SPIRE Spectroscopic Observations of Mars: Search for Rotational Modulation at Sub-mm Wavelengths

Sunil Sidher and the SPIRE ICC

sunil.sidher@stfc.ac.uk : RAL SPACE

Introduction

Rotational modulation of Mars in the far infrared was first detected by the LWS instrument on-board the Infrared Space Observatory by Sidher et al. (Icarus **147**, 35-41, 2000). They used the thermophysical model developed by Rudy et al (Icarus **71**, 159-177, 1987) to demonstrate unequivocally a ~ 3% modulation in the brightness temperature in all 10 LWS detectors, covering the wavelength range 43-196 µm. The thermal inertia and albedo data employed by the Rudy model relied on results from the Viking Infrared Thermal Mapper (IRTM) at 5° resolution. The model was then able to derive whole-disk dielectric constants and sub-surface densities. In this investigation we have extended the Rudy model to sub-mm wavelengths and applied it to Mars spectra taken with the SPIRE Imaging Fourier Transform Spectrometer (FTS).

Spectral Observations

The spectral coverage of the SPIRE FTS is provided by 2 spider-web bolometer detector arrays operating at ~287mK:
SSW covering 194 – 324 µm (926 – 1550 GHz)
SLW covering 316 – 672 µm (446 – 950 GHz)
Our dataset consists of 13 high resolution observations of Mars observed in "Bright Source" mode. In this mode the SSW/SLW detectors are biased at a much higher voltage of ~176.4mV and de-phased to ~62° (see Nanyao Lu's presentation in this Workshop entitled SPIRE Spectrometer: Calibration of the Bright Mode).

***Table** 1 List of SPIRE FTS Observations in this study*

Date	Time (UT)	Season Ls (°)	Sub-Earth Longitude (°)	Sub-Earth Latitude (°)	Sub-Solar Longitude (°)	Solid Angle (sr/10-10)
2010-May-31	22:41	98.2	329.65	22.40	289.49	6.668
2010-June-22	14:19	108.0	354.82	24.74	316.28	5.403
2011-Oct-16	15:17	16.0	330.98	19.81	4.47	5.584
2011-Oct-16	18:32	16.1	18.42	19.83	51.92	5.592
2011-Oct-16	21:33	16.1	62.46	19.85	95.98	5.596
2011-Oct-17	00:26	16.2	104.54	19.86	138.09	5.605
2011-Oct-17	03:38	16.2	151.25	19.88	184.82	5.609
2011-Oct-17	06:37	16.3	194.80	19.90	228.38	5.617
2011-Oct-17	09:30	16.4	236.89	19.92	270.49	5.621
2011-Oct-17	12:56	16.4	287.01	19.94	320.62	5.629
2012-May-16	02:01	110.0	334.20	24.32	293.39	14.387
2012-Jun-30	22:00	132.5	194.17	26.16	152.55	8.066
2012-Jul-01	03:50	132.6	279.32	26.16	237.72	8.046

Data Processing & Calibration

Data from all the observations were processed using the New Bright Source Mode Pipeline (Version 11 – as described in Lu et al., this workshop).
In addition, the resulting SSW and SLW spectra were corrected for the angular size of Mars using the semi-extended correction tool (as described in Wu et al., this workshop).

The Model

The thermophysical model of Rudy et al (1987) was enhanced in house using the thermal inertia and albedo maps (0.125 degree resolution) derived from the Thermal Emission Spectrometer experiment on-board the Mars Global Surveyor. These maps were binned up to 1 degree resolution. Dielectric constant of 2.25 was used for latitudes between 60 degrees South and 60 degrees North. As in the original Rudy model, surface absorption was ignored in the polar-regions and a dielectric constant of 1.5 in the CO_2 frost layer was assumed. Disk-averaged brightness temperatures were computed at several discrete continuum frequencies, carefully avoiding the H_2O and CO lines. These brightness temperatures were finally converted to flux densities for the times of the observations.
For comparison with the models, the observed and modelled flux densities were normalised to the projected solid angle of the first Mars observation. At each frequency the following flux density ratios were calculated:

$R_O(v,i) = F_O(v,i)/ F_O(v,0)$ $\qquad$ $R_M(v,i) = F_M(v,i)/ F_M(v,0)$

Where $F_O(v,i)$ and $F_M(v,i)$ are the observed and modelled flux densities for the i^{th} observation, while $F_O(v,0)$ and $F_M(v,0)$ are the observed and modelled flux densities for the first observation listed in Table 1. These flux density ratios are plotted in Figure 2.

Frequency /GHz	Spearman Rank Correlation Coefficient	Significance
500	0.83	0.00045
530	0.87	0.00012
570	0.88	0.00006
600	0.86	0.00018
650	0.86	0.00018
720	0.86	0.00015
780	0.91	0.00001
850	0.91	0.00001
900	0.92	0.00001
1020	0.87	0.00012
1070	0.85	0.00022
1350	0.82	0.00053

Table 2 Correlation coefficients between the Mars Model and SPIRE FTS continuum frequencies. A smaller value of the significance indicates a more significant correlation.

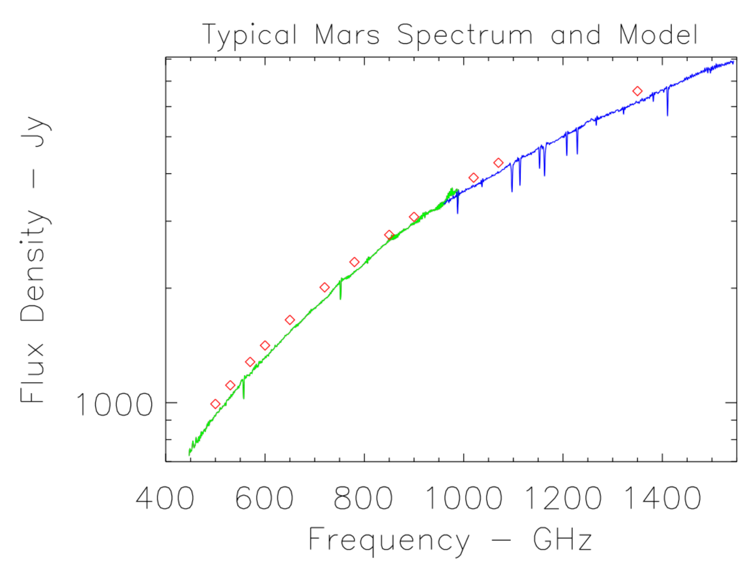

Figure 1 Typical Mars Spectrum (first observation in Table 1) showing the SLW and SSW sub-spectra. The enhanced thermophysical model points are shown as red diamonds

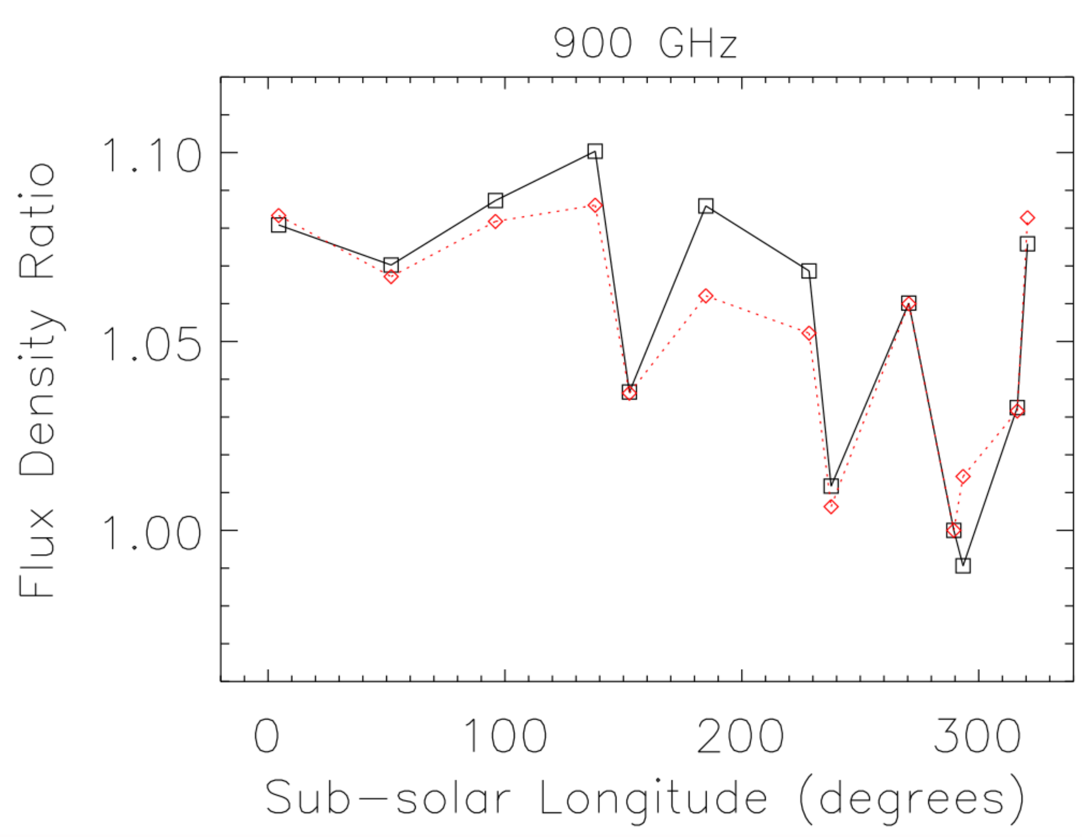

Figure 2 Observed and Predicted Rotational Modulation at 900GHz. Solid line (represents SPIRE data and dotted red line is the enhanced thermophysical model.

Conclusions

There is convincing evidence to suggest that rotational modulation has been detected by the SPIRE FTS, consistent with predictions of a thermophysical model. However, there are still issues with some of the observations which dilute the modulation (viz. fringing, pointing offsets, etc). Hence further work is needed if these effects are to be corrected in the future.