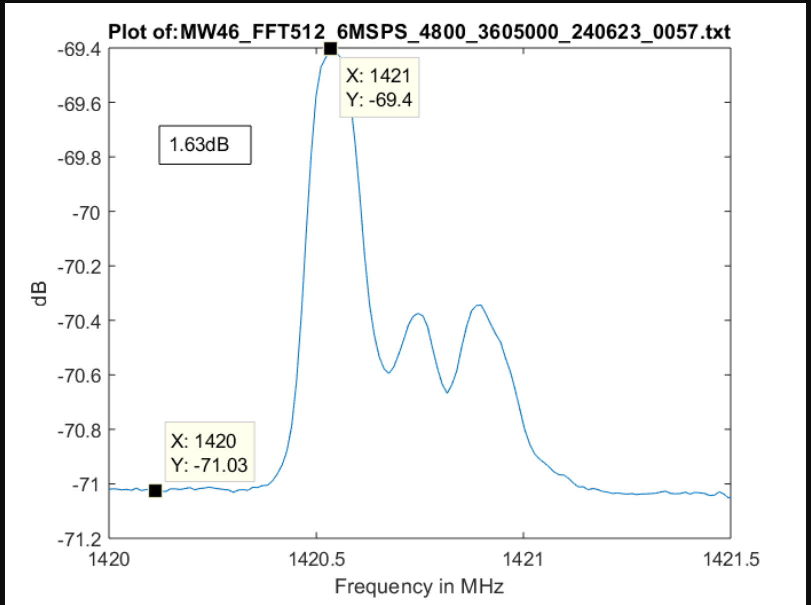
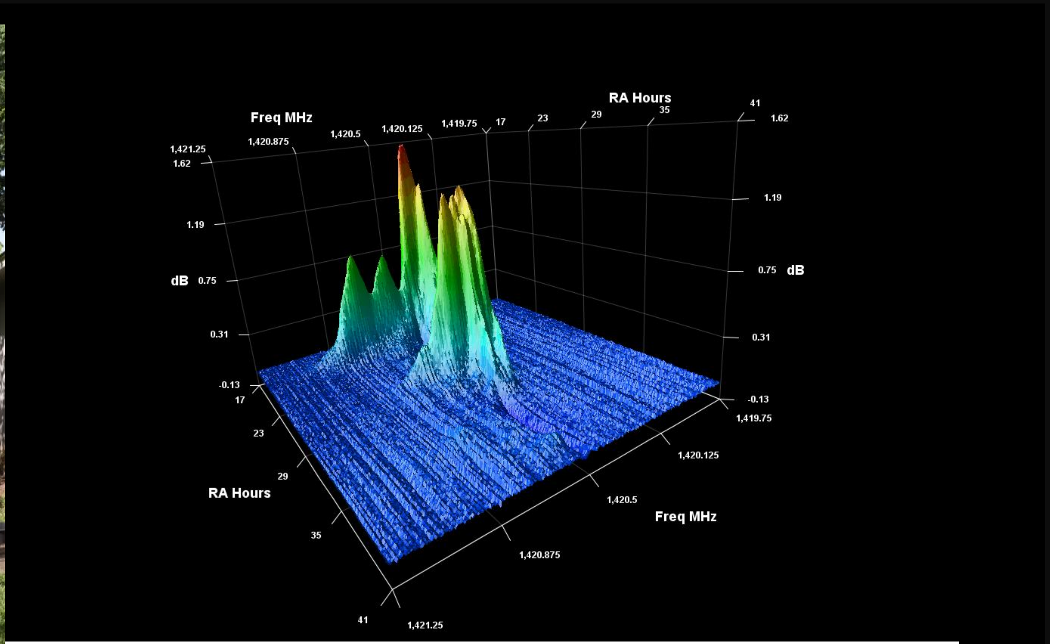
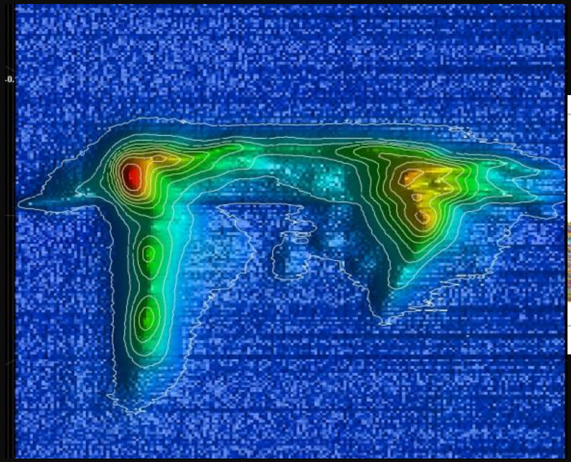
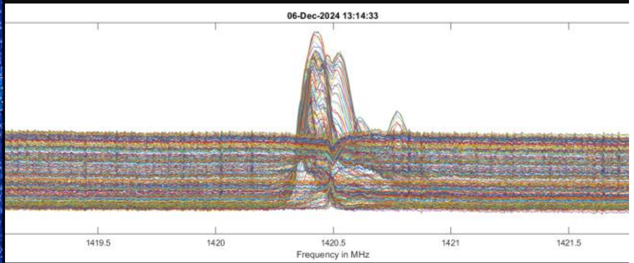
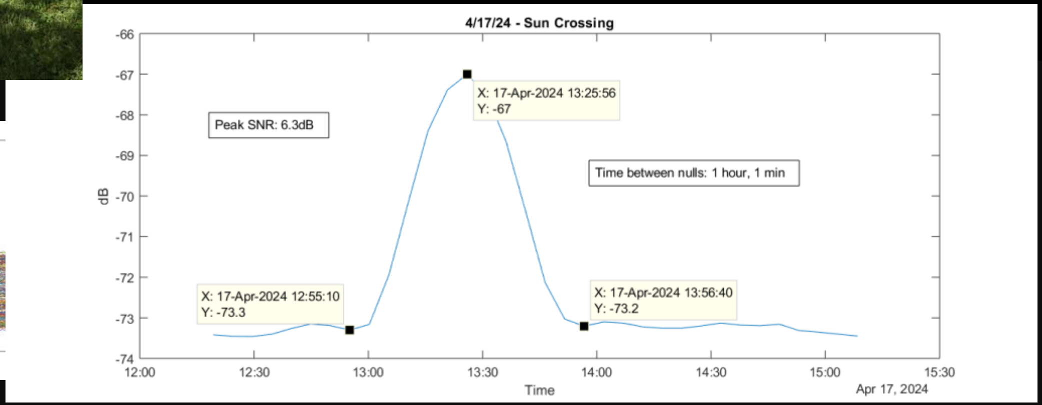
DIY Radio Astronomy







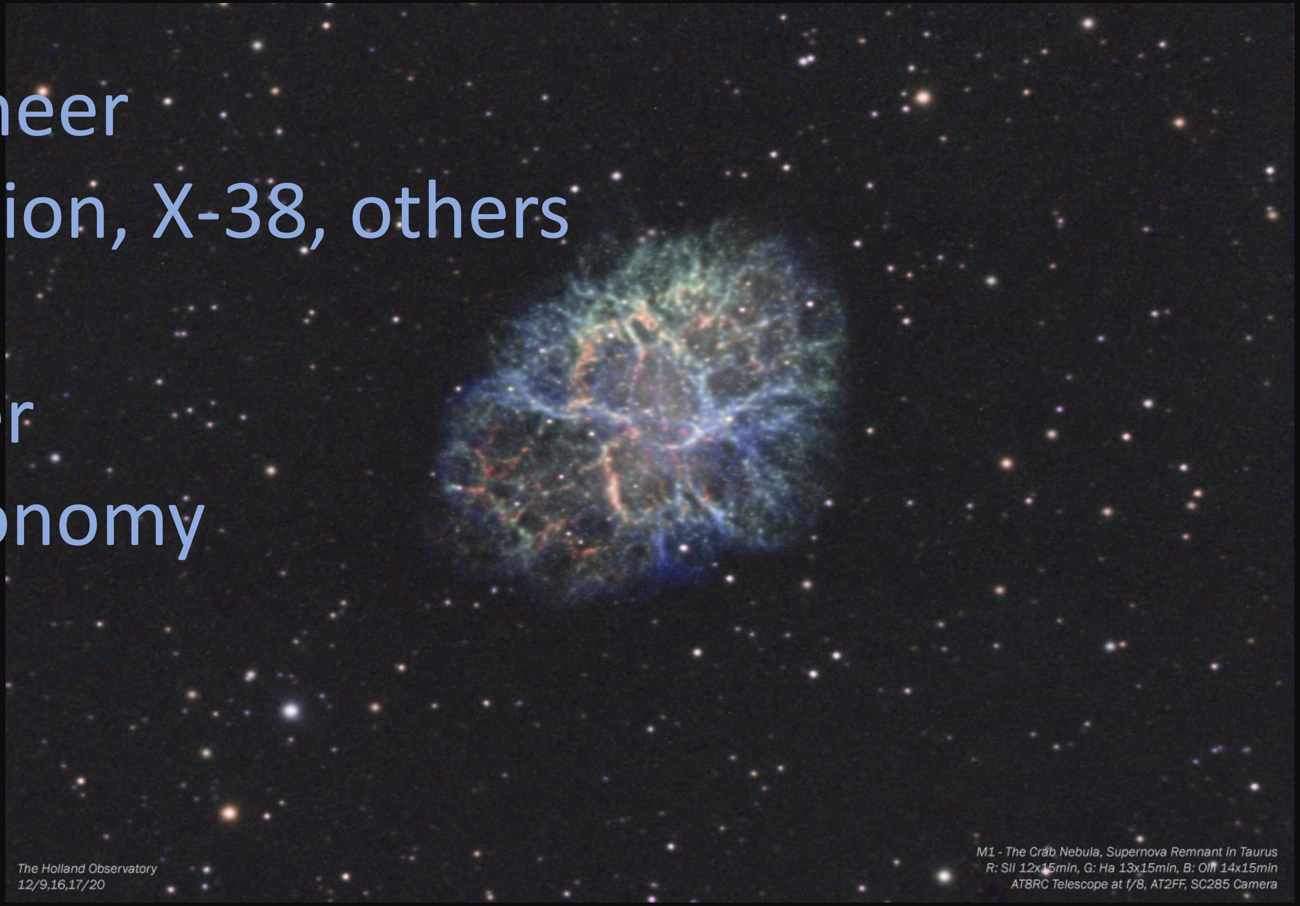




Doug Holland

Who Am I, and Why Am I Standing Up Here Talking to You?

- Member (President) of Johnson Space Center Astronomical Society
- Former NASA Electrical Engineer
  - Space Shuttle, Space Station, X-38, others
- Current Amateur Astronomer
  - Astroimaging, Radio Astronomy



Presentation Outline

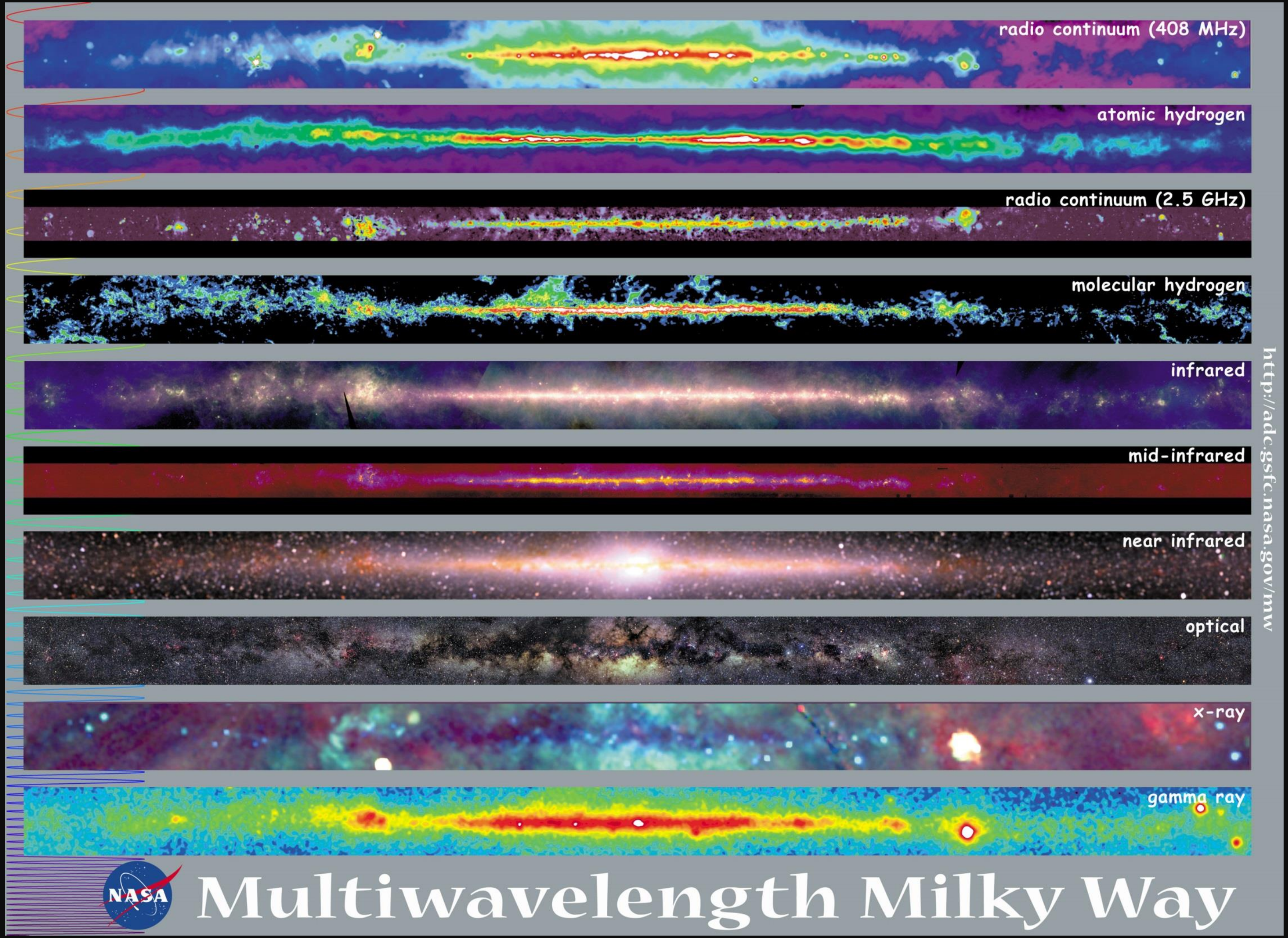
- General Radio Astronomy Information
- The Architecture of an Amateur Radio Telescope
- Three Configurations Used for this Presentation
- Projects
  - Project 1 – 21cm Neutral Hydrogen with WiFi Antenna
  - Project 2 – Improved 21cm Neutral Hydrogen with 2.1m Antenna
  - Project 3 – Total Power Measurements with 2.1m Antenna
  - Project 4 – What Can be Accomplished with a Satellite TV Dish Antenna
- Other Projects that Can Be Done
- Resources Available for Amateur Radio Astronomy

The Holland Observatory
9/14,20-23,26-30/22

NGC6823 - Open Cluster with Nebula in Vulpecula
R - SII: 36x12min, G - Ha: 30x12min, B - OIII: 36x12min (L:Ha)
AT8RC Telescope at f/8, SC8300 Camera

General Radio Astronomy Information

Why do Radio Astronomy =>



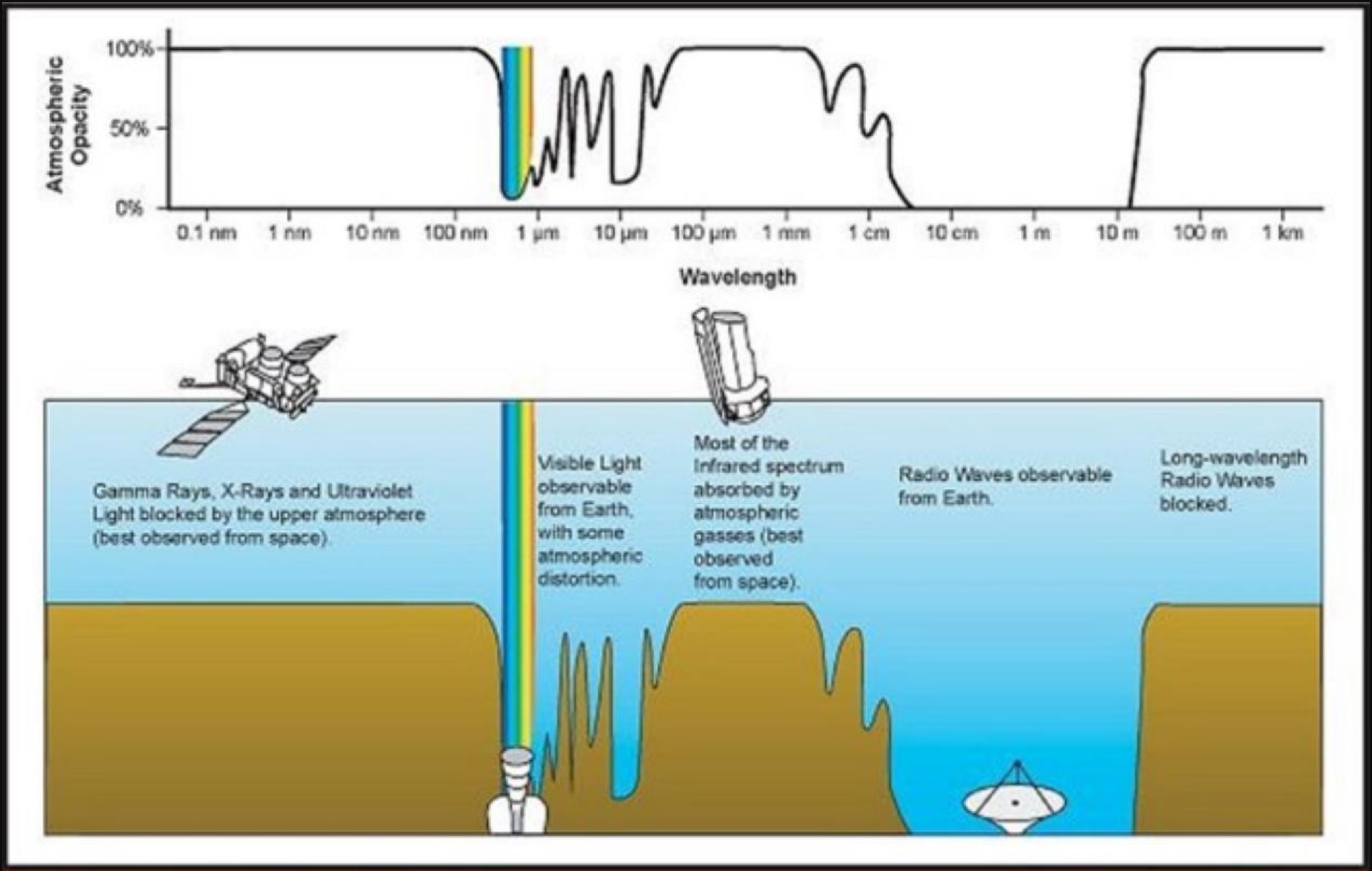
NASA: Multiwavelength Milky Way

Our galaxy / universe appears very different at different wavelengths

- Physical processes
- Hidden features
- > understanding

Doug Holland

General Radio Astronomy Information (cont'd) Atmospheric Opacity =>



Atmospheric Opacity low for:

Visible Light Wavelengths

Radio Wavelengths

Able to do visible & radio astronomy from the ground

SARA (Society of Amateur Radio Astronomers) Tutorial

Doug Holland

General Radio Astronomy Information (cont'd)

Can be done =>

Doug Holland

General Radio Astronomy Information (cont'd)

Wavefront Error =>

astroreflect.com

For λ/20 Error:

At 550nm, approx. 27 nm

* Very difficult to make parabola to 27 nm

At 21cm, approx. 1 cm

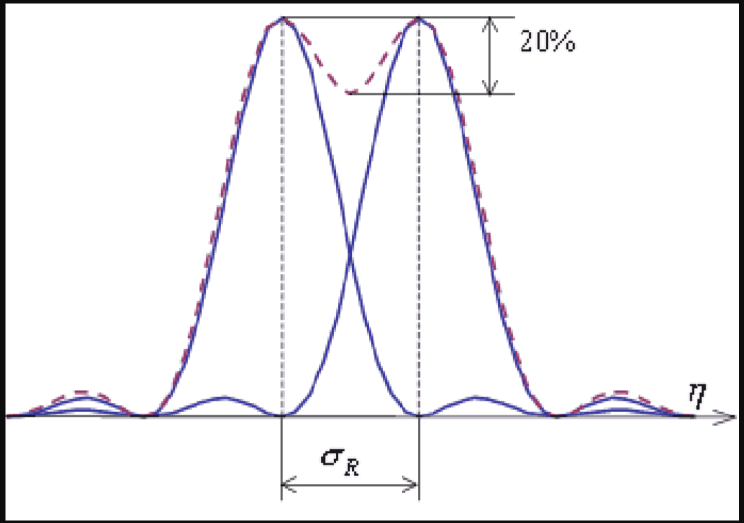
* Pretty easy to make parabola to 1 cm

Doug Holland

General Radio Astronomy Information (cont'd)

Resolution =>

$$Resolution \propto \frac{\lambda\ (wavelength)}{D\ (diameter)}$$



Rayleigh Criteria for resolution
researchgate.net

$\underline{\lambda\ (wavelength)}$

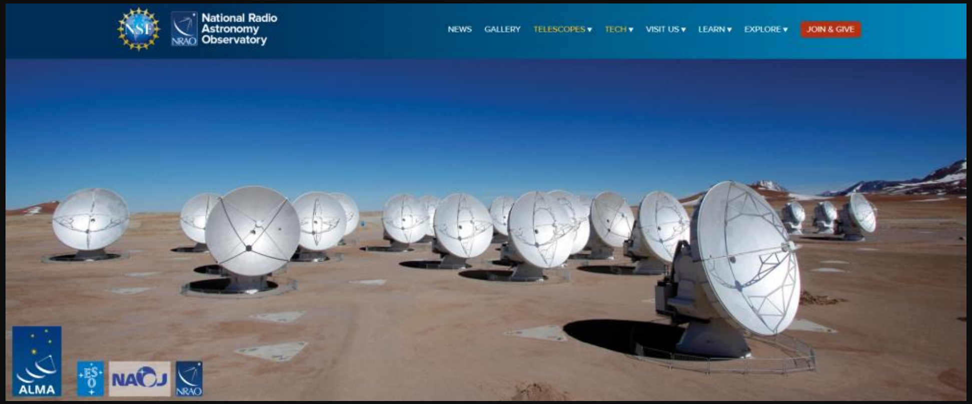
- Light: 400 to 700nm (10^{-9} m)
- Radio: 1mm (10^{-3} m) to 30m

$\underline{Resolution}$

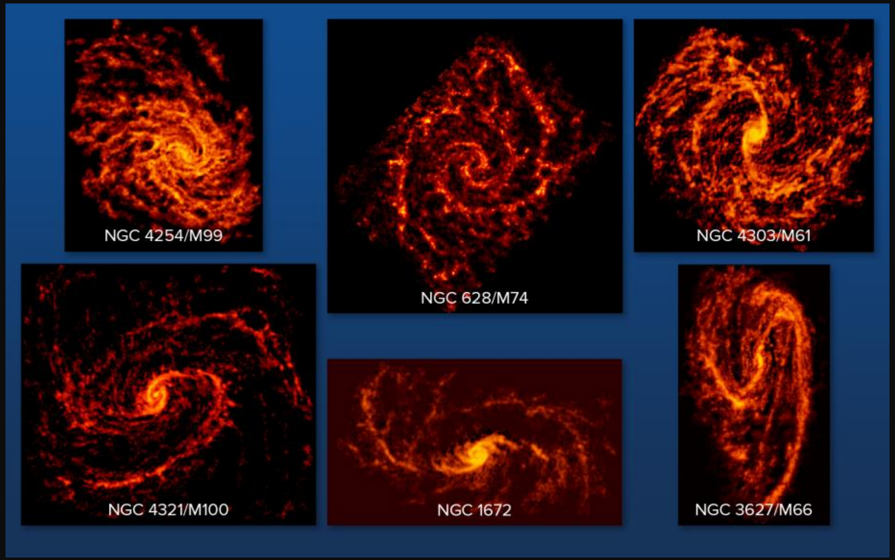
- Visible / Astrophotography : on the order of arcseconds (")
- Radio Astronomy (amateur): on the order of degrees (°)

General Radio Astronomy Information (cont'd)

Large arrays can create high resolution images



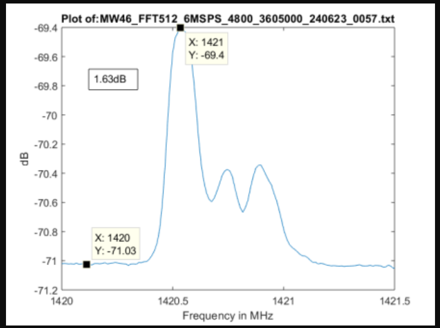
ALMA: **Atacama Large Millimeter/submillimeter Array**

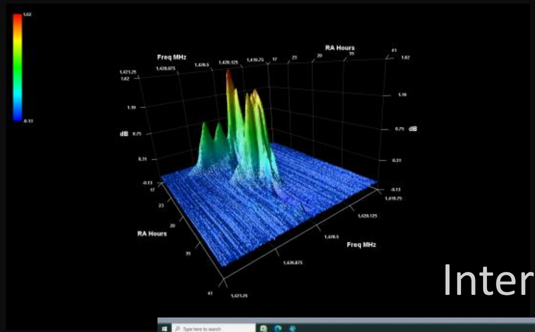


https://public.nrao.edu/telescopes/alma/science/#galaxies

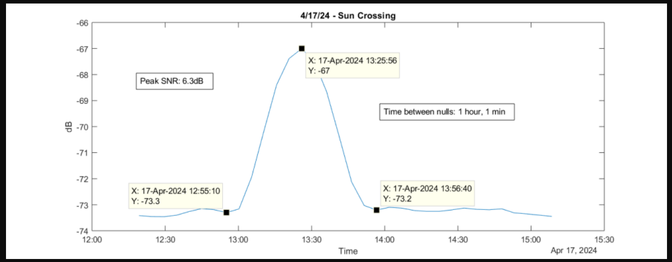
Small amateur radio telescopes can 'detect' objects

Spectrums

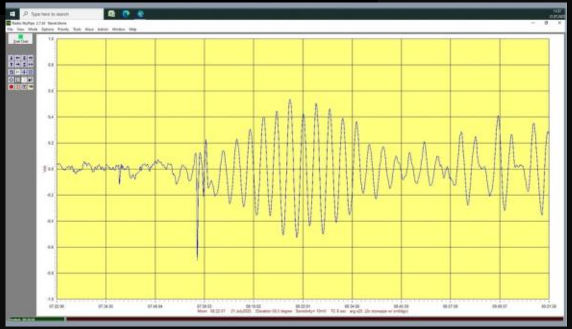




Interferometer



Total power



Jan Henning Holmedal Lustrup,
fb Amateur Radio Astronomy

Doug Holland

General Radio Astronomy Information (cont'd)

Even though <u>amateur</u> radio astronomers do not generally create high resolution images, there are many exceptional things that can be done =>

- Capture the evidence of the Milky Way's multiple spiral arms
  - Create a model / image of the overall structure of our galaxy
- Measure the rotation rate of our galaxy
- Determine the location of our solar system within the Milky Way
- Measure the changing radio frequency (RF) output of the Sun
- Measure the temperature of the Moon
- Detect:
  - active / radio galaxy
  - star forming region not visible to optical telescopes
  - super nova remnant (SNR)
  - masers (water, OH, methanol)
  - meteors
- Listen to radio emissions from Jupiter
- & a whole lot more

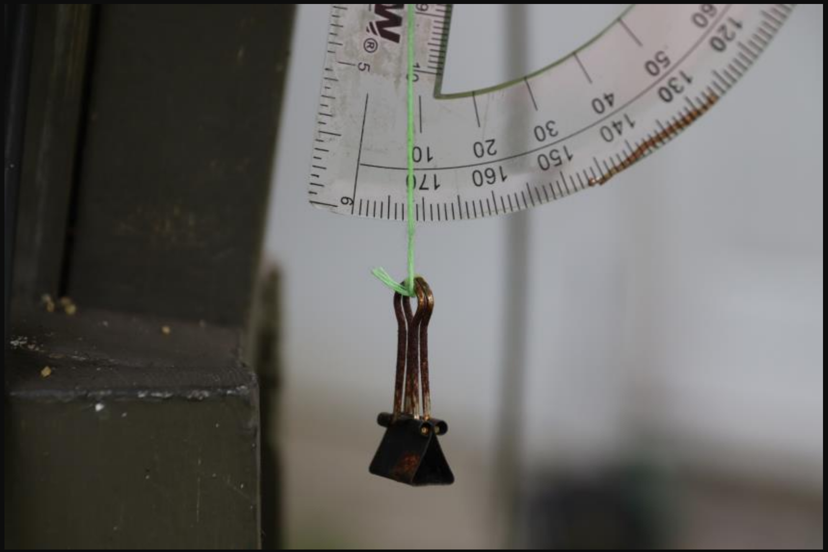
Milky Way Galaxy in the direction of Perseus, 30x4 minute exposures
Rokinon 16mm Lens at f/4, Modified Canon 450D Camera, ISO200

General Radio Astronomy Information (cont'd)

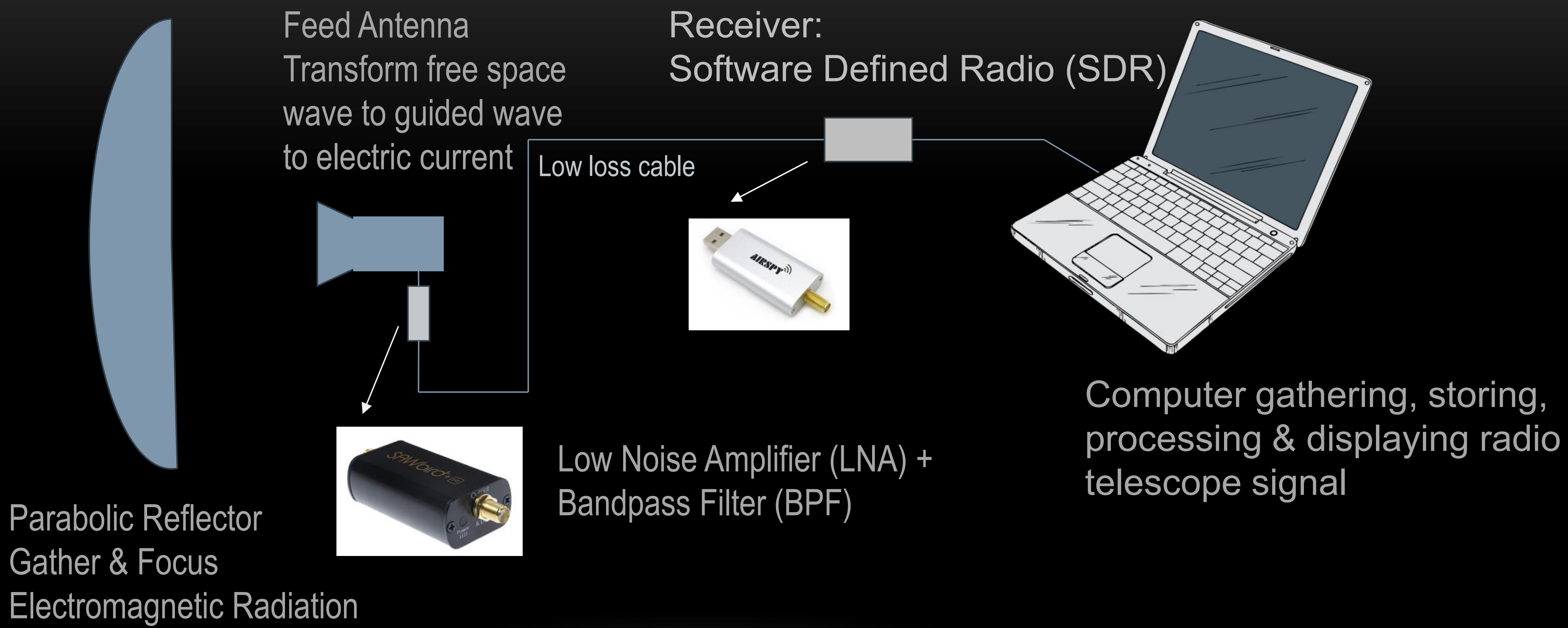
Pointing =>

Many amateur radio telescopes do not track sky

- Line up North / South along local meridian
- Move up and down to set Declination using protractor
- Points at fixed point in the sky, objects cross with Earth rotation [Drift Scan]



The Architecture of an Amateur Radio Telescope



Typical, simplest configuration

Three Configurations Used for this Presentation

Wifi Antenna

2.1m / 7’ Radio Telescope

Satellite TV Antenna

Doug Holland

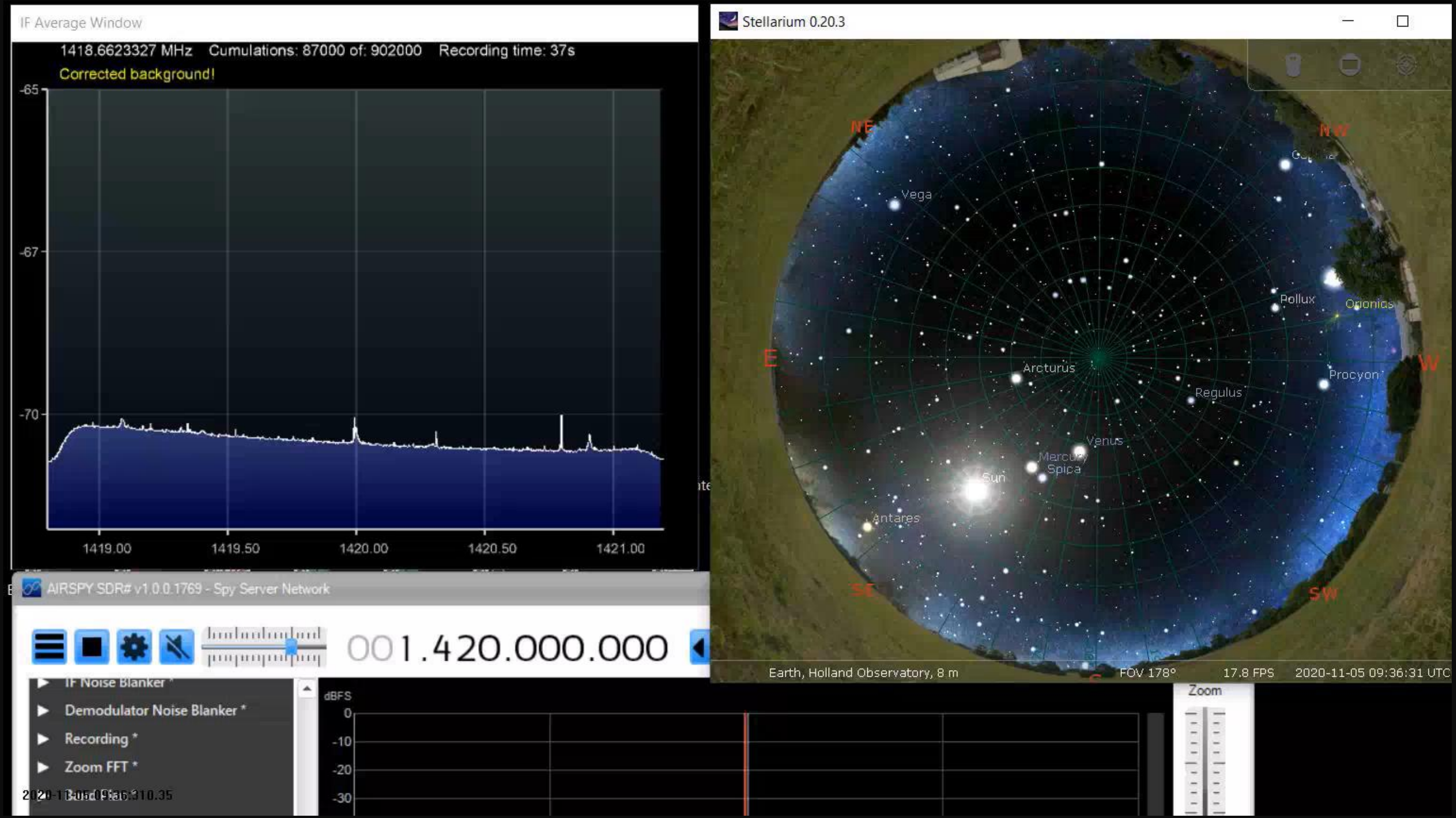
Project 1 – 21cm Neutral Hydrogen with WiFi Antenna

★ **Project 1A**

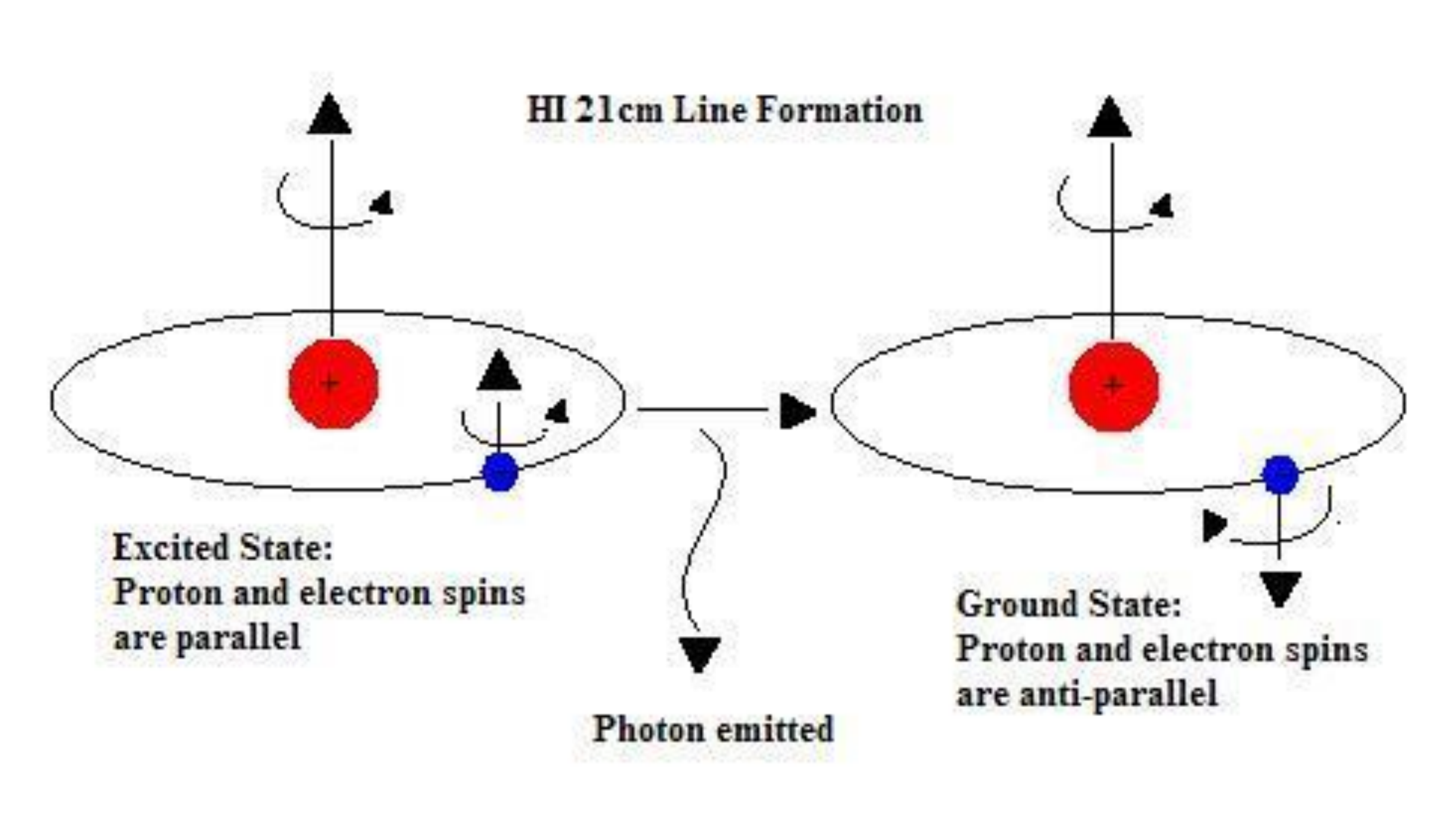
Screen Capture Video of Neutral Hydrogen in Milky Way

Project 1 – 21cm Neutral Hydrogen with WiFi Antenna (cont'd)

First, results =>



Project 1 – 21cm Neutral Hydrogen with WiFi Antenna (cont'd)



astrobites.org

Why does neutral hydrogen emit at 21cm? =>

Project 1 – 21cm Neutral Hydrogen with WiFi Antenna (cont'd)

How to do =>

<u>21cm Radio Telescope</u>
(21cm => 1.42GHz)
Hydrogen Emission

WiFi Dish Antenna: $82.99
eBay
- 24dBi gain
- 2.4GHz but works at 1.42GHz
- 14º x10º beam width

Low Noise Amplifier: $44.95
Amazon
- Nooelec H1 LNA
- 40dB, Designed for 21cm

Software Defined Radio: $24.95
https://www.rtl-sdr.com/
- USB interface, v3

Project 1 – 21cm Neutral Hydrogen with WiFi Antenna (cont'd)

Makes 21cm Neutral Hydrogen Detection Possible !!

Nooelec SAWbird+ H1 - Premium Saw Filter & Cascaded Ultra-Low Noise Amplifier (LNA) Module for Hydrogen Line (21cm) Applications

Project 1 – 21cm Neutral Hydrogen with WiFi Antenna (cont'd)

Software Defined Radio (SDR) interfaces via USB

SDR# software controls SDR (free)

IF Average Plugin used to average multiple samples to decrease noise and increase signal (free)

Stellarium or other planetary program to view Milky Way transit (free)

Chronolaps – screen capture video (free)

Project 1 – 21cm Neutral Hydrogen with WiFi Antenna (cont'd)

Low Noise Amplifier (LNA)

Software Defined Radio (SDR)

Project 1 – 21cm Neutral Hydrogen with WiFi Antenna (cont'd)

Link to Source of Design

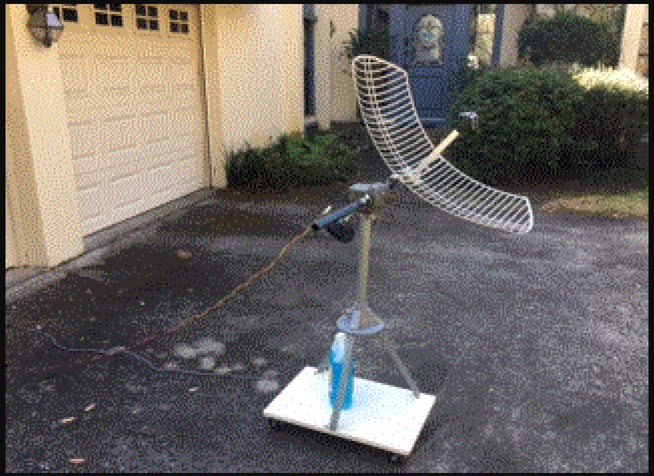
https://www.rtl-sdr.com/cheap-and-easy-hydrogen-line-radio-astronomy-with-a-rtl-sdr-wifi-parabolic-grid-dish-lna-and-sdrsharp/

Or – search 'Easy Hydrogen Line Radio Astronomy'

Presentation posted on webpage: www.holland-observatory.net

Project 1 – 21cm Neutral Hydrogen with WiFi Antenna (cont'd)

If you would prefer to buy a kit:



Scope in a Box, $350

SOCIETY OF AMATEUR RADIO ASTRONOMERS
www.radio-astronomy.org

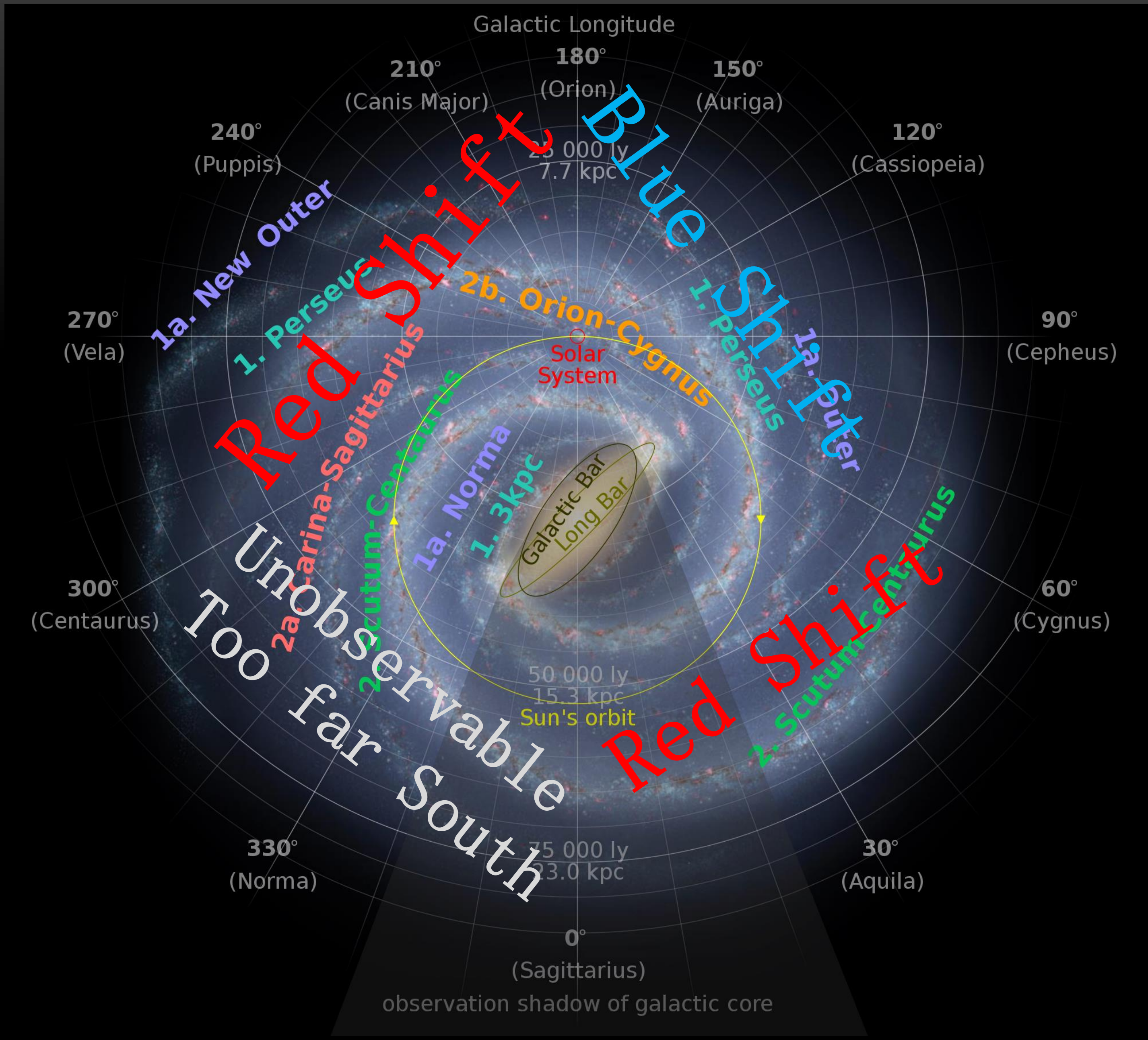
Project 1 – 21cm Neutral Hydrogen with WiFi Antenna (cont’d)

What else can be done with this system?

!!! Measure where our solar system is located within the Milky Way !!!

Solar System Distance from Center of Milky Way

★ **Project 1B**



 Kraus, RADIO ASTRONOMY, 2nd ed.

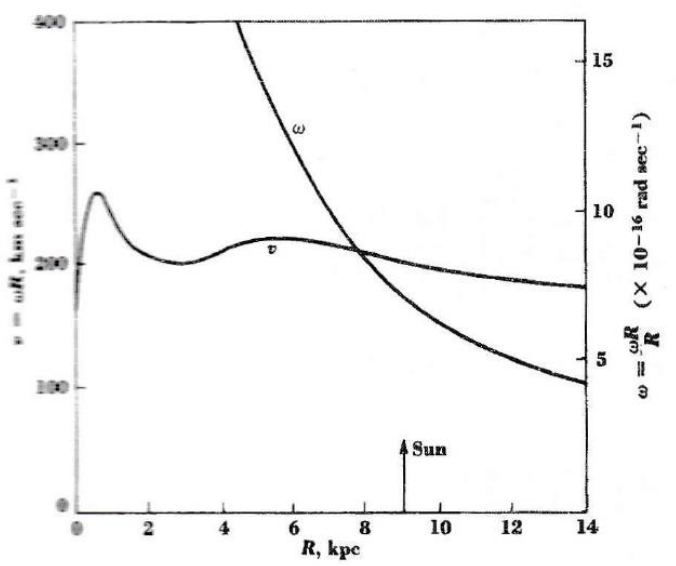


Fig. 8-63. Circular velocity v and angular velocity ω in our galaxy as a function of distance R from the center. (*After Rougoor and Oort*, 1960.)

Angular velocity (w) decreases with distance from center of galaxy

Can see intuitively from image of Milky Way. Spiral arms - Closer in areas, higher angular velocity.

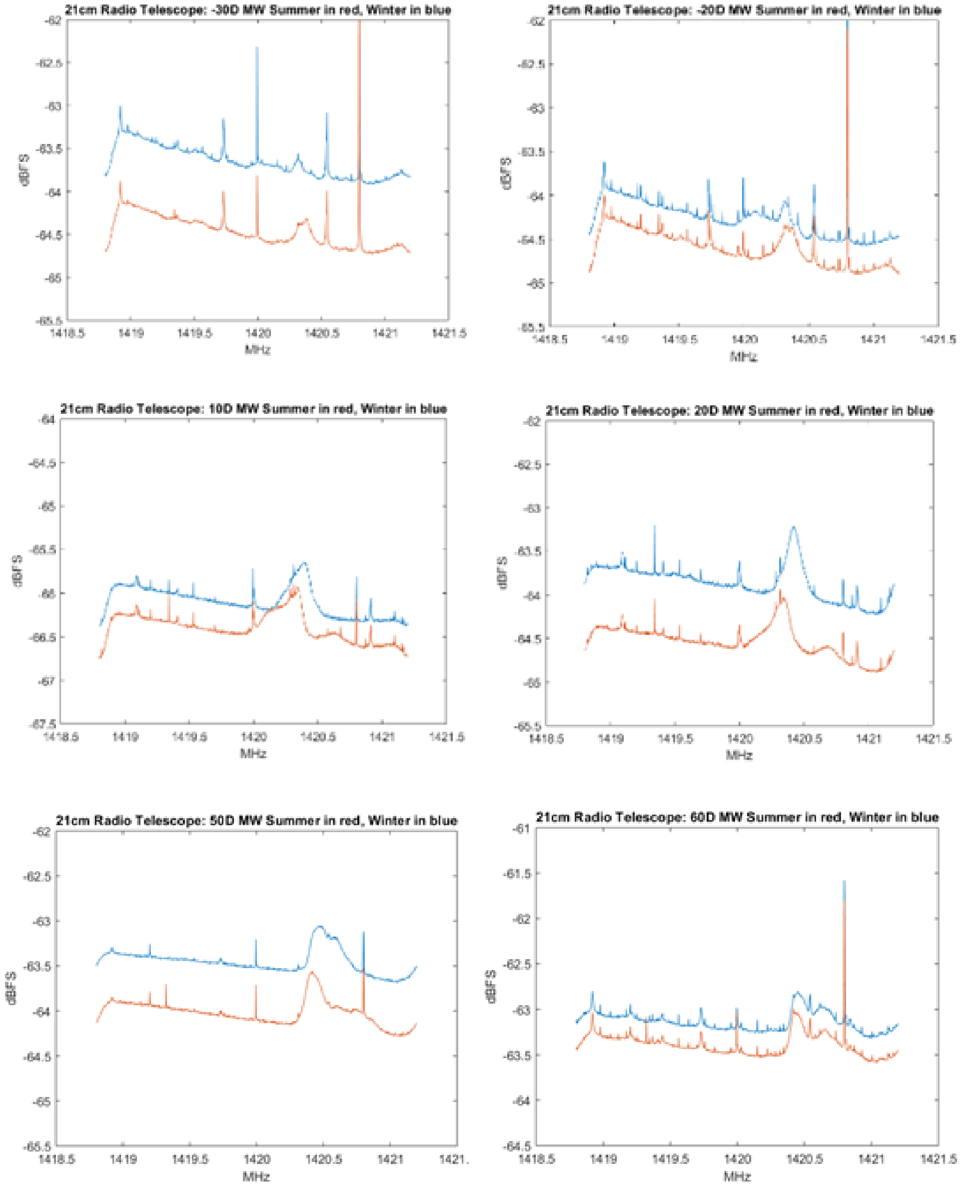
https://earthsky.org/upl/2020/01/milky-way-arms-suns-location-orion-cygnus-arm.png

21cm Radio Telescope
(21cm => 1.42GHz)
Hydrogen Emission

- WiFi Antenna, Software Defined Radio (SDR)
- Raspberry Pi Configuration

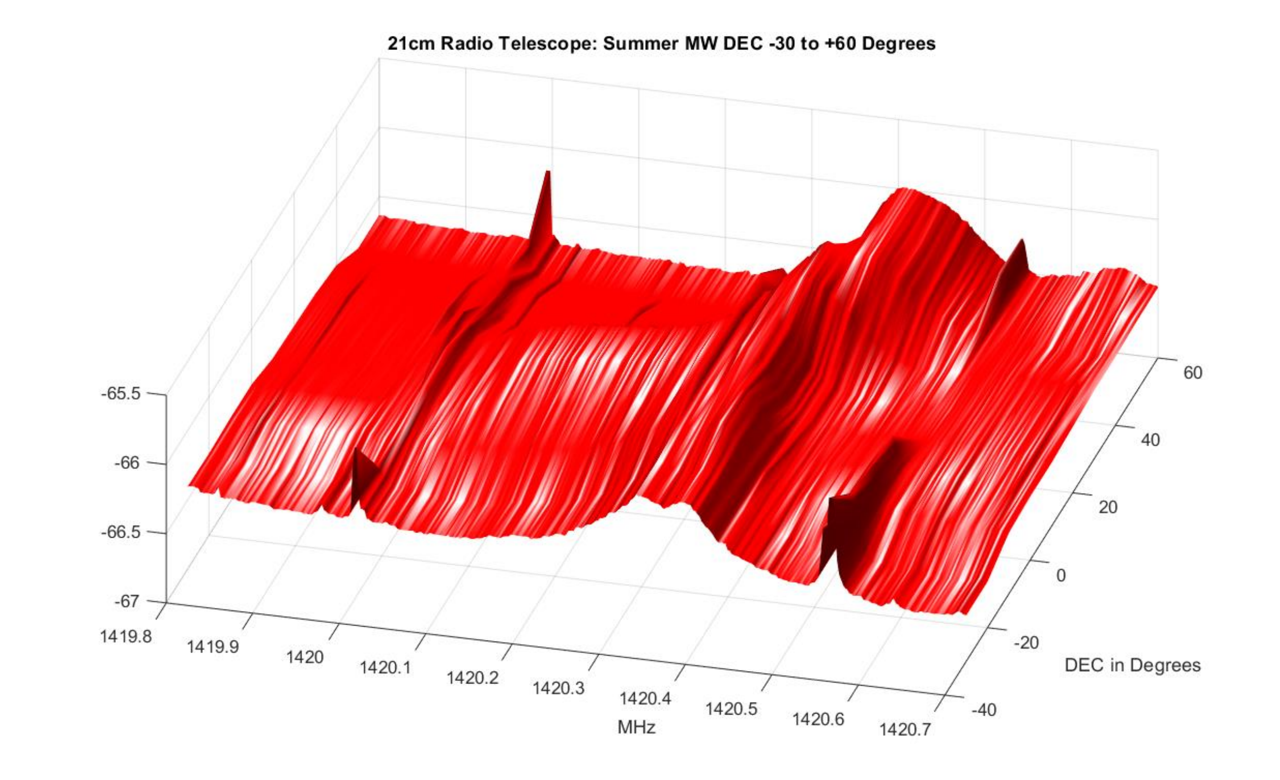
Data gathered along *galactic equator at 10º* increments 11/3 to 11/17, 2020

21cm Plots at Galactic Equator – Spaced at 10 Degrees Declination

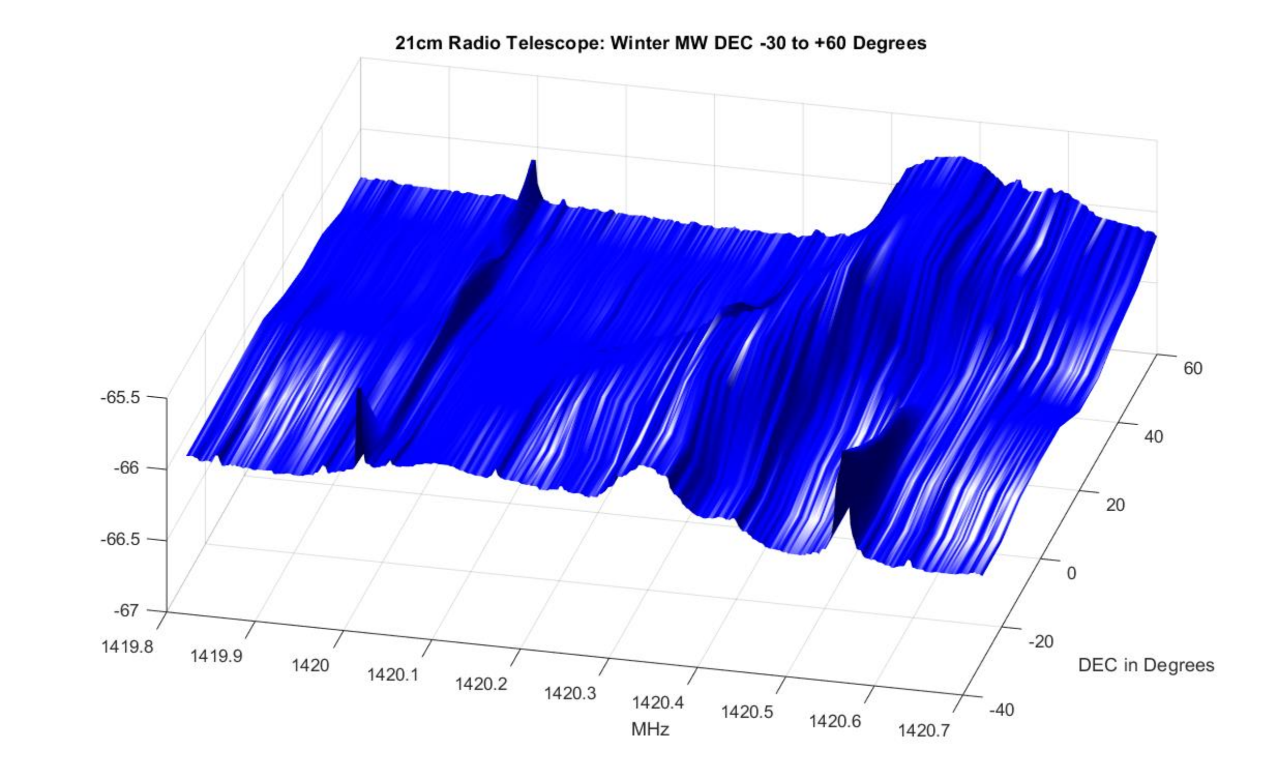


Red = Summer Milky Way
Blue = Winter Milky Way

3D Surface Plots of Summer (Red) and Winter (Blue) Milk Way Data



- The **diameter of** the luminous **Milky Way** is between 100,000 and 120,000 light years across.
- Sun (Solar System) is 1/2 to 2/3rds from center (www.universetoday.com)



Declination vs. Amplitude vs. Frequency
-30^0 DEC: Center of galaxy (Sagittarius)
$+60^0$ DEC: Most Northerly point of galactic equator (all data taken along galactic equator)

=> Transition between red shift and blue shift is approx. 1/2 to 2/3 from center of galaxy to most Northerly point

Project 2 – Improved 21cm Neutral Hydrogen with 2.1m Antenna

After having some success =>

=> What could we do to improve our results?

Project 2 – Improved 21cm Neutral Hydrogen with 2.1m Antenna (cont’d)

Obviously, make it BIGGER =>

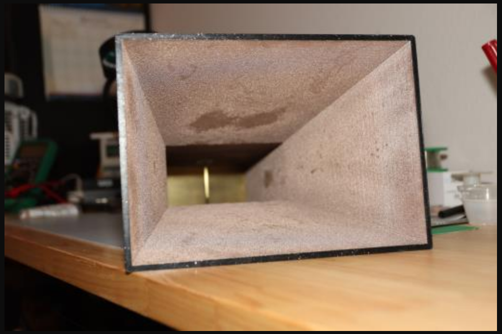
2.1m / 7’ Parabolic Dish
f/0.4
Resolution ≈ 7° (HPBW)
6mm spaced hardware cloth
Collected flux ∝ Dish Area

Doug Holland

Project 2 – Improved 21cm Neutral Hydrogen with 2.1m Antenna (cont'd)

Note – Wifi Antenna came with built in feed antenna

=> Now we need to design and build a feed antenna



3D Printed Pyramidal Horn

Helical Beam Antenna

Loop Antenna

Circular Waveguide Horn Antenna

End Result –
Circular Waveguide Horn Best
(aka Cantenna, Stove Pipe Antenna)
* Many online examples

Project 2 – Improved 21cm Neutral Hydrogen with 2.1m Antenna (cont'd)

Things to know about feed antennas 1 =>

You may think that focus is at ¼ wave antenna

BUZZ - Wrong – It is near the aperture of the Circular Waveguide (CWG) Antenna

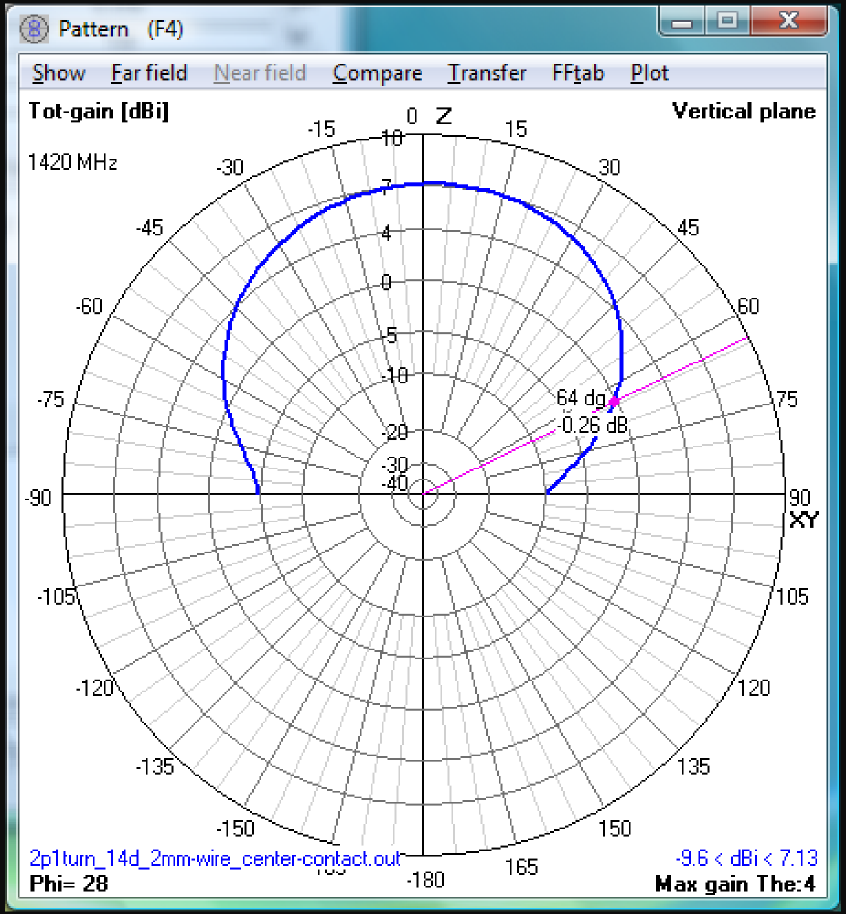
*** Also – just to confuse everyone, the radio astronomers call focus point the 'phase center'

*** Depth of focus is wavelength dependent – more relaxed at radio wavelengths

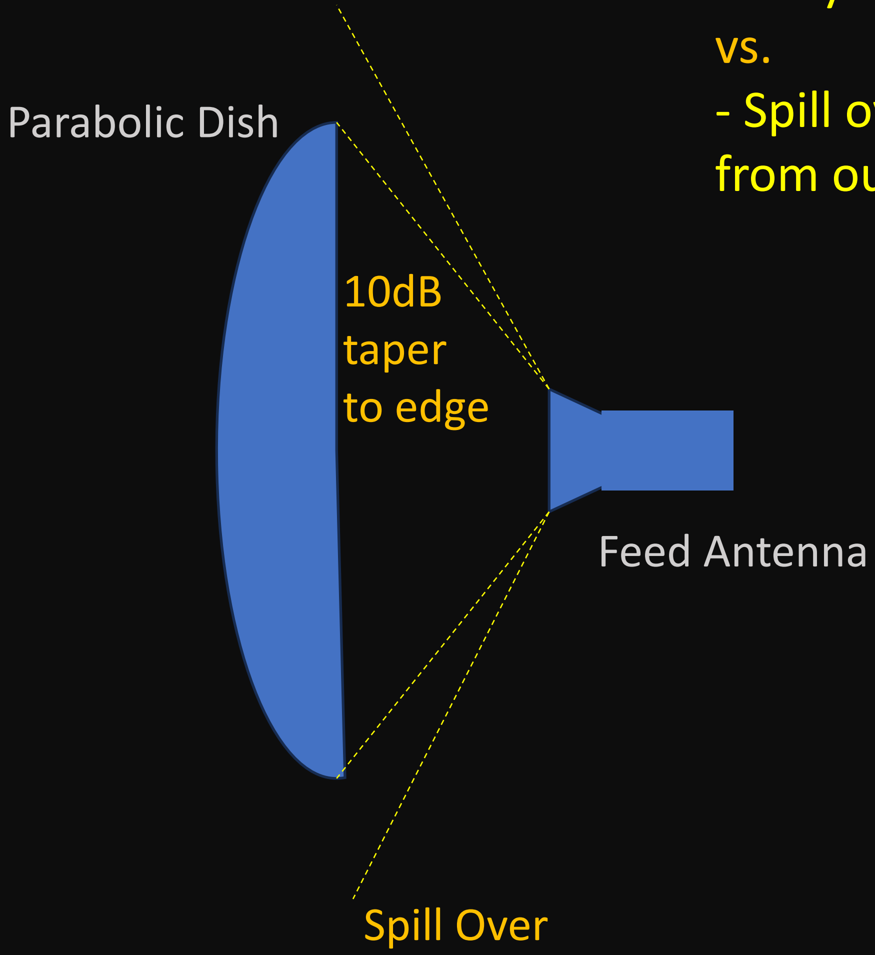
Doug Holland

Project 2 – Improved 21cm Neutral Hydrogen with 2.1m Antenna (cont'd)

Things to know about feed antennas 2 =>



4NEC2 Software



Trade-off

- Fully illuminated dish

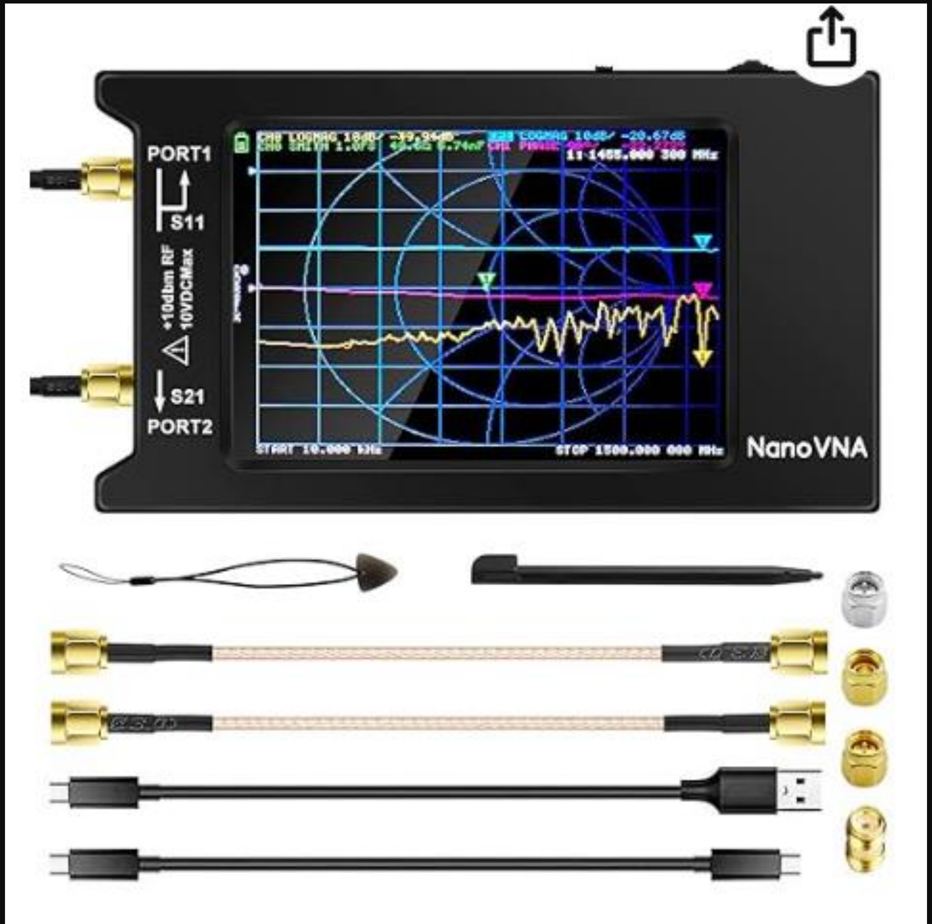
vs.

- Spill over (signal from outside dish)

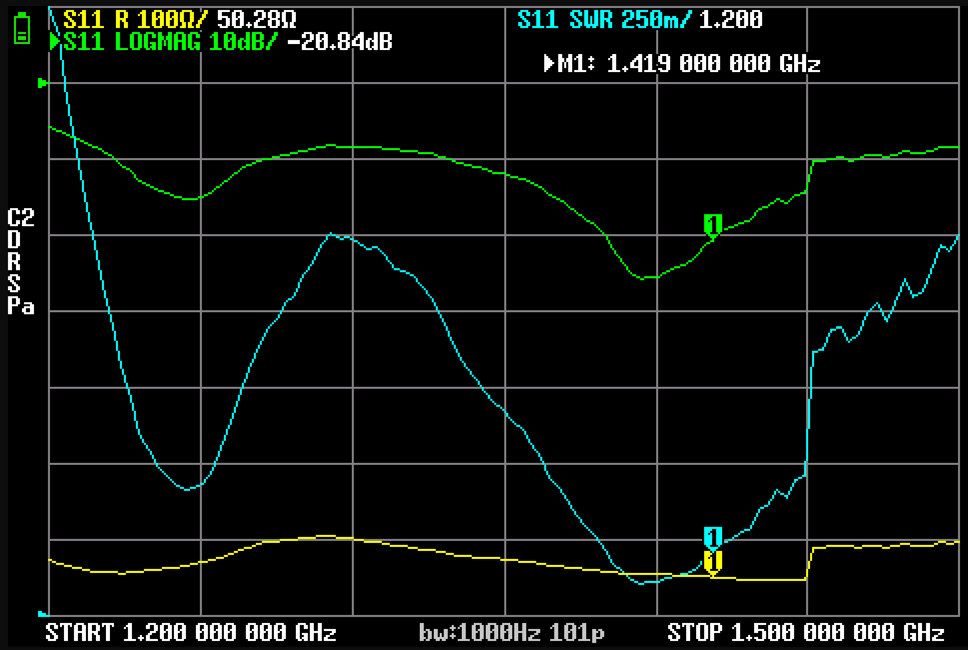
Doug Holland

Project 2 – Improved 21cm Neutral Hydrogen with 2.1m Antenna (cont'd)

Things to know about feed antennas 3 =>



NanoVNA-H4 (Vector Network Analyzer) – very useful for testing feed antennas [$68 on Amazon]



Doug Holland

Project 2 – Improved 21cm Neutral Hydrogen with 2.1m Antenna (cont'd)

Things to know about feed antennas 4 =>

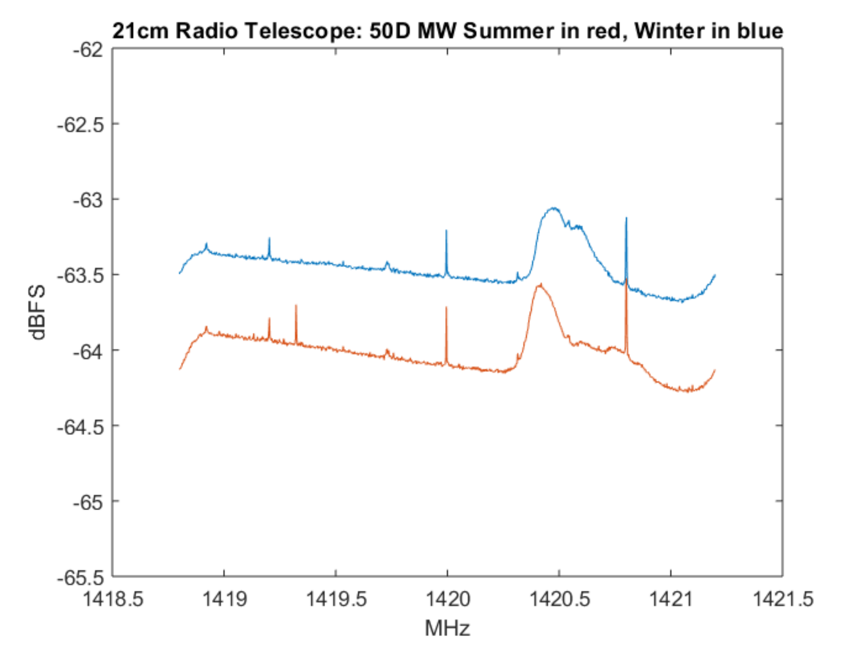
Low Noise Amplifier (LNA) is mounted directly on feed antenna

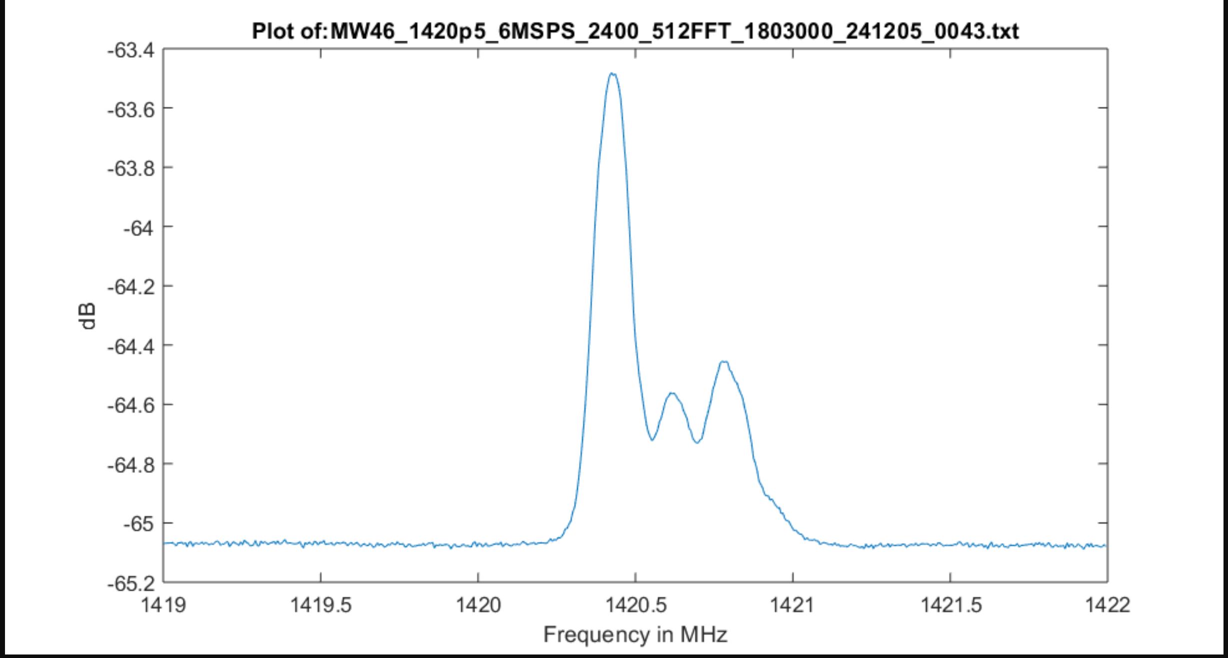
Otherwise, LNA will amplify noise from cabling

Doug Holland

Project 2 – Improved 21cm Neutral Hydrogen with 2.1m Antenna (cont'd)

Did we improve our results?



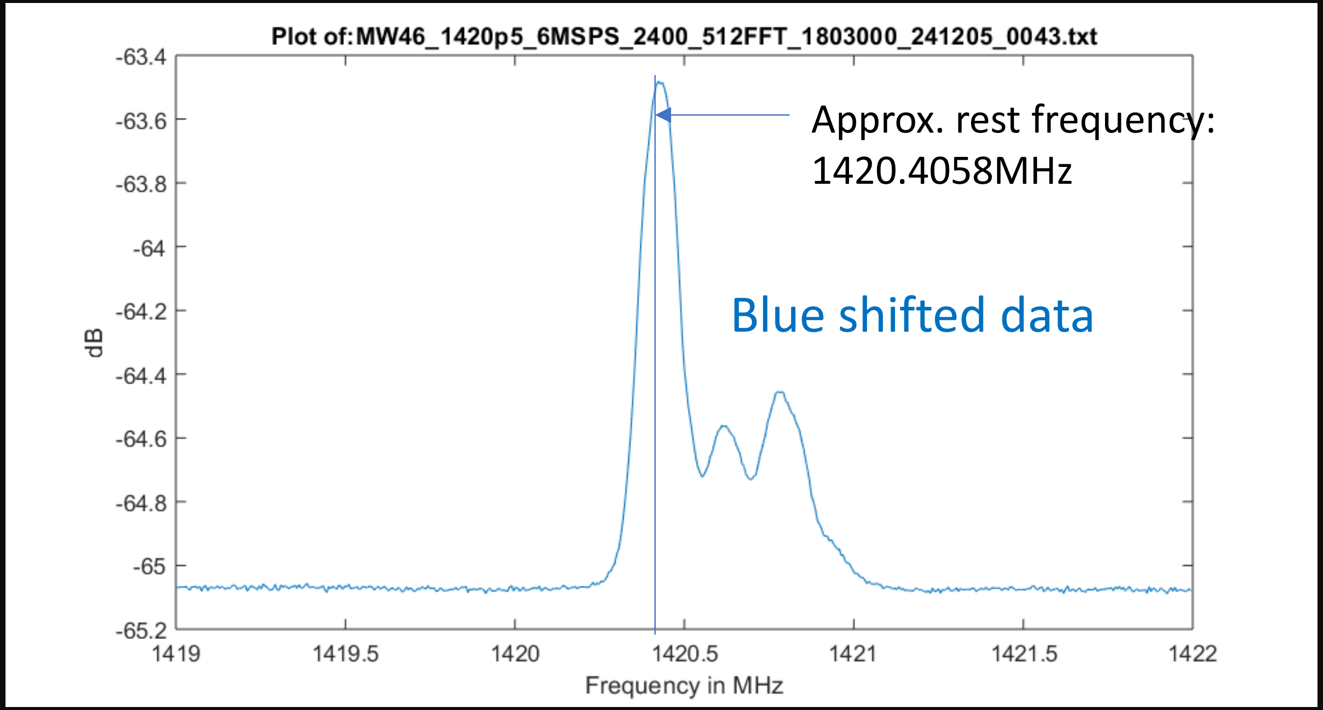


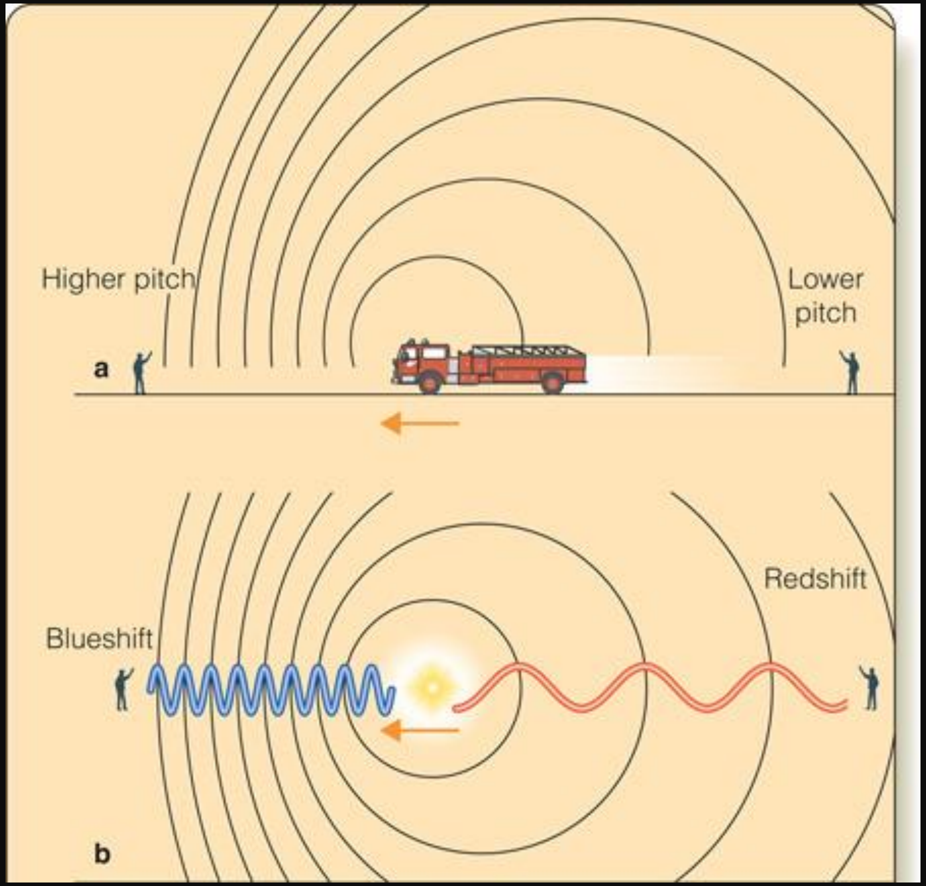
Doug Holland

Project 2 – Improved 21cm Neutral Hydrogen with 2.1m Antenna (cont'd)

What can we do with our improved data => ★ **Project 2A**

Evidence of Multiple Spiral Arms in Milky Way





The Doppler Effect

From: Fundamentals of Astronomy, Seeds & Backman

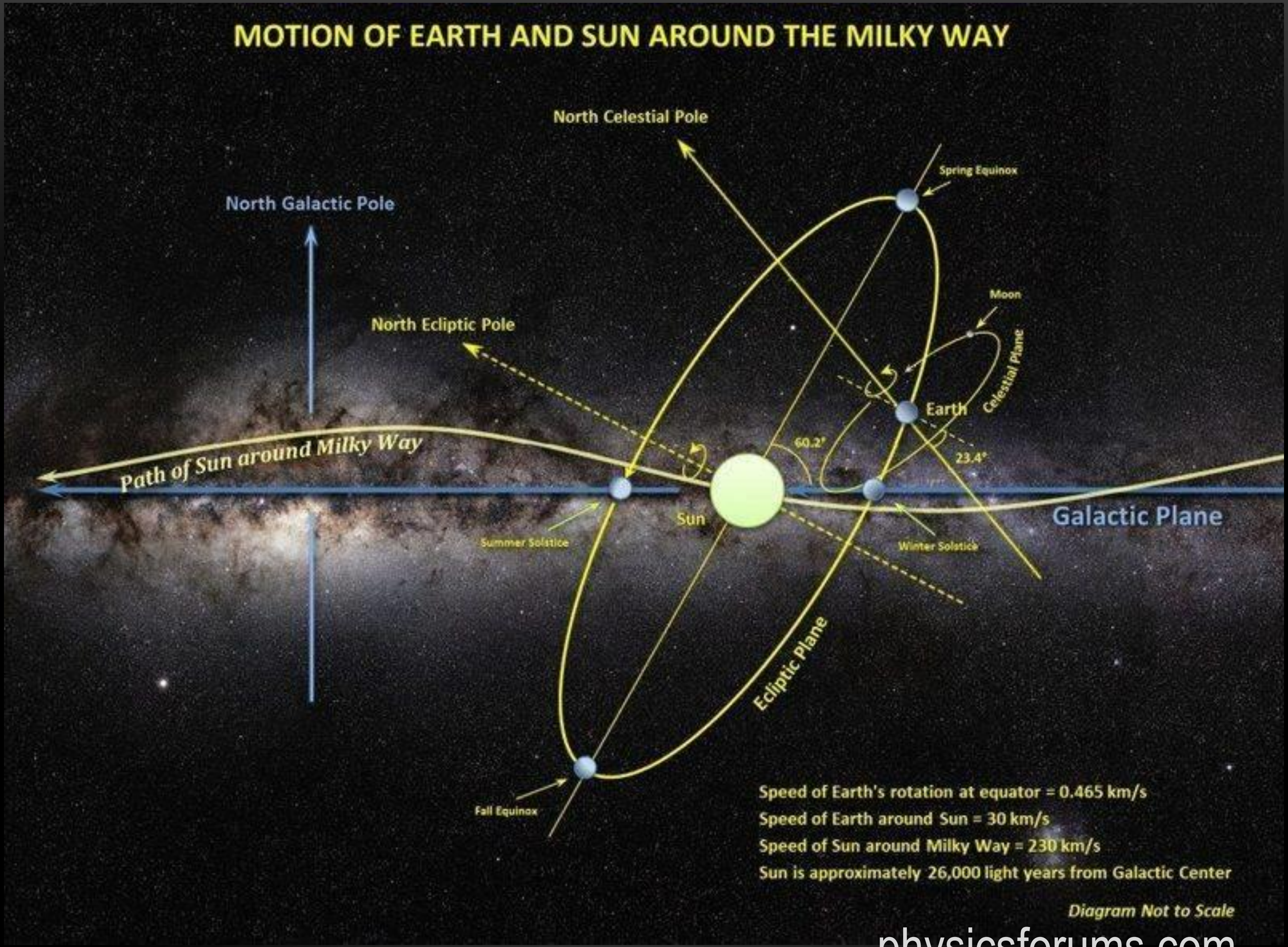
- Neutral Hydrogen rest frequency = 1420.4058MHz
- Blue shift humps are evidence of the Milky Way having multiple spiral arms

Doug Holland

Project 2 – Improved 21cm Neutral Hydrogen with 2.1m Antenna (cont'd)

"Observations of the 21-cm hydrogen line have enabled radio astronomers to deduce for the first time a picture of the spiral structure of our galaxy" Radio Astronomy by John D. Kraus

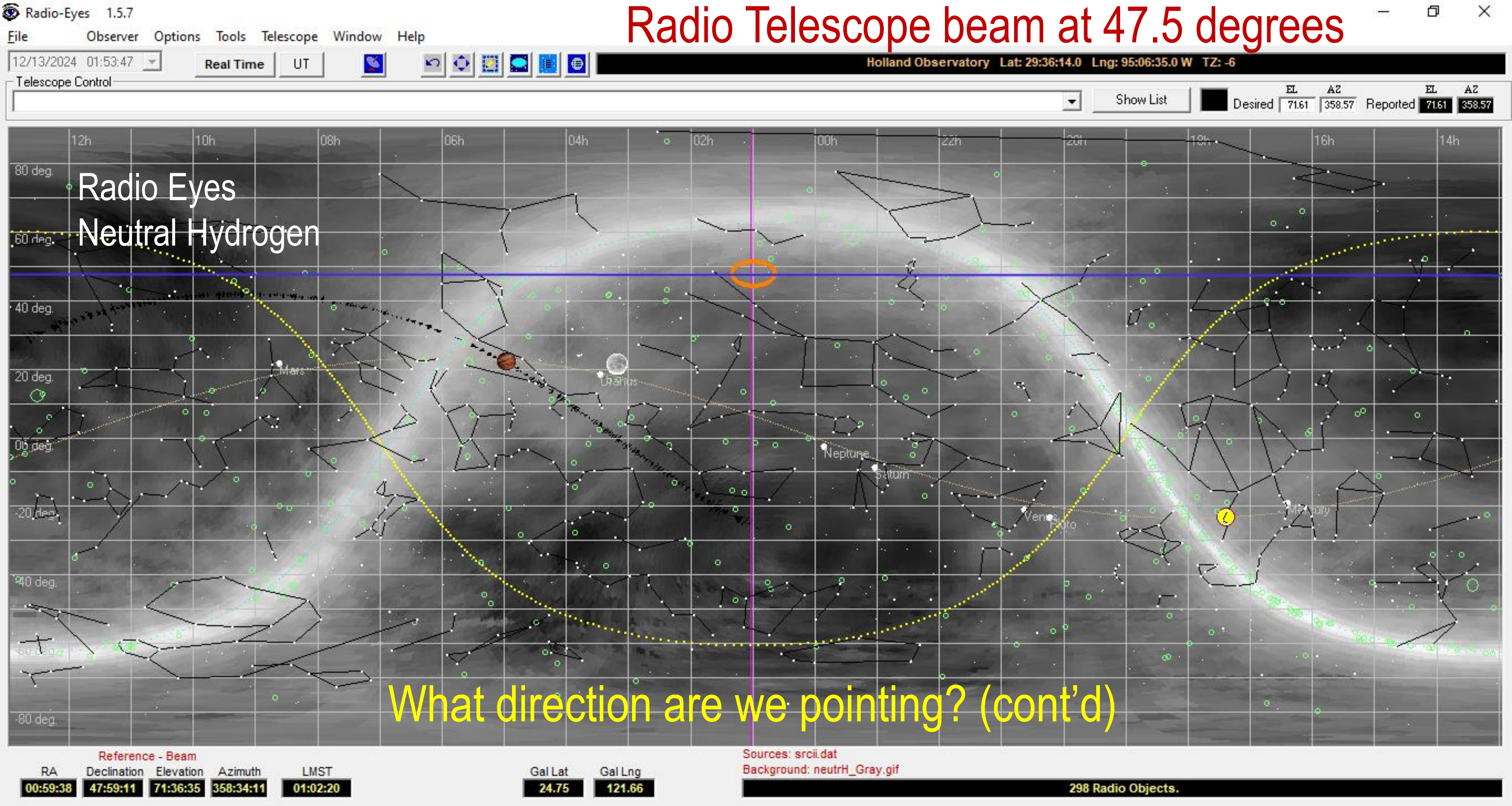
How can we correlate our data to existing models of our galaxy?



physicsforums.com

What direction are we pointing?

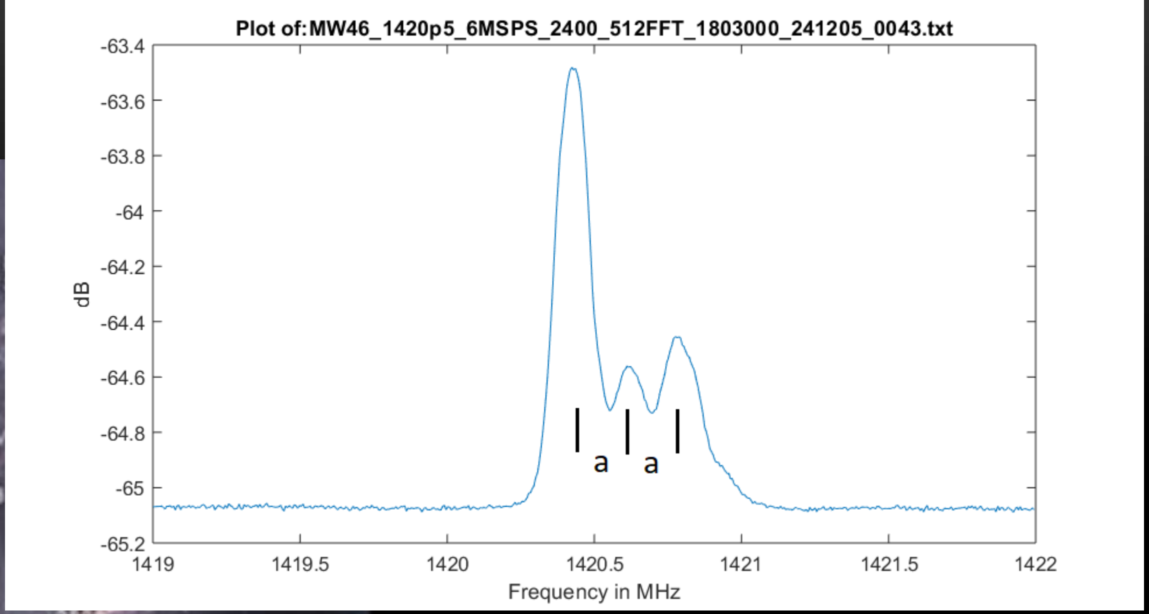
Radio Telescope beam at 47.5 degrees



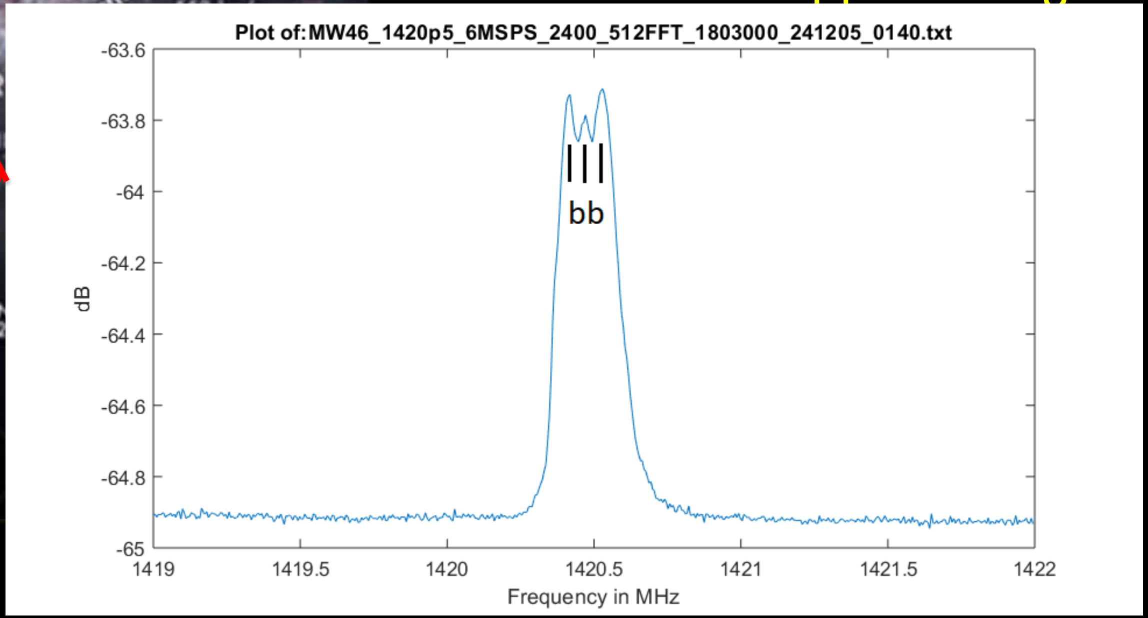
What direction are we pointing? (cont’d)

Approximate directions

pablocarlosbudassi.com



Blue shifted data => approaching



Measured data correlates to accepted models of our galaxy

Project 2 – Improved 21cm Neutral Hydrogen with 2.1m Antenna (cont'd)

★ **Project 2B**

Creating 3D Representation of Our 21cm Neutral Hydrogen Data

Configuration Used for Data

- 2.1m f/0.4 Dish Reflector
- 1420MHz Cylindrical Waveguide Horn
  - With 6 to 7” flared aperture
  - SWR: 1.19
- Noelec H1 LNA
- Airspy Mini Software Defined Radio (SDR)
- Very short USB cable (4 inches)
- Local laptop running SDR# software with IF_Average plugin

New Radio Astronomy Software

- Facebook ‘Amateur Radio Astronomy’ group

➢ IFAvg2CSV (free)

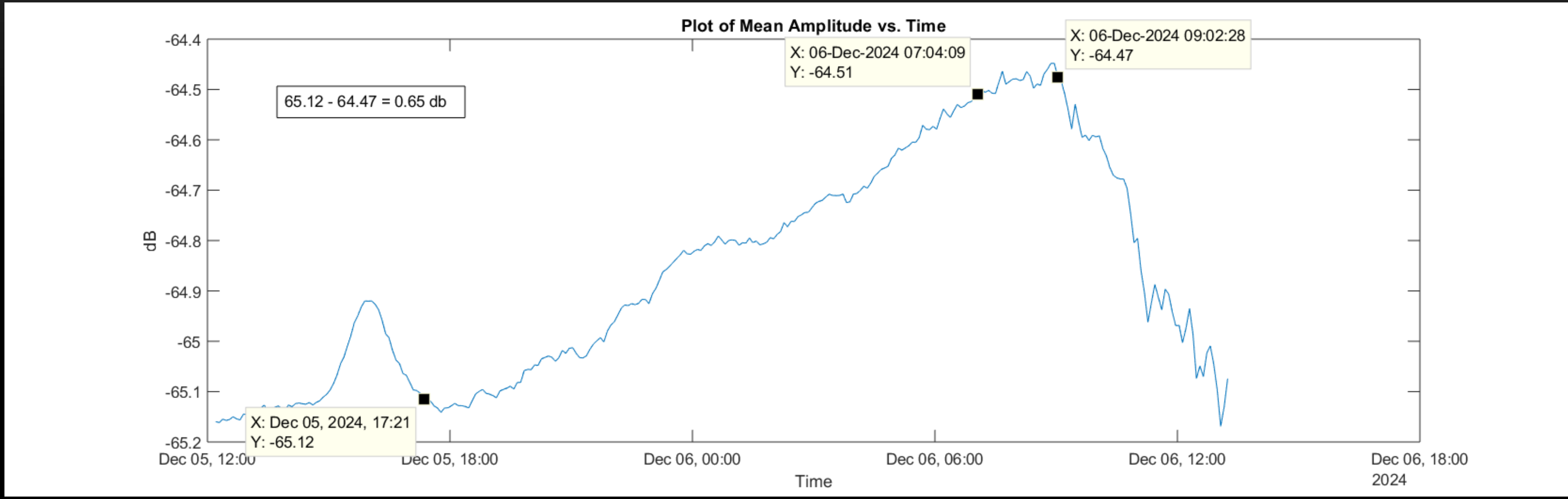
❑ Takes files made by SDR# and converts to CSV (CSV – comma separated values)

➢ Rinearn Graphics (free)

❑ Takes CSV files and plots: 2D and 3D versions

Perseus Molecular Cloud flanked by IC348 (left) and NGC1333 (right) Reflection Nebulae
LRGB - L: 49x5min, R: 24x5min, G: 12x5min, B: 18x5min, 200mm Canon L Series Lens at f/3.4, SC8300 Camera

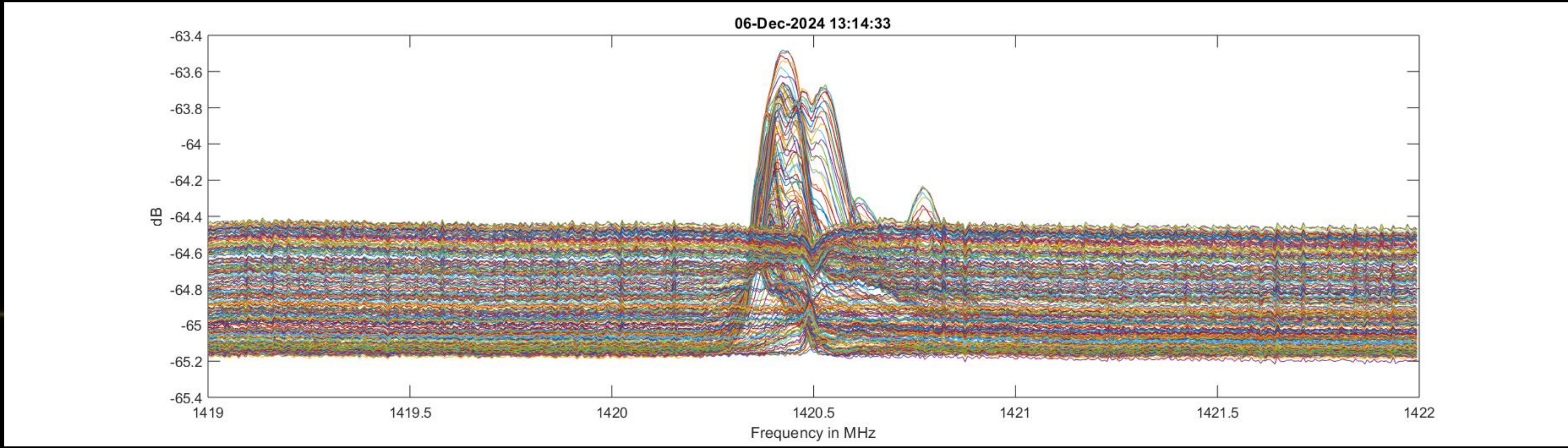
- IFAvg2CSV
  - Takes files made by SDR# and converts to CSV



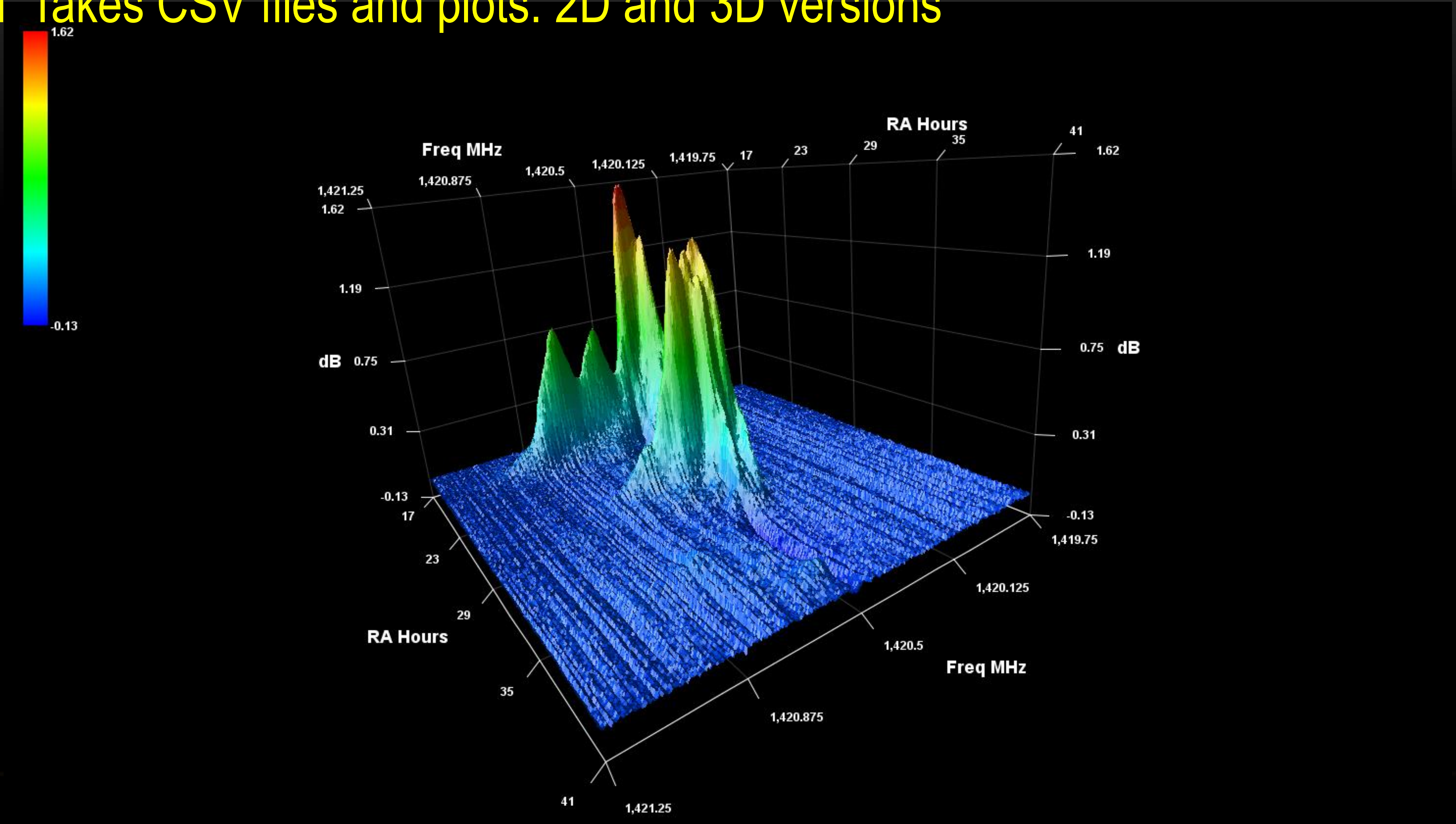
24 hours

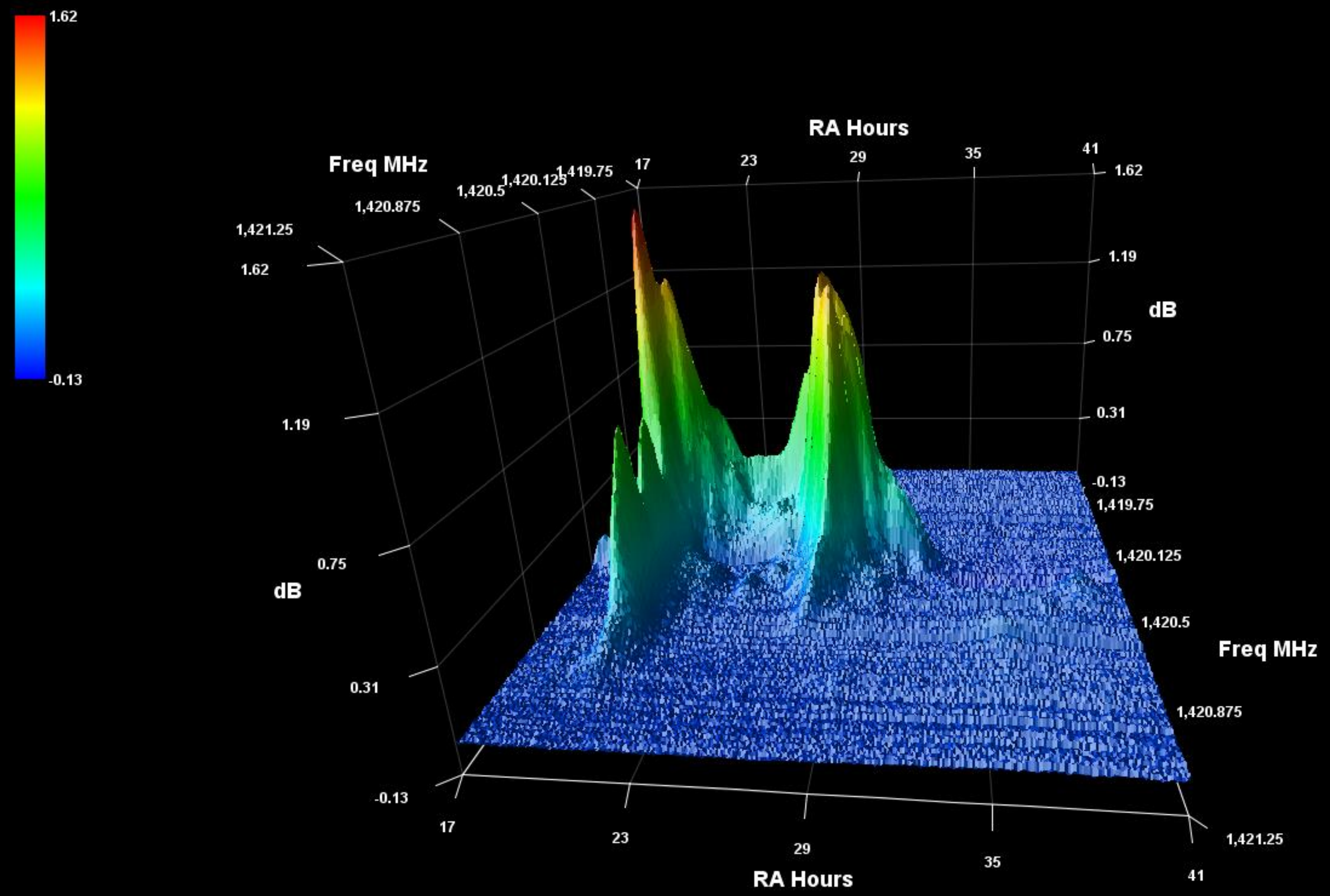
DEC 47.5°

Normalizes Data (original data has gain / baseline drift)

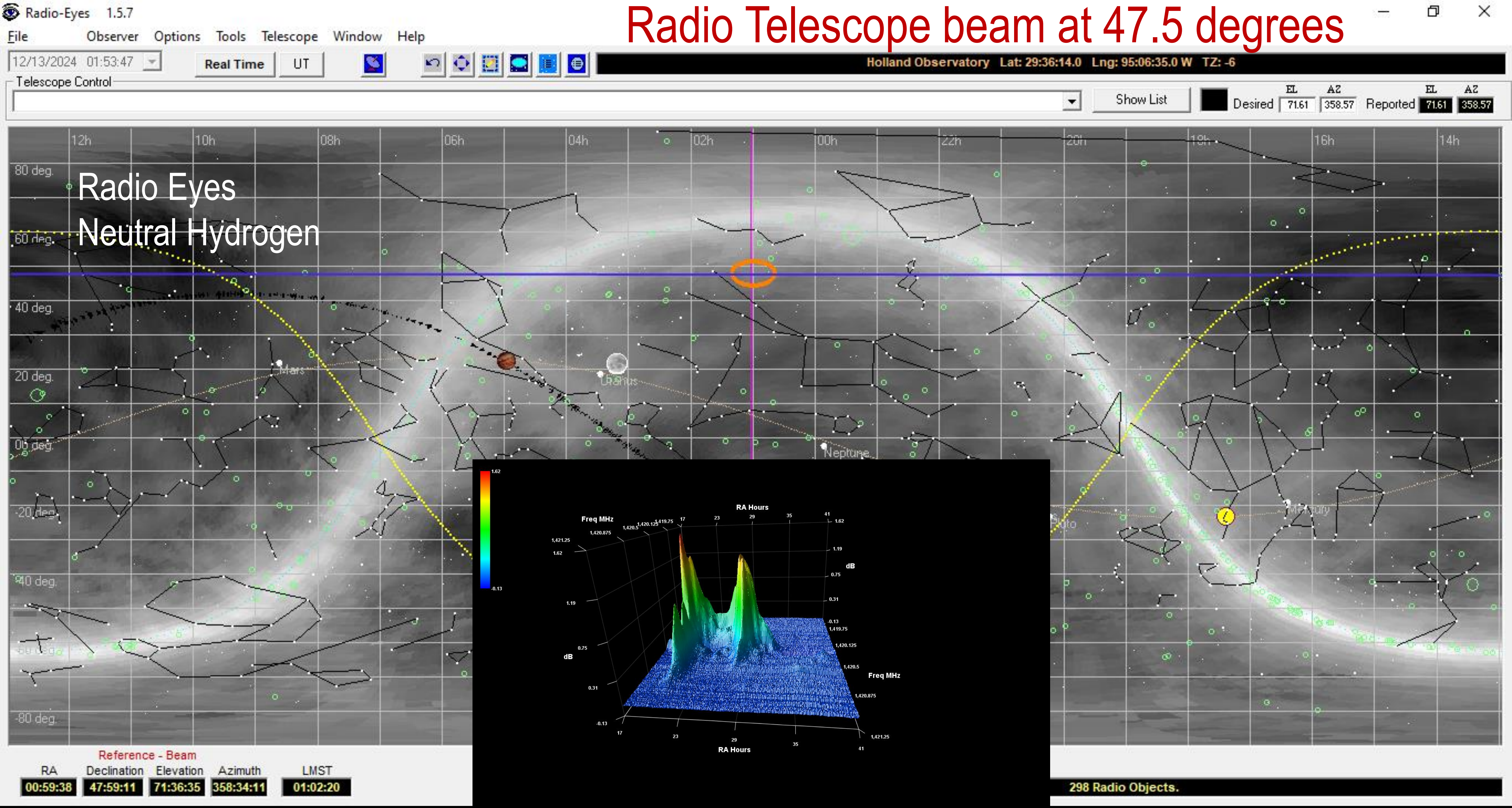


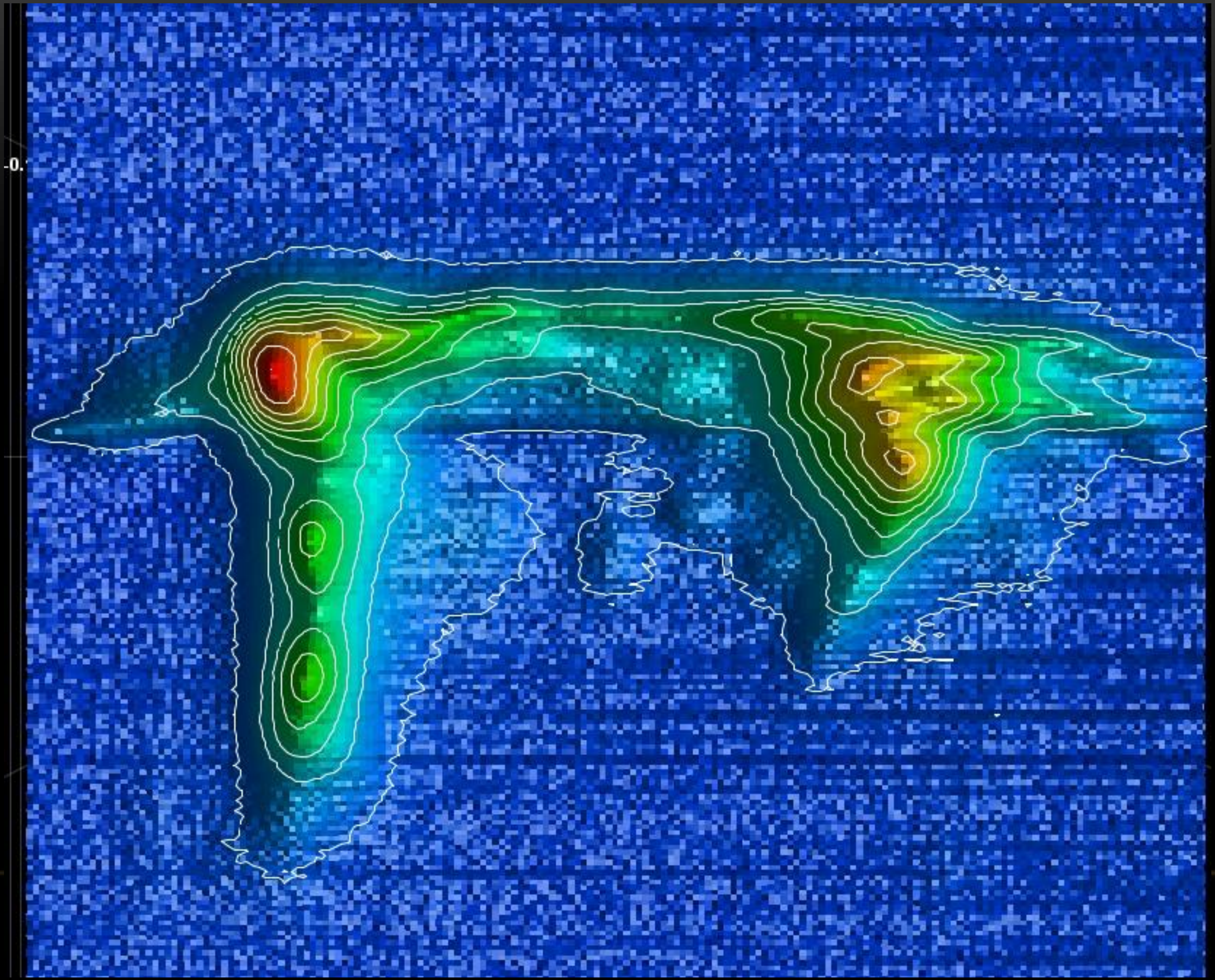
- Rinearn Graphics
  - Takes CSV files and plots: 2D and 3D versions




1.62
-0.13
RA Hours
17
23
29
35
41
Freq MHz
1,421.25
1,420.875
1,420.5
1,420.125
1,419.75
dB
1.62
1.19
0.75
0.31
-0.13
RA Hours
Freq MHz
dB

Radio Telescope beam at 47.5 degrees

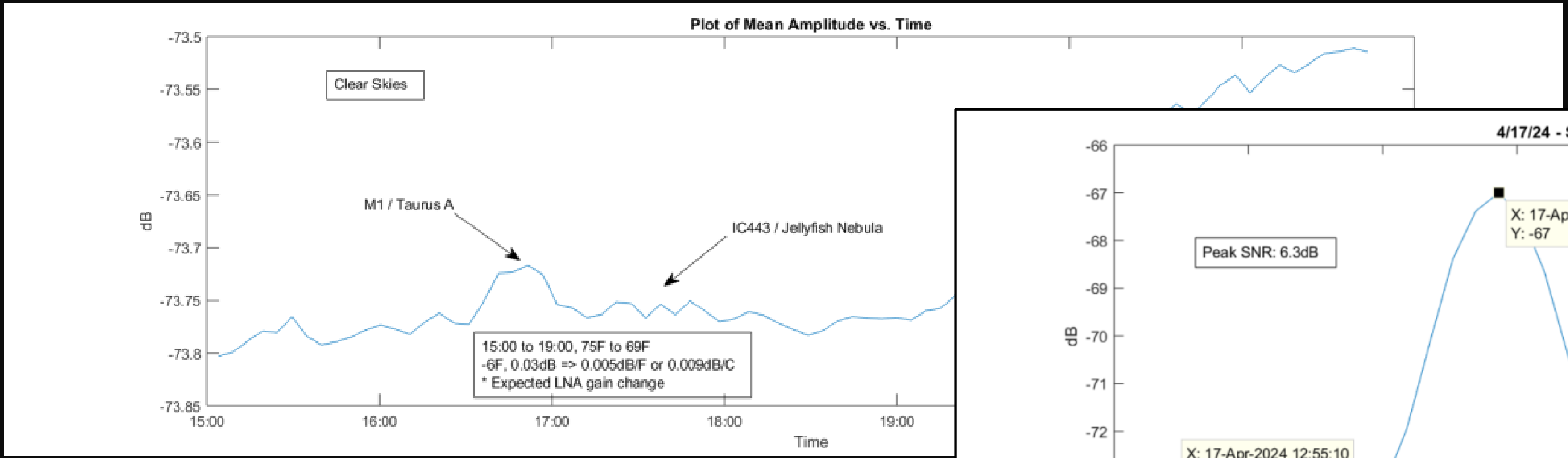


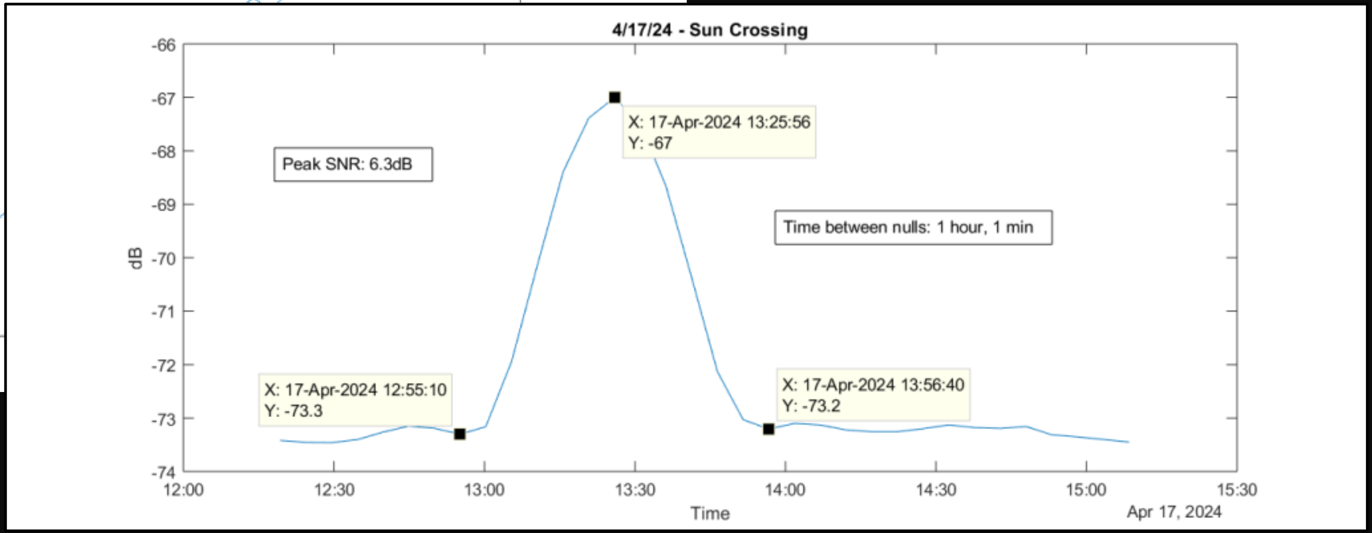


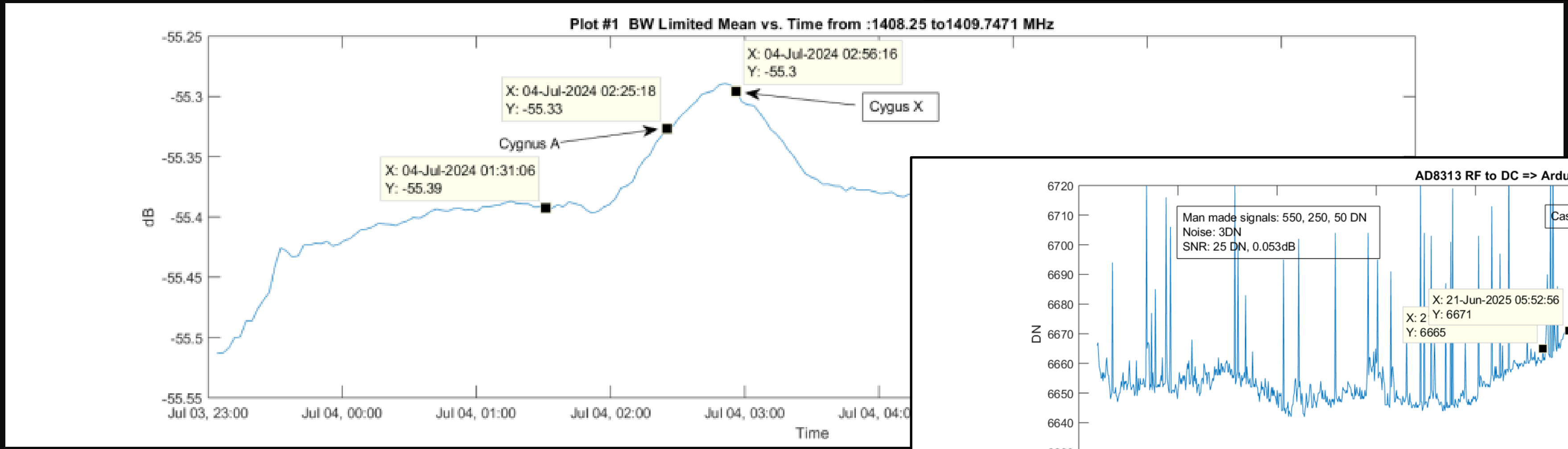
Contour Plot

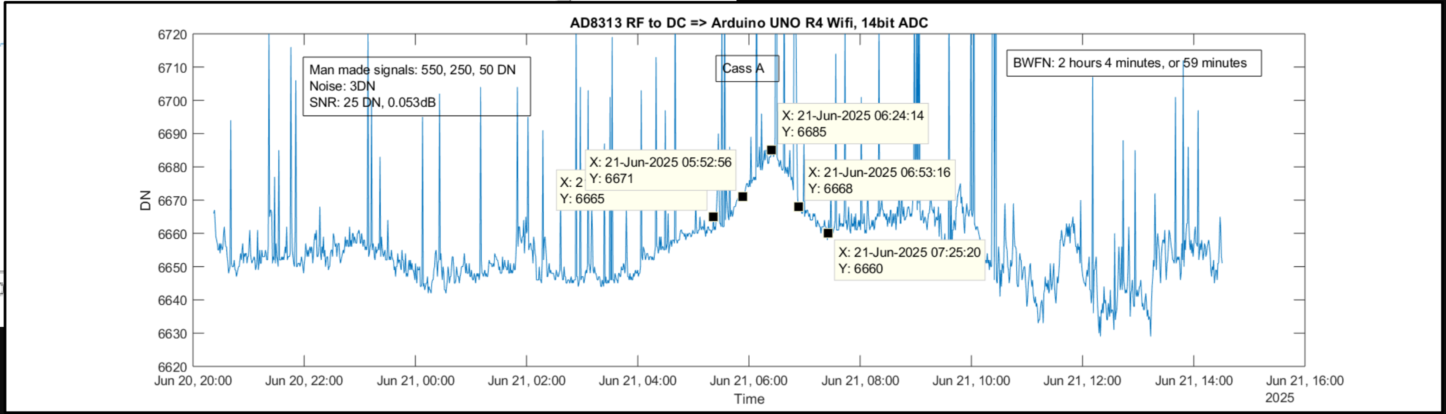
Produced by Alex Pettit

Project 3 – Total Power Measurements with 2.1m Antenna



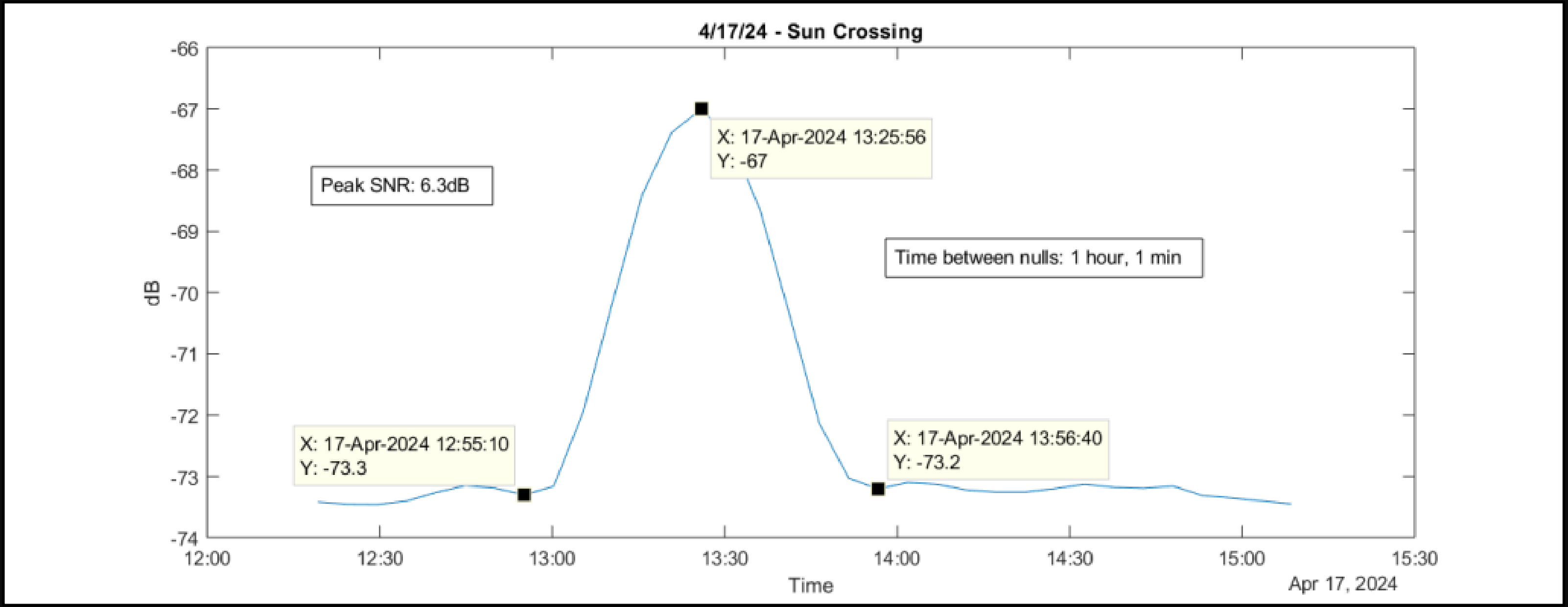






Project 3 – Total Power Measurements with 2.1m Antenna (cont'd)

- What is a Total Power Measurement?
  - Previous measurements were spectrums: Frequency vs. Amplitude
  - Total Power: Time vs. Amplitude => Total power contained in entire bandwidth detected plotted over time (hours, minutes)



Example – Sun Crossing: signal received as Sun crosses over radio telescope beam

Bandwidth of Software Defined Radio (SDR) can be set. Max = 4.8MHz

Project 3 – Total Power Measurements with 2.1m Antenna (cont'd)

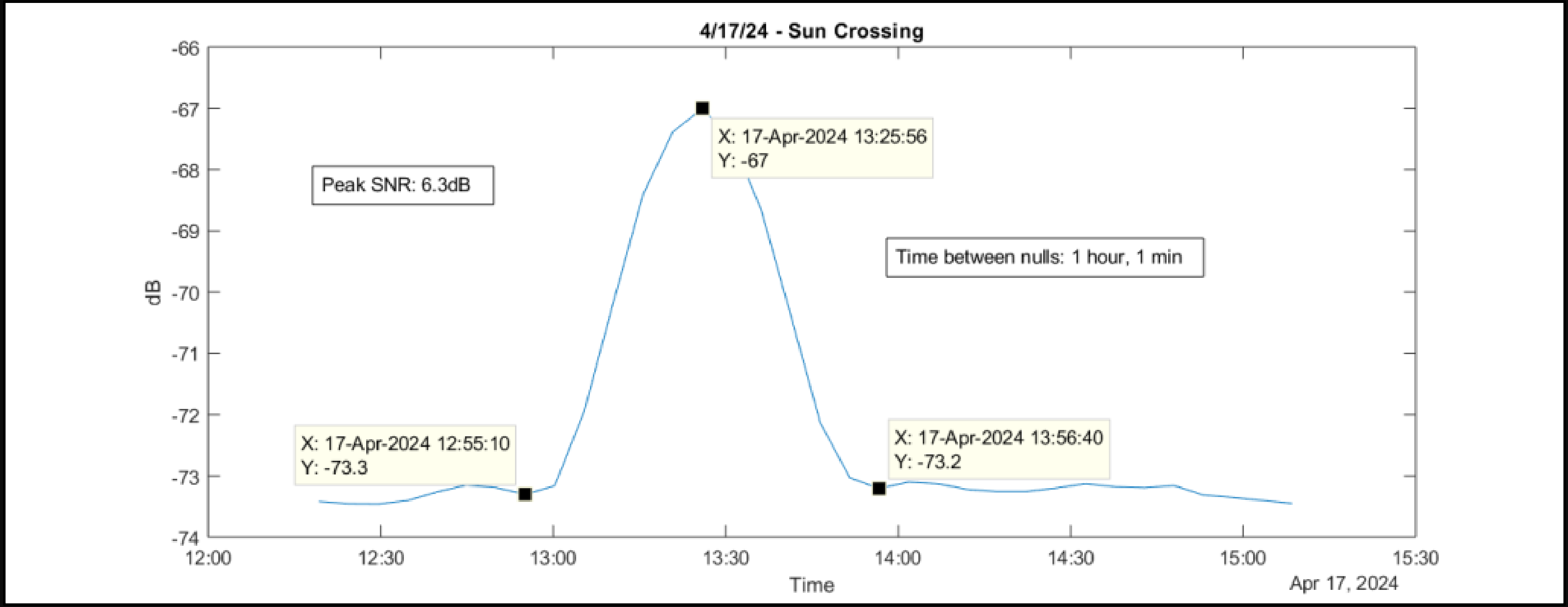
★ Project 3A

Sun Crossings and the Solar Flux Unit SFU

Doug Holland

Project 3 – Total Power Measurements with 2.1m Antenna (cont'd)

- We can perform Sun crossings to measure the changing solar flux from day to day and over the solar cycle
- NOAA website lists the Sun's Solar Flux Unit (SFU) for each day for various frequencies: https://services.swpc.noaa.gov/text/solar_radio_flux.txt



Doug Holland

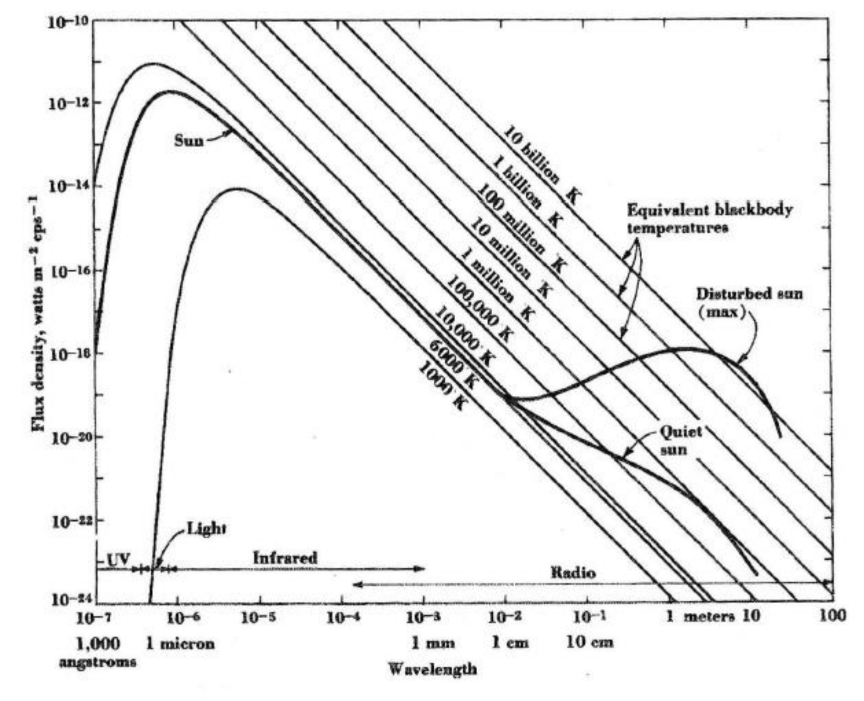


Fig. 8-34. The solar spectrum from the ultraviolet to radio wavelengths (heavy curve). The solar flux density is equal to that from a blackbody radiator at 6000 K at wavelengths less than 1 cm but is greater than this at longer wavelengths. At radio wavelengths the radiation is between that of the quiet- and disturbed-sun curves. The other (lighter) curves give the flux density corresponding to blackbody radiators at various temperatures in degrees Kelvin.

Radio Astronomy by John D. Kraus

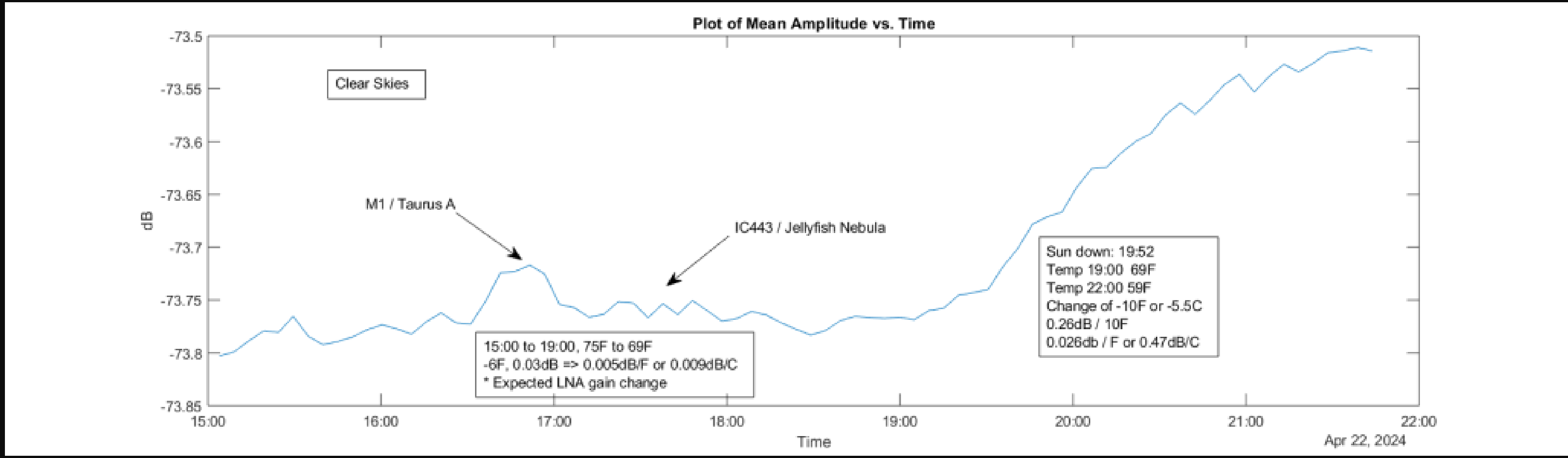
Project 3 – Total Power Measurements with 2.1m Antenna (cont'd)

★ **Project 3B**

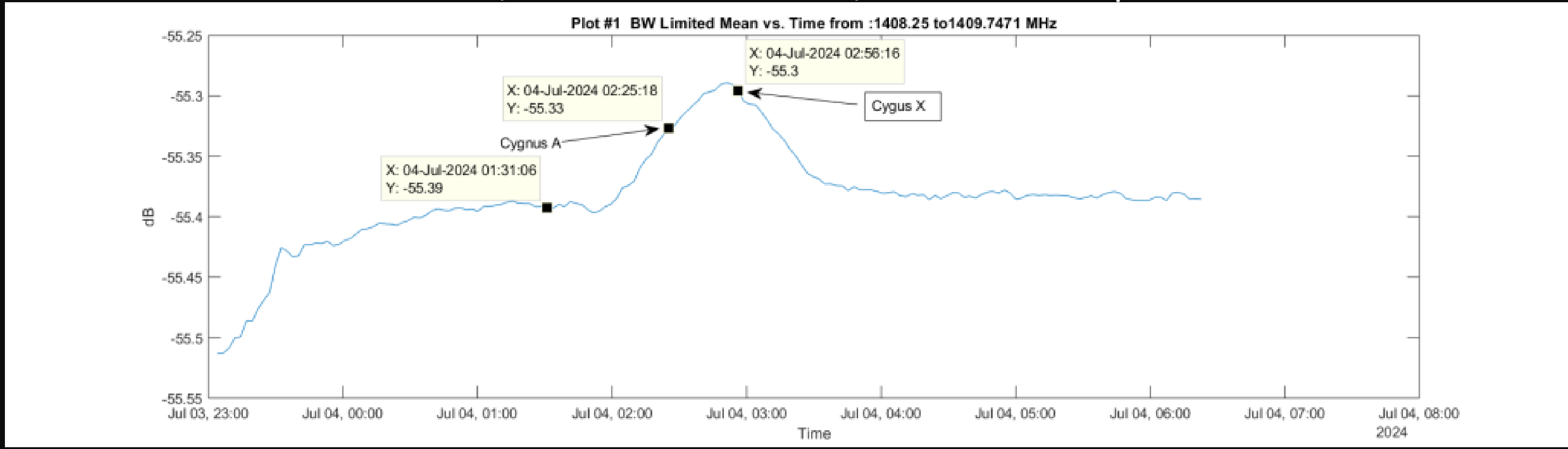
Total Power Measurements of Celestial Objects

Doug Holland

Project 3 – Total Power Measurements with 2.1m Antenna (cont'd)



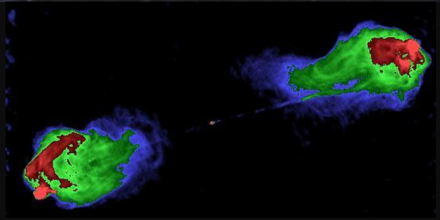
1407 MHz, 4.8MHz Bandwidth, 5 minute samples



1409 MHz, 1.2MHz Bandwidth, 3 minute samples

2.1m Radio Telescope, H1 LNA, Airspy mini SDR, SDR# software

Doug Holland



https://en.wikipedia.org/wiki/Cygnus_A#/media/File:3c405.jpg

https://en.wikipedia.org/wiki/Cygnus_X_(star_complex)

Project 3 – Total Power Measurements with 2.1m Antenna (cont'd)

★ **Project 3C**

Total Power Measurements using Power Detector Receiver

Project 3 – Total Power Measurements with 2.1m Antenna (cont'd)

We would like to increase the sensitivity of our radio telescope without having to make it bigger, and bigger

$$F_v(\text{min}) = \text{SNR}\left(\frac{4k}{A_{eff}}\frac{T_{sys}}{\sqrt{bw * nt}}\right)$$

Sensitivity Formula

$F_v(\text{min})$ = *minimum flux density*

$Tsys = system\ noise$

$bw = bandwidth$

$n = number\ of\ subsamples$

$t = sampling\ time$

SNR = signal to noise ratio

$4k = 4\ x\ Boltzmann's\ constant$

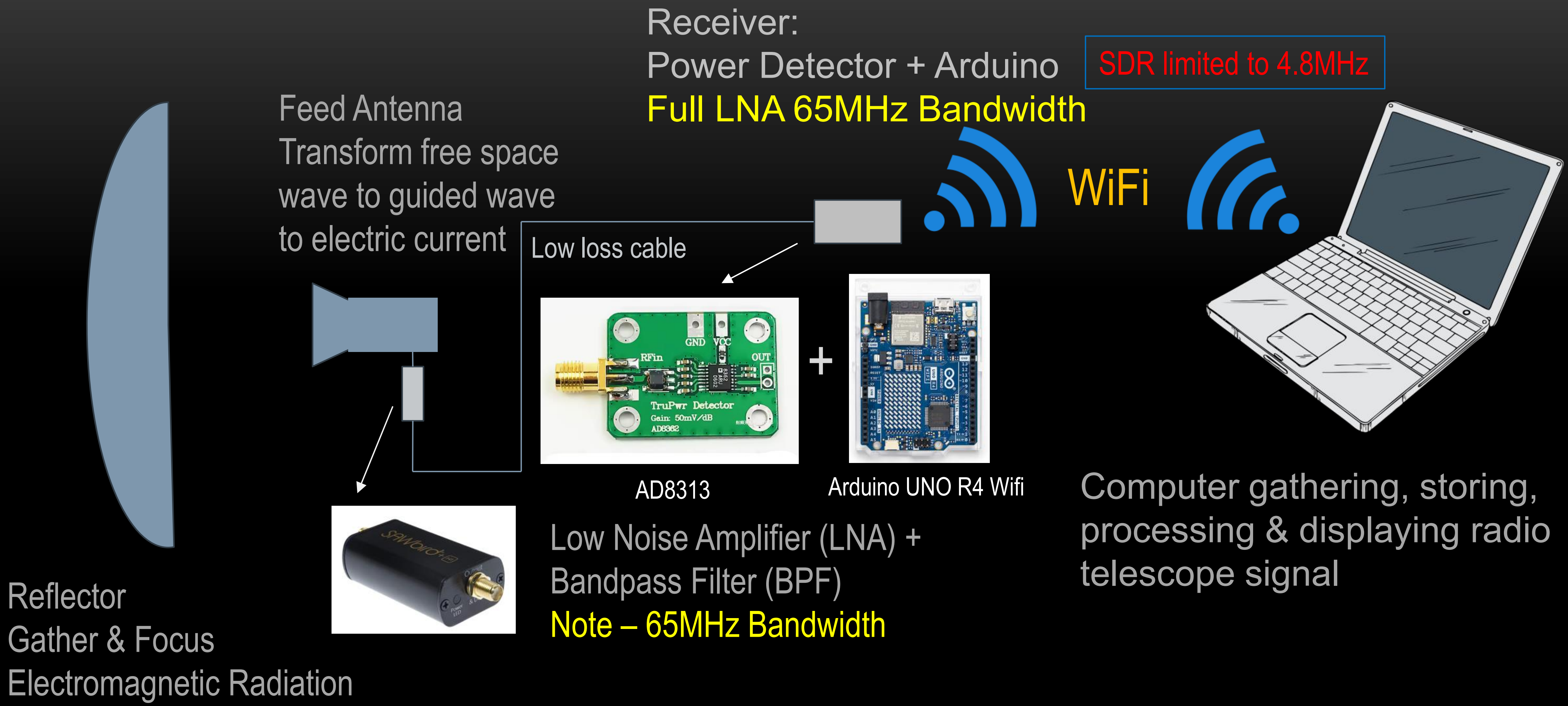
As $\sqrt{bw}$ increases, minimum flux decreases

Increasing bw improves radio telescope sensitivity

The Holland Observatory
Ha: 10/29,30/16
OIII: Okie Tex 9/29/24
SII: 10/7,8,10/24

Doug Holland

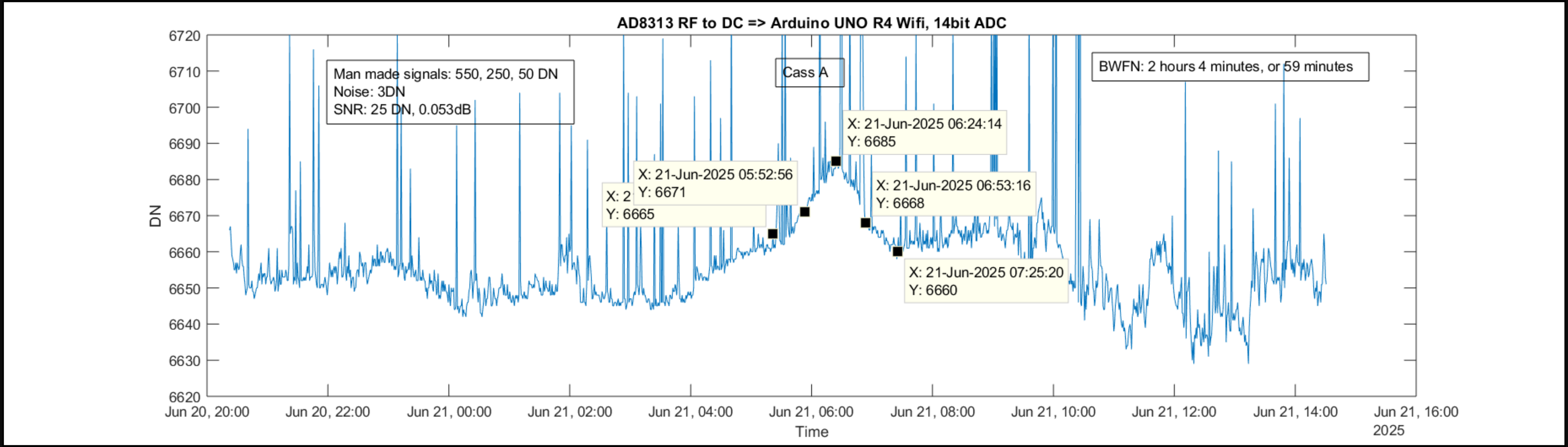
NGC7380: The Wizard Nebula in Cepheus
SII: 56x15min, Ha: 44x15min, OIII: 28x15min
AT8RC Ritchey Chretien Telescope at f/8, SC8300 Camera

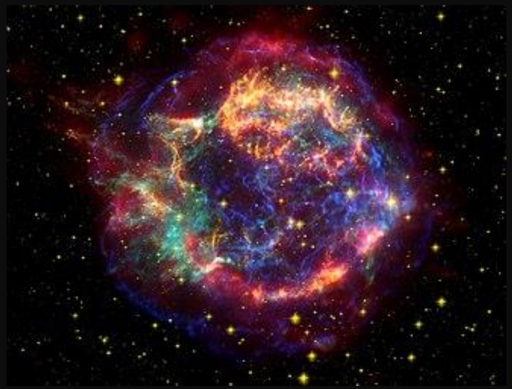


*Note – schematic of Power Detector receiver on web page
www.holland-observatory.net

Power Detector for Receiver

Project 3 – Total Power Measurements with 2.1m Antenna (cont'd)





https://en.wikipedia.org/wiki/Cassiopeia_A

Increasing bandwidth (bw) improves sensitivity, *but* lets more man-made noise through

Doug Holland

Project 4 – What Can be Accomplished with a Satellite TV Dish Antenna

Doug Holland

Member of our astronomy club asked –

Can a satellite TV dish be used for radio astronomy?

Rule of thumb – When someone tells you something cannot be done, someone else is probably already doing it -

SARA – the Society of Amateur Radio Astronomers

Under projects

The itty bitty radio telescope

=> Another member asked about measuring the temperature of the Moon <=

Measuring the Temperature of the Moon

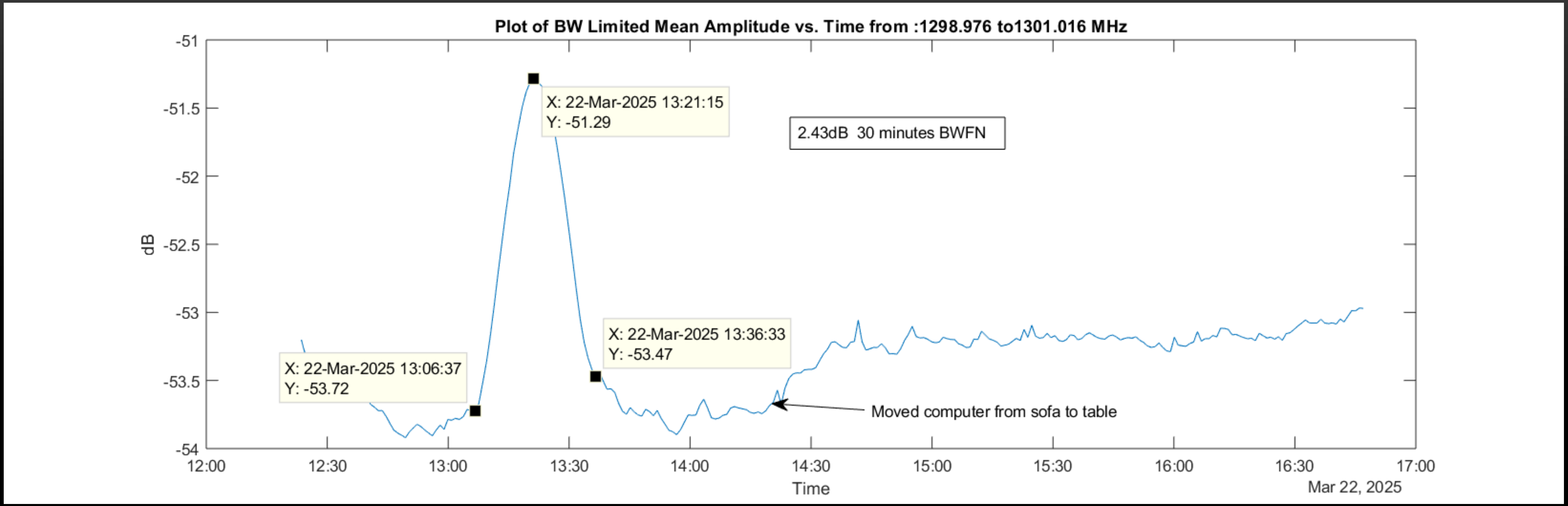
★ **Project 4**

WE WILL ATTEMPT TO USE A SATELLITE TV DISH ANTENNA TO MEASURE THE TEMPERATURE OF THE MOON

despicableme.wikia.com

First question – Can a satellite dish be used to detect celestial objects?

How about try something really bright, like the Sun



Answer – YES! A satellite dish can detect the Sun!

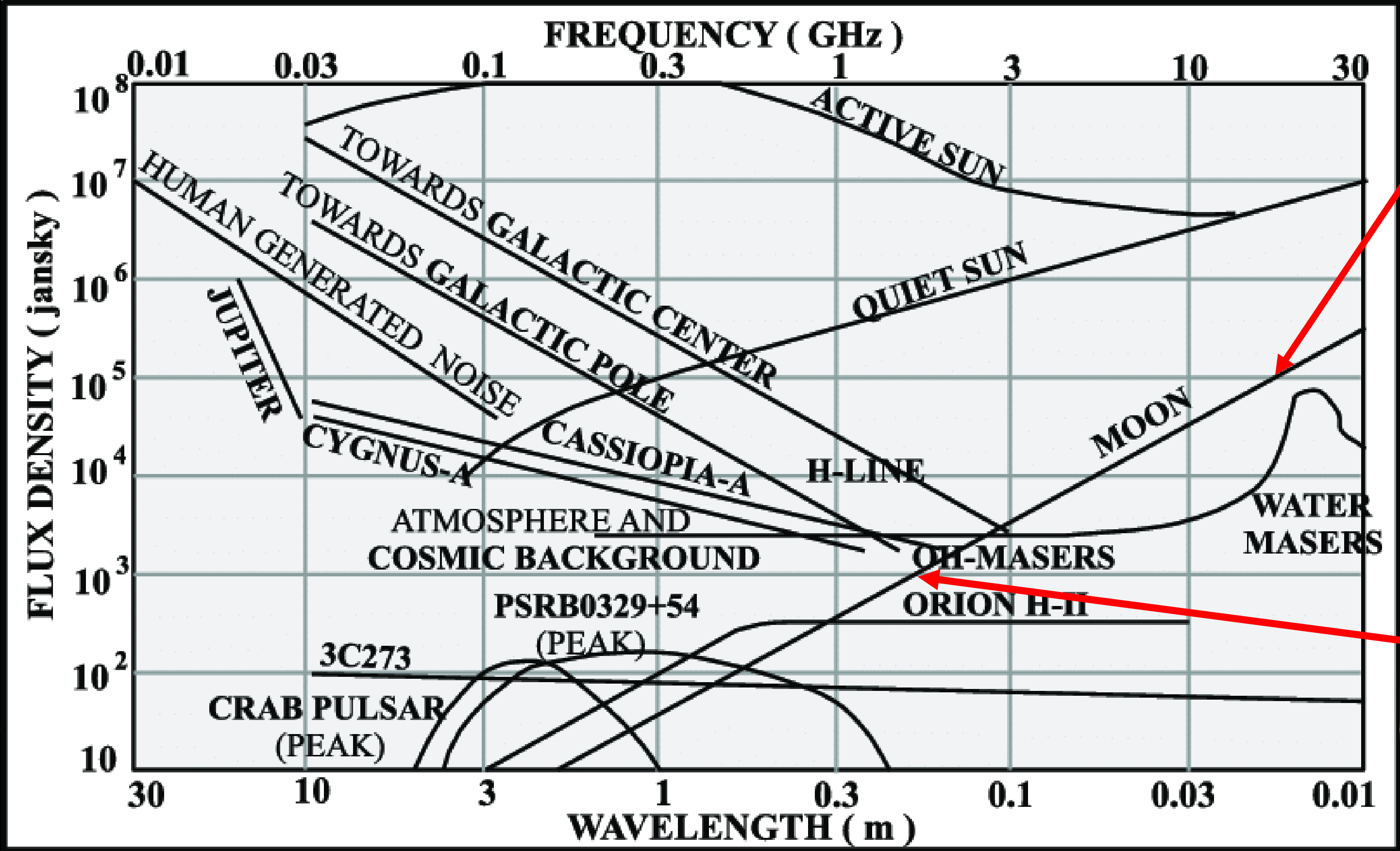
One challenge -

Date of measurement 3/22. Spring Equinox was 3/20.

Anyone got an idea why this could cause a problem?

Second question – Is there any chance a satellite dish could detect the Moon?

1. What frequencies do these detect?
   - From Internet search: 12.2 to 12.7GHz
2. Can we detect the Moon at these frequencies?



Radio Astronomy and Super-Synthesis: a Survey (Researchgate.net)

Approx. 2.36cm (12.7GHz)

!! Moon is about 100x brighter at 12.7GHz than 1.4GHz !!

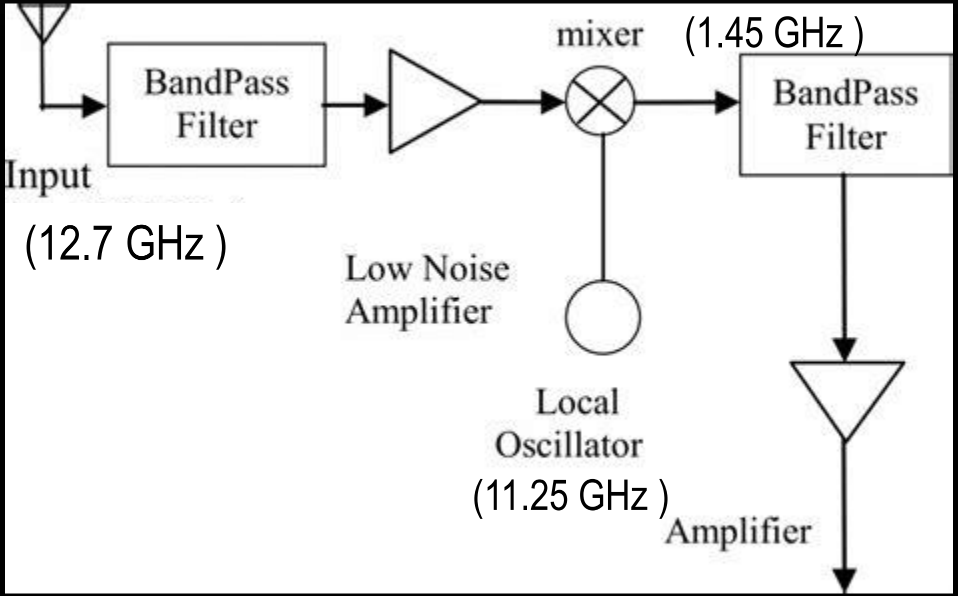
Approx. 21cm (1.4GHz)
Previous frequency area

Third question – Can we use a Software Defined Radio (SDR) for our receiver?

- Freq range of RTL-SDR: 500KHz to 1766MHz
- Freq range of Airspy Mini: 24 to 1700MHz

Signal 12GHz

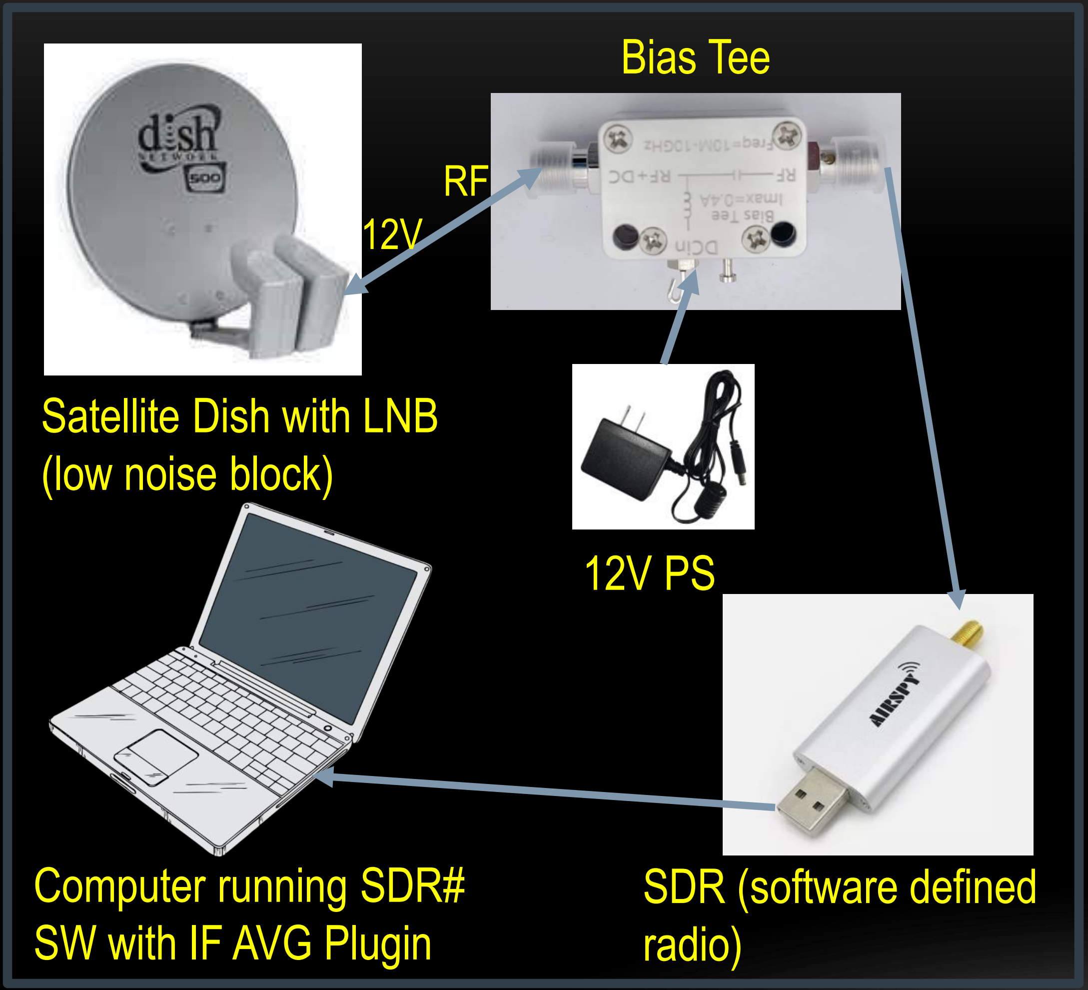
Low Noise Block (LNB)



wiringdigital.com

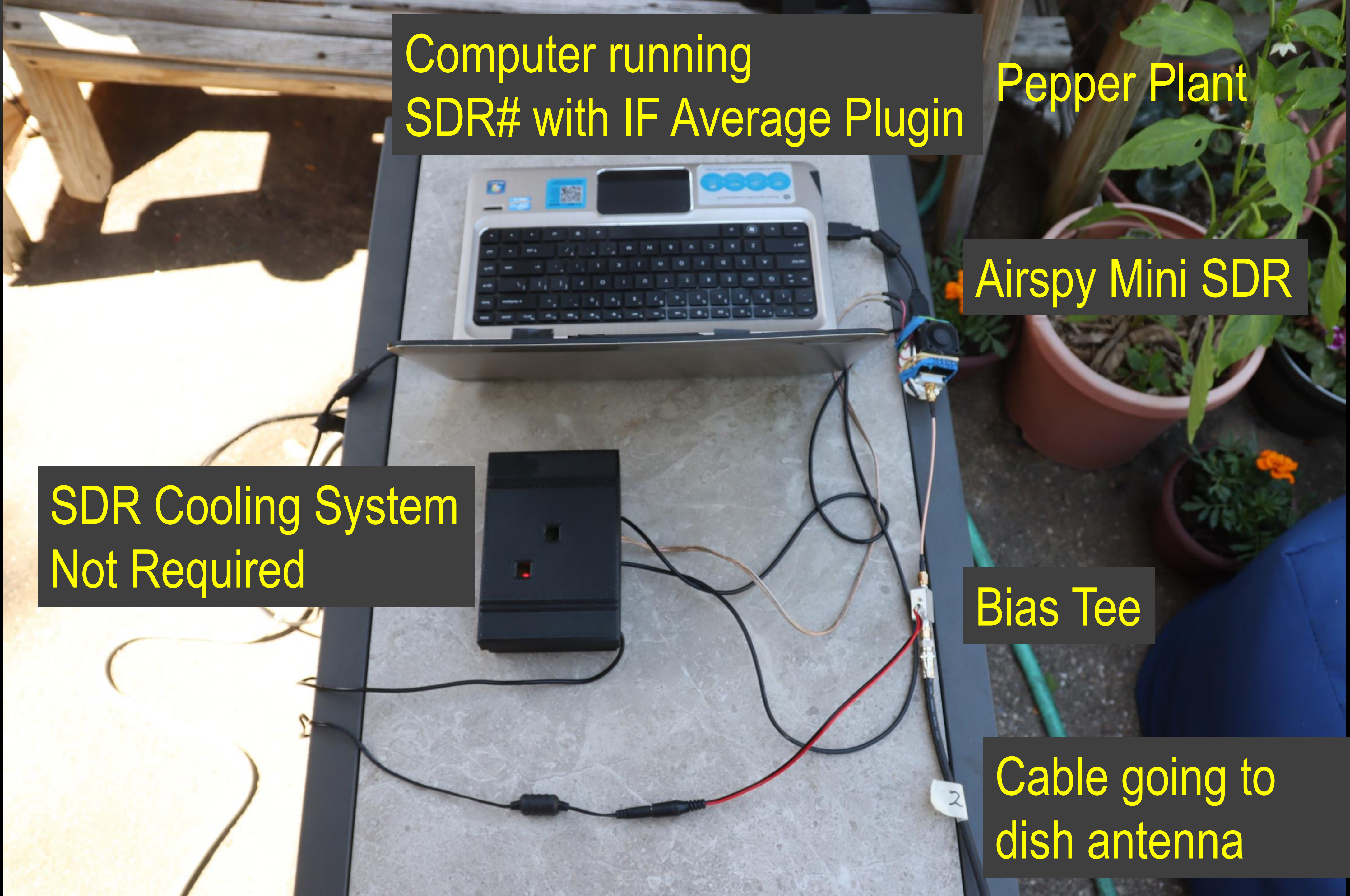
12.7GHz – 11.25GHz = 1.45GHz (1450MHz) => within range of SDR => YES !!

Fourth question – How do you power the LNB (12V) without blowing up SDR?



Signal Path

Aliexpress: Bias Tee / DC Block – routes power to LNB but not to SDR


Computer running
SDR# with IF Average Plugin
Pepper Plant
Airspy Mini SDR
SDR Cooling System
Not Required
Bias Tee
Cable going to
dish antenna

Fifth question – How do you know where antenna is pointing?

- Shape is a section of a parabola, offset feed antenna (LNB)

- *There is a plate on the bottom*

??? Any chance that the angle of the plate corresponds with direction of the antenna beam ???

!!! Turns out that it does => meaning that a protractor with weight on string can be used to set Declination !!!

=> Use compass to align antenna North / South along local meridian

Making the Measurement, Requirements

- Need to determine location of Moon
  - DEC changes every day
    - Find for that day's transit (when it crosses over local meridian – the line in the sky, overhead from North to South)
  - Use Planetarium Software: Kstars, The Sky, Stellarium, etc.

- Need to find usable frequency
  - Satellite interference experienced from 12.45 to 12.65GHz
  - Used 12.7GHz (1450MHz SDR) for measurement

Moon Temperature Measuring Configuration (with cat)

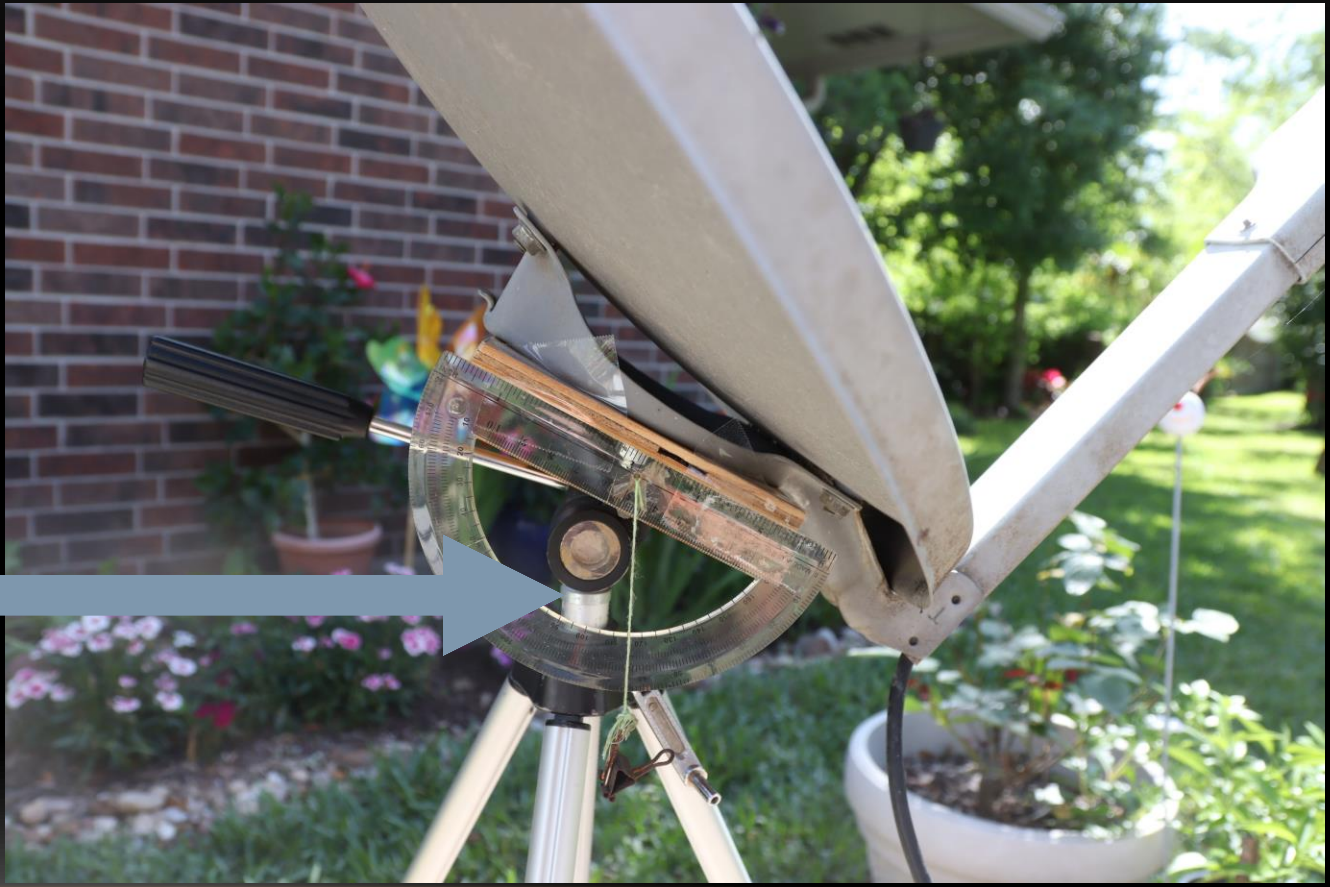
Using the Moon’s Declination (at transit) to Set Protractor

Local Latitude – Moon’s DEC = Protractor Setting

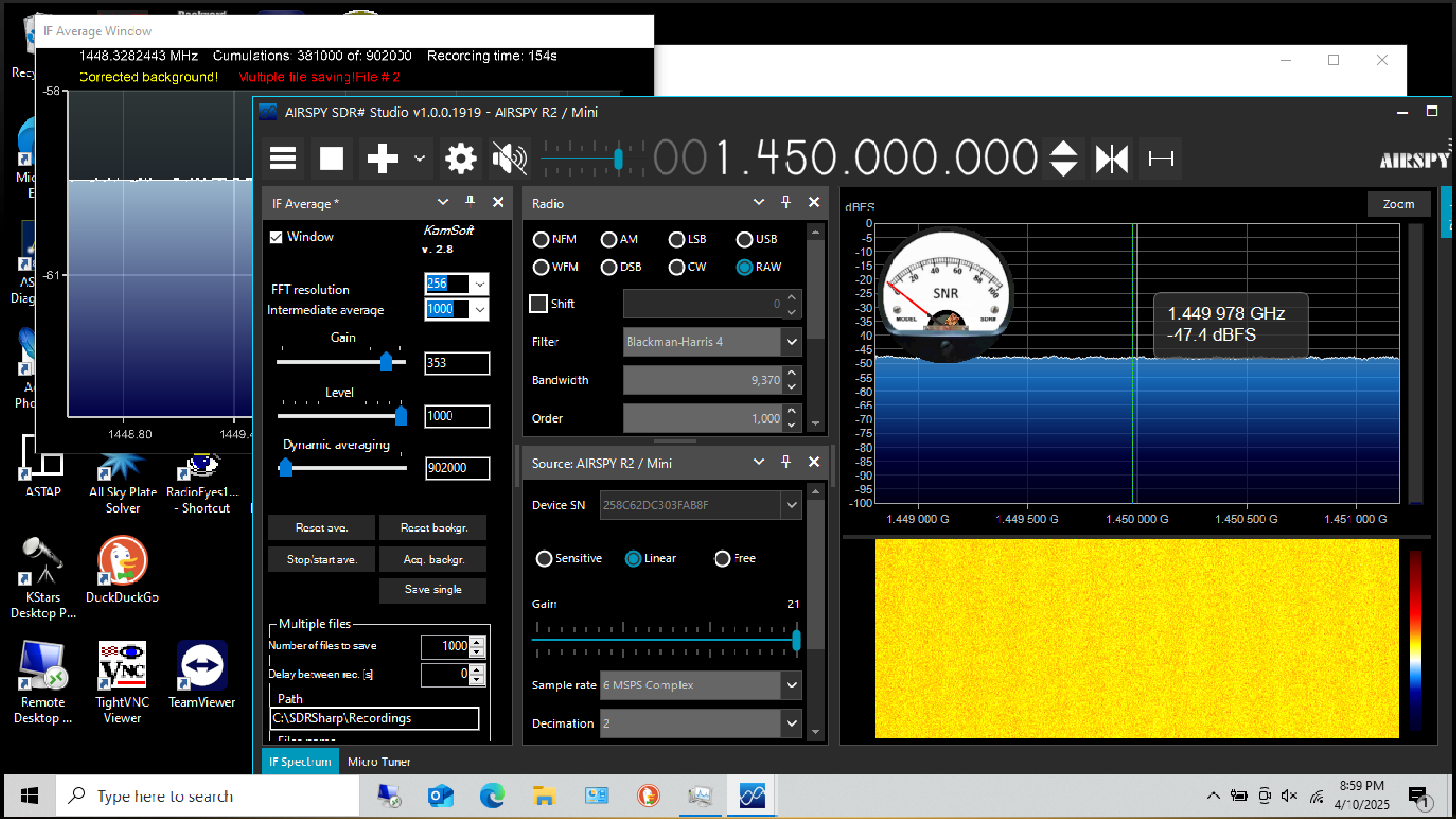
Example:

29º 36’ - 04º 24’ = 25º 12’

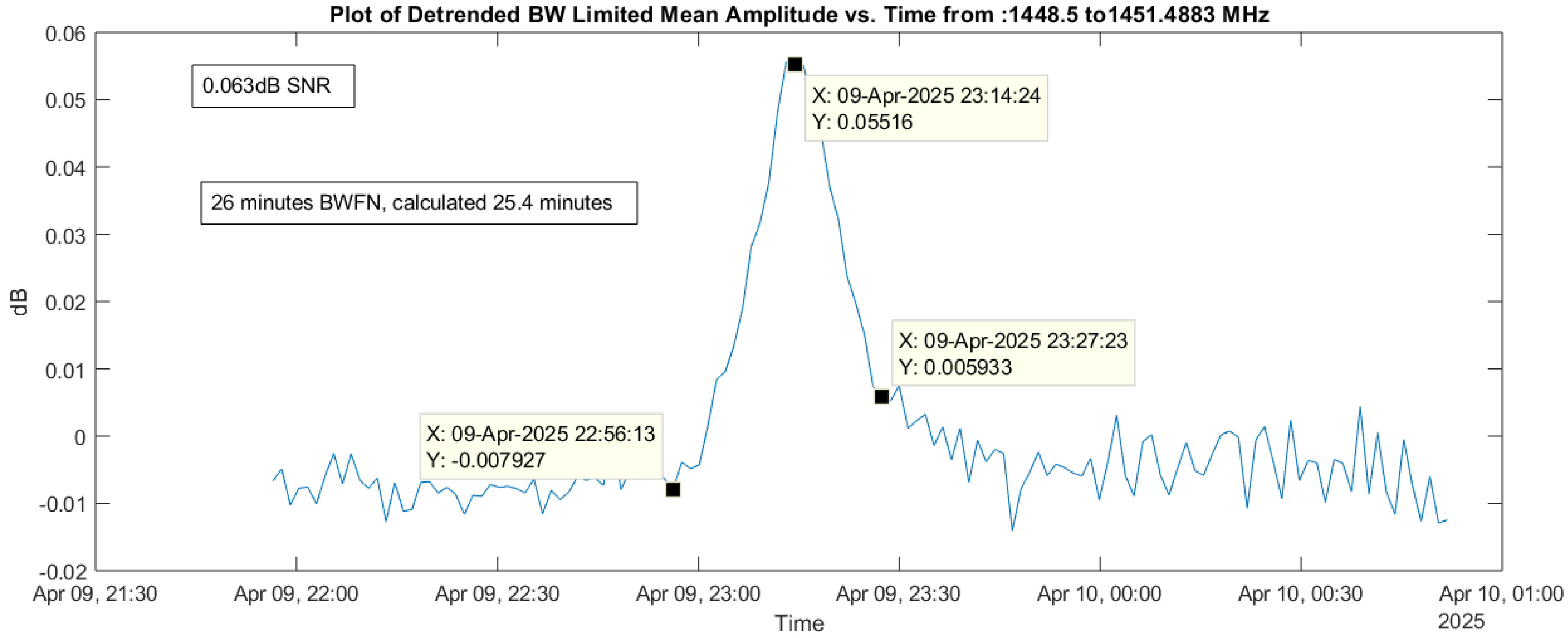
=> Set protractor 25º 12’
South of straight up



Making the Measurement, Software



SDR# with IF Average Plugin (free) – IF Average Plugin creates data files that can be plotted in other program (Excel, Matlab, etc.; example uses Matlab)



Moon Measurement – Amplitude vs. Time

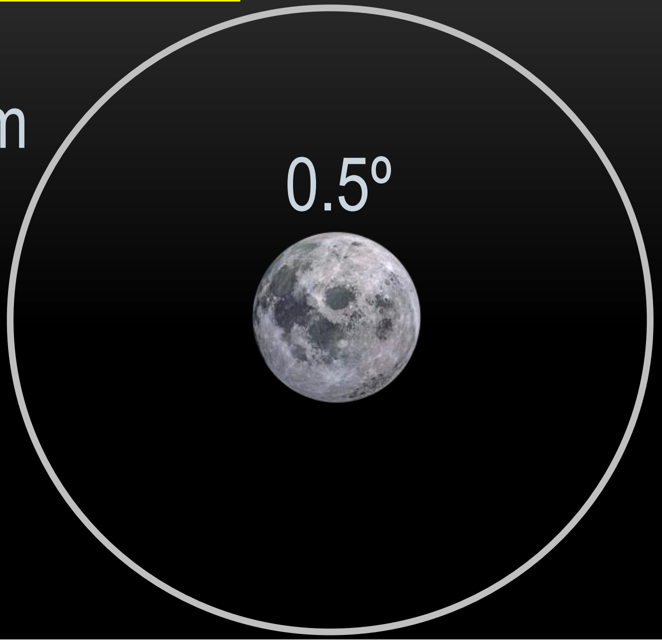
How to use measurement to determine temperature of the Moon

Math is Fun !!

$$Tmoon = \frac{Teff}{R}$$

Antenna Beam

HPBW 3.17°



$$R = \frac{Moon(solid\ angle)}{Antenna\ HPBW\ (solid\ angle)} = \frac{\pi r_{Moon}^2}{\pi r_{HPBW}^2}$$

$$R = \frac{\pi \cdot (0.25^0)^2}{\pi \cdot (1.59^0)^2} = 0.0247$$

From SARA instruction videos

HPBW (half power beam width)

$$HPBW = 70^0 \frac{\lambda}{D}$$

λ = wavelength, D = diameter

$$HPBW = 70^0 \frac{0.0236m}{0.5207m} = 3.17^0$$

Method used for calculations from Klaus Henning, facebook Amateur Radio Astronomy Group 1/10/25

$$Teff = Ttotal - Tsys$$

$$Tsys = system\ noise\ level$$

$$Tsys = \frac{Th - yTc}{y - 1}$$

$Th = temperature\ of\ hot\ area, garage\ wall\ (82^0F)$

$Tc = temperature\ of\ cold\ area, sky\ (10K)$

Need Th in Kelvin, K

$$(((82^oF - 32^0F)\frac{5}{9}) + 273.15K) = 300.9K$$

$$Tsys = \frac{300.9K - 2.0893(10K)}{2.0893 - 1}$$

$$Tsys = 257K$$

$$PwrhotdB - PwrcolddB = 10\log(y)$$

$PwrhotdB = Hot\ power\ measured\ in\ dB$

$PwrcolddB = Cold\ power\ measured\ in\ dB$

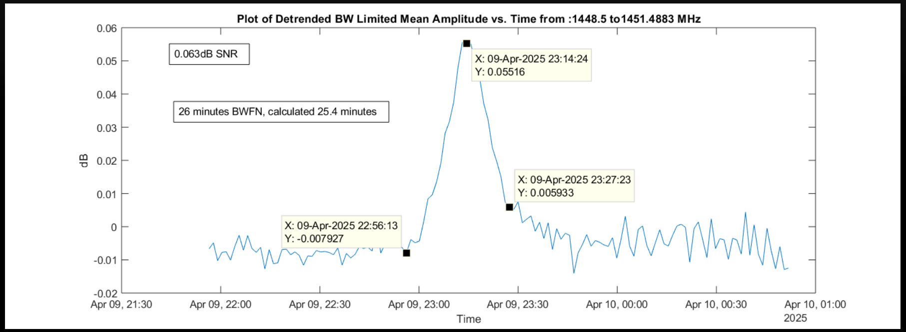
$$-47.5\text{dB} - (-50.7\text{dB}) = 3.2\text{dB} = 10\log(\text{y})$$

$$\text{y} = 2.0893$$

$$Teff = Ttotal - Tsys$$

$$\frac{Ttotal}{Tsys} = 10^{\Delta Tdb/10}$$

$$\Delta TdB = MoondB\ above\ cold\ sky = 0.063dB$$



$$\frac{Ttotal}{Tsys} = 10^{0.063db/10} = 1.0146$$

$$Ttotal = Tsys \cdot 1.0146 = 257K \cdot 1.0146 = 260.75K$$

$$Teff = Ttotal - Tsys = 260.75K - 257K = 3.75K$$

$$Tmoon = \frac{Teff}{R} = \frac{3.75K}{0.0247} = 151.8K$$

Measured temperature of the Moon: 151.8K

Expected temperature, a little above 200K?

The Radio Sky, Spectra, the Solar System and Our Galaxy 8-55

Wavelength = 2.36cm

Changes with phase of the Moon

Data taken about half way between first quarter and full Moon

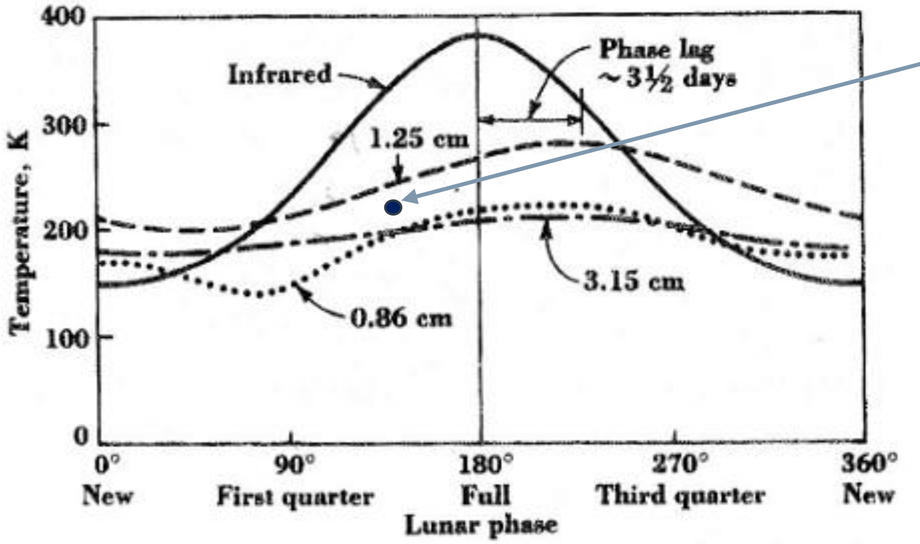
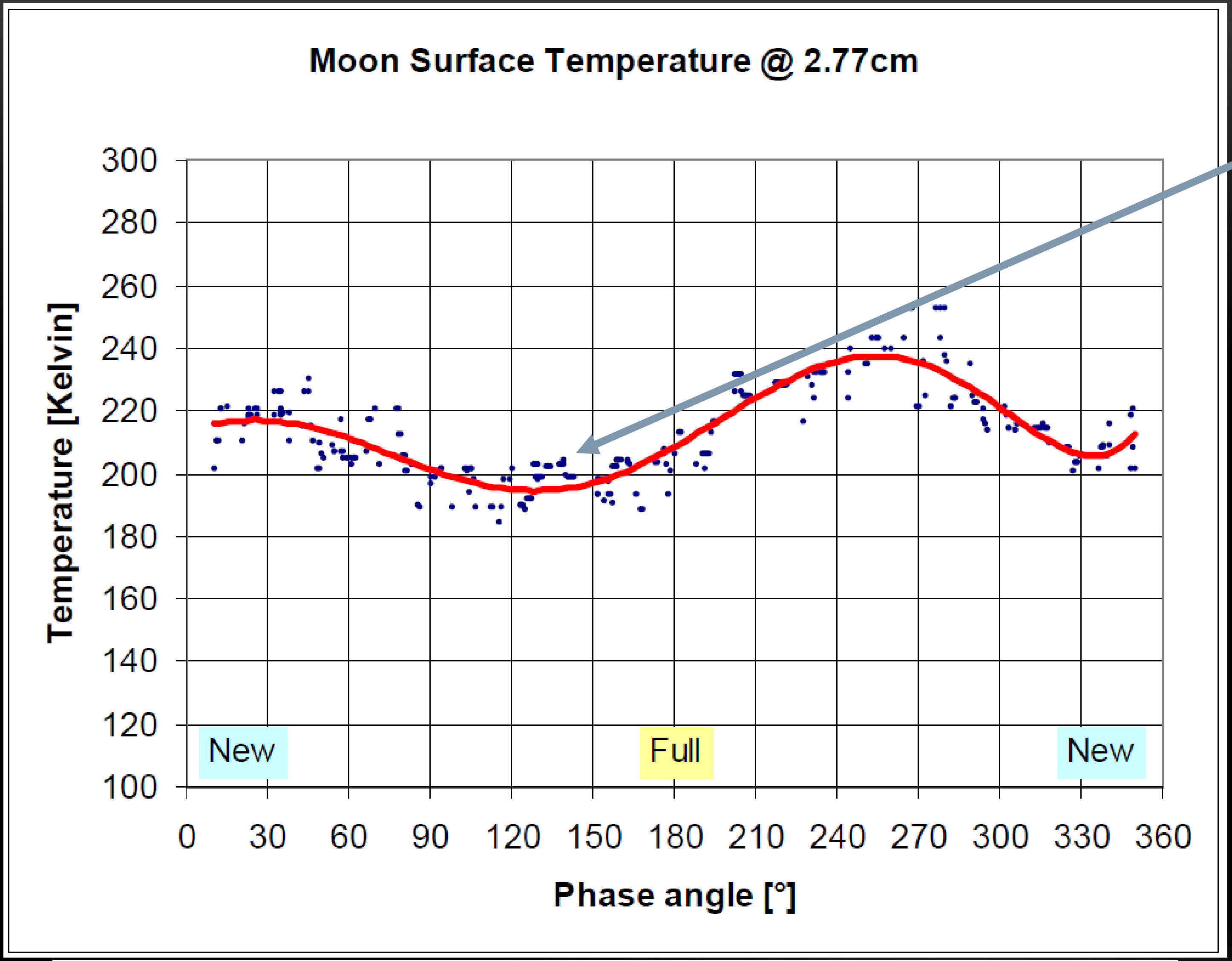


Fig. 8-41. Lunar temperature in kelvins as a function of lunar phase, showing the temperature variation, at infrared wavelengths and at wavelengths of 0.86, 1.25, and 3.15 cm. The temperatures are those of an equivalent blackbody radiator.

Radio Astronomy by John D. Kraus

"The smaller temperature range of the radio temperatures as compared to the infrared values is taken to indicate that the microwave radiation originates at some depth below the surface of the Moon, whereas the infrared radiation comes from a thin surface layer."



Actual measurements just above 200K

Another reference at approx. same wavelength: 2.77cm vs. 2.36cm

ETH Zürich RADIO ASTRONOMY AND PLASMA PHYSICS GROUP

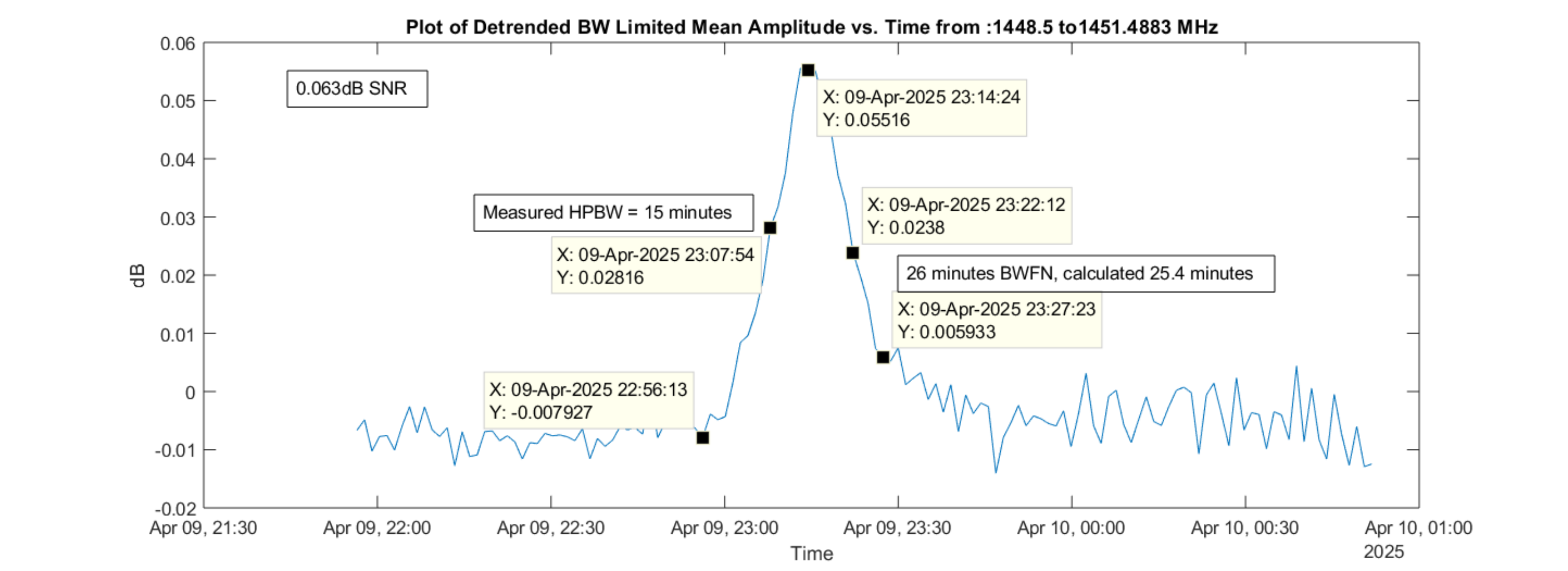
The Moon's Temperature at λ=2.77cm

Christian Monstein

Where could there be errors in our method or calculation?

What about if we measure HPBW rather than calculate it?

15min/60min x 15⁰/hour = 3.75⁰



$$R = \frac{\pi \cdot (0.25^0)^2}{\pi \cdot (1.875^0)^2} = 0.0178$$

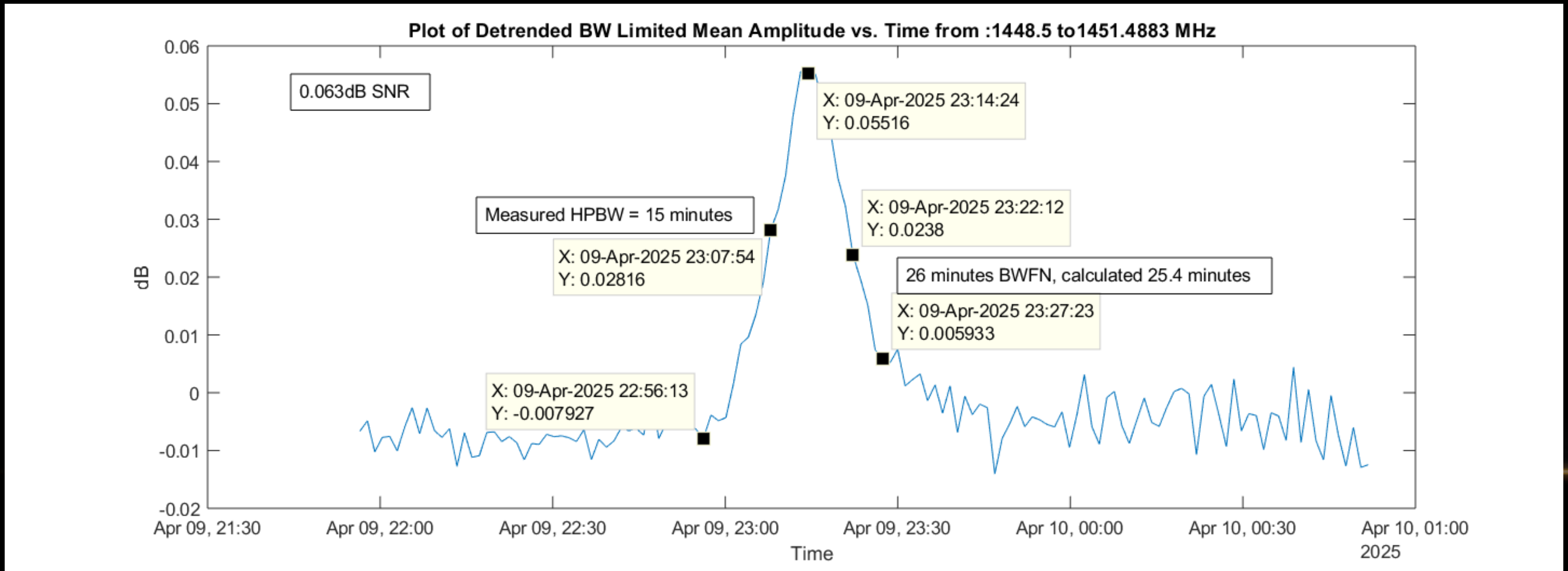
About expected value

$$Tmoon = \frac{Teff}{R} = \frac{3.75K}{0.0178} = 210K$$

Conclusion =>

1. A reasonably ok signal can be received from the Moon at 12.7GHz with a Satellite TV Dish antenna

2. The temperature of the Moon can be measured, with relaxed precision, if measured HPBW is used, and patience



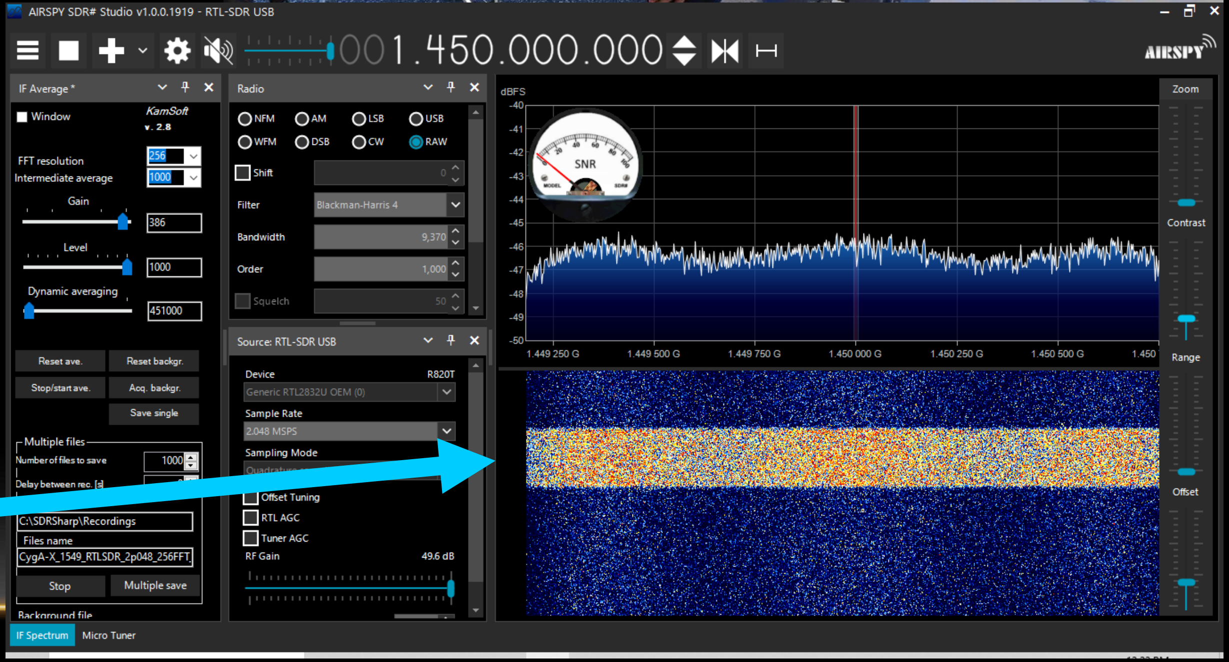
One more thing =>

Doug Holland

Public Outreach (Star Party) Radio Astronomy display!

Ric

not Ric



Detection of radiation from human bodies

Live demonstration of a Radio Telescope

Other Projects that Can Be Done

- Measure rotation rate of our galaxy, the Milky Way
- Interferometer
- Detect meteors – Sudden Ionospheric Disturbances (SID)
- Detect solar flares – Sudden Ionospheric Disturbance (SID)
- Receive radio signals from Jupiter – Radio Jove
- Detect Water Masers at 22GHz (W49), OH Masers at 1612MHz (NML Cyg), Methanol Masers at 12GHz (W3)
- More…

The Holland Observatory
10/9/21; 9/20-23,26-30,10/1/22

vdB 142 - Elephant Trunk Nebula in IC1396 in Cepheus
R - SII: 36x12min, G - Ha: 24x12min, B - OIII: 36x12min (L:Ha)
AT8RC Telescope at f/8, SC8300 Camera

Resources Available for Amateur Radio Astronomy

- Radio Astronomy, 2nd Edition by John D. Kraus, 1986
- Fundamentals of Radio Astronomy, Observational Methods by Jonathan M. Marr, 2016
- Essential Radio Astronomy by James J. Condon and Scott M. Ransom Online book, https://www.cv.nrao.edu/~sransom/web/xxx.html
- Society of Amateur Radio Astronomers (SARA), $20 per year (well worth it) https://www.radio-astronomy.org/
- Facebook: Amateur Radio Astronomy (group), 6.3K members

The Holland Observatory
9/29/20 & 10/5/20 Home Ha
10/12,13,14/20 Eldorado Star Party SII OIII

Doug Holland

Cederblad 214 - Emission Nebula in Cepheus
LRGB - L&G: Ha 31x15min, R: SII 29x15min, B: OIII 33x15min
200mm Newtonian f/5, MPCC, SC8300 Camera


www.holland-observatory.net
The Holland Observatory
10/11,12,13/25
NGC7000 - North America Nebula and IC5070 - Pelican Nebula in Cygnus
Narrowband - Ha: L&G 30x5min, SII: R 36x5min, OIII: B 36x5min
Canon 200mm Camera Lens at f/3.4, SC8300 Camera