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High-Resolution Spectroscopy of Titan with SOFIA/EXES

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Abstract

We present the first observation of Titan with the high-resolution Echelon cross-Echelle Spectrograph (EXES) instrument on the Stratospheric Observatory for Infrared Astronomy (SOFIA, Fig. 1). These show clear detection of multiple spectral lines in the R-branch of the acetylene vibrational band at 13 μm. These are compared to similar observations with the ground-based sister instrument TEXES (Texas Echelon cross-Echelle Spectrograph) on the IRTF (Infrared Telescope Facility), showing that EXES will have access to an enlarged spectral range as expected, through reduced atmospheric opacity. In future EXES will be used to complement TEXES for spectral line searches on Titan, geared to detect new molecular species, focusing on spectral regions that are inaccessible from the ground.

Figure 1: The Stratospheric Observatory for Infrared Astronomy (SOFIA). Credit NASA/DLR.

1. Introduction

Titan, Saturn's largest moon, has a dense atmosphere rich with complex hydrocarbon and nitrile gases. These lead to a forest of spectral lines in the mid-infrared, due to multiple vibrational modes of these molecules. Low resolution instruments such as Cassini CIRS (R ~ 2000) [1] suffer from an inability to separate out the overlapping emissions of various gases, especially at 700-850 cm^{-1} dominated by the strong bands of HCN, C_2H_2 (acetylene) and C_2H_6 (ethane). Ground-based telescopes may carry higher-spectral resolution infrared instruments, such as TEXES [2] which is used on the NASA IRTF and Gemini telescopes Mauna Kea. However, these telescopes cannot overcome the intrinsic blocking of many spectral regions due water vapor, ozone, CO_2 and other gases in the Earth's atmosphere (telluric absorption). EXES [3], the sister instrument to TEXES, is now available on SOFIA, a NASA-DLR observatory based on a Boeing 747 aircraft that flies at 39,000-43,000 feet to make measurements: more than twice the altitude of Mauna Kea. SOFIA's unique vantage point greatly reduces telluric absorption and opens up wavelengths inaccessible from the ground.

2. Observations

Titan was observed with SOFIA/EXES during commissioning time on March 5th 2015, with a duration of 1560 seconds, spectral resolution of 89,000. IRTF/TEXES observations of the same spectral region were taken on July 16th 2017, with a duration of 978 seconds, and spectral resolution of 80,000.

3. Results

TEXES data were reduced using the nominal calibration pipeline described in [2]. EXES data were reduced using the Redux pipeline [4] which uses a modified version of the Spextool package [5] for performing wavelength calibration and spectral extraction.

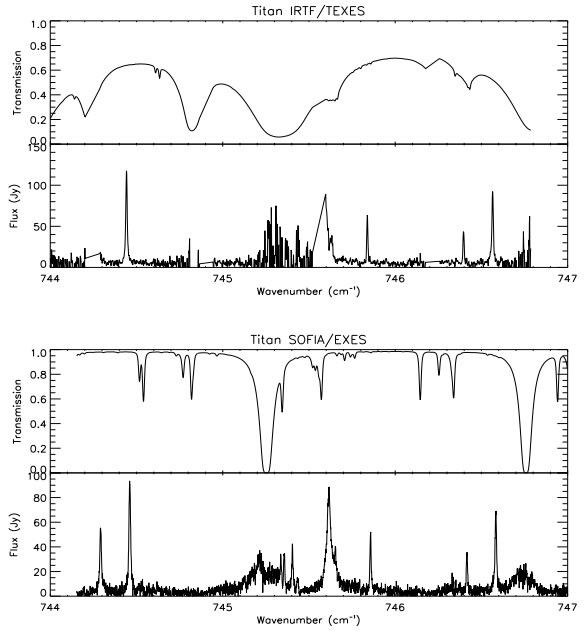

Figure 2: Top – IRTF/TEXES observation of Titan showing atmospheric transmission (top) and flux after calibration against a reference (asteroid). SOFIA/EXES observation of

Fig. 2 shows TEXES and EXES observations of the same spectral region on Titan in the R-branch of the acetylene ν_5 band at comparable spectral resolution. Both atmospheric transmission and the final Titan spectrum are shown in each case. Atmospheric transmission and spectral noise are clearly much improved by altitude, e.g. at 745.3 cm^{-1}.

4. Summary and Conclusions

The data are currently being analyzed to permit a full identification of all spectral features and to search for unidentified lines, that could indicate new gas detections. In future, we anticipate that TEXES and EXES will be deployed in a complementary manner, with TEXES being used regularly to measure Titan gases in the spectral region accessible from Mauna Kea (especially 8-13 μm), while EXES at higher altitude will be used to extend the searchable spectral range, especially at longer wavelengths.

Acknowledgements

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