Report on the GISMO summer pool 2012

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Abstract

The second GISMO pool took place from October 30th to November 13th, 2012. Bad weather heavily hindered the pool, allowing observations only for a total of ~40 hours. Data for 7 over 11 projects were collected, although no project could be observed for the total amount of allotted hours. In the following some plots about detector stability, weather, and GISMO calibration are presented.

80% of observations were performed with a number of healthy channels>90, and 44% with healthy channels ≥100. The NEFD did not show any trend depending on the tau, as for the April pool. The median NEFD was 17.7 $mJy \cdot \sqrt{sec}$, considering only scans with a number of healthy channels ≥100 (257).

The new taumeter, measuring the sky opacity at 225 GHz, did not work during almost the entire 40 hours when observations took place: the opacity values (lambda) were retrieved from the old taumeter to correct for atmospheric transmission as much as possible, noting that the old taumeter does not have a calibration unit and may therefore drift. Also, a comparison between old and new taumeter values were performed, using measurements from both the November and the April GISMO pool. The discrepancy between the tau measurements of the the two instrument is large for unknown reasons. For the next run in April 2013, we plan to conduct skydips with GISMO to obtain an independent and reliable measure of the sky opacity.

Using the lambda values from the old taumeter, some science targets and pointing sources were reduced using CRUSH 2.13-b1 to test the flux calibration: the scatter of Galactic Center point-sources flux density at elevations of less than 25 deg was found to be better than 20%. The scatter of Uranus and Mars was found to be 6% and 39%, respectively: this last value, mainly due to the lower flux density measured with an opacity greater than 0.8, could be due to the discrepancy found between the lambda values from the old taumeter and the opacity values derived from the flux density attenuation on Mars and Uranus, indicating an underestimate of the opacity by the old taumeter.

Finally, also Galactic Center observations from the April pool were reduced using the latest version of CRUSH (2.13-b1), to analyze the flux-density stability at low-elevations (~25 degrees). An RMS of 10% was found, confirming the goodness of the tau measurements from the new taumeter and the reliability of the atmospheric calibration factor.

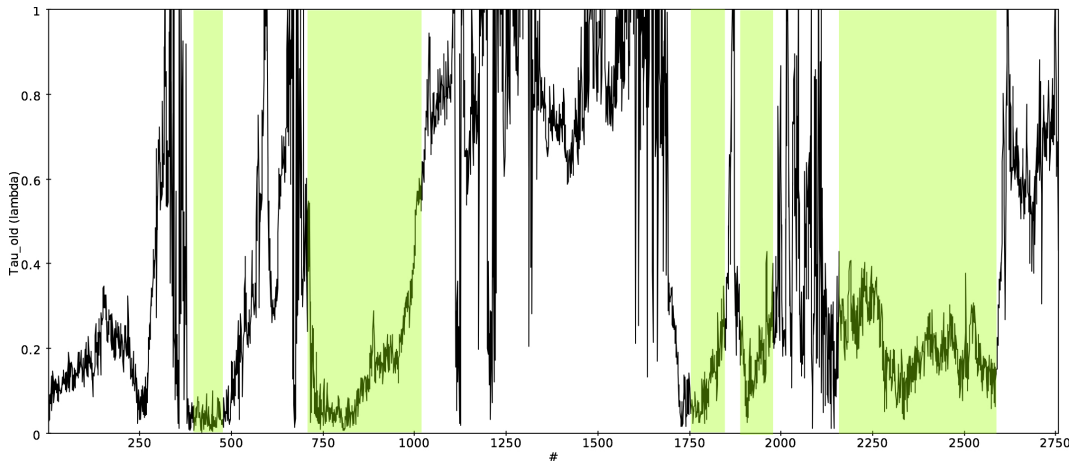

Figure 1: Tau measurements (lambda) taken with the old taumeter from October 29th (15:06 LT) to November 13th (23:52 LT). Intervals during which observations were carried out are highlighted in green.

1 Atmospheric opacity

Bad weather heavily affected observations, allowing to collect healthy data only for ~40 hours. During the run the new taumeter was not continuously working, and its opacity measurements were taken only for very limited time intervals. Values (lambda) from the old taumeter, which worked, were retrieved and compared with the almost simultaneous values from the new one (~2 minutes difference or less), over a time interval of ~7 hours. The opacity values taken with the old-taumeter are shown in Fig. 1 for the entire pool, while a comparison between old and new taumeter is shown in Fig. 2, for a total of 61 values. A linear fit shows a mild correspondence between the two measurements, with a slope m of 0.86, an intercept value c of 0.11, and a correlation factor $R = 0.72$. In Fig. 3 the differences between lambda values and tau from the new taumeter are plotted: a mean value of 0 and a RMS of 0.1 has been found.

1.1 Comparison between taumeters from the April pool

As a comparison, the readings from old and new taumeter from the April GISMO pool have been considered. Figure 4 shows old vs new taumeter measurements taken during two days of good weather (20/04 11:44 LT - 22/04 15:45 LT), matched in time considering a maximum interval of 3 minutes. Also, a filter was applied, considering only values derived from a good opacity fit ($\chi^2 < 1$ for the old and correlation factor $R^2 > 0.98$ for the new taumeter), resulting in a total of 729 pairs. The linear fit of the values results in a $m = 0.83$ and a $c = 0.05$, this last value being compatible with the typical error of the measurements. A plot showing the differences between the two readings (Tau(old) - Tau(new)) is presented in Fig. 5, giving a mean value of -0.03, and an RMS of 0.06. 87% of the pairs have an absolute difference <0.1, the bigger difference being 0.19. An uncertainty of 0.1 in tau would be reflected in a scatter of the calibrated flux density

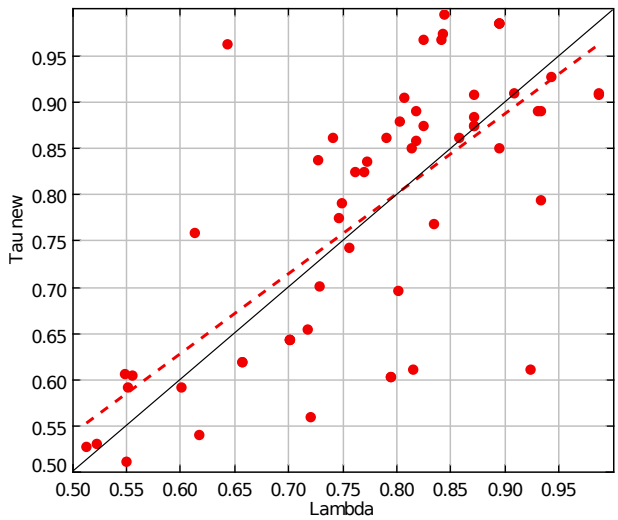

Figure 2: Comparison between the old and new-taumeter measurements from 11:28 to 17:50 LT, on November 2nd. Dashed line is a linear fit of the data, giving a $m = 0.86$, a $c = 0.11$ and a correlation factor $R = 0.72$ (for the standard formula $y = m \cdot x + c$). Solid black line is the expected relation.

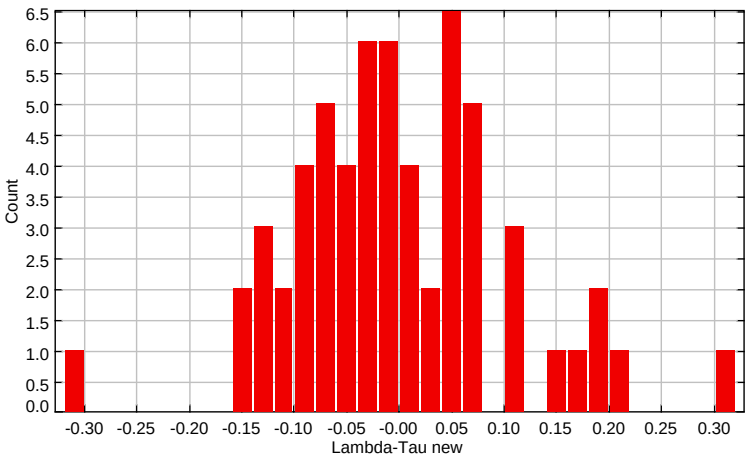

Figure 3: Distribution of the differences between old and new taumeter readings in the same time interval of Fig. 2.

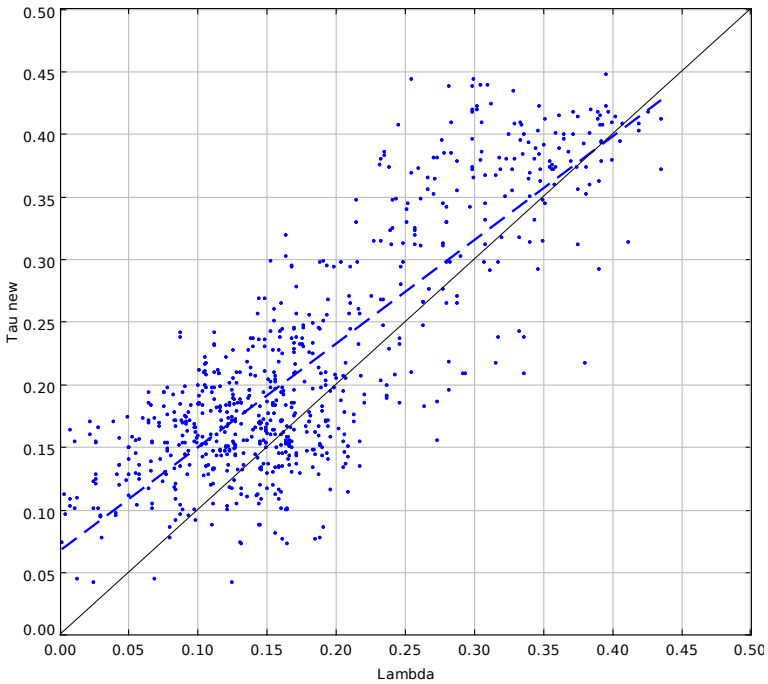

Figure 4: Comparison between the old and new-taumeter measurements, taken during 2 days of good weather of the April GISMO pool (20-22/04). Dashed line is a linear fit of the data, giving a $m = 0.83$ and a $c = 0.05$ (for the standard formula $y = m \cdot x + c$), solid black line is the expected relation.

of ~15% at low elevations (~25 degrees) and only ~5% at an elevation >60 degrees (see next section).

2 GISMO behaviour

In Fig. 7 the statistic about the number of healthy channels in the GISMO array is presented: 80% of observations were performed with a number of healthy channels >90, and 44% with healthy channels≥100. The NEFD was under 50 $mJy \cdot \sqrt{sec}$ in 89% of scans. Considering only the scans with a number of healthy channels>100 (257), the mean NEFD was 23 $mJy \cdot \sqrt{sec}$ and the median 18 $mJy \cdot \sqrt{sec}$, with a RMS of 16 mJy. Fig. 8 shows NEFD vs Tau for the time interval during which the new taumeter was working (11:28 to 17:50 LT, on November 2nd) for a total of 61 values: no trend has been found, confirming the result from the April pool (see [1]).

Figure 9 the NEFD is plotted against scan velocity: the highest scanning velocities correspond to the Galactic Center observations. The NEFD seems to improve at velocities above 60 "$/sec$, staying below ~40 $mJy \cdot \sqrt{sec}$, but a more complete statistic would be necessary to clarify the possible trend.

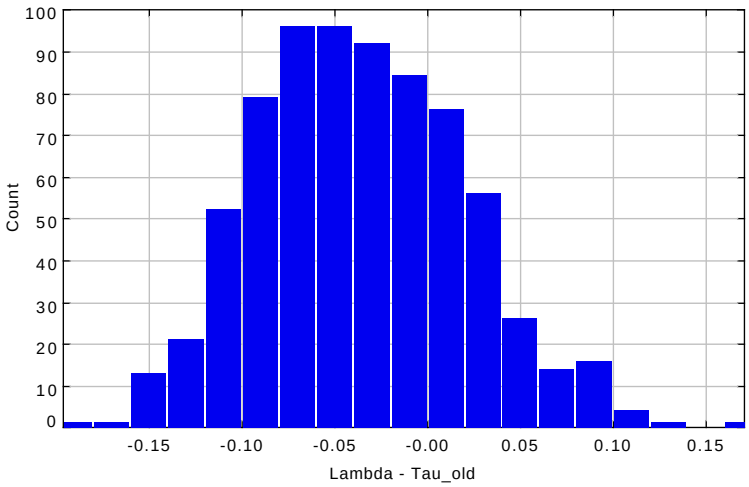

Figure 5: Distribution of the differences between old and new taumeter readings in the same time interval of Fig. 4.

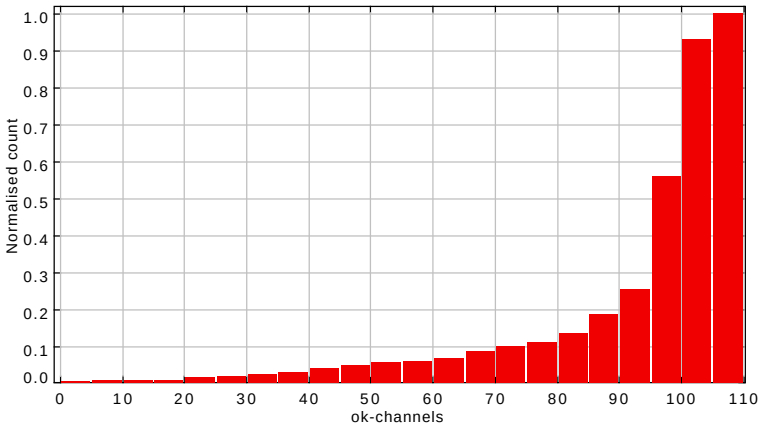

Figure 6: Statistic of the number of healthy channels during the run: 80% of the observations have been performed with more than 90 healthy channels.

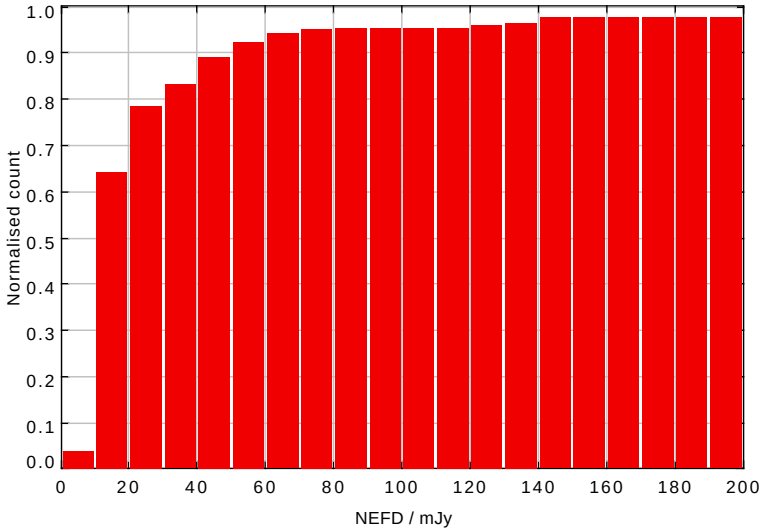

Figure 7: Statistic of the NEFD during the run: 89% of observations were performed with a NEFD<50 $mJy \cdot \sqrt{sec}$.

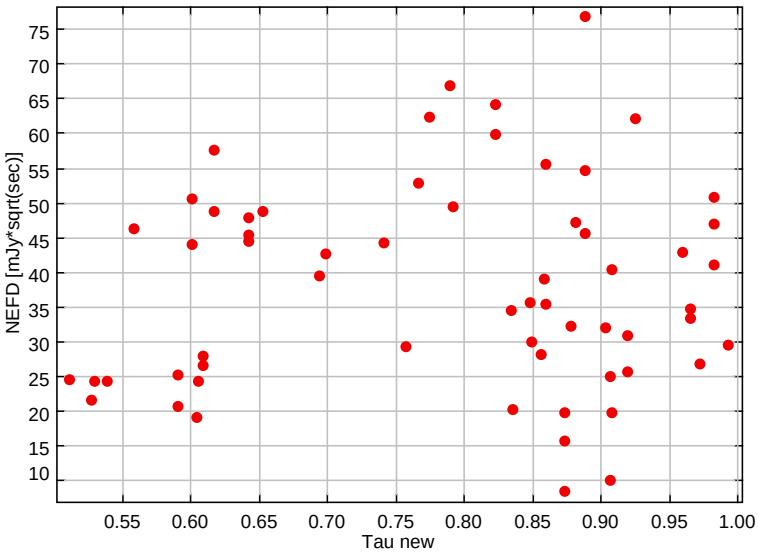

Figure 8: NEFD vs Tau for the time interval during which the new taumeter was working (11:28 to 17:50 LT, on November 2nd - 61 values).

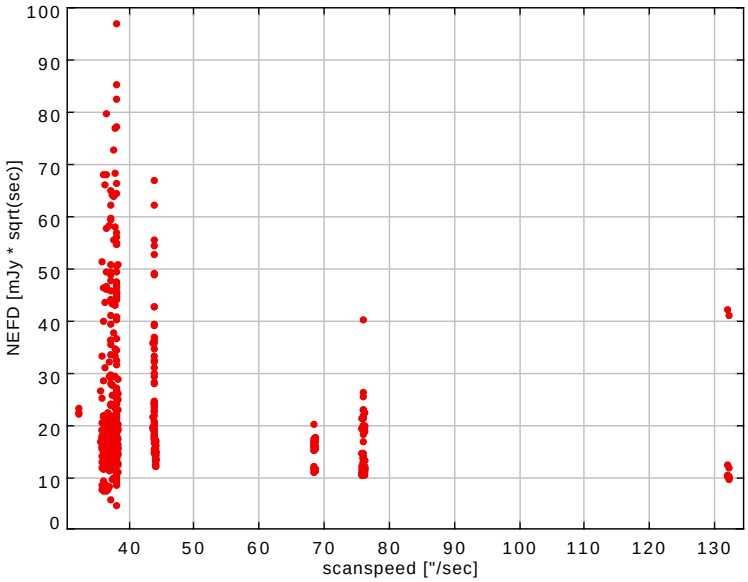

Figure 9: NEFD versus scanspeed during the November pool.

2.1 Flux density calibration

In Fig. 10, the calibration factor for GISMO, used to account for the atmospheric absorption, is plotted against elevation, for different fixed values of the opacity (Tau). The factor is defined as:

$$T_{cal} = e^{\tau_{(150)} * airmass} \tag{1}$$

where the airmass is defined as $1/sin(Elevation)$, and considering the following relation between Tau at 225 GHz (measured from the taumeter) and Tau at the GISMO observing frequency (150 GHz), derived from the atmospheric model in ATM Jan07:

$$Tau(150) = \frac{\tau_{(225)}}{2.1} \tag{2}$$

From Fig. 10, showing the factor vs elevation for various τ fixed values, it is evident how, to account for the opacity, the correction can change up to a factor of 4, the most critical interval being at elevation<40 degrees.

2.1.1 Calibration of the Galactic Center observations from the April pool.

Observations of the Galactic Center performed during the April 2012 pool (April 11th to 22nd, 2012; project 190-11, PI: Staguhn J.) were reduced using the latest version of CRUSH (2.13-b1), to test the stability of the flux density measurements of SgrA* (elevation of ~25 degrees). The same options were applied to all the maps *-faint -extended -rounds=25*. An aperture of 50" around the point source was used (see Fig. 11). 18 frames were considered for the statistic,

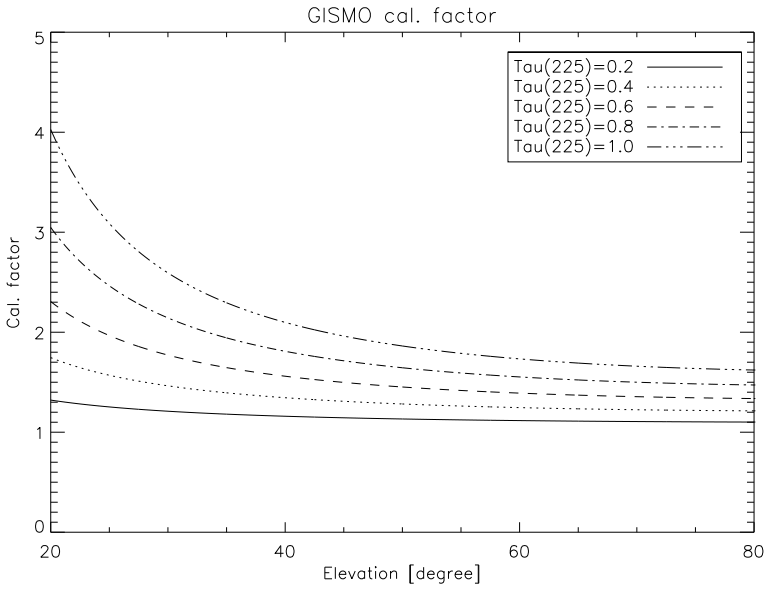

Figure 10: GISMO calibration factor ($e^{\tau_{(150)}*airmass} = e^{(\tau_{(225)}/2.1)*airmass}$) at different elevations, for fixed values of $\tau_{(225)}$.

resulting in a mean flux density of 15.8 mJy, with an RMS of 1.6 mJy (10%). This results confirm the goodness of the calibration factor used for GISMO also at low elevations.

2.1.2 Calibration of the observation from the November pool.

During the November pool observations of SgrA* were not performed, but other two point sources from the Galactic Center observations could be used to check the flux density stability at low elevations (see Fig. 13). The correct values from the old taumeter were applied for the reduction, together with the same options applied before (*-faint -extended -rounds=25*). A plot of the measured values, showing mean and RMS, are in Figs. 14 and 15. A mean value of 27.9 and 20.8 Jy were found for region 1 and 2, respectively, with an RMS of 5.7 (20%) and 3.6 Jy (17%). Only 10 frames could be used for this statistic. Reducing the same frames with the wrong tau values contained in the NEXUS logsheet (recorded while the new taumeter was not properly working) gives mean flux densities of 24.4 Jy and 17.8 Jy, respectively, but the RMS is similar, being 18% for both regions. The consequent discrepancy in flux density for the two regions, with respect to the reduction using the correct tau values, is 30% . The tau values from the new taumeter during these observations were about 0, with a difference of up to 0.2 with respect to the old taumeter readings.

The stability of pointing sources flux density was checked using scans on Mars and Uranus, using the lambda value from the old taumeter for the reduction: in Figs. 16 and 17 the integrated flux density versus lambda is shown. Mars has a RMS of 39%, higher with respect to the April pool (see [1]). Considering only scans performed with a lambda<0.8, the RMS is lower (14%). Uranus confirms the previous result with a RMS of 6%. The solid, purple line in the

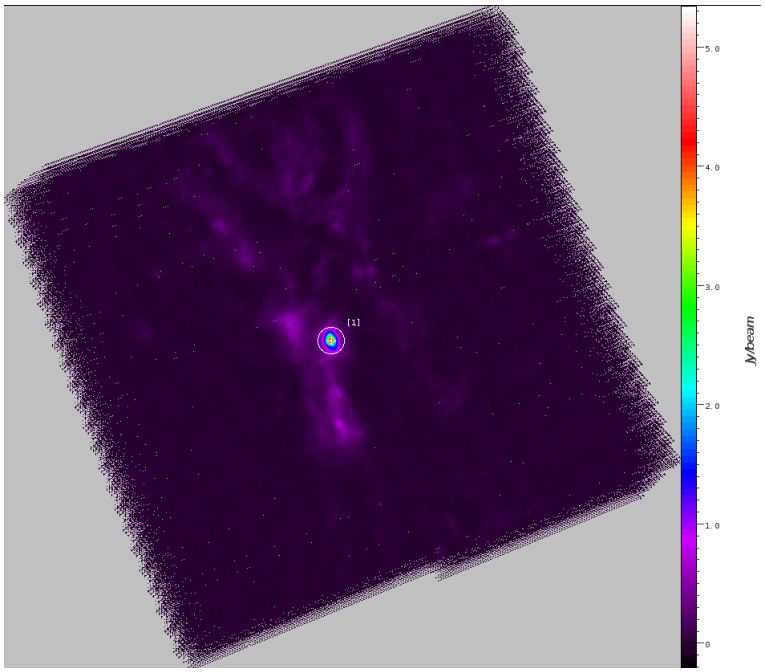

Figure 11: Galactic Center map from the April pool, showing the 50” region used to extract the flux density of SgrA*.

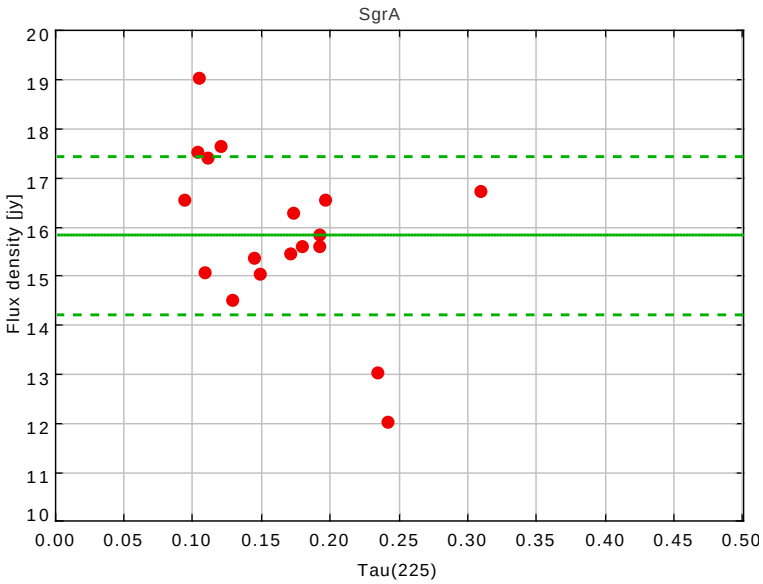

Figure 12: Measured flux densities of SgrA* versus tau(225) from the April pool. Mean (solid line) and ±1 RMS (dashed lines) are plotted in green.

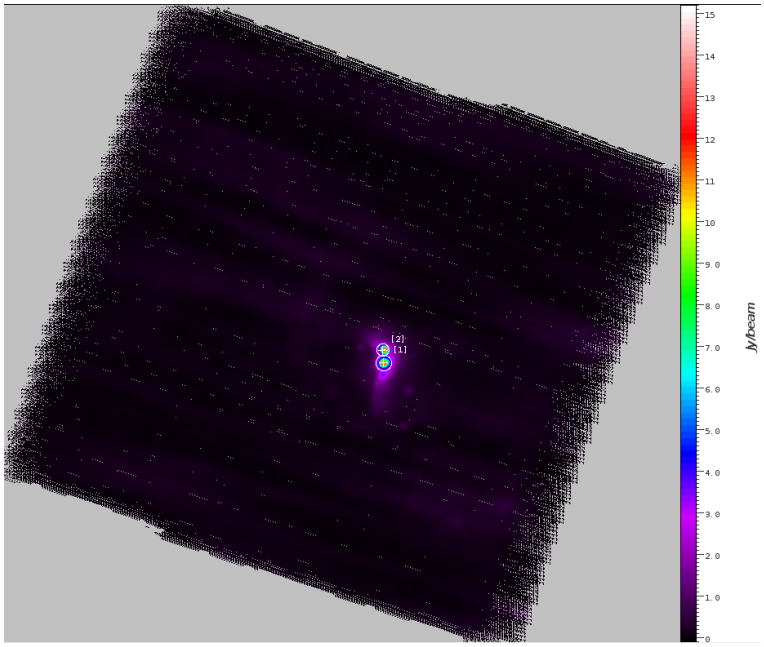

Figure 13: Galactic center map from the November pool, showing the two regions (28" and 23") used to extract the flux densities.

two plots indicate the expected flux density, according to the ASTRO values. Both planets has values lower than the expected ones: since this might be due to an underestimate of the atmospheric opacity, the opacity values were re-derived from Mars and Uranus scan, neglecting the atmosphere attenuation with the CRUSH option *-tau=0*, and using formula (1) and (2) to estimate the $\tau_{(225)}$ value for every scan. In Fig. 18 and 19 the derived opacity versus lambda is shown: in both cases the derived values are larger than the lambda ones. The discrepancy can be comprised between 0.06, compatible with the typical error, and 1.3 for the most critical scans on Mars, taken with a lambda of $\sim$1. This discrepancy can be also the cause of the large scatter of Mars.

References

[1] Bruni G., Kramer C., Billot N., Quintana-Lacaci G. 2012, *The first GISMO pool: bolometer behaviour*,
URL: http://www.iram.es/IRAMES/mainWiki/GoddardIramSuperconductingTwoMillimeterCamera

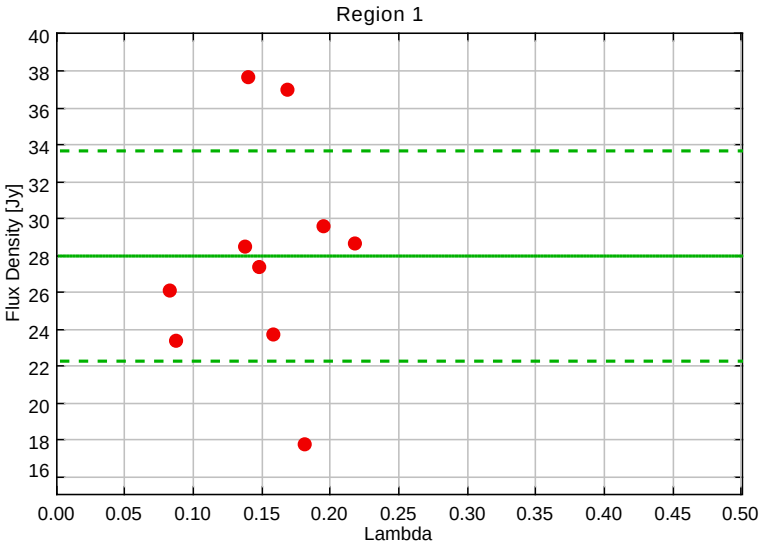

Figure 14: Measured flux densities of region 1 from the Galactic Center observations (shown in Fig. 13) versus lambda from the November pool. Mean (solid line) and ±1 RMS (20%, dashed lines) are plotted in green.

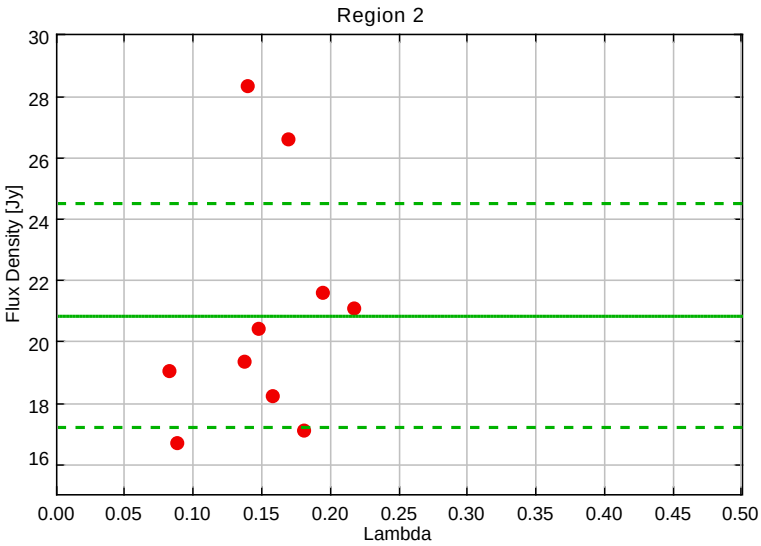

Figure 15: Measured flux densities of region 2 from the Galactic Center observations (shown in Fig. 13) versus lambda from the November pool. Mean (solid line) and ±1 RMS (17%, dashed lines) are plotted in green.

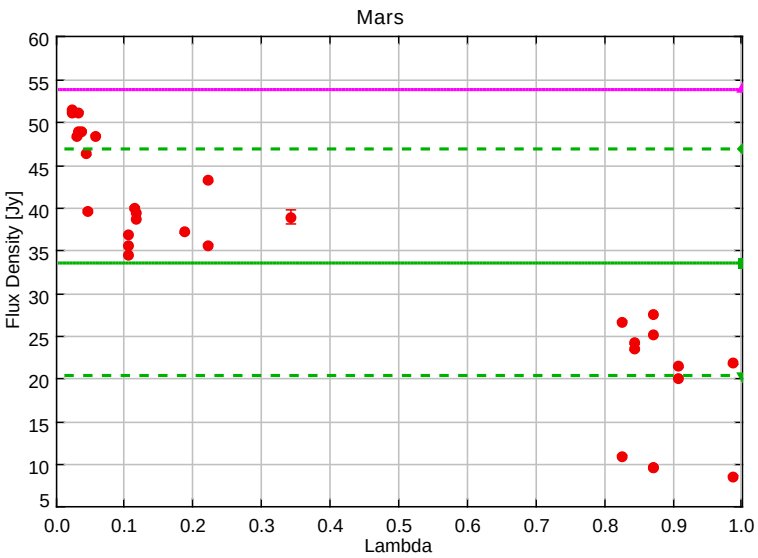

Figure 16: Measured flux densities of Mars versus lambda from the November pool. Mean (solid line) and ±1 RMS (39%, dashed lines) are plotted in green. Considering only scans taken at tau(225)<0.8 the RMS is 14%. The solid purple line indicates the correct flux density from ASTRO.

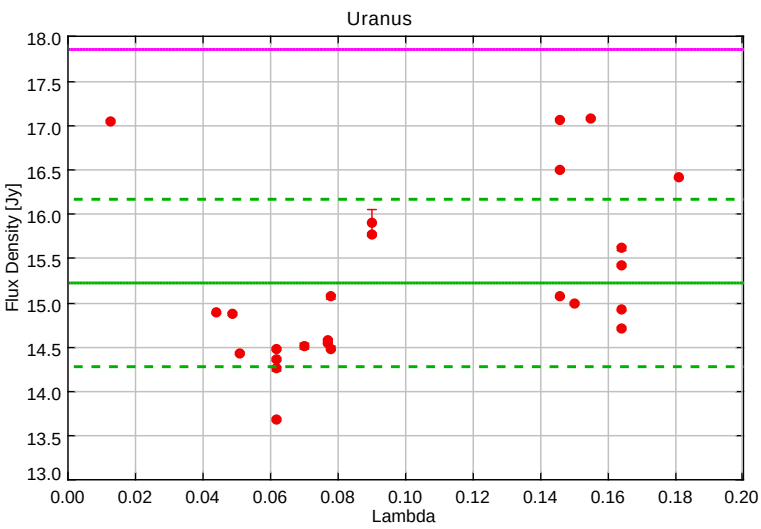

Figure 17: Measured flux densities of Uranus versus lambda from the November pool. Mean (solid line) and ±1 RMS (6%, dashed lines) are plotted in green. The solid purple line indicates the correct flux density from ASTRO.

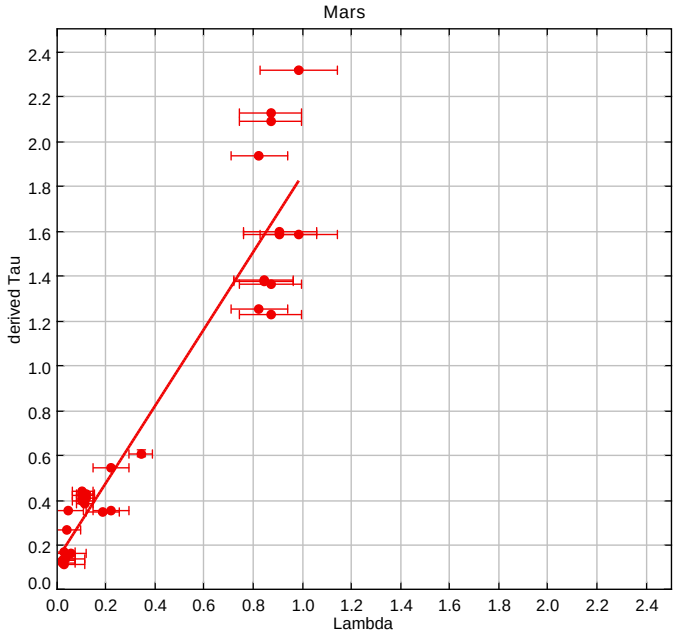

Figure 18: Derived tau values, obtained reducing Mars scans with the *-tau=0* option, versus lambda.

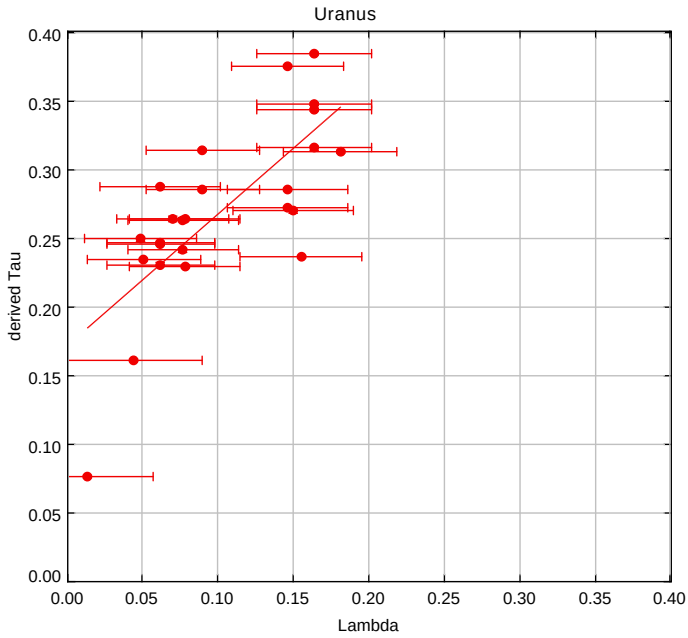

Figure 19: Derived tau values, obtained reducing Uranus scans with the *-tau=0* option, versus lambda.