CTA200H Computing Project for Leo Rizk:
Background study on SETI searches figure of merit

The goal of this project is to get a feeling for the completeness / sensitivity of a number of previous/on-going SETI surveys by comparing some of the figures of merit. We will look into each of the telescope specifications, the number of stars searched, the distance covered by these stars, and any other relevant parameters. This will prepare us for the main project which is to design an optimal SETI search for the ngVLA as outlined in this proposal. I'd encourage you to create a repo on a github page where you can upload some of these results. That would help build up your research portfolio!

Software/data requirement:

- Python
- TOPCAT (http://www.star.bris.ac.uk/~mbt/topcat/sun253/index.html)
- Spreadsheet SETI transmitter rate
- GBT & Parkes observed star database from Wlodarczyk-Sroka et al., 2020 can be downloaded at this link
- Simulated MeerKAT observation database (link pending)

Exercise:

- Collect data: I have started a spreadsheet (SETI transmitter rate), which lists key parameters for a number of SETI searches. But the information is incomplete (many surveys missing, also need a double check of the existing fields!) Expand on the spreadsheet: you can find information on a number of other previously conducted searches by reading Enriquez et al, 2017. For some newer surveys (post 2017) we can ask people in the Breakthrough Listen slack.

- Calculate the Transmitter rate (column U) and the minimum detectable Equivalent Isotropic Radiated Power (EIRP; column O) of these surveys. Multiply them to get the Continuous Waveform Transmitter Rate Figure of Merit (CWTFM; column X). The CWTFM is normalized to the transmission power of Arecibo. It is considered that CWTFM<1 indicates a more complete survey and/or with high survey sensitivity. Which of these SETI surveys studied meet the cut?

- Using python, visualize the comparison of Transmitter rate vs EIRP by using the data in this spreadsheet to recreate Figure 7 in Enriquez et al, 2017.

- One of the improvements that has been made to this plot is to include "shells of stellar distances" in the EIRP, similar to what has been done in Section 3.1 of Wlodarczyk-Sroka et al., 2020. Read in the GBT+Parkes observed data set VOTable using the TOPCAT tool. Group the observations in shells based on minimum detectable

EIRP as a function of the stellar distance. [*Extension*:] Add the data point from the MeerKAT search on the plot (link pending).

- This transmitter rate plot introduced by Enriquez et al 2017 is not perfect. One of the issues is that the x-axis is showing "power" which isn't a direct metric of a telescope itself, but got a distance term folded into it. It is not easy to say which survey is better. We can try to visualize a number of other metrics to see if any other parameters might provide a more insightful comparison. Let's try some of the following using python:
    - Plot minimum detectable flux as the x-axis. This is a quantity that only relates to the telescope, and could be a more fair assessment of the survey strengths. And we can then add to the plot the flux of a hypothetical transmitter (e.g. Arecibo) and show the flux density of it at a few hypothetical distances. We will then be able to see easily whether some of the surveys would have been able to detect such a signal
    - [*Extension*]: plot other figures of merit, including the Drake Figure of Merit (DFM) and survey speed (SSFM), frequency band range, drift rate
    - [*Extension*]: Separate the number of stars and fractional bandwidth of the y axis into two separate axes. Make a 3D plot instead.

Background reading:

- Enriquez et al, 2017 The Breakthrough Listen Search for Intelligent Life: 1.1-1.9 GHz Observations of 692 Nearby Stars
- Bart Wlodarczyk-Sroka et al., 2020 Extending the Breakthrough Listen nearby star survey to other stellar objects in the field
- Bart's thesis which is maybe quite similar to his paper above
- ngVLA SETI community study proposal
- This 10-min talk I gave about MeerKAT and the VLA on youtube

General SETI reading, not required by this computing exercise:

- "How to find ET" memo https://github.com/UCBerkeleySETI/breakthrough/blob/master/GBT/README.md
- L-band data memo https://www.kaggle.com/tentotheminus9/l-band-2017
- The VLA SETI search proposal https://www.overleaf.com/read/psmyvtpmhyzc