Scientific biography

Ashot Chilingarian is the Head of the Cosmic Ray Division (CRD) at A. Alikhanyan National Laboratory. He earned his Ph.D. in 1984 and a Doctor of Science in Physics and Mathematics in 1991, both from Yerevan Physics Institute (YerPhI). From 1971 to 1993, he worked as a scientist, senior scientist, and data analysis group leader. In 1993, he became deputy director and head of the Cosmic Ray Division. He served as director of the Yerevan Physics Institute from 2008 to 2018, during which time he transformed it into a National Laboratory.

Prof. A. Chilingarian has extensive experience in high-energy astrophysics, cosmic ray physics, radiation physics, machine learning, data acquisition, multivariate statistical data analysis, space weather, atmospheric electricity, and lightning physics. He has substantially contributed to measuring the cosmic ray composition and energy spectrum using facilities on Mt. Aragats, Armenia, and Karlsruhe, Germany. He developed advanced analysis methods for gamma-ray shower identification, substantially enhancing the sensitivity of gamma-ray imaging telescopes. In the 80s, Prof. A. Chilingarian developed a machine learning methodology for high-energy physics and astrophysics experiments. He is the author of the ANI (Analysis and Nonparametric Inference) computer code library, which has been extensively used over the past few decades for multidimensional analysis of data from modern cosmic ray detectors. He introduced the multidimensional nonlinear cut method for analyzing data from the Atmospheric Cherenkov Telescopes (ACT); these techniques help reliably establish the existence of a flux of very-high-energy gamma rays from the Crab Nebula measured by the Whipple Cherenkov Telescope, thus opening a new window into the Universe. The methodology of event-by-event analysis of Extensive Air Shower experiments, introduced by him, allows the estimation of the energy spectra of separate groups of primary nucleons; the partial spectra of primary cosmic rays measured by MAKET-ANI and KASCADE detectors prove the mass-dependent position of the knee and help develop particle acceleration models in supernova explosions, as confirmed by gamma-ray observatories on board the AGILE and FERMI satellites. A. Chilingarian introduced a new probability distribution for calculating the chance probability of “peak” detection in searches for “new physics,” which will help avoid false inference that often occurs when dealing with small statistics and applying multiple cuts. Recently, these techniques were successfully used to galaxy distributions and analyses of globular clusters.

The statistical models developed by A. Chilingarian, i.e., the nonparametric methods for probability density estimation, Bayesian and neural network models for particle classification, and background rejection, play a key role in data analysis from several important high-energy astrophysics experiments. In a new topic in high-energy physics in the atmosphere, the Aragats group first measures and explains the correlated, large fluxes of electrons, gamma rays, and neutrons from thunderclouds.

Outside his field, Prof. Chilingarian has been interested in applying his data analysis methods to pattern recognition and genome analysis. In 2000-2001, he collaborated with the Huntsman Cancer Institute in Utah, USA, to develop multivariate methods for treating DNA microarray data based on quantifying different types of gene expression in normal and tumor-affected tissues. This work culminated in a patent application by Utah University.

During his scientific tenure, A. Chilingarian achieved significant results and discoveries across various fields, including applied mathematics, artificial intelligence, Astroparticle physics, Solar physics, Space weather, and Atmospheric high-energy physics.

Applied Mathematics and Artificial Intelligence

1. Development of Neural Network and Bayesian statistical models for gamma-ray image purification and galactic nuclei classification.
2. Development of random search methods for NN training; implementation of the ANI package for statistical analysis for the WIPPLE, MAGIC, KASCASE, and ANI experiments.
3. K-nearest neighbors methods of multivariate nonparametric probability density estimation, Rennie dimensionality estimation.
4. Bootstrap methods for the variance estimation of the limited sample.
5. Development of the MRSES (multiple random searches with early stop) method for big data analysis and selecting the best set of relevant variables.
6. Development of genome analysis and selection of gene assemblies responsible for genetic diseases.

Astroparticle physics, Solar Physics, Space weather

1. Determination of the mass and energy of the primary galactic particles by the measured extensive air shower.
2. The measurements of the "knee" in the energy spectra of the light and heavy galactic cosmic rays with the MAKET-ANI experiment.
3. Confirmation of supernova explosion and shock-wave acceleration as the origin of cosmic rays.
4. Introducing multivariate analysis of gamma-ray images registered by Atmospheric Cherenkov Telescopes (ACTS) for the Whipple and MAGIC experiments.
5. Neural Network methods of suppressing images of cosmic ray hadrons in the purification of gamma-ray images.
6. Correlated analysis of the Forbush decreases and Interplanetary coronal mass ejections observed during the 23rd solar activity cycle.
7. Organization of the first alert service for the dangerous consequences of violent solar flares.
8. Determination of the maximum energy of solar proton accelerators by 20 January 2005 GLE.

High-energy physics in the atmosphere and radiation physics

1. The discovery of simultaneous fluxes of electrons, positrons, gamma rays, and neutrons, as well as prolonged radiation from ^{222}Rn progeny, constitutes a new phenomenon in geoscience known as thunderstorm ground enhancement (TGEs).
2. Organization of the Aragats Space Environmental Center (ASEC) collaboration for the measurement of fluxes and energy spectra of most species of cosmic rays, electric and geomagnetic fields, atmospheric parameters, lightning flashes, and transient luminous events.
3. Organization of an open-access database with a time series of count rates and energy spectra of most species of secondary cosmic rays, geomagnetic and electric fields, atmospheric discharges, and weather parameters for the multivariate correlation analysis.
4. Measurements of the TGE electron and gamma-ray energy spectra prove the relativistic runaway electron avalanche (RREA) model and reveal the space-time structure of enhanced particle fluxes.
5. Development of the SEVAN particle detector network installed on the highest mountains of Eastern Europe and Germany.

6. Estimating the maximum achievable atmospheric electric field on mountain tops in Aragats, Armenia, and Lomnicky Stit, Slovakia.
7. Discovery of the Radon circulation effect during thunderstorms.
8. Discovery of WiGRS- wind induced gamma -ray bursts during snowstorms
9. Discovering the muon stopping effect and the positron modulation effect in atmospheric electric fields.

These discoveries are connected to more than 500 publications in peer-reviewed journals from APS, AGU, Elsevier, and many others. The scientific community recognizes the value of the presented work, evidenced by more than 20000 citations.

He is currently Armenia's representative to the International Space Weather Initiative. He is the founder and spokesperson for the ANI and ASEC collaborations and a fellow of the American Physical Society.

Prof. Chilingarian has served on numerous international scientific and editorial boards. He has been chair of several international conferences, including Solar Extreme Events (SEE-2005), Forecasting of the Radiation and Geomagnetic Storms (FORGES 2008), and Thunderstorm and Elementary Particle Acceleration (TEPA- 2010-2023). He has given numerous presentations on high-energy and cosmic ray physics and on high-energy phenomena in the atmosphere.

Awards:

"Data Visualization Interactive Network for the Aragats Space-environmental Center" – *DVIN for ASEC* received the World Summit on Information Society award in Geneva in December 2003 as the world's best project in the e-science category.

Armenia President Award in Physics: High Energy Phenomena in the Thunderstorm Atmosphere (2013).

Nomination as a best reviewer of Astroparticle Physics and Advances in Space Research, Elsevier Journals, 2014.

Armenian Engineers and Scientists of Americas (AESA's) Scientist of the Year Award – 2017;

First prize in the competition of best scientific publications, Institute of Space Research, Russian Academy of Science, 2017.

His current interests include the galactic and solar cosmic ray origin and acceleration, atmospheric electricity and lightning phenomena, detection of secondary cosmic ray fluxes at the Earth's surface, and space weather.

Prof. Chilingarian is continuing his research projects on the Aragats Space Environmental Center and is dealing with the following research topics:

1. Research on high-energy physics in Earth's atmosphere. High-energy physics in the atmosphere is a new field that investigates fluxes of elementary particles originating from relativistic electrons accelerated in the strong electric fields of thunderstorms. These fluxes are directed both into space, where they are detected by orbiting gamma-ray observatories, and to Earth's surface. The largest facilities on Earth's surface that detect electrons, gamma rays, neutrons (TGEs), radio bursts, electric fields, and lightning flashes are located in Aragats, Armenia.

2. The modulation of the Atmospheric Electric Field (AEF) affects particle fluxes of various species of cosmic rays. Thundercloud electrification and how lightning is initiated inside thunderclouds are among the biggest unsolved problems in atmospheric sciences. The relationship between thundercloud electrification, lightning activity, wideband radio emission, and particle fluxes has not yet been established. New methods are under development to use

changes in fluxes of different species of cosmic rays as messengers of thundercloud charge structure.

3. Solar Physics and Space Weather. The unexpected surge in solar activity in fall 2023, following a period of calm sun during the previous small 24th solar activity cycle, indicates the approach of the solar maximum of the 25th cycle, expected in 2024. Facilities of ASEC measure ground-level enhancements, Forbush decreases, and magnetospheric effects using the SEVAN network. For the first time, Aragats facilities register energy spectra of neutrons and muons initiated by the flux of solar protons reaching the atmosphere. This allows the recovery of the spectral index and the maximum energy of solar protons, which are invaluable for Space weather issues.

4. Radiation physics. Wind-induced gamma-ray storms (WiGRS) were first identified during the 2024/2025 winter natural gamma-ray (NGR) monitoring campaign on Aragats, with pronounced gamma-ray enhancements recorded by gamma-ray detectors at the research station during strong winds. WiGRS observations combine precise spectrometric and meteorological data to characterize new physical phenomena and place them in the broader context of variability in natural gamma-ray radiation.

5. Updating the ANI package for cosmology research. As astronomical datasets grow in size and complexity, characterizing their structure in an unsupervised, data-driven way becomes increasingly important. Local intrinsic dimensionality offers a window into the shape of data in high-dimensional spaces, making it a more dependable and practical tool. By combining insights from statistical theory, computer science, and domain knowledge in cosmology, we achieved a solution that meets the rigor demanded by both mathematicians and astronomers. We expect this approach to facilitate discoveries by revealing hidden low-dimensional manifolds in survey data and ensuring the fidelity of computational experiments, thereby contributing to the overarching goal of understanding the structure of the Universe through the lens of data.

6. The muon physics program includes experiments with horizontal muon beams with energies above 10 TeV, which offer a powerful probe of high-energy hadronic interactions, heavy-flavor production, and the transition from conventional to prompt atmospheric components.
Development of muonography techniques and the Cosmic Ray Navigation System (CRoNS) for Autonomous Navigation in GPS-Denied Environments

Contemporary scientific research relies heavily on international cooperation, underscoring the importance of involving young researchers in global projects from the outset of their education. Professor Chilingarian has recognized this importance and established master's courses for the emerging generation of students at the Space Education Center of YerPhI. The YerPhI master's program includes courses such as High-energy Experimental Physics (Experiments, Data Analysis, and Physical Inference), Machine learning, and Neural Networks. Additionally, he taught courses in High-Energy Physics in the Atmosphere, Introduction to High-Energy Astrophysics, Cosmic Rays, Modeling of Physical Processes, and Multivariate Methods of Data Analysis at the Faculties of Applied Mathematics and Physics of the Yerevan State University and National Research Nuclear University MEPhI. In 2025, a consortium of 10 European countries wins the Mary Curie doctoral network named GRAAL. 2 PhD students will start their program in the Cosmic Ray Division in Yerevan in 2026. Professor Chilingarian's guidance has been instrumental in supervising 15 Ph.D. students' research. Collaborative work with DESY on the established SEVAN detectors in Hamburg and at the highest mountain in Germany, Zugspitze, as well as with the Institute for Data Processing and Electronics in Karlsruhe (IPE, KIT) on the development of the platform for multivariate data analysis, are such joint projects, where lively international knowledge exchange and long-term experience gained through practical work on Aragats provide a fruitful ground for better understanding of the impact of cosmic rays on Earth's atmosphere.

RESEARCH GRANTS (7 selected):

1. 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 received – $250,000.
2. ISTC A216, “Detection of the Neutron Flux from the Solar Flares at the Aragats Cosmic Ray Observatory,” project manager A. Chilingarian, period 2001-2003, funding parties Japan and USA, total funds promised $280,000.
3. ISTC A1058: Development of a Prototype Detector System for Space Weather Monitoring and Forecasting World-Wide Network. ” Project manager A. Chilingarian, period 2004-2006, status approved, funding parties Europe, USA, total funds—$676,000.
4. ISTC A1554, “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 – implementing, funding parties Europe, total funds - $967,00;
5. Russian Science grant No 17-12-01439, Comprehensive research of high-energy particle sources and powerful VHF radiation in the electrically active atmosphere based on ground-based measurements and satellite observations, Project manager A. Chilingarian, period 2017-2019, status – implementing, funding parties Russia, total funds - 18 Million Rubles
6. Armenian government grant for advanced research, “Natural radioactivity and cosmic rays”, 2021-2025, total funds – 150 mln AMD.
7. DESY grant, Installing a SEVAN spectrometer on ZugSpitse in the Bavarian Alps, 2022-2025, total funds: 96,000 euros.
8. National research program “Natural Radioactivity and Cosmic Rays” (2022-2026), funded at AMD 170 million.

Under Prof. Chilingarian’s supervision, operations at the Aragats research facilities and additional national funding could be secured to support the research, which is an asset to Armenia and a shining example of the effective use of limited resources to conduct internationally competitive science. The research on Aragats is an important signal to the young generation in Armenia that research is a viable and worthwhile endeavor in their home country. Prof. Chilingarian has attracted a group of young scientists working on cosmic rays and atmospheric electricity. The new generation of students educated within the master’s program is strongly involved in joint projects with the international community. It will certainly contribute to further discoveries in the field of research concerning galactic, solar, and atmospheric cosmic rays.