

Modelling the atmospheric CO₂ 10-um laser emission at high spectral resolution in Mars and Venus

Miguel A. López-Valverde *IAA/CSIC, Granada, Spain*

G. Sonnabend, M. Sornig and P. Kroetz *Univ.Cologne, Germany*

Introduction

Model simulations on both planets

Sensitivity studies

Conclusions

Introduction

Strong emission at 10 μm was discovered long ago (Johnson et al, AJ, 1976)

Speculation about strength ...

Modelling with specific non-LTE model including solar pumping at 4.3 μm

(Deming and Mumma, 1983, Gordiets & Panchenko, 1983)

Recent development of high spectral resolution spectroscopy instruments

are used on ground based telescopes to observe Mars and Venus at 10 μm

The data are used to infer T & winds, isotopes, ...

at regular campaigns, supporting validation of space missions

Important for sounding a region of very difficult access by other

means, the upper mesosphere...

But there is not yet a consistent frame/benchmark to interpret the data

and to drive suggestions for further observations, This requires modelling.

OBJECTIVES :

Apply a detailed model to understand the peculiarities of those observations
and / or to validate the model

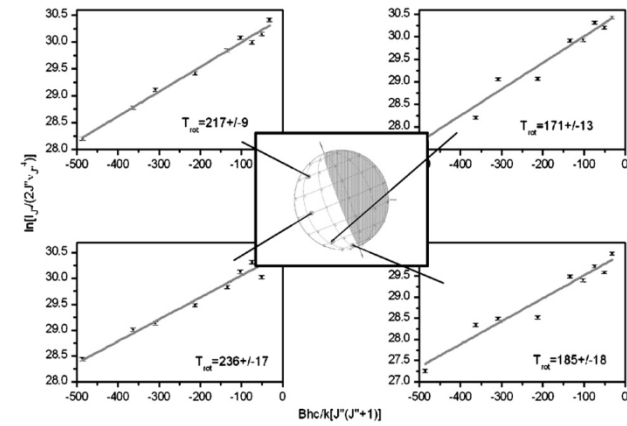
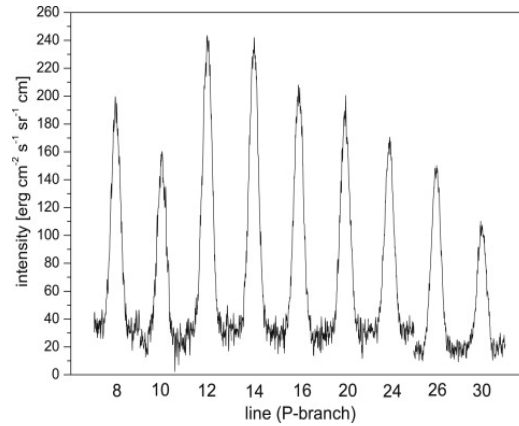
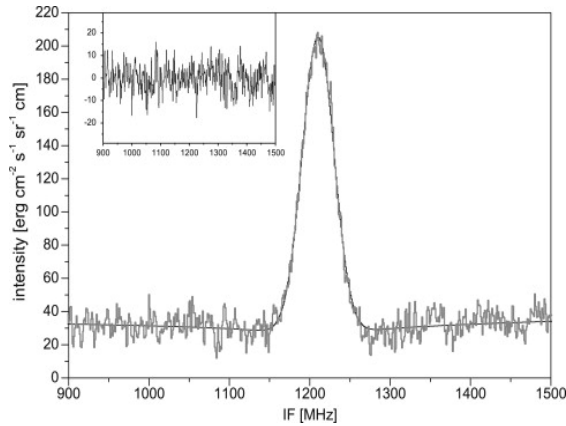
Discern possible atmospheric variability from non-LTE phenomena

Suggest observational strategies

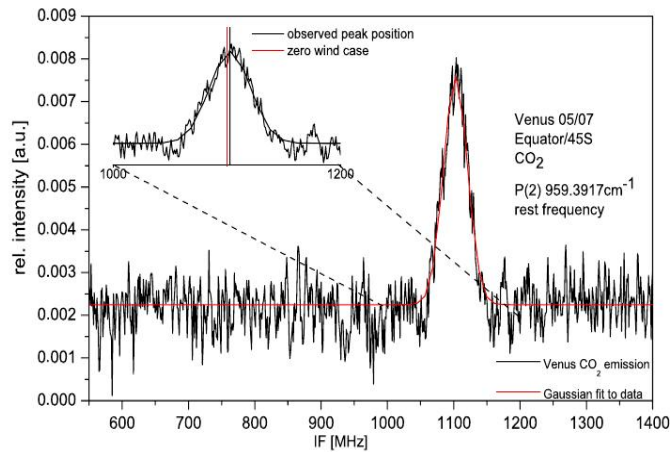
Compare between planetary mesospheres

Some (recent) measurements

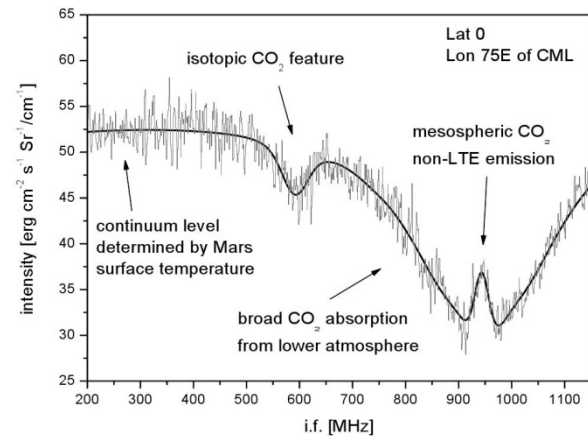
Sonnabend et al, PSS, 2008



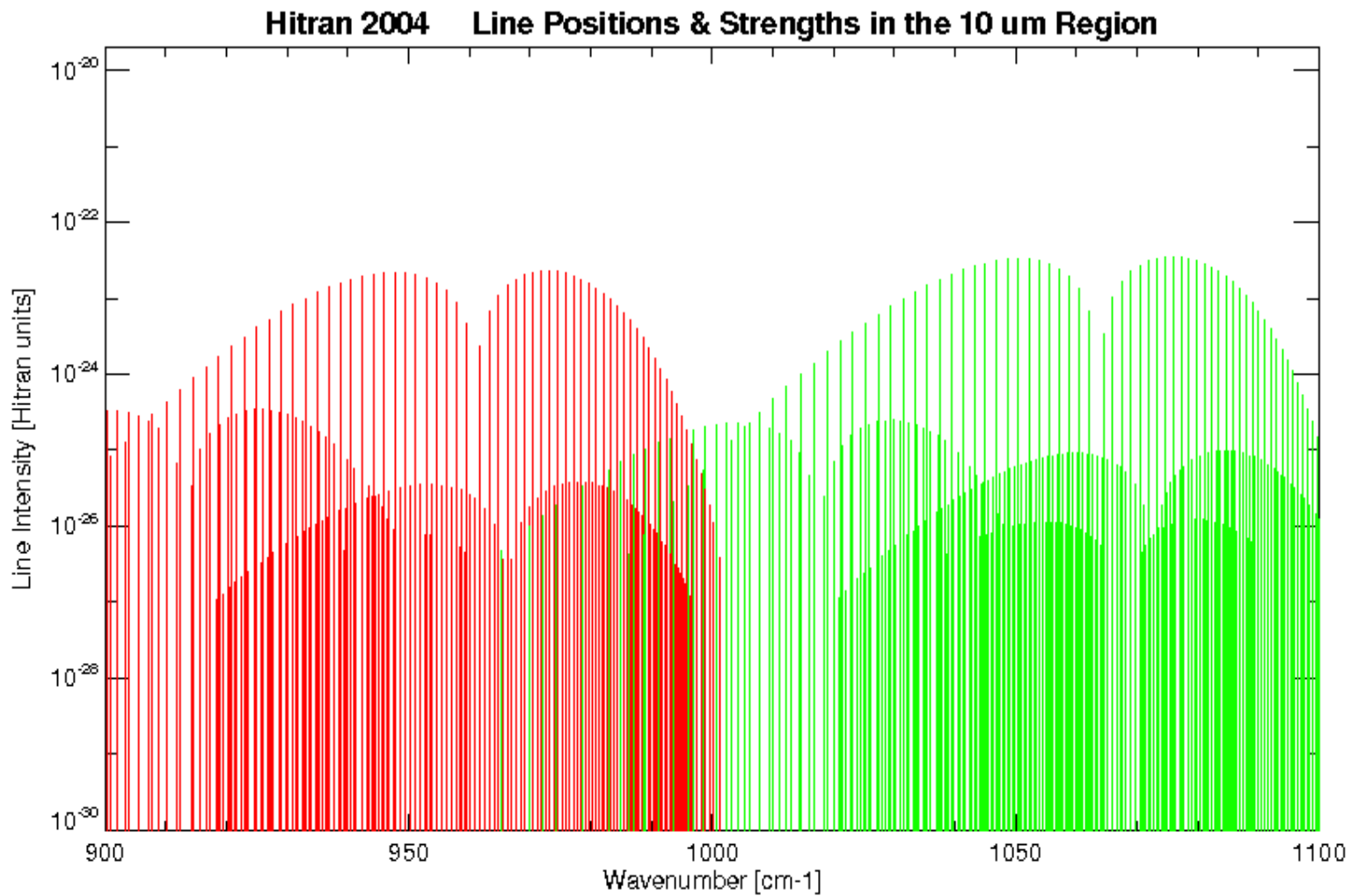
Sornig et al, PSS, 2008



Typical Martian line



Which are these lines ?



The non-LTE model

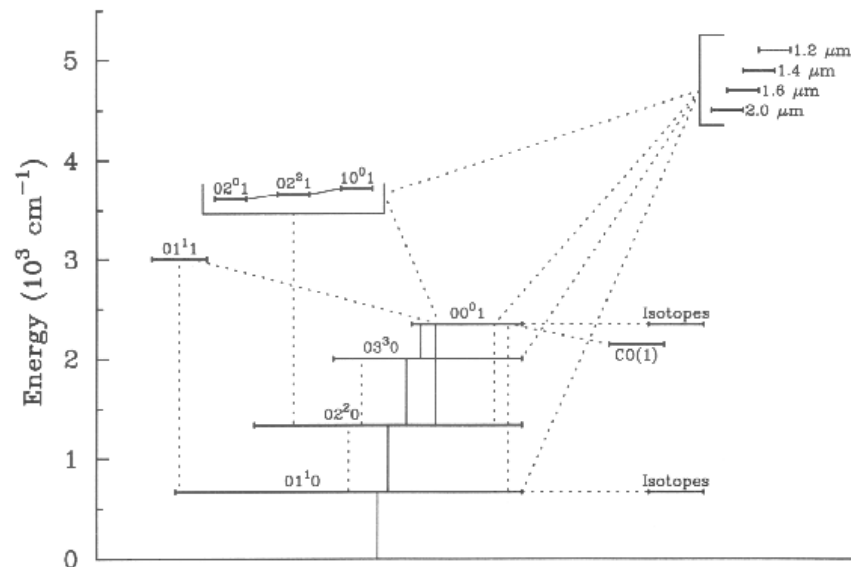
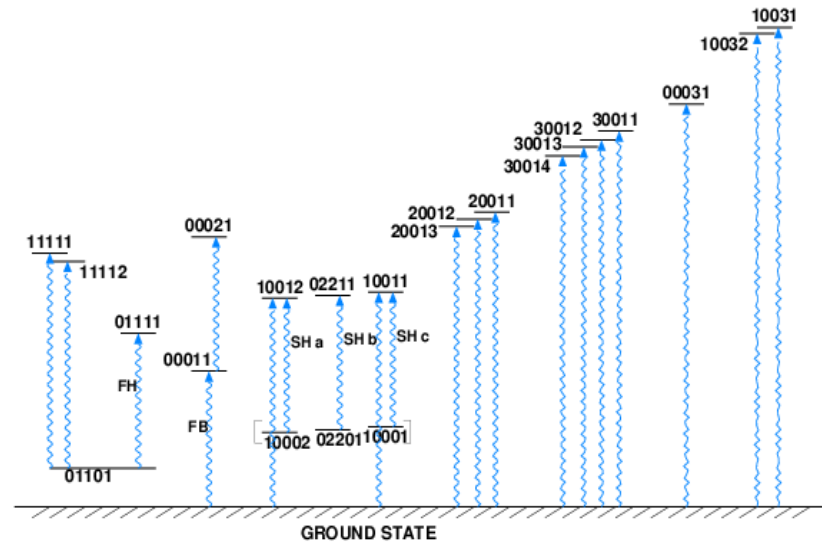
Radiative transfer is used to simulate absorptions and emissions by each CO₂ state

Under LTE, temperature determines the states' populations, but only valid at large densities. At low densities, a microscopic analysis is needed. Non-LTE models can be complex and CPU expensive if many levels are included and there are interactions between them.

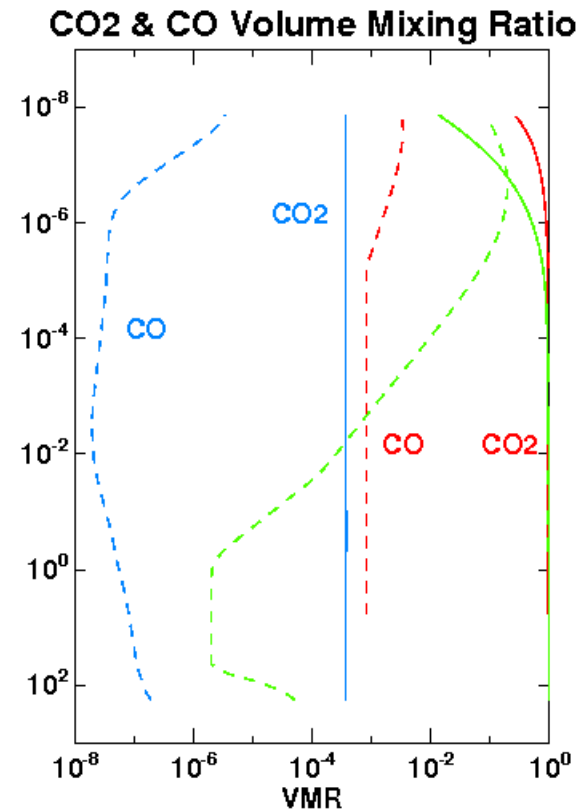
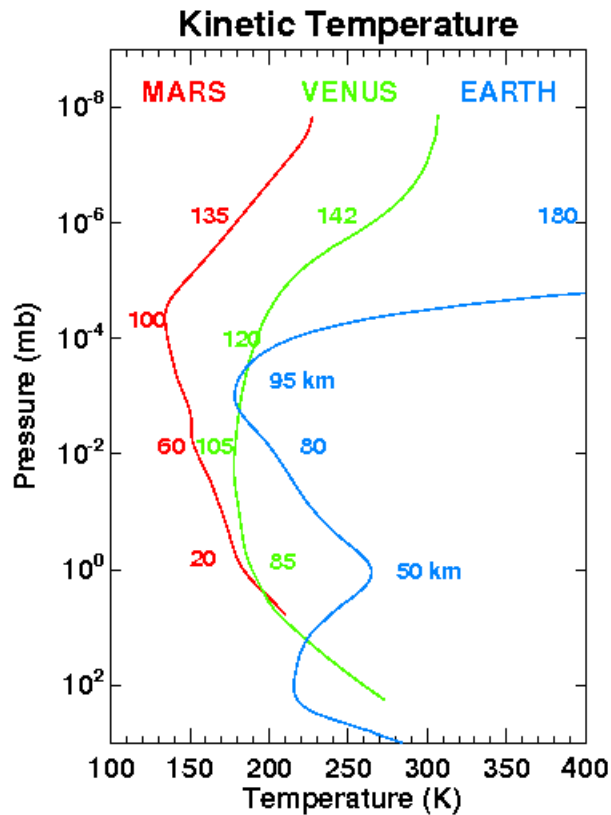
This is the case of a CO₂ atmosphere
 Many vibrat-rot transitions are opt.thick
 Many collisional energy transfers are fast

Coupled equations RTE + SEE
 Non-linearities

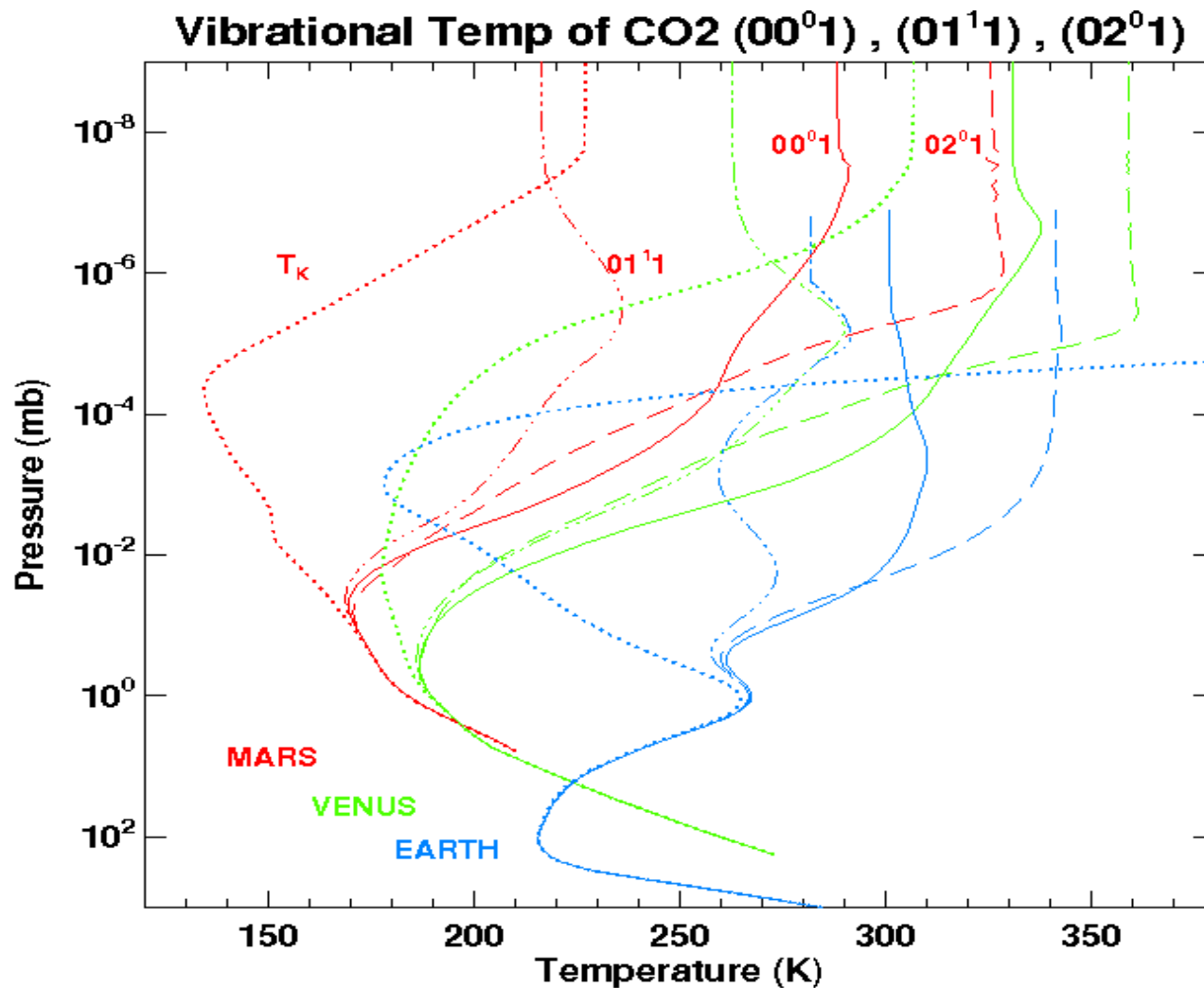
Granada's NLTE model: Curtis Matrix method
Mars: Lopez-Valverde and Lopez-Puertas, 1994
Venus: Lopez-Valverde et al, 1997



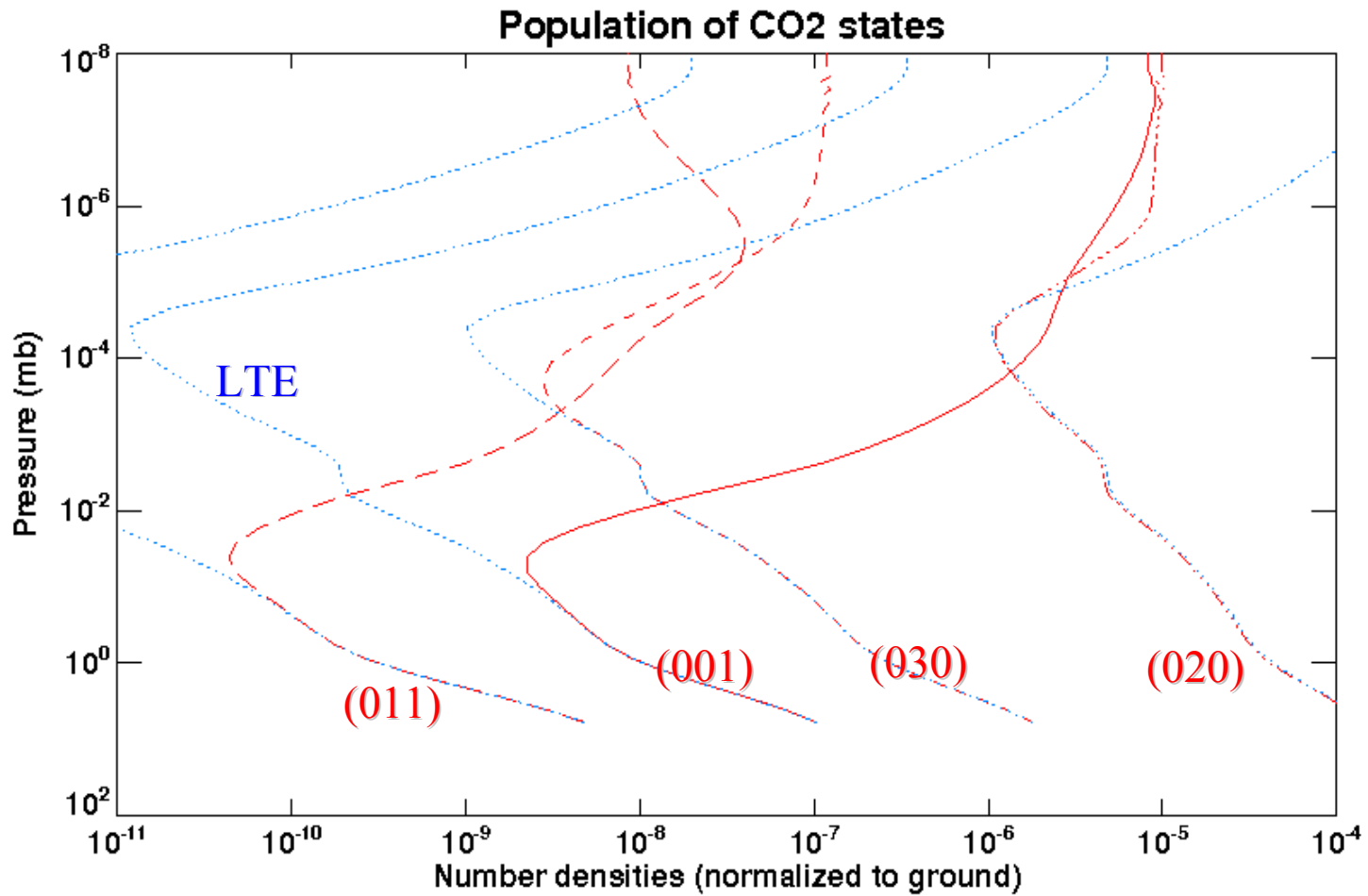
Differences among planets



Results of the Model : Vibrational temperatures

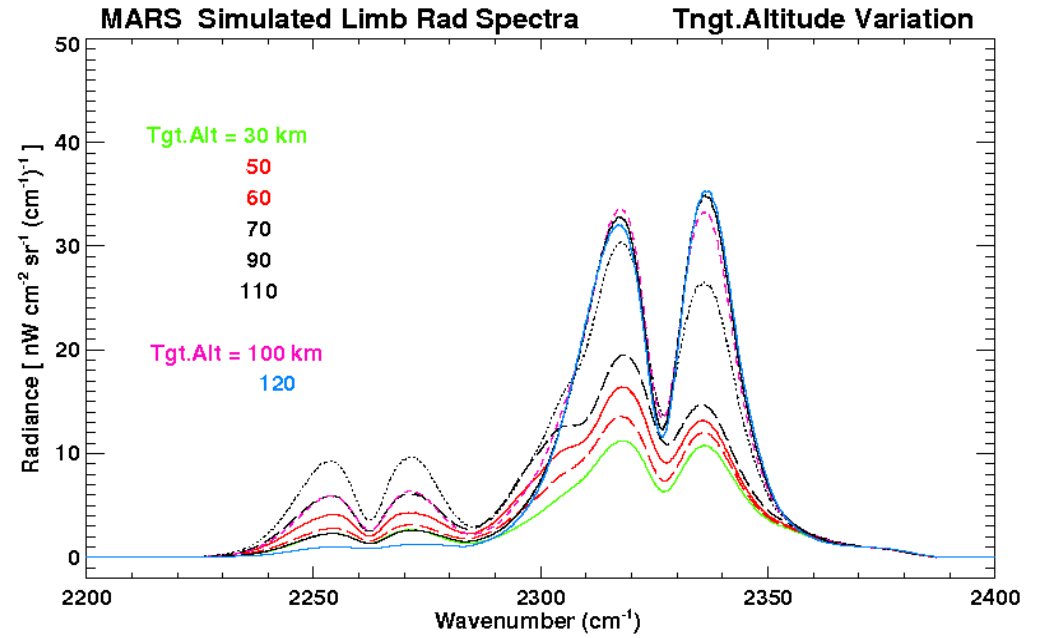


State Population Ratios on Mars

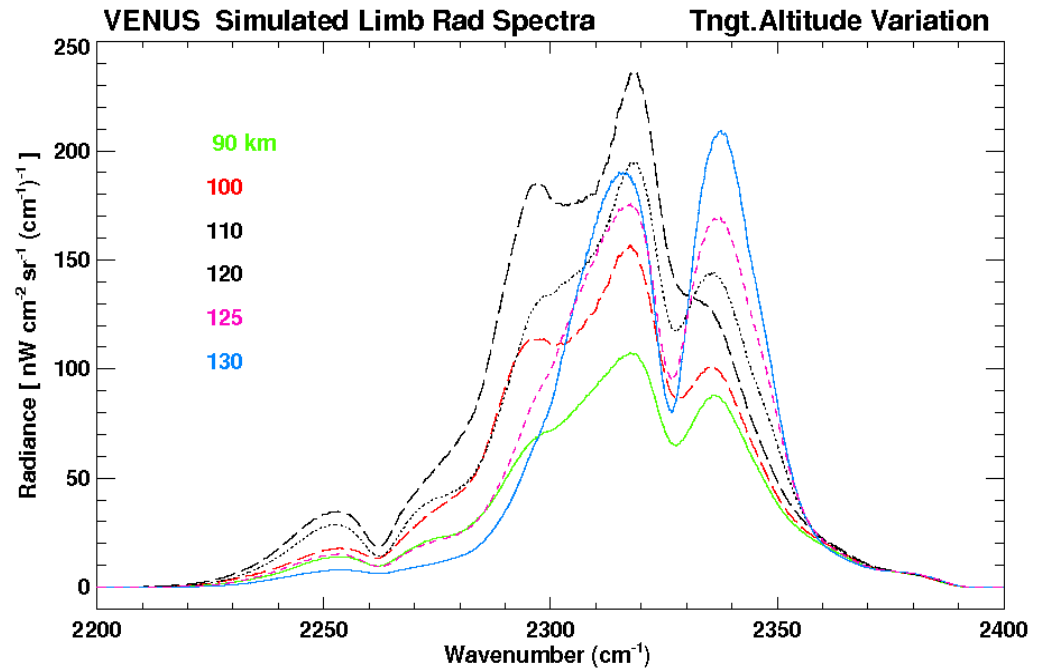


Emissions at 4.3 μm

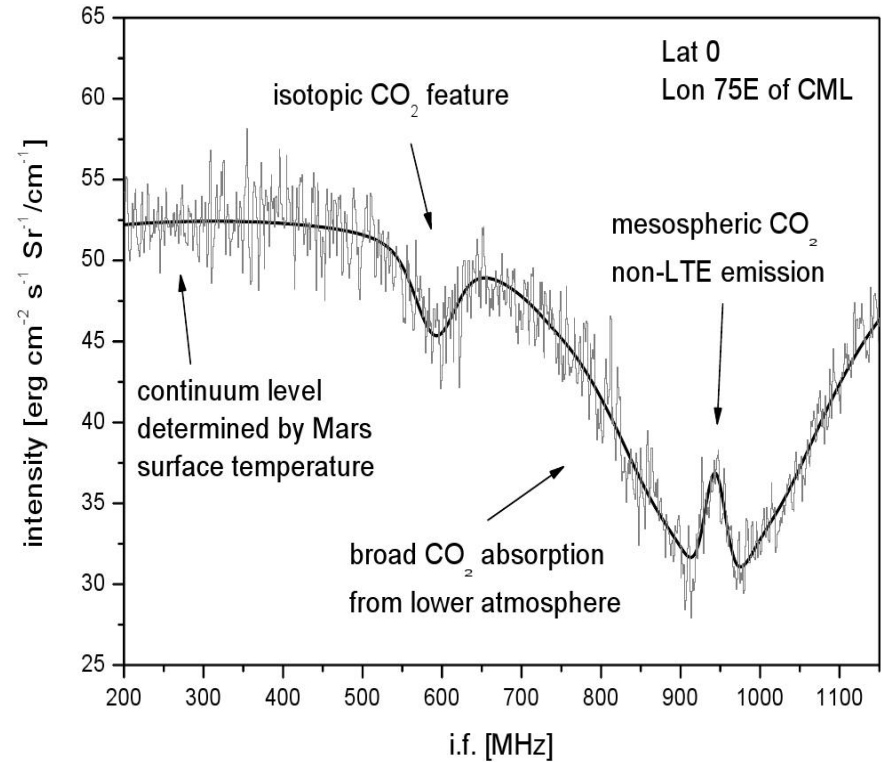
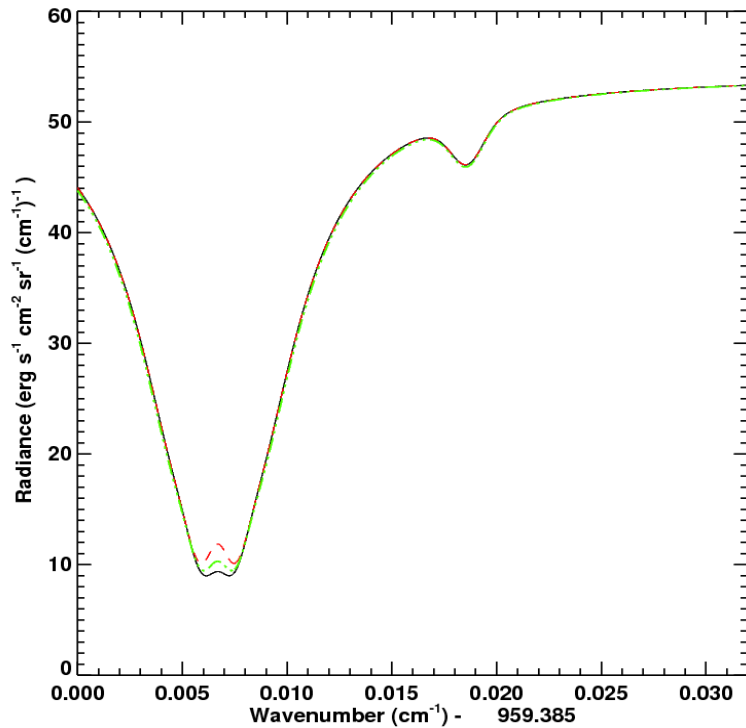
MARS



VENUS

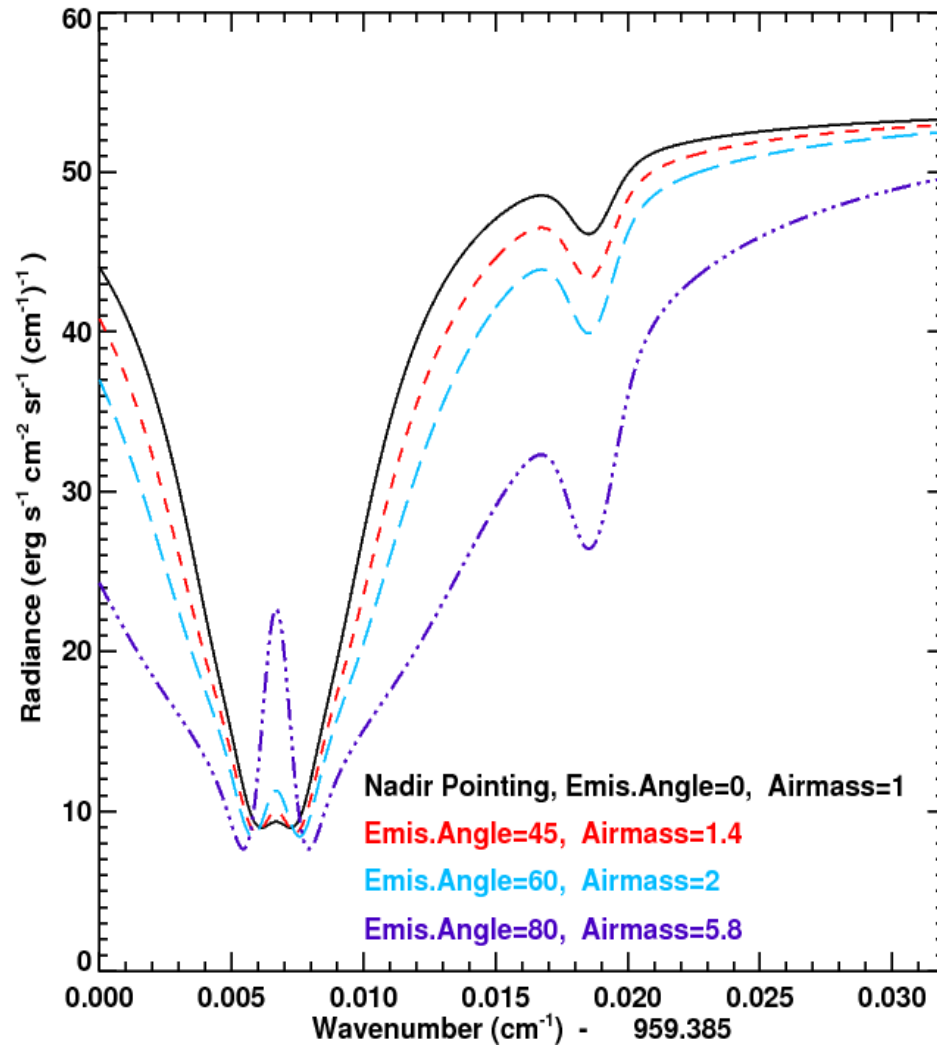


First try at Mars ...



Even fine-tuning non-thermal collisional parameters for maximum excitation

Seond try ... with larger emission angle!



Much better agreement because larger emission → Careful pointing

Further analysis : Altitude of emission

VENUS

Venus Nadir CO₂ 10um 626-FB P12 (1053.9235 cm⁻¹) Emission altitude

SZA,EA = 00,85

Altitudes: 70,74,78,...., 146,150, 200

LBL Spectral Res: 0.00005

Rad.Units: (erg s⁻¹ cm⁻² sr⁻¹ cm)

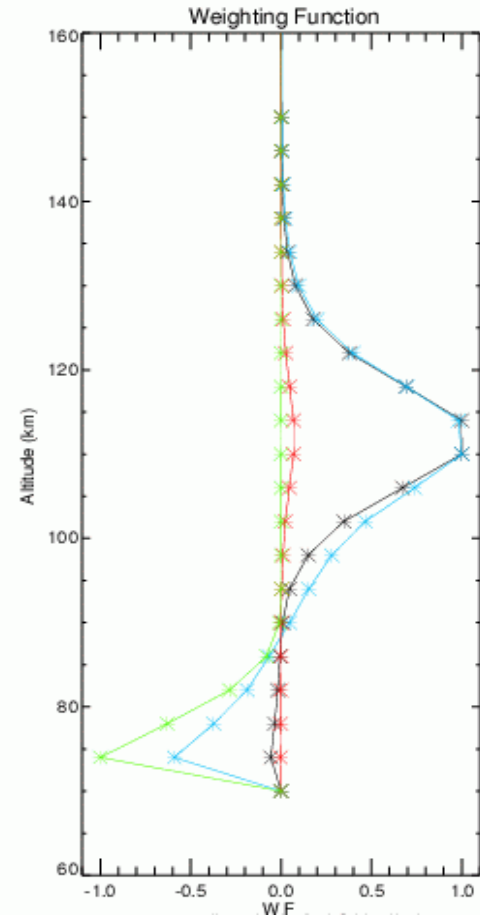
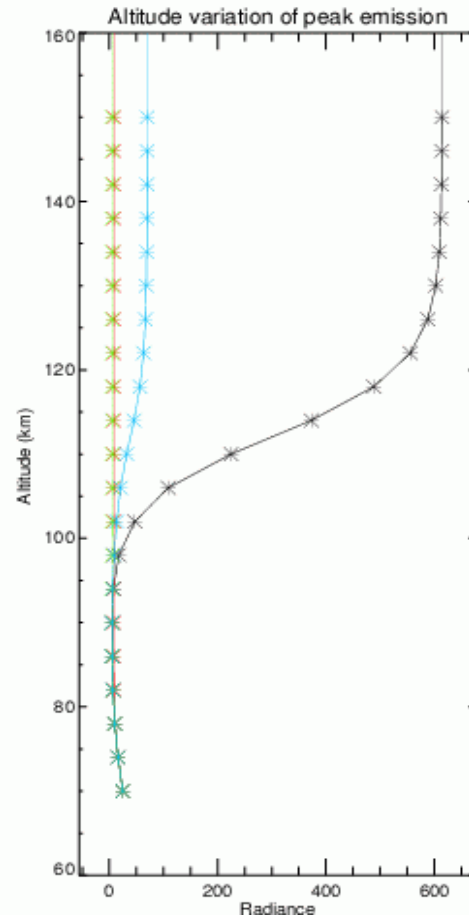
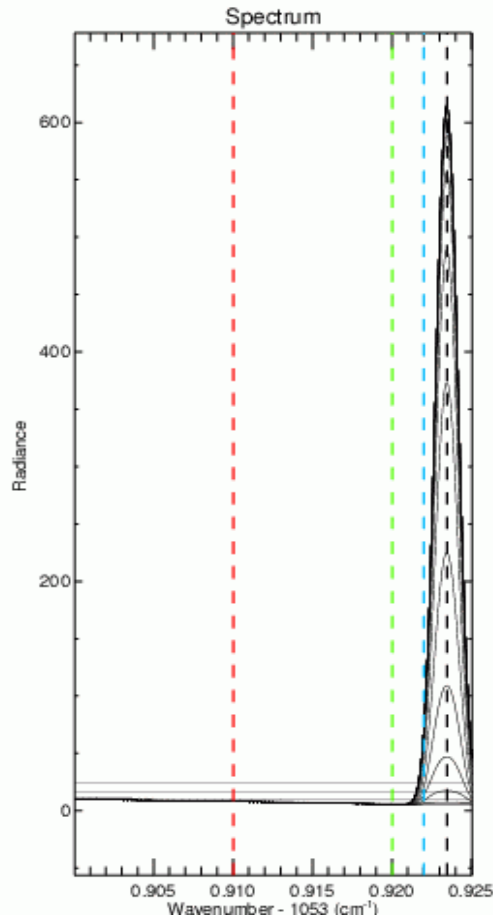
Interval: [1051,1056] cm⁻¹

All CO₂ Bands Isotopes: 626,636,628,627

Ref.Atmosphere: daytime

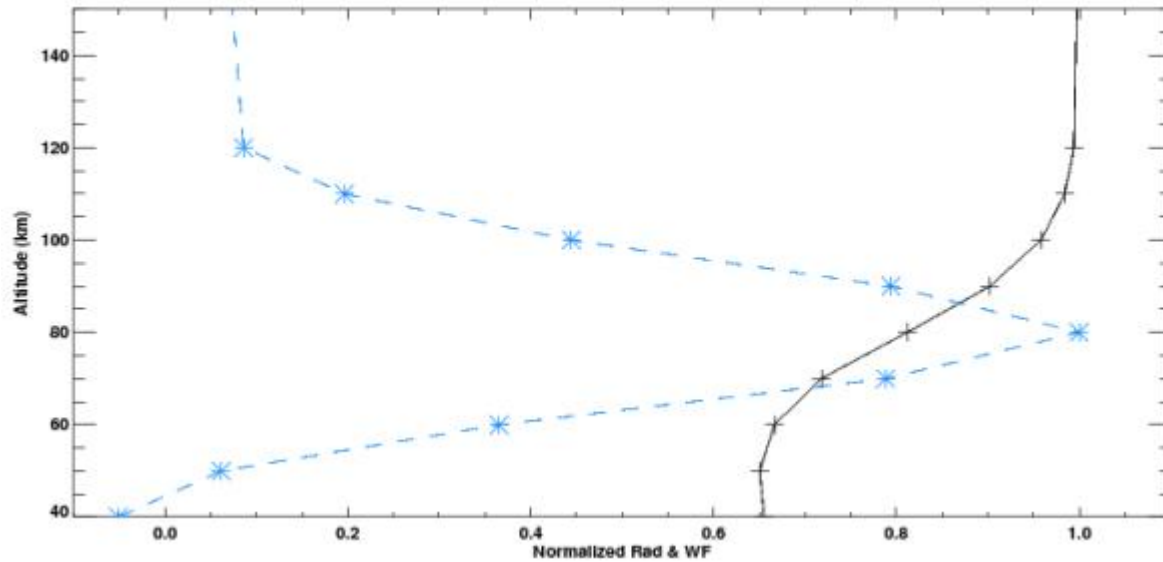
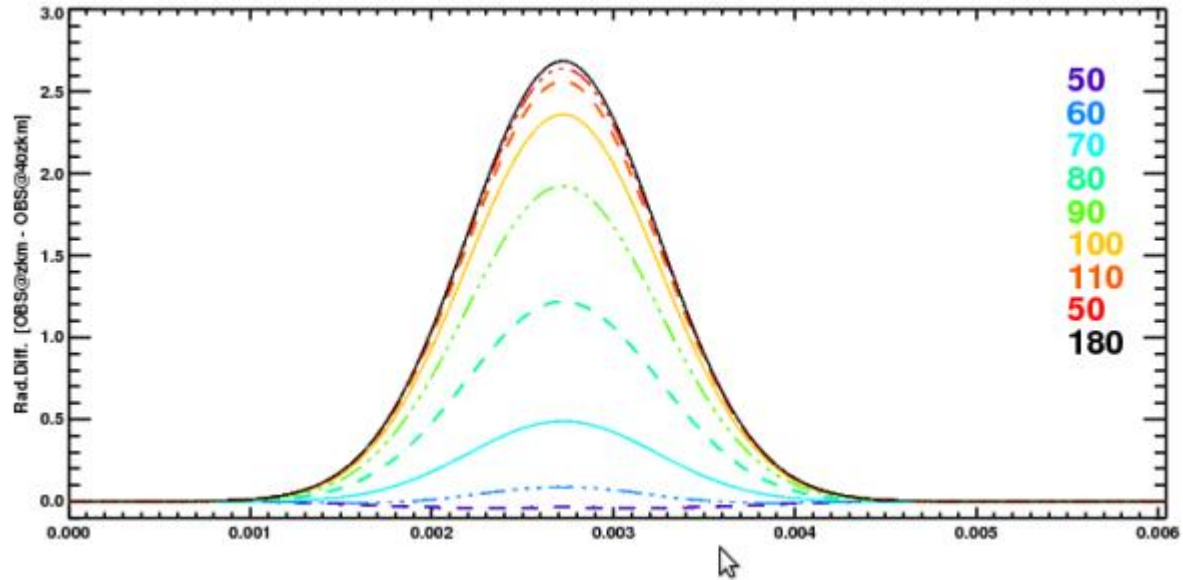
[60-200] km

T(clouds top)=180 K



Further analysis : Altitude of emission

MARS



Perturbation study

Change of 1 K at each altitude

Selected strong line, P6
Maximum SZA & EA

Venus

Peak emission 110 km

Rad Change : 1.3 %

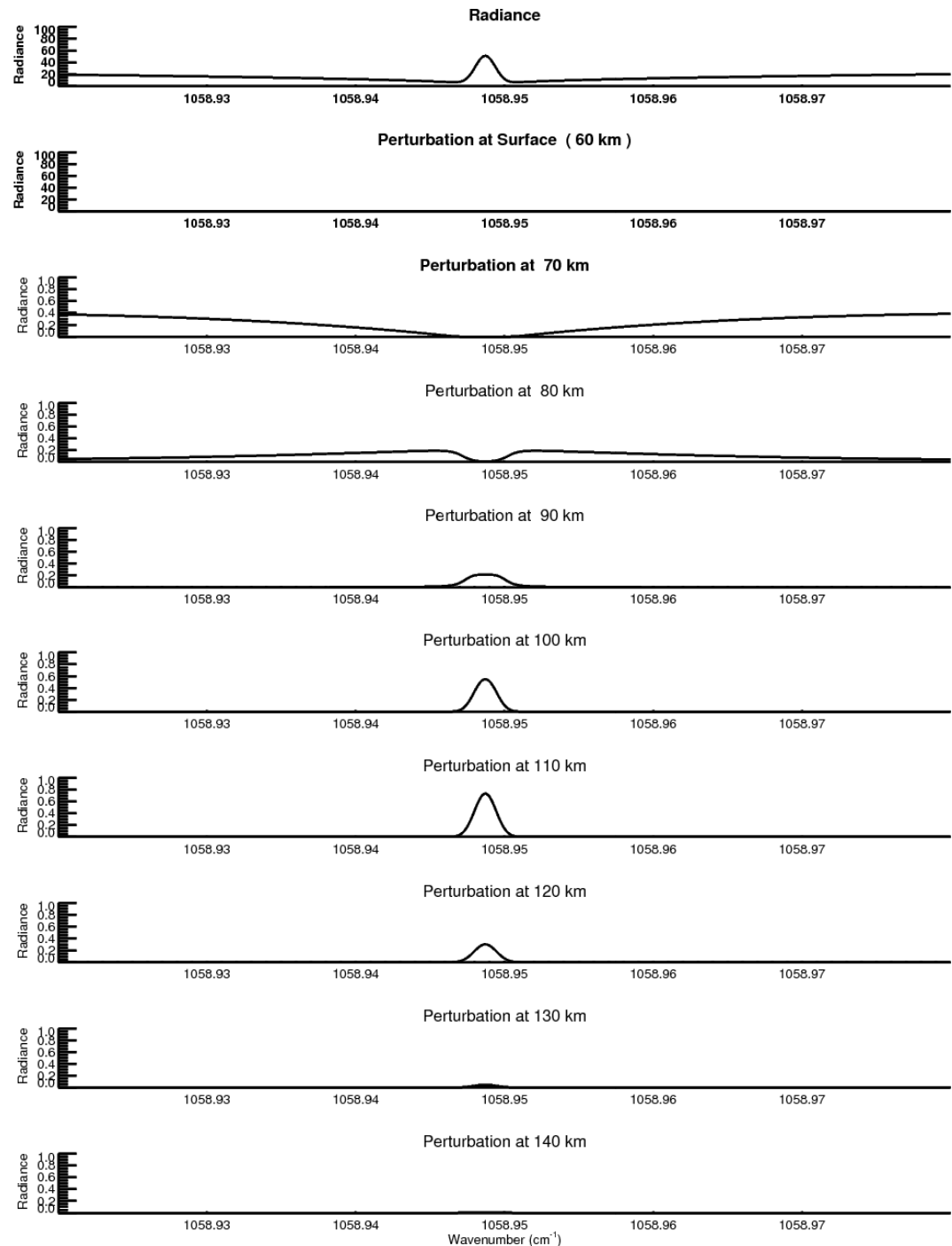
Noise level?

5 % radiance \rightarrow 3 K sensitivity

Ratio of line intensities

P6 & P44

Ratio's Change : 0.1%



Perturbation study

Change of 1 K at each altitude

Selected strong line, P6
Maximum SZA & EA

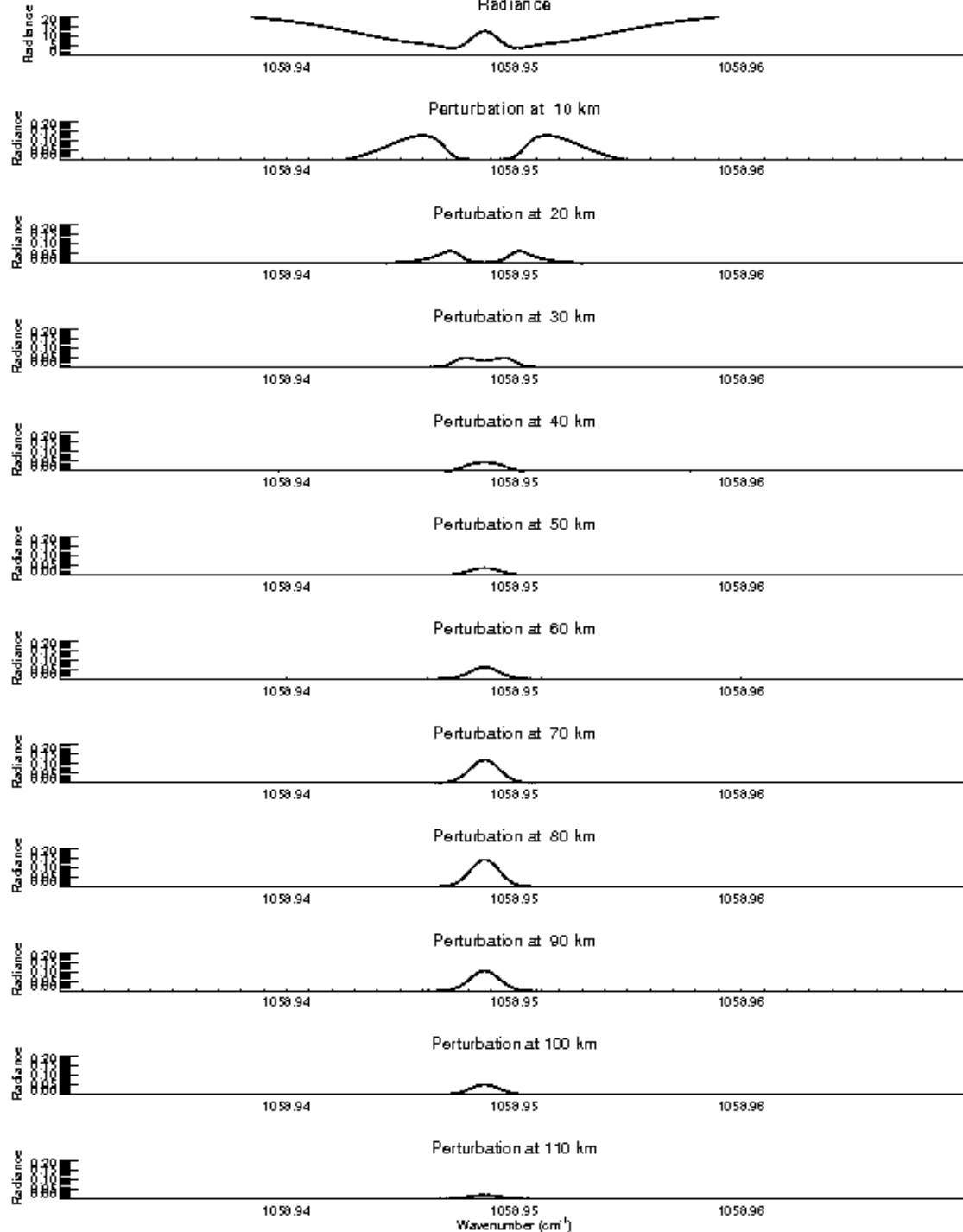
MARS

Peak emission 80 km

Rad Change : 0.77 %

Noise level?

5 % radiance \rightarrow 6.5 K sensitiv



Density perturbations

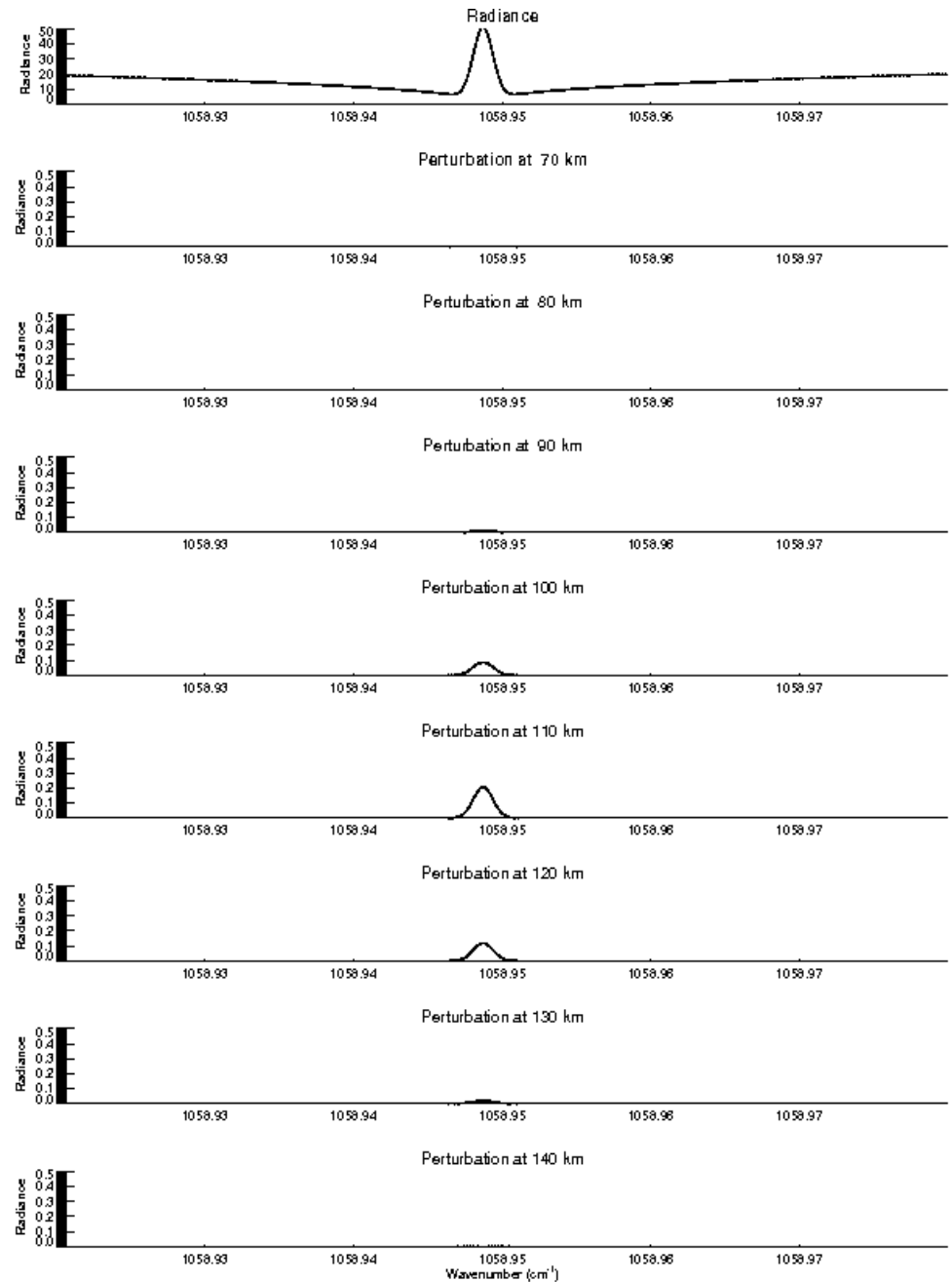
Important for possible density determinations ... not attempted so far

VMR 1% changes

Rad change obtained: 0.1 %
But increases to 0.24% with EA=80

Peak at 110 km (Venus)

Noise level 5% → Sensitive to changes of 50% VMR if EA=0
20% if EA=80



Summary

Simulations with a generic non-LTE model for CO₂ bands in Mars and Venus explain the laser emissions observed recently with heterodyne spectrographs at high spectral resolution on both planets without any special tuning.

The emissions are due to solar pumping of the (001) state at 4.3 μm and are stronger in Venus. This is due to a higher vibrational temperature of the (001) state, which is produced by a larger solar flux available on Venus.

The emissions are very dependent on the SZA, as expected, but also on the Emission Angle, with large variations when both are high. For a similar SZA, larger signals will be obtained near the planets' limb (high EA).

The emission in the line centers is originated in a distinct emission layer in the upper mesosphere of both planets, with a peak around 80 km on Mars and 110 km on Venus (1 microbar).

Our sensitivity study can evaluate the error in radiance units associated to changes in temperature and density at every altitude of the peak emission layer.

We suggest to use this emission not only for temperature and wind determinations but also for density mapping at the altitudes of the emission layer.

Study to be completed:

- Evaluate impact of non-LTE model uncertainties (collisional rates)
- Precise averages of beam-size on both planets near terminators (high SZA)
- Run for high EA to support campaigns near the limbs