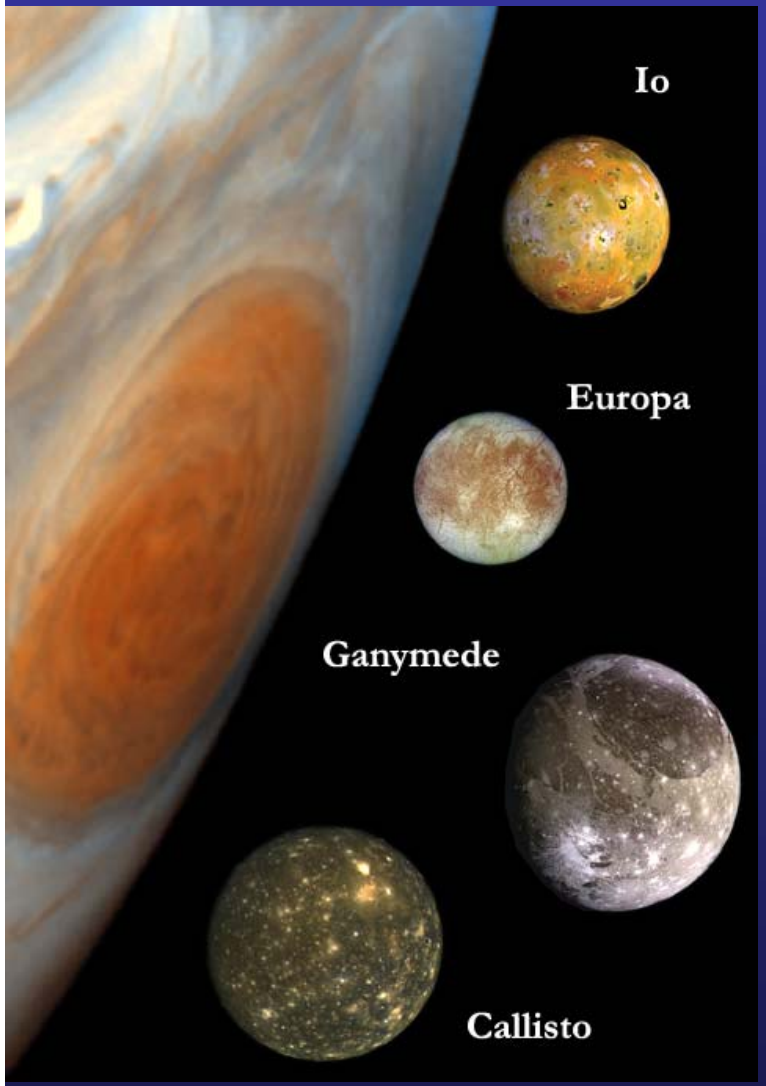
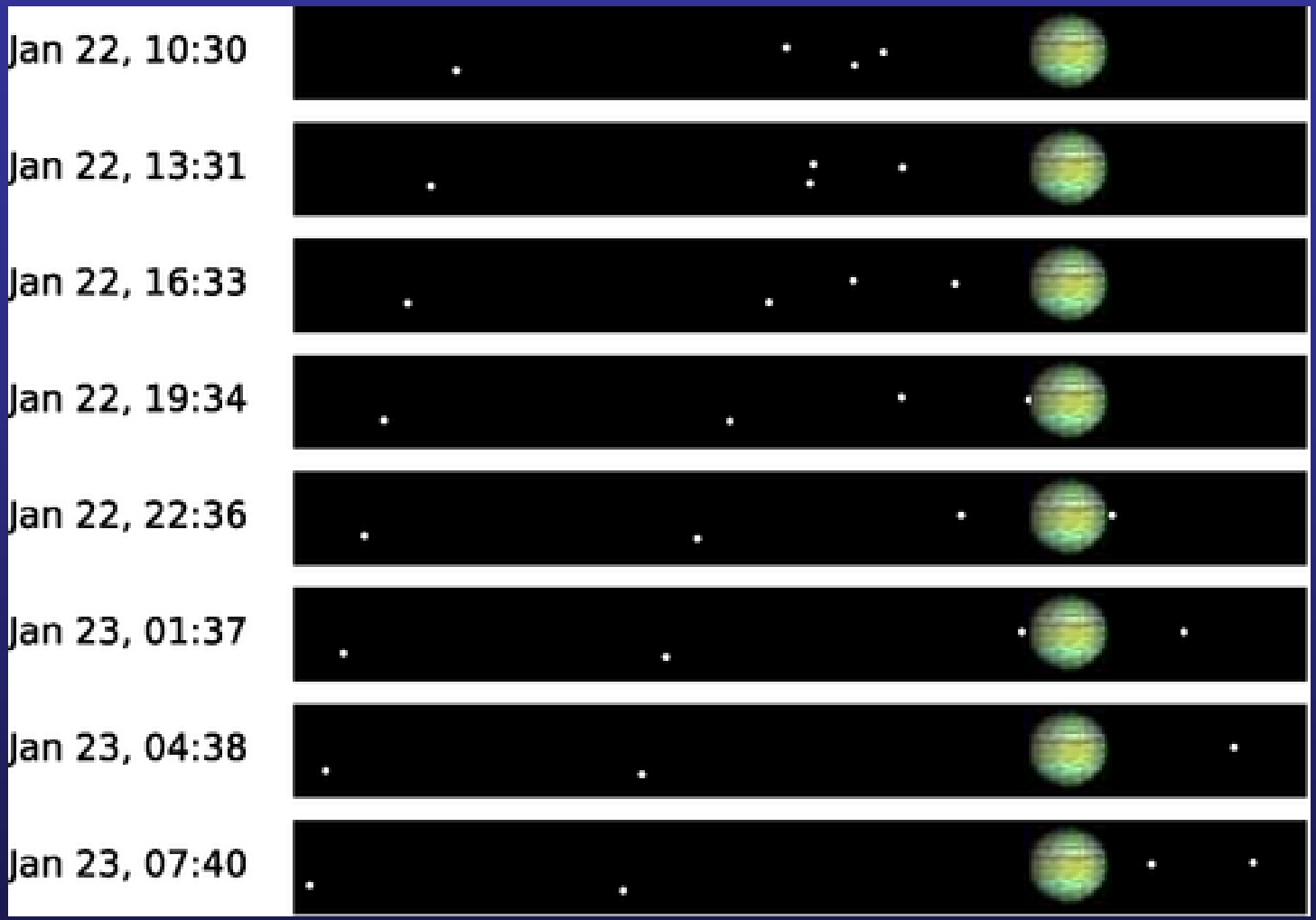


Galilean Moons: Potential for Herschel Absolute Calibration

Mark Gurwell (CfA)
Raphael Moreno (ObsPM)

	Io	Europa	Ganymede	Callisto
Diam (km)	3642	3121	5262	4821
(at 4.5 AU)	1.12”	0.96”	1.61”	1.48”
Max. Δ (R_{JUP})	5.95	9.47	15.10	26.6
(at 4.5 AU)	129”	205”	328”	576”
Period (days)	1.77	3.55	7.15	16.70

Moving Targets…



(fig 5 from '**Vibrations and Waves**', by Benjamin Crowell)

Ganymede & Callisto: What do we know?

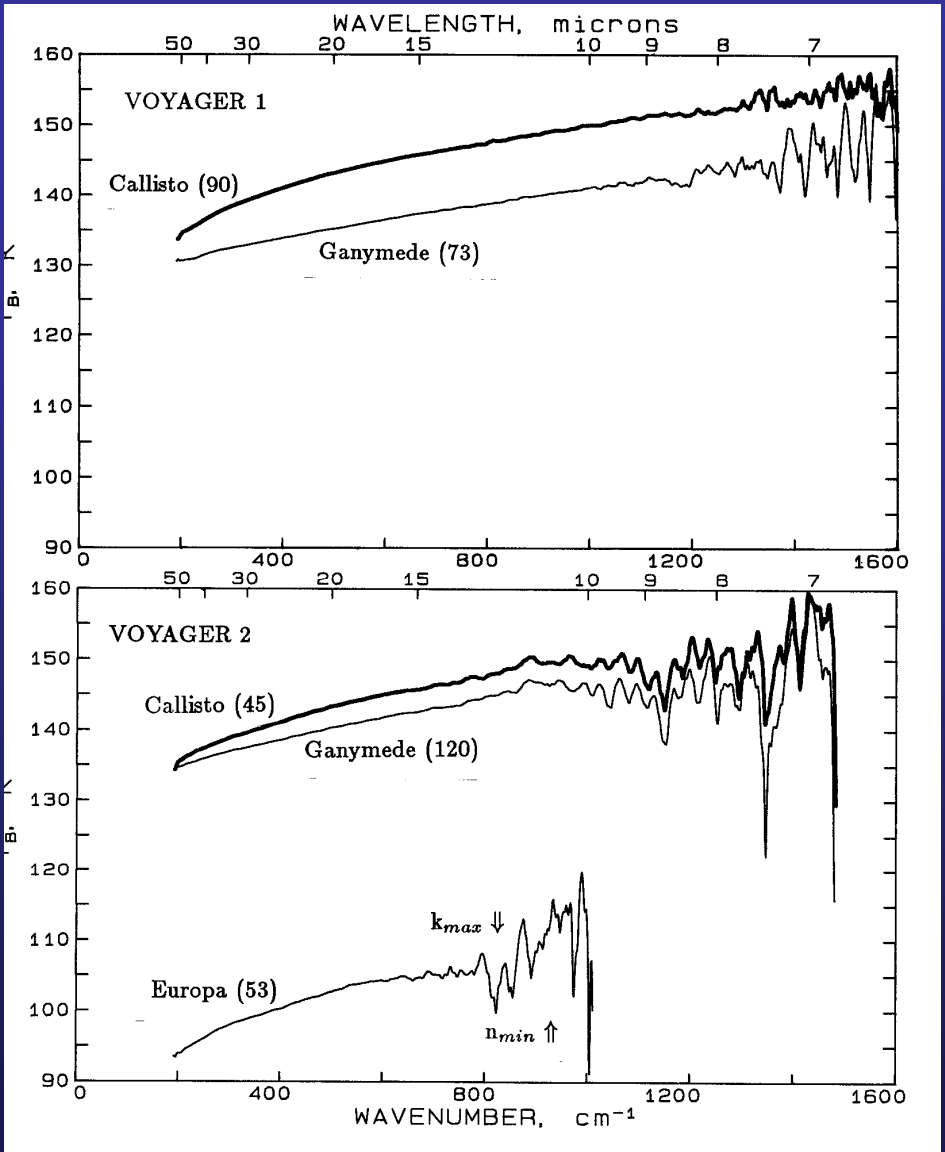
•Thermal IR - Ground-based observations and Voyager IRIS Spectra (both 1 and 2)

G: 136-147 C: 147-158 K

•Radio/mm/submm - Single dish and interferometric observations show conflicting results (see Muhleman and Berge 1991)

	G:	C:
cm:	< 70 K	~90 K
submm:	~110 K	~130 K

Extremely low temperatures for Ganymede in radio very low emissivities = very high dielectric constants

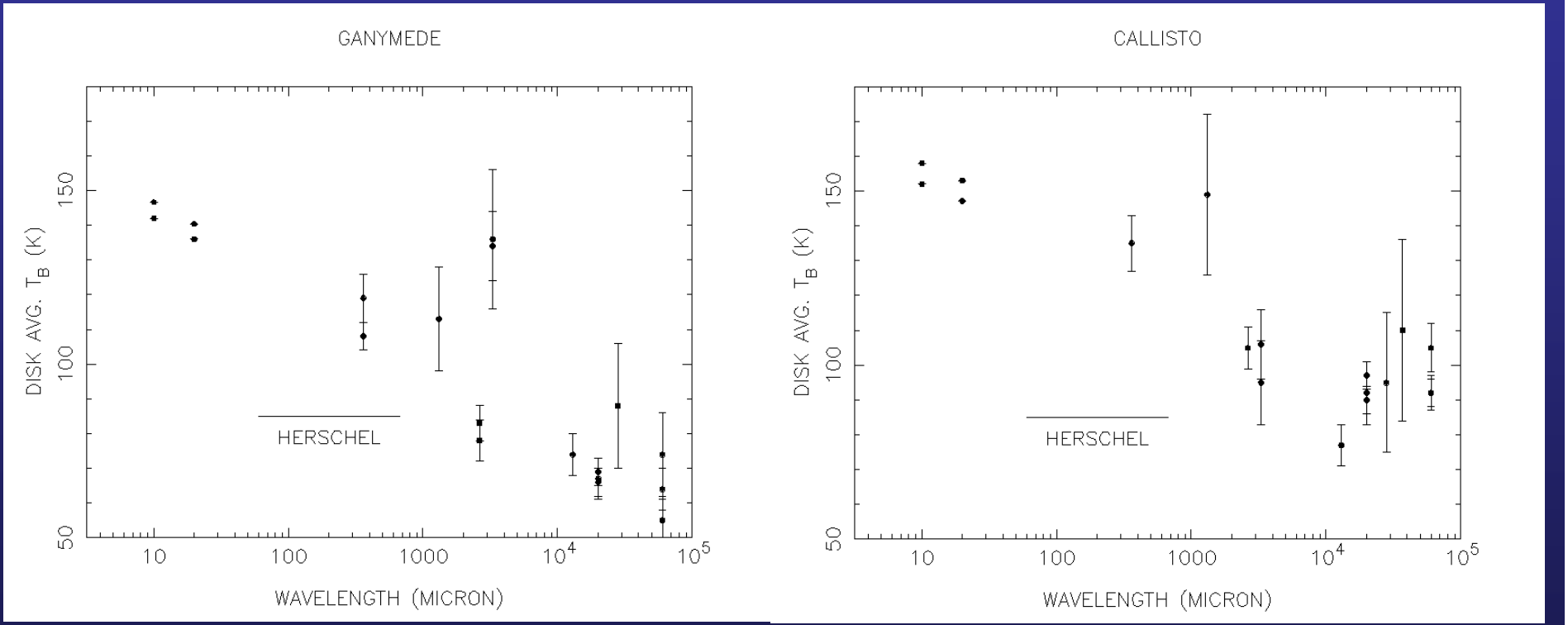


Voyager IRIS

Discussed extensively in work by John Spencer, inc. his dissertation (1989) where I've cribbed some figures…

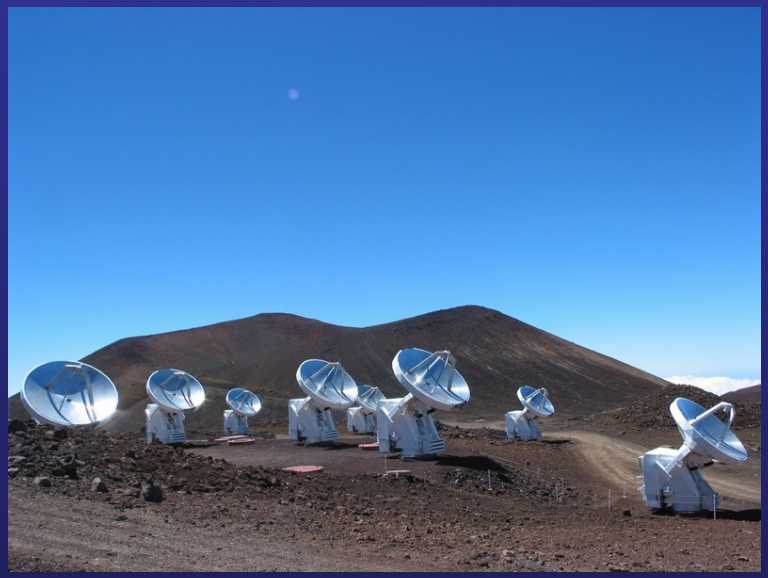
TB ~ 140 -150 K for Callisto, 130 - 143 K for Ganymede, no obvious spectral features in 10--50 micron region.

Historical Brightness Measurements



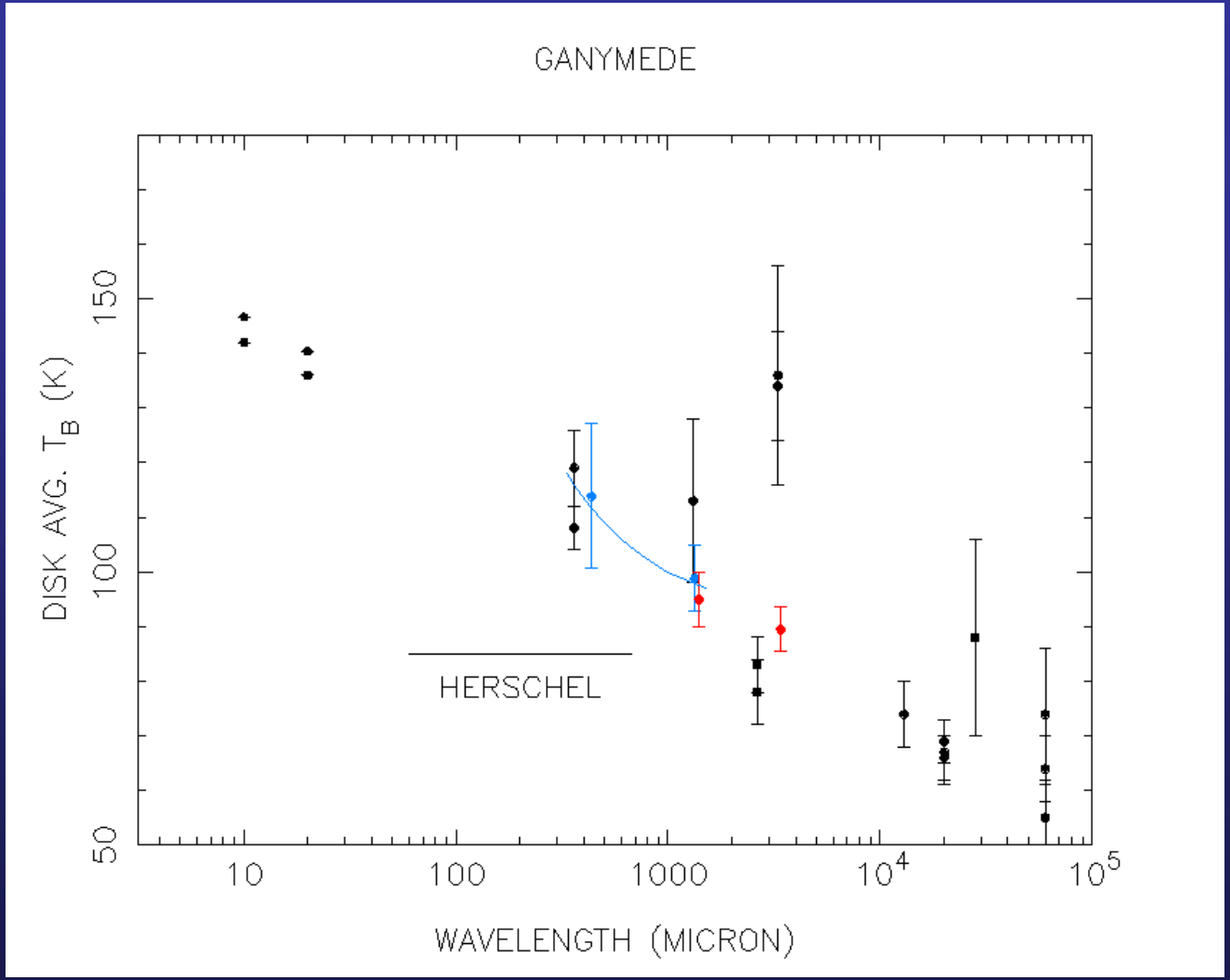
Recent mm/submm calibration

IRAM PdBI 6x15m

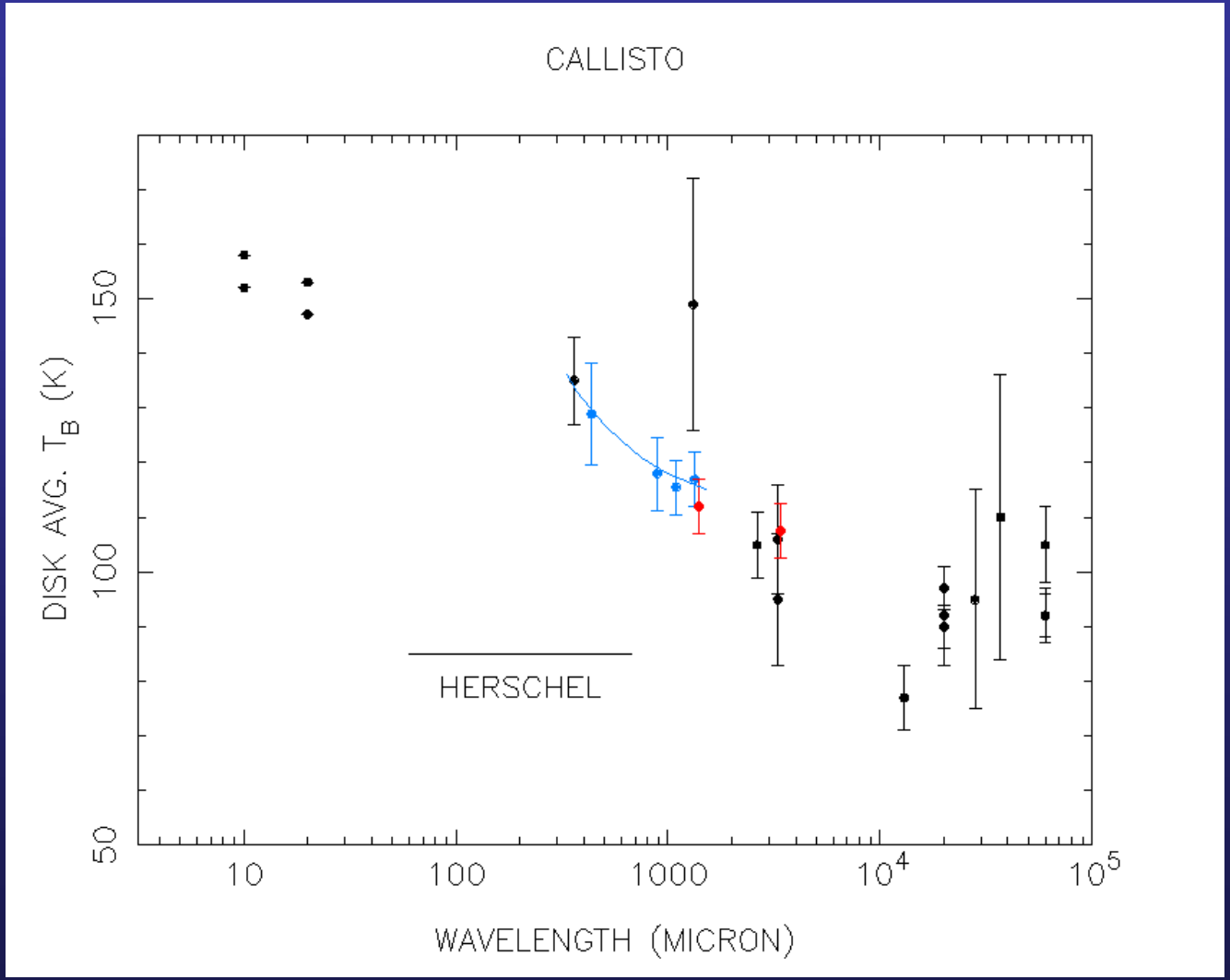


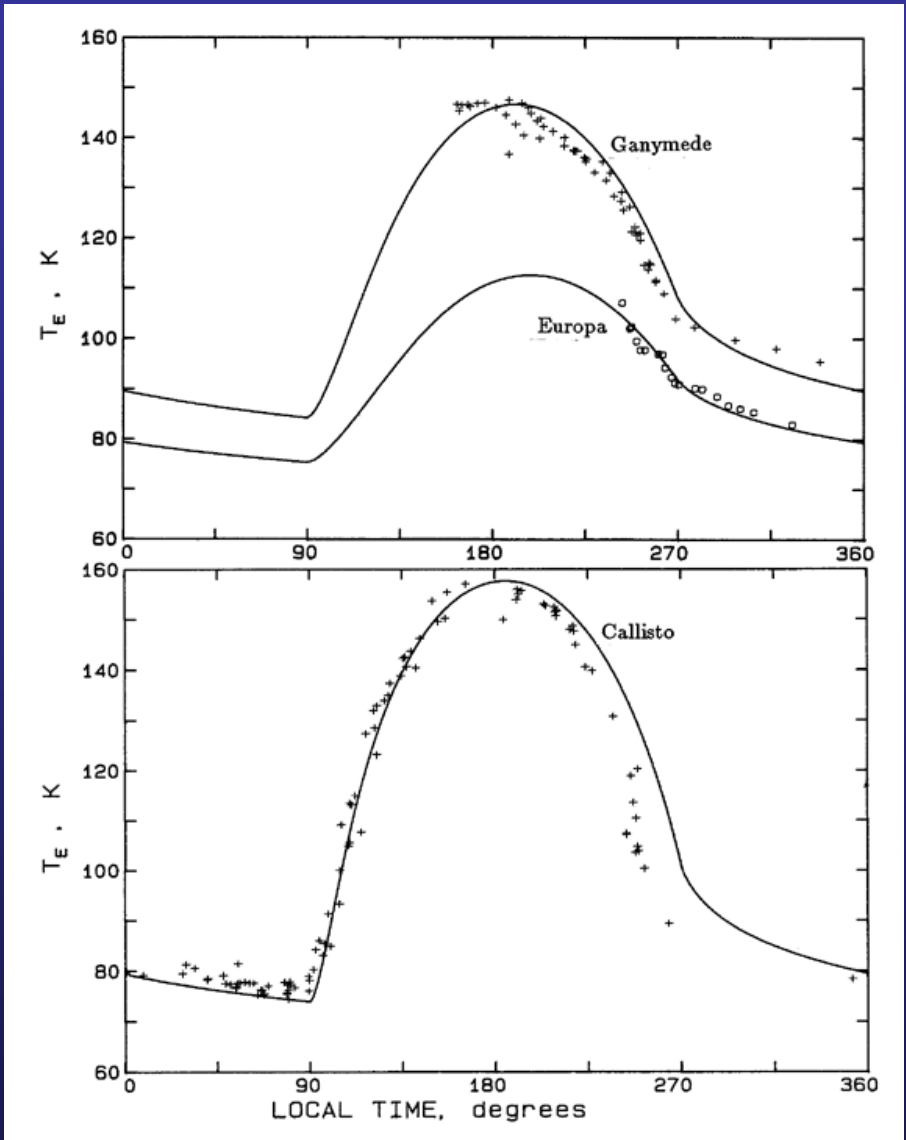
SMA 8x6m

Ganymede: New measurements



Callisto: New Measurements



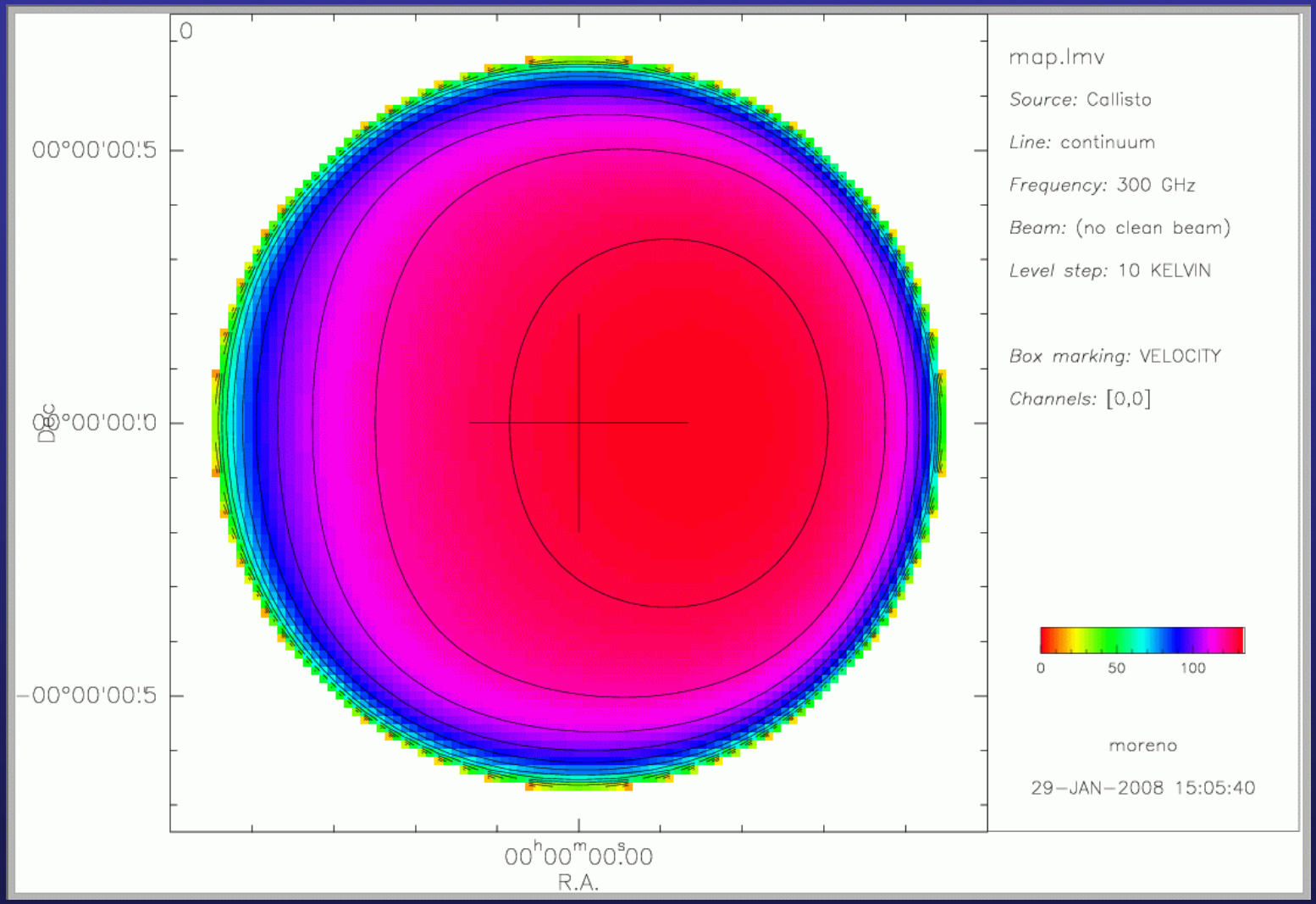


Voyager IRIS modeling: diurnal variability

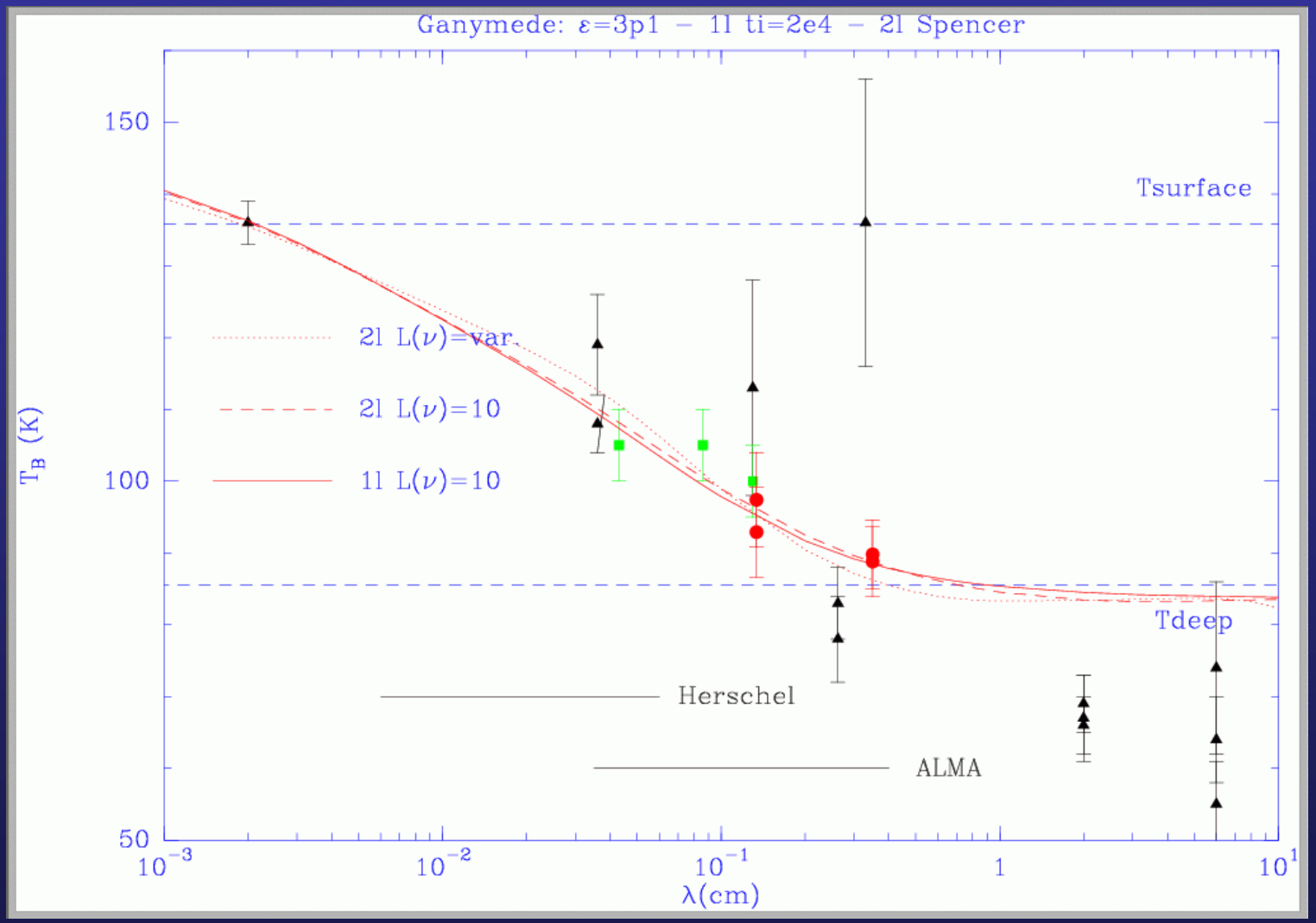
Continued into mm/submm regime by R. Moreno

1 layer and 2 layer models considered, as with Spencer etc.

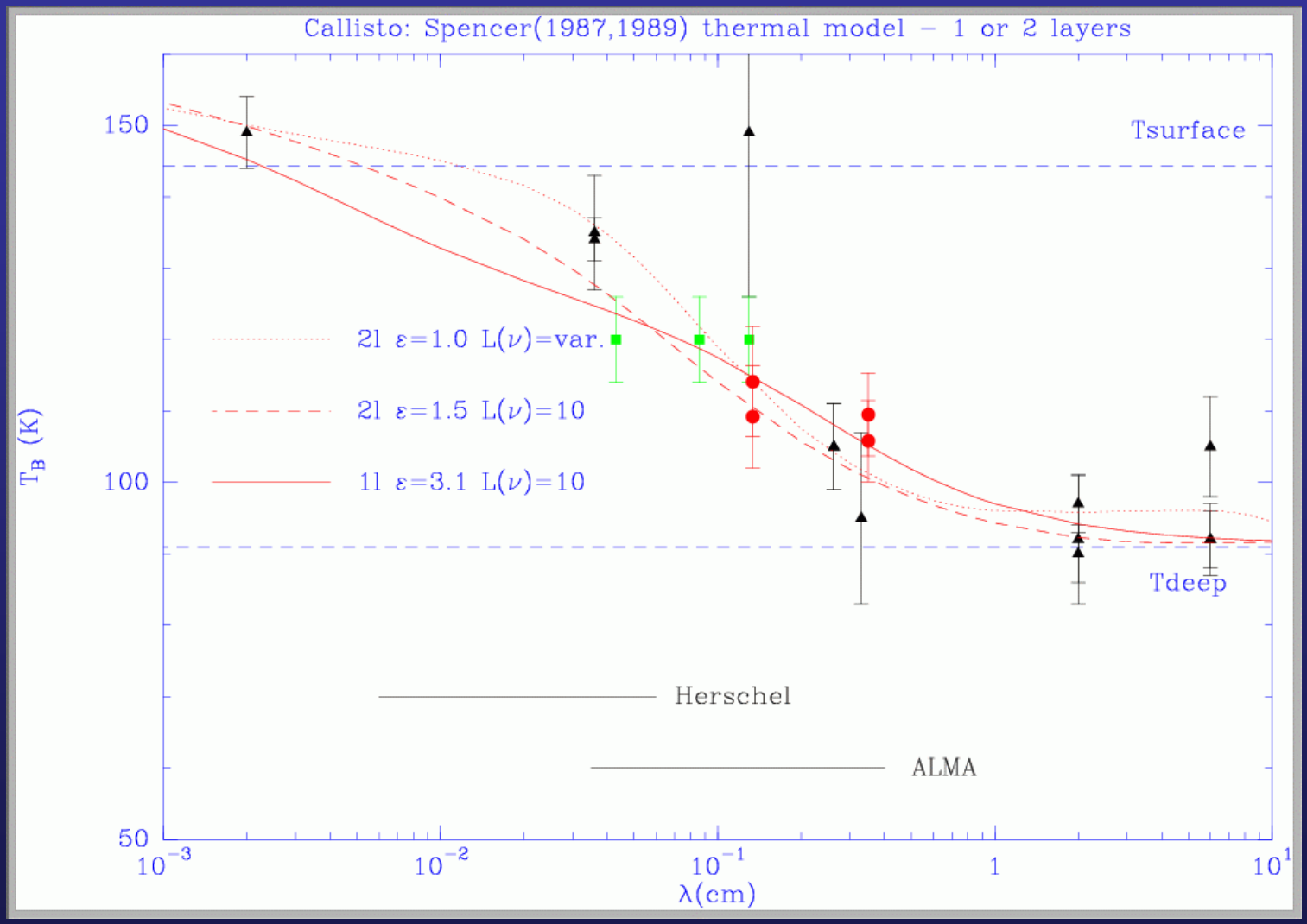
Thermal modeling example: Callisto



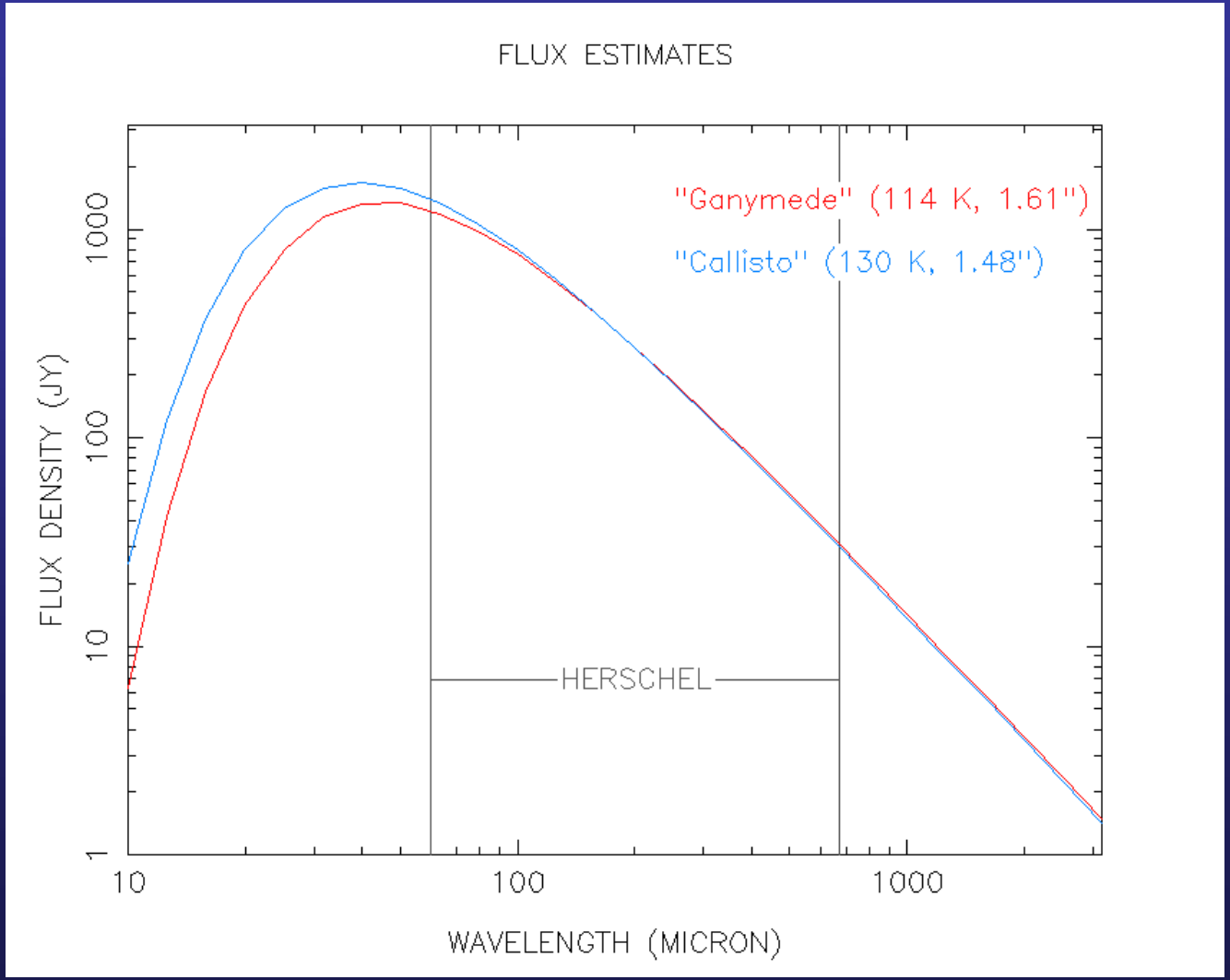
Ganymede


Ganymede: ε=3p1 – 1l ti=2e4 – 2l Spencer
150
100
50
Tsurface
Tdeep
2l L(ν)=var.
2l L(ν)=10
1l L(ν)=10
Herschel
ALMA
T_B (K)
10^-3
10^-2
10^-1
1
10^1
λ(cm)

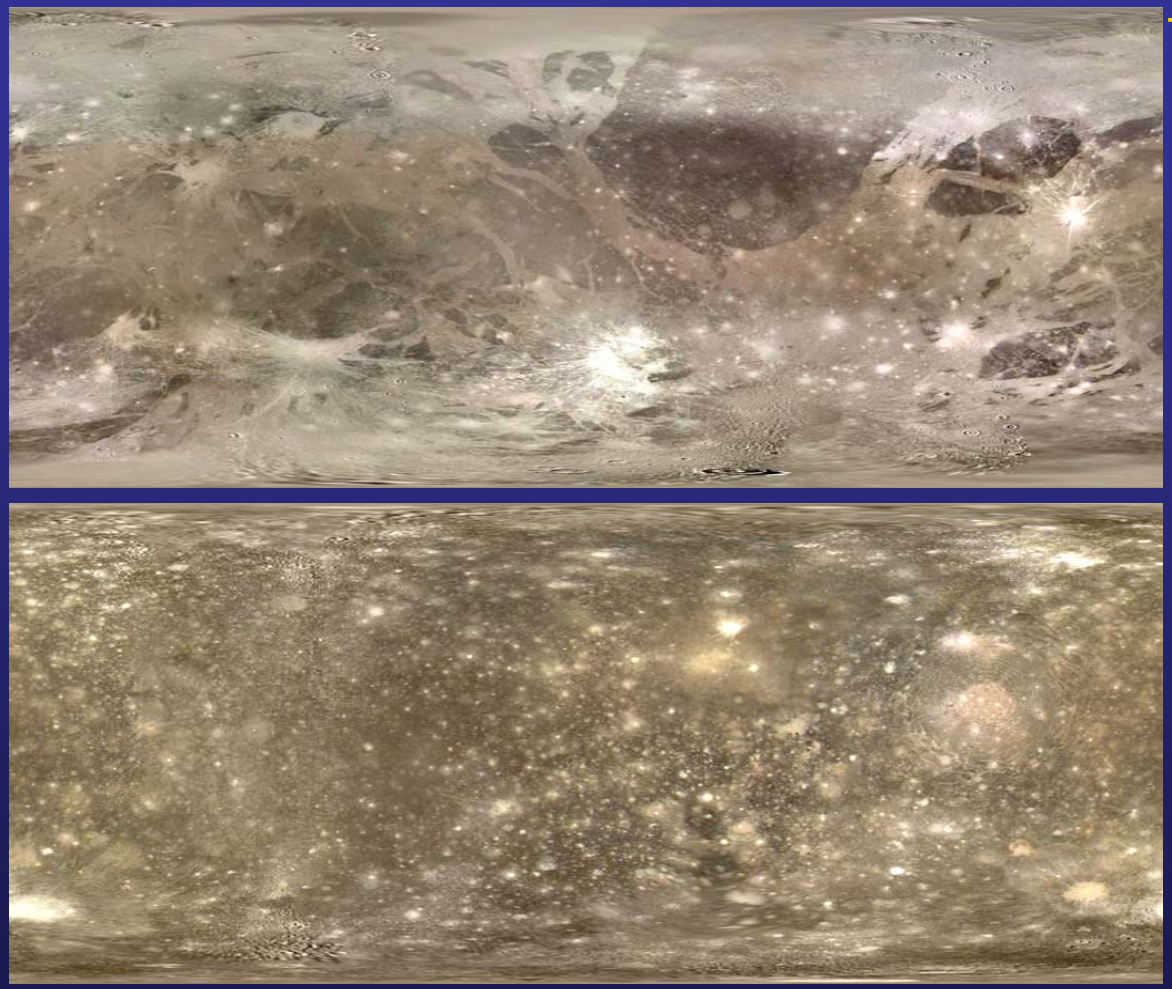
Callisto


Callisto: Spencer(1987,1989) thermal model – 1 or 2 layers
150
100
50
Tsurface
Tdeep
2l ε=1.0 L(ν)=var.
2l ε=1.5 L(ν)=10
1l ε=3.1 L(ν)=10
Herschel
ALMA
T_B (K)
10^-3
10^-2
10^-1
1
10^1
λ(cm)

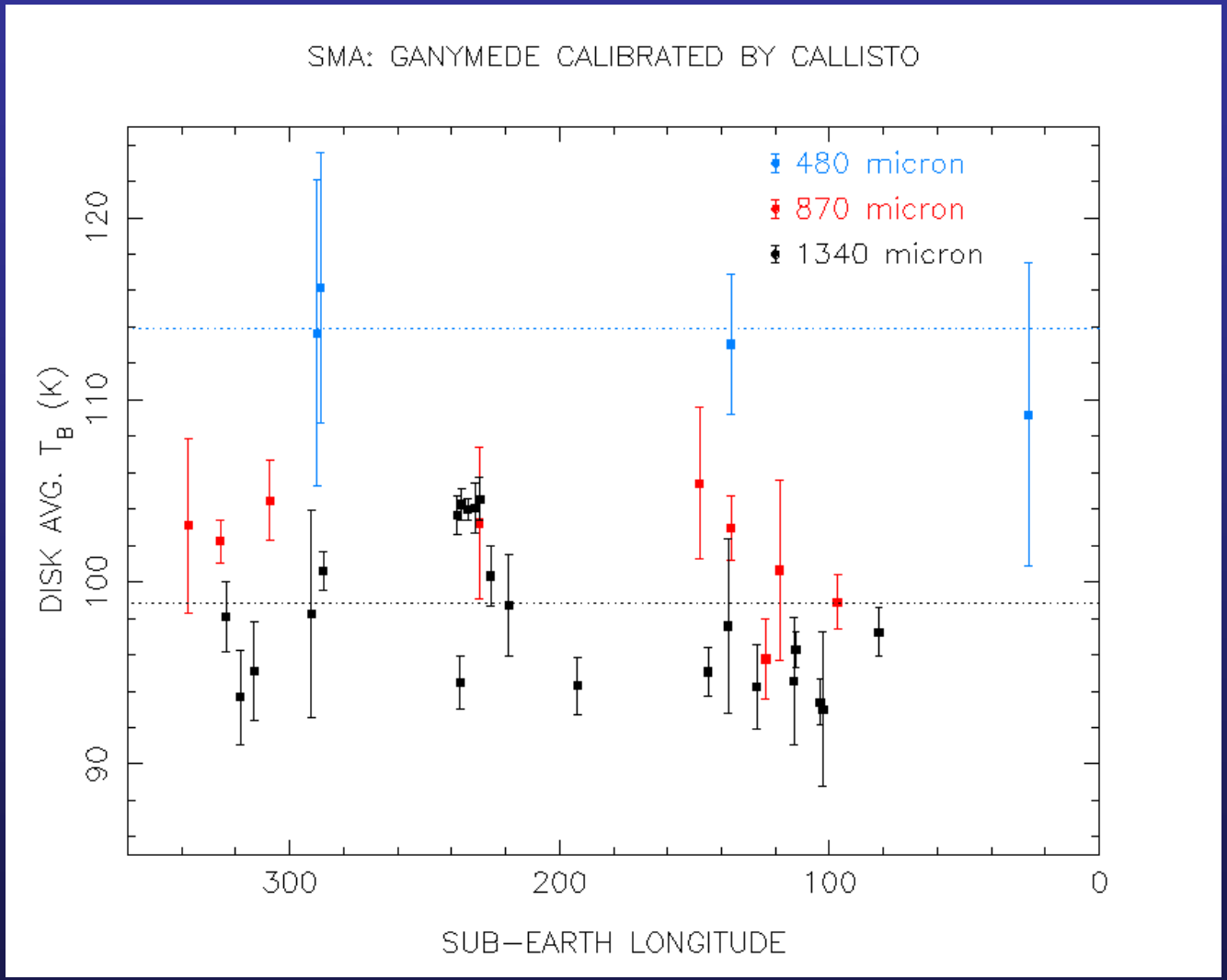
Model Flux Densities



Surface Features



Ganymede: Relative Calibration



Spectral Features? ISO observations

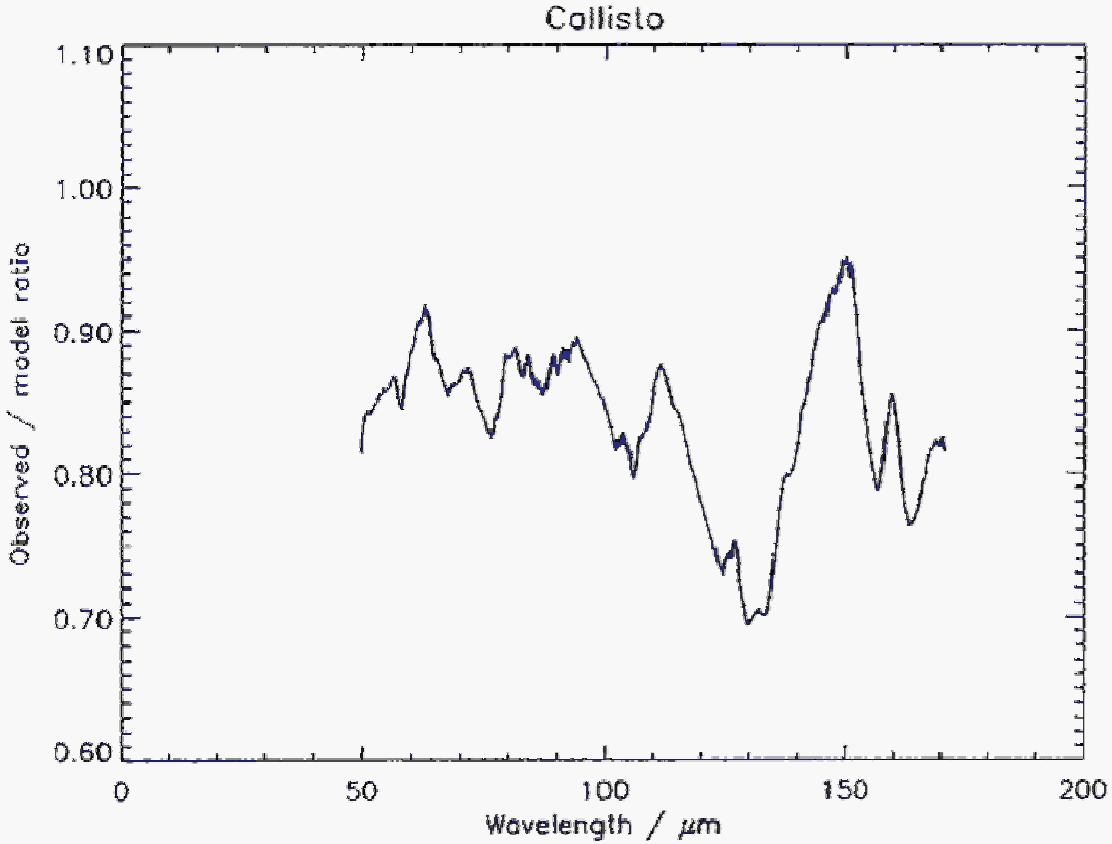


Figure 3. Ratio between measured and model spectrum of Callisto.

Burgdorf et al 2000

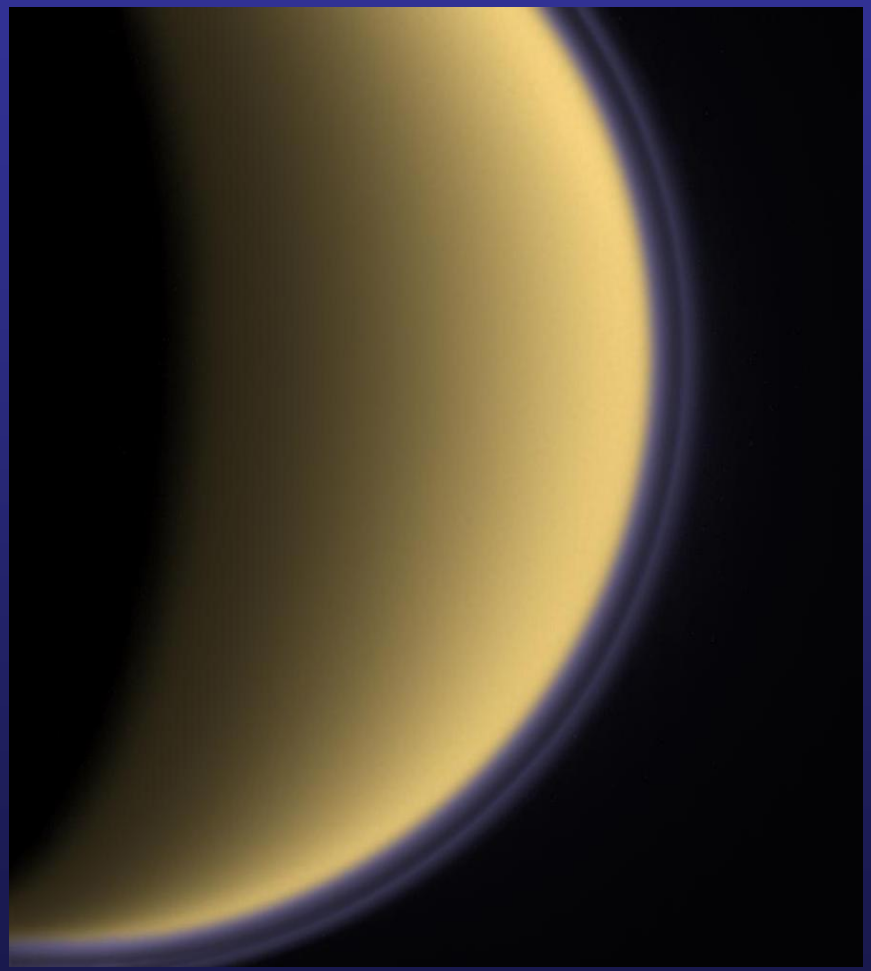
Summary

Ganymede and Callisto are good alternatives for absolute flux calibration standards, with Callisto being preferred as it is:

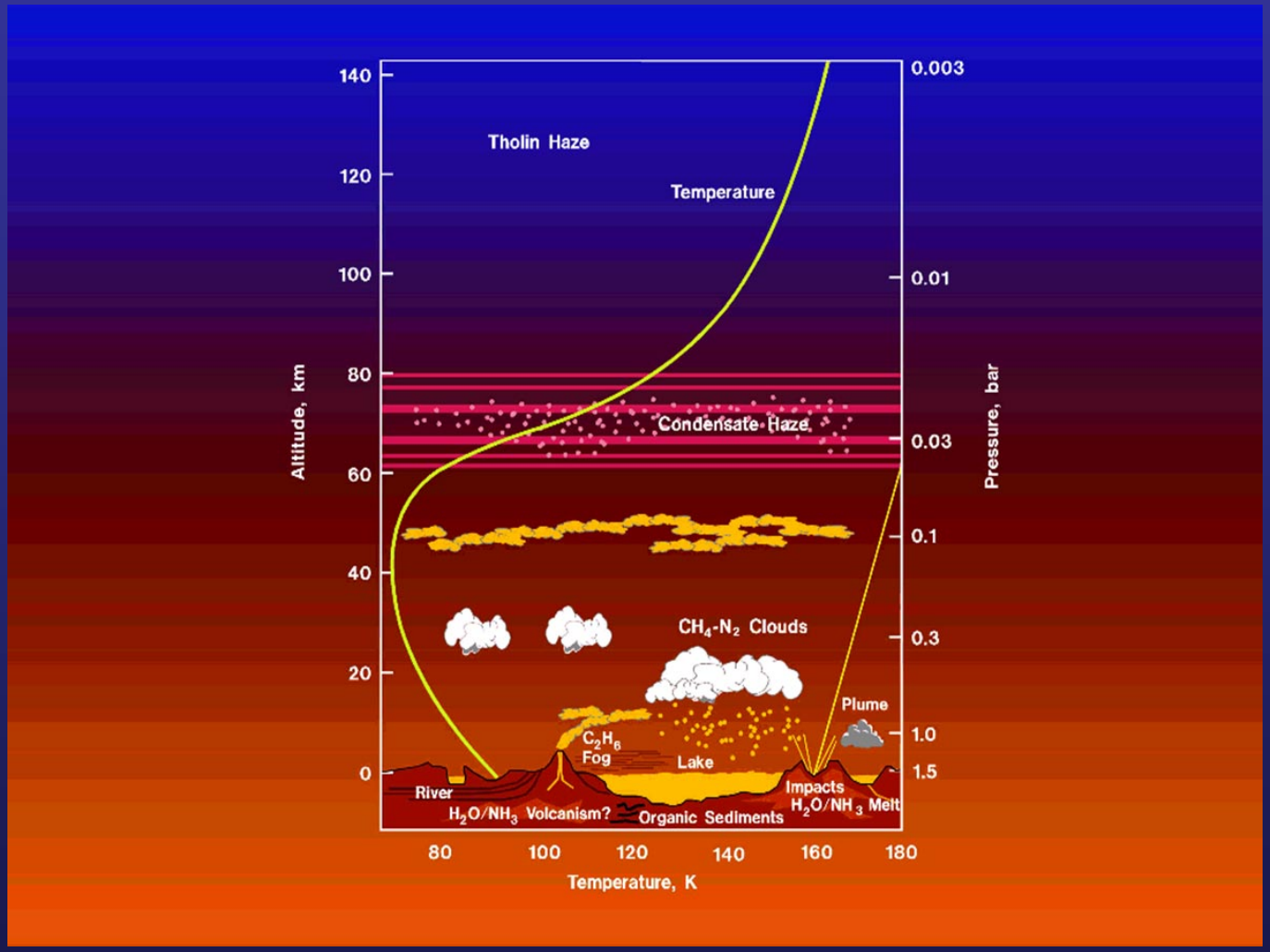
- Warmer
- Typically far* from Jupiter
- Surface emissivity better understood at least at longer wavelengths

Absolute errors are estimated to be less than 7% in T_B which might be acceptable at >200 micron

Bonus Material: Titan!



Titan Atmospheric Structure



Titan Thermal Continuum

Formed from N_2-N_2, N_2-CH_4 collision induced absorption

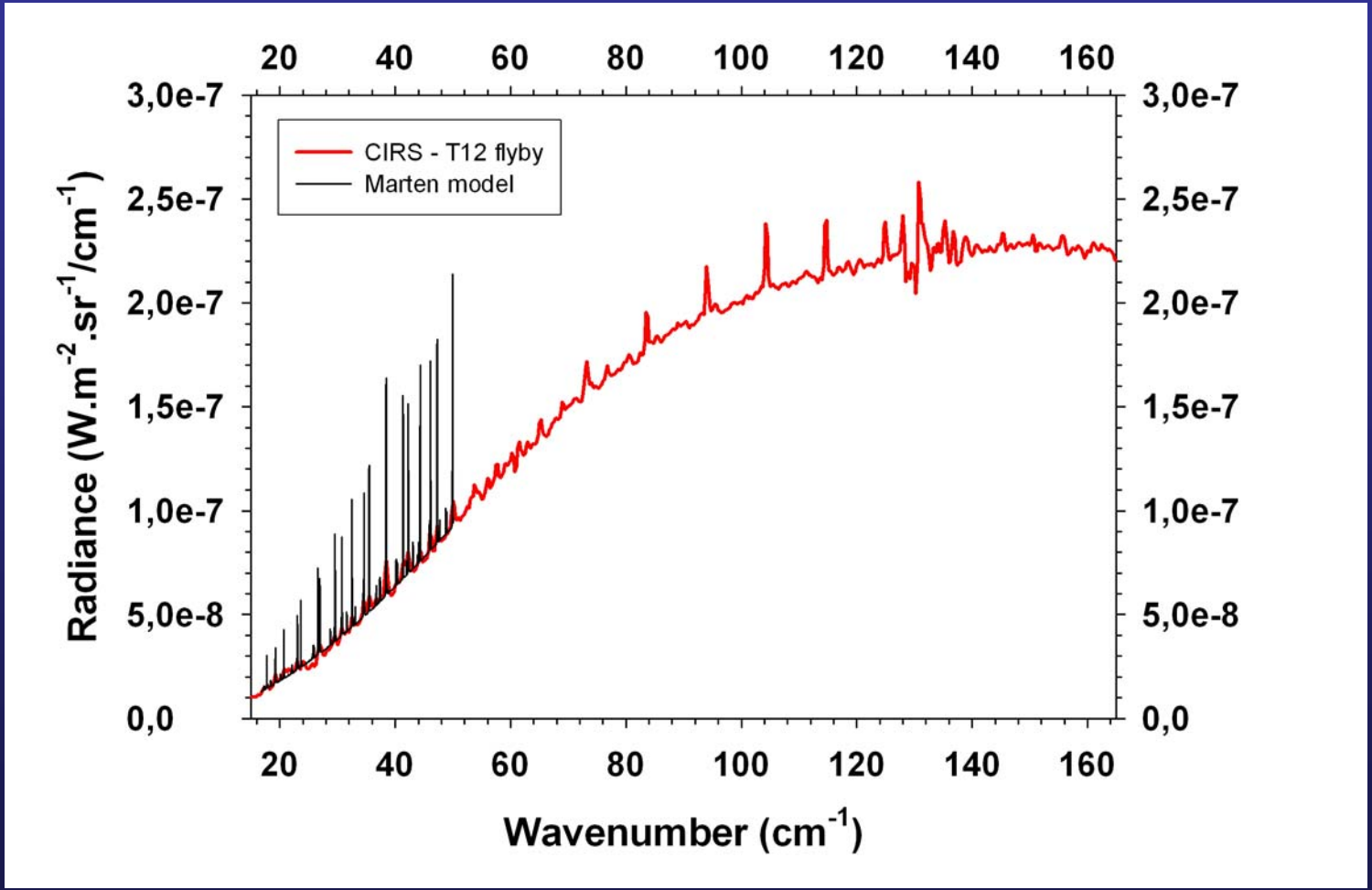
Scales as $P^2\ T^{-5}\ \nu^2$ (in submm, more complicated into far IR)

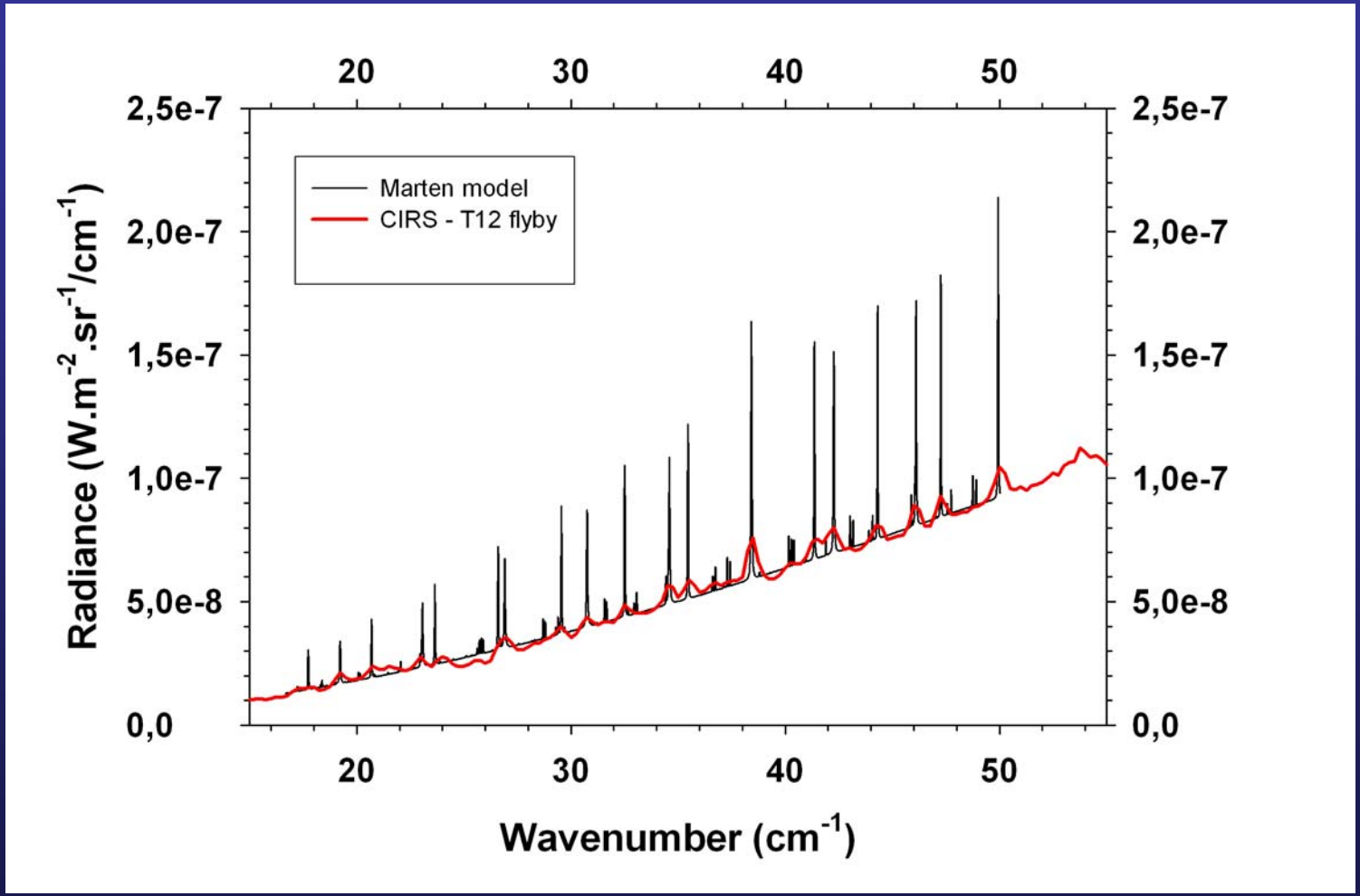
Temperature structure stable and well known (due to Cassini observations).

MANY lines throughout spectral range

Titan: comparison of CIRS data (T12 flyby) with synthetic spectrum (from R. Courtin)

(Resolutions: CIRS=2.5 cm^{-1} ; synth.=0.03 cm^{-1})




Marten model
CIRS - T12 flyby
Radiance (W.m-2.sr-1/cm-1)
Wavenumber (cm-1)
20
30
40
50
2,5e-7
2,0e-7
1,5e-7
1,0e-7
5,0e-8
0,0

Submillimeter Titan Model