Models of the Giant Planets

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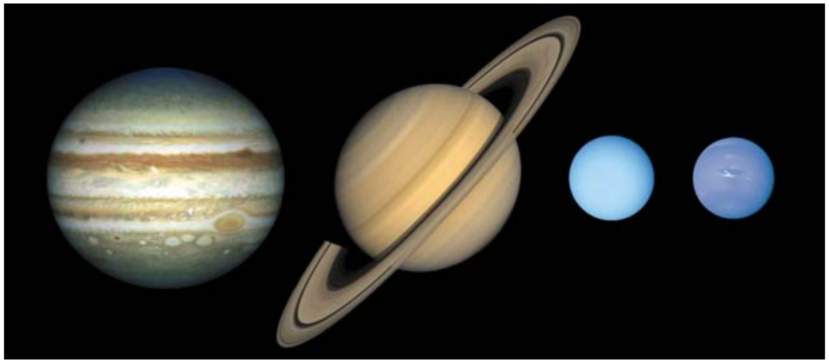


- Knowledge of giant planets
- Radiative transfer Modelling
- Giant planets submm spectrum and uncertainties

Thermal Structure of Giant Planets

•Thermal Profiles : P(T)

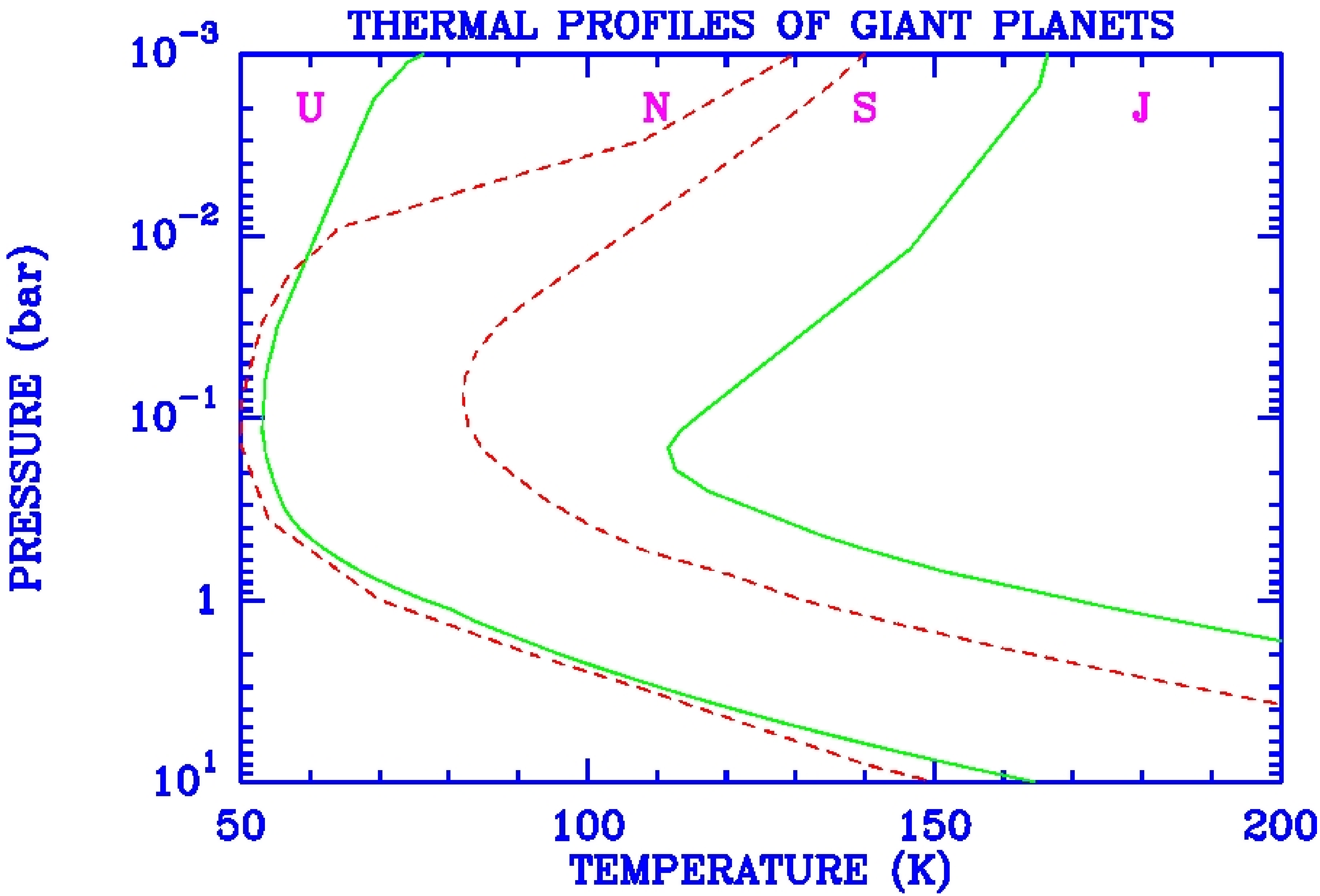
Troposphere : From Voyager radio-occultation

Stratosphere : From IR continuum and Line

•Trospospheric Variations with latitudes:

$\Delta T/T < 2\%$

Thermal Profiles

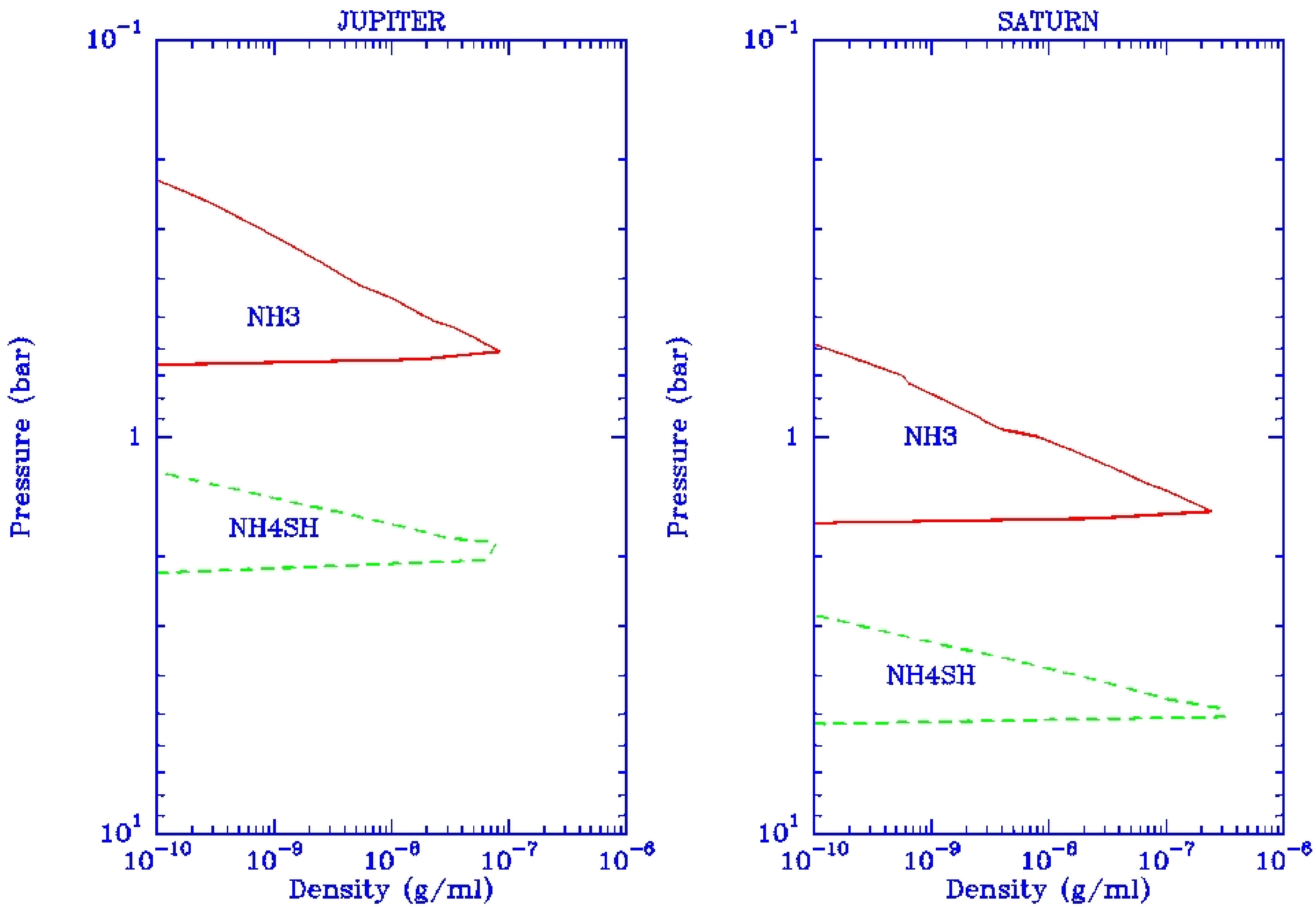


Composition of Giant Planets

- Major species H_2 H_e
- Minor species CH_4 NH_3 PH_3 H_2S

- Cloud Chemistry: $NH_3(g) + H_2S(g) \leftrightarrow NH_4SH(s)$

Jupiter and Saturn Clouds

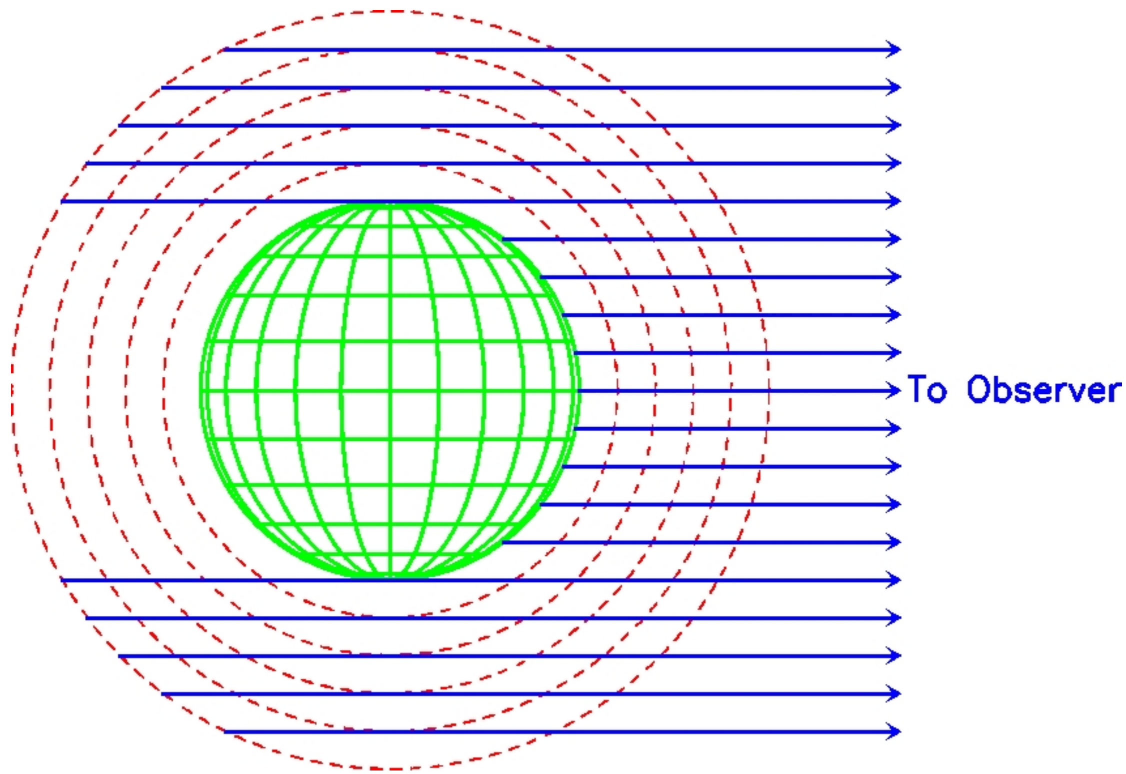


Modelling

- Radiative Transfert

$$J_{tot}(\nu) = J_S(\nu)\exp^{-\tau_m} + \int^{\tau_m} S(\nu)\ \exp^{-\tau}\ d\tau$$

- Spherical geometry



Modelling (II)

- Collision induced opacity : H_2- H_2; H_2- H_e ; H_2- CH_4

(Birnbaum 1996, Borysow and Frommhold 1986)

See A.Borissow web page

- Molecular Opacity : NH_3 ; CH_4 , CO, H_2O

-- Absorption Coefficient (JPL Catalog)

-- Pressure broadening coefficient

-- Lineshape: Ben-Reuven, Van-Vleck & Weisskopf,

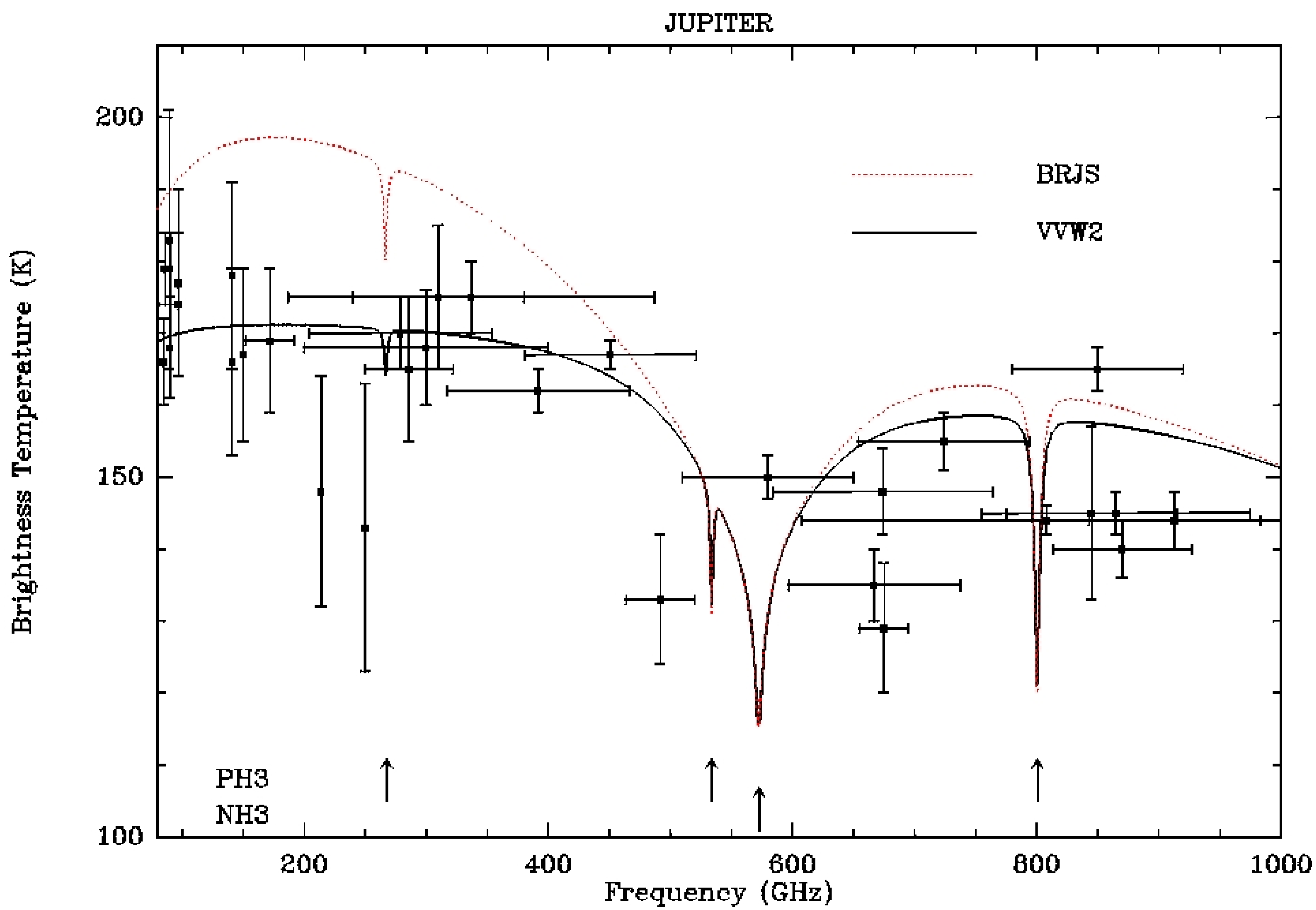
Lorentz, Voigt, Doppler

Modelling (III)

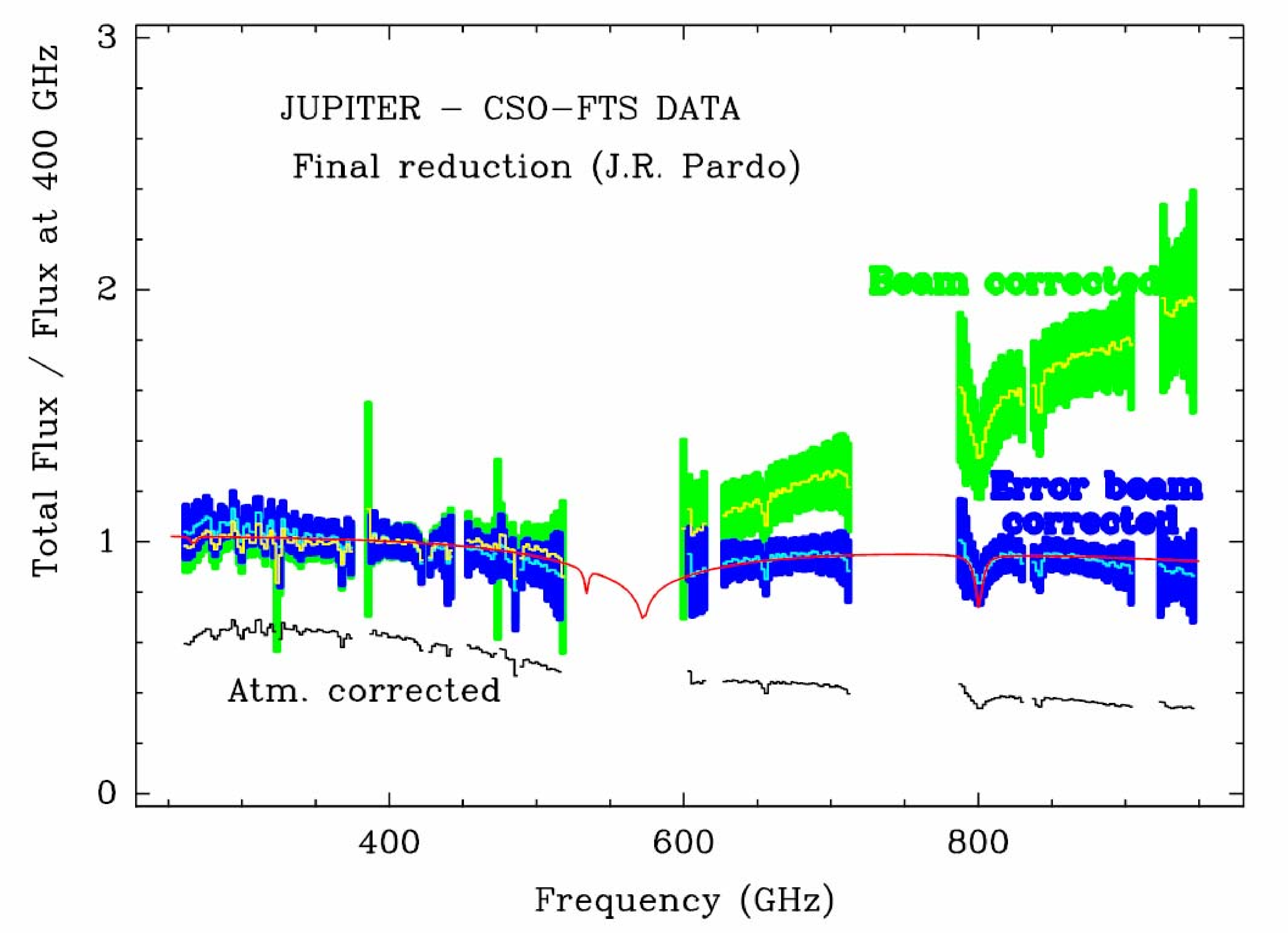
Physical parameters Inputs :

- Thermal Structure
- He/H_2
- Vertical distribution of minor species

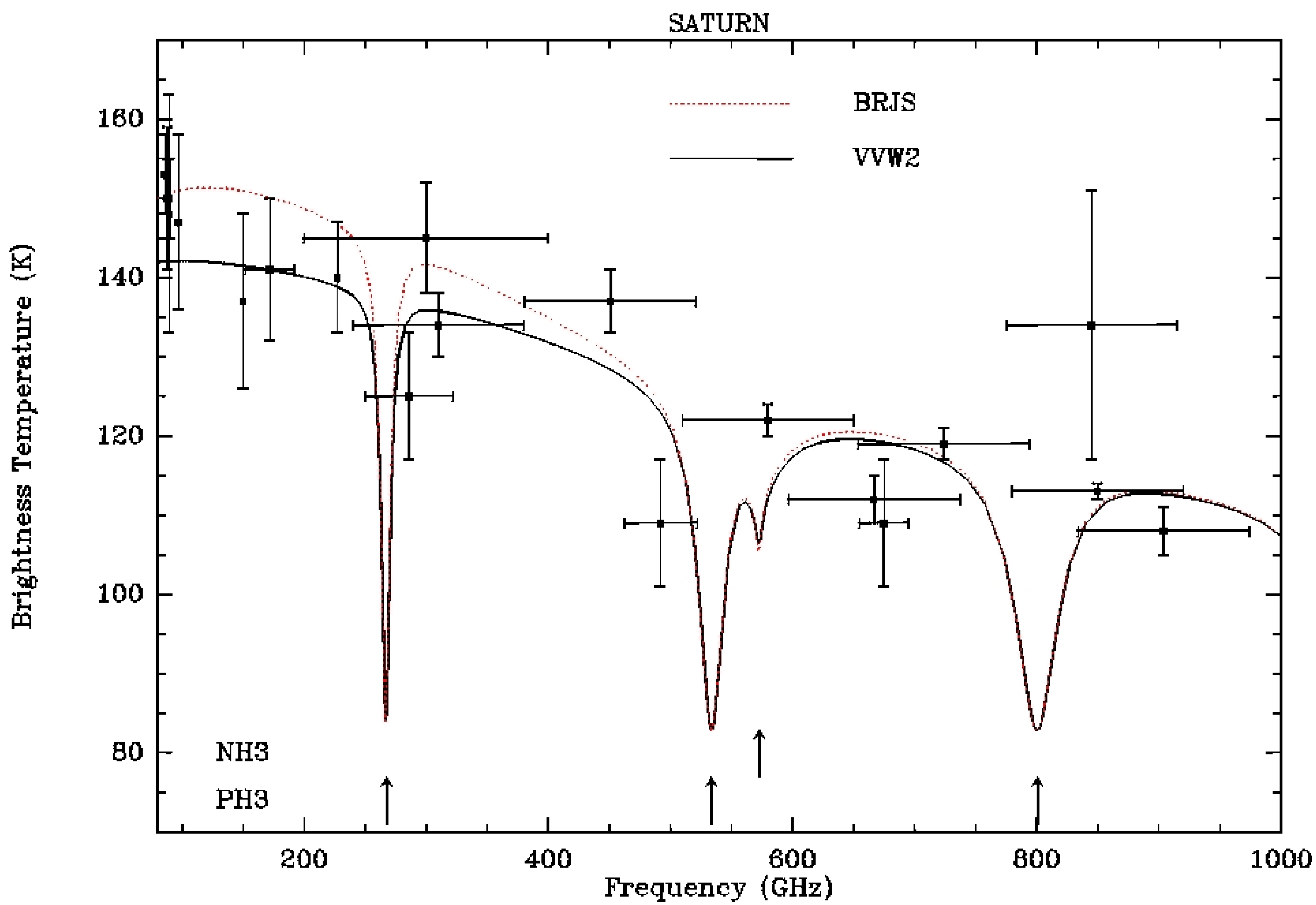
Jupiter mm spectrum



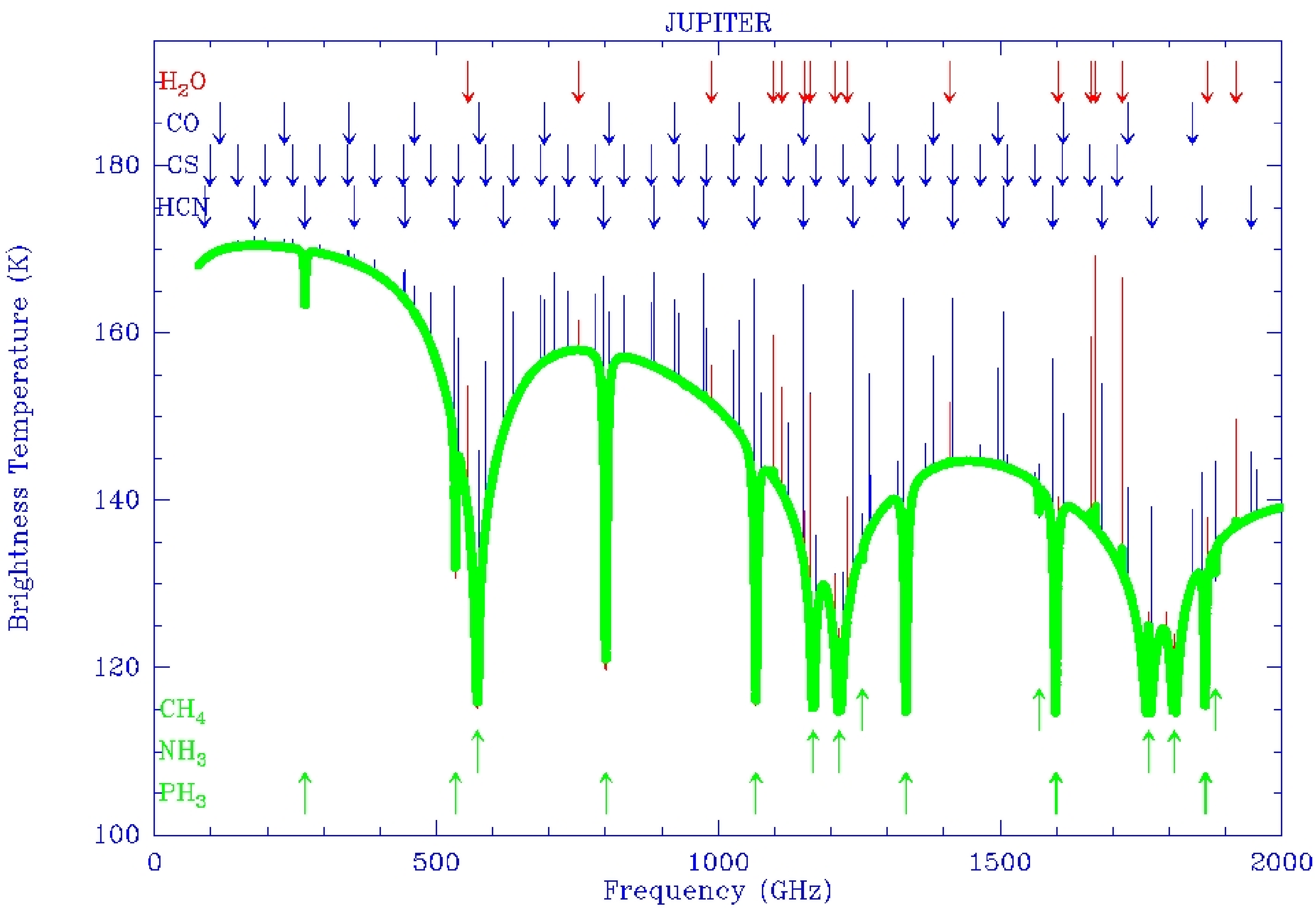
Model comparison with CSO data (<10%)



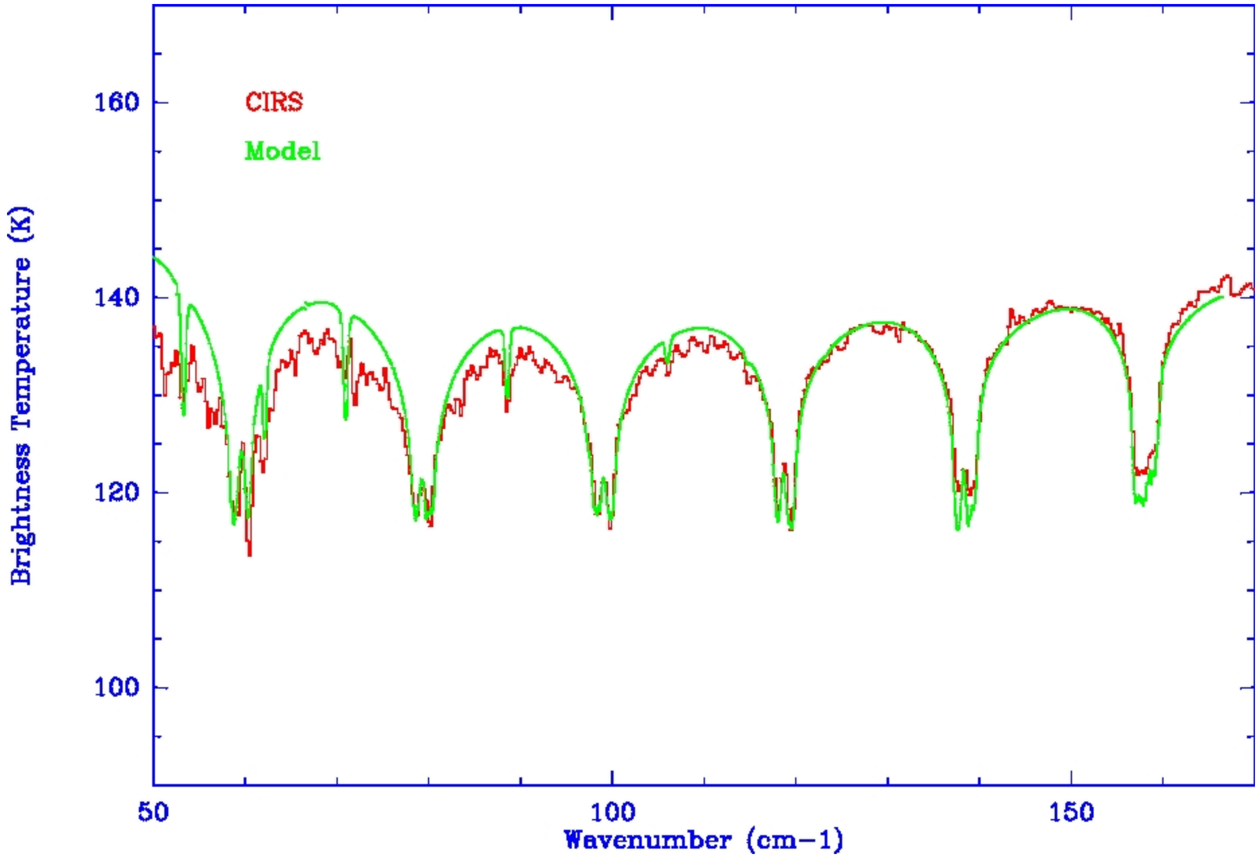
Saturn mm spectrum



Jupiter submm spectrum



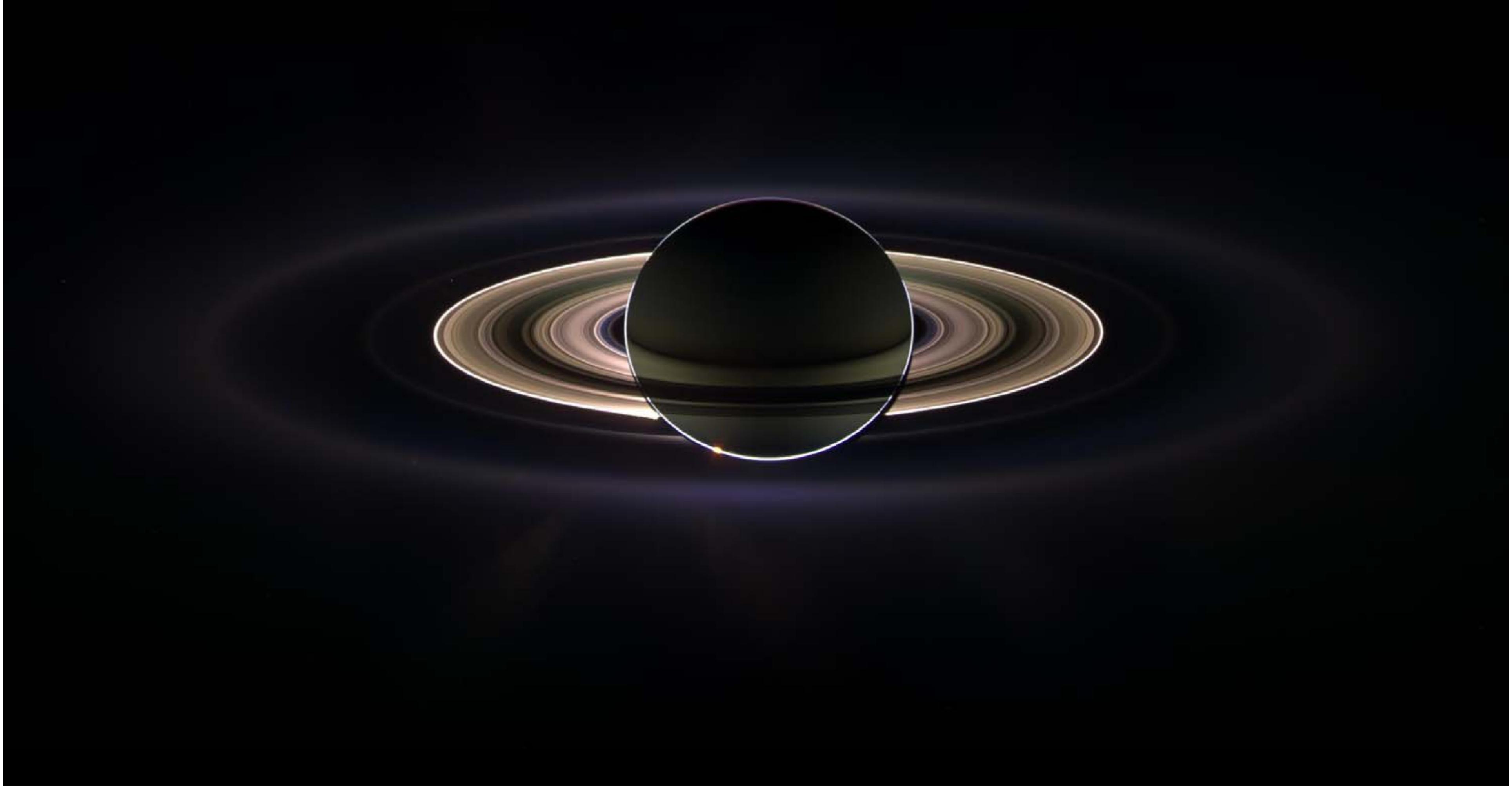
CIRS spectrum of Jupiter

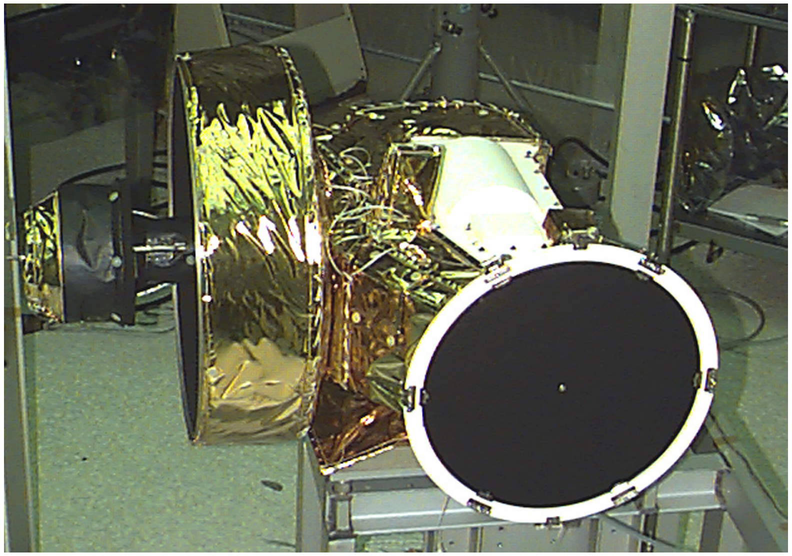


➔Improvement of Jupiter spectrum in the submm/FIR

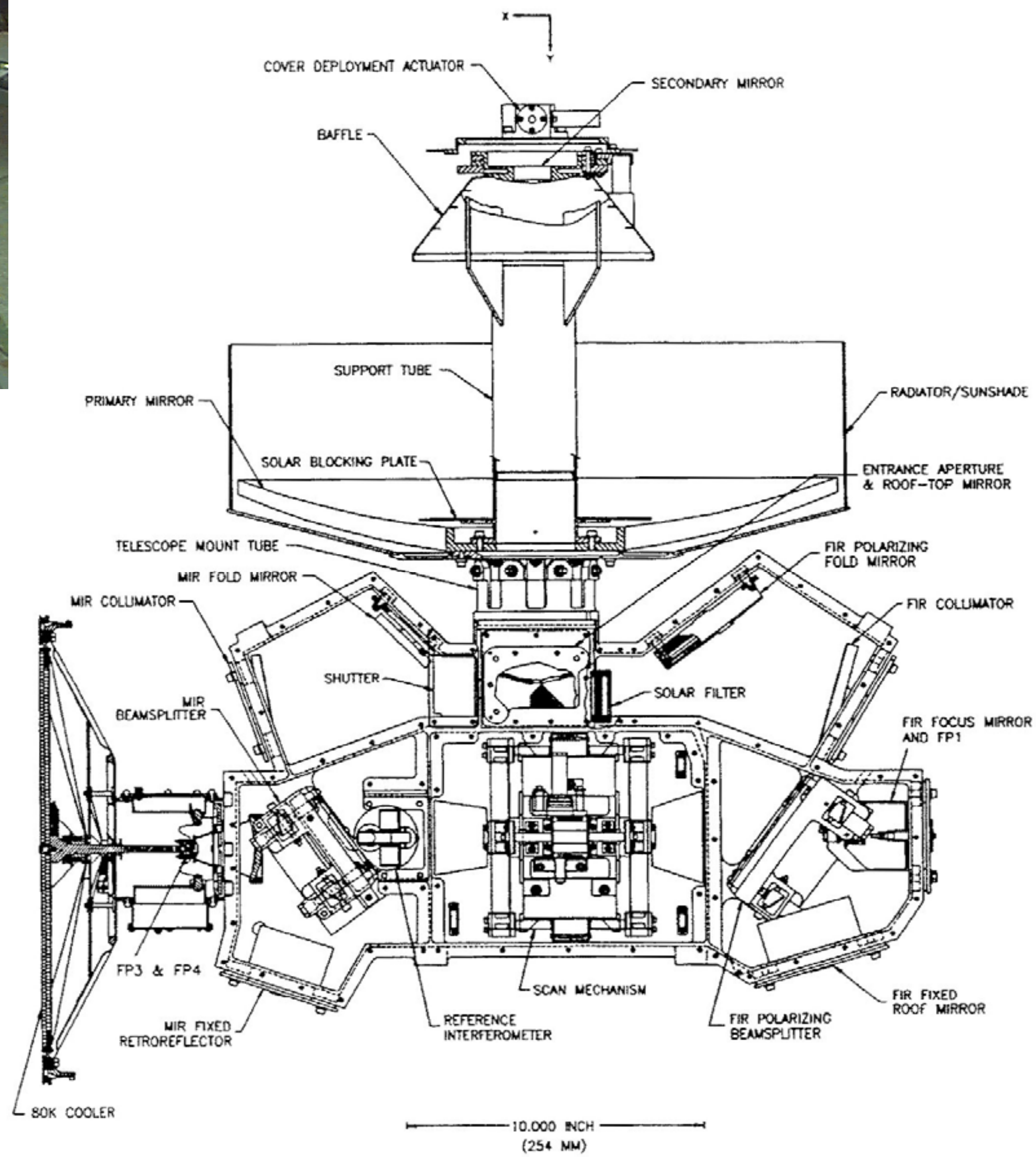
Saturn :
Constrains from Cassini/CIRS data

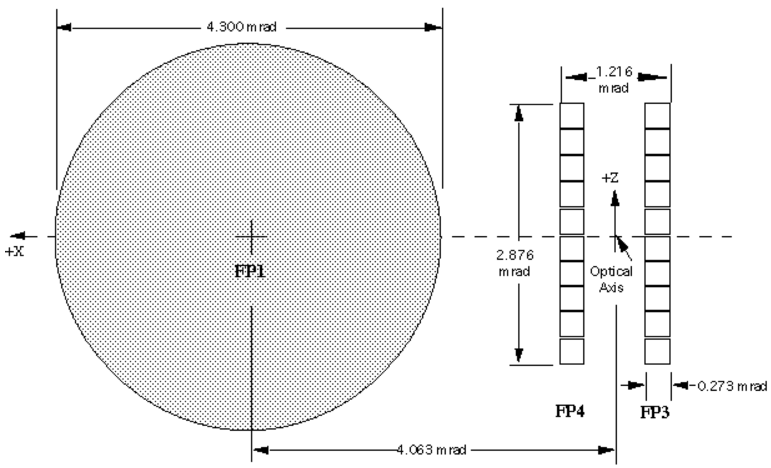
Régis Courtin and Raphaël Moreno



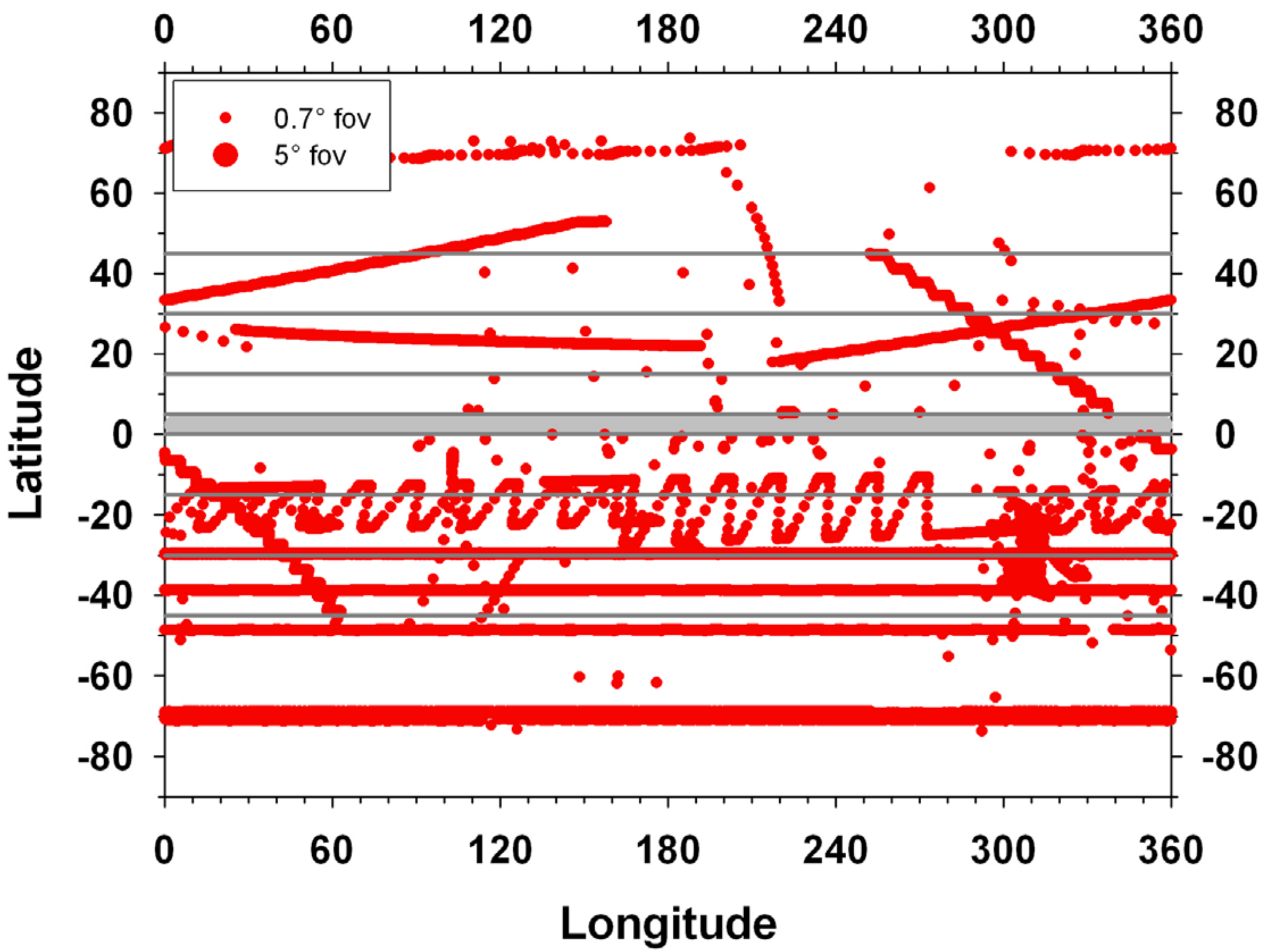


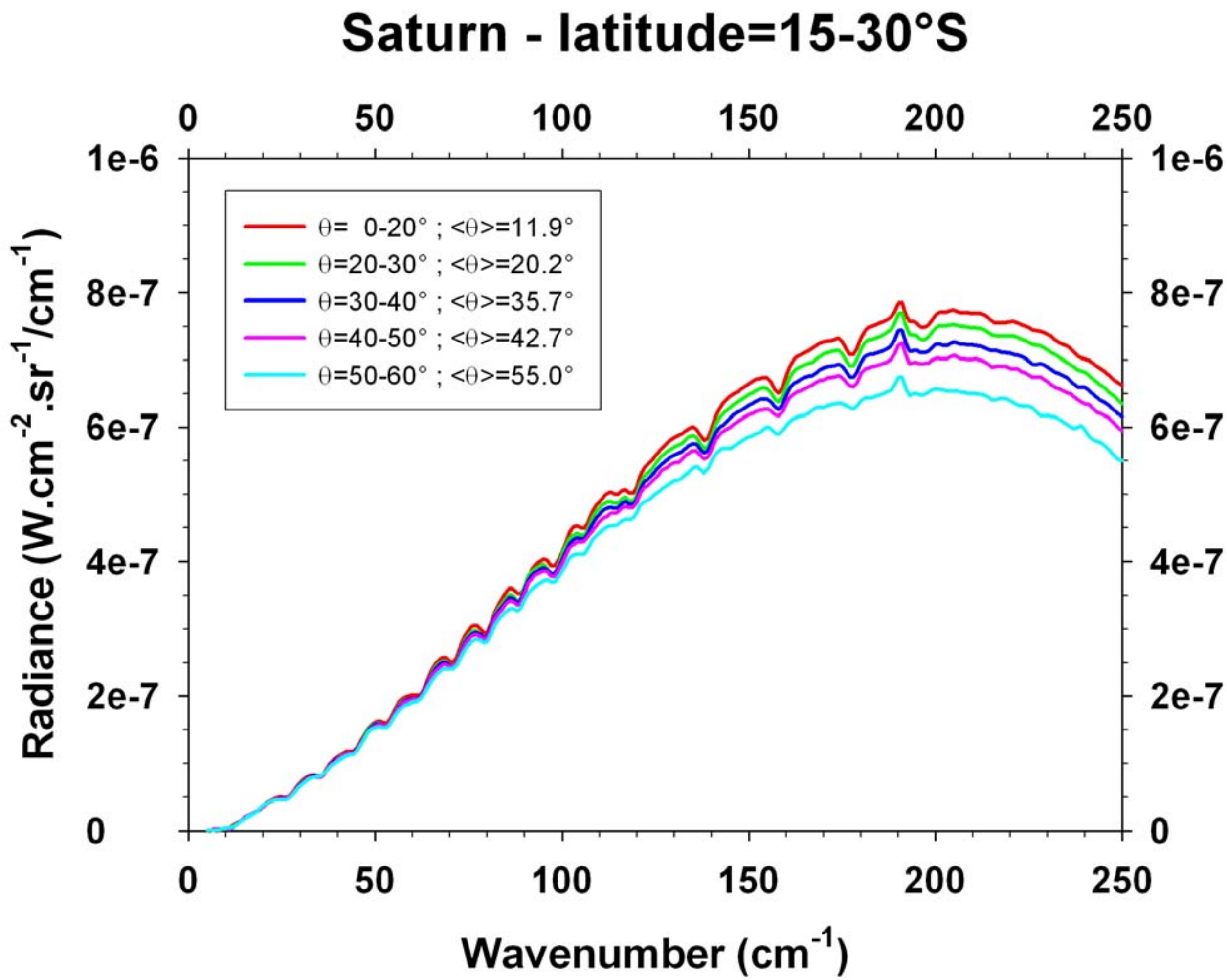
CIRS: FTS 10-1400 cm-1 (1000-7 μm)





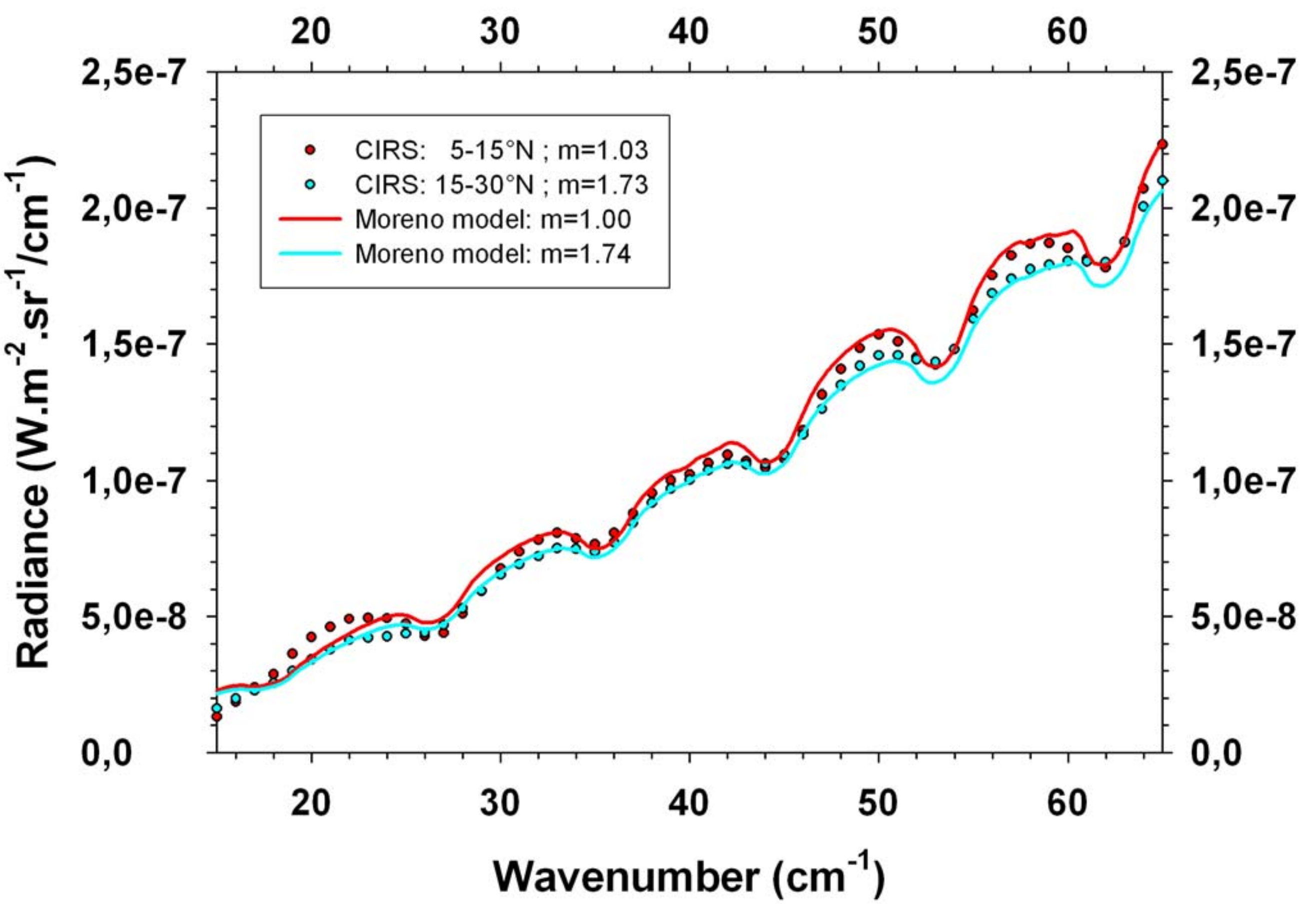
Saturn nadir-mode observations (jan.-june 2005)

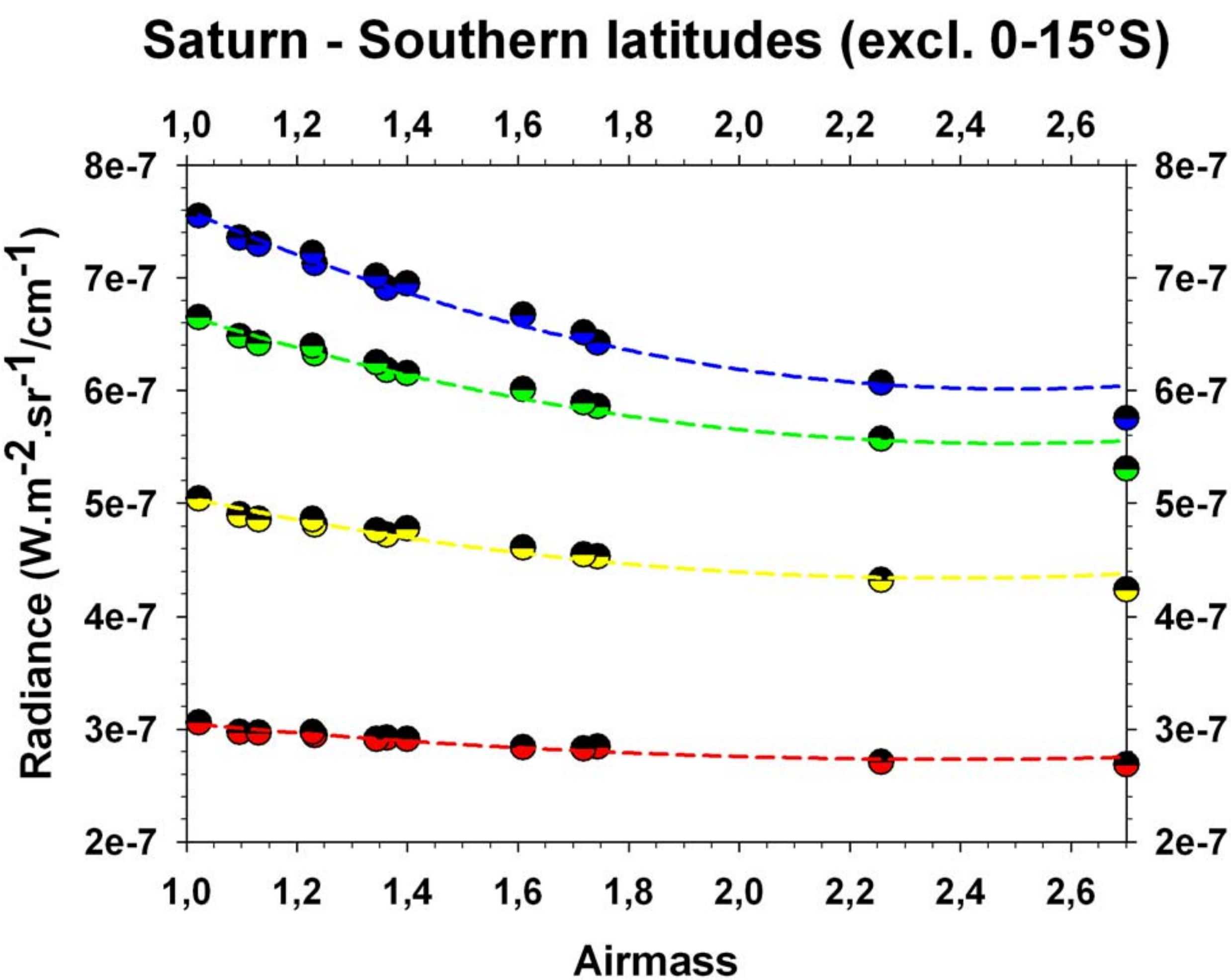




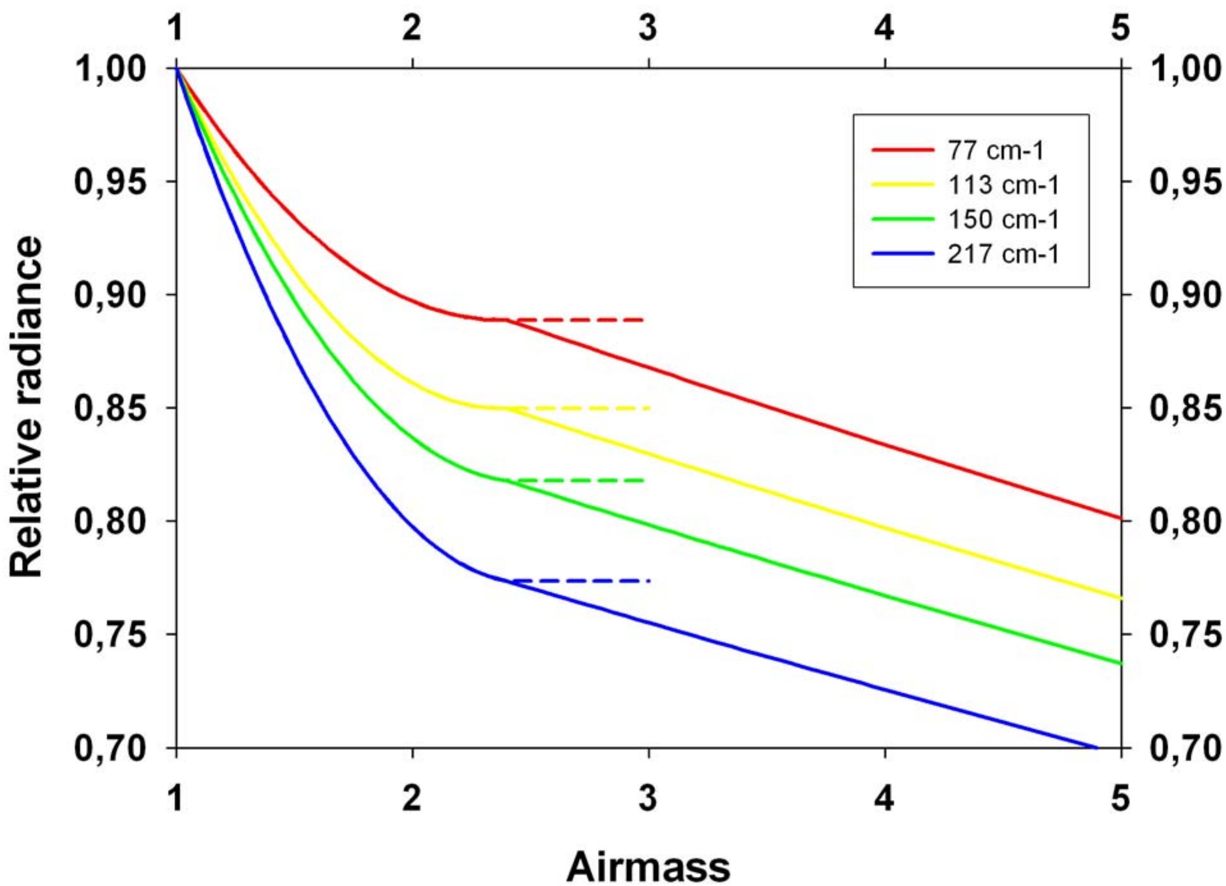
Saturn - latitude=15-30°S
θ= 0-20° ; <θ>=11.9°
θ=20-30° ; <θ>=20.2°
θ=30-40° ; <θ>=35.7°
θ=40-50° ; <θ>=42.7°
θ=50-60° ; <θ>=55.0°
Radiance (W.cm-2.sr-1/cm-1)
Wavenumber (cm-1)
0
50
100
150
200
250
0
2e-7
4e-7
6e-7
8e-7
1e-6

Comparison with synthetic spectrum based on Voyager results

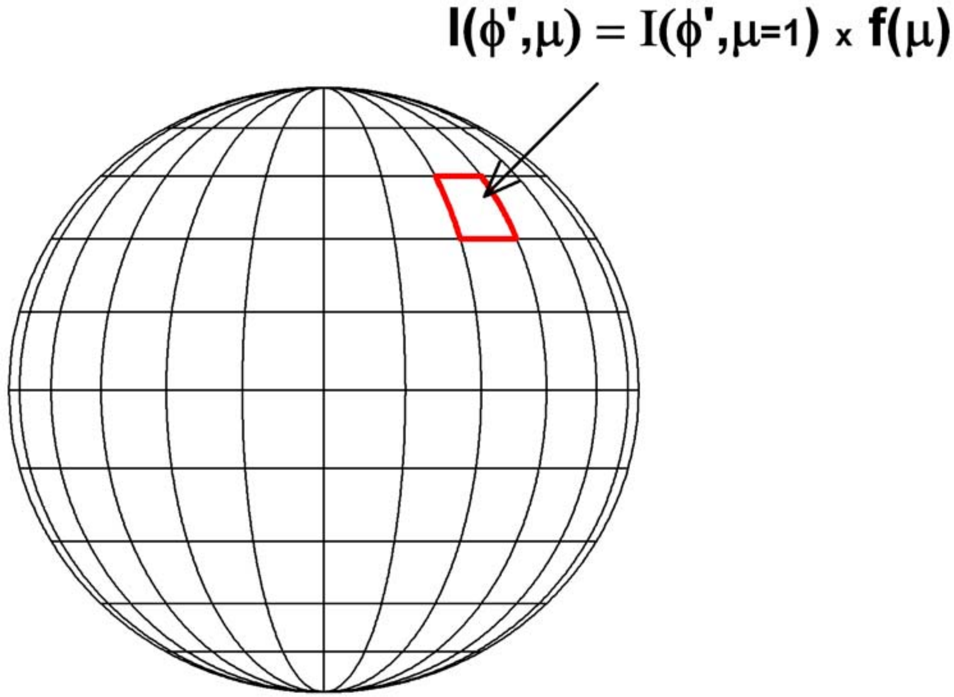



Saturn - Southern latitudes (excl. 0-15°S)
1,0
1,2
1,4
1,6
1,8
2,0
2,2
2,4
2,6
8e-7
7e-7
6e-7
5e-7
4e-7
3e-7
2e-7
Radiance (W.m-2.sr-1/cm-1)
Airmass

Model fit to observed center-to-limb variation



Full-disk radiance integration
(without rings!)



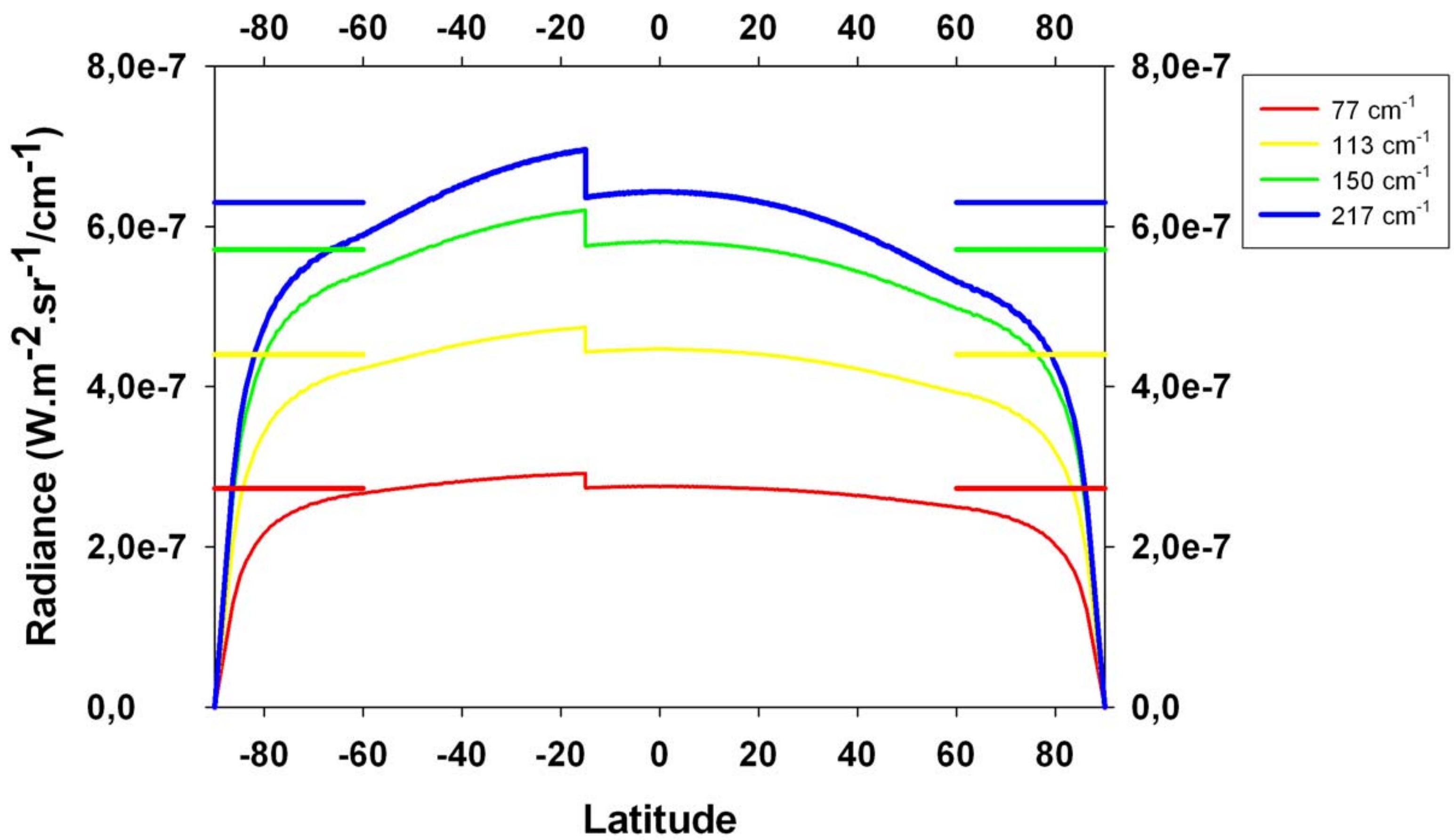
$$\mu = 1/m = \cos(\theta) = \cos(\phi')\cos(\psi')$$

with $\phi' = \phi - B$ and $\psi' = |\psi - \psi_{CM}|$

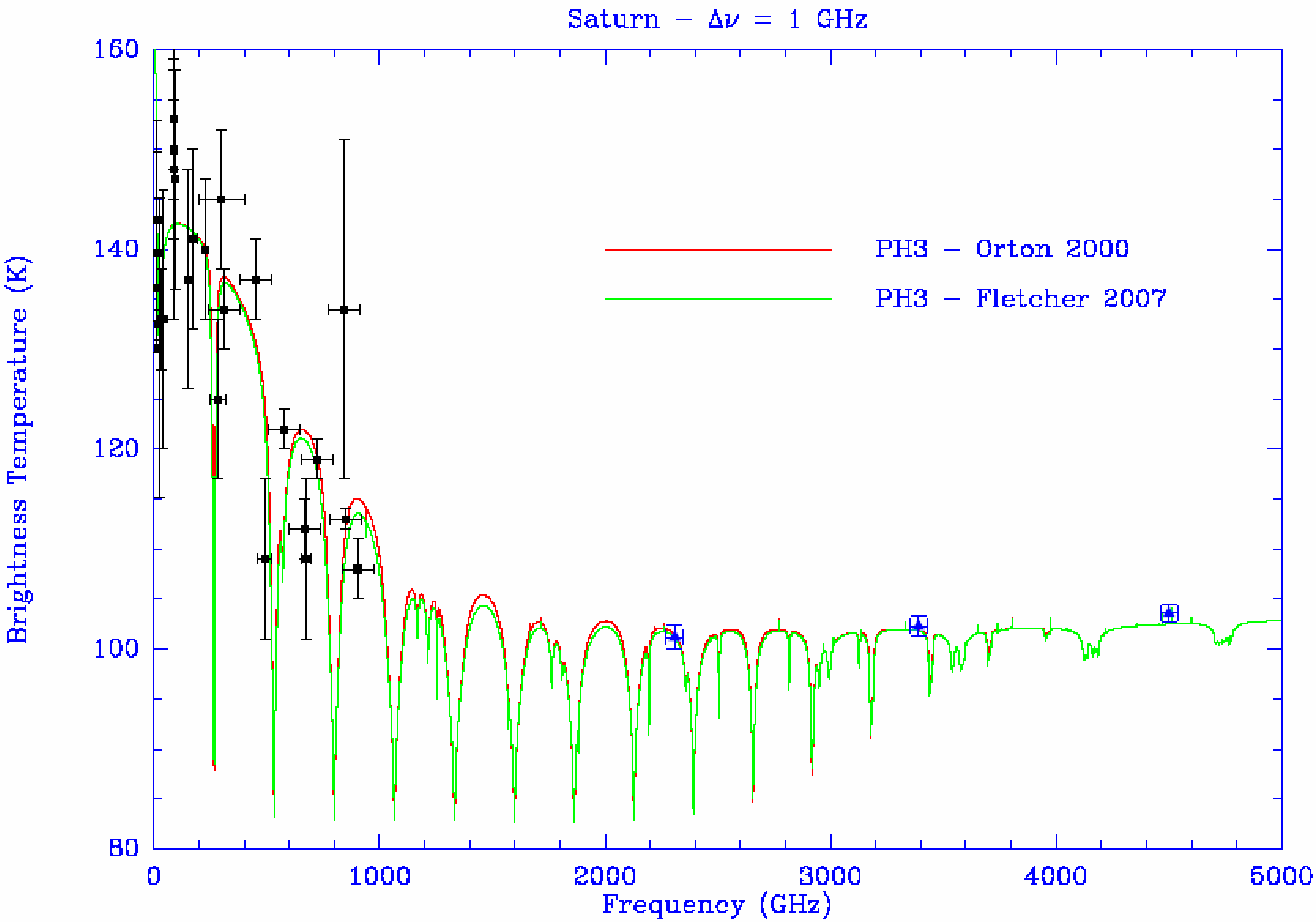
ϕ=latitude ; B: Saturnicentric latitude of the Earth

ψ=longitude ; ψ_{CM}=longitude of Central Meridian

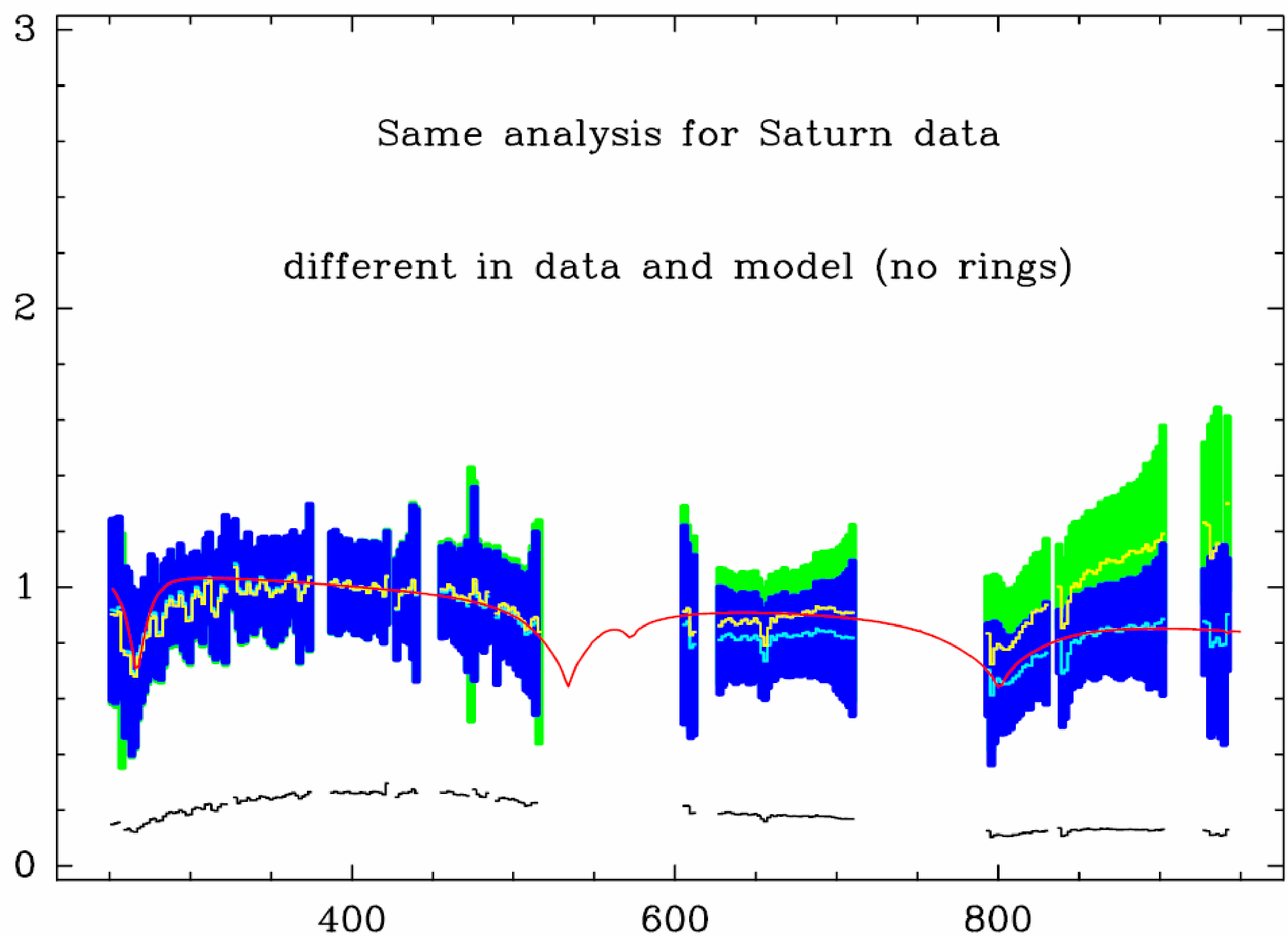
Results: disk profiles and full-disk radiances



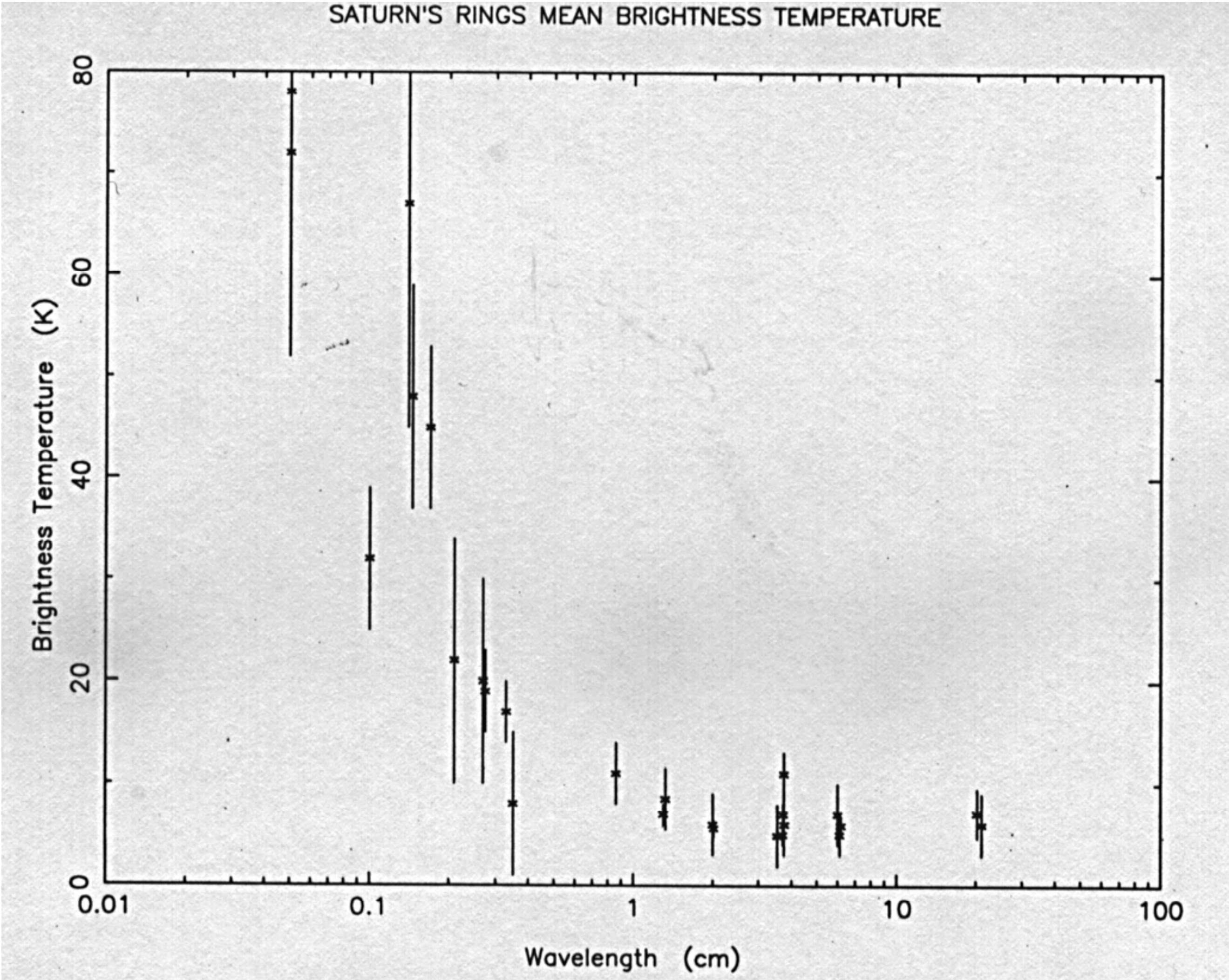
Saturn mm-submm Spectrum



Comparison with CSO data (<5%)

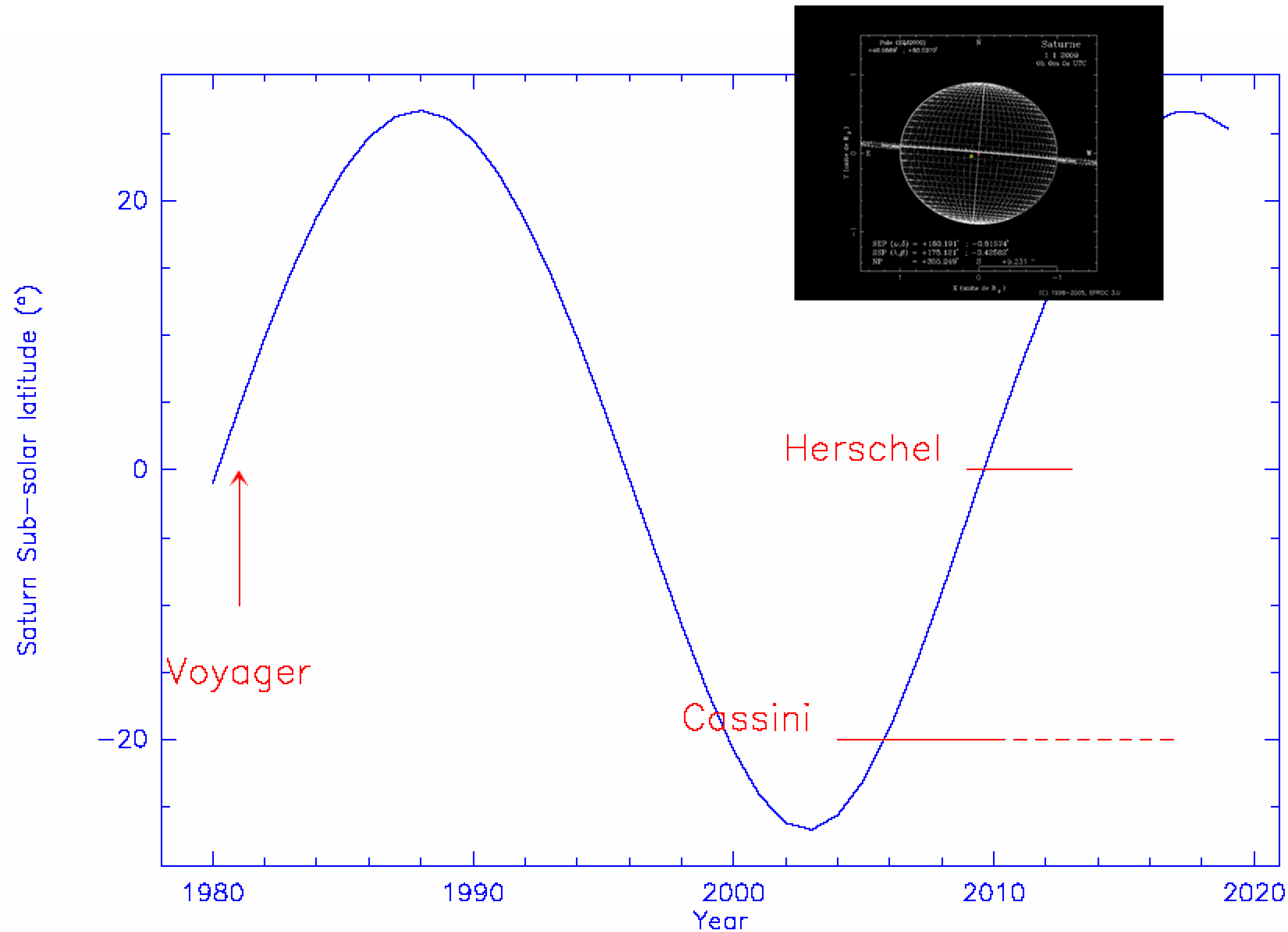


Saturn's ring brightness in the submm



From De Pater 89

Saturn's ring visibility

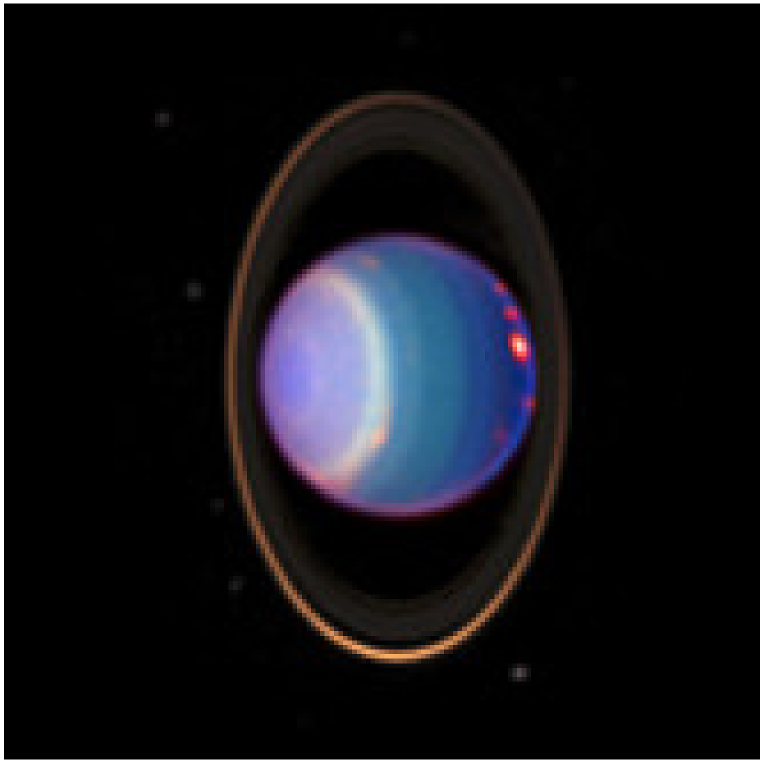


Saturn Summary

- CIRS measurements : absolute accuracy < 2%
- FIR Simulated spectra within uncertainties
- Submm model uncertainty : composition 1-2%

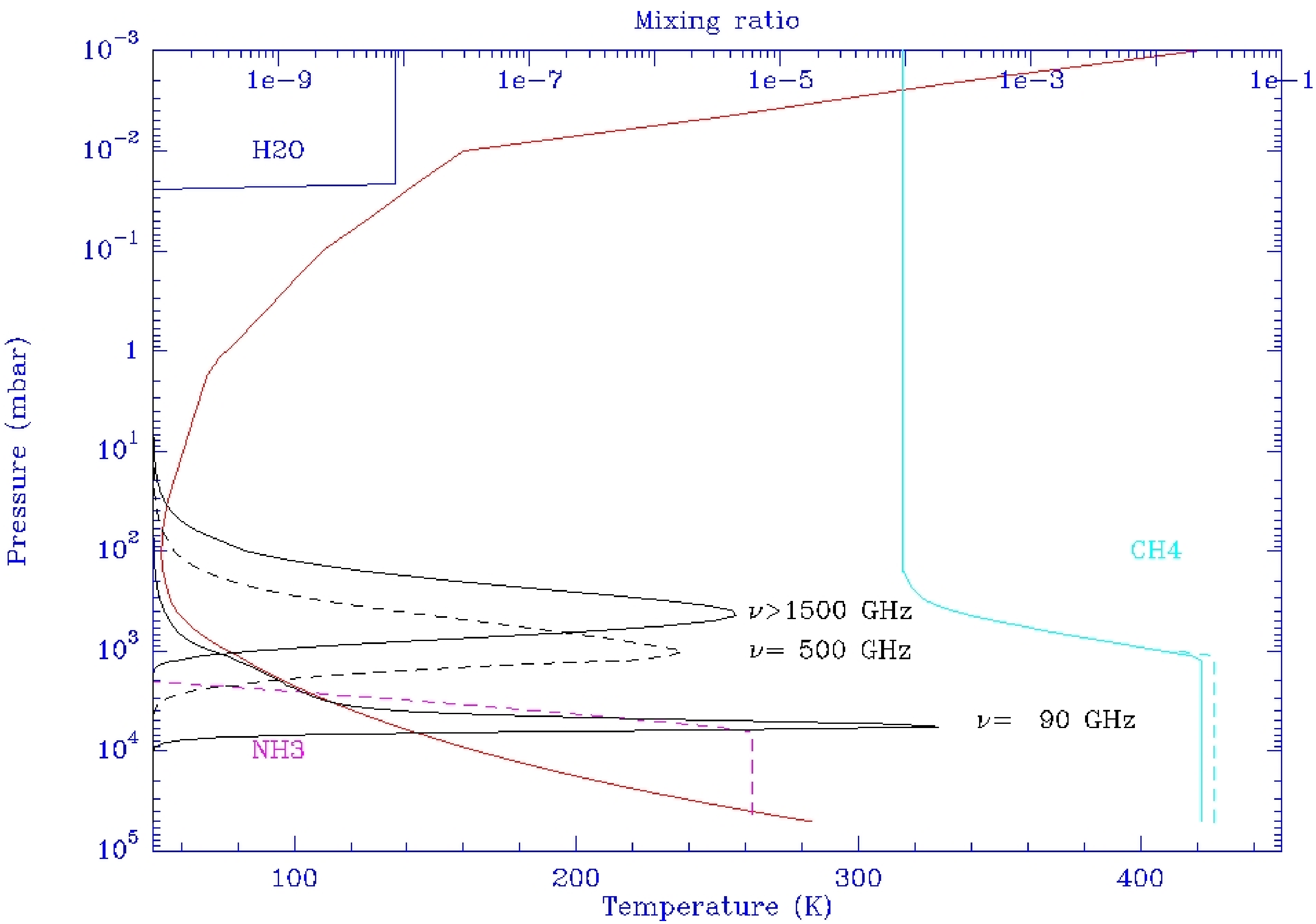
- in 2009 : small ring contributions to Saturn
- Sarturn is a very good absolute flux calibrator

Uranus

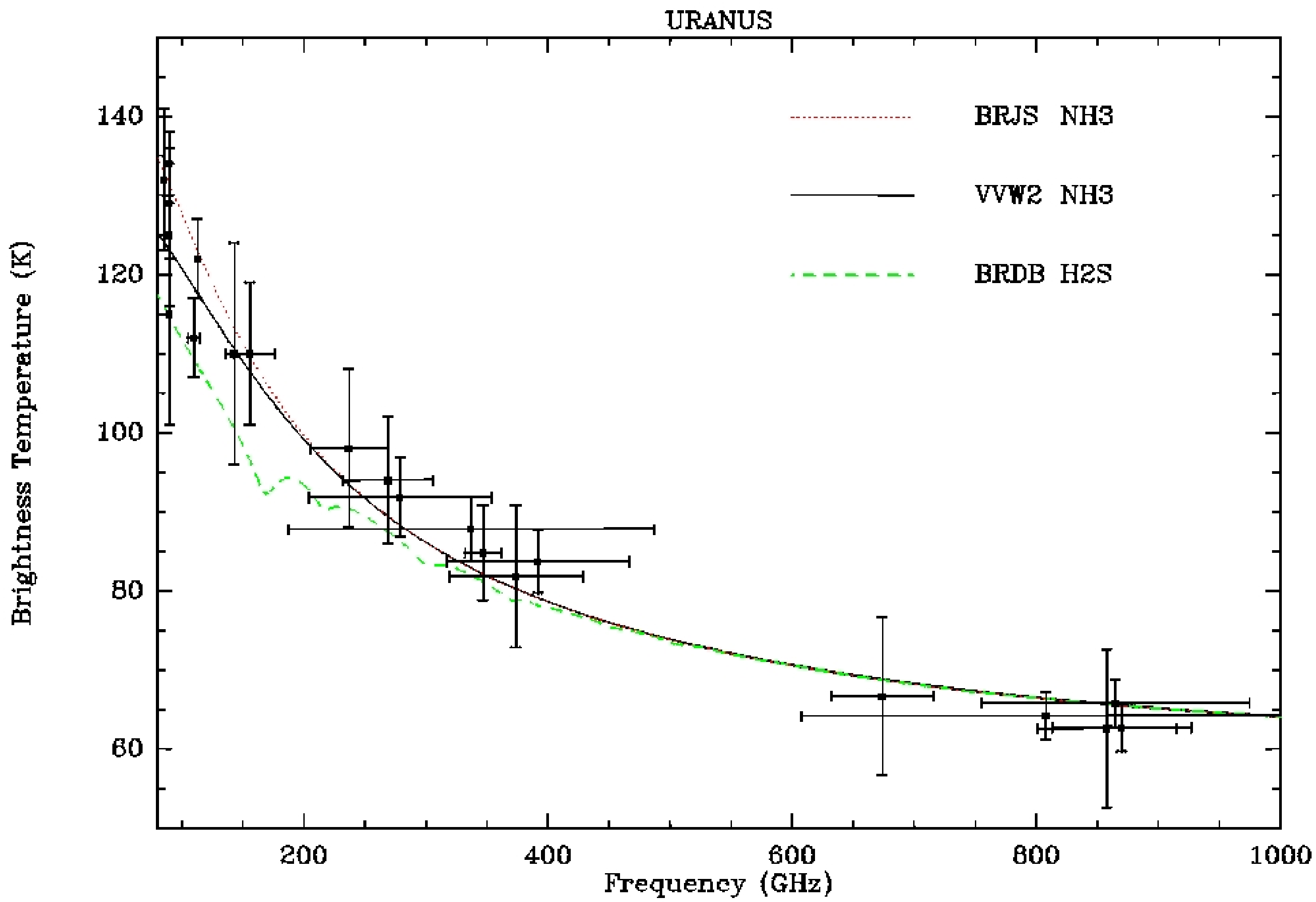


Rings and satellites contribution are negligible (<0.2%)

Vertical Structure of Uranus



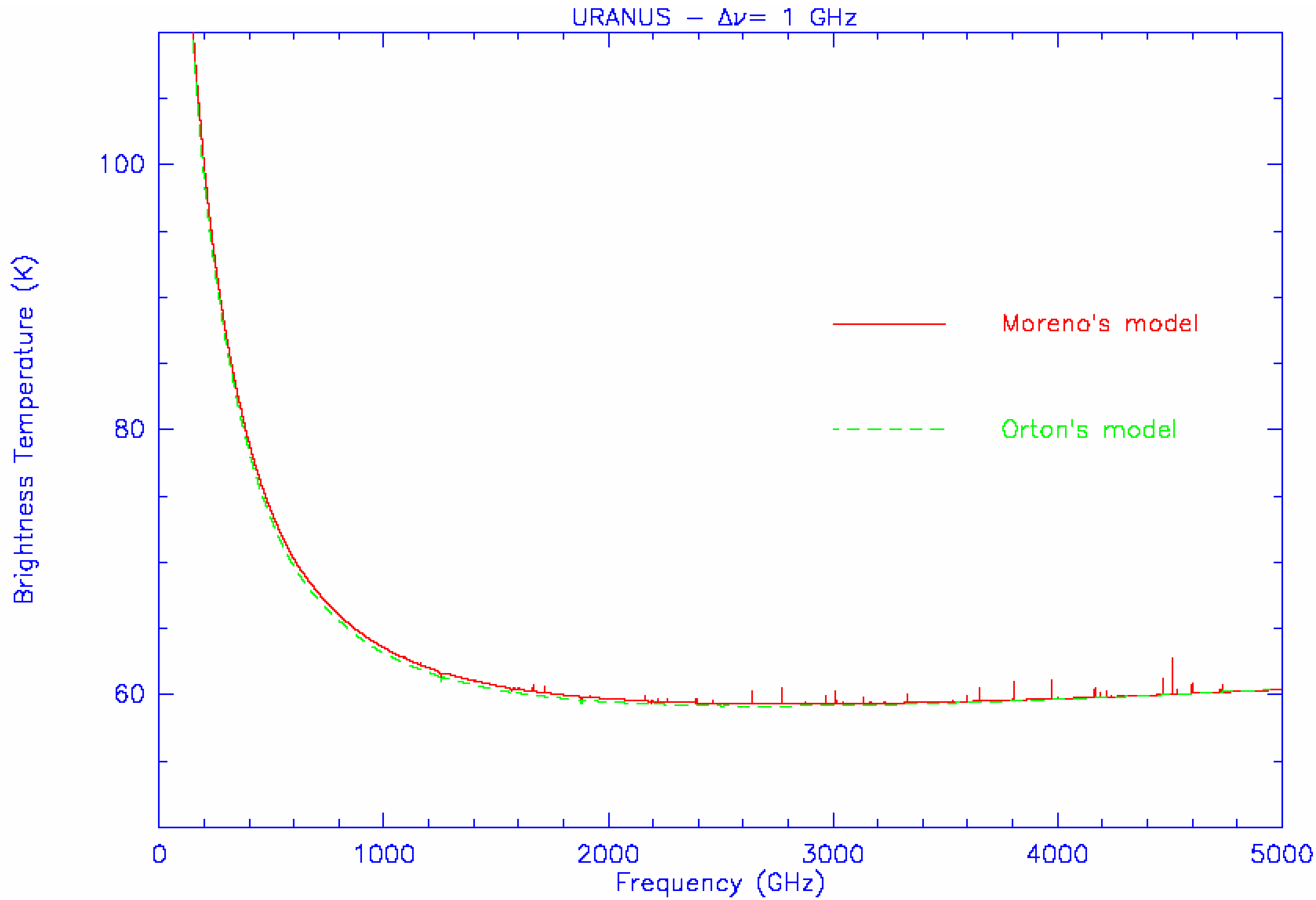
Uranus mm spectrum



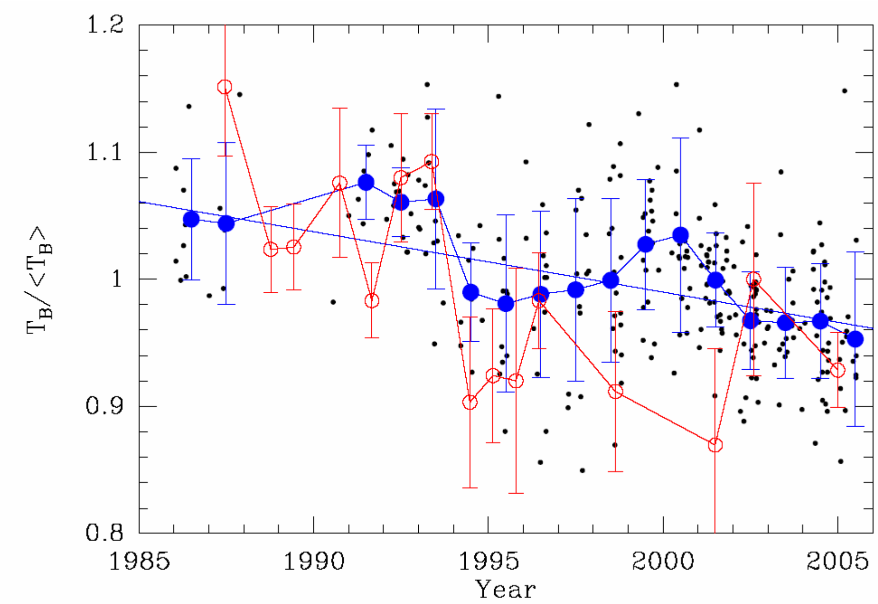
Continuum uncertainties

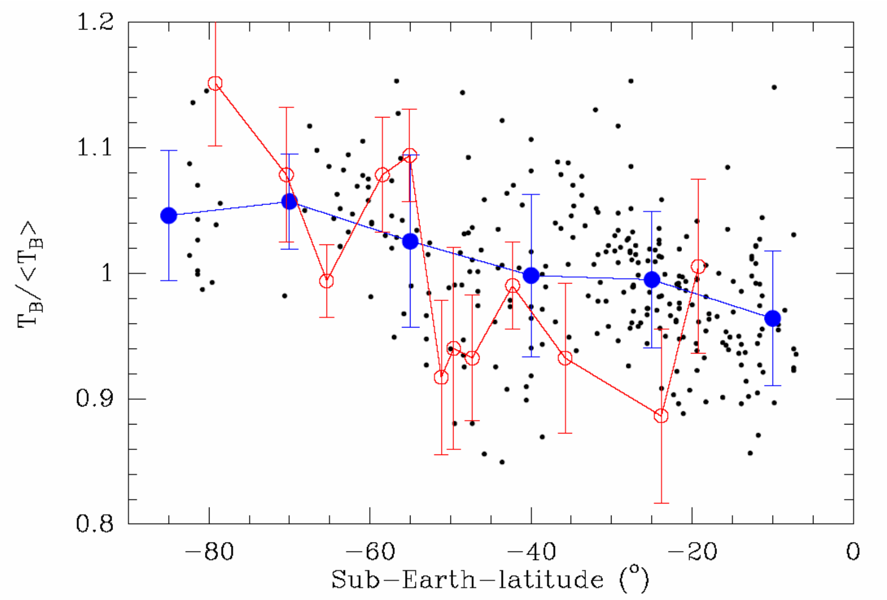
	Δ	ΔTB/TB (%) 500 / 2000 / 5000
Abs. Coefficient	+10%	-1.5 / -0.8 / -0.8
He	+3%	+0.6 / 0.0 / -0.2
CH_4	+0.6%	-0.3 / 0.0 / 0.0
Total		2% / 0.8% / 1%

Model Comparison: < 1%



Uranus cm-mm variations





RED cm (Hofstadter)- BLUE mm (Kramer)

Uranus' Variations

- Time variation of Uranus' brightness temperature at frequencies < 90 GHz start to be predictable.

- At frequencies > 500 GHz, we probe at higher altitudes, less sensitive to NH_3 or other Deep opacities.

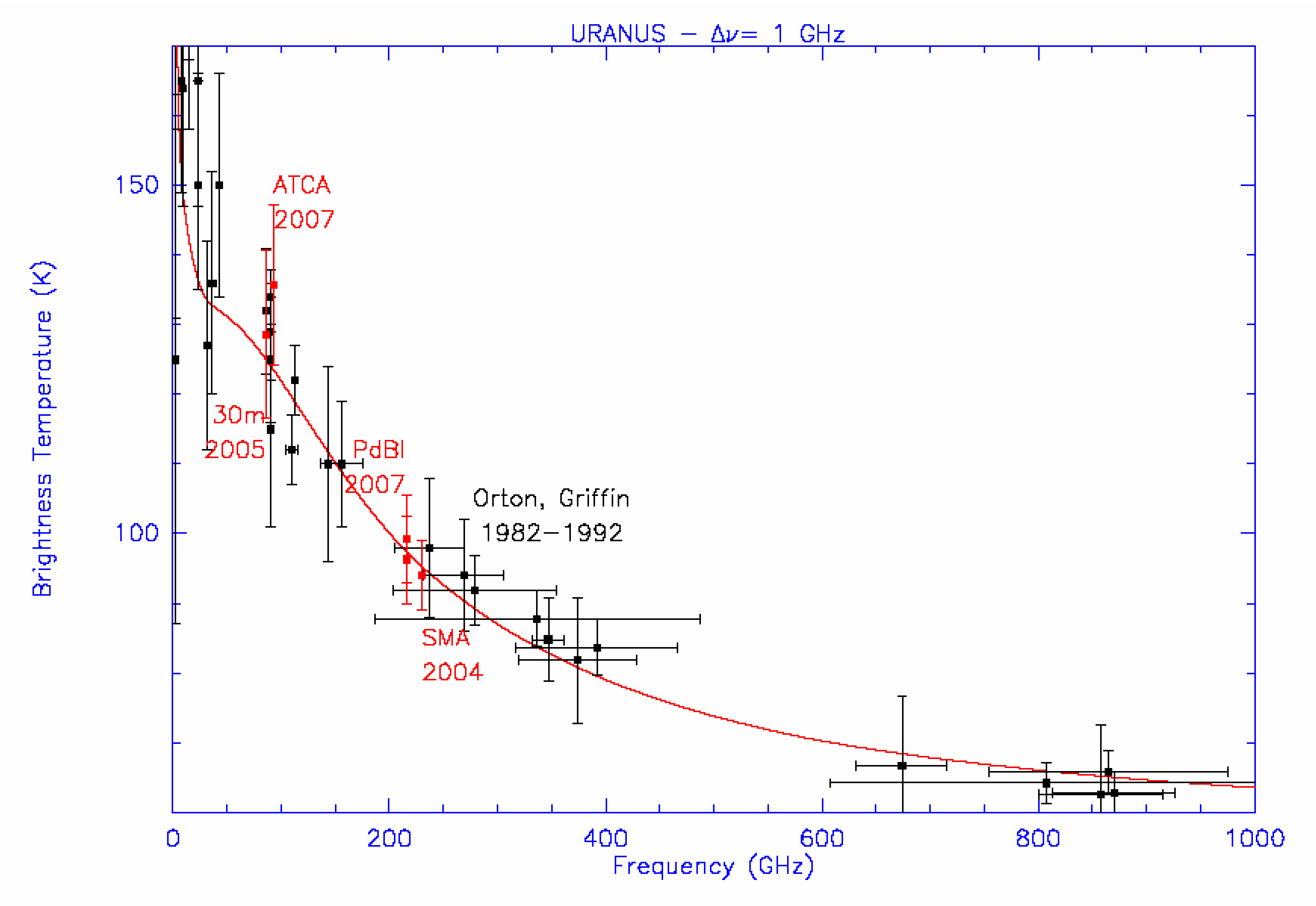
- The possible time variation at $\nu > 500$ GHz is still not established, and accurate ground-based measurements at 230-690 GHz are absolutely needed to disentangle this problem.

New mm measurements

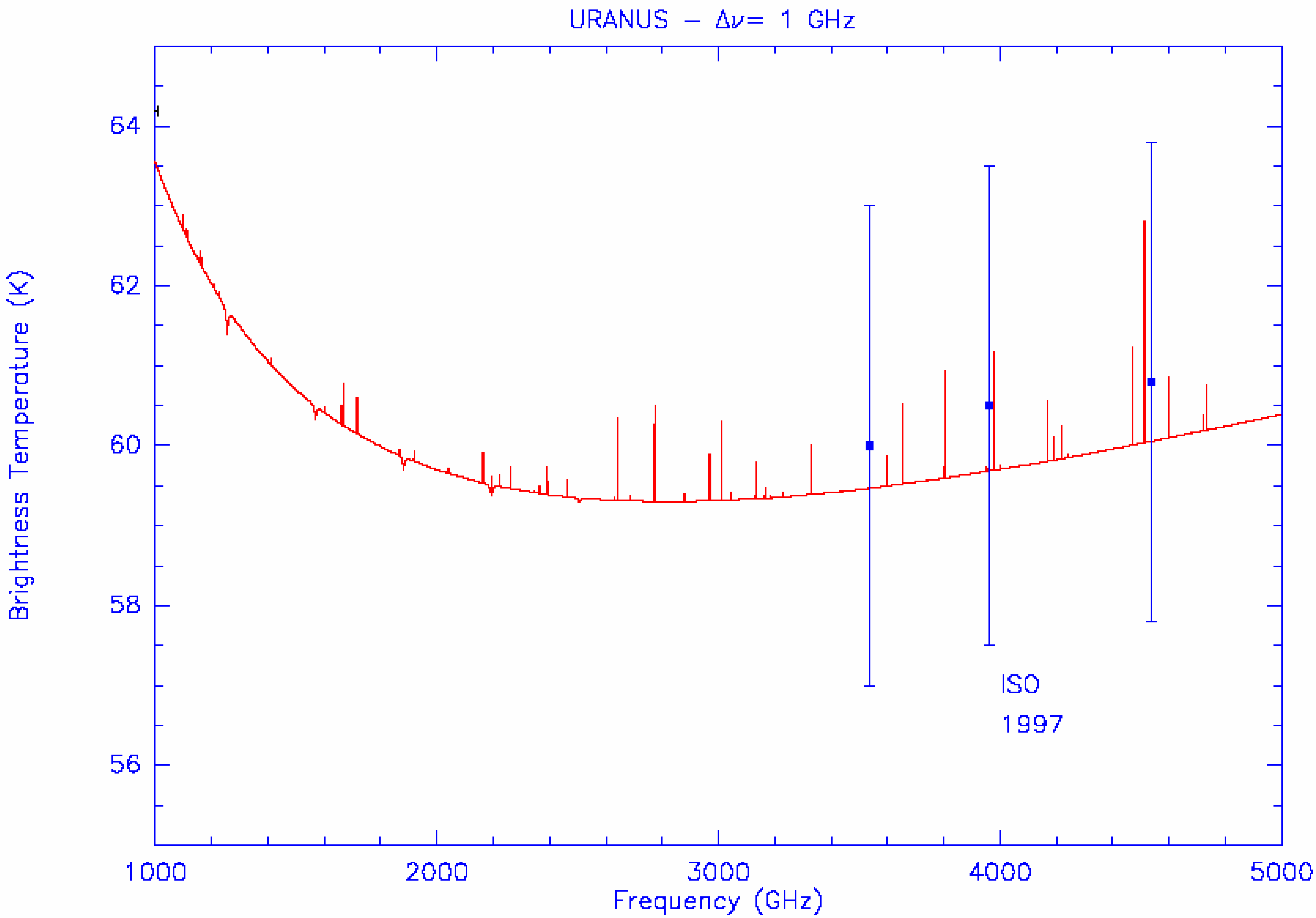
- 2004 - SMA 230 GHz – M. Gurwell – (Neptune)
- 2005 – IRAM-30m 86 GHz – C. Kramer (2nd Cal)

- May 2007 - ATCA 93 GHz –T. Mueller (Mars)
- May 2007 - PdBI 215 GHz – R.Moreno (Mars)

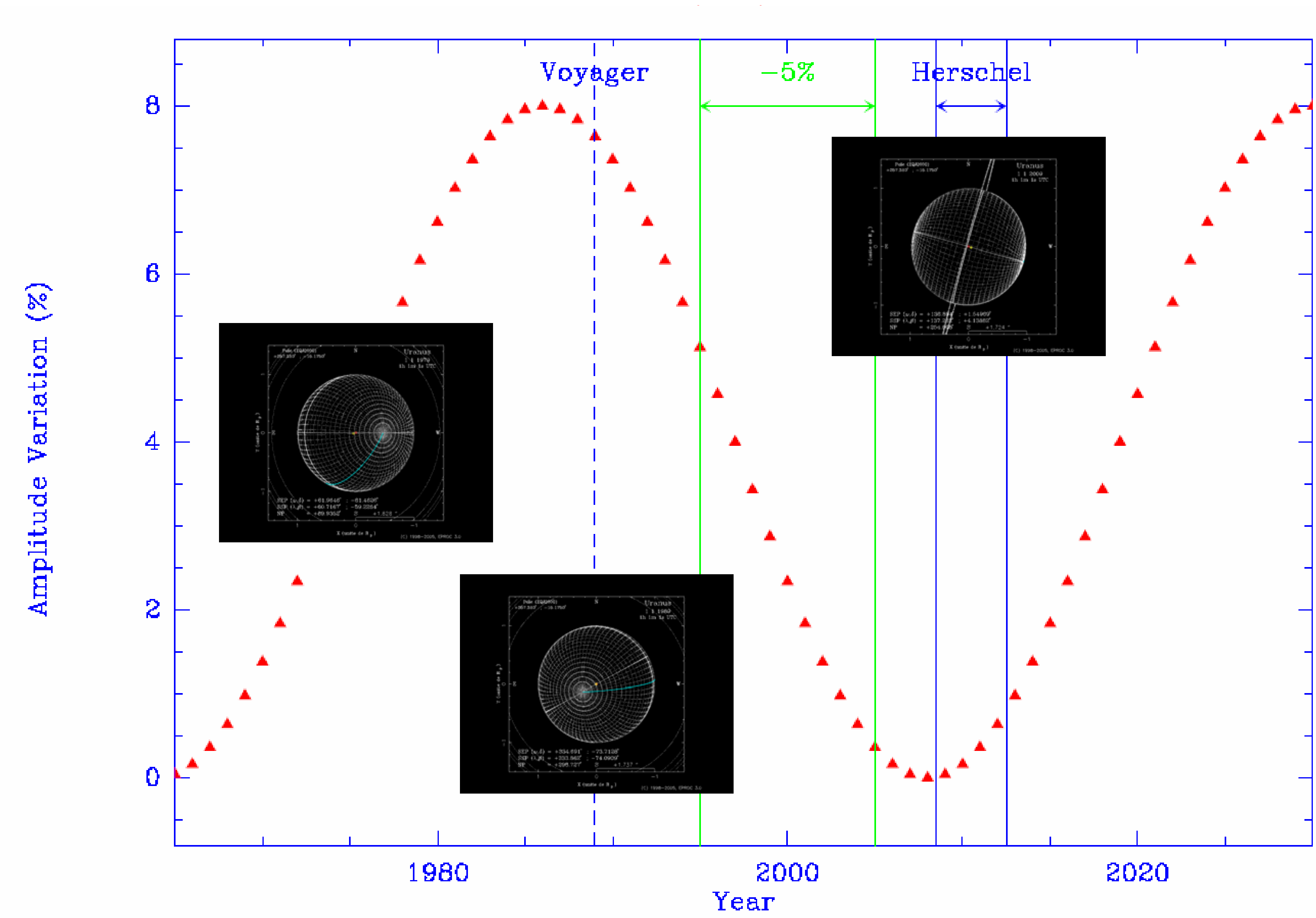
Uranus mm-submm spectrum



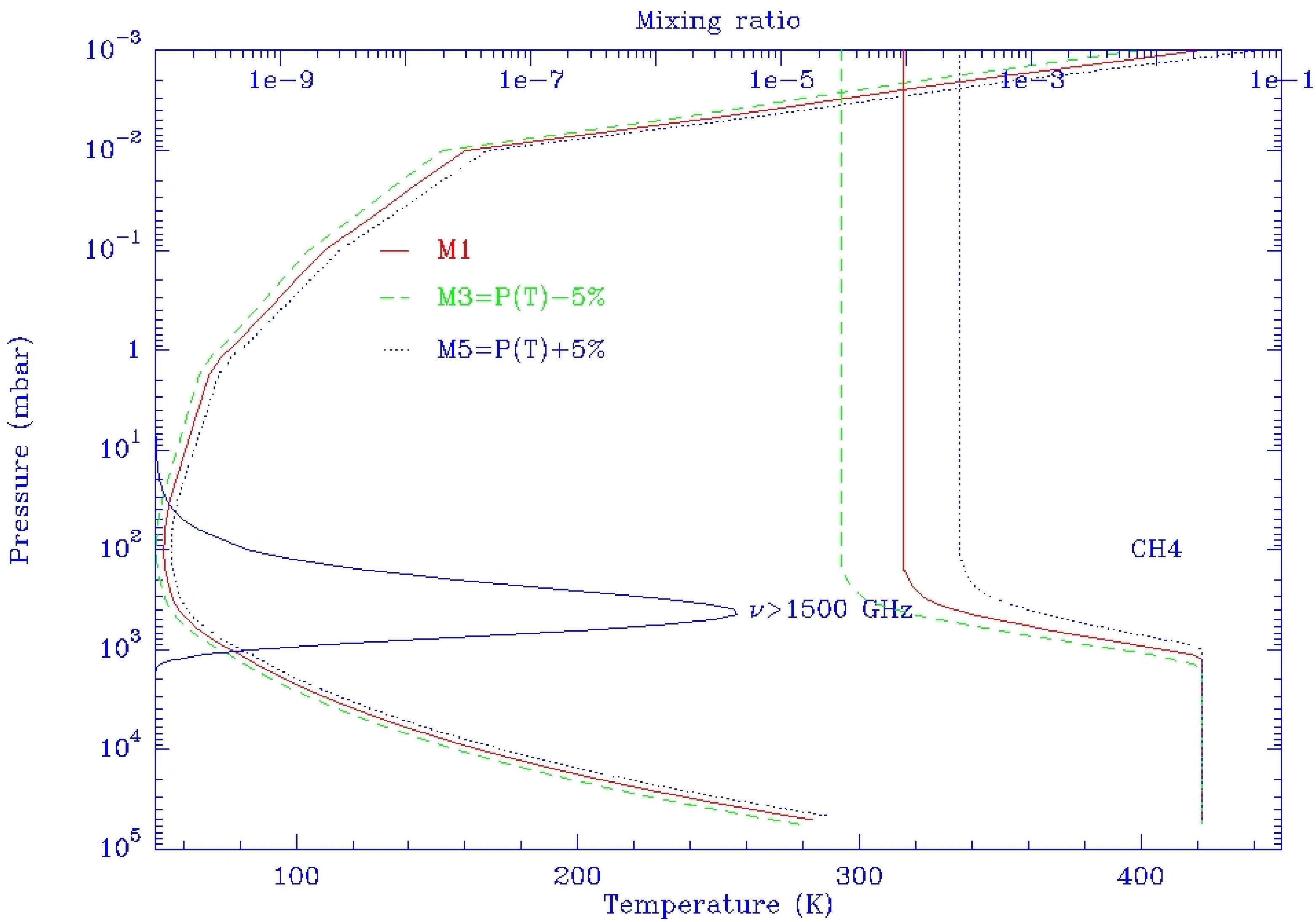
Uranus FIR spectrum



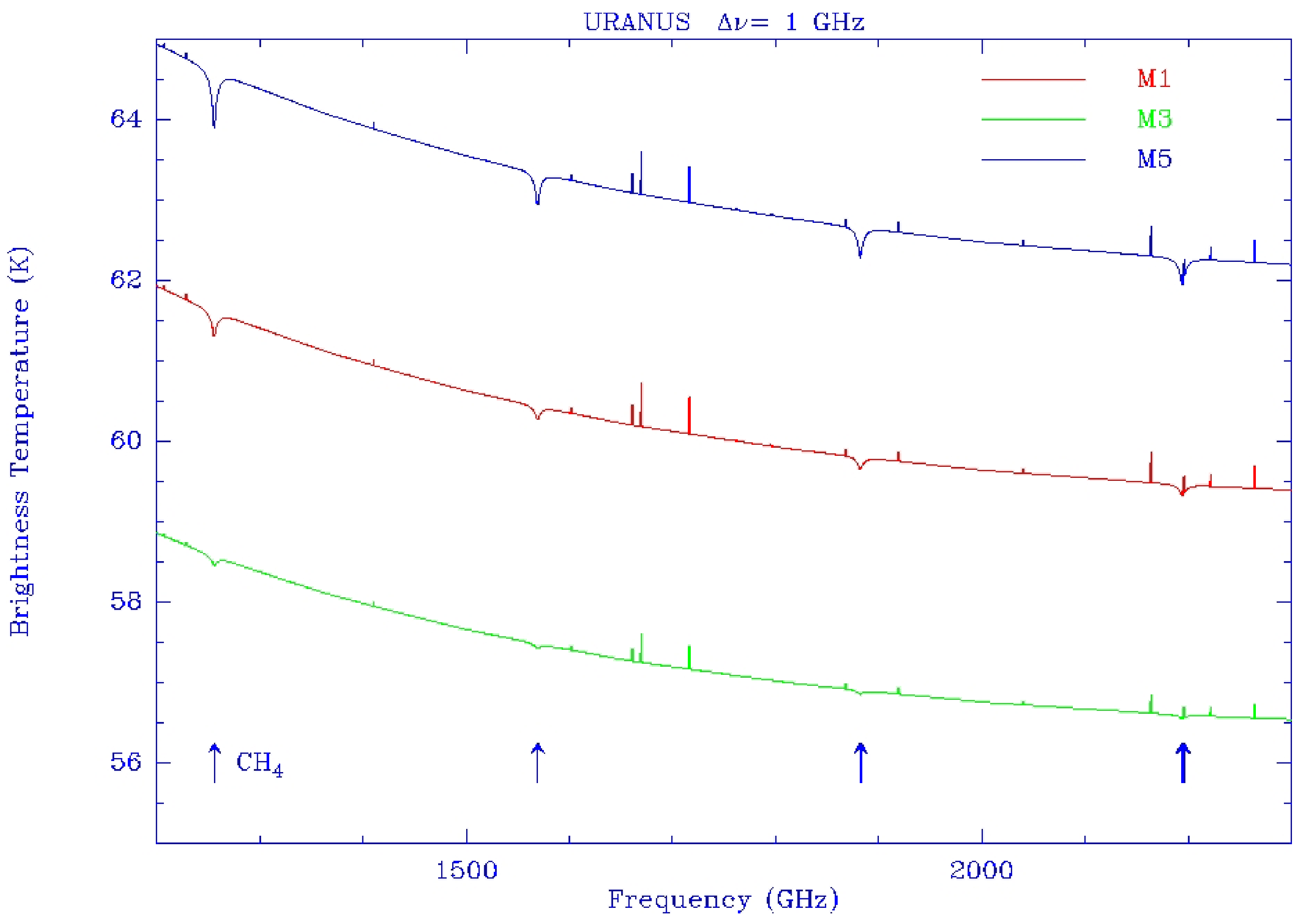
Possible Uranus amplitude variation during Herschel



Thermal Structure Uncertainties

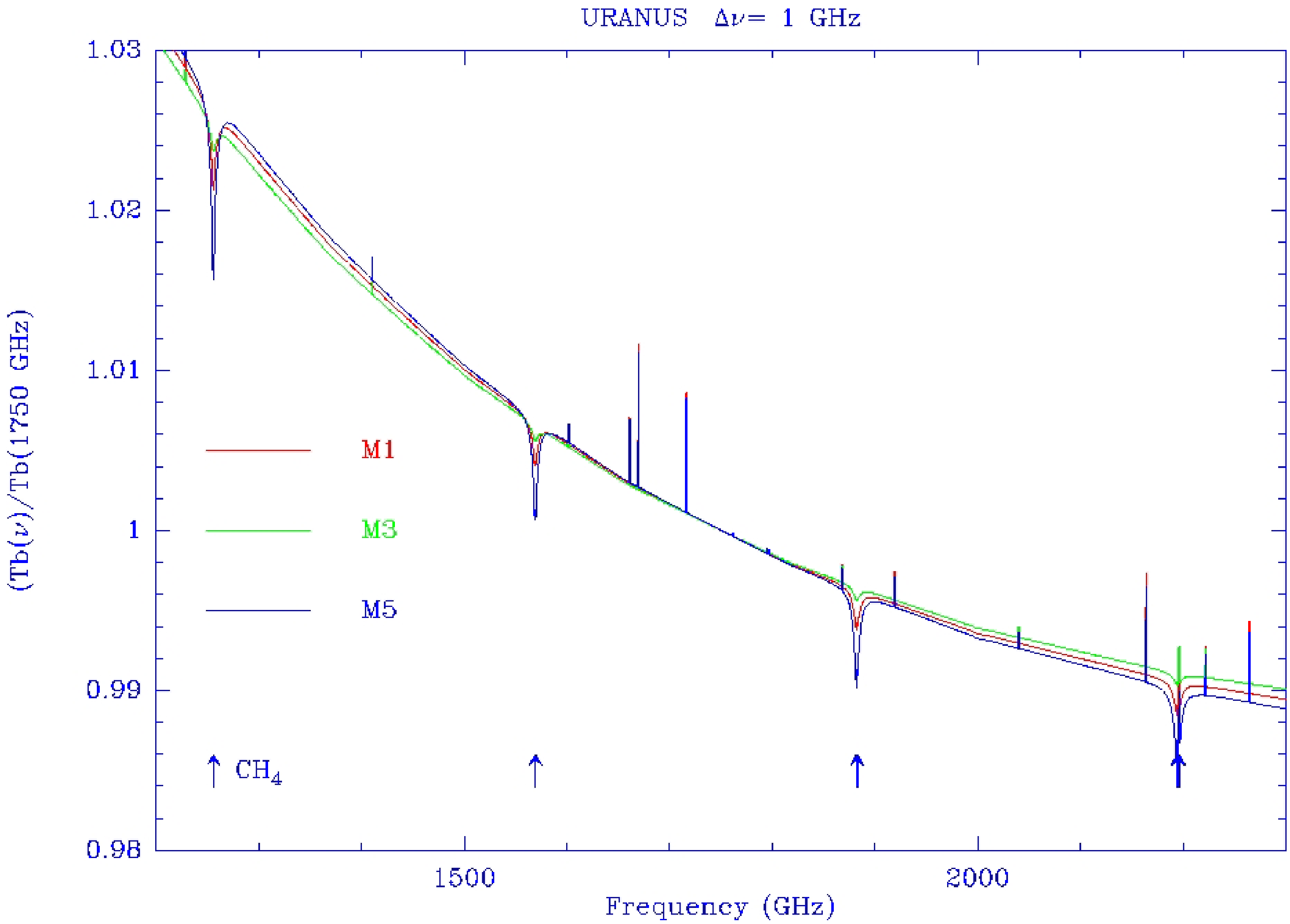


P(T) Uncertainties

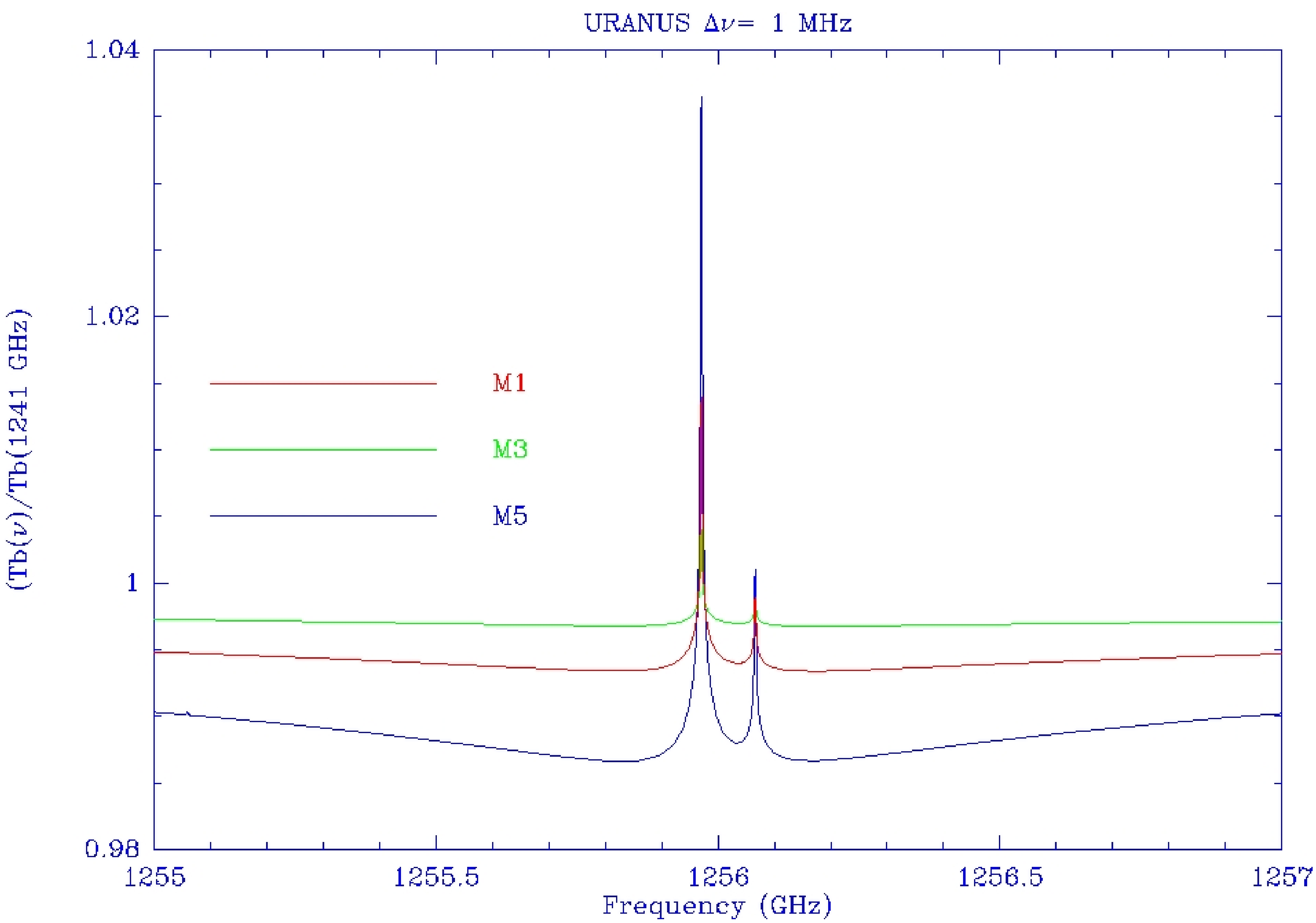


➔1 % in P(T) is 1% in Calibration

Line-to-Continuum ratio



Line-to-Continuum ratio (2)



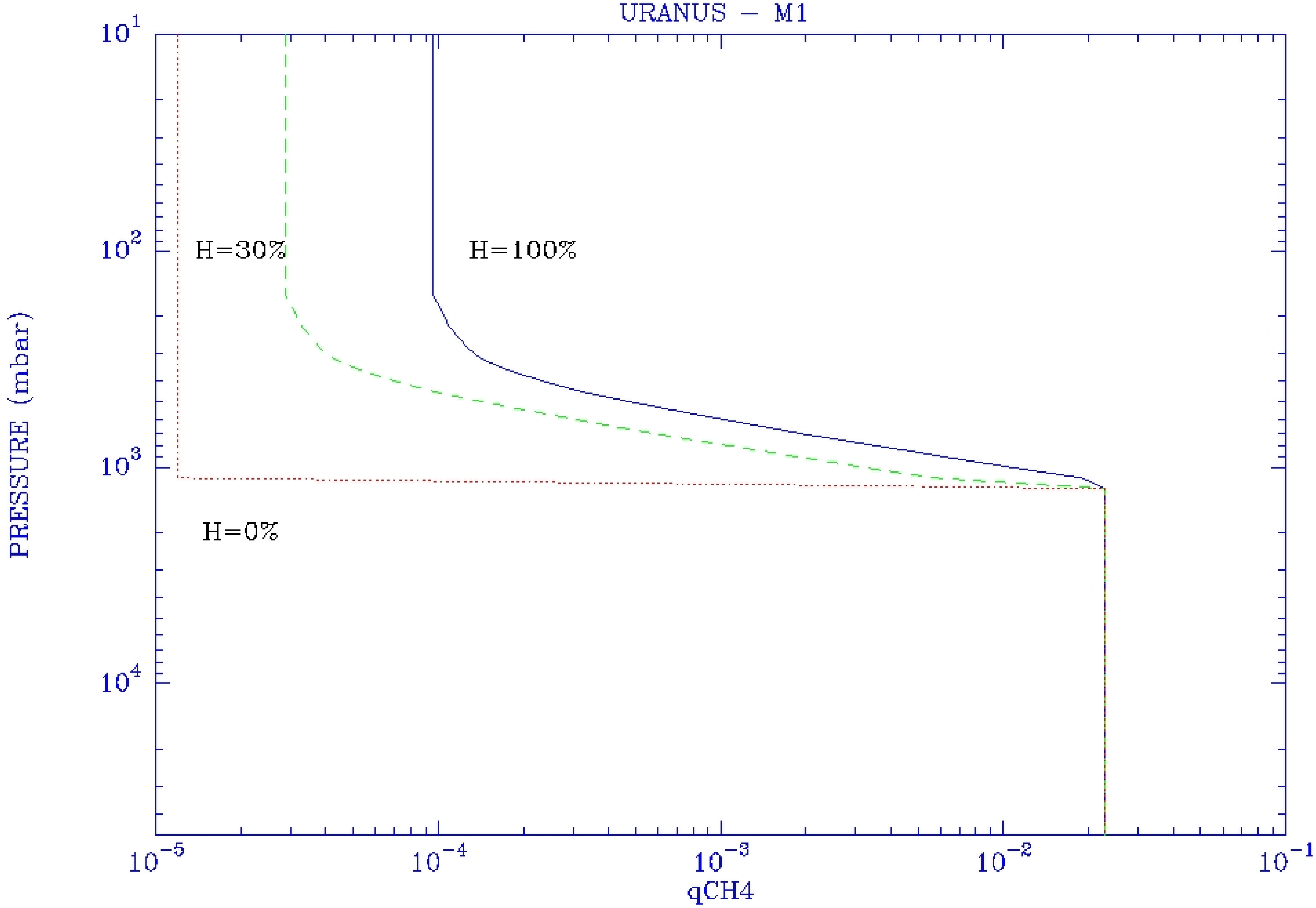
Possible Improvement

CH_4 Line-to-Continuum ratio vary with Temperature :

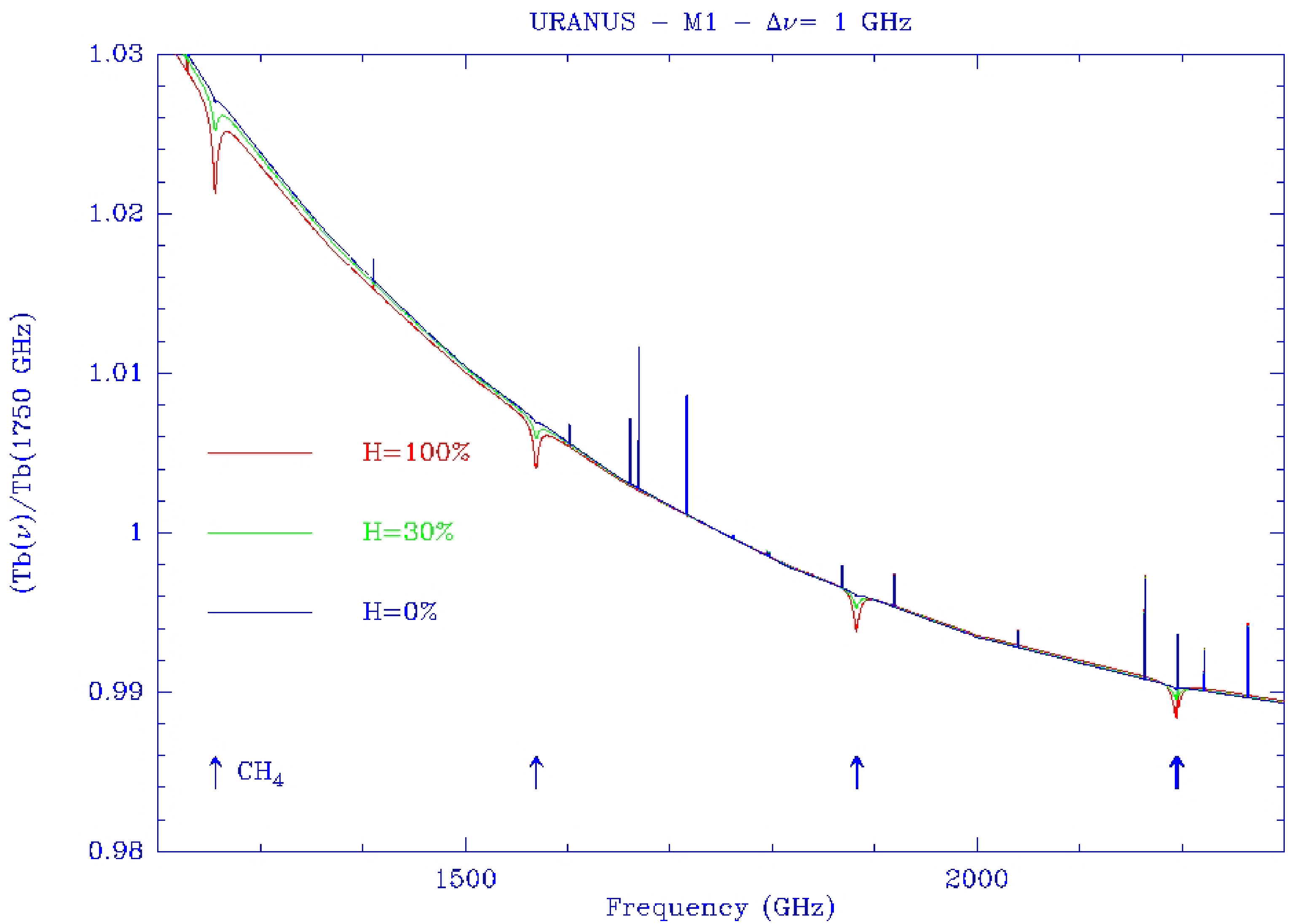
➔1% / 10K (Detectable)

But HUMIDITY …

CH_4 Humidity



CH_4 Humidity Line-to-Continuum ratio



Constrains on Humidity

• CH_4 humidity Uncertainties on the Line-to-Continuum ratio can be ~ 0.5%   (1% /10 K for P(T))

•Measuring the stratospheric CH_4 could give some constrains on its humidity (HIFI)

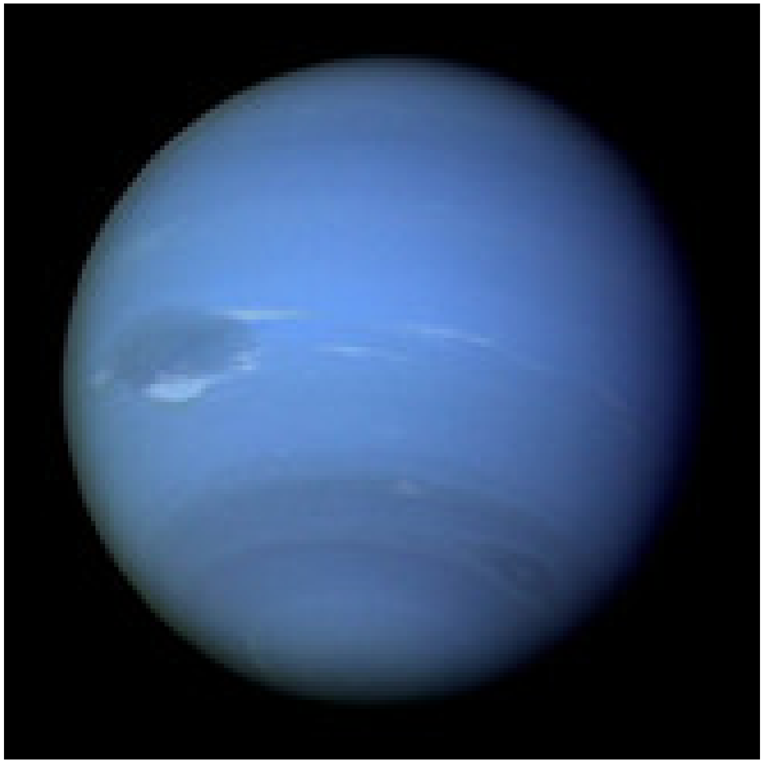
•Nevertheless, CH_4 detection constraint the minimum temperature close to the tropopause

➔ May improve the continuum spectrum

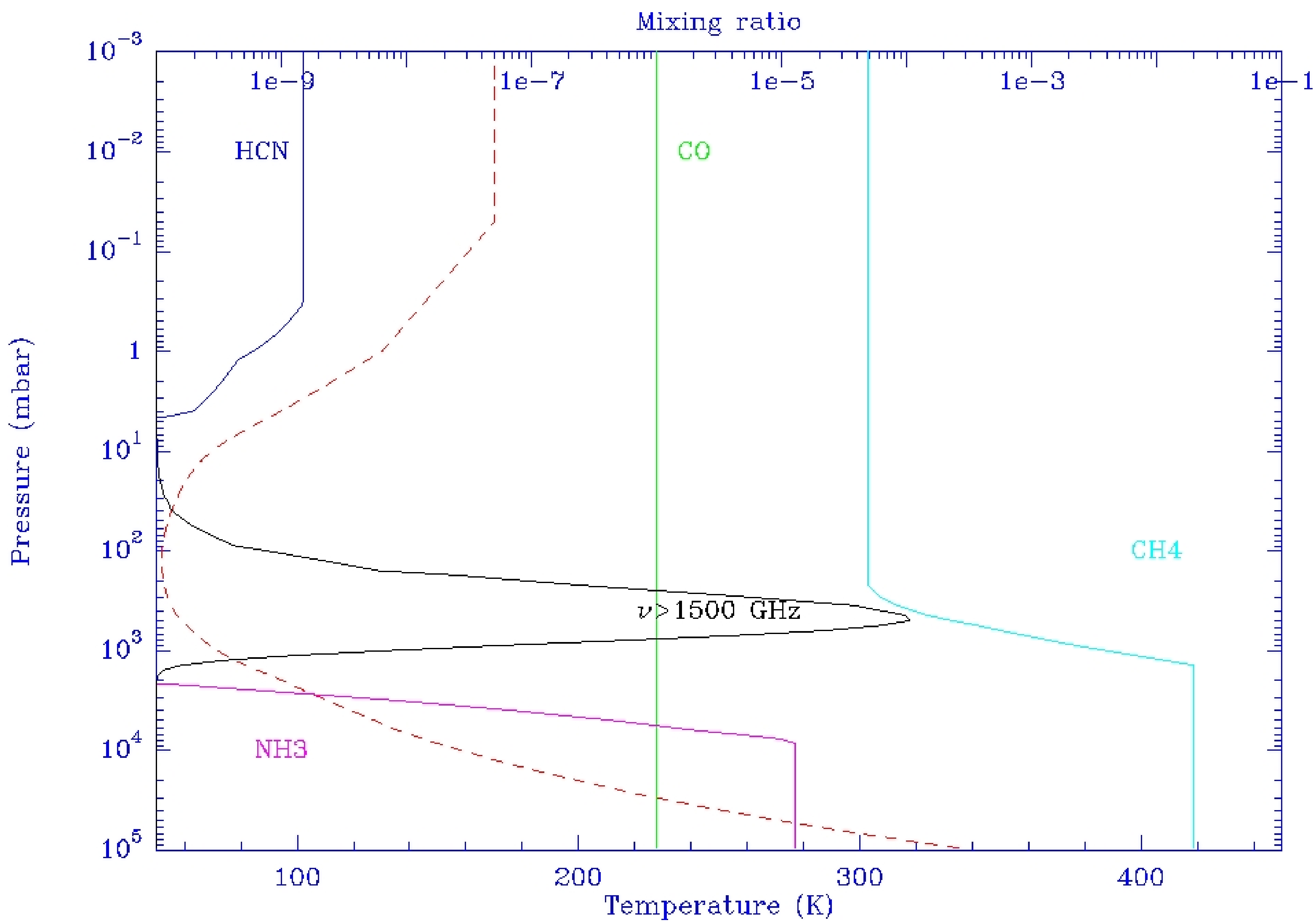
Uranus' summary

- Model uncertainties 1-2%
- Comparison with Orton's Model within 1%
- Current Absolute uncertainties limited by our knowledge of the thermal structure (5%)
- CH_4 detection may improve the P(T) accuracy

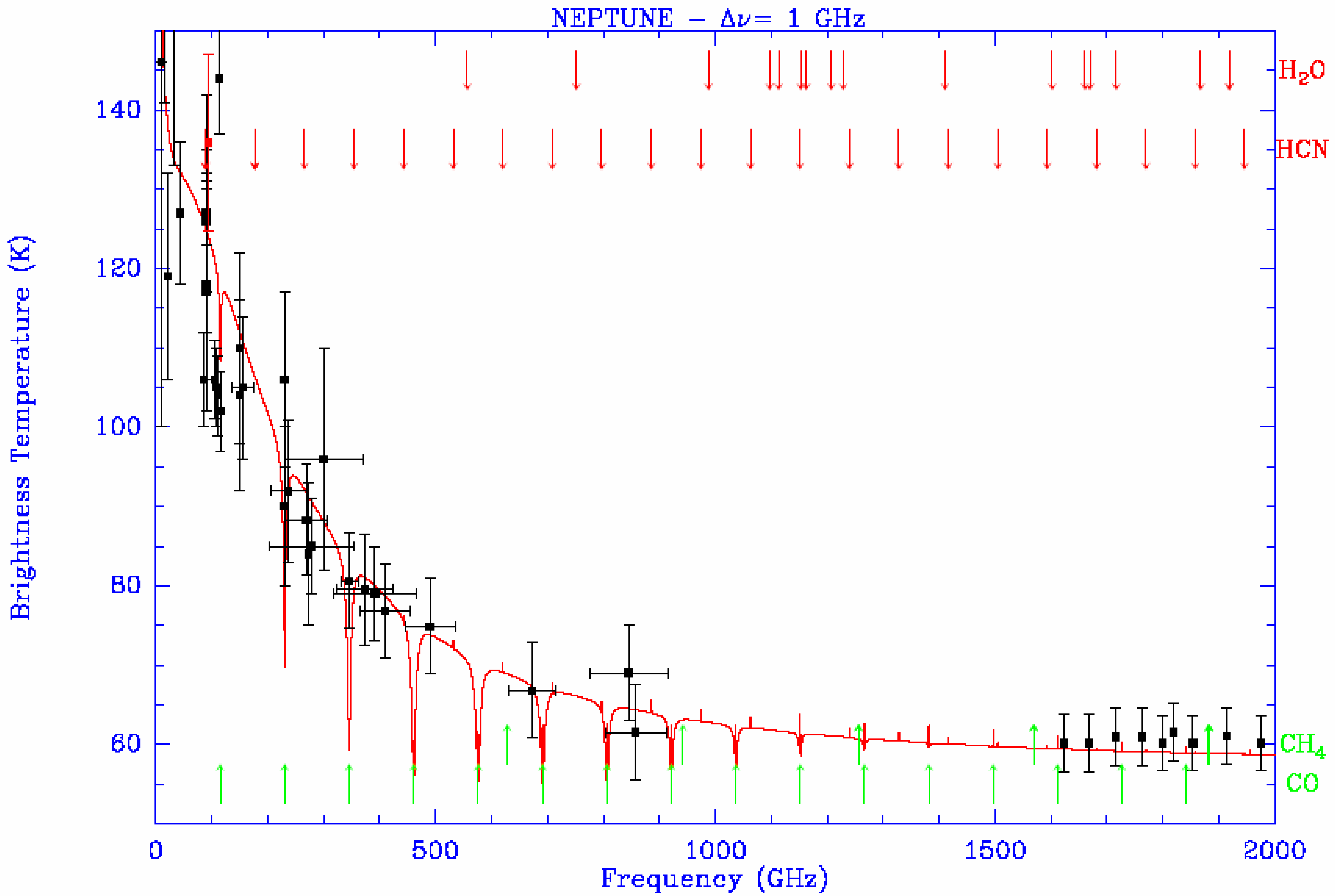
Neptune



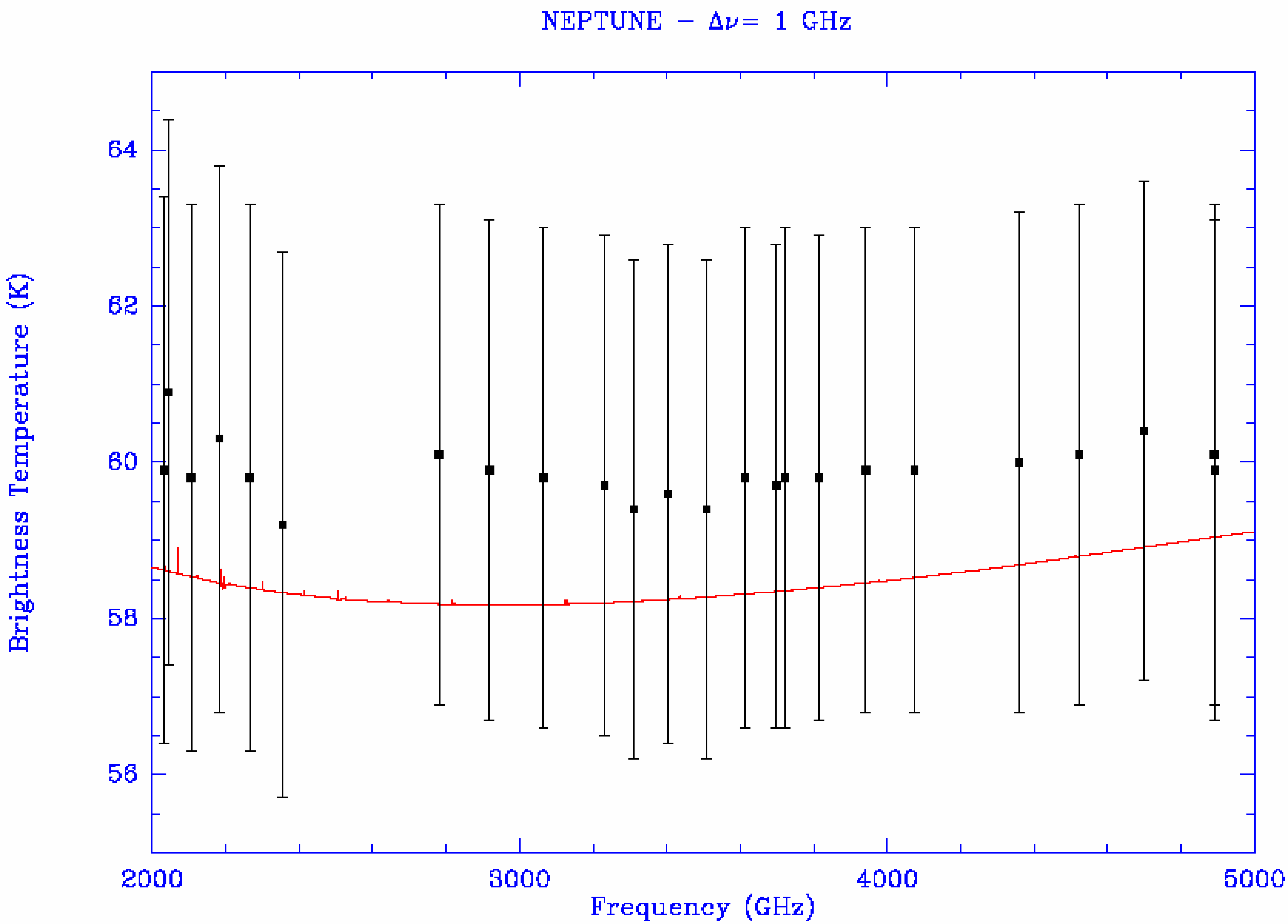
Vertical Structure of Neptune



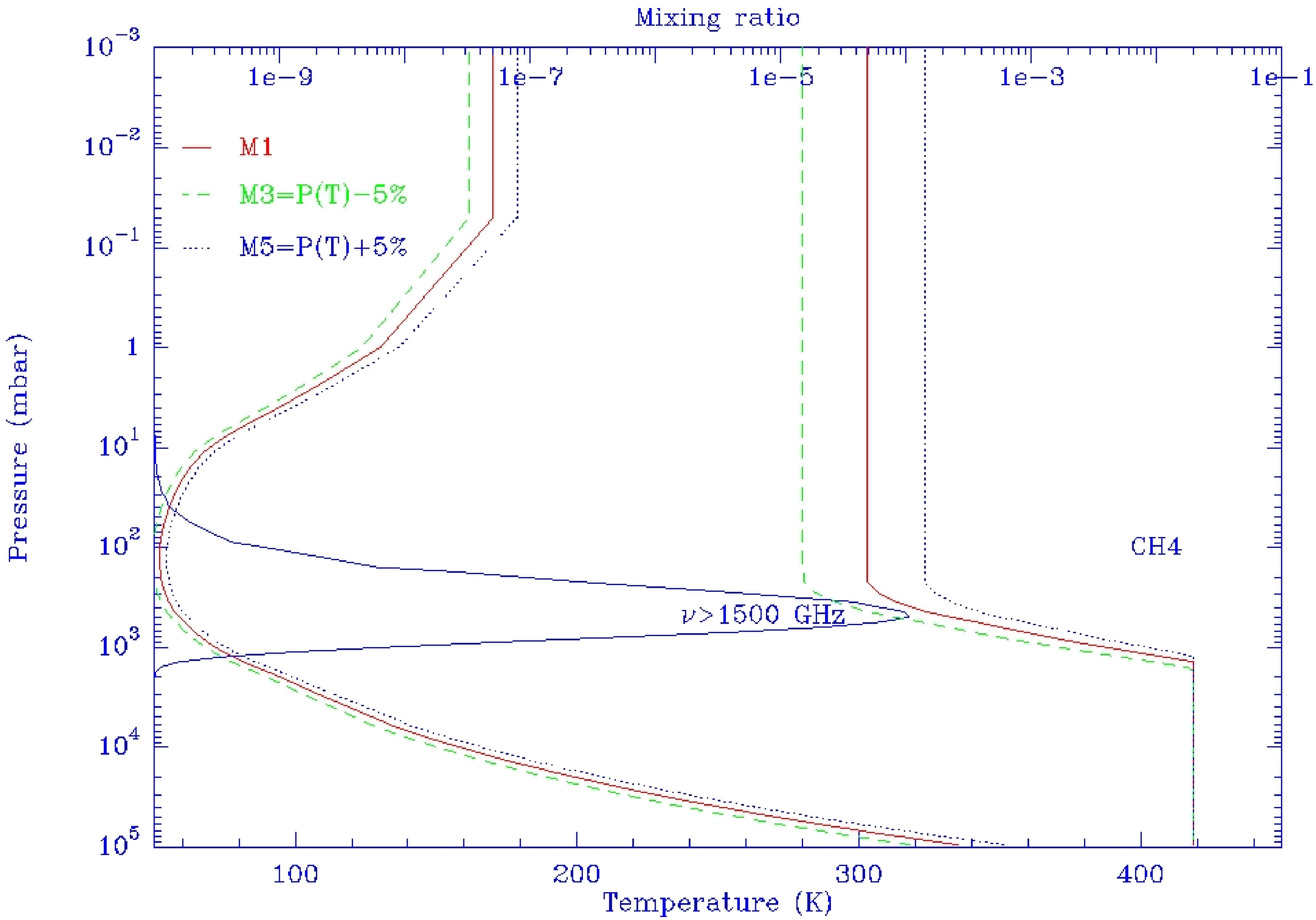
Neptune mm-submm spectrum



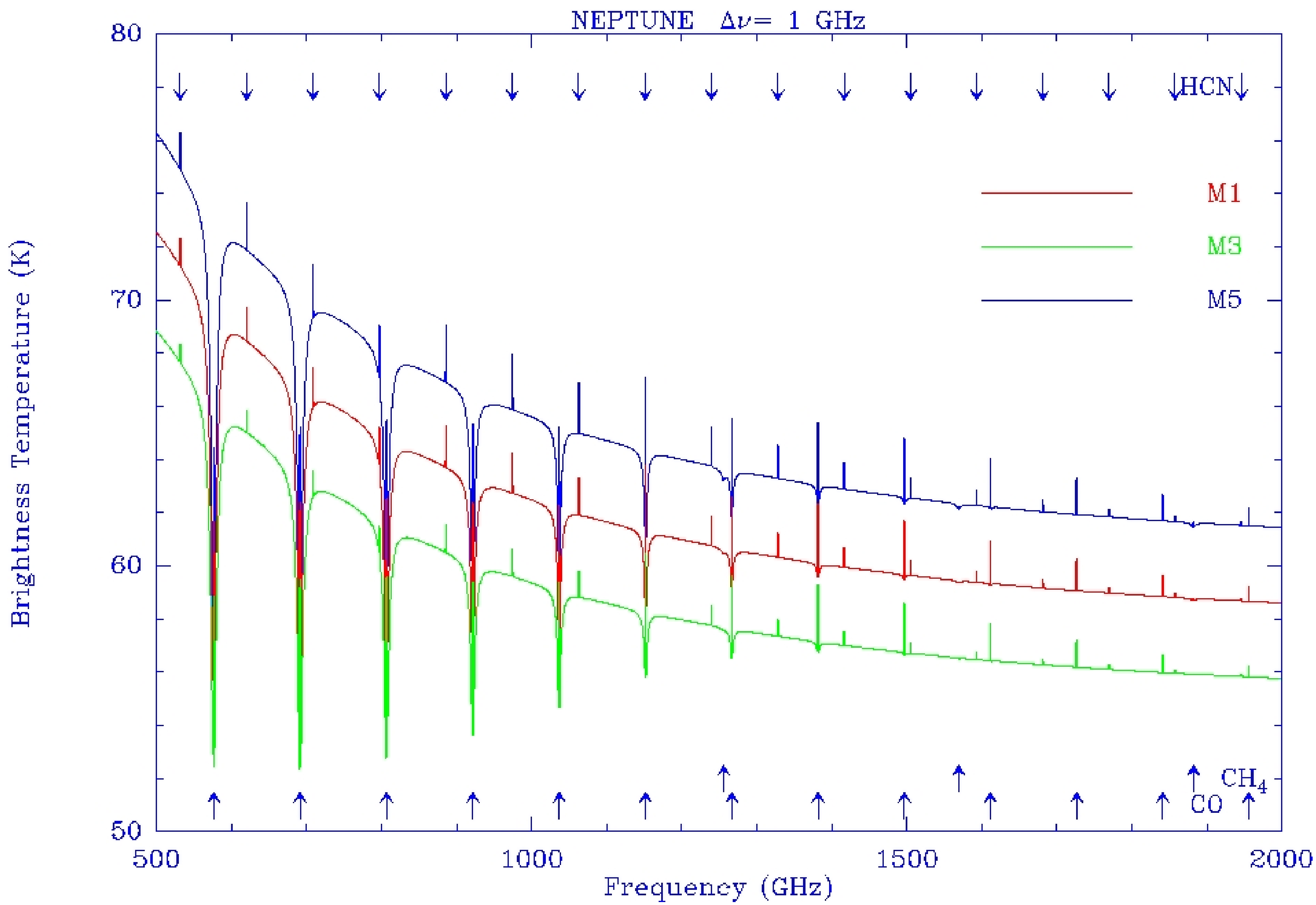
Neptune FIR spectrum



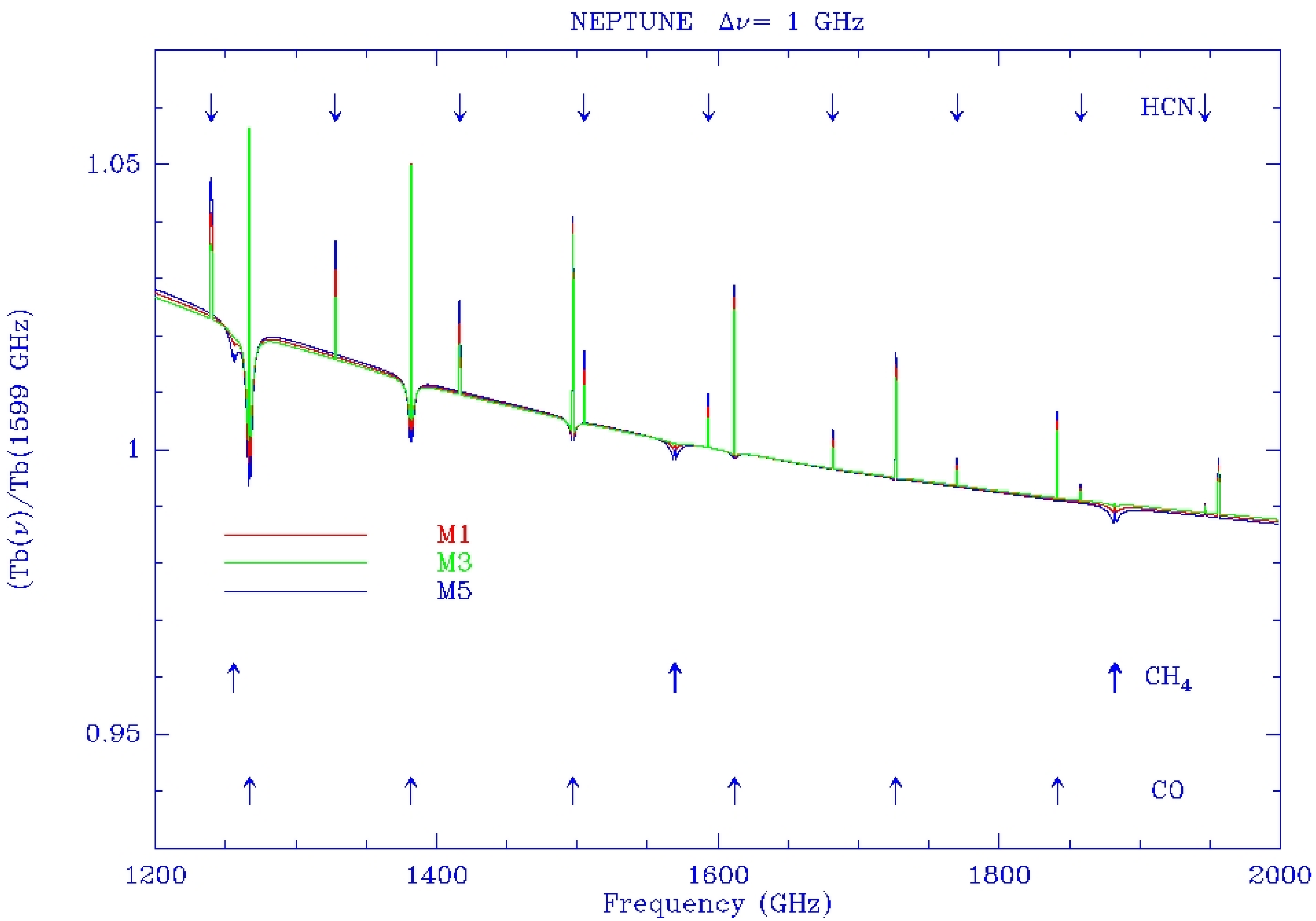
Thermal Structure Uncertainties



P(T) Uncertainties



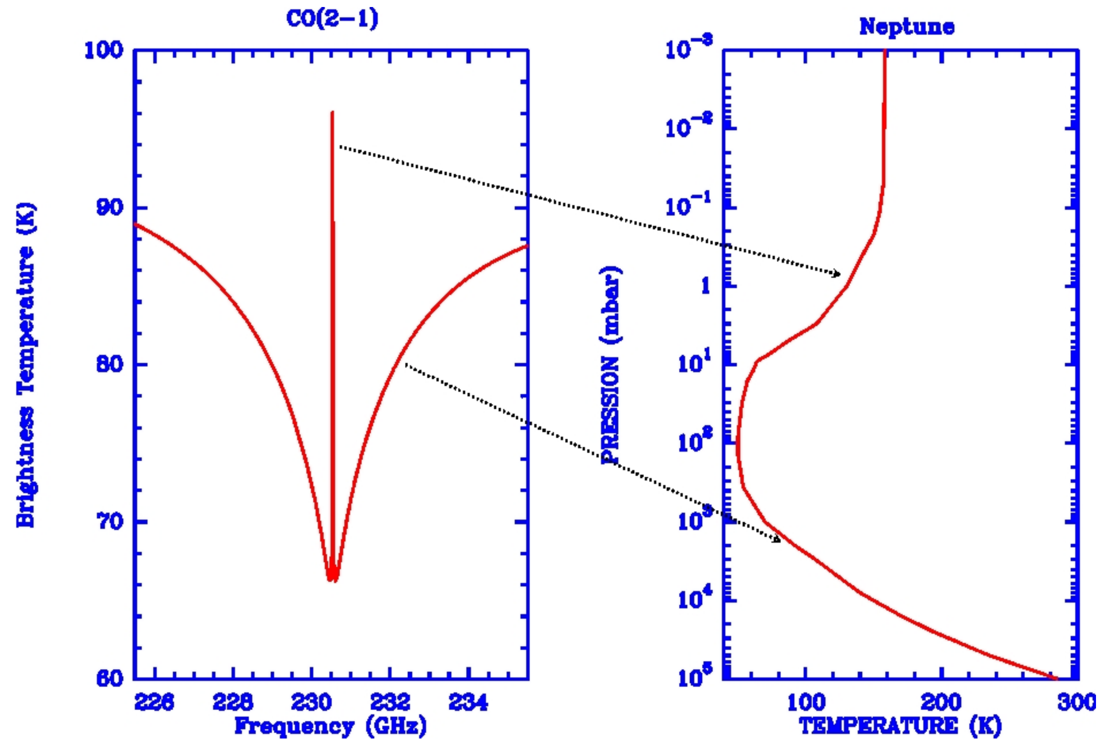
Line-to-Continuum ratio



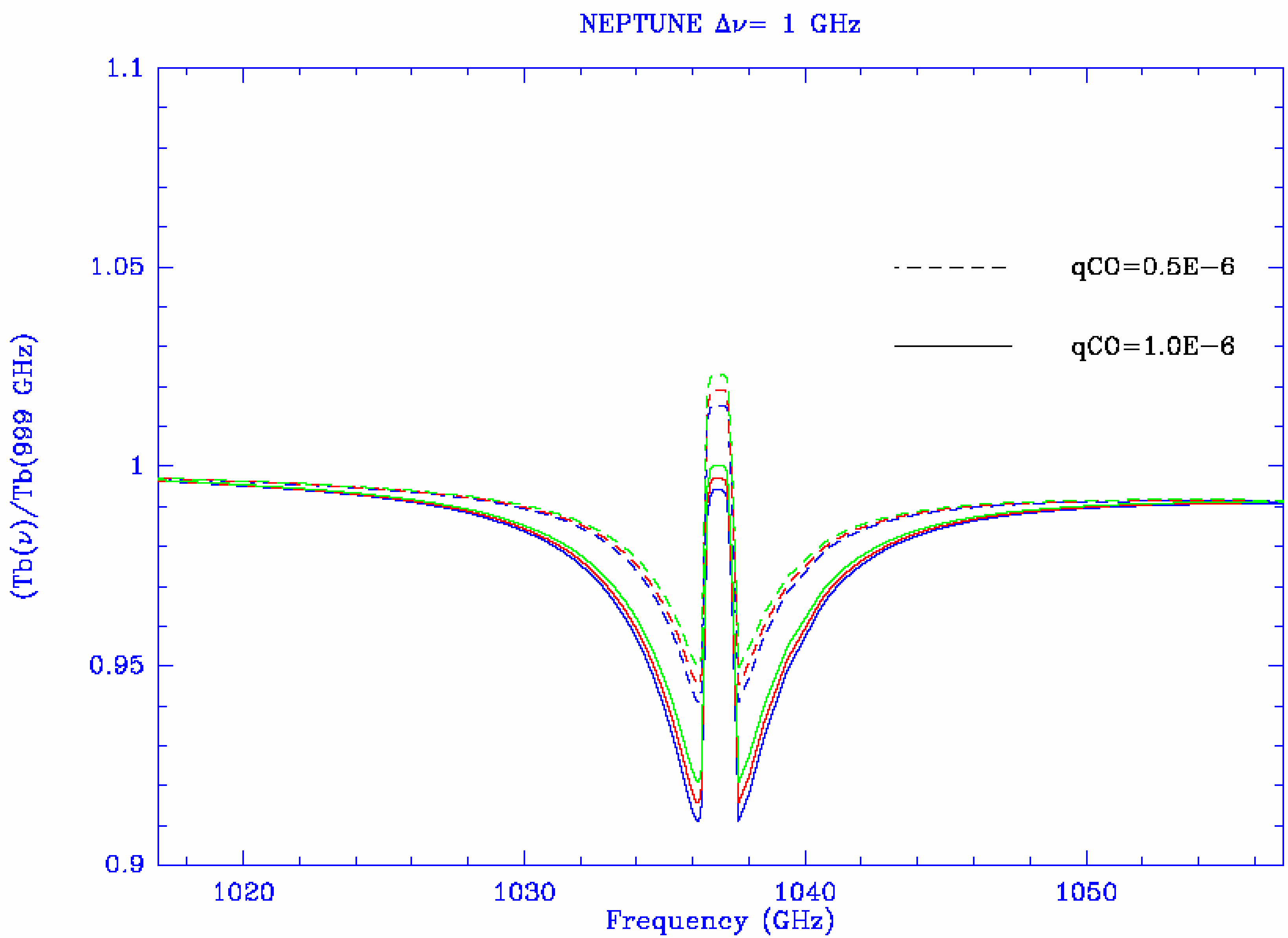
CO on Neptune

- Observations of CO absorption lines

➔ Constraints on tropospheric CO and Thermal structure



CO on Neptune (2)



Neptune Summary

- CO/CH4 Line-to-Continuum variation with Temperature : 0.1 % / K

- Each Kelvin known relative to the standard P(T) is a gain of ~1.5% in the Herschel Absolute calibration

- Obtain a large bandwidth spectrum (PACS/SPIRE) with 0.1% relative accuracy and HIFI spectrum (stratospheric CH4) - Integration time needed ~ 1 hour

Conclusions

- Giant Planets are well known/modeled in the submm/FIR

➔ Good Calibrators (absolute uncertainties <5%)

- Improvement : Better knowledge of thermal structure

Jupiter/Saturn : constraint with Cassini/CIRS (absolute uncertainties <2%)

Uranus/Neptune accurate CO/CH4 measurements with Herschel ➔Constraints the Thermal structure

- Herschel measurement of the full spectrum of Giant Planets and Cross-calibration with Mars, satellites, …