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Challenges of space weather and space radiation predictions for human explorations in deep space

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Space agencies such as ESA, NASA, the Chinese space agency and even private companies are launching new human deep space exploration programs to the Moon and Mars. Radiation is one of the most important long-term risks to such missions. In preparation, this requires a very timely and thorough study to better understand the space weather conditions and their effects as a baseline for the development of mitigation strategies against radiation risks.

Radiation damage in space comes mainly form two sources, Galactic Cosmic Rays (GCRs) and Solar Energetic Particles (SEPs). The GCR is omnipresent, ubiquitous, and increases the chance of long term health consequences. Its flux is modulated by and anti-correlated with the solar activities and this modulation is also energy-dependent. Such an effect has been measured by the radiation assessment detector (RAD) on the surface of Mars and modeled via the HZETRN particle transport code (Guo et al 2017 JGR).

On the other hand, intense SEP events can result in very high dose rates that may exceed the threshold for acute radiation syndrome (ARS) or sickness or poisoning or toxicity after a whole body exposure to high doses of radiation at the Gy [J/kg] level. Such events, despite of being rather infrequent, could result in severe damage to humans and equipment and lead to failure of the entire mission and therefore should be detected as immediately as possible.

Under different shielding environment, the intensity and composition of the GCRs/SEPs may vary due to the interactions of primary particles (of different energies and charges) with the surrounding material (such as the spacecraft and the planetary atmosphere) and the generation of secondaries. Habitable shelters on the Moon and Mars with regolith shielding could provide sufficient protection against such radiation hazards. However the situation of a transit spacecraft in deep space or an astronaut carrying out extra-vehicle or planetary surface activities may be much more severe, especially during the onset of a solar particle event (SPE). This is because SPEs generally have a sudden and sporadic nature and can be very intense, dynamic and vary drastically in time and location. Therefore radiation and particle enhancements measured near Earth (such as the onset time and intensity) may be completely different from of that detected elsewhere in the heliosphere such as on the surface Mars (Guo et al 2018 AJ).

Radiation exposure from Solar Particle Events is the result of three major procedures: (1) the acceleration process at the Sun which are often related to the flare eruptions and associated shocks, (2) the properties of the accelerated particles injected into the open magnetic fields which are connected to the missions (that can be very differently connected compared to Earth), and (3) the atomic and nuclear interactions of particles with the local shielding environment (such as the spacecraft or the Martian atmosphere). Taking into consideration of these 3 factors, we will show our recent study (Guo et al 2018 GRL) of the September 2017 event which is seen on the surface of both Earth and Mars as well as at STEREO-A (a spacecraft surrounding the Sun at 1 AU). These three locations have a heliospheric longitudinal separation of more than 240 degrees apart and they all saw the SPE with different time profiles, particle spectra and radiation intensities. We highlight the utmost importance of utilizing multi-spacecraft in-situ and remote sensing observations of the Sun and the heliosphere to better understand such dynamic events and their dynamic effects across the heliosphere in particular at locations where human explorations may take place.

Authors: Dr GUO, Jingnan (IEAP, University of Kiel, Kiel, Germany); Prof. WIMMER-SCHWEINGRUBER, Robert (IEAP, University of Kiel, Kiel, Germany); Dr ZEITLIN, Cary (Leidos, Houston, Texas, USA); Dr HASSLER, Donald (Southwest Research Institute, Boulder, CO, USA)

Presenter: Dr GUO, Jingnan (IEAP, University of Kiel, Kiel, Germany)

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