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Cosmic Ray Division (CRD): recent achievements

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.

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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.