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PREFACE

In 1946, immediately with the foundation of the Byurakan Astrophysical Observatory (BAO), its founder Viktor Ambartsumian also established a new scientific bulletin, which was called "*The Communications of the Byurakan Observatory*" (although the English version of the periodical's title then was written as "Contributions from the Byurakan Observatory"). The managing editor of it was Viktor Ambartsumian. Then it was the only magazine in Armenia, where the staff of the BAO could publish results of their research, as well as other articles concerning the many-sided activity of the observatory. Research papers have been published mainly in Russian, but one can find some papers in Armenian as well.

The brief foreword in Armenian and Russian by the director of the observatory Viktor Ambartsumian opens the first issue of the new periodical. This foreword defines the purposes of the new observatory as follows:

30 kilometers north-west of the city of Yerevan, near the village of Byurakan, Ashtarak region, on the southern slope of Aragats, a new Observatory of the Academy of Sciences of the Armenian SSR is under construction. A number of new instruments are being installed at the Observatory. There are also transferred instruments from the ones that existed so far in the Yerevan Observatory. The Byurakan Observatory suggests dedicating its forces, mainly, the problems of stellar astronomy and especially stellar statistics. The publication of the Communications of the Byurakan Observatory begins hereby. In this connection, the publication of the Bulletin of the Yerevan Observatory is interrupted.

Initially, all the individual issues, inclusive up to the XV, were devoted to the publication of one article. The first one published in 1946, was the paper "*The Fluctuations in the Apparent Distribution of the Stars and the Cosmic Absorption*" by Beniamin Markarian. For the next two years, not a single issue was published, but in 1949 three numbers of Communications were issued. There was the joint article by Viktor Ambartsumian and Beniamin Markarian, then a paper by Haik Badalian in Armenian, and in the fourth number, a paper by Grigor Gurzadyan came out.

Today, the study of past issues of "Communications" allows one to understand better the process of becoming the Byurakan Observatory and the choice of its main scientific topics. The number of published articles has increased significantly since 1956, when three issues with nine articles were published. The same number of issues with eight works one finds for the next year. In 1958, sixteen papers were published in two issues, eleven of them published in the second one(issue XXV) dedicated to the 50th birthday of Viktor Ambartsumian.

It is interesting that abstracts of papers in English appear since the issue XXX published in 1962. There was not an issue published in 1965. Most probably, that happened because in 1965 the Armenian Academy of Sciences started publication of the new astrophysical magazine “Astrophysics”. Ambartsumian was the Editor-in-Chief of the new magazine and, surely, it was taking a lot of time. Nonetheless, in the following year the publication of the "Communications" resumed and continued until the very collapse of the Soviet Union and the beginning of Armenia's independence. Due to the deteriorating economic situation in the country, the publication of "Communications" was suspended. The last one was release number LXIII.

In 2017, the administration of the Byurakan Astrophysical Observatory decided to recommence publication of the "Communications of the Byurakan Astrophysical Observatory" in electronic form. In order to preserve traditions, the first issue of the new version we represent as the issue 1 (LXIV). Like its predecessor, this journal will publish both original scientific papers and reviews, as well as articles of technical character. Under the heading "Legacy", the renewed magazine will republish some old articles of high value in English. The heading “Guest articles” will bring to the attention of readers the articles of researchers who are not employees of the Byurakan Observatory.

Editorial Board

Alternative Paradigm for the Cosmic Objects Formation: New Prospects

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Abstract

We consider here briefly the cosmogonic concept suggested by Viktor Ambartsumian in the last century for explaining the formation of cosmic objects. He grounded his concept using the observational facts available in 40s-60s of the last century. The analysis of observational data allowed him to conclude that cosmic objects formation takes place up to nowadays. The second and more "heretical" conclusion he arrived at persuades that the origination and further evolution of cosmic objects goes on in course of gradual decay of proto-stellar matter at all hierarchical levels. We argue that this approach appeared first time in Ambartsumian's papers devoted to the problems of quantum electrodynamics. Later on his concept on objects formation due to decay of protostellar dense matter was rejected because the known laws of physics do not allow existence of huge masses consisted of superdense matter. We bring to the readers' attention, that the discovery of dark energy changes the situation drastically and opens new rooms for the ideas forgotten by the scientific community.

Keywords: *Universe expansion – dark energy – stellar associations – active galactic nuclei – atomic nuclei – mass-energy transformation*

1. Introduction

The scientific community at any epoch disposes of certain storage of knowledge and tools to use the knowledge available. Consequently, every epoch brings into use some amount of the new knowledge. Appearing on the basis of the available for the given epoch knowledge is not surely correct in a broad sense. It only should satisfy the requirement of the self-consistency and credibility within the frame of existing knowledge.

The process of cosmic objects formation was always a subject of debates since the time of ancient philosophers. Newton's discovery of the gravitation low created for the first time for construction of scientifically based hypothesis on the stellar and planetary formation. The first one to suggest a hypothesis on the star formation was Immanuel Kant who put forward an idea that the stars and planets formed due to a

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process of collapsing in of thin and dim clouds of gas and dust on themselves as a result of gravitational interaction between the countless faint particles. According to nowadays cosmogony, stars form in giant molecular clouds, which are gravitationally unstable. Owing to instability, the matter within clouds coalesces into many separate and denser clumps forming stars later on.

Although that was a scientifically based hypothesis for the observational data available for that time, which initiated many new studies, subsequently it became inhibitory for the further progress in this field. Every step of scientific progress in this and related areas inevitably should fit the basic cosmogonic idea. Due to the above dictate, astronomical community believes that almost all the cosmic objects and their systems are gravitationally bound. Moreover, this issue is not disputable, though never proved observationally or theoretically.

Greatest cosmological discoveries of the twentieth century – the Universe expansion and, later on, its accelerated behavior – made the physical picture of the Universe very odd. Following to the adopted ideas on the Universe structure, one arrives at a conclusion that the expanding as a whole, the unique entity of matter, energy and space is composed of embedded cells of various scales collapsing independently. Where is the discontinuity boundary and how it evolves, remains obscure.

One of the oddest creations resulted by Kant's hypothesis and its theoretical modifications is the "dark matter" which was initially invented by Zwicky (1933) for vouching the stability of clusters of galaxies. The only reason for introducing the idea of dark matter was and up to nowadays is the surmised stability of clusters, resulted from their hypothesized negative total energy at the very beginning of their formation. A lot of cunning observations and experiments implemented up to our days did not provide any encouraging results. Nevertheless, the search is going on. It is obvious, that one could decline this idea if refused the mechanism of cosmic objects formation built on the basis of Kant's hypothesis.

2. Birth of objects according to quantum electrodynamics

In late 20s of the last century, researchers knew that photon could appear or disappear during the interaction of elementary particles. Absorption or emission of photons by atoms during the light multiple scattering in atmospheres of stars and planets were under intensive studies and radiation transfer theory was developing rapidly. However, there was no any hint concerning the similar process involving particles possessing of nonzero rest mass.

Nonetheless, this issue became crucial after the suggestion of the atomic nucleus model by Rutherford (1911). Atomic nuclei in this model consisted of protons and electrons. Rutherford proceeded from the experimental fact that some nuclei showed β-decay, and protons could emerge from others. Thus, he arrived at a conclusion, that atomic nuclei could contain free protons and electrons. The number of protons, according to Rutherford, provided the mass and atomic number of nucleus and the corresponding number of electrons balanced its electric charge, neutralizing the excess of protons total charge. Rutherford's model seemed to be corresponding to observable characteristics of atomic nuclei. However, detailed studies of atomic nuclei showed later on, that the model led to certain paradoxes. One paradox followed from the uncertainty principle requiring very powerful interaction between protons and electrons to provide the nucleus stability. No experiments ever showed such interaction. Another one called "the nitrogen catastrophe", and related to the spin of the nitrogen nucleus, was also impossible to resolve in the frame of the suggested model. The point is that according to the model of Rutherford the nucleus ^{14}C should show physical behavior of a fermion while empirical data argued in favor of Bose statistics.

Ambartsumian and Ivanenko were the first to solve these paradoxes. They put forward the idea that no free electron could exist in the atomic nuclei and "the whole phenomenon is completely analogous to the emission of photons by an atom, i.e., the electron, like a photon (quantum of light) has no individuality inside the nucleus prior to its ejection" (Ambartsumian & Ivanenko, 1930b). Moreover, they suggested in the same paper that atomic nuclei might consist of protons and some uncharged unknown elementary particles of nearly proton's mass. That was two years prior to neutron discovery by Chadwick.

That was the second paper of the same authors devoted to the problems of elementary particles. The first one published in the same year (Ambartsumian & Ivanenko, 1930a) did not pursue a particular issue like the structure of atomic nuclei (if one considers it particular). In the first paper, the authors succeeded in showing that not only mass-less particles can occur and disappear due to interactions but also the particles possessing rest mass have the same properties. The conclusion they arrived at undoubtedly became one of the fundamental results, which highly supported the further development of quantum electrodynamics.

3. Birth of objects according to quantum electrodynamics

Ambartsumian (1947) was the first to draw attention of the scientific community to stellar associations, as a distinct class of stellar aggregation. The main structural features of stellar associations Ambartsumian listed as followed. Their surface density is smaller, compared with the density of galactic stellar field. On the other hand, the partial concentration of stars belonging to certain spectral classes makes them prominent. In stellar associations always are stars with matter outflow, frequently showing P Cyg type spectral line profile. In some cases, there are open stellar clusters in the center of these systems.

He also made some important conclusions by analyzing the kinematics of the Galaxy. Considering the movement of a stellar association stars in the gravitational field of the Galaxy, one can easily find that the Galaxy differential rotation makes mutual distances of stars larger leading thus to the expansion of these systems in the Galaxy plane. If there are no other mechanisms, which expand the stellar system in the perpendicular direction stellar associations should look like highly flattened. However, the shapes of all the studied stellar associations argue in favor of their isotropic expansion. Therefore, one arrives at a conclusion that besides the differential rotation of the Galaxy there is a kind of inner physical mechanism expanding stellar associations. Moreover, the intrinsic expansion effect should play bigger role than differential rotation effect affects.

The conclusion on the isotropic expansion of stellar associations, in our view, was one of the important results of the observational data analysis. We would like to mention especially the sophisticated estimate of expansion velocity suggested by Ambartsumian. Limitations put to the rate of expansion are coming from the requirement of the isotropy in shape and the fact that this effect of expansion remained unnoticed in terms of radial velocities. The point is that for surpassing the effects of the Galaxy differential rotation, one should expect that the expansion rate is above 1km/sec and, on the other hand, the velocities cannot be above 10 km/sec, otherwise radial expansion is easily detectable. Therefore, he arrived at a conclusion that the expansion velocity was about 5 km/sec. This estimate provides about 10-20 million years for the ages of stellar associations.

Surprisingly the researchers, criticizing conclusion on the expansion of stellar associations, usually forget the arguments relevant to the isotropic shape of these systems. However, those arguments played decisive role in build-up of the new concept on the existence of younger stars. Expansion effects and the velocity estimates were the main tools to lead to the stellar age estimate. Evidently, that was the first outstanding result speaking distinctly in favor of star formation processes in our epoch. The series of papers mentioned above finally initiated intensive research in the new scientific field of studying the newborn stars and star formation regions.

Nowadays it seems clear that Kant-Laplace cosmogonic hypothesis adopted, as the dominant concept for the cosmic objects formation, is the only conceptual barrier requiring the rejection of expansion possibility. For the adherents of the mentioned ideology it is more than clear that the mechanism of star formation from a protostellar cloud a negative total energy for the star forming cloud is required. Hence, any bearer of this concept cannot take seriously the idea that a group of newborn stars possesses of positive total energy. One has to consider only self-consistent physical pictures while discussing the building blocks of that or stay within the same physical frame constructing any physical mechanism.

On the other hand, a concept built on wrong or untenable initial conditions, which fits the empirical or observational data at the beginning, will disagree with new data in the course of their revealing. It resembles the approximation of unknown function by a polynomial, which gives good approach while remaining within the range of given values but diverges violently everywhere out of that range.

In this field of research, an essential clarification of situation one might expect before long, since the astrometric accuracy of orbital observatory Gaia is high enough to reveal at least for nearest associations the expansion velocities estimated by Ambartsumian seven decades ago. If no expansion is registered, undoubtedly one is entitled to strengthen the base for rejection of Ambartsumian's concept. Does it mean that the revealing of expansion rehabilitates the concept rejected for decades? History of science shows that such a continuation is not evident. The inertia of mentality is rather strong, and one always tries to find an explanation for encountered breach of established conceptions by empirical and observational data in the familiar frame of thinking. Nevertheless, in the case of stellar associations the observational accuracy allows already precious implementation of a dedicated program for this purpose. Unfortunately, any similar observations are impossible for extragalactic objects, and for solving of this kind of problems, one should invent some ingenious approaches.

4. Galaxy formation

In 1950s, Ambartsumian for the first time suggested a new scenario for the process of galaxy formation (see Ambartsumian 1955, 1956a, 1956b, 1958).This series of analyses he initiated starting studies of multiple systems of galaxies since the multiplicity of objects in any such system might characterize its deviation from the thermodynamic equilibrium. On the basis of simple statistical estimates, he arrived at a conclusion at the very beginning that the relative number of multiple systems within any given cluster of galaxies exceeds many times the one expected for thermodynamically balanced systems(Ambartsumian 1955). He reported his view on the problem at the IAU symposium No 5, held in Dublin. This talk was published also by the Armenian academy of sciences in Russian in the same year. That was the first but not the only statement leading the author to the necessity for putting to use a new concept on galaxy evolution completely inconsistent with previous ideas and scenarios. One might consider the paper mentioned above as a brief enumeration of the relevant systems and views on the base of which the author finally established the backbone of the new idea.

We mentioned above the main physical motivation, which served a basis for the series of studies. First, he claimed that the relative number of multiple systems among the all galaxies within any given cluster of galaxies exceeds many times the one expected for the thermodynamic equilibrium. This fact without any additional assumption leads to the conclusion on the joint formation of member galaxies in multiple systems. On the other hand, the analysis of multiplicity type shows that, in contrast to stellar ordinary multiplicity, the high majority of multiple galaxies belong to the Trapezium type systems possessing positive total energy. Hence, at least some of these multiple systems formed recently and are diverging at present. One obtains the same result analyzing differences of radial velocities of binary galaxies.

One of the essential issues he considers in the mentioned first paper devoted to the problems of extragalactic astronomy, in our opinion, is the comparison of needed M/L ratios for binary, galaxies, multiple systems and clusters of galaxies to suppress the kinetic energy of galaxies and keep these systems dynamically balanced. One can find easily now, the higher the multiplicity the larger M/L ratio is necessary for this purpose. In other words, the highest mass to luminosity ratio one needs to provide equilibrium require clusters of galaxies – the systems of galaxies having the highest multiplicity. That is why the idea of dark matter initially appeared when Zwicky (1933, 1938) was studying the clusters of galaxies.

However, one should keep in mind always that the requirement of being in the dynamical balance for gravitational objects and their systems actually comes from the dictate of Kant-Laplacian concept of cosmic objects formation only. There are no other serious reasons to expect them being in dynamical equilibrium. The situation is repeating the one we discussed for the stellar associations. The only difference, one might point out, comes from the diversity of geometric scales, bringing its fingerprints also onto mass and time scales describing the objects of the given hierarchical level.

One can find a series of papers by Ambartsumian with considering the physical picture of processes occurring in multiple galaxies. However, one of his papers entitled "On the evolution of galaxies" could serve an introduction for the idea of galactic nuclei activity (Ambartsumian, 1958). It is worth mentioning, that Ambartsumian published his original papers in the little known for the international astronomical community journals of Armenian Academy of Sciences, though one could become acquainted with the new ideas thanks to his reports in international meetings. The one mentioned above one could find in the proceedings of Solvay Conference held in 1958.

Actually, that one is kind of survey of his own papers in this field which represents in detail all the observational data used by the author, which led him to the formulation of new approaches and ideas. Unfortunately, the new generation of astronomers actively working in the field of extragalactic astronomy and dealing with the ideas of activity in galactic nuclei, have a few or no notion of argumentations used in late 50s of last century for basing the idea about the activity of galactic nuclei. Moreover, no any topic survey on the AGN phenomenon prepared during last decades mentions Ambartsumian's contribution to this aria. In their turn, the pioneer ideas, very fruitful for establishing the concept of AGN, which are not proved of being useless, are forgotten.

We would like to emphasize again that the main idea concerning the formation of objects from huge bunches of superdense matter met insurmountable obstacle since no gravitational theory could predict the stable existence of such formations. The modern theory of gravitation insists on their inevitable turning into black holes. Therefore, it is obvious that one could not expect any further development of the mentioned concept if one stays in the framework of classical physics.

5. Nowadays progress in the old problem

It seems now that one can find new solutions for the Ambartsumian's concept using completely new possibilities opened owing to revealing of the Universe accelerated expansion. Actually, it should completely change the dominant ideas dealing with the cosmic objects formation process. No doubts, it would, if the revealing of the acceleration phenomenon apprehended in a more comprehensive manner and declined some odd stereotypes dictating the main line of thinking. There are some prerequisites listed here for further considering the changes one expects owing to the mentioned discovery.

First, one should consent to the fact that the dark energy, taken as primary source implementing the Universe acceleration, interacts with the ordinary baryonic matter (Statement A). No any exotic scenario invented can help one to refuse this conclusion. If there is no interaction between the dark energy and the baryonic matter no any acceleration of the Universe expansion might be revealed.

Second, the dark energy fills all the space and is not prerogative of only the large scales (Statement B). No any valid explanation exists to show why it should affect large distances and remain indifferent for the smaller scales. Hence, nobody can indicate the boundary where the effect of dark energy begins to exhibit. Moreover, there is no any logical reason for discussing the issue of space discontinuity of the dark energy. One can suggest that for the homogeneous distribution of dark energy its total amount decreases when one considers smaller volumes. Therefore, it is very hard to reveal its influence at short distances. Nevertheless, one can find its fingerprints if not constrained by dominant ideas forbidding alternative thinking (Harutyunian, 1995; 2011; 2016).

Third, what we call recognizable matter, accessible for empirical investigation, is the baryonic matter having describable atomic structure (Statement C). All other forms of matter (including dark matter) are only mental inventions but unavailable for empirical (including observational) studies. However, calculating any gravitational configurations, researchers pay attention only to the mass of modeled baryonic objects, but not to the atomic structure of matter. On the other hand, atomic structure of matter is its main feature. One of the key features of atoms is the defect of mass, providing their nuclei stability.

Another key feature is that the defect of mass, namely, the part of mass lost by baryons in a nucleus changes from one nucleus to another. In other words, one might establish the fact that elementary particles indistinguishable from the viewpoint of quantum physics, appear in various nuclei with various masses. Actually, this is very important property of baryons, meaning, that their mass in atomic nuclei depends on physical conditions. Then an essential question arises in connection with this: are these conditions changeable for the given nucleus or no any change can happen. Up to nowadays the adopted scientific doctrine asserts that no atomic nucleus we know changes its physical properties. One should consider this issue in detail taking into account the relevant physical laws and regularities based upon available knowledge.

Let us consider now the Statement A in the light of modern physics involving Statements B and C as well. One should recall that according the dominant ideas all the baryonic objects and their systems, including atomic nuclei possess of negative or zero total energy. For atomic nuclei, this lack of energy is the compensating the defect of mass "nuclear binding energy", which does not change for any given nucleus according to quantum theory. However, if there is interaction between the carrier of dark energy and baryonic objects one might consider the issue of energy exchange owing to interaction. One of the general laws of physics is the second law of thermodynamics certifying that the entropy of whole system should increase.

Taking into consideration that the dark energy is purely positive and the total energy of baryonic objects is negative or zero, one arrives at a conclusion that last ones obtain additional energy due to this interaction.

Although the modern quantum physics rejects any idea concerning the change of nuclear binding energy, the logics and the physical intuition suggest the opposite. One should comply that physical interaction leads to the energetic equilibrium and this process always takes place with continuous redistribution of energy between interacting particles. Let us accept now, that the physical essence of the dark energy is a subject of the quantum world, which is able to change the space with quantum baryonic objects. In this frame of casual determinacy, one arrives inevitably at a conclusion that the binding energy of atomic nuclei decreases in the course of the Universe evolution thanks to the work the dark energy implements at all hierarchical levels. Then one should consider the consequences of such, let us say, thought experiment.

This process leads to the growth of nuclear mass for all nuclei, accompanied with the decrease of their stability. Then one concludes that in the past of the Universe the atomic nuclei we know were comparatively less massive and more stable. Moreover, it seems plausible, that the nuclei showing various types of radioactivity at present were stable in the past, and there existed other radioactive nuclei consisted of much more baryons of much less masses. Continuing the virtual excursus into the past keeping the same logic for the baryonic matter transformation, one arrives at a conclusion that the dipper in the past, the less should be the total mass of baryons, provided that the number of baryons remains constant.

It does mean that the mass of the ordinary (baryonic) matter in the past was much less if comparing the objects consisted of the same number of baryons. It seems more plausible that considering the amount of baryonic matter one should proceed from requirement of the baryon number conservation law rather than from the mass conservation law. Hence, speaking about the hypothetical superdense matter, one should refer to baryons' number density but not to its ordinary mass density. The point is that the mass is changeable and it can transform into energy and vice versa. Therefore, if there can exist some clumps of baryonic matter, delayed in their evolution, one might conclude that getting to normal (for our era) conditions they will rapidly increase their mass to fit the conditions.

This possibility solves the problem of superdense matter. The "old matter" existing in the center of massive objects, presumably composed of huge number of baryons, actually may possess of negligibly small mass. It obtains its real mass corresponding to the nowadays mass-energy balance when ejected into, let to say, present day space, where atomic nuclei are described by Mendeleev periodic table and the known abundances. This process should go on in a way to increase baryons mass and decay the heavy nuclei. Moreover, one should expect then this process accompanied with a huge energy release as it takes place when known radioactive nuclei decay, although the amount of energy release in this case will surpass the known decomposition reactions.

By the way, this suggestion helps to solve some paradoxes existing for rather long time. One is associated with the mass creation during the Big Bang hypothesis. All the contemporary theories based on the mentioned hypothesis agreed that all the matter exists since the very beginning after the grand explosion. However, no any explanation exists why the Universe started and continues its expansion. It is clear, that the mass of the Universe was within the Schwarzschild radius, and it did not have any chance for expansion according to laws of modern physics. This conclusion does not depend does one believe in Big Bang hypothesis or not. This is only coherent application of physical laws to analyze very briefly the situation long used hypothesis. Contemporary physics predicts existence of a plenty of black holes at all hierarchical levels of matter autoregulation. Most of astrophysicists believe in the real existence of these hypothetical objects and are sure also that many of these hypothetical objects have primordial origin. Of course, the black holes' subject is a separate theme and we will not consider it here. However, we would like to emphasize one key issue. Since their first prediction by John Michell at the end of the eighteenth century, no any direct evidence appeared yet proving their existence. Therefore, taking also into account the reasoning above, one might suggest a scenario where any matter aggregation goes in a self-consistent way to prevent formation of singularities owing to the structural changes. It seems to be more natural than accepted scenarios of gravitational monsters formation. We will consider this issue in more detail in one of the next papers.

6. Conclusion

Ambartsumian suggested his cosmogonic concept on the formation of stars and galaxies about 60-70 years ago. The approach for analyzing the cosmogonic problems was methodologically different from the one adopted by the scientific community. This different approach allowed obtaining qualitatively new results in regard of cosmic objects' evolution process. Moreover, this concept, which he derived completely from the observational data, successfully created very strong philosophical basis as well, since for the first time the author considered the continuity of objects' formation process.

However, we may establish the fact that the scientific community was unready for apprehending adequately the significance of the suggested concept. There was no sufficient theoretical base for new ideas and, in addition, observational data allowed apply even controversial views for their interpretation of the same phenomena because of the scanty measurements. Nevertheless, in contrary, in the same situation the black hole concept unexpectedly begun flourishing since 90s of the last century.

In our opinion, the situation in this field of science bears a strong resemblance to the Ptolemaic model of the world, which provided rather good results on whole, but missed a little here and there. That was a model, which served for about one and a half millennium – incredibly long time for a model constructed on a wrong basis. However, at time of its usage the Ptolemaic model was the only working system giving acceptable results for practical purposes, although it was conceptually incorrect, and the heliocentric model suggested by Aristarchus of Samos existed long before it. Therefore, giving good results on whole is only necessary condition for any model but is not yet sufficient for acknowledging it as a correct one. Speaking straight about present-day cosmogonic models, one cannot guarantee that the adopted concept of cosmic objects' formation, which seemingly "gives good results in whole" leaving some empty rooms in the whole picture, corresponds adequately to the really going on evolutionary processes.

In fact, the only obstacle, which stipulated for rejecting the key idea in Ambartsumian's concept, was impossibility of modelling high mass aggregations of superdense matter in the frame of modern gravitational theory. Now it seems more likely that the theoretical discrepancy occurred not because of the lack of the concept, but it only shows the limitations of the theory and the gravitational models used. Considering consistently the observational data and known features of the baryonic matter one arrives at a conclusion that one should take into attention also the key structural features of baryonic matter while modeling gravitational configurations. The most essential feature to take into account, we are sure, is the atomic structure of the baryonic matter with its concentration in atomic nuclei. The atomic nuclei play a role of energy-to-mass transformation stabilizers in the course of the Universe evolution, using for that the mass defect change mechanism. We argue that interaction of the baryonic matter with the carrier of dark energy inevitably leads to the decrease of mass defect. Therefore, one concludes inevitably that deep in the past of the Universe the mass defect was much larger and consequently the mass of baryons in atomic nuclei – much less. All the processes taking place in the expanding Universe and all the forms of matter, including the energetic forms participate in a self-consistent process of global evolution.

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Multiwavelength Search and Studies of Active Galaxies and Quasars

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Abstract

The Byurakan Astrophysical Observatory (BAO) has always been one of the centres for surveys and studies of active galaxies. Here we review our search and studies of active galaxies during last 30 years using various wavelength ranges, as well as some recent related works. These projects since late 1980s were focused on multiwavelength search and studies of AGN and Starbursts (SB). 1103 blue stellar objects (BSOs) on the basis of their UV-excess were selected using Markarian Survey (First Byurakan Survey, FBS) plates and Markarian's criteria used for the galaxies. Among many blue stars, QSOs and Seyfert galaxies were found by follow-up observations. 1577 IRAS point sources were optically identified using FBS low-dispersion spectra and many AGN, SB and high-luminosity IR galaxies (LIRG/ULIRG) were discovered. 32 extremely high IR/opt flux ratio galaxies were studies with Spitzer. 2791 ROSAT FSC sources were optically identified using Hamburg Quasar Survey (HQS) low-dispersion spectra and many AGN were discovered by follow-up observations. Fine analysis of emission line spectra was carried out using spectral line decomposition software to establish true profiles and calculate physical parameters for the emitting regions, as well as to study the spectral variability of these objects. X-ray and radio selection criteria were used to find new AGN and variable objects for further studies. We have estimated AGN content of X-ray sources as 52.9%. We have also combined IRAS PSC and FSC catalogs and compiled its extragalactic sample, which allowed us to estimate AGN content among IR sources as 23.7%. Multiwavelength approach allowed revealing many new AGN and SB and obtaining a number of interesting relations using their observational characteristics and physical properties.

Keywords: *active galactic nuclei – X-ray – infrared – radio – quasars – Seyfert galaxies – LINERs – starburst galaxies – ULIRGs.*

1. Introduction

The Byurakan Astrophysical Observatory (BAO) has always been one of the centres for surveys and studies of active galaxies, since mid-1950s, when V. A. Ambartsumian put forward his hypothesis on the activity of the galactic nuclei (Ambartsumian 1956a; 1956b; 1958; a detailed review on the development of Ambartsumian's ideas in this field is given by Harutyunian & Mickaelian 2010). Very soon, B. E. Markarian

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started the first systematic survey for active galaxies (Markarian 1967; Markarian et al. 1989), using UV-excess method. Lists of candidate active galaxies were compiled also by M. A. Arakelian (1975) and M. A. Kazarian (Kazarian et al. 2010) using similar methods (Arakelian used the surface brightness criterion). Thousands of active galaxies were revealed and studied.

Since late 1980s, our research group was involved in search and studies of active galaxies using Markarian Survey observing material, then through optical identifications of IR and X-ray sources, statistical analysis of large multiwavelength catalogues and databases. We introduced multiwavelength (MW) research in BAO and accomplished a number of projects. Most of them were focused on MW search and studies of AGN and Starbursts (SB). The following directions may be mentioned:

- Search for QSOs and Seyferts among FBS Blue Stellar Objects (BSOs),
- Optical identification of IRAS PSC sources; active galaxies in the BIG sample,
- Optical identification of ROSAT FSC sources and BHRC AGN,
- Multiwavelength study of the bright AGN and Starbursts,
- Spectral and multiwavelength study of Markarian galaxies,
- IRAS PSC/FSC Combined Catalogue and its extragalactic sample,
- Study of extremely high IR/opt flux ratio galaxies with Spitzer,
- HRC/BHRC Combined Catalogue and its extragalactic sample,
- NVSS-FIRST cross-correlation: variable radio sources and their optical variability,
- ROSAT-NVSS AGN sample, search for new blazars,
- Multiwavelength study of blazars,
- Fine analysis of emission line spectra of active galaxies,
- DFBS and search for fainter Markarian and other active galaxies,
- AGN zoo and classifications by activity types,
- Activity of the galactic nuclei.

Many BAO collaborators have taken part in these projects and studies: H. V.Abrahamian, K. S. Gigoyan, S. A. Hakopian, S. K. Balayan, L. K. Erastova, L. A.Sargsyan, P. K. Sinamyan, L. R. Hovhannisyan, H. V. Abrahamyan, G. M. Paronyan,G. S. Harutyunyan and G. A. Mikayelyan, as well as foreign colleagues: P. Véron,M.-P. Véron-Cetty, D. Engels, D. Weedman, J. Houck, E. Massaro, R. Nesci, C. Rossi, A. C. Gonçalves, D. Barry, H. Hagen, F.-J. Zickgraf, W. Voges, A. N. Burenkov, S.N. Dodonov, V. L. Afanasiev, A. V. Moiseev, R. Mujica, V. H. Chavushyan, D.-W.Xu, P. Prugniel, N. Gavrilovi´c, and others.

Collaborations were established with Observatoire de Haute-Provence (OHP, France), Cornell University (Ithaca, N.Y., USA), Hamburger Sternwarte (HS, Germany), La Sapienza Università di Roma (Italy), Observatoire de Lyon (France), Max-Planck-Institutfür Extraterrestrische Physik (MPE, Garching, Germany), Special Astrophysical Observatory (SAO, Russia), Instituto Nacional de Astrofisica, Optica y Electronica (INAOE, Mexico) and others.We have used many facilities, including ground-based and space telescopes / missions, databases, and dedicated software, such as BAO 1m Schmidt and 2.6m, SAO (Russia) 6m, OHP 1.93m, Calar-Alto 2.2m, Palomar Observatory 5m, INAOE 2.12m, San Pedro Martir (Mexico) 2.12m ground-based telescopes, IRAS, ROSAT and Spitzer space missions, DSS1/DSS2, SDSS, MAPS, Super COSMOS, DFBS, NED, Hyper LEDA, Vizier and other databases, Aladin, MIDAS, SMART and other software systems, Armenian Virtual Observatory (ArVO) and other VO tools. Dozens of papers have been published with the results of these studies and dozens of talks at important international meetings (IAU symposia and colloquia, JENAM / EWASS meetings, other dedicated meetings and workshops, etc.) and seminars have been given. Our group was awarded a number of research grants for accomplishment of these projects, including CRDF, ISTC, RA MES SCS, ANSEF, NASA, PICS / Jumelage, INSU ANR, DFG, DAAD grants and others.

Here we describe the most important projects related to search and studies of active Galaxies and their content among X-ray, IR and radio sources. Most important results, achievements and products are given at the end.

2. Multiwavelength search and studies of active galaxies

2.1. Search for QSOs and Seyferts among FBS Blue Stellar Objects

The 2ndpart of the First Byurakan Survey (FBS; Markarian et al. 1989) was conducted in 1987-1996 (Mickaelian 2000; 2008, and references therein) for selection and further study of blue stellar objects (BSOs) on the basis of the FBS observational material. The main purpose of this work was to discover new bright QSOs, Sy galaxies, other compact galaxies, as well as cataclysmic variables (CVs), white dwarfs (WDs), hot subdwarfs, HBB stars and other peculiar stellar objects. 1103 objects were selected(Figure 1), including 716 new BSOs. In total, 11 lists were published (Abrahamian & Mickaelian 1996, and references therein) and the FBS BSOs catalogue is available at CDS in Strasbourg (Abrahamian et al. 1999). The completeness of the sample for objects with B < 16.5 and U-B < -0.5 was estimated at about 67%. Subsamples of candidate QSOs, WDs, CVs and other objects were constructed for their further detailed studies. Cross-correlation of FBS lists with ROSAT BSC and FSC (Voges et al. 1999; 2000) and radio catalogues NVSS and FIRST (Condon et al. 1998;

Helfand et al. 2015) revealed candidate QSOs. Spectroscopic observations were carried out with BAO 2.6m, OHP 1.93m and SAO 6m telescopes, as well as SDSS data were used. We have discovered 12 new bright QSOs and S1 galaxies, including a bright 14^mNLS1 at z = 0.118. The total number of FBS QSOs is 42 (Mickaelian et al. 1999; 2001; Véron et al. 1999). We have constructed the most complete sample of bright QSOs (B < 16.6^m) over a large area (2250 deg^2, the subarea of FBS common with Palomar-Green (PG) survey with |b| > 30◦(Green et al. 1986) and estimated their surface density as 0.012 deg^{-2}. The completeness of the bright quasar survey (BQS; Schmidt & Green 1983) was revised to 53%. New methods were suggested for accurate measurements of the positions, proper motions, magnitudes, colours and variability of FBS objects (Mickaelian 2004; Mickaelian & Sinamyan 2010; Mickaelian et al. 2011).

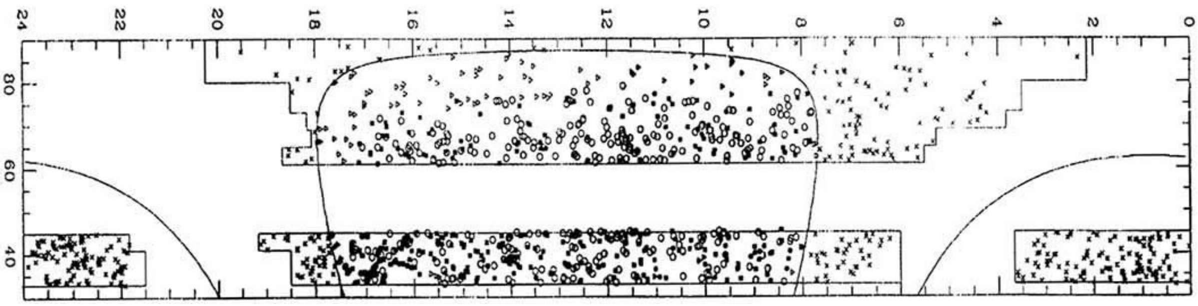

Figure 1. Distribution of 1103 FBS blue stellar objects on the sky. The lines show the Galactic plane (b=0°) and b=+30°latitude. Crosses – 388 objects with |b|<30°, triangles – 97 objects with |b|>30°but outside the PG area, dots – 276 objects detected by PG survey, circles – 342 objects within the PG area but undetected.

2.2. Optical identification of IRAS PSC sources and BIG sample

A program of mass optical identifications of all IRAS (1988) PSC sources in a large (1487 deg^2) area on the basis of FBS low-dispersion spectra was conducted in the region with +61◦ < δ < +90◦ at Galactic latitudes |b| > 15◦ (Mickaelian 1995; 1997; Mickaelian & Sargsyan 2004, and references therein).

Among the 1577 identified sources, there appear to be late-type stars, planetary nebulae, candidate QSOs, single and multiple galaxies and small groups. A new sample of IRAS galaxies was constructed, Byurakan-IRAS Galaxy (BIG) sample containing 1967 objects, including 789 previously known galaxies in this area and 1178 newly identified galaxies. Studies of BIG objects include spectroscopic follow-up for the brighter (V<18) objects (redshift survey; Mickaelian et al. 1998; 2002; Balayan et al. 2001), discovery and study of new AGNs and ULIRGs, 2D spectroscopy of interacting and merging systems, search for obscured IRAS galaxies, and study of starburst (SB), AGN and interaction phenomena and their interrelationship. Spectral observations have been carried out using SAO (Russia) 6m, OHP 1.93m and BAO 2.6m telescopes, as well as SDSS spectra are being used. 346 spectra for 229 BIG objects corresponding to 181 IRAS sources were obtained. Redshifts are in the range 0.008-0.173 and FIR luminosity is $3\times10^9 < L\mathit{fir}/L_\odot < 7.5\times10^{12}$. Classification were made by diagnostic diagrams (Veilleux & Osterbrock 1987).

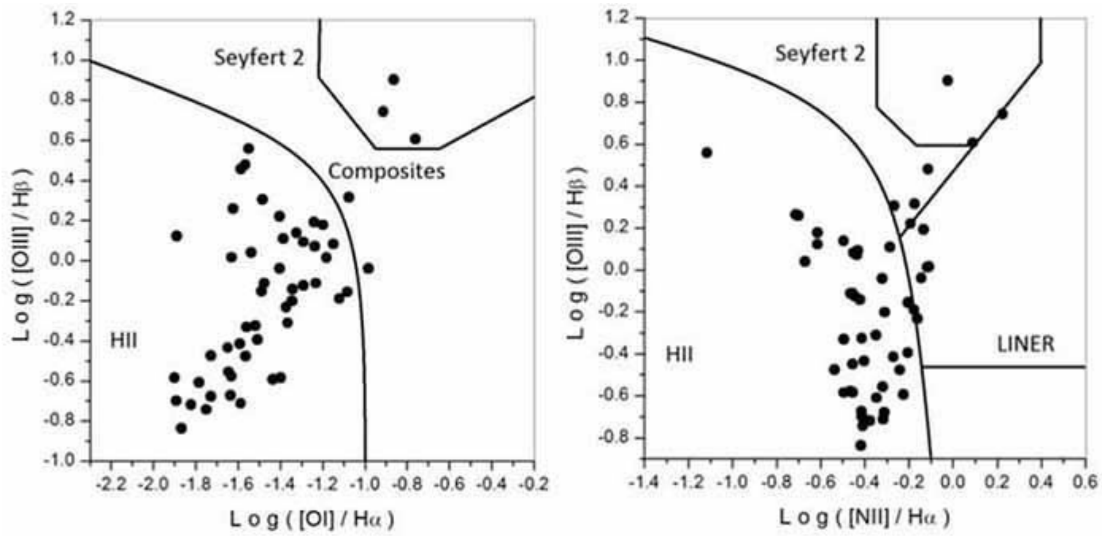

Figure 2. Diagnostic diagrams for BIG objects observed in SDSS. Many objects are located in the intermediate region between Seyferts, LINERs and HII galaxies showing composite spectrum.

BIG objects were grouped into several subsamples on the basis of their appearance, structure and nature: AGN (Sy galaxies, LINERS, composite-spectrum objects, etc.), high-luminosity IR galaxies, interacting/merging galaxies (Fig. 3, 4) and distant groups. The maximum IR luminosity for a single spiral galaxy was estimated (Mickaelian et al. 2001). High luminosity IR galaxies were revealed (Fig. 5).

2.3. Optical identification of ROSAT FSC sources and BHRC AGN

Two large works on optical identifications of ROSAT sources were carried out, using ROSAT BSC and FSC (Véron-Cetty et al. 2004; Mickaelian et al. 2006). A collaboration between Armenian (BAO), French (OHP), Hamburg quasar survey (HQS) and ROSAT teams with participation of scientists from INAOE (Mexico) and China was conducted to study the Hamburg-ROSAT identifications and to select NLS1 galaxies for further detailed investigation. Moreover, sources from the ROSAT FSC were identified and were observed as well. Beside NLS1 galaxies, X-ray sources identified with AGNs contain other interesting subsamples: QSOs, BLS1 galaxies, BLL, etc. An X-ray and optically flux-limited sample of ~1000 Seyfert 1 galaxies was created.

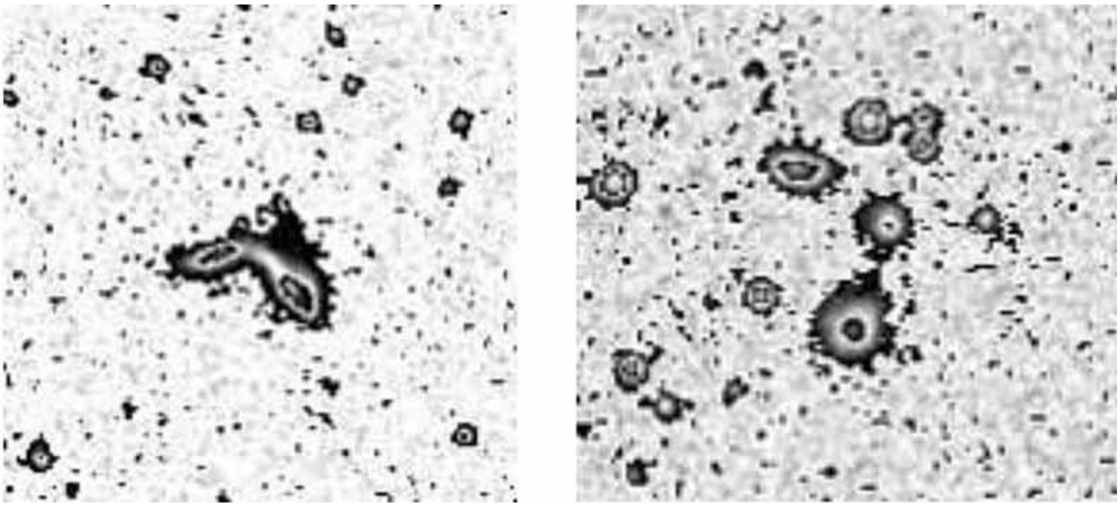

Figure 3. Two examples of multiple BIG objects IRAS 16358+6709 and IRAS 18380+8640. Image processing reveals signs of interactions between different formations. The physical groups have been confirmed by our spectroscopic observations; for the 2 components of IRAS 16358+6709 system the average redshift and the dispersion are 0.053565 and 0.000165, respectively, and for the 3 components of IRAS 18380+8640 corresponding numbers are 0.077853 and 0.000041.

Figure 4. BAO 2.6m telescope ByuFOSC image of the interacting galaxy BIG284 = IRAS 12120+6838 obtained on 18.02.2002. The physical group have been confirmed by our spectroscopic observations. The 4 components have average redshift0.060203 and the dispersion is 0.000702.

2.4. Multiwavelength study of bright AGN and Starbursts

The bright AGN/SB sample from Véron-Cetty & Véron (2010) Catalogue was retrieved for further statistical analysis. Some 10,000 objects are involved brighter than 17.5^m.The project is aimed at accurate measurements of the magnitudes, including the core-host galaxy separation (as the Catalogue gives contaminated data), correction of absolute magnitudes (and hence, re-classification between QSOs and Seyferts), study of the morphology of AGN, and MW study of the whole sample aimed at revealing many relations by using various colour-colour and other diagrams. SEDs for bright AGN were built and studied (Mickaelian et al. 2012).

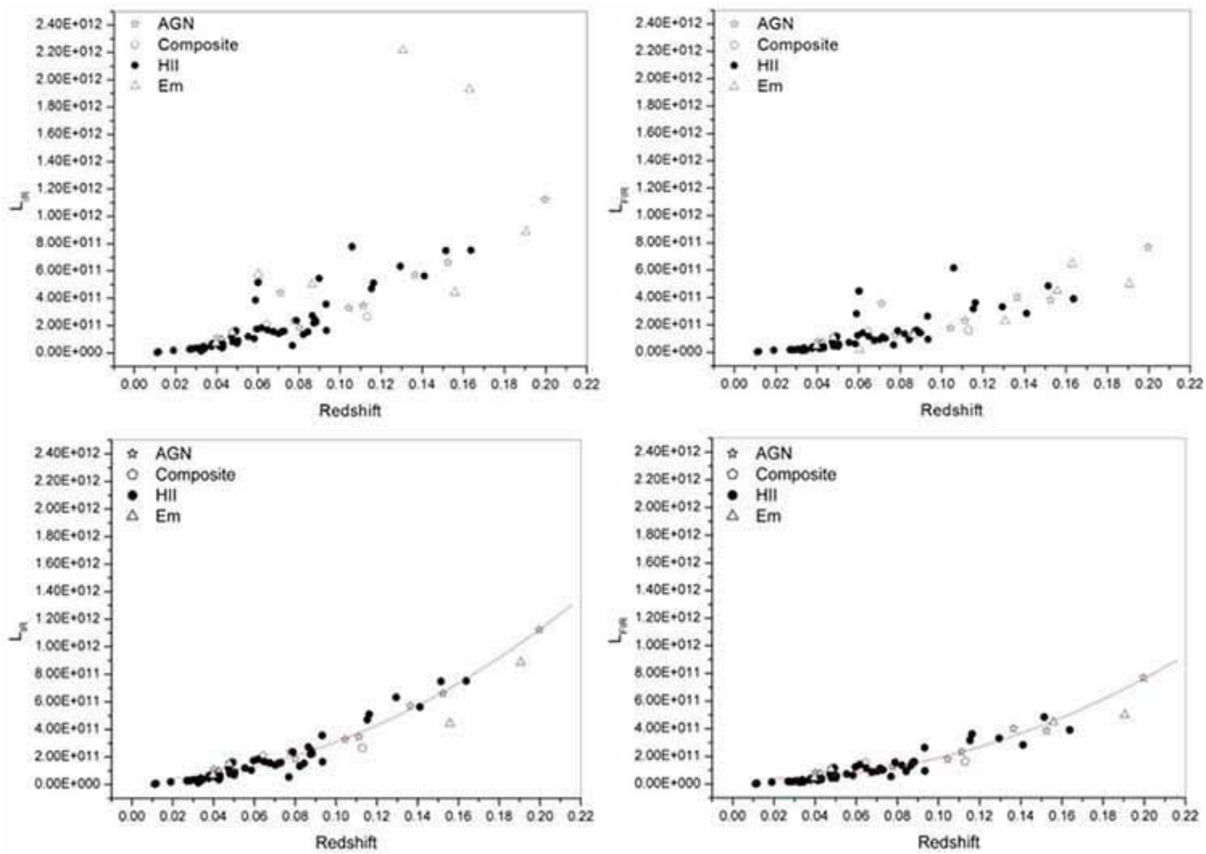

Figure 5. IR and FIR luminosities of BIG objects vs redshift. Top panels: most o fthe objects are located along a "main sequence", while there are 4 galaxies obviously having higher IR/FIR compared to what would be expected from the typical distribution. Bottom panels: Polynomial fits for the "main sequence" galaxies showing the accuracy of the correlation between IR/FIR and the redshift for this sample.

2.5. Spectral and multiwavelength study of Markarian galaxies

Markarian galaxies were published in a series of 15 papers and then in several catalogues (Mazzarella & Balzano 1986; Markarian et al. 1989; Bicay et al. 1995; Petrosianet al. 2007). SDSS covered a significant area of Mrk survey. Markarian survey was digitized (Mickaelian et al. 2007; Massaro et al. 2008), and digital low-dispersion spectra are available for all Mrk galaxies. Using all available data on Markarian galaxies that appeared during the recent years, it is possible to carry out their homogeneous study to better characterize the sample in respect of various (including MW) parameters. We have classified 779 Mrk galaxies based on SDSS. These spectra give better classification and reveal fine details for these objects (Fig. 6). The distribution of galaxies by activity types is given in Table 1. We have built MW SEDs for all Mrk galaxies to study them using the whole electromagnetic range (Fig. 7).

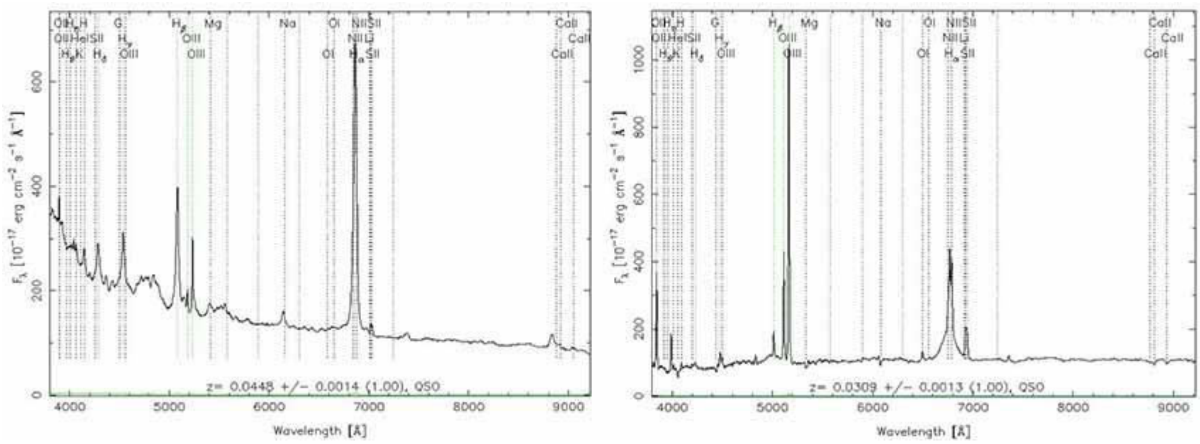

Figure 6. Examples of SDSS spectra of Mrk galaxies and their fine classification; Mrk 142 (Narrow Line Seyfert Galaxy, NLS1) and Mrk 1469 (S1.8 showing broad emission components both for Hα and Hβ).

Table 1. *Distribution of 779 Mrk galaxies by activity types based on SDSS spectra*

Activity type	Number	Activity type	Number
HII	533	Sy1.2	21
Composite (LINER/HII, Sy/HII, Sy/LINER or Sy/HII/LINER)	31	NLS1	4
LINER	12	Sy1.0	4
Sy2.0	4	QSO	2
Sy1.9	5	AGN *(without an exact type)*	11
Sy1.8	8	Em (HII or AGN)	52
NLS1.5	5	Abs	65
Sy1.5	11	Star	3
NLS1.2	8	**Total**	**779**

2.6. IRAS PSC/FSC Combined Catalogue and its extragalactic sample

We have compiled a joint catalogue of IRAS PSC and FSC by means of cross-correlation of these two lists (Abrahamian et al. 2015). We have used a new tool for cross-correlations and as a result we obtained 73,770 associations. In addition, we have made cross-correlations with AKARI-IRC, AKARI-FIS and WISE catalogues. As a result, we created a catalogue with high positional accuracy and with 17 photometric measurements from 1.25 to 160 µm range, providing a detailed catalogue for 345,163 IRAS point sources. 145,902 (42%) of them are candidate galaxies, subject for our further studies of this large IR selected galaxy sample. The number of genuine galaxies (available from catalogs) is 78,240 and among them 18,567 are found to be AGN (from VCV-13, BZCAT v5 and SDSS QSOs catalogs), which makes their fraction

23.7%. Redshifts are available in total for 22,970 galaxies (mainly AGN and a small part of absorption galaxies).

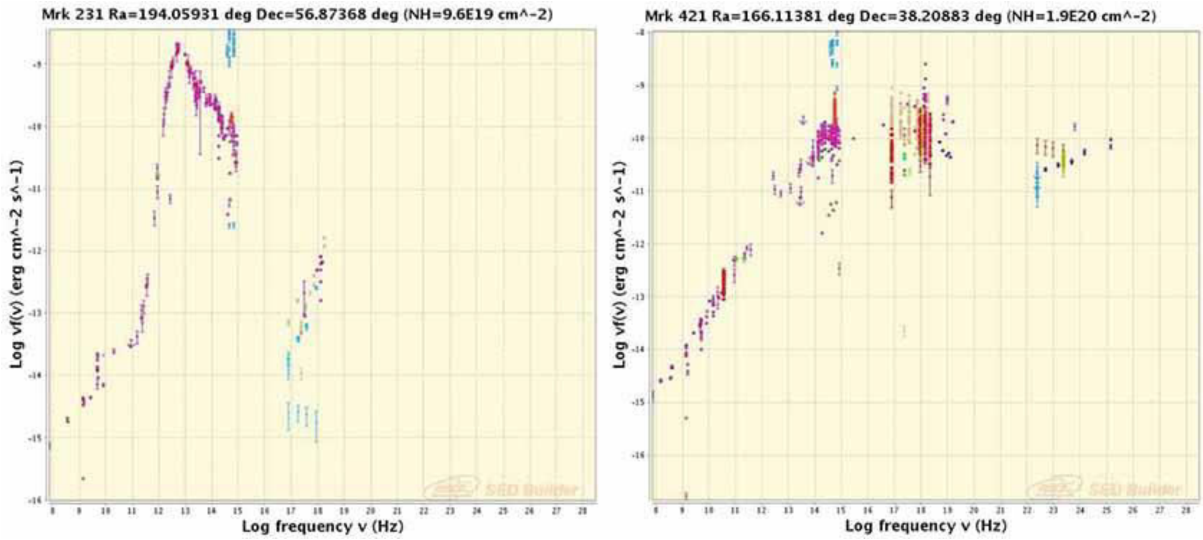

Figure 7. SEDs for two famous Markarian galaxies, Mrk 231 (the closest ULIRG,BAL QSO and most luminous IR galaxy in the Local Universe) and Mrk 421 (a blazar that is among the highest known energy sources), taken from ASI Science Data Centre, built by SED tool V2.0.

2.7. Study of extremely high IR/opt flux ratio galaxies with Spitzer

Based on the selection of IRAS FSC sources by means of cross-correlations with radio (FIRST) and optical (MAPS) catalogues, we have created a sample of extremely high IR/opt flux ratio galaxies and performed IR spectroscopy by Spitzer IRS (Sargsyan et al. 2008). Sources have $0.12<z<1.00$ and luminosities ($erg \cdot s^{-1}$) $43.3<\log[\nu L\nu(5.5\ \mu m)]<46.7$, encompassing the range from local ULIRGs to the most luminous sources discovered by Spitzer at z~2. Approximately half of the sources have luminosity dominated by an AGN and approximately half by a starburst (Fig. 8).

We analyzed the spectroscopic results for all galaxies observed with Spitzer IRS that also had total IR fluxes measured with IRAS, also using AKARI photometry. IR luminosities and SEDs from 8μm to 160μm were compared to PAH emission from SB galaxies or MIR dust continuum from AGN at rest-frame wavelengths ~8μm (Sargsyan et al. 2011). A sample of 230 galaxies was compiled based on their IRAS FSC fluxes to study their MW properties and carry out comparative analyses with other similar samples. We estimated the extinction for these 230 objects using SFRs calibrated from the PAH feature compared to UV flux, which showed that only 1% of the UV continuum typically escapes extinction by dust within a SB (Hovhannisyan et al. 2011).

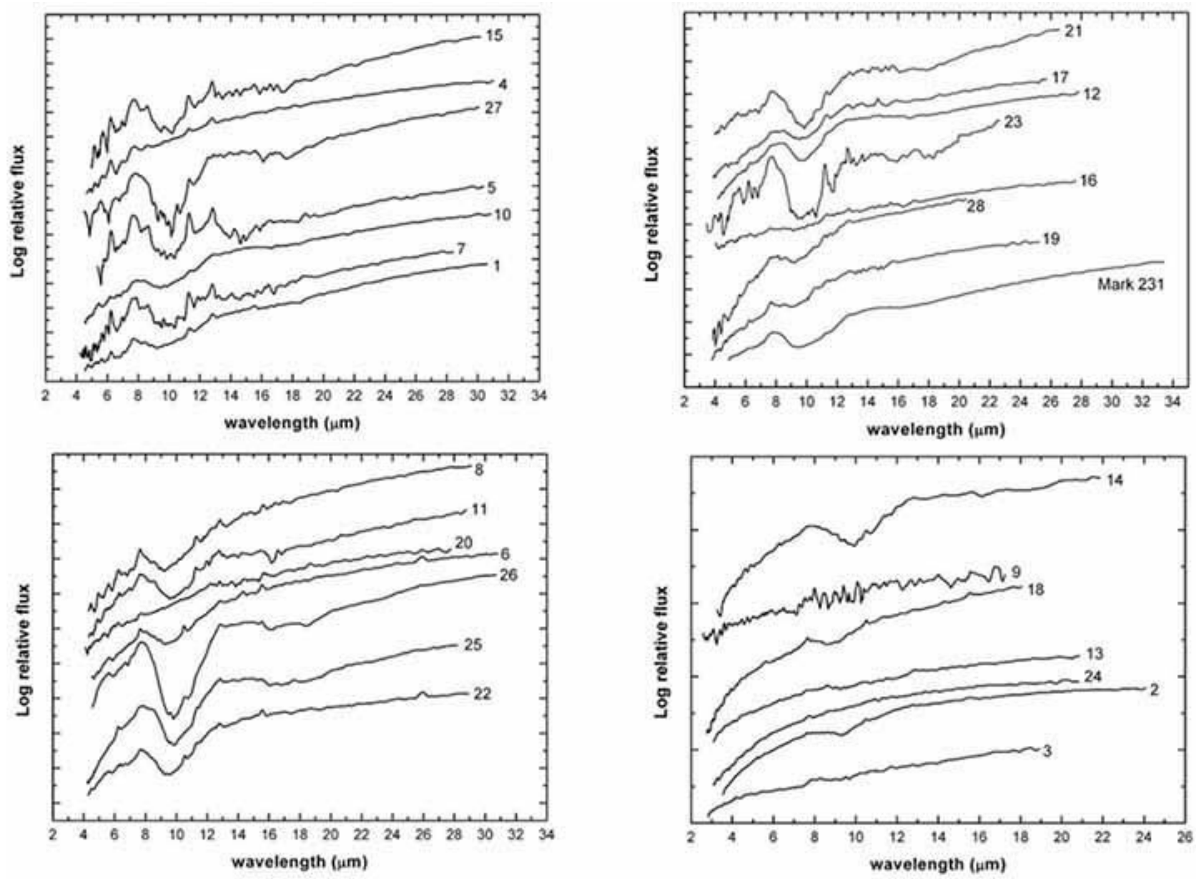

Figure 8. Spitzer IRS spectra of IRAS FSC sources in rest frame, ordered by νL_ν (5.5μm). The lowest luminosity galaxy is given on the top. Sources of higher luminosities continue from top left to bottom right panels.

2.8. HRC/BHRC Combined Catalogue and its extragalactic sample

The joint catalogue of AGN selected from optical identifications of X-ray sources was created as a combination of two samples: Hamburg-ROSAT Catalogue (HRC; Zickgraf et al. 2003) and Byurakan-Hamburg-ROSAT Catalogue (BHRC; Mickaelian et al. 2006). Using the recent optical and MW catalogues we have revised both samples excluding false AGN and adding new genuine ones. Thus, a new large homogeneous complete sample of 4253 X-ray selected AGN was created. 3352 of them are listed in the Catalogue of QSOs and Active Galaxies (Véron-Cetty & Véron 2010) and 387 also are in Roma BZCAT (Massaro et al. 2015). 901 candidate AGN are subject for further study. We classified 173 of these objects using their SDSS DR12 spectra(Fig. 9). Various activity types were revealed. A special emphasis is made on narrow-line Sy1.0-Sy1.5 galaxies and QSOs, as many of them have soft X-ray, strong FeII lines, and relatively narrow lines coming from BLR. We have retrieved MW data from recent catalogues and carried out statistical investigations for the whole AGN sample. An attempt to find connections between fluxes in different bands for different types of sources, and identify their characteristics thus confirming candidate AGNs have been carried out. We have analyzed X-ray properties of these sources to find a limit between normal galaxies and X-ray AGN (Paronyan et al. 2014a; 2014b; Mickaelian & Paronyan 2014; Mickaelian et al. 2016; Paronyan & Mickaelian 2016). Table 2 gives the grouped types of optical counterparts for 8037 X-ray sources.

Table 2. *Types of optical counterparts for 8037 X-ray sources and their fractions*

Type	Number	%
Galaxy	492	6.1
AGN	4253	**52.9**
Star	1800	22.4
Unknown	1492	18.6
Total	**8037**	**100.00**

After having more optical spectroscopic data from SDSS and combining AGN with Galaxy types (which may also contain AGN and SB), we have the following distribution by activity types (Table 3).

Table 3. *Distribution of activity types for all HRC/BHRC extragalactic objects using SDSS DR12 spectra and other available data*

Activity type	Number	%
BL Lac + HPQ	320+13	7.0
QSO	1309	27.6
Sy1.0-1.5	1876	39.5
Sy1.8-2.0	111	2.3
Sy:	37	0.8
LINER	21	0.4
AGN	82	1.7
AGN:	451	9.5
Starburst / HII	25	0.5
Abs	8	0.2
Bright galaxy	492	10.4
Total	**4745**	**100.0**

2.9. NVSS-FIRST cross-correlation: variable radio sources

NVSS (Condon et al. 1998) and FIRST (Helfand et al. 2015) have been carried out at the same wavelength (21 cm) or frequency (1400 MHz), which gives a unique possibility to study radio variability of the common sources. The cross-correlation enabled us to find 556,282 radio sources present in both catalogs. Using the 3σ criteria we distinguished 6,301 variable radio sources, and with certain limitations specified the 260 strongest radio variables. We cross-correlated these 260 sources with other catalogs at different wavelengths (APM, SDSS DR10, VCV-13, BZCAT, 2MASS, WISE). As a result, we obtained photometric data for optical, NIR, MIR and radio ranges for these 260 variable radio sources to study them in details (Abrahamyan & Mickaelian 2014a; 2014b). The same will be done with all 6,301 sources, which we consider as AGN (**1.1%** among associated radio sources).

2.10. ROSAT-NVSS AGN sample

X-ray and radio radiation is typical of many active galaxies, but there are other X-ray and radio sources as well. However, the cross-correlation of these two kind of sources results in mostly AGN, especially if we use not very deep surveys. We attempted to create an X-ray/radio AGN catalog and make its MW studies. We have cross-correlated ROSAT catalogs with NVSS one with a search radius of 30″. 9,193 associations have been found. To distinguish AGN from the normal bright galaxies and clusters, Véron-Cetty & Véron (2010) AGN catalog was used. 3,094 AGN were found. We were left with 6,099 X-ray/radio sources without an optical identification. Brighter objects are normal bright galaxies, while we believe that all faint ones are candidate AGN with some contamination of distant clusters. SDSS spectroscopic survey allows us classify objects by activity types, and a number of our candidate AGN is found to be present in SDSS. We attempt to find connections between the fluxes in different wavelength ranges, which will allow us to confirm AGN and blazars candidates and in some cases find new ones (Paronyan et al. 2014). If we consider all associated sources as AGN (given that both X-ray and radio is present), then they make up 7.4% among 124,730 ROSAT X-ray sources and only 0.5% among 1,773,484 NVSS radio ones. However, it is obvious that these numbers are underestimated, as we consider only one private method to reveal AGN.

2.11. Multiwavelength study of blazars

Blazars are the most interesting objects among AGN, both for their high luminosities and physical properties. We have conducted a project on MW studies of blazars based on the compilation of a homogeneous large sample of such objects (~5000 blazars) and cross-correlations with available catalogues from γ-ray to radio. Roma-

BZCAT (Massaro et al. 2015) and Véron-Cetty & Véron (2010) Catalogue, as well as new SDSS QSOs are being used as a basis. Statistical analysis of the sample will be carried out to establish average properties of blazars and possibly find their subclasses. Optical and radio variability for the blazar sample will be established. A revised classification of blazars using the new data will be accomplished. MW SED for all blazars using automated software will be built. The evolution of various characteristics of blazars with luminosity and redshift will be studied. The luminosity evolution of various blazar sub-samples will be compared. Our data will make possible the study of their physical properties and establish the homogeneous definition of blazar phenomenon.

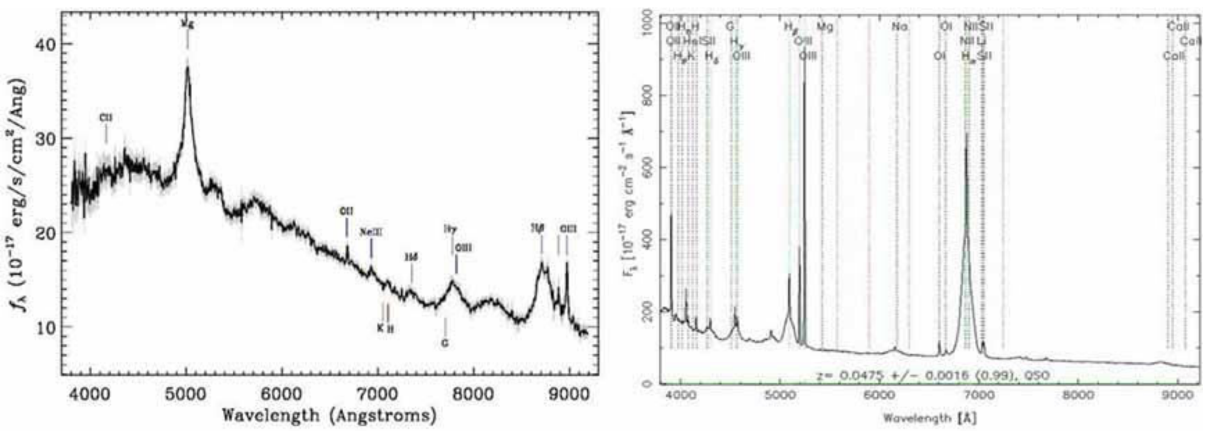

Figure 9. Example of SDSS spectra of HRC/BHRC AGN and their fine classification; left: a QSO also showing FeII lines on the left of H_ typical of NLS1 and classified to NLQSO, right: S1.5 showing both narrow and broad emission lines with approximately equal intensity.

2.12. Fine analysis of emission line spectra of active galaxies

Most of type 1 AGN have contaminated spectral lines so that the broad component is overlapped on the narrow ones. A programme of fine analysis of emission line profiles and detailed spectroscopic classification of bright S1 galaxies (including NLSl ones) was conducted in collaboration with Véron & Véron-Cetty (OHP, France). Itwas aimed at studying the differences between the classical BLS1 and NLS1 galaxies (Osterbrock & Pogge 1985) and correlations between FeII and Balmer lines, Fe II and[OIII], and better understanding of the physics of AGN central regions. However, it appears that there is not a strict separation between the BLSl and NLSl galaxies (the line width limit at 2000 km·s^{-1} is arbitrary), and the intermediary objects may fill the gap. High-dispersion spectroscopy of 90 S1s having intermediate FWHMs was carried out at OHP 1.93m telescope with 0.9 Å/pix dispersion, the spectral resolution being3.2Å. S1s from Véron-Cetty & Véron (2010) with V<16 and z<0.1 were selected, including well-known objects (Fig. 10).

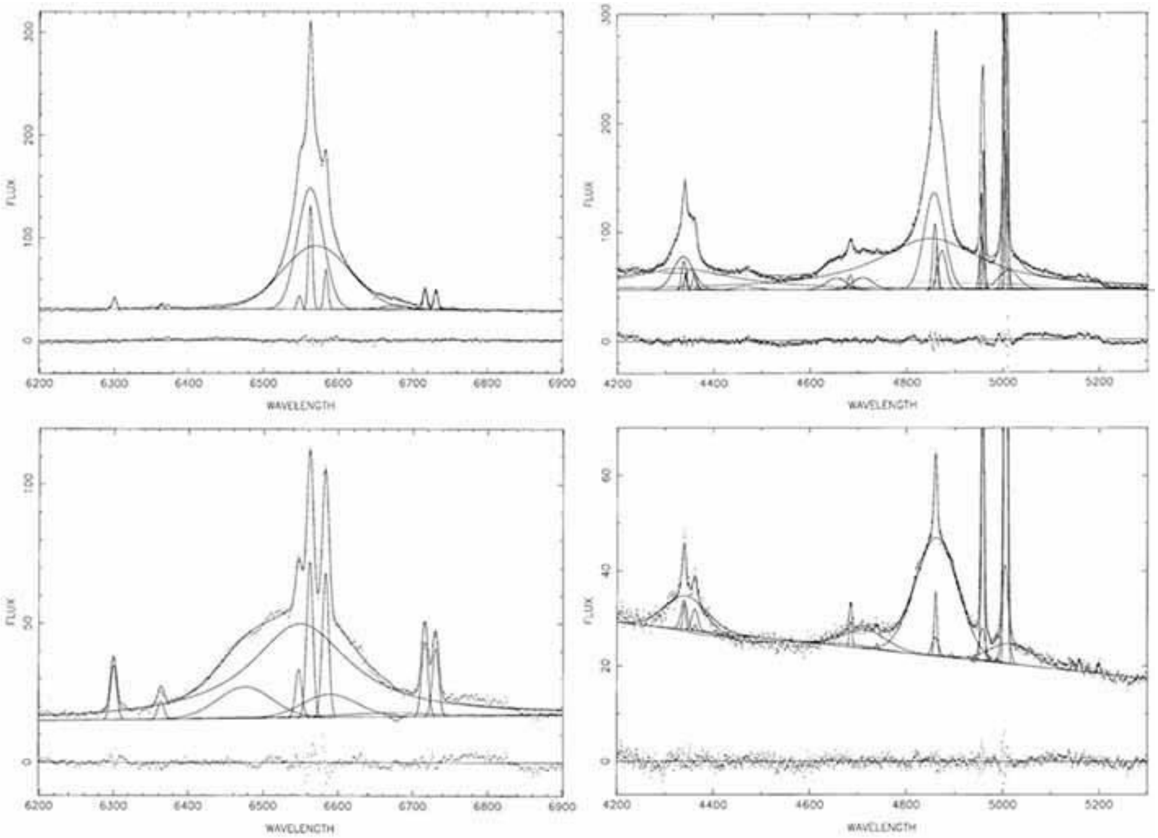

Figure 10. Fine analysis of the emission-line spectra of active galaxies with the dedicated software SPECTRAI. Examples of the results of the fitting in ranges around Hα (left panels) and Hβ (right panels). Top left panel: 3C 120 (an example of the easiest cases), top right panel: Mrk 509, bottom left panel: Mrk 926,bottom right panel: NGC 985.

The analysis was made using the special program SPECTRAI to fit the spectral lines profiles to the observed spectra (Véron et al. 1980). A comparison was made between the Hα and the Hβ ranges observed in the framework of the same project. I n most cases, Balmer lines (and other permitted lines, such as HeI, HeII and SiII) are characterized by 2 broad components (2 Gaussian profiles or 1 Gaussian and 1Lorentzian) and 1 or 2 narrow components, and the forbidden lines ([NII], [OIII], [OI],[SII], etc.) by the same 1 or 2 narrow components. FeII and other Fe lines are often significant in the observed spectra. Together with the main emission lines (Balmer,[OIII] and [N II]), HeI, HeII, OI, SiII and others are often present. There are objects with a number of high-ionization lines ([FeV]-[FeX], [AIII]-[AV], etc.) contrary to LINERS having strong low-ionization lines (Heckman 1980). We have constructed diagnostic diagrams using [FeVII] 6086Å/ Hα*vs* [OI] 6300Å/ Hα, as well as [FeVII]6086Å) / [OI] 6300Å*vs* [OI] 6300Å/ Hα. Thus we try to classify objects by the strength of their high-ionization lines. The distribution is well arranged and the objects are in as equence according to the ionization degree, with a good separation for those objects that we believe are of special interest. A study of variability of Kaz galaxies was also conducted (Kazarian & Mickaelian 2007).

2.13. DFBS and search for fainter Markarian and other active galaxies

Even before the digitization project, some FBS spectra were scanned with the Machine Automatique de Mesures Astronomiques (MAMA, Observatoire de Paris, France) to reveal low-contrast spectral features. Five known QSOs were revealed, confirming the nature of these objects, including one discovered during our observations at OHP. Other objects have continuous spectra and may turn out to be QSOs, BL Lacs or DC WDs (Mickaelian et al. 2002).

Markarian Survey was accomplished with a goal of revealing new active galaxies and this was achieved by eye selection. We have digitized this survey plates and created the Digitized First Byurakan Survey (DFBS; Mickaelian et al. 2007; Massaro et al. 2008). Fig. 11 shows how efficient may be the low-dispersion spectra for optical identifications and search for new bright AGN.

The Armenian Virtual Observatory (ArVO; Mickaelian et al. 2009b) was created based on DFBS and many science projects have been discussed and tested (Mickaelian2007; Mickaelian et al. 2009a), including the search for new bright AGN and other active galaxies.

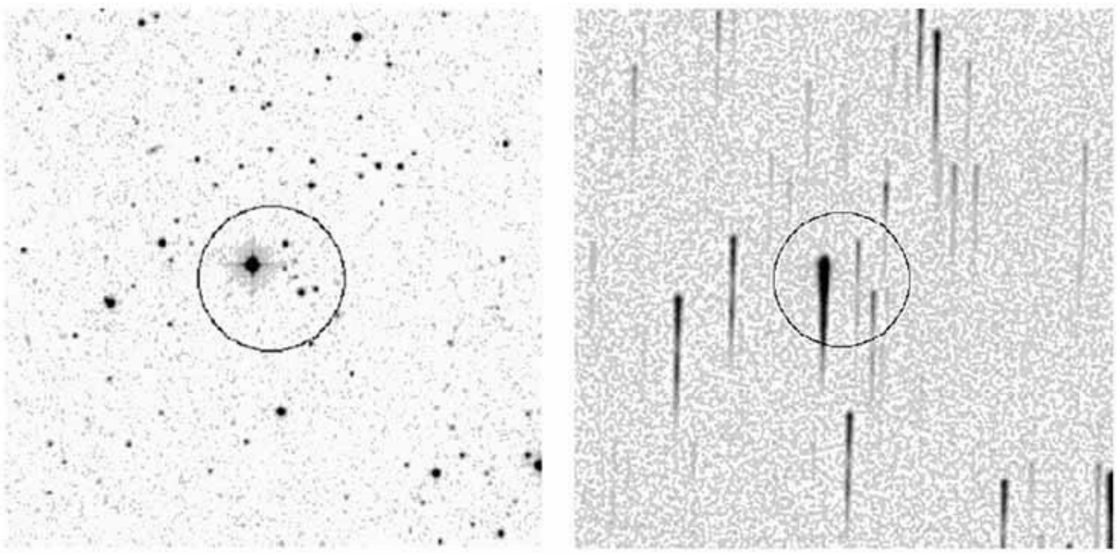

Figure 11. DFBS (low-dispersion spectra) significantly contributed in optical identifications of X-ray, IR and radio sources from ROSAT PSC/FSC, IRASPSC/FSC, NVSS, FIRST and other catalogues. Low-dispersion spectra reveal the genuine counterpart by SED and presence of emission and/or absorption lines, while direct images have no information rather than the positions and extension of objects.

2.14. AGN zoo and classification by activity types

Many types of active galaxies have been introduced since 1950s. We have analysed all types and subtypes and suggested a joint scheme for Hyper LEDA database (Gavrilovîcet al. 2007). Classifications from all available sources were taken into account. We introduced in Hyper LEDA information characterizing the nuclear and SB activity, as in particular the Véron & Véron catalogue. We also described each type of AGN. It is now possible to retrieve an "activity type" for the Hyper LEDA galaxies having this attribute, and it is possible to select list of objects from constraints on "activity type". More detailed and justified version of such joint classification, as well as combination of MW data from -ray to radio is given in our recent publication (Mickaelian 2015).

3. Summary and future projects

A number of results were achieved by our search and studies of active galaxies at various wavelength ranges:

- discovery of 42 new bright AGN (QSOs and Seyferts) among the FBS BSOs, re-estimation of the completeness of BQS (53%) and estimation of the surface density of bright QSOs/AGN (0.012 deg^{-2}),
- optical identification of 1577 IRAS unidentified IR sources, including 1279 galaxies (BIG objects) and 287 stars (BIS), discovery of new bright AGN (Seyferts and LINERs) and ULIRGs among BIG objects, discovery of dozens of new pairs and multiple galaxies among IRAS sources, estimation of the maximum luminosity of a single spiral galaxy (10^{12} $L_{\odot}$), study of interrelationship of AGN / interaction / starburst phenomena for IRAS galaxies,
- optical identification of 3212 ROSAT FSC X-ray sources; discovery of new bright AGN (QSOs and Seyferts) among X-ray sources, optical identification of 2791 ROSAT FSC X-ray sources (BHRC objects); estimation of the abundance of various types of objects among X-ray sources, discovery of new types of X-ray galaxies: interacting pairs and multiples,
- discovery of 32 highest IR/opt flux ratio extragalactic sources selected from IRAS FSC and observed with Spitzer, discovery of the highest IR/opt flux ratio (40-1000) extragalactic objects,
- a new sample of 330 IRAS / 2MASS / FIRST / SDSS selected galaxies, useful for comparative study of properties of IR sources,
- establishment of accurate magnitudes for AGN and the first statistical study of AGN catalogue,

- discovery of the spectral variability of Akn 564 and Kaz 102; fine analysis of emission lines,
- homogeneous classification of 779 Markarian galaxies by activity types,
- based on the combined ROSAT BSC/FSC catalogue of optical identifications, we estimated AGN content of X-ray sources as 52.9%,
- we have combined IRAS PSC and FSC catalogs and compiled its extragalactic sample, which allowed to estimate AGN content among IR sources as 23.7%,
- definition of HINERs (High Ionization Nuclear Emission-Line Regions),
- complete AGN classification for HyperLEDA database and elsewhere.

The results are published in the listed papers and books (DFBS, etc.), BAO, and ArVO web pages, the discovered objects are included in the most important databases (NED, Hyper LEDA, etc.), a number of catalogues are published in Vizier:

- First Byurakan Survey (FBS), 2nd Program (1999), Catalogue II/223
- FBS blue stellar objects DSS1/DSS2 astrometry (2004)
- Optically bright AGN in ROSAT-FSC (2004)
- Digitized First Byurakan Survey plate database (2005), Catalogue VI/116
- Optical identification of ROSAT-FSC sources (2006)
- Revised and updated First Byurakan Survey (FBS, 2008), Catalogue III/258
- IRS spectra of faint IRAS sources (2008)
- Proper motions of FBS blue stellar objects (2010)
- Variability of FBS blue stellar objects (2011)
- IR spectra and SEDs for starbursts and AGNs (2011)
- Study of 230 IRAS-FSC galaxies (2011)
- IRAS PSC/FSC Combined Catalogue (2015), Catalogue II/338.

Many new projects are possible based on our studies and using our data products (DFBS database, published catalogues, etc.). We give in Table 4 the summary of our projects on search and studies of active galaxies: short project name, years of accomplishment, objectives and number of involved objects.

Table 4. *Summary of projects on multiwavelength search and studies of active galaxies*

Project	Years	Objectives	Objects
FBS QSOs/Seyferts	1986-2001	Bright QSOs and Seyferts	1,103
IRAS BIG sample	1994-2010	AGN, SB, ULIRGs	1,178
ROSAT BSC/FSC sources	2002-2006	Search for new AGN	2,791
Bright AGN	2001-pres.	Statistical studies	~10,000
Markarian galaxies	2010-pres.	Spectral and MW study	1,515
IRAS PSC/FSC	2011-pres.	Large IR galaxies sample	145,902
Spitzer ULIRGs	2003-2010	High IR/opt flux ratio galaxies	32
HRC/BHRC AGN	2010-pres.	AGN content in X-ray	4,253
NVSS-FIRST	2013-pres.	Study of radio variability	6,301
ROSAT-NVSS	2013-pres.	Search for new AGN, statistics	9,193
MW study of blazars	2014-pres.	New blazars, definition	3,561
Fine analysis of spectra	2001-2007	Physical properties of AGN	90
DFBS AGN	2002-pres.	New bright active galaxies	~10,000
Fine classification	2006-pres.	Accurate types and subtypes	~10,000

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Color-Color Diagrams in Near Infrared: (J-H)/(H-K). I.

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Abstract

In the paper are presented the color-color diagrams (J-H)/(H-K) for all stars with visible values B<11, for which in the known catalogs the values of J, H, K, and also spectral classes and luminosity classes of these stars are given. The diagrams are constructed for luminosity classes Ia, Ib, II, III, IV, V. The similarity of diagrams for classes Ia and Ib (super giants) and II (giants), is obvious from these diagrams. The diagrams obtained by us can be used for discovering of new young stars and also for determining of color excesses of investigating stars. Maximal amounts of stars are registered in the classes V and III. There is a tendency of increasing of J-H and H-K along the sequence of spectral classes O – M, which is correct for all luminosity classes.

Keywords: *color-color diagrams: near infrared colors.*

1. Introduction

Several surveys in the different parts of stellar spectra were done during last decades. One of these surveys was the Two Micron All Sky Survey (2MASS survey). The 2MASS survey is a joint project of University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. This survey was done during (1997-2001) years, on 1.3 m telescopes at Mt. Hopkins and CTIO (Cerro Tololo Inter-American Observatory, Chile). The 2MASS survey includes three spectral bands in near infrared. 1. J band (centered on 1.236μm). 2. H band (centered on 1.662μm). 3. K band (centered on 2.159μm).The K-band image sometimes traces the emission in Br_{γ} (2.166μm) and HeI (2.058 μm) (Comeron et al., 2005). In our paper we represent the color-color diagrams in near infrared, (J-H)/(H-K). The color-color diagrams a useful tool in examining the membership, rough spectral types, and possible existence of infrared excess in the spectra of stars.

To identify young lower mass stars it is possible to use the position in the (J-H)/(H-K) diagram as a diagnostic for the existence of hot circumstellar discs remnant

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from their formation, a very common signature of youth among intermediate-mass, pre main sequence stars, and a frequently used approach to the identification of distributed star formation in molecular clouds (see review by Lada and Lada, 2003).

To assess the amount of IR excess in (Comeron et al., 2005) was used the reddening-free quantity Q = (J-H) – 1.70·(H-K), which measures the separation between the position in color-color diagram of a star with colors (J-H), (H-K) and a reddening vector, that traces the Rieke and Lebofsky (1985) extinction curve having its origin at the intrinsic colors of a A0V star. Red giants, which align along a narrow strip running above this reddening vector in the diagram, have Q>0, while early-type stars with no IR excess, cluster around Q = 0. Stars with Q<0 can be either late-type M dwarfs or stars with IR excess. For the stars satisfying Q<-0.10 criterion, that was imposed in (Comeron et al., 2005) as a threshold, defining the stars suspected to display IR excess. Hence we can conclude, that it is possible to find YSO's, using the values of J-H and H-K. By Gyulbudaghian (2011, 2014, 2016) many new YSO's were found, using such values.

2.The (J-H)/(H-K) diagrams

Houk and Fesen (1978) using the Michigan Spectral Catalogue (where the data of good quality determined spectral classes are collected), was constructed the Hertzsprung-Russell diagram for 36382 stars (diagram M_V/spectral class). They obtained, that the red giants KIII are the most numerous among other types, the second position occupythe main sequence stars A0V, and the third position - the main sequence stars F5V. We used the catalogs by Zacharias et al. (2005) and the catalog by Kharchenkoet al. (2004), where the data on J, H, K colors, and also the spectral classes and classes of luminosity of stars are presented. We chose the stars with visible value $B<11^m$. The number of stars, used by us, is 42456. The most numerous stars are red giants, KIII, 10458 stars, the second position occupy the stars of main sequence, FV (7859 stars), at the third position are the main sequence stars GV (4725 stars), and at the fourth position are the main sequence stars AV (3819 stars).Hence we can make a conclusion, that the difference between the spectral distribution of stars in our paper and in paper by Houk and Fesen is not big.

As the number of obtained diagrams is large for introducing all of them, we will present some of them, and will describe others shortly. In Fig.1, a and b, the diagrams (J-H)/(H-K) for the luminosity classes Ia and Ib (the super giants), respectively, are presented.

2.1. The stars of luminosity class Ia

There are only two stars of spectral class O, they are situated near the point J-H = 0.2, H-K = 0.2. The stars of spectral class B cover the area: 0.0<J-H<0.25, 0.0<H-K<0.3. The stars of spectral class A cover the area: 0.0<J-H<0.2, 0.0<H-K<0.3. The stars of spectral class F cover the area: 0.1<J-H<0.3, 0.2<H-K<0.5. The stars of spectral class G cover the area: 0.1<J-H<0.3, 0.4<H-K<0.6. There are only two stars of spectral type K, they are near the point J-H = 0.25, H-K = 0.6. There is only one star of type M: J-H = 0.35, H-K = 0.9.

2.2.The stars of luminosity class Ib

Almost the same distribution (as for class Ia) of stars is on the diagram for stars of luminosity class Ib (see Fig.1b, the amount of stars included in the diagram is 453).The stars of class O cover the area: 0.0<J-H<0.1, 0.0<H-K<0.1. The stars of spectral class B cover the area: -0.02<J-H<0.2, -0.1<H-K<0.1. The stars of spectral class A cover the area: 0.0<J-H<0.2, 0.0<H-K<0.3. The stars of spectral class F cover the area: 0.0<J-H<0.25, 0.0<H-K<0.25. The stars of spectral class G cover the area: 0.0<J-H<0.3, 0.3<H-K<0.8. The stars of spectral class K cover the area: 0.2<J-H<0.35, 0.5<H-K<1.0.The stars of spectral class M cover the area: 0.3<J-H<0.4, 0.55<H-K<1.1.

In Fig.1c the compiled diagram of luminosity classes I, Ia and Ib is presented. There are very few stars of luminosity class I, so we decided not to present them separately.

2.3.*The stars of luminosity class II*

The next diagram, presented in the paper, is the diagram of stars of luminosity class II, bright giants (see Fig. 2).This diagram is a compiled diagram for the stars of all spectral classes. From Fig. 2 is obvious, that there is a tendency of increasing of J-H and H-K in the sequence of spectral classes O – M. We have constructed the diagrams for all spectral classes separately, but we have no such possibility to include all of them in the paper. The stars of spectral classes O and B cover almost the same area in the diagram (-0.05<J-H<0.15, -0.02<H-K<0.1); the stars of spectral classes A and F also cover almost the same area on the diagram, but this area has higher values of J-H and H-K than the previous area (0.0<J-H<0.2, 0.0<H-K<0.2). The stars of other spectral classes cover areas with increasing values of J-H and H-K in the sequence G – K – M (for class G: 0.07<J-H<0.2, 0.35<J-H<0.6; for class K: 0.1<J-H<0.3, 0.4<H-K<0.8; for class M: 0.2<J-H<0.3, 0.7<H-K<1.1).

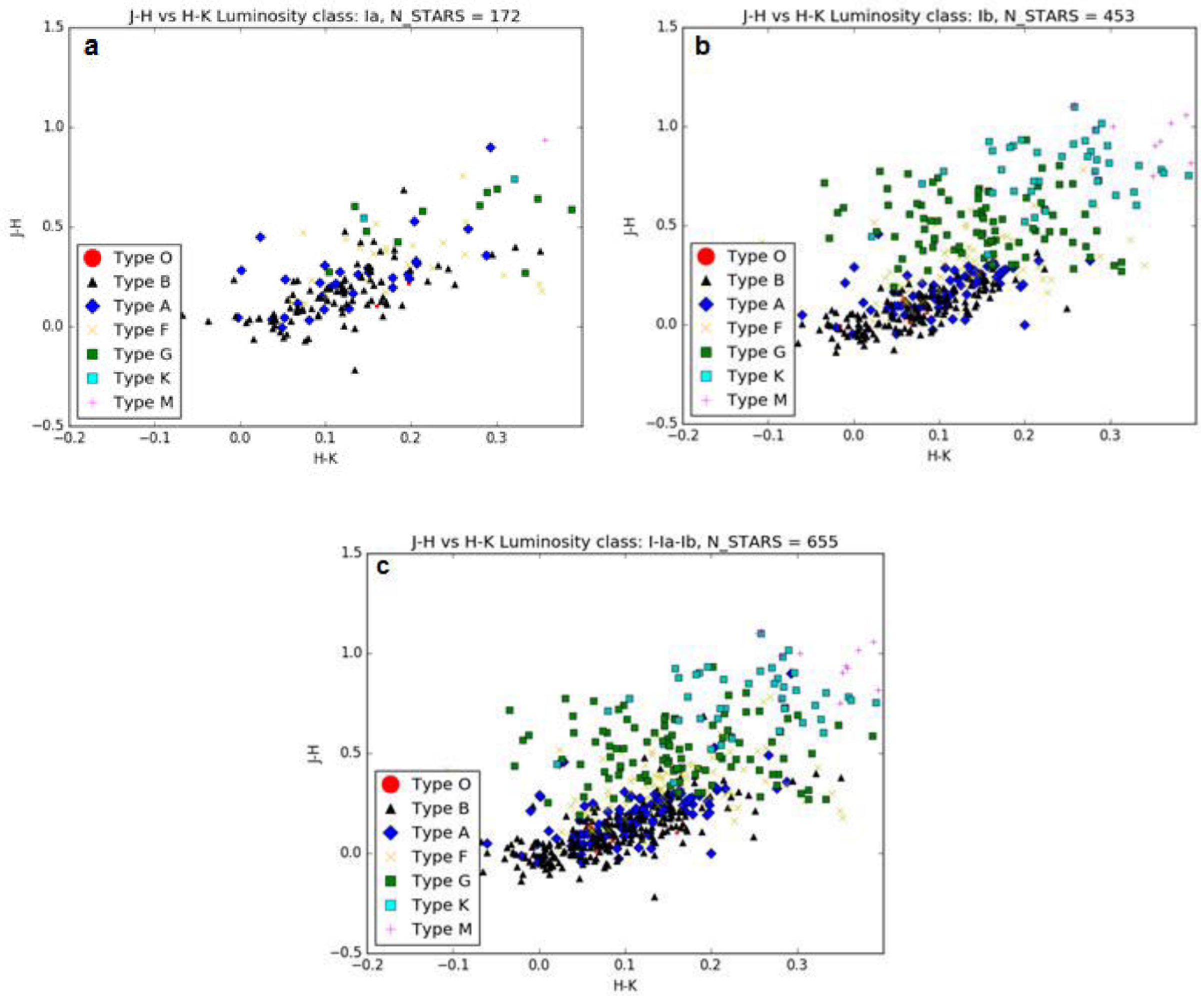


Figure 1. (J-H)/(H-K) diagrams for the stars of luminosity classes I, Ia and Ib (supergiants): a – diagram for the stars of luminosity class Ia; b – diagram for stars of luminosity class Ib; c – the compiled diagram for luminosity classes I, Ia and Ib.

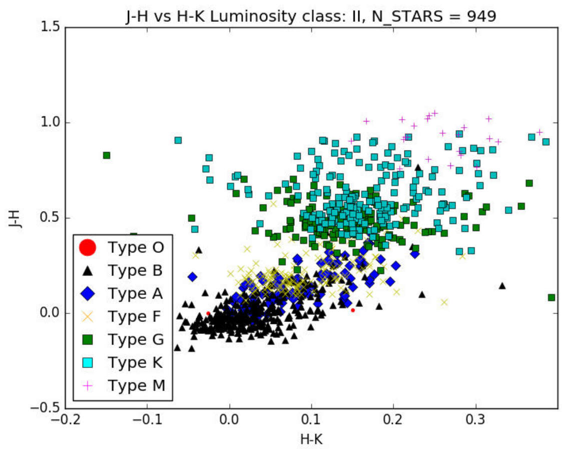
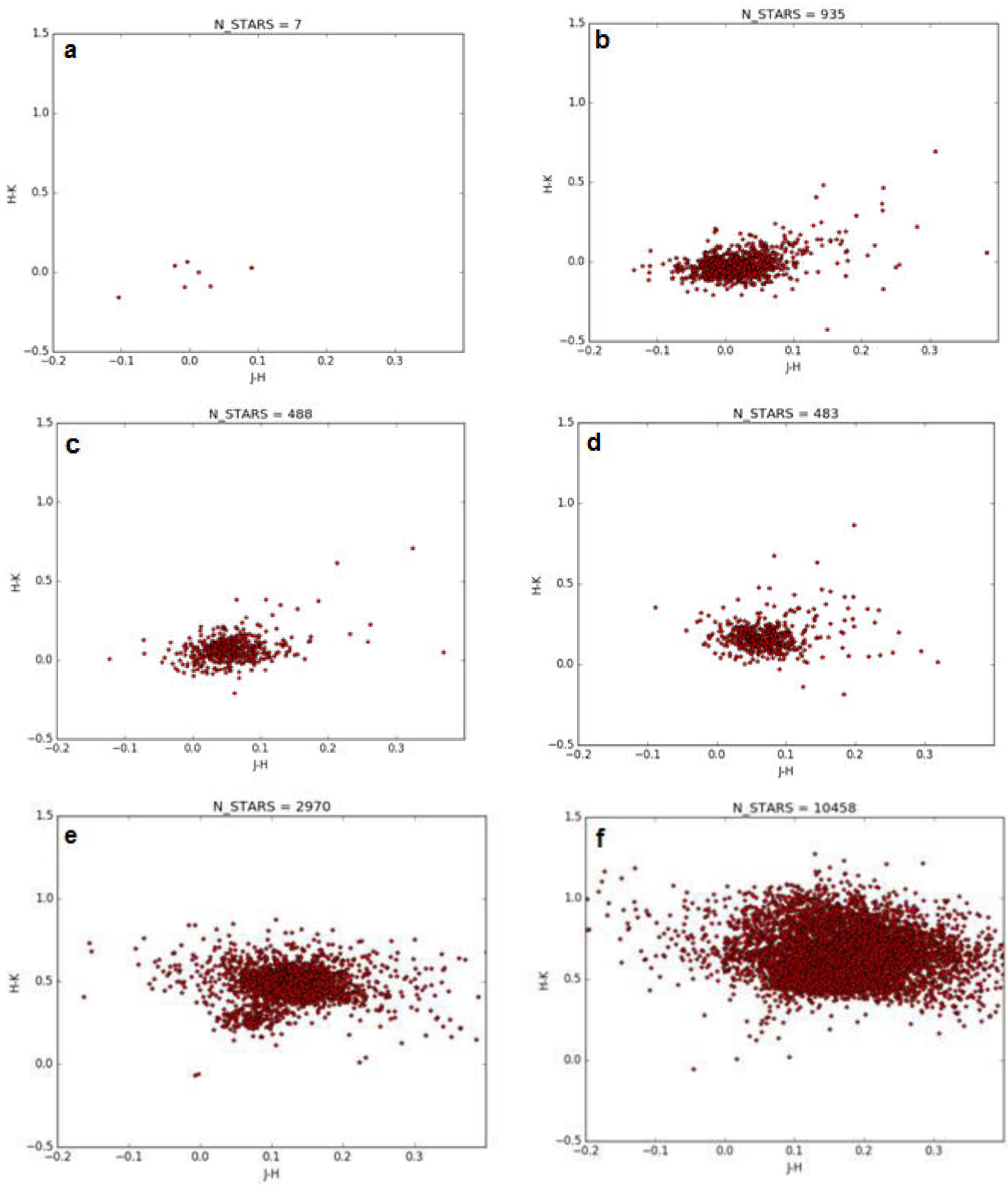


Figure 2. (J-H)/(H-K) diagram for the stars of luminosity class II, bright giants (for all spectral classes).

2.4. *The stars of luminosity class III*

The next diagrams, presented in the paper, are the diagrams of luminosity class III, the giants. Because the amount of stars of composite diagrams for all spectral classes for luminosity class III, is very large, 16809, we decided instead of presenting of that very complicating diagram, to present separately the diagrams for each spectral class.



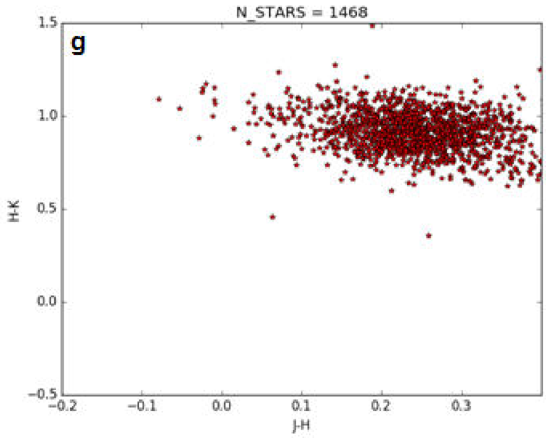


Figure 2. (J-H)/(H-K) diagrams for stars of luminosity class III, giants: a – diagram for stars of spectral class O; b – diagram for stars of spectral class B; c – diagram for stars of spectral class A; d – diagram for stars of spectral class F; e – diagram for stars of spectral class G; f – diagram for stars of spectral class K; g – diagram for stars of spectral class M.

In Fig. 3, c and d, the diagrams of luminosity class III, spectral classes A and F, respectively, are presented. It is obvious, that the stars cover the same region in J-H for both spectral classes, but for H-K in class F the stars cover higher values, than the stars of class A.

In Fig. 3e the diagram of luminosity class III, spectral class G, is presented. The distribution of stars has values of J-H and H-K higher, than for previous spectral classes. It is obvious, that there are two concentrations of stars on this diagram: one centered on (J-H = 0.08, H-k = 0.25), the second on (J-H = 0.13, H-K = 0.5). Sucha phenomena is unique for all diagrams obtained.

In Fig. 3, f and g, the diagrams of luminosity class III, spectral classes K and M, respectively, are presented. The amount of stars included in class K, is the highest in luminosity class III, almost 62 % of all the stars in that class III. The distribution of stars of spectral class K, comparing with previous spectral classes, has higher values of J-H and H-K. As we can see, in spectral class M much less stars are present, than in spectral class K. The stars of spectral class M have higher values of J-H and H-K, than the stars of spectral class K.

In the next paper the diagrams for luminosity classes IV and V will be presented.

3. *Conclusions*

Having in mind the importance of data, concerning the values of near infrared colors J, H, K, we decided to construct the (J-H)/(H-K) diagrams for stars with known spectral classes and classes of luminosity. We used the data of 2MASS survey on values of J, H, K, and also the values of spectral classes and classes of luminosity from the catalogs [5, 6]. The constructed by us diagrams are presented for luminosity classes I,Ia, Ib, II, III, IV, V. We have chosen the stars, which have visible values B<11 from the known catalogs (Zacharias et al., 2005, and Kharchenko et al., 2004). The next criteria for our choice, was the presence of values of J, H, K, of spectral classes and luminosity classes for these stars. We can mention the following results. The most stars used are in the luminosity classes V and III. The values of (J-H) and (H-K) are increasing along the sequence of spectral classes O – M, the phenomena which we could anticipate. The red giants KIII are the most numerous (10458 stars), the second position occupy the main sequence stars FV, and the third position occupy the main sequence stars GV. On the diagram for stars GIII there are two concentrations in star distribution, which is unique and is not repeated for other types of stars in our diagrams. The diagram for supergiant stars (the compiled diagram for luminosity classes I, Ia and Ib) is almost the same as the diagram for bright giants (luminosity class II).

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Calculation of Gaussian Quadrature with High Accuracy Mathematics Package

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Abstract

We are checking here the dependence of numerical integration accuracy on the quantity of integration points and the accuracy of machine representation of numbers. For this purpose, the package HAHMath is applied. This package allows one to carry out calculations with arbitrary long machine decimal numbers, presented as vectors of integers. Integrals are substituted for Gaussian sums where Hermite polynomials zeros and corresponding weights, computed by the same package are used. It is shown that the chosen case accuracy of final calculations depends on the used machine numbers' length more strictly than on the quantity of the integration points.

Keywords: *Numerical calculations – Gaussian quadrature – Hermite polynomials: zeros and weights.*

1. Introduction

While carrying out numerical computing one can encounter a need for calculation of definite integral taken from function between some limits. Undoubtedly, each case of such calculation requires individual solution, depending on the properties of the integration elements. Nevertheless, one can classify quadrature procedures starting with trapezium rule and Simpsons rule and up to highest order Newton-Cotes formulae, which can serve as appropriate numerical methods for integration of a rather wide class of functions.

On the other hand, the method of Gaussian quadrature is a more, let us say, function-depending procedure. It depends on the integrand properties and therefore the quadrature should be chosen carefully according the type of expression under the integral sign and limits of integration.

In the present paper, we intend to verify the dependence of the accuracy of substitution of the integral by the quadrature sum on the number of summation points (on the order of the polynomial, zeros of which are used) and on the number of significant digits in the machine representation of numbers. Since in the sequel we will be interested in calculating integrals of expressions that are given on an infinite

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range of argument values, while having a specific dependence appropriate for interpolation by the Hermite polynomials, we use Gaussian quadrature defined using the zeros and weights of the mentioned polynomial.

2. Gaussian quadrature

The word quadrature means numerical integration. Speaking about a quadrature one means numerical integration of definite integrals. The replacement of a definite integral by a quadrature formula is a common technique in the numerical solution of mathematical problems. There are various quadrature methods and any particular technique must be chosen based on the form of the integrand.

Any Gaussian quadrature has a purpose to obtain the best numerical estimate of an integral by picking optimal abscissas x_i for the best evaluating the function $f(x)$. The fundamental theorem of Gaussian quadrature states the optimal abscissas of the m-point Gaussian quadrature formulas are precisely the roots of orthogonal polynomial for the same interval and weighting function. Gaussian quadrature is optimal because it fits all polynomials up to degree $2m-1$ exactly.

For Gauss Quadrature Rule first we need specify an infinite, complete, orthogonal sequence of polynomials where the domain of the polynomials matches the desired integration interval. The rule is states as below

$$\int_a^b f(x)dx \approx \sum_{i=1}^{m} f(x_i)w_i \quad . \tag{1}$$

One can obtain good result producing such substitution if the function $f(x)$can be well approximated by a polynomial function within the integration range (a, b). If the integrated function can be written in the form as follows: $f(x) = g(x)w(x)$ where $g(x)$ is polynomial and $w(x)$ is determined then according to Gauss Quadrature Rule integral (1) can be calculated as follows:

$$\int_a^b f(x)dx = \int_a^b g(x)w(x)dx = \sum_{i=1}^{m} f(x_i)w_i \, , \tag{2}$$

where the quantities x_i, called zeros represent the roots of the chosen polynomial andw_i are weights for given quadrature.

The problems, we are going to study involving numerical calculations deal with integrands, which have special forms given in the infinite interval $(-\infty, +\infty)$, and one can use for their computing, so called, Gauss–Hermite quadrature. Moreover, taking into account that expressions under the integral are even functions, one can calculate the integrals in the interval $(0,+\infty)$ only. Then we conclude that one should apply the following computational scheme for our purposes:

$$\int_0^{+\infty} f(x)dx = \int_0^{+\infty} \exp(-x^2) f(x)dx = \sum_{i=0}^{m} f(x_i)w_i \quad . \tag{3}$$

Therefore, one needs to calculate, the quantities $\{x_i\}$ and $\{w_i\}$ for computing the required integrals given by (3). For this purpose, one should find zeros of Hermite polynomials of various orders. One can find can find lists of the mentioned quantities in the literature, however those lists are only for limited orders of the polynomials (see, for example, Abramowitz & Stegun 1979).

3. Hermite polynomials

Hermite polynomials form an orthogonal system and are among the most extensively studied polynomials. These polynomials arethe solutions of the following linear, second-order ordinary differential equation:

$$y'' - 2xy' + 2ny = 0 \ , \tag{4}$$

where n is a non-negative integer and y' and y'' are the first and second derivatives $y(x)$ function. It is easy to see that the polynomial of n-th order derived using the following expression:

$$H_n(x) = (-1)^n \exp(x^2) \frac{d^n}{dx^n} \exp(-x^2) \tag{5}$$

for any non-negative n is a solution for equation (4).We list below the first five Hermite polynomials

$$H_0(x) = 1,$$

$$H_1(x) = 2x,$$

$$H_2(x) = 4x^2 - 2,$$

$$H_3(x) = 8x^3 - 12x,$$

$$H_4(x) = 16x^4 - 48x^2 + 12 \ .$$

One can immediately verify that all these functions are solutions of the equation (4). These polynomials have some important properties, which makes them very useful for various fundamental and practical implementations. First, as we mentioned it above, these polynomials make up an orthogonal with the weight function e^{-x^2} and complete system on the infinite interval $(-\infty,+\infty)$.This property makes them a very useful tool for the expansion into series of some type of functions over these polynomials.

The orthogonality condition for the Hermite polynomials will have the following general form:

$$\int_{-\infty}^{\infty} \exp(-x^2) H_n(x) H_m(x) dx = \sqrt{\pi}\, 2^m m!, \text{ if } m = n \qquad (6)$$

and

$$\int_{-\infty}^{\infty} \exp(-x^2) H_m(x) H_n(x) dx = 0, \text{ if } m \neq n \ . \qquad (7)$$

These integrals showing the orthogonality condition, on the other hand, can be used for testifying the numerical integration accuracy. In one of our next papers devoted to the numerical calculations' accuracy, we are going to consider this issue in its general form. Here we will check it for a particular case only.

4. Numerical results

All numerical procedures are carried out applying the package HAHMath compiled on FORTRAN programming language. This package compiled by H. Harutyunian in 1992,allows one producing computations with many significant digits, decreasing thus accumulation of errors inevitable otherwise due to machine rounding of numbers. All numbers in this package are given as vectors consisting of single-byte integers, the sequence of which represents a number. For providing precise results of numerical computing, long type integers are used in this package. In computer science long integer means a data type, which has range greater than the standard data type integer and represented as a set of binary digits.

Each integer in the common vector storages four consecutive digits of a long number. This representation of the numbers puts its special requirements on the organization of computer calculations. In particular, one needs to perform all arithmetic operations using special separate subroutines. It makes computational programs rather complicated. On the other hand, this package creates a flexible computing environment if one needs to perform calculations with numbers of several tens or hundreds of significant digits. All subroutines are testified using calculations repeatedly. As a handy test for implementation of multiple computation, the package has been successfully used for calculation of the number π with 160 significant digits.

Using the program package HAHMath we calculated with very high accuracy the needed zeros $\{x_i\}$ and corresponding weights $\{w_i\}$ for Hermite polynomials of the required order. For this calculation, the method of progressive approximation was used. It allows one finding the polynomial roots with desired accuracy, provided, that numerical computations guarantee the required accuracy. Since the length of the used numbers is an input parameter, one always can choose it according to the requirements.

After these sets of numbers are ready, one can use them for calculation of integrals. Here we make some simple calculations for checking the dependence of the computation results on both the number of integration points (or polynomial order) and the accuracy of number representation (the quantity of significant digits in the used numbers).

If we put in the equation (6) $m = n = 0$ we will obtain

$$\int_{-\infty}^{\infty} \exp(-x^2)dx = \sqrt{\pi} \quad . \tag{8}$$

Having the numerical value of π, one can check easily how changes the substitution of integral (8) by its Gaussian quadrature the accuracy of calculations. It is obvious, that there are two factors, which determine the accuracy of the quadrature calculation accuracy. One of those factors, as we mentioned above, the order of the interpolation polynomial. And second one is the numbers' length or the quantity of digits in the representation of the used numbers. No doubts, the integrand in the relation (8) has a simple form, which suggests that in this case no need for extremely high order polynomials. However, one can assert it for sure only having implemented the numerical experiment. Hence, we carried out all the necessary calculations for checking the accuracy dependence on the parameters enumerated above.

Thus, making the following substitution of the integral in the equation (8) by a Gaussian quadrature one will obtain

$$\int_{0}^{\infty} \exp(-x^2)dx = \frac{\sqrt{\pi}}{2} \approx \sum_{i=1}^{m} w_i \exp(-x_i^2) \, . \tag{9}$$

Carrying out the corresponding calculations, we obtained a set of results for various orders of polynomials and different lengths of the used numbers. In the Table below, we show the results of computations in the form of differences between the values of π obtained by direct calculations and having all the used digits correct and using the approximate formula given by the expression (9). For this purpose, we used "long numbers" characterized by various significant digits, designed by L (10, 20, 40, 60, 80 and 100) and zeros of polynomials of order N (10, 20, 30, 100).

As one can see from the Table, the length of numbers is more essential, at least for such kind calculations, where the integrand has a simple form. The accuracy of calculations practically does not depend on the number of quadrature integration points (the order of polynomials).

Table 1. The accuracy of calculations carried out according the formula (9).

L \ N	10	20	30	100
10	1.18D-09	-1.45D-10	-3.17D-10	-2.77D-10
20	-3.26D-20	-3.95D-20	-2.75D-20	-3.60D-20
40	4.98D-40	2.91D-40	2.58D-40	6.51D-41
60	2.36D-60	-1.48D-60	2.61D-60	-4.08D-60
80	-3.16D-80	1.44D-80	6.71D-81	-1.70D-80
100	-3.80D-101	-5.55D-100	-2.31D-100	-9.64D-100

5. Conclusion

Substitution of definite integrals by Gaussian quadrature gives rather good results for the integrands having a multiplier of the type e^{-x^2} . It is important to notice that the main impact on calculations have our given accuracy for the used numbers or their length. It is easy to see that all results given in the Table 1 are of the same order in each row independently of the polynomial's order. On the contrary, the results in the columns differ from each other drastically. Therefore, one arrives at a conclusion that in these calculations the number length has a crucial significance.

Acknowledgement. The author thanks H.A.Harutynian for valuable discussions and his help in applying the programming package HAHMath.

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Cosmological Views of Anania Shirakatsi

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Abstract

Since the ancient times the usage of cosmological ideas in mythology and poetry has contributed to the formation and development of human's philosophical thought.It is believed that before the M. Mashtots'salphabet, ancient Armenians have expressed their astronomical knowledge through stone structures and rock art.In the Armenian reality, the cosmological views, the idea of the spherical shape of the Earth and information of other celestial bodies more vividly were manifested in the works of Movses Khorenatsi, David Anhaght (5th century) and Anania Shirakatsi (7th century).Anania Shirakatsi is an Armenian Astronomer, Mathematician, Philosopher, Geographer and Alchemist.The importance of his work is also noted by foreign authors and he was called 7th century Cosmologist, First Scientist of Armenia and Middival Astronomer.Shirakatsi's works are united in his comprehensive knowledge, his insight of the mind, the ability of combining and analyzing facts and his literature talent.His works have simultaneous historical, cosmic, geographical, religious, literary and mystical significance. In the present study we will show Anania Shirakatsi's cosmological ideas and observations.

Introduction

In the medieval Armenian literature, Shirakatsi was the first author who distinguished and developed natural sciences as independent sciences, thus becoming the founder of natural sciences in Armenia.The source of Shirakatsi's research was: Yeznik Koghbatsi "Yeghts Aghandots", Yeghishe "Meknutyun Araratsots", David Anhaght "Sahmank Imastutyan", Ptghomeos "Almaghest", Kosma Hindikoplevst "Kristoneakan Teghagrutyun", Barsegh Kesaratsi "Vecorya", Keghts Aristotel "Yaghags Ashkharhi", Yepipan Kipratsi "Tankagin Karer", Grigor Nyusetsi "Yaghags Kazmutyan mardoy", Yvsebios Kesartsi "Kronikon" and other works. However, Shirakatsi often criticized those authors and brought his scientific observations.Besides, in almost all his works Shirakatsi used the Bible. Especially,

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Shirakatsi'sCosmological works are of great value (see R. Abramian and B. Tumanyan, K. Ter-Davtyan and S. Arevshatyan, A. Abrahamyan). For some of his works have been dedicated to books or other works by individual authors, such as “Cosmology” (K. Ter-Davtyan, S. Arevshatyan, 1962), "Astrology" and "Heavenly phenomena" texts, "The Sun in Constellations" and "Moon Period" (A. Abrahamyan, 1960), as well as a number of works dedicated to the calendars,which are also based on astronomical knowledge such as"Lunar Vernal Equinoctial Tables", "Moon’s Special Rotund", "Moon-showing Tables" (A. Abrahamyan, 1962), "532 Years Table" (A. Abrahamyan, 1940), "Kharnakhoran" (G. Brutian, 1998),“Peoples’ Months Names” andArmenian Ancient Months and Hours Names (H. Acharyan, 1950).Shirakatsi’s main cosmological views are expressed in his "Cosmology" work (K.S. Ter-Davtyan, 1962) which is based on ancient Greek Astronomy, further transformations and his personal observations.

It should be noted that in the era of Shirakatsi Greek science has been declining,and Arabic science (in particular, highly advanced Astronomy) still had to be developed, so maintaining valuable knowledge and, in some cases, even developing it was a difficult task.The work "Cosmology" has a great literary and scientific value, The Shirakatsi wrote it with beautiful examples and figurative descriptions.It covers the following ten chapters:

1. “Mathematician Anania Shirakatsi's words to those who have promised a brief introduction”(Anania Shirakatsoy hamaroghi ar khostacealn)
2. “About Sky” (*Yaghaks Yerkni*)
3. “About Earth” (*Yaghaks Yerkri*)
4. “About Sea” (*Yaghaks Tsovu*)
5. “About Celestial Treasures” (*Yaghaks* Yerknayin Zardots)
6. “AboutMovements and Phenomena Occurring between Heaven and Earth”(Yaghaks vor i mech Yerkni yev Yerkri en sharjmunk yev tesytunk)
7. “About Milky Way” (*Yaghaks Tsir Katni*)
8. “About the Northern Stars” (*Yaghaks*Hyusisayin Asteghats)
9. “About Moon” (*Yaghaks Lusni*)
10. “About Sun” (*Yaghaks Aregaki*)

It should be noted that in the 7th century, it was still difficult to separate the Earth and the seas from the Universe, because the perception of the world was one, and everything unattainable was mysterious,including the seas and oceans,as long as geographical journeysdid not start.Moreover, any travel was limited, so many monthes was needed to travel from Armenia to Greece or Rome.That is why the "world" and, accordingly, the perception of the world was limited.

Mathematician Anania Shirakatsi's Words to Those who have Promised a Brief Introduction

“Mathematician Anania Shirakatsi's Words to those who have Promised a Brief Introduction”work was copied by Ghukas (son of David) in 971.The manuscript is a collection of historiographical materials, but some pages have not been preserved.The Shirakatsi precisely expresses his attitude towards pagan scholars and church fathers.He wants to take advantage of the "externalities that the Apostle Paul commands and rejects the sayings of the pagan scholors of the wise, who refused to recognize the existence of God as an existence, The basis of this material and existence” (A. Abrahamyan, 1940). Anyway, Shirakatsi considered it worthy to mention the observations of the ungodly and then reject them in order to show the virtue and wisdom of the great fathers. About 14 centuries ago, Shirakatsi manifested a special approach to modern scientific and literary works, when the previous work on the subject was analyzed,in order to clarify the right and wrong thoughts expressed in them.

About Sky

“About Sky”work was copied by Priest Grigor in 1342.This chapter is devoted to the essence of heaven and its discovery,which begins with a simple concept of scientific methodology.Shirakatsi noticed that for himself and for all those who are doing exact sciences,the sayings of glorious ancestors seem to be true and that everything they say can be explained in terms of words and accessible to reason.In this chapter, talking about the sky, Shirakatsi separates the upper sky and the inner heaven.In his opinion, the upper sky as the Greeks call is "*airtime*", and the Chaldeans call it "*flaming fire*" “this is an unmatched body, a simple fire, which has come from nothing and nothing has arisen from it,… it blocks all kinds of creatures inside and all the elements closely surrounding the inferior sky.And it is enough for him to expand his circle, which blocks everything from the outside,in order to show the spherical globe of its vast expanse … and under the arch, matched by its shape, it is the place where we call heaven.They say that it is air and water, not frozen or condensed, but real water, in liquid form, like a heavenly one.Like after the rain, air bubbles come out of the air,which are round shaped under the air and moisture of the rain, such as a dome,so is the heavenly institution, which is surrounded by a circular shape as a result of air blowing (A. Abrahamyan, 1940): Shirakatsi’s words speak out both of his admiration for heaven,as a phenomenon above everything else,and both his knowledge and comparative analytic mind.

About Earth

Shirakatsi's "About Earth" chapter starts with more representation of more common ideas.Some pagan "good" philosophers say that Earth looks like a tray.And some of them say that it's spherical or that it is a six angled cube that has been raised and placed in the center of the sky by the force of the wind, pushing the Earth down. Shirakatsiis for the idea that the Earth is spherical one, which proves his ability to correctly orientate in many facts.

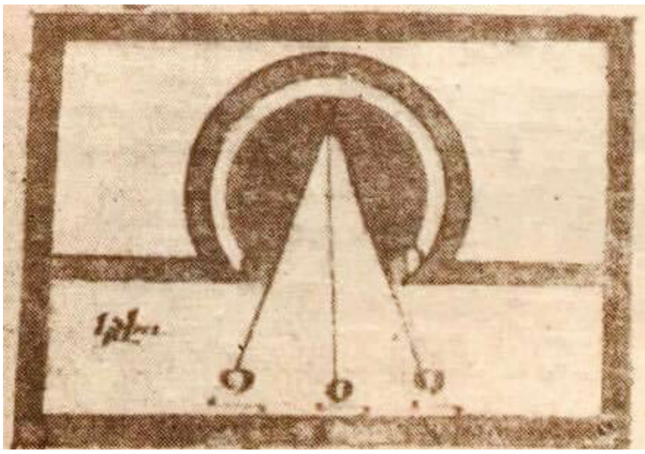

Figure 1. Earth centered Universe by Anania Shirakatsi

He thinks that the Earth is like an egg, and is colored spherical situated in the middle, the protein around it, and the peel is surrounded by four sides,likely the Earth is right in the middle, the air around it, and the sky is surrounded by all four sides."Such an idea was consistent with the Indo-European, Egyptian, and Chinese mythologies about the cosmic myth about the World Egg" (V. Toporov, 1992).Shirakatsi comes from the idea of the earth's spheres as well as explaining the formation of night and day.

To his mind the daytime emerges from the Sun and its light, and the night comes out of the shadow, which falls from the mass of the Earth. According to Shirakatsi, when the Earth's shadow falls on half the globe, we are in the night, and in the opposite half is the day.

About Sea

In the chapter "About Sea", Shirakatsi speaks about the outer sea that surrounds the Earth and about the seas and lakes on the Earth. On these issues Shirakatsi cites "evil" and "good" philosophers' opinions.Shirakatsi agrees with "good" philosophers, considering that the seas are on the earth and that “there is no other sea outside the country” (A. Abrahamyan, 1940).Shirakatsi tries to explain the reason for being present at the Earth's Center of the Universe for a rational reason, rejecting the idea of being placed on the water.He claims that the Earth maintains its position as a result of a rapid cycling of heavenly zones and two opposing forces,Earth's gravity and wind forces that balance each other.The heaviness of the Earth stretches it down, and the strength of the winds upward, and so it is balanced, retains its stable position in the center of the Universe.He asserts that these seas are divided by borders, but they form a whole, they are connected to each other, though they are far from the outer boundaries.In this section, Shirakatsi also mentions about the sea water balance and the saltiness and bitterness of the waters.According to Shirakatsi, the cause of water intoxication and bitterness is evaporation caused by the solar heat. “The heat of the sun reduces the excess of water and leads to the sweetness of the water” (A. Abrahamyan, 1940):Here, Shirakatsi’s united worldview is manifested, and finding parallels between the sea and the Sun, he also substantiates the involvement of the work of the seas in his "Cosmology".

About Celestial Treasures

“About Celestial Treasures” section Shirakatsi speaks about astrology in details, considering it "foolishness" and "misguidance".Shirakatsi considers meaningless work to tell about Haldians observations about celestial bodies. Anyway, in order to inform his reader, Shirakatsi narrates on several pages the Haldian art of astronomical constellations and planets using astrology. He notes that astronomical science has begun and developed by the Chaldeans, and later on by the Egyptians and Greeks.Shirakatsi believes that in parallel with it, the Chaldeans have also created astronomy, which was gradually spreaded to other countries.The Chaldeans referred to heavenly bodies and the constellations to divine attributes and to the fate of the human being, to the duration of his life, and to his actions during his lifetime.It should be noted that the denial of astrology is one of the most crucial steps by Shirakatsi.Until the 17th and 18th centuries, some astronomers continued to believe in the influence of stars on destiny, and asrology in the form of horoscopes are still acceptable by many.

About Movements and Phenomena Occurring between Heaven and Earth

In the chapter "About Movements and Phenomena Occurring between Heaven and Earth", Shirakatsi thoroughly describes the essence of wind, cloud, rain, hail, snow, lightning, thunder, rainbow and other atmospheric phenomena.Shirakatsi believed that atmospheric phenomena were happening at the same time, but the eye sees only the scene of the phenomenon, and the ear will hear it only after a while until the voice reaches us from the scene.In fact, Shirakatsi was well aware that the speed of light propagation was much greater than the speed of the sound. "Scientists of the time did not know the actual speed of light or sound, they were determined later in the 18th-19th centuries (L. Nazaryan, 2003): Again, talking about these heavenly phenomena, Shirakatsi manifests a common perception of the world and tries to find a connection between all phenomena.

About Milky Way

In the chapter "About Milky Way" Shirakatsi compares the Myths about the Milky Way to the myths of various peoples without agreeing with none of them.Shirakatsi also mentions an ancient Armenian tradition, according to which Vahagn stole the royal stump of Assyrian King Barsham on his way to Armenia and drowned in the sky and now it shines.For this reason, in the Middle Ages, Milky Way in Armenian was called "The Way of Stump Stoler". Criticizing myths, Shirakatsi gives a scientific explanation of the Milky Way."Throw all this and do not believe in such things as they are many large and small stars that are accumulated in a blend of light" (A. Abrahamyan, 1940). "Sometimes, the idea of the Milky Way starry character is attributed to Shirakatsi, considering that he had understood a thousand years before the creation of the telescope, that this zone actually consists of many far awaystars (H. Harutyunian, A. Mickaelian, 2014). It should be noted that the Milky Way stellar composition was revealed only in the 17th century by Galileo Galilei.

About the Northern Stars

Unlike the other chapters, In the chapter "About the Northern Stars" Shirakatsi does not refer to "good" philosophers and does not criticize "evil" philosophers. Instead, he briefly presents his ideas and observations about the Northern Stars.He assures us that the stars that are called the heavenly pole are neither rise nor set into the moon, but are traveling with a man, whether on the land or on the sea.He is referring to the Polar Star and some of the weaker stars around it that are constantly visible in the sky. Shirakatsi considers the stars as gift from God, as it directs people to sailing.This is reflected in Shirakatsi's broad way of thinking and travel experience, as being Armenian scientist whose country does not have a seafront, speaks about remote navigation, which, in fact, had not yet expanded.

About Moon

In the chapter of the "About Moon" Shirakatsi mentions that the Moon is a thick, hard and spherical body that does not have its own light and is illuminated by the sunlight. Shirakatsi also mentions the occurrence of the Moon's sphases.According to him, the Moon does not always have the same shape, once it grows, once it becomes thick one, while they are in the same direction during the circle, at that time the Sun illuminates the upper part of the Moon, and the bottom remains mysterious.Then the Moon leaves the Sun and we see its lighted part. In this chapter, Shirakatsi also interprets the eclipses of the Sun and the Moon. He writes that the Moon is the cause of the solar eclipse, as the Sun, covers the light coming to us.Shirakatsi also thinks that sea fluxes and refinements are also tied to Lunar phases. The Shirakatsi conceptions about the Moon and its influence essentially coincide with modern ideas.

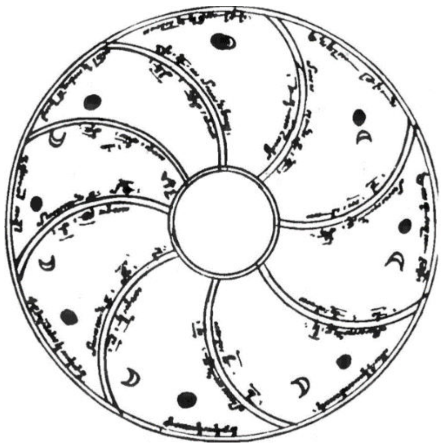

Figure 2. Phases of the Moon

About Sun

The "About Sun" chapter was copied in 1687 by Martiros writer. In this chapter, Shirakatsi adheres to ancient philosophers, recognizes that the Sun is a solid, spherical body, its warmth and lighting gets from the *Arpi* (Sun light) and drives to the atmosphere by which it illuminates and warms the Earth.Shirakatsi notes that the Sun, Moon, and many stars move from West to East, but those celestial bodies, wherever they are, are shown to people with the same size. And in the sky they are small, as they are far away and not small in size.According to Shirakatsi, the Sun exceeds its size by the Moon and the Earth.Here Shirakatsi also mentions the occurrence of the seasons and the night and day shifts.He links the seasons of the year with the visible movement of the Sun in heaven, not the axis of the Earth.

Conclusion

In the field of cosmology, these problems were perhaps the most important thing for a seventh century educated reader or for students who were keen on learning. In the current stage development of Astronomy and Astrophysics most of these fields remain modern one, especially for the public at large and from the point of effects of heavenly bodies on human kind (H. Harutyunian, A. Mickaelian, 2014).By summarizing Shirakatsi's cosmological views, B. Tumanian in his "History of Armenian Astronomy" work presents the following to conclusions:

1. His adopted idea of Earth-centered system, position of the Sun, and the presence of the fire arch is unique and differs from well-known earth-centered systems.
2. Shirakatsi with great diligence studied the works of his predecessors and scholars of his time, he approached them critically, combined with his own studies and gave probable and natural conclusions.

Shirakatsi's works are united in his comprehensive knowledge, his insight of the mind, the ability of combining and analyzing facts and his literature talent.His works have simultaneous historical, cosmic, geographical, religious, literary and mystical significance.

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Rock Carvings of Armenia

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Rock-art in Armenia began in the Neolithic period, reaching its peak during the Bronze Age. Rock-carvings have great cognitive value as a cultural source. Their role is important for revealing the historical realities of the Armenian Highland in VII-I millennium BC, to determine the origins of the Armenian people and demographic processes.

Their great number, themes, style and variety testify the sacralized attitude of our ancestors to the rock-art sphere.

A group of petroglyphs in Geghama Mountains

The petroglyphs of Armenia, by their great number, variety of styles and rich content occupy a unique place in our cultural heritage in the Ancient World.

There are not many petroglyphs adjacent to the Armenian Highland regions, while in the Highland their high concentration is observed, as well as thematic and typological diversity.

The main part of the ancient etched petroglyphs is located at altitudes up to

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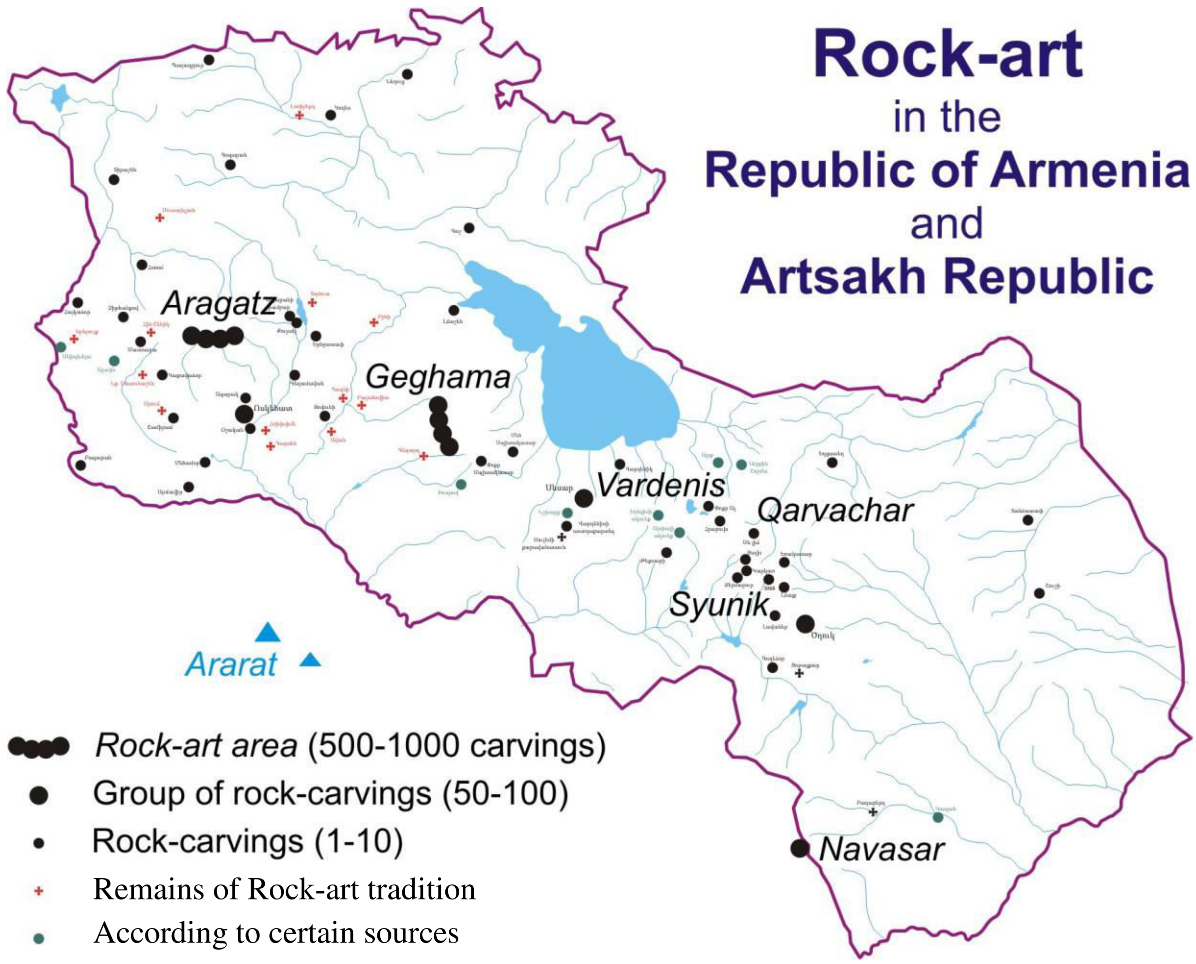
3300 m a.s.l., but they are also preserved in the foothills and valleys. The ancient inhabitants of Armenia have created huge galleries, mountain sanctuaries, consisting of tens of thousands drawings. There are also found vishaps (stone-dragons), summer open-air sites, caves, huge cromlechs, etc nearby the petroglyphs. Such a variety of monuments indicates that the petroglyphs are not isolated phenomena of high mountains, but part of the historical and cultural environment, formed as a result of the human vigorous activity.

Vishaps /dragon-steles/ on Aragats and Geghama mountains

Location. On the territory of the Republic of Armenia petroglyphs are found in Aragatzotn (Agarak, the SE slopes of Aragats, *Aruch*, Geghamavan, Ernjatap, Kaqavadzor, Aragatsotn, Mastara, Shamiram, *Old Shenik*, Voskehat, *Tghmut*, Quchak, Oshakan), in Armavir (Metsamor, Armavir, *St. Gayane, St. Hripsime*,), in Gegharquniq (Lchashen, Sevsar, Vardenik, Vardenyats pass, Vardenis Ridge), in Yerevan (*Avan*), in Lori (Loriberd, Koges, Neghuts), in Kotayq (*Balahovit, Bjni*, Geghama Ridge, Geghard, Zovuni, *Ptghnavanq*), in Shirak (*Yereruyq*, Haykadzor, Horom, Dzithanqov), in Syunik (Zoratsqar, Tzghuk-Ukhtasar, Jermajur), in Vayotsdzor (Teqsar, nearby of the headwaters of rivers Arpa and Yeghegis, Sartsali, in Tavush (Gosh).

In the Artsakh Republic petroglyphs are on the outskirts of Shushi and near the village of Tandzatap, in Karvachar area – in Eghtsategh, on the slopes of the mountains Erakatar, Harsnakar, Ishkhanasar, and Lulpar, on the banks of lakes Tsalq, Sev, and Al.

Petroglyphs have been found to the east from Javakhk in the area of Tsalka, in Nakhichevan - near ancient settlements Astapat, St. Mariam, Paraka and on the west slopes of Navasar. The oldest rock-carvings are known on the west shore of the Caspian Sea, on the Apsheron peninsula and in Gobustan area, which at certain stages of history were part of the Great Armenia, or were in the sphere of its influence.



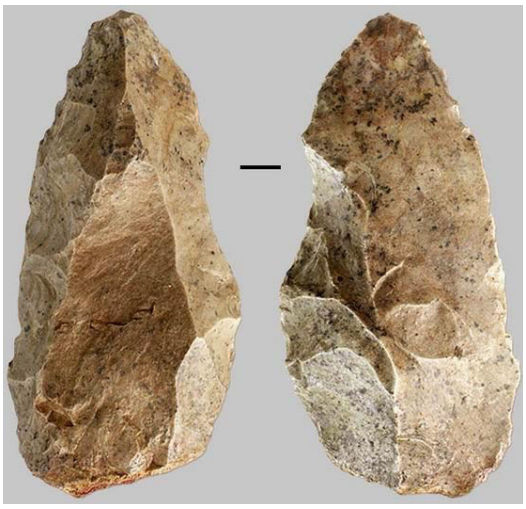
In Western Armenia many Rock-art sites are known: nearby of headwaters of Aratsani river, Azat, **Zarishat** (in Vanand), Gomshut (in Kaghzvan), *Tsolakert* on the northern slope of Mt. Ararat-Masis, in the east of Vaspurakan - on the right bank of the Araks river (Araksberan, Vanestan, Songun) and in the vicinity of the river Tghmut (**Bastam**), the western shore of Kaputan Lake (mountain **Zambil**), near Van Lake - **Andzav**, **Artamet**, Buth, **Gaytis, Haykaberd**, *Marvana*, Nar, the **citadel of Van**, Pakan, **Ororan**. A huge cluster of petroglyphs has been found in Shatakh mountains - in Tirishin, and in Jogha Mountains - Gavarak, Sat, Sev Ler. They are also in Alki (in Korduq), in Armenian Mesopotamia, and in the west of the Armenian Highland (Adyaman, Aryutsablur, **Bagarich**, **Partizak**, Malatya, *Portablur*, Kharberd), and in the SE of Cilicia (Latakia, Kassab).[1]

[1] Shown in italic are sites of carvings on flat stones, as well as antique and medieval remains of rock art tradition, in bold - huge, deeply carved signs. Images in Loriberd, Buth, Aryutzablur, Antalya and Kortun are colour paintings.

Rock-art sites of the Armenian Highland

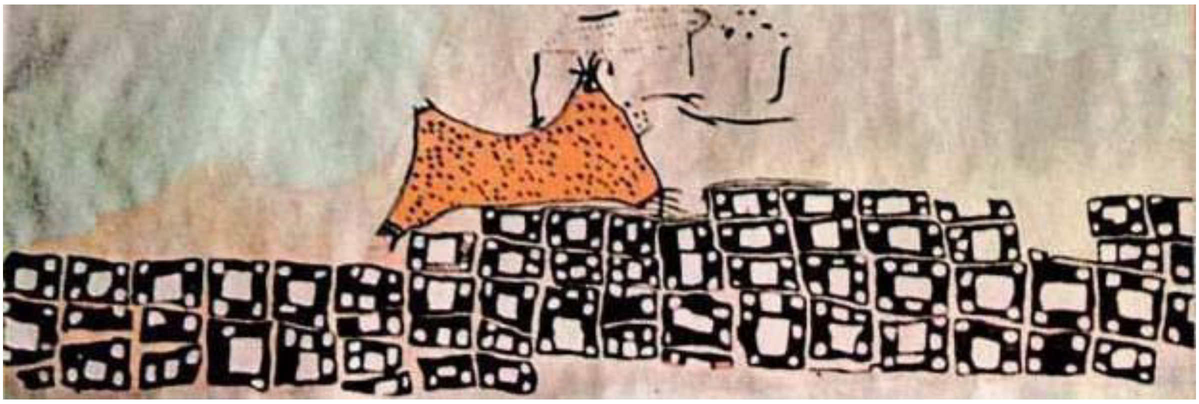
To the west of Great Armenia ancient rock carvings are known in the vicinity of Attalea (Antalya), in the mountains of the Cilician Taurus (Kortun cave), in Nigde, in SE - in Iran (Kangavar, Hamadan, Lor, Mirmirlas, Teymere, Golpaegan). To NE there are early medieval drawings - in Dagestan (Buynaksk, Kapchugay, Chirkata), in Georgia (Mghvimevi - near Chiaturi), in Abkhazia (caves Agtsa and Guarap), and in the slopes of Caucasus Mountains (Gundelen, Urushten).

Types and technique. The vast majority of ancient petroglyphs of Armenia are carved on unhewn surfaces of hard volcanic stones - boulders and splitted outcrops. Dimensions of drawings vary from 10 cm to 4 m, with depth of 1-20 mm and furrow width of 5-30 mm. There are both stand-alone and grouped engravings.

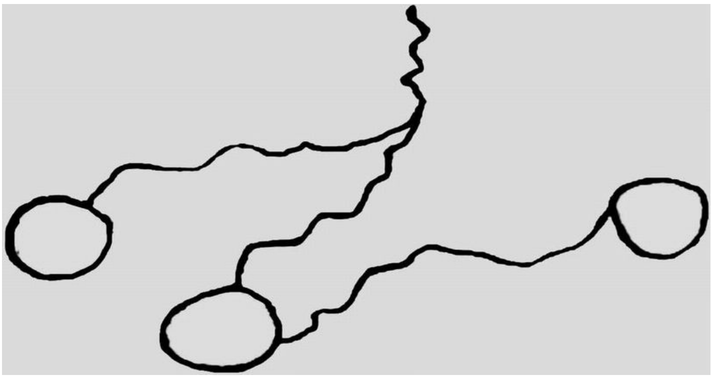


The petroglyphs are carved out on dark- shiny and sunburned surfaces of andesite- basalt rocks by stone-cutters, later substituted by metal ones. The rocks are extremely hard. During millenia the influence of oxidation and erosion processes made on surfaces of stones a thin, shiny sunburned layer.

Content. Almost all spheres of human life are reflected in Rock Art. They convey valuable information about the environment, life and traditions, crafts and skills, arts and knowledge of ancient people, about their spiritual world – mythology and world perceptions. Rich subject of Armenian Rock Art is divided into 30 thematic groups: static elements of environment (mountain, volcano, river, lake, spring), natural phenomena (lightning, clouds, rain, rainbow), the heavenly luminaries (Sun, Moon, star, stellar group, constellation), Earth, rare celestial phenomena (eclipse, meteor, comet).



Araler, Hatis, and Aragats mountains.



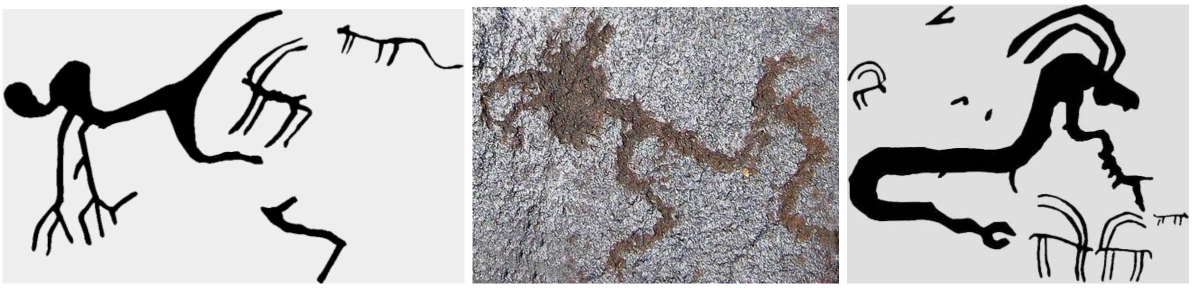
Volcano. Lakes and rivers in Navasar

Sun, Moon, a star, a comet, Globe

The majority of images are those of flora and fauna (bezoar, mouflon, deer, gazelle, horse, bull, tour, bison, wild boar, bear, leopard, cheetah, lion, wolf, dog, fox, snake, birds),

Goats, bull, man with deer, gazelle, birds, leopard, bear, fox, snake

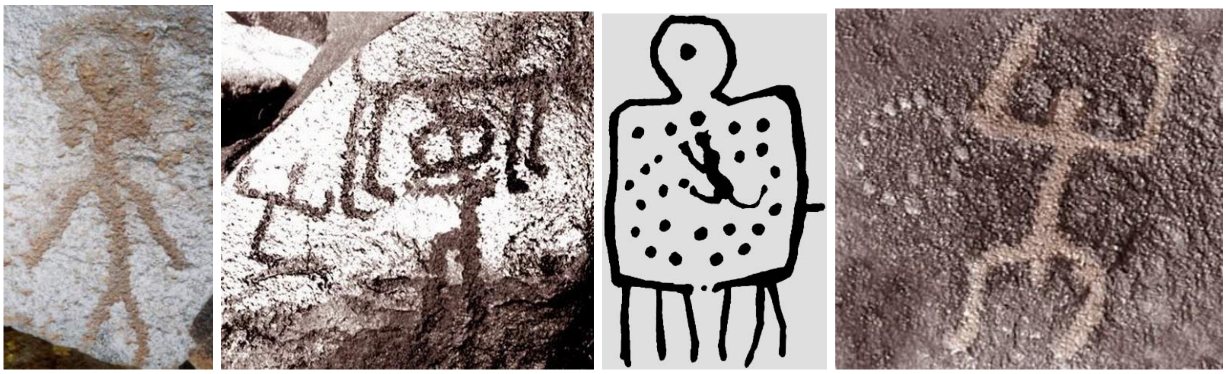
A group of wild animals in Geghama mountains as well as mythical creatures, vishaps /dragon/



Vishaps /dragons/

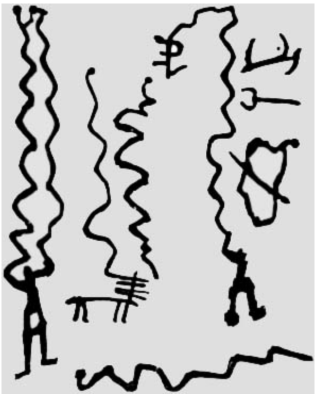
Most commonly life and activities of man are reflected (hunting, fighting, animal husbandry, domestication, land cultivating, plowing),

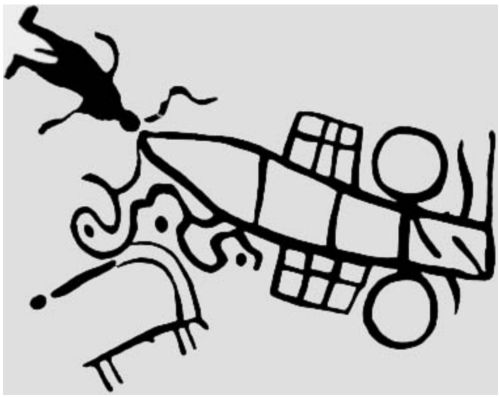
ceremonial life and rituals (the worship of motherhood, ancestors, deities, heroes, twins, good spirits, fertility, and time).



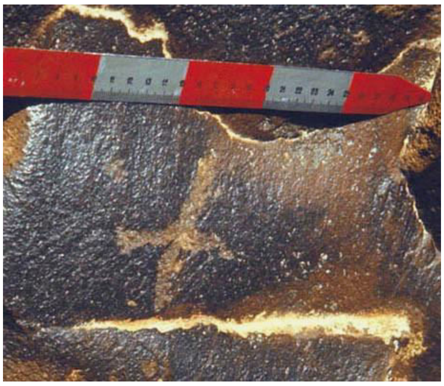
Many images depict men in scenes of sports and competing, playing games and dancing, weapons,

tools and accessories (bow and arrow quiver, shield, spear, mace, baton, hook, lasso, a plow, a network, a ladder), vehicles and transportation means (cart, chariot, boat, skiing, sleigh).





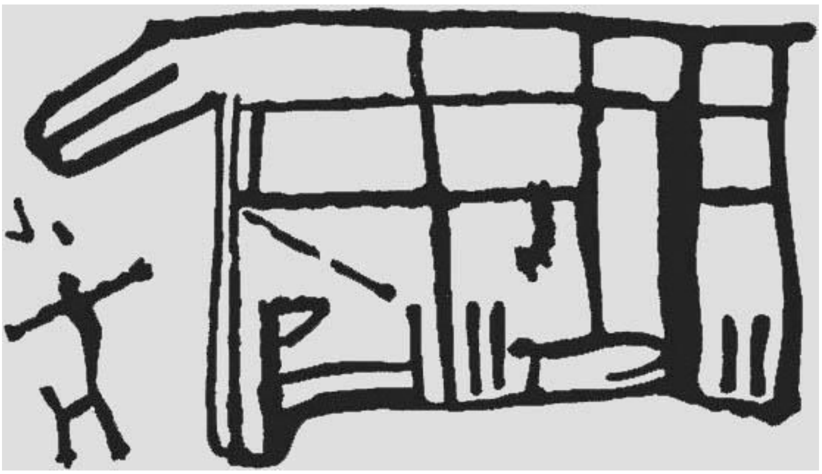
Ancient scientific thought is expressed in sky maps, calendars, compasses, and in the plans of surroundings and irrigation systems,



A compasse

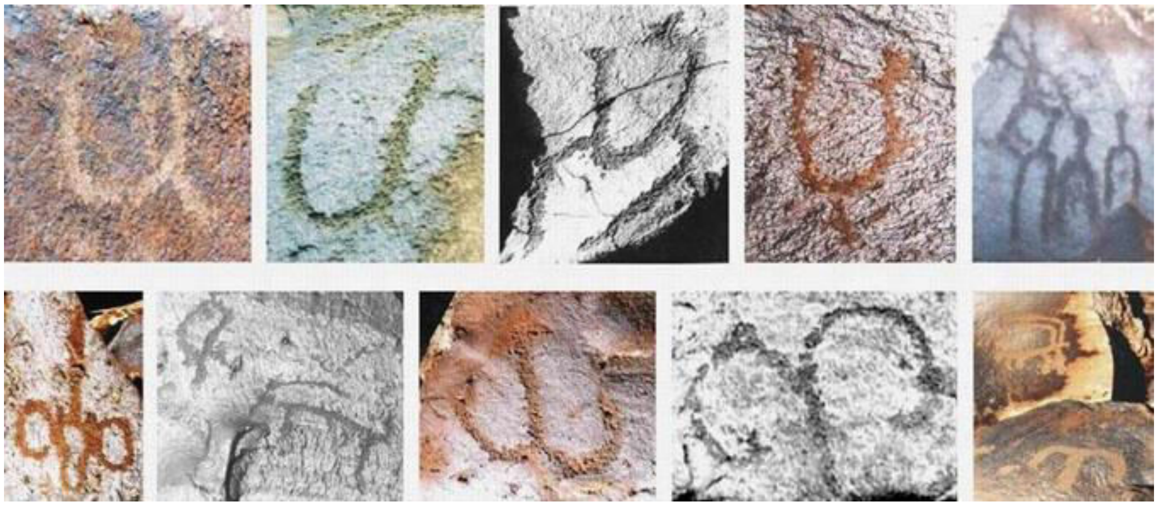
A plan of irrigation system

in the drawings of buildings (settlement, shelter).



Some rock-carvings had an applied astronomical significance: solar (30/31-day, 12-month, 354/365-day annual) and 7, 14 and 28/29-day lunar calendars, sunrise/sunset and Earth poles' markers.

There is a variety of patterns, symbols, including signs, similar to the letters of the Armenian and other ancient alphabets.



Some signs almost in the same shape and meaning were used up to medieval times in Armenian ideogram system. One can see many sketches, hyperbolic, schematic, precise and unfinished images, as well as examples of complex projection and perspective, palimpsest and portrait.

Most of those figures are impressive in their realism and expressiveness, dynamics and tension of pose and action.

Some of the above mentioned thematic groups – star charts, letterlike signs, dragons, calendars are either absent in other parts of the world or rarely met. Armenian petroglyphs differ from the others by one more very important and significant aspect: violent scenes are completely absent among them, apparently as a result of the taboo on such images.

Research methodology. This unique type of informatic source is reliable only in the case of considering the petroglyphs together, study them comprehensively and systematically, i.e. to find all the pictures, fix them by technical means (photography, video, copying, aerial photography, accurate GPS mapping, and 3D recording).

Rock Art must be reviewed in an historical-archaeological culture context. Attaining this aim is possible only through a **classification**, which takes into account the influence of almost all known natural and human factors, beginning from the formation of rock-fragments through to engraving and up to our days. Classification can be done through nearly 350 parameters and properties, grouped in seven categories: **monument**, **stone**, which carries picture, engraved **surface**, **drawing**, **furrows** and **lines**, **surroundings** of monument, **groupness**.

Thanks to such a theoretical and practical classification it will be possible to reveal the meaning, role and function of each rock-carving, each group of rock-images, and by determining **Rock-art Tradition** and **Rock-art Culture**, finally of Rock-art in general. The classification of available material is a prerequisite for the development of this branch of science.

Dating. Commonly scientists have used comparative biological, geological, archaeological methods and complex studies for age determination in general. In case of engraved images their precise dating is extremely difficult, since it is impossible to apply traditional well-known methods of natural sciences (radiocarbon dating, dendrochronology, pigment, spectral, palaeomagnetic, pollen, ultrasonic, collagen analyses, etc.). The achievements of contemporary Rock-art investigations have not managed to develop a precise dating of rock-carving yet.

Consequently, the only methods are relative-comparatives, based on the analysis of content, style and technique of drawing with other archaeological monuments: nearby structures (settlement, burial place) and artifacts found nearby (tools, weapons, ornaments, pattern, and painting on ceramics). These historical-cultural comparisons give too approximate evaluations and indicate the age with accuracy up to 1-2 thousand years, and then indirectly.

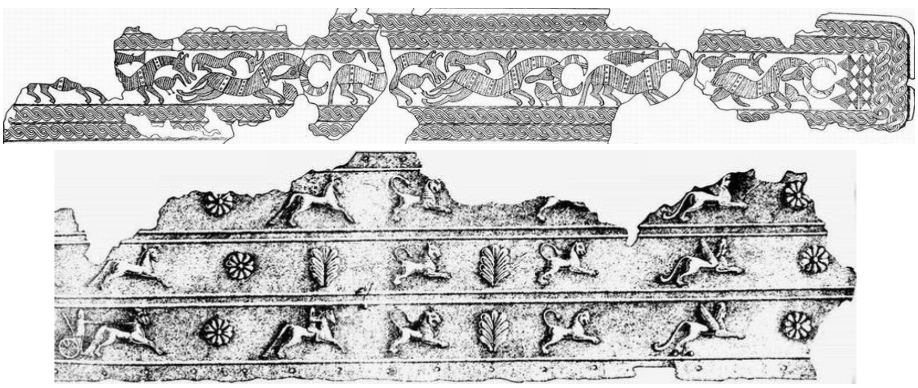
Thus, it is admitted that the era of our ancestors' rock-carving activity has lasted from VII up to the I millennium BC.

For solving the problem of dating the complex materiological, traceological, ethnographical, cosmological studies and, in general, a variety of combined approaches are important. For absolute dating of carved images most reliable are the astronomical methods.

To make it easier for orientation in the dark sky, about 5000 years ago man folded from the bright stars sustainable and memorable images - constellations. The description of constellations comes from the Alexandrian poet Arattes (315-240 BC), written upon Eudoxes' work (408–355 BC)[22]. Arattes speaks about deep and unknown antiquity of the origins of constellations.

In 1910, the historian of astronomy W. Olcott, summing up the assumptions of the archaeologist Ed. Maunder, astronomers K. Swartz, C. Flammarion and A. Berry, came to the conclusion that the Zodiac constellations were formed and got their names on the latitudes of 36-42°, between the Caspian and Aegean Seas, by people lived in the Euphrates valley and in the vicinity of Ararat Mountain, in 30-28 ce. BC[33].

These conclusions scientists have made theoretically, by examining astro-geographical (with which latitude and in what period of the past were seen those constellations), zoo-geographical (on areas of residence of the animal represented in the Zodiac) and general archaeological data. They could even not know about the cosmological perceptions and their material realization in form of artifacts (astronomical constructions, observatories, belt-calendars, shield-calendars, and especially the astronomical rock-drawings) in Armenia.

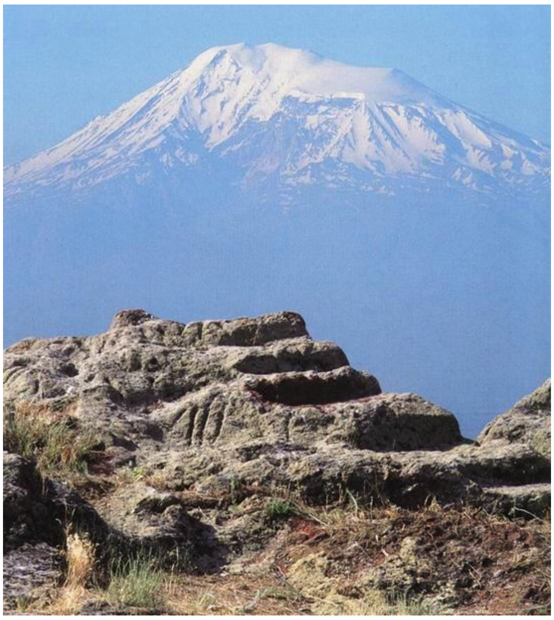


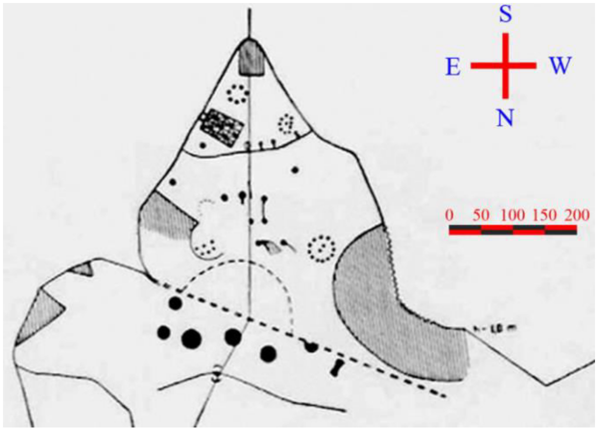
Bronze belt-calendars from Lchashen and Metsamor (III millennium BC)

[2] Житомирский С. В., Итальянская Е.Г, Астрономия. Энциклопедия, 2013, с. 77.

[3] Mounder Ed., Astronomy, Without a Telescope, London & New York, 1904; Swartz K., 1809, Flammarion C., Histoire du ciel, Paris, 1873; Flammarion C., Astronomie populaire, Paris, 1880; Berry A., A Short History of Astronomy, London, 1898, p. 3, 12-14; Olcott W., Star Lore of All Ages, New York, 1911, pp. 7-8.

The European authors' analytical conclusions are corroborated by material discovered during the last 35 years – engraved star-groups, calendars, maps, astronomical centers (**Metsamor, Vardenyats, Sevsar, Zoratsqar, Portablur**, etc.), findings in the archaeological sites (**Astghaberd, Koghes, Agarak**, etc.). It is obvious that those who first divided the sky into constellations were prehistoric inhabitants of the Armenian Highland.





Metsamor (III millennium BC)

Zoratsqar in Syunik (VI-V millennia BC)

Portablur (Umbilical hill) (X-VIII millennia BC)

About Armenia as a cradle of ancient astronomy, witness also some new archaeological discoveries.

In 1964, architect S. Petrosyan found at the top of the Vardenyats pass (2410 m), a dozen large stone slabs engraved with rings. Being on the edge of the ancient caravan route (branch of the Silk Road), protected by cyclopean fortresses and connecting Sevan Lake Basin and Arpa River valley, they very likely have had ritual and orientation significance serving as a guide. In 1969, the Armenian historian of astronomy B. Tumanyan identified those images with Zodiac constellations of Leo, Sagittarius and Scorpio. The stars are represented by dots and circles, accordingly to their brightness[4].


In 1995 was developed an astronomical method of their absolute dating.[5] It is a common knowledge from astronomy that all the stars have their proper movements. The movements are too slow and the derivations too small in order to be noticed by man during a lifetime, but perceptible enough to shift noticeably during millennia. Thus, engraved stellar configurations, though different from their current-day arrangement, remain recognizable. The method is based on the comparison of the engraved configuration of a certain constellation with its present view, and the assumption that the image was made with enough precision, i.e. was similar to the shape of that constellation at the moment of engraving. By reconstructing the shape and position of the constellation in the past and comparing them with the view of the rock-carving, **the precise time it was carved can be ascertained**, i.e. the **absolute age.** Thus, the age of the above mentioned rock-carving with images of Zodiac constellations of Leo, Sagittarius and Scorpio is determined as 27-25 centuries BC.

In 1965, on the North slope of mt. Sevsar of Vardenis Ridge at a distance of 9

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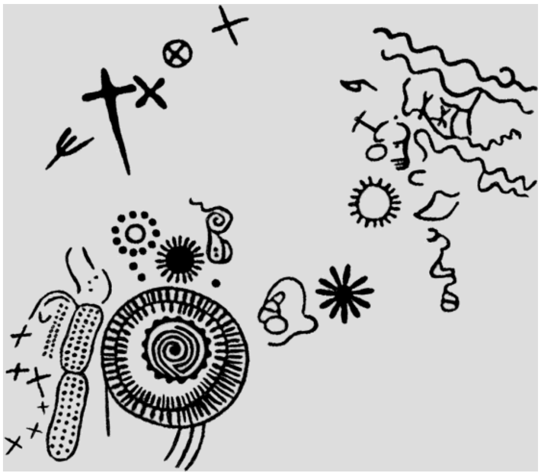
[4] Թումանյան Բ.Ե., Աստղագիտական բնույթի ժայռապատկերներ.- Գիտություն և տեխնիկա, 1969, №3, էջ 7-9:

[5] Tokhatyan K.S., The Chronology of Rock-Carvings with Cosmological Meaning from the Geghamian Range.- Theses of Reports 2nd International Congress of Rupestrian Archaeology, Valcamonica, Italy, 1997.

km from these astronomical maps, at an altitude of 2650 m S. Petrosyan found a great complex of carvings with astronomical content - 20 pictured rock-pieces within an area of 50 by 20 m.

B. Tumanyan interpreted the image on the huge main stone as a result of observations of a rare celestial phenomenon - a large meteor. He concluded that the big round image represents a bright bolide and the adjoining pictures are constellations and the Milky Way branche. So, this is a stellar map, which shows a sector of the Sky from where the bolide descended[6].



In 2000 the author expressed an opinion that **Sevsar** could give opportunity for its dating. Supposing that the three lines on the right part of the image show the direction of the bolide's flight, he pointed to notice the 30-meter diameter and 5 m deep crater at the foothill of mt. Azhdahak (3597 m) and proved that it was the result of the meteorite's falling.

When the meteorite (or its fragments) and the traces of its impact are found in the crater, the time of the collision (formation of crater) may be scientifically defined. Respectively, this will afford the opportunity to more precisely define the

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[6] Туманян Б., Астрономические наскальные рисунки Армении.- 1963, №3, с. 107-108.

absolute age of the Sevsar astronomical complex, dating back supposedly to II-I millennia BC. These two astronomical methods make possible the absolute dating of about 35 rock-images.

During the following decades ancient observatories were discovered dated III-II millennia BC: Metsamor[7], Zoratsqar[8], Koghes, Agarak, Portablur. In Basen field, at village Tandzut there is a huge structure called Sharvan Qarer. On the north shore of Van Lake, at village Lezq huge rows of stones are preserved, with possible calendaric meaning. Also the bronze calendars of kings and priests of the Van Kingdom are preserved.

Koghes in Lori

Agarak in Aragatsotn

Past references to Rock Art. Father of Armenian historiography Movses Khorenatsi (V c.) knew about rock images in Armenia. He retained in the form of a mythical narrative two striking evidences of rock-art. In connection with the rock-carvings and iconography by epic hero and demiurge Torq Angegh the historian writes: *They sang that he took in his fist hard stones, ... crunch them into large and small pieces at will, polish them with his nails, and form them into tablet shapes, and likewise with his nails inscribe eagles and other such designs on them.*[9] And in connection with creation of the alphabet by Mesrop Mashtots (V c.), the historian writes: *And he sees no sleep the night vision and reality, but in his heart beating opened eyes of the soul right hand writing on the stone Ա, Ե, Է, Ի, Ո, Ւ. Stone just like snow, retains traces of faces.*[10]

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[7] See in the book on Metsamor by Khanzadyan E., Mkrtchyan K.H., Parsamyan E.S.: Խանզադյան Է.Վ., Մկրտչյան Կ.Հ., Պարսամյան Է.Ս., Մեծամոր, Եր., 1973

[8] Парсамян Э.С., О возможном астрономическом назначении коолец Ангелакота.- Сообщения Бюраканской обсерватории, 1985, 57, с. 101-103, Геруни П.М., Доисторическая каменная обсерватория Карахундж-Карениш.- Доклады АН, 1998, 4, с. 307-328

[9] Մովսիսի Խորենացւոյ Պատմութիւն Հայոց, աշխ. Մ. Աբեղեան և Ս. Յարութիւնեան, Տփղիս, 1913 (Եր., 1991), Բ գիրք, Ը, էջ 115:

[10] Մովսիսի Խորենացւոյ Պատմութիւն Հայոց, Գ գիրք, ԾԳ, էջ 327: Almost the same tells Ghazar Parpetsi (Ղազար Փարպեցի, Պատմութիւն Հայոց, Թուղթ առ Վահան Մամիկոնյան, քնն. բնագիրը Գալուստ Տեր- Մկրտչյանի և Ստ. Մալխասյանցի, Եր., 1982, Ժ, էջ 34): See also Գարագաշեան Ա.Մ., Քննական պատմութիւն հայոց, մասն Գ, Թիֆլիս, 1895, էջ 191-3

Lezq (II millennium BC)

Bronze shields of the kings of the Van Kingdom

More direct is Armenian philosopher, mathematician and astronomer Anania Shirakatsi's information: *the receptors of our ancestors were more sensitive than ours, due to which they could **notice** not only the movement of the Sun but also inscribe, i.e. **carve** and **recognize** the movements of all the other luminaries and stars.*[11]

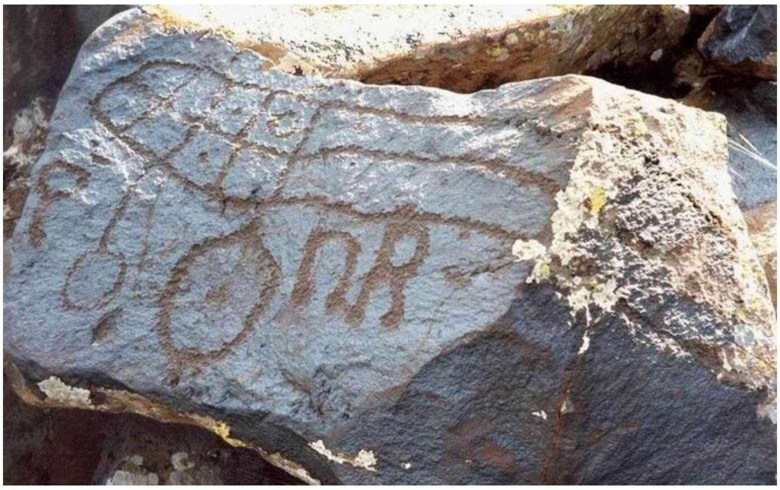
This fragment saved by the coryphaeus of Armenian science, is the earliest in

[11] Անանիա Շիրակացի, Տիեզերագիտութիւն և տոմար, աշխ.՝ Ա.. Աբրահամյանի, Եր., 1940, ԾԹ, էջ 83-84.

the world written evidence about the existence and antiquity of rock-drawings, because the word "carve" in Armenian also means *inscript, make sculpture*.

It is very important that Shirakatsi mentions this sequence of studying phases: *carve* and *recognize*, i.e. first the **noticed** positions of heavenly bodies had to be **recorded, fixed** (collecting and accumulating the knowledge), and only after that they had to be **researched and recognized** (understanding the rules of luminaries' movements). It must be taken into account that astronomical processes are very slow, and man cannot notice and remember the considerable displacements of stars during his lifetime. Therefore, periodical recordings were needed: every day, every week, or every year and so on.

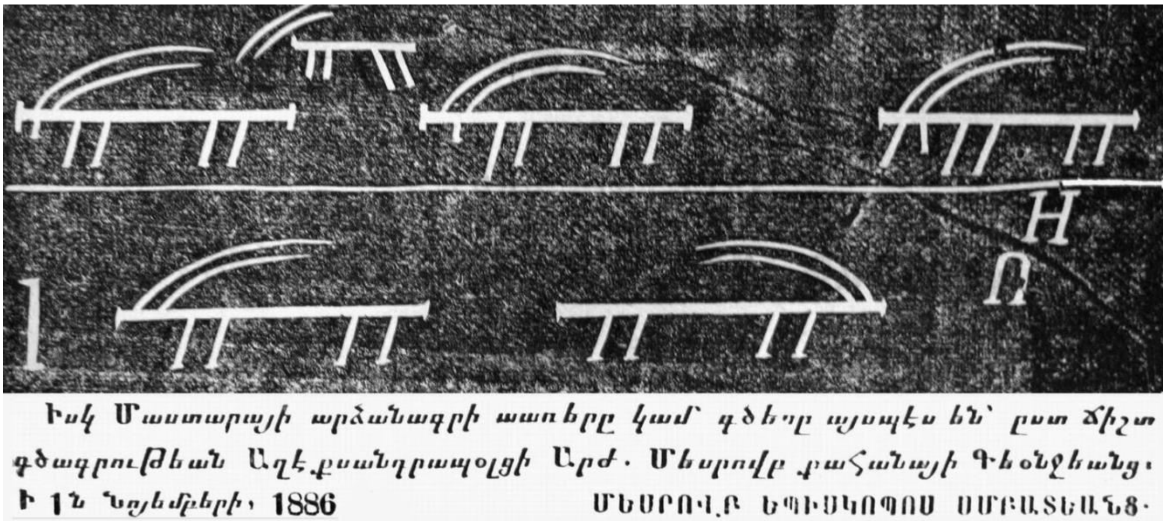
Thus, Shirakatsi knew that in past times the observational data on the movement of the heavenly luminaries used to be recorded on stones (as it was the best material to fix and preserve the information). Moreover, his information is witness to the existence of **astronomical** rock-carvings. A striking example of this is the petroglyph in Geghama mountains, at the foot of mt. Astghaberd, at an altitude of 2920 m. The rock is situated on the top of the dominating hill, it has 1 m length and is firmly fixed among the other stones. The image looks to the North, so that the observer sees both drawing and the southern part of the sky, the most convenient and effective point for astronomical observations.



The author suggested it as a table of astronomical records, which shows the visibility of two certain celestial bodies being observed, perhaps planets, stars or constellations. Such an imaging makes it possible to compare the relative movements of luminaries.

Our ancient ancestor, an astronomer of his time, in this manner could accumulate information about the position and visibility of luminaries, and only then, with their help, made conclusions about their movements. This is significant as the most ancient bibliographical evidence about rock art in general. And this may be considered as the earliest evidence of antiquity and trustworthiness, reliability of the rock-carvings with astronomical content. Thus, the above mentioned citation of Shirakatsi and this petroglyph are witness to the origins of cosmological ideas in the Armenian Highland.[12]

Research history. Petroglyphs were first published and interpreted in Armenian scientific periodicals - in journal "Ararat", 1886, 1893.



At the beginning of the 20th century M. Ter-Movsesian, A. Kalantar, Gr. Ghapantsyan investigated hundreds of petroglyphs on mt. Aragats, and L. Lisitsyan - in Geghama mountains[13]. Since the second half of the century, archaeologists and amateurs found several thousand images in Syunik, Vardenis and Geghama Ridges[14], and also in lowland areas. Later Armenian archaeologists **H. Martirossyan, S.**

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[12] About the cosmological percepitions of Anania Shirakatsi see also in the works of E.Danielyan: Даниелян Э.Л., Армянские космографические труды VII в. о строении Вселенной, Ер., 1978; Դանիելյան Է.Լ., Անանիա Շիրակացու տիեզերագիտական և բնափիլիսոփայական հայացքները.- «Աստղագիտական ժառանգությունն ազգային մշակույթում». Անանիա Շիրակացու 1400-ամյակին նվիրված պատմա- աստղագիտական գիտաժողովի նյութերի ժողովածու (Բյուրական, 2012), Եր., 2014, էջ 76-86:

[13] About the cosmological percepitions of Anania Shirakatsi see also in the works of E.Danielyan: Даниелян Э.Л., Армянские космографические труды VII в. о строении Вселенной, Ер., 1978; Դանիելյան Է.Լ., Անանիա Շիրակացու տիեզերագիտական և բնափիլիսոփայական հայացքները.- «Աստղագիտական ժառանգությունն ազգային մշակույթում». Անանիա Շիրակացու 1400-ամյակին նվիրված պատմա- աստղագիտական գիտաժողովի նյութերի ժողովածու (Բյուրական, 2012), Եր., 2014, էջ 76-86:

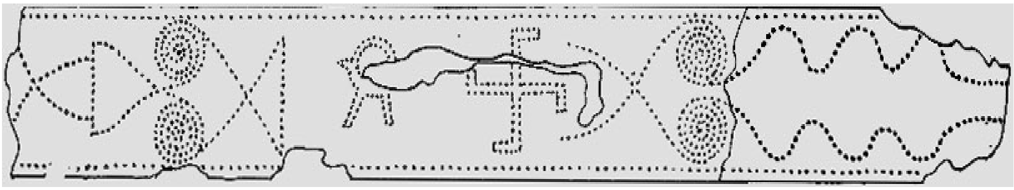
[14] Մարտիրոսյան Հ.Ա., Իսրայելյան Հ.Ռ., Գեղամա լեռների ժայռապատկերները, Եր., 1971: Կարախանյան Գ.Հ., Սաֆյան Պ.Գ., Սյունիքի ժայռապատկերները, Եր., 1970: Պետրոսյան Ս., Հայկական ժայռապատկերներ, Եր., 2005: Թոխաթյան Կ., Ժայռապատկերները Հայկական լեռնաշխարհում հայոց հարակայության վկաներ.- Հարք, 2006, №1, էջ 52-59:

Sardaryan, G. Karakhanyan published four volumes of their studies (1320 copies of rock-carvings). This area of research is currently coordinated by the **Institute of History** and by **"ARARA–T"** (Armenian Rock Art Research Academy - Tir).

Conclusions. Thus, the creators of rock-art have possessed a unified ethno- cultural identity as it is evidenced by the thematic, stylistic and technical uniformity of the known monuments of the Armenian Highland. The thematic connection between rock-art and other spheres of Armenian culture is obvious, particularly with fine art and decorative-applied arts (ceramics, miniature, carpet weaving, weapons, national costume), with dance, theater, types of combat, vehicles, architecture, as well as with calendar, writing, folklore, and mythology. The same style of narration and drawing is observed in rock art and in the mentioned spheres of culture.

Petroglyph (Geghama mountains)

Ceramics (III millennia BC)



Bronze belt

Stamp

Ani (X century)

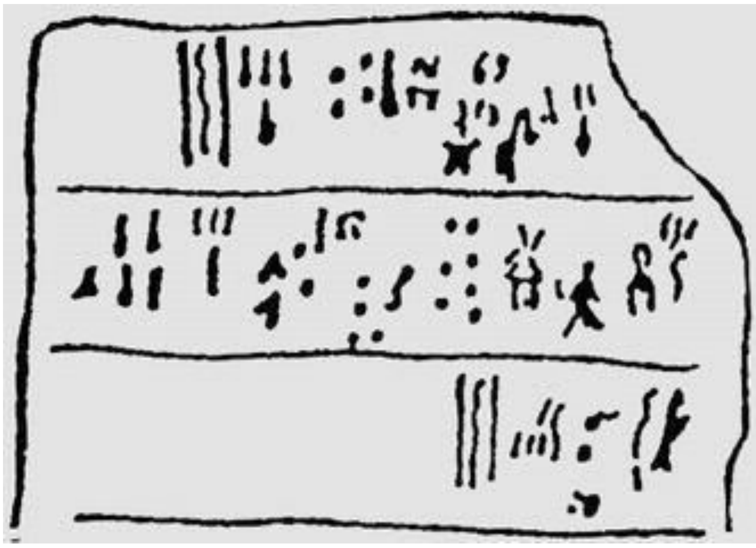
Miniature of Grigor Tatevatsi, 1378


Khachqar


Carpet

The traditions of rock-art have been preserved in the Armenian Highland for millennia. Extension in time, succession and continuity of this sphere of culture is obvious. A striking evidence of this is the close thematic correlations of technology and art between the petroglyphs and other fields of culture (sculpture, lapidary inscriptions, construction and architecture) at different ages.


Tghmut in Aragatsotn


Mokhrablur in Van

Commonality of petroglyphs indicates the presence of a united worldview, of the same linguistic thinking, of a system of beliefs and pantheon, as well as of the beginning of centralized government - the elements of statehood. Culture, in all spheres of its manifestation, is distributed in the Armenian Highland almost equally, so it is presented as one entity for the reason that anthropological and cultural pictures had never been interrupted in the course of the time and space (about 400

000 km^2).

The creators of petroglyphs led a sedentary life for the span of millennia that helped to create for generations. Accumulation and transmission of information by petroglyphs have provided viability and effectiveness of the individual and society through the preservation of knowledge, skills and traditions. This, in its turn, contributed to the preservation of the natural environment, the mentality of the society, and as a result, the security and the very existence of the people.

The Armenian Highland is a cradle of Rock-art. Adjacent to the Highland regions ancient rock carvings are almost completely absent, while in the Highland their high concentration and thematic diversity is observed.

Powerful ethnocultural impulses spread from the Armenian Highland. The tradition of rock art, its semantics and mastery of performance demonstrate radial distribution. There was a dissemination of worldview from the ancient centers of civilization in the form and by means of petroglyphs. Linguistic data concerning the concept of localization of the Indo-Europeans' homeland in the Armenian Highland[15], and theories systematizing numerous credible extra linguistic facts (archaeological, ethnographic, astronomical, calendar and general archaeological data) are evidence of the leading role of the deep rooted Armenian culture in Ancient World civilization.

Rock art was an original and primary traditional sphere of creation inherent to native Armenians, and in terms of time - also exclusive. Petroglyphs are the creative heritage of the millennia-old, indigenous Armenian nation of the Armenian Highland.

Speckle Interferometric Observations on 2.6 m telescope of BAO

J.A.Docobo[1], J. Gomez[1], N.D.Melikian[2] , G.Paronyan[2]

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Abstract

Speckle observations with a Photon Max EMCCD detector from Princeton Instruments were carried out for the first time in the 2.6 m telescope of BAO. Three observing campaigns were already completed. More than four hundred objects had been observed, relative positions and differential photometry information will be published during next months. Throughout the text we provide general information regarding the campaigns, the camera configuration, the EMCCD technical characteristics, and the reduction procedure. Also a brief discussion on how to determine the angle without the 180º ambiguity is included .

1. Introduction

Speckle observations of binary stars contribute to obtain thousands of new measurements every year (Horch et al. 2017, Tokovinin et al. 2016). The monitoring of these systems remains as an important tool to understand stellar structure and evolution, as they provide empirically-determined masses. Also generously sized samples of orbital information and differences of the magnitudes can be used to explore the role that stars play in formation mechanisms, and the difference between single and multiple scenarios. In addition, speckle interferometry allows to observe even when the conditions are far from being ideal, from the photometrical point of view, and the acquisition times lie in the range of a couple of minutes. The use of electron-multiplying CCDs (EMCCDs) has increased the capabilities and the quality of the data recorded in the last decade. The new possibilities that these cameras provided, together with their market value, turn them into an excellent tool to conduct observations using different techniques not only speckle interferometry, but also lucky imaging or lunar occultations.

J.A. Docobo, Director of the Astronomical Observatory Ramón María Aller of the University of Santiago de Compostela (OARMA, Galicia, Spain) and H.A.Harutyunyan, Director of the Byurakan Astrophysical Observatory (BAO, Armenia) signed an agreement in January 2010 to allow that the OARMA sent its own EMCCD speckle interferometry camera to BAO with the aim to attach it to the 2.6 m telescope of BAO. The objective of the agreement is to obtain data that could be

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used for astrometric and astrophysical investigations of single and multiple objects in stellar aggregates, associations and within Solar vicinity. Technical complications and maintenance work in the telescope, including mirror aluminized, delay the use of the camera several years.

Recently, speckle observations were carried out for the first time in the 2.6 m telescope of BAO. We observed during five nights in October 2016, eight nights between May and Jun 2017, plus ten nights in October and November 2017. General information regarding each campaign can be found in Table 1.

Table 1. *Campaigns Resume*

Campaign	Nights	Objects	Science Blocks	Dark Blocks	Flat Blocks	Wide Field Blocks
Oct 2016	5	67	228	15	0	4
May Jun 2017	8	183	429	24	14	11
Oct Nov 2017	10	183	435	65	48	19

2. Description of the camera

We used a camera that merge a speckle oriented optical configuration together with a Photon Max EMCCD detector from Princeton Instruments. The detector utilizes a 512 × 512 pixel, back-illuminated EMCCD with >90% quantum efficiency and < 1 e^- rms read noise, allowing single photon sensitivity with sufficient multiplication gain. Deep thermoelectric cooling down to -70° C reduces the dark current below 0.01 e^-s^{-1} per pixel. The detector has a pixel size of 16 × 16 µm, and an imaging area of 8.2 × 8.2 mm^2 is covered. It corresponds to the angular field of view of 168″.7 in the prime focus of the 2.6 m telescope (F/3.85, scale 20″.6 mm^{-1}) and a resolution of 0″.33 $pixel^{-1}$. With 8x and 20x objective microscopes, angular fields of 21″.1 and 8″.4 are covered, respectively. The system is capable of acquiring and storing 16 bit digitized data at a frame rate of up to 20 fps at full resolution, with ~38 ms readout time per frame. Single photoelectron events are recorded with a signal-to-noise ratio of about 50. Details regarding previous observations with this camera can be found in (Tamazian et al. 2008, Docobo et al. 2010).

The preliminary estimations are show that under good seeing conditions, binary components as faint as 12 mag in optical wavelengths are observed. The diffraction-limited resolution in the optical wavelengths is below 90 mas. Filters with the centre wavelength/ bandwidth of 550/20 nm, 600/40 nm, 650/40nm, 700/80nm and 800/100 nm were used. Additional information regarding the EMCCD, the filters characteristics, and the Risley prisms for Atmospheric Dispersion Correction can be found in (Maksimov et al. 2009).

We used the 10Mhz frequency operating readout in Frame Transfer mode and the Low Light option was selected in the controller gain. It sets the relation between the electrons acquired in the CCD and the ADUs generated. The highest multiplication gain value, 4095, were used to most, except for a few bright objects. It implies a multiplication gain factor in excess of 1000x. Before each exposure the CCD is cleaned two times. No flip or rotation had being apply to the images. According to our installation the south is in the top of the frame, the north in the bottom and west/east in the left/right sides. More information regarding all the possibilities that the PhotonMax offers in both, standard application as normal CCD and high speed low light level multiplication gain mode can be found in its manual.

3. Observing procedure

In preparation for the observing campaigns, we tested the components and the installation procedure during May/June 2016. The camera observed his first light in BAO at Oct 12, 2016, when we checked if all the components were working properly. Another tests, mainly related with the behaviour of the camera under usual and non-usual settings (binning, operating readout frequency of 5Mhz, light mode, etc.) had being carried during moments where the observations were not feasible because of the weather.

The observing program selection and the efficiency on the part of the telescope operators are the base of an optimal use of the allocated telescope time. In average, we were able to observe about four stars per hour, dedicating ten minutes to selection the desired object and guiding the telescope, as well as five minutes to data acquisition and recording. In general two data cubes are obtained per object. More than two blocks were recorded in the case of high priority systems, but also for those triple systems with separation between components bigger than the field of view provided by the 20x microscope objective. Each data cube contains 1000 images of 512 x 512 format, with 16 bits per pixel. Few objects had being observed in more than one campaign at the moment.

Most often, at the beginning of each night of observations, a reference star is observed. Usually a close to zenith bright single object selected by the telescope operator. For direct calibration of the camera scale and orientation angle we have observed speckle interferometric binaries with orbits graded 1 or 2 taken from the updated version of the Sixth Catalogue of Orbits of Visual Binary Stars (Hartkopf et al.

2001). We also obtained images from open systems with the aim to do an independent calibration.

The camera creates a SPE archive per observation into the camera operator's computer memory. As the software was not interfaced neither to the telescope guiding software nor to the camera optical settings, which include filters, prism and microscopes configuration, all this information must be incorporated by hand to our logbook. Using it, plus the original SPE files, we generate the final FITS blocks. Most of the relative positions and magnitude differences of each binary are derived after the end of the campaign. Object identification must be checked *post factum* and corrected in the few cases that we did not point to the correct component of the system observed.

4. Reduction procedure

To calculate the relative positions, we use the ensemble-averaged power spectrum (PS) of speckle interferograms without compensation for the atmospheric transfer function. If we denote as ν a spatial frequency vector, the Fourier transform of the object intensity distribution as $O(\nu)$, $<|S(\nu)|^2>$ being the speckle interferometric transfer function (STF) and $N(\nu)$ representing the power spectrum of noisy events, then the power spectrum of an image cube, that is calculated by summing the square modulus of the Fourier Transform of each image, must verify,

$$<|I(\nu)|^2> = |O(\nu)|^2 <|S(\nu)|^2> + N(\nu)$$

Pluzhnik (Pluzhnik et al. 2005) described how $N(\nu)$ is mainly determined by read-out noise and photon noise, where the second one is much larger in modern detectors. Meanwhile, as can be observed in Figure 1, our camera shows a slightly increase in the mean intensity of the dark frame until it reaches a stable value after 350-400 images. To correct this effect we obtain the frame-to-frame average of different dark blocks to create a "super-block" and subtract frame by frame our science images minus the correspondent dark one. In order As these images share the same position within the block, the read-out effect from "super-dark" and science observations should be similar. We found this method to be more reliable concerning to our camera characteristics than just subtract the average dark frame of a single block. Considering now the photon bias influence, the aforementioned author decompose it as $N_p(\nu)=N_0 n_p(\nu)$, where N_0 reflects the photon bias amplitude and the other term is defined as the normalized photon bias term. The normalized photon bias is linked with the photon bias shape, and it can be removed dividing the power spectrum by the normalized power spectrum of a flat field block obtained with the same configuration as the science block. The difference between both power spectrums calculated with and without corrections can be appreciated comparing them in Figure 2.

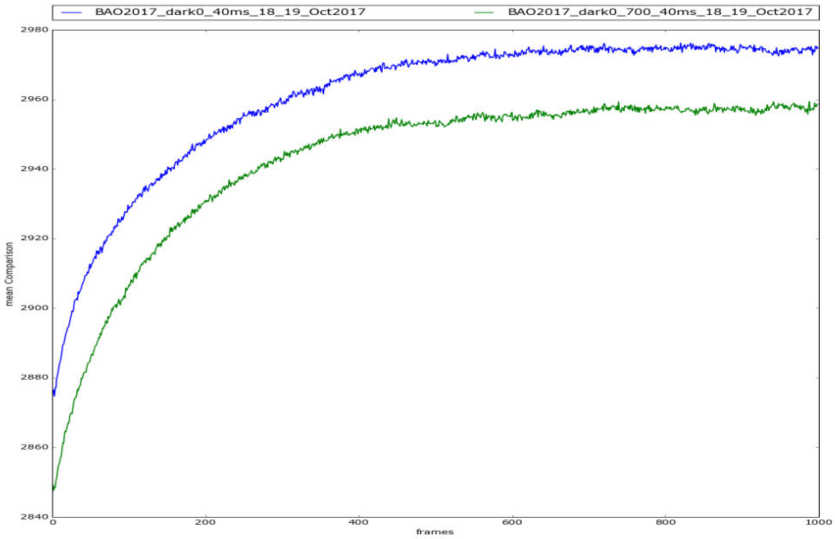

Figure 1. Comparative between two darks

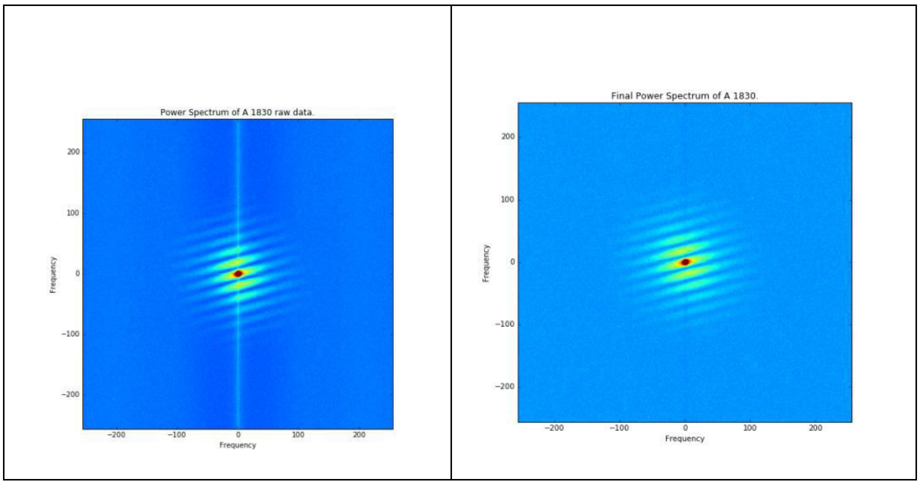

Figure 2. Power spectra of A1830 without any kind of correction (left) and after subtract superdark image by image and correct by flat power spectrum (right).

Whereas, the photon bias amplitude N_0 can be obtained averaging the power spectrum beyond the cutoff frequency of the telescope where $|O(\nu)|^2 <|S(\nu)|^2>$ must be equal to zero. The mean of this outer region is subtracted from the power spectrum. After performing these corrections, we mask the central peak plus the central column and row (see Fig. 3).

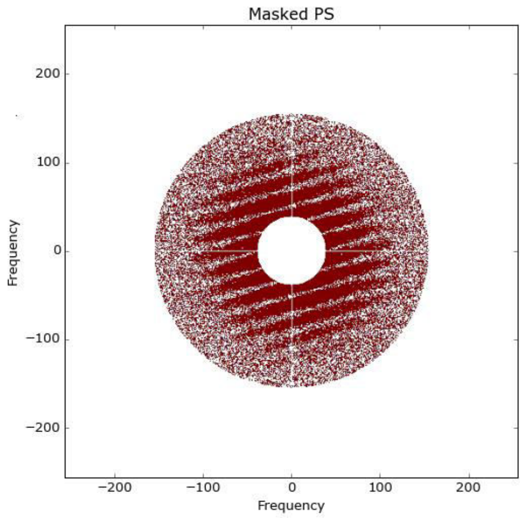

Figure 3. Masked image of the previous spectrum. The cutoff frequency is determined by the diameter of the telescope, the filter used for the observation and the pixel size. The central mask is 10% of the cutoff value in this example. We also masked central row and column.

Finally, we calculate its autocorrelation function (ACF), using the image generated to detect the secondary peak position. Nevertheless, the ACF duplicates the information generating a "phantom" peak symmetrical to the real one, as it can be seen in Figure 4. At this point we have just determined the angle with an uncertainty of 180º. In some cases past observations can appoint which is the real and the phantom peak. In other cases, the absolute quadrant determination problem arises.

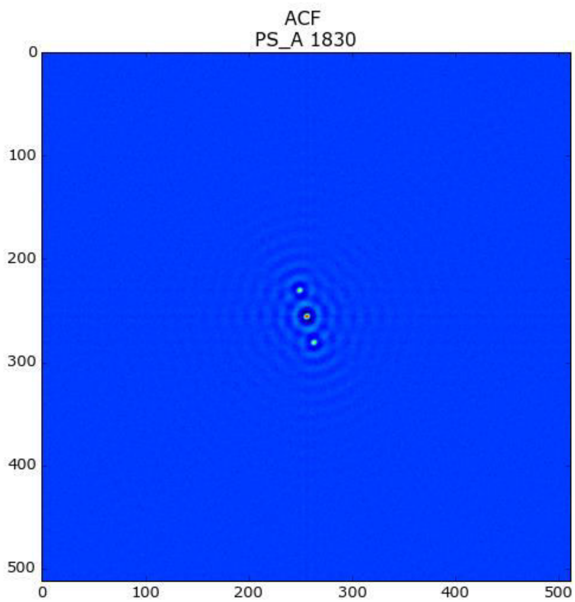

Figure 4. Autocorrelation function showing the central and both secondary peaks.

5. Quadrant determination

Several techniques can be applied to determine the real peak. "Shift-and-add" techniques used on the read-out noise corrected speckle frames will solve most of the wide and middle open pairs, depending not only in the separation but also in seeing conditions and difference in magnitude between components. Close pairs require more advanced techniques as bispectrum or, once that we are able to determine accurately the position and the difference in magnitude between both components, we can multiply each speckle frame by a function that changes monotonically in the direction from the primary to the secondary component resulting in a change in the magnitude difference between components as suggested by Walker (Walker et al.1978). All these techniques had being used in the past by different research teams but, up until now, a comparison between them had not been published.

6. Conclusions

Summarizing the preliminary results of our three campaigns, which had been completed using the OARMA speckle camera attached to the 2.6 m telescope of BAO we have to note the following:

a) More than four hundred double and multiple objects with the intention to obtain their relative positions and differential magnitudes has been observed during the last three observational campaigns.

b. The preliminary estimations are show that a separation limit between the binaries beyond 90 mas could be measured, and the objects as faint as 12 magnitudes could be able to solved in present observations.

The first scientific results of these observations we hope to present for publications in May-June 2018.

Acknowledgement. J. Gómez would like to thank all the BAO staff for their scientific support, and to D.A. Rastegaev, A.F. Maksimov, V.V. Dyachenko, E.V. Malogolovets and Yu.Yu. Balega, from SAO's speckle group. We have to express authors thanks to BAO's Director A. M. Mickaelian and Deputy director H. A. Harutyunyan for permanent interest to our observations.

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New Capabilities of One-Meter Schmidt Telescope of the Byurakan Astrophysical Observatory after Modernization

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Abstract

Within the framework of cooperation between Byurakan Astrophysical Observatory and Special Astrophysical Observatory during 2013–2015 y the 1-m Schmidt telescope of the Byurakan Astrophysical was upgraded. We completely redesigned the control system of the telescope: we replaced the actuating mechanisms, developed telescope control software, and made the guiding system. In the Special Astrophysical Observatory the 4k×4k Apogee (USA) liquid-cooled CCD was reworked and prepared. Detector was mounted in the focus of the telescope and provides 1 degree field of view with pixel-size of 0.868, and RON~11e$^-$. The detector is equipped with a turret with 5 holes for filters. The 20 intermediate-band filters (FWHM= 250A) uniformly covering the 4000–9000 AA wavelength range, five broadband filters (u, g, r, i, z SDSS), and three narrow-band filters.

During the first year of test operation of the 1-m telescope we performed pilot observations within the framework of three programs: search for young stellar objects, AGN evolution, and stellar composition of galaxy disks. We confirmed the possibility of efficiently selecting of young objects using observations performed in narrow-band Hα and [S II]filters and the intermediate-band 7500Åfilter.Three-hours long exposures with SDSS g, r, and i band filters allow us to reach the surface brightness level of 28^{m}from square arcsecond when investigating the stellar content of galaxy disks for a sample of nine galaxies. We used observations performed with the 1-m telescope in five broadband (SDSS u, g, r, i, and z) and 15 intermediate-band filters (4000–7500A) to construct a sample of quasar candidates with0.5<z<5(330objects) in about one-sq. degree SA 68 field complete down to R_{AB}=23^m. Spectroscopic observations of 29 objects (19.$_m$5<R<22$_m$) carried out at the 6-m telescope of the Special Astrophysical Observatory of the Russian Academy of Sciences confirmed the quasar nature of 28 objects.

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1. Introduction

Wide field cameras as Schmidt telescopes made huge amount of astronomical surveys during last century using large photographic plates (Schmidt, 1931). The era of photographic observations, which ended in mid-1080s, left many telescopes without use. Such famous instruments as Palomar Schmidt, Barrell Schmidt, Asiago Schmidt, and Byurakan Schmidt played important part in the development of astronomy. Despite their excellent optics and mechanics their outdated control systems and obsolete observation methods rendered them noncompetitive against more modern telescopes. The 1-m Schmidt telescope of Byurakan Astrophysical Observatory of National Academy of Sciences of Armenia is one of the worlds's top five and three Schmidt telescopes in terms of the size of the mirror and the size of objective prisms, respectively, and has one of the highest aperture ratios (*f/*2.1) among the world's top instruments of its class. The telescope was made by the State Optical-Mechanical Plant named after Joint State Political Directorate (now LOMO) and installed at Byurakan Observatory in 1960 (Dobichin 1961). In mid-1960s B. E. Markarian used this telescope to undertake the first program aimed at searching for extragalactic objects with UV excess in the continuum (Markaryan 1967) via the technique of slit-less spectroscopy. In the process of the survey many new AGNs were discovered, which are now known as Markarian galaxies and are targets of comprehensive studies. It was before B. E. Markarian completed the program of the First Byurakan Survey that the task was set to extend low-dispersion spectroscopic studies to fainter magnitudes and expand the range of selected objects. This idea formed the basis of the Second Byurakan Spectroscopic Sky Survey. Observations within the framework of the survey program started in 1974 and were finished in 1991 (Markaryan & Stepanyan 1983, Stepanyan 1994). No systematic observations were performed on the telescope after the end of the Second Byurakan Sky Survey and the telescope was abandoned in mid-1990s. The lack of detectors of appropriate size and quality posed a particular problem—huge fields of view of the telescopes (e.g., 35.5×35.5 cm photographic plates were used for Palomar Schmidt) could not be filled with CCD detectors, which were too small at the time. The development of observing technologies (high quantum efficiency of detectors; their sizes, which can now be as large as 10 × 10 cm; higher than 90% transmission of the filters, and efficient broadband coatings) made it possible at the beginning of the new century to bring wide-field Schmidt telescopes back to regular operation. Control systems were replaced on the telescopes to turn them into robotic instruments for remote observations, and photographic equipment was replaced by CCD detectors. Such upgrades are rather costly and therefore not all such telescopes are currently in use. The special interest in Schmidt telescopes is due to their large field of view, high transmission (because of the small number of optical elements), low level of scattered light, and high focal ratio. Such telescopes are good for detecting low surface brightness levels, performing surface photometry of galaxies, and photometry of stars. In this paper we report the results of our efforts aimed at restoring the 1-m Schmidt telescope (100/125/213) of Byurakan Astrophysical Observatory of National Academy of Sciences of Armenia to working condition. Section 2 describes the upgrade of the control system and observational tasks that we plan to perform on this telescope; Section 3 describes the detector mounted at the focus of the telescope and its main parameters; Section 4 describes the filter properties, and Sections 5 and 6 describe the technique of observations and calibration of the data and presents the results of the first observations.

2. Observational tasks

We plan to use the telescope to perform several observing programs that take advantage either of its high aperture ratio or large field of view. The former include the program of the search for and study of young stellar objects with mass outflows (observations in narrow-band — *FWHM* = 100 A and intermediate-band — *FWHM* = 250 A filters); the program of deep surface photometry of galaxies (observations in broadband filters); study of the distribution of ionized gas in galactic disks and beyond the optical radii (observations in narrow-band — *FWHM* =100A and intermediate-band — *FWHM* = 250A — filters). The search for AGNs in selected sky areas using the technique of intermediate-band photometry is a program of the second kind. We modeled broadband and intermediate-band filter observations on the 1-m telescope. According to our estimates, we can reach the brightness levels of $28–29^{m}$/ • '' with 3–5-hour exposures in *g*-SDSS, *r*-SDSS, *i*-SDSS filters. For the AGN search program we estimated the optimum number of spectral bands uniformly distributed throughout the entire optical range, the accuracy of the classification of objects and determination of their photometric redshifts, and the total observing time per field. We plan to use 20 intermediate-band filters with 250 A pass band and higher than 90% transmission in the 4000–9000 A wavelength interval. In this case, with a total of 30 exposure hours (detector DQE of about 60%) and 2seeing we can achieve a signal-to-noise ratio of *S/N* = 5 in each filter for objects with AB $\sim 23^{m}$. We believe that for the given survey depth in each filter AB = 23^{m} we can completely trace the QSO luminosity function out to z = 3.2 (*MB* = -23) and z = 5 (for objects with *MB* > -24.7).

3. Control system for the Schmidt telescope

In 2006 the work began to recommissioning the telescope and restore it to working condition. We completely upgraded the telescope control system: replaced the actuating mechanisms, developed telescope control software, made the guiding system, reworked the CCD detector and prepared it for mounting at the telescope focus. The software that we developed makes it possible to control the detector, the wheels, the movements of the telescope and the dome, and automatically focus the telescope.

The telescope control system is built from universal control modules, each responsible for a certain part of the telescope. From a hardware point of view all the modules have the same structure. Each control module is programmed and customized for a certain task before being installed on the telescope. The operator computer acts as the Master device for all of these modules. The control modules are the Slave devices that are controlled from the computer. This Master-Slave mechanism is initiated by creating a wireless network between the computer and the control modules using RF Data Modules. The system also has the option to be setup through a wired network using an RS485 interface. This option can be used in places where RF restrictions apply or where there is too much interference.

Below is the list of modules that are installed on the telescope.

1. Alpha module
2. Delta module
3. Focus module
4. Dome module
5. Guide module

Alpha and Delta modules are installed on the right ascension and the declination axis of the telescope. The semodules' operations include:

- Reading the telescope's position from a 25 bit absolute encoder
- Reading data from safety limit switches
- Controlling a Stepper motor for slow navigation and trace
- Controlling a 3 phase asynchronous motor for fast navigation
- Displaying information on a built-in LCD
- Reading the temperature and the humidity of the module's surroundings

The Focus module is installed in the optics area of the telescope pipe. The main function of this module is to read the position of the focus lens of the telescope using high precision ADC circuitry and to position the lens by driving the stepper motor.

The Dome unit is positioned on the dome wall. It obtains the dome position from an absolute encoder and sends it to the master computer. The module also controls the dome shutters and the dome rotation depending on the telescope's position and the operator's command.

The Guide module is programmed to control 2 stepper motors which are installed on the secondary optical system's guiding router. The operator uses this system to navigate the narrow field of view CCD to a guide star, after which the guiding process takes place automatically. The whole control chain is also equipped with a secondary system that goes through the whole telescope and measures the humidity and the temperatures in different areas of the building and the telescope.

4. Detector

We acquired a two-staged Peltier cooled amateur Apogee Alta 16M CCD camera (Apogee, USA)with air cooled hot Peltier junction to mount on to the telescope. The camera is equipped with a KodakKAF-16803 4096 × 4096 CCD with a pixel size of9 × 9 μm. Laboratory tests of the camera showed that it has a readout noise and gain of RON = 11.1 $e^-$and ADU = 1.487 e^-, respectively, and that the camera has sufficient linear response range for observations. The spectral response of the camera allows it to be operated practically throughout the entire optical wavelength range. Figure 1 shows the spectral response measurements that we performed in the laboratory. We redesigned the camera by replacing air cooling with liquid cooling and vacuumed the volume where the detector is located. These modification sallowed us to significantly reduce the dependence of the temperature of the detector and electronic components on the ambient temperature and decrease the working temperature of the detector down to-40°± $0^\circ.1$C with a coolant temperature of +10°±$0^\circ.1$C. We mounted a two-component post-rectifying anti reflection lens specially computed to correct the curvature of the focal plane of the 1-m telescope throughout the entire optical wavelength range. We mounted a filter turret with replaceable filter wheels(HSFW, manufactured by Optec, USA) onto the camera box, with each wheel hosting five 50-mmdiameter filters. In October 2015 a CCD camera was installed onto the standard focusing unit of the telescope and a coolant supply line was set to connect the camera to the cooling system (Minichiller, manufactured by Huber, Germany) located in the dome space of the telescope. We use a mixture of ethanol with distilled water as a coolant. As a result, the telescope equipped with

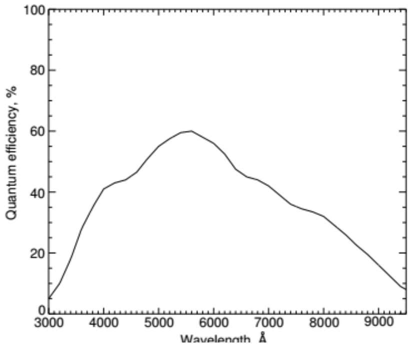

Figure 1. Spectral response of Apogee Alta 16M camera according to laboratory measurements

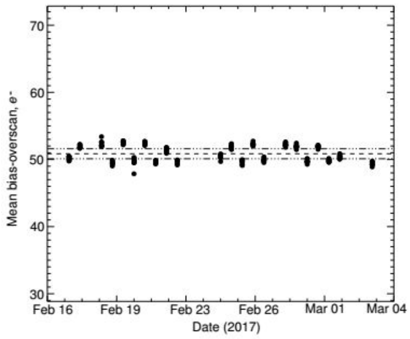

Figure 2. Measurements of the base level of bias-overscan under real conditions on the telescope at dome temperatures ranging from -18◦C to +2◦C. The dashed line shows the average level and the dashed-and-dotted lines, the average level ±0.5 ADU.

Alta 16M camera has a field of view of about $1^{\circ}$with a resolution of 0'' .868/pixel. We investigated the photometric stability of the detector under real observing conditions: we measured the base level with respect to which the object brightness is determined (bias-overscan) for over two weeks. The dome temperature varied from -18°C to +2°C (Fig. 2). The measurements showed that the rms deviations of the variations of the base level did not exceed 1.4 e^{-}, i.e., 1 ADU of the detector, without any appreciable trends.

5.Filters

In line with our scientific goals we acquired 20 intermediate-band filters (*FWHM* = 250A) uniformly covering the 4000–9000A wavelength interval, and three narrow-band filters (5000A, 6560A and 6760A, *FWHM* = 100A). The ˚ filters were manufactured by Optec (USA) using ion bombardment technology, they have high transmission (more than 90%) at the response peak, and efficiently suppress light in "blind" wavelength domains (>4D). We also acquired a set of five broadband filters (*u,g,r,i*, and *z* SDSS) manufactured by Astrodon, USA. The filters have a clear aperture of 50 mm. Figure 3 shows the results of laboratory measurements in an *F/2* convergent beam. Filters are mounted on six filter wheels, and can therefore be changed during observations. The filter turret is controlled from the same shell that is used to control the camera.

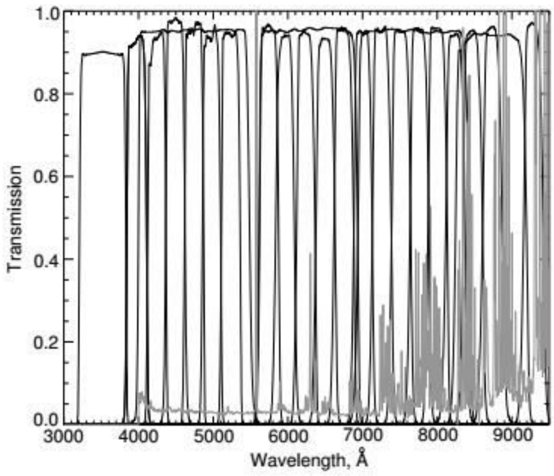

Figure 3. Results of filter measurements made in a laboratory in a converging beam with an aperture ratio of *F/2*.

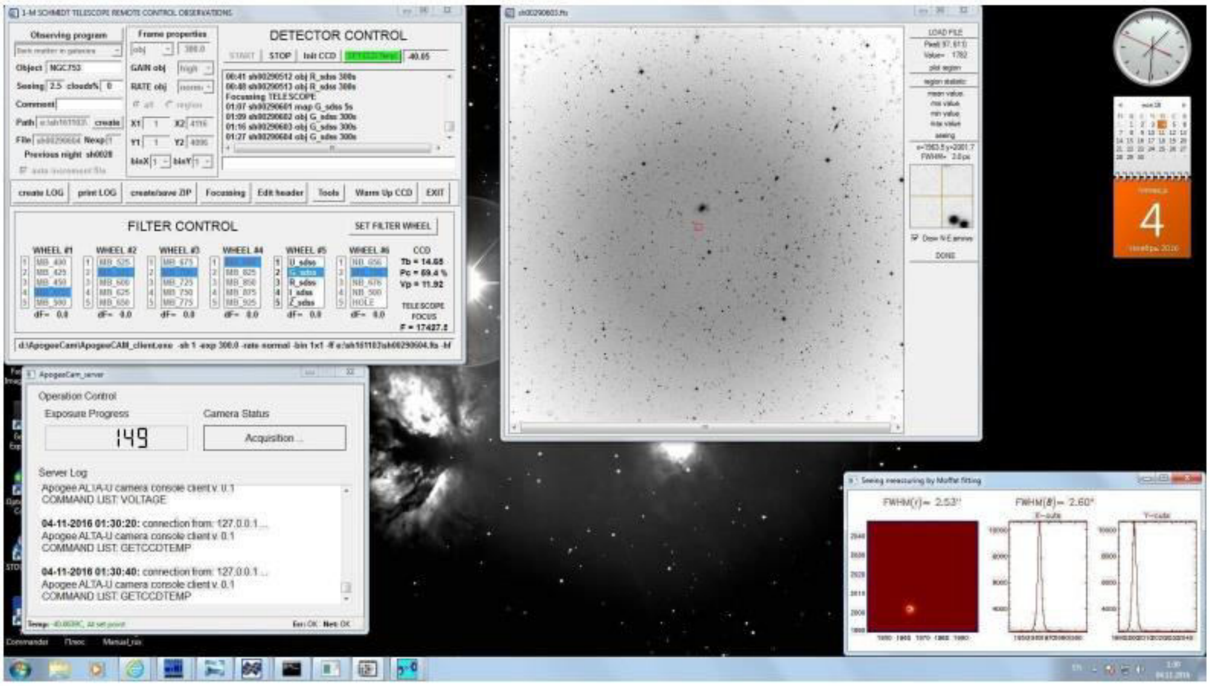

Figure 4. Screenshot of the detector control monitor during observations on the 1-m telescope.

6. Observations and data calibration

Multicolor photometry toward which we reoriented the 1-m telescope allows the observational technique to be significantly formalized, and this is the key aspect of the transition to fully automated observations. While developing the telescope control software we had in mind the possibility of future remote observations and subsequent transition to practically automatic mode of observations in accordance with a preset program. We also developed a software environment for controlling the detector, which can be used not only to control the detector state, set the exposure and image integration modes, but also to control the filter turret while interacting with the telescope control program, focus the telescope, retarget it, calibrate the data, and archive the data obtained and produce the log of observations performed during the past night (see Fig. 4).

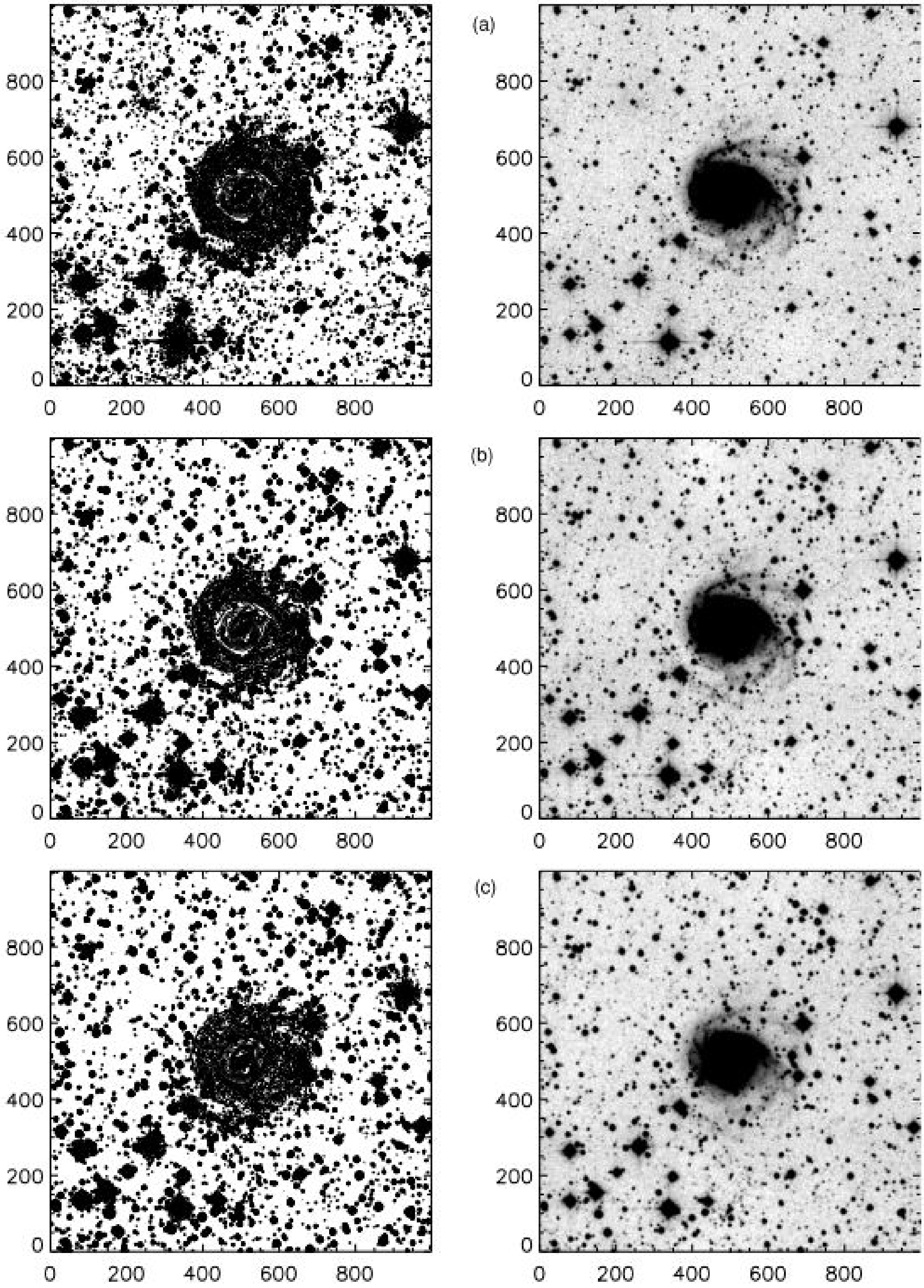

Figure 5. UGC 03685 as observed with the 1-m Schmidt telescope of Byurakan Astrophysical Observatory of the National Academy of Sciences of Republic of Armenia. Left: surface photometry contours; right: images of the object taken in *i*SDSS (a), *r*-SDSS (b), and *g*-SDSS (c) filters with 6000 s, 10 500 s, and 8100 s exposures, respectively. The outermost isophotes correspond to the levels of $26^{m}.5$/• '', $27^{m}.7$/• '', and $28^{m}.0$/• '', respectively.

Details of data reduction methods and techniques, as well as results of first observations are presented in (Dodonov 2017). In this paper we will present some images and spectral energy distributions of some interesting objects (see Fig. 5 and 6).

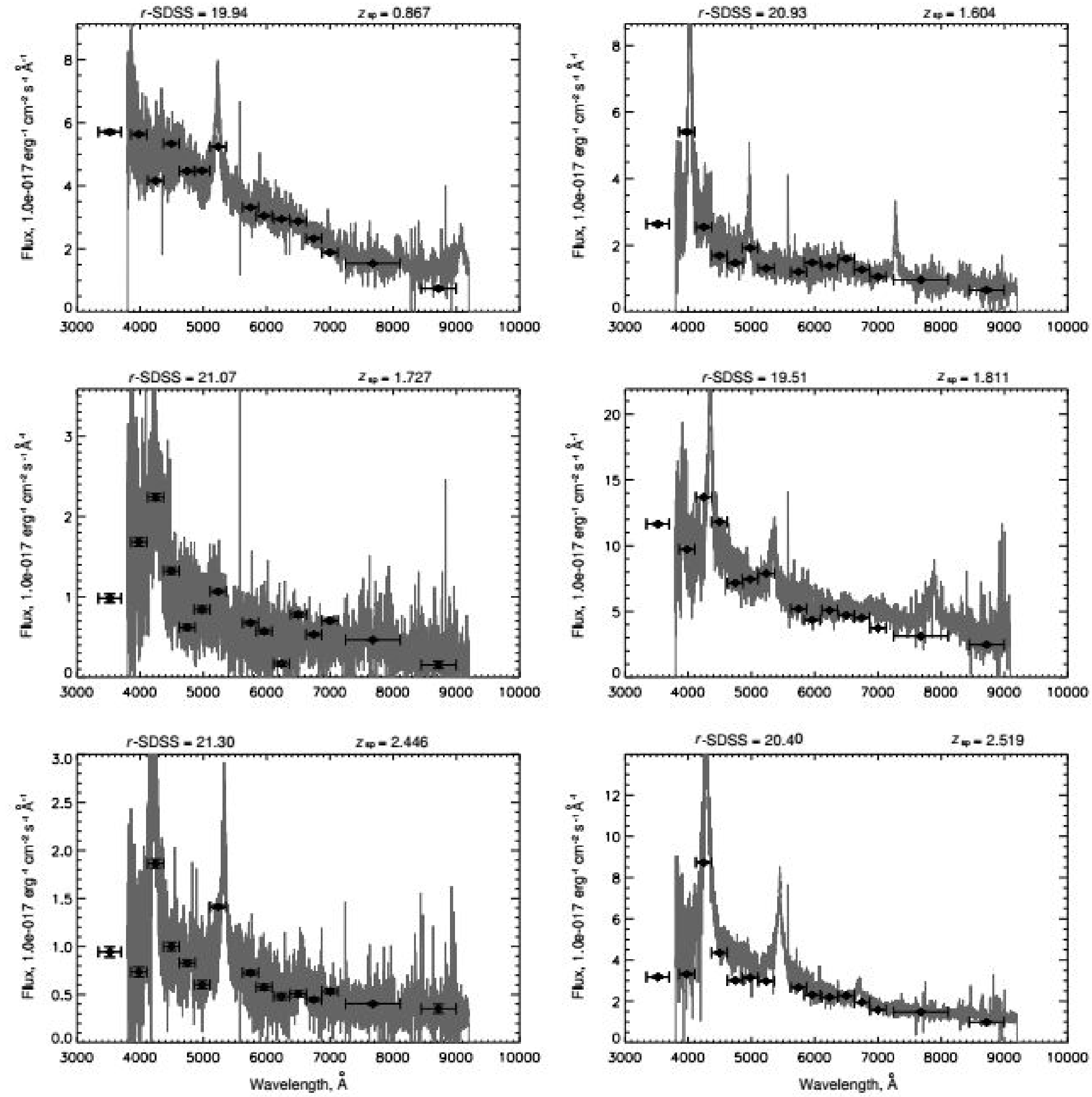

Figure 6. Spectral energy distribution in six quasars in the HS 47.5-22 field according to multicolor photometric observations made with the 1-m Schmidt telescope (the points with the error bars: the horizontal and vertical bars correspond to the filter passband and error of the photometry of the object in the given band, respectively) and the SDSS spectra of these objects (the solid line).

7. Conclusions

Returning to regular observations on the 1-mSchmidt telescope of Byurakan Observatory expands the opportunities for Russian and Armenian astronomers to tackle the key problems of modern astrophysics: study of the evolution of active objects, investigation of gamma-ray bursts at early stages of their detection, search for distant (out to $z \sim 1$)clusters of galaxies, study of the environments of giant radio galaxies, investigation of the connection of AGNs and clusters of galaxies, study of the distribution of ionized gas in galaxy disks and beyond the optical radius, and investigation of star-forming regions in the Galaxy. We hope to greatly increase the efficiency of observations on the 1-m telescope in the foreseeable future by mounting a mosaic detector at the focus to cover the entire 16° field of view of the telescope.

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BAO Plate Archive Project

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Abstract

We present the Byurakan Astrophysical Observatory (BAO) Plate Archive Project that is aimed at digitization, extraction and analysis of archival data and building an electronic database and interactive sky map. BAO Plate Archive consists of 37,500 photographic plates and films, obtained with 2.6m telescope, 1m and 0.5m Schmidt telescopes and other smaller ones during 1947-1991. The famous Markarian Survey (or the First Byurakan Survey, FBS) 2000 plates were digitized in 2002-2005 and the Digitized FBS (DFBS, www.aras.am/Dfbs/dfbs.html) was created. New science projects have been conducted based on this low-dispersion spectroscopic material. Several other smaller digitization projects have been carried out as well, such as part of Second Byurakan Survey (SBS) plates, photographic chain plates in Coma, where the blazar ON 231 is located and 2.6m film spectra of FBS Blue Stellar Objects. However, most of the plates and films are not digitized. In 2015, we have started a project on the whole BAO Plate Archive digitization, creation of electronic database and its scientific usage. Armenian Virtual Observatory (ArVO, www.aras.am/Arvo/arvo.htm) database will accommodate all new data. The project runs in collaboration with the Armenian Institute of Informatics and Automation Problems (IIAP) and will continues during 4 years in 2015-2018. The final result will be an Electronic Database and online Interactive Sky map to be used for further research projects. ArVO will provide all standards and tools for efficient usage of the scientific output and its integration in international databases.

Keywords: *photographic plates – plate archives – digitization – astrometry – photometry – spectroscopy – databases – virtual observatories.*

1. Introduction

The astronomical plate archives created on the basis of numerous observations at many observatories are the most important part of the astronomical observational heritage. The necessity of digitization of astronomical plates was emphasized and current progress in various national and international projects was given at Astroplate workshops (e. g. Osborn 2014; Hudec 2014; Kazantseva 2014; Nesci et al. 2014a; Stupka & Benesova 2014).

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Byurakan Astrophysical Observatory (BAO) Plate Archive is one of the largest astronomical archives in the world and is considered to be BAO main observational treasure. It is the results of decades' hard work of Armenian astronomers and the work of BAO telescopes and other expensive equipment, as well as the results of their activities. Today BAO archive holds some 37,000 astronomical plates, films or other carriers of observational data. However, previous observational and informational registration methods currently do not make it available to wide range of scientists, and especially its usage for solution of new research problems. Digitization of BAO plates will be a significant contribution to the Wide-Field Plate Data Base (WFPDB) developed in Sofia, Bulgaria (Tsvetkov & Tsvetkova 2012).

A project on Digitization of BAO Plate Archive and creation of BAO Interactive Astronomical Database (shortly BAO Plate Archive project, BAO PAP) has started in February 2015. It is aimed at preservation of BAO valuable observational material accumulated during 1947-1991, creation of full Database of all BAO observations, creation of BAO Interactive Sky Map with visualization of all observations and quick access to the data, development and accomplishment of new research projects based on the existing observational material, and integration of BAO observations into the international databases. A number of BAO young astronomers are involved in this project and it will last 3 years.

Project objectives are the preservation of BAO observational archive, preservation of scientific information contained in photographic plates and other careers, creation of opportunity of dissemination and wide usage of observational data, putting in correspondence of observational material to modern standards and usage methods, proposing new science projects and creation of possibility of their further accomplishment, and making BAO activities visible.

A short description of BAO Plate Archive was given by Mickaelian (2014) and more detailed paper is given in Mickaelian et al. (2016b).

2. BAO telescopes and observing programmes

BAO observers worked with a number of BAO telescopes during 1947-1991 and obtained several dozens of thousands of plates, films and other products. The table gives general understanding on observations of 10 BAO telescopes that worked on photographic photometry, electrophotometry, slit and objective prism spectroscopy, and polarimetry of many thousands astronomical objects.

Table 1. *Overview of BAO telescopes and produced observational material*

Telescope	**Sizes** (cm)	Years	Observing methods	Plates
5" double–astrograph	13	1947–1950	photometry	3000
6"	15	1947–1950	photometry	3000
8" Schmidt	20/20/31	1949–1968	photometry	4500
20" Cassegrain	51/800	1952–1991	electrophotometry	
10" telescope–spectrograph	25	1953–19??	spectra	
Nebular spectrograph		1954–19??	spectra	
16" Cassegrain	41/400	1955–1991	electrophotometry	
21" Schmidt	53/53/183	1955–1991	photometry	12000
40" Schmidt (AZT–10)	102/132/213	1960–1991	photometry, spectra	7500
ZTA–2.6m	264/1016	1975–1991	photometry, spectra	7000
All telescopes		**1947–1991**		**37000**

We give in Table 1 an overview of BAO telescopes and produced observational material. Telescope "Sizes" are given for the mirror and focal length for classical telescopes and for the correcting lens, mirror and focal length for Schmidt type telescopes. Here we list the main observational projects accomplished on the three most important BAO telescopes (2.6m classical reflector, 1m Schmidt and 0.5m Schmidt; Figure 1).

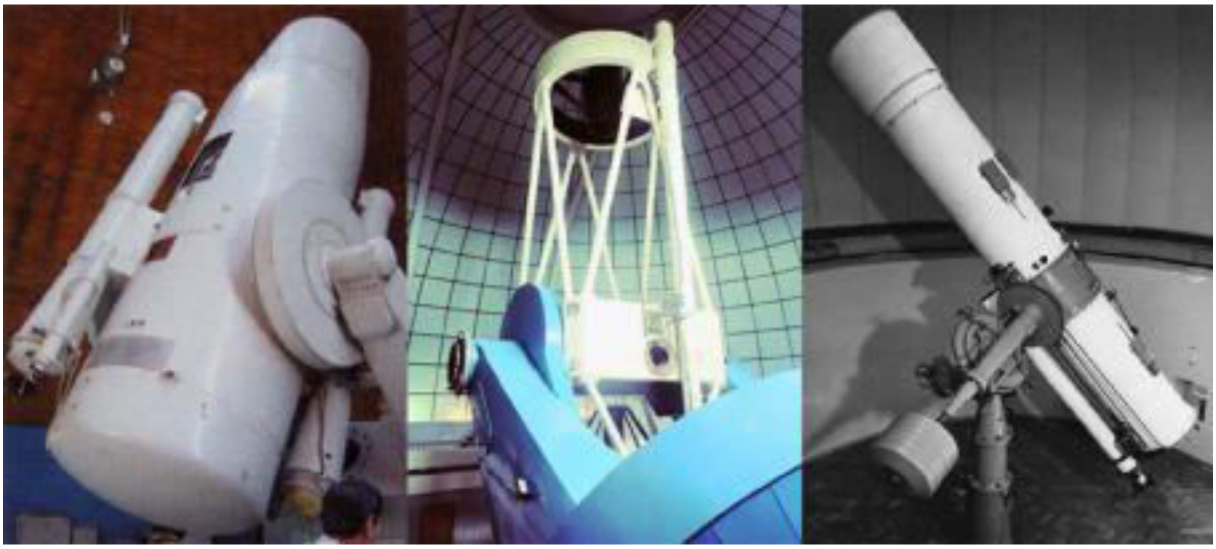

Figure 1. BAO most important telescopes (from left to right): 1m Schmidt, 2.6m classical reflector and 0.5m Schmidt.

21" (0.5m) Schmidt telescope:

- Polarization of cometary nebula NGC 2261
- Nuclei of nearby Sa and Sb galaxies
- Nuclei of nearby Sc galaxies
- Search for flare stars in Pleiades
- Search for flare stars in Orion

- Search for flare stars in NGC 7000 (Cygnus)
- Search for flare stars in Praesepe
- Search for flare stars in Taurus Dark Clouds (TDC)
- Variability of Markarian galaxies
- Monitoring of extragalactic supernovae in certain areas

40" (1m) Schmidt telescope:
- Detailed colorimetry of bright galaxies
- First Byurakan Survey (FBS, Markarian survey; Markarian 1989)
- Search for flare stars in Pleiades
- Search for flare stars in Orion
- Search for flare stars in NGC 7000 (Cygnus)
- Search for flare stars in Praesepe
- Search for flare stars in Taurus Dark Clouds (TDC)
- Second Byurakan Survey (SBS; Stepanian 2005)
- Extension of the FBS in the Galactic Plane

ZTA-2.6m telescope:
- Morphological study of Markarian galaxies
- Investigation of star clusters
- Investigation of groups and clusters of galaxies
- Spectroscopy FBS blue stellar objects
- Spectroscopy FBS late–type stars
- Spectroscopy SBS galaxies and stellar objects (BAO/SAO)
- Direct images of the central regions of Markarian galaxies
- Spectroscopy of T Tauri and flare stars
- Spectroscopy of Byurakan-IRAS Galaxies (BIG objects)
- Spectroscopy of ROSAT AGN candidates (BAO/HS/OHP/INAOE)

Summarizing, the main observational projects run on these telescopes were: **21" (0.5m) Schmidt:** Polarization of cometary nebula NGC 2261, Nuclei of nearby Sa and Sb galaxies, Nuclei of nearby Sc galaxies, Search for flare stars in Pleiades, Orion, NGC 7000 (Cygnus), Praesepe and Taurus Dark Clouds (TDC), Variability of Markarian galaxies, Monitoring of extragalactic supernovae in certain areas, etc.; **40" (1m) Schmidt:** First Byurakan Survey (FBS, Markarian survey; Markarian 1989), Second Byurakan Survey (SBS; Stepanian 2005), Extension of the FBS in the Galactic Plane, Detailed colorimetry of bright galaxies, Search for flare stars in Pleiades, Orion, NGC 7000 (Cygnus), Praesepe and Taurus Dark Clouds (TDC), etc.; and **ZTA-2.6m**

telescope: Morphological study of Markarian galaxies, Investigation of star clusters, Investigation of groups and clusters of galaxies, Spectroscopy of FBS blue stellar objects, FBS late–type stars, SBS galaxies and stellar objects (BAO/SAO), T Tauri and flare stars, Byurakan-IRAS Galaxies (BIG objects) and ROSAT AGN candidates (BAO/HS/OHP/INAOE), and Direct images of the central regions of Markarian galaxies. Especially efficient were Byurakan surveys accomplished by Markarian and colleagues: FBS and SBS.

Scientific Programs Board (SPB) is created to evaluate the existing observational material, to select sets of priorities to be scanned first and to propose new research projects. It consists of BAO Director, DFBS Principal Investigator and ArVO Project Manager Areg Mickaelian (Chair), the Head of BAO Astroinformatics Department Tigran Magakian and 7 other most experienced BAO observers, as well as researchers from NAS RA Institute of Informatics and Automation Problems (IIAP) Vladimir Sahakian and Hrachya Astsatryan are involved for their experience in computer science related to databases and computational methods.

Project Executing Team (PET) consists of 14 members: Kamo Gigoyan (Project Manager, SPB member), Marietta Gyulzadyan (Deputy Manager on Observing Programs), Gurgen Paronyan (Deputy Manager on Technical Issues, Person in charge for BAO Plate Archive), 6 other PET members involved in scanning and reduction of data, Gor Mikayelyan (Database Manager, Web Designer), Sona Farmanyan (Webpage content, dissemination, outreach, and organizational issues) and Aram Knyazyan (NAS RA IIAP, Database Manager).

The project consists of the following tasks:

- Development of technical principles of the Project, necessary Equipment, Timeline and the Budget
- Collection of all photographic plates (until recently only plates obtained before 1974 had been collected in BAO Plate Archive)
- Revision and accounting of the plates and observing journals in BAO Plate Archive,
- Scanning of a few dozens of plates for test and educational reasons to set up the necessary parameters for the scanning in frame of the main Project
- Input of data from observing journals; Creation of the Project Database and development of the principles of organization of data in it
- Creation of the Project Webpage and User Interface

- Scanning of photographic plates and films
- Astrometric solution; Extraction of images and spectra; Wavelength calibration; Density and flux calibration; Multiband (UBVR) photometry
- Making up template low-dispersion spectra; Numerical classification of low-dispersion spectra
- Visualization of BAO observations on sky map; Creation of electronic interactive sky map and search system
- Scientific analysis of existing observational material and providing new research possibilities; Proposing and discussing new research projects

BAO PAP webpage (http://www.aras.am/PlateArchive/; Figure 2) was recently open and contains a lot of information on BAO observations, previous digitization projects, present Project details, teams, follow-up research projects, deliverables and related links (many items will be filled in during the next months). The main products will be **"Data Access"** and **"Interactive Sky Map"**. The first one will contain BAO Observational Database, Search by any parameter (Dates / Julian dates, Telescope, Observing modes/methods, Instrument, Receiver, Emulsion, Filters, Seeing, Project name, Project PI, Observers, Targets / coordinates, Sky area, Surface, Scale, Spatial resolution, Spectral range, Spectral resolution, Limiting magnitude, Number of nights, Number of exposures, Links), Data Visualization and Download of the digitized plates, films, part of them or individual objects images or spectra. "Interactive Sky Map" will visualize the observed by BAO telescopes sky and will give possibility to check observed areas for a given observational project, given telescope, observer, observing method, limiting magnitude, etc. There will be possibility to check individual fields for presence and number of plates to propose further research projects. Main expected projects are supposed to be those on variability and proper motions, as well as studies of the Solar System objects.

4. DFBS and other digitization projects at BAO

A number of digitization projects have been accomplished at BAO, including the most important one, **Digitized First Byurakan Survey (DFBS**; http://www.aras.am/Dfbs/dfbs.html; Mickaelian et al. 2007; Massaro et al. 2008) based on the digitization of the famous Markarian Survey (Markarian et al. 1989). Its main scanning and resulting features are given in Table 2.

Figure 2. BAO Plate Archive Project webpage**.**

Table 2. *Main scanning and resulting characteristics of the DFBS*

Items	Description
Teams	Byurakan Astrophys. Obs., Univ. Roma "La Sapienza", Cornell Univ.
Years	2002–2005
Instrument	Epson Expression 1680 Pro scanner
Scanning options	1600 dpi (15.875μ pix size), 16 bit, transparency mode, "scanfits"
Plate size	9601$\times$9601 pix, 176 MB file
Spectra	107$\times$5 pix (1700μ in length)
Dispersion	33 Å/pix average (22–60 Å/pix), 28.5 at Hγ
Spectral resolution	50Å (average)
Astrometric solution	1" rms accuracy
Scale	1.542"/pix
Photometry	0.3^m accuracy
Data volume	1874 plates, ~400 GB
Number of objects	~20,000,000 (~40,000,000 spectra)

We give in Figure 3 (left panel) a piece of visualized DFBS field together with its corresponding DSS2 area. Some 40,000,000 DFBS low-dispersion spectra have been extracted from 1874 plates, measured and analyzed by means of the dedicated software bSpec (Figure 3, right panel), written by Giuseppe Cirimele.

The spectra extraction and analysis software is described in Mickaelian et al. (2010) and Knyazyan et al. (2011). DFBS plate database is available in Vizier, Strasbourg (Mickaelian et al. 2005).

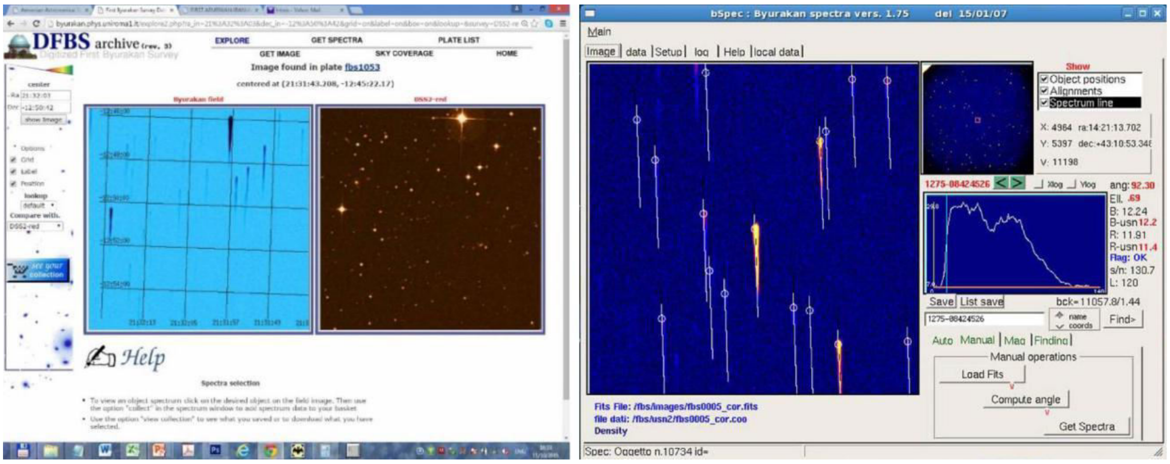

Figure 3. Left: DFBS data visualization with comparison of similar DSS2 field. Right: DFBS spectra extraction and analysis software bSpec.

In Figure 4 we give an example of extraction of an asteroid spectrum from DFBS using VO software SkyBoT proving how useful the DFBS plates can be for follow-up studies (Thuillot et al. 2007; Berthier et al. 2009; Sarkissian et al. 2012). The search for asteroids in DFBS jointly with IMCEE (Observatoire de Paris, France) colleagues was the most advanced research project. Bright (<15^m-16^m) asteroids observed in DFBS are being studied, which are divided into "fast" and "slow" ones depending on their motion during the typical DFBS plate exposure time (20 min), more or less than 3 . All asteroid spectra are being extracted after they are found by means of SkyBoT. Sample spectra are being modelled similar to Solar spectra. Using these spectra and by means of comparisons with other catalogues, new candidate asteroids are being searched. Spectra analysis of asteroid spectra is being accomplished aimed at obtaining definite physical parameters.

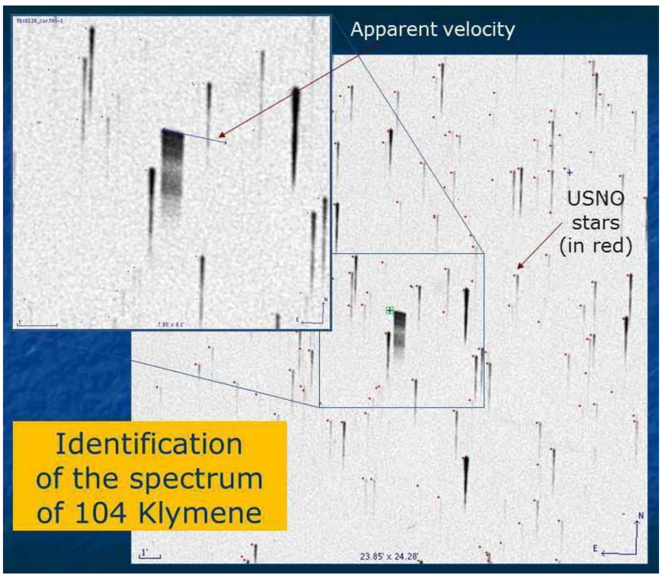

Figure 4. Extraction of an asteroid spectrum from DFBS using VO software SkyBoT.

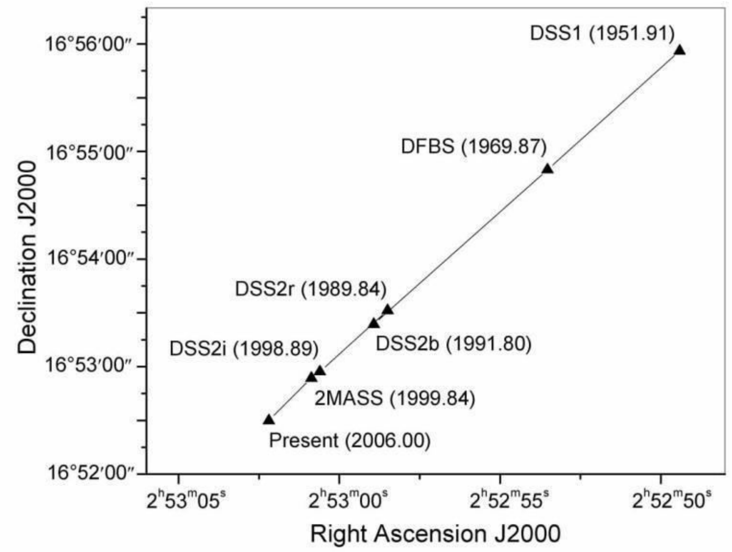

Figure 5. Direction of the motion of the high proper motion (PM=5.050 /yr) star FBS 0250+167, which was found due to DFBS plates.

The efficiency of studies of AGB stars based on DFBS low dispersion spectra and follow-up spectroscopy was shown by Nesci et al. (2014b). Gigoyan & Mickaelian (2007) have found a very high proper motion (PM) M7 type dwarf star, lying about 3 pc from the Sun, FBS 0250+167. Its PM is 5.050 /yr and it is in the list of the 10 known highest PM stars. Figure 5 shows that only existence of additional observational material, namely DFBS plates from 1969, linked measurements between DSS1 and DSS2 and helped identifying this object and measuring its PM.

The Second Byurakan Survey (SBS; Stepanian 2005) plates are also subject for digitization, as they are hypersensitized and their emulsion is more sensitive for deterioration. 180 plates have been digitized so far. Due to SBS smaller photographic grains, 2400 dpi (10µm pixel size) is being used and 512 MB files are being obtained for each plate.

Photographic spectra of the FBS blue stellar objects (BSOs) have been obtained using 2.6m telescope and UAGS spectrograph on photographic films. ~700 such spectra have been scanned with 1600 dpi, 16 bit and 650 21 pix sizes images were obtained (FBS BSOs; Mickaelian 2008 and late-type stars; Gigoyan & Mickaelian 2012). All spectra were put in a standard format, so that automatic reduction was possible (Figure 6). 101 FBS blue stellar objects were published and a number of planetary nebulae, white dwarfs, hot subdwarfs and HBB stars have been revealed (Sinamyan & Mickaelian 2009).

Another project was the study of long-term variability of ON 231, which appeared in the Coma field, where photographic chains for discovery of flare stars were carried out. In total 189 plates with a total number of more than 1200 exposures in 1969–1976 with the Byurakan 21" and 40" Schmidt telescopes were obtained. This was a valuable material for study of ON231 long-term variability (Figure 7; Erastova 2004).

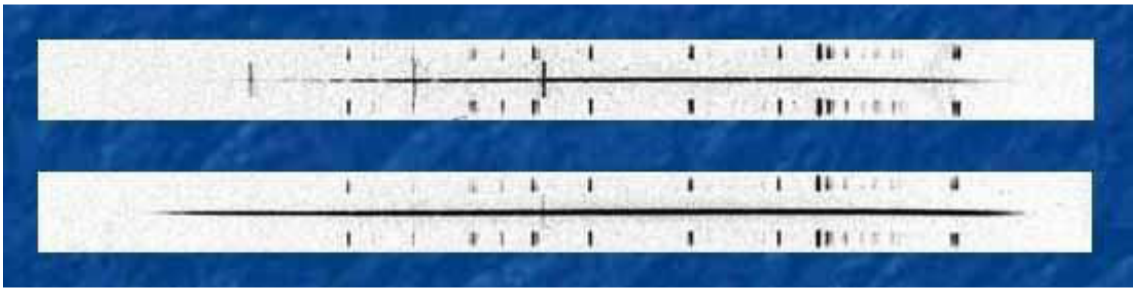

Figure 6. Standard format of FBS spectra with 650 21 pix sizes images for automatic reduction.

Having digitized plates and modern digital observational data, a number of efficient research projects have become possible, such as data discovery, spectral analysis, SED building and fitting, modelling, variability studies, cross-matching, etc. Some examples are variability studies (Samus & Antipin 2012), Cross-matching of Astronomical Catalogs (Malkov 2012), Search for Asteroids and Exoplanets using VO tools (Sarkissian et al. 2012).

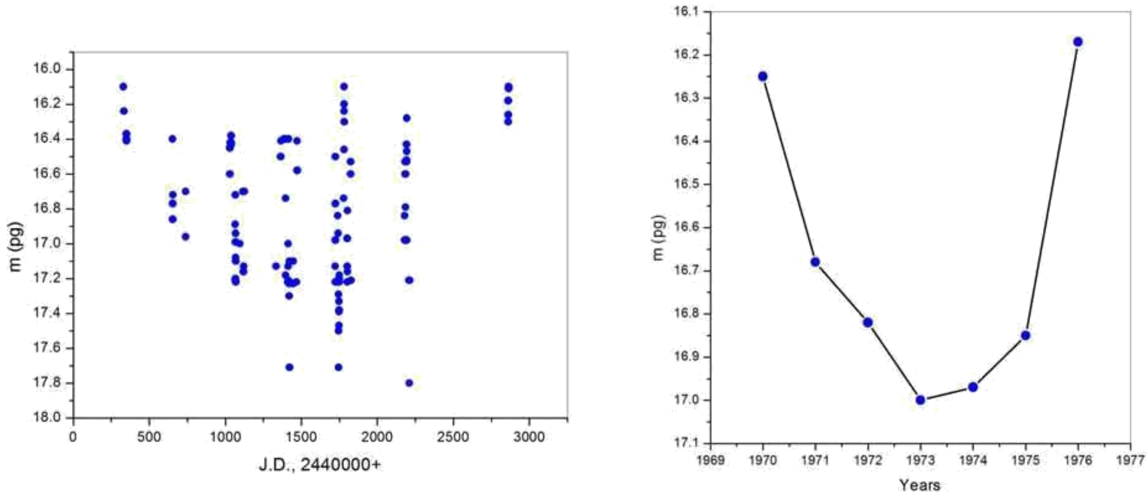

Figure 7. Photometric measurements and variability study of the blazar ON 231 observed in the Coma field.

Our science projects are aimed at discoveries of new interesting objects searching definite types of low-dispersion spectra in the DFBS, by optical identifications of non-optical sources (X-ray, IR, radio) also using the DFBS and DSS/SDSS, by using cross-correlations of large catalogs and selection of objects by definite criteria, etc.

In one of our papers (Abrahamyan et al. 2012), a new tool for cross-correlation of catalogs is presented (Knyazyan et al. 2011), where individual positional error for each object instead of a standard search radius is being taken into account, thus making the result much more accurate and confident (Figure 8).

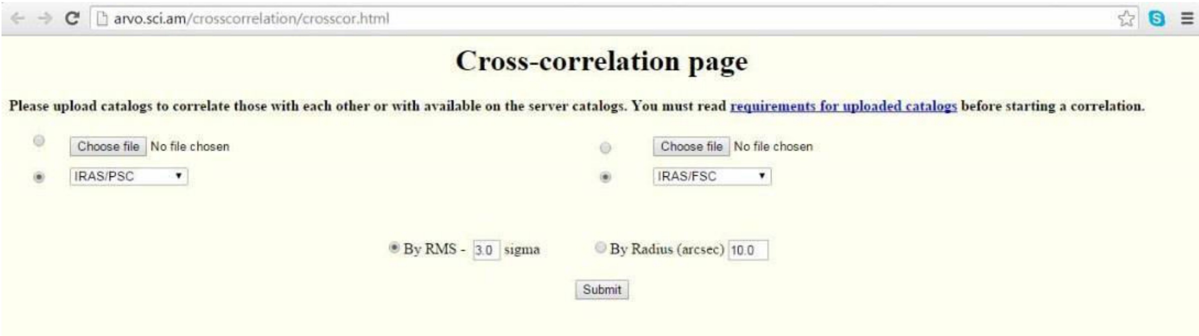

Figure 8. Cross-correlation software developed in frame of ArVO.

6. Summary

At present the main part of the project, the scanning of the plates has produced more than 15,000 digital images of roughly 200 MB files (each image). All they have been stored and double copies are available.

BAO Plate Archive Project will lead to preservation of BAO valuable observational material obtained during 1947-1991. However, our goal is not only to create a passive archive of scanned plates and films, but also to make use of especially those fields, where more studies are possible.

Proper motion and variability studies are most important, as time domain material is contained in historical plates. Such possibilities based on DFBS were shown by Mickaelian et al. (2006); DFBS as a unique database for proper motion, variability studies, and object classification. New variable stars discovered on digitized plates of Moscow collection was reported by Sokolovsky et al. (2014).

There are a number of further **possible research projects** that will be conducted having the plates digitized:

- Correction of ephemerides of known asteroids and search for new asteroids (ex. Thuillot et al. 2007; Berthier et al. 2009)
- Discovery and study of variable stars (ex. Mickaelian et al. 2011; Nesci et al. 2009)
- Revealing high proper motion stars (ex. Mickaelian & Sinamyan 2010)
- Study of variability of known blazars and discovery of new blazars
- Revealing Novae and Supernovae progenitors
- Discovery of new QSOs
- Discovery of new white dwarfs (ex. Sinamyan & Mickaelian 2011)
- Discovery of new late-type stars (ex. Gigoyan et al. 2010)
- Discovery of optical sources of gamma-ray bursts

- Optical identifications of X-ray, IR and radio sources (ex. Mickaelian & Sargsyan 2004; Mickaelian & Gigoyan 2006; Mickaelian et al. 2006; Hovhannisyan et al. 2009).

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New observational project for revealing natural and anthropogenic threats at the near-Earth space

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Abstract

In 2014, a new monitoring project started at the observational base Saravand of the Byurakan astrophysical observatory. This project initiated for revealing natural and artificial objects at the near-Earth space. This is a kind of continuation of earlier observational projects implemented at the observatory prior the collapse of Soviet Union. This time, near-Earth space monitoring is carried out at the request of the Russian agency ROSKOSMOS. For observations, the EOP-1 module is used, which includes small telescopes with a mirror diameter of 40cm, 25cm and 19cm.

Keywords: *Near-Earth space – artificial satellites – cosmic junk - monitoring*

1. Introduction

The cosmic epoch started about six decades ago with the launch of Soviet Sputnik 1 in October 4, 1957. During this period, thousands of artificial objects were launched to various orbits, which make the space gradually more and more junked with metallic debris. These are named space junk colloquially. Actually, these are orbital bits that do nothing useful, namely, spent rocket stages, fragments splayed by collisions and erosion, old satellites no one cares about anymore. In total, they amount to millions of pieces of debris, many of which are large enough to damage satellites. Scientists estimate that there are about 7,500 tons of rubbish in space and we are reaching a critical point.The low-Earth orbit is already overpopulated. Even in the unrealistic case of no new launch politics, the number of debris will grow rapidly. The point is that collisions cascade into more collisions, which create more debris that causes more collisions that cascade into more collisions – the effect called Kessler Syndrome.Just one collision in space can create thousands of new high-speed, out-of-control pieces and threaten other spacecraft.

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On the other hand, governmental and private space agencies continue launching new cosmic vehicles increasing the population of unusable garbage in the Earth vicinity. SpaceX alone, for example plans to send up nearly 12,000 small internet-beaming objects over time. Scientists warn that the growing problem of space debris is putting spacecraft and astronauts at risk. It is estimated that there are about half a million pieces of manmade rubbish orbiting the Earth, ranging from huge defunct satellites, to spent rocket boosters, lost astronaut tools and more. This dangerous orbital garbage is moving roughly 10 times faster than a speeding bullet and takes a long time to crash back to earth. These pieces of metal can stay up there very long. For instance, the lifetime of geosynchronous satellites in high orbits can amount even thousands of years.

2. Early projects at BAO and Armenia for revealing of artificial satellites.

First observations of artificial satellites in Armenia started in 1957 immediately after the first Soviet Sputnik launch. By the decision of the Astronomical council of the Soviet academy of sciences Yerevan astronomical observatory (Yerevan State University Observatory at present) began observations of the first artificial satellites of the Earth, using the small telescopes for this purpose. The 20cm refractor was the largest telescope implemented in this project. Professor Benik Tumanian was the one responsible for observations. There was a small staff implementing observations, and the students of YSU were involved in observations. This project lasted up to beginning of 1970s.

Observations of artificial satellites have become more regular and systematic since 1973, when a department of practical astronomy began its activity in the Byurakan Observatory. That was the time of arms race between "East and West". The number of satellites in circumterrestrial orbits was growing rapidly. In spite the fact that both super states of that time, i.e. the USSR and US were proclaiming their commitment to the ideas of the peaceful usage of the space, some unannounced launches happened periodically. Undoubtedly, the latter ones had military objectives mainly and implemented for reconnaissance data collecting. Potential adversaries used their scientific and technological potential for scouting out the capability of the other side. Therefore, both of the sides continuously looked for any reliable information to contain the assumed enemy. That was the reason for establishing the observational department mentioned above.

Newly organized department was located at Saravand – the area about two km far from the main territory of the BAO, previously used for radio astronomical observations. The staff observed the near-Earth space with several small telescopes, mounted under the semi-cylindrical dome. The observers' team, as well as all the engineers providing the maintenance of the equipment have been graduated from Armenian institutes.

Figure 1. Observational base at the Saravand base, meant for revealing of artificial satellites

The project of revealing the "spy" and lost satellites continued up to the very beginning of 90s of the last century, right up to collapse of the Soviet Union. After that, all the activity in Byurakan aimed at the monitoring of near-Earth space interrupted for decades. Besides the huge role, which played the collapse of the Soviet Union for this situation, there was another strong factor bringing to stop of the mentioned activity. That was the sharp deterioration in the economic situation of Russia itself, which was the main observer of observational data.

3. New stage of observations.

Observations of satellites interrupted when Armenia became sovereign country and old resolutions made by the government of the USSR lost their force. Over time, this followed the devastating earthquake in Armenia, and coincided with military actions on the border of Artsakh with Azerbaijan. The economics of Armenia was completely destroyed, and scientific organizations were surviving at a very low financial level. Interruption of contract made for satellites revealing closed one of serious sources of funding for the Byurakan observatory. Therefore, since 1995 the observatory tried to find ways for restoring the old project or finding new partners to re-operate the unused observational equipment.

Figure 2. The control room and dome-containers of the module EOP-1 at the airport Zvartnots

However, only about ten years after beginning of activities for recommencement of the mentioned observations appeared some chances for it. The group headed by Igor Molotov from the Keldysh Institute of Applied Mathematics was the first to take note the observational opportunities of the Byurakan observatory potentially qualified for joint research of the near-Earth space. Of course, in the center of their attention were the large telescopes of the BAO. They were interested in using large telescopes of the observatory, since they needed to investigate more closely the near-Earth space in order to detect rather small pieces of cosmic debris. For this purpose, the Russian counterpart even suggested to change optical focuses of the telescopes for providing wider observational field. However, it could mean that the telescopes turn into instruments designed for solving only similar problems, which rejected at the very beginning of cooperation.

Nevertheless, this initiative was continued, and in 2011, the foundation for the observational station EOP-1 was laid at the Saravand base. In parallel, the observatory renewed completely the power supply of the Saravand area, for which the transformer substation was fully equipped. At the end of 2013, the Russian company “Astronomical Scientific Center” airlifted all the necessary equipment of the EOP-1 with small telescopes to Armenian airport Zvartnots. The same day all the equipment with the containers designed as observational domes and control room were transferred to the Saravand area.

In February 2014, the EOP-1 started first observations. Nearly at the same time rebuilding of practically destroyed two-store laboratory building. It turned out to be an incomparably long and hard work, because last almost twenty-five years, passed after the last operations in this area, was a period of complete breakdown for this base. During this time, the roof of the building, and then the entire internal structure became into complete disrepair. Repairs in the building are going on up to now, although a huge part is over already.

Figure 3. The fundaments of telescopes and containers-domes built at Saravand.

At the beginning of August 2014, the BAO observing crews started observations as well. Since August 2014, four crews have been working each consisting of three observers who perform scheduled observations on a shift basis. Each observation crew consists of two specialists from the Byurakan Observatory and one specialist from Russia. The schedule of work is drawn up in such a way that Armenian participants work every fourth week, and Russian specialists every fourth month. Since the very beginning of these observations, the working conditions improve continuously. Depending on various responsibilities at the observatory as well as on the changes in marital status, some members of crews have left the group of observers and new ones were involved as observers.

4. EOP-1 module

It is obvious that for observing the near-Earth space one needs high aperture and wide field telescopes. These telescopes should have focal field of, at least, a few square degrees.

The largest at present telescope operating in the frame of module EOP-1 is the OES-1 with the objective diameter 400mm and the focal length 1200mm. The focal field of this telescope has sizes 1.75°x1.75° giving total about 3 square degrees. In the dark and astronomically good night, one can reveal objects up to 17.5^m.

Figure 4. Observational module EOP-1 operating at the Saravand base of the BAO

Figure 5. 250 mm aperture telescope mounted in the container-dome.

The second telescope included into EOP-1 is a little bit smaller, providing good results of observations up to15.5^m.This telescope has an aperture, which is equal to 250mm, and gives rather good images in the rectangular field of sizes3.3°x2.2°. The focal length is 627mm.

At last, the smallest telescope consists of two identical cameras VT-78 designed by Valeriy Terebizh. Those are 190mm aperture and 295mm focal length cameras, providing wide rectangular field of sizes 7.1°x4.7°.

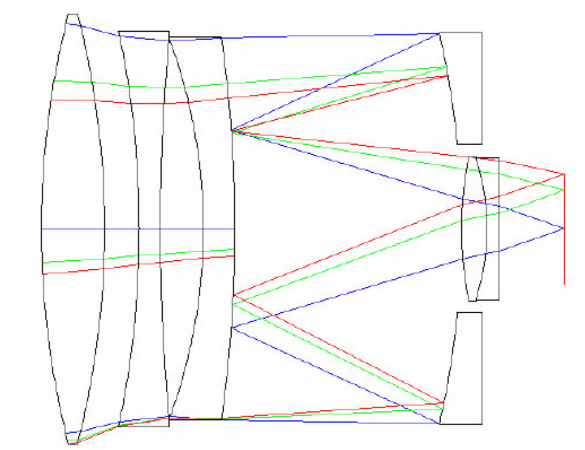

Figure 5. The optical scheme of the camera VT-78.

All these telescopes are equipped with modern light detectors, built on the base of modern CCD matrices. The central computer controlling telescopes guiding and movement collects observational data as well.

5. Working and living conditions

The observational base of the BAO at Saravand exists since the beginnings of 1960s. At that time, in this territory there was located the department of radio astronomy of BAO, for the life of which the entire infrastructure was created. There were two laboratory buildings (two-storied and one-storied constructions, built of Byurakan red-yellow tuff), a transformer substation, central heating, a water pipe, etc. In laboratory buildings, all the working rooms, workshops and laboratory facilities were located. When the project aimed to observations of artificial satellites began, a part of the two-storied building was used for the new project, but some new buildings were built as well (some are shown in Fig.1).

As we noticed above the last decade of last century and the first decade, when the Byurakan observatory was in grave conditions, the situation at the Saravand base was much worse. Since these buildings were not used for almost a quarter of a century, all of them were dilapidated, some of them no longer had a roof and the water of atmospheric precipitations flowed to the basement. It was clear that in these conditions, the exploitation of these buildings is impossible. There were few alternatives: either one had to repair the existing buildings, or build a new residential and working module for carrying out the scheduled work on the project. We preferred the first alternative, since the existing buildings, although partially fractured due to difficult environments and lack of maintenance, the buildings built about fifty years ago, could provide all the necessary conditions to implement the project. There was a lot of space for offices, bedrooms, a conference hall, a kitchen dining room, domesticity etc. Therefore, the two-storied building was renewed for these purposes.

Figure 6. The two-storied laboratory-living building before and after the renewal.

Now, after three years of restoration work, the two-storied laboratory building is almost completely renovated. The renovated building has an autonomous heating system, and observers can stay there and work.

6. Outlooks

This project is carried out within the framework of the Center for Applied Astronomy of the Byurakan Observatory. It is envisaged that in the future the monitoring capacities of this station will increase. As a first step, the introduction of a new telescope with an aperture of 650 mm is being considered. This will make it possible to detect objects at least one stellar magnitude fainter than what is currently possible with a 400mm telescope.

On the other hand, the Center for Applied Astronomy undertakes for other activities as well. The Byurakan Observatory and the Corporation “Russian Cosmic Systems” have signed a preliminary Agreement for establishing here also an access point for telecommunication and information exchange. At present, the observatory has only radio connection with the Internet. When this agreement comes into force and the relevant work commences, the Byurakan Observatory will receive a fiber-optic connection to the Internet as a by-product.

Of course, Byurakan astrophysical observatory is established mainly for the fundamental research in the field of astrophysics. Therefore, the Byurakan observatory is well known for its results obtained in the fundamental research, namely, in the fields of stellar and extragalactic astronomy, especially, for the new ideas concerning the active phenomena and evolution issues. However, in the modern world adaptation of scientific knowledge to the practical problems becomes more challenging.

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Ecology of Near-Earth Space

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Abstract

The technical achievements of our civilization are accompanied by certain negative consequences affect the near-Earth space. The problem of clogging of near-Earth space by "space debris" as purely theoretical arose essentially as soon as the first artificial satellite in 1957 was launched. Since then, the rate of exploitation of outer space has increased very rapidly. As a result, the problem of clogging of near-Earth space ceased to be only theoretical and transformed into practical.

Presently, anthropogenic factors of the development of near-Earth space are divided into several categories: mechanical, chemical, radioactive and electromagnetic pollution.

1. Introduction

Development of our civilization is always inevitably crossed with the questions of preservation of natural and favourable conditions for our life. The mankind aspires forward, mastering all new and new spaces, including, near-Earth. Achievements of scientific and technical progress, including the launch and operation of spacecrafts, entered very strongly in our life. However, the technical achievements of our civilization are accompanied by certain negative consequences, which, first of all, affect the environment around us, including near-Earth space. This contributed to the origin of one of the youngest areas of science - ecology, the science of the relationship of organisms, their communities and the environment. One of the directions of ecological researches is studying of the consequences of our activity in near-Earth space. Unfortunately, it is not always possible to evaluate accurately a real situation, and furthermore, to calculate the consequences. In many cases we can assess current situation only statistically. What can be said for sure is that the environment surrounding us is an interconnected mechanism and that an unreasonable exploitation of which can lead to irreversible consequences.

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2. Near-Earth space

Near-Earth space (NES) is the global environment surrounding the biosphere of our planet. The zone of its action modern authors define differently, depending on the tasks they solve. Many researchers consider that NES can be prolonged up to the Earth incidence border that makes about 930 000 km. Most often it is the area from the layers of the neutral terrestrial atmosphere (160-200 km) up to the lunar orbit, which is about 384,400 km.

The composition of the NES includes the upper layers of the atmosphere, the ionosphere, and the magnetosphere with radiation belts. It is penetrated by gravitational, geomagnetic, geoelectric and interplanetary magnetic fields, solar wind, streams of charged particles of solar and galactic origin. Comets, asteroids and their fragments, meteor showers, interplanetary dust, etc. fall on it. The interaction of the components of the NES with each other causes complex exchange processes which exert both direct and indirect influences on the biosphere of the Earth, affecting to a certain extent the course of physical, biological, evolutionary processes in animate and inanimate nature.

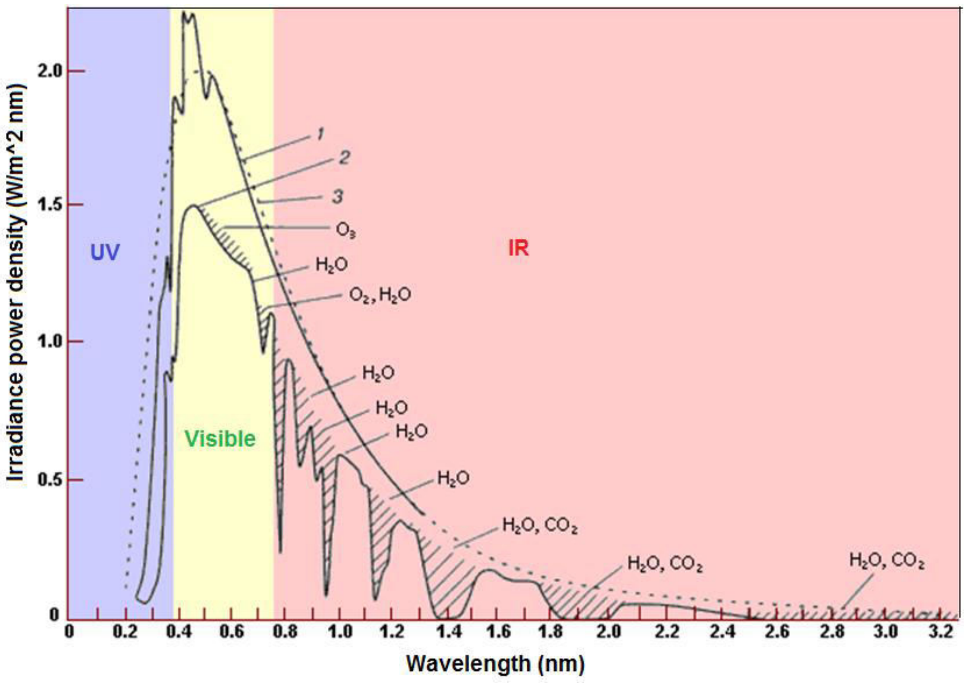

Figure 1. Solar spectra in UV, visible and IR ranges: 1 - outside the atmosphere; 2 - on a sea level; dashed line - the radiation of a black body with a temperature of 6000° K. The shaded areas show the absorption by the atmospheric constituents.

Undoubtedly, the main energy supplier in NES is the Sun, under the influence of which the overwhelming number of processes in the Earth-NES system take place. The spectra of the solar radiation is shown on Fig. 1 (Муртазов, 2008). In the visible and infrared wavelengths it is close to the spectrum of a black body with a temperature of 6000° K. The solid curves 1 and 2 in Fig. 1 show the spectra of the solar radiation outside the Earth's atmosphere and at sea level. In the second case, the radiation intensity is reduced due to an absorption in the atmosphere. Due to selective absorption (shaded areas) by the atmospheric constituents (O_2, H_2O, CO_2, etc.), the radiation attenuation is uneven. Solar ultraviolet radiation in 200 - 400 nm range is biologically active, i.e. has a high ability to affect organisms and the biosphere. This range is usually divided into two intervals: 320-400 nm (UV-A) and 200-320 nm (UV-B). Only UV-A radiation reaches the surface of the earth. The harmful to all living matter UV-B radiation is almost completely absorbed by ozone (O_3).

The atmosphere around the Earth not only provides the air we need, but also performs a protective function. It has a complex layered structure. The lowest layer (troposphere), which extends to a height of 12-15 km, contains 90% of the mass of the entire atmosphere. The ozone layer, which is currently the subject of active debate, locates at an altitude of 10 to 60 km, with a maximum concentration at an altitude of 20 - 25 km. Let's note that the percentage of ozone is a fraction of a percent. If to distribute the ozon evenly on all atmosphere, then its thickness will be less than 3 mm. But ozone substantially provides absorption of harmful UV. In addition, atomic oxygen and nitrogen are also involved in this process.

Above an altitude of 30 to 1000 km is the ionosphere, named so, because the substance there is in an ionized state. It is due to the ionosphere, such a need for us a distant radio shortwave is carried out. In addition, the ionosphere, and to a greater extent the uppermost layer - the magnetosphere, regularly protect us from penetrating into the lower layers of the atmosphere of high-energy cosmic rays.

In addition to protecting from short-wave radiation harmful to humans, the atmosphere also protects us from the penetration of meteoric bodies and the debris of spacecrafts, which in total is called natural and technogenic space debris. Bursting with great speed into the atmosphere, fragments of space debris create local regions with an increased degree of ionization.

Despite the great distance, there are many undeniable facts that all changes in the atmosphere lead to certain consequences on the surface of the Earth and vice versa. According to modern estimates, the changes in physical parameters (for example, electron concentration), which human activity brings in this area, is still small. They are almost two less, than natural. However, the scale of human activity is growing exponentially. Furthermore, the density in the upper atmosphere is very small. If the molecular density in air in the upper layers of the troposphere is $3{\cdot}10^{19}$ particles/cm^3, the density at a height of 100 km is $3{\cdot}10^{13}$ particles/cm^3, then at an altitude of 300 km it already drops to $3{\cdot}10^{9}$ particles/cm^3. Because of the high sparseness of matter, any changes in the upper layers of the atmosphere are restored much more slowly than in the lower layers. For example, the increase in the radiation background in the uppermost layers of the atmosphere - the magnetosphere, which was formed as a result of a series of nuclear explosions conducted on the surface of the Earth in the 1960s, lasted more than 10 years.

3. Ecology of near-Earth space

In 1957, with the launch of the first artificial satellite was launched near-Earth space exploration. Presently, it is very difficult for us to imagine our life without satellite technology. According to the functional purpose, satellites are classified into the following categories: scientific, geodesic, meteorological, navigational, military and engineering.

The problem of clogging of near-Earth space by "space debris" as purely theoretical arose essentially as soon as the first artificial satellites were launched. At present, as a result of active exploitation, the problem of clogging of near-Earth space ceased to be only theoretical and transformed into practical. Anthropogenic factors of the development of near-Earth space are divided into several categories: mechanical, chemical, radioactive and electromagnetic pollution.

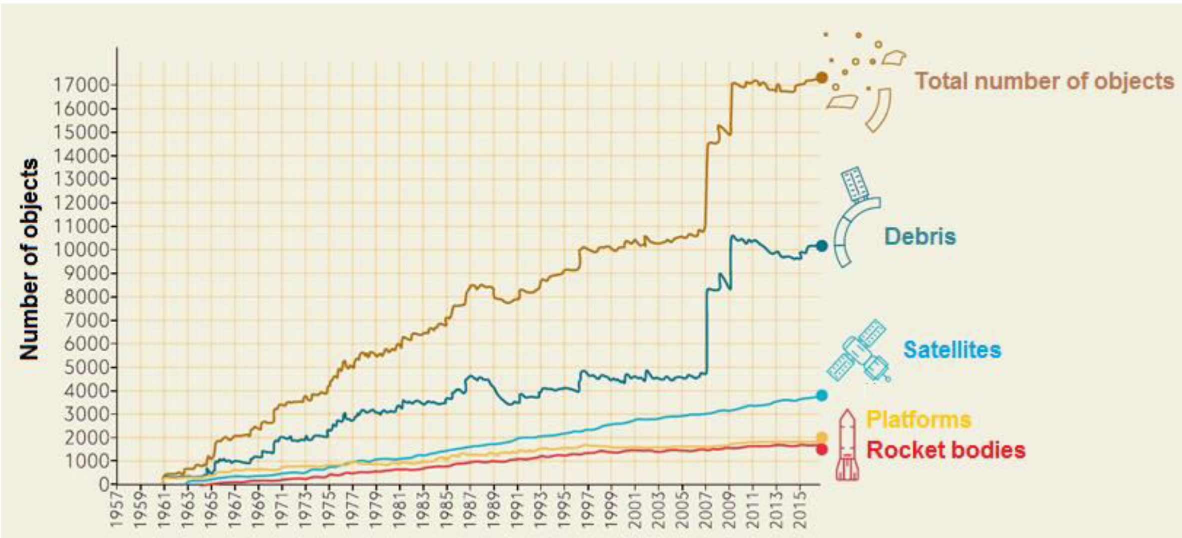

Figure 2. History of pollution of near-Earth space by objects of different categories since 1957 (Вениаминов, 2016).

Mechanical pollution

According to the data of 2015, over 17,000 space objects of artificial origin are catalogued on near-earth and geostationary orbits. Their total mass is close to 7000 tons. On Fig. 2 the distribution of the total number of registered artificial objects of various categories is shown. The graphs clearly show that the number of fragments over the past years has grown very rapidly. The part, suppressing in a percentage ratio is the share of fragments or scraps. Of the total number of objects, only about 6% are "active", i.e. functional satellites. The remaining 94% can be attributed to space debris (see Fig. 3), which does not perform any useful work. It should be noted that the data represent only the registered objects. Their real number is undoubtedly greater.

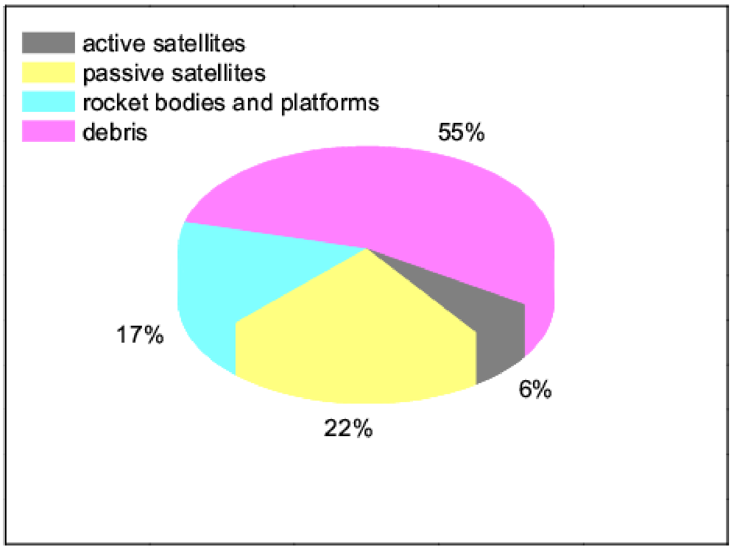

Figure 3. The composition of artificial space bodies.

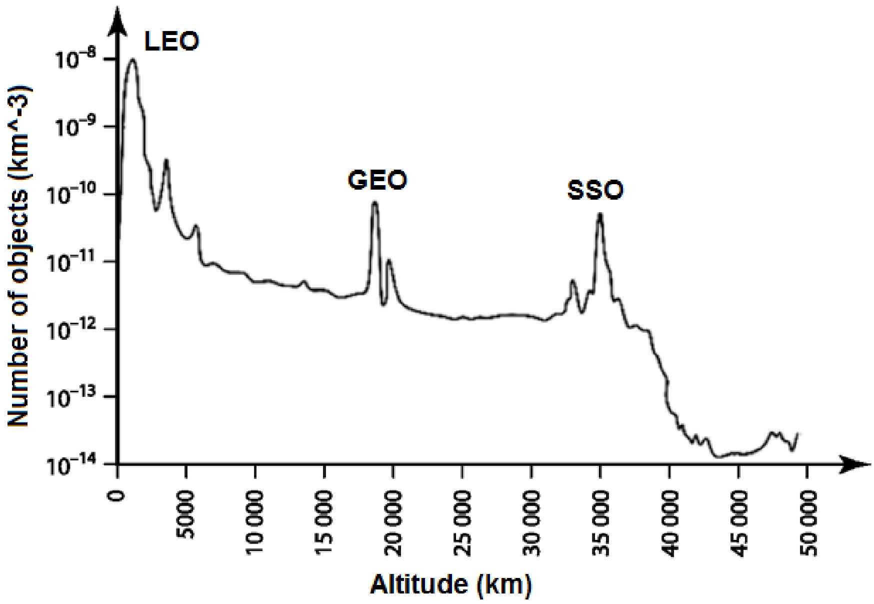

Figure 4. The height distribution of catalogued artificial space objects (data from Kaman Sciences Corporation).

Artificial, technogenic bodies are not equally distributed in the near-Earth space. Most clogged those of Earth's orbit, which are most often used for spacecrafts. These are Low Earth orbits (LEO), Geostationary orbits (GEO) and Sun-Synchronous orbits (SSO).

Presently, as a result of human activity in near-Earth space, the flow of fragments of artificial origin in LEOs is comparable to the flow of bodies of natural origin (meteoritic matter), which is reflected in Fig. 5 (Новиков, 2006). It should be noted that the figure shows the data only for objects with a diameter greater than 10 cm.

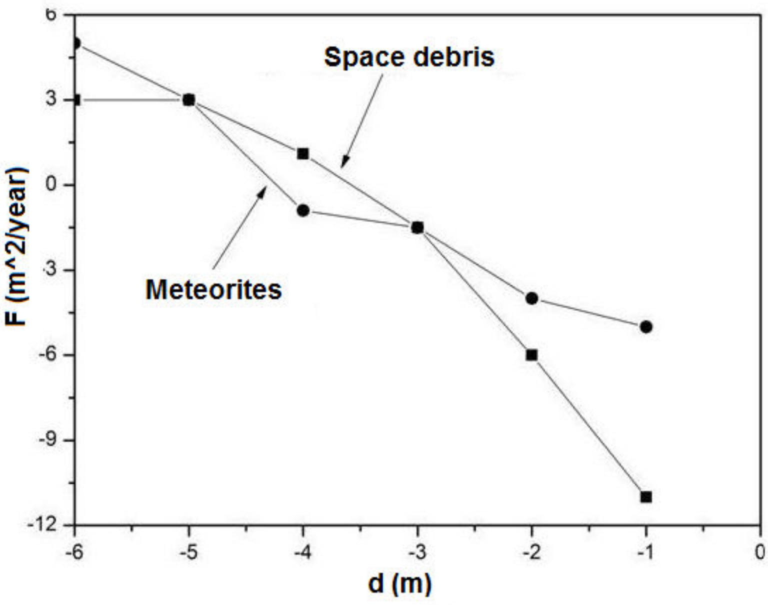

Figure 5. The ratio of flows of technogenic objects and meteoroid matter of various sizes in the region of low near-Earth orbits.

In addition to the "large" particles in the universe, there are many smaller particles that emerge during explosions on satellites or as a result of collision with the meteorites. According to various estimates, the number of fragments with 1 -10 cm diameter reaches 200 - 250 thousands, and with 0.1 - 1 cm range from 80 to 100 millions. Viewing and calculating the objects with these dimensions are very difficult. In addition, there is a very large number (about 1016) of particles with a diameter of 1 to 10 microns, which are fragments of solid propellant, paint, etc. Although their lifetime is relatively small and makes up to 1 to 10 days, their number (mainly due to clashes) is rapidly growing and at present the density of these small particles is about 4 g/cm^3.

Chemical pollution

Chemical pollution is mainly caused by the release of rocket fuel into the atmosphere. This has a much greater effect on the lower layers of the atmosphere than on near-Earth space. In general, this occurs at an altitude of 10-40 km, in the region of the location of the ozone layer. However, in defense of rocket technology, it should be noted that this is an insignificant part, in relation to the anthropogenic impacts of industry. In addition, the release of rocket fuel also affects the ionosphere, forming, at an altitude of 400-500 km, so-called ionospheric holes, i.e. regions with a lower electron concentration, which affects the propagation of radio emission and creates interference in radio communication lines.

Electromagnetic pollution

Electromagnetic pollution is called the technogenic radiation that created by satellites and their transmitters. Penetrating in the ionosphere and magnetosphere the electromagnetic pollution also causes environment ionization degree changes, which, in turn, can affect the quality of radio communication.

Radioactive pollution

Radioactive pollution occurs due to the fact that in certain satellites the radioactive substances is used. These substances can penetrate in the atmosphere and even reach the Earth's surface.

4. Prediction of the ecological situation in the near-Earth space

Thus, the achievement of cosmic space, the exploitation of space equipment, has dramatically widened the range of environmental issues. We will never abandon our technical achievements. On the contrary, there are all reasons to assume that the rate of exploitation of outer space will be increasing. That is why we should be able to make accurate estimates of the inevitable consequences and take timely action to prevent them, or at least mitigate them.

Unfortunately, at present we can only control the near-Earth space. The monitoring includes observations and constant control of the general condition, the degree of natural and anthropogenic pollution. It is also necessary to develop methods for assessing the physical state of near-Earth space as part of the natural environment, both for a given period of time and in the future. To assess the state of near-Earth space in the near future computational models are created: Russian SDPA (Space Debris Prediction and Analysis), European MASTER (Meteoroid and Space debris Terrestrial Environment Reference model), American ORDEM (Orbital Debris

Engineering Model), etc. Fig. 6 shows the results of the forecast for the next 50 years, made with SDPA model. This figure shows the relative change in the total number of technogenic space objects larger than 1 cm in the region of LEOs (below 2000 km). In the simulations 5 different scenarios of near space operation were used:

1. The intensity of clogging of near-Earth space will remain at the level of the previous 10 years,
2. Scenario 1 plus the exclusion of the accompanying fragments of the launching rockets;
3. Scenario 1 plus the exclusion of explosions of artificial space objects;
4. Decreasing by 2 times the number of the launches of spacecraft;
5. Simultaneous application of the scenarios 2 - 4.

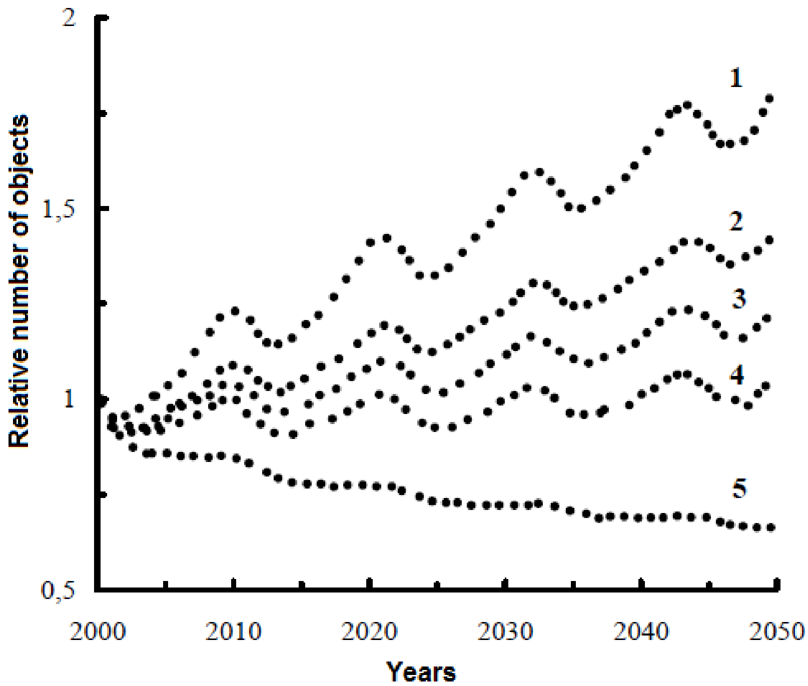

Figure 6. A forecast of the total number of technogenic space objects larger than 1 cm in LEOs (Муртазов, 2008).

On graphics it is visible that at scenario 1-4 is predicted the growth of the number of man-made objects. Periodic fluctuations in the number of objects on the graph are associated with the 11-year cycle of solar activity, which causes modulation of the average density of the upper atmosphere of the earth and, accordingly, increased braking of space objects during the period of maximum solar activity. First option - the most unfavourable. In accordance with it, in 2050 the number of man-made objects will increase by 1.8 times. The most effective method is to exclude explosions of spacecraft. Under scenario 5, the probability of reducing the level of pollution of near-Earth space in 2050 will be 25-30%.

Figure 7 shows the forecasts of the number of collisions per year between catalogued objects for the following scenarios:

1. Preservation on the same level the intensity of launches;
2. Preservation on the same level the intensity of launches during 20 years and their further termination;
3. Termination of further launches.

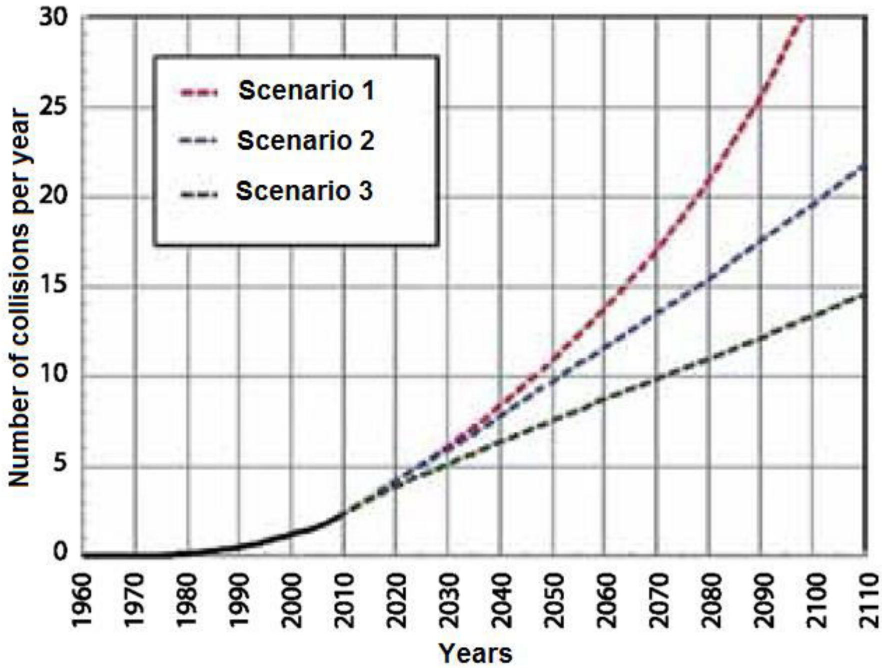

Figure 7. Forecasts of the number of collisions per year between catalogued objects.

In all cases, the forecasts are not comforting, especially taking into account the fact that there is no reason to expect a reduction in the number of launches of new spacecrafts. There is a need to develop ways to clean fragments already flying in space. Similar developments are already under way. However, their implementation requires very large investments and joint, international efforts.

We want, nevertheless, to finish on an optimistic note. Mankind is not the first time to face global problems and the way out has always been.

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IAU South West and Central Asian Regional Office of Astronomy for Development

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Abstract

The International Astronomical Union (IAU) announced its Strategic Plan on *Astronomy for Development* in 2009, during the International Year of Astronomy (IYA). One of its main components was the creation of the Office of Astronomy for Development (OAD) and corresponding Regional Offices (ROADs) for implementation and coordination of its aims. The OAD was created in Cape Town, South Africa and later on ROADs were created in 8 regions. Since 2015, Armenia hosts one of them, IAU South West Asian (SWA), later renamed to South West and Central Asian (SWCA) ROAD. At present, already 6 countries have officially joined (Armenia, Georgia, Iran, Kazakhstan, Tajikistan, and Turkey), but the Office serves for a rather broad region, from Eastern Europe to Central Asia. Armenia's geographical location and its historical role in astronomy (both for well-known archaeoastronomical heritage and the presence of the famous Byurakan Astrophysical Observatory (BAO) founded by Viktor Ambartsumian in 1946) serve as a link between Europe and Eastern Partnership countries, Middle East and Asia in general. We run activities in 3 directions, Task Forces (TF): TF1 *Universities and Research*, TF2 *Children and Schools* and TF3 *Public Outreach*. We present our projects and all other accomplishments and discuss the role of our ROAD in maintaining contacts and development of astronomy in the region, as well as contacts between Europe and the Eastern Partnership countries. Most up-to-date information about the IAU SWCA ROAD is available on its webpage at http://iau-swa-road.aras.am/eng/index.php.

Keywords: *IAU – OAD – regional offices –astronomy development – astronomical education – public outreach.*

1. Introduction

The International Astronomical Union (IAU) developed and adopted in 2009 a decadal Strategic Plan (SP) now entitled *"Astronomy for Development"*. The SP significantly increases the role of astronomy for other sciences, technology, culture and society, as it is tightly linked to all this(Figure 1). This plan has been resulted from an extensive process of consultation beginning with a meeting of stakeholders in Paris in January 2008 and including feedback from key stakeholders during the

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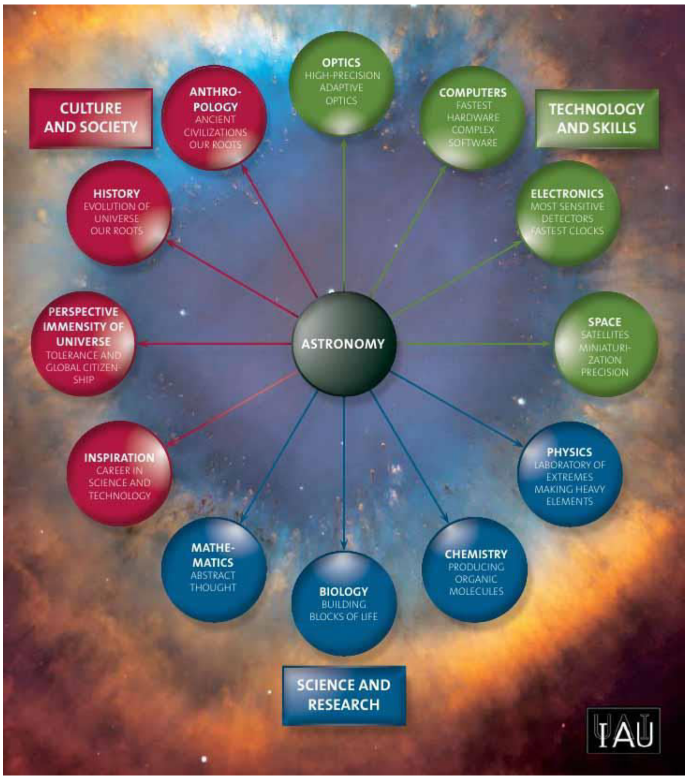
various drafts of the SP. It was endorsed by the General Assembly of the IAU in Rio de Janeiro in August 2009, and builds on the momentum of the very successful International Year of Astronomy 2009 (IYA). The objective of this SP is to use Astronomy to stimulate development in all regions of the world. Crucial to the implementation of the SP was the creation of a global "Office of Astronomy for Development" (OAD). The OAD is tasked with establishing and strategically coordinating Regional Offices (ROADs) and Language Expertise Centres (LOADs) across the world as well as three Task Forces, namely (i) *Astronomy for Universities and Research*, (ii) *Astronomy for Children and Schools*, and (iii) *Astronomy for the Public*.



Astrophysics
Astrochemistry
Astrobiology
Astrogeology
Space research
Instrumentation
Astroinformatics
Astrostatistics
VO / e-Science
Astronomy in Culture
Archaeoastronomy
Astro tourism
Astro journalism
Astronomical Education
Amateur Astronomy
Popular Astronomy

Figure 1. The relation of Astronomy with other sciences, technology, culture and society. A number of inter- and multi- disciplinary sciences and other fields are listed having tight relation to astronomy.

Through a strong partnership with the South African government, the OAD is hosted at the South African Astronomical Observatory (www.astro4dev.org), a facility of the National Research Foundation. Furthermore, 8 regional offices were created, one of them in Armenia.

2. The Establishment of the IAU SWA ROAD

Armenia showed interest and activities in the establishment of one of the regional IAU offices since the beginning of the initiative (2009-2011). Armenia's proposal to host a ROAD was rather strong both from the point of view of the available facilities and ongoing activities. The proposal was finally approved on 10 June, 2015 and an agreement was signed between the IAU and the Byurakan Astrophysical Observatory (BAO) on 6 August 2015. The office was formally established on 1 September 2015 and was called **IAU South West Asian(SWA) ROAD**. *Dr.* Areg Mickaelian became its Director. SWA Regional Steering Committee was created in September 2015, as well as SWA webpage was opened also in September 2015 (http://iau-swa-road.aras.am, Figure 2). The staff members joined on 1 October 2015; Naira Azatyan (TF1 coordinator), Sona Farmanyan (TF3 coordinator), and Gor Mikayelyan (webmaster). Finally, the Inauguration Ceremony was held on 13 October 2015. IAU OAD / SWA ROAD Workshop was also attached to this event. Representatives from the IAU (General Secretary Piero Benvenuti, former Vice-President George Miley, OAD Director Kevin Govender) and representatives of regional and some other countries (Georgia, Iran, Turkey, Russia, Israel, Jordan) were present.

Like our long tradition to organize joint Armenian-Georgian (Byurakan-Abastumani) workshops (colloquia) since 1974, we conducted a new series of Armenian-Iranian Astronomical Workshops (AIAW). The first one was organized on 13-16 October, 2015 in Byurakan, so that all Iranian guests were able to participate in the IAU SWA ROAD Inauguration Ceremony.

Figure 2. IAU South West and Central Asian ROAD webpage.

Georgia and Iran were the first countries along with Armenia to officially join the SWA ROAD. During many years and centuries, these countries have had numerous relations in all areas, including science and Astronomy.

Figure 3. Abastumani Astrophysical Observatory in Georgia.

Astronomy in Georgia is generally represented in Abastumani Astrophysical Observatory (AbAO) founded in 1932. It is one of the leading scientific institutes in the country. Main fields of research are Solar System bodies (including near-Earth asteroids), various aspects of Solar physics, stellar astronomy (including binary stars and open clusters), extragalactic objects (AGNs), theoretical astrophysics, cosmology, atmospheric and Solar-terrestrial physics. Although research in these fields are carried out in other institutions in Georgia as well: Institute of Theoretical Physics at Ilia State University, Javakhishvili Tbilisi State University, School of Physics at Free University of Tbilisi. In AbAO, several telescopes are operational today, as well as the instruments for atmospheric studies. At present, in AbAO the 70-cm Maksutov meniscus telescope, 53-cm azimuthal reflector, 22-cm reflector ORI, 40-cm double astrograph, 53-cm large and 11.5-cm small solar coronagraphs are operational. They are equipped with CCD cameras. Spectroscopic and photometric observations are carried out. The instruments for atmospheric studies include: aerosol lidar M-10 system, GRIPS-5 to measure the mezopause temperature, all-sky imager for measurements of some parameters of the nightglow, as well as the ozonometer. The new magnetometer to monitor the Earth's magnetic field has been installed recently. Astroclimatic conditions of Abastumani makes the location favourable for installation of advanced astronomical instruments, which is one of the main goals of the

Observatory in the nearest future. In 2007 the Observatory was integrated with Ilia State University, merging scientific research and education which facilitated the growth of a new generation of researchers. There are groups of astronomers and astrophysicists in other Georgian universities and institutions as well. Georgian scientists collaborate with research centers and universities worldwide. Research groups participate in various international scientific projects. In the recent years the interest in astronomy in Georgia has been growing, which increases future perspectives of its development in the country.

Astronomy in Iran routes back to many thousand years ago. When Cyrus the Great, the founder of the Persian Empire, captured Babylon in 539 B.C., Magi who migrated there transformed Babylonian astronomy. They were the first to record planetary motion through constellations. In turn Magi learned from the Babylonian astronomers as well and translated Babylonian books into the early Persian language. Andromeda galaxy was first identified by a Persian astronomer Abd al-Rahman al-Sufi calling it a little cloud in his book of fixed stars around 964. In 13thcentury, Maragheh Observatory with a unique place in the history of Medieval Astronomy, was established, representing a new wave of scientific activities in the Islamic world. It had a key role in the development of sophisticated pre-Copernican non-Ptolemaic systems for explaining the planetary motions, and it was the model for several observatories that were built in Persia, Transoxiana, and Asia Minor up to the 17thcentury. At present, research in Astronomy and Astrophysics has been conducted in a number of universities in Iran. There are two dedicated research institutes in Iran, IPM School of Astronomy in Tehranand Research Institute for Astronomy and Astrophysics in Maragheh (RIAAM). Among the most active universities in Astronomy one could name IASBS in Zanjan, Ferdowsi University of Mashhad (FUM), University of Tabriz, Shiraz, Birjand, Kerman and Zanjan universities, and Amirkabir University of Technology and Sharif University of Technology, both in Tehran. With nearly 400 members, the Astronomical Society of Iran (ASI) is a non-governmental organization that represents the Iranian community of astronomy internationally and with IAU, it coordinates various activities for professional and amateur astronomers and organizes training workshops, throughout the year. Iranian astronomers gather twice a year to share their ongoing research activities. The ASI also publishes an International Journal of Astronomy and Astrophysics (IJAA) which is a peer reviewed open access journal dedicated to original research and invited/review articles by distinguished astronomers around the world. Astronomy is also popular in Iranian schools. International Olympiad of Astronomy and Astrophysics (IOAA), in which

Iranian teams do very well, see a participation of a few thousand students in a national exam. The Iranian National Observatory (INO, Figure 4) is under construction at an altitude of 3600m at Gargash summit 300km southern Tehran. The site selection was concluded in 2007 and the site monitoring activities have begun since then, which indicates high quality of the site with a median seeing of 0.7 arcsec through the year. One of the major observing facilities of the observatory is a 3.4m Alt-Azimuthal Ritchey-Chretien optical telescope which is currently under design. This f/11 telescope will be equipped with high resolution medium-wide field imaging cameras as well as medium and high-resolution spectrographs.

Figure 4. Iranian National Observatory (INO) at Gargash summit.

Since the beginning, IAU SWA ROAD developed activities in all three Task Forces. A number of meetings and schools were organized and a number of other projects were accomplished. Especially, successful were the activities related to Scientific Tourism in Armenia and in the region. We were awarded two grants in 2016: OAD grant for the development of Astro Tourism in the South West Asia and Swiss SDC grant for the development of Scientific Tourism in Armenia.

SWA ROAD representatives, the Director Areg Mickaelian and BAO Director Haik Harutyunian took part in the IAU Arab World ROAD opening inDecember 2015. In February-March 2016, Areg Mickaelian and Sona Farmanyan took part in the OAD/ROADs meeting in Cape Town, South Africa. The whole SWA team (Areg Mickaelian, Susanna Hakopian, the new TF1 coordinator, Sona Farmanyan, and Gor

Mikayelyan) visited Georgia in March-April 2016 for tightening the collaboration and exchange of scientific knowledge. In August 2016, Areg Mickaelian and Sona Farmanyan were invited to RIAAM, Maragheh, Iran to participate in a workshop and gave talks.

We hold regular telecons both with OAD/ROADs andwith the SWA ROAD Steering Committee to give short reports on the accomplished affairs, and to discuss all current and future matters.

3. Expansion to IAU SWCA ROAD

In May 2016, Areg Mickaelian and the Scientific Secretary of BAO Elena Nikoghosyan visitedthree Central Asian countries, Uzbekistan, Kazakhstan and Tajikistan to recover our former contacts and collaboration. As a result, during June 2016, Kazakhstan and Tajikistan with official letters also joined our ROAD. This significantly strengthens our centre and expands its sphere of activities to Central Asia.

In Kazakhstan, Fesenkov Astrophysical Institute (APhI), Almaty (founded in 1941) is the main astronomical centre. At present *Dr.* RashitValiullin is the Director. One of the outstanding scientists, *Prof.* Eduard Denissyuk, was one of the first astronomers to spectroscopically observe Markarian galaxies and has long-year collaboration with BAO astronomers. There are three attached observatories to APHI: Kamenskoe Plateau Observatory (altitude 1450m, AZT-8 70cm, Zeiss-600 60cm, Hertz telescope-reflector 50cm, Wide aperture Maksutov meniscus telescope 50cm), Tian-Shan Observatory (TShAO, altitude 2735m, two 1m telescopes) and Assy-Turgen Observatory (altitude 2750m, 1m telescope). The research subjects are: *physics of stars and nebulae; physics of the Moon and planets; cosmology, stellar dynamics & computational astrophysics; nuclear astrophysics; artificial Earth satellites; advanced astrophysical research.* Kazakh National University (KazNU) (with 16,000 students) is the main university preparing professional astronomers/astrophysicists.

Figure 5. Main building of Fesenkov Astrophysical Institute in Almaty, Kazakhstan.

In Tajikistan, Institute of Astrophysics of Academy of Science of the Republic of Tajikistan, in Dushanbe (founded in 1932) is the main astronomical centre. At present, *Dr*. Gulchehra Kokhirova is the Director. *Profs*. Pulat Babadjanov and Khursand Ibadinov, former directors and most eminent Tajik astronomers, are still active and strongly supported collaboration in frame of IAU ROAD as well. There are three attached observatories: Hissar Observatory (HisAO, altitude 730m, AZT-8, 40cm astrograph), the observatory "Sanglokh" (altitude 2300m) in Dangara area (1m telescope, 60cm Carl Zeiss) and its branch, the observatory "Pamir" (altitude 4350m) in Murghab district of Badakhshan (70cm telescope). Sanglokh Observatory was recently re-operated and the President of Tajikistan was present at the opening ceremony. The Institute's research subjects include: *comets and asteroids, experimental astrophysics, meteor astronomy, ionospheric, astrometry, variable stars, structure and dynamics of stellar systems.*

Figure 6. 1m telescope of Sanglokh Observatory, Tajikistan.

Due to the involvement of Kazakhstan and Tajikistan, our regional centre was renamed to **IAU South West and Central Asian (SWCA) ROAD**. Corresponding changes and additions were done at our webpage.

On November 17, 2017, **Turkey** officially joined the South West and Central Asian ROAD office and expressed its desire to carry out its activities for the development of Astronomy by adopting Armenia's coordinating role. It is important to state that we also made a political big step. Armenia recognized as an astronomical centre by Turkey. Although it was set up by the IAU, however at present Turkey also accepts it and joins. Now our cooperation will be closer, visits and exchange of scientific experience more active. We hope to work on various astronomical topics to develop astronomy, to organize conferences, to carry out all the activities that this cooperation assumes.

4. Other Collaborations

Beside activities for the regional countries, IAU SWCA ROAD also encourages and strengthens collaboration with other regions and countries. Especially, promising are contacts with two neighbouring ROADs: **East Asian** (based in Beijing, China) and **Arab World** (based in Amman, Jordan). The first one is coordinating a huge region (China, Mongolia, North Korea) and is especially interested in the development of Silk Road projects that also relate Armenia. Arab World ROAD is in fact in the same big region (Middle East) and is our closest neighbour. We have discussed possibilities to tighter collaborate in all areas (TFs) and establish new programs.

In addition, recently we have discussed with Indian astronomers the possibilities to collaborate, as India is not a member of any ROAD and the closest one is SWCA.

5. Projects and Other Activities

It is a rule that both senior and young scientists from regional countries (especially Georgia and Iran) most often participate in our meetings, schools and other events. We also have many missions to the regional countries, again most often Georgia and Iran.

Armenia is rather active in organizing astronomical meetings, schools and other events. Among the most important meetings and schools held in Armenia, we would like to mention the **IAU Symposia and Colloquia**: IAU S029: *Non-Stable Phenomena in Galaxies* (1966), IAU S129: *Observational Evidence of Activity in Galaxies* (1986), IAU S137: *Flare stars in Star Clusters, Associations and Solar Vicinity* (1989), IAU S194: *Activity in Galaxies and Related Phenomena* (1998), IAU C184: *AGN Surveys* (2001), and IAU S304: *Multiwavelength AGN Surveys and Studies* (2013). Another large event was the all-European annual astronomical meeting in 2007, **JENAM-2007**(Joint European and National Astronomical Meeting), held in Yerevan, Armenia. It was the biggest ever scientific event in Armenia. Out of other meetings, one may mention joint meetings with a given country, namely Byurakan-Abastumani (Armenian-Georgian) Colloquia in 1974–2013, Armenian-French Workshops in 1995 and 2009, and the Armenian-Iranian Astronomical Workshop in 2015, as well as many meetings dedicated to the anniversaries of BAO, Viktor Ambartsumian, Anania Shirakatsi, Beniamin Markarian, Ludwik Mirzoyan and others. Especially many guests from the regional countries were present at BAO-70 anniversary meeting in September 2016. Our office has been awarded an OAD grant for organization of a **Regional Summer School and Workshop** in September 2018, and many regional guests are expected as well.

Among the summer schools, **Byurakan International Summer Schools (BISS)** are already very famous. We have started this initiative in 2006 and so far, have organized 5 such events: 1BISS in 2006, 2BISS in 2008, 3BISS combined with the IAU International School for Young Scientists (ISYA) in 2010, 4BISS in 2012, and 5BISS in 2016. 6BISS will be organized in September 2018. **Byurakan Summer Schools for YSU students (BSS)** are our local schools. They have been organized in 1995, 2005, 2009, and 2013. For the school students, on the initiative of Sona Farmanyan, we organize **BAO Science Camps (BSC)**;4 such events were held in 2014-2017. **ArAS School Astronomical Lectures** program was started in 2012 on the initiative of Yervant Terzian and Areg Mickaelian. During 2012-2017, we have organized 4 such programs. In addition, in 2016 and 2017, we had "My Universe" contest and the winners visited BAO.

Our ROAD representatives are rather active in participating in many international and regional meetings and have given numerous talks at such events related to our activities: scientific, educational, public, and in general about our SWCA ROAD.

In frame of the collaboration between Armenia and Iran, on 15-18 August 2016, Areg Mickaelian (IAU SWCA ROAD Director) and Sona Farmanyan (IAU SWCA ROAD TF3 Programme Coordinator) were invited to the **Research Institute for Astronomy and Astrophysics of Maragha (RIAAM)**. During these days, the 8thAdvanced Astrophysics Workshop of Maragheh was organized. Areg Mickaelian delivered two lectures on *"Astronomical Surveys, Catalogues, Databases, Archives, and Virtual Observatories"* and *"Multi-Wavelength Studies of Active Galaxies"*. Sona Farmanyan delivered two talks on*"Archaeoastronomy and Cultural Astronomy in South West and Central Asia"* and*"Ancient Mythology and Cosmology"*. Sona also presented the IAU SWCA ROAD activities during 2015-2016.A number of discussions were held with Iranian astronomers, including *Prof.* Hossein Ebadie (RIAAM Director) and *Prof.* Pantea Davoudifar, with whom there is a collaboration in co-supervising of two Iranian students.

The fourth **Middle East and African IAU Regional meeting (MEARIM IV)**, was jointly hosted by Entoto Observatory & Research Center(EORC) and East African Regional Office of Astronomy for Development (ROAD-IAU) and was conducted from 22-25 May 2017 in Addis Ababa, Ethiopia with the theme of *"Exploring our Universe for the benefit of Humankind"*. The purpose of the meeting was to strengthen and build capacity of Middle East and African Regional development in Astronomy, to provide a forum and network for scientists and students in the region to exchange ideas and experiences, share research outputs and knowledge, to brief and updates current status of Astronomy development in the region , to build joint working groups of research networks, to provide an opportunity for young and upcoming scientists in training, education and cross border co-supervision and sharing of resources and to put forward cooperation of the Middle East and African in furthering Astronomy and Space Science in the region. During the symposium there were activities such as scientific paper presentations, Plenary Guest and Invited speaker sessions, meetings and discussion on the general progress and Assessments of Astronomy and Astrophysics development in the Middle East and Africa Region. From Armenia, Areg Mickaelian (Director of BAO and SWCA ROAD) and Sona Farmanyan (Public Outreach Coordinator of SWCA ROAD) participated to the meeting and presented 5 talks on various subjects, including the one about SWCA ROAD.

The International Conference *"Astronomical Heritage of the Middle East"* approved by UNESCO Director General within UNESCO Participation Program for 2016-2017 was devoted to the role of Astronomy in Culture and other fields of human activities was held on 13-17 November, 2017 in Armenia(Figure 7). The conference brought together over 70 participants from 20 countries. A discussion of the problems of astronomy-related interdisciplinary sciences and further possible collaborations was organized. The Proceedings of the Meeting will be published by the Astronomical Society of the Pacific Conference Series(ASP CS), which is a world-wide known publication and the papers will appear in all libraries and electronic databases (including ADS).

We have given many **presentations on our ROAD** and its activities at a number of international meetings: NKAS (Belgrade, Serbia, 2015), IAU GA XXIX

(Honolulu, Hawaii, USA, 2015), EWASS-2016 (Athens, Greece), EWASS-2017 (Prague, Czech Rep.) Armenia-Brandenburg Workshop (Nor Amberd, Armenia, 2017), MEARIM-IV (Addis Ababa, Ethiopia, 2017), etc.

Figure 7. The International Conference "Astronomical Heritage of the Middle East".

We maintain a tight relation between the **IAU SWCA ROAD and Eastern Europe**. This includes collaboration with European countries, ArAS affiliation to the European Astronomical Society (EAS), ArAS collaboration with the Euro-Asian Astronomical Society (EAAS), Armenia's participation in South-East Regional European Astronomical Committee (SREAC), H2020 program (since 2016 Armenia is an associate member), collaboration between the Armenian Virtual Observatory (ArVO)and EuroVO, VO-France (also VO-Paris), GAVO, and VObs. We also have contacts with other European organizations; Euroscience, SEAC, etc.

6. Summary

The status of the regional astronomical centre supports the regional and international contacts and collaboration both for Armenia and the neighboring countries; this way Armenia, by holding such a centre, strongly contributes to collaborations at all levels: professional, educational and popular. Astronomy in fact plays an important political role in establishing and strengthening friendship and cooperation of the regional nations, which is especially important in our complicated area.

Among our future plans, we envisage to enlarge the number of participating countries (involving more Central Asian and maybe some other ones), work harder for fundraising for implementation of various projects, organize regional meetings, workshops, schools and camps.

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