An Introduction to the Mars Atmospheric Trace Molecule Occultation Spectrometer (MATMOS)

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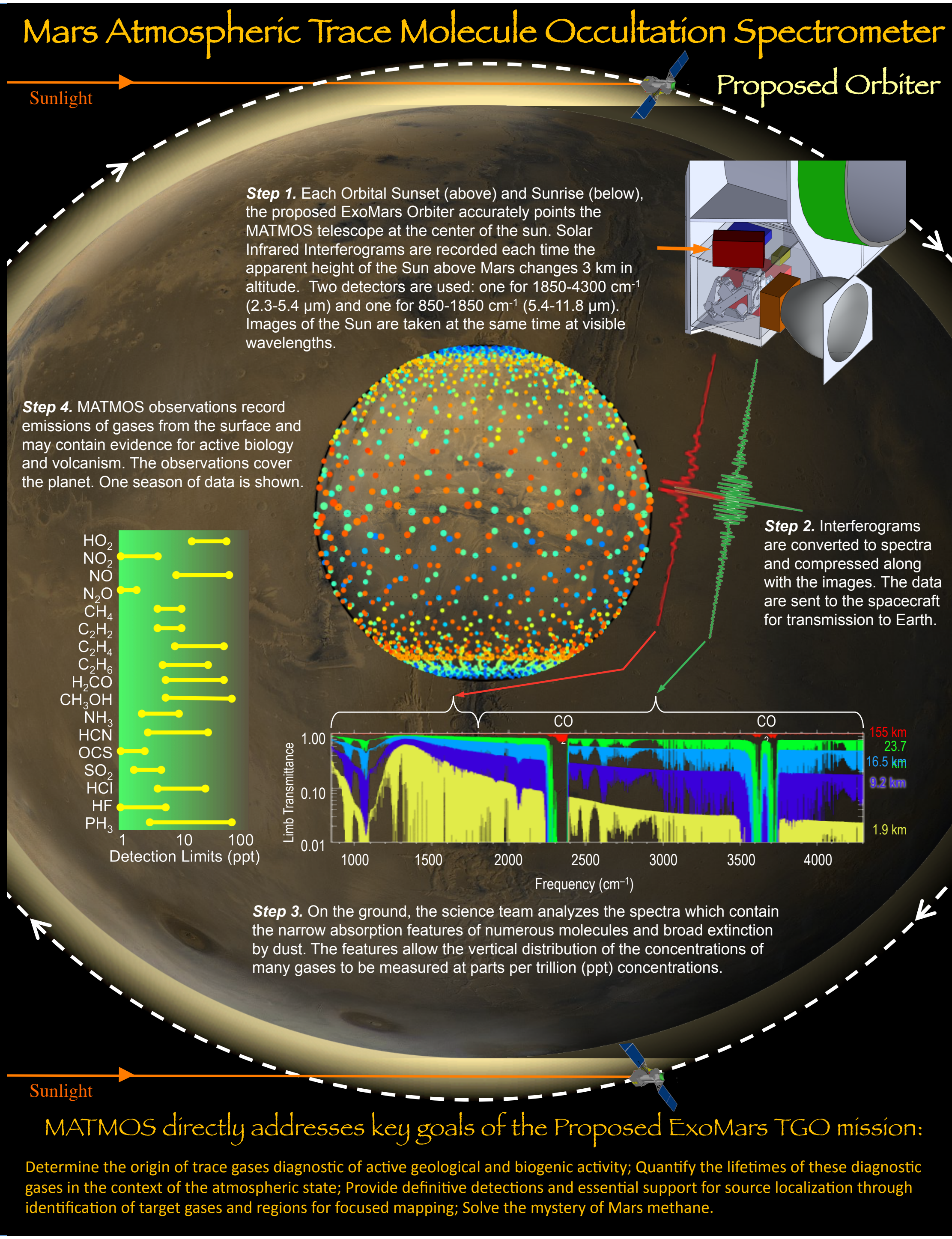
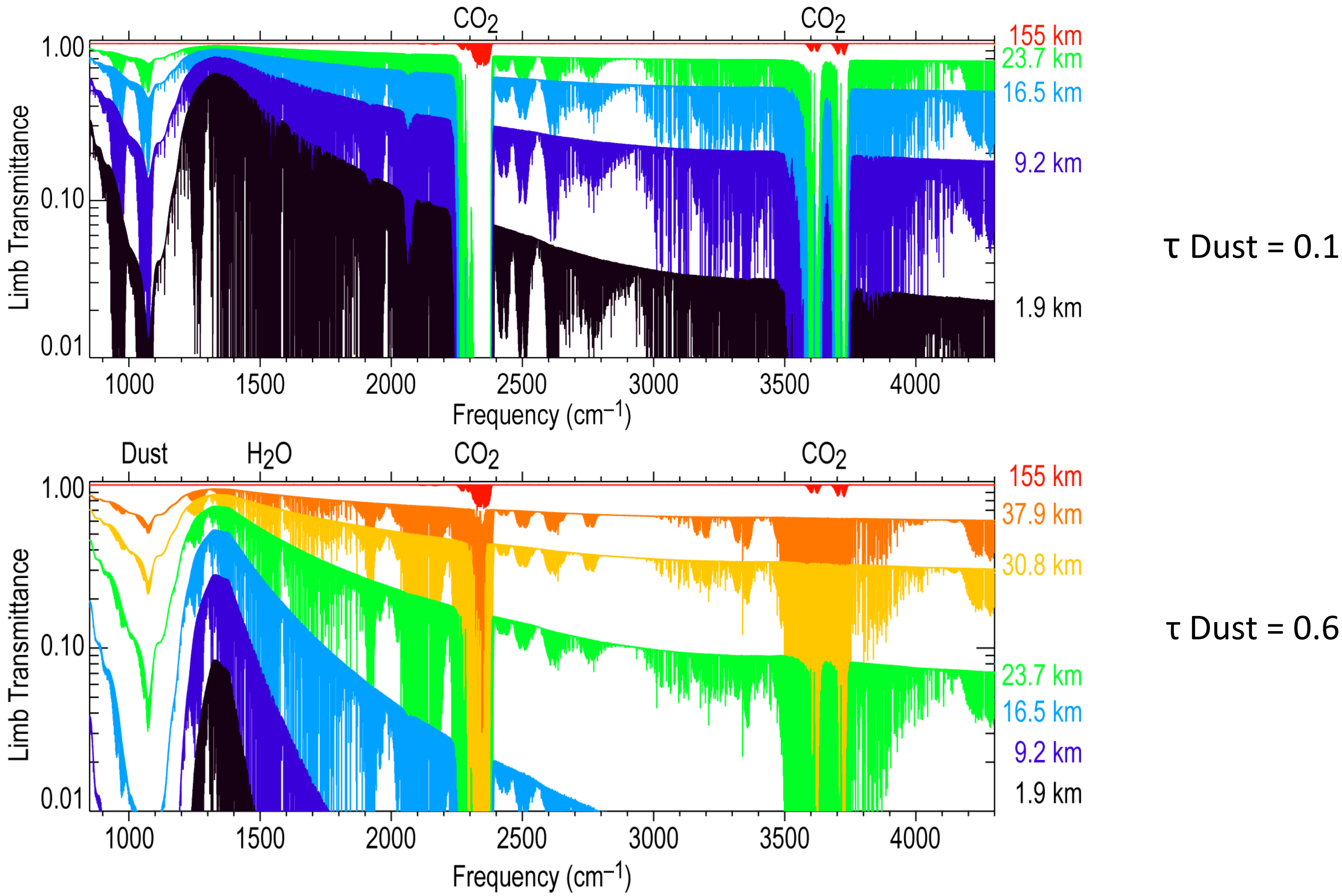


Mars Atmospheric Trace Molecule Occultation Spectrometer
Proposed Orbiter
Sunlight
Step 1. Each Orbital Sunset (above) and Sunrise (below), the proposed ExoMars Orbiter accurately points the MATMOS telescope at the center of the sun. Solar Infrared Interferograms are recorded each time the apparent height of the Sun above Mars changes 3 km in altitude. Two detectors are used: one for 1850-4300 cm-1 (2.3-5.4 μm) and one for 850-1850 cm-1 (5.4-11.8 μm). Images of the Sun are taken at the same time at visible wavelengths.
Step 4. MATMOS observations record emissions of gases from the surface and may contain evidence for active biology and volcanism. The observations cover the planet. One season of data is shown.
Step 2. Interferograms are converted to spectra and compressed along with the images. The data are sent to the spacecraft for transmission to Earth.
HO2
NO2
NO
N2O
CH4
C2H2
C2H4
C2H6
H2CO
CH3OH
NH3
HCN
OCS
SO2
HCl
HF
PH3
1
10
100
Detection Limits (ppt)
CO
CO
1.00
0.10
0.01
Limb Transmittance
1000
1500
2000
2500
3000
3500
4000
Frequency (cm-1)
155 km
23.7
16.5 km
9.2 km
1.9 km
Step 3. On the ground, the science team analyzes the spectra which contain the narrow absorption features of numerous molecules and broad extinction by dust. The features allow the vertical distribution of the concentrations of many gases to be measured at parts per trillion (ppt) concentrations.
Sunlight
MATMOS directly addresses key goals of the Proposed ExoMars TGO mission:
Determine the origin of trace gases diagnostic of active geological and biogenic activity; Quantify the lifetimes of these diagnostic gases in the context of the atmospheric state; Provide definitive detections and essential support for source localization through identification of target gases and regions for focused mapping; Solve the mystery of Mars methane.

Objectives of the MATMOS Investigation

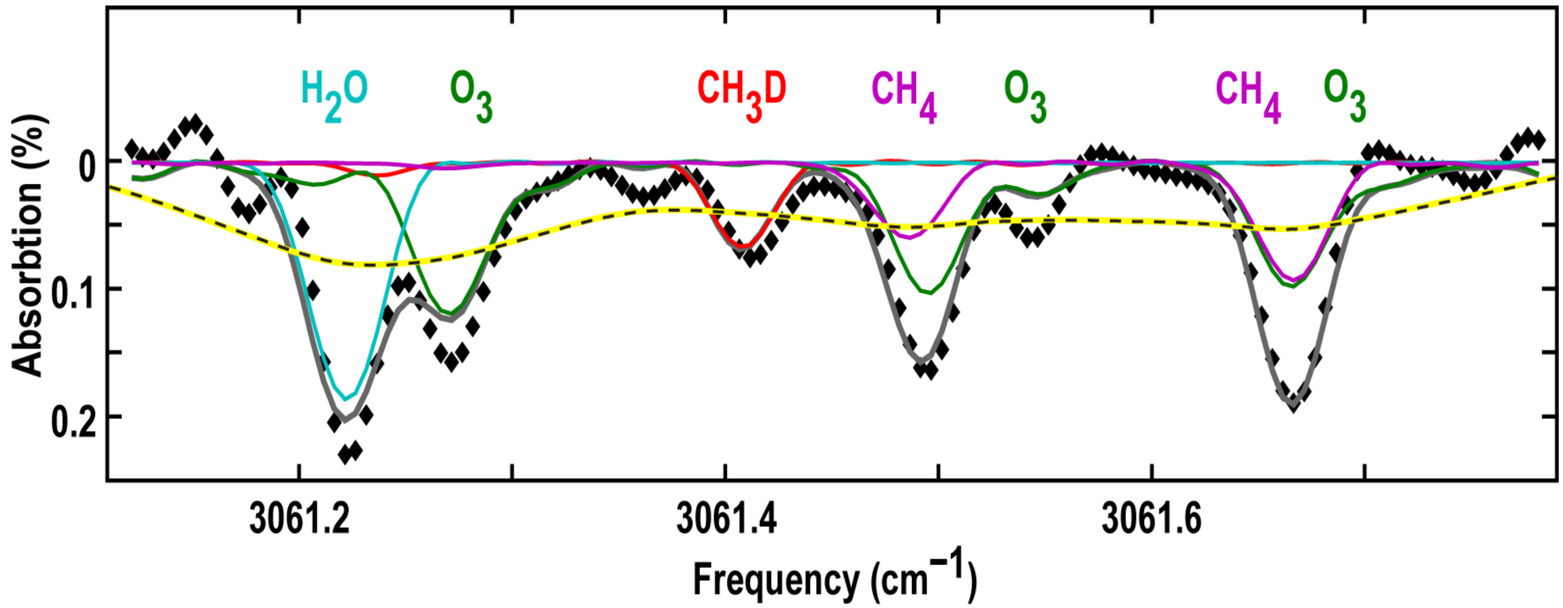
- Search in the atmosphere for chemicals indicative of geothermal or biological activity.
- Investigate the oxidative chemistry of the atmosphere (lifetimes of gases).
- Provide new constraints on the exchange of volatiles (CO_2 & H_2O) with cloud and surface.
- Evaluate the chemical composition and vertically-resolved size distribution of dust and cloud.
- Describe the coupling of the lower atmosphere to the upper atmosphere via measurements of the abundance and isotopic composition of major and minor gases.
- Is there any (e.g. > a few ppt) methane on Mars?

Calculated Mars Limb Transmittance Spectra



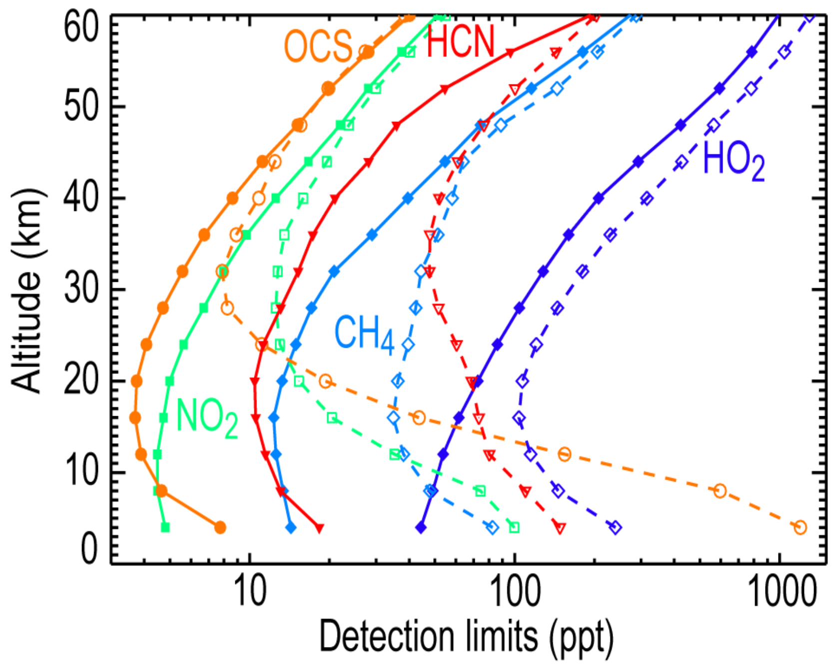
With extra atmospheric spectra obtained on each occultation, the SFTIR technique yields a series of self-calibrated limb transmittance spectra spaced by a few km

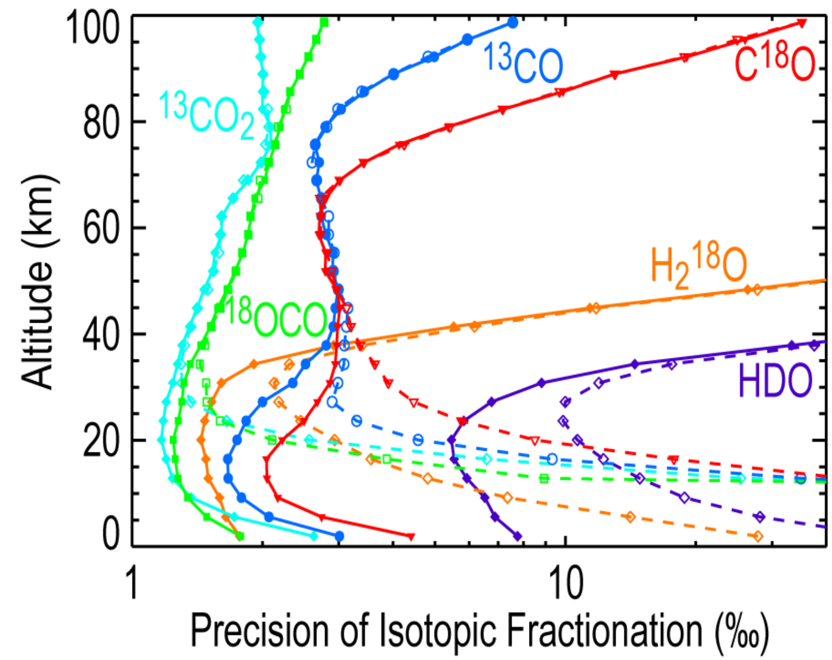
SFTIR – Terrestrial Example



The average of 189 spectra acquired at ~50 km altitude in the Earth's stratosphere by ACE-FTS (tangent pressure ~1 hPa), illustrate the capability of SFTIR for trace gas detection. The black points are the data; the gray line shows the fitted calculation using the retrieval code that will be adapted for MATMOS. This small region (less than 0.04% of the total spectral range of MATMOS) is one of dozens in which CH_4 can be measured. The spectra are fit to 0.02%, consistent with photon source noise limited performance (single spectrum SNR of 350:1). For comparison, the individual gas absorption features would not be resolved using a lower resolution spectrometer such as SOIR on Venus Express (yellow). Though NOMAD is expected to have spectral resolution similar to SOIR, it will have better vertical resolution and signal to noise, providing information on heterogeneity within the MATMOS field of view.

Trace Gas Retrievals





MATMOS will produce profiles of the concentrations of numerous trace gases and the isotopic abundance of CO, CO_2, and H_2O to high altitude. Shown is the expected performance for 100 occultation average under clear ($\tau = 0.1$, solid) and dusty ($\tau = 0.6$, dashed) conditions. The graphic table on the Fact Sheet illustrates the limits of detection for trace gases under high (right end of bar) and low (left end of bar) dust averaging 100 occultations over all altitudes.

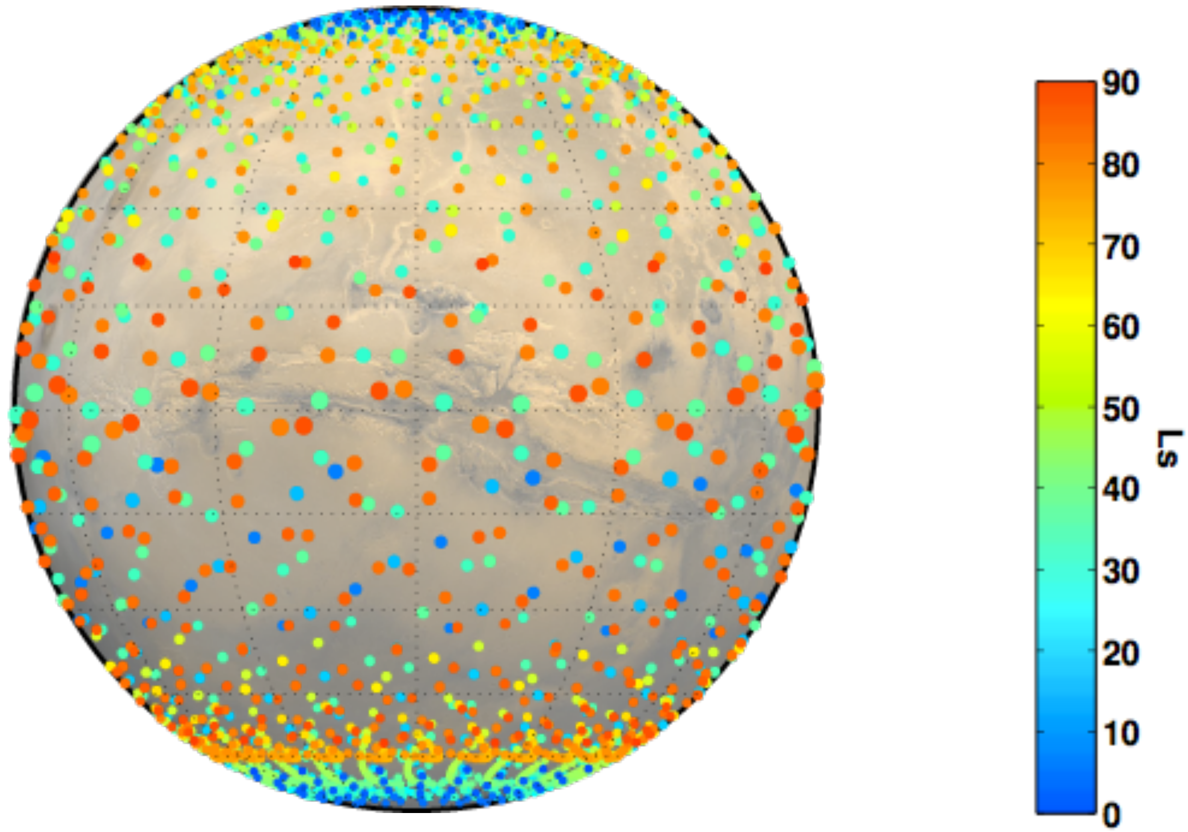
Trace Gas Retrievals

Gases Not Yet Detected	Measured Upper Limit[7] (ppt)	Predicted Abundance (ppt)	Expected Detection Limit (ppt)	
			τ=0.1	τ=0.6
HO_2		PC: 800	12	46
NO_2	<10,000	PC: 84	1	4
NO		PC: 300	8	45
N_2O	<100,000	PC: 1	1	2
C_2H_2	<2,000		3	10
C_2H_4	<500,000		8	42
C_2H_6	<400,000	G:1000	5	23
H_2CO	<3,000		6	42
NH_3	<5,000		2	10
HNO_3			2	5
CH_3OH			6	60
CH_3CN			26	107
HCN		G: 5-2000	3	21
H_2S	<20,000	G: <<1	500	2500
OCS	<10,000	G: <<1	1	3
SO_2	<1,000[8]	G: <<1	2	5
HCl	<2,000		4	26
HF			1	7
PH_3	<100,000		3	74

Expected precision: Single occultation
Limit of detection: Averaged over 100 occultations and altitude
Predicted abundance: PC (photochemical model[9]), G (geology, §1.2.1.2)
Zenith opacity at 1075 cm^{-1}: τ=0.1 (low-dust); 0.6 (high-dust)

MATMOS limits of detection for trace gases under high (tau=0.6) and low (tau=0.1) dust averaging 100 occultations over all altitudes.

L3 – Observations Over One Season



With the planned EMTGO orbit as describe in the E-PIP, occultations would be observed at all latitudes each season.