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A novel concept for exploration and characterization of subsurface water-ice on the Moon

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The water-ice deposits confined in the lunar regolith form a potential reservoir of water, hydrogen and oxygen for the human settlements, scientific research, in-situ resource extraction, construction, and rocket propellants. However, before such volatile resources can be extracted, they have to be found. Like with mineral exploration on Earth, the first task is to choose the most prospective areas within the larger permissive regions for the given resource. There are strong indications that, on the Moon, the likelihood for the presence of regolith-bounded subsurface water-ice is the greatest in the permanently shadowed regions (PSRs) in the lunar poles. The largest PSRs are found mainly on the floors and lower interior walls of the impact craters there. We propose that the finer details on where to focus the drilling stage exploration activities can be carried out by applying a swarm of automatically operating self-charging cosmic-ray muon telescopes mounted on mobile lunar rovers. These Muon Telescope Rovers (MTRs) would negotiate themselves into the PSRs located close to their host crater's lowermost walls, whereupon they would detect muon particles emerging from the crater wall with relativistic energies. Muons are particles generated by the interactions between primary cosmic-rays and material, in this case lunar regolith. Our preliminary simulations with Fluka suggest muons are indeed generated in these processes on the Moon.

The above method is called muography and it is based on repeated muon flux measurements as means to get a 2D or 3D density profile of the volume of interest. On Earth, muons have the capability to travel through rocks for up to thousands of meters, until stopped by energy loss caused by the material. Because of the lack of atmosphere, the reaction kinematics of cosmic rays is different on the Moon resulting in some contrasting peculiarities. Regardless of the object, the attenuation of muons is the more severe the denser the rocks are. The used method is conceptually like the X-ray imaging of human body, although in this case the imaged object is drastically larger and a way denser. In our preliminary concept, the MTRs would be positioned roughly regularly so that each of them would face a slightly different part of the crater wall. The concept is based on the detection of density anomalies in the rocks facing the MTR swarm by comparing the muon fluxes measured by each MTR. Ideally, some MTRs could be positioned to face a segment of the crater which gets at least occasionally sunlight and hence is not part of the PSRs. The combined data would allow high-resolution density modelling of the permanently shadowed crater walls with the baseline density profiles of non-PSRs. The relatively lower density parts of the PSRs could then be interpreted as areas of high prospectivity for trapped water-ice, while also the unexplained high-density anomalies could warrant further studies (e.g., due to potential mineral resources). [2996]