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Understanding the energy spectra of scattered solar wind ions using low energy ion scattering

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The solar wind, a stream of charged particles from the Sun, interacts with planetary bodies in a variety of ways. One such interaction is the reflection of solar wind ions from regolith surfaces where particles may be scattered as ions or undergo neutralisation processes, leading to the formation of energetic neutral atoms (ENAs). In either case, the scattered particles can in turn be observed by space missions providing valuable insight on the space weathering of rocky bodies and the interaction of their surfaces with the solar wind. Such information is available for, e.g., the reflection of protons at the Moon [1] or Phobos [2,3].

Similarly, the scattering of light ions off sample surfaces, referred to as low energy ion scattering (LEIS), is a commonly used ion beam analysis technique. In LEIS, the energies of ions scattered into a certain detector geometry are recorded. In these energy spectra, the positions and heights of peaks are indicative of the chemical surface composition. Consequently, LEIS is usually employed to monitor composition changes during processes like material deposition, erosion or chemical reactions [4]. Conventional LEIS setups commonly use electrostatic analysers, and thus the neutralised fraction of projectiles is not accessible. Quantifying the neutralisation probability is therefore tedious and also not available in binary collision approximation (BCA) simulations like SDTrimSP [5]. Because however the physics behind the ion scattering processes is the same as in the space environment, LEIS experiments are an ideal tool to study the reflection of solar wind ions in a simplified, controlled laboratory setting.

In this study, we present measurements using He projectiles of energies ranging between 1 keV and 5 keV on samples prepared from the pyroxenoid wollastonite ($CaSiO_3$). The samples were prepared as flat thin films on Si substrates such that in a first step, surface roughness or regolith-like porosity would not obfuscate our understanding of the underlying physical processes. While He is significantly less abundant in the solar wind than H, it is chemically inert and thus simplifies interpretation of the results. The Ca in the sample facilitates a greater relative mass difference to the projectile and therefore a better separation from the low-energy background compared to using silicates containing lighter elements, like Na or Mg. The experiments were carried out using a commercial LEIS setup (ionTOF Qtac) with an electrostatic analyser. Additionally, we performed BCA simulations with the codes SDTrimSP and IMINTDYN [6]. Using the former, we can model the surface composition changes during sputter cleaning of the sample, while the latter is capable of calculating the resulting LEIS spectra under consideration of the actual experimental geometry, ignoring however the charge state of the scattered ions. A key feature of IMINTDYN is further that it can separate the spectra into contributions from ions that scattered once, twice or multiple times, as well as by the sample species at which the scattering event took place.

Using this combined experimental and numerical approach, we find that the multiple scattering contribution from deeper sample layers is suppressed by roughly an order of magnitude compared to single and double scattering events. Furthermore, since the simulations consider all scattered particles as neutral, while the analyzer detects only ions, comparison of the two allows for estimation of the charge fraction of scattered projectiles. This capability to assess the ion-to-neutral ratio is highly relevant for ENA studies and goes beyond what is accessible with conventional BCA simulations alone.

[1] C. Lue et al., *J. Geophys. Res. Space Phys.* **123** (2018) 5289–5299.
[2] Y. Futaana et al., *J. Geophys. Res. Space Phys.* **115** (2010), A10213.
[3] Y. Futaana et al., *J. Geophys. Res. Planets* **126** (2021) e2021JE006969.
[4] H.H. Brongersma et al., *Surf. Sci. Rep.* **62** (2007) 63–109.
[5] A. Mutzke et al., IPP Report (2019).
[6] H. Hofsäss, A. Stegmaier, *Nucl. Instrum. Methods Phys. Res. B* **517** (2022) 49–62.