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Study of planetary atmosphere using continuous monitoring by Mid-Infrared LAser Heterodyne Instrument (MILAHI)

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Abstract

In this paper, an overview of the science addressable with Mid-Infrared LAser Heterodyne Instrument (MILAHI) onboard our dedicated telescope at the top of Mt. Haleakala, Hawaii, is given. This is the unique observatory for continuous monitoring of various temporal variability of planetary atmosphere with ultra-high resolution from the ground-based obsearvatory.

1. Introduction

Many molecules of atmospheric and astronomical interest exhibit rotational-vibrational spectra in the middle infrared regime. Fully resolved molecular features with high spectral resolution are possible retrieval of many physical parameters, such as density, velocity, pressure, excitation condition, temperature, and the vertical information from single line profile. In mid-infrared wavelength region, the highest spectral resolution is provided by the infrared heterodyne technique (Kostuik and Mumma, 1983). It is for the applications to astronomy and planetary atmospheric science in 7-13 micron wavelength at a spectral resolution of up to $10^{7\text{-}8}$ with a very high sensitivity. Infrared heterodyne spectroscopy has been applied to study of planetary atmosphere to date (e.g., Goldstein et al., 1991; Kostuik, 1996; Fast et al., 2011; Sonnabend et al., 2008; Sornig et al., 2013; Nakagawa et al., 2013).

2. Instrument & Characteristics

We have developed a new infrared heterodyne instrument, called Mid-Infrared LAser Heterodyne Instrument (MIAHI), for our dedicated new telescopes (1.8m & 60cm) at the summit of Mt. Haleakala, Hawaii, under the international collaboration. This project would be milestone in order to increase our understanding of various temporal variability (diurnal, seasonal, and solar cycle effect) of planetary atmospheric dynamics, photochemistry, and meteorology. Remarkable advantages of this instrument are as follows: (i) ultra-high velocity resolution up to 10 m/s with a bandwidth of two times of 1 GHz, (ii) compactness within 600mm x 600mm including the calibrators, (iii) excellent system noise temperature less than 2700 K at 9.6 micron wavelength. In order to provide wider wavelength range, a room-temperature type quantum cascade laser QCL) was applied for the first time. Its operating spectral range achieved to be 5 cm^{-1}. As the backend spectrometer, a compact digital FFT spectrometer was first applied for our system in order to obtain (a) a high frequency resolution, (b) stability and flexibility, and (c) a wide dynamic range.

The list of the scientific objectives is shown in Table 1. The operating wavelength range of the instrument is determined by the tuning range of the local oscillator and the electronic range of the spectral line receiver. For MILAHI 3- (or 4-) QCLs are mounted, and provide continuous access to different wavelengths. This tuneability greatly expands the accessible wavelength range.

3. Summary

First light of this instrument would be performed on November 2013 at the summit using 60cm-telescope in the verification process. Full-scale operation using 1.8m-telescope would be in 2014. Main targets in the verification process in 2013 are Mars, Venus, and Comet ISON. Regarding the Martian atmosphere, we focus on (i) measurement of isotopes of water vapor and carbon dioxide, (ii) detection of hydrogen radicals H_2O_2 and O_3, (iii) detection of biomaker CH_4, (iv) direct measurements of wind velocity and temperature of the middle atmosphere, for the verification of its instrumental performance, and their temporal variations.

Many interesting scientific issues have been targeted and more will be addressed in the future. The list is certainly not exhaustive and proposals for future projects are very welcome. With the configuration described below the instrument MILAHI can be used for research in the atmospheres of solar system objects, i.e., planets, moons, comets, the Earth and the Sun. Extra solar objects like stars and stellar envelopes, proto-planetary disks are possible targets of interest.

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4. Tables

Table 1: The list of the scientific objectives.

Molecule	Wavelength [cm^{-1}]	Target	LO
CO_2(626)	1045	Mars	1
	972	Venus	2
CO_2(627)	1293-1294	Mars Venus	3
CO_2(628)	1293-1294	Mars Venus	3
H_2O	1297	Mars	3
	1239	Venus	4
	1244	Comet Jupiter	4
HDO	1293-1294	Mars	3
	1237	Venus Comet Jupiter	4
H_2O_2	1293	Mars	3
	1296		3
	1234		4
N_2O	1294		3
O_3	1043-1046	Mars	1
CH_4	1294	Mars	3
	1241	Jupiter	4
NH_3	972	Jupiter Comet	2
C_2H_2	1294	Comet	3
CH_3OH	1040-1050	Comet	1

Table 2: The MILAHI bands.

LO	Spectral band [cm^{-1}]	Tsys [K]	Beam size (") with 1.8m
1	968-973 (10.3 um)	3000	1.18
2	1043-1048 (9.6 um)	2500	1.10
3	1230-1245 (8.0 um)	TBD	0.92
4	1293-1297 (7.7 um)	TBD	0.88