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Initial results from the GRAIL lunar gravity mission

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Abstract

In Sept 2011 the GRAIL Discovery mission was launched to the Moon. GRAIL consists of 2 spacecraft that fly in formation in polar orbits around the Moon and measure the gravity field of the Moon from the changes in the distance between the 2 spacecraft.

1. Introduction

The primary mission objectives of GRAIL are to (1) Determine the structure of the lunar interior, from crust to core, (2) Advance understanding of the thermal evolution of the Moon. The secondary objective is to extend knowledge gained from the Moon to other terrestrial planets.

GRAIL science focuses on 6 investigations: 1. Structure of lunar crust and lithosphere. 2. Asymmetric thermal evolution. 3. Subsurface structure of impact basins and origin of mascons. 4. Temporal evolution of crustal brecciation and magmatism. 5. Interior structure from lunar tides. 6. Constraints on whether Moon has an inner core.

GRAIL measures the lunar gravity by making very accurate distance measurements between the two spacecraft in lunar orbit. During the 3-month prime mission the GRAIL spacecraft are between 50 and 200 km apart, in a polar orbit at an average altitude of 55 km. As the spacecraft orbit the Moon the distance between them changes due anomalies in the lunar gravity field. The changes in distance between the spacecraft are measured to the micron level every few seconds and from these measurements the acceleration of gravity beneath the spacecraft is derived. The configuration of the spacecraft in lunar orbit, the tracking of the spacecraft from Earth and the ranging between the two spacecraft is shown in figure 1. The ranging measurement between the two spacecraft provides gravity information even when the spacecraft are on the lunar far side and not visible from Earth and thus provide a uniform measure of the lunar gravity impossible with only measurements from Earth.

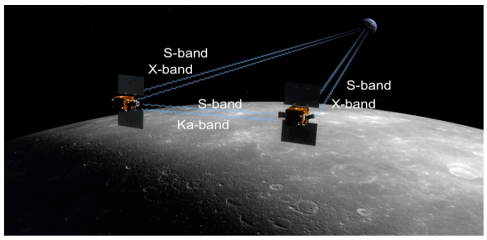

Fig 1 GRAIL twin spacecraft configuration at the Moon and the microwave links to Earth and to each other.

2. Cruise

The cruise trajectory from Earth to the Moon took 3 months. During cruise the ranging system between the spacecraft underwent checkout, and calibrations were conducted for the small non-gravitational forces that would be critical when in lunar orbit since they would mask or mimic the lunar gravity signal. In addition, the long cruise provided time for the spacecraft to outgas.

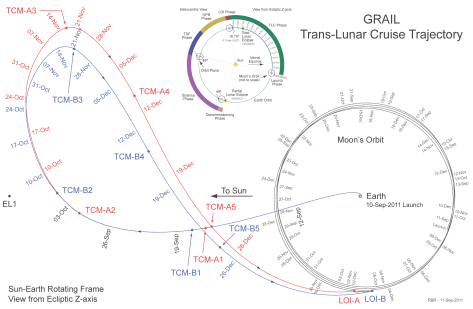

Fig 2 Cruise trajectory of the twin GRAIL spacecraft from Earth out toward the libration point then falling

back to the Moon and arriving Dec 31, 2011 and Jan 1, 2012.

The cruise trajectory about a fixed Earth-Sun line is shown in Figure2.

3. Science Data

After aligning the twin spacecraft in their desired lunar orbit the inter-satellite tracking measurements for the 3-month Prime mission began on March 1st, 2012 and was completed on May 29, 2012. The data quality is at least as good as hoped and many of the prime measurement objectives have been accomplished ahead of schedule. The demonstrated quality of the global GRAIL gravity data is ~ 0.1 mGal for a 1 degree square, two orders of magnitude better than before GRAIL.

Figure 3 shows an example of the GRAIL gravity field in the vicinity of Tycho crater.

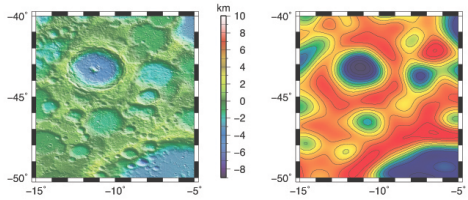

Fig 3: Tycho is an 86-km diameter complex crater. Left is LOLA topography and right GRAIL gravity. In the gravity map red correspond to mass excesses and blue to mass deficits.

Beginning at the end of August this year the GRAIL spacecraft will begin a 3-month extended mission in the same polar orbit but at the lower average altitude of 23 km above the mean radius thus bringing the spacecraft to within less than 10 km of the surface in many locations.

6. Summary and Conclusions

The GRAIL Mission has completed its prime mission and the gravity data have exceeded expectations in quality and enabling a new global gravity model to be developed for the Moon with every expectation that GRAIL will successfully address all the proposed science investigation.