Visualization of Signal Processing for Radio Astronomy: A GNU Radio Companion Based Spectrometer for CHART

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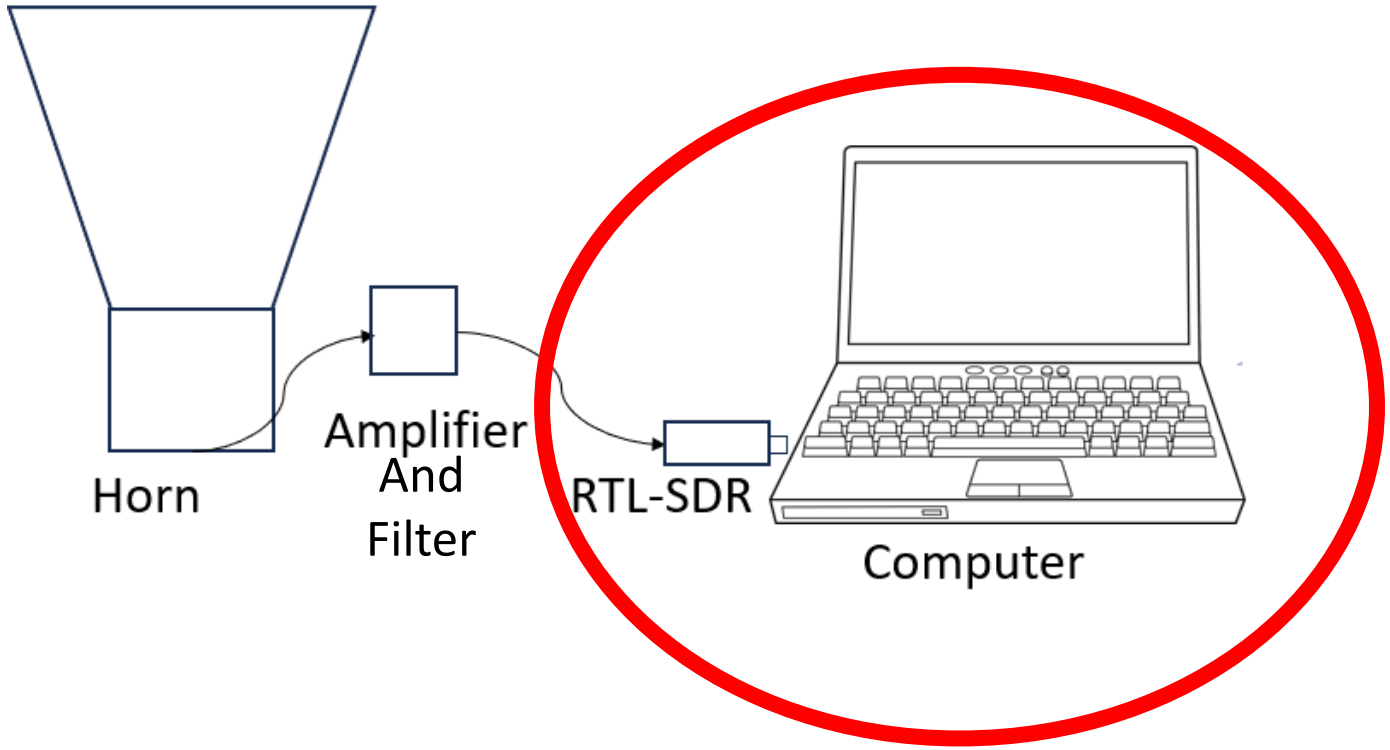
What is CHART and Who is Using it?

- CHART (Completely Hackable Amateur Radio telescope) project targets students and educators interested in radio telescope astronomy
- CHART is being used by undergraduats and high school students

What is in the CHART Project

- CHART has telescope-making tutorials, computer programs, and Jupyter notebook tutorials set up to teach people how to make a functioning program.
- Previous work set up a robust data capture system, but the code is a black box
- This project is for users interested in pursuing signal processing in more detail, GNU Radio companion makes this process transparent.

GNU Radio and CHART makes hard programming friendly

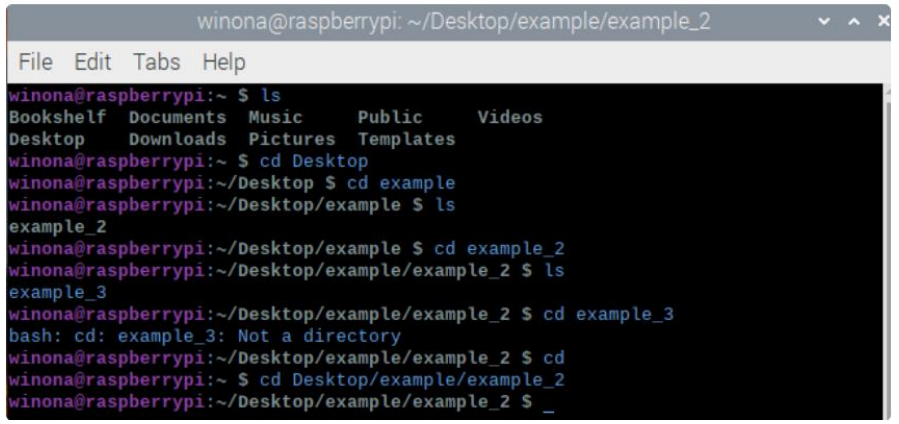


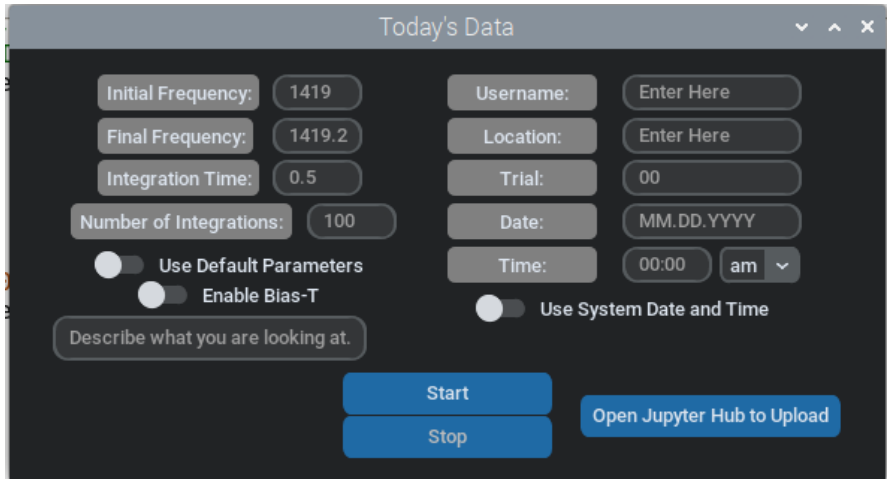
- Simple hardware and cardboard design makes the antenna easy to build.
- System is designed to be as simple as possible, with easy-to-swap-out components
- My focus was on the data collection and file writing process. A few different data collection programs are offered depending on user interest.

Working on the user-friendly RTL-SDR software

The Black Box

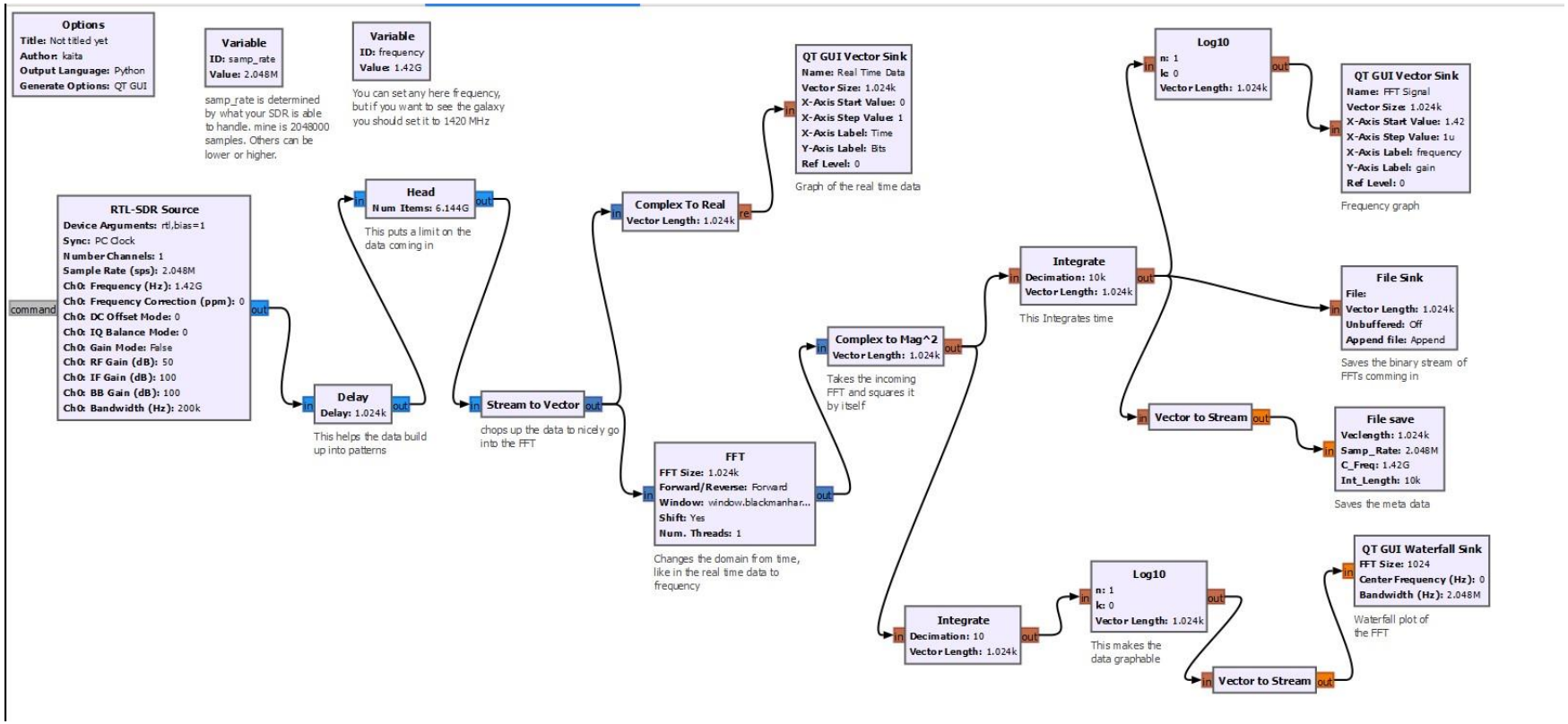
• Offers a Linux-based Python data collection script accessed through a terminal, as well as a GUI
•Both methods use the GNURadio package and Python
•Well Functioning UI
•Good data collection
•But the code was hidden from the user
•Code required high skill
•Linux based does not work on windows technology.
•Don’t reach the goal of education





The Second Type of Data Collection

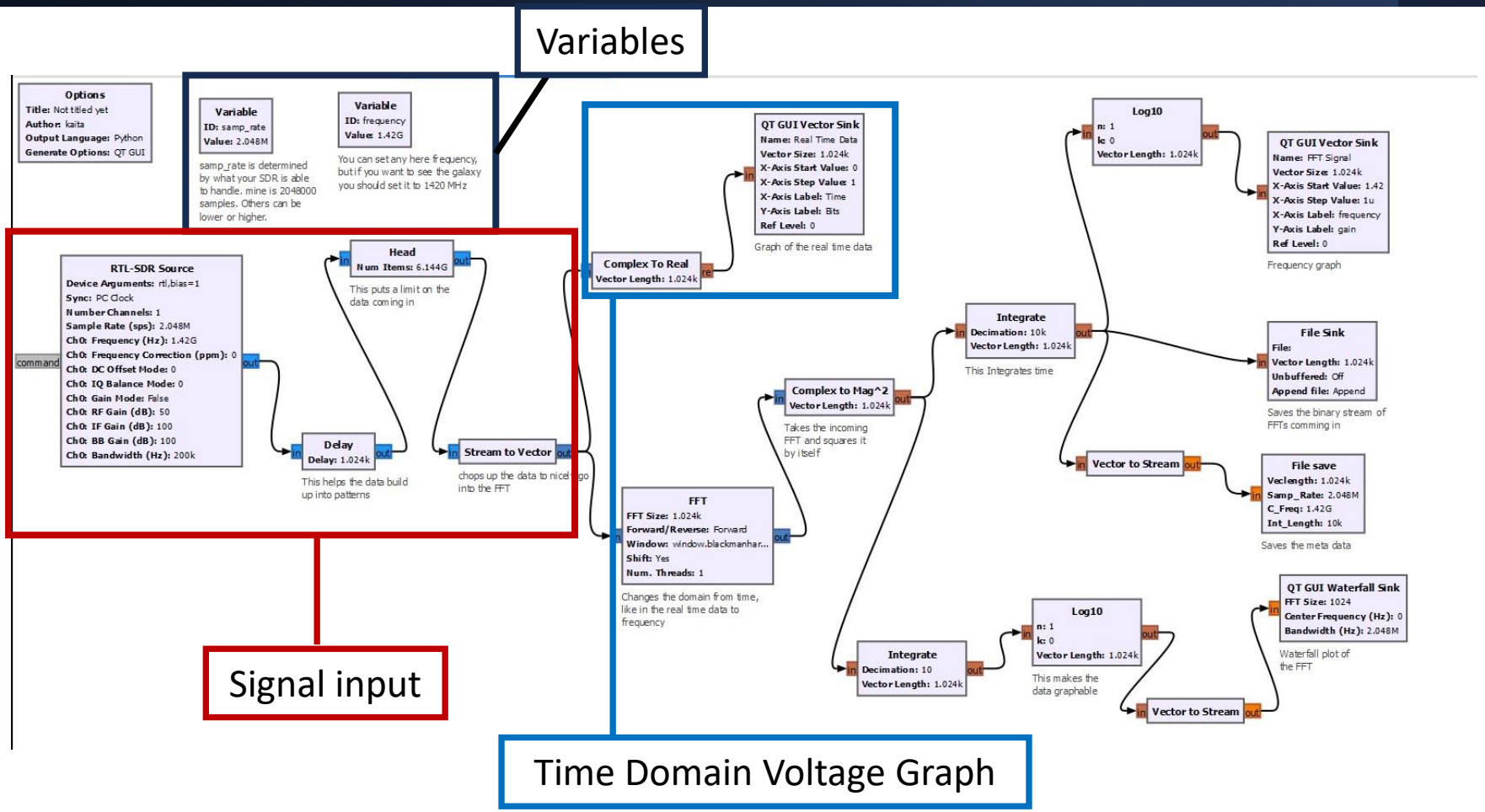
The Flowgraph



- GRC offers a more visual way of understanding the steps involved in collecting your data
- The flowgraph performs the FFT, power calculation, integration, and file writing steps.
- It also includes a number of “break out” points where the user can inspect their signal live.

The Second Type of Data Collection

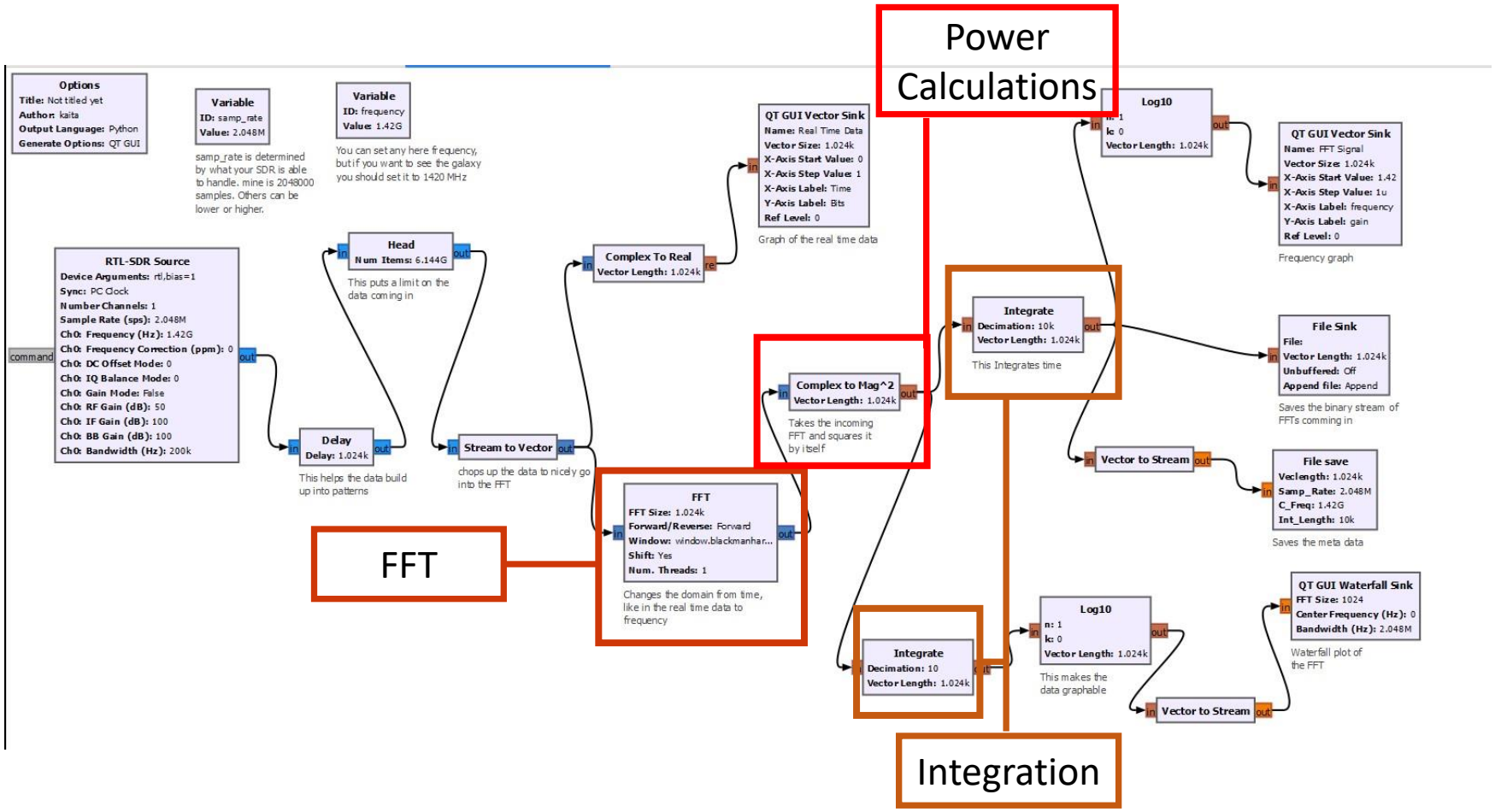
Time Domain Voltage Graph



- Variables: frequency and sample rate
- Signal Input: RTL-SDR source, delay, head, stream to vector
- Time Domain Volage Graph: Complex to real, GUI Vector Sink

The Second Type of Data Collection

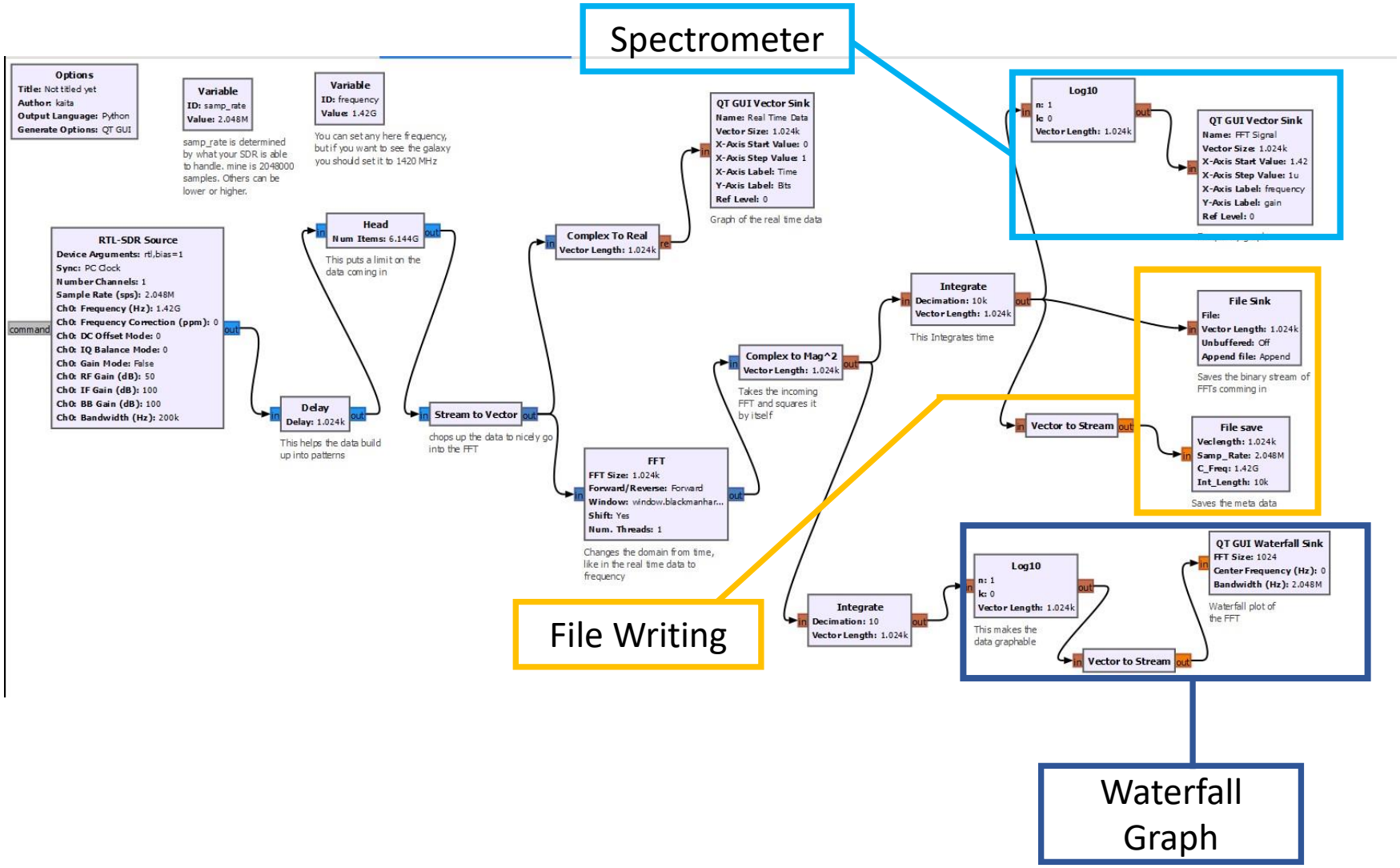
The Average Power



- FFT: Takes the signal from the time domain to the frequency domain
- Complex to Mag^2: Power Calculations
- Integration: 2D Averaging

The Second Type of Data Collection

The File Save and Live Graphs



- Spectrometer: Log10, GUI Vector Sink
- File Writing: Custom Python script saving Metadata, and File Sink
- Waterfall Graph: Log10, vector to stream, and GUI Waterfall Sink

The Three Live Graphs in Real Experiment

Raw

FFT

Waterfall

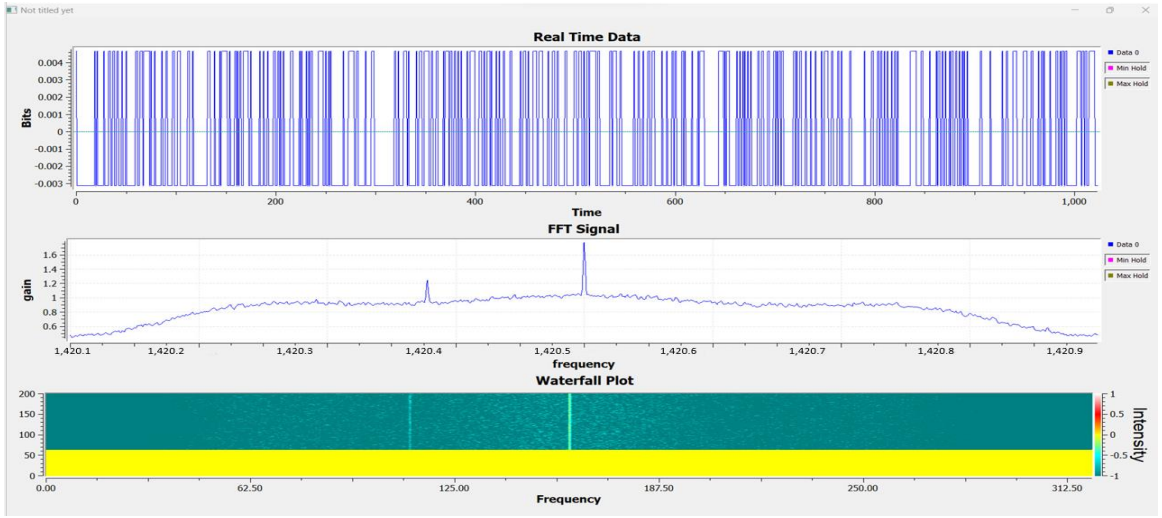


Fig. 3 The horn is pointed at Zenith

- **Time Domain voltage**: Quick display of the quality of the signal and allows easy diagnostics of hardware problems.
- **FFT/spectrum:** Integration and FFT processing capture the interesting radio signals
- **Waterfall:** Time variations in astronomical signals are easy to identify.

Results (file writing)

- The CHART project provides a number of Jupyter notebooks.
- Students can share and learn from CHART-guided tutorials.
- This graph is one single pointing at 75 degrees above the horizon, near the galactic center. The 21 cm line is clearly visible.

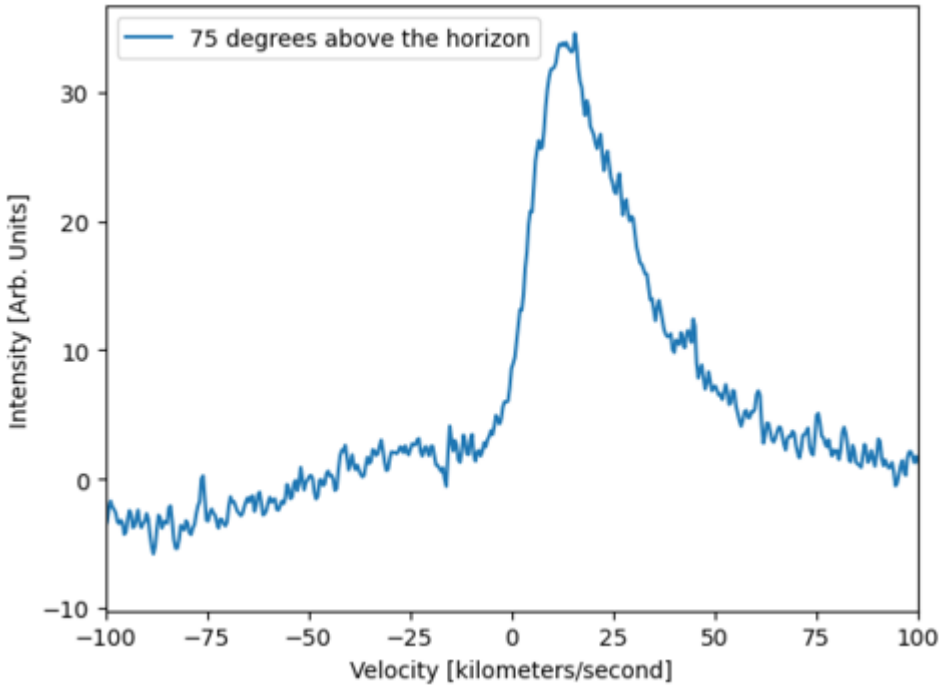


Fig. 3 An experiment performed by me using GNU and analyzed using Jupyter notebooks. Point at the 75-degree zenith.

Acknowledgements

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