Compositional Analysis of Titan's Atmosphere Using Spitzer Infrared Spectrograph Data

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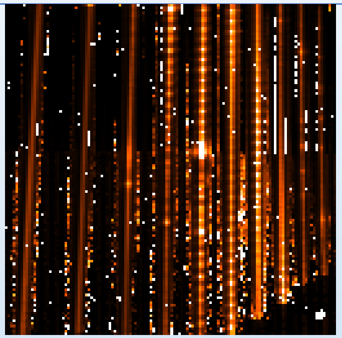
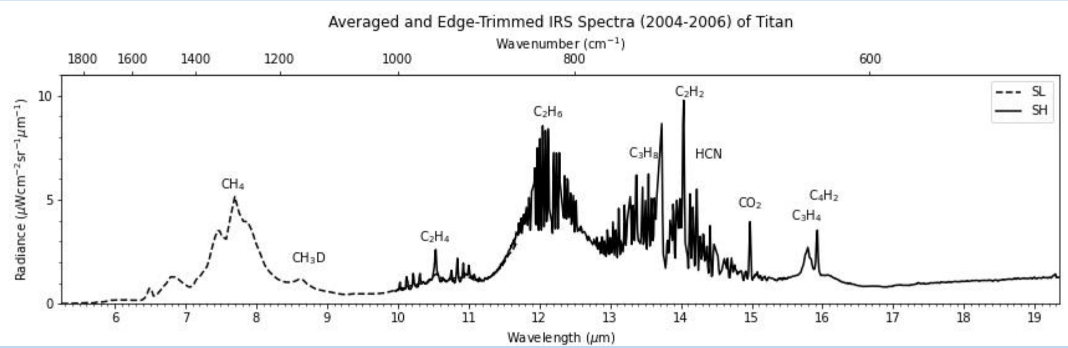
Spitzer Infrared Spectrograph (IRS) Overview

- Contains four modules: two short-wavelength modules: short wavelength low resolution SL (5.13-14.29 μm, R=60-127) and short wavelength high resolution SH (9.89-19.51 μm, R=600) and two long-wavelength modules that were not used
- High-res data of Titan spanning 2004-2009
- Titan exposures originally taken as calibration data, never analyzed/published
- Wavelength range covers a portion of the 17-20 μm range of Cassini CIRS that has historically been noisy
- Can serve as a check to systematic/cyclic noise in CIRS presented in Jennings et al. 2017



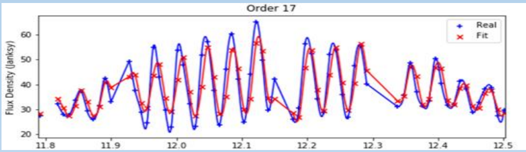


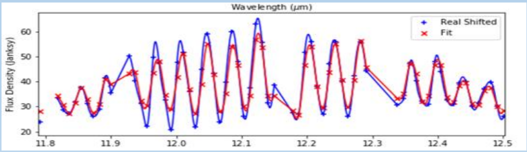
Above: Example raw spectral data of Titan from IRS, split into 10 separate wavelength-based 'orders'/arrays

Left: Averaged spectral data of Titan from IRS after pipeline processing

Changes to the IRS Pipeline

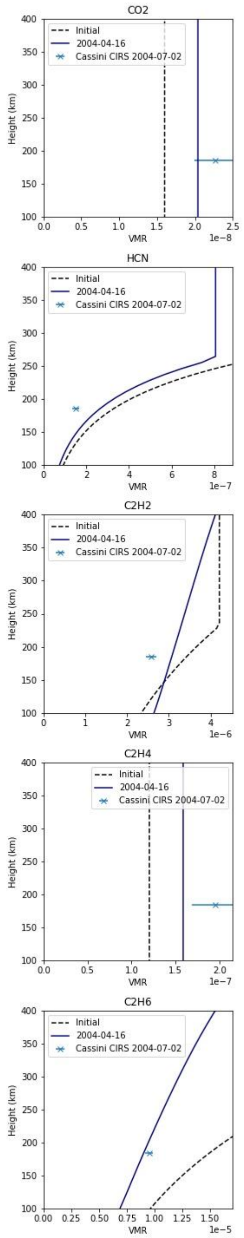
- Most baseline alterations were followed in accordance with Uranus observations presented in Rowe-Gurney et al. 2021
- Data was originally taken in 'mapping mode', an observation mode designed for extended sources. This means that Titan was not necessarily centered in each exposure. We calculated how much of Titan was encased by the telescope's slits in each exposure and only used exposures fully filled by Titan
- The SL module is split into 3 sub-modules: SL1 (7.46-14.29 μm), SL2 (5.13-7.60 μm), and SL3 (7.33-8.66 μm). SL1 and SL2/SL3 data are time separated and contain a small overlap region (7.46-8.66 μm). The overlap region was used to scale SL1 Flux to SL2/SL3
- Small wavelength-based noise was discovered in the SH module, likely due to internal feedback from the telescope. Observational and model fit data were fit to a cubic spline and shifted to minimize noise---maximum observed shift of ~.18 dλ





Next Steps

Spitzer's high resolution 9.89-19.51 μm wavelength range allows us to calculate an upper limit for the presence of fullerenes in the atmosphere. Neutral C_{60} emission bands centered at 17.4 and 18.9 μm have been observed in young planetary nebulae (Cami et al. 2010)). C_{60} production in the upper atmosphere of Titan through carbon chain folding has been theorized (Sittler et al. 2020).

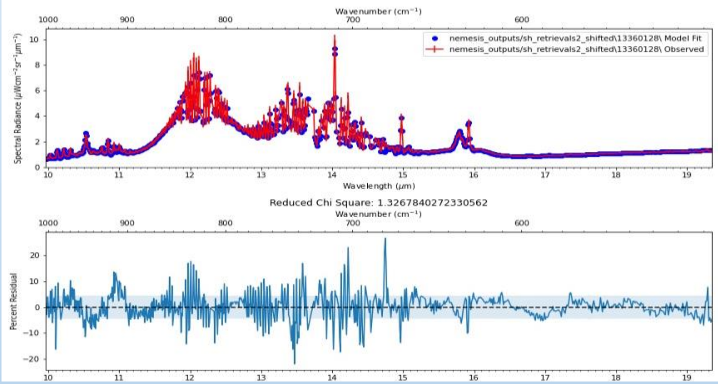


Profile Retrievals

- Vertical profiles for gas composition and temperature were retrieved using the Nonlinear optimal Estimator for MultispEctral analySIS (NEMESIS) [Irwin et al. 2008]
  - The spectral band of methane near 7.8 μm, located in the low-resolution SL module wavelength range, was used to retrieve temperature profiles
- High resolution SH data were used to retrieve gas volume mixing ratios, haze mass density, and surface temperature
  - Data was treated as a global average
- Haze *a priori* taken from estimates based on Huygens data presented in Tomasko et al. 2008 with aggregate particle cross-sectional area wavelength dependence based on data in Vinatier et al. 2012

Left: Example gas profile retrieval results compared to our a priori and CIRS results

Right: Example full spectral retrieval (top) with residuals (bottom)



Comparison to Cassini CIRS

- Preliminary retrieval results were compared to similar retrievals performed based on CIRS data (2004-2017) presented in Teanby et al. 2019
- Results were comparable in most cases and showed significant improvement (when compared to CIRS) over our *a priori*

References

- Cami et al. 2010, Detection of C_{60} and C_{70} in a Young Planetary Nebula, Science, 329, 1180-1182
- Irwin et al. 2008, The NEMESIS Planetary Atmosphere Radiative Transfer and Retrieval Tool, Journal of Quantitative Spectroscopy and Radiative Transfer, 109 (6), 1136-1150.
- Jennings et al. 2017, Composite Infrareed Spectrometer (CIRS) on Cassinin, Applied Oprics, 56 (18), 5724-5294.
- Sittler et al. 2020, Titan's Ionospheric Chemistry, Fullerenes, Oxygen, Galactic Cosmic Rays and the Formation of Exobiological Molecules On and Within its Surfaces and Lakes, Icarus, 344:113246
- Teanby et al. 2013, Constraints of Titan's Middle Atmosphere Ammonia Abundance from Herschel/SPIRE Sub-Millimetre Spectra, Planetary and Space Science, 75, 136-147
- Teanby et al. 2019, Seasonal Evolution of Titan's Stratosphere During the Cassini Mission, Geophysical Research Letters, 46 (6), 3079-3089.
- Tomasko et al. 2008, A Model of Titan's Aerosols Based on Measurements Made Inside the Atmosphere.
- Vinatier et al. 2012, Optical Constants of Titan's Stratospheric Aerosols in the 70-1500 cm^{-1} Spectral Range Constrained by Cassini/CIRS Observations, Icarus 219 (1), 5-12.