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**CELESTIAL MESSENGERS  
COSMIC RAYS. THE STORY OF A SCIENTIFIC  
ADVENTURE**

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Great discoveries which compelled a change of common views about the physical world always had a long story, a long incubation period spangled with inexplicable experiments, adventurous hypotheses, harsh discussions and disputes. Then a refinement of experimental methods and new findings led to the rule that the number of conflicting explanations is inversely proportional to that of new experiments. When at last just two opposite theories survived, the *experimentum crucis* – often the only one told in textbooks – solves the issue. Good for the man of the street who learns about the happy end of a long story, and even better for science, whose step forward opens a window over many new unsolved questions – the happy start of new adventures. Not just the ultimate test told in textbooks but the whole story, from the early mysteries to the new adventures, is real pedagogy. An honest and well-grounded formulation of a wrong theory and its dismissal by a new experiment are often far more instructive than fortuitous discoveries.

The long story of cosmic rays, beautifully told by Mario Bertolotti in his “Celestial Messengers” from the first mysterious signals in Coulomb’s experiments to the most recent search for dark matter, is perhaps the most exemplary and pedagogical of all stories told in modern physics. Suffice it to mention the discovery of antimatter, of lepton families, including neutrinos and muons, etc., and who knows how many secrets of the universe shall be unveiled by the study of ultra-energetic cosmic particles, of the cosmic microwave background (CMB), etc. Last but not least, elucidating the nature of cosmic rays led to the explanation of geophysical phenomena, one for all the *aurora borealis*.

The book is organized in 13 chapters, which succeed in extracting a coherent sequence of the essential facts out of story which can hardly be considered coherent. One clear reason is that the cosmic messages started being detected just during the development of quantum mechanics, special and general relativity and relativistic cosmology.

Understanding cosmic rays was often parallel to (triggered by) that of quantum mechanics, e.g., Dirac theory and the positron, but not all was that linear. The prologue (Chap. 1) tells the discovery of the spontaneous electric charge loss of charged bodies through air, then the Wilson cloud chamber and the great ingenuity of Domenico Pacini’s experiments. The discovery of cosmic rays by Victor Hess (Chap. 2) with temerarious balloon ascents led to another Wien Congress, luckily two years before the centenary of the more famous one and one year before the burst of WWI, where cosmic rays were officially born. It is Millikan who unambiguously confirmed Hess’s discovery in US (Chap. 3), putting however all his reputation and authority, as one of modern physics fathers, in a theory of cosmic rays known as the “birth cry” of atoms in space. While Hess and Millikan concurred in establishing the truth of cosmic rays, they offer two conflicting aspects of the scientific endeavour: Hess showed how arduous and risky the search for scientific truth can be, Millikan showed (unintentionally) how the scientific truth can be obfuscated by a prejudice.

The current belief that cosmic radiation is made of gamma rays and the Birth-Cry theory start looking weary: Skobelzyn cloud chamber experiment, the advent of Geiger-Müller counters, Bothe and Born works, and Bruno Rossi experiments address the story towards elementary particles (Chap 4). Actually with Bruno Rossi the birth-cry is dead! Millikan gets enraged with Rossi, although being credited to have said: “Who did not make incorrect assertions on cosmic rays?” Very often ideas which could not be applicable to the case which they were conceived for, will turn out to be useful in other contexts. This is another lesson which we may extract from this story.

The geophysical and geomagnetic effects of cosmic rays, while confirming their nature, allowed Stoermer to explain the *aurora borealis* – another phenomenon which, for being known since antiquity, concerned intellectuals much longer than cosmic rays (Chap. 5) also with harsh controversies. The

most spectacular was however a recent one, that about the cosmic ray latitude effect, again involving Millikan (against) and Compton (for). “Obviously amused at the performance of two Nobel laureates engaged in such a ‘dogfight’, as Millikan called it, the press raised the issue to the front-page of newspapers”.

Cosmic rays had their *Annus Mirabilis* in 1932: with the discovery of the positron (in cosmic rays) and the neutron (in lab experiments), the structure of atomic nuclei and antimatter start being understood (Chap. 6). Since then gamma rays and particles are peacefully living together : the study of electromagnetic showers (Chap. 7), besides fostering the development of QED, yields a wonderful shower of new particles like muons (Chap. 8), pions and strange particles (Chap. 9). The discovery of extended atmospheric showers and the idea of using the atmosphere as a detector (Chap. 10) open a window on primary cosmic rays, whose nature and their energy limits constitute a conundrum of present physics (Chap. 12).

One of the most fascinating chapters concerning cosmic rays is however that of neutrinos, especially solar neutrinos and their oscillations. The birth of a neutrino astronomy is one of the most exciting endeavours of modern physics (Chap 11) together with the great open question: where do the celestial messengers come from? The reader will find several hypotheses in the last chapter of the book, enough to show how wonderful is the history of science: a problem solved generates hundreds new intriguing questions, together with the conviction that they will be solved the same way the original one was solved.

The book is intended for a general audience with a good scientific background, but even more for first-year physics and high-school students thanks to its particular clarity and high pedagogical quality, all this improved by a rich collection of biographical sketches.

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