CONFIRMING A LUNAR LAVA TUBE WITH ROVER BASED GRAVIMETRY AND GROUND PENETRATING RADAR. A. Braun[1], K. Carroll[2], S. Bringeland[1], F. de Veld[3], [1]Queen's University, Department of Geological Sciences and Geological Engineering, 36 Union St, Kingston, ON, K7L3N6, Canada, [2]Canadensys Aerospace Corporation, 10 Parr Boulevard, Caledon, Ontario, L7E 4G9, Canada., [3]Technical University Delft, PO Box 5 2600 AA Delft, The Netherlands

Introduction: Lunar lava tubes have been suspected for decades, but only in 2009, imagery acquired by SELENE in the Marius Hills region provided first evidence that lunar lava tubes may exist. While that and subsequent images only show a pit crater, or an opening into a void, there is a sinuous rille associated with the pit crater which could signal an underlying lava tube. To confirm the existence of a lunar lava tube is the key objective proposed herein. The study of lunar lava tubes is attractive for two main reasons, i) to illuminate the geological evolution of the Moon, and therefore the Earth-Moon systems, and ii) to investigate how lava tubes could serve as shelter/habitat for humans on the Moon. We are proposing two complementary geophysical techniques to confirm the existence of a lunar lava tube in the Marius Hills region, rover based gravimetry and Ground Penetrating Radar (GPR). Both techniques have been extensively used to study the Earth' subsurface, but only a very few such surveys have been carried out on the Moon, i.e., the Apollo 17 Traverse Gravimeter Experiment (TGE) and the Chang'e-4/5 Lunar Penetrating radar missions.

Proposed Site: The Marius Hills region on the nearside of the Moon exhibits a 900 m wide lunar rille, co-located with the Marius Hills pit crater. The depth of the pit crater has been estimated to be at least 30-50m. Considering the width of the rille, and other consideration of lunar lava flow, the diameter of lunar lava tubes should far exceed (>100m) those of terrestrial tubes, which are limited to about 20m. Hence, a lunar lava tube is a much stronger target for a gravimeter survey, even in greater depth. If an extended lava tube can be confirmed at this site, this would de-risk many future missions dedicated to exploring for human habitat protected from radiation, temperature extremes and impacts.

Survey methods: Gravimetry from a micro-rover is feasible with current technologies. Transects of several 100m are achievable up to several kilometers in a lunar day. We have modelled lunar lava tubes with realistic regolith and basalt lithology, varying diameter and depth, for many different survey routes including terrain effects and other sources of uncertainty [1]. Based on these results, rover based gravimetry should be able to validate the existence of a lave tube. However, mapping structure and depth of a lava tube would require a second technique, and we propose GPR. Due to the relative dry regolith and basalt on the Moon, radar penetrates much deeper than on Earth, which means that even high frequency radar can detect structures down to 100m. This means that antenna size can be reduced and spatial resolution can be enhanced compared to GPR used obn Earth. Forward models of realistic lava tube models show that complex shaped lava tubes can be resolved reasonably well, and GPR data can be fused with gravimetry data in joint inversion. GPR has strong localization power, and gravimetry has strong integration power. In combination, these methods are very capable of conforming a lava tube, its dimensions, as well as its content (air or collapsed material).

Proposed Technology: In order to be deployable on a micro-rover, the payload must be limited in mass and size. A space gravimeter such as VEGA [2] with a mass of 2 kg and dimensions of 2000 cm^3, meets both the scientific requirements in terms of sensitivity as well as the payload/power requirements to cover sufficient distances on the lunar surface. A rover-based GPR for the lunar surface could evolve from the current unmanned aerial vehicle GPR systems, which are low weight and low power, but would work better in lunar environments; or from the RIMFAX GPR currently in use on the Perseverance rover on Mars.

Expected Outcomes: The confirmation of lunar lava tubes from in situ surveys would be a major discovery, which in combination with the collection of samples would shed light at the magmatic processes on the Moon, the densities of the lunar regolith and basalt as well as their dielectric properties. In combination, it would put constraints on the thermal evolution of the Moon, which controlled the formation of lava tubes and their ages. While this proposed exploration program focuses on the Marius Hills region as there is some evidence for the existence of a lava tube, any other volcanic region on the lunar surface could serve as a targets site as well, as long as there is some evidence from pit craters or lunar rilles.

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References:

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