ENERGETIC CHARGED PARTICLE DOSE RATES IN WATER ICE ON THE MOON. A. P. Jordan[1,2], J. K. Wilson[1,2], and H. E. Spence[1], [1]EOS Space Science Center, University of New Hampshire, Durham, NH, USA (author email address: a.p.jordan@unh.edu), [2]Solar System Exploration Research Virtual Institute, NASA Ames Research Center, Moffett Field, CA, USA.

Introduction: Some permanently shadowed regions (PSRs) on the Moon seem to contain water (H_2O) ice and hydrocarbons [e.g., 1], and a number of crewed and robotic missions are planned to study this ice in situ. It may preserve a record of the organic history of the Solar System, and thus of Earth, but energetic charged particle radiation, i.e., galactic cosmic rays (GCRs) and solar energetic particles (SEPs), may have altered that record, in part by synthesizing organic compounds [e.g., 2, 3]. GCRs and SEPs can affect even buried ice, penetrating millimeters to centimeters into the regolith. To help understand how this radiation has changed the chemistry of the ice, we estimate the total dose that lunar water ice has received over the past 1 Gyr [4].

Radiation doses in water ice: We use the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) [5] onboard the Lunar Reconnaissance Orbiter (LRO) [6] to measure GCR and SEP dose rates over a full solar cycle's worth of measurements (the first 11 years of CRaTER data). The GCR and SEP dose has been relatively constant over the past ~1 Gyr [e.g., 7], so we can extrapolate these dose rates into the past. The CRaTER instrument consists of three pairs of detectors sandwiching two blocks of tissue-equivalent plastic (one detector pair is between the blocks). This enables CRaTER to measure the dose rate behind three different amounts of mass shielding, which we convert to three different depths in the lunar regolith.

We analyze GCRs and SEPs that traveled through CRaTER toward the Moon while the instrument was in its nominal zenith-nadir orientation. We find that in the least shielded (zenith) detector pair, the SEP dose rate is comparable to the GCR dose rate, but in the more shielded pairs, the GCR dose rate dominates by an order of magnitude. This is because GCRs are more energetic and thus more penetrating. In addition, the GCR dose rate in the most shielded (nadir) pair was over two orders of magnitude lower than the dose in the least shielded pair. Thus, we assume the radiation dose at greater depths to be negligible.

To convert the dose rates into total doses, we estimate the time the ice-bearing regolith has resided at the three shielding depths using a simple impact gardening model from Jordan et al. [8, 9]. This model accounts for how impacts bury and expose regolith. We calculate that ice with an age of 1 Gyr has had a total radiation dose of at least 0.1-1 eV/molecule (Fig. 1), sufficient to synthesize organics [11]. Our result is about an order of magnitude lower than the estimates of prior studies that did not include the effects of impact gardening [e.g., 3, 10], showing the importance of accounting for this process.

Conclusion: Using the CRaTER instrument, we measure the dose rate behind three different amounts of shielding over the past solar cycle. When combined with a model for impact gardening, we estimate the total radiation dose over the past ~1 Gyr is sufficient to have synthesized organic molecules in lunar ice. These results place a valuable constraint on the doses that should be used in experiments that study the chemical evolution of irradiated water ice on the Moon.

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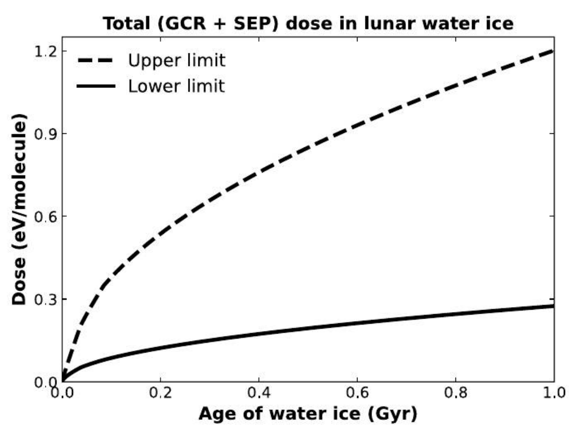

Fig. 1: The upper and lower limits of the total (GCR + SEP) dose in lunar water ice as a function of the age of the ice. These values combine the doses measured by CRaTER's three pairs of detectors. Water ice that is at least 1 Gyr old may have received a radiation dose sufficient to synthesize hydrocarbons.