

EHT 2021, Apex Gain

(T. Krichbaum, v.1, 17-08-2021)

1 Method

This document describes the determination of the APEX telescope antenna gain for the April 2021 EHT VLBI run. The analysis is based on cross-scans, which are performed in gaps between the VLBI scans. Gaussian fits to the cross-scans were performed with the standard data analysis package in an automated way by Dirk Muders. A data files containing the results of these Gaussian fits was provided and the following analysis is based in this data file (apex-vlbi-cross-scans-2021-04.txz, gauss-fits.dat).

The new NFLASH230 receiver was tuned to the 1mm band and provides output in the following channels.

Table 1:

Feed: 1, Pol: X, Sideband: LSB, IF: 4-8, Frequency: 214.696 GHz

Feed: 2, Pol: Y, Sideband: LSB, IF: 4-8, Frequency: 214.696

Feed: 3, Pol: X, Sideband: USB, IF: 4-8, Frequency: 227.273

Feed: 4, Pol: Y, Sideband: USB, IF: 4-8, Frequency: 227.273

Feed: 1 Pol: X, Sideband: LSB, IF: 8-12, Frequency: 211.022

Feed: 2 Pol: Y, Sideband: LSB, IF: 8-12, Frequency: 211.022

Feed: 3 Pol: X, Sideband: USB, IF: 8-12, Frequency: 230.946

Feed: 4 Pol: Y, Sideband: USB, IF: 8-12, Frequency: 230.946

The data were split by frequency and polarisation. After averaging over the two scanning directions (Az/Elv) of the Gauss-fits, the antenna temperatures of the planets were extracted and stored in separate tables for plotting and further analysis.

2 Elevation dependence

The data contain a sufficiently large number of cross scans only for 2 sources, Mars and Jupiter. Saturn was measured only a few times and showed bad fits. It was therefore disregarded. Also for Mars and Jupiter about 10% of the data showed bad fits, these data were flagged. In Figure 1, the antenna temperatures are plotted versus elevation for the 4 observing bands for Mars and Jupiter. 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=2021>) and plot the main beam size versus frequency. From this plot we fit the function $beam = a0/f + a1$ and use the fitted function to recalculate the actual beam size for each of the observed sub-bands (see Tab. 1). The frequency dependence of the beam size and the fit is shown in Figure 2.

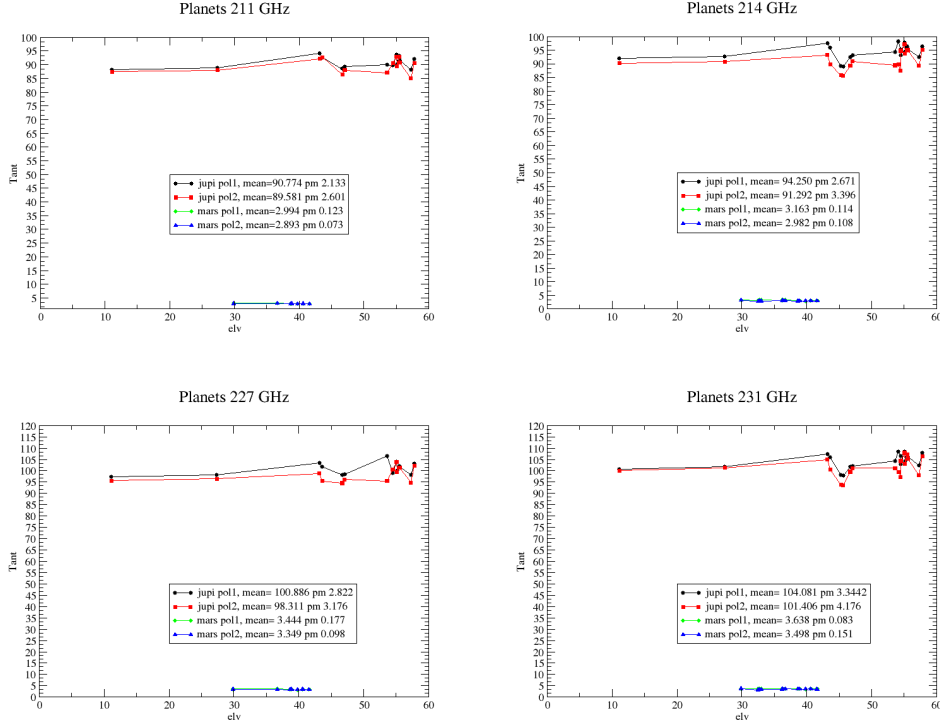


Figure 1: Observed antenna temperature in [K] of the planets plotted vs. elevation for the 4 frequency bands, as denoted in the header of each panel. The mean value and its error is shown in the legend, the black and red symbols mark the polarisations Pol1 & Pol2, respectively.

4 Results

We use the ASTRO Program within the IRAM Gildas software package to calculate the total flux of Mars and Jupiter in [Jy]. Using the diameter of the planets and the beam size (for each sub-band), a correction factor was calculated, which leads to the 'in beam' flux of the planet, which is lower than the theoretical total flux density. For this correction we follow the equations summarized in Kramer, Moreno and Greve, 2008, AA 482, 395. We repeated the calculation, but not using the ASTRO Program, but a script which extracts similar numbers from the latest CASA release.

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) for both from ASTRO and CASA. For Jupiter the agreement between ASTRO and CASA is within $\sim 2\%$, for Mars it is $\sim 7\%$. The details of the calculations are summarized in the attached spreadsheet ("Apex-Planets-Gain-Apr-2021.ods"). In Figure 3 we plot the combined DPFU values vs. frequency. We note a $\sim 3\%$ difference between the two polarisations: $\text{Pol1/Pol2} \simeq 1.03$. The final gain is rather independent on frequency and has a value of $\text{DPFU} \simeq 0.027 \text{ K/Jy}$ (37 K/Jy) with a $\sim 9\%$ error, which is close to the reported gain on the calibration web site (<https://www.apex-telescope.org/telescope/efficiency/index.php?yearBy=2021>). Table 3 summarizes the numbers for each band and polarisation.

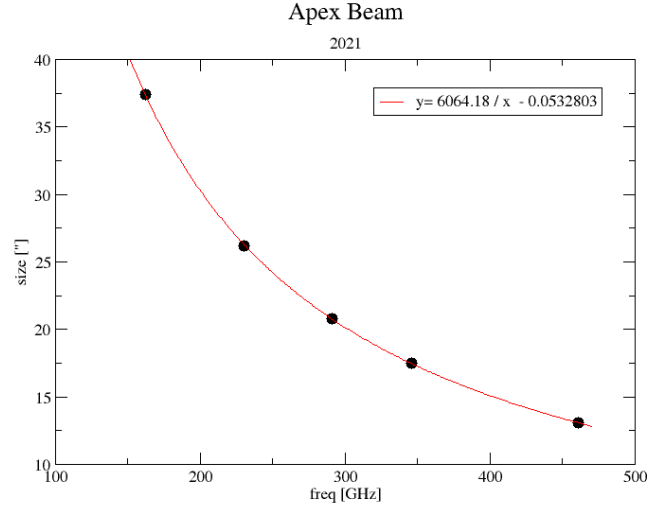


Figure 2: Main beam size (FWHM) plotted vs. frequency. The frequency dependence is approximated via a power-law fit (red line) of the following form: $beam[''] = 6064.18/f[GHz] - 0.0532803$.

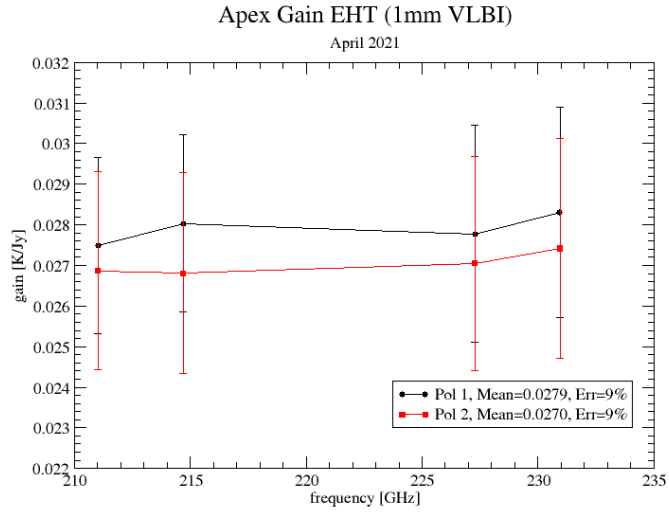


Figure 3: Apex antenna gain (DPFU in [K/Jy]) plotted vs. frequency in [GHz]. The different colors denote the two polarisations.

Table 1: Apex antenna gain

Freq. [GHz]	Pol.	DPFU +\ - err [K/Jy]		Pol1/Pol2
211.022	1,X	0.02749	0.00218	1.02
211.022	2,Y	0.02687	0.00243	
214.696	1,X	0.02803	0.00218	1.05
214.696	2,Y	0.02681	0.00247	
227.273	1,X	0.02778	0.00267	1.03
227.273	2,Y	0.02705	0.00263	
230.946	1,X	0.02831	0.00259	1.03
230.946	2,Y	0.02742	0.00271	