Japan Geoscience Union Meeting 2015
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PPS05-01 会場:106 時間:5 月 27 日 14:15-14:30

火星大気散逸探査（のぞみ後継機）のミッション計画とシステム検討
Examination of Mission Strategy and Spacecraft System to Study Martian Atmospheric Escape

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火星の大気の変遷には、太陽風との相互作用が大きく影響したと考えられているが、今現在の火星においてさえ、大気と太陽風との相互作用の物理プロセスは明らかになっていない。
地球と異なり、現在の火星は惑星固有の磁場を持たない。その結果、太陽風は低い高度にまで達し、火星の大気と直接相互作用して、火星大気の一部は散逸される。この過程は、長い間には火星大気の組成を変化させるまでの作用を及ぼし、火星大気や、ひいては地上・地下の二酸化炭素（ドライアイス）や水・氷の変遷に大きく影響した可能性があると考えられている。大気散逸の様子は、太陽活動や太陽との距離によって影響を受けるため、大気の長期的な変遷を考えるためには、様々な太陽の状態について相互作用の働きを知らなければならない。
我々は、2011 年 12 月に JAXA 宇宙科学研究所理学委員会において火星大気散逸探査検討ワーキンググループを発足させた。このワーキンググループは、大気散逸に焦点を当て、２つのオービターによって散逸の全体像とプロセスを同時に観測することを検討している。１つのオービター（親衛星）によって、大気散逸が起きているその場のプラズマや中性粒子の観測、散逸する大気等から発せられる光をリモートで撮像し、もう１つのオービター（子衛星）によって同時に太陽風をモニターするというものである。大気散逸の物理プロセス、グローバルな全体像、物理プロセスを決める太陽風のモニターを同時に行うことは、複数衛星によって初めて可能となる、真に大気散逸の全容解明に迫る観測である。
現在我々は、2024 年頃の太陽活動極大期における火星観測を行う大気散逸観測オービターの実現に向けて、サイエンス・観測機器・衛星の検討を行っている。科学目標の定量的・具体的な策定、それを達成するために必要な観測機器技術、計画を実現させるための衛星システムおよび軌道計画を検討している。 検討内容の報告と、今後の開発計画を発表する。

キーワード: 火星, 惑星大気, 太陽風, 惑星磁場, プラズマ
Keywords: Mars, Planetary atmosphere, Solar wind, Planetary Magnetic Field, Plasma

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MARS PLATE-TECTONIC-BASEMENT
MARS PLATE-TECTONIC-BASEMENT

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Introduction: The Hadean-age-equivalent (>4.0 Ga) Martian basement complex has heretofore been difficult to characterize. This is due to extensive modification by the Late Heavy Bombardment and subsequent impacts, as well as chemical alteration of the primary rocks (including weathering rinds, clay minerals, Al/Fe oxides/hydroxides, sulfates, and evaporite deposits). Obscuration of a felsic basement includes erosion of the terrain predominantly through wind and water activity, as well pervasive mantling by wind- (e.g., aeolian), water- (e.g., fluvial, alluvial, colluvial, glacial, periglacial), and volcanic- (airfall deposits, lava flows materials, fine-grained volcanic spherules transported by wind) related materials.

Yet, unlike the Hadean rocks that have been obliterated on Earth, the Hadean-age-equivalent ancient Martian basement is still preserved. This is because an Earth-like phase of Mars, including an active dynamo and hypothesized plate tectonism, terminated sufficiently early in its evolutional stage to archive early Mars rocks, early solar system history, and possibly evidence of early life. New evidence for plate tectonism includes a systematic, spatial arrangement of landforms, referred to as the Claritas subduction zone region that is strikingly similar to the plate-tectonic-modified landscapes of the western US that resulted from plate migration and subduction, including the subduction of the denser mafic Farallon Plate beneath the lighter felsic North American Plate. We will present this finding and additional evidence for a Hadean-age-equivalent phase of plate tectonism on Mars and its implications. For greater details see [1].

[1] Dohm, J.M., Spagnuolo, M.G., Williams, J.-P., Viviano-Beck, C.E., Karunatillake, S., Alvarez, O., Anderson, R.C., Miyamoto, H., Baker, V.R., Fairen, A., Mahaney, W.C., Hare, T.M., Robbins, S.J., Niihara, T., Yin, A., Judice, T., Olsen, N., Maruyama, S., 2015. The Mars Plate-Tectonic-Basement hypothesis. 46th Lunar and Planetary Science Conference, Abstract 1741.

Keywords: mars, plate tectonics, basement, felsic

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PPS05-03 会場:A03 時間:5 月 28 日 09:00-09:15

火星大気と表層水の初期進化：同位体組成からの制約
Early Evolution of Martian Atmosphere and Hydrosphere: Constraints from Isotopic Compositions

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現在の火星は極域に少量の氷があるのみの寒冷で乾燥した表層環境を持つ惑星である。一方で、初期の火星は大量の液体の水が存在する温暖な気候であったという証拠が続々と発見されてきている (DI Achille & Hynek, 2010 など)。初期の火星大気と表層水は天体衝突による大気剥ぎ取りと熱的/非熱的大気散逸によって失われた可能性がある (Lammer et al., 2008) が、その時期と各過程がどの程度寄与したかについてはよくわかっていない。

熱的/非熱的大気散逸は重い同位体が火星大気と表層水に濃集する同位体分別を引き起こす。一方、天体衝突剥ぎ取りは同位体分別を引き起こすことなく、大気の一部を取り除く。初期の火星大気と表層水の進化は 41 億年前の結晶化年代 (Lapen et al., 2010) を持つ火星隕石 Allan Hills 84001(ALH 84001) の記録する揮発性元素同位体組成によって制約できる。ALH 84001 の記録する 41 億年前の高い水素同位体比 (始原的な水の 2-4 倍の D/H 比、Boctor et al., 2003; Greenwood et al., 2008) は、火星形成後の 4 億年間にその後の時代を上回る大量の水が熱的/非熱的大気散逸によって失われたことを示唆している (Kurokawa et al., 2014)。一方で、41 億年前の希ガス同位体比は分別していない値を示すことから、大気は 41 億年前より最近の時代に失われたと考えられている (Mathew & Marti, 2001; Jakosky & Phillips, 2001)。また、ALH 84001 の窒素同位体組成の見積もりは過去の研究によって異なる (Miura & Sugiura, 2000; Mathew & Marti, 2001)。

我々は天体衝突剥ぎ取りと熱的/非熱的大気散逸を考慮して、大気と表層水の総量と同位体組成の進化をそれぞれ独立に計算した。まず、確率論的衝突モデル (Kurosawa et al., 2013) を用いて、大気全圧の進化を計算した。天体衝突頻度分布は月クレーターに基づくモデル (Chyba, 1991) を用いた。剥ぎ取り効率は sector blow-off モデル (Vickery & Melosh, 1990) を用いて計算した。岩石蒸気の運動量はエントロピー法 (Ahrens & O'Keefe, 1972; Kurosawa et al., 2012 など) とフォルステライトの熱力学データ (Sekine et al., 2012) を用いて計算した。次に、得られた大気全圧進化のもとで、熱的/非熱的大気散逸による微量揮発性元素の同位体比 (D/H, $^{15}N/^{14}N$, $^{38}Ar/^{36}Ar$) の進化を計算した。酸素と窒素、アルゴンについては、Jakosky et al. (1994) と Pepin (1994) のイオンピックアップ、スパッタリング、光化学的散逸の散逸率を用いた。水素の熱的散逸率は酸素の散逸率に律速される (Liu & Donahue, 1976) と仮定した。水素の分別係数は 0.016 を仮定した (Krasnopolsky et al., 1998; Krasnopolsky 2000)。窒素とアルゴンの分別係数は Jakosky et al. (1994) の値を用いた。

大気全圧は隕石重爆撃期に対応する初期数億年の間で数桁減少するが、その後の変化は小さい。窒素とアルゴンの同位体比は大気全圧が減少するに従って増加する。一方、水の主要なリザーバーは表層水であるため、水素同位体比は大気全圧進化とは独立に増加する。我々の計算結果を火星隕石 ALH 84001 に記録された 41 億年前の元素同位体比と比較することにより、我々は火星の大気と表層水の損失は 41 億年以上前から進行していたという仮説を提案する。隕石重爆撃期の衝突剥ぎ取りによって厚い初期大気が失われた後、熱的/非熱的大気散逸による大気中の窒素と希ガスの同位体分別が進んだ可能性がある。

キーワード: 火星, 大気, 水, 同位体, 天体衝突, 大気散逸
Keywords: Mars, atmosphere, hydrosphere, isotope, impact, atmospheric escape

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Spectral observation of mesospheric CO_2 ice clouds in the Martian mid-low latitude using PFS onboard Mars Express

Spectral observation of mesospheric CO_2 ice clouds in the Martian mid-low latitude using PFS onboard Mars Express

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Mars is the only known planet where CO_2 ice clouds can be observed. CO_2, main component of Martian atmosphere, can condense and form 'CO_2 ice clouds' in the coldest region; in the troposphere above polar night and in the mesosphere around equator. CO_2 ice has narrow spectral emission peak feature at 4.3 um. Unfortunately, polar cloud in the lower altitude is below thick atmosphere and this spectral feature can not be detected by strong CO_2 gas absorption. However, mesospheric cloud in low-mid latitude is enough high. Dayside nadir observation of OMEGA aboard the Mars Express spacecraft first detected such feature.

In this study, we attempted to detect the spectral feature of mesospheric CO_2 ice clouds in low-mid latitude at 4.3 um band by Planetary Fourier Spectrometer (PFS) onboard Mars Express. In this wavelength, its spectral resolution is ˜1,000, about 10 times higher than that of OMEGA. It enables us to resolve the spectral features of CO_2 ice clouds with enough resolution to estimate their particle size comparing with synthetic spectra. We confirmed that PFS could detect this spectral profil on the orbits where OMEGA detected CO_2 ice clouds. In the PFS spectral resolution, we identified two spectral types, i.e., 'single-peak case' at 4.25 um and 'double-peak case' at 4.25 and 4.28 um, which were not resolved by OMEGA.

Based on this confirmation, we statistically surveyed the CO_2 ice features in all PFS data in 2004-2014 which covers MY 27-32. We identified 272 single-peak cases and 9 double-peak cases. Spatial and seasonal distributions of CO_2 ice clouds agreed with the previous studies. In spatial distribution, CO_2 ice clouds were detected in the latitude range of 20 degS to 20 degN and the longitude range of 100 degW to 30 degE and around 170 degE. In seasonal variation, almost all of CO_2 ice clouds were detected just after spring equinox (L_s: 0-30 deg).

In these samples, the spectral peak in the single-peak case and the first peak of double-peak case was centered at 4.252 um. From this observed feature, we derived the typical particle size of CO_2 ice clouds by the comparison with the synthetic spectra derived by a radiative transfer model with the assumption that cloud particles were made of pure CO_2 ice and had spherical shape. Refractive index of CO_2 ice is from experimental one. Although the observed single-peak feature was reproduced by the model, the peak wavelength appeared at ˜4.27 um, shifted to 0.02 {¥mu}m longer position than the observed one. Such shift of the peak position could not be reproduced by various particle parameters, including radius, size variance, and column density. In addition, the synthetic spectra could not reproduce the double-peak structure observed by PFS. We proposed three possible cases to explain these discrepancies; (1) the uncertainty of the refractive indices, (2) non-spherical particle shape, and (3) different core material in CO_2 ice. For (1), we simply assumed that the model refractive index could be shifted 20 nm toward shorter wavelength. After that, we got satisfied agreement between the observed and model spectrum. Based on the matching of both spectrum, effective radii of observed CO_2 ice cloud were constrained in the range between 0.63 to 1.0 um. This is the first quantitative estimation of the CO_2 ice clouds using 4.3 um feature of CO_2 ice. The effective radii obtained by our model follows the line of CRISM observation (0.5-2.0 um) but slightly small compared with that of previous works. For (2) and (3), they can potentally produce double-peak features observed by PFS. It means that non-spherical haze with a core material might be actual characteristics of the Martian mespheric CO_2 ice cloud.

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氷上のサイクリックステップ:火星北極冠のスパイラルトラフ形成機構解明のためのアナログ実験と理論解析
Cyclic step on ice: experiments and theoretical study aiming to spiral troughs on Mars' North Polar ice cap

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The spiral troughs observed on the Mars' North Polar Layered Deposits (NPLD) contain a detailed stratigraphic record of surface processes in Mars' recent polar history. SHARAD radar data showed that the troughs have migrated towards the north during the accumulation of the uppermost ~600 m of NPLD, and Smith et al. (2013) concluded that the spiral troughs should be a kind of cyclic steps formed by katabatic wind blowing on the ice cap. Cyclic steps are spatially periodic bedforms where each wavelength is delineated by an upstream and downstream hydraulic jump. They migrate upstream keeping the same wavelength. Cyclic steps have been reported from various environments on the Earth, such as fluvial and deep-sea settings, and in various bed materials, such as bedrock, non-cohesive sediments, and cohesive sediments. While the formation of cyclic steps on bedrock or beds composed of sediment is a mechanical process, the formation of cyclic steps on ice is not only a mechanical but thermodynamic process. There have not been many studies on the thermodynamics of the formation of cyclic steps on ice to authors' knowledge. In this study, we conducted a series of experiments on the formation of cyclic steps on ice due to flowing water over it. In addition, we performed a linear stability analysis of the water-ice interface and show that the formation of cyclic steps can be explained by the results of the analysis in part.

The experiments were conducted in the cold chamber owned by the Institute of Low Temperature Science, Hokkaido University. We have conducted 8 cases of experiments by the use of the experimental apparatus that consists of a flume, a cooling system of the flume, and a circulating system of water. We kept the ice temperature to be below zero degrees in Celsius, the flowing water temperature to be from 0.2 to 2 degrees in Celsius, and the room temperature to be about 5 degrees in Celsius. As a result, it is found that trains of steps are formed when the Froude number is larger than a value around unity. Those steps are associated with hydraulic jumps, and steps mostly migrate in the upstream direction. Based on these diagnoses and the morphologic feature, these steps can be evaluated as cyclic steps on ice bed.

We performed a linear stability analysis on instability of interface between flowing water and ice, and made physical explanation of the formation of cyclic steps. According to the results of the analysis, the interface becomes unstable when the Reynolds number is relatively large under the condition that the heat flux from ice is sufficiently weak, that is to say, the temperature at the ice bottom is not so low, and the ice thickness is sufficiently large. In addition, the unstable region in the wave number - Reynolds number plane hardly depends on the heat transfer coefficient of air normalized by the heat diffusivity of water and the flow depth.

We compared the results of experiments and the analysis, and found that the experimental data fall on the unstable region both in the wave number - Reynolds number plane and the wave number - Froude number plane where interfacial instability takes place. This indicates that at least the experimental results are consistent with the analytical results. The critical Froude number derived from the analysis is approximately unity in the range of small slope angles, and slightly increases with the slope angle. In the experiments, cyclic steps are not formed in the case of the Froude number smaller than unity while cyclic steps are formed in all the case of the Froude number larger than unity. In terms of the critical Froude number, the experimental results are well explained by the analysis.

キーワード: サイクリックステップ, 氷床, スパイラルトラフ
Keywords: cyclic step, ice, spiral troughs

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火星生命探査の意義と計画
Life search plan on Mars surface and the significance

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近年の探査により火星の描像は大きく変化し, 現在も動的な火星という描像が誕生した．そして火星で液体の水の存在が確実視される場所として, リカリング・スロープ・リニア (RSL) と呼ばれる場所がある．本計画は, 火星史における現在も動的な火星という描像を検証し, 特に現存する生命の最も可能性の高い場所で生命の存否を検証する．

1970 年代のバイキング探査では, 3 つの生命代謝反応を測定する実験を行った．3 番目の実験では, 生命が存在するかもしれない反応が検出された (Levin and Straat 1977)．しかし, 有機物が検出限界以下であったため, 火星表面には生命は存在しないと結論された．2000 年代に入って, バイキングの有機物分析装置の再検討が進んだ．バイキングの有機物分析装置は, 1g 土壌あたり 10^6〜10^7 細胞の検出感度しか無い事が明らかとなった (Glavin, et al.2001; Navarro-Gonzalez, 2006). これは地球上であっても, 深海底, アタカマ砂漠, 南極砂漠等の微生物濃度が極めて低い場所 (1g 土壌あたり 10^4 細胞) では, 生命を検出できない感度である．

MSL: Curiosity が Gale crater で検出した有機物は, 火星由来かどうかは分からないが, 検出された CH3Cl の量は 1g 土壌あたり 4 μ g であった (Ming et al.,2014)．これを総有機炭素量で有ると考え, アタカマ砂漠で検出された総有機炭素量と土壌中微生物量との比率 (Connon et al．2007) を考えると, 1g 土壌あたり 4×10^4 細胞の微生物がいる事になる．本計画では最も水の存在の確実視される場所をターゲットとしている．ゲールクレータで検出された CH3Cl が細胞由来であれば, 確実に検出できる感度で探査を行う．

生命が発見された場合, 火星生命を対象として分析が行われ, 新 (真) 生物学が誕生する．

第二段階の生命探査では遺伝物質 DNA とアミノ酸の分析を行う。もし、火星生命が DNA を持たないあるいは、持っていても AGCT を用いていないことがわかれば、地球とは独立した生命であることがわかる。同じ DNA(AGCT) を用いていることが明らかとなった場合には、第三段階の生命探査では遺伝子の系統解析を行う。遺伝子を調べて地球生物との類似性が無ければ、独立に誕生した DNA 生物であることがわかる。類似性がある場合には、系統関係をしらべ、地球だけで生命が誕生し地球から火星へ移動したのか, 逆に火星だけで生命が誕生し火星から地球に生命が移動した可能性があるのかを系統解析で判別することが可能である

仮に火星に生命が検出されなかった場合, 生命誕生に多くの課題を与える．A．もし火星と地球の双方で生命が誕生したのであれば, 地球でのみ生命を存続させた条件は何なのか．B．生命が地球でだけ誕生したのであれば, 火星で生命が誕生し得なかった決定的条件は何なのか．C．火星でのみ生命が誕生したので有れば, 火星で生命が絶滅した理由はなにか．D．地球と火星以外から生命が飛来したのであれば, 火星で生命が定着しえなった要因は何なのか．いずれの場合にも, 生命誕生モデルの大幅な再検討が必要になる． 火星で生命が誕生しなかったにせよ, 地球から生命が移動する可能性が十分あることを考えるならば, 火星に移動した生命は今日までに絶滅したことになる．火星にはどのような条件が生命存続に欠けていたのか.

火星に置ける前生命環境探査は惑星科学会の工程表の中に含まれ, 生命探査はアストロバイオロジーネットワークと宇宙生物学会の工程表に位置づけられている．

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キーワード: 蛍光顕微鏡, 蛍光色素, 生命の起源, 進化系統樹
Keywords: Fluorescence microscope, Fluorescence pigment, Origin of life, Phylogenetic tree

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Life-Detection Microscope (LDM) onboard 2020 Mars Mission MELOS
Life-Detection Microscope (LDM) onboard 2020 Mars Mission MELOS

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Life-Detection Microscope (LDM) is the primary science payload onboard the MELOS rover which we propose to launch in 2020. LDM is designed to achieve a sensitivity (10^4 cells per gram soil) which is two orders of magnitude better than the Viking Lander experiments. The strategy to achieve this high sensitivity includes: 1) cells, if exist, are dyed with SYTO24, PI, and CDMA pigments; 2) the fluorescence from dyed cells (excited with blue light at 488 nm) is imaged with 1 um/pixel resolution; 3) the field of view in one image is 1 mm^2; and 4) 2 mm^3 volume of Martian soil is scanned.

LDM consists of 3 components: Sample-Handling System (SHS), Fluorescence Microscope (FluM), and Driver and Data Processor (DDP). To receive soil sample from the robotic arm of the rover, one ”empty” sample container is selected and is moved to the sample inlet position (X and Y movements in SHS). After receiving the soil sample, the dye is injected and then the container lid is closed so that the rapid evapolation of the solvent under the atmospheric pressure (6 hPa) of Mars is avoided. A set of regolith and dust images in white light are acquired before ”fluorescence” mode is started. In ”fluorescence” mode, a set of images with different focal depths (0 to 0.1 mm) are acquired at each of 20 (X, Y) positions, achieving scan of desired volume (2 mm^3) of soil sample. The images are examined for suspicious objects and small sections of images which include such objects, if any, are stored in the rover’s data recorder for later downlink to the earth.

We will report progress in development of LDM and will discuss the operation strategy of LDM in the mission period on Mars.

キーワード: Mars, Life, Microscope, Fluorescence, Soil, Rover
Keywords: Mars, Life, Microscope, Fluorescence, Soil, Rover

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Exploration of carbonate and clay mineral on Mars: clues for climate, atmosphere, and deep hydrosphere of early Mars

Exploration of carbonate and clay mineral on Mars: clues for climate, atmosphere, and deep hydrosphere of early Mars

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High-resolution remote sensing data of Mars Noachian terrains show the widespread existences of clay minerals formed by groundwater circulations [1]. This suggests that hydrothermal activity in deep crusts may have played a major role in hydrological cycles on early Mars [1], which is contrast to those on current Earth and might be similar to those occurred on Europa or Enceladus [2, 3]. To date, however, Mars rovers have performed analyses at outcrops of sedimentary rocks formed mainly by open water activity [4, 5]. Lack of knowledge on the nature of groundwater activity obscures us to understand a whole picture of hydrological cycles, aqueous geochemistry, and habitability on early Mars.

Recent observations and models suggest that there are some locations where groundwater upwelled on the surface of early Mars [6]. These include one of the deepest craters on Mars, McLaughlin Crater, which exhibits layered deposits of carbonates and Mg-Fe-bearing phyllosilicates on the crater floor [6]. The proposed mineral assemblages suggest the occurrence of geochemistry between CO2-bearing, alkaline groundwater and ultramafic rocks [6]. This implies that the outcrops of McLaughlin Crater could serve as a unique window to look into the nature of groundwater activity and its interactions with the atmosphere of early Mars.

Here we propose a Mars rover mission to perform geological and geochemical analyses of outcropped carbonates and clay minerals on McLaughlin Crater. Geological observations of the outcrops would determine the formation processes of these layered deposits. The aqueous geochemical conditions (e.g., the composition, redox state, and pH of groundwater, water-rock ratio, and temperature) would be determined based on results of detailed chemical and mineralogical compositions of the outcrops. These observational data enable us to constrain redox potentials of groundwater, which could support deep biosphere on Mars. In addition, we can estimate the partial pressure of atmospheric CO2 equilibrated with the groundwater. This, in turn, means that our mission will be able to answer the long-standing question whether early Mars had a dense CO2 atmosphere, which will provide critical insights into the habitable zone [7] and formation process of terrestrial planets in the solar system and beyond.

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キーワード: 火星, 探査, 地球化学, 炭酸塩, 熱水活動, 大気
Keywords: Mars, exploration, geochemistry, carbonate, hydrothermal activity, atmosphere

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MEMS pirani pressure sensor for the Mars Organic Molecule Analyzer (MOMA) of the ExoMars Mission

MEMS pirani pressure sensor for the Mars Organic Molecule Analyzer (MOMA) of the ExoMars Mission

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ADACHI, Tomoko[1*] ; SOUTHARD, Adrian[2] ; BROWN, Gary[3] ; JOHNSON, Christopher[3] ; GONNSEN, Zach[4] ; RIEMANN, Lisa[5] ; AREVALO, Ricardo[3] ; PINNICK, Veronica[3] ; DANELL, Ryan[3] ; BRINCKERHOFF, William[3] ; MAHAFFY, Paul[3]

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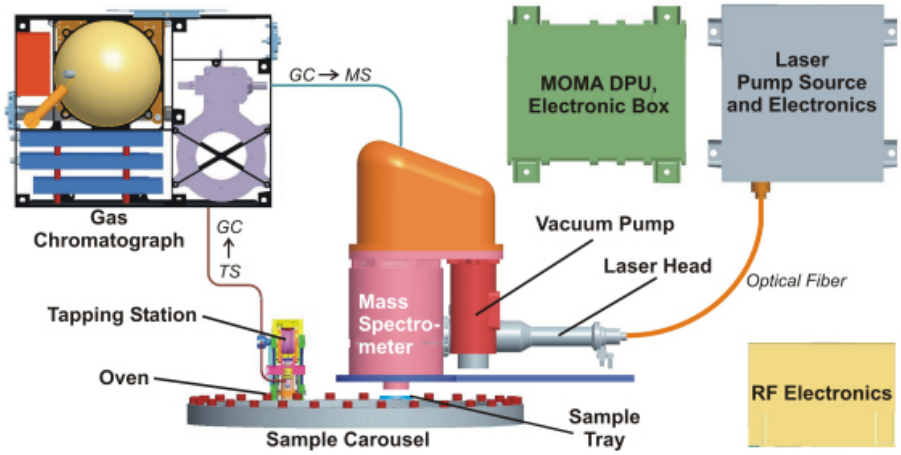
The Mars Organic Molecule Analyzer, MOMA is a collaborative mission by European Space Agency, and NASA Goddard Space Flight Center. MOMA is a key analytical instrument aboard the ExoMars rover, set to launch in 2018. The rover will search for past and present evidence of martian life The twin rovers Spirit and Opportunity have confirmed that water was long standing on the surface of Mars long ago. The Curiosity rover found aromatic, organic compounds in the mudstone at the bottom of a possible ancient lake. Mars Science Laboratory scientists found that chlorobenzene was formed during the reactions inside the Sample Analysis (SAM) instrument from martian chlorine and carbon during the heating of perchlorates known to be present in martian soil. The ExoMars rover will sample martian soil/rock at depths of up to 2 meters, deeper than any instrument before it. The rover collect the sample and analyze them by MOMA. The MOMA has two operation modes: Gas Chromatograph-Mass Spectrometry (GC-MS); and Laser Desorption-Mass Spectrometry (LD-MS). (Please see the image) LD-MS employ laser desorption ionization to avoid the need to heat the sample, thereby preventing perchlorate reactions, which complicate identification of compounds in the sample. GC-MS will identify the chirality of organic molecules, improving understanding of how these molecules were formed.

The MEMS (microelectro-mechanical system) pirani pressure sensor is a critical component that will be used to ensure the ion trap mass spectrometer/s time sensitive operation in the LD-MS mode. It employ a high voltage for ionizations, and knowing the pressure of the MS chamber by miliseconds time scale is critical. The pressure data is used for the telemetry of the MS operation. Also the pirani pressure sensor has a critical function that pressure changes as a discontinuous inlet and pump work together to sample the Mars atmosphere in LD-MS mode. It also has to work at ambient temperatures varying from -20 to 80 degrees Celsius and be calibrated for both carbon dioxide for sampling martian atmosphere and helium during use of the gas chromatograph. The MEMS pirani sensor provides better than 0.1 mtorr accuracy over the critical pressure range from 1 mtorr to 0.1 mtorr and has a usable pressure range from 0.1 mtorr to 0.1 torr. This paper will focus on the characterization of the pirani sensor and its electrical interface and modeling ideas of a next generation of MEMS pressure sensor for future planetary and space missions.

キーワード: Robotic Rover Mission on Mars, MEMS pirani pressure sensor, Organic molecule analysis, Ion Trap, Laser Desorption Mass Spectroscopy, Gas Chromatograph Mass Spectroscopy
Keywords: Robotic Rover Mission on Mars, MEMS pirani pressure sensor, Organic molecule analysis, Ion Trap, Laser Desorption Mass Spectroscopy, Gas Chromatograph Mass Spectroscopy

PPS05-09 会場:A03 時間:5 月 28 日 10:30-10:45



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PPS05-10 会場:A03 時間:5 月 28 日 11:00-11:15

火星着陸探査機におけるその場 K-Ar 年代測定に向けた着陸地点検討
Possible landing sites on Mars for an in-situ K-Ar dating by future Japan's Mars rover mission

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Mars shows a variety of surface features affected by geologic processes. Though the crater-based dating has estimated surface ages, ranging from nearly 4.5 Ga age to recent, the absolute ages have not been determined for Martian samples except a mudstone at Gale crater by the Curiosity rover mission (4.21 ± 0.35 b.y.) and meteorites that come from somewhere on Mars. The authors have been developing an in-situ K-Ar dating system for future Japan's landing mission on Mars (e.g., Cho et al., 2014, 2015). In this paper, aims of the chronologic investigation using the system onboard a Mars rover/lander and appropriate landing sites are discussed.

Studies of impact crater densities present three representative eras for geologic history of Mars; Noachian, Hesperian and Amazonian (e.g., Tanaka, 1986). Abundant water should have existed early in Martian history (likely the Noachian and a part of the Hesperian), but most of them disappeared. In order to understand habitable environment, climate changes and atmosphere evolution of Mars it is important to determine the absolute ages of geologically-well-defined Noachian/Hesperian samples. Considering crater chronology, mineralogy, geological setting and engineering requirements (altitude, latitude and thermal inertia), we propose three regions that are covered by Hesperian volcanic rocks as candidates of chronologic investigation; Syrtis Major Planum, north-east side of Tharsis and peripheral area of Amazonis Planitia. Crater counting based on CTX and HRSC images applied to five specific areas in Syrtis Major provides ages ranging in 3.0 - 3.6 Ga (where the model by Hartmann and Neukum, 2001 is adopted). Among which, two areas reveal resurfacing evidences; the crater frequency gives older ages of 3.7 - 3.8 Ga for the sizes >1 km in diameter and the thickness of the younger lava (for the sizes <1 km) is estimated to be ~ 40 m. Syrtis Major, having gentle slope and less abundant dust, is a highly recommended region for the landing site. Further information such as local morphology and shock and alteration phenomena should also be considered.

キーワード: 火星, 火星探査, K-Ar 年代, 年代学, ヘスペリアン, Syrtis Major
Keywords: Mars, Mars exploration, K-Ar dating, chronology, Hesperian, Syrtis Major

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火星ローバ搭載電磁波・音波観測による火星地表面現象の遠隔観測
Remote sensing of Martian surface events by Electro-magnetic and Sonic Wave observation aboard a Martian rover

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In order to detect many kinds of surface events on Mars, a small instrument with electro-magnetic and sonic wave receivers has been considered as one of the remote sensing equipments onboard a future Japanese Mars rover.

By combining the observation of 3-axes electro-magnetic waves and sonic waves, precise identification of the events source coordinates with respect to the rover position can be realized because of the phase difference of each detecting waves and large difference of the speed of light (c) and sound (Cs). The observation plan has been discussed as a remote sensing instrument for distribution measurement of Martian discharge events (like lightning and thunder on the Earth), however, it can also be applied for the Martian surface studies as a very unique equipment, moreover, the size, weight, and power resources for the instrument is small and suited for installing on the small rover system planned to land the Mars.

On the Mars, as a result of the most recent research activities mainly by the NASA MSL (Opportunity) rover and several orbiters, many possible surface events like fluid motion on the edge of craters, so called RSL (Recurring Slope Lineae) seen as a narrow dark-tones streak activities depending on the Martian season change. Moreover, some scientists reported the possible regions of gas eruption from the surface of the Mars.

Here, we will introduce the recent progress of the instrumentation design and environment test results of the electro-magnetic and sonic wave observation instruments for the future exploration by landing explorer on the Mars.

キーワード: 火星, 電磁波, 音波, 地表面現象, ローバ, 遠隔観測
Keywords: Mars, Electro-magnetic wave, Sonic wave, Surface events, Rover, Remote sensing

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Characterization of Martian Regolith: Toward 2020s Mars Exploration Missions
Characterization of Martian Regolith: Toward 2020s Mars Exploration Missions

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Mars once had surficial liquid water (paleo-ocean/lake) and shows a promising sign of current subsurface water/ice. The existence of hydrosphere and cryosphere makes Mars the unique accessible habitable planet next to the Earth. The water-rock interaction between the lithosphere and hydrosphere/cryosphere through the history of Mars has produced a variety of surface rocks (regolith) containing sheet-silicates, phosphates, sulfates, and carbonates, which are closely linked to climate and the potential for life on Mars. This study characterizes the physico-chemical properties (chemical composition, mineral abundance, reflectance feature, and geometric distribution) of Martian regoliths. We further present a way to leverage the database on Martian regoliths as a tool for interpreting remote sensing analyses by onboard instruments (e.g. Life Detection Microscope) for Mars exploration missions in 2020s.

キーワード: Mars, regolith
Keywords: Mars, regolith

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MELOS 着陸候補地点の地質学的考察
Geological implications of landing-site candidates of the MELOS mission

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Ancient Mars is now considered to have had environment somewhat similar to that of Earth in terms of the existence of large bodies of water, a wide range of surface oxidation states, appearances of variety of chemical components potentially building blocks of life, and a magnetic field. Endogenic activities have continued even until very recently, and recent water-related geological features indicate prolonged existence of an aquifer system, where a habitable environment may exist for a significant period of time. Occasional releases of volatiles from such an aquifer system may ultimately account for the inconclusive result (not unambiguous denial) of metabolism-detection instrument onboard Viking landers. Japanese MELOS Mars mission is proposed to carry an in-situ life detection package onboard a 150kg-sized rover, as well as a visible-near IR camera and a Ground Penetrating Radar system to perform geological investigation.

Because the primary purpose of the MELOS mission is to perform the Life Detection Microscope (LDM) instrument experiment, which is designed to detect less than 10^4 cells in 1 gram clay, orders of magnitude higher than previous attempts performed by Viking landers, landing-site candidates of the MELOS mission are selected in terms of the possibility of the existence of near-surface water and recent geological and hydrological activities including the possible release of volatiles (specifically, relatively high water activity (Aw>0.6), a relatively higher maximum environmental temperature (T>250), and an existence of gradients of free energy). We propose Melas chasma as a prime candidate because of the existence of recurring slope lineae (RSL), where traces of possible liquid water and seasonal flow have been reported, as well as the fact that Valles Marineris provides the best exposures of the ancient geologic history of Mars. The latter includes: (1) Melas chasma being the widest and deepest part of the Valles Marineris; (2) it being connected to the outflow channels; (3) Interior Layered Deposits (ILDs) showing various sulfates deposits, suggesting the existence of abundant past water; and (4) various phyllosillicates having been detected among the canyon units. As for the current volatile release, we find Tharsis/Elysium Corridor region is the best candidate, which shows evidence of long-lived water enrichment and recent geologic activity, including recent venting that could bring materials from the subsurface to the surface environment. In this talk, we examine the morphologic characteristics of these features and discuss geological context of the candidate landing sites.

キーワード: 火星, MELOS 計画, 生命探査, 水, 活動度
Keywords: Mars, MELOS, life detection, water, current activity

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火星着陸探査の気象測器
Meteorological Instruments of Mars EDL

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Mars Exploration plan is started for Landing at 2020.
Landing to Mars surface, Moving with Rover, and Searching Life itself.
We, Melos Meteorological Sub Working group, also proposal some instruments.
Those are including Thermometer, Anemometer, Barometer, Radiation Meter, Radiation Thermometer and Navigation camera, LIDAR, Particle counter.
We call first 5 instruments basic instruments set, and last 3 instruments Dust sensors.
This presentation is to introduce developing and testing sate of progress of these sensors.

[Thermometer] We use 3 different color thermos-sensors. Difference of radiative absorption makes difference temperature of sensor. Sensible heat is calculated it's difference. And 1 thermo-sensor is heated, for calculating wind velocity.
[Barometer] This instruments is in TRL-5. Using Impedance of Cristal
Oscillator is changing with friction of atmosphere.
If we know the air components, the friction is a function of Pressure, so it works as a barometer.
[Radiation Thermometer] Thermocouple seeing to the surface of Mars. It can measure Surface temperature.
[Anemometer] Same as Thermometer. But we use 4 couple of sensor, for calculating wind direction.
[Navigation Camera] This is a BUS-equipment to monitor around the rover. We use this camera to detect dust-devils.
[LIDAR] Counting the back scatter of LASER, We obtain a sum of cross-section of dusts along LASER path. Resolution along path is around 1m.
[Particle Counter] Small In-situ sensor, mechanism is similar to LIDAR.
Counting the scatter of light within very small (0.5x2x1mm) region.
This can measure number of particle for separated to 5 bin of size.

State of developing is very different each other, some is only discussion,
The others are tested with Mars like environment, Mars Environment Simulation Chamber settled in PERC/Chiba Institute of Technology).

キーワード: 火星, 気象
Keywords: Mars, Meteology

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火星探査のための表層環境評価: 雲解像モデル CReSS の火星大気への適用
Assessment of Mars surface environment for a exploration program: application of CReSS to Martian atmosphere

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日本の宇宙惑星コミュニティにおいて計画中の火星探査計画では, 着陸機の設計および運用計画立案のために, 着陸候補地点の表層環境評価が必要とされている. 我々は表層環境評価を実施するための環境整備の一環として, 雲解像モデル CReSS (Tsuboki and Sakakibara, 2002) の火星大気への適用を進めている.

CReSS は準圧縮方程式系 (Klemp and Wilhelmson, 1978) に基づいた数値モデルである. 火星大気に適用するために, 惑星大気大循環モデル DCPAM (Takahashi et al. 2012) で使われている 火星用の放射計算コード (Takahashi et al., 2006) を導入した. 地形, アルベド, 熱慣性の値としては Mars Global Surveyor の観測データを用いる. CReSS に含まれている地球用の暦は火星の自転および公転周期にあわせて変更した.

モデルの動作検証として, 地形と大規模循環の効果を考慮しない理想化実験を多数実施した. まず始めに, 同じ放射計算コードを用いる鉛直 1 次元の放射対流計算 (DCPAM-1D) と設定を揃えた比較実験を行い, 地表面温度の日変化と地表面熱収支が両計算で概ね一致することを確認した. 次に, NASA の火星探査ローバー Spirit と Opprtunity の観測地点の日射量条件を与えた数値実験を行った. Spiga et al. (2010) と同様に乱流過程における混合長の定式として Deardorff (1980) を用いることで, 火星探査ローバーの観測した日中の鉛直温度プロファイルと整合的な計算結果が得られることを確認した. これらの理想化実験を踏まえ, 我々は着陸候補地点を想定したより現実的な数値実験を実施している. この実験においては地形と大規模循環の効果を考慮する. 大規模循環の効果は初期値および境界値として DCPAM によってシミュレートされた火星全球気象データを導入することで考慮する.

本発表では, 数値モデルの概要を示すと共に, これまで行った数値実験の結果を紹介する.

キーワード: 火星大気, 惑星探査, 数値計算, 雲解像モデル
Keywords: Martian atmosphere, planetary exploration, numerical modeling, cloud resolution model

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Scientific significance of sample return from Martian moons
Scientific significance of sample return from Martian moons

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The asteroid explorer Hayabusa2 began a six-year round trip in December 2014 to return surface samples of a near-Earth carbonaceous-type asteroid 1999 JU_3 following Hayabusa's successful return of the first asteroid samples to Earth. Hayabusa2 will arrive at 1999 JU_3 in mid-2018, and fully investigate and sample the asteroid at three locations during its 18-month stay. The samples from 1999 JU3 will be delivered to the Earth in December 2020. Primitive small bodies are the evolved remnants of planetesimals that were the building blocks of planets, and detailed on-site observation by a spacecraft and analyses of return samples will provide direct evidence of planetesimal formation and dynamical and chemical evolution of the solar system. Moreover, such small bodies could have delivered volatile components to rocky planets in the early solar system.

Sample return missions to primitive small bodies such as main belt asteroids, Jovian Trojan asteroids, icy satellites, and comets require a timescale of decades, and it is important to plan short-term exploration missions to primitive bodies. Here we propose a sample return mission to Martian moons (Phobos and Deimos), of which characteristics resemble those of C-type or D-type asteroids. If they are captured main-belt asteroids, their surfaces have not been heated as much as near-Earth asteroids are. Martian moons are thus likely to preserve more primitive materials such as ice, which is one of possible constituents responsible for their low bulk-densities. If they are remnants of building blocks of Mars, the returned samples will provide us the first and direct information on the formation of Mars, the bulk chemistry of Mars, and the isotopic compositions of volatile elements as a starting point of Martian environmental evolution. Isotopic compositions of returned samples will be a key to address this issue on the origin of Martian moons. Surface regolith of Martian moons may contain ejecta from the Martian surface and/or the escaped Martian atmosphere, and the returned samples may enable us to put constraints on the crustal and environmental evolution of Mars. The remote-sensing observation of Martian atmosphere and surface from the spacecraft can also be done from the spacecraft. In this presentation, we will describe the outline and scientific rationales of the sample return mission from Martian moons.

キーワード: 火星, 衛星, フォボス, ダイモス, サンプルリターン
Keywords: Mars, Satelite, Phobos, Deimos, Sample return