FAIR for Space Radiation Research

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The exposure to the space radiation environment remains a major limiting factor for human long-duration space missions due to its high biological effectiveness and the difficulties to effectively shield the radiation. The next decade in human spaceflight will be characterized by a continuous presence of human beings in Low Earth Orbit (LEO), by their return to the Moon and by longer stays in a Moon orbit on the Lunar Orbital Platform - Gateway (LOP-G). These endeavours are also performed to prepare for a human Mars mission.

To support and enable these missions, ongoing improvement of radiation dosimetry for accurate and continuous monitoring and the development of shielding approaches including personal shielding equipment are necessary. Such equipment should be tested using very high energy heavy ions. An ideal setting would be the combination of several beams, e.g. protons, alpha-particles and one or more heavy ions. Furthermore, experiments with human phantoms can contribute to risk assessment.

In the last decades, the cancer risk induced by exposure to galactic cosmic rays was in the focus of attention. Numerous animal experiments and mechanistic studies were performed to derive the relative biological effectiveness of heavy ions to induce cancer and to elucidate the mechanisms and patterns specific to heavy ions. Radiation quality factors and dose-rate modifying factors based on these results were integrated into a model to estimate space radiation cancer risk (NASA Space Cancer Risk (NSCR) model) [1].

Now, target organs for degenerative effects induced by galactic cosmic rays, especially the brain, the cardiovascular system and the eye lens, are in the focus of the radiobiological research. A suspected cognitive decline by chronic exposure to galactic cosmic rays has achieved some celebrity as “Space Brain”. The role of neurons, glia cells including astrocytes, oligodendrocytes and microglia remain to be elucidated – even sex-specific differences in the involvement of microglia have to be considered [2]. Experiments with accelerated heavy ions will help to elucidate the mechanisms of the degenerative effects of space radiation and will set the foundation to develop countermeasures. Here, besides the combination of beams to simulate better the radiation field in space, low dose rate experiments are of high interest.

Besides the chronic space radiation exposure, astronauts experience a quite unique combination of possibly health-deteriorating environmental factors such as microgravity, noise, smell, disturbed circadian rhythm, increased carbon dioxide concentrations and decreased sleep quality. The interaction of radiation exposure with these space environmental factors such as microgravity or changes in the atmospheric conditions might influence the cells’ capability to cope with radiation damage. Therefore, settings at FAIR allowing simultaneous exposure to simulated microgravity on a clinostat or control of atmospheric conditions will enable the investigation of combined effects.

Finally, it has to be considered that humans are not only composed of their body cells that can be affected by heavy ion hits, but they also carry a microbiome inside and at the surface that quickly colonizes the surroundings, also spacecraft. The knowledge on how the human-microbiome and microbiome-environment interactions change under chronic space radiation exposure is very scarce and interesting model systems could be investigated at FAIR.

In conclusion, FAIR can smooth the way to Mars.

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