Master thesis project in computational space physics Date: 2021.10.18

Title: Modeling plasma observations on the lunar surface by a lunar rover

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1. Aims & Purpose

The present-day Moon lacks a global, internally generated magnetic field, but its crust has localized magnetization [1]. Some crustal magnetic fields coincide with one of the most mysterious surface patterns observed in the solar system, known as "*lunar swirls*" [2]. The swirls are unusual markings with optically distinct features on the lunar regolith (Fig. 1). They are suggested to be formed by differential surface weathering of the regolith underlying crustal fields due to deflection of the incident solar wind plasma (charge particles) by crustal magnetic fields [3]. The aim of this project is to use state-of-the-art high-performance computer simulations to investigate the role of the solar wind particles on the lunar surface albedo markings.

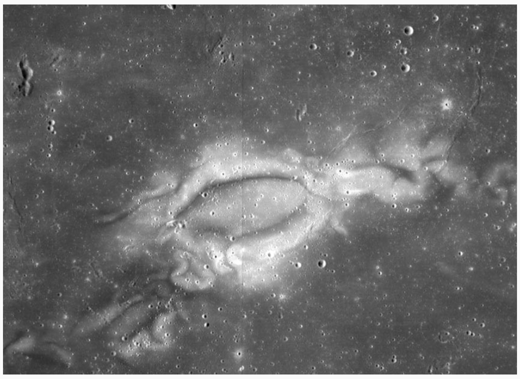

Fig. 1: *Lunar swirls (sinusoidal albedo anomalies with high reflectance at visible wavelengths) at Reiner Gamma [Image Credit: NASA].*

2. Methodology & Tasks

In this project, we will use Amitis, a well-established plasma simulation code that runs on Graphics Processing Units (GPUs) for high performance computation developed by Dr. Fatemi [4]. First, we will simulate the solar wind plasma interaction with realistic lunar crustal fields at Reiner Gamma. Then, we will examine the effects of different solar wind configurations on the solar wind plasma precipitation onto the lunar surface. After that, we will estimate surface brightness through the simulated plasma flux that impacts on the lunar surface and compare with observations. Finally, we will predict plasma observations by a lunar rover that traverses the Reiner Gamma magnetic anomaly. Fig. 2 shows an example of our simulations with lunar crustal magnetic fields.

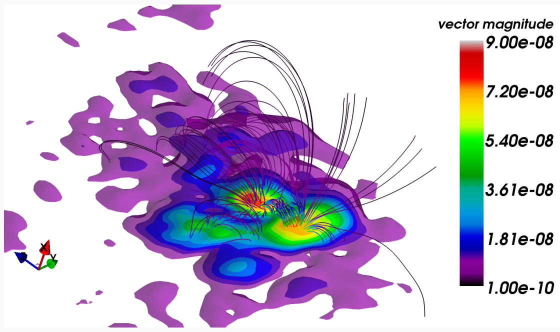

Fig. 2: *An example of the solar wind interaction with lunar crustal magnetic fields obtained from our simulations. The background color shows the intensity of the magnetic fields and the thin lines show the magnetic field line tracing.*

3. Significance & Importance

The *Lunar Vertex* mission, selected by **NASA** for PRISM-1a in 2021, contains a lander and a rover that is going to land near Reiner Gamma, one of the most famous swirl patterns on the Moon (Fig. 1). Reiner Gamma, located in the western Oceanus Procellarum, is an example of both a magnetic anomaly and a lunar swirl. The main objectives of the Lunar Vertex mission are, and not limited to investigate the origin and formation of the swirls and lunar crustal magnetization as well as the solar wind characteristics near the Reiner Gamma magnetic anomaly. Umeå University, through Dr. Fatemi, is a collaborator on this exciting mission. The simulation results obtained from our explained project above will help the Lunar Vertex team to better understand their future plasma observations at Reiner Gamma.

4. Requirements

Basic understanding on plasma physics is essential to pursue this project. Since the project is simulation-based, you are expected to be familiar with at least one computer programming language, e.g., Python.

5. Contact Information

The project will be conducted under the direct supervision of Shahab Fatemi, a researcher at the space physics group at the department of Physics at Umeå University. If you have any questions or interested in working on this project, please do not hesitate to contact Shahab Fatemi (shahab.fatemi@umu.se).

References

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2. Blewett, D. T. , E. I. Coman, B. R. Hawke, J. J. Gillis-Davis, M. E. Purucker, and C. G. Hughes, “Lunar swirls: Examining crustal magnetic anomalies and space weathering trends,” J. Geophys. Res., vol. 116, p. E02002, 2011.
3. Hood L. L. and G. Schubert, “Lunar magnetic anomalies and surface optical properties,” Science, vol. 208, no. 4439, pp. 49–51, 1980.
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