PREFACE: Cosmic ray origins: The Viktor Hess centennial anniversary

The 39th COSPAR Scientific Assembly, held in Mysore, India, in July 2012, was a celebration of the 100-year anniversary of the discovery of cosmic rays. Viktor Hess, who is credited with their discovery, found that the ionization level of the atmosphere rises with altitude. He correctly concluded that the ionization was caused by highly penetrating radiation coming from outside the atmosphere. This was a culmination of dedicated efforts of many scientists that span for over a century.

It took decades to develop techniques to measure cosmic rays and analyze their composition. Studies of cosmic ray interactions in the atmosphere led to discoveries of new elementary particles. Development of balloon-borne and spacecraft instrumentation and ground-based arrays enabled studies in different energy ranges and with drastically different fluxes. The spectrum of cosmic rays appeared to extend up to hardly imaginable energies of about $10^{21}$ eV per particle that are coming at the rate of 1 particle per km$^2$ per century.

Cosmic rays are the only pieces of matter available to us that come from Galactic and extragalactic distances. Their spectrum, composition, and, at highest energies, direction provide invaluable information about their origin and propagation history. The bulk of Galactic cosmic rays is associated with the most energetic events such as supernova explosions, but some fraction may also come from pulsars and interstellar shocks. The origin of extragalactic cosmic rays is still a mystery with speculations ranging from nuclei of active galaxies to gamma-ray bursts and primordial shocks.

Studies of cosmic rays accelerated at the end of 20th century and the beginning of 21st century. It has become possible to measure the detailed isotopic composition and spectra of individual species with fine energy resolution. Gamma-ray telescopes launched in space opened up a new dimension in cosmic ray studies. Through observation of emissions produced by energetic particles interacting with interstellar gas and radiation field, it has become possible to probe cosmic-ray spectra and densities in distant regions of the Galaxy and even in other galaxies.

Apparently new techniques of the last decade brought us new puzzles that we have yet to decipher. In particular, it was found that the positron fraction, $e^+/(e^- + e^+)$, increases above $\sim 10$ GeV, indicating a significant contribution of an unknown source of perhaps primary positrons (e.g., HEAT, PAMELA, Fermi-LAT, AMS-02). The all electron ($e^- + e^+$) spectrum is flatter than expected at high energies with an abrupt cutoff at $\sim 1$ TeV (e.g., ATIC, Fermi-LAT, PAMELA, HESS). The spectrum of protons is steeper than the spectra of heavier nuclei (e.g., CREAM, PAMELA). The spectra of protons, He, and perhaps heavier elements, become flatter above $\sim 230$ GV (e.g., PAMELA, ATIC, CREAM) although a preliminary AMS-02 proton spectrum did not confirm the feature at $\sim 230$ GV reported by PAMELA. The gamma-ray sky revealed by Fermi-LAT shows glorious details of cosmic ray interactions in the interstellar medium. It also shows that cosmic rays are a universal phenomenon that is present in other normal star-forming galaxies. Our own Galaxy displayed many surprises; the most famous are the so-called Fermi Bubbles, kpc-size structures above and below the Galactic plane apparently aligned with the Galactic center and filled with energetic particles, the dark gas that is not visible in radio, and the excess emission in the outer Galaxy where the sources of cosmic rays are very rare.

As it often happens in other areas of physics, the more we know about cosmic rays the more puzzles we encounter. The latter is an indicator of the active research and a very dynamic field. Interestingly, 100 years after the discovery of cosmic rays we are still searching for their origin, but this search has gone a long way from the original question about the origin of the mysterious radiation coming from outside the atmosphere. High expectations are associated with AMS-02, which has yet to unveil its first results. A lot of effort has been put into the finest experiments of the nearest future, such as GAPS, ISS-CREAM, CALET, JEM-EUSO, HAWC, CTA, and others. It is a great pleasure to witness that new chapters of the astrophysics of cosmic rays are about to unfold as the experimental teams are hurrying to put their instrumentation to work.

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The 39th COSPAR Assembly was truly a success. It covered all aspects related to the history of the discovery and early research in astrophysics of cosmic rays, as well as its current development. After the COSPAR Assembly a call for papers was issued inviting scientists to contribute to this special issue independently of whether or not they attended the COSPAR session. All submitted papers were refereed by at least two reviewers, many of them are acknowledged at the end of this issue.

Finally, we wish to thank all authors for their contribution to this special issue, reviewers for their fair judgment and helpful advice, and especially Dr. Peggy Ann Shea, ASR Co-Editor for Special Issues, for her precious guidance and support that made it possible for us to publish this issue.

Guest Editors
Eun-Suk Seo
IPST & Dept. of Physics, University of Maryland, College Park, MD 20742, USA
E-mail address: seo@umd.edu

Igor V. Moskalenko
Hansen Experimental Physics Laboratory and Kavli Institute for Particle Astrophysics and Cosmology, Stanford University, Stanford, CA 94305, USA
E-mail address: imos@stanford.edu

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