Detecting molecular hydrogen line in Milky Way using Ptarmigan Triffid Military Phased Bipole Array Aerial

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Talk for BAA RAG
13/11/2023

Today’s talk is about setting up the 1420MHz radio telescope

In January I will be giving longer talk on the results and other work at Lichfield Radio Observatory (LRO)

Detecting molecular hydrogen line in Milky Way using Ptarmigan Triffid Military Phased Array Aerial

- 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 a project for this called "Scope in a Box", which led me to give this a try.

PEOPLE I WOULD LIKE TO THANK AND WITHOUT WHO I WOULD NOT BE GIVING THIS TALK TODAY

- Andrew Thomas from BAA for giving me the Ptarmigan Triffid Array

From SARA:

- Lester Veenstra for his fantastic Scope in a Box concept and for sharing both hardware requirements and software with me and giving me great support.
- Ted Cline for the truly incredible mentoring he has given me and for his amazing ezRA software suite.

From BAA/UKRAA:

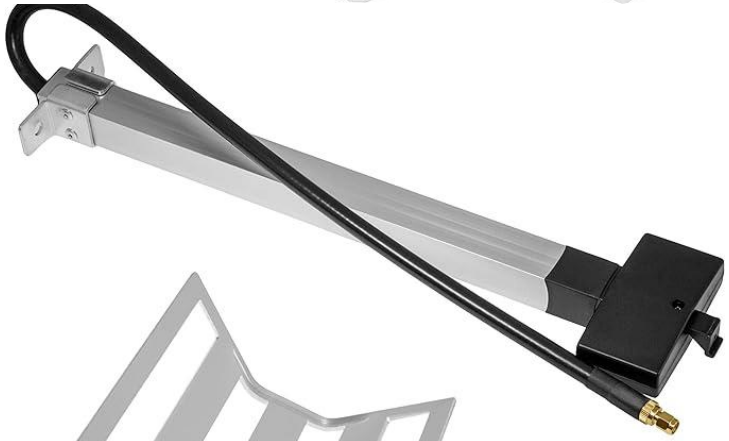
- Andrew Thomas, Andrew Lutley, Paul Hearn – who have also helped me get my VLF receiver, magnetometer and meteor scatter experiments working

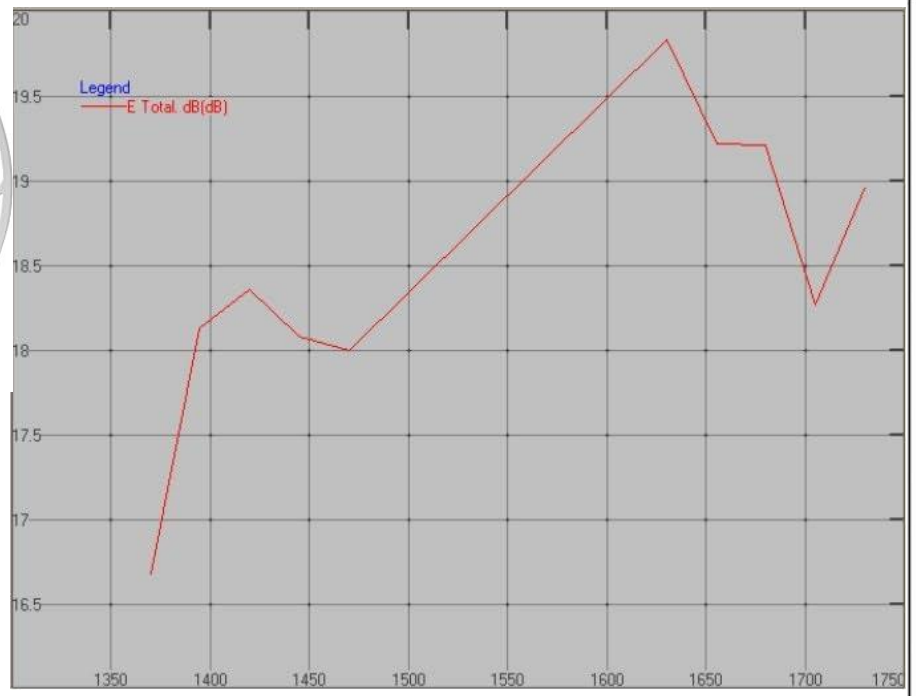
IN THE INTERESTS OF FULL DISCLOSURE…

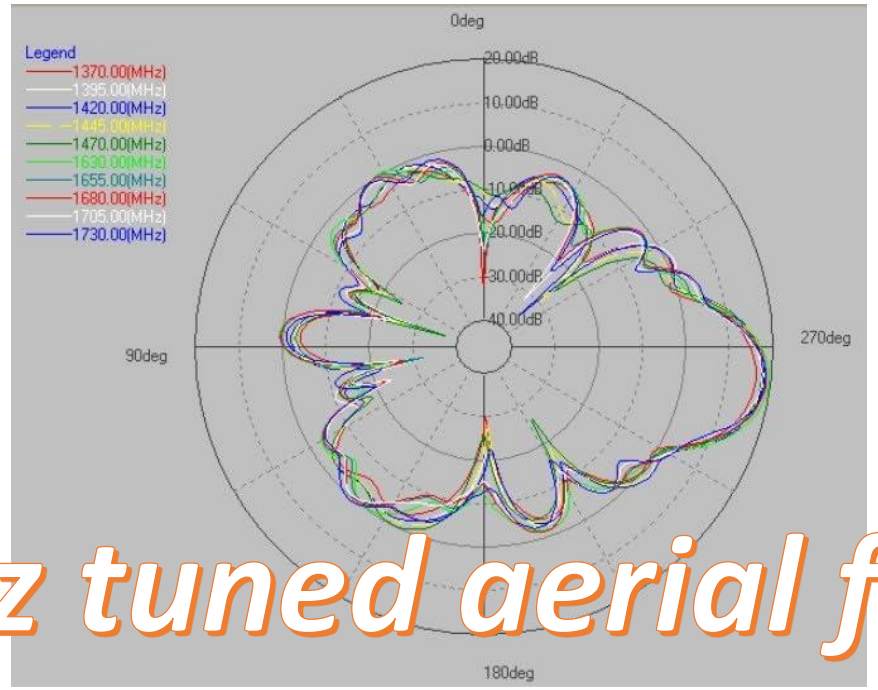
- I was asked to give this talk to encourage others.
- I would definitely like to do that! I have a radio licence (M6THO) but this is only foundation licence and I know very little about electronics or science or engineering of radio.
- HOWEVER:
- Although I got the following working in 2-3 months….
- It has taken hundreds of hours – I have been off work and this has given me the time.
- And taken a LOT of support to get there!
- BUT IT IS VERY EXCITING!!! AND WORKS WHEN IT IS CLOUDY OR RAINING!!!!!

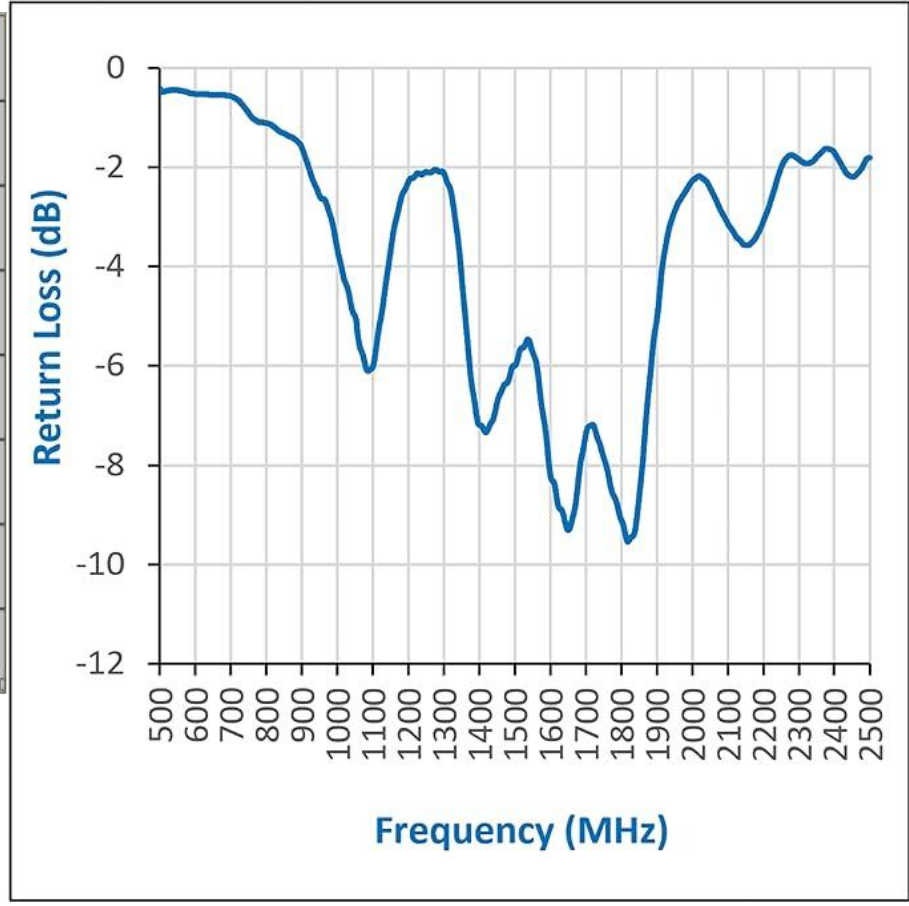
SARA Scope in a Box

This aerial is not ideal as tuned to 1.7GHz rather than 1.4GHZ

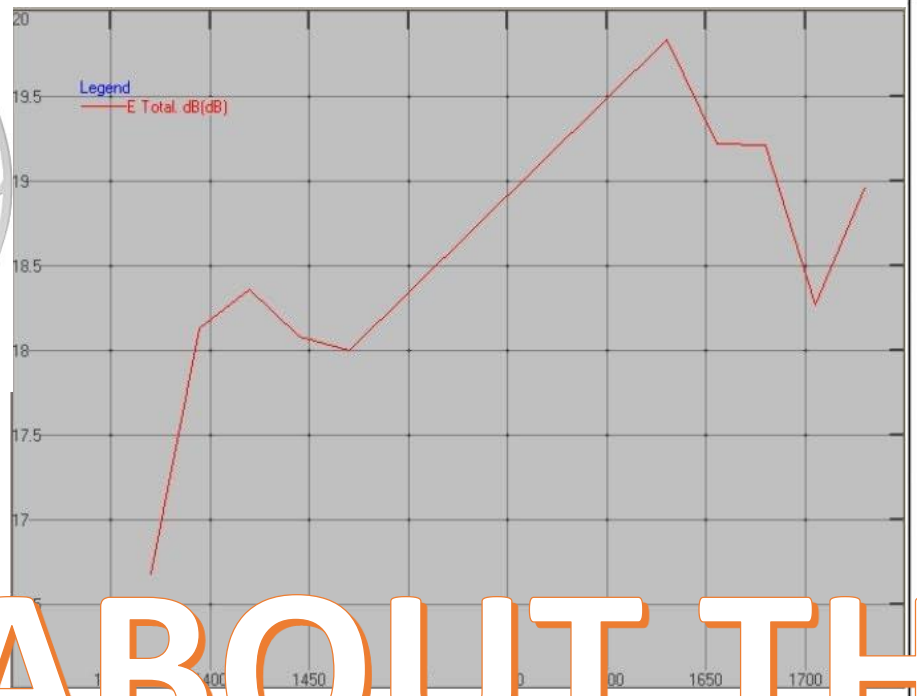


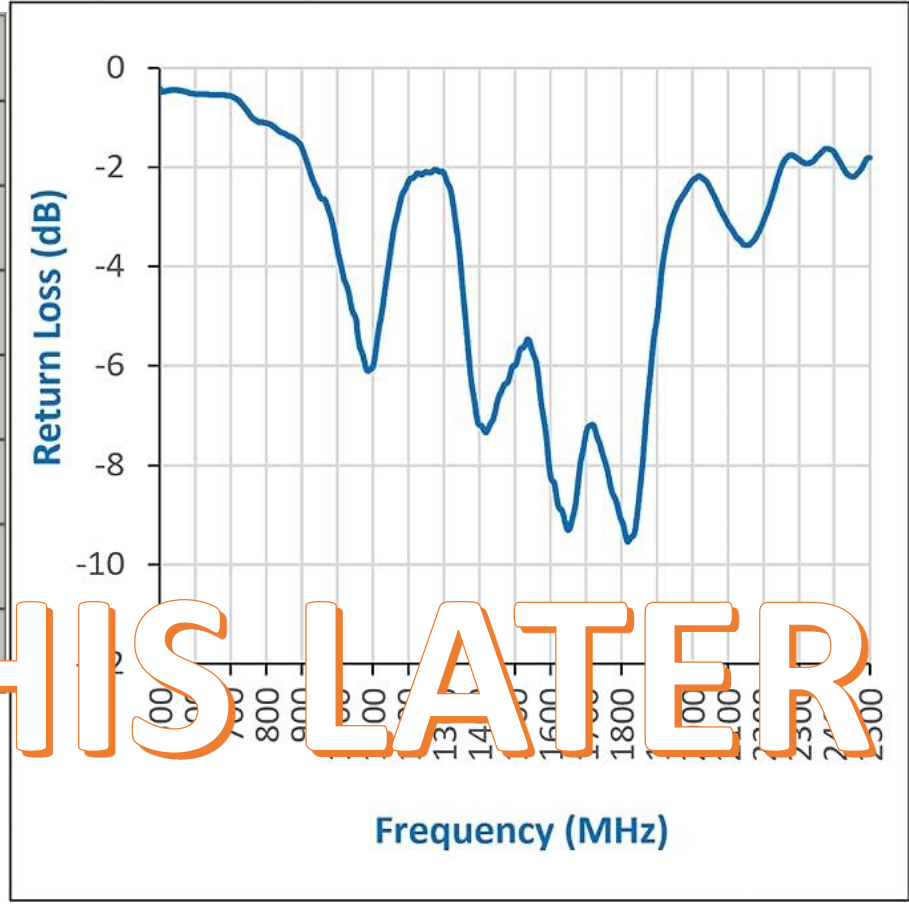




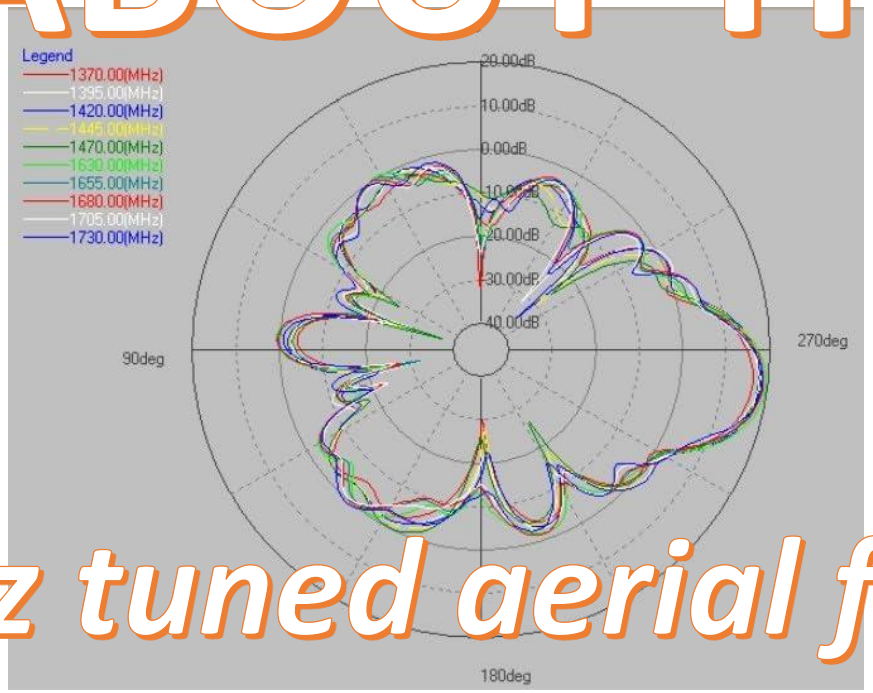


New 1.4GHz tuned aerial from Nooelec





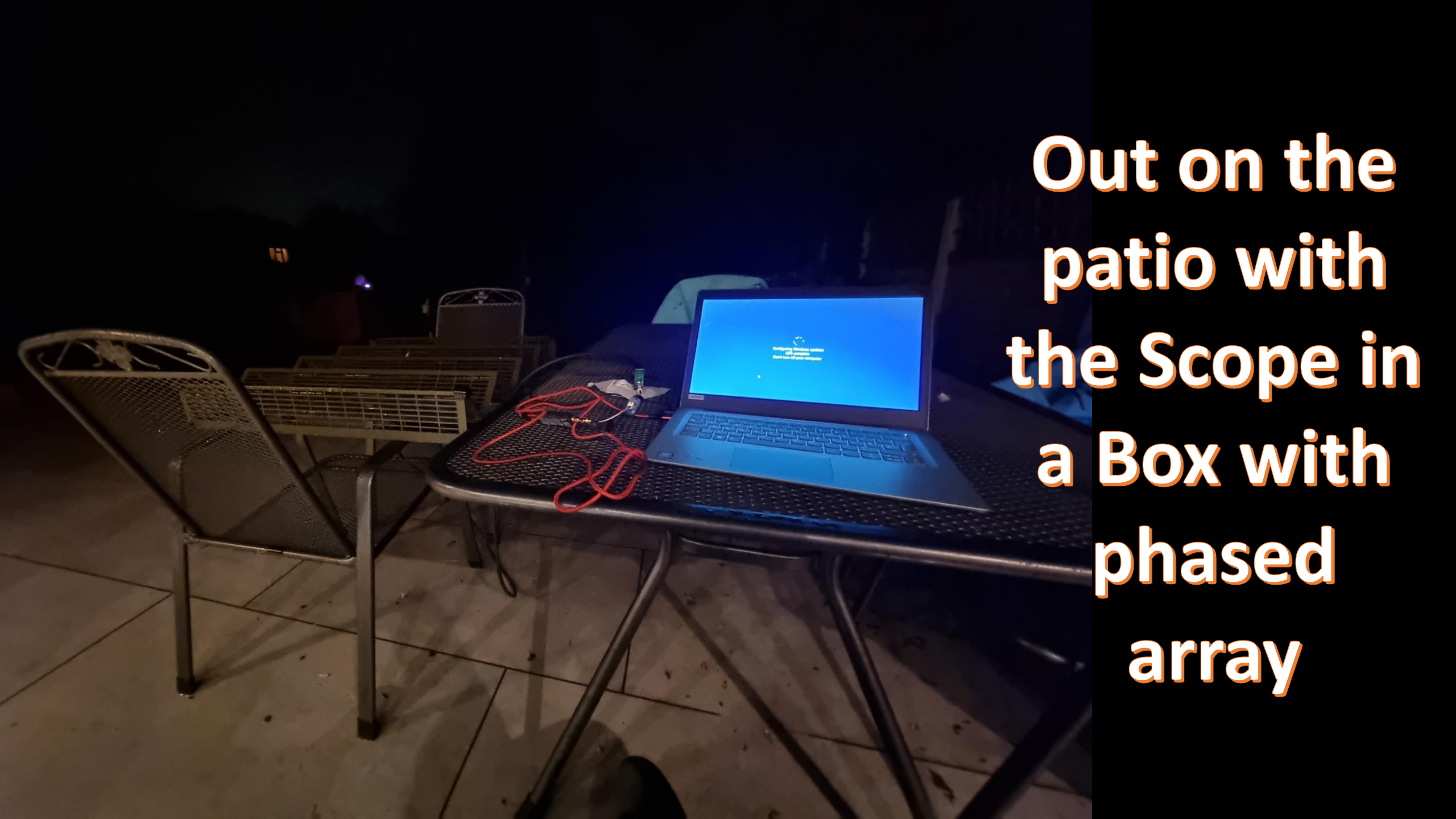
MORE ABOUT THIS LATER

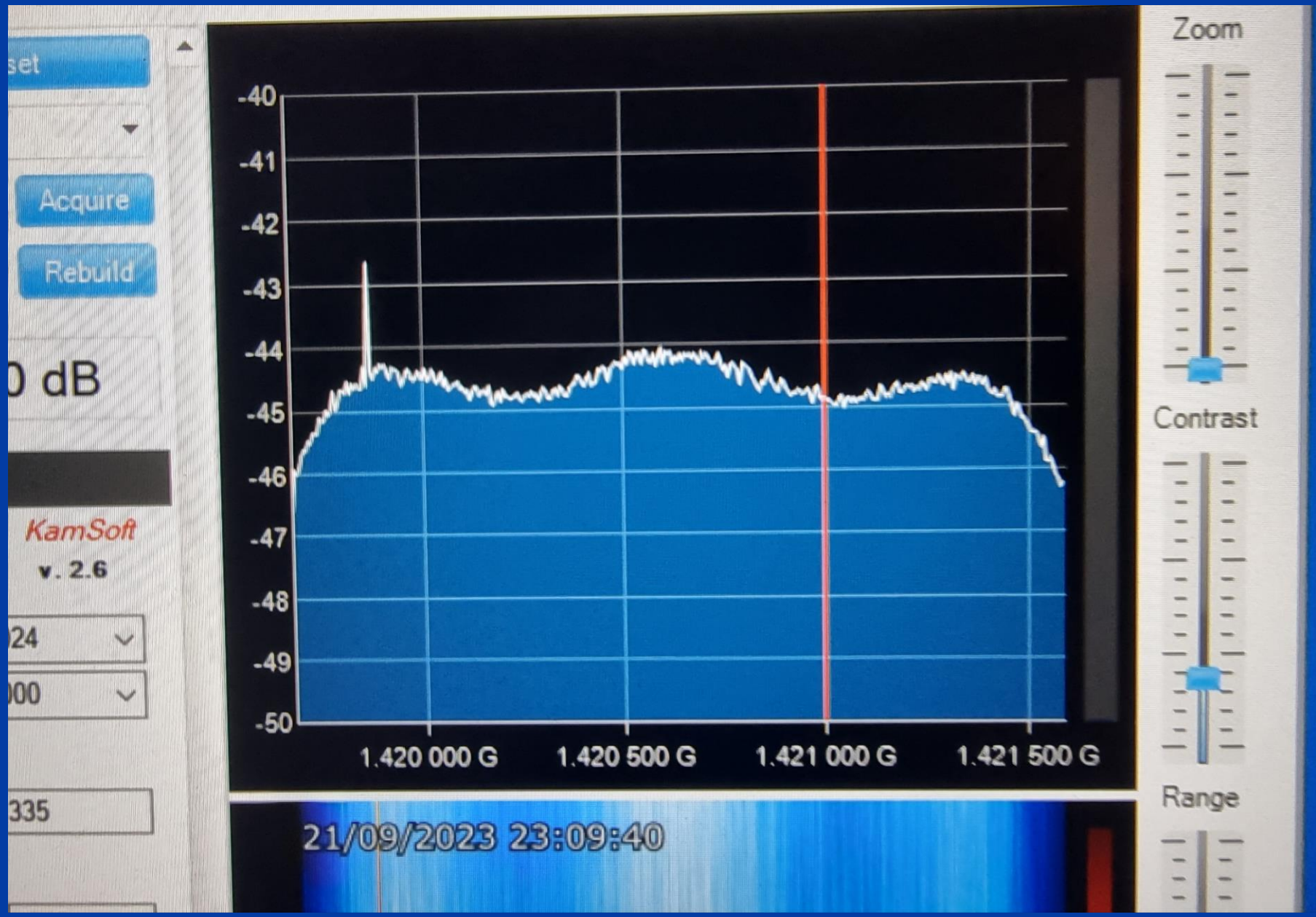


New 1.4GHz tuned aerial from Nooelec

I have been very lucky & have been given one of these…

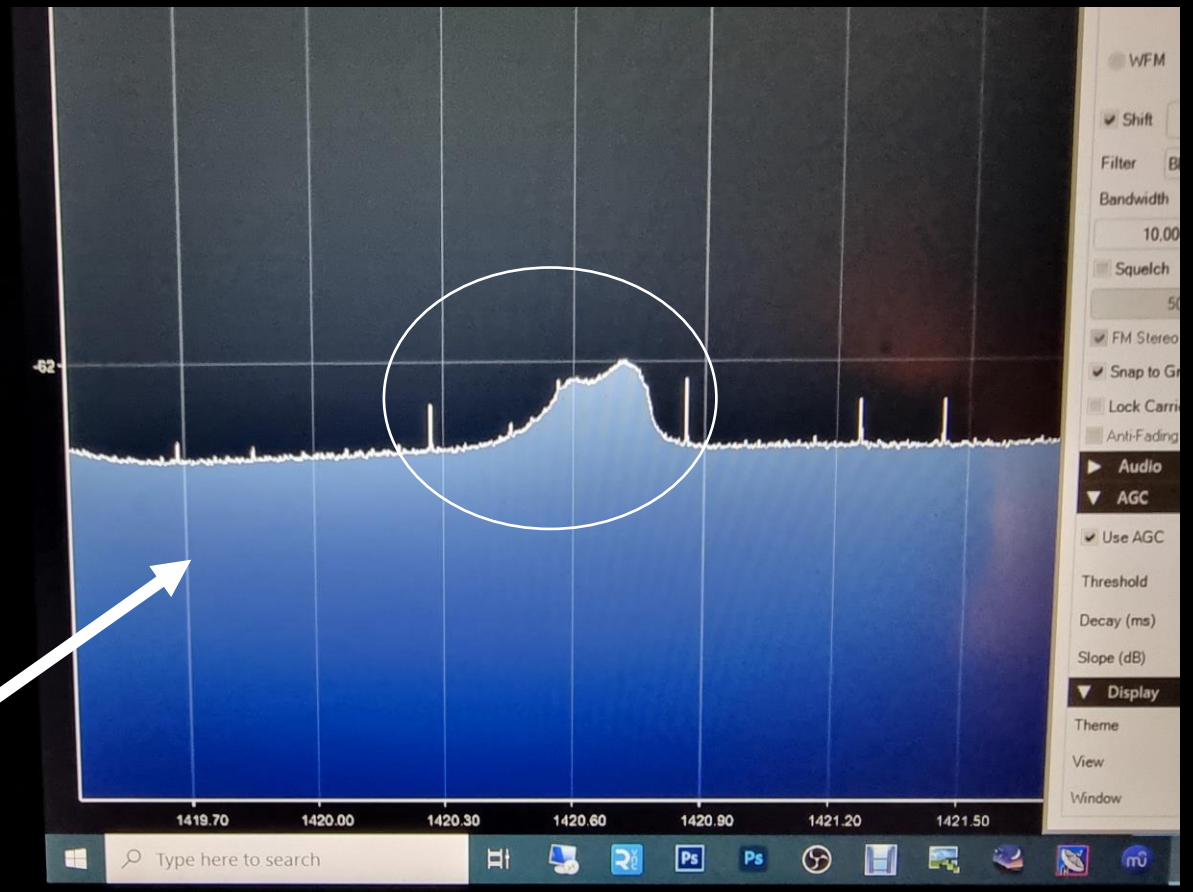
Ptarmigan Triffid Military Phased Array


Out on the patio with the Scope in a Box with phased array

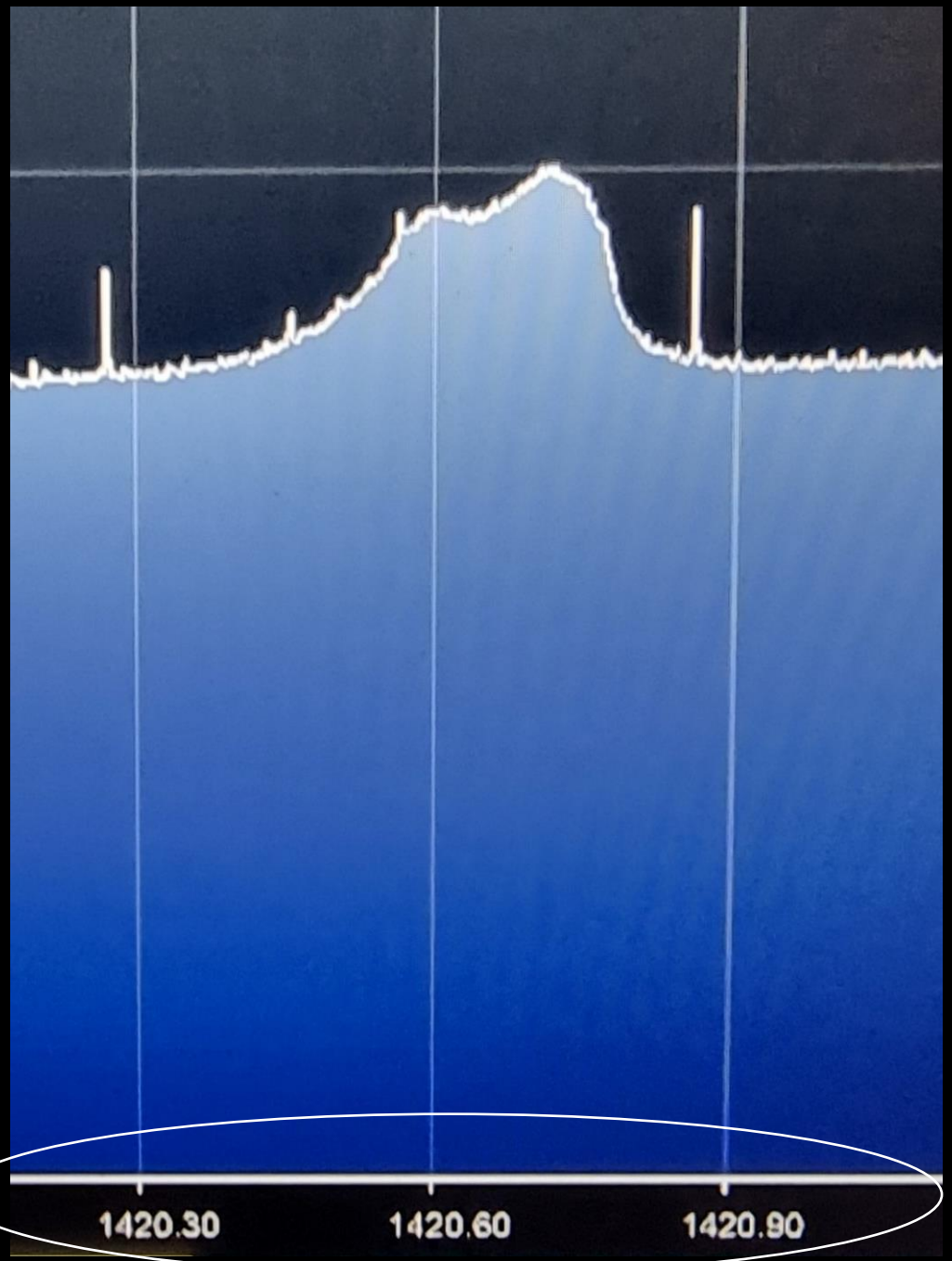


Raw Data on SDR#

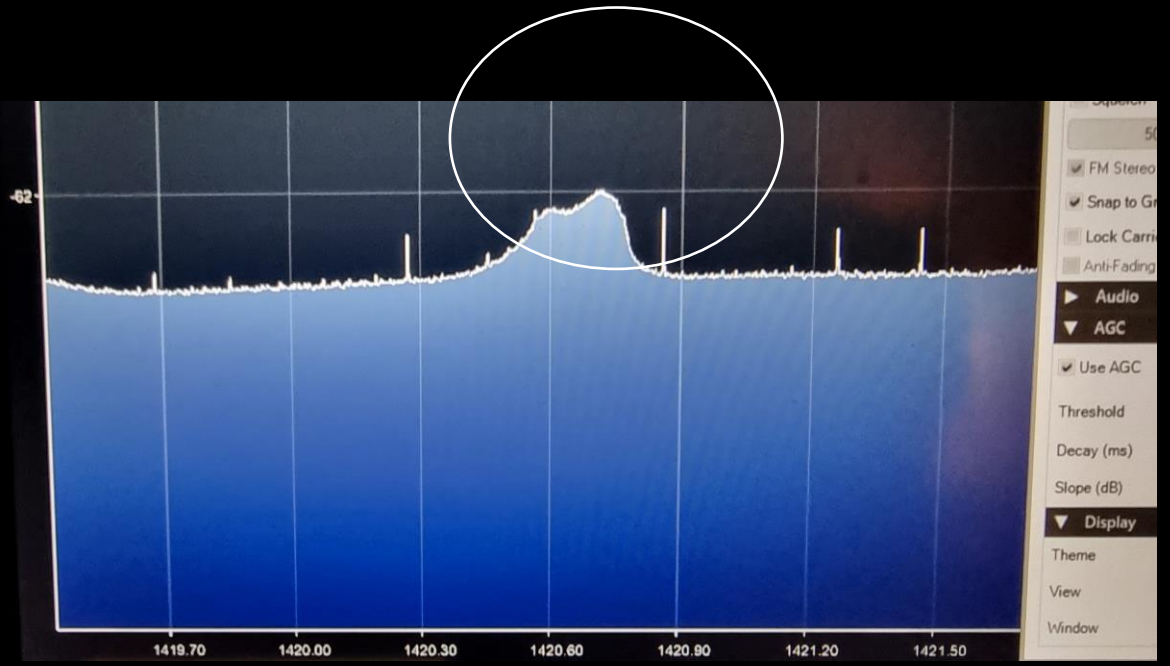
Success! Detected galactic hydrogen



Cygnus Cassiopeia



Note this shows hydrogen at expected 1420MHz frequency



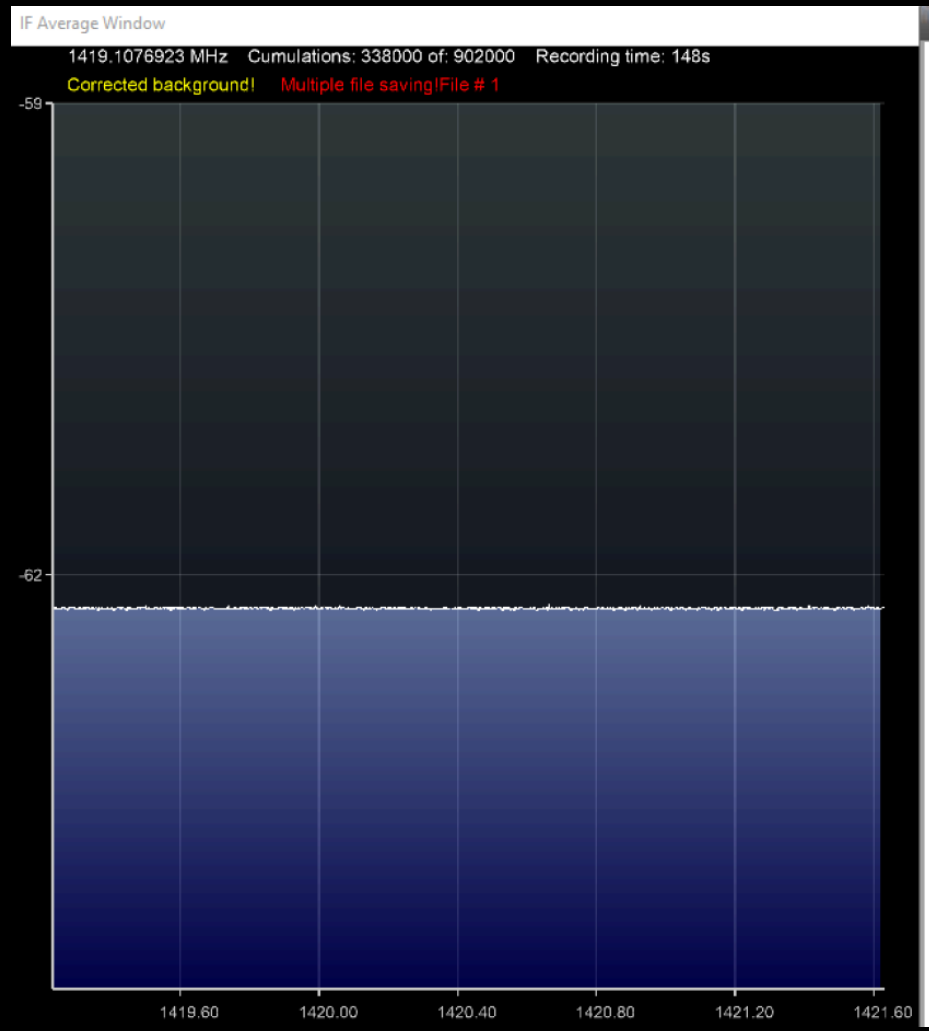
Calibration of Scope in a Box in SDR# Software with IF Average plug in

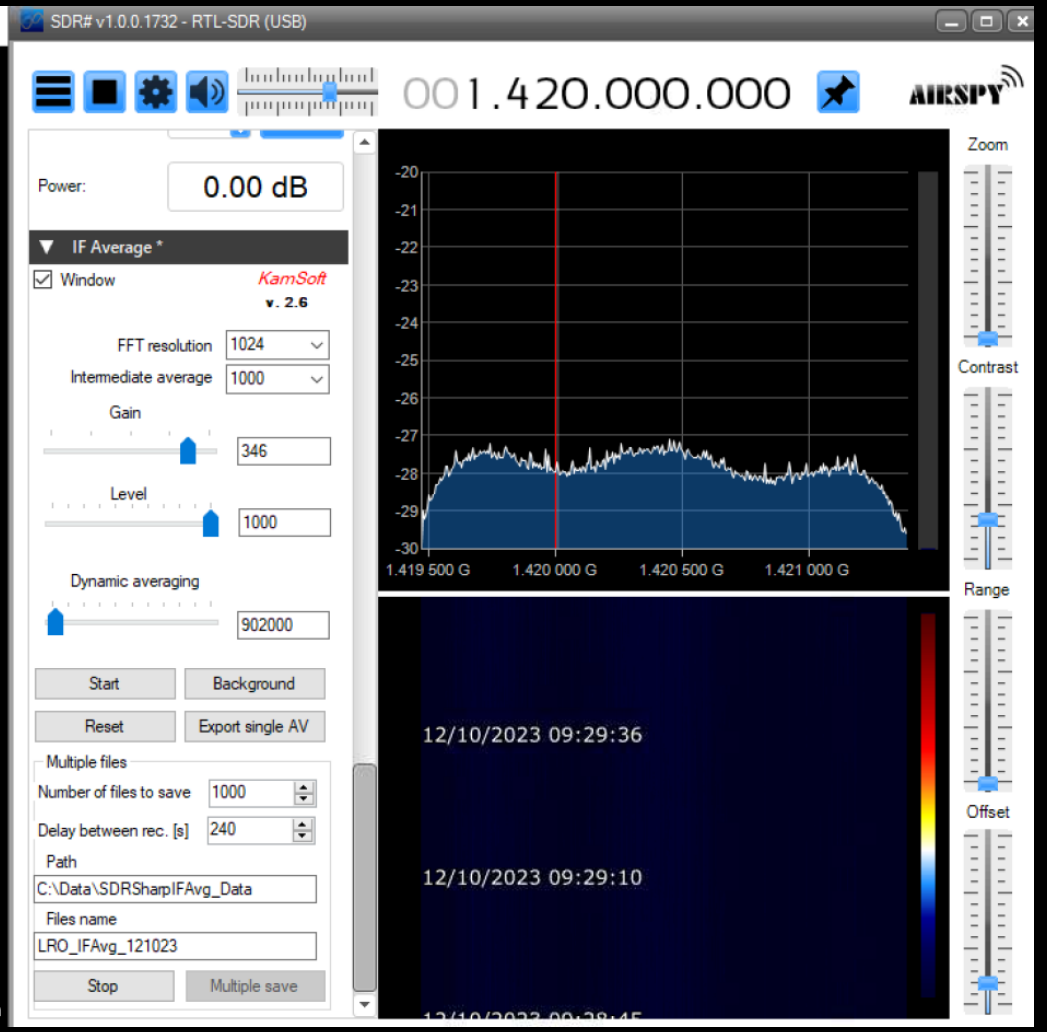
This does similar job to flats and darks in astrophotography

50 ohm load used in place of aerial

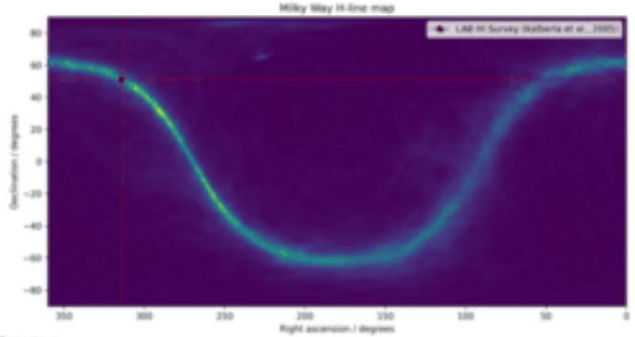
Correct image (left) vs uncorrected image (right)

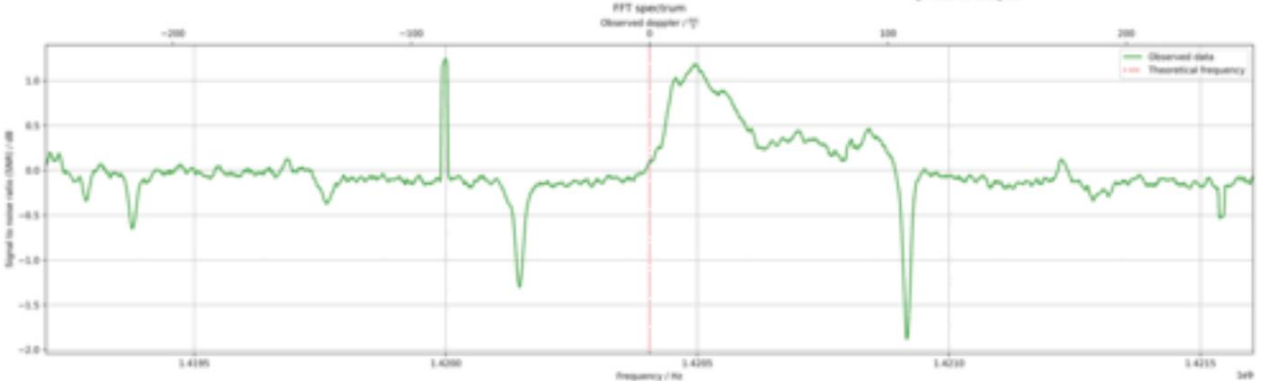
Note on calibration = I seem to get better calibration by pointing away from Milky Way than 50 Ohm dummy load





	Values
RA	313.9°
Dec	51.1°
Peak SNR	1.244dB
Doppler	-85.5$\frac{km}{s}$
Observer vel.	36.1$\frac{km}{s}$
Source vel.	-121.6$\frac{km}{s}$



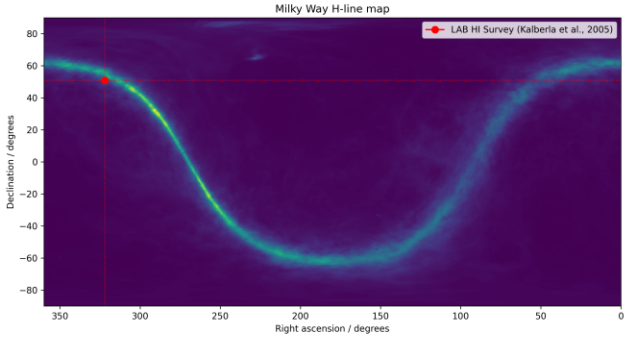


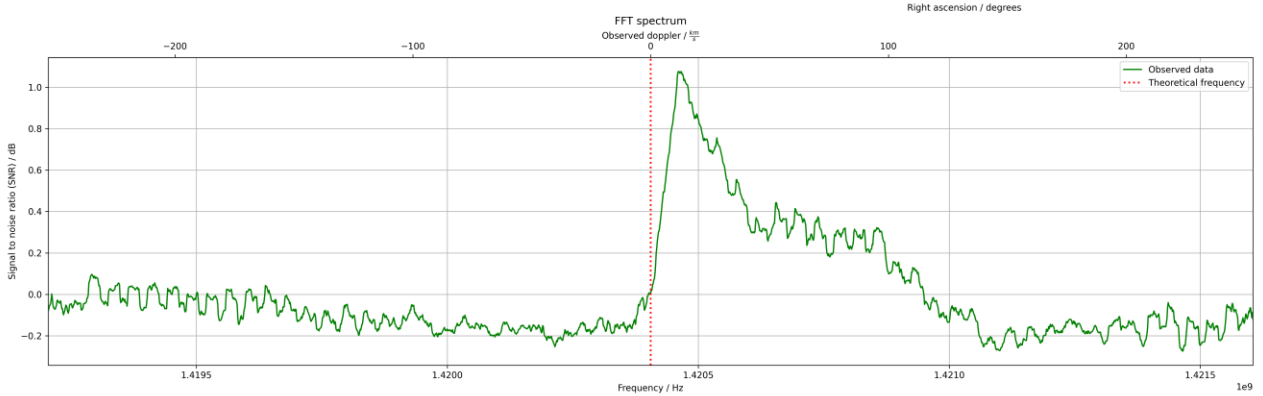
From SteveBz from Stargazers Lounge

Shows profound effect of turning off electronics on noise on plot

H-line observation

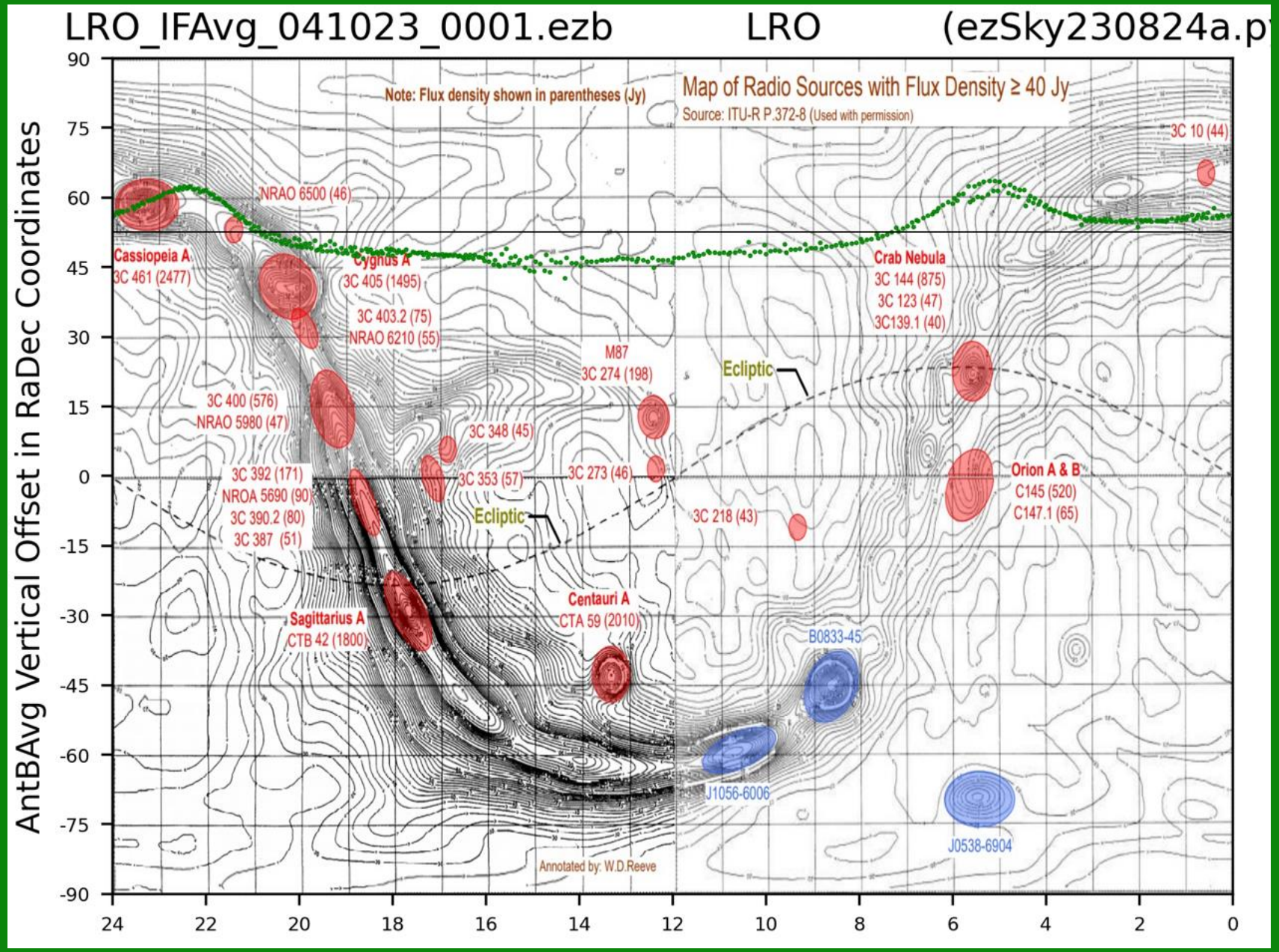
	Values
RA	321.9°
Dec	50.9°
Peak SNR	1.077dB
Doppler	11.8$\frac{km}{s}$
Observer vel.	214.8$\frac{km}{s}$
Source vel.	-203.0$\frac{km}{s}$



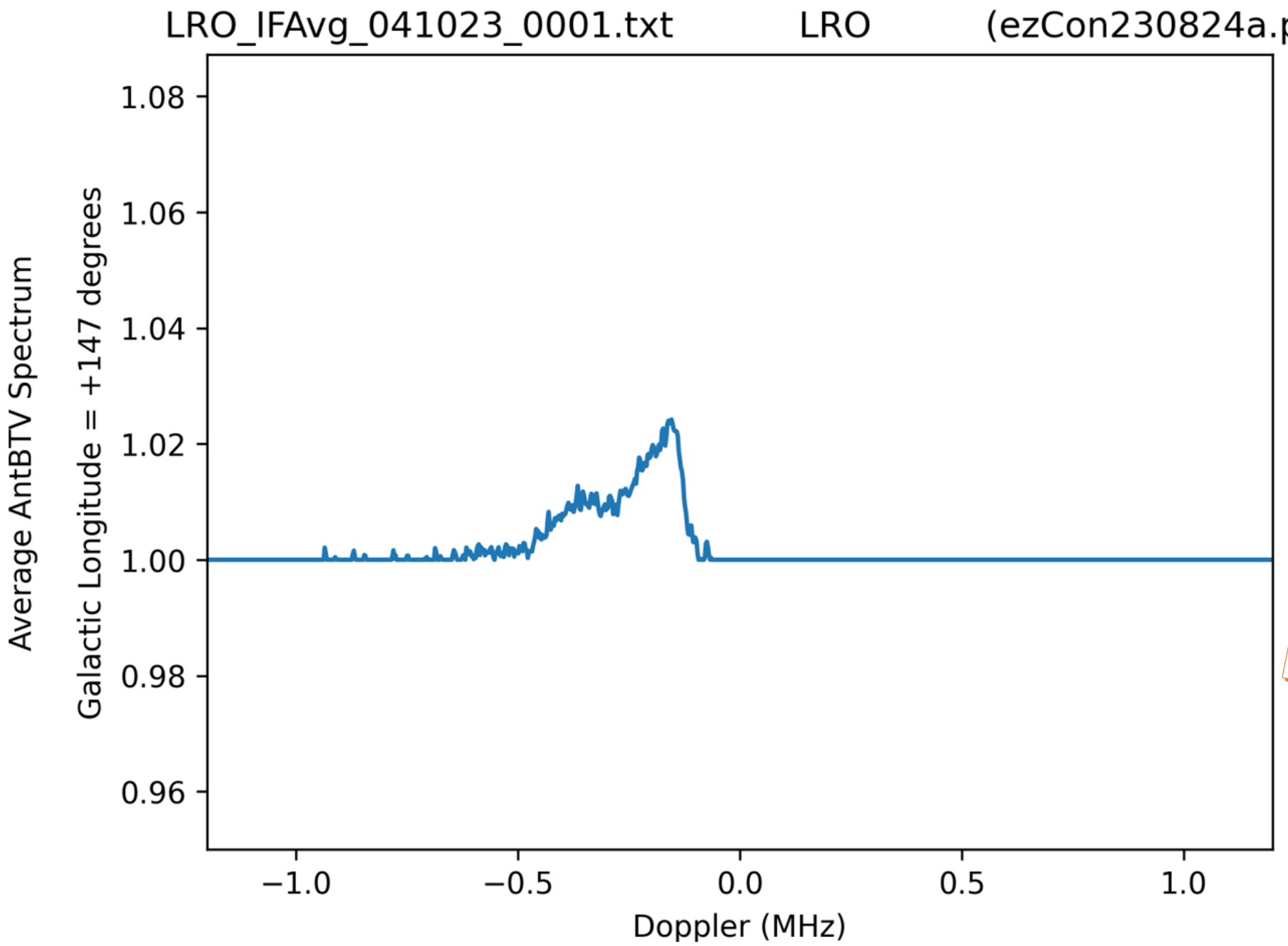


ezRA software for collecting and processing data and mapping it over known background of radio sources in Milky Way

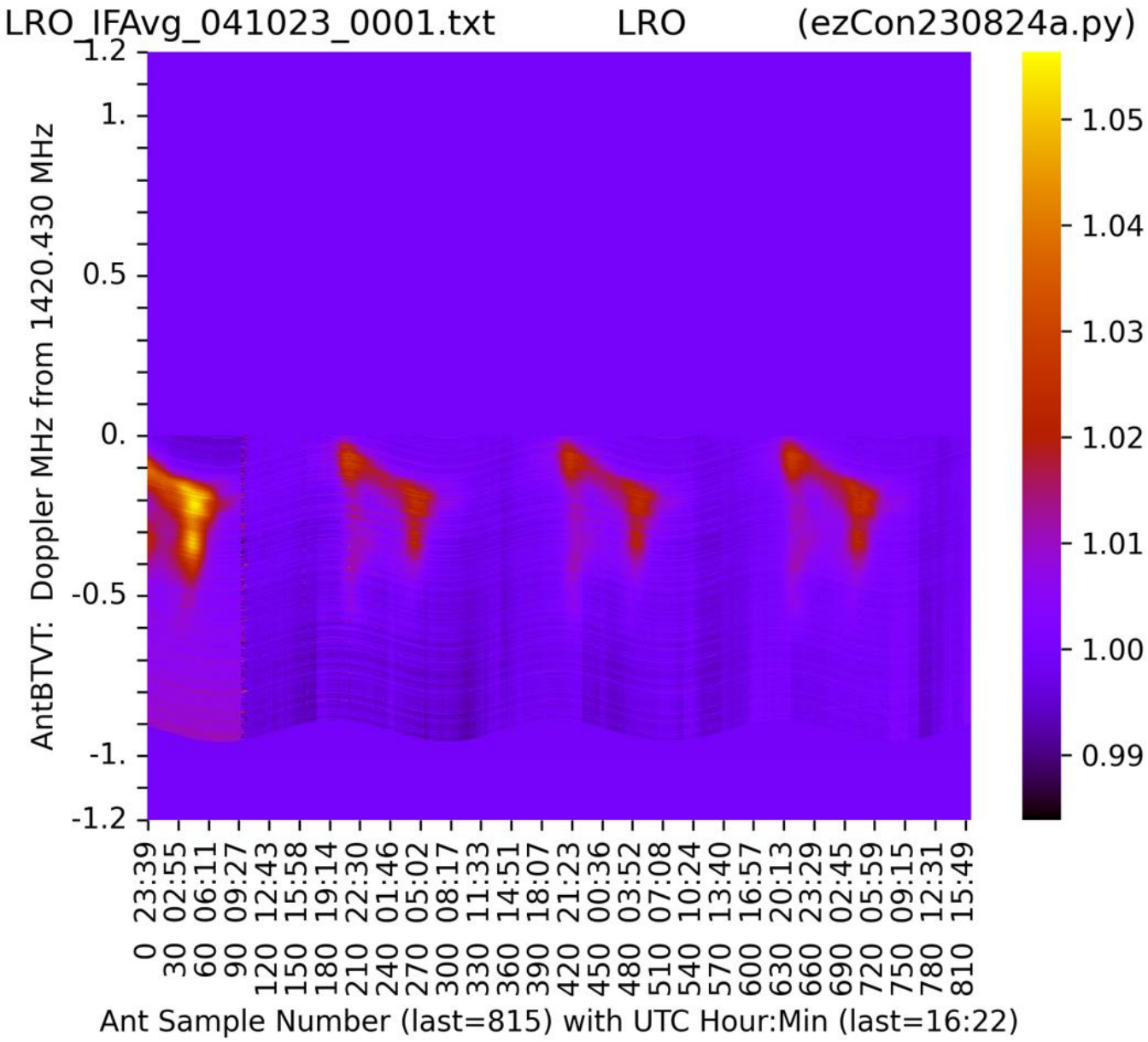
(Has own collection program, alternative= SDR# IFAverage Plug-In to collect data)

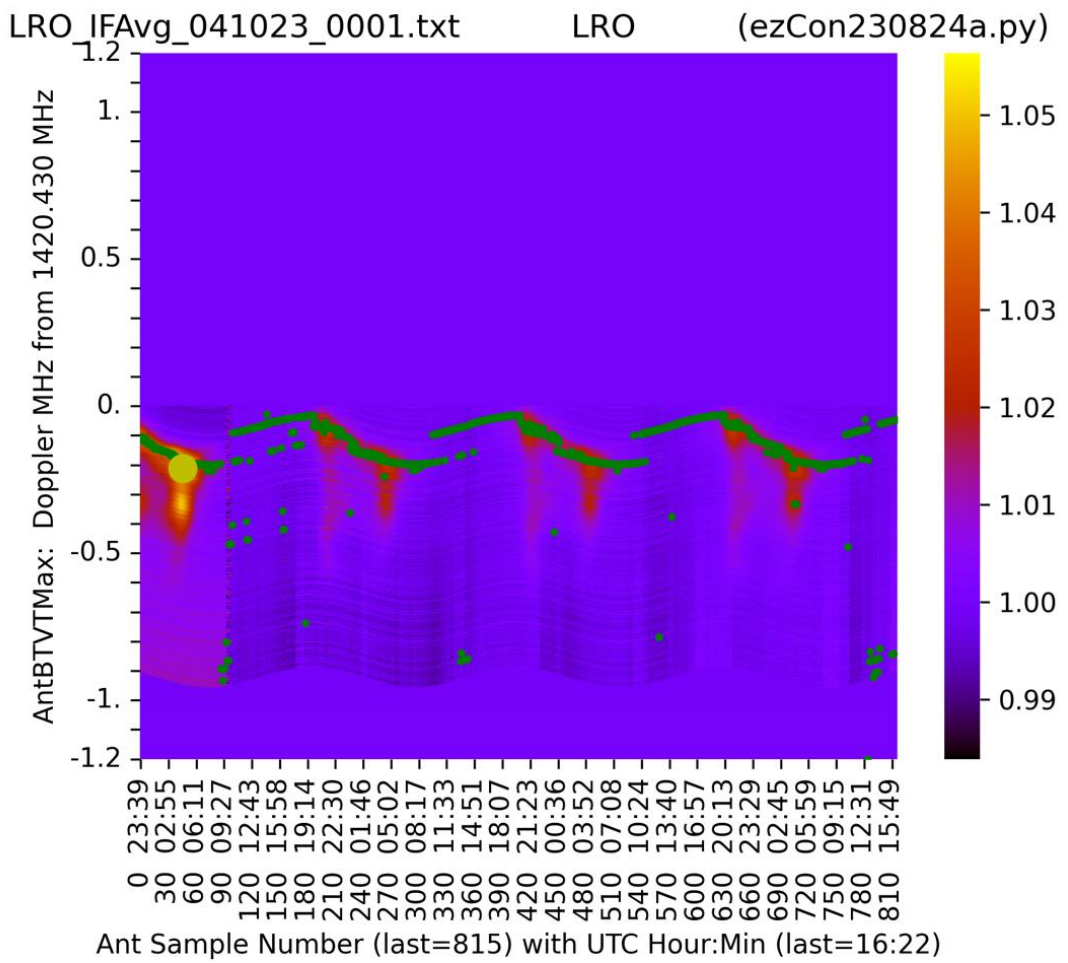


4 day drift scan of Zenith Oct 2023 from Lichfield, UK

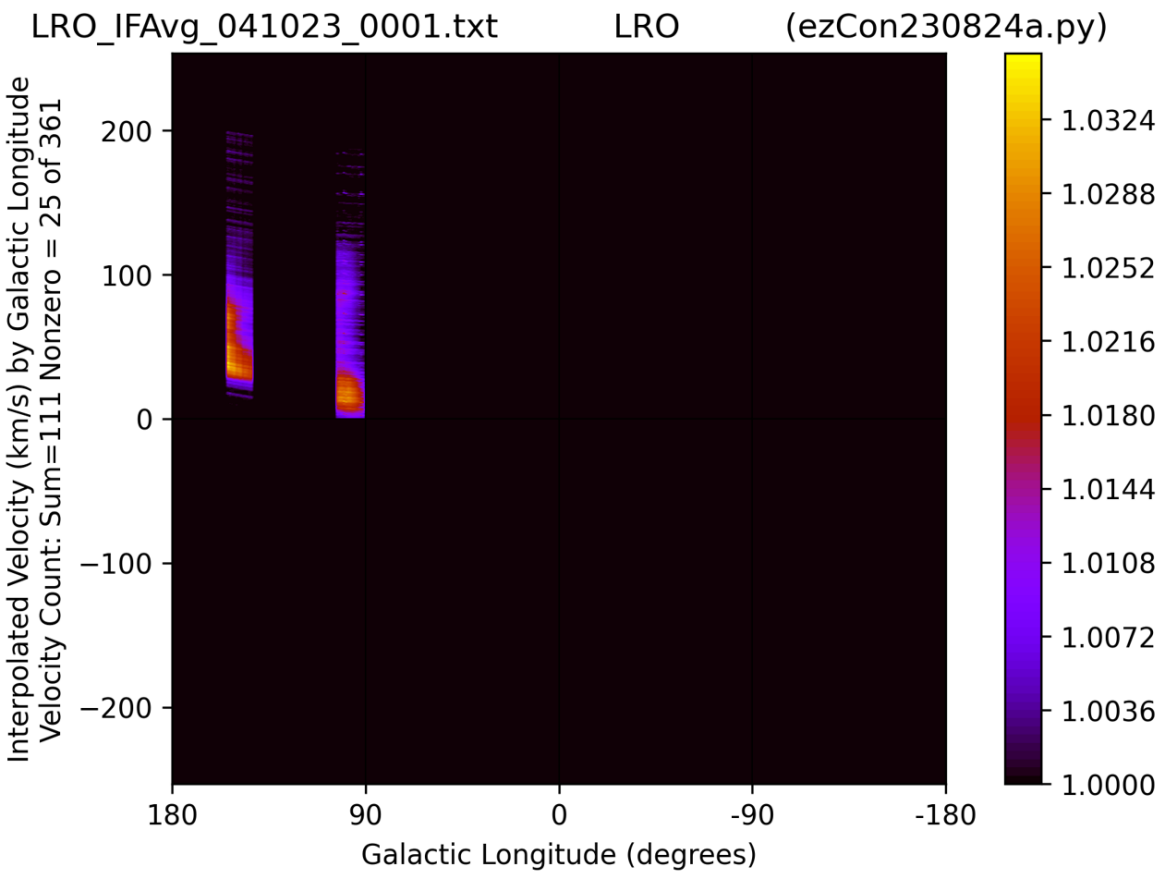


Radio Spectra By longitude

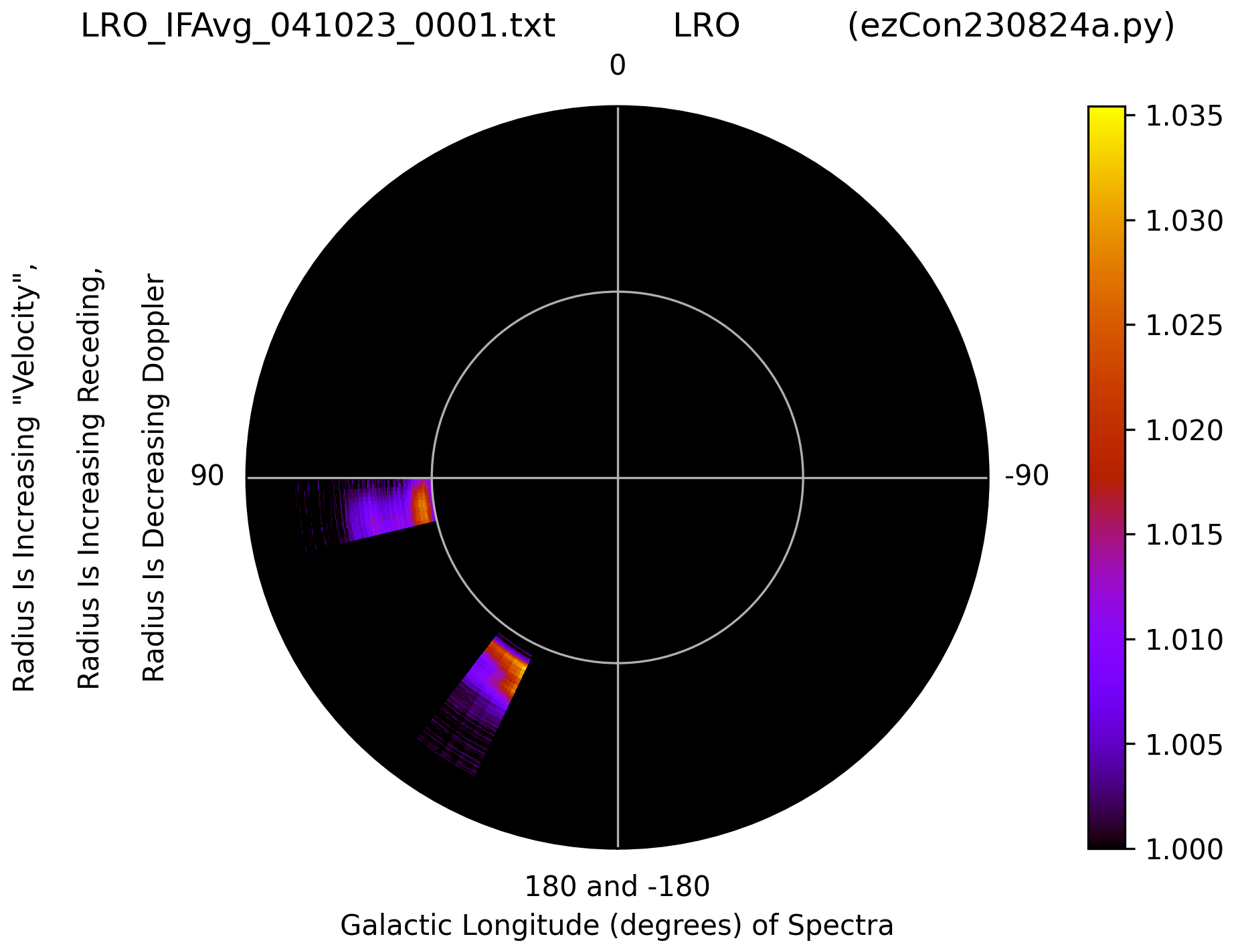




Doppler Shift



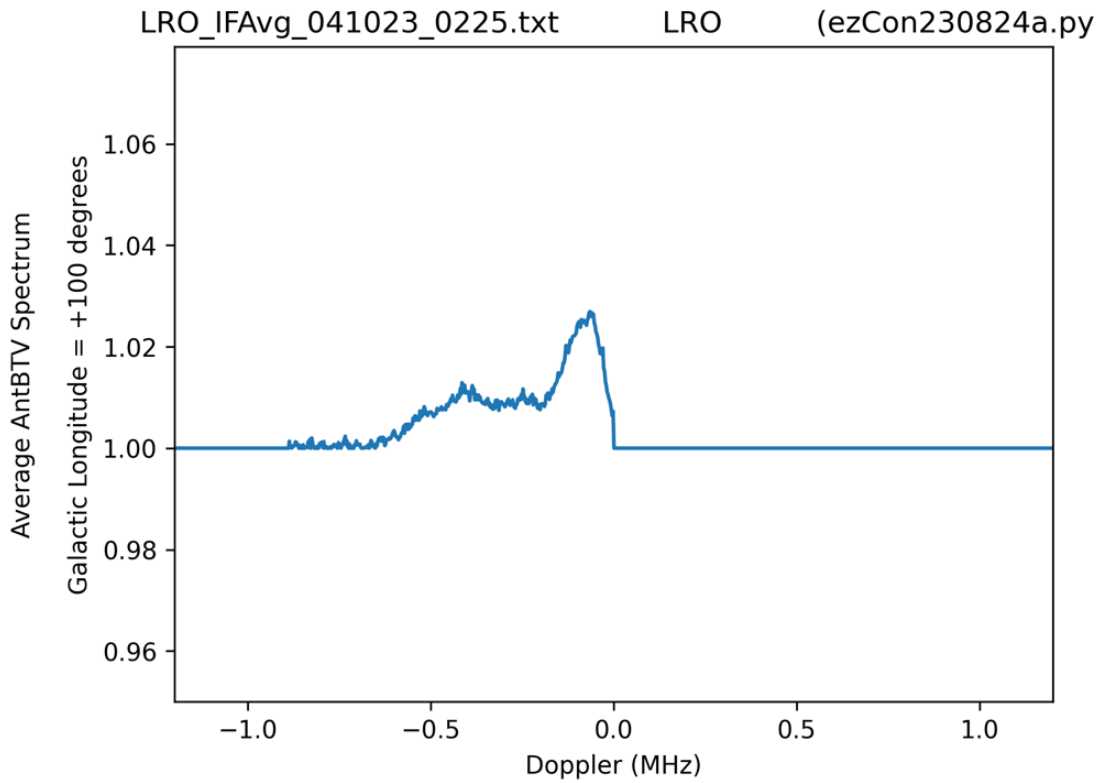
Velocity Plots



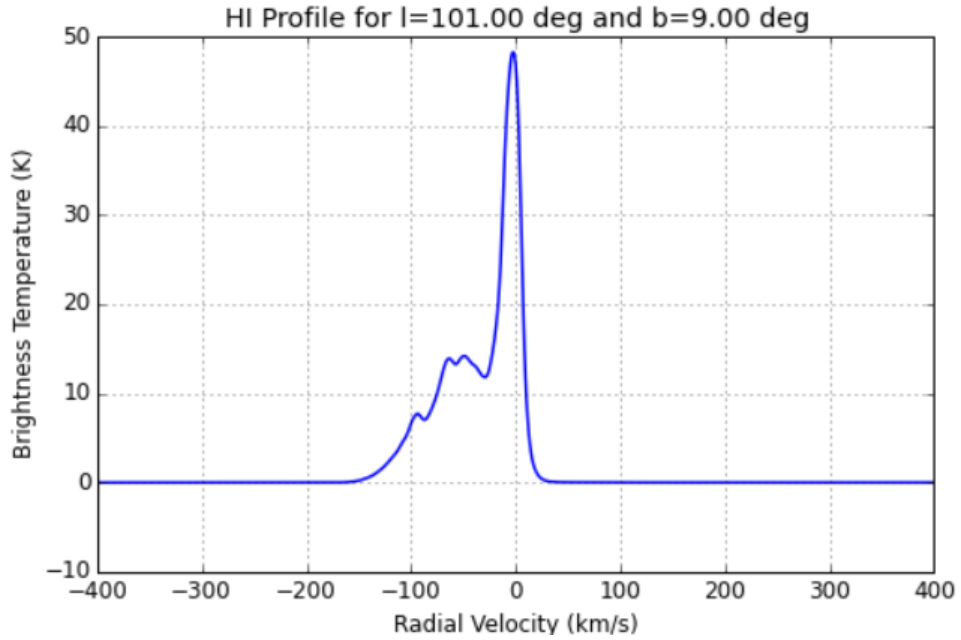
https://www.astro.uni-bonn.de/hisurvey/euhou/LABprofile/index.php

My results (left) = good match for simulated results (right)

Select Position		
Coordinate system	Galactic coordinates (l, b)	
Position	RA [h m s]/ l [°]	101
	DEC [±° ' "]/ b [°]	9
Effective beamsize FWHM [°]		17.00
Velocity Window for display	Minimum [km/s]	-400.00
	Maximum [km/s]	400.00
Search data		



Result

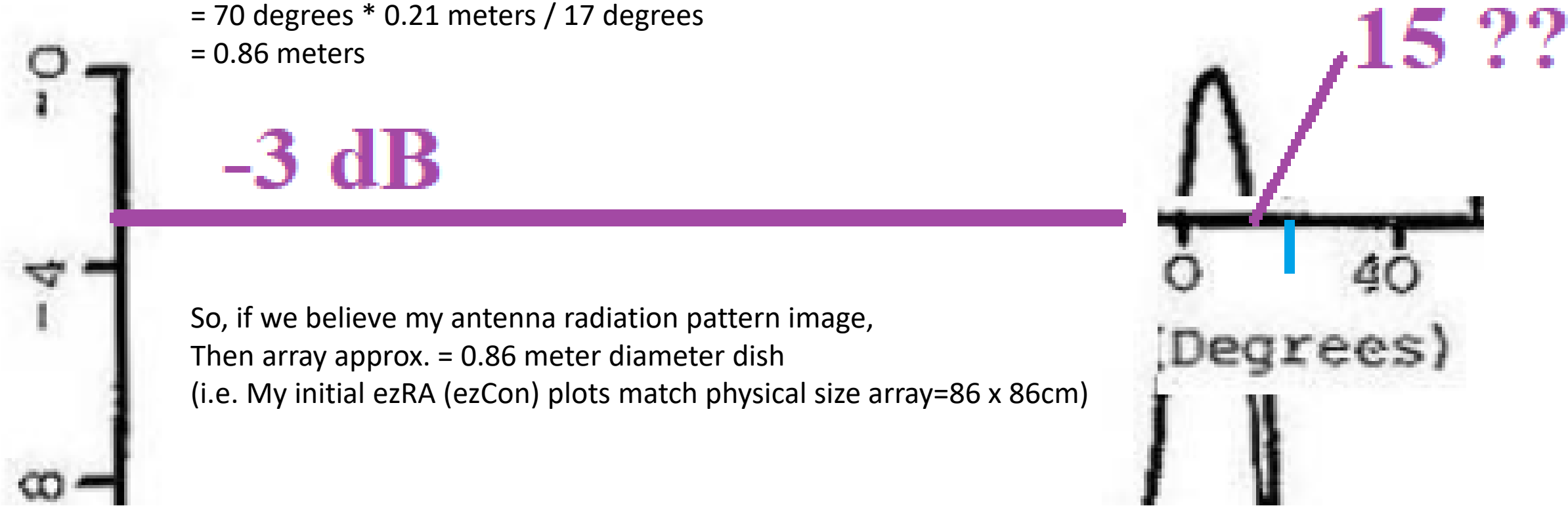


Beamwidth of array

Half power on my initial data is -3 dB.

Ted Cline SARA calculates ca. 15 degree Half Power Beamwidth (HPBW).

Parabolic Dish Half Power Beamwidth
HPBW = 70 * wavelength / diameter
which is the same as
diameter = 70 * wavelength / HPBW
= 70 degrees * 0.21 meters / 17 degrees
= 0.86 meters

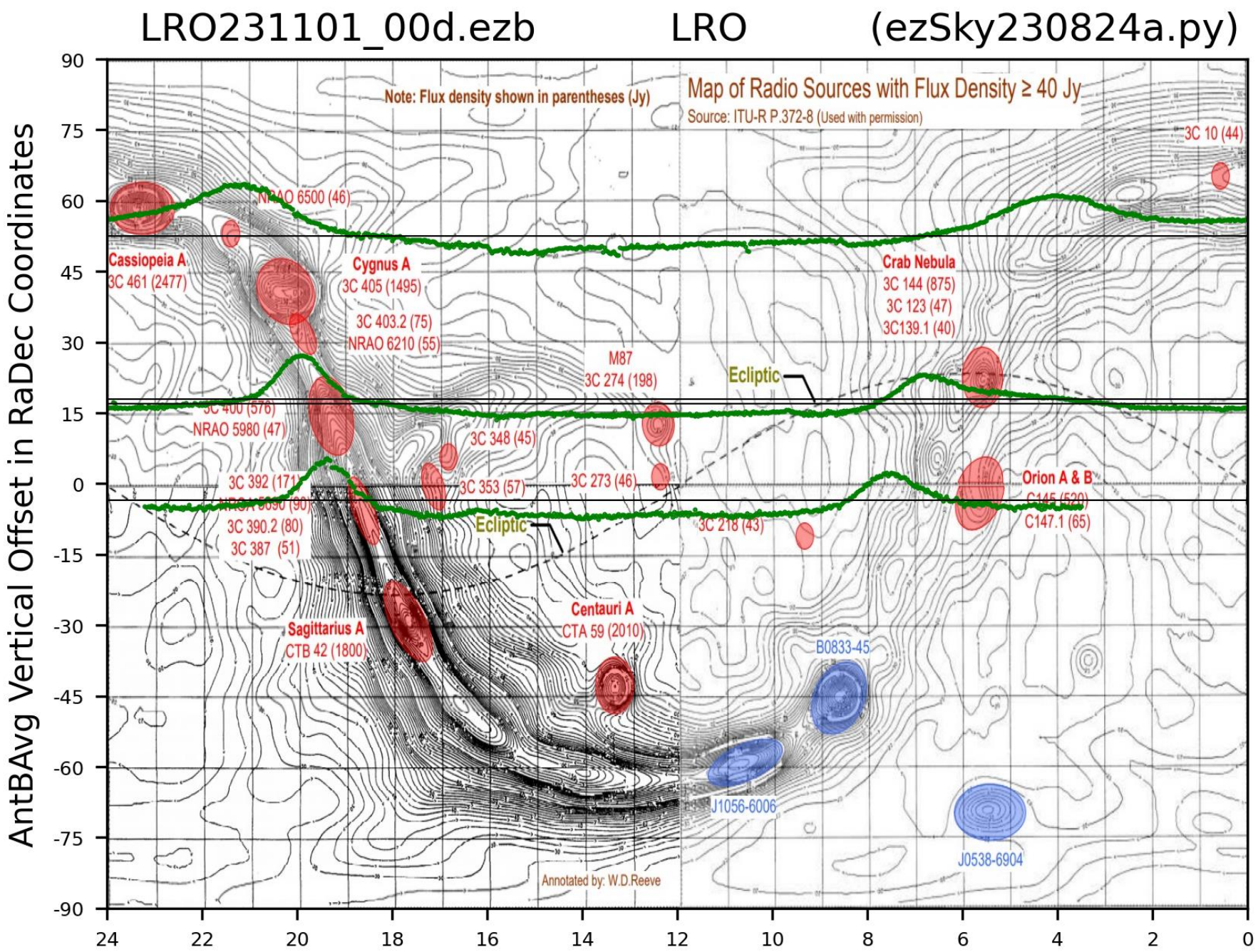


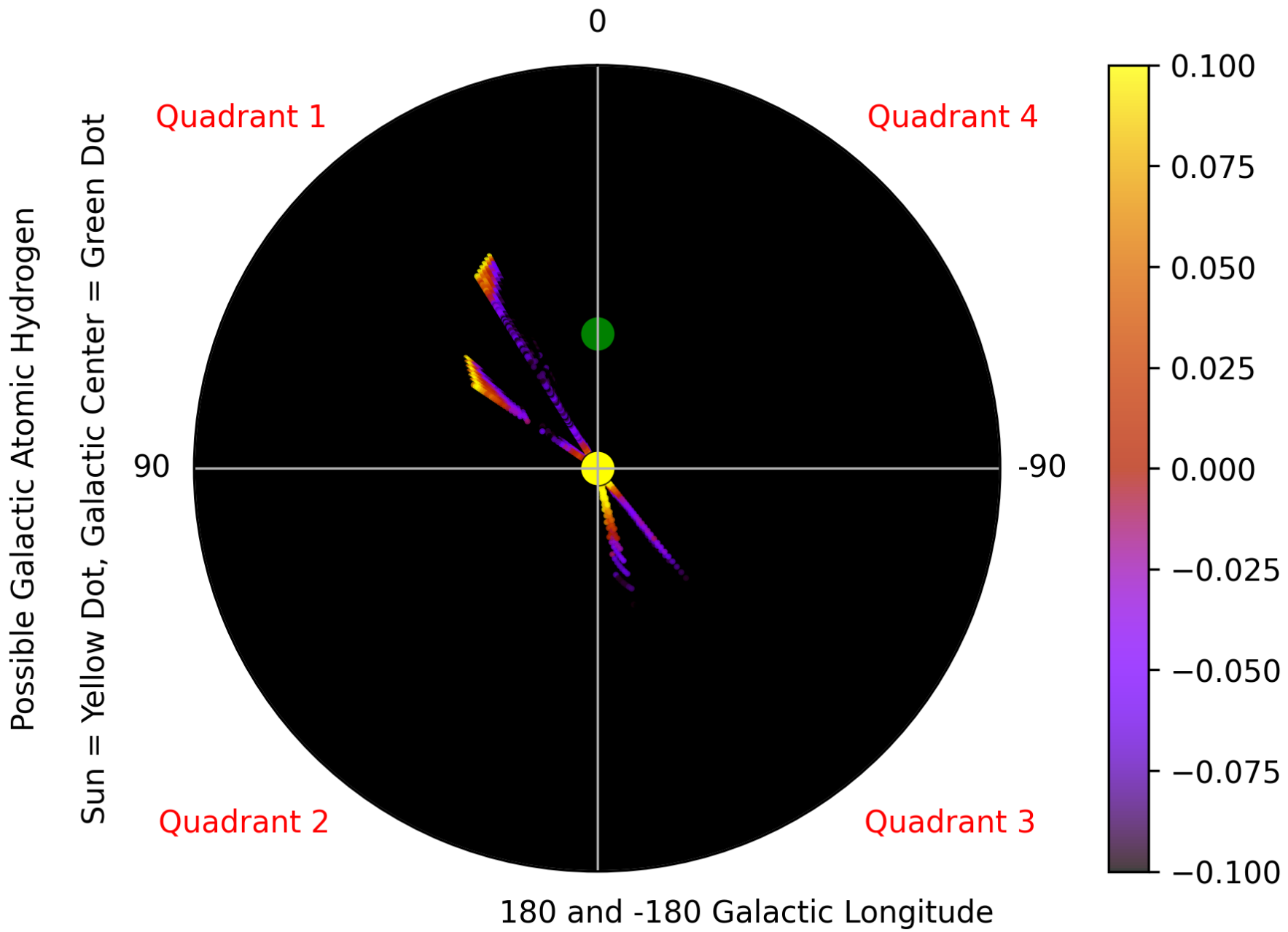
So, if we believe my antenna radiation pattern image,
Then array approx. = 0.86 meter diameter dish
(i.e. My initial ezRA (ezCon) plots match physical size array=86 x 86cm)

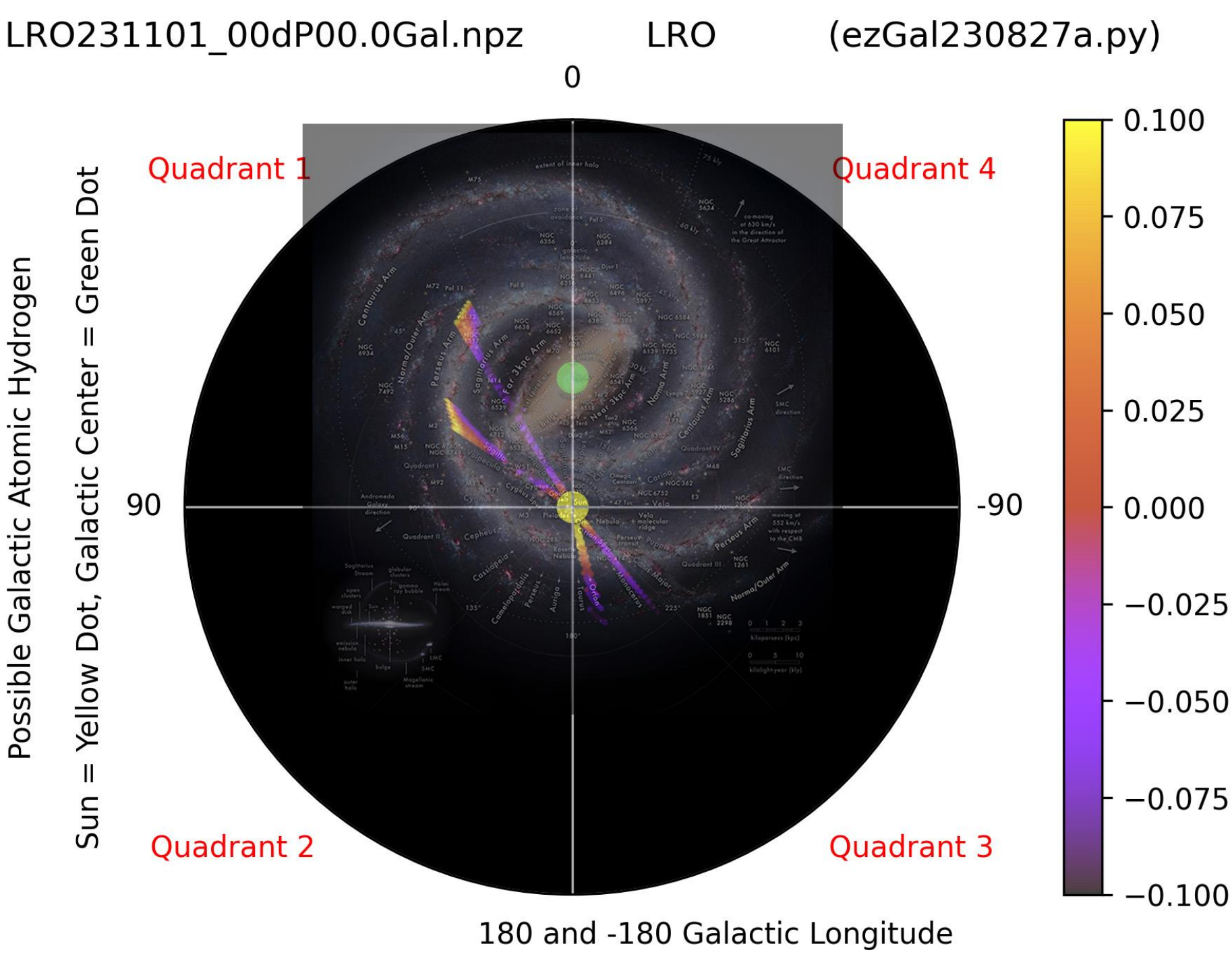
Mounting telescope so that altitude can be varied

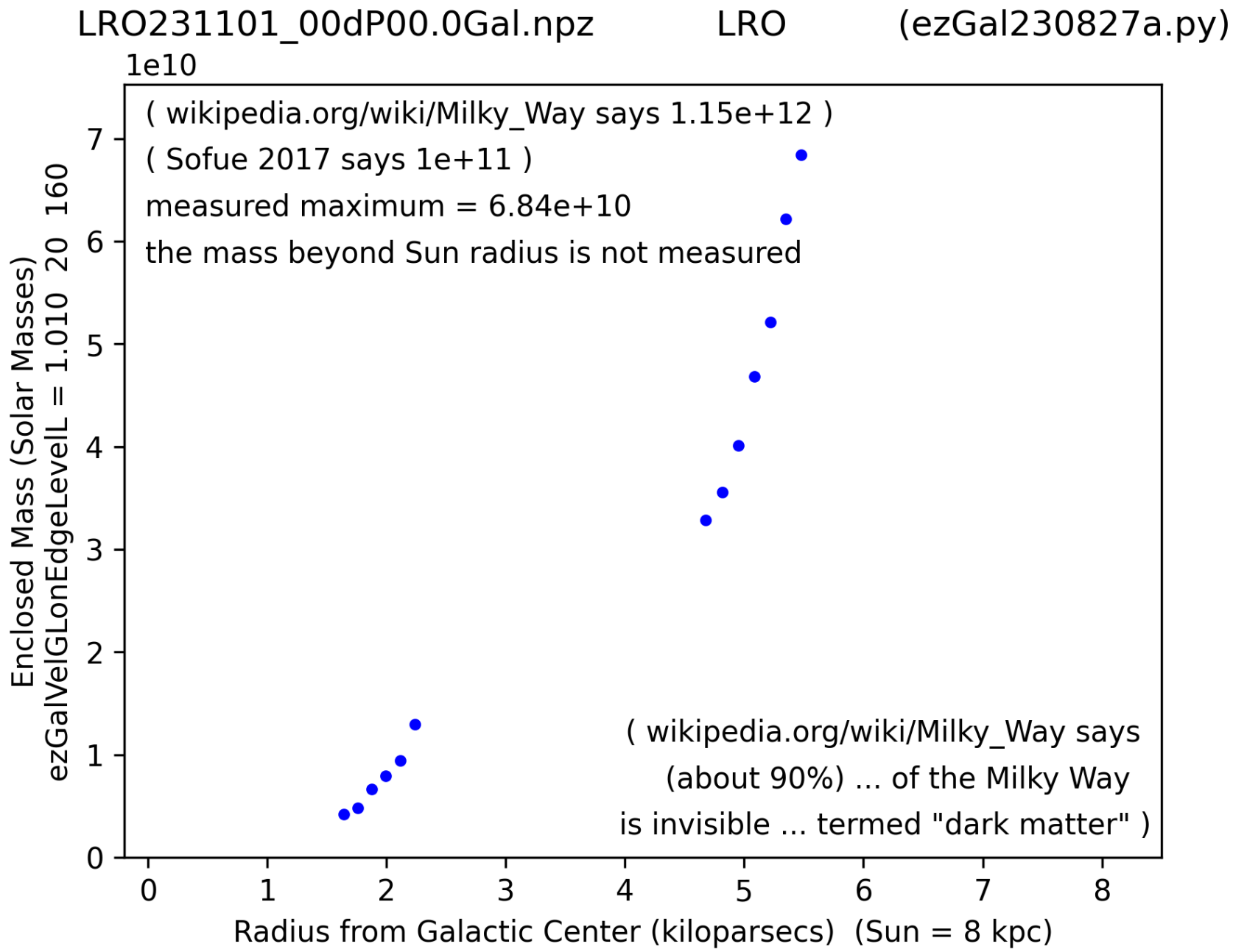

Dealing with dew – a MAJOR problem!!

Initial Results



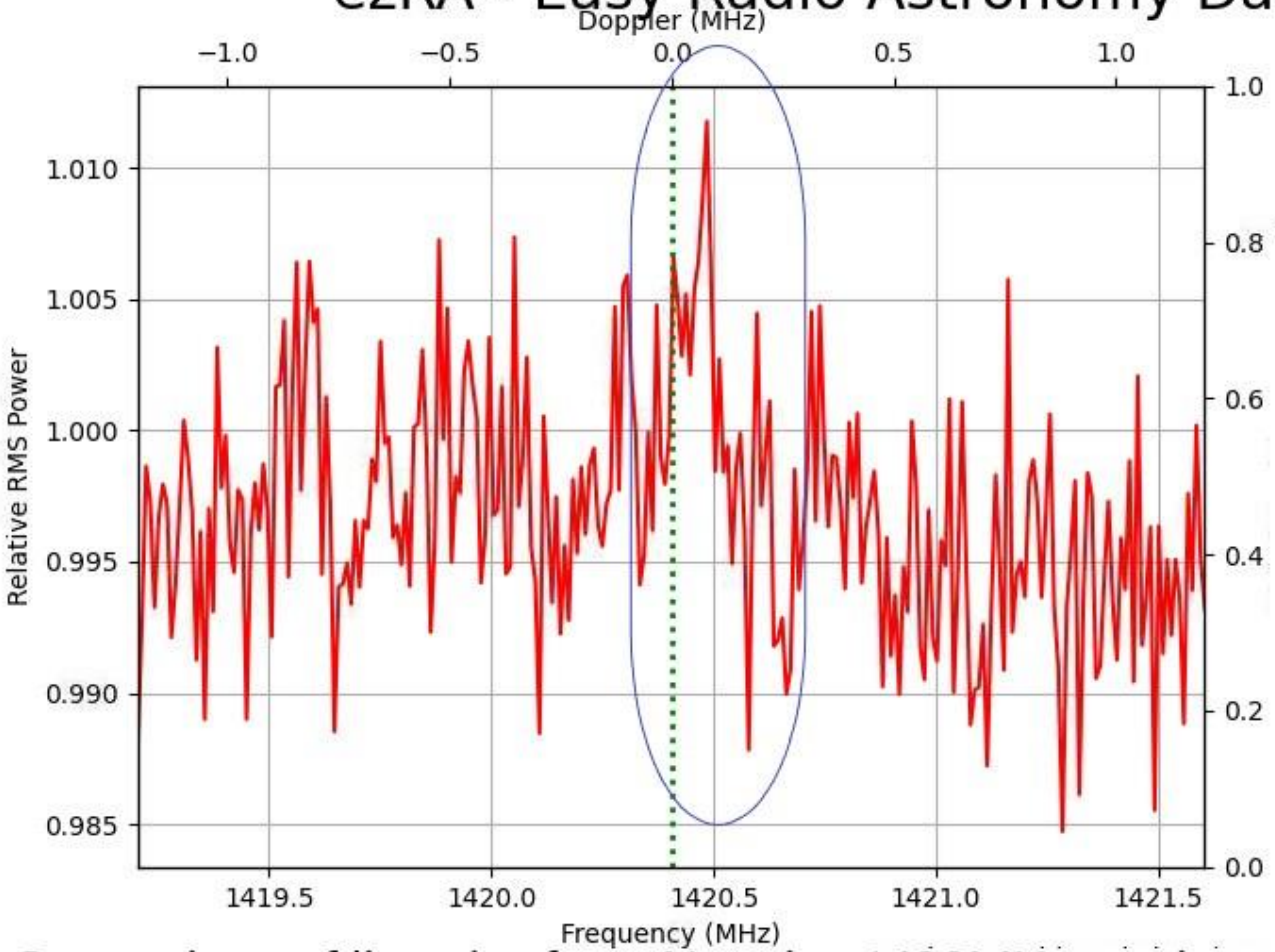

LRO231101_00dP00.0Gal.npz LRO (ezGal230827a.py)
0
Quadrant 1
Quadrant 4
90
-90
Quadrant 2
Quadrant 3
Possible Galactic Atomic Hydrogen
Sun = Yellow Dot, Galactic Center = Green Dot
180 and -180 Galactic Longitude
0.100
0.075
0.050
0.025
0.000
−0.025
−0.050
−0.075
−0.100


LRO231101_00dP00.0Gal.npz
LRO
(ezGal230827a.py)
0
90
-90
180 and -180 Galactic Longitude
Possible Galactic Atomic Hydrogen
Sun = Yellow Dot, Galactic Center = Green Dot
Quadrant 1
Quadrant 2
Quadrant 3
Quadrant 4
0.100
0.075
0.050
0.025
0.000
−0.025
−0.050
−0.075
−0.100


LRO231101_00dP00.0Gal.npz LRO (ezGal230827a.py)
1e10
(wikipedia.org/wiki/Milky_Way says 1.15e+12)
(Sofue 2017 says 1e+11)
measured maximum = 6.84e+10
the mass beyond Sun radius is not measured
(wikipedia.org/wiki/Milky_Way says
(about 90%) ... of the Milky Way
is invisible ... termed "dark matter")
Enclosed Mass (Solar Masses)
ezGalVelGLonEdgeLevelL = 1.010 20 160
Radius from Galactic Center (kiloparsecs) (Sun = 8 kpc)
0
1
2
3
4
5
6
7
8

Testing the new Nooelec 1420MHz mesh aerial

ezRA - Easy Radio Astronomy Data Collector - ezCol230406a.py



New Plot | New File

LRO

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

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

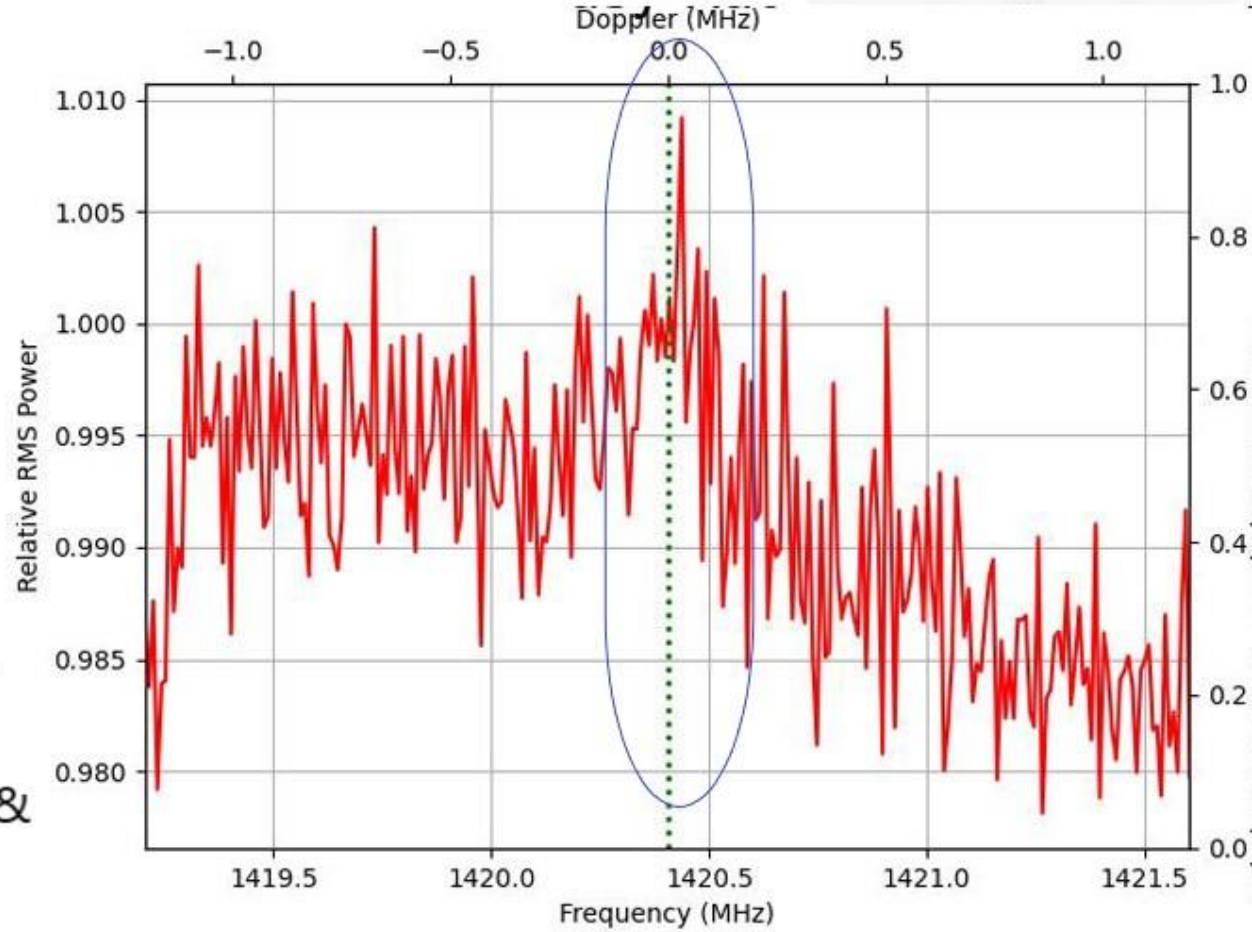
Azimuth	180.0	180.0
Elevation	75.6	75.6

LRO231104_15.txt
SampleQty 10

FreqBinQty	256
Gain	49.6
Integration	21.9 sec

2023-11-04 15:34:19 UTC
2023-11-04 15:34:19 PC

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



Comparison of live plot from Nooelec 1420MHz mesh aerial (right) vs. Ptarmigan band 3 military 86x86cm array 4/11/2023 @ 15:30, Lichfield, UK, showing hydrogen in Milky Way (circled). RTL-Blog V3 Software Defined Radio & SAWBird+ H1 1420Mhz filter+amplifier.

IMPORTANT ADVICE FOR NEWBEES WITH LITTLE KNOWLEDGE LIKE ME:

- Get ***support and advice*** from BAA/SARA 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!*