REFINING THE LATITUDE TREND OF ALBEDO PROTONS TO CHARACTERIZE HYDROGEN IN SHALLOW REGOLITH ON THE MOON.

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Introduction: Understanding the large-scale distribution of the Moon's water ice is a key component to understanding the history of its sources and losses. For example, the location of large-scale maxima in polar ice can constrain the timing of the emplacement of ice, as shown by data from the Neutron Spectrometer on Lunar Prospector [1]. The maximum concentrations of hydrogen (~50 cm) in both polar regions are offset from the Moon's current poles, yet they are also antipodal to each other. This suggests the hydrogen—a proxy for water ice—was deposited more than ~3.5 Gyr ago, when the Moon had a different spin axis (palaeopoles). In addition, secondary maxima are located at the current poles, implying another, more recent depost of water ice.

These conclusions may also apply to water ice exposed at the surface. Near-infrared reflectance spectra from the Moon Mineralogy Mapper (M^3) on Chandrayaan-1 show that the large-scale distribution of surface ice may be shifted in the direction of these palaeopoles [2]. This suggests that the surface ice could have the same source as the deeper deposit.

To further test this common origin, it would be necessary to measure the large-scale distribution of ice between ~50 cm and the surface. This can be done with albedo protons, which are produced by galactic cosmic rays colliding with nuclei in the regolith (Fig. 1). These collisions release secondary protons and neutrons, and those neutrons can collide with hydrogen nuclei, i.e., protons, and eject them as albedo protons. In other words, the same process that decreases the flux of albedo neutrons also enhances the flux of albedo protons [4].

Albedo protons are detected by the Cosmic Ray Telescope for the Effects of Radiation, or CRaTER [3], on the Lunar Reconnaissance Orbiter (LRO). They originate from depths of ~1-10 cm [4]. Consequently, these observations can link the surface measurements with the neutron data.

A New Technique: Previous analysis suggests that the abundance of hydrogen in the upper ~10 cm of regolith could increase with increasing latitude[4]. These results, however, have a spatial resolution that is too low to determine whether this large-scale distribution hydrogen is offset from the current poles. Since then, a technique has been developed to decrease the statistical uncertainty in identifying albedo protons [5], which would help increase the spatial resolution of the albedo proton data.

In applying this technique, however, we have found a previously unnoticed source of background. Simulations suggest this background is created by cosmic rays releasing electrons, called delta rays, from material in the telescope.

To have confidence that we are correctly identifying albedo protons, we must ensure that we properly subtract this background. Therefore, we will characterize this source of background particles and use this characterization to revisit the latitudinal trend in the albedo protons. We will discuss the implications of our results. If a trend remains, further analysis could show whether polar hydrogen at a depth of ~1-10 cm is symmetric about the current poles or palaeopoles and thus show whether albedo protons can help link the near-infrared and neutron studies above.

References: [1] Siegler M. A. et al. (2016), *Nature, 531,* 480-484. [2] Li, S. et al. (2018), *PNAS, 115,* 8907-8912. [3] Spence, H. E. et al. (2010), *Space Sci. Rev., 150,* 243-284. [4] Schwadron N. A. et al. (2016), *Icarus, 273*, 25–35. [5] Schwadron N. A. et al. (2018), *Icarus, 162,* 112-132.

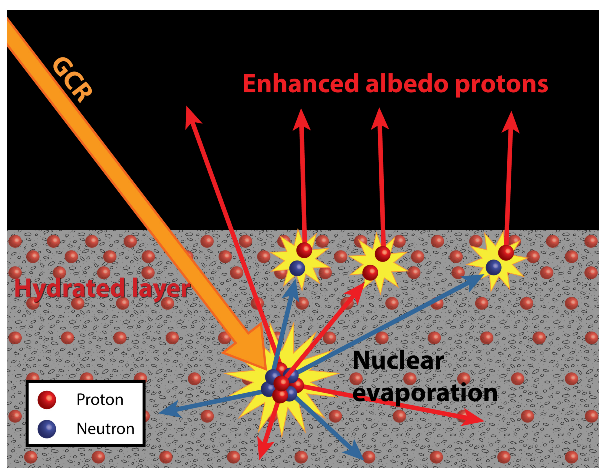

Fig. 1. Cartoon showing how a glactic cosmic ray (GCR) can excite an atomic nucleus in the lunar regolith, causing nuclear evaporation. The nuclear fragments include protons and neutrons. Some of the neutrons can eject hydrogen nuclei, i.e., protons, from the regolith, thus enhancing the yield of albedo protons. (Figure from [4].)