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The origin of Galactic Cosmic Rays: theory confronts observations

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This year, the world celebrates the centennial of the discovery of Cosmic Radiation by the austrian-american physicist Victor Hess. With his balloon flights, Hess provided an answer to a major mystery of the times, proving that the anomalous radiation measured by electroscopes came from the sky rather than from some unknown radioactive source on Earth. This Nobel Prize worth discovery, quickly followed up by the finding that the cosmic radiation consisted of highly energetic particles, started the quest for the astrophysical sources of cosmic rays and for the physical processes behind their acceleration. Cosmic ray physics has been a very active field of research, attracting the attention of some of the most brilliant minds of the century. While the measured cosmic ray spectrum extends up to energies exceeding a billion TeV (namely a billion times the energy of collisions at LHC) this talk will focus on particles up to PeV energies. These are thought to be of Galactic origin and a long standing paradigm assumes them to be accelerated in Supernova Remnants by the process of "Diffusive Shock Acceleration." This paradigm has been eluding definite proof for many decades and only recently the combination of theoretical and experimental progress has become such as to finally prove or disprove it. I will review recent theoretical progress on the subject of particle acceleration at Supernova Remnant shocks and of cosmic ray propagation in the Galaxy. I will then discuss how theory compares with observations and the current challenges to existing paradigms on the origin and propagation of Galactic Cosmic Rays.