Limb data from OMEGA/MEX

Characterization and dust retrievals

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IAPS-INAF, Rome, Italy

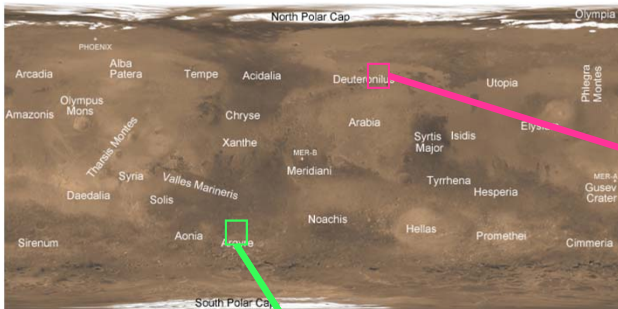
27-28 February 2018, «From Mars Express to Exomars» ESAC, Madrid, Spain.

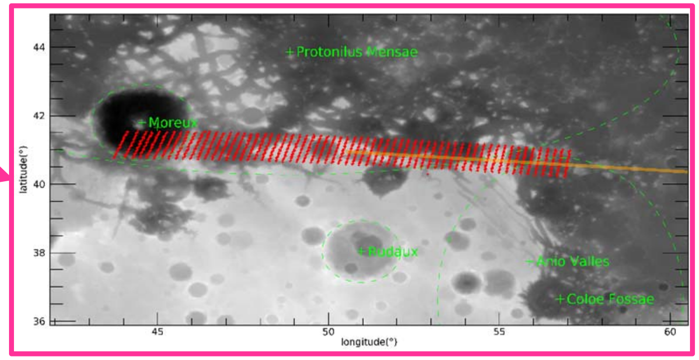
Outline

- Assessing information content in OMEGA limb data
- Addressing issues for quantitative retrievals
- Testing retrieval of dust vertical profiles
- Planning application to the whole OMEGA limb dataset

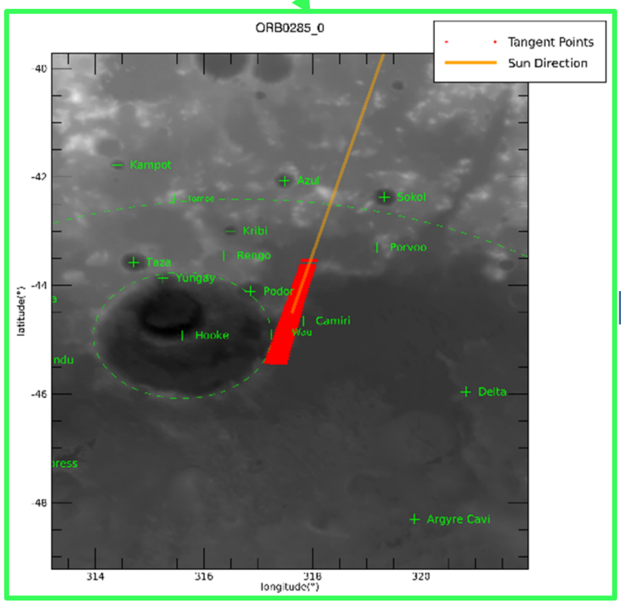
Two working cases

Two OMEGA cubes have been selected in very different conditions





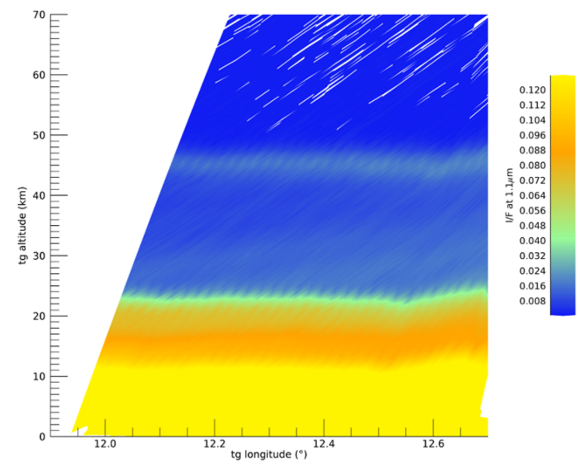
Latit	40N
Ls	100°
Loc time	18h
resol	7 km



Latit	40S
Ls	15°
Loc time	11h
resol	1.5km

A «detached» dust layer is visible in this case

1.1 µm reflectance projected on the «tangent plane» (locus of tangent points, not really tangent to anything)



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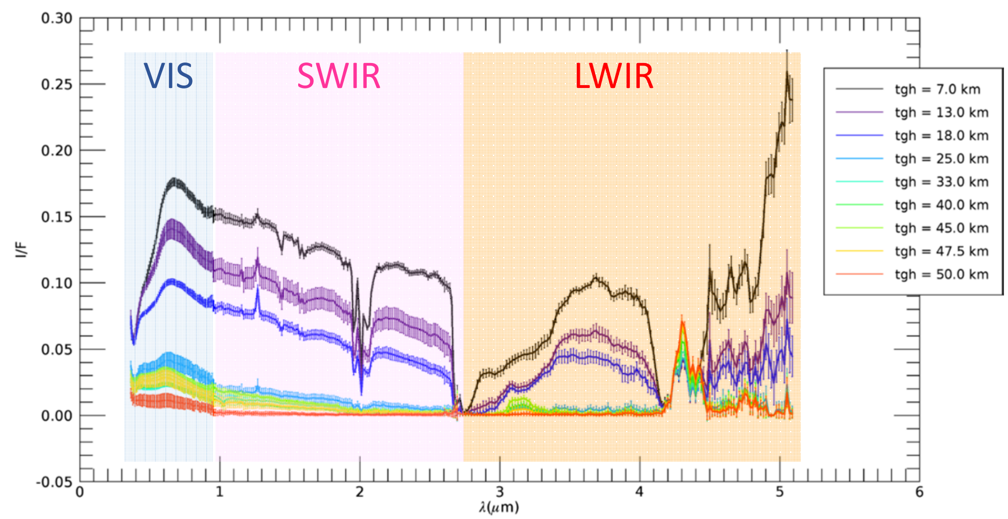
Instrumental issues

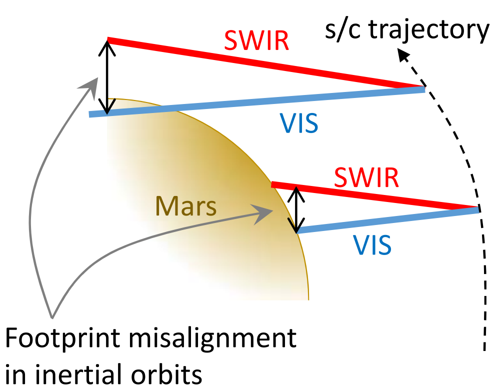
Spectra from the 3 OMEGA channels can be averaged in bins of tangent altitude to achieve homogenous spectral scans in the range 0.4-5 µm.

The pixel footprints differ among channels, due to:
- Pointing misalignment
- IFOV slight different
- Push-broom vs. whiskbroom acquisition scheme

In the **nadir** case the channels are usually co-registered with a **rigid shift** by matching *surface features*.

In the **limb** case the **surface curvature** makes the footprint misalignment larger and not uniform in the same orbit.





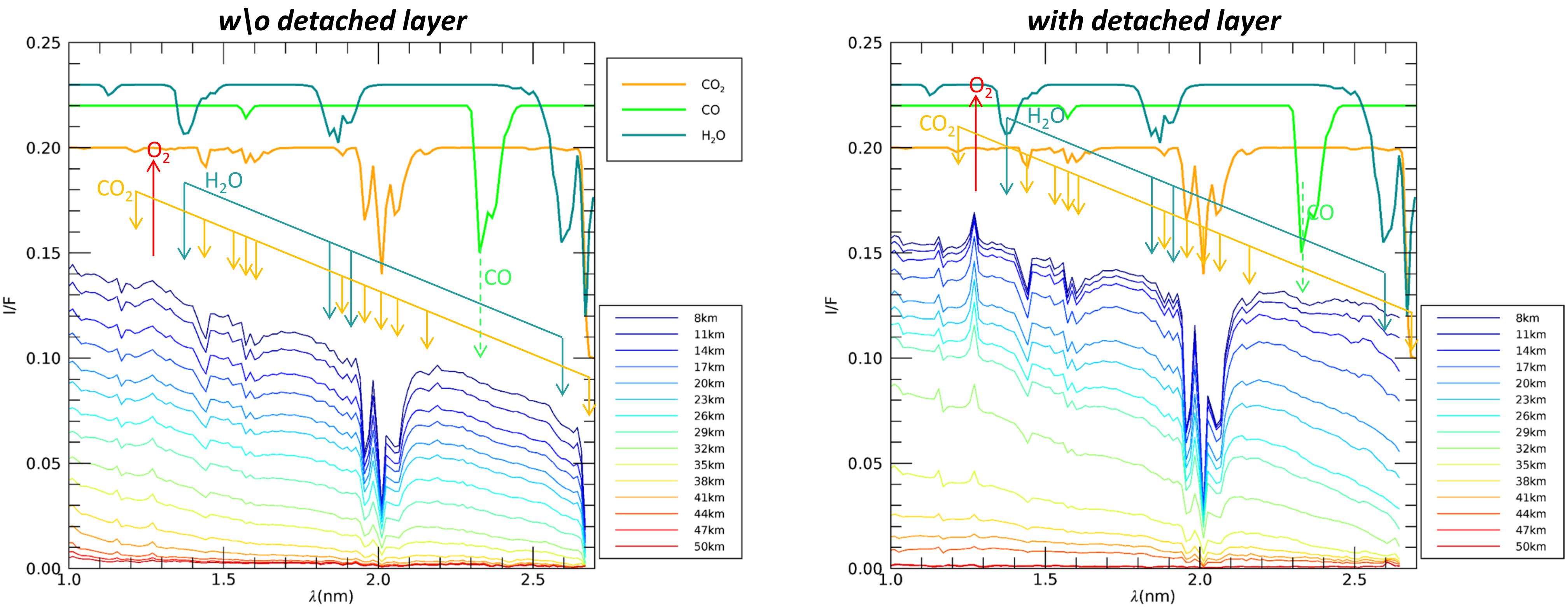
Moreover spectral junctions are often affected by enhanced straylight. Deep space spectra can be partially useful for correcting this effect, but straylight is an additive signal depending on the distance from the target.

Spectral features in SWIR channel

Limb spectral scan after vertical binning

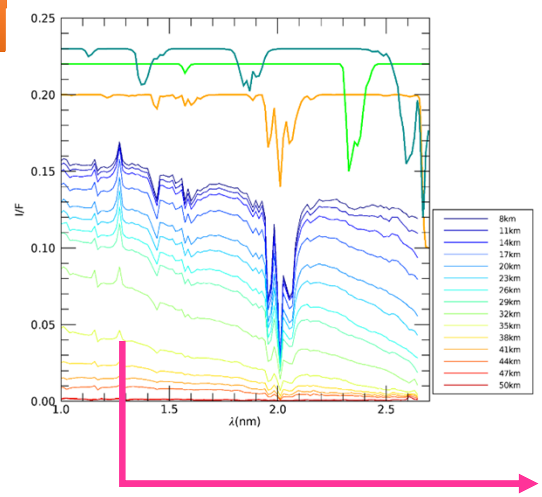
Main features are

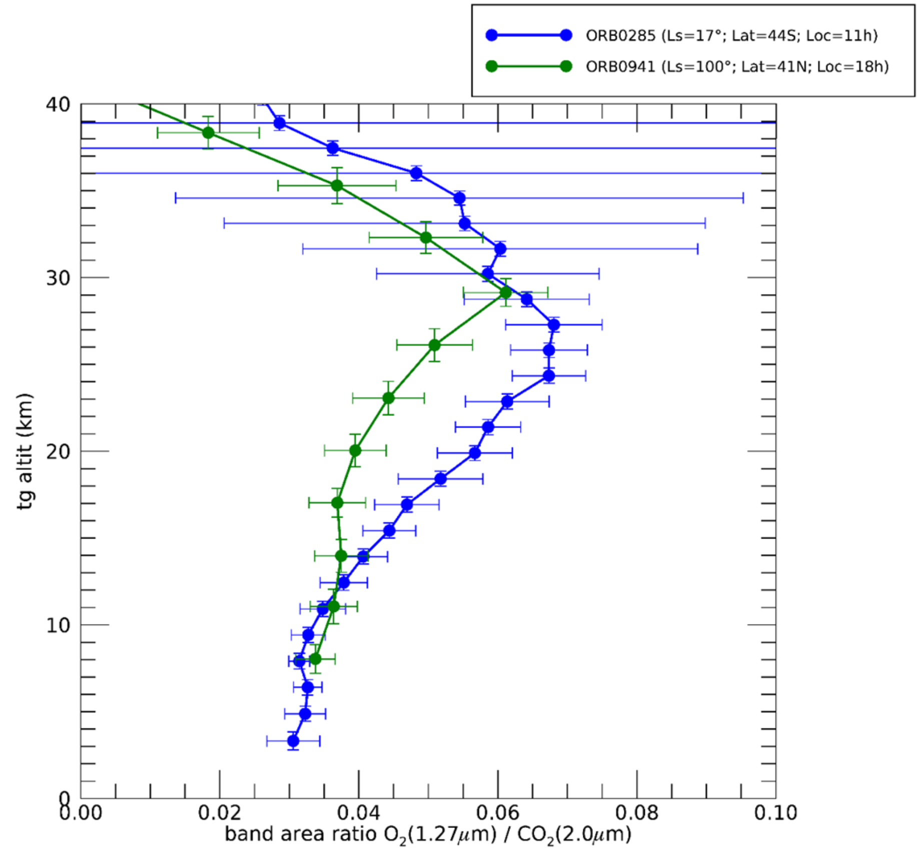
- O_2 emission at 1.27 µm
- H_2O gas absorption at 2.6 µm
- CO 2.35 µm band undetected



O_2 emission

1.27µm emission can be mapped to produce O_2 vertical profiles





O_2 band area at 1.27 µm is shown here ratioed by the CO_2 band area at 2 µm, to grossly normalize the path length.

The peak altitude is related to chemical equilibrium among H_2O dissociation products and is known to be variable with season, latitude and local time.

O_2 abundances can be retrieved with non-LTE modeling and compared with H_2O profiles retrievable from the same observations (not shown here, see e.g. Mahieux et al. in this workshop)

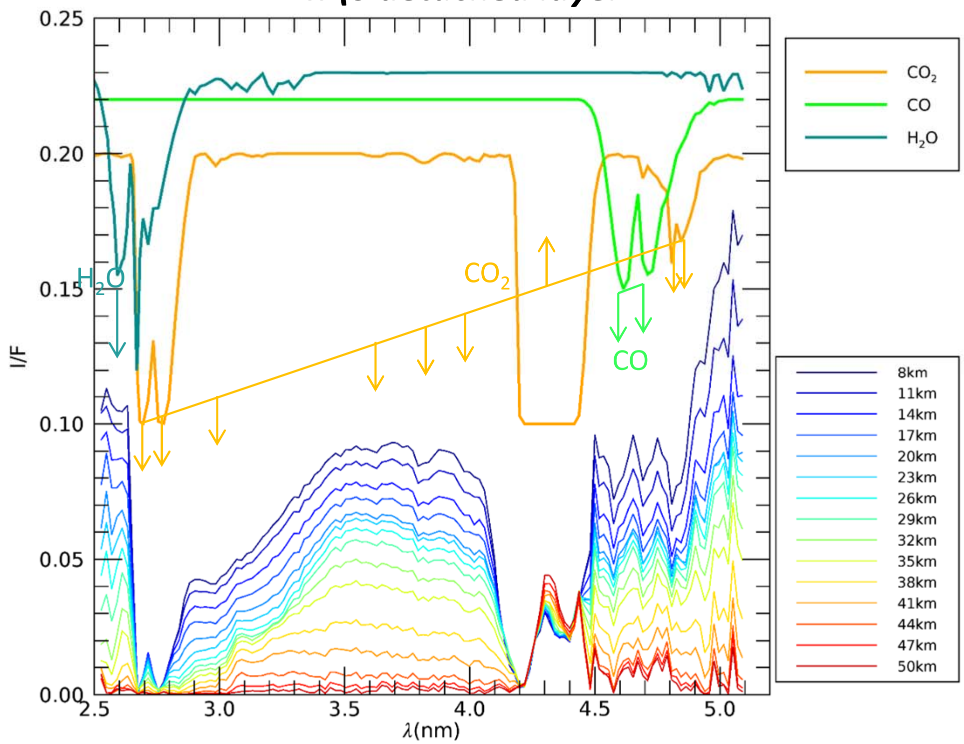
Spectral features in LWIR channel

Limb spectral scan after vertical binning

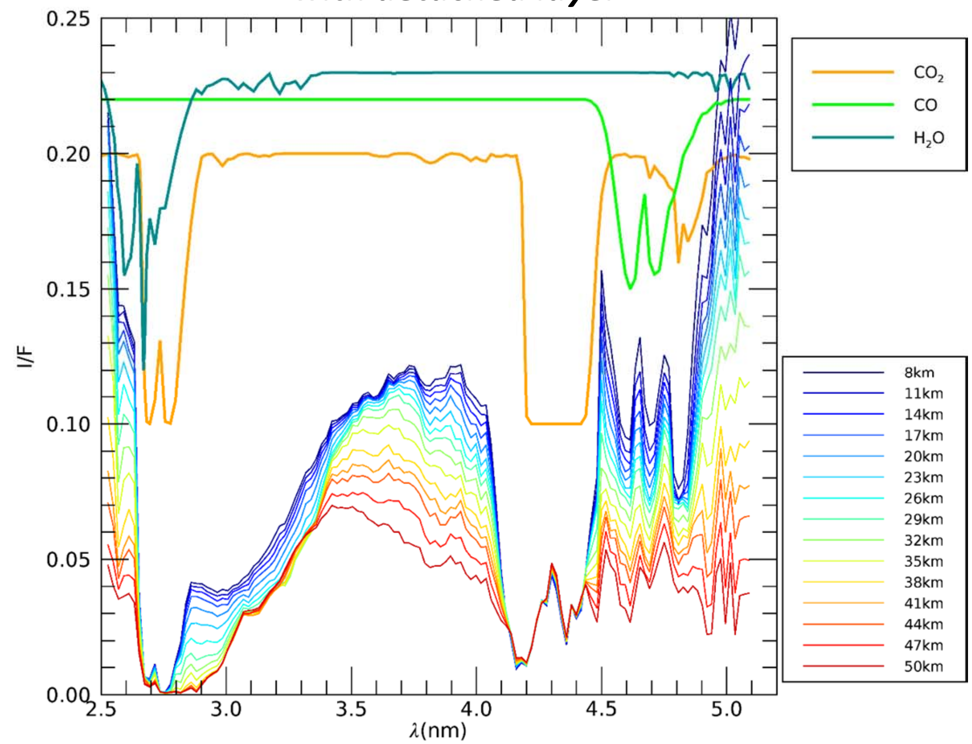
Main features are

- CO_2 emission at 4.3 µm
- CO absorption at 4.6-4.7 µm
- H_2O gas absorption at 2.6 µm

w\o detached layer

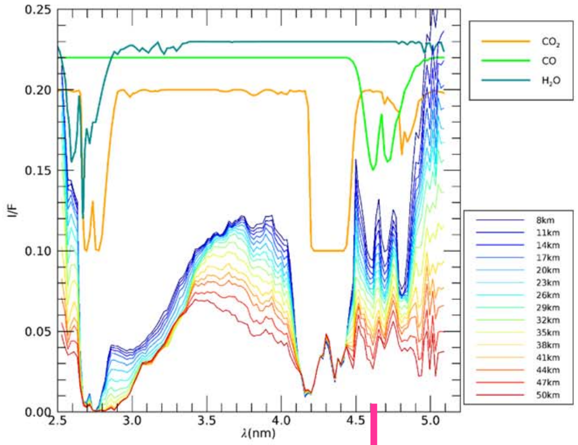


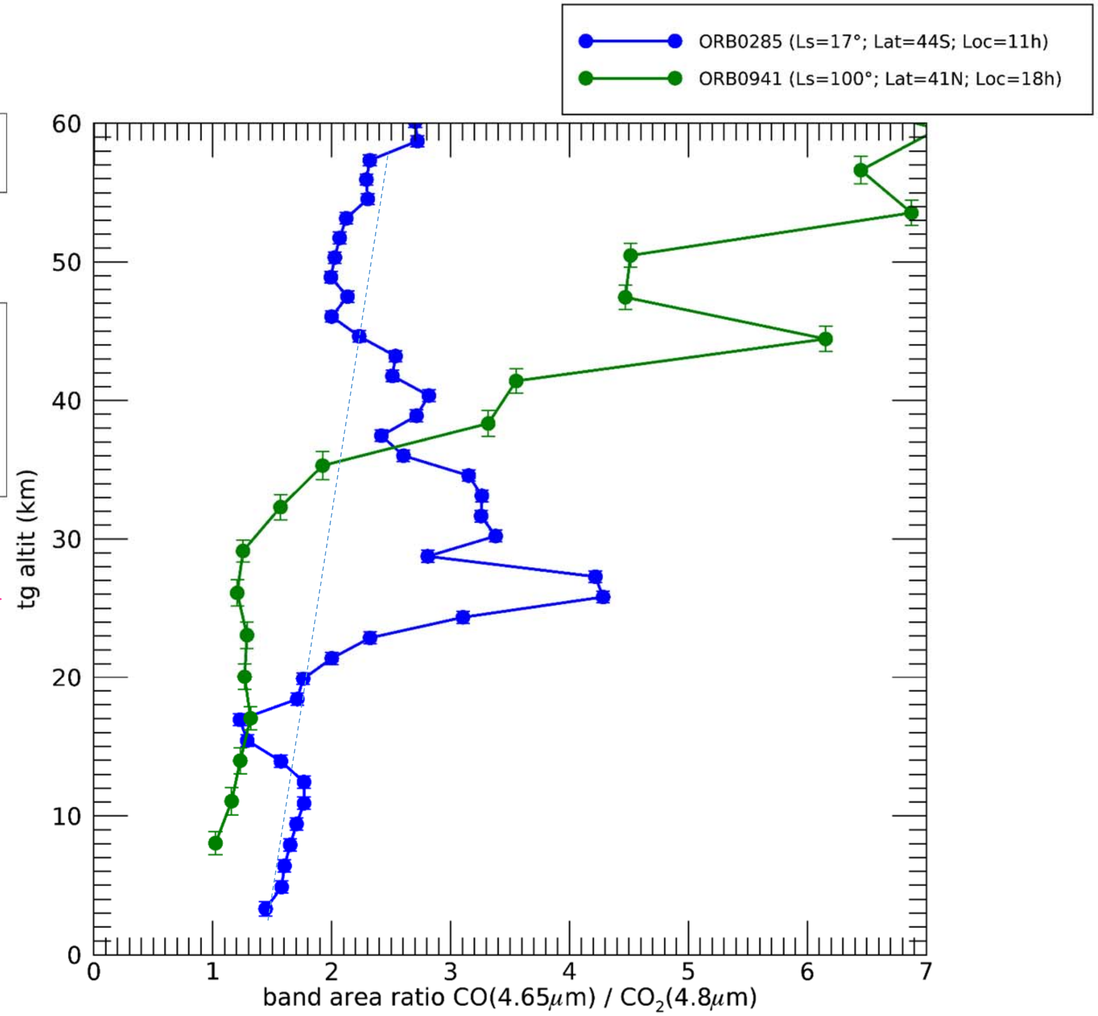
with detached layer



CO absorption

CO absorption band at 4.6-4.7 µm is seen against the thermal emission background





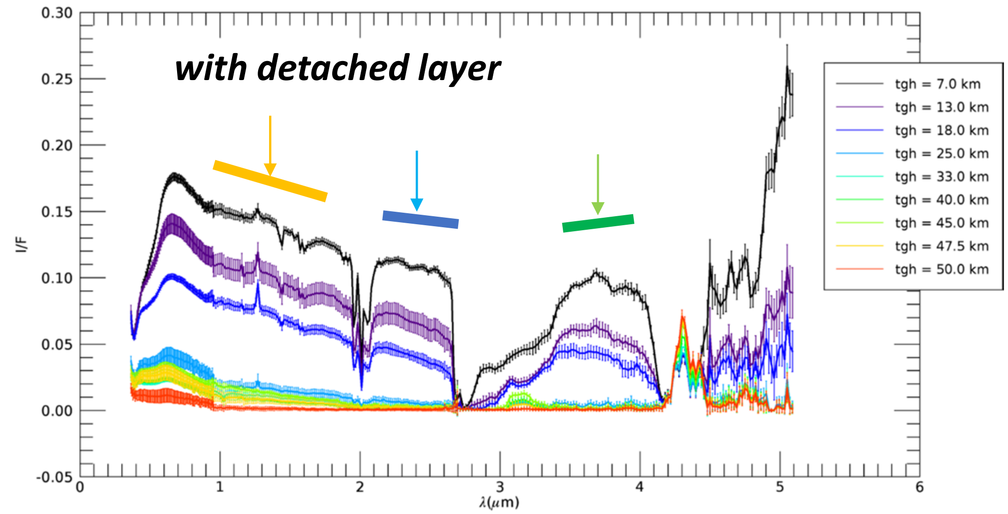
CO band area at 4.6-4.7 µm is shown here ratioed by the CO_2 band area at 4.8 µm, to grossly normalize the path length.

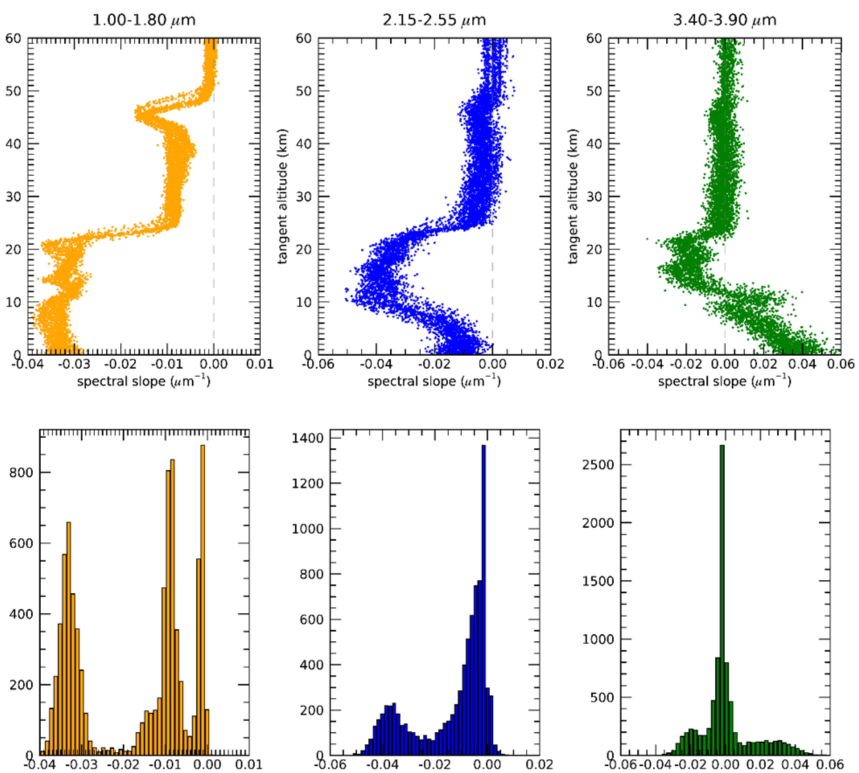
Vertical profile of band ratio shows an increasing CO with altitude, but can be biased by scattering and thermal profile. RT modeling is of course needed to derive abundances.

Dust

The overall spectral shape at limb is dominated by scattering by dust (and molecules in the blue range).

Spectral slopes in between the main of gaseous absorptions can be related the composition and/or grains size of the scatterers.



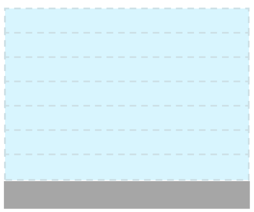


Slopes identify changes in scattering regimes with altitude, but quantitative retrievals require full modelling of radiative transfer with multiple scattering in spherical geometry…

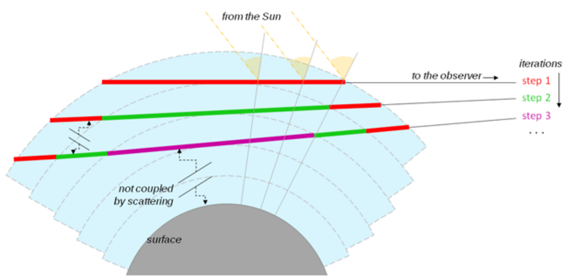
Radiative Transfer at limb – **modeling scheme**

Pros and cons of some Radiative Transfer schemes

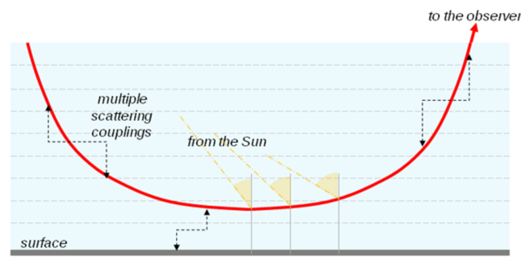
Plane-parallel



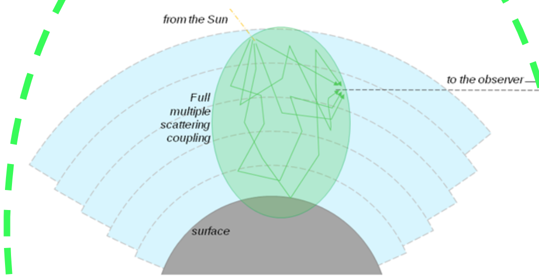
Onion-peeling



Pseudo-spherical



Monte Carlo



Plane-parallel

- ✓ Multiple scattering
- ✓ Many solvers available
- P Small incidence and emission angles

Onion-peeling

- ✓ Fast convergence
- P Single scattering

Pseudo-spherical

- ✓ Multiple scattering
- ✓ PPA approach
- P Complex angles management

Monte Carlo

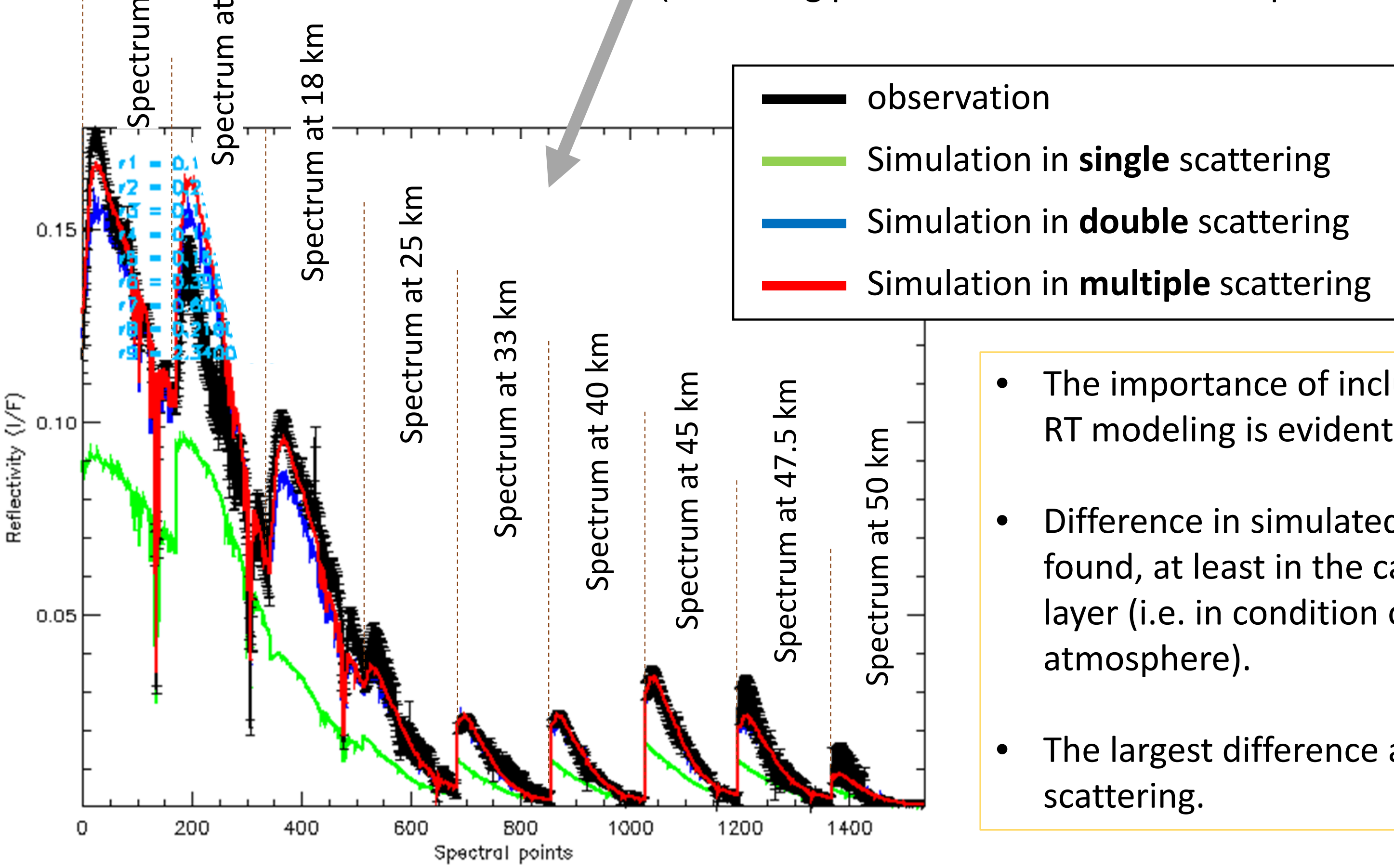
- ✓ Multiple scattering
- ✓ Accurate physics
- P Time consuming

MITRA tool

- Backward Monte Carlo as forward RT model
- Bayesian inversion for retrieval of dust properties (and gases)

Radiative Transfer at limb – **multiple scattering**

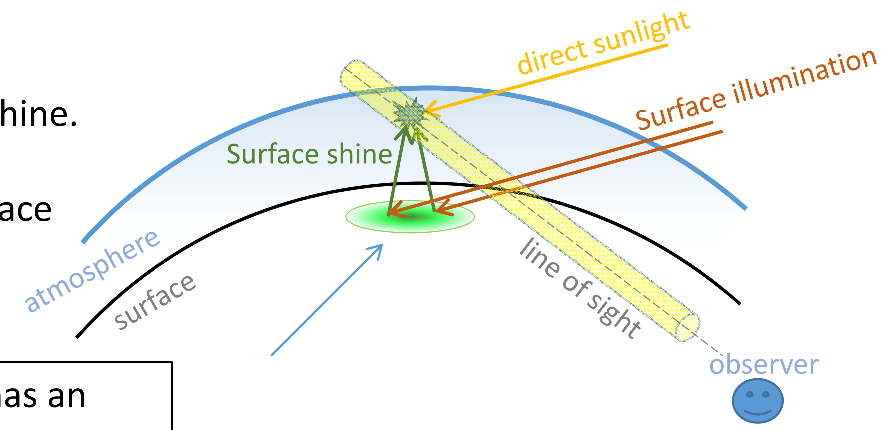
9 limb spectra for increasing tangent altitude are shown here side-by-side (the fitting procedure involves all limb spectra simultaneously)

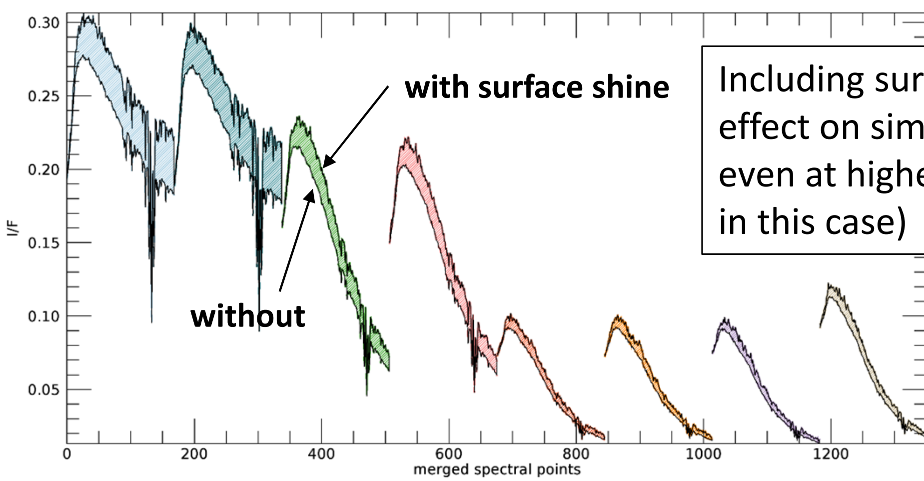


- The importance of including multiple scattering terms in RT modeling is evident **even at higher altitudes**.
- Difference in simulated reflectance by **40-50%** are found, at least in the case of the cube with detached layer (i.e. in condition of enhanced dust suspended in atmosphere).
- The largest difference appears between single and twice scattering.

Radiative Transfer at limb – **surface shine**

The whole limb atmospheric column is illuminated from the surface shine.
Full treatment would require a 3D RT model.
Simplified treatment: average amount of light scattered from the surface toward a given tangent altitude of the limb observation.

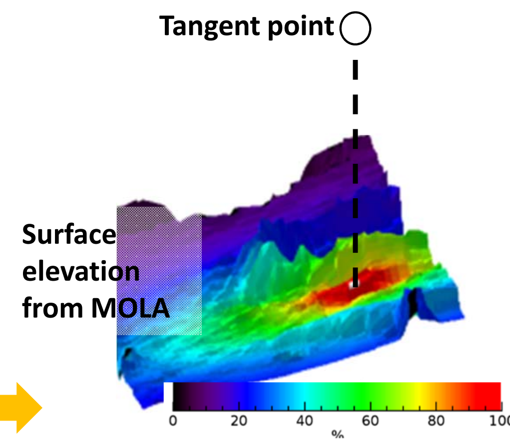




Including surface shine has an effect on simulated reflectance even at higher altitudes (12-15% in this case)

We obtained spectra for surface shine by:

a) Selecting OMEGA nadir cubes covering the region below the limb observation;
b) Correcting them with SAS method to remove contribution from gases and dust;
c) Averaging this dust-free surface albedo weighted by illumination and viewing angles relative to the given tangent point.

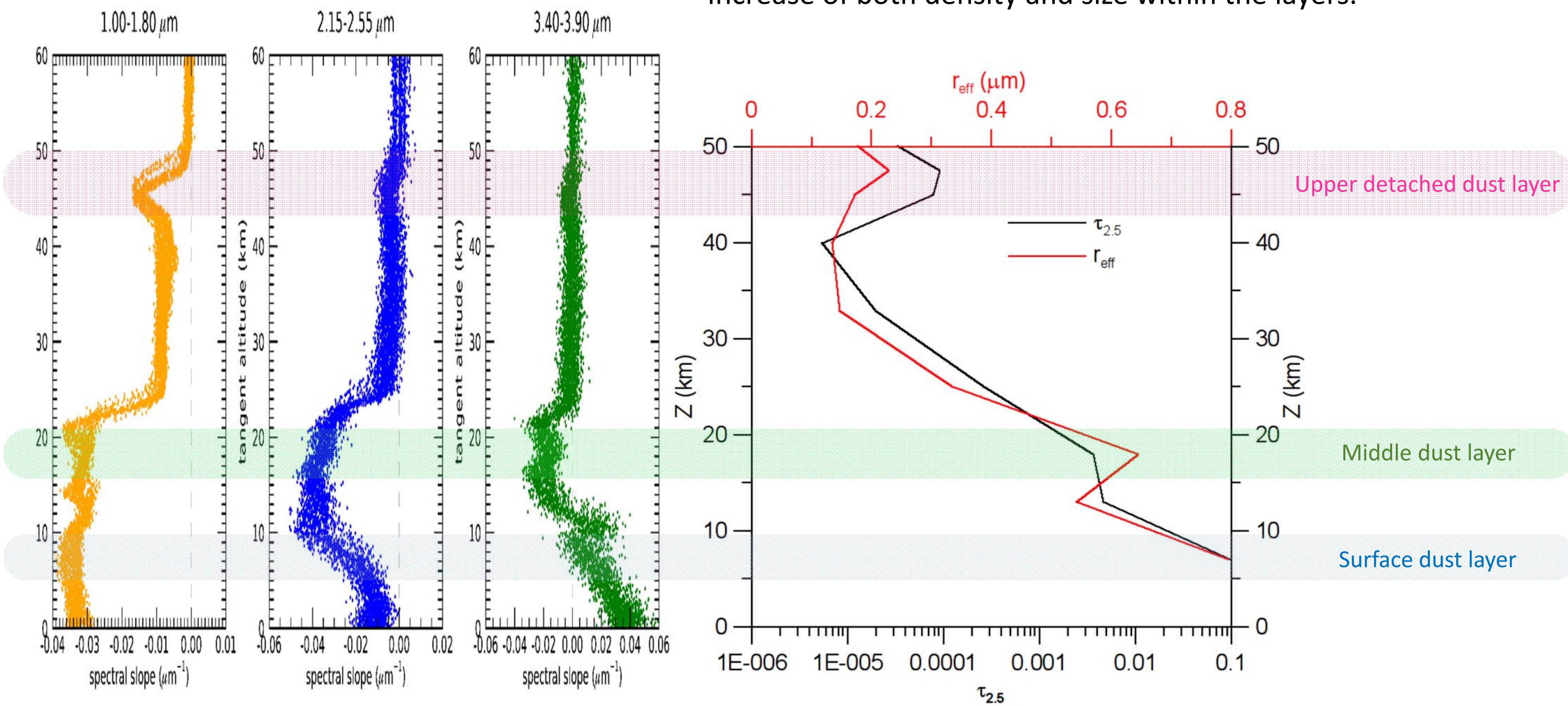


Simulated shine intensity as viewed from tangent point

Dust profiles – first results for detached layer cube

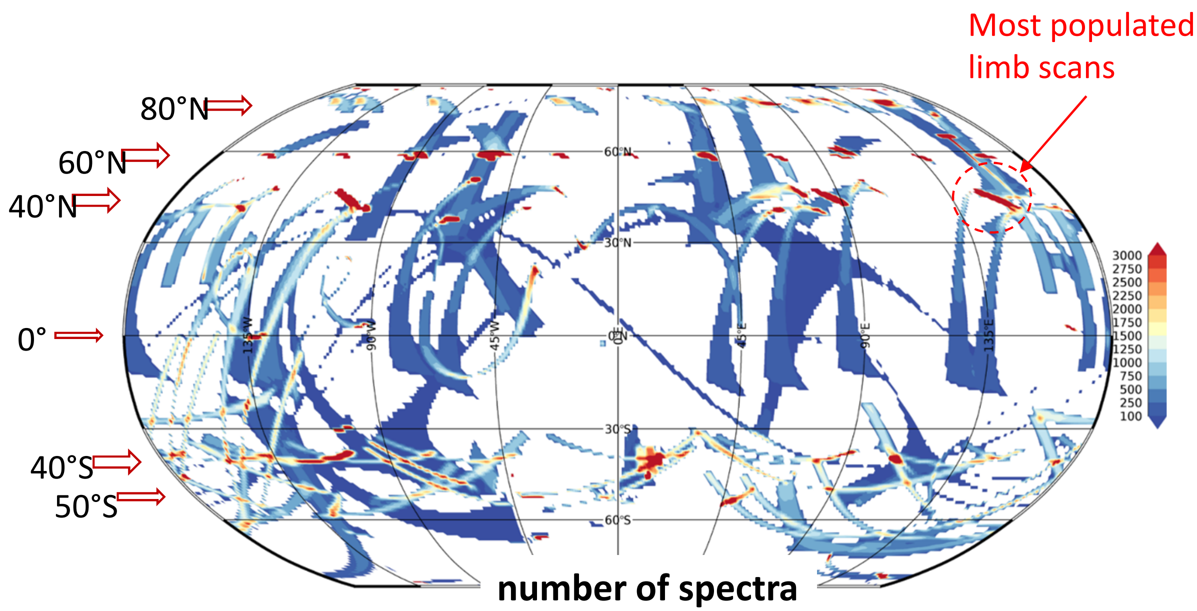
Retrievals obtained **from 0.5 to 2.5 micron**, by assuming:
- single population of dust grains (lognormal constant Veff)
- constant composition (Wolff et al.)

- Two enhanced dust layers at 45 km (detached) and 18 km (not detached).
- Increase of both density and size within the layers.



Conclusions

- OMEGA limb data are promising for retrieval of **vertical profiles** of both **gases** (H_2O, CO, O_2), **dust** properties (abundance and grain sizes) and **water ice** when present.
  - Several issues must be addressed for quantitative retrievals, both instrumental (misalignment, straylight) and for Radiative Transfer modelling (multiple scattering in spherical geometry, surface shine).
    - The first attempt to study a limb spectral scan in presence of a detached layer was successful in retrieving **two dust layers** overlapped to an exponential background dust distribution.



- OMEGA data include several limb vertical spectral scans that will be studied in the future. They appear mostly concentrated at mid latitudes (*red zones*), but are characterized by variable vertical resolution (about 1.5 to 10 km/pixel) and observing conditions (incidence, phase, season).
- Final results may be valuable in providing insight on atmospheric vertical structure in a climatological framework.