Surface and Buried Lava Tube Detection with GRAIL data

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INTRODUCTION

The success of the NASA's GRAIL mission now provides the highest resolution and most accurate gravity data for the Moon. The low altitude at which some of this data was collected potentially allows the detection of small-scale surface or subsurface features. We have focused on the specific task of detecting the presence and extent of empty lava tubes beneath the mare surface. In addition to their importance for understanding the emplacement of the mare flood basalts, open lava tubes are of interest as possible habitation sites safe from cosmic radiation and micrometeorite impacts [1]. The existence of such natural caverns is now supported by Kaguya's discoveries of deep pits in the lunar mare [2]. In this investigation, we developed tools to best exploit the rich gravity data toward the numerical detection of these small features. Two independent strategies are considered: one based on gradiometry techniques and a second one that relies on cross-correlation of individual tracks.

GRADIOMETRY

Detect topographical or underground structures by inspecting the gravitational potential through maps of the eigenvalues of the potential Hessian. The eigenvalue with largest magnitude depicts the

CROSS-CORRELATION

Exploit individual tracks as gravity acceleration profiles to detect lava tubes using cross-correlation with a know reference signal

Reference signal

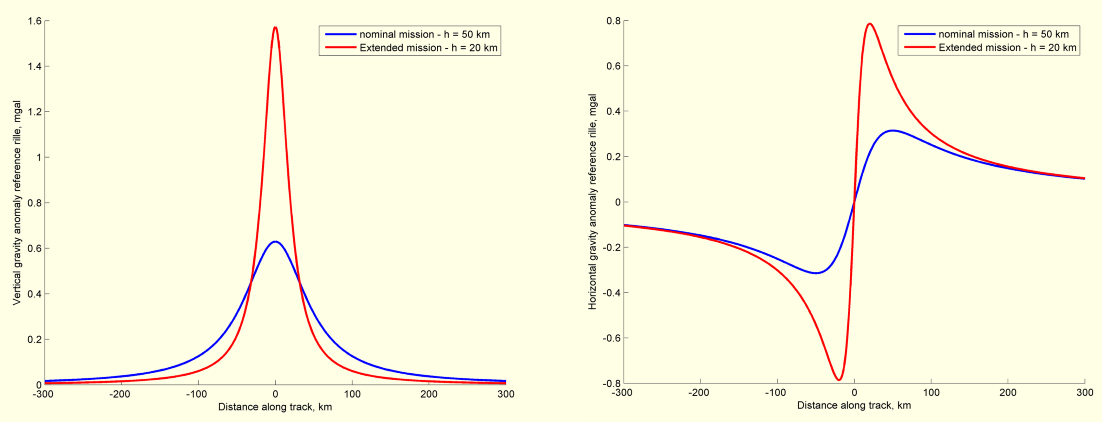

Fig.1: Analytical vertical (left) and horizontal (right) gravity anomaly.

SCHROTER SIMULATION

Bouguer | Free Air – Original | Free Air - Forward

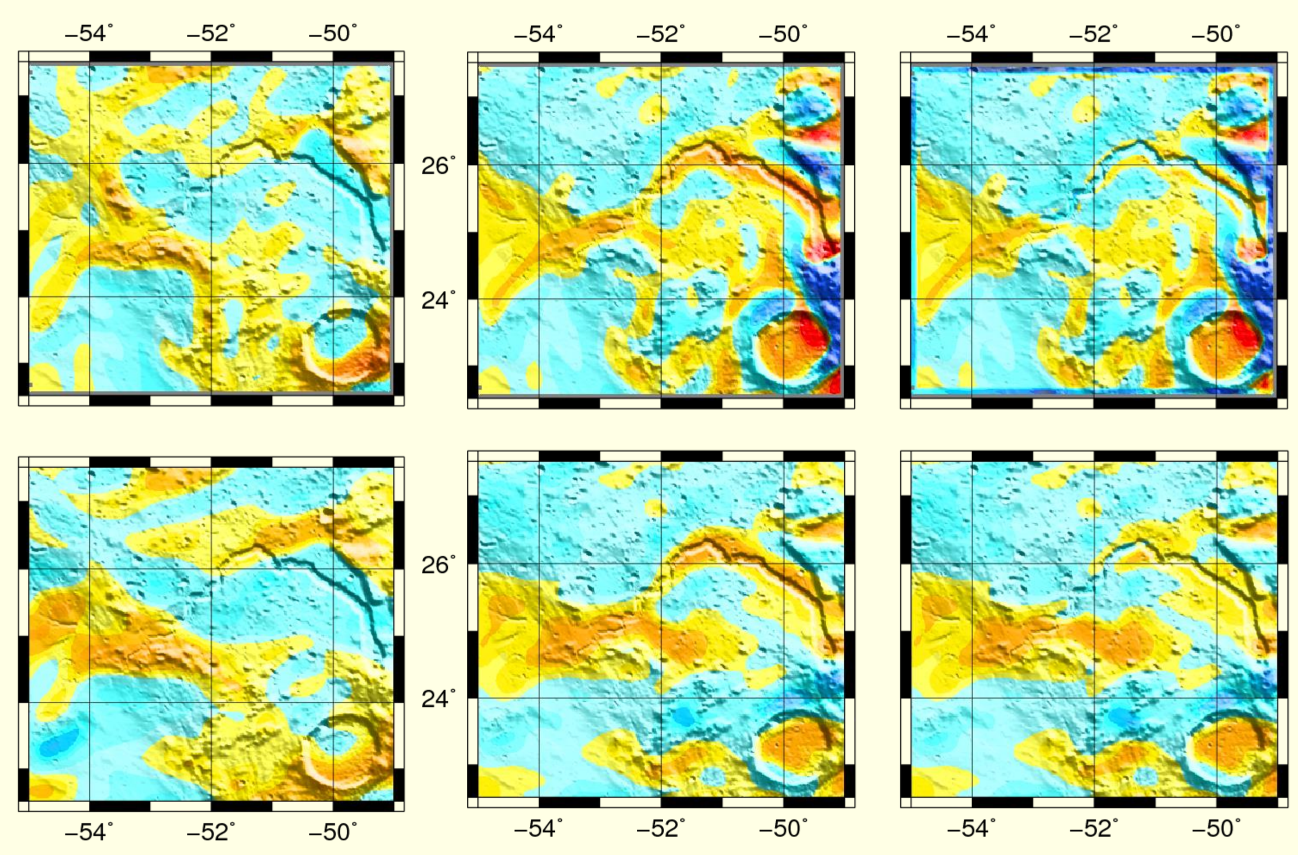

Fig.2: Bouguer (left), free-air (center), and free-air with forward rille model (right) local eigenvalue (top) and cross-correlation (bottom) map in the Schroter Valley region with topography overlaid.

FORWARD MODELING

Reproduce gravity signature of known features and infer characteristics of underground features employing:

- Point mass distribution along a profile
  - Estimate mass w/ trapezoid
  - Distribute point masses

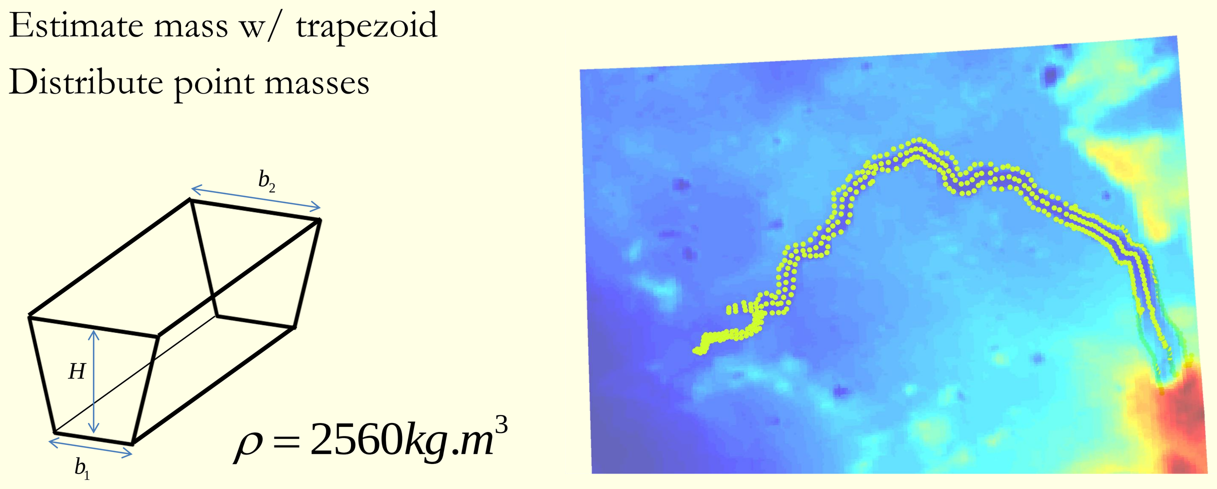

Fig.3: Schroter point mass model.

- Polyhedron shape model

L~70 km
D~4 km

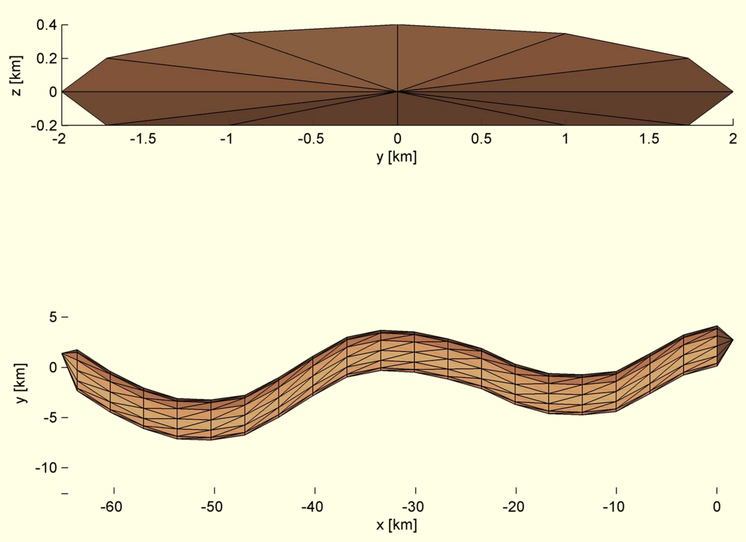

Fig.4: Polyhedron model for potential unknown gravity anomaly.

REMARKS

- GRAIL gravity data unprecedented resolution enables both strategies to detect Schroter's Valley.
- A weak gravity anomaly signal that connects the lunar skylights is observed.
- A robust unknown gravity anomaly consistent with a buried mass deficit is detected south of Rima Sharp.
- Further development of tools to include gravity residuals

References: [1] De Angelis et al. (2001) BAAS 33, 1037. [2] Haruyama et al. (2009), GRL 36, L21206. [3] Hanna et al. (2012) Science DOI:10.1126/science.1231753 .

FEATURES OF INTEREST

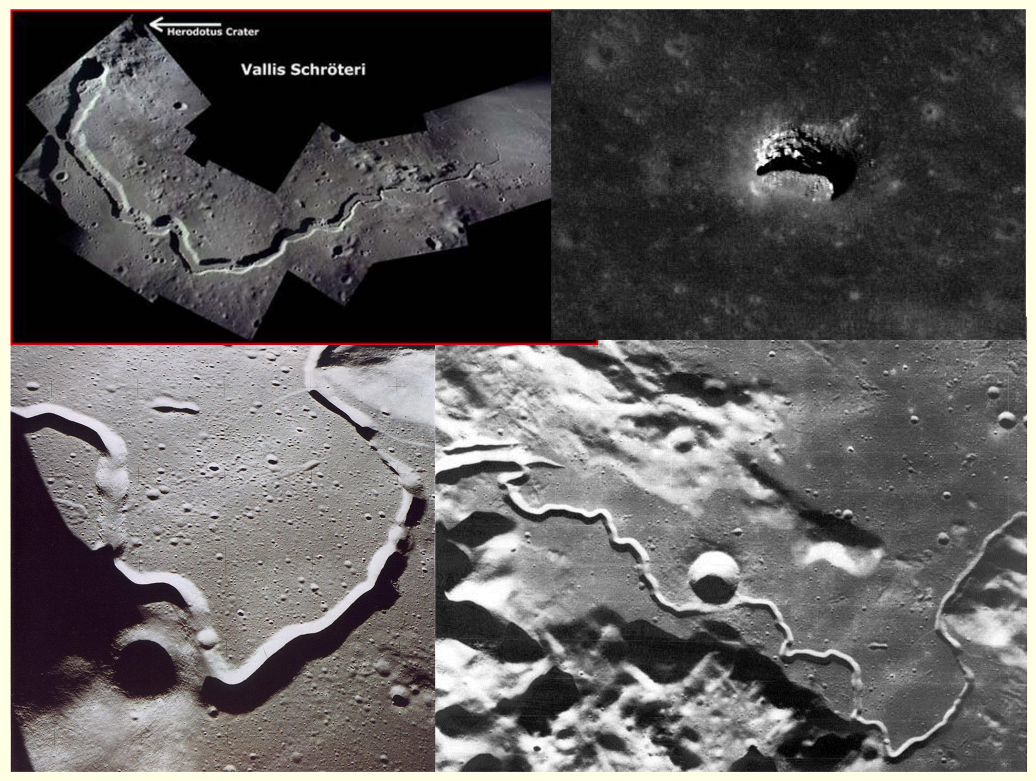

Fig.5: Known sinuous rilles and caves

SOUTH OF RIMA SHARP

Maximum eigenvalue | Cross-correlation

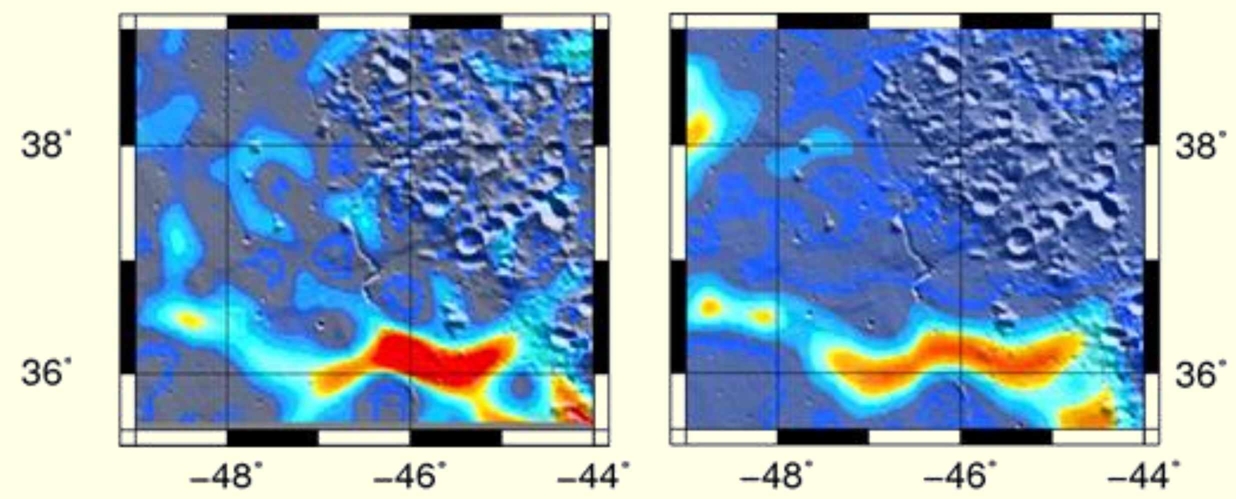

Fig.6. Correlation between free-air and Bouguer eigenvalue (left) and cross-correlation (right) map south of Rima Sharp with topography overlaid depicting an unknown gravity anomaly.

SKYLIGHT

Maximum eigenvalue | Cross-correlation

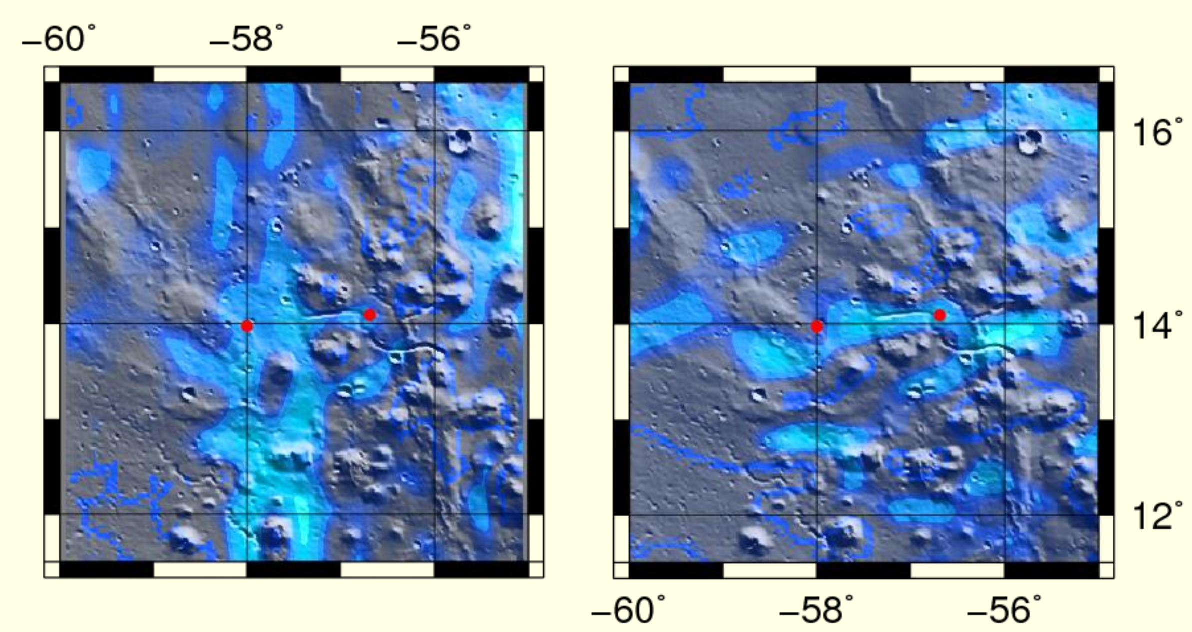

Fig.7. Correlation between free-air and Bouguer eigenvalue (left) and cross-correlation (right) map near lunar skylights depicting a weak gravity anomaly connecting the two caves.

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