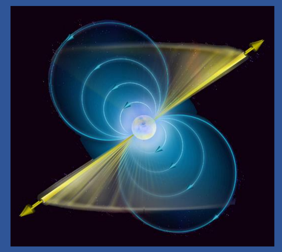

Analysis of Background Noise vs. Elevation of the 20-Meter Telescope at the Green Bank Observatory

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Background

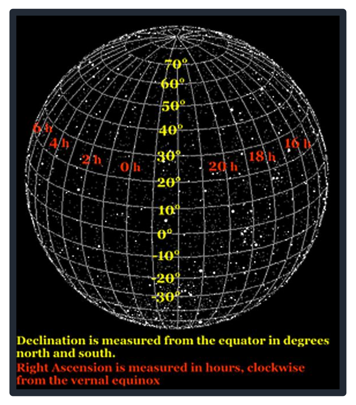
Radio telescopes utilize a variety of parameters to determine the strength of a source. Integral to the discovery and analysis of new cosmological phenomena, there are parameters to account for before analyzing a detected source. This is especially true for the 20-meter radio telescope in the Green Bank Observatory at Green Bank, West Virginia, a telescope with no currently known calibration.

One such parameter is the system temperature, or the collective noise, such as the noise in space, on Earth, and in the telescope's electronics. The following equation describes the calculation to find the system temperature: $T_{sys} = T_{rec} + T_{spill} + T_{atm} + T_{sky}$ with T_{rec} representing telescope receiver noise, T_{spill} representing the "spillover" noise from ground sources , T_{atm} representing the noise from the atmosphere, and T_{sky} representing sky background noise.

Circular polarization is the process of the electric field of the radio wave rotating. The two polarization channels will be XL1 and YR1 in this study.

Fig. 1 The Green Bank 20-meter taken by Ann Schmiedekamp

Fig. 2 A visualization of RA, or Right Ascension, and DEC, or Declination, provided by Honolulu Community College.



Objective

After reviewing a similar system temperature calibration performed with the Arecibo Observatory radio telescope, the goal of this study is to determine whether the system temperature of the 20-meter telescope in the Green Bank Observatory, varies depending on the elevation of the telescope.

Methods

- First, observation campaigns were conducted on the 20-meter radio telescope using Skynet, the web interface that allows for remote observations.
- Throughout a few days, observations consisted of RAs, or Right Ascensions, in increments of 4 hours from 0h to 23h 59m 59s. DECs, or Declination, ranged from -45° to 0° in intervals of 5°, then from 0° to 90° in intervals of 10°.
- Observations lasted 10 seconds each at a 0.3 second integration time. The frequency range of the observations were between 1350MHz and 1750MHz with 109 total observations conducted.
- The text (.txt) files that contain information about the observation, such as the system temperature values, the gain values, and MJD were then downloaded to a directory.
- A Jupyter Notebook, or an environment to write Python code, is then produced to loop through each file in the directory. The validated the type of observation based on the output filename and system temperature value.
- This program also calculated several formulas for further statistical analysis.
- The program outputs a .csv file containing all the information. From there, the .csv is transferred to Microsoft Excel for data visualization.

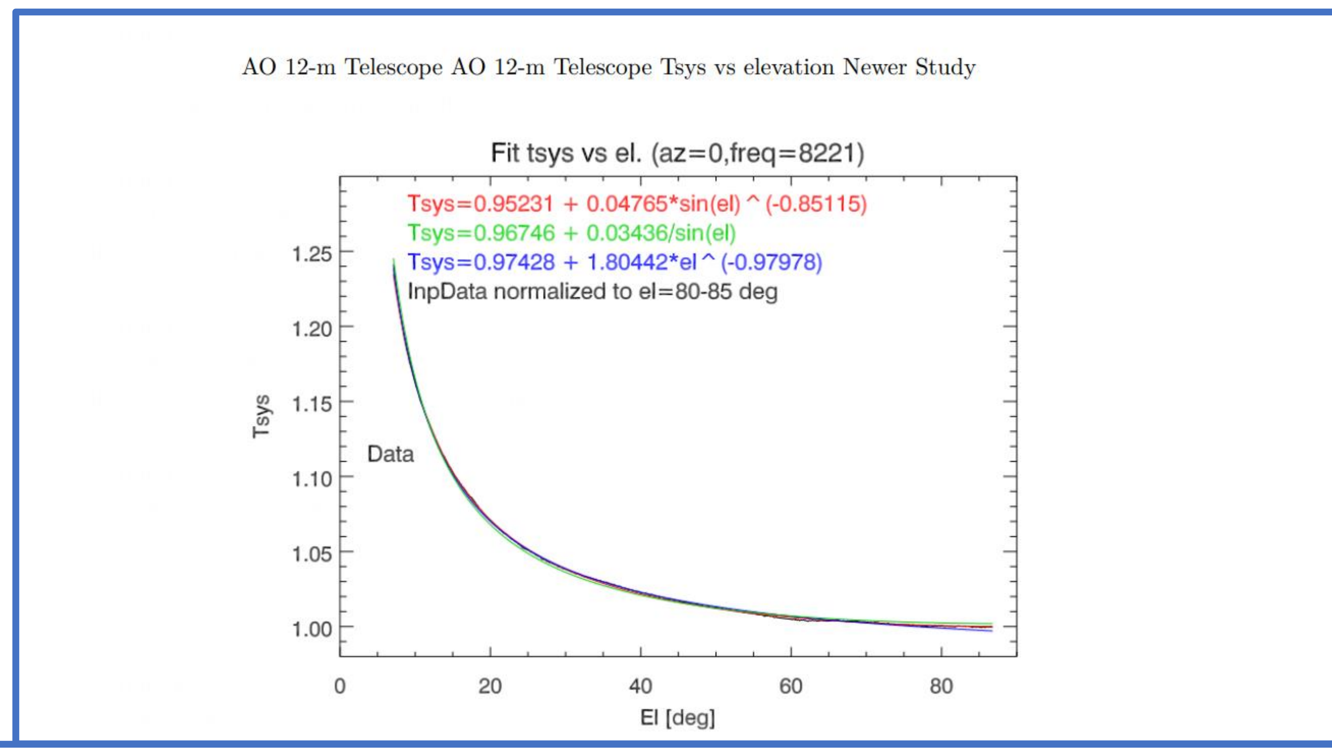


Fig. 3 The original Arecibo system temperature calibration study. In this study, the comparisons of system temperatures and elevation angles are performed, as well as variations of elevation such as Sin of Elevation in Radians and 1/Sin of Elevation in radians.

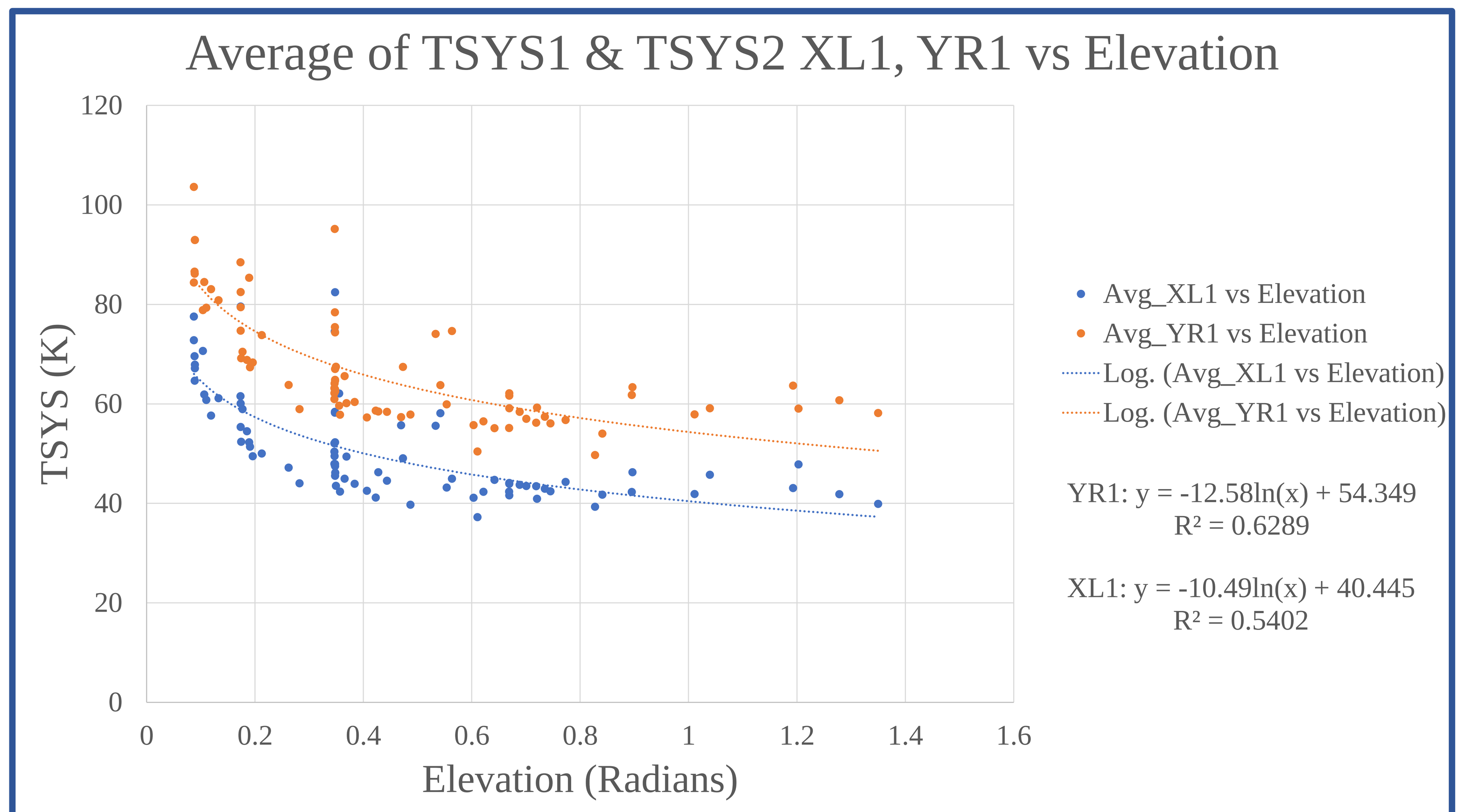


Fig. 4 Analysis of average system temperatures for XL1 and YR1 polarizations compared to Elevation in radians.

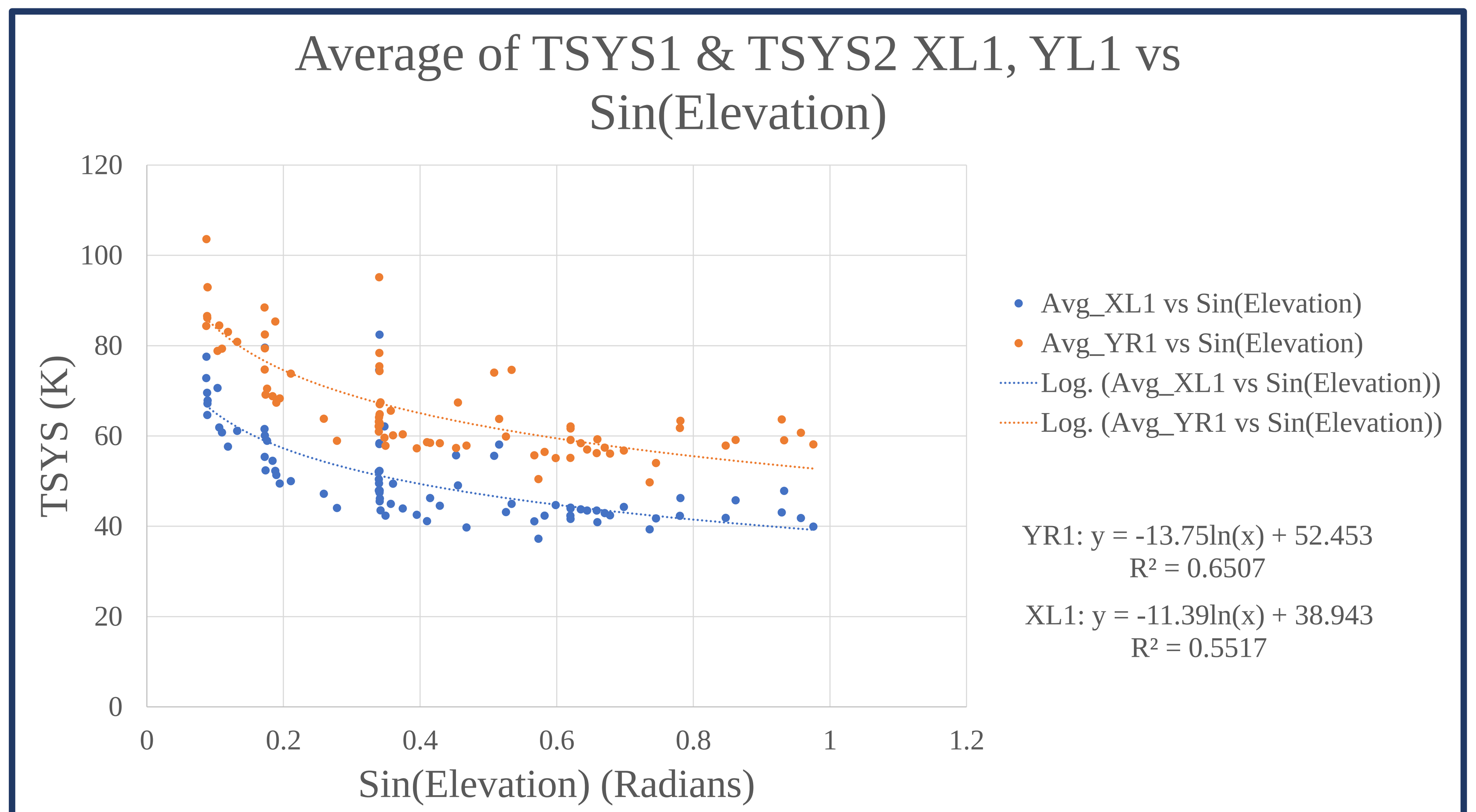


Fig. 5 Analysis of average system temperatures for XL1 and YR1 polarizations compared to Sin of the Elevation in Radians.

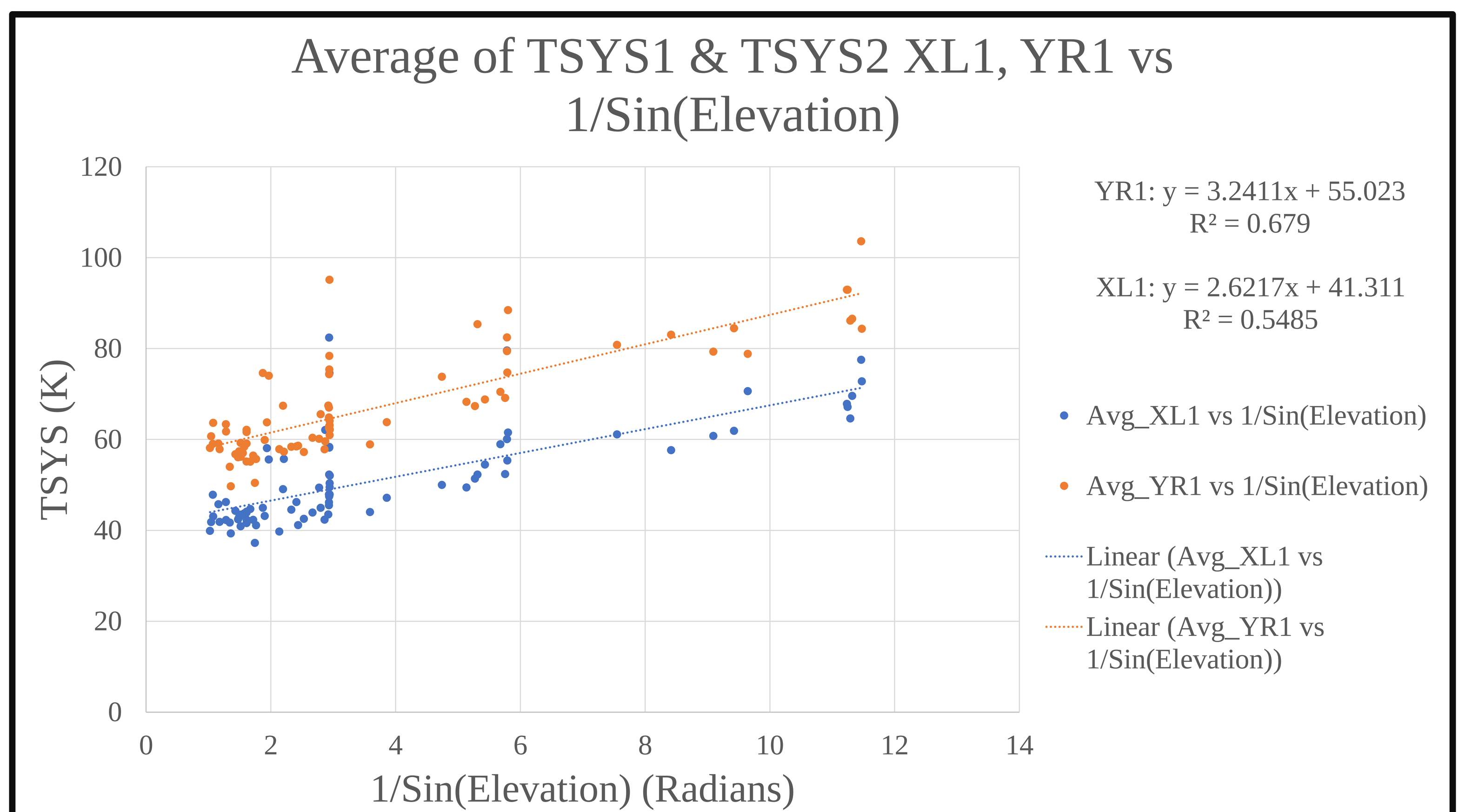


Fig. 6 Analysis of average system temperatures for XL1 and YR1 polarizations compared to 1/Sin(Elevation).

Conclusions

- System temperature analyzed from 20-meter changed based on elevation, similarly to the Arecibo calibration study.
- When compared to Elevation in radians, the XL1 polarization has a best line-of-fit equation of -10.49ln(x) + 40.445. The YR1 polarization has a best line of fit equation of -12.58ln(x) + 54.349.
- Compared to Sin(Elevation) in radians, the XL1 polarization has a best line of fit slope of -11.39ln(x) + 38.943, and the YR1 polarization has a best line of fit slope of -13.75ln(x) + 52.453.
- Compared to 1/Sin(Elevation) in radians, the XL1 polarization has a best line of fit slope of 2.6217x + 41.311, and the YR1 polarization has a best line of fit slope of 3.2411x + 55.023
- Other parameters included in .txt files did not agree with the literature based on the magnitude of difference observed. Need to get precise units from the 20-meter team to conduct further analysis.
- This study provided a quick basis to get started on more robust T_{sys} calibration methods by validating the correlation to elevation angle.
- Goal of future work is to finalize T_{sys} calibration and validate other parameters crucial to solving the radiometer equation.
- Radiometer equation will be critical in validating the spectral flux density (or the strength) of future pulsar data collection in Janskys (Jy).

$$S_{pulse} = \frac{(S/N)T_{sys}}{G\sqrt{n_P t_{int} \Delta f}} \sqrt{\frac{W}{P - W}}$$

Fig. 7 The radiometer equation modified to calculate the spectral flux density of pulses from a pulsar source. *S/N* is signal-to-noise, T_{sys} is system temperature, *G* is gain, n_p is number of polarizations, t_{int} is integration time, Δf is frequency bandwidth, *W* is width of pulse, and *P* is period of the pulsar.

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- (Software)Ransom, Scott, PRESTO, https://www.cv.nrao.edu/~sransom/presto/