) // English translation in: Astrophysics, Vol. 14, No. 3, p. 209-217, 1978

4. Ambartsumian's legacy

In this paragraph we list those scientific items that relate to Viktor Ambartsumian's achievements and were named after him. They may serve as scientific commemoration of his legacy.

Ambartsumian's Hypothesis on the Activity of GalacticNuclei. In 1956, a hypothesis on the activity of galactic nuclei was proclaimed. The various forms of activity were presented as different manifestations of the same phenomenon of activity. The evolutionary significance of the activity in the galactic nuclei was emphasized and further hypothesis was suggested on the ejection of new galaxies from the active galactic nuclei. The hypothesis on the superdense protostellar matter was engaged to explain the observational data.

Ambartsumian (or Byurakan) School in Cosmogony. The hypotheses on superdense matter giving origin of stars and nebulae and on activity of galactic nuclei led to the establishment of a new approach in cosmogonic interpretation of the evolutionary processes in the Universe. The Ambartsumian (Byurakan) school in cosmogony appeared, describing the evolution of cosmic matter from more dense states to less dense ones. In contrary, the widely accepted classical school describes the evolution of cosmic matter from less dense states to more dense ones (origin of the stars from gas and dust).

Ambartsumian's Hypothesis on the Superdense Matter. In 1949, a theoretical prediction of the phenomenon of expansion of stellar associations was made. In 1951, Ambartsumian carried out a statistics of Trapezium Orionis type systems and proved the disintegration of young stellar systems. He showed the nonthermal nature of the continuous emission observed in the spectra of non-stable stars and put forward an idea about new possible sources of stellar energy, the hypothesis of the superdense protostellar matter (1954). Theoretical studies of the hypothetical superdense degenerate protostellar matter led to the development of the principles of the theory of baryonic stars (1960-1961).

Ambartsumian Principle of Invariance. Development of light scattering theory in turbid medium, theory of Invariance. The principle of invariance was proposed for solving the radiative transfer problems. A very simple physical reasoning that the reflection properties of the semi-infinite plane-parallel medium do not change if a very thin layer of the same physical properties is added to its boundary gave an excellent base for creation of a new research method (1941-1942).

Ambartsumian's ϕ function. The main function defining the coefficient of reflection from semi-infinite medium by means of the principle of invariance. In the case of redistribution by frequencies it coincides with Chandrasekhar's H function.

Ambartsumian's Method for determination of the temperature of the Planetary Nebulae Nuclei. New method (modification of Zanstra's method) for determination of the planetary nebulae's central stars surface temperature giving the probabilistic definition of short-wave energetic photons transformation into less energetic ones. This definition led to the determination of the radiative equilibrium of planetary nebulae (1932).

V.A. Ambartsumian's Knot. The elliptical galaxy NGC 3561 has a jet outcoming from its central region and containing a very high luminosity condensation (this condensation is called Ambartsumian's Knot) comparable with the luminosity of such galaxies as for example the satellites of Andromeda nebula. There is no doubt that we encounter with a huge outflow from the nucleus. This outflow is actually a dwarf galaxy, which has been separated from the nucleus of the giant galaxy.

References

Harutyunian, H. A.; Mickaelian, A. M.– Viktor Ambartsumian: Most Important Scientific Results // Yerevan, Edit Print, 2008, 20 p., 2011, 32 p. (in Armenian and English)

Mickaelian, A. M.(compiler) –Viktor Ambartsumian(DVD), Yerevan, 2008 and 2010 (in Armenian, Russian, and English)

Mickaelian, A. M.– Viktor Ambartsumian: Life and Activities, Yerevan, "Antares" Publishing House, 2014, 48 p. (in English)
Shahbazyan, K. V. (compiler) – Academician V. A. Ambartsumian. Life Episodes, Yerevan, NAS RA "Gitutyun" Publishing House, 2001, 168 p. (in Russian)
Shahbazyan, K. V. (compiler) – Academician V. A. Ambartsumian. Life Episodes, Yerevan, NAS RA "Gitutyun" Publishing House, 2003, 144 p. (in Armenian)