A Mars continuum model for calibration of the Herschel data

E. Lellouch and R. Moreno (Obs. Paris)
E. Millour (LMD, Paris)

Why use Mars for calibration ?

- Mars is bright and generally well-understood

- Availability of several *General Climate Models,* reproducing accurately climate data as a function of latitude, longitude, season, and available as database
  - surface pressure and temperatures
  - temperature and winds in lower and middle (0-40 km) atmosphere

- Here, use surface and sub-surface temperatures taken from Mars Climate Database **(www-mars.lmd.jussieu.fr)**

- Reasonable knowledge of surface radio-properties (dielectric constant, penetration length, surface roughness)

Methods (1)

- Integrate local radiance from Mars as:

$$\Phi_{\lambda} = (1 - R(\phi)) \int_0^{\infty} B_{\nu}(T(x)) e^{-k_\lambda x/\cos\theta} k_\lambda \, dx/\cos\theta$$

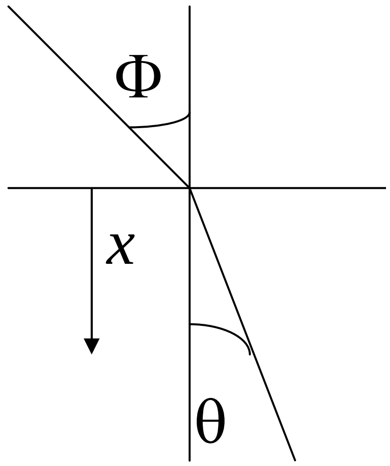
where:

- T(x) = subsurface temperature profile
- $\boldsymbol{k_\lambda}$ = **subsurface absorption coefficient**
- *R*(ϕ) = Fresnel reflection coefficient,

depending on **dielectric constant** ε

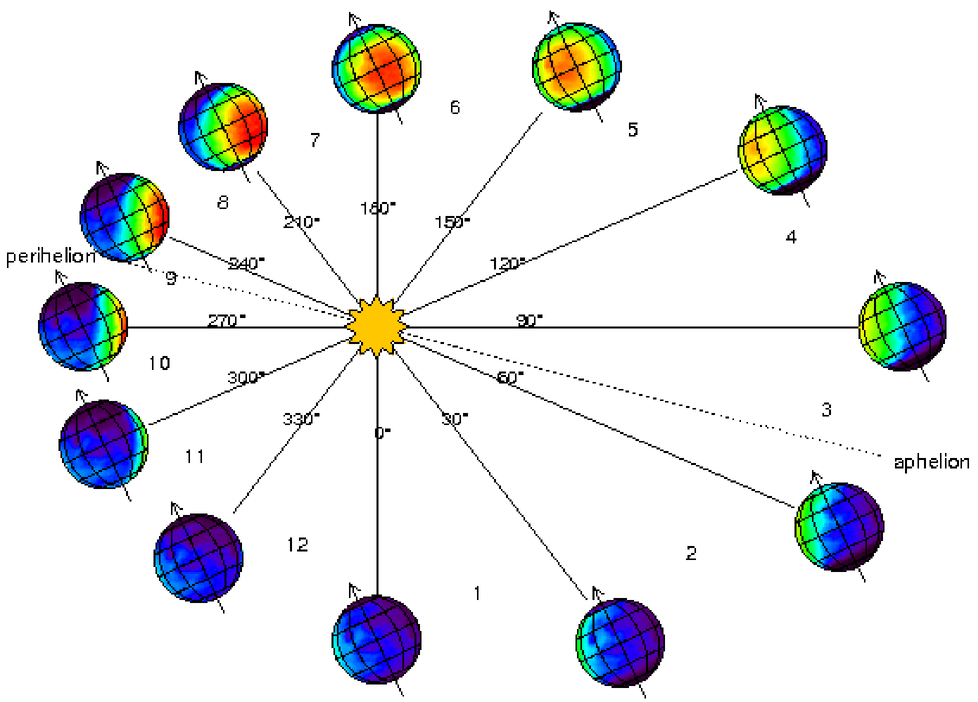
- ϕ = effective emission angle, depending

on **surface roughness**



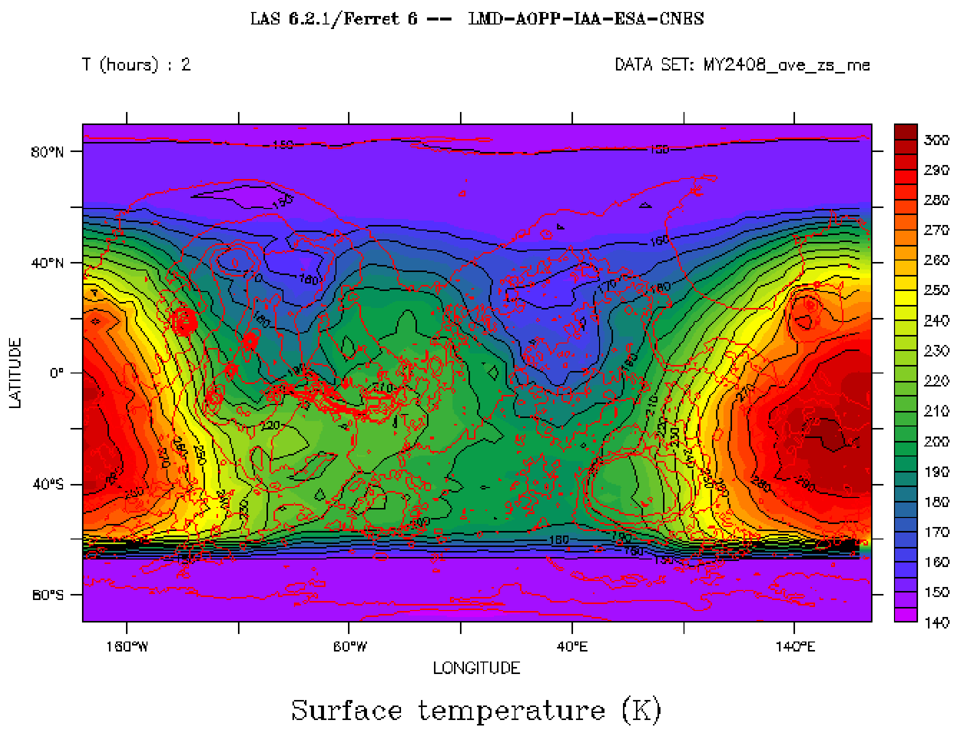
Methods (2)

- For each observing date
  - Read from ephemeris geometric parameters (sub-Earth latitude and longitude, sub-solar longitude, apparent radius)
  - Determine appropriate season (i.e. L_s and sol number)



Methods (3)

- For each observing date
  - Partition martian disk in 50x50 bins
  - For each bin
    - calculate latitude, longitude and local time
    - Query database for surface temperature and 7 sub-surface temperatures, using appropriate Ls and sol

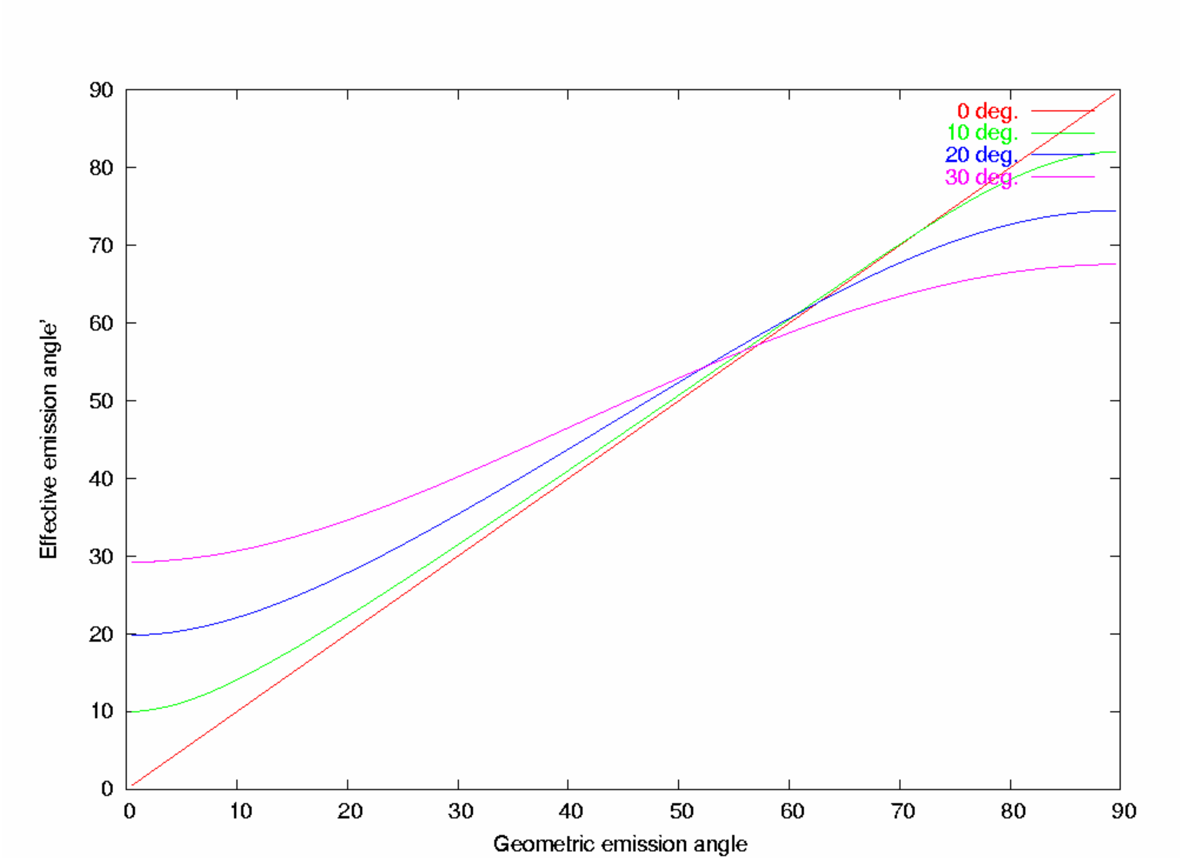


Methods (4)

- For each bin on Mars and each frequency, calculate outgoing radiance and local brightness temperature from previous equation
- Integrate radiances over disk for 1) *total flux* 2) *and average brightness temperature*
- Convolve radiances with specified telescope beam to provide 3) *main-beam flux* 4) *mean Tb in main beam* 5) *main-beam Rayleigh-Jeans tempeature*

Surface roughness description

$$\cos\phi_{eff} = \int_{-\pi/2}^{\pi/2} \cos(\phi - \alpha)\; e^{-\alpha^2/2r^2}\, d\alpha \Big/ \int_{-\pi/2}^{\pi/2} e^{-\alpha^2/2r^2}\, d\alpha$$



r = surface roughness
(slope angle dispersion)

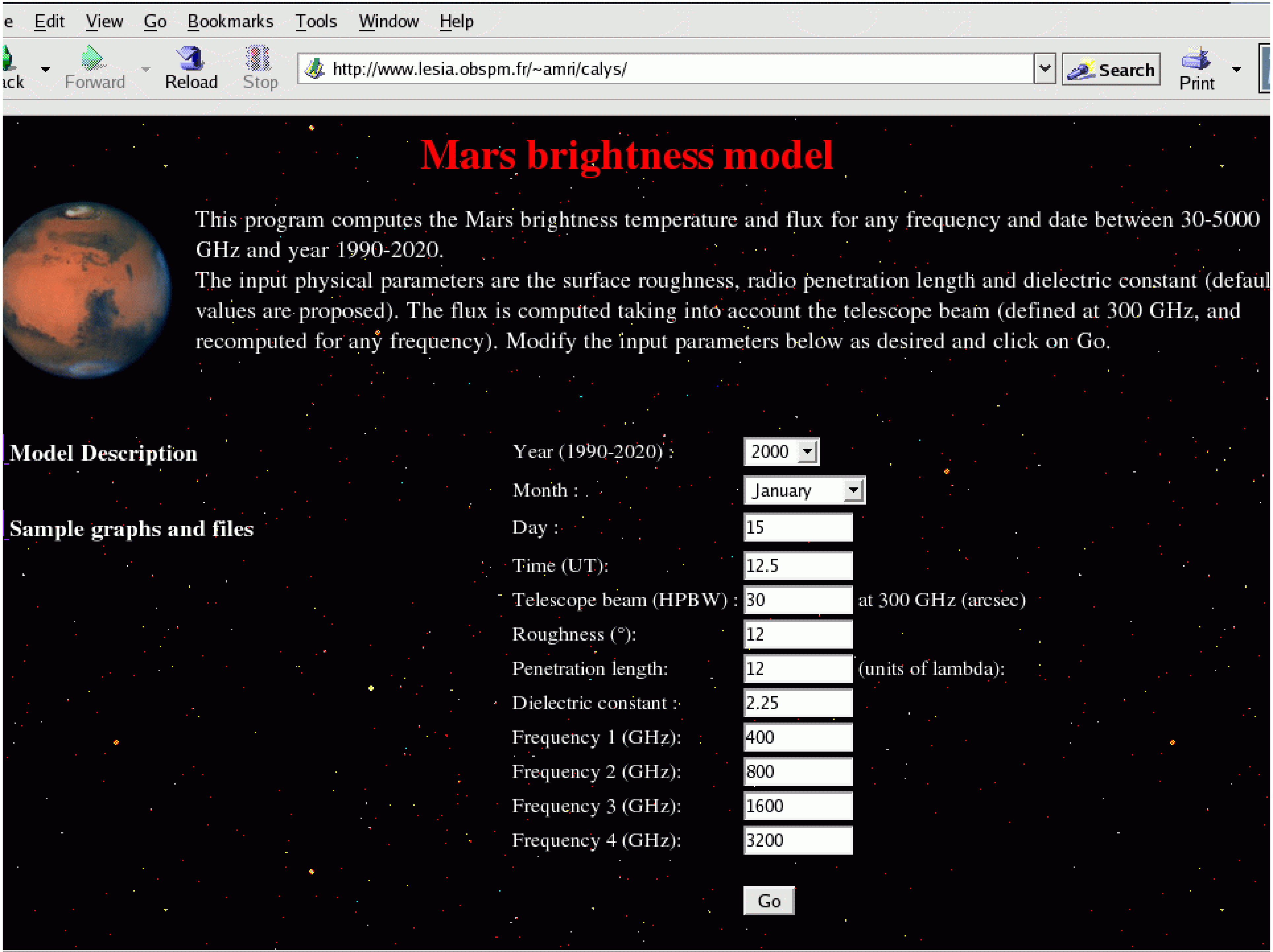
Uncertainties

Quantity	Value	Effect (K)	%
Physical T	+/-5 K [1]	5	2.5%
Dielectric cst	2.25+/-0.25	3	1.5%
Roughness	12°+/-8° (?)	3	1.5%
Abs. Coefficient (λ)	12+/-5(?) λ	2 K at > 1500 GHz ~0 below	1 %
Total, absolute			< 5 %
Total, relative			1-2 %

[1] Except for global dust storm

Access from :

www.lesia.obspm.fr/~lellouch/mars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Mars brightness model
This program computes the Mars brightness temperature and flux for any frequency and date between 30-5000 GHz and year 1990-2020.
The input physical parameters are the surface roughness, radio penetration length and dielectric constant (defaul values are proposed). The flux is computed taking into account the telescope beam (defined at 300 GHz, and recomputed for any frequency). Modify the input parameters below as desired and click on Go.
Model Description
Sample graphs and files
Year (1990-2020) : 2000
Month : January
Day : 15
Time (UT): 12.5
Telescope beam (HPBW) : 30 at 300 GHz (arcsec)
Roughness (°): 12
Penetration length: 12 (units of lambda):
Dielectric constant : 2.25
Frequency 1 (GHz): 400
Frequency 2 (GHz): 800
Frequency 3 (GHz): 1600
Frequency 4 (GHz): 3200
Go

Model Description - Mozilla

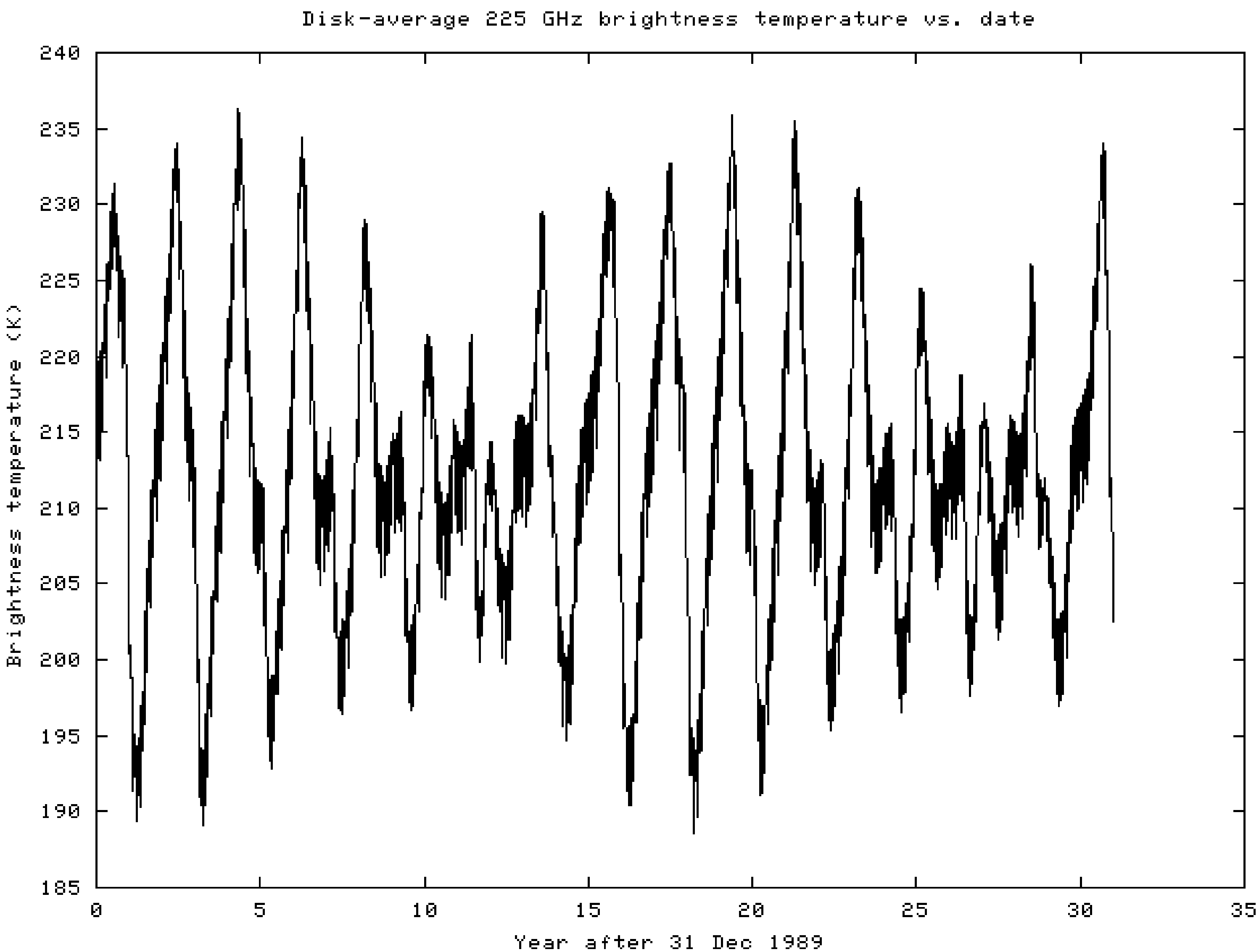
http://www.lesia.obspm.fr/~amri/calys/description.html

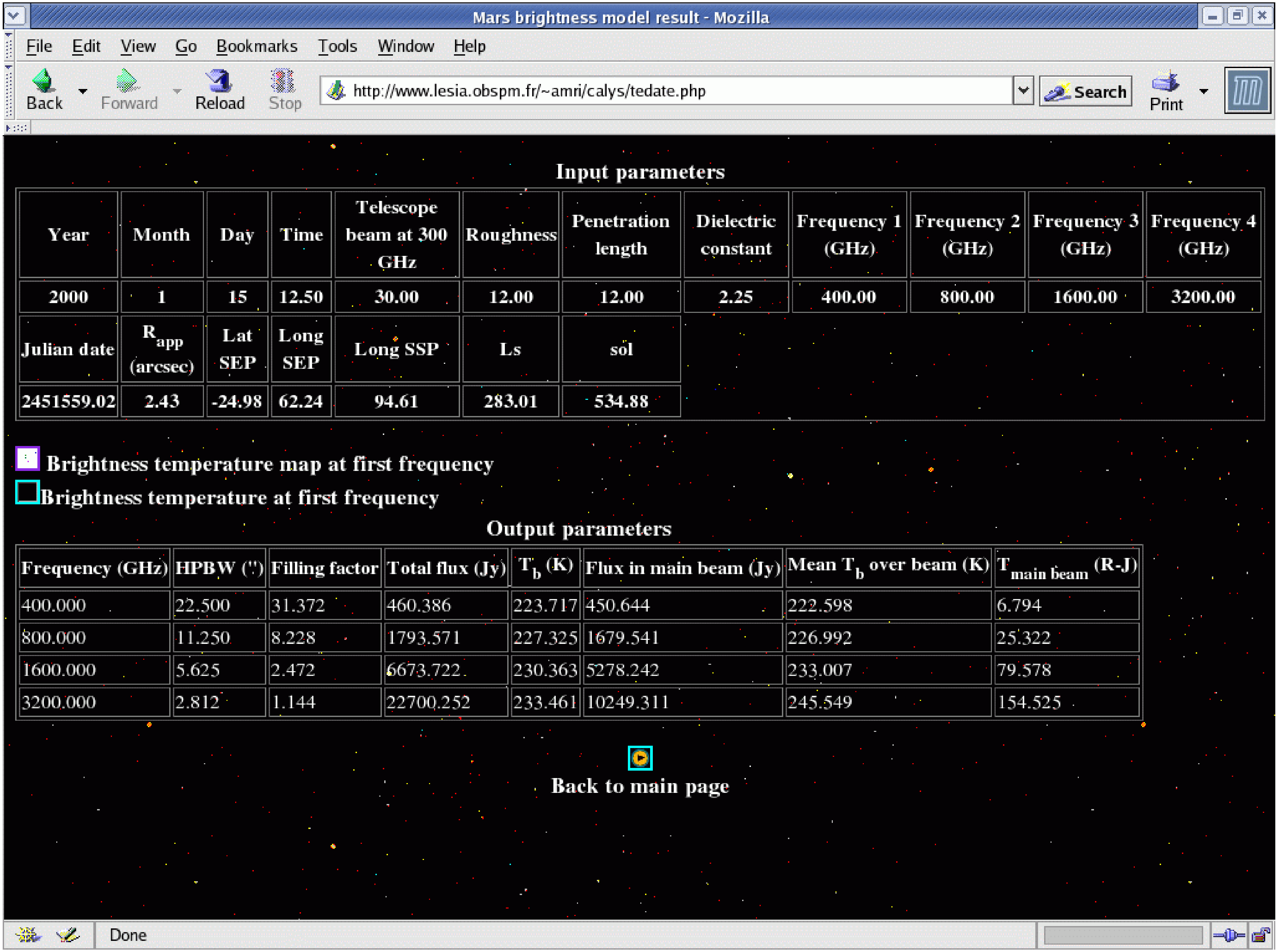
Model description

This model calculates the thermal emission of Mars for any date between 1990 and 2020
and any frequencies between 30 and 5000 GHz. Input parameters are:
- Date, including decimal time
- The telescope beam (HPBW = FWHM) at a reference frequency of 300 GHz. This is used to calculate the telescope beam at any frequency assuming it is exactly proportional to wavelength.
- The surface roughness, expressed in rms degrees of the slopes
- The penetration length of the radiation, expressed in units of the wavelengths (typically 12-15)
- The surface dielectric constant (typically 2.2-2.5)
- Four frequencies can be calculated at a time.

Output parameters are:

- a number of physical parameters of Mars for the considered date
- for each frequency
* the beam HPBW
* the filling factor of Mars in the beam, defined as
f = 1/ (1 - 2** [-(R_app/HWHM)^2], where R_app is the apparent radius of Mars
and HWHM = 1/2 HPBW is the beam half-width at half-maximum
* the total flux (Jy) emitted by Mars
* the associated mean Planck brightness temperature over the planet (Tb), with no
beam convolution
* the flux in the main beam (Jy)
* the associated Planck brightness temperature. This brightness temperature is
essentially the mean (beam-weighted) brightness temperature over the regions
of Mars encompassed in the beam. It is noted Tb_beam.
* the main-beam Rayleigh-Jeans temperature (T_mb), accounting for filling factor.
T_mb is related to antenna temperature T_a* by Ta* = T_mb * B_eff/ F_eff.


Disk-average 225 GHz brightness temperature vs. date
Brightness temperature (K)
240
235
230
225
220
215
210
205
200
195
190
185
0
5
10
15
20
25
30
35
Year after 31 Dec 1989



Input parameters

Year	Month	Day	Time	Telescope beam at 300 GHz	Roughness	Penetration length	Dielectric constant	Frequency 1 (GHz)	Frequency 2 (GHz)	Frequency 3 (GHz)	Frequency 4 (GHz)
2000	1	15	12.50	30.00	12.00	12.00	2.25	400.00	800.00	1600.00	3200.00
Julian date	**R_{app} (arcsec)**	**Lat SEP**	**Long SEP**	**Long SSP**	**Ls**	**sol**					
2451559.02	2.43	-24.98	62.24	94.61	283.01	534.88					

Brightness temperature map at first frequency

Brightness temperature at first frequency

Output parameters

Frequency (GHz)	HPBW (")	Filling factor	Total flux (Jy)	T_b (K)	Flux in main beam (Jy)	Mean T_b over beam (K)	$T_{main\ beam}$ (R-J)
400.000	22.500	31.372	460.386	223.717	450.644	222.598	6.794
800.000	11.250	8.228	1793.571	227.325	1679.541	226.992	25.322
1600.000	5.625	2.472	6673.722	230.363	5278.242	233.007	79.578
3200.000	2.812	1.144	22700.252	233.461	10249.311	245.549	154.525

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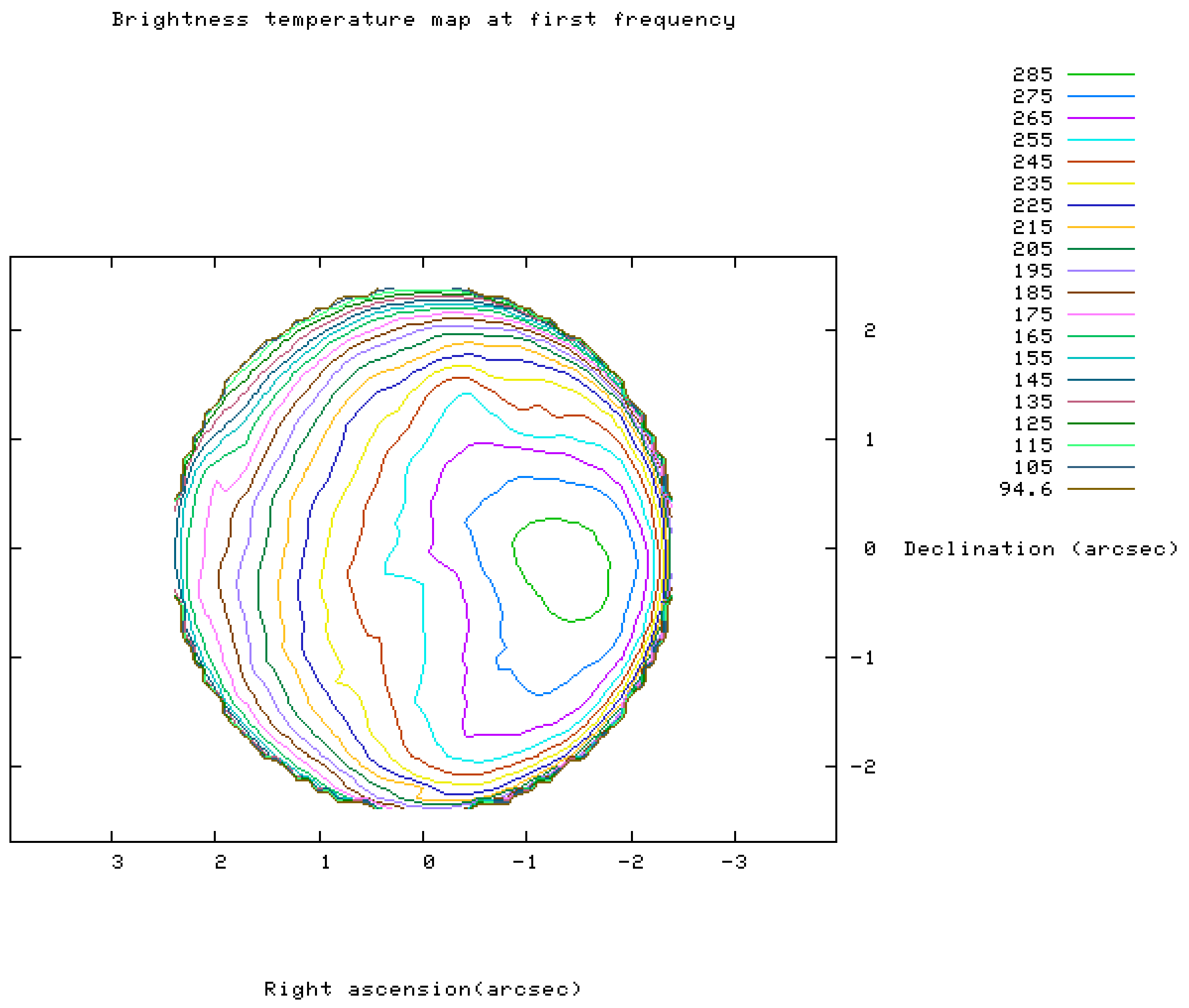
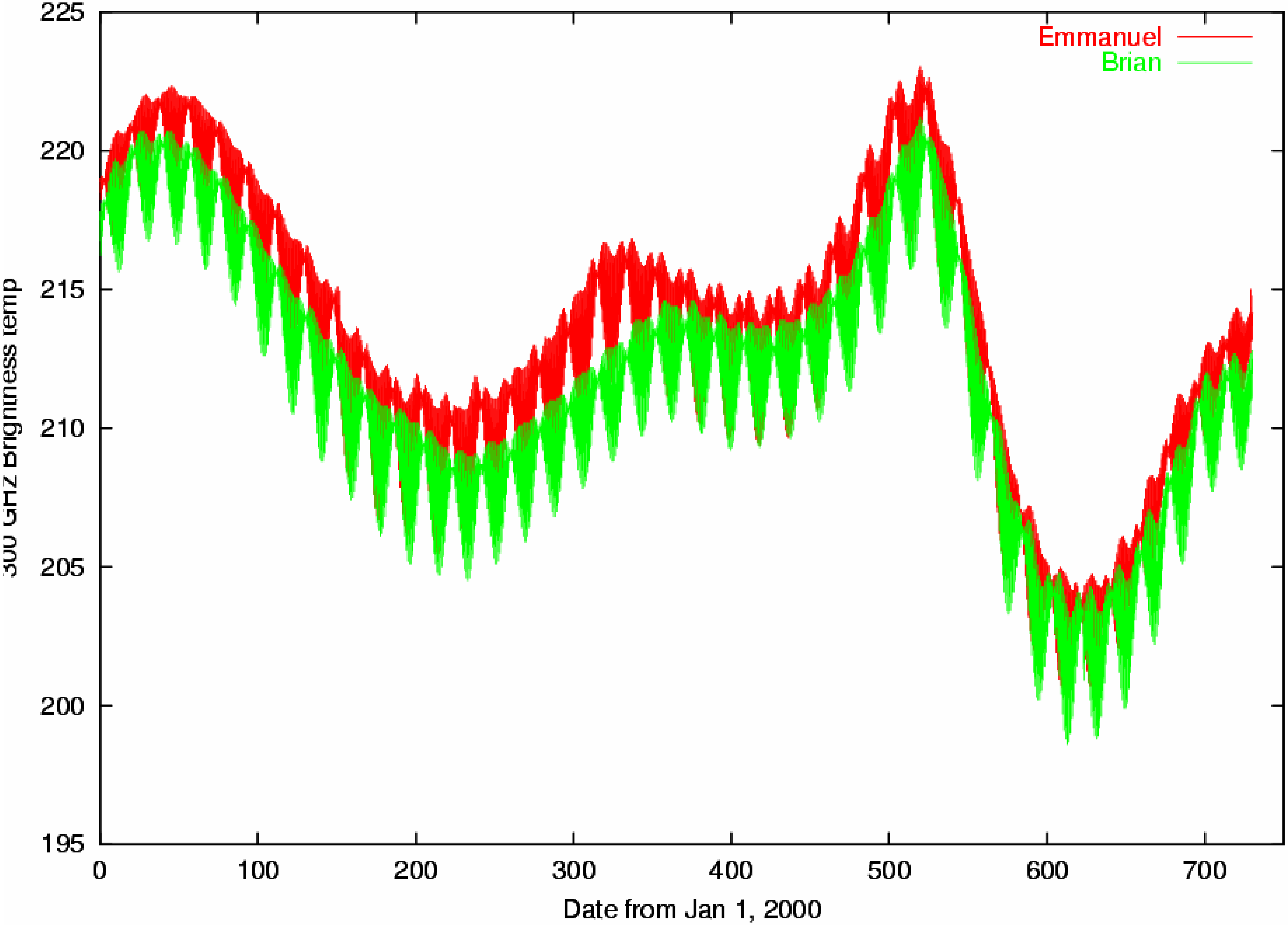


Brightness temperature map at first frequency
285
275
265
255
245
235
225
215
205
195
185
175
165
155
145
135
125
115
105
94.6
2
1
0
-1
-2
Declination (arcsec)
3
2
1
0
-1
-2
-3
Right ascension(arcsec)

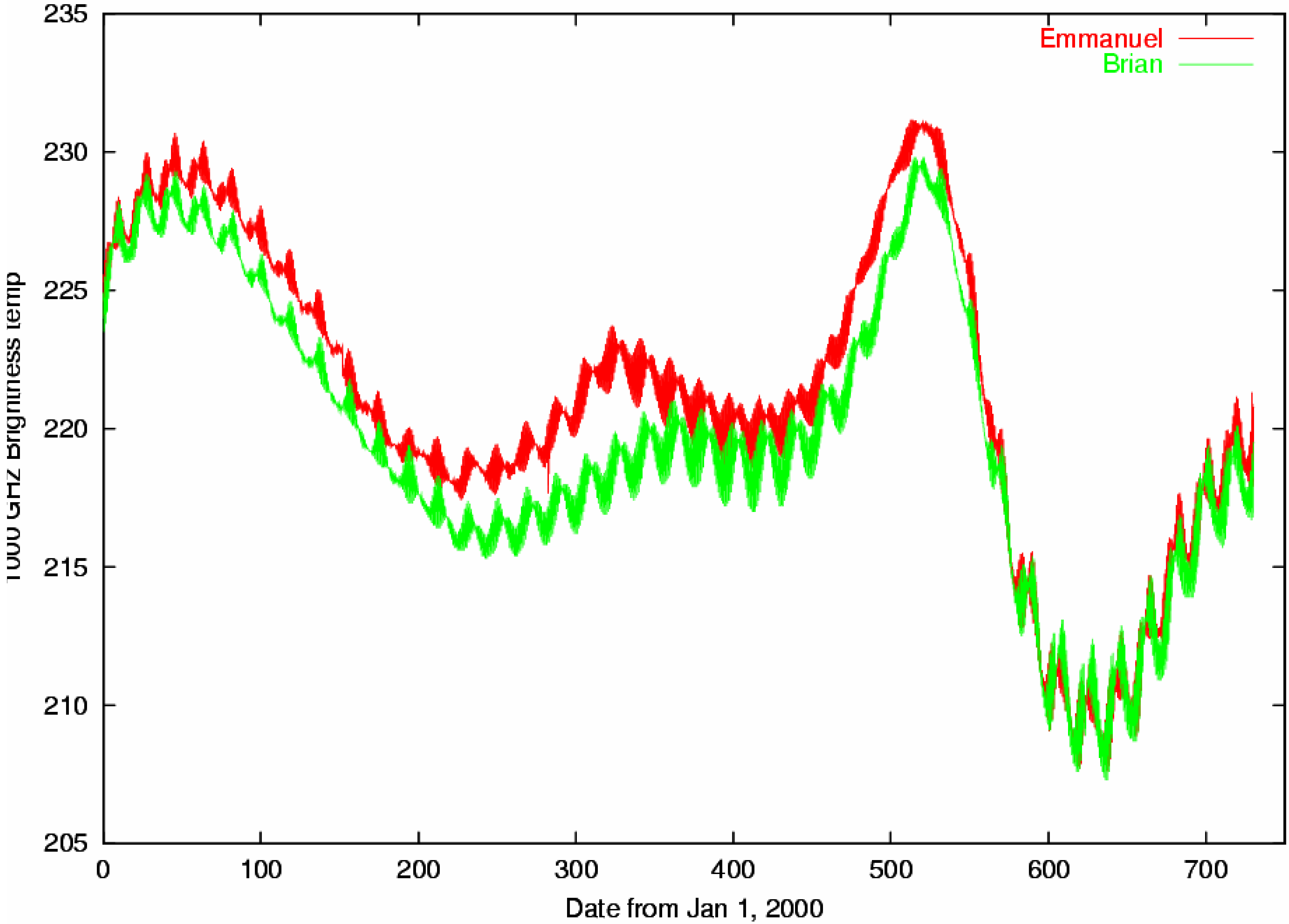
This file tabulates the local brightness temperature (K) at the first frequency (400.00
as a function of RA, DEC displacement from disk center (in arcsec).Zero value means that

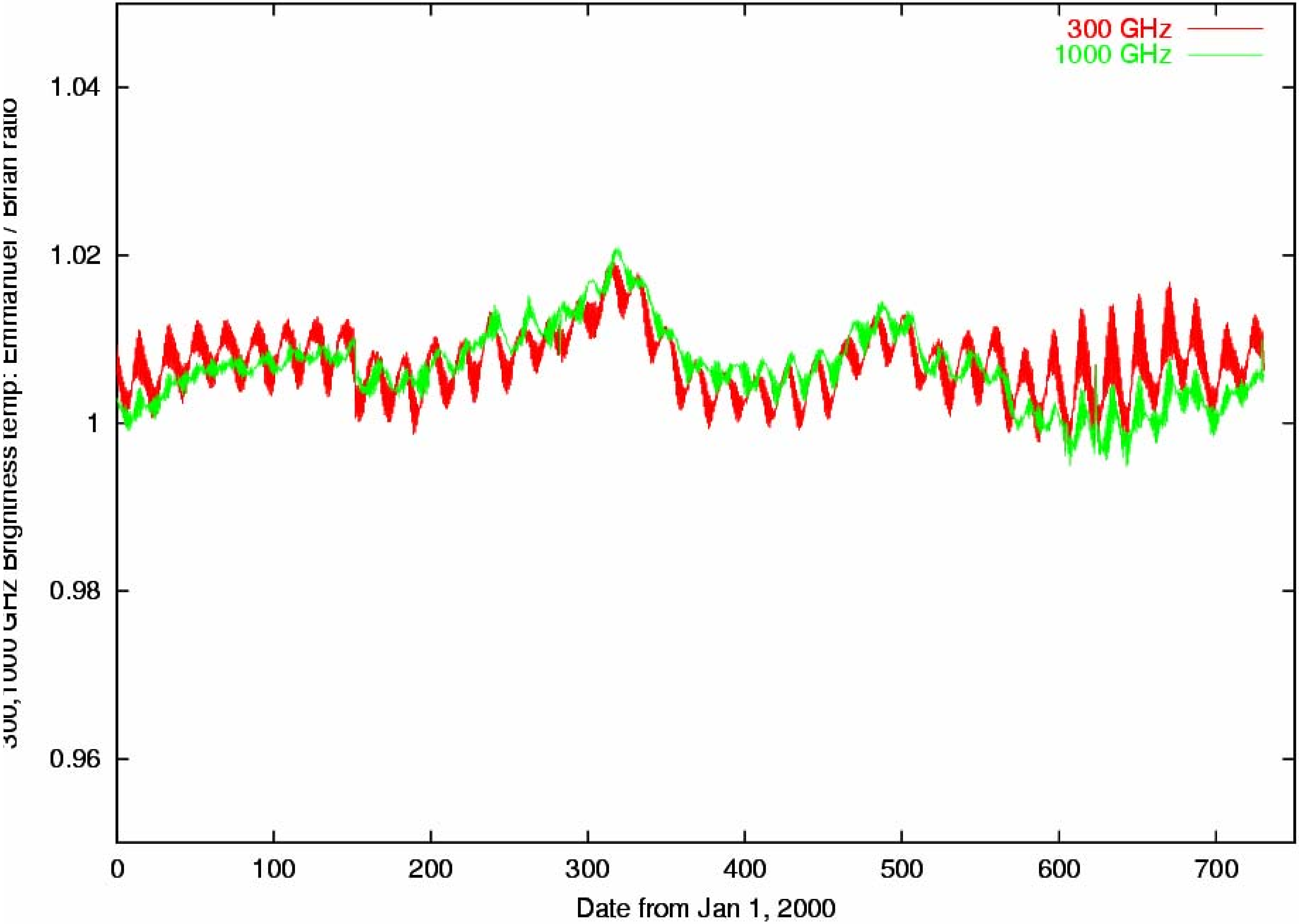
RA	DEC	TB
2.38	-2.38	0.0
2.29	-2.38	0.0
2.19	-2.38	0.0
2.09	-2.38	0.0
1.99	-2.38	0.0
1.90	-2.38	0.0
1.80	-2.38	0.0
1.70	-2.38	0.0
1.61	-2.38	0.0
1.51	-2.38	0.0
1.41	-2.38	0.0
1.31	-2.38	0.0
1.22	-2.38	0.0
1.12	-2.38	0.0
1.02	-2.38	0.0
0.92	-2.38	0.0
0.83	-2.38	0.0
0.73	-2.38	0.0
0.63	-2.38	0.0
0.54	-2.38	0.0
0.44	-2.38	162.2
0.34	-2.38	172.3
0.24	-2.38	181.2
0.15	-2.38	187.7
0.05	-2.38	190.2
-0.05	-2.38	192.7
-0.15	-2.38	193.4
-0.24	-2.38	192.6
-0.34	-2.38	189.3
-0.44	-2.38	181.5
-0.54	-2.38	0.0
-0.63	-2.38	0.0
-0.73	-2.38	0.0
-0.83	-2.38	0.0
-0.92	-2.38	0.0
-1.02	-2.38	0.0

Some comparisons with Brian Butler's model



Emmanuel
Brian
300 GHz Brightness temp
225
220
215
210
205
200
195
0
100
200
300
400
500
600
700
Date from Jan 1, 2000


Emmanuel
Brian
1000 GHz Brightness temp
235
230
225
220
215
210
205
0
100
200
300
400
500
600
700
Date from Jan 1, 2000


300 GHz
1000 GHz
1.04
1.02
1
0.98
0.96
0
100
200
300
400
500
600
700
Date from Jan 1, 2000
300,1000 GHz brightness temp: Emmanuel / Brian ratio