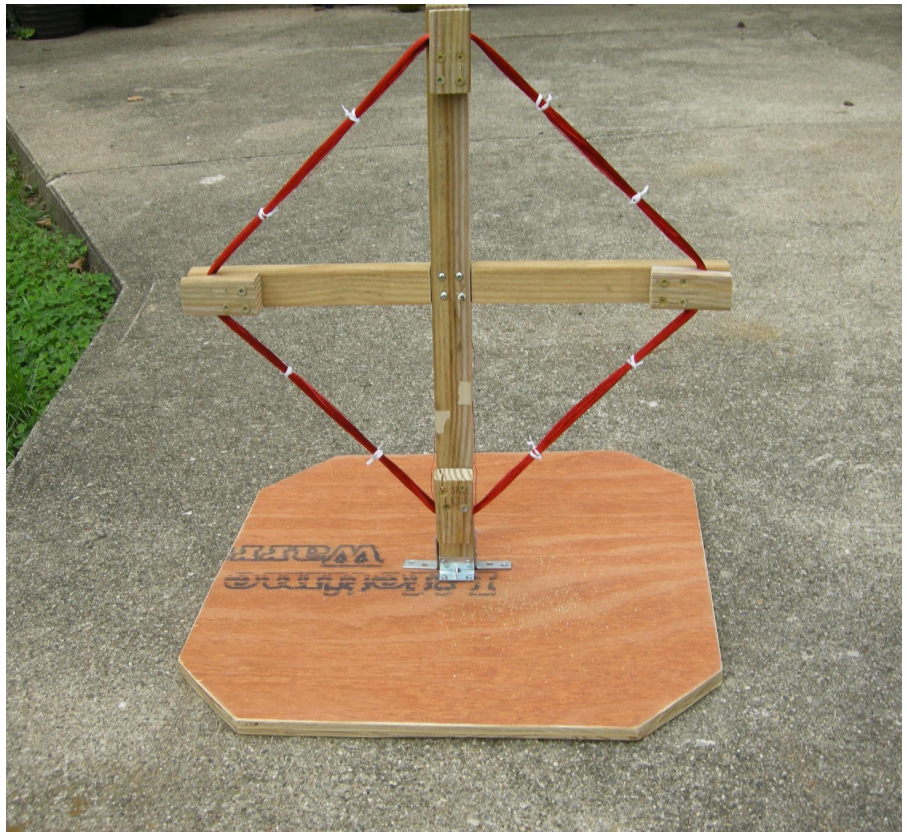
*observe the invisible universe...*

# OPEN SOURCE RADIO TELESCOPES




**Evan Smith, Ellie White, Richard Prestage, & Martin Braun**

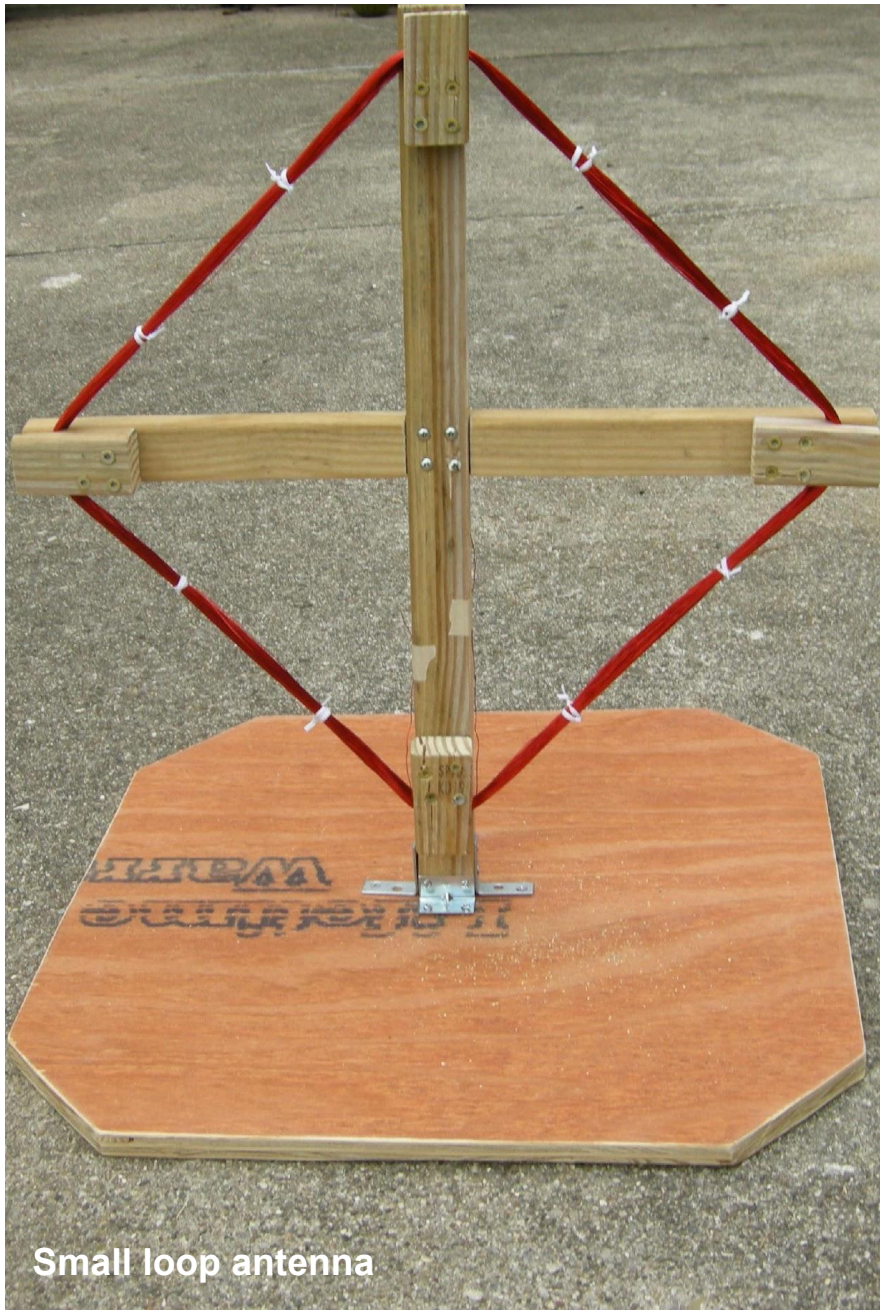
**FOSDEM 2018**

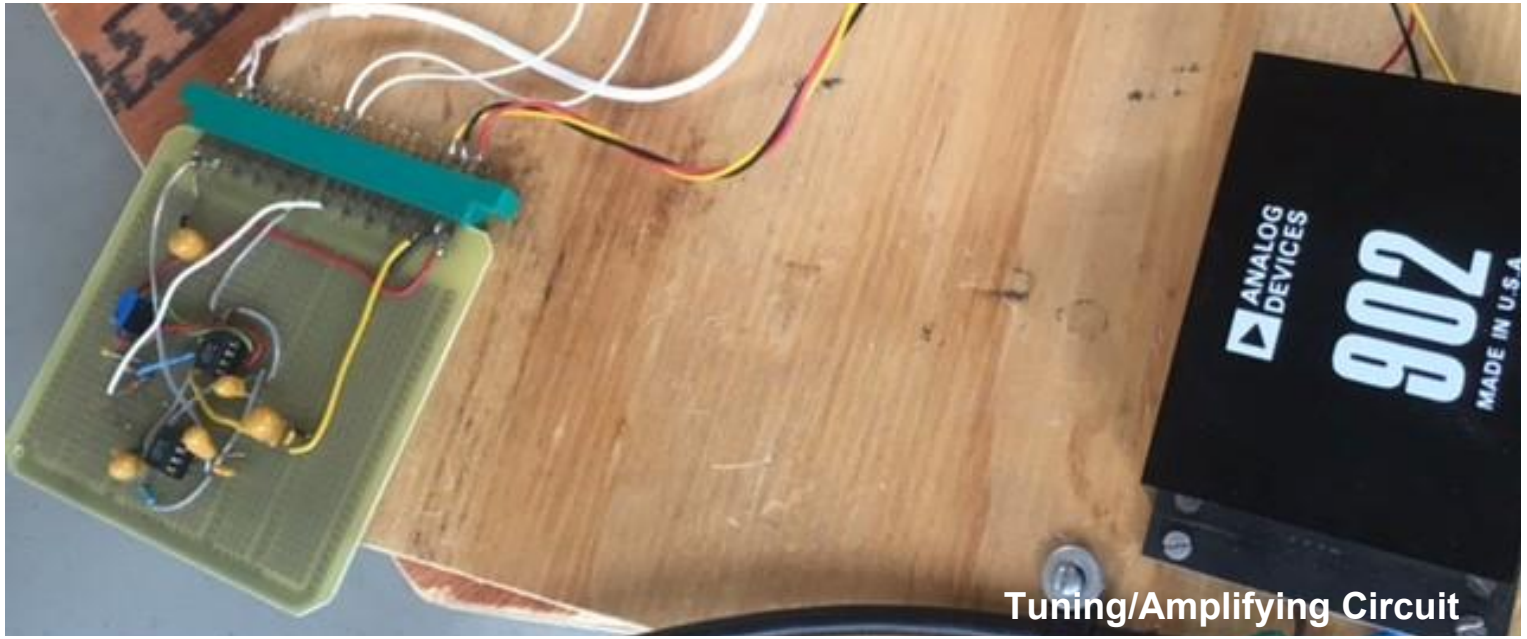
# What is Open Source Radio Telescopes?

- An open, collaborative, and free collection of ideas and designs for radio telescope construction
- OSRT provides plans and learning resources that are accessible to anyone with an interest in citizen science or STEM education, from middle school to graduate students and beyond
- OSRT promotes discussions about digital signal processing and using GNU Radio software with off-the-shelf electronics, such as low-noise amplifiers, filters, and software defined radios.

# Some projects we are currently pursuing...

- Designed, built, and tested a 21cm Horn Antenna, capable of detecting neutral hydrogen and mapping the Milky Way
- Developed a Small Loop Antenna, which is capable of detecting solar activity by monitoring the signal strength of Very Low Frequency (VLF) submarine stations.
- In the process of developing instruction manuals and kit prototypes for both antenna designs, which we will distribute to students and teachers to promote STEM education.
- Each of these projects involves the use of RTL-SDR dongles and GNU Radio flowgraphs.


Small loop antenna

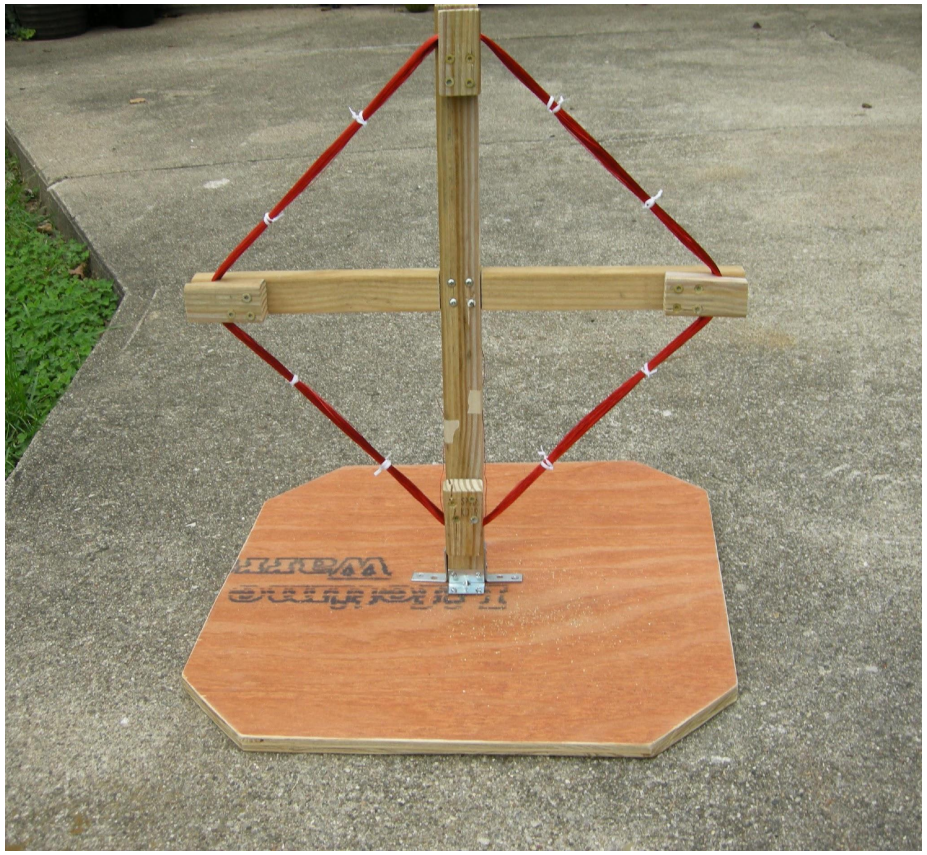


Tuning/Amplifying Circuit

# The Small Loop Antenna

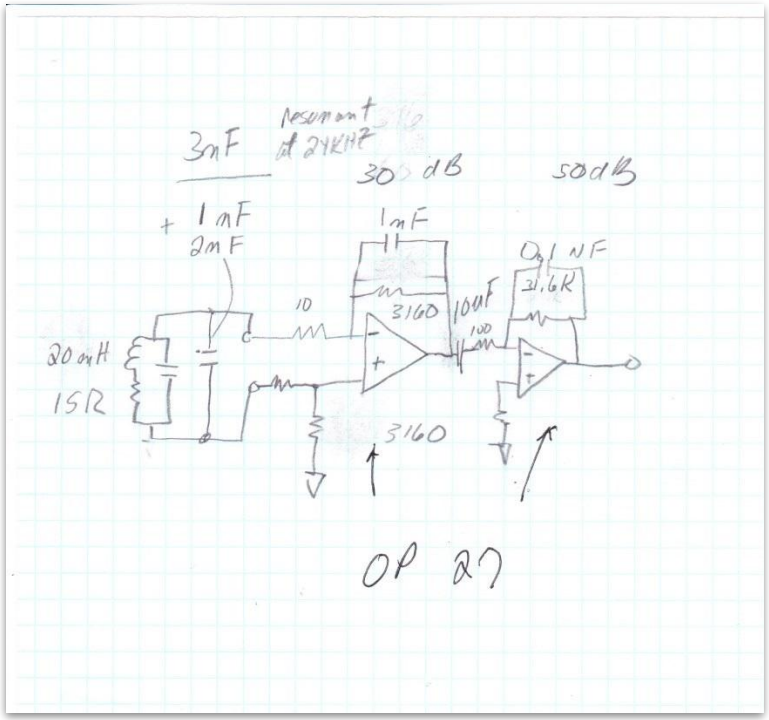
(< $100, easy to make, middle-school level)

# Physical construction of the loop



- Cross-frame built with scrap wood
- Frame wound with 125 turns of 24 awg magnet wire
- Mounted antenna to baseboard with L-brackets

# Tuning/Amplifying circuit




Tuning/amplifying circuit schematic (credit Steve White, Green Bank Observatory)

- Steve White of Green Bank Observatory built the tuning-amplifying circuit for the antenna.
- The LC circuit is tuned to 24 kHz, the frequency of the 2MW Cutler, Maine VLF station.
- Op-amps were used to amplify the signal enough for us to detect it.

# How the loop antenna detects solar flares

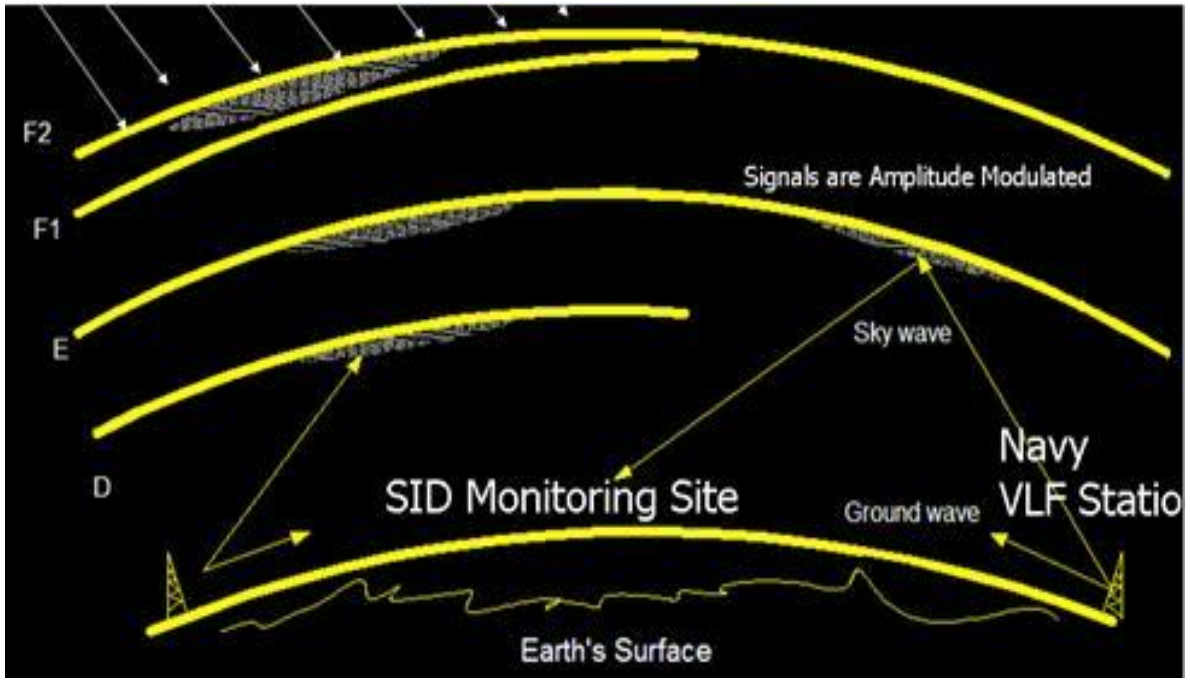
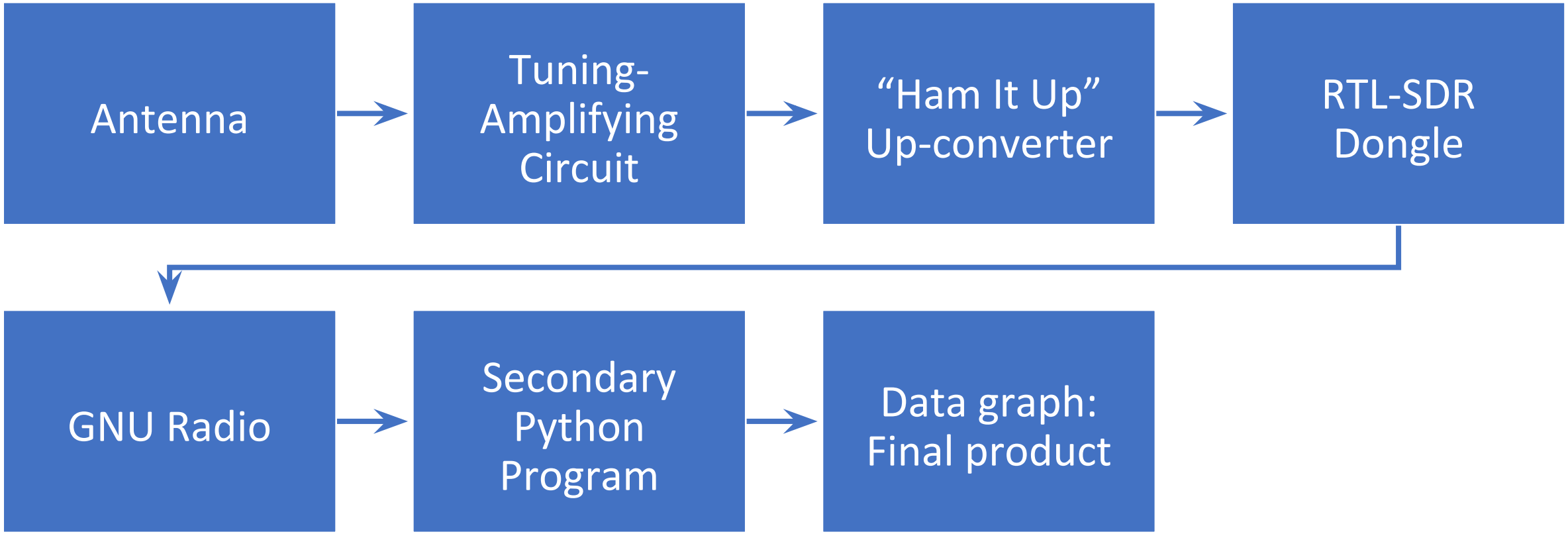



Image source: http://solar-center.stanford.edu

- Extra solar activity, like solar flares or solar wind, causes the ionosphere to become more ionized.
- The increase in ionization means that the VLF signal will bounce off the D-Region instead of the higher E or F-Regions, as it normally does
- The signal travels a shorter distance and loses less of its signal strength along the way.
- Therefore, by monitoring the strength of the radio signal, we can detect solar activity!

# Loop Antenna



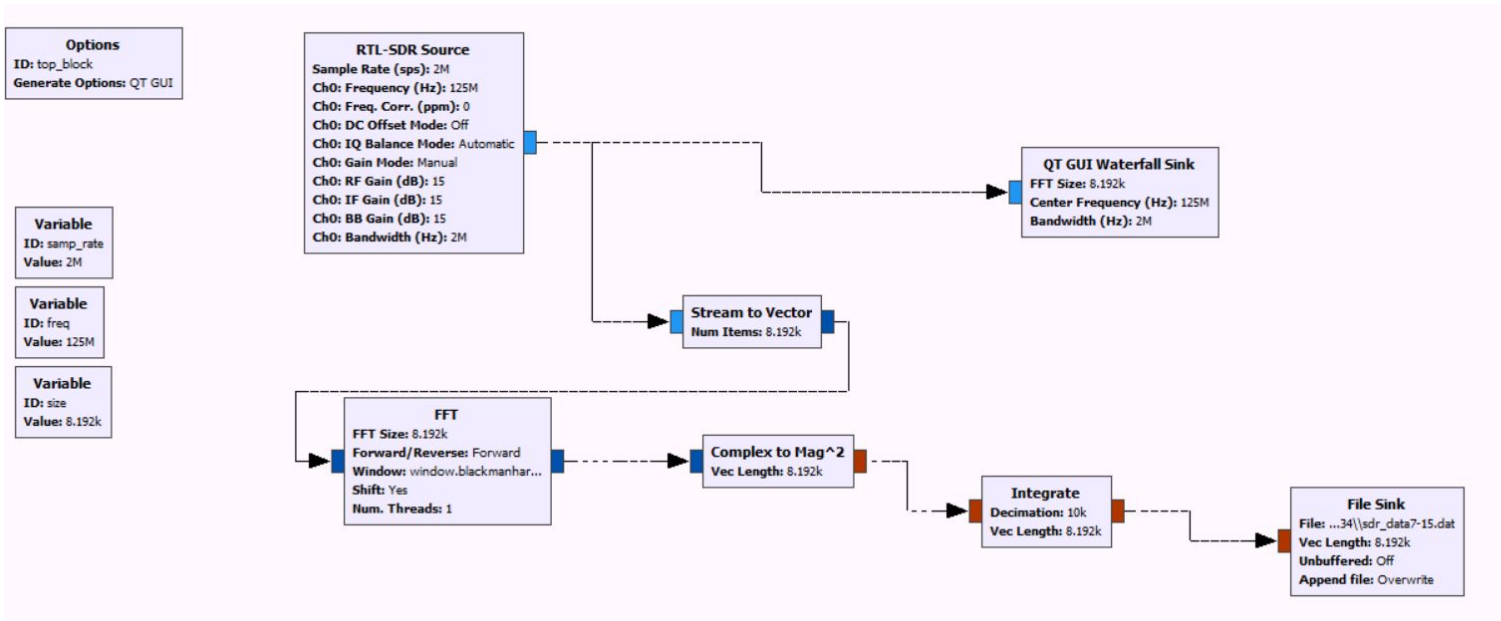
# Software Comparison: SDR# vs. GNU Radio

- SDR#:
  - Pros: SDR# is easy to use and requires no setup complications
  - Cons: There is no convenient way to record the signal for further processing, and the DSP steps are less user-adjustable
- GNU Radio:
  - Pros: offers many user-friendly DSP blocks, which can be used to visualize, manipulate and record antenna data
  - Cons: slightly bigger learning curve, displays are not as clear for testing as SDR#'s
- We used SDR# to test the antenna and make sure we were picking up the signals we should be.
- GNU Radio was employed to do the actual DSP and to record the input from the antenna for further processing.

# DSP with GNU Radio

- SDR dongle as input source
- Set sampling rate to 2M/sec
- Performed 8192 point FFT on the data streamed from the dongle to achieve a spectral resolution of 244 Hz
- Squared the complex FFT output
- Integrated signal every 10k samples
- Saved output to file sink, and displayed in Waterfall Sink

# DSP with GNU Radio

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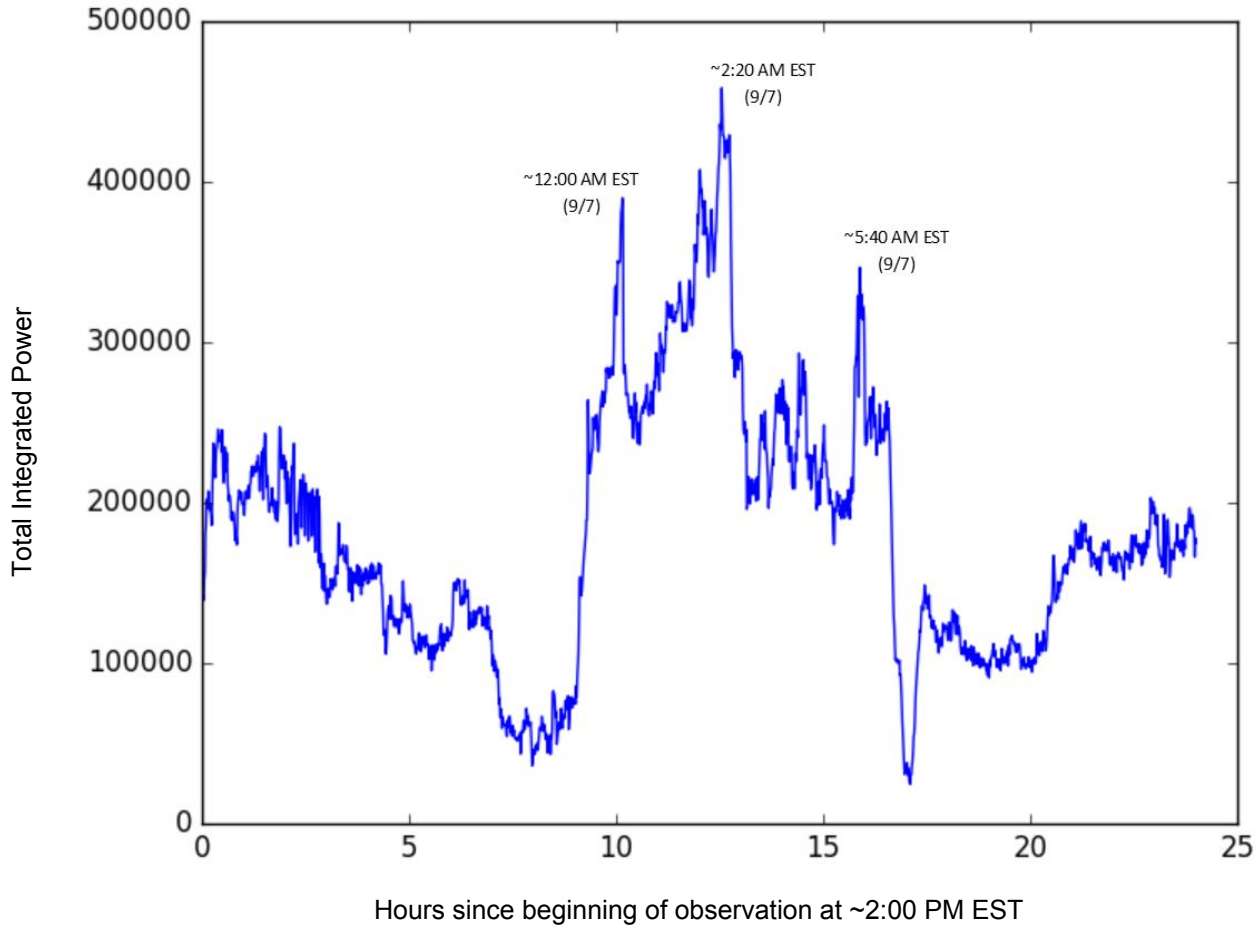
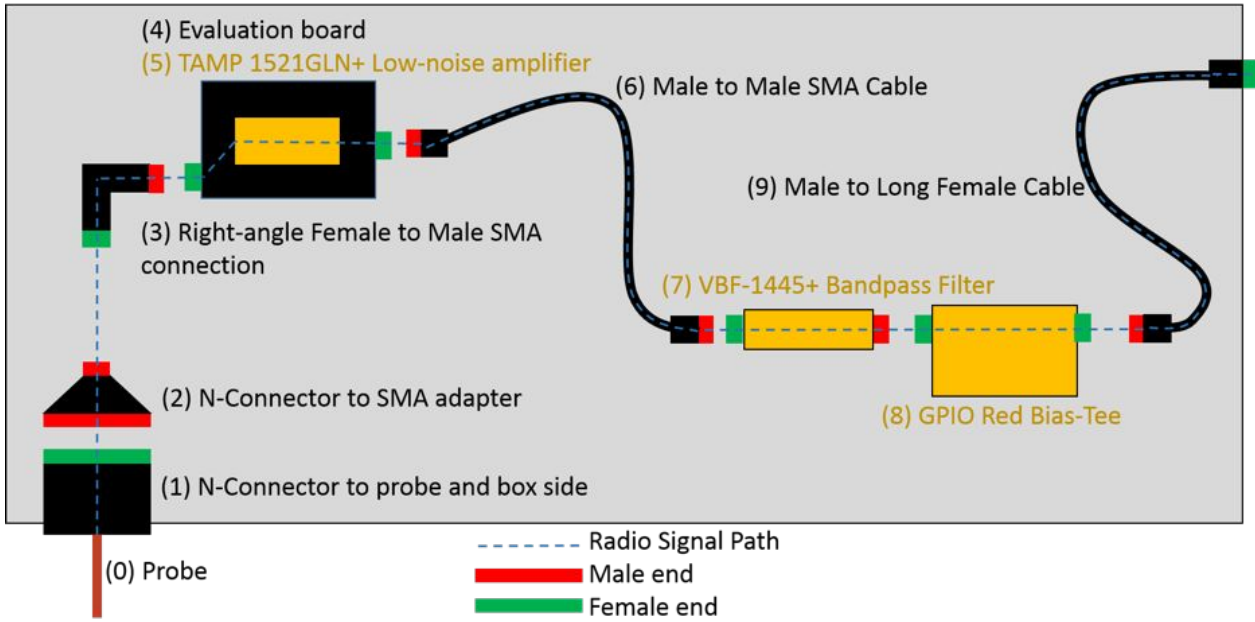
# Possible detections...




- This data was taken on September 7, 2017, during a time of reported high solar activity.
- The three labelled peaks may be records of solar disturbances in the ionosphere.
- The dips in intensity are likely due to known effects caused by sunrise and sunset.

# The HI Horn Antenna


# Horn Antenna Flowgraph




SDR Dongle

GNU Radio → Secondary Python Program → Data graph: Final product

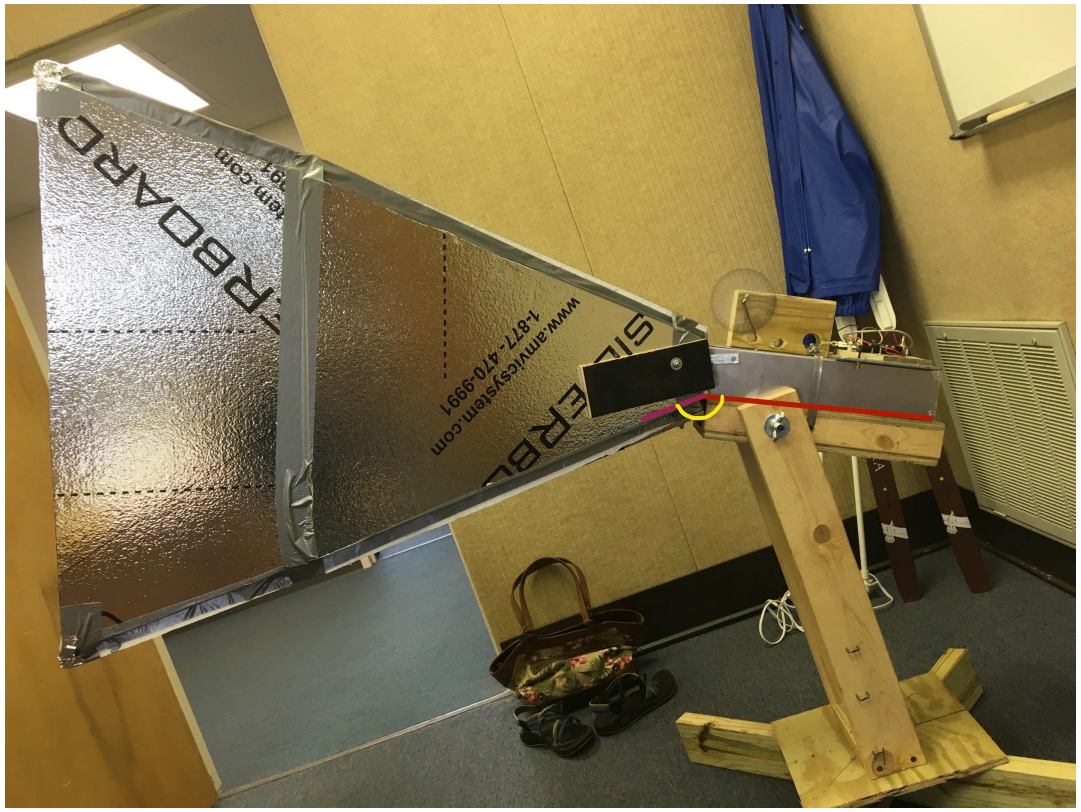
# The idea behind the 21cm horn

- Mapping the neutral hydrogen of the Milky Way galaxy is possible with an easily-built horn antenna
- The difficulty level of constructing the horn is perfect for high school and undergraduate students
- Provides a great lab/workshop experience

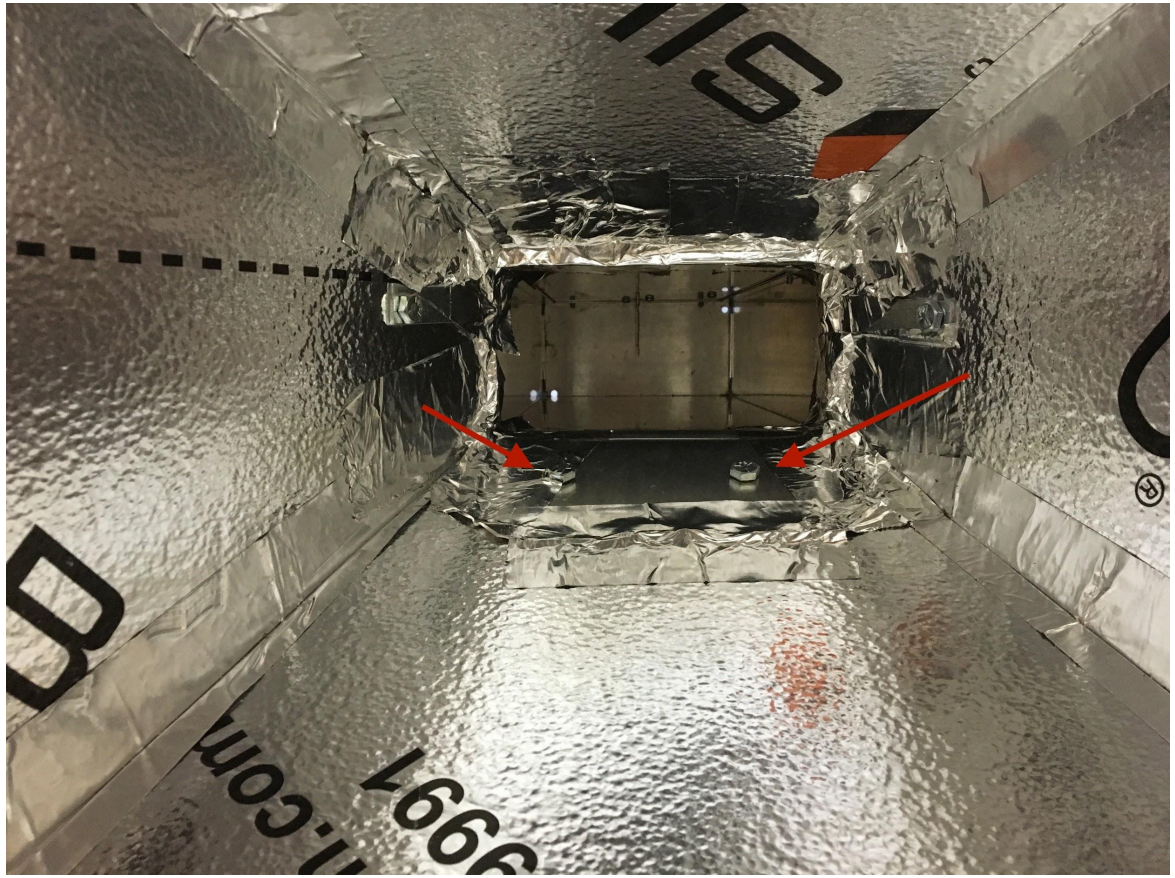
- (~$250, bit more complicated than loop antenna, about 7 degrees beamwidth)

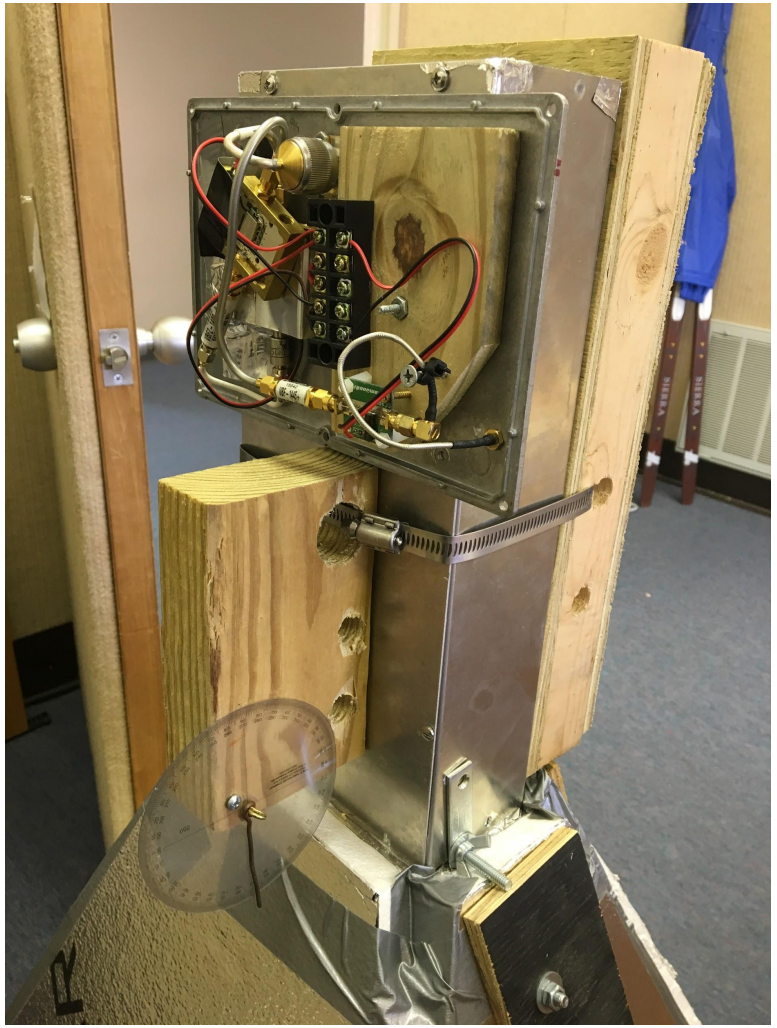
# Horn construction

Horn constructed with styrofoam boards coated with radio-reflective material

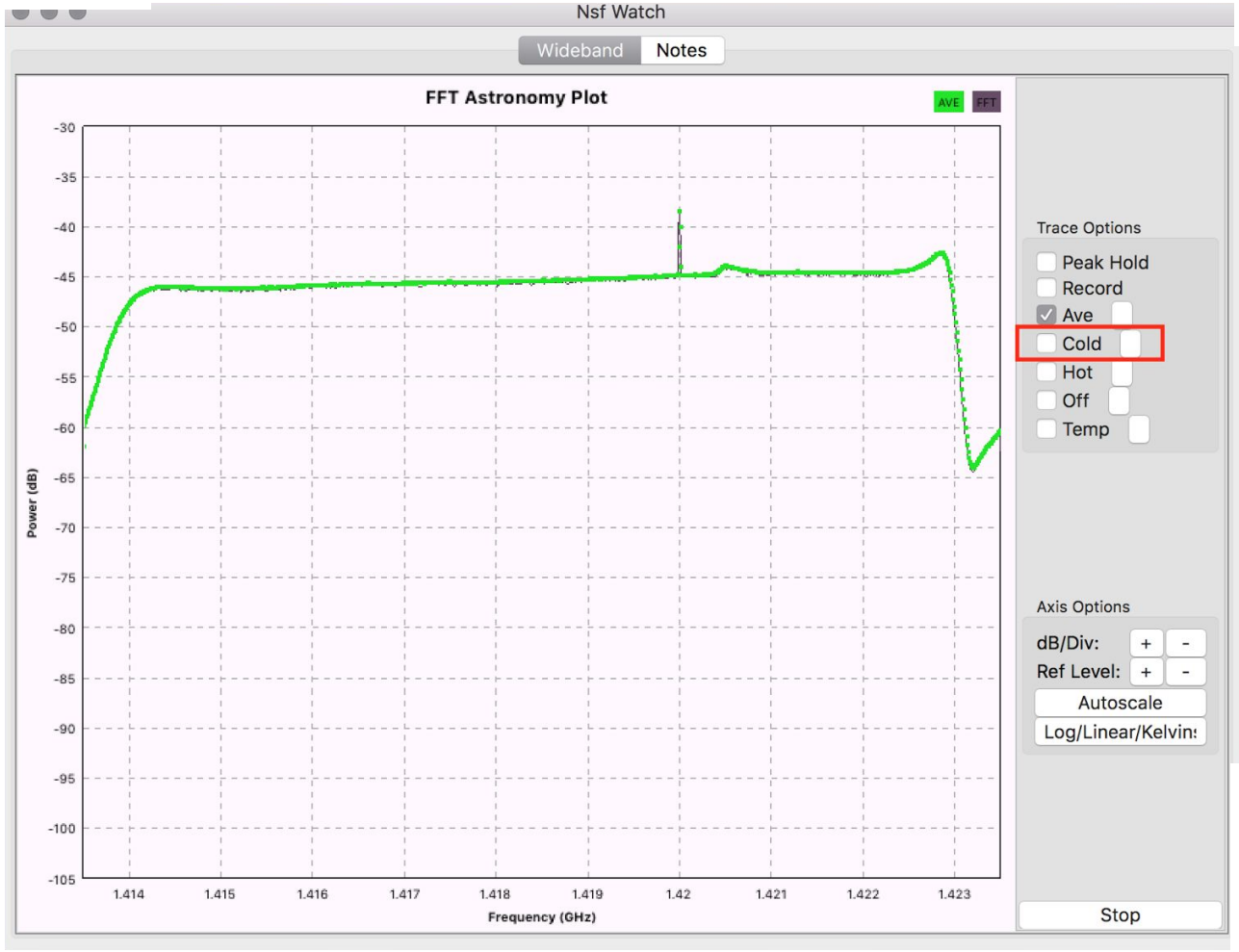


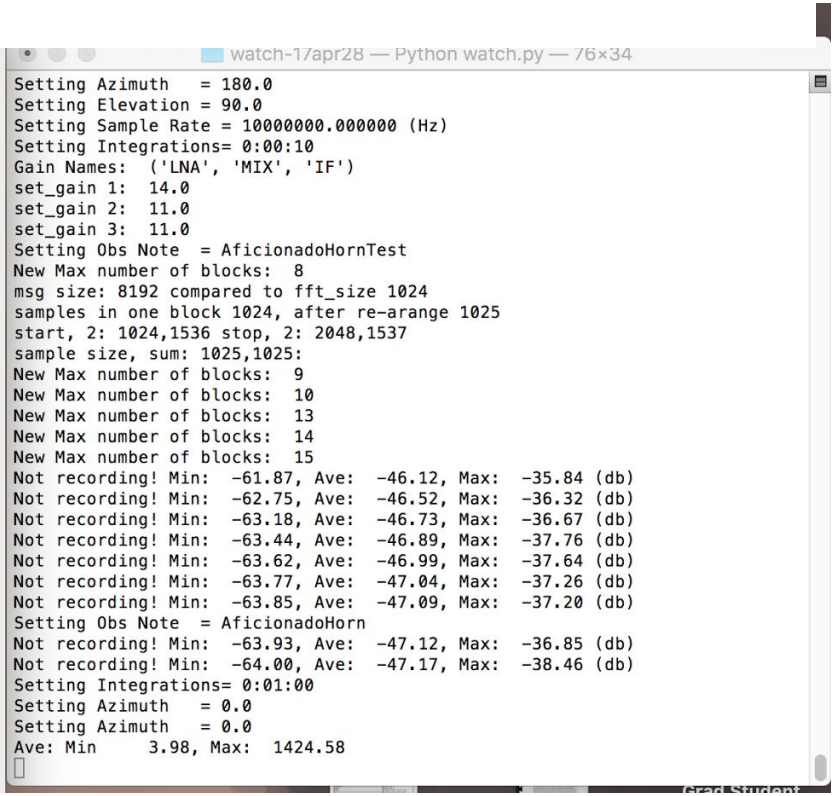
# The Waveguide and LNA



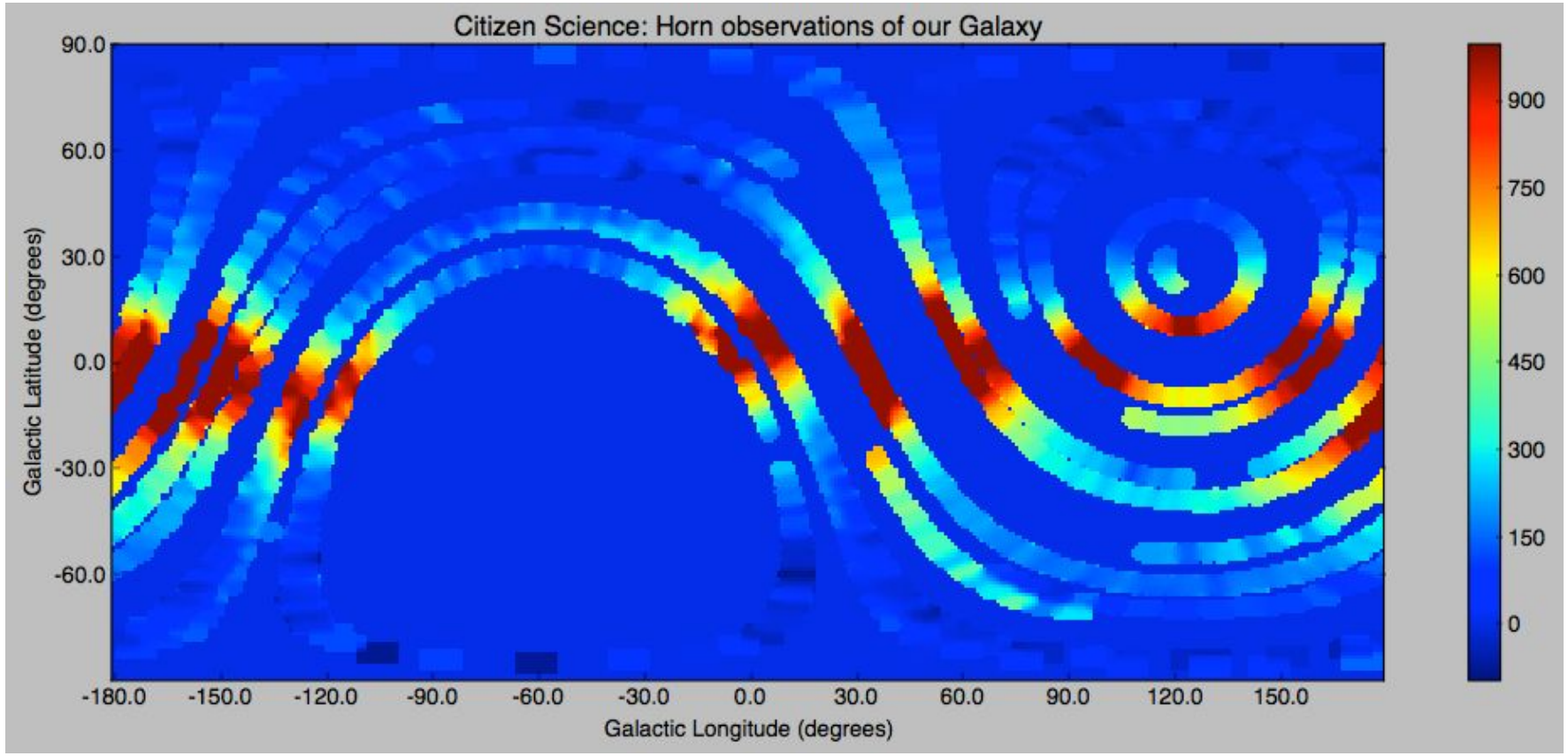


# Digital Signal Processing with GNURadio



# Observational Results



# How can you get involved with Open Source Radio Telescopes (OSRT)?

- **Check out our website:** opensourceradiotelescopes.org and Wiki page, which contain in-progress instructions, educational resources, documentation, and open-source software as the project develops.
- **Teachers:** Build an HI horn or small loop antenna with your students, and share your questions and results with the OSRT community.
- **Join our mailing list!** Visit opensourceradiotelescopes.org/community/
- You can also **contact us** directly to share your ideas:
    - Ellie White – orionnebula42@outlook.com
    - Evan Smith – etsmit12@gmail.com
    - Richard Prestage – richard.prestage@gmail.com

# Summary: Lessons learned

- Patience and persistence pay off!
- The process of doing a project like this is not as simple as it seems; it takes many attempts and detours to get to a working end result.
- If something works in theory, that doesn’t necessarily mean it will work as well in practice.
- The best way to learn about amateur radio astronomy is by doing, and by talking to those who are happy to share their experiences and knowledge.

# Acknowledgements


- Horn design and construction:
  - Kevin Bandura
  - Sue Ann Heatherly
  - Sophie Knudsen
  - Glen Langston
  - Noreen Prestage
  - Richard Prestage
  - Pranav Sanghavi
  - Evan Smith
- Loop antenna development:
  - Ellie White
  - Steve White
  - Richard Prestage

# Thank you!