赤外ヘテロダイン分光器 MILAHI を用いた火星・金星大気観測

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IR heterodyne spectrometer MILAHI observations of atmospheres on Mars and Venus

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Mid-Infrared LAser Heterodyne Instrument (MILAHI) is one of a facility science instruments aboard Tohoku University-60cm dedicated telescope (T60) at the top of Mt. Haleakala (h=3,055m), Hawaii, which is well suited for infrared spectroscopy by low humidity. MILAHI is designed to explore the planetary atmospheres and study its dynamics, thermal structure, and compositions. The instrument with more than million spectral resolution is one of the most powerful spectroscopy in the mid-infrared regime with several key capabilities: (1) fully resolve molecular features to address the atmospheric temperature and abundance vertical profiles, (2) direct measurement of the mesospheric wind and temperature with high precision, (3) sensitive detection of minor trace gases and isotopic ratios without any ambiguity with the strong terrestrial absorptions. In addition, T60 enables us to perform long-term monitor including the support campaign for orbiter missions. Transient events and time-sensitive applications, such as dust storm on Mars and cometary activities can also be measured flexibly.

The IR heterodyne detection is analogous to spectroscopy technique in radio frequency range. An IR source from the plants is combined with a laser local oscillator, and focused onto a MCT photodiode mixer with 3 GHz bandwidth. The resultant intermediate frequency is in the radio region of the electromagnetic spectrum and it preserves the intensity and spectral information of the IR spectrum. Notable successes on Venus, Mars, Jupiter, Titan, and Earth were accomplished by NASA/GSFC, University of Cologne, and Tohoku University so far. Thanks to a wide coverage of combination of quantum cascade lasers (30-100 mW) and a compact CO2 gas laser (400mW), MILAHI derives atmospheric properties through spectroscopic measurements of IR emissions and absorptions of atmospheric gases in 7.69-7.73, 9.54-9.59, 10.28-10.33, and 10.53-10.61 micron. Frequency stabilization could be 1MHz with optical feedback, which corresponds to 10ˆ7 spectral resolution. Specifically, MILAHI will be able to the compositions, dynamics and structure of the atmosphere by measuring:

1. CO2 absorption spectrum in nightside for temperature and wind vertical profiles in the altitude of 0-30km on Mars, and 70-90km on Venus
2. CO2 non-LTE emission in dayside for wind and temperature in the middle atmosphere (in the altitude of 70km on Mars and 110km on Venus (0.15 Pa pressure level))
3. Column abundance maps of O3, H2O2, H2O and CH4 with moderate spatial resolution
4. Isotopologues of water vapor (HDO) and carbon dioxide (17O-C-O, 18O-C-O)

We have currently accomplished the relocation of T60 from Fukushima, Japan to the summit of Mt. Haleakala on September 2014. Although it is a small telescope, MILAHI will provide ˜3”” spatial resolution with 60cm-telescope. T60 can be remotely operated in order to achieve continuous measurements of planetary atmospheres, and have successfully operated with the support of ATRC (IfA, University of Hawaii). First CO2 non-LTE emission on Venus has successfully observed on March 2015 (Nakagawa et al., submitted), which is not possible with other instruments. Typical sensitivity over the full 1 GHz bandwidth reached 2.500 K at 10 micron and 3,500 K at 7.7 micron. These system noise temperature obtained by MILAHI is only 70 % above the quantum limit at 10 micron. This corresponds to a minimal detectable brightness temperature difference of 50 mK for extended source with 1.5 MHz resolution and 10 mininute-integration. For example, 2 VSMOW-determination of water vapor isotope (HDO) on Mars can be obtained by 15 minute-integration. Here we report MILAHI initial results obtained during August-September 2015, and discuss observational plan in 2015-2016 with several spacecraft on flight, i.e., Akatsuki around Venus, Mars Express, MAVEN around Mars. The nature of atmospheric activity on various time-scales will be investigated.