The newest lunar digital elevation model (DEM) from SELENE and LRO data

Junichi Haruyama

Keywords: Moon, digital elevation model, DEM, Terrain Camera, SELENE, Kaguya

2007年に我が国が打ち上げた月探査機 SELENE（かくや）に搭載された地形カメラによる月球の 10 m/画素の解像度で立体視データを基礎に、SELENE 搭載マルチバンドイメージデータならびに米国月探査 LRO に搭載された高度計データ（LOLA）によって補完された月球の数値標高モデル（DEM）の最近版について、本講演では紹介する。

これまでも、SELENE 形状カメラのワイド視野画像を基にした数値地形モデル（Digital Terrain Model）データが、画像データとともに、SELENE レベル 2 データベース（LINK参照）で配布されている。また、これらを基に、月全体についてモザイク処理を施した DTM マップとオルソ画像マップも公開されている（LISM 高次プロダクト；プロダクト名は、DTM マップ、TC オルソマップ）。これらモザイクデータは、極端にいたるまで等経緯度線図で表された 3deg x 3deg のタイル状となっており、1 画素あたりの解像度は、赤道带では 7m/画素となるよう、リサンプリングを施している。

形状カメラデータは、ほぼ月球の観測を行ったが、裏側の高地帯に隣接軌道で数%以下程度ながら抜けが生じた（ただし、全体に対する被覆抜けは 1%以下）。また、極域については、隣が多く数値地形モデルが作成出来ないと考え難しい。そこで、形状カメラデータを基に、抜けの部分を他データによって埋めて、より被覆率の高い地形標高モデルが作成されている。この計算方法を用いたのは、SELENE 搭載マルチチャンネルイメージ（MI）可視域（VIS）データからの DTM と、LRO 搭載 LOLA（高度計）データである。MI-VIS データは、水平解像度 20 m である。MI-VIS では、二次元の検知器において、5 つのラインを残し、後はマスクすることで、各ラインが、あたかも一次元センサーのようににして月面をスキャンし、二次元画像を得る。そして、MI-VIS の異なるラインの間には、視差が生じることになる。この視差を補正して、DTM 作成ができる。最も前側と最後ろ側のライン間の画角は、\( \pm 5.48 \) deg である。MI-DTM によって、特に裏側の高地で抜けたところが補完された。

LRO に搭載された LOLA は、スポット半径 20m の 5 つのピームが打たれる仕様になっており、各ピームの衛星進行方向の出射間隔は 10～20m である。経度方向の水平解像度は、軌道間隔で決まるが、極域は、非常に密なデータが得られることになる、形状カメラの数値地形モデルデータより、経度 85° 以上で、LOLA の水平方向のデータ密度が上回る。

これら MI-DTM と LOLA データを統合して、新たに全球の数値標高モデル (Digital Elevation Model:DEM) 「SLDEM2012」が作成されている。ただし、これまでの検証で、全球的に数 m のオフセットが LOLA データと、SLDEM2012 との間に残っていた。そこで、このオフセット処理を取り除く補正処理を行い、新たな DEM の作成を試みている。この DEM が出来れば、これまでの月面全体を覆う DEM マップとしては、世界最高精度のものとなる。この DEM マップは、月科学研究、更には将来の月探査において、非常に重要かつ有意義なものとなることが期待される。

【LINK】
SELENE データアーカイブサイト
（日本語）http://l2db.selene.darts.isas.jaxa.jp/
（英語） http://l2db.selene.darts.isas.jaxa.jp/index.html.en

キーワード: 月, 数値標高モデル, デム, 形地カメラ, セレーネ, かくや

Keywords: Moon, digital elevation model, DEM, Terrain Camera, SELENE, Kaguya
Mare volcanism: Reinterpretation based on Kaguya Lunar Radar Sounder data

Shoko Oshigami

The volumes of single geological units with different ages and compositions are essential for revealing characteristics of mare volcanism and for constraining the thermal history of the Moon. Recently, the thicknesses of mare basalt units defined by previous lithofacies maps were indirectly estimated from Clementine multispectral data. That is, the depth-diameter relationship of the craters fringed with ejecta from the underlying basaltic units placed the constraints for the estimation. The results are derived for only limited areas in Oceanus Procellarum and Mare Serenitatis.

At present, the geological structures under the lunar maria are directly investigated using sounder observations. The Lunar Radar Sounder (LRS) onboard Kaguya (SELENE) detected widespread horizontal reflectors under some nearside maria. The LRS detects, using FM-CW radar (4-6 MHz), echoes from subsurface horizons with abrupt changes in dielectric constants at the apparent depths smaller than about 1 km. Oshigami et al. [2012] concluded that the reflectors correspond to the interfaces between basalt units with different FeO contents, suggesting that buried regolith layers were responsible for the radar returns. Therefore the LRS data have great potential to determine a lava effusion volume during a series of magmatism in lunar maria and its time dependence.

Thicknesses of mare basalt units with different ages and compositions are directly estimated from the LRS data in the several regions of lunar maria. Using the technique of Ono et al. [2009], we correlate subsurface reflectors with the surface geologic units, the ages of which have been estimated by several researchers, to evaluate the volumes of the units.

The estimated thicknesses of the geologic units were of the order of 10^1-10^2 meter, and showed a positive correlation with their ages. The resolution of our estimation was limited by the range resolution of the LRS data. Previous studies indicated that the typical thicknesses of single basalt flows were about 10 m or less in most of the studied sites. These estimations suggest that the geologic units are made up of dozens of lava flows.

Weider et al. [2010] estimated the thicknesses of a number of mare basalt units in Oceanus Procellarum and Mare Serenitatis, ranging from about 80 to 600 m. For the purpose of comparison, we took the unit S15 in Serenitatis defined by Hiesinger et al. [2000]: Weider et al. concluded that the representative thickness was about 500 m although individual data derived from craters located on the unit showed a wide variation, implying large uncertainty of their estimation. In contrast, the LRS data exhibit that the averaged thickness of the unit S15 is about 150 m.

The volumes of the geologic units estimated in this study were of the order of 10^3 km^3, and showed a clear positive correlation with their ages. Again, the resolution of our method was limited by the range resolution of the LRS data. This volume range is consistent with flow volumes derived from numerical simulations of thermal erosion model for lunar sinuous rilles formation. The large sinuous rilles are estimated to have formed by thermal erosion with sustained lava flows of volume in the range 300-1200 km^3. The volume range derived from our study also comparable to the average flow volumes of continental flood basalt units forming after the Paleozoic and calculated flow volumes of Archean komatiite flows, both possibly originated from mantle plume activities on the Earth. The estimated volumes of the geologic mare units and their age variation on each maria potentially constrain key factors for the thermal evolution of the Moon; magma buoyancy and crustal thickness, impact basin topography effects on the ascent of magma, and thermal evolution trend.

Keywords: Kaguya, Lunar Radar Sounder, Lunar maria, Subsurface structure, Volcanism
Melting of the Fe-O-S system and reaction between olivine and iron melt at lunar core conditions

Despite recent insight regarding the Moon from satellite sensing and analyses of Apollo-era seismic data, there are still several unknown issues on the deep lunar interior. It is suggested that the Moon has a small iron-rich core with a radius between 220 and 450 km based on the calculated value of the mass and moments of interior (Konopliv et al., 1998), but the question about its feature is still under debate. Recent studies suggest the presence of a solid inner core and liquid outer core in the Moon (Weber et al., 2011). If we could constrain the temperature and composition of the lunar outer core, this would help us for better understanding of the lunar interior. Here, we focused on the interaction between liquid iron-alloy and solid silicate, and revealed the nature of the outer core of the Moon. The lunar mantle is characterized by high FeO content compared to the Earth’s mantle. This implies that Moon is oxidizing and oxygen can be in the lunar core. Therefore, Fe-O-S system is considered and we performed the partition experiments of oxygen between silicate and molten metal in this study.

High pressure experiments were conducted at 5 GPa from 760 C to 1400 C using 3000 ton Kawai-type multi-anvil apparatus of Tohoku University. We used powder mixtures of Fe, FeO and FeS as the metallic component of the starting material. Olivine crystals with Mg number of about 83 from Miyakejima, which is similar to the lunar mantle olivine, were used for the silicate component of the starting material. The sulfur content was 24 wt.% and the oxygen content varies 0~7 wt.% for the starting iron-alloys. Scanning electron microscope (SEM) was used for the texture observation of the recovered samples, and the electron probe micros-analyzers (EPMA) with Energy-dispersive X-ray spectroscopy (EDS) and wavelength-dispersive X-ray spectroscopy (WDS) were used to obtain the chemical compositions of recovered run products.

Some differences in reactions between the experiments made at 1000 C and at 1400 C were observed in the recovered samples. At 1000 C, the metallic sample melted partially and liquid phase had magnesiowustite crystals were observed at the boundary between the molten iron alloy and olivine. The Mg number of the olivine crystals increased with increasing the distance from the metal phase. At 1400 C, the metallic sample was totally-melted. Pyroxene and olivine crystals with reverse zoning were observed in the silicate phase, whose Mg number was higher than starting materials. The effects of oxygen content in metallic phase on silicate phase were not observed in this experimental condition. We calculated the distribution coefficient D of FeO between metal liquid and olivine crystal. Using this value, the amount of FeO in the lunar liquid outer core is 4.45 at.% at 1000 C and 1.63 at.% at 1400 C when the mantle Mg number is 80. If the amount of FeO is 4.45 at.%, the lunar outer core might have two layers because of existence of the immiscible two-liquid regions in the Fe-S-O system.
Mare Imbrium 周辺の地殻物質
Crustal materials around Mare Imbrium: result of Kaguya data integration science

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In order to understand lithological distribution and geological structure of the lunar crust, it is important to conduct analysis of spectral images with high spatial resolution considering 3D geological structure by using high-spatial resolution topographic map. In this presentation, lithological distribution and it relationship with geological structure around Mare Imbrium will be discussed by using the Kaguya data acquired by MI, TC, KGRS and LALT. As well known, Imbrium basin is situated in Procellarum KREEP Terrane (PKT). Therefore this investigation would contributes to understand lithological structure of the PKT and influence of Imbrium basin formation on the PKT evolution. In addition to discussion on crustal materials around the PKT, implication for origin of high-Th (i.e. KREEPy) crustal materials will be discussed.

キーワード: 月, 地殻, かぐや, Procellarum KREEP Terrane, マグマオーシャン, 初期進化
Keywords: The Moon, Lunar crust, Kaguya/SELENE, Procellarum KREEP Terrane, Magma ocean, Early evolution
Presence of impact melts on central peaks of lunar craters and its implications

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Introduction: Impact melts within complex impact craters are known to be flat and smooth deposits filling the floors or wall terraces [1]. Recent studies suggest that compositionally different layers with smooth surfaces are present on the central peaks in several lunar craters, implying impact melts [2, 3]. Impact melts on the central peaks could constrain the central peak formation timescale because impact melts will flow out if peaks are uplifted too quickly. However, little evidence and few examples of impact melts on the central peaks were reported. In this study, we investigate the central peaks of all lunar complex craters listed by [4] to check for the presence of impact melts morphologically and compositionally.

Methods: Central peak morphologies and topographies are identified using SELENE data obtained by the Terrain Camera (TC, 7.4 m/pixel) and Multiband Imager (MI, visible: 20 m/pixel and near-infrared: 60 m/pixel); MI spectral data also provide compositions of geologic units. Impact melt textures are identified by characteristic features, such as cooling cracks and flowing features (lobes or levees), using data from the Narrow Angle Camera (NAC, 0.5-1.2 m/pixel) aboard the Lunar Reconnaissance Orbiter (LRO) in addition to SELENE data.

Results: At least 13 of the analyzed central peaks have distinctive impact melt morphologies on their slopes. Seventy craters (including the above mentioned 13 craters) have spectrally unique geologic units on their gentler slopes with smooth surfaces exhibiting low albedo and weak absorption depth similar to their floor melts. The 70 craters vary in setting, diameter, and formation age, while almost all the 13 distinctive melt morphologies are observed in the craters formed in Copernican period [4], which is the latest selenological period.

Discussion and Conclusions: Our observation that impact melts are found on the central peaks of more than half of the Copernican period craters implies that many central peaks could have impact melts. My analysis suggests that the unique geological units on the 70 central peaks are possibly impact melt origin, and melt morphologies on the older central peaks are probably obscured by erosion, which implies it is common that impact melts did not flow out completely from the central peaks when the peaks were uplifted. This suggests that impact melts already had relatively high viscosity but were not completely solidified when central peaks were uplifted.


Keywords: central peak, moon, SELENE, impact crater, impact melt
Estimating the origin and thickness of high-thorium-content rock units on the lunar surface

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The abundance and distribution of thorium, an incompatible element, within a planetary body are very important for understanding the thermal history of a terrestrial planet because it correlates to the heat-source elemental abundance of these planets. Gamma-ray remote-sensing data depicts the global distribution of thorium of the lunar surface, in which thorium concentrates in the western hemisphere of the lunar near side around the mare region. Within this high thorium area are several hot spots, which have significantly higher thorium content. Lunar rocks containing abundant incompatible elements are called KREEP-rich rocks based on the Apollo sample analyses. KREEP should be formed in the boundary area between the lower crust and the upper mantle. However, the KREEP-rich rock is exposed on the lunar surface. Two processes were proposed as the mechanism for transporting KREEP-rich rocks from under the crust to the surface. One is an igneous process, in which KREEP-rich basalts erupt from magma generated in a deep area at the bottom of the crust. The other mechanism is the ejecta origin of Imbrium basin, in which a basin-formation event excavated the lower crust including KREEP-rich rocks and spread it as ejecta on the surface. The thorium hot spots can be considered to have been formed by either mechanism. However, because of a low spatial resolution of gamma-ray observation from orbit, we cannot identify the corresponding rock types of the thorium hot spots. Therefore, the actual distribution of the high thorium unit and its thorium abundance has not been well understood.

In this study, we used high-resolution visible to near-infrared band images obtained by Kaguya (SELENE) and combined them with a simulated thorium abundance based on Lunar Prospector gamma-ray data to estimate the origin of the thorium-rich rocks and their thorium concentrations. We selected two hot spots (Aristillus and Copernicus) to analyze as candidates of the two KREEP origins. Aristillus is a crater within the Imbrium basin, while Copernicus is located outside of the Imbrium basin.

Our results indicate that KREEP-rich rocks around Aristillus contain high calcium pyroxene, and its thorium abundance is estimated to 35 ppm, while there appears to be no thorium inside the crater. In contrast, KREEP-rich rocks around Copernicus contain low-calcium pyroxene with 12 ppm thorium content. By combining the results with their geologic contexts, KREEP-rich rocks in Aristillus (Copernicus) are estimated to originate from KREEP basalts (Imbrium ejecta). The KREEP layer around Aristillus is estimated to be 1.6 km thick, and that around Copernicus is estimated to be 9 km thick. These results suggest that the thorium concentration within the crust is not uniform as assumed in a previous model but it forms a layer. It also clearly demonstrates that the previous model assuming constant thorium content within the crust from surface to the bottom (60 km deep) needs modification. Our estimation based on our new thorium abundance model for the Procellarum KREEP terrane derives much lower thorium abundance (50% less) than previously estimated.

Keywords: moon, thorium, thermal history
The formation and reactivation of a mare ridges in northern Imbrium

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Mare ridges are the manifestations of horizontal compressions in the shallow part of the lunar crust. They have been interpreted as the folds that determined the basaltic lava layers in mare basins. Since the distribution of the ridges is usually concentric with respect to basin centers, the compressional stress is thought to be originated from the flexure of lithosphere caused by the loading of mare basalts, which is called mascon tectonics. Possible mantle viscosity allowed such deformations to have had delay time of the order of 0.1 Gyr from the deposition of the basalt, which means the deformation was almost synsedimentary. However, recent investigations on the underground structures showed that there is no lateral change of thickness of basalt lava around ridges, and this fact supports the post-depositional formation of ridges. On the lunar surface, the majority of mare basalts deposited before 3.0 Ga. Thus, the most of the ridge formation should have occurred before 3.0 Ga. The timing of the formation will be the clue to distinguish their origin, among global cooling, orbital evolution of the Earth-Moon system and mascon tectonics. This study found a crosscutting relationship between a ridge and a basalt unit, then constrained the formation age of the ridge using depositional ages of basalt lava units derived from the crater-size frequency distribution (CSFD).

By means of optical data taken by the cameras onboard SELENE (Kaguya), an ENE-WSW trending mare ridge that dammed up a relatively high-Ti basaltic unit was found near Sinus Iridum, northern Imbrium. The ridge is 300–400 m high, ~30 km wide and ~150 km long. Relatively high-Ti unit is dammed up by the ridge and relatively low-Ti unit made up the ridge. It was also found that the lowermost part of the ridge is partially covered by high-Ti unit, that is, a part of the ridge was uplifted after the deposition of the high-Ti basalt. In addition, there is a smaller ridge of ~50 m in the younger unit. The smaller ridge runs roughly parallel to the ridge mentioned above. The reactivation and the formation of the small ridge showed that a compressional deformation occurred in the area after the deposition of high-Ti basalt. This study determined the depositional ages of high-Ti unit and low-Ti unit by performing CSFD measurements. The estimated ages were 3.0 Ga and 2.1 Ga for low-Ti unit and for high-Ti unit, respectively. The cross-cutting relationship showed that the major formation age of the ridge was between 3.0 to 2.1 Ga. Furthermore, it was revealed that the reactivation and the smaller ridge formation occurred after ~2.1 Ga. Since most of the mare basalts were deposited before 3.0 Ga in the Imbrium basin and the ridge is a part of concentric ridges of the basin, the formation of the ridge was possibly induced by the latest stage of the mascon loading. However, the reactivation of the large ridge and the formation of the small ridge were too young for the mascon, requiring some mechanisms other than the loading. Global cooling and the increasing Earth-Moon distance are possible explanation.

Keywords: mare ridge, chronology, formation age
The impact craters on planetary surface show random spatial distribution. However, lunar surface expect to have a bias of spatial distribution of crater because the Moon have same rotation and revolution periods.

The previous research showed that rayed crater density at the apex (0 N, 270 E) is highest than antapex (0 N, 90 E). I compared crater size-frequency distribution of apex and antapex side about craters of over 20 km in diameter. In the result, the crater size-frequency distribution of the antapex side was higher than the apex side.

Purpose of this research is to develop an algorithm to assess spatial distribution of craters on lunar farside by using clustering analysis for finding where bias of craters is. In this algorithm, I apply the nearest single-linkage clustering (S-LINK) to simulated and actual craters, and assess whether the crater is random or not by comparing both of results. As a result, 2870 of 3112 craters were decided to non-random (1403 craters are at the apex side, and 1467 craters are at the anapex side). I investigated the crater frequency variation with longitude and latitude. The high frequency of non-random craters was found at north high latitude region, apex side (210 to 270 E) and antapex side (90 to 150 E).

Keywords: Crater, Spatial distribution, Clustering analysis, apex
Present Status of the next lunar landing mission SELENE-2 (3)

SELENE-2 project has been started from 2007 as the first Japanese lunar lander. The main prior object of the SELENE-2 mission is to develop safe and precise landing system on middle to large planets and satellites such as the Moon and Mars for a future lunar and planetary exploration. Another key technologies under investigation are surface mobility by a rover, and long night survival module without using nuclear power. In addition, some instruments for lunar science and future utilization have been so far investigated.

The Strategic Headquarters for Space Policy of Japanese government established "Basic Plan for Space Policy" in June, 2009. Following the plan, a concrete strategy of Japanese lunar exploration had been discussed in "Study group for lunar exploration" of Japanese government which was organized from August, 2009 to July, 2010. The final report of the group indicates that a spacecraft should land on lunar surface in around 2015 to promote lunar exploration using advanced robot technology in 2020. Despite of this result, the SELENE-2 is delayed and still remains as the Phase-A study. Presently, the earliest launch date is 2018 when we successfully proceed to Phase-B within the fiscal year 2013.

One of our meager but important progresses are that technological development of candidate instruments, especially, we have developed seismometry system and camera system, both of which were considered to be main scientific instruments for geophysical and geological instruments. As for the seismometry system, we have almost successfully performed interface tests which were done by international collaboration. Development of a sensor of the visible to near infrared camera system, on the other hand, also conducted good performance under the suitable temperature condition on board the rover.

We are preparing for the upcoming review board to proceed to phase-B study. In order to achieve it, we are under investigation to make high reliable system, and realistic scenario of the mission profile assuming some appropriate landing sites which have been selected among the Japanese lunar scientists. Further technical development is also to be aggressively continued for reducing risks.

Keywords: Moon, Lunar exploration, SELENE-2
We proposed a VLBI (very long baseline interferometry) radio source mission for the Moon lander SELENE-2. The purpose of our mission is to improve the lunar gravity field and to estimate the lunar interior structure. Differential VLBI observations between an orbiter and a lander are carried out to determine the position of the orbiter and the lander in addition to the conventional 2-way Doppler observation (Fig.1). VLBI measures a difference in an arrival time of a signal transmitted from a radio source to two ground stations. This measurement gives plane-of-sky position information of the radio source in contrast to 2-way Doppler measurement that gives line-of-sight position information. The combination of VLBI with Doppler is effective for precise position determination of the spacecraft.

This presentation shows the recent status of the VLBI radio source mission of SELENE-2.

1. A simulation study of the lunar gravity field estimation is carried out. The result shows that a potential Love number k2 accuracy better than 1% can be achieved by 3 months of the VLBI mission duration provided that arc length is 14 days and that historical tracking data including SELENE are combined with.

2. The sensitivity of the geophysical parameters, in particular that of k2, the moment inertia of the Moon, and the seismic travel time, for the lunar deep interior structure is evaluated. A preliminary result shows that a density and a radius of the lunar core can be estimated within the error of 10%.

3. We have conceptual design for an antenna that will be used on the lunar surface. A simulation evaluates the electric characters of the antenna, which are the gain, the beam pattern, and its temperature characteristics.

4. In order to decrease the power consumption of the VLBI radio source, the observation method and the manner of the operation are reconsidered.

Keywords: selene-2, vlbi, moon, internal structure
波形の類似性を考慮した大規模月地震データの可視化システムの実装
An implementation of a visualization system for large scale moonquake data considering waveform similarity

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1969-1977 の 7 年半の間, NASA のアポロミッションで月面に設置された地震計での連続観測により膨大な量の月地震データが取得された。これまでの月地震データの解析より, 月深部および 700-1200km で起こる深発月震は同一の震源から周期的に発生する事が明らかにされており, (e.g., Lammlein, 1977) 特に, 同一震源から発生する深発月震間では高い波形の類似性が見られている。(e.g., Nakamura, 2003) この波形の類似性は震源を分類し, かつ月地震の発生原因を究明する上での重要な情報となるので, 現在に至るまで, 人手による月地震の分類が進んでおり, 特に長周期月震計で観測されたデータの多くについては月地殻の種類及び震源のラベル付けがされている。(Nakamura et al., 2008)

しかし, 膨大な数の月地震データ全てを人手によって分類することは困難である。コンピュータを用いて月地震の分類を行う場合, 正確な分類データが存在せず, データ自体も非常にノイズが大きいという特性を持っているため, 相互関係などの分類手法を直接適用としても全ての月震データに対して必ずしも有益な結果を得る事は限らない。

そこで, 本研究では, 月震データの分類分類を促進するため, 波形の類似性を考慮した月震データを可視化するための Web システムの実装を目指す。本システムでは, まず Self-Organizing Map (SOM) を用い, 月震データを 2 次元空間上にマッピングする事で波形の類似性の観点から可視化を行う。また, 处理のパックエンドに Hadoop を用いることで, 膨大な量のデータに対する SOM の処理に応じる。SOM は, あら設定した特徴量に注目して機械的に波形を分類するので, 物理条件を反映させた分類結果を提示することが期待できる。Web インターフェースを通して, SOM の結果及月震データを提示することにより, 複数の研究者がその評価結果を参照し, 質学に反映させる事が可能となる。本発表は, これまで実施した SOM による月震分類の結果と Web インターフェースの開発状況についての報告を行う。

キーワード: 月地震, 可視化, 自己組織化マップ, Hadoop
Keywords: Moonquake, Visualization, Self-Organizing Map, Hadoop
月レーザ測距用ホロー型逆反射板の材料選定及び重力・熱変形計算
Development of the retro-reflector on the moon for the future lunar laser ranging

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Developing a test model of Laser-Induced Breakdown Spectroscopy for mounting lunar and planetary rovers

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LIBS (Laser Induced Breakdown Spectroscopy) is a technique that uses a laser to create a plasma in a sample, which is then analyzed for chemical composition. This technique is particularly useful for analyzing remote locations such as the surface of the Moon or Mars.

Keywords: elemental compositions, LIBS, Moon, Mars
Performance of a visible-InGaAs sensor onboard a lunar exploration camera

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Information of the lunar highland could help us to know the solidification of the lunar magma ocean and to estimate the internal structure of the Moon. We are now planning to develop a visible-SWIR macro camera with rock abrasion tool (RAT) which is required to establish a light-weighting for setting on a head of rover’s arm. The purpose of this camera is to observe the texture of polished rock surface (grain size, shape, species, and crystal configuration) to investigate the geologic history of the rock. The target crystal grain size is about 200 um in average diameter. We thus need a 500 x 500 pixel sensor to achieve 20 um/pixel spatial resolution with fields of view exceeding 100 mmphi. Spectra in the 0.8 ? 1.7 um region is important to analyze major mineral species found on the Moon. So, these requirements are achieved by a visible-InGaAs sensor which has sensitivity from visible to infrared wavelength. It is important to know the performance for using space exploration, especially, an environment at the lunar surface. We’ll report the details of the examinations about a dark current test of a visible-InGaAs sensor.

Keywords: visible-InGaAs sensor, dark current
High-resolution spectroscopic observation of sodium atom emitted from the lunar surface using a Haleakala 40cm telescope

Kagitani et al., 2010, Planetary and Space Science, 58, 1660-1664, Variation in lunar sodium exosphere measured from lunar orbiter SELENE (Kaguya)
ライナーガンマ、リマシルサリスでの月磁気異常における表面下の磁化ソース
Subsurface magnetization source of Reiner Gamma and Rima Sirsalis magnetic anomalies on the Moon

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アポロ計画以降、磁力計を含む電子反射計の観測により月面では磁気異常が複数存在することが知られている。しかしながら、これらの磁気異常の起源はまだ明らかになっていない。起源の推定のために、磁気異常ソースの磁化の情報を知ることは非常に重要である。本研究では、それらの形成過程に対する洞察を得るために2つの地域での月磁気異常をモデル化した。Reiner GammaとRima Sirsalisの磁気異常を対象とした。モデル化には低高度観測を行った期間でのLunar Prospectorの磁力計データを使用した。まず、磁気双極子による単純なモデルをたて、その結果に基づいて磁気異常を一様に磁化した月面に垂直な直方体によりモデル化した。結果として、2つの磁気異常地域について計5つの磁気異常ソースモデルが得られた。Reiner Gammaでの磁気異常では、直方体の位置と形状は高いアルベドを持つスワールの形状のような表面の特徴とよく一致することがわかった。このような一致は、表面での高いアルベドと磁気異常ソースとの間に相関があることを示唆している。Rima Sirsalisでの磁気異常では、2つの細長いソースはともに6 kmの深さに位置し、シルサリス渓谷に沿って延びている。この結果から、磁気異常ソースは表面下の渓谷と関係があるのではないか。本研究により表面や表面下での構造と磁気異常との関係を議論するためには、磁気双極子よりも直方体のような有限の大きさを持った磁化したソースを考える方が有効であることが実証された。

キーワード: 月, 磁気異常, 直方体ソース, スワール, 渓谷
Keywords: moon, magnetic anomaly, prism source, swirl, rille