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Study of trace gases in the Martian atmosphere: Ground-based observation using SUBARU/IRCS and development of radiative transfer model for MEX/PFS limb observation

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Abstract

We observed Martian atmosphere to investigate CH_4, H_2O, and HDO on 30 November 2011, 4-5 January 2012, and 12 April 2012 using SUBARU/ IRCS. This observation aims to verify CH_4 on Mars, constrain its source, and investigate the distribution of H_2O/HDO ratio. Our observation covered possible source areas of CH_4, i.e. the areas where the extend plumes of CH_4 were detected by previous ground-based and MEX/PFS observations [1,2] and the potential mud volcanism areas [3,4]. This paper will show some preliminary results.

Vertical profiles of these trace gases are crucial for understanding their chemistry and transportation. Limb observations by MEX/PFS are a powerful tool to retrieve vertical profiles of H_2O, CO, and CH_4. For this purpose, we adapted the SARTre model, a radiative transfer code which includes multiple scattering for limb geometry observations developed for the terrestrial atmosphere [5], to the Martian atmosphere. In order to validate our model, SARTre model for Martian limb, we first compared of our synthetic spectra in nadir geometry with the result from ARS [6] which has been widely used for previous studies of MEX/PFS nadir-observation. We concluded that the difference between them is small offset (below 3%) in the spectral range between 3000 and 3030 cm^{-1}.

1. Introduction

The recent discovery of CH_4 on Mars has led to much discussion on its source and sink [1,2]. It is suggested that the release of CH_4 (whether abiotic or biotic) is closely linked to the presence of water [7]. It is therefore important to establish the HDO/H_2O in water released with CH_4 on Mars because the HDO/ H_2O ratio is contributed by a surface-atmosphere interaction. For this purpose, we observed CH_4, H_2O, and HDO simultaneously using SUBARU/IRCS. Our observations covered possible source areas of CH_4, i.e. the areas where the extend plumes of CH_4 were detected by previous ground-based and MEX/PFS observations [1,2] and mud volcanism areas suggested around the mounds in Acidalia Planitia and Utopia/Isidis pitted cones (UIPC) [3,4]. In the terrestrial case, mud volcanism vents major quantities of CH_4 (10×10^6 tons/year). Moreover, it is remarkable that the areas where the extended plumes of CH_4 were detected are on the same outer ring of the Isidis basin that intersects UIPC [2]. The mud volcanism on Mars might contribute to the release of CH_4.

Furthermore, the vertical profiles of these trace gases are crucial for their chemistry and transportation. For example, a recent study reports that the vertical profile of H_2O shows a super-saturation [8], which is important to understand water cycle. However, the vertical profiles of the trace gases is still not well-investigated. Limb observations of MEX/PFS can retrieve vertical profiles of H_2O, CO, and CH_4. For this objective, we have developed a radiative transfer model based on SARTre, a radiative transfer code which includes multiple scattering for limb geometry observations developed for the terrestrial atmosphere [5].

2. 2011-2012 observing campaign using SUBARU/IRCS

We observed Mars using SUBARU/IRCS on 30 November 2011, 4-5 January 2012, and 12 April 2012. The observation of April is simultaneous with MEX/PFS. **Table 1** is summary of our observing campaigns in 2011-2012 periods.

The IRCS is an echelle spectrometer with high spectral resolution (R=20,000) at SUBARU telescope (8.2m) in Maunakea observatory [9]. We observed Mars with 6.69” ×0.14” slit in the five spectral bands, 2.85-2.93 µm, 3.01-3.10 µm, 3.28-3.36 µm, 3.48-3.57 µm, and 3.71-3.81 µm. One of the advantages of IRCS is the wide spectral coverage. The spectral ranges have multiple lines of CH_4, H_2O, HDO and CO_2 isotopes. This will allow us to simultaneously retrieve CH_4 and H_2O/HDO abundance, and perhaps put some constrains to the subsurface-atmosphere interaction. In addition, it was pointed out that the previous ground-based observations had a large uncertainty because they used single band of Martian CH_4 included the terrestrial $^{13}CH_4$ lines [10]. Therefore, using multiple CH_4 lines can improve the reliability of our results. It may be crucial important to verify the detection of Martian CH_4.

Figure 1 shows an example of measured spectrum in the spectral range 2977-3050 cm^{-1} (top) and 2645-2685 cm^{-1} (bottom) observed on 5 January 2012. In the top spectrum, telluric lines of CH_4 and H_2O are the major features. In the bottom spectrum, telluric lines of HDO and Martian lines of CO_2 isotopes are the major features. In order to detect the Martian H_2O, HDO and CH_4, contributions from Martian and telluric lines have to be separated. For that, we will develop a dedicated radiative transfer model for our observation. In future, we will attempt to retrieve the abundance of CO_2 isotopes, H_2O, HDO and CH_4 using the model.

3. Development of radiative transfer model for MEX/PFS limb observation

In addition, vertical profiles of these trace gases are also crucial for their chemistry and transportation. However, it is difficult to retrieve it by a ground-based observation. Space-born limb observation is a powerful tool to investigate vertical profiles.

In order to retrieve vertical profiles of trace gases from MEX/PFS limb observation, we adapt the SARTre model, a radiative transfer code which includes multiple scattering in limb geometry observations developed for the terrestrial atmosphere [5], to be applied for the Martian atmosphere. In order to validate our model, we performed comparison of synthetic spectra by our model and ARS model [6], which is widely used in PFS Nadir data analysis, in the spectral range 3000 and 3030 cm^{-1}. We used nadir geometry for the first step. We conclude that the difference between the results of the two models is small offset (below 3%) in the entire spectral range and for all the phase angles we tested. As a second step, we will compare our synthetic spectra in limb geometry with a Monte Carlo model.

Table 1: Summary of SUBARU/IRCS observations

Observing date (HST)	(a) 2011/12/1 AM 4:00- AM 5:30 (1.5h) (b) 2012/1/5 AM 1:00- AM 6:00 (5h) (c) 2012/1/6 AM 1:00- AM 6:00 (5h) (d) 2012/4/12 PM 8:00- AM 2:30 (4h) [joint observation with PFS]
Diameter	(a) 7" (b,c) 9" (d) 11"
Doppler shift	(a) -16km (b,c) -15km/s (d) +11km/s
Ls	(a) 37° (b,c) 52° (d) 96°
Slit direction	(a,c,d) N-S direction (b) E-W direction
Target Areas	(a) North pole [70-90N] (b) Utopia/Isidid [20-40N, 250-270W] Nili Fossae [15-30N, 270-290W] Sytris Major [-15-15N, 270-290W] (c) Utopia/Isidid Nili Fossae Sytris Major,North pole (d) Acidalia Planitia [30-60N, 0-60W] Terra Sabae [-30-30N 300-330W] North pole

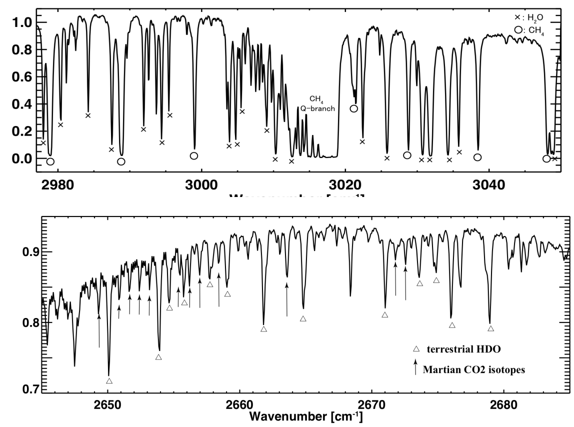

Figure 1: The measured spectrum of IRCS in the spectral ranges between in 2977-3050 cm^{-1} (top) and 2645-2685 cm^{-1} (bottom). Circular symbols indicate terrestrial CH_4 lines, cross symbols indicate terrestrial H_2O lines, triangle symbols indicate terrestrial HDO lines, and arrows indicate Martian CO_2 isotopes lines.

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