



# *Lichfield Radio Observatory (LRO)*

*Dr Andrew Thornett, M6TH0*

[www.astronomy.me.uk](http://www.astronomy.me.uk)

*Mapping Milky Way at 1420.405MHz  
(Hydrogen)*

LRO in the Snow  
3/12/2023

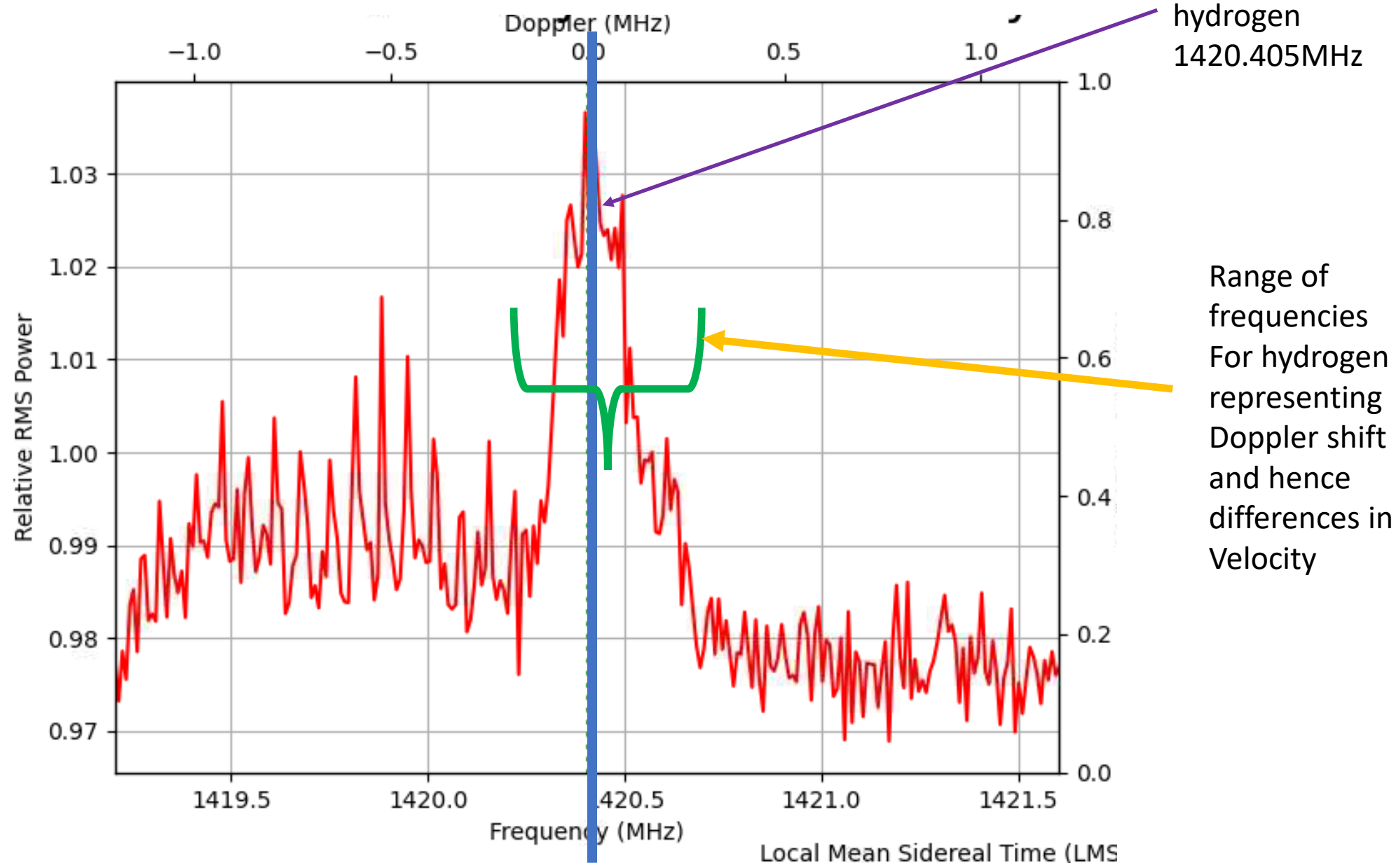


# Detecting molecular hydrogen line in Milky Way can now be achieved easily and cheaply

- Milky Way hydrogen detection used to be expensive but can now be achieved with very cheap equipment from Amazon/elsewhere, using Software Defined Radio (SDRs) and hydrogen line filter/pre-amp, and satellite dish/other aerial.
- The Society of Amateur Radio Astronomers (USA/"SARA") has produced a project called "Scope in a Box", which led me to give this a try.

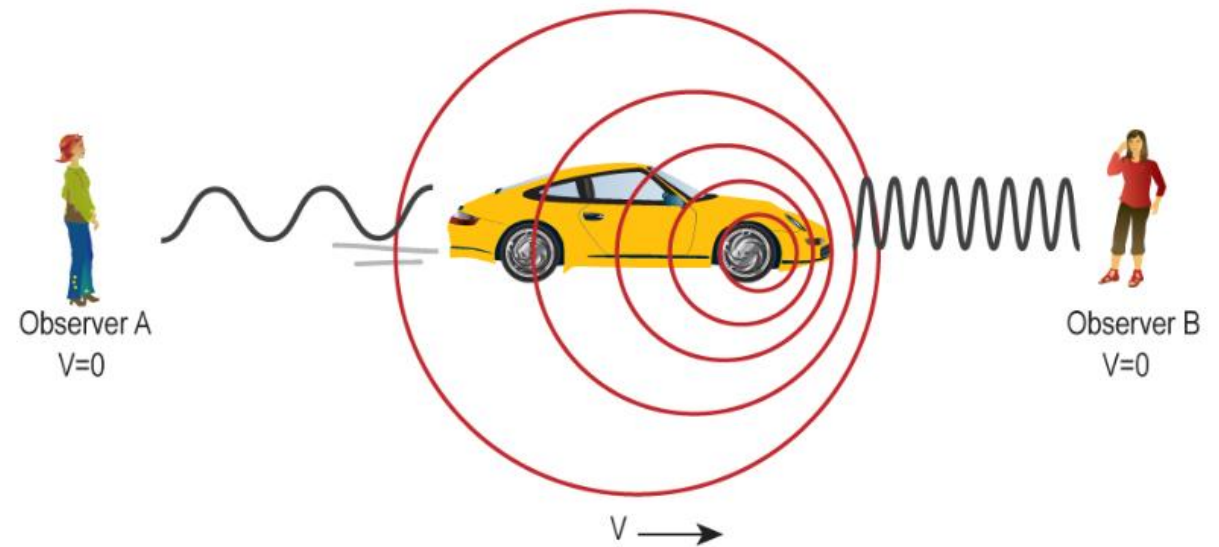
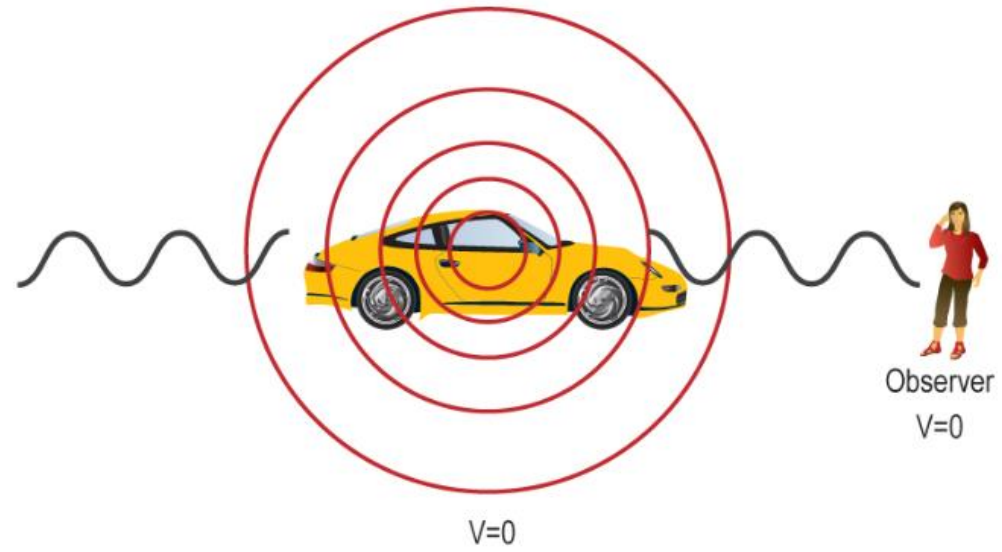
*Hydrogen line (1420.405MHz)*  
*Mapping Exercise of the Milky Way*  
*@ LRO*

# An example of a detection of the hydrogen line

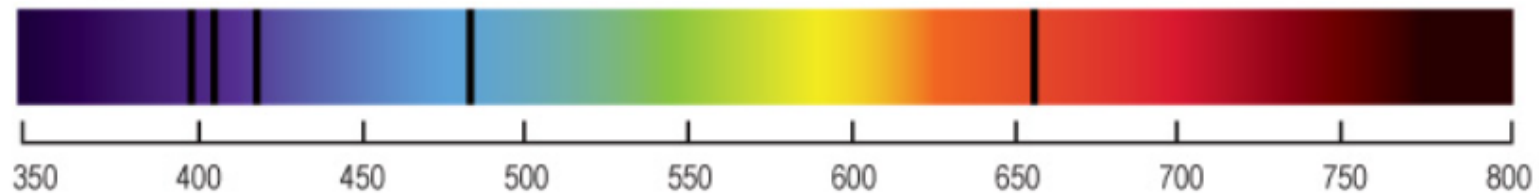




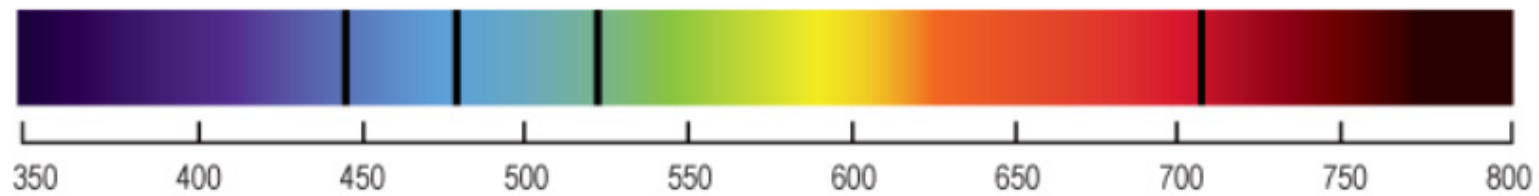
# *Doppler shift*



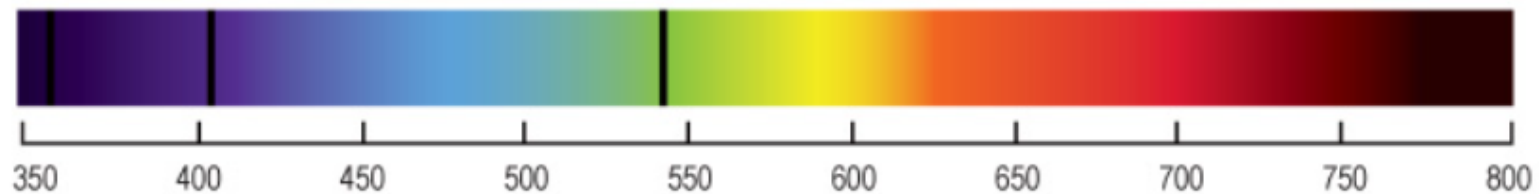
Hydrogen



Hydrogen Redshifted



Hydrogen Blueshifted



Wavelength (nanometers)

*Red-shifted is  
moving away  
from us*

# Aerials & Mounts





*3m dishes come with mounting problems...*

***Corner  
aerials  
from  
chicken  
wire***

Very big corner aerial





*Perhaps more  
practical and  
easier to buy  
off the shelf is  
something  
Like this?*

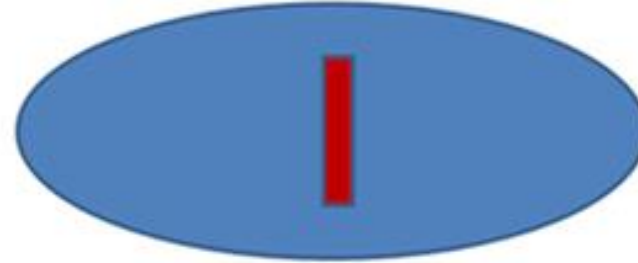




## Para Grid WiFi Dish



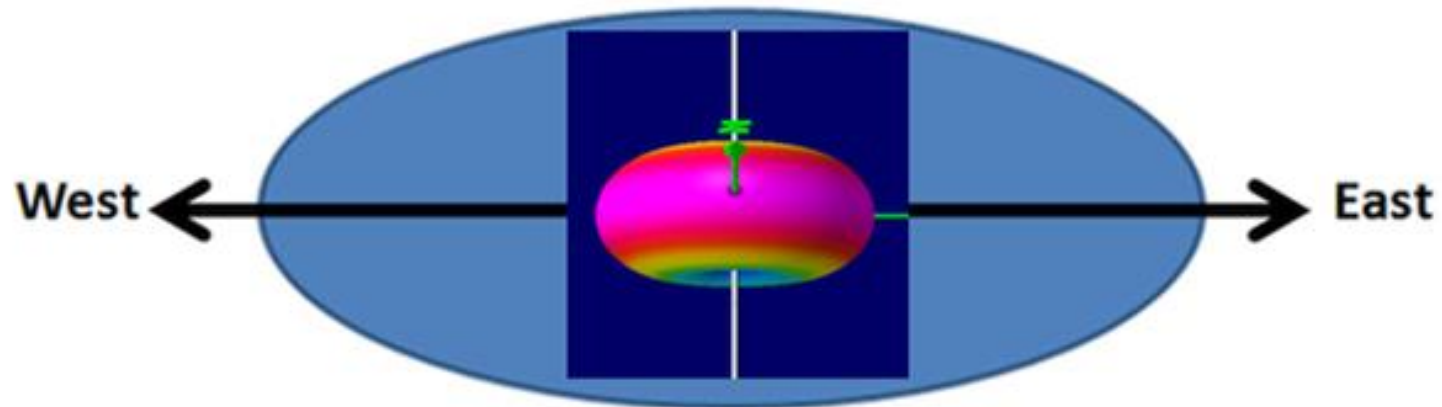
Broadside of the Dipole toward the long ends of the dish



### WiFi 100cmx60cm Para-grid Orientation

Recall that beam-width is inversely proportional to dish size.

For optimal angular resolution of H1 drift scans, align the **1m side E<>W**



*From  
Alex  
Pettit*

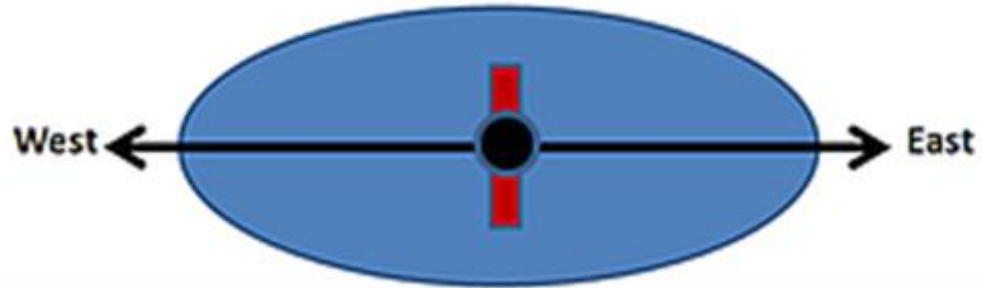
# Para Grid WiFi Dish

WiFi 100cmx60cm Para-grid Orientation

Recall that beam-width is inversely proportional to dish size.

**1/2wl Dipole**

For optimal angular resolution of H1 drift scans, align the 1m side E↔W

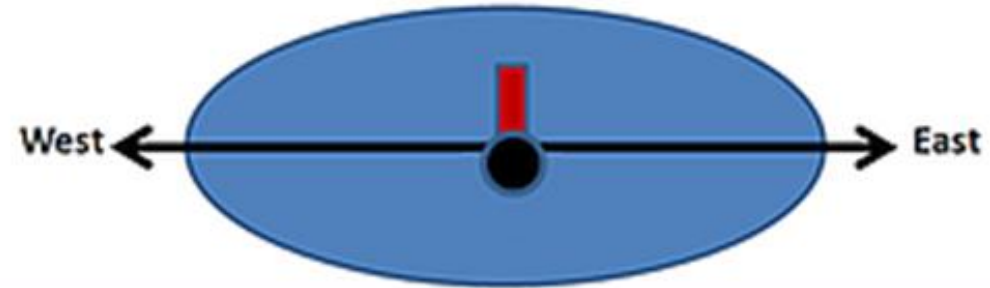


WiFi 100cmx60cm Para-grid Orientation

Recall that beam-width is inversely proportional to dish size.

**1/4wl Mono**

For optimal angular resolution of H1 drift scans, align the 1m side E↔W

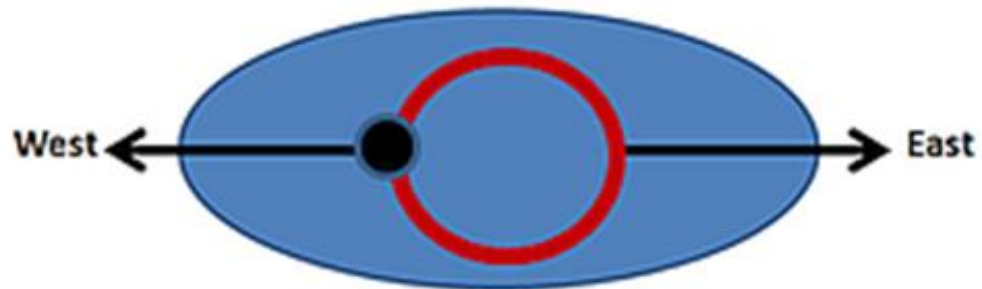


WiFi 100cmx60cm Para-grid Orientation

Recall that beam-width is inversely proportional to dish size.

**1wl Loop**

For optimal angular resolution of H1 drift scans, align the 1m side E↔W

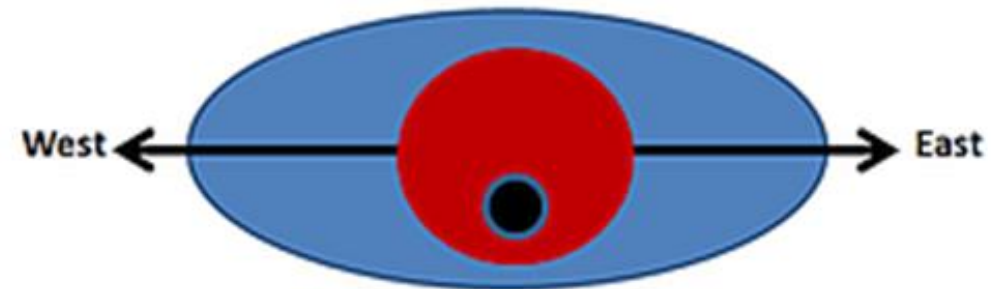


WiFi 100cmx60cm Para-grid Orientation

Recall that beam-width is inversely proportional to dish size.

**Patch**

For optimal angular resolution of H1 drift scans, align the 1m side E↔W



*From  
Alex  
Pettit*





*I have been very lucky  
& have been given one  
of these...*

**Ptarmigan Triffid  
Military Phased Array**  
*Not many of them  
around!*



# Ptarmigan Triffid Band 3 Ex-Military Dipole Array (UK)







**Homemade wooden manual  
telescope mount so that  
altitude can be varied**



# Nooelec SAWbird+ H1 - Saw Filter & Cascaded Ultra-Low Noise Amplifier (LNA)





For folks starting to explore radio  
astronomy,

ezRA - Easy Radio Astronomy

Free 1420 MHz Galactic hydrogen  
data collection and analysis

**<https://github.com/tedcline/ezRA>**

Windows and Linux

*ezRA software for collecting and  
processing data and mapping it over  
known background of radio sources in  
Milky Way*

*(Has own collection program, alternative=  
SDR# IFAverage Plug-In to collect data)*

# ezCol = ezRA's Data Collection Program

Figure 1

## ezRA - Easy Radio Astronomy Data Collector - ezCol230406a.py

New Plot New File

● Collect ○ Off  
○ Pause ● RefDiv  
○ Exit ○ RefSub

LRO  
Latitude 52.7  
Longitude -1.8  
Amsl 81  
FreqCtrRef 1423.405000  
FreqCtr 1420.405000  
FreqMin 1419.205000  
FreqMax 1421.605000

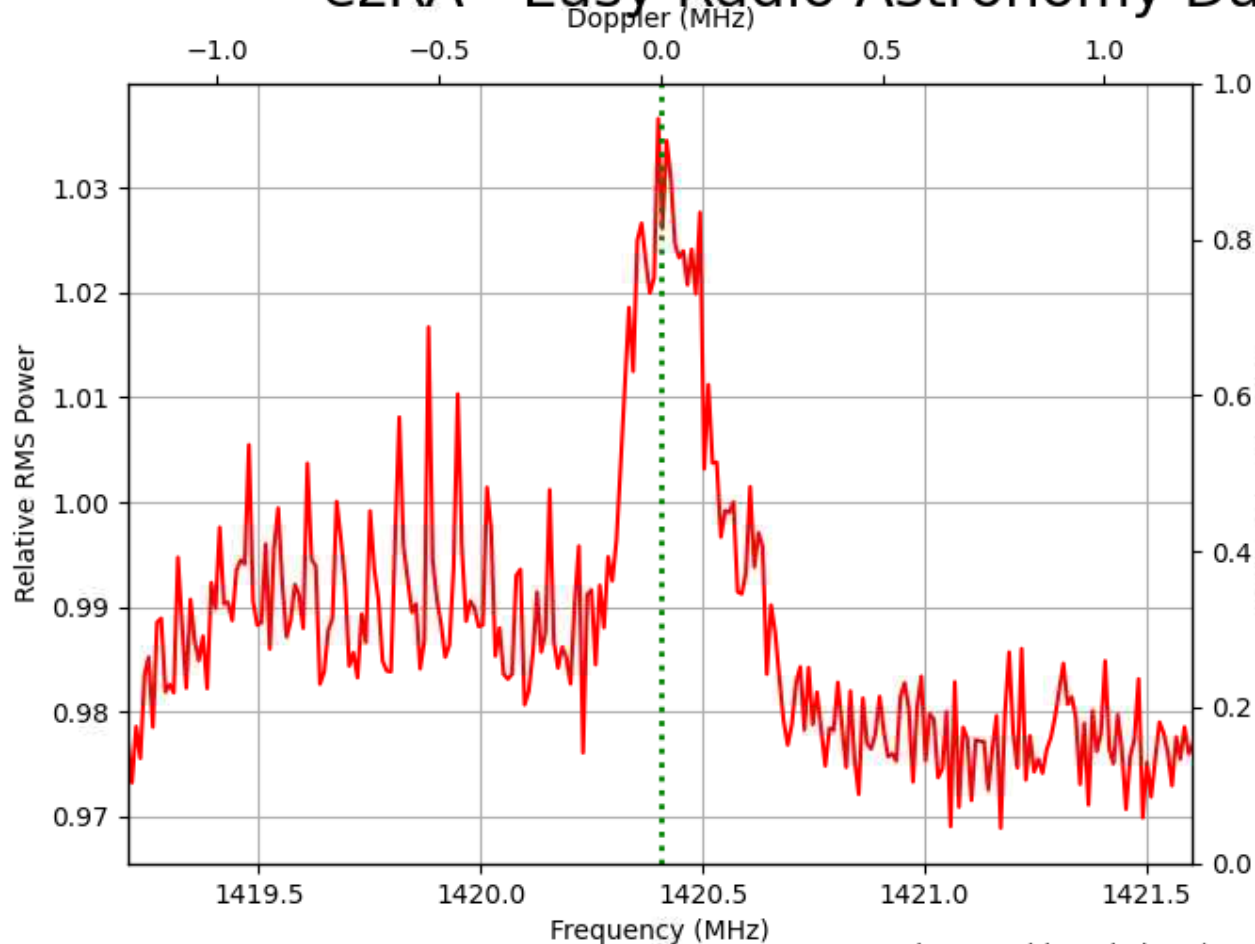
Azimuth 163.0  
Elevation 78.8

LRO231214\_00.txt  
SampleQty 3248 R

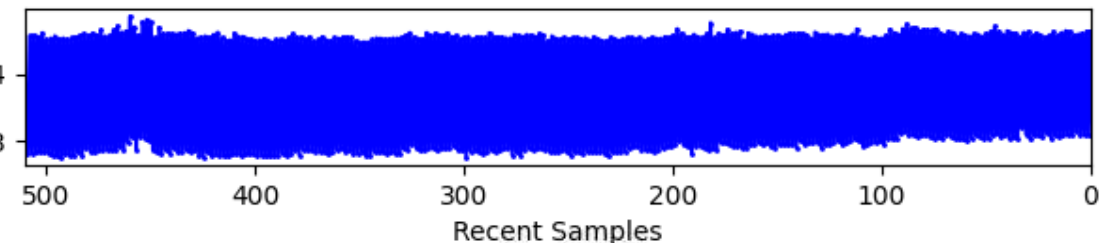
FreqBinQty 256  
Gain 49.6  
Integration 30.6 sec

2023-12-14 23:07:24 UTC  
2023-12-14 23:07:24 PC

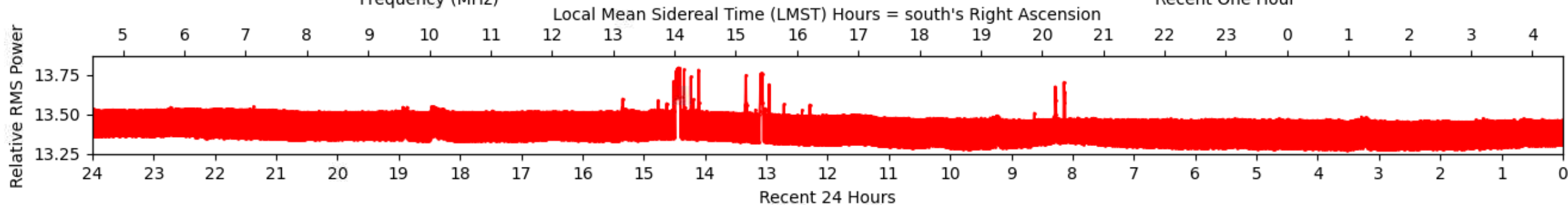
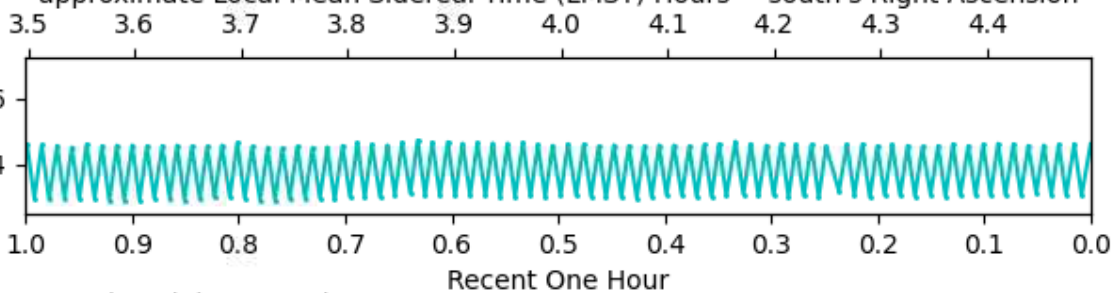
ezColIntegQty 31000  
Fraction of  
Y Auto Scale, Min and Max 0.0 1.0



Relative RMS Power

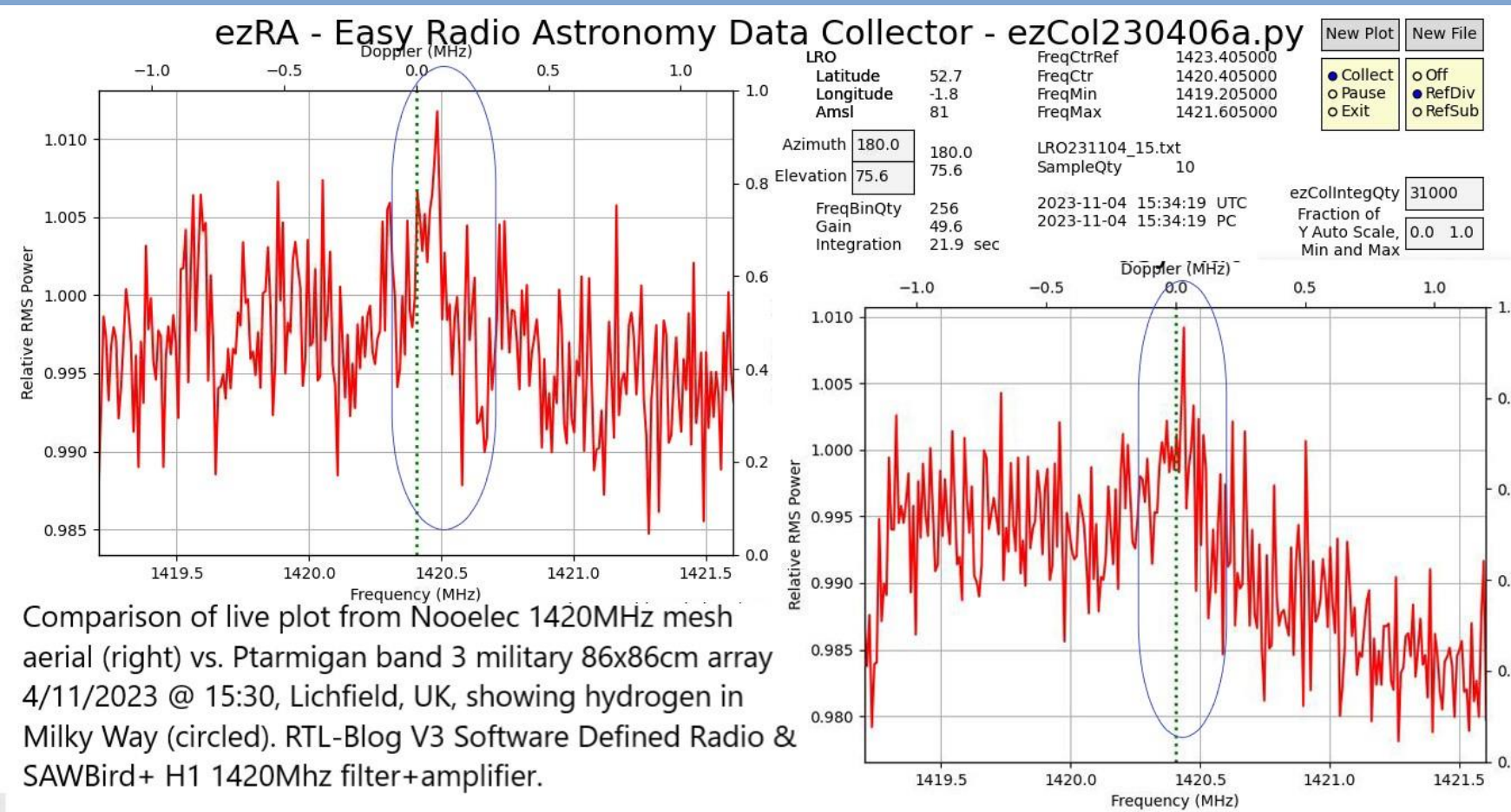


approximate Local Mean Sidereal Time (LMST) Hours = south's Right Ascension





# Testing the new Nooelec 1420MHz-tuned mesh aerial



*Quite capable of detecting hydrogen*



*Data is improved if calibrated*

*Calibration of Scope in a Box in  
SDR# Software with IF Average  
plug in*

**This does similar job to flats and  
darks in astrophotography**



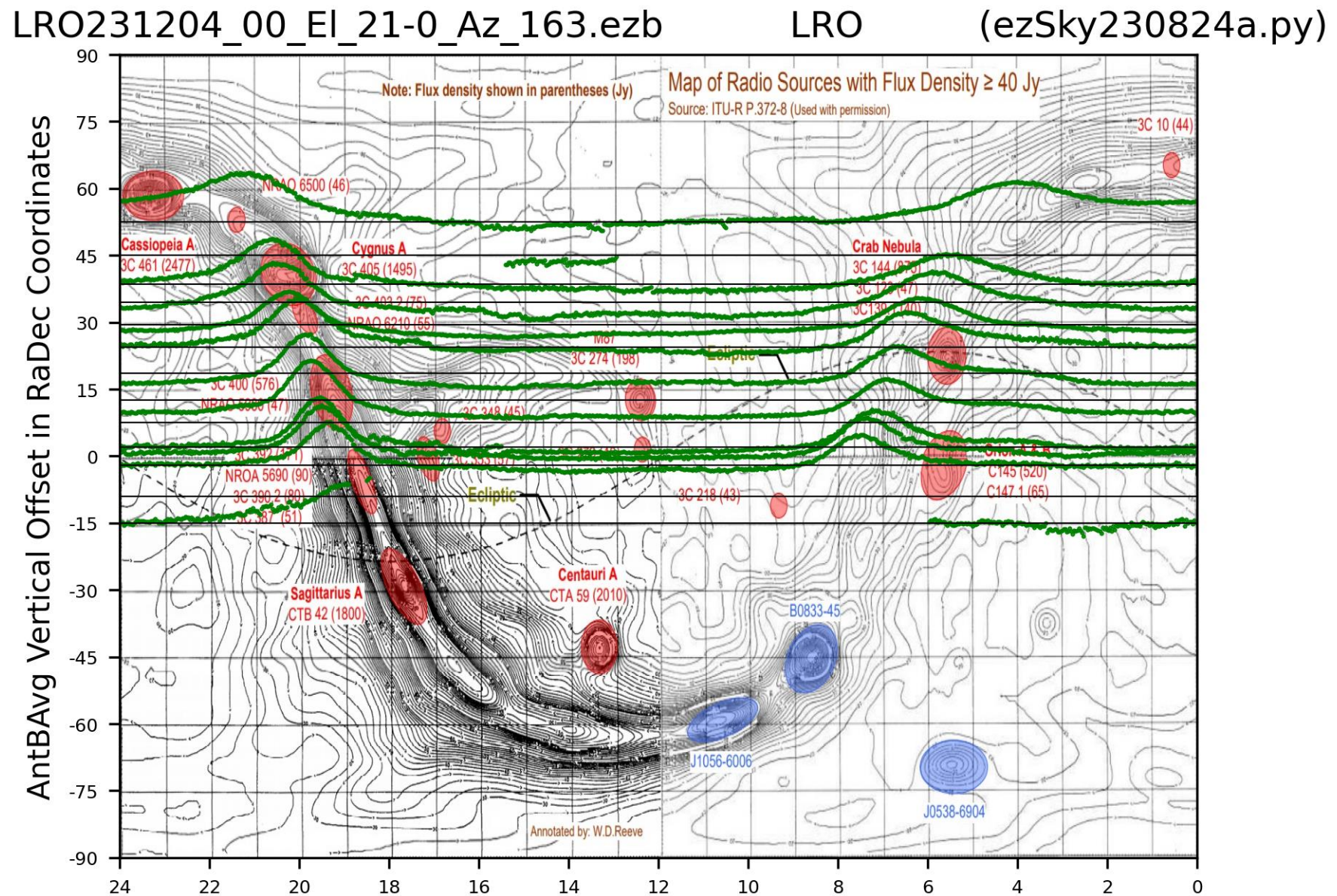
# 50 ohm load used in place of aerial



*Although now I use signal offset 3MHz  
to 1423MHz every other sample for  
calibration.*



***Results of  
the first  
LRO Milky  
Way  
Hydrogen  
Map  
- elevation  
coverage***











*Latest data from LRO 1/4/2024 coming  
next – note I now think I didn't match  
the two maps correctly in above  
diagrams*



LRO240331\_00P00.0Gal.npz

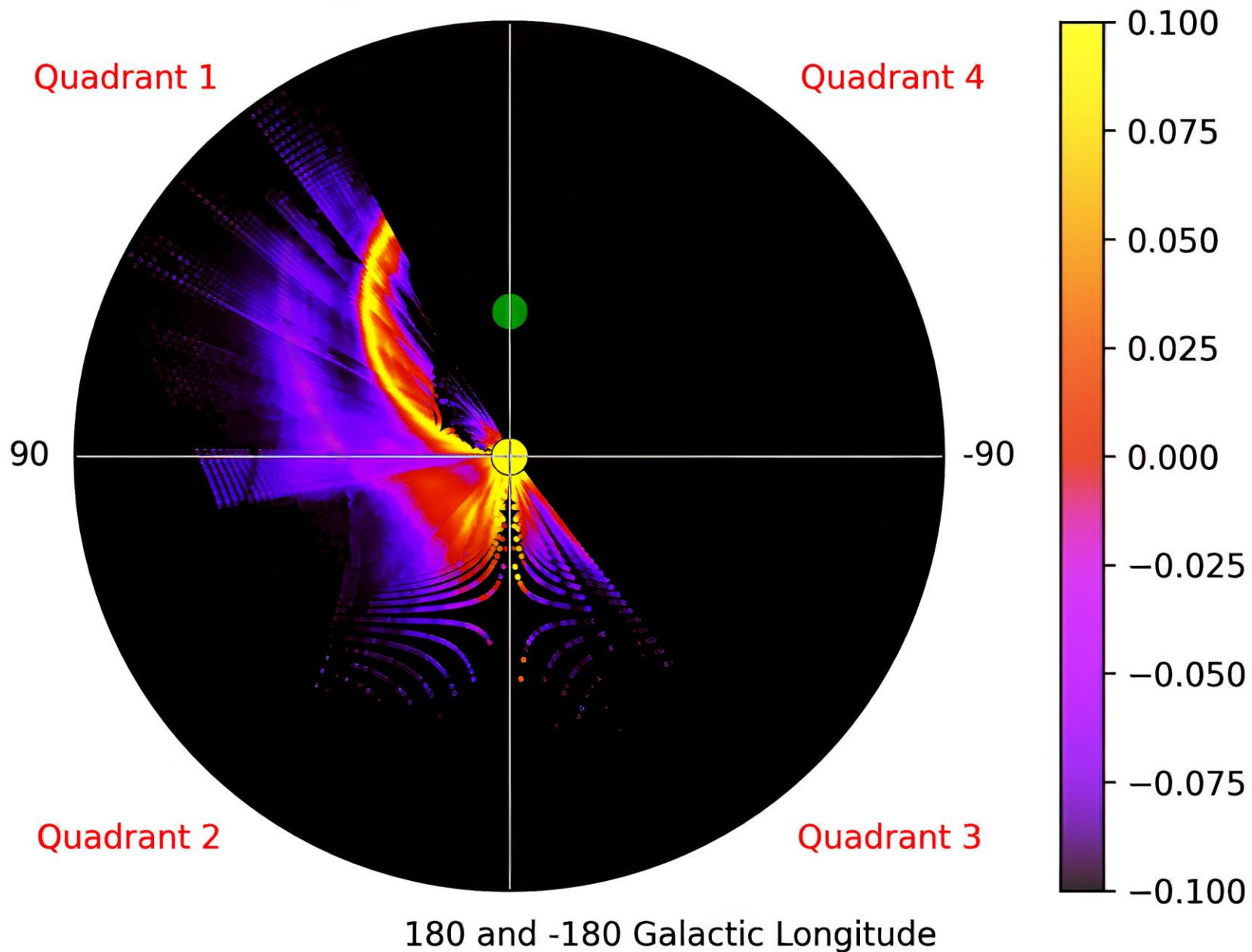
LRO

(ezGal231212a.py)

0

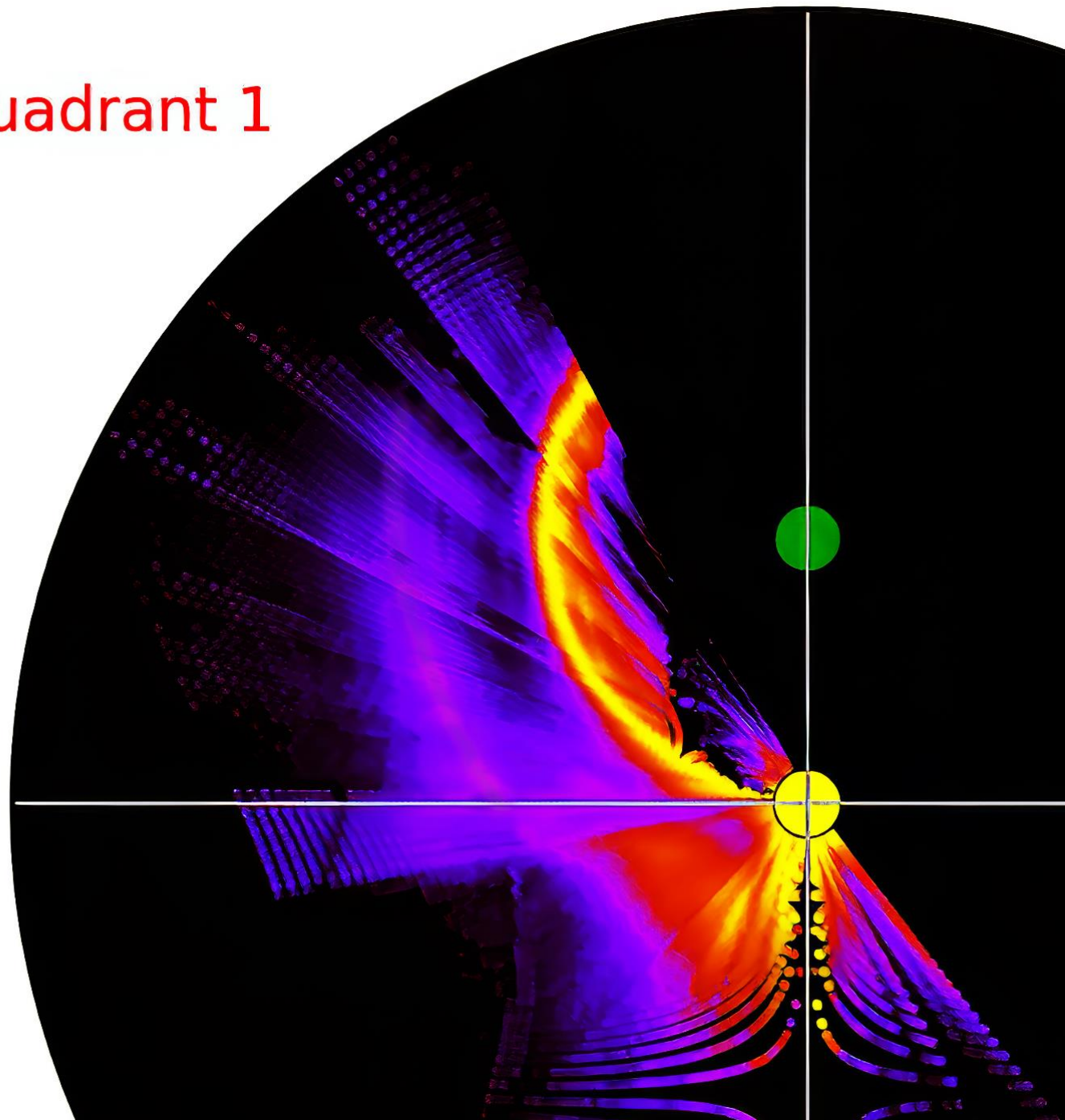
Possible Galactic Atomic Hydrogen

Sun = Yellow Dot, Galactic Center = Green Dot



Quadrant 1

90

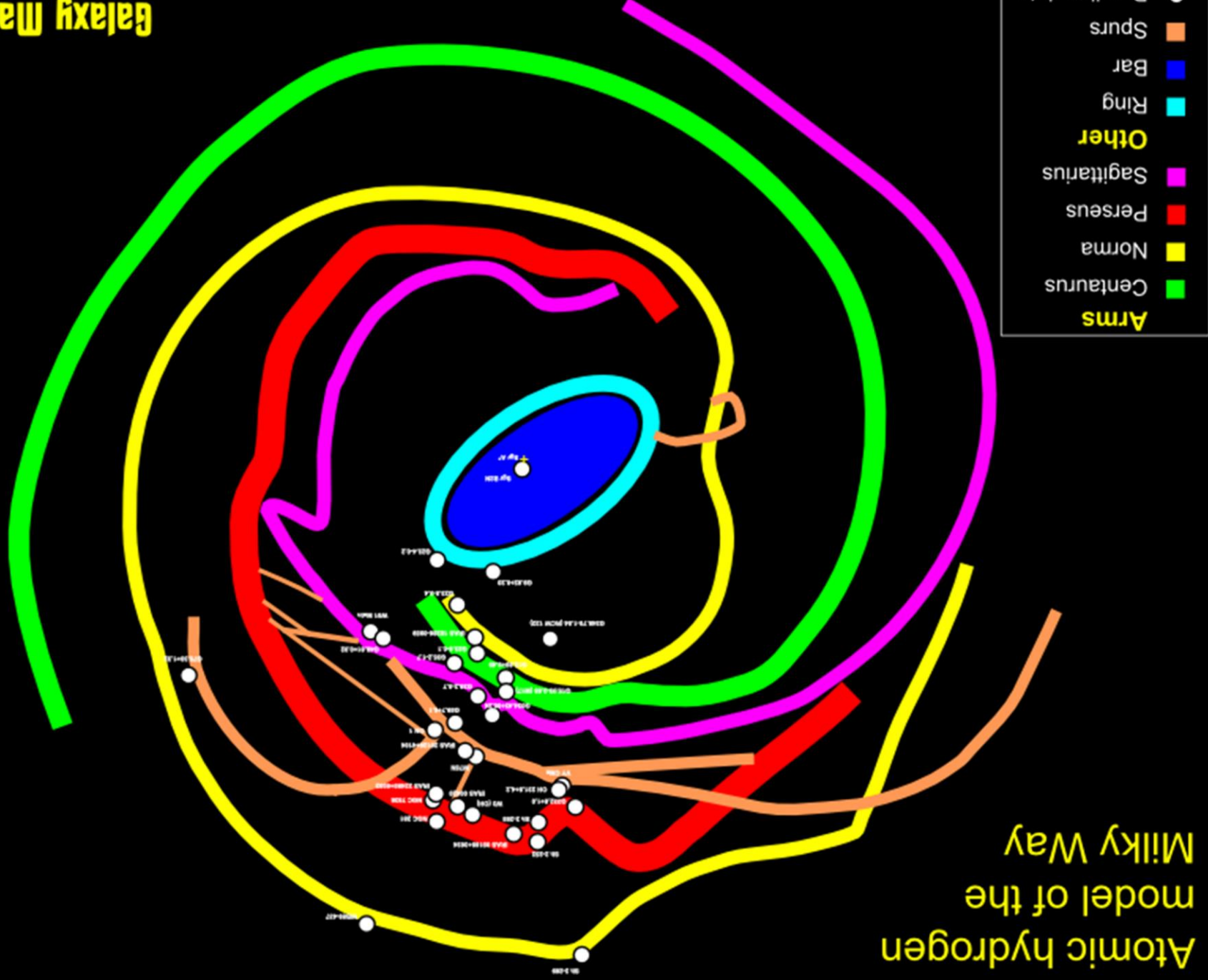




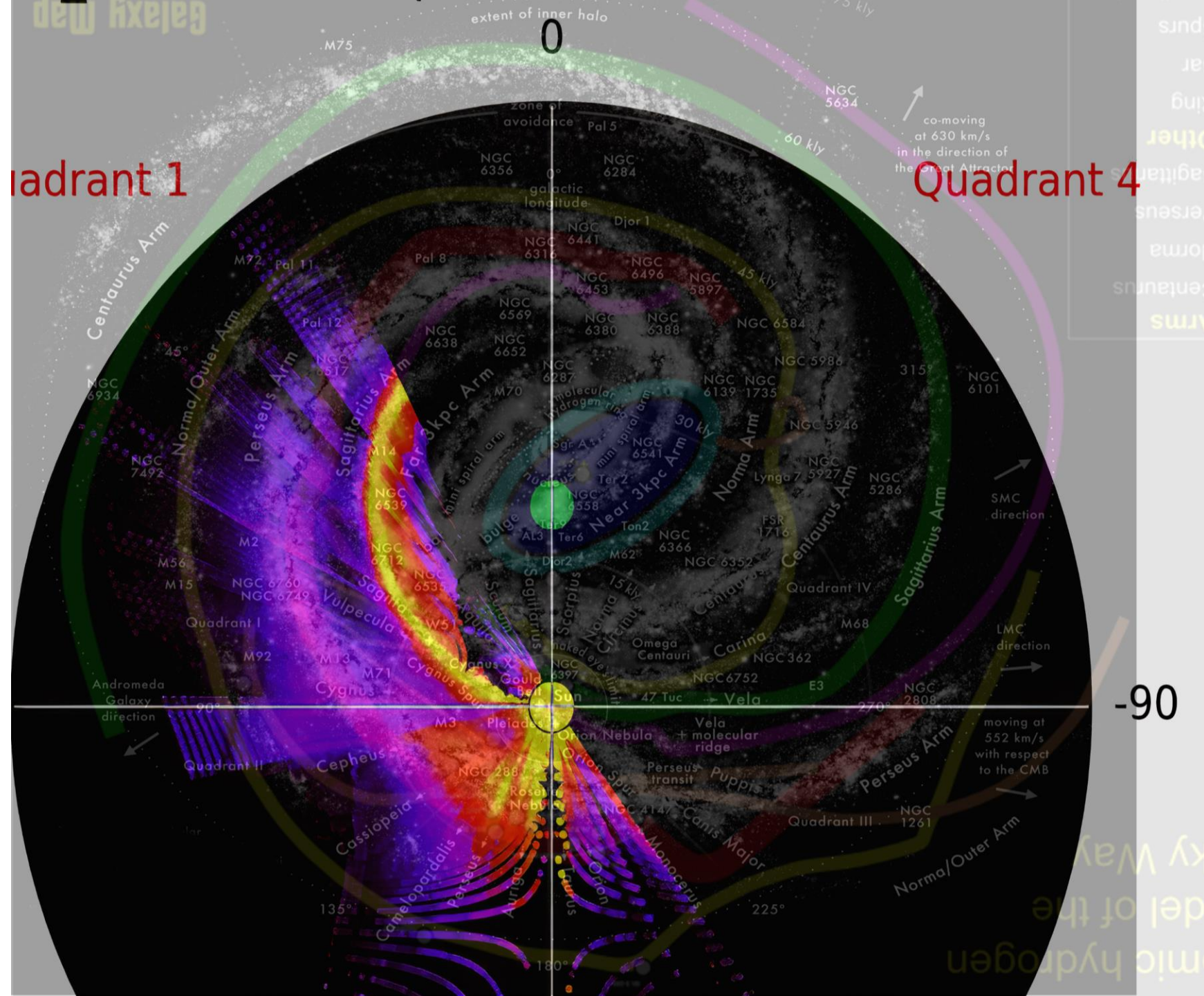
(ezGal231212a.py)



# Atomic hydrogen model of the Milky Way









# New labels

## Quadrant 4

Quadrant 1

# Norma/Outer Arm

# Sagittarius Arm

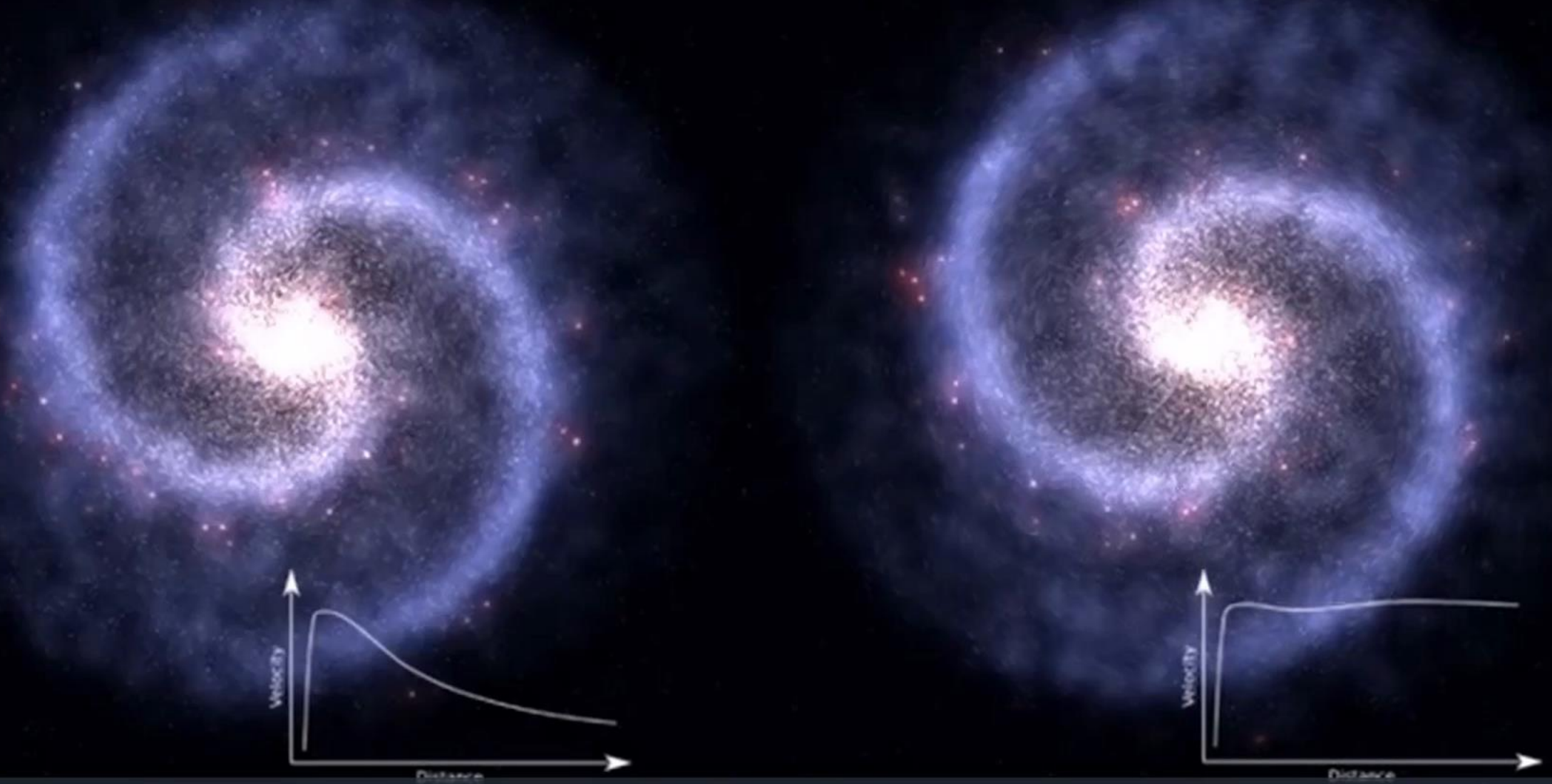
# Perseus Arm

# Cygnus Spur

# Perseus Arm.

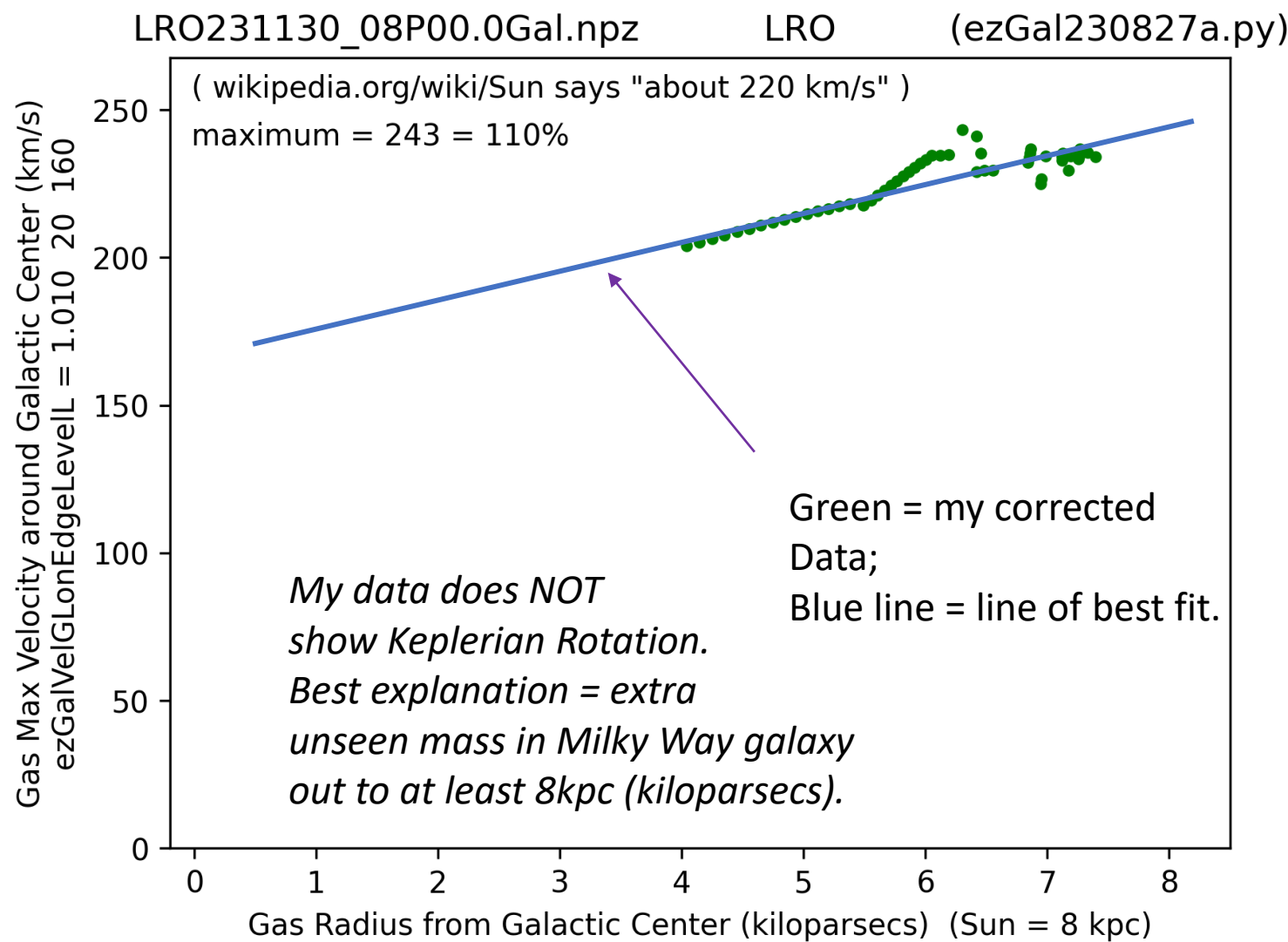
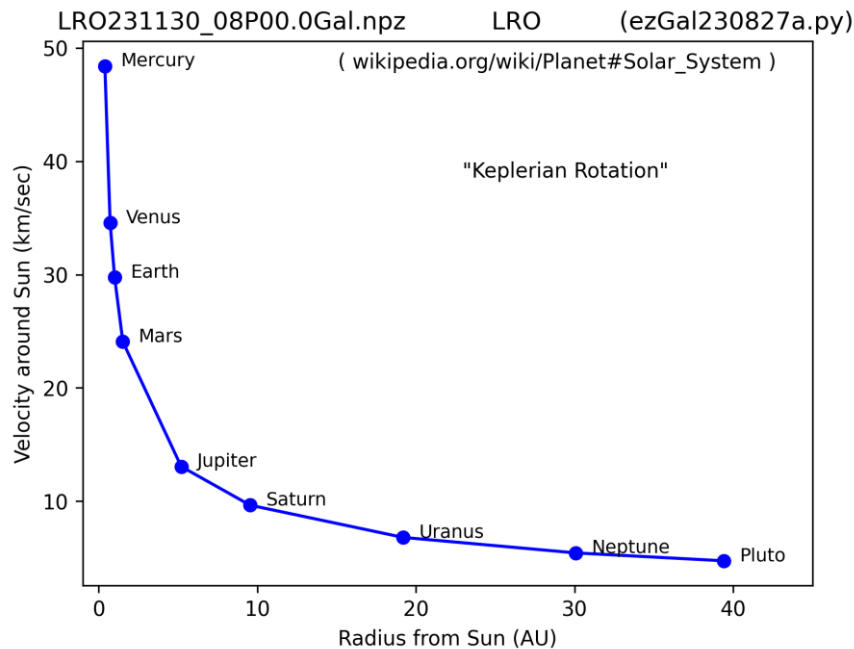


***Simulation of galactic rotation WITHOUT Dark Matter (Left) vs  
WITH dark matter (Right); From Wikipedia***



# Dark Matter – galactic rotation curve from my data

Below is typical Keplerian Rotation Curve which would be expected without dark matter, on right my data (ezRA suite/Pharmigan array)





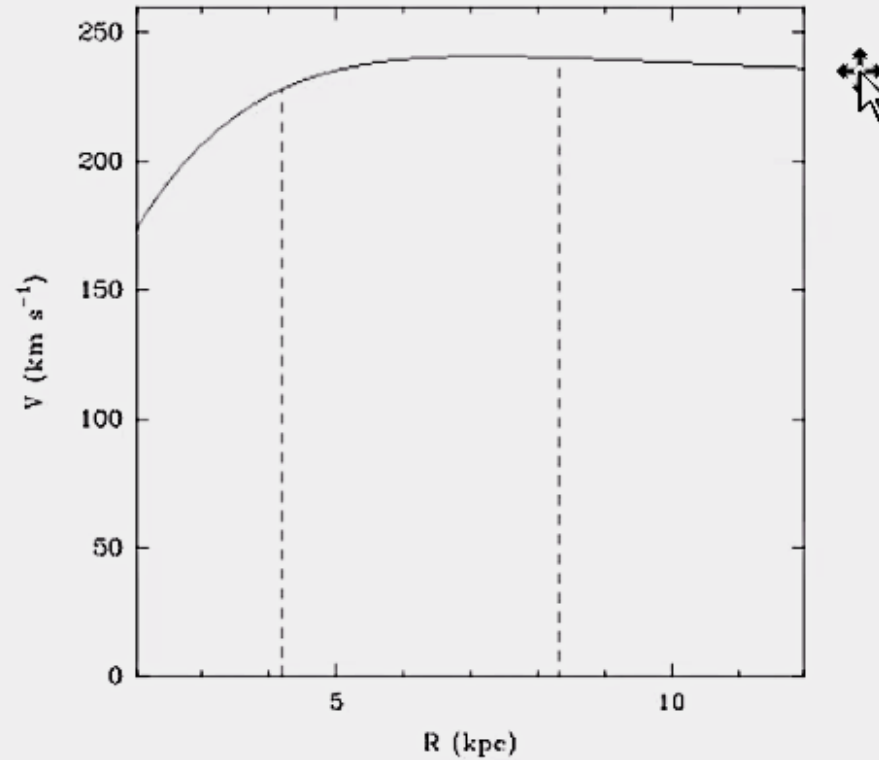


Fig. 2.— A rotation curve fitted to 80 VLBI parallaxes and proper motions of high-mass star forming regions by Reid et al. (2014), using the “Universal” rotation curve formulation of Persic, Salucci & Stell

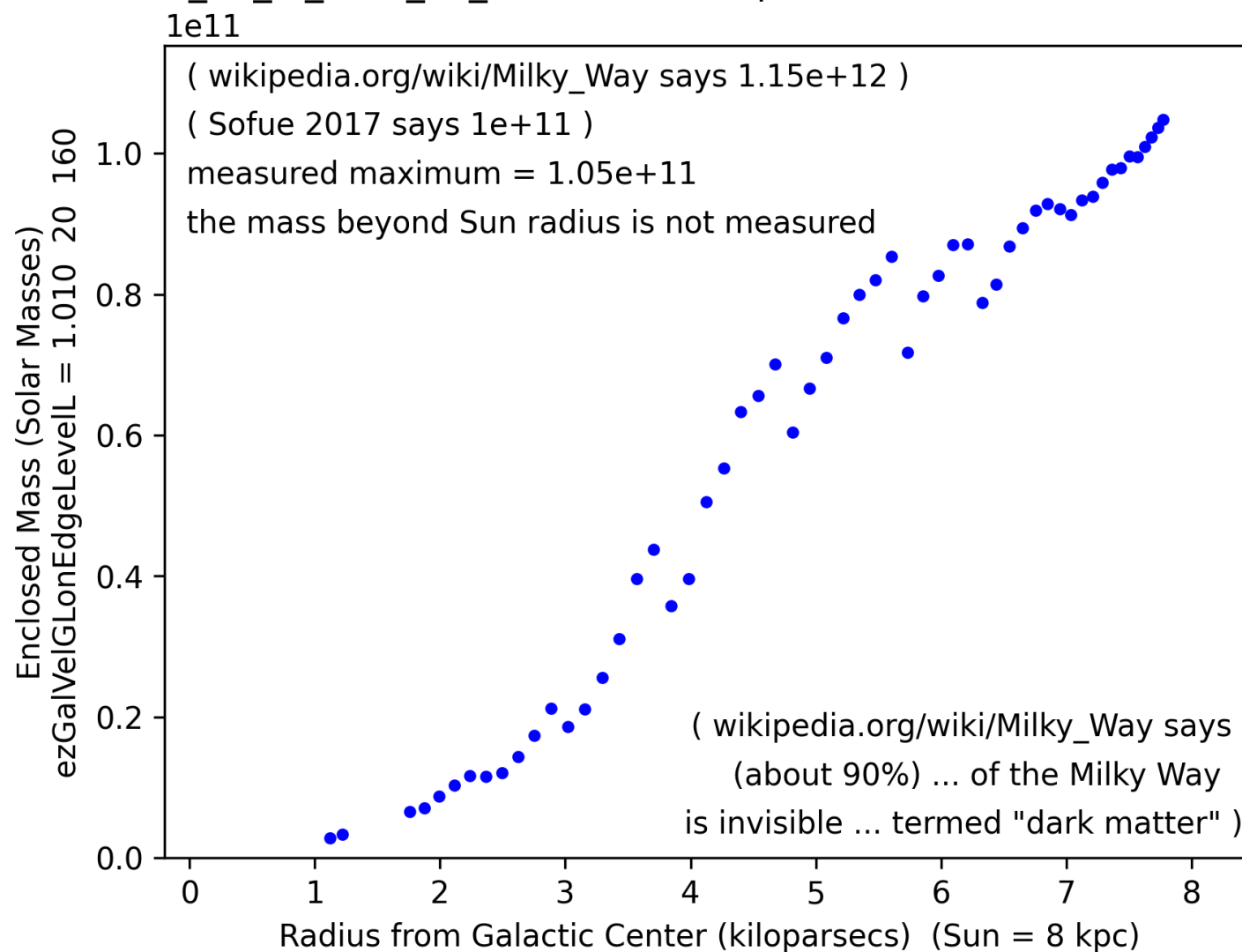
Compare my rotational data against this  
published data

# Enclosed Milky Way galactic mass

LRO231204\_00\_EI\_21-0\_Az\_163P00.0Gal.npz

LRO

(ezGal230827a.py)





# Choosing a PC to record data

## – I chose Windows-based Mini-PC

- 2<sup>nd</sup> hand mini-PCs are very cheap - £85 buys off ebay Levono i5, 8GB RAM, 256GB SSD. A little extra increases RAM and SSD.
- RealVNC for remote connection – I opted for this rather than Remote Desktop as latter causes issues with audio inputs on remote computer – free RealVNC account gives three remote PCs per account – I now have three accounts!
- Raspberry Pis, Ardinos, Linux machines are all options too





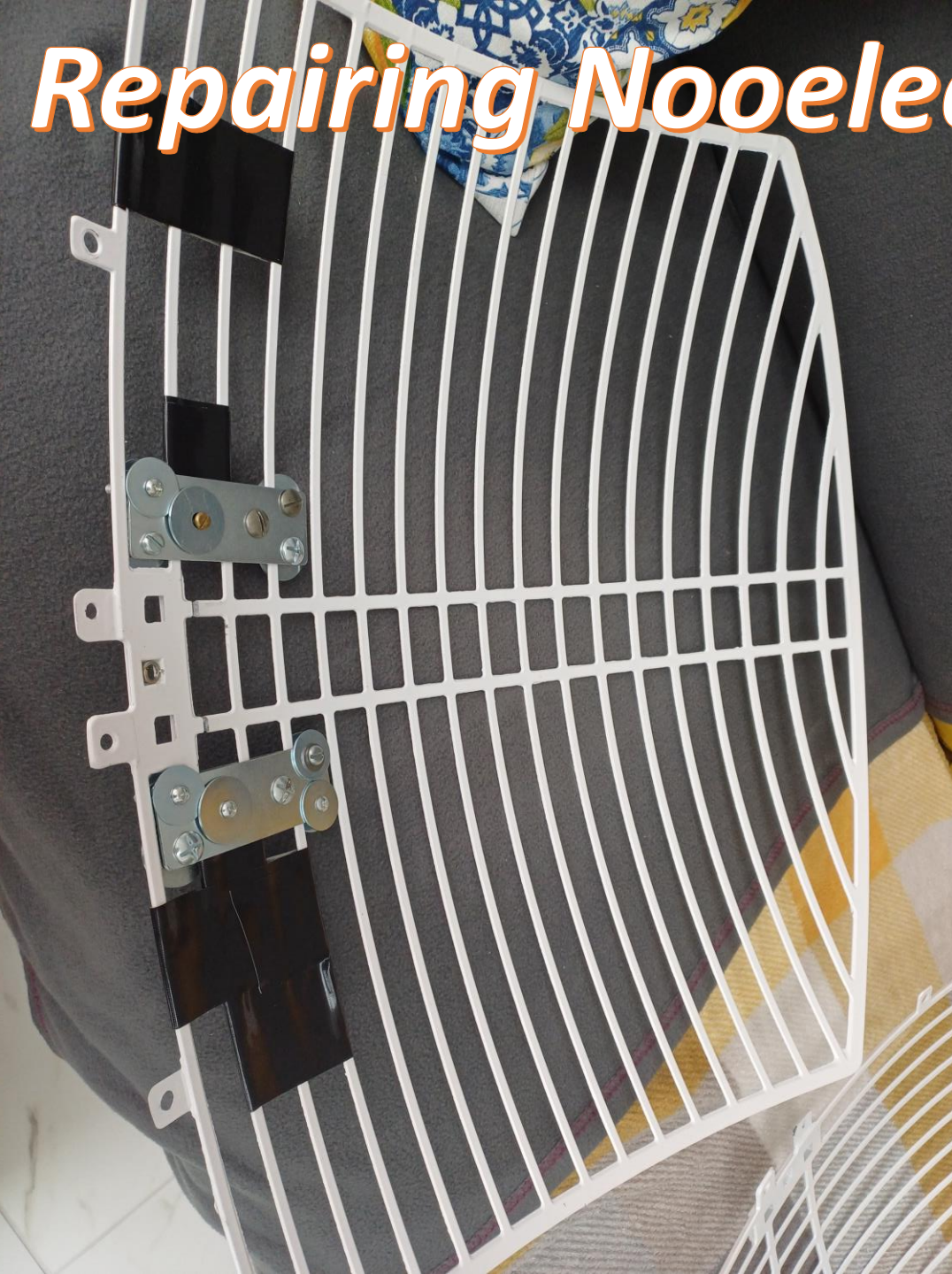


*Dealing  
with dew –  
a MAJOR  
problem!!*

Causes some interference but ezRA  
Is very resilient to this



# *Repairing Nooelec mesh dish when it split*





# *Cantennae*

*My next project was  
to build one of  
these and try and  
replicate my findings*







Freq. of operation [MHz]

2450

Can Diameter [mm]

90

Cut-Off Freq. for TE<sub>11</sub> Mode [MHz]

Cut-Off Freq. for TM<sub>01</sub> Mode [MHz]

Waveguide Wavelength  $L_g = \lambda_g$  [mm]

$0.25 * \lambda_g$  [mm]

$0.75 * \lambda_g$  [mm]

Free space Wavelength  $\lambda$  [mm]

Length of Monopole  $\lambda/4$  [mm]

Diameter of Monopole [mm]

CALCULATE

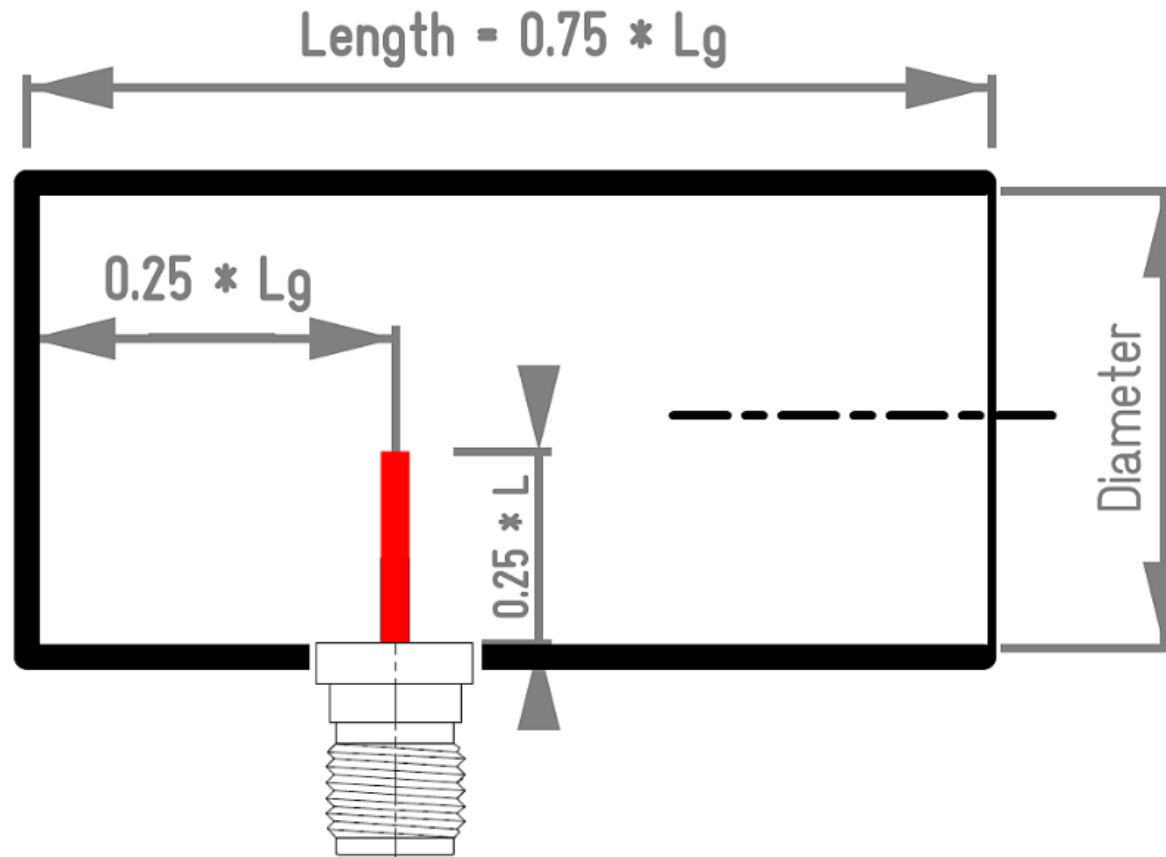
## CATEGORIES

- Projects (Antiques) 🐉
- Micro Projects • Tools 🔧
- Arduino Projects 📖
- Arduino Final Projects : IPA's
- Arduino Knowledgebase 📄
- Bluepill • Blackpill Projects 📖
- Teensy Projects 📖
- Python Lab Experiments 🐍
- Power Supplies • Calculations
- Amplifiers • Calculations
- Opamp Circuits • Knowledge
- Antenna Designer 📡
- Filter Designer (Audio, AF)
- Filter Designer (Radio, RF)
- PLL, VCO, DDS, Oscillators
- Mixer • Freq. Converters
- Noisy Things
- QO Toolbox 3599
- QO Basics • Photodiodes
- Components • Networks 📡
- Conversions 📄
- misc. Calculations 📄
- Hardware • Software 📄

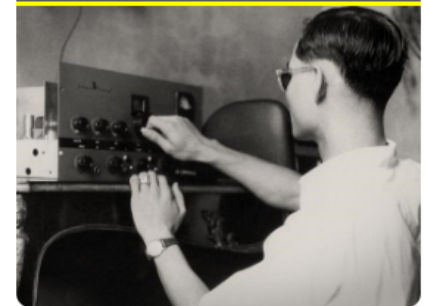
CANTENNA.PHP 6415 BYTES 01-07-2022 05:06:04

## Cantenna Calculator

### Aka Circular Waveguide Antenna



เราจะทำแบบวิศวกรผู้ยิ่งใหญ่



12. JANUARY 2024

15:13:54

YOUR VALUABLE OPINION :



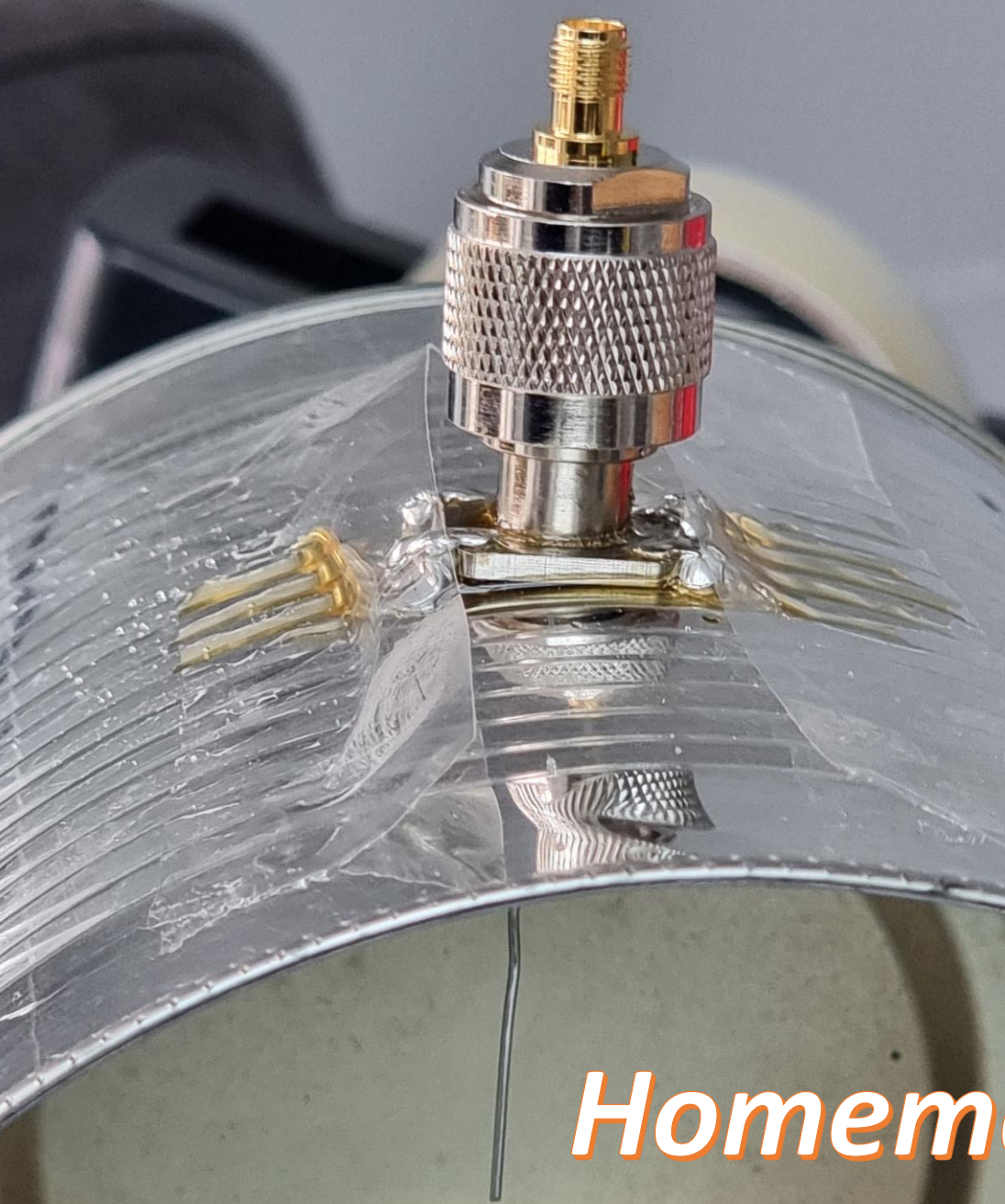
Avg. 6 from 402 votes.

1 2 3 4 5 6

COUNT YOUR OPINION



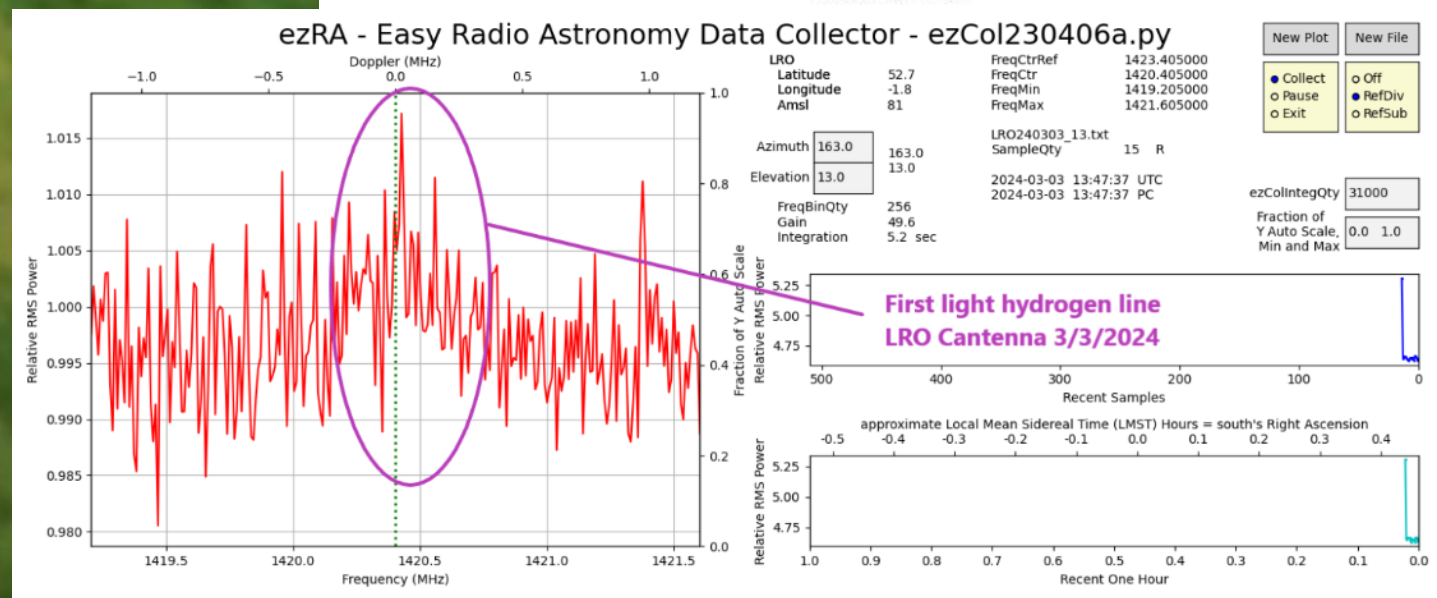
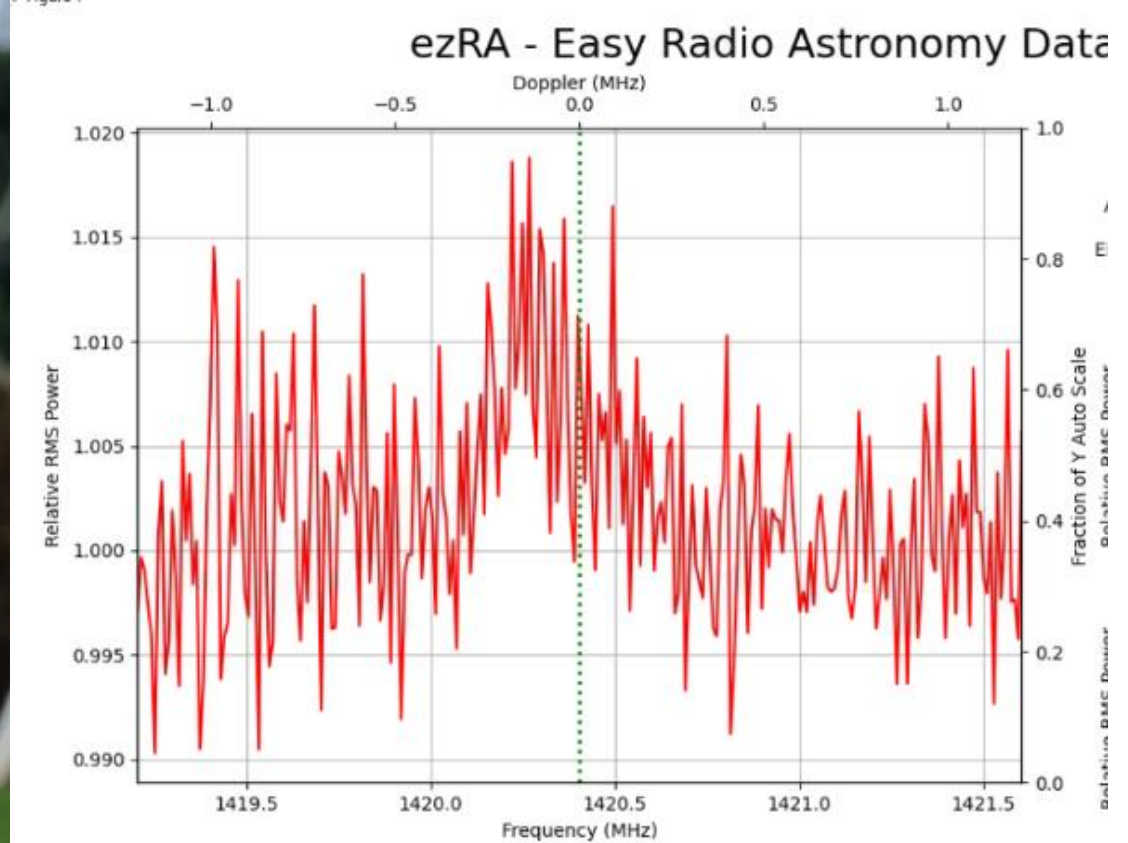
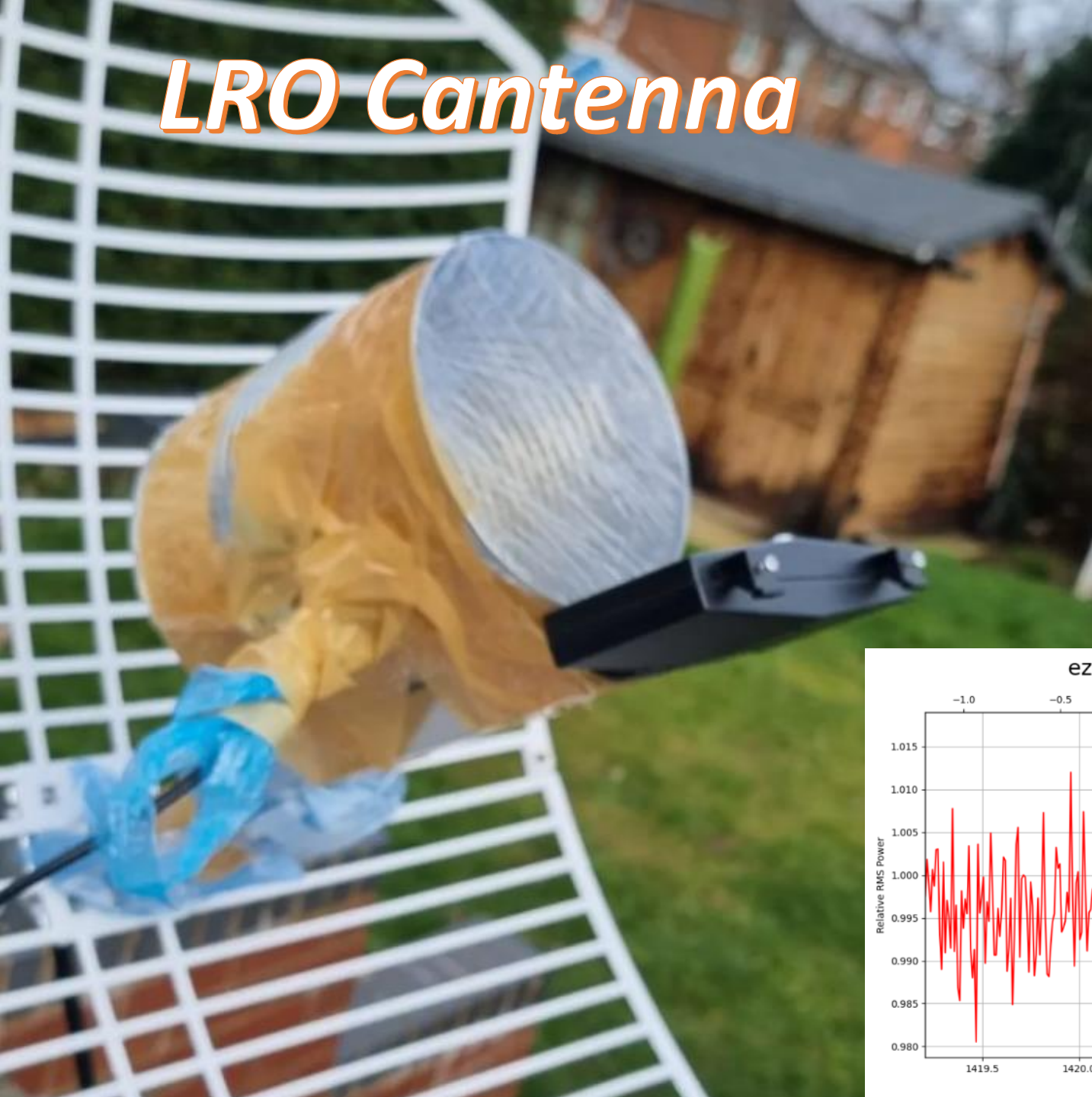




***Homemade LRO Cantenna:  
15cm diameter tin, 49mm waveguide***



# LRO Cantenna

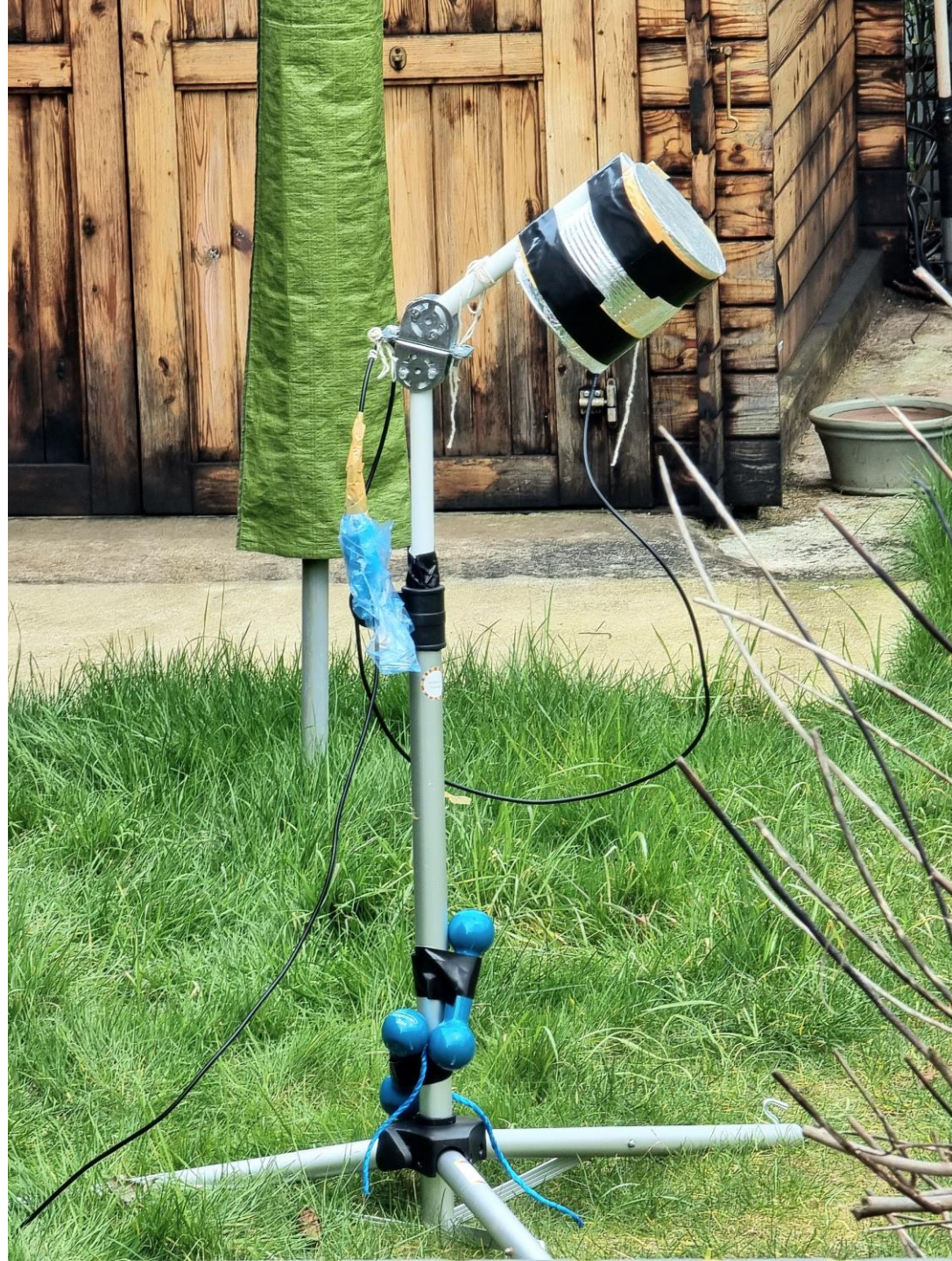






*Aerial brackets from ebay used to change elevation & white painted steel tubing*







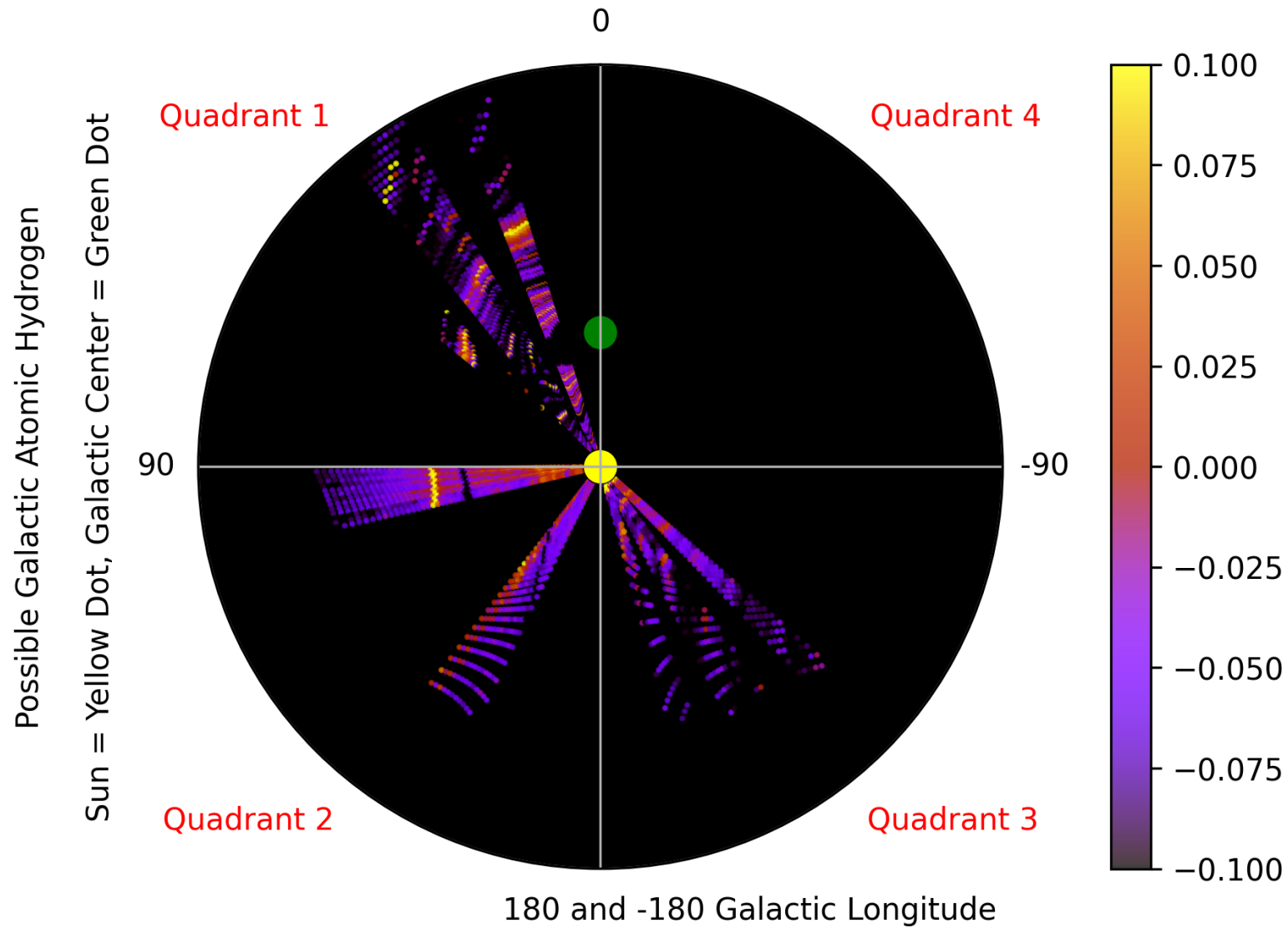


***But...***

LRO240326\_00\_Cantenna\_El\_90-0\_Az\_163P00.0Gal.npz

LRO

(ezGal231212a.py)

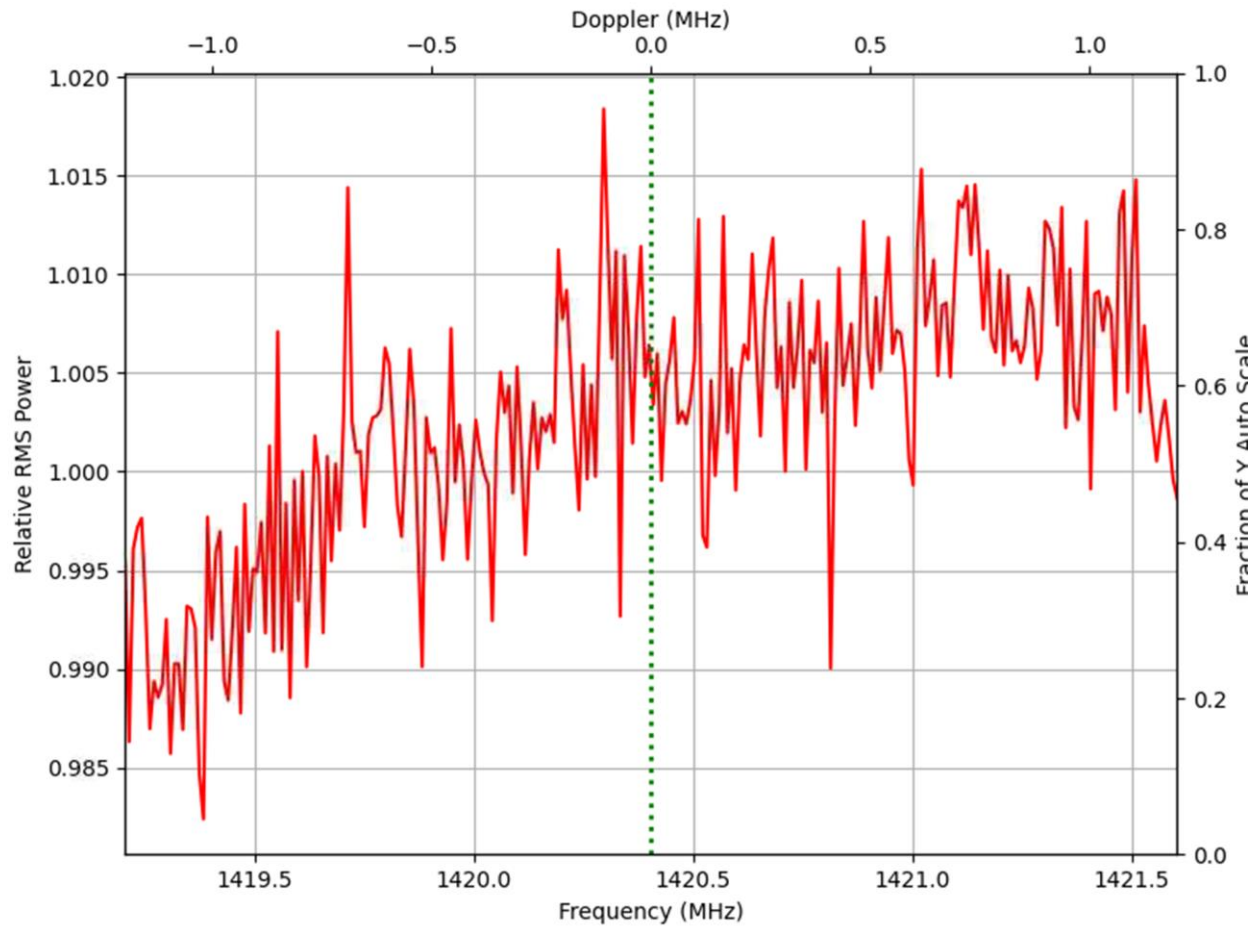


*Sadly, data from LRO shows lot of interference*



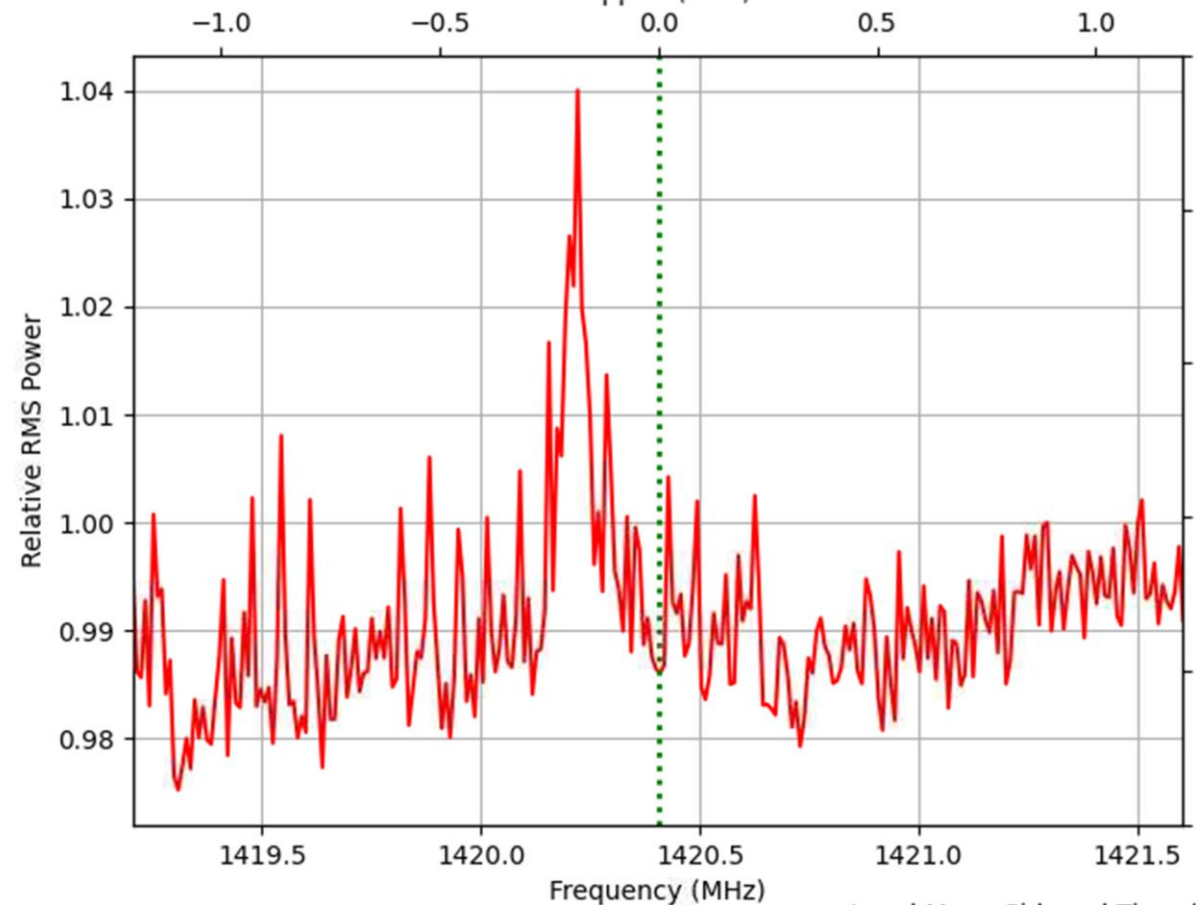
# *Finding the problem with Cantenna*

*Both ezCol images below 29/3/24 LRO El 56.5 Az 163*



**Cantenna**

## **Pharmigan Array**



# IMPORTANT ADVICE FOR NEWBEES WITH LITTLE KNOWLEDGE LIKE ME:

- Get *support and advice* from SARA/BAA members.
- Realize you need to *dedicate lots of time* to get it working.
  - Making mistakes and starting again is part of the fun.
  - *Don't feel embarrassed* that you do not know enough.
- If your kit works then do not get too worried when someone else says should be done differently – E.g. your aerial has too much ground noise/your dish isn't deep enough or too deep.
- Finally, *do NOT estimate* elevation and azimuth because your beamwidth seems large, *MEASURE IT!*
  - *ezRA suite is quite robust to interference*





Windows Update Blocker v1.8



## Windows Updates Option

- ☒ Enable Updates
- ☐ Disable Updates
- ☐ Protect Services Settings

## Service Status



**Apply Now**

Menu

*Contact Details:*

*Dr Andrew Thornett*

*M6THO*

*andrew@thornett.net*

*www.astronomy.me.uk*