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Astroparticle Experiments to Improve the Biological Risk Assessment of Exposure to Ionizing Radiation in the Exploratory Space Missions: a Research Topic Initiative

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The actual and next decade will be characterized by an exponential increase in the exploration of the Beyond Low Earth Orbit space (BLEO). Moreover, the firsts tentative to create structures that will enable a permanent human presence in the BLEO are expcted. In this context, a detailed space radiation field characterization will be crucial to optimize radioprotection strategies (e.g., spaceship and lunar space stations shielding, Moon / Mars village design), to assess the risk of the health hazard related to human space exploration and to reduce the damages potentially induced to astronauts from galactic cosmic radiation. On the other side, since the beginning of the century, many astroparticle experiments aimed at investigating the unknown universe components (i.e., dark matter, antimatter, dark energy) have collected enormous amounts of data regarding the cosmic rays (CR) components of the radiation in space. Such experiments essentially are actual cosmic ray observatories. And the collected data contains valuable information that can enhance the space radiation field characterization and, consequently, improve the radiobiology issues concerning one of the most relevant topics of space radiobiology represented by the dose-effect models. This paper describes a research topic initiative titled "Astroparticle Experiments to Improve the Biological Risk Assessment of Exposure to Ionizing Radiation in the Exploratory Space Missions". We launched it in December 2021 on three different Frontiers Journal (Astronomy and Space Science/Astrobiology, Public Health/Radiation and Health, Physics/Detectors and Imaging).

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1. Introduction

Cosmic rays (CR) approaching our planet interact with the Earth's magnetic field and atmosphere, and such interaction protects humans living on the Earth's surface. The Magnetosphere rejects most particles (99%) while the rest lose most energy going through the atmosphere before reaching the Earth's surface. The situation is completely different in space where the CR interacting with the human body release some energy and can be dangerous for health. In this regard, this is one of the main concerns for safe space exploration as planned for the coming years by all the national space Agencies. The research on the space radiation environment and its effect on biological, mechanical, and electronic systems covers a time range of about 40 years. In 1983, J.A. Simpson published a review of galactic CRs(GCRs) elemental and isotopic composition measurements [1] highlighting fundamental GCR characteristics still relevant to space radiation effects today. Several of fundamental studies for space exploration are cited in [2, 3, 4], representing excellent overviews of research conducted over time. Moreover, NASA has an obvious and intense research focus in this area including the Space Radiation Analysis Group, developing the Space Radiation Laboratory, and supporting Space Radiation Element research projects under the Human Research Program NASA initiative. Nevertheless, the research on the space radiobiology represents hot topics up to date.

In this context, all the different components of space radiation have been extensively studied and measured during the last decades by a particular class of experiments the CR Detectors (CRD), designed to produce a complete inventory of charged particles and nuclei in CR since the knowledge of this information is crucial to solve fundamental physics open problems (e.g.. AMS02[5], PAMELA[6], DAMPE[7], CALET[8]) and the information contained in the data taken by such experiments are expected to improve the radiation health risk assessment (RHRA) for humans in future space missions.

2.Radiation Health Risk Assessment for Humans in Space Mission

Since 2018, the INFN Roma Sapienza AMS group has collaborated with researchers and scientists to investigate the possibilities of using the CRD to improve the RHRA for humans in space missions. Collaborations were mainly focused on creating synergy within different scientific communities (radiobiology, medical physics, radiotherapy, and nuclear medicine) and Institutions (Research, Universities, and National Space Agencies).

In many studies [9-11] we analyze and discuss the capabilities and possibilities in that direction, especially regarding the AMS02 and also we identify many opportunities for improvement [12], for example:

Environmental Model Characterization: Current environmental model used in the risk assessment process are based on a subset of the CR spectrum poor in the information of CR components of energy > 1GeV due to limited information collected in the past years. This affects the accuracy and precision of the risk assessment potentially underestimating the actual damage. Indeed, space radiation for LET greater than several keV/micron causes more serious damage than low-LET radiation to living cell/tissues. Many successful CRD space missions have been collecting crucial data in the last decade and they will continue in the years. These data have an unprecedented precision on the spectrum and LET distribution of charged particle fluxes that

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compose the CRs. This precision is essential for improving the space risk assessment models thanks to the capability of monitoring the CR fluxes and their variation over time (including the frequency and duration of solar events).

Space Exposition Scenario Dose Computation: MC codes can be implemented to calculate the dose and so predict/describe the effects of GCR particles interacting with cells, tissues/organs and astronauts, which can be modeled as geometries with increasing details and complexities. The CRDs data could be used as input to the MC codes for determining the absorbed dose in the forecast exposition scenario (e.g. lunar gateway/lander or spacecrafts).

Among the others the AMS Roma Sapienza group focused his research on the space radiobiology dose-effects model as one of the most important and promising research fields for possible collaborations [13,14].

3.Creating Synergies: The Research Topic Initiative

Progressing in the research activity raised the awareness that to make progress in such a field a new scientific language was required able to connect and create synergy between different scientific communities. Firstly, to understand the relationship between ionizing radiation and biology and to solve problems in this field, researchers incorporate fundamentals of biology, physics, astrophysics, planetary science, and engineering. Further space exploration and colonization collects the worldwide hopes of a new era characterized by transparency and peacefully development. In that sense, these expectations coincide with the primary scientific interest, and science could play a breakthrough role in such direction. Among the many possibilities thus, we decided, supported by the Frontiers Editorial team, to launch this research topic named ”Astroparticle Experiments to Improve the Biological Risk Assessment of Exposure to Ionizing Radiation in the Exploratory Space Missions”. We created a research topic editorial board representative of different scientific cultures and geographic areas and invited many researchers and scientists from many different research areas due to the strong interdisciplinarity of the topic.[15]. The characteristics of the CDRs of great interest for the research topic include:

• **CR components identification**:They can measure the light components like electrons and protons and the nuclei from the lighter (i.e.,Helium) up to heavier one (i.e.,Iron,Z=25).

• **Wide Energy Measurement Range**: data collected from the operating CRDs ranges from a few MeV up to hundreds of TeV.

• **CR Solar Modulation Measurements**: one of the most important aspects to be evaluated is the differences in IR exposition due to the interference of the solar activities and cycles with the GCR part of the space radiation. In this regard, the CRDs took data during cycles 23 and 24 and some will continue for the 25th.

At the moment many scientists and researchers expressed the intention to participate to the topic collection, 5 papers were sent for publication and 2 was yet published [15, 16]. Other details on the topic and instructions to take part to the project are in the research topic WebSite[17].

4.Acknowledgements

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