AY121 Lab 2: 21-cm Hydrogen Line Observations

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February 23, 2026

ABSTRACT

1. Introduction

2. Theory

2.1. Time measures

Discuss different time keeping systems and also digital timekeeping and synchronization.

2.2. Coordinate systems and measures

Introduce the different coordinate systems.

Why rotation matrices are a convenient choice.

Instrumentation

Diatribe on the different components of the instrumentation and observables, from the 21-cm hydrogen line emmissions from celestial objects, to the radio dish, to signal propagation through transmission lines, to signal capture.

2.3. The 21-cm hydrogen line

- Hyperfine emission from neutral hydrogen

2.3.1. Doppler shifting

The Milky Way is rotating and different arms of the Milky Way are moving at different velocities with respect to us, which leads to different Doppler shifts in the 21-cm line.

2.4. The radio dish

2.4.1. Antenna

2.4.2. Efficiency of the big horn antenna

2.5. Signal propagation through transmission lines

2.5.1. The transmission cable

2.5.2. The terminals

There are different types of connectors, e.g. F-type connectors.

2.5.3. Signal propagation and degradation

Introduce castingt the signal as a $\exp(-i\omega t)$ wave, then discuss how the impendance (somewhere in the equation) determines how the signal degrades as it propagates through the cable.

2.5.4. Signal reflections

Same as above but on impedance and reflections.

2.6. The Software Defined Radio

2.6.1. Schematic

3. Materials and Methods

3.1. Equipment

- RTL832U Software Defined Radio
- Keysight N9310A RF Signal Generator DS345
- (whatever cables we used)
- Horn antenna on New Campbell Hall

3.2. Software engineering

3.3. Data Collection Pipeline

Include a flowchart of the data collection pipeline, and discuss how the data is collected, stored, and processed.

Include a schema of the data storage, and how the data is processed to get the final results.

3.4. Physical calibration

Discuss how horizontal (topological) coordinates can be elucidated by the altitude notches on the horn antenna, and how the azimuthal coordinates can be elucidated by using a compass.

Discuss the Rayleigh criterion of the horn antenna and the resolution of the antenna.

Using the two above discussions, discuss the tolerances of the measurements, mentioning drifts and ideal observation windows for the same patch of the sky.

3.5. Signal calibration pipeline

1. Refer to `cal_intensity.pdf`.

2. Using a smoothing kernel/convolution to smooth the power spectrum density of the signal:
   (a) Rectangular
   (b) Gaussian
   (c) Savitzky-Golay

4. Experiments

4.1. Experiment 1: Finding out what is a good `nblocks` to use

- Point at North Galactic Pole to compare noise levels (via radiometer equation and other methods).

4.2. Experiment 2: Calibrating the power of the signal (find out a scale for the power spectrum density of the signal)

5. Results

Ensure all results are reproted with error bars.

Create simualted phenomenological models to compare each experiment with.

6. Discussion

6.0.1. How do we know what we are seeing is the spiral arms of the Milky Way?

7. Conclusion

Acknowledgements

Special thanks to my lab partners Nathaneil and Kayhan for their help in this Lab, and Aaron and Ben for their guidance and support throughout the Lab. Also, I would like to acknowledge the use of `numpy`, . . .

8. Appendix

8.1. Fourier Analysis interpretation of Gaussianity, the Central LImit Theorem, and Experimental Noise

(Gaia Collaboration et al. 2018)

REFERENCES

Gaia Collaboration, Babusiaux, C., Van Leeuwen, F., et al. 2018, Astronomy & Astrophysics, 616, A10, doi: 10.1051/0004-6361/201832843