Design and Development of a Software Defined Radio Telescope

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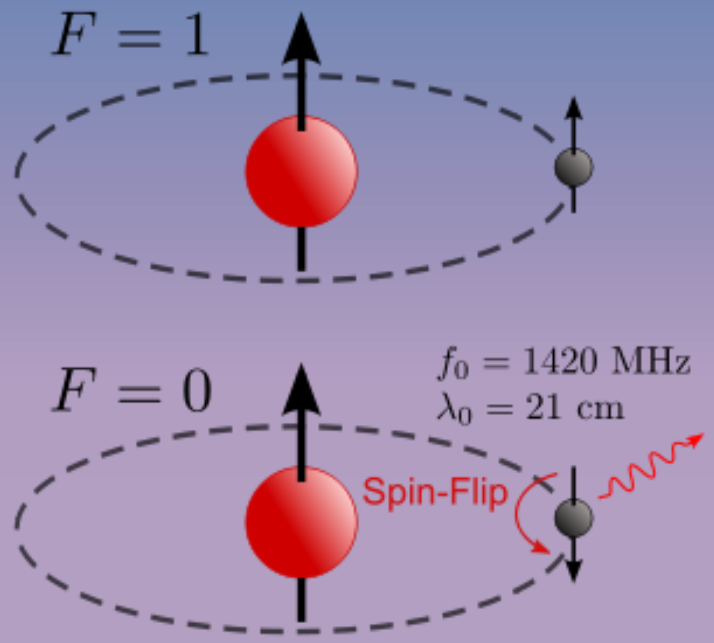
Outline

- Background and Premise
- Circuit Setup
- Horn Antenna Construction
- Weather Antenna
- Software
- Data
- Horn Antenna vs Weather Antenna
- Issues and Setbacks
- Looking Forward

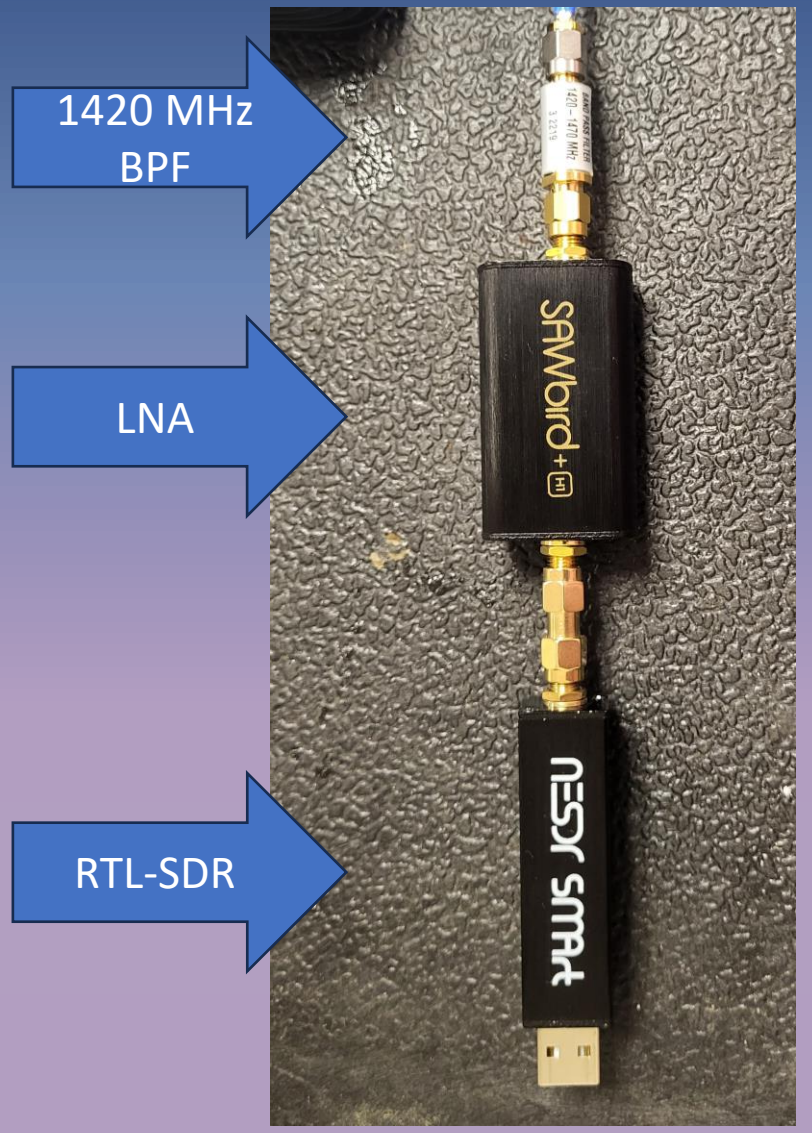
Background and Premise

- 21 cm wavelength radiation emitted by cold Hydrogen Clouds
  - Cold Hydrogen is that which makes up most of the Inter Stellar Medium (ISM)
- The observation of this helped Astronomers determine the shape and structure of our Galaxy.
- We hope to create a telescope capable of observing this using a Software Defined Radio



Circuit Design

- SDR circuit consisted of 4 parts
  1. The Antenna and feedline to collect and focus the information
  2. A Bandpass filter (BPF) to filter out unwanted frequency bands
  3. A Low Noise Amplifier (LNA) to amplify our target frequency
  4. An RTL-SDR to allow the analysis of the data on a laptop using SDRSharp



Horn Antenna Construction

- Design comes from ***American Astronomical Society, AAS Meeting #224, id.415.01***
- Dimensions used to optimize size while still being convenient to move
- Construction:
  - Used a 9”x6”x4” can as the waveguide.
  - 5.3 cm piece of copper wire for feed line
  - Cut cardboard into shape and wrapped with aluminum foil.
  - Taped everything together with aluminum conducting tape.

Horn Antenna Construction

Weather Antenna

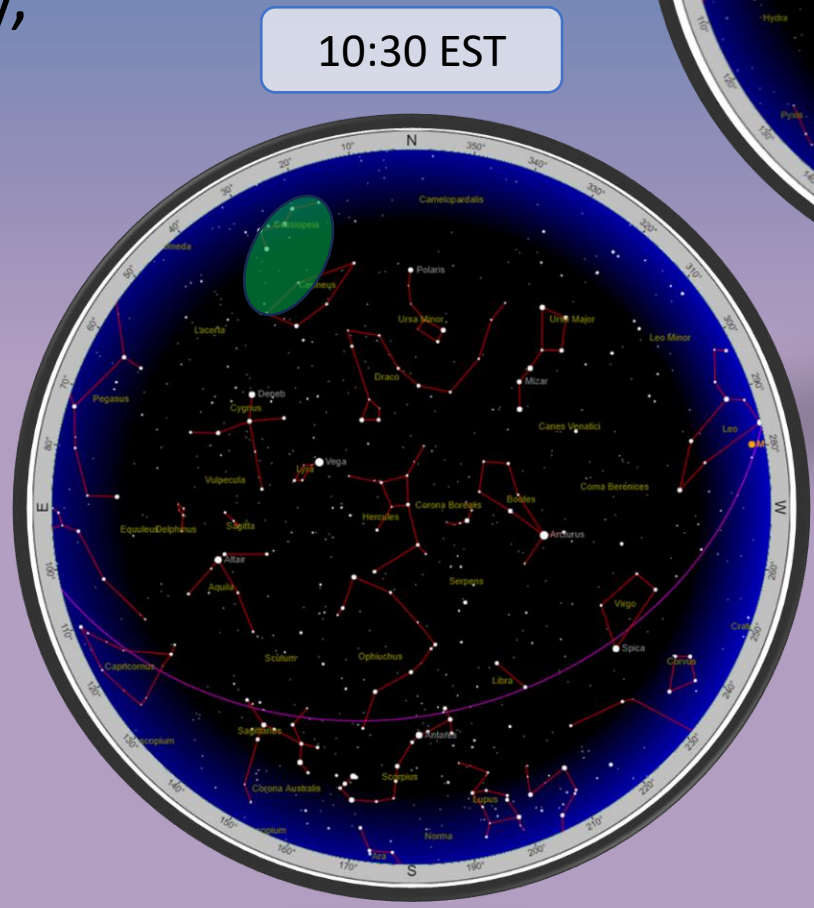
- Noelec GOES Weather Satellite Parabolic Antenna
  - 1.7GHz Center Frequency
  - 200 MHz+ Bandwidth

Software

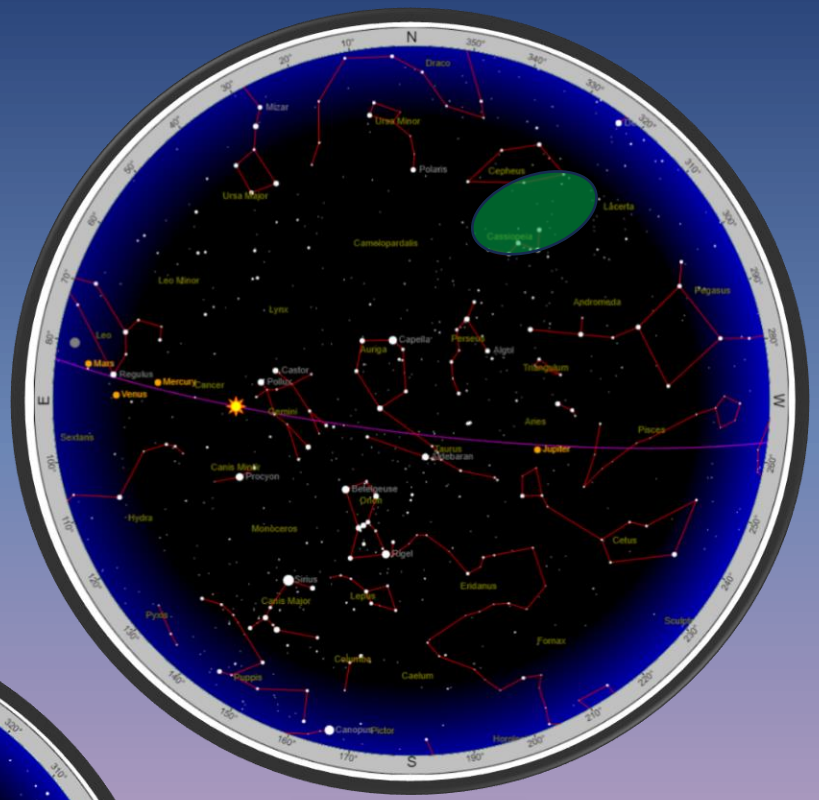
- All free open-source software used for creating software defined radios
  - Limited in their use for radio astronomy
- Used SDRSharp (SDR#)
  - Easy UI and simple display
  - Limited scope and data collection
- SDRAngel was another option
  - Included data save option, didn’t work properly
  - More complicated UI

Observation Conditions

- Location: Nevins Hall roof, Valdosta State University, Valdosta, Ga.
  - 30.84847916421404, -83.28885987900686
- Weather: Varied, mostly Sunny
- Time: 10:30 EST and 22:30 EST

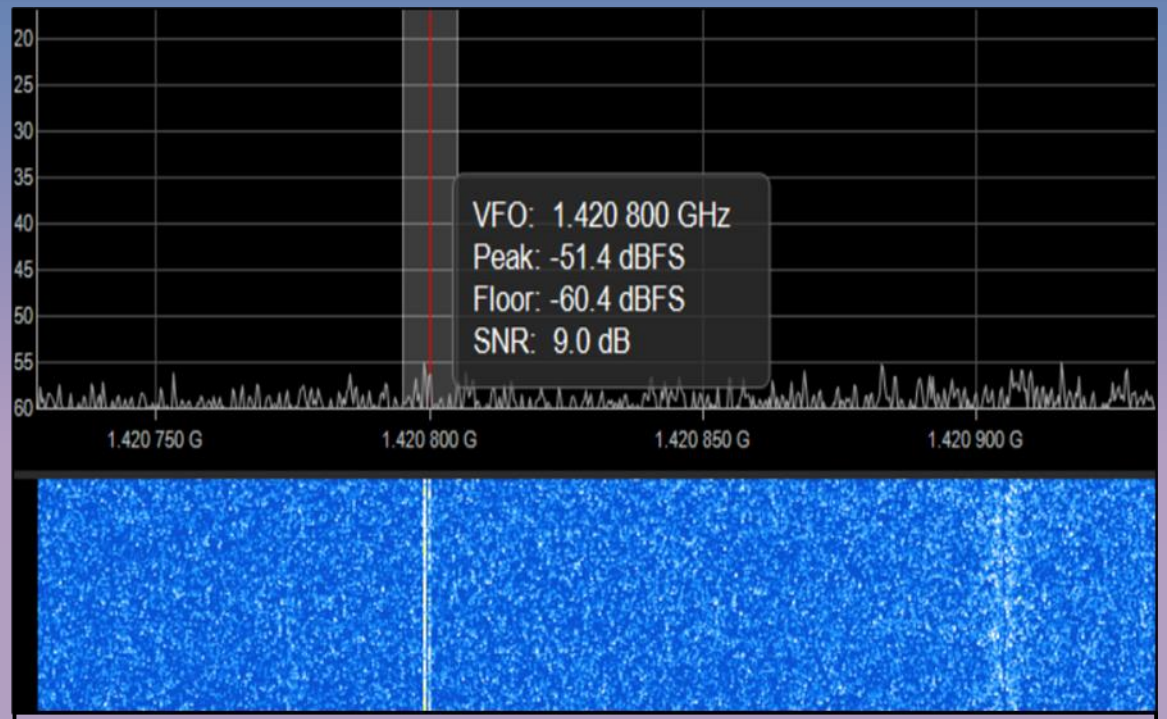


10:30 EST

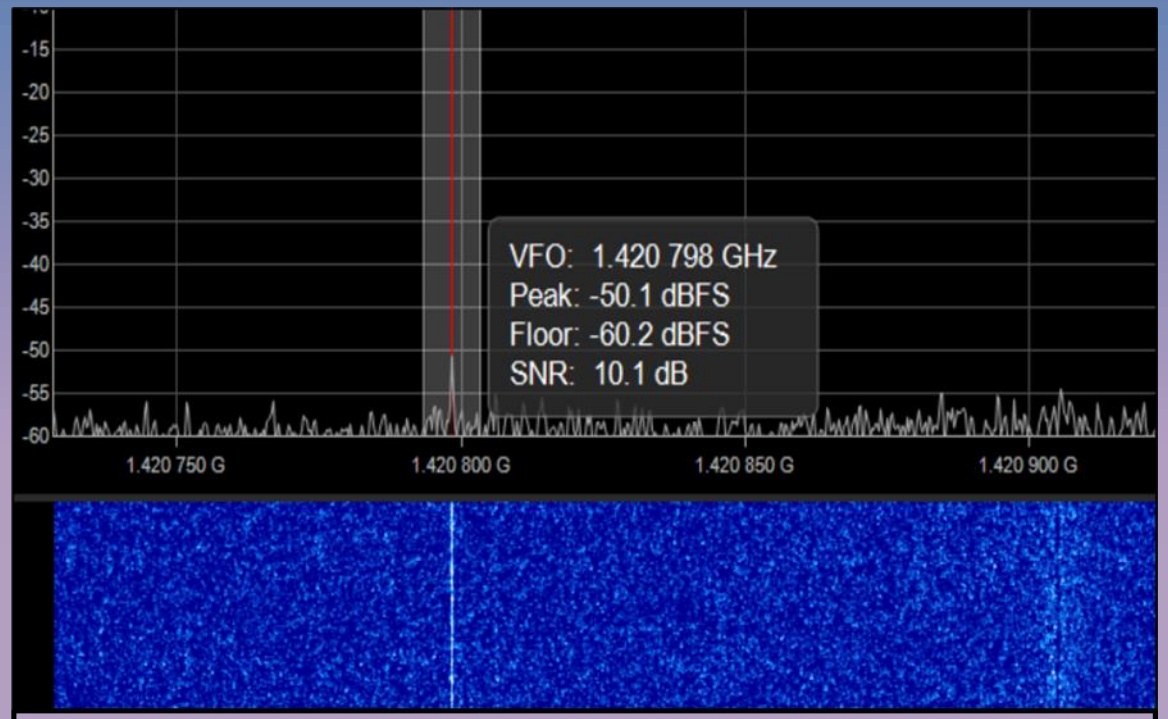


22:30 EST

Horn Antenna at Night

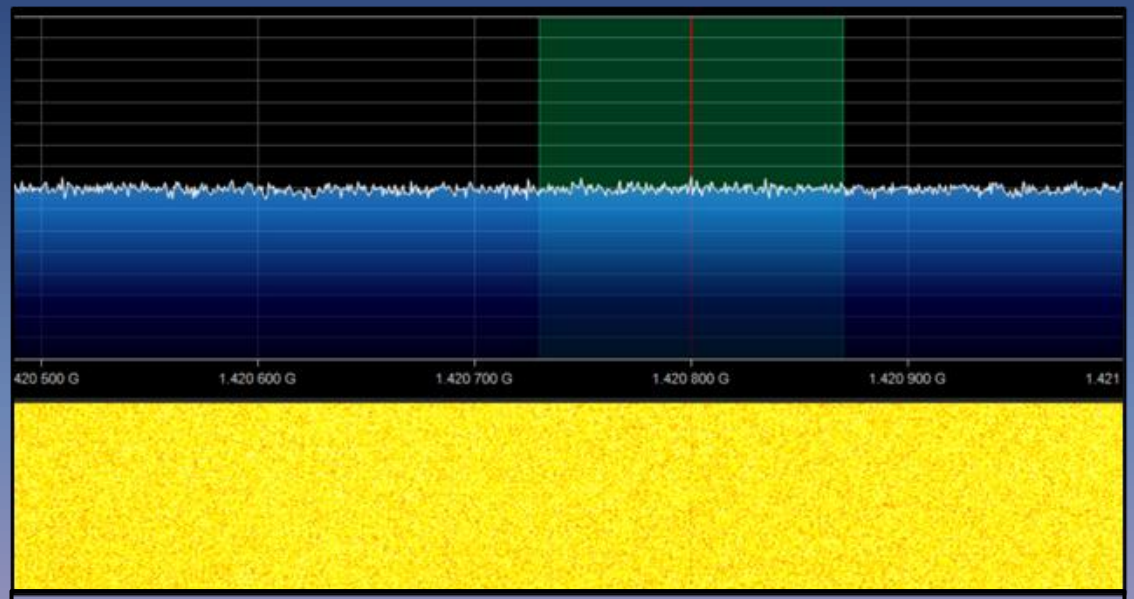


Data taken as we were focusing the antenna on Cassiopeia and Cepheus

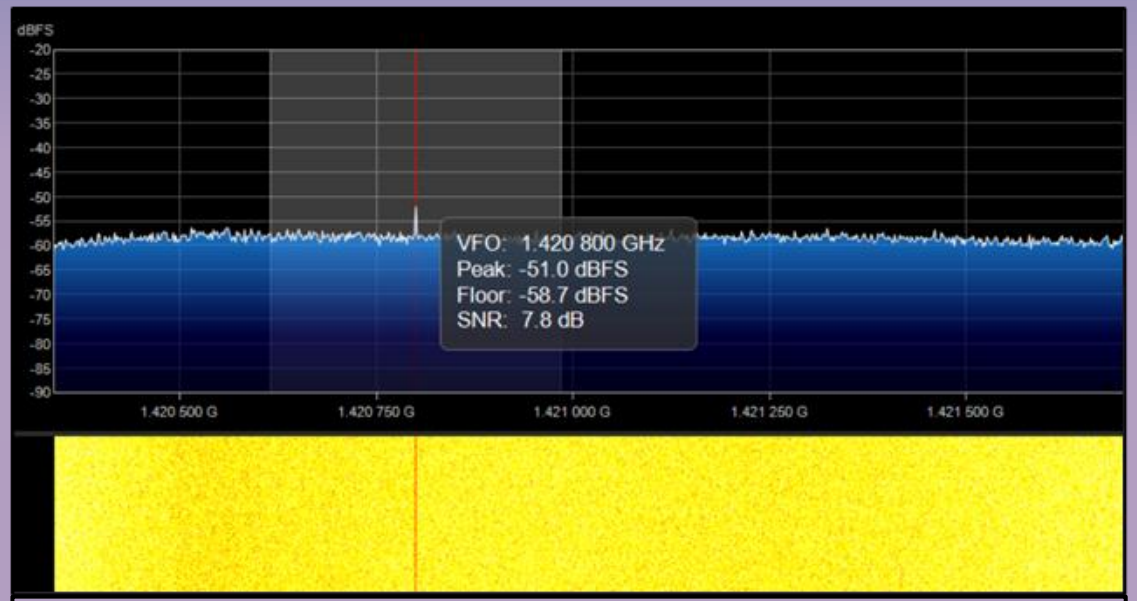


Data taken focused on the area of the Milky Way between Cassiopeia and Cepheus.

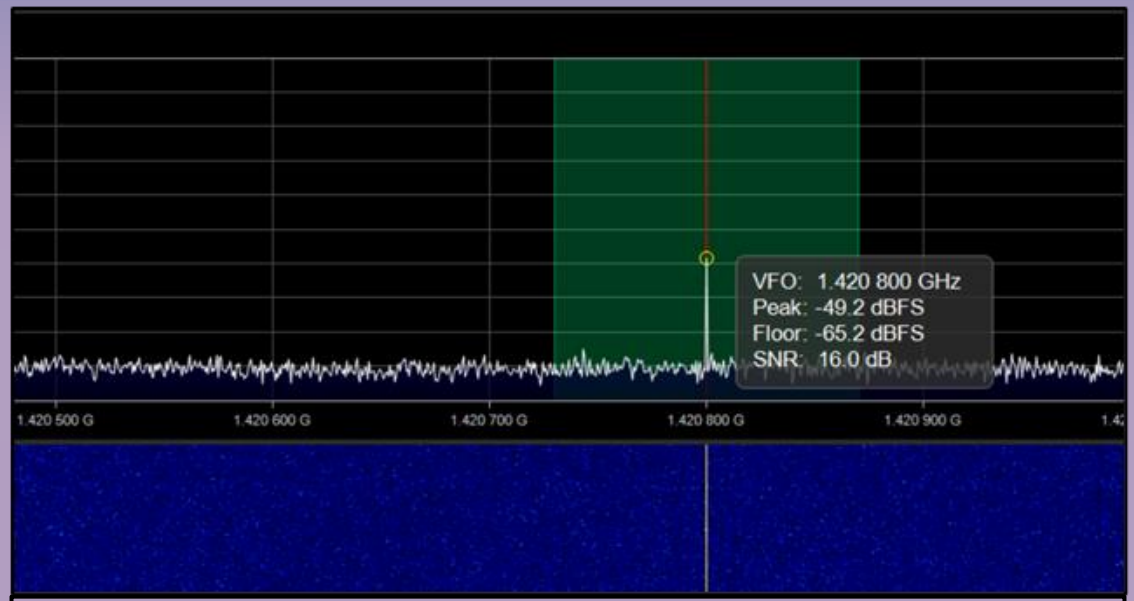
Data: Horn Antenna in the Morning



Data as we moved away from target region.

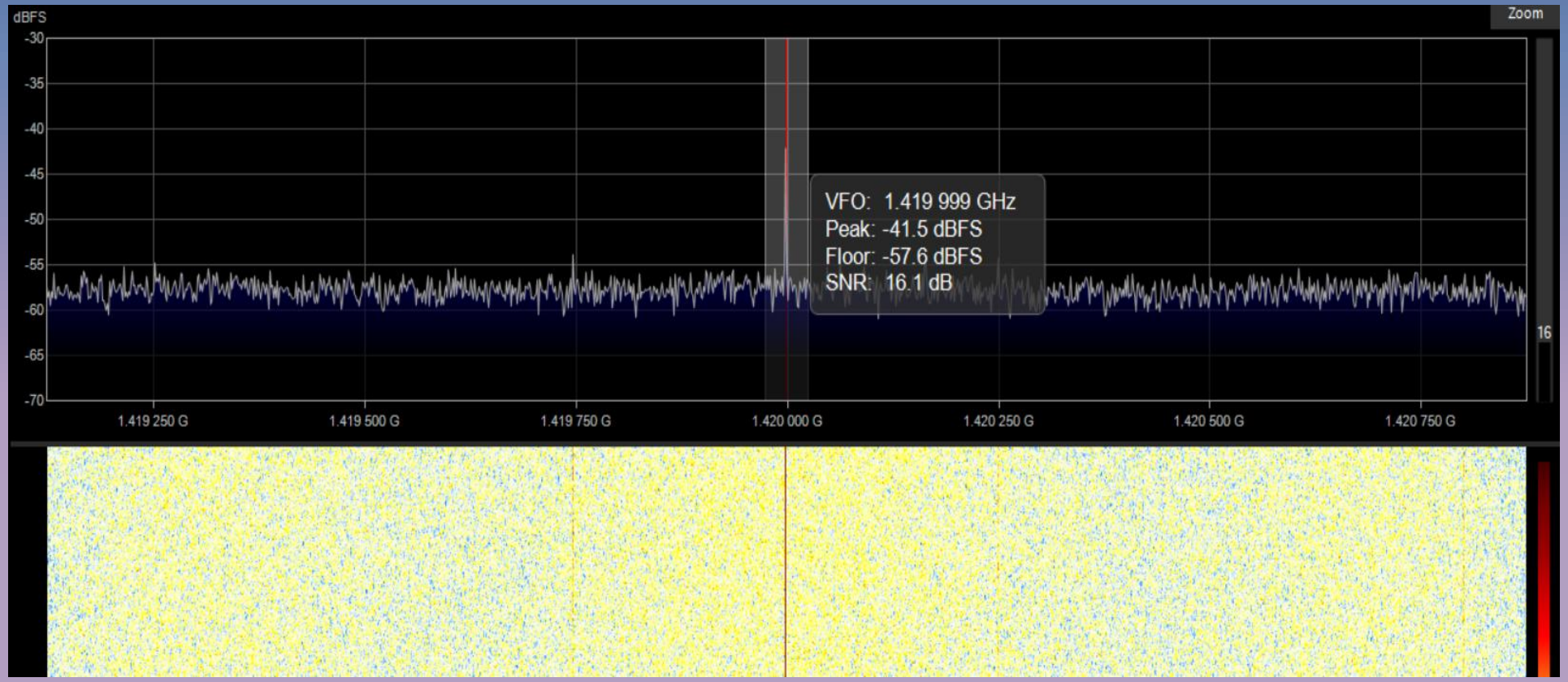


Data from horn antenna pointed near target region.



Data when antenna was directly on our target region

Data: Weather Antenna



Horn Antenna vs Weather Antenna

Horn Antenna

- Pros
  - Directional
  - Optimized for 1420 MHz band
  - More customizable
- Cons
  - Lower gain
  - Harder direction control (no mount)

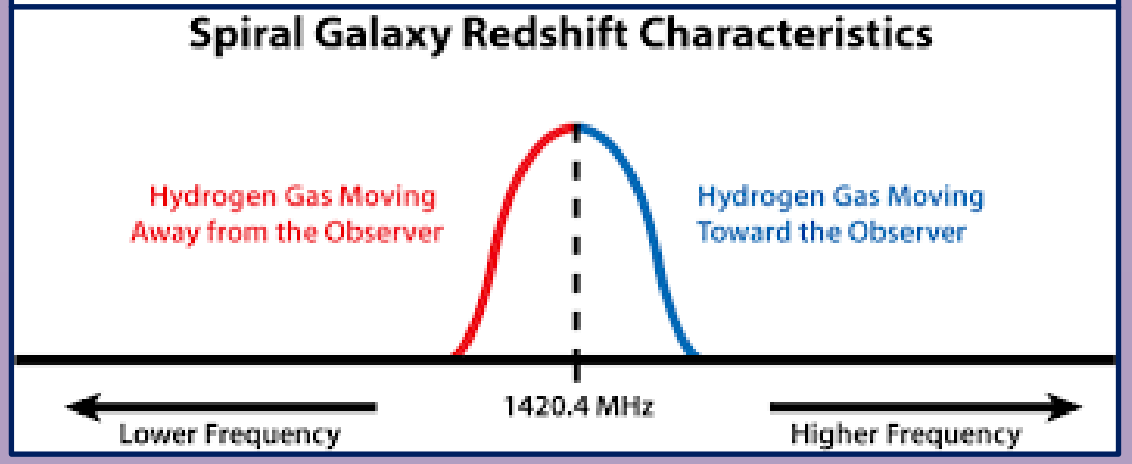
Weather Antenna

- Pros
  - Higher gain
  - Easier direction control (came with a mount)
- Cons
  - Wider beam angle
  - Not optimized for 1420 MHz
  - Less consistent data

Setbacks and Limitations

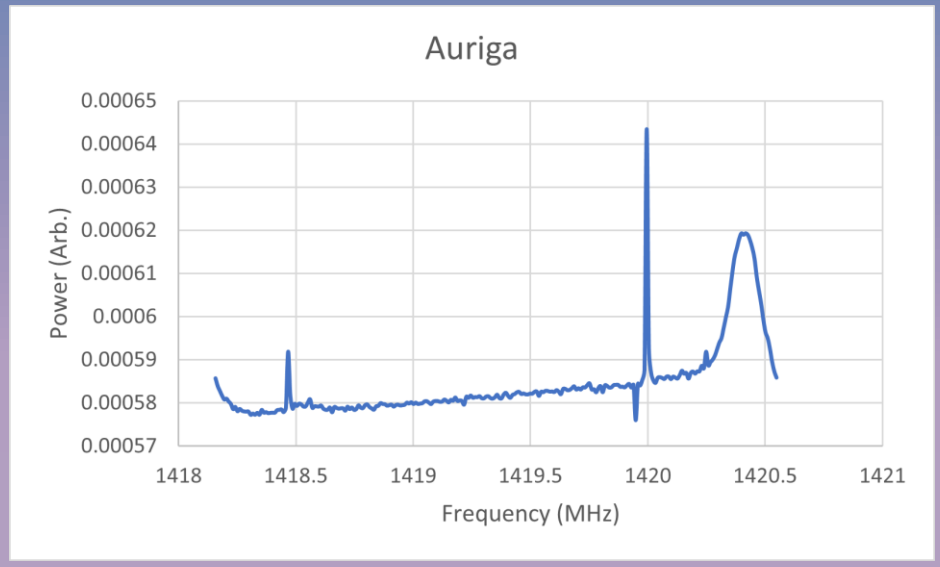
- Possible reflection sources
- Software
  - Crashes/file issues
  - No obvious ways to integrate signal over time
- Hardware
  - RTL-SDR heating
  - Angle measurement
- Weather Conditions
- Blue/Red shift

$$\nu_{observed} = \nu_{source} \sqrt{\frac{1 + \frac{v_s}{c}}{1 - \frac{v_s}{c}}}$$



Looking Forward

- Software
  - Found plugin to perform FFT (Fast Fourier Transform) of audio signal and save as Power vs Frequency
- Hardware
  - Parabolic dish antenna
  - Larger/more precise horn antenna
  - Mount with Altazimuth coordinates
- Observations
  - More open locations
  - Other regions of the sky such as Cygnus and Sagittarius



References

- https://en.wikipedia.org/wiki/Hydrogen_line
- http://hyperphysics.phy-astr.gsu.edu/hbase/Relativ/reldop2.html
- https://www.heavens-above.com/
- http://www.ccera.ca/papers/memo-0011-a-21cm-map-of-the-northern-sky/
- https://radio-astronomy.org/node/191
- http://mercury.pr.erau.edu/~prcphysics/observatory/hydrogen.htm