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1

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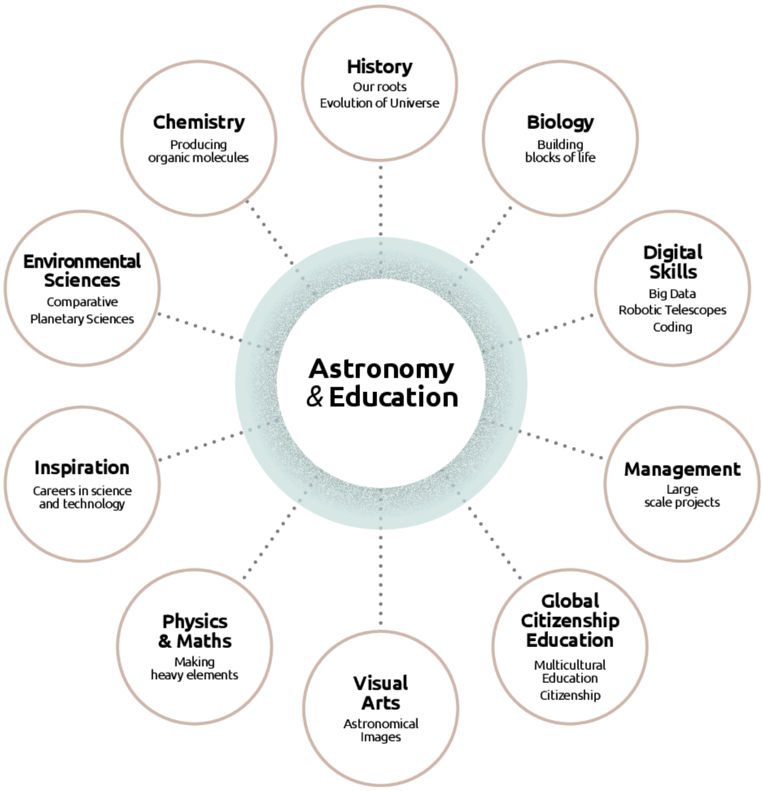
Introduction

Editorial board *

NAS RA V. Ambartsumian Byurakan Astrophysical Observatory (BAO)

"The Connection of Astronomy with Other Sciences, Culture, and Society" conference is dedicated to the 25th anniversary of the Armenian Astronomical Society. The current trend in scientific development emphasizes interdisciplinary and multidisciplinary approaches, with astronomy playing a pivotal role. Astronomy can be considered a leader in inter-branch and multi-branch sciences, particularly within the natural sciences. Fields such as astrophysics, astrochemistry, astrobiology, astromedicine, astrogeology (planetary science), astroinformatics, and historical astronomy have all emerged and continue to develop through interdisciplinary connections. Astronomy significantly contributes to advancements in space research, the study of extraterrestrial civilizations, artificial intelligence, global warming, and other multidisciplinary sciences.



Since the early 2000s, elements of interdisciplinary sciences have been present in numerous scientific conferences organized at the Byurakan Astrophysical Observatory (BAO). Notably, in 2014, an interdisciplinary conference titled "The Connection of Astronomy with Other Sciences, Culture, and Society" was held at BAO, with the proceedings published by the National Academy of Sciences of the Republic of Armenia. In 2021, BAO hosted another international conference, "Astronomy at the Crossroads of Interdisciplinary and Multidisciplinary Sciences," with the collected materials published in ComBAO.

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The topics of *"The Connection of Astronomy with Other Sciences, Culture, and Society"* conference cover a wide range of scientific directions:

- Sun and the Solar System
- Stars and Nebulae
- Active Galaxies, Galaxy Systems
- High Energy Astrophysics and Cosmology
- Theoretical Astrophysics
- Astronomical Surveys
- Astrochemistry, Astrobiology, and Exoplanets
- Planetary Science and Asteroseismology
- Astroinformatics and Virtual Observatories, Big Data in Astronomy
- Astronomical Heritage, Historical Astronomy, and Cultural Astronomy
- Astronomy Education, Astrotourism, and Astro-journalism

Active scientific discussion of the presented tasks will undoubtedly serve as a guarantee for further fruitful cooperation.

This issue of Communications of BAO includes the proceedings from the conference *"The Connection of Astronomy with Other Sciences, Culture, and Society"*. All the papers have undergone a thorough peer review.

Communications of BAO, Vol. 71, Issue 1, 2024, pp. 3-12

Armenian Astronomical Society: report of 25-years activities

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Abstract

The history of the Armenian Astronomical Society (ArAS) foundation and its goals and a summary of ArAS activities during 1999-2024 is presented. The following have been among the most important activities: ArAS formation, increase of ArAS membership, consolidation of foreign Armenian astronomers, ArAS webpage with full of useful information, creating a Database of Armenian Astronomers, ArAS Electronic Newsletters (ArASNews), ArAS Annual Meetings, Byurakan International Summer Schools (BISS) and other events for young astronomers and students, ArAS School Lectures series, Byurakan Science Camps (BSC) and other events for school pupils, ArAS Annual Prize for Young Astronomers (Yervant Terzian Prize), award of Galileo Teacher Training Program (GTTP) International Certificates and other teacher training programs, Armenian Archaeoastronomy webpage, initiation and development of Scientific (Astro) Journalism and its Annual Awards, initiation and development of Scientific (Astro) Tourism, as well as UNESCO/IAU International Year of Astronomy (IYA-2009) activities and others.

Introduction: Foundation, Main Goals, etc.

The Armenian Astronomical Society (ArAS) is a Non-Governmental Organization (NGO) that works on the development of astronomy in Armenia, promotion of collaboration between the Armenian and foreign astronomical institutions, strengthening contacts and collaboration between the Armenian and other astronomers, support of astronomical education and popularization of science in Armenia. ArAS was created in 1999 and officially registered in 2001. Since the same year, it is one of the Affiliated Societies of the European Astronomical Society (EAS). ArAS has 104 members both from Armenia and a number of other countries and may in fact be considered as an international organization.

The idea to establish an Armenian Astronomical Society was born in early 1980s when it was known already that a number of Armenian astronomers were working out of Armenia and a need to keep contacts between them and for collaboration was obvious. Vahé Petrosian and Yervant Terzian were among the initiators of this idea. However, the real society was not created. Later on, in the middle of 1990s, Areg Mickaelian in Byurakan started to collect information on all Armenian astronomers all over the world to prepare the foundation of the society. A few years later, after discussions with many people, including the IAU officials, a meeting was held to discuss this initiative. The decision to found the Armenian Astronomical Society (ArAS) was made on June 22, 1999 in Byurakan at the meeting of 16 astronomers. An initiative group was elected to prepare suggestions on the ArAS activities, work out its By-Laws, membership form, etc. Areg Mickaelian, Haik Harutyunian, Elena Nikoghossian, Susanna Hakopian, and Tigran Magakian made up this group. Y. Terzian took an active part in this process: the main principles of the Society were discussed during the visit of A. Mickaelian to Cornell University in September 1999. However, the official registration of the Society came 2 years later. The Ministry of Justice of Armenia approved the By-Laws and registered ArAS as a Non-Governmental Organization (NGO) on August 29, 2001 (registration document No. 03A 051334).

On September 13, 2001 at the European Astronomical Society (EAS) Council Meeting, ArAS was officially recognized by the EAS, becoming one of its at that time 21 Affiliated Society Members (at present there are 32 affiliated societies). Thus, we also have international recognition.

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The **main goals** of ArAS, according to its By-Laws, are:

- promotion of astronomy,
- promotion of collaboration between all astronomy-related institutions in Armenia,
- promotion of contacts and collaboration between the Armenian and other astronomers all over the world,
- development of the astronomical education and knowledge in Armenia.

The **main activities** of ArAS are:

- Providing detailed information on Byurakan Astrophysical Observatory (BAO), Armenian and world astronomy through its webpage,
- Enlargement of the membership so that ArAS becomes a really All-Armenian organization. Astronomers of any nationality may enter ArAS. There is also a status of Honorary members, people who have made great contribution to science and to Armenian astronomy;
- Creation and maintenance of a Database of Armenian Astronomers;
- Establishment of several ArAS branches (beside the Armenian branch itself), particularly in North America, Europe, and the FSU (former Soviet Union), where most of the Armenian astronomers live and work (10-20 in each). This is not done yet, though planned at ArAS creation;
- Publication of an Electronic Newsletter (1 issue per 3 months, then much often) starting with 2002. They give information on different Armenian scientists, Armenia itself, as well as publish some scientific abstracts and short papers;
- Publication of an annual Calendar of Astronomical Events;
- Organization of Annual Meetings in Armenia with participation of as many Armenian astronomers as possible. The scientific program is open to all subjects;
- Organization of Byurakan International Summer Schools (BISS) for Young Astronomers;
- Organization of the European Annual Astronomical Meeting (JENAM-2007), the largest scientific event ever held in Armenia;
- Collaboration with other Armenian and International organizations (IAU, EAS, EAAS, Armenian Physical Society, All-Armenian Scientific Society, Society of Armenian Scientists and Engineers, etc.);
- Award of the ArAS Annual Prize for Young Astronomers (Yervant Terzian Prize) and establishment of Annual Prizes for outstanding astronomers: one for work in theoretical astrophysics (Ambartsumian Prize), and one for work in observational astrophysics (Markarian Prize).
- Various educational activities;
- Promotional / public outreach activities, including Scientific Journalism in Armenia through its regular press-releases.
- Current work of ArAS Administration.

ArAS Membership

As for 31.05.2024, altogether there are 104 ArAS members from 21 countries, including 11 founding members, 1 honorary, 72 full, and 20 junior ones. Among the 50 foreign members, we have:

Canada (1) – Arsen R. Hajian

France (5) – Isabelle Baraffe, Daniel Kunth, Mustapha Meftah, Alain Sarkissian, Parandzem K. Sinamyan

Germany (6) – Tigran G. Arshakian, Dieter Engels, Gohar Harutyunyan, Tigran V. Khanzadian, Razmik Mirzoyan, Armen D. Sedrakian

Greece (1) – Vassilis Charmandaris

Hungary (1) – Ishtvan Jankovich

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India (1) – Arun Kumar Singh

Iran (3) – Shant Baghram, Habib Khosroshahi, Sohrab Rahvar

Ireland (1) – Felix A. Aharonian

Italy (2) – Hripsime Kh. Navasardian, Massimo Turatto

Mexico (2) – Vahram H. Chavushyan, Gagik H. Tovmassian

Netherlands (1) – Bernhard Brandl

Portugal (1) – Vardan Zh. Adibekyan

Romania (1) – Magda Stavinschi

Russia (3) – Anatol M. Cherepashchuk, Vardan G. Elbakyan, Igor D. Karachentsev

Spain (2) – Garik Israelian, Vakhtang S. Tamazian

Switzerland (1) – Michel Mayor

Thailand (1) – David E. Mkrtichian

UK (1) – Mihran Vardanyan

USA (16) – Vladimir S. Airapetian, Noretta K. Andreassian-Thomas, Timothy C. Arlen, Smbat K. Balayan, Donald Barry, Richard D. Belian, Adam Burrows, Igor V. Chilingarian, Varoujan Gorjian, Marietta V. Gyulzadian, Lilit R. Hovhannisyan, Emmanuel Momjian, R. Brent Tully, Daniel W. Weedman, Artashes R. Petrosian, Vahe Petrosian

There are many ArAS membership benefits:

- ArAS has created and maintains an up-to-date website providing society's general information, information on Meetings, Prizes, Grants, Summer/Winter Schools, Members, Publications, etc.;
- ArAS maintains a database of its membership, available on the web, as well as a database of all Armenian astronomers;
- ArAS publishes its monthly electronic newsletter ArASNews that is distributed to its members and other interested scientists and societies;
- ArAS awards yearly prizes to young astronomers;
- ArAS individual members participate to the election of ArAS Council, they may nominate candidates for the ArAS Annual Prize and other ArAS awards and have a right to vote at the Annual meetings;
- ArAS holds yearly ArAS meetings. These meetings bring together the Armenian astronomical community, they include typically various scientific topics and organizational matters. ArAS members are granted discounts for participation in these meetings and other ArAS events;
- ArAS publishes the Proceedings of its meetings and some other books, and ArAS members have discounts on them (often ArAS provides these books free of charge to its members);
- ArAS provides free space for personal webpage for all members;
- ArAS maintains close professional relationships with most of the European national astronomy societies, and gives possibility to exchange practice and develop collaboration;
- ArAS members can participate in ArAS projects, as ArAS School Lectures, etc.;
- ArAS runs a number of educational and public outreach activities.

ArAS Webpage

ArAS has a very rich webpage with a lot of information on the Armenian and world astronomy, a detailed webpage on the Byurakan Astrophysical Observatory (BAO), A Database of all Armenian astronomers in the world, a page for Famous Armenian astronomers, ArAS activities, including the ArASNews, Annual Meetings, Annual Prizes, etc., the Digitized First Byurakan Survey (DFBS), the Armenian Virtual Observatory (ArVO), BAO Plate Archive Project, webpages for the journals "Astrophysics" and "Communications of BAO".

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Figure 1. ArAS webpage home and BAO webpage created at ArAS with some more information that is available on BAO official webpage.

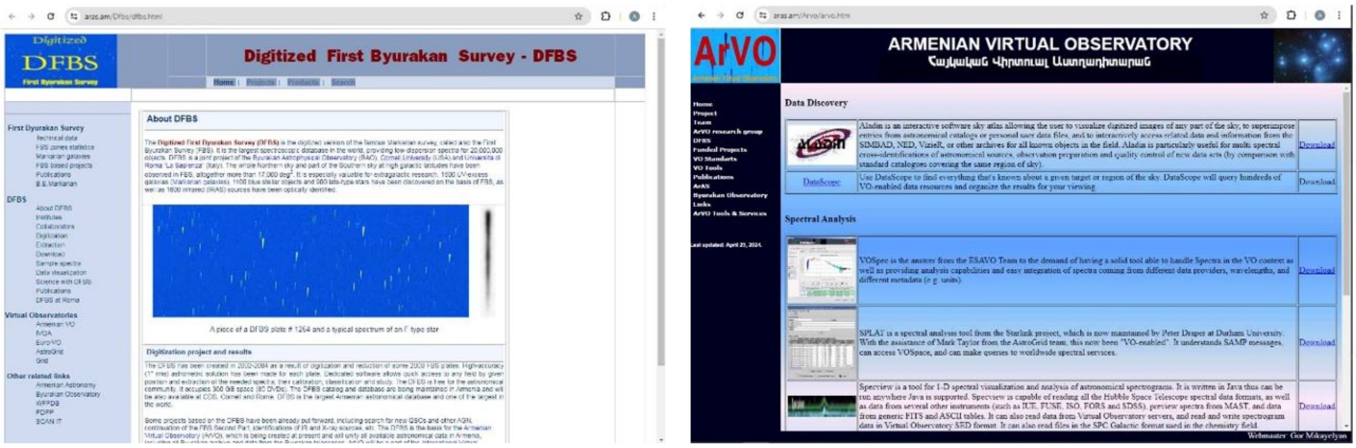

Figure 2. Webpages of the Digitized First Byurakan Survey (DFBS) and the Armenian Virtual Observatory (ArVO).

ArAS Electronic Newsletters

ArAS Electronic Newsletters ArASNews have been created and are being released since 2002. All details are given in another paper of this Issue (Asryan et al., 2024).

ArAS Annual Meetings

ArAS Annual Meetings were started in 2022. We maintain webpages for each such meeting individually. Many Annual Meetings were combined with some important events held in BAO, ex. ArAS Annual Meeting VI in 2007 was combined with the European Astronomical Society (EAS) Annual Meeting (JENAM: Joint European and National Astronomical Meeting; this one was held in Yerevan at the Yerevan State University), ArAS Annual Meeting XIV in 2015 was combined with the Armenian-Iranian Astronomical Workshop (AIAW), ArAS Annual Meeting XVI in 2017 was combined with the UNESCO Regional Conference, etc.

We give in Table 1 the list of all ArAS Annual Meetings with their details.

Meeting #	Year & Dates	Place	Meeting title/topic	Combined with	Dedicated to
I	2002.07.25	BAO	*Achievements of the Armenian Astronomy*		
II	2003.06.11-13	BAO		XIII Joint Colloquium of the Byurakan and Abastumani Astrophysical Observatories	L. V. Mirzoyan's 80th anniversary

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III	2004.08.30-31	BAO			
IV	2005.08.29-30	BAO			
V	2006.09.01-03	BAO	*Active Universe*	International Conference	60^{th} anniversary of BAO
VI	2007.08.20-25	YSU	*Our Non-Stable Universe*	Joint European and National Astronomy Meeting (JENAM) – 2007	
VII	2008.09.15-18	BAO	*Evolution of Cosmic Objects through their Physical Activity*	International Conference	V. A. Ambartsumian's 100^{th} anniversary
VIII	2009.07.06-08	BAO			
IX	2010.11.26	BAO			
X	2011.12.19	BAO			
XI	2012.09.25-26	BAO	*Astronomical Heritage in the National Culture*	Archaeoastronomical Meeting	Anania Shirakatsi's 1400^{th} anniversary
XII	2013.08.26-28	BAO	*Instability and Evolution of Stars*	XIV Joint Colloquium of the Byurakan and Abastumani Astrophysical Observatories	L. V. Mirzoyan's 90^{th} anniversary
XIII	2014.10.07-10	BAO	*Relation of Astronomy to other Sciences, Culture and Society*	Conference on Interdisciplinary and Multidisciplinary Sciences	
XIV	2015.10.13-16	BAO		Armenian-Iranian Astronomical Workshop	Opening of the IAU SWA ROAD
XV	2016.12.21	NAS RA	*Non-Stable Universe: Energetic Resources, Activity Phenomena and Evolutionary Processes*	International Symposium	70^{th} anniversary of BAO
XVI	2017.11.13-17	NAS RA	*Astronomical Heritage of the Middle East*	UNESCO Regional Conference	
XVII	2018.09.20	BAO		IAU SWCA 2^{nd} Regional Astronomical Workshop	
XVIII	2019.09.11-13	BAO		IAU SWCA 3^{rd} Regional Astronomical Workshop	
XIX	2020.09.14-18	BAO	*Astronomical Surveys and Big Data 2*	International Symposium	
XX	2021.09.22-25	BAO	*Astronomy in the Crossroads of Interdisciplinary and Multidisciplinary Sciences*	International Conference	75^{th} anniversary of BAO
XXI	2022.09.19-23	BAO	*Space Sciences and Technologies*	International Conference	
XXII	2023.05.01-05	BAO	*XV Joint Colloquium of the Byurakan and Abastumani Astrophysical Observatories*		L. V. Mirzoyan's 100^{th} anniversary
XXIII	2024.05.06-08	BAO	*Relation of Astronomy to Other Sciences, Culture and Society*	Symposium	25^{th} anniversary of ArAS foundation

Table 1: The list of ArAS Annual Meetings 2002-2024.

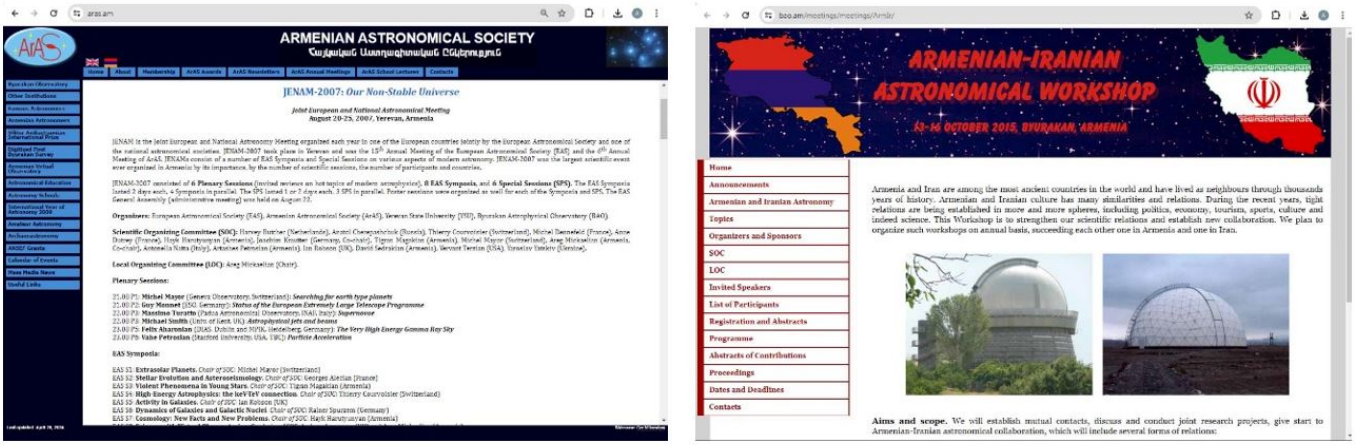

Figure 3. Webpages of individual ArAS Annual Meetings: ArAS Annual Meeting VI in 2007 combined with the EAS Annual Meeting (JENAM: Joint European and National Astronomical Meeting) and ArAS Annual Meeting XIV in 2015 combined with the Armenian-Iranian Astronomical Workshop.

ArAS Annual Prize for Young Astronomers

ArAS Annual Prize for Young Astronomers was established in 2004 by Areg Mickaelian and was supported by *Prof.* Yervant Terzian (Cornell University, N.Y., USA), who donated USD 100, then USD 200 and later on, USD 500 yearly. The prize is being awarded to a young scientist under 35 working in astronomy or related field and showing significant results in research and/or other scientific activities connected anyhow with the Armenian astronomy. Nominations may be made by ArAS members or any research organization from Armenia or elsewhere and should be sent to one of the ArAS Co-Presidents. They should include personal data for the nominee and a brief description of his/her achievements during the year, including important scientific results, all published papers, participation in meetings, given talks, etc., whatever is considered to be important. The deadline for applications is December 1 each year. A special committee (typically, the ArAS Council) makes the selection and the results are being announced in the last issue of ArAS Newsletter at the end of each year. A diploma and sum of $500 are being awarded to the winner. Since 2009, the Prize is named after Yervant Terzian.

Here we give the list of all ArAS Annual Prize Winners:

2023 – Arus HARUTYUNYAN

2022 – Naira AZATYAN

2021 – Gor MIKAYELYAN

2020 – Hasmik ANDREASYAN, Gor MIKAYELYAN

2019 – Naira AZATYAN

2018 – Sona FARMANYAN

2017 – Naira AZATYAN

2016 – Anahit SAMSONYAN

2015 – Artur HAKOBYAN

2014 – Gurgen PARONYAN

2013 – Hayk ABRAHAMYAN, Avet HARUTYUNYAN (Italy)

2012 – Vardan ADIBEKYAN (Portugal)

2011 – Marine AVTANDILYAN

2010 – Parandzem SINAMYAN

2009 – Lusine SARGSYAN

2008 – Vardan ADIBEKYAN, Artur HAKOBYAN

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2007 – Igor CHILINGARIAN (USA)

2006 – Lilit HOVHANNISYAN, Parandzem SINAMYAN

2005 – Artak HARUTYUNYAN, Elena HOVHANNESSIAN

2004 – Lusine SARGSYAN

In 2004-2023, there have been 20 awards; 5 times shared between 2 winners; totaling 25 recipients. There have been in total 18 young astronomers, ArAS Annual Prize Winners, some of them have received the Prize twice and one of them, Naira Azatyan, even 3 times (asterisk is given when the Prize was shared). We give in Table 2 ArAS Annual Prize Winners with the number of awards and the years.

Number of Awards	ArAS Annual Prize Winners	Awards Years
3	Naira AZATYAN	2017, 2019, 2022
2	Lusine SARGSYAN	2004, 2009
2	Parandzem SINAMYAN	2006*, 2010
2	Vardan ADIBEKYAN	2008*, 2012
2	Artur HAKOBYAN	2008*, 2015
2	Gor MIKAYELYAN	2020*, 2021
1	Igor CHILINGARIAN	2007
1	Marine AVTANDILYAN	2011
1	Gurgen PARONYAN	2014
1	Anahit SAMSONYAN	2016
1	Sona FARMANYAN	2018
1	Arus HARUTYUNYAN	2023
1	Artak HARUTYUNYAN	2005*
1	Elena HOVHANNESSIAN	2005*
1	Lilit HOVHANNISYAN	2006*
1	Hayk ABRAHAMYAN	2013*
1	Avet HARUTYUNYAN	2013*
1	Hasmik ANDREASYAN	2020*

Table 2: The list of ArAS Annual Prize Winners 2004-2023.

The distribution by countries is the following: Armenia – 22, Italy – 1, Portugal – 1, USA – 1. Gender distribution is such: Male – 8, Female – 10.

ArAS Educational Programs

ArAS runs many educational activities, including those for university students, school pupils and for the general public. Among them most active ones are:

- Byurakan Summer Schools (BSS) for YSU students, since 1995, 5 schools organized
- Byurakan International Summer Schools (BISS), since 2006, 9 schools organized
- ArAS School Lectures “From School to Space”, since 2012, 11 events held
- Byurakan Science Camps (BSC), since 2014, 10 camps organized
- Teacher Training Programs (TTP), since 2010, 8 events organized

All details related to ArAS Educational Activities are given in another paper of this Issue (Baleyan et al., 2024).

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ArAS Outreach Programmes

Many public outreach activities have been accomplished by ArAS mainly since 2009, starting with the UNESCO/IAU International Year of Astronomy (IYA-2009). Among the projects and activities, one could mention:

- Scientific (Astro) Tourism, since 2009. All details are given in another paper of this Issue (Farmanyan et al. 2024);
- Scientific (Astro) Journalism since 2010. A Facebook group was created and maintains network of scientists (mainly young researchers) and journalists. Scientific Journalism seminars have been organized and Scientific Journalism Annual Prizes have been established;
- Database of Famous Armenian Astronomers with biographies in Eng and Arm for 21 most important Armenian astronomers/astrophysicists and astronomy related physicists, among them Anania Shirakatsi (612-685 A.D.), 10 former BAO researchers, 2 from Yerevan State University (YSU) and 8 foreign Armenians. Especially detailed pages are built for Viktor Ambartsumian, Beniamin Markarian and Anania Shirakatsi;
- Database of Armenian astronomers, containing data for 257 Armenians from BAO, other Armenian research institutions and foreign researchers;
- Annual Calendars of Astronomical Events since 2012 (including Sky Events, International Events and Armenian Astronomy Events); in addition, all Solar and Lunar eclipses, Triple Conjunctions and Periodic Comets for 2001-2050 are given;
- A database of all our astronomical books (books published either by BAO and/or BAO researchers and related to BAO and/or BAO researchers, the latter mostly related to V. A. Ambartsumian);
- Online Journal "Astghagitak" ("Star Expert"), where all available astronomy-related articles in Armenian are given and which is being systematically updated.
- Armenian Archaeoastronomy webpage;
- Mass Media news webpage;
- Popular Astronomical TV program (Armenia TV) in 2003-2004.

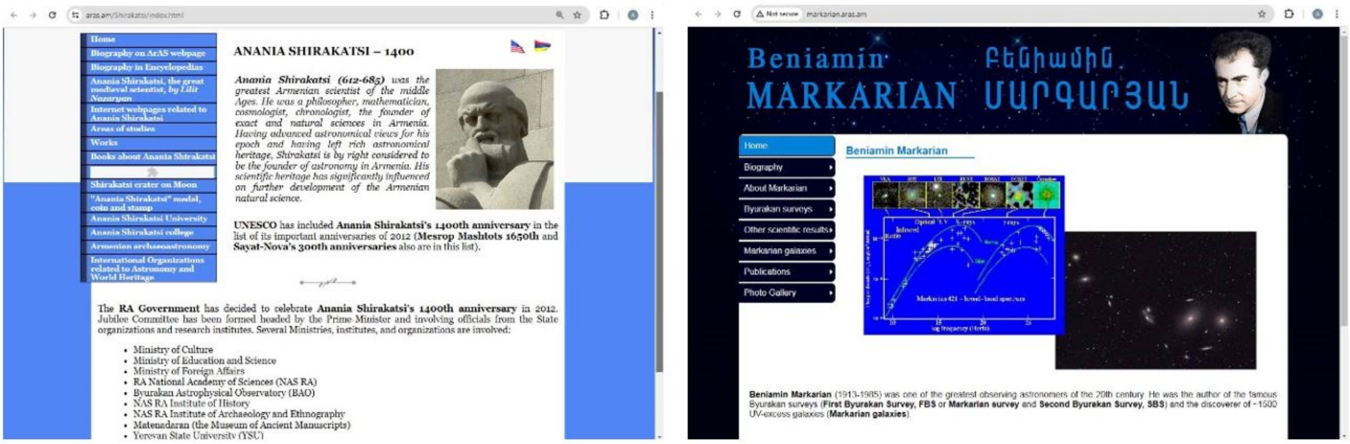

Figure 4. Anania Shirakatsi webpage created on the occasion of Shirakatsi's 1400^{th} anniversary and Beniamin Markarian webpage created on the occasion of Markarian's 100^{th} anniversary.

ArAS Finances

Though ArAS membership fees are not large (for Armenian residents it is USD 10 for Regular Members and USD 5 for Junior Members), anyway ArAS could find various sources and ran many activities requiring a lot of funds. We have a very nice collaboration with the EAS, due to which ArAS members do not pay EAS membership fees. Among the sponsors and supporters, one should mention the following individuals:

- *Prof.* Yervant Terzian: ArAS Annual Prize, ArAS School Lectures
- Fund for Armenian Relief (FAR): ArAS School Lectures, BSC
- *Prof.* Radik Martirosyan: ArAS meetings and events at NAS RA
- *Prof.* Daniel Weedman: partial support of 1BISS in 2006
- *Mr.* David Nelson (Jinishyan found.): partial support of ArAS events
- *Prof.* Michel Mayor, *Prof.* Garik Israelian, *Prof.* Nuno Santos: partial support of 3BISS/ISYA-2010
- *Dr.* Mihran Vardanyan: support of ArAS/OxArm Prizes in 2011
- *Dr.* Marietta Gyulzadyan: organization of many educational events
- *Dr.* Lusine Sargsyan: organization and release of ArAS TV programmes
- Gor Mikayelyan: creation and maintenance of ArAS webpage since 2009
- Sona Farmanyan: ArAS Newsletters and organization of many other events
- Meline Asryan: ArAS Newsletters, public outreach activities

ArAS expenses during all these years included and at present include the following:

- Internet Domain and Hosting at web.am
- Office and Postal expenses
- Publication of promotional materials (ArAS pens, certificates, medals, etc.)
- Production of Astronomy for Schools and other DVDs, etc.
- Purchase of 100 Celestron FirstScope telescopes in frame of IYA-2009
- Organization of ArAS Annual Meetings, since 2002
- ArAS Annual Prize for Young Astronomers; 100-200-500 USD
- ArAS School Lectures 2012, 2013, 2014, 2016 (the others were supported by sponsors)
- Byurakan Summer Schools (BSS, BISS, RASS) and Camps (BSC)
- Other events: Olympiads, GTTP courses, etc.
- EAS membership fees 2002-2011 (ArAS payed for all its members)
- IYA-2009 activities: visits, promotional materials, etc.
- Celebrations of anniversaries, etc.
- Fiscal office expenses; Bank account service expenses
- A lot of activities are done for free (webpage, Database, ArASNews, Calendar of Events, etc.)

Summary and Conclusion

During its 25 years of existence, the Armenian Astronomical Society (ArAS) has conducted and accomplished a huge number of various activities; scientific, organizational, networking, educational and public outreach. Here we list the most important ones:

ArAS Membership: Armenia (54) and other countries (50)

ArAS webpage (since 2002)

Byurakan Astrophysical Observatory (BAO): detailed info (at present also available on BAO webpage)

ArAS Electronic Newsletters (ArASNews) (since 2002)

ArAS Annual Meetings (since 2002)

Byurakan Summer Schools (BSS) for YSU students (since 2005)

Byurakan International Summer Schools (BISS) for young astronomers (since 2006)

ArAS School Lectures (since 2012)

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- **Byurakan Science Camps (BSC)** (since 2014)
- **ArAS Prize for Young Astronomers** (Yervant Terzian Prize) (since 2004)
- ArAS Prizes for Outstanding Astronomers (2009)
- ArAS certificates and medals (2009-2019, 2024)
- EAS affiliation (2001), other international organizations (IAO, IPDA, etc.)
- **Database of Armenian Astronomers** (257 individuals)
- Biographies of the **Famous Armenian Astronomers** (21 individuals)
- Popular Astronomical TV program (Armenia TV) (2003-2004)
- **Calendar of Astronomical Events** (since 2012)
- **"Astghagitak" online journal**
- **International Year of Astronomy (IYA-2009)** activities
- **Scientific (Astro) Tourism** (since 2009)
- **Scientific (Astro) Journalism** (since 2009)

section*Acknowledgements The author is thankful to the Armenian Astronomical Society (ArAS), Byurakan Astrophysical Observatory (BAO), RA National Academy of Sciences (NAS RA) and the IAU South West and Central Asian Regional Office of Astronomy for Development (IAU SWCA ROAD).

Related Links

ArAS Webpage: https://www.aras.am/

ArAS Membership: https://www.aras.am/Members/members.html

ArASNews: https://www.aras.am/ArasNews/arasnews.html

ArAS Annual Meetings: https://www.bao.am/meetings/meetings.php

ArAS Annual Prize: https://www.aras.am/Prize/prize.htm

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The Digitized First Byurakan Survey Database. Late-type stars candidates. New confirmations.

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Abstract

More than 3000 Late-Type Stars (LTS) candidates was confirmed among the sample, selected on the Digitized First Byurakan Survey (DFBS) spectral plates. The DFBS is the digitized version of the First Byurakan Survey (FBS, or Markarian survey). This objective-prism survey was carried out in 1965-1980 by B. E. Markarian and colleagues using the 1 m Schmidt telescope of the Byurakan Astrophysical Observatory (BAO). FBS spectral plates have been used long period to search and study faint LTS (C-type (carbon) and M-type) stars at high Galactic latitudes. Thousands of objects was confirmed as LTS. The confirmation is based on Gaia DR3 BP/RP low-resolution spectral database. In previous studies of the DFBS plates, these objects were presented as LTS candidates. Some objects are located more than 10 kpc. The predominant part of the new confirmed objects are M dwarfs.

Keywords:*late-type -stars: M dwarfs, M giants, carbon stars*

1. Introduction

Markarian survey (or the First Byurakan Survey (FBS)), is the first systematic survey of the extragalactic sky. This objective-prism (op) low-resolution (lr, 1.5^0 prism, a reciprocal dispersion of 1800 Å/mm near H_β, providing a 3400-6900 Åspectral range) survey was carried out in 1965-1980 by Markarian and collaborators using the 1 m Schmid telescope of the Byurakan Astrophysical Observatory (BAO, Armenia) and resulted in discovery of 1517 UV-excess galaxies (Markarian et al., 1989). FBS lr spectral plates have been used to search and study faint Late-Type Stars (M-type and C-type stars at high Galactic latitudes, Gigoyan et al. (2001)). All FBS lr spectral plates have been now digitized, resulting in the creation of the Digitized First Byurakan Survey (DFBS) database. Its images and spectra are available on the web portal in Trieste (online at https://www.ia2-byurakan.oats.inaf.it). All DFBS plates are analyzed with help of analysis softwares FITSView and SAOImage ds9. A second version of the "Revised and Updated Catalogue of the First Byurakan Survey of Late-Type Stars", containing data for 1471 M and C stars was generated (Gigoyan et al., 2019), CDS Vizier Catalogue http://cdsarc.u-strasbg.fr/viz-bin/Cat?J/MNRAS/489/2030. This visualization allows to detect very red and faint C and M star candidates close to the detection limit in each plate (Gigoyan, 2022). Candidates of N-type (Asymptotic Giant Branch-AGB) C stars and M-type giants, for which very short (~6600-6900 Å) spectra is visible on the DFBS plate, no C_2 and TiO molecule absorption bands are detectable. Moderate-resolution slit spectroscopy was carried out for some of them, confirming the C-rich nature of them (Gigoyan et al., 2012). Several of such candidates could be M dwarfs also (Gigoyan, 2022). Meanwhile, a huge amount of such candidates detected on the DFBS plates, remained to be confirmation on spectral types (Gigoyan, 2022). To classify LTS candidates, we use Gaia DR3 BP/RP lr spectroscopic database, which allows us to confirm the spectral types for candidates very easily.

2. New confirmations. Gaia DR3 spectra

The European Space Agency (ESA) mission Gaia (Gaia Collaboration, Prusti et al., 2016), has already released three catalogues to the astronomical community, of increasing richness in terms of content, and

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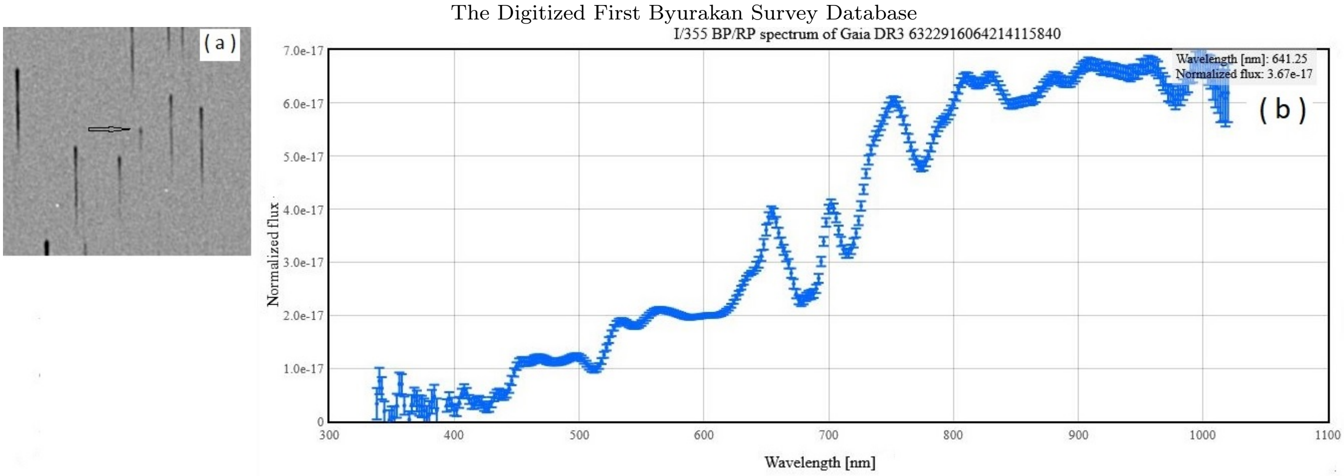

Figure 1. DFBS lr spectral shape (1a) for LTS candidate object with RA = $15^h23^m09.021^s$ and DEC = -$05^d50^m08.15^s$ (DFBS J152309.20-055005.8). Figure 1b present Gaia DR3 spectra confirmed. This object is M dwarf, r = 56.5644 pc and V = 15.75 mag..

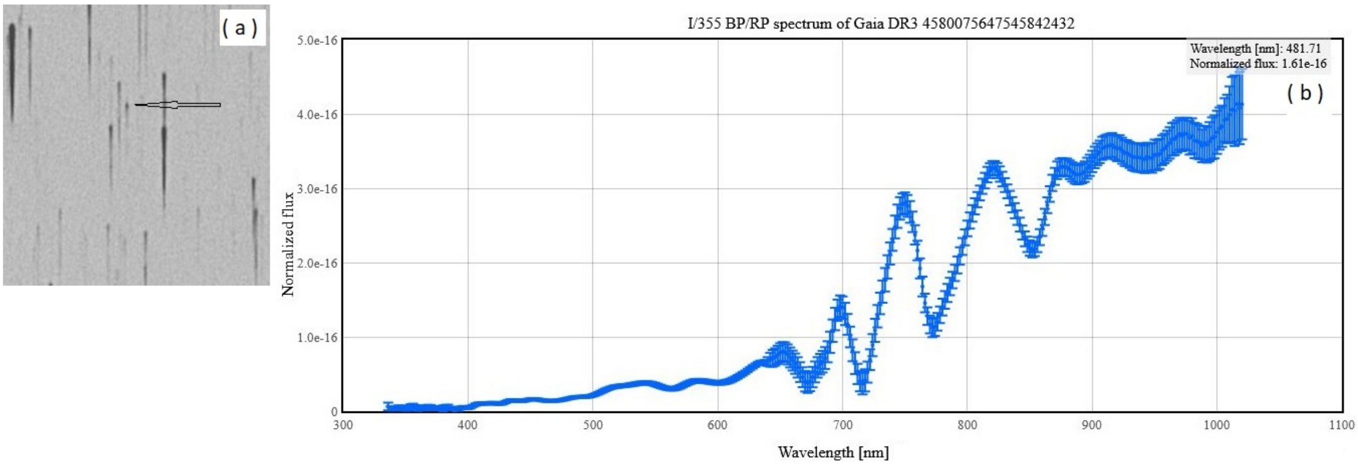

Figure 2. DFBS lr spectral shape (1a) for LTS candidate object with RA = $18^h12^m31.207^s$ and DEC = +$26^d35^m47.95^s$ (DFBS J181231.22+263548.0). Figure 2b present Gaia DR3 confirmed spectra. This object is M giant at a distance r = 8150 pc and high (Z) from the Galactic plane Z = 2780 pc.

accuracy. With respect to previous Gaia Early Data Release 3 (EDR3, Gaia Collaboration, Brown et al., 2021), Gaia Data Release 3 (Gaia Collaboration, Vallenari et al., 2023) introduces a number of new data products based on the same source catalogue, including a total 1.8 billion objects based on the period of 34 months satellite operation. Blue (BP) and Red (RP) photometer lr spectral data are one of the exciting new product in Gaia DR3 (CDS VizieR Catalog I/355/gaiadr3). Time-averaged mean spectra covering the optical to near-infrared (NIR) wavelength range λ 3300-10500 Å are published for approximately 220 million objects (CDS VizieR Catalog I/355/spectra). Most of them are brighter than G=17.65 mag (De Angeli et al., 2023). M-type stars can be detected very easily in the Gaia DR3 lr spectral database by the presence of the broad absorption bands of the TiO molecule in the range 6500-7000 Å, 7000-7500 Å, and 8000-8500 Å, and C stars display strong Swan bands at 4383, 4737, 5165, and 5636 Å of C_2 molecule (Gigoyan et al., 2024). The list of DFBS LTS candidates (~3200 objects) were cross-correlated with the Gaia DR3 lr spectroscopic database. We confirm the LTS nature practically for all of them. The great part of the confirmed objects are M dwarfs and M giants. We confirm C-rich nature for 13 objects also.

As examples, Figure 1(a,b) and Figure 2(a,b) shows spectral shapes for DFBS LTS candidates and Gaia DR3 confirmed spectra.

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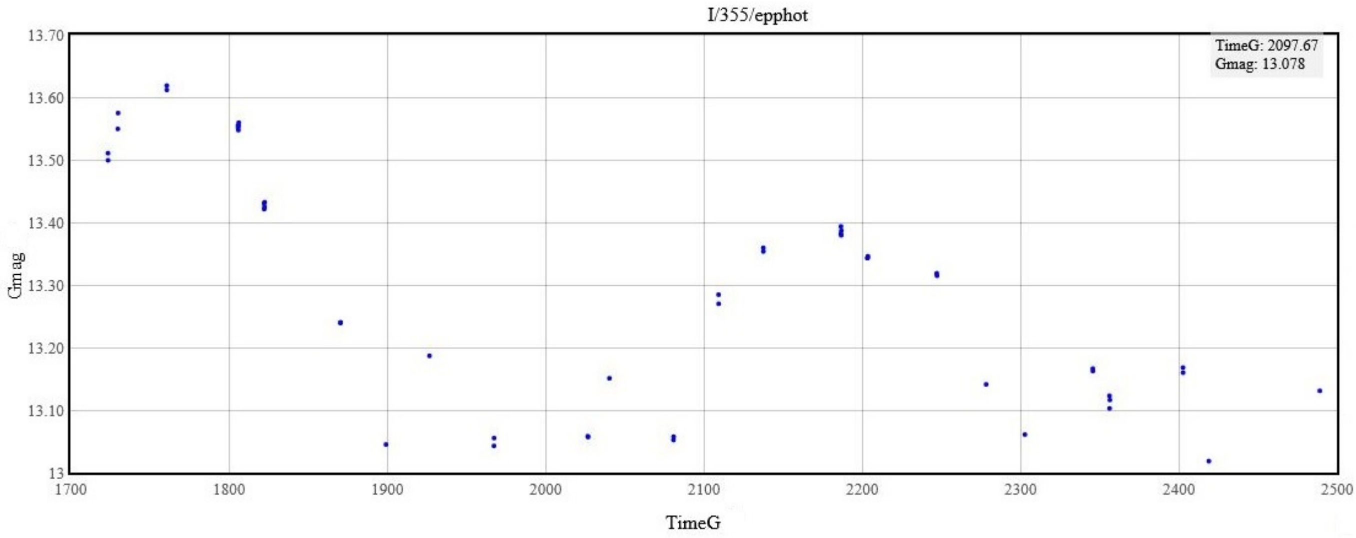

Figure 3. Gaia G-band phase dependent light curve for new confirmed M giant DFBS 181231.22+263548.0 (available on-line at https://vizier.cds.unistra.fr/viz-bin/VizieR?-source=I/355/.

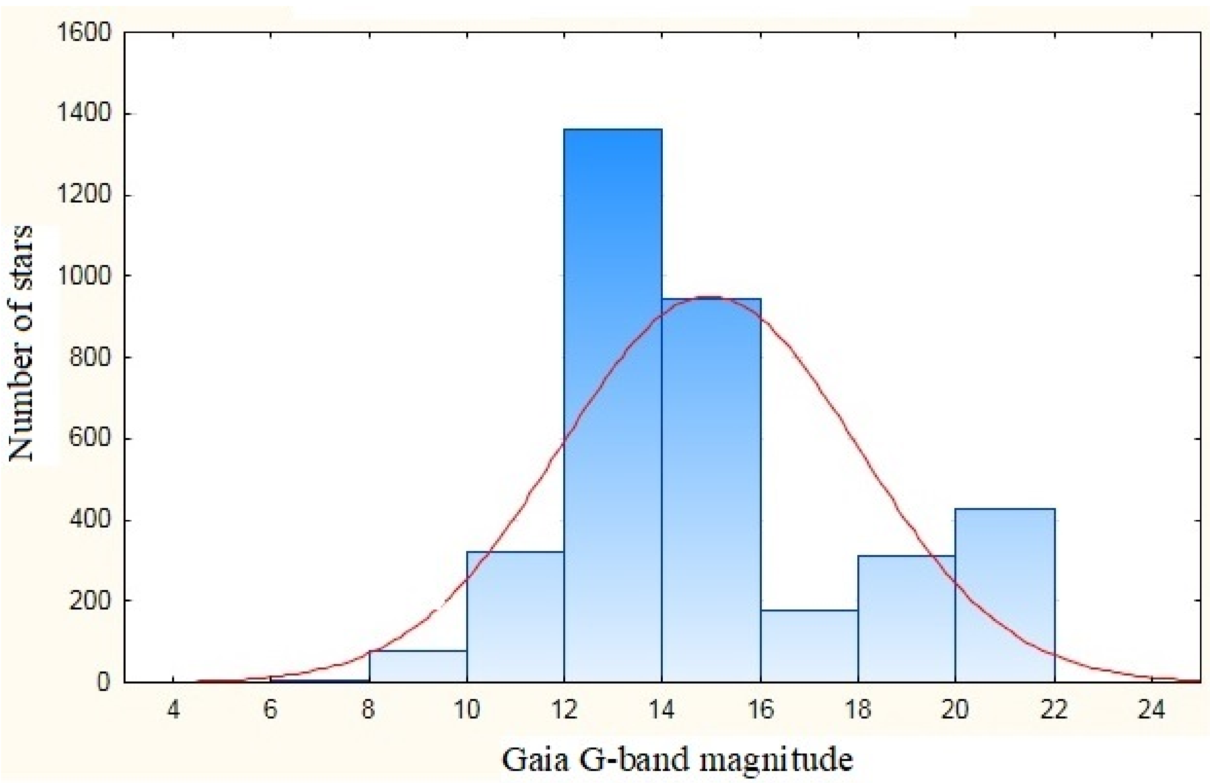

Figure 4. Gaia G-band magnitude distribution for 3200 DFBS LTS.

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3. Variability

Figure 3 present light curve in Gaia G-band for object DFBS J181231.22+263548.0. This object is a long period variable.

Figure 4 presents the histogram of the Gaia DR3 G-wide band magnitude distribution for near 3200 new confirmed DFBS LTS.

4. Summary and future works

In this paper we report on a large number of new LTS confirmed in the Gaia DR3 spectral database. All these faint objects (V mag. in the range $14.0^m \div 17.0^m$) were presented as LTS candidates in DFBS database before the present study. We significantly extended the previous FBS survey for LTS. A study of the new LTS is now in progress, and the results will be appear very soon.

The list of all spectroscopically conformed DFBS LTS candidates, reported as a supplementary (value-added) catalogue to the second edition of the "Revised and Updated Catalogue of The First Byurakan Survey" will be presented in SIMBAD astronomical database very soon.

Acknowledgements

This work has made use of data from the European Space Agency (ESA) mission Gaia (http://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC). This research has made use of the VizieR catalogue access tool, CDS, Strasbourg, France.

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New M dwarfs found in DFBS plates

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Abstract

In this paper we report about 100 new M dwarfs, confirmed in the DFBS database. The DFBS is the digitized version of the First Byurakan Survey (FBS, or Markarian survey). FBS plates have been used to search and study faint Late-Type Stars (LTS). The confirmations is based on Gaia DR3 BP/RP spectral database. In previous studies of the DFBS plates, these objects were presented as LTS candidates. TESS phased light curves for some of them shows flares. In SEDs of these objects the infrared excess is clearly visible.

Keywords: *late-type -stars: M dwarfs, surveys: TESS and Gaia*

1. Introduction

The Digitized First Byurakan Survey (DFBS) is the digitized version of the First Byurakan Survey (FBS, or Markarian survey). This objective-prism survey was carried out in 1965-1980 by B.E.Markarian and his colleagues using the 1m Schmidt telescope of the Byurakan Astrophysical Observatory (Markarian et al., 1989). FBS low-resolution spectral plates have been used for a long time to search and study faint Late-Type Stars (LTS, M-type and C stars) at high Galactic latitudes (Gigoyan et al., 2019, 2024).

The M-type dwarfs occupy the lower third right-hand corner of the main sequence. They are a diverse bunch of objects that range in mass from a little over half that of the Sun down to around a thirteenth (approximately 0.075 - 0.5M$\odot$) its size (Stevenson, 2019). M-dwarf stars are most common stars, representing more than 75% of all stars within our Galaxy (Henry et al., 2006, 2018). They dominate the stellar populations by number, but have a effective temperature (T_eff) less than 4000K (Delfosse et al., 2000). M – type stars can easily be distinguished because of the titanium oxide (TiO) molecule absorption bands at 4584, 4762, 4954, 5167, 5500 and 6200 Å.

We present data for 100 newly found DFBS M dwarfs, confirmed in the Gaia Data Release 3 (DR3) low-resolution (lr) spectroscopic data base. This paper is structured as follows: Section 2 introduces the Gaia DR3 lr spectral data base, which is used to validate the spectral types of the DFBS LTS candidates. TESS observations and analysis of TESS light curves of FBS M dwarfs are presented in Section 3. Investigation of infrared emission from M dwarfs is presented in Section 4. We conclude with a short summary and an outlook in Section 5.

2. DFBS and Gaia DR3 low-resolution spectra

To classify LTS candidates, we use Gaia DR3 BP/RP lr spectroscopic database (Gaia Collaboration, Vallenari et al., 2023), which allows us to confirm the spectral types for candidates very easily. M-type stars can be detected very easily in the Gaia DR3 lr spectral database by the presence of the broad absorption bands of the TiO molecules in the range 6500-7000 Å, 7000-7500 Å, and 8000-8500 Å.

Figure 1 presents the spectra of DFBS binary system of M dwarfs, which have low-resolution spectra in Gaia DR3 spectroscopic database. Gaia DR3 lr spectra of binary system are presented in Figure 2.

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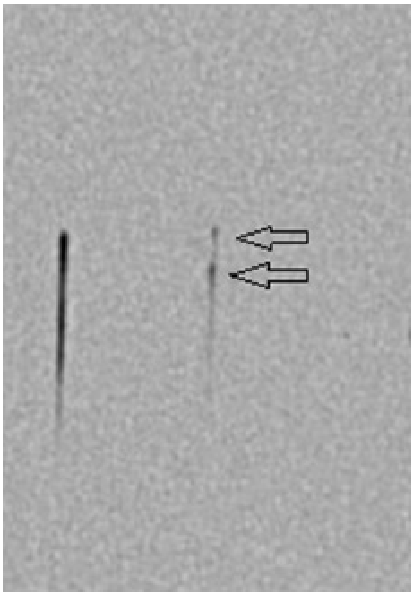

Figure 1. Low-resolution spectra of DFBS binary system of M dwarfs.

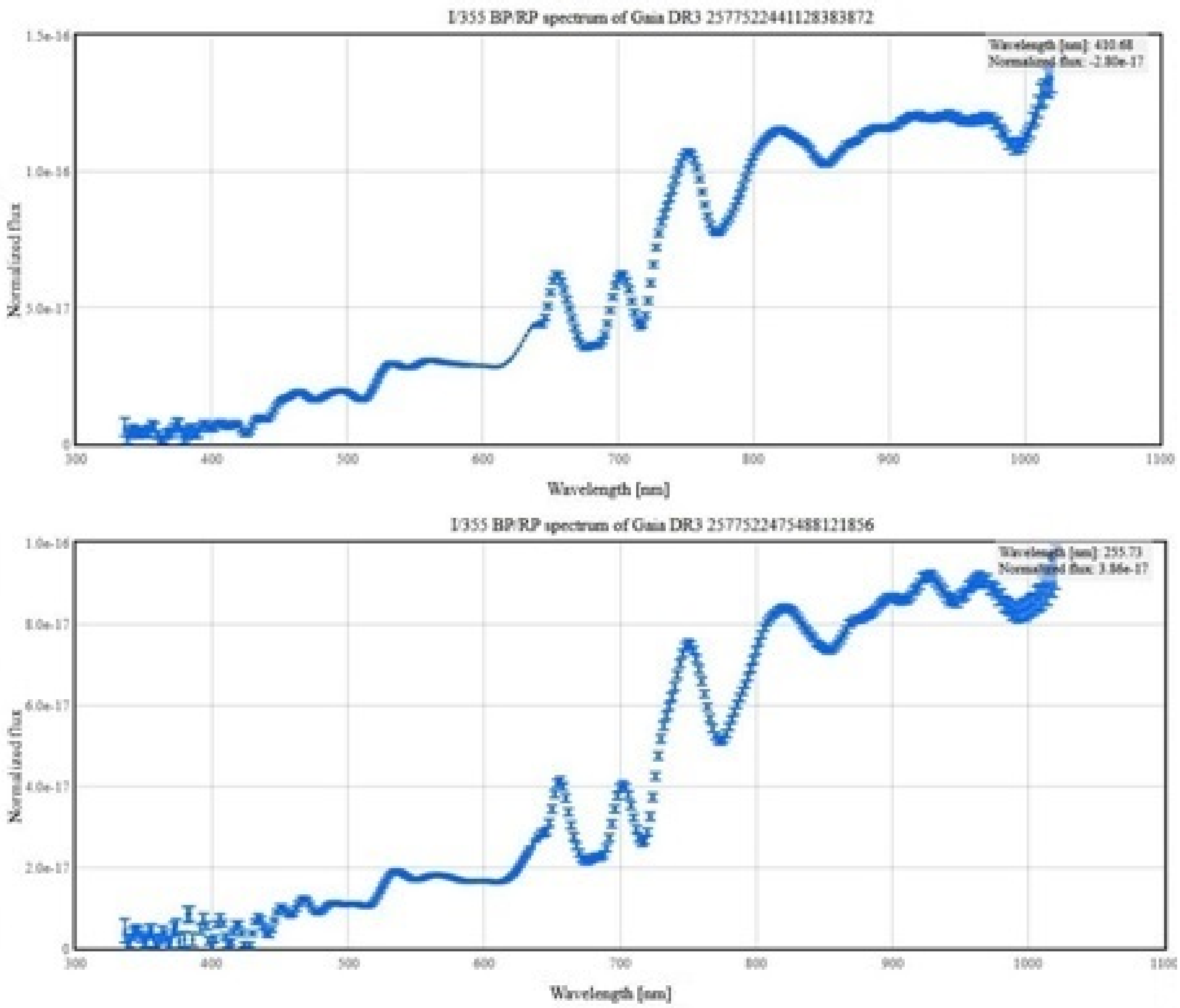

Figure 2. Gaia DR3 low-resolution spectra of DFBS binary system of M dwarfs.

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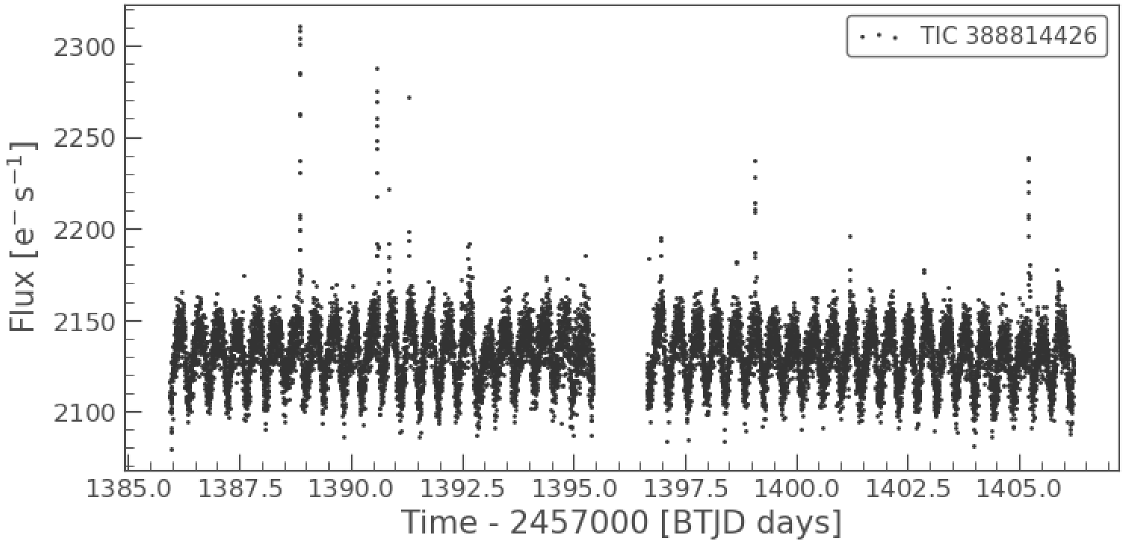

Figure 3. TESS phase-dependent light curve of new confirmed M dwarf with RA = $01^h13^m26.^s$ 8920 and DEC = $+00^d01^m07^s.706$.

3. TESS observations and analysis of TESS light curves of FBS M dwarfs

M dwarfs are favourable targets for transiting exoplanet surveys. NASA's Transiting Exoplanet Survey Satellite (TESS) is an allsky space-based mission designed to search for planets transiting around nearby M dwarfs (Ricker et al., 2014). Launched in 2018 April, it started regular science operation on 2018 July 25. Its observed $\sim 73\%$ of the sky across 26 sectors, each lasting 27.4 d and covering a $24^0 \times 96^0$ field of view. TESS observed a number of stars at 2-min cadence and collected full frame images (FFIs) every 30 min, covering the entire mission phase.

Some M-type dwarfs belong to a class of variable stars called UV Ceti stars. Strong magnetic fields and a fast rotation stir and heat plasma in their atmospheres, producing powerful flares. These flares brighten the stars by 1–3 magnitudes and generate powerful X-ray and radio bursts. Indeed, the X-ray and radio flares produced by these stars are over one hundred times as energetic as those on the Sun. It seems that these mice can occasionally roar. The precise mechanism by which these magnetic fields arise in the smallest stars is a little unclear, but it must involve some combination of star-wide convection and stellar rotation (Stevenson, 2019).

We downloaded the Presearch Data Conditioning Simple Aperture Photometry (PDC-SAP) light curves from the Mikulski Archive for Space Telescopes (https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html). We then used lightkurve (http://docs.lightkurve.org) to download the target pixel files (TPFs) and to analyse light curves for FBS M dwarfs monitored by TESS. TESS phase-dependent light curves show flares for many new M dwarfs. Figure 3 shows example of such flares in TESS light curve for new confirmed M dwarf with RA = $01^h13^m26^s.8920$ and DEC = $+00^d01^m07^s.706$

Figure 4 presents lr spectrum of Gaia DR3 for this object.

4. The infrared emission. Spectral energy distribution (SED).

Infra-Red emission from M dwarfs has been investigated in multiple studies. Extra flux in the IR range characterized the circumstellar dust which mark certain stages in the life of a planetary system (protoplanetary disc, and final stage is a debris disc, Luppe et al. (2020). Sgro & Song (2021) used *Gaia* DR2 and ALLWISE W3 and W4 passbands to search for M dwarfs with IR-excess, within 100 pc. Using a special SED fitting algorithm, Sgro & Song (2021) developed a photospheric model for each sampled star, determined its significance of excess (SOE), and discussed the nature of IR excess in more detail.

We examine visually the SEDs for all FBS M dwarfs to search for possible dusty discs signature around them. All these SEDs have been built and taken from the SIMBAD VizieR data base (access via https://vizier.unistra.fr/vizier/sed/) using the SED builder tool. The SED of M dwarf (RA = $01^h13^m26.^s$ 8920 and DEC = $+00^d01^m07^s.706$) with very clear IR-excess is shown in the Figures 5, where the excess IR radiation is clearly visible after 10 μm (in WISE W3 and W4 passbands). An IR excess emission is not

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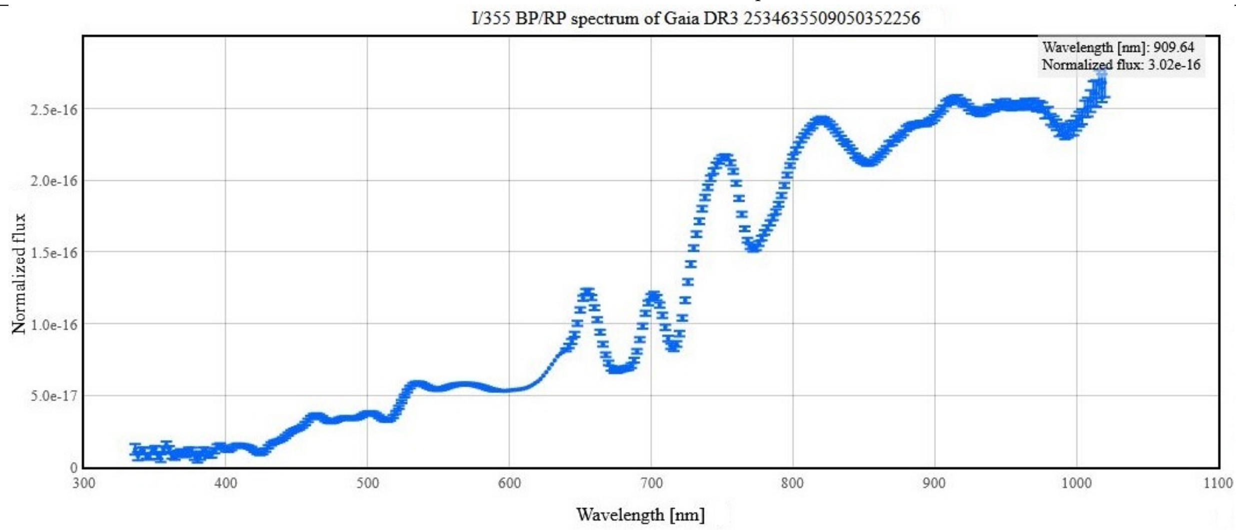

Figure 4. Gaia DR3 spectum of the new confirmed M dwarf with RA = $01^h13^m26^s.8920$ and DEC = $+00^d01^m07^s.706$.

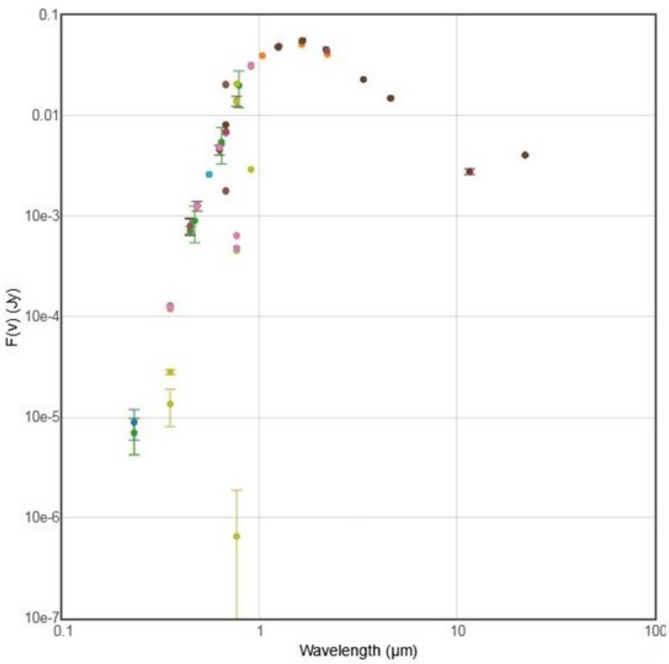

Figure 5. Gaia DR3 spectum of M dwarf with RA = $01^h13^m26^s.8920$ and DEC = $+00^d01^m07^s.706$.

obvious in the SEDs of the other FBS M dwarfs.

5. Conclusion

In this paper we inform a some amount of new M dwarfs, confirmed in the DFBS lr spectroscopic data base. Confirmation was made using Gaia DR3 BP/RP spectroscopic catalogue. TESS phase-dependent light curves show flares for many FBS M dwarfs. The SED of new confirmed M dwarf with RA = $01^h13^m26.^s$ 8920 and DEC = $+00^d01^m07^s.706$ shows clear IR-excess. The excess IR radiation is clearly visible after 10 μm (in WISE W3 and W4 passbands). An IR excess emission is not obvious in the SEDs of the other FBS M dwarfs.

The list of all spectroscopically confirmed DFBS M dwarfs, reported as a supplementary (value-added) catalogue to the second edition of the "Revised and Updated Catalogue of The First Byurakan Survey" will be presented in SIMBAD astronomical database very soon.

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Acknowledgements

This work has made use of data from the European Space Agency (ESA) mission Gaia (http://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC). This research has made use of the VizieR catalogue access tool, CDS, Strasbourg, France.

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The digitized First Byurakan Survey database. New carbon stars confirmed.

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Abstract

Some amount of the new carbon (C) stars was confirmed among the sample of the Late-Type Stars (LTSs) candidates, selected on the Digitized First Byurakan Survey (DFBS) spectral plates. The DFBS is the digitized version of the First Byurakan Survey (FBS, or Markarian survey). The FBS was the first systematic survey of the extragalactic sky. This objective-prism survey was carried out in 1965-1980 by B. E. Markarian and colleagues using the 1 m Schmidt telescope of the Byurakan Astrophysical Observatory. In this work we present Gaia DR3 photometric data, spectra, light curves, distances, high above/below Galactic plane, radial velocities (RV), and other important physical characteristics from modern astronomical catalogues for some amount new confirmed DFBS carbon stars. The confirmation is based on Gaia DR3 BP/RP low-resolution spectral database. In previous studies of the DFBS plates, these objects were presented as LTSs candidates. Some objects are located more than 7 kpc from the Galactic plane. Four of them are N-type C stars, from which two are Mira-type variables. The remaining objects are CH-type giants at high Galactic latitudes. Most probably they present binary systems.

Keywords: *late-type stars: carbon stars*

1. Introduction

Markarian survey (or the First Byurakan Survey-FBS), was the first systematic survey of the extragalactic sky. This objective-prism (op) low-resolution survey was carried out in 1965-1980 by B. E. Markarian and collaborators using the 1 m Schmidt telescope of the Byurakan Astrophysical Observatory (BAO) and resulted in discovery of 1517 UV-excess galaxies (Markarian et al., 1989). FBS spectral plates have been used for a long time to search and study faint Late-Type Stars (LTS, M -type stars and C (carbon) stars)) at high Galactic latitudes (Gigoyan et al., 2001). All FBS spectral plates have now been digitized, resulting in the creation of the Digitized First Byurakan Survey (DFBS) database (on-line at https://www.ia2-byurakan.oats.inaf.it). All DFBS plates are analyzed with help of analysis softwares FITSView and SAOImage ds9. A second version of the "Revised and Updated Catalogue of the First Byurakan Survey of Late-Type Stars", containing data for 1471 M and C stars was generated (Gigoyan et al., 2019) CDS Vizier Catalogue https://vizier.cds.unistra.fr/viz-bin/VizieR-3?-source=J/MNRAS/489/2030. This visualization allows to detect very red and faint C and N star candidates close to the detection limit in each plate (Gigoyan, 2022). Meanwhile, a large amount of such faint candidates detected on the DFBS plates, remained to be confirmation on spectral types. In this study we present some important data for newly confirmed CH-type and N-type C stars. This paper is structured as follows: Section 2 introduces the Gaia DR3 spectra for some amount of new confirmed C stars. Section 3 present Gaia DR3 important data for C stars. Phase dependent light curves for new C stars is presented in Section 4. Section 5 recalls the main results obtained for new objects and provide concluding remarks and future works.

2. Gaia DR3 spectra

The European Space Agency (ESA) mission Gaia (Gaia Collaboration, Prusti et al., 2016) has already released three catalogues to the astronomical community. With respect to previous Gaia Early Data Release 3 (EDR3, Gaia Collaboration, Brown et al., 2021), Gaia Data Release 3 (Gaia Collaboration, Vallenari et al.,

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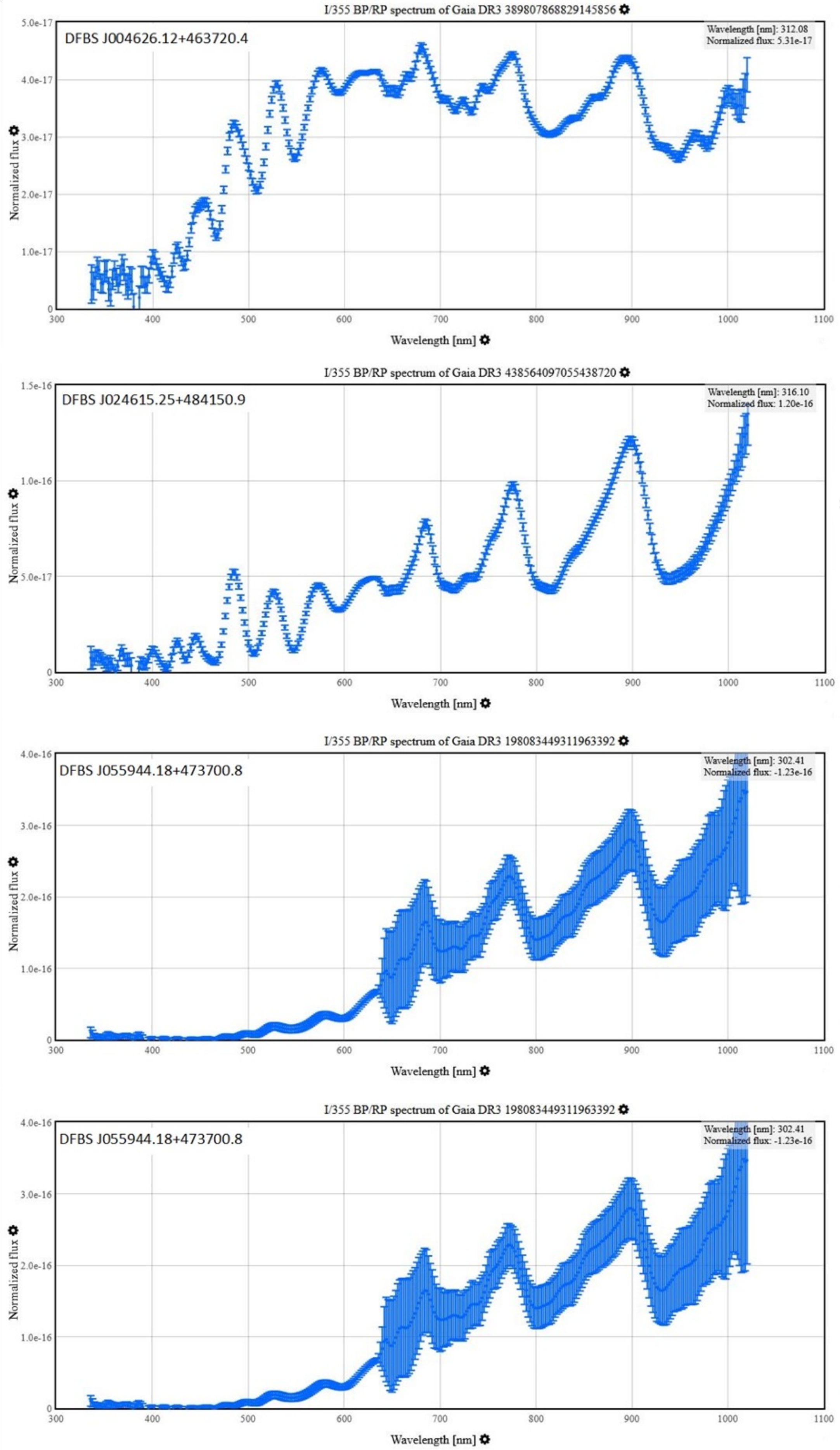

Figure 1. Gaia DR3 low-resolution spectra for new confirmed DFBS C stars.

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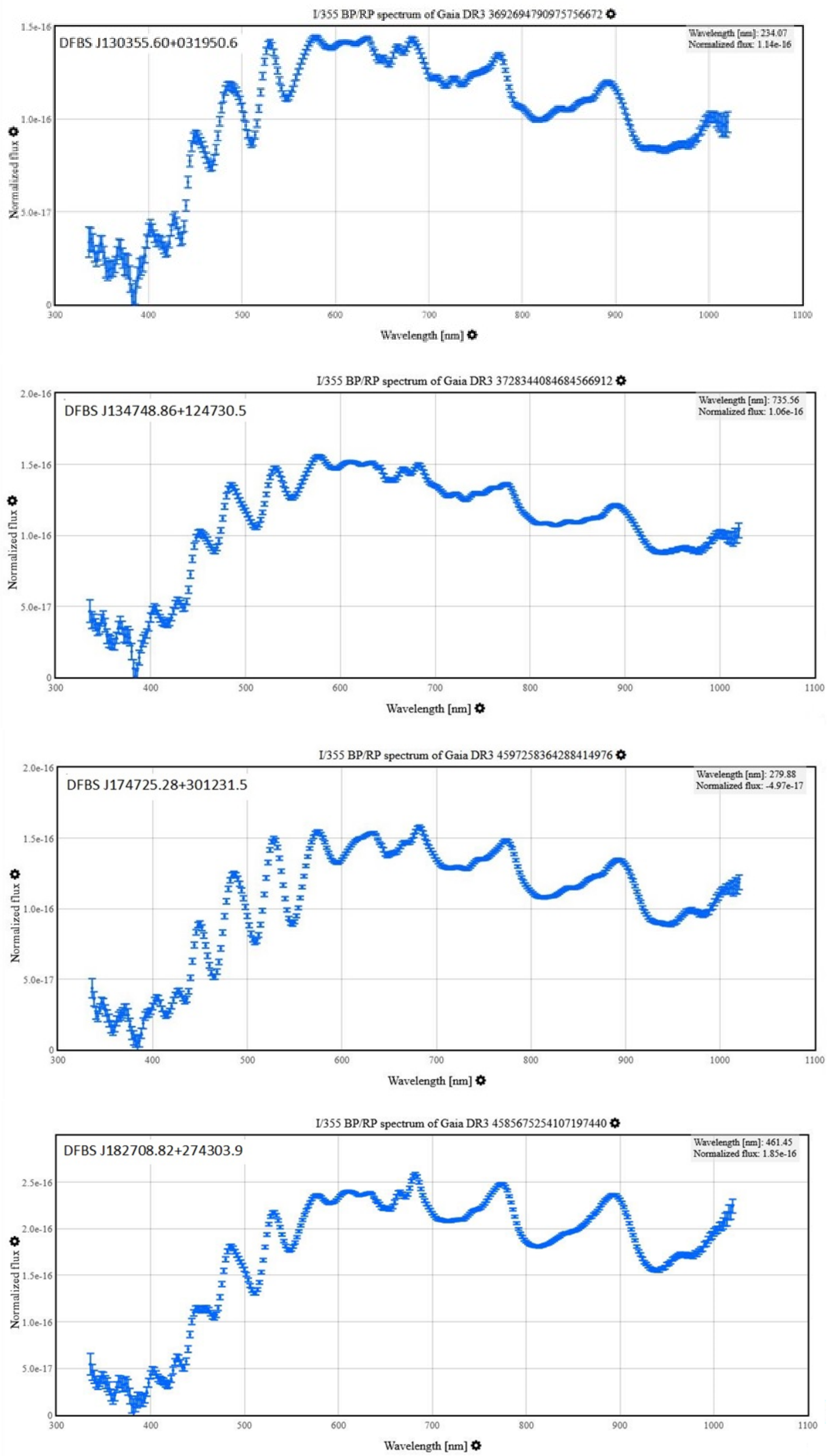

Figure 2. Gaia DR3 low-resolution spectra for new confirmed DFBS C stars.

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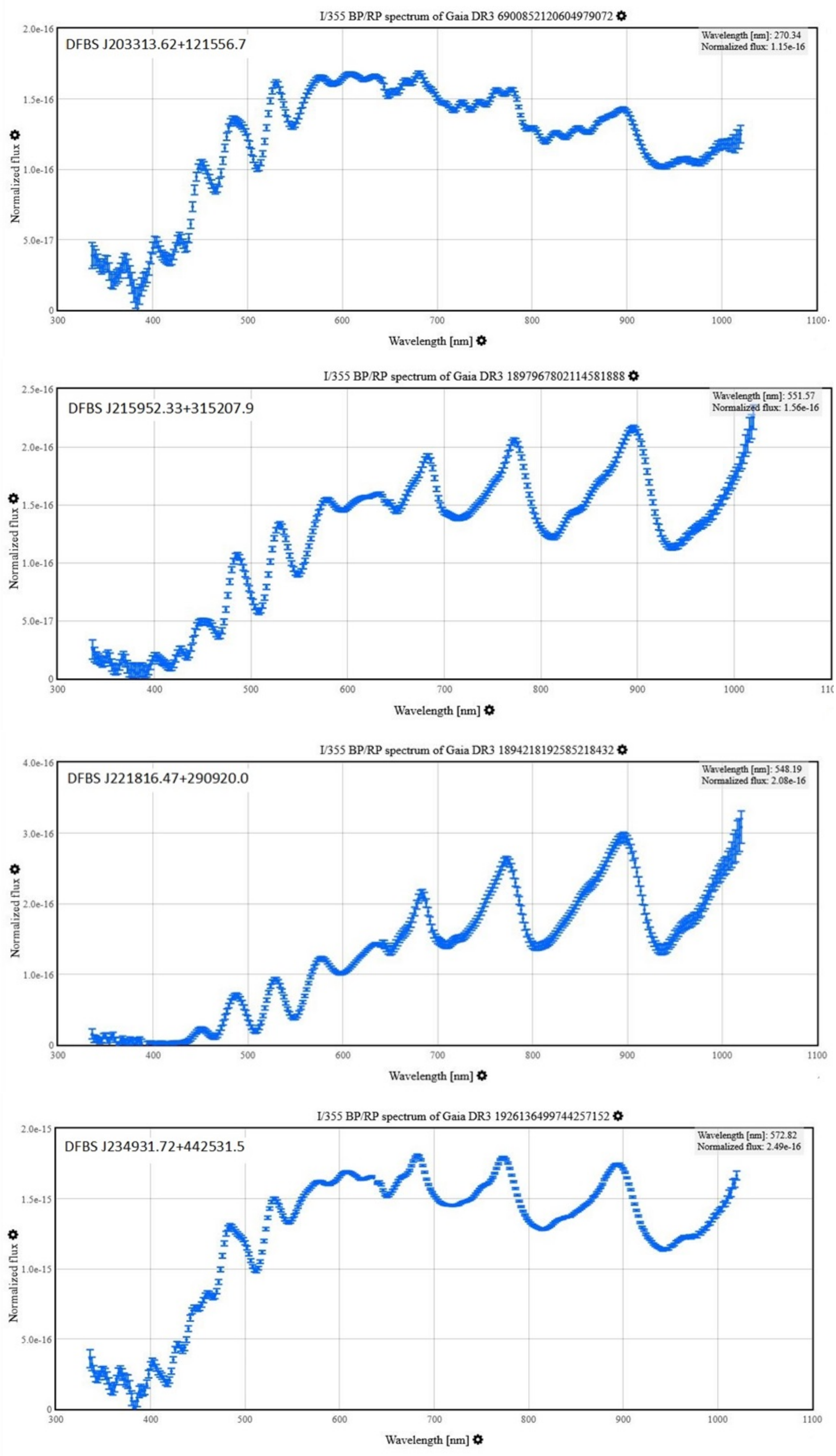

Figure 3. Gaia DR3 low-resolution spectra for new confirmed DFBS C stars.

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Table 1. 15 DFBS candidates.

DFBS Number	Gaia DR3 Source Number	Gaia DR3 Source Number	SP. Type
J004626.12+463720.4	389807868829145856		C-CH
J024615.25+484150.9	438564097055438720		C-CH
J055944.18+473700.8	198083449311963392	NSVS 4490482	C-N
J082310.36-015325.7	3070045067018279040	ATO J125.7932-01.8905	C-N
J130355.60+031950.6	3692694790975756672		C-CH
J134748.86+124730.5	3728344084684566912		C-CH
J174725.28+301321.5	4597258364288414976		C-CH
J182708.82+274303.9	4585675254107197440		C-CH
J203313.62+121556.7	1755523764342918784		C-CH
J203956.64-063740.4	6908005165297040896		C-CH
J215432.69+373839.7	1949989717315919232		C-CH
J215952.33+315207.9	189796802114581888		C-CH
J221816.47+290920.0	1894218192585218432		C-CH
J234931.72+442531.7	1922548170531464448		C-CH

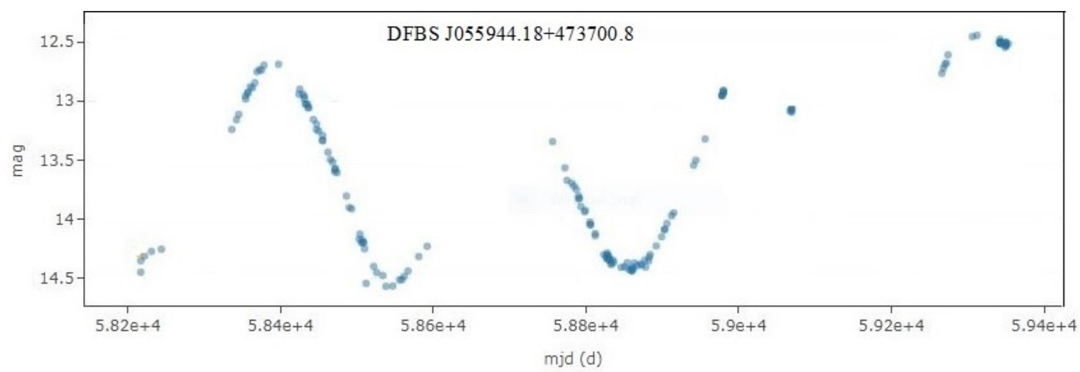

Figure 4. Zwicky Transient Facility light curve for DFBS J055944.18+473700.8 (available on-line at https://irsa.ipac.caltech.edu/missions/ztf.html/). X-axis presents the period in Julian Data and Y-axis presents ZTF g-band magnitude. The observational identifier is 74510700000050 (P ≈ 307d ay).

2023) introduces a number of new data products in Gaia DR3 (CDS Vizier Catalog I/355/gaiadr3/). Time-averaged mean spectra covering the optical to near-infrared (NIR) wavelength range 3300-10500 Å are published for approximately 220 million objects (Catalog I/355/spectra). Most of these objects are brighter than G=17.65 mag (De Angeli et al., 2023). M-type stars can be detected very easily in the Gaia DR3 lr spectral database by the presence of the broad absorption bands of the TiO molecule in the range 6500-7000 Å, 7000-7500 Å, and 8000-8500 Å, and C stars display strong Swan bands at 4383, 4737, 5165, and 5636 Å of the C_2 molecule (Gigoyan et al., 2024).

Table 1 presents 15 DFBS candidates, confirmed as C stars, it gives the DFBS Number, the Gaia DR3 (I/355/gaiadr3) source name, other association in SIMBAD database, and our spectral type determination (C -N or C-CH).

Figures 1, 2 and 3 present Gaia DR3 Catalogue BP/RP lr spectra for objects of Table 1. There are no spectra for object DFBS J215432.69+373829.7 in Gaia DR3 low-resolution database. We assume, that this object is N-type carbon stars according to location in J-K vs. BP-RP diagram (see more detail in Gigoyan et al. (2021).

3. Gaia DR3 photometric data. Distances and absolute magnitudes.

Table 2 presents Gaia DR3 Catalogue (VizieR CDS Catalogue I/355/gaiadr3) key data for new confirmed C stars and their high (Z) above/below the Galactic plane. The distance estimation is based on Gaia DR3 trigonometric parallaxes (absolutely the same value parallaxes, as presented in Gaia EDR3 catalogue (CDS

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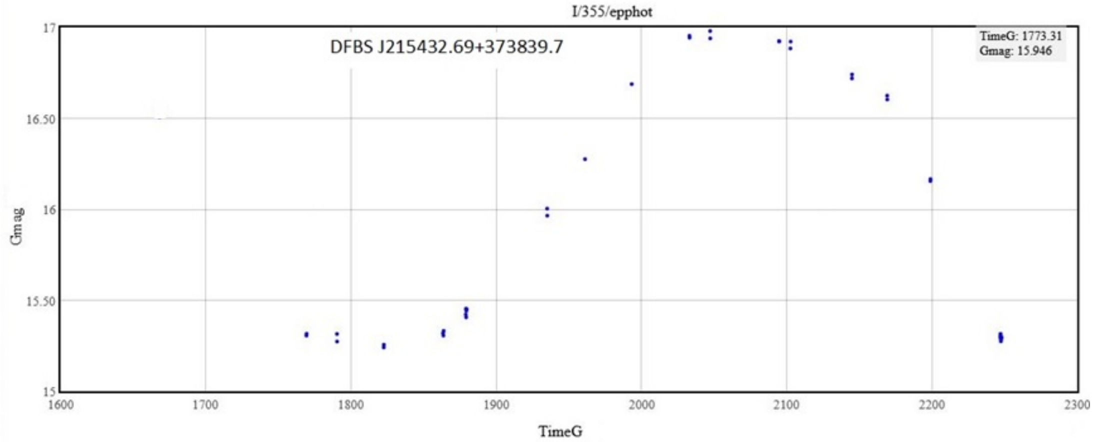

Figure 5. Phase dependent light curve for DFBS J215423.69+373839.7. This object is a Mire variable (P ≈ 450 day).

Table 2. Some important Gaia DR3 data for new confirmed carbon stars.

DFBS Number	Gaia G mag	BP-RP color	RV (km/s)	r(pc)	M(G)	Z(pc)
J004626.12+463720.4	14.68	1.53	-247.70(±3.14)	9783(±1500)	-0.50(±0.30)	-2737(±400)
J024615.25+484150.9	14.28	2.17	-137.35(±2.57)	6642(±800)	-0.20(±0.07)	-1147(±150)
J055944.18+473700.8	13.45	3.03	-33.70(±0.99)	9169(±1000)	-1.50(±0.20)	1850(±100)
J082310.36-015325.7	14.19	2.63	+210.10(±0.87)	11560(±900)	-1.10(±0.1)	3833(±300)
J130355.60+031950.6	13.35	1.33	-81.20(±1.72)	8791(±1000)	-1.37(±0.3)	8031(±800)
J134748.86+124730.5	13.28	1.28	-47.94(±1.58)	4680(±800)	-0.20(±0.1)	4411(±600)
J174725.28+301231.5	13.30	1.44	-351.18(±0.92)	6690(±400)	-0.80(±0.15)	2953(±100)
J182708.82+274303.9	12.77	1.49	-130.77(±0.38)	7541(±500)	-1.61(±0.16)	2250(±100)
J203313.62+121556.7	20.03	0.89		2415(±500)	??	??
J203956.64-063740.4	13.57	1.58	-283.63(±0.47)	9035(±1000)	-1.20(±0.20)	-4117(±400)
J215432.69+373839.7	16.16	4.50	-19.28(±0.03)	4758(±1000)	+2.77(±0.1)	-1-80(±200)
J215952.33+315207.9	13.18	1.76	-491.45(±0.43)	11288(±600)	-2.08(±0.1)	-3533(±200)
J221816.47+290920.0	13.17	2.32	-110.71(±0.31)	13504(±2500)	-2.48(±0.20)	-5237(±900)
J234931.72+442531.7	10.64	1.49	-13.93(±1.91)	1658(±40)	+1.04(±0.3)	-487(±5)

Vizier Catalog I/350/gaiaedr3). Therefore, we used the distance information from Gaia EDR3 by Bailer-Jones et al. (2021). We estimate the absolute G-band magnitude via the usual equation:

$$M(G) = G - 5Logr + 5 - A(G) \tag{1}$$

4. Variability

The object DFBS J055944.18+473700.8 is classified as Mira -type variable by Usatov & Nosulchik (2008). Phase dependent light curve for this object is available in “ASAS-SN Variable Star Database”(on-line at https://asas-sn.osu.edu/variables/, DFBS J055944.18+473700.8= ASASSN-V J055944.17+473700.7, Vmean = 14.98 mag), Figure 4 below shows ZTF (Zwicky Transient Facility (Masci et al., 2019) light curve for N-type C star DFBS J055944.18+473700.8. X-axis presents the period in Julian Data and Y-axis presents ZTF g-band magnitude. The observational identifier is 74510700000050 (P ≈ 307day). Figure 5 presents Gaia DR3 G-band magnitude phase dependent light curve for object DFBS J215432.69+373839.7. Figure 6 presents phased light curves for DFBS J174725.28+301231.5 and DFBS J182708.82+274303.9.

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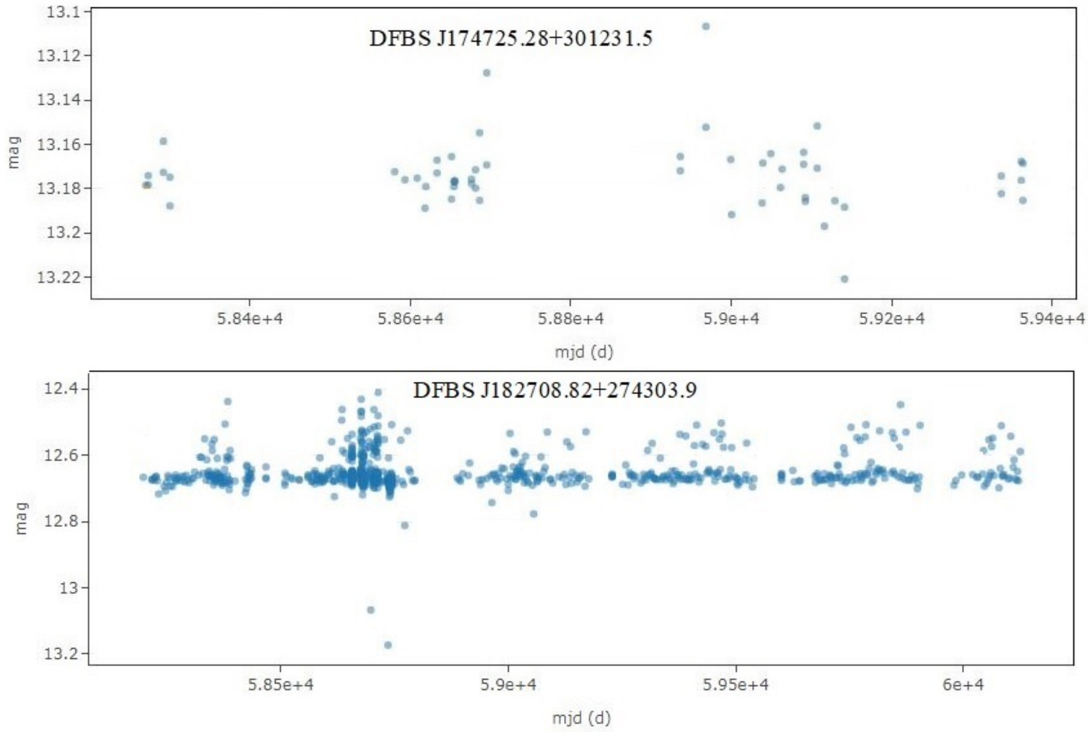

Figure 6. ZTF phased light curves in r-band for DFBS J174725.28+301231.5 and for DFBS J182708.82+274303.9. For last object the periodic variability in r-band with amplitude $\triangle m \approx 0.3$ mag is evident.

5. Summary and future works

We present data for 15 new detected DFBS Carbon stars which are presented previously as C star candidates. We plan to carry many-sided investigations of near 160 FBS carbon stars, such as distribution in our Galaxy, kinematics, absolute magnitudes, masses, et al. in near future.

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Stellar Membership of RCW 34 HII Star-Forming Region

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Abstract

The Vel OB1 association, located at a distance of 1.5-1.9 kpc, is one of the most actively studied star formation regions in the southern hemisphere. Our study focuses on an "Arclike" structure within the Vel OB1 association, which may have been formed from a shock wave caused by a supernova explosion about 2-2.5 Myr ago. Optical Gaia data revealed probable stellar members only in the southern part of the Arclike structure, where the RCW34 HII (IRAS 08546-4254) region is located. In contrast, the northeastern part of the Arclike structure, in the vicinity of the IRAS 08563-4225 source, hosts more embedded stellar population. Using near-infrared astrometric and photometric data from the 2MASS survey, we identified well-defined clusters of young stellar objects in the vicinity of both IRAS 08546-4254 and IRAS 08563-4225. The members of the cluster associated with IRAS 08563-4225 exhibit stronger infrared excess.

Keywords: *Open clusters and associations: Vel OB1- stars: formation - stars: early type stars*

1. Introduction

Star-forming regions and molecular clouds are intriguing parts of space where new stars are born. These areas, filled with dense, cold gas and dust, appear as dark patches against the bright Milky Way. They play a crucial role in the formation and evolution of stars in our Galaxy and beyond.

Molecular clouds come in two main types: giant molecular clouds (GMCs) and smaller molecular clouds. GMCs have masses ranging from tens of thousands to millions of solar masses and are large enough to birth hundreds of thousands of stars. Meanwhile, smaller molecular clouds, although smaller, still provide the right conditions for new stars to form. Deep within molecular clouds, star formation cores emerge as dense centers of stellar birth. Gravitational forces dominate here, causing gas and dust to collapse and form protostars. In various massive star-forming regions or associations, star formation in these clumps seems to be triggered by compression from external shocks. Other clusters can form by the self-gravitation of dense regions in molecular clouds (e.g. Elmegreen & Lada, 1977, Zinnecker et al., 1993). If star formation is triggered by compression, the age spread of the new generation of stars should be small, while the age spread of young stellar clusters is expected to be larger in self-initiated condensations. Therefore, understanding the characteristics of young stellar populations in star-forming regions is essential for deriving insights into the star formation processes within parent molecular clouds.

Massive stars play a very important role in the star-forming process. They affect their environment by shaping the morphology, energy, and chemistry of the interstellar medium (ISM) through outflows, stellar winds, and supernovae (McKee & Tan, 2003).

The main objective of this study is to search for the young stellar population in the "Arclike" molecular cloud within the Vel OB1 association. Vel OB1, located at a distance of 1.5-1.9 kpc, is one of the largest OB associations and has a complex, multi-component structure (Humphreys, 1978). One of its structures is the RCW 34 emission nebula, located at a distance of about 1.5-1.9 kpc. The age of the RCW 34 HII region is estimated to be around 2 Myr (Bik et al., 2010). Previous studies have shown that RCW34 is located in the southern part of the "Arclike" elongated molecular cloud (Azatyan et al., in preparation). The view of the cloud in WISE wavelengths is shown in Figure 1. In the northern part of the "Arclike" cloud, the IRAS

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08563-4225 star cluster is located at a distance 1.7 kpc (Beuther et al., 2008). Azatyan et al. suggested that the "Arclike" structure was created by a shock wave resulting from a supernova explosion about 2-2.5 Myr ago. This assumption is evidenced by bow-shock like shape of the cloud.

The paper is organized as follows: Section 2 describes the data used; Section 3 presents the results obtained and their discussion, including the selection of members of the "Arclike" star-forming region in optical range, radial surface density distribution of infrared (IR) point sources, and the identification of young stellar objects (YSOs) using colour-colour (c-c) diagrams. Finally, the conclusions drawn from the obtained results are presented in Section 4.

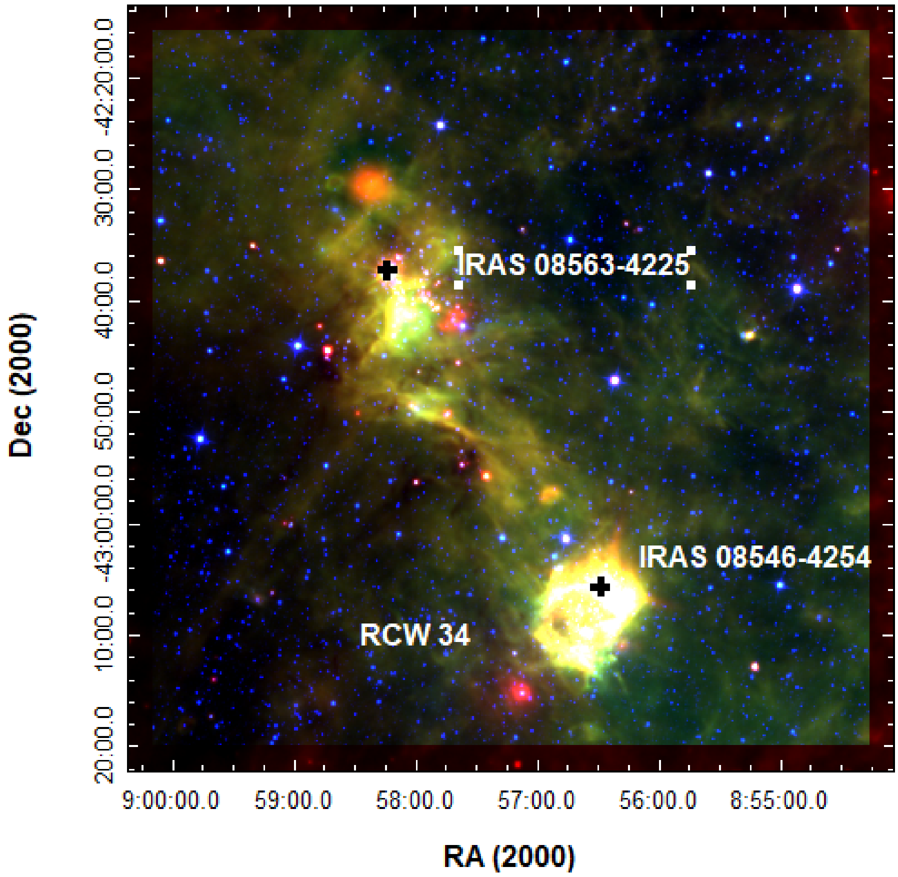

Figure 1. WISE colour-composite image of Arclike molecular clouds (blue - W2, green - W3, and red - W4). The positions IRAS sources are marked by black crosses.

2. Used data

To solve the tasks at hand, we used the Gaia Data Release 3 (Gaia DR3) optical database. This database provides the proper motions (pm) and parallaxes of stars, which enable us to estimate their distances and verify their association with the region of interest. We selected the region from the archive defined by the galactic coordinates $263^\circ.89 \leq l \leq 264^\circ.41$ and $1^\circ.3 \leq b \leq 2^\circ.3$, encompassing distances from 500 to 5000 pc. This domain completely covers the "Arclike" molecular cloud. We excluded sources with a fractional parallax uncertainty greater than 5% to ensure reliable parallax measurements.

For IR range, we used near-infrared (NIR) photometric data in the J, H, and K bands from the Two Micron All-Sky Survey (2MASS) with a resolution of 2 arcsec/pix. The photometric limits for point sources with a $5\,\sigma$ signal-to-noise ratio 16.3 mag in the J band, 15.8 mag in the H band, and 15.0 mag in the K_s band. These limits are essential for studying the structure and composition of star-forming regions (Skrutskie et al., 2006).

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3. Results

3.1. Optical range

Astronomical Data Query Language (ADQL) codes were used to obtain the necessary data from the Gaia archive. Additionally, we used the Tool for OPerations on Catalogs And Tables (TOPCAT) (Pössel, 2020), an interactive desktop application, for searching, analyzing, and managing tabular data. The distribution of stars in the domain according to their pms is given in Figure 2. The distribution clearly reveals a well-defined concentration of stellar objects (black dots) with pms relative to the right ascension (pmra) around -5 mas/yr and relative to the declination (pmdec) around 4.6 mas/yr. The minimum and maximum means of the pmra and pmdec for the selected group are presented in Table 1. This indicates that in the considered region, there is a group of stars moving at nearly the same velocity relative to the interstellar medium. Furthermore, the members of this group have very similar parallaxes, corresponding to a distance of 2200 ± 500 pc (see Figure 3 and Table 1). Together, this testifies to the existence of a star cluster located at almost the same distance as RCW 34. The map of the cluster is shown in Figure 4.

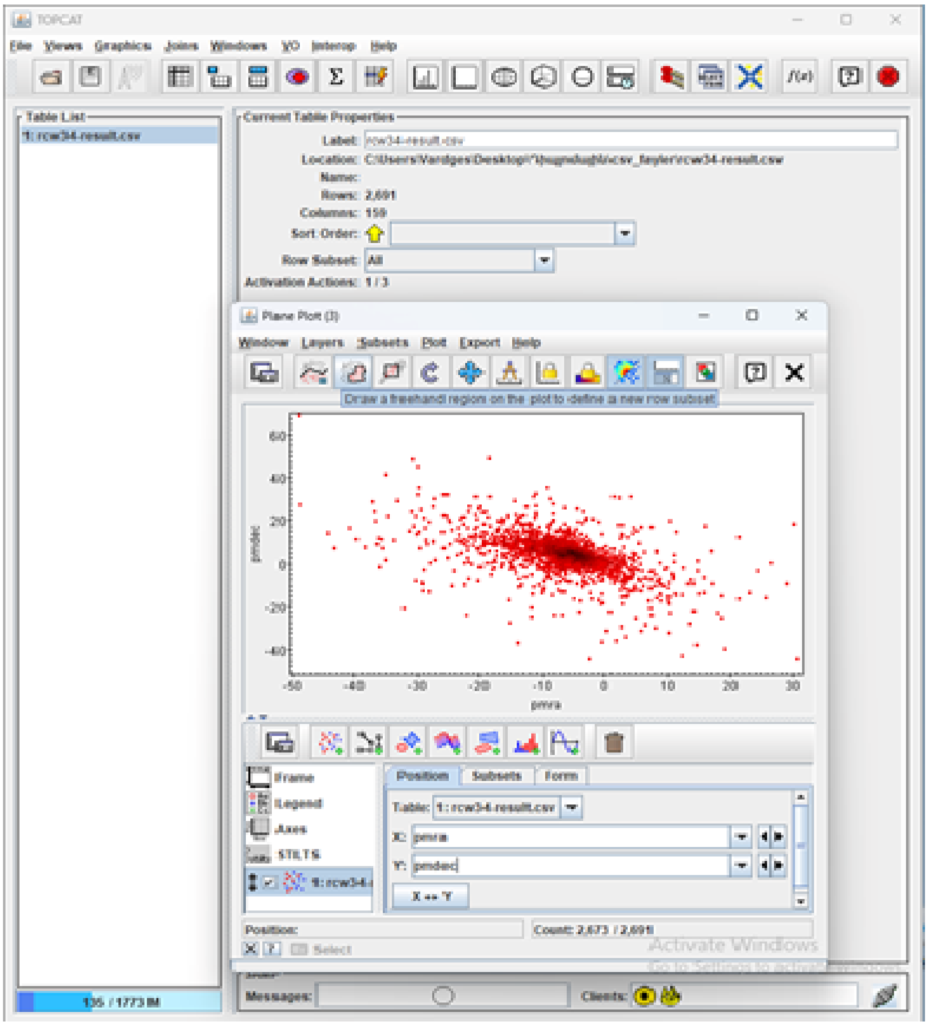

Figure 2. Distribution of the proper motions of the stars in the region defined by the coordinates $263°.89 \leq l \leq 264°.41$ and $1°.3 \leq b \leq 2°.3$.

Table 1. Distance and proper motions of the cluster

Distance (pc)	pmra min (mas/yr)	pmra max (mas/yr)	pmdec min (mas/yr)	pmdec max (mas/yr)
2200 ± 500	-5.61	-4.60	3.35	5.94

In Figure 4 we observe that the cluster members form a concentration in the RCW 34 region. However, the clusters members avoid the northern part of the “Arclike” cloud. The most obvious explanation for the absence of optically detected stellar objects in the vicinity of the IRAS 08563-4225 source is the existence of

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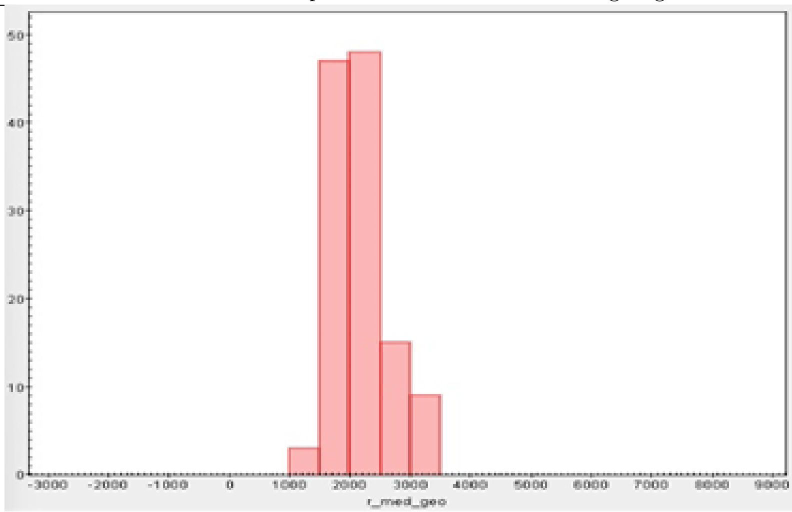

Figure 3. Distribution of the parallaxes of the stars in the region defined by the coordinates $263°.89 \leq l \leq 264°.41$ and $1°.3 \leq b \leq 2°.3$.

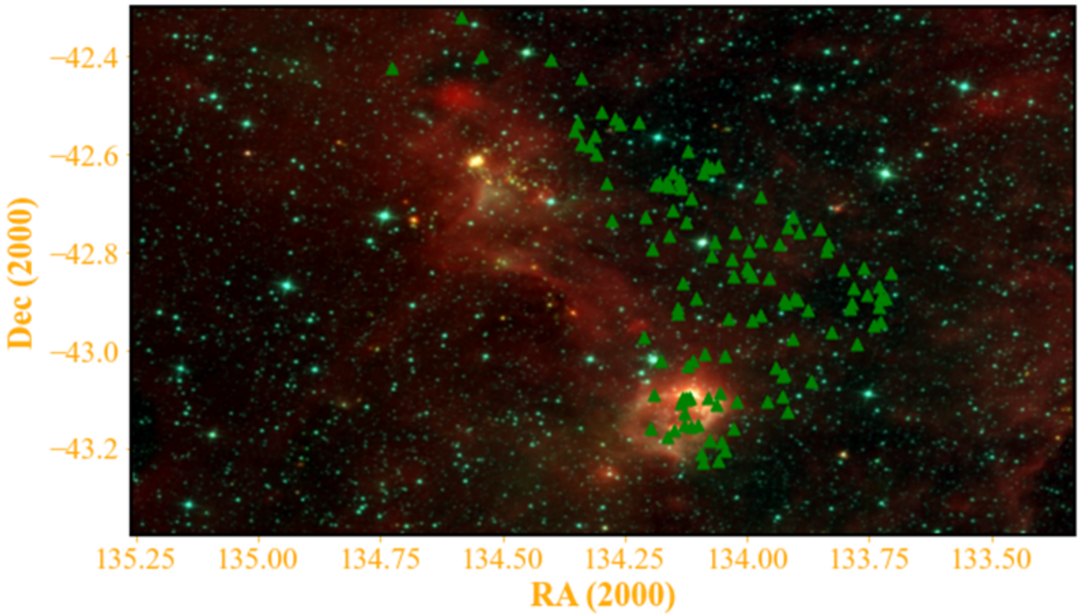

Figure 4. Colour-composite *Herschel* map of the cluster (blue - 160 μm, green- 350 μm, and red - 500 μm). Cluster members marked by green triangles.

a dense foreground molecular cloud which significantly absorbs optical radiation (Yamaguchi et al., 1999). This necessitates the use of the IR range to search for the stellar population in the region.

3.2. Infrared range

3.2.1. Radial surface stellar density distribution

The first stage of using IR astrometric and photometric data is to confirm the existence of IR clusters in the vicinity of both IRAS sources. For this purpose, we constructed the radial density distributions of the point sources from the 2MASS database with K_s mag < 15.0 in the areas around both IRAS sources. These areas are marked by larger circles in Figure 5. The centers of circles are coinciding with the coordinates of the IRAS sources. To determine the surface density of point source, we divided the regions into rings of a certain width and then divided the number of stars in each ring by the surface of the ring. The standard error of the number of stars in the rings was used as a measure of uncertainty. The stellar density distributions for the clusters are presented in the Figure 5. The radial density distributions show well-defined concentrations of stars around the IRAS sources, confirming the the existence of clusters. Starting from radii of $3'$, and $2.5'$

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in the IRAS 08546-4254 and IRAS 08563-4225 regions, respectively, the stellar density does not exceed the average density of the field. These radii can be considered as the cluster radii and are marked by smaller circles in Figure 5.

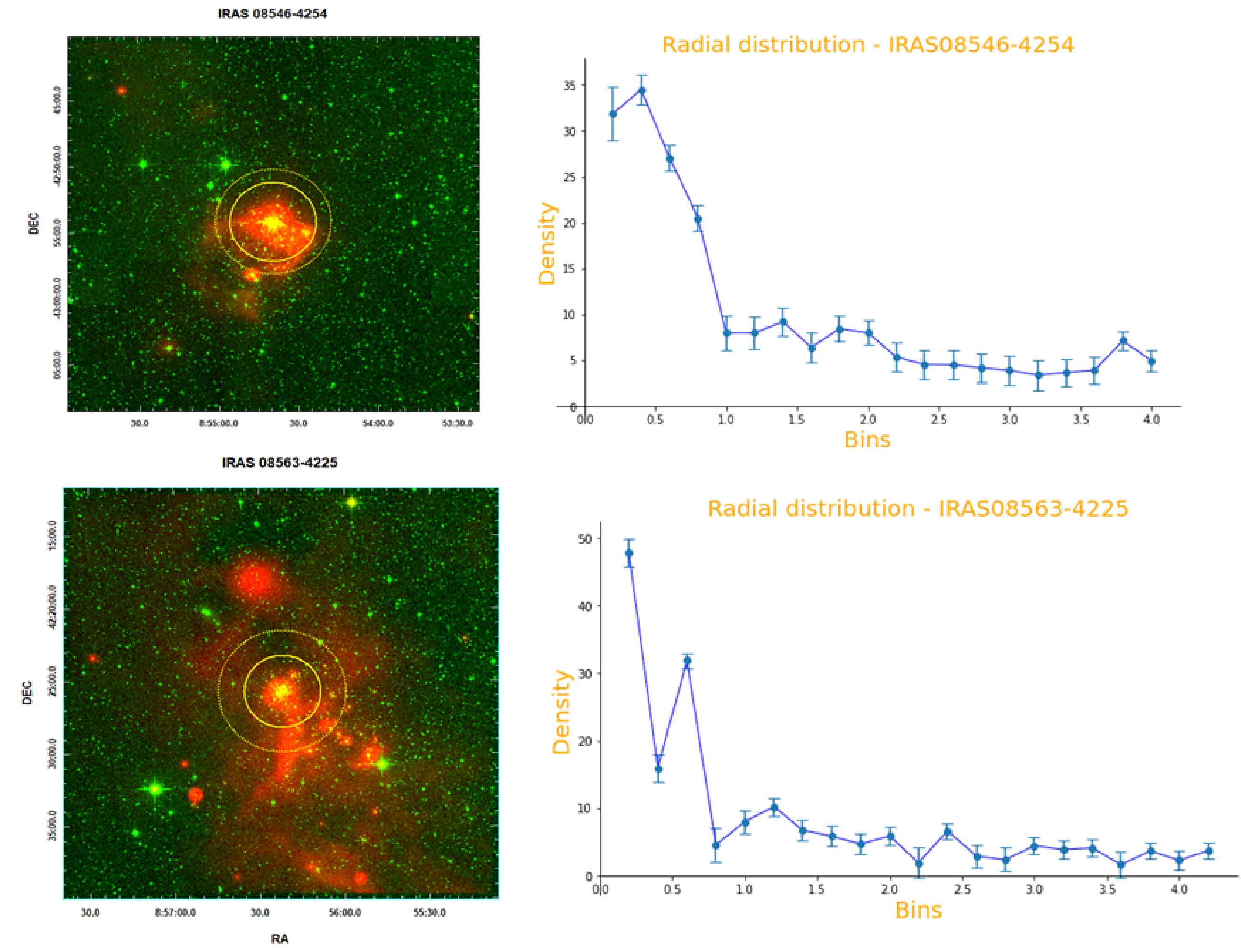

Figure 5. *Left panel*: Colour-composite images of the regions in the vicinity of the IRAS 08546-4254 and 08563-4225 sources (green - 2MASS and red - WISE 22 μm). The larger circles define the areas in which the radial distributions of stellar surface density were plotted, and the smaller circles outline the regions of increased density. *Right panel*: Radial distribution of surface stellar density (stars/arcmin^2) relative to the IRAS sources.

3.2.2. Colour-Colour NIR diagram

The next stage of IR research is to show that most of the stellar objects located in the region of increased density belong to the star formation region under consideration. Since, unlike the optical range, we cannot determine the distance of IR sources, we assume that most of the members of the considered active star-forming region are YSOs. One of the main observational characteristics of YSOs is an IR excess due to the presence of circumstellar discs and envelopes (Hartmann, 2009, Lada & Lada, 2003). Furthermore, the measure of the IR excess in the NIR and/or MIR ranges can be used to characterise the evolutionary stage of a YSO (Class I and II). Therefore, YSO candidates can be identified based on their IR colour indices, i. e., their position in c-c IR diagram. Numerous studies have provided theoretical justifications that explain the placement of YSOs in the c-c diagrams, correlating specific positions with different evolutionary stages. For our analysis we employed (J–H) vs. (H–K) c–c NIR diagram (Hernández et al., 2005, Lada & Adams, 1992, Meyer et al., 1997) for the 2MASS IR point sources within the clusters' radii. The diagrams for both regions are presented in Figure 6.

The deviation of stars from the main sequence (MS) on the (J–H) vs. (H–K) c–c NIR diagram can have two reasons: the presence of an IR excess and interstellar absorption, which also leads to reddening of

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objects. However, in the latter case, the deviation from the MS will be directed along the reddening vectors. Therefore, the IR excess of objects to the right of the reddening vectors cannot arise solely from interstellar absorption; at least in part, their IR excess must be due to the presence of the disk and envelope surrounding them. Hence, objects to the right of the reddening vectors can be considered as YSO candidates. We also consider objects with $J - K > 3$ as YSO candidates. According to Lada & Adams (1992), those objects may be considered as Class I evolutionary stage YSOs.

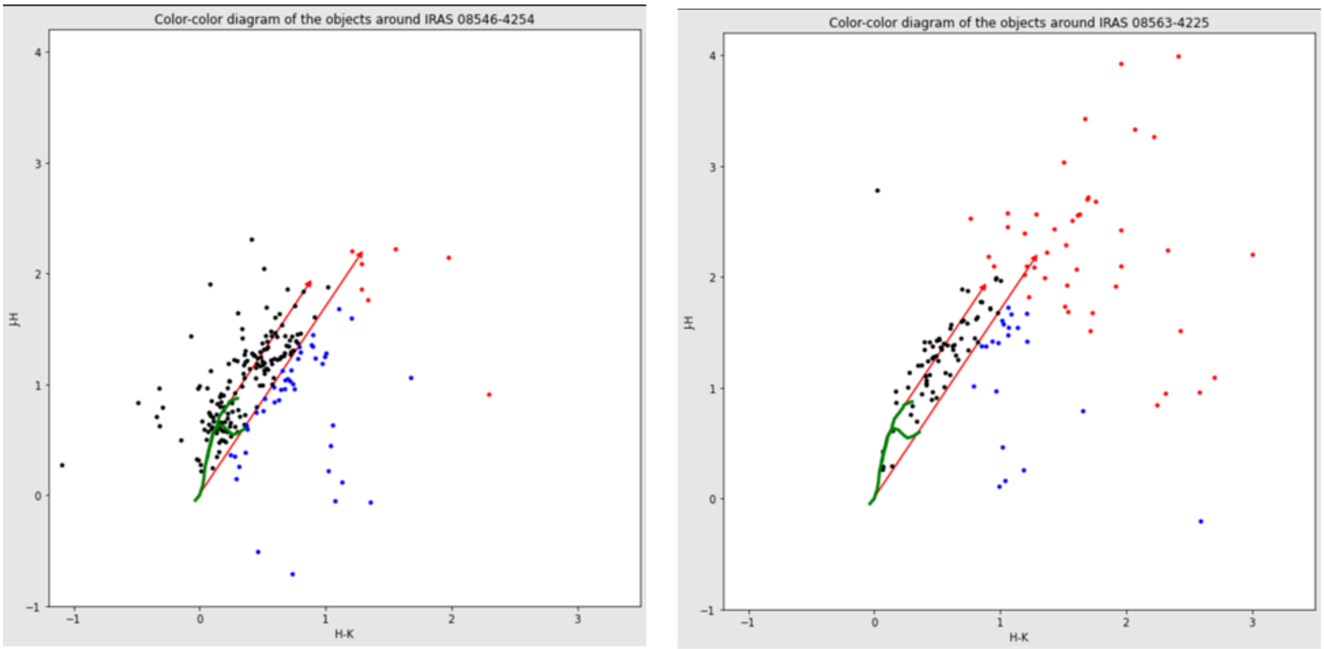

Figure 6. *Left panel*: (J–H) versus (H–K) colour-colour diagrams for the clusters. The green curves represent the positions of dwarfs and giants (Bessell, 1988), converted to the CIT photometric system (Carpenter, 2001). The red vectors are reddening vectors reflecting interstellar absorption (Rieke et al., 1985). Objects with different evolutionary stages are marked by different colors: red for Class I with J-K > 3 (Lada & Adams, 1992), blue for objects with IR excess (Class I/II), and black for objects, which were not selected as potential YSOs.

In total, on the NIR c-c diagram we identified 7 and 65 objects with J-K > 3, as well as 43 and 21 objects located to the right of the reddening vectors in IRAS 08546-4254 and IRAS 08563-4225 regions, respectively. Such a significant number of stars with a distinct IR excess confirms the presence of young star clusters near both IRAS sources. Notably, the IRAS 08563-4225 cluster contains a very large number of YSOs at the Class I evolutionary stage. This may indicate that the cluster is at an earlier stage of evolution and that a dense shielding cloud is present, leading to greater interstellar absorption.

4. Conclusion

The main goal of our work is to search for the young stellar population in the “Arclike” molecular cloud within the Vel OB1 association, which may have been formed from a shock wave caused by a supernova explosion about 2-2.5 Myr ago. The molecular cloud includes two subregions around the IRAS 08546-4254 (RCW 34 HII) and IRAS 08563-4225 sources.

Using the Gaia DR3 optical database, we identified a stellar cluster located in the RCW 34 region. However, the optically identified cluster members avoid the northern part of the “Arclike” cloud, around IRAS 08563-4225, most likely due to significant interstellar absorption, necessitating the use of the IR range to search for the stellar population in this region. The radial density distributions of IR point sources from the 2MASS NIR database show well-defined concentrations of objects around the both IRAS sources, confirming the existence of clusters with radii of $3'$ and $2.5'$ in the IRAS 08546-4254 and IRAS 08563-4225 regions, respectively. To identify YSOs in the clusters, we used NIR colour indices. i.e. the positions on the (J–H) vs. (H–K) c-c diagram of point sources within the clusters’ radii. In total, we identify 123 YSOs. The significant number of identified YSOs in the clusters further supports that “Arclike” molecular cloud is an

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active star-forming region, deserving of much more detailed study. Notably, the IRAS 08563-4225 cluster contains a very large number of YSOs at the Class I evolutionary stage. This may indicate that the cluster is at an earlier stage of evolution and that a dense shielding cloud is present, leading to greater interstellar absorption.

It is important to note that the selection of YSOs is only the initial stage of the overall research. The next step involves determining their parameters, specifically their masses and evolutionary ages, as well as the density and temperature of the ISM. These determinations will enable us to draw comprehensive conclusions about the entire star formation process in the region.

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Identification of the young stellar clusters in the G345.5+1.5 Star-Forming Region

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Abstract

Star-forming regions, their formation and evolution are a subject of active study. The subject of our research is the G345.5+1.5 region, which is composed of two dusty ring-like structures referred to as G345.45+1.5 and G345.10+1.35. The region is located at a distance of 1.8 kpc and classified as HII regions. According to previous studies, G345.45+1.5 could have been created by a supernova explosion represented by the 36.6 cm source J165920-400424 in its center. Despite the considerable interest, only a few works are devoted to this region, and there is very little information about its stellar population. Our work focuses specifically on the stellar population in this region. Using 2MASS astrometric and photometric data, we identified three well-defined clusters of young stellar objects (YSOs) in the vicinity of the IRAS 16561-4006, 16571-4029, and 16545-4012 sources.

Keywords: *stars: formation, stars: pre-main sequence, stellar cluster: G345.5+1.5*

1. Introduction

Even in our current era, star formation within the Galaxy continues (Ambartsumian, 1947). Regions of star formation, identified by dense molecular clouds that exhibit gravitational instability, serve as crucial sites where the complex interplay of physical forces initiates the birth of stellar objects. Thorough investigation of these regions is essential for enhancing our understanding of stellar evolution in general. Within these molecular clouds, dense regions form and initiate star formation as gas and dust collapse. The complex interaction of forces determines the location and movement of star-forming cores, impacting the later development of newborn stars (Lada & Lada, 2003). Therefore, the study of star formation regions serves multiple objectives. Firstly, it offers a window into the initial phases of stellar birth, providing insights into the physical conditions and dynamical processes governing the formation of protostellar cores. By employing high-resolution observations of molecular gas and dust, astronomers can delineate the hierarchical structure of star-forming regions and investigate the mechanisms driving their fragmentation and collapse. In turn, understanding the characteristics of young stellar populations is essential for deriving insights into star formation processes within parent molecular clouds.

The main goal of our work is to search for the stellar population in the G345.45+1.5 and G345.10+1.35 molecular clouds, which are part of the G345.5+1.5 star formation region (see Figure 1). These molecular clouds are located 1.8 kpc apart and classified as a single HII region (Figueira et al., 2019). They contain a significant number of IRAS sources (see right panel of Fig. 1). According to López-Calderón et al. (2016), the northern cloud, G345.45+1.5, could have been caused by a supernova explosion. This is supported by the bow-shock shape of the interstellar medium (ISM) in G345.10+1.35, which is clearly visible at the WISE 22 μm wavelength (see left panel of Fig. 1). To date, there are only a few studies on this star-forming region, resulting in limited information about its stellar population. On the other hand, understanding the properties of the stellar population, including spatial distribution, mass function, and evolutionary age spread, can provide clarity in understanding their formation and evolution.

The paper is organized as follows: Section 2 describes the data used; Section 3 presents the results obtained and their discussion: radial distribution of the surface stellar density and identification of young

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stellar objects (YSOs) using colour-colour (c-c) diagrams. Finally, the conclusions drawn from the obtained results are presented in Section 5.

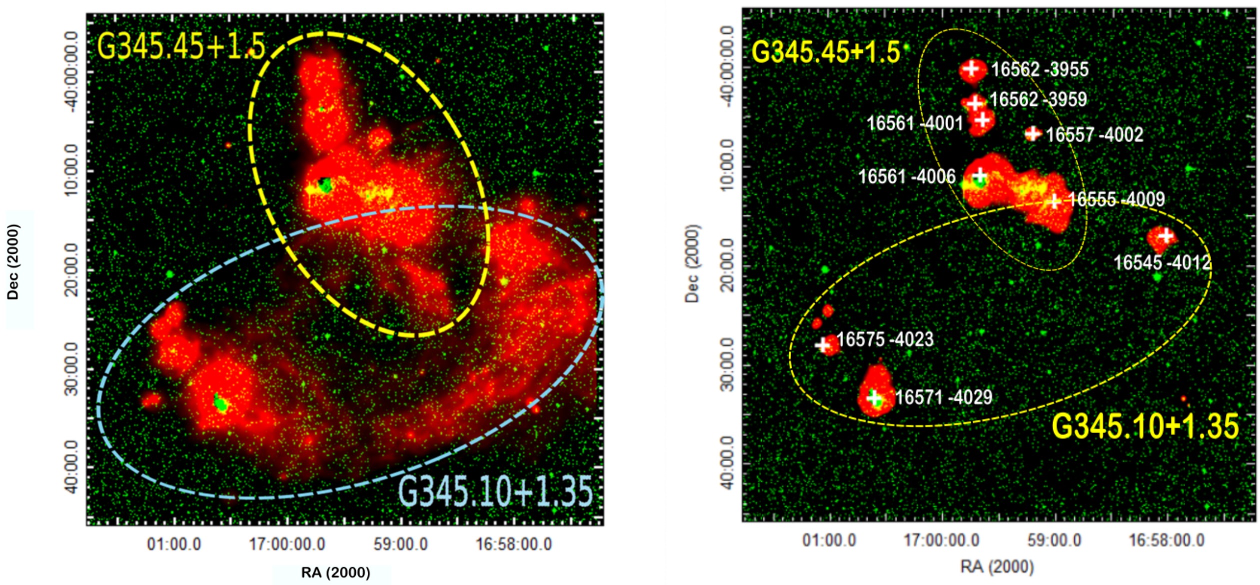

Figure 1. Colour-composite images of the G345.45+1.5 star formation region (green - 2MASS K and red-WISE 22 μm) with different contrast. The IRAS sources are marked by crosses and labeled on the right panel.

2. Used data

In our study, we used near- and mid-infrared (NIR and MIR, respectively) data. The first dataset comprises archival NIR photometric data in the J, H, and K bands of the Two Micron All-Sky Survey (2MASS) with a resolution of 2 arcsec/pix. The photometric limits for point sources with a 5 σ signal-to-noise ratio 16.3 mag in the J band, 15.8 mag in the H band, and 15.0 mag in the K_s band. These limits are essential for studying the structure and composition of star-forming regions (Skrutskie et al., 2006).

Archival MIR observations were obtained from the Galactic Legacy Infrared Midplane Survey Extraordinaire (GLIMPSE, Churchwell et al., 2009). These observations were conducted using the Infrared Array Camera (IRAC, Fazio et al., 2004) on the Spitzer Space Telescope. The four IRAC bands are centred at ∼ 3.6, 4.5, 5.8, and 8.0 μm with a resolution of 0.6 arcsec/pix.

3. Results and discussion

Figure 1 shows that stellar population in the G345.5+1.5 formation region has a multicomponent, hierarchical structure, making its detailed study of considerable interest. The point sources are mostly concentrated around the IRAS sources, forming three well-defined clusters. We named these clusters as IRAS 16575-4023 & 16571-4029, G345.45+1.5, IRAS 16545-4012 (see Fig. 2).

3.1. Radial surface stellar density distribution

The first step of our work is to confirm the existence of these clusters. For this purpose, we constructed the radial density distributions of the point sources from 2MASS database with K_s mag < 15.0 in areas, which exceed the dimensions of the bright nebulae in the IRAS 16575-4023 & 16571-4029, G345.45+1.5, IRAS 16545-4012 regions. These areas are marked by white circles in Figure 2. The centers of circles are given in Table 1. In the IRAS 16575-4023 & 16571-4029 and G345.45+1.5 region, we used the geometric centers, while for IRAS 16545-4012, the center coincides with the IRAS source coordinates. Table 1 also contains the radii of the searching areas and clusters (see text below).

To determine the surface density of point source, we divided the regions into rings of a certain width and then divided the number of stars in each ring by the surface of the ring. We used the standard error of the

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number of stars in the rings as a measure of uncertainty. The stellar density distributions for the clusters are presented in the Figure 3. The radial density distributions show a well-defined concentrations of stars around the IRAS sources, confirming the the existence of clusters. Starting from radii of 8′, 11′, and 3′ in the IRAS 16575-4023 & 16571-4029, G345.45+1.5, IRAS 16545-4012 regions, respectively, the stellar density does not exceed the average density of the field. These radii can be considered as the cluster radii. These regions are marked in yellow in Figure 2.

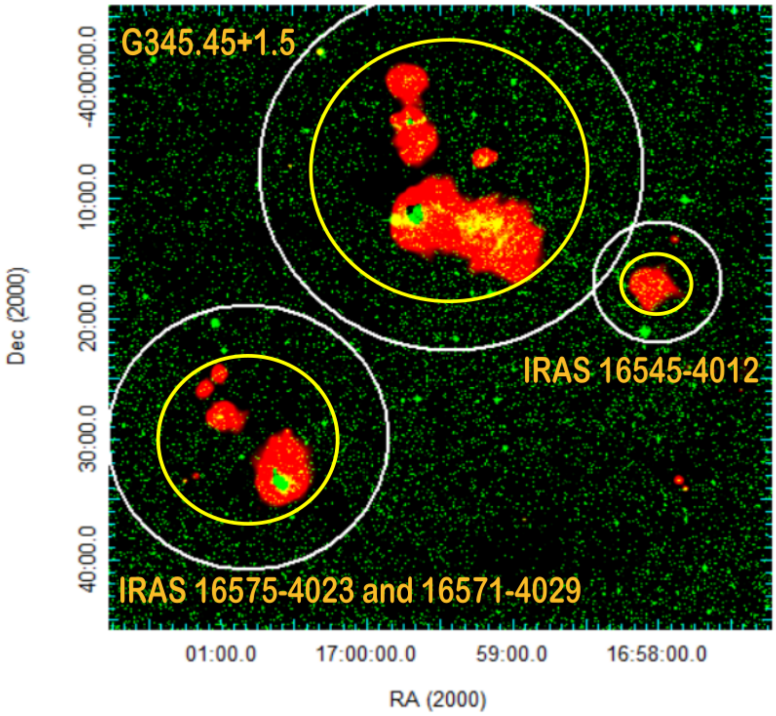

Figure 2. Colour-composite image of the G345.45+1.5 star (green - 2MASS and red - WISE 22 μm). The white circles define the region in which the radial distribution of stellar surface density was plotted. Yellow circles outline areas of increased density.

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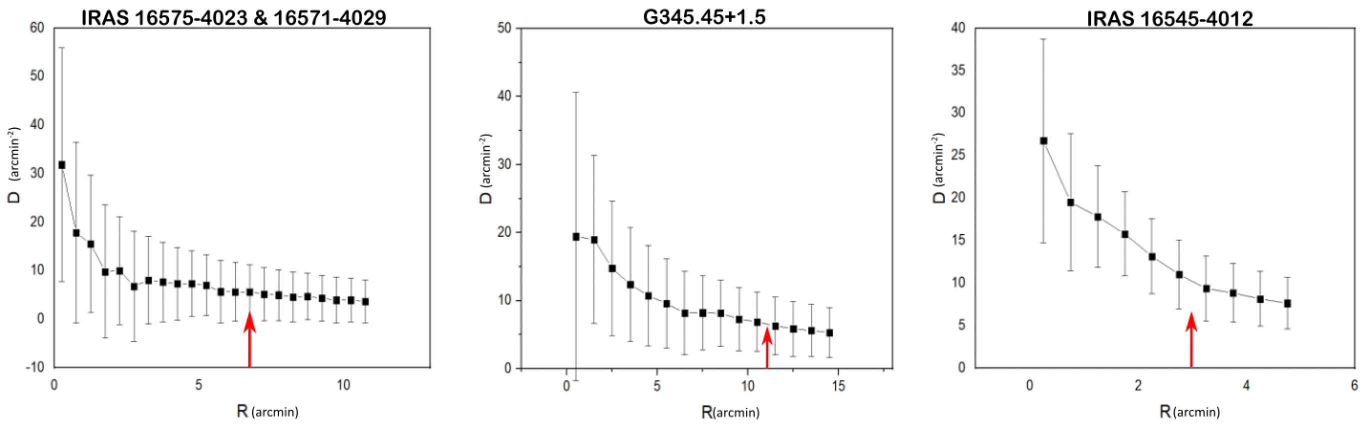

Figure 3. Radial distribution of surface stellar densities, with red arrows indicating the clusters' radii.

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4. Colour-colour diagrams

When selecting potential cluster members from stars located in the direction of the molecular cloud, we assumed that most of the members of the considered active star-forming region are YSOs. One of the main observational characteristics of YSOs is an infrared (IR) excess due to the presence of circumstellar discs and envelopes (Hartmann, 2009, Lada & Lada, 2003). Furthermore, the measure of the IR excess in

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Table 1. Coordinates of the centers and the radii of the searching areas and clusters

Cluster name	RA (2000)	Dec (2000)	R of seraching area	R of cluster
IRAS 16575-4023 & 16571-4029	17:00:48	-40:30:00	11'	6'
G345.45+1.5	16:59:25	-40:07:50	15'	10'
IRAS 16545-4012	16:58:01.0	-40:17:09	5'	3'

the NIR and/or MIR ranges can be used to characterise the evolutionary stage of a YSO (Class I and II). Therefore, YSO candidates can be identified based on their IR colour indices, i. e., their position in c-c IR diagrams. Numerous studies have provided theoretical justifications that explain the placement of YSOs in the c-c diagrams, correlating specific positions with different evolutionary stages. For our analysis we employed three distinct c-c diagrams for IR point sources within the clusters' radii:

- (J–H) vs. (H–K) c–c NIR diagram (Hernández et al., 2005, Lada & Adams, 1992, Meyer et al., 1997);
- K–[3.6] vs. [3.6]–[4.5] c–c diagram, which combines NIRand MIR photometric data (Allen et al., 2007);
- MIR [3.6]-[4.5] vs. [5.8]-[8.0] c-c MIR diagram (Allen et al., 2007).

Aside from YSOs, other objects can also display an IR excess and may be mistakenly identified as YSOs. These objects include: (i) star-forming galaxies and narrow-line active galactic nuclei (AGNs), which exhibit increasing excesses at 5.8 and 8.0 μm due to hydro-carbon emissions; (ii) broad-line AGNs, whose IRAC colours closely resemble those of YSOs. To maintain the purity of our YSO sample, we excluded all point sources with colour indices typical of the aforementioned categories, as identified by Gutermuth et al. (2008). The positions of the point sources from 2MASS and GLIMPSE databases within the clusters' radii on the c-c diagrams are presented in Figures 4 and 5.

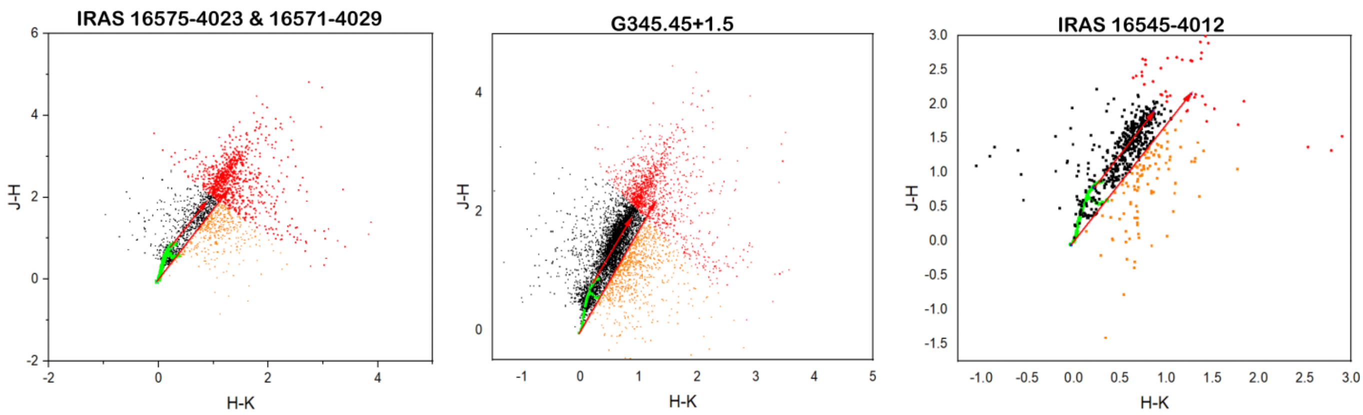

Figure 4. (J–H) versus (H–K) colour-colour diagrams for the clusters. The green curves represent the positions of dwarfs and giants (Bessell, 1988), converted to the CIT photometric system (Carpenter, 2001). The red vectors are reddening vectors reflecting interstellar absorption (Rieke et al., 1985). Objects with different evolutionary stages are marked by different colors: red for Class I with J-K > 3 (Lada & Adams, 1992), orange for objects with IR excess (ClassI/II), and black for objects, which were not selected as potential YSOs.

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The deviation of stars from the main sequence (MS) on the (J–H) vs. (H–K) c–c NIR diagram can have two reasons: the presence of an IR excess and interstellar absorption, which also leads to reddening of objects. However, in the latter case, the deviation from the MS will be directed along the reddening vectors. Therefore, the IR excess of objects to the right of the reddening vectors cannot arise solely from interstellar absorption; at least in part, their IR excess must be due to the presence of the disk and envelope surrounding them. Hence, objects to the right of the reddening vectors can be considered as YSO candidates. We also consider objects with $J - K > 3$ as YSO candidates. According to Lada & Adams (1992), those objects may be considered as Class I evolutionary stage YSOs.

MIR wavelengths are also used to identify YSOs with different evolutionary stages. The positions of the stellar objects with different evolutionary stages based on the *Spritzer* IRAC photometric bands are well developed by Allen et al. (2007).

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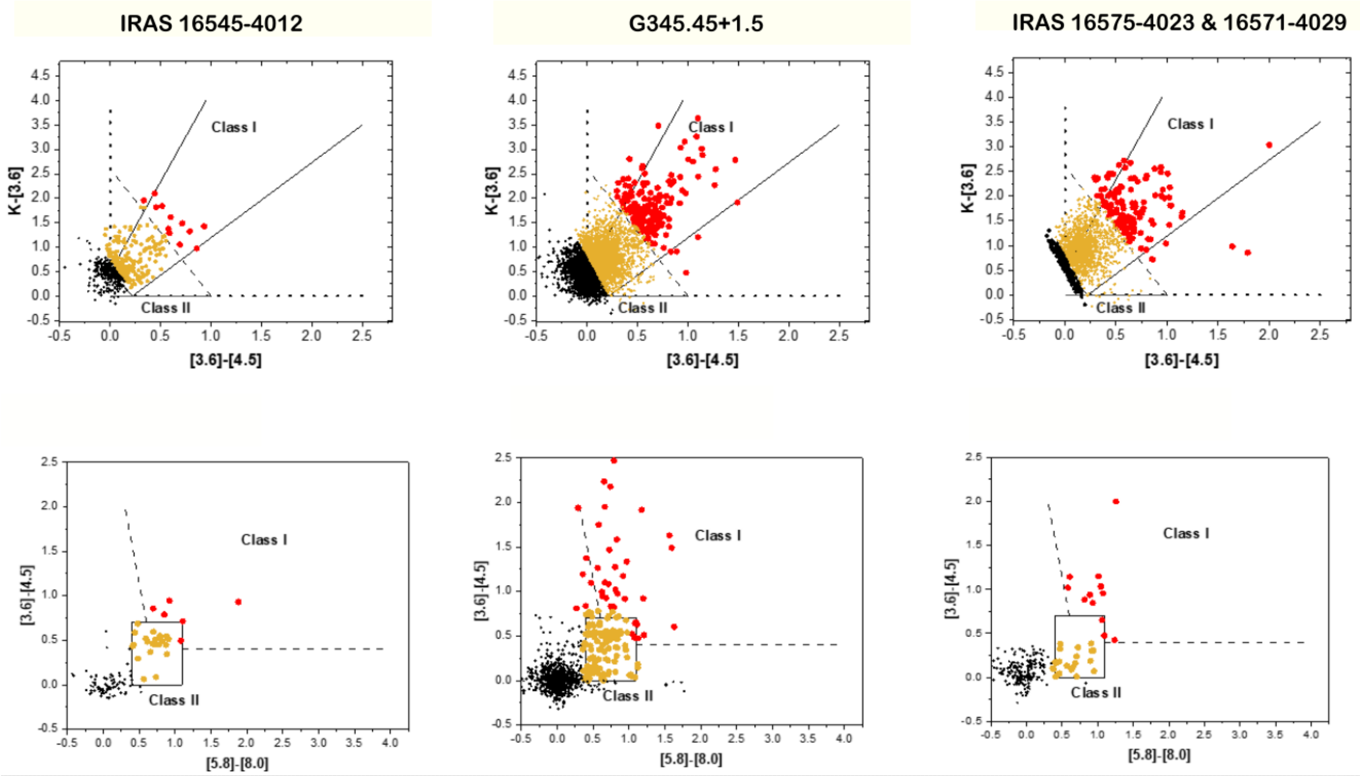

Figure 5. Colour–colour diagrams of the clusters. *Top panels:* K–[3.6] versus [3.6]–[4.5] diagrams and *bottom panels*: [3.6]–[4.5] versus [5.8]–[8.0] diagrams. In all diagrams, Classes I and II domains are separated by the dashed lines. All lines are from Allen et al. (2007). Objects with different evolutionary stages are marked by different colours: red for Class I, orange for Class II, and black for objects, which were not selected as potential YSOs.

Table 2. Number of identified YSOs at different stages of evolution

Cluster name	Class I	Class II
IRAS 16575-4023 & 16571-4029	8	118
G345.45+1.5	44	607
IRAS 16545-4012	6	67

Object selection based on photometric data alone cannot be considered very accurate for several reasons:

- There is a possibility that objects, which do not belong to the molecular cloud may be selected;
- Stellar objects with small NIR excesses are excluded from the selection;
- Young stars can be positioned differently relative to us, which can result in varying classifications across different wavebands.

To minimize the possibility of incorrect selection, we chose YSOs classified as IR excess objects in at least two diagrams. The final results for the identification of YSOs in clusters are given in Table 2. The significant number of identified YSOs in the clusters is further evidence that G345.45+1.5 is a very active star-forming region, deserving much more detailed study. Moreover, the number of YSOs directly depends on the size of the surrounding nebulae. This is most likely due to the fact that the greater mass of the ISM causes more active star formation. However, the percentage content of Class I YSOs in the clusters is almost the same (6 - 8 %). Could this be a consequence of the fact that star formation in all three clusters was initiated simultaneously? This and other questions require further research.

5. Conclusion

The main goal of our work is to search for the young stellar population in the G345.45+1.5 and G345.10+1.35 molecular clouds, which are part of the G345.5+1.5 star formation region. For this pur-

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pose we used NIR and MIR photometric data obtained from 2MASS and GLIMPSE databases. The point sources in the region are mostly concentrated around the IRAS sources, forming three well-defined clusters. We named these clusters as IRAS 16575-4023 & 16571-4029, G345.45+1.5, and IRAS 16545-4012.

The first step of our work is to confirm the existence of these clusters. For this purpose, we constructed the radial surface density distributions of the point sources from the 2MASS database with K_s mag < 15.0 in areas that exceed the dimensions of the bright nebulae in the clusters' regions. According the radial density distributions the radii of the clusters are $8'$, $11'$, and $3'$ for the IRAS 16575-4023 & 16571-4029, G345.45+1.5, and IRAS 16545-4012 regions, respectively.

For the identification of YSOs in the clusters, we used NIR and MIR colour indices. i.e. the position on the c-c diagrams of point sources within the clusters' radii. We used three c-c diagrams: (J–H) vs. (H–K), K–[3.6] vs. [3.6]–[4.5], and [3.6]-[4.5] vs. [5.8]-[8.0]. In total, we identify 850 YSOs, of which 58 are at Class I evolutionary stage. The significant number of identified YSOs in the clusters is further evidence that G345.45+1.5 is a very active star-forming region, deserving much more detailed study.

It is important to note that the selection of YSOs is only the initial stage of the overall research. The next step involves determining their parameters, specifically their masses and evolutionary ages, as well as the density and temperature of the ISM. These determinations will enable us to draw comprehensive conclusions about the entire star formation process in the region.

Acknowledgements

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The runaway nature and origin of α Crucis system

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Abstract

Massive stars are always the focus of astronomical research and a significant part of them (10–20%) moves in space at a high (supersonic) velocity. This paper presents the results of a study of the α Crucis system, located at ∼114 pc distance from the Sun, with an observed bow shock around it. We used data and images from the Gaia and WISE space telescopes. The coordinates, distance, and proper motion of the α Crucis system were used to determine its space velocity. We managed to find a stellar cluster to which the α Crucis system belongs, that is, it has not been ejected from its parent cluster, but is moving in space together with other members of the cluster. The α Crucis system has a velocity of ∼1.3 km/s relative to the star cluster. The geometric parameters of the bow shock are compatible with other known bow shocks. The bow shock is unaligned, i.e., most likely interstellar medium (ISM) large-scale motions are responsible for the resulting bow shock, which is further evidence that the α Crucis system is not runaway in nature.

Keywords: *Infrared: ISM – Open clusters and associations: Scorpius-Centaurus – Stars: individual: HD 108248, HD 108249, and HD 108250*

1. Introduction

The massive stars within the Milky Way are not randomly dispersed; approximately 80% of the O-type stars are part of OB associations located in the galaxy's spiral arms (Brown et al., 1999). The kinematic characteristics of the remaining 20%, which belong to the field population, indicate that these O stars are runaways—originating from OB associations but subsequently escaping (Blaauw, 1993). Two primary scenarios are widely accepted to explain the presence and high velocities of runaway stars: (1) the supernova explosion of a companion star within a massive binary system (Blaauw, 1961), and (2) the dynamic ejection from a young star cluster during its early developmental stages (Poveda et al., 1967). Identifying the original OB association of a runaway star is crucial, as it provides insights into the star's evolutionary history. By knowing the proper motions of both the runaway star and its parent OB association, the kinematic age of the runaway star can be determined.

Another method of searching for high-velocity runaway star candidates is to bow-shocks associated with these objects, which are generated by the interaction of the star's wind with the interstellar medium (ISM) (e.g., Peri et al., 2012, van Buren & McCray, 1988, Azatyan et al. submited). Therefore, OB runaways can be used also as probes of the ISM. As rule, bow shocks emit strong radiation in the mid-infrared range (e.g., Gvaramadze et al., 2011).

In our paper, we have chosen the α Crucis system as the target of study. The α Crucis system consists of three stars: HD 108248, HD 108249, and HD 108250. HD 108248 and HD 108249 are known as a^1 Cru and a^2 Cru with spectral types B0.5IV and B1V, respectively (Houk & Cowley, 1975, Reed, 2005). HD 108250 is also known as α Cru C with spectral type B4V (Reed, 2005, Tokovinin et al., 1999). Figure 1 shows a combination of 22 μm (red), 12 μm (green), and 3.4 μm (blue) images of the α Crucis system and the bow shock detected around it. The three stars of the system are indicated by white arrows. The HD 108248 and

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HD 108249 pair is significantly brighter compared to HD 108250. HD 108250 is 90 arcseconds away from the pair HD 108248 and HD 108249 and has the same space motion, suggesting they may be gravitationally bound (Shatsky & Tokovinin, 2002). Rizzuto et al. (2011) calculated that this system, including HD 108250, is a member of the Lower Centaurus–Crux subgroup in the Scorpius–Centaurus association with a 66% probability. The radial velocities of stars HD 108248, HD 108249, and HD 108250 are 11.2±2, 0.6±2, and 27±5 km/s, respectively (Wilson, 1953). The parallaxes and proper motions of the three stars in the system are almost the same. The parallaxes and proper motions of HD 108248 and HD 108249 are 10.13±0.50 mas, -35.83±0.47 mas/yr, and -14.86±0.43 mas/yr, respectively (van Leeuwen, 2007). The third data release of Gaia observatory (Gaia DR3) provides reliable information only on the star HD 108250. The parallax is 9.3964±0.1289 mas (Gaia Collaboration, 2022), giving a distance of ∼114 pc from the Sun. The fractional parallax uncertainty (`parallax/parallax_error`) is ∼73. The proper motion in RA is -39.548±0.117 mas/yr and in Dec is -13.760±0.132 mas/yr (Gaia Collaboration, 2022). The Renormalized UnitWeight Error (`ruwe`) coefficient is 1.316, indicating good quality astrometric solutions for this star.

Although the star HD 108250 is at the center of symmetry of the observed bow shock, this bow shock has previously been associated with the HD 108248 and HD 108249 pair (Bodensteiner et al., 2018). Since these three stars are physically connected, the observed bow shock is most likely associated with all three. The aim of this work is to elucidate the runaway nature of the α Crucis system, find the parent star cluster, calculate the relative velocity of the system with respect to the parent star cluster, and determine the kinematic age. Another goal is to study the properties of the observed bow shock.

We have organised the paper as follows: Section 2 describes the data used; Section 3 details the results along with discussions, covering the search for a parent star cluster, the determination of the relative velocity of the α Crucis system, and the characteristics of the observed bow shock; the summarising of the results is in Section 4.

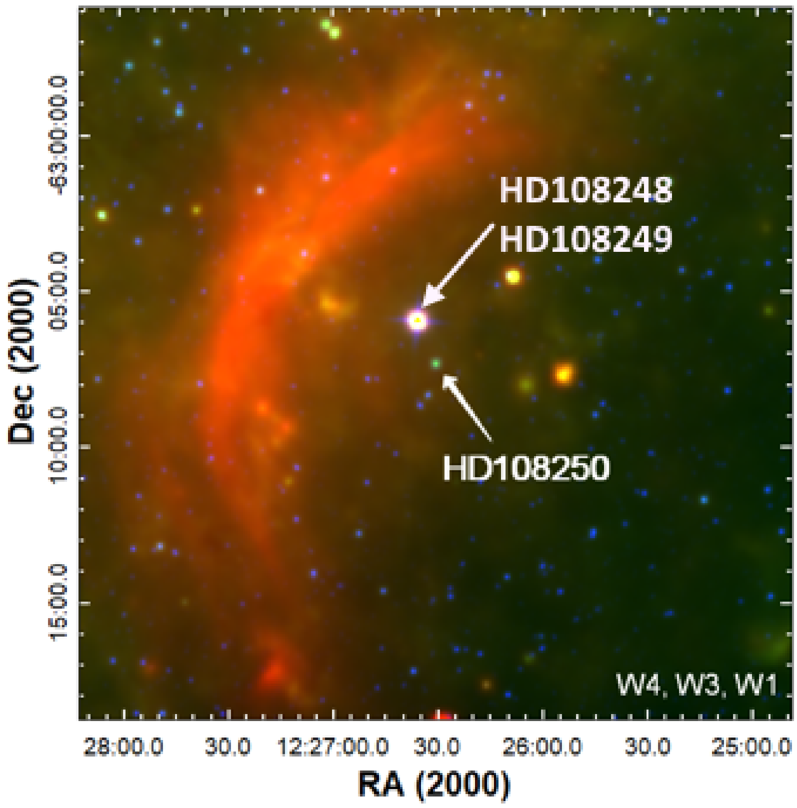

Figure 1. Colour-composite image of α Crucis system and the bow shock around it: 3.4 μm (blue), 12 μm (green), and 22 μm (red) bands. The three stars of the system are indicated by white arrows.

2. Data used

Since the bow shock observed around the α Crucis system radiates in the mid-infrared range, we used the Wide-field Infrared Survey Explorer (WISE; Wright et al., 2010) images at 3.4, 4.6, 12, and 22 μm

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wavelengths. For kinematic parameters, we used the Gaia Data Release 3 (Gaia DR3; Gaia Collaboration, 2022) catalog data.

3. Results and discussion

3.1. Searching for a parent star cluster

We searched for members of candidate parent stellar cluster/association of HD 108250 in the Gaia DR3 catalog in the range $(l, b) = (291.0^\circ$ to $320.0^\circ, -3.5^\circ$ to $+3.5^\circ)$. Since Gaia DR3 only provides reliable data for the star HD 108250, we assume that the obtained results are correct for the entire system. We apply a series of filters on the data, which are briefly described below:

- We excluded sources with `ruwe` greater than 1.4, which probably indicates poor astrometric solutions for these sources.
- We excluded sources for which the ratio of parallax to parallax uncertainty (`parallax/parallax_error`) was less than 5.
- We excluded sources for which the parallax is not in the range of 8.3 to 10.3 mas.

As a result, 3959 sources were obtained. The obtained sample were reflected by Tool for OPerations on Catalogs And Table (TOPCAT; Pössel, 2020) through the distribution of proper motions. The left panel of Figure 2 shows the distribution of the proper motions of objects obtained based on the search in the direction of the star HD 108250. The blue arrow indicates a star cluster with its proper motions clearly separated from the field. The star HD 108250, with its measured proper motions and distance, most likely belongs to that cluster. On the right panel of Figure 2 is the histogram of object distances. The red one is the histogram of all objects, and the blue one – the cluster members, which again stands out clearly from the field stars and has a maximum at the distance where the α Crucis system is located. There are 93 members of the cluster. The average parallax of the cluster members is 9.33 ± 0.25 mas, which means that the cluster is located at 107 ± 3 pc distance. The average proper motion of members in the direction of RA is -37.91 ± 0.89 mas/yr, and in the direction of Dec is -10.62 ± 1.41 mas/yr. Performing a comparison between the parameters of the star HD 108250 and the members of the cluster, namely the parallax (and hence the distance) and proper motions, it is clear that the star HD 108250 or the α Crucis system has not escaped from its parent cluster and is gravitationally bound to the other members, i.e., together they are moving in space with almost the same space velocity. The cluster is one of the subgroups in the Scorpius–Centaurus association, and these subgroups are located quite far from each other, but move as a whole (Blaauw, 1964, Goldman et al., 2018).

Figure 3 shows the distribution of cluster members in the field. Members are marked with blue circles. The green arrow shows the position of the bow shock observed around the α Crucis system. As can be seen, the members have a large dispersion in the field and the α Crucis system is located in the peripheral part of the star cluster.

3.2. Relative velocity of the α Crucis system

One of the conditions for the runaway nature of the α Crucis system is its high space velocity relative to its parent star cluster. To determine the space or peculiar velocity relative to the parent cluster, the coordinates, distance, proper motions, and apparent radial velocities of HD 108250 and the parent cluster members are required. Since the radial velocities in Gaia DR3 are known for only a part of the cluster members, i.e., the data are incomplete, we therefore set the radial velocity component equal to zero and calculated the relative transverse velocity of HD 108250. Therefore, the peculiar velocity of the star HD 108250 or the α Crucis system relative to the parent cluster is approximately 1.3 km/s. This finding supports the conclusion that the α Crucis system, despite the bow shock observed around it, is not a runaway system, since the relative velocity of runaway stars exceeds 30 km/s (Blaauw, 1961).

3.3. Bow shocks

Runaway stars move in the ISM at velocities that exceed the speed of sound. Their stellar wind hits the ISM and produces so-called bow shocks (Wilkin, 1996). Due to the stellar wind, the dust is heated and

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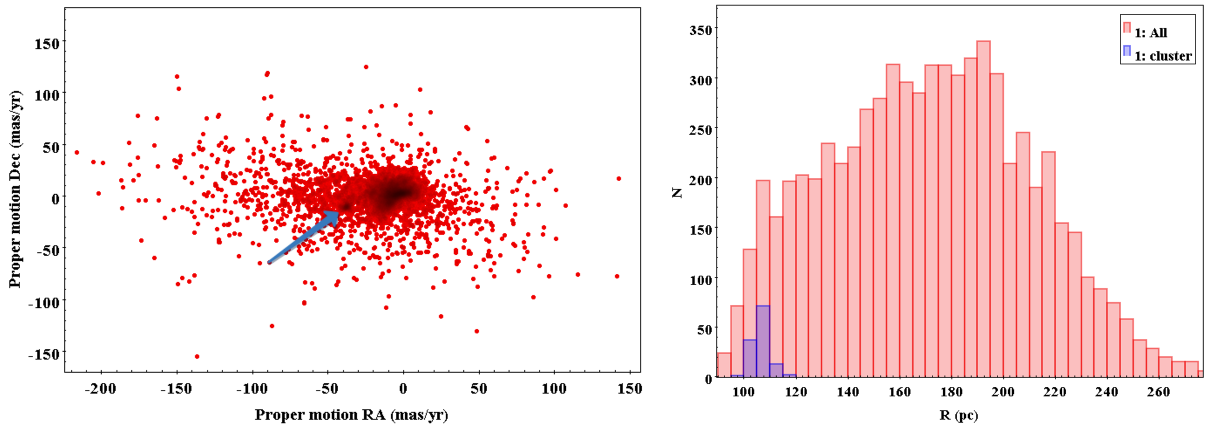

Figure 2. Left: Distribution of proper motions of the objects obtained based on the search in the direction of the star HD 108250. Red circles are objects obtained based on the search. Blue arrow shows the star cluster clearly separated from the field. Right: Histogram of object distances. The red histogram is for all objects, and the blue one is for the cluster members.

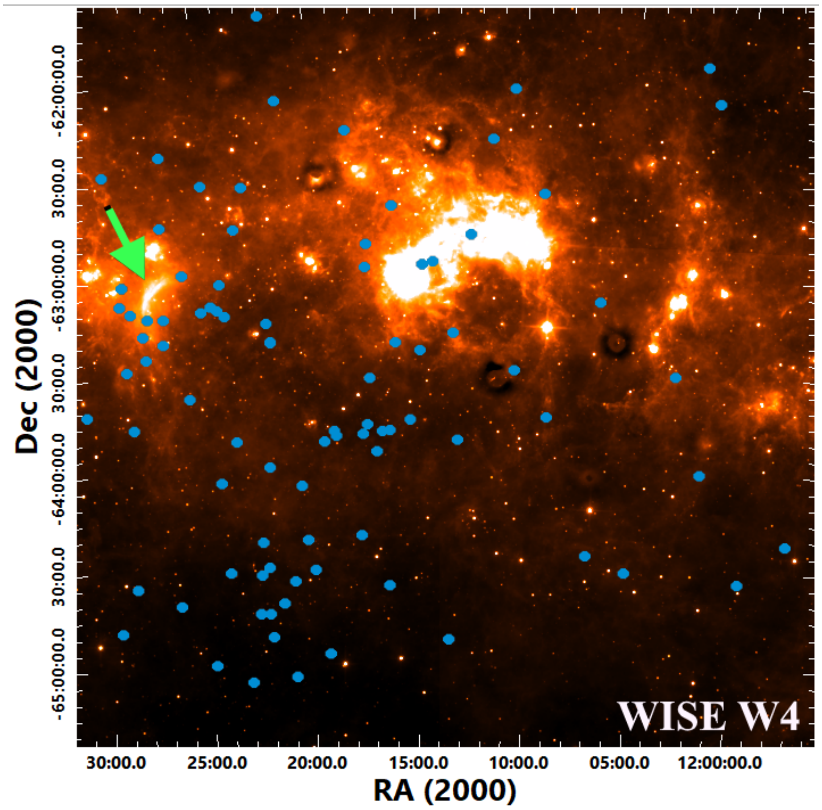

Figure 3. Distribution of the cluster members in the field on WISE W4 (22 μm) image. The members are marked with blue circles. The green arrow shows the position of the bow shock observed around the α Crucis system.

re-radiates at infrared wavelengths. Bow shocks have also been observed in the optical range (e.g., Brown & Bomans, 2005) and in a few cases at radio wavelengths (Benaglia et al., 2010). The α Crucis system and the surrounding bow shock is well resolved in the mid-infrared wavelength range. Figure 4 shows the bow shock around the system in the WISE 22 μm channel. The open red circle shows the position of HD 108250, and the white arrow shows the direction of motion of the α Crucis system. As we see, the observed bow shock is unaligned, that is, the apparent motion of the system does not coincide with the angular opening of the nebula (bow shock). This can be explained by large-scale motions in the ISM, which may also be responsible for the high relative velocity between the star and the ISM (Bodensteiner et al., 2018). This is probably why the bright pair HD 108248 and HD 108249 in the α Crucis system, with which the observed bow shock was previously associated, is offset from the center of symmetry of the bow shock, which is usually observed

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in unaligned bow shocks (Wilkin, 2000). The fact that the bow shock is unaligned probably proves that the α Crucis system is not runaway.

To compare the properties of the observed bow shock with other known bow shocks, we measured its geometrical parameters, such as the spatial length $l = 17.2 \pm 0.57$ pc, the width $w = 4.2 \pm 0.14$ pc, and the distance from the star to the center of the bow shock (standoff distance) $R = 5.5 \pm 0.18$ pc. Table 4 presented in Peri et al. (2012) paper contains the same parameters for a number of other bow shocks. We compared them with our results and concluded that the parameters of the bow shock surrounding the α Crucis system are compatible with the parameters of those already known bow shocks.

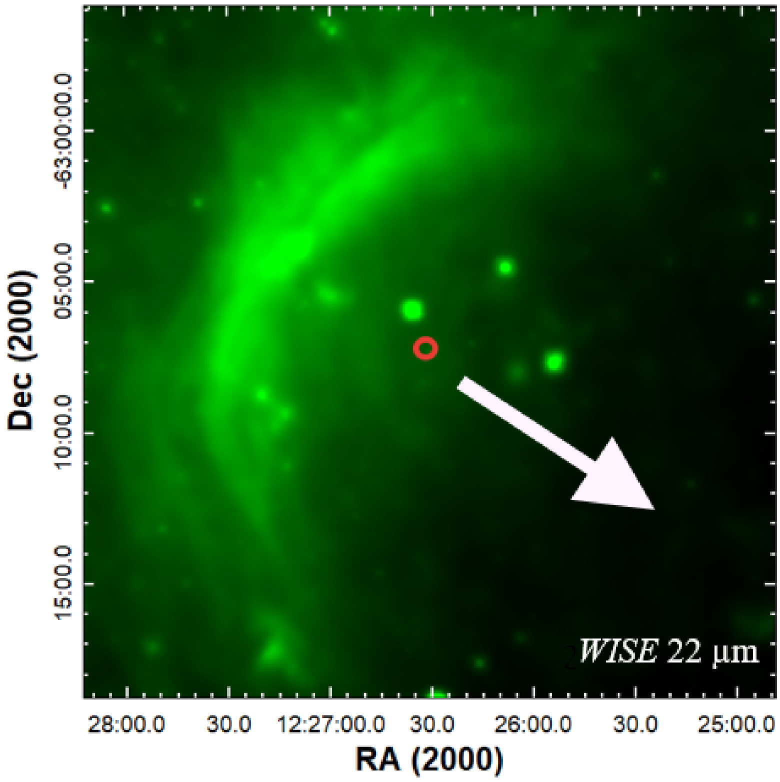

Figure 4. The bow shock observed around the α Crucis system on WISE W4 (22 μm) image. Open red circle shows the location of HD 108250 star. White arrow indicates direction of motion of the α Crucis system.

4. Conclusion

Within the framework of this paper, the results of the study of the α Crucis system at a distance of ∼114 pc and the bow shock observed around it are presented. We have discovered a star cluster that is clearly separated from the stars of the field by their proper motions and distances, the number of members of which is 93. The cluster is one of the subgroups in the Scorpius-Centaurus association. The α Crucis system, with its proper motion and distance, most likely belongs to that cluster. We concluded that the α Crucis system has not escaped from its parent star cluster and is gravitationally bound to the other members, that is, they move together in space, having almost the same space velocity. The peculiar velocity of the α Crucis system with respect to the star cluster is ∼1.3 km/s.

We also studied the parameters of the bow shock observed in the mid-infrared wavelength around the α Crucis system. By measuring the geometrical parameters of this bow shock, we concluded that its properties are similar to other known bow shocks. The apparent motion of the α Crucis system does not match the angular opening of the nebula (bow shock), i.e., the observed bow shock is unaligned. This means that the bow shock was formed because of the large-scale motions in the ISM, not the velocity of the α Crucis system.

Taking the above results into account, we note as the main conclusion that the α Crucis system, despite the bow shock observed around it, is not runaway.

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Classification of Blazars by Activity Types

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Abstract

We have carried out a spectral classification by the Activity Types for all sample of Blazars from the BZCAT v.5 Catalogue, namely the BZB, BZG, BZQ and BZU type objects. The classification is based on the Sloan Digital Sky Survey (SDSS) homogeneous medium-resolution optical spectroscopy and along with the standard BPT-type diagnostic diagrams, we have applied our newly introduced fine classification scheme with subtypes of AGN and considering many more features. Out of 3561 BZCAT objects, 1363 (38.3 %) having SDSS spectra were classified. After the new classification, 749 (54.9 %) of 1363 objects have changed their optical class.

Keywords: *blazar, quasar: active galactic nuclei, optical spectral classification, activity types, BL Lac objects, Flat Spectrum Radio Quasars*

1. Introduction

Blazars are considered to be the most energetic sources in the Universe. BL Lac was discovered by Hoffmeister (Hoffmeister (1929)). The originally discovered source was considered to be a variable star. Later, a thorough study of this source showed that it was extragalactic radio source. Discovered source was a radio source which had optical variability. Nowadays 3,561 blazars are known. The revealed sources have been published by Massaro et al. (2015) as a general list. In this catalog, Massaro grouped all blazars in four main classes: BZB (BL Lacs), BZQ (Flat Spectrum Radio Quasars, FSRQ), BZG (Blazar-like Galaxies) and BZU (Unclassified candidate objects). According to the definition, blazars should be radio sources and have optical variability. But information about variability is not complete in this catalogue. Information for optical variability of blazars is given by Abrahamyan et al. (2019b).

From BZCAT catalog, we cannot understand which sources are called Blazars. Using this catalogue, we plan to derive the definition of blazars. But in the first step we must understand properties of different types of Blazars. To summarize different physical properties of blazars we must understand which properties show different types of blazars (BZU, BZB, BZG and BZU).

2. Observational data

For our investigation we use BZCAT v.5 (Massaro et al. (2015)), which includes 3561 blazars. In BZCAT, blazars have 4 types (table 1).

We have done optical classification of those Blazars (38.3 %), which have optical spectra from SDSS catalogue (Abdurro'uf et al. (2022)).

3. Classification Method

Mickaelian et al. in 2022 and in 2024 (Mickaelian et al. (2022), Mickaelian et al. (2024c)) have introduced a new optical classification scheme (https://www.bao.am/activities/projects/21AG-1C053/mickaelian/). In this paper we have carried out optical classification using this method. To guarantee the

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Table 1. Distribution of the types of blazars from BZCAT catalogue.

N	Type		Number of objects		Number of objects with spectra in SDSS	
			Number	%	Number	%
1	BZB	BL Lac	1151	32.3	552	47.9
2	BZG	Galaxies	274	7.7	150	54.8
3	BZQ	Quasars	1909	53.6	618	32.4
4	BZU	Unclassified	227	6.4	43	18.9
All			**3561**	**100.0**	**1363**	**38.3**

best accuracy and consider all possible details, we classify the objects in several ways and then consider all obtained types and subtypes:

- By the 1st diagnostic diagram (DD1) using line intensity ratios [OIII]/H_β vs. [OI]/H_α
- By the 2nd diagnostic diagram (DD2) using line intensity ratios [OIII]/H_β vs. [NII]/H_α
- By the 3rd diagnostic diagram (DD3) using line intensity ratios [OIII]/H_β vs. [SII]/H_α
- By comparison and using the 1st, 2nd and 3rd diagnostic diagrams simultaneously
- By eye (considering all features and effects). Very often, the diagnostic diagrams do not give full understanding for all objects and only eye can reveal some details.

For many objects, the lines H_α and H_β were mainly absent in the spectra (due to high redshifts), so we

4. Classification of Blazars by Activity Types

4.1. BZU (Unclassified)

In table 1 we can see 227 objects out of 3561 have uncertain types of blazars. For our investigation we take these 227 BZU objects (Abrahamyan et al. (2019a)). In the First step we cross-corelated these objects with SDSS (Abdurro'uf et al. (2022)). As a results, we have 81 identification from which 43 have spectra. In Figure 1, we give redshift distribution of BZU and distribution of 43 objects, which have spectra in SDSS. In figure 1 BZU source mainly have 0 to 2.2 redshift and our studied sources have 0 to 1.75 redshift. For these 43 sources we have carried out classification using SDSS spectra.

Using our classification method (Mickaelian et al. (2022) and Mickaelian et al. (2024c)) we have carried out classification of 43 sources which have uncertain type.
As a result, 37 BZU objects out of 43 changed their classification to BZQ, BZG and BZG. In table 2 (for 10 objects, the whole list is given in Abrahamyan et al. (2019a)) we give the new classification and redshifts from SDSS.

So, having optical spectra of 43 BZU, we reclassified these objects. As the main results we have:

- 37 (86 %) objects from 43 changed classification (table 3).
- For 5 objects these numbers are different (5BZUJ0933+0003, 5BZUJ1051+4644, 5BZUJ1058+0133, 5BZUJ1302+5748, 5BZUJ2156-0037).
  We checked and corrected redshift and for 4 (5BZUJ0933+0003, 5BZUJ1051+4644, 5BZUJ1302+5748, 5BZUJ2156-0037) sources is given by SDSS and for 1 (5BZUJ1058+0133) source is given by BZCAT.

4.2. BZG (Galaxies)

In table 1 we can see 274 objects out of 3561 have galaxy types of blazars. For our investigation we take these 274 BZG objects (Abrahamyan et al. (2023)). In the First step we cross-corelated these objects with SDSS (Abdurro'uf et al. (2022)). As a result, 150 of the 274 BZG objects have optical spectra in the SDSS

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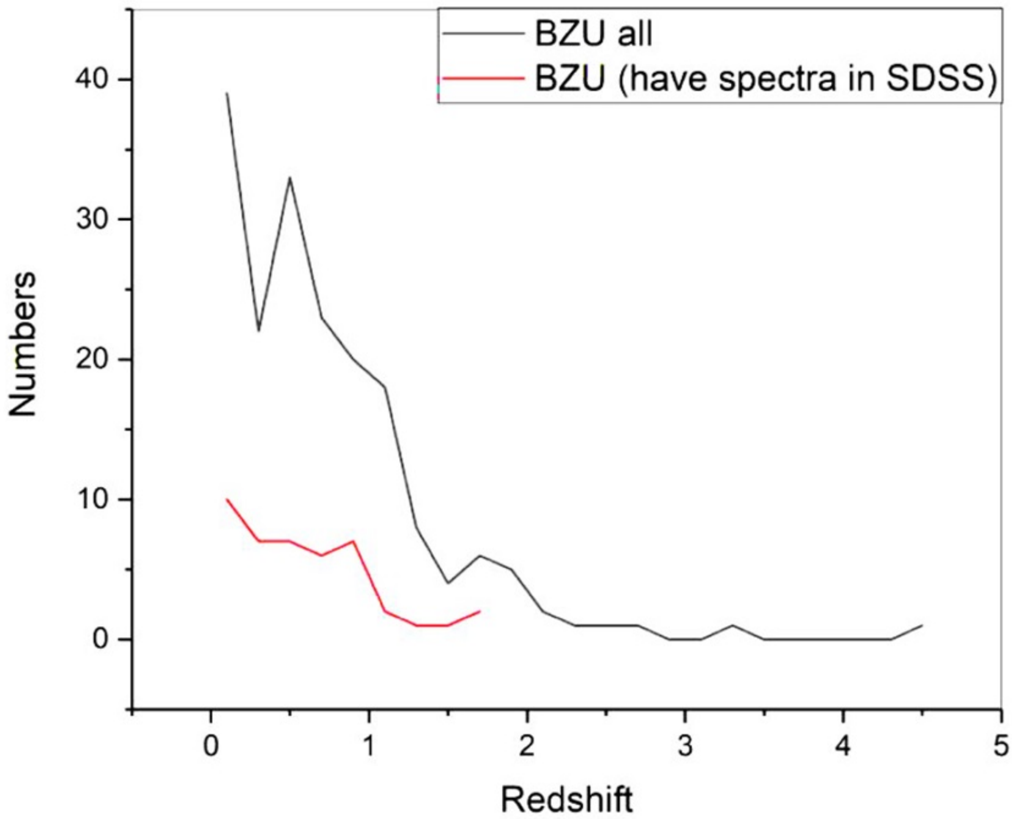

Figure 1. Redshift distribution of BZU objects.

Table 2. New classification of BZU objects.

BZCAT v.5		Our classifaction		Redshift		
Source name	Type			BZCAT	NED	SDSS
5BZUJ0217-0820	BZU	NLQSO	BZQ	0.607	0.606538	0.60654
5BZUJ0304+0002	BZU	QSO1.2	BZQ	0.564	0.56417	0.56366
5BZUJ0742+3744	BZU	QSO1.5	BZQ	0.806	0.806274	0.80574
5BZUJ0840+1312	BZU	QSO1.2	BZQ	0.681	0.6808	0.68037
5BZUJ0849+5108	BZU	QSO	BZQ	0.583	0.584701	0.58345
5BZUJ0856+0140	BZU	Unknown	BZU	0.448	0.448184	0.44807
5BZUJ0909+4253	BZU	QSO	BZQ	0.670	0.669915	0.67041
5BZUJ0933+0003	BZU	Unknown	BZU	0		0.71107
5BZUJ0954+5719	BZU	QSO	BZQ	0.981	0.981193	0.98121
5BZUJ1000+2233	BZU	Sy2.0	BZG	0.419	0.418732	0.41874

Table 3. New classification of BZU.

N	Old	New	Numbers
1	BZU	BZB	1 (2 %)
2	BZU	BZG	14 (33 %)
3	BZU	BZQ	22 (51 %)
4	BZU	BZU	6 (14 %)
All			43 (100 %)

catalog.

Using our classification method (Mickaelian et al. (2022) and Mickaelian et al. (2024c)) we classified all 150 objects.

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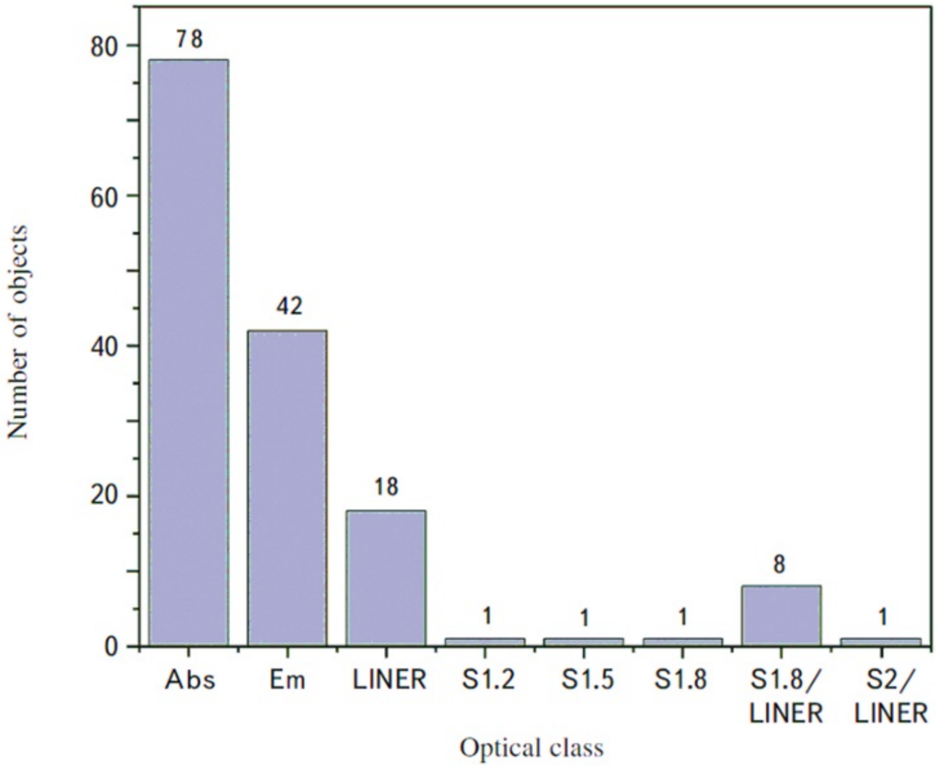

Figure 2. The new classification of the BZG objects using the SDSS spectra.

Table 4. New classification of BZG.

N	Old	New	Numbers
1	BZG	BZB	0 (0 %)
2	BZG	BZG	150 (100 %)
3	BZG	BZQ	0 (0 %)
4	BZG	BZU	0 (0 %)
All			150 (100 %)

In Table 4 and in Fig. 2 we show our spectral classification for 150 BZG objects using the SDSS spectra. We provided a new detailed spectral classification for 149 of the objects and only one object remained with its previous classification as a LINER.

Figure 2 shows that of the the 150 objects, 78 have Abs spectra, although they are presented as BZG objects in the BZCAT catalog. Our detailed radio and optical study of these objects showed that in them the radio fluxes (1400 MHz, FIRST) form a fraction of 0.16 of the optical flux ($SDSS_r$). And also, of the 78 objects, 66 are x-ray sources. This again confirms our assumption that these objects may be hidden AGN.

4.3. BZQ (Quasars)

In table 1 we can see 1909 objects out of 3561 have galaxy types of blazars. For our investigation we take these 1909 BZQ objects (Mickaelian et al. (2024a)). In the First step we cross-corelated these objects with SDSS (Abdurro'uf et al. (2022)). In results e 618 of the 1909 BZQ objects have optical spectra in the SDSS catalog. Using our classification method (Mickaelian et al. (2022) and Mickaelian et al. (2024c)) we classified all 150 objects.

Using our classification method (Mickaelian et al. (2022) and Mickaelian et al. (2024c)) we classified all 618 objects.

In Table 5 and in Fig. 3 we show our spectral classification for 618 BZQ objects using the SDSS spectra. It is clear from Table 5 and Fig. 3 that these objects are mostly classical QSOs (about 56.31 %) and other QSO subtypes (almost 17.8%).

After our new classification, 327 (52.91 %) of 618 have not changed their optical class, and 291 (47.0 %) of

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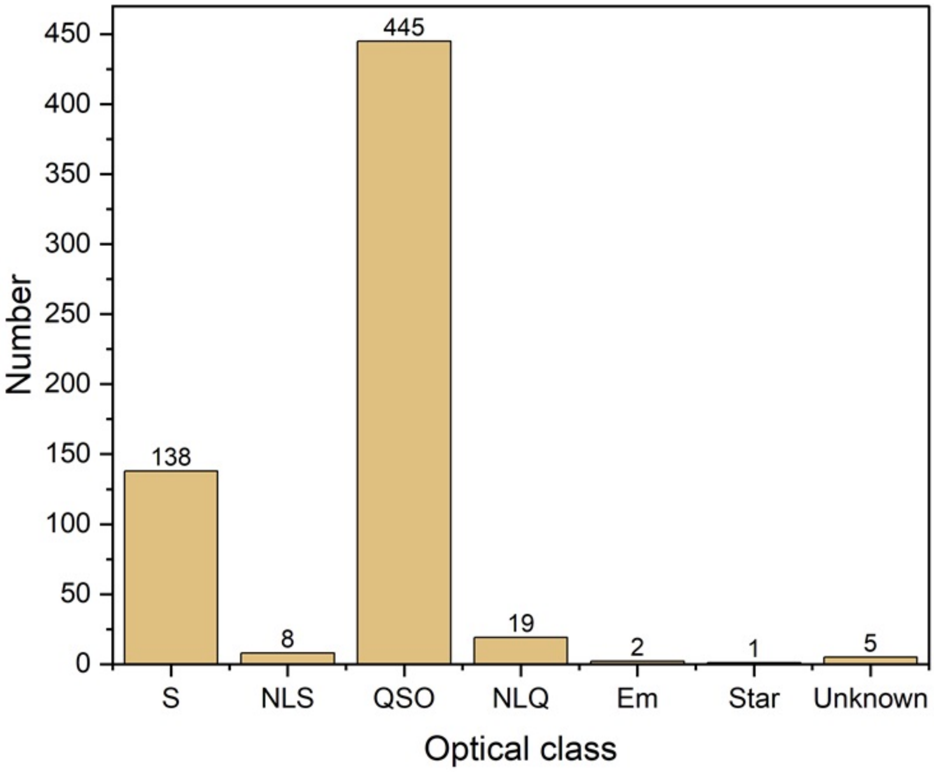

Figure 3. The new classification of the BZQ objects using the SDSS spectra.

Table 5. New classification of BZQ.

N	Old	New	Numbers
1	BZQ	BZB	0 (0 %)
2	BZQ	BZG	6 (1 %)
3	BZQ	BZQ	606 (98 %)
4	BZQ	BZU	6 (1 %)
All			618 (100 %)

these objects have changed their optical class.

4.4. BZB (BL Lac)

We have picked out 1151 BL Lac candidates from table 1, which make up our investigation data. 552 out of the 1151 BZB objects have optical spectra in the SDSS (Mickaelian et al. (2024b)). For these objects we have carried out a detailed classification using the SDSS spectra.

In figure 4 we give distribution of BZB objects by redshift; this information is taken from SDSS. Most of these objects have redshift smaller than 1.5 (the average is 0.95).
Using our classification method (Mickaelian et al. (2022) and Mickaelian et al. (2024c)) we classified all 552 objects.

Table 6. New classification of BZB.

N	Old	New	Numbers
1	BZB	BZB	259 (46.9 %)
2	BZB	BZG	130 (23.6 %)
3	BZB	BZQ	18 (3.3 %)
4	BZB	BZU	145 (26.3 %)
All			552 (100 %)

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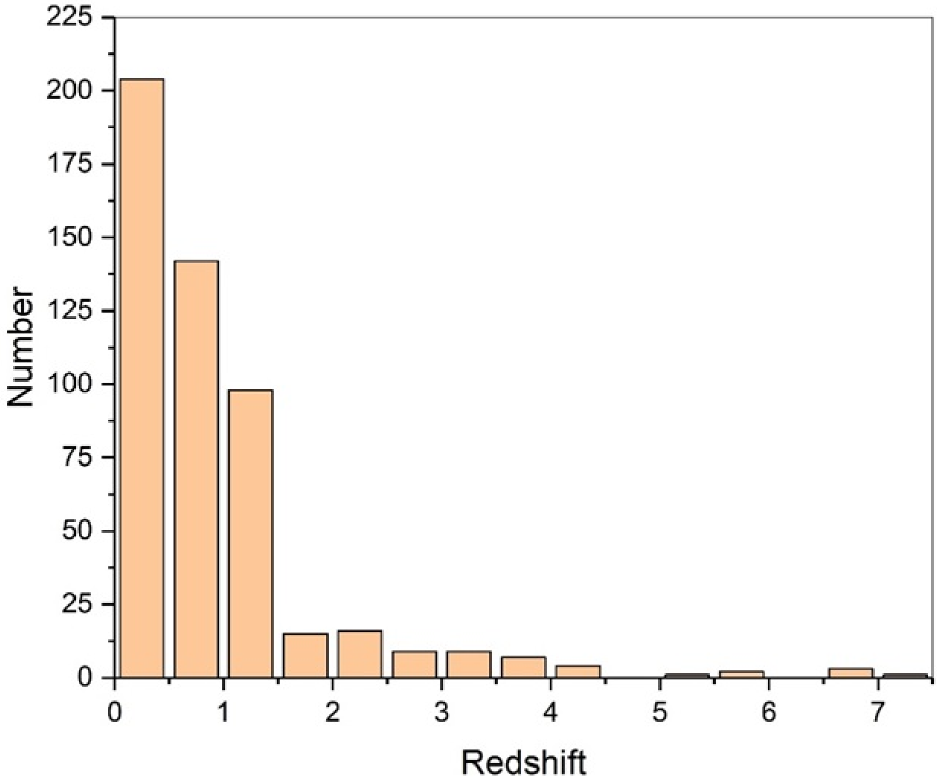

Figure 4. The distribution of BZB objects by redshift.

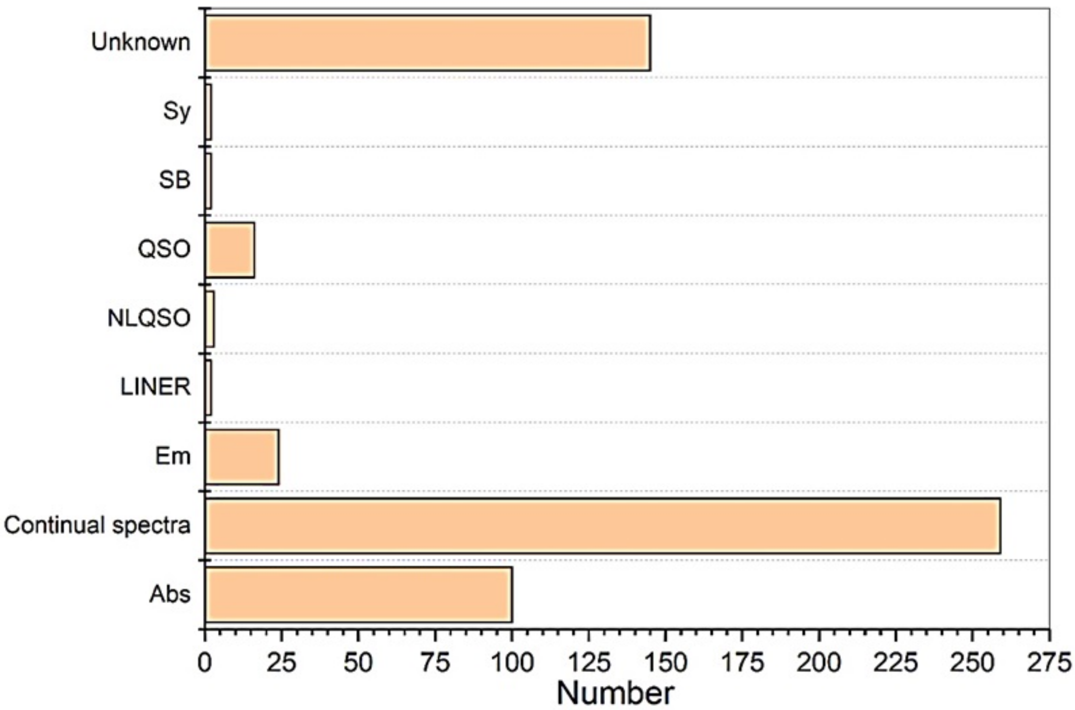

Figure 5. The new classification of the BZB objects using the SDSS spectra.

In Table 6 and in Fig. 5 we show our spectral classification for 552 BZB objects using the SDSS spectra. It is clear from Table 6 and Fig. 5 that these objects mostly have “Continual spectra”, which dominated BZB objects (about 46.82 %).

After our new classification, 259 (46.1 %) out of 552 have not changed their optical class, and 293 (53.1 %) out of these objects have changed their optical class.

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5. Summary of the Results

As a result, out of 3561 BZCAT objects, 1363 (38.3 %) having SDSS spectra were classified. After the new classification, 749 (54.9 %) of 1363 objects have changed their optical class:

- 293 (53%) BZB objects from 552 changed classification,
- 149 (99%) BZG objects from 150 changed classification,
- 270 (44%) BZQ objects from 618 changed classification,
- 37 (86%) BZU objects from 43 changed classification.

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Dark Energy as a Key Player in the Evolution of Cosmic Objects

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Abstract

Researchers have been searching for the speed at which the universe's expansion is slowing for decades. The dominant cosmological model predicted the inevitable process of braking. The discovery of the opposite process should have alerted researchers. However, the basic cosmological model has not changed at all. Although it is estimated that approximately 70 percent of all existing mass energy is dark energy, its role is not fully understood. In this paper, we show that the evolution of cosmic objects and their systems at all hierarchical levels occurs due to the interaction of ordinary matter with dark energy. Moreover, the interaction also increases the mass of ordinary matter. The mass increase occurs due to the conversion of some part of the dark energy into mass. Namely, it happens both due to a decrease in the mass defect of atomic nuclei and because of the fission of the same nuclei. It is noted that the role of dark energy should be studied much deeper than is currently being done, considering the known laws of physics.

Keywords: *Dark energy, baryon matter, interaction, energy exchange; activity phenomena, energetic resources.*

1. Introduction

Scientific schools form and develop based on several hypotheses and a main paradigm as the backbone for all overlaying theories and models. Over time, the theoretical models can be lightly modified due to the new empirical data but the main ideas remain unchanged. In other words, any scientific school carries out its inertial system of thinking. That is natural since any global change in the scientific backbone makes a revolutionary changing the whole main ideas which is undesirable for any scientific school.

Modern cosmology is based on two key ideas - the Kant-Laplace hypothesis (KLH) about the space objects' formation and the Big Bang hypothesis (BBH). Everything that we observe and measure, which relates to space objects, their systems, and ways of their evolution, clearly or implicitly agrees with these instruments and what follows from their application. If any observational data contradicts the key ideas, a new physical factor is usually invented to fit the scientific backbone. This method of free parameters can provide any fitting you need for the desired limited time interval and space volume. This method was first applied by Ptolemy in his geocentric system of the Universe, using many free parameters to construct his system of the world.

When in the 30s of the last century Fritz Zwicky, one of the brilliant astrophysicists discovered that the velocity dispersion of galaxies in the clusters is very high for stability, required inexplicitly by the KLH, he suggested the well-known hypothesis on the existence of dark matter ((Zwicky, 1933, 1937). It happened almost a century ago, then it was a convenient tool parameter in various unresolved problems and became irreplaceable for the interpretation of galaxies' rotation curves. It was accepted a priori that dark matter was everywhere, although it has not been revealed until now.

Equally suitable for many physical situations appeared to be the gravitational tool called black holes. It became intensively usable after two centuries of its description by John Michell. At the end of the last century, astronomers were still very cautious when speaking about black holes, located within real astronomical objects. However, the situation changed rapidly, and a black hole of the appropriate mass in the center of cosmic objects became a sign of a good scientific manner. It was needed both for energetic and gravitational issues.

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On the other hand, nobody was looking for dark energy ((Perlmutter et al., 1999, Riess et al., 1998). At least, after the discovery of the Universe expansion when the antigravity term in Einstein's equation of gravity lost its importance, it became not actual. In 1997 Alan Sandage published a list of 21 key problems, to be solved in the 21st century, and the problem of determining the rate of deceleration of the Universe expansion was on his list. Amazingly, the next year the first paper on the acceleration of the Universe's expansion was published. So, it was something that nobody was looking for. Dark energy was introduced as the only player required to accelerate galaxies' recession velocity. In other words, the acceleration of galaxies is happening due to interaction between the dark energy carrier, whatever it is, with baryonic objects, i.e., galaxies.

This paper considers the physical consequences of the interaction between the baryonic objects and the carrier of dark energy. Unlike the cases listed above, the introduction of dark energy itself, if we consider it in a self-consistent way, is dictated by natural laws but not accepted a priori hypotheses. However, an issue exists to emphasize always when this energy is under discussion. This is the fact that the interaction between baryonic matter and the carrier of dark energy is encoded in the method of its discovery or making a cosmological tool. Indeed, it could not be revealed or introduced without observed acceleration of galaxies which in turn resulted from the interaction between these two types of substances. Then, if the baryonic objects interact with the carrier of dark energy, one should consider the physical consequences of such interaction obeying the physical laws and regularities.

2. Energy of baryonic objects vs dark energy.

The total energy of all cosmic objects and their systems is accepted to be negative based on their stability. The stability paradigm has been used for a long time and is one of the cornerstones of modern understanding of the Universe construction. One should analyze all the relevant physical processes, occurring in these objects and their systems at all hierarchical levels, to consider the possibly accurate physical picture backed by physical laws and objective facts.

Modern physics suggests that dark energy fills all space at all geometrical scales homogeneously with very low density. According to the definition, dark energy is purely positive since it implements physical work accelerating the Universe's expansion.

It does mean that two interacting systems, representing the baryonic world with its objects and various aggregates of the objects from one side and the carrier of dark energy from the other side differ dramatically. The first one possesses positive energy, implementing work and the second one is characterized by a lack of energy. Then the second law of thermodynamics states that the first one should transfer some portion of energy to the second one.

The result of such interaction is seen in the cosmological scales as the acceleration of galaxies' removal. Therefore, it was revealed comparatively easily, like how the Universe expansion effect was discovered in the 30s of last century. However, there was no hint about the expansion effects at the smaller scales. There were two main reasons for this. First, expansion effects should be negligibly small, if any, especially for cosmic systems like our planetary system considered a balanced one. Second, the dominant paradigm of stellar and galactic cosmogony is based on the KLH, requiring that all objects and their systems are formed from rare clouds possessing negative total energy, and, therefore, they can't expand after reaching a balanced state.

It could be expected that the discovery of dark energy should change drastically all the approaches to old problems of cosmology and cosmogony. Indeed, a new reservoir was found which contains around 70 percent of all mass/energy of our Universe. It should be kept in mind if we consider the behavior of the much smaller part, interacting with it and gaining some non-zero portions of energy from it. Energy is a cumulative quantity which means that in the process of interaction, it accumulates in the objects and can reach a noticeable amount even if its density is very low. Then one should consider the problem in much more detail. Let us write the virial theorem (VT) for any system of cosmic objects, which has the following form:

$$W = 2T + U, \tag{1}$$

where $T$is the kinetic energy, and U is the potential energy of the system. Any system of objects is balanced if the virial theorem is zero. The system is contracting, if VT is negative, and it is expanding when it is above zero. Then, let us suppose the systems of cosmic objects have reached a balanced state sometime during their formation process, as the adopted hypotheses state. Even in that case, they will inevitably

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gain an energy portion, $\Delta E > 0$ during the time, and the virial theorem should be positive. Moreover, the portion $\Delta E > 0$ should gradually increase over time while the interaction between two substances continues.

Therefore, we conclude, that in the presence of dark energy, all systems of baryonic objects should be expanding or should become expanding independently from the size of the system. On the other hand, it does mean that one should look for expansion effects at smaller scales, especially in gravitational systems, which are considered balanced ones from the traditional point of view. In not balanced systems it should be extremely complicated to reveal geometrical changes equal to the Hubble growth of lengths amounting to 7.0×10^{-11}per year.

Starting the comparative study of the influence of dark energy on various systems one should keep in mind that modern science considers dark energy homogeneous for all scales. It does mean that its total amount in any volume is proportional to that volume. Consider a spherical baryonic object of mass M and radius R. Its volume is

$$V_s = \frac{4\pi}{3} R^3. \tag{2}$$

Then the amount of dark energy in this volume should be $E_{de} = V_s \rho_{de}$, where $\rho_{de}$is the density of dark energy. The gravitational energy maintaining the object's integrity has the following form:

$$E_{gr} = -kG\frac{M^2}{R}. \tag{3}$$

One can introduce a coefficient

$$\eta = \frac{|E_{gr}|}{E_{de}}, \tag{4}$$

showing, let's say, the "measure of resistance" (MoR) of this object. The bigger this coefficient, the more resistant the object to changes forced by dark energy. It is easy to find then that

$$\eta \sim \frac{\rho_{gr}^2 R^2}{\rho_{de}}, \tag{5}$$

where ρ_{gr} is the average density of the given baryonic object. The MoR for a family of objects possessing different masses does not change with the mass of $\rho_{gr} R = const$. It increases with mass if $\rho_{gr} R$ grows up with radius and decreases in the opposite case. For instance, this coefficient for the Sun is about 25 times greater than the one calculated for the Earth. The same coefficient can also be calculated for stellar systems including galaxies and their clusters.

3. The Earth-Moon system.

Perhaps the binary system Earth-Moon is one of the cosmic systems studied most minutely. It is well established that the Moon retreats from our planet at a rate 3.82 ± 0.07cm per year (Dickey et al. (1994)). Traditionally this speed is explained using the tidal mechanism. There is no doubt, that the tidal mechanism is a correct working instrument for the mentioned physical process. However, there is an issue that makes this mechanism vulnerable. The angular momentum lost by our planet is not enough to provide the mentioned rate of the Moon's retreat. It is easy to show, that there is a lack of angular momentum of about 25 percent even if we assume that no other losses occur.

The researchers, who are aware of the history of this hypothesis, know also, that initially, the situation was not so critical. All estimates of the lunar retreat had given much lesser value to its rate and the deceleration of the Earth's axial rotation, on the contrary, was accepted to be greater. However, the improvement in measurement accuracy over time gradually changed the situation making it worse. Therefore, the situation at present requires new approaches. A needed solution may be the influence of dark energy, which injects a certain portion of energy into the Earth-Moon system. The received additional energy expands the system. Since we do not know how much is the injected energy, we can use the geometrical effect of expansion observed for galaxies as the first approximation and make a scale transformation for the Earth-Moon distance.

We have considered this problem in detail, involving all the effects relevant to this issue, including the possible increase in the radius of the Earth. By the way, many researchers usually criticize the hypothesis on the growth of the Earth's radius, emphasizing that such an effect could be noticed by observing the corresponding changes in the coordinates of the quasar, proceeding from the assumption that the increase in the radius of our planet should be resulted by its inflation affecting the radio telescopes basement. However,

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the radius of the Earth can also increase due to the ejection of a corresponding amount of matter, which does not change the direction of radio telescopes. This is a separate issue, which can be considered in detail.

Our calculations show, that all the modern observational data available explain the lunar removal in a self-consistent way, showing also the contribution of each physical mechanism. Applying this approach, one concludes that the tidal mechanism provides only about 30 percent of lunar retreat while the dark energy gives the rest. No contradiction or lack of angular momentum appears. Moreover, this absolute accordance has been established only owing to improved observational data during the last decades. About forty years ago we could not notice this accordance.

4. Growing of the Astronomical Unit.

Another expansion phenomenon is connected with the enlargement of the Sun-Earth distance. According to the measurements, the average distance between our planet and the Sun increases on a tiny interval of 15 cm (Krasinsky & Brumberg (2004)). Although this is a small value, the known physical mechanisms cannot explain this removal. Therefore, some researchers try to use the tidal mechanism, though there is no observational data on the deceleration of the Sun's axial rotation. So, using this mechanism, one can use a sufficient number of free parameters to construct any convenient model.

We proceed from our conclusion that the Sun-Earth system should expand due to interaction with the dark energy carrier. Suppose one accepts the same geometrical approximation for calculating the Sun-Earth distance enlargement, as we did for the Earth-Moon distance. In that case, one finds a much larger value than the observed one – about 10.5m ((Harutyunian & Grigoryan, 2018)). The difference is two orders of magnitude! This seems to be a catastrophe for the physical picture we are presenting here.

It is evident that there are two possible versions, namely, our reasoning on the interaction between baryonic matter and the carrier of dark energy is not correct (not well-grounded) or there exists some physical mechanism not taken into account. Let's suggest the second version. From the general physical reasonings, one can conclude that the continuous mass growth of the Sun could prevent the high rate of the Earth's removal. Of course, from the classical point of view, we know only the mechanism of decreasing the Sun's mass. Nevertheless, let us consider the hypothesis on the possible mass growth and calculate its necessary rate which can diminish the removal speed from 10.5m per year down to 15cm per year.

One can easily solve this problem assuming the mass of the Earth is unchanged. Then one finds that the picture we observe can occur if the Sun's mass grows yearly. If this is true then one can make some significant conclusions. First, this effect cannot be a privilege only of the Sun. It means that all stars grow in mass, consequently, the mass of our baryonic Universe increases over time. This conclusion solves a long-standing paradox regarding the mass of the newborn Universe. What is the point? In the frame of the Big Bang hypothesis, when we go back into the past, the size of the Universe decreases but the mass remains unchanged (or slightly grows to be more precious). It does mean that after the Big Bang event and before the definite moment the baryonic Universe should have been within the Schwarzschild radius.

Calculations give the tiny value of $6.7 \times 10^{-11} M_{\odot}$ for the annual growth of the solar mass ((Harutyunian & Grigoryan, 2018)). It is significant, that if only 0.1 percent of the additional mass transforms into radiative energy, that is enough to provide solar luminosity. Amazingly, this mechanism provides the necessary energy using not very high-efficiency energy production.

5. In atomic nuclei dark energy transforms into mass and vice versa.

Our baryonic world consists of atoms with their mass concentration in atomic nuclei. A marvelous property of atomic nuclei (and separate baryons) is the so-called mass defect providing nuclei's existence. The mass of baryons in the nuclei is less than the free baryons' mass. Moreover, in various nuclei, the average mass of baryons differs significantly. It means that baryons can possess different masses depending on the physical conditions of the environment. That is very important.

Now let us consider the interaction between the dark energy carrier and atomic nuclei, keeping in mind, that dark energy homogeneously fills the space at all scales. Like gravitational objects, atomic nuclei's binding energy is negative and quantitatively equal to the mass defect of the given nucleus. Therefore, as a result of interaction atomic nuclei should gain energy. It is not important how much the portion of the energy is injected into the nuclei per unit of time, since injected energy is positive and energy is a cumulative substance and accumulates over time.

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Gaining energy due to the interaction with the carrier of dark energy has some definite physical consequences. The first one is the growth of the nuclear mass and, as was mentioned above, the reduction of the nuclear binding energy. Owing to this process the mass of the baryonic Universe grows over time. On the other hand, this effect leads to the destabilization of the nuclei involved in this process. It is obvious that after some critical level of binding energy, any nucleus will move into a range of radioactive nuclei since it sooner or later will reach its margin of safety. Then it should eject some energy to return to the safe state. This excessive energy might be ejected as radiation, mass, or both.

Therefore, as the second consequence of the interaction one can mention the radioactive decay and formation of less massive nuclei, the effect investigated in detail. One can formulate this conclusion in the following more comprehensive form: Lighter elements form from heavy ones due to the interaction of atomic nuclei with the carrier of dark energy. So, it means, that the relative number of light elements grows over time. This process is one of the direct manifestations of the second law of thermodynamics.

One can formulate the third significant consequence as follows. In the past, any given nucleus should have possessed a larger binding energy and a smaller mass than modern values. Therefore, nuclei consisting of much more baryons, than any today's nucleus, could exist in the past. The deeper one goes into the past, the more baryons can expect in the atomic nuclei. Moreover, the deeper in the cosmological past, the smaller the mass of the baryonic Universe.

This last conclusion is important because of a long-standing paradox that is usually kept silent. The fact is that, according to modern ideas about the Big Bang, all the laws of nature were in effect after the Planck time, and matter in the form of hydrogen and helium nuclei existed already a few minutes after the Big Bang. Thus, our baryonic universe at the beginning of its formation should resemble the last stage of a black hole formation, when all the matter was inside the Schwarzschild sphere. Then it is not clear how it could expand with acceleration.

6. Evolution of the baryonic matter.

As was mentioned in the previous item, the structural units of our baryonic universe are the atoms with their mass concentration mainly in atomic nuclei. Atoms or nuclei are objects of our Universe equivalent to stars, planets, galaxies, etc. We are sure that all objects and the Universe evolve, we have created models for calculation and demonstrate the evolutional changes, using our knowledge of physical laws and regularities. However, there is no hint about the evolution of atoms, atomic nuclei, and elementary particles. Where comes from this "discrimination"? Its reason could be hidden in the quantum-mechanical character of the microworld objects. We have been taught and were thinking in studentship that all elementary particles are indistinguishable and identical, that there are no differences between two protons or two electrons, and that they are the same as were born during the Big Bang event. Nevertheless, it was already known that baryons change their mass while being a part of atomic nuclei. It means that the physical conditions determine the mass of these particles. On the other hand, it hints that the change in physical conditions due to the expansion and evolution of the Universe could also change the particles' mass. Our above analysis shows that it is not implausible, and one should look for observable "fingerprints" of this process. Let's look at some of these fingerprints here. One such "fingerprint" is seen in galaxies' metallicity. Researchers have known about some of them for a long time and even found explanations within the framework of traditional cosmology. Since the 1970s, the mass-metallicity relation has been known, stating that the more massive (luminous) galaxies possess higher metallicity. This relationship has a natural interpretation in the frame of paradigm considered here. From formula (5) it follows that the larger the galaxy, the slower its evolution. On the other hand, one of the consequences of evolution is the destabilization of atomic nuclei and radioactive decay, which results in the formation of lighter elements, including hydrogen. Therefore, the faster the evolution process, the lower the metallicity. So, the low metallicity of dwarf galaxies in this paradigm differs dramatically from that used by traditional cosmology. We argue that the low metallicity of galaxies is not a result of their formation in the early epochs after the big bang, but a consequence of the more rapid evolution of baryonic matter. Another effect associated with the metallicity of galaxies is easily and naturally explained if the evolution of baryonic matter is considered. We are talking about a negative metallicity gradient with distance from galactic nuclei found in almost all galaxies. The fact is that within the framework of this paradigm, the formation of any galaxy occurs due to the ejection of matter from the core. Suppose the proto-galaxy did not have or had a small rotational moment. In that case, the mass ejections are caused only by the influence of dark energy, occur from the outer layers, and are distributed

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more or less isotropically. If the proto-galaxy has a significant rotational moment, then the centrifugal force, which is strongest in the equatorial area, is also added to the influence of dark energy. Therefore, emissions can occur from deeper layers, where the evolution of matter is longer than on the surface. This can explain both the high metallicity of the disk compared to halos or elliptical galaxies, and the metallicity gradient in both cases. The disk's high metallicity is ensured by baryonic matter being ejected from the deeper layers of the core. The negative metallicity gradient results from the fact that the farther from the galaxy's center, statistically, the more time the matter has evolved under new conditions. Another "fingerprint" is related to the "Hubble tension" paradox ((Harutyunian, 2021)). The gradual increase of measurements finally has led to the strange situation that the Hubble constant measured by two different methods gives different results. The values differ from each other on the level. All groups involved in these measurements assert that all methods used are correct and the final results should be the same. However, there is an issue, which has not been considered. The difference occurs between the results obtained using the real cosmic objects (galaxies' distances and velocities) from one side and the geometry of microwave background radiation from the other. Since the value obtained by the first method is larger, it hints that the reason for this difference could be hidden in the properties of matter. Indeed, if our conclusion on the growth of the masses of atomic nuclei due to evolution is correct, a physical mechanism leading to an additional spectral blueshift can be mentioned. This effect follows from the Rydberg formula written for the hydrogen atom

$$\frac{1}{\lambda_{mn}} = Ry\frac{1}{hc}\frac{M_p}{M_p + m_e}\left(\frac{1}{m^2} - \frac{1}{n^2}\right), \tag{6}$$

where $Ry = \frac{m_e e^4}{8\varepsilon_0^2 h^2}$ is the Rydberg constant. In general instead of protons mass M_p one could write $M_n$for denoting hydrogen-like atoms consisting of several baryons. We see that the wavelengths of spectral lines depend inversely on the reduced mass of the nucleus and electron

$$m_r = \frac{M_n m_e}{M_n + m_e}. \tag{7}$$

When the nucleus and electron masses increase, spectral lines get blueshifted. It means that the closer a galaxy the longer its evolution path and the more its blueshift. In other words, the measurements should include some additional spectral shift increasing the Hubble constant value. One can easily calculate how much the masses of the nucleus and electrons should grow to provide the observed difference of Hubble constant value. The difference is 6.6 km per sec per Mpc. The distance of 1 Mpc in terms of time equals 3.26 million years. One should proceed from the fact that these additional 6.6 km/sec per Mpc appear due to the increase in mass over 3.26 million years. Then one obtains the annual blueshift for the atoms

$$\Delta z_{year} = 6.75 \times 10^{-12}, \tag{8}$$

which in turn should be given by the change of the reduced mass (7) as follows

$$\Delta z = \frac{\Delta\lambda}{\lambda} = \frac{m_{r2} - m_{r1}}{m_{r2}} = \frac{\Delta m_r}{m_r} = 6.75 \times 10^{-12}. \tag{9}$$

This value is an order less than we have obtained for the solar mass growth. It seems natural, since in this case only the evolutionary change plays a role while the solar mass grows through the contribution of the massive nuclei's decay processes. So the Universe's mass growth occurs more rapidly than the increase of the nuclei's mass.

7. The need to change the main paradigm.

Our scientific hypotheses and corresponding theories are models of natural regularities simplified in more or fewer degrees. Only the improved observations and more accurate experiments can serve as correction tools for our ideas update. On the other hand, on the base of scientific ideas research schools and whole directions create which in turn provide the further life and safety of existing dominant ideas. Therefore, one can speak about the inertia of thinking which provides the survival of the aged and useless ideas.

Modern telescopes continuously reveal new phenomena and facts that can't be interpreted naturally in the frame of old ideas on the formation of cosmic objects and their systems. One of the most striking facts is the discovery of "mature" galaxies located at a distance of about 13.4-13.5 billion light years. The

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galaxy JADES-GS-z13-0 revealed by the JWST, is located at an extremely distant point of the Universe and currently holds the record for the most confirmed distant galaxy we have ever discovered with a redshift of z=13.2 ((Robertson et al., 2023)). Because of its huge distance, one can conclude that we see this galaxy as it was only about 300 million years after the Big Bang. It does mean that 300 million years after the Big Bang there were already mature galaxies possessing several hundred million solar masses.

There is another strange thing that is not easy to explain in the adopted by cosmologists framework. It is widely accepted that the most luminous objects are quasars. However, the most distant objects are galaxies, not quasars. The quasar UHZ1 at the redshift of approximately 10.1 is the most distant known quasar ((Bogdán et al., 2024)). Of course, this redshift is comparable with the ones of the most distant galaxies but, strangely, quasars suggested the most powerful extragalactic emitters are not discovered at higher redshifts than galaxies.

So we would like to return to our conclusions on the baryonic matter's evolution. At any hierarchical level, dark energy-induced evolution stimulates a mass ejection process from baryonic objects. Galactic nuclei are the most massive baryonic objects containing vast amounts of baryonic embryos in their entrails. If some mass of this substrate is ejected from the deep layers of the nucleous entrails it should have some remarkable properties. The first is the redshift of the belated in the evolution matter of the ejected mass. The second should be the intensive emission of radiation energy from this matter suddenly moved into different physical conditions. The dipper is the original location of the ejected mass, the larger the redshift, the stronger the radiation.

The new paradigm does not require any beginning or birth of our Universe. The Universe existed and exists in infinite time and infinite volume. It only evolves under the constant influence of dark energy. The evolution process occurs according to the same universal scheme, i.e., due to the interaction of various substances one of which possesses the positive dark energy and others – the negative energy of different attraction processes. We live in a period of evolution when negative attraction forms of energy are the gravitational and strong forces. Namely, this process provides the dominant role of the entropy growth law within all natural laws.

During this comprehensive process of interaction evolution of all objects takes place in one direction when any object gives birth to new objects belonging to its own or lower hierarchical levels. For example, a galaxy can generate new galaxies of lower mass, stars, gas, etc. Or, a radioactive atomic nucleus can eject an alpha particle, neutrons, electrons, and gamma radiation. All these processes increase the entropy. In this paradigm under consideration, the key player determining both the physical interactions and the general direction of processes is dark energy instead of gravitation, playing a key role in all modern physical hypotheses. When dark energy and its unknown carrier are involved one needs to consider the matter's structural features as well, while the gravitational configurations are at the center of our ideas, only the mass of objects plays an essential role.

8. Conclusion.

New observational data often contradict key ideas and hypotheses of modern theories of the formation of space objects. The scientific mainstream resolves these apparent disagreements by applying a method of free parameters, reminiscent of the epicycle model of the geocentric world system. However, it is clear that with the help of many free parameters, any process can be described using a completely unsuitable model. Therefore, the need to introduce many free parameters almost always indicates a discrepancy between the model and the true physical picture.

This situation almost always indicates the need for a critical revision of the basic hypotheses that form the basis of the paradigm used. First of all, you should pay attention to those assumptions that were made *a priori* and without proper empirical basis. In modern cosmology and cosmogony, there are several such, to put it mildly, not entirely substantiated assumptions. The most obvious among them seems to be the Kant-Laplace hypothesis about the formation of cosmic objects and their systems from more rarefied matter (gas-dust clouds) through its fragmentation and condensation. The second hypothetical tool is a gravitational monster called a black hole, which turns into a singularity over a finite time. The third not entirely certain hypothesis, in our opinion, is the Big Bang, which is considered the beginning of the formation of the material Universe and three-dimensional space and the beginning of time.

We would like to emphasize very important at least for us notion. It concerns the "Byurakan concept" of cosmogony, put forward by Ambartsumian in the last century. The paradigm under consideration mar-

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velously fits the concept and transparently shows why it could not be accepted decades ago when no hints existed about dark energy ((Harutyunian, 2022)). Moreover, we hope that this approach can provide tools to show the genuine value of the mentioned concept.

All aspects of the mentioned mental tools should be carefully studied to identify their weaknesses and vulnerabilities. We have focused on some of them in the present report, but many more appear almost everywhere. This issue publishes another work by the author and Arpine Torosyan, which indicates that the spectral blueshift of the nebula is not the result of this galaxy's approach, but that this galaxy has gone through a greater evolutionary path than our galaxy. In the future, we will try to prove this more thoroughly.

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Investigation of QSO spectra having measured L_α from GALEX FUV

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Abstract

Active Galactic Nuclei, especially quasars, have not been thoroughly investigated in far UV range. There are few observations in this range, and most of this range is available for objects with high redshifts, whose UV range is shifted to the optical one. But on the other hand, there is GALAXY Evolution Explorer (GALEX) space UV telescope catalog, where 82,992,086 near-UV (NUV, 1750–2800 Å) and far-UV (FUV, 1350–1750 Å) flux measurements in UV bands are available. In order to find a connection between the fluxes of two of the most important emission lines, λ5007 ([OIII]) and λ1216 (L_α) in the spectra of quasars, we created a sample of quasars with measured L_α. For this, we took the Milliquas 2023 catalog, which contains 1,021,800 objects. From these objects, we selected those having redshifts lying between $0.15 < z < 0.40$, so that L_α spectral line is located in GALEX FUV window. As a result, we have 42,150 objects. These sources were identified with SDSS DR16 and GALEX DR6+DR7, and as a result we have 11,697 identifications which have data from both SDSS and GALEX. Using a pilot survey (for 177 objects), we found a preliminary connection between L_α and [OIII] lines.

Keywords: *Active Galactic Nuclei, Quasars, UV sources, redshifts, emission lines*

1. Introduction

For our investigation we used catalogues: **Milliquas 2023, GALEX DR6+DR7** and **SDSS DR16**. Milliquas (Million Quasars) (Flesch, 2023) quasar catalogue which presents all published quasars to 30 June 2023, including quasars from the first releases of the Dark Energy Spectroscopic Instrument (DESI) and the SDSS-DR18 Black Hole Mapper. Its totals are 907,144 type-I QSOs/AGN and 66,026 high-confidence (∼99% likelihood) radio/X-ray associated quasar candidates. Type-II and Bl Lac type objects are also included, bringing the total count to 1,021,800. Gaia-EDR3 astrometry is given for most objects.

The Galaxy Evolution Explorer (GALEX) (Bianchi et al., 2017) imaged the sky in two ultraviolet (UV) bands, far-UV (FUV, 1350–1750 ÅÅ, λeff $\sim$ 1528 Å), and near-UV (NUV, 1750–2800 Å,λeff $\sim$ 2310 Å), delivering the first comprehensive sky surveys at these wavelengths. The GALEX database contains FUV and NUV images, ∼500 million source measurements and over 100,000 low-resolution UV spectra. The UV surveys are a unique resource for statistical studies of hot stellar objects, $z \lesssim 2$ QSOs, star-forming galaxies, nebulae and the interstellar medium, and provide a roadmap for planning future UV instrumentation and follow-up observing programs. We present science-enhanced, "clean" catalogs of GALEX UV sources, with useful tags to facilitate scientific investigations.

The **Sloan Digital Sky Surveys (SDSS-16)** (Ahumada et al., 2020), the fourth and penultimate from the fourth phase (SDSS-IV). This is the first release of data from the Southern Hemisphere survey of the Apache Point Observatory Galactic Evolution Experiment 2 (APOGEE-2); new data from APOGEE-2 North are also included (see Tables 1 and 2).

Using Milliquas 2023 catalogue we selected 11,697 objects which have data from both SDSS and GALEX catalogues.

Figure 1 shows examples of spectra where it can be seen that the L_α and [OIII] 5007 lines in our sample are among the strongest lines, and we were able to separate them from the continuum.

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Table 1. SDSS DR16 imaging data statistics

SDSS DR16 imaging data statistics	
Total unique area covered	14,555 square degrees
Number of catalog objects	1,232,051,050
Number of unique detections	932,891,133

Table 2. SDSS DR16 optical spectroscopy data statistics

SDSS DR16 optical spectroscopy data statistics	
All programs combined	
Total spectra	5,789,200
Useful spectra	4,846,156
Galaxies	2,863,635
Quasars	960,678
Stars	1,021,843
Sky	475,531
Standards	108,603
Unknown	352,320

2. Investigated data

In order to find a connection between the fluxes of the λ5007 ([OIII]) and λ1216 (L_α) lines in the spectra of quasars, we created a sample of quasars with L_α line. For this way, we took the Milliquas 2023 catalog, which contains 1,021,800 objects. From those objects we selected objects having redshift between 0.15<z<0.40, so that L_α spectral line located in GALEX FUV window. As a result, we have 42,150 objects. These sources were identified with SDSS DR16 and GALEXY DR6+DR7; as a result we have 11,697 identifications which have data from both SDSS and GALEX (see Table 3).

Table 3. Number of QSOs in Milliquas 2023 with z between 0.15<z<0.40 and associated objects in SDSS and GALEX catalogues.

Catalog/Database	**Studied objects**	**Fraction of Milliquas 2023 objects**
Milliquas 2023 all	1,021,800	100.00
Milliquas 2023 z-selected	42,150	4.12
SDSS DR 16 associations	33,607	3.29
GALEX DR6+DR7 associations	**11,697**	**1.14**

We see that very small fraction of Milliquas 2023 objects can be studied for the connection between L_α and [OIII]. However, this may be a key for the rest of the QSOs to calculate (or at least estimate) L_α flux just having [OIII] flux. Thus, such approach may be very efficient for numerous QSOs.

3. Connection between L_α and [OIII] lines

For 177 objects we found initial connection between L_α and [OIII] lines.

In Figure 2 we created the plot for these sources. In the further work we will create connection between L_α and [OIII] lines for all 11697 objects. We obtained a preliminary linear relationship for the spectral lines of 177 objects (empirically described by the formula y= 0.624X -6.11). More sources are needed to verify the reliability of this result.

4. Color-color diagrams

Having information from SDSS catalogue for 11,697 investigated objects we build color-color diagrams. In Figure 3 we can distinguish 2 groups. At this moment we cannot say anything about these groups, because we need more information about optical classification of these sources.

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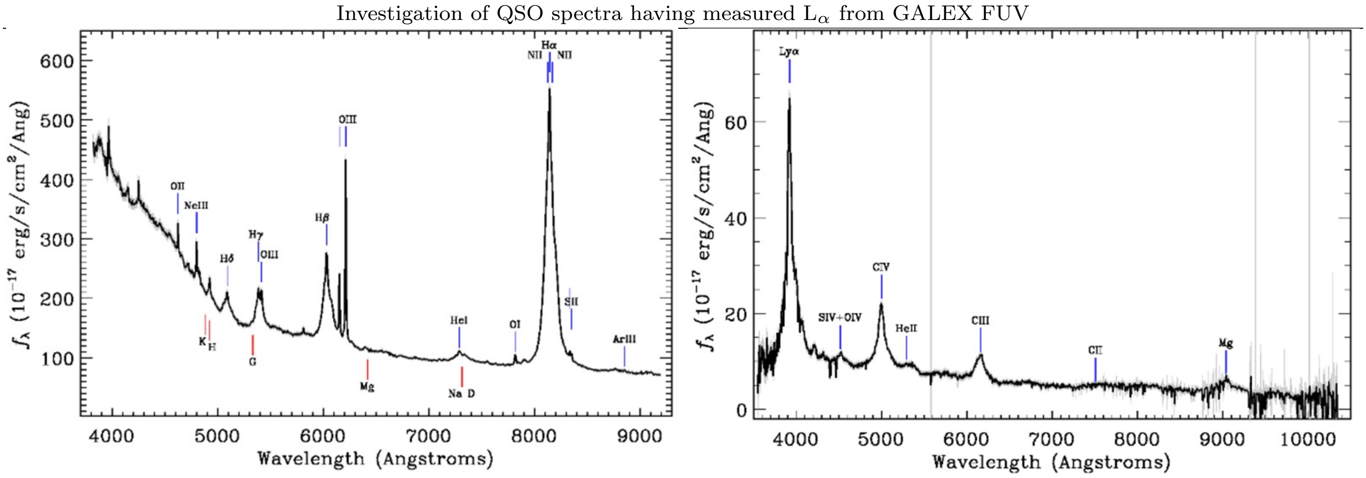

Figure 1. Examples of spectra of QSOs. Typically, L_α line is dozens of times stronger than the continuum, so that GALEX FUV flux may be presented as L_α for the respective redshifts.

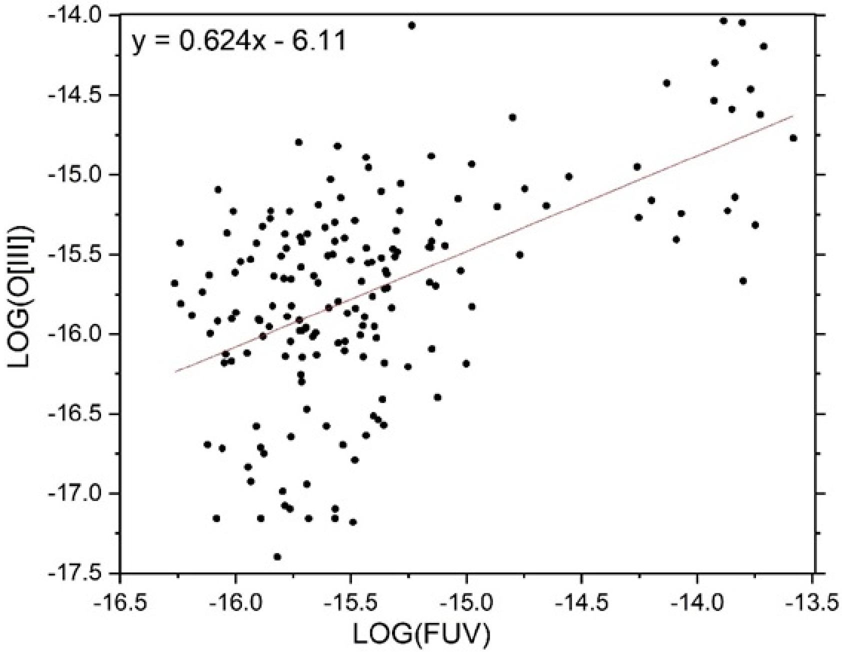

Figure 2. Connection between L_α (GALEX FUV flux) and [OIII] lines for 177 objects.

5. Summary

Active Galactic Nuclei, especially quasars, have not been thoroughly investigated in the far UV range. There are few observations in this range, and this range is mostly available for objects with a high redshift, having UV shifted to the optical range. But on the other hand, there is GALAXY Evolution Explorer (GALEX) space UV telescope catalog, where 82,992,086 near-UV (NUV, 1750–2800$\mathring{A}\mathring{A}$) and far-UV (FUV, 1350–1750$\mathring{A}\mathring{A}$) flux measurements are available. In order to find a connection between the fluxes of the λ5007 ([OIII]) and λ1216 (L_α) lines in the spectra of quasars, we created a sample of quasars with measured L_α. For this, we took the Milliquas 2023 catalog, which contains 1,021,800 objects. From these objects we selected objects having redshift between $0.15 < z < 0.40$, so that L_α spectral line is located in GALEX FUV window. We suppose that FUV flux may be considered as L-alpha flux as its width for QSOs is enough large (occupying almost the whole FUV range) and the continuum is typically 10 times weaker. As a result, we have 42,150 objects. These sources were identified with SDSS DR16 and GALEX DR6+DR7, and as a result we have 11,697 identifications which have data from both SDSS and GALEX. As a result (for 177 objects) we found preliminary connection between L_α and [OIII] lines.

In further work we plan to do a similar work using GALEX NUV, which will give us connection for more

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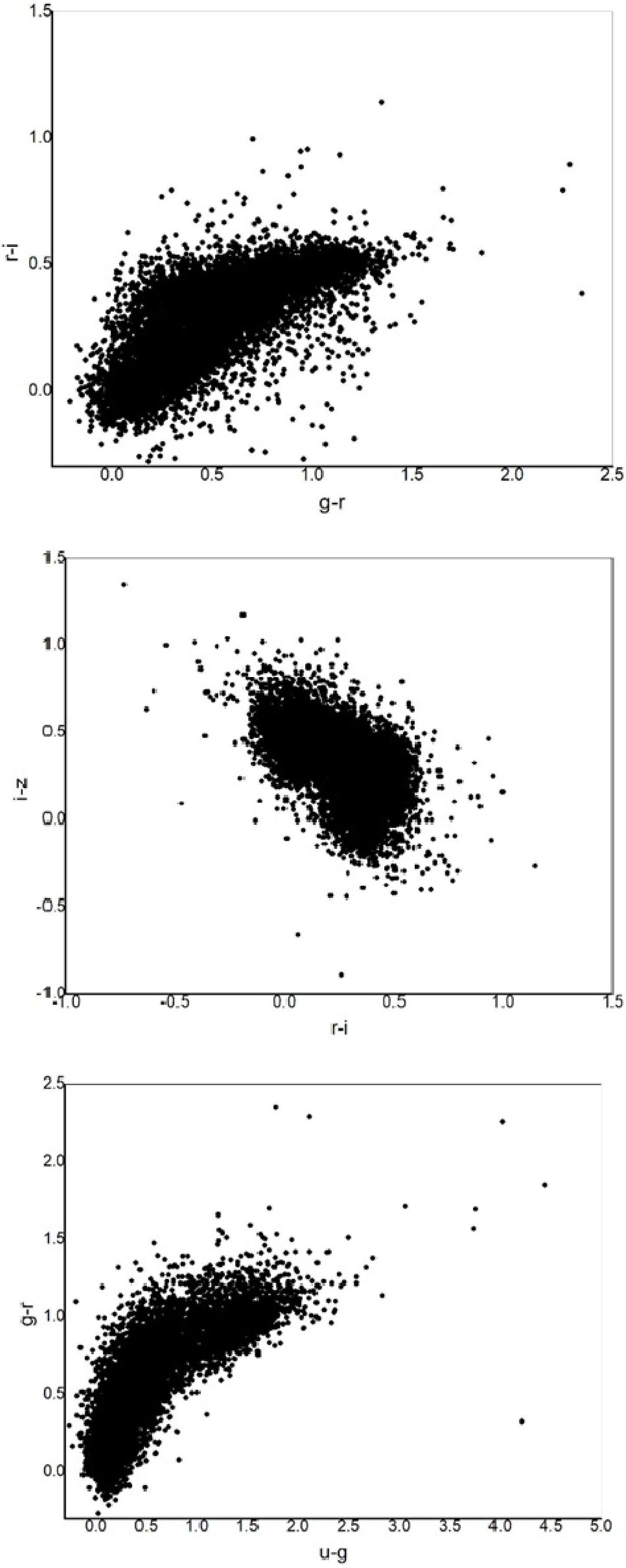

Figure 3. SDSS color-color diagrams for 11,697 investigated objects.

QSOs having z between 0.40 and 1.2 (we expect 60000 more QSOs), thus having L_α located in GALEX NUV. We will have L_α/[OIII] relation to make larger statistics and derive a better empiric formula. We

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plan also to investigate MgII line of quasars and try to find connection of our fine classification with UV range.

Acknowledgements

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On the Blueshift of the Andromeda Galaxy

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Abstract

The observed spectral shift of galaxies is usually interpreted using the Doppler effect. However, attention should be paid to other possible mechanisms of spectral shift. For example, suppose baryon matter evolves due to interaction with the carrier of dark energy. In that case, the objects that pass through longer evolutionary paths compared to our galaxy will be blue-shifted for us. Since the evolutionary spectral shift is a rather weak effect, it can only be detected at small cosmological distances, where the redshift due to the expansion of the Universe is not very large. From this point of view, the Andromeda Nebula is undoubtedly an appropriate example. It is one of the main members of the Local Group of galaxies and has a small blueshift. Here we review observational data and theoretical generalizations in favor of interpreting the blueshift of our neighboring galaxy as an evolutionary effect.

Keywords: *Dark energy, ordinary matter, interaction, evolution of matter; Andromeda galaxy: spectral blueshift, evolution path*

1. Introduction

Expansion is the preferred direction of motion in the Universe, at least on cosmological scales. This has become generally accepted since the relation between the distances of galaxies and their redshifts, discovered by Hubble, was officially recognized as the dependence of the speed of retreat of galaxies on their distances. Therefore, at present, only a few researchers doubt the real expansion of the Universe.

On the other hand, the same researchers always reject any idea associated with the existence of expansion on smaller scales like cosmological expansion. Smaller scales are the sizes of galaxy clusters and down to planetary systems. There is only one serious problem preventing the discussion of such ideas. Such a barrier is the dominant paradigm about the formation of space objects and their systems, which states that they all reach an equilibrium state through compression. In other words, the Universe, as a whole, is expanding, while all its parts were formed through compression.

This is why almost all interacting galaxies are considered "merging", although they could just as easily be interpreted as "separating". However, separation as a special case of expansion is inconsistent with the general idea of galaxy formation, and modern theories do not consider this possibility. Therefore, the observed blueshift of the famous Andromeda Galaxy is readily interpreted as an effect of its movement toward our Galaxy. Consequently, their collision and merger are predicted.

In this report, we consider another possibility for the observed blueshift, which is associated with the evolution of baryon matter under the influence of dark energy. Based on the analysis of observational data and known physical laws, this approach allows us to conclude that the observed blueshift may be a consequence of the baryon matter of the Andromeda Nebula has undergone a longer evolution than our Galaxy.

2. Interaction of baryonic matter with the carrier of dark energy.

After the discovery of dark energy ((Perlmutter et al., 1999, Riess et al., 1998)), the main content of the toolkit, used for cosmological and cosmogonical studies should change drastically. It did not happen. The significant point about the carrier of this energy should have always been mentioned, although we do not

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know what it is. However, no energy form exists without a carrier. Therefore, the issue of the interaction of baryonic matter and the dark energy carrier has been repeatedly considered and substantiated in the works of one of the authors of this report (Harutyunian, 2022, Harutyunian & Grigoryan, 2018, Harutyunian et al., 2019). We will not dwell on this issue in detail, but will only note the following.

It has been shown that such an interaction inevitably leads to the transfer of dark energy to baryonic matter. It does not matter how much energy transfers to the baryonic matter. Energy is a cumulative substance, and it accumulates over time. This follows from two issues: These issues are the interaction between two substances and the application of the second law of thermodynamics. This conclusion is also consistent with the law of entropy growth.

Let's consider any baryonic object or system of objects interacting with a dark energy carrier. Due to this interaction, the baryon part of the interaction receives some energy ΔE. It doesn't matter how much energy the baryon structure receives. Energy is a cumulative substance and therefore it accumulates in the baryon structure. This means that the virial theorem for a given baryonic matter becomes positive, even if it was zero before the interaction. In turn, this leads to an increase in the size of baryon structures. Moreover, if the interaction continues, these structures continue to increase. And this is nothing more than an expansion.

There is another important issue to investigate more carefully. Let us introduce a parameter

$$\eta = \frac{|E_{gr}|}{E_{de}}, \tag{1}$$

where E_{gr} and E_{de} are the gravitational energy of the baryon structure and the dark energy in the volume of this baryon structure. This coefficient can be called the "measure of resistance" (MoR) of the gravitational baryon structure. Indeed, from general physical considerations, it follows that the baryon structure is more difficult to influence by dark energy, the larger the parameter introduced here.

It is well known that gravitational energy is proportional to the second power of mass and inversely proportional to the characteristic linear size. In other words, it is proportional to the square of the volume of the baryon structure, the square of the density of the baryon matter, and inversely proportional to the size. Taking into account the homogeneous distribution of dark energy in space, accepted by modern science, one can conclude that the parameter introduced above has the following dependence on size and density:

$$\eta \sim \frac{(R\rho_b)^2}{\rho_{de}} \tag{2}$$

whereρ_b andρ_{de} are the baryon mass and the dark energy density and $R$is the characteristic size of the baryon system. In the relation (2)ρ_{de} is constant according to the modern concepts of dark energy. Then the parameterη depends on the physical characteristics of the baryon structure only. It is easy to see that the relation (2) has the following form as well

$$\eta \sim \left(M\rho_b^2\right)^{2/3}. \tag{3}$$

Thus, if in a family of gravitational objects (systems), the value of d increases with increasing mass, then massive objects are less compliant to the influence of dark energy and more strongly resist any evolutionary changes, if any. Possible evolutionary changes under the influence of dark energy should be studied to test this conclusion. To check the conclusions made, we should clarify what we mean when baryon matter or baryon objects are considered. The concept of mass masks the properties of baryons. When solving problems about the formation of space objects, the main parameter is the mass of matter, and they rarely remember the structural features of this substance. However, the properties of any clump of matter are based on its structural features, the fact that baryon matter consists of atoms, the mass of which is concentrated in their nuclei. On the other hand, the atomic nucleus has one remarkable property, called mass defect, determining the nuclear binding energy. Without this property, atomic nuclei would not exist. This property is a universal mechanism for converting energy into mass and vice versa. Namely, this property of atomic nuclei will interest us as the main instrument for the absorption or emission of dark energy during the interaction of baryon matter with dark energy. Two key points must be considered while studying the interaction process between dark energy and baryon structures. We have already touched on one aspect above. This applies to the spatial scale where baryon structures physically feel the influence of dark energy. If, according to generally accepted modern concepts, thematic energy uniformly fills all space, from the microcosm to cosmological distances, then we inevitably conclude that baryon structures of any scale undergo such an

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influence. The second thing to note is that the baryon structures exist owing to different binding forces. On large scales, gravitational forces dominate, and binding energy is gravitational. The electric, weak, and nuclear forces dominate at much smaller scales. Therefore, understanding how dark energy affects the physical characteristics of structures that exist due to these forces is crucial. All the structures exist due to the negativity of energy, or rather, the lack of energy that could destroy these structures. As we have noted many times, dark energy is positive and therefore, when transferred to these structures, reduces their stability.

3. Spectral changes of the baryonic object due to the evolution process.

The interaction of atomic nuclei with the carrier of dark energy inevitably leads to a decrease in the nuclear binding energy. In turn, reduces the mass defect of the interacting nucleus, which leads to the mass growth of the nucleus. One can easily find that the greater the mass of the nucleus, the more the difference in energetic levels. It follows from the classical Rydberg relation. In other words, owing to such an interaction, spectral lines of the given atom should show some blueshift, determined by the mass-growth value. The blueshift value shows the difference between the evolution length for the emitter and observer systems. As the Doppler effect is based on the velocity difference, the evolutional spectral shift shows the difference between the evolutional paths of baryon structures. The length of the evolution path depends on the time of evolution as the first parameter. However, as it follows from the relation (3), the baryon structures of different mass will have different evolution lengths, dependent on their mass and density. For example, the lesser the mass of a galaxy the longer its evolution path for the same period. Interestingly, the evolution rate is higher also for the same mass and lesser density. This aspect is important for the study we implement in the next section of this report. Previously, we used the statistics of redshifts of galaxies of different masses belonging to individual galaxy clusters. Bearing in mind that clusters contain galaxies of different luminosities (mass), we studied the dependence of the average redshift on the stellar magnitudes of the galaxies of cluster members. Based on our findings about the evolutionary blueshift, we expected that the redshift of low-luminosity galaxies should have been smaller. These studies' results confirmed our expectations for the nearby clusters in Virgo and Fornax (), and the cluster in Coma (). Undoubtedly, studies in this area can provide much more information on the issue under consideration. Therefore, one should continue similar research to reach a higher significance of the results. One of the authors of the present report used this mechanism of the baryonic matter evolution to solve the paradox of the "Hubble tension" ((Harutyunian, 2021)). It was shown that the difference between Hubble constant values could be solved if the matter evolution process is considered. This effect increases the Hubble constant value. Moreover, this approach allows us to find the mass-growth rate in atomic nuclei. The mass-growth mechanism was also implemented in the growth of the Astronomical Unit (AU) and again a method was suggested for the mass change in such baryonic structures as stars (Harutyunian & Grigoryan, 2018, Harutyunian et al., 2019).

4. Andromeda galaxy's blueshift.

In the previous article of the authors (Harutyunian et al., 2023), we first formulated the problem of blueshift in the spectrum of the Andromeda nebula, which is interpreted as the approach of this galaxy to the Milky Way. Then we noticed that the blue shift may have a different mechanism, unrelated to the Doppler effect. Two reasons lead us to this conclusion. Firstly, it seems unnatural to us that, against the background of the general expansion of the Universe, a convergence of galaxies is occurring in the Local Group of galaxies. This would mean they first moved away from each other, as every material point in our Universe. Then, we should accept that this movement has been stopped at some distance, and the reversal movement began. The second point is related to the newfound mechanism of blueshift formation. That is the evolutionary mechanism, which does not deal with any mechanical movement. Moreover, this mechanism is better manifested at short distances.

However, on the other hand, one can ask what evidence there is that the Andromeda Nebula has gone through a longer evolutionary path than our galaxy. To answer this question thoroughly, many characteristics of the two galaxies must be examined and compared. Such describing parameters include mass, geometric size, metallicity, metallicity gradient, structural features, and much more.

Here we will only focus on discussing relation (3). According to new measurements, the mass of the Andromeda Nebula is approximately the same as that of our galaxy (see (Kafle et al., 2018) and references

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therein). But in terms of geometric dimensions, it is twice as large as the Milky Way ((Chapman et al., 2006)). With the same mass, twice the size indicates lower density. Moreover, the density of baryon matter will be four times less if we consider only the disk component and eight times less if the density is calculated over the entire volume.

In relation (3) the density of matter is included in the power of 4/3. Then we find that with equal mass and twice the size, the "Measure of Resistance" of the Andromeda Nebula is from 6.3 to 16 times less than that of our galaxy. If they formed at approximately the same time, then the Andromeda Nebula took much longer in the evolution of its baryon matter.

Thus, even a fairly simple analysis shows that the Andromeda Nebula has gone through a longer evolutionary path of baryon matter. Therefore, our cosmic neighbor may have a blueshift relative to our galaxy. We will do a more detailed analysis involving other characteristics of the two galaxies in the future.

5. Concluding remarks.

The blueshift of the Andromeda galaxy provides an excellent opportunity to test the hypothesis of the evolution of atomic nuclei under the influence of dark energy. The self-consistent application of the laws of physics suggests that the interaction of atomic nuclei and free baryons with the dark energy carrier should lead to a gradual increase of their mass. The nuclear mass increase, in turn, shifts the spectral lines of these atoms to the blue end of the spectrum. The more an object is evolved under the influence of dark energy, the greater its blueshift for an observer who is in an environment where the evolution of matter lags behind.

It is on the basis of these considerations that we approach the question of the spectral blueshift of the Andromeda nebula, which is usually interpreted as a result of Doppler effect, suggesting that the neighboring galaxy is approaching to the Milky Way. By studying all relevant features of the neighboring galaxy and comparing with the same characteristics of our own galaxy, we are going to find out whether it is ahead of our Galaxy in the sense of the evolution of matter itself. First of all we need to find the physical features, which show clear dependence on the matter evolution and compare them for two galaxies.

For this purpose, at the first stage of research, we are going to compare the stellar content of two galaxies, various manifestations of activity, the metallicity dependence on the galactocentric distances for all components of galaxies, the content and distribution of globular clusters, the content of gas and dust etc. All these physical characteristics which somehow depend on the age of galaxy should provide the necessary keys for the comparison we need.

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The eigenfunctions method in relation to diffuse reflection problems of the radiative energy transfer theory

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Abstract

Using the new method proposed earlier by the author, a solution of diffuse reflection problem is given in this report. A case of diffuse reflection of radiation from a semi-infinite absorbing and isotropically reflecting medium is presented, when in the elementary act of scattering there is a general law of redistribution of radiation by frequencies. In the approach presented here, conventionally called the method of "decomposition of the resulting field" - DRF, in contrast to the previously widely used traditional method of "decomposition of a single act" of scattering - DSA, the problem of diffuse reflection is solved without the use of any decomposition or special representation of the characteristic of the elementary act of scattering, i.e., the redistribution function of radiation by frequencies. The resulting radiation field, formed in the medium by means of multiple scatterings, is sought and constructed directly in the form of a bilinear series through a specially derived system of its own eigenfunctions. The physical basis of this approach lies in the fact that after each successive act of scattering, the field formed in the medium becomes more and more smoothed, so its direct representation in a decomposed form is more expedient than the traditionally used decomposition of a pre-known "unsmoothed" characteristic of the elementary act of scattering.

Keywords: *radiative transfer, diffuse reflection problem, partial redistribution of radiation by frequencies, separation of variables, nonlinear Ambartsumian's functional equation, eigenfunctions and eigenvalues problem*

1. Introduction and purpose of the report.

The problem of diffuse reflection is one of the classical problems of theoretical astrophysics, which also has a wide application value in various related fields of science. Its solution in the case of a semi-infinite scattering-absorbing medium under isotropic monochromatic scattering by introducing the principle of invariance (Ambartsumian (1942, 1943a,b, 1944a,b,c)) was obtained in the form of

$$\rho\left(\mu,\mu'\right)=\frac{\lambda}{2\mu'}\frac{\varphi\left(\mu\right)\varphi\left(\mu'\right)}{\frac{1}{\mu}+\frac{1}{\mu'}},\varphi\left(\mu\right)=1+\int_0^1\rho\left(\mu,\mu'\right)d\mu', \tag{1}$$

$$\varphi\left(\mu\right)=1+\frac{\lambda}{2}\mu\varphi\left(\mu\right)\int_0^1\frac{\varphi\left(\mu'\right)}{\mu+\mu'}d\mu'. \tag{2}$$

Here's $\rho\left(\mu,\mu'\right)d\mu$ the probability of diffuse reflection of the quantum from the medium in the direction of μ (cosine of the angle of the quantum leaving the medium in relation to the normal to its boundary), in the solid angle of $2\pi d\mu$ on condition that it enters the medium from the direction μ' . The value of λ indicates the probability of survival of the quantum in the elementary act of scattering or the so-called albedo of a single scattering. In solution (1) there is a phenomenon of separation of angular variables, i.e., the desired function of many (here – two) independent variables is expressed through a function of a smaller number (here - one) of the angular variable. Later, Sobolev showed that a separation of the same type takes place for frequency variables in the case of a complete redistribution of radiation over frequencies in isotropic scattering of quanta (see, e.g., (Sobolev, 1963)). In the case of anisotropic monochromatic scattering, the separation of angular variables was first achieved in the work (Ambartsumian, 1943b, 1944b). For this purpose, the scattering indicatrix was preliminarily decomposed according to Legendre polynomials (Ambartsumian, 1941). Then, the Fourier cosine expansion was performed along the azimuths, and for the azimuthal harmonics of the scattering indicatrix, a bilinear expansion was obtained by the associated Legendre functions

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$$\chi^m(\mu,\mu') = \sum_{i=m}^{N} c_i^m P_i^m(\mu) P_i^m(\mu'). \tag{3}$$

Substituting this decomposed form of the scattering indicatrix into the Ambartsumian's functional equation, after simple calculations, leads to the solution of the diffuse reflection problem in an explicit form. The azimuthal harmonic of the diffuse reflection function, which depends on two independent angular variables, is explicitly expressed through the system of auxiliary functions of one angular variable. These auxiliary functions were derived from a system of functional nonlinear integral equations. The number of equations in this system was naturally equal to the number of terms in the bilinear expansion of azimuthal harmonics of the scattering indicatrix (3) by the associated Legendre functions. Later, when considering the problem of diffuse reflection in the case of incoherent scattering, under the general law of redistribution of radiation over frequencies - $r(x,x')$, in order to achieve the separation of frequency variables (x,x'), the special representation of the characteristics of elementary act of scattering was also used. The function of redistribution of radiation by frequencies was given by a bilinear series of a specially constructed system of its eigenfunctions ((Engibaryan, 1971, Engibaryan & Nikogosyan, 1972))

$$r(x,x') = \sum_{i=1}^{N} A_i \alpha_i(x)\alpha_i(x') \tag{4}$$

In this way, it was possible to achieve the separation of frequency variables. In some real-world applications, however, a much larger number of terms (on the order of 100 or more) must be taken into account in series (3) or (4), in order to achieve the necessary accuracy (see, e.g., Smokity & Anikonov (2008)). In this case, the calculation of the diffusely reflected field by the above-mentioned "traditional" method of decomposition of the characteristics of the elementary act of scattering will obviously be very difficult or inexpedient due to the corresponding increase in the number of equations in the system, which is subject to decision. The purpose of this report is to briefly present the result of solving the problem of diffuse reflection obtained using a new original method recently introduced by the author in his works (Pikichyan (2023a,b,c)). The expediency of the above method is illustrated below by analyzing the problem of diffuse reflection from a semi-infinite medium under isotropic incoherent scattering in the case of the general law of radiation redistribution over frequencies. It is shown that, in contrast to the hitherto known methods of analysis, the problem of diffuse reflection can be solved without any decomposition or special representation of the characteristics of the elementary act of scattering. Here, an explicit solution to the problem is sought directly in a decomposed form, through a specially constructed system of eigenfunctions that depend on a smaller number of independent variables. In order to find these eigenfunctions and their eigenvalues together, a general system of nonlinear integral functional equations and nonlinear algebraic equations is obtained. Such an approach, in contrast to the well-known methods of "decomposition of a single act" (DSA), should be conventionally called the method of "decomposition of the resulting field" (DRF).

2. Physical basis and expediency of finding a solution to the problem by means of DRF

It is obvious that in the process of multiple scattering of light in a medium, after each successive act of scattering, the radiation field in it becomes more and more smooth. The reason is that the function describing the previous distribution of the radiation field after each new scattering act is once again integrated with the nucleus of the single scattering act. It follows that the representation of the characteristics of this "smoothed" resulting field formed in process of multiple scatterings by a bilinear series will be more efficient. I.e., in the end, the same accuracy will be provided by a smaller number of series terms than in the case of decomposition of the original "unsmoothed" field of a single scattering (Pikichyan (2023a,b,c)).

3. Mathematical formulation of the problem

To solve the problem of diffuse reflection in the case of isotropic scattering, we previously obtained an explicit expression (Pikichyan (1978, 1980)):

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$$\rho\left(x, \mu ; x^{\prime}, \mu^{\prime}\right)=\frac{\lambda}{2 \mu^{\prime}} \frac{\int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \varphi\left(x^{\prime \prime} ; x, \mu\right) r\left(x^{\prime \prime}, x^{\prime \prime \prime}\right) \varphi\left(x^{\prime \prime \prime} ; x^{\prime}, \mu^{\prime}\right) d x^{\prime \prime} d x^{\prime \prime \prime}}{\frac{\alpha(x)}{\mu}+\frac{\alpha\left(x^{\prime}\right)}{\mu^{\prime}}}, \tag{5}$$

$$\varphi\left(x^{\prime}, x ; \mu\right)=\delta\left(x^{\prime}-x\right)+\int_0^1 \rho\left(x, \mu ; x^{\prime}, \mu^{\prime}\right) d \mu^{\prime}, \tag{6}$$

$$\varphi\left(x^{\prime}, x ; \mu\right)=\delta\left(x^{\prime}-x\right)+\frac{\lambda}{2 \mu^{\prime}} \int_{-\infty}^{+\infty} \varphi\left(x^{\prime \prime} ; x, \mu\right) d x^{\prime \prime} \int_{-\infty}^{+\infty} r\left(x^{\prime \prime}, x^{\prime \prime \prime}\right) d x^{\prime \prime \prime} \int_0^1 \frac{\varphi\left(x^{\prime \prime \prime} ; x^{\prime}, \mu^{\prime}\right)}{\frac{\alpha(x)}{\mu}+\frac{\alpha\left(x^{\prime}\right)}{\mu^{\prime}}} d \mu^{\prime}. \tag{7}$$

Where is the desired diffuse reflection function $\rho(x, \mu; x', \mu')$ dependent on the four independent variables is explicitly expressed in terms of an auxiliary function $\varphi(x', x; \mu)$ of a smaller number i.e., three, of independent variables. It is obvious that the decrease in the number of angular variables, like in the case (1), is also due to the isotropy of the elementary act of scattering. As for the frequency variables (the value $\alpha(x)$ represents the absorption profile), the property of separation does not take place for them, due to the absence of it in the elementary act of scattering $r(x'', x''')$. It has been already pointed out above that in order to achieve the separation of frequency variables, the DSA method has been traditionally used, i.e., the method of decomposition of the characteristic of an elementary act of scattering in the form (4). Indeed, by substituting the expansion (4) into the relation (5), the well-known solution is directly obtained:

$$\rho\left(x, \mu ; x^{\prime}, \mu^{\prime}\right)=\frac{\lambda}{2 \mu^{\prime}} \frac{\sum_{i=1}^N A_i \varphi_i(x, \mu) \varphi_i\left(x^{\prime}, \mu^{\prime}\right)}{\frac{\alpha(x)}{\mu}+\frac{\alpha\left(x^{\prime}\right)}{\mu^{\prime}}}, \tag{8}$$

$$\varphi_i(x, \mu) \equiv \int_{-\infty}^{+\infty} \alpha_i\left(x^{\prime}\right) \varphi\left(x^{\prime} ; x, \mu\right) d x^{\prime}, \tag{9}$$

$$\varphi_i(x, \mu)=\alpha_i(x)+\frac{\lambda}{2} \sum_{i=1}^n A_i \varphi_i(x, \mu) \int_{-\infty}^{+\infty} \alpha_i\left(x^{\prime}\right) d x^{\prime} \int_0^1 \frac{\varphi_i\left(x^{\prime}, \mu^{\prime}\right)}{\frac{\alpha(x)}{\mu}+\frac{\alpha\left(x^{\prime}\right)}{\mu^{\prime}}} \frac{d \mu^{\prime}}{\mu^{\prime}}. \tag{10}$$

Our task is to simplify the solution (5) by the DRF method, achieving the separation of frequency variables without involving any expansions or special representations of the elementary act of scattering.

It is well known that from the symmetry of the elementary act of scattering follows the symmetry of the diffuse reflection function itself

$$r\left(x^{\prime \prime}, x^{\prime \prime \prime}\right)=r\left(x^{\prime \prime \prime}, x^{\prime \prime}\right) \Rightarrow \rho\left(x, \mu ; x^{\prime}, \mu^{\prime}\right) \mu^{\prime}=\rho\left(x^{\prime}, \mu^{\prime} ; x, \mu\right) \mu, \tag{11}$$

then the function introduced by notation

$$K\left(x, \mu ; x^{\prime}, \mu^{\prime}\right) \equiv \mu^{\prime}\left[\frac{\alpha(x)}{\mu}+\frac{\alpha\left(x^{\prime}\right)}{\mu^{\prime}}\right] \rho\left(x, \mu ; x^{\prime}, \mu^{\prime}\right) \tag{12}$$

will also be symmetrical

$$K\left(x, \mu ; x^{\prime}, \mu^{\prime}\right)=K\left(x^{\prime}, \mu^{\prime} ; x, \mu\right). \tag{13}$$

For this positive and symmetric kernel, we can formulate a problem for eigenvalues ν_j and eigenfunctions $\beta_j(x, \mu)$:

$$\nu_j \beta_j(x, \mu)=\int_{-\infty}^{+\infty} \int_0^1 K\left(x, \mu ; x^{\prime}, \mu^{\prime}\right) \beta_j\left(x^{\prime}, \mu^{\prime}\right) d \mu^{\prime} d x^{\prime}, \tag{14}$$

with orthonormalization condition

$$\int_{-\infty}^{+\infty} \int_0^1 \beta_i(x, \mu) \beta_j(x, \mu) d \mu d x=\delta_{i j}. \tag{15}$$

If, in some approximation N , the nucleus $K(x, \mu; x', \mu')$ to be replaced by a bilinear series of its own eigenfunctions

$$K\left(x^{\prime}, \mu^{\prime} ; x, \mu\right) \backsim K_N\left(x, \mu ; x^{\prime}, \mu^{\prime}\right)=\sum_{j=1}^N \nu_j \beta_j(x, \mu) \beta_j\left(x^{\prime}, \mu^{\prime}\right), \tag{16}$$

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then, taking into account (12) and (16), an explicit solution to the initial problem of diffuse reflection in the same approximation N is obtained

$$\rho\left(x,\mu;x',\mu'\right)=\frac{1}{\mu'}\frac{\sum_{i=1}^{N}\nu_i\beta_i\left(x,\mu\right)\beta_i\left(x',\mu'\right)}{\frac{\alpha(x)}{\mu}+\frac{\alpha(x')}{\mu'}}. \tag{17}$$

Here we have the desired separation of variables (x',μ') of quanta entering the medium from variables (x,μ) of quanta leaving the medium. Thus, the problem was reduced to finding the eigenfunctions $\beta_i\left(x,\mu\right)$ and the eigenvalues of ν_i of the unknown kernel $K\left(x,\mu;x',\mu'\right)$.

4. Construction of an analytical solution to the problem using the DRF method

From the ratios (5), (6) and (12) follow the expressions

$$\frac{2}{\lambda}K\left(x,\mu;x',\mu'\right)=\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\varphi\left(x'';x,\mu\right)r\left(x'',x'''\right)\varphi\left(x''';x',\mu'\right)dx''dx''', \tag{18}$$

$$\varphi\left(x';x,\mu\right)=\delta\left(x'-x\right)+\int_0^1\frac{K\left(x,\mu;x',\mu'\right)}{\frac{\alpha(x)}{\mu}+\frac{\alpha(x')}{\mu'}}\frac{d\mu'}{\mu'}, \tag{19}$$

with the help of which it is not difficult to obtain a functional equation for the nucleus $K\left(x,\mu;x',\mu'\right)$

$$\frac{2}{\lambda}K\left(x,\mu;x',\mu'\right)=r\left(x,x'\right)+$$

$$\int_{-\infty}^{+\infty}r\left(x,x''\right)dx''\int_0^1\frac{K\left(x',\mu';x'',\mu''\right)}{\frac{\alpha(x')}{\mu'}+\frac{\alpha(x'')}{\mu''}}\frac{d\mu''}{\mu''}+\int_{-\infty}^{+\infty}r\left(x'',x'\right)dx''\int_0^1\frac{K\left(x,\mu;x'',\mu''\right)}{\frac{\alpha(x)}{\mu}+\frac{\alpha(x'')}{\mu''}}\frac{d\mu''}{\mu''}+$$

$$\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_0^1\frac{K\left(x,\mu;x'',\mu''\right)}{\frac{\alpha(x)}{\mu}+\frac{\alpha(x'')}{\mu''}}\frac{d\mu''}{\mu''}r\left(x'',x'''\right)\int_0^1\frac{K\left(x',\mu';x''',\mu'''\right)}{\frac{\alpha(x')}{\mu'}+\frac{\alpha(x''')}{\mu'''}}\frac{d\mu'''}{\mu'''}dx''dx'''. \tag{20}$$

Thus, the eigenvalue and eigenfunctions problem (14) – (15) must be solved for the unknown function $K\left(x,\mu;x',\mu'\right)$, which satisfies to the functional equation (20).

Using the integral operator $\int_{-\infty}^{+\infty}\int_0^1\ldots\beta_j\left(x',\mu'\right)d\mu'dx'$ to the equation (20), a system of nonlinear algebraic an algebraic system of nonlinear integral equations is obtained

$$\frac{2}{\lambda}\nu_j\beta_j\left(x,\mu\right)=Z_j\left(x\right)+\sum_{k=1}^{N}\nu_kD_{kj}\left(x,\mu\right)+\sum_{k=1}^{N}\sum_{l=1}^{N}\nu_k\nu_lV_{klj}\left(x,\mu\right). \tag{21}$$

The following notations are accepted here:

$$Z_j\left(x\right)\equiv\int_{-\infty}^{+\infty}r\left(x,x'\right)\overline{\beta}_j\left(x'\right)dx',\quad\overline{\beta}_j\left(x'\right)\equiv\int_0^1\beta_j\left(x',\mu'\right)d\mu',$$

$$D_{kj}\left(x,\mu\right)\equiv\int_{-\infty}^{+\infty}r\left(x,x''\right)w_{kj}\left(x''\right)dx''+\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}w_k\left(x'',x,\mu\right)r\left(x'',x'\right)\overline{\beta}_j\left(x'\right)dx'dx'',$$

$$V_{klj}\left(x,\mu\right)\equiv\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}w_k\left(x'',x,\mu\right)r\left(x'',x'''\right)w_{lj}\left(x'''\right)dx''dx''',$$

$$w_{kj}\left(x''\right)\equiv\int_{-\infty}^{+\infty}\int_0^1w_k\left(x'',x',\mu'\right)\beta_j\left(x',\mu'\right)d\mu'dx'\ ,\quad w_k\left(x'',x',\mu'\right)=\beta_k\left(x',\mu'\right)\int_0^1\frac{\beta_k\left(x'',\mu''\right)}{\frac{\alpha(x')}{\mu'}+\frac{\alpha(x'')}{\mu''}}\frac{d\mu''}{\mu''}. \tag{22}$$

The use of the operator $\int_{-\infty}^{+\infty}\int_0^1\ldots\beta_j\left(x',\mu'\right)d\mu'dx'$ by the relation (21) taking into account the normalization condition (15), a system of nonlinear algebraic equations is obtained

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$$\frac{2}{\lambda}\nu_i = b_i + \sum_{k=1}^{N}\nu_k c_{ki} + \sum_{k=1}^{N}\sum_{l=1}^{N}\nu_k\nu_l f_{kli}, \tag{23}$$

where free terms in equations and coefficients for eigenvalues are given by notation:

$$b_i = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\overline{\beta}_i(x)\, r(x,x')\,\overline{\beta}_i(x')\,dx'dx,$$

$$c_{ki} = 2\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} w_{ki}(x'')\, r(x'',x')\,\overline{\beta}_i(x')\,dx'dx'',$$

$$f_{kli} = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} w_{ki}(x'')\, r(x'',x''')\, w_{li}(x''')\,dx''dx'''. \tag{24}$$

Thus, using the DRF method, the problem of determining the desired eigenvalues ν_j and eigenfunctions $\beta_j(x,\mu)$ of the core $K(x,\mu;x',\mu')$ is reduced to the solution of a general system consisting of two more partial subsystems: nonlinear integral equations (21) and algebraic nonlinear equations (23).

5. General scheme of numerical calculation

To implement the numerical calculation as the initial zero approximation $\beta_i^{(0)}(x,\mu)$, we can take some system of orthonormalized polynomials, for example, Hermite, and use notation (24) to compute zero approximations of the remaining quantities:

$$\beta_i^{(0)}(x,\mu) \;\rightarrow\; b_i^{(0)},\quad c_{ki}^{(0)},\quad f_{kli}^{(m)},\quad \nu_i^{(0)} \equiv b_i^{(0)}. \tag{25}$$

Then, using (25), the first approximation of the eigenvalues of $\nu_i^{(1)}$ is calculated by applying the formula

$$\nu_i^{(1)} = \frac{\lambda}{2}\left[b_i^{(0)} + \sum_{k=1}^{N}\nu_k^{(0)}c_{ki}^{(0)} + \sum_{k=1}^{N}\sum_{l=1}^{N}\nu_k^{(0)}\nu_l^{(0)}f_{kli}^{(0)}\right] \tag{26}$$

After that, by values (22) and $\nu_i^{(1)}$:

$$\nu_i^{(1)},\quad \beta_i^{(0)}(x,\mu) \;\rightarrow\; Z_i^{(0)}(x),\quad D_{ki}^{(0)}(x,\mu),\quad V_{kli}^{(0)}(x,\mu) \tag{27}$$

the first approximation of eigenfunctions is calculated using the formula

$$\beta_i^{(1)}(x,\mu) = \frac{\lambda}{2\nu_i^{(1)}}\left[Z_i^{(0)}(x) + \sum_{k=1}^{N}\nu_k^{(1)}D_{ki}^{(0)}(x,\mu) + \sum_{k=1}^{N}\sum_{l=1}^{N}\nu_k^{(1)}\nu_l^{(1)}V_{kli}^{(0)}(x,\mu)\right], \tag{28}$$

and then the scheme is consistently applied

$$\nu_i^{(m+1)} \rightarrow \beta_i^{(m+1)}(x,\mu) \rightarrow \nu_i^{(m+2)} \rightarrow \beta_i^{(m+2)}(x,\mu) \rightarrow \cdots \rightarrow \nu_i^{(M)} \rightarrow \beta_i^{(M)}(x,\mu). \tag{29}$$

Successive iterations continue at $m = 1,\ 2,\ 3,\ldots$ and at each successive value of m, the accuracy of convergence is evaluated in a standard way until the M - th iteration provides the necessary accuracy. Thus, the joint iterative scheme described above has the form of

$$\begin{gathered}\beta_i^{(m+1)}(x,\mu) = \tfrac{\lambda}{2\nu_i^{(m+1)}}\left[Z_i^{(m)}(x) + \textstyle\sum_{k=1}^{N}\nu_k^{(m+1)}D_{ki}^{(m)}(x,\mu) + \sum_{k=1}^{N}\sum_{l=1}^{N}\nu_k^{(m+1)}\nu_l^{(m+1)}V_{kli}^{(m)}(x,\mu)\right],\\ \nu_i^{(m+1)} = \tfrac{\lambda}{2}\left[b_i^{(m)} + \textstyle\sum_{k=1}^{N}\nu_k^{(m)}c_{ki}^{(m)} + \sum_{k=1}^{N}\sum_{l=1}^{N}\nu_k^{(m)}\nu_l^{(m)}f_{kli}^{(m)}\right].\end{gathered} \tag{30}$$

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6. Relationship between the auxiliary functions of the DSA method and the eigenfunctions of the DRF method

By comparing the explicit analytical solutions of the same diffuse reflection problem obtained by the DSA-(8) and DRF-(17) methods, it is not difficult to write a two-way relationship between the values sought with their help: the auxiliary functions $\varphi_i\left(x,\mu\right)$ of the DSA method and the eigenfunctions - $\beta_j\left(x,\mu\right)$ with the eigenvalues ν_j of the DRF method (see Pikichyan (2023b)).

a) Suppose the values of $\varphi_i\left(x,\mu\right)$ are known, but it is necessary to find the values $\beta_j\left(x,\mu\right)$ and ν_j with their help:

$$\beta_j\left(x,\mu\right)=\frac{\sum_{i=1}^{N}A_i\varphi_i\left(x,\mu\right)q_{ij}}{\sum_{i=1}^{N}A_i q_{ij}^2},\quad q_{kj}=\frac{\sum_{i=1}^{N}A_i a_{ik}q_{ij}}{\sum_{i=1}^{N}A_i q_{ij}^2},\quad \nu_j=\frac{\lambda}{2}\sum_{i=1}^{N}A_i q_{ij}^2. \tag{31}$$

b) Assuming the values $\beta_j\left(x,\mu\right)$ and ν_j, it is necessary to use them to find the $\varphi_i\left(x,\mu\right)$

$$\varphi_i\left(x,\mu\right)=\alpha_i\left(x\right)+\sum_{j=1}^{N}\nu_j\beta_j\left(x,\mu\right)\int_{-\infty}^{+\infty}\alpha_i\left(x'\right)dx'\int_0^1\frac{\beta_j\left(x',\mu'\right)}{\frac{\alpha(x)}{\mu}+\frac{\alpha(x')}{\mu'}}\frac{d\mu'}{\mu'}. \tag{32}$$

Expressions (31) and (32) make it possible: a) with the same choice of the number of terms N in the expansions (4) and (17), to determine the comparative accuracy of the DSA and DRF methods, and b) to find those values of the N_1 and N_2 of the number N at which the DSA and DRF methods provide the same accuracy.

7. Conclusion

The report emphasizes an obvious, but very important physical fact that in the process of multiple scatterings of a quantum in a scattering-absorbing medium, after each successive single act of scattering, the radiation field formed in the medium becomes more and more smooth. The presence of such a property of the resulting radiation field allows us to develop a new view to the solution of the classical, well-studied problem of diffuse reflection. Indeed, in this case, it is more efficient to search for the unknown resulting field of multiple scatterings directly in the decomposed form through a specially constructed system of eigenfunctions (the DRF method) than to derive the final decomposed field form by means of preliminary decomposition of the characteristics of a single act of scattering (the DSA method). That is, the quality of variable separation, in contrast to the methods traditionally used until now (DSA methods), can be directly introduced into the solution of the problem from the very beginning (DRF method), without using any preliminary decomposition or a special representation of the characteristics of the elementary act of scattering. In summary: a) an explicit solution to the problem of diffuse reflection from a semi-infinite medium under isotropic incoherent scattering in the case of the general law of frequency redistribution was presented above by the DRF method, where the variables (x',μ')-frequency and angle of the quantum entering the medium are "separated" from the same quantities (x,μ) of the quantum leaving it, b) a general iterative scheme for numerical calculation of a system of functional nonlinear integral equations and algebraic equations for the joint determination of both eigenfunctions and eigenvalues of the problem is also shown. c) in order to compare the effectiveness of the DSA and DRF methods in an explicit analytical form, some two-way relationships between the desired values of both methods was also obtained .

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Astrochemistry and Astrobiology over the last 20 years

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Abstract

A review of the achievements of astrochemistry and astrobiology over the past 20 years is given. Advances in astrochemistry in understanding the processes of emergence and survival high molecular weight chemical compounds are directly related to the conditions of prebiomolecules origin, like -amino acids and complex hydrocarbons. And if on the case of amino acids and hydrocarbons synthesis , the astrophysical picture seems quite clear, then on the case of the emergence of chiral amino acids, of which the proteins of living organisms are composed, there is no generally accepted point of view. Probably they occurred in certain photochemical transformations under the influence of circularly polarized radiation in the conditions of star formation regions of molecular clouds.

Keywords: *astrochemistry, astrobiology, complex molecules, irradiation, molecules suvervability under hard radiation, origin of life*

1. Introduction

1.1. Content

1. About astrochemistry
2. Dust particles and origin of complex species
3. On astrobiology
4. Life in expanding Universe
5. Conclusion

1.2. Astrobiology, astrochemistry and all that - list of clarifying definitions

Astrochemistry is the science (as a part of astrophysics) about the origin and existence of chemical compounds in the Universe, including dust grains. Dust plays a particularly important role in the formation of molecules and more complex ones, in general, and in elementary processes in physics and chemistry of molecular clouds, in particular. Interstellar dust consists of particles of graphite or silicates 0.05-1 μ in size, which may have ice mantles (H_2O, CO, CH_4...) an order of magnitude larger. Astrobiology is mainly concerned with the origin of prebiomolecules (amino acids, complex hydrocarbons, sugars, etc.) and their survival, from the point of view of the only form of terrestrial life as we know it.

It should be highlighted now that since discovery of helium in the solar spectrum in 1868 astrophysics was based essentially on theory of atoms (and ions). A good example is the book of S. Rosseland, 1931, Astrophysics - on the base of atomic theory (Astrophysik: Auf Atomtheoretischer Grundlage) Rosseland (1931).

Ambartsumyan's article of 1933 should also be mentioned Ambarzumian (1933) (concerning again with atoms and ions), by the way one of the first related to the study of the physics of the interstellar medium.

After 100 years, however, the successes of observational astrophysics are associated primarily with molecular astrophysics Shaw (2022). By early 2024, more than 256 molecules had already been observed in the Universe (without isotopic differences). Also part of molecules are identified in circumstellar disks around newborn stars.

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It is clear that today to study astrobiology, at first, prebiomolecules (that is large and very large chemical compounds), it is necessary to use theoretical and observational methods of Molecular astrophysics, which is obviously known as Astrochemistry.

Important molecules like H_2, CO, H_2O, CO_2, NH_3, CH_4, H_2CO, CH_3OH,...etc. usually origin and survive inside of molecular clouds in star-formation regions Shaw (2022). Also PAH (polycyclic aromatic hydrocarbons, for example, $C_{24}H_{12}$ - coronene), fullerens (C_{60}), aminoacids, shugars, alcohols etc. are observed in such regions. Corresponding timescales are quite appropriate: if ages of star-formation regions are a few millions years, while dust and ice covers of grains origin in dense environment of protostellar clouds for only a few thousands - a few ten thousands years.

There is one contradiction to standard picture that dust is originated in dense cold outflows of AGB stars with masses less than 8 solar, and in supernovae explosion. The case is that due to supernovae only silicate dust is arrived, while graphite dust is originated in AGB phase for which 1-2 billions years are necessary. On the other hand, PAHs molecules, for which graphite is necessary, were detected in the farthest galaxy SPT0418-47 in 2023 by James Webb Space Telescope Spilker et al. (2023). That galaxy is 12.3 billion years old, and we note the problem concerning with the modern estimate of the Universe age, 13.8±0.2 billions years. So PAH couldn't have time to origin. Also survivability of PAHs under hard conditions of early Universe should be taken into account, to have balance between originated and destroyed molecules, PAH is connected with graphite, which is created in AGB stars with C/O>1 in 1.5 b.y. The following explanation is that probably such a dust was originated via binary carbon-enhanced metal-poor like stars, or specific single AGB in such a shortened time concerning conditions of first generation of stars.
At last but not least the most important thing is a homochirality of pre-biomolecules, aminoacids, heavy hydrocarbons etc. Meierhenrich (2008). That is, proteins of Earth living organisms (and any other molecular complexes with asymmetric C-atom) consist of only L - "aminoacids" (L - alanine etc). But homochirality of such molecules couldn't be originated on Earth ! This is the most important conclusion of last 20-30 years and this is a reason to include astrophysics into the common picture !

2. Important dates concerning origin of life on Earth

The Sun was formed 4.6±0.1 billion years ago, the Earth a little later, 4.54±0.05 billion years ago **?**. Heavy bombardment of the Earth by giant comets and asteroids has ceased 3.8 b.y. ago. They have delivered primary atmosphere and (partly) water of oceans. The oldest sedimentary rocks of the Earth date back to 3.8 b.y. ago. First traces of life on Earth have found 3.8 b.y. ago. First blue-green algae in oceans have arrived 2.7 b.y. ago. Atmospheric oxygen with relative abundance larger than 1 % has age 2.4 b.y.

Currently known is that the origin of life on Earth was preceded by a period of chemical complexity of molecular compounds outside the Earth. In the amino acids of proteins of living organisms, molecular symmetry is broken; only their left-handed forms exist Meierhenrich (2008). The laws of heredity of self-reproducing systems representing terrestrial life forms are implemented through the "genetic code", the structure of the components of which significantly depends on the presence of chirality, because exactly a sequence of nucleotide triplets in nucleic acids determine the corresponding order of amino acids in a protein structure. The origin of such amino acids on Earth with broken chiral symmetry has been ruled out due to the lack of suitable physical agents to induce their synthesis, such as circularly polarized light with photon energies in the range of 6-12 eV. At the same time, the sources of such radiation in star formation regions are known, and were quite capable of causing their genesis. Other forms of chiral synthesis are much less efficient, on the order of many magnitudes.

Now let us list 5 steps that are obviously necessary for the emergence of the known form of life (on Earth).
1. Origin of molecules - (H_2 etc.).
2. Dust particles and their ice mantles (with sizes about 0.01-0.3 μ).
3. Molecules chemical complexisation.
4. Origin of prebiomolecules (separation from environment by membranes).
5. Chiralization - proteins of terrestrial living organisms are product of polymerisation of only left-handed amino-acids.

Let's discuss these steps separately.

1. Origin of molecules, beginning with chemistry of simple molecules, (H_2 etc.). Molecules are synthesized either in gaseous or in the solid form, and hydrogen efficiently form on the surface of dust particles Shaw

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(2022). In star formation regions (SFR) of Molecular Clouds behind the photodissotiation regions (PDR) H_2 may originate on dust grain surfaces (that is not in gas-phase) with time-scale

$$t(H_2) = 1.5 \cdot 10^9/n \text{ yr}, \quad (1)$$

that is for SFR density of $n \geq 10^6$ cm^{-3}, $t(H_2) \leq 1500$ yr. Characteristic time-scale t(PD) for a H_2 photo-dissociation in the typical unshielded region of the ISM, for standard UV radiation measure and without other sources present would be in the range of 33-3300 years.

As is mentioned above 256 molecules are observed in the ISM till 2024. The most important are H_2, CO, CO_2, H_2O, NH_3, CH_4, H_2CO, HCN, CH_3OH etc. and their ions (up to $HC_{11}N$ and PAH, like $C_{24}H_{12}$, and even fullerens C_{60} and C_{70}).

2. Dust particles and their ice mantles.

Dust grains come now with supernovae (SN) ejections and asymptothic giant branch (AGB) star winds. Initial sizes of graphite grain (AGB) and silicate (SN) cores are about $0.01\,\mu$ and icy mantles grow up to sizes of about $0.1\,\mu$. Time-scale for dust growth in a dense cold medium of SFR is

$$t(\text{mantle}) = 3.0 \cdot 10^9/n \text{ yr}. \quad (2)$$

Rapid growth in the SFR with $n \geq 10^6$ cm^{-3} gives $t \sim 10^3$ years at $T \sim 10-20$ K.

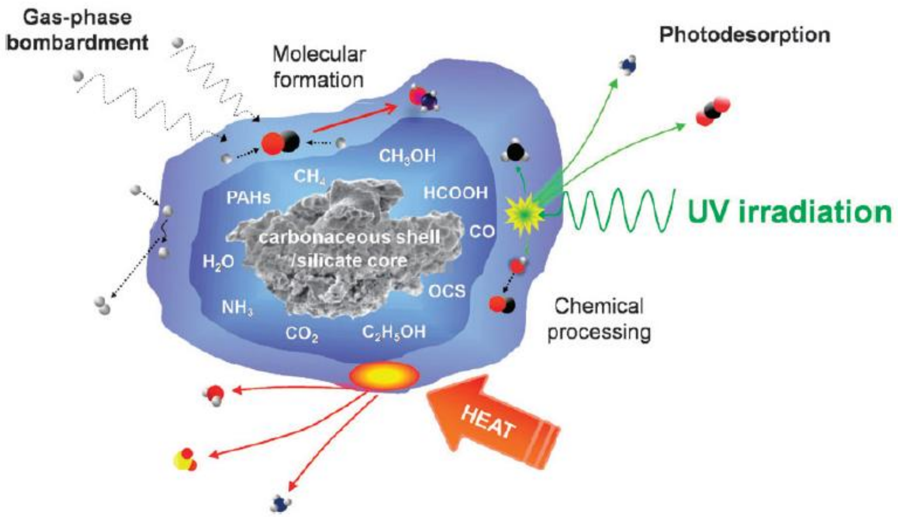

Figure 1: Graine surface chemistry is very important Shaw (2022).

3. Chemical complexification of molecules Molecules consisting on many atoms is possible to synthesize only in solid state, via what is known as radiation chemical polymerization in solid phase, which comes from laboratory experiments. And the successes of experimental physics of molecules under conditions close to the interstellar medium (which is known as laboratory astrophysics) over the past 20-30 years can be briefly summarized as follows Munoz Caro and Escribano (2018). Irradiation by Vacuum Ultraviolet with photons energy in the range 6-13.6 eV (VUV), and Cosmic Ray particles (1 MeV – 1 GeV (CR) induced solid-phase radiation chemical polymerization (polycondensation) from ices (H_2O, CO, CO_2, NH_3, CH_4, CH_3OH (the most abundant ices) and their mixtures. Resulting compounds are aminoacids, heavy hydrocarbons and other organics synthesized at low temperatures down to 5 K. Sources of corpuscular radiation chosen in experiments are protons, electrons and heavy nuclei (α particles etc.) predominantly of MeV energies beaming from various accelerators and sources (e.g. $60^{C}o$ gun). Sources of UV radiation are photons of 10-12 eV by the hydrogen lamp.

Here we mean radiation chemical polycondensation of methane (CH_4) because polycyclic aromatic hydrocarbons (PAH) and aliphatic hydrocarbons (alkanes, alkens, up to 29 carbon atoms in molecule), are synthesized in prebiotic simulation experiments. Radiation chemical yield of alkanes C_nH_{2n+2} (up to 29 C) received from experimental data Yeghikyan et al. (2001), amounts to G $\sim$ 1 synth.mol /100 eV and the fraction of new molecules would be $Q \sim G \cdot D$ where the dose $D_{exper.} \sim 6$ eV/molecule (0.3 eV/amu).

It should be noted that threshold doses in the Far UV experiments in the Ames RC, NASA, USA (Dworkin et al. (2004)) where an ice mixture (15 K) was irradiated (H_2O:CH_3OH:NH_3:CO - 100:50:1:1)

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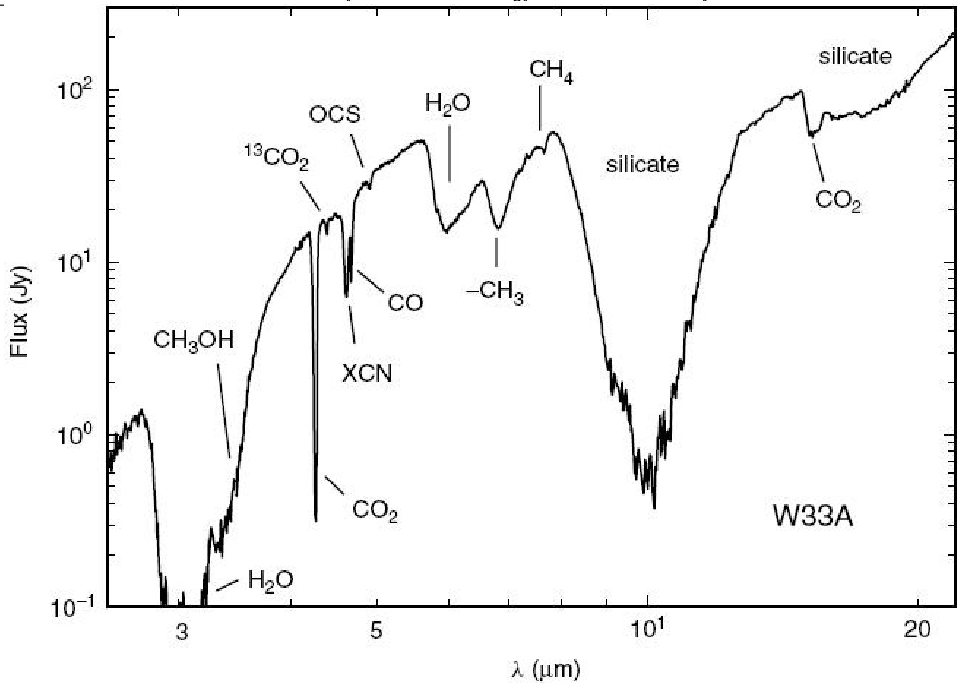

Figure 2: Ices are observed in all star-formation regions.

with photon fluxes $F \sim 3 \cdot 10^4$ photons/cm^2 s, then heavy hydrocarbons and HMT have been originating at doses of $D_{exper.} \sim 25$eV/molecule ~ 1.4 eV/a.m.u. Time-scales are quite appropriate, about Myrs in molecular clouds of SFR (depending on fluxes of radiation and duration of available processing, may be $\sim$ a few million years). Now a few words how to calculate UV photon and MeV particle doses (Yeghikyan (2017)). For UV irradiation

$$\mathrm{n(ice)} \cdot D_i = \int_{\nu_1}^{\nu_2} F_i \cdot \alpha_\nu \cdot d\nu \ \ \mathrm{eV/(cm^3 \cdot s)}. \tag{3}$$

Here α_ν is an ice absorption koefficient, which is related with cross-section σ_ν via $\alpha_\nu = n(ice) \cdot \sigma_\nu$, cm^{-1}, and $\alpha_\nu(\lambda = 4\pi m_{im}/\lambda$ with m_{im} as an imaginery part of a refraction index. For CR proton flux doses of absorbed energy between E_1 and E_2 would be

$$\mathrm{n(ice)} \cdot D_r = \int_{E_1}^{E_2} F_E \cdot S(E) \cdot dE/M(n) \ \ \mathrm{eV/(cm^3 \cdot s)}. \tag{4}$$

4. Origin of prebiomolecules (separation from environment by membranes). It should be highlighthed here that Deamer et al. (2002) suggested "membrane first" hypothesis to isolate potential protocell from the enviromnent which needs the lipid bilayer (lipids, pospholipids, et cetera) for aqeous medium to get units of terrestrial life as we know it. This is possible only on the exoplanets surface and chemically active droplets probably could serve as a model for protocells on the early Earth - Zwicker et al. (2017). In general form such idea were proposed by Oparin, 1924 and Haldane, 1955. McCarthy and Calvin (1967) put forwards demands to the potential membrane as polyisoprenoid compounds by their nature McCartly & Calvin (1967). Keheyan et al. (2004), Yeghikyan (2015) enlarged discussion to formulated general conditions for protolife origin.

5. Chiralisation as Homochirality is a key distinguisher of life. Chiral molecules should be important "precursor" to build compounds of first living organisms. Moreover the essense of the Genetic code is based on the Chiralization to accurately self-reproduce what is given. Chiral molecules older than the Earth itself have been spotted in meteors and comets. The most effective mechanism to get enantiomeric enhancement is enantiomerically selective photochemistry, induced by CPL - circularly polarized light of 6 – 13.6 eV - only out of the Earth **?**.

The fact is that the origin of life, as a subject of paleobiology, was studied on the basis of experiments of the Miller-Urey type, when amino acids were found in a mixture of methane, ammonia, hydrogen, carbon monoxide and water vapor under the influence of electrical discharges after some time on the order of a day (sometimes a week) , hydrocarbons, lipids, sugars, etc. were identified. But it should be recognized that these experiments were not adequate, because the amino acids were obtained in the form of a racemic

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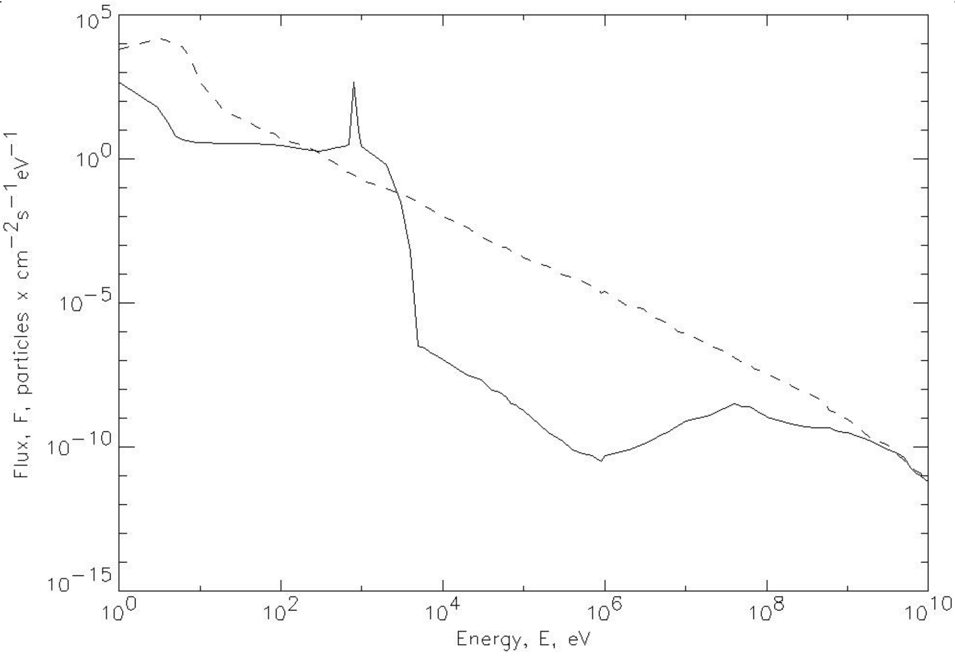

Figure 3: Fluxes of cosmic ray (and solar wind) protons in (solid) and out (dashed) of heliosphere.

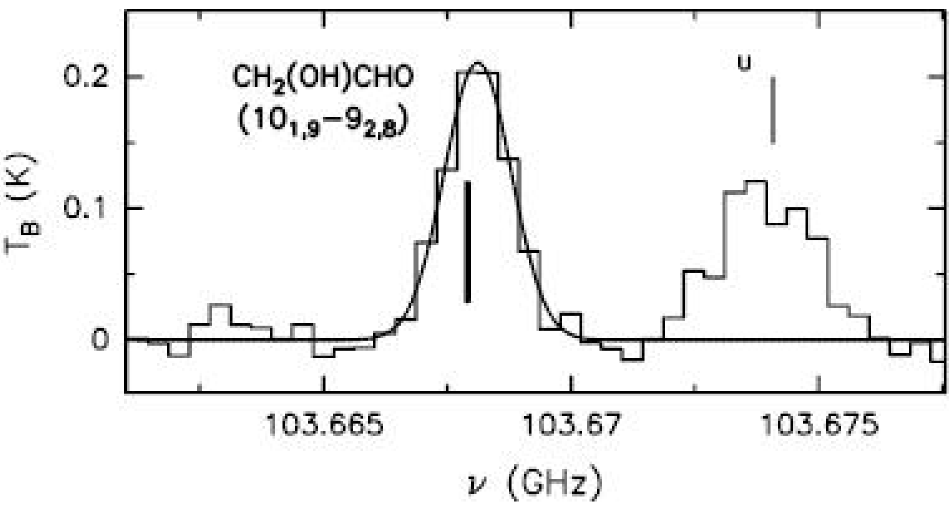

Figure 4: Glycolaldehyde in hot molecular core (HMC, Beltran et al., 2009).

mixture, without a predominance of any (left or right) form, which is important for self-reproduction (and genetic code). For asymmetric synthesis, a carrier of asymmetry is required, in this case photochemical polymerization reactions caused by circularly polarized light in the photon energy range 6-13.6 eV. Other processes that cause molecular symmetry breaking during synthesis are much less efficient (?). In any case, asymmetric synthesis was not possible on Earth; the degree of polarization from scattering of sunlight did not exceed several percent, with the required 20! There are not so many such places with the presence of both the necessary molecules and the radiation demanded; these are either star formation regions of a molecular cloud, next to which a supernova with necessary radiation exploded or disk around a newborn star. Details of transfer such a radiation are still under discussion.

It is also little known where in fact these molecules come from: natal cloud, disk around a star or they may be are synthesized on the exoplanet's surface ?

It turns out that approximately the first half of the age of the Universe, 13.8 billion years, was absolutely unsuitable for the existence of prebiomolecules, such as amino acids and hydrocarbons. They, of course, were synthesized and then destroyed, since the dose of hard radiation exceeded the carbonization threshold, that is, they decayed and simultaneously hydrogen was displaced from mentioned complex compounds, and this process is known as carbonization. Preliminary calculations show (formulae 3-4) that during first 5-7 billion years after the Big Bang the calculated dose in star forming regions was over 1000 eV/amu, which is over the carbonization dose, and only after that this decreased down to 50 eV/amu. Also properties of

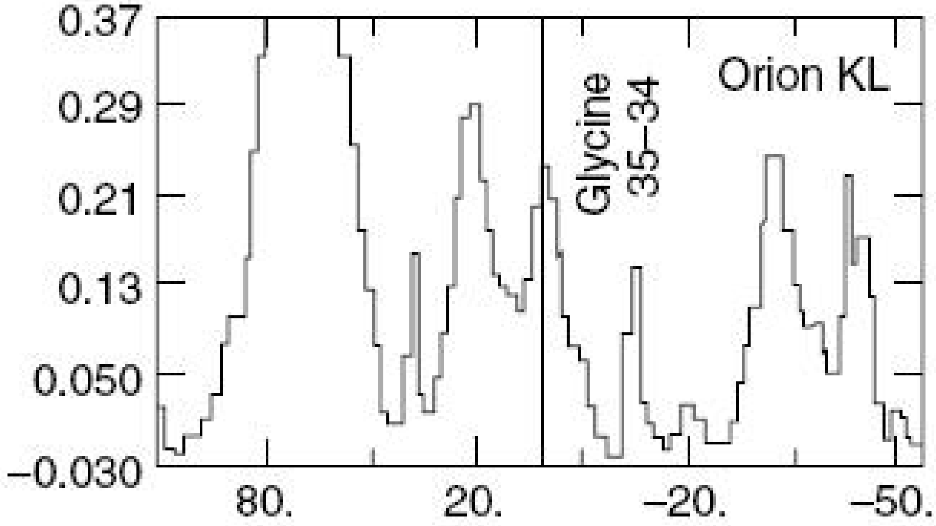

Figure 5: Glycine ($C_2H_5O_2N$, 206.468 MHz), (optically not active), Kuan et al. 2003

Compound class	Concentration (ppm)
Amino acids/CM meteorites	17–60
Amino acids/CI meteorites	~5[a]
Aliphatic hydrocarbons	>35
Aromatic hydrocarbons	3319[b]
Fullerenes	>100[c]
Carboxylic acids	>300
Hydrocarboxylic acids	15
Dicarboxylic acids and Hydroxydicarboxylic acids	14
Purines and Pyrimidines	1.3
Basic N-heterocycles	7
Amines	8
Amides linear	>70
Amides cyclic	>2[d]
Alcohols	11
Aldehydes and Ketones	27
Sulphonic acids	68
Phosphonic acids	2

Figure 6: Carbon containing species in meteorites – amino acids with enanthiomeric excess !

optical activity under irradiation and over-radiation has not been verified yet. So we came to the conclusion that terrestrial form of life based on aminoacids and hydrocarbons probably was the first.

3. Conclusion

1) The biological evolution of prebiomolecules on Earth was preceded by chemical evolution outside the Earth, in star formation regions, and probably in the disks of newborn stars..

2) Calculations show that 13.8-7 billion of years the dose $D > 1000$ eV/amu, which is greater than the laboratory threshold value and should have led to carbonization.

3) Only after that, 7-5 billion of years ago $D < 50$ eV/amu and species needed for the origin of life may exist.

4) Doses were calculated inside of star formation regions.

5) Amino-acids and hydrocarbons begin to exist permanently starting 5-7 billion years ago.

6) Terrestrial form of life was one of the first.

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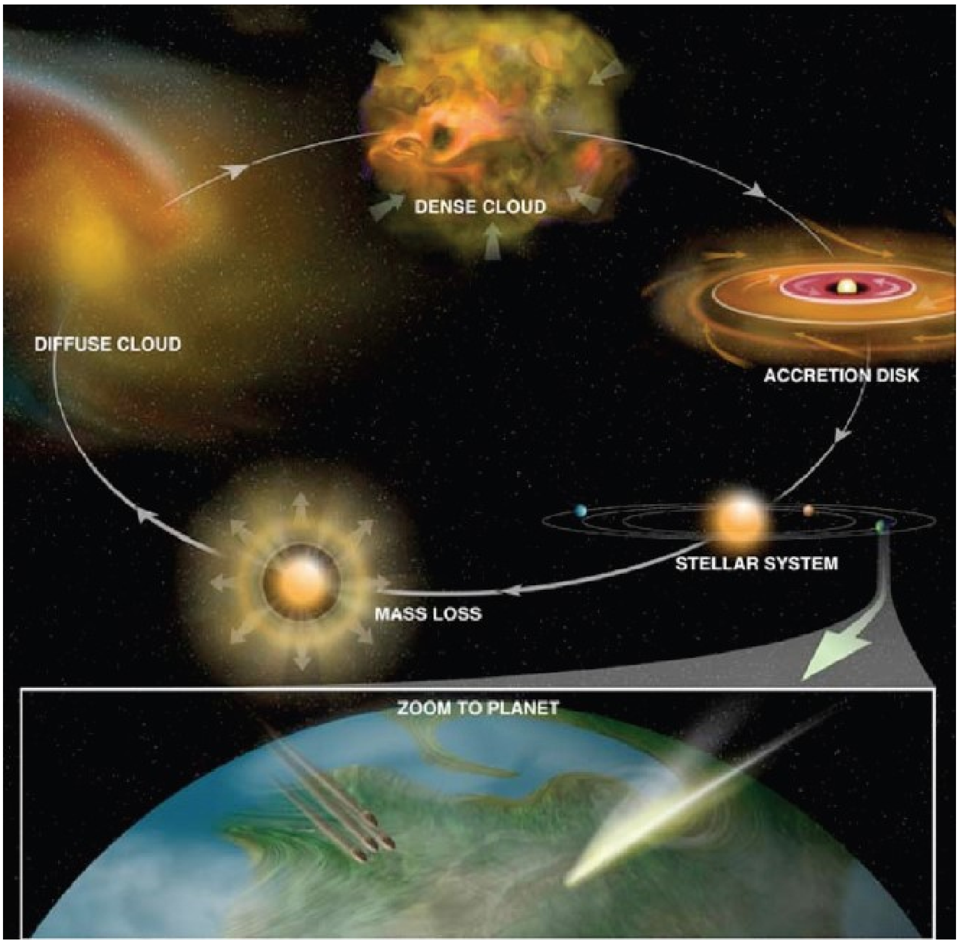
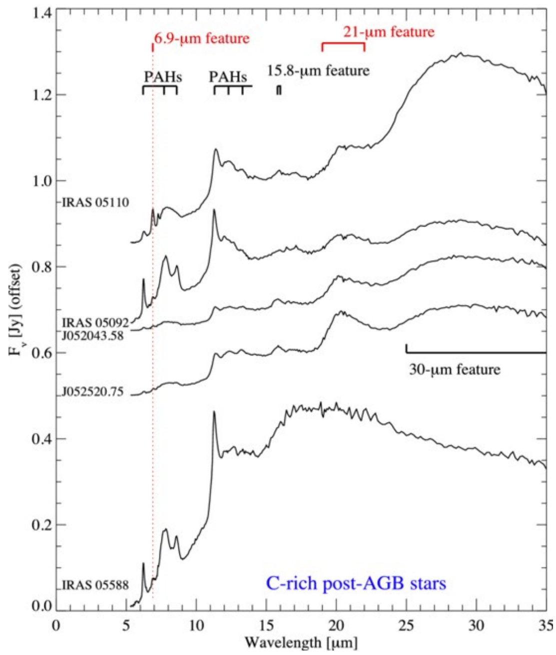


Figure 7: "Organics" recycling in the Galaxy – Kwok, 2010

(a) Cold stellar outflows.



(b) PAH in the post-AGB stars.

Figure 8: Post-AGB stars with spectra where PAH features are visible.

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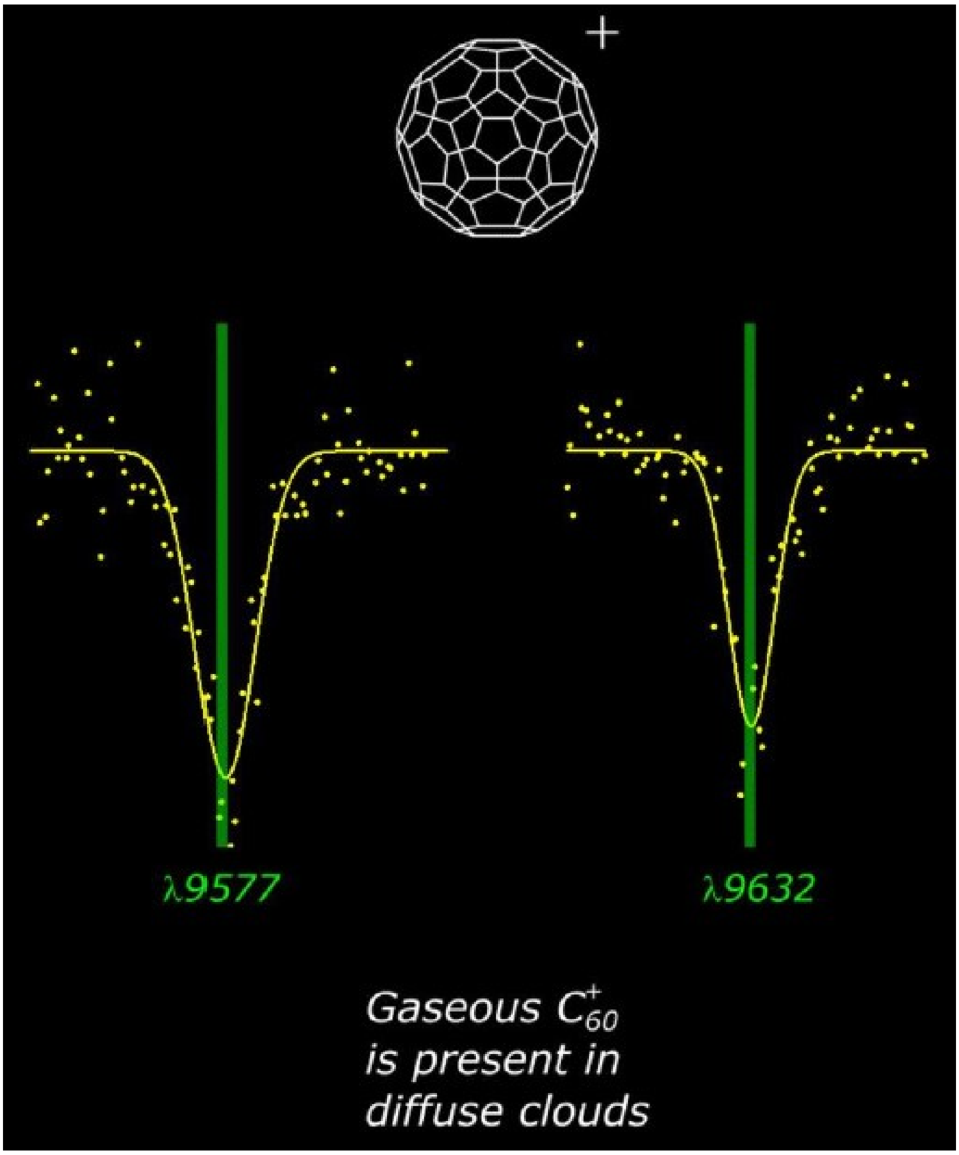

Figure 9: C_{60} in the ISM

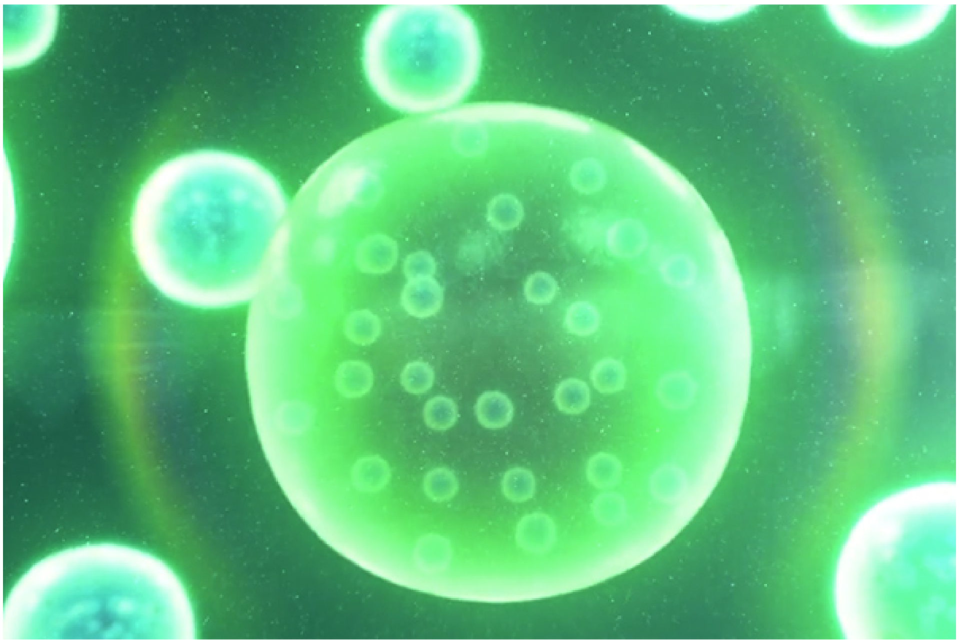

Figure 10: Cell formation - segregation from the environment

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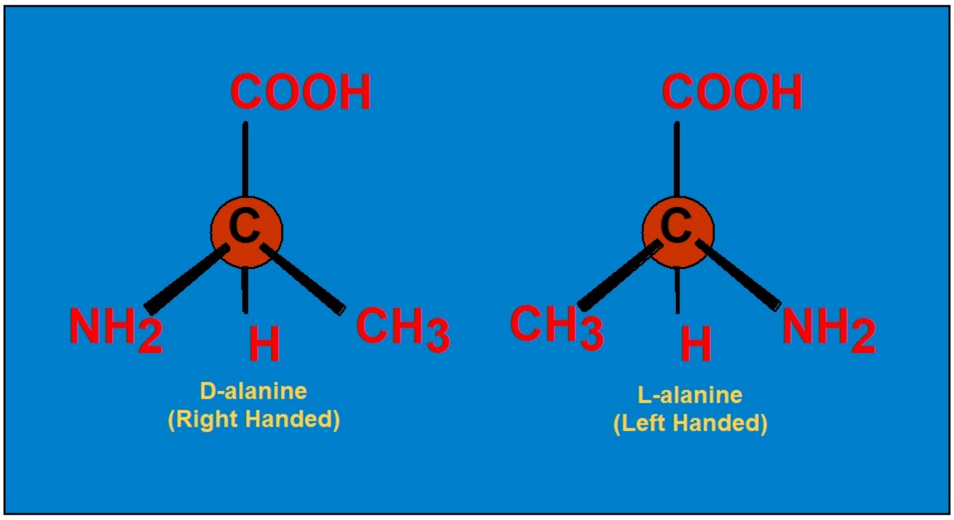

Figure 11: Terrestrial organisms use one enantiomer only

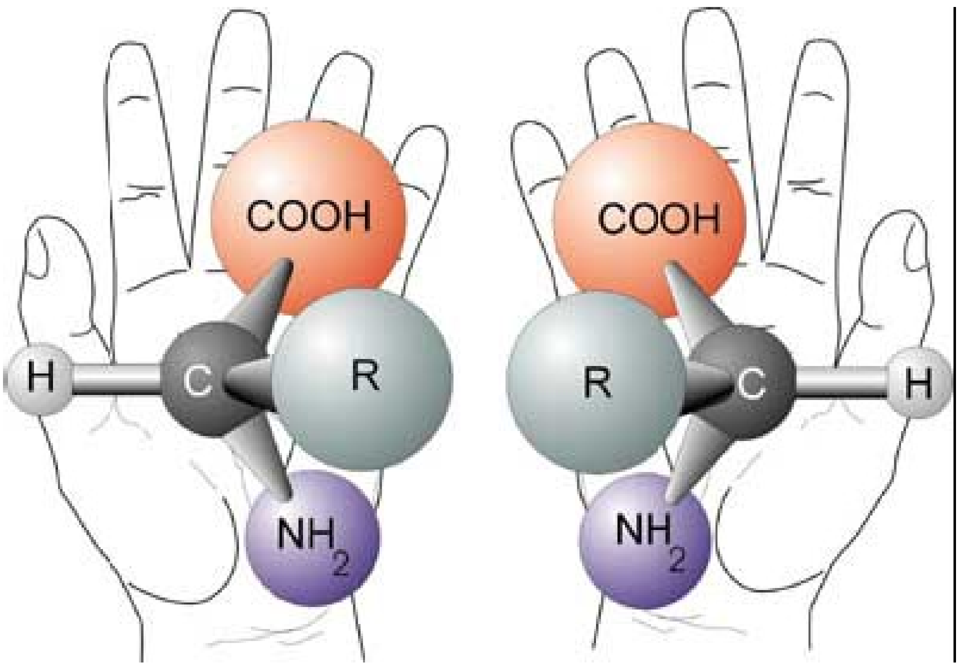

Figure 12: Protein synthesis, gene transcription, metabolism essentially depend on homochirality

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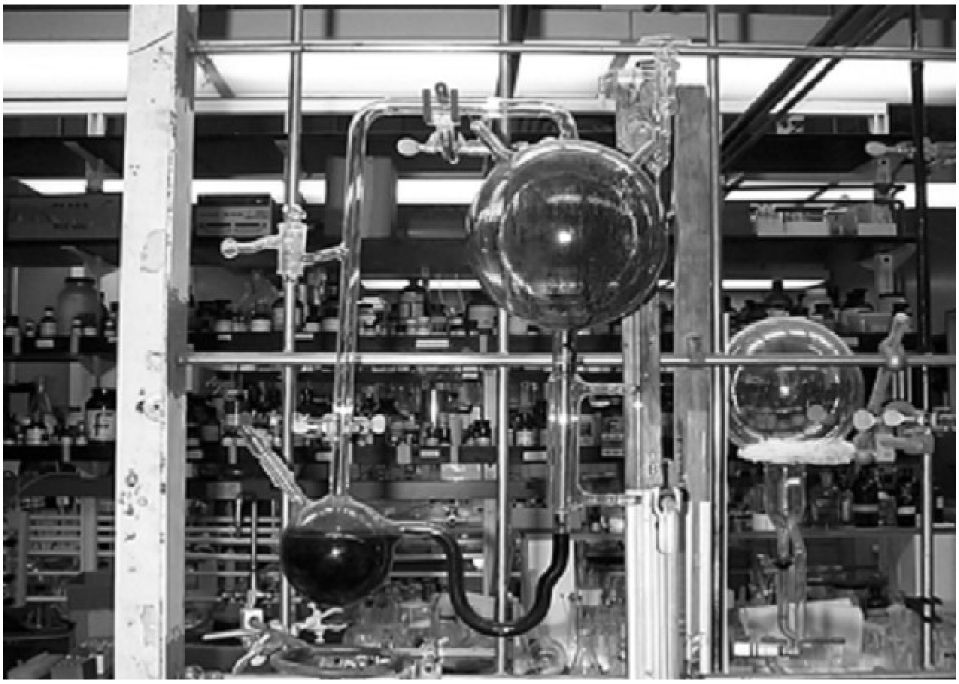

Figure 13: Produced aminoacids are racemic.

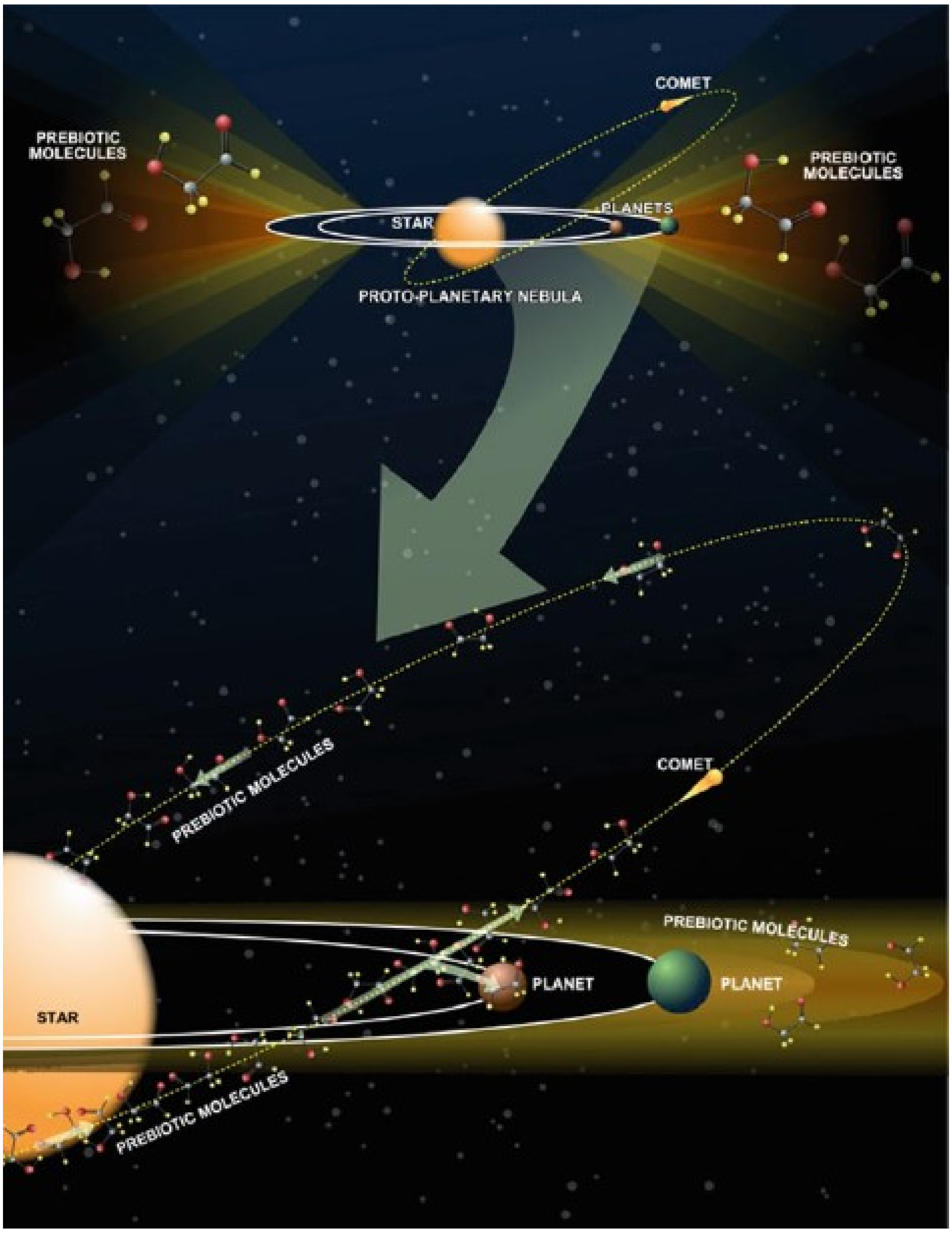

Figure 14: Where do Prebiotic molecules come from ?

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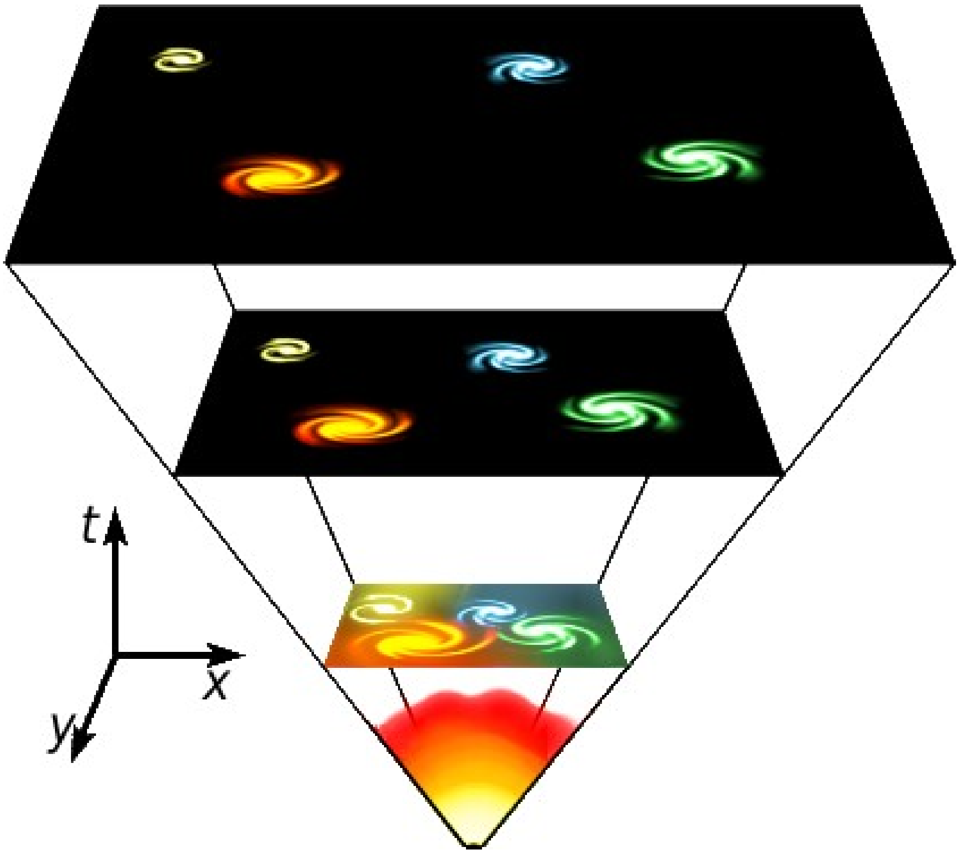

Figure 15: About Possibilities of Life in an Expanding Universe

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Effects of Geomagnetic Disturbances on Human Health and Cardiovascular Diseases

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Abstract

Geomagnetic disturbances (GMD) are significant perturbations in Earth's magnetosphere caused by solar wind interactions. This paper explores the impact of GMD on human health, particularly cardiovascular diseases (CVD). The proposed mechanisms include alterations in the autonomic nervous system, circadian rhythm disturbances, changes in blood viscosity, and psychiatric effects. Understanding these impacts can enhance medical protocols and patient care during geomagnetic storms.

Keywords: *Geomagnetic disturbances, cardiovascular diseases, solar (geomagnetic) storms, stroke, myocardial infarction*

Introduction

Geomagnetic disturbances (GMD) are major disruptions of the Earth's magnetosphere resulting from the efficient transfer of solar wind energy into the Earth's space environment. This typically occurs when a southward-directed solar wind magnetic field interacts with Earth's magnetosphere. GMD events can disrupt communication systems, damage satellites, create power grid failures, and affect human health. This paper aims to investigate the effects of GMD on human health, with a focus on cardiovascular diseases (CVD), and proposes mechanisms by which these effects may occur.

What is Geomagnetic Disturbance?

GMDs are primarily caused by solar flares and coronal mass ejections (CMEs), which release charged particles that interact with Earth's magnetic field. These interactions can induce strong electric currents in power lines and other electrical systems, leading to power outages and other disruptions. The types of GMDs of interest in this study include solar flares, CMEs, high-speed solar wind streams (HSSWS), and interplanetary magnetic field (IMF) disturbances, which have been known to affect human health by influencing physiological and psychological functions.

Formation of GMD

Geomagnetic disturbances form when solar wind, a stream of charged particles released from the sun's atmosphere, corona, interacts with Earth's magnetic field. When the solar wind's magnetic field is oriented southward, opposite to Earth's northward field, energy is efficiently transferred into Earth's magnetosphere, causing geomagnetic storms.

Types of GMD

The main types of geomagnetic disturbances include:

- **Solar Flares**: Sudden flashes of increased brightness on the sun, releasing vast amounts of energy and charged particles. These flares can cause radio blackouts and impact satellite operations.

- **Coronal Mass Ejections (CMEs)**: Large expulsions of plasma and magnetic field from the sun's corona that can travel through space and interact with Earth's magnetosphere. CMEs can induce geomagnetic storms and auroras.

- **High-Speed Solar Wind Streams (HSSWS)**: Fast-moving streams of solar wind that originate from coronal holes on the sun. These streams can compress Earth's magnetosphere and enhance geomagnetic activity.

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- **Interplanetary Magnetic Field (IMF) Disturbances**: Variations in the magnetic field carried by the solar wind as it flows through space. Changes in the IMF can influence the coupling between the solar wind and Earth's magnetosphere, leading to geomagnetic activity.

Known Effects of GMD

Disruption of Communication Systems

One of the most significant impacts of GMD is the disruption of communication systems. Solar flares can cause radio blackouts that last for hours or even days, particularly affecting emergency responders and coordination efforts. This disruption can lead to challenges in managing emergency situations, highlighting the need for robust and resilient communication infrastructures.

Damage to Electronic

Charged particles from solar flares can damage satellite electronics, affecting data collection and communication. This can lead to failures in GPS, weather forecasting, and other satellite-dependent systems. The damage to satellites not only impacts technological operations but can also have economic implications, necessitating the development of protective measures for satellite systems.

Power Grid Failures

GMD-induced electric currents can damage power grid infrastructure, leading to prolonged outages. These currents can induce strong electric fields in power lines, causing transformers and other electrical equipment to fail. Power grid failures during GMD events can have widespread effects, disrupting daily life and critical services, and emphasizing the need for resilient energy infrastructure.

Human Health Impacts

Research suggests that GMDs can influence blood pressure, heart rate, and overall cardiovascular health. Other potential effects include changes in mood and behavior. These disturbances can exacerbate existing health conditions and increase the risk of cardiovascular events. Understanding the pathways through which GMDs affect human health is crucial for developing preventive strategies and mitigating adverse outcomes.

Auroras

Despite their potential negative impacts, GMDs can also create beautiful auroras. These natural light displays occur when charged particles collide with atmospheric molecules, producing colorful lights visible near polar regions. Auroras serve as a reminder of the complex interactions between solar activity and Earth's magnetosphere.

Proposed Mechanisms of GMD Effects on Human Health

Autonomic Nervous System (ANS) Activity

GMDs can alter heart rate variability (HRV), an indicator of autonomic nervous system function. Changes in HRV are associated with cardiac arrhythmias, myocardial infarctions, and increased blood pressure.

Studies have demonstrated that GMDs can influence the ANS, leading to increased sympathetic activity and reduced parasympathetic activity, which may contribute to cardiovascular events (Alabdulgader et al., 2018).

Impact on Cardiac Arrhythmias

GMDs have been linked to an increased incidence of cardiac arrhythmias. The alterations in ANS activity can lead to imbalances in cardiac autonomic regulation, increasing the susceptibility to arrhythmias. Patients with pre-existing cardiovascular conditions may be particularly vulnerable during geomagnetic storms, highlighting the need for careful monitoring and management during these periods.

Myocardial Infarctions

The relationship between GMDs and myocardial infarctions has been a subject of interest. GMDs can trigger myocardial infarctions by increasing myocardial oxygen demand while simultaneously reducing coronary blood flow. The stress response induced by GMDs can exacerbate underlying coronary artery disease, leading to acute myocardial infarctions (Feigin et al., 2014).

Blood Viscosity Changes

Increased blood viscosity during GMD events can slow blood flow and enhance the risk of cardiovascular events. This phenomenon is potentially due to the aggregation of red blood cells influenced by electromagnetic properties, increasing the likelihood of thrombosis and other vascular issues. Higher blood viscosity can lead to reduced tissue perfusion and increased risk of clot formation, which are critical factors in the development of cardiovascular events (Baevsky et al., 1997).

Mechanism of Blood Viscosity Changes

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Geomagnetic disturbances can influence the electromagnetic properties of blood, leading to changes in blood viscosity. These changes can affect the rheological properties of blood, increasing the risk of thrombosis and cardiovascular events. Understanding these mechanisms is crucial for developing targeted interventions to mitigate the impact of GMDs on cardiovascular health.

Circadian Rhythm Disturbances

GMDs can disrupt circadian rhythms, which are physical, mental, and behavioral changes following a 24-hour cycle. Such disturbances may increase inflammation, fatigue, and worsen existing health conditions, especially in older and diseased individuals. This disruption can lead to periodic spikes in infectious and chronic diseases, highlighting the importance of maintaining circadian rhythm stability (Martel et al., 2023).

Impact on Cardiovascular Health

Circadian rhythm disturbances can exacerbate cardiovascular conditions by increasing inflammatory responses and altering metabolic processes. The synchronization of biological rhythms with environmental electromagnetic fields may represent an adaptive mechanism that becomes disrupted during geomagnetic storms, leading to adverse cardiovascular outcomes.

Psychiatric Effects

GMDs have been statistically linked to increased hospital admissions for depression and other psychiatric conditions. Potential mechanisms include phase shifts in melatonin synthesis and alterations in neurotransmitter activity. These effects may amplify negative emotional states and reduce the threshold for convulsive readiness (Kay, 1994).

Mechanisms of Psychiatric Effects

The influence of GMDs on psychiatric health may involve changes in cell membrane permeability, calcium channel activity, and retinal magneto-receptors. These biochemical mechanisms can affect neurotransmitter systems, leading to mood disturbances and increased risk of psychiatric conditions during geomagnetic storms.

Heart Rate Variability (HRV) Changes

Studies have shown that GMDs can significantly alter HRV, indicating a direct impact on cardiovascular function. Periods of low geomagnetic activity combined with higher cosmic ray activity have been associated with increased cerebral strokes and sudden cardiac deaths. An anticipatory reaction to GMD events, occurring days before a storm, may involve significant changes in blood pressure, HRV, heart rate, and physiological symptoms (Krylov, 2017).

Anticipatory Reactions

The anticipatory reactions to GMD events suggest a complex interaction between environmental electromagnetic fields and human physiology. These reactions may be due to reorganization of ionospheric currents and their influence on biological systems. Understanding these anticipatory responses is critical for developing preventive measures to protect cardiovascular health.

Case Studies and Data Collection

Current research involves using space weather archives to compare the intensity of GMD events with cardiovascular incidents, such as myocardial infarctions and strokes. Biomarkers like troponin and aPTT levels in cardiac patients, as well as arrhythmic episodes in healthy individuals, are monitored during and outside of GMD events. Comparative studies are essential to understand the correlation between GMD intensity and health outcomes.

Methodology

- **Data Collection**: Utilizing space weather archives and medical records to gather data on GMD intensity and cardiovascular incidents.
- **Biomarker Analysis**: Monitoring cardiac biomarkers (e.g., troponin, aPTT) in patients during GMD events.
- **Holter Monitoring**: Observing arrhythmic episodes in healthy individuals using Holter monitors during and outside of GMD events.

Analysis of Results

The analysis involves comparing the frequency and severity of cardiovascular incidents during periods of high geomagnetic activity versus periods of low activity. This approach helps identify potential triggers and mechanisms by which GMDs influence cardiovascular health.

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Implications and Future Research

Understanding the effects of GMD on human health can lead to improved medical protocols and preparedness during geomagnetic storms. Adjustments in patient medications, healthcare staffing, and emergency response can mitigate the adverse impacts of GMDs. Further multidisciplinary research is needed to explore the mechanisms linking GMD to various health outcomes and to validate these findings across larger populations.

Practical Applications

- **Medication Adjustment**: Protocols to adjust patient medications during storm days using forecast tools.
- **Healthcare Staffing**: Adjusting healthcare staff to correspond with increased demand during geomagnetic storms.
- **Emergency Preparedness**: Developing standby protocols to receive at-risk patients when a storm is expected.

Enhancing Patient Care

Implementing these practical applications can enhance patient care by anticipating and mitigating the effects of geomagnetic disturbances on cardiovascular health. Tailored interventions based on space weather forecasts can improve outcomes for patients with cardiovascular conditions.

Conclusion

GMDs represent a significant yet underexplored factor influencing human health, particularly cardiovascular diseases. Early identification and monitoring of GMD impacts can enhance medical responses and improve patient outcomes during geomagnetic storms. Continued research is essential to fully understand the mechanisms and develop effective strategies to protect public health.

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The Space and Time in Rock Art of Armenia

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Keywords: *Shrakatsi, Aragats, Ayrarat, calendar, constellation, dragon-stelae, Geghama mountains, Olcott, petroglyph, rock-carving, Tumanyan*

1. Introduction

Rock carvings of Armenia are of great cognitive importance as a historical and cultural primary source of the pre-literate era, which reflects the deep past in a pictorial way. These monuments, representing almost all the main and important spheres of our ancestors' life, have convay a peculiar picture of their mental activity and worldview.

Rock-art in Armenia arose in the Neolithic period, reaching its peak during the Bronze Age. It existed as a means of human cognition and communication, carrying out the functions of expressing, recording, accumulating, storage, transmitting information and feelings, thus ensuring the connnection of generations, the continuity of life experience, mentality and culture, preserving the wisdom and essence of the past. They are closely and harmoniously intertwined with the surrounding natural and historical environment, forming the cultural landscape.

The role of heavenly luminaries and phenomena, on which life and safety mainly depend, has been understood since ancient times. The connection between the heavenly and earthly phenomena was reflected in the mythological thinking, manifested iconographically in the products of almost all significant spheres of Armenian culture. Rock paintings stand out among them, as an ancient expression of human observation abilities and worldview.

The manifestations of ancient perceptions of space and time are abundant in rock-art of the Armenian mountains. They are expressed in compositions consisting of images of the Sun and the Moon, stars and stellar groups, atmospheric phenomena, the Earth and planets, comets and meteors, and geometric symbols. In this way were formed calendars, drawings and maps of the starry sky and surroundings, Earth's pole marks, time of day, eclipse, ideograms, etc. They were also objectified in observatory structures, stone alignments, later vividly expressed in the culture of the Urartian period (IX-VI ce. BC) and in medieval manuscripts. All that greatly predetermined the development of the Armenian scientific mind.

2. Distribution and themes of petroglyphs

Armenian rock art is distinguished by a huge number of images, stylistic diversity and rich content, and occupies a special place in the cultural heritage of the Ancient World. In the regions adjacent to the Armenian Highland, ancient petroglyphs are rare, while on the Highlands their high density of distribution, thematic and typological richness is observed (fig. 1). In the Highlands, petroglyphs are highly concentrated in and around Airarat Province: Kars, Horom, Gosh, Lchashen, Geghama mountains, Zovuni, Quchak, Aparan reservoir, Tghmut, Ashtarak, Oshakan, Voskehat, Agarak, Aragats, Mastara, Kaqavajor, Shamiram, Geghamavan, Metsamor, Armavir, Artin mountain, Dashtadem and Gomshut (in Kaghzvan) (figs. 2-3).

In rich content of Armenian rock art, four main areas are distinguished: nature, everyday life, results of human creation and the inner world. I have organized their rich diversity into 31 thematic groups: terrain elements, the Earth, heavenly luminaries, celestial, atmospheric and terrestrial phenomena, plants,

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Figure 1.

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Figure 2.

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animals, agriculture, hunting, animal fighting, battles, sports, competitions, dance, weapons, instruments, transportation means, constructions, applied images, learning tools, play aids, garment, cult, mythical creatures, anatomy of creatures, portrait, uncertain image, ornament, symbols, letter-like signs.

3. SPACE: Earth

Large and prominent elements of the terrain are reflected in petroglyphs.
Since ancient times for orientation in space there have been used simple graphic and cognitive forms using symbols, which indicate the expression of space, the connection with the visible landscape. Rock painting, the result of pictorial reflection of the ancient thought system, was also a powerful means by which the habitants understood and expressed their place in environment, formed the sacred space.
The great armenian plilosopher Grigor Tatevatsi presented the connection between nature and the culture-creating activity of man. “They will beautify the land with various paintings and dexterity” (Grigor Tatevatsi, 156). There are many reflections of space and spatiality, which are manifestations of human cognitive thought, life experience and scientific knowledge (Tokhatyan 2021, 12-13, 19).

- Orientation land-marks, as a simple ”map”: natural and man-made static elements, mainly mountains, hills, ridges, sometimes rivers, lakes, ponds, rocks, caves, most often drawings indicating the location of a spring and a stream, trees, path, passage, road [figs. 4-5].

- Drawings of partial separation, demarcation, functional zoning and development of the territory:

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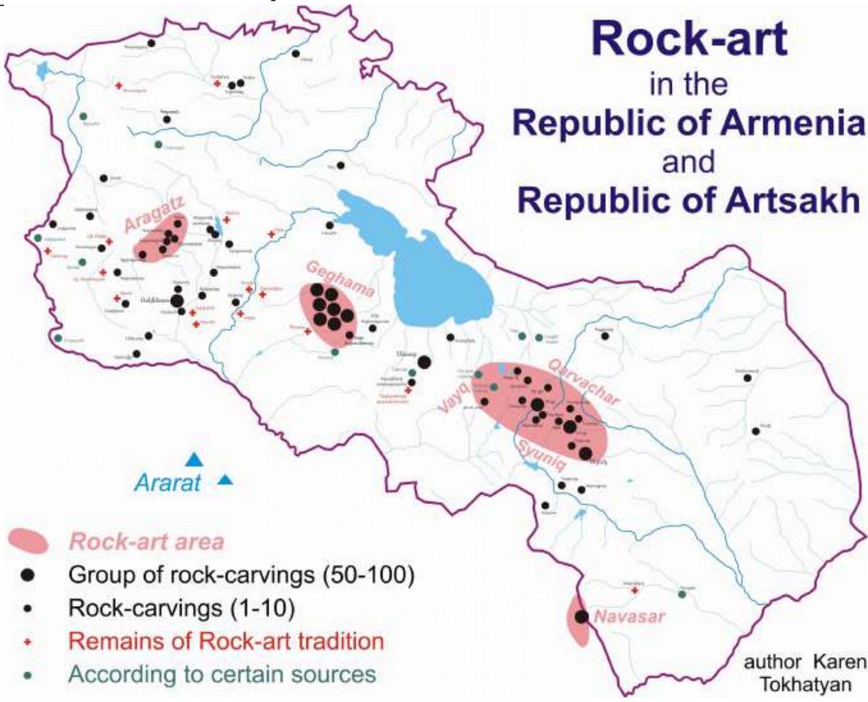

Figure 3.

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ambush, kites, hunting place [figs. 6-8], cultivated land, irrigation network, etc. [figs. 9-10].

- The need for orientation in space stimulated the direct marking of Earth's poles with a cross sign [fig. 11 (1-4)], also the positions of the sunrise and sunset points [fig. 11 (5-8)], celestial luminaries, star groups and constellations [fig. 12].

In one of the high valleys of Geghama mountains, a unique petroglyph shows three of the Armenian worshiped mountains rising in a row: Hatis (2528 m), Araler (2577 m) and Aragats (4090 m). The contours of the two-peaked Hatis and the broad cone-shaped Araler are especially prominent [fig. 13 (1)].

A petroglyph on Aragats (on 3150 m) depicts the three visible peaks of Aragats with acute angles on the right, and a radial wheel of the setting Sun on the left. This can be considered the earliest image of the eternity sign, which may have symbolized the rotation of the Sun [fig. 13 (2-4)]. Another petroglyph on Aragats (on 2850 m) reminds of a four-peaked mountain and two rivers sourcing from it: Gegharot, Anberd or Arqashen.
In the Astghaberd site of the Geghama Mountains, there is a petroglyph marking the place of the water source between the hills; another one is a map indicating the location of streams flowing into and out of the pond [fig. 51]. On the western slope of Kaputjugh, in the Navasar rock-art site, there is a sketch of three lakes near the summit and the tributaries connecting them [fig. 5 (2)].

Sacred space. Among the mythological creatures seen in the rock paintings, dominate dragons, both in solitary and in group scenes, in peaceful position, mostly long-bodied, bull-like, snake-like, tailed, one-headed, often multi-horned and multi-legged [fig. 14]. Related to them are the "Armenian brand" dragon stones found in sacred mountain areas, mainly near water sources [fig. 15]. These monuments are not only the result and bearers of fertility cult, but also indicators of sacred area having landmark function. In particular, it has been found out that at least two or three of the highest mountains can be seen from each of them. **Buildings.** These are mostly dwelling-like pictures (Tokhatyan 2021, 7-12, 17-18). The four-sided type predominates, with the entrance marked in the upper corner of the drawing [fig. 163-15]. This is comparable to the earthen house described by Xenophon (430-355 BC) in Karin (Upper Hayq Province). Some rectangular and round-shaped figures remind of a dwelling are similar to plans of Teghut, Shengavit settlements (V-IV mill. BC). They are also similar to the ones excavated in the last twenty years in Lernagog, Aratashen, Aknashen, Masis Blur (VII-VI mill. BC), the constructive compositions in Gegharot and Tsaghkahovit (IV mill. BC), the groups of III-II BC cup-marks in Agarak-1 site and the horizontal forms of a number of temples of Ancient Armenia [fig. 16 (23-27)].

Figure 4.

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Dual projection. This type of petroglyph is a form of spatial juxtaposition, when the three-dimensional reality is shown in the same petroglyph from different viewing angles, as if seen simultaneously from two or three points. With such duality, with an unnatural, seemingly "wrong" approach, the painter was able to harmoniously combine what he saw from different sides on the flat surface. He did not depict what he saw directly, but what he considered most understandable and appropriate for that subject and situation, its "universal, acceptable" nature. This way of presentation makes the reality more complete and dinamic, which is seen from the most essential, characteristic and recognizable aspects [fig. 17].

Perspective. Some petroglyphs are flat reflections of three-dimensional reality, viewed and pictured from one point. The purpose of perspective is to emphasize spatial depth, horizon, and also movement direction. It is implemented by direct or angular projecting from the point of view along contours converging in the distance. At first glance, such a picture may seem imperfect, even "wrong": uneven, torn legs, disproportional torso and horns [fig. 18]. In this way, the painter tried to emphasize the depth, which may mean that space has been perceived on an empirical level since ancient times. "In the group paintings, there are characteristic ways indicatimg that there is already a more definite idea of space and depth" (Sardaryan 1967, 115). Large-scale discoveries of rock paintings in the world prove that the perception and expression of perspective was present even in the Paleolithic age[1].

Panorama. In some multi-element large compositions, "seen" from a high or far point, without horizon,

[1]The oldest source on the rules of perspective is the treatise "Optika" by Euclid (325-270 BC), translated into Italian (La prospettiva di Euclide, Fiorenza, 1573). Perspective has been widely used since the 14th century, during the Renaissance.

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Figure 5.

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they used upper projection method [fig. 19]. The participants and the whole situation seem to be observed from above: people, animals and things are in different positions and directions, mixed or arranged in a circle, the horizon line, up and down are indistinct. In this way, they differ from ordinary, simple petroglyphs, in which the horizon of the plot, the carving, and therefore our view point is certain and the only one. The artist imagined himself as an observer or the main actor, in the center of the participants and events. Such a complex image had to be formed by the power of thought and fantasy. In order to fully and completely perceive, understand such a "multi-viewpoint" rock painting, we still go around today, perhaps involuntarily repeating it, reproducing an ancient hunting or another ritual, fulfilling a message from an ancestor. **Globe**. These are cross-in-circles, often isolated without an accompanying sign. In this way the Globe was usually pictured [fig. 20]. The idea of Earth sphericity described by Pythagoras (570-495 BC) and Aristotle (384-322 BC), was introduced to Armenia by Anania Shirakatsi, later developed by Grigor Tatevatsi, Hakob Ghrimetsi and others. At the southern foot of Paytasar volcano, in the Geghama Mountains, there is a unique petroglyph, which seems to be a direct image of the Earth and the people living on its four sides, a reflection of the ancient concept of sphericity [fig. 201]. It could also symbolize the "antipodes" living on opposite sides of the Earth. It was interpreted as a manifestation of the divine forces guarding the four gates of the world, the quadripartite division of the Earth. In a broader sense, it can be considered the Imago Mundi. With its four-sided and four-pointed design, it is also comparable to the swastika [fig. 21].

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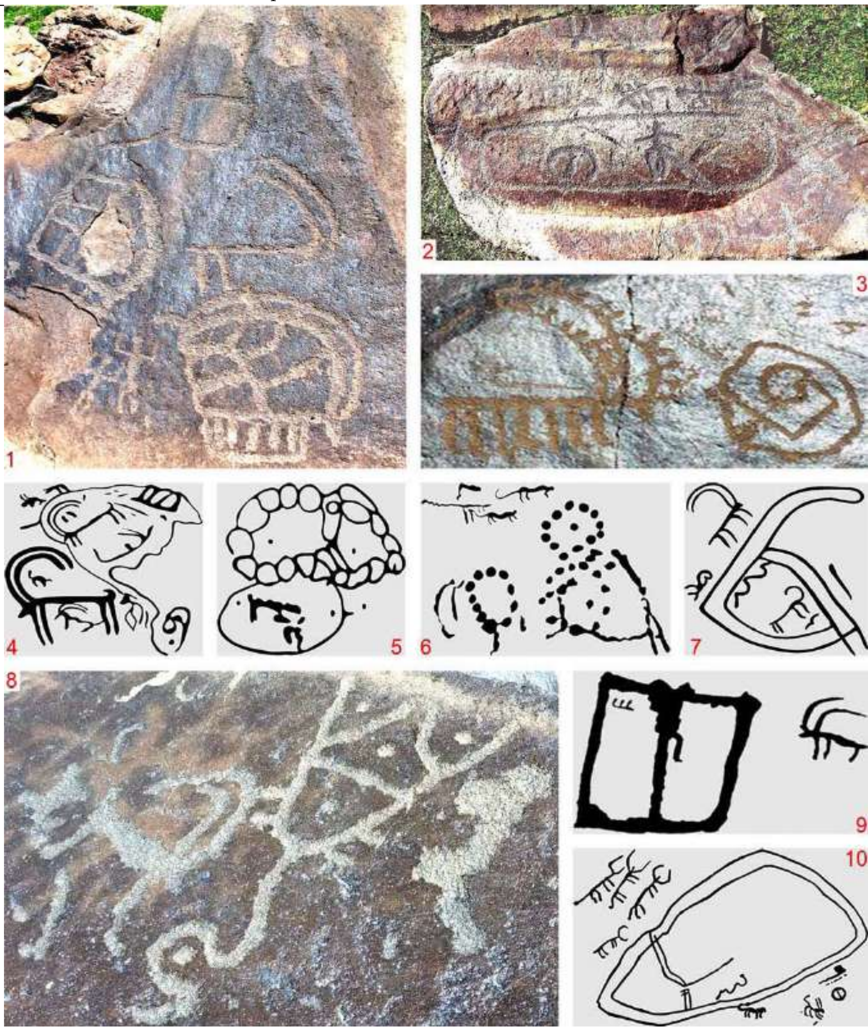

Figure 6.
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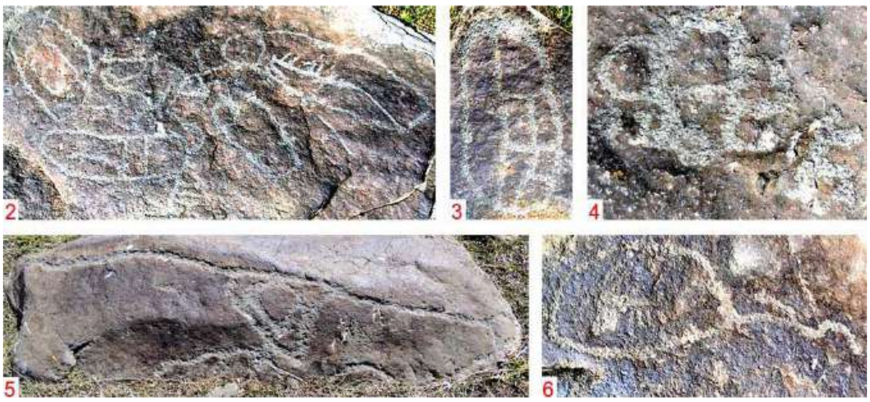

Figure 7.
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4. SPACE: Heaven

There are many reflections of visible objects in the sky in the rock-art of Armenia.

- Luminaries, celestial bodies, periodic and sudden, random phenomena (comet, eclipse, meteor) [figs. 22, 36 (3), 27].
- Maps of the sky showing the Milky Way [fig. 23], star groups [fig. 12], Zodiac and other constellations with a sign or image of their beings [fig. 24], cup marks or engraved rings [fig. 25].

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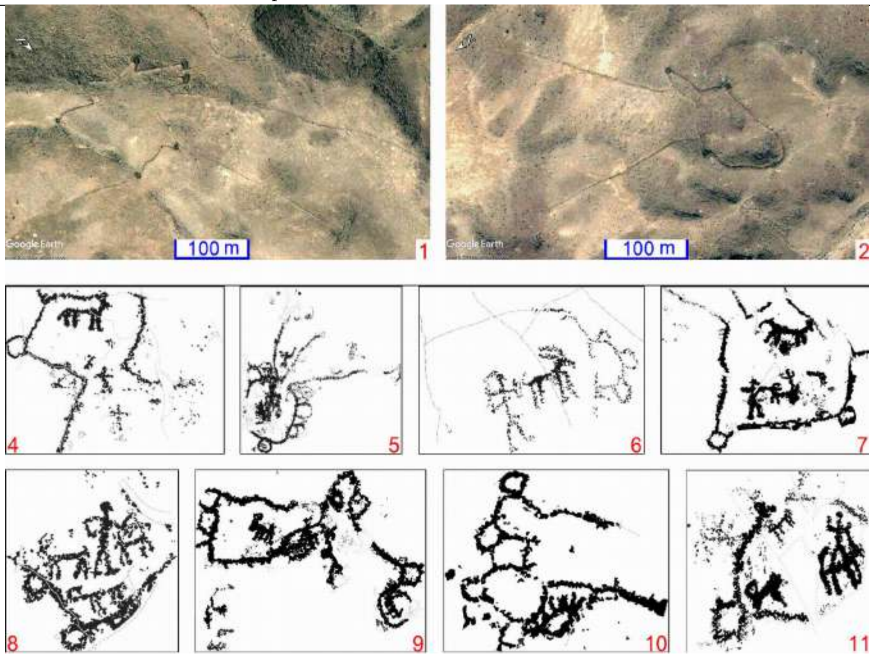

Figure 8.

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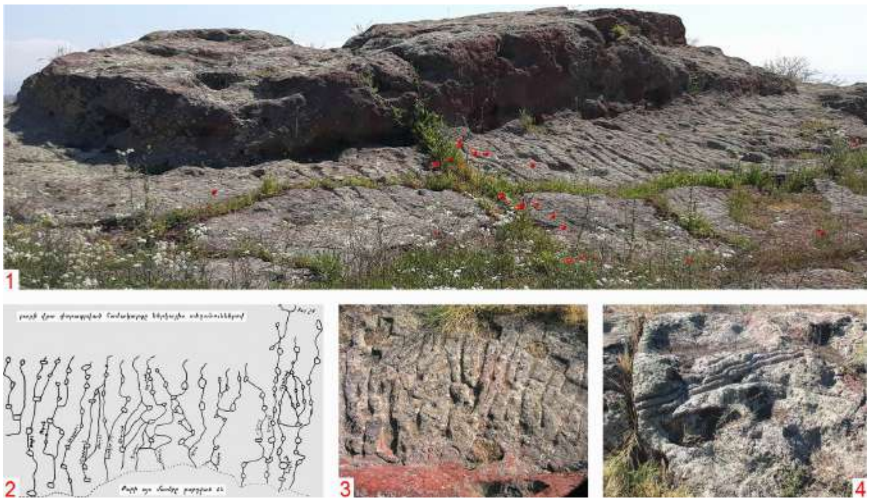

Figure 9.

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- Records of the position and appearance of luminaries and other celestial bodies [fig. 26].

For easier orientation in the dark sky, about 5000 years ago man formed from the bright stars sustainable and memorable images – constellations. Their description comes from the alexandrian poet Arattes, written upon Eudoxes' work (IV ce. BC). Arattes speaks about deep and unknown antiquity of the origins of constellations.
The tradition of dividing the sky into constellations began among native people of the Armenian Highlands–Armenians, who separated and named the Zodiac in the star field visible from the northern hemisphere.

In 1910, the historian of astronomy William Olcott, summing up tha assumptions of the archaeologist Edward Maunder, astronomers Carl Swartz, Camille Flammarion and Arthur Berry, came to the conclusion that the Zodiac constellations were formed and got their names on the latitudes of 36^0-42^0, in XXX-XXVIII ce. BC. He wrote: "Astronomy unites with history and archaeology in pointing to the Euphrates Valley, and, as we might expect, the region of Mt. Ararat, as the home of those who originated the ancient constellation figures... We have left Asia Minor and Armenia, a region bounded by the Black, Mediterranean, Caspian, and Aegean seas, as the logical birthplace of the stellar figures" (Olcott 1911, 7-8).

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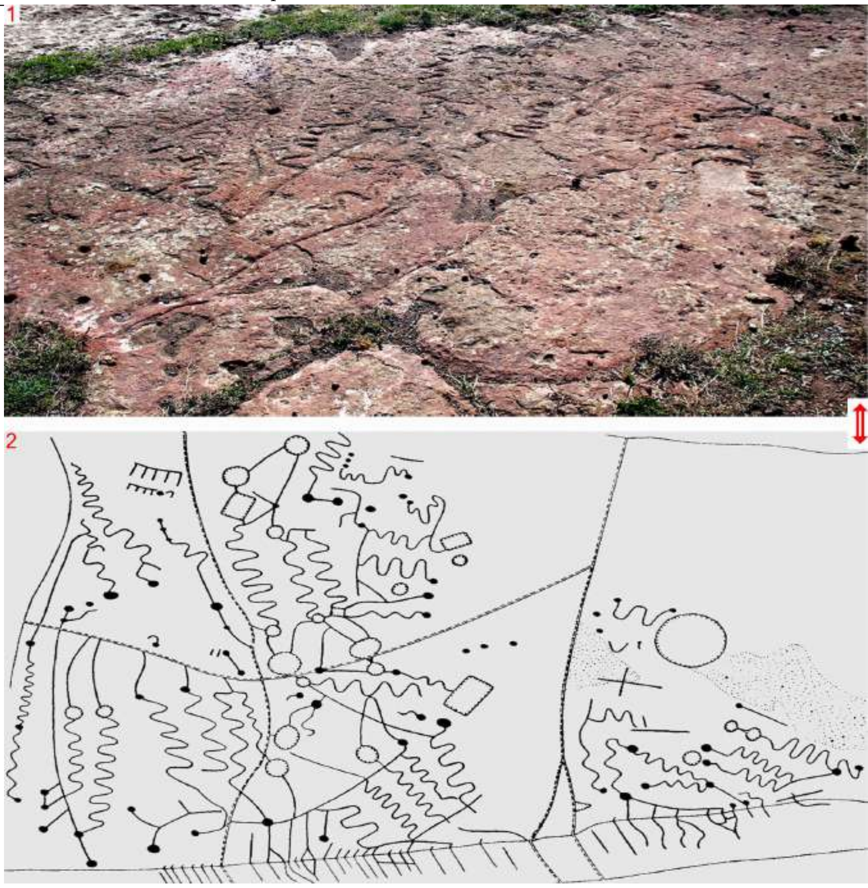

Figure 10.

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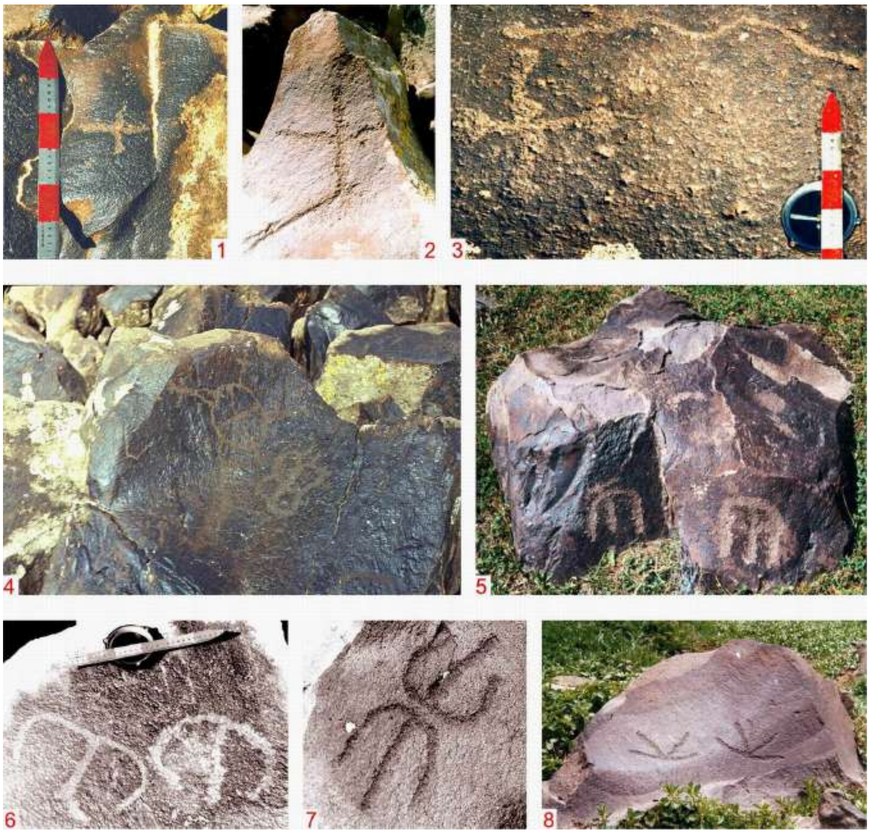

Figure 11.

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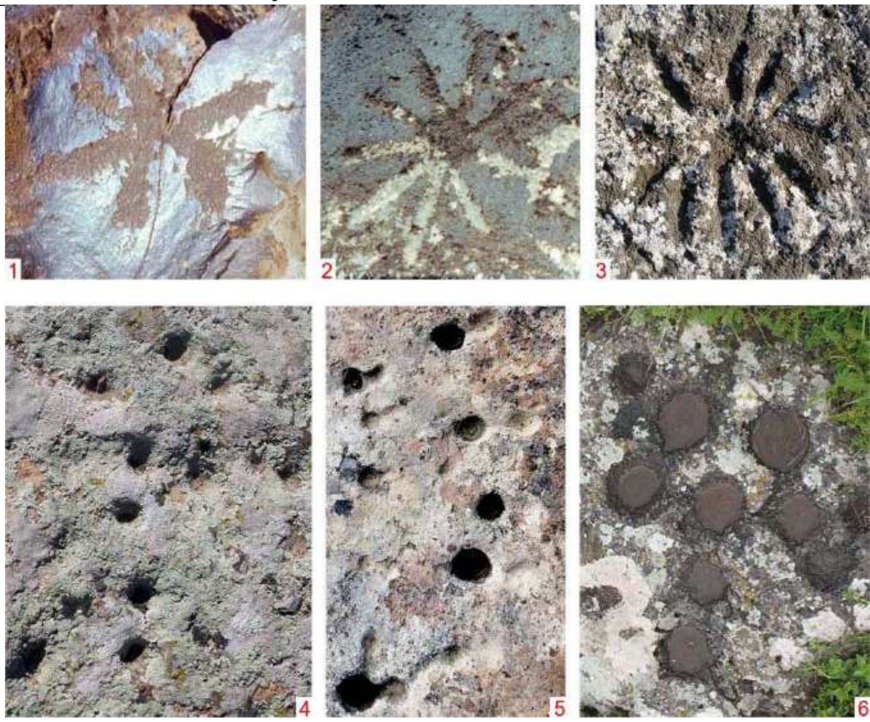

Figure 12.
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The scholars have made these conclusions theoretically, by examining astro-geographical (from which latitude and which period of the past were seen those constellations), zoo-geographical (areas of animals represented in the Zodiac) and general archaeological data. They did not know about the cosmological perceptions and their material realization in form of artifacts in Armenia: astronomical constructions, observatories, belt-calendars, shield-calendars, and especially the astronomical rock-drawings.

I found out that all-Armenian poet Hovhannes Tumanyan knew about this very important for world culture and history theory of W. Olcott, and in 1921, in his report[2] related it to Armenian thinking and thesaurus[3]. W. Olcott's theory conclusion was objectified and brilliantly proven decades later.

In the past 60 years, the following have been discovered and interpreted in terms of astronomical meaning:

- astronomical observation structures: Sevsar[4] (1967) [figs. 27-28], Metsamor (1967), Zoratsqar (1893/1984), Portablur (1995) [fig. 29],
- petroglyphs with astronomical meaning: stellar maps of the Vardenyats Pass[5] (1967) [figs. 25(2-3),

[2]The handwritten "Dictionary of the Armenian Epic" (Tumanyan archive, №64, p. 1-98) was published only 38 years later, in 1959. Probably not being aware of its publication, W. Olcott's theory was circulated four years, further by the astronomer Hayk Badalyan (Badalyan 1963, 63-74):

[3]Examining the connection of patriarch Hayk with Orion constellation, Hovh. Tumanyan has referred to astronomy. "To what extent were the inhabitants of ancient Armenia connected with the heavenly luminaries, did the worship and science of the stars develop among them, and did they have a love and inclination to the stars and stargazing or not? Fortunately, great astronomers and scientists give a positive answer to this question. The inhabitants of ancient Armenia, hunters, shepherds and herdsmen, always talked to the starry sky in their high celestial world, always under the open sky. And scientists have already confirmed that the ancient region which determined the constellations and gave names to the stars, was Asia Minor, and Armenia is especially mentioned in Asia Minor (Olcott, Legends of star world, p. 7). They said that the ancient names of the stars have got the names of the tools that were used in those countries, the names of the animals that were known in those countries, and the language that the ancient inhabitants of those countries spoke" (Tumanyan 1959, 372-373), see Tokhatyan 2019, 221-223.

[4]This unique and famous astronomical site was discovered by architect Suren Petrosyan. As interpreted by Armenian historian of astronomy prof. Benik Tumanyan, these are engraved images of large meteorite fall, the constellations Aquila, Gemini, Serpens, and the part of Milky Way. Nearby, on an area of 200x100 m, about two dozen carved boulders are scattered, which allow to suppose that it was a graet astronomical and cult center.

[5]This group was also found by S. Petrosyan, at the top of the pass (2410 m). It consists of 12 large stone slabs with engraved rings. Being on the ancient caravan route (later – a branch of the Silk Road), protected by number of cyclopean fortresses,

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Figure 13.

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30], calendars and constellation images in Sevsar [fig. 31(1, 7-8,] and Geghama Mountains[6] (1989) [fig. 31(2-6, 9)], star groups in Agarak-1 (1990) [fig. 12(4-5)] and Lchashen (2004) [fig. 12(6)] sites, the image of sunrise near Arpi village (2018),

- tens and hundreds of meters long single-line, two-line and three-line regular rock alignments near the villages Navur, Artsvaberd, Choratan, Ashotsk, Zuygaghbyur, Hartashen[7] [fig. 32] and Khnatsakh, single-line rock lines in Aragats, Syunik and Geghama mountains],

- rock circles: near the villages of Koghes[8] in Lori marz (1990) [fig. 33], Lezk[9] (1874/2006) [fig. 34] and

these carvings very likely had ritual and orientation significance. In 1969, B. Tumanyan identified those images with Zodiac constellations Leo, Sagittarius and Scorpio. The stars are represented by dots and circles, accordingly to their brightness.

[6]There is a couple of images on the slope of the Astghaberd (3139 m). In one, an archer shoots a bull, in another, instead of man is pictured man-like swastika [fig. 25(4-6)]. We must assume that the archer and swastika symbol were identical or equivalent. This is exactly how the constellations Orion and Taurus are located in the sky. The images looking towards the east where the constellations rise. This may be an iconographic evidence of the worship of patriarch Hayk and constellation Hayk. The eponym Hayk is deified and finds a place in the starry sky.

[7]Archaologie in Armenien, 2011, 73-113.

[8]Tonakanyan, Tokhatyan 1991, 31-34; Tokhatyan 2017, 62, 73, 77; Tokhatyan 2020, 132, 141, 146.

[9]To the 7 km north of Van, near the ancient village Lezq, at the foot of hill "Adamants Qarer", on an area of 400 m^2, are spread 2475 standing stones with about 1 m height. The distance between the stones is almost the same, located evenly along parallel lines. This "stone forest" may have an astronomical and calendar meaning. From nearby tombs was found IX-VII BC

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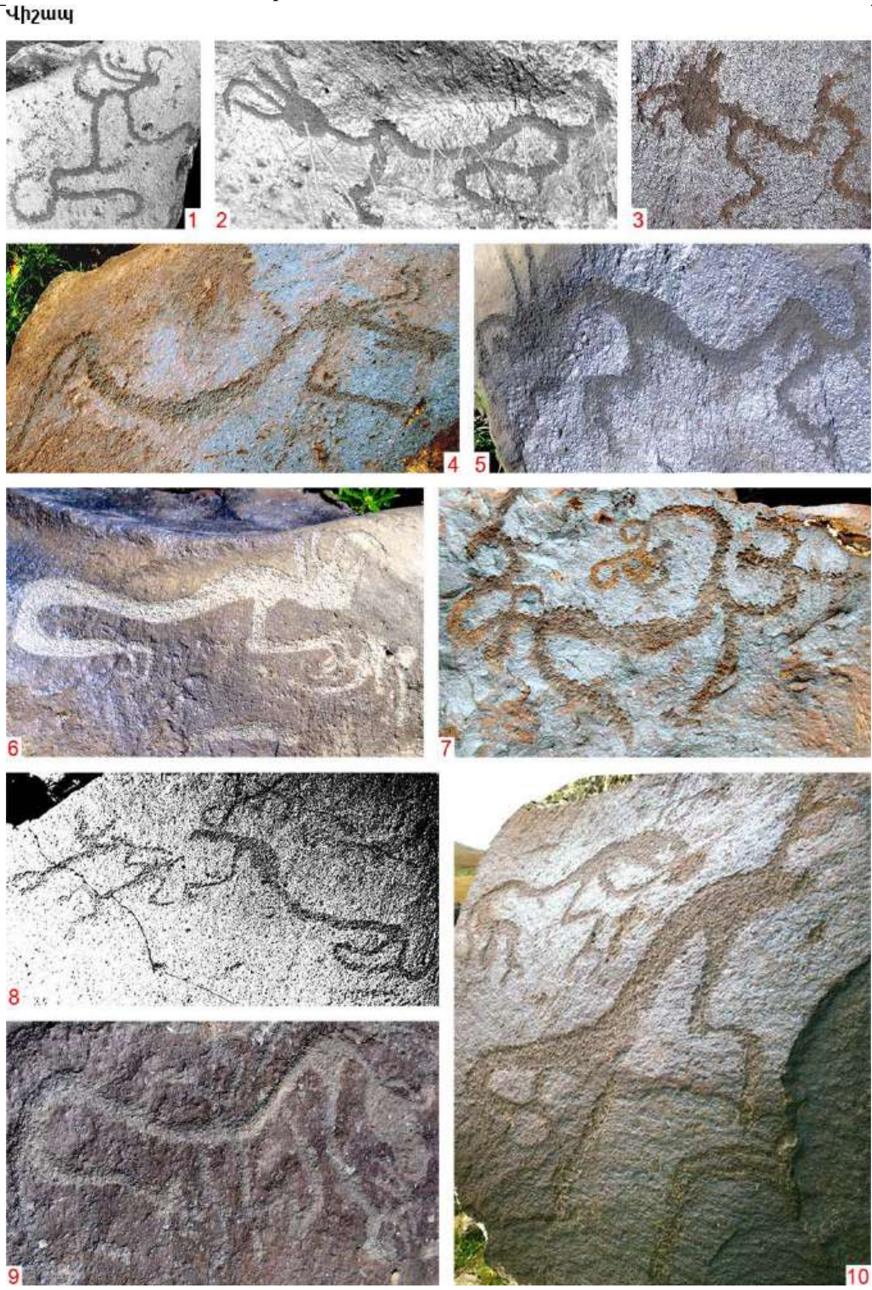

Figure 14.

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Datvan[10] (1864/2003) in Van Lake basin, "Sharvan stones"[11] (1974/2003) of Tandzut village in the Basen field, Maratuk's "Row of Stones" (1965/2023) in Sassoon and other[12].

- bronze belt-calendars from Sanahin (1946) and Metsamor (1970) sites [fig. 35(1-2)], bronze disc from Baralet village of Javakhk (1989) [fig. 35(9)],
- bronze decorative shields of Urartian kings (1955) [fig. 35(6)], many gold and bronze jewelry, bronze military items, seals, etc. [fig. 35(3-5, 7-8)].

The founder of Armenian natural science, Anania Shirakatsi, VII ce. philosopher, mathematician, astronomer, provides direct evidence of the connection between sky watching and rock engraving: "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 of all the other luminaries and stars, and could **carve** and **recognize** them" (Anania

ce. ceramics.

[10] To the southeast of Nemrut volcano, near the Datvan village there is a 330 m long group of vertical stones.

[11] To 5 km south from village, according to an eyewitness description (before the Genocide in 1915), there was a huge stone circle with diameter of about 60 m.

[12] About this and many other menhirs and stone alignments see Ghanalanyan 1969, 51-78.

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Figure 15.

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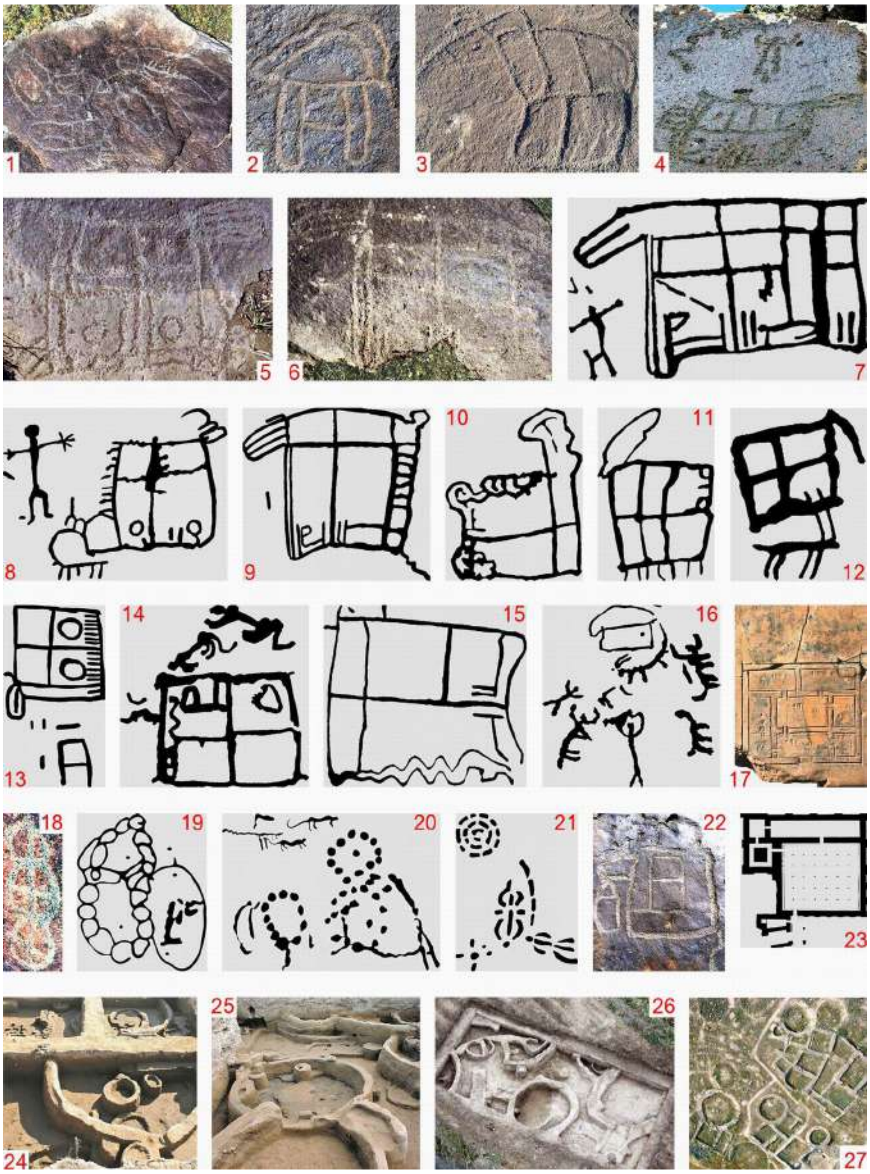

Figure 16.

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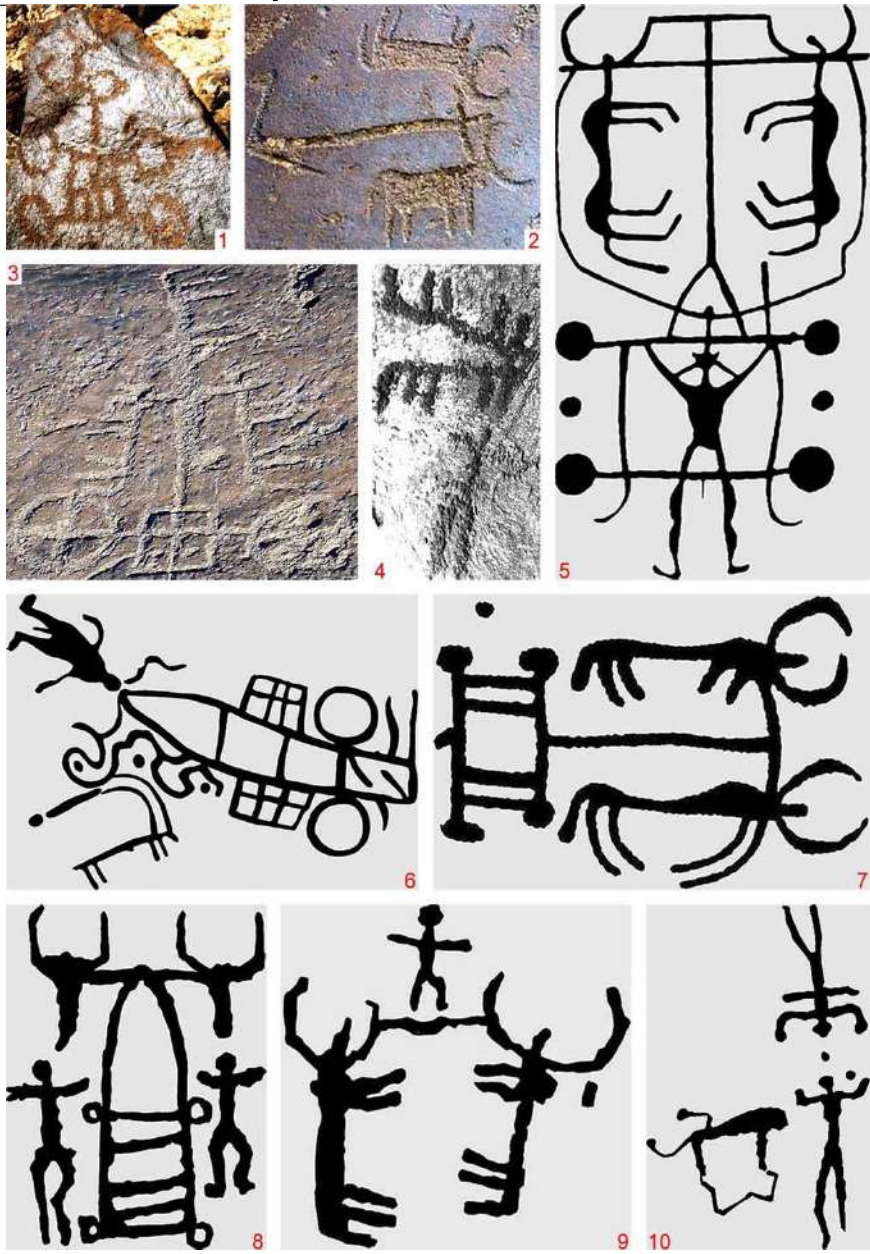

Figure 17.

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Shirakatsi 1940, 83-84). This directly applies to records of the position and appearance of luminaries and other celestial bodies. It is best seen in this unusual carving which represents a table of astronomical records [fig. 26].

This fragment is the world's earliest written evidence about the existence and antiquity of rock-drawings. 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). As mentioned above, astronomical processes are very slow, and man cannot notice and remember the considerable displacements of stars during his lifetime, therefore, periodical recordings were needed.

These are arguments in favor to the theory of the European astronomers-historians that the Zodiac was formed and named in the territory of Armenia, also testifying that it is one of the cradles of ancient astronomy.

A star map formed by the spatial arrangement of petroglyphs.

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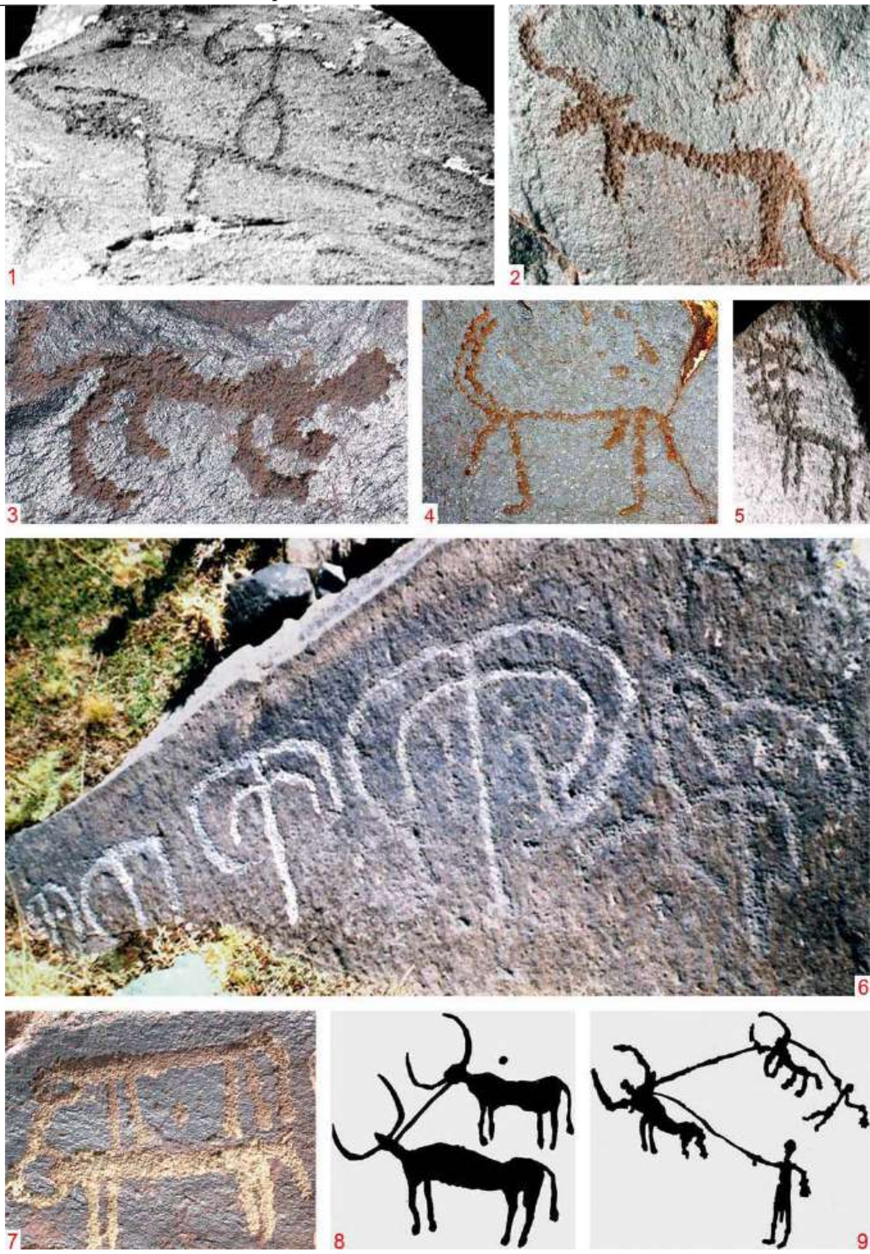

Figure 18.

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Some petroglyphs in compact groups remind a being (sometimes an object) that is the picture-basis of any star-group and constellation. The spatual arrangement of these carved stones can be similar to the mutual positions of star-groups and constellations in the sky. In other words, adjacent petroglyphs may mark some large domain of the sky.
This is very probable, because it is difficult to fit a group of several constellations even on a large surface (with signs, cup-marks, rings signifying stars or with animal figures). By carving on stones close together, the ancient astronomer could easily have a map of a large area of the sky.

5. TIME: calendar

The need for time orientation arose in the immemorial past. The ancient hunter, shepherd, and farmer became the first primitive explorers of the starry sky, weather changes, and other natural phenomena. Archaeological, cultural and natural science researches proves that the simplest astronomical-calendaric knowledge originated 20-30 thousand years ago. Since ancient times, observations of the starry sky have been made throughout the world to regulate economic and ritual life.
Parallel with the development of human observational and analytical abilities, a number of ways of perceiv-

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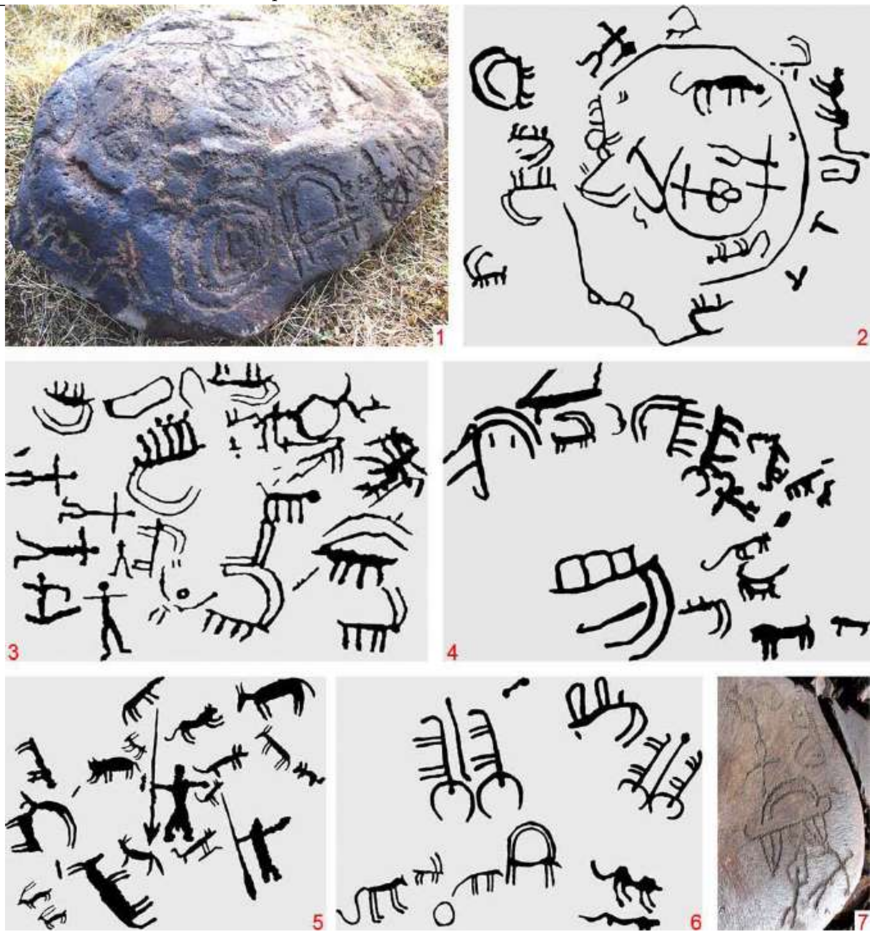

Figure 19.

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ing and measuring time periods have emerged, based on the temporal characteristics of vital, terrestrial, and celestial phenomena. In the VII-IV mill. BC, the first astronomically based calendars appeared, when people had already realized that some of the phenomena of earthly life are the result of the movement of the luminaries, the Sun, the Moon, and the planets. Hundreds of calendars have been formed in different countries and times, which are united by the definition of the term "calendar" - a system of counting long periods of time that has a specific order and starting point for counting days and larger units.

There are many reflections of the time perception in the petroglyphs. Astronomically based calendars are manifestations of human cognitive mind, life experience and scientific knowledge. In Armenia IV-III mill. BC, lunar and lunisolar calendars were used up to X ce. BC. Material evidence of this is a number of rock paintings with 14, 27 and 29 dashes, regularity of ornament of ceremonial ceramics (III mill. BC), patterns of belt-calendars and shields of Urartian kings [figs. 31, 35].

A few petroglyphs depicting action and living beings sometimes have a sun-like symbol at the top, left or right. It probably indicated the time of day: afternoon, morning or evening (depending on the position of the petroglyph in relation to the Sun). Some archeological and ethnographic artifacts also reflect a similar meaning [fig. 36]. Mythological evidences are the 7 worship pillars, the 7 viewing platforms for observing the Sun, the Moon and the 5 planets in Metsamor observatory, and the 14 gods in Hayasa (half moon).

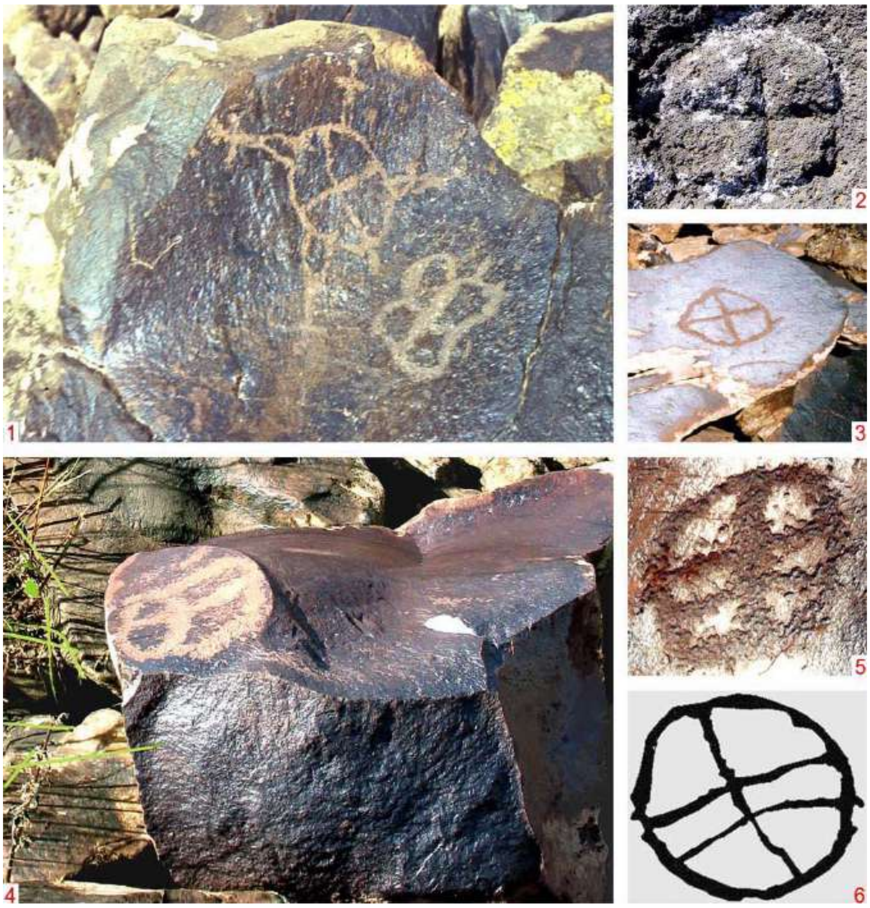

Figure 20.
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Figure 21.
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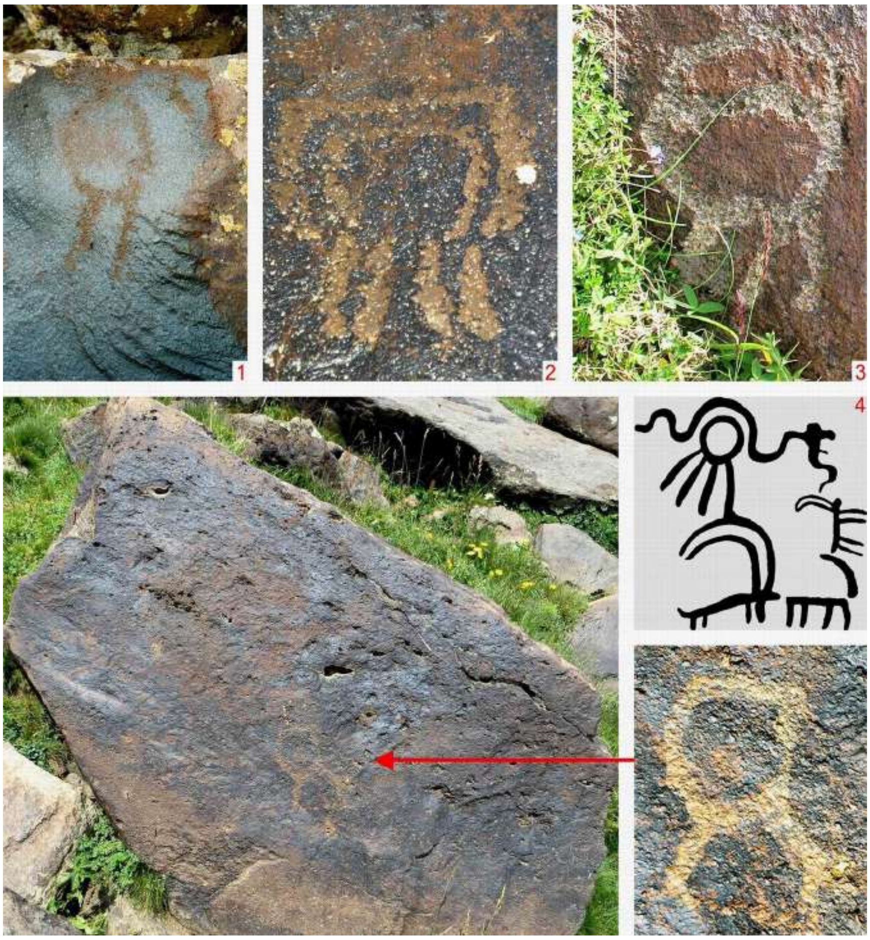

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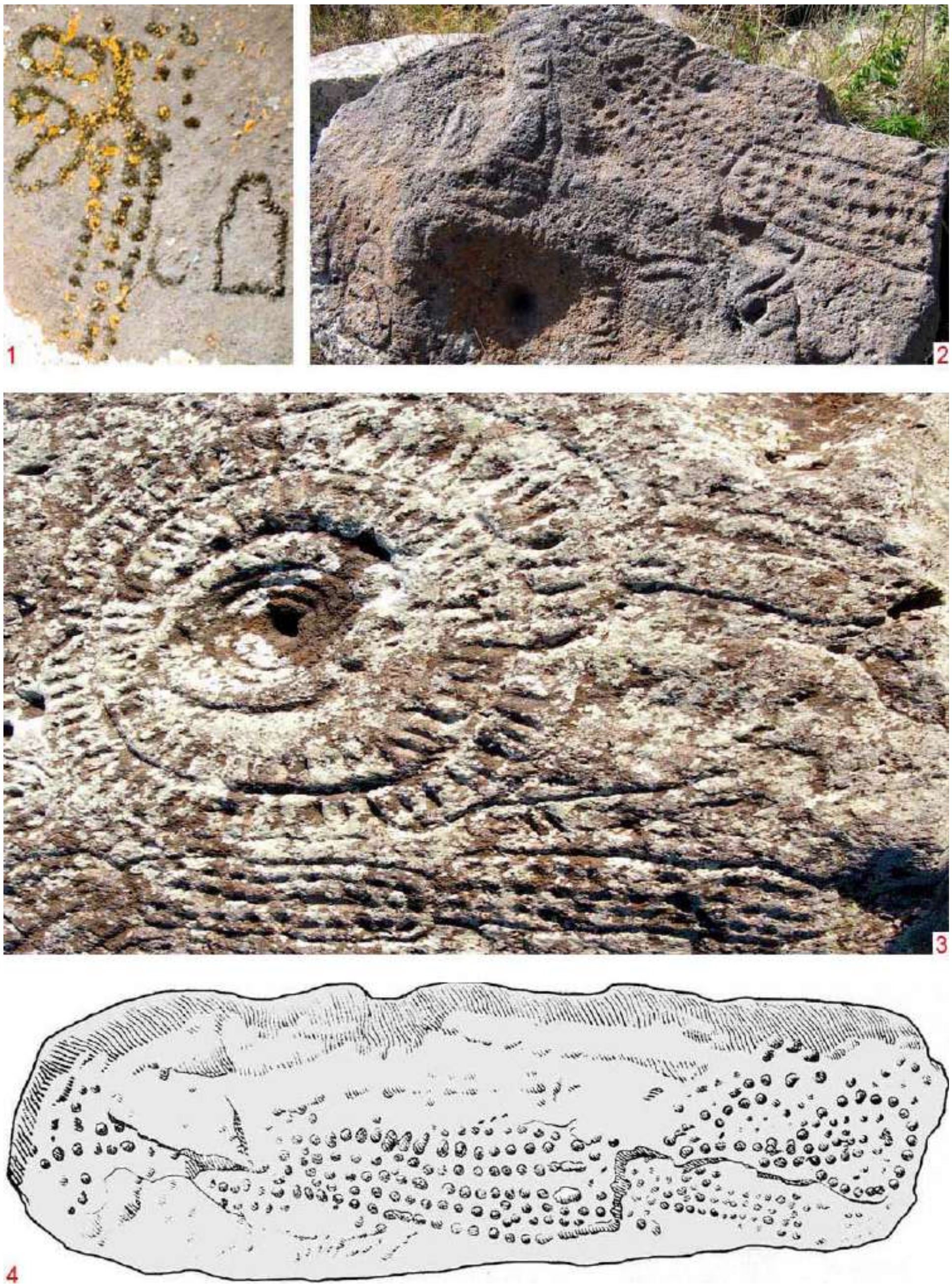

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Figure 24.

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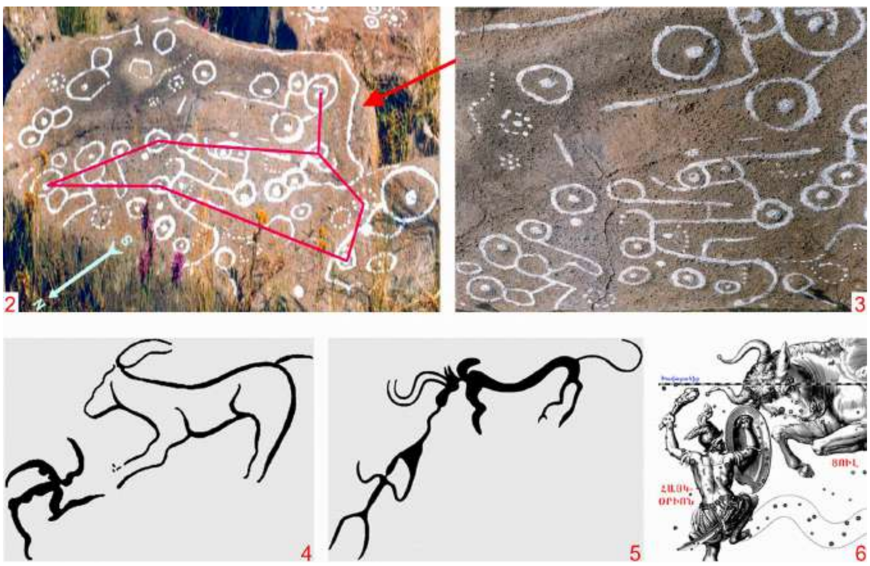

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Figure 26.

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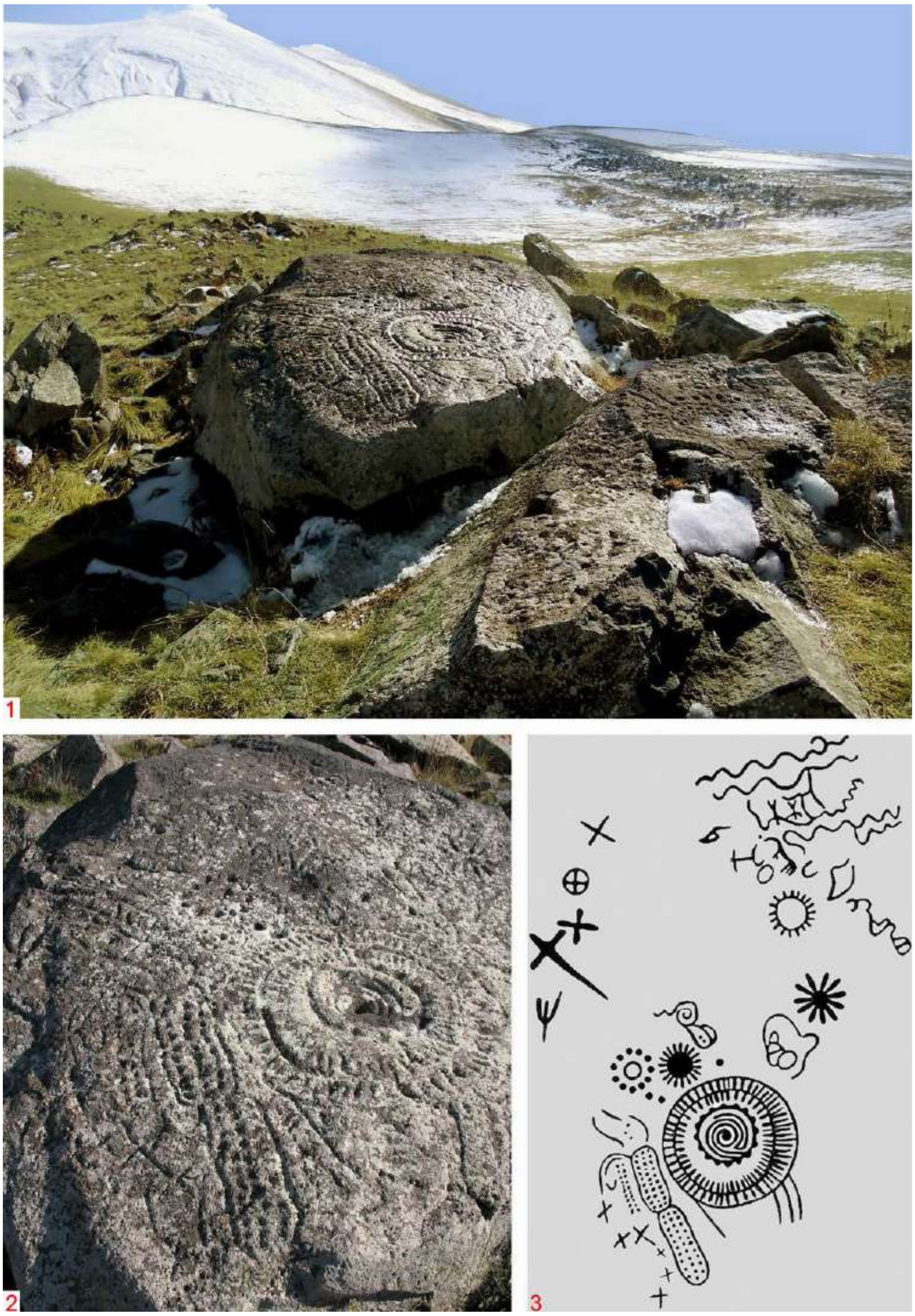

Figure 27.

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Figure 28.

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Figure 29.

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Figure 30.

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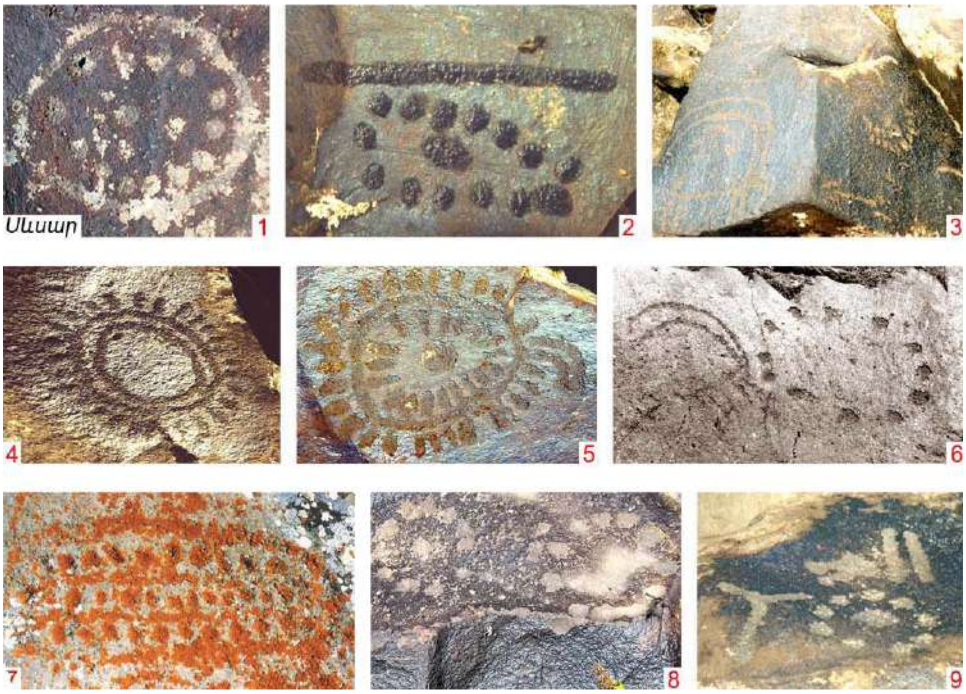

Figure 31.

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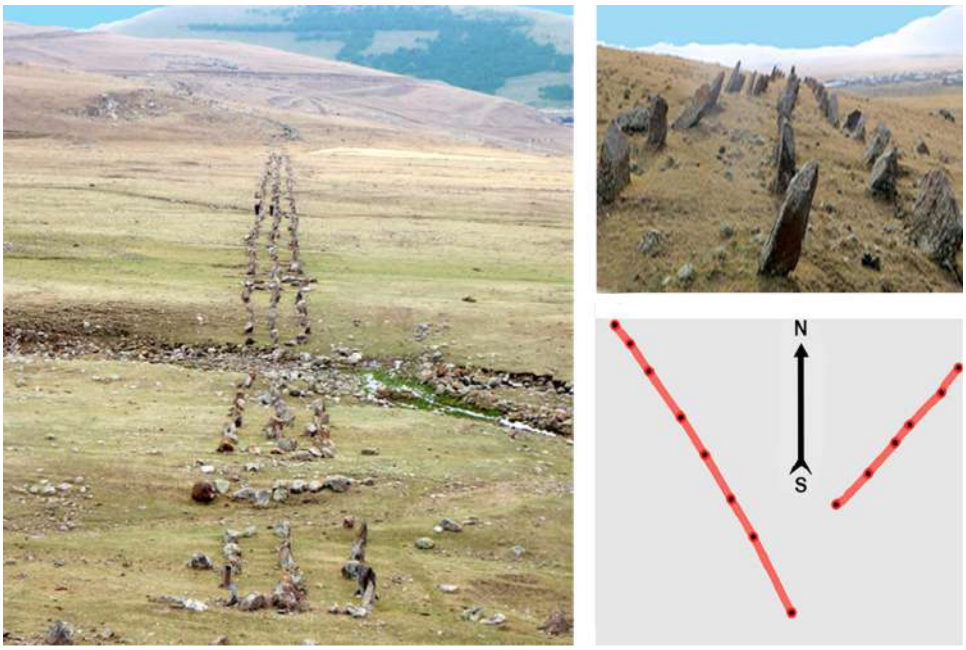

Figure 32.

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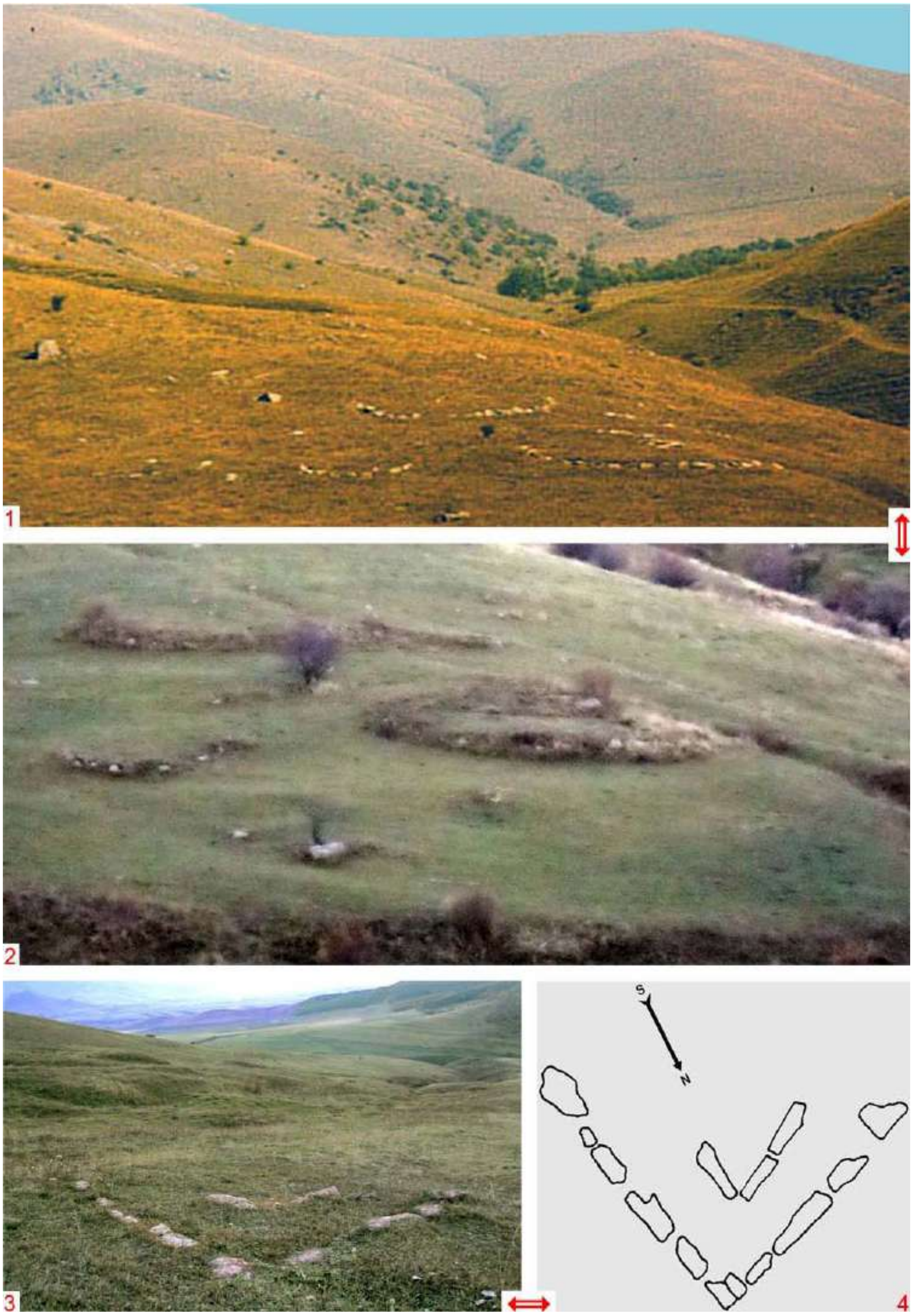

Figure 33.

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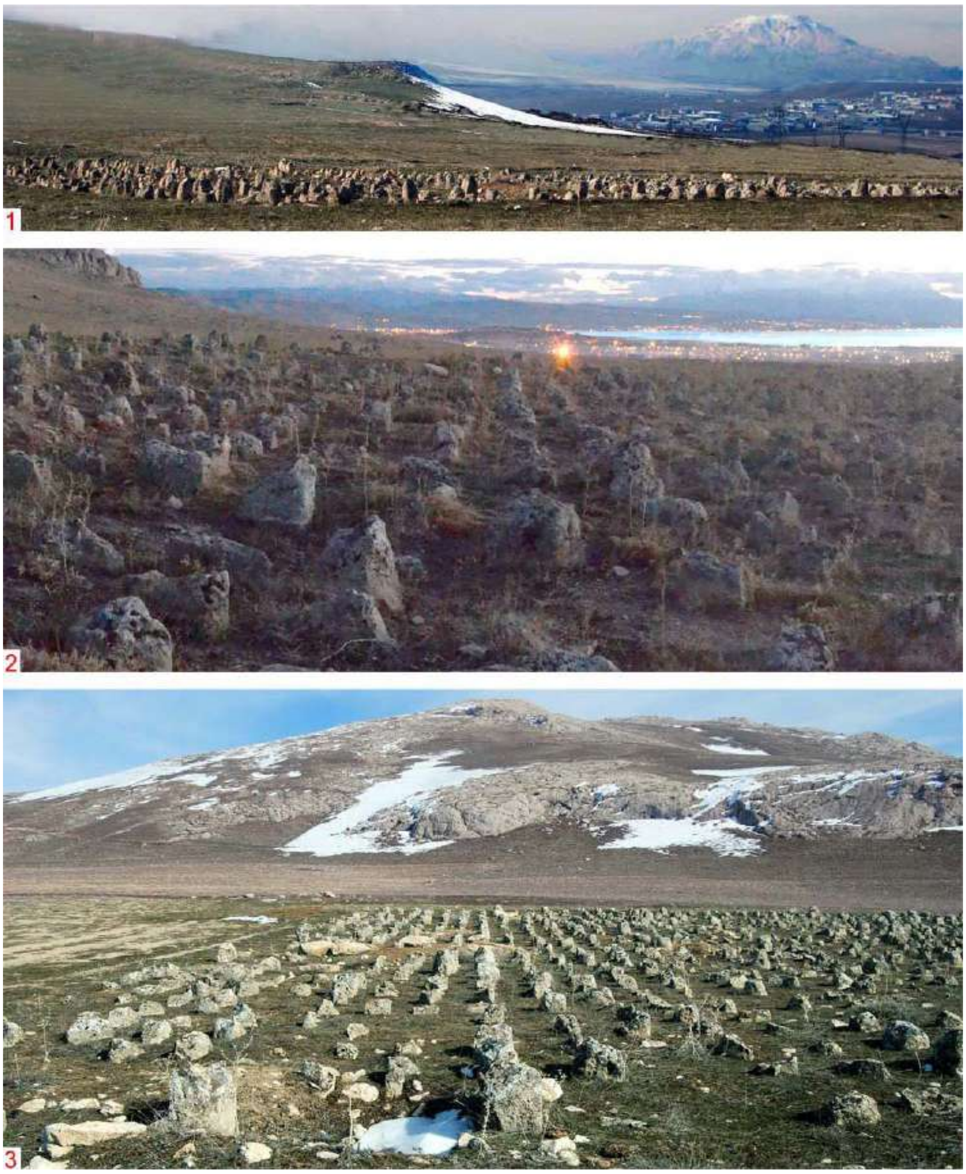

Figure 34.
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Figure 35.

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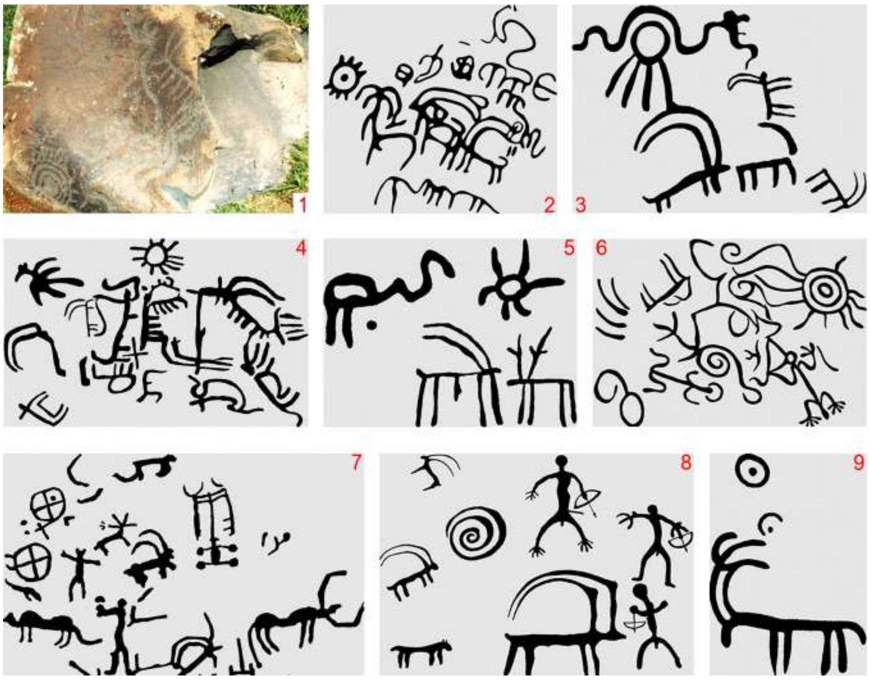

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6. Summary

Ancient perceptions of space and time are abundant in the main areas of Armenian culture: in thesaurus and folklore, in fine arts and architecture. Astronomical knowledge and perceptions have been expressed in various ways and in different spheres. Their ancient bearers are petroglyphs, stelae and observational structures, applied art and household items, weapons and jewelry.

All this was vividly expressed in the Urartian culture, in medieval manuscripts, and greatly predetermined the development of Armenian mythological and naturalistic mind. For thousands of years, the investigation of time and space, their correlation in the Cosmos and the Earth has created new scientific ideas in Armenian natural and historical sciences.

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Heaven and Earth in Ancient Armenian Mythology

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1. Introduction

In the Armenian Highlands, various state formations existed in III-I mill. BC, and each of them had its own mythology, cults and rituals (fig. 1). The entire nature surrounding man from top to bottom, from heaven to Earth, with its various manifestations, is reflected in ancient Armenian mythology. Human life with all its components: existence, daily activities, security, social life, economic relations, etc., depended on nature, the earthly and heavenly environment. Over the millennia, ancient beliefs about the four elements – air, fire, water and earth, were transformed into images of gods and goddesses, and formed pantheons.
Ideas about the cosmic ocean and the heavenly sea occupy a special place in the Armenian mythological thinking, and reflect the ancient cosmological knowledge, as well as beliefs and cults connected with them. And among all celestial bodies the most worshiped was the Sun, *called the Eye of the Universe, the chief of all Luminaries, . . . the most obvious reminder of divine and divinity (Alishan 1895, 84).*
Ideas about the earth were represented in the form of beliefs related to natural environment: mountains, gorges, soil, dungeon, trees, flowers, as well as underground and surface waters, rivers, lakes, springs and streams, etc., all this embodied in images of various spirits, then – deities. Later, all these representations crystallized in worship of such images that are connected with the ideas of homeland, native country, i.e. ancestors, eponyms, patron gods.
Evidences about ancient gods and goddesses symbolizing heaven and Earth, earthly and heavenly phenomena, natural environment, etc., are preserved in archeological, linguistic, folklore, ethnographical sources, as well as in the works of ancient Greco-Roman and medieval Armenian authors.

2. Armenian eponymous patriarchs

1) The Father of Armenian historiography Movses Khorenatsi (V ce.) in his "History of the Armenians" has preserved many ancient myths in the form of archaic epos, the narratives of which describe victories of the Armenians' eponymous prefathers – Hayk and Aram. Patriarch (Arm. Nahapet) Hayk, who winned a glorious victory against the Babylonian tyrant Bel, laid the foundation of the Armenian native land and its people (fig. 2). And from that time on "our country is called Hayk' after the name of our ancestor Hayk" (Movses Khorenatsi, 88).
Thanks to his glorious victory, Hayk was deified, and his patriotic deed was preserved in people's memory for many centuries. As a mythological figure, Hayk was the founder and defender of the Armenian homeland, he defined the place for Armenians to live, the country Hayk'. He is also the creator of time and eternity, who defines the cosmic order in his country, and appears in the Universe in as constellation Hayk, corresponding to Greek Orion[1] (figs. 3-4).
Hayk also defined the beginning of Armenian history – the datum when he defeated Bel, Navasard 1 (August 11) 2492 BC. The Haykid Calendar starting from this day, proclaims the origins of Armenian history, its separation from prehistoric times, and the calendar months are named after his sons and daughters (Vardumyan 1991, 87-91). Up to our days, in the annual calendar of the Mother See of Holy Ejmiatsin, the native Armenian Haykid months are still fixed along with the Christian ones.

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[1]The mythic giant huntsman whom Zeus placed among the stars as a constellation (Dictionary of classical mythology 1987, 184-185)

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2) The second patriarch, from Hayk's sixth generation, Aram Haykazun, also was a great ancestor who defeated the enemies attacking Hayk' from the east, south and west (fig. 5). He extends the borders of the country on every side, becomes so powerful and famous that "by his name all races call our land: like the Greeks, Armenia, and the Persians and Syrians, Armenik" (Movses Khorenatsi, 92). Patriarch Aram was a solar god, the patron and protector of the united Armenia, the definer of new cosmic order in Armenian world. He was a creative figure, who expanded the country, populated almost the entire Armenian Highlands with Armenians, assimilated the tribes living in the new territories, ordered them "to learn the Armenian speech and language" (Movses Khorenatsi, 95). His enemies were zoomorphic titans and gods whom he defeated with his invincible divine solar power (Vardumyan 1991, 91-94).

3) The next Haykid, Tork, from the Anghea region, was connected with the earth elements: stone and rock, as well as sea. Movses Khorenatsi describes how Tork throws huge stones on the enemy ships coming from Pontus (Black Sea) to attack Armenia, and the waves rise and sink the ships (fig. 6). Tork, like Hayk and Aram, was the defender of the country, the god-demiurge of art and writing, as well as rock-carving, he would "polish with his nails hard stones and inscribe eagles and other such [designs] on them" (Movses Khorenatsi, 141). On the other hand, the tribe name Angegh is associated with vulture – Arm. Angl, which appears to have been a totem bird for this lineage, suggesting that the cult had deep roots in archaic beliefs (Vardumyan 1991, 99-101).

4) Movses Khorenatsi writes also about one of Aram's descendants, Ara the Handsome, king of Armenia who rejected "dissolute and lascivious" Shamiram's (Semiramis) love, queen of Assyria, and declined her offer to ascend the Assyrian throne. She became "exceedingly angry" and attacked Armenia with war during which Ara was killed (Movses Khorenatsi, 96-98). In the original version of the legend Ara was reborn (as Egyptian Osiris, Phrygian Attis, Greek Adonis, etc.)[2]. As a dying god he was connected with the underworld, meanwhile, his rebirth symbolized the awakening nature in spring and the beginning of agricultural works (fig. 7). Ara's legend indicates the importance of the worship of dying and rising deities as mythic personifications of sunrise and sunset, as well as the hibernation of the nature in winter and awakening in spring. In Armenian folk beliefs there are dog-like deities – Aralezes, who resurrect heroes fallen on the battle against enemies. Ara's image was also connected with the red planet Mars, like Greek Ares and Roman Mars (Vardumyan 2018, 219). Ara does not accept Shamiram's passionate love and remains faithful to his country and queen Nuard (Movses Khorenatsi, 107), with whom they constitute the male (solar), and female (lunar) beginnings in Armenian mythology. According to folk beliefs, the names of the Ararat Valley and Mount Ararat derive from Ara; Mount Aragats is his royal throne, and Mount Ara – his deathbed. The Haykazuns (Haykids) symbolize Hayk'-Armenia country as the cradle of Armenian nation and have remained in historical tradition as deified ancestors (Kavoukjian 1987, 155-167; Vardumian 2010, 431-435; Haykazounis 2013).

3. Gods of Hayasan Pantheon

In the next period, which includes XVI-XIII ce. BC, in a treaty known from Hittite inscriptions, the names of 14 city-gods of the neighboring country Hayasa (Hayk') are mentioned. The supreme god dU.GUR, heading the pantheon, the god of thunder and lightning and the underworld, is on the first line of the inscription. In the second line is the supreme goddess dINANNA, the patroness of fertility and plentity, who is also associated with heaven and earth. The next deities are patron of different Hayasan towns (Kapantsyan 1940, 84-99; Khachatryan 1971, 148, § 6); Petrosyan 2002, 128-131; Ghazaryan 2023, 102-112; Vardumyan, Tokhatyan, 2023, 215).

4. Pantheon of Van Kingdom

The IX-VI ce. BC, represents the rich state pantheon of Van Kingdom (Urartu/Ararat), mainly recorded on a rock called Mheri Dur (Mher Door), (fig. 23). 70 deities, 35 gods, 35 goddesses, and a number of devine

[2] Ara's resurrection is confirmed by Plato's description of an Armenian soldier, Er's (Ar) death at the battle-field, and rebirth: "Er, the son of Armenius, ...once upon a time was slain in battle, and when the corpses were taken up on the tenth day already decayed, was found intact, and having been brought home, at the moment of his funeral, on the twelfth day as he lay upon the pyre, revived, and after coming to life related what, he said, he had seen in the world beyond" (Plato, Republic, X, 614b).

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attributes are mentioned in the inscription (Hmayakyan 1990; Wartke 1993; Salvini 1995; Zimansky 1998; Badalyan 2015; Ayvazyan 2017, 22-50; Grekyan, Badalyan, Tiratsyan, Petrosyan 2018). The supreme couple, Haldi (DHal-Die) and Arubani (DWaruba(i)ne), are the patrons of heaven and earth, sciences, arts and crafts, fertility and agricultural work, they rule over everyone and everything in heaven and on earth (figs. 8-9).

Gods and goddesses personifying celestial bodies and phenomena were worshiped, and this fact proves the advanced level of astronomical knowledge in Urartu. Haldi, the first god of the supreme triad, is the embodiment of Jupiter, the largest planet in the Solar System. The second god, Teisheba (DTeišeba), personifies Mars and thunder and lightning (fig. 10). The third god, Shivini (Šivini) is the Sun, his symbol on the seals with sacral contents is the winged solar disk (fig. 11). The Moon – Melardi or Selardi (DSielardi), as well as the planets are mentioned in the inscription: Mercury – Ardi (DArdi), Venus – Sardi (DSardi), Saturn – Tsinuardi (Dsinuiardi). In Urartu the idea of the Tree of Life – the symbol of connection between Heaven (Universe) and Earth (Dungeon) was developed (Vardumyan 2018, 220-221; Vardumyan, Tokhatyan, 2023, 215), (fig. 12).

Sacrifices were made to all these celestial-cosmic gods, as well as to the earth gods of mountains, plains, seas, sacred places, and cities. Especially the works related to viticulture were considered sacred, every stage of which – tun, care, harvesting and other details – was done under the auspices of the supreme couple, accompanied by certain rituals, up to a special wine festival. And this attitude towards viticulture and winemaking is preserved in the Feast of Blessing of Grapes (Assumption of the Virgin) of the Armenian Apostolic Church, which is the only Christian church having such celebration, meanwhile, wine festivals, such as the Greek Dionysias, Roman Bacchanalias, etc., were widespread in ancient Mediterranean (fig. 13).

5. Pan-Armenian Pantheon

In the post-Urartian period, including the Yervanduni-Artashesian-Arshakuni (Orontid-Artaxiad-Arsacid) dynasties with their pan-Armenian pantheon (VI ce. BC – IV ce. AD), gods and goddesses personifying cosmic bodies or celestial phenomena were worshiped, as well as Earth and the whole nature.

1) The Universe was perceived as the Cosmic Sea (Tsov Tsirani – Purple Sea), from which everything in heaven and on earth had begun. Movses Khorenatsi mentions the song “Birth of Vahagn”.
   Heaven was in travail, earth was in travail,
   The purple sea was also in travail,
   In the sea, travail also gripped the red reed.
   From the tube of the reed came forth smoke,
   From the tube of the reed came forth flame.
   From the flame, a blond young boy ran out.
   He had fire hair, and had flame beard,
   And his eyes were suns (Movses Khorenatsi, 1978, 123).
   This verse, as stated by the Russian scholar V. Toporov, is one of the most ancient Indo-European cosmogonic and theogonic myths (Toporov 1977, 88-106). The relations between the Earth and Sky, the Seawater and Plant life, the Sun and Fire are obvious (in folk beliefs the Sun is the celestial fire and fire is the terrestrial one). The world elements make the interconnection in entire universe whose cosmic waters give birth to the sun personified in Vahagn (Vardumyan 2020, 167-183). He kills the dragon symbolizing darkness, and is called Vahagn-Vishapakagh (Dragon Slayer) (Movses Khorenatsi, 1978, 123), (figs. 14-16).

2) In Armenian mythology, a special reflection has received the Milky Way (fig. 17). Astronomer Anania Shirakatsi (VII ce.) in his “Cosmography and calendar” tells an ancient myth about the Armenians’ ancestor Vahagn who steals some straw from the Assyrians’ ancestor Barsham in order to warm his people in a cold winter time. And the trace of his scattered straw is called the Straw-Thief’s Path, which is the Milky Way galaxy (Anania Shirakatsi, 37). Shirakatsi also gives the scientific explanation of this cosmic object.

3) The gods of the pan-Armenian pantheon symbolized heavenly luminaries, planets or phenomena. The supreme couple, Father-god Aramazd and Mother-goddess Anahit, were the rulers of gods in heaven and the protectors of people on earth. Aramazd embodied Jupiter, the greatest planet in the Solar System, and Mars as the god of thunder and lightning (similar to Greek Zeus and Roman Jupiter).

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The rainbow was the divine belt of Aramazd. Anahit, the goddess of maternity and fertility (as Greek Hera and Roman Juno) personified the Moon but was also called Gold-haired and Gold-fingered, 'gold' symbolizing the Sun-color and rays (fig. 18). Their daughter Astghik (Arm. 'star'), was the goddess of love and beauty (as Greek Aphrodite) personifying Venus – the brightest star in the morning and evening sky (fig. 19). The other daughter, Nane, the goddess of feminine skills and war, was Saturn. Aramazd's messenger Tir – the god of writing, the dream-sender and the conductor of souls into the afterworld, personified the planet Mercury (Greek Hermes, the messenger of Olympian gods) (Melik-Pashayan 1963; Vardumyan 1991, 103-125; Vardumyan, Tokhatyan, 2023, 217-221).

The magnificent archeological monument in Commagene, built in 62 BC by king Antiochus I Ervanduni (Orontide, 69–34 BC) on the slopes of Nemrut Mountain of the Armenian Taurus, is also devoted to the Sun (figs. 20-22). The monument is a unique architectural-sculptural embodiment of Sun worship. The huge stone sculptures of gods Zeus-Oromasdes (Arm. Aramazd), Apollo-Mithra (Arm. Mihr), Artagnes-Heracles (Arm. Vahagn), patroness-goddess of Kommagene (Arm. Anahit), and Antiochus I himself, together with the huge heads of Lion and Eagle – symbols of royal power, stand on eastern and western sides of the artificial hill of 50 m high. Sun Gods, King and the whole group until today meet the celestial luminary in the morning, and see it off to retire in the evening (Vardumyan 2020, 167-183).

4) A typical solar god was Mihr (Mher) whose widespread image is reflected in such words as 'mehyan' – heathen temple; the name of February in the Armenian calendar is 'Mehekan' meaning 'Mihrian'. Mihr was the Armenian parallel of Indo-Iranian deities – Vedic Mitra and Zoroastrian Mithra, whose cults were spread in the Roman Empire as Mithraism (I – IV ce. AD). But unlike Roman Mythra, Armenian Mihr lasted long: echoes of his cult appear in the images of Armenian epic (VII – X ce. AD) heroes Great Mher (Lion of Sassoun), the rising sun, and Little Mher, the setting sun. The latter closed himself in the Raven Rock called Mher Door (Caldean Gates near the Van fortress), because he outraged at the world's injustices, and with his Fiery Horse, Lightning-Blade and War-Cross, he will stay there "till judgement day, the end of this world, it will be destroyed, and a new world built" (Daredevils of Sassoun, 71-94, 231-250), when honesty, peace and prosperity will reign in the world (Vardumyan 2023, 7-23). According to a folk legend, in the stone-prison of Mher there is a rotating wheel-of-fate hanging from the sky, keeping the connection between the Cosmos and the Earth, and in some way – between the Space and the epic hero (fig. 23).

5) The gods of pan-Armenian pantheon were mostly space-dwelling, in the sky, sometimes they came down to the earth to participate in a celebration dedicated to a god or goddess. The underworld was personified in the image of Sandaramet, the god of dungeon. In general, they believed that in the world around – in mountains and gorges, in caves and underground, in rivers, streams, trees, everywhere, there live evil and good spirits which can either harm or help people. This is how arose beliefs connected with mountain spirits qajk', thunder and lightning dragons – vishap, nereids – jranuysh, sky spirits – odanuysh, and many others (Alishan 1895, 148-233).

They also believed that on New Year day, Navasard, celebrated on August 11, the seven deities – Aramazd, Anahit, Mihr, Vahagn, Astghik, Nane, Tir, descend from heaven, sit on high mountains and watch the festival. The Navasard Games (Armenian Olympic Games) used to take place in Bagavan-Ditsavan, Ashtishat, Armavir and other large cult centers, where altars set up for gods and goddesses (fig. 24). Plants and animals, the first harvest of fruits was sacrificed to them. The custom of the so-called matagh also comes from those days, when they used to sacrifice a bull or a ram or a rooster. And an important part of the Navasard cycle was the Astghik's feast Vardavar (fig. 25) when the folk used to gather near springs, rivers, and the ritual of sprinkling each other with water was the important part of the holiday (Manukyan 1969, 177-190; Kharatyan-Arakelyan 2005, 201-226, 249-254). The celebration of Vardavar is kept up to our days, and even now, especially in the villages of Gegharqunik Marz, they always go to highlands to do their open-air matagh.

6) Another ancient feast, Trndez, the feast of sun's magic rebirth celebrated on February 14, was dedicated to god Mihr. Greek historian Xenophon witnesses that at Mihr's festivals in Armenia they used to sacrifice a huge number of stallions, as the horse was one of solar symbols, and he himself gives his horse to the chief of an Armenian village to be sacred to the sun god (Xenophontis, Anabasis, IV, 34, 98). People performed a ritual to warm the earth by lighting a bonfire, so that the warm days would come sooner, and the whole month was dedicated to the solar god and was called Mehekan in

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Armenian calendar. This celebration is very popular up to now, especially among the youth who make bonfire, sing and dance around and jump over when it begins to fade. The top of the festivity is the new-weds' jump; the idea is to achieve good luck and happiness, to have fertile marriage with a lot of children, and prosperous family (fig. 26). The Armenian Apostolic Church celebrates on the same day the feast of Jesus Presentation to the Temple when he was 40 days old (Christmas by the Armenian Apostolic Church calendar is on January 6), and blesses the candles that people take home to make Trndez bonfires in their yards (Manukyan 1969, 59-70; Kharatyan 2005, 53-62).

7) The earth in mythology was depicted in the form of mountains and valleys, trees and flowers, stones and soil, rivers and lakes, with them various beliefs were connected, which over time were transformed into the worship of deities. The idea of fertility was associated with goddess Anahit, the underworld – with Sandaramet. Anahit was the patroness of both cattle breeding and agriculture, and on her holidays wreaths and branches, newly grown grain and other harvest were presented to the goddess. Adjacent to the Anahit temples were lands where sacred heifers with a white crescent mark on their foreheads grazed. Goddess Astghik was also connected with nature: the myth tells that when she walked through fields, the blood dripping from her delicate feet turned into red roses.
A further continuation of the Great Mother Goddess Anahit is Tsovinar – the mother of the heroes of the national epic "Daredevils of Sassoun" (fig. 27). Tsovinar includes both heavenly and earthly elements. In her archaic stage, Tsovinar is the primordial Chaos, the Heavenly Ocean or the Purple Sea, which gives birth to the universe-cosmos, the world order, and the sun god Vahagn (see "Birth of Vahagn"). Later, transformed into different images – the lightning spirit Tsovian, then the goddess Nar, finally in the Middle Ages, during the Arab invasions (VII-IX ce.), is crystallized in the epic figure, who gives birth to Sanasar and Baghdasar, the heros of the first branch, the founders of Sassoun Fortress (Daredevils of Sassoun 1964, 32-70; Vardumyan, Tokhatyan, 2023, 215).
Ancient myths have evolved over time into folk legends, in which earth and sky often appear together. In one legend, it is told how "the golden-haired youth Sun crosses the sky every day in his golden chariot, rests on the top of Mount Ararat in the afternoon, then in the evening goes into lake Van, and while having his night rest there is caressed by Sun-Mother and sun-fairies, at dawn, refreshed and radiant, drives again his chariot across the roof of heaven" (fig. 28).

8) In ancient ideas of heaven and earth, a special place occupy dragons which symbolize the elements of wind, storm, thunder and lightning. In folk tales, they are either good beings, guardians of the sacred water, or evils closing the source of the water, the immortal spring, and no one could approach to drink water. In another legend, dragons swallow the Sun and cause eclipses, but are slain by the thunder-warrior, Dragonfighter hero who frees the luminary and brings light and warmth to people[3].
Some folk beliefs about the soul are also related to cosmological ideas, according to which, after being separated from the body, the soul moves into the universe, becoming a good or an evil spirit. The souls are identified with the stars, among which the bright ones are considered the souls of the righteous, and the dim ones – the souls of the sinners, and at the moment of death, his star falls and darkens. According to these spiritual concepts, the spirits of dead ancestors need to be sacrificed and courted, and they will be powerful in all things to the living, and will cause harm if they are neglected or disrespected. These and other similar ideas about the soul and death give rise to the ideas about the underworld, the judgment of the soul and the afterlife, the development of which leads to the formation of the underworld, soul-accompanying, dying-resurrecting deities, which are numerous in ancient myhologies, Armenian in their number (Vardumyan 2020, 10-21).

9) The worship of Heaven and Earth in heathen Armenia had many other manifestations, which were preserved in pantheistic beliefs and still survive in the form of folk Christianity in our holiday-ritual life, habits and customs, and national mentality in general. The pagan temple of Garni (not far from Yerevan), dedicated to the solar god Mihr (fig. 30), 24 pillars symbolize the rotation of the heavenly luminary during a day. The Armenian New Year, Amanor (on March 21, spring equinox) and other holidays are still celebrated here, in which there is a revival of ancient knowledge about the universe (Vardumyan 2020, 163-186).

[3]It should be noted that the worship of dragons was widespread in many countries of the Old World, from China to Britain, but only in Armenia it turned into the art of dragon stone steles, which can be considered an exclusive phenomenon of our pre-Christian sculpture, like khachkars in Christian culture (fig. 29).

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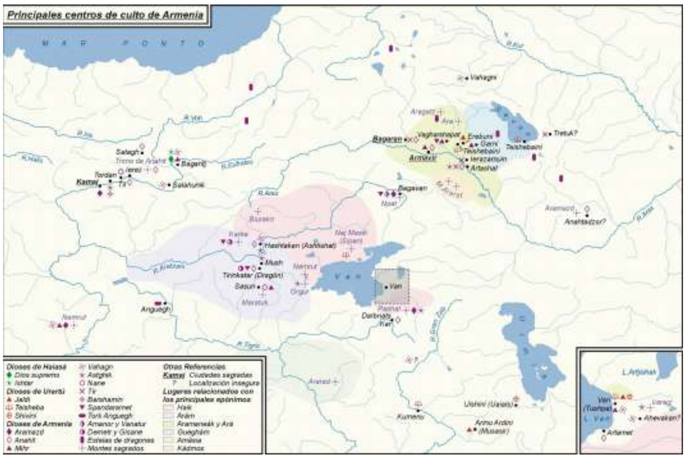
6. Summary

Ancient Armenians, being one of highly developed peoples of the Ancient World, had certain knowledge about the five planets of the solar system visible to the naked eye, and each of them was represented by a god or goddess in different panthons of ancient Armenia during III-I mill. BC. They not only had knowledge about the universe, planets of the Solar System, as well as earth with its nature, but also created myths and legends about them. The interweaving of mythology and cosmology in the Armenian worldview was prominent in the cults of gods and goddesses personifying heavenly bodies and luminaries. The planets appearing in the starry sky, as well as the Sun, the Moon, constellations, the Milky Way, and everything on the Earth were worshiped, many temples dedicated to them were built all over the country. Festivals and holidays devoted to those deities were held in different regions of ancient Armenia, and some of customs and rituals of those celebrations, mixed with Christian traditions, are vivid up to now in festive life.

Many images of ancient mythology were transformed into heroes of the national epic "Sasna Tsrer". And many ideas about heaven and earth in a survival form have been preserved in folklore, ethnographic reality and the national mentality of the people to the present day. All this indicates not only the high level of development of the mythological thinking of our distant ancestors, but a continuous process of world recognition from the earliest stages of Armenian history.



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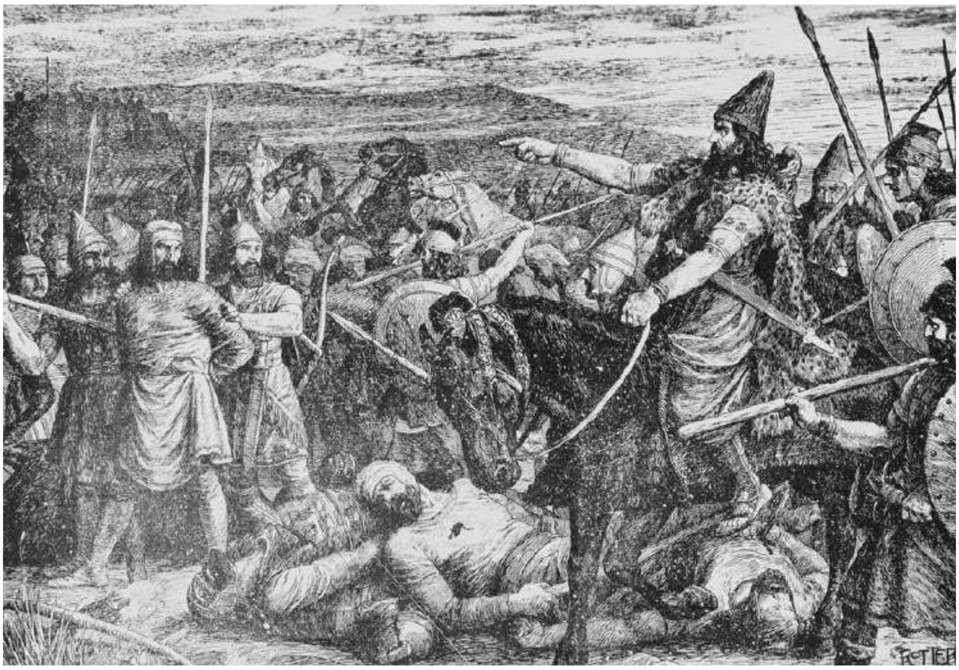

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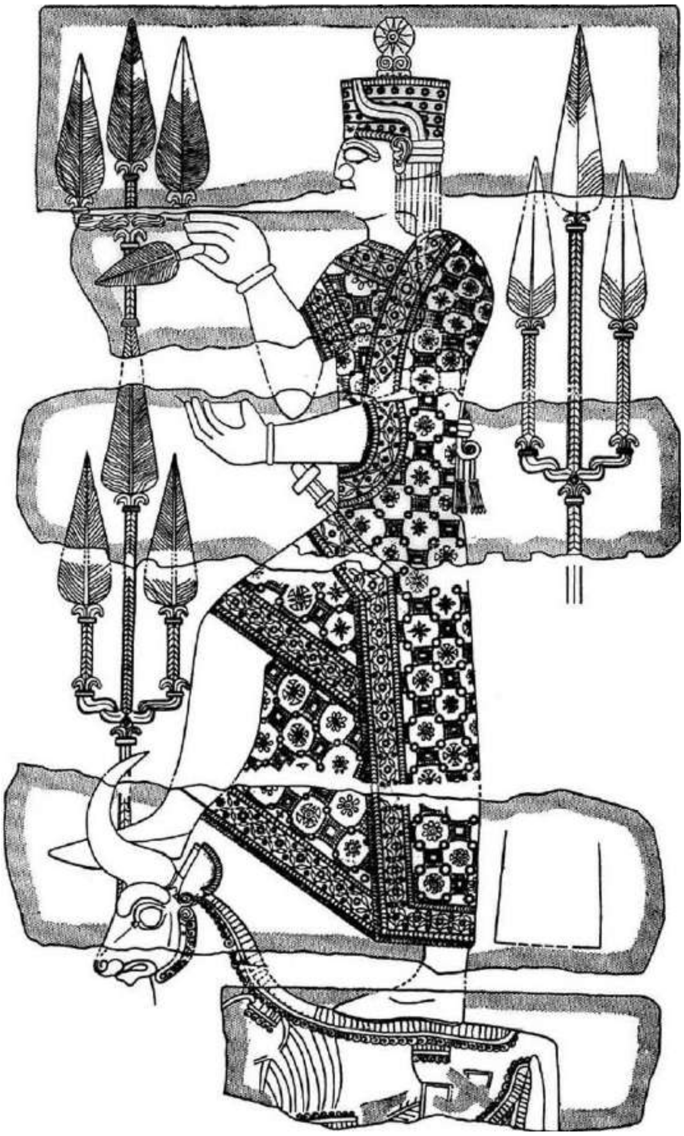

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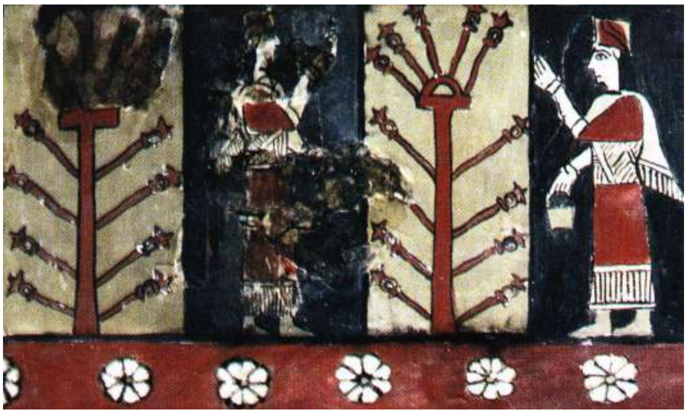

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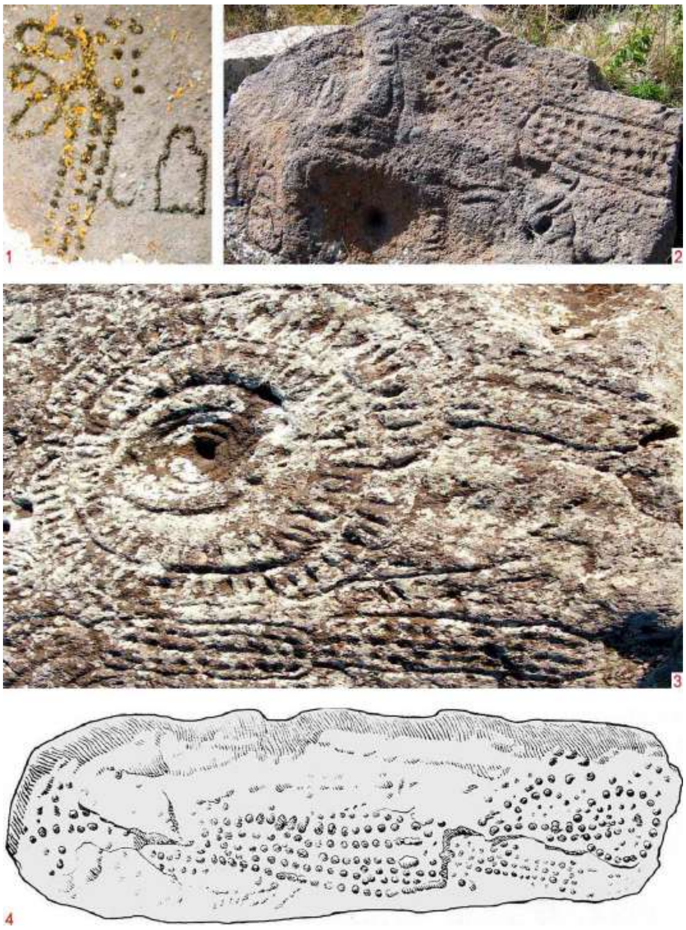

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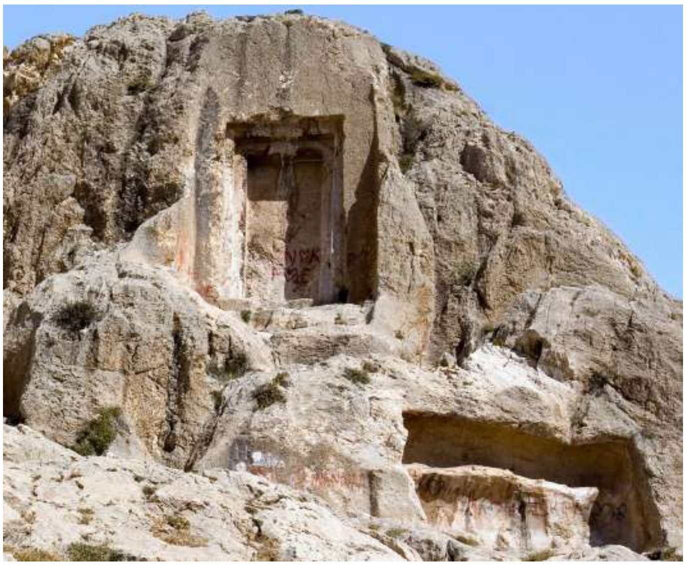

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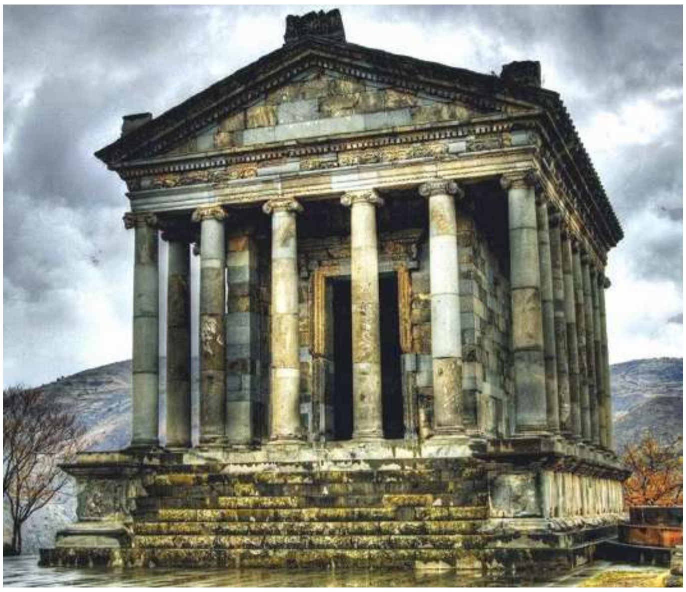

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Toumanian and the Universe

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Abstract

Toumanian's poetic intelligence indeed ignited the universe, ensuring the continuous flow of creation on Earth and into the hearts and minds of people. The rapprochement with the universe represents a cultural endeavor in life organization, aimed at not only rectifying past and present mistakes but also guiding pathways to harmony with the universe and God. His lyrical hero embodies the ultimate human, seamlessly integrated into the universe, reverting to their inherent creator nature and origin. Through this, Toumanian established space as an essential element of identity, a perpetual value. The article explores the connection between Toumanian and space.

Keywords: *universe, sky, self-awareness, Sirius, Venus, existential area, eternity, psychological identification, soul-transmission.*

Terms such as sky, sun, star, cloud, light, universe, God, eternity, Sirius, Venus, and other cosmic concepts are frequently present in Toumanian's works, spanning various periods of his creativity. The issue of self-awareness brought the All Armenian Poet into contact with the universe. Psychological identification and rapprochement, sensory and emotional empathize with the universe, psychological attributions and projections, introspection, whose path flows into the universe, eternity and boundlessness.

"I gazed upon the magnificence of the universe, immersing myself in its vastness... I comprehended the life of the stars and the insignificance of humanity. I observed nature and all its creatures. And what does a person boast of? Merely being one among them, unknown to them. I observed all people, from princes to commoners, from the poor to the rich. The happiest person is the strongest, lacking nothing, unafraid, serene, and healthy. I observed a person from birth to death... in every circumstance; the only upright are those who stand firmly on their own feet, the only radiant are those who shine with their own light, illuminated by their inner brilliance (Toumanian (1999b))." Essentially, the purity and greatness of the universe is contrasted with the smallness and sinfulness of mortal man. The universe becomes the context of regulation of life, although Toumanian's "how to live" mentality does not become the culture of life.

The quatrain with the beginning "AT my baptism the sky was a church; the sun, a holy lantern", which is, in fact, the "birth certificate" of the poet, is a multi-meaningful and multi-colored canvas that contains the symbolic system of the life and mission of the All-Armenian poet.

AT my baptism the sky was a church; the sun, a holy lantern;

The rainbow, a braided laurel; everyone's love, a font.

The mountain was my godfather; the dew, vital myrrh;

And my Baptist was He who consecrated me a Poet (Toumanian (2004c)).

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Over time, existentialism has undergone dynamic development across various genres of literature, yet the urge for existential rebellion has been most pronounced.

MY soul is a celestial traveler in the Universe,

A passenger from Earth, indifferent to earthly glories,

My soul has left and diffused among the distant stars,

A stranger to anyone who stayed below (Toumanian (2004b)).

The works related to the universe serve as dominant reflections of the transcendental whole, where the universe acts as the most significant concept in assigning meaning. Approaching the universe becomes a tendency to align one's spiritual and physical qualities, thoughts, and ambitions, primarily embodying existential impulses and messages.

The universe becomes the area of existential certainty of the value-based system of living, and the concept of limit only acquires the meaning of perfection. In all the poems and quatrains related to space, Toumanian existentially transcends himself and the world, reigning over the vastness of the secret universe. In the poem "Exploring the Universe" not only is the phenomenon of existential aesthetics evident, but also spiritual dynamics. It is not merely a description of a life lived. In the text and the context, the inertia of semantics gives different dimensions and limits to what Toumanian received and possessed from the universe.

A gaze you gave me upward

To sink into the upper bounds of the sun,

A thought you gave me celestial and bright

To fathom the vast expanse of the horizon,

A tie you used to own my soul

To give my soul infinite joy,

A ray you used to grace my brow

To burn, adorn with sunny toy...

And these self-overcoming are not ends in it. He not only preaches but also affirms the existence of the highest values with the "infinite joy of the soul", preferring them to human willfulness and evil.

My cheerful soul is up till end

No near or far, above, below,

The whole space – a house and land

A distant, free Lord – myself alone (Toumanian (1985b)).

The sky, as an existential space, fascinated Hovhannes Toumanian since childhood. Perhaps it was also due to his frequent encounters with the sky that he remained so crystalline, clear, and epic in his personal life and in his works. The sky was his silent teacher. “When I was young, I loved to lie on my back in our grassland and on the hills, under the trees, and immerse myself in the sky or nature for hours. I was always in the mood to fly, and it always seemed to me that I could fly in the air; I felt so light, and even now it seems to me that I was flying or that I had flown. In the silence of the nights, I always listened to the sound

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of Debed, which came from the deep valley, sometimes deaf and deep, sometimes clear and scary. And it seems that it was talking to my soul. My great teacher was the rushing Debed, sleeping under the starry sky, and lying alone in the grasslands for hours, staring at the sky (Toumanian (1999a))."

Sky, stars, sun, universe. We read in the memoirs of Nvard Toumanian. Once, he said in the midst of conversation, "The idea of infinity is a great one: thinking for an hour is a very hard thing - something that leads to madness... People are not in the habit of looking at the sky, while it is very important... (Toumanian (2021))" He was talking about the universe, the secrets of life and death, the vanity of life, the feeling of satisfaction; he was referring to the sages of the East. "Omar Khayyam says it well: ...What then is life to us, what is our life in this bottomless ocean - a single wave that passes..." Deep identifications with the vastness of the sky expanded the boundaries of the poet's mental world and cognitive field.

"At the age of seven or eight, he was a "herder", but being a very dreamy child, he would often lose the oxen. He would take them to the field, set them free, and then sit on a rock or lay down under a tree, indulging in his dreams.
For hours, he admired the pink clouds of the sunset, the interplay of clouds on Chatindagh's peak, their slow and smooth movement, and dreamed... He lay in the valley, listening to the rush of the Debed River, the chirping of birds, and the crickets. Late in the evening, he stretched out under the open sky, gazing at the starry heavens, lost in thought and dreams....... (Toumanian (1983))" .

The poet's epic purity and harmony emerge from communion with the sky, stars, and universe. Each phrase within a poetic monologue or dialogue is either directly or mentally addressed to the speaker. The interlocutor, at times, becomes the universe; at others, the sky and the stars.

O shining stars!

Eyes of the night,

Glowing ardent,

You smile so bright.

Just as you smiled

When still a child

Lively and brisk,

Bright as yourselves

I would frolic and frisk

Without sorrow…

You smile today,

When weak and gray

I weep with grief

For my lost belief…

You will smile tomorrow

Upon my grave… (Toumanian (1985a))

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N. Toumanian wrote: “He loved, especially, Sirius and Venus, their brilliance and color. Often, we were awakened at dusk to see the wonderful twinkling of Sirius or the fantastic glow of Venus. We also loved the stars, and each of us chose a star for ourselves: one chose Venus, another Sirius, Orion, etc. The result of Daddy’s enthusiasm was the poems ’Venus’ and ’The Farewell of Sirius (Toumanian (1987a)).’”

Of course, the impulse to write came from the visit of 14-year-old Viktor Hambardzumyan to the poet. It was the summer of 1922. During their conversation, the future greatest scientist told Toumanian about Sirius. N. Toumanian recalled that it was during the summer of 1922 when “He was interested in the stars and wrote ’The Farewell of Sirius’ (Toumanian (1985c)) in those days.”

O say, from what remoteness do you hail,

Sirius, mighty traveler of the sky,

What is the heaven to which you sail,

With speed untold

On endless routes,

As he centuries unfold?

The attainment of existential-spiritual independence occurs through connection with the universe and the eternal.

How many eyes gazed at you before

Just as we do tonight,

And how many more

As yet unborn.

The poem ’Venus’ contains remarkable material. In it, the poet expresses love and anticipation for the appearance of Venus. Venus is portrayed as a force that must arrive to overcome ’evil and devil’, dispelling darkness.

. . . When you will rise?

Arise, arise,

Hit it, hit it,

Evil and devil

Chase the darkness,

Venus!

Open the door

Of the daylight,

Venus! . . .

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Which door is it related to? The one through which 'Light by day shall flow,' the doorway to a vision of fair and honest coexistence. By creating equivalent relations of identity with the universe and the stars, the poet becomes distinct, a part of the people in which he remained until his last days, but also distinguished by his self-sufficient integrity and the confidence of belonging to that integrity. The carrier of the universe and the infinite has strengthened and will continue to strengthen the spiritual foundations of society and its continuity through his literature.

Perfection becomes an attainable desire, while Venus acquires a valuable foundation and imparts spiritual stability. In the poem 'Anoush,' it is no coincidence that the sky, stars, and enchanting night form the backdrop for the Ascension night and the lovers' meeting. The overture and epilogue of Ascension Night not only foreshadow its profound meaning and mystery but also encapsulate the essence of the poem, tracing its spiritual journey from inception to culmination. The author imbues the stars with strength, power, and magic, anticipating their intercession and radiant smile.

The water and the flowers she has placed

Beneath the stars, to plead from them,

Her heart filled to bursting with eagerness,

That they may smile kindly upon her lover... (Toumanian (1989))

In “divine, inscrutable conception” the depiction of ‘Out of the distant depths of the infinite heaven’ intertwines with ‘a happy, wondrous moment,’ symbolizing the opening of the gates to the golden sky.

It is Ascension night, that enchanting night,

When at a happy, wondrous moment,

The golden gates of Heaven are opened:

Down below all grow speechless and silent

And with divine, inscrutable conception

It is filled with God's holy compassion.

At that sublime moment of the beauteous night,

Out of the distant depths of the infinite heaven

There fly out and come together the two stars. (Toumanian (1989))

Quatrains are also reflections of existential literature. Existential areas of space are accommodated in quatrains too. Reality here also becomes a pure whole.

My soul has come into its own,

Great as the Universe it has grown;

I am the lord of the whole world,

Yet who knows of it? I alone! (Toumanian (2018))

In this quatrain, the universe becomes the refuge of Toumanian's soul, an ideal world where he also takes the reader to confront not only the evil and infinite tragedies of the world, but also death. In other words,

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man is not a separate existence and a possessive part here, because the line "I am the lord of the whole world" signifies a state of elevated being, evaluating things and phenomena from a heightened perspective (referring to a crystallized, soul-transmission (conversion) state).In the following quatrain, "exalts the omniscient soul" as well, approaching the "deep melody and murmur" of the universe.

I feel the breath of the living God all around me,

I hear his unsilent call and response —

The deep melody and murmur of the Universe

Exalt and dispel my omniscient soul.

With this individualized perception of the universe, Toumanian makes the reader a participant in the highest experiences, expanding the latter's socio-cultural space, in which there is no social tension.

In starry dreams' world, a beam of light,

In the far reaches of pure great mind,

Deep in the mists of timeless memories,

Sometimes I feel I will reach Him...

This quatrain reflects a unique psychological mechanism: identification. The unchanging source and core of human existence, the universe, becomes the object of bio-semantic identification. An exemplary instance of psychological identification with heaven is found in the following quatrain.

My soul, an expanse as vast as the sky,

Unfolds above, unseen yet nigh.

In secret, it beholds both near and far,

Glimmers of light, shadows of a star.

Here, the sky is not just an object of psychological identification. It becomes a part of the sky and reveals what is invisible and incommunicable to many. Toumanian referred to the last period of his creative life as philosophical. On January 21, 1923, he said during a conversation: 'My last period – philosophical period – is the period of "cosmic thoughts" (Toumanian (1987b)).

The poet's connection with the universe became closer on his deathbed. From the memories of his daughter, Nvard: "In the morning, he asked us to arrange the bed to have a view of the sky (Toumanian (1987b))."

A thousand years before or since, what can ever matter-

I have existed and will exist, so what can ever matter!

I assume a thousand forms, all of them for a time,

With the soul universal my soul is one, so what can ever matter! (Toumanian (2004a))

Toumanian's poetic intelligence set the universe in motion, allowing creation to continue on earth and flow into the minds and hearts of people. This rapprochement with the universe is nothing but a cultural project of organizing life, where not only the mistakes of the past and present are corrected, but also the ways of harmonizing with the universe and God are marked. His lyrical hero becomes the superior man

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assimilated into the universe, which has returned to its creator nature and beginning. This is how Toumanian made the universe a necessary component of identification, a permanent value.

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On The Proto-form of the Native Armenian Word *Yerkin* "Heaven" and ist Armenian Parallels

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Abstract

The native Armenian word *yerkin* (heaven) is absolutely incomprehensibly derived from the Indo-European root "*d(i)ui-n-, *dei - "to shine, to beam" with the root determinative *-u", the Armenian parallel of which is the root ***tiv***. At the same time, it is noted that "there are phonetic difficulties", which is too mild a statement.

The comparative study of the vocabulary of Armenian and Polynesian languages has already proven its effectiveness and ***mutual benefit:*** Rapanui-Armenian lexical parallels help to clarify the boundaries of the Polynesian word-form and the structure of the word, and with the help of the ancient roots preserved in the Polynesian languages, it was possible to etymologically analyze many Armenian words of unknown origin, incomprehensible, as well as the ones considered loanwords and find out their origin and initial meaning.

A similar comparative examination reveals that the most probable form of the native Armenian word *yerkin* "heaven" is the word ragi (rangi) "heaven" from the Pan-Polynesian vocabulary. Not only the real living proto-form of the native Armenian word *yerkin* is revealed, but also the basic meaning, as well as a genealogical bunch of words with the same root in Armenian, three of which are presented in this article.

Keywords: *Rapanui-Armenian lexical parallels, Pan-Polynesian rangi "heaven", Proto-form, Native Armenian word yerkin "heaven", Genealogical bunch, Addition of a pre-sound.*

1. Introduction

Today, more than ever, there is a need to compare Armenian with non-Indo-European languages, taking into account the extreme scarcity of the latter's roots recognized native Armenian - only 10% of the total number of roots, 1and the huge number of roots considered of unknown origin and loanwords (90%). G. Jahukyan believed that Armenian is the most mysterious among the living Indo-European languages, substantiating this opinion by the fact that its "...unanalyzed word-roots of unknown origin by approximate calculations make up at least half, if not more than half, of the total number of word-roots". One of the ways to solve such mysteries of Armenian can be the comparison of wordstock of Armenian and languages of other language families.

The comparison of the vocabulary of Armenian and Polynesian languages has already proven its effectiveness and ***mutual benefit***. For example, the Rapanui-Armenian lexical parallels help to clarify the boundaries of the Polynesian word-form and word structure, to clarify the still very vague form-word-particle concepts, to prove the belonging of some Polynesian words of unknown origin to the Pan-Polynesian vocabulary.

And through comparison with Polynesian languages, it becomes possible to etymologically analyze Armenian words of unknown origin and considered to be misspellings, sometimes to put forward the point of view of their indigenization, to reveal the true direction of borrowing of words considered to be loanwords from different languages in Armenian, and also to correct the real, living proto-forms of some words that are already considered to be native Armenian. The latter are the words whose

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obvious patterns showing dual-plan (morpho-semantic) overlaps are found in Polynesian languages, while the restored Indo-European proto-forms show significant phonetic or semantic deviations.

Let us bring some examples:

Rapan. $huri_4$ “to turn over”, “to wrap, to twist, to shrink”, $hiro_1$ “to twist, to turn” - Grb.[1] hiṙ “turnover, circle, coil” (derived from *per-s-, *sper- “to turn, to turn around”);

Rapan. hau_5 “mild wind” - Grb. hov “breeze, canopy, wind” - (derived from the PIEL root *pou-, *p(h)u- “to blow, to swell”);

Rapan. $hagu_1$ “breathing, to breathe” – Grb. hagag; root - hag “breath, articulation” (*pouiio-, *pu “to blow”);

Rapan. tao “husband’s sister” – Grb. tal “husband’s sister” (*glōu-);

Rapan. $tara_1$ “trunk (of a tree), thorn”, $tari_4$ “name of seaweed” - Grb. taṙ “the seed or grain of a tree”, also ĉaṙ “tree” (*ǵers- “to twist, to bend, to weave from branches, bushes”, ĉaṙ < ǵrso-) (Jahukyan (2010) p. 360) etc.

Among such words is also our subject matter - the word *yerkin* recognized by G. Jahukyan as native Armenian.

The Armenian word ***yerkin*** “heaven, sky” is incomprehensibly derived from the restored Proto-Indo-European language root “*d(i)ui-n-, *dei- “to shine” with the root determinative *-u, as “shining sky”. At the same time, it is mentioned that “...there are phonetic difficulties” (which is too mild a statement), a possible homonymous effect of the word *yerkir* “earth” is assumed, and it is compared to Old Indian dyau “heaven”, divām “day”, Lith. diena “day” (Jahukyan (2010) p. 227).

At the very first glance, it is obvious that the Armenian equivalent of these words, among the parallels of different languages is the native Armenian word ***tiv*** “day, light of the day”, “light” (Malkhasiants (1944) p. 1443) mentioned by Jahukyan, which shows undeniable commonalities both in phonetic and semantic terms with the above-mentioned words.

The question arises as to what made G. Jahukyan attach the phonetically incompatible word into the Indo-European restored root *d(i)ui-n-, *dei- “to shine, to beam”. In our opinion, the following facts played a significant role here:

1) no word or proto-form was found in the restored Proto-Indo-European language and related Indo-European languages more or less phonetically and semantically close to the Armenian word *yerkinkʻ* “heaven, sky” from which it would be possible to derive the root *yerkin* and

2) the word *yerkinkʻ* is a very important component of the basic vocabulary of the language. In Armenian, it is recorded in writing in the peculiar “prelude” to the birth of the cosmos in an undated story with the conventional name “Vahagn’s birth”, which begins with the phrase “Yerkner *yerkin*...”. Such a word could not be of unknown origin or non-native, and therefore Jahukyan had to attach it to the domain of such an inappropriate proto-form, in order not to doubt the Indo-European character of Armenian.

So, what is the more or less acceptable form of the word *yerkin*? It is necessary to find the answers to such questions through comparison with the languages of other language families, which we will do below.

2. Material and methods

The word meaning “heaven” belongs to the Pan-Polynesian vocabulary: PPN[2] lani, Rapan. ragi, Maori rangi, Mang. ragi, Tuam. ragi, Tahit. raʻi, Samoan lagi, Tongan langi, etc. Generalizing, let’s note that the root meaning *yerkinkʻ* in Polynesian languages, particularly Rapanui, is known as **ragi**, or the same, in the form of rangi. the back-lingual *ng* roughly expresses the sound-combination (ng) and is replaced by the letter g in writing for reasons of simplicity. It is obvious that the Polynesian root ragi and the Armenian word for *yerkin* have a complete semantic correspondence and closeness of the phonetic plan. The presence of a large number of Rapanui-Armenian diverse commonalities

[1] Old Armenian – Grabar.
[2] PPN – Proto-Polynesian.

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creates a basis for assuming that the closest proto-form of the native Armenian word *yerkin* is the word ragi "heaven, sky" belonging to the Pan-Polynesian vocabulary.

In order to understand the phonetic changes that this word underwent, we consider it necessary to recall some phonetic patterns revealed in Rapanui-Armenian word commonalities.

2.1. Addition of a pre-sound

According to the ruling point of view, "...in Old Armenian, it was impossible to start a word with **r**, so even in borrowed words, the word beginning with **r** received **a** or **e** in front of it" (Aghayan (1964) p. 161)[3].

Examination of Rapanui-Armenian lexical parallels has revealed that this pattern of pre-sound addition also works in Rapanui-Armenian lexical parallels, which excludes the borrowing of these words.

Let us bring some examples:

Rapan. **rua** "hole, ditch", "water well" - Arm. ***aṙ*u** "water course, stream";

Rapan. **rog**o "announcement, notification" - Arm. ***aṙ*og**em "to say, to talk";

Rapan. **rer**e "to go aside", "to retreat" - Grb. ***ye*-rer** "wobble, wavering" (derived from the root ***tres-** "to tremble, to waver");

Rapan. rerarera (**rer**a-rera) "the surface of the sea" - Grb. ***ye*-rer**, of which ***ye*-reral**, ***ye*rerun** "wavering, tottering".

In exactly the same pattern, from the Polynesian word **ragi** (rangi) "heaven, sky", with the addition of the pre-sound ē *(e)* and the drop-out of the unaccented **a**, we get the form ē′rgi "heaven", which we find preserved in the Aslanbeg dialect, as well as the native Armenian word **yerkin**. In most Armenian dialects, it sounds like this: (Pl.) ērgink‘, (Agl.) e′rgink‘, yērginq, (Krb., Mrgh.) yērg;inq, (Gor.) yē′rgink‘, (Khrb.) ērginq, (Vozm.) yērkēnq, (Ant.) yrge′nq, (Asl.) ē′rgi, ē′rgink‘ etc (Acharyan (1926) vol. 2, pp. 62-63).

Thus, the Pan-Polynesian word rangi "heaven, sky" is semantically identical, and phonetically is the closest to the Armenian word yerkink‘. For this very reason, it can rightly be considered as a living proto-form of the native Armenian word *yerkin*, from which the Grabarian *yerkin* and many Armenian dialectal forms legitimately originate. Therefore, we have reason to believe that it is an archaism preserved in remote eastern islands.

Perhaps one could question this correspondence as a unique example, if other words of the same origin were not discovered in Armenian, which are also the result of regular phonetic transitions specific to Rapanui-Armenian commonalities.

2.2. Drop-out of the final sound

It is known that most Rapanui-Armenian lexical parallels are roots resulting from the regular drop-out of the final sound of the Rapanui word, for example:

Rapan. ***kit***e_2 "to see, to notice", "to know" - Grb. ***gēt/git***- "knowledgeable, knowing", "to know", "magician", derived from the root *ueid-/*uoid- "to see, to know" (Jahukyan (2010) p. 160);

Rapan. ***tek***a "to turn (around)" - Grb. ***t‘ek‘***, from which: t‘ek‘el "to bend, to change into" (from the root *tek- "to weave");

Rapan. turuturu (***tur***u-turu) "to pour drop by drop (water, liquid)" - Grb. ***t‘or*** "flowing, flow, stream, drip", from which t‘orel/t‘urel, t‘ort‘orel (derived from the root *(s)ter- "impure liquid");

Rapan. hinihini$_2$ (***hin***i-hini) "ancient, old" - Grb. ***hin*** "old", derived from the root *seno- "old" (Jahukyan (2010) p. 461);

Rapan. ***tov***a "sea" - Grb. ***ĉov*** "sea", derived with some doubts from the root *gob- (Jahukyan (2010) p. 366);

Rapan. ***tak***i$_2$ "bottom of the net", ***tak***i$_5$, taki eeve "place to sit" – Grb. ***tak*** "bottom", "under, depth" (Acharyan (1926) vol. 4, p. 360)[4] etc.

[3] It is also noted that in the dialects of the new period (? L.S.) it is borrowed in the form of rang).

[4] Considered a loan from Middle Persian assumed root *tak, Pers. tak.

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With exactly the same regularity, from the Polynesian word ***rang****i* “heaven, sky” we get the Armenian dialect (Ar., NB, Tb., Krm. Krb. Hvr. (Knd.), Shmkh., Mghr. (Krch.), Urm., Kr., Msh. (Mks.) ***ṙang***, (Ss. (Mtk.)) ***ṙng*** “color”, ***ṙangeṙang*** “multi-colored”, “pretty, patterned” (DDAL (2001) pp. 227-228) non-analyzable word ***ṙang (rang)***[5] meaning “color in general”.

It is known in many dialects of Armenian in the form of ***ṙang*** and in the sense of ***“color** in general”*, from which we have the dialectal (Tb.) *ṙangavor/ṙangavur* “colorful” (DDAL (2001) p. 228), (Krb.) *ṙang-ṙang* “multicolored, motley, variegated” (Sargsyan (2013) p. 167), *ṙang t‘aluk, ṙang t‘ṙaĉ* “pale”, “faded, discolored” (Malkhasiants (1944) p. 228), is said mainly for old multicolored rugs, carpets, clothes (DDAL (2001) pp. 227-228). It is considered a loan from Pers. rang (Malkhasiants (1944) p. 157). Taking into account the presence of Armenian-Polynesian multi-character commonalities and the chronological factor, the Armenian word **rang/ṙang**, derived from the Polynesian word **rang**i, with the well-known and active pattern of final sound drop-out, can be considered a native Armenian word.

We can be objected by reminding the ruling opinion that Armenian did not have roots beginning with ***r***. This opinion needs revision, because a number of Polynesian words beginning with ***r*** have Armenian parallels beginning with ***r/ṙ*** (and not only) in Grabar and Armenian dialects (In more detail see (Stepanyan (2015) pp. 80-86)), such as:

Rapan. ra_1 “here”, “there” - *dial.* (J.) **r**es “here is, this is”, **r**ed “there is, that is”, **r**en “there is, that is”;

Rapan. raa “sun” - *dial.* (Krb.) **r**egnak/**r**ignak “sun”;

Rapan. raega “first fruits” - *dial.* (Krb.) **r**ač‘in “first”;

Rapan. rae_1, te rae, rahe “first”, rae1, i rae “firstly, first” - *dial.* (Krb.) **r**aškan/**r**ašken “first, at first”;

Rapan. rivariva (riva-riva) “big”, “rich”, “to surpass” - *dial.* (Krb.) **ṙ**aval, which is the same as Grb. aṙavel “more, with advantage, with superiority” (Sargsyan (2013) pp. 167);

Rapan. riki, rikiriki “small” - Armenian diminutive particle -**r**ik, etc.

Thus, we consider quite possible the existence, i.e. the nativity of the word ***rang/ṙang*** “color” in Pre-Proto-Armenian, taking into account its prevalence in many and territorially distant dialects of Armenian. Our opinion is supported by the word **raku** “evening” of the Meghri dialect lacking the pre-sound ***e*** which was added to it in literary Armenian *ye**reko*** “evening”.

*In order to understand the semantic connection between **heaven** and **color**, let’s note that Polynesian color names are not only color names, but names of the objects bearing it. For example, the signifiers of green color are associated with the meanings of “young and tender plant, small, young”.*

*Pan-Polynesian **mata** “green” and “sprouting plant”, Rapan. $mata_3$ “green” and “unripe (fruit)” , “juvenile, immature, green”, $mata_9$ “fruit, embryo”, Samoan moto “green” and “young”, Tonga mata “green” and “unripe (fruit)”, Maori mata “fresh plants”, which correspond to the dialectal Armenian (Ar., Hvr.) **mat** “excess parts of the grape vine that are pruned”, from which the native Armenian **matał** “young, baby calf” (*mad- “wet., damp, to drip, juicy, rich, well-fed”)(Jahukyan (2010) pp. 513). Acharyan, relying on Slavic parallels (Old Slavic: mladu, (young)), derives it from the root *mel- “to grind” with the root-determinative *d- and its change (Acharyan (1926) vol. 3, p. 267).*

*A similar alternation of the words denoting colors and objects is also present in Armenian. Let’s give one example. G. Jahukyan believes that “it is possible that the word **dalar** was used in ancient times not only for greens, but also for the color green itself” (Jahukyan (1987) p. 270). In our opinion, G. Jahukyan is absolutely right: the root **dal** of the Armenian word **dalar** originates from the native Armenian word **tal** (derived from *dhel) with the sonorization of **t**. Its ancient form is preserved in the Rapanui word **tar**a_1 “trunk of a tree”, “thorn” with the alternation (r>l). It is identical to the Armenian dialect (Krb.) root **tal** “tree branch”, from which we also have dial. (Krb.) words talar, telar, tilar “young, fresh” (Sargsyan (2013) p. 707). As we can see, even the Polynesian words denoting an object of the given color have native Armenian parallels.*

*Since the sky (heaven) is the area where various colors change each other continuously during the day, also in the blue sky you can see a parade of white, gray, black, yellow, red clouds, then the word **ragi** “sky, heaven” could rightly be understood as meaning both the concept of “sky” and the concept*

[5] Rapanui lacks the (**ṙ**) sound, but in the Rapanui-Armenian parallels there is a Rapanui r - Armenian ṙ correspondence.

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*of "color in general". The proof of the aforesaid can be considered the Rapanui word ragi-ragi (**rangi-rangi**) "heaven, sky". Its literal parallel is the Armenian dialectal (Ar., Tb., Krb.) word **rang-rang** "multicolored, colorful".*

According to the above-mentioned regularity of adding the pre-sound **e**, from the Polynesian word **rangi** "heaven" we also get the Armenian ***yerang*** "color, paint"; in the modern literary language, the word with the meaning "shade, subtle difference", from which we have yerang-yerang "colorful", yeranganerkut'yun, yerp'nerang, bazmerang or bazmerank, karmrerang. It is considered a loan from an Iranian source, and is compared to Parth. rang, Mid. Pers. and Pers. rang (Acharyan (1926) vol. 2, p. 39; Jahukyan (1987) p. 270; Jahukyan (2010) p. 221). It is also noted that in the dialects of the new region (?) it is borrowed in the form of rang (interrogative: L.S.). Acharyan brings the following parallels to the latter: Phl. rang, Pazend. rang, Pers. rang, arang, ranǰ, Kurd. reng, renk, Afghan. Beluj. rang, Sanskr. ran′ga, all with the meaning "color" (Acharyan (1926) vol. 2, p. 39). As we can see, it is widely used in various languages of a vast region.

3. Results

Thus, the most likely proto-form of the native Armenian word *yerkin* "heaven, sky" is the word ***ragi (rangi)*** "heaven, sky" preserved in the Pan-Polynesian lexicon, from which the Armenian words ***yerkin***, ***ṙang/rang*** and ***yerang*** are obtained as a result of regular phonetic alterations. According to the accepted opinion, the first of these words derives from a phonetically and semantically unconvincing proto-form, the second and third are considered borrowings from Iranian languages.

A living and close archetype of these Armenian words is found in the ancient Polynesian languages, which are estimated to be 50 000 years old or more. The chronological factor, the presence of Armenian-Polynesian diverse (toponymic, mytho-onomastic, lexical, grammatical) commonalities, the phonetic regularities revealed in the Rapanui-Armenian lexical commonalities and particularly in the above-mentioned words

a) prove the nature of these words as having the same root, the same origin;

b) allow to substantiate the native Armenian origin of the latter and

c) determine the actual direction of borrowing from Armenian to other languages.

Through the Pan-Polynesian word ***ragi (rangi)*** "heaven, sky", a genealogical bunch of words is revealed in Armenian, of which, due to the lack of space and time, only three have been presented in this article.

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Moon in the Poetry of Misak Metsarents and it's Lingual-stylistic Features

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Abstract

Celestial bodies, luminaries and phenomena have accompanied mankind since time immemorial. Heavenly luminaries have been an inexhaustible source of inspiration for poets. Creators praised creation, marveled at the beauty of luminaries, perceived man as a part of nature and in inseparable connection with all other elements. Heavenly bodies and phenomena have often served as a way to reveal the inner world of a person, his past path, hopes and expectations for the future. In this sense, Western Armenian lyric poetry of the beginning of XX century is not an exception. The mentioned topic received remarkable comments in the work of Siamanto, Daniel Varoozhan, Ruben Sevak, especially Misak Metsarents. Celestial bodies, luminaries and phenomena are a significant number in Metsarents' poetry have a great stylistic role. One of these the noun moon and its various synonyms, which very often become the core and body of the poetic image, endow the speech with incomparable nuances, beauty and originality, causing the reader the greatest aesthetic pleasure, transporting him to an extraterrestrial light sphere [1].

Keywords: *Misak Metsarents, celestial body, luminary, moon, full moon, crescent, people, nature, poetry.*

1. Introduction

Celestial bodies, luminaries and phenomena have accompanied mankind since time immemorial. One of the oldest written testimonies about the luminaries is found in the first pages of the Bible, during the history of creation, in the book of "Genesis". "The God made two great lights- the greater light to govern the day and the lesser light to govern the night. He also made the stars" (Bible).

Heavenly luminaries have been an inexhaustible source of inspiration for poets. Creators praised creation, marveled at the beauty of luminaries, perceived man as a part of nature and in inseparable connection with all other elements. The great poet of the Middle Ages, St. Grigor Narekatsi, wrote in "Vardavar Tagh". "They got engaged gradually, The stars come and go, They took the moon in bunches, And all over the arch of the sky They radiated in groups" (Armenian Ancient and Medieval Lyric Poetry, 1987, 114, word for word translation).

Heavenly bodies and phenomena have often served as a way to reveal the inner world of a person, his past path, hopes and expectations for the future. In this sense, Western Armenian lyric poetry of the beginning of XX century is not an exception. The mentioned topic received remarkable comments in the work of Siamanto, Daniel Varoozhan, Ruben Sevak, especially Misak Metsarents.

2. Lingual-stylistic Features of Moon and its Synonyms in the Poetry of Misak Metsarets

A lot has been said and written about the famous lyricist Misak Metsarents being a nature-loving author, and it is a fact that a large part of his poems are dedicated to the description of nature. In these descriptions, heavenly luminaries, bodies and phenomena have their special place, and this is not accidental,

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[1] https://www.bible.com/bible/111/GEN.1.NIV, https://en.wikipedia.org/wiki/Sonnet_61

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but has a clear purpose. In a letter addressed to his sister's husband, priest Vardan Arslanyan, Metsarents, responding to the latter's request, reveals this very important feature of his work. "I read the letter written on the occasion of "Rainbow" and was even once more touched . You write: "Why don't you talk to the Soul of the universe?", but it can be observed that almost all of my works yearn towards that great conversation, no matter how much it is not a face to face conversation with God, but isn't God everywhere? My prayer in the Clear Winter Night and my prayer to the Sun were for them, therefore also for Him. What a happiness, to see the secret of the cosmic power in the corner of a leaf and from this little detail have a journey to infinity" (Metsarents, 1981, 288, Henceforth, pages of quotations from this book will be indicated in parentheses next to the essay, word for word translation).

Let's turn to the facts, which are more than talkative. The noun "Sun" is one of the most frequently occurring words in Metsarents' lyric poetry: it is used 62 times in the entire verse (Arakelyan, 2008, 28), the word "Star" is used four times, and "Meteor" - twice. The Moon has fourteen uses throughout the verse, in addition to which there are synonyms of the word: full moon, crescent, half-moon, used both literally and figuratively.

Let's recall some of them. In the poem "Song", the author used the trick of animation. Animation arises when "inanimate objects breathe, we attribute to them special characteristics of animals or humans, to inanimate objects and animals - intelligence and the gift of speech" (Poghosyan, 1991, 185).

In the poem, the night luminary is depicted as a beauty whose silvery face reflection brings peace and pleasure: "The moon it's silvery face in the mirror of the gentle stream" (133). But the changing course of the world darkens the idyllic mood, and change leads to sobriety and sadness: "The moon fades in the darkness, the stream loses its voice and disappears" (133).

In another poem, "Irrevocable," the moon is part of a metaphor, again in the context of the respiration and humanization of nature; "The indifferent splash of water falls thread by thread into the mist, a pair of arms of the stream stretched out into the moonlight, and the surrounding area becomes a voluptuous greedy" (91).

Metsarents sketches the image of the moon in the poem "To My Dear Sister Moon". Who, after all, is the night luminary? Is it an unattainable beauty, whose "distant charms" are enough to give the greatest joy, or is it a desired sister, whom you will reach even if she is "hidden behind a cloud"?

The essence of the moon is in the close connection with the theme of the night, which was also in the center of the author's attention. In the article "An attempt of self-criticism as regards "Rainbow"" he wrote: "Isn't it in the night, that dreams have brighter and faster flights? In the night, when the magnificent view opens up, and expectation is so delightfully poignant" (242).

The charm of the night is largely associated with the moon, as: "And I looked at the other side of the flower garden, at the blue lilacs, and the moon was stretching out her beautiful, coquettish, careless wrist ..." (128).

The luminary is not cold and lifeless, but has spirit and soul, taking part in one's emotional state. The moon is a relative, the moon is a sister, its light dispels not only the material darkness, but also the darkness of the soul, it gives happiness, a sense of harmony, inspiration to create. And certainly "nature... serves the poet as a mean to show a fragment of human life, to reveal a line of character, a fold of the soul" (Papoyan, 1970, 252).

In the poem "To my Dear Sister Moon" the crescent is used twice, the full moon - once, the moon - three times, we are actually dealing with a beautiful example of synonymous repetition. "Synonyms always have also non-matching elements, either in objective-logical meaning or in connotation. Therefore, synonymous repetition provides an opportunity to more fully and comprehensively identify and describe the subject" (Arnold, 1973, 130).

In world literature, we find a vivid example of synonymous repetition in Shakespeare's sonnet LXI,

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where the poet talks about his love and the insomnia born of that love. Shakespeare used many synonyms to describe insomnia more accurately, such as: keep open my heavy eyelids, my slumbers should be broken, keep mine eye awake, doth my rest defeat, to play the watchman, for thee watch I (Sonnet 61).

In the works of Metsarents, the moon and its synonyms received many epithets. Epithet is a determinant that characterizes an object or phenomenon aesthetically, and its role is great in terms of style. Sometimes the adverbial moon received several epithets that beautified the speech, enriched it with delicacy, tenderness, made it more poetic, as in the poem "Paper". "And the pleasant, sweet, kind, moon sends a ray of light through the curtain, which falls directly into the girl's hands, to light up the paper, which is still whispering..." (171).

The moon has also received voluminous epithets. In the poem "New Year", the old men and children eagerly await the arrival of the new year, full of new hopes and expectations. The moon is consistent with their emotional state, which seems to be a New Year's gift and a sign of the fulfillment of beautiful expectations. "New year's gift bright moon decorated all the mountains in the village. The songs of the old man, the cries of the children echo strongly with stray notes" (16).

The noun Crescent is synonymous with the moon or half moon and is used as such in the author's verse, as: "Golden crescent, tonight I shivered again in your blissful light" (130). In another instance, the moon and the crescent are used side by side as one of the other's attribute: "When the crescent moon gently shads it's liquid, rain-like slide of light on the steps..." (72). Reading these and similar lines of masterpiece of art, it is appropriate to remember the words of the famous linguist Charles Bally: "It's more difficult catch and characterize the emotional coloring of the expression rather than its logical content" (Bally, 1961, 185).

Misak Metsarents' lyric poetry has always been considered apolitical, but careful examination shows that especially in recent period, he was extremely concerned about the fate of his homeland and his people. The cozy poem "Song", as well as the fragments preserved from those verses, which for obvious reasons were not published in time and remain unknown to the reader today testify about it. In one of these fragments, the moon is also present, but in a completely different context, with a different coloring, with a different emphasis. "The moon was the suffocated eye of my homeland" (191).

It is interesting that the moon in the context of national pain is also reflected in the works of another Western Armenian poet of the early 20th century, Daniel Varoozhan. In the poem "A Letter of Longing", Varoozhan addresses a very painful and relevant topic of his time and even today: the wandering. As a result of emigration of the masculine population, particularly young men, the Mother land loses defenders and working people, families and parents lose their support, and young girls are left alone. The poem describes the sufferings of a mother, whose son wanders in unknown worlds. The mother is waiting impatiently for her son's return, experiencing the bitter agony of loneliness, and, as surprising as it may seem, only the moon is beside her, full of grief and compassion.

I wait in vain for your return every night,

I watch the brave men pass by our door.

The farmer passes by, so does the shepherd,

Lonely I remain, the moon and I (Markarian, 2015,162).

In the works of Metsarents, the moon is also present in the translations. Metsarents started to make translations from his teenage years, in parallels his first steps in the literary arena. Translated works of popular authors: Chaucer, Kipling, Peacock, Field, Wilde, Mamin-Sibiryak and others, both in prose and verse. Among the writers mentioned, Eugene Field is an American poet known for his children's poems. Metsarents translated his poems "Little Blue Boy" and "Danish Lullaby". The characters of this lullaby are fairy-tale fishermen sailing in wooden shoe. When asked by the old moon where they are going and what they want, the little fishermen answer that they have come to catch herrings. They add that they have gold

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and silver nets. And as an answer to it:

The old moon laughed and sang a song

As they rocked in the wooden shoe,

And the wind that sped them all night long

Ruffled the waves of dew (Field).

3. Conclusions

Of course, the use of the word moon and its synonyms in the poetry of Misak Metsarents is not limited to the mentioned. They are very diverse and multifaceted, and unfortunately we could not cover them all within the scope of one article. It is undeniable, however, that these units very often become the core and body of the poetic image, endow the speech with incomparable nuances, beauty and originality, causing the reader the greatest aesthetic pleasure, transporting him to an extraterrestrial light sphere.

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ArAS educational activities: history and statistics

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Abstract

A review of ArAS Educational activities is given. ArAS initiated a number of projects and events related to Astronomical Education, teacher training, as well as public activities. Among the most important are: Byurakan International Summer Schools (BISS, since 2006, 9 such schools have been accomplished), Regional Astronomical Summer Schools (RASS, since 2019, 3 such schools have been accomplished), Byurakan Summer Schools for YSU students (BSS, since 1995, 5 such events have been accomplished), ArAS School Lectures *"From School to the Space"* (since 2012, 11 projects have been organized), Byurakan Science Camps (BSC, since 2014, 10 events have been organized), Armenian Republican Astronomical Olympiads final phase (since 1999), a number of astronomy teacher training programs (since 2010, in total 9 events) and others. The history and statistics of all these events are presented.

1. Introduction

Among all ArAS activities, those related to Astronomy Education have been especially productive. Astronomy Education is in general one of the main ArAS goals and tasks. Since its foundation, ArAS has been active in organizing various events and running many projects. Astronomical Olympiads are among the first ones; we started these events in 1995 and then, in 1999, they were officially recognized by the Armenian Ministry of Education and Science and ArAS became the Official representative of the International Astronomical Olympiads (IAO) in Armenia. We have contacts and relations with a number of other international organizations and projects, such as Galileo Teacher Training Program (GTTP), Network for Astronomy School Education (NASE), and, most important, the International Astronomical Union Office of Astronomy for Education (OAE). Here we describe the most important and regular projects, both for students, pupils and teachers. Many other projects are also active. ArAS Astronomy Education webpage gives most of the relevant activities (https://www.aras.am/Education/education.html).

2. Astronomical Olympiads

Astronomy at school in Armenia was taught for many years (however, in 2009, it was included in the course of the 9^{th} year Physics). Two attempts to organize Armenian National Astronomical School Olympiads were made in early 1980s. Then, in 1995, we tried to initiate regular Olympiads in Armenia. At that time, it was organized by ourselves at BAO. And only in 1999, the Armenian Ministry of Education and Science officially included Astronomical Olympiads in its school Olympiads program. During all these years, these annual competitions for revealing gifted pupils in astronomy are organized by the Ministry in collaboration with ArAS, BAO and Yerevan Physical-Mathematical School. The country winners successfully participate and win prestigious prizes in the international astronomical Olympiads as well. Late *Dr.* A. V. Oskanian was the person who raised the Armenian school astronomy to a very high level, so that Armenian pupils won a number of high ranked prizes at International Astronomical Olympiads (IAO). Other people that contributed in the preparation of Armenian pupils and organizations of astronomical Olympiads were and are: *Dr.* V. S. Airapetian, A. E. Grigoryan, *Dr.* A. M. Mickaelian, *Dr.* M. V. Gyulzadyan, *Dr.* A. A. Hakopian, *Dr.* S. E. Nersisyan, *Dr.* H. A. Harutyunian, *Dr.* T. Nazaryan, V. Mambreyan and others. ArAS is the official representative of the Armenian Olympic team at the International Astronomical Olympiads (IAO), A. V. Oskanian and M. V. Gyulzadyan have been members of the Council of IAO. There are three kinds of International and Regional Olympiads where Armenian pupils participate:

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- Commonwealth of Independent States (CIS) Astronomical Olympiads
- International Astronomical Olympiads (IAO)
- International Olympiads on Astronomy and Astrophysics (IOAA)

Our pupils are the best among all subject Olympiads in Armenian teams. On the other hand, they are among the best teams among all countries at International Astronomical Olympiads. We have won 10 I rank, 10 II rank, and 20 III rank prizes, totaling to 40 prizes.

3. Byurakan Summer Schools (BSS) for YSU students

The first attempt to organize Byurakan Summer School (BSS) for Yerevan State University (YSU) Physics Faculty students (considering some of them as future astronomers) was made on 20-28 August 1995. This event was joint with the Republican School Astronomical Olympiad final stage so that the pupils could interact with the students. Then, since 2005, the event became more or less regular and II-IV schools were organized in 2005, 2009 and 2013. It was supposed to make the event with 4-year periodicity, however, not always it was possible. The last such event, which was this time a winter school, happened in 2022.

Here we give the list of the BSS with the main data.

BSS	Year and Date	Participants	Comments
1BSS	1995.08.20-28	36 students and pupils	Joint with Republican School Astronomical Olympiad final stage
2BSS	2005.08.22-30	14 students, mainly BSc level	Attached to ArAS IV Annual Meeting
3BSS	2009.07.01-08	YSU students of BSc level	Attached to ArAS VIII Annual Meeting
4BSS	2013.08.19-23	15 students from Physics and Radiophysics Faculties and 25 students as IAU S304 LOC supporting team	Combined with IAU Symposium #304 training for LOC supporting team
5BWS	2022.02.26-27	20 students from YSU Physics Faculty 1^{st} course	The 5^{th} Byurakan Winter School for YSU students

4. Byurakan International Summer Schools (BISS)

The idea to organize international summer schools at BAO goes back to 1987, when on V. A. Ambartsumian's and Richard West's initiative a single event was organized between BAO and ESO. It was an International School for Young Astronomers with a topic *"Observations with Large Telescopes"*, organized jointly by ESO and the Byurakan Astrophysical Observatory on 22-28.09.1987. Unfortunately, the idea to make it regular was not continued due to the disintegration of the Soviet Union. After thorough discussions and preparations, we could start the series of the Byurakan International Summer Schools (BISS) in 2006, with a 2-year periodicity. It was Prof. Daniel Weedman who supported a lot and finally we made it happen. 32 students from Russia, Ukraine, Iran, Georgia, Jordan, Italy, Serbia, Romania and Armenia participated in 1BISS, as well as 14 lecturers from USA, Germany, France, Italy, Russia and Armenia and the school was great success. Only once, in 2014, we missed this event. Otherwise, it is almost 20 years that we conduct these schools. One, in 2010, the 3BISS, was combined with the IAU 32^{nd} International School for Young Astronomers (ISYA). Several records were registered for ISYAs; the 32^{nd} ISYA had 117 applications, 21 countries were represented and there were 56% female participants (maximum numbers for all ISYAs). As it was announced at the IAU General Assembly in Vienna by the IAU Division C President *Prof.* John Hearnshaw, BISS are among the top-3 world astronomical summer schools (the 2 others are ISYA and VOSS – Vatican Observatory Summer Schools). The analysis was made based on the regularity, duration, number of accomplished events, numbers and level of students and lecturers, the program, represented countries, etc. It is worth to mention that Nobel Prize Winners, IAU President, V. Ambartsumian International Science Prize Winners and other outstanding scientists have been among BISS lecturers, among them Michel Mayor, Jayant Narlikar, Igor Novikov, Robert Williams, Daniel Weedman, Yervant Terzian, Jaan Einasto,

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Ajit Kembhavi, Daniel Kunth, Gennady Bisnovatyi-Kogan, Michel Dennefeld, et al. In total, 141 lectures and 42 tutorials were given during all events, as well as 94 students' short presentations.

Here we give the list of the BISS with the main data.

BISS	Year and Date	Participants	Comments
1BISS	2006.08.26-09.03	32 students from 9 countries and 14 lecturers from 6 countries	Attached to BAO 60th anniversary meeting
2BISS	2008.09.20-30	31 students and 13 lecturers	Dedicated to V. A. Ambartsumian's 100th anniversary
3BISS	2010.09.12-10.02	48 students from 19 countries, 19 lecturers from 8 countries	Combined with the IAU 32nd ISYA
4BISS	2012.09.15-23	36 students, 15 lecturers	Dedicated to Anania Shirakatsi's 1400th anniversary
5BISS	2016.09.12-23	27 students, 15 lecturers	Attached to BAO 70th anniversary meeting
6BISS	2018.09.10-15	32 students and 11 lecturers	Attached to V. A. Ambartsumian's 110th anniversary
7BISS	2020.09.07-11	50 students and 12 lecturers	Virtual. Attached to the International Symposium *"Astronomical Surveys and Big Data 2"*, also virtual
8BISS	2022.09.12-16	36 students and 12 lecturers	Virtual. Attached to the International Conference *"Space Sciences and Technologies"*
9BISS	2024.09.09-13	30 students and 10 lecturers (expected)	Attached to the 4th Regional Astronomical Workshop

Figure 1. Group photo of 1BISS students and lecturers and 3BISS participants near BAO 2.6m telescope.

5. ArAS School Lectures *"From School to Space"*

In 2012, ArAS initiated a major program of visiting Armenian schools by professional scientists from BAO for astronomical lectures. During the first years, Yerevan, Armenian Provinces and Artsakh were included and later on the main emphasis was put on the Armenian Provinces, as well as Artsakh. ArAS and BAO collaborated with the RA Ministry of Education and Science and/or RA Provinces administrations for the selection of the schools and during the recent years, we make announcements and receive applications directly from the schools. The interest from the schools is rather high; in 2023, 132 schools expressed a wish to organize such lectures. Along with the interactive lectures, astronomers distribute books and

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promotional material to the schools, very often – small telescopes. Areg Mickaelian, Haik Harutyunian, Hovhannes Pikichian, Ararat Yeghikyan, Ruben Andreasyan, Grigor Brutean, Susanna Hakopian, Marietta Gyulzadyan, Elena Nikoghosyan, Hayk Malkhasyan, Avetik Grigoryan, as well as young scientists Naira Azatyan, Hasmik Andreasyan, Hayk Abrahamyan, Gohar Harutyunyan and Sona Farmanyan have been lecturers of the program. They typically make presentation on the topic *"Our Understanding of the Universe: from Ancient Times to Nowadays"*, as well as several other topics. They also distribute feedback forms to collect info on the pupils who are most interested in astronomy and wish to maintain further contacts with astronomers. The Fund for Armenian Relief (FAR), *Prof.* Yervant Terzian, *Dr.* Noretta Andreasyan-Thomas and several other sponsors have been supporting this program during all these years. Areg Mickaelian is the Manager of this program and Sona Farmanyan is the Coordinator.

Here we give the list of all ArAS School Lectures with the main data.

SL #	Year and Dates	Schools	Lecturers	Comments	Sponsors
I	2012.11.07-30	30	8	Yerevan and RA Provinces	Yervant Terzian and Araxy Bablanian (USA), Yeran Tchelikjian (Canada)
II	2013.05.06-07	10	3	Artsakh	Yervant Terzian (USA) and Artsakh Ministry of Education and Science
III	2014.10.28-31	30	7	Yerevan and RA Provinces	Yervant Terzian and Araxy Bablanian (USA), Yeran Tchelikjian (Canada)
IV	2016.11.21-25	27	6	Yerevan and RA Provinces	FAR
V	2018.05.01-24	30	5	RA Provinces and Artsakh	Nora Andreassian-Thomas
VI	2019.04.01-05.15	20	4	RA Provinces	FAR, BAO
VII	2020.12.01-20	23	3	RA Provinces	FAR, BAO
VIII	2021.04.15-05.31	30	5	RA Provinces	FAR, BAO
IX	2022.04.01-29	30	6	RA Provinces and Artsakh	FAR, BAO
X	2023.04.04-27	33	5	RA Provinces	FAR, BAO
XI	2024.04.03-26	30	4	RA Provinces	FAR, BAO

6. Byurakan Science Camps (BSC)

The series of the Byurakan Science Camps (BSC) was initiated by Sona Farmanyan in the frames of ArAS educational activities in 2014. It is intended for extracurricular education and attracting interest to young generation, typically pupils of 10-15 age (slightly different from year to year). During the schools, a very extended program is offered to the participants: meetings with famous people (writers, poets, composers, artists, scientists), lectures (on Astronomy, related and other sciences), tutorials, night observations, acquaintance to the night sky (constellations and bright stars), cognitive excursions in BAO, visits to other research institutions, visits to Armenian sightseeing around Byurakan (Amberd Fortress, Tegher Monastery, Aghdzk Armenian Kings Cemetery, Monument to Armenian Alphabet, Saghmosavank and Ohanavank Monasteries) and in Byurakan village, films, intellectual games, competitions, sports and leisure. Several times robotics courses were held and small rocket launch was performed for the participants. The topics of the lectures are related to the importance of science for the society, our understanding of the Universe, different astrophysical topics, archeoastronomy and cultural astronomy, etc. During the Closing Ceremony, all participants get prizes and gifts: small astronomical telescopes, books on astronomy and other topics, sports items, games, etc. Areg Mickaelian is the Manager of this program and Sona Farmanyan is the Coordinator.

Here we give the list of all BSC with the main data.

BSC	Year and Dates	Participants	Sponsors
1BSC	2014.10.19-25	28 pupils, 10 lecturers	ArAS

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2BSC	2015.10.25-31	18 pupils, 9 lecturers	ArAS
3BSC	2016.08.22-27	27 pupils, 10 lecturers	FAR, ArAS
4BSC	2017.08.21-26	23 pupils, 12 lecturers	FAR, BAO
5BSC	2018.07.03-09	51 pupils, 6 lecturers	Nora Andreassian-Thomas
6BSC	2019.07.07-12	30 pupils, 6 lecturers	Stepan Gishian Fund
7BSC	2021.10.24-30	30 pupils, 6 lecturers	FAR, BAO
8BSC	2022.07.25-31	40 pupils, 7 lecturers	FAR, BAO
9BSC	2023.07.16-22	26 pupils, 6 lecturers	FAR, BAO
10BSC	2024.06.02-09	30 pupils (expected), 10 lecturers	FAR, BAO

Figure 2. Group photo of 4BSC (left) and observations of the Sun with a Solar filter at 5BSC (right).

7. Teacher Training Programs (TTP)

A number of Teacher Training Programs have been accomplished in Byurakan. These were in collaboration with the Galileo Teacher Training Program (GTTP), due to a joint Polish-USA project by Ewelina Gradzka and in frame of the Network for Astronomy School Education (NASE). At present we also work with the IAU Office for Astronomy Education (OAE). GTTP was initiated during the International Year of Astronomy (IYA-2009), when Armenia joined the international project. Rosa Doran is the international Coordinator. We have organized one event for the teachers in 2010 and the second one is planned for 2024. On the other hand, GTTP awards Galileo Teachers Certificates to most active teachers and those teaching with novel methods. NASE events were organized in 2019, 2023 (virtual) and 2024. These are training courses for astronomy teachers with extracurricular activities and methods. Rosa Maria Ros (Spain) is the chair of this program. The OAE was established in 2019 in Heidelberg, Germany. Armenia participates in its activities with its National Astronomy Education Coordinators (NAECs). The Teacher Training Event in 2024 will be a joint one between OAE, GTTP and NASE.

Here we give the list of all Teacher Training Programs with the main data.

Program	**Year and Dates**	**Coordinator**	**Description**
GTTP Course	2010.08.19	Rosa Doran, Areg Mickaelian	Physics/Astronomy Teachers Training, 24 teachers from 16 schools
GTTP Certificates	2011-2023	Rosa Doran, Areg Mickaelian	Annual Certificate Award to most active teachers and those teaching with novel methods

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Under Armenian Sky	2018.07.29-08.02	Ewelina Gradzka, Sona Farmanyan	Teacher Training Program for Astronomy teachers
Young Explorers Club	2018.10.06-07	Ewelina Gradzka, Sona Farmanyan	Teacher Training Program for Primary School teachers
Young Explorers Club	2019.04.13-14	Ewelina Gradzka, Sona Farmanyan	Teacher Training Program for Primary School teachers
Under Armenian Sky	2019.04.19-21	Ewelina Gradzka, Sona Farmanyan	Teacher Training Program for Astronomy teachers
NASE	2019.05.05-08	Rosa Maria Ros, Areg Mickaelian	Training Program for Yerevan State Pedagogical University students
NASE	2023.06.05-30	Rosa Maria Ros, Arus Harutyunyan	Teacher Training Program for Astronomy teachers (Virtual)
OAE/GTTP/NASE	2024.07.23-26	Sona Farmanyan, Lilit Darbinyan, Areg Mickaelian	Teacher Training Program for Astronomy teachers

8. GTTP Certificates

ArAS agreed with the International Project *"Galileo Teachers Training Program"* (GTTP) to award Certificates to those Armenian teachers who are actively involved in educational activities and/or have introduced novel methods in Astronomy Education. *Prof.* Rosa Doran (Portugal) is GTTP International Coordinator and Areg Mickaelian is the Armenian one.

During 2011-2023, there were in total 13 awards, including 7 times awarded to 2 persons; in total 20 recipients. Among them there are BAO Astronomers and PR Department Members, teachers and educators. Here are all Galileo Teachers:

BAO: Hayk Abrahamyan (2015), Levon Aramyan (2016), Naira Azatyan (2022), Marietta Gyulzadyan (2011), Ashot Hakobyan (2014), Arus Harutyunyan (2019), Gor Mikayelyan (2019), Varduhi Mkrtchyan (2023), Tigran Nazaryan (2011), Sergey Nersisyan (2014), Gayane Baleyan (2022), Ani Davtyan (2021), Sona Farmanyan (2016).

Others: Educators, Teachers, et al.: Avetik Grigoryan (Yerevan, Ayas, 2012), Robert Sargsyan (Yerevan, 2013), Vardges Mambreyan (Yerevan Phys.-Math. School, 2018), Armine Patatanyan (Yerevan, Teacher, 2017), Kristine Mkrtumyan (Syunik, Teacher, 2018), Lilit Hovhannisyan (Gyumri, Teacher, 2023), Ewelina Gradzka (Poland, 2020).

The distribution by countries is such: Armenia – 19 (BAO – 13), Poland – 1, and the gender distribution is Male – 9 and Female – 11.

9. Summary and Conclusion

Among other educational programs not described in this paper there are:

- Regional Astronomical Summer Schools (RASS), since 2019, every 2 years, in total 3 schools have been organized, Program Coordinator – Areg Mickaelian
- Byurakan Summer School for Artsakh students (BSSA), once in 2022
- Byurakan Science Camp for Artsakh pupils (BSCA), once in 2022
- Byurakan Summer School for Engineers (BSSE), once in 2021
- Mathematical Camp for Artsakh pupils, since 2021, 3 events organized, Coordinator – Gaiane Panina (Steklov Mathematical Institute, Moscow, Russia)
- International Astronomical Olympiads Armenian team training, since 1999, Coordinator – Marietta Gyulzadyan

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- YSU Physical Faculty 3^{rd} year students practice in BAO, organized jointly by YSU and BAO, Coordinator – Emilia Karapetian
- *"My Universe"* essays contest for Shamshadin region pupils, since 2016, 4 events organized so far, Coordinator – Sona Farmanyan, Supported by FAR
- *"World of Knowledge"* essays contest, 2021, 1 event organized, Coordinator – Sona Farmanyan, Supported by FAR
- E-ROAD & SWCA ROAD Erasmus+ *Project Writing and Management*, 2023-2024, Coordinator – Sona Farmanyan
- Royal Astronomical Society (RAS) Educational Project *"Our Unstable Universe"*, 2021-2022, Coordinator – Armine Patatanyan

Acknowledgements

The authors are thankful to the Armenian Astronomical Society (ArAS), Byurakan Astrophysical Observatory (BAO), RA National Academy of Sciences (NAS RA) and the IAU South West and Central Asian Regional Office of Astronomy for Development (IAU SWCA ROAD).

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Links

IAU: https://www.iau.org/

IAU OAE: https://astro4edu.org/

GTTP: https://galileoteachers.org/

NASE: https://www.naseprogram.org/

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Scientific (Astro) tourism activities in Armenia and in South West and Central Asian region

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IAU South West and Central Asian Regional Office of Astronomy for Development (SWCA ROAD)

Abstract

Scientific Tourism activities have been initiated in a number of countries during the recent decades. Armenia was among the first countries developing Scientific Tourism and most probably the first to develop Astro Tourism. We were the first to introduce the term "Astronomical Tourism" (or "Astro Tourism"). This includes visits to astronomy-related sites (astronomical observatories, astronomical institutes, astronomy-related university departments, ancient sky/astronomy-related sites, medieval universities, planetariums, space/astronomy museums, etc.) but not only. The organization of astronomical meetings, schools, camps and other events with involvement of many visitors, we also consider as Astro Tourism activities. We give an overview of our activities, including the main project; development of Astro Tourism in the SWCA region. A detailed study of Astro Tourism sites in Armenia, Georgia, Iran, Kazakhstan, Tajikistan, Turkey and (in addition) Uzbekistan was carried out, namely, modern astronomical observatories and institutes, ancient astronomy-related sites, medieval universities, planetariums, astronomy/space museums, etc. A webpage was built representing Astro Tourism in SWCA region. We also discuss the Scientific Tourism and Tourism in general as disciplines for studies and not only as service. We will share our experience on Scientific/Astro tourism activities and discuss how different items may be implemented in different regions.

1. Scientific (Astro) Tourism Initiatives and Activities in Armenia and in South West and Central Asia

We have started Scientific (Astro) tourism activities in 2009, since the International Year of Astronomy (IYA-2009). It was one of our main initiatives. Several projects have been accomplished, including the webpage of the Byurakan Astrophysical Observatory (BAO) as a scientific tourism centre (www.aras.am//BAO/SciTourism/eng), BAO visits page (https://www.bao.am/visits/tours.php) and those funded as IAU OAD projects (http://iau-swa-road.aras.am/eng/AstroTourism/) and IAU-100 projects (http://astrotourism.aras.am). We have accomplished the following activities:

- Developing the vision and the strategy of the Scientific Tourism
- Seminars on Scientific Tourism for scientists and tourism representatives
- Cognitive tours to Scientific Tourism sites for representatives of Travel Agencies
- Scientific Tourism Conferences in BAO, Armenian Institute of Tourism (AIT) and elsewhere
- Building of Scientific and Astro Tourism webpages
- Printing a map of Armenia with Scientific Tourism sites, *"Armenia – Land of Science"* (where 4 types of sites are given: 1) ancient sites, 2) medieval universities, 3) astronomical observatories/institutes, 4) planetariums/museums)
- Screening a film about Scientific Tourism sites in Armenia
- Opening Scientific Tourism Chair (the 1st such Chair) at AIT
- B.Sc. and M.Sc. theses on Scientific Tourism by students

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- Talks at different science/astronomy meetings on the Scientific Tourism
- Articles on the Scientific Tourism in scientific and popular journals

We collaborate with Tourism related organizations in Armenia, namely RA Ministry of Economy Tourism Committee, Armenian Tourism Federation, Armenia Tourism Board, Armenian Tourism Development Agency, Armenian Tourism Development Foundation (ATDF), Armenian Institute of Tourism (AIT, a branch of Russian International Academy of Tourism), Union of Incoming Tour Operators of Armenia and The Armenian Guides Guild (AGG).

2. Scientific (Astro) Tourism Items and Sites

We classify the Scientific (Astro) Tourism items and sites as follows:

- Astronomical/Astrophysical Observatories
- Astronomical/Astrophysical and Space related Institutes
- Related University Departments/Faculties/Chairs
- Space Centers
- Ancient Observatories and Sites
- Sun/Fire Temples
- Sundials
- Astronomical Rock Art / Petroglyphs
- Astronomical/Space Museums
- Planetariums
- Science Cities / Science Centers

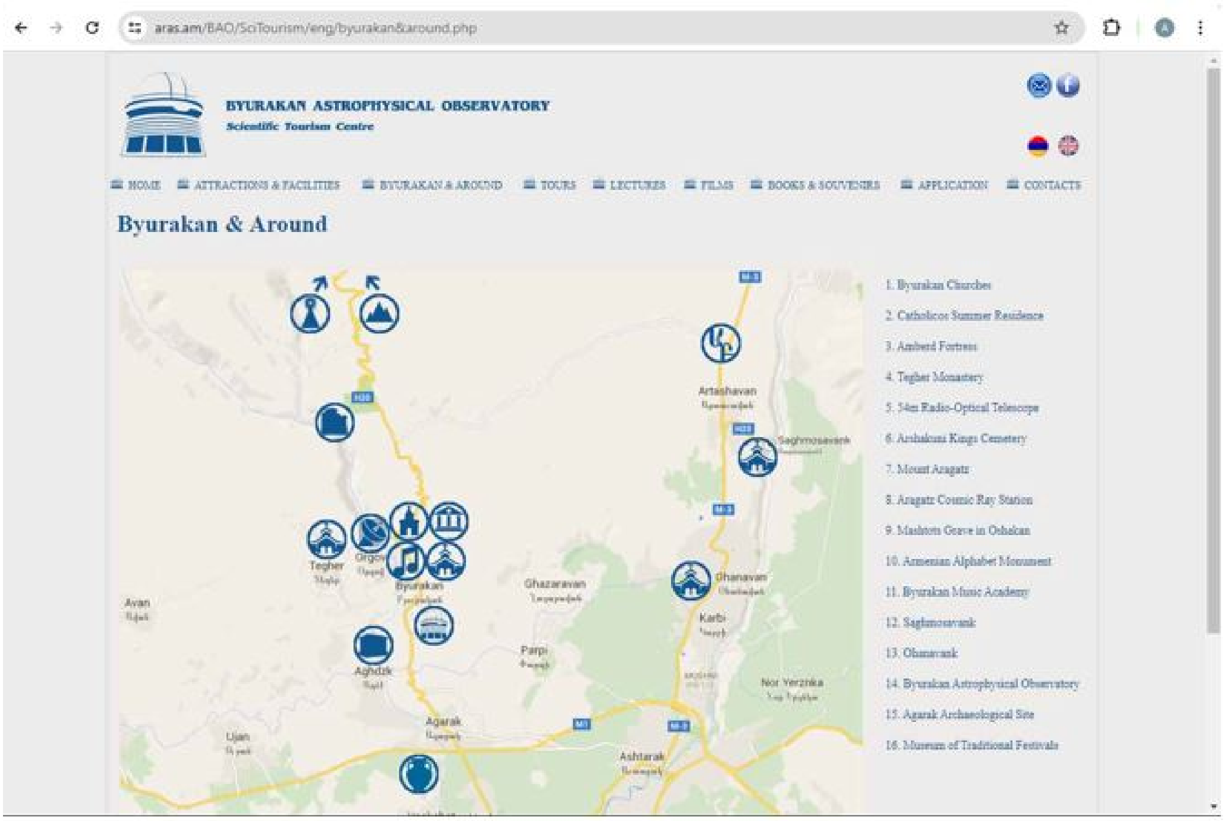

Figure 1. BAO Scientific Tourism webpage with sightseeing around BAO.

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3. Scientific (Astro) Tourism Projects for Armenia and South West and Central Asia

We have run several **projects related to Scientific (Astro) Tourism**. A major project was the development of Astro Tourism in South West and Central Asia (http://astrotourism.aras.am) resulted in building of an official webpage for Astro Tourism and suggestion to the IAU other regions to join with similar webpages for all regions. In total, 4 funded projects were accomplished:

- IAU Office of Astronomy for Development (OAD) grant 2016: *Development of Astro Tourism in SWA*
- Swiss Development Cooperation (SDC) grant 2016: *Development of Scientific Tourism in Armenia*
- Stepan Gishyan fund grant 2018-2019: *Development of Scientific Tourism in Armenia*
- IAU-100 grant 2019 (extension of OAD-2016 grant): *Astro Tourism in SWCA*

Seminars on Scientific Tourism for scientists and tourism representatives (topics: Extraterrestrial Civilizations, Ancient Astronomy, etc.), **Cognitive Tours** to Scientific Tourism sites for representatives of Travel Agencies, **Scientific Tourism Conferences** in BAO, Armenian Institute of Tourism (AIT) and elsewhere have been organized. For the first time in Armenia, tourism representatives were gathered together to discuss scientific tourism matters.

Scientific and Astro Tourism webpages were built, in total, 4 webpages: BAO as a scientific tourism centre: www.aras.am//BAO/SciTourism/eng; BAO visits page: https://www.bao.am/visits/tours.php; IAU OAD project Astro Tourism in SWA: http://iau-swa-road.aras.am/eng/AstroTourism/ and IAU-100 project Astro Tourism in SWCA: http://astrotourism.aras.am.

We have prepared and published an **Armenian Scientific Tourism map**, where 4 types of site are given: 1) ancient sites, 2) medieval universities, 3) astronomical observatories/institutes, 4) planetariums/museums.

A **film about Scientific Tourism sites** in Armenia was screened. This was the result of our visits and cognitive tours to all these sites and collection of all possible information from the Internet and elsewhere, taking many photos.

Figure 2. The main page of the project Astro Tourism in SWCA.

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Figure 3. Armenia, Iran and Uzbekistan maps from the project Astro Tourism in SWCA with Astro Tourism sites.

4. The vision, the strategy and the development of the Scientific Tourism

The Scientific Tourism comes to prove that Tourism is not only service but a discipline to be studied, coordinated and properly managed. The Scientific Tourism may be expressed in the following:

- Touristic studies (Touristic discipline); History, Theory and Statistics of the Tourism
- Developing the vision and the strategy of the Scientific Tourism
- Identification of the types of science-related sightseeing
- Identification of Science related sightseeing in each country
- Organizing Scientific Tourism Sites Cognitive Tours, Visits
- Seminars and Conferences on Scientific Tourism
- Scientific Meetings: attracting people to travel
- Organizing Summer/Winter Schools and Camps for students and school children
- Visits to Planetariums, Science Cities, Science/Astronomy Museums
- Opening Tourism Chairs at the universities, Tourism Education, Preparing Experts
- Archaeoastronomy & Cultural Astronomy Studies
- Publication of articles on the (Scientific) Tourism in scientific and popular journals

In addition, there should be scientific research and dissemination for Scientific (Astro) Tourism as well; Talks at different science/astronomy meetings on the Scientific Tourism, articles on the Scientific Tourism in scientific and popular journals. Concerning the Scientific Tourism education in Armenia, we have opened Scientific Tourism Chair (one of the 1^{st} such Chairs in the world) at the Armenian Institute of Tourism (AIT). There are many B.Sc. and M.Sc. theses on Scientific Tourism by students both from AIT and several other universities having tourism-related faculties or chairs (in Armenia, in total 12 such units).

Related Links

Byurakan Astrophysical Observatory (BAO): https://www.bao.am

IAU SWCA ROAD: http://iau-swa-road.aras.am/eng

Armenian Astronomical Society (ArAS): https://www.aras.am

Armenian Virtual Observatory (ArVO): https://aras.am/Arvo/arvo.htm

BAO as a scientific tourism centre: www.aras.am//BAO/SciTourism/eng

BAO visits page: https://www.bao.am/visits/tours.php

IAU OAD project Astro Tourism in SWA: http://iau-swa-road.aras.am/eng/AstroTourism/

IAU-100 project Astro Tourism in SWCA: http://astrotourism.aras.am

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A Journey Through the History and Statistics of ArASNews

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Abstract

A review of ArAS Electronic Newsletter ArASNews (e-newsletter of the Armenian Astronomical Society – ArAS) is given. ArASNews has been published since 2002 and during these years it has largely contributed to the circulation of information among the Armenian astronomical community, as well as other astronomical societies and organizations. It is being distributed monthly to all ArAS members. ArASNews publishes informative materials on ArAS, Byurakan Astrophysical Observatory (BAO), and Armenian astronomy in general, reports on ArAS Annual Meetings and other astronomy-related events in Armenia, participation of the Armenian astronomers in important international meetings. Additionally, it features articles commemorating notable Armenian astronomers, announcements of new ArAS members, and discussions on various astronomical topics including archaeoastronomy and public outreach initiatives, acceptance of new ArAS members, achievements of the Armenian astronomers, ArAS Annual Prizes for Young Astronomers and other international and local prizes, Astronomical Education and Public Outreach in Armenia, Armenian Archaeoastronomy, as well as scientific articles (reviews) on important studies. We will give some statistics on the number of published articles and pages, the distribution of articles by topics, and more. ArASNews' numerous useful articles may be accessed through its Reference List.

1. ArASNews Foundation and History

ArASNews has been a beacon of information for astronomers and enthusiasts alike, since its inception in 2002. Founded by the Armenian Astronomical Society (ArAS), ArASNews chronicles the advancements, achievements, and events within the Armenian astronomical community.

Initially released quarterly (2002-2009), the e-newsletter published 8 issues per year from 2009 to 2014 and has been releasing a monthly issue since 2015. Despite its electronic format, a few copies remain available in different locations including the Byurakan Astrophysical Observatory (BAO) library, the ArAS secretariat, and archives, serving as tangible reminders of Armenia's contributions to the field.

Over the years, ArASNews has seen a succession of dedicated editors. From Tigran Magakian, the inaugural editor (2002-2004, 1-12 issues), to Lusine Sargsyan (2005, 13-16 issues), Lilit Hovhannisyan (2006-2007, 17-24 issues), Areg Mickaelian (2008-2014, 25-76 issues), and Sona Farmanyan (2015-2020, 77-117 issues), each editor has played a pivotal role in shaping the content and direction of the Newsletter. Since May 2021, Meline Asryan has been leading the editorial team, continuing the tradition established by its predecessors (2021-present, 141-177 issues).

2. ArASNews Contents and Topics

The creation of ArASNews consists of five main steps: topic research, content writing, review by the astronomer, design, and dissemination via email and on the web.

ArASNews serves as a platform for disseminating information on a myriad of topics. From updates on ArAS itself to reports on annual meetings and the participation of Armenian astronomers in international conferences, the newsletter provides a comprehensive overview of Armenian Astronomy. Articles commemorating the anniversaries of notable Armenian astronomers, introducing the readers to the biographies of more than 100 astronomers, presenting new ArAS members, and highlighting achievements within the community underscore the rich history and vibrant present of Armenian astronomy.

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A testament to its commitment to education and outreach, ArASNews also covers topics such as astronomical education in Armenia, Armenian Archaeoastronomy, and science reviews of seminal studies. By providing insights into these areas, the Newsletter not only fosters a deeper understanding of astronomy but also promotes the exchange of knowledge among enthusiasts and professionals alike.

The breadth of topics covered in ArASNews is vast, encompassing everything from international astronomy awards to announcements, news, and cultural insights related to astronomy. Topics range from ANSEF grants or the participation of young Armenian astronomers in international summer schools, the Newsletter serves as a hub of information for those invested in the advancement of astronomy in Armenia and beyond.

Over the years, the e-newsletter has developed a separate section where discoveries or the latest papers by Armenian astronomers are presented.

Here are ArASNews topics that we have presented over these years:

Local News

- ArAS activities (current projects, new collaborations)
- BAO activities (current projects, new collaborations)
- Meetings and Schools held in Armenia
- Participation of Armenian astronomers in international meetings
- Participation of young Armenian astronomers in international summer schools
- Release of new research papers and important studies
- Popular articles and review papers on the research of BAO astronomers and Research Departments
- Achievements of Armenian astronomers (prizes, other awards)
- Viktor Ambartsumian International Science Prize (calls and awards)
- ArAS Annual Prize for Young Scientists (calls and awards)
- Publication of books and other materials by BAO/ArAS astronomers
- ArAS new members acceptance
- Astronomical Education in Armenia
- Armenian Archaeoastronomy and Astronomy in Culture
- Public Outreach activities
- Announcements, news and other info
- Mass Media and Scientific Journalism

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International News

- Meetings and Schools held abroad
- IAU events (General Assemblies, Symposia, ISYA) and announcements
- EAS events (Annual Meetings) and announcements
- NASA and ESO news
- International Prizes (IAU, EAS, Nobel Prize, Shaw, Kavli, Balzan, Gruber, etc.)
- International Astronomy/Science special days
- International Astronomy discoveries
- Release of other astronomy-related newsletters and information bulletins

Anniversaries and Obituaries

- ArAS members
- BAO researchers
- Foreign Armenian astronomers, astrophysicists and physicists
- Other famous scientists
- Anniversaries of important historical astronomical events

3. Publication History

In Table 1, we give the history and some statistics of the ArASNews publication. Unfortunately, there was a gap in its regularity in 2018-2020 and the beginning of 2021. We plan to collect the corresponding events and news and post them on ArASNews webpage to preserve this information and to recover the missed issues as well.

Table 1: History and statistics of ArASNews publication.

Years	**ArASNews Issues #**	**Number of Issues**	**Periodicity** (Issues per year)	**Editors**
2002-2003	1-8*	6	3	Magakian
2004-2008	9-28	20	4	Magakian, Sargsyan, Hovhannisyan, Mickaelian
2009-2014	29-76	48	8	Mickaelian
2015-2020	77-117	41	12**	Farmanyan
May 2021-	141-177	37	12**	Asryan
Total	**1-177**	**152**	**3-12**	**TM, LS, LH, AM, SF, MA**

* Issues ## 3/4 and ## 7/8 were combined and published as single Issues.
** Missed Issues in 2018-2020 and the beginning of 2021. Not yet complete for 2024.

4. Conclusion

In conclusion, ArASNews stands as a testament to the commitment of the Armenian Astronomical Society (ArAS) to foster collaboration and outreach within the astronomical community. By its regularity, the total volume of information, variety of covered topics, ArASNews is one of the most informative newsletters among such for all astronomical societies. Some ArASNews articles are even republished in other newsletters (e.g. EAAS Newsletters).

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The dedication of its successive editors has ensured the continuity and evolution of its content, developing new topics over time. In order to facilitate and guide readers through the newsletter's previous issues, we have created a reference list, which allows easy navigation through its general topics.

Looking ahead, ArASNews remains committed to its mission of informing and inspiring readers about Armenian astronomy and the wonders of the universe.

Acknowledgements

The authors are thankful to the Armenian Astronomical Society (ArAS), Byurakan Astrophysical Observatory (BAO), and the IAU South West and Central Asian Regional Office of Astronomy for Development (IAU SWCA ROAD).

Related Links

ArAS: https://www.aras.am/

ArASNews: https://www.aras.am/ArasNews/arasnews.html

ArASNews Reference List: https://www.aras.am/ArasNews/arasnewsreference.html

Related References

Asryan, M. A.; Farmanyan, S. V.; Mickaelian, A. M. 2020 – *BAO Outreach Activities and Scientific Journalism in Armenia*, Communications of BAO, Vol. 67, p. 119

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X-ray AGM activity classes based on SDSS spectra

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Abstract

Sources of X-ray radiation are very interesting and at the same time little studied. Their class mainly includes objects that exhibit a certain activity, such as AGNs, cataclysmic variable stars, white dwarfs, pulsars, etc. Identification of X-ray sources is a rather difficult task, and it is not always possible to detect an optical object. In this work, we tried to carry out a spectral classification of X-ray AGNs and identify activity classes, taking as a basis the ROSAT BSC/FSC catalog of X-ray AGNs, compiled on the basis of low-dispersion spectral plates of the first Byurakan survey. We identified these objects with the SDSS spectral catalog and tried, by carefully studying the spectra, to find out their activity classes, as well as to understand which activity class is more common in these sources.

Keywords: active galactic nuclei, radio source, quasar, X-ray, ROSAT

1. Introduction

ROSAT data are mainly listed in two catalogs: ROSAT Bright Source Catalogue (BSC) (Voges 1999) and ROSAT Faint Source Catalogue (FSC) (Voges 2000). They are clearly distinguished from each other by X-ray flux expressed in count-rate (CR; the number of particles registered by the receiver per unit time, namely per 1 sec).
Among the identification works, the ROSAT Bright Sources (RBS,Schwope 2000) is well-known. 2012 BSC sources with CR ≥ 0.20 and $|b| > 30^o$ have been optically identified. However, most of the identified sources come from the Hamburg Quasar Survey (HQS, Hagen 1995), which was used as a basis for optical identifications.

Three main projects have been carried out: Hamburg-ROSAT Catalogue (HRC, Zickgraf 2003), Byurakan-Hamburg-ROSAT Catalogue (BHRC, Mickaelian 2006) and HRC/BHRC catalouge (Paronyan 2021). HRC is based on ROSAT-BSC and BHRC is based on ROSAT-FSC fainter sources (down to CR=0.04 to have confident X-ray sources) at $|b| > 20^o$ and $\delta > 0^o$ area.

Table 1. Source of combine catalogue

Tupe	Number	Percent
GAL	492	6.0
AGN	4253	53.0
STAR	1800	22.4
Ukn	1495	18.6
Total	8037	100.0

We combined these two Catalogues and created a new homogeneous and complete catalogue of X-ray selected AGN, which covers all the northern sky limited by high galactic latitudes ($\delta > 0^o$, $|b| > 20^o$), and

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with CR > 0.04 (Paronyan 2021). After some checks from various available catalogs, we have excluded a number of objects and included some missed AGN and finally it contained 4253 AGN or their candidates.

Out of the 4253 HRC-BHRC objects, 3369 sources were confirmed as AGN by means of optical spectral classifications; the main criteria in VCV-13 and BZCAT (Veron-Cetty 2010, Massaro 2012), 173 in (Paronyan 2019), 198 in (Paronyan 2020).

2. Observing material

These 3369 objects have been cross-correlated with GALEX (Bianchi 2011), SDSS, 2MASS (Skrutskie 2006) NIR, All WISE (Cutri 2013) , IRAS PSC (Beichman 1988) and FSC (Moshir 1992), NVSS (Condon 1988), FIRST (Becker 1997) catalogues.

Table 2. Cross-correlated catalogues

Gamma-ray	**X-ray**	**UV**	**Optical**	**IR**	**Radio**	**Catalog**
FERMI	INTEGRAL	GALEX	APM	2MASS	NVSS	RC3
INTEGRAL	ROSAT		USNO-B1.0	WISE	FIRST	VCV-13
			GSC 2.3.2	IRAS		Roma Blazar
			SDSS	AKARI		

Asobserving material wehad 1426 spectra of HRC-BHRC objects from SDSS DR10-16 (Ahn 2014, Alam 2015, Albaretti 2017, Abolfathi 2018, Ahumada 2020). Spectroscopic redshifts, intensities (assigned as "heights") and equivalent widths of spectral lines for 123 of them from SDSS DR10-DR16 are available.

Very often SDSS measurements from their spectra are based on very low-quality lines at the level of noise. These automatic measurements give some artificial numbers that indicate non-real data. So, one needs to carefully check the spectra along all wavelengths and decide which measurements should be used for further studies. Especially important are those, which are being used in the diagnostic diagrams (Hβ, [OIII] 5007$\AA$, [OI] 6300$\AA$, Hα, [NII] 6583$\AA$, and [SII] 6716+6731$\AA$) (Veilleuxand 1987).

3. Classification Principles

We have used several methods for classification of our spectra

- By eye examination (taking into account all features and effects)
- By diagnostic diagram using [OIII]/Hβ and [OI]/Hα ratios
- By diagnostic diagram using [OIII]/Hβ and [NII]/Hα ratios
- By diagnostic diagram using [OIII]/Hβ and [SII]/Hα ratios

Classification by eye has been done to compare with the classification by diagnostic diagrams and because not all objects appeared on them. Besides, the broad emission line component is not taken into account on the diagnostic diagrams, and this may be crucial for the classification of Seyfert 1.2-1.9 subclasses. Roughly, we distinguish Seyferts from LINERs by the criteria: [OIII]/Hβ > 4, and AGN from HII by [NII]/Hα > 2/3, [OI]/Hα > 0.1 criteria.

4. Results of Study of Spectra and Classification

We started studying spectra with identifications of spectral lines. We have used only lines having intensities 3σ over the noise level. Hβ also appears in absorption on most of these spectra.We studied the

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FERMI 5	10-100 Gev	SDSS i	7480 A	IRAS	100 μm
FERMI 4	3-10 Gev	DSS I(N)	8060 A	AKARI	140 μm
FERMI 3	1-3 Gev	SDSS z	8932 A	AKARI	160 μm
FERMI 2	300-1000 Mev	2MASS J	1.235 μm	NVSS	21 cm
FERMI 1	100-300 Mev	2MASS H	1.662 μm	FIRST	21 cm
INTEGRAL	60 kev	2MASS K	2.159 μm		
INTEGRAL	30 kev	WISE 1	3.35 μm		
INTEGRAL	10 kev	WISE 2	4.6 μm		
ROSAT	1.25 kev	AKARI	9 μm		
GALEX FUV	1550 A	WISE 3	11.6 μm		
GALEX NUV	2275 A	IRAS	12 μm		
SDSS u	3551 A	AKARI	18 μm		
DSS B(O)	4450 A	WISE 4	22.1 μm		
SDSS g	4686 A	IRAS	25 μm		
DSS V	5510 A	IRAS	60 μm		
SDSS r	6166 A	AKARI	65 μm		
DSS R(E)	6580 A	AKARI	90 μm		

Figure 1. Filters from which we received data.

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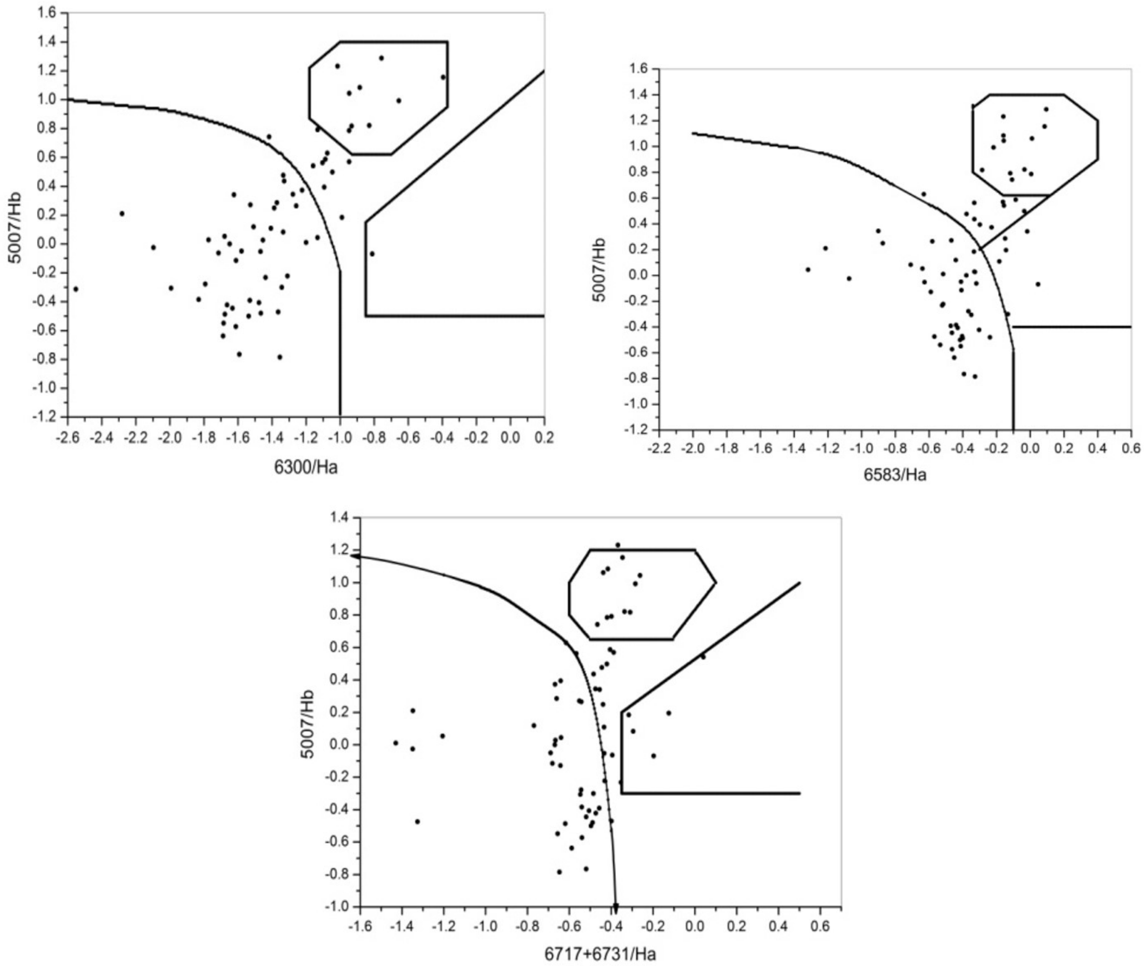

Figure 2. Diagnostic diagrams

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influence of Hβ absorption component on the emission one, which is important for using of the numerical data given in SDSS tables. After identifications of the emission lines we decided which of them should be used to build diagnostic diagrams (Veilleuxand 1987).

On diagnostic diagrams the narrow-line AGN are separated into 3 main groups (HII, Sy, LINER). In addition, there are objects in intermediate areas, which have been classified as Composites (Veilleuxand 1987) having both AGN and HII features.

Table 3. Source of combine catalogue

Type	**Percent**	**Type**	**Percent**
QSO	2.5	H II	14.5
Sy1.0 & nSy1.0	1	ELG	10
Sy1.5 & nSy1.5	3.5	Comp	4
Sy1.8 & nSy1.8	12.7	Galaxy	47
Sy1.9 & nSy1.9	7	WD, CV, C star	1.7
LINER	0.6	Uc Cl	4.5

5. Summary and Conclusion

We have created sample of X-ray selected AGN candidates and carried out spectroscopic investigation for those objects having SDSS spectra. 1426 objects appear in this list and we have classified them by activity types using three diagnostic diagrams and eye examination of the spectra (to be complete in classification of broad line AGN). Many Seyferts, LINERs, Composites and Starburst have been revealed. We

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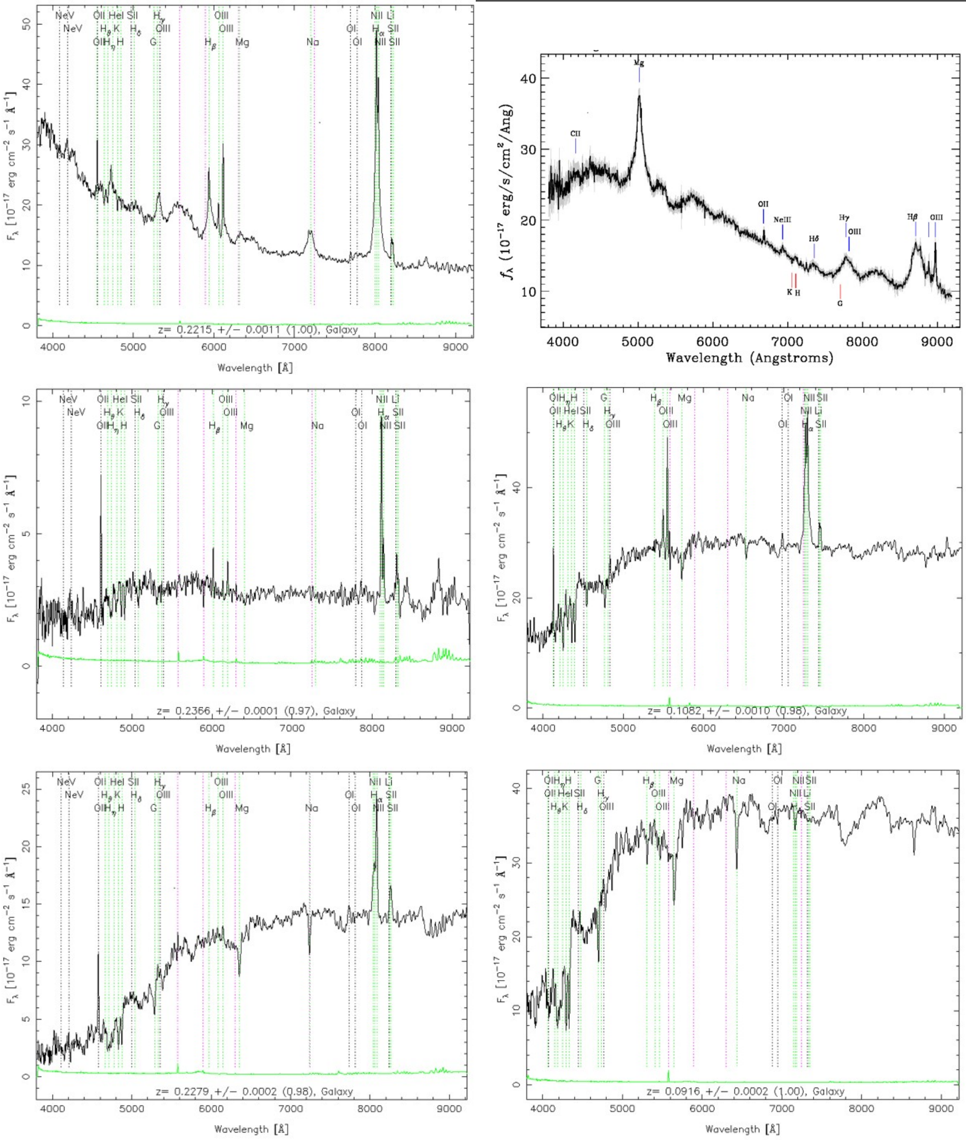

Figure 3. Classified spectra

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have applied all possible parameters for fine classification to distinguish between narrow and classical broad line Seyferts, and to identify all details related to Seyfert subtypes depending on the strength of their broad components. We have introduced subtypes of NLS1, namely NLS1.0, NLS1.2, NLS1,5 and NLS1.8 giving more importance to these details (Osterbrock 1980, Winkler1992, Osterbrock 1985, Heckman 1980, Ho 1997, Weedman 1977, Veron 1997). Further accumulation of statistics may provide possibilities to understand the physical differences.

These 3369 objects have been cross-correlated with GALEX (Bianchi 2011), SDSS, 2MASS (Skrutskie 2006) NIR, All WISE (Cutri 2013) , IRAS PSC (Beichman 1988) and FSC (Moshir 1992), NVSS (Condon 1988), FIRST (Becker 1997) catalogues.

We have calculated all possible physical parameters of the studied objects: radial velocities, distances, absolute magnitudes, luminosities, etc.

One of the most intriguing class of objects among the X-ray sources are absorption line galaxies. The brightest ones may just appear in this sample due to their integral high luminosity, however we find that many such objects have low luminosity and still appear to be strong X-ray sources. We consider these objects as possible hidden AGN (We have 543 possible hidden AGNs). The optical spectra do not show any signatures of emission.

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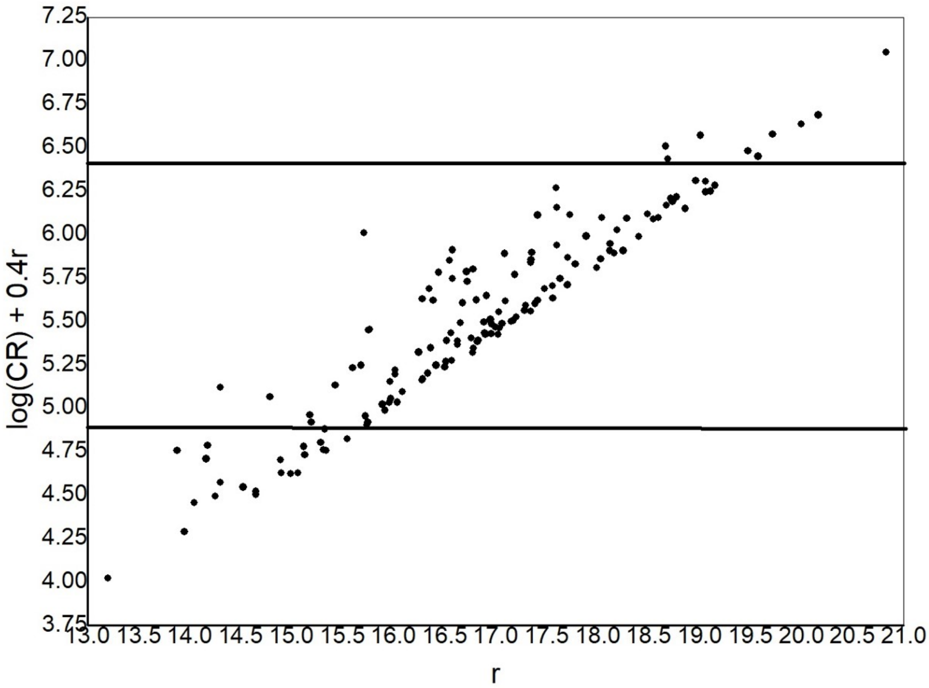

Figure 4. Possible hidden AGNs.

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On the Possible Astronomical Function of Portasar's (Göbekli Tepe) Pillar 27

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Abstract

The examination of Portasar's Pillar 27 in Enclosure C from an archaeoastronomical point of view reveals four distinct directions. Considering the directions obtained as observational shows that they could have served to observe the simultaneous culminations of *Pleiades*, *α Persei*, and *36 Draconis* pointing towards the North Ecliptic Pole during the activity period of the *September ε-Perseid* meteor shower. On the same day (perhaps a few days apart) before sunrise, it was most likely possible to observe the star disappearance of the constellations Hercules and Centaurus at their culmination points. At the same time, the T-shaped structure of Pillar 27 could serve as a shadow meter (gnomon) to show the specified day of the mentioned observations. Additionally, 36 days after the summer solstice (*Perseids* activity period), the simultaneous appearance of the stars *β Andromedae* and *γ Draconis* at their culmination points was observable.

On the other hand, there are principal parallels with the possible observations with the help of Portasar's Pillar 27 and the function of Platform 3 (as well as some angular stones (No. 7, 12, 158, etc.)) of the Zorats Qarer megalithic monument, which refer to the same millennium (9000 BC). There are also commonalities with ancient calendar patterns that relate to ancient mythological concepts. Their detailed analysis is still in progress.

Keywords: *Göbekli Tepe, Pillar 27, Pleiades, Perseid Meteor Shower, Observational Instruments, Archaeoastronomy, Ancient Calendar, Zorats Qarer, Megalithic Monuments.*

1. Introduction

The importance of the ancient site of Portasar (Göbekli Tepe) in studying the immemorial layers of the historical-cultural heritage of the civilization is indisputable (Bengisu, 2023). The monument has been reliably dated to 9500-8500 BC using the radiocarbon method (Dietrich, 2011, Dietrich & Schmidt, 2010). Dating has become a necessary support for various specialists, including archaeoastronomers (Henty (2022) pp. 60-64) to understand the functional significance of the monument. Particularly, an attempt was made to connect the monument with the setting of the star Deneb (*α Cygni*) in one case (Collins, 2014, 2018, Collins & Hale, 2013), and with the rise of Sirius (*α Canis Majoris*) in another case (Magli, 2015), as well as with the worship of Taurus, Orion (Schoch, 2012, Seyfzadeh & Schoch, 2019) and Gemini (Coombs, 2023) constellations. The connection of the monument with Deneb has been considered in more detail. As a result, some clarifications were made regarding correctly accounting the atmospheric conditions of observations on the horizon (De Lorenzis & Orofino, 2015). Although most archaeoastronomical studies relate to the orientations of the main structures, the low-reliefs of Pillar 43 (Enclosure D) are more discussed objects. An attempt was made to identify the images with some constellations. The most interesting thing is identifying the vulture image on Pillar 43 and the constellation Swan (Armenian Angegh-Vulture) (Collins, 2014, Collins & Hale, 2013, Vahradyan & Vahradyan, 2010). However, this bird was later associated with the Sagittarius constellation (Burley, 2017, Sweatman & Tsikritsis, 2017a), which immediately became a reason for heated discussions (Burley, 2017, Furter, 2018, Notroff *et al.*, 2017, Sweatman & Tsikritsis,

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2017b). However, today, similar juxtapositions of low-reliefs continue (Coombs, 2023, Sweatman & Coombs, 2018). Without referring to the details of these researches, let us mention only one of the latest publications, where the author questions the connection of the monument with astronomy, generalizing the existing studies (Banning, 2023). Thus, clarifying the monument's functional significance and connection with the sky becomes very important.

The presented research aims to shed some light on the problem above. Below, it will be shown that Pillar 27 of Enclosure C of the historical-cultural complex of Portasar (Figure 1) most likely served as an astronomical "observational instrument".

2. Material and Methods

The T-shaped Pillar 27 is located in the thickness of the western wall of Enclosure C (Figure 1b) of the Portasar complex. Two animals are depicted on its eastern face: the lower bas-relief is a baby boar image with a high relief of predator[1] above it (Dietrich *et al.*, 2012). Its vertical position can be considered preserved from the beginning and it probably has a West-East orientation (Figure 1a) (Schmidt (2010), Dietrich *et al.* (2014) fig. 2, p. 12).

The high relief of the "predator" is distinguished by its spatiality from the depictions of the remaining monument Pillars. Noteworthy are the two through holes on it: the first (southern, No. 1) is made at the tail base, and the other (northern, No. 2) is at the tail tip (Figure 2).

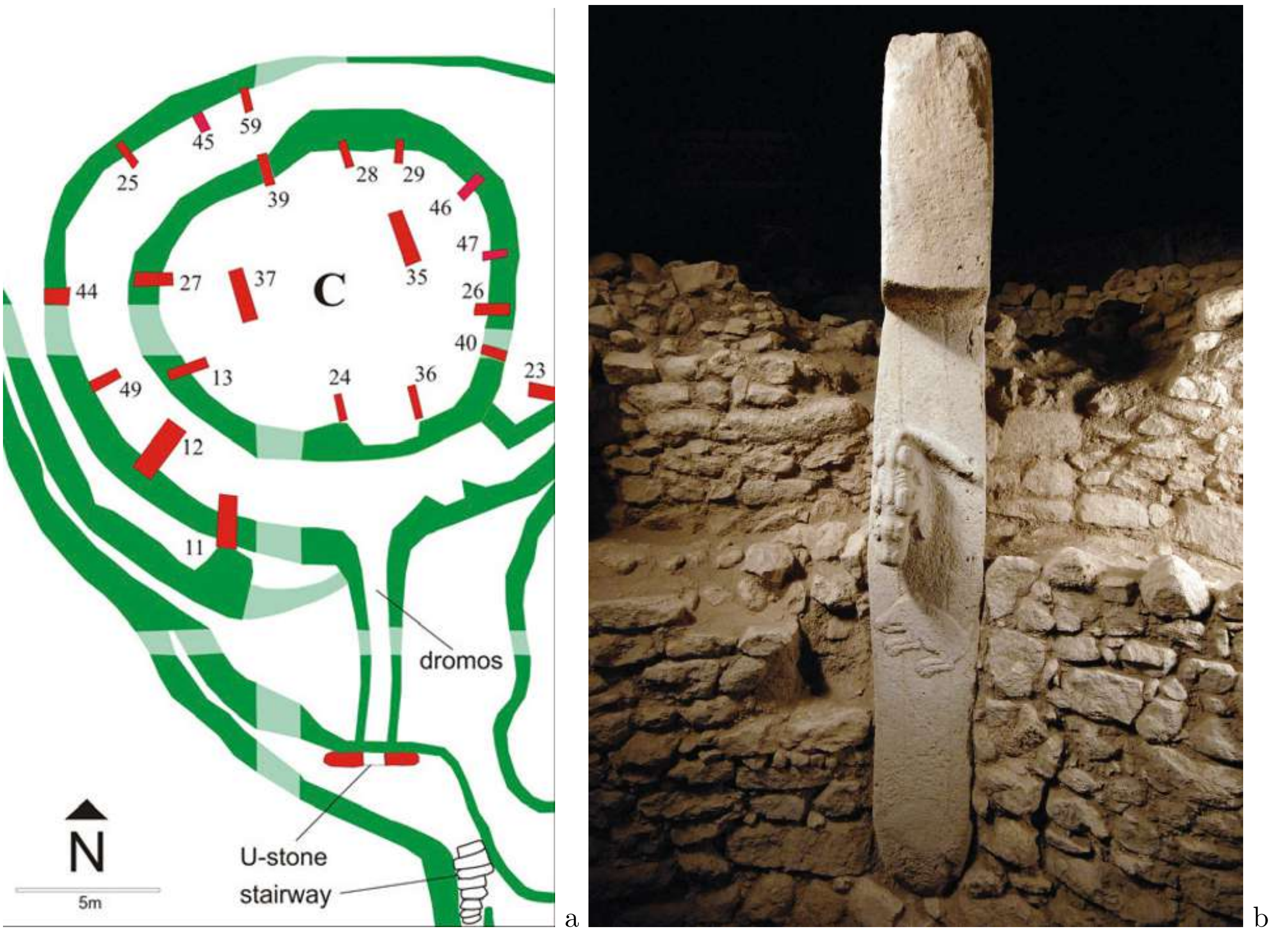

Figure 1. (a) West-East orientation of Pillar 27 in Portasar's Enclosure C (Dietrich *et al.* (2014) fig. 3, p. 12); (b) vertical position of Pillar 27 and the sculptures on its East face (Dietrich *et al.* (2012) p. 680) *(photograph: D. Johannes).*

[1]For some reasons, we think this animal should be called **"wolf-headed dragon"** ("vishap" in Arm.).

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Figure 2. Two through holes of the "predator" tail of Pillar 27 of Enclosure C: (a) view from the north; (b) view from below. (https://humanoriginproject.com/gobekli-tepe-oldest-temple/)

2.1. The Holes and Their Direction

We could not find any publication on the significance of these holes. Obviously, their existence must have a logical reason, so this question needs a special examination. Taken separately, the holes cannot clearly orientate the observer. If we assume that they are made for celestial body observations, the bottom-up direction should be accepted for hole No. 2, and the observer's eye should be located at the tip of the "predator's" tail for No. 1. In this case, we will get a clear direction *(D_s)* extending from the tail tip to the southern hole, whose azimuth *(A)* is the South point *(A_s=0°)*, and the elevation *(h_s)* corresponds to the angle formed by the inclination of the "predator's" tail. In other words, by determining the angle of the tail inclination from the horizontal line, we will get the angular height *(h_s)* of the southern direction (Figure 3). It should be specially emphasized that the field of view will be limited by the thickness of the tail when viewed from higher points, and by the thickness of the left hind leg of the high relief when viewed from lower points. Figure 2a clearly shows the groove between the tail and the left hind leg, pointing towards hole No. 1. It should also be noted that if we look at hole No. 1 from the northeast, such as the camera position in Figure 2a, no clear direction will be formed. Thus, if hole No. 1 is designed for observations, the only clear direction that can be formed in this structure is the South direction from the tail tip to the hole. It is worth noting that the height from the ground to the tail tip corresponds approximately to the height of the eyes of a person of medium height in a standing position. This can be seen in many photos that are available on the Internet[2].

Now consider the direction of hole No. 2. The diameter of this hole is about half the thickness of the tail. Thus, even assuming the hole is cylindrical, the angular direction error would be about 30°, which is too large to solve an astronomical problem. We cannot unconditionally consider that the axis of hole No. 2 is perpendicular to the axis of the tail, although the pictures do not exclude this. In Figure 2b, it is clearly seen that the field of view is open to the North; that is, the direction of the line of sight *(D_n)* should touch the eastern surface of Pillar 27 (Figure 3). In this case, there

[2]See for example https://orientlight.co/wp-content/uploads/2022/11/IMG_3525-scaled.jpg (10 Feb, 2024).

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is a clearly expressed North direction *(A_n=180°, from the South point)*. It remains to determine the vertical component of this direction *(h_n)*. If D_n is directed to the North, it is clear that observing right through the hole is very problematic, because the "predator's" high relief does not leave such possibility. Hence, it must be observed from a certain distance as in the case of D_s. Therefore, the highest point from which one can see through the hole must pass down the "predator's" left front leg. If we draw such a line, it will touch a baby boar's nose (proboscis, tusk). Thus, the elevation of the direction D_n will be the angle *(h_n)* formed with the horizontal line (Figure 3). Of course, observing through hole No. 1 from lower positions is possible. However, a clear direction will not be formed in that case. Therefore, we will consider the direction D_n.

Thus, with the help of the high relief of Pillar 27 and the holes on it, two directions (Figure 3, Table 1) for observing the sky are clearly distinguished:

a) D_s, which tangent to the "predator's" tail and directed to its base hole No. 1,

b) D_n, which passes from the boar's nose through the hole on the tip of the "predator's" tail.

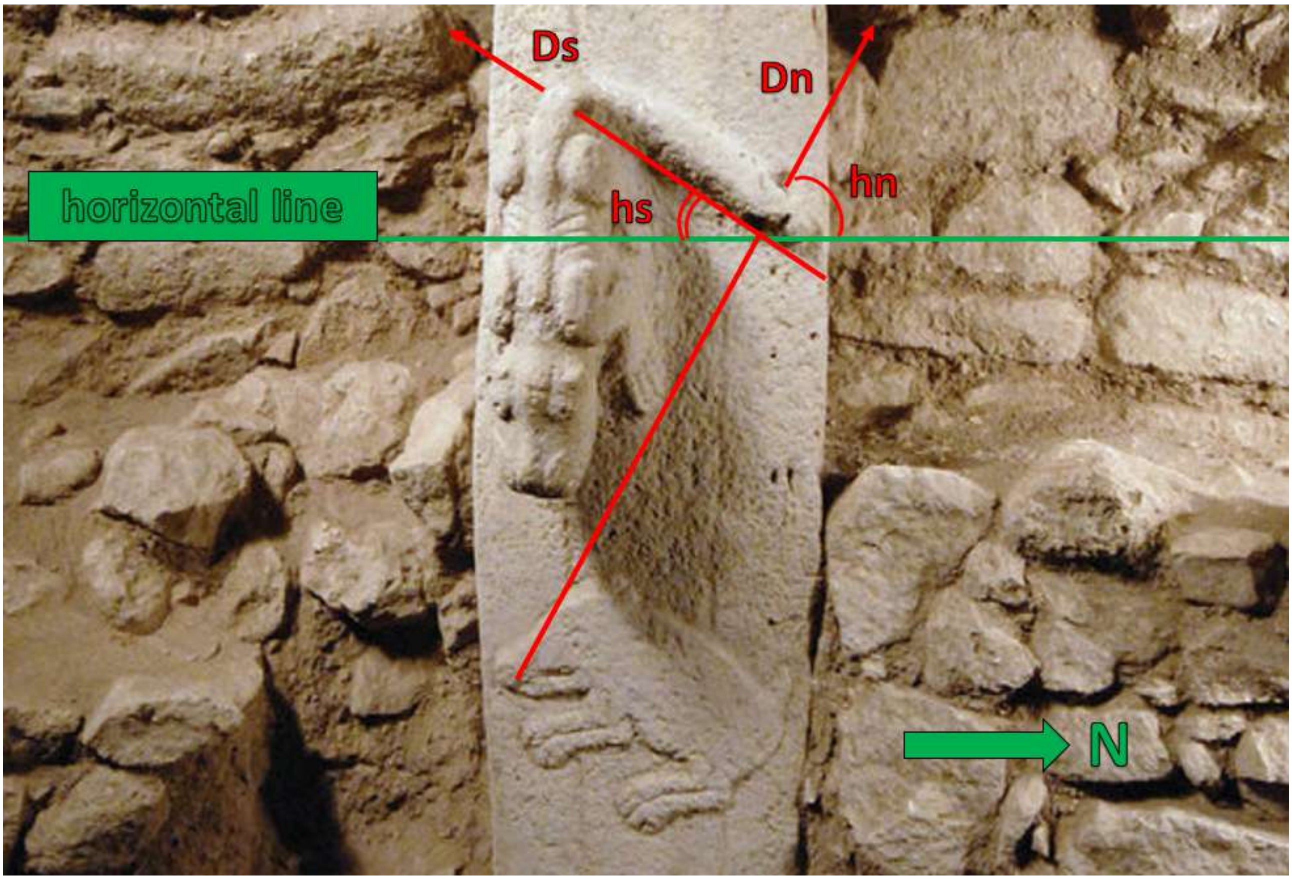

Figure 3. Described directions D_s and D_n and their elevation angles h_s and h_n.

2.2. A Possible Function of the T-shaped Form of Pillar 27

On the upper part of the eastern face of Pillar 27, there is a certain shadow (Figure 1b), which is a consequence of its T-shaped structure. Starting at noon, right after the highest position (culmination) of the Sun, the eastern flat surface of the Pillar will be completely shadowed. However, until noon, as the Sun climbs, the border of light and shadow will move from top to bottom. That is, the shadow line position will move down the surface of the Pillar during the day until the highest position of the Sun, after which the entire surface will be in shadow. Thus, the position of the boundary line between light and shadow in the noon depends on the elevation of the Sun's culmination. Therefore, the border position of light and shadow on the eastern surface of the Pillar can be repeated twice a year, except for the days of the solstices. The presence of a hole distinguishes the "predator's" tail

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tip. Thus, the case when the border of light and shadow reaches the "predator's" tail tip in the noon deserves special consideration (Figure 4). Indeed, with the help of the tail tip and the southern angle crest of the T-cut, a south direction D_{ts} with an elevation h_{ts} is clearly formed (Figures 4 and 5), which is applicable for observing the culminations of the celestial bodies. On the other hand, the D_{tn} with the elevation h_{tn} can also be considered a similar direction. It is formed by the upper point of the "predator's" tail base and the northern corner of the T-cut (Figure 5). By combining the Pillar T-cut form and the predator, we can see that two more directions are clearly distinguished: D_{ts} and D_{tn}.

Thus, the above-mentioned four directions (D_s, D_n, D_{ts} and D_{tn}), can be measured with the help of a protractor, accepting that:

1) Pillar 27 stands vertically in its initial position
2) It has a West-East orientation along its transverse axis
3) Its eastern surface is perpendicular to the transversal axis and has a North-South orientation
4) The horizontal mark in the photo (Figure 1b) corresponds to the actual horizontal line.

Of course, a slight inaccuracy may occur in the above-mentioned points, which cannot qualitatively change the main result of the study, because the possible error in the measured data will be of the order of 1° (Table 1).

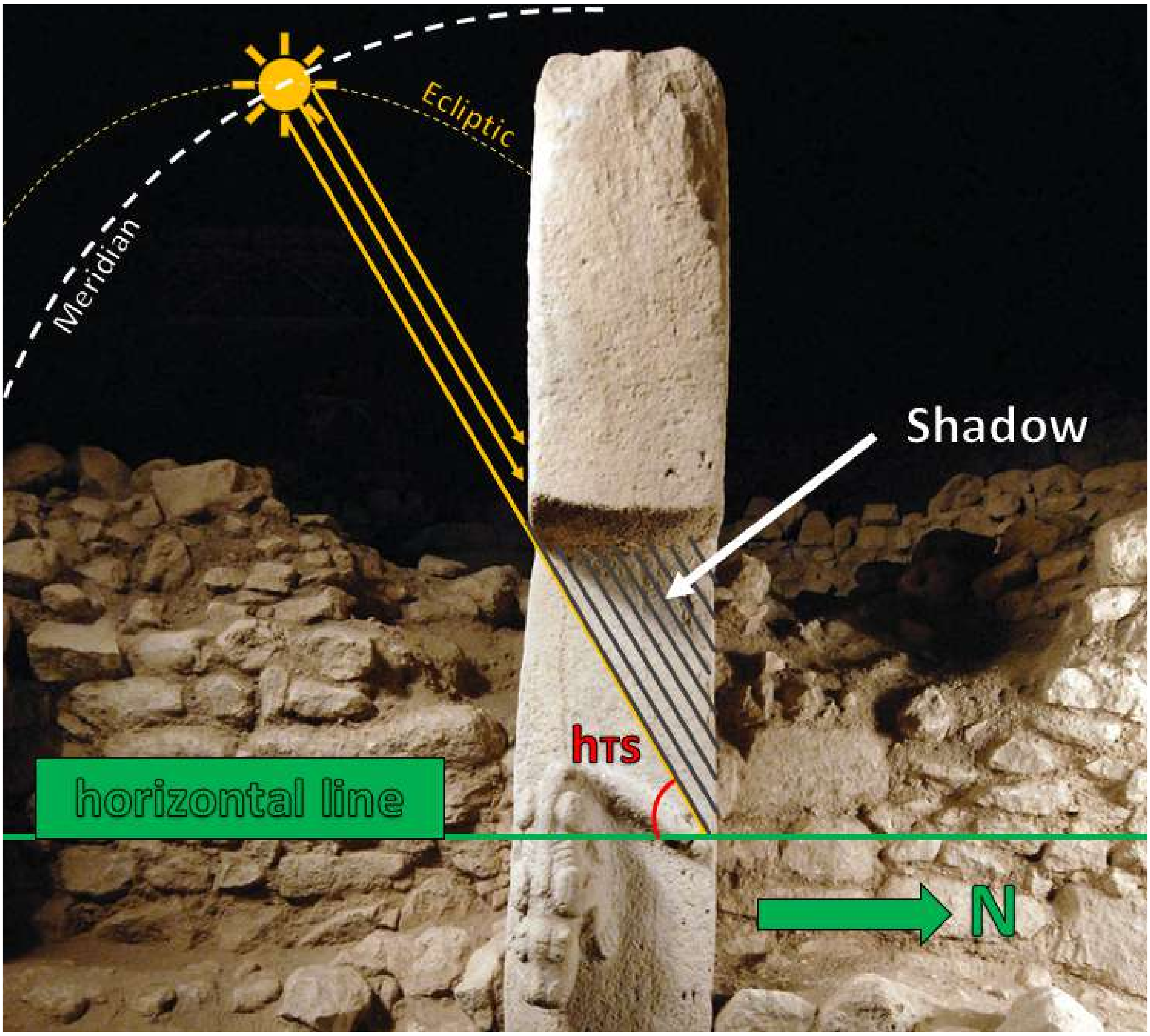

Figure 4. The elevation of the culmination of the Sun at noon, for the case when the border of light and shadow coincides with the tip of the "predator's" tail. h_{ts} - the elevation angle.

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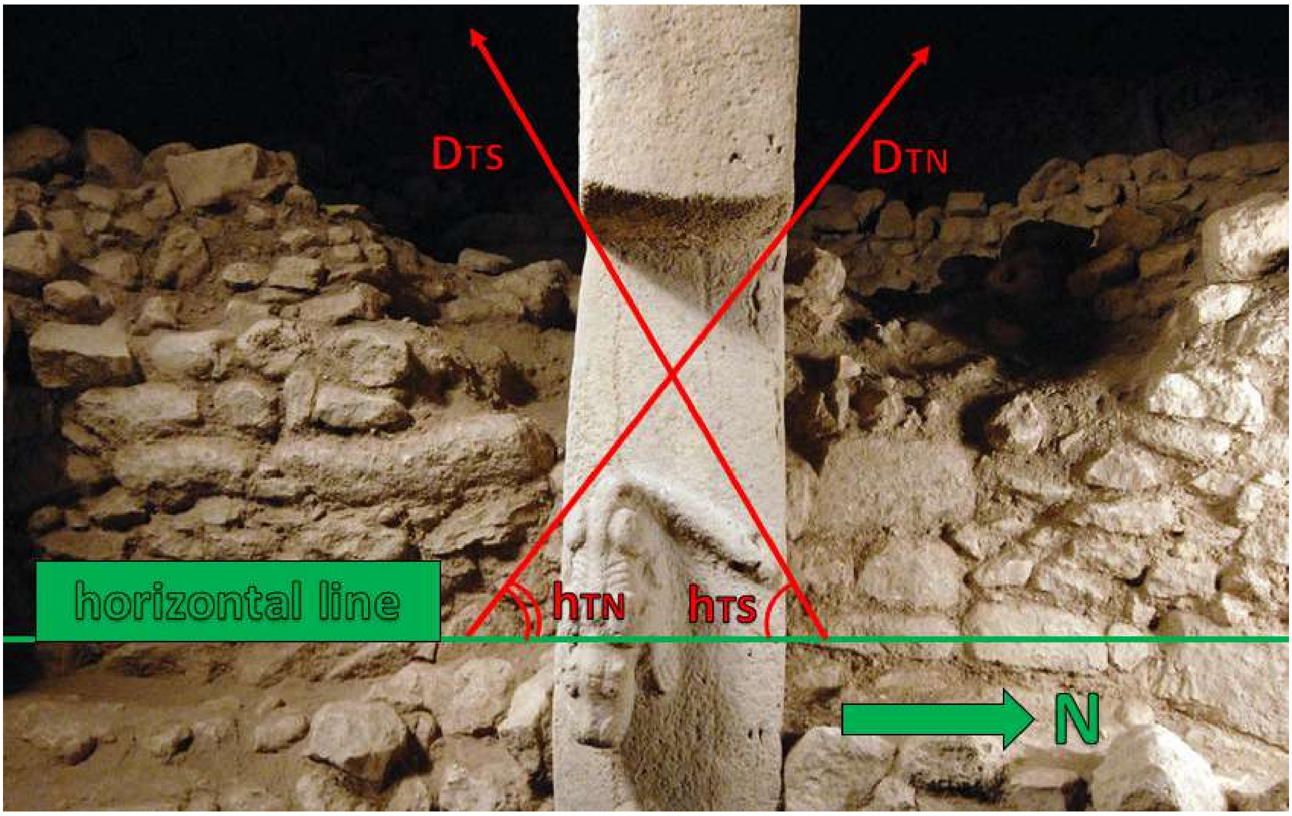

Figure 5. Directions formed by the corners of the T-cut of Pillar 27 and the contours of the high relief.

3. The Observable Celestial Bodies

It is necessary to examine the possible observational significance of the above-mentioned four directions. To find out which celestial bodies would be observed in the received directions (Table 1), it is necessary to have the geographic latitude of the site and activity epoch. The site is located at 37°13′ N latitude, and archaeological methods date Enclosure C of the monument to 9500-8500 BC (Dietrich, 2011). It should also be noted that the study data from Deneb's observations (9230-9080 BC) through the *Cartes du Ciel (CDC)*[3] project are in harmony with the above archaeological estimate (De Lorenzis & Orofino, 2015). Accepting 9000 BC as the date corresponding to the above two estimates, the examination can be performed using *Stellarium v0.20.4*[4].

Table 1 shows that in two of the four directions (D_n and D_{ts}), the transitions of the Sun, Moon, and visible planets are excluded, and with D_s and D_{ts}, observations of all visible celestial bodies are possible. The culminations of the Moon and the visible planets will not be discussed below, because they will not answer any question clearly regarding the calendar.

It is also clear that observations with the naked eye would refer to celestial objects with high apparent magnitude (m). Only objects with an apparent magnitude of up to $6^m.00$ are visible to the naked eye. However, only the brightest stars with a magnitude of up to $3^m.00$ are included in the present study, as the brightest stars have traditionally been given great importance in mythology and worship. In Tables 2 and 3, the celestial objects and their possible observation days are given.

For calendar purposes, the appearance of a star at its culmination point right after sunset and its disappearance right before sunrise are more important than its annual repeated culminations since they occur once a year. We effectively applied the same approach to find calendar information in the Zorats Qarer megalithic monument (Broutian & Malkhasyan, 2021, Malkhasyan, 2021a,b, 2022a,b, 2023a, 2024b).

[3]CDC accessed https://www.ap-i.net/skychart/it/start (3 June, 2024)
[4]Accessed https://stellarium.org (3 June, 2024)

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Direction	D_s	D_n	D_{ts}	D_{tn}
Azimuth Elevation	A_s=0° h_s=33°	A_n=180° h_n=60°	A_{ts}=0° h_{ts}=59°	A_{tn}=180° h_{tn}=51°

Table 1. The measurement data for the four directions are given. The possible error is about 1°. Azimuths from the South point are given.

Direction	λ	β	δ	α	Elevation (h)	Date
D_{ts}	+167°11′	+1°20′	+6°27′	11^h15^m	59°13′	AE - 12
	+17°14′	-0°50′	+6°13′	1^h05^m	58°59′	VE + 18
D_s	+234°44′	-0°06′	-19°39′	15^h29^m	33°07′	WS - 36
	+309°50′	+1°28′	-19°46′	20^h51^m	33°01′	WS + 42
D_n	North Ecliptic Pole	+90°	-	-	-	AE - 18
	(36 Draconis, m = 4^m.95)	+89°09′	+66°35′	17^h57^m	60°38′	VE + 12

Table 2. The days of the Sun culmination in the southern directions in 9000 BC (ε=24°12′20.02″). VE - vernal equinox, AE - autumn equinox, WS - winter solstice.

In Table 3, some observation day overlaps are noteworthy. We will highlight three of them below (subsections 3.1, 3.2 and 3.3). It is clear that if the mentioned astronomical observations were realities, their mythological concept may have been preserved in the folklore of the later period. In the present study, we will not discuss the mythological parallels of the visible coincidences (Tables 2 and 3) and their interpretation, because they need a comprehensive and detailed separate examination.

3.1. Pleiades and Perseus

Remarkably, the *Pleiades* and *α Persei* appear at their culmination positions at the same time on the same day of the year. If we look at the coordinates of their right ascension (α) (Table 3), we will see that they appear at their culmination positions (that is, they reach the same celestial meridian) with a difference of about 10 minutes. Moreover, on the same day, the Sun's culmination position corresponds to the direction D_{ts} (Table 2, Figure 4). In other words, the following picture is obtained. At noon, 14 ± 4 days before the autumn equinox, the shadow of the T-shaped protrusion of the Pillar reaches the tip of the "predator" tail, as shown in Figure 4, and shortly after that, the entire eastern surface of the Pillar stays in shadow. On the same day, right after sunset, *Pleiades* and *α Persei* almost simultaneously appear at their culmination points (Figure 6). At the same time, D_n is directed to the Ecliptic Pole, which is adjacent to *36 Draconis* in this millennium (Table 2).

Direction	Star	δ	α	m	Elev. (h)	App.	Disapp.
D_s	η Tauri (Pleiades)	-20°56′	17^h57^m	$2^m.85$	31°51′	AE - 16	VE +11
	β Centauri	-19°11′	5^h43^m	$0^m.55$	33°35′	VE - 7	AE
D_n	β Herculis	+67°58′	5^h57^m	$2^m.75$	59°16′	VE - 6	AE + 5
	α Coronae Borealis	+66°25′	3^h27^m	$2^m.20$	60°49′	VE - 38	AE + 25
D_{ts}	γ Leonis	+6°13′	23^h38^m	$2^m.20$	58°59′	WS + 7	SS + 19
	α Persei	+5°04′	18^h07^m	$1^m.75$	57°50′	AE - 10	VE + 11
	β Andromedae	+4°54′	16^h13^m	$2^m.05$	57°41′	SS + 36	VE - 36
	δ Corvi	+5°11′	2^h57^m	$2^m.90$	57°57′	WS + 45	AE - 30
	γ Hydrae	+6°43′	3^h48^m	$2^m.95$	59°30′	VE - 34	AE - 19
	ι Scorpii	+6°24′	7^h44^m	$2^m.95$	59°11′	VE + 15	AE + 27
D_{tn}	ζ Herculis	+77°10′	6^h18^m	$2^m.85$	50°03′	VE - 1	AE + 9
	γ Draconis	+76°57′	16^h16^m	$2^m.20$	50°17′	SS + 36	VE - 34

Table 3. Observable stars with apparent magnitude up to $3^m.00$ and their observation days in 9000 BC. App. - appearance, Disapp. - disappearance, SS - summer solstice.

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The same picture would be observed 14 ± 4 days after the vernal equinox when the above-mentioned stars disappear at their culmination points right before sunrise.

Therefore, the fitting of the shadow to the predator's tail tip at noon becomes a clear indicator for the observation of the appearances of *Pleiades* and α *Persei* at their culmination points on the same day, right after sunset (14 ± 4 days before the autumn equinox), and for the observation of the disappearances of the same stars at their culmination points right before sunrise (14 ± 4 days after the vernal equinox). Thus, we see that the **T-shaped Pillar is most likely an ancient astronomical instrument, at the same time adapted as a noon shadow meter, to show what two simultaneous astronomical phenomena can be observed at sunrise or sunset on the same day** (the certain two days during the year).

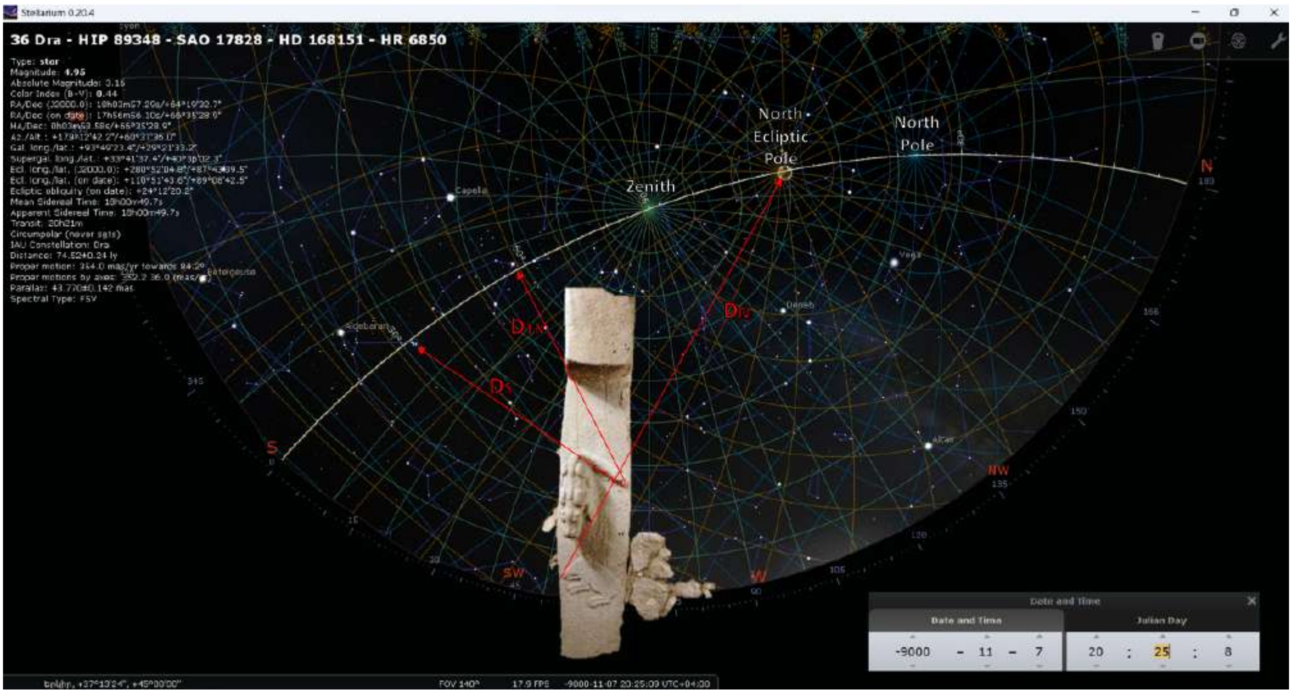

Figure 6. Synchronous culminations of the *Pleiades* and α *Persei* in 9000 BC. The direction D_n is drawn towards the North Ecliptic Pole (*36 Draconis*) simultaneously.

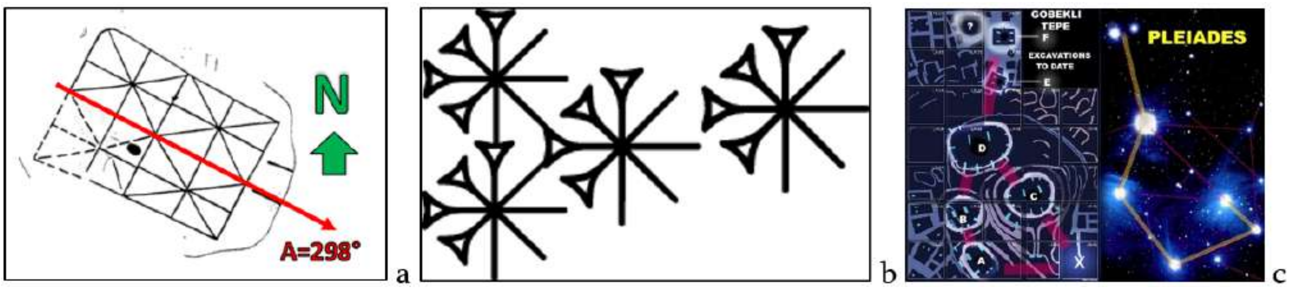

Figure 7. (a) Petroglyph on the small hill platform in Metsamor (Parsamyan, 1985), the directions are drawn by us; (b) Sumerian cuneiform symbol *mul-an* (ePSD, 2024); (c) a comparison of Portasar's Enclosures A, B, C, and D positions with the brightest stars of *Pleiades* (Hershel, 2003).

The simultaneous *Pleiades* and α *Persei* observations were likely related to ancient mythological and calendar concepts. As an additional piece of information, the orientation ($A = 298°$) of the petroglyph on the small hill platform of the Metsamor archaeological site (Armenia) is noteworthy (Parsamyan, 1985, Parsamyan & Mkrtchyan, 1969), which could serve for observing the heliacal rising of the *Pleiades* near to the winter solstice (9000 BC) (Broutian, 2017). The petroglyph itself almost

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repeats the Sumerian cuneiform symbols **"mul-an"** (Figures 7a and b), meaning the "heavenly stars" (ePSD, 2024). It should be emphasized that the petroglyph on the platform in Metsamor Hill corresponds well with the shape of the four largest Enclosures (A, B, C, and D) of Portasar (Figure 7c), the similarity of which with the arrangement of *Pleiades* was also observed before (Hershel, 2003). The "interest" in the *Pleiades* in different monuments already tells about the importance of its observations in ancient times.

The fact that the appearance date of the α *Persei* corresponds to the period of activity of the *September* ε*-Perseids* meteor shower (Gregorian - Sept. 4-14) is also worthy of attention, especially since its radiant coordinates are adjacent to "Medusa's Head" (β *Persei*, Algol, Gorgonea Prima) (Figure 8) (*Stellarium v0.20.4*). **Apparently, the abundance of snake images in Portasar** (Peters & Schmidt, 2004) **should also be related to interpreting such heavenly phenomena**.

Figure 8. The *Perseus* constellation and the position of the radiant of *September* ε*-Perseids* at its maximum activity (Gregorian - Sept. 4-14).

3.2. Hercules and Centaurus

With the help of Pillar 27, the observations of the stars of the *Hercules* constellation were also possible (Table 3). Indeed, the culminations of the β, ζ *Herculis*, and β *Centauri* occur almost simultaneously (Figure 9). The simultaneous disappearances of these stars in the indicated directions would be observed 5 $\pm$ 4 days after the autumn equinox and their appearances 4 $\pm$ 3 days before the vernal equinox. In mythological terms, these observations can be linked to the famous Greek conflict between Hercules and the Centaurs (Kun (1989) pp. 206-208). At that exact moment, the lower culmination of *36 Draconis* (the North Ecliptic Pole) would occur (Figure 9). There is a 180° opposite position of the sky relative to the moment described in point 3.1 (Figure 6). That is, **all the mentioned stars (**η ***Tauri (Pleiades),*** α ***Persei,*** β ***Centauri,*** β**,** ζ ***Herculis, 36 Draconis*****) fall in the same meridian plane** (Tables 2, 3), which is extremely remarkable. If we attribute the approximately 10-day difference between the observations in points 3.1 and 3.2 to the roughness of the calculation, we can also assume that we are dealing with the sunrise and sunset of the same day.

3.3. Draco and Andromeda

β *Andromedae* and γ *Draconis* also reach their culmination points simultaneously, 36 days after the summer solstice, right after sunset, and 35 $\pm$ 1 days before the vernal equinox, right before sunrise (Table 3). Notably, these star culminations corresponded to when the Milky Way plane passed through the zenith point (Figure 10). In other words, the bright layer of the Milky Way had the shape of an

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arc passing through the zenith for the observer from the Earth at that moment, which may have been given a significant meaning in ancient times.

It is also important to note that **the appearance day of *Andromeda* and the *Draco* in the specified directions (Gregorian - July 28) coincides well with the time of activity of the *Perseid* meteor shower** (Gregorian - July 17-August 24, maximum activity: August 13).

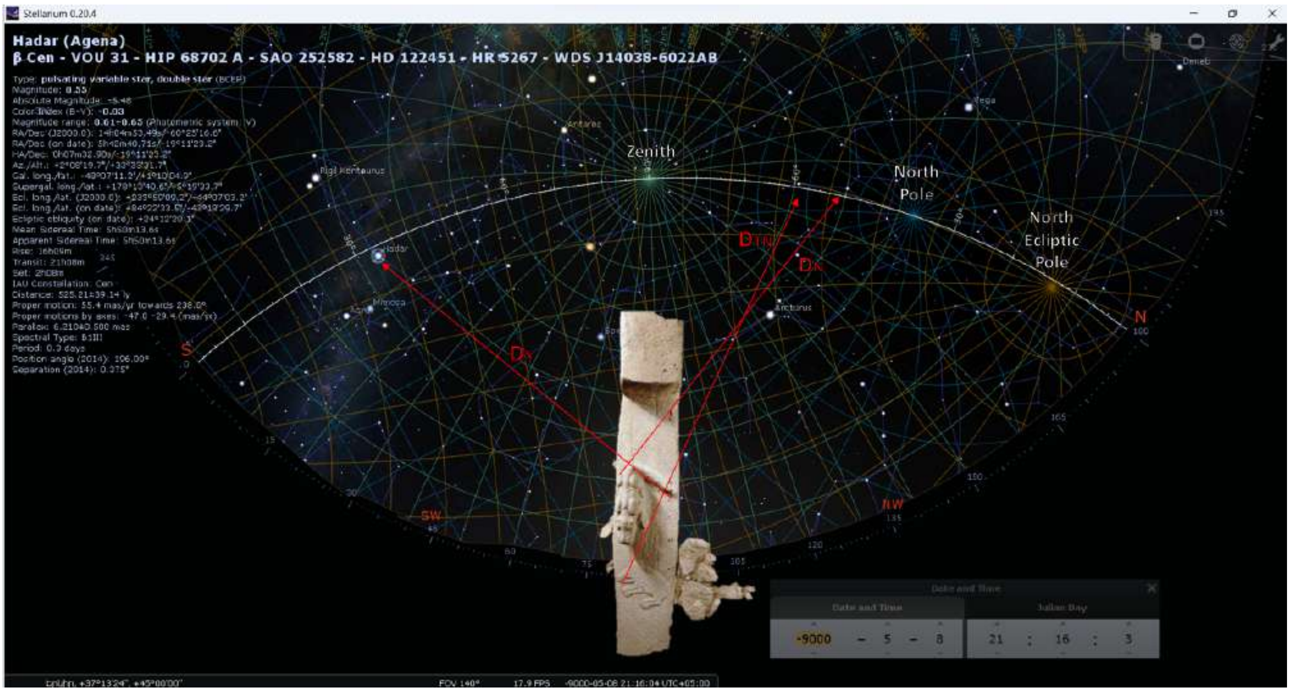

Figure 9. The simultaneous culminations of the stars of *Centaurus* and *Hercules* in 9000 BC. The North Ecliptic Pole (*36 Draconis*) at the lower culmination point.

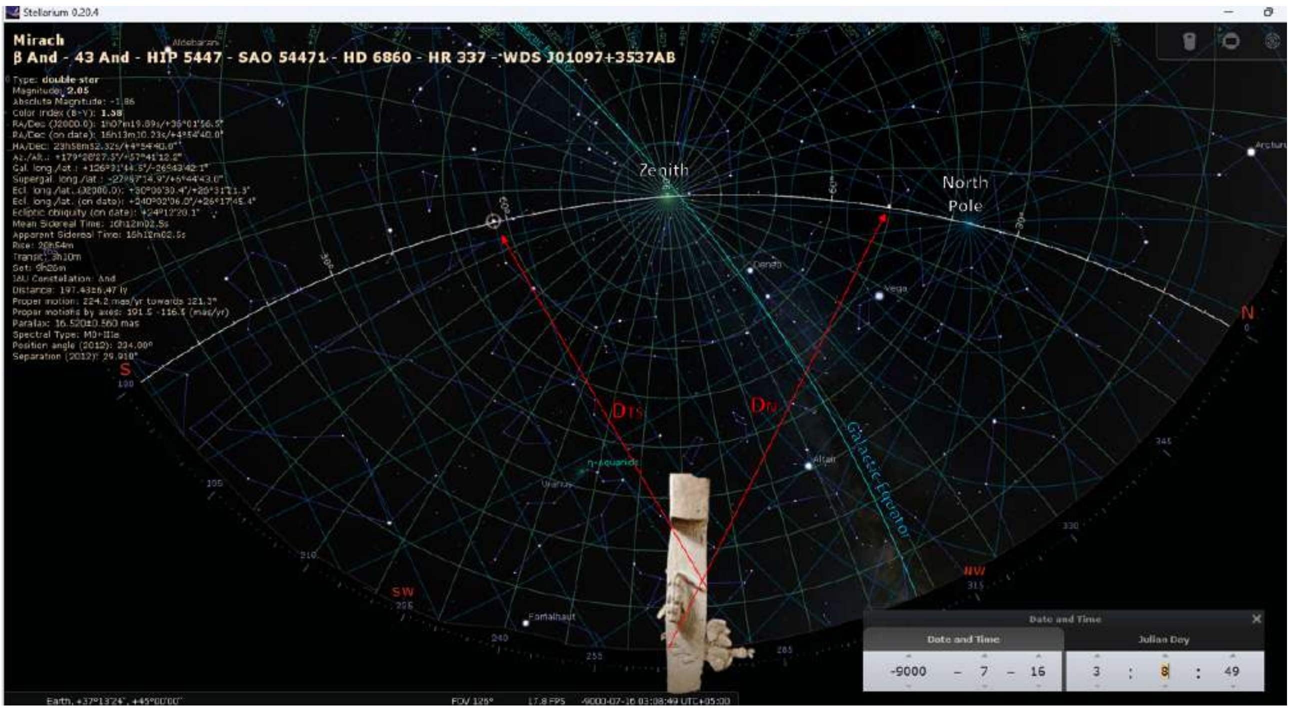

Figure 10. Simultaneous culminations of β *Andromedae* and γ *Draconis* in 9000 BC. The plane of the Milky Way (Galactic Equator) passes through the zenith point.

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β *Andromedae* was observable at the same time as the γ *Draconis*. It is known from Greek mythology that the monster (dragon) is described in two main characters: fish-like (when swimming in the waves of the rough sea) and boar-like (when climbing above the sea) Kun (1989) pp. 151-153). It is interesting that at the time when the mentioned stars were observable, on the western horizon (at about 4° altitude) the Southern Fish (Piscis Austrinus) constellation was visible (Figure 10), which we identify with the mythical Dragon-Fish (Malkhasyan, 2023b). At the same time when the α *Persei* appears at its culmination point, the Southern Fish stars are no longer visible (below the horizon, "dead", "defeated") (Figure 6). We should also note that parallel to the culminations of the above-mentioned stars, the ζ *Cephei* (Cepheus constellation, King Cepheus, Andromeda's father) also reaches its culmination, very close to the zenith point, approximately at the intersection point of the Milky Way plane and celestial meridian (Figure 10). On the other hand, at the time of the Perseus star's culmination, the other star of the Cepheus constellation, γ *Cephei*, reaches its highest position very close to the zenith point (Figure 6). From a mythological point of view, this is a very important circumstance because the events described above occur in the kingdom of Cepheus (Kun (1989) pp. 151-153). Examination of the remaining overlaps presented in Table 3 requires additional data. Therefore, it will be left to the future.

4. Some Parallels with the Megalithic Monument Zorats Qarer

Similar results were obtained in the study of Platform 3 of the Zorats Qarer monument (39°33′ N latitude, Armenia). In particular, from Platform 3 on the top of guiding stone No. 7 (*A=282°32′, h=2°49′*), the acronical rising of the β *Gemini* 37 days after the summer solstice and the heliacal rising 33 days before the vernal equinox were observable in 9000 BC (Malkhasyan, 2024b). We are dealing with the same day and position of the sky. That is, at the time of the culminations of the β *Andromedae* and γ *Draconis* (in the D_{ts} and D_{tn} directions of Portasar) β *Gemini* rises (on the top of the stone No. 7 from Platform 3 of Zorats Qarer). This can be considered an exceptional coincidence. In two different monuments, different stone "instruments" were used to the stars on the same day and at the exact moment. This is especially interesting in that the Portasar monument is also associated with the constellation Gemini worship (Coombs, 2023). Moreover, in 9000 BC, from Platform 3 of Zorats Qarer, in the direction to the top of guiding stone No. 27 (*A=345°32′, h=2°44′*), the heliacal rising of the λ *Velorum* was observable 40 days after the summer solstice and the acronical rising 27 days after the winter solstice (Malkhasyan, 2024b). This is interesting in the sense that at the moment of the λ *Velorum* rising, the plane of the Milky Way coincides with the plane of the horizon, and parallel to it, the β *Centauri* also rises, the culmination of which, as we saw in point 3.2, was observable in the D_s direction of Pillar 27. In other words, Platform 3 in Zorats Qarer served for two observations. In one of them, the Milky Way plane crosses the zenith point (which we see in Portasar (Figure 10)); in the other, it coincides with the horizon plane. Such coincidences allow us to discuss the close relationship between the two monuments. We have also touched on some connections primarily related to the low relief of the vulture on Pillar 43 (Enclosure D) and the constellation Swan (Cygnus) before (Malkhasyan, 2020, 2021b, 2023a, 2024b).

We should also note that similar "observational instruments" were discovered as a result of the studies of the Zorats Qarer monument, which refer to 9000 BC (Malkhasyan, 2022a,b), i.e., the exact date of Portasar (Dietrich, 2011). The observation device made of stones No. 60, 62, and 63 of the Zorats Qarer monument works on the same principle. The two directions formed by their holes stretch to the South and are directed to the culminations of the celestial bodies (Herouni (2006) pp. 64-67).

In almost the same way, the double-angled stone No. 12 was used for simultaneous observations of the main stars of Gemini constellation in 9000 BC (Malkhasyan, 2022b). Besides, the day of these observations corresponds to the midpoint of the period between the summer solstice and the autumn equinox, which corresponds to the result of examining the orientation of Portasar's Enclosure F (De Lorenzis & Orofino, 2015). The authors associated the day with a harvest festival, which was later criticized (Banning, 2023). However, we do not rule out this correspondence if we take our region's grape harvest festival, celebrated around astronomical midsummer (Malkhasyan, 2024b).

A similar "observational instrument" is stone No. 158 in Zorats Qarer, with its two angles simul-

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taneously directed to the bright stars of the constellations Cassiopeia and Ophiuchus four days after the summer solstice (Malkhasyan, 2021b, 2022a). This day already corresponds well to the harvest of autumn cereal crops. As we can see in both monuments, the astronomical calendar and worship content are common in the same millennium context.

It should be noted that in addition to the possible observations of the *Pleiades* in the ancient site Metsamor (Broutian, 2017), an observation device was also found in Zorats Qarer, which is pointed at the rising of the *Pleiades* in a later period. In particular, in 5800 BC, from the same Platform 3 to the top of the stone No. 201 ($A=290^\circ 44'$, $h=2^\circ 13'$), it was possible to observe the heliacal rising of *Pleiades* 38 days before the vernal equinox and the acronical rising 30 days after the summer solstice (Malkhasyan, 2024b). The zenith point crosses the constellation Swan and the Milky Way's plane at that moment. As we can see, the days of such observations are very close to some of the data in Table 3, which we referred to in point 3.3.

As for the function of Pillar 27, its principle parallel was also found in Zorats Qarer in the form of stone No. 137, which was apparently used in much earlier times to specify the observation day of the stars due to the Sun's position (shadow meter, gnomon). With the help of stone No.137, it is possible to determine the summer solstice related to sunrise and the Sun's culmination, which indicates the appearance of the γ *Cygni* (Sadr) in the hole direction ($A=173^\circ 58'$, $h=34^\circ 09'$) on the same day of right after sunset in 15500 BC (Malkhasyan, 2024a).

Summary

The archaeoastronomical analysis of Pillar 27 of Enclosure C in Portasar (Göbekli Tepe) reveals four distinct directions, two of which (D_s and D_n) are formed with the help of the tail of the "predator's" high relief, and the two holes on it. The other two directions (D_{ts} and D_{tn}) are formed due to the T-shaped structure of the Pillar. Examining the received directions as observational, we found out they could have served to observe the culminations of some celestial bodies. In particular:

1) The simultaneous appearance of the *Pleiades* and α *Persei*, as well as *36 Draconis* pointing towards the North Ecliptic Pole, at their culmination points during the activity period of the *September ε-Perseid* meteor shower. The T-shaped structure of Pillar 27 could have served as a shadow gauge to indicate the date of such observations.

2) On the same day (perhaps a few days apart), it was most likely possible to observe the disappearance of the stars of the constellations Hercules and Centaurus at their culmination points.

3) The appearance of the stars Andromeda and Draco at their culmination points was observable 36 days after the summer solstice during the activity period of the *Perseid* meteor shower (as well as the disappearance 35 ± 1 days before the vernal equinox).

4) Principled parallels with the possible observations with the help of pillar 27 and the functional significance of Zorats Qarer Monument (Platform 3, angular stones No. 7, 12 and 158, as well as the stone whit hole No. 137, etc.) dating back to the same millennium (also to an earlier period) are highlighted.

All four points above relate to ancient mythological concepts, which are very superficially examined here. There are also commonalities with ancient calendar patterns, which are still being investigated in detail.

Of course, the measurement method of the directions formed with the help of the structural features of Pillar 27 used in this work is rough because no accurate data is available. However, we think such deviations cannot qualitatively affect the obtained results. It is highly desirable to revise our results if accurate on-site (*in situ*) measurement data are available.

Based on the obtained results, it can be confidently asserted that the search for such "observational instruments" in the Portasar monument is a necessity.

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On the Astronomical Significance of Stone Number 137 of Zorats Qarer Megalithic Monument

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Abstract

The work is dedicated to discovering a new type of "observational device" in the Zorats Qarer megalithic monument and uncovering a new layer of the continuous function of the monument using the "new device." The possible use of the "new device" significantly differs from the observation platforms and angular stones in the same monument. Stone No. 137 in question was previously considered a "periscope" based on some assumptions. By examining the astronomical and structural application of the mentioned stone in more detail and without preconceived assumptions (or with much simpler, obvious suppositions), new functions of its application are revealed. One relates to the observations of circumpolar stars in the direction of the stone hole. The other relies on the puddle and the special structure of the stone. The latter makes it possible to determine the days of the equinoxes and the summer solstice due to the Sun's positions. By combining these two functions, the probable date of the use of the stone is determined: 15500 BC, when it was possible to observe the appearance of the star γ *Cygni* (Sadr, Swan constellation) after sunset on the summer solstice in the direction of the hole.

Thus, a new layer of the "calendar observations" (15500 BC) is added to the already identified layers (9000, 5800, and 2341 BC), which is in harmony with the logic regarding this and other similar monuments (for example, Göbekli Tepe) and essentially complements the evolutionary chain of ancient cultural concepts with its content and time.

Keywords: Keywords: *Zorats Qarer, Stone No. 137, Megalithic Observatories, Swan Constellation, Ancient Gnomons, Observational Instruments, Archaeoastronomy, Ancient Calendar.*

1. Introduction

The recent studies of the Zorats Qarer megalithic monument have revealed many observational devices: platforms, angular stones, and mixed-type "observational instruments" (Broutian & Malkhasyan, 2021, Malkhasyan, 2021b, 2022a,b, 2023a, 2024b). However, the first attention-grabbing feature of the monument was the presence of the stones with holes. Those holes allowed the first researchers to comment on the astronomical significance of the monument (Herouni, 1998a,b, 2006, Khnkikian, 1984, Parsamian, 1985). Later, the hypotheses regarding the observational significance of the holes in the stones received various sharp criticisms (Piliposyan, 2016a,b, Piliposyan *et al.*, 2019). Notably, the large size of the holes was cited as a counterargument. Indeed, the stone holes average from 4 to 5 cm in diameter at their narrowest point, while their two-sided openings are conical and wide, up to 8 to 12 cm in diameter. Therefore, the observation field of the hole includes such a wide angular range that it becomes impossible to single out a specific direction and solve astronomical problems. Therefore, it is necessary to have additional means of guidance to use the holes as an "observational device." The "guiding stones," adapted to the observation platforms, serve that purpose (Malkhasyan, 2022a). Paris Herouni also discussed the difficulty concerning the hole sizes, offering the following:

A. The observer should be positioned 1 m from the hole. The angular error of the direction would then be reduced to 172 arcmin (Herouni (2006) pp. 25-26). To unequivocally claim that the observers were positioned at this distance, an objective argument has yet to be found, especially if we consider

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it was practically impossible for some stones, such as stone No. 137. Moreover, the monument studies have already shown that the observations were made at various distances from the stones, up to 40 m and more (Broutian & Malkhasyan, 2021, Malkhasyan, 2021b, 2022a,b, 2023a, 2024b), while standing, sitting, or kneeling (Malkhasyan, 2022a). Thus, no data regarding the fixed distance of the observation position is currently available.

B. The tension axis direction of the hole should be considered the observation direction (Herouni (2006) pp. 26-28). There is also uncertainty about the latter because most holes are like tubes with different angular refractions.

The issue gets completely different when it comes to the guiding stones, and P. Herouni also studied this issue in the context of the complex description of the holed stones No. 60, 62, and 63. Here, stone No. 63 is described as a guide for the holes in stones No. 60 and 62 (Herouni (2006) pp. 64-67), so the directions determined for these holes are utterly acceptable from an astronomical point of view. However, the same stone complex still requires an additional, more detailed examination to increase the accuracy of the direction determination. For now, it is impossible because the results of laser precision measurement are still being refined.

In Herouni's works, the observation hole description of stone No. 137 is also worthy of attention; the author called it a "periscope." As the author notes (Herouni (2006) pp. 57-59), the hole axis breaks its course upwards (Figures 3b and 4). Therefore, if a polished obsidian piece was placed in the fractured part of the hole, it could serve as a "periscope" to observe the bright stars transitions through the zenith point by refracting the light vertically coming from bright stars to the horizontal direction (Herouni (2006) pp. 57-59). It should be noted that at the zenith point, it would make sense to observe only the appearance of any star immediately after sunset or its disappearance immediately before sunrise in the calendar context (Malkhasyan, 2022b). During such observations, the sky is sufficiently illuminated by the light of the Sun not yet risen or just set, so the reflective properties of an obsidian mirror will not be sufficient, to put it mildly, under such lighting conditions.

The bowl-shaped pit (puddle) on the northern slope of the stone (Figure 1b) is an additional justification in favor of the "periscope." It is assumed that by pouring water into that pit, it was possible to adjust the vertical axis of the hole by moving the stone (Herouni (2006) pp. 57-59). First, it should be noted that changing the water level in the puddle makes it possible to adjust any direction, and it does not necessarily have to be the vertical direction. Moreover, to regulate the position of the stone at the water level, a horizontal mark would be needed on the inner walls of the pit so that the dislocation of the stone could be noticed immediately[1]. A detailed observation did not find such marks. In addition, the stone itself has a broad base, and the probability of its displacement is minimal. Of course, the function of the obsidian mirror and the puddle used to adjust the stone position are hypotheses included to offer such a solution. **The thesis of using stone No. 137 as a "periscope" will not be applicable without these assumptions**.

The present work aims to provide a more detailed analysis of the unique structure of stone No. 137 being researched and the functional significance of the hole in it by including the minimum possible and more obvious assumptions necessary for solving the problem.

2. The Description of Stone Number 137

Stone No. 137 is located on the northern wing of the monument, about 40 m north of the central cromlech. It is part of the main stone row (Figure 1a). Its shape resembles an irregularly cut four-sided pyramid: the upper, relatively flat surface is inclined to the northeast. Descending at a 75° slope, the northern "slope" of the stone forms a bowl-shaped (or triangular) pit at the bottom (Figure 1b). The western wall of the pit continues to the top of the stone, forming about 90-100° angle with the northern "slope." The top of the stone is about 1.2 m above the ground. The hole "entrance" opening which has a diameter of about 10 cm is on the south side. It deepens in a conical horizontal direction to the north by about 10 cm, reducing in its diameter to 5.5 cm, then bends upward at an angle of about 110-120° and begins to widen in diameter, reaching 11 cm in the "exit" opening (Figures 3b and 4). The distance between the "entrance" and "exit" of the hole is about 20 cm.

[1] Astronomer Karen Tokhatyan expressed a similar opinion during a private discussion (Dilijan, 10 July, 2023).

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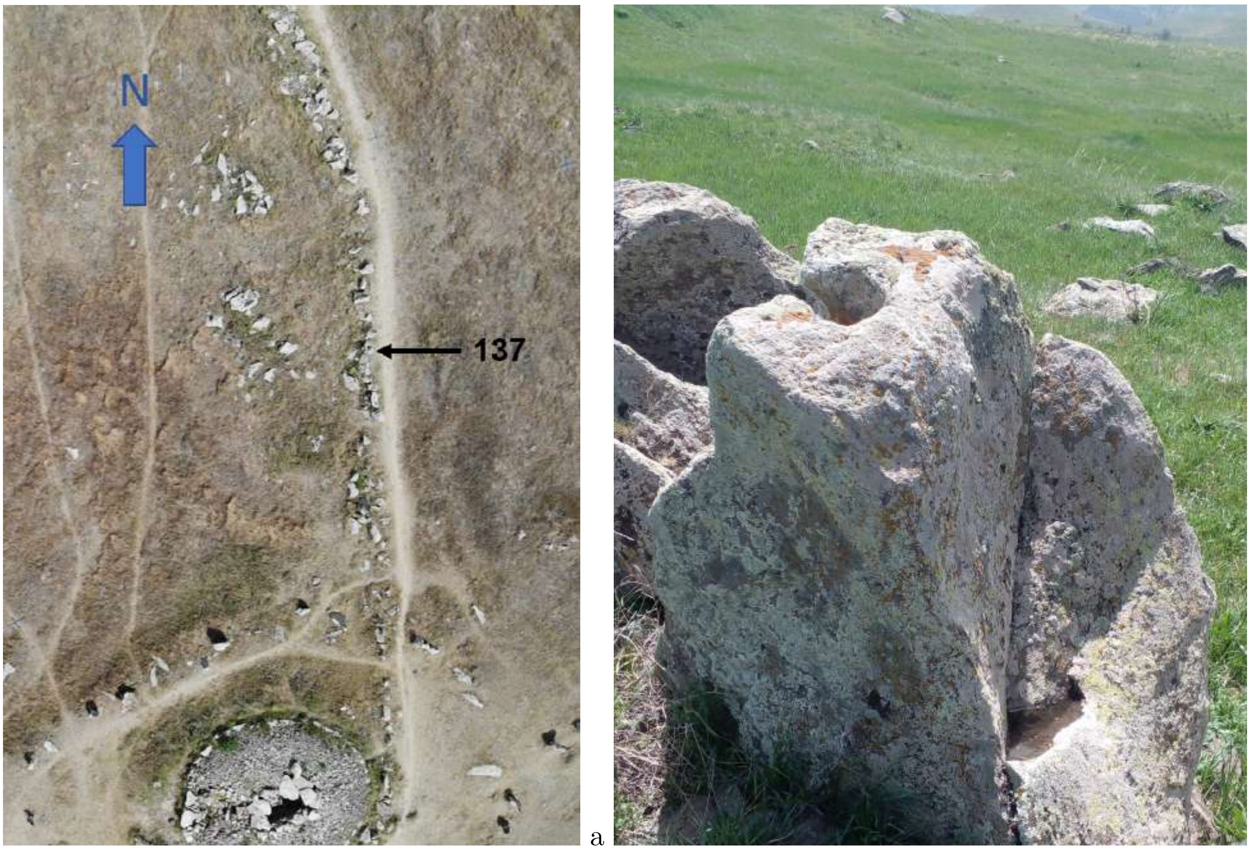

a b

Figure 1. Stone No. 137 of the Zorats Qarer monument: (a) location in the stone row; (b) photo of the same stone from the northeast. Our expedition team took all the photos in the article in 2020.

a b

Figure 2. Hole of stone No. 137. The arrows indicate the groove in the exit part of the hole: (a) photo from above; (b) photo from the south.

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The hole "entrance" is about 1m above the ground, which is a regularity in making observations in a kneeling position in the case of this monument (Malkhasyan, 2022a,b, 2023a). A small part of the upper arch of the hole (3-4 cm long) is broken (Figure 2a, b). The fracture surface and the entire processed surface of the hole are covered with a dense lichen layer, which is macroscopically characteristic of the lichen layer on the outer surface of the stone. There is a straight groove on the upper flat surface of the stone on the north side of the "exit" opening, the axis of which roughly coincides with the hole axis (directed approximately to the north). The groove is located on the northern side of the "exit" opening of the stone and has a radial arrangement to the circle of the opening (Figure 2a, b).

As we can see, stone No. 137 is very different from the other stones of the monument due to its structure. Let us take a detailed look at the features mentioned above separately to clarify the purpose of the structure.

2.1. Structure and Direction of the Hole of Stone Number 137

For simplicity, let us consider the hole structure on the section along the meridian plane (Figures 3a, b, and 4) and consider that the hole was complete during the use of the stone. If we connect the lower point of the "entrance" opening to the northern point of the "exit" opening, this line will touch (or be very close to) the upper point of the section with the smallest diameter of the hole (Figures 3b, and 4). Thus, the observer's field of view will be drastically limited when the eye position moves vertically. This structure allows us to specify the vertical component of the observation direction (H-137)[2] (the elevation angle from the mathematical horizon). However, such limitation of the observation field remains quite broad in the horizontal direction. The observation field gets horizontally almond-shaped (Figure 4). The accuracy problem of the horizontal component (azimuth) of the H-137 direction is solved by the above-mentioned approximately 1 cm deep groove on the northern curve of the "exit" opening (Figures 2a, b, and 4).

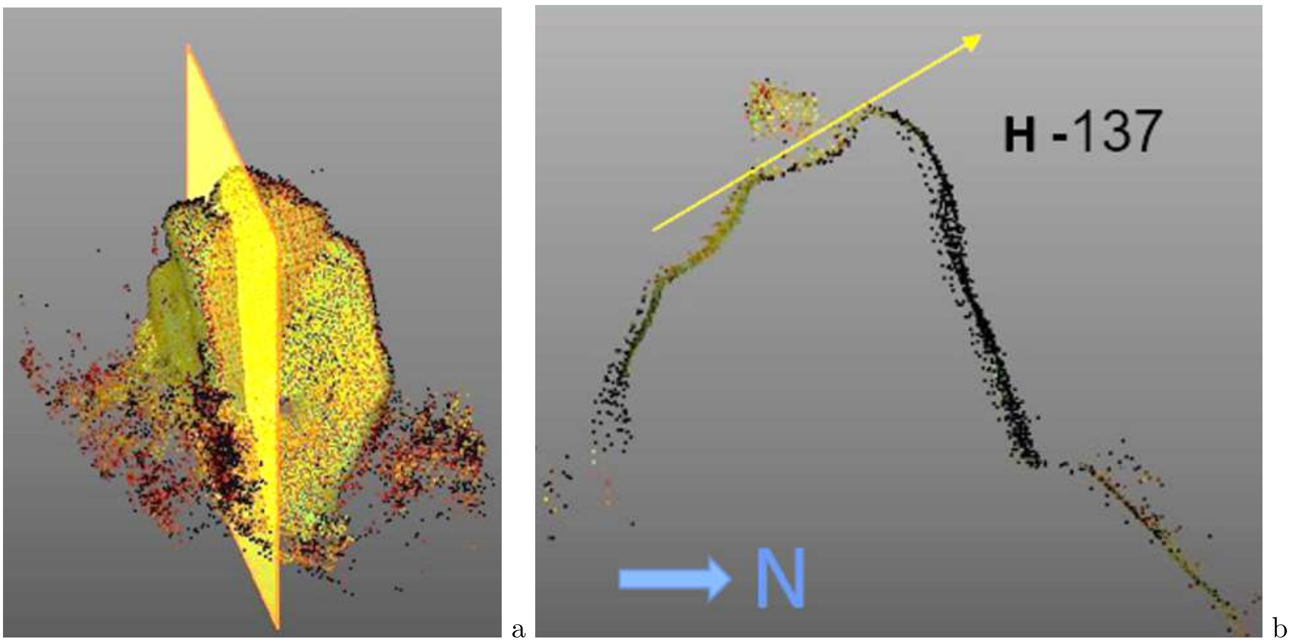

Figure 3. Digital point cloud of stone No.137; (a) position relative to the meridian plane; (b) hole configuration projected on the meridian plane: the yellow arrow shows the H-137 direction of the hole.

[2]Such designation of direction is not an end in itself. In the previous works, the letter P (platform) is used to designate the directions from the observation platforms to the guiding stones, and the letter A (angle) is used to designate the directions of the angular stone corners (Malkhasyan, 2022a). From now on, the letter H (hole) will denote the directions of the stone holes to avoid confusion.

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Figure 4. Schematic reconstruction of the integrity of the hole and the orientation of H-137 direction on the longitudinal section of the hole structure.

Star (m)	Right ascension	Azimuth	Disapp.	App.	Date (BC)
α Ursae Minoris ($1^m.95$)	23^h41^m	173°52′	AE + 38	VE + 28	808 (AD)
β Ursae Minoris ($2^m.05$)	16^h29^m	173°51′	SS + 44	WS + 31	375
	19^h29^m	173°53′	AE - 11	VE - 23	1725
α Lyrae ($0^m.00$)	10^h28^m	173°50′	VE + 48	AE + 30	11070
	1^h39^m	173°52′	WS - 32	SS - 38	13140
γ Cygni ($2^m.20$)	7^h04^m	173°53′	VE - 36	SS + 32	14935
	4^h56^m	173°54′	WS + 15	SS - 2	15500
α Cygni ($1^m.25$)	9^h54^m	173°49′	VE + 37	AE + 17	15075
	2^h06^m	173°53′	WS - 25	SS - 36	16990
α Cephei ($2^m.45$)	14^h52^m	173°53′	SS + 26	WS + 12	17845
	21^h04^m	173°52′	AE + 6	VE - 6	20235
α Ursae Minoris ($1^m.95$)	10^h45^m	173°53′	SS - 39	AE + 35	23085

Table 1. Stars of apparent magnitude up to $2^m.50$ and their data that have been observable in the H-137 direction during the last 26000 years; (A=173°58′; h=34°09′); m - apparent magnitude, VE – vernal equinox, SS – summer solstice, AE - autumn equinox, WS - winter solstice, Disapp. – day of disappearance, App. – day of appearance.

Hence, the significant refraction of the axis of the stone hole and the groove on the "exit" opening together specify the vertical and horizontal components of the direction under examination (elevation and azimuth). Our expedition team measured the data related to this direction (H-137) in 2020; the data are in Table 1. The same table also shows the stars observable in the H-137 direction during the last 25776 years (one complete Earth's Precession) and their observation days and conditions. Notably, the obtained direction is very close to the North Pole direction (the angular elevation of the North Pole at the geographic latitude of the monument is 39°33′, and the azimuth is 180° from the South point). Thus, **one can observe only stars but not other celestial bodies in the given direction**.

2.2. Possible Function of the Puddle on Stone Number 137

The puddle has a triangular structure with two walls continuing upwards but accessible on the third, northern side (Figures 1b, 5). The continuing western and southern walls form an approximately 90-100° angle with each other. The southern wall is inclined to the south, forming an angle of 15°06′ to the vertical axis of the latitudinal plane (Figure 3b) and about 30° to the horizontal axis (Figure 5). The western wall is inclined to the west, forming an approximately 40° angle with the vertical axis

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of the meridian (Figure 5). Starting from the top of the southern wall corner, the intersection line of the western and southern walls forms a clear direction upwards with the following components: 39°34′ height from the mathematical horizon and 49°17′ azimuth from the south point (Figures 1b, 5). Let us find out what kind of practical significance this structure could have.

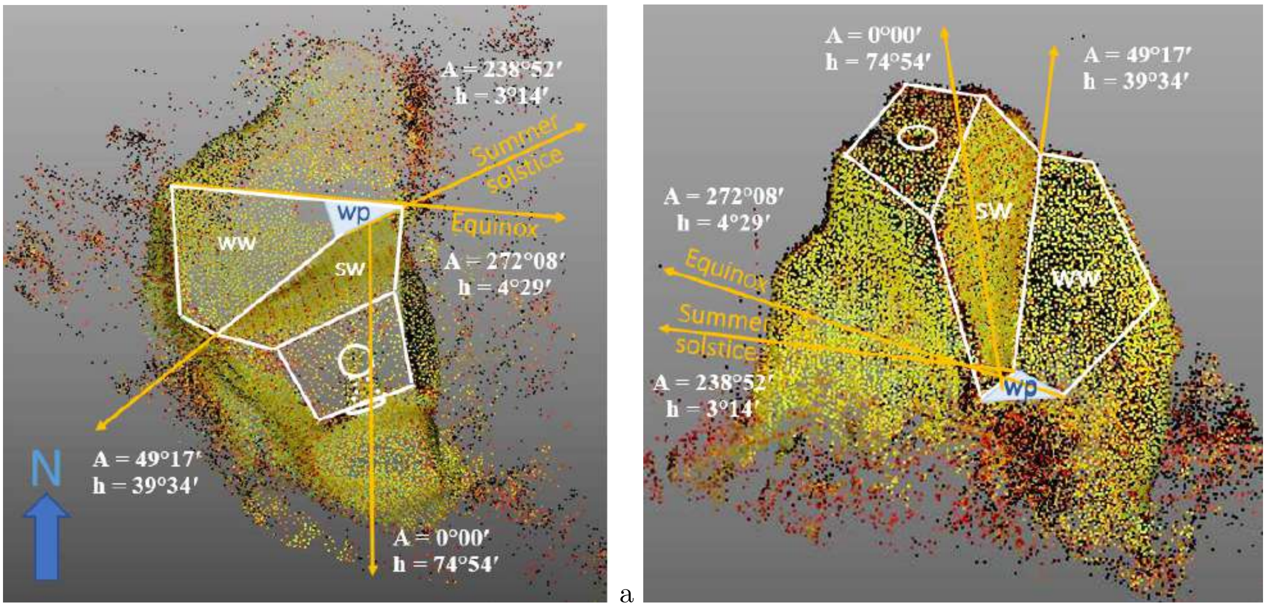

Figure 5. Digital point cloud of stone No. 137: (a) some directions are indicated from above; (b) from the northeast, the southern (northern "slope") and western walls are highlighted, which form the two sides of the triangular puddle.

In the simplest case, the puddle can relate to the Sun's light reflection, which has been noticed before (Herouni, 2006)[3]. First, no matter how reflective the water surface is, it is hard to imagine that it can reflect the light from bright stars or visible planets. On the other hand, we already know other ways of observing stars in the monument (for example, the angular stones) (Malkhasyan, 2022a), which are easier to use and do not require any "mirror" observations. As for the Moon's disk, its constantly changing shape and large orbital obliquity (5.14°) are questionable regarding regular observations. Additionally, it is unsuitable for calendar purposes since the Moon can appear in the same position more than once during its yearly cycles, at different phases, on different days and hours. At the same time, there is no strict need for any instrument to observe the Moon's phases and periods. Therefore, the connection between the puddle function and the Sun's light reflection is more than logical. Now, let us see how the Sun's visible movement in the sky can be expressed in the puddle under discussion.

First, let us consider the most obvious direction, formed by the intersection of the western and southern walls and resembles the angular stone structure (Malkhasyan, 2021b). In this direction (A = 49°17′, h = 39°34′) (Figure 5), the Sun makes a brief transition about 3.5 hours before sunset, two days after the vernal equinox, and three days before the autumn equinox (Figure 6), under the conditions of today's Ecliptic obliquity ($\varepsilon = 23°26'18.9''$)[4]. If we consider the upper point coordinates of the Sun's disk rather than its center point coordinates, we will be one day closer to the equinoxes. **Notably, the elevation of this direction is equal to the geographical latitude of the monument location (39°33′ N latitude), that is, the elevation of the North Pole**. At the same time, the first sunbeams (A=272°08′, h=4°29′) will illuminate the northern edge of the western wall at sunrise on the same days. The western wall cannot be illuminated during the winter period between these two days (vernal and autumn equinoxes). The point is that the slope of the southern wall of the stone

[3]In Figure 27 of the book, the sunlight is reflected in the puddle of stone No. 137. The photo is dated 23 June 1996 (one day after the summer solstice). However, he does not address this issue in his works and attributes a stone-position regulating function to the puddle.

[4]All the data in the article were taken and calculated with the help of the *Stellarium v.0.20.4* computer package. (https://stellarium.org)

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shadows the puddle and part of the western wall throughout the year, from sunrise to noon. The puddle can be illuminated throughout the day at the Sun's northernmost positions (at its maximum declination) only on days close to the summer solstice (Figures 5 and 6. At the summer solstice, at the Sun's culmination, the zenith distance of the upper point of the disk[5] is 15°51′ under the circumstances of today's ecliptic obliquity ($\varepsilon = 23°26'18.9''$). However, if we consider the puddle size, which is about 10 cm[6] in the north-south direction, the Sun's disk will be fully reflected in the puddle because the zenith distance of the southern wall slope is 15°06′ (Figure 6). After noon, when the sunlight begins to change its direction from north to northeast, the Sun can be reflected in the puddle during the summer period from the vernal to autumn equinoxes. Thus, we have the following picture. Sunlight illuminates the puddle for about 180 days from the vernal to autumn equinoxes, only during the afternoon. Moreover, from sunrise to noon, a part of the western wall is always in shadow, except for the days close to the summer solstice, when there is no shadow on the western or southern walls. The puddle and the western wall are not illuminated from the autumn to vernal equinoxes (Figure 7). **This device can help accurately determine the equinox and summer solstice days**. In addition, considering the shadow position of the western wall at sunrise can also provide guidance. For example, if we divide the western wall into three longitudinal parts (even with markings), the shadow will coincide with them for 30 days with great accuracy. This way, using the movement of the Sun's shadow, one can determine the limits of six months, each consisting of 30 days. Since the conditions of today's ecliptic obliquity are discussed, the stone can perform the same function even today, and today, **the obtained results can be verified through experimental observations.**

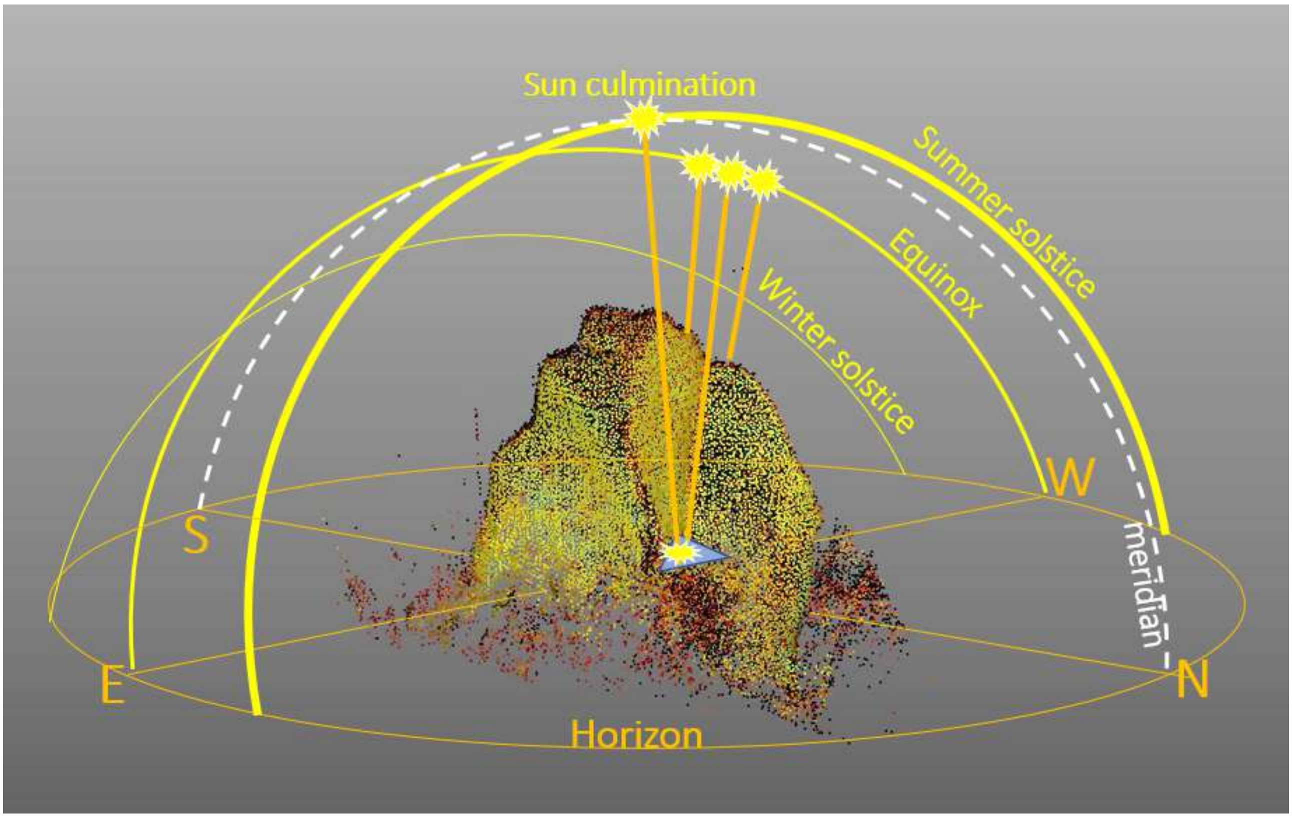

Figure 6. The visible movement of the Sun towards the geographical directions on the days of the equinox and solstices is described. The diagram shows the Sun's reflection in the puddle at the summer solstice, at the Sun's culmination, and when the Sun is reflected in the puddle approximately 3 hours 30 minutes before sunset at the equinoxes. It is taken into account in terms of today's angle formed by the Ecliptic and Equatorial planes ($\varepsilon = 23°26'18.9''$).

[5]The visible angular diameter of the Sun's disk is about 32′.
[6]It depends on the water level.

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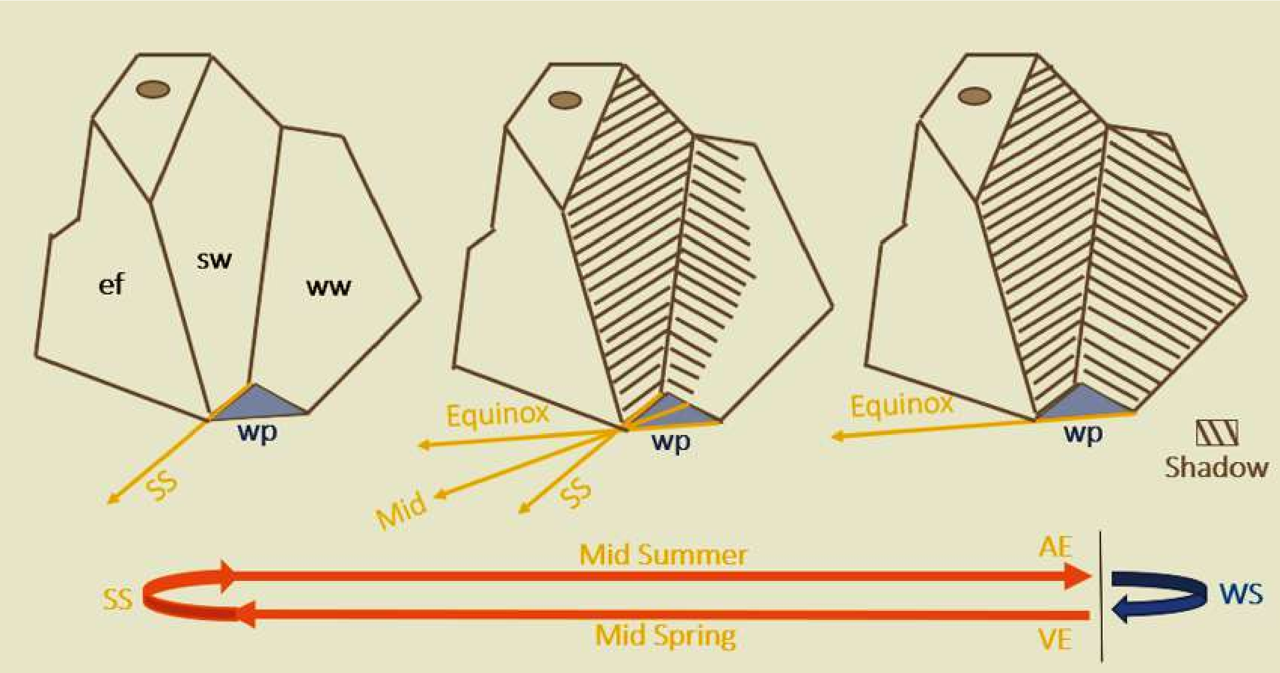

Figure 7. Position of the shadow on the western and southern walls of stone No. 137 on the days of equinoxes and summer solstice. Schematic simplified diagram: ef – eastern face, sw- southern wall, ww – western wall, SS – summer solstice, VE – vernal equinox, AE – autumn equinox, wp – puddle (triangular water pit).

Thus, the puddle function and the unique structure of the northern part of stone No. 137 are fully explained, which is related to determining the days of the equinoxes and the summer solstice[7]. However, it is noteworthy that when the Sun rises and goes up, the puddle is illuminated only on the days close to the summer solstice (± 15 days, depending on the ecliptic obliquity and the water level in the puddle). On other days, the descending Sun's light can only illuminate the puddle in the afternoon. Moreover, the eastern face of the stone almost coincides with the meridian plane, so immediately after the Sun's culmination, its luminous surface will be shadowed immediately, thus serving as an indicator for determining the midday. This is important to the extent that **the ancient world gave immense importance to the worship of the rising and culminating Sun, which is strongly expressed in the stone function described here and is associated with the summer solstice.**

3. Results and Discussion

As we have seen, stone No. 137 has several functions. On the one hand, its hole was most likely intended to observe the circumpolar stars and, on the other hand, to determine the equinoxes, especially the summer solstice, with the help of the puddle. **Hence, if the stone has two functions, it can be surely assumed that they must be somehow related. Particularly, circumpolar star observations in the direction of the hole can relate to the equinoxes and the summer solstice.** This point of view has a full right to exist because the results of the studied parts of the monument testify to the fact that if the same stone performs more than one function, they are necessarily connected to each other (Broutian & Malkhasyan, 2021, Malkhasyan, 2021b, 2022a,b, 2023a, 2024b). Now, let us consider the data in Table 1 in this context.

[7]The determination of equinoxes and solstices with the help of shadows is also known in many other monuments. Particularly, such a function is attributed to the Sev Sar's petroglyph (Armenia) (Frincu *et al.*, 2021).

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3.1. Probable Date of Full Application of Stone Number 137

First, as shown in Table 1, no bright star observation has been possible in the astronomical "layers" of the monument studies obtained so far (9000, 5800, and 2341 BC). At the same time, Stone No. 137 under discussion cannot be classified among observation platforms and their guiding stones or angular stones. Though the reciprocal arrangement of its southern and western walls resembles the angular stone structure, no observations are possible from this angle, and, as we have seen, its function is probably related to the sunlight reflection in the puddle. **These considerations allow us to attribute the observational use of stone No. 137, especially its hole, to another date.**

Next, in Table 1, it is noteworthy that in 20235 BC, star α *Cephei* was possibly observed six days before the vernal equinox and six days after the autumn equinox because the second function of the stone, as we have seen, is related to the equinoxes. Notably, these days differ by six to seven days from the days pointed by the "shadow meter" described above. Thus, the second function does not coincide with the days of the appearance or disappearance of α *Cephei* in the indicated direction because the sunlight does not illuminate the western wall and the puddle of the stone in any way. Therefore, this date can be considered less likely. **The days when the other stars are observable differ significantly from the equinoxes and the summer solstice days, except for 15500 BC, the appearance date of star γ *Cygni*, which almost exactly corresponds to summer solstice day** (Table 1). If we consider that the observation of this star was possible two days before the summer solstice immediately after the sunset, the following day's sunrise differs from the summer solstice by one day, which is directly related to the second function of the stone – the determination of the summer solstice. Now, let us look at this date in more detail.

3.2. Additional Reasoning Regarding the Date 15500 BC

Notably, the 15500 BC is consistent with the results we have obtained regarding the preliminary expansion date of the monument (29300 BC) (Malkhasyan, 2020). At the same time, stone No. 137 is not a part of the central cromlech; the latter's construction date we obtained refers to 9000 BC (Malkhasyan, 2022b, 2023a, 2024b). In addition, this is not related to the observation platforms studied; therefore, there is no contradiction with the previous results. It is more than possible that the stone could have been placed at an earlier date related to the operation of the monument and used in later times as well. The reason is that, as we have seen, its function of determining the Sun's positions still applies today. Moreover, in 15500 BC, the ecliptic obliquity ($\varepsilon = 23°32'04.5''$) does not significantly differ from today's value ($\varepsilon = 23°26'18.9''$). Therefore, there is no need to recalculate the results obtained for the mentioned date.

The fact that **the summer solstice is closely related to the beginning of the year in ancient Armenian calendars (Navasard Festival)** (Broutian, 1997, 2016, Malkhasyan, 2021a) makes the possibility of this observation more significant, especially when considering the following:

1) The examination of Platform 3 of Zorats Qarer monument has already revealed that the appearance of star γ *Cygni* was observable in the angle direction of stone No. 7 in 9000 BC, 27 days before the summer solstice, especially as the detailed examination of this star's calendar and ideological content unveils close connections with the summer solstice, the Navasard month, and the Holiday of Navasard (Malkhasyan, 2024b).

2) On the same occasion, this star is also associated with the "mythical bird's" crop, the content of which is explained by moving the highest Sun from the beak right into the crop (Malkhasyan, 2024b). We have the same thoughts concerning Stone No. 137. The sunlight reflection in the stone puddle on the summer solstice can definitely be explained in the same context if we consider the puddle as the "stone (bird's) crop" and its upper part as the beak.

3) Stone No. 137 is located between the center of the monument and its northern wing, which does not contradict these ideas either and is expressed, for example, in the bas-relief of the vulture on Portasar's (Göbekli Tepe) Pillar 43 and the bird decoration on the Early Bronze Age vessel from Keti (Armenia) (Malkhasyan, 2024b), which has a calendar content (Broutian, 2007).

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4) The plan structure of the monument is related to the Swan (Angegh-Vulture) constellation (Malkhasyan, 2020, Vahradyan & Vahradyan, 2010).

5) The astronomical calculation of the age of an episode of the "Sasnay Tsrer" epic resulted in a qualitatively similar date, and it is vitally important to note that this calculation is based on the time having the closest coordinates to the north pole of star α *Cygni* in the same constellation. Moreover, in 15500 BC, o_1 and o_2 *Cygni* stars (Vulture's Beak) were polar (Broutian, 2021, Malkhasyan, 2020).

6) The obtained date (15500 BC) entirely fits into a regularity previously obtained in a different way. The point is that the astronomical dating of the Fish-shaped Vishap (dragon) stones resulted in a regular period of the change of the calendar's main star (with a difference of 3250 ± 50 years) (Malkhasyan, 2023b). Since 18800 BC was revealed as the time of Dragon-fish's worship, one should assume another change occurred 3300 years after that, which refers to the date obtained for the use of Zorats Qarer's stone No. 137 (15500 BC).

The listed considerations allow us to discover the stars performing heliacal rising on the summer solstice in 15500 BC, that is, to discover the calendar's main star of that time. Our examination shows that the heliacal rising of only several stars was observable on the summer solstice at that time, depending on the angular elevation of the visible (real) horizon. These stars are ε *Pegasi*, β *Aquarii*, and β *Capricorni*. A separate detailed examination is necessary to determine which of the mentioned stars had the paramount significance, which is beyond the scope of the main problem of this article.

It is worth giving a solid explanation to one more question here. **What is the reason for such accuracy of the hole direction on stone No. 137 if most of the holed stones in the monument lack such features? The point is that high accuracy is needed to notice the daily coordinate changes of the stars near the North Pole.** This is the fundamental reason for providing exceptional accuracy to the hole direction, and this, in turn, additionally confirms that we are dealing with circumpolar star observations in this case.

As we can see, there are many arguments in favor of considering the γ *Cygni* star observations in 15500 BC realistic, which are expressed in the results of these calculations, previous research on the monument, astronomical examination of the Armenian folklore material, and the analysis of the iconography present in the archaeological monuments found elsewhere (particularly in Portasar(Göbekli Tepe) (Malkhasyan, 2024b)).

Summary

The detailed astronomical examination of stone No. 137 of the Zorats Qarer monument reveals several observational functions unrelated to being a "periscope," as previously assumed (Herouni (2006) pp. 57-59).

a) The unique structure of the stone hole and the additional groove were intended to improve the accuracy of observations of circumpolar stars.

b) The most likely observation refers to the appearance of star γ *Cygni* right after sunset in 15500 BC on the summer solstice.

c) The structural features of the stone and its water puddle, serving as a solar shadow meter, enable quite precise determination of the days of the equinoxes and summer solstice. The presence of a stone with this function in this monument can be considered a new reality.

d) The above-mentioned stone functions are directly related to each other and refer to the summer solstice. A similar principle of "observation devices" was also used for later calendar times (9000 BC) of the same monument (Malkhasyan, 2024b) and in the case of Portasar's (Göbekli Tepe) Pillar 27 ((Malkhasyan, 2024a).

e) The shape and structure of the stone fully correspond with their content to the summer solstice and its ancient pictorial and substantive perceptions. Moreover, if the observation of star γ *Cygni* in later periods relates to the morphological expressions of the mythical bird (in this case, the Vulture's crop) swallowing the Sun, we deal with its deeper perception here. Thus, the Sun's being on the bird's

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beak and in the crop simultaneously (Malkhasyan, 2024b) is expressed by the Sun's culmination on the summer solstice and its reflection in the puddle of stone No. 137.

Hence, a new temporal observational (calendar) "layer" dating to 15500 BC is revealed in the Zorats Qarer monument, outlined in the previous studies to some extent. The "observation device" described in this layer significantly differs from the observation platforms and angular stones. However, Portasar's Pillar 27 has a very similar use in principle, which is again a shadow meter and is covered with holes oriented towards same-day observations (Malkhasyan, 2024a). Here, it is also possible to identify the calendar's main star for the mentioned period. It is necessary to look for other similar stones in the Zorats Qarer monument, which will allow us to distinguish the given "layer" more clearly and make the changes made in later periods evident.

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A study of the Shk40 compact galaxy group

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Abstract

A compact group represents a specialized type of galaxy system where member galaxies are separated by distances roughly equivalent to the size of galaxies themselves. The intense interactions among these galaxies make compact groups ideal laboratories for investigating the environmental impacts on galaxy evolution. In this study, we aim to investigate the Shk40 cluster from the Shahbazian catalog of compact groups of galaxies.

Keywords: *galaxy; Galaxy compact group*

1. Introduction

Galaxies are the building blocks of the visible universe, inhabiting a variety of environments from isolated fields to dense galaxy clusters. Observations show that over half of the galaxies are located in group systems, which have members ranging from a few to dozens (Huchra & Geller, 1982, Yang et al., 2007). Among the various clusters and groups of galaxies, significant attention is given to compact clusters or groups composed of compact galaxies. These systems are particularly noteworthy due to the minimal redshift dispersion observed among the brightest and most compact galaxies within them. A compact group represents a specialized type of galaxy system where member galaxies are separated by distances roughly equivalent to the size of the galaxies themselves. The intense interactions among these galaxies make compact groups ideal laboratories for investigating the environmental impacts on galaxy evolution. Both simulations (Brasseur et al., 2009), and observations (Lee et al., 2004) have shown that the fraction of early-type galaxies in compact groups is significantly higher than in normal groups. Galaxies within compact clusters exhibit a systematically larger concentration index and higher surface brightness, suggesting that star-forming galaxies are more likely to be quenched in such environments clusters (Coenda et al., 2012).

The study of compact groups of compact galaxies was initiated at the Byurakan Observatory during the 1960s. The first catalog of 30 compact groups of compact galaxies was published by Shakhbazyan (1973). Between 1973 and 1979, Shahbazian, Petrossian, and their colleagues, using red maps from the Palomar Sky Survey, found and published ten lists of compact groups of compact galaxies. In 1998, the HEASARC included a related database table, SHK GALAXY, which contains data on the individual galaxies in the Shakhbazian Compact Groups. This catalog is a compilation of the ten lists and includes 377 groups of compact galaxies. It provides identifications, equatorial coordinates, numbers of constituent galaxies, magnitudes of the brightest member, sizes of the groups, and coefficients of relative compactness: VizieR On-line Data Catalog: VII/89B (Stoll et al., 1998).

2. Observation

The images of group Shk40 were obtained in 2023 with the 1-m Schmidt telescope of Byurakan observatory, which was upgraded during 2013 – 2015 and equipped with CCD detector. Reworked 4K×4K Apogee (USA) liquid-cooled CCD camera was used as a detector with a pixel size of 0.868" and field of view of about 1 square degree, which is suitable for the study groups of galaxies (Dodonov et al., 2017). Wide-band filter centered on 6200 Å to 7000 Å, were used. Such data ensure the successful classification of objects and measurement of redshifts by analysis of energy distribution in the objects spectra. Bad weather conditions did not make it possible to observe the Shk40 group with different filters and for different periods of time.

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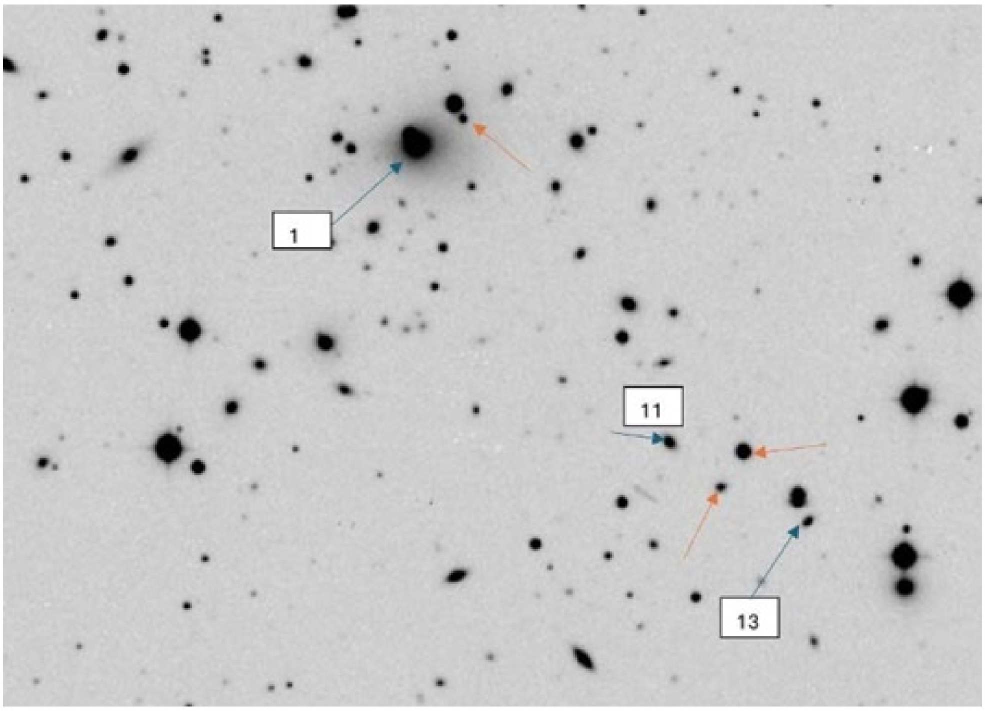

Figure 1. Image of Shk40 taken with 1m telescope BAO

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3. Results

The images of group Shk40 taken in 2023 with the 1-m Schmidt telescope of Byurakan Observatory were processed using the standard IDL package, which includes bias subtraction, cosmic ray removal, and flat fielding using "super flat-field", constructed by several images.The image of Shk40 is given in the picture. Galaxies Shk40-17 and Shk40-59 are not visible in the image, and members Shk40-9, Shk40-21, Shk40-22, Shk40-40, Shk40-53 and Shk40-54 are barely visible. Shk40 is a relatively rich and compact galaxy cluster, originally cataloged with 60 galaxies. Our objective was to identify the galaxies within this cluster, accurately determine their coordinates using Gaia DR3 data, and discover any additional galaxies that belong to the cluster but were not included in the original catalog. We include the 4 newly discovered galaxies marked in red in the Figure 1, which data are given in Table 1. The corrected coordinates of galaxies the Shk40 compact group , Gaia DR3 and 2MASS photometric data are given in Table 2.

Table 1. Newly Discovered Galaxies in Shk40

Galaxy ID	RAJ200	RAJ2000	GaiaDR3	G	2MASS	J	H	K	Z	Galaxy
-	"h:m:s"	"d:m:s"		mag	mag	mag	mag	mag	Redshift	identification
Shk40-61	01 24 50.81	+08 37 43.32	Gaia DR3 2578884117559664768	21.21	01245081+0837432	15.79	15.15	14.78	0.04136	WINGS J012450.82+083743.3
Shk40-62	01 24 31.25	+08 38 24.42	Gaia DR3 2578881403140332672	21.13	01243126+0838244	15.06	14.38	14.03	0.04719	WINGS J012431.24+083824.4
Shk40-63	01 24 49.86	+08 38 12.28	Gaia DR3 2578887072497163904	21.21	01244986+0838122	11.17	10.53	10.3	0.050719	[TSK2008] 2056
Shk40-64	01 25 05.29	+08 42 20.66	Gaia DR3 2578889168441231232	21.27	01250576+0842314	12.16	11.69	11.64	-	LEDA 138365

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4. Summary

During the study of group Shk40, we performed the following steps:

- *Identification of Galaxies:* We began by cross-referencing the original catalog with current astronomical databases to confirm the listed galaxies' identities and properties
- *Coordinate Determination:* Utilizing the high-precision data from Gaia DR3, we precisely determined the celestial coordinates of each galaxy in the cluster. This data provided us with accurate positions, which are crucial for detailed astronomical studies.
- *Search for Additional Members:* We conducted a thorough search within the region of the cluster to identify potential cluster members that were not included in the original catalog. This involved analyzing photometric and spectroscopic data to confirm their membership.
- *Catalog Update:* Finally, we have updated the Shk40 catalog (which data are given in Table 2.), and include the 4 newly discovered galaxies marked in red in the Figure 1, which data are given in Table 1.

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Table 2. Corrected Coordinates and Photometric Data for Shk40 Galaxies

Shk40	RAJ200 "h:m:s"	RAJ2000 "d:m:s"	GaiaDR3	G mag	2MASS mag	J mag	H mag	K mag	Z redshift
Shk40-1	01 25 07.63	+08 41 57.11	GaiaDR3 2578889168441231744	19.71	01250762+0841576	12.87	12.27	11.83	0.0501
Shk40-2	01 25 03.04	+08 42 45.02	GaiaDR3 2578889237160675968	20.09	01250304+0842450	15.2	14.61	14.28	0.0601
Shk40-3	01 24 59.25	+08 42 07.18	GaiaDR3 2578887725332188800	19.4	01245925+0842070	14.14	13.42	13.05	0.0479
Shk40-4	01 24 58.46	+08 42 16.13	GaiaDR3 2578887931490618624	20.57	01245846+0842160	15.68	15.02	14.74	-
Shk40-5	01 25 00.24	+08 41 31.20	GaiaDR3 2578887725331667968	20.29	01250024+0841311	15.45	14.94	14.53	-
Shk40-6	01 24 58.78	+08 40 39.76	GaiaDR3 2578887617957441408	20.82	01245878+0840396	15.55	14.97	14.67	0.0514
Shk40-7	01 24 55.19	+08 41 20.44	GaiaDR3 2578887690972682112	21.13	01245518+0841204	15.82	15.22	15.03	0.0494
Shk40-8	01 24 56.12	+08 40 02.27	GaiaDR3 2578887519173981568	19.31	01245612+0840022	14.21	13.57	13.21	0.0467
Shk40-9	01 24 53.74	+08 39 57.27	GaiaDR3 2578887484813505536	21.06	01245373+0839573	16.00	15.27	15.09	-
Shk40-10	01 24 54.10	+08 39 17.96	GaiaDR3 2578887484814259968	21.86	01245413+0839180	16.27	15.78	14.81	0.0501
Shk40-11	01 24 53.62	+08 38 16.27	GaiaDR3 2578884151919622272	20.08	01245362+0838162	15.05	14.46	13.99	0.0528
Shk40-12	01 24 50.81	+08 37 43.32	Gaia DR3 2578884117559664768	20.37	01245081+0837432	15.79	15.15	14.78	-
Shk40-13	01 24 46.14	+08 37 19.75	Gaia DR3 2578886969418168704	20.82	01244615+0837196	15.78	14.96	14.89	-
Shk40-14	01 24 40.89	+08 36 32.19	Gaia DR3 2578881059542951296	19.79	01244089+0836322	13.85	13.20	12.75	0.0481
Shk40-15	01 24 42.78	+08 39 55.42	Gaia DR3 2578887347375068800	20.47	01244277+0839554	15.22	14.47	14.23	0.0466
Shk40-16	01 24 41.13	+08 40 46.75	Gaia DR3 2578888206368526976	20.07	01244112+0840467	15.84	15.12	14.61	0.0484
Shk40-17	01 24 54.21	+08 36 56.21	Gaia DR3 2578884044544635136	21.44	01245422+0836565	16.48	15.96	15.60	0.0437
Shk40-18	01 24 57.59	+08 35 24.50	Gaia DR3 2578883670883285760	19.88	01245759+0835245	14.22	13.59	13.24	0.0426
Shk40-19	01 25 04.46	+08 36 24.18	Gaia DR3 2578883052407994880	20.06	01250445+0836241	14.63	13.90	13.46	0.0521
Shk40-20	01 25 10.82	+08 38 45.12	Gaia DR3 2578884323718124416	20.57	01251081+0838450	15.85	15.12	14.74	0.0488
Shk40-21	01 25 15.33	+08 39 01.37	Gaia DR3 2578885835546811136	20.74	01251534+0839015	15.55	14.84	14.32	0.0486
Shk40-22	01 25 16.70	+08 38 27.07	Gaia DR3 2578883602163817344	20.45	01251670+0838271	15.37	14.63	14.45	0.0501
Shk40-23	01 25 11.94	+08 39 20.69	Gaia DR3 2578884358078061056	20.17	01251193+0839207	14.13	13.49	13.14	-
Shk40-24	01 25 05.90	+08 40 41.00	-	-	-	-	-	-	-
Shk40-25	01 25 09.73	+08 40 52.00	GaiaDR3 2578886110424517760	20.19	01250972+0840520	14.99	14.43	14.07	0.0499
Shk40-26	01 25 11.80	+08 40 41.00	-	-	-	-	-	-	-
Shk40-27	01 25 11.83	+08 42 00.78	GaiaDR3 2578886316582947328	19.05	01251182+0842007	14.75	14.0	13.74	-
Shk 40-28	01 25 11.10	+08 41 53.05	GaiaDR3 2578886213503732352	19.32	01251109+0841529	14.93	14.2	13.99	-
Shk40-29	01 25 22.71	+08 41 39.19	GaiaDR3 2578886007345302400	19.34	01252271+0841392	15.25	14.57	14.24	0.0435
Shk40-30	01 25 23.48	+08 40 31.39	GaiaDR3 2578885217071520000	20.79	01252349+0840313	15.51	14.82	14.48	0.0457
Shk40-31	01 25 22.44	+08 40 01.68	GaiaDR3 2578885217071320960	16.65	01252243+0840016	15.44	15.15	14.88	-
Shk40-32	01 25 20.46	+08 39 29.85	GaiaDR3 2578885113992106240	16.76	01252046+0839298	14.52	13.92	13.67	-
Shk40-33	01 25 26.49	+08 37 36.97	GaiaDR3 2578884731739404800	20.83	01252649+0837370	15.86	14.97	14.54	0.0769
Shk40-34	01 25 31.32	+08 36 50.95	GaiaDR3 2566875148481711488	16.55	01253132+0836509	15.33	14.95	14.91	-
Shk40-35	01 25 32.83	+08 37 04.55	GaiaDR3 2566875079762450304	20.1	01253283+0837046	15.38	14.69	14.3	0.0497
Shk40-36	01 25 25.23	+08 39 48.90	GaiaDR3 2578885148351844352	17.27	01252522+0839489	15.37	14.83	14.82	-
Shk40-37	01 25 28.16	+08 41 17.20	GaiaDR3 2578885625092618752	17.42	01252816+0841172	15.81	15.18	15.39	-
Shk40-38	01 25 26.06	+08 41 36.45	GaiaDR3 2578886385302424576	19.51	01252607+0841365	15.38	14.69	14.33	0.0462
Shk40-39	01 25 29.44	+08 42 45.20	GaiaDR3 2578886522741577472	19.41	01252943+0842453	14.16	13.54	12.97	0.0451
Shk40-40	01 25 27.43	+08 42 22.88	GaiaDR3 2578886419662370304	21.24	01252743+0842229	16.41	15.9	14.91	-
Shk40-41	01 25 23.29	+08 42 46.99	GaiaDR3 2578886454021442176	18.37	-	-	-	-	-
Shk40-42	01 25 24.46	+08 43 12.14	GaiaDR3 2578886488381838976	21.22	01252446+0843121	15.08	14.36	13.88	0.0326
Shk40-43	01 25 24.37	+08 43 52.36	GaiaDR3 2578886797619282176	20.73	01252439+0843523	15.67	15.05	14.7	-
Shk40-44	01 25 24.15	+08 44 06.74	GaiaDR3 2578886797619281920	19.39	01252415+0844069	14.39	13.64	13.27	0.0462
Shk40-45	01 25 27.13	+08 44 17.50	GaiaDR3 2578886797619281792	20.09	01252713+0844175	15.15	14.5	14.28	0.0484
Shk40-46	01 25 18.40	+08 43 29.64	GaiaDR3 2578886728899806080	17.51	01251842+0843298	16.34	15.85	15.39	-
Shk40-47	01 25 13.76	+08 42 58.84	GaiaDR3 2578886350942684416	19.14	01251374+0842587	14.74	14.00	13.72	0.0493
Shk40-48	01 25 11.84	+08 43 38.96	GaiaDR3 2578889305880183296	19.31	01251183+0843388	14.38	13.74	13.47	0.0492
Shk40-49	01 25 11.84	+08 43 38.96	GaiaDR3 2578889305880183296	19.31	-	-	-	-	-
Shk40-50	01 25 08.75	+08 44 28.73	GaiaDR3 2578889580758089472	20.17	01250874+0844286	15.37	14.62	14.41	0.0458
Shk40-51	01 25 10.61	+08 45 49.10	GaiaDR3 2578889993075152000	20.57	01251059+0845491	15.46	14.86	14.54	0.4582
Shk40-52	01 25 07.52	+08 47 52.04	GaiaDR3 2578890989507360640	20.92	-	-	-	-	0.0505
Shk40-53	01 25 07.85	+08 48 12.37	-	-	-	-	-	-	-
Shk40-54	01 25 05.48	+08 47 27.68	-	-	-	-	-	-	0.0528
Shk40-55	01 25 04.17	+08 45 11.92	GaiaDR3 2578889649477006976	20.8	01250417+0845119	15.72	15.33	14.94	0.0494
Shk40-56	01 25 01.01	+08 44 25.51	GaiaDR3 2578889615118020608	20.05	01250100+0844254	14.6	13.97	13.63	0.0459
Shk40-57	01 24 57.50	+08 44 30.55	GaiaDR3 2578890267953049472	19.83	01245750+0844305	13.92	13.28	12.91	0.0472
Shk40-58	01 24 43.61	+08 46 34.82	GaiaDR3 2578902328221216128	21.35	01244361+0846350	15.45	14.77	14.36	0.0518
Shk40-59	01 24 45.26	+08 45 35.56	GaiaDR3 2578890577190694400	21.08	01244526+0845357	16.2	15.49	15.04	-
Shk40-60	01 24 46.77	+08 42 45.95	GaiaDR3 2578888618684860672	18.63	01244675+0842456	14.93	14.2	14.05	-

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