NON-LTE LIMB EMISSION AT 4.7 μM IN THE UPPER ATMOSPHERE OF VENUS, MARS AND EARTH: *OBSERVATIONS AND MODELLING*

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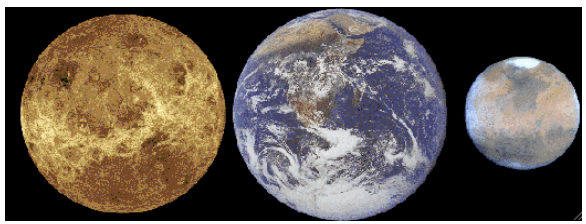


Outline:

OBSERVATIONS

- CO limb observations @ 4.7 μm with Virtis/VEx, PFS/Mex, MIPAS/Envisat

THEORY AND MODEL

- Principal differences/similarities of terrestrial planets thermospheres
- Non-LTE model descriptions and results.

COMPARATIVE ANALYSIS

- Comparison model-data, planet-planet

SUMMARY AND CONCLUSIONS

Instruments characteristics and data set

VIRTIS/*VEx*: Visible Infra Red Thermal Imaging Spectrometer

VIRTIS-M = imaging spectrometer R ≈ 400

V-M-vis 0.25 - 1 μm V-M -IR 1 - 5 μm IFOV ≈ 300m/pix periapsis

VIRTIS-H = spectrometer R ≈ 1800 (Δν ≈ 1.3 cm -1)

IR 2 - 5 μm IFOV ≈ 1.5 km/pix periapsis

Day-time limb measurements from May 2006 to Oct 2008, about 460 Orbits.

PFS/*Mex*: *Planetary Fourier Spectrometer*

LW channel 5.5-45 μm (250 -1700 cm-1) IFOV ≈ 7 km/pix periapsis

SW channel 1.2-5.5 μm (1700-9200 cm-1) IFOV ≈ 12 km/pix periapsis

Δν ≈ 1.5 cm -1

Two special orbits studied in the literature.

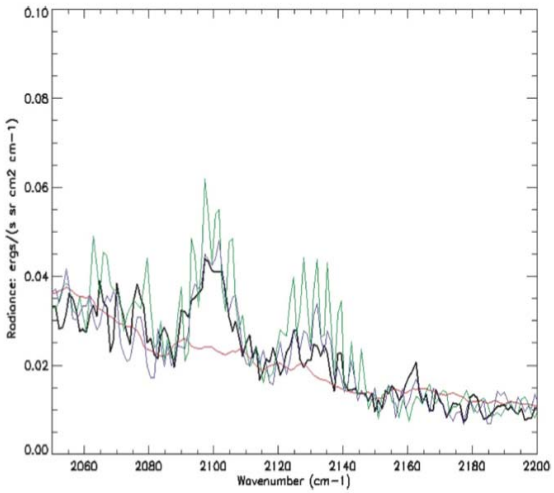
MIPAS/*Envisat*: *Michelson Interferometer for Passive Atmospheric sounding*

Δν ≈ 0.035 cm -1 (unapodized) IFOV ≈ 3 km

Limb tracking observations 19-27 Sept 2002 = more than 6000 limb scans in the upper atmosphere

CO non-LTE limb observations on terrestrial planets:

PFS Mars observations:



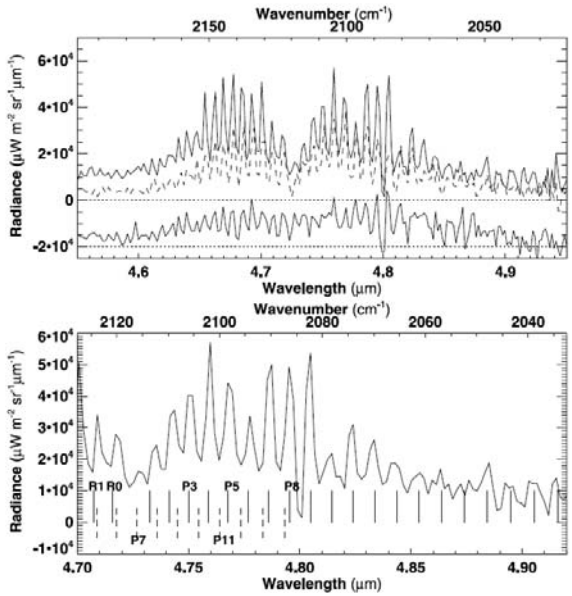
Formisano et al. 2006

Average spectra:

@ 80km-120km (green, blue)

@110km-180km (black)

VIRTIS Venus observations:



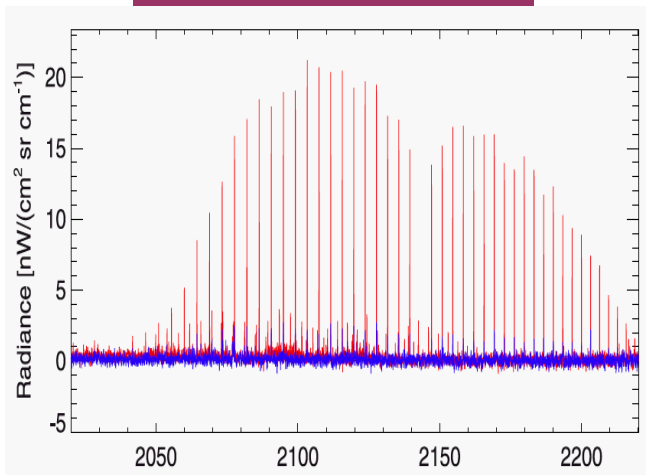
Gilli et al. 2009

Individual spectra:

@ 85 km, SZA= 60º, 70º

@118, SZA = 60º

MIPAS Earth observations:



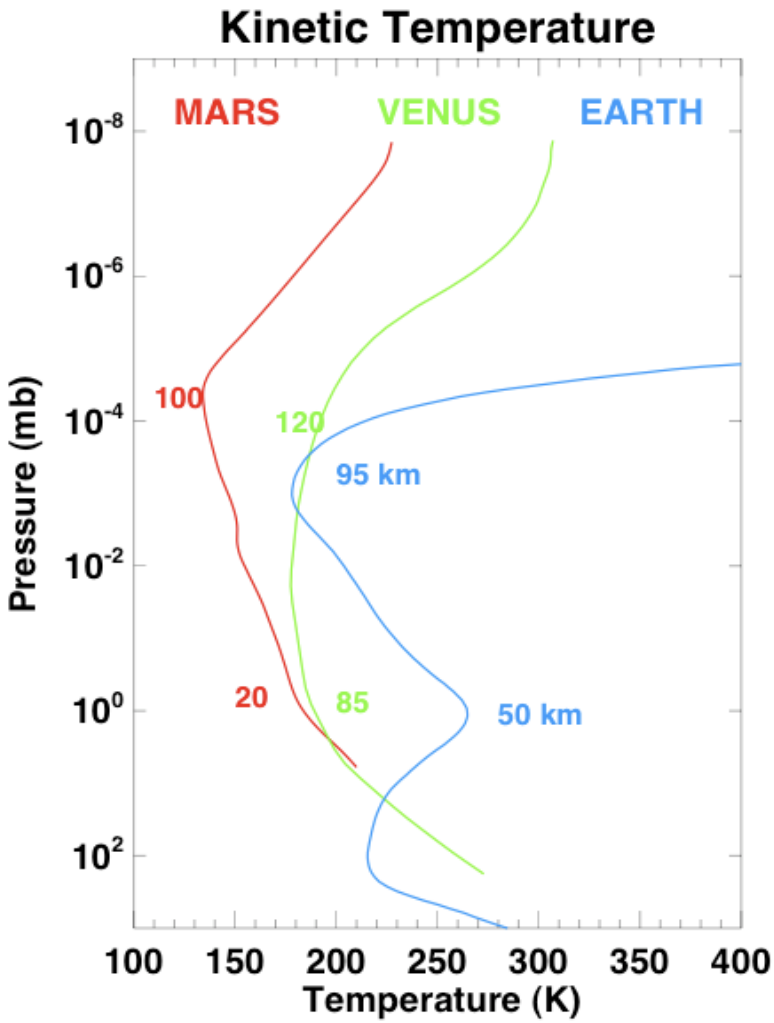
Funke et al. 2006

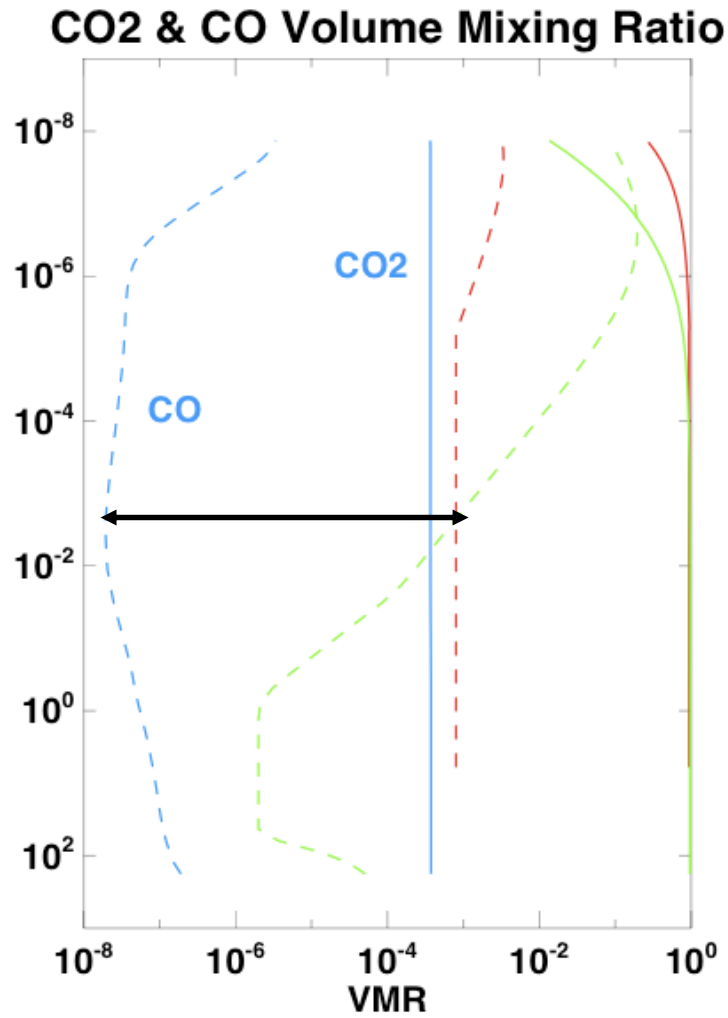
Coadded daytime spectra (red)

Coadded nightime spectra (blue)

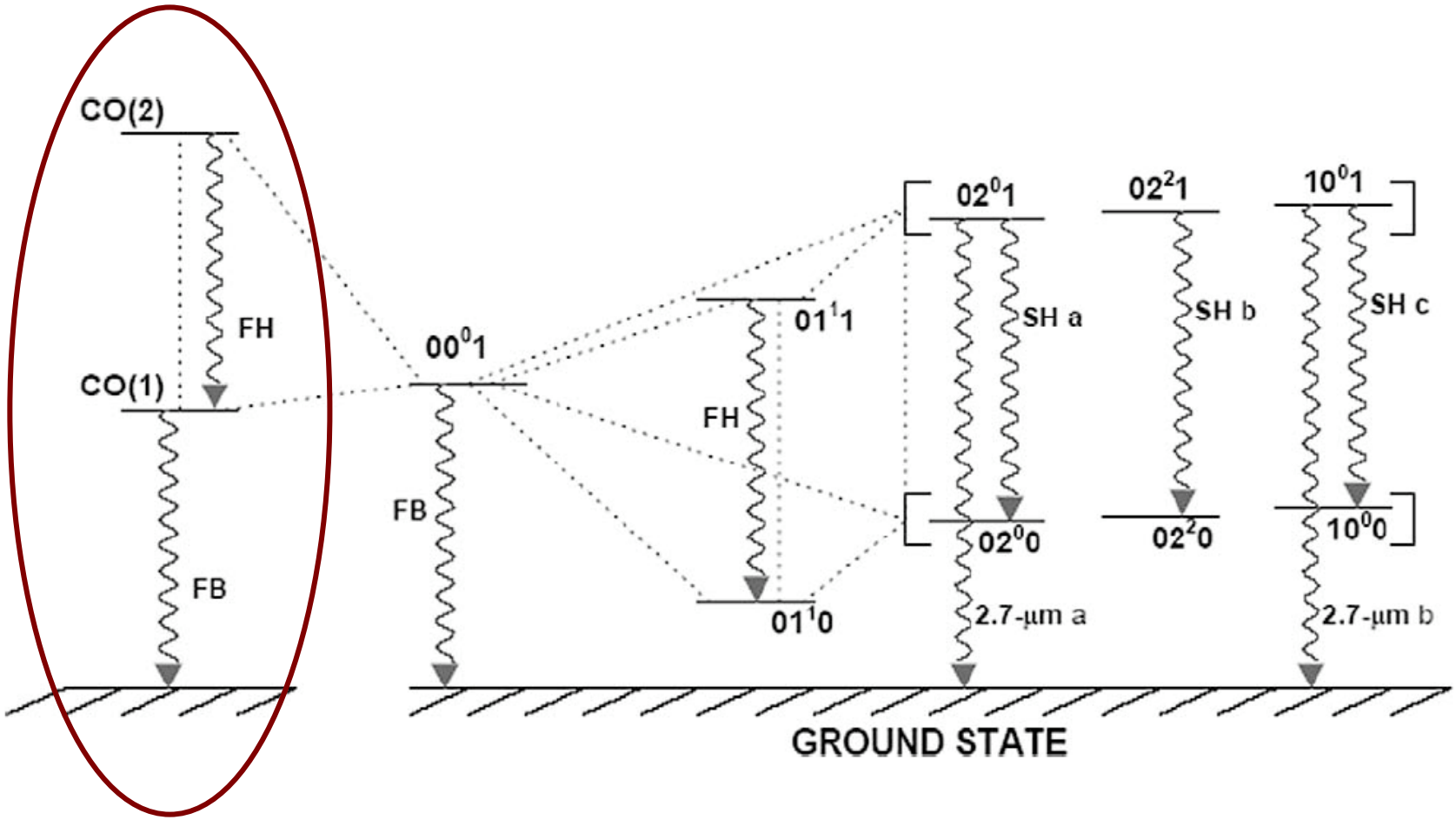
@ 68 km

Terrestrial Planets thermospheres





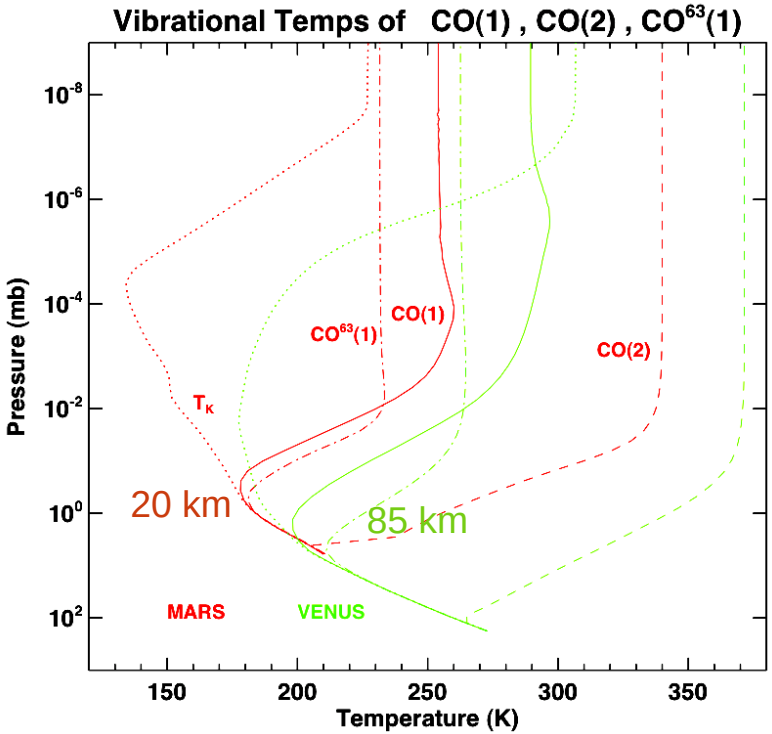
CO and CO_2 vibrational levels included in the non-LTE models (see poster by López-Valverde, this conference)



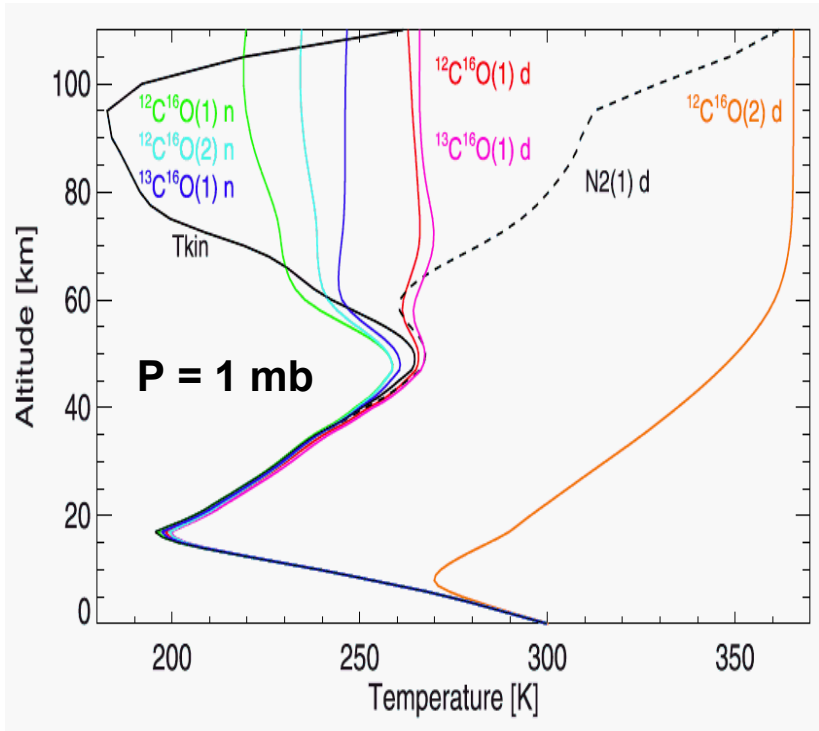
Non-LTE models results

CO Vibrational temperatures

MARS & VENUS



EARTH



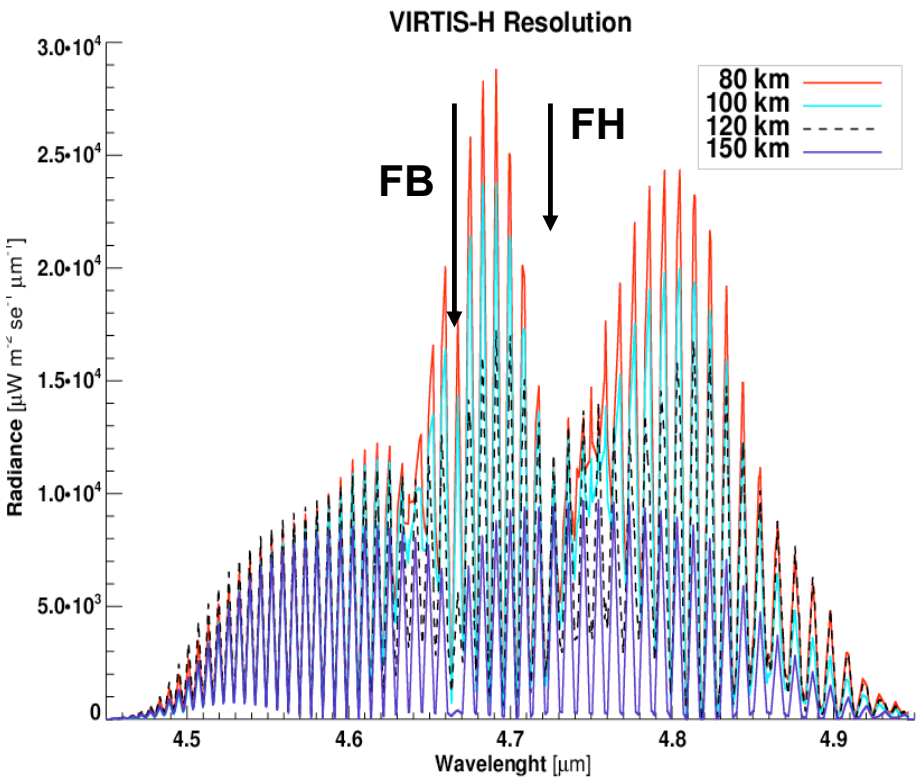
Funke et al. 2006

Non-LTE model results

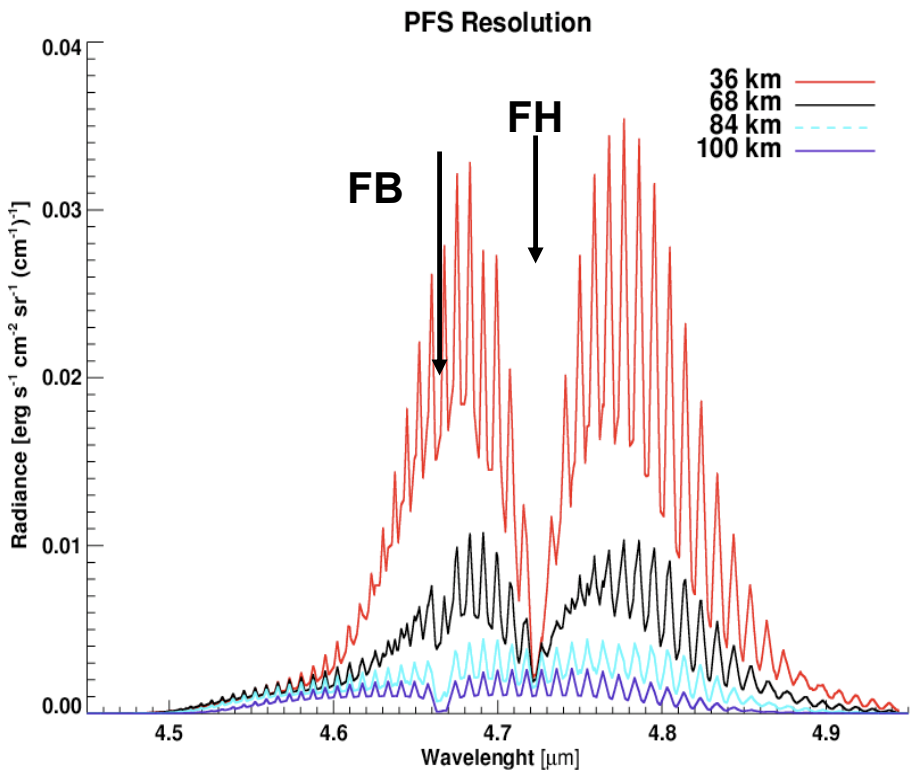
Simulated CO spectra

RFM forward model: line-by-line calculations

VENUS



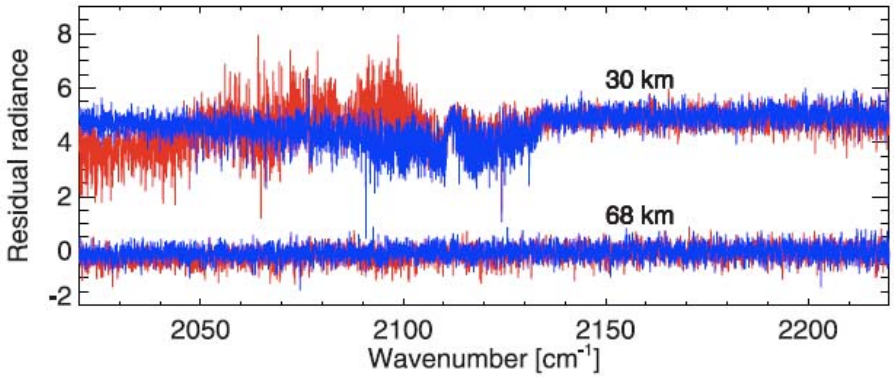
MARS



Comparison non-LTE models-data

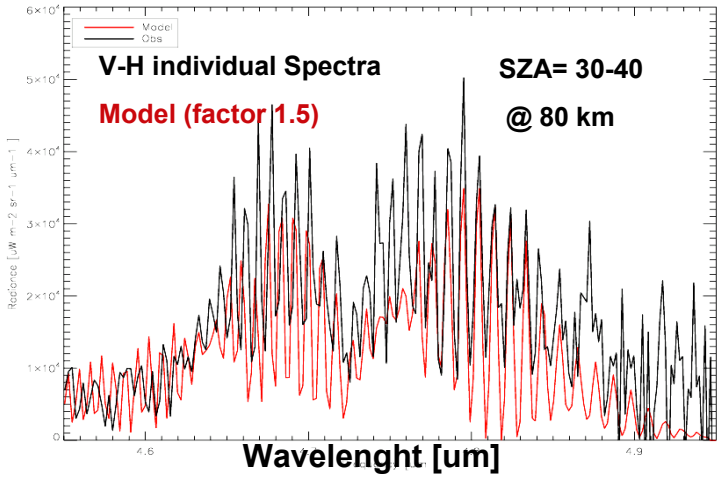
EARTH

Funke et al. 2006

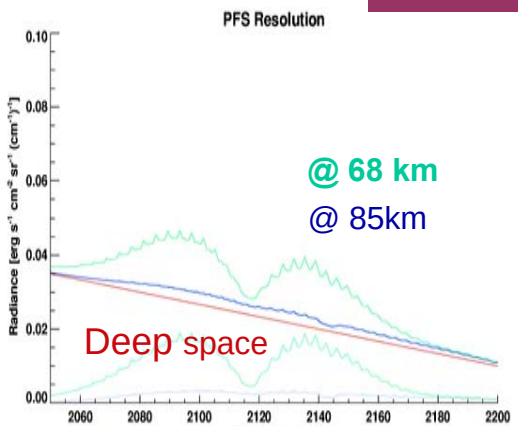


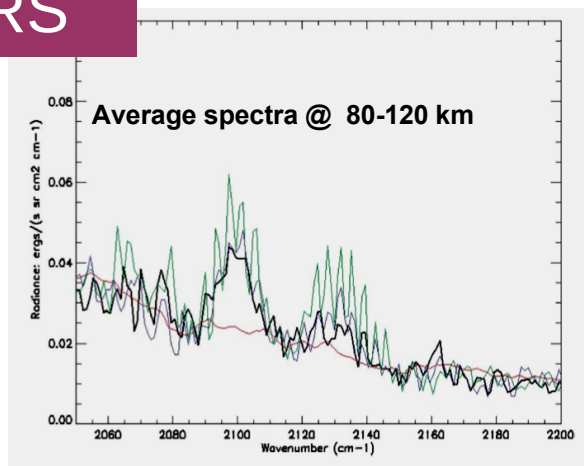
Simulated - measured coadded daytime/nightime radiances (red/blue)

VENUS



MARS





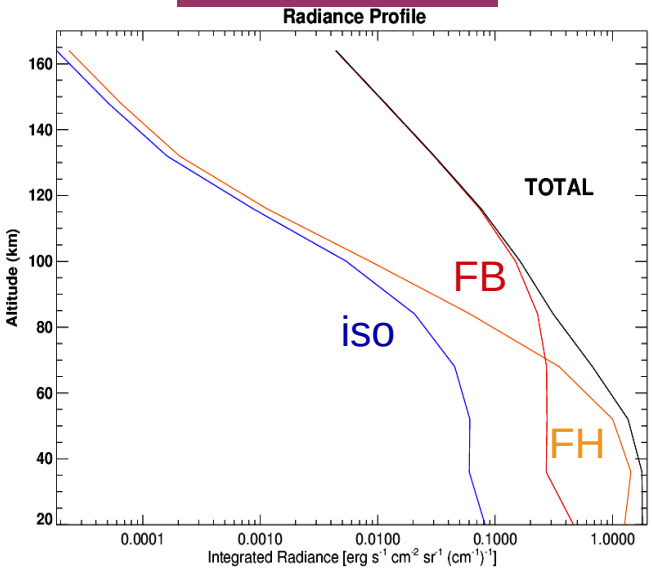
Formisano et al. 2006

Non-LTE model results

Simulated radiance profiles

integrated in all spectral region of 4.7-μm CO emission

MARS



Optically thin condition

$R \propto n^*$

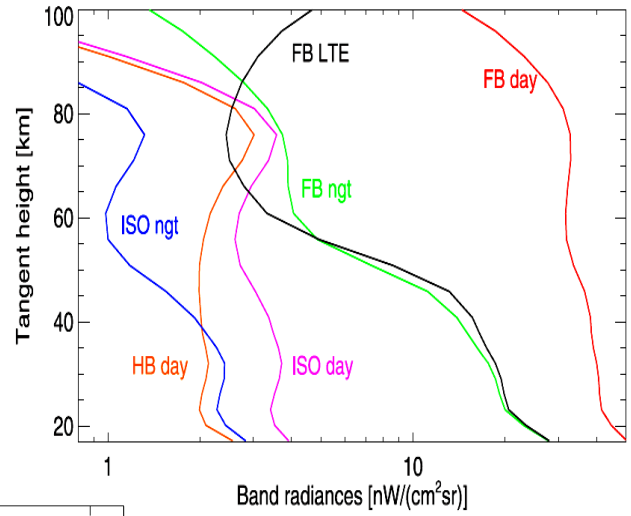
FB n^* > FH n^*

Optically thick condition

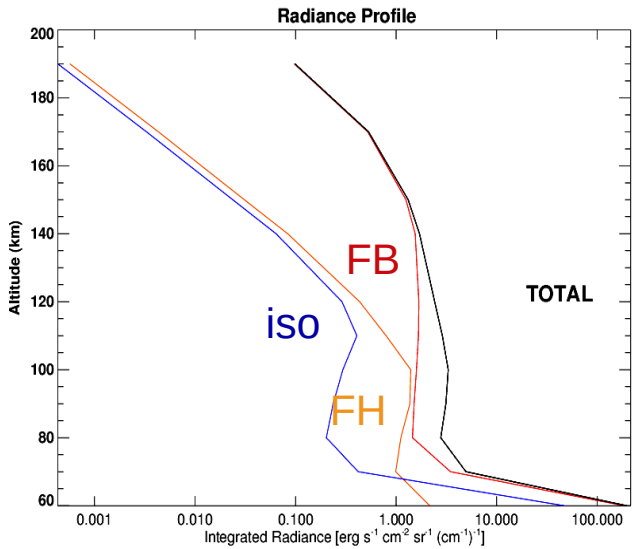
$R \propto J \propto T_{vib}$

FH T_{vib} >> FB T_{vib}

EARTH



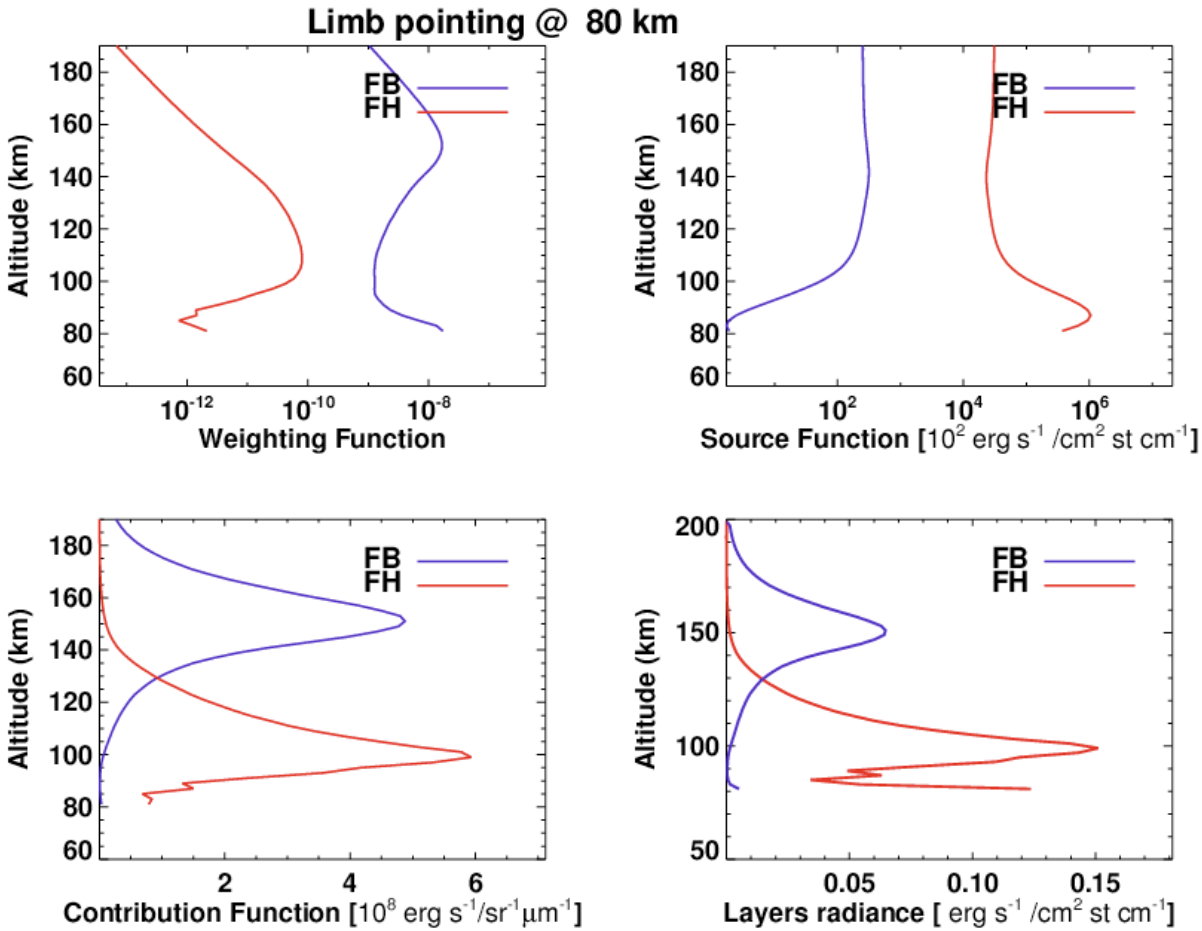
Funke et al. 2006



VENUS

Contribution Function study for Venus

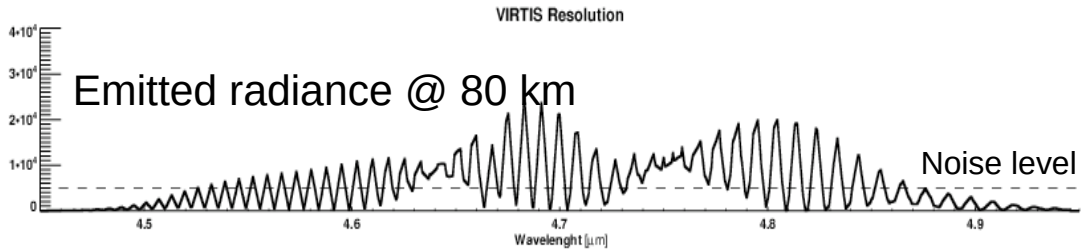
Spectrum convolved to VIRTIS-H resolution



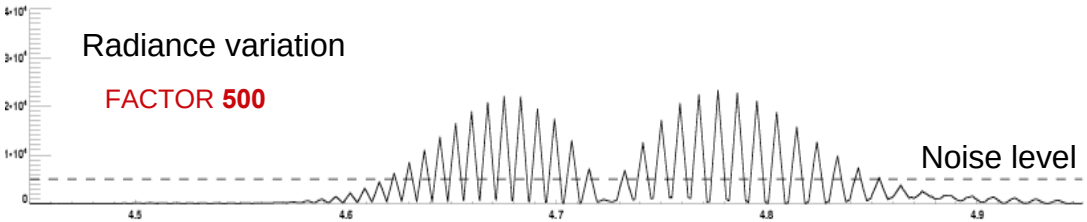
FB band is **optically thick**: its emission comes from the upper layers

FH band is **optically thin** from above 100 km

Sensitivity study for VIRTIS measurements

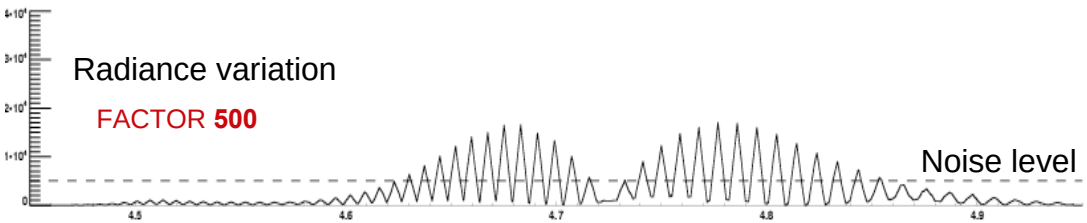


*1% density perturbation @**100 km***

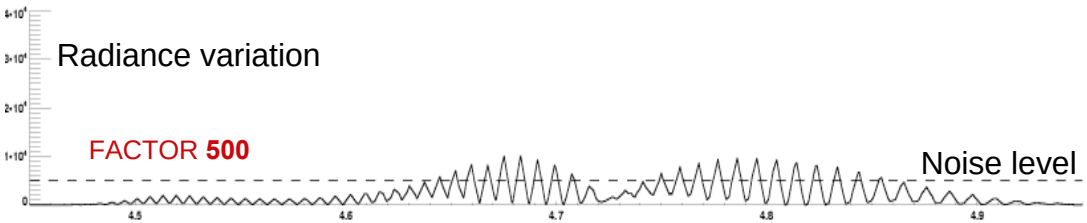


Density retrieved with uncertainty ≈ 125 %

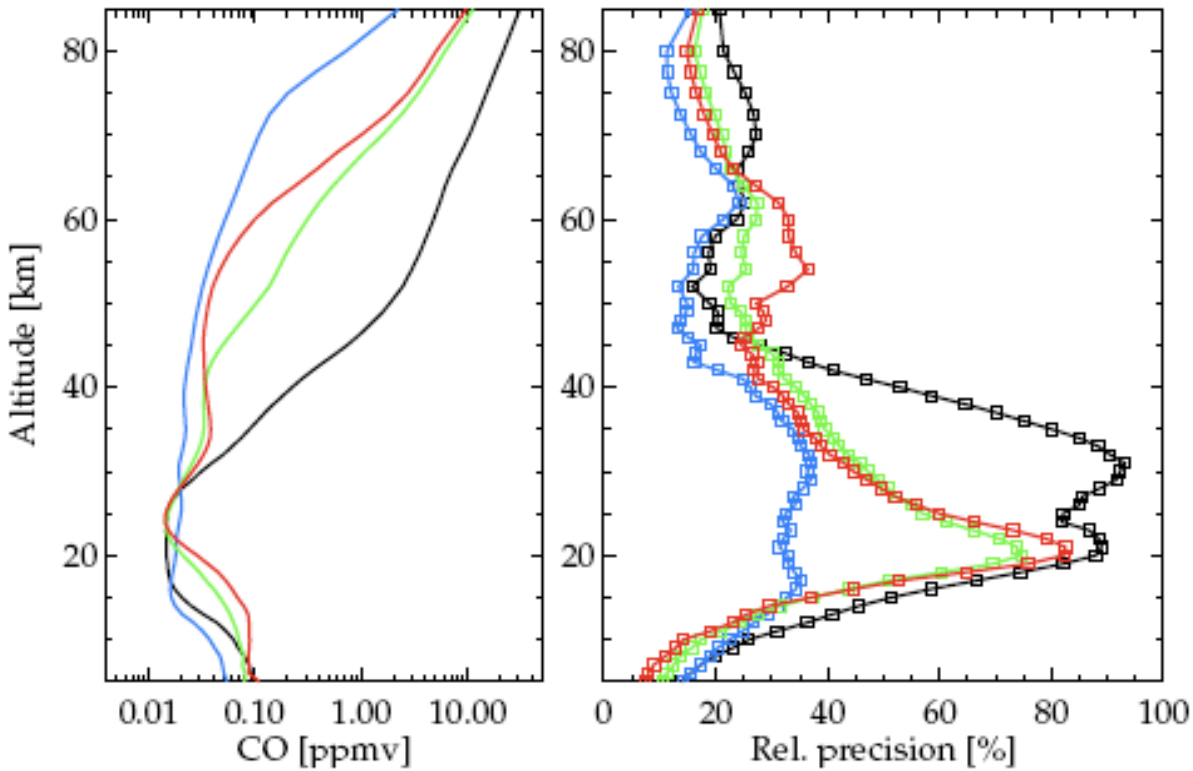
1% density perturbation *@**110 km***



1% density perturbation **@120 km**



CO abundances on Earth from **non-LTE retrievals** of MIPAS



Funke et al. 2009

Retrieved average CO vmr profiles and relative precision:

Polar winter, Polar summer,

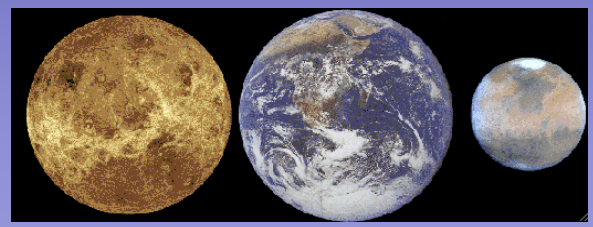
mid-latitudes ,tropics

Summary & conclusions

1. Typical double ro-vibrational structure of CO diatomic molecule observed
2. On Mars & Venus FH band dominates CO limb spectra
3. On Earth lower CO VMR ⟹ bands are optically thinner
4. Good qualitative agreement with our non-LTE model simulations
5. High spectral resolution & good sensitivity: key to derive atmospheric parameter from measurements.
6. Nowadays, investigation on Earth is leader
7. VIRTIS is potentially useful to retrieve densities in the upper atmosphere of Venus using a non-LTE retrieval.

Thank you!

Good lunch!



VIRTIS-H Venus observations:

Orbit 712

Cube 2