RELATIVE CONTRIBUTIONS OF GALACTIC COSMIC RAYS AND LUNAR PARTICLE ALBEDO TO RADIATION DOSE AND DOSE RATES NEAR THE MOON. H. E. Spence[1], C. Joyce[1], M. D. Looper[2], N. A. Schwadron[1], S. S. Smith[1], L. W. Townsend[3], and J. K. Wilson[1], [1]Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, NH 03824, USA., [2] The Aerospace Corporation, El Segundo, CA 90009, USA., [3] Department of Nuclear Engineering, University of Tennessee, Knoxville, TN 37996, USA.

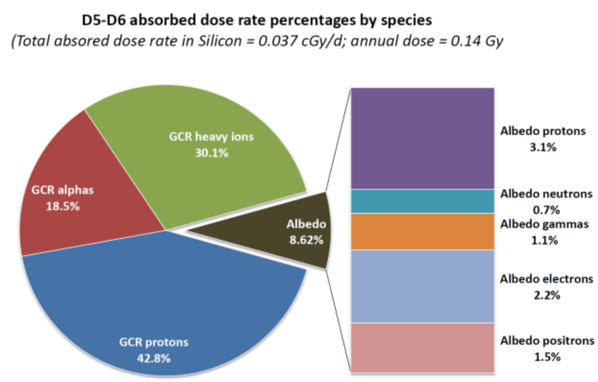
Introduction: The Cosmic Ray Telescope for the Effects of Radiation (CRaTER) [1] has been immersed in the ionizing radiation environment near the Moon since its launch on NASA's Lunar Reconnaissance Orbiter (LRO) [2] and insertion into lunar orbit in June 2009. CRaTER measurements yield robust estimates of the linear energy transfer (LET) [3] of extremely energetic particles traversing the instrument, a quantity that describes the rate at which particles lose kinetic energy as they pass through and interact with matter. The resultant ionizing radiation of these interactions poses a radiation risk for human and robotic space explorers subjected to deep space energetic particles [4].

Methodology: CRaTER employs strategically placed solid-state detectors and tissue equivalent plastic (TEP), a synthetic analog for human tissue, to quantify radiation and shielding effects [5] pertinent to astronaut safety. Though designed to measure galactic cosmic rays (GCR) and solar energetic protons [6] coming from zenith and deep space, CRaTER observations have been used also to discover an energetic proton "albedo", caused by a process known as nuclear evaporation coming from the lunar surface [7]. We use validated radiation transport models of the CRaTER instrument and its response to both primary GCR and secondary radiation [8], including lunar protons released through nuclear evaporation, to estimate [9] their relative contributions to total dose rate in silicon (0.037 cGy/day) and equivalent dose rate in water (0.071 cSv/day).

Results: In the figure to the right, taken from [9], we show that near the Moon the GCR accounts for ~91.4% of the total absorbed dose, with GCR protons accounting for ~42.8%, GCR alpha particles ~18.5%, and GCR heavy ions ~30.1%. The remaining ~8.6% of the dose at LRO altitudes (~50 km) arises from secondary lunar species, primarily "albedo" protons (3.1%) and electrons (2.2%). Other lunar nuclear evaporation species contributing to the dose rate are positrons (1.5%), gammas (1.1%), and neutrons (0.7%).

Relative contributions of these same species to the total effective dose rate in water, a quantity of more direct biological relevance, favor those with comparatively high weighting factors, including neutrons. Consequently, the primary GCR components are collectively higher (~96.5% of the total) with the GCR heavy ions alone contributing 62%, and the albedo neutrons jumping to over 3%. In recognition of the biological importance of the neutron dose, not just in lunar orbit but even more so at the lunar surface, a new exploration-motivated instrument, Dose Spectra from Energetic particles and Neutrons (DoSEN) is presently under development. DoSEN leverages the considerable flight heritage of the CRaTER design but with a novel, compact neutron detection capability [10].

Finally, we note that when considering the lunar radiation environment, although the Moon blocks approximately half the sky, thus essentially halving the dose rate near the Moon relative to deep space, the secondary radiation created by the presence of the Moon adds back a small, but measurable amount (~4-8%) that can and should now be accounted for quantitatively in radiation risk assessments at the Moon and other exploration targets.



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Acknowledgements: We thank all CRaTER and LRO team members whose dedication, skills, and labor made this experiment and mission possible. This work was funded by the NASA under contract numbers NNG11PA03C and NNX13AC89G.