Digital Signal Processing in Radio Astronomy

An NSF Research Experience for Teachers Program

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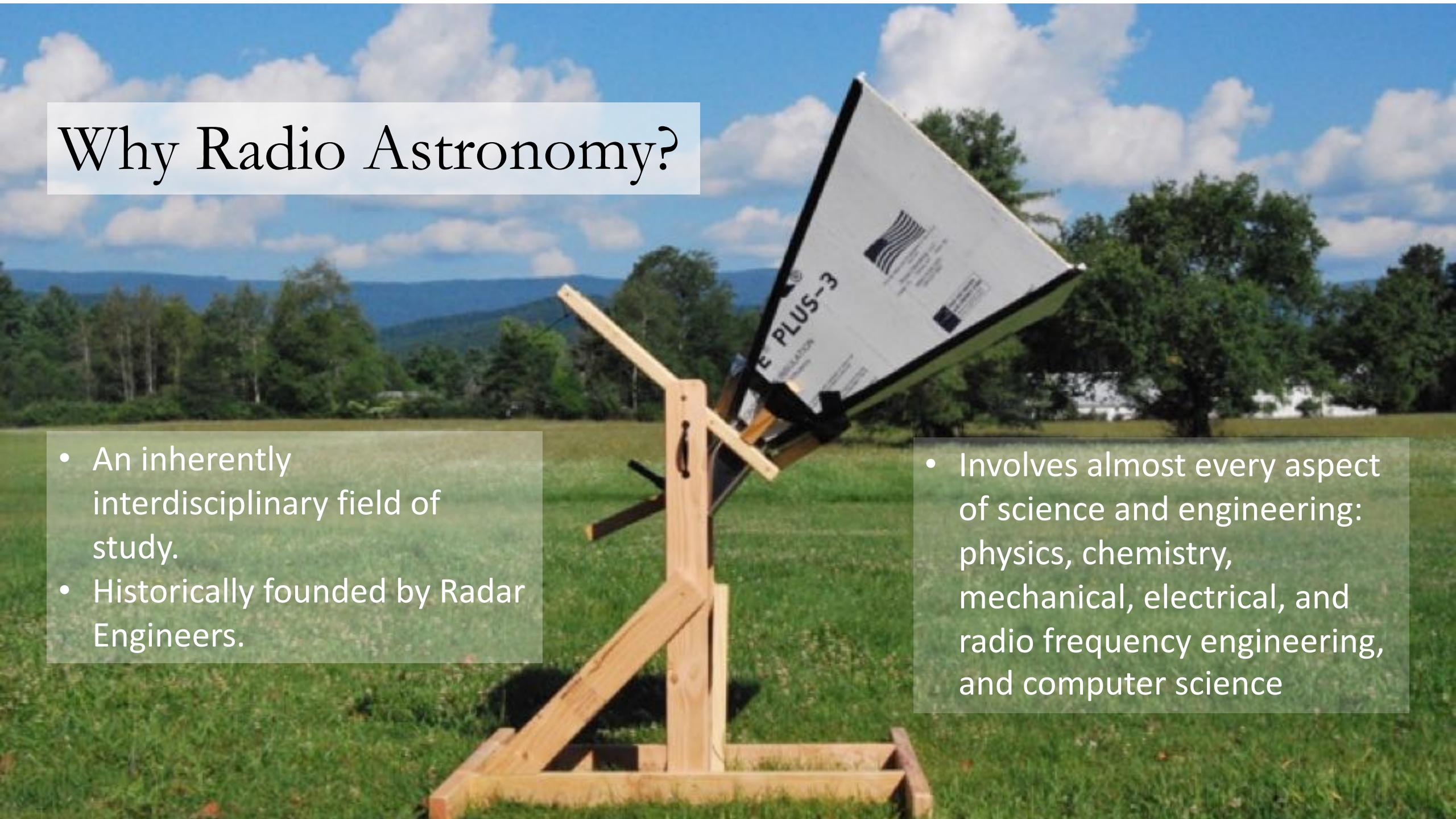
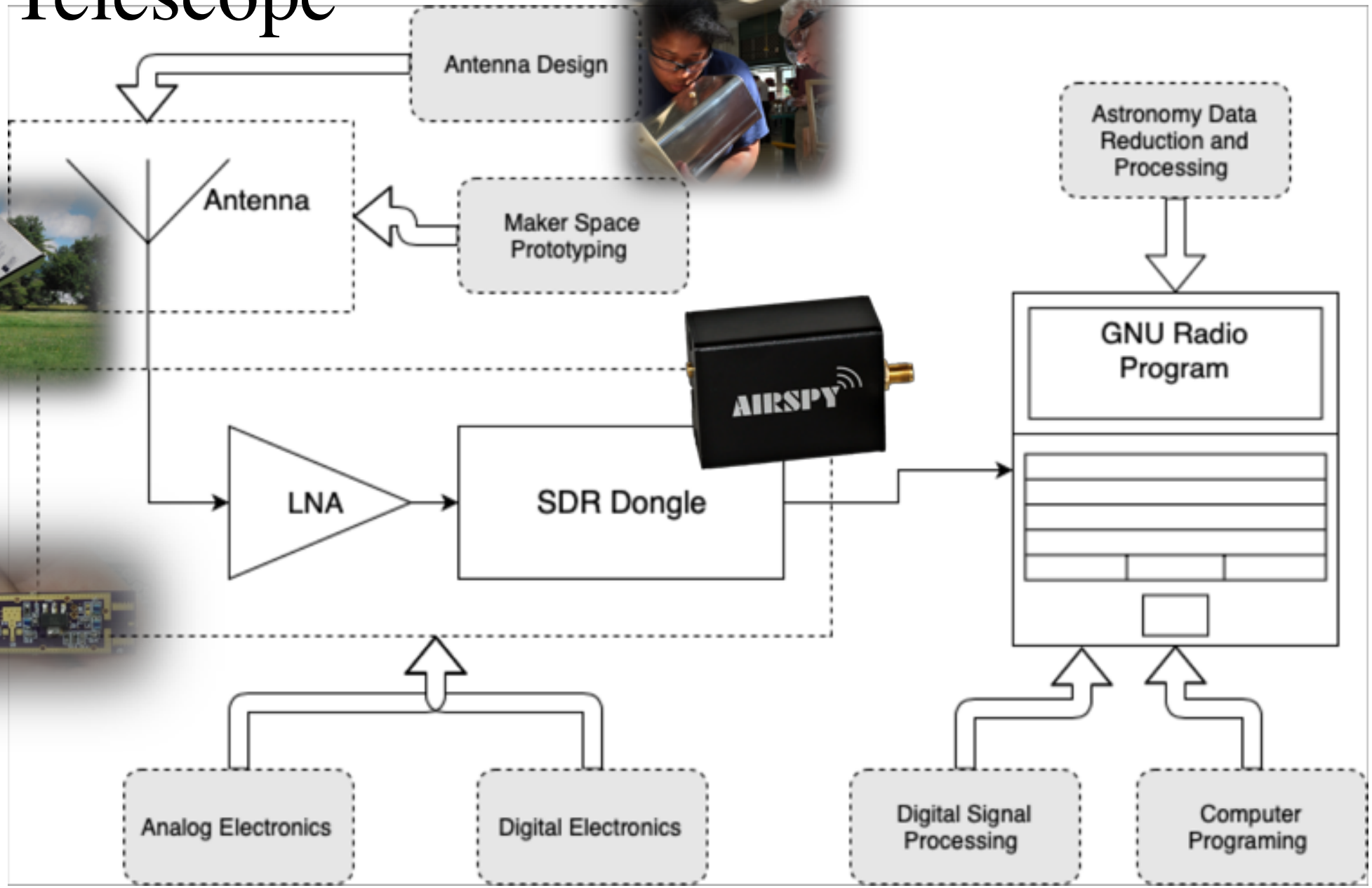
Why Radio Astronomy?

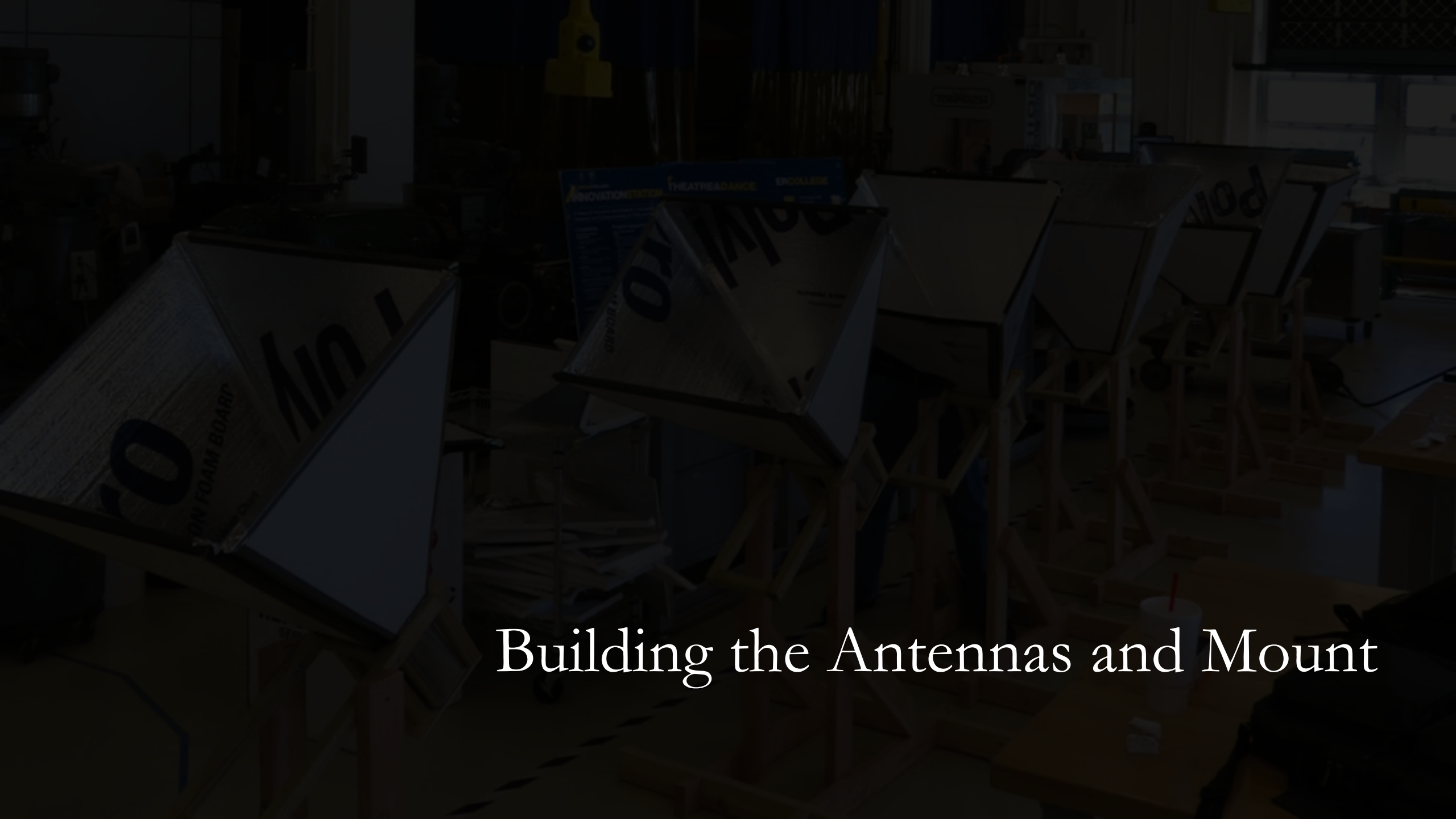


- An inherently interdisciplinary field of study.
- Historically founded by Radar Engineers.

- Involves almost every aspect of science and engineering: physics, chemistry, mechanical, electrical, and radio frequency engineering, and computer science

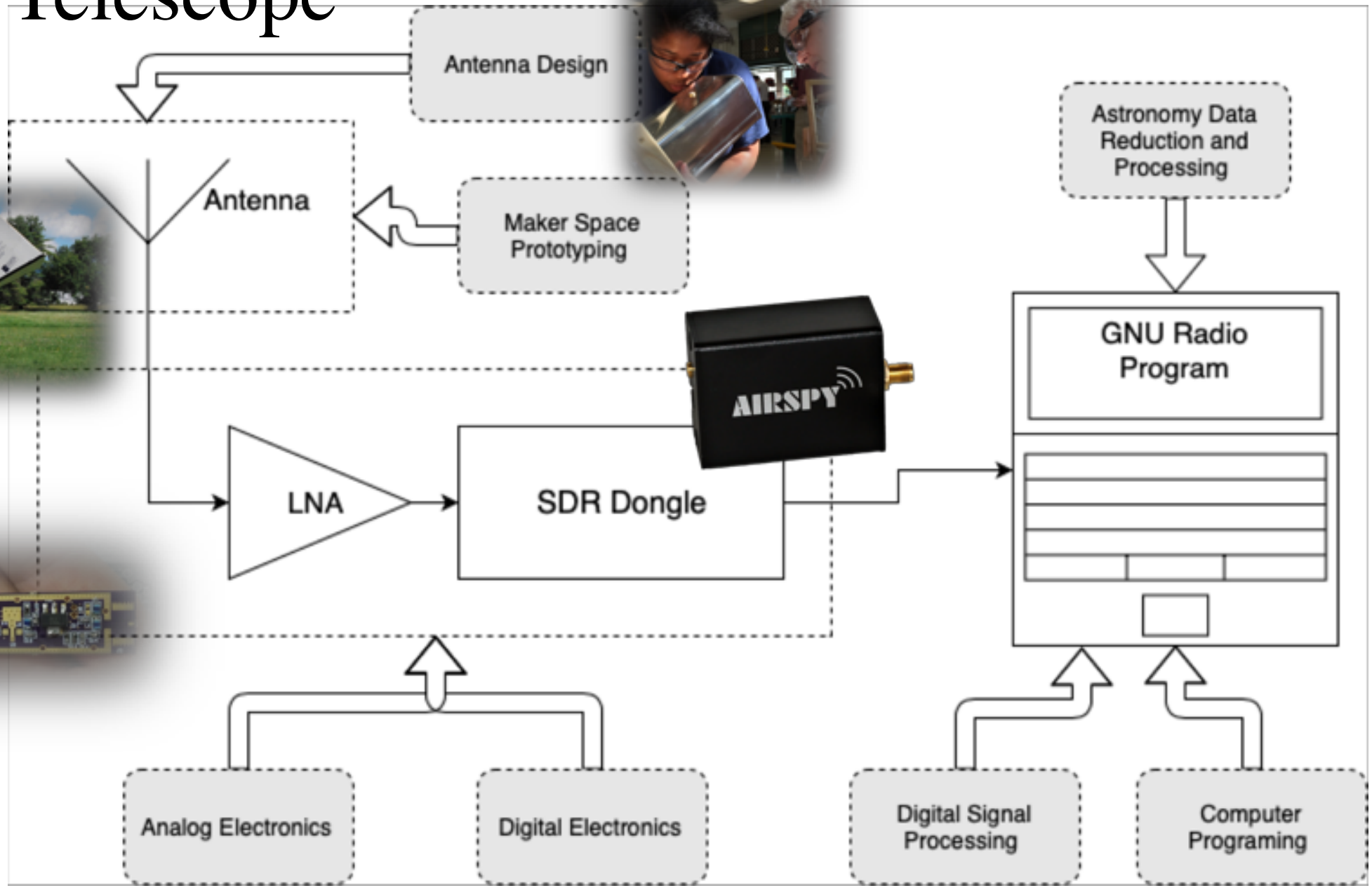
A Radio Telescope Pipeline





Building the Antennas and Mount

A Radio Telescope Pipeline



Assembling Low Noise Amplifiers

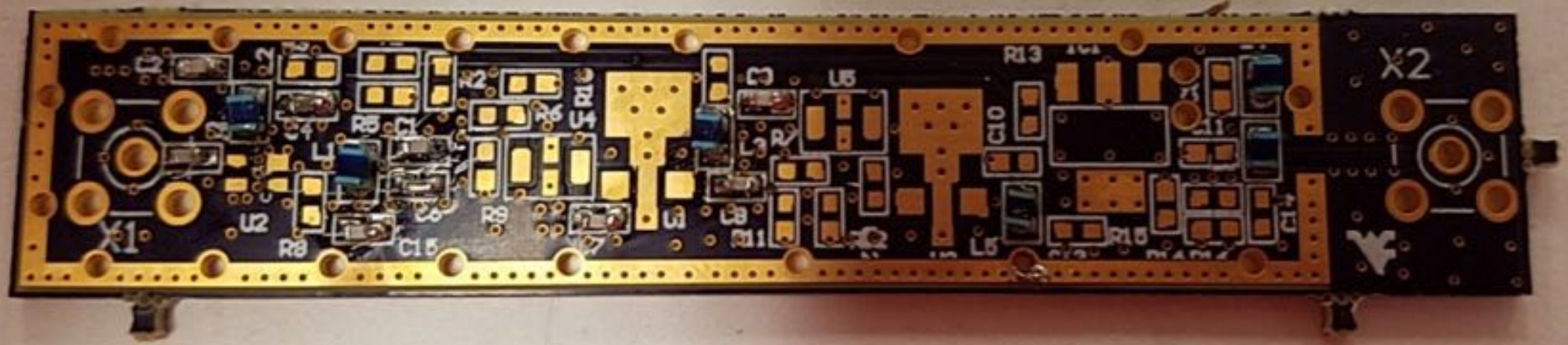
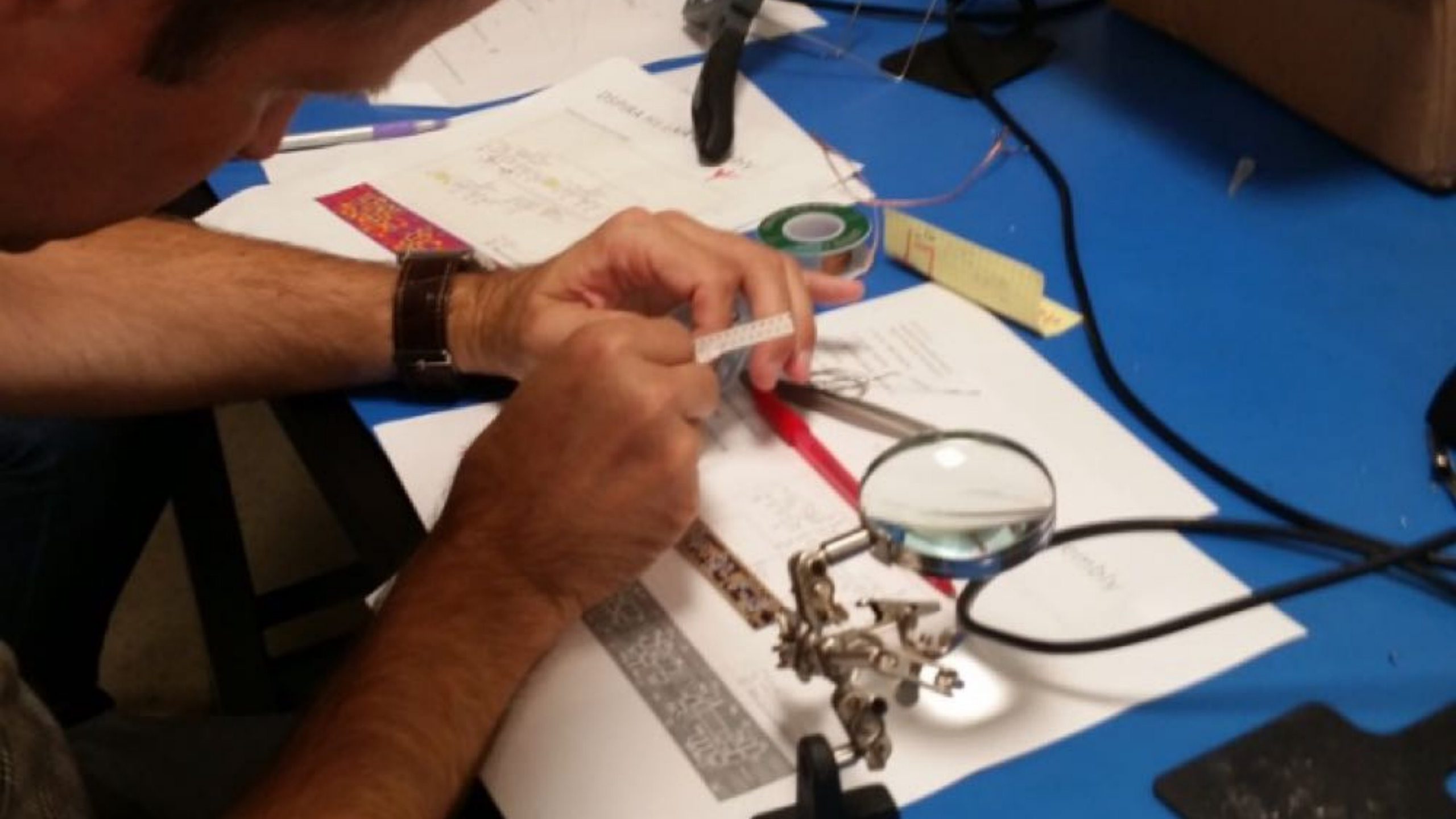
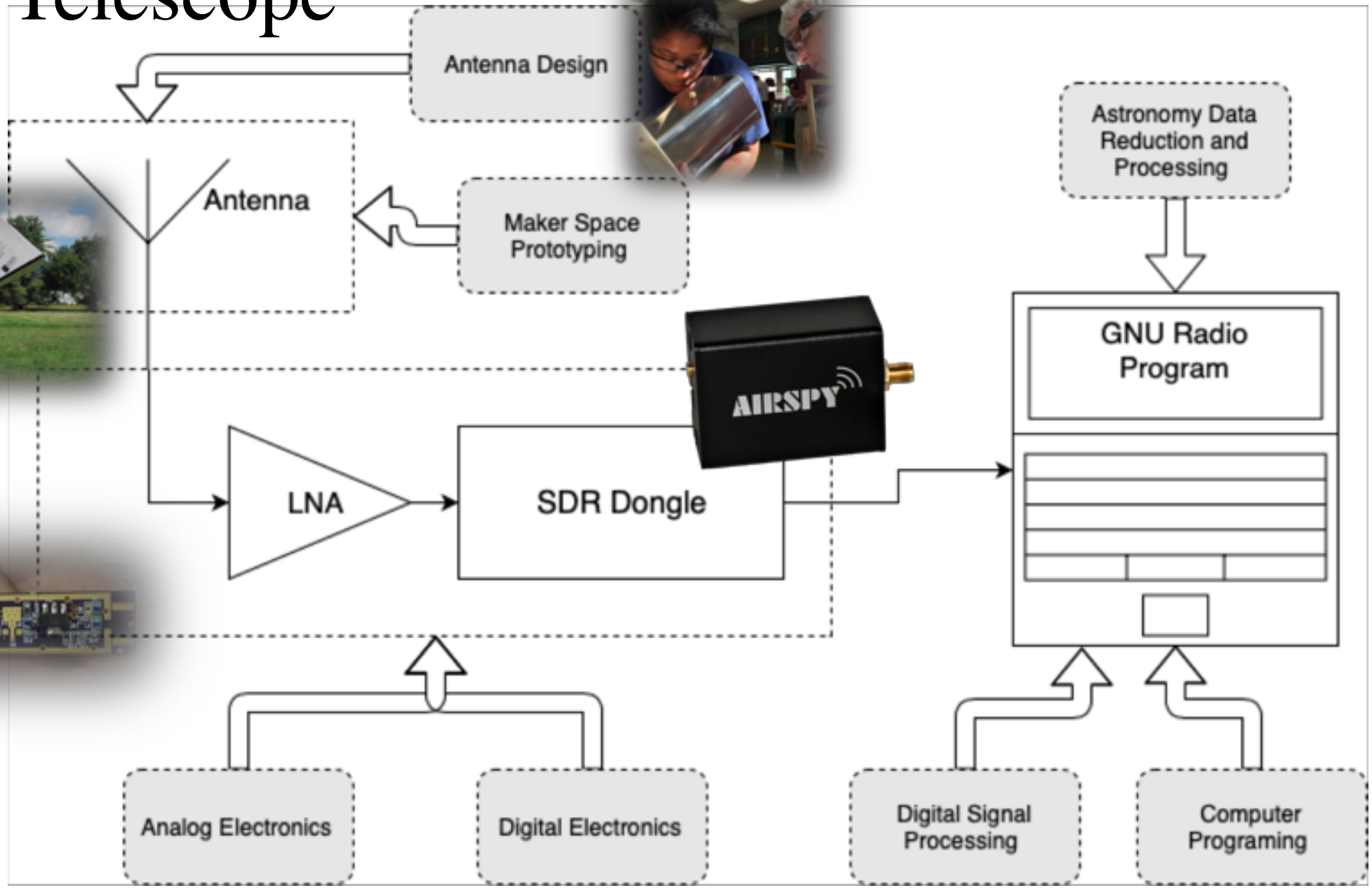


Figure 2: Schematic of the LNA circuit



A Radio Telescope Pipeline



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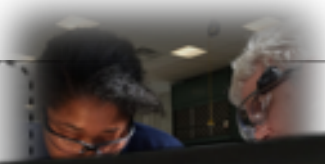


Antenna Design

Astronomy Data Reduction and Processing

GNU Radio Program

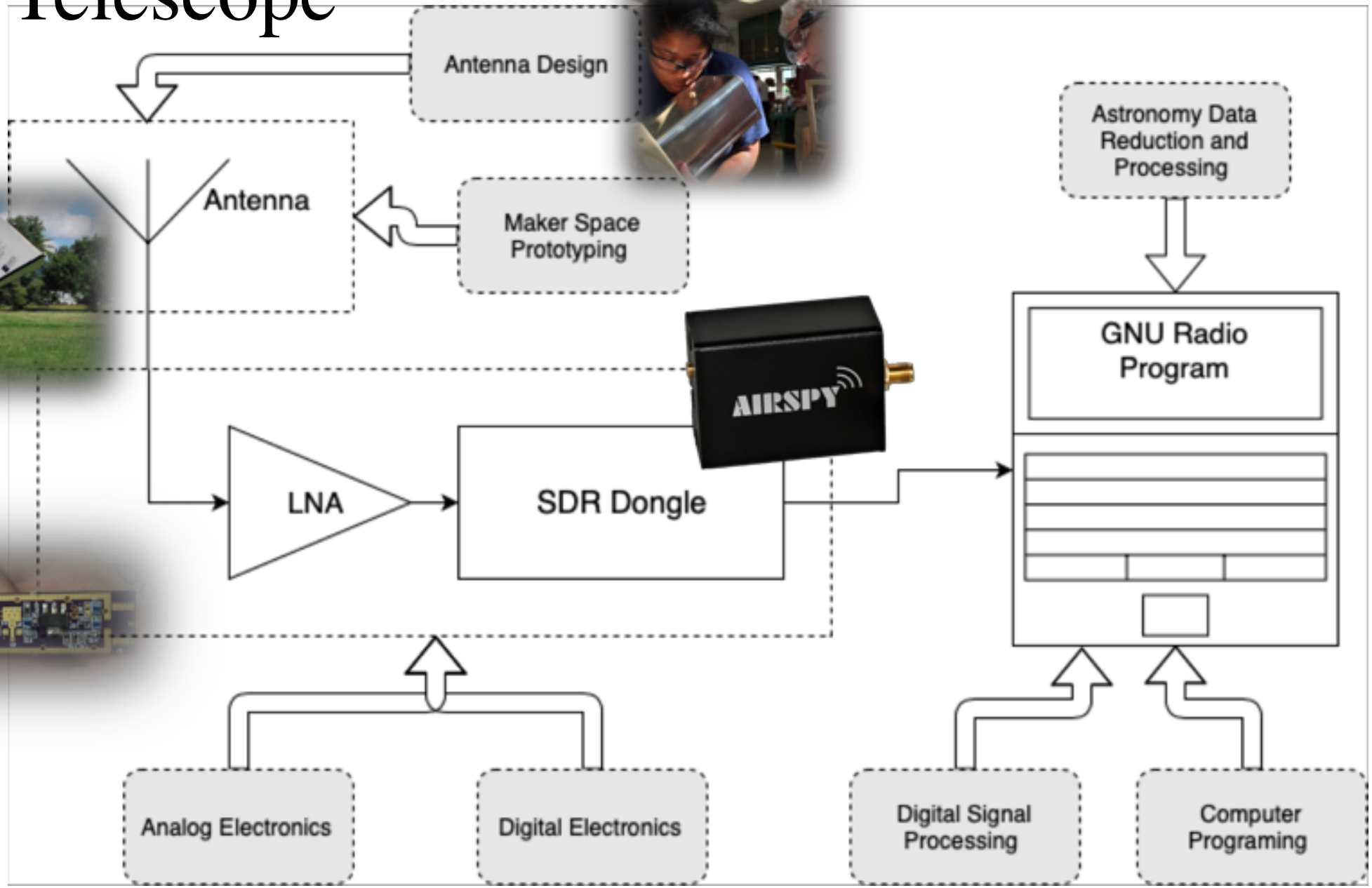
Analog Electronics

Digital Electronics

Digital Signal Processing

Computer Programing

A Radio Telescope Pipeline

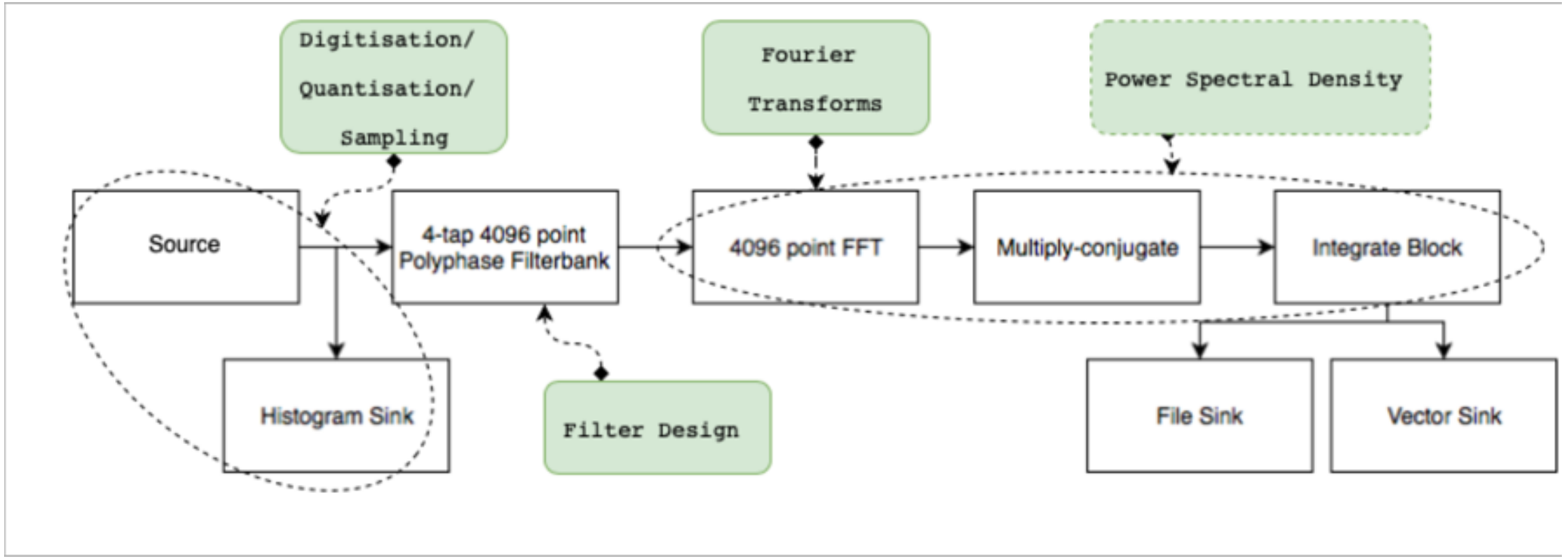


Tool of Choice: GNURadio

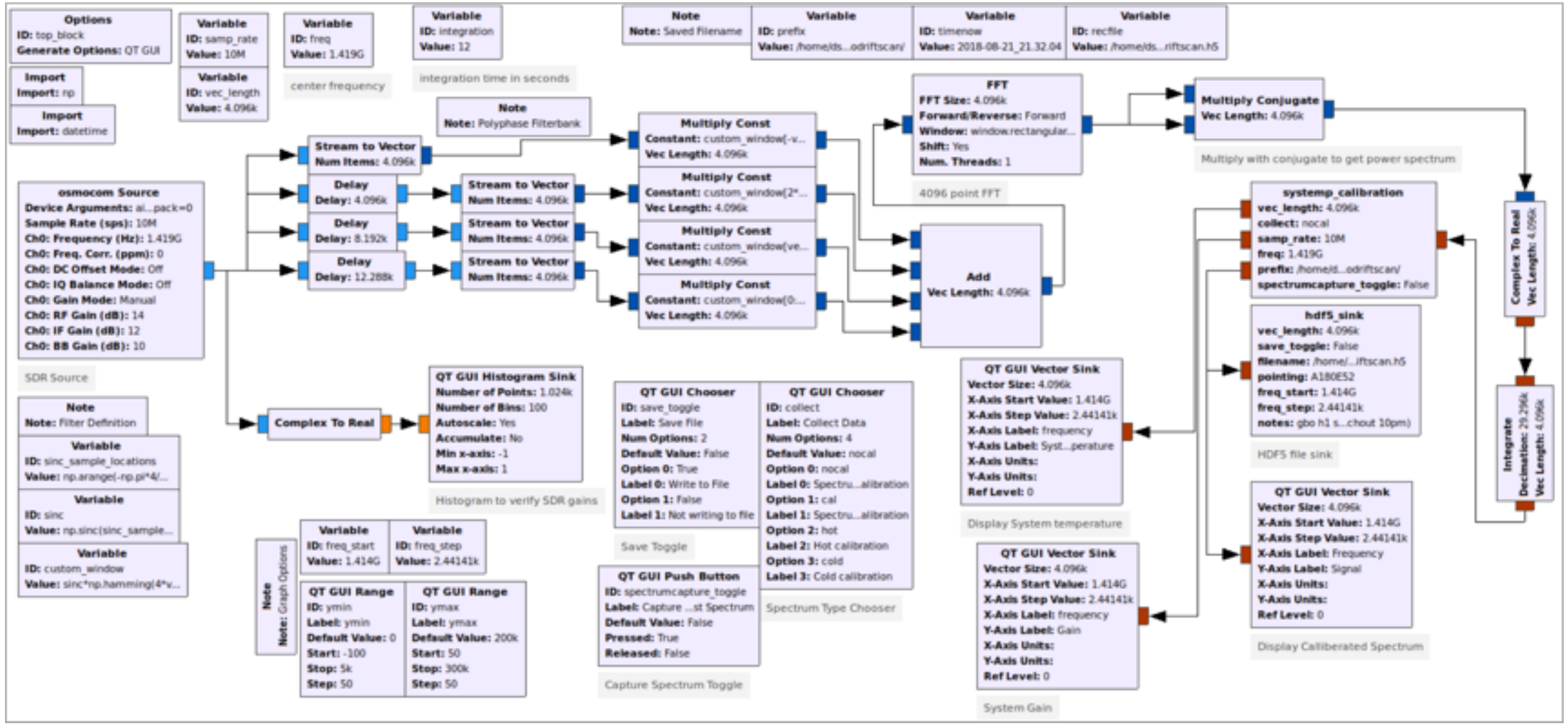
- GNURadio is a free and open source software ecosystem that allows for immense flexibility
- Programming with GNURadio is based on a flow based paradigm
- The hardware required is inexpensive (as low as $30. We use a device that costs <$200)

The DSP Pipeline of Our Radio Telescope

A Spectrometer



The DSP Pipeline Implemented in GNURadio



The DSP Pipeline of Our Radio Telescope

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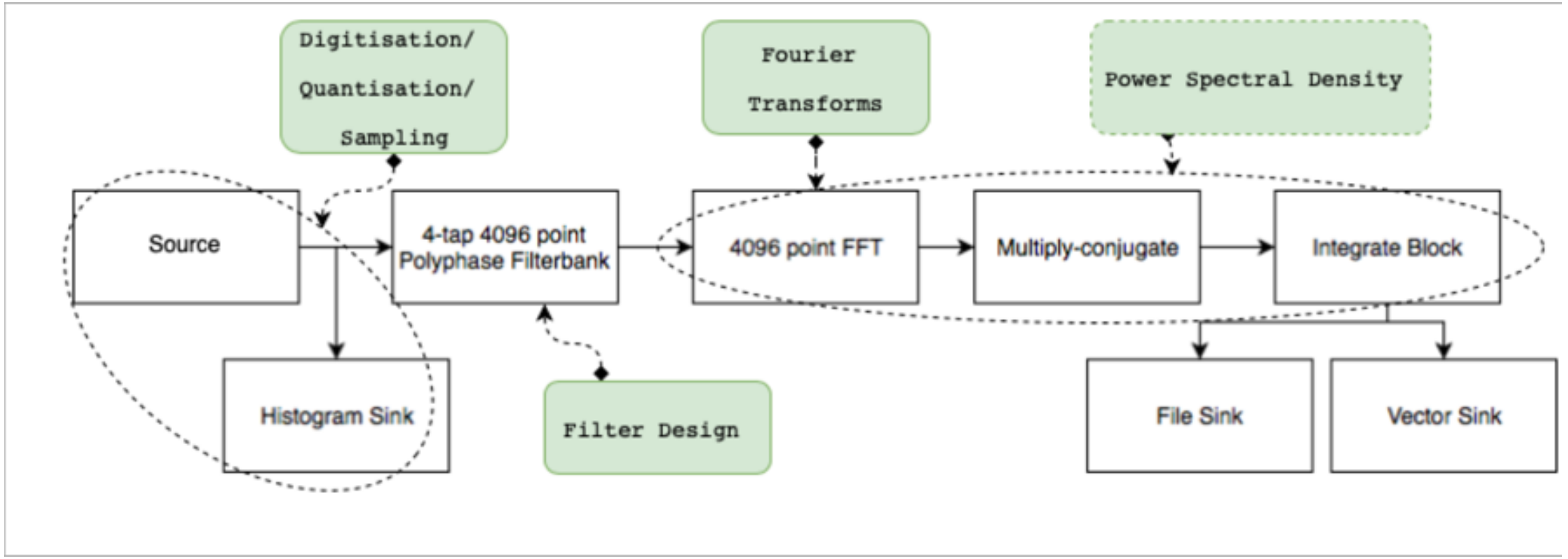

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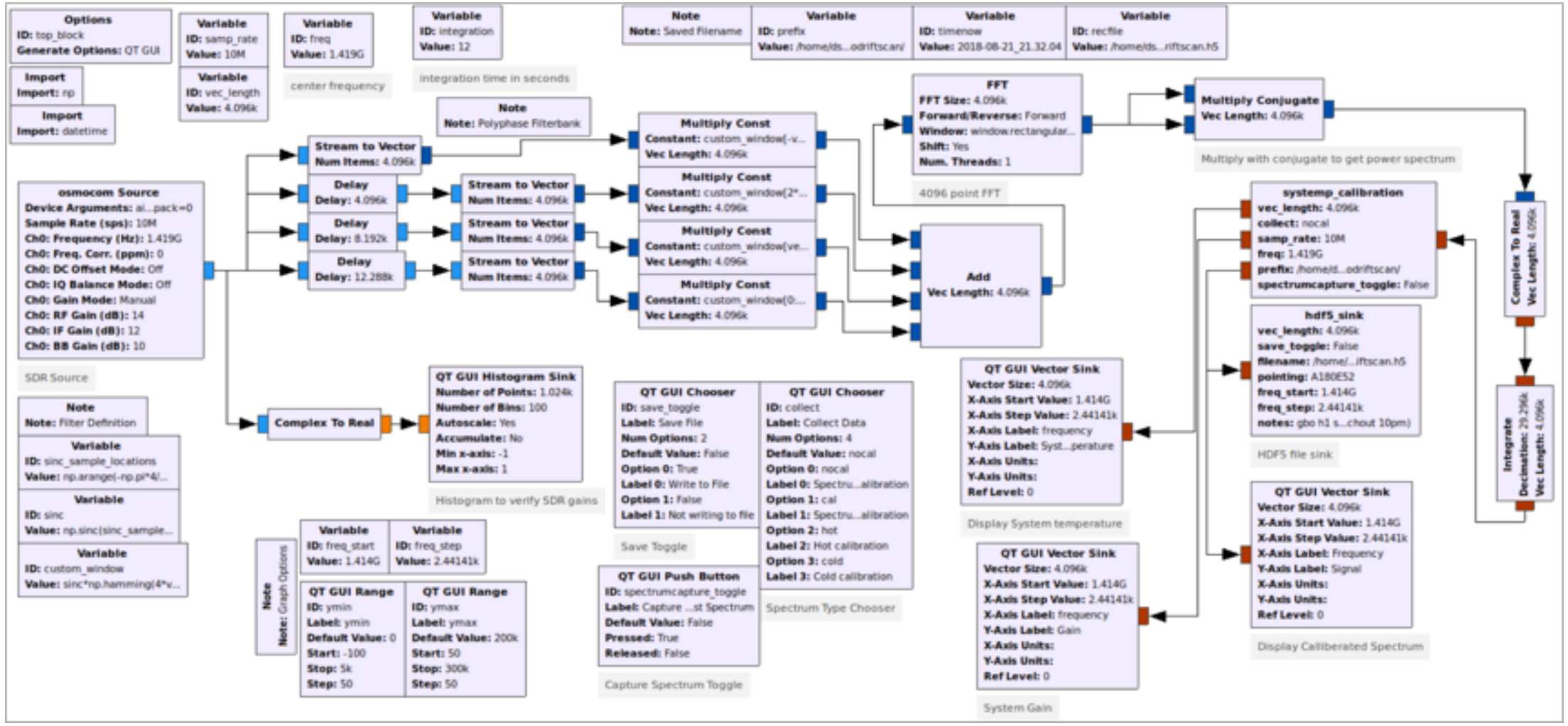
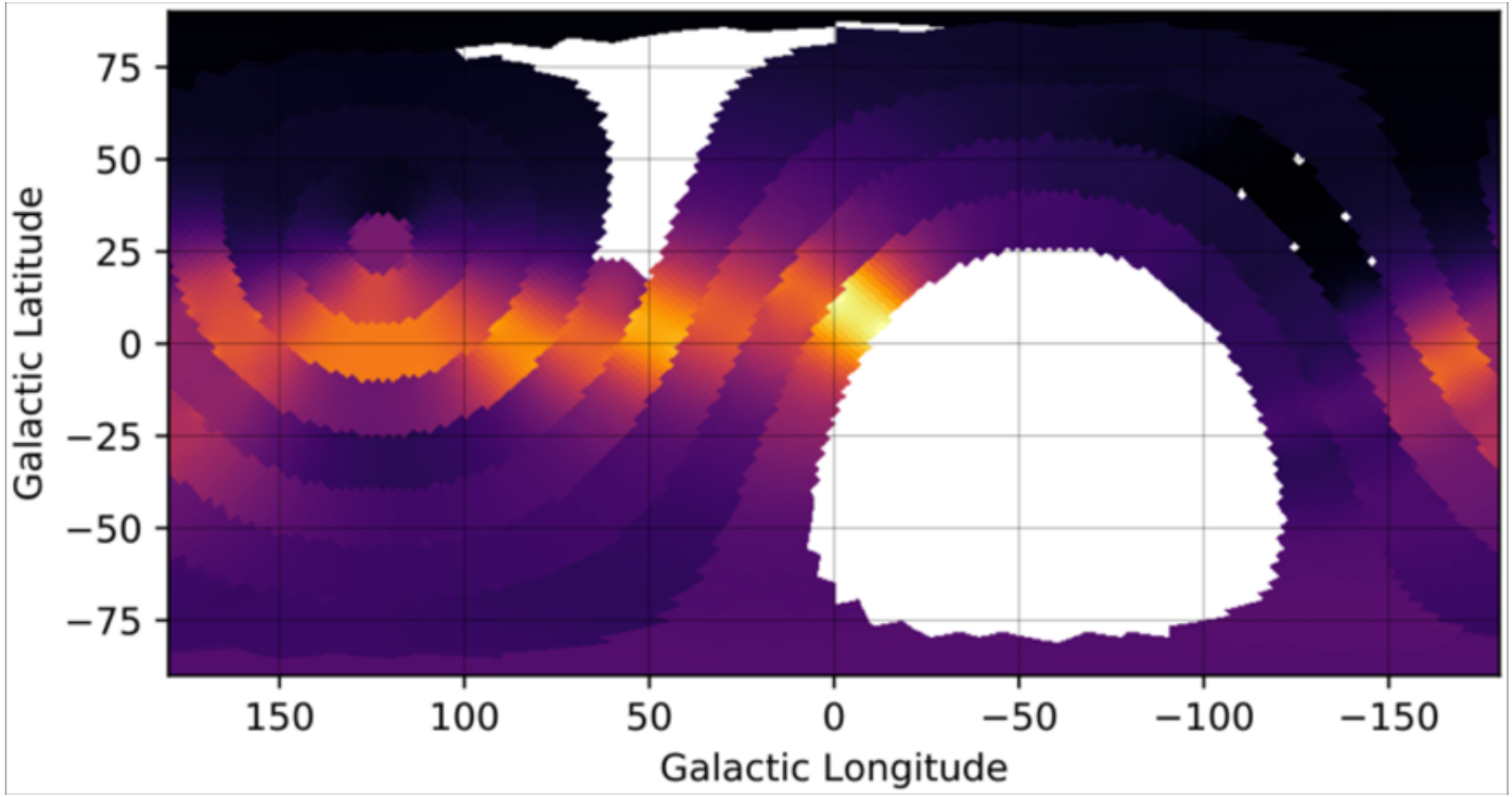
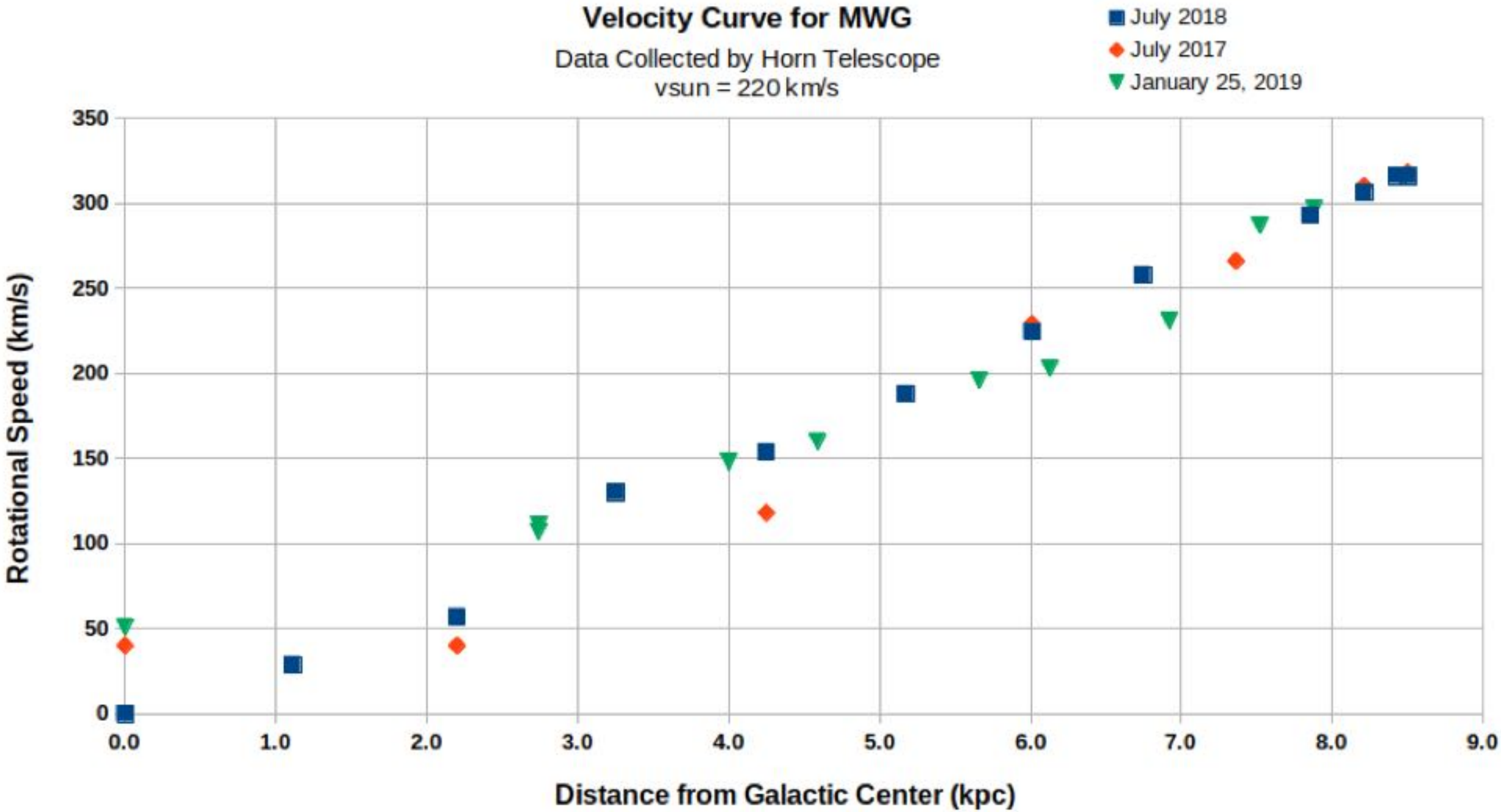
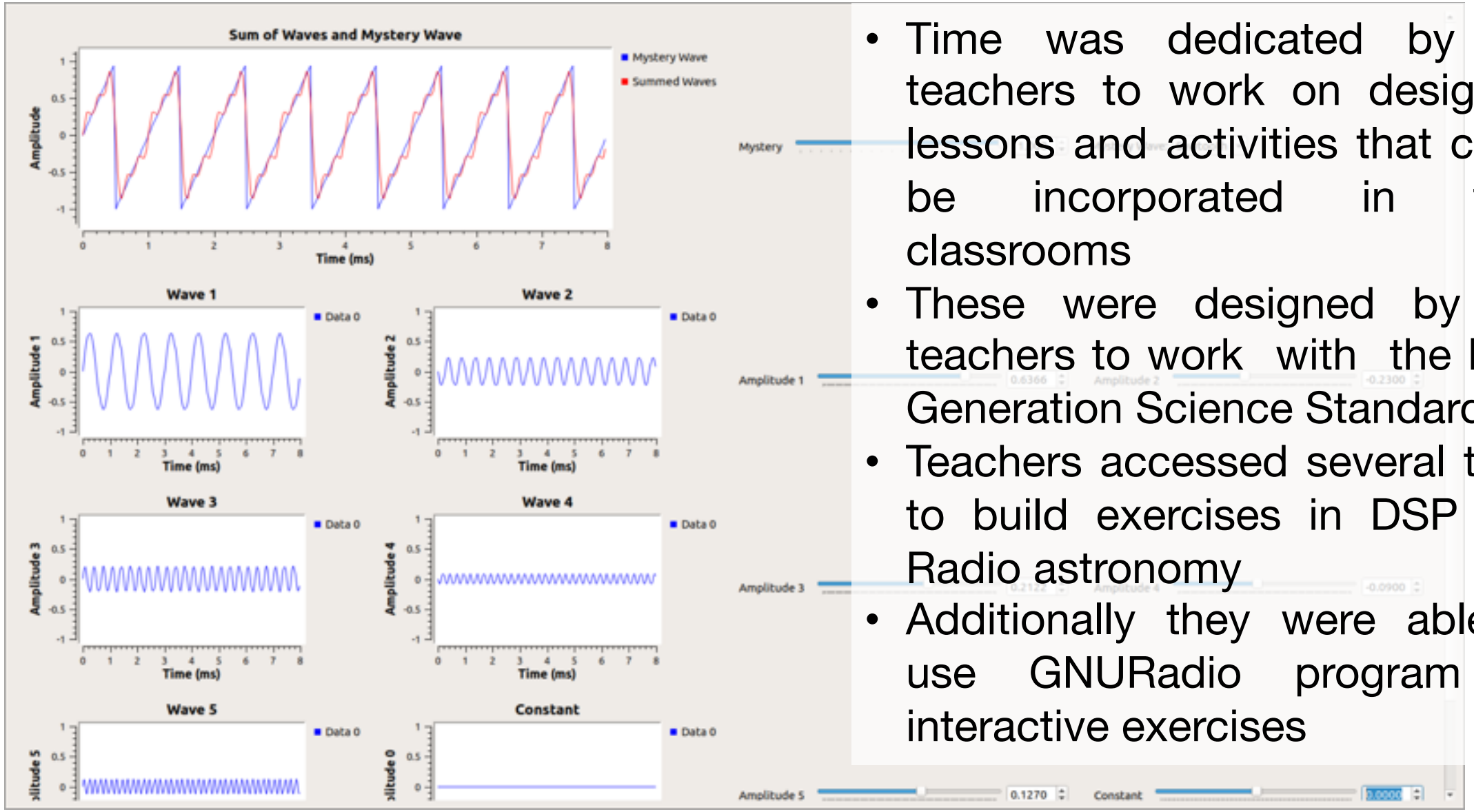



Observing with the Horn
Antenna Telescope


75
50
25
0
−25
−50
−75
Galactic Latitude
150
100
50
0
−50
−100
−150
Galactic Longitude


Velocity Curve for MWG
Data Collected by Horn Telescope
vsun = 220 km/s
July 2018
July 2017
January 25, 2019
Rotational Speed (km/s)
350
300
250
200
150
100
50
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
Distance from Galactic Center (kpc)

Lessons and Curricula



- Time was dedicated by the teachers to work on designing lessons and activities that could be incorporated in their classrooms
- These were designed by the teachers to work with the Next Generation Science Standards
- Teachers accessed several tools to build exercises in DSP and Radio astronomy
- Additionally they were able to use GNURadio program as interactive exercises

These lessons and activities are available online. They are hosted on the website:
http://wvurail.org/cra/

The Lessons and Activities were used at summer camps held at the Green Bank Observatory


GREEN BANK SCIENCE CENTE

Challenges of taking Radio Astronomy back to classrooms

- The computing requirements depend on the Linux operating system
- Acquiring an appropriate LNA is expensive and building it non-trivial
- Disseminating the material:
  - The teachers involved have a created a living repository of lessons and activities created during the program
  - It is maintained on an online web page (http://wvurail.org/cra/)
  - Lessons are to be added by individual teachers as they conduct them in their respective classrooms
  - The website also has instructions and resources that would allow one to build a radio telescope on their own.

Challenges of taking DSP back to classrooms

- The teachers have access for their reference all the detailed lessons and exercises they went through during the program
- They are available to them and all on an online web page (http://wvurail.org/dspira/)
- Despite conducting small DSP exercises in their schools, it has been a challenge for the teachers to incorporate these into regular STEM classes and still cover the required materials.
- This contrasts with Radio Astronomy, which our teachers have been rather successful at incorporating into regular classes.

Thank You

Link to presentation and details for the program:
wvurail.org/dspiratalk

Our next session is in Summer 2019

You are all encouraged to apply: http://wvurail.org/dspira-2019/