EHT 2018, Apex Gain

(TPK, v.1, 18-02-2021)

1 Method

In the following we determine the ratio of the measured antenna temperature of the planets and their known flux density, to determine the K/Jy conversion factor, which is known as the so called DPFU value. The flux density of the planets are calculated under the assumption of black body emission using the Planck equation and an a-priori assumption of the corresponding black body temperature.

Before and after each VLBI experiment, and partly also during observing gaps between VLBI scans, APEX has observed the planets in cross-scan mode. The receiver backend provided data for both polarisation (Pol1, Pol2), but with unknown assignment to RCP and LCP. For each scan a total of 8 observing bands (each of 4 GHz bandwidth, center frequency noted below) was recorded, with the following assignment:

baseband 1/2 LSB – 215.103 GHz (Pol1/2)
baseband 3/4 USB – 227.103 GHz (Pol1/2)
baseband 5/6 LSB – 211.103 GHz (Pol1/2)
baseband 7/8 USB – 230.903 GHz (Pol1/2)

The results of the Gaussian fits for the two scanning profiles (in azimuth and elevation) were written into an ASCII file ('gauss-fit.dat'). After averaging the two scanning directions, the antenna temperatures of the planets were extracted and stored in separate tables for plotting and further analysis.

2 Elevation dependence

In Figure 1, the antenna temperatures are plotted versus elevation for the 4 observing bands and for Mars, Jupiter and Saturn. No significant elevation dependence is found. Therefore the gain elevation curve is flat.

3 Beam size

Since the planets are extended relative to the beam size, a good knowledge of the telescope beam and planet size is required for the deconvolution. We refer to the APEX antenna efficiencies (`http://www.apex-telescope.org/telescope/efficiency/index.php?yearBy=2018`) and plot the main beam size for Mars vs. frequency. We also double checked with Uranus, which has a smaller angular extend than Mars, that the beam sizes for both planets are similar and that any effect from a finite extend of Mars can be ignored. From Figure 2 we derive an expression to calculated the beam size of the APEX telescope for the range of frequencies covered by the 8 basebands:

$$beam[''] = 50.491 - 0.10473 * f[GHz]$$

4 Results

We use the ASTRO Program within the IRAM Gildas software package to calculate the total flux of Mars, Jupiter and Saturn in (Jy). Using the diameter of the planets and the beam size (for each baseband), a correction factor is then calculated, which leads to the 'in beam' flux of the planet, which is lower than the

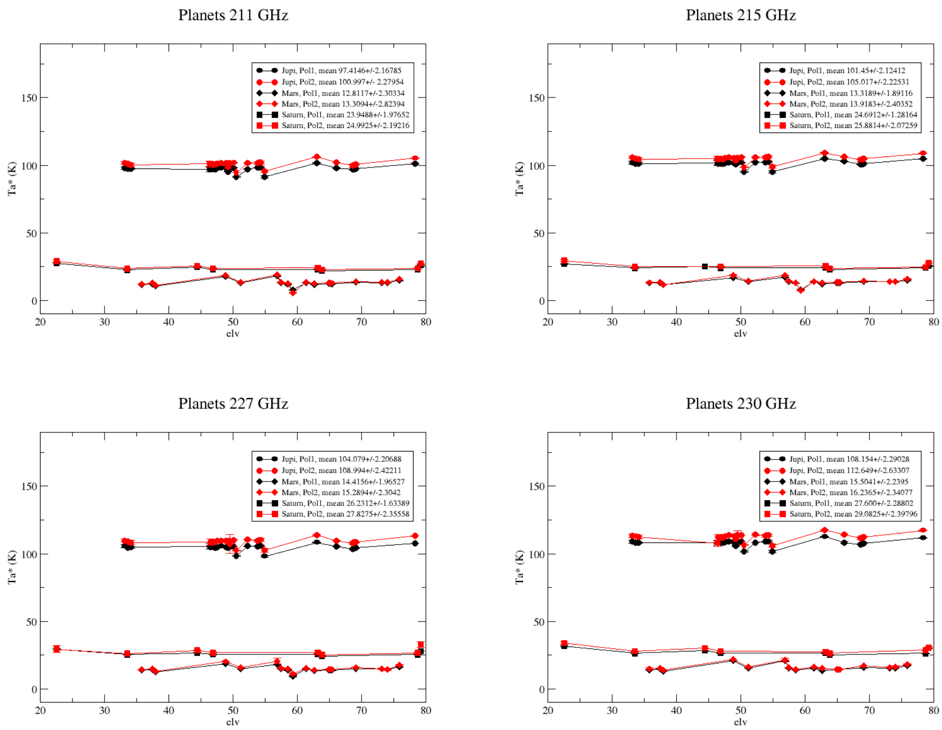

Figure 1: Observed antenna temperature (K) of the planets plotted vs. elevation for the 4 frequency bands. The mean value and error bars are shown in the legend, the black and red symbols mark the polarisations Pol1 & Pol2, respectively.

theoretical total flux density. For this correction we follow the equations summarized in Kramer, Moreno and Greve, 2008, AA 482, 395. From the ratio of the observed antenna temperature and the beam-corrected flux density of the planet, we derive for each planet the K/Jy conversion factor (DPFU value). The details of the calculations are summarized in the attached spreadsheet ("Planet-All-Gain.v3.ods"). We note that for Jupiter and Mars the DPFU's come out very similar, while for Saturn, the DPFU values come out 5-7 % larger. The reason for this is unclear. We therefore decided to ignore Saturn for the final gain determination, which is based on the average of the data for Jupiter and Mars only. In Table 1 we list the averaged antenna gains for all 4 frequency bands and both polarisations. In column 4 of Table 1, we list the formal error, which was determined from error propagation, however without taking the systematic uncertainty of the total flux of the planets into account. Adopting a 5 % systematic error for the latter and adding it quadratically, results in the total error, which is printed in column 5 of Table 1. Column 6 lists the same error, but as a percentage value. We further note that the DPFU values for polarisation 1 are on average a factor 0.96 lower than for polarisation 2. In Figure 3 we display the antenna gain graphically.

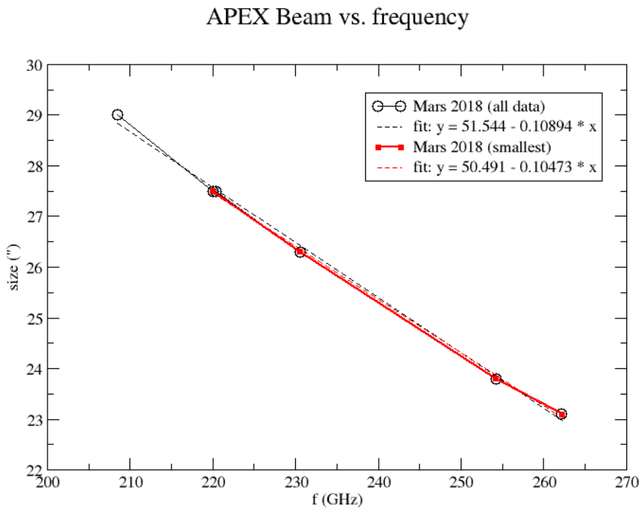

Figure 2: Deconvolved size of Mars plotted vs. frequency. The black dashed line marks all measurements, the red line marks an edited subset of the smallest sizes, which was used in the following calculations. The frequency dependence of the beam size is approximated via a linear regression of the following form: $beam['']=50.491-0.10473*f[GHz]$.

BAND (GHZ)	POL	DPFU (K/Jy)	err (K/Jy)	tot err (K/Jy)	tot err (%)	Pol1/Pol2
211.303	1	0.025283	0.000560	0.001382	5.468005	0.963569
211.303	2	0.026239	0.000590	0.001438	5.481763	
215.103	1	0.025631	0.000537	0.001389	5.420467	0.961516
215.103	2	0.026657	0.000564	0.001447	5.429341	
227.103	1	0.025102	0.000529	0.001362	5.426640	0.952179
227.103	2	0.026362	0.000582	0.001441	5.465622	
230.903	1	0.025863	0.000543	0.001403	5.423150	0.957525
230.903	2	0.027010	0.000623	0.001487	5.506469	
					average ratio:	0.958697

Table 1: The average antenna gains (DPFU or K/Jy values) for the 8 basebands. We note that the gains in polarisation 1 are about $\sim 4\,\%$ lower than polarisation 2.

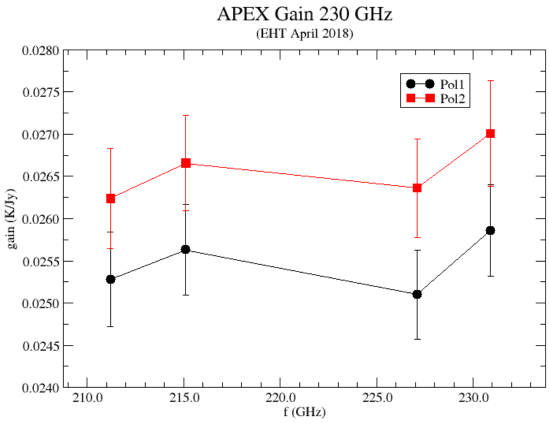

Figure 3: Antenna gain in (K/Jy) plotted vs. frequency for both polarisations. The labeling for RCP/LCP should be done empirically via inspection of correlated flux densities in the parallel hand visibility amplitudes.