"Advancing Space Radiobiology Through Interdisciplinary Research": Insights from the Alpha Magnetic Spectrometer Roma Sapienza Group

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Author Note

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Abstract

Space radiobiology, a multidisciplinary field investigating the biological effects of ionizing radiation on astronauts during space missions, plays a pivotal role in understanding and mitigating health risks associated with Galactic Cosmic Rays and solar radiation. The INFN Roma Sapienza Alpha Magnetic Spectrometer research group has been at the forefront of advancing research in this critical domain over the last five years. This presentation highlights the interdisciplinary approach employed in our research activities, em-

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phasizing the collaborative efforts that have significantly contributed to the assessment of health risks induced by GCR radiation exposure. Our research endeavors delve into dose-effects models, establishing crucial relationships and providing a theoretical framework for modelling non-target effects resulting from space radiation—a paramount consideration in evaluating carcinogenic risks associated with deep space exploration. Furthermore, the discussion sheds light on the roles played by data collected from astroparticle experiments operating in space, with a specific focus on the mid and heavy nuclei components of space radiation. An integral aspect of our recent initiatives involves collaboration with esteemed research institutions, notably the National Institute for Laser, Plasma, and Radiation Physics (INFLPR) in Bucharest. This collaborative effort aims to explore the potential of reproducing space radiation conditions through ground experiments, employing innovative Laser Plasma Accelerators and the launch of a research topic collection dedicated to space radiobiology. This initiative further amplifies our commitment to advancing knowledge in this multidisciplinary field.

Keywords: Human Space Exploration, Cosmic Ray, Space Radiobiology, Interdisciplinary Research

"Avanzando en la radiobiología espacial a través de la investigación interdisciplinaria": conocimientos del espectrómetro magnético alfa Grupo Roma Sapienza

Resumen

La radiobiología espacial, un campo multidisciplinario que investiga los efectos biológicos de la radiación ionizante en los astronautas durante las misiones espaciales, desempeña un papel fundamental en la comprensión y mitigación de los riesgos para la salud asociados con los rayos cósmicos galácticos y la radiación solar. El grupo de investigación del Espectrómetro Magnético Alfa del INFN Roma Sapienza ha estado a la vanguardia del avance de la investigación en este dominio crítico durante los últimos cinco años. Esta presentación destaca el enfoque interdisciplinario empleado en nuestras actividades de investigación, enfatizando los esfuerzos de colaboración que han contribuido significativamente a la evaluación de los riesgos para la salud inducidos por la exposición a la

radiación GCR. Nuestros esfuerzos de investigación profundizan en los modelos de dosis-efectos, estableciendo relaciones cruciales y proporcionando un marco teórico para modelar los efectos no objetivo resultantes de la radiación espacial, una consideración primordial en la evaluación de los riesgos cancerígenos asociados con la exploración del espacio profundo. Además, el debate arroja luz sobre el papel que desempeñan los datos recopilados en experimentos con astropartículas que operan en el espacio, centrándose específicamente en los componentes de los núcleos medios y pesados de la radiación espacial. Un aspecto integral de nuestras iniciativas recientes implica la colaboración con prestigiosas instituciones de investigación, en particular el Instituto Nacional de Física de Láser, Plasma y Radiación (INFLPR) en Bucarest. Este esfuerzo de colaboración tiene como objetivo explorar el potencial de reproducir las condiciones de radiación espacial a través de experimentos terrestres, empleando innovadores aceleradores de plasma láser y el lanzamiento de una colección de temas de investigación dedicada a la radiobiología espacial. Esta iniciativa amplifica aún más nuestro compromiso con el avance del conocimiento en este campo multidisciplinario.

Palabras clave: Exploración espacial humana, rayos cósmicos, radiobiología espacial, investigación interdisciplinaria

"通过跨学科研究推进空间放射生物学"：来自Roma Sapienza阿尔法磁谱仪研究组的见解

摘要

空间放射生物学是一个用于研究太空任务期间电离辐射对宇航员的生物效应的多学科领域，在理解和减轻与银河宇宙射线(GCR)及太阳辐射相关的健康风险方面发挥着关键作用。过去五年，INFN Roma Sapienza 阿尔法磁谱仪研究小组一直处于推进这一关键领域研究的前沿。本文强调了我们研究中采用的跨学科方法，强调了对"GCR辐射暴露引起的健康风险评估"作出重大贡献的合作努力。我们的研究致力分析剂量效应模型，建立关键关系，并为空间辐射造成的非目标效应建模提供理论框架——这是评价与深空探索相关的致癌风险的首要考虑因素。此外，讨论还阐明了从"太空中运行的天体粒子实验"收集的数据所发挥的作用，特别聚焦于空间辐射的中核和重核成分。我们近期倡议中的一个组成部分涉

及与著名研究机构的合作，特别是位于布加勒斯特的国家激光、等离子体和辐射物理研究所(INFLPR)。这项合作旨在探索“通过地面实验再现空间辐射条件”的潜力，采用创新的激光等离子体加速器并推出专门针对空间放射生物学的研究主题集。这一举措进一步增强了我们对推进该多学科领域知识的承诺。

关键词：载人太空探索，宇宙射线，空间放射生物学，跨学科研究

Since 2017, the Alpha Magnetic research group at Roma Sapienza has adopted an interdisciplinary approach to advance the field of space radiobiology. This approach involves merging expertise in astrophysics and cosmic ray measurements with knowledge from the clinical field, where radiation has been utilized for diagnosis and treatment across various medical disciplines since the early 20th century. The initiative gained prominence due to the resurgence of human space exploration beyond low Earth orbit, a venture that had been abandoned after the closure of the Apollo mission in the 1970s. The concern arises from the exposure of astronauts, and potentially future space workers or tourists, to prolonged periods outside the protection of Earth's geo-magnetosphere and atmosphere (Bartoloni et. al., 2022). Leveraging data captured by the AMS02 detector, the Roma group is delving into the investigation of accurate dose-effects models. These models enable the prediction of expected effects resulting from radiation exposure in space (Strigari et. al., 2021).

Furthermore, the group has initiated collaboration efforts with other institutions to broaden its capabilities and spearhead a paradigm shift in the approach to investing in the field. Noteworthy is the collaboration with the National Institute for Laser, Plasma, and Radiation Physics (INFLPR) in Bucharest, focusing on the innovative use of Laser Plasma Accelerators as tools for space radiation production on Earth (Bartoloni et. al., 2023). Additionally, the group has launched a research topic collection (Bartoloni et. al., 2022) to enhance awareness among scientists regarding this interdisciplinary approach.

The Research Topic Initiative: A Sample Paper

As an illustrative participant in the research topic collection, the activities of the research group engaged in space radiobiology at the Wake Forest Institute for Regenerative Medicine were showcased, providing a glimpse into the high level of interdisciplinary engagement within the research topic. In this instance, the group leveraged its expertise in hematopoiesis and stem cell assay systems to investigate the effects of solar particle

events, galactic cosmic ray radiation, and microgravity conditions on the human hematopoietic/immune system. The ultimate objective is to define the risks astronauts may encounter regarding hematological malignancies during extended missions in deep space—such as those planned by NASA to near-Earth asteroids and Mars—and to develop effective countermeasures ensuring astronaut safety (Almeida et.al, 2018, Rodman et. al., 2017).

The SESA2023 Conference Panel

We had the privilege of organizing a panel at the Space Education & Strategic Applications Conference (SESA2023), hosted by the Policy Studies Organization. This panel aimed to explore the effectiveness of interdisciplinary research in addressing the complex problems that currently characterize the scientific landscape. Space radiobiology serves as a prime example of such a comprehensive field, gaining heightened relevance with the resumption of beyond low orbit human space exploration. During our panel, where we presented our research group's activities, the discussion revolved around three key themes:

1. **Interdisciplinary Collaboration:** Space radiobiology inherently requires a melding of expertise from diverse fields such as biology, physics, and space science. The panel raises the fundamental question: How has collaborative effort among experts in these distinct domains contributed to our comprehension of the biological impacts of radiation in space? Exploring the synergies between these disciplines becomes essential in unravelling the complexities associated with space radiobiology.

2. **Translating Research into Space Policy:** The panel recognizes that interdisciplinary research often yields invaluable insights. Consequently, it poses a crucial query: How can the findings and models derived from collaborative research efforts be effectively translated into space policy and incorporated into astronaut safety measures? Bridging the gap between research outcomes and actionable policies is imperative for ensuring the well-being of astronauts in the challenging environment of space.

3. **Education and Training:** Given the intricate nature of space radiobiology and the necessity for interdisciplinary expertise, the panel focuses on the future. It raises the question of how we can promote education and training programs that equip the next generation of researchers with the skills needed to work seamlessly across different fields. Developing programs that foster a holistic understanding of space radiobiology will be essential for cultivating a new cadre of researchers capable of addressing the evolving challenges of space exploration.

In essence, the panel aims to explore not only the current state of interdisciplinary collaboration in space radiobiology but

also its future implications for research, policy, and education. Also, the discussion triggered a lot of interest from the audience that propose main interesting question, e.g., "How can interdisciplinary research involving radiobiology and other scientific fields contribute to advancing our understanding of radiation effects on living organisms?" This question propels us into a realm where the synergy of diverse disciplines converges to unravel the mysteries of radiobiology. Interdisciplinary collaboration, bridging radiobiology with realms like physics, chemistry, and genetics, serves as a catalyst for groundbreaking discoveries. By amalgamating expertise, researchers forge comprehensive insights into the intricate interplay between radiation and living organisms. This collaborative approach not only broadens the scope of inquiry but also sheds light on nuanced aspects of radiation's impact on biological systems. Yet as the exploration deepens, ethical considerations surface. The implications of radiobiology research on human health, with its potential applications in medical contexts and beyond, raise profound ethical questions. Navigating these considerations becomes integral to responsibly harnessing the power of radiobiology for the betterment of humanity. Moreover, radiobiology emerges as a cornerstone in the development of personalized medicine. Recognizing the individual variations in response to radiation exposure, researchers explore avenues where tailored medical interventions can be crafted, ushering in an era where healthcare is precisely calibrated to each person's unique physiological landscape. Challenges abound in the current landscape of radiobiology research. However, the audience questions not only highlighted these challenges, but also beckon us to envision a future in which interdisciplinary efforts become the linchpin for overcoming obstacles and driving progress. The collaborative fusion of diverse fields promises to chart new trajectories, offering solutions to the pressing issues faced in the realm of radiobiology. The far-reaching impact of radiobiology extends beyond terrestrial boundaries, finding resonance in the challenges faced by astronauts exposed to cosmic radiation during space travel. As we strive for the next frontier, interdisciplinary advancements in radiobiology become instrumental in fortifying the safety and efficacy of space exploration. Yet the conversation transcends the cosmos, delving into the profound societal implications of radiobiology. Interdisciplinary collaboration takes center stage in addressing the long-term health effects observed in survivors of nuclear accidents or atomic bombings, offering a glimmer of hope for understanding and mitigating the enduring consequences of such catastrophic events.

Conclusion

In conclusion, the panel provided a thorough exploration of the motivations, as well as the strengths and weaknesses, inherent in interdisciplinary research. Navigating the complex landscape of radiobiology, the audience's keen interest and probing ques-

tions served as guiding beacons, illuminating uncharted realms of knowledge. Interdisciplinary collaboration doesn't merely function as a scientific tool; it emerges as a transformative force, shaping the trajectory of radiobiology and significantly influencing our understanding of life, health, and the cosmos.

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