August 2021

Conference: Lunar Surface Science Workshop: Fundamental and Applied Lunar Surface Research in Physical Sciences

Density characterization of the lunar lava tube surroundings with cosmic-ray based muography method

Holma, M.[1,2,3,4], Enqvist, T.[1], Joutsenvaara, J.[1,2,3], Kuusiniemi, P.[1,2,4], Loo, K.[1,4], Leone, G.[5,4] & Tanaka, H.K.M.[6,7,4], 2021.

[1]Muon Solutions Oy, Finland (*corresponding author: marko.holma@muon-solutions.com)
[2]Arctic Planetary Science Institute, Finland
[3]Kerttu Saalasti Institute, University of Oulu, Finland
[4]Virtual Muography Institute (global)
[5]University of Atacama, Chile
[6]Earthquake Research Institute, University of Tokyo, Japan
[7]International Muography Research Organization (MUOGRAPHIX), University of Tokyo, Japan

Atmospheric muons are formed in planets' atmospheres as a by-product of natural interactions between atmospheric nuclei and primary cosmic rays. On Earth, this continuous process is feasibly utilized for the density characterization of material by using a method called muography, which is based on measuring muon attenuation in natural and man-made structures, including those of geological nature. On atmosphereless objects, however, the production of muons takes place directly in the uppermost layer of the solid object. This also happens on the lunar surface, as our earlier simulations indicate. We propose that muon imaging offers several applications on the Moon, especially if a swarm of highly automatized self-charging Muon Telescope Rovers (MTRs) are applied. The muographic mapping of lunar lava tubes with such rovers is one of them.

In our concept, the MTRs are used to study lava tubes together with other types of research rovers and robots (unless they are integrated). It may be beneficial if the tunnel network has already been detailly mapped with a LiDAR robot or similar, as this would provide an opportunity for pre-programming the MTR's research route to obtain the best possible results with the least effort. An MTR would navigate through the tunnel from one place to another and occasionally stop for recording muon counts from the direction of the facing wall. Provide the muon detection continues long enough, the growing muon statistics would eventually reach a pre-determined threshold of the total recorded muons. Next, the MTR would navigate back to the fixed link station, which would then transfer the data back to the base (or Earth) where the data analysis team (or automated software) could provide a density model of the lunar rocks behind the lava tube walls. If such measurements are repeated in many locations and especially if the same volumes of rocks are imaged from different angles, a detailed density model of the lunar underground above the MTR level can be constructed. Albeit the tomographic density models provide the best value, even 2D radiographic density images are beneficial to the research team that runs the muography campaign as they would allow to (1) conduct geological modelling of the host rocks of the lava tube, (2) recognize structurally broken zones (possibly important from the safety point of view), and (3) detect mineral and other resources behind the walls. Any of these data sets would be valuable for evaluating the suitable lava tubes as a base for a shielded human settlement, temporal shelter, storage room or a source of raw materials.

We continue to apply Fluka simulations on the particle propagation (hadronic interactions) through lunar regolith to obtain better understanding about the feasibility to deploy muography on the Moon.