CRD Research profile and main achievements

In 1942, the famous physicists brothers Abram and Artem Alikhanian organized a scientific expedition to Mount Aragats and started cosmic ray detection with various particle detectors. They have found high-energy protons and deuterons in the flux of cosmic rays and several new unstable particles (called by them varitrons). These studies laid the foundation for the regular study of cosmic rays and many further discoveries. Currently physicists of Cosmic rays division of AANL (YerPhI) with a reequipped and renewed facilities continue research in the field of galactic and solar cosmic rays, solar-terrestrial connections, atmospheric physics and space weather. The world's largest center for registration of the fluxes of elementary particles from thunderclouds, electric and geomagnetic fields, meteorological parameters and lightning occurrences was established on the slopes of Mount Aragats. The created experimental complex allows Armenian physicists play a leading role in the study of high-energy atmospheric physics. At research stations Aragats and Nor Amberd Cosmic Ray Division physicists perform research in almost all areas of the Astroparticle physics:

- CR Origin and acceleration mechanisms.
- Solar-terrestrial connections; solar modulation of galactic CRs.
- Acceleration of protons on Sun.
- High Energy phenomena in Atmosphere, Thunderstorm Ground Enhancements (TGEs).
- Lightning physics.
- Monitoring of geophysical parameters.
- Scientific instrumentation.
- Multivariate data analysis.

Among the main achievements of recent years are:

- Discovery of the features of Galactic Cosmic Ray spectra such as: the very sharp change of the power spectral index (~1) for the light nucleus group at 2-4 PeV and no pronounced change in the heavy nucleus group (at least for energies 20-30 PeV). Discovery of the charge depended “knee” in the energy spectra pointing to the shock acceleration initiated by the supernova blasts as a most probable mechanism of particle acceleration.
- Discovery of energetic protons (with energies greater than 20 GeV) accelerated in the vicinity of the Sun during Ground Level Enhancement (GLE) event N 69.
- Development of the methodology of machine learning for high-energy physics and astrophysics experiments. ANI (Analysis and Nonparametric Inference) computer

code library has been extensively used during the last few decades for multidimensional analysis of data from modern cosmic ray detectors.

- The "multidimensional nonlinear cuts" method for analyzing data from the Atmospheric Cherenkov Telescopes (ACT) techniques help to reliably proof existence of the flux of very high-energy gamma rays from the Crab nebula measured by the Whipple Cherenkov telescope thus establishing the new window to the Universe.
- The methodology of the event-by-event analysis of the Extensive Air Shower experiments, was successfully applied to MAKET-ANI and KASCADE experiments;
- Discovery of simultaneous fluxes of electrons, gamma rays and neutrons measured at mountain altitudes, proving the existence of the new high-energy phenomenon (TGEs) in the thunderstorm atmospheres.
- Discovery of the “Cloud Extensive Showers - CESs”.
- Discovery of long lasting radiation from the thunderclouds (up to several hours).
- Development of the Aragats Space Environmental Center (ASEC) and Armenian Geophysics Network.
- Founding of the worldwide network of new particle detectors, named SEVAN (Space Environment Viewing and Analysis Network). Nodes of the SEVAN network are now operating in Armenia, India, Bulgaria, Croatia, Slovakia and Czech Republic.
- Introducing of a new model of lightning initiation.
- Founding of Armenian Geophysics Network in Armenia and Arcakh (Shushi university).

Connected to these discoveries are many international publications in peer-reviewed journals as Physical Review (Phys.Rev), Astroparticle physics, Atmospheric Research, Nuclear Instruments and Methods in Physics, Advances in Space Research, and many others. The value of the presented work is excellent and is absolutely honoured by the scientific community, which is evidenced by more than 10000 citations.

Physicists of Cosmic Ray Division publish their tenth paper in Physical Review journal of American Physical Society (APS). The Constitution of the APS states that the objective of the Society shall be the advancement and diffusion of the knowledge of physics. Research results should be recorded and maintained in a form that allows analysis and review, while experimental data should be immediately available to scientific collaborators. Following these principles, Armenian physicists have presented detailed descriptions of their discoveries on Natural Gamma Radiation (NGR) and particle fluxes of the last decade in 10 issues of the Physical Review journal. The discovery of the Thunderstorm Ground enhancements (TGEs) registered by a variety of particle detectors located on Mt. Aragats and explanation of the TGE origin were published in first two papers. Another two papers proved registration of the neutron component of TGEs, explaining that photonuclear reactions of the gamma rays are responsible for the neutron flux. The structure of the electric field inside thundercloud and energy spectra of the electrons and gamma rays were described in subsequent papers. The lightning initiation is directly related to the geomagnetic avalanches in the lower part of the

thundercloud, that was demonstrating by the special TGE events abruptly terminated by the atmospheric discharges. The last papers on this research topic were devoted to long-lasting TGEs and Radon progenies' contribution to the winter enhancements of particle fluxes.
The entire history of the development of the new scientific discipline, namely, the High-Energy Physics in Atmosphere (HEAP) and the revealing the sources of the NGR can be followed by CRD's publications in Physics Reviews journal of American Physical Society (see references below).
The paper "Catalog of 2017 Thunderstorm Ground Enhancement (TGE) events observed on Aragats" (SREP-18-27065-T) has been scheduled for online publication in *Scientific Reports* on the 18th of April 2019. On publication, the paper will be freely available online at www.nature.com/articles/s41598-019-42786-7
The natural electron accelerator in the clouds above Aragats high-altitude research station in Armenia operated continuously in 2017, providing more than 100 Thunderstorm Ground Enhancements (TGEs), bursts of radiation, which to some extent mimic cosmic rays. Thorough analysis of the extensive data collected in 2017 resulted in a detailed description of the long-lasting TGEs. The first catalog of TGE events was produced, which described two classes of events according to the presence or absence of the high-energy radiation particles. The catalog summarizes several key parameters of TGEs and observations of atmospheric discharges, together with related meteorological data. The statistical analysis of the data recorded in the tables reveals the months when TGEs are more likely, the time of day when TGEs most frequently occur, the mean distance between a lightning flash that terminates a TGE, and many other interesting relations. The sharp rate of decline of high-energy particles after a lightning flash is also discussed. Applying the Advanced Data Extraction Infrastructure (ADEI) to multivariate visualization and statistical analysis greatly simplified the analytical work on a very sophisticated problem. This allowed many hypotheses about the processes involved in TGEs to be analyzed and resulted in the validation of a definite conclusion. The ADEI platform facilitates merging of data from disparate sources, which is recorded at different times.

The paper is co-authored by CRD master degree and PhD students. During the second semester of CRD master courses, Prof. Chilingarian instructs students about the preparation of scientific papers and submitting them for publication in scientific journals. The scholarly work usually culminates in the research paper being published in the proceedings of the annual conference on Thunderstorms and Elementary Particle Acceleration, and sometimes also in high-ranking scientific journals. Publication of student research provides additional enthusiasm and motivation for them to continue their scientific work, and enhance their skills. Current master degree students are preparing two new papers: Natural Gamma Radiation (NRL), and Winter Gamma Ray Flux Enhancements, which they also plan to submit to the top scientific journal**s.**

One of the most important accomplishments of the CRD in 2018 was the launching the of the Armenian Geophysical Network (AGN); measuring and analyzing tens of important

environmental parameters for global change research and natural disaster forecasting. AGN's facilities operate on the slopes of Armenia's Mt. Aragats on heights of 2000 and 3200 m; in Yerevan; on the shore of lake Sevan; at Dilijan International High School; and at Shushi University in Artsakh.

In 2017 natural electron acceleration within the clouds above the Aragats high-altitude research station in Armenia operated continuously providing more than 100 Thunderstorm Ground Enhancements (TGEs). For the first time the CRD prepared a catalog of TGE events now undergoing review in Scientific Reports of Nature. The catalog summarizes several key parameters of the TGEs and related meteorological and atmospheric discharge observations. The publication [16] was prepared with the active participation of Yerevan Physics Institute (YerPhI) master students. In 2017 CRD experts installed another SEVAN (Space Environment Viewing and Analysis Network) module in Czech Republic, enlarging European network to 4 stations [7].

A continuous data stream from various particle detectors and field meters located on Aragats (3200 m a.s.l.) is entering a MySQL database in Yerevan's CRD headquarters; data is available on-line via the ADEI interactive WEB platform. In 2019 it will be 10 years since CRD physicists started research in the new direction of High-Energy Atmospheric Physics (HEAP). Important results were obtained in proving a runaway mechanism of particle acceleration and multiplication in thunderclouds [1,5].

The most important result from 2017 was the observation and description of long-lasting TGEs (LL TGE); particle fluxes which continued for many hours making thunderclouds the most intensive natural radiation source on the Earth. We showed that radiation detected on Aragats originated in the electric field within the thunderclouds [5,8,10]

We also determined the types of the lightning flashes that abruptly terminated TGEs [4]. Another finding was connected with the enigmatic problem of lightning initiation. CRD physicists discovered a direct relation between particle fluxes and subsequent atmospheric discharges [3]. New findings were made relating to estimations of the intracloud electric field strength by measurements of the energy spectra of the "thundercloud" particles. This very important and very difficult to assess topic has been examined by CRD since 2014 and was continued by our former researcher Bagrat Mailyan, now working in NASA [6].

The atmospheric electric field influences measurements made by large Astroparticle experiments using the terrestrial atmosphere as a target for multiplication of ultra-high energy particles accelerated in the most violent star explosions in the Universe. In 2018 we investigated these effects with models of particle propagation in the strong atmospheric electric fields [12].

CRD actively participated in the GloCAEM (Global Coordination of Atmospheric Electricity Measurements) project that brought together experts and data in atmospheric electricity to take the first steps towards an effective global network for atmospheric electricity monitoring. The GloCAEM database presents the largest single analysis of electrical field data obtained from multiple datasets at geographically distinct locations [15].

In 2018 we received an Armenian government research grant for the project "*Environmental research; cosmic rays; space weather; atmosphere electricity; lightning initiation; dangerous consequences of storms*". Unfortunately, another applied project, "*Comprehensive monitoring and prediction of potentially dangerous processes in the magnetosphere and atmosphere of the Earth*", was not funded by the Armenian government. This loss unfortunately reduces the possibility of collecting necessary information on radiation hazards in Armenia. Almost all European countries have such a program, and for a country running an atomic power plant it is of the first necessity. Armenia can have such a program very inexpensively. All equipment will be produced by CRD and will partly be funded with the support of the Armenian diaspora in US.

In the low energy domain (0.3 – 3MeV) the natural gamma radiation coming from long living isotopes in Earth's crust and surrounding rocks makes major contributions to the background radiation measured by gamma spectrometers on Aragats. To distinguish the fluctuations of natural radiation from the enhancements due to electron-photon avalanches initiated in the atmospheric electric fields, in 2018 we started monitoring Rn-222 (Radon) concentration at Aragats with high-precision spectrometers.

In 2018 we continued negotiations to enlarge our particle detector networks in Europe, adding two SEVAN units at DESY's Hamburg and Berlin sites for research on some of the most interesting problems of solar and atmospheric physics. We plan to install new facilities on Aragats for lightning research and a new seismological station in Nor Amberd in collaboration with the Institute of Geophysics and Engineering Seismology of the National Academy of Sciences of Armenia. This will be a unique facility measuring electric and geomagnetic fields, neutron fluxes, and seismic waves.

Our research results were discussed at the TEPA symposia in Nor-Amberd (see conference report [9]); Topical Problems of Nonlinear Wave Physics (NWP-2017), Moscow - St.-Petersburg, July 2017; NMDB workshop, Athens, March 2018; AGILE symposium Results, Challenges and Prospects of Gamma-Ray Astrophysics [14]; Horizon 2020 COST (Porto, October 2017, Cyprus, September 2018); ISSI meeting, Bern, January, 2018; GloCAEM project meeting, March 20018; EORADOS meeting, Prague, October 2018; CRREAT board meeting, October 2018; Atmospheric monitoring and calibration for high-energy astroparticle detectors and experiments, AtmoHEAD, Capri, September 2018; and at the American Geophysical Union annual meeting, AGU, December, Washington.

In April 2018 A. Chilingarian delivered colloquium seminar in Joint Institute of Nuclear Research (JINR) with participation of SEVAN hosts from Eastern Europe. JINR is interested in hosting SEVAN as an astroparticle physics project.

CRD research includes projects with institutions from many countries where CRD installed new particle detectors or shares data from the world's largest cosmic ray center on Mt. Aragats. Recently several US universities have proposed research projects, which include

Aragats as a site where they would like to install modern detectors. CRD international collaborations are shown at the end of this report.

The Thunderstorms and Elementary Particle Acceleration (TEPA-2018) conference was devoted to the 10 Years of Thunderstorm Ground Enhancement (TGE) observations on Mt. Aragats. In the TEPA-2018 Proceedings, 17 reports are collected. Some reports have already been published, while others have been submitted for publication. All are compiled under one cover to provide a comprehensive picture of advances in the high-energy atmospheric physics as reported at the TEPA-2018 conference. This is the 4th publication of TEPA proceedings, which includes results from the previous 7 conferences. TEPA conferences and the proceedings are helping to shape a new scientific direction - High-Energy Atmospheric Physics (HEAP). HEAP is a rather new scientific discipline aimed at classifying and explaining thunderstorm correlated fluxes of electrons and gamma rays. In the Near-Earth space these consist of Terrestrial Gamma Flashes – TGFs; in the troposphere - gamma glows; and on the earth's surface, Thunderstorm Ground Enhancements - TGEs. All three types of experiments (in space, in the troposphere, and on the earth's surface) are accompanied by observations of lightning flashes and atmosphere electrification. TGF observations are synchronized with worldwide lightning location networks and by optical observations of lightning flashes by orbiting high-frequency cameras. Gamma glow and TGEs are measured by detecting electric fields on the earth's surface and high in the atmosphere.

The central engine initiating TGEs is believed to be the Relativistic Runaway Electron Avalanches (RREAs) which accelerate and multiply seed electrons from an ambient population of Cosmic Rays (CRs) in the large-scale strong atmospheric electric fields. These initiate minute-long bursts of radiation and electrons, and sometimes neutrons, with energies up to many tens of MeV. The complementary mechanism, electron energy Modification Of Spectra (MOS), leads to enhancement of gamma radiation from the atmosphere even in weak electric fields. These enhancements can last for a very long time, up to hours. The recent observations of numerous TGFs, TGEs, and gamma glows prove that RREA and MOS are robust and realistic mechanisms for explaining HEAP physics. Models using CERN GEANT4 code and CORSIKA code from Karlsruhe Institute of Technology, now both supplemented by the atmospheric electric field option, are in agreement with in situ measurements of electron and gamma ray energy spectra.

The 7-th edition of TEPA symposia held at Nor Amberd, Republic of Armenia, in September 2018, coincides with 10 years of TGE observations on Mt. Aragats. Nearly 500 TGEs detected at Aragats during the past decade can be widely used for the validation of models aimed at explaining high-energy phenomena in the atmosphere. The ground-based experiments have a huge advantage over the space and atmospheric based ones, because a "beam" of electrons is frequently located directly above the particle detectors, and usually at distances of few tens of meters. Thus, on Aragats, it was possible to measure the RREA avalanches initiated by a single CR electron, estimate the energy spectra of TGE electrons and gamma rays, and perform well synchronized measurements of lightning discharges and particle fluxes. This explained the phenomenon of the abrupt decline of the high-energy part

of TGEs and provided clues to the dynamics of atmospheric electric fields.

The problem of thundercloud electrification is one of the most difficult ones in atmospheric physics. The structure of electric fields in the atmosphere still remains hidden from the detailed in situ measurements. A few balloon flights, although providing us with overall knowledge on possible structures and strengths of the atmospheric electric fields, cannot reveal the dynamics of the intracloud electric field. By simultaneously observing the origination and decline of TGEs with atmospheric discharges we can understand how the charge structure of the cloud is changing during a thunderstorm and how lightning itself originates.

Physicists and students from Russia, US, Italy, Japan, and Armenia discussed these and other problems of high-energy physics in the atmosphere through the 4-day long meeting. During a visit to the Mt. Aragats high-altitude research station, the operation of numerous particle detectors, lightning sensors, and field meters were demonstrated, the measurements of which were jointly analyzed to reveal the relationships between atmospheric discharges and particle fluxes. TEPA proceedings appear also in Repository of the International Nuclear Information System (INIS).

At the end of January, 2019, a formal collaboration was established by physicists and engineers employed by the Yerevan Physics Institute working in Cosmic Ray Division, and by organizations and individuals participating in ASEC activities and/or promoting Cosmic Ray research in Armenia. The formation of the collaboration board was concluded in April.

The mission of the ASEC is to:

- Encourage and facilitate real-time monitoring of the secondary particles of Cosmic Rays at altitudes 2000 m and 3200 m. at Mount Aragats and in several newly established sites in Armenia that are within the framework of the Armenian geophysical network;
- Prepare and install sensitive particle detectors, field meters and other facilities for research in cosmic ray physics, atmospheric physics and seismology;
- Develop methods of prediction of Space Weather conditions, including particle fluxes and disturbances of the Interplanetary Magnetic Field (IMF) near Earth;
- Investigate the influence of local atmospheric conditions (intracloud electric fields, lightning flashes, natural radiation, etc…) on the intensity of the measured particle fluxes;
- Investigate the influence of the solar-terrestrial connection on the intensity of particle fluxes and on different aspects of life;
- Provide on-line access of the space-environment data products and services to collaborators and clients world-wide;
- Provide information about serious consequences of space storms and meteorological conditions to the public and to relevant organizations of the Republic of Armenia.

The basic functions of ASEC are:

- Provide the development of new experimental and analysis techniques for solar and atmospheric physics research and for the forecasting of space weather events and earthquakes;
- Organize data collection, ensure data quality standards, and develop modern methods of multivariate display of big datasets on space weather events, including machine learning methods for the physical inference using big data;
- Prepare an ASEC web page with exhaustive information on space weather conditions as measured by the ASEC monitors.
- Provide courses on High Energy Astrophysics, Atmospheric Physics, and Machine learning for students of master and PhD programs at the Yerevan Physics Institute.

See WIKI of ADEI crd.yerphi.am/adei for the list of equipment with pictures and explanations. The world's leading experts have agreed to participate in the board of the ASEC collaboration http://www.crd.yerphi.am/ASEC_BOARD_MEMBERS . The chairman of collaboration is A.Chilingarian; the secretary is Mery Zazyan.
The ASEC collaboration board meeting was hold on 17 May on premises of Nor Amberd research station. The board members listen report of ASEC chairman, made numerous suggestions and finally confirm the working plan of ASEC collaboration.

Journal publications in 2017-2018

1. Chilingarian A., Comments on the models based on the concept of runaway electrons for explaining high-energy phenomena in the terrestrial atmosphere, *Izvestiya Rossiiskoi Akademii Nauk, Seriya Fizicheskaya, 2017, Vol. 81, No. 2, pp. 254–257, © Allerton Press, Inc., 2017.*
2. Chilingarian A., Do relativistic elementary particles originate in the lightning discharges? *Izvestiya Rossiiskoi Akademii Nauk, Seriya Fizicheskaya, 2017, Vol. 81, No. 2, pp. 258–261.*
3. Chilingarian A., Chilingaryan S., Karapetyan T., et al., 2017, On the initiation of lightning in thunderclouds, Scientific Reports 7, Article number: 1371, DOI:10.1038/s41598-017-01288-0.
4. Chilingarian, A., Y. Khanikyants, E. Mareev, D. Pokhsraryan, V. A. Rakov, and S. Soghomonyan, 2017, Types of lightning discharges that abruptly terminate enhanced fluxes of energetic radiation and particles observed at ground level, J. Geophys. Res. Atmos., 122, 7582–7599.
5. Chilingarian A., Hovsepyan G., Mailyan B., 2017, In situ measurements of the Runaway Breakdown (RB) on Aragats mountain, Nuclear Inst. and Methods in Physics Research, A

874,19–27.

6. Cramer, E. S., B. G. Mailyan, S. Celestin, and J. R. Dwyer (2017), A simulation study on the electric field spectral dependence of thunderstorm ground enhancements and gamma ray glows, J. Geophys. Res. Atmos., 122, 4763–4772, doi:10.1002/2016JD026422.
7. A. Chilingarian, V. Babayan, T. Karapetyan, et al., The SEVAN Worldwide network of particle detectors: 10 years of operation, Advances in Space Research 61 (2018) 2680–2696
8. Chilingarian A., Long lasting low energy thunderstorm ground enhancements and possible Rn-222 daughter isotopes contamination, PHYSICAL REVIEW D 98, 022007 (2018).
9. Chilingarian, A. A. (2018), High-energy processes in Earth's atmosphere and lightning, Eos, 99,https://doi.org/10.1029/2018EO100941. Published on 09 July 2018.
10. A.Chilingarian, G.Hovsepyan, S.Soghomonyan, M.Zazyan, M.Zelenyy, On the structures of the intracloud electric field supporting origination of Long Lasting Thunderstorm Ground Enhancements (LL TGE), PHYSICAL REVIEW, 98, 082001(2018).

CRD International collaborations

1. SEVAN Collaboration (Solar Physics, Atmospheric physics and Geophysics) includes Yerevan Physics Institute, Armenia, Institute of Nuclear Research and Nuclear Energy, Bulgaria, Ustav Jaderne Fyziky AV, Czech Rep., Ustav Experimentalnej Fyziky, Slovakia, Zagreb Observatory, Croatia.
2. NMDB Collaboration: Real-Time Database for high-resolution Neutron Monitor measurements; more than 40 European, Asian and American groups including CRD join efforts for research in solar physics and space weather.
3. GloCAEM project (global network for atmospheric electric field monitoring) – International project headed by the group of Redding Univ. UK, for atmospheric electricity research funded by NERC International Opportunities Fund grant NE/N013689/1.
4. Horizon 2020 COST Action: CA15211: "Atmospheric Electricity Network: coupling with the Earth System, climate and biological systems"
5. International Space Science Institute (ISSI) research group for "High-Energy Particles Sources and Powerful VHF Radiations in Electrically Active Atmosphere: Theoretical Models and Space Borne Instruments"
6. DESY – research and measurements of intracloud electric field for Cherenkov Telescope Array project.

7. Russian Scientific Foundation project 17-12-01439/2017, "Comprehensive research of high-energy particles sources and powerful VHF radiation in electrically active atmosphere based on ground-based measurements and satellite observations", joint project of CRD with Institute of space Research of RAS, Moscow and Institute of Applied Physics of RAS, Nizhny Novgorod, headed by A.Chilingarian.

8. Work according to bilateral agreements with National Research Nuclear University MEPhI, and Scobeltcin Nuclear Physics institute, MSU, Moscow, Russia successfully continued.

9. MAGIC is European collaboration, operating is a system of two 17 meter Imaging Air Cherenkov Telescopes, located at the Observatorio Roque de los Muchachos at an altitude of 2200 meters on the Canary island of La Palma. MAGIC detects gamma rays in the very high energy regime between a few tens of GeV and tens of TeV.

10. Network of Solar Neutron Telescopes coordinated by Solar-terrestrial Environmental Laboratory, Nagoya University, Japan.

11. European Horizon 2020 CRREAT (Center of *C*osmic *R*ays and *R*adiation *E*vents in the *At*mosphere) project, Nuclear Physics Institute of the CAS.

12. European Radiation Dosimetry Group (EURADOS).

13. World-Wide Lightning Location Network (WWLLN), University of Washington in Seatle.

14. MIT, Prof. Earle Williams, TGEs and atmospheric conditions;

15. Florida University, Prof. V.Rakov, TGEs and lightning types

List of the International projects
wined by the Cosmic Ray Division of Yerevan Physics Institute
1997-2016 (total ~M3 USD)

Armenian Government Projects

1. RA Thematic Funding "High-energy physics in atmosphere and Lightning initiation" Project manager A. Chilingarian, period 2015 – 2017, total funding expected in 2 years **$ 40,000.**

2. RA Applied Project Funding "The Armenian Geophysical Network", Project manager G. Hovsepyan, period 2016-2018, total funding in 2 expected years **$ 60,000.**

3. **Project 2000-784, "Investigations of the Galactic and Solar Cosmic Rays. Aragats Regional Space Weather Center". Project manager A. Chilingarian, period 2001-2002, status – accomplished, total funds received - $40,000.**

4. **Project 2000-015, "Hardware Implementation of the Feed-Forward Neural Networks". Project manager A. Vardanyan, period 2001-2002, Status – accomplished, total funds received - $3,000.**

5. **Project 1465, "Investigation of the sources and acceleration mechanisms of very high energy cosmic rays". Project manager A. Chilingarian, Period 2002-2004, status – accomplished, total funds received - $200,000.**

6. **Project 0092, "Coordinated studies of the Space Weather and Galactic cosmic rays". Project manager A. Chilingarian, Period 2005-2007, status – accomplished, total funds - $350,000.**

7. **Research of Space weather with networks of particle detectors detected charged and neutral components of the cosmic rays, Project manager A. Chilingarian, Period 2008-2010, status – accomplished, funding parties Armenia, total funds promised - $150,000.**

8. **RA thematic, "Investigation of the energetic processes in atmosphere", Project manager A. Chilingarian, period 2011-2013, status – finished, total funds allocated - $50,000.**

9. Science & Technology Cooperation (STC) Germany with the Republic of Armenia (RA), "Web-based Data Analysis Platform for Space Weather Observations", **Project manager** A. Chilingarian, period 2013-2015, status – completed, total funds allocated - $12,000.

10. RA thematic, "Research of the High-Energy Phenomena in Thunderstorm Atmosphere", **Project manager** A. Chilingarian, period 2013-2015, status – completed, total funds allocated- $70,000.

NATO Projects

11. **NATO Networking Infrastructure Grant N 975436, "Computer network for real-time data transfer using wireless connections". Project co-directors A.**

Chilingarian, and H. Gemmeke (FZK, Germany), period 1999-2001, status – accomplished, total funds – $30,000, .

12. **NATO Collaborative Linkage Grant N 975954, "Construction of reliable data acquisition system for modern Astroparticle Physics experiments". Project co-directors A. Chilingarian and H. Gemmeke (FZK, Germany), Period 1999-2001, status – accomplished, total funds – $8,000.**

13. **NATO Collaborative Linkage Grant, "Investigations of the air-shower development in the primary energy region of PeV". Project co-directors A. Chilingarian and A. Haungs (FZK, Germany), period 1999-2001, status – accomplished, total funds – $8,000.**

INTernational ASsociation for the promotion of co-operation with scientists from former Soviet Union (INTAS) Projects

14. **INTAS 8777 "Solar and galactic cosmic ray particle acceleration and modulation", Project manager A. Chilingarian, period 2007-2008, status – implementing, funding party Europe, total funds promised - $120,000.**

15. **INTAS Infrastructure Action Grant, "Improvement of the infrastructure of the Aragats international cosmic ray research center". Project coordinator M. Fleishner (DESY), project contractor A. Chilingarian, period 2002-2004, status - accomplished, total funds - $80,000.**

16. Civilian Research and Development Fund (CRDF) Projects

17. **CRDF Cooperative Grant Program Grant N AB-2005, "Patterns of Gene Expression in Normal and Neoplastic Tissues and Associated Statistical Problems". Project principal investigators A.Chilingarian and A.Yakovlev (Huntsman Cancer Institute, Utah University), period 2000-2001, status - accomplished, total funds - $38,000.**

18. National Faundation of Science and Advanced Technologies

19. **NFSAT Graduate Research Support Program (GRSP), Project manager A. Chilingarian, period 2007, status – accomplished, funding parties USA-Armenia, total funds - $5,000.**

International Science and Technology Center (ISTC) Projects

20. **ISTC A116, "The Development and Implementation of Applied Neural Information Technologies". Project manager A. Chilingarian, period 1997-1999, status – accomplished, funding party – European Union, total funds – $250,000.**

21. **ISTC A216, "Detection of the Neutron Flux from the Solar Flares at the Aragats Cosmic Ray Observatory". Project manager A.Chilingarian, period 2001-2003, status – accomplished , funding parties – Japan, USA, total funds – $280,000.**

22. **ISTC A-757, "Nonparametric methods of data analysis in Cosmic Ray Astrophysics. An applied theory of Monte Carlo statistical inference. Monograph". Project manager A. Chilingarian, period 2002-2003, status – accomplished, funding parties USA, , total funds - $30,000.**

23. **ISTC A1058 "Development of a Prototype Detector System for Space Weather Monitoring and Forecasting World-Wide Network. ". Project manager A. Chilingarian, period 2004-2007, status – accomplished, funding parties Europe, USA, total funds - $668,000.**

24. **ISTC, CSP -042, "Development of Regional Communication Network in Armenia", Project manager A. Vardanyan, period 2007, status – accomplished, funding parties Europe, total funds for CRD - $47,000.**

25. **ISTC, "Planetary Space Weather Research and Forecasting by Networks of Hybrid Particle Detectors measuring neutral and charged fluxes", Project manager A. Chilingarian, period 2008-2010, status – finished, funding parties Europe, total funds - $977,000. 2008 -2012.**
26. **ISTC sustainability project "Applied" cosmic ray physics", manager A. Chilingarian, period 2012-2013, status – finished, total funds 70,000.**

EOARD projects

27. **EUROPEAN OFFICE OF AEROSPACE RESEARCHAND DEVELOPMENT (EOARD) FA865-01-1.3014, "Development and installation of the new hybrid particle detectors for the creating world-wide network aimed on the space weather research", Project manager A. Chilingarian, period 2007-2008, status – acomplished, funding parties USA, total funds promised - $30,000.**

28. **EUROPEAN OFFICE OF AEROSPACE RESEARCHAND DEVELOPMENT (EOARD) FA8655-09-1-3053,**"Correlated measurements of the disturbances of geomagnetic field and
    a. changes of secondary particle fluxes at Aragats-Spavce Environmental Center (ASEC)", **Project manager A. Chilingarian, period 2009, status – acomplished, funding parties USA, total funds - $30,000.**

FP7 Projects

29. **Integrated Infrastructures Initiative project (I3) proposal Infrastructures Call 1, FP7-INFRASTRUCTURES-2007-1Real-Time database for high resolution Neutron Monitor measurements, Project coordinator C. Steigies, period 2008-2009, status acomplished, funding parties: EU, total requested funds - $35,000.**