TEPA 2013 workshop was devoted to the presentation and discussion of recent observations and simulations of the high-energy phenomena in the earth's atmosphere.

The **Thunderstorms and Elementary Particle Acceleration (TEPA-2013)** conference was hold from September 9 through 13, 2013 in the Nor Amberd international conference centre of Yerevan Physics Institute (YerPhI) in Armenia.

Studying of the High-energy Phenomena in the atmosphere is important for several reasons:

- *It provides unique information about particle acceleration and multiplication in the lower and upper atmosphere during thunderstorms;*
- *Generation and propagation of large fluxes of electrons, positrons, gammas and neutrons in atmosphere and in the near space is related to the development of thunderstorm and may be used for the monitoring of dangerous consequences of extremely weather;*
- *Electromagnetic emissions connected with thunderstorms trigger various dynamic processes in the Earth's magnetosphere, causing global geo-effects and changing electrodynamics properties of the ionosphere;*
- *The large fluences of energetic electrons, photons and neutrons produced by runaway electron avalanches can potentially be a danger to aircraft crew, passengers and onboard electronic systems.*

The Cosmic Ray Division (CRD) of YerPhI and Skobeltsyn Institute of Nuclear Physics (SINP) of Moscow State University organized the workshop. YerPhI and the Armenian State Science Committee sponsored it. 30 scientists and students from USA, Germany, Norway, Russia and Armenia attend the workshop. The presentations were focused on the following issues:

- **Research of the Thunderstorm ground enhancements (TGEs)**
- **Research of the Terrestrial gamma-ray flashes (TGFs)**
- **Atmospheric High-energy phenomena observations by space-born facilities**
- **Instrumentation**

The discussions on the most intriguing problems of new emerging topic of high-energy physics in atmosphere covers:

- **TGEs and TGFs - what we can learn by comparisons of both?**

Thunderstorm Ground Enhancements (TGEs) originated from the lower dipole between the main negatively charged layer in the middle of thundercloud and emerging Lower positive charge region (LPCR) in the bottom of thundercloud. Lower dipole is accelerated electrons from the ambient population of the secondary cosmic rays (CR) downward. The electric field effectively transfers energy to electrons MOdifying their energy Spectra (MOS process) and enlarging their

time of live and consequently the probability to radiate gamma rays. As thunderclouds on mountain altitudes usually are very close to earth's surface measured electron and gamma ray fluxes enhance for several percent in energy range up to 100 MeV. If the electric field strength exceed the critical value the Relativistic Runaway Avalanches (RREA) may be unleashes enlarging the electron and gamma rays flux several times. RREA avalanches, called Extensive cloud showers (ECS) are systematically different from the Extensive air showers (EASs) originated from the galactic or high-energy solar cosmic rays incident on earth's atmosphere. Very low location of thunderclouds at Aragats allows direct observation of the RREA avalanches and "switching on" rather rare RREA mechanism. The simulation of the TGEs with GEANT4 code applying rather plausible electric field and thundercloud parameters (strength ~ 1.8 km, elongation ~ 1 km, height above earth's surface 50-200 m) using as seeds electrons from ambient population of CR successfully reproduces observed on Aragats TGE events including electron, gamma ray and neutron fluxes.
Terrestrial Gamma flashes (TGFs) are originated from electrons accelerated by the upper dipole between the main negative and main positive layer on the top of the thundercloud. Gamma ray emitted by accelerated upward electrons propagate in the space (possibly generating electron-positron pairs) and reach gamma ray spectrometers on orbiting several hundreds kilometers above earth's surface gamma ray observatories primarily intended to detect gamma bursts and other energetic processes in the Universe. Modified triggers of gamma ray events allow copious detection of the TGFs mostly from the equatorial thunderstorms. However, distant location of the fast moving particle detectors leads to several difficulties in the development of the TGF model:

- Required number of seed electrons greatly exceeds the available electrons of secondary CRs; proposed mechanism of "cold runaway" – acceleration of electrons by the strong electric fields in front of lightning leaders still is not observed;
- Due to scarcity of detected particles only cumulative energy spectra from all detected events are available for analysis and comparisons with simulations; it smears information about particular events, which, as we know from the TGE observation, may be very different.

Direct measurements of the intense particle fluxes on the earth's surface may be used for tuning the parameters of TGF models. The spatial and energetic characteristic of the ECSs, measured energy spectra of the TGE gamma rays and electrons may be used for checking characteristics of the particle fluxes obtained by the TGF simulations.

- **Particle fluxes and atmospheric discharges - any causal relation?**

Observed relation of lightning occurrences detected during TGFs and TGEs do not support assumptions on their causal relations. Most likely TGFs and TGEs constitute alternative type of the intracloud discharges: IC+ - corresponds to TGF and IC- - to TGEs. During TGEs the cloud-to-ground (CG-) lightning flashes are highly suppressed. It is interesting to investigate short bipolar pulses (pulse trains) during TGEs before CG lightning flashes. Possibly they manifested the creation of the LPCR.

- **Data bases of TGEs and TGFs are they available for community? Presentation how to access the data bases of Cosmic ray division;**

NASA maintains TGF data correspondent to different hierarchy of triggers. On-line data on particle fluxes, electrical and geomagnetic fields, lightning occurrences and meteorological information enters MSQL data bases of Aragats Space Environmental Center (ASEC). These

multiple one-minute and one-second time series contain information on hundreds of TGEs. On-line data and 10 year data archives are in free access with possibility of multivariate visualization and statistical analysis. However, additional instruction should be prepared and user-friendly TGE selection procedures should be added to make data available to community.

- **Transient energetic events in in the Earth' s atmosphere (TGF, TGE, TLE, particle precipitation…) can they all be explained in one theoretical framework?**

The precipitation of electrons from radiation belts can trigger energetic processes in the atmosphere. Precipitation can be triggered by the huge electromagnetic pulses emitted during thunderstorms.

The participants of workshop agree that the research of the high-energy phenomena in thunderclouds is entering intensive development stage. New satellite and balloon missions are prepared exclusively for detection of optical, radio and gamma ray emissions from the thunderclouds. Research groups from new countries worldwide are installing on earth surface particle detectors for TGE detection. New models aimed to explain TGF and TGE events are currently developed and tested. Vast amount of experimental evidence on TGE, TGF and TLE is available for tuning the models and for the crosschecks.

During workshop also lecture on frontiers of the very high-energy gamma-ray astronomy was presented.

Besides scientific program participants visit Aragats research station of YerPhI located on 3200 m altitude in 18 km from the Nor Amberd. Excursion program include the 8-th century Amberd fortress, the museum of ancient manuscripts in Yerevan, cafedral in Echmiadzin and several archeological excavations nearby Aragats mountain.

The slides of presentations and videos of discussions are available from conference site.

Figure 1 Aragats station, near Vishap stone erected in vicinity of Kare lake. The highest north peak of Aragats (4070 m) is seen in background to the right.

Figure 2 Workshop official picture on the entrance of Nor Amberd conference center