

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 undergraduates and high school students

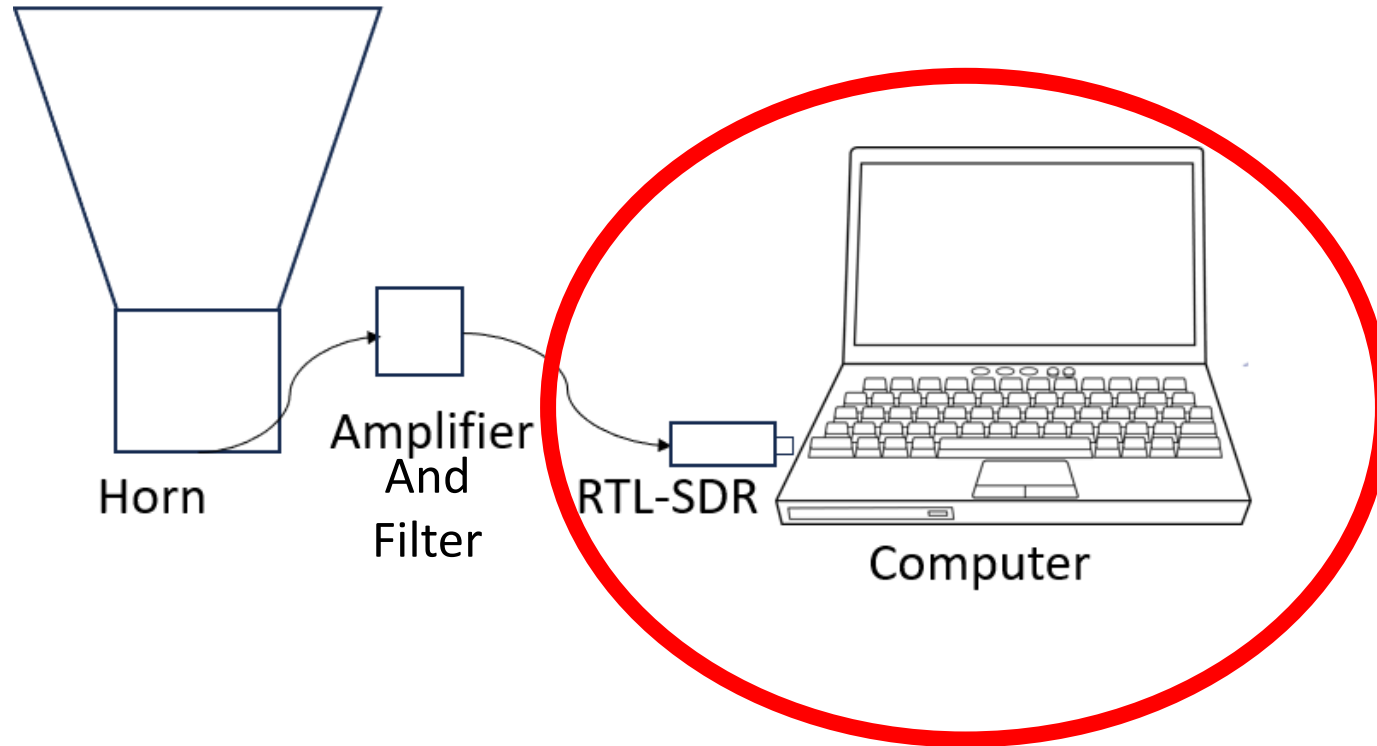


What is in the CHART Project

- 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

```
winona@raspberrypi: ~/Desktop/example/example_2
File Edit Tabs Help
winona@raspberrypi:~ $ ls
Bookshelf Documents Music Public Videos
Desktop Downloads Pictures Templates
winona@raspberrypi:~ $ cd Desktop
winona@raspberrypi:~/Desktop $ cd example
winona@raspberrypi:~/Desktop/example $ ls
example_2
winona@raspberrypi:~/Desktop/example $ cd example_2
winona@raspberrypi:~/Desktop/example/example_2 $ ls
example_3
winona@raspberrypi:~/Desktop/example/example_2 $ cd example_3
bash: cd: example_3: Not a directory
winona@raspberrypi:~/Desktop/example/example_2 $ cd
winona@raspberrypi:~ $ cd Desktop/example/example_2
winona@raspberrypi:~/Desktop/example/example_2 $
```

The GUI titled "Today's Data" features a dark theme with light-colored text and buttons. It contains several input fields for data collection parameters:

- Initial Frequency: 1419
- Final Frequency: 1419.2
- Integration Time: 0.5
- Number of Integrations: 100
- Username: Enter Here
- Location: Enter Here
- Trial: 00
- Date: MM.DD.YYYY
- Time: 00:00 am

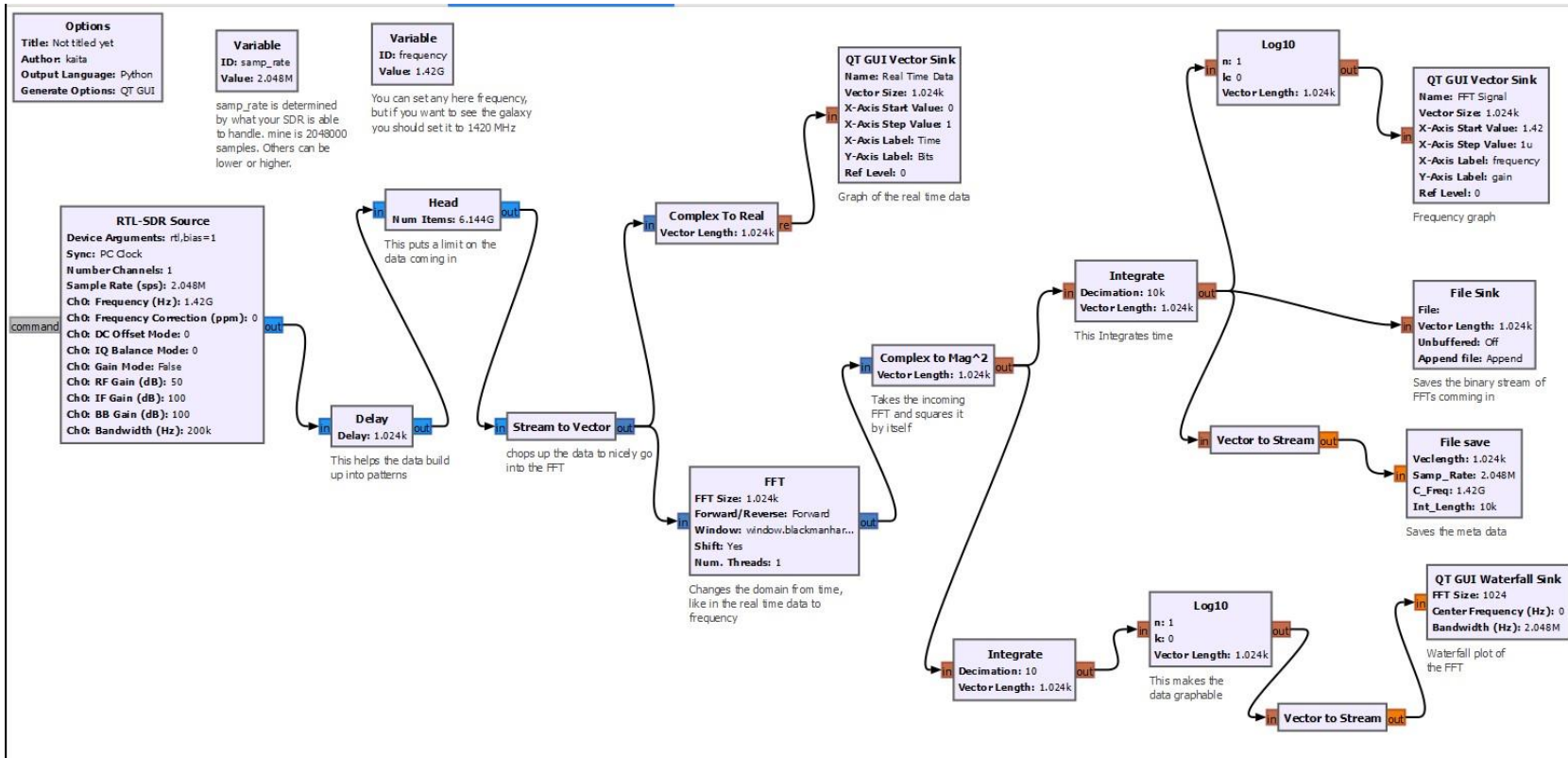
There are also three toggle switches:

- Use Default Parameters (disabled)
- Enable Bias-T (disabled)
- Use System Date and Time (disabled)

A text input field at the bottom left is labeled "Describe what you are looking at." At the bottom right, there are three buttons: "Start", "Stop", and "Open Jupyter Hub to Upload".

The Second Type of Data Collection

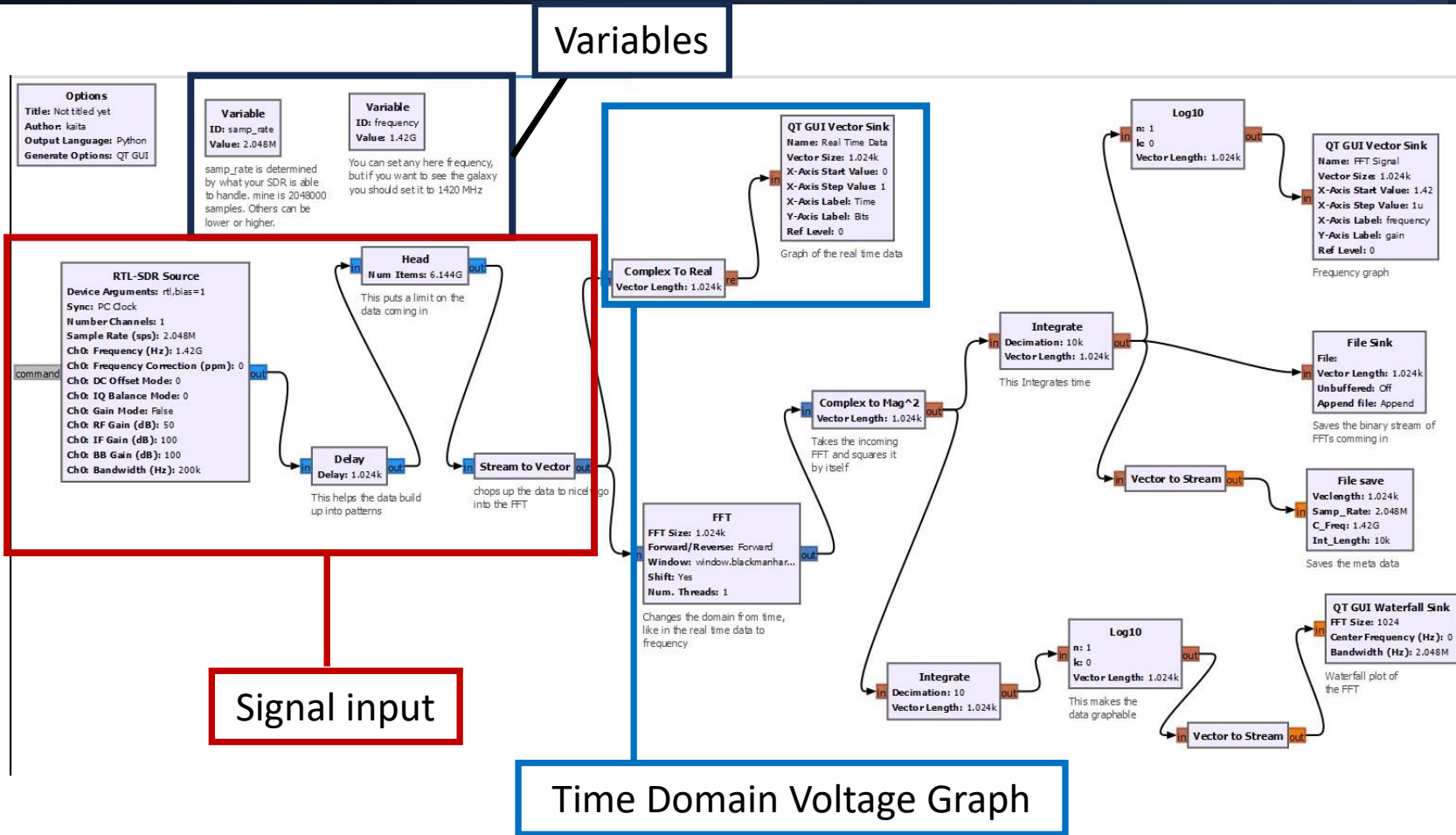
The Flowgraph



- 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

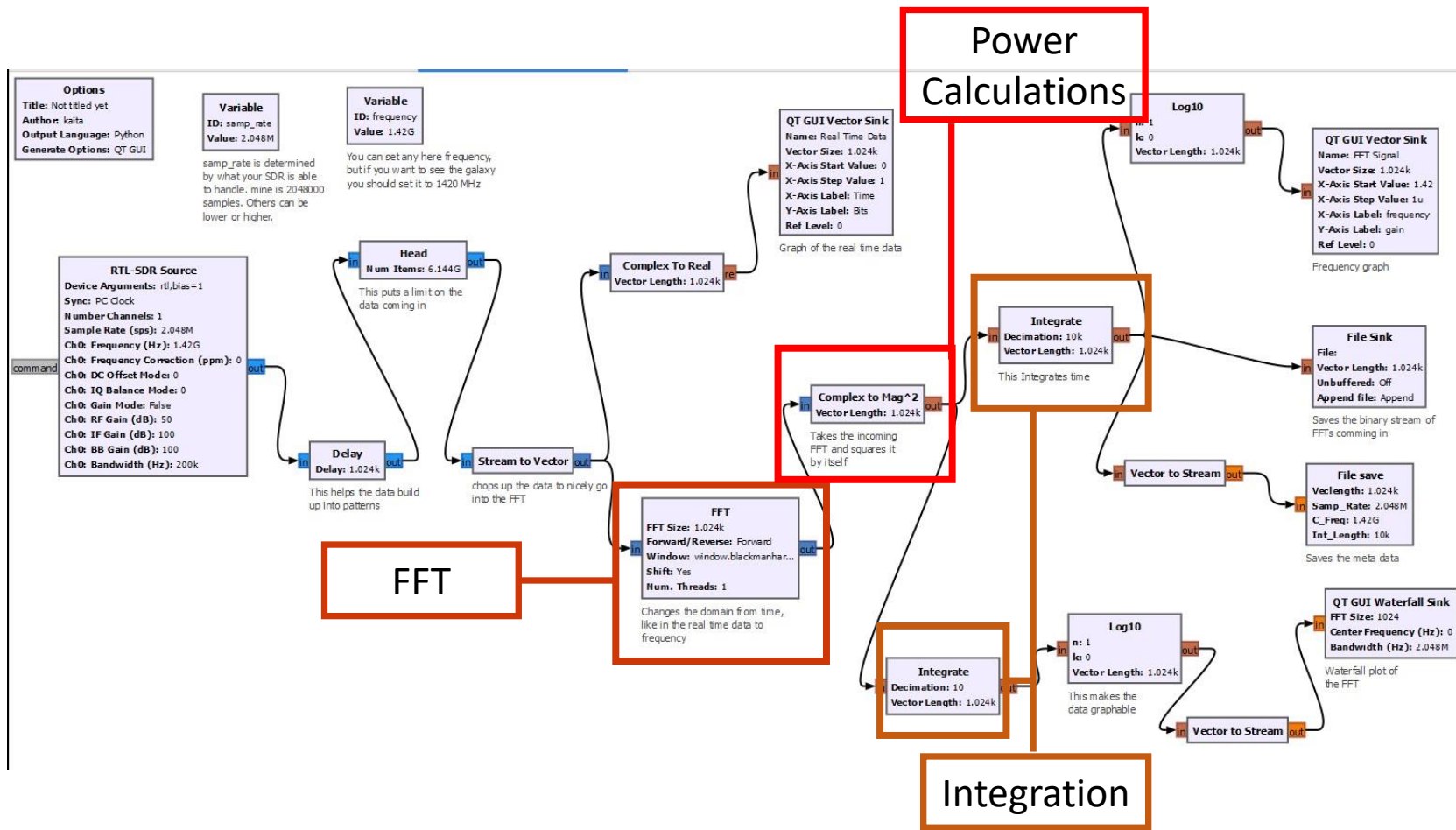
Time Domain Voltage Graph



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

The Second Type of Data Collection

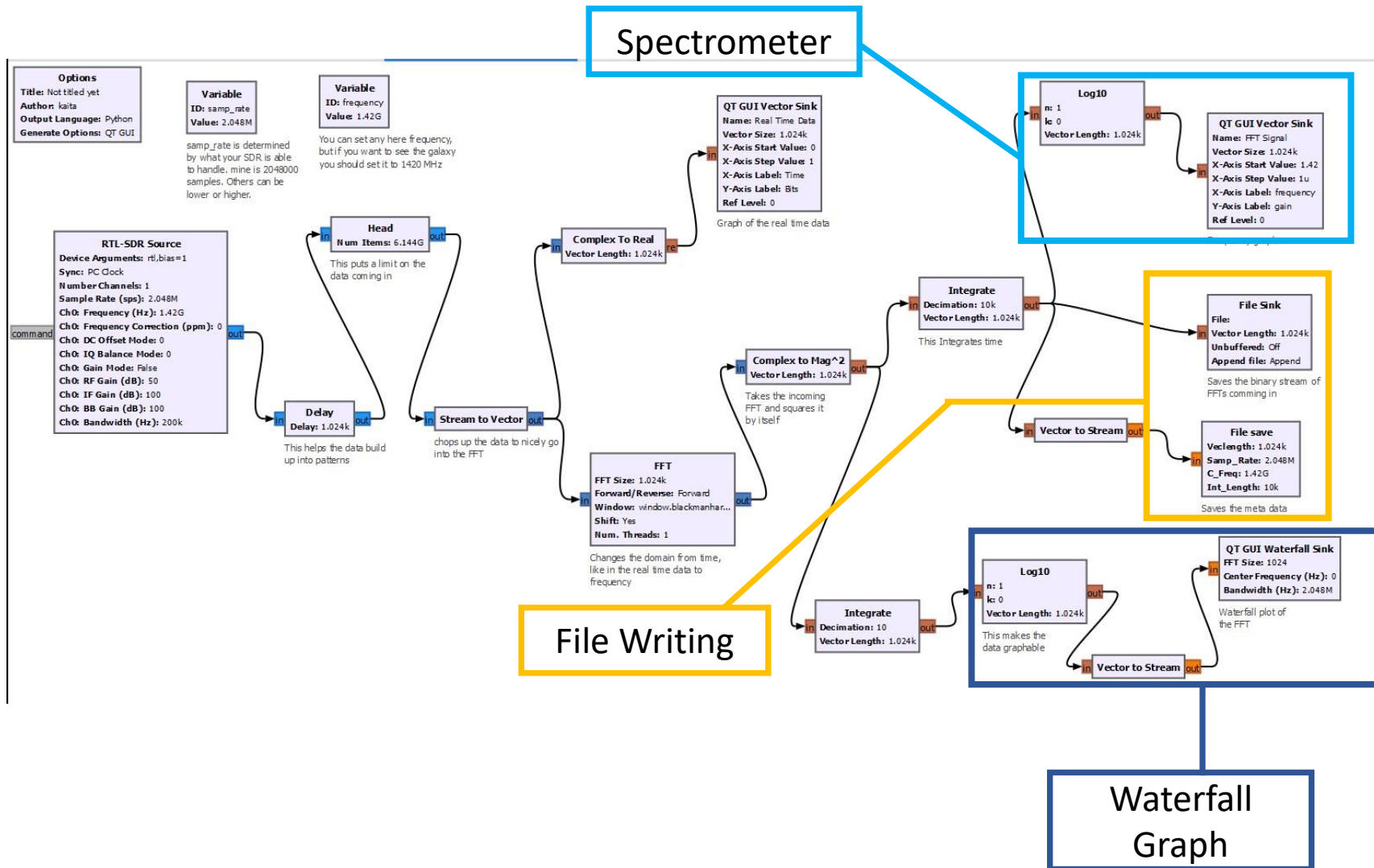
The Average Power



- FFT: Takes the signal from the time domain to the frequency domain
- Complex to Mag²: 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

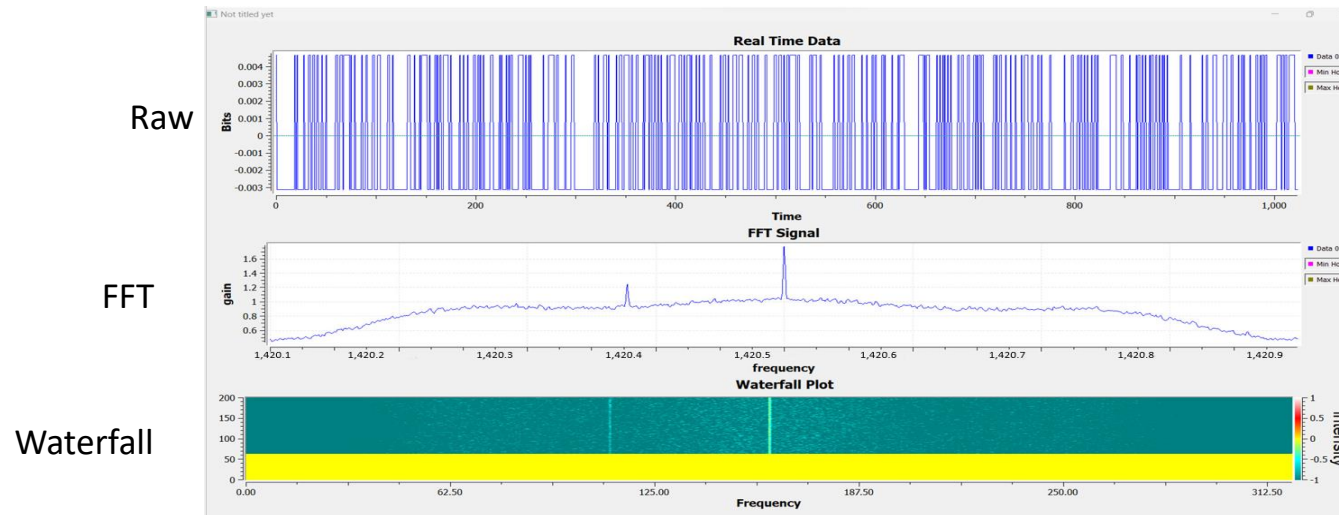


Fig. 3 The horn is pointed at Zenith

- **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.

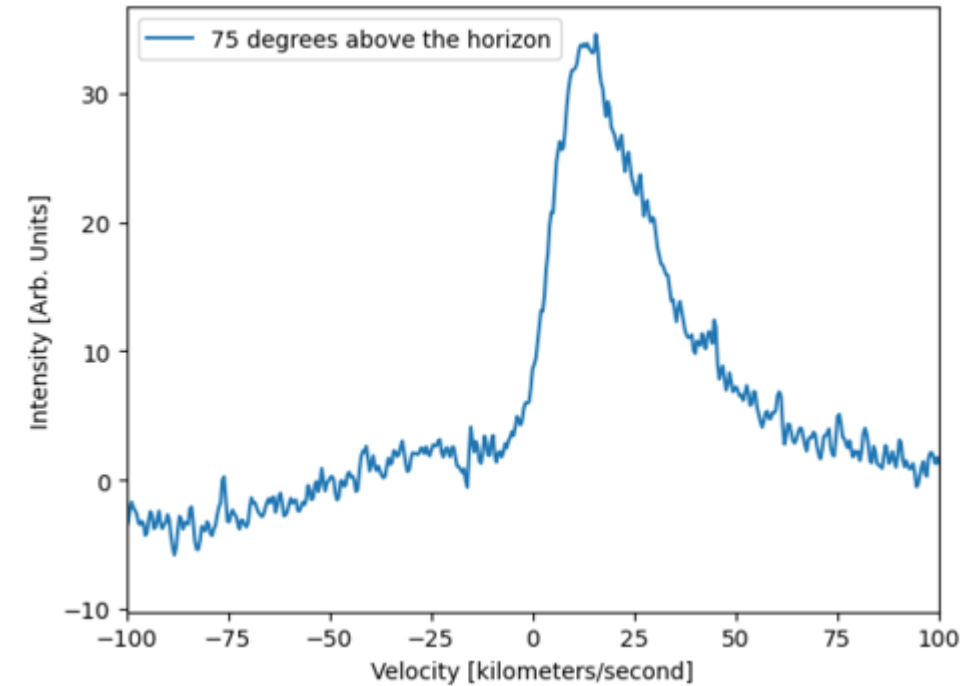


Fig. 3 An experiment performed by me using GNU and analyzed using Jupyter notebooks. Point at the 75-degree zenith.

Acknowledgements



BROWN



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