Getting started in radio-astronomy: Equipment, software, projects

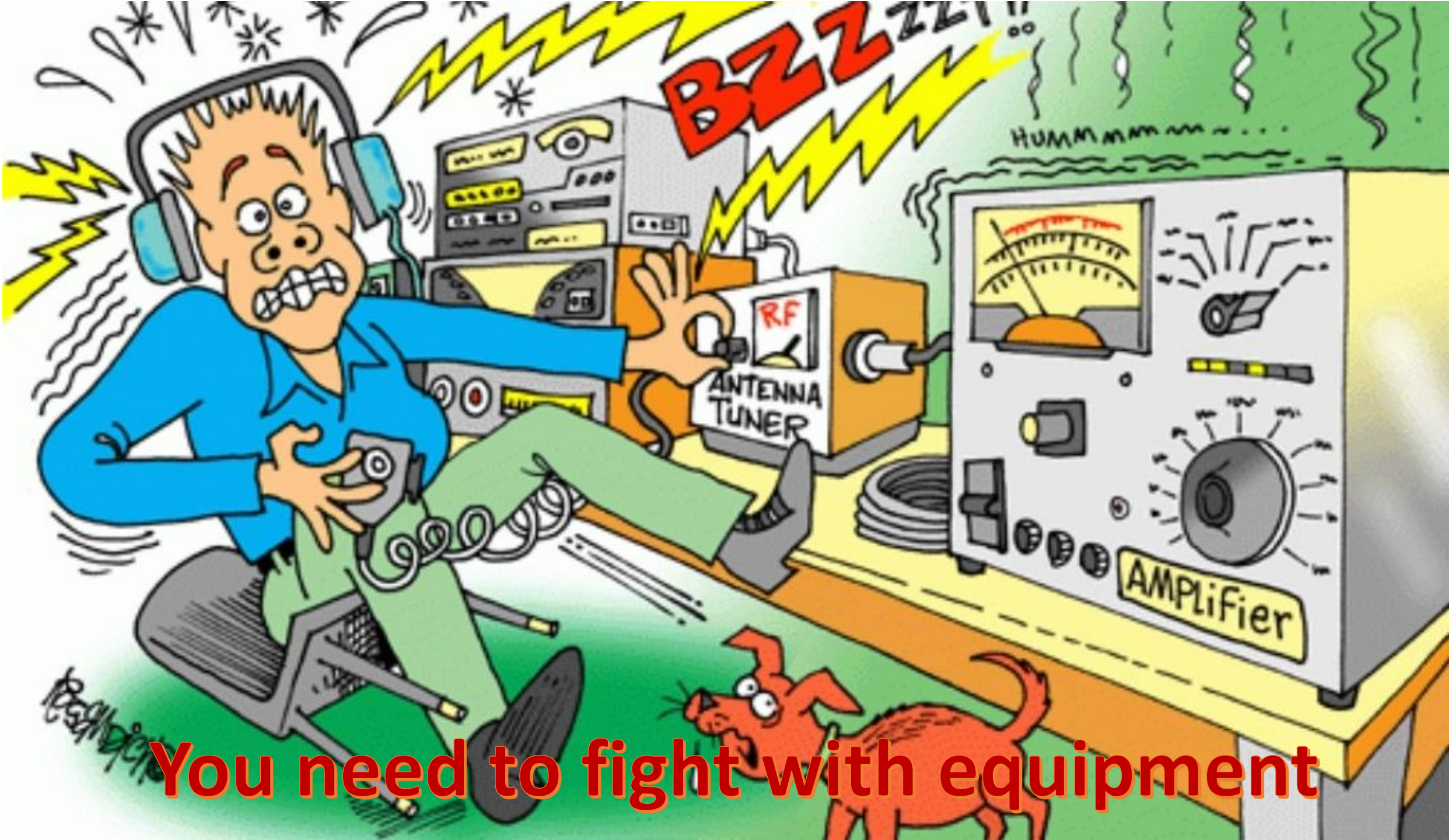
Dr Andrew Thornett

Some myths about radioastronomy

Bigger aerials are always better

But need more space and can cost a lot

Much radio astronomy possible with smaller equipment!

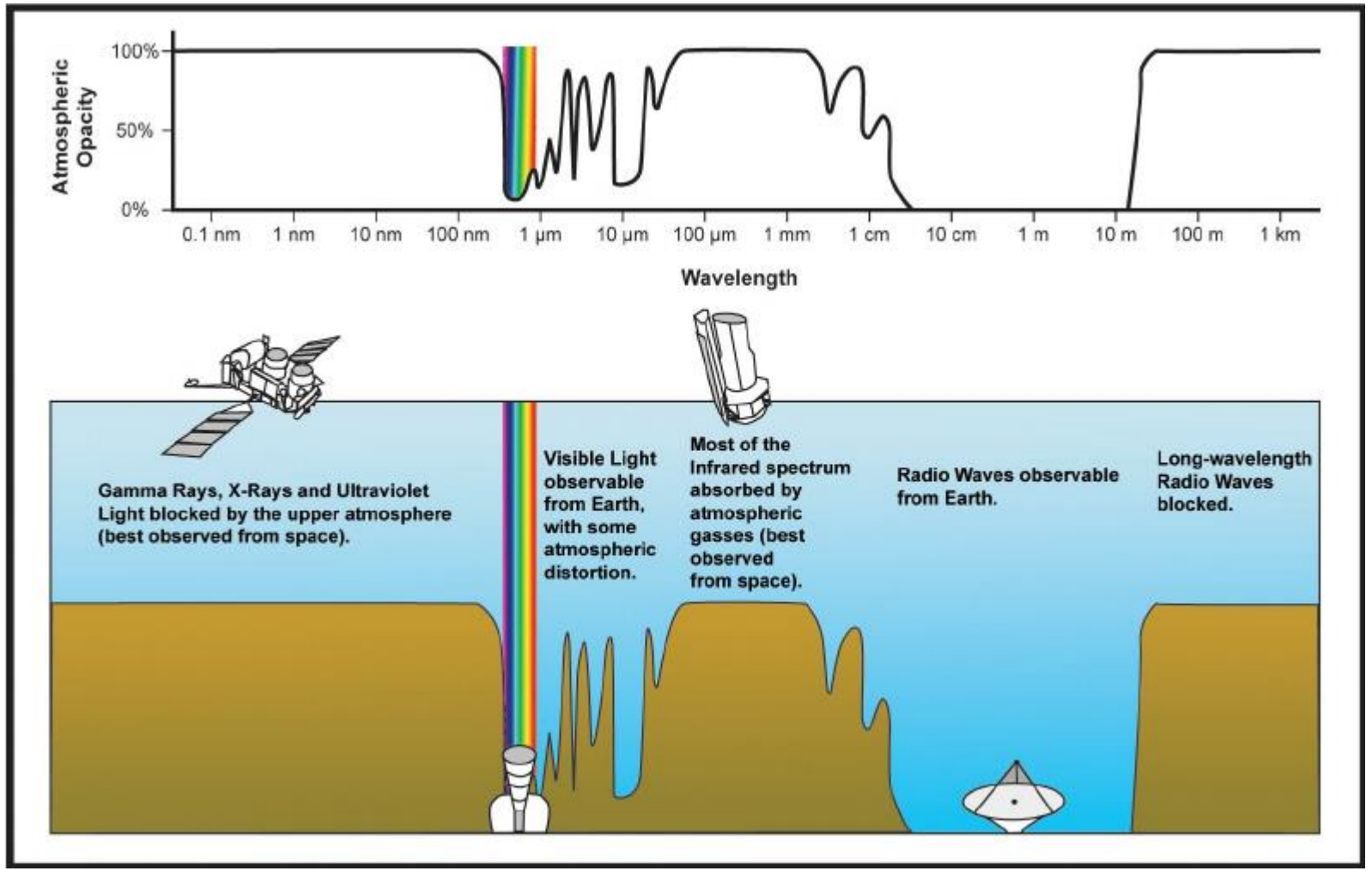


You need to fight with equipment

You need to find a way to monitor your Radio all night and possible all day

And you might even get in contact with aliens

Penetration of electromagnetic radiation through Earth's atmosphere.



Radio Window = Region of radio spectrum that penetrate Earth's atmosphere. Lower limit of radio window's range has value of about 10 MHz ($\lambda \approx 30$ m); the best upper limit achievable from optimal terrestrial observation sites is approx. 1 THz ($\lambda \approx 0.3$ mm).

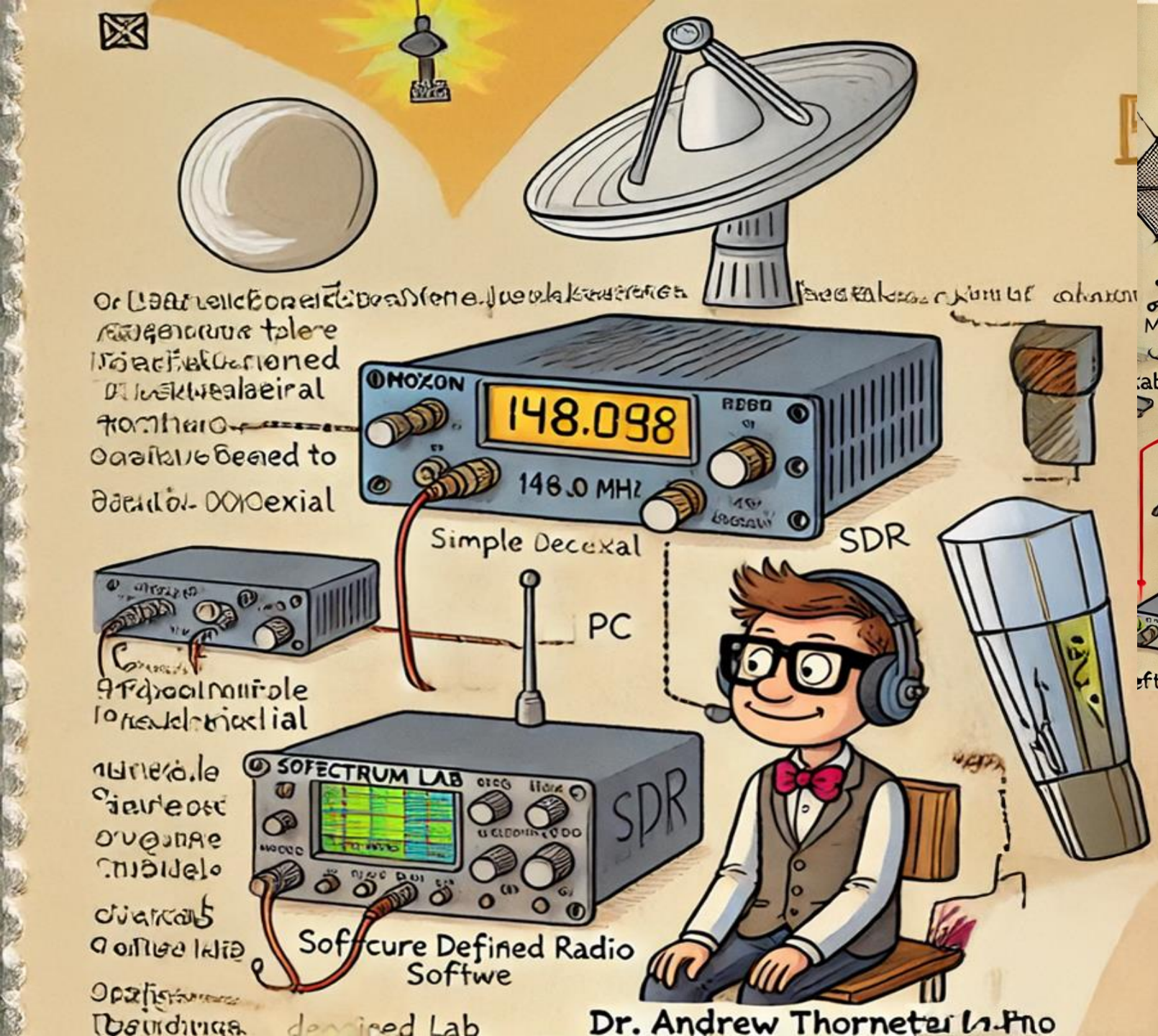
I would recommend starting with
Projects designed by NASA and SARA for schools
And projects for amateur from UKRAA/BAA

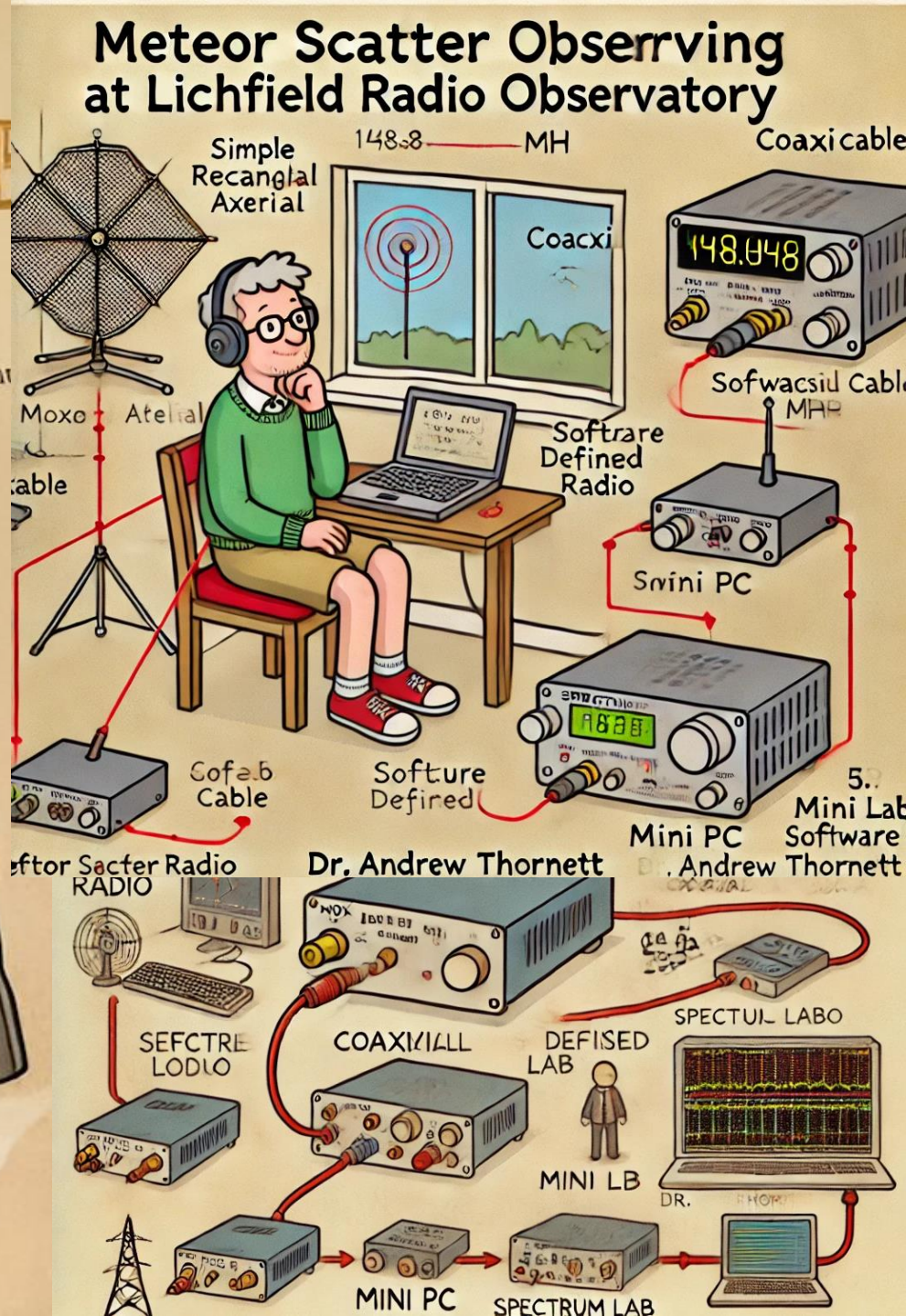
What projects can an amateur astronomer do in their backyard?

- Listen to amateur radio on ISS.
- Record meteors and measure peak of showers even if in daytime.
- Detect solar flares as they hit the atmosphere.
- Record radio emissions from Jupiter.
- Detect hydrogen line in the Milky Way.

Listening to Amateur Radio on ISS

Frequencies for Amateur Radio ISS contacts (QSOs):
1. Voice and SSTV Downlink: 145.80 MHz (Worldwide) (Receive ONLY)
2. Voice Uplink: 144.49 MHz for ITU Regions 2 & 3 (Americas, Pacific, Southern Asia)
3. Voice Uplink: 145.20 MHz for ITU Region 1 (Europe, Russia, Africa)
4. VHF Packet Uplink & Downlink: 145.825 MHz (Worldwide)

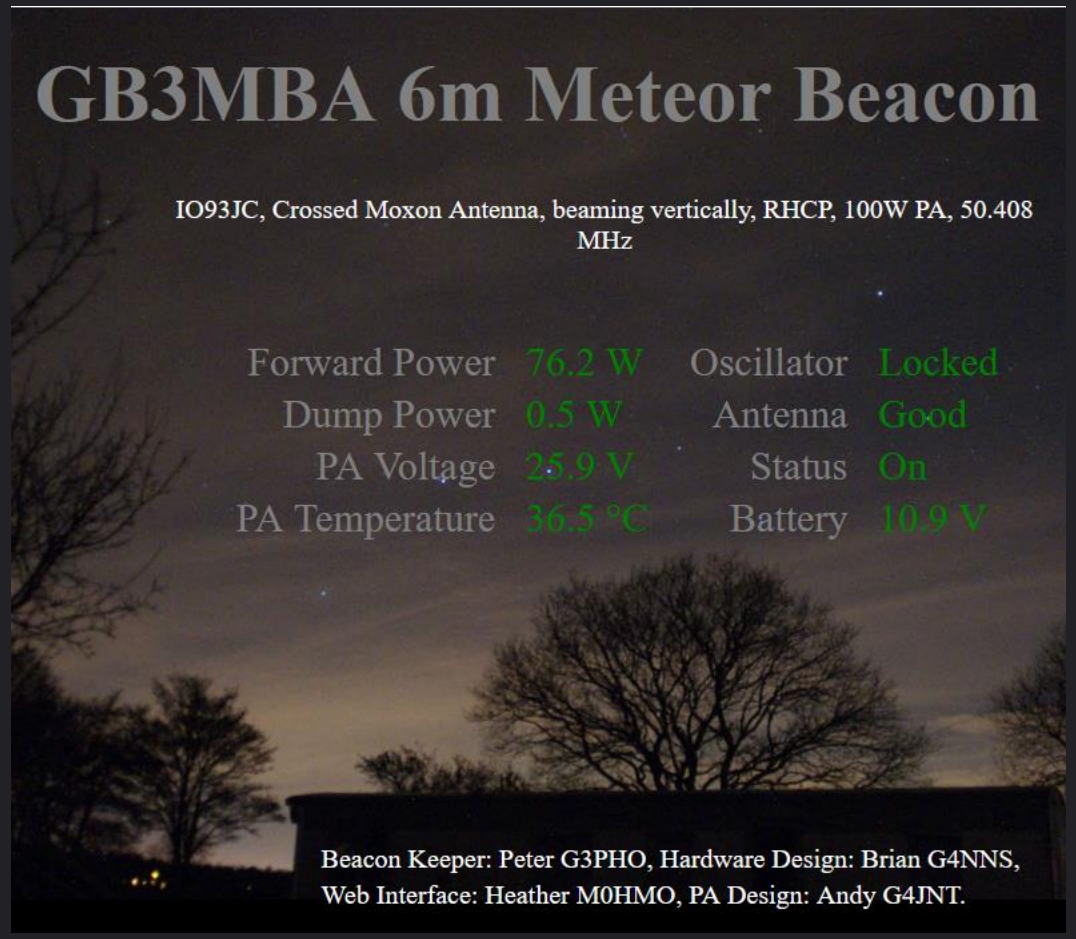

148.098
SDR
PC
SOFECTRUM LAB
SDR
Dr. Andrew Thornett


Meteor Scatter Observing
at Lichfield Radio Observatory
Simple
Recangial
Axerial
148.8 MH
Coaxi cable
148.048
Coaxi
Softrare
Defined
Radio
Smini PC
Cofe.b
Cable
Softure
Defired
Mini PC
Dr. Andrew Thornett
RADIO
SEFCTRE
LODLO
COAXIALL
DEFISED
LAB
SPECTUL LABO
MINI LB
DR.
MINI PC
SPECTRUM LAB

BAA Meteor Beacon Project, GB3MBA.

Top Left: Vertical 1m crossed Moxon Antenna - 50.408 Mhz.

Below Left: Beacon Hardware.



Supported by BAA

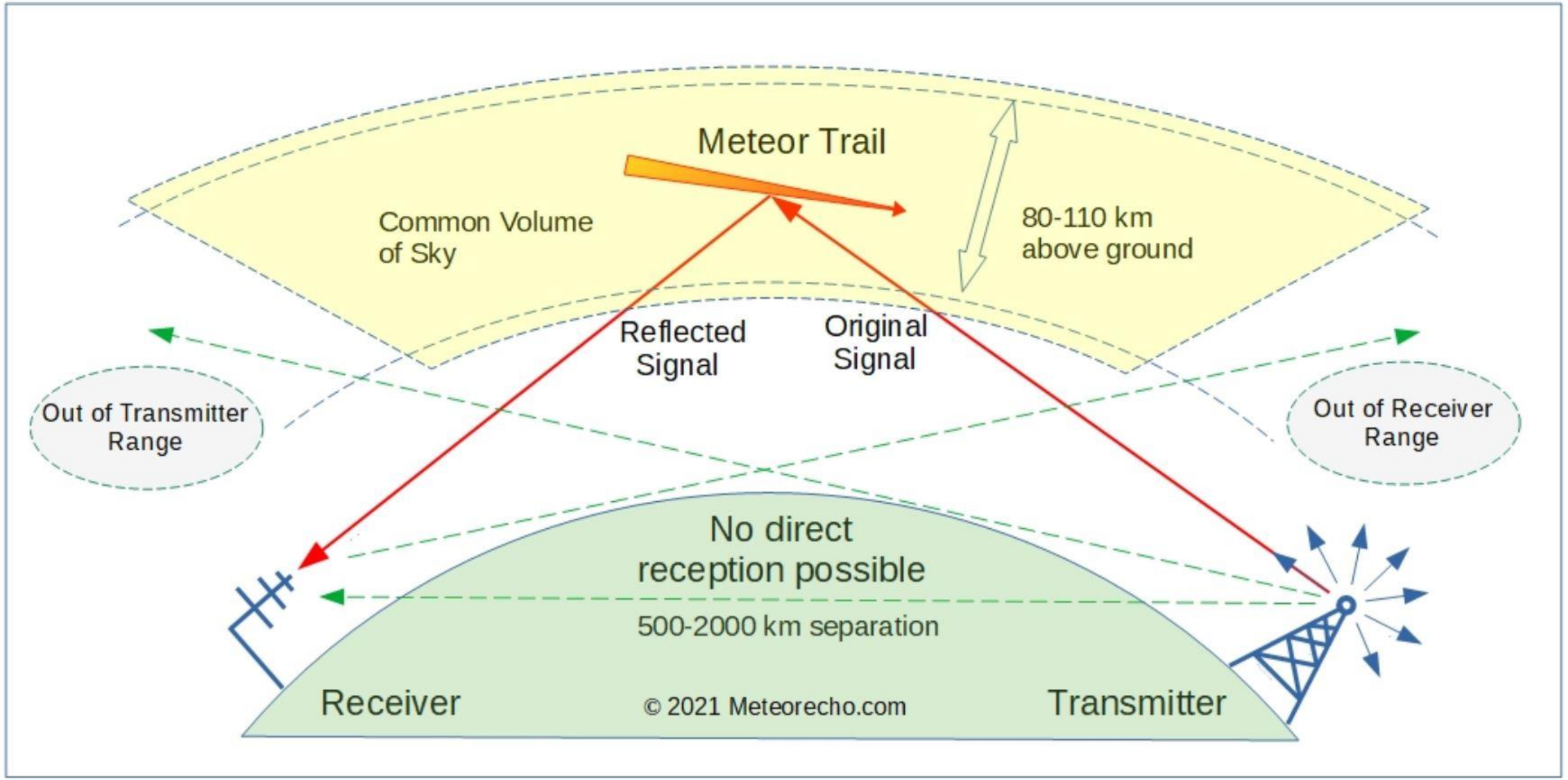
Radio Society of Great Britain
Advancing amateur radio since 1913

SHERWOOD OBSERVATORY

SDRplay

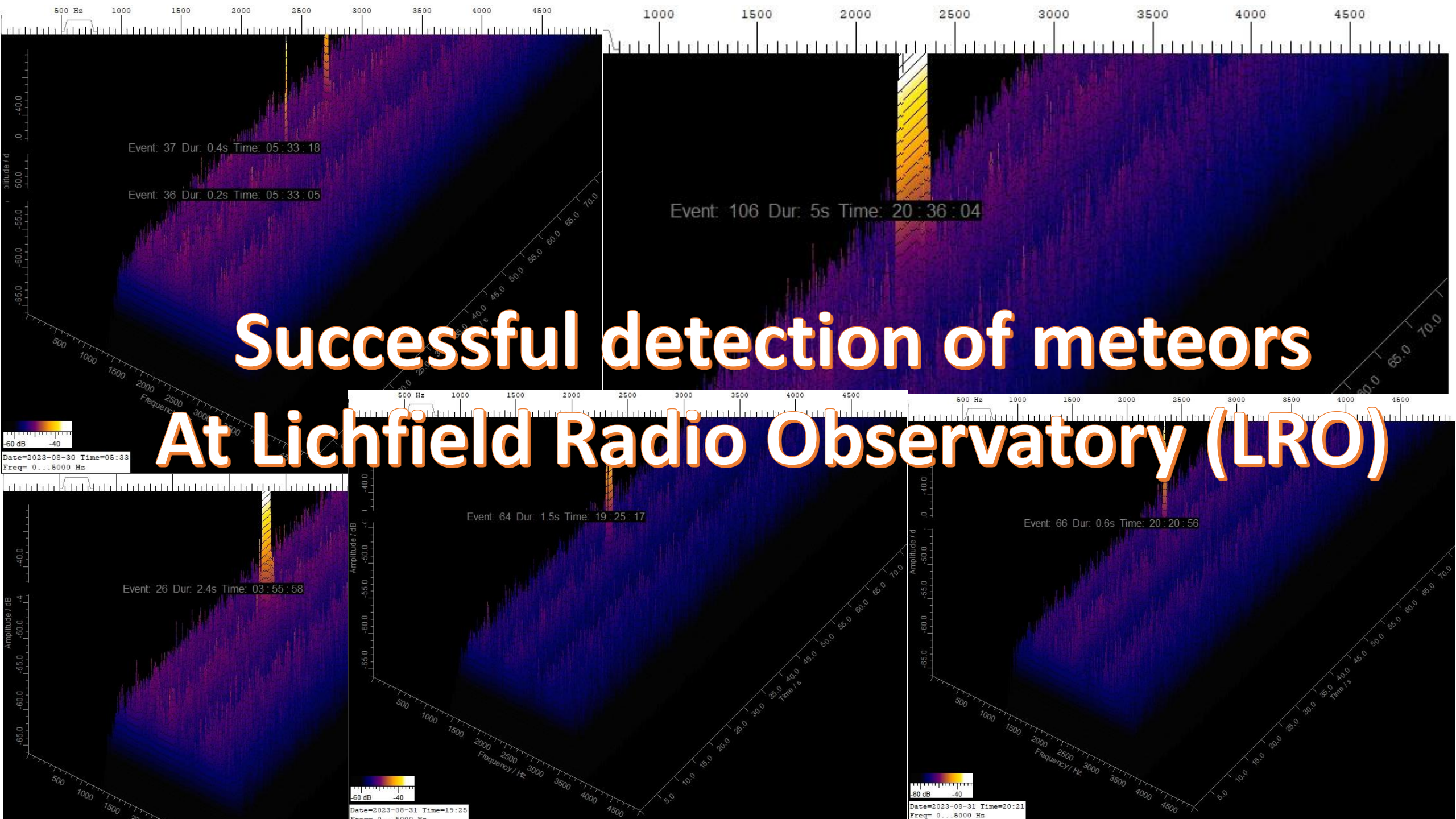
Meteor detection by radio scatter from Grave’s

GRAVES (Grand Réseau Adapté à la Veille Spatiale) = French radar-based space surveillance system, akin to the American Space Force Space Surveillance System.


Meteor Trail
Common Volume
of Sky
80-110 km
above ground
Reflected
Signal
Original
Signal
Out of Transmitter
Range
Out of Receiver
Range
No direct
reception possible
500-2000 km separation
Receiver
© 2021 Meteorecho.com
Transmitter

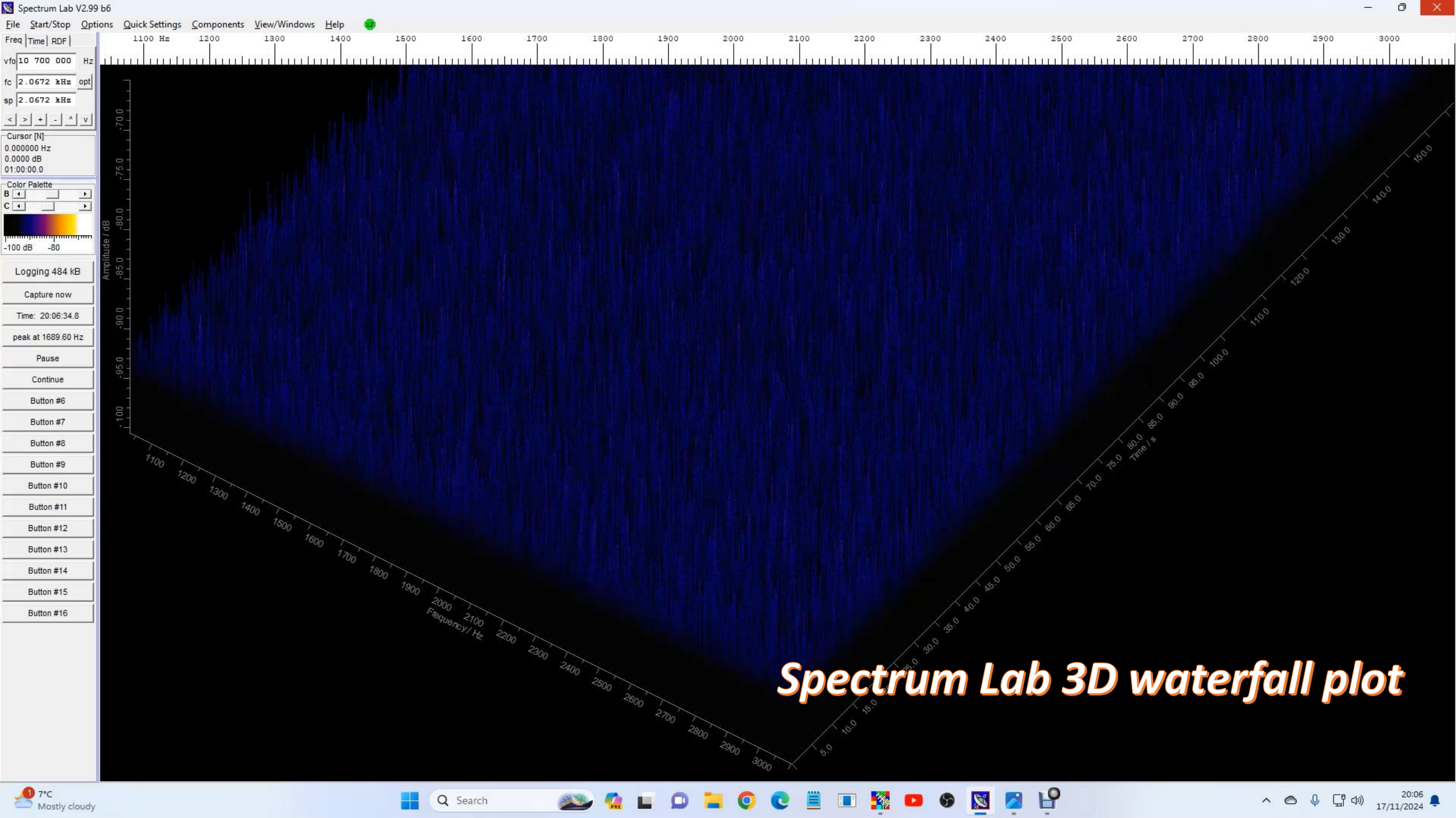
The Major Showers

1. Quadrantids (early January)
2. Lyrids (mid to late April)
3. Eta Aquarids (early May)
4. Delta Aquarids (late July)
5. Perseids (mid August)
6. Orionids (mid to late October)
7. Leonids (mid November)
8. Geminids (mid December)



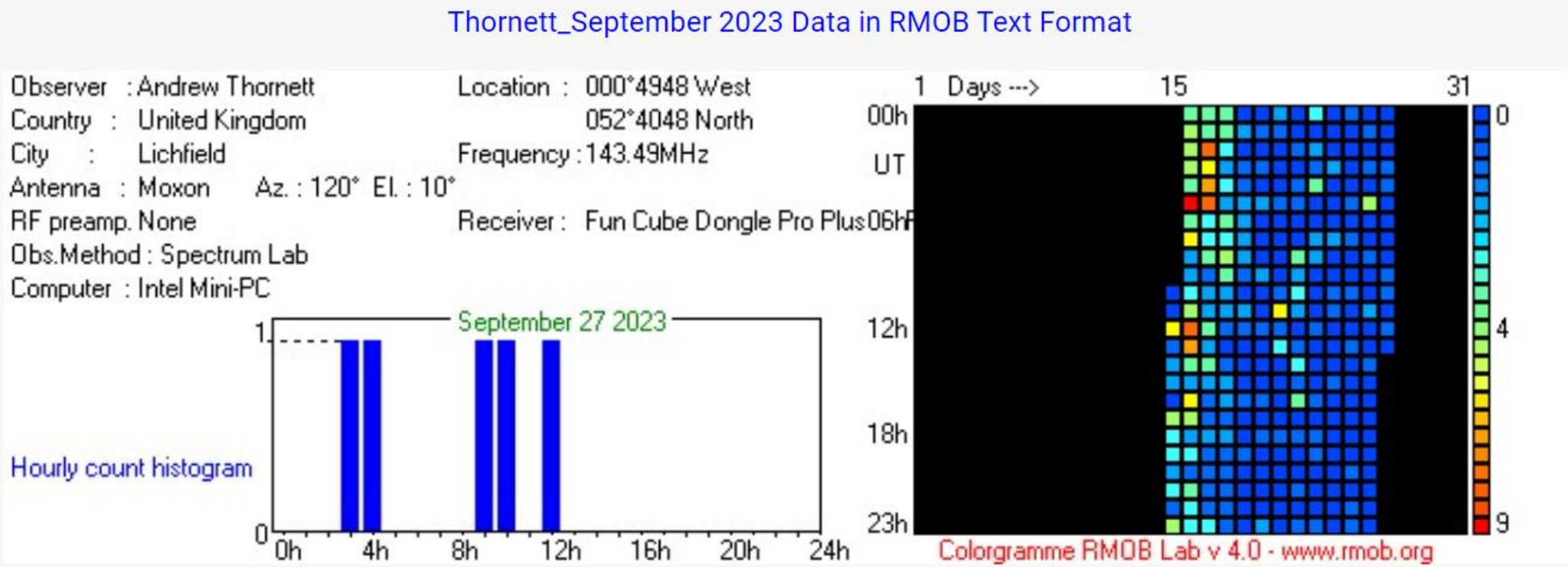
Successful detection of meteors At Lichfield Radio Observatory (LRO)


Spectrum Lab V2.99 b6
File Start/Stop Options Quick Settings Components View/Windows Help
Freq Time RDF
vfo 10 700 000 Hz
fc 2.0672 kHz opt
sp 2.0672 kHz
Cursor [N]
0.000000 Hz
0.0000 dB
22:36:40.1
Color Palette
B
C
-100 dB -80
Captured at 22:43..
Capture now
Time: 22:43:54.7
peak at 1724.87 Hz
Pause
Continue
Button #6
Button #7
Button #8
Button #9
Button #10
Button #11
Button #12
Button #13
Button #14
Button #15
Button #16
1100 Hz 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500 2600 2700 2800 2900 3000
22:43:45
22:43:30
22:43:15
Event: 727 Dur: 1.3s Time: 22:43:10
22:43:00
22:42:45
22:42:30
22:42:15
22:42:00
22:41:45
22:41:30
22:41:15
22:41:00
Spectrum Lab 2D waterfall plot
0°C
Mostly cloudy
Search
22:43
20/11/2024

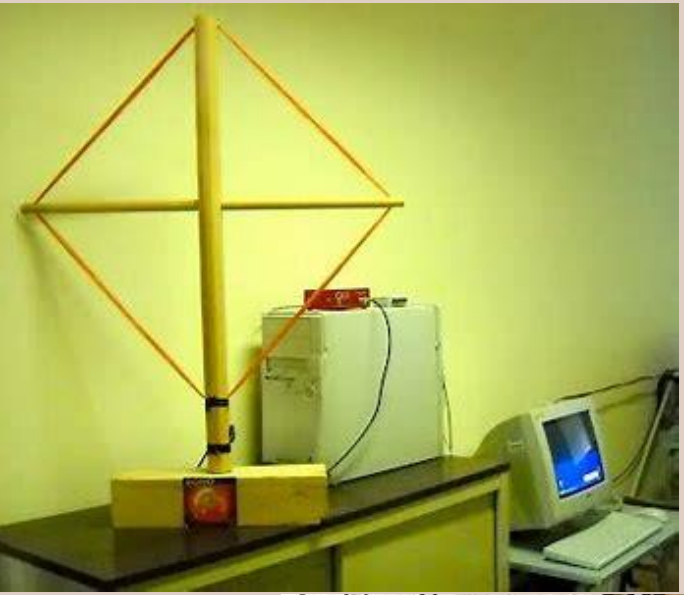

Spectrum Lab V2.99 b6
File Start/Stop Options Quick Settings Components View/Windows Help
Freq Time RDF
vfo 10 700 000 Hz
fc 2.0672 kHz opt
sp 2.0672 kHz
Cursor [N]
0.000000 Hz
0.0000 dB
01:00:00.0
Color Palette
-100 dB -80
Logging 484 kB
Capture now
Time: 20:06:34.8
peak at 1689.60 Hz
Pause
Continue
Button #6
Button #7
Button #8
Button #9
Button #10
Button #11
Button #12
Button #13
Button #14
Button #15
Button #16
Amplitude / dB
Frequency / Hz
Time / s
Spectrum Lab 3D waterfall plot
7°C
Mostly cloudy
Search
20:06
17/11/2024

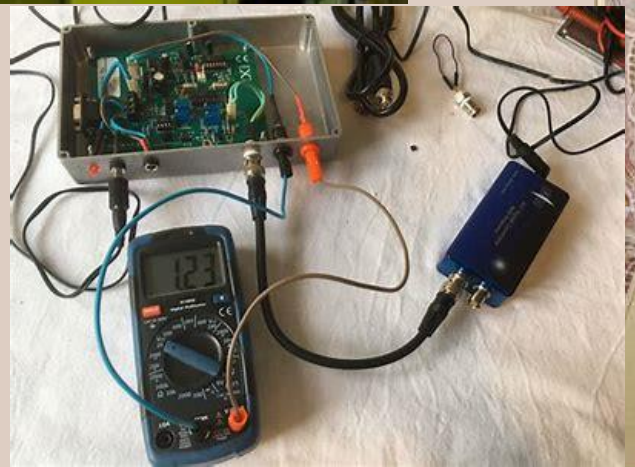
WWW.RMOB.ORG

Sharing your meteor radio observations with wider community

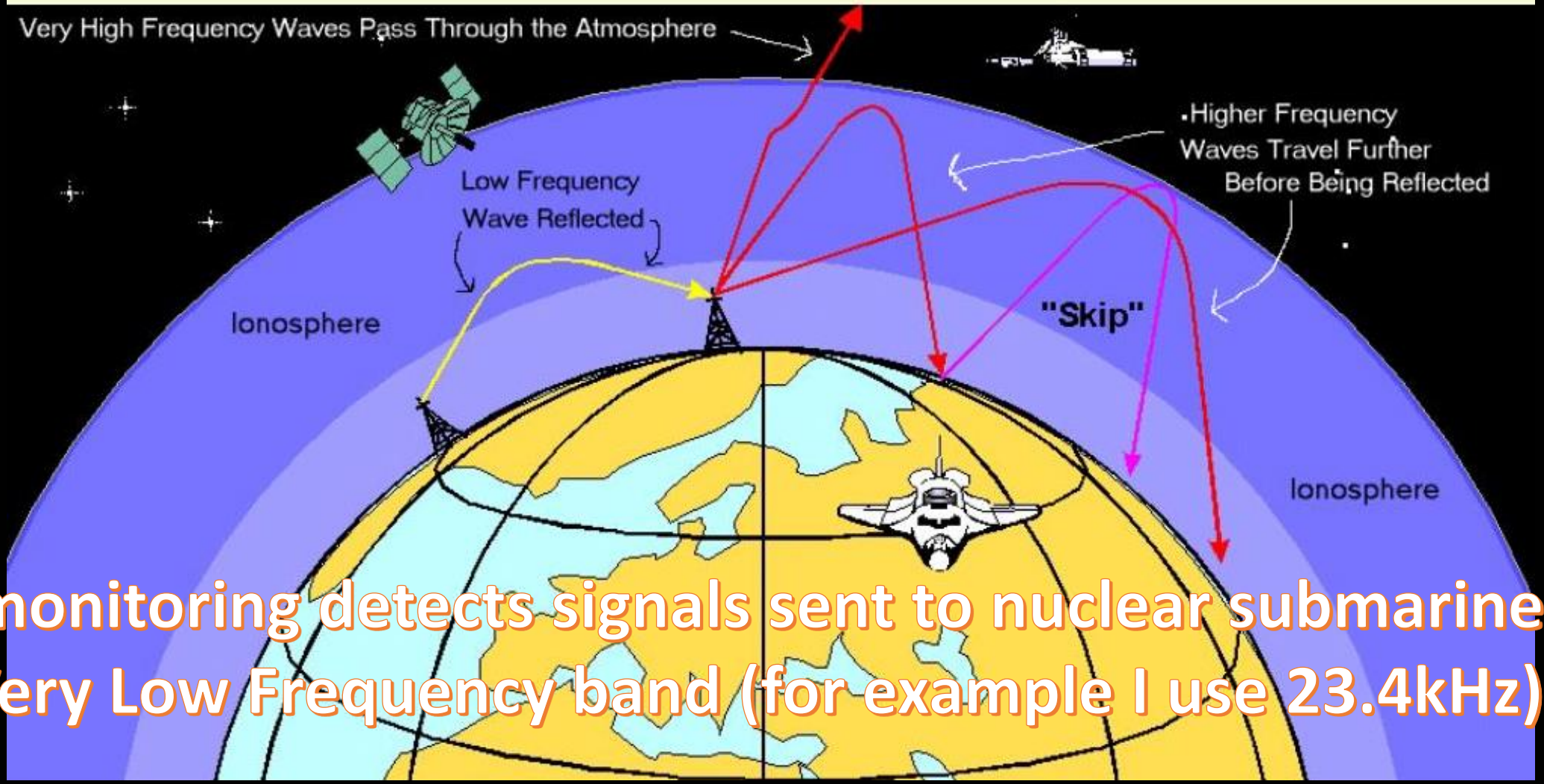


Detection of solar flares that hit Earth (Sudden Ionospheric Disturbances, SIDs)

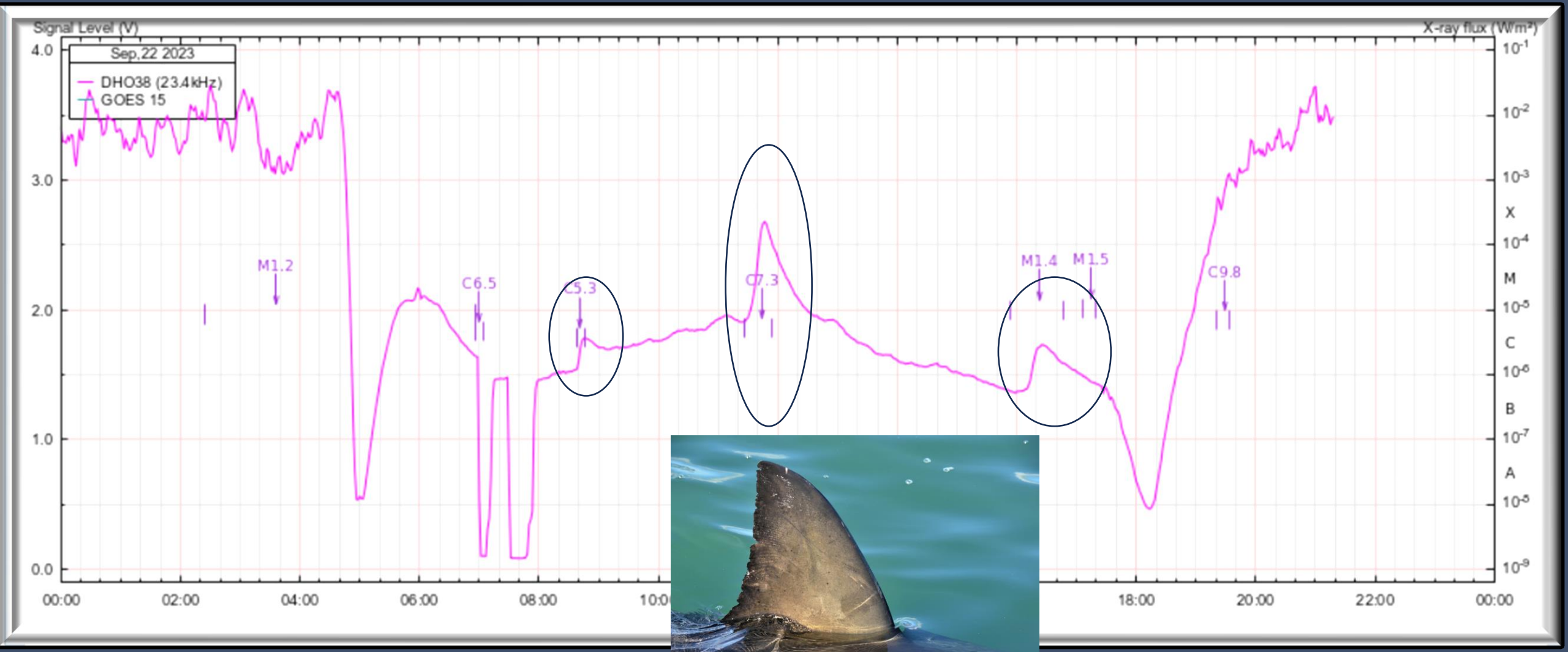




Reflection of Radio Waves from the Ionosphere

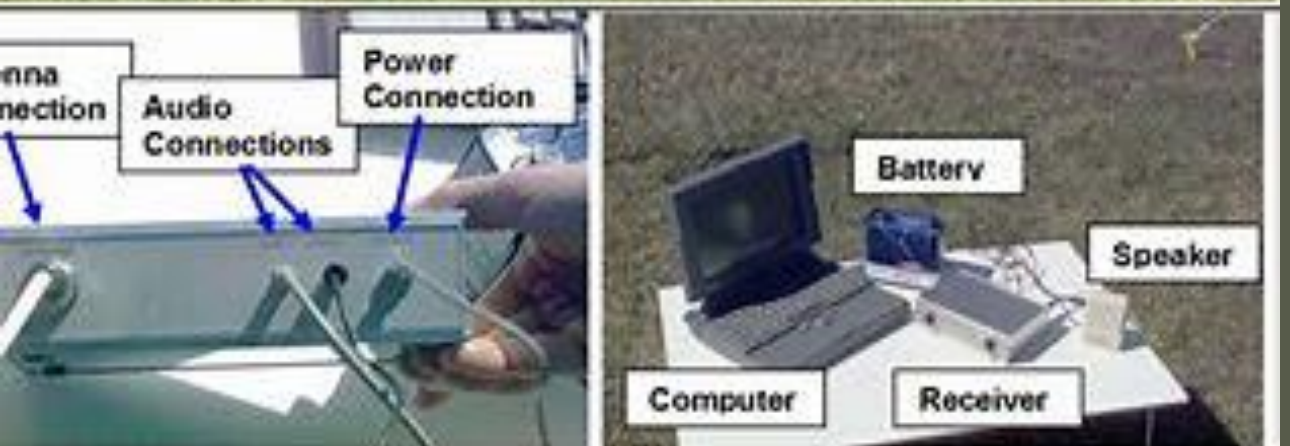


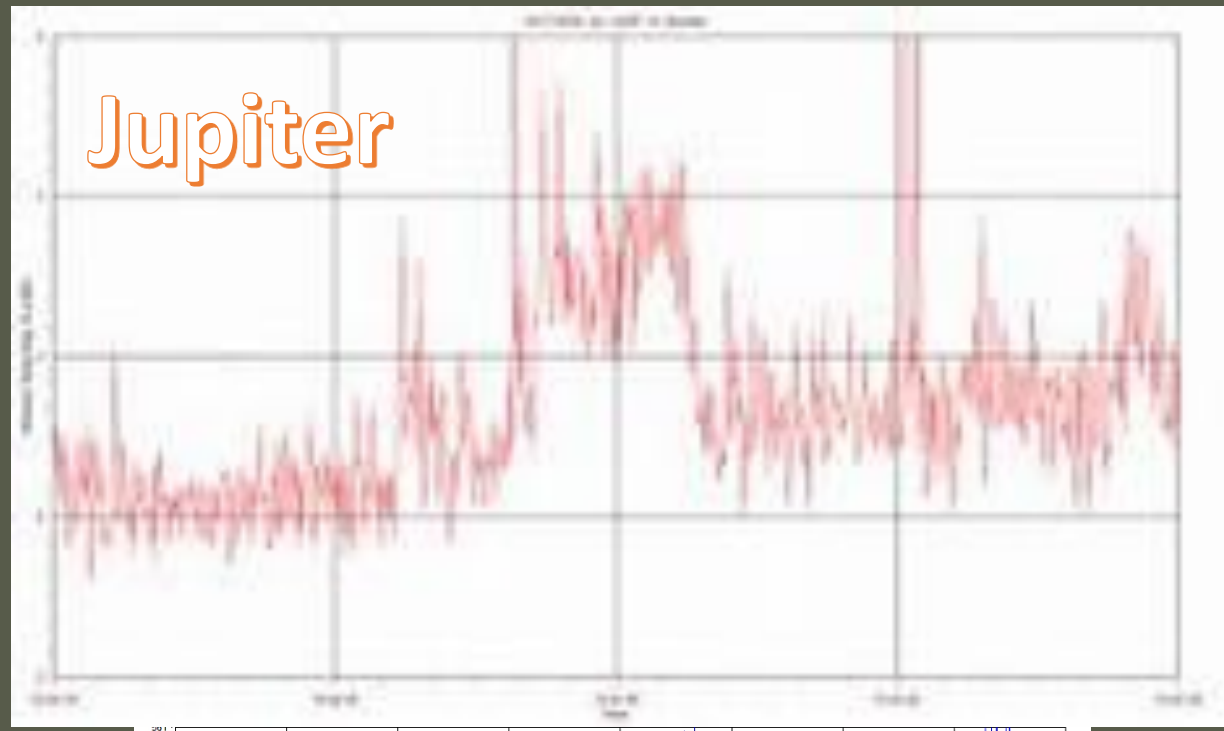
SID monitoring detects signals sent to nuclear submarines in Very Low Frequency band (for example I use 23.4kHz)

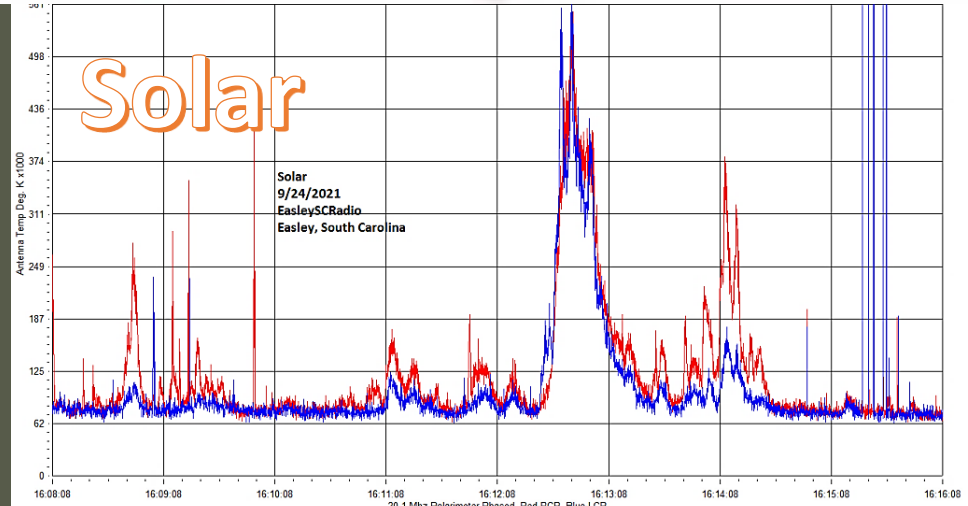


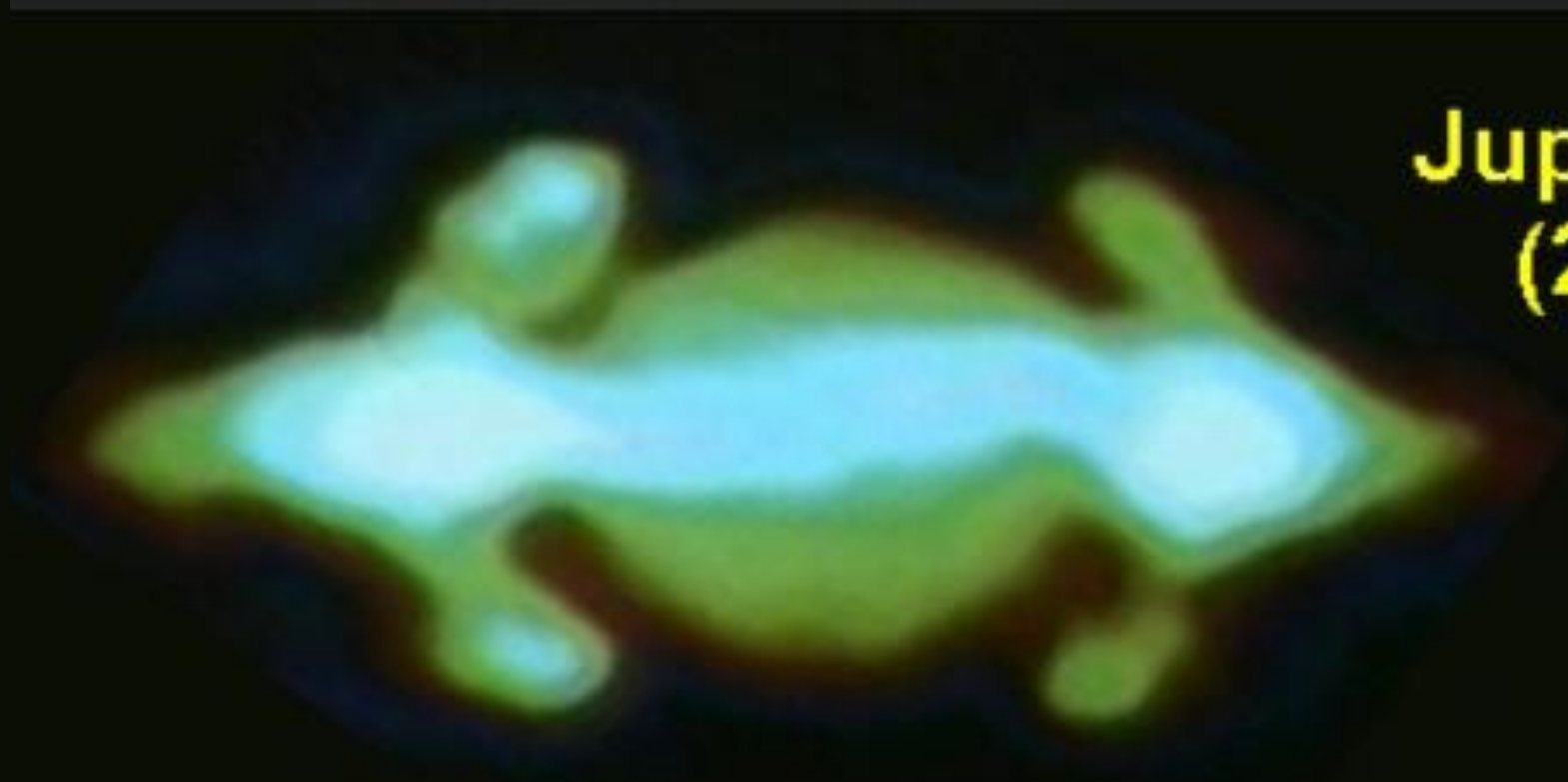
Famous Shark's Fin pattern of SIDs

Radio Jove: Detect radio emissions from Jupiter & Sun









Radio coverage sky vs visual coverage sky

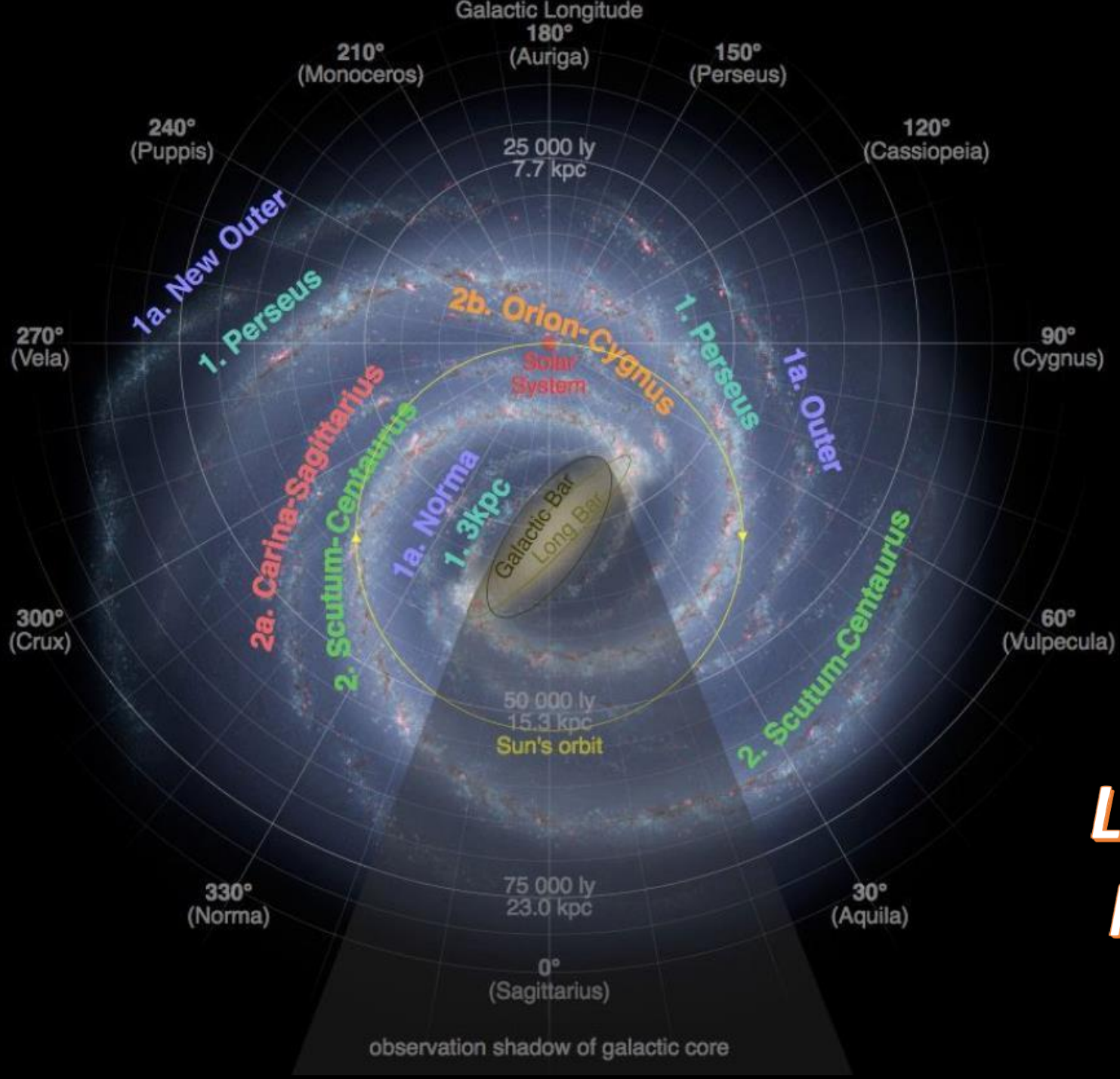
Jupiter: visible

Radio Hydrogen Mapping of the Milky Way, weighing the galaxy and demonstrating dark matter

- Possibly the most incredible project possible from our backyards!
- Used to be expensive but can now be achieved with very cheap equipment from Amazon, using Software Defined Radio (SDRs) and hydrogen line filter, and satellite dish.
- The Society of Amateur Radio Astronomers (USA/”SARA”) has a project for this called “Scope in a Box”.
- Hydrogen Line = 1420.405 MHz

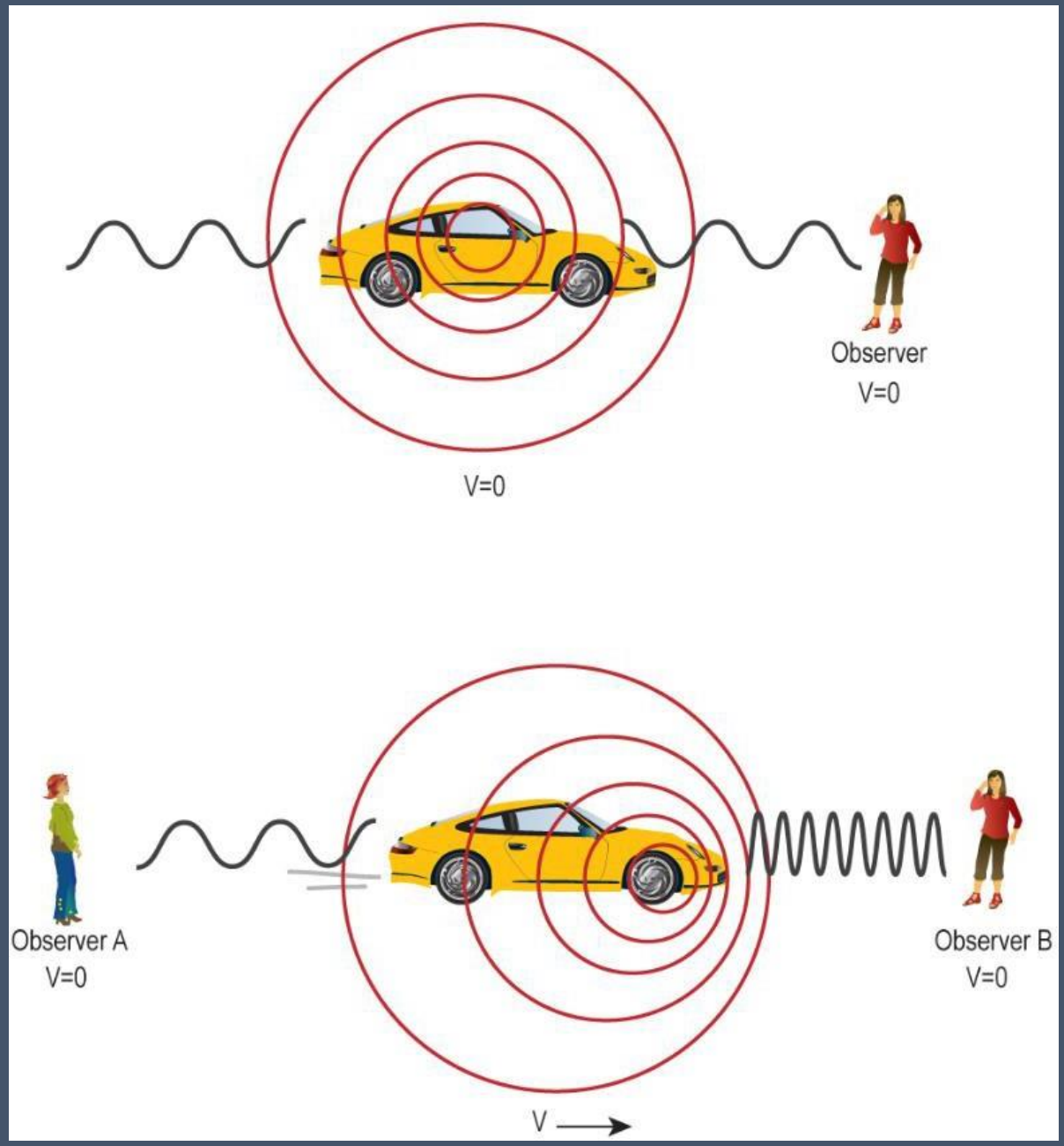
Looking from top down

How about if you could take picture like this?

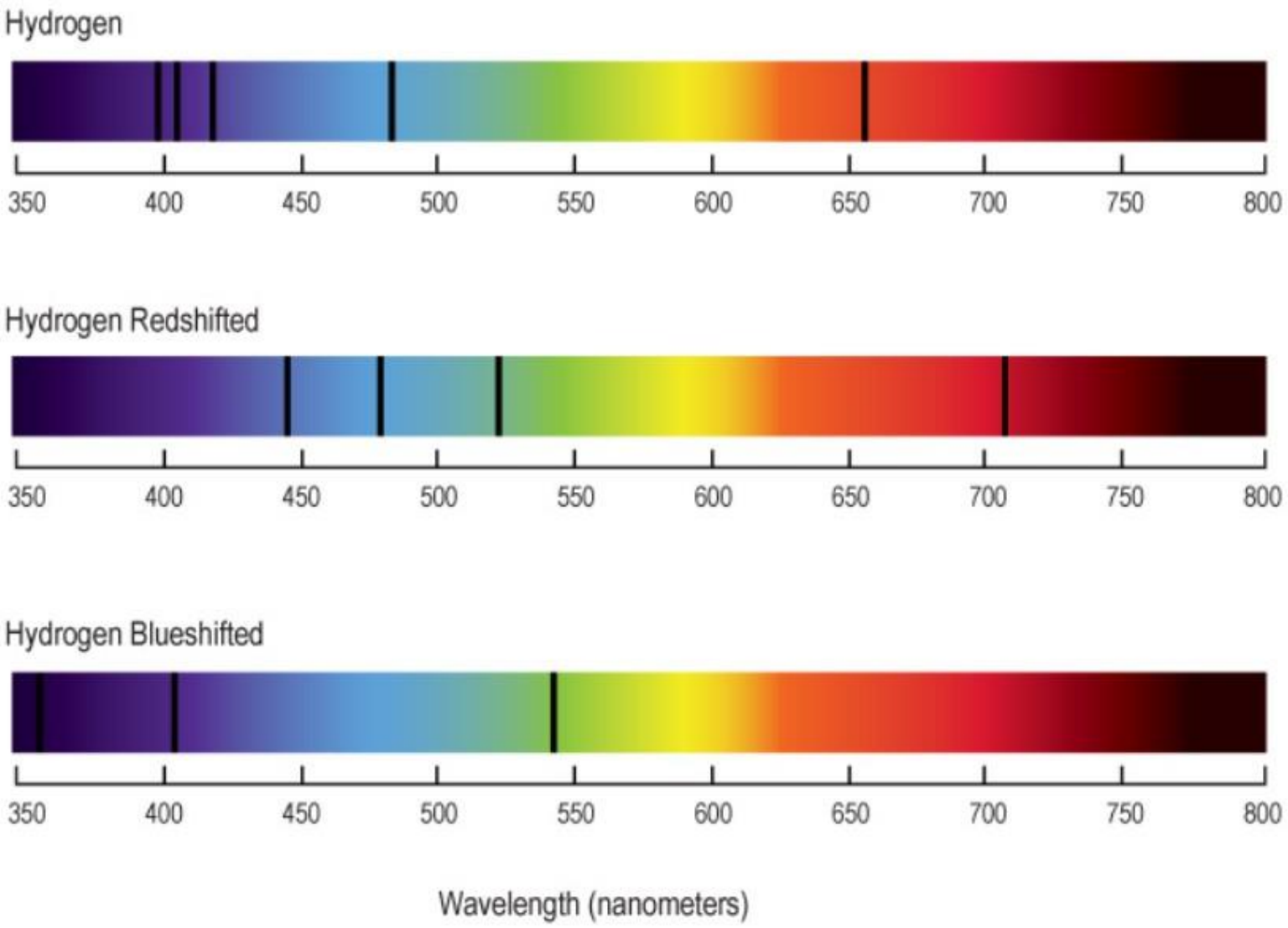


Looking down on Milky Way from outside

Measure velocity of material in the Milky Way arms using Doppler shift



Doppler effect heard in sound of train horn as passers observer on side of track



Red-shifted is moving away from us

Blue-shifted is moving towards us

Hardware

Perhaps more practical and easier to buy off the shelf is something

Like this – Nooelec 1.4GHz grid antenna

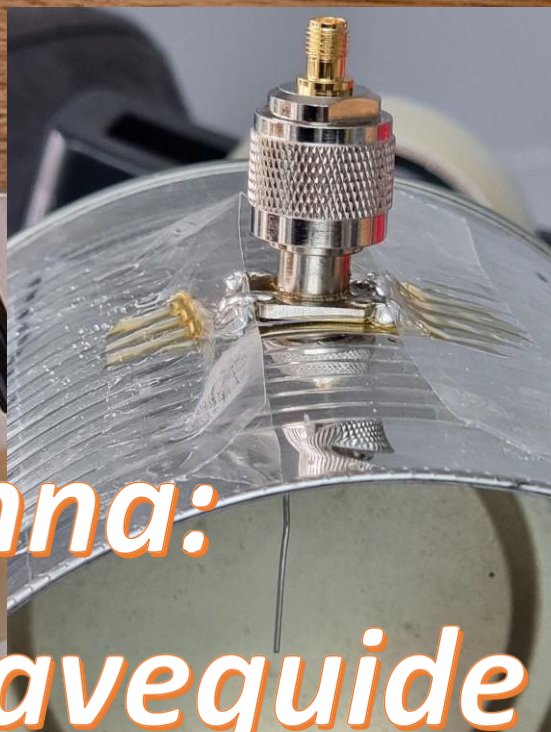
PARABOLIC MESH ANTENNA

My own aerial

Ptarmigan Triffid Band 3 Ex-Military Dipole Array

SKAO teach people how to make their own hydrogen line radio telescopes from items found in most homes

Homemade aerials



Homemade LRO Cantenna:

15cm diameter tin, 49mm waveguide

Software-defined radio (SDR)
I personally use RTL-SDR Blog V3

Nooelec SAWBird H1 LNA

Software

SDR Sharp with IFAverage Plugin

For folks starting to explore radio astronomy,

ezRA - Easy Radio Astronomy

Free 1420 MHz Galactic hydrogen data collection and analysis

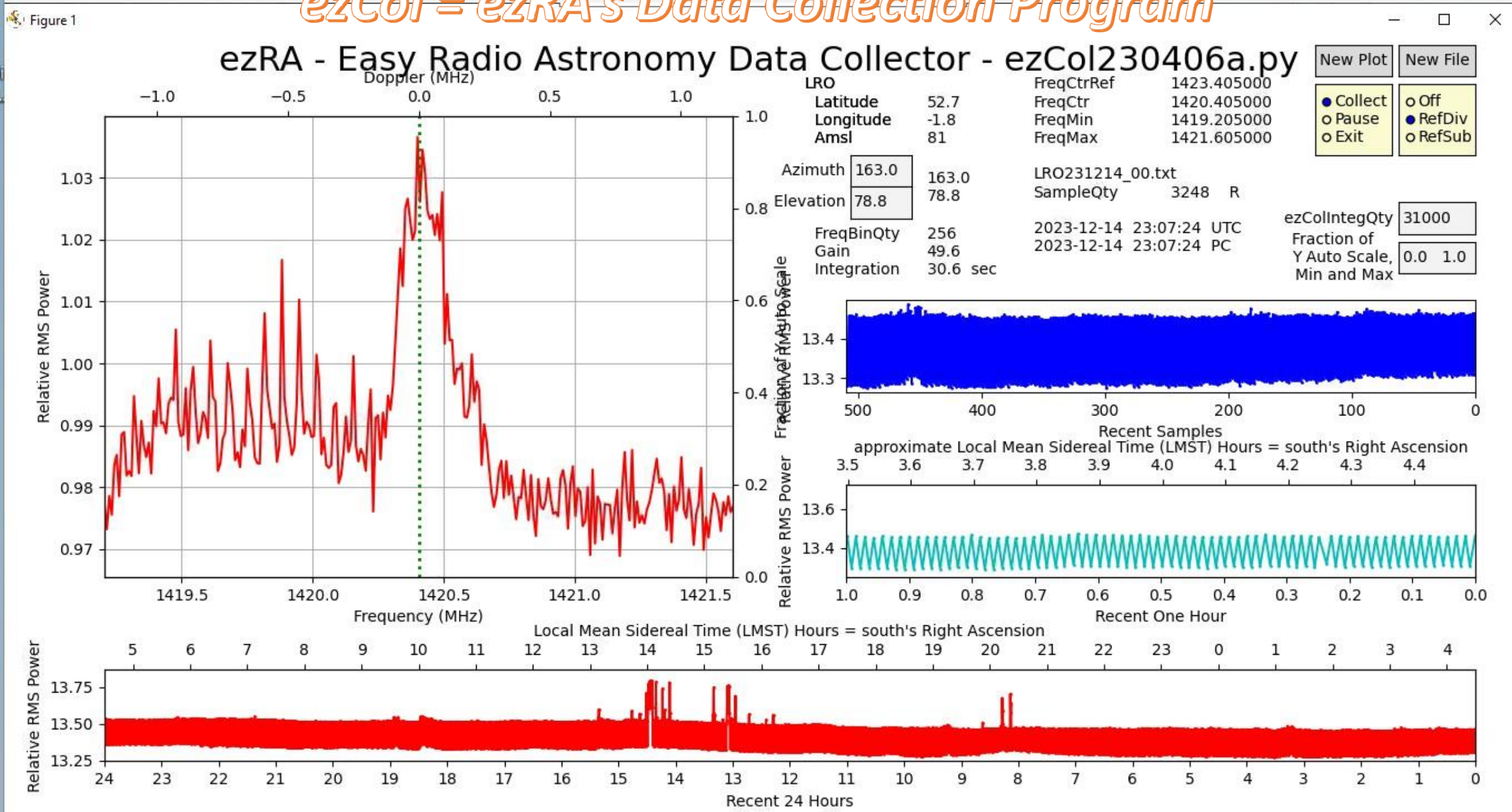
https://github.com/tedcline/ezRA

Windows and Linux

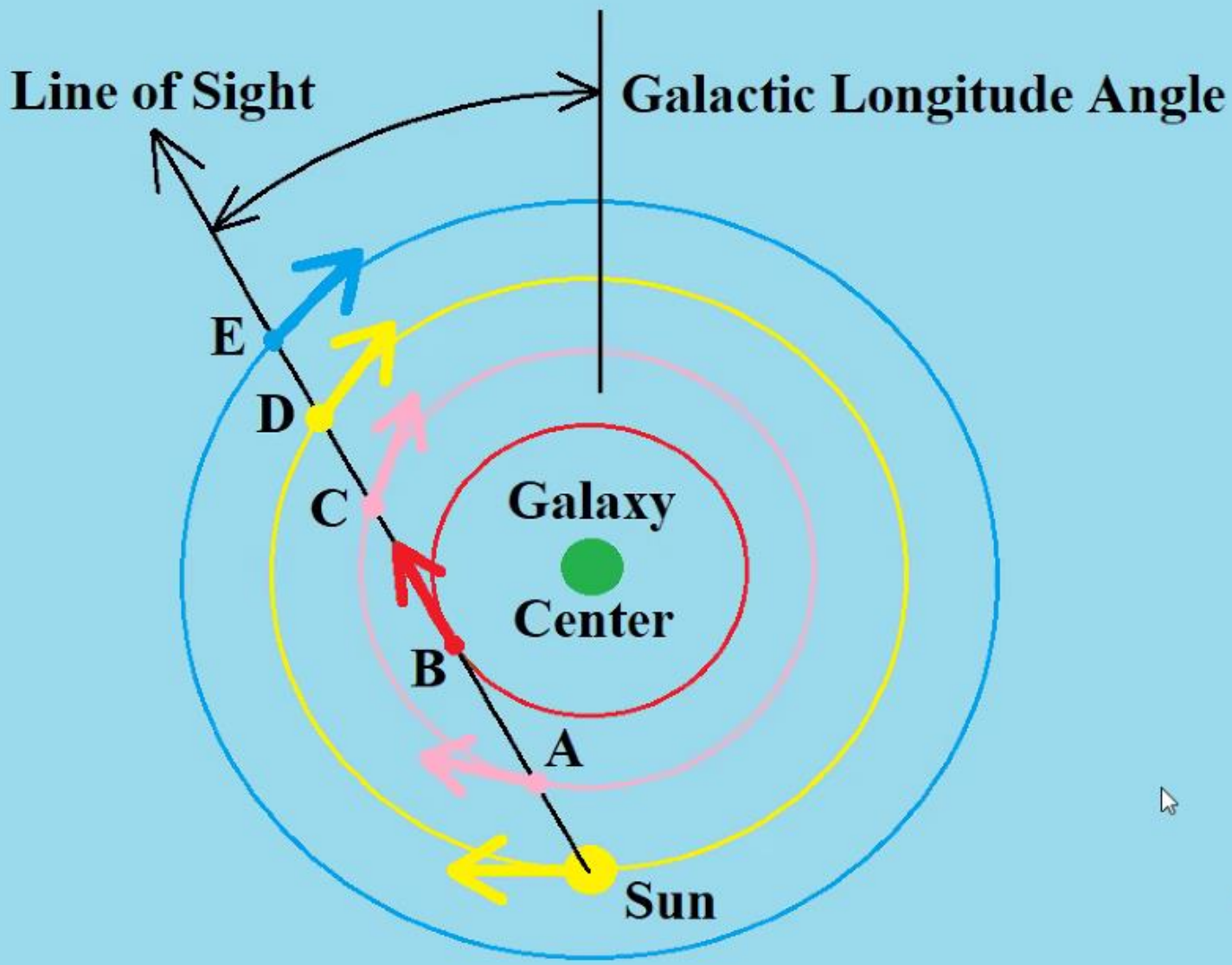
LRO-PharmiganArray (LRO-LAP-03) - RealVNC Viewer

ezCol = ezRA's Data Collection Program

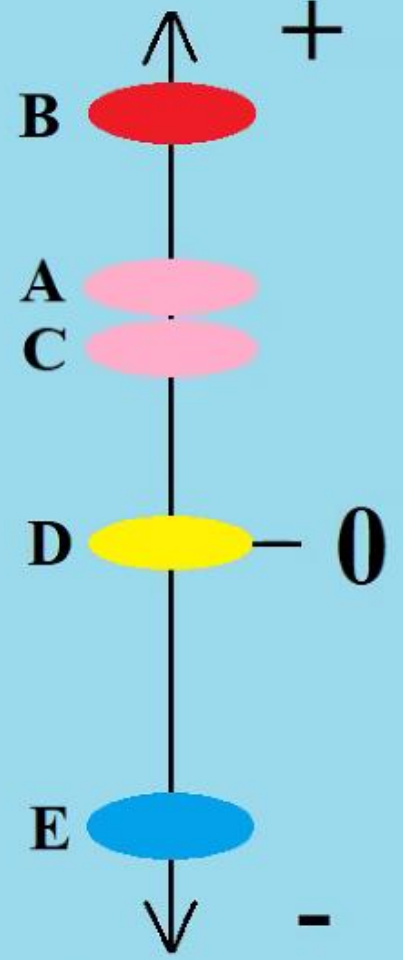
Figure 1



Measure Velocity Difference



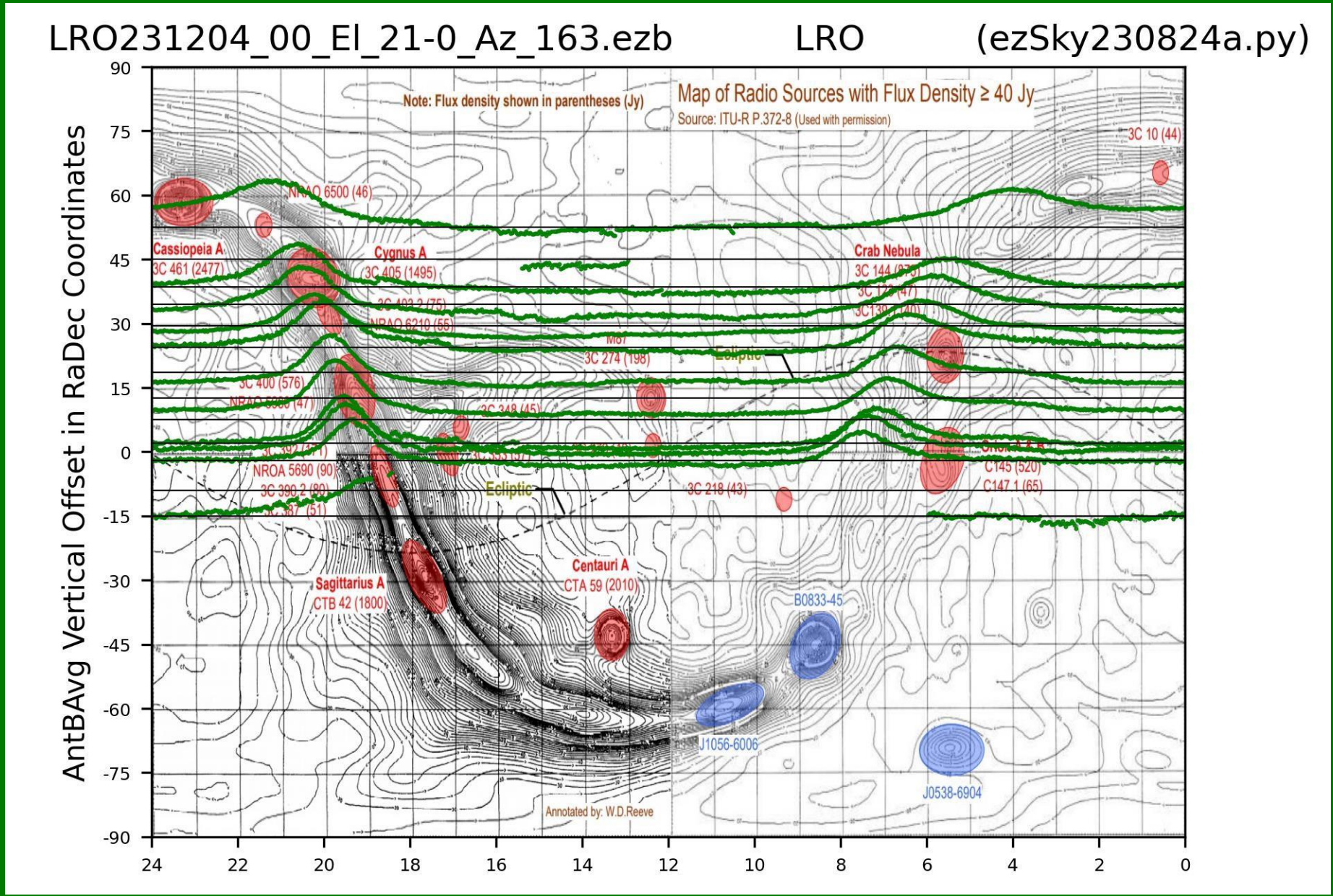
Receding Velocity



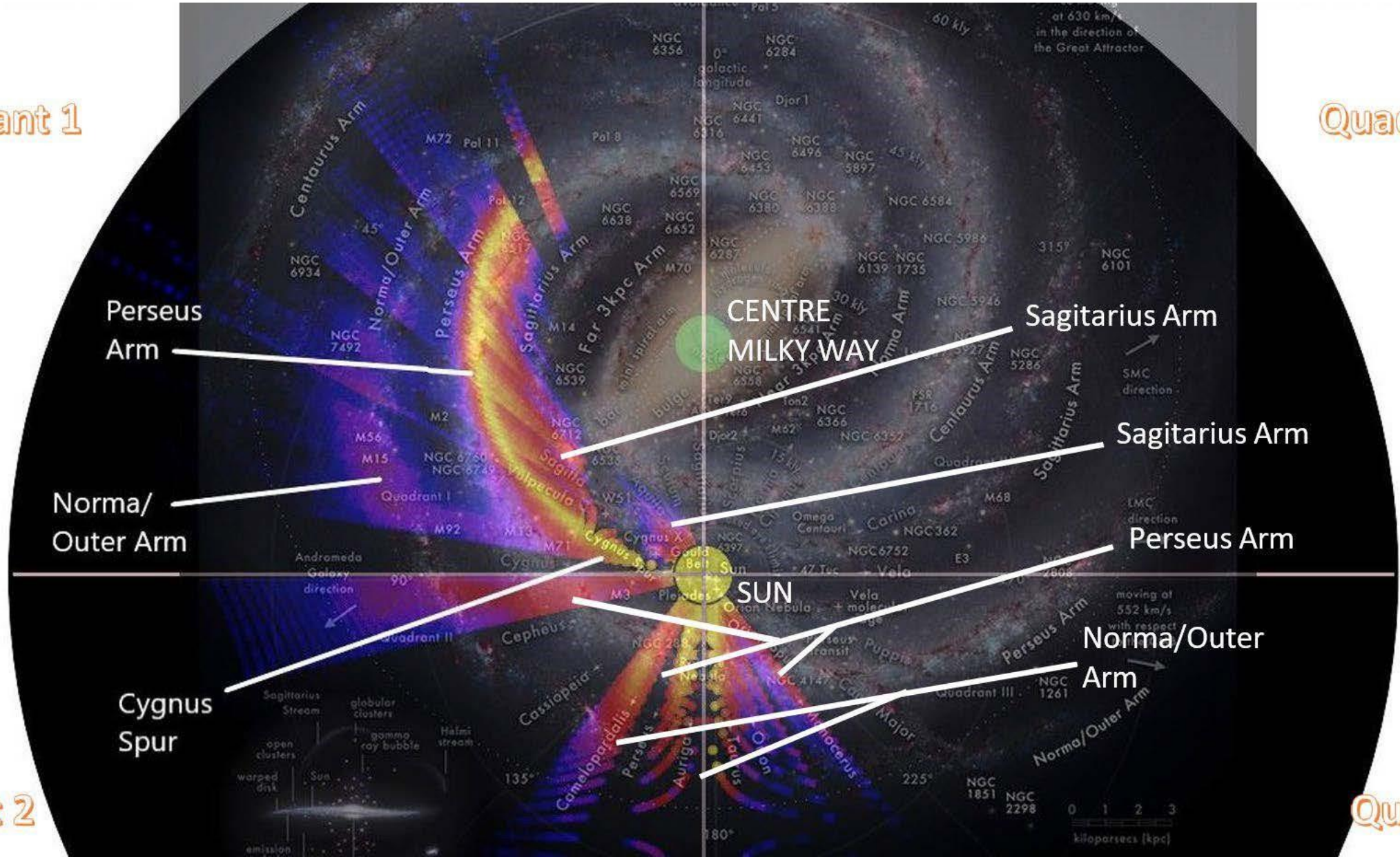
Approaching Velocity

The results!

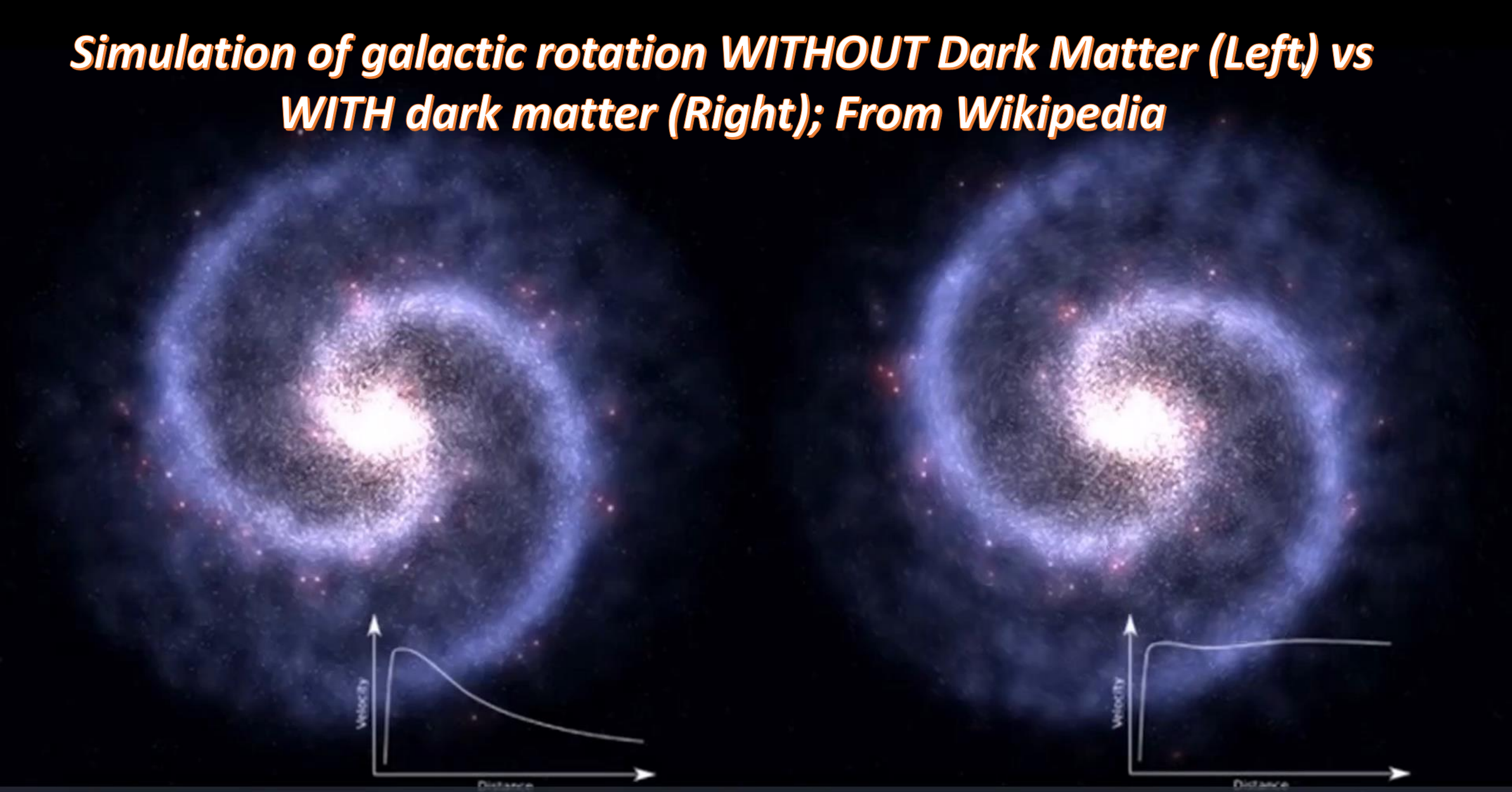
Data collected at LRO with Pharmigan Array plotted by ezRA on background Milky Way radio map



Mapping the Milky Way Arms



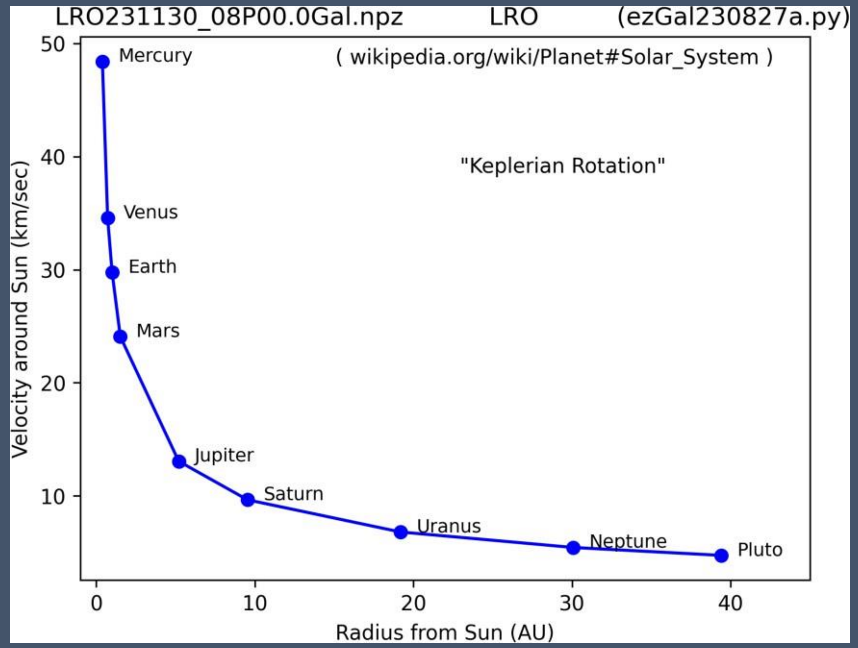
Simulation of galactic rotation WITHOUT Dark Matter (Left) vs WITH dark matter (Right); From Wikipedia

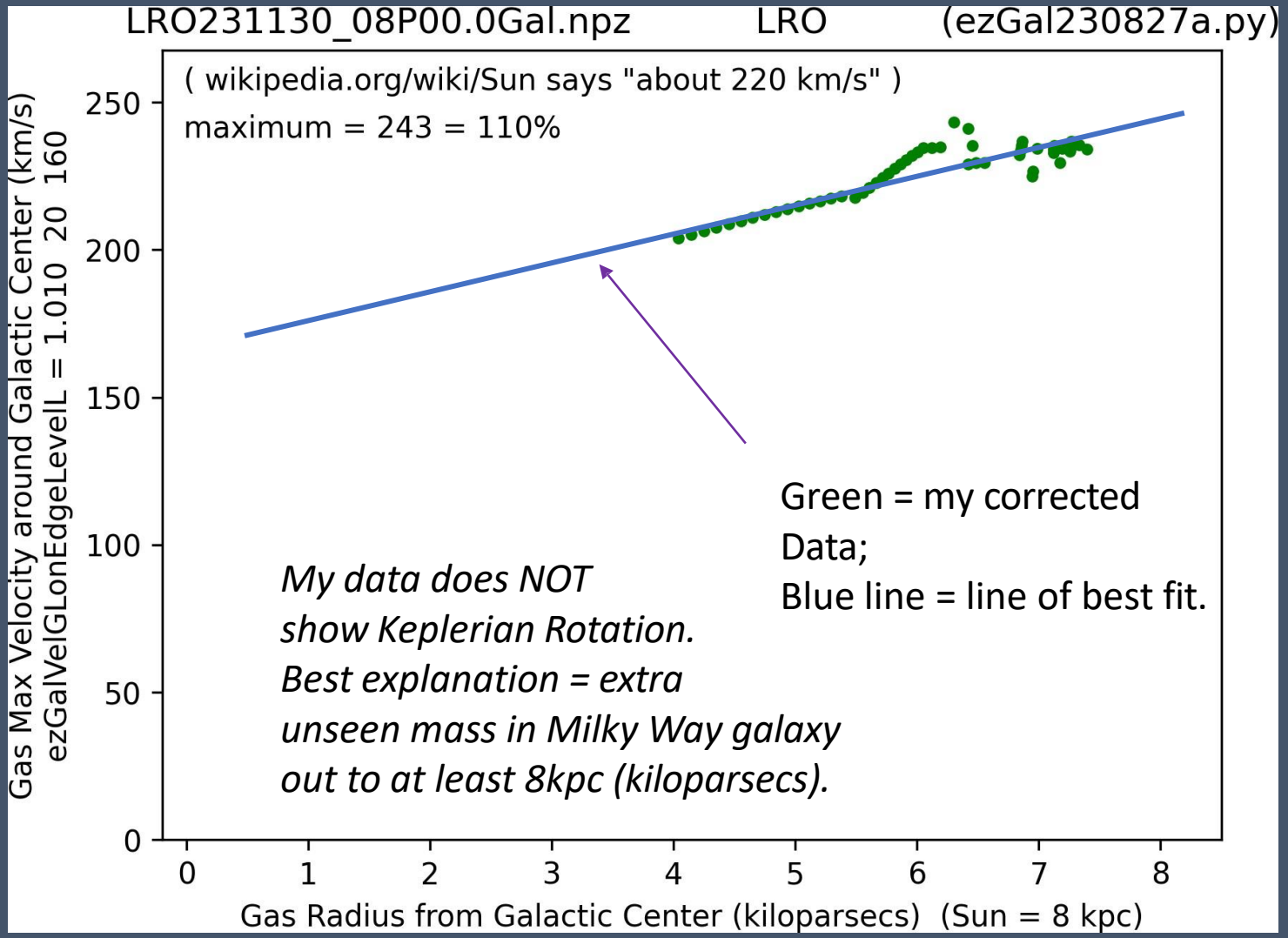


0:00 / 0:15

Dark Matter – galactic rotation curve from my data

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





Compare my rotational data (right) to published data (below)

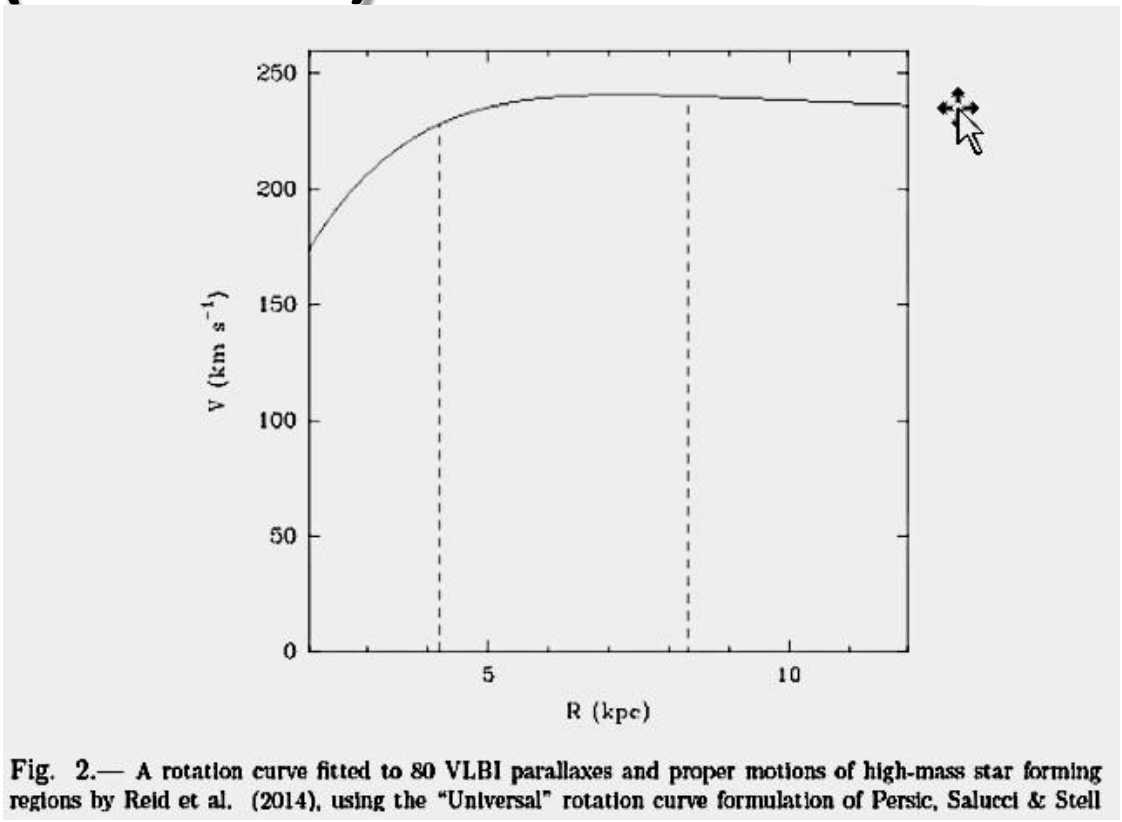
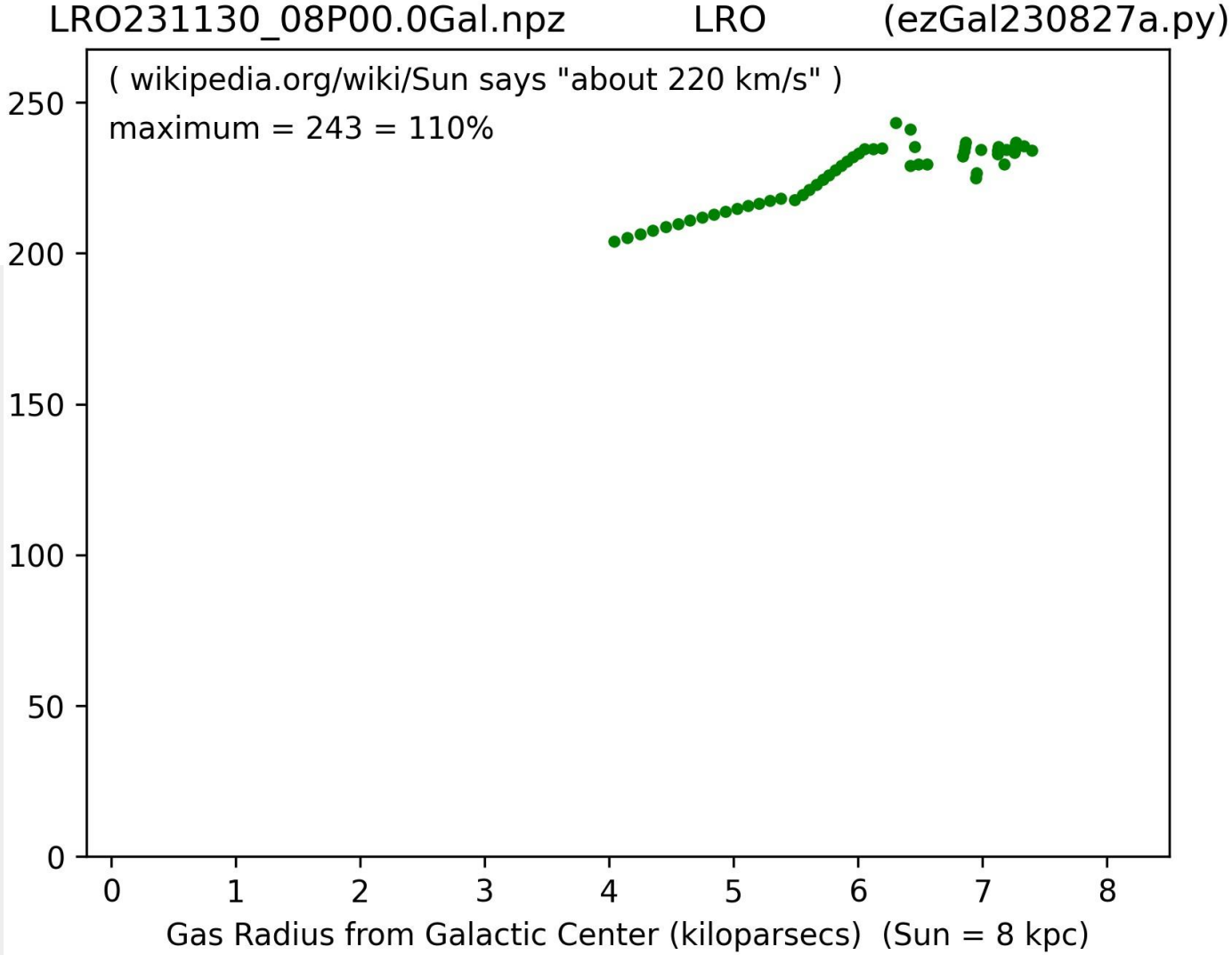
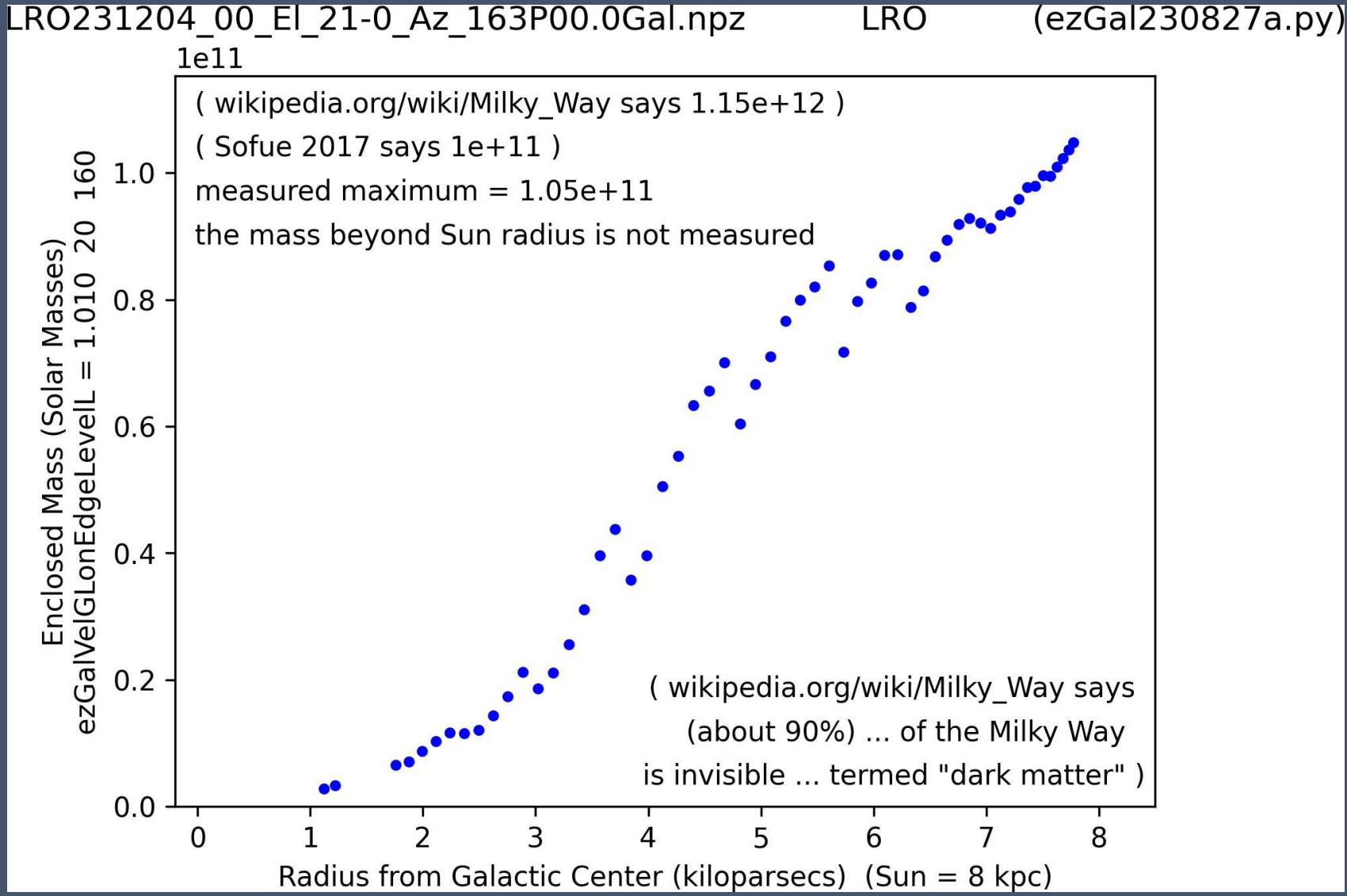


Fig. 2.— A rotation curve fitted to 80 VLBI parallaxes and proper motions of high-mass star forming regions by Reid et al. (2014), using the "Universal" rotation curve formulation of Persic, Salucci & Stell

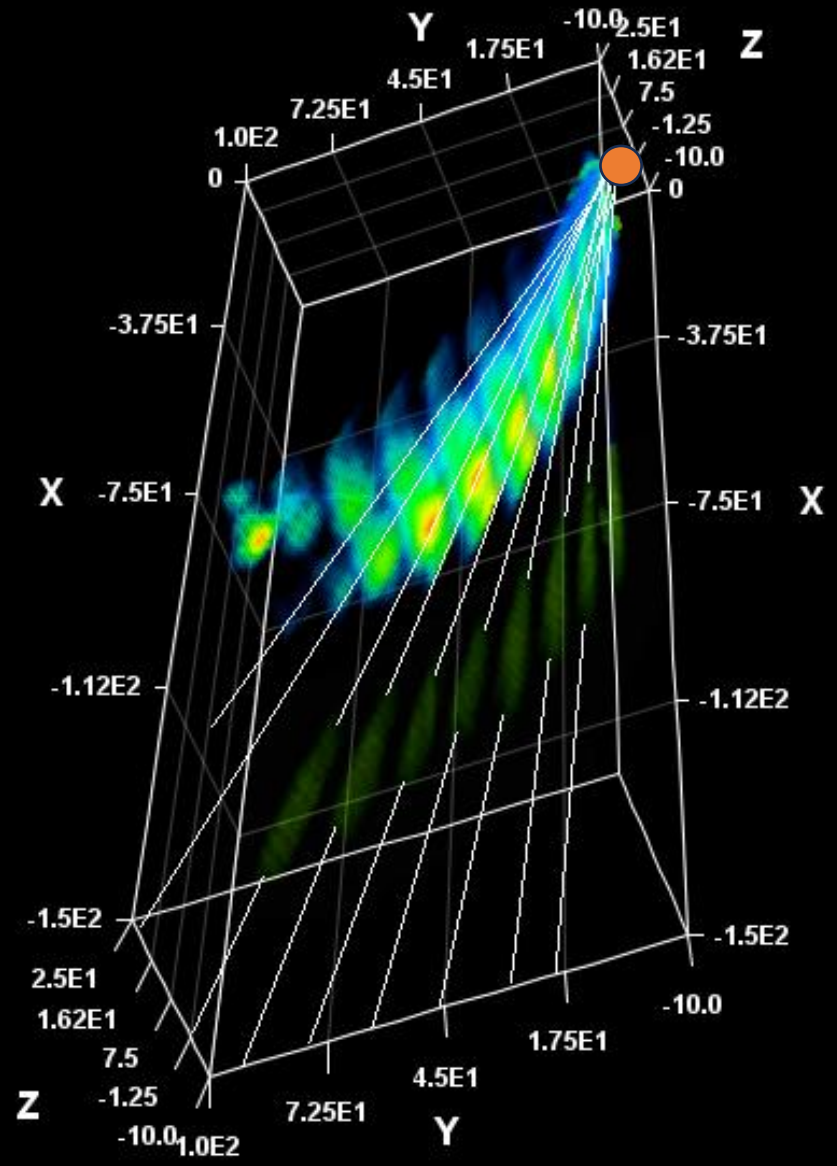


Enclosed Milky Way galactic mass

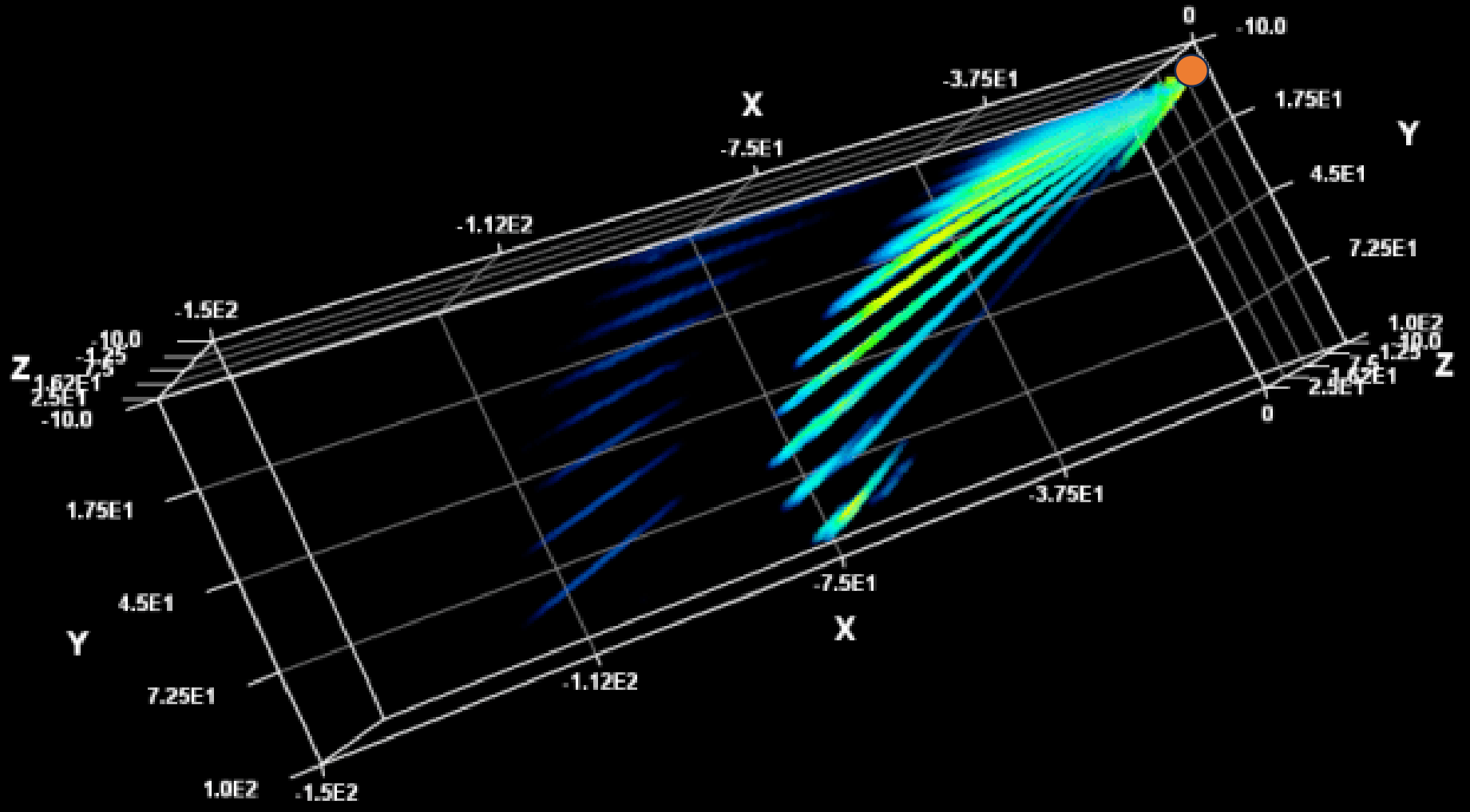


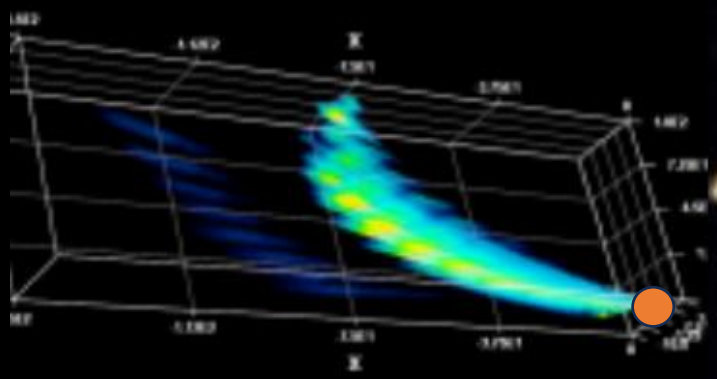
What happens when you plot the data from these hydrogen telescopes in 3D?

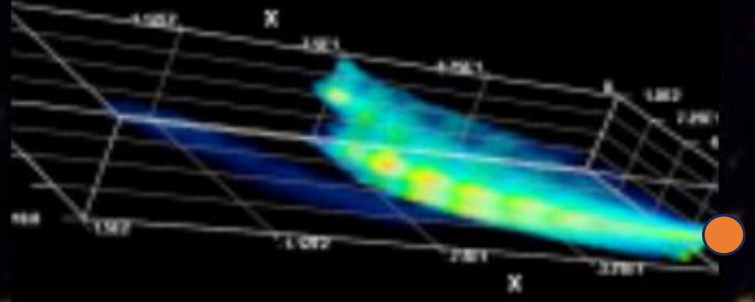
Location of Sun

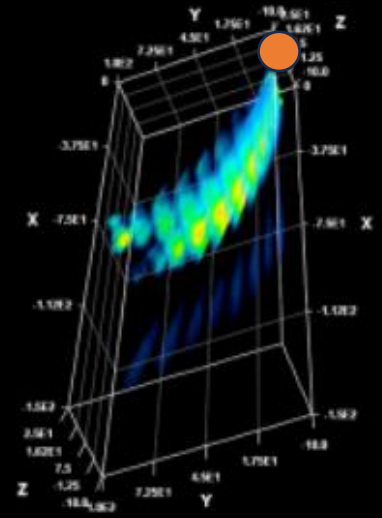


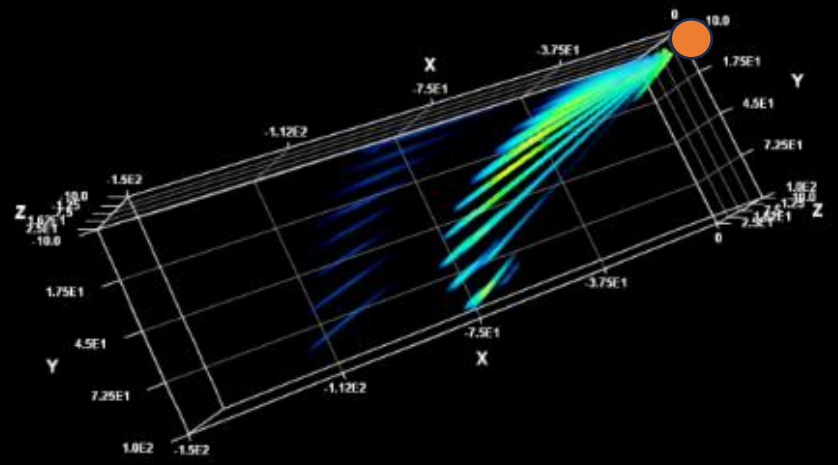
Location of Sun

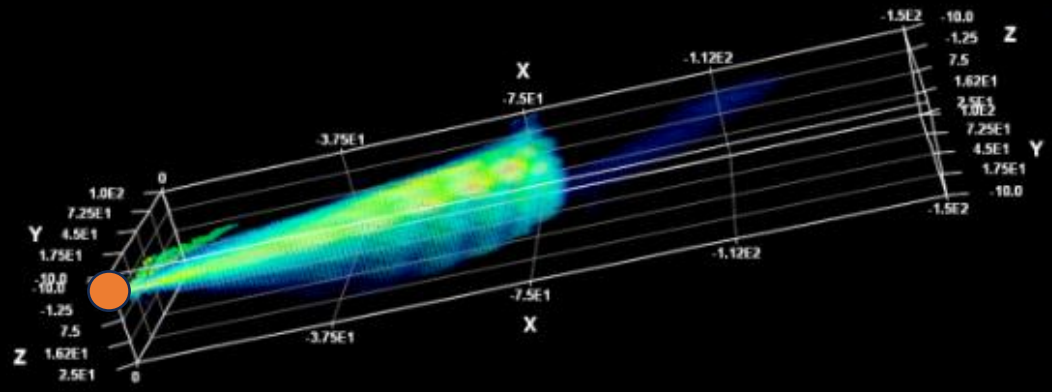


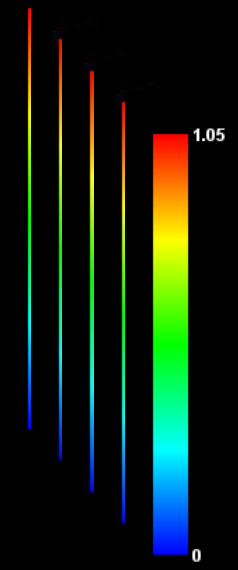

X
X


X
X

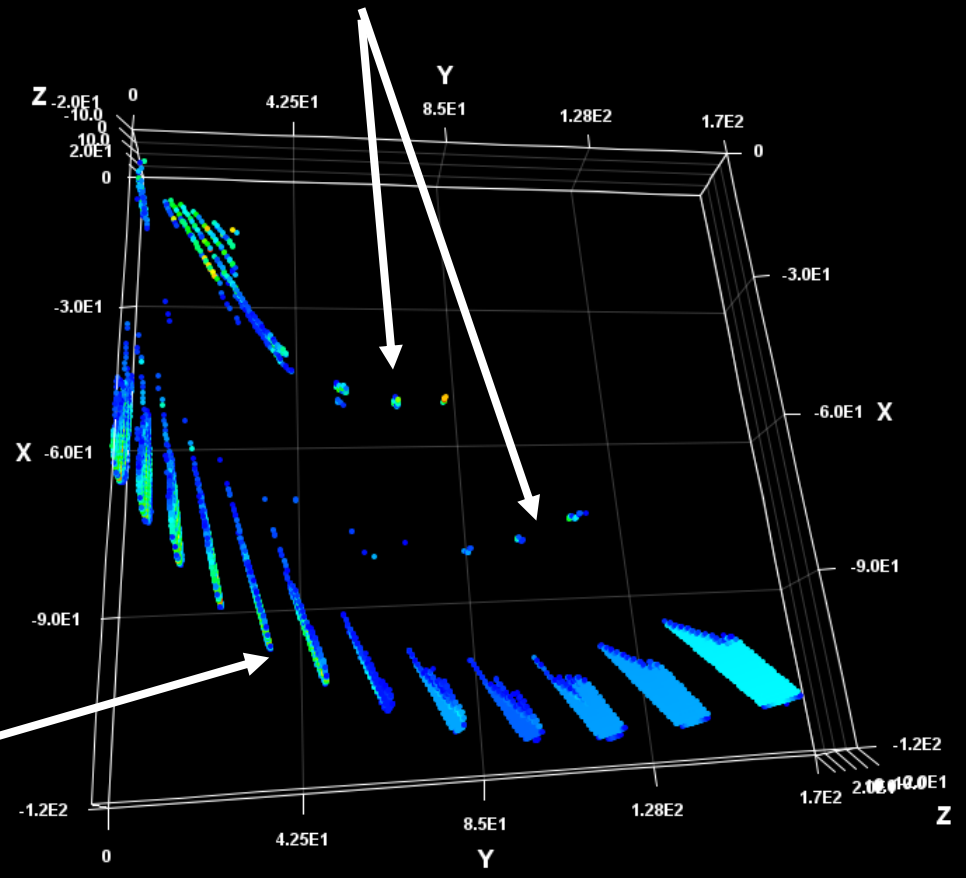

Y
Z
X
X
Z
Y


X
-7.5E1
-1.12E2
-1.5E2
-3.75E1
0
10.0
1.75E1
Y
4.5E1
7.25E1
1.0E2
Z
-7.5E1
X
-1.12E2
-3.75E1
Y
4.5E1
7.25E1
1.0E2


X
-7.5E1
-3.75E1
-1.12E2
-1.5E2
-10.0
-1.25
Z
7.5
1.62E1
2.5E1
7.25E1
4.5E1
1.75E1
Y
-10.0
1.0E2
Y
7.25E1
4.5E1
1.75E1
-10.0
-1.25
7.5
Z
1.62E1
2.5E1
-3.75E1
X
-7.5E1
-1.12E2



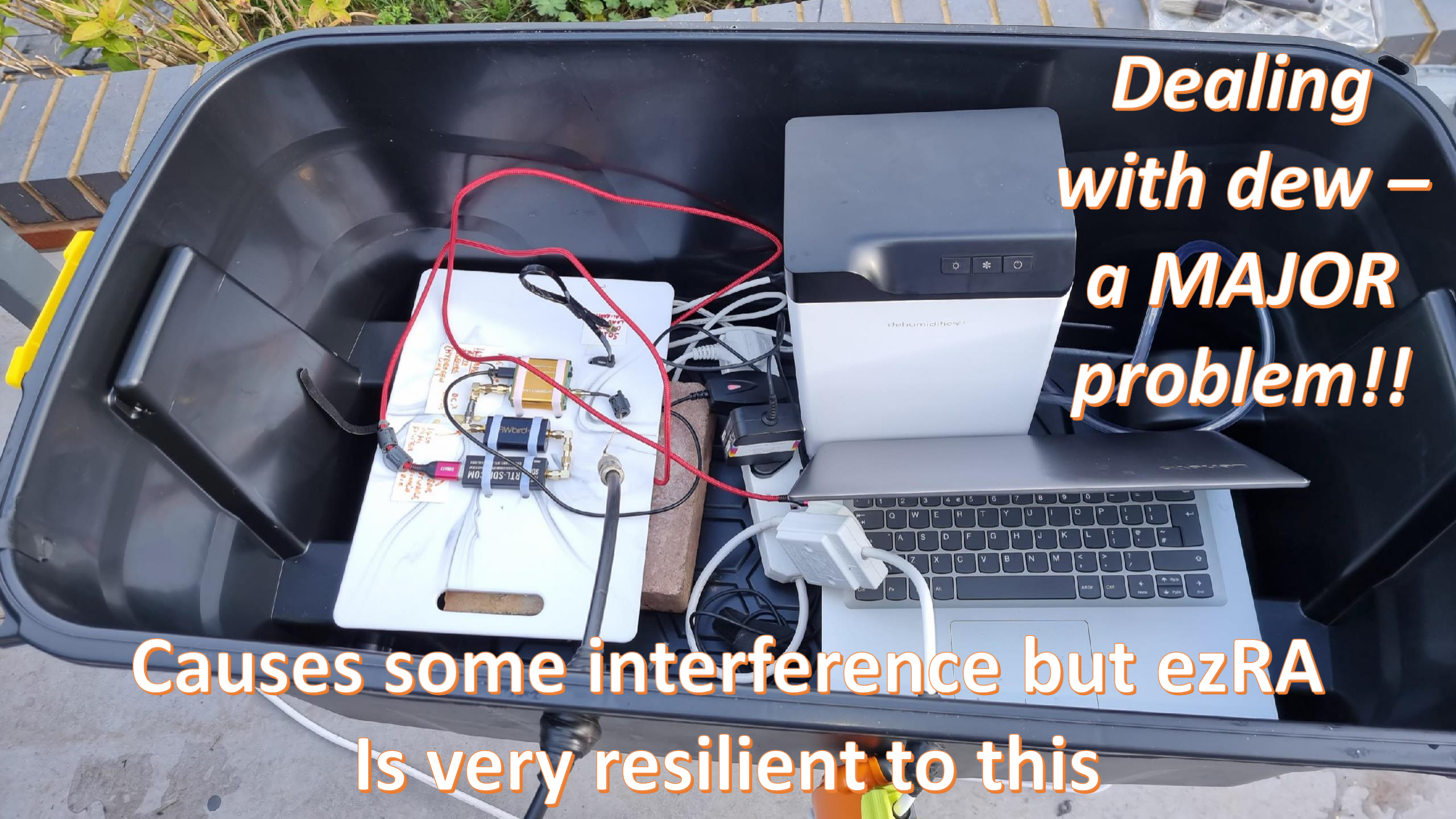
Inner arms/spurs more visible in 3D than in 2D



Sagittarius Arm of Milky Way

Choosing a PC to record data – I chose Windows-based Mini-PC

- 2nd 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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Lichfield Radio Observatory (LRO)

Dr Andrew Thornett, M6THO

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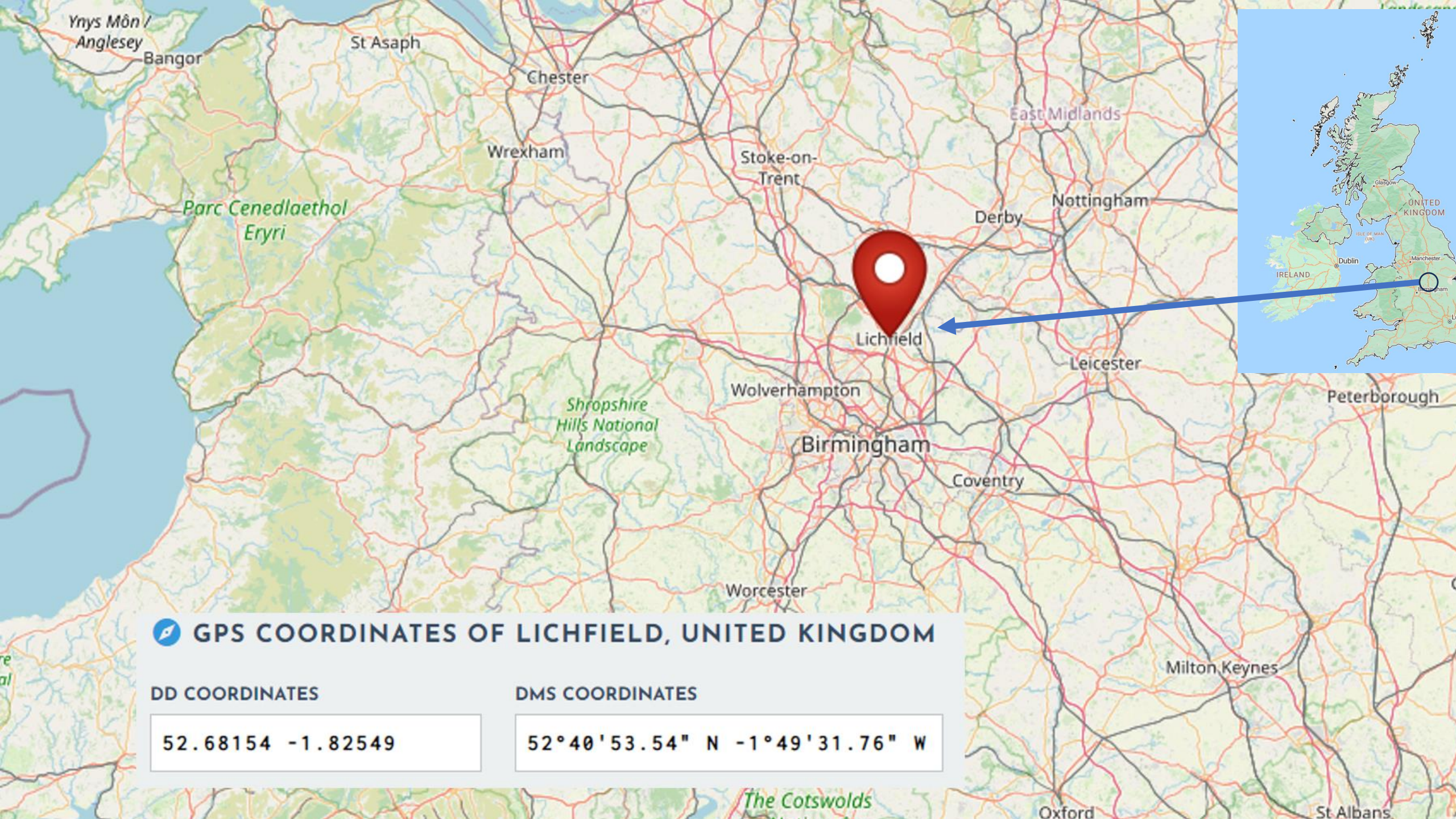
Optional Extra Slides

LRO in the Snow

Lichfield, England, UK



GPS COORDINATES OF LICHFIELD, UNITED KINGDOM

DD COORDINATES

52.68154 -1.82549

DMS COORDINATES

52°40'53.54" N -1°49'31.76" W

Priorities in Professional Radio Astronomy Research

ALMA:

- tracing the cosmic evolution of key elements from the first galaxies (z>10) through the peak of star formation (z=2-4) by imaging their cooling lines, both atomic ([CII], [OIII]) and molecular (CO), and dust continuum, at a rate of 1-2 galaxies per hour.
- examining the evolution from simple to complex organic molecules through the process of star and planet formation down to solar system scales (10-100 AU) by performing full scans of frequency band at rate of 2-4 protostars per day.
- imaging protoplanetary disks in nearby (150 parsec) star formation regions to resolve Earth-forming zone (1 AU) in dust continuum @ wavelengths < 1 mm, enabling detection of tidal gaps+inner holes created by forming planets.

VLA:

- new VLA sky survey
- unveil the formation of Solar System analogues
- probe the initial conditions for planetary systems and life with astrochemistry
- characterize the assembly, structure, and evolution of galaxies from the first
- billion years to the present
- employ pulsars in the Galactic Centre as fundamental tests of gravity and
- understand the formation and evolution of stellar and supermassive black holes
- in the era of multi-messenger astronomy.