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Influence of V. A. Ambartsumian on the Development of Astronomy

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This is a great honour for me to present a report on the influence of the outstanding scientist academician V.A. Ambartsumian. I was well familiar with V.A. Ambartsumian, but unfortunately, I did not manage to work with him in scientific research. When, in 1948, I arrived in the Leningrad State University (LSU) V.A. Ambartsumian already had left LSU and worked in Armenia. My teacher in LSU, academician V.V.Sobolev, was the best student of V.A. Ambartsumian. Therefore, to some degree, I can consider myself as a scientific grandson of V.A. Ambartsumian. However, I very frequently met V.A. Ambartsumian at scientific conferences, discussed with him scientific problems and problems of organization of scientific research. Contacts with this outstanding, strong and talented person have rendered large influence on my formation as a scientist.

When I was asked to prepare a lecture on scientific activity of V.A. Ambartsumian, I reviewed his scientific articles and came to the conclusion that it is an excessive task for a half-hour or even one-hour report. Therefore, having consulted with my colleagues, I have decided to choose several results, which have exerted decisive influence on the development of astronomy and which characterize the versatile activity of V.A. Ambartsumian. Certainly it is difficult to make an unequivocal choice from the large scientific heritage of V.A. Ambartsumian, therefore my choice is rather subjective. Someone else would make his choice on other results. But I hope I will manage to show an outstanding role of V.A. Ambartsumian in the development of astronomy, as well as other sciences.

V.A. Ambartsumian lived a long scientific life and results achieved by him 70 years ago now may seem trivial, but in that time they were certainly new data frequently overthrowing existing views on those or other phenomena.

One should bear in mind the level of development of astronomy in those days when V.A. Ambartsumian began his research activity. Nuclear reactions were unknown as the energy source in stars, the chemical composition of stars was not determined. There were neither ultraviolet nor infrared observations. Radio astronomy and high-energy astronomy did not exist. Astronomers knew only positions of stars in the sky, their proper motions (for nearby stars) and radial velocities (for bright stars), as well as visual magnitudes and an approximate temperature scale.

Among early works in the field of study of non-stationary stars I would like to pay attention to the method of determination of temperatures of nuclei of planetary nebulae proposed by V.A. Ambartsumian.

Planetary nebulae are very interesting objects. The variety of their forms is amazing. Their spectra consist mainly of intensive emission lines drastically different from absorption spectra of stars.

Shortly before the work of V.A. Ambartsumian an opinion was stated, that the radiation from a planetary nebula is a re-emission of the radiation of the central star. Zanstra offered a method to determine temperatures of central stars, using intensities of emission lines of hydrogen measured with respect to the continuous spectrum of the star. The temperature, a very important characteristic of the star, appeared to be very high, close to 100000 K. The difficulty in applying the method by Zanstra was that it was necessary to measure very intense emission lines relative to a very weak continuum, where the star's radiation itself is strong. So, 24-year old V.A. Ambartsumian, in 1932, offered to determine temperatures from the ratio of the HeII line 4686 and the hydrogen line 4861, located close to each other in the spectrum and having comparable intensities [1]. He considered in detail the process of formation of the recombination spectrum of HeII. He showed that, with the exception of chemical composition, this ratio only depends on temperature.

V.A. Ambartsumian calculated and tabulated the function $F(T)$ which describes the dependance of the ratio of line intensities on stellar temperature. Having determined from observations the ratio of intensities, we immediately obtain from the table the temperature of the central star of the planetary nebula. It is a very simple and fast method of determining the temperature. A graceful method!

This work put a beginning to the whole cycle of works devoted to problems of radiation transfer in planetary nebulae and envelopes of non-stationary stars [2]. The results of these works were generalized in the book by V.A. Ambartsumian "Theoretical astrophysics" [3], the first book of this sort which has rendered huge influence on a whole generation of astronomers.

The cycle of works concerning the study of processes of scattering of light adjoins the listed works. The problem of scattering of radiation is paramount in astronomy, as all our knowledge of celestial objects is received from analysis of electromagnetic radiation frequently named by the short word light. Mostly between a source of radiation and detectors there is absorbing and scattering matter. We can include here the atmosphere of a star, circumstellar envelopes, interstellar medium, and terrestrial atmosphere. Their influences should be carefully taken into account to deduce correct data on the source of radiation, as well as characteristics of the scattering matter. For this reason the works of V.A. Ambartsumian are of great importance.

The theory of radiation transfer is rather complex and it comes down to the solution of a system of integro-differential equations. Its presentation for non-specialists, which a large audience inevitably consists of, is rather boring business, but the merits of V.A. Ambartsumian in this area are so great, that it is impossible to pass by in silence this topic. Therefore I shall dwell upon one point, which I consider to be one of the masterpieces of scientific ideas, the method of invariancy [4,5].

V.A. Ambartsumian attacked the problem completely from another side. He considered a case, when radiation S falls on a semi-infinite medium at an angle ξ and it is necessary to determine the intensity I of radiation scattered at

an angle η. In real life there are many such cases. For example, a sea illuminated by the Sun.

V.A. Ambartsumian proposed to add a layer of very small optical thickness to the layer of infinite optical thickness. It is clear, that general characteristics of the whole layer do not change. But this small addition allowed him to consider how the radiation in a direction η arises. This is scattering in the layer $\triangle\tau$, reflection from the border A, scattering of the reflected radiation, and secondary reflection. Additional absorbtion in a layer $\triangle\tau$ was also taken into account. The appropriate equations were compiled and their solution resulted in a functional equation.

The functional equation can be rather simply solved by the successive approximation method. It was many a time and oft done later, and there exist rather detailed and exact tables of their values. Also, using this method V.A. Ambartsumian solved the problem of radiation transfer through a layer of restricted optical thickness, by taking away a small layer at one border of the medium and adding it to the other border. The problem was reduced to solution of two functional equations by the successive approximation method. The paper by V.A. Ambartsumian was published in the Reports of the Academy of Sciences of the USSR in 1943 [4]. The same solution was achieved by the great American scientist Chandrasekhar in 1947, who recognized the priority of V.A. Ambartsumian.

The method offered by V.A. Ambartsumian and named as the method of invariancy has found wide application not only in astronomy and not only in investigations of radiation transfer, but also in other areas of science and in studies of other phenomena, for example scattering of neutrons in nuclear reactors. This is surely one of the great achievements of V.A. Ambartsumian. He not only proposed the method but also obtained solutions for various configurations of scattering matter and different kinds of the scattering medium.

In the 1930s V.A. Ambartsumian published some outstanding papers on stellar dynamics, which gave him, a 28-year old scientist, world popularity. In those days stellar dynamics was one of most active directions of astronomy.

One of most interesting problem in those times, as well as now, is determination of the age of the universe. Just then, practically the only way to determine the age of the universe or one of its parts was a statistical investigation of the general characteristics of stars.

It was supposed that after formation of stars their ensemble eventually comes to statistical equilibrium as a result of gravitational interaction. The low-mass stars would have high spatial velocities, and vice versa. There should be a very small number of wide pairs, and so on.

Jeans calculated that the time for establishment of equilibium, that is the relaxation time of the system, amounts to 10^{13} years. He also found that, provided the distribution of binary stars over energy, i.e. over distance between components, is in equilibrium, the distribution of eccentricities of orbits should be proportional to ε^2, as is observed. Based on this point, Jeans concluded that the age of the universe is more than 10^{13} years. It agrees well with his hypothesis concerning the evolution of stars along the main sequence. V.A. Ambartsumian convincingly showed that the consideration of Jeans is wrong [6-9]. He showed that irrespective of the kind of distribution of binary stars over the sizes of their

orbits, the distribution of binary stars over eccentricities mentioned above always should be fulfilled. Therefore, the analysis of eccentricities yields no answer for the question whether there is a statistical equilibrium. Thus, the conclusion by Jeans on the long time scale appeared to have no foundation. V.A. Ambartsumian analysed the distribution of binary stars over energy, that is the orbit size, the ratio of the numbers of wide and close pairs, the ratio of the number of wide pairs to the number of single stars, etc. He came to the conclusion that the ensemble of stars is still very far from equilibrium and its age is 10^{10} years (the short time scale). The modern data on the age of the Universe yields $(1.5-2.0)^{10}$ years. The accuracy is amazing. The discussion lasted about two years. There was an exchange of letters to the world-wide journals. V.A. Ambartsumian won. V.A. Ambartsumian acquired fame due to this discussion and since then his name was usually considered in relation with a foundation of modern astronomy.

It is pleasant to note that V.A. Ambartsumian was awarded the State Prize of Russia in 1996 for this cycle of works on stellar dynamics.

In the middle 40s V.A. Ambartsumian paid attention to the fact that the non-stationary stars such as T Tauri are located not homogeneously but in separate groups. Their sizes are appreciably larger than those of usual star clusters. V.A. Ambartsumian called them stellar associations (T-associations). The T Tau-type stars seem to be young by reason of many of their features. Therefore it was decided to analyze how the other young stars behave. The O-type stars also appeared to group in the sky, forming O-associations. The evidence that associations are young is given also by the presence in their structure of multiple stars of the Trapezium type, where the distances between components are close unlike usual multiple stars with a hierarchy of distances. For example, ξ U MA is a usual multiple system, θ Ori is a Trapezium. V.A. Ambartsumian showed that the time of disintegration of a Trapezium amounts to a few million years.

Astronomers all over the world began to actively investigate associations which were called aggregates by Western astronomers.

The main idea in investigation of associations is that the process of star formation occurs till now and stars are born in groups. A new direction of astronomy has appeared. Certainly, during the past 50 years, particularly due to appearance of infrared observations, the accents of the problem of star formation have been strongly shifted to researches of protostars, cocoons, and other objects. But we should remember that the study of associations was one of the basic sources of the science of star formation.

The ideas of V.A. Ambartsumian have also given rise to other important diretion of astronomy, to which the present astronomical symposium in Byurakan is devoted - investigation of active galactic nuclei. It seems to me that conferencies on this subject occur more often than on any other topic of astronomy. It means that this subject is of current interest.

The main idea put forward by V.A. Ambartsumian was as follows. Most galaxies can be roughly subdivided into elliptical (with few details), spiral (with details observed as spirals) and irregular (with unclear details). V.A. Ambartsumian noted that besides this subdivision the galaxies differ from each other by the brightness and size of the central nucleus. There are galaxies having no nucleus, but in others nuclei are very strong.

As the other parts of a galaxy rotate round the nucleus and the density of the nucleus is several orders higher than that of the other parts of a galaxy, V.A. Ambartsumian argued that the nucleus essentially influences the life of the galaxy as a whole and suggested that astronomers investigate the nature of this influence; many of them have studied the problem until now.

The recognition of the importance of the galactic nuclei problem raised by V.A. Ambartsumian was demonstrated by the fact that he was invited to present several reviews on the topic in the early 1960s [12,13], including the review lecture at the IAU General Assembly in Berkeley in 1961 [14], and also by the huge development of these investigations during the last 60 years. Let me not dwell more on this subject. There are here a lot of astronomers much more qualified about the topic than I am. Those who wish to learn more about galactic nuclei will do it during the symposium.

Let me finish a brief and subjective review of the huge scientific heritage of V.A. Ambartsumian.

I would like also to say some words about organizational activity of V.A. Ambartsumian in the field of astronomy.

V.A. Ambartsumian was the Vice-President of the Astronomical Council at that time when it was a powerful organization, the President of the IAU, the President of the Scientific Council of Scientific Unions. He created the Department of Astrophysics in Leningrad University and the Byurakan Astrophysical Observatory in Armenia. He was a Full Member of the USSR Academy of Sciences and a Member of the Academies of more than a dozen countries, including the main ones. Besides he occupied many responsible posts in governmental circles, i.e. he was a rather influential man. People came to him for help and advice and he never refused support if the business concerned the development of science. It can be surely said that no single serious measure in the field of astronomy has been made without the participation of V.A. Ambartsumian. The shining example was the construction of 2.6-m and 6-m telescopes, which are the largest ones in Russia.

It may safely be said that the influence of V.A. Ambartsumian on the development of astronomy, particularly in the USSR and Armenia, was very great. We were lucky, that such a brilliant person as V.A. Ambartsumian was with us.

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