

探査機「かぐや」が見た月



ロッチ2007-9-14T10:31:01JST
@JAXA種子島宇宙センター

加藤 學、JAXA「かぐや」サイエンスマネージャー

2011. 9. 14¹



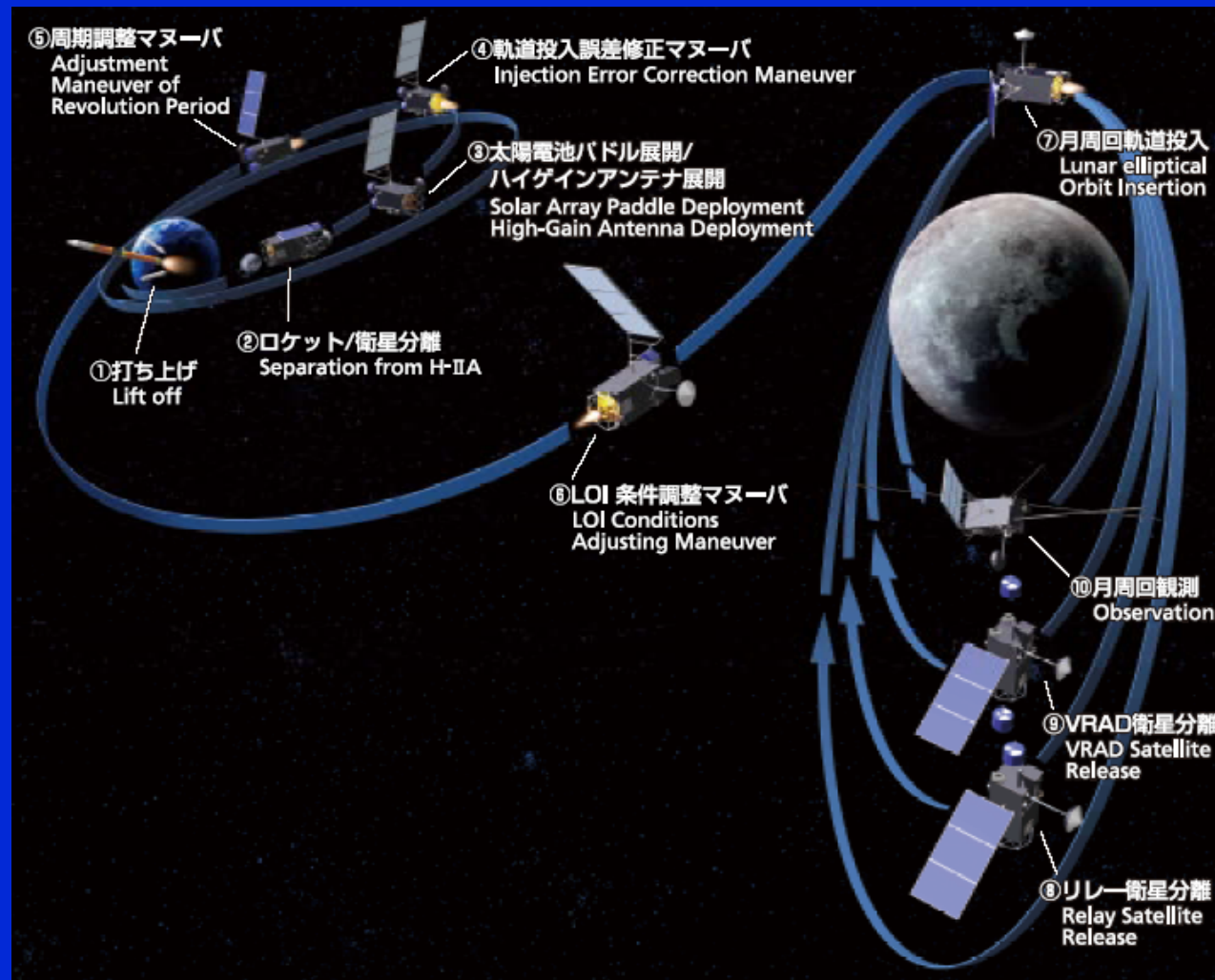
Outline of Kaguya (SELENE) Mission

- **Spacecraft configuration:**
Main orbiter Kaguya,
Relay satellite (Rstar) Okina,
and VRAD satellite (Vstar) Ouna
- **Mission period :** 1 year nominal and extended
- **Orbits :** Polar orbit $i=90$ [deg]
Main orbiter : 100 km x 100 km, circular
Vstar : 100 km x 800 km, elliptical
Rstar : 100 km x 2400 km, elliptical
- **Mass:** Total 3020 kg, wet
Science instruments: ca. 300 kg
Sub-satellites: ca. 50 kg each
- **14 Science instruments** onboard
- **Launch** by H2A No.13 rocket from TNSC





Mission Profile from Launch to Nominal Observation Orbits



Phasing orbit should be applied for enhancing reliability of the insertion:
2.5 cycles of Earth-Moon orbit

アポロ計画でわかったこと

1969年、人類は初めて地球以外の天体の上を歩きました。
それが月です。

1969年から1972年までNASA（アメリカ航空宇宙局）
がすすめた「アポロ計画」では、宇宙飛行士が月面でさまざま
な調査や実験を行いました。その結果、月は地球と同じおよそ
45億年前に原始太陽系星雲のほぼ同じ場所でつくられたこと、
38～40億年前に巨大な隕石が降り注ぎ、巨大なクレータ
ーができたことなどがわかりました。

なかでも、合計387キログラムもの月の石を持ち帰ったこ
とは、大きな成果となりました。それまでは月の表面を撮影す
るなど、観察するだけでしたが、月の石を直接調べることがで
きたのです。

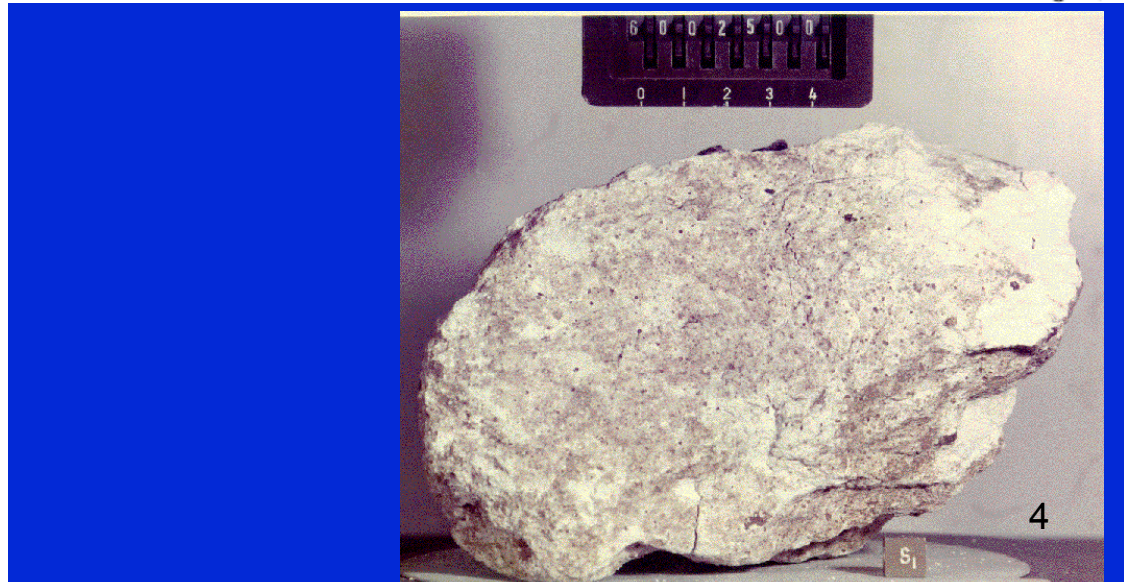
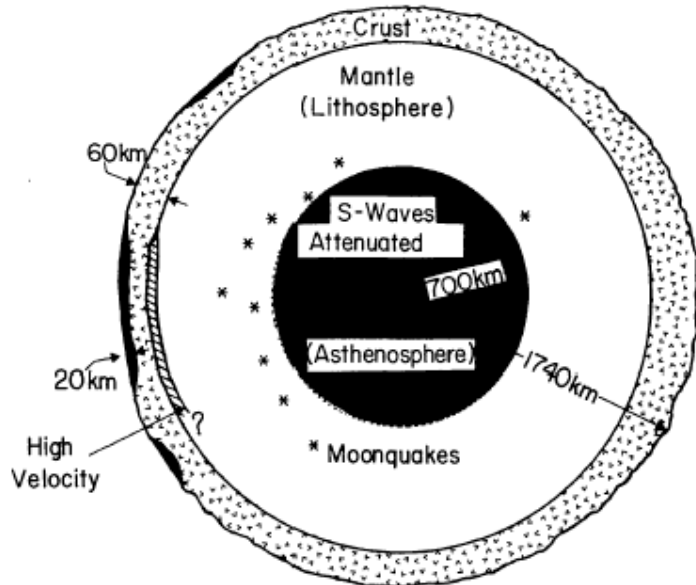
でも、月にはまだまだ、わからないことがいっぱいあります。



アポロ11号で人類
は初めて月に降り立
った。写真はオルド
リン宇宙飛行士
©NASA

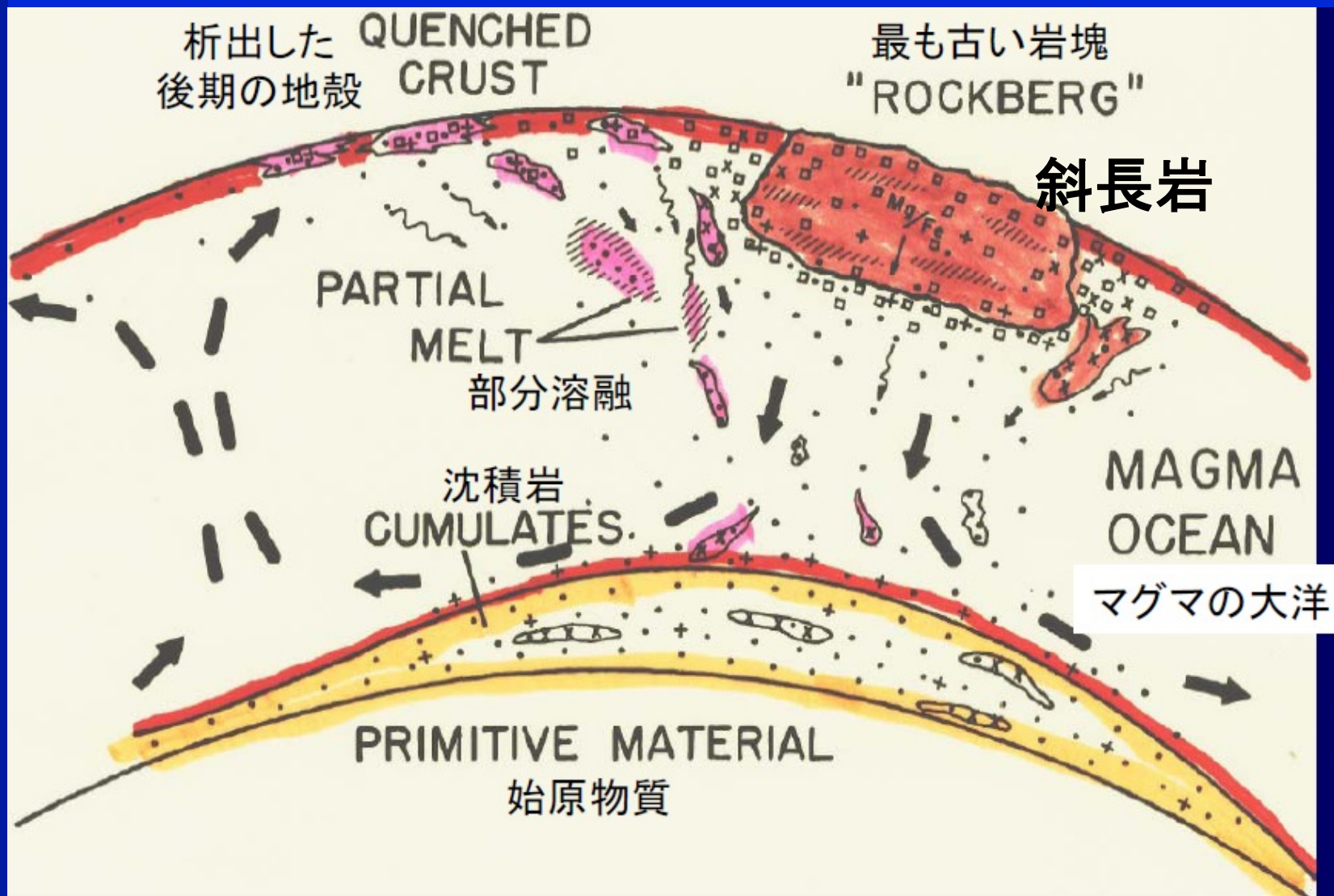


アポロ計画によって持ち帰られた月の
石は、現在も研究が続けられている
©NASA





マグマオーシャン





月の起源

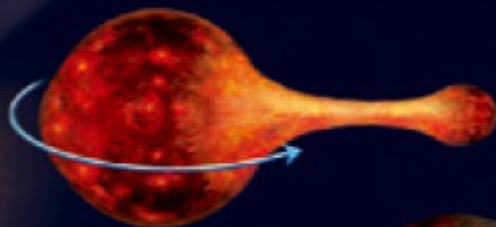
ジャイアントインパクト説

地球に火星サイズの原始惑星が衝突して、その破片が月になったとする説。



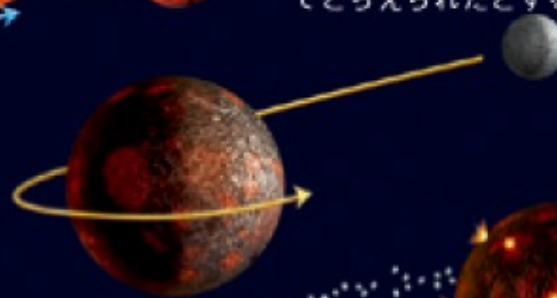
分裂説

地球の自転のいきおいによって、地球から物質が飛び出して月ができたとする説。



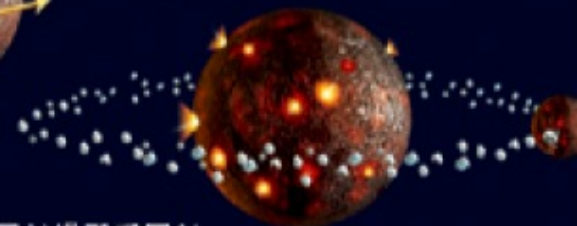
捕獲説

他の場所でできた月が地球の重力でとらえられたとする説。



共成長説

月と地球は同じ場所で同じ時期に成長したとする説。



月の大きさは？

ナ1

月は地球の1/4の大きさです。衛星を持つ太陽系の惑星の中で、惑星と衛星の大きさの比率をみると、月はとても大きい衛星になります。たとえば火星のふたつの衛星フォボスとダイモスは、火星の1/100の大きさしかないのです。



月にマグマの海があった？

ナ3

月の石の成分の研究から、月が誕生したところにはマグマ（岩石がどろどろにとけたもの）の海があったと考えられています。でも、本当に月にマグマの海があったのでしょうか？ また、それはどのくらいの規模だったのでしょうか？



月のなかみは？

ナ2

地球の内部は、コア（核）とマントルに大きく分かれています。コアは鉄やニッケルでできたかたまりです。マントルはコアのまわりを包む層で、地球の内部でゆっくり動いています。月も地球と同じようなつくりになっているのでしょうか？



月の磁場はなくなった？

ナ4

地球では磁石が南北の方向を教えてくれます。これは、地球全体に磁場があるためです。月には地球のような磁場がありません。しかし、アポロ計画で持ち帰ってきた月の石を調べるとわずかに磁力があり、かつて月に磁場があったことがわかりました。月で磁場を発生させたしくみや、なぜそれがなくなってしまったのか、大きなナゾのひとつです。



地球から見えない月の裏側はどうなってるの？

ナゾ5

月をよーく目をこらして見てみると、月には明るいところと暗いところがあります。月の明るい部分は「高地」と呼ばれ、暗い部分は平らな地形で、水はありませんが「海」と呼ばれています。

また、地球からは月の表側しか見えません。地球から見えない月の裏側は、表側とはずいぶんちがいます。裏側はいん石の衝突でできた山のふん火口のようなデコボコ（クレーター）がたくさんあります。最近では地下のつくりもちがうことがわかってきました。どうして表と裏で地下のつくりがちがうのか、それもナゾのひとつです。



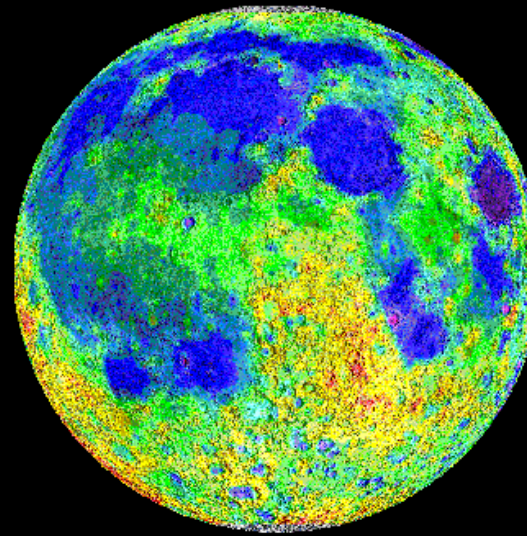
表



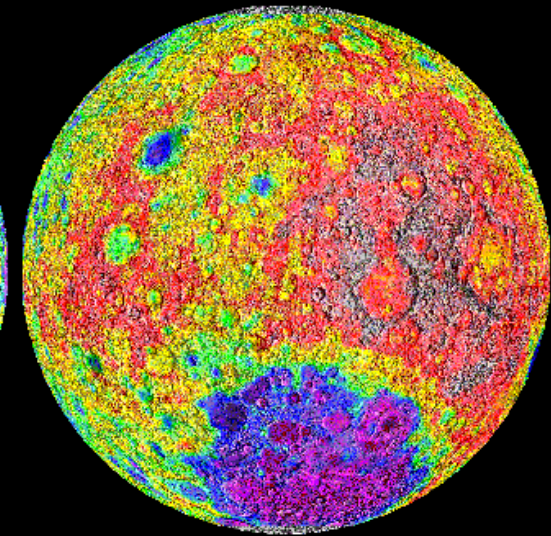
裏

Clementine Topographic Map of the Moon

Contour Interval - 500 m



Near Side



Far Side

-8 -6 -4 -2 0 2 4 6 8

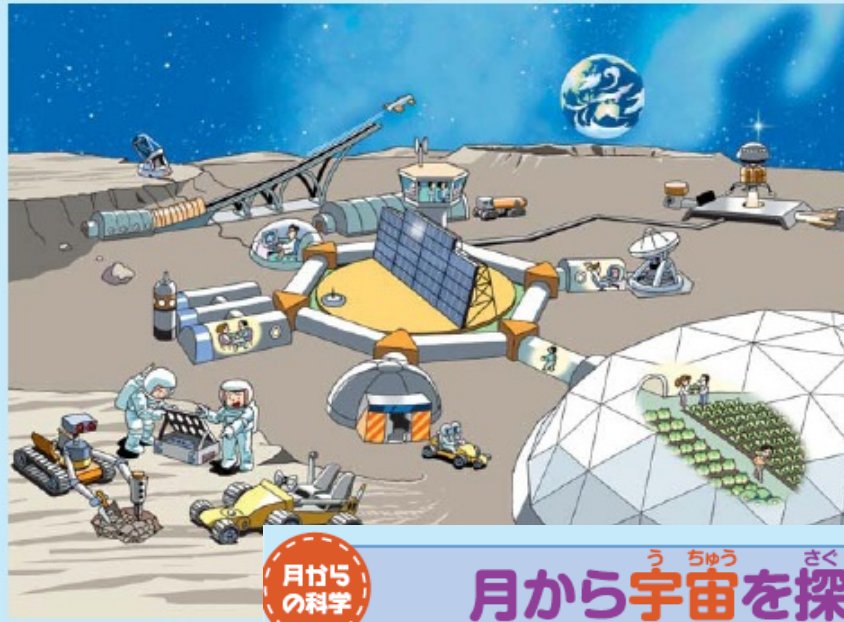
Kilometers

月の二分性

月の環境を調べる

月での
科学

地球には大気がありますが、月にはありません。そのため、太陽の光は月の表面に直接届いています。「かぐや」は約1年間、月のまわりを回りながら、いろいろな観測機器を使って、太陽が月にどんな影響をあたえているかなど、くわしく調べます。このような観測結果は、将来、月面基地をつくるなど、人類が月で活動するための重要な情報にもなることでしょう。



月からの
科学

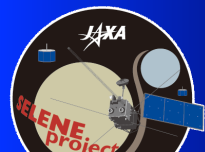
月から宇宙を探る

「かぐや」には、月以外の観測を行う機器も積まれています。月は太陽が地球にあたえる影響を調べるのに、いちばん良い場所です。たとえば、太陽の影響によって地球の北極と南極あたりで発生するオーロラの活動を、月から同時に観測します。また、地球ではテレビや携帯電話などの電磁波が飛びかっているため、宇宙からの

電磁波を調べるのは困難です。しかし、月は地球からの電磁波を受けないので、宇宙のさまざまな電磁波を調べるのにもとても良いところ

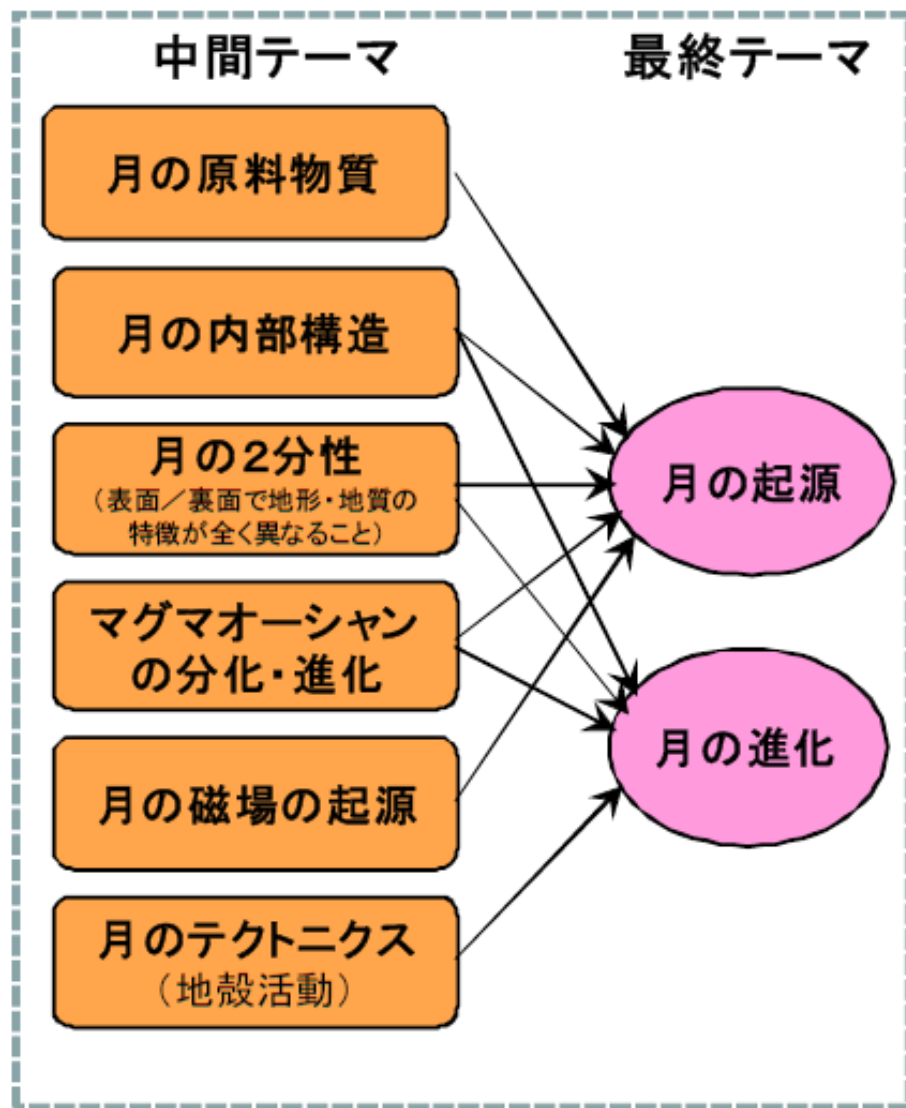
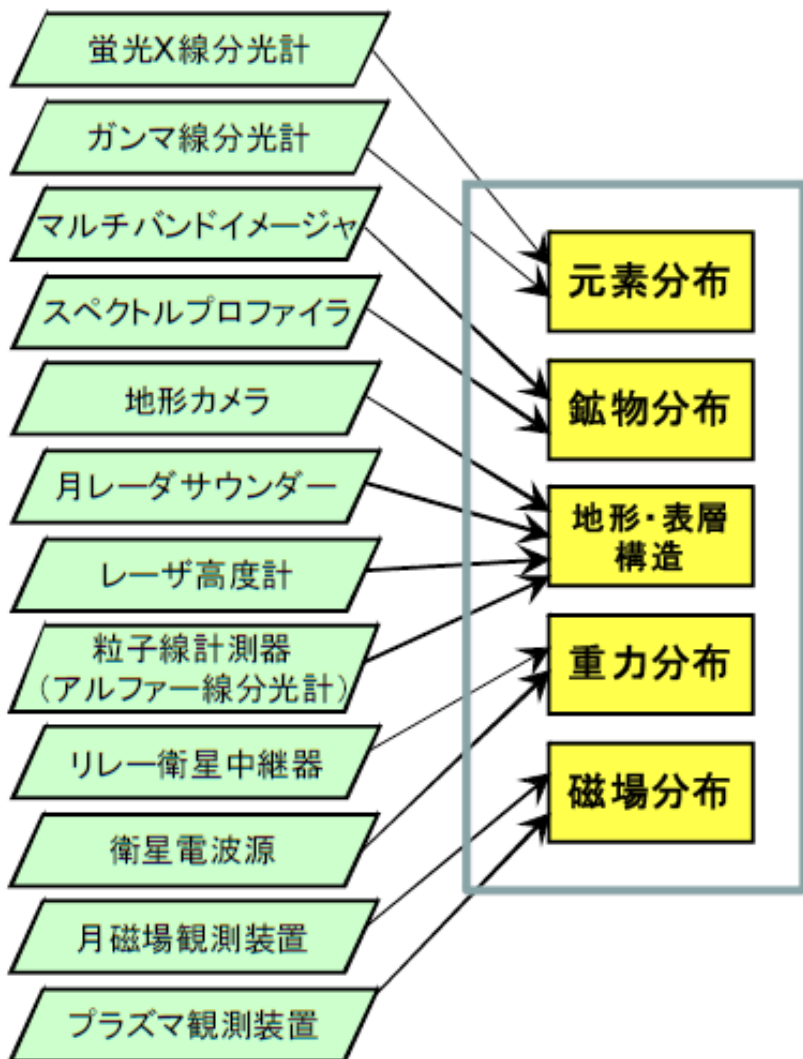
です。また、ハイビジョンカメラで、青く美しい地球が月の地平線から現れる「地球の出」を、きれいな映像で撮影します。

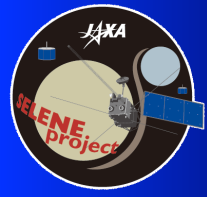




「かぐや」観測機器、めざす月の科学

月の科学





Kaguya (SELENE) Mission Objectives

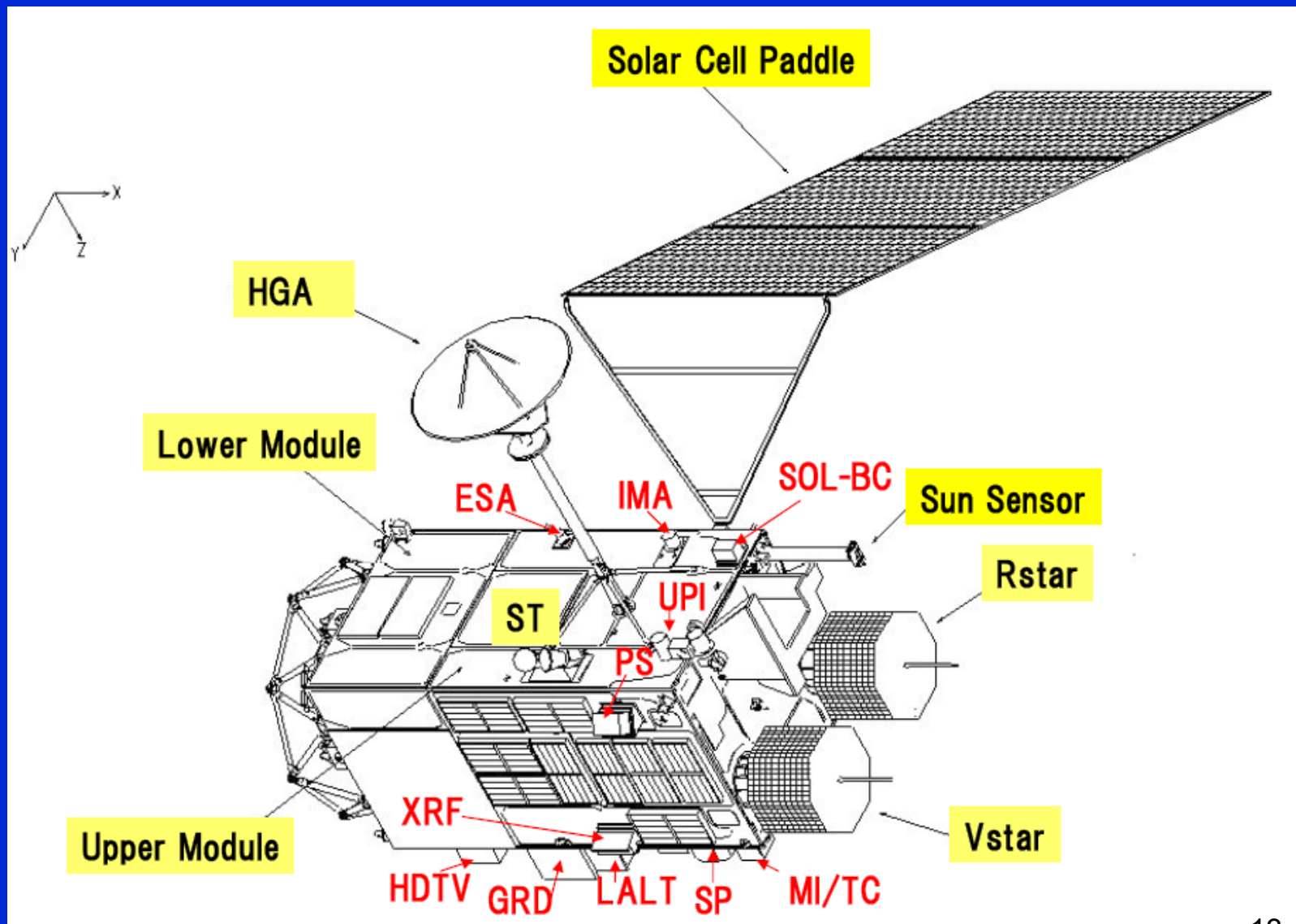
- **Global survey of the Moon**
Composition, 3D-Topography, Gravity, Magnetic Field, Lunar environment
- **Technology development for future lunar exploration**
Lunar insertion, Orbital correction maneuver, Telecommunication
- **Public outreach of the lunar exploration**
Broadcasting High-Definition TV movie of the Earth-rise/lunar surface

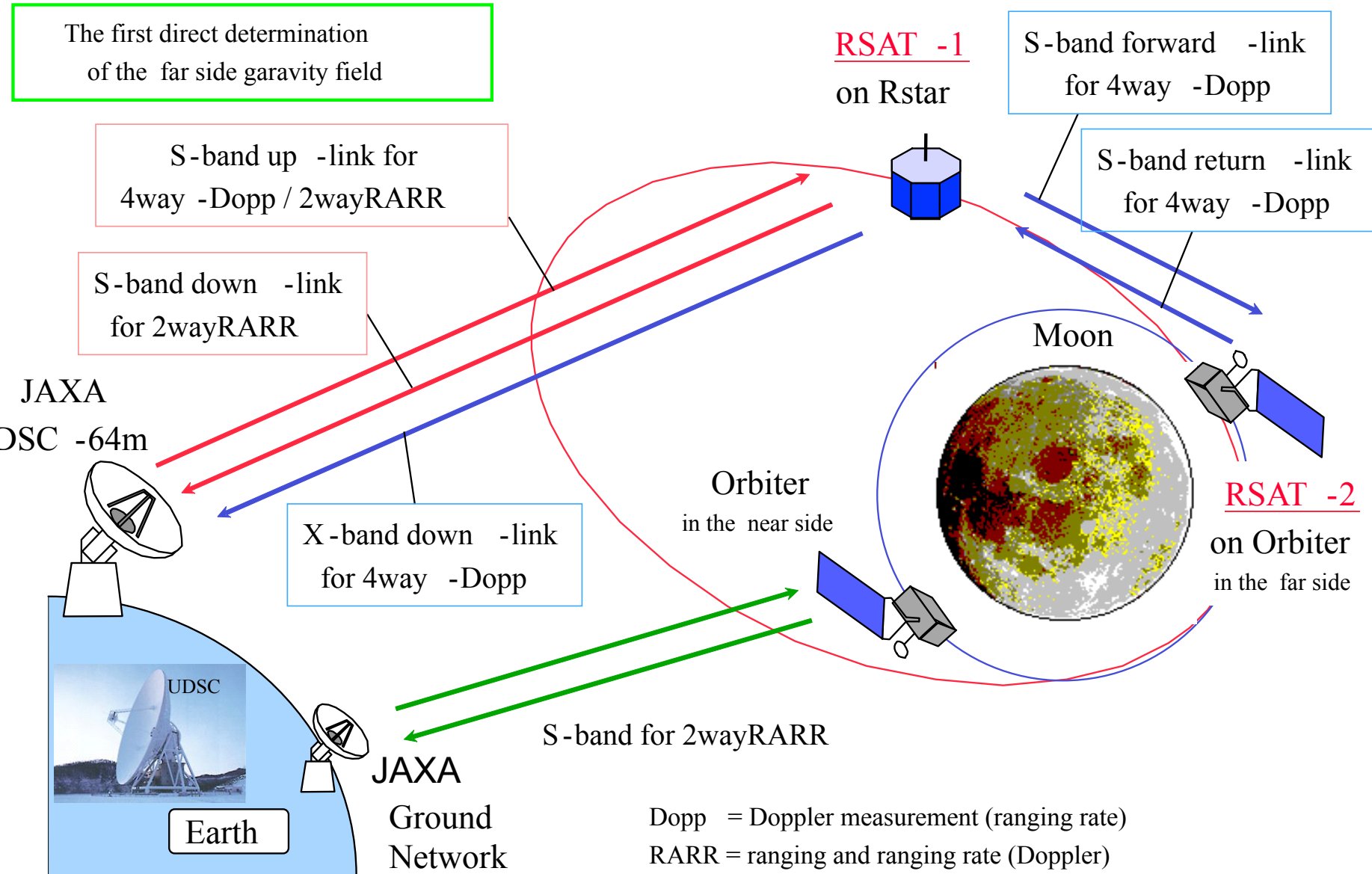
Kaguya (SELENE) Science Mission and Instruments

X-ray Spectrometer (XRS)	Global mapping of Al, Si, Mg, Fe distribution using 100 cm ² CCD, spatial resolution 20 km , Energy range 0.7-8 keV, 5 μ m Be film, Solar X-ray monitor
Gamma-ray Spectrometer (GRS)	Global mapping of U, Th, K, major elements, distribution using 250 cm ³ large pure Ge crystal, Spatial resolution 160 km , Energy range 0.1-10 MeV
Multi-band Imager (MI)	UV-VIS-NIR CCD & InGaAs imager, spectral bandwidth from 0.4 to 1.6 microns, 9 bands filters, spectral resolution 20-30 nm, spatial resolution 20-60 m
Spectral Profiler (SP)	Continuous spectral profile ranging from 0.5 to 2.6 microns, spectral resolution 6-8 nm, spatial resolution 500 m
Terrain Camera (TC)	High resolution stereo camera, spatial resolution 10 m
Lunar Radar Sounder (LRS)	Mapping of subsurface structure using active sounding, frequency 5 MHz, echo observation range 5 km, resolution 75 m, Detection of radio waves (10k-30MHz) from the Sun, the Earth, Jupiter, and other planets
Laser Altimeter (LALT)	Nd:YAG laser altimeter, 100 mJ output power, height resolution 5 m, spatial resolution 1600 m with pulse rate 1 Hz, Beam divergence 3 mrad
Differential VLBI Radio Source (VRAD)	Differential VLBI observation from ground stations, selenodesy and gravitational field, onboard two sub-satellites, 3 S-bands and 1 X-band
Relay Satellite Transponder (RSAT)	Far-side gravimetry using 4 way range rate measurement from ground station to orbiter via relay satellite, perilune 100 km, apolune 2400 km in altitude, Doppler accuracy 1 mm/s
Lunar Magnetometer (LMAG)	Magnetic field measurement using flux-gate type magnetometer, accuracy 0.5 nT
Charged Particle Spectrometer (CPS)	Measurement of high-energy particles, 1-14 MeV(LPD), 2-240 MeV(HID), alpha particle detector, 4-6.5 MeV
Plasma Analyzer (PACE)	Charged particle energy, angle and composition measurement, 5 eV/q – 28 keV/q
Radio Science (RS)	Detection of the tenuous lunar ionosphere using S and X-band carriers
Plasma Imager (UPI)	Observation of terrestrial plasmasphere from lunar orbit, XUV(304A) to VIS
High Definition TV System	Public Outreach



Kaguya (SELENE) Configuration before separation of sub-satellites







Published Kaguya Science 1.

- **GRS**: First Results of High Performance Ge Gamma-Ray Spectrometer Onboard Lunar Orbiter SELENE (KAGUYA), Hasebe et al., *J. Phys. Soc. Jpn.* **78** (2009) Suppl. A, 18-25/ Germanium Gamma-Ray Spectrometer on SELENE(KAGUYA), N. Yamashita et al., *J. Phys. Soc. Jpn.* **78** (2009) Suppl. A, 153-156/ Radioactive element U distribution in addition to Th and K distributions, Karouji et al., *Adv. Geosci.* **19**(2010), 43-56. /Uranium on the Moon: The Global Distribution and U/Th Ratio, Yamashita et al., *GRL* **37**(2010) L10201. /Determining the Absolute Abundances of Natural Radioactive Elements on the Lunar Surface by Kaguya Gamma-ray Spectrometer, Kobayashi, S. et al., *Space Sci. Rev.* **154** (2010), 193-218./ Lunar Gamma-Ray Observation by Kaguya GRS, N. Hasebe et al., *Adv. Geosci.* **19** (2010) 57-68./ **Neutron production in the lunar subsurface from alpha particles in galactic cosmic rays**, Ohta et al., *EPS* **63** (2011) 25-35.

- **MI**: The global distribution of pure anorthosite on the Moon, M. Ohtake et al., *Nature* **461**(2009), 236-241. / Characterization of Multiband Imager aboard SELENE: Pre-flight and inflight radiometric calibration, Kodama et al., *Space Sci. Rev.* **152**(2010) 79-102./ Deriving the absolute reflectance of lunar surface using SELENE (Kaguya) Multiband Imager data, Ohtake et al., *Space Sci. Rev.* **154** (2010) 57-77.

- **SP**: Discoveries on the lithology of lunar crater central peaks by SELENE Spectral Profiler, Matsunaga et al., *GRL* **35** (2008), L23201./ Ultramafic impact melt sheet beneath the South Pole-Aitken basin on the Moon, R. Nakamura, et al., *GRL* **36** (2009), L22202. /Possible mantle origin of olivine around lunar impact basins detected by SELENE, Yamamoto et al., *Nature Geosci.* **3**(2010) 533-536. / **The widespread occurrence of high-calcium pyroxene in bright-ray craters on the Moon and implications for lunar-crust composition**, Ogawa et al., *GRL* **38** (2011) in press.

- **TC**: Lack of exposed ice inside lunar south pole Shackleton, Haruyama et al., *Science* **322** (2008), 938-939./ Volcanic history of lunar far side revealed by Terrain Camera on SELENE, Haruyama et al., *Science* **323**(2009), 905- 908. /Formation age of the lunar crater Giordano Bruno, Morota et al., *MePS* **44**(2009), 1115-1120./ Mare Volcanism in the Lunar Farside Moscoviense Region: Implication for Lateral Variation in Magma Production of the Moon, Morota et al., *GRL* **36**, L21202./ Possible lunar lava tube skylight observed by SELENE cameras, Haruyama et al., *GRL* **36**(2009), L21206. /**Timing and duration of mare volcanism in the central region of the northern farside of the Moon**, Morota et al., *EPS* **63**(2011), 5-13. / **Timing and characteristics of the latest mare eruption on the Moon**, Morota et al., *EPSL* **302**(2011), 255-266.

- **LRS**: Lunar radar sounder observation and founding of subsurface strata below the nearside lunar maria, Ono et al., *Science* **323**(2009), 909-911./ Distribution of the subsurface reflectors of the western nearside maria observed from Kaguya with Lunar Radar Sounder, Oshigami et al., *GRL* **36** (2009), L18202./ Detectability of subsurface interfaces in lunar maria by the LRS /SELENE sounding radar: influence of mineralogical composition, Pommerol et al., *GRL* **37** (2010), L0320115The Lunar Radar Sounder (LRS) onboard the Kaguya (SELENE) spacecraft, Ono et al., *Space Sci. Rev.* **154**(2010) 145-192./



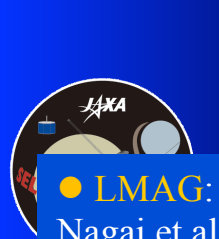
Published Kaguya Science 2.

● **LALT**: Illumination conditions at the lunar polar regions by KAGUYA (SELENE) laser altimeter, Noda et al., *Geophys. Res. Lett.* **35** (2008), L24203 / Lunar global shape and polar topography derived from KAGUYA-LALT laser altimetry, Araki et al., *Science* **323** (2009), 897-899. / **Accuracy assessment of lunar topography models**, H.S. Fok et al., *EPS* **63** (2011) 15-23.

● **RSAT**: Far side gravity field of the Moon from four-way Doppler measurements of SELENE (Kaguya), Namiki et al., *Science* **323**(2009), 909-911. / Crustal thickness of the Moon: Implications for farside basin structures, Ishihara et al., *GRL* **36**, L19202. / An improved lunar gravity field model from SELENE and historical tracking data: revealing the farside gravity features, Matsumoto et al., *J. Geophys. Res.* **115**(2010), E06007. / Ground compatibility tests for gravity measurement of SELENE: Accuracies of two-and four-way Doppler and range measurements, Namiki et al., *Space Sci. Rev.* **154** (2010) 103-121. / Effect of Phase Pattern of Antennas Onboard Flying Spin Satellites on Doppler Measurements for Lunar Gravity Field, Q. Liu et al., *IEEE Trans., Aerospace Electron. Syst.*, **47**(2010) 405-419. / **Anomalous Moscoviense basin: Single oblique impact or double impact origin?**, Ishihara et al., *GRL* **38**(2011) L03201.

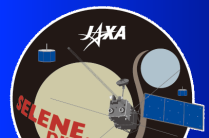
● **VRAD**: Pico-second accuracy VLBI of the two-subsatellites of SELENE (Kaguya) using multi-frequency and same beam method, Kikuchi et al., *Radio Sci.* **44**(2009), RS2008. / Overview of differential VLBI observations of lunar orbiters in SELENE(Kaguya) for precise orbit determination and lunar gravity field study, Hanada et al., *Space Sci. Rev.* **154**(2010) 123-144. / Same-beam VLBI observations of SELENE (KAGUYA) for improving lunar gravity field model, Q. Liu et al., *Radio Sci.* **45** (2010) RS2004.

● **PACE**: Solar wind proton reflection at the lunar surface: Low energy ion measurement by MAP-PACE onboard SELENE (KAGUYA), Saito et al., *Geophys. Res. Lett.* **35** (2008), L24205. / First direct detection of ions originating from the Moon by MAP-PACE IMA onboard SELENE (KAGUYA), Yokota et al., *GRL* **36**(2009), L38185. / Solar-wind proton access deep into the near-Moon wake, Nishino et al., *GRL* **36** (2009), L16103. / Pairwise energy gain-loss feature of solar wind protons in the near-Moon wake, Nishino et al., *GRL* **36**(2009), L12108. / First in situ observation of the Moon-originating ions in the Earth's Magnetosphere by MAP-PACE on SELENE (KAGUYA), Tanaka et al., *GRL* **36**(2009), L22106. / Effect of the solar wind proton entry into the deepest lunar wake, Nishino et al., *GRL* **37**(2010), L12106. / In-flight Performance and Initial Results of Plasma Energy Angle and Composition Experiment (PACE) on SELENE(Kaguya), Saito et al., *Space Sci. Rev.* **154** (2010) 265-303. / Interaction between terrestrial plasma sheet electrons and the lunar surface: SELENE (Kaguya), observations, Y. Harada et al., *GRL* **37** (2010), L19202. / New views of the lunar plasma environment, J.S. Halekas et al., *Planet. Space Sci.* **59** (2011) in press. / **Anomalous deformation of the Earth's bow shock in the lunar wake: Joint measurement by Chang'E-1 and SELENE**, Nishino et al., *Planet. Space Sci.* **59** (2011), 378-386.



Published Kaguya Science 3.

- **LMAG**: Plasmoid formation for multiple onset substorms: observations of the Japanese Lunar Mission “Kaguya”, Nagai et al., *Ann. Geophys* **27** (2009), 59- 64, 2009./Thermal core-mantle coupling in an early lunar dynamo: Implications for a global magnetic field and magnetosphere of the early Moon, Takahashi et al., *GRL* **36**(2009), L24202./In-orbit calibration of the lunar magnetometer onboard SELENE (KAGUYA) , F. Takahashi, et al., *Earth Planets Space*, **61** (2009) 1269-1274. / Lunar magnetic field observation and initial global mapping of lunar magnetic anomalies by MAP-LMAG onboard SELENE (KAGUYA), Tsunakawa et al., *Space Sci. Rev.* **154**(2010) 219-251./ Magnetic Cleanliness Program Under Control of Electromagnetic Compatibility for the SELENE (KAGUYA) Spacecraft, Matsushima et al., *Space Sci. Rev.* **154**(2010) 253-564./ **Non-monochromatic whistler waves detected by Kaguya on the dayside surface of the moon**, Nakagawa et al., *EPS* **63** (2011) 37-46.
- **RS**: Studying the Lunar Ionosphere with SELENE Radio Science Experiment, Imamura et al., *Space Sci. Rev.* **154** (2010) 305-316.
- **UPI**: First optical observation of the Moon’s sodium exosphere from the lunar orbiter SELENE (Kaguya), Kagitani et al., *Earth Planets Space* **61**(2009), 1025-1029./ The Upper Atmosphere and Plasma Imager/the Telescope of Visible Light (UPI/TVIS) onboard the Kaguya spacecraft, Taguchi et al., *EPS* **61** (2009) 17-23. / Variation in lunar sodium exosphere measured from lunar orbiter SELENE(Kaguya) , Kagitani et al., *Planet. Space Sci.* **58**(2010) 1660-1664./ Plasmaspheric EUV images seen from lunar orbit: Initial results of the extreme ultraviolet telescope on board the Kaguya spacecraft, Yoshikawa et al., *J. Geophys. Res.* **115** (2010) A04217./ Conjunction study of plasmopause location using ground-based magnetometers, IMAGE-EUV, and Kaguya-TEX data, Obana et al., *J. Geophys. Res.* **115** (2010) A06208. /First sequential images of the plasmasphere from the meridian perspective observed by KAGUYA, Murakami et al., *EPS* **62** (2010) e9-e12.
- **HDTV**: High Definition Television System on board Lunar Explorer KAGUYA(SELENE) and Imaging of the Moon and the Earth, Yamazaki et al., *Space Sci. Rev.* **154** (2010) 21-56.
- **SOAC**: Data Processing at KAGUYA Operation and Analysis Center, Hoshino et al., *Space Sci. Rev.* **154** (2010) 317-342.
- The Kaguya Mission Overview, Kato et al., *Space Sci. Rev.* **154** (2010) 3-19.
- Pre-launch studies: *Earth Planets Space* **60** (2008), 241-444. / *Adv. Space Res.* **42** (2008), 259-346.
- Proc. 26th Inter. Space Tech. Sci., *Trans. Japan Soc. Aeronaut. Space Sci. Aerospace Tech. Japan* **7** (2009) on line.



HDTV Earth Views in May 9, 2008

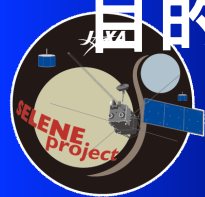


and ENG

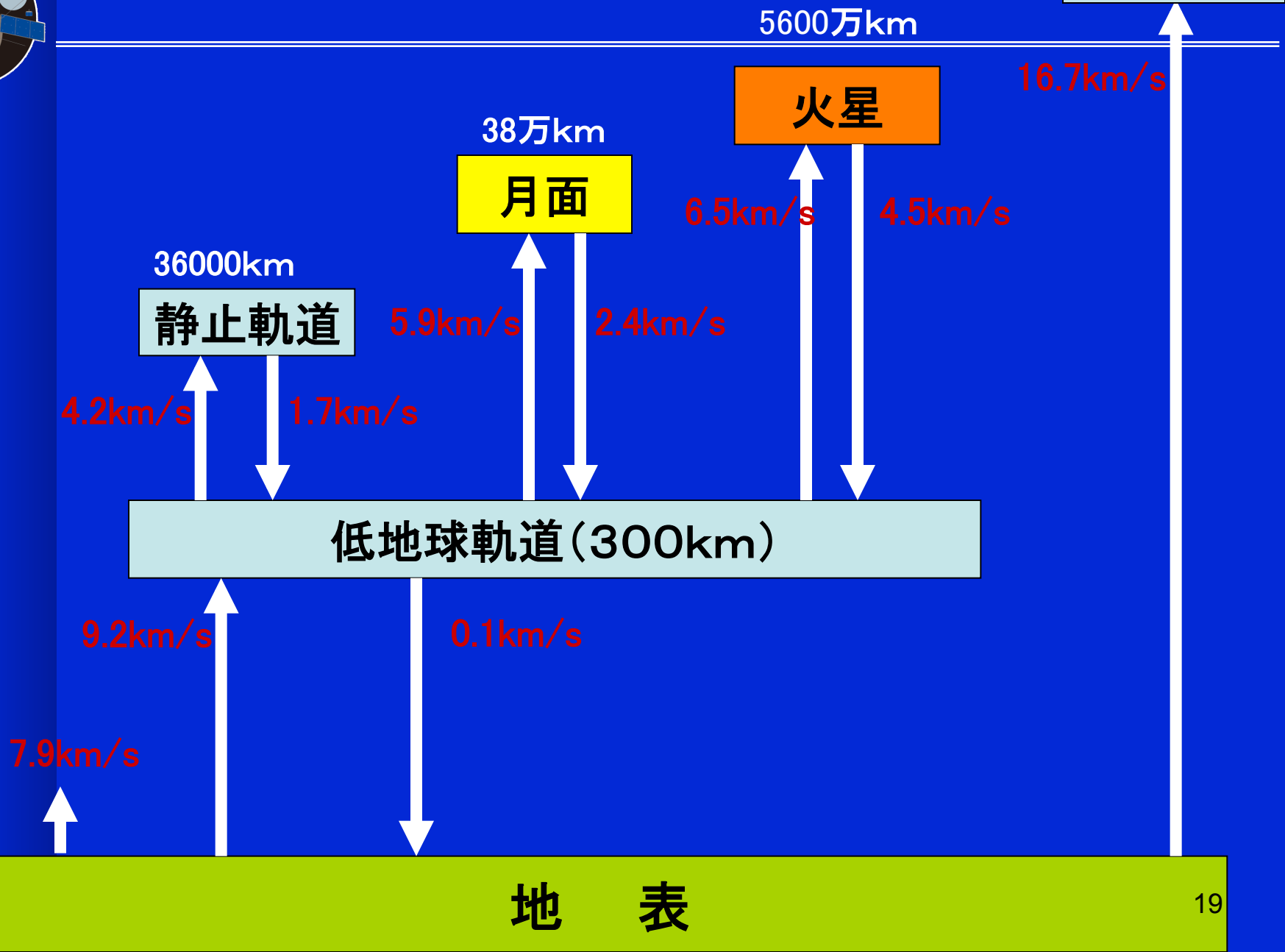
HDTV Crescent Earth in Jan. 27, 2008



目的地別速度増分



SELENE Project and Engineering Explorer



地表

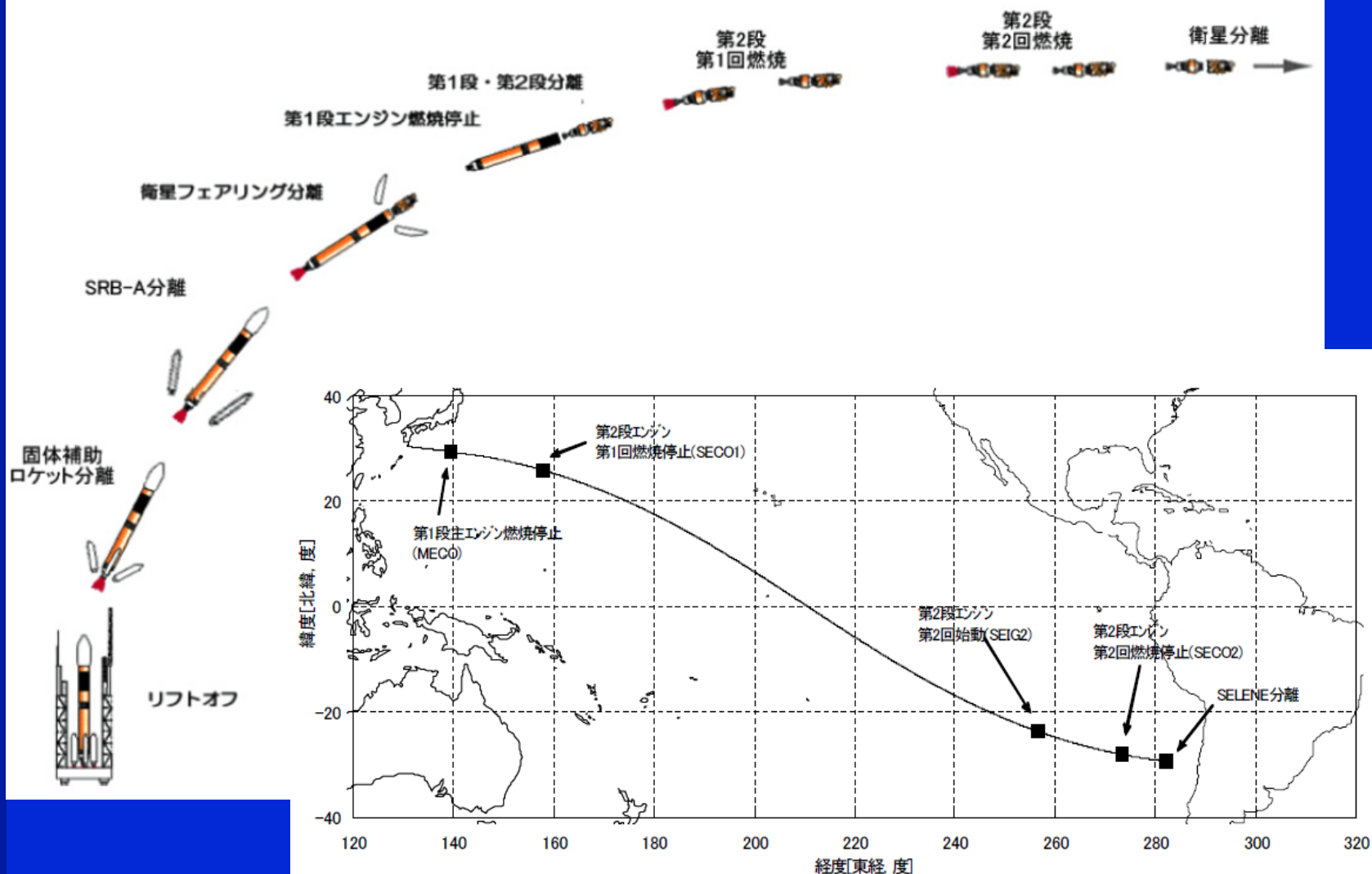


ロッチ、2007-9-14 T10:31:01 日本標準時





飛行経路



注) 13号機は月遷移軌道投入ミッションであり、打上げ日によりSEC01～SEIG2の慣性飛行期間が変動することから、代表ケースとして慣性飛行期間最長ケースを示した。

R o a d t o t h e M o o n

月までの道のり かぐや

① 打ち上げ・衛星分離

H-IIAロケットにより10.5km/sまで加速され、周期約5日・遠地点約20万kmの長楕円軌道（第1周回）に投入。

② 太陽電池パドルなどを展開

太陽電池、アンテナ展開、三軸姿勢制御確立などを行う。

③ マヌーバ（軌道投入調整修正）

「かぐや」の位置や速度を電波を使って精密に測定。それに基づいてスラスターを噴射する方向と量を決め、命令を送り、軌道の調整を行う。

④ マヌーバ（周期調整）

第2周回では遠地点約40万kmで約10日の周期を持つ楕円軌道に投入される。月までの平均距離は約38万kmなので、それより遠い位置まで到達することになる。第1周回の終わりの近地点（ペリジ）での噴射量を調整することで、第2周回の周期を変えることができる。第2周回は、月軌道投入の精度を高めると同時に、打ち上げ日の空変に伴う軌道の違いを調整するバッファーとしても機能する。

⑤ マヌーバ（月周回条件調整）

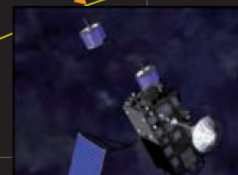
月と「かぐや」が正確に出会うための条件の微調整を行う。ゴルフでいうアプローチショットに相当する。

⑥ 月周回軌道投入

地球に対する月の公転速度は約1km/s。いっぽう月軌道投入時の「かぐや」は約100m/s。月の重力につかまえてもらうためには、「かぐや」を月の公転方向に沿って加速する必要がある。走り込んでくる自動率に飛び乗るような、カースタントさながらのクリティカルな瞬間だ。長野福白田・鹿児島県内之浦のJAXAの大型アンテナから月が見えている間にこのイベントが起こるよう逆算して、軌道設計が行われた。

⑦ 子衛星分離

この後、リレー衛星とVARD衛星の2機の子衛星を異なる高度で分離。「かぐや」主衛星はその後も徐々に高度を下げながら高度100kmの円軌道で観測準備に入る。



第1周回 (9/14～9/19)

第2周回 (9/19～9/29)

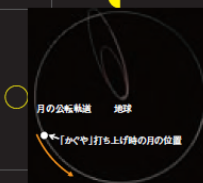
第3周回 (9/29～、10/4に月と会合)



信

じられないようなロングバットをクラブにぶつけるグリーンの帝王や、意表を突くパスを味方の足下にすりとり、取めるファンタジックなフアンタジーの太極拳をレシーブするスーパースター。

超一流のフライング・プレーヤー「かぐや」の軌道設計が起きているのは、その場「フィールド」を支配する物理の法則に忠実であるからだ。宇宙に芝目はなく風も吹かないが、地球は自転し、その周りを公転し、スラスターが発する推力には上乗せがあり、推進力も有難い。与えられた制約の中で、力強い大躍進を遂げることでフライング・プレーヤーは成り立つが、「かぐや」はそれを一度きり



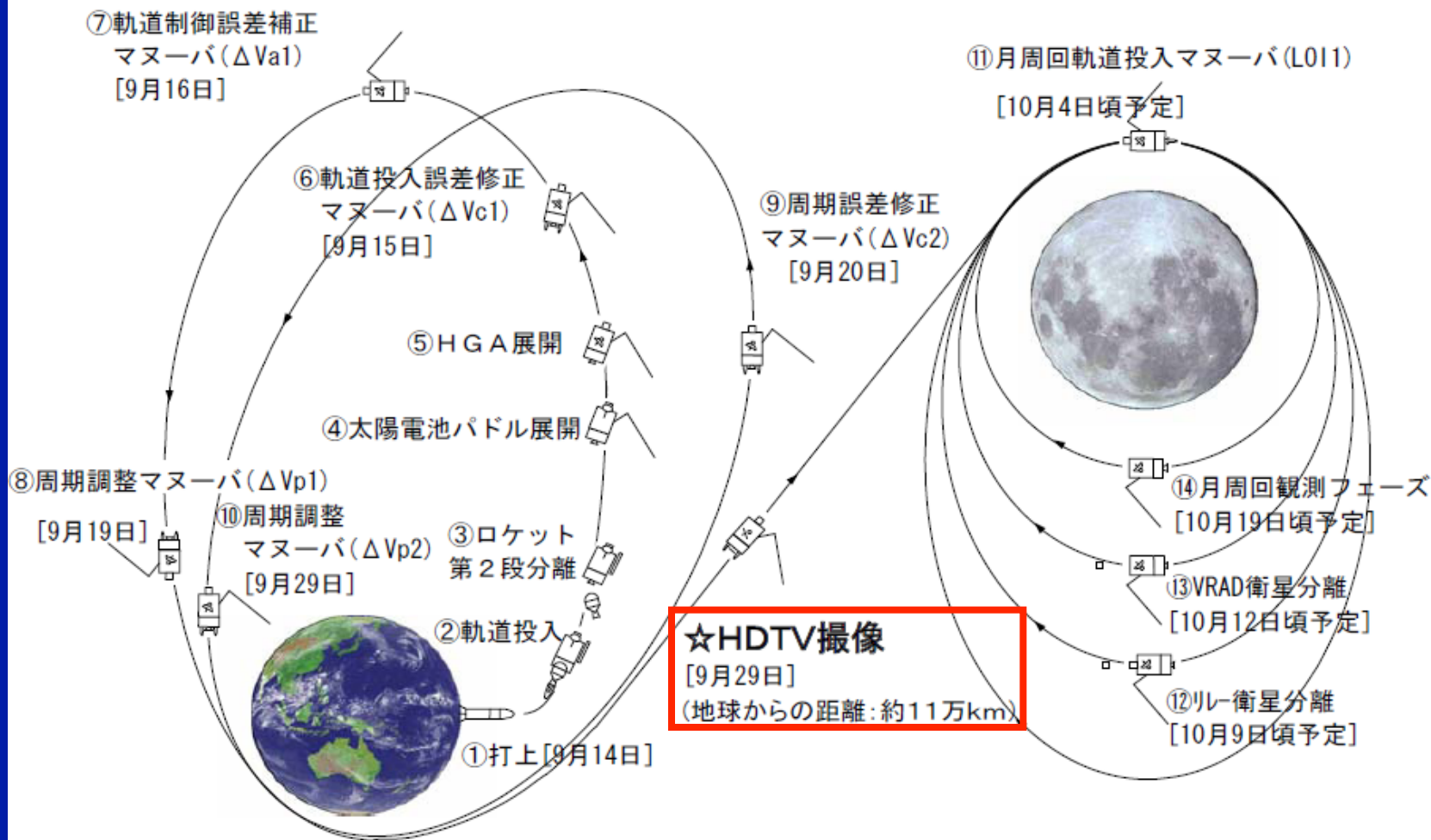
月の公転面を上から見た軌道の全体図「かぐや」の長楕円軌道の軌道面は赤道面から約30度傾いている。

北極の上空から見た軌道の全体図「かぐや」の打ち上げから月到達までの間に、地球の周りを約4分の3周することになる。到達するまでのほぼ全期間で、地球から見た「かぐや」は月とは逆方向に動くことになる。

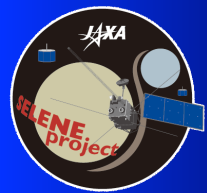
※月軌道外側のイラストは、地球から見た月の満ち欠け



打ち上げから月軌道投入まで

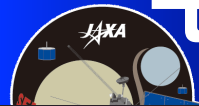


「かぐや (SELENE)」の月までの道のり (模式図)



HDTV画像1. 遠ざかる地球



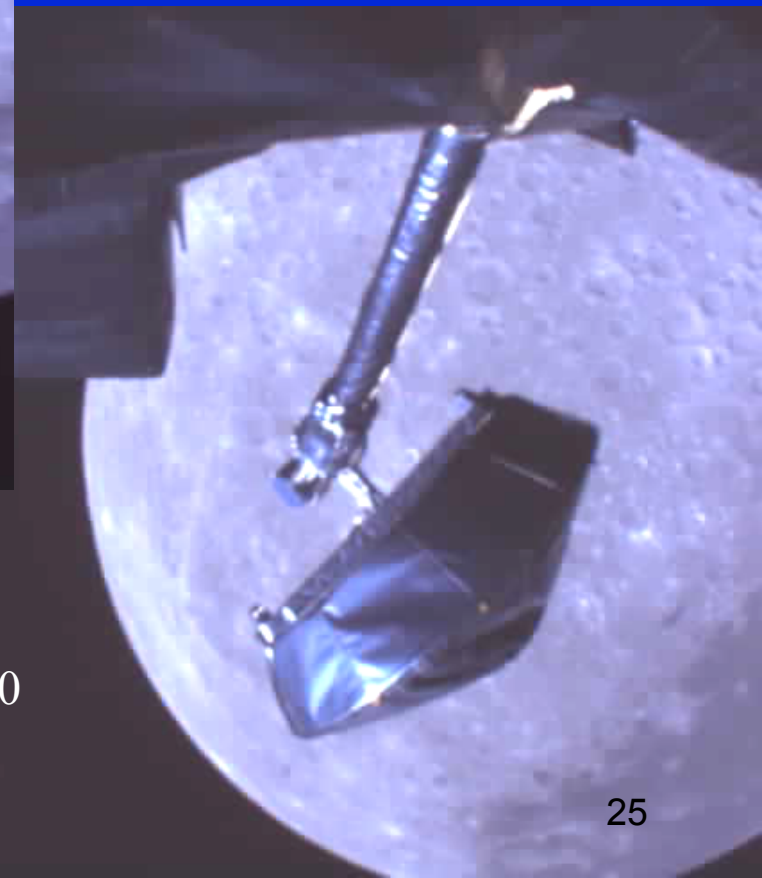


モニターカメラによる初めての月の姿

2007-10-5. 5:50:00
Alt.: 1500 km

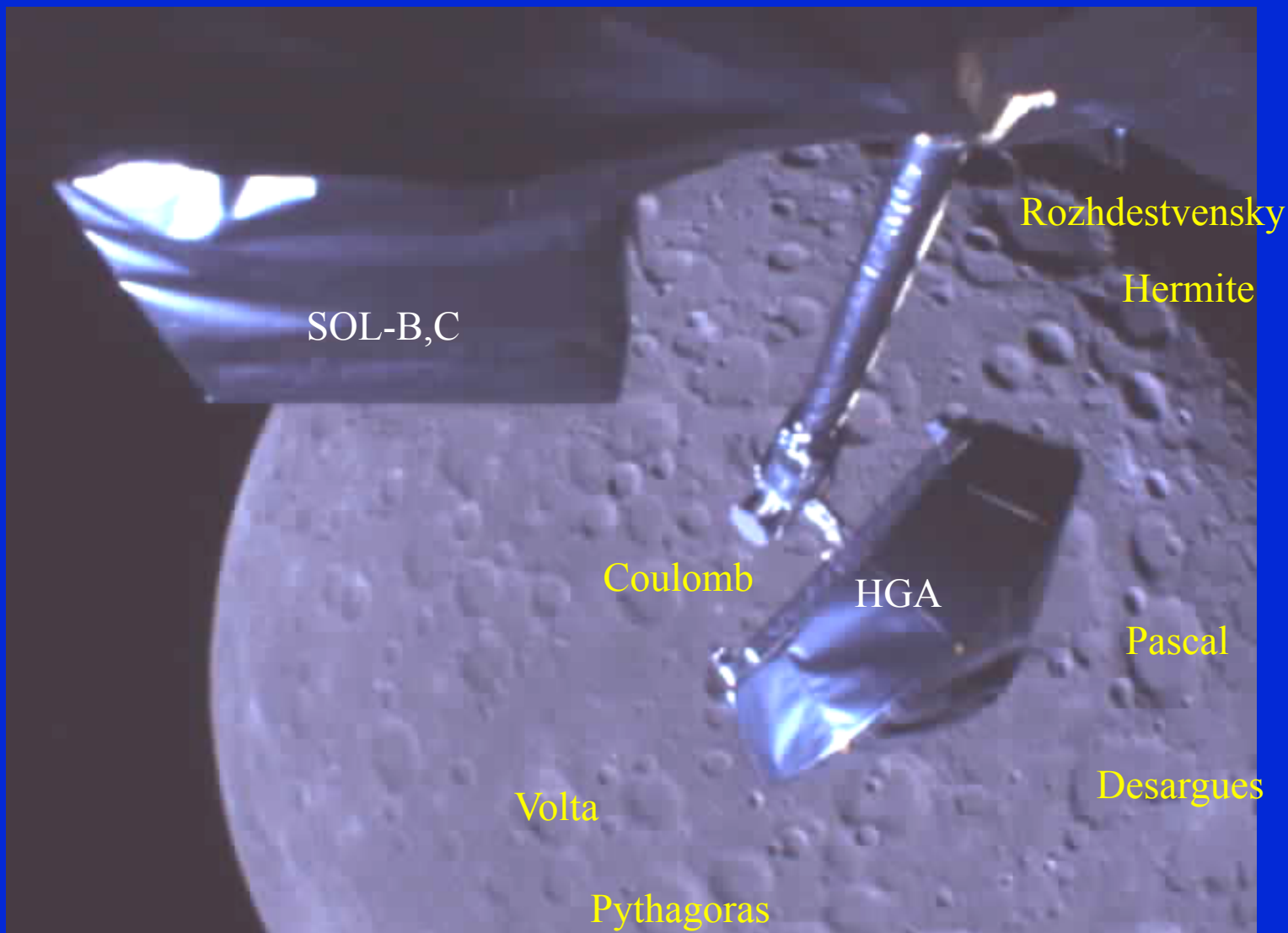


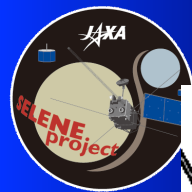
2007-10-5. 6:00:00
Alt.: 1200 km





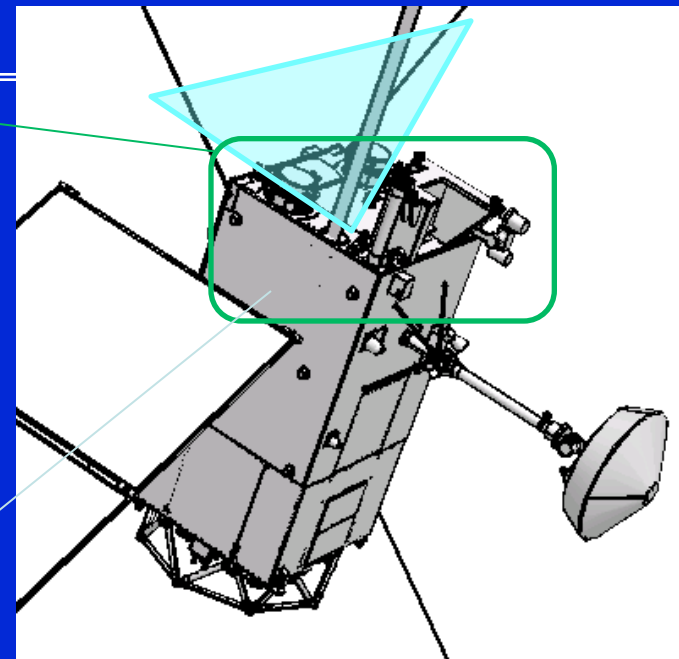
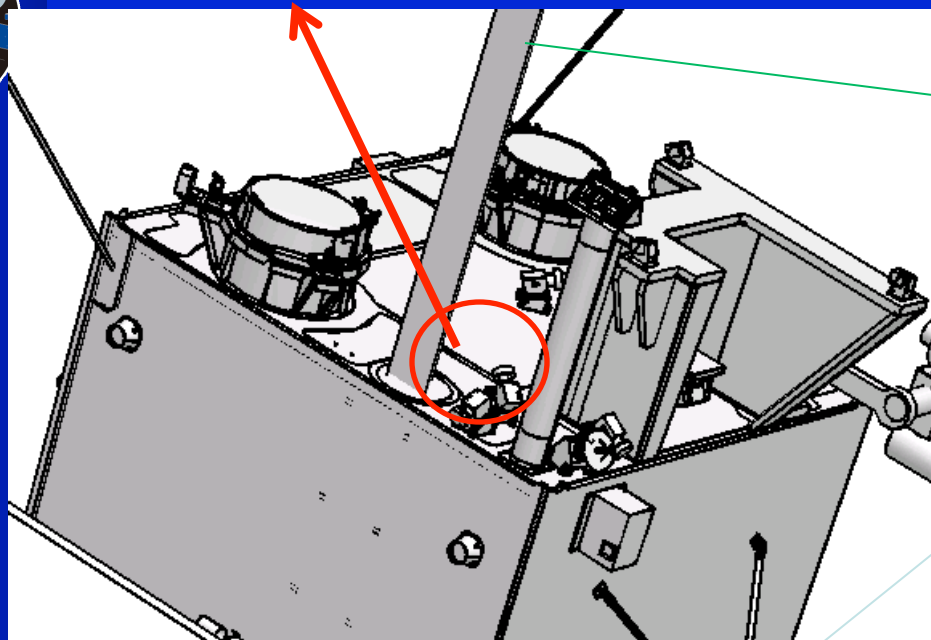
2007-10-05 06.10 UT, 高度800 km



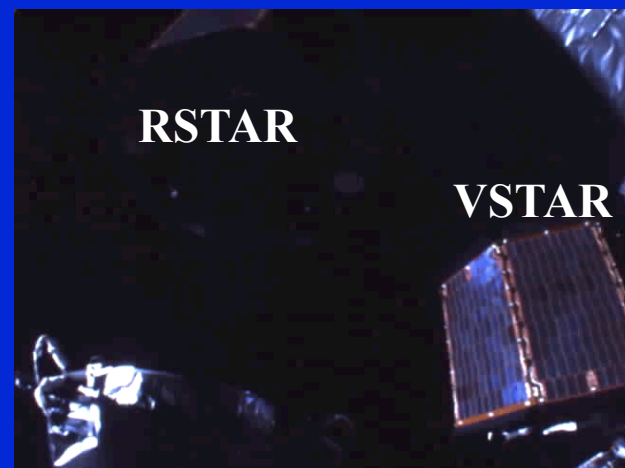


RSTAR (おきな)の分離 10/9

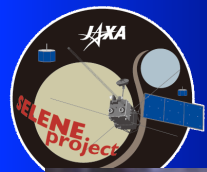
Camera FOV



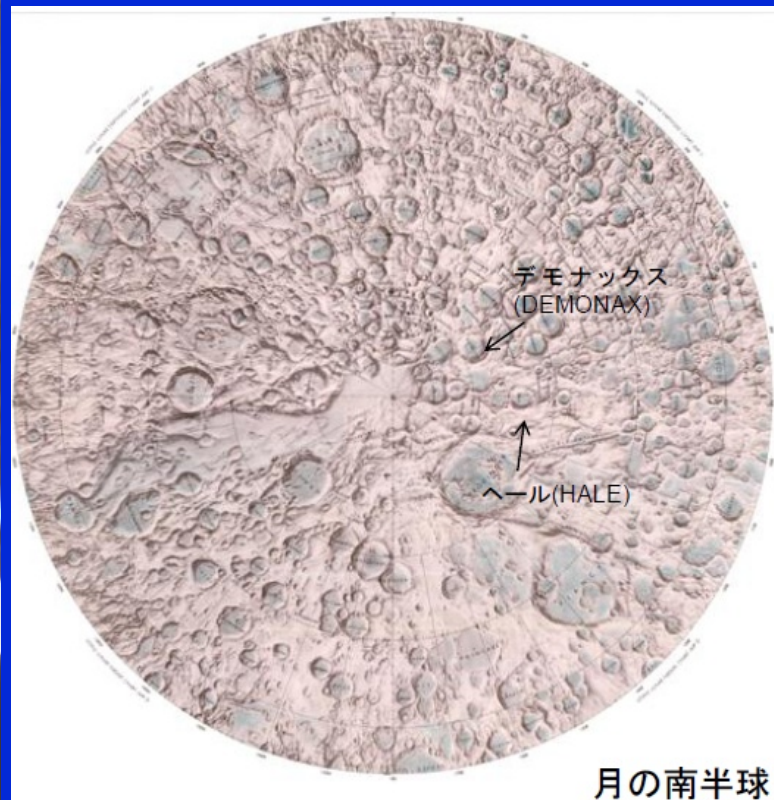
Before separation



After separation

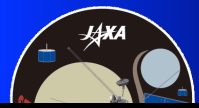


高度100kmへ入った直後の月面



SELENE

South hemisphere



「かぐや」のイベント

2007年

9.14 打上げ

9.19 1周目近地点通過

9.29 2周目近地点通過

10.4 月(長橢円)軌道投入

10.9 リレー衛星「おきな」分離

10.12 VRAD衛星「おうな」分離

10.19 月円軌道投入

10.28 LMAGマスト伸展

10.29 LRSアンテナ伸展

10.30 UPI展開

11.1 観測機器機能確認開始

12.21 定常観測開始

2008年 2.20 月食

4.3 ヨーアラウンド

8.16 月食

10.7 ヨーアラウンド

10.31 定常観測終了

11.1 後期観測開始

2009年 2.1 低高度観測開始

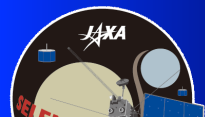
2.12 おきな裏側に衝突

6.11 かぐや制御落下

6.29 おうな通信停止



© JAXA/NHK



レーザ高度計 LALT



図1: LALT-E外観(左)と放熱板側から見たLALT-TR(右)

表1: LALT仕様及び性能表

諸元	数値
質量 (総計)	19.09 kg
(LALT-TR)	15.34 kg
(LALT-E)	3.75 kg
サイズ (LALT-TR)	360mm*450mm*408mm
々 (LALT-E)	241mm*301mm* 88mm
消費電力	44.2 W
レーザタイプ	Diode pumped, Q-switched, Cr doped Nd:YAG laser
波長	1064+/-1 nm
パルスエネルギー	100+/-5 mJ
レーザパルス頻度	1Hz or 0.5Hz
軌道沿い分解能	1.54 km or 3.08 km
時間パルス幅	17+/-3 nsec. (FWHM)
レーザコリメータ	ガリレオ式屈折 口径: 73mm
ビーム拡がり角	0.4+/-0.1 mrad
受信用望遠鏡	カセグレン式反射, 口径: 100mm
望遠鏡視野	1mrad
測距値分解能	1m
測距距離	50~150 km or 0~150km
測距精度(*)	5m

* 時間パルス幅17 nsec.に相当.

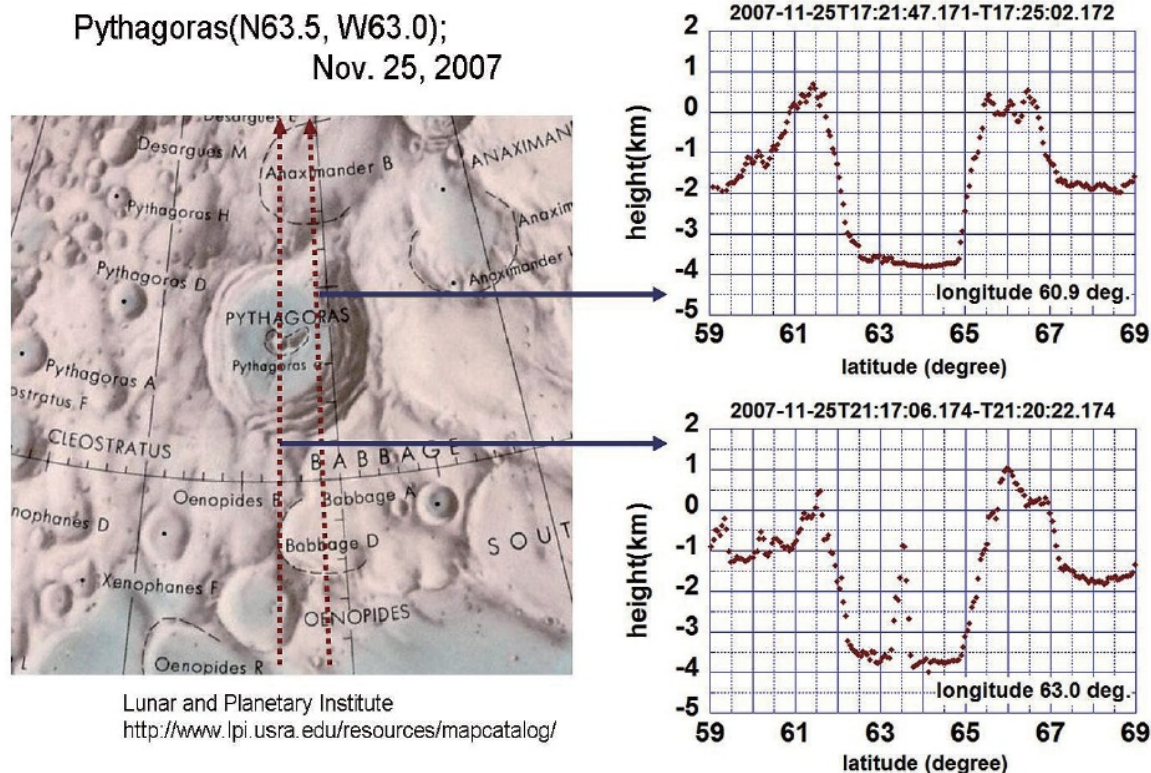
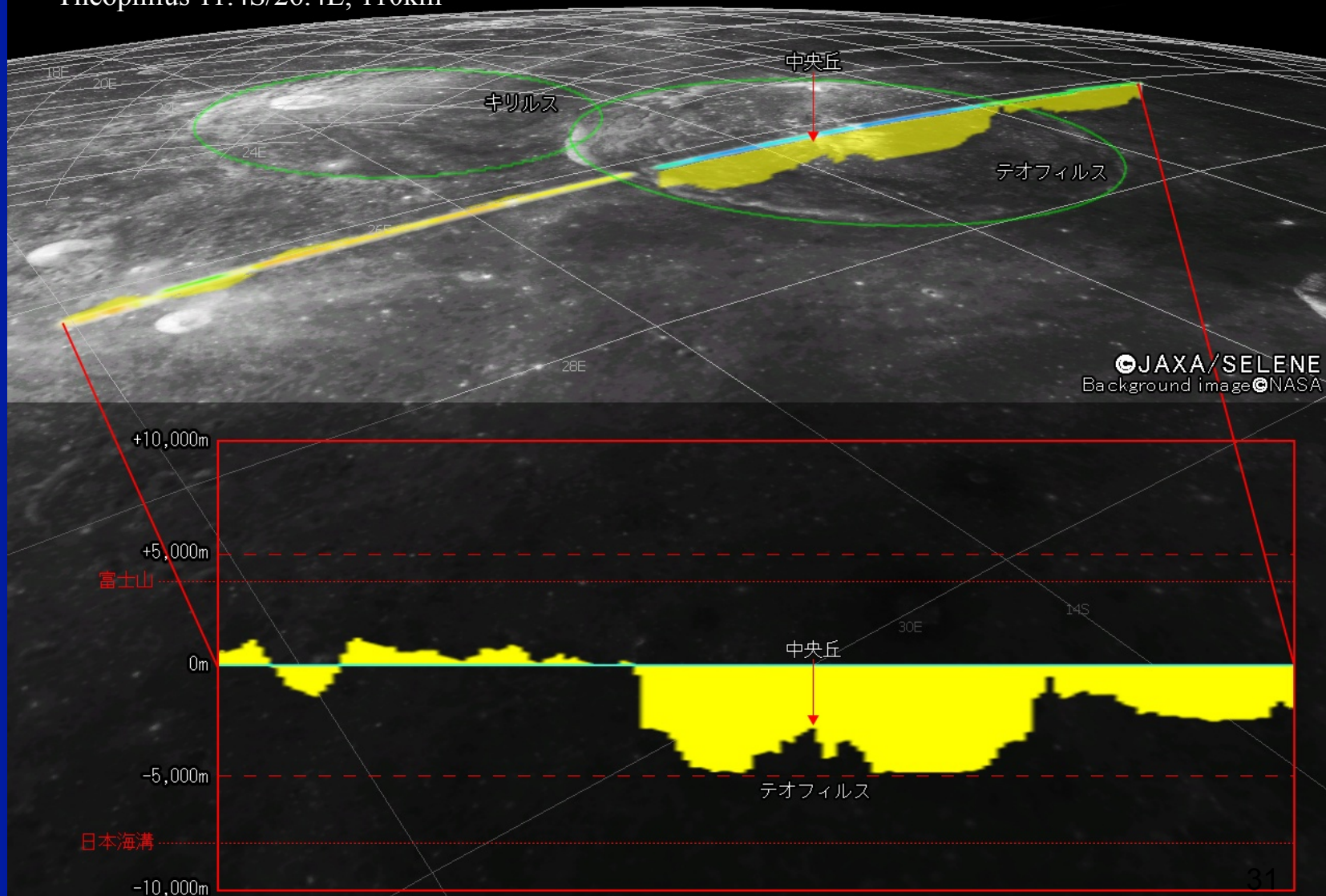


図2: LALT初観測時のピタゴラスクレータ高度プロファイル.測線が中央丘を横切る場合とそうでない場合の違いが捉えられている。



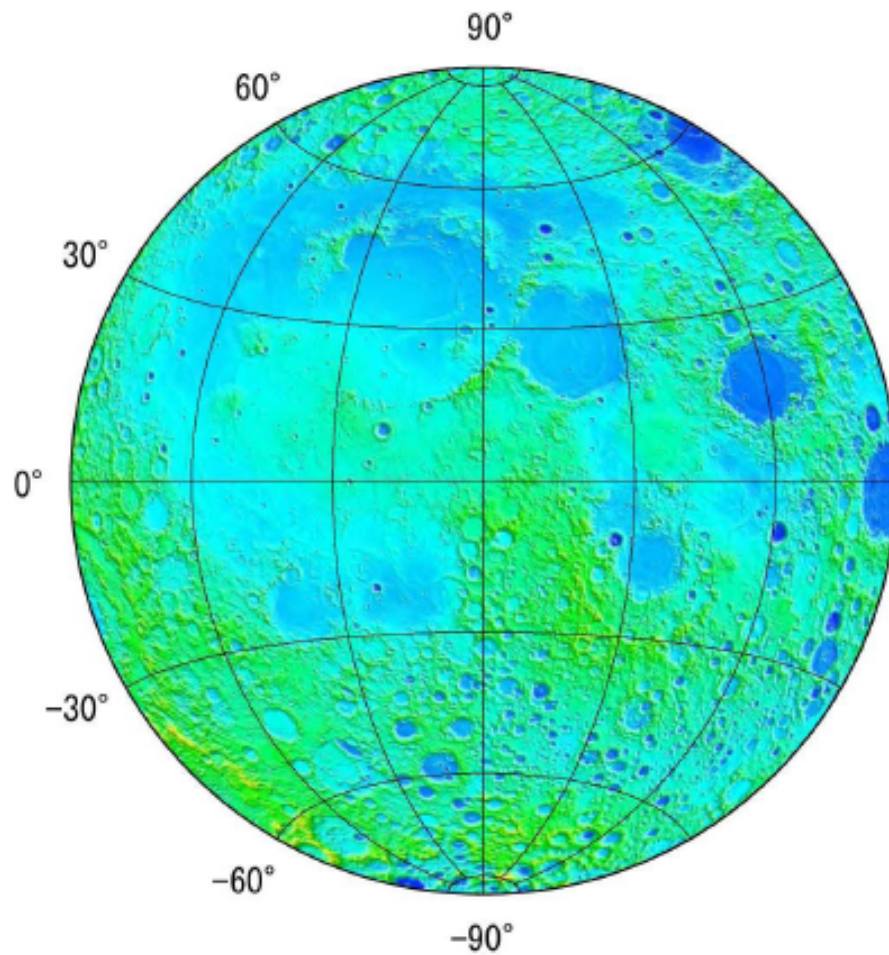
レーザ高度計 (LALT) によるクレータ観測

Theophilus 11.4S/26.4E, 110km

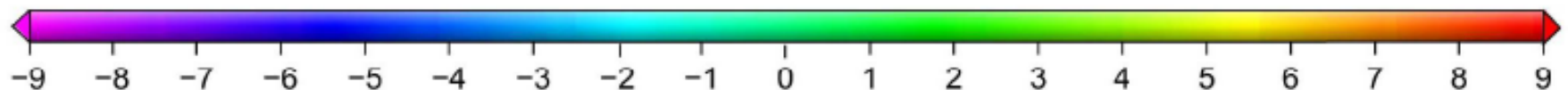
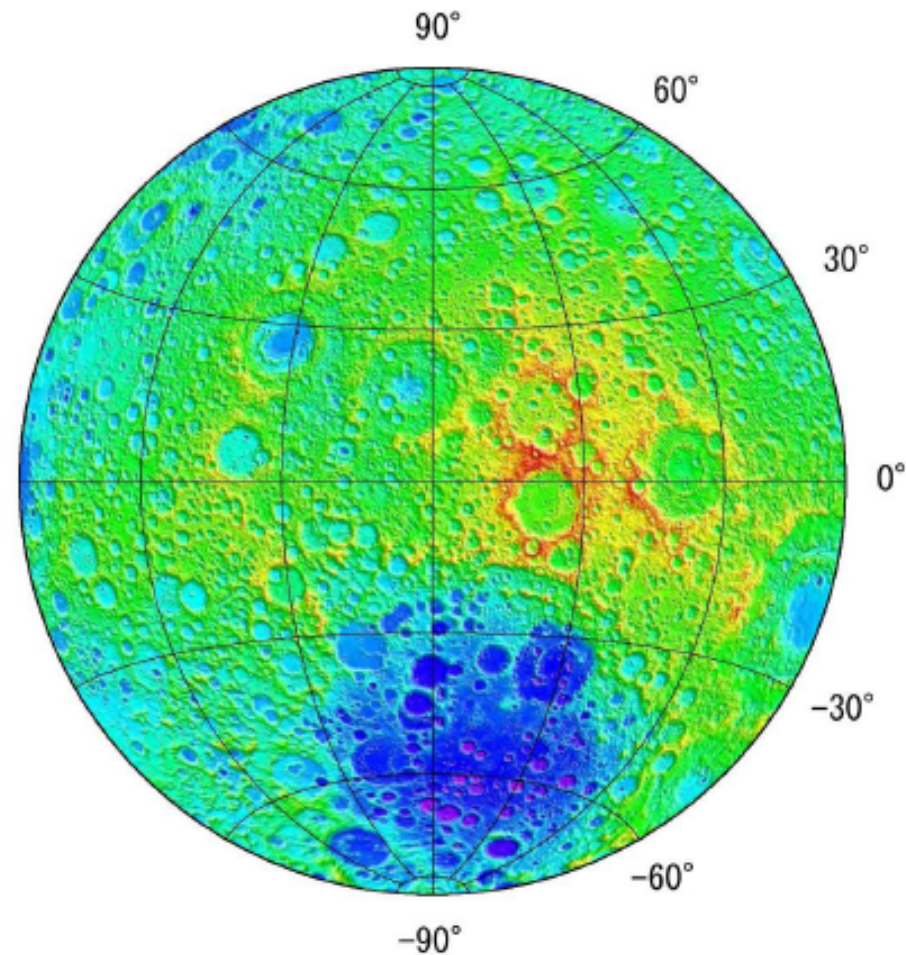


Lunar Shaded Topographic Map (~30. June, 2008)

Near Side

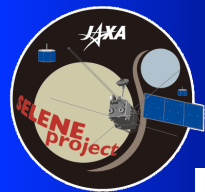


Far Side

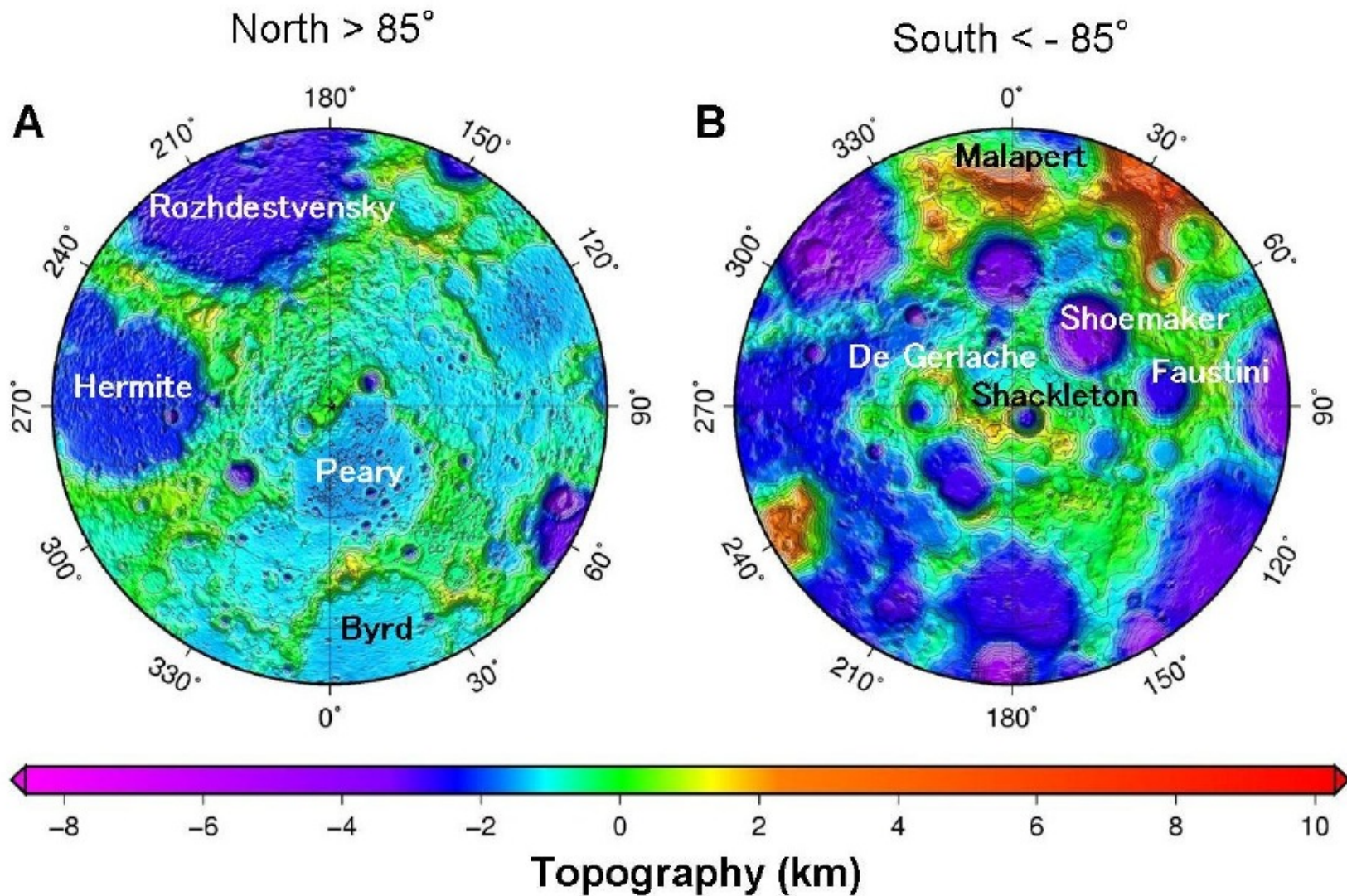


ME/PA: 1737.4km

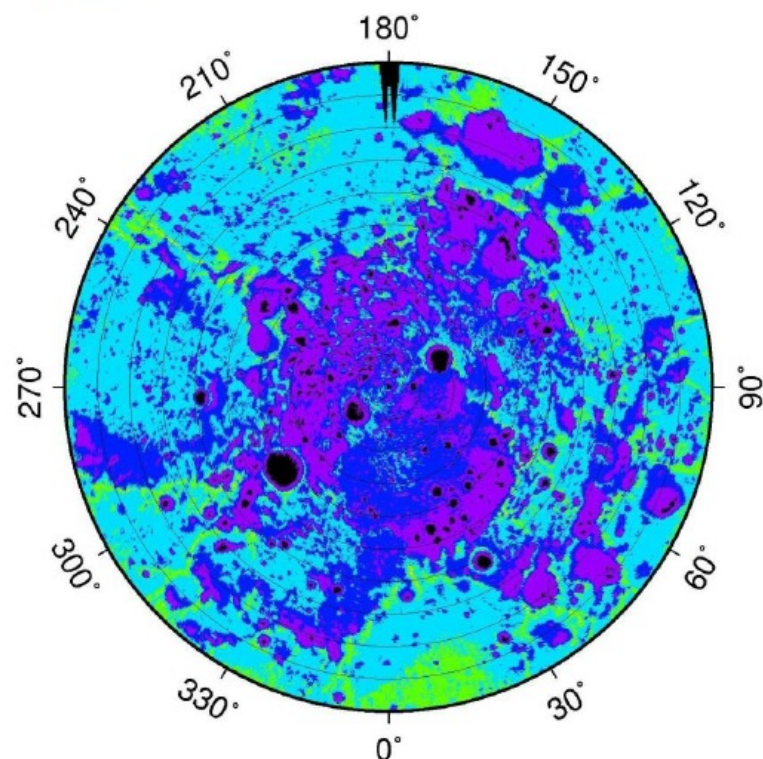
Topo [km] Lambert Azimuthal Equal Area Projection



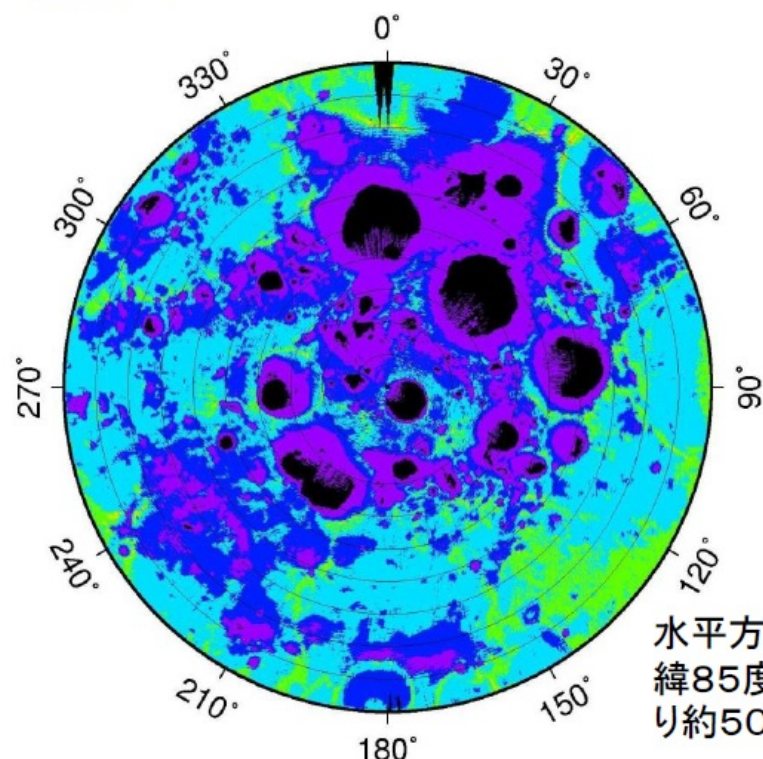
極域のLALT観測



北極 North > 85



南極 South < -85



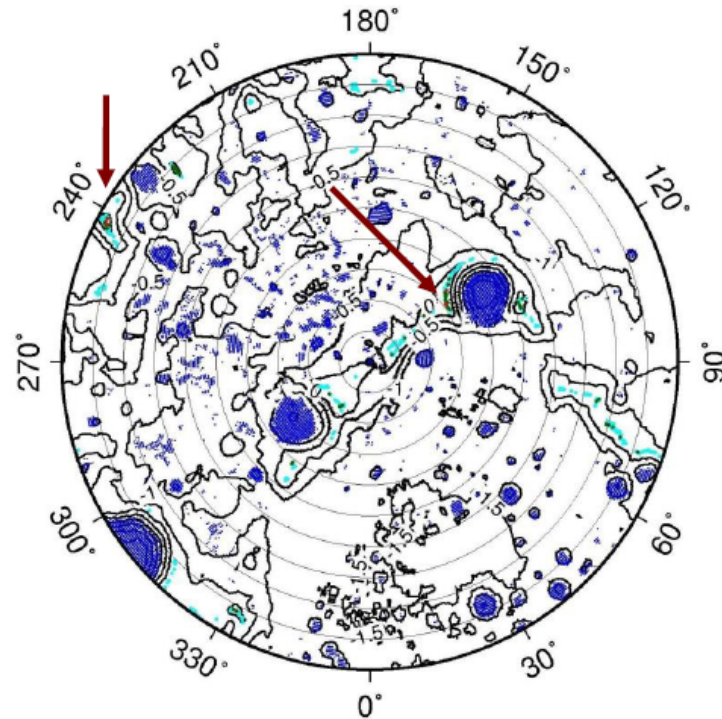
水平方向分解能は北緯85度で1画素あたり約500m×500m。



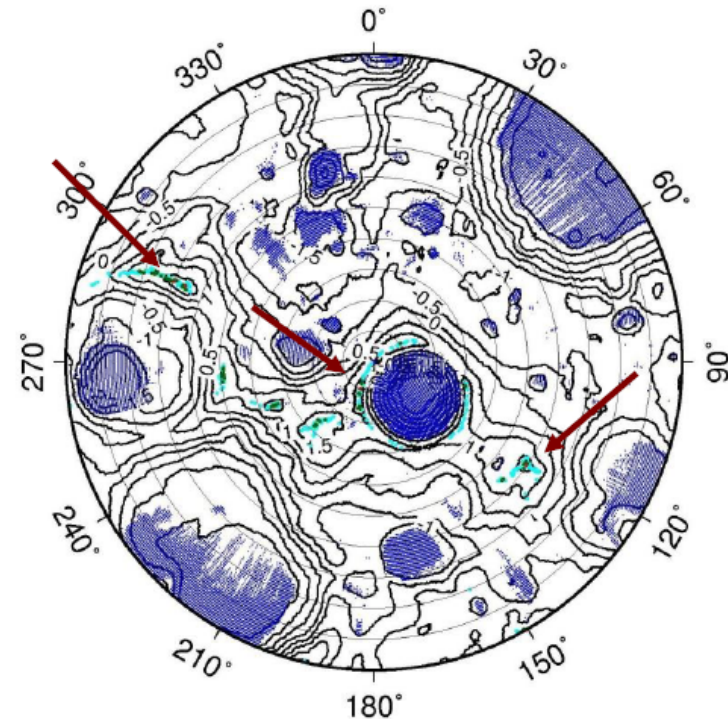
- 黒い部分が「永久日影」領域、ただし2次散乱光は考慮していない。
- 面積は北、南それぞれ1236km²、4466km²で、クレメンタインなどのこれまで研究による面積の見積もりから変化はあまりない。

88度以北(以南)拡大図

北極 North > 88



南極 South < -88

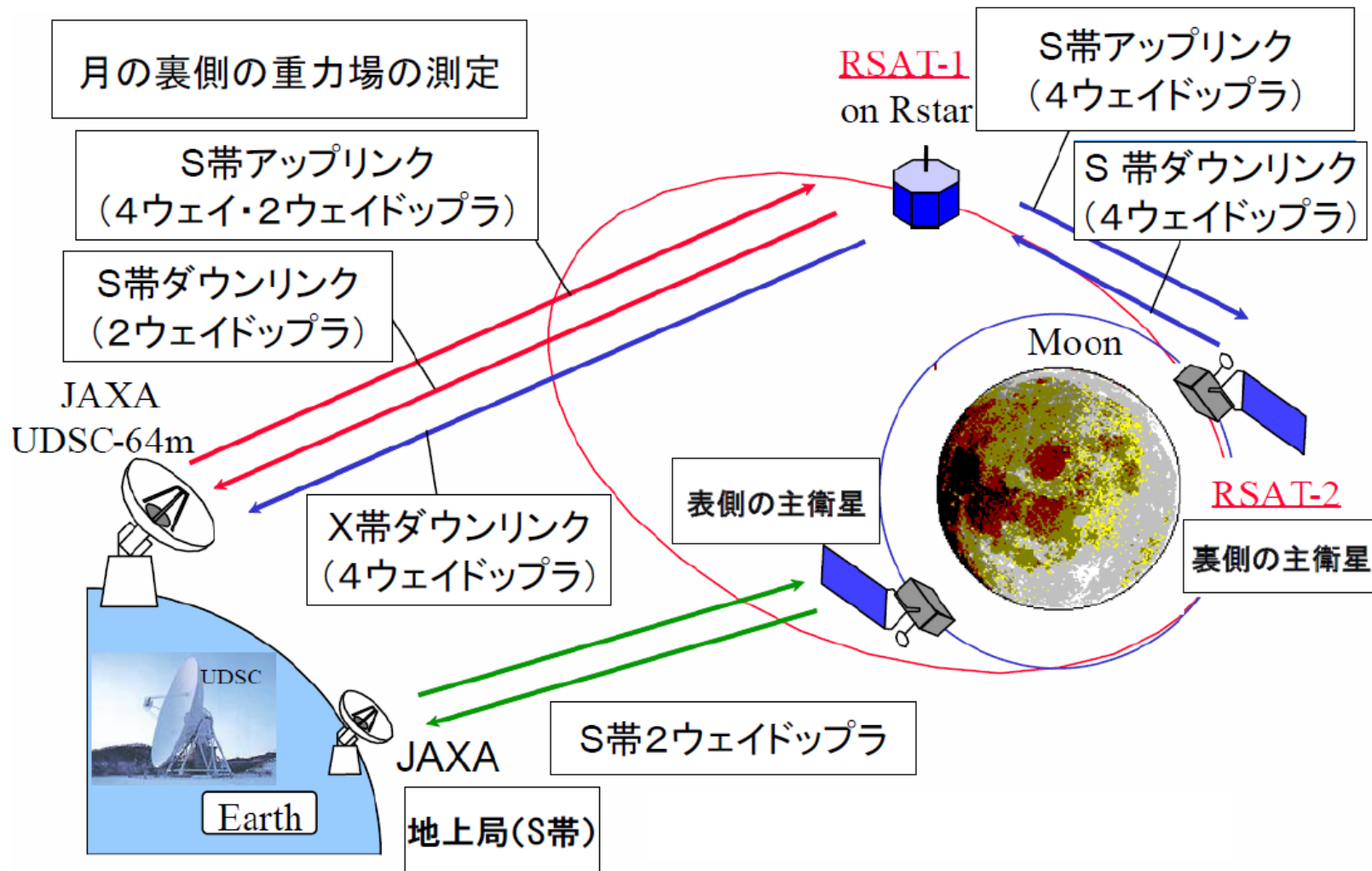


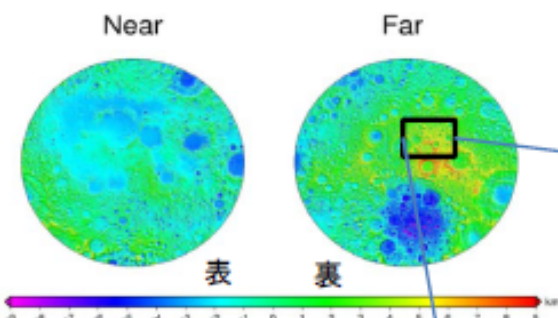
- 80%以上の領域はクレータ周縁(リム)の限られた部分のみに存在する(矢印)。

>80%	赤
70-80%	緑
60-70%	水色
0%	青



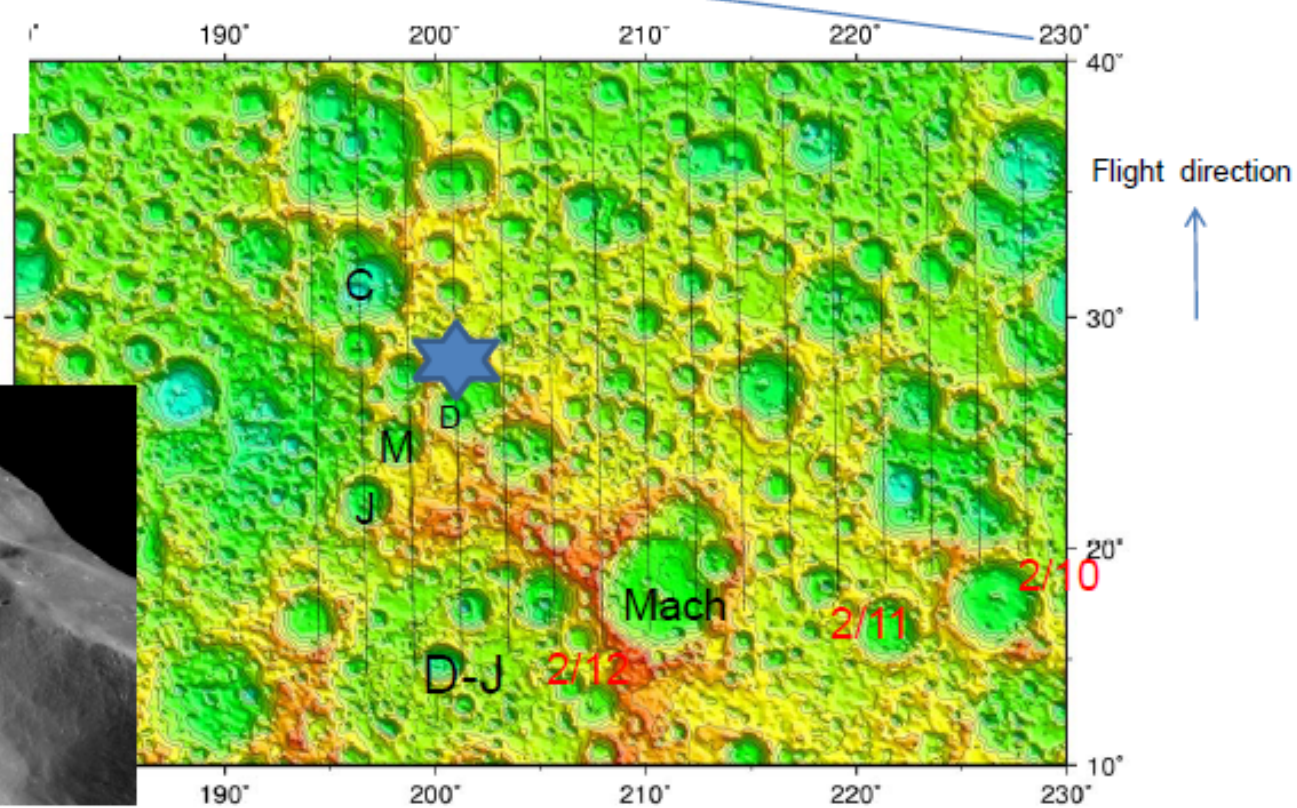
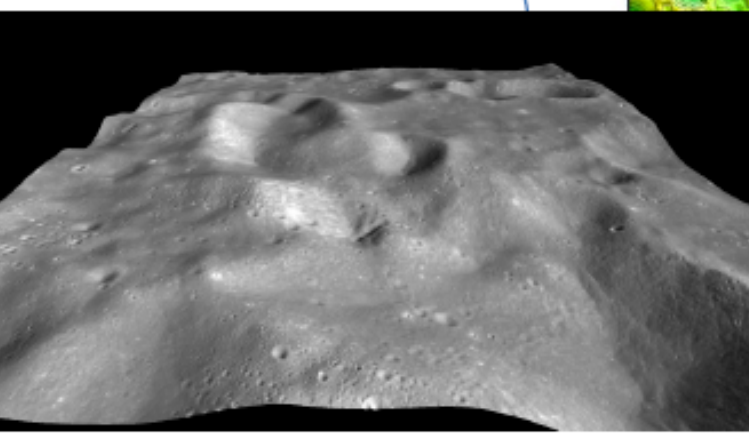
4-ウェイ ドップラー計測 裏側の重力場計測





Orbits of relay satellite Okina for Feb. 10 and 20 with altitude lower than 20 km

Rstar Okina crash
In lunar farside,
February 12, 2009.



- C = Cockcroft
- J = Jackson
- M = Mineur
- D = Mineur D
- D-J = Dirichlet-Jackson盆地
- F-S = Freundlich-Sharonov盆地



Topography ©JAXA/SELENE NAOJ

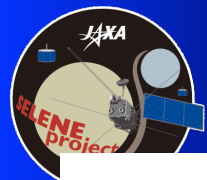
★: Estimated impact point of Okina, North of Mineur D crater
(200.97E/28.21N)

Estimated impact time: Feb. 12, 2009. 10:46:13 UT



New Gravity Model, Resources

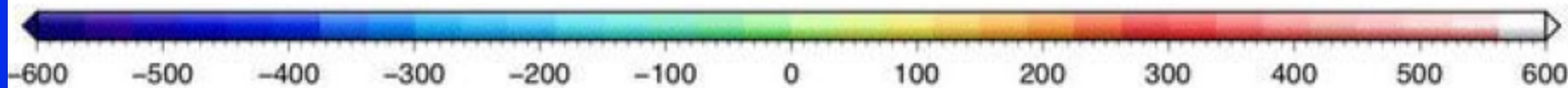
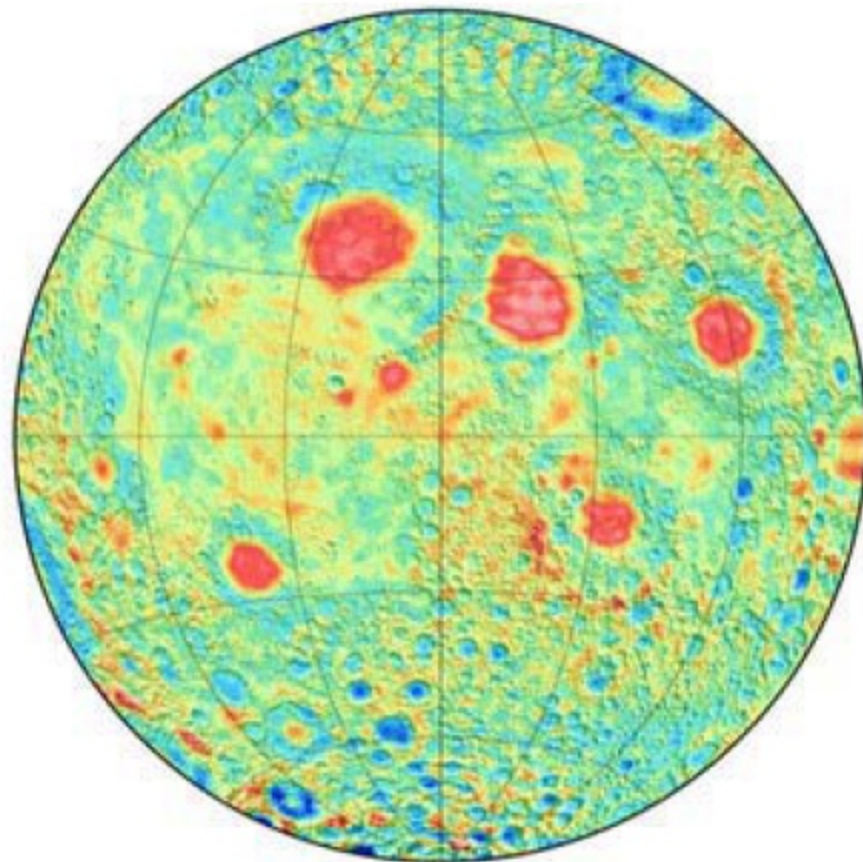
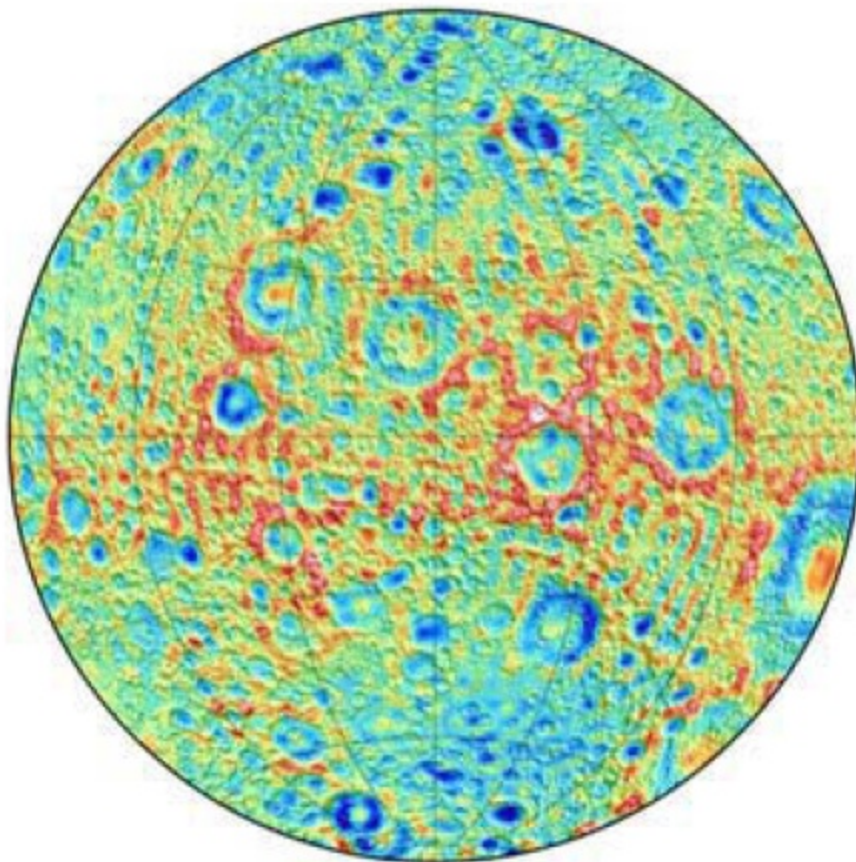
	Satellite	Data type	Amount	Arc length	Data weight
Far side	SELENE 4-way	Doppler	66,968	2.33 days	1 mm/s
	SELENE Main	Doppler UDSC	1,666,446	12 hours	1 mm/s
		Doppler GN			2 mm/s
		Range	60,884		5 m
	SELENE Rstar	Doppler	137,146	2.33 days	1 mm/s
		Range	129,333		5 m
	SELENE Vstar	Doppler	42,852	2.4 days	1 mm/s
		Range	35,386		5 m
	LO I-V	Doppler	3,861,375	12 hours	4.5 mm/s
	A15/16ss	Doppler		8 hours	4.5 mm/s
Near side	Clementine	Doppler		2 days	3 mm/s (Pommonkey 10 mm/s)
		Range			4 m
	LP nominal mission	Doppler		2 days	2 mm/s
		Range			4 m
	SMART-1	Doppler		15 hours	10 mm/s

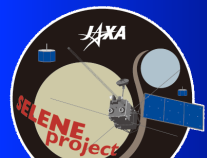


「おきな」を使った裏側重力場観測

Farside

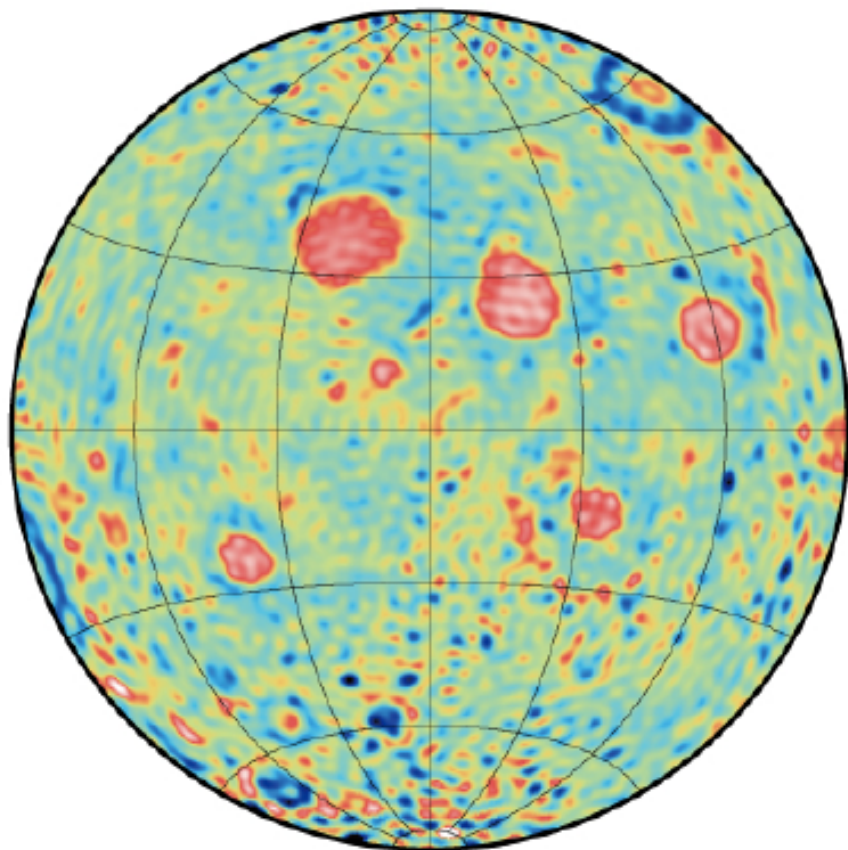
Nearside



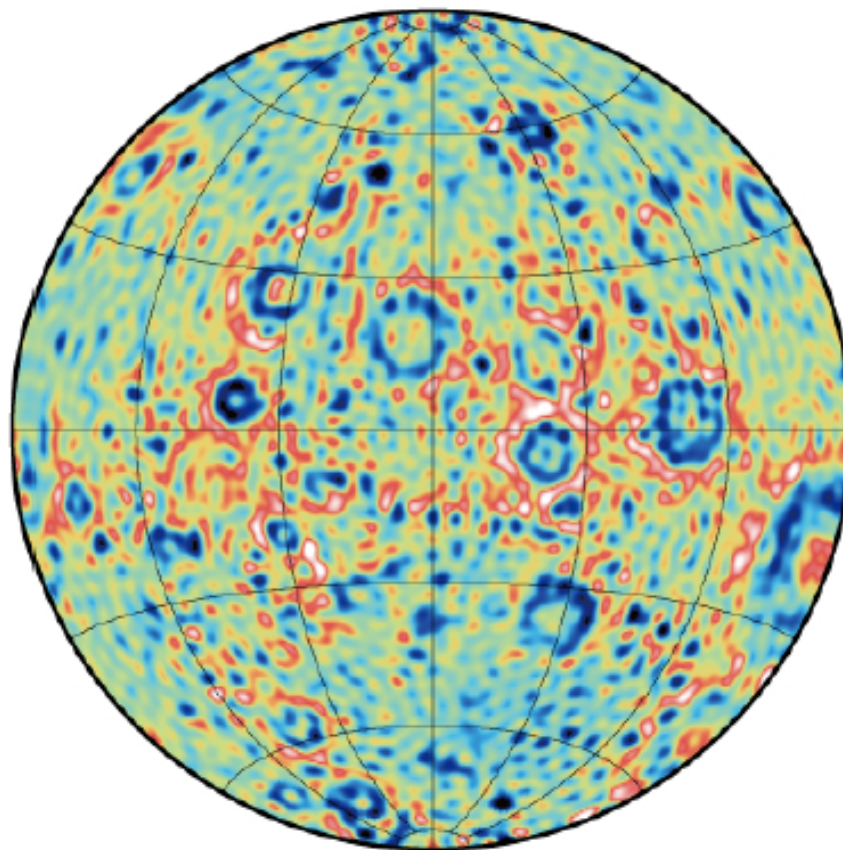


Gravity Model Version Up, SGM100h

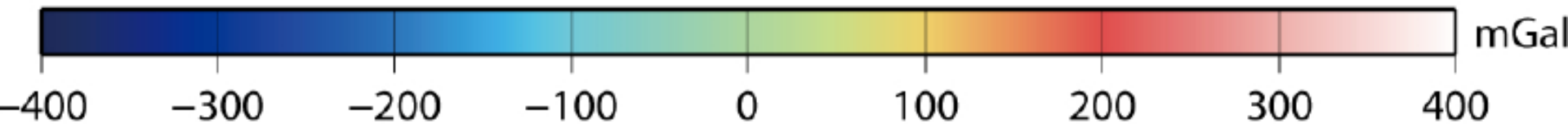
SGM100h nearside



SGM100h farside



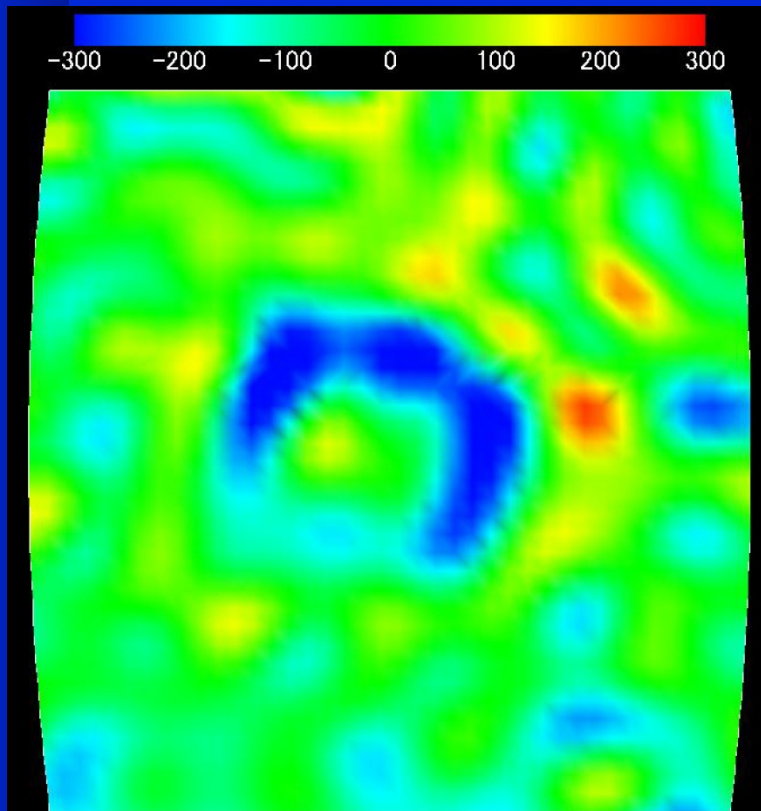
Matsumoto et al., JGR115 (2010)



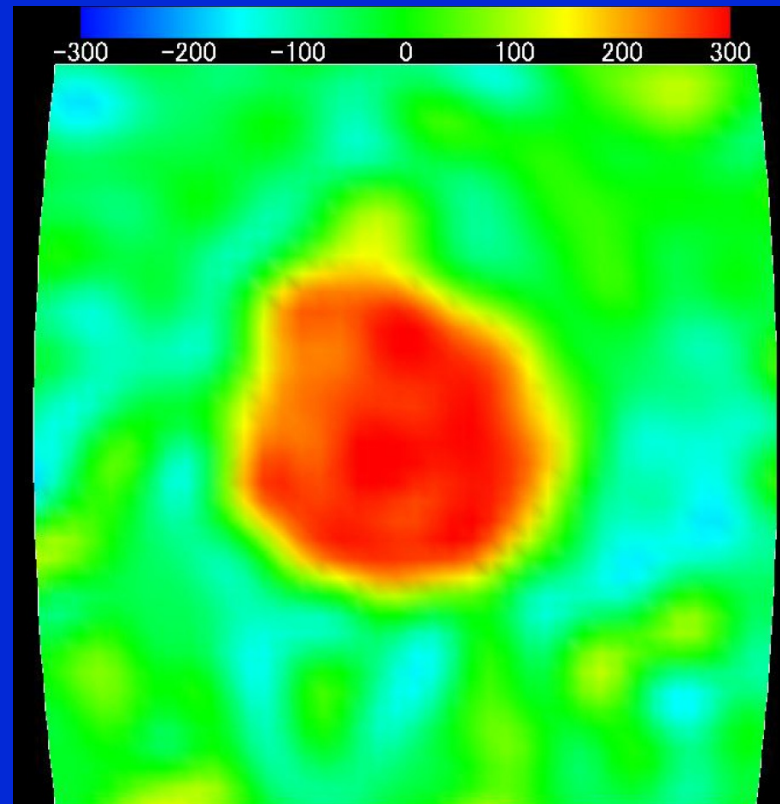


表側と裏側の重力異常の比較

Lenological and ENGINEERING Explorer

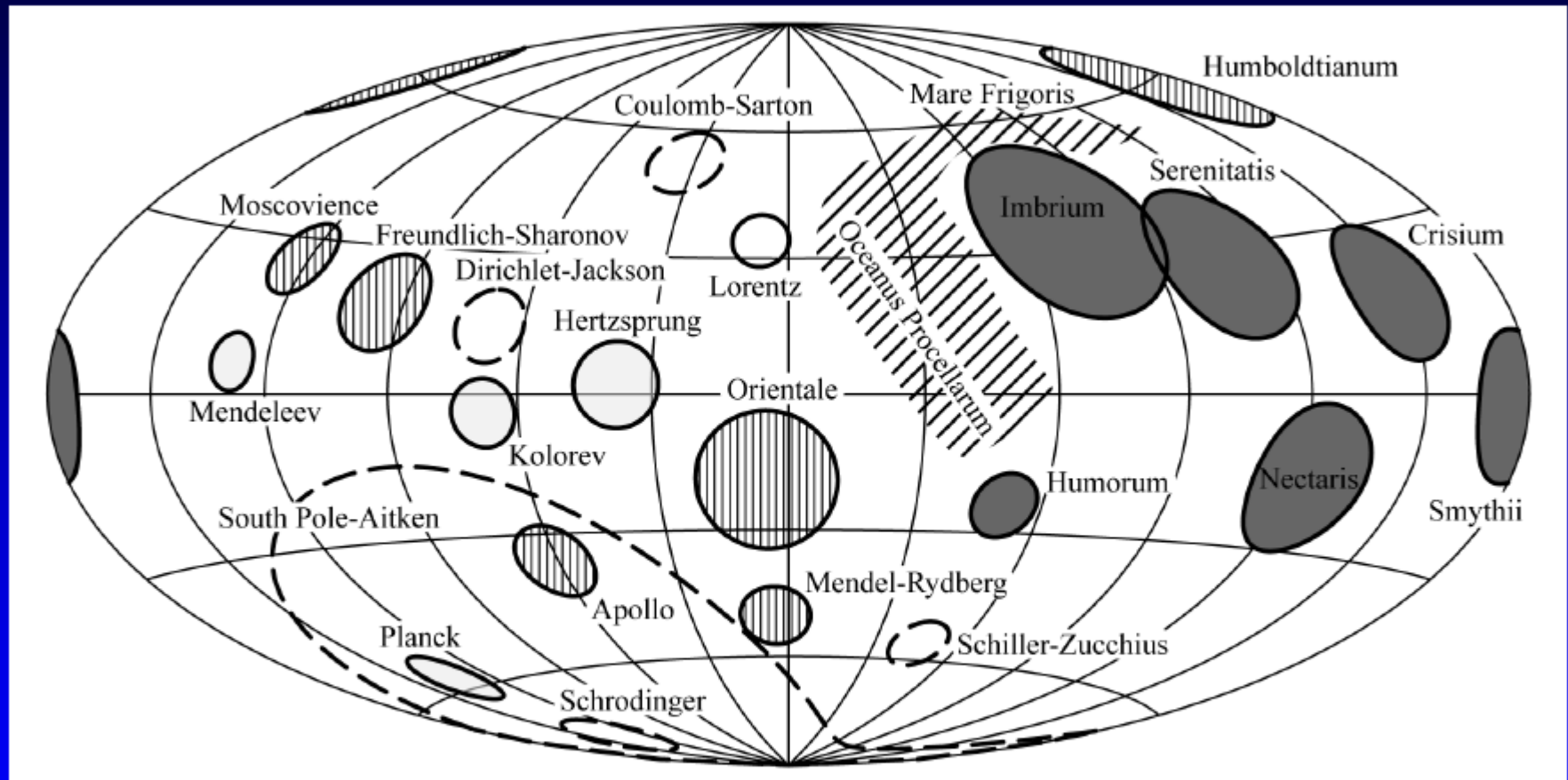


アポロクレータ
36.1S/151.8W、直径537.0 km



静かの海
28.0N/17.5E、直径707.0 km

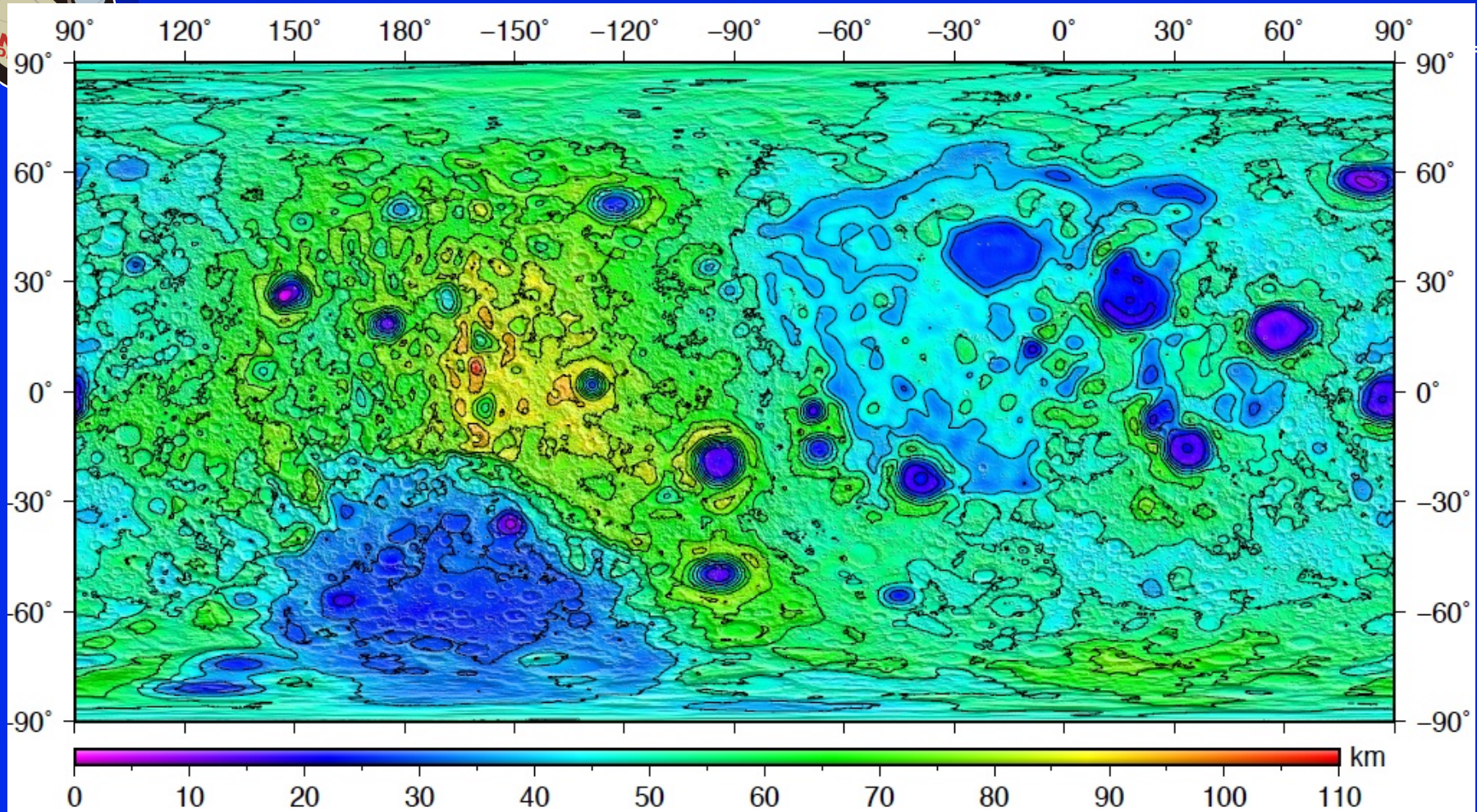
Distribution of major lunar basins



Shaded = primary mascon basins, Lightly shaded = Type I basins
Hatched = Type II basins, Dashed = unclassified.

地殻の厚み

Ishihara et al., 2009, GRL 36, L19202



最大：110km、ディリクレジャクソン クレータの南縁
(199.719E, 6.90625N)

最小：0 km モスクワの海の下

地殻の密度：2800 kg/m³、マントルの密度：3360 kg/m³、玄武岩の密度：
3200kg/m³ と仮定して算出



マルチバンドイメージャの特徴

MI-VIS 可視

20m/pixel@100km



- $415 \pm 10\text{nm}$
- $750 \pm 5\text{nm}$
- $1000 \pm 20\text{nm}$
- $950 \pm 15\text{nm}$
- $900 \pm 10\text{nm}$

MI-NIR: 近赤外

62m/pixel@100km



- $1050 \pm 15\text{nm}$
- $1000 \pm 15\text{nm}$
- $1550 \pm 25\text{nm}$
- $1250 \pm 15\text{nm}$

探査機進行方向

2つの直下視望遠鏡

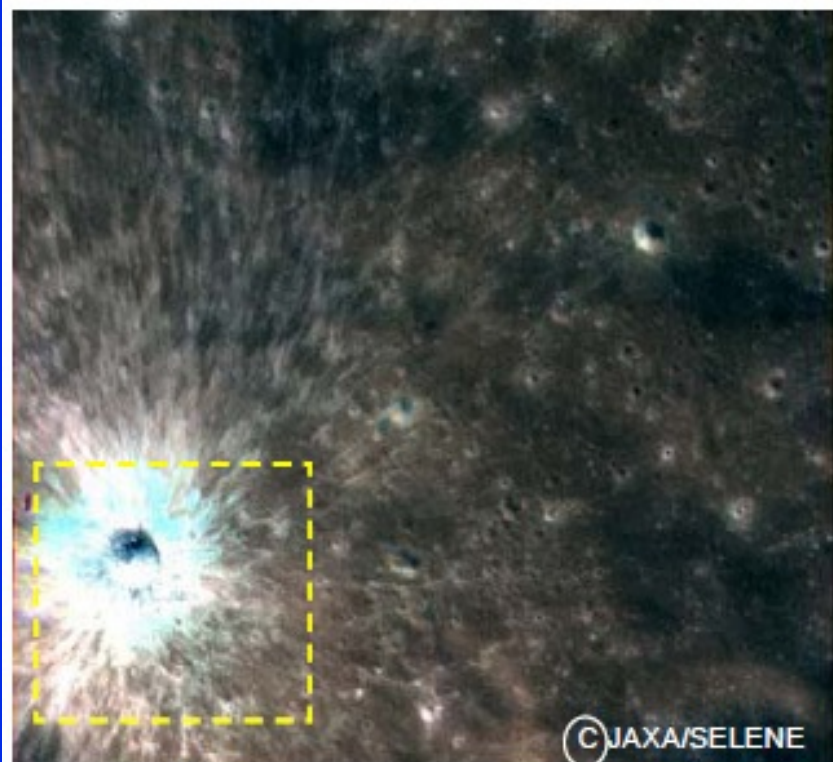
100km

プッシュブルーム方式撮像

19.3km 観測幅 (視野角 11°)

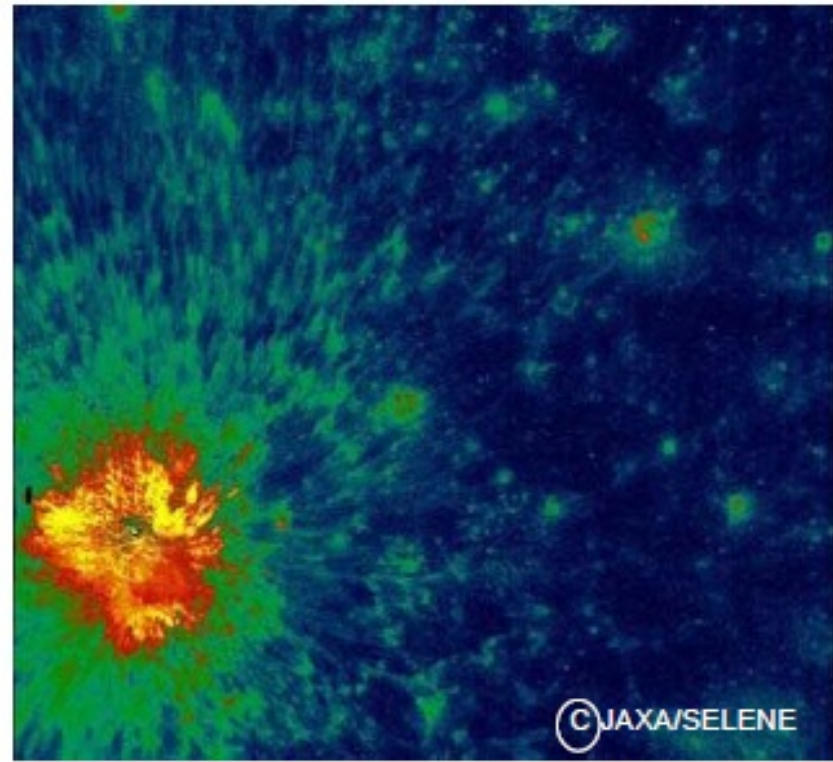


マルチバンドイメージャの初画像



4km

©JAXA/SELENE



Low

High

©JAXA/SELENE

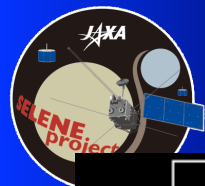
SELENE

900,750,415 nm 擬カラー画像

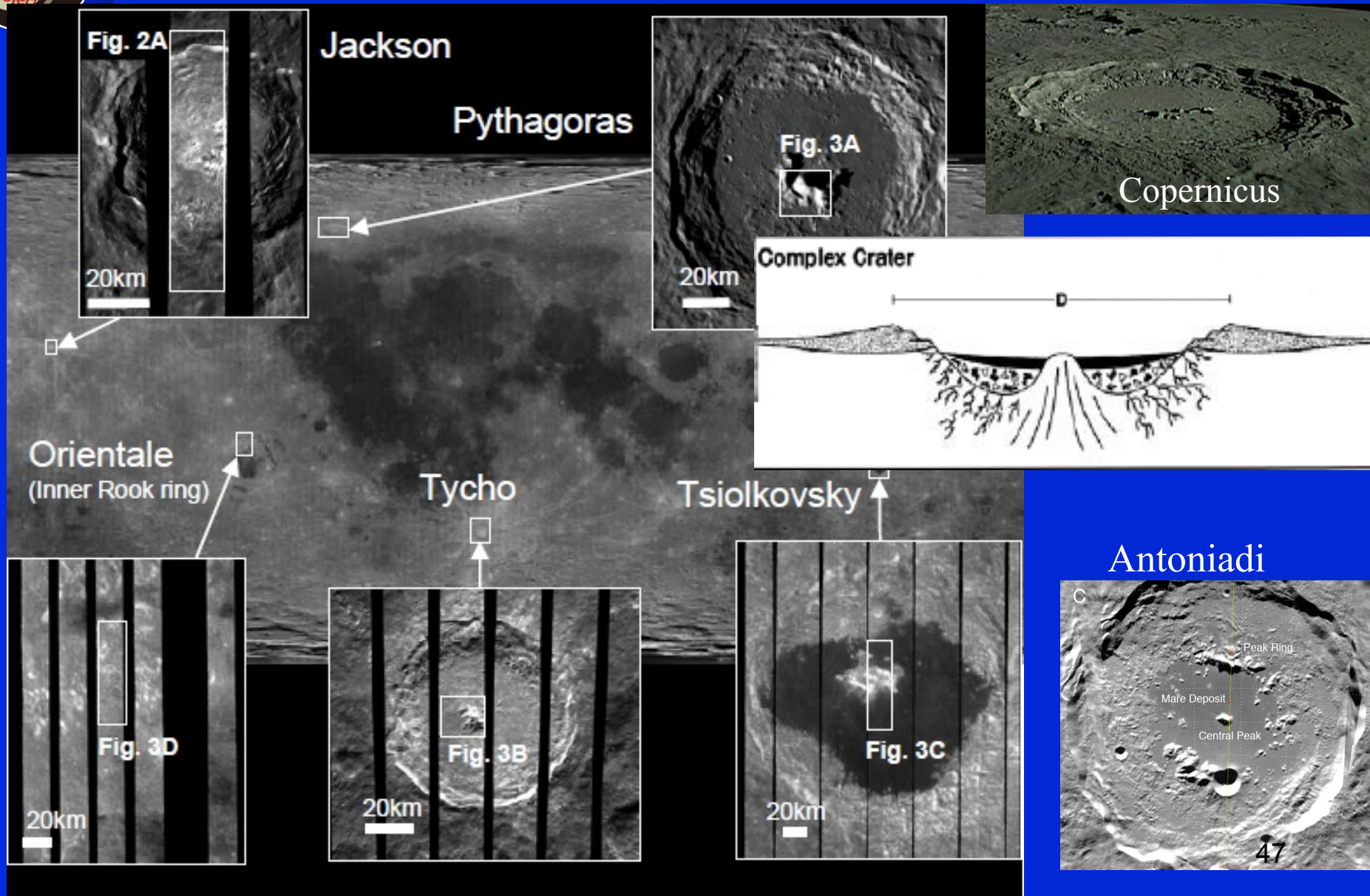
750/1000 nm コンポジット画像

37N, 240E: オリエンタル盆地1000km東

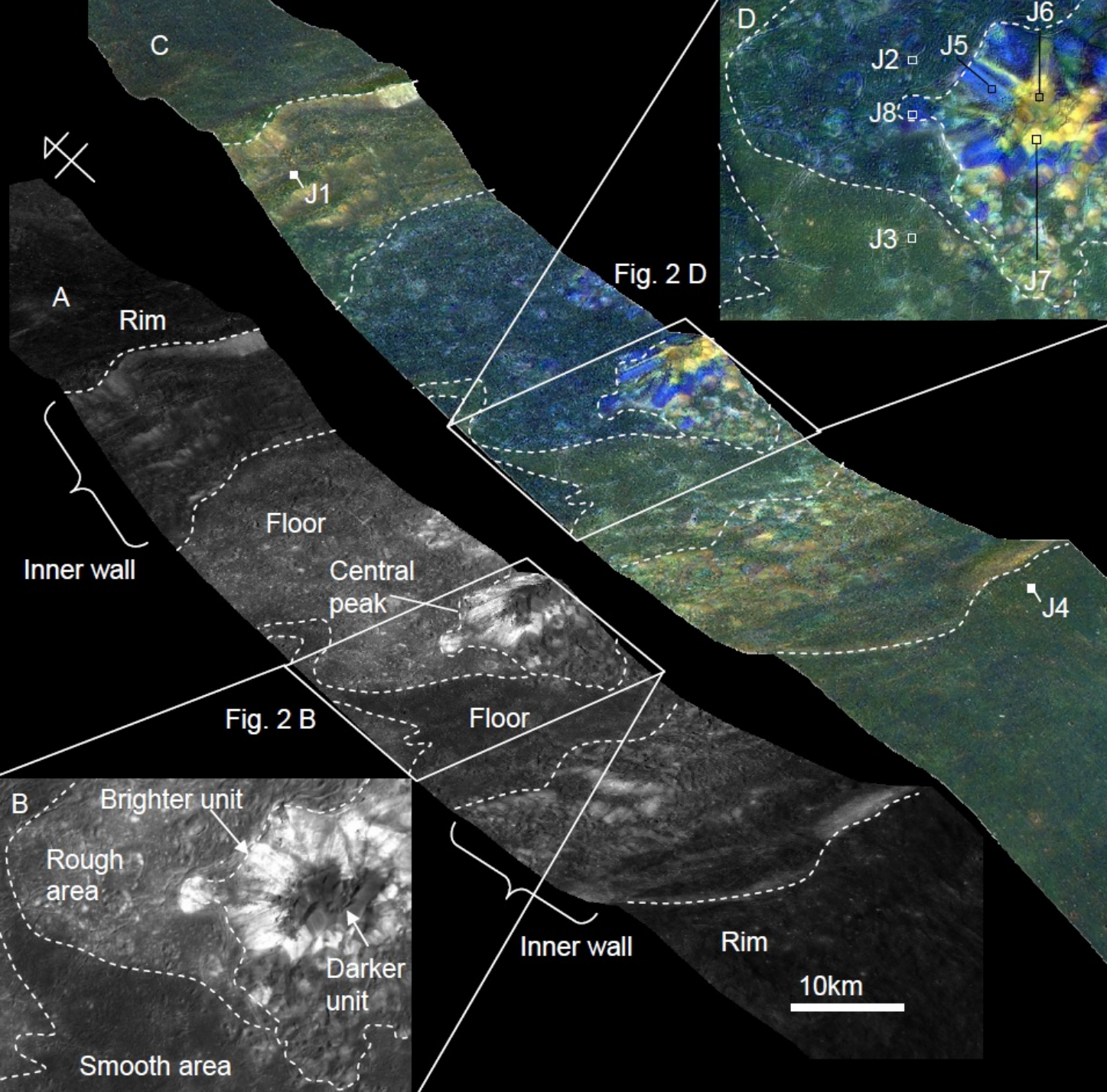
2007.11.26



月内部の“のぞき窓”、クレーター中央丘



マルチバンドイメージャによる測定



A: ジャクソンクレータ, 750nm

B: クローズアップ

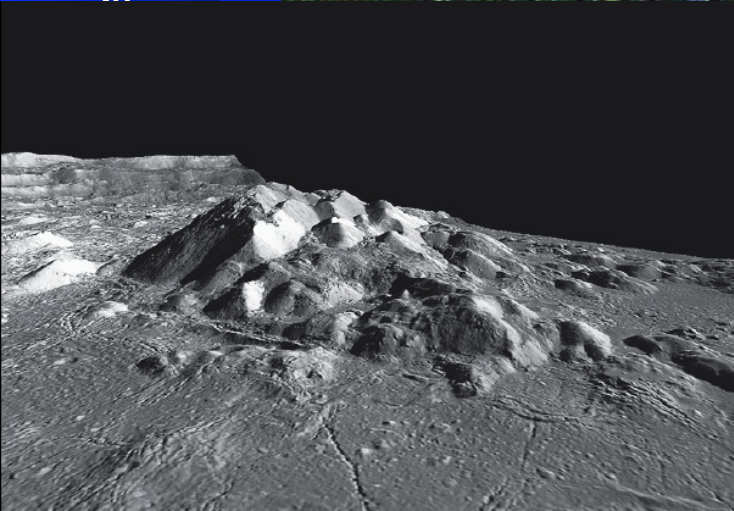
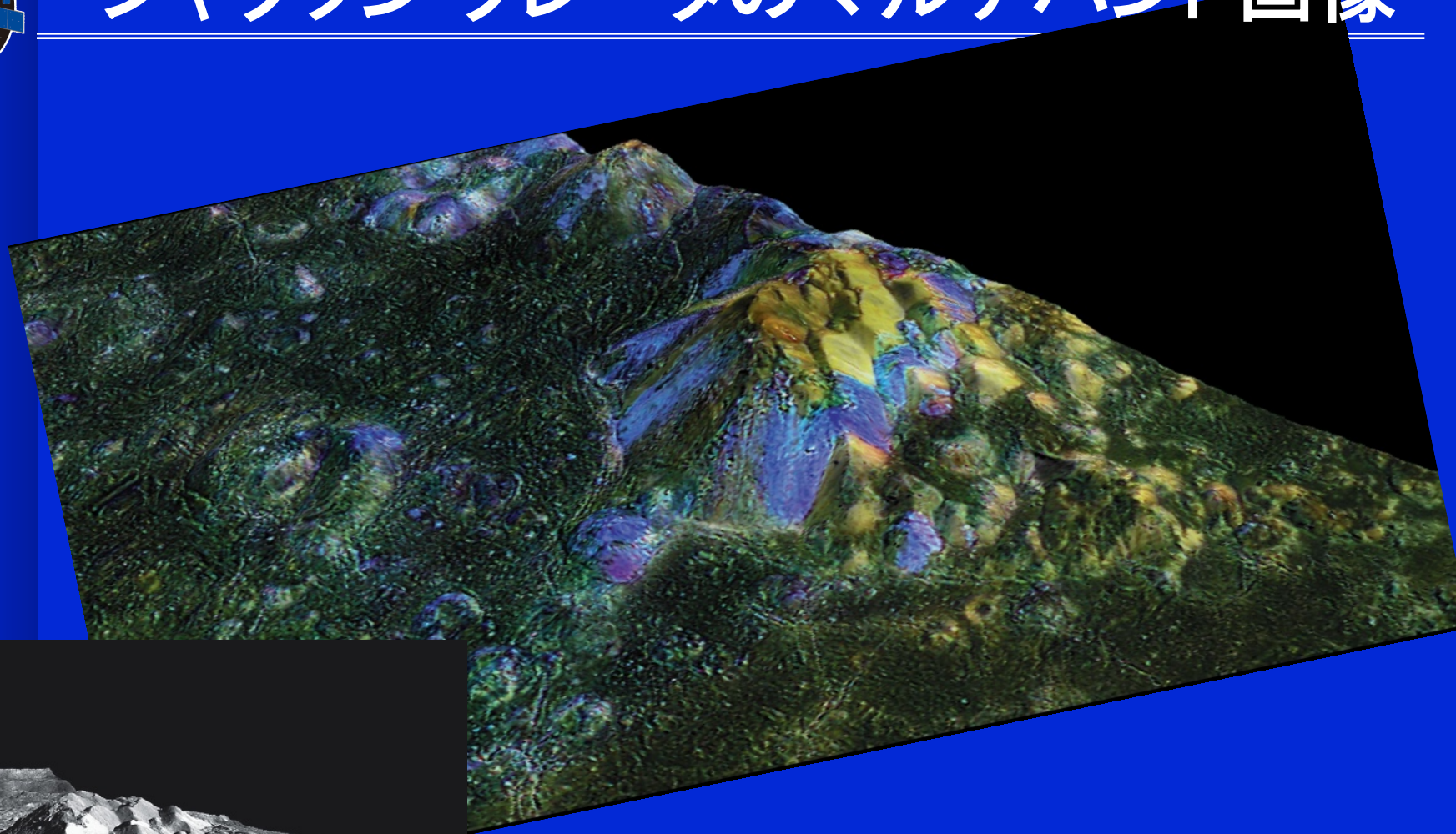
C: カラーコンポジット
950nmR, 1050nmB,
and 1250nmG

D: クローズアップ

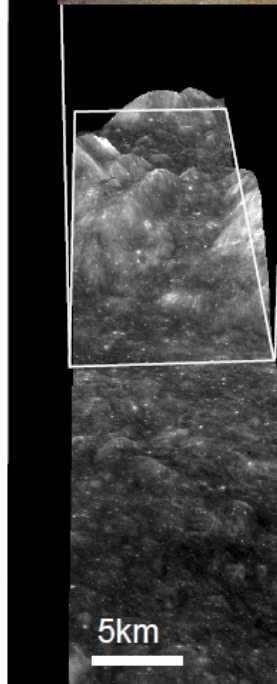
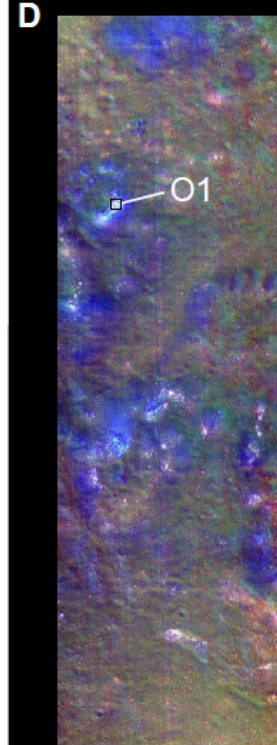
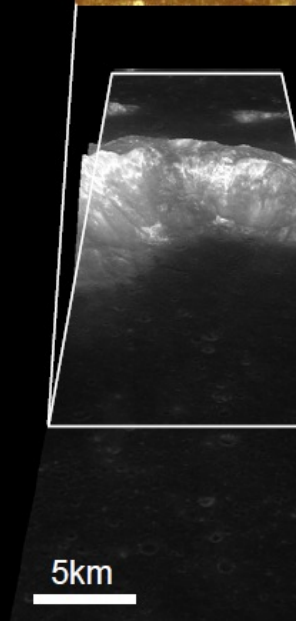
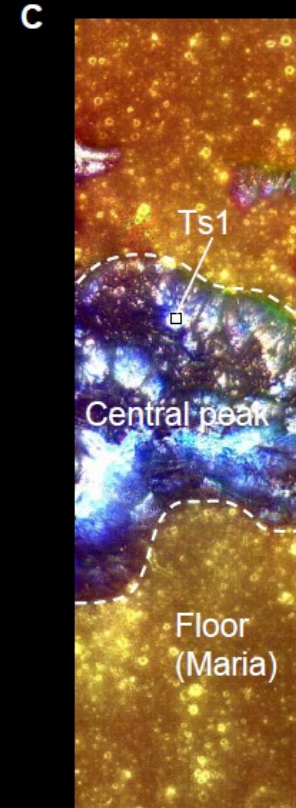
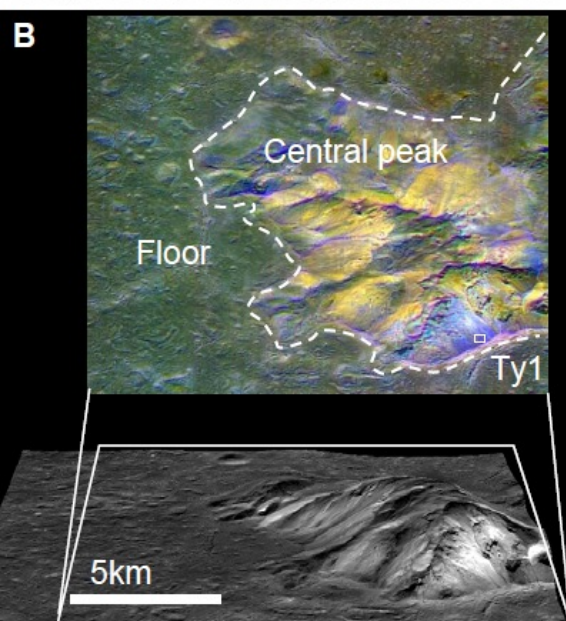
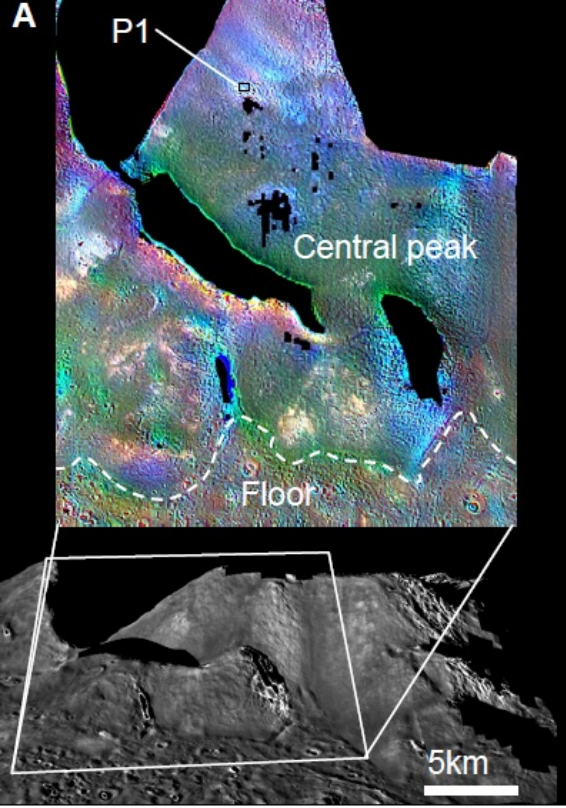


and Engineering Explorer

ジャクソン クレータのマルチバンド画像



Color composite,
950nm:R, 1050nm:B,
1250nm:G



A: ピタゴラスクレータの
カラーコンポジット

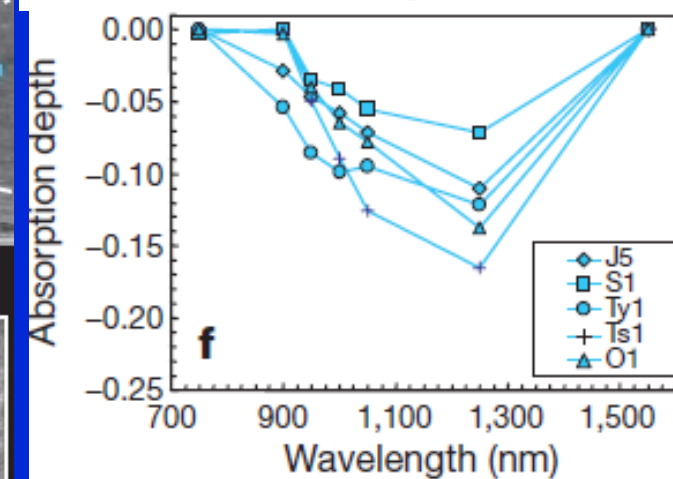
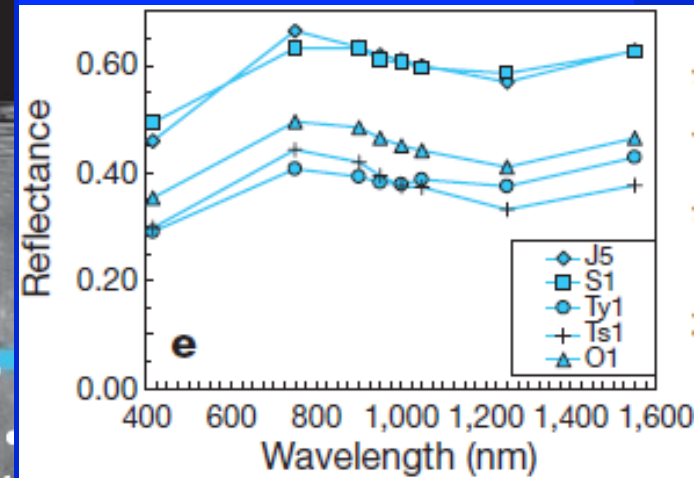
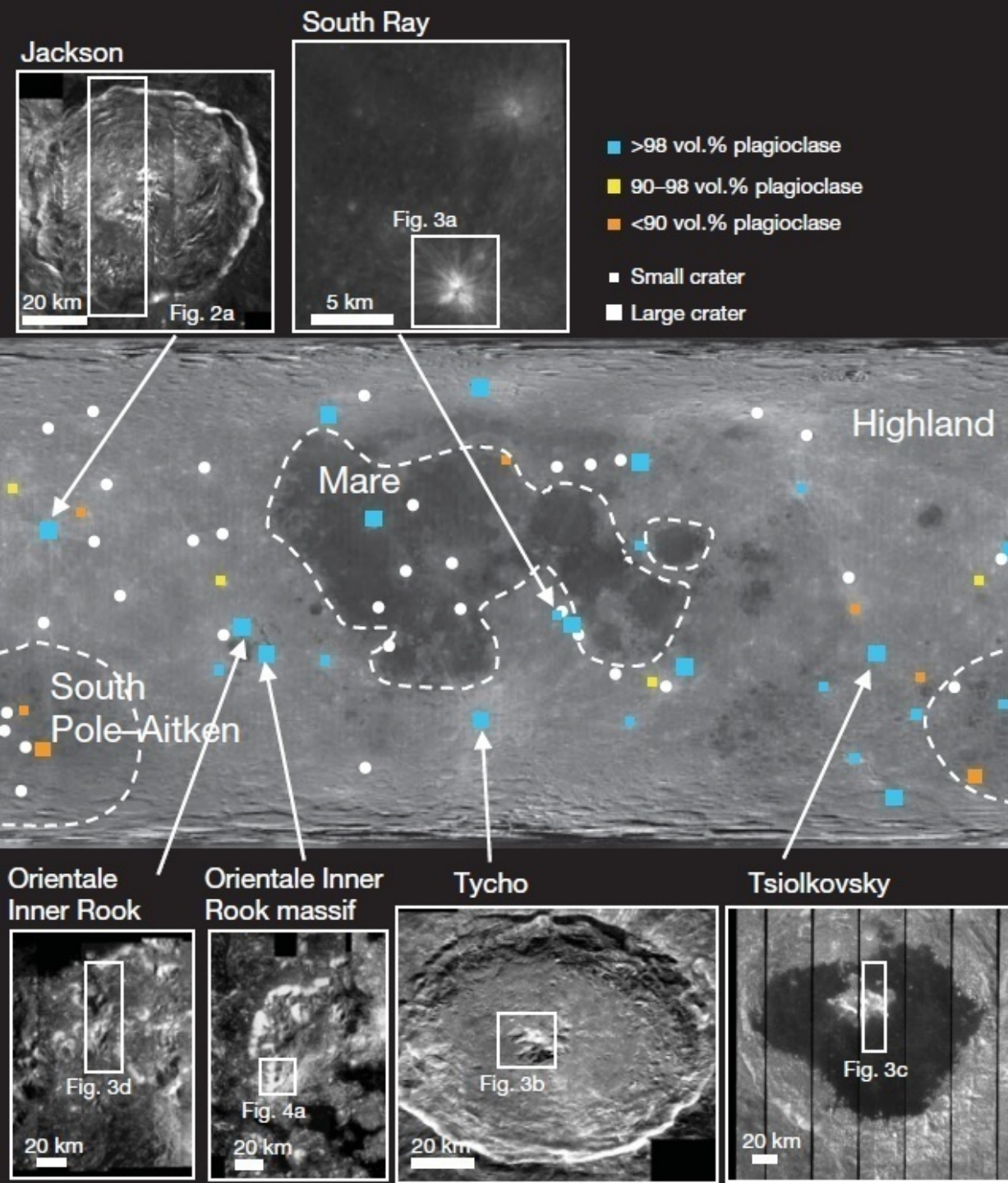
B: ティコクレータの
カラーコンポジット

C: ツオルコフスキークレータ
の
カラーコンポジット

D: オリエンタールクレータ
内リングの
カラーコンポジット

Ohtake et al., 2008

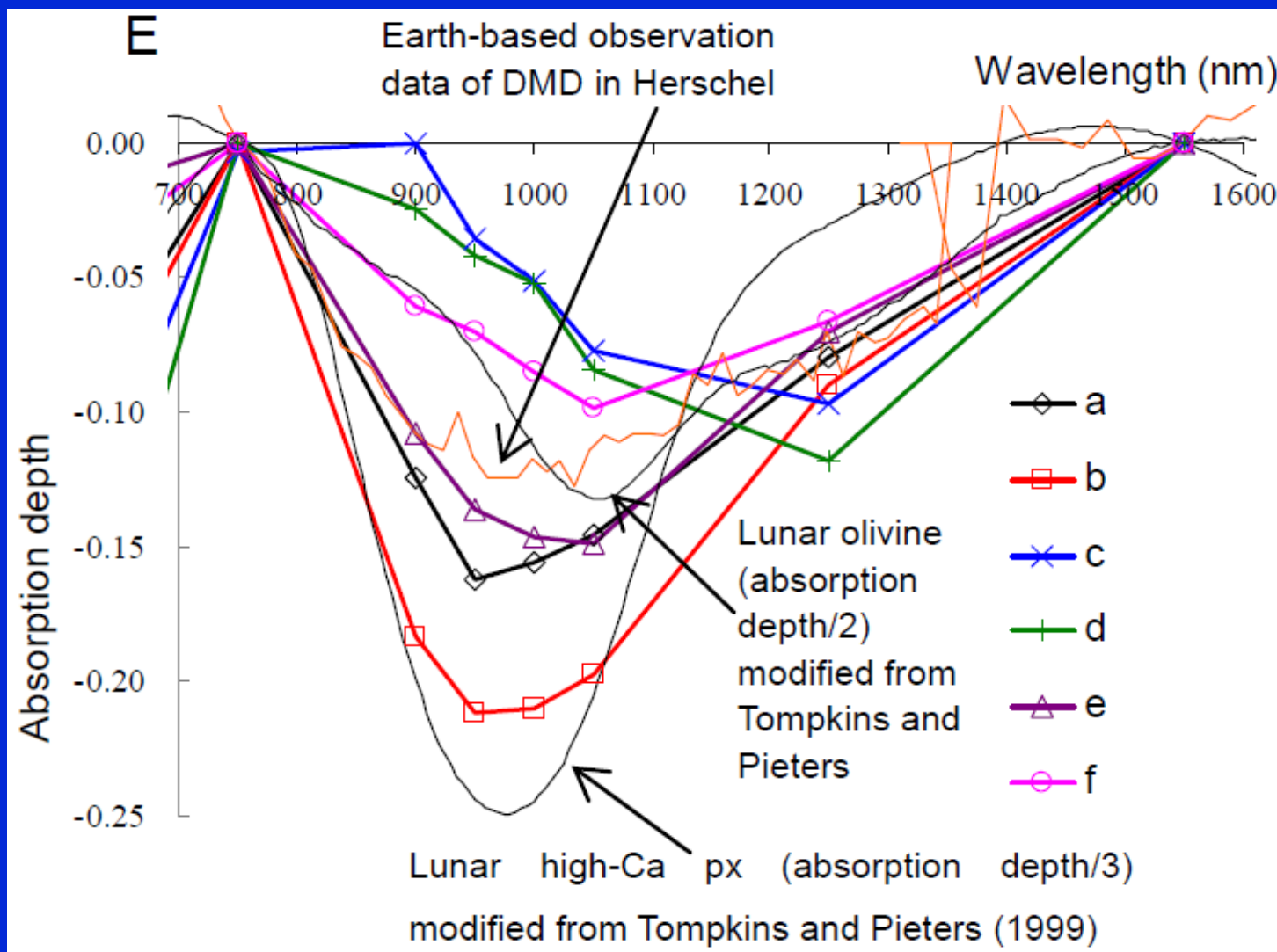
Global distribution of rocks of high plagioclase abundance



Ohtake et al., *Nature* **461**
(2009), 236-241

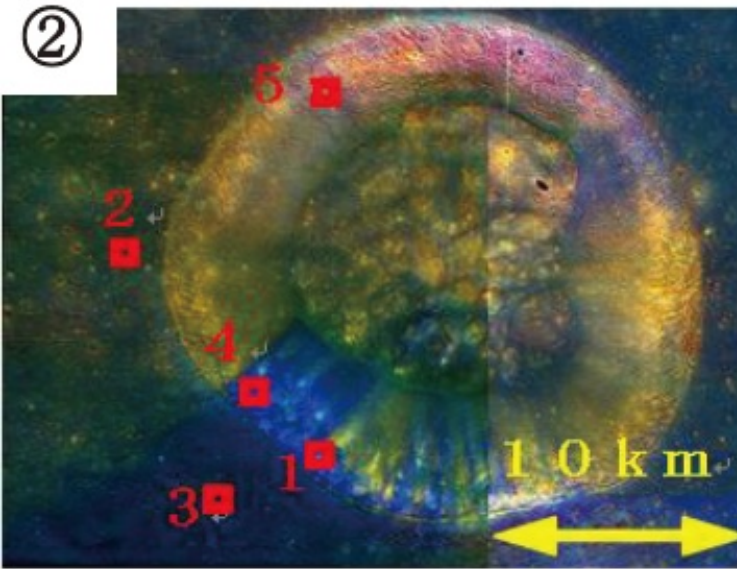
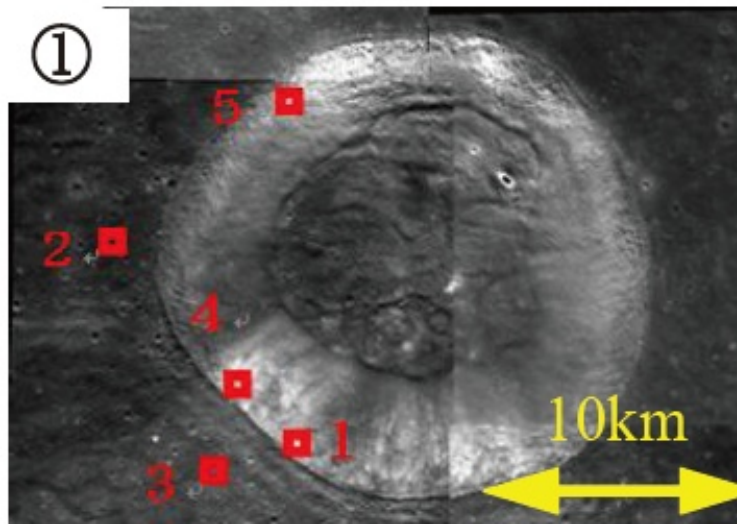


マルチバンドイメージャによる観測3.



E. B図中a-f点におけるマルチバンドスペクトル

South Pole-Aitken Lithology 2.



MI color composite of Poincare NE

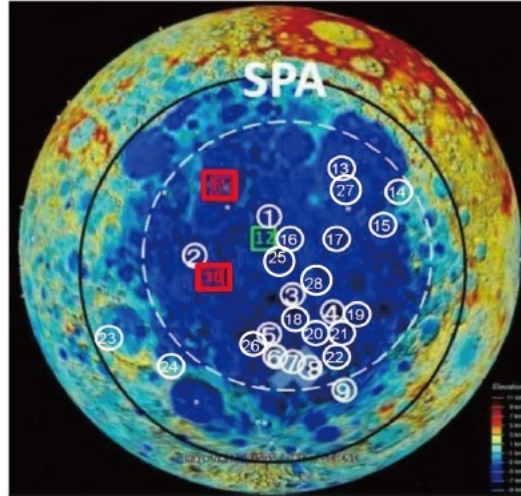
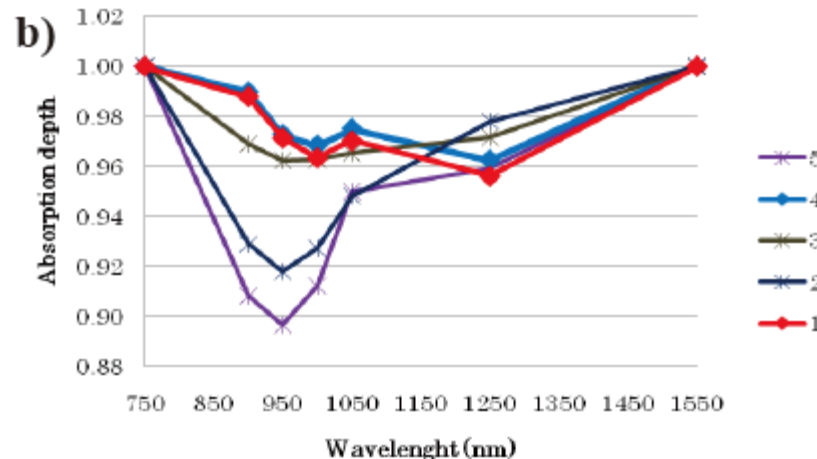


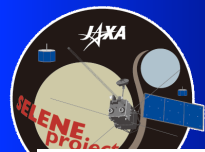
Figure 1. Distribution of the craters we analyzed in this study.

	CraterName	latitude	longitude	diameter(km)	PurestAnorthositic
1	AlderN	42S	181W	15	No
2	Hopmann	51S	180E	88	No
3	Bellingsgauzen	61S	164W	20	No
4	LemaitreW	62S	155W	8	No
5	MinnaertNE	64S	175W	20	No
6	Antoniadi	70S	168W	143	No
7	NumerovE	70S	154W	40	No
8	NumerovC	70S	163W	113	No
9	ZeemanN	70S	137W	30	No
10	PoincareNE	53S	161E	20	Yes
11	(Leipnitz)	47S	178W	77	Yes
12	(Alder)	38S	181W	245	(Yes)*
13	ApolloWa	35S	157W	334	No
14	BuffonSW	41S	134W	3	No
15	RidelW	48S	142W	42	No
16	AlderS	49S	177W	75	No
17	CoriE	50S	150W	56	No
18	Cabannes	61S	170W	73	No
19	FizeauW	58S	137W	96	No
20	Lemaitre	61S	149W	86	No
21	EijkmanE	62S	137W	50	No
22	Crommelin	68S	147W	88	No
23	VallisPlanckW	58S	122E	43	No
24	Schrodinger	66S	128E	35	No
25	AlderSrim	50S	177W	75	No
26	AntoniadiWrim	68S	177W	143	No
27	ApolloWb	36S	155W	7	No
28	BoseW	54S	170W	4	No

Table.1 The list of the craters we analyzed



Uemoto et al., 2010



スペクトルプラファイラーの特徴

SP

衛星進行方向
Spacecraft orbit

SP VIS(可視光): 500 - 1000 nm
SP NIR1(近赤外): 900 - 1700 nm
SP NIR2(近赤外): 1700 - 2600 nm
(波長分解能 Resolution 6 - 8 nm)

回折格子による連続分光

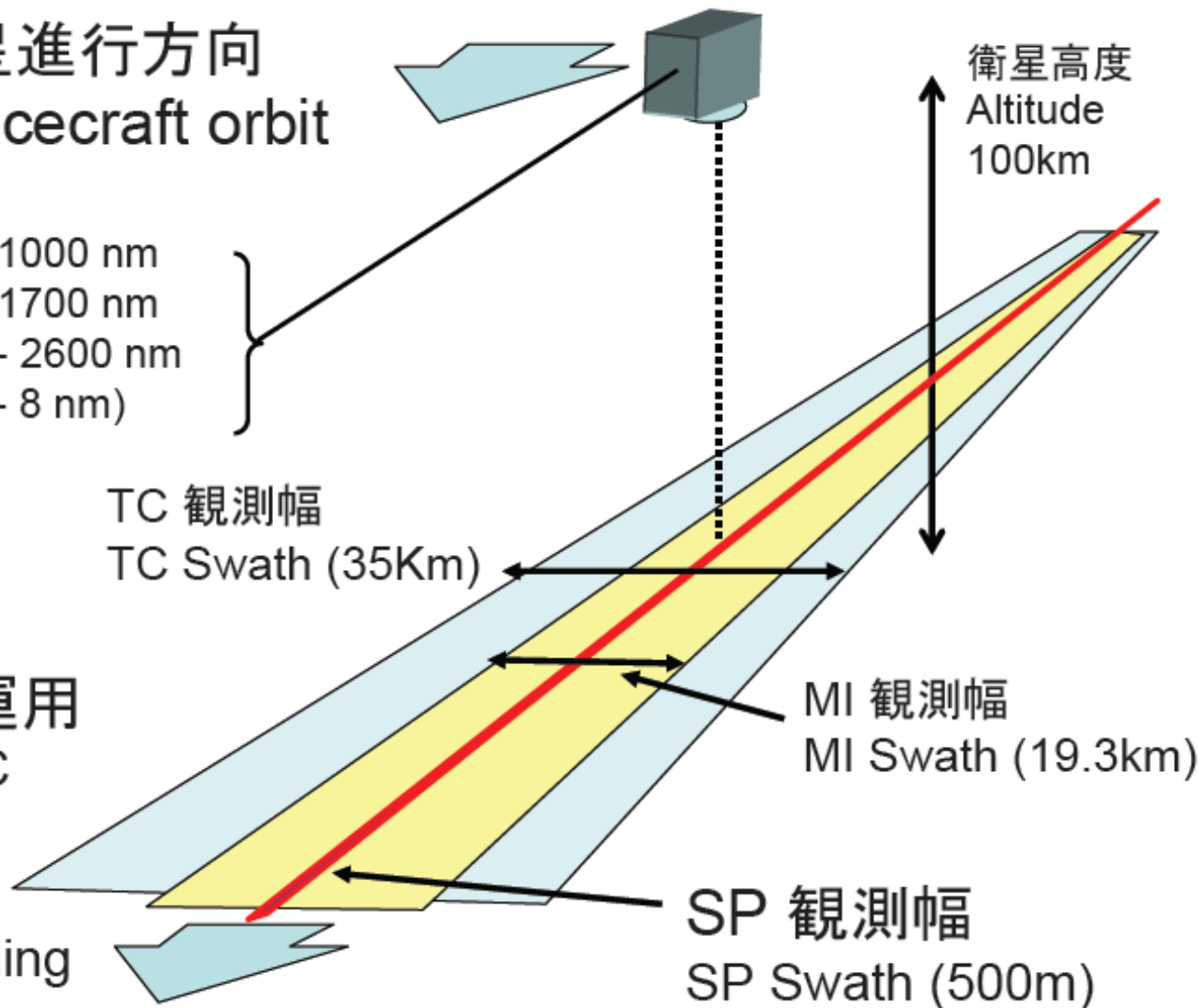
TC 観測幅
TC Swath (35Km)

MIやTCとの同時運用
Operation with MI/TC

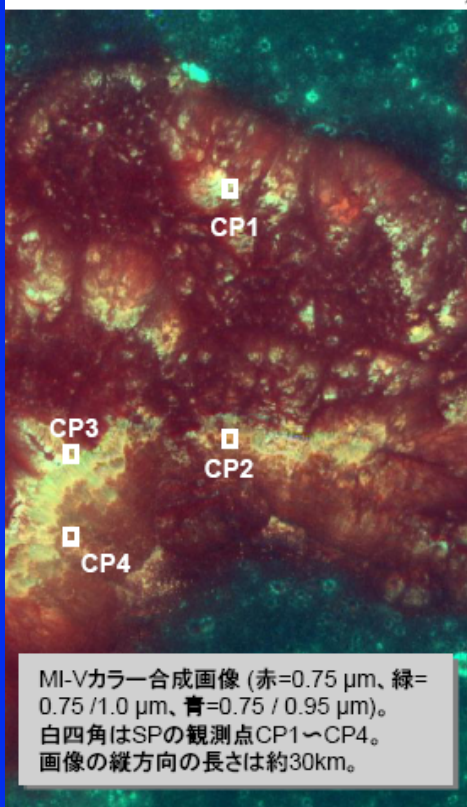
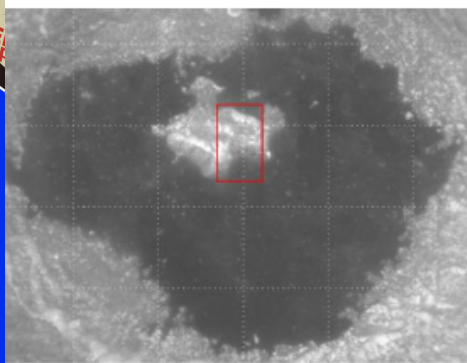
MI 観測幅
MI Swath (19.3km)

測線観測 Line profiling

SP 観測幅
SP Swath (500m)

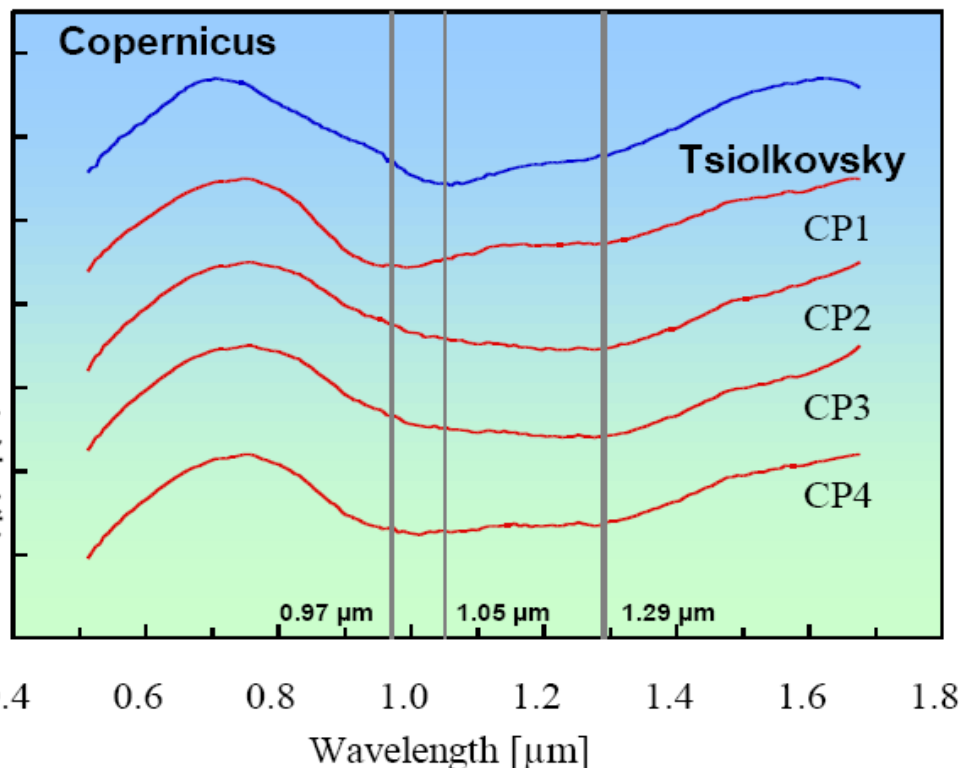


月裏側のTsiolkovsky中央丘の岩相の解明



MI-Vカラー合成画像 (赤=0.75 μm 、緑=0.75 / 1.0 μm 、青=0.75 / 0.95 μm)。
白四角はSPの観測点CP1～CP4。
画像の縦方向の長さは約30km。

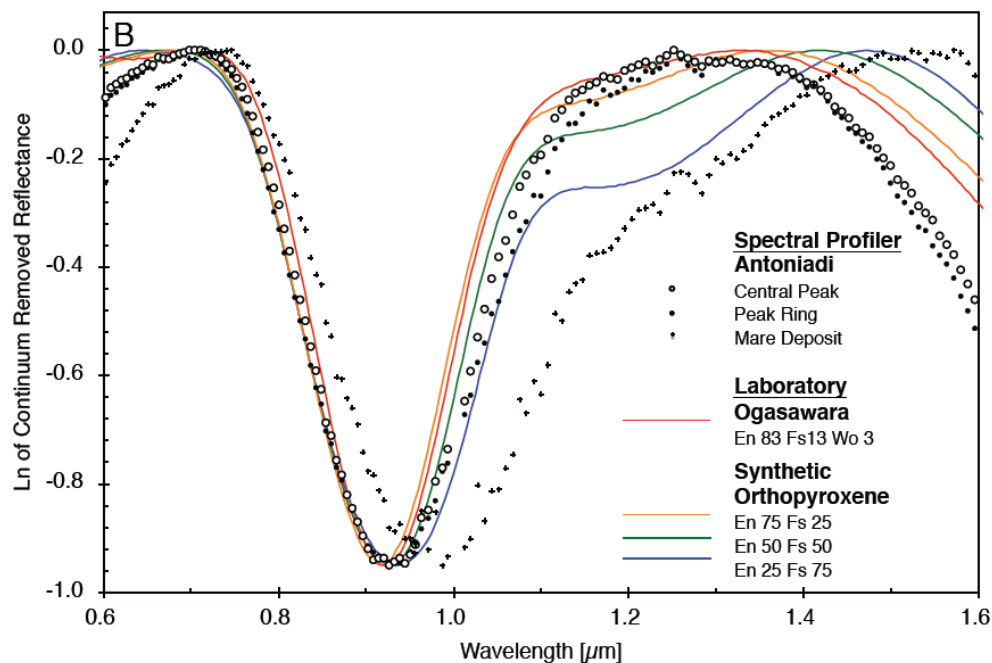
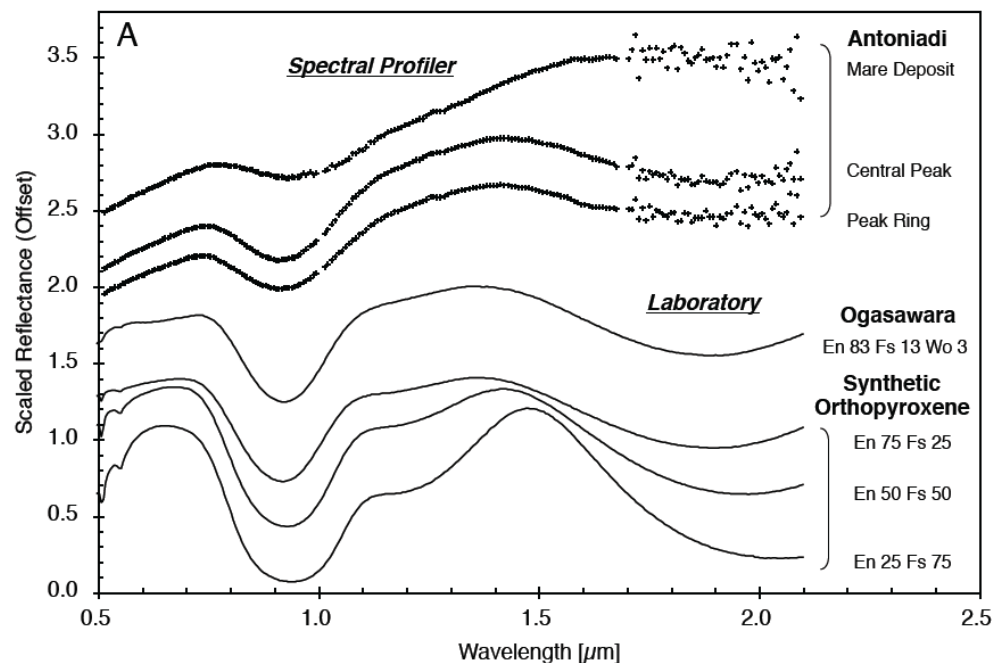
Scaled reflectance(反射率)



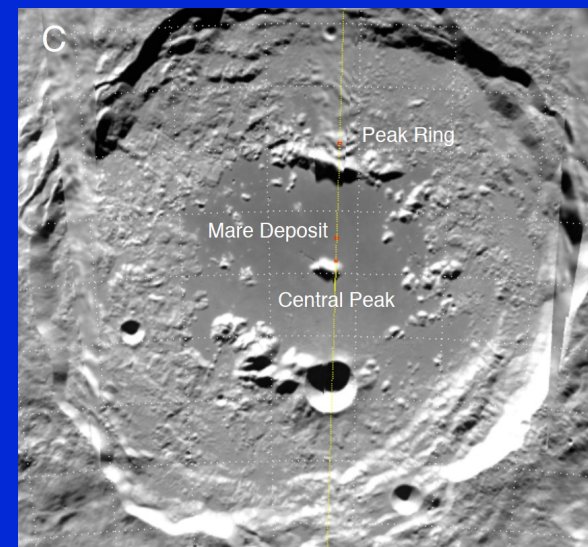
図の説明:
横軸: 波長
(単位: μm)
縦軸: 宇宙風化の影響を軽減
するため、接線除去処理を
適用した後の月面反射率
(目盛りは、0.1刻み)。
※見やすくするため、5つの
グラフはオフセットを与え、
上下にずらした。
データ:
SPの観測データ
青: Copernicusクレータ
の中央丘。
かんらん石を含む
典型的な中央丘。
赤: Tsiolkovskyクレータ
の中央丘。MI画像中
で黄色の部分
(4箇所)。

SPの観測結果:

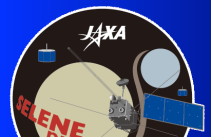
- Copernicus: 1.05 μm に極小値を持つ典型的なかんらん石のスペクトルが見られた。
- Tsiolkovsky: 反射率が、0.9 μm > 0.95 μm > 1 μm (右下がり) となっはいるが、1 μm より長波長側において、かんらん石の特徴である1.05 μm に極小値を持つものではなく、0.97 μm と1.29 μm に極小値が見られた。前者は輝石、後者は斜長石の吸収の中心波長に相当する。従ってこの地域には、かんらん石ではなく、斜長石と輝石の混合物が分布していると考えられる。
- これまでの研究で「かんらん石が露出している」とされたクレータにおいても、SPによる再調査が必要と考えられる。



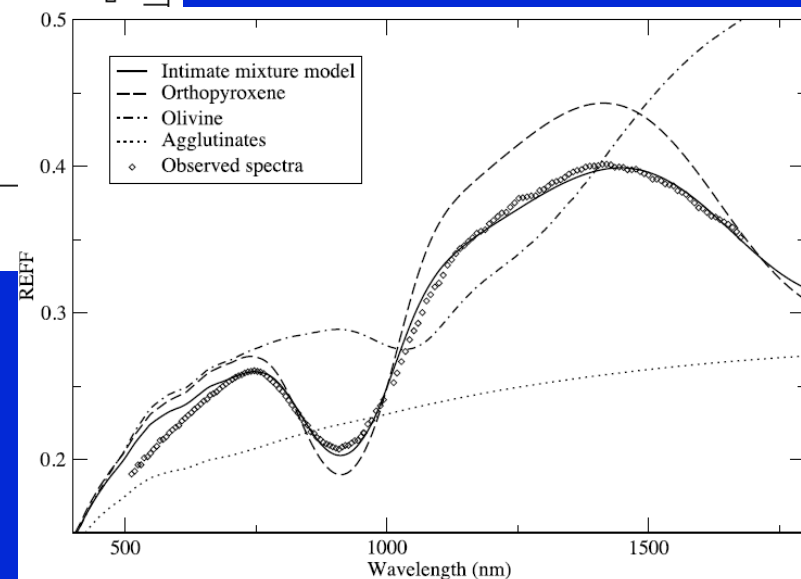
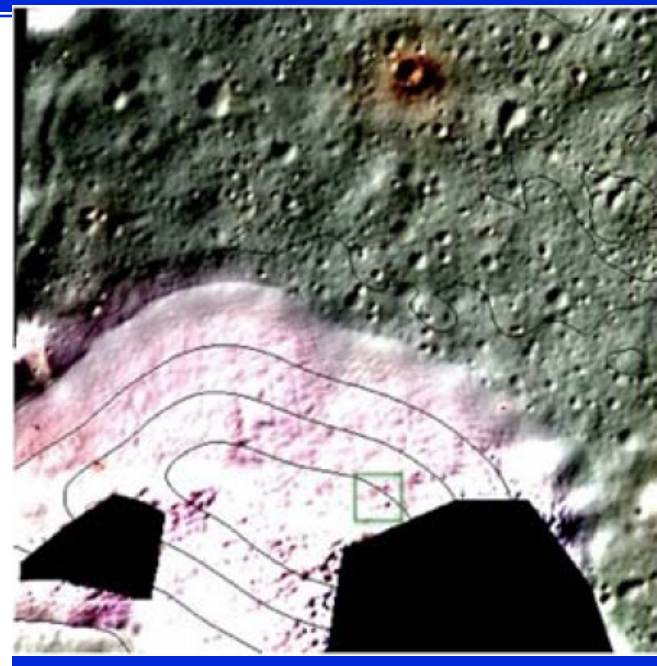
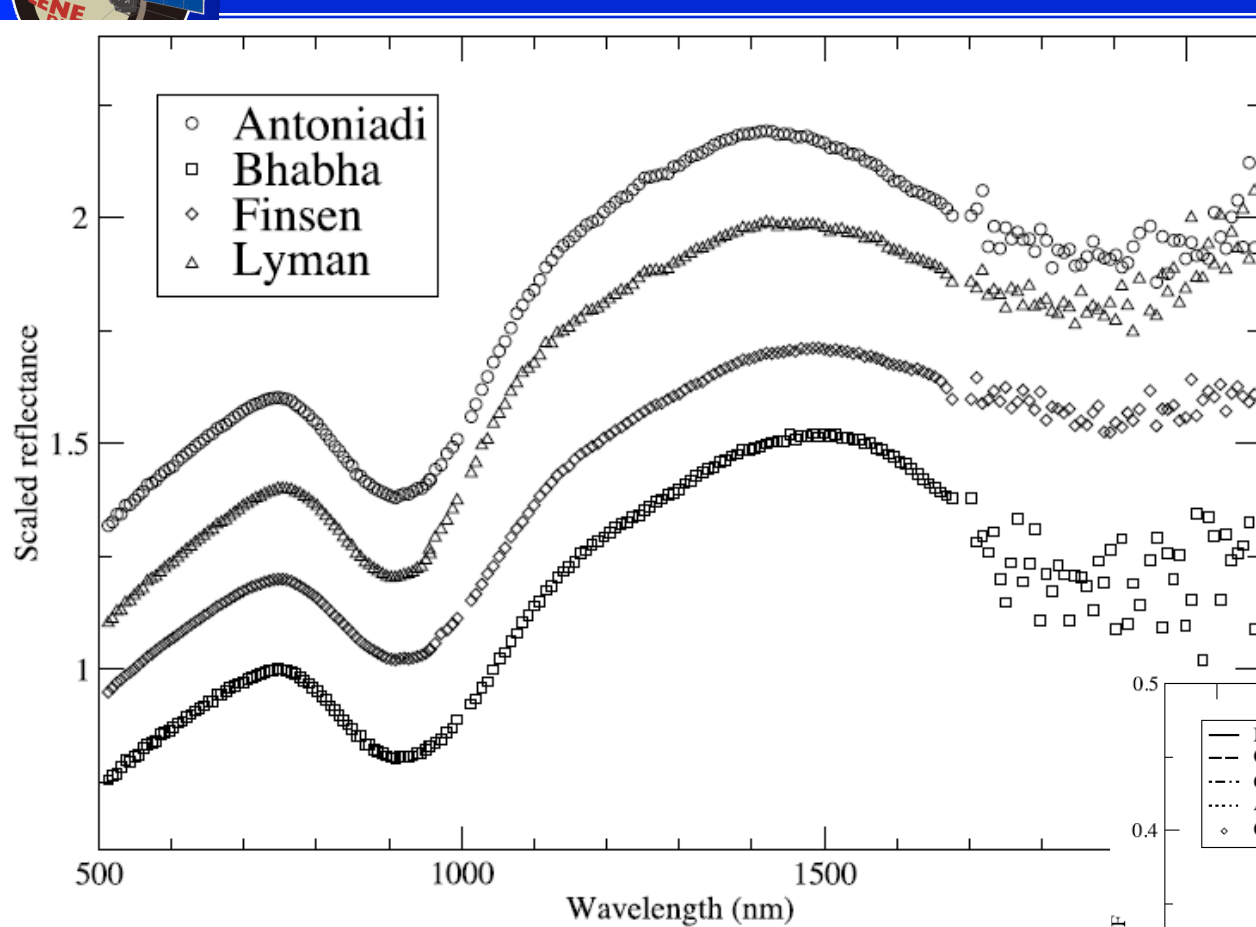
Spectral Profiler SP Observation of Antoniadi Crater



Matsunaga et al., 2008



South Pole-Aitken lithology 1.



SELENE

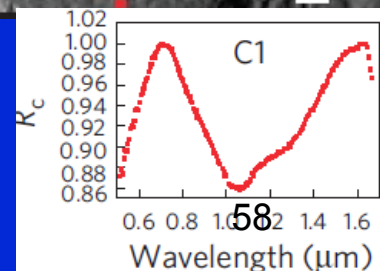
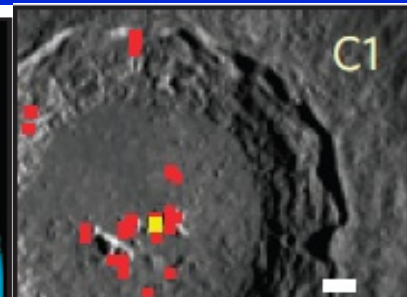
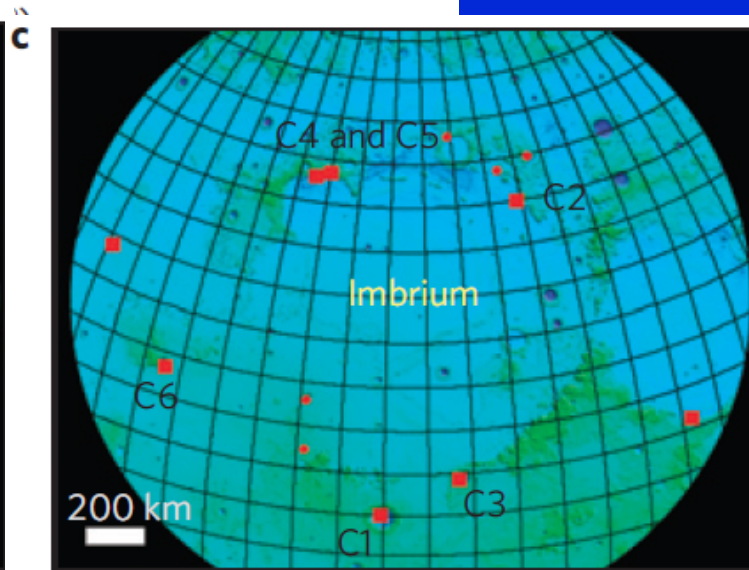
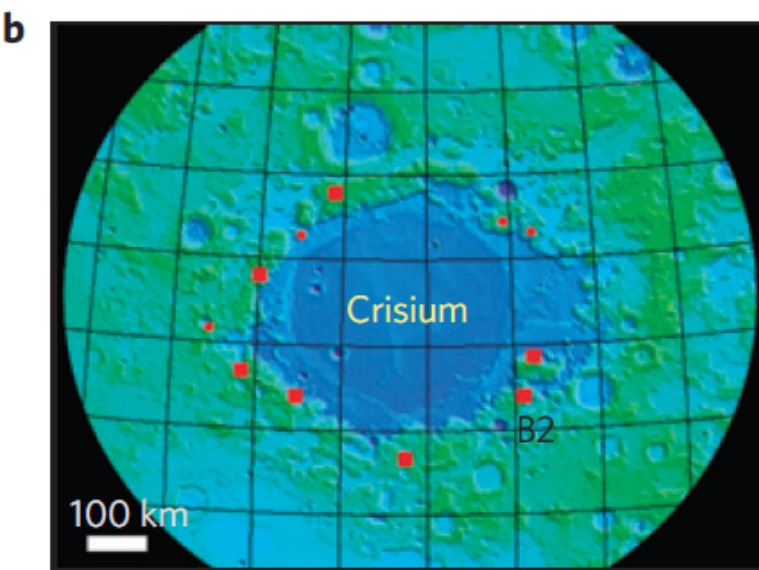
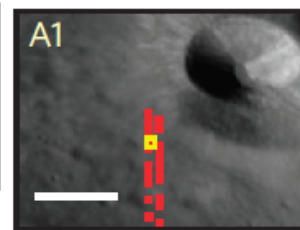
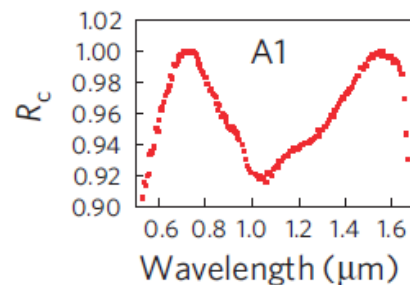
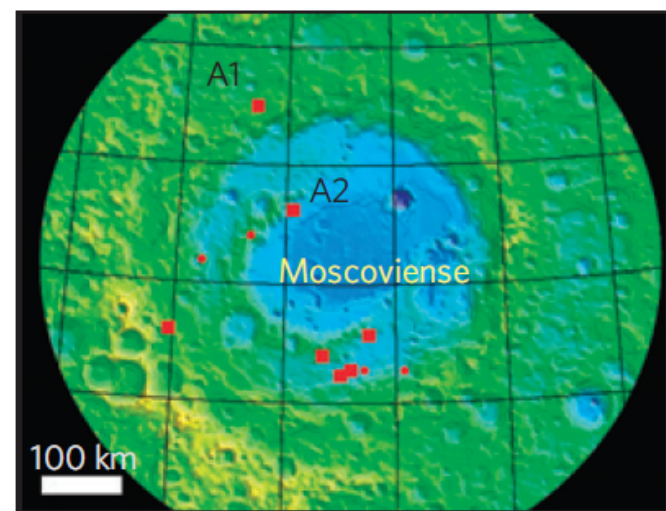
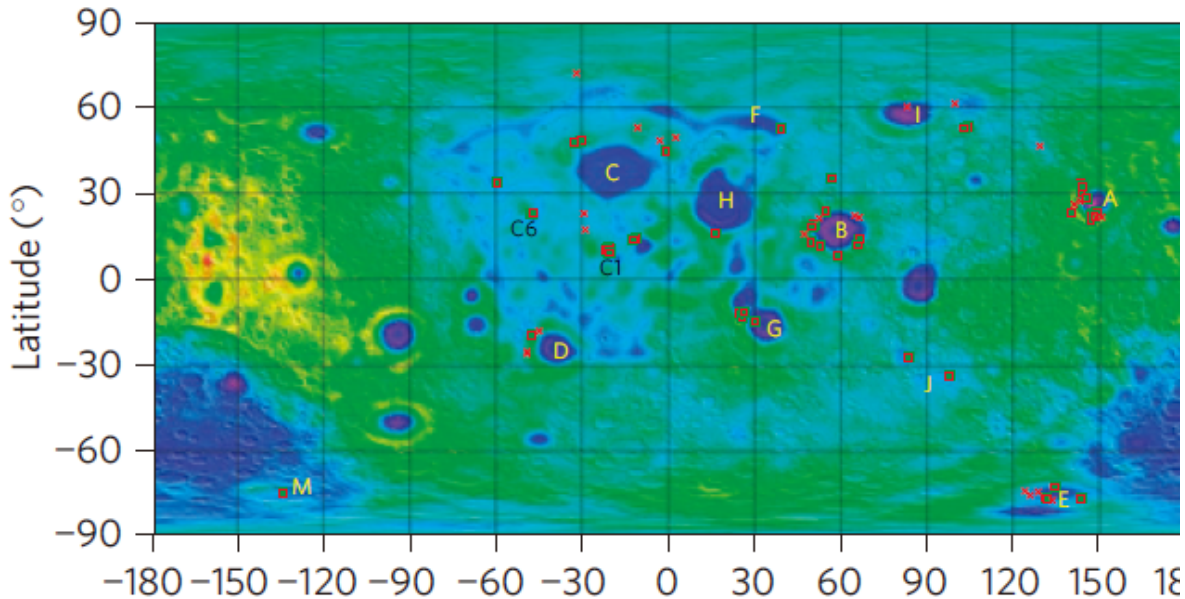
Nakamura et al., *GRL* 36(2009), L22202

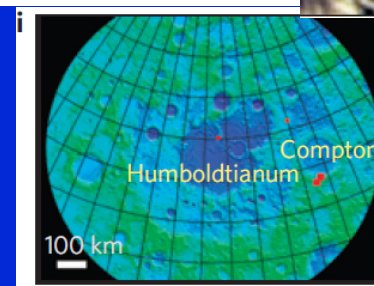
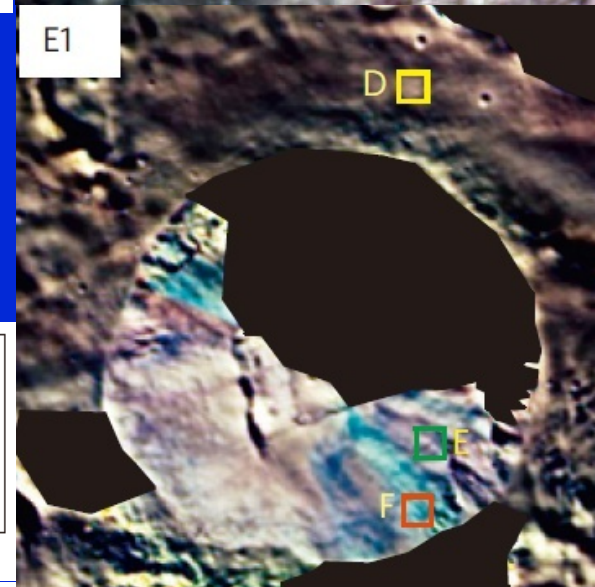
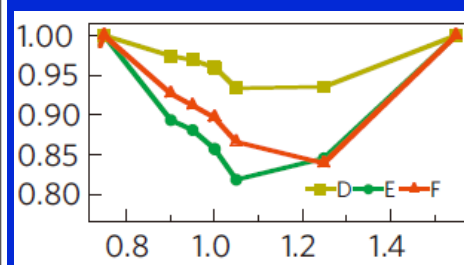
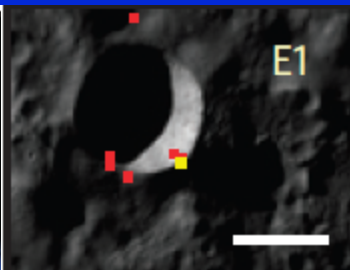
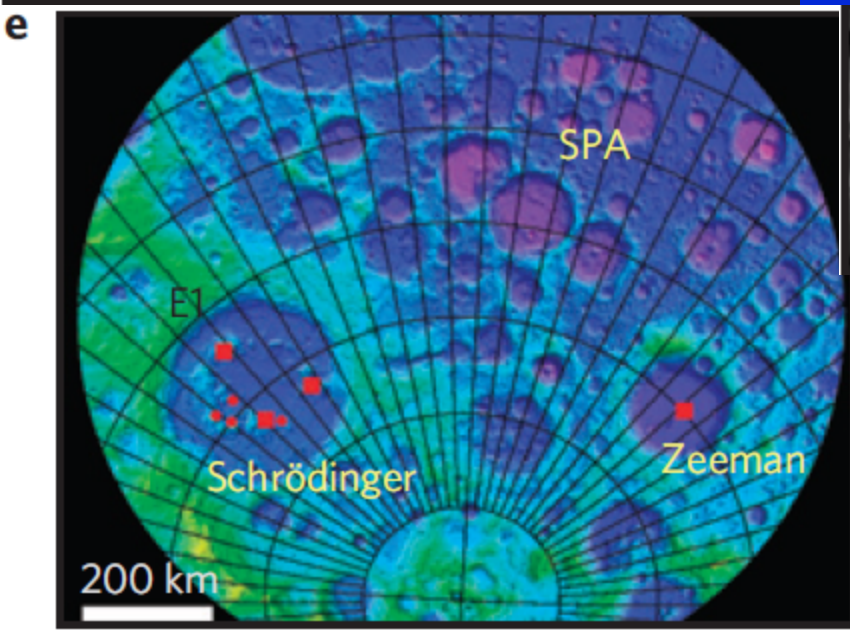
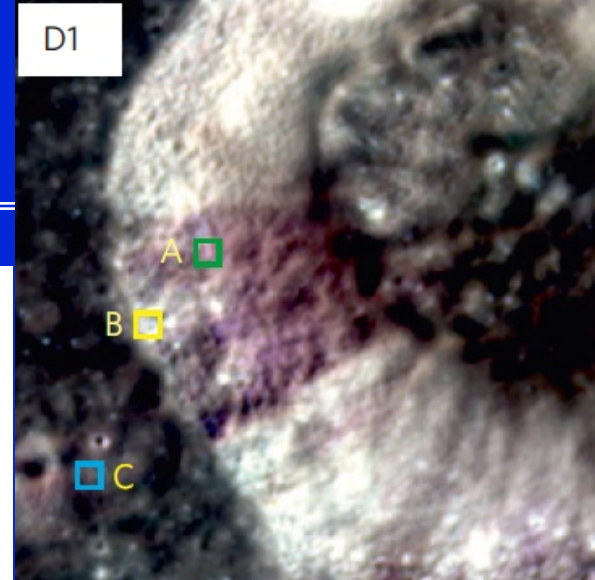
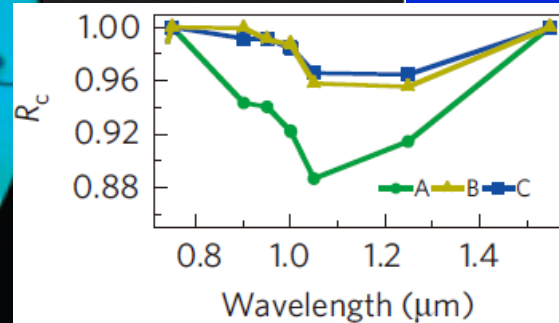
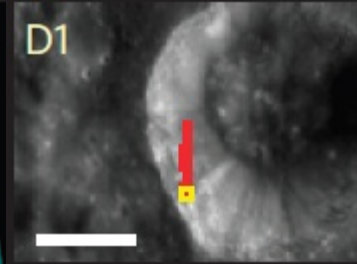
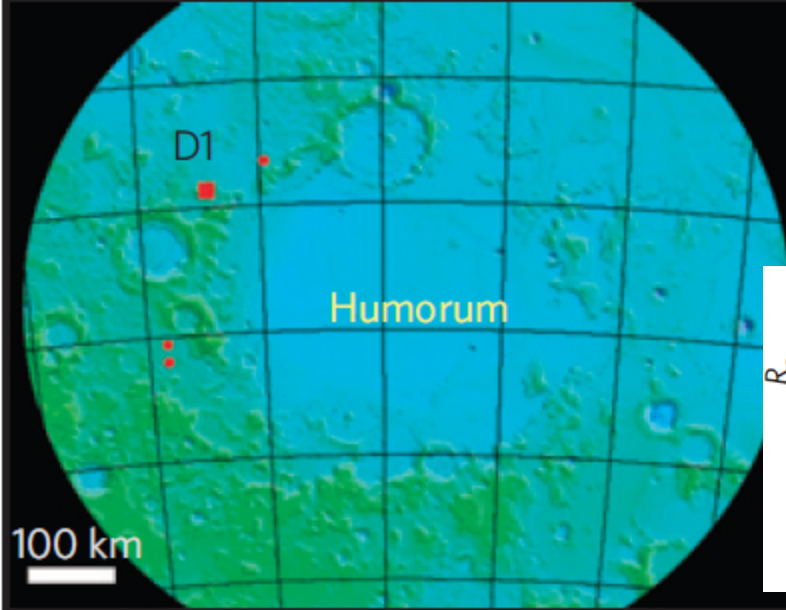
c.p. of Antoniadi crater:
74.1wt%Opx+ 11.1%Ol+14.8%Aggl.

Possible mantle origin of olivine around lunar impact basins detected by SELENE

Nature Geosci. **3** (2010)

Satoru Yamamoto^{1*}, Ryosuke Nakamura², Tsuneo Matsunaga¹, Yoshiko Ogawa³, Yoshiaki Ishihara⁴, Tomokatsu Morota⁵, Naru Hirata³, Makiko Ohtake⁵, Takahiro Hiroi⁶, Yasuhiro Yokota¹ and Junichi Haruyama⁵



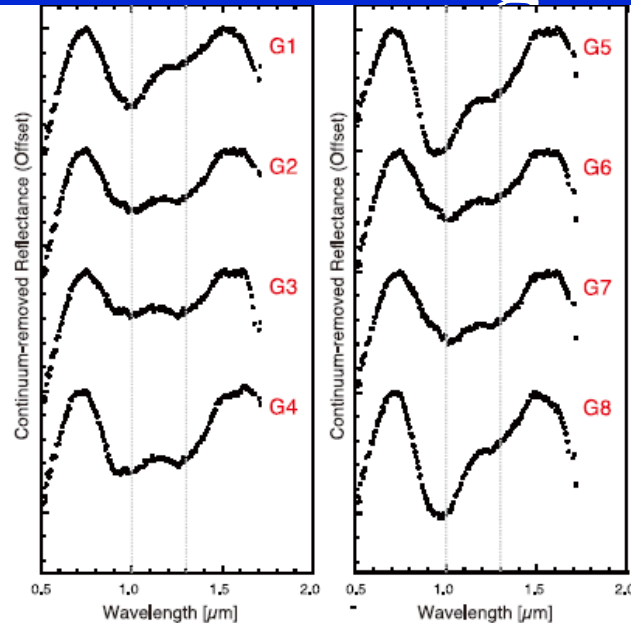
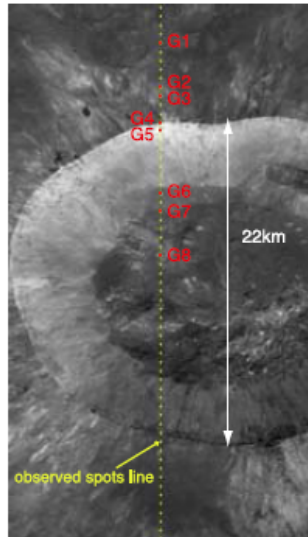


SE

Mineralogy of fresh rayed craters in highlands



(a)



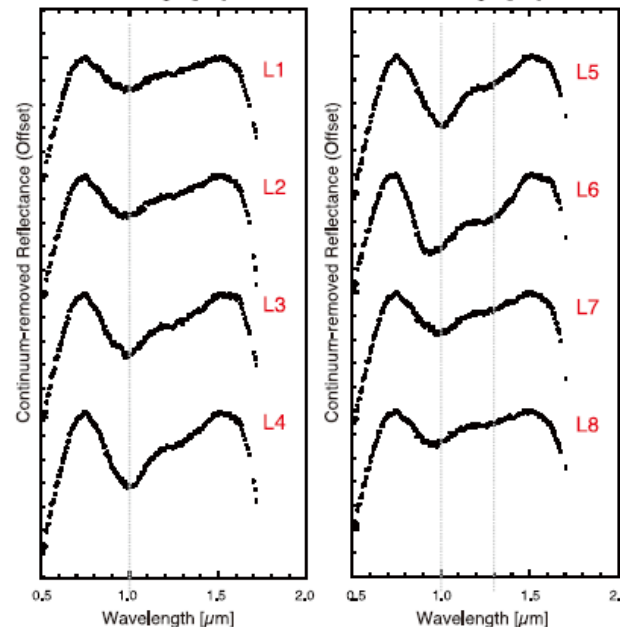
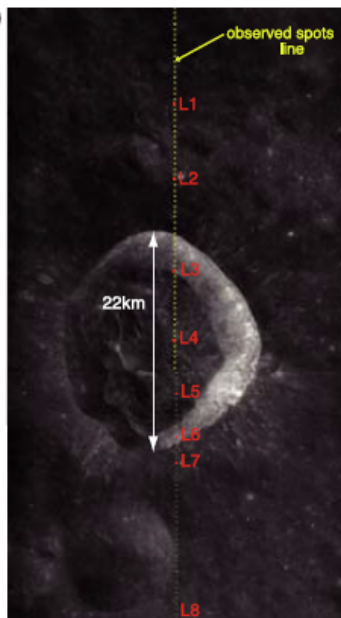
HCP - LCP

Giordano Bruno

22 km dia.

35.9N/102.8E

b)



Larmor Q

22 km dia.

28.6N/ 176.2E

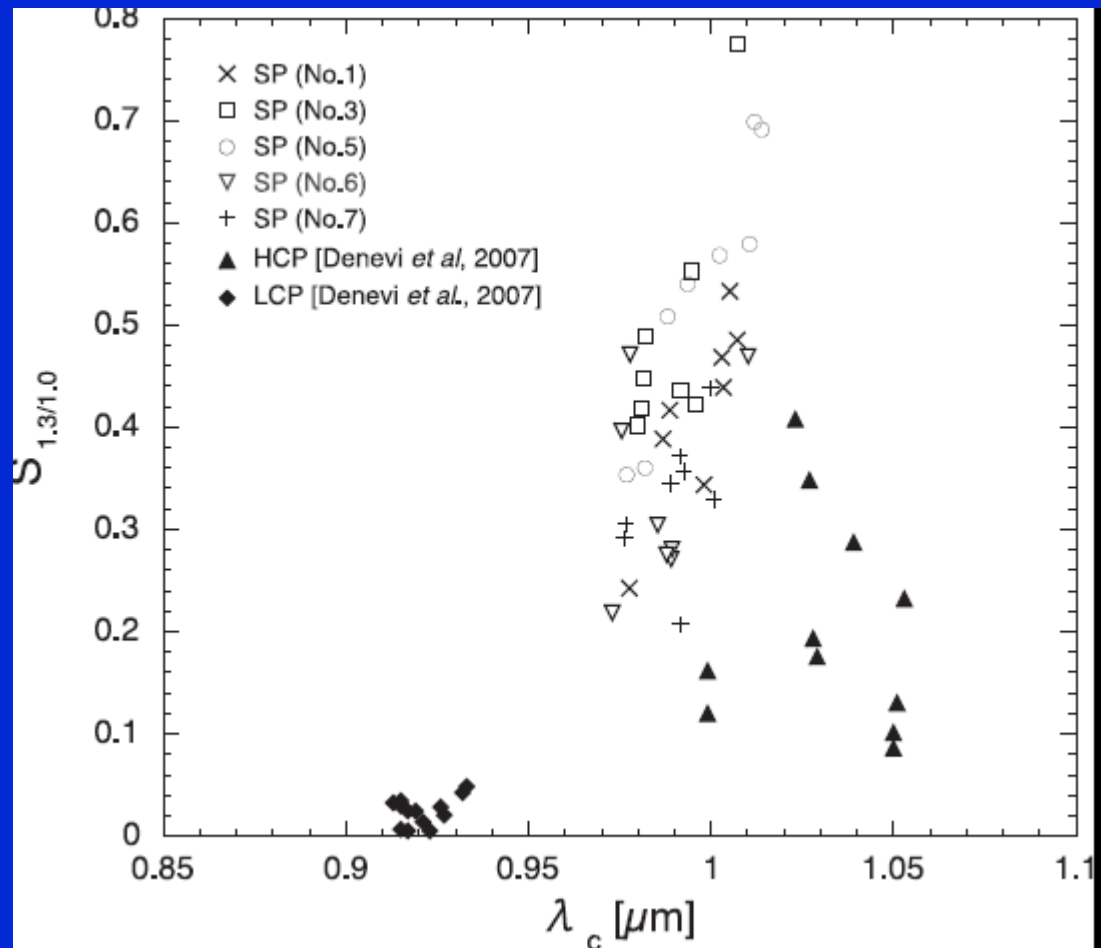
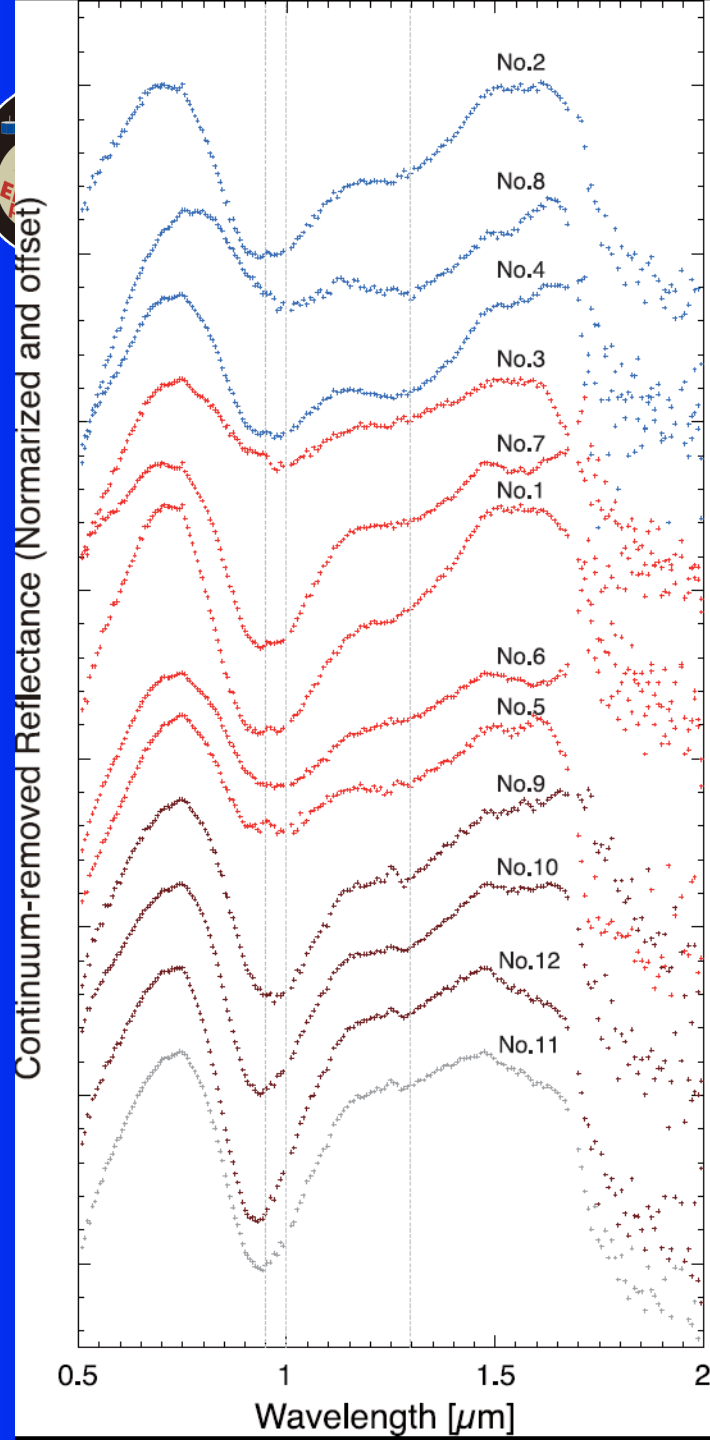
Ogawa et al., *GRL*38, in press

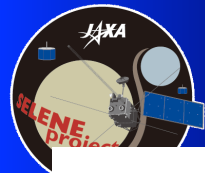
HCP dominant craters

Blue plots: Type A

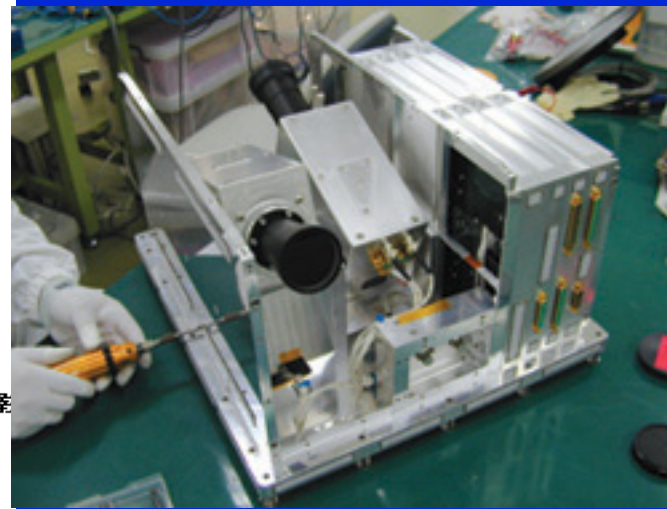
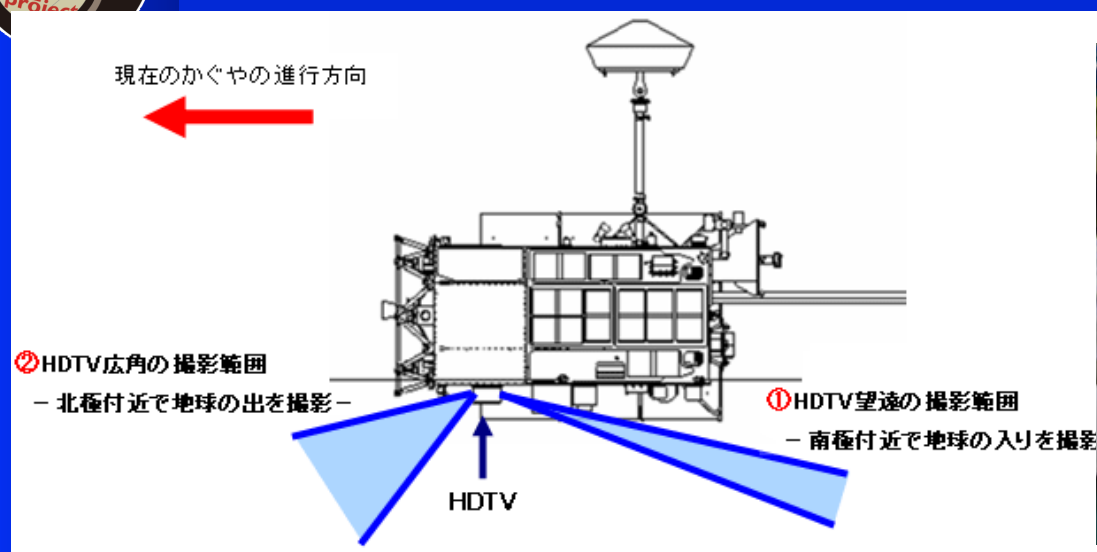
Red plots: Type B

Grey plots: Type B, Ejecta Blankets

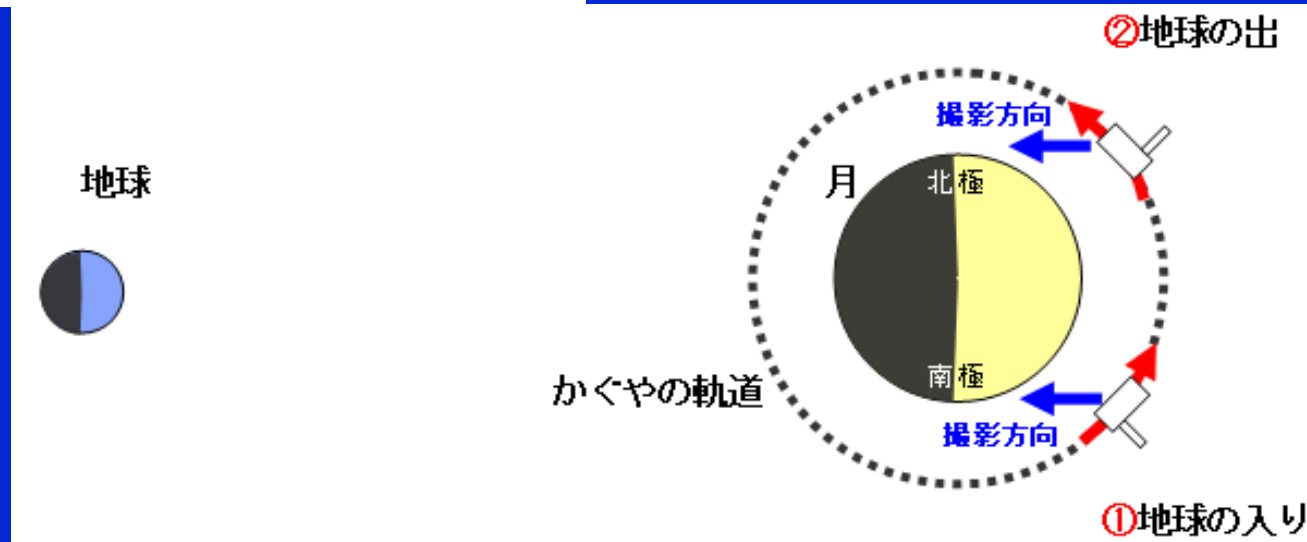




ハイビジョンカメラHDTV



SELenological and EN



Optic System of HDTV

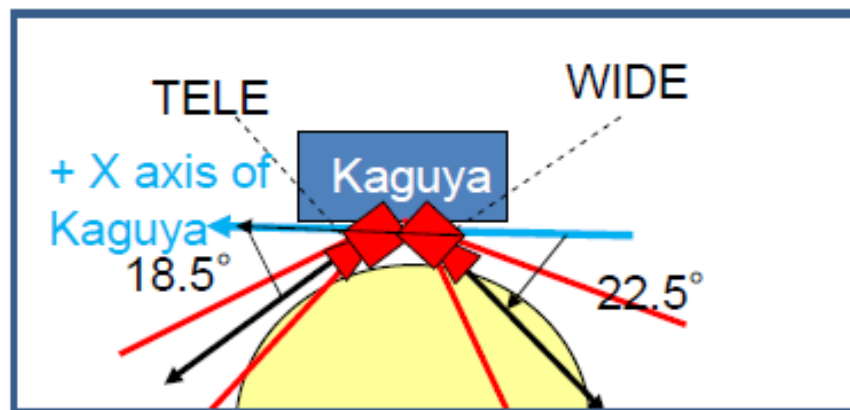
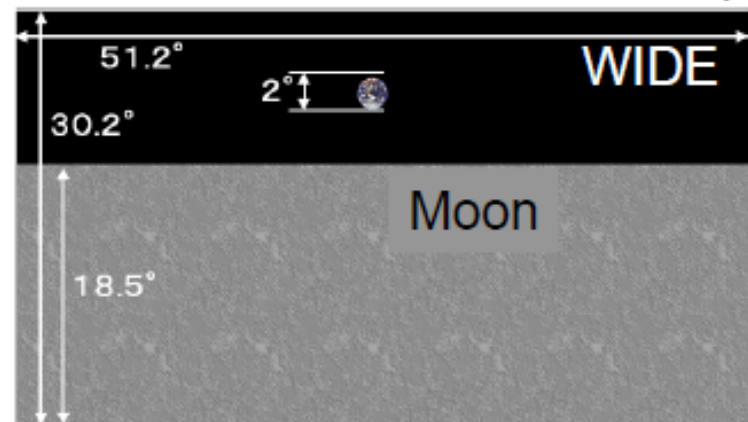


Figure 3 Mounting location of HDTV

Table 1 Specification HDTV optics

Item	Telephoto	Wide-angle
Focal length	35 mm	10 mm
View angle	15.5 (H) x 8.7 (V), 17.8 (D)	50.1 (H) x 29.5 (V), 56.3 (D)
F number	F5.6 (fixed)	F5.6 (fixed)
ND filter	1/8	1
Dimensions	81.5 (L) x 60 (D)	112.5 (L) x 60 (D)
Weight	260 g	330 g
Mounting Angle	18.5 deg.	22.5 deg.
Field of view	15.5 deg x 8.8 deg	51.5 deg x 29.5 deg
Main object	Earth	Moon

Resolution > 85m/pixel



Resolution > 45 m/pixel

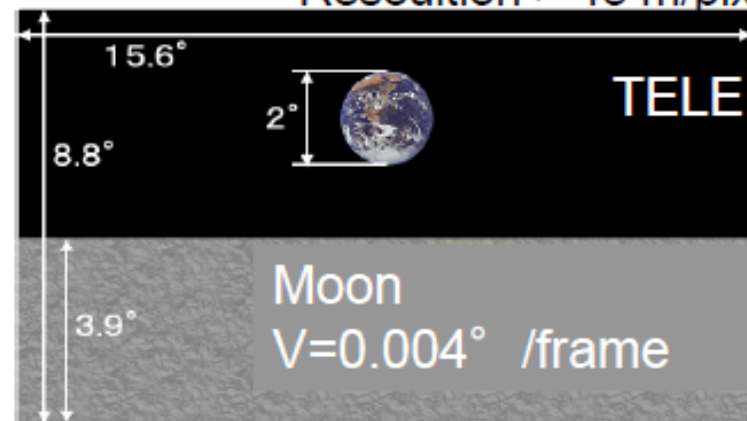


Figure 4. Schematic view of HDTV images for WIDE and TELE.
1920pixel x 1080pixel

Coverage (as of 26th Nov., 2008)

- 128 movies and 141 still images are acquired (corresponding to 229858 images in total).
- The data amounts to 1.37 TB after decompression.

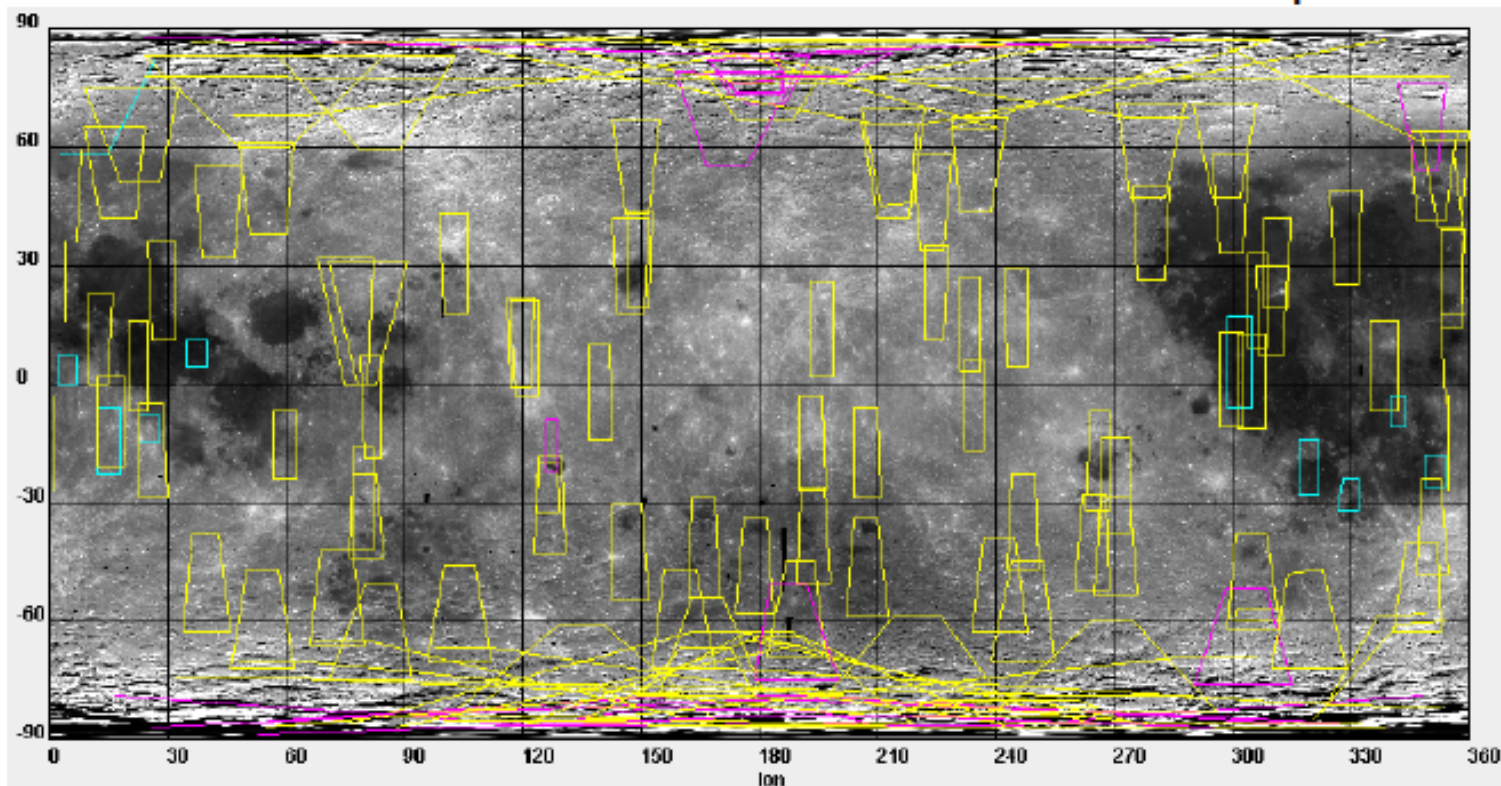
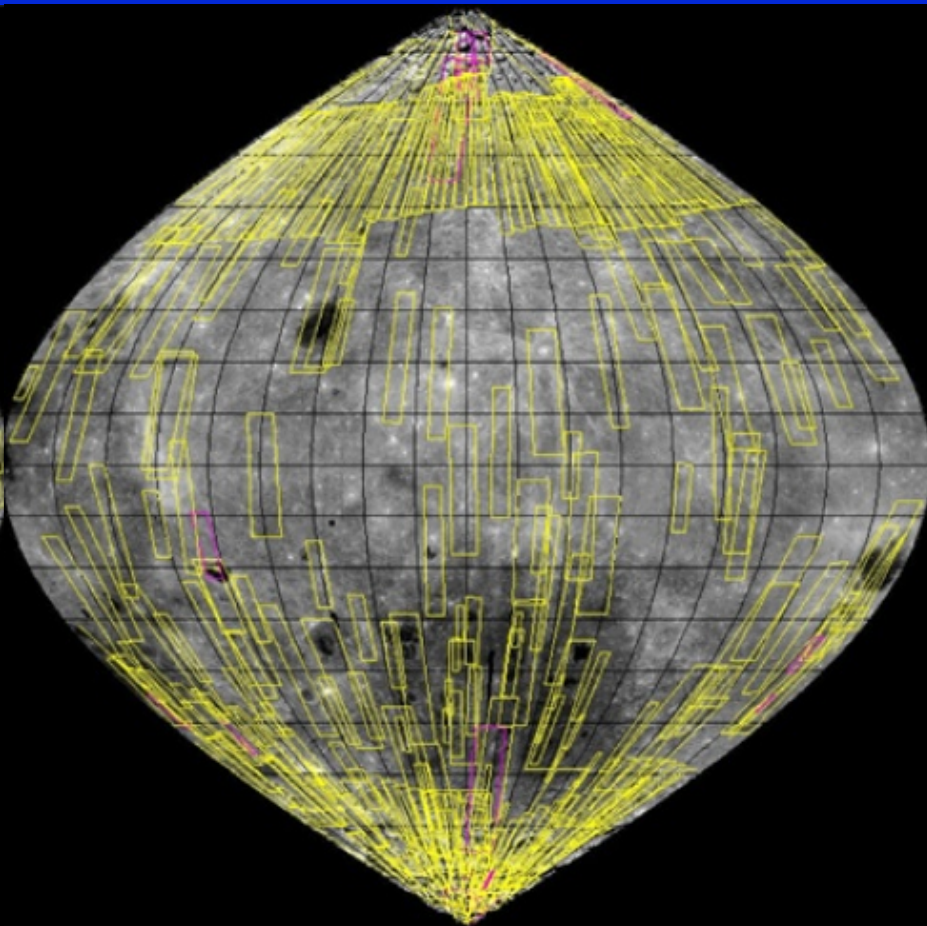
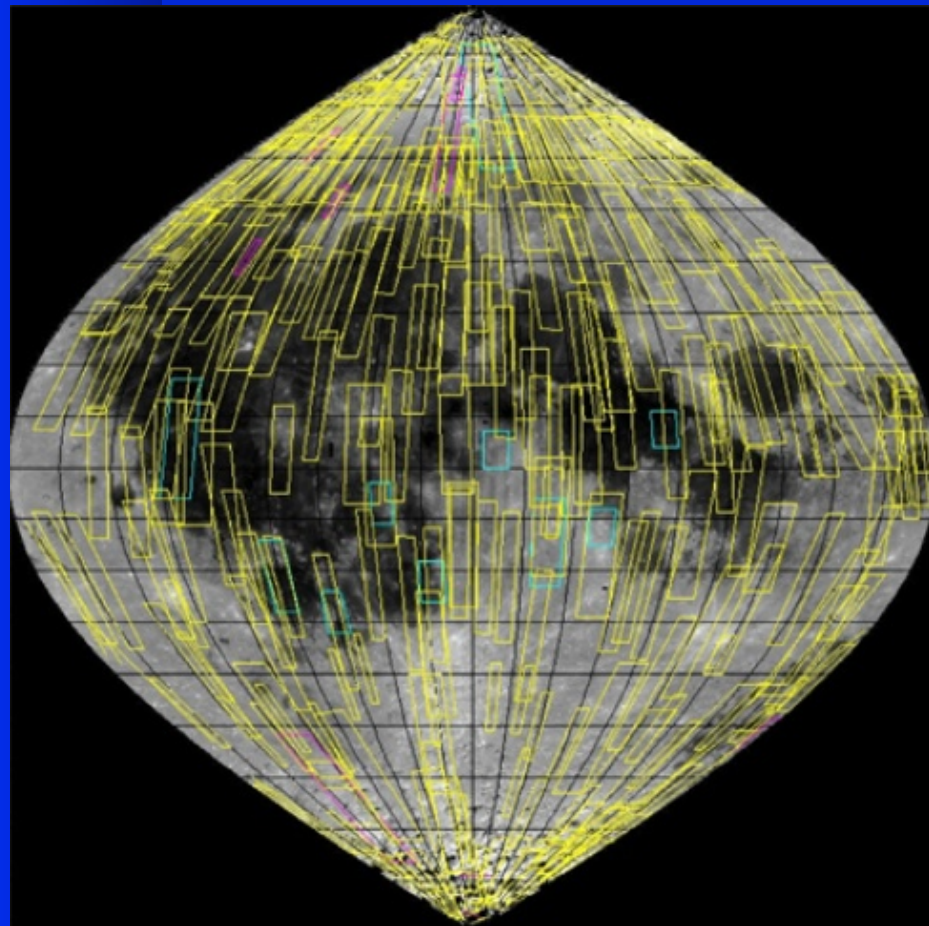
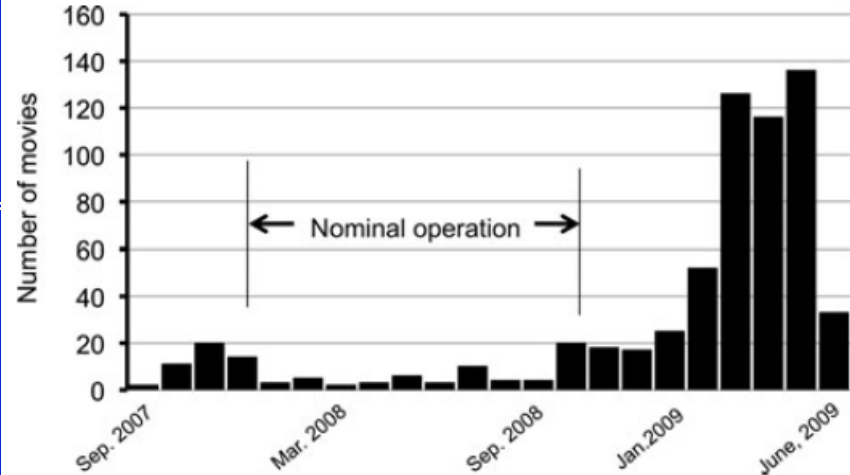


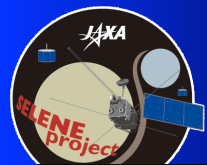
Fig. 6 Footprints of HDTV movies obtained.



Explorer

HDTVによる月面の 高精細撮影





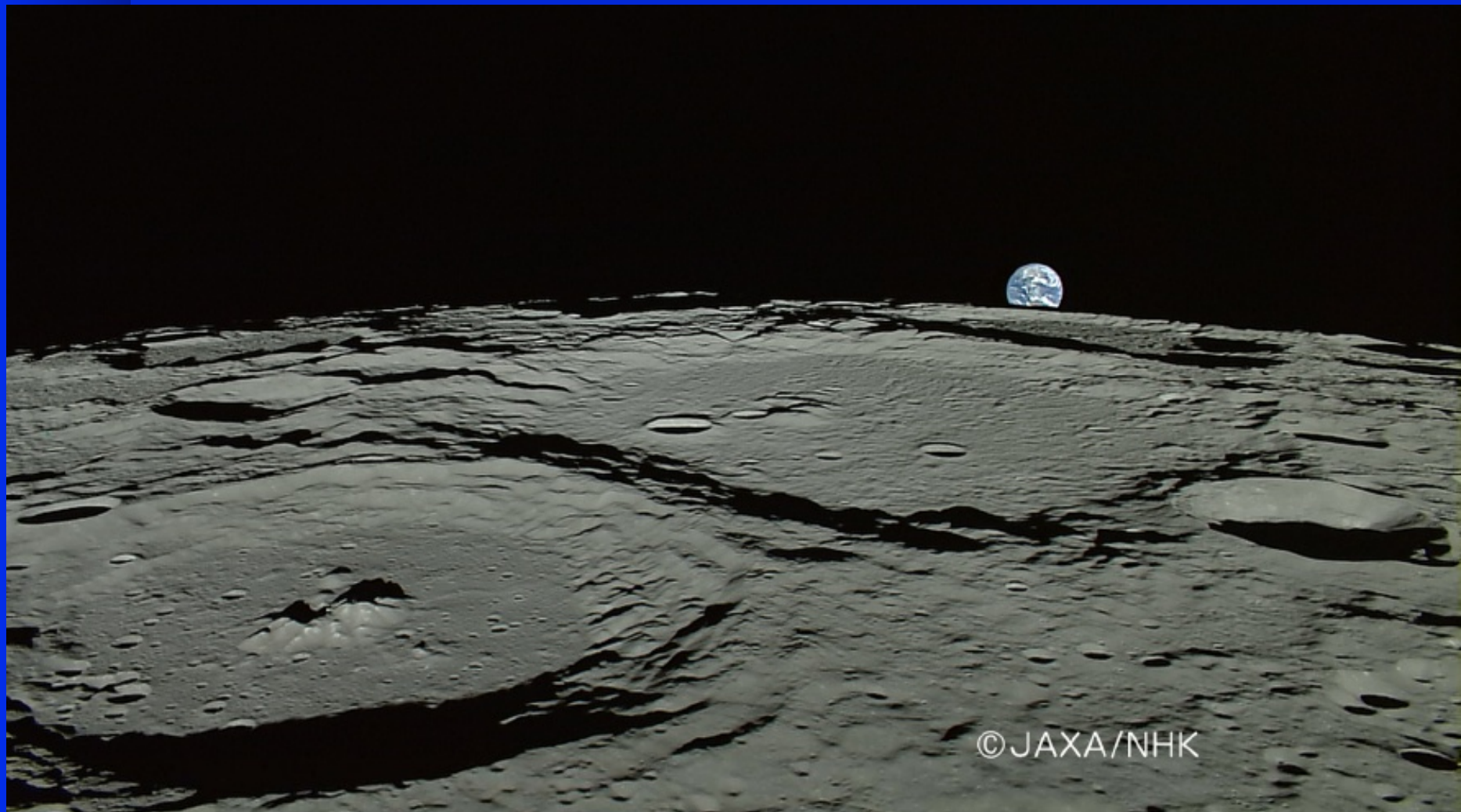
南極に上る“満地球”

©JAXA/NHK





北極に沈む“満地球”

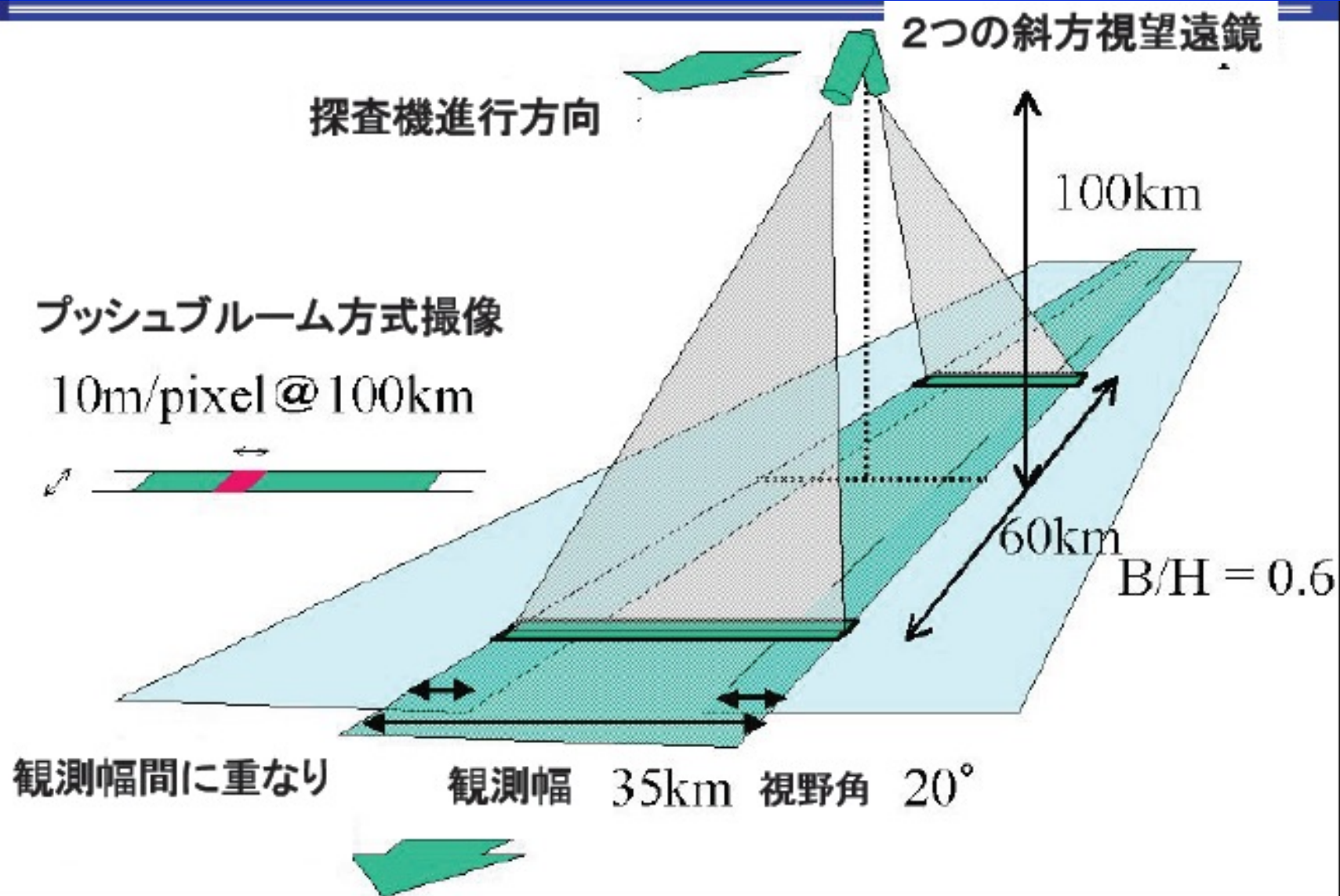


©JAXA/NHK

プラスキットクレータ(直径109km)、ロジェスト Bensキークレータ(直径177km)

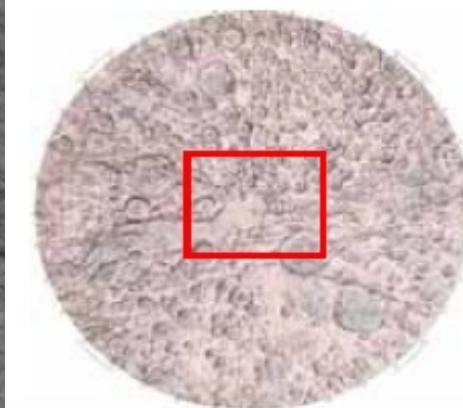
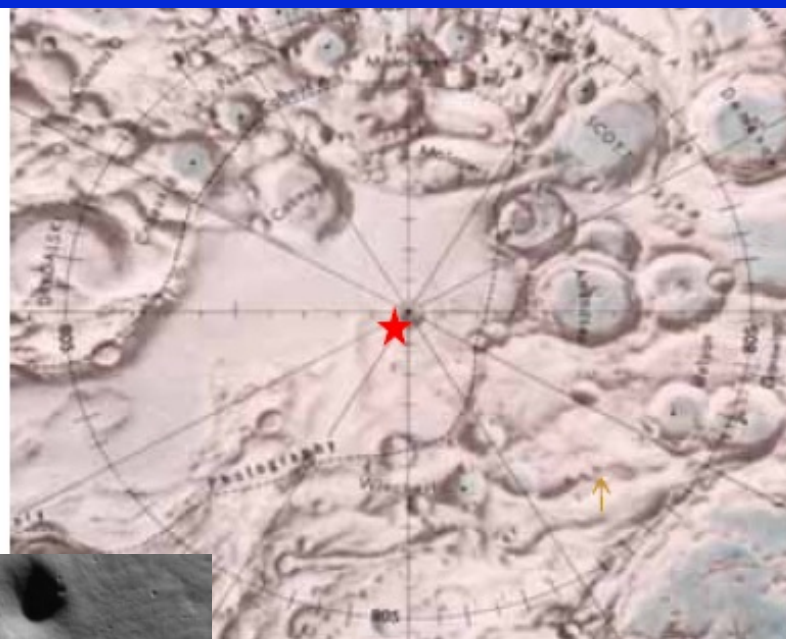
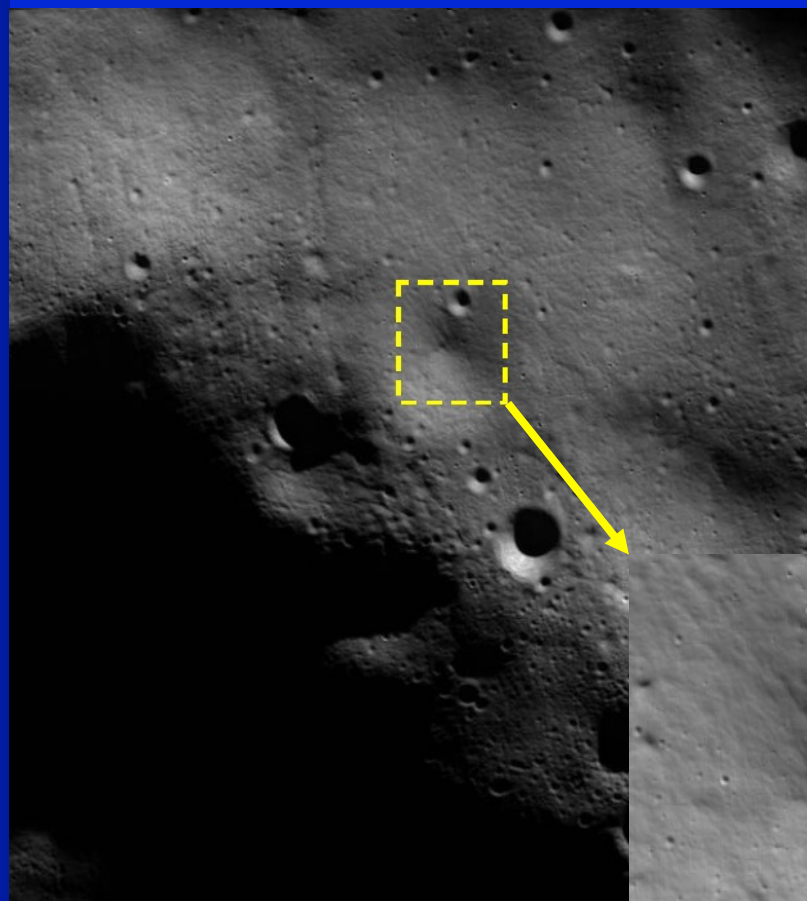


地形カメラの特徴





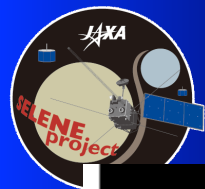
地形カメラTCの初画像



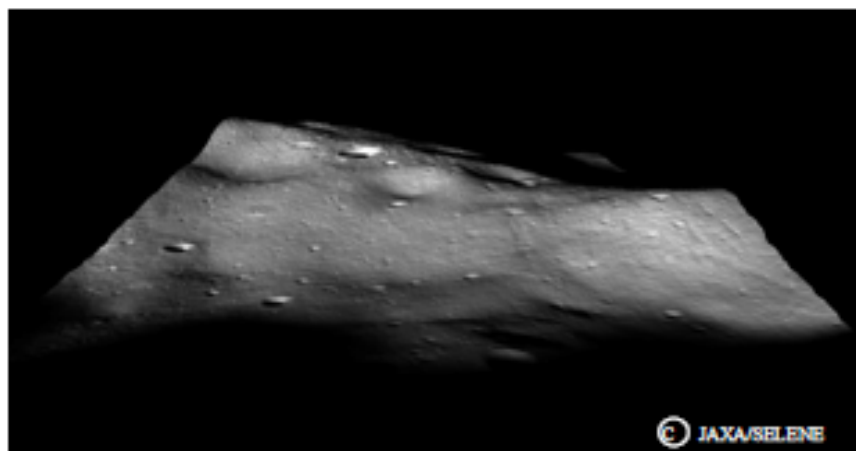
↑
地球
方向

地形カメラ初画像データ
(南緯89° 東経240°) 11月3日撮影
月の裏側で、南極点から約30kmの位置

出典<http://www.lpi.usra.edu/resources/mapcatalog>

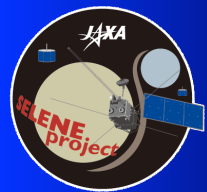


3次元地形画像



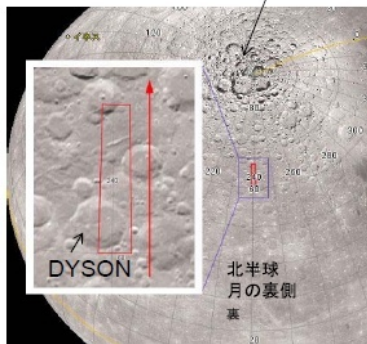
地形カメラ立体視データから作成した3次元地形画像

左上の画像：西から東を見る。右上の画像：南から北を見る。左下の画像：北から南をみる。右下の画像：東から西を見る。

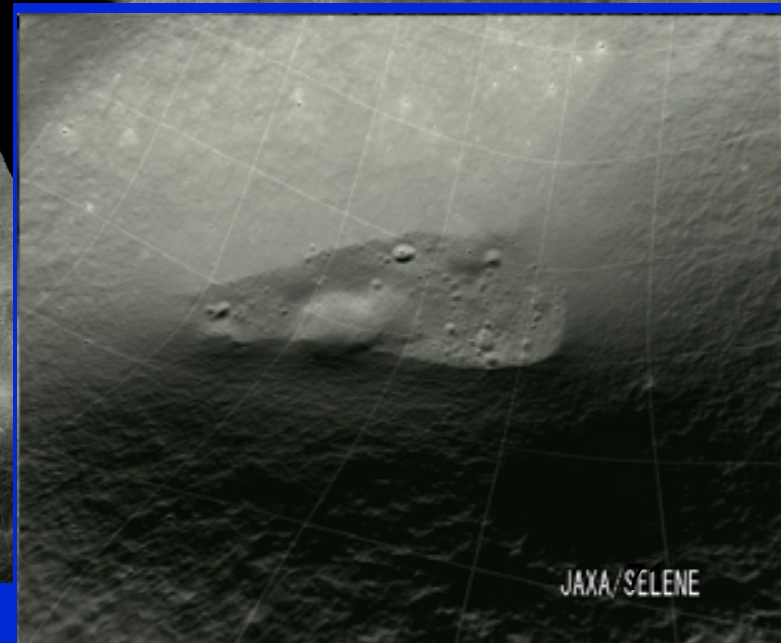
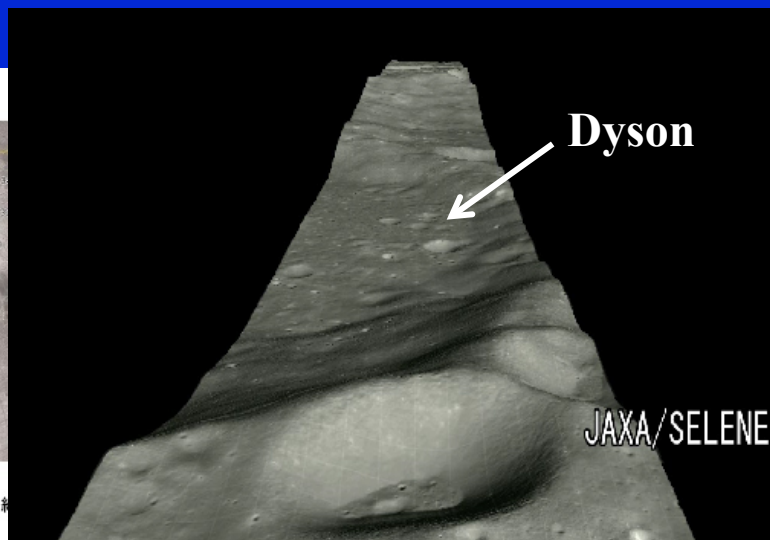


地形カメラ 3D 画像

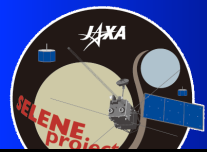
北極点



•観測日:平成19年11月3日
•取得場所:東経 240° 近辺(月の裏側) 北緯
(DYSONクレータ付近)



SELenological and EN



地形カメラ(TC)の画像4.



120E



170E

50N

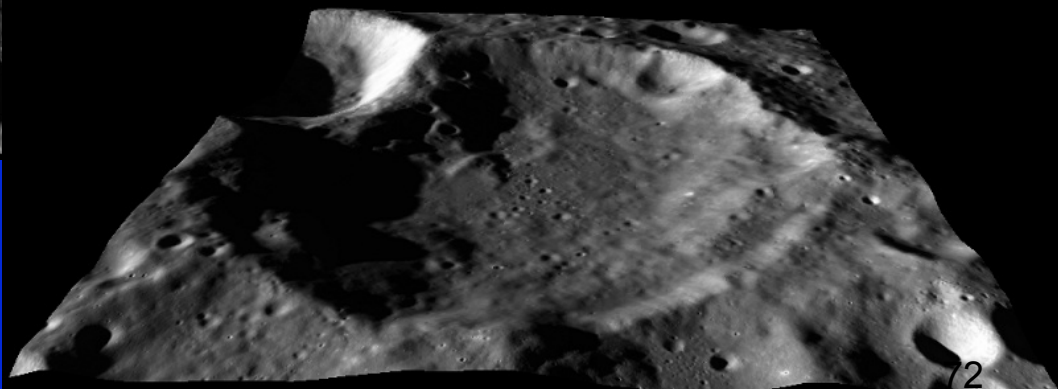
モスクワの海

ナガオカ

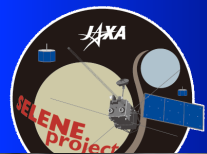
10N

ナガオカクレータ Mosaic
19.4N, 154.0E D:46km

3D

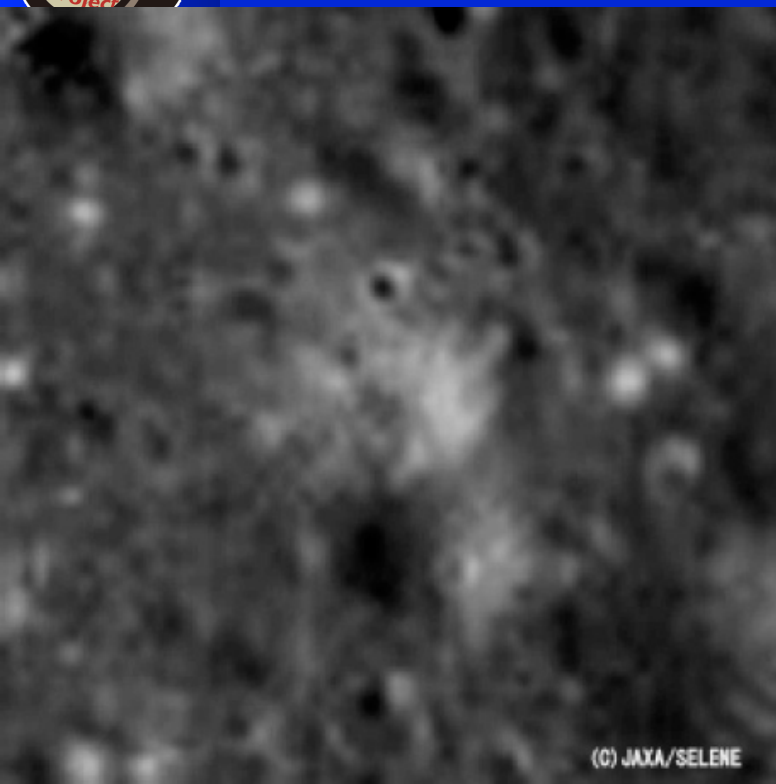


12

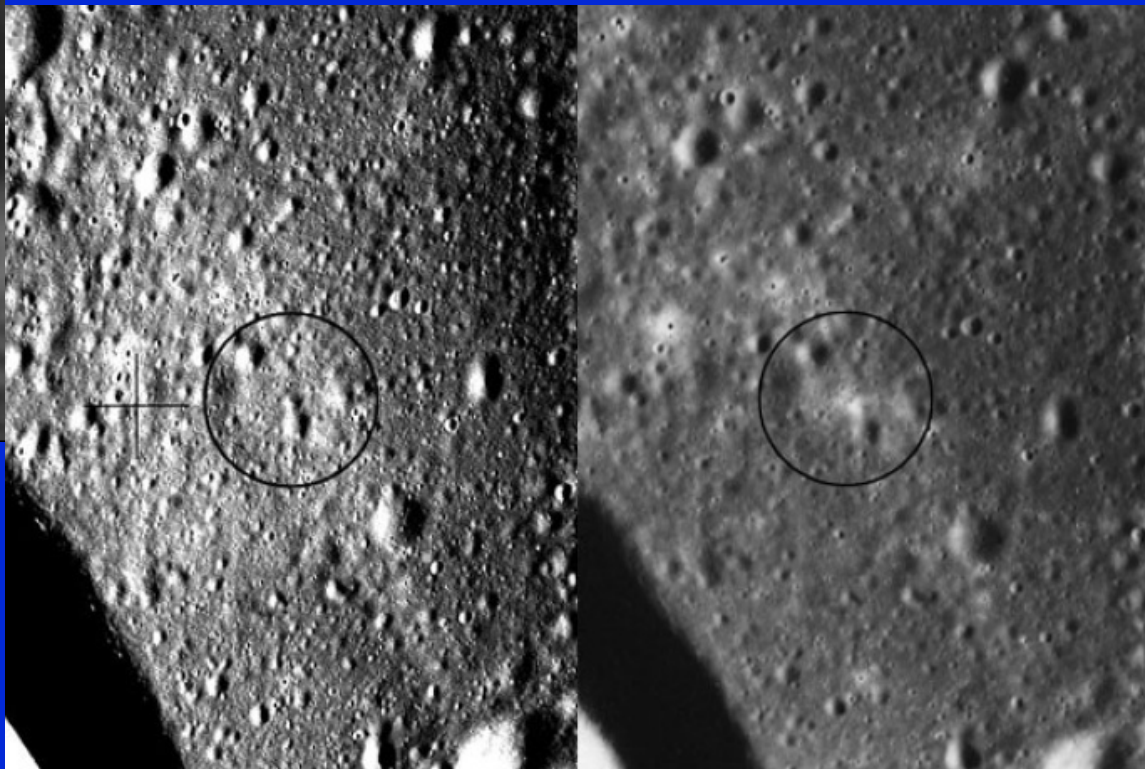


地形カメラの画像 5.

アポロ15号着陸地点
ハドレー谷
26.17N/3.38E
1971.7.30

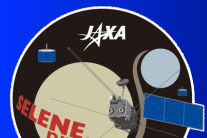


(C) JAXA/SELENE

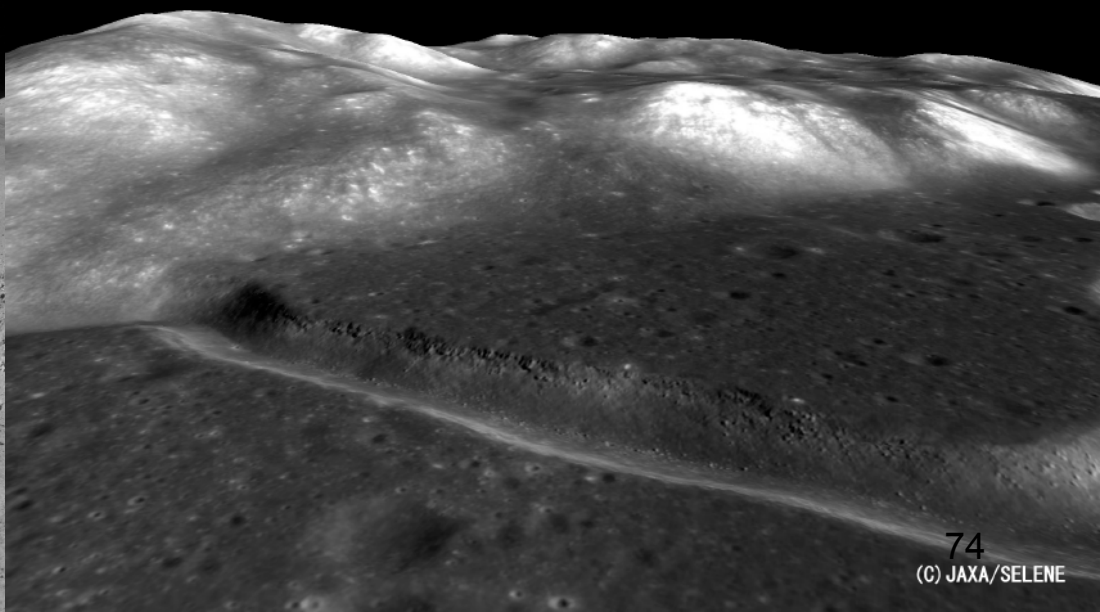
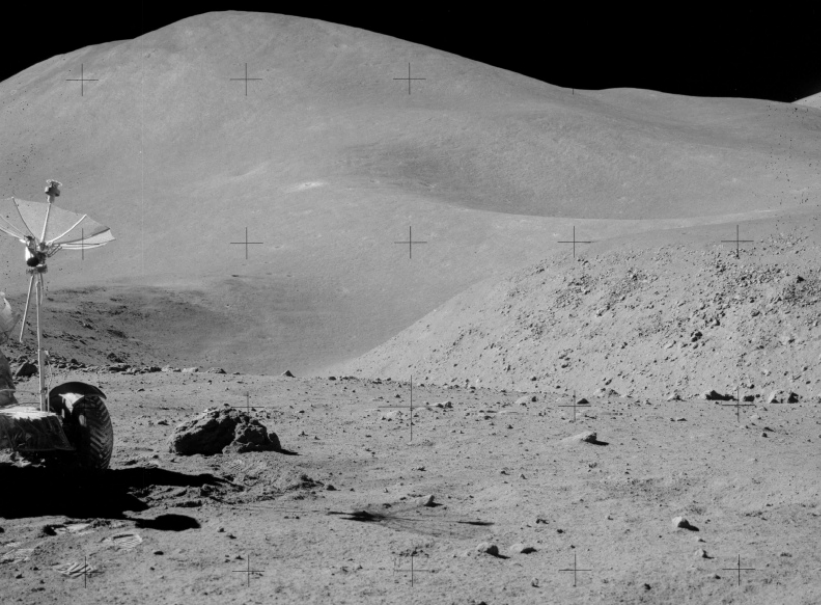
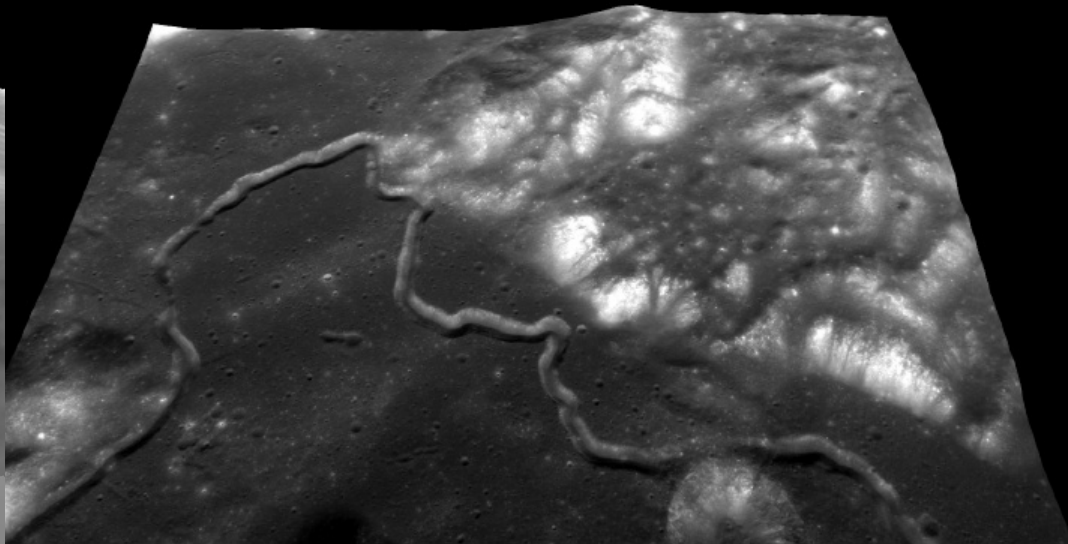
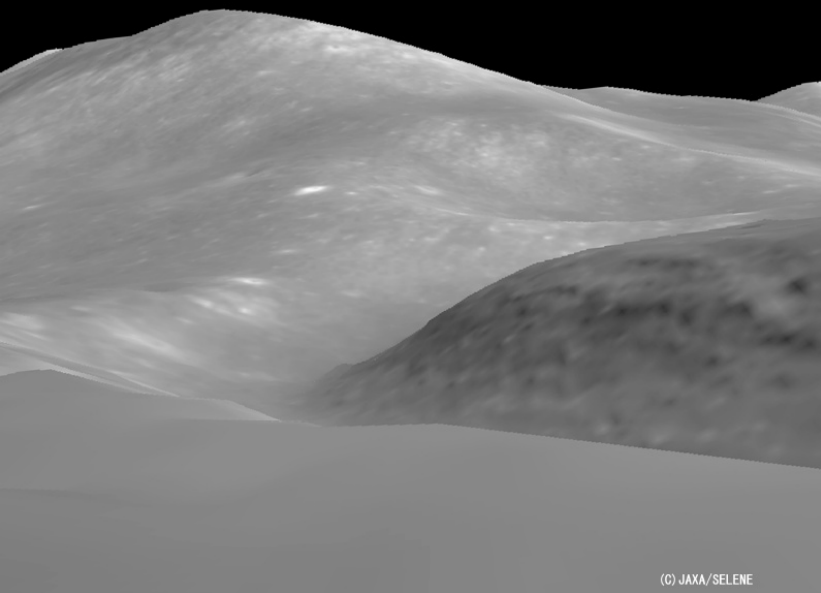


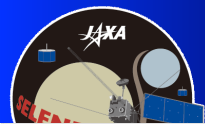
A15着陸前

着陸後

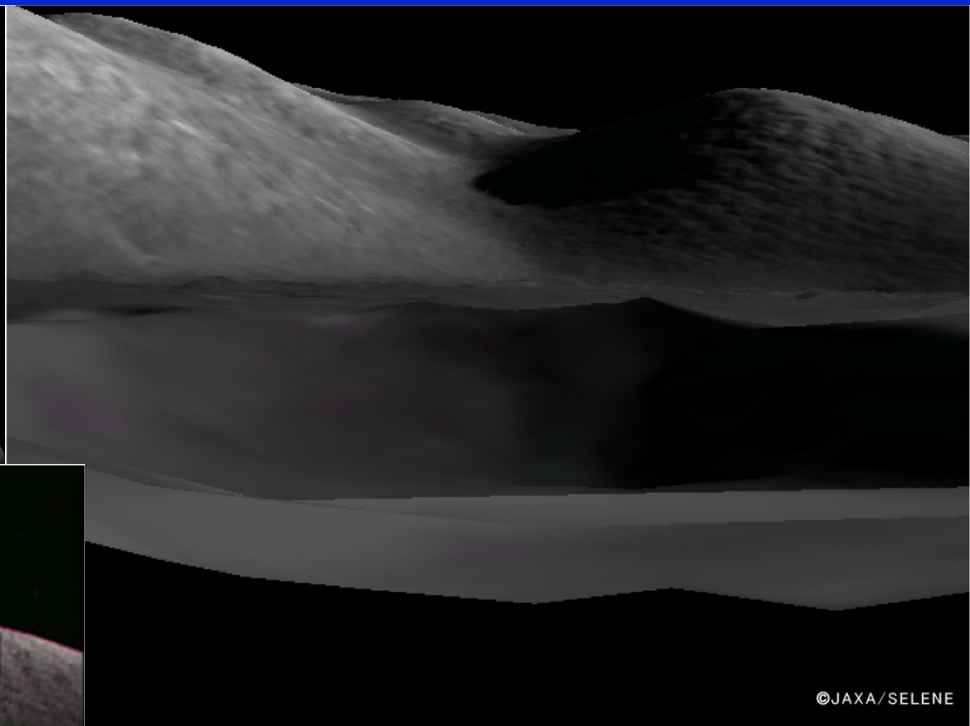
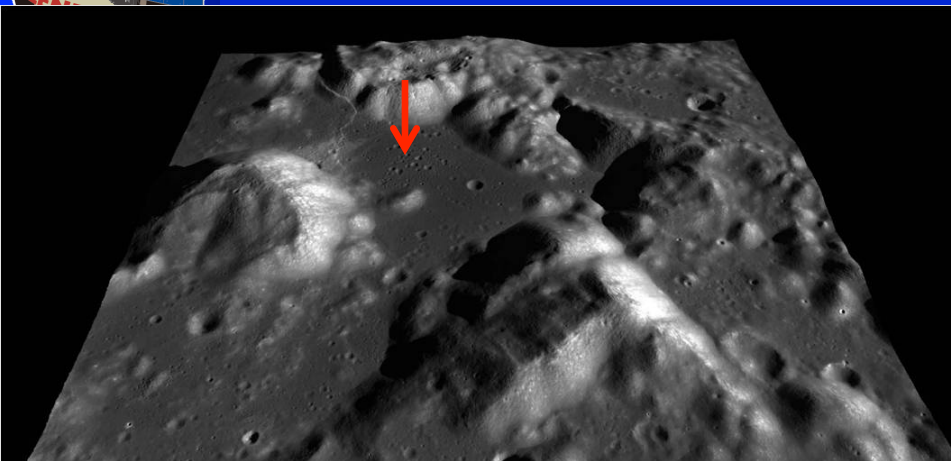


地形カメラの映像 5.

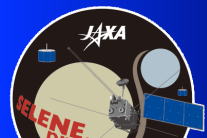




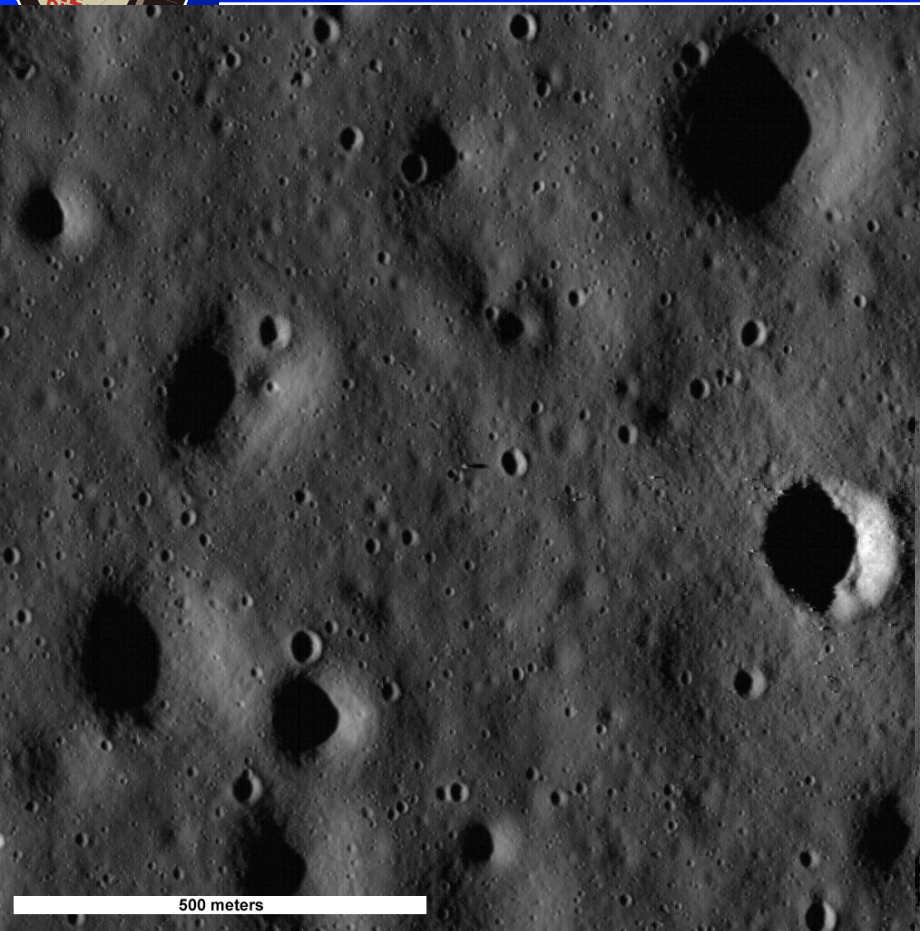
地形カメラの映像6. Apollo 17



Taurus Littrow Valley

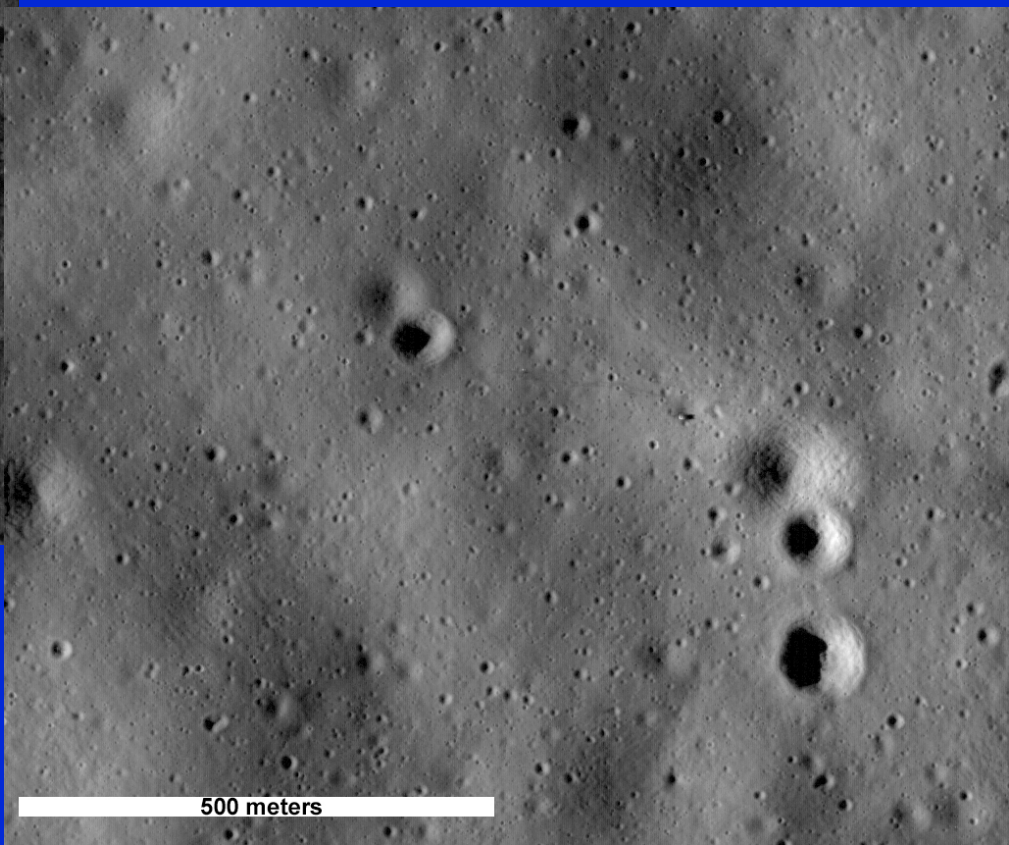


ルナー・リコネッサンス・オービター



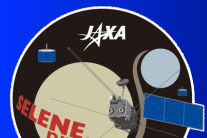
Apollo 11 Eagle in
Mare Tranquillity

500 meters

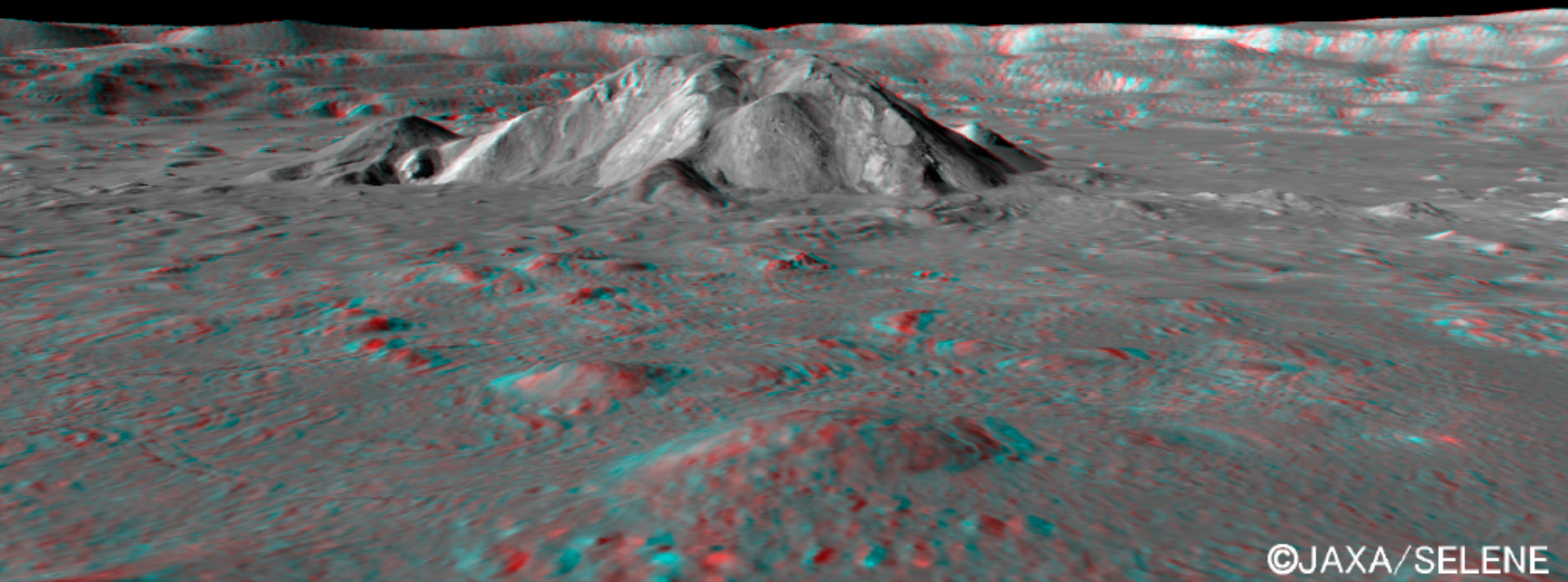


Apollo 14 Antares in
Fra Mauro Basin

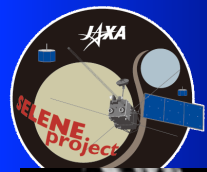
500 meters



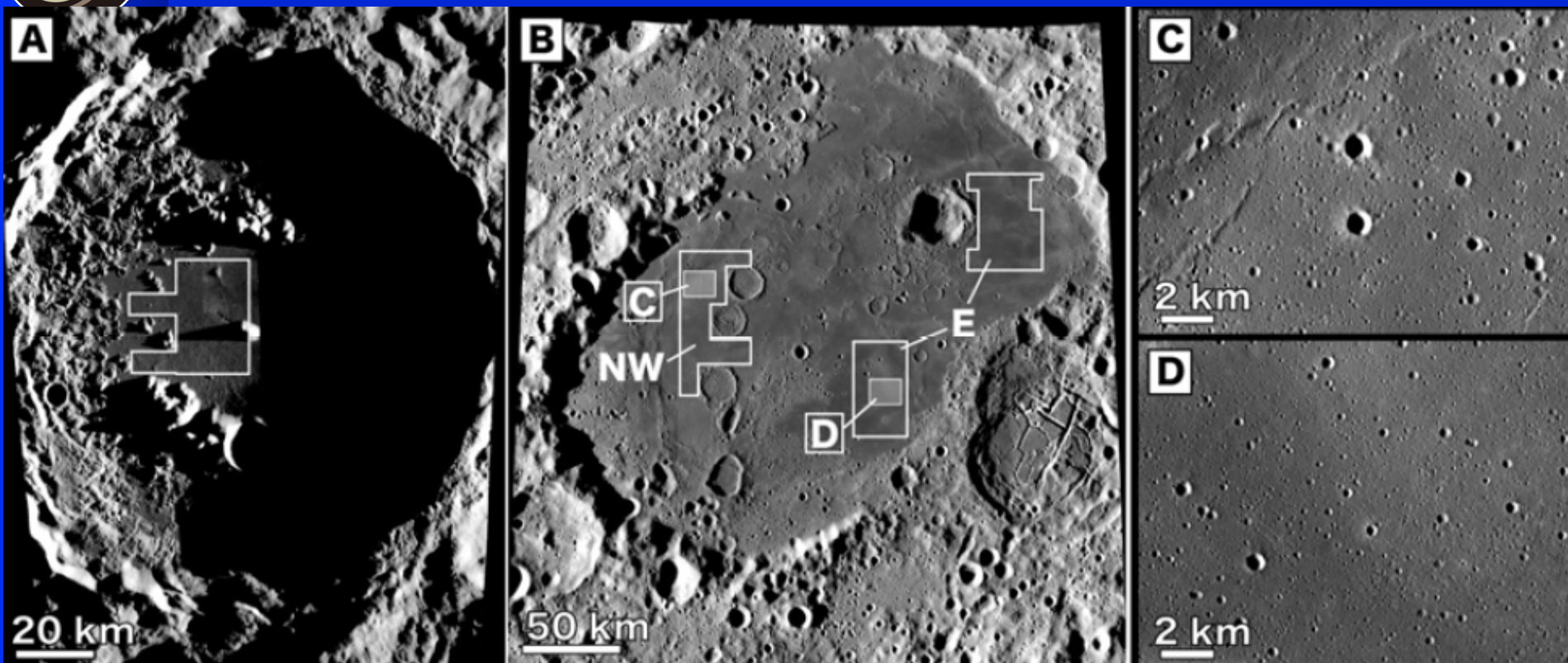
TCによるティコクレータの3次元映像



©JAXA/SELENE



地形カメラによる裏側の海の観測

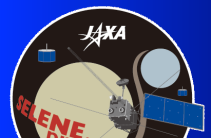


SELENEologi

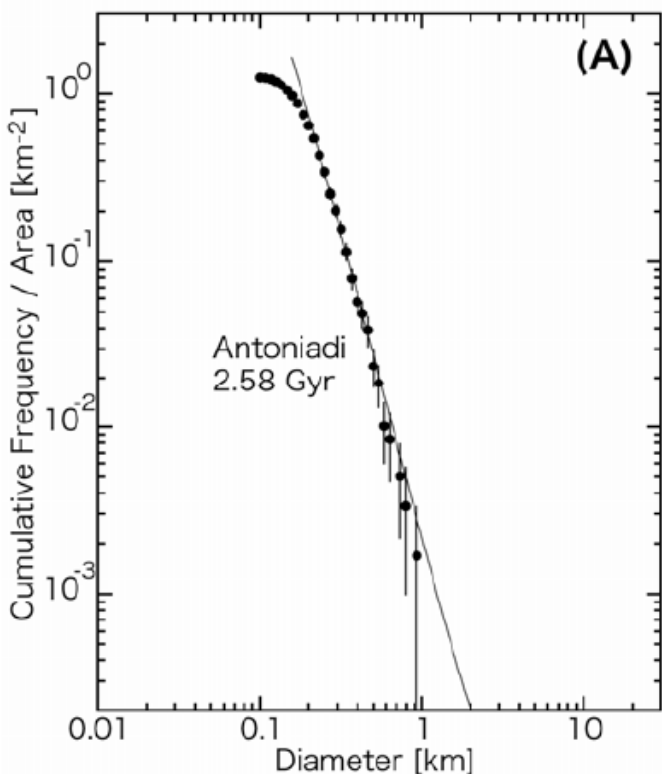
地形カメラ高分解能映像を使ってクレータ年代測定が行われた地域

- A. アントニアディAntoniadiクレータ、
- B. モスクワの海Mare Moscoviense
- C. B図中C領域のクローズアップ
- D. 同図中D領域のクローズアップ

Haruyama et al., 2008

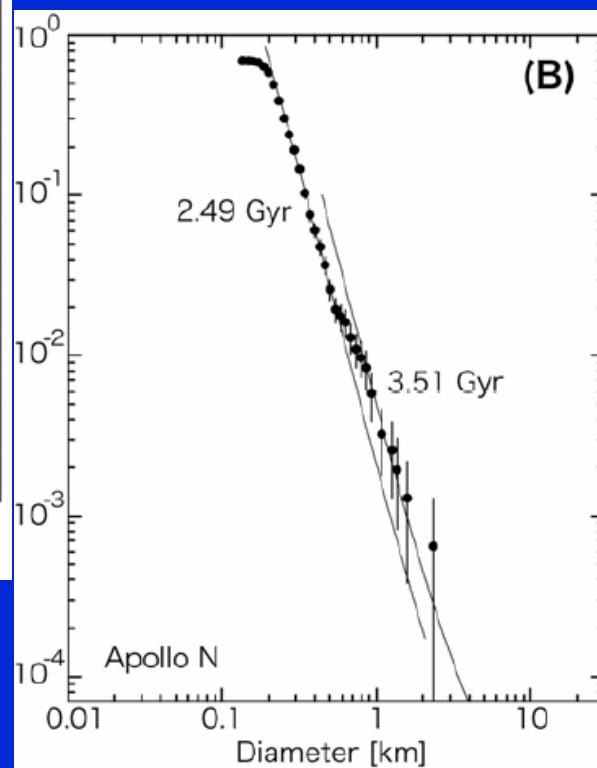


地形カメラによる海の観測2.

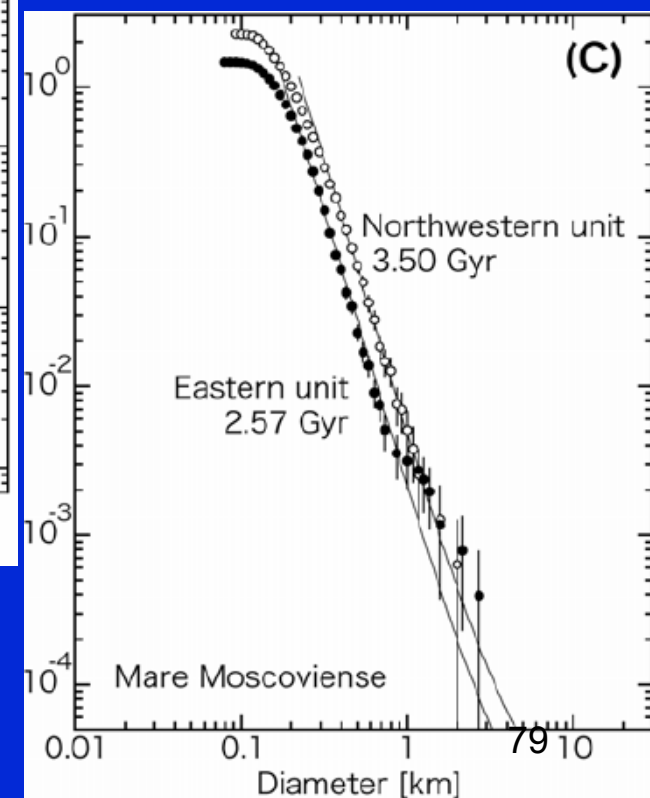


クレータ分布計測による形成年代決定
A. アントニアディAntoniadiクレータ

Haruyama et al., 2008

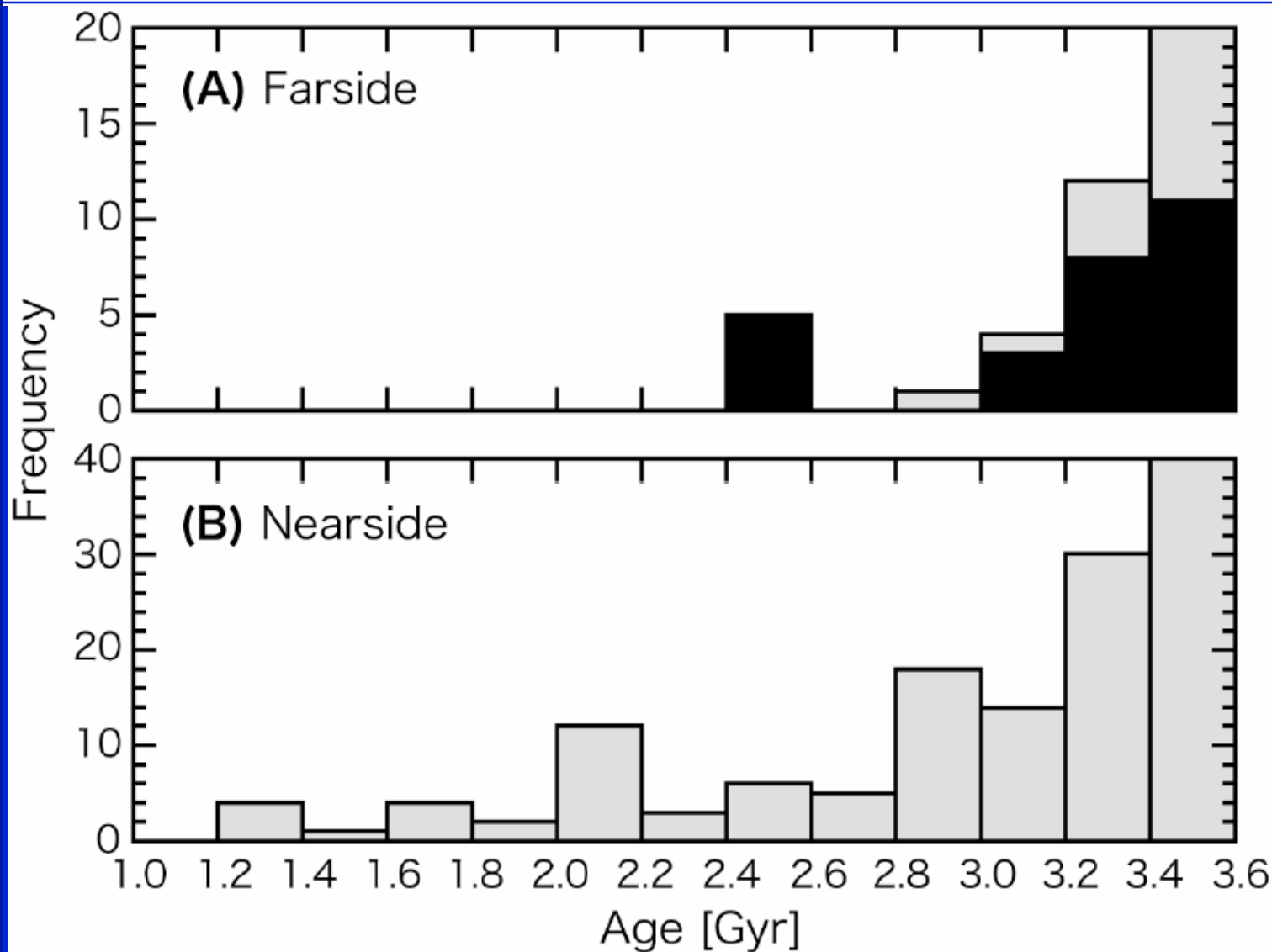


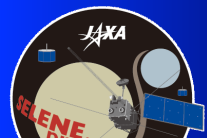
B. あぽろApollo N盆地
C. モスクワMoscovienseの海



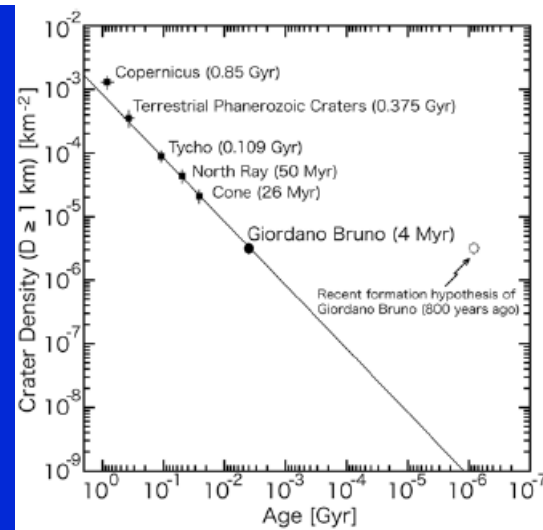
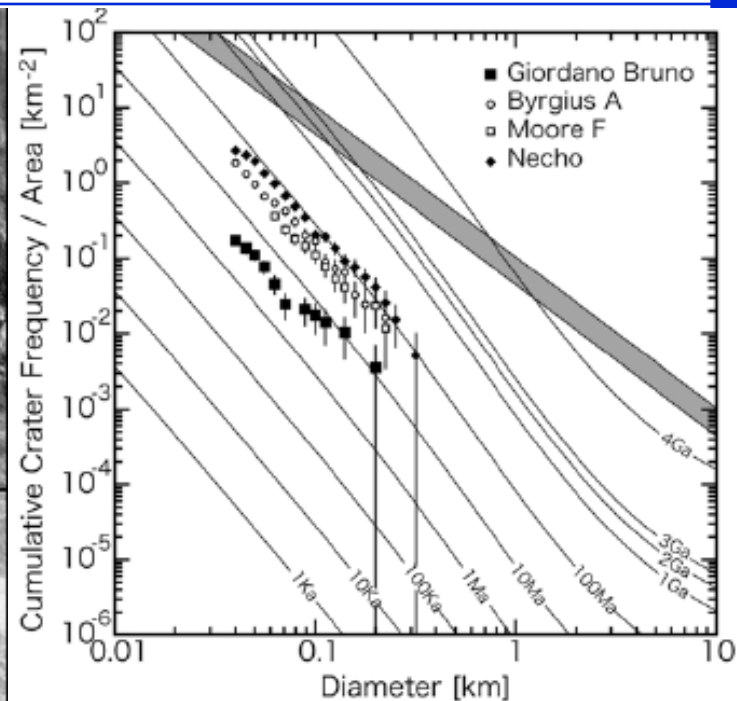
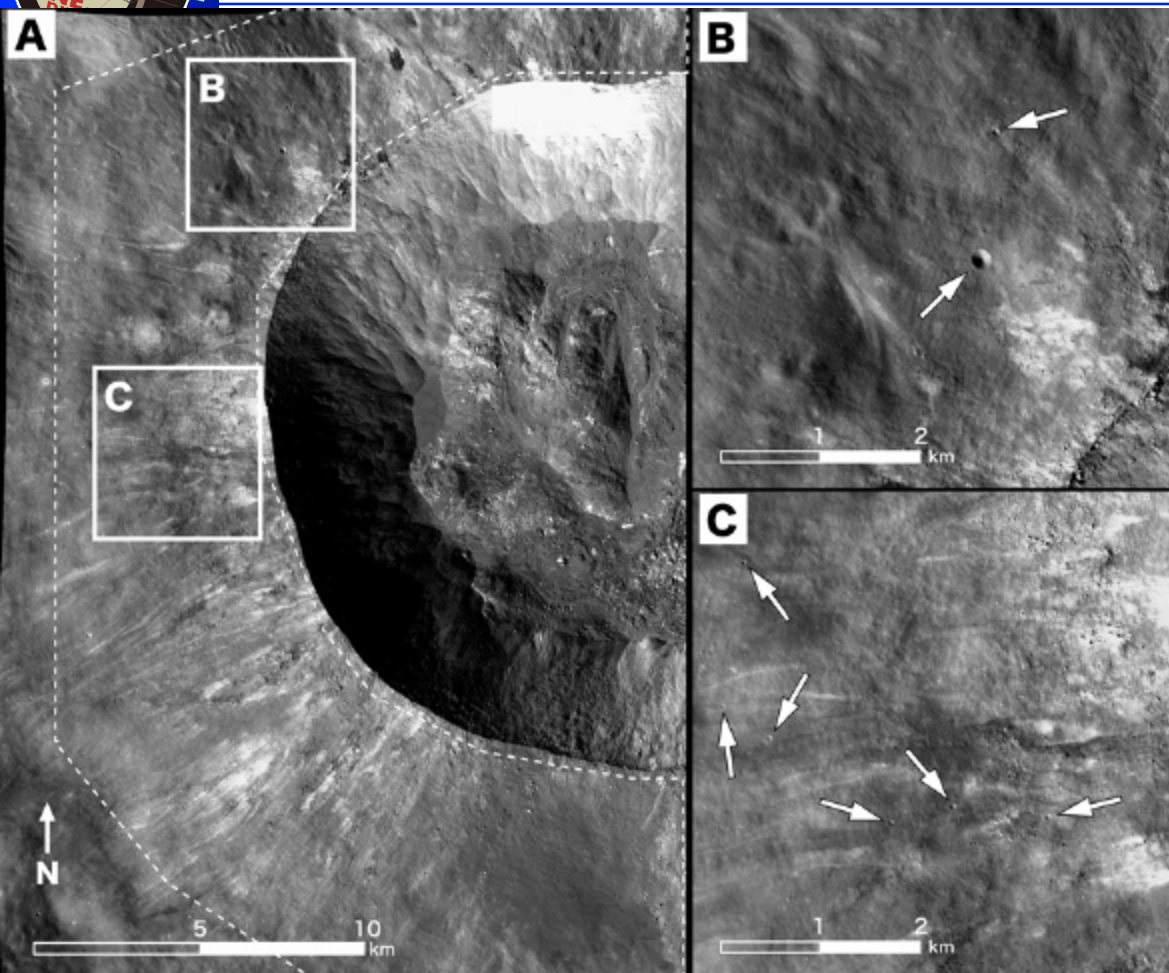


地形カメラによる海の観測3.





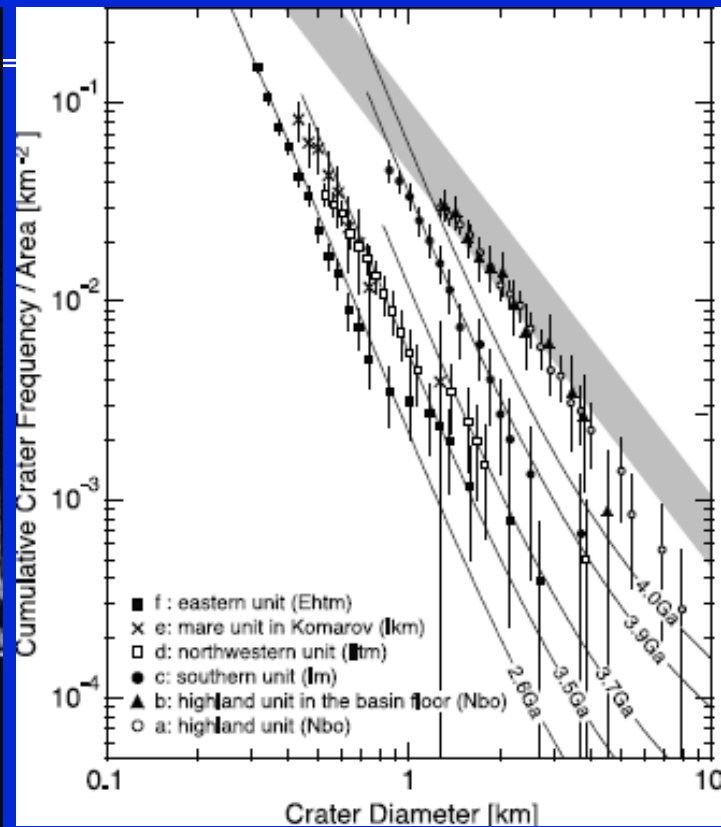
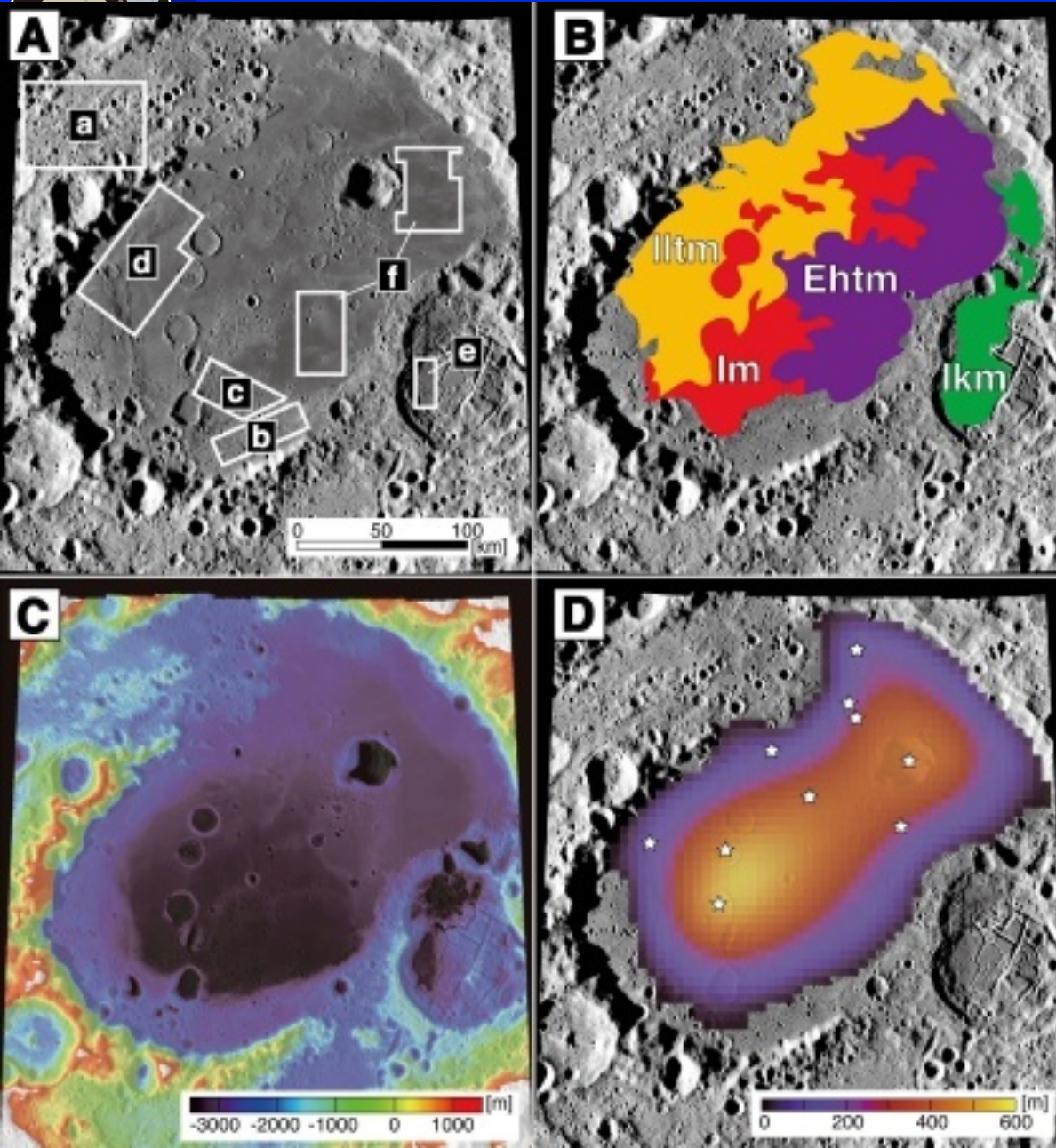
ジョルダナーノ・ブルーノ クレータ形成



36N/103E, 22 km

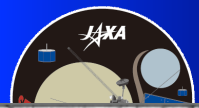
Morota et al., *MePS* 44 (2009), 1115

モスクワの海の深さは？

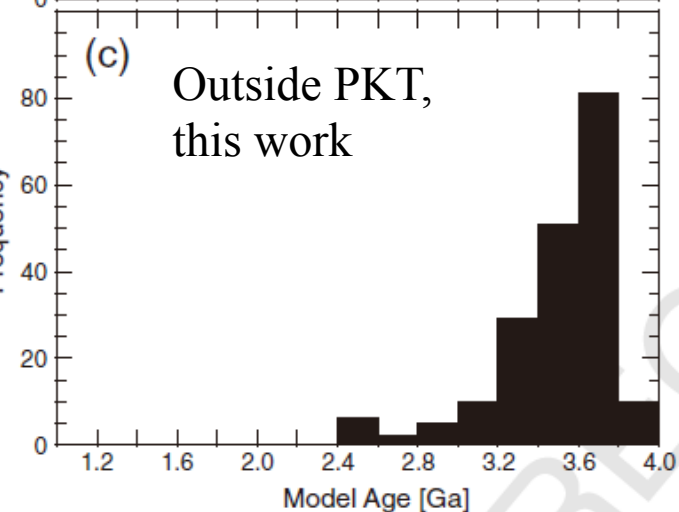
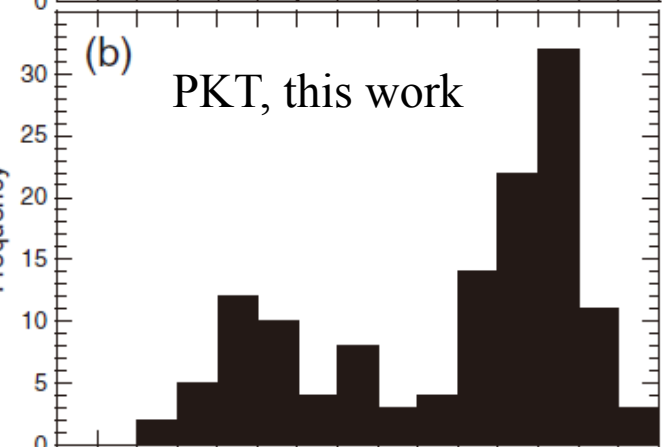
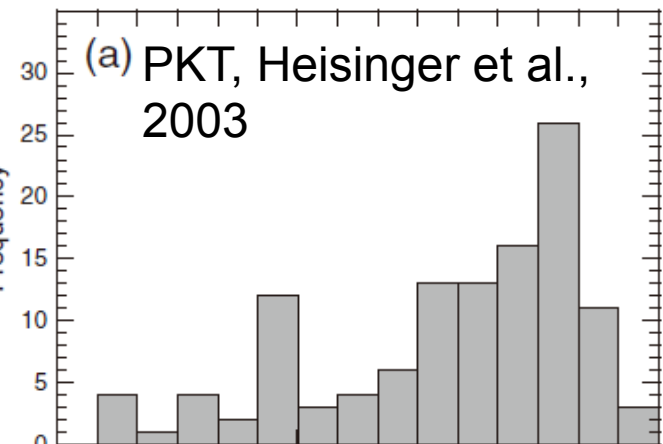
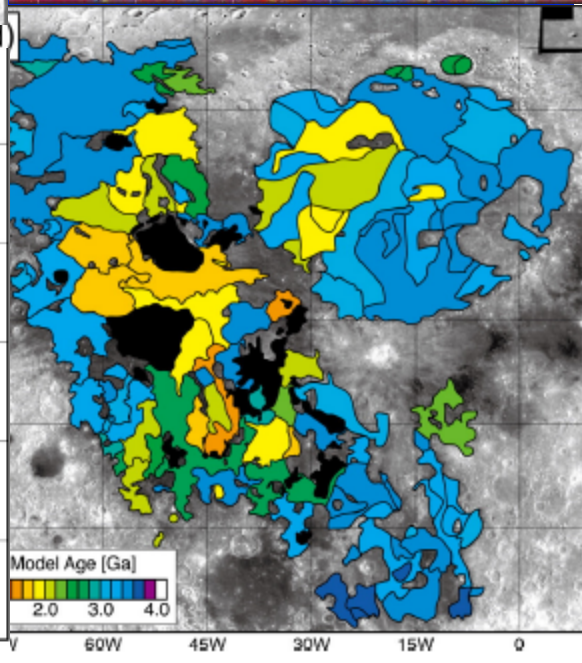
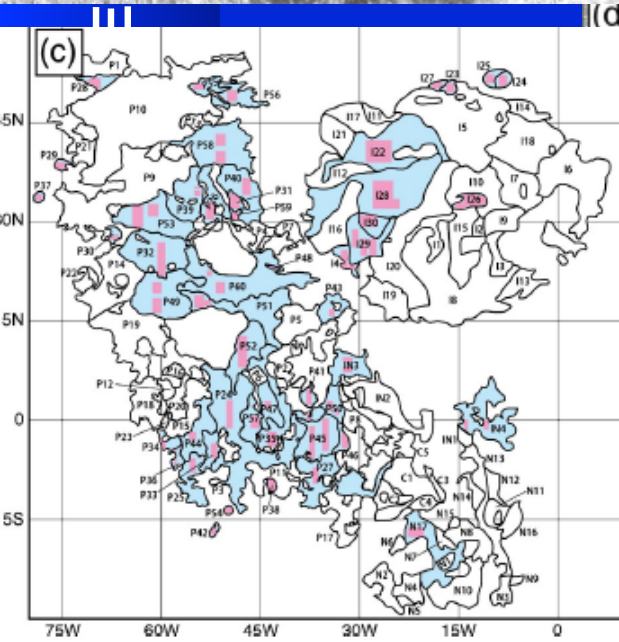
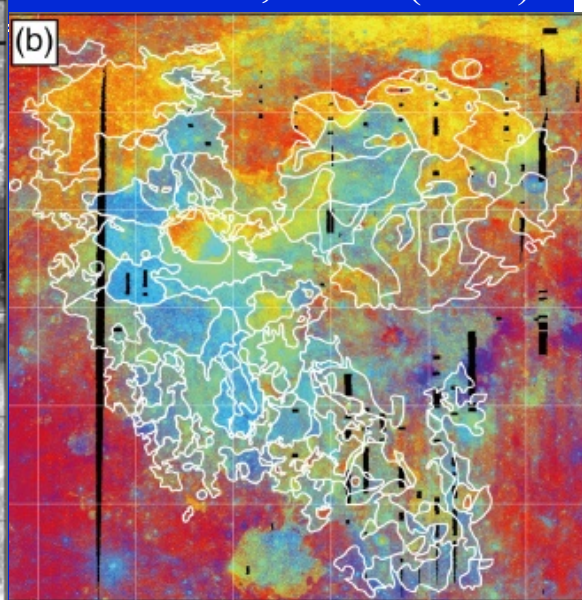
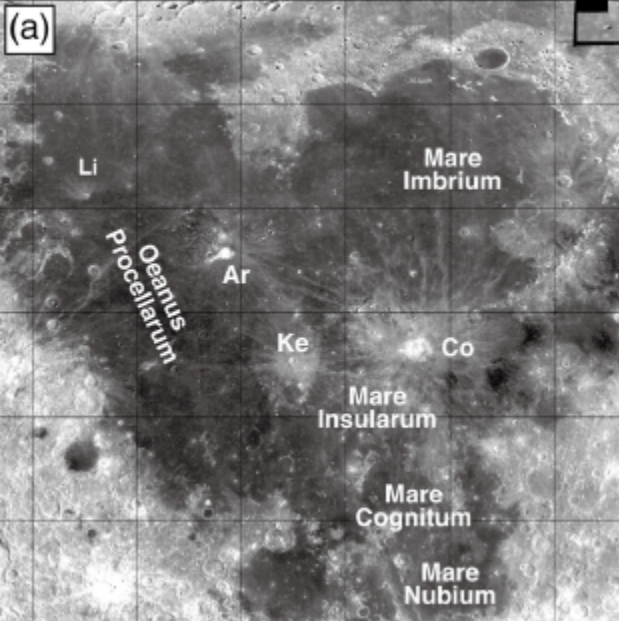


Morota et al., *GRL* 36,
in press

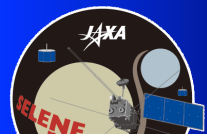
History of Mare Volcanism



Morota et al., *EPSL* (2010)



Global Map of Mare Basalts and Formation Ages



10

T. Morota et al. / Earth and Planetary Science Letters xxx (2010) xxx–xxx

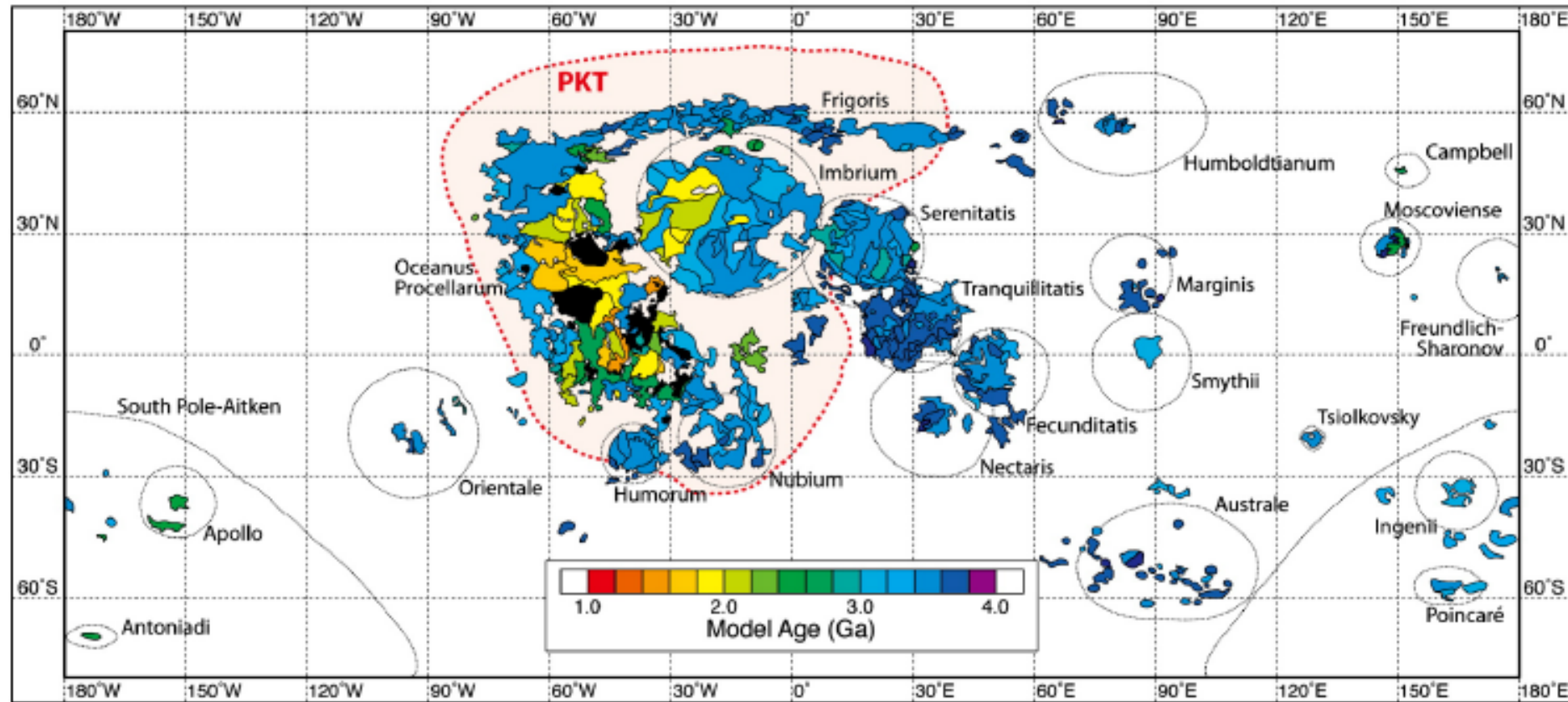
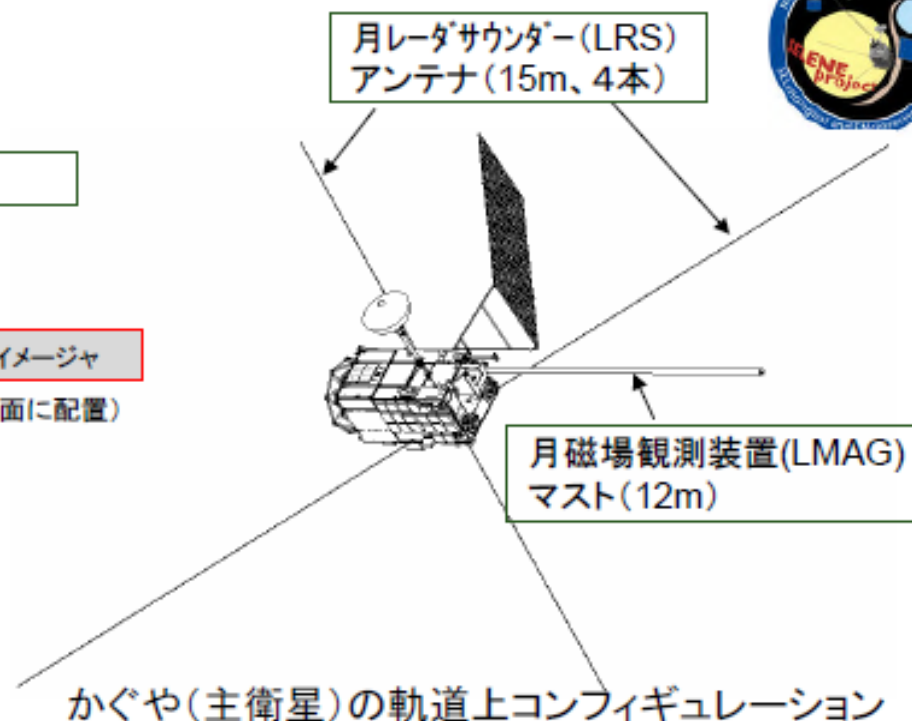
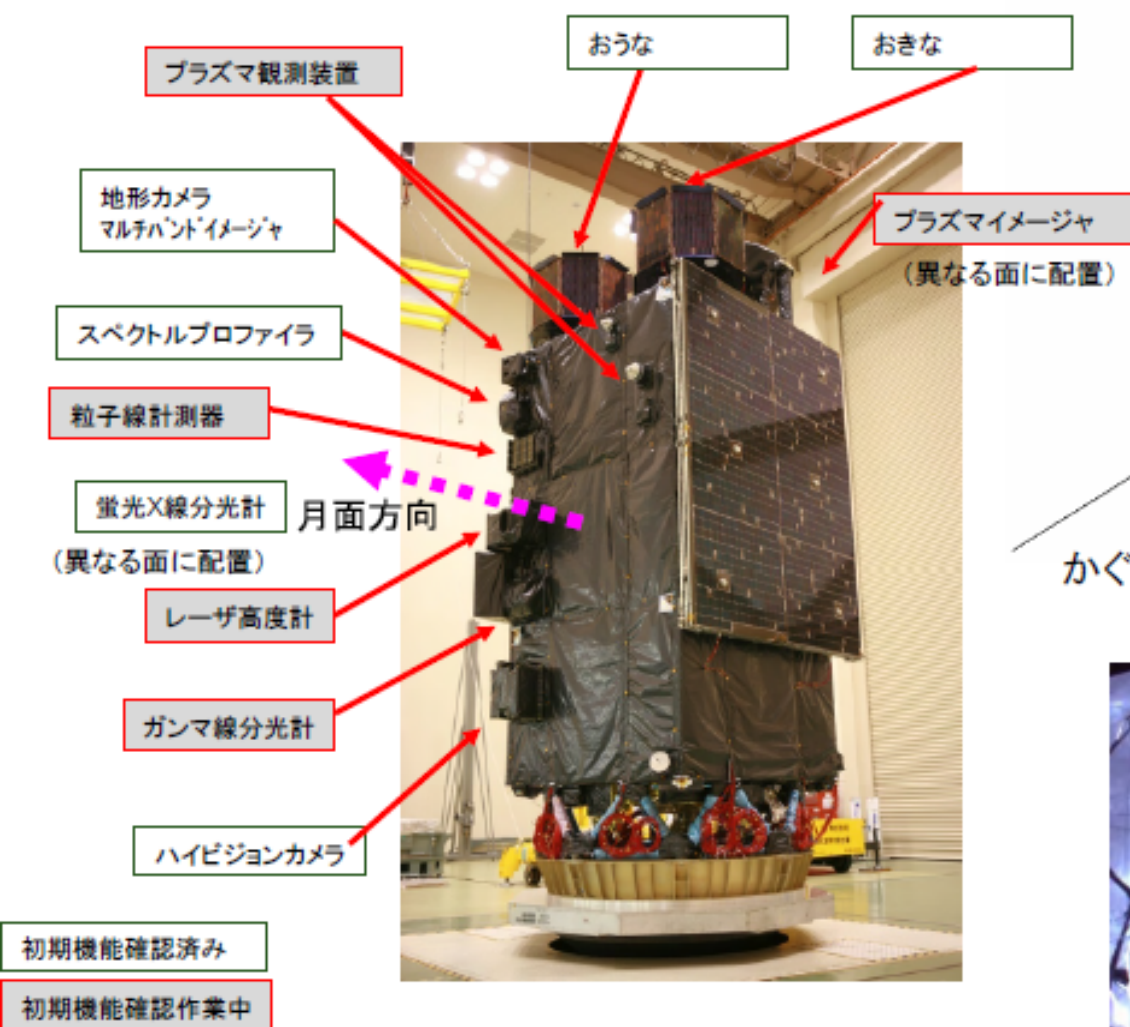
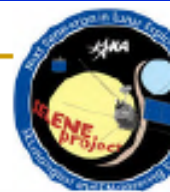


Fig. 5. Global map of the model ages of mare basalts on the lunar surface, including Oceanus Procellarum, Mare Imbrium, Nubium, Insularum (This study; Hiesinger et al., 2000, 2003), Mare Orientale (Greeley et al., 1993), Mare Serenitatis, Humorum, Tranquillitatis, Humboldtianum, Australe (Hiesinger et al., 2000), Mare Cognitum (Hiesinger et al., 2003), Mare Fecunditatis (Hiesinger et al., 2006), Mare Frigoris and other nearside maria (Hiesinger et al., 2010), Mare Moscoviense (Haruyama et al., 2009; Morota et al., 2009), and those within the South Pole–Aitken basin (Haruyama et al., 2009), the Freundlich–Sharonov basin, the crater Campbell, the crater Kohlschütter (Morota et al., in press), and the crater Tsiolkovsky (Tyrie, 1988).

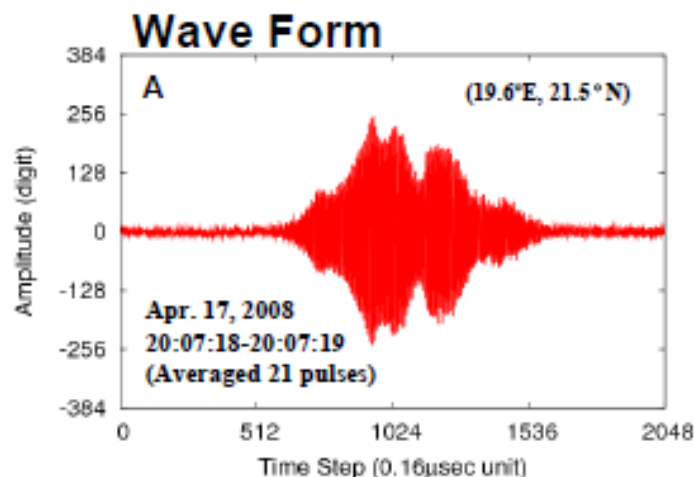
ミッション機器配置図



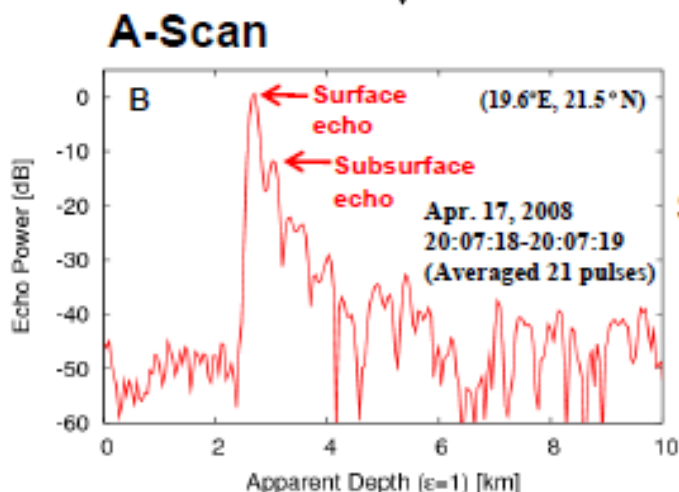
ミッション機器のセンサー部の配置
(打ち上げ時のコンフィギュレーション)

月磁場観測装置 (LMAG) マスト及び月レーダサウンダー (LRS) アンテナの進展後の様子

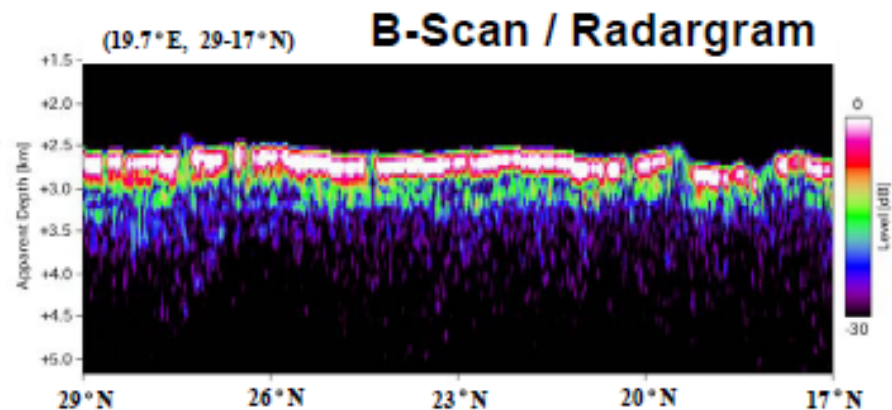
Raw Data Analysis



Fourier
Transform



Series of
A-Scan

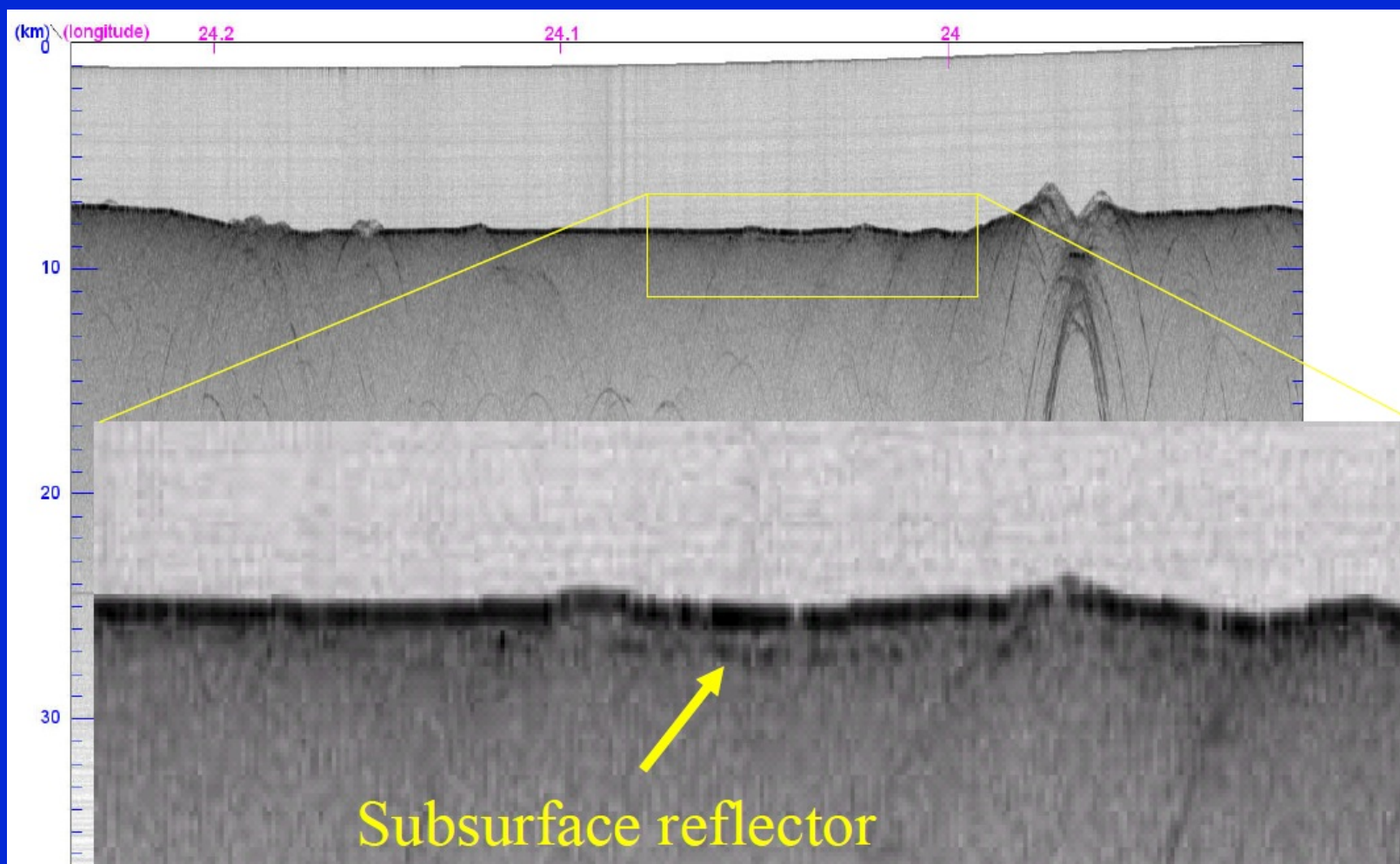


Parameters

Spacecraft Altitude [km]	100
Frequency (FMCW) [MHz]	4-6
Pulse Width [μsec]	200
Range Resolution [m]	75
Transmitter Peak Power [W]	800
Pulse Repetition Rate [Hz]	20
Horizontal Resolution [m]	76



レーダサウンダーLRSによる静かの海の地下構造探査

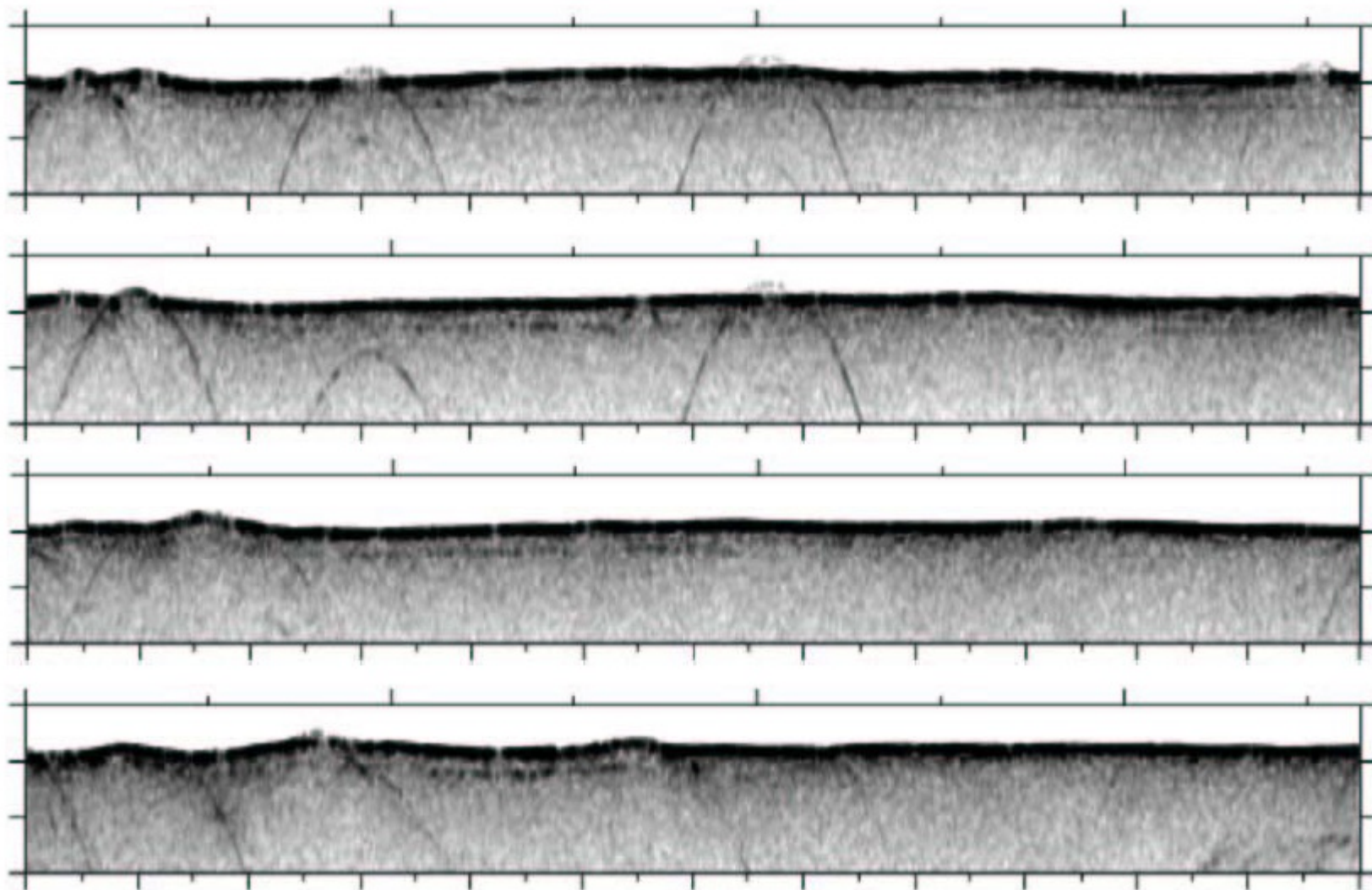


Ono et al., 2008

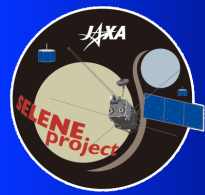


静かの海地下探査、拡大図

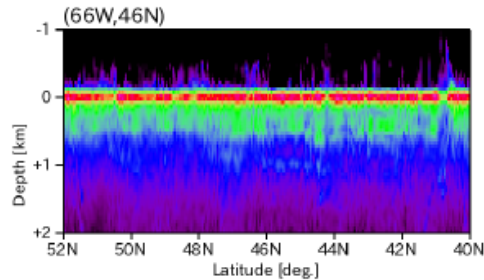
Subsurface reflectors in Mare Serenitatis



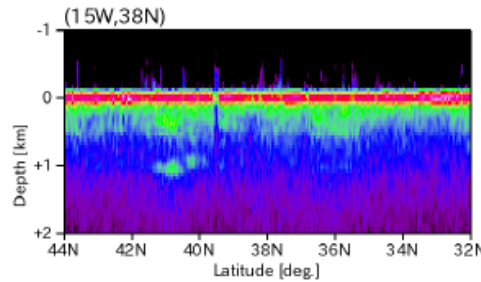
レーダサウンダーによる海の地下構造の測定



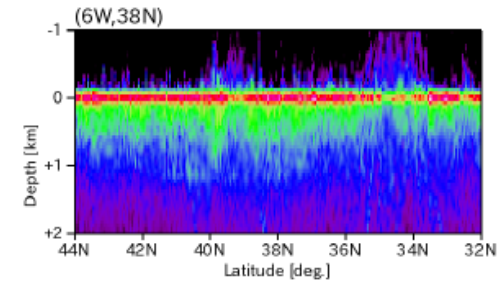
SELENE Project and Engineering Explorer



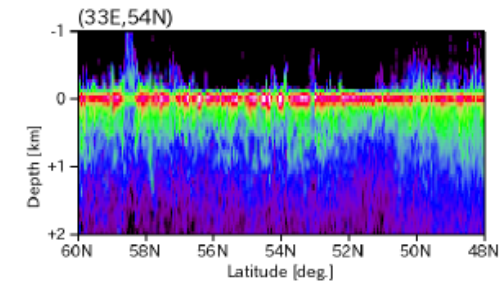
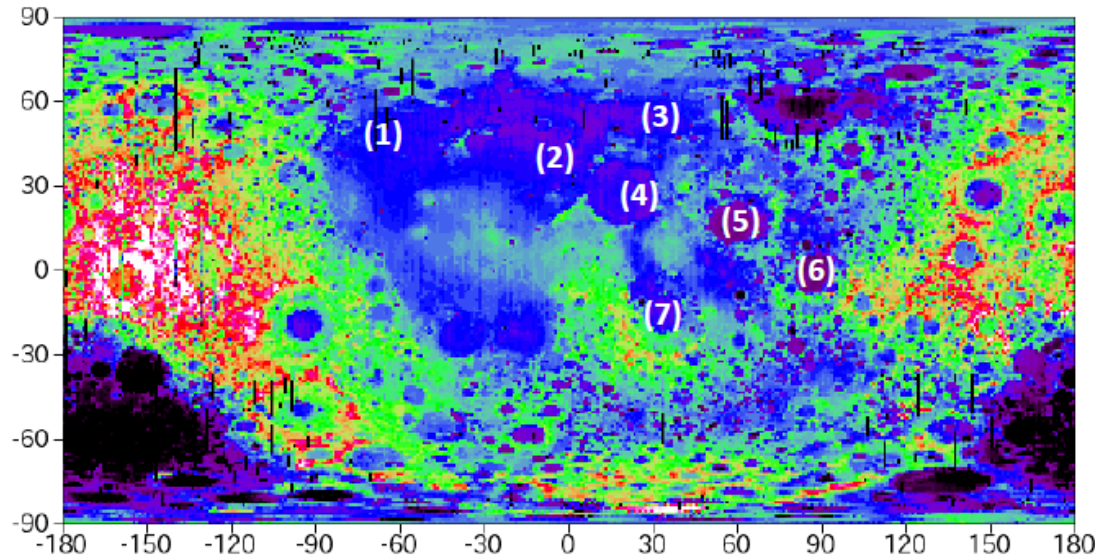
(1) Oceanus Procellarum ~440,1010km



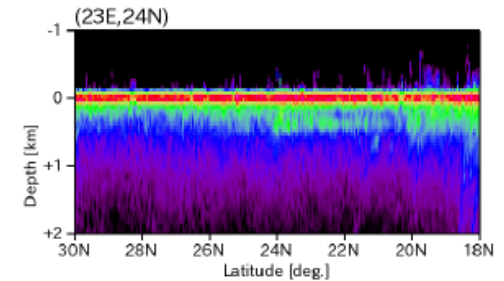
(2) Mare Imbrium ~1040km



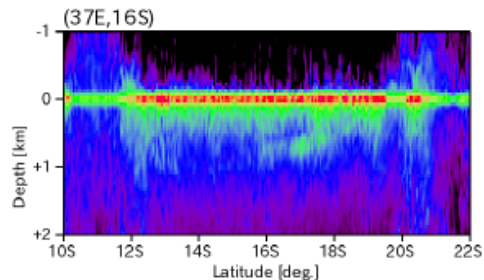
(2) Mare Imbrium ~1160km



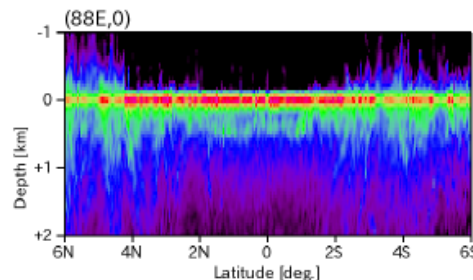
(3) Mare Frigoris ~920km



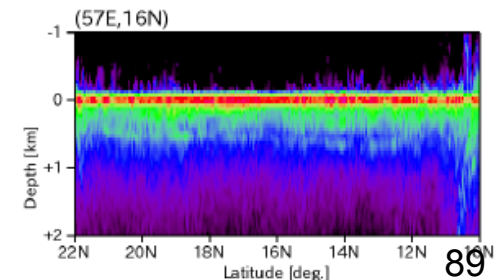
(4) Mare Selenitatis ~400km



(7) Mare Nectaris ~970km

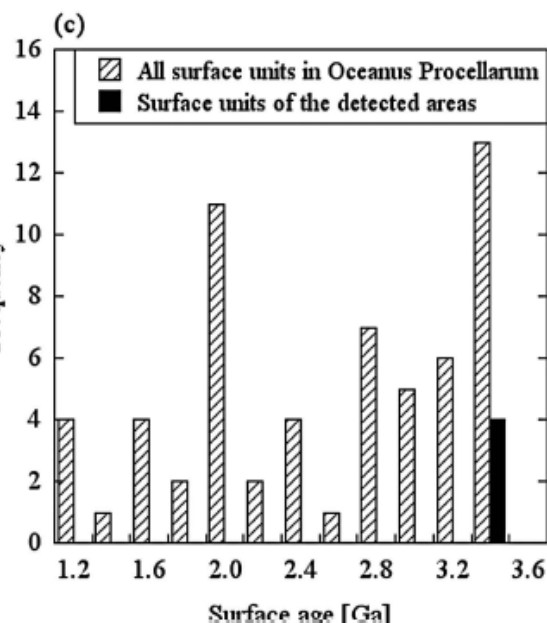
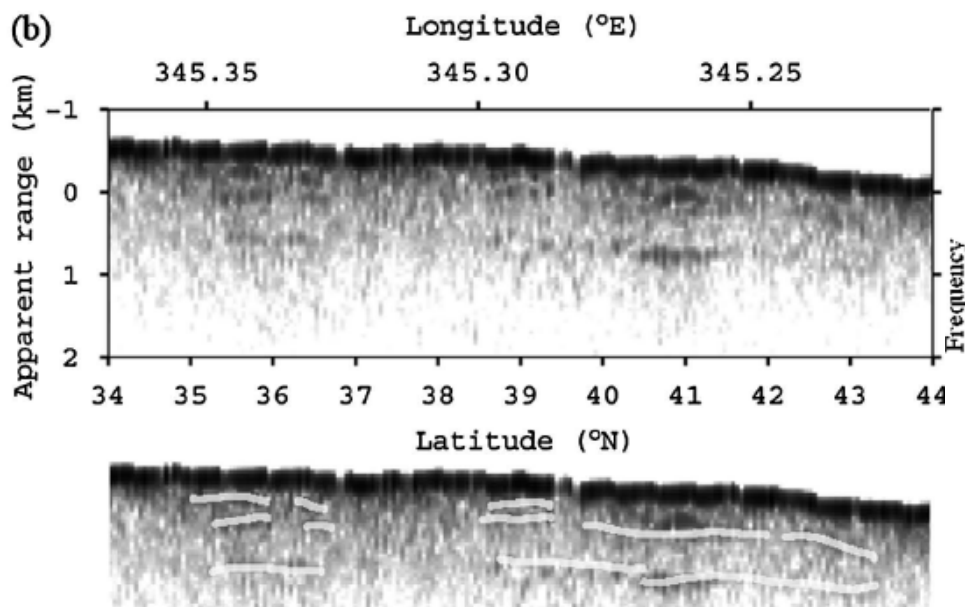
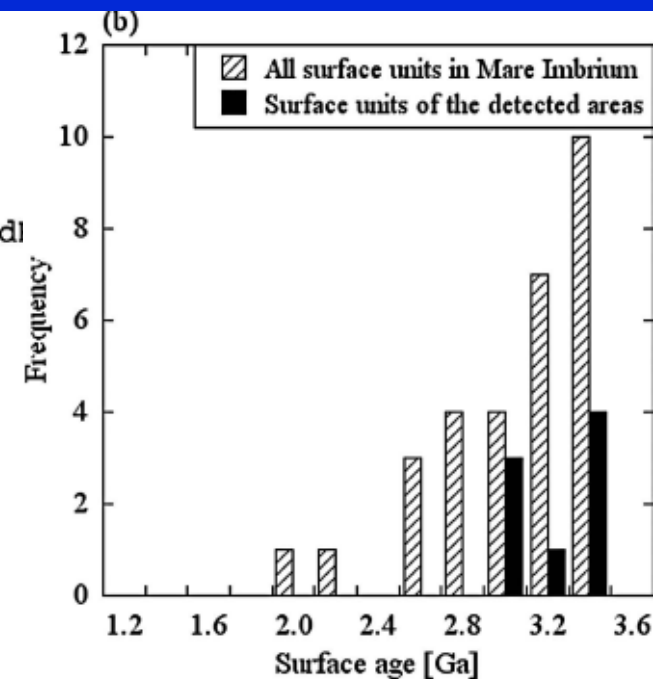
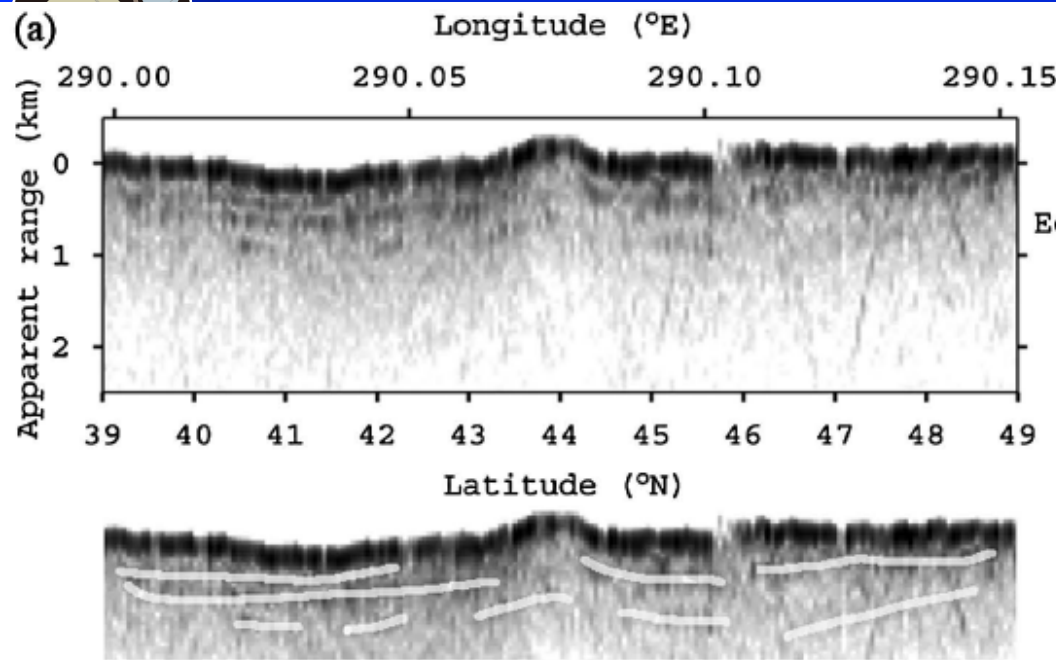


(6) Mare Smythii ~450km



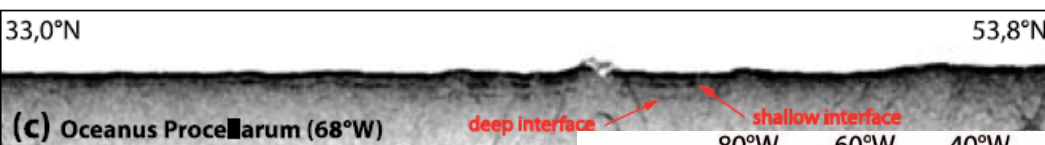
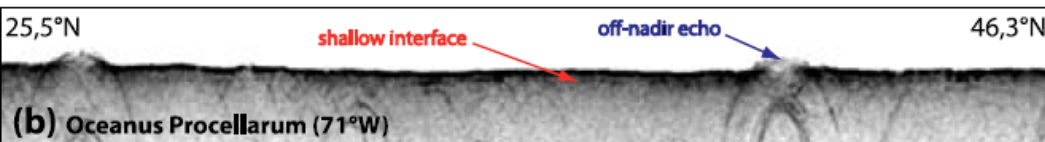
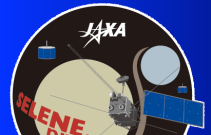
(5) Mare Crisium ~370, 640km

雨の海 & 嵐の大洋



Oshigami et al.,
GRL 36, 2009,
L18202.

Subsurface Interface detectability with TiO_2 content

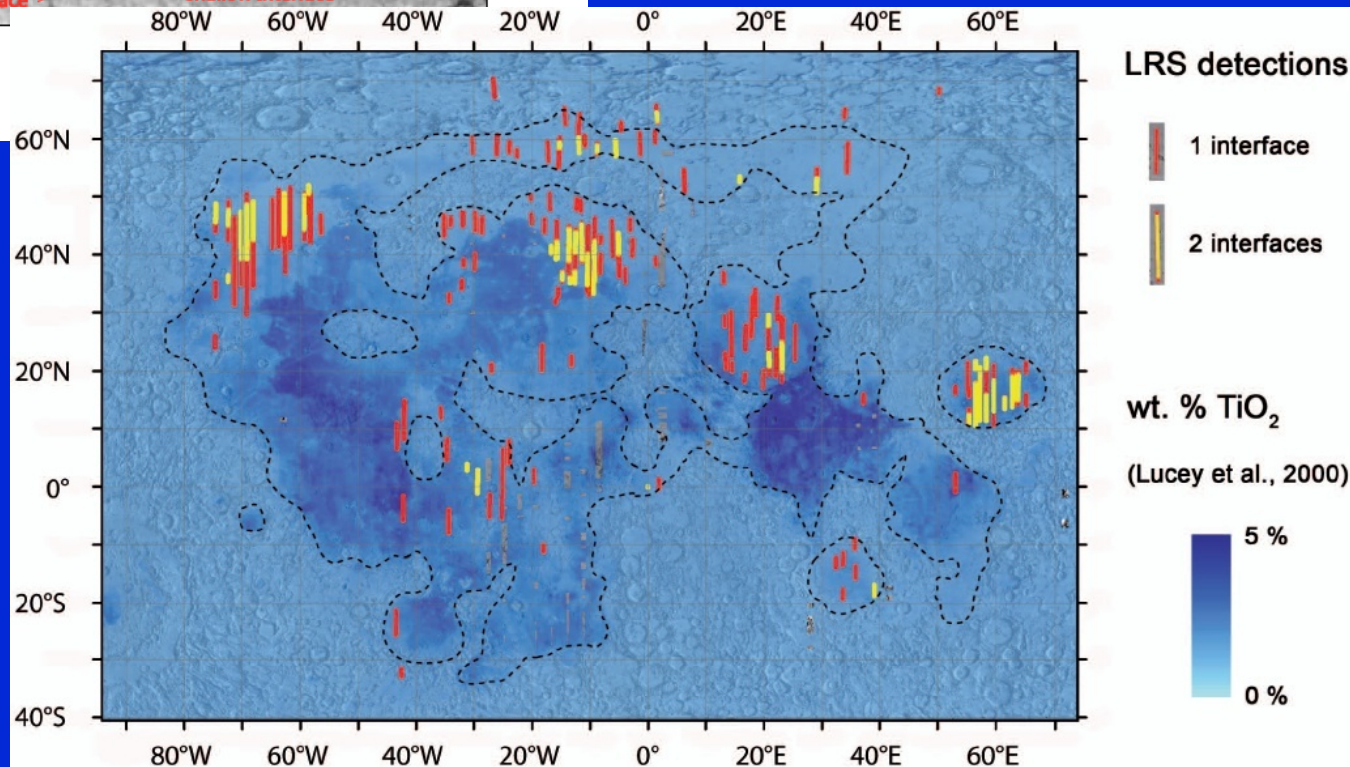


1 km

Pommerol et al.,
GRL 37(2010),
L03201

100 km

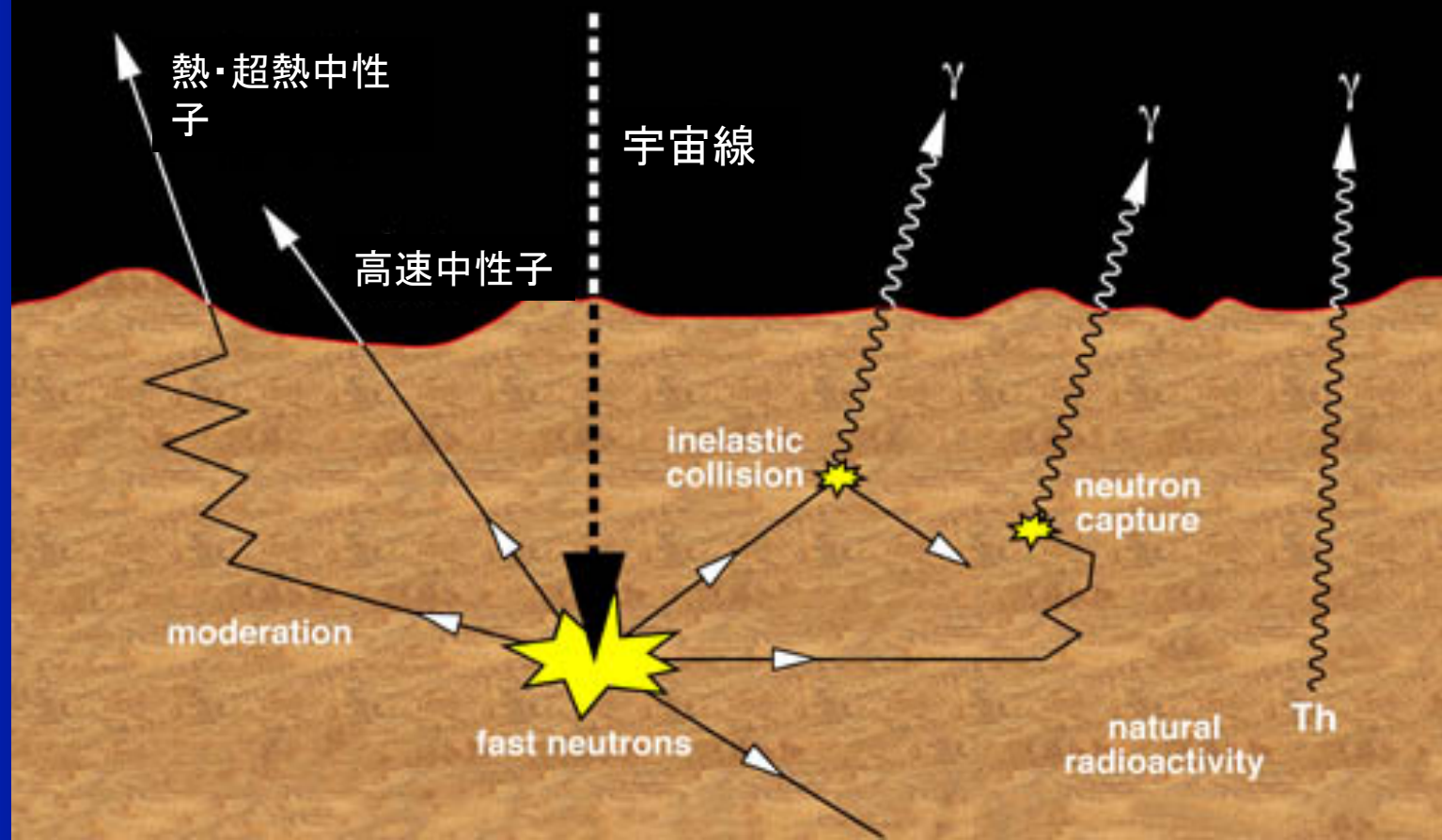
SELenological and E

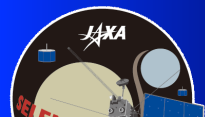




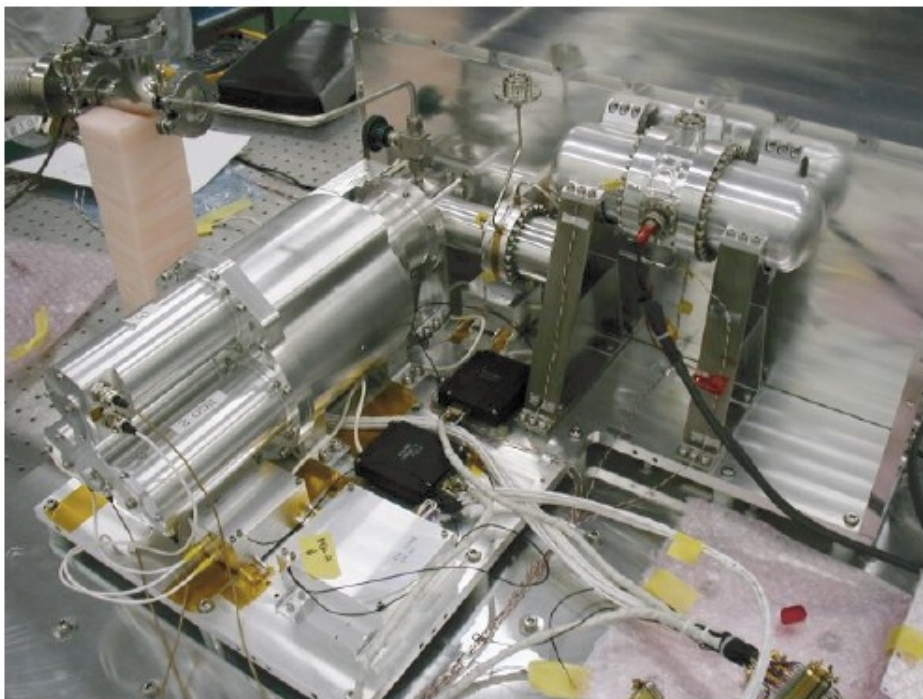
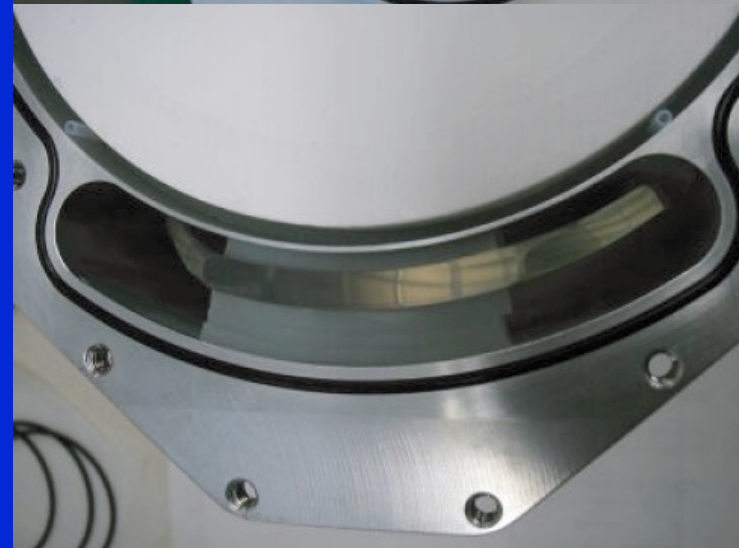
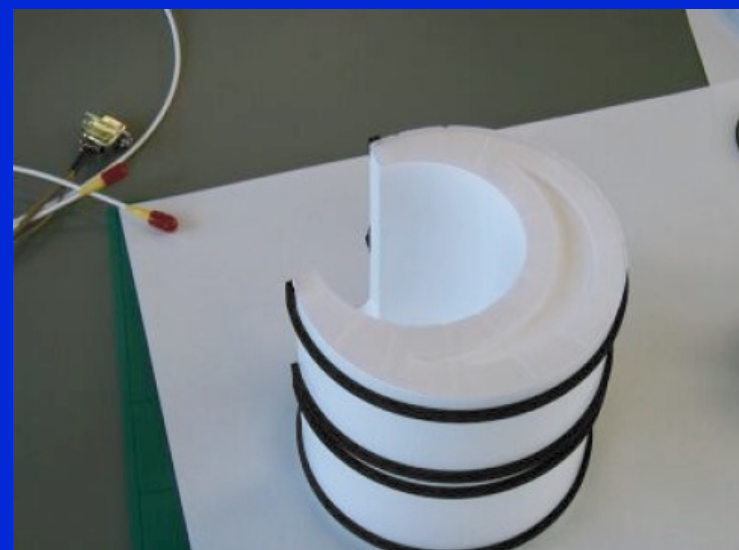
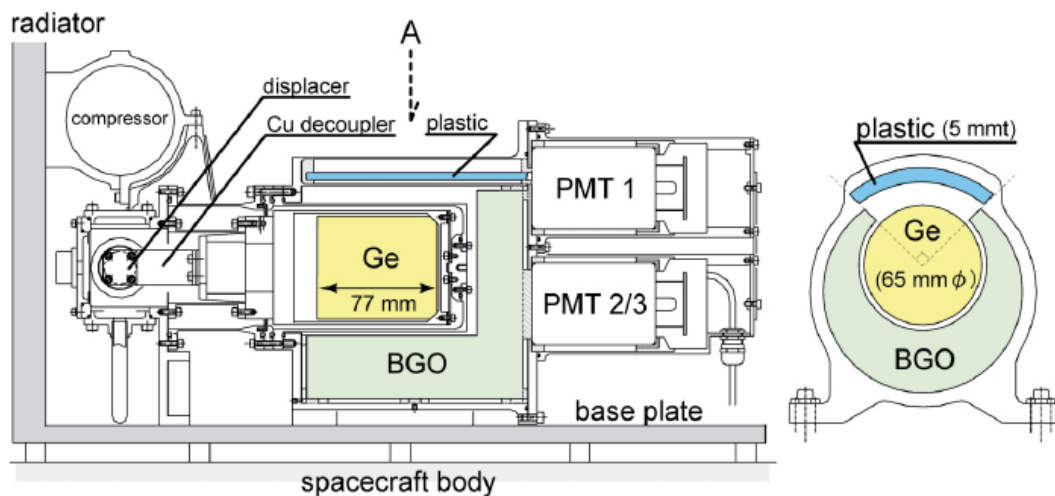
ガンマ線分光計GRSによる元素測定

月表面からのガンマ線・中性子線の放出メカニズム



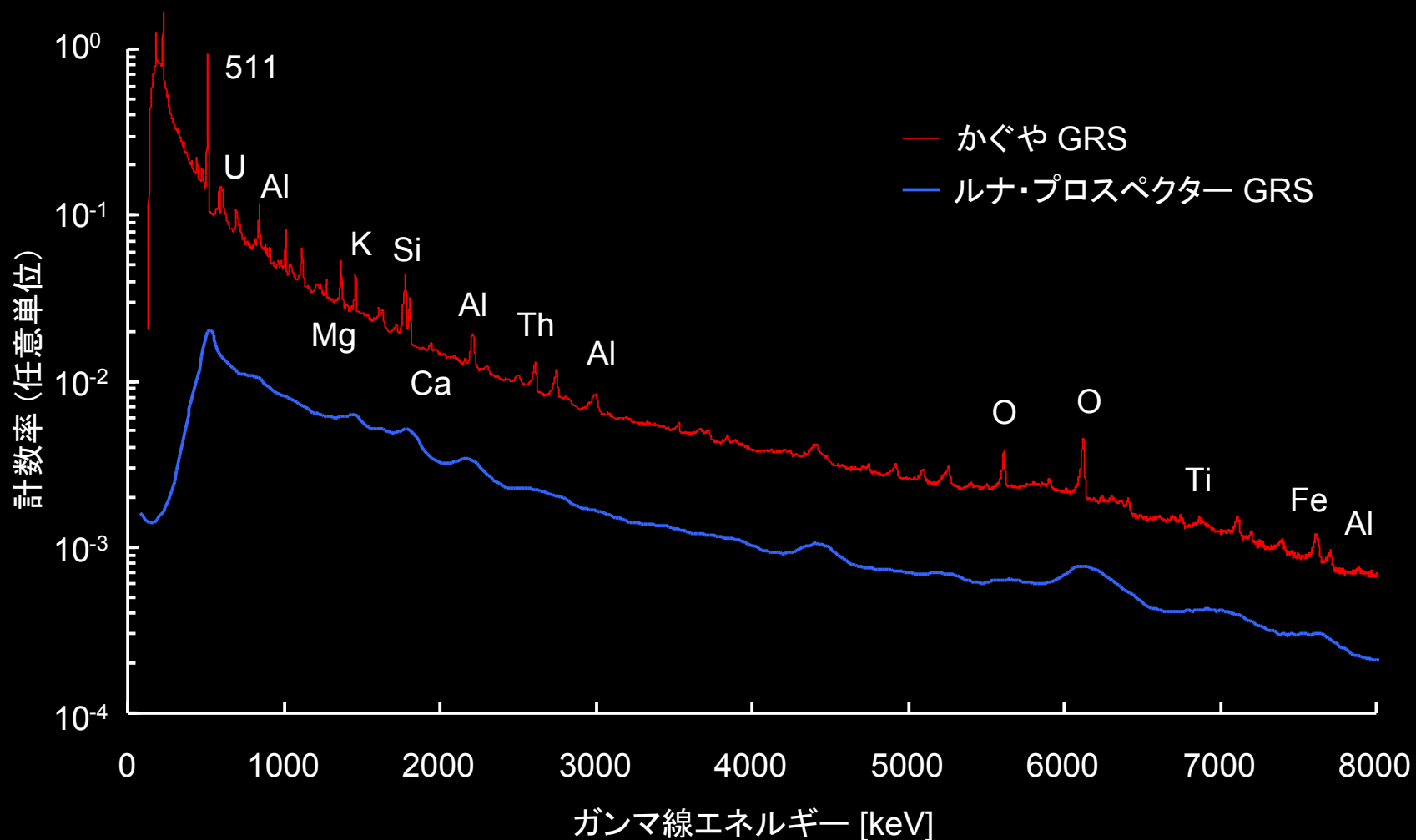


ガンマ線分光計GRSの構成



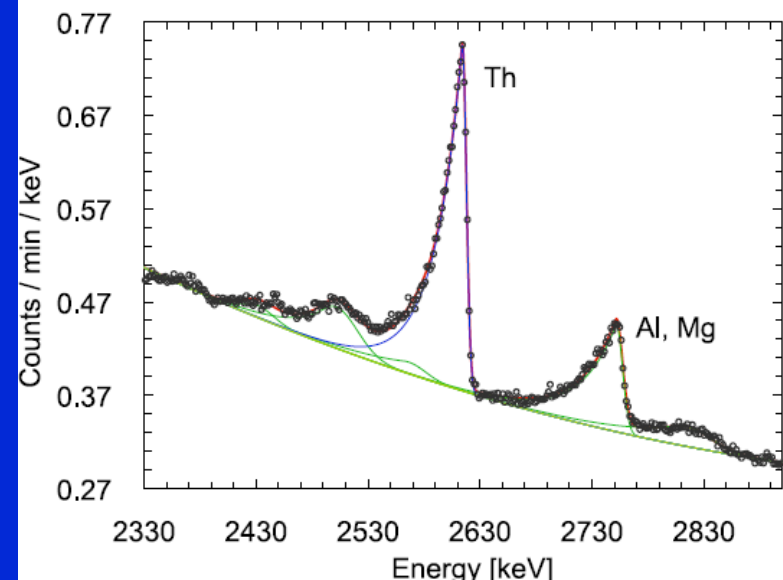
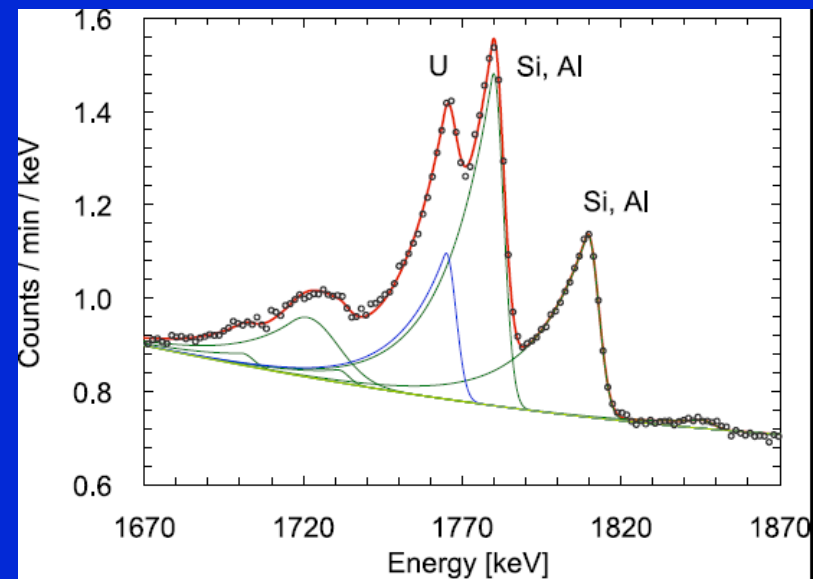
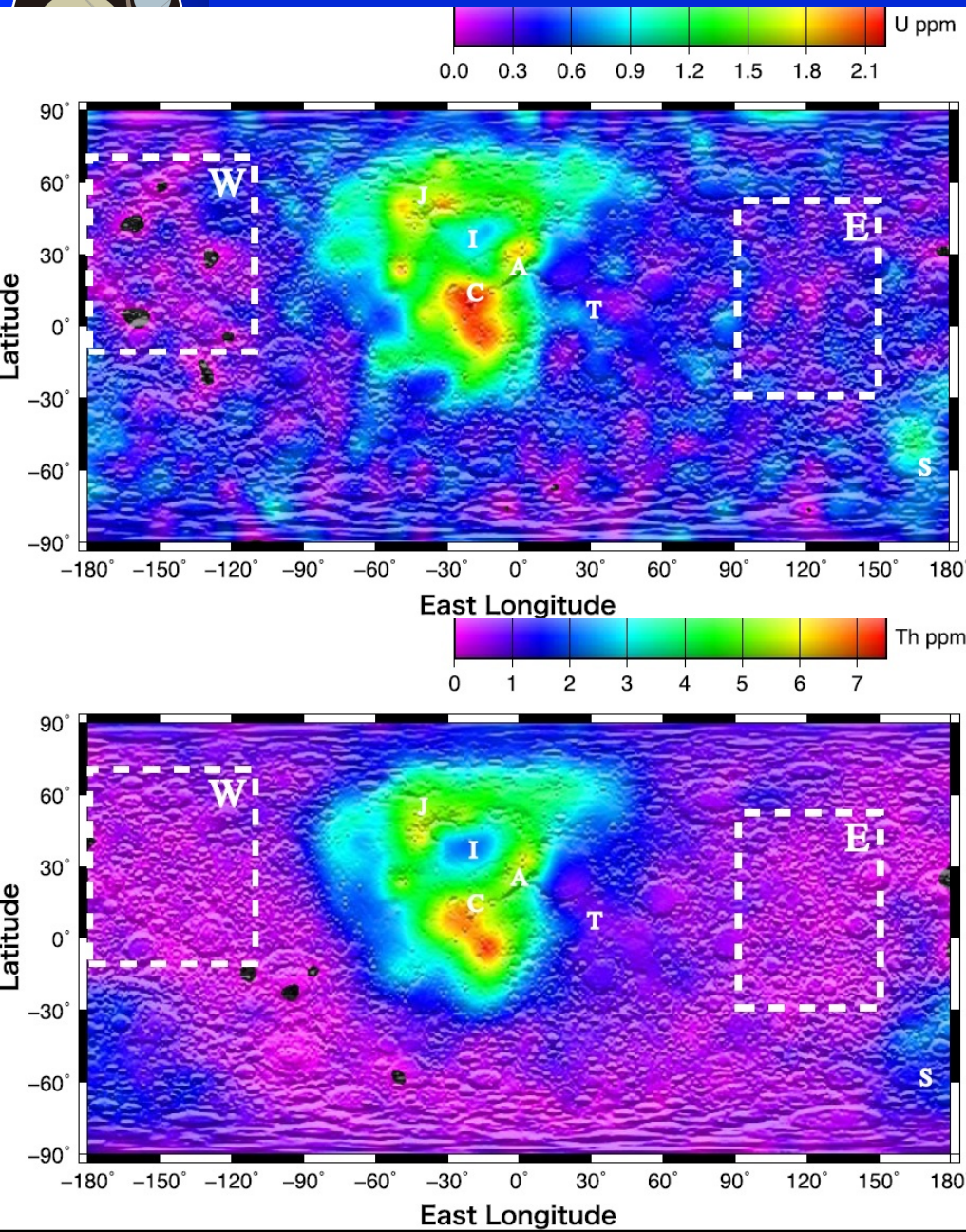


ガンマ線分光計による全球観測



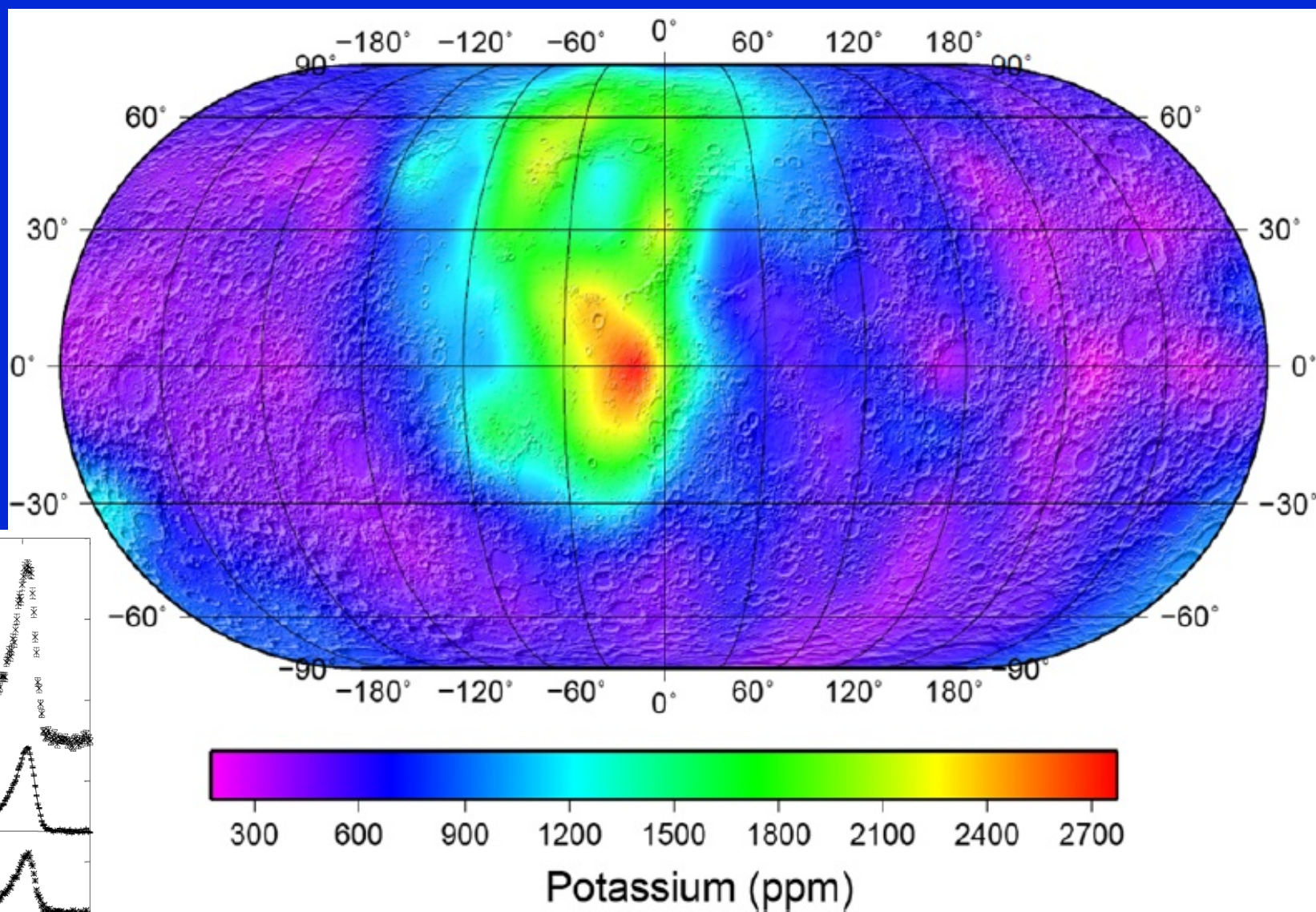
Uranium & Thorium distribution

Yamashita et al., 2010





Potassium distribution

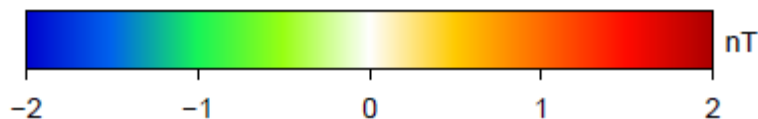
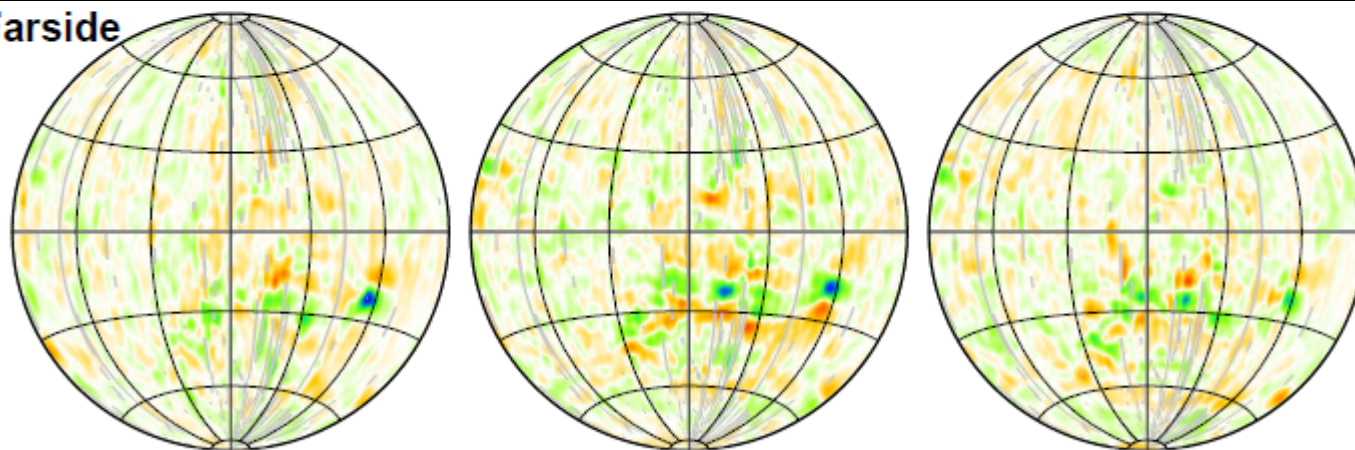




LMAG@100km vs LMAG@50km (Farside)

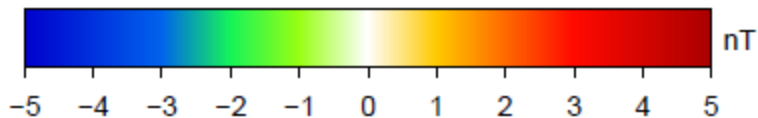
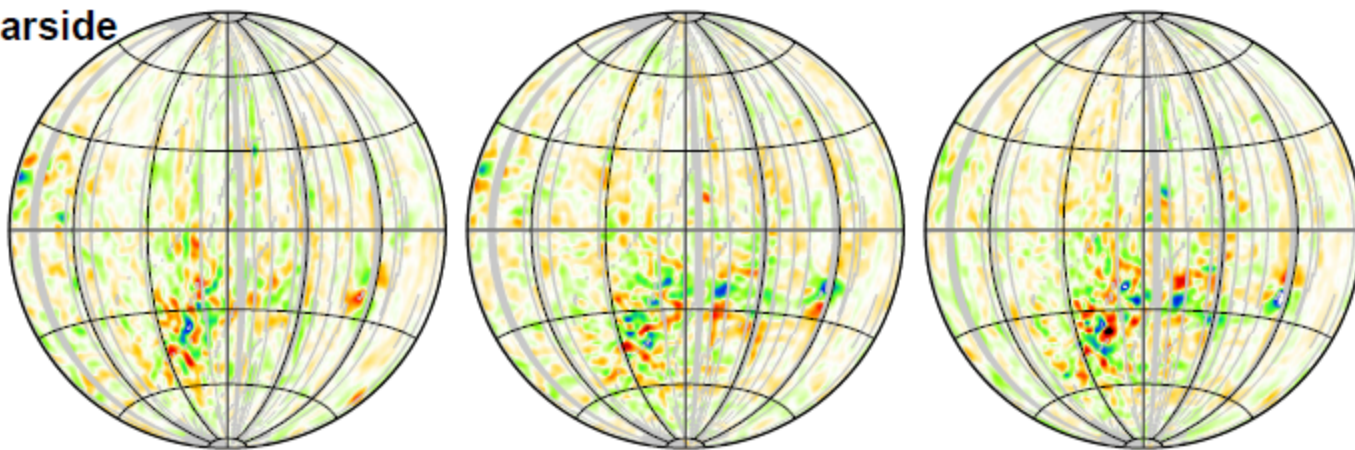
@100km

Farside



@50km

Farside



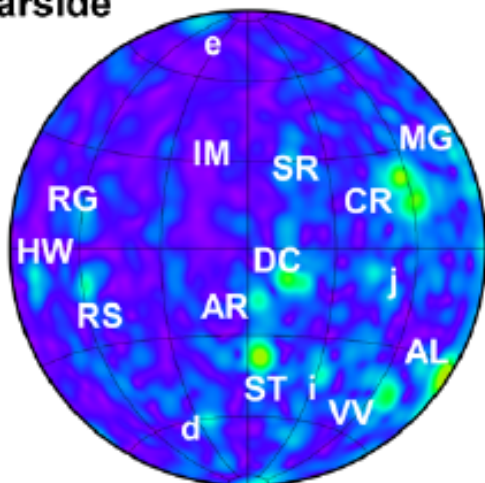


Magnetic Anomaly by Kaguya LMAG

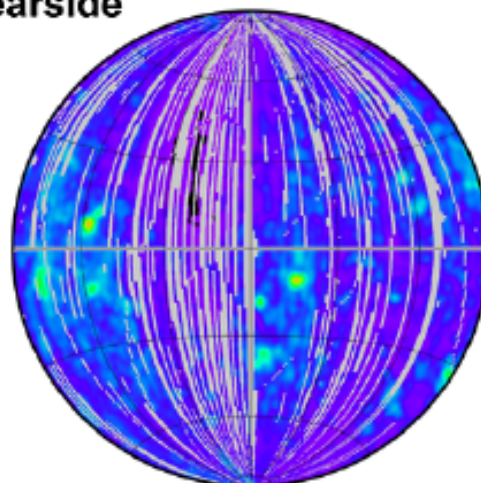
(a) 100 km altitude (Kaguya)

(b) 30 km altitude (RH08)

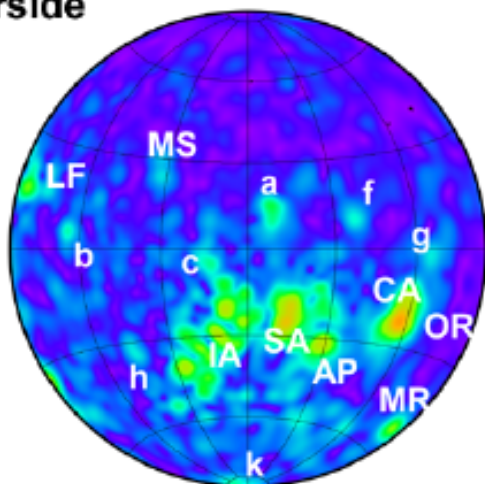
Nearside



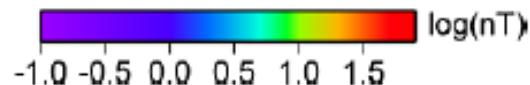
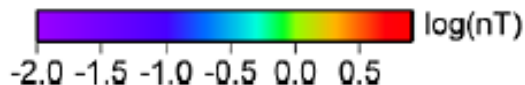
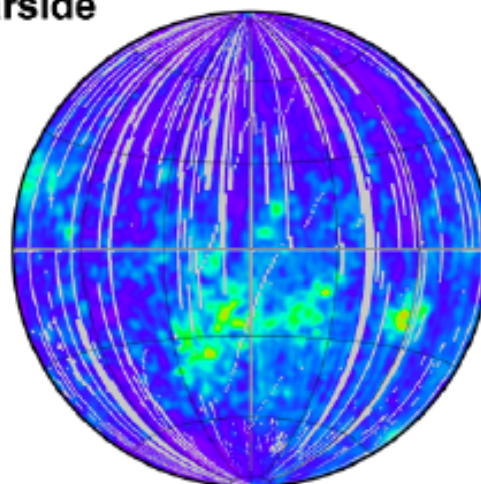
Nearside



Farside



Farside



LP data (Richmond & Hood, 2008)

Tsunakawa et al., 2010

月磁気異常と高反射率地域の対比

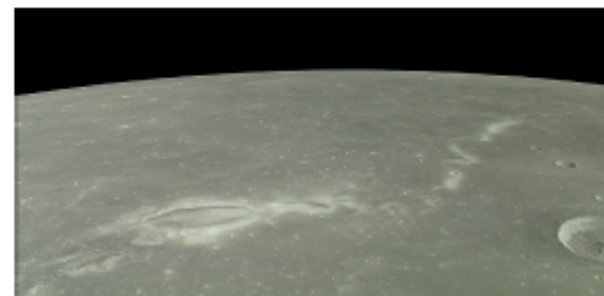
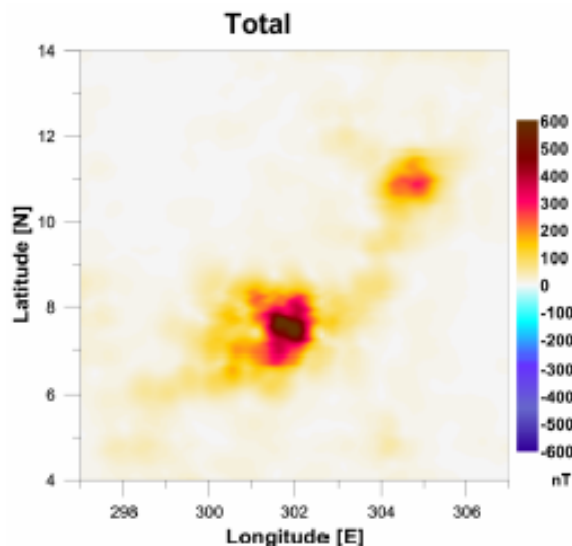
月面上ミニ磁気圏による宇宙風化の回避(?)

Reiner Gamma

LP

Alt. = 16.7 – 39.7 km

Max. of Btot = 663 nT



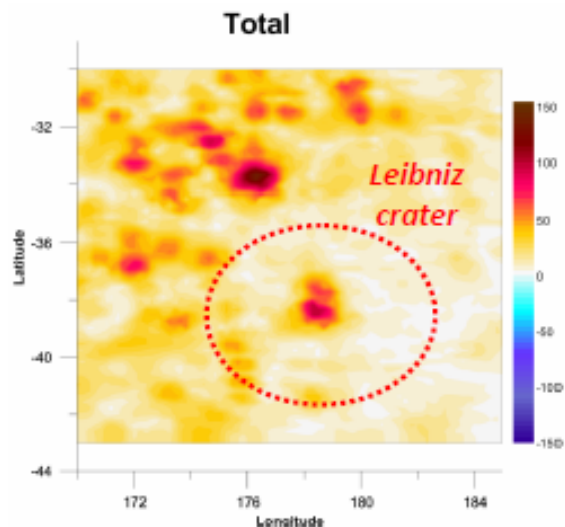
(Kaguya-HDTV)

Leibniz

LP

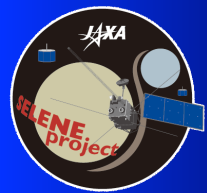
Alt. = 25.6 – 37.3 km

Max. of Btot = 100nT
(@ -5km)



(Kaguya-HDTV)

2010/11/3

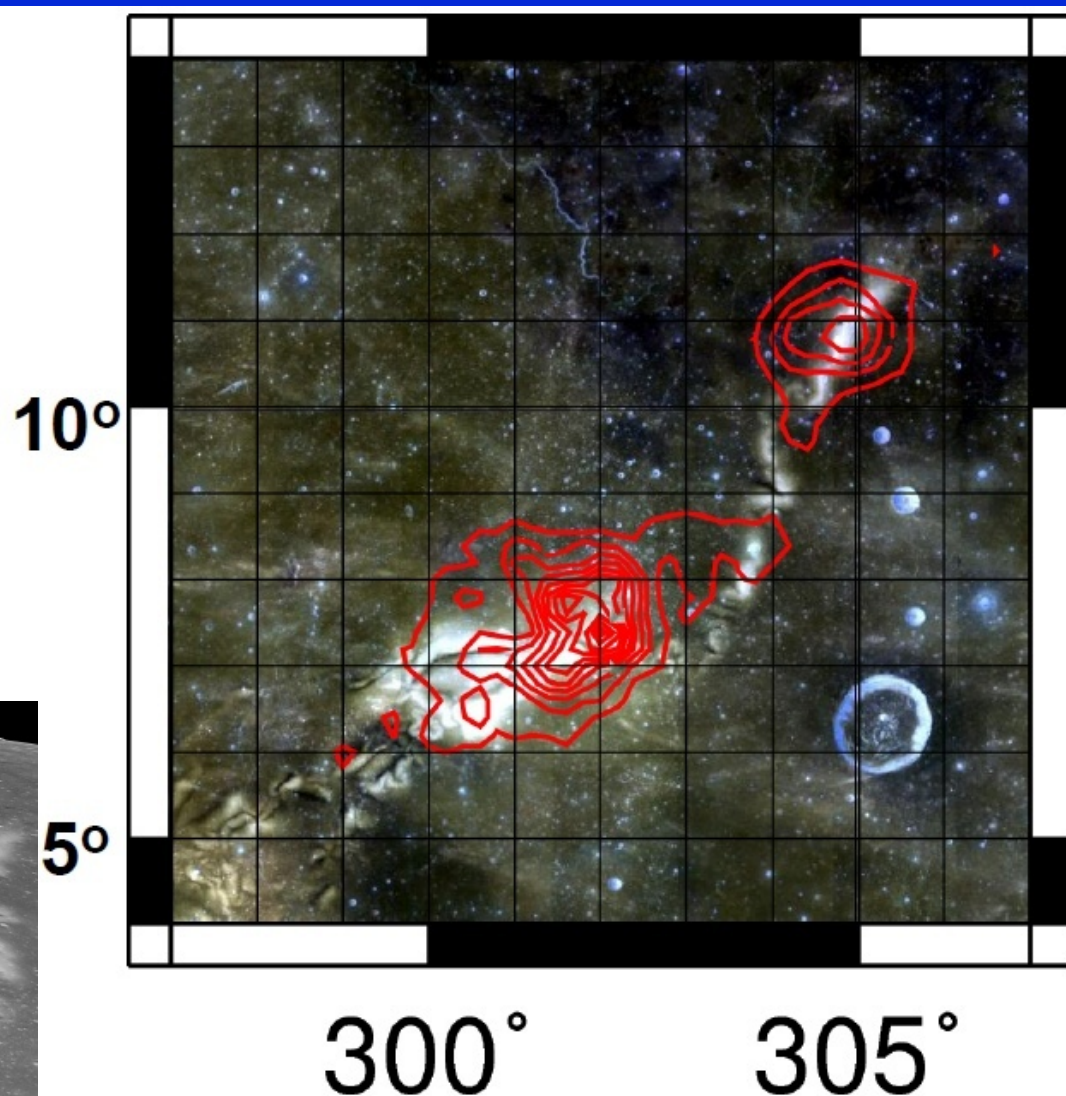
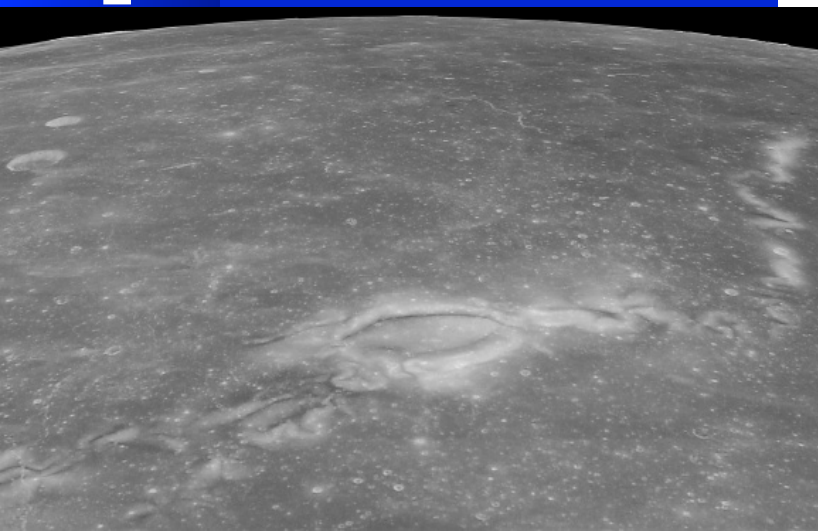


nd ENGINEERING Explorer

Magnetic Anomaly Research

Reiner- gamma

Max. 677nT@surface

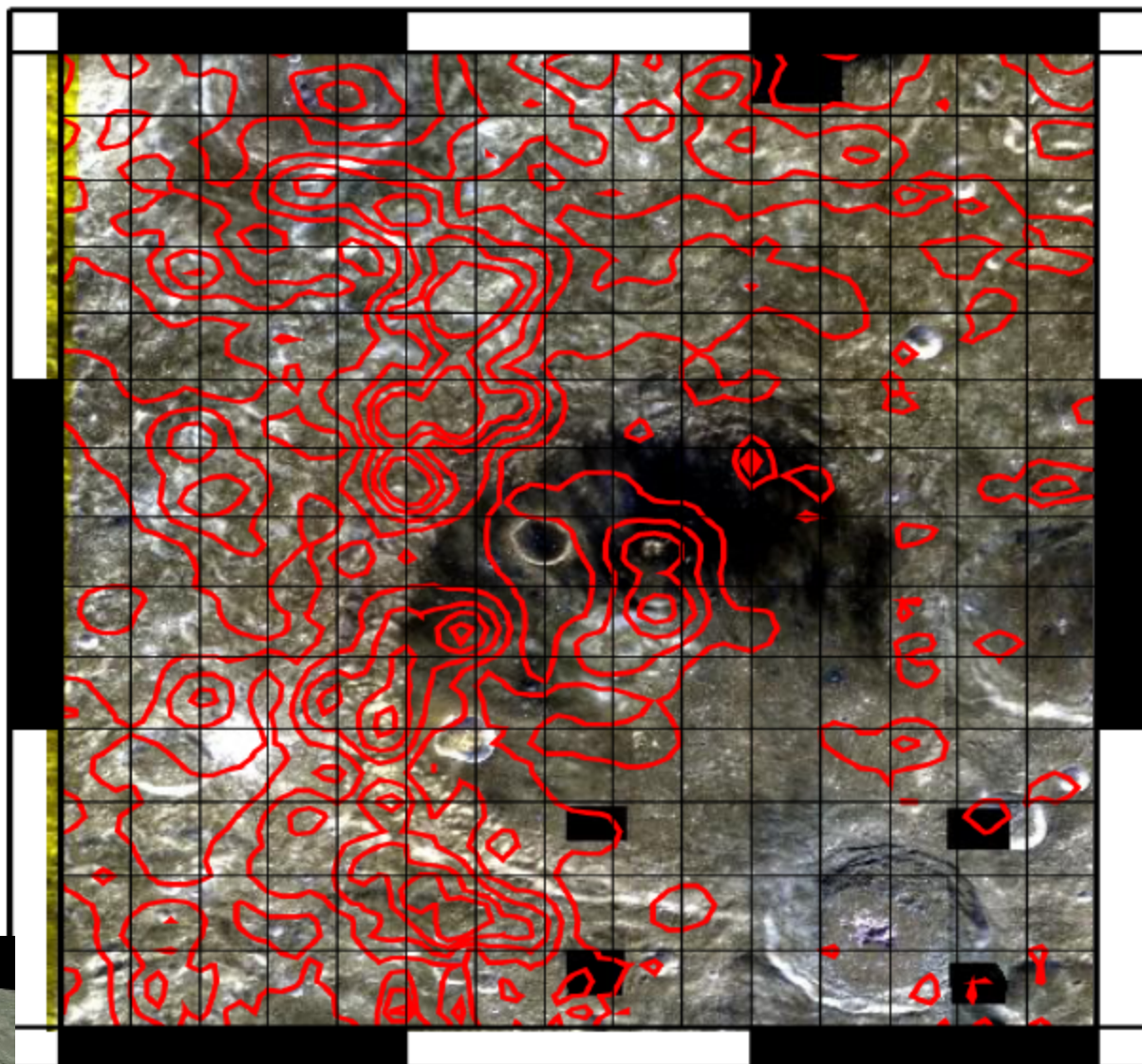
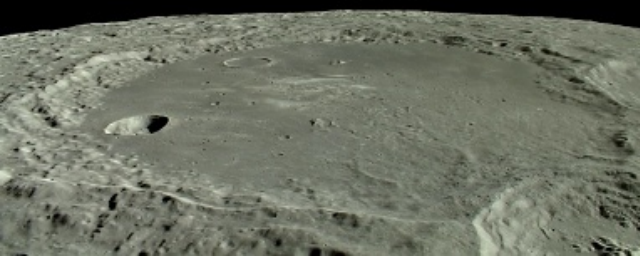
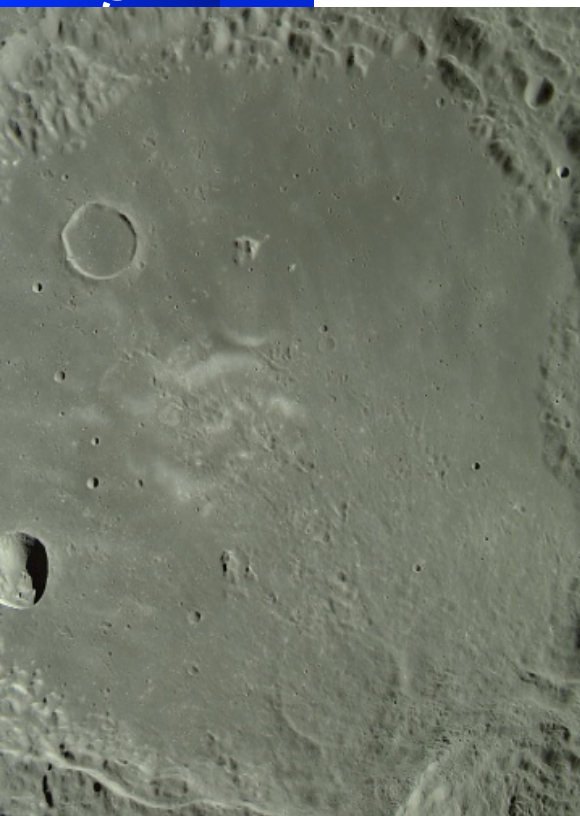




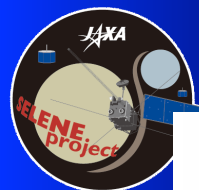
Leibnitz crater swirl

Max. 99.6 nT@surface

-30°



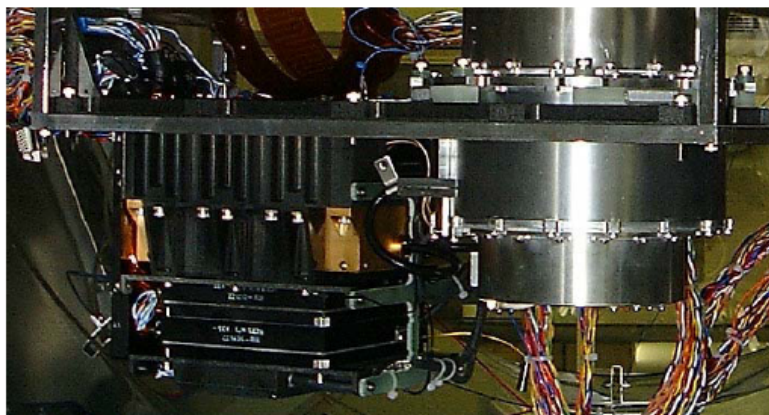
70° 175° 180° 185°



Plasma Experiments PACE 1. IMA

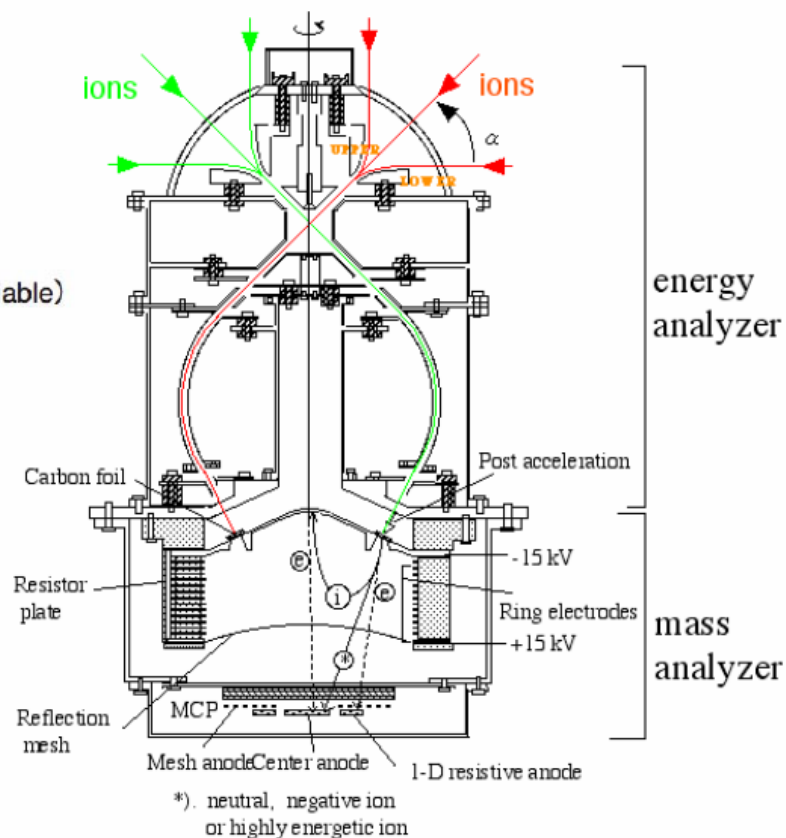
Specifications of IMA

Energy Range	5eV/q - 28keV/q
Mass Range	1 - 60
Energy Resolution	5% (FWHM)
Energy Sweep Step	32
Mass Resolution	$m/\Delta m \sim 15$
Field of View	2π str.
Angular Resolution	$5^\circ \times 10^\circ$ (FWHM)
Time Resolution	1second
FOV Sweep Range	$45^\circ \pm 45^\circ$
g-factor ($5^\circ \times 22.5^\circ$)	$10^{-6} \sim 10^{-4} \text{ cm}^2 \text{ str keV/keV}$ (variable)

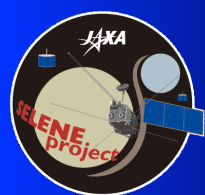


TOF Ion Energy Mass Spectrometer

IMA-S



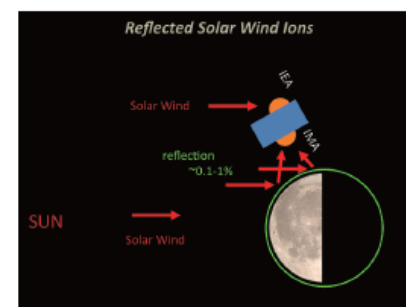
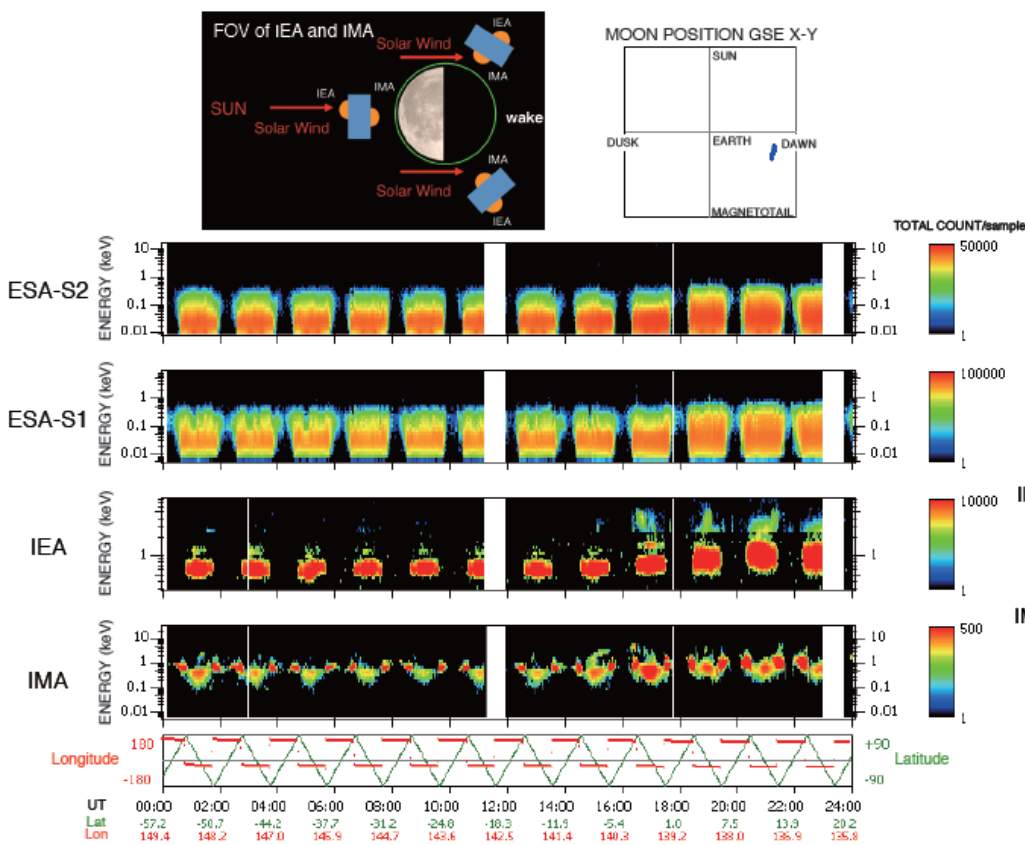
10cm



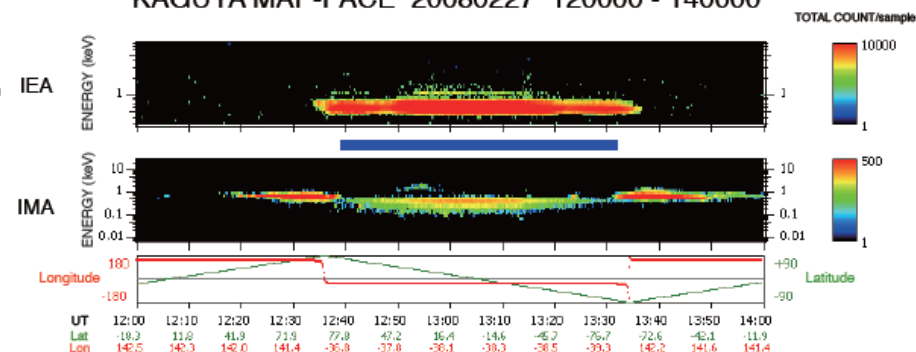
Solar Wind Observation of Plasma Instrument

Solar Wind Ion Reflection on the Lunar Surface

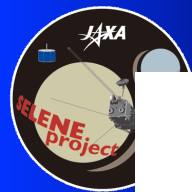
KAGUYA MAP-PACE 20080227 000000 - 240000



KAGUYA MAP-PACE 20080227 120000 - 140000

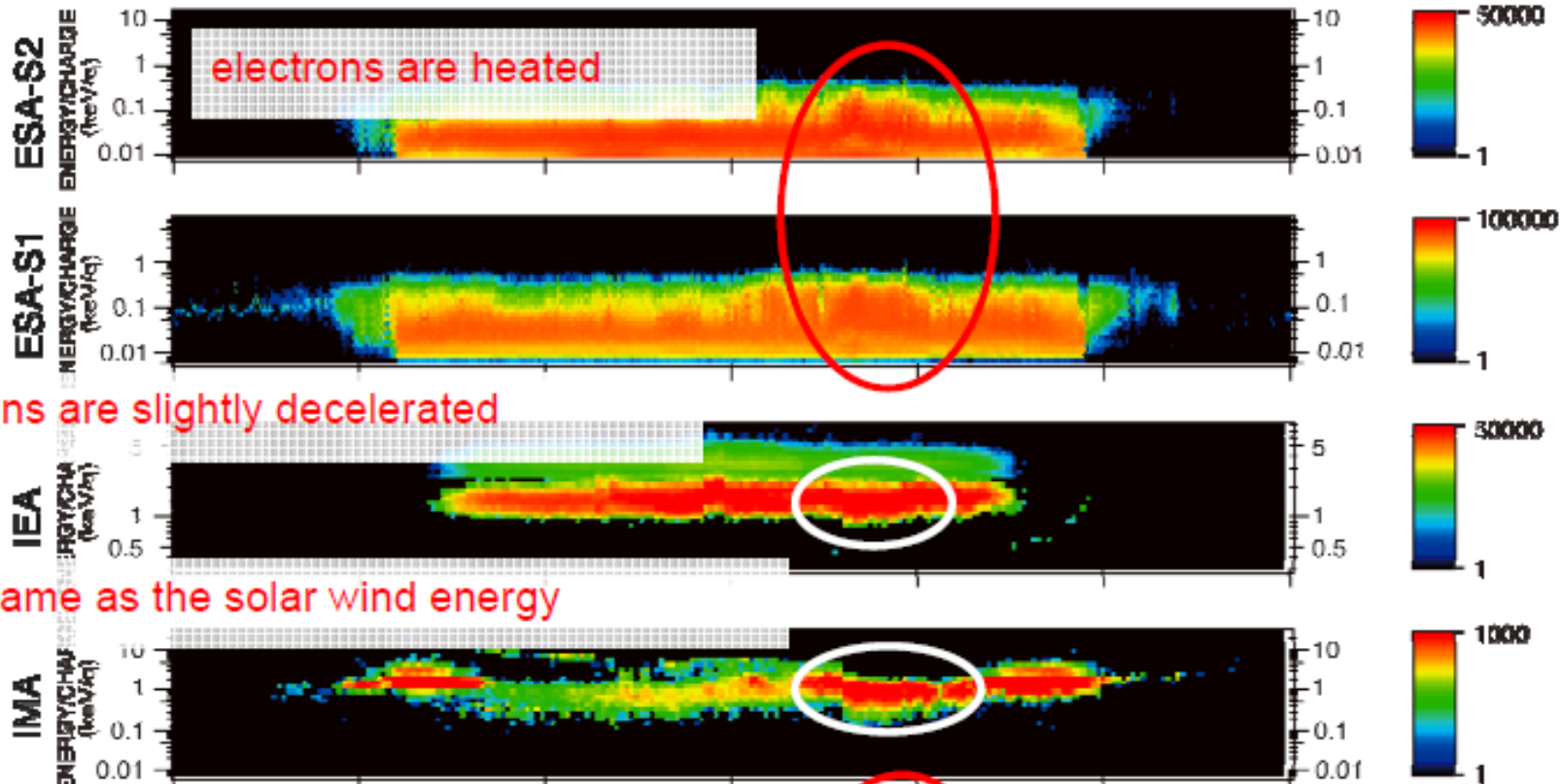


Solar Wind Reflection over magnetic anomaly



KAGUYA MAP-PACE 20080504 123000 - 143000

TOTAL COUNTS/sample



electrons are heated

ions are slightly decelerated

~same as the solar wind energy

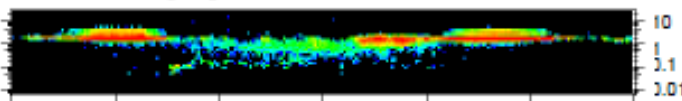
Lon. -158 Lat. -20 ~ -80
over magnetic anomaly
in South Polar Aitken

Time (UTC)	Longitude (Lon.)	Latitude (Lat.)	Altitude (km)
13:30	158.9	-21.4	150
13:50	157.9	-22.2	150
14:10	-20.5	-21.6	150

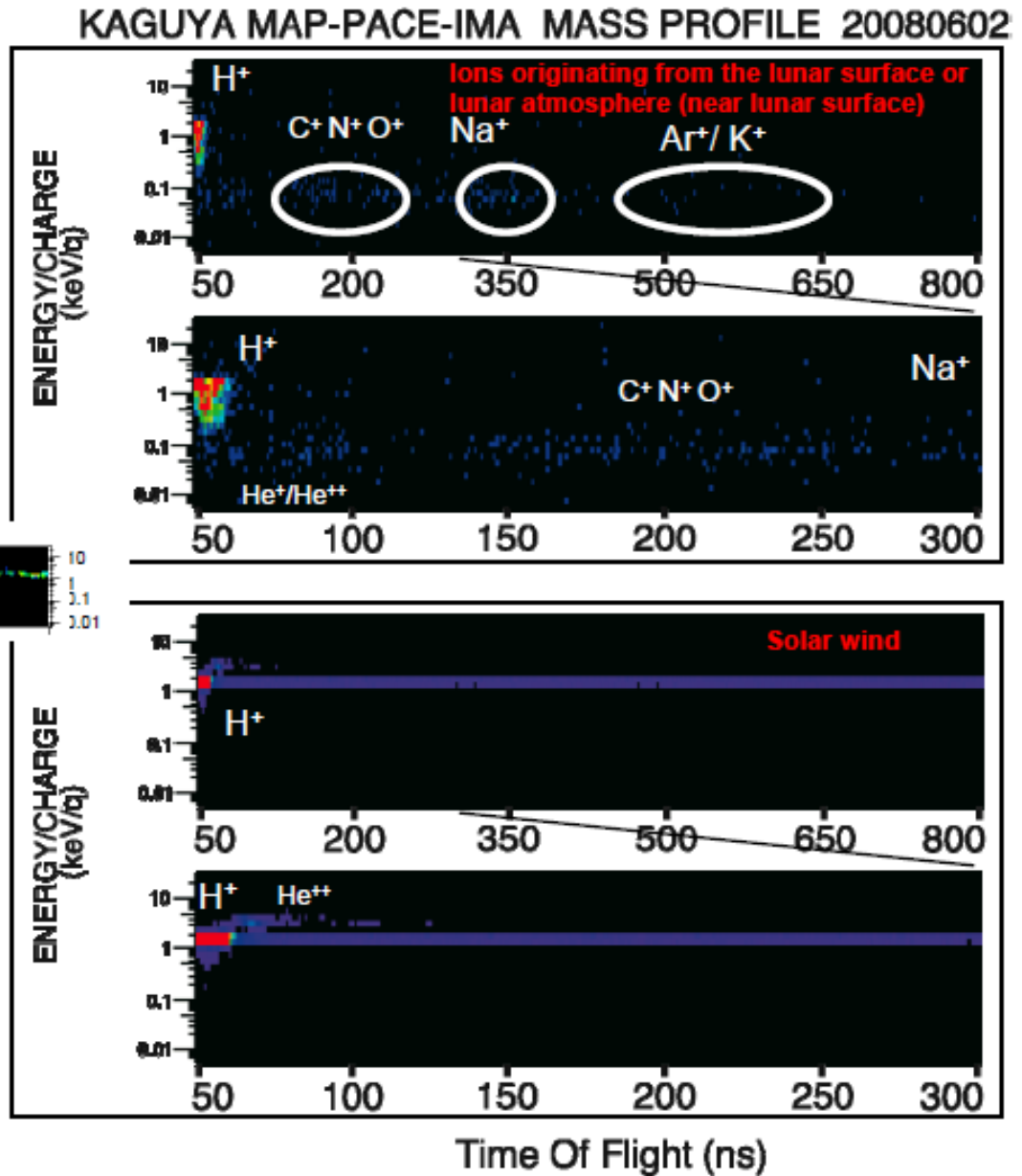
Sputtering surface ions



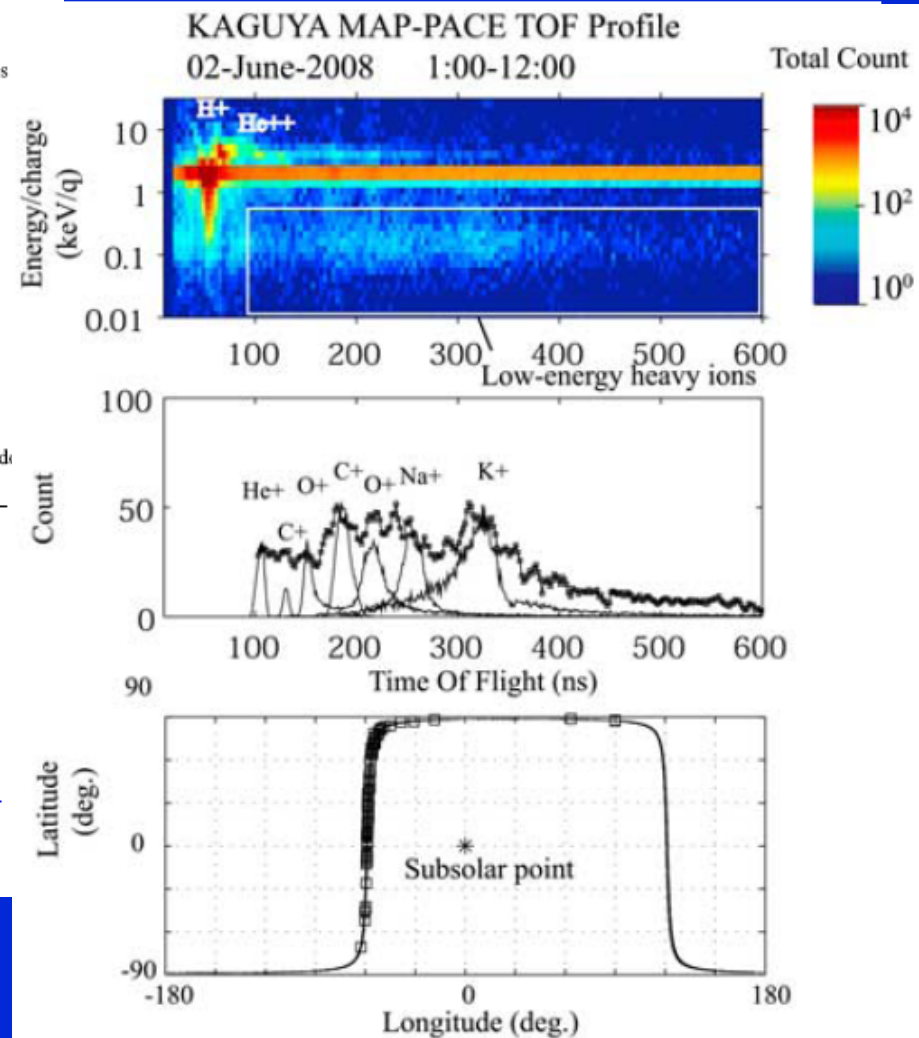
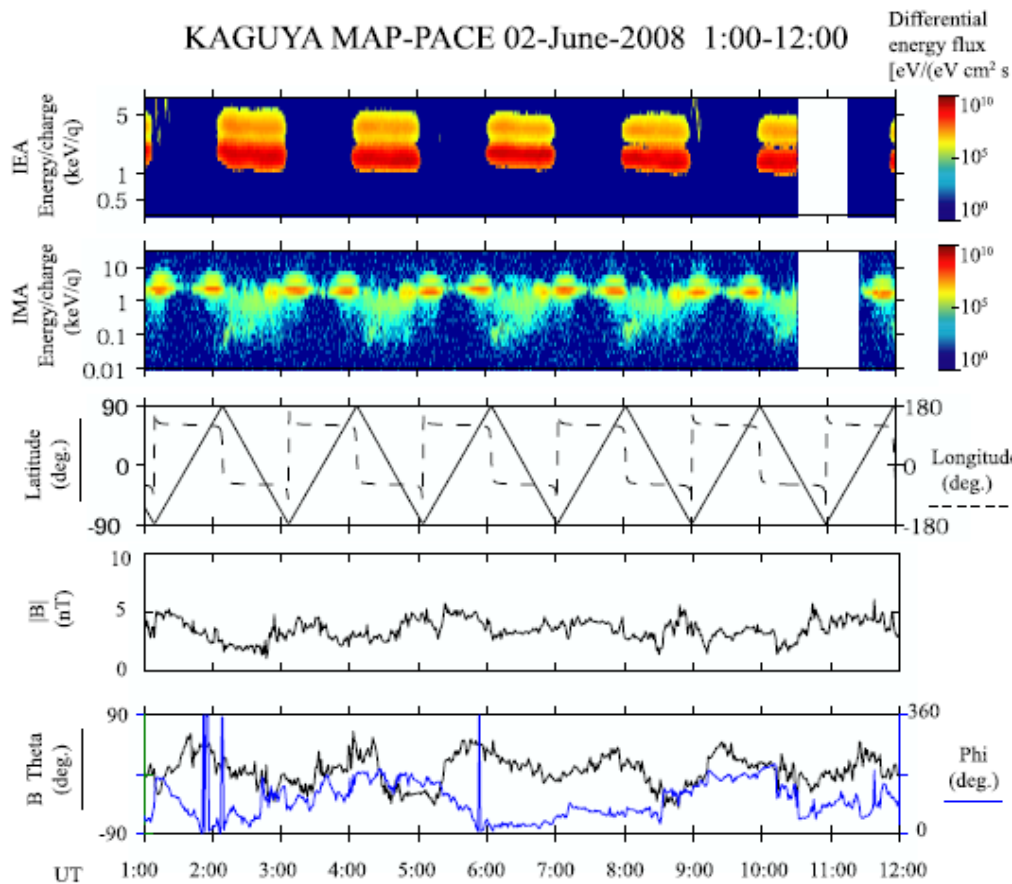
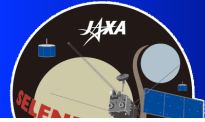
0210UT - 0220UT



0310UT - 0320UT



Sputtering surface ions by PACE

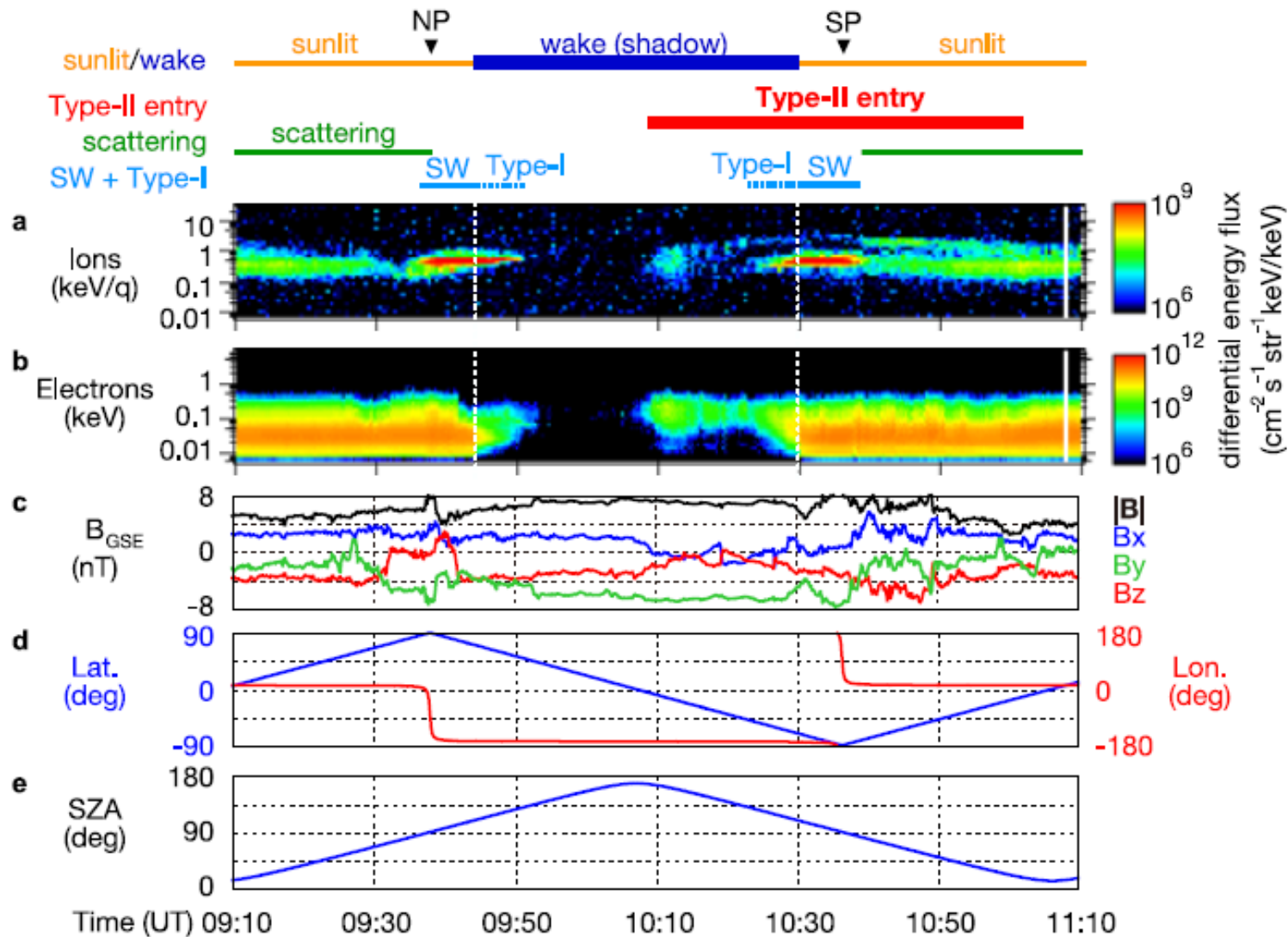


Yokota et al., *GRL* 36(2009), L38185



SW protons access into Moon wake

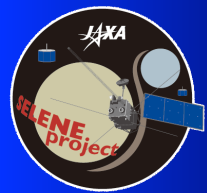
SELENE PACE and LMAG September 24, 2008 09:10-11:10 UT



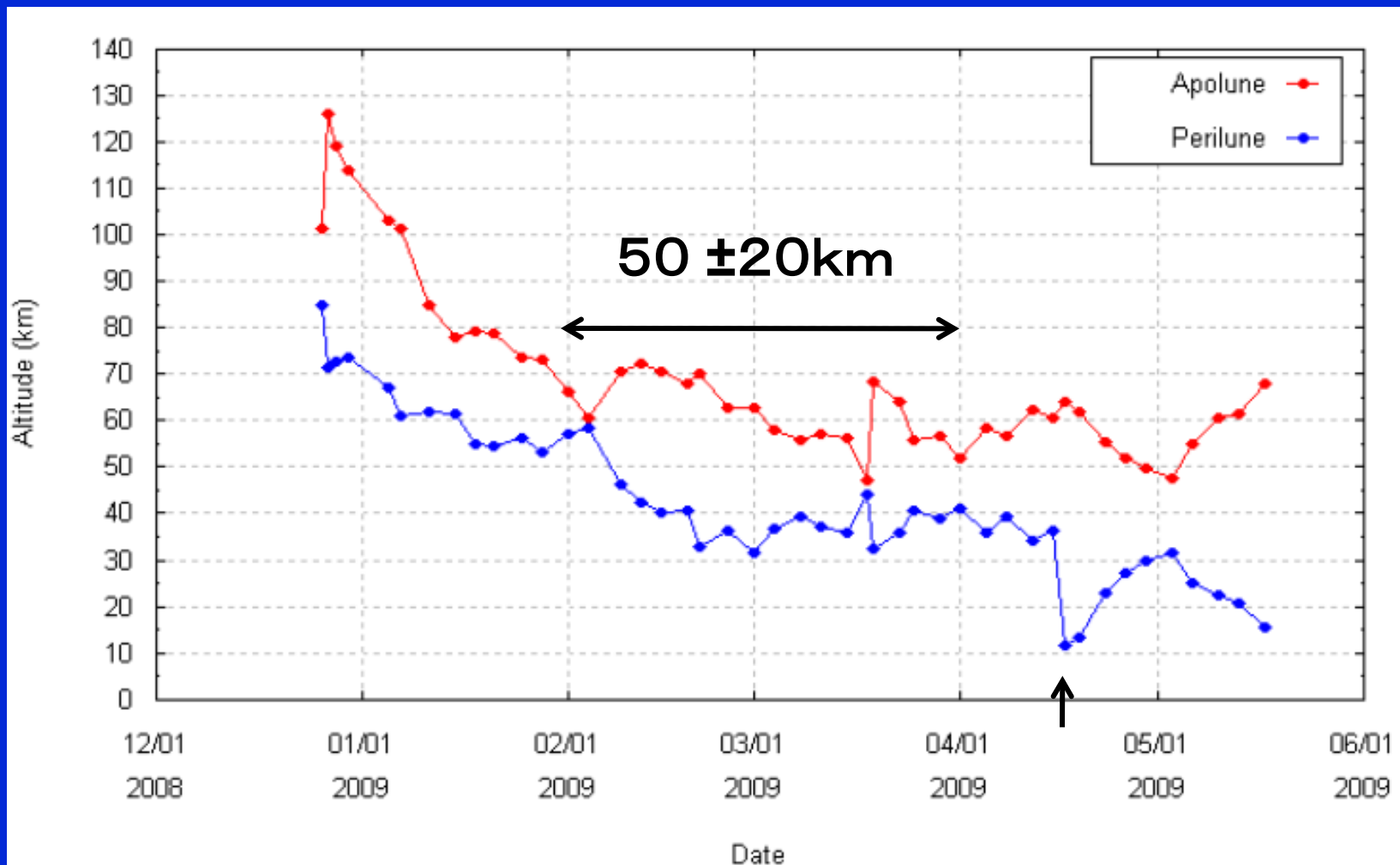


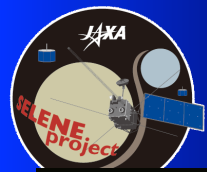
「かぐや」による発見

- 月裏側の重力異常 --- 二分性
- 月裏側の陰しい地形 --- 二分性
- 南極、北極の地形 --- 日照率
- 裏側の火山活動 --- 月の熱史
- 海の形成過程 --- 月の熱史
- 広範囲な斜長岩の同定 --- マグマオーシャン仮説を支持
- ミニ磁気圏の発見 --- 月のダイナモ
- 太陽風と月面の相互作用
- 全球表層物質の同定



Altitudes in the extended mission phase





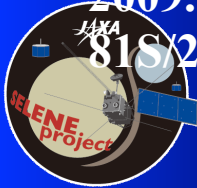
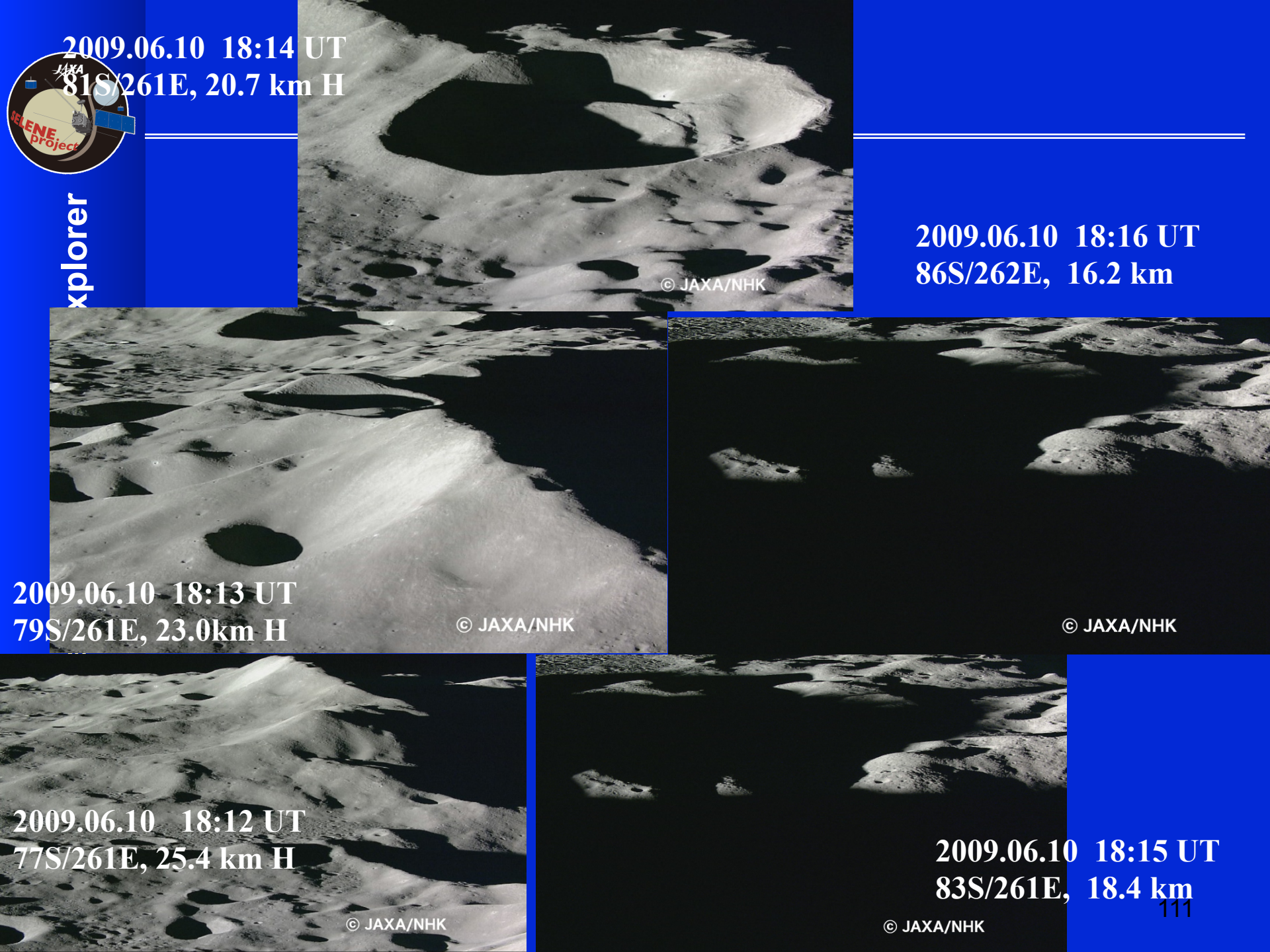
Low Altitude Images HDTV

Rutherford



5

Clavius Crater: 58.8S/14.1W, 245 km dia.



2009.06.10 18:14 UT
81S/261E, 20.7 km H

explorer

© JAXA/NHK

2009.06.10 18:16 UT
86S/262E, 16.2 km

© JAXA/NHK

© JAXA/NHK

2009.06.10 18:13 UT
79S/261E, 23.0km H

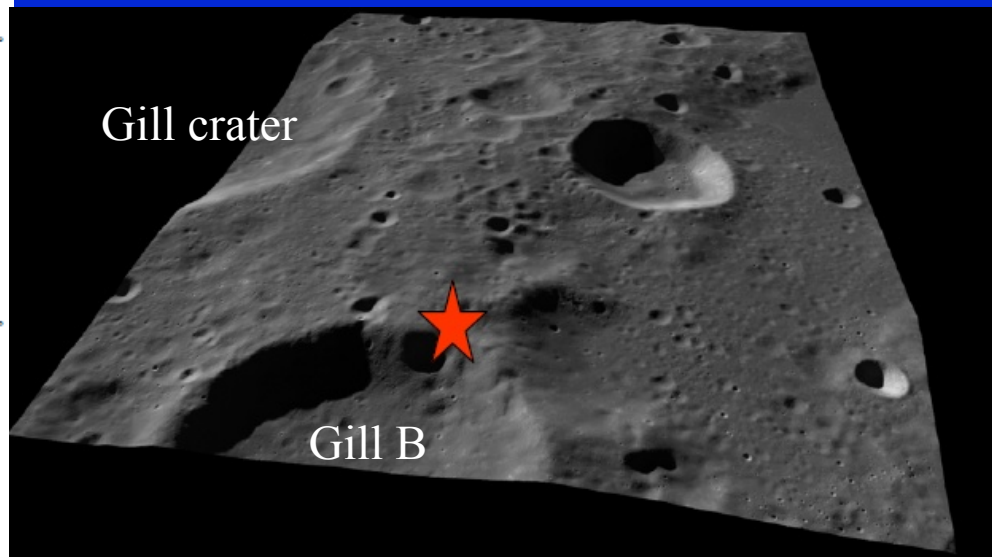
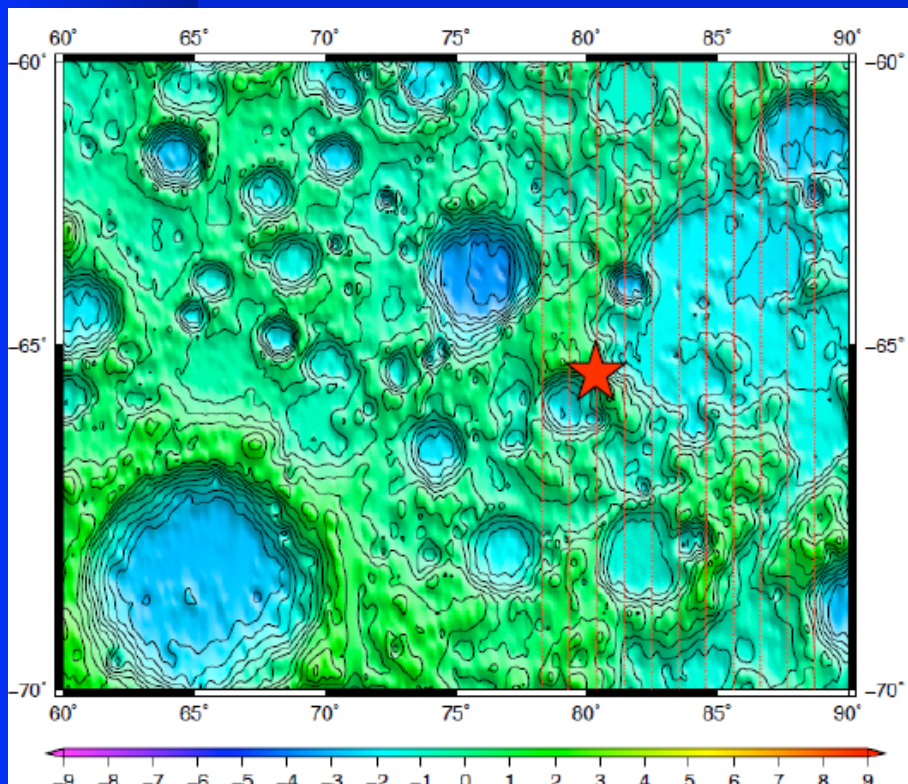
© JAXA/NHK

© JAXA/NHK

2009.06.10 18:15 UT
83S/261E, 18.4 km



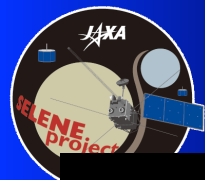
Kaguya Impact on the Moon



TC image of impact area

Impact Time: 09.06.10 T18:25:08.368

Impact point: 65.521S/80.418E



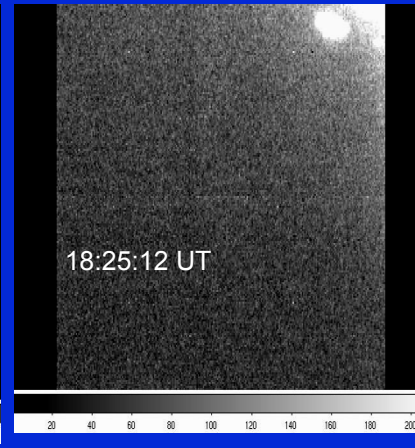
「かぐや」による衝突発光



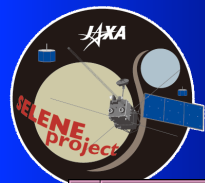
1.6 sec cycle time

J. Bailey (UNSW) & S. Lee (AAO)

3.9m Anglo Australia Telescope, IRIS-2 Infrared Camera

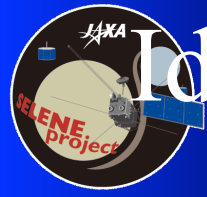


Physical Research Lab, Mt. Abu observatory in India



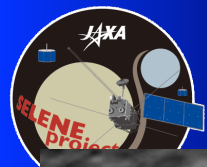
Final telemetry of Kaguya/LALT



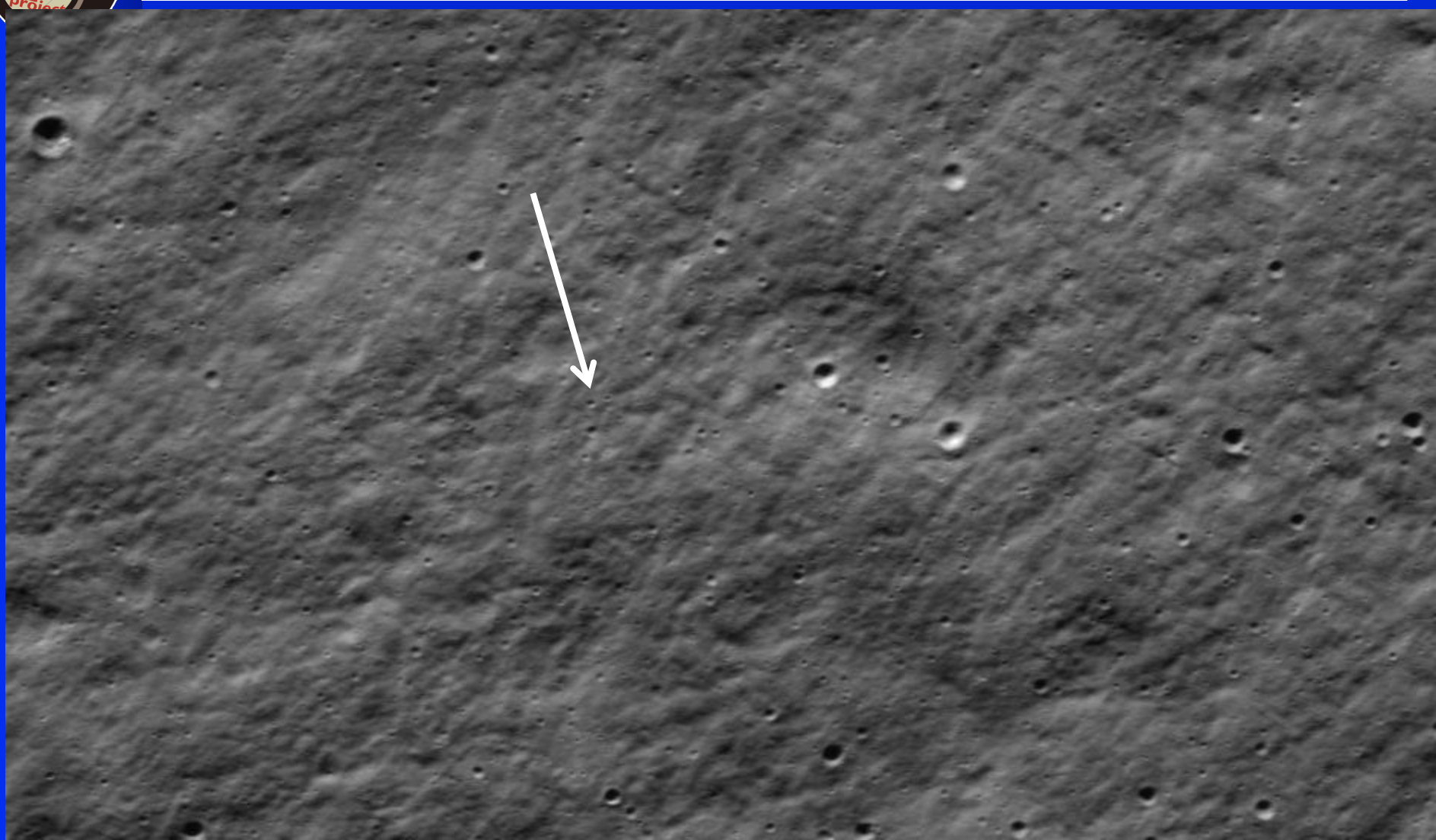


Identification of Kaguya Impact Crater

- Kaguya impacted near Gill-B crater rim at 2009-6-10T18:25:08.386.
- Evidenced by termination of telecommunication signals, ground observations of impact flash
- Estimation of impact site and time using orbital estimation after deceleration ΔV and LALT topography data
- Press released the impact point 65.521S / 80.418E
- Impact crater search using LROC-NAC images



Press-released Kaguya I.S.



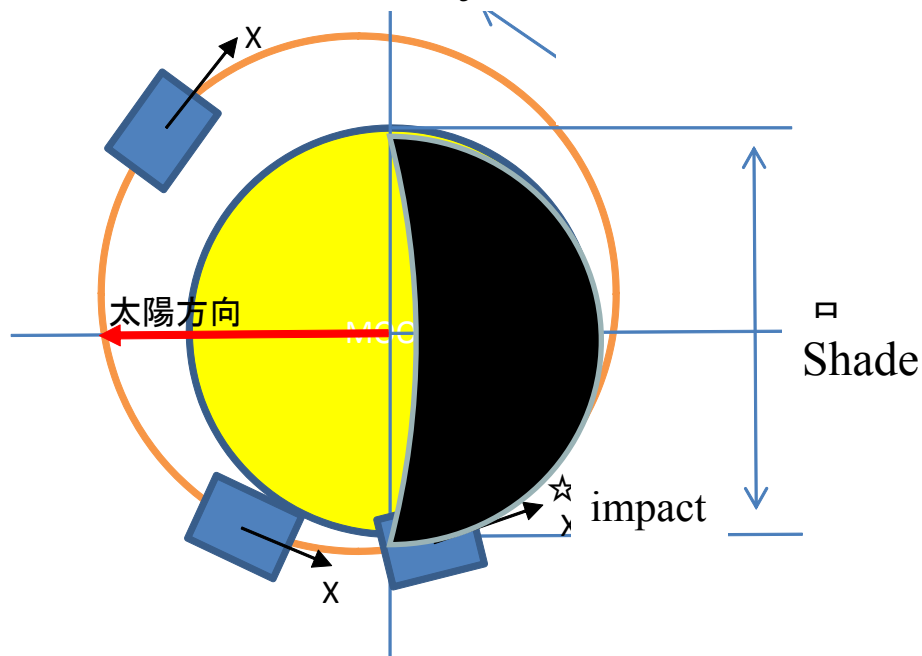
65.521S/ 80.418E

LROC/NAC M141751486R

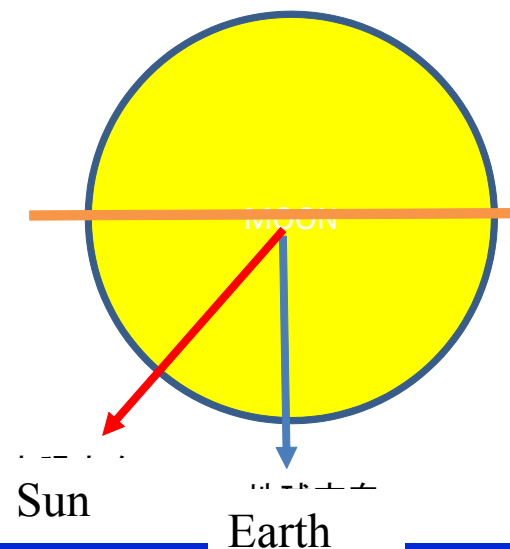


Kaguya Maneuver for controlled infall

Orbital Plane Projection



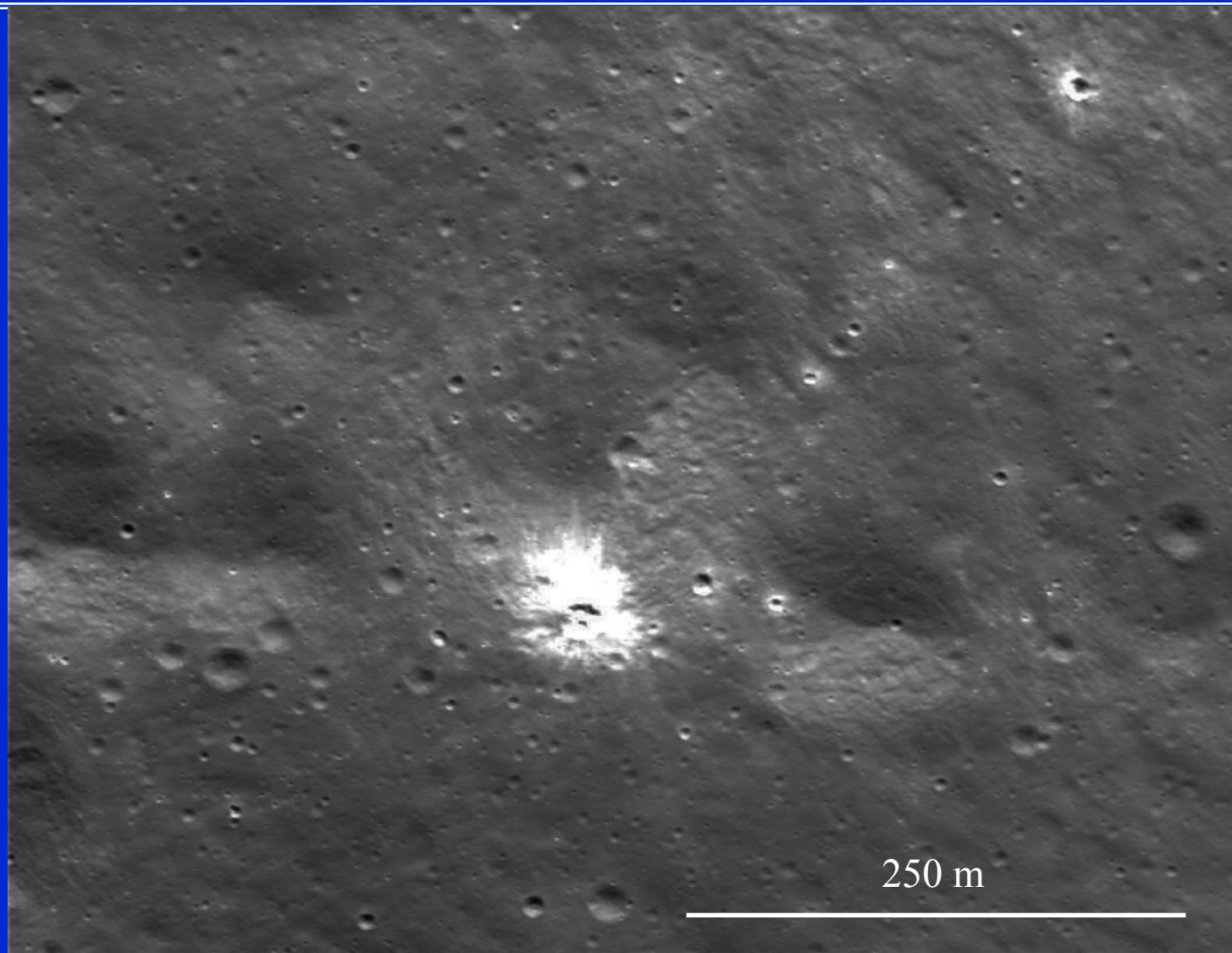
北極上空から見た図
Projection from North Pole





SELenological and ENgineering Explorer

Kaguya Impact Crater

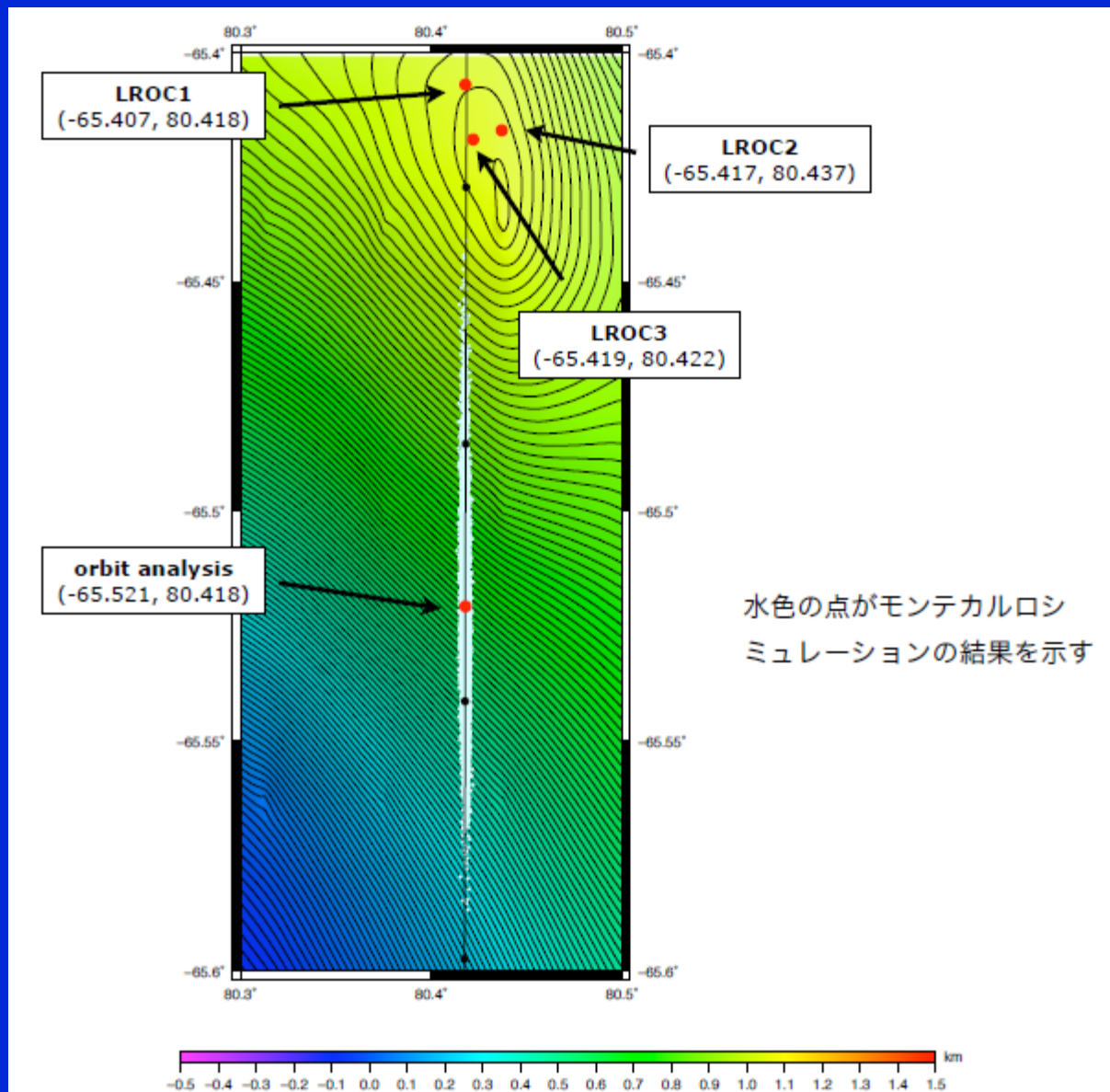


Center of crater (65.407S / 80.418E)

LROC-NAC M141751486R



落下の許容範囲





2025年日本人宇宙飛行士月に立つ！！

SELENE and Engineering Explorer

