Single Dish Experiments Report

Contents

1 Introduction

The basic principle of a single very long baseline interferometry (VLBI) configuration consists of two (2) radio telescope stations separated by a baseline, while simultaneously observing the same extragalcatic source. However, each of these telescopes sends telemetry data back from the observed space/source. This telemetry data is in the form of system temperature, $Tsys$, phase calibration, $Pcal$, system equivalent flux densities, $SEFD$, and GPS clock difference data, Δt. Viewing each station as an individual entity, we can use the telemetry data for monitoring purposes from baseline statistics, and theoretically diagnose any potential misallignments to the station sensors. We call this point of view a single dish experiment (SDE). These SDE's are of two main types, (a) stow position, which is when the antenna is set to a 'fixed position' throughout the duration of the experiment; and (b) moving, of which there are two types, (i) Dipping curve, which is when the antenna only moves in the elevation direction, and (ii) total movement, which is when the antenna moves in both elevation and azimuth.

2 Telemetry visualization

We have thus far developed a library package *atp* for the processing and visualization of the telemetry data. The *atp* library is written to only take, so called, antenna calibration files (antcal), either in ASCII or binary format. However, the experiment files are recieved from the stations as log files, which we first have to convert to an ASCII antcal using the program *log2ant*, which forms part of the *nuSolve* library. Within *atp* are routines to read and parse the ASCII antcal data. Due to the nature of ASCII files being typically large, and taking much longer to be read, we transform them to binary files.

The full log files for vlbi experiments submitted to the Crustal Dynamics Data Information System (CDDIS) can also be taken through the same pipeline, with each station log viewed as an SDE.

2.1 System Temperature

For a given experiment, the raw $Tsys$ section contains $Tsys$ values in Kelvin at multiple frequencies. For each frequency the $Tsys$ is given at various time stamps and look angles, i.e., at a given frequency, f, with a fuly moving antenna, we have $Tsys(f) = F(t, e, \alpha)$, where t is the time, e is the elevation, and α is the azimuth. If the SDE is of a stow type, then $Tsys(f) = F(t)$, and for a dipping curve we have $Tsys(f) = F(t, e)$.

For our purposes, we need to be able to visualise the $Tsys$ at a given frequency over the entire observation period, and the averages of each scan. The main steps to this procedure are described below:

1. over the IF of interest, filter out any timestamps where the $Tsys$ was not observed. These are denoted by the filler -99.9 in the antcal file. Also remove any outlier values that are not in the range of $5K < Tsys < 600K$. Figure 1 shows a visualisation of this.
2. Using the filtered values, compute the averages and root mean square errors (*rms*) of each scan. Figure 2 shows this for the raw data of Fig. 1

Analogous to the frequency plots, we can also plot for the $Tsys$, at given time stamps, across the spectrum of the telescope, as shown in Figure 4 and Figure 3.

2.1.1 moving antenna

As aforementioned, on top of running the experiments in a stow position, we can also run them with the antenna moving. For such experiments, we can view the telemetry in terms of the look angles. Figure 5 and Figure 6 illustrate this for elevation, and azimuth, respectively. As with the time and frequency plots discussed above, we can view the raw and average plots of the look angles. However, for demonstrative purposes in this write up, we will only show the latter.

2.2 Phase Calibration

Independent of the $Tsys$ section, the Phase Calibration, $PCal$, section contains *Pcal* values at multiple frequencies. For each frequency the *Pcal* are given in the form of phase, φ, and amplitude, A. In order to visualize these values, we follow a procedure similar to the one described for $Tsys(f)$, as follows:

1. to ease the process of computing the averages, we first convert the *Pcal* to complex values, using eq 1.

$$Pcal = Ae^{i\varphi}, \tag{1}$$

2. over the IF of interest, filter out any timestamps where the *Pcal* was not observed. Figure 7 shows an example of this.
3. Using the filtered values, compute the complex averages and individual *rms* values of phase and amplitude of each scan. Figure 8 shows an example of the results of this.

2.3 System Equialent Flux Density

The *system equivalent flux density* is an indicator of the combined sensitivity of both an antenna and its receiver system. It can be formulated as simply a quotient of $Tsys$ and the gain; both of which are functions of elevation. For most VGOS sessions uploaded to CDDIS, there is at least one $SEFD$ provided for the $Tsys$ each given Tsys centre. Since the Gain curve is fairly stable in time, for dipping curve SDE's, we can use the average scan Tsys values to compute the $SEFD$ for that session, and to also expand on the VLBI computed $SEFD$. This feature is currently being developed for *atp* library.

$$SEFD(t,e) = \frac{Tsys(t,e)}{Gain(e)}, \tag{2}$$

3 Plots

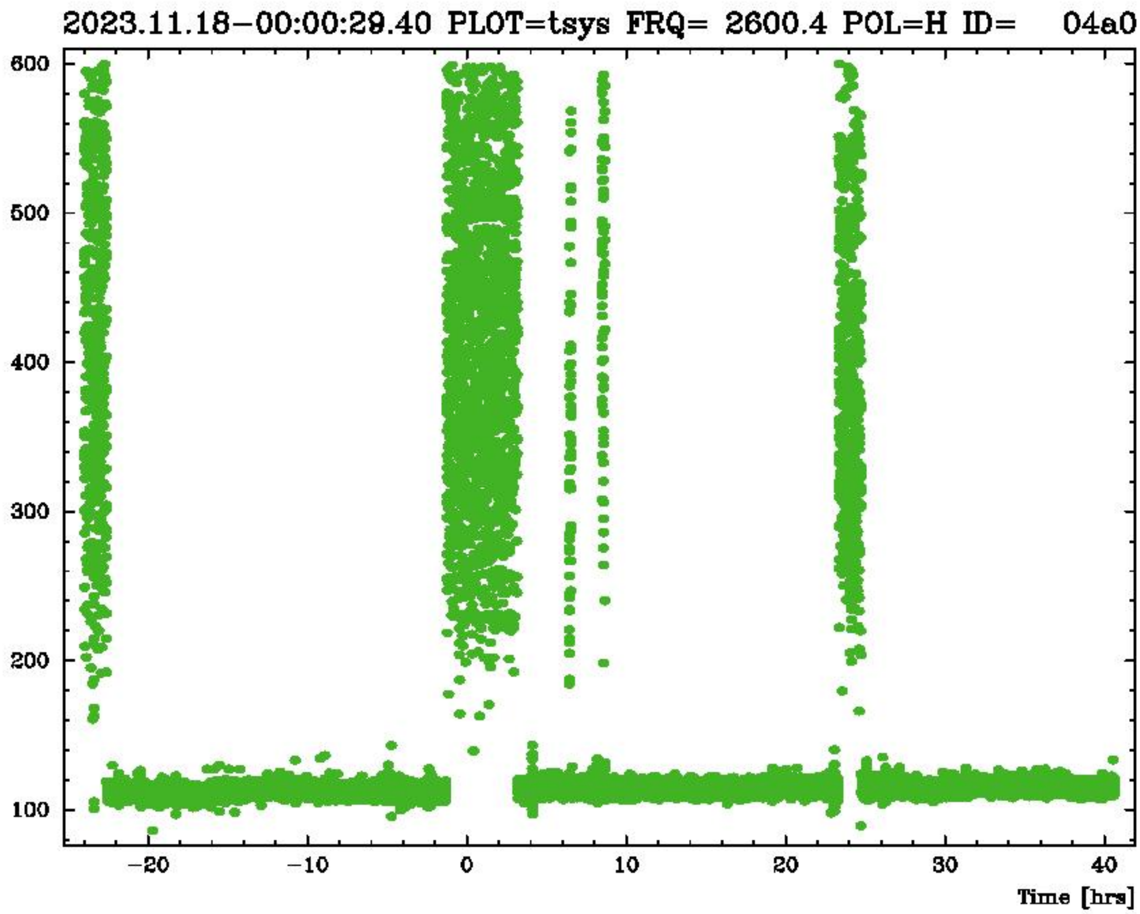

Figure 1: Observations at Kokee Park Geophysical Observatory (KPGO) taken at $2,600MHz$ in H pol. The abscissa shows $time$ in Hrs from midnight UTC, and the ordinate is $Tsys$ in K. The plot clearly indicates high levels of radio frequency interruption (RFI) at midnight UTC. Observations were made through the weekend of $November$ 18^{th}, 2023.

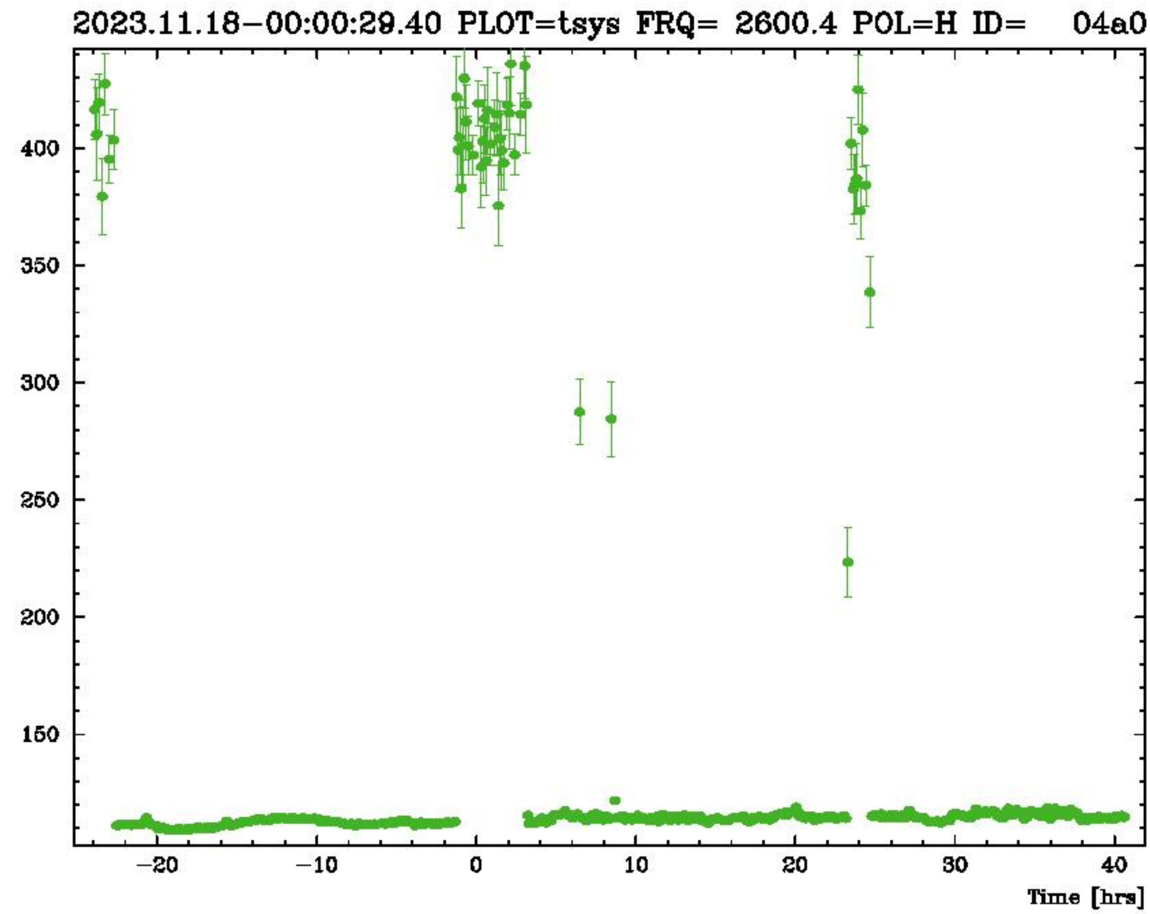

Figure 2: Average H pol $Tsys$ observations in K at the Kokee Park Geophysical Observatory (KPGO) observed at $2,600MHz$ through the weekend of $November$ 18^{th}, 2023. The abscissa show $time$ in Hrs from midnight UTC, and the ordinate are average scan $Tsys$ values in K. The error bars of each point, are the rms of each scan.

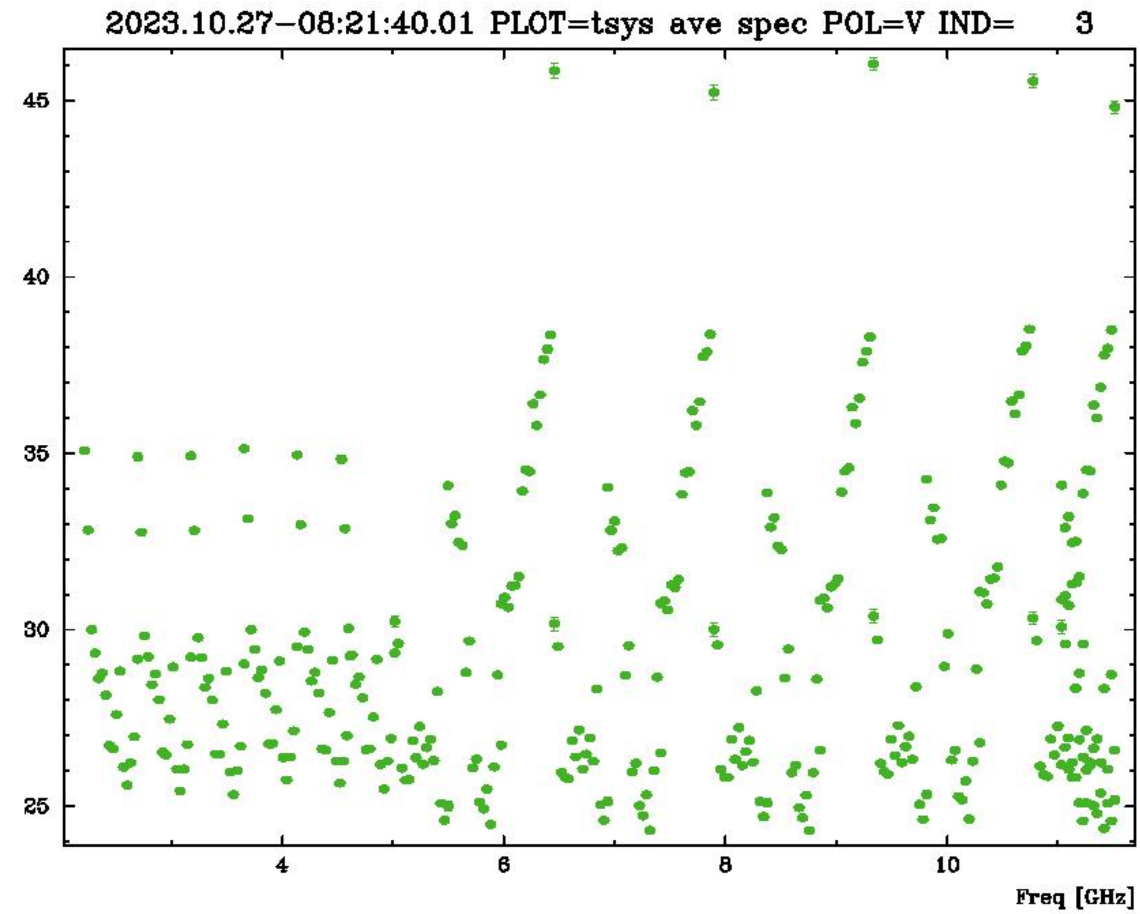

Figure 3: Average $Tsys$ values in K from the MacDonald Geophysical Observatory (MGO) across the telescope's entire spectrum from a scan that began at $08:21:40UTC$ on $Friday$, $October$ 27^{th}, 2023 in V pol. The abscissa are the frequency in GHz and the ordinate denotes the $Tsys$ in K.

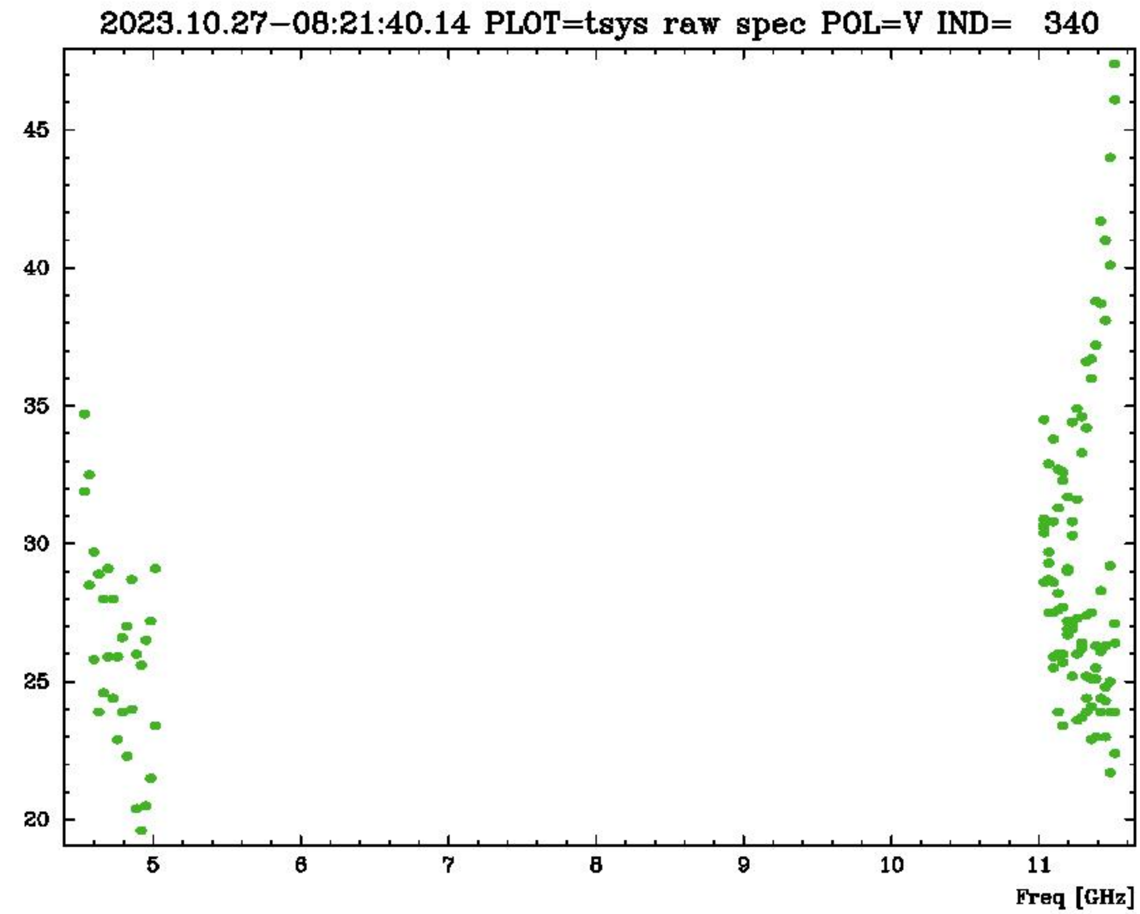

Figure 4: Raw $Tsys$ values in K from the MacDonald Geophysical Observatory (MGO) across the telescope's entire spectrum from observations at $08:21:40UTC$ on $Friday$, $October$ 27^{th}, 2023 in V pol. The abscissa are the frequency in GHz and the ordinate denotes the $Tsys$ in K.

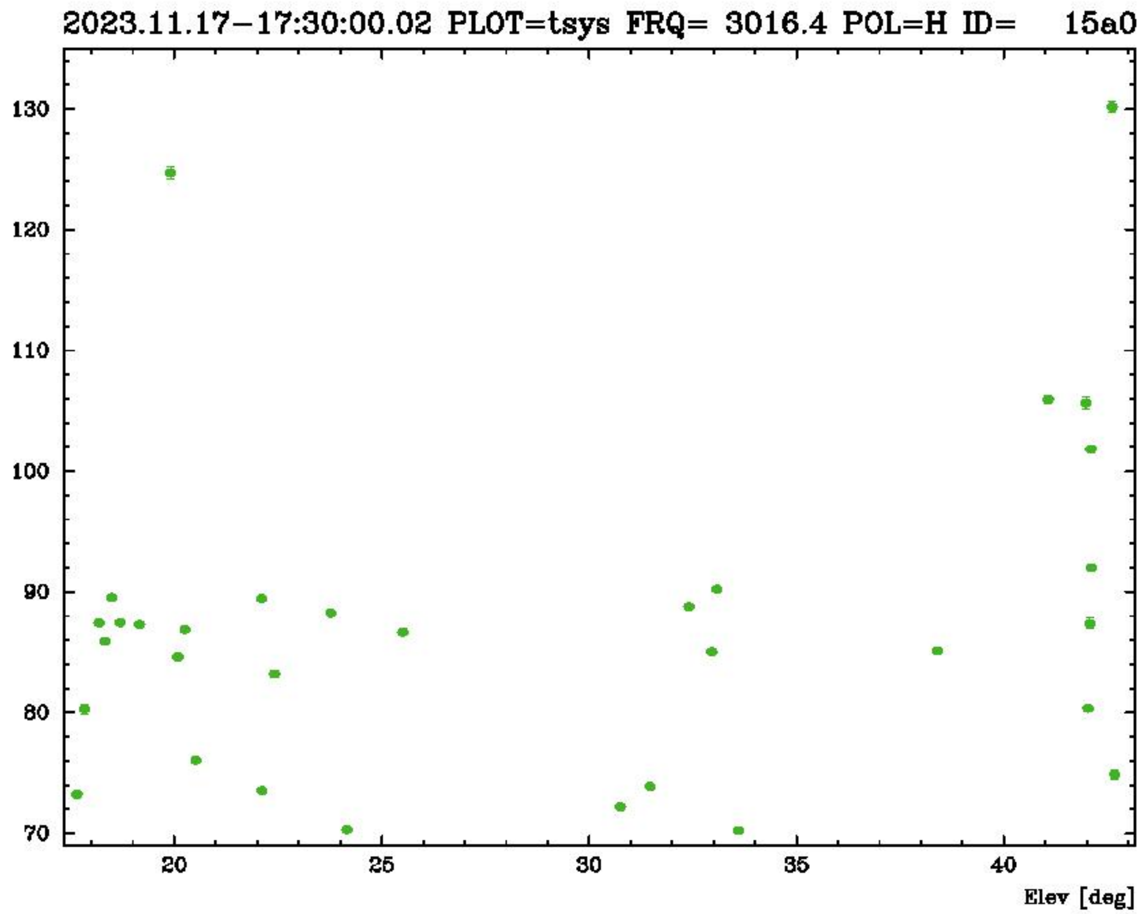

Figure 5: Average $Tsys$ values in K from the Kokee Park Geophysical Observatory (KPGO) across at varying elevations, deg, from the VGOS experimant v23321.

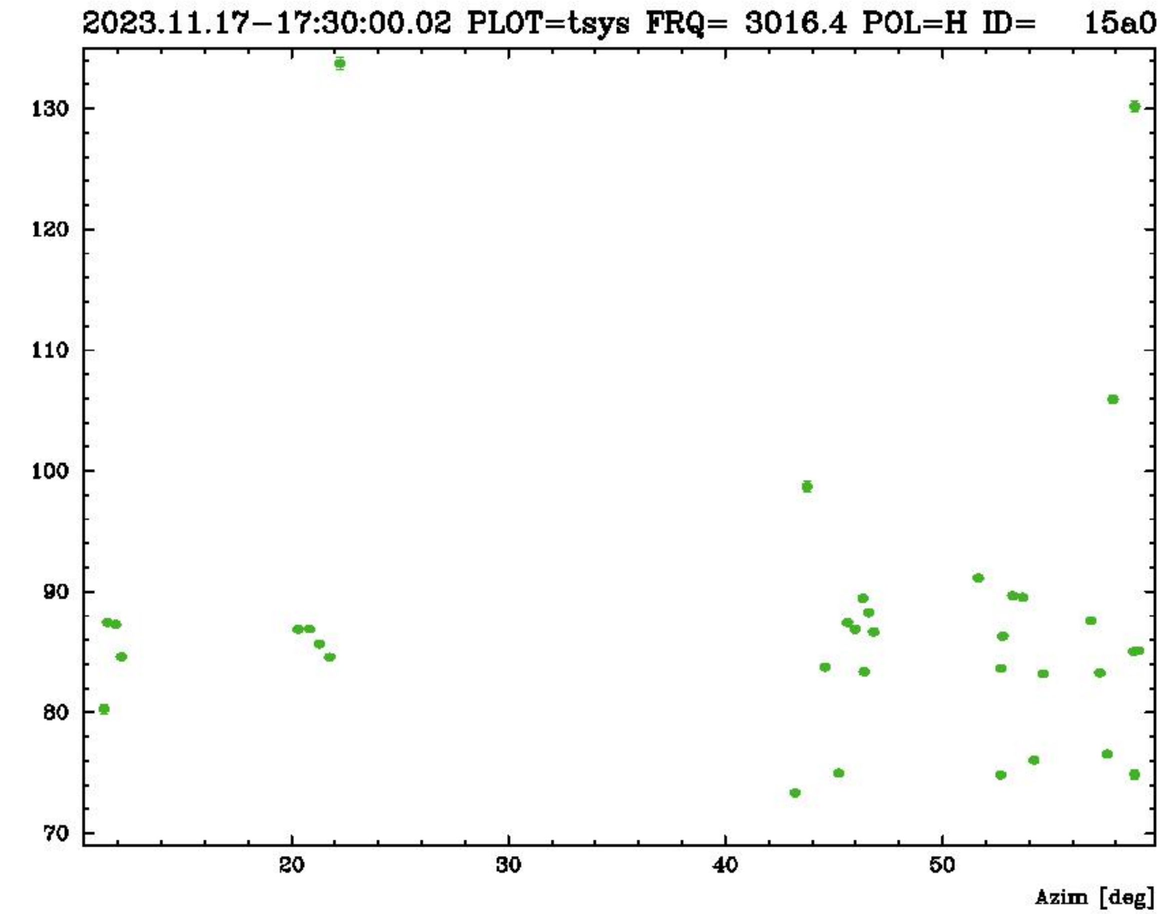

Figure 6: Average $Tsys$ values in K from the Kokee Park Geophysical Observatory (KPGO) across at varying azimuths, *deg*, from the VGOS experimant v23321.

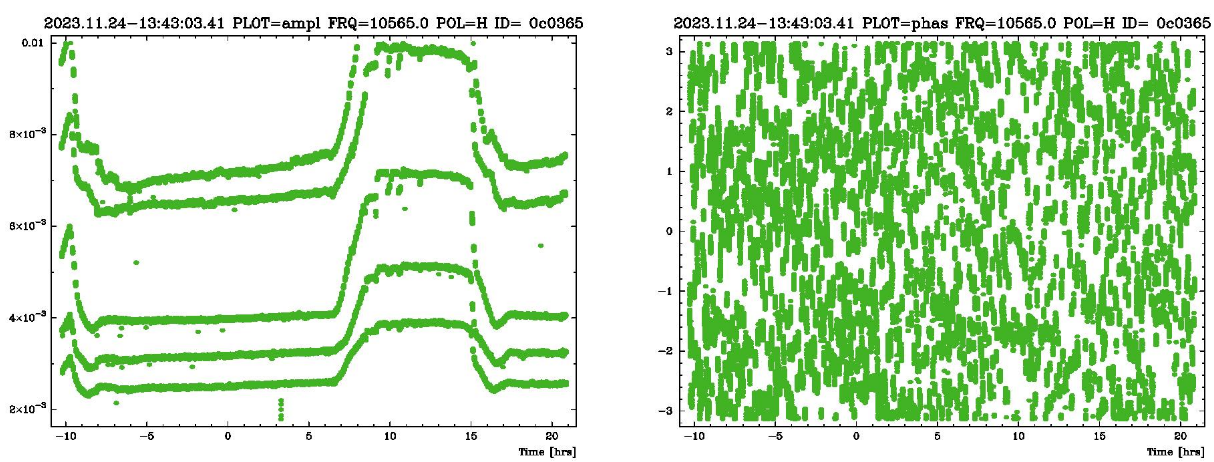

Figure 7: *Pcal* values taken at Goddard Geophysical and Astronomical Observatory (GGAO) through the weekend of $November\ 24^{th}$, 2023. All observations are from the Horizontal polarization. The right figure is the amplitude plots, while the left is phase values (in *rad*).

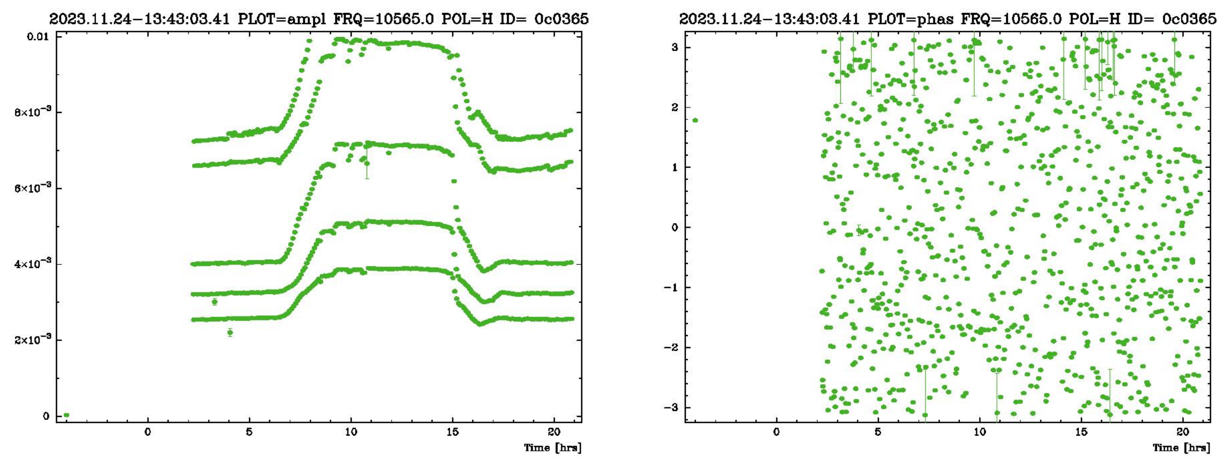

Figure 8: Average scan *Pcal* values from observations at GGAO on *November* 24^{th}, 2023. All observations are from the horizontal polarization. The right figure is the amplitude plots, while the left is phase values (in *rad*). Each point is a scan average with error bars representing the *rms*.