RADIO ASTRONOMY

Journal of the Society of Amateur Radio Astronomers
November - December 2024

SARA 2024

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SARA President and Editor

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Contributing Editor

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It is the mission of the Society of Amateur Radio Astronomers (SARA) to: Facilitate the flow of information pertinent to the field of Radio Astronomy among our members; Promote members to mentor newcomers to our hobby and share the excitement of radio astronomy with other interested persons and organizations; Promote individual and multi station observing programs; Encourage programs that enhance the technical abilities of our members to monitor cosmic radio signals, as well as to share and analyze such signals; Encourage educational programs within SARA and educational outreach initiatives. Founded in 1981, the Society of Amateur Radio Astronomers, Inc. is a membership supported, non-profit [501(c) (3)], educational and scientific corporation.

Cover Photo:
Alex Pettit

Contents

President's Page

Another fantastic year for SARA!

I would like to start with a quote from Wolfgang;" SARA was organized over 40 years ago to provide a resource and forum for amateur radio operators to expand their skills in the design of advanced antennas, receivers, and processing equipment. With advances of technology over time weaker and weaker sources became accessible to amateurs. Observations are possible today which people back in the founding time of SARA could only dream of."

SARA Accomplishments in 2024

- Smithsonian Institute Collaboration – granted an IBT and Scope in the Box for the Smithsonian team to demonstrate to the crowds.
- SARA Grant Committee – Tom Crowley has organized several grants for qualifying organizations
- SARA Store – Lester Veenstra (Store Manager) has done an outstanding job with the Scope-in-a-Box radio telescope program.as well as James Pettingale – SuperSID program coordinator, and Dr. Chuck Higgins – Radio Jove Coordinator
- Chip Sufitchi – Outstanding support as the SARA Web administrator
- Special thanks to outgoing VP Jay Wilson and VP Marcus Fisher, Treasurer Brian O'Rourke, Secretary Bruce Randall, Contributing Editors Bogdan Vacaliuc & Whitham Reeve, and treasurer Tom, as well as Past President Dennis Farr
- *Jay Wilson and David Westman for their significant efforts in organizing the Eastern and Western conferences this year!*

Other Accomplishments:

- SARA Journal (Radio Astronomy) – published six times per year
- Fully indexed references to all journals, conference proceedings and video presentations – invaluable for doing research for your radio astronomy project.
- Monthly Zoom session – Drake's Lounge (forum to discuss technical challenges with leading experts)
- Monthly Zoom session – Radio Telescope Observation Party (forum to discuss how to observe astronomical sources)
- • Monthly Zoom session – Australia Drake's Lounge (forum to discuss radio astronomy with Australia members)
- SARA – Listserv – real-time forum to provide 24/7 technical interchange between members.
- SARA YouTube Channel – provides presentations on all aspects of amateur radio astronomy. This includes tutorials and radio astronomy observations. https://www.youtube.com/@radio-astronomy
- Two major conferences each year (East Coast and West Coast) in which the members meet and present results from the past year.
- 60% Increase in membership and 20% increase in SARA YouTube channel subscriptions
- SARA members wrote the first Radio Astronomy Section of the 2025 ARRL Handbook

There has been a significant amount of volunteer activity this year! We appreciate everyone's involvement in making SARA a premier international amateur radio astronomy organization.

Thanks! Rich

Editor's Notes

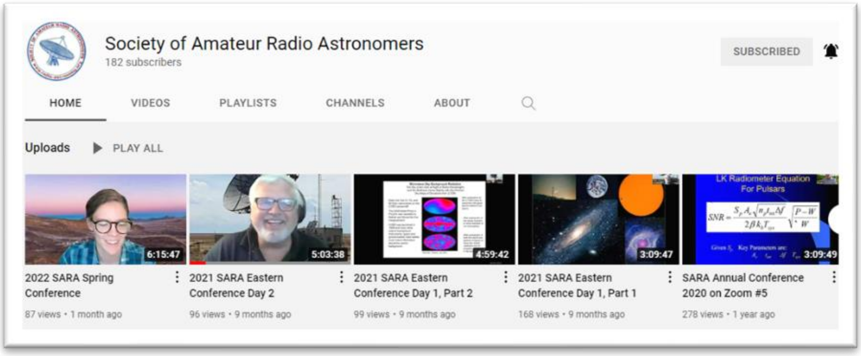
We are always looking for basic radio astronomy articles, radio astronomy tutorials, theoretical articles, application and construction articles, news pertinent to radio astronomy, profiles and interviews with amateur and professional radio astronomers, book reviews, puzzles (including word challenges, riddles, and crossword puzzles), anecdotes, expository on "bad astronomy," articles on radio astronomy observations, suggestions for reprint of articles from past journals and other publications, and announcements of radio astronomy star parties, meetings, and outreach activities.

Subscribe to the SARA YouTube Channel

SARA has a YouTube channel at: https://www.youtube.com/@radio-astronomy

Don't forget to LIKE the videos! It helps with the YouTube distribution algorithm.

We are also looking to add content to the site. Anyone who wants to help produce a series of 5 - minute videos relating to radio astronomy technology or observations please contact me. (drrichrussel@netscape.net)



Observation Reports

We are now accepting 1-2 page observation reports. These reports should include the astronomical object's RA/DEC plus UTC of the observation. Also include the telescope configuration, process used to observe the object and results. Picture of the setup and plots of the observation are a plus to the report.

If you would like to write an article for Radio Astronomy, please follow **the newly updated Author's Guide** on the SARA web site:
http://www.radio-astronomy.org/publicat/RA-JSARA_Author's_Guide.pdf.

Let us know if you have questions; we are glad to assist authors with their articles and papers and will not hesitate to work with you. You may contact your editors any time via email here: edit@radio-astronomy.org.

The editor(s) will acknowledge that they have received your submission within two days. If they do not reply, assume they did not receive it and please try again.

Please consider submitting your radio astronomy observations for publication: any object, any wavelength. Strip charts, spectrograms, magnetograms, meteor scatter records, space radar records, photographs; examples of radio frequency interference (RFI) are also welcome.
Guidelines for submitting observations may be found here: http://www.radio-astronomy.org/publicat/RA-JSARA_Observation_Submission_Guide.pdf

2025 SARA Western Conference
Socorro, New Mexico, USA

The 2025 SARA Western Conference will be held at the Pete V. Domenici Science Operations Center in Socorro, NM and the Very Large Array near Magdalena, New Mexico on March 14 to 16, 2025.

The town of Socorro is the home of NRAO operations in New Mexico (NM). Located on the campus of the New Mexico Institute of Mining and Technology (New Mexico Tech), the Pete V. Domenici Science Operations Center houses scientific, engineering, technical, computer and support staff for both the Expanded Very Large Array (EVLA) and the Very Long Baseline Array (VLBA). The Science Operations Center also houses the control center and correlator for VLBA observations and hosts personnel working on the Atacama Large Millimeter/submillimeter Array (ALMA) project.

We will have a tour of the Very Large Array (VLA) site west of Socorro. We will also tour the Long Wavelength Array (LWA) (http://lwa.unm.edu) which is next to the VLA. In addition to presentations by SARA members, we plan to have presentations by speakers from the National Radio Astronomy Observatory Array Operations Center (NRAO AOC) in Socorro. Additional details will be published online and in the SARA journal as we get closer to the conference date. Register now to avoid the rush and to guarantee a seat at the conference.

VLA site tour: The Very Large Array consists of 27 parabolic dish reflector antennas in a Y-shaped configuration on the Plains of San Agustin approximately fifty miles west of Socorro: http://www.vla.nrao.edu/ . Each antenna is 25 m in diameter.

LWA site tour: The Long Wavelength Array (256 bent dipole antennas) LWA-1 is located next to the VLA

There are three LWAs in New Mexico, two in the vicinity of the VLA and one north of Socorro in the Sevilleta National Wildlife Refuge. Each array consists of 256 crossed-dipole antennas and each antenna is about 1.5 m high.

Hotel
(575) 838-0556 Best Western (Socorro, NM).
SARA Western Conference (group name)

The "drop date" for all unused rooms is 2 weeks prior to arrival date

At this time, we only have 10 rooms reserved.

Ken Redcap
Western Conference Coordinator

NEW The BYTE

A new section is being added to the bimonthly SARA journal focused on system software applicable for amateur radio astronomy (RA).

Society of Amateur Radio Astronomers (SARA) **2025 SARA Eastern Conference**	

Block off your calendars and start thinking about your travels for next summer! We have teamed up with the Radio Jove group and are holding a combined conference next year!

- 2025 SARA Eastern Conference and Radio Jove
- June 7 (Sat) – June 11 (Wed) 2025
- Green Bank Observatory (GBO) West Virginia (WV)

Planning is underway and more information will be coming as it develops. Any comments and/or suggestions please reach out to the committee chair Marcus Fisher (vicepresident@radio-astronomy.org)

2025 *EU Conference on Amateur Radio Astronomy* (EUCARA25)

We are pleased to announce the date of the 2025 *EU Conference on Amateur Radio Astronomy* (EUCARA25) - Friday September 5th - Sunday 7th.

This will be held at the Visitor Center on the Harwell Campus. Further details will be published soon on our website – www.**eucara.org** .

We are honored that **Professor Jocelyn Bell Burnell** will be our keynote speaker.

When registration is open, we will let you know via the forums.

SARA Student & Teacher Grant Program

All, SARA has a grant program that is, sad to say, very underutilized. We will provide kits or money to students and teachers including college students to help them with a radio telescope project. SARA can supply any of the following kits:

[1] SuperSID
[2] Scope in a Box
[3] IBT (Itty Bitty Telescope)
[4] Radio Jove kit
[5] Inspire
[6] Sky Scan

We can also provide up to five hundred dollars ($500.00 USD) for an approved radio telescope project.

We have on occasion provided more money based on the merits of the project and the SARA Grant Committee approval.

More information on the grant program can be found at the URL below.
[SARA Student and Teacher Project Grants | Society of Amateur Radio Astronomers (radio-astronomy.org)]

All that is required is the SARA grant request form be filled out and sent in. If it needs more work for approval, we will work with the students to help ensure their success.

Please pass the word that SARA will fund any legitimate radio telescope project anywhere in the world.

If you have a question, contact me at crowleytj@hotmail.com .
Tom Crowley - SARA Grant Program Administrator

Drake's Lounge Australia

This new zoom forum is geared to the Melbourne, Australia time zone (UTC+10) in order to improve coordination with our Australia, New Zealand, and Japanese members. The meetings are scheduled for the 4th Friday of every month, 9 AM Melbourne time. A zoom announcement will be sent out to all SARA members before the meeting.

Radio Telescope Observation Party (RTOP)

RTOP is designed to demonstrate how to take observations using various radio telescopes. It will also cover how to record and analyze data.

RTOP is every month on the 1st Sunday at 2 pm Eastern time (1800 UTC). ZOOM email notifications will be sent to all members.

Drake's Lounge

Join the SARA community as we discuss the latest astronomy and radio astronomy news. The lounge also provides a forum to share and get advice on your radio astronomy projects from very experienced amateur radio astronomers.

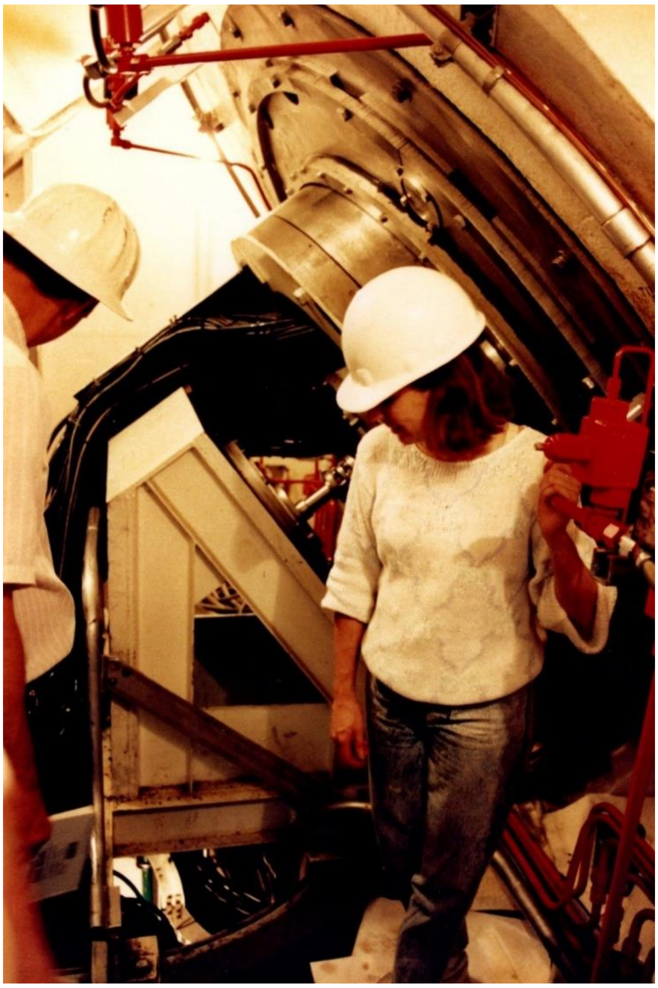
Drake's Lounge is every month on the 3rd Sunday at 2 pm Eastern time (1800 UTC). ZOOM email notifications will be sent to all members.

Vintage SARA

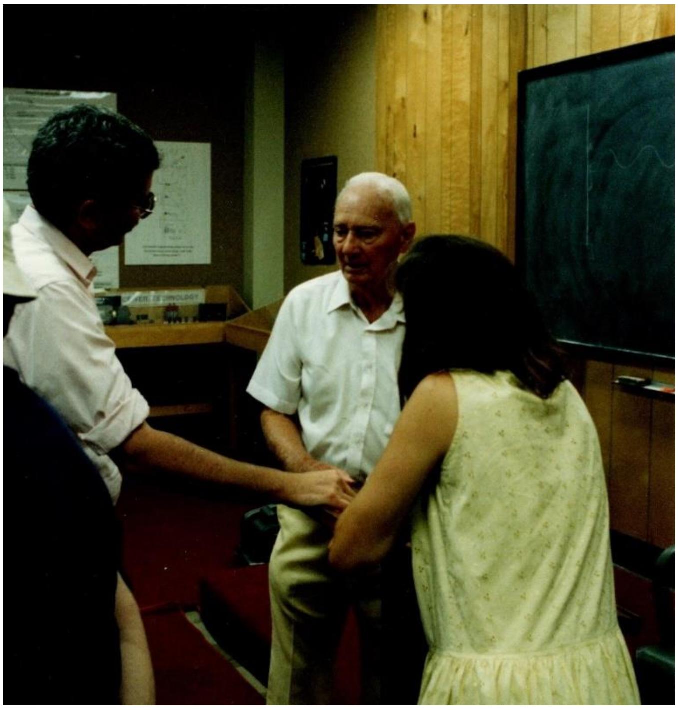
Charles Osborne, SARA Historian

Sue Ann Heatherly Retires

For as long as I've been in SARA (34 years) Sue Ann Heatherly has been a key interface between SARA and NRAO/GBO. She has recognized that SARA members are typically interested in access to a more in depth look at Green Bank's people, projects, and antennas than the average public visitor. She's gotten us lab tours and visits to the feed of the GBT numerous times making every conference special. And through Sue Ann we've helped on projects like the 40 footer, Itty Bitty Telescopes, and many of her other educational projects in any way we can.



Sue Ann leading SARA members' tour up inside the 140ft dish cable wrap/bearing area in 1992.



Paul Goldsmith (then NAIC/Arecibo Director), Grote Reber, and Sue Ann Heatherly at Grote's "Big Bang Is Bunk" lecture during the SARA Conference in 2002 I believe.

One of Sue Ann's impressive accomplishments was being a driving force in planning and making the GBO Visitors' Center a reality.

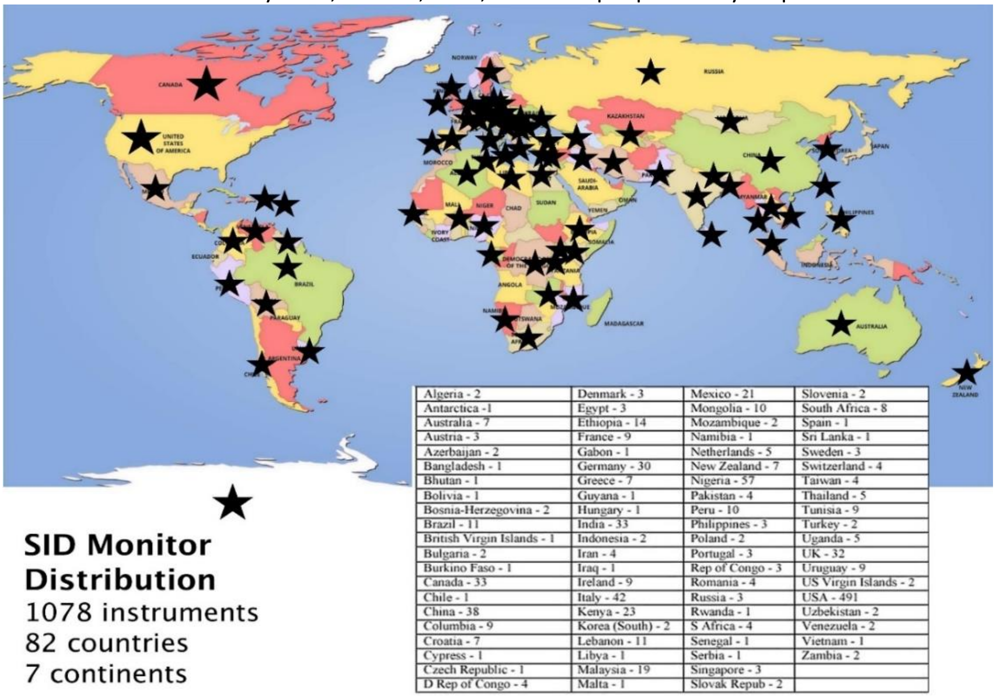
Ken Redcap giving Sue Ann an award in 2015.

As Sue Ann begins her retirement, we hope she can help keep us connected with the right people at GBO. I know her role will shift to Volunteer on projects she wants to pursue. And we wish her well in all her future endeavors.

SuperSID

SuperSID
Collaboration of Society of Amateur Radio Astronomers and Stanford Solar Center

- Stanford provides data hosting, database programming, and maintains the SuperSID website
- Society of Amateur Radio Astronomers (SARA) sells the SuperSID monitors for 48 USD to amateur radio astronomers and the funds are then used to support free distribution to students all over the world (image below as of Fall 2017)
-
- Jonathan Pettingale at SARA is responsible for building and shipping the SuperSID monitor kits: SuperSID@radio-astronomy.org
- SuperSID kits may be ordered through the SARA SuperSID webpage: http://radio-astronomy.org/node/210
- Questions about the SuperSID project may be directed to Steve Berl at Stanford: steveberl@gmail.com
- Jaap Akkerhuis at Stanford is responsible for the SuperSID software and SARA has provided financial support for his efforts
- SuperSID website hosted by Stanford: http://solar-center.stanford.edu/SID/sidmonitor/
- SuperSID database: http://sid.stanford.edu/database-browser/
- The data is searchable by time, station, date, and multiple plots may be placed on the same graph for comparison.



Algeria - 2	Denmark - 3	Mexico - 21	Slovenia - 2
Antarctica -1	Egypt - 3	Mongolia - 10	South Africa - 8
Australia - 7	Ethiopia - 14	Mozambique - 2	Spain - 1
Austria - 3	France - 9	Namibia - 1	Sri Lanka - 1
Azerbaijan - 2	Gabon - 1	Netherlands - 5	Sweden - 3
Bangladesh - 1	Germany - 30	New Zealand - 7	Switzerland - 4
Bhutan - 1	Greece - 7	Nigeria - 57	Taiwan - 4
Bolivia - 1	Guyana - 1	Pakistan - 4	Thailand - 5
Bosnia-Herzegovina - 2	Hungary - 1	Peru - 10	Tunisia - 9
Brazil - 11	India - 33	Philippines - 3	Turkey - 2
British Virgin Islands - 1	Indonesia - 2	Poland - 2	Uganda - 5
Bulgaria - 2	Iran - 4	Portugal - 3	UK - 32
Burkino Faso - 1	Iraq - 1	Rep of Congo - 3	Uruguay - 9
Canada - 33	Ireland - 9	Romania - 4	US Virgin Islands - 2
Chile - 1	Italy - 42	Russia - 3	USA - 491
China - 38	Kenya - 23	Rwanda - 1	Uzbekistan - 2
Columbia - 9	Korea (South) - 2	S Africa - 4	Venezuela - 2
Croatia - 7	Lebanon - 11	Senegal - 1	Vietnam - 1
Cypress - 1	Libya - 1	Serbia - 1	Zambia - 2
Czech Republic - 1	Malaysia - 19	Singapore - 3	
D Rep of Congo - 4	Malta - 1	Slovak Repub - 2	

-

For official use only
Monitor assigned: __________
Site name: ________________
Country: __________________

SuperSID Space Weather Monitor

Request Form

	Your information here		
Name of site/school *(if an institution)*:			
Choose a site name: *(3-6 characters) No Spaces*			
Primary contact person:			
Email:			
Phone(s):			
Primary Address:	Name School or Business Street Street City State/Province Country Postal Code		
Shipping address, if different:	Name School or Business Street Street City State/Province Country Postal Code		
Shipping phone number:			
Latitude & longitude of site:	Latitude: ____________________________ Longitude: ___________________________		

I understand that neither Stanford nor the Society of Amateur Radio Astronomers is responsible for accidents or injuries related to monitor use. I will assure that a surge protector and other lightning protection devices are installed if necessary.

Signature: ____ **Date:** ___________________________

I will need:

What	*Cost*	*How many?*
SuperSID distribution USB Power	$48 (assembled)	
USB Sound card 96 kHz sample rate *(or provide this yourself)*	$40 *(optional)*	
Antenna wire (120 meters) *(or you can provide this yourself)*	$23 *(optional) with connectors attached and tested*	
RG 58 Coax Cable (9 meters) *(or provide this yourself)*	$14 *(optional) with connectors attached and tested*	
Shipping	US $12 Canada & Mexico $40 all other $60	
	TOTAL	$

____ **I have included a $____________ check** (payable to SARA)

____ **I will make payment thru** www.paypal.com to treas@radio-astronomy.org

or

____ If you are a Minority-serving institution, in a Developing or economically deprived nation, and/or you are using the monitor with students for educational purposes, you may qualify for obtaining a monitor at reduced or no cost. Check here if you wish to apply for this designation. Then tell us how you want to use the SuperSID monitor. Include type of site, number of students involved, whether public or private school, grade levels, etc. and describe your program.

The goal of the SuperSID project is to provide as many students with systems as possible. If you are able to pay for a system, even if you qualify for a free one, please do so and help support our goal.
For more details on the Space Weather Monitor project, see: **http://sid.stanford.edu**

To set up a SuperSID monitor you will need:

1 Access to power and an antenna location that is relatively free of electric interference (could be indoors or out)

2 A **PC**** with the following minimal specifications:

a. A sound card that can record (sample) up to 96 kHz, or a USB port to connect such a sound card (for North and South America)
    i. All other countries can use AC97 sound card with 48 kHz record (sample) rate. Most computers made after 1997 will have AC97.
b. Windows 2000 or more recent operating system
c. 1 GHz Processer with 128 mb RAM
d. Ethernet connection & internet browser (desirable, but not required)
e. Standard keyboard, mouse, monitor, etc.

3 An inexpensive antenna that you build yourself. You'll need about 120 meters (400 feet) of **insulated** wire. Solid wire is easier to wind than stranded. Magnet wire will work but be more fragile. You can use anything from #18 to #26 size wire. The antenna frame can be made of wood, PVC pipe, or similar materials. We'll provide instructions. You can purchase the wire from us or obtain your own.

4 RG58 coax cable with a BNC connector at one end to run from the antenna to the SuperSID receiver. 9 meters is recommended, but the length will depend on where you place the antenna. You can purchase the coax from us or obtain your own.

5 Surge protector and other protection against a lightning strike

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Return this form to: SuperSID@radio-astronomy.org
or mail to:

SARA Treasurer
c/o Thomas Jacobs
P. O. Box 4245
Wilmington, NC 28406.

Announcing Radio JOVE 2.0

The Radio JOVE Team

Radio JOVE students and amateur scientists from around the world observe and analyze natural radio emissions of Jupiter, the Sun, and our galaxy using their own easy to construct radio telescopes.

Our Project announces Radio JOVE 2.0, where participants assemble a 16-24 MHz radio spectrograph to observe solar, Jupiter, Galactic, and Earth-based natural radio emissions and share their observations with fellow participants.

In the Beginning

Radio JOVE started as a NASA sponsored educational outreach project in 1999. We developed a radio telescope kit suitable for receiving signals from Jupiter, the Sun, the Galaxy, and Earth-based radio emissions. The original kit comprised a radio receiver (RJ1.1) and a dual dipole antenna for 20.1 MHz. An important goal was to teach electronic principles including how to build, solder, and assemble the radio receiver and antenna.

Figure 1. A Radio JOVE RJ1.1 receiver and a schematic of the dual-dipole antenna.

In addition to the hardware, three software packages were developed. These were Radio Jupiter Pro (Jupiter emission prediction program), Radio-SkyPipe (strip chart program) and Radio Sky Spectrograph (control and display of radio spectrograph data).

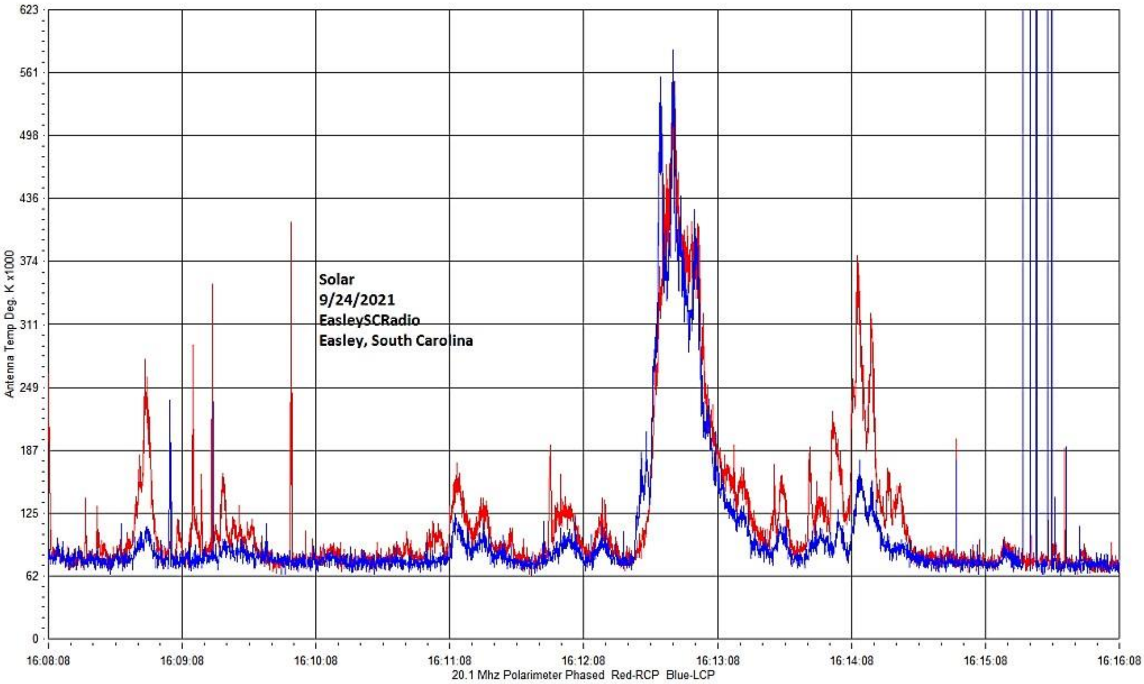

Figure 2. A SkyPipe strip chart showing multiple solar bursts using a JOVE receiver. John Cox, SC.

The Growth of Radio JOVE

As of Autumn 2021, over 2,500 kits have been sold at cost to schools and individuals around the world. Thousands of data submissions from observers have been made to the Radio JOVE data archive.

The Radio JOVE web site has always provided a wealth of information describing observation methods and various educational materials intended to teach radio astronomy techniques and scientific methods. Biannual newsletters are produced, and several telephone help sessions are held each year.

A sub-group of experienced observers known as the Spectrograph Users Group (SUG) evolved from the core JOVE group. These observers developed data collection and analysis techniques using more advanced equipment and techniques. SUG members have contributed to articles published in peer-reviewed scientific journals. This group remains active under the Radio JOVE listserv at https://groups.io/g/radio-jove/.

Moving Forward with New Technology

In the past, Radio JOVE provided the hands-on experience of building a radio kit. We have many RJ1.1 receivers in operation successfully contributing scientifically valuable data. It has, however, become increasingly difficult to obtain parts for the RJ1.1 receiver kits and we therefore decided to replace the RJ1.1 receiver with a new SDR-based design for the receiver portion of our radio telescope kits. While we continue to support the hardware and software for the original RJ1.1 receivers, the only kits now available for purchase from Radio JOVE contain this newly designed system.

In recent years, new technologies have made software defined radios (SDRs) ever more affordable. These radios can operate on a single frequency like the original JOVE receiver but can also generate spectrograms which depict radio activity as a function of both time and frequency. Such displays offer new insights into our studies of the Sun, Jupiter, the Galaxy, and both natural and artificial Earth-based radio emissions.

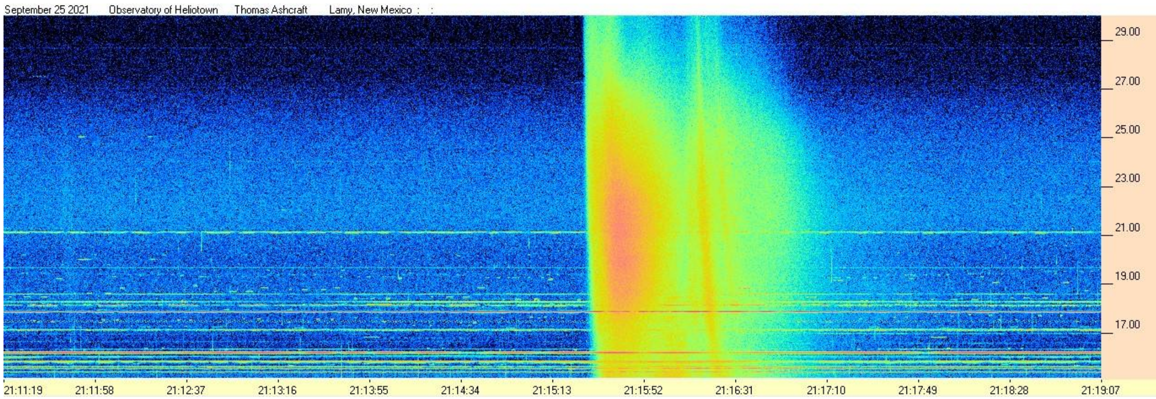

Figure 3. Radio spectrogram showing multiple solar bursts received by Tom Ashcraft in New Mexico. Horizontal scale is time, and the vertical scale is frequency. Amplitude is displayed using different colors corresponding to the strength of signals.

Radio JOVE continues to sell radio telescope packages including an antenna, receiver, and software; however, the receiver is now a commercially built SDR.

Figure 4. The JOVE team has had considerable success with the SDRPlay RSP1A unit and will provide support for using this instrument for our radio astronomy program. Not all SDR types can be supported, but it is our intent to provide support for some other SDRs as they become available during this period of rapid SDR development.

It continues to be our goal to introduce new observers to the scientific method and help them experience the thrill of receiving cosmic radio signals. Through a series of educational training modules and observing and analysis projects we aim to guide new observers to levels where they can contribute to Citizen Science projects.

We continue to support our large user base that uses JOVE RJ1.1 receivers – both in terms of technical support for the receivers but also with new and exciting observing projects for both RJ1.1 and SDR users.

We welcome both new and experienced observers to the JOVE 2.0 program as we share the excitement of receiving, studying, and understanding radio signals from our corner of the galaxy.

Please see the Radio JOVE web site at https://radiojove.gsfc.nasa.gov for more information.

RADIO JOVE 2.0 RADIO TELESCOPE KIT ORDER FORM

Order Online using PayPal™

* * * Please allow 2 to 3 weeks for delivery. * * *

IMPORTANT: Before you order the Jove receiver kit and/or the antenna kit, we suggest that you read the on-line manuals. You will need to provide additional materials and tools to complete the antenna. The cost of additional materials for the antenna support structure (masts, etc.) may be in the range of US$75 to US$100. Also note that the optimal antenna height can be up to 20ft, depending upon your latitude.

Item # RJK2u – Complete 2.0 Kit: Receiver + Unbuilt Antenna Kit + Software This kit includes an SDRplay RSP1A, USB Cable, SMA/BNC cable, F-adapter, unbuilt Antenna Kit (RJA), printed assembly manuals, and Radio-Sky Spectrograph (RSS) software. Note: Kit does not include antenna support structure. **Price: $215 + Shipping (See reverse for shipping)**	**Item # RJK2p** – Complete 2.0 Kit: Receiver + Professionally Built Antenna Kit + Software This kit includes an SDRplay RSP1A, USB Cable, SMA/BNC cable, F-adapter, Professionally Built Antenna Kit (RJA2), printed assembly manuals, and Radio-Sky Spectrograph (RSS) software. Note: Kit does not include antenna support structure. **Price: $384 + Shipping (See reverse for shipping)**
Item # RJA – Unbuilt Antenna Kit The RJA Radio JOVE Antenna Kit includes a printed construction manual, stranded copper easy-to-solder antenna wire, ceramic insulators, RG-59 easy-to-solder coax cable, screw-on F connectors, and a power combiner. Note: Kit does not include antenna support structure. Assembly requires a soldering gun and other tools. **Price: $90 + Shipping (See reverse for shipping)**	**Item # RJA2** – Professionally Built Antenna Kit The RJA2 Radio JOVE Antenna Kit includes a printed installation manual, two professionally assembled dipole antennas constructed of #14 Copperweld wire with Budwig center insulators and center support rope attachment points, high quality RG-6 coax with pre-installed commercial grade connectors, and a power combiner. Note: Kit does not include antenna support structure. **Price: $249 + Shipping (See reverse for shipping)**
Item # LTJ2 – Listening to Jupiter, 2nd Ed. by R. S. Flagg PDF download of Richard Flagg's book "Listening to Jupiter, 2nd Ed., 2005". The file is downloaded from a secure website. **Price: $10 + $0 shipping (PDF file download)**	**Item # RJR2** – Radio JOVE 2.0 Receiver-Only Kit This kit includes one SDRplay RSP1A SDR receiver, USB Cable, SMA/BNC cable, and F-adapter, printed assembly manuals, and Radio-Sky Spectrograph (RSS) software. **Price: $135 + Shipping (See reverse for shipping)**

RADIO JOVE 2.0 RADIO TELESCOPE KIT ORDER FORM (continued)

Order Online at https://radiojove.net/kit/order_form.html
OR
Complete this form and mail with payment

Payment may be made by Credit Card via PayPal™, U.S. Check, U.S. Money Order, International Money Order in U.S. funds drawn on a U.S. bank, or Western Union Money Transfer made payable to **The Radio JOVE Project**. No bank-to-bank wire transfers are accepted. Purchase Orders are accepted from U.S. Institutions.

Send to: The Radio JOVE Project
1301 East Main St
MTSU Box 412
Murfreesboro, TN 37132, USA
email: chiggins@mtsu.edu
FEIN: 20-5239863

Item	Description	Quantity	Item Price	Shipping (see below)	Subtotal
RJK2u	Complete Radio JOVE 2.0 Kit Receiver + unbuilt Antenna		$215		
RJK2p	Complete Radio JOVE 2.0 Kit Receiver + Professionally Built Antenna		$384		
RJA2	Professionally Built Antenna-Only Kit		$249		
RJA	Unbuilt Antenna-Only Kit		$90		
RJR2	Receiver-Only Kit		$135		
LTJ2	Listening to Jupiter, 2nd Ed., by R.S. Flagg (PDF download)		$10	$0	
				Total:	

Shipping Fees for Radio JOVE: We ship all packages using USPS Priority Mail flat rate boxes.
U.S.A.: $17.00
Canada: $57.00
All Other International Shipping: $85.00

Ship to: (Please print clearly)

Name: ____

Address: ____

City, State, Postal Code: ____

Province, Country: ____

Email: ____

Visit the Radio JOVE web site and fill out the team application form at https://radiojove.net/sign_up_form.php even if you are just an interested individual so that you can receive important information about kit updates, online services, and activities within the project as they occur!

The British Astronomical Association
A company limited by guarantee
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Founded in 1890

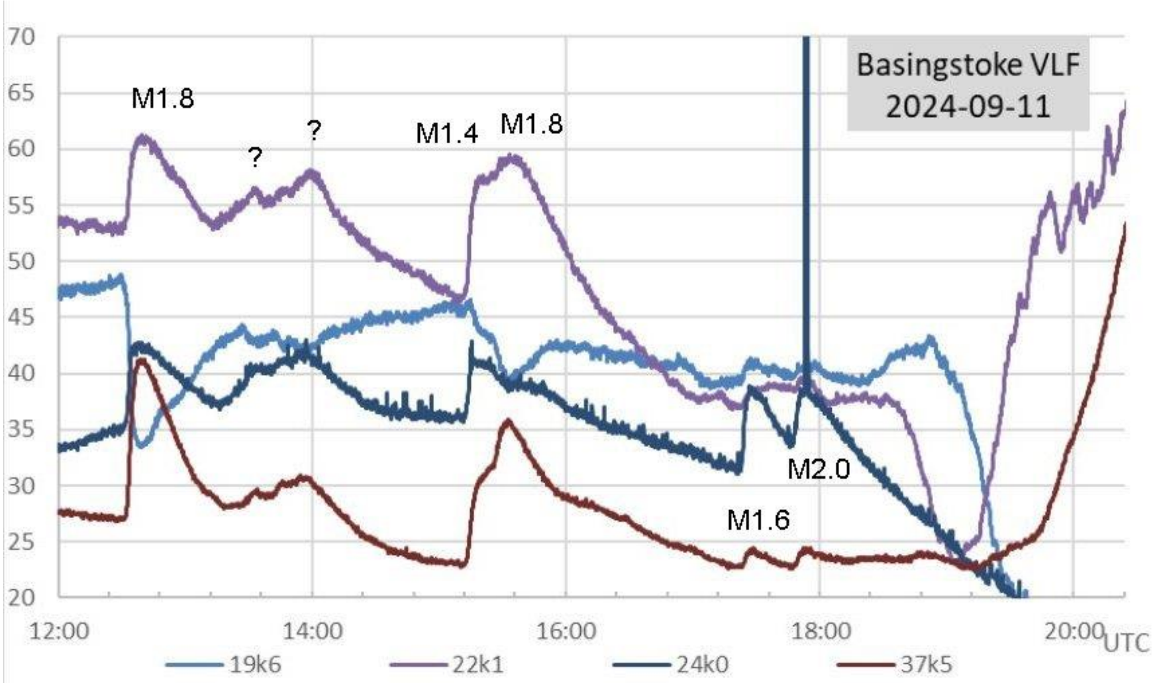
PO Box 702, Tonbridge, TN9-9TX 020-7734 4145
www.britastro.org

Please send questions, reports, and observations to John Cook: jacook@jacook.plus.com
BAA Radio Astronomy Section, Director: Paul Hearn

RADIO SKY NEWS **2024 SEPTEMBER**

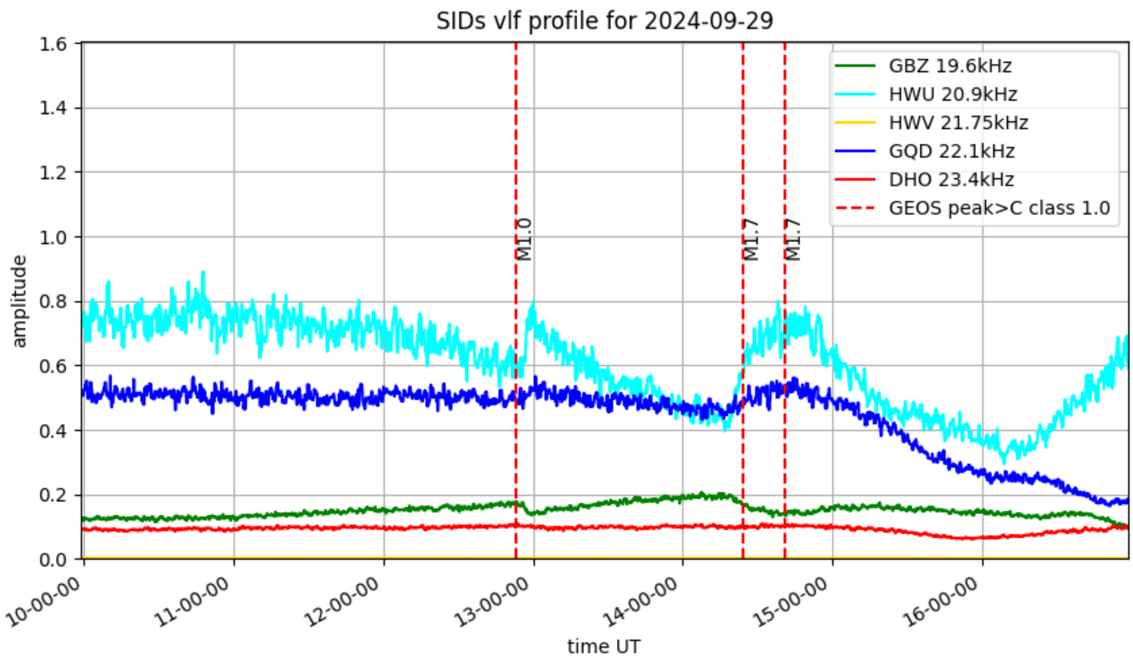
VLF SID OBSERVATIONS

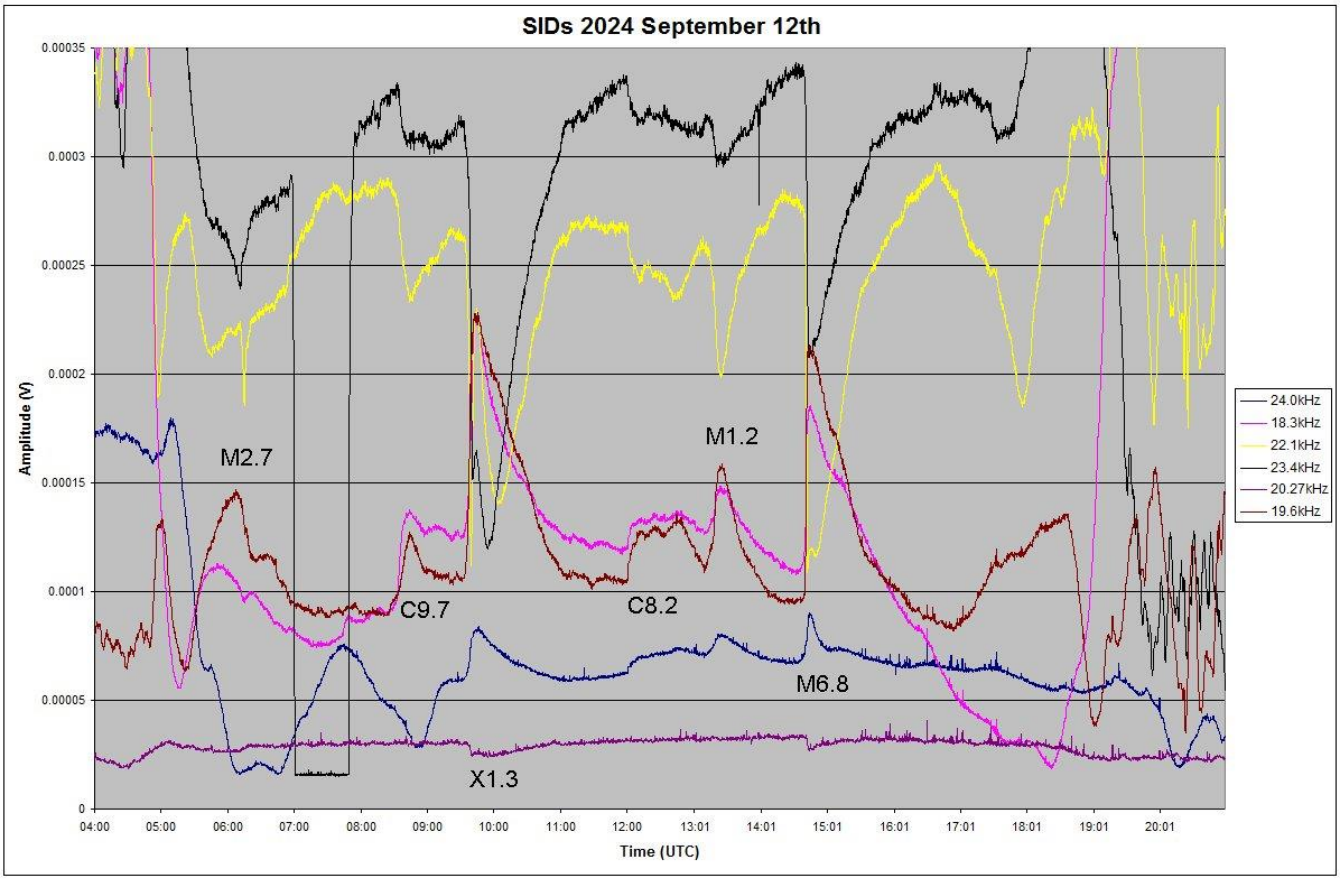
Solar activity in September started strongly but faded away mid-month. We recorded 132 classified flares compared with 305 in August. This lower level was last recorded in February, with a count of 134. Many of the flares were fairly strong, with 34 M-class and two X-class. There were also plenty of multiple peaked flares, some of which merged to give a single SID depending on the frequency monitored.



Paul Hyde's recording from the 11th shows the merging of the M1.4 and M1.8 flares, giving a double peaked SID. The SWPC satellite bulletin lists these as being from AR 13811, with peaks just 12 minutes apart. The recording also shows a pair of unlisted events earlier in the afternoon. The M1.6 and M2.0 flares later in the afternoon have produced smaller SIDs, although the 24kHz Atlantic path are much stronger. This was just 10 days before the autumnal equinox, the days getting noticeably shorter and the sunset effect clearly seen at 19.6kHz and 22.1kHz.

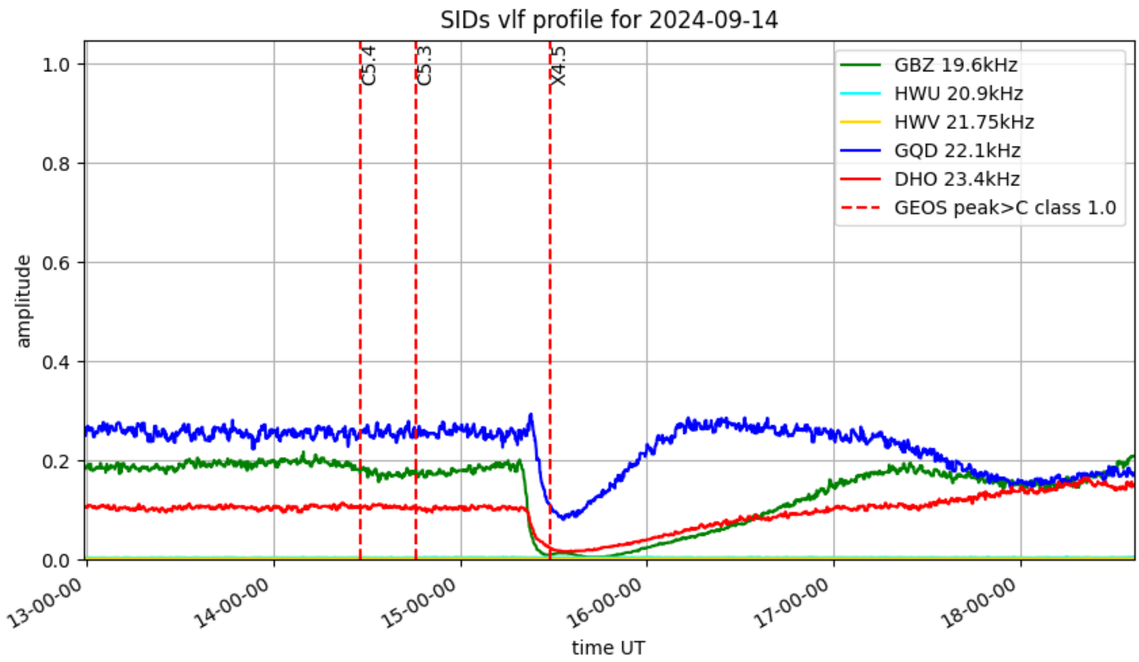
There was a similar pair of merging flares on the 29th. The SWPC bulletin lists two M1.7 flares from AR13842 just 17 minutes apart. They were immediately followed by an unclassified flare lasting until 15:11. A single SID is shown in the recording by Mark Prescott, with just a hint of a second peak at 19.6kHz.

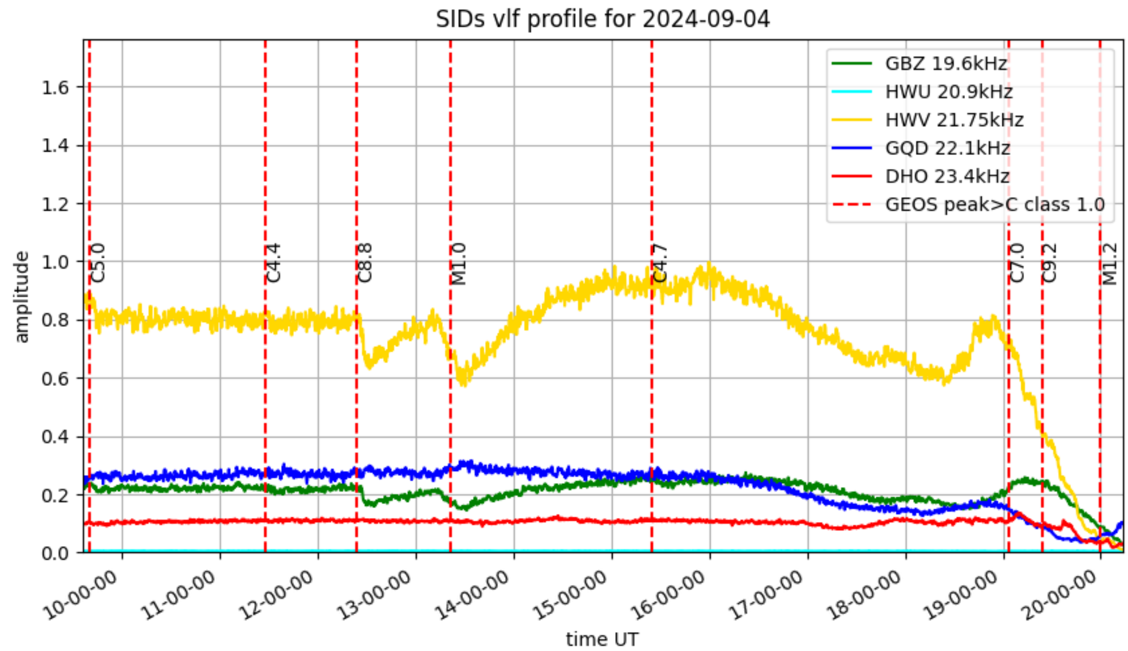




The first of the X-flares was recorded on the 12th, shown in Mark Edwards' recording along with the rest of the day's activity. I have labelled the strongest of the SIDs, but there were also several unclassified flares appearing as more multiple peaked SIDs. The southern path at 20.27kHz has only been weakly affected by the activity, while 19.6kHz and 22.1kHz show a much greater response to the flares.

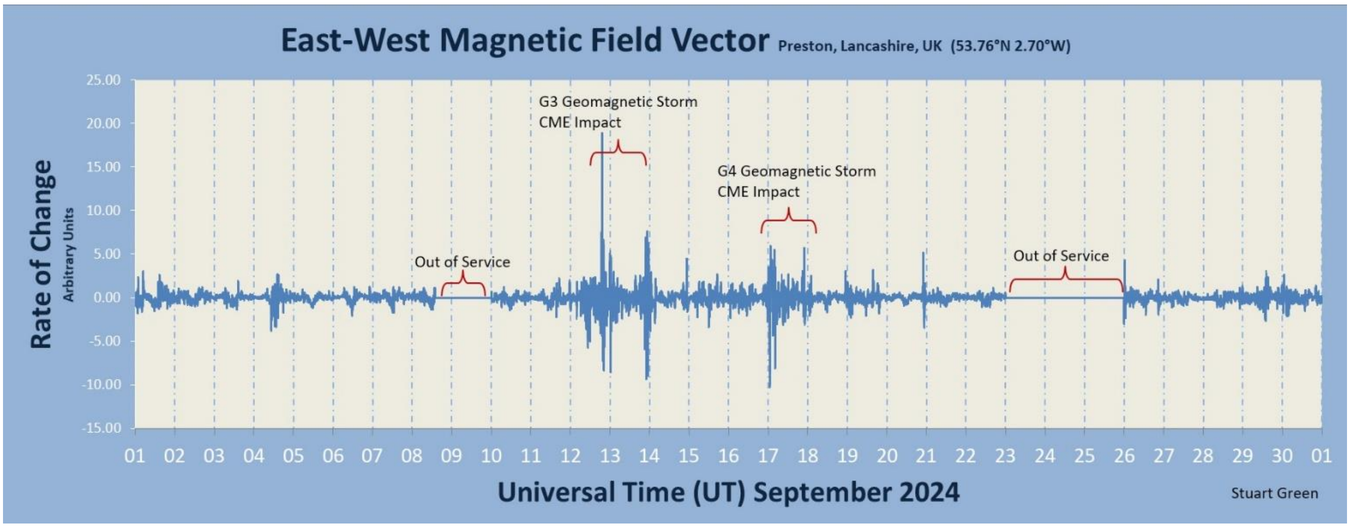
The X4.5 flare on the 14th was towards the end of the strong activity, with just two other flares shown in the SWPC satellite data for the 14th. Mark Prescott's recording (below) shows a pair of similar SIDs at 19.6kHz and 23.4kHz, with what appears to be a much shorter SID at 22.1kHz. This is really a spike and wave SID with just a very small spike at the start of the flare that is followed by a very long recovery period. Mark Edwards reported a spread of over 90 minutes in the end timing of this event over the seven signals monitored.



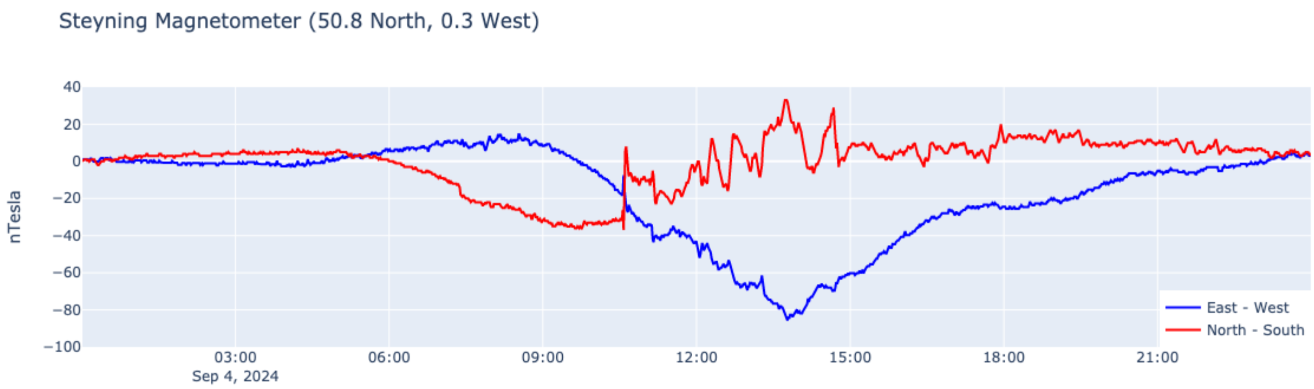


Mark Prescott's recording on the 4th shows a series of SIDs at 21.75kHz, much clearer than the other signals. 23.4kHz has not responded at all, while 19.6 and 22.1kHz just give some weak SIDs. The smaller C-flares are not so clear, but the high background X-ray flux level meant that the C-flares gave only a very small increase in flux. The reduced activity later in the month resulted in a lower background level, and so more C-flares were recorded.

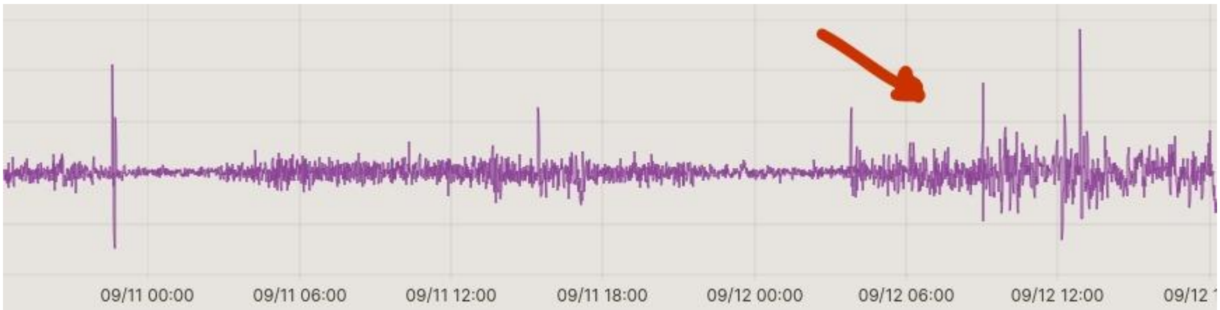
MAGNETIC OBSERVATIONS



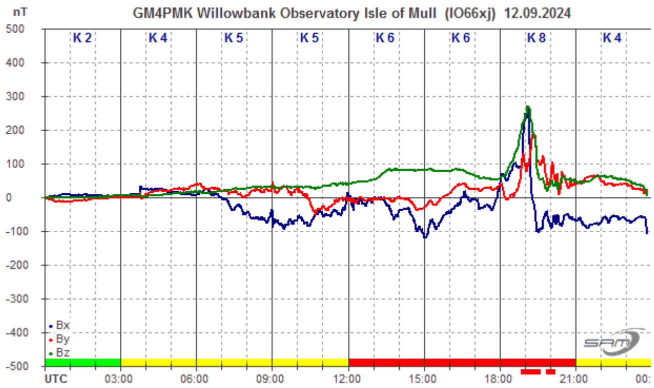
Stuart Green's summary of the month's magnetic activity shows just a couple of strong storms around mid-month. There are also two short periods where the sensor was not operating.

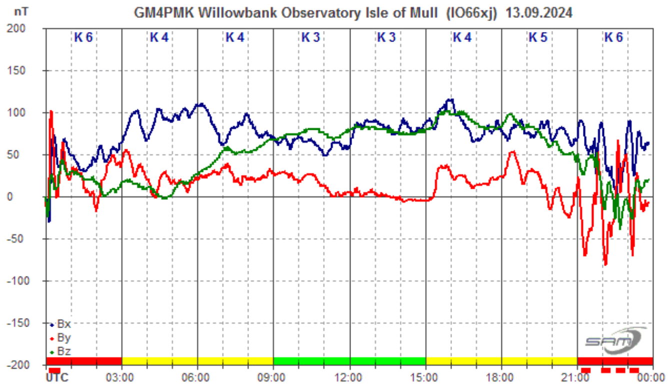


There was a strong sudden impact on the 4th, shown in Nick Quinn's recording. My own recording gives a time of 10:32UT. The source of the SI is not clear, the STCE bulletin suggesting a CME from September 1st. This however was from the back of the sun and was not expected to have any effect. The subsequent disturbance was rather mild, and only lasted through the afternoon. There had been some mild disturbance over the previous days, probably from a turbulent solar wind.

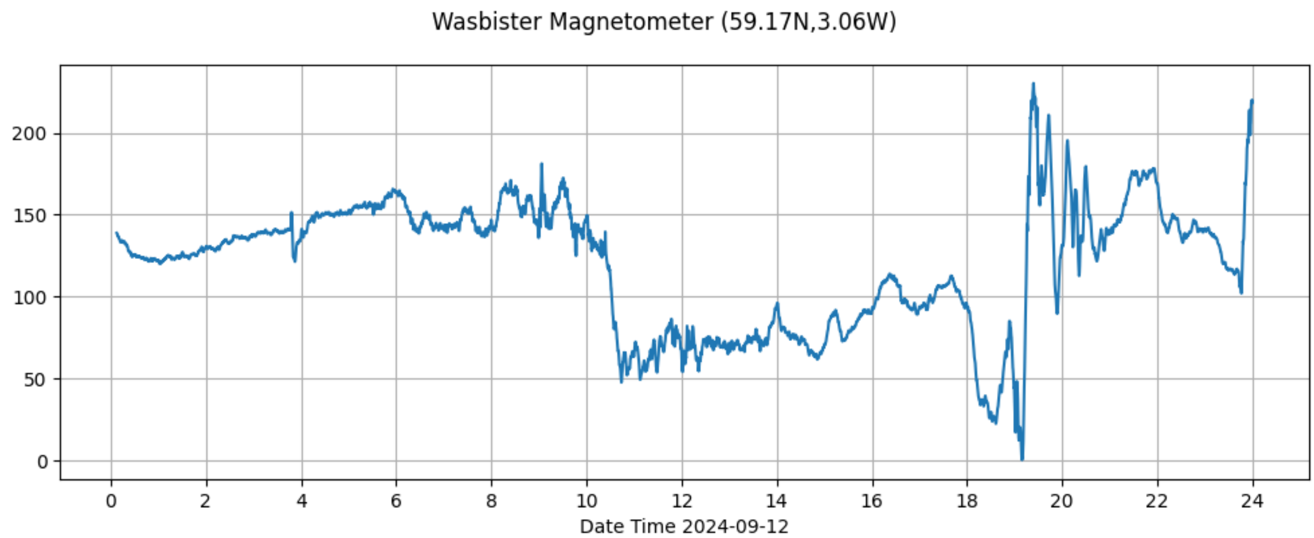


There were some short periods of mild disturbance over the following week, but the first strong activity started on the 12th, shown in this chart from Thomas Mazzi in Italy. The activity continued into the 13th, shown in Roger Blackwell's recording:

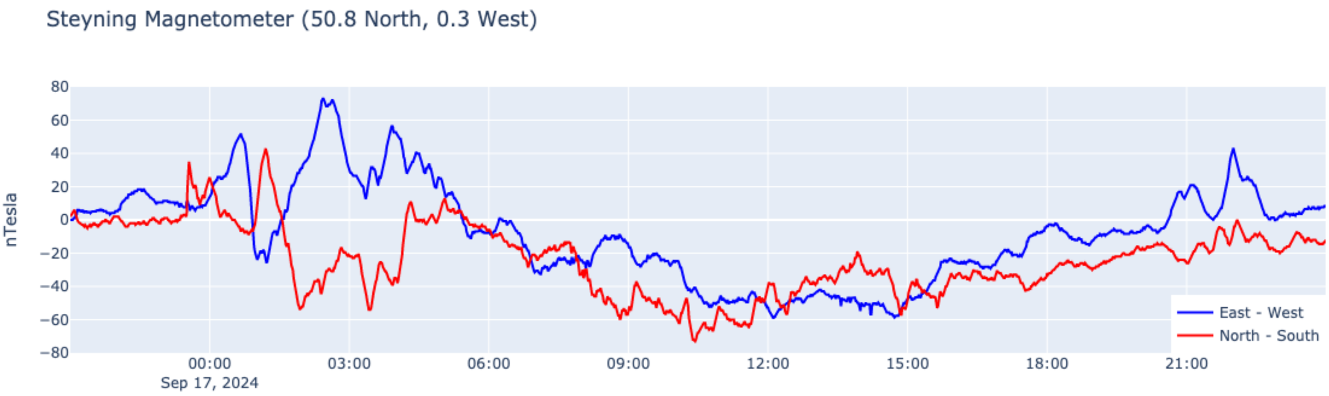




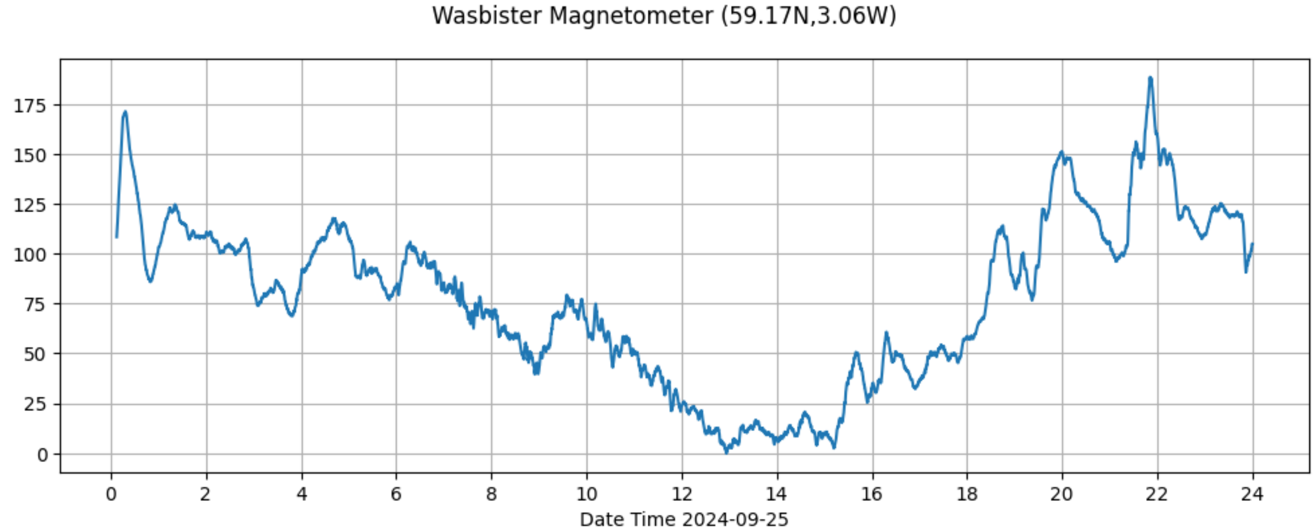
The vertical scale changes between the two charts, the strongest peak being around 18-20UT on the 12th. There is a small impact spike at about 03:45, also seen in Callum Potter's recording:



The STCE bulletin lists a CME from the 10th as being the source of the disturbance. Mild disturbance continued through the 14th to 16th, increasing again just before midnight on the 16th. Nick Quinn's recording shows another impact just before midnight on the 16th, with a more active period in the morning of the 17th.



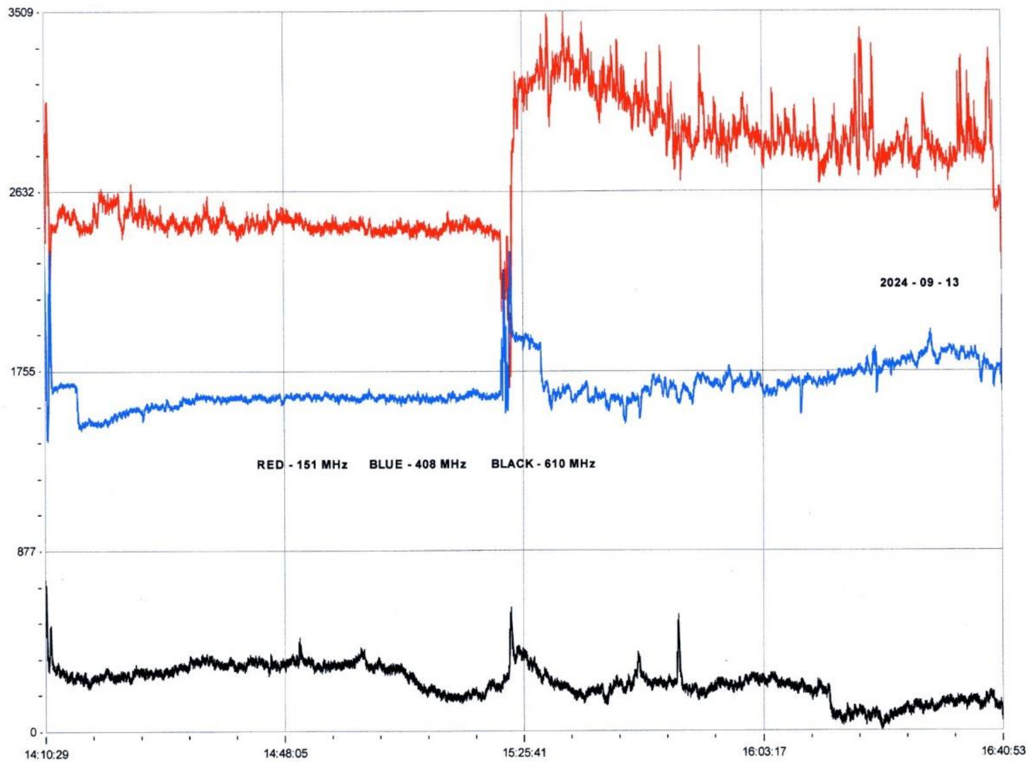
The STCE bulletin gives the source as a CME from the 14th. This activity continued through the 18th to 24th, before another more active period on the 25th. Callum Potter's recording shows magnetic turbulence all day on the 25th:



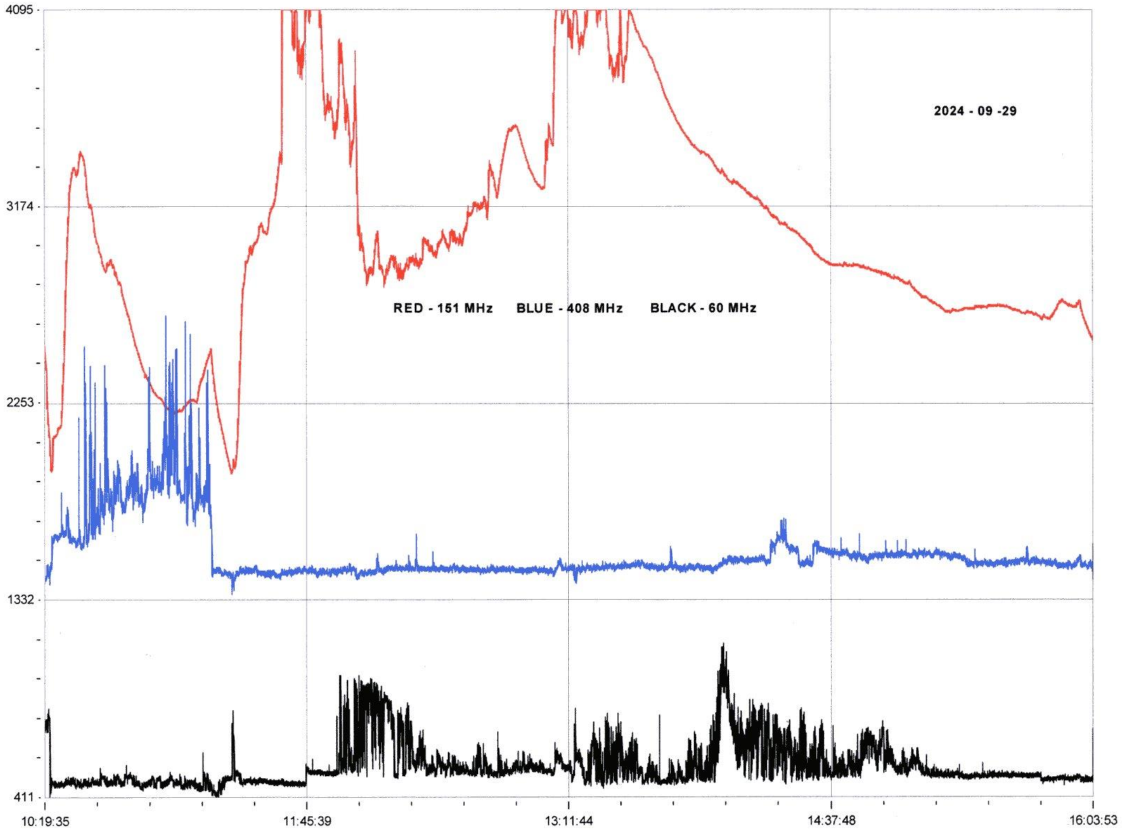
It was much quieter after this, with just a few minor disturbances on the 29th and 30th.

Magnetic observations received from Roger Blackwell, Thomas Mazzi, Callum Potter, Nick Quinn, and John Cook.

SOLAR EMISSIONS

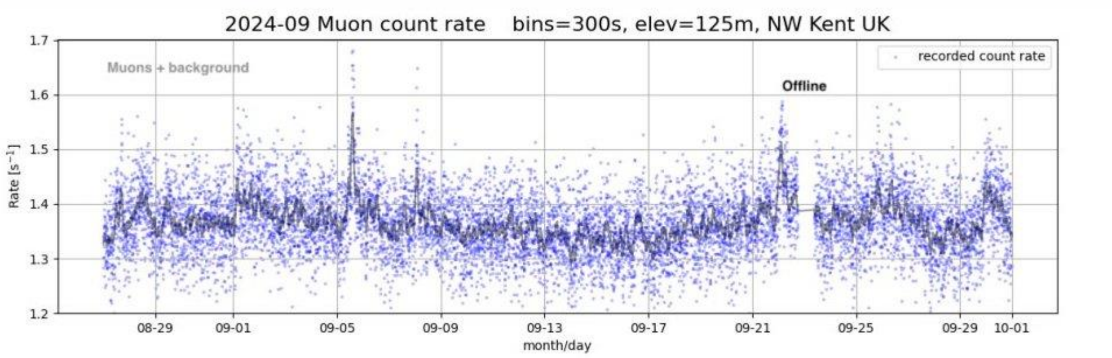


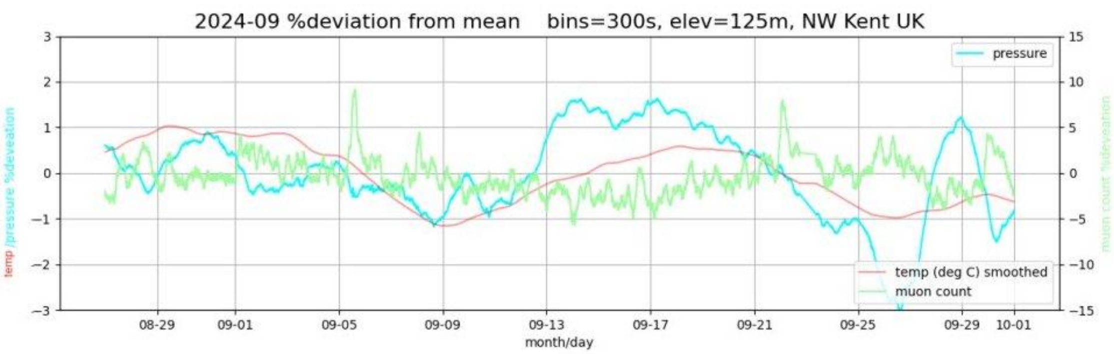
Colin Clements' recording from the 13th shows a strong 151MHz emission starting at 15:05UT, matching the M1.2 flare. The flare lasted for over an hour based on our SID timings, the 151MHz noise lasting rather longer. Much shorter noise bursts were recorded at 408MHz and 610MHz.

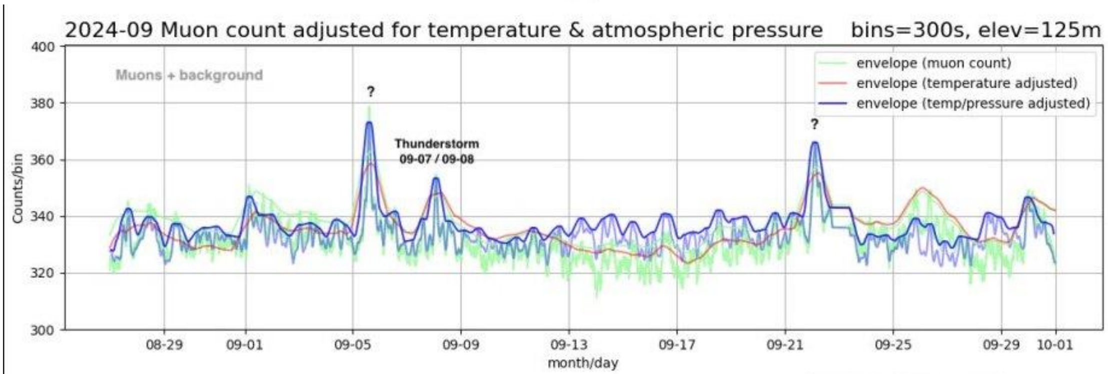


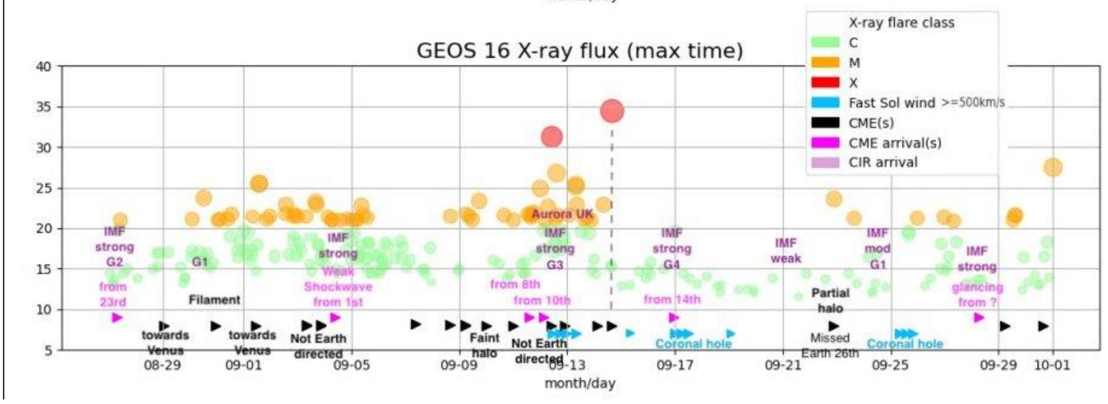
Colin's recording from the 29th shows a lot of 151Mhz activity. The strong peak around 13:00 matches the M1.0 flare, possibly with a contribution from the first of the M1.7 flares at 14:21. The SWPC bulletin includes an unclassified flare at 11:07 which may be linked with the earlier 151MHz and 408MHz activity. Colin has also recently installed a 60MHz antenna in the loft, aimed to catch the Autumn / Winter activity. This has shown activity for nearly three hours from midday, covering the M1.0 and both of the M1.7 flares.

MUONS









Mark Prescott's Muon charts show three very pronounced peaks. One of these was due to a local thunderstorm, and is a common effect, the other two do not appear to match any significant solar activity. There had been multiple minor CMEs early in September, but no significant magnetic disturbances were recorded on the 5th or 22nd. The weather here in the UK has been fairly turbulent with a large variation in air pressure, but the peaks remain after the raw data has been corrected for temperature and pressure.

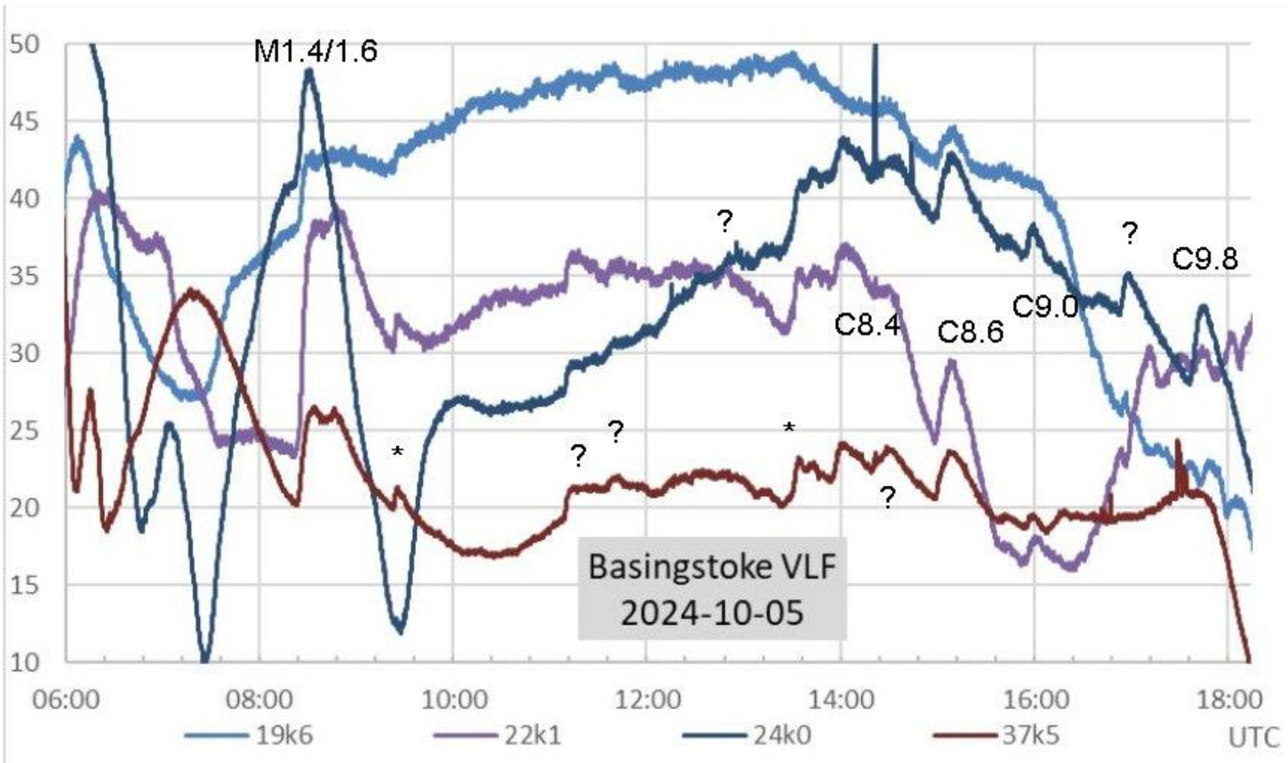
The August BAA journal included an interesting item describing the construction of a Muon detector. One of the members of our local library astronomy group has built a version of this design, bringing it along to a recent meeting. The results were quite interesting, with several captures during the short period that it was operating. It is essentially a miniature cloud chamber, so events are seen visually rather than being logged and counted. To demonstrate its operation, we had as small web camera aimed into the chamber, with the activity seen on a monitor screen.

Section webinars continue, with a talk on the development of a global network for cosmic ray Muon detection on Friday December 6th. If you are not on the mailing list for the webinars, then do contact Paul Hearn for details.

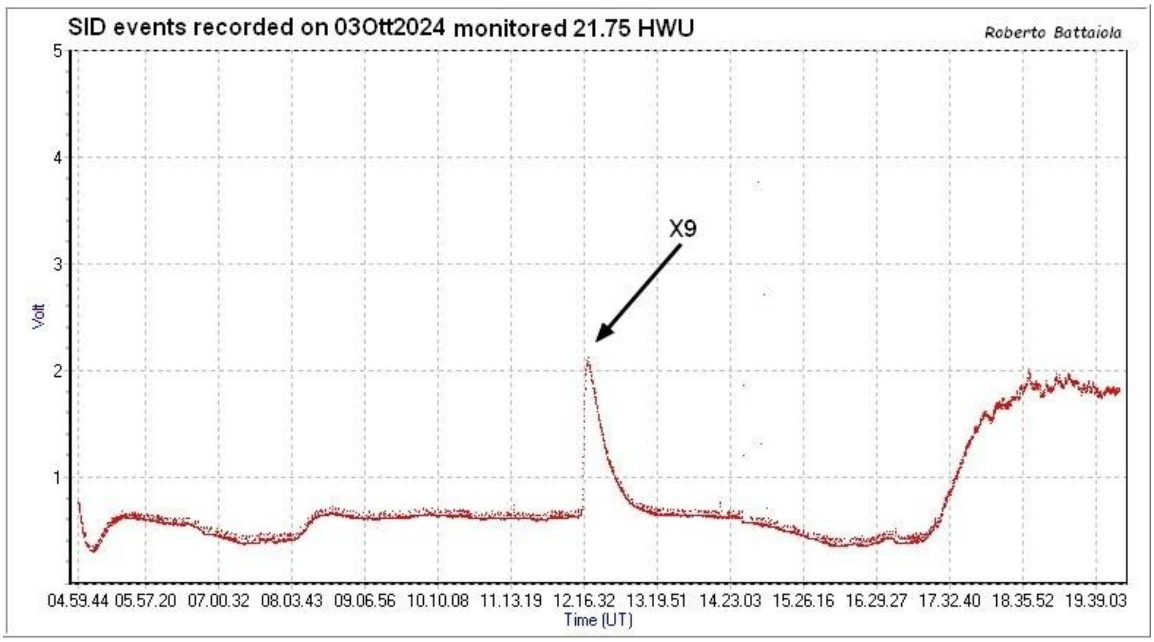
RADIO SKY NEWS **2024 OCTOBER**

VLF SID OBSERVATIONS

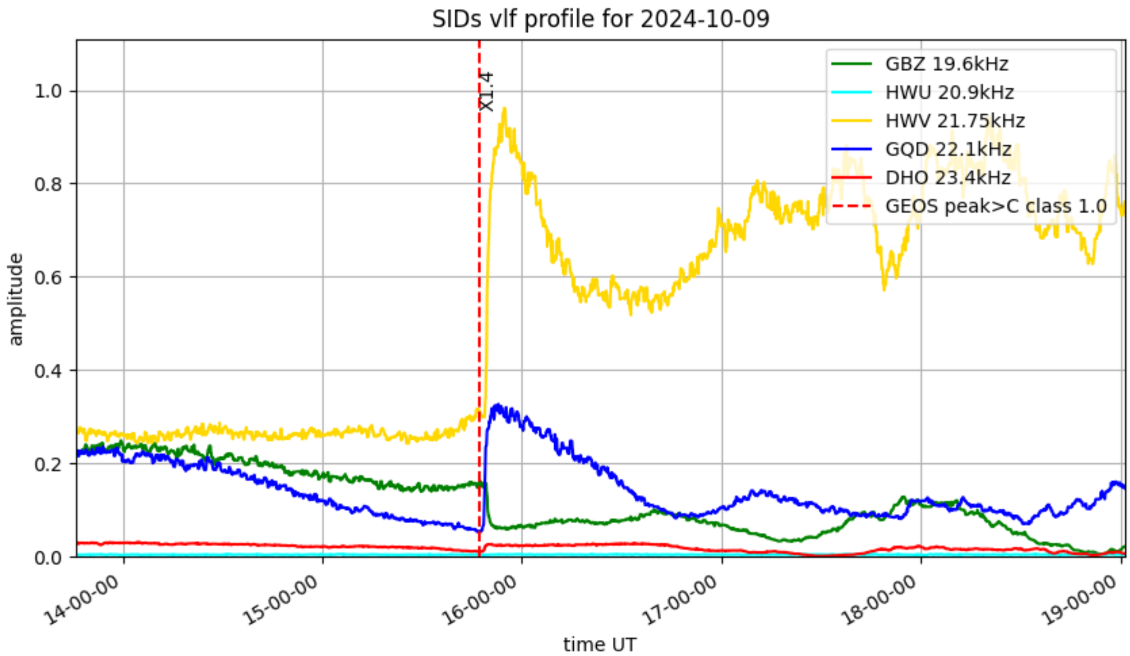
Solar flare activity in October was at a similar level to that in September, with another 3 X-class flares recorded as SIDs. Once again many of the flares had multiple peaks, and there were plenty of well-observed events that were not classified or not listed in the GOES satellite data.



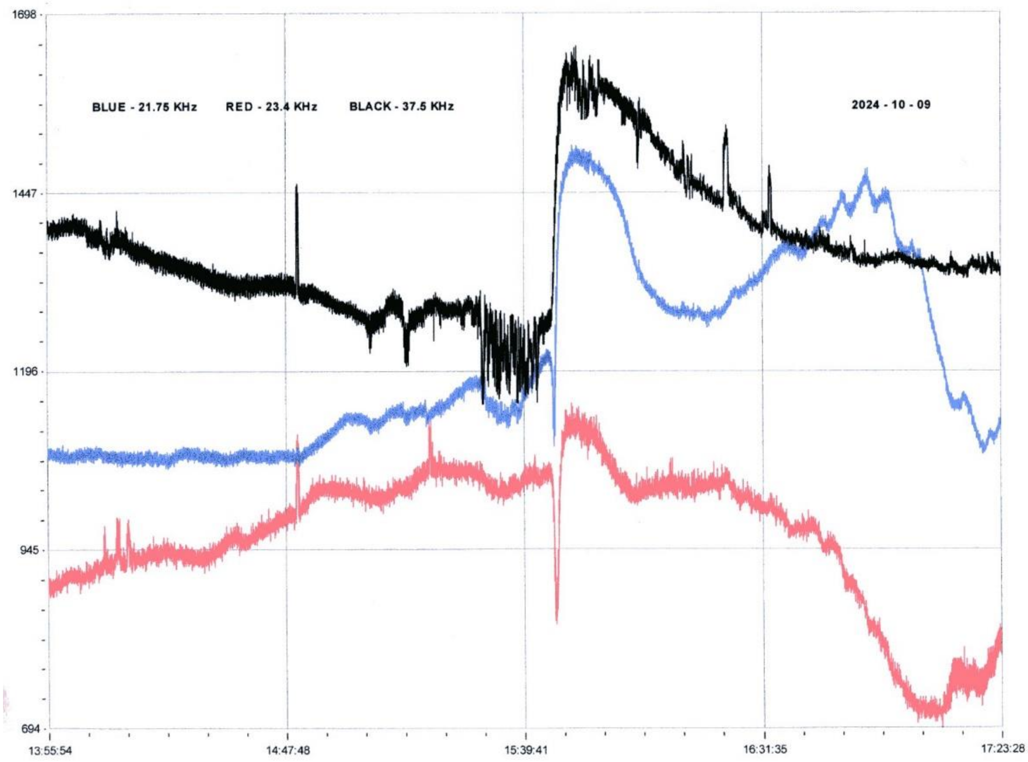
This recording from Paul Hyde shows plenty of activity on the 5th, much of it being unclassified. The M1.4 and M1.6 flares around 08:30UT were merged into a single SID in many recordings, occurring at the end of the local sunrise disturbance. This was followed by a series of small SIDs of unknown origin, before some strong C-class flares leading into the sunset. The last C9.8 flare was too late for the UK signals at 19.6kHz and 22.1kHz. During the autumn period, especially in October, the Earth-Sun alignment is perfect for minor magnetic disturbances to strongly influence the ionosphere, perhaps explaining some of the smaller SIDs shown in our recordings.



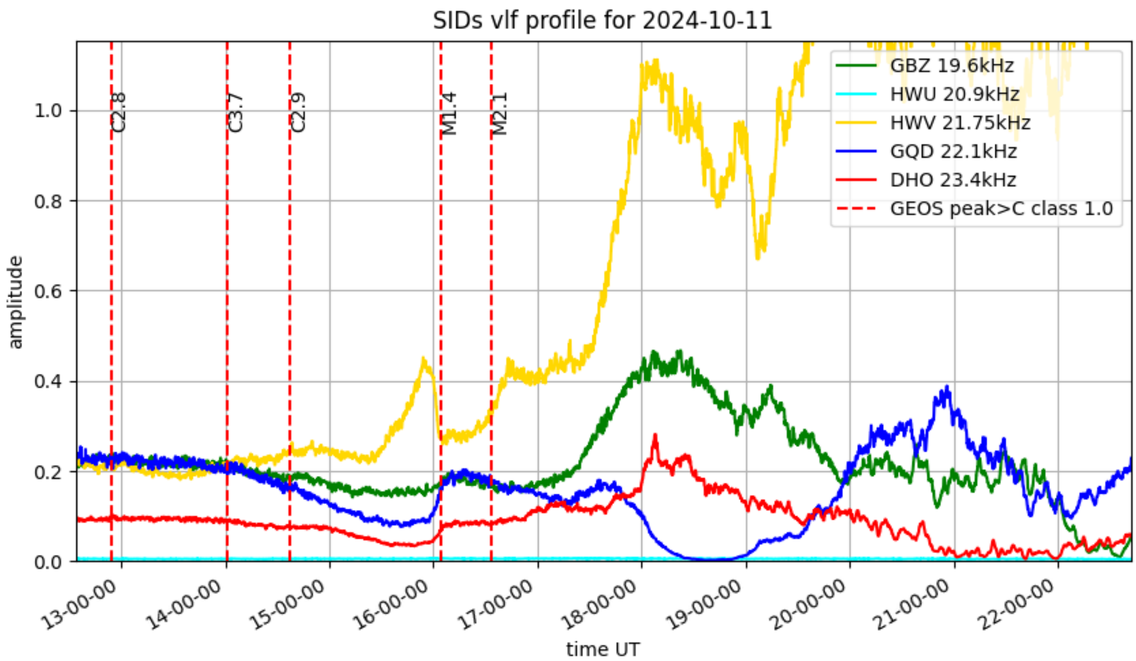
The strongest flare was the X9.0, well timed just after midday on the 3rd, shown here by Roberto Battaiola. There is also a small SID from the pair of M1.5 flares earlier in the morning. The GOES data gives peak times of 08:28 and 08:36 for these, producing a single, rather slow, SID. The later M1.5 flare at 17:20 has been lost in the sunset. The general background is much quieter compared to that shown on the 5th.



The X1.4 flare on the 9th was rather later in the afternoon, peaking just before 16:00UT. Mark Prescott's recording shows a pair of mirror SIDs at 19.6 and 22.1kHz, both with a clear decay phase. 21.75kHz shows a very strong rise to the peak, but then seems to hover at a much higher level than pre-flare. This path runs south into France, and so the sunset should be slightly later than with the northern UK paths. A rather strange behaviour. The flare was widely recorded, but I only have one other recording that shows this frequency, from Colin Clements:

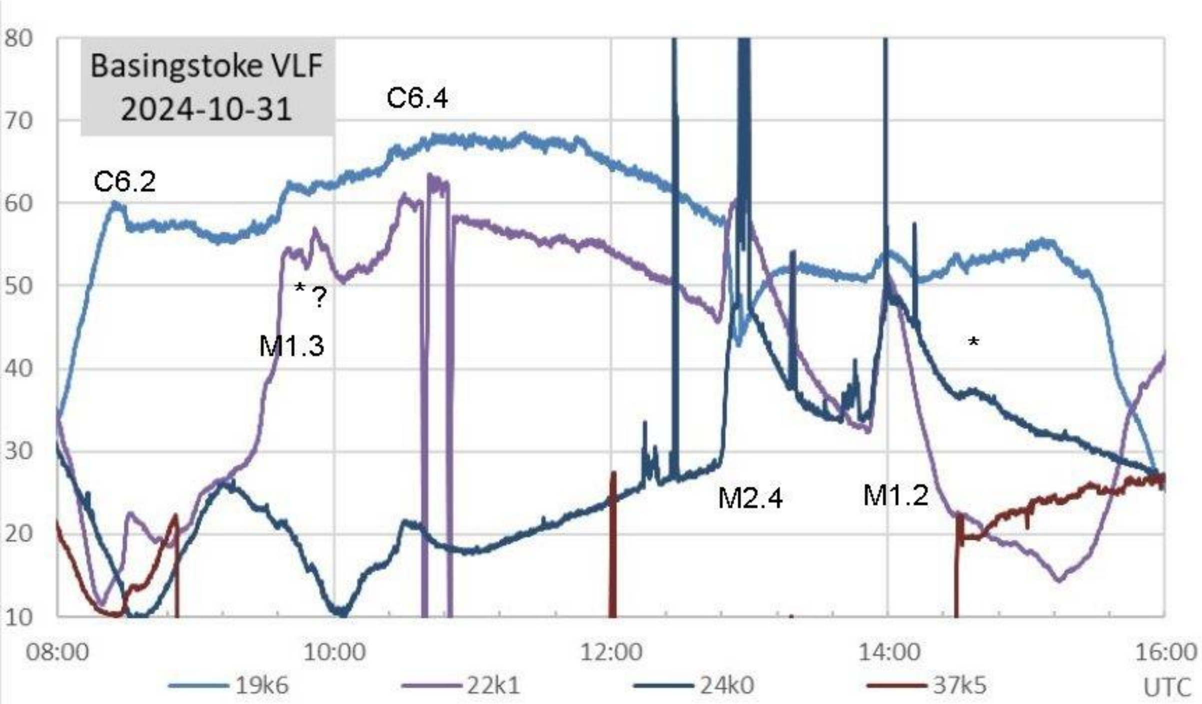


21.75kHz is shown in blue, with a spike-and-wave SID. It also shows the signal rising again after a short decay. 23.4kHz (red) has an eastern path and shows an earlier sunset. 37.5kHz (black) is from Grindavik, Iceland, and so does not show any sunset effects.



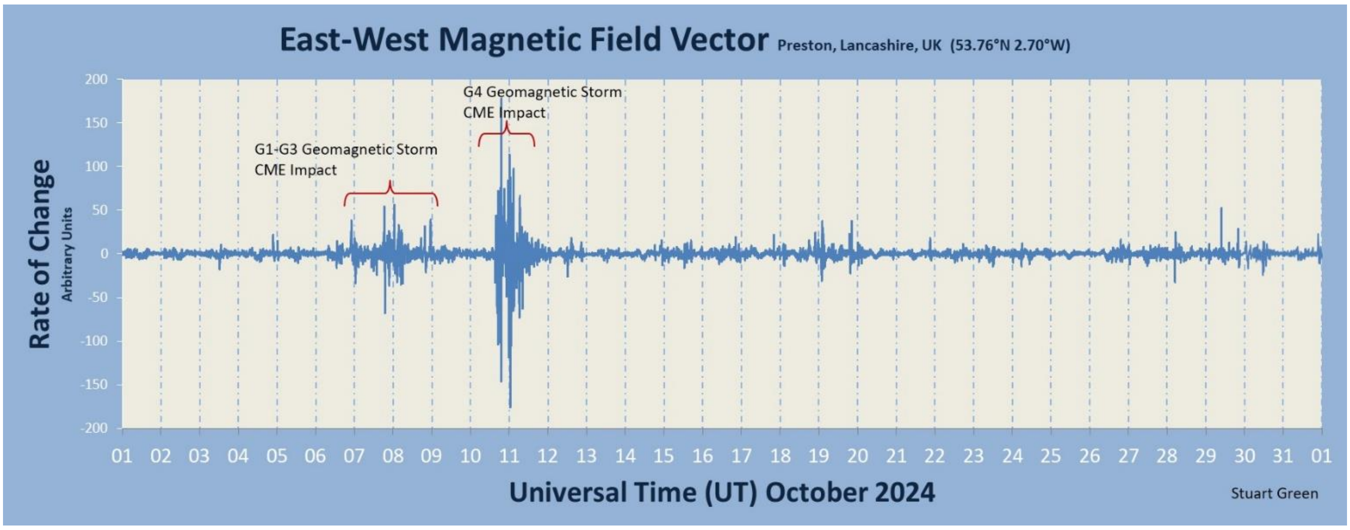
The M2.1 and M1.4 flares in the afternoon of the 11th merged to produce a single SID in all of our observations. The GOES data shows that they were both produced from the same active region, AR 13854. Mark Prescott's recording clearly shows a single SID at 19.6 and 22.1kHz, with a more complex SID at 21.75kHz. The GOES data lists peaks at 16:04 and 16:33, joining at 16:07UT. Our spread of peak timings from 16:02 to 16:21 reflects this complexity.

Activity through the middle of October was rather lower, increasing again at the end of the month.

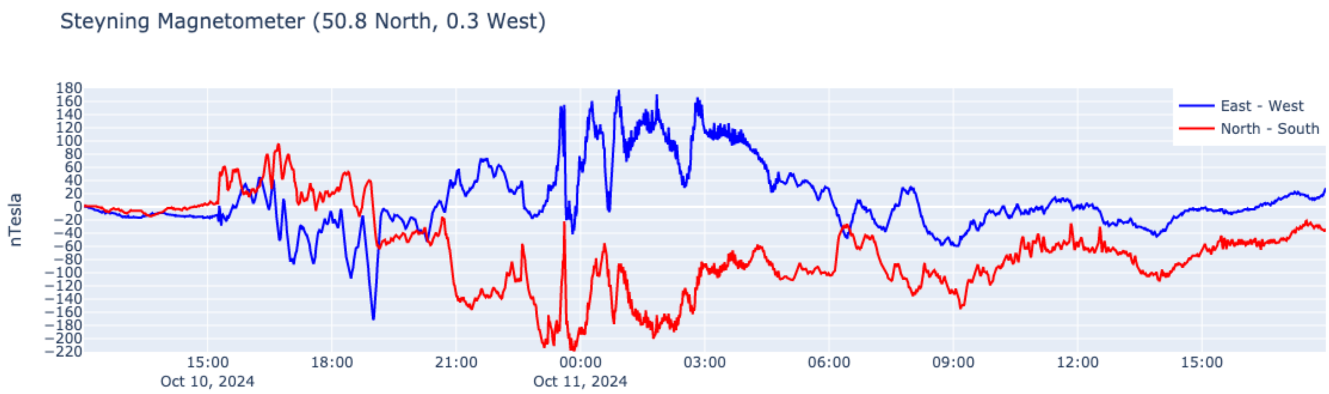


Paul Hyde's recording on the 31st shows the activity along with some significant interference. 22.1kHz shows the best SIDs, including the multiple peaks between 09:30 and 10:00UT.

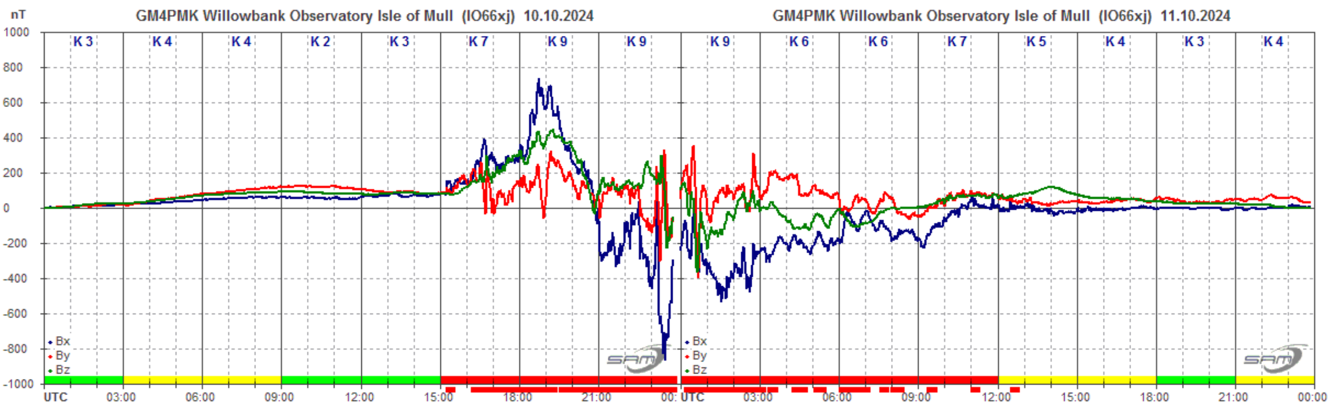
MAGNETIC OBSERVATIONS



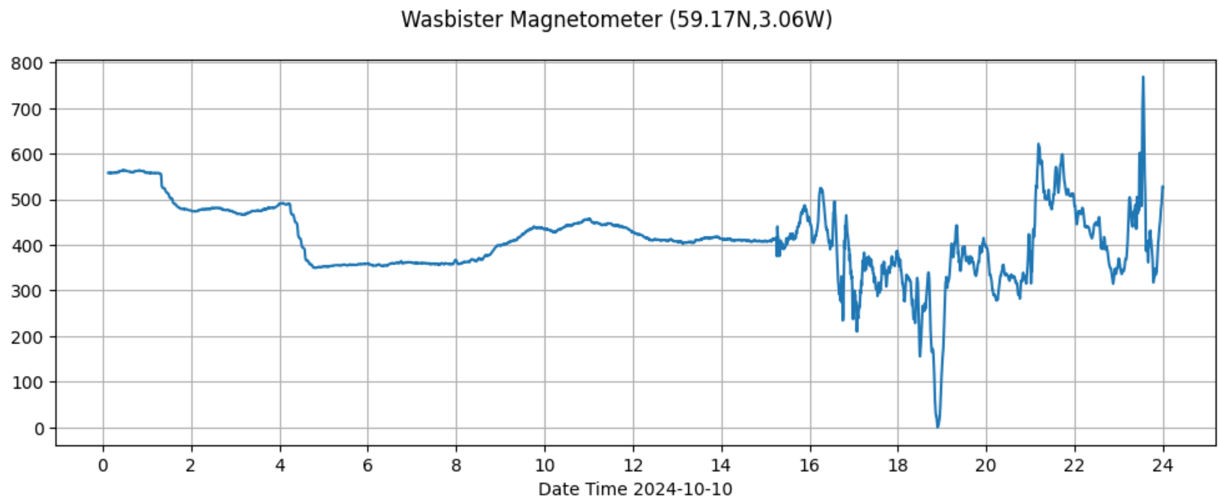
Stuart Green's summary of the month's magnetic activity shows just two periods of major disturbance, the storm on the 10th-11th of similar magnitude to that seen back in May. The STCE bulletin lists the source as a CME associated with an X1.8 flare on the 9th. This flare was at about 02:00UT, and so sadly not recorded as a SID. We do, however, have some excellent magnetic recordings showing its arrival impact at about 15:15 on the 10th, giving a transit time of 37 hours and 15 minutes. This makes it the third fastest CME that we have recorded, the first being on 2012 March 7th at 34h 41m.



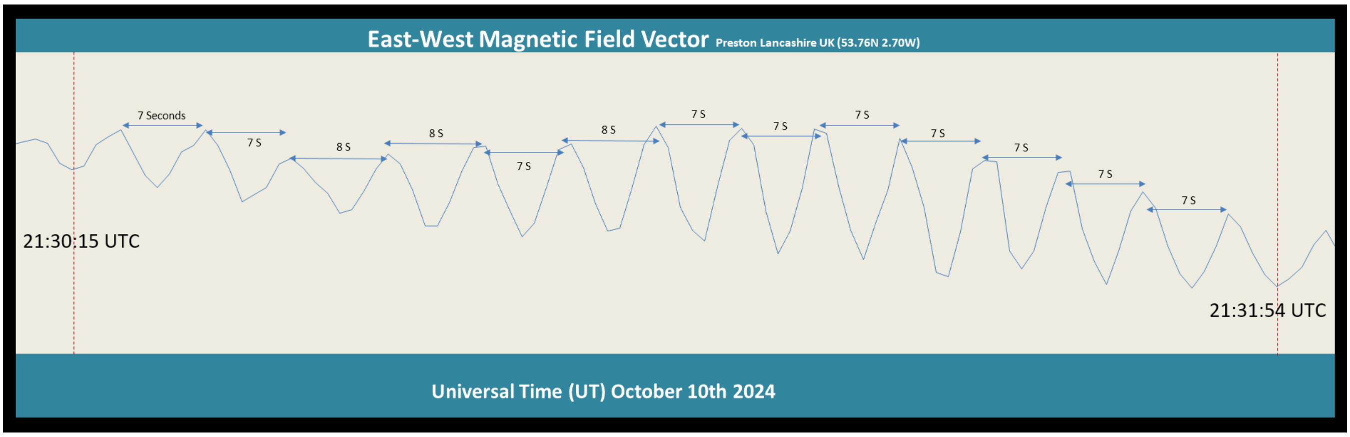
Nick Quinn's recording shows the CME impact followed by strong activity into the afternoon of the 11th, from the south coast. Roger Blackwell's recording from the Isle of Mull shows a stronger magnetic disturbance:



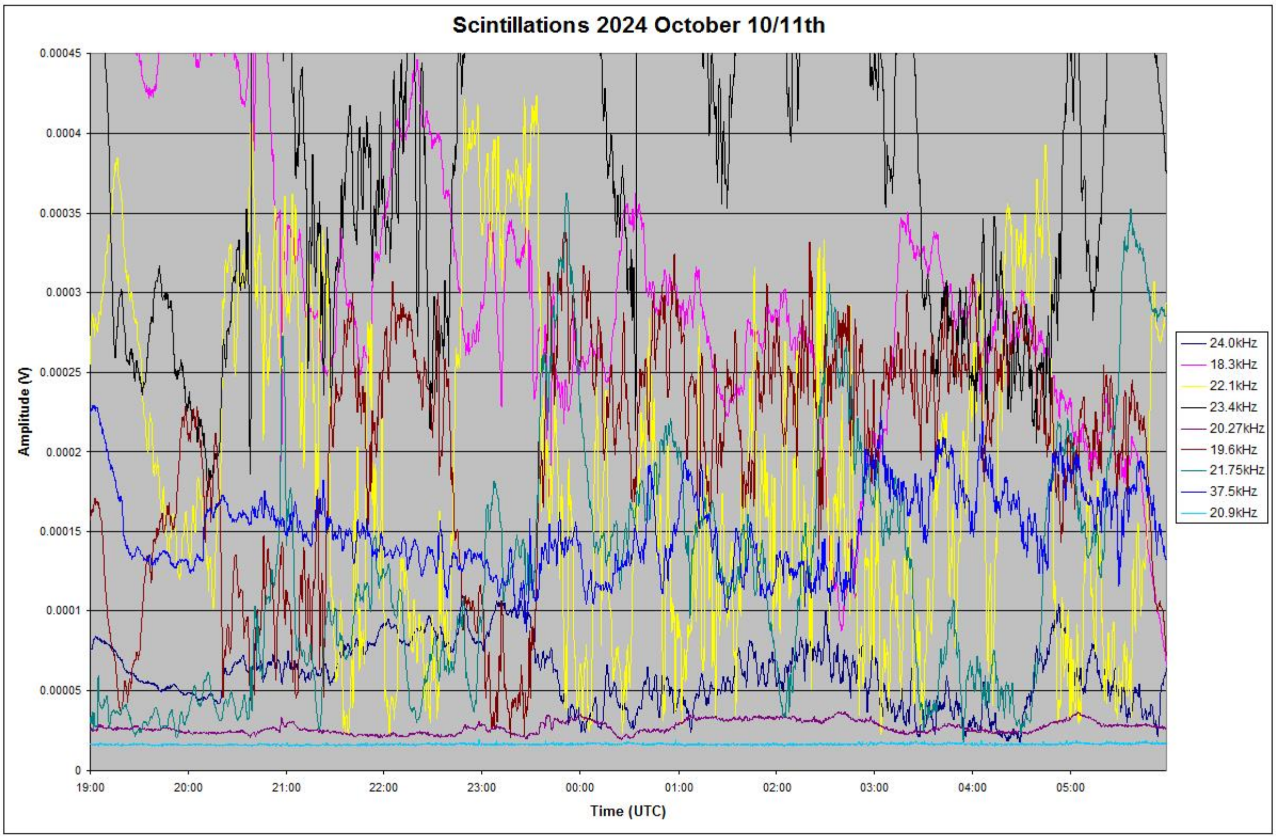
The CME impact is again clear, followed by a greater amplitude swing in the magnetic field.



A similar magnetic variation was recorded by Callum Potter, further north in Orkney. The single axis sensor records a vector sum of the three axes shown in Roger Blackwell's recording, and so appears slightly less when comparing the nT scales.



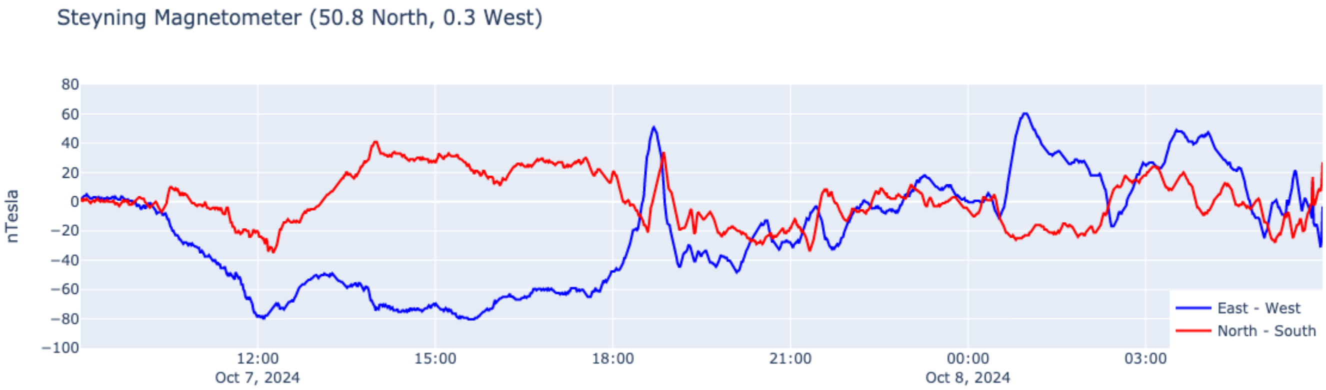
Stuart Green looked at his recordings in more detail, discovering this period of very stable oscillation during a very turbulent evening. They are a very rare example of PC2 waves, produced by Ultra Low Frequency magnetic waves travelling through the Earth's magnetosphere. The oscillation period is mostly 7.5 seconds, with some of the earlier ones at 8.5 seconds. These waves are classified according to the period, PC2 being in the range 5 to 10 seconds. PC1 are 0.2-5s, PC3 are 10-45s. Stuart received confirmation of this from Dr Tony Phillips at SpaceWeather.com (NASA). Stuart was also lucky to see another superb auroral display during this storm.

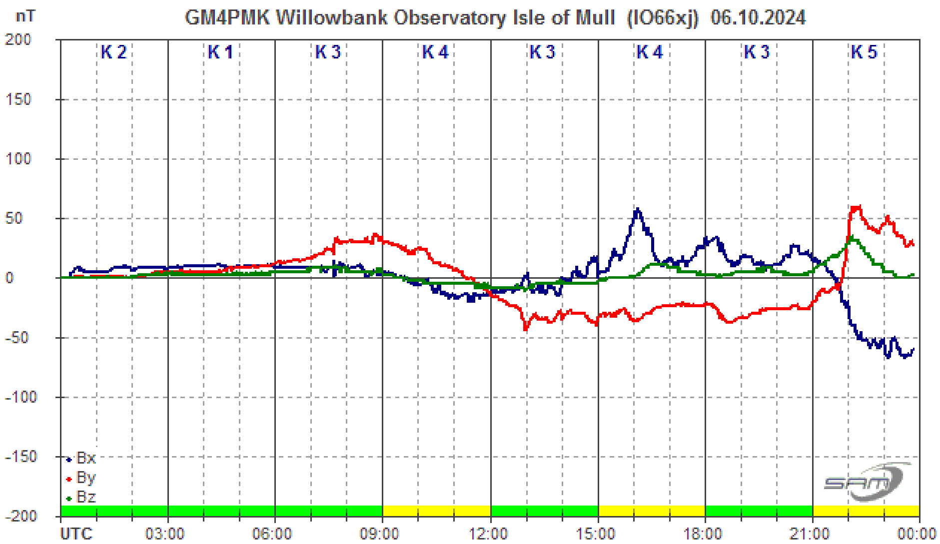


There were also some significant effects seen on the VLF signals during the storm, shown in this very chaotic chart from Mark Edwards. We often see magnetic induced VLF disturbances in the Trans-Atlantic signals, but the greatest effect here seems to have been on the European and UK signals. 24kHz shows a mild disturbance, while the Italian signal at 20.7kHz shows little disturbance. 20.9kHz appears to be off-air. Mark's recording from the following night still shows some scintillation, but with much smaller amplitude.

A recent STCE bulletin (STCEnews20241115.pdf) includes an item on Geomagnetic Induced Currents (GICs) produced within the Earth from these very strong magnetic storms. The huge storm of 1989 March showed how destructive they can be when the electricity distribution network in Quebec, Canada, was taken out due to the excess currents. The oil pipeline that runs from the north coast of Alaska to its south coast has regular insulating sections to prevent such currents from developing. This year's storms do not appear to have caused any such problems.

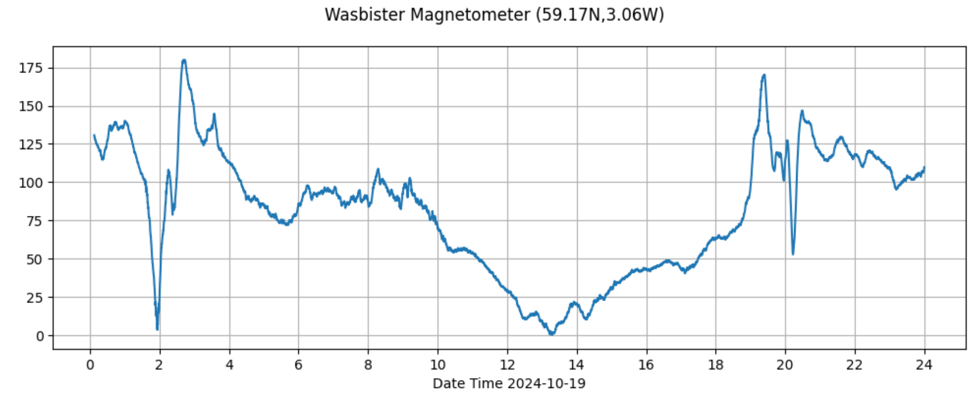
There was a much smaller magnetic storm from the 6th to 9th, the most active part shown in Nick Quinn's recording:





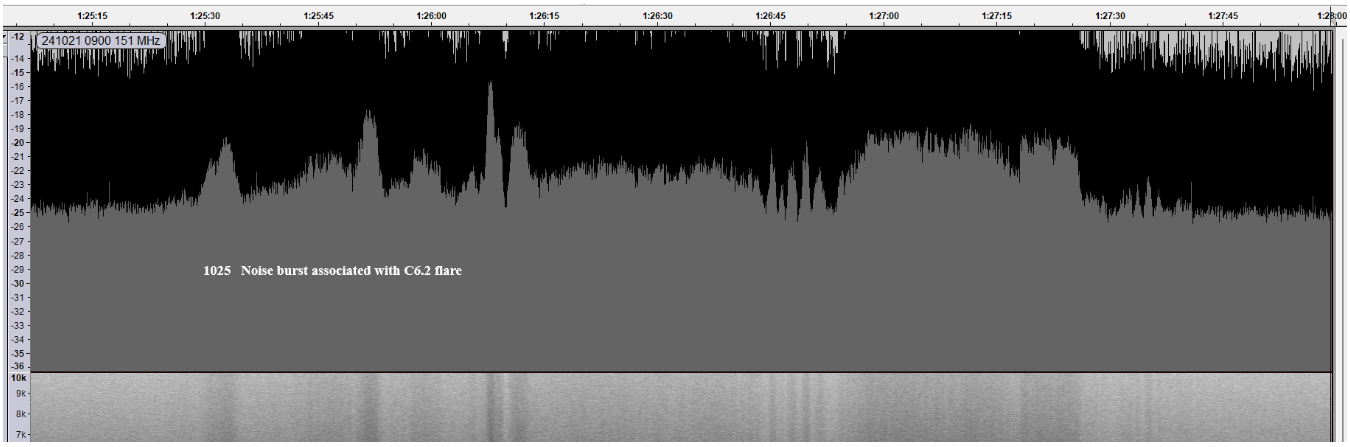
Roger Blackwell's recording shows the start of the disturbance on the 6th, with a very small CME impact visible at about 07:45UT. The STCE bulletin links this to CMEs from the 3rd. Activity continued into the 9th but was very mild in comparison with the 10th/11th.

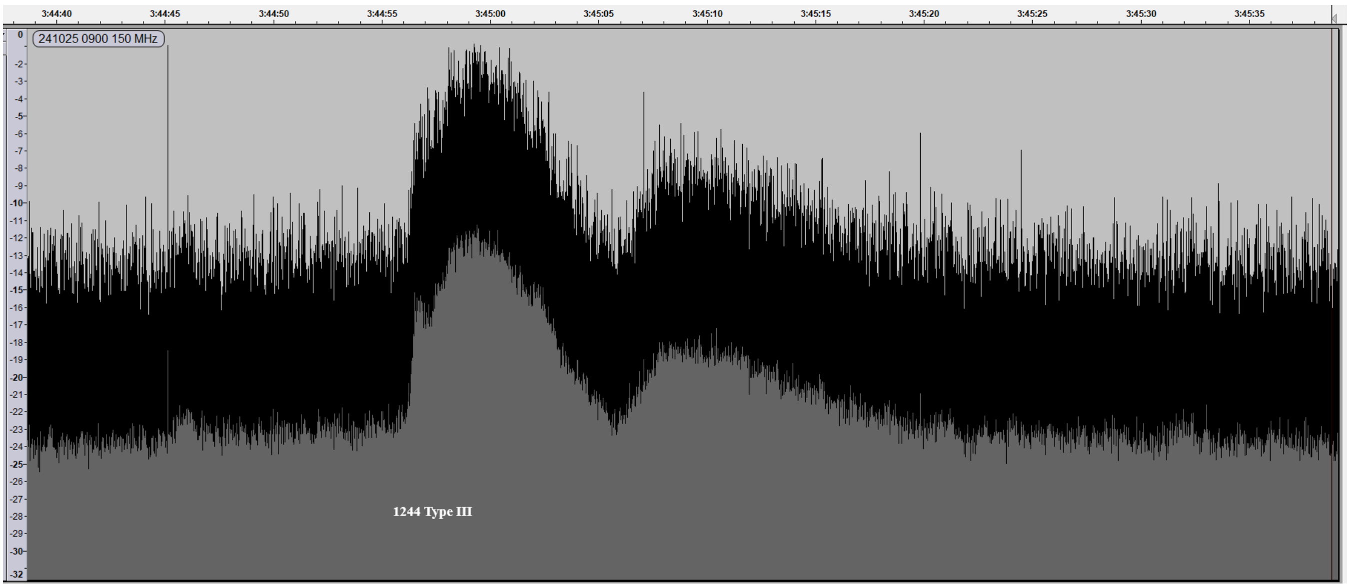
There were several periods of very mild magnetic activity later in the month, Callum Potter's chart on the next page showing activity on the 19th.



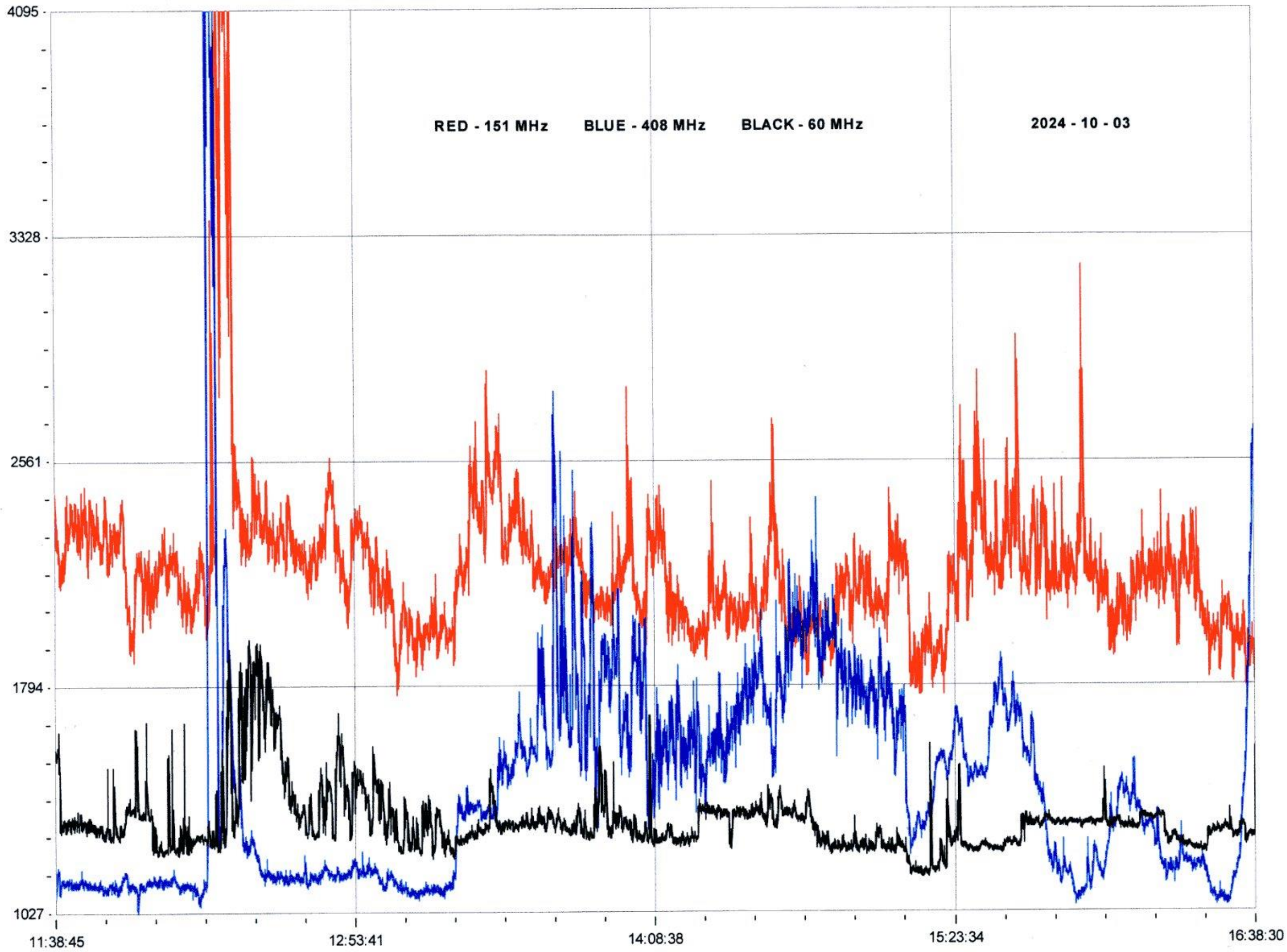
Magnetic observations received from Roger Blackwell, Thomas Mazzi, Callum Potter, Nick Quinn, and John Cook.

SOLAR EMISSIONS



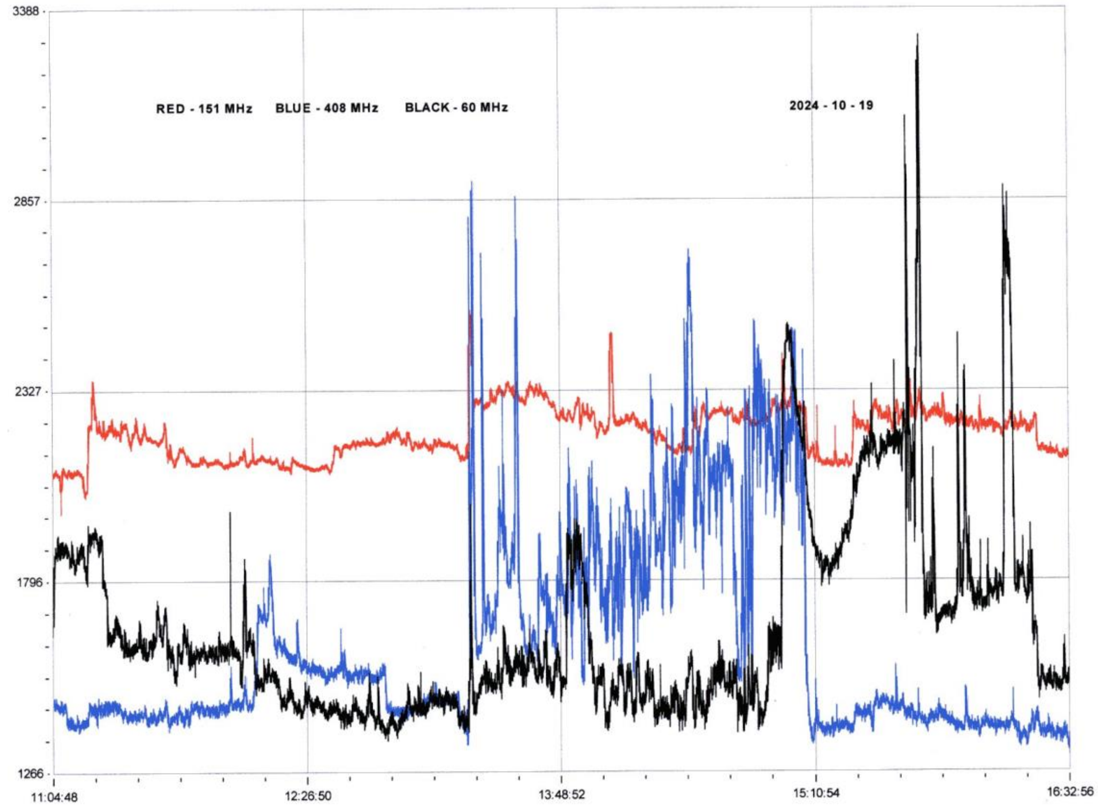


Colin Briden recorded two periods of solar emissions, shown above. The first (151MHz) was at 10:25 on the 21st, matching well with a C6.2 flare that we did not record as a SID. The active period in this chart is 2 minutes and 20 seconds, with about 21 individual peaks. The average amplitude is about 10dB. The second chart (150MHz) is a much more straight-forward type III emission at 12:44 on the 25th. It does not seem to match any individual flare, although there had been some earlier small C-flares. It has an amplitude of about 12dB.

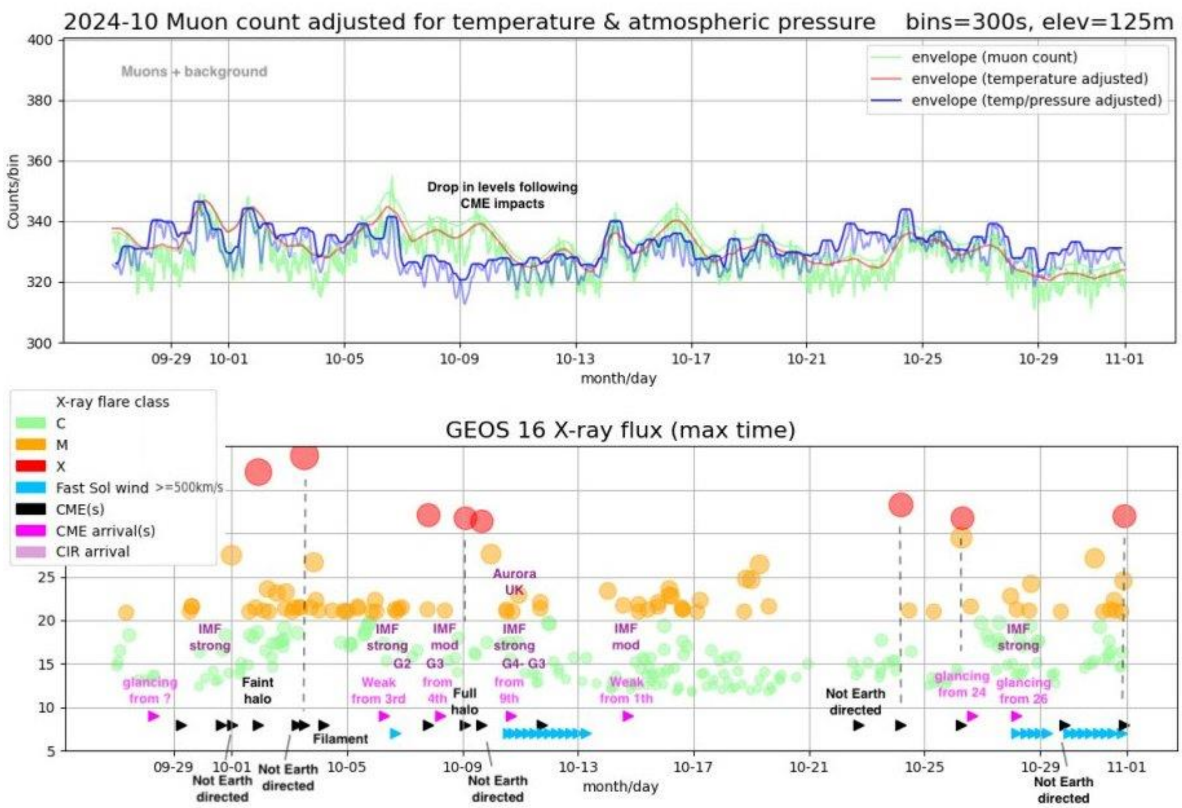


Colin Clements recorded a very strong noise burst starting at 12:00UT on the 3rd, matching the X9 flare that we recorded as a SID. All three of the monitored frequencies show the noise, although 60MHz (black) is much weaker than the others. 408MHZ (blue) also shows some prolonged emissions during the afternoon, although no further flaring was recorded until the M1.5 flare starting at 17:20.

Colin also recorded strong emissions on the 19th, shown on the next page. All three frequencies show the noise starting about 13:00UT, with 408MHz being the strongest. We did not record any SIDs at this time, although the SWPC satellite data does list a small C1.9 flare at 13:14. We did record the M1.7 flare at 14:35 covered by the emission which rises in strength before ending at 15:00. It also lists a C2.5 at 15:36 and a C2.1 at 16:27 that may be linked to the stronger 60MHz bursts in the chart. Colin also recorded emissions on the 4th, 16th and 24th.

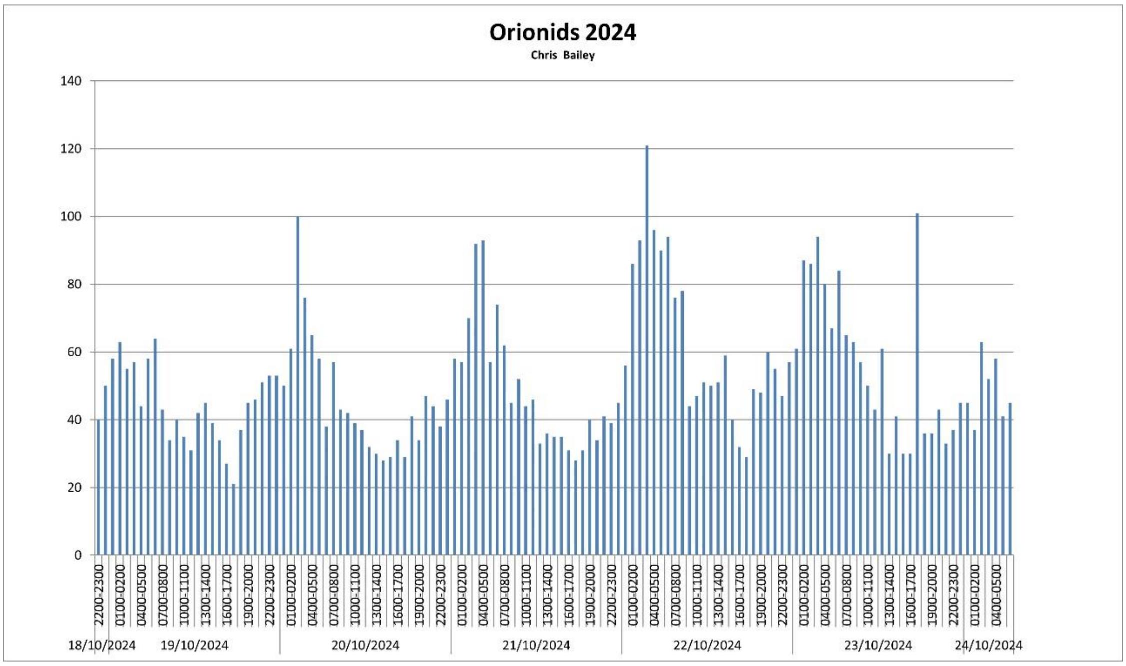


MUONS

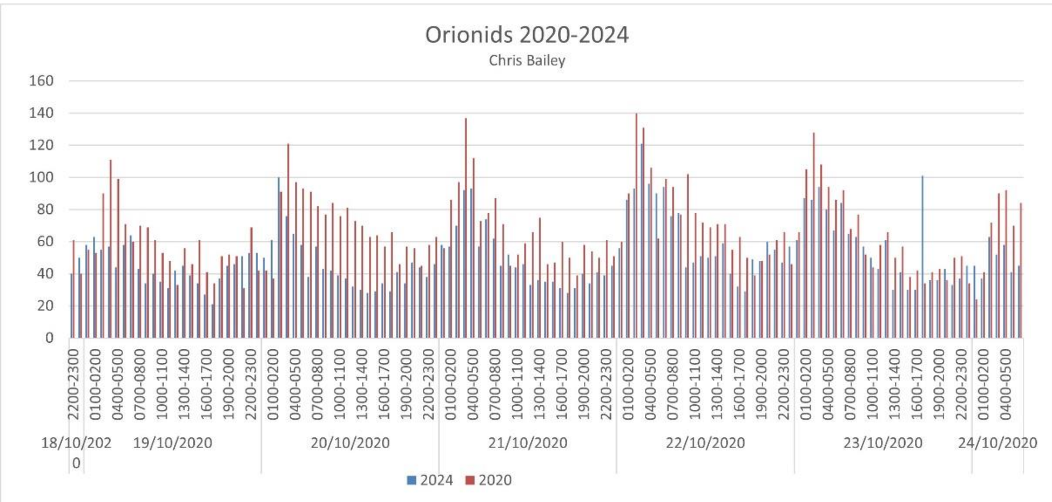


The strong flaring at the start of the month along with the subsequent magnetic storm had a very noticeable effect on the muon counts, shown in Mark Prescott’s chart. The pressure/temperature adjusted trace shows a sharp drop on the 7th, while the raw count had previously had quite a distinct peak. The raw count remained fairly high through the 9th, and then dropped significantly with the strong solar wind through to the 13th. The adjusted trace also shows some slightly lower muon counts towards the end of October, with just a couple of smaller peaks on the 24th and 28th.

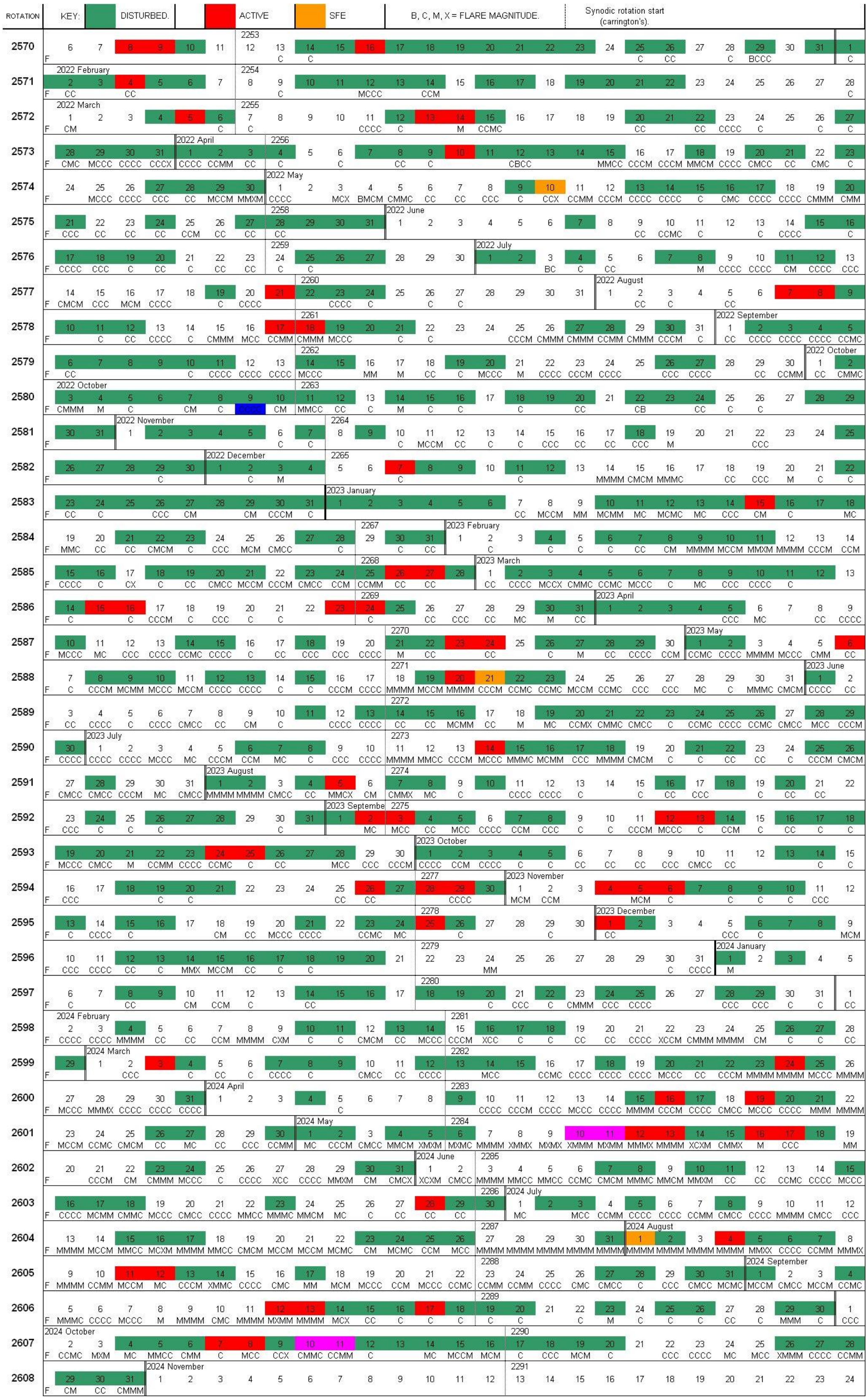
ORIONIDS

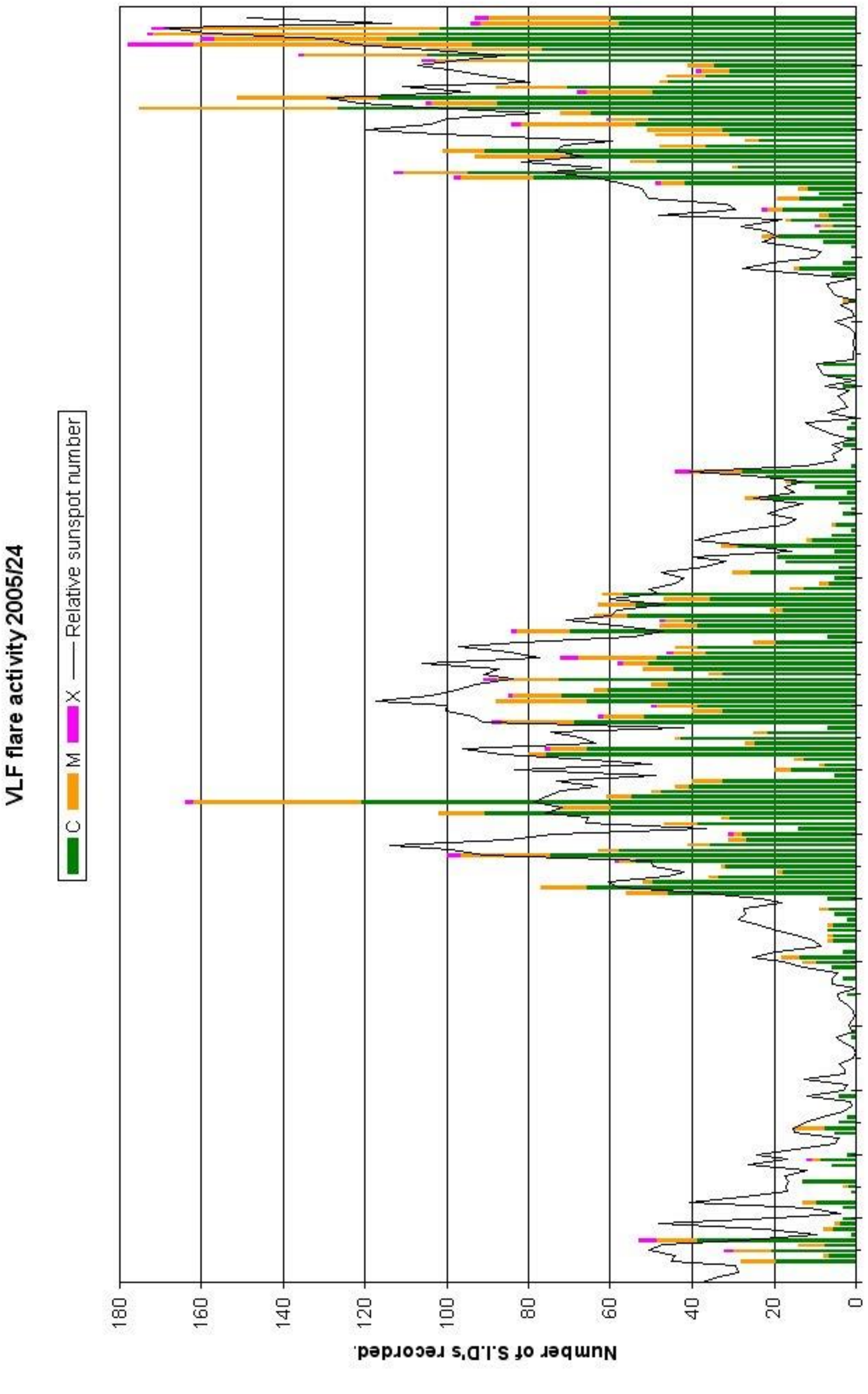


Chris Bailey made counts of the October Orionid meteor shower, his chart showing some strong activity peaks in the early morning from the 20th to 23rd. The strongest peak being around 03UT on the 22nd. Chris uses the GRAVES radar, counting by eye to remove the numerous starlink satellite trails. Chris has also made a comparison with 2020 counts, showing generally lower activity this year.



BARTELS CHART





VLF flare activity 2005/24
C
M
X
Relative sunspot number
Number of S.I.D's recorded.
0
20
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Jan 2018
Jan 2019
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Jan 2021
Jan 2022
Jan 2023
Jan 2024

British Astronomical Association
Supporting amateur astronomers since 1890
Radio Astronomy Section


Director: Paul Hearn

The Radio Astronomy Section aspires to encourage and support the construction of radio telescopes by amateurs, their use for observing programmes, and the development of a deeper understanding of the science underlying what is being observed. Programmes can be aimed at any radio astronomical phenomenon, at any radio frequency. This encouragement will be through the operation of continuing group programmes, and through building communication and information exchange between individuals and groups pursuing their own projects. The main purpose of the Group is to act as a reservoir and clearing house for information on radio telescope design, construction and debugging, and how to use these instruments effectively. This will include the discussion of observing techniques and data analysis. Members should be able to exchange ideas, give advice and help each other. Establishing a pool of design information and software suitable for use in observing and data processing is a priority.

BAA Radio Astronomy Section Seminar programme.

Friday January 10th 19:30 (19:30 UTC)

Developing and deploying an instrument for measuring ionization in the atmosphere

Dr Justin Tabbett Bristol University, School of Civil, Aerospace and Design Engineering
High energy particles from space – cosmic rays - contribute significantly to the ionization of the atmosphere and can affect electronics as well as the weather and climate. Having tools which can be deployed during periods of changing cosmic ray activity are vital to understanding the effects of cosmic rays in different regions of the atmosphere. This talk explores the development and then the deployment of such an instrument on a balloon flight in July 2024.

February 7th 19:30 (19:30 UTC)

Terrestrial Navigation from Cosmic Radiation
Jaron Samson Radio Frequency Systems Division ESTEC, European Space Agency

EU Conference on Amateur Radio Astronomy - EUCARA25
The conference for the amateur Radio Astronomer - check out the details and register interest at: www.eucara.org

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Society of American Radio Astronomers
UK Radio Astronomy Association (UKRAA)
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Paul Hearn
BAA Radio Astronomy Section Director
UKRAA Trustee

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Featured Articles

Creation of a Right Ascension - Declination Map of The Milky Way Galaxy With The Neutral Hydrogen Line

Annabel Lee - Paul Duke STEM High School, Mentor - Tom Crowley

I. Introduction

Even with current technology, studying the Milky Way galaxy is problematic, as it involves cataloging billions of stars, dark matter, and celestial objects (Joardar, 2015; Graham-Smith, 2013; Kraan-Korteweg et al., 2000). It is estimated to have 100 to 400 billion stars (Brennan, 2019), a mass of about 1.5 trillion solar masses, and a radius of 129,000 light-years (Nix et al., 2021). Due to its vast size, only a fraction has been explored, even though findings are critical for understanding the universe (Graham-Smith, 2013; Sun, 2022). One of the largest datasets of stars discovered in the Milky Way comes from the European Space Agency Gaia mission, which cataloged about two billion stars (Brown et al., 2021). While some may argue that efforts to explore the galaxy offer no substantive benefits, given other concerns on Earth, research has shown it aids in understanding the universe and driving technological advances in fields such as medicine and climate studies (National Academies of Sciences, Engineering, and Medicine, 2023). As such, studying the galaxy is an important field of research.

Radio astronomy focuses on observing electromagnetic waves emitted naturally by celestial objects. Astronomers in this field have made key contributions to the current understanding of the Milky Way, notably discoveries regarding the distribution of matter in the galaxy and dynamics of its rotation that lead to theories of dark matter within the galaxy (Kalberla et al., 2009; Terekhova, 2012). Despite these recent findings, ongoing research in radio astronomy and astronomical surveys remains crucial for further exploring the galaxy (Graham-Smith, 2013). Neutral Hydrogen (1 proton and 1 electron, HI), is one of the most abundant substances in the universe, making it important to research when examining galactic properties. It is detected during the spin-flip transition, where the electron's spin changes alignment and energy is emitted detectable with a radio telescope (Mahdi & Mohsin, 2017; Sofue, 2020; Storey et al., 1994) at 1420 MHz. It is most commonly found in dense HI clouds in the galaxy located in the interstellar medium, which contains ordinary matter between stars (Dawson et al., 2022). HI has a substantial role in galaxy evolution and formation in this region, as HI is the source of star formation (Djorgovski et al., 2013; Dutta, 2019). It is estimated that 90% of hydrogen in the galaxy is HI (Liu, 2008). Further findings have shown it is distributed in a disk-like shape throughout the galaxy and can be used to model the galaxy's rotation (Mahdi & Mohsin, 2017; Swaters et al., 2012).

Various methods exist for gathering HI data from the galaxy, notably sky surveys. These surveys systematically observe and document data from celestial objects across the sky, adhering to specific observational parameters (Burke et al., 2017). HI spectroscopy (studying spectral lines formed by HI) is commonly used, as this process allows astronomers to determine its composition, and associated properties (Hernández & Andernach, 2018; Higginson-Rollins & Rogers, 2013). These are essential to astronomers, as they provide the data for new findings, serve as the dominant source for data about the galaxy, and create visualizations and maps (Gómez de Castro et al., 2018). For instance, the VLASS sky survey was conducted over 5550 hours and covered 33,855° of the sky, which includes all parts of the north sky with a declination of −40°- about 82% of the sky (Kalberla et al., 2009; Lacy et al., 2020). The data collected in this study can be further refined to create a detailed map of the galaxy, revealing more insight into the Milky Way. However, even with the advancements in instrumentation, researchers note there is contamination from HI outside the galaxy, including hydrogen clouds in our galaxy's halo, suggesting the need for improvements when creating maps.

One of the first maps created was by Oort et al. in 1958, which was the first model of the shape of hydrogen within the galaxy including the spiral structure and movement. Their approach involved measuring the intensity and velocity of hydrogen clouds at certain galactic longitudes and plotting them in the galactic plane (Müller & Oort, 1951; Oort et al., 1958). This early approach allowed them to discover several important features, including the location of spiral arms in the galaxy. More recently, the HIPI4 Survey generated a map showing the Milky Way and the galactic center at its core, while also revealing the presence of other features (Ben Bekhti et al., 2016). Due to technological advances, these studies have high angular resolutions, where the telescopes can detect and distinguish fine objects in the sky. However, the survey still experiences contamination from outside radio sources and inconsistencies between the source data, resulting in incomplete coverage and potential gaps within the dataset. Consequently, this compromises the accuracy of the data.

Due to the complexity and equipment requirements for creating galaxy maps on the galactic plane with large-scale surveys and equipment, this study focuses on specific low-cost telescope systems. They typically consist of an antenna, electronic components in a receiver chain (components that process the signal), and a computer (Saje & Vidmar, 2017; Friederich, 2010; Johnson & Rodgers, 2012). Studying low-cost radio telescopes is relevant, as these are more accessible to the public and can still contribute to the current Milky Way Galaxy research (Mhaske et al., 2022; Pandian et al., 2022).

Regarding previous research with low-cost telescopes, Pandin et al. (2021) designed a simple receiver for HI applications, and Mhaske et al. 2022 designed a low-cost horn-antenna telescope for university research. Both of these projects then observed HI in the galactic plane, recording the velocity of the gas and performing calculations to produce rotation curves of the galaxy. These studies show that research with low-cost telescopes can contribute valuable findings into the observed rotation of the galaxy, benefiting the broader field of astronomy. The most prominent research in creating maps of the galaxy with these low-cost telescopes (Russel, 2019b) used drift scans to collect data on HI concentrations at different points in the sky. Drift scanning is a technique where the telescope has a stationary position and takes multiple data measurements as the sky rotates past (Figure 1). When this procedure is repeated at different elevations, the curvature of the Milky Way can be revealed. The researcher used a circular 9-ft diameter dish, paired with two low noise amplifiers (LNA) to carry the signal over a significant distance. The final plot generated appeared pixelated and discontinuous because they measured only one sample (signal strength at certain frequencies) per right ascension and declination, resulting in only 24 data points taken in a single scan and a total of 312 HI samples collected. Additionally, they used a circular dish, which has a lower gain (signal quality) than a parabolic dish, which allows for better focusing of the signals, resulting in a lower signal quality.
This could have caused their study to miss weaker hydrogen emission regions in the Milky Way.

The purpose of this study is to improve Russel's work by using a more advanced telescope configuration and design to collect more accurate HI data and create a more precise right ascension-declination plot. The telescope consists of a more advanced antenna, for 1.4 GHz HI observations, with a higher gain, and is connected to a receiver chain with more components, to refine the signal further. Drift scans were used to continuously collect the data at each elevation in the sky for 24 hours to generate a more detailed final plot. The open-source software ezRA was used to collect data and create the right ascension-declination map. Furthermore, a comparative analysis is used to evaluate both the data and telescope design, comparing it to previous work and determining how effective the new design is.

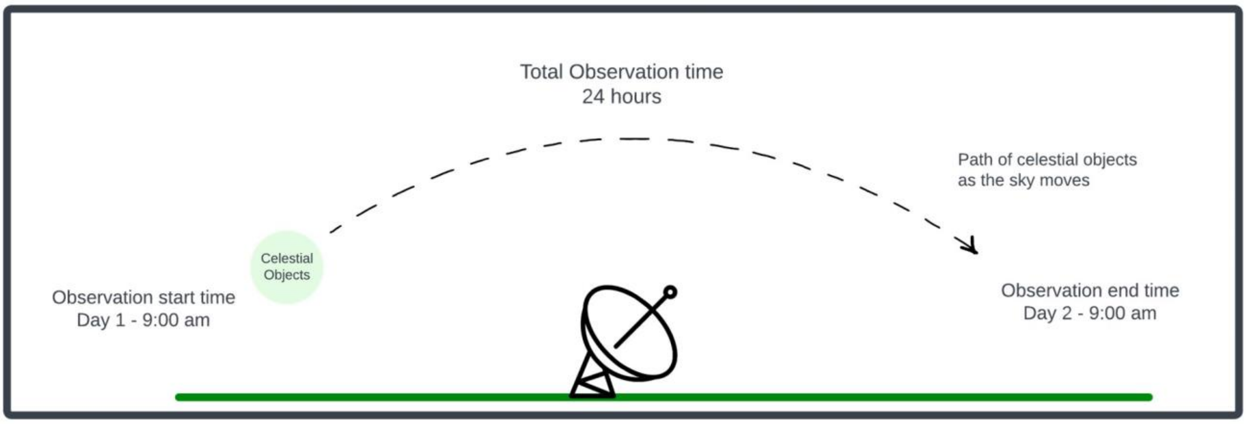

Figure 1 - Schematic Demonstrating the Process of Drift Scanning
Note: Telescope position and elevation remain stationary throughout the entire scan.

II. Methods

2.1 Materials

The telescope configuration used in this study consisted of two main components: the antenna and the receiver chain (components to process the signal). The antenna was a Nooelec 20dBi Parabolic Antenna, with a metal parabolic reflector and a Nooelec Satellite Mesh Antenna Boom, designed for 1.4 GHz applications. It was chosen for its high gain; when signals were collected at the focal point of the antenna and amplified due to the parabolic shape. This allows it to detect considerably weak signals and reduce the unwanted off-axis noise signals. Additionally, parabolic antennas are directional, allowing for precise positioning and focus. The first component is the Low Noise Amplifier (LNA), a NooElec SAWbird+ HIm, designed to amplify the signal with minimal outside interference. It enhanced the sensitivity of the receiver chain by boosting the strength, and this model was specifically tailored to HI applications since it operates at the frequency of HI, 1420 MHz to pass through. The next component is the bandpass filter, which allows signals in the desired frequency range, 1420MHz ±50 MHz. It used the TA2494A SAW component, dedicated to radio astronomy applications, and has a low insertion loss (decrease in signal strength) of 3.5 dB. The bandpass filter was connected to a HAB-FLTNOSAW wideband amplifier, which amplified the signal across the entire bandwidth.

This model was designed to be placed between the telescope antenna and the Software Designed Radio (SDR) model used in this study for its frequency coverage. A 10MHz-6GHz bias tee component was used to isolate the signal from the incoming DC 5v power, mitigating interference. The last component of the receiver chain was the SDR module, a Nooelec NESDR SMArt v5 SDR receiver. It digitized the signal using an R820T2 tuner and was connected to a Windows 10 (PC) computer running analysis and collection software. These components were provided by the Society for Amateur Radio Astronomers (SARA) with a grant and arranged as shown in Figure 2.

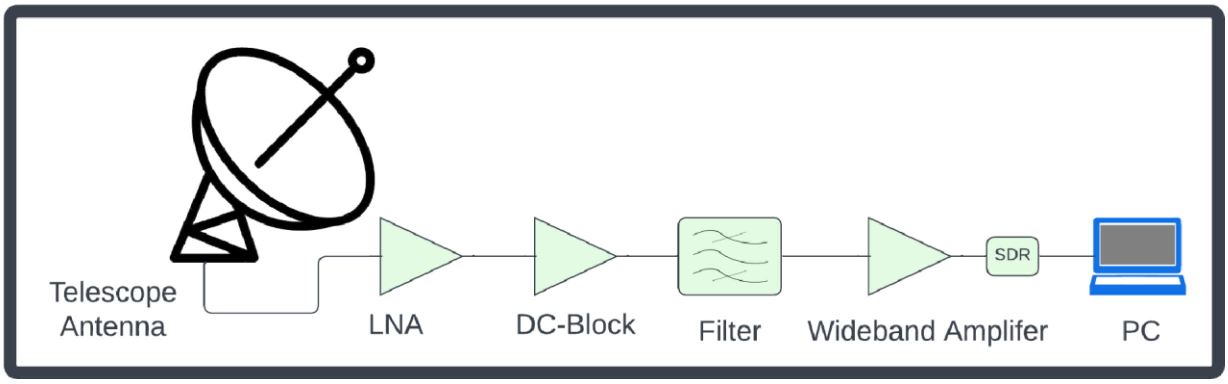

Figure 2 - Block Diagram of the Components for the Telescope Receiver Chain

Table 1 - Components used in this Study

Components	Model/Description
Telescope Antenna	Nooelec Satellite Mesh Antenna
Low Noise Amplifier (LNA)	Nooelec SAWbird+ H1
Bandpass Filter	RF Low Pass Filter 1420±50MHz
Wideband Amplifier	Topincn 0.01-4GHz RF Wideband 21DB
Bias Tee	Jeanoko 10MHz-6GHz
SDR Module	Noelec NESDR SMArt v5 SDR

The software used is ezRA, a set of open-source Python-based programs to simplify data collection and signal processing (Cline, 2024). The software used to collect the data and control the receiver is the program ezCol; It collects data according to the SDR module, combines signals from a range of radio frequencies received by the telescope over a given period, and stores them as an integrated frequency spectrum. These contain data representing the signal power distribution across different frequencies across the observed range. Samples at the center frequency (1420.405 MHz) and reference frequency (1423.405 MHz) to minimize the impact of interference at the reference frequency since it was removed in data processing with ezRA. These raw data files were combined with the program ezCon to create a single file with data from the entire trial. To ensure that initial fluctuations from the SDR warming up would not skew the data, the first 50 samples from each drift scan (approximately 20 minutes) were disregarded. To create the final plot of data, the program ezSky was used to plot the data from previous files on a right ascension-declination plot, which shows the curve of the galaxy. It also generates a map of the strength of the signal on the galactic plane. ezRA programs were chosen for their simplicity and wide range of capabilities, from collecting data, condensing it, and producing the final plot.

2.2 Location

The survey was conducted at 33.99° latitude, -84.22° longitude, and about 290 meters above sea level. It was placed in the middle of an open area for an optimal view of the sky. The local area is residential, and the only nearby structures are houses and trees, which should not interfere with the project, due to signal filtering and adjustments from the advanced receiver chain (Figure 2). It was selected for its view of the sky, is away from most sources of interference, and is located in a neighborhood where it can be accessed and observed daily. The trial was conducted from April 14th, 2024, to April 24th, 2024, since the southern half of the sky was at its highest point in the night sky, providing optimal visibility and minimizing atmospheric interference. Additionally, April typically offers clearer skies and less atmospheric turbulence, enhancing the quality of observations. The receiver chain was placed near the antenna in an outdoor cooler, isolated from any sources of interference.

2.3 Observation Procedure

The main data collection methodology used in this study was drift scanning, where the telescope was oriented to the southern meridian (right ascension 180°) and positioned at an elevation. Data was collected over the following 24 hours as the earth rotated, producing a full coverage of the sky. This was repeated at multiple elevations until a full image was obtained. The southern meridian was chosen to orient the telescope to maximize coverage of the Milky Way galaxy, which is more prominent in the southern hemisphere sky. The inclinations cover a range of 0°- 90° to collect the widest range, starting at 90° and decreasing by 10° every scan. To minimize background interference and noise, reference samples were collected at 1423.405 and later filtered in the data processing.

2.4 Analysis

To evaluate the data collected and plots generated in this study and the telescope system, a comparative analysis between data from this study and research in the field was conducted. The analysis focused on the final right ascension-declination plot created in this study and compared the results to existing literature. Two other plots from past literature were selected, from Russel's research (2019b) and professional Radio Astronomy software, Radio Eyes (Sky, 2023) due to their similarity in design. The maps created are compared by analyzing qualitative features such as trends and features of each plot and determining which map matches the data collected in this study.

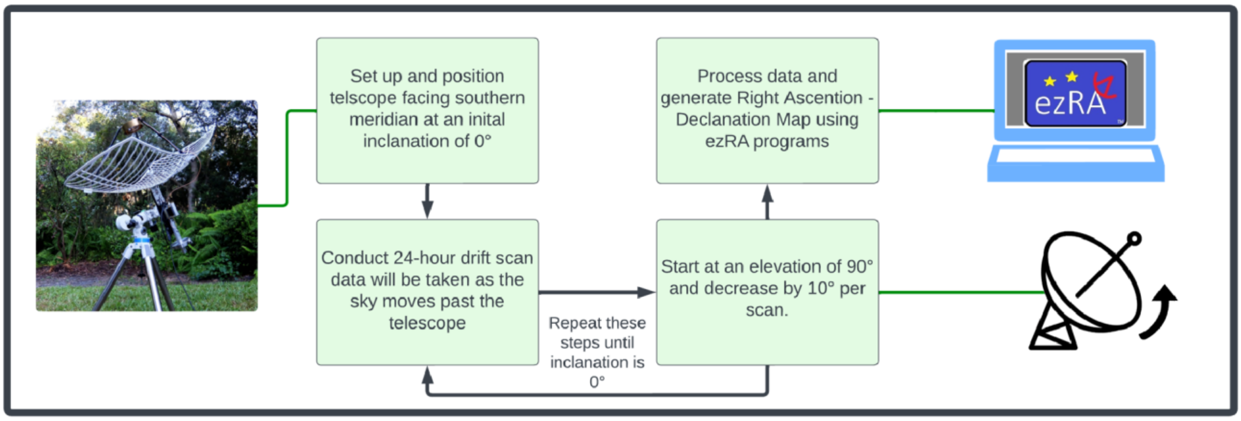

Figure 3 - Schematic of methods

III. Results

3.1 Overview of Data Collection

This project uses a parabolic-grid antenna telescope and advanced receiver chain to conduct 24-hour drift scans to survey HI in the galaxy. Utilizing ezRA software, the telescope was oriented to the southern meridian with a clear view of the sky and collected data on the signal strength of HI centered at 1420 MHz. Drift scanning methodology was chosen for continuously tracking the sky while the Earth rotates, and the telescope's elevation was adjusted every 24 hours for a full view of the sky. On average, samples were collected every 208 seconds (3:28 minutes). The software used to collect data in the project was ezRA, a set of open-source Python programs. Figures 4, 5, and 6 were generated with ezRA.

Table 2 - Parameters and Specifications for Data Collection

Study Parameter	Value
Total Samples Collected	40,470
Total Reference Samples	20,237
Center Frequency	1420.405 MHz
Reference Sample Frequency	1423.405 MHz
Telescope Elevation	90° to 10°
Observed Declination	-56.3° to 33.7°
Right Ascension/Azimuth	180°
Elevation Above Sea level	290 meters
Coordinates	33.99, -84.22
Start Date	April 14th 20:00 UTC
End Date	April 24th 20:33 UTC

Table 2 shows the specifications and parameters for data collection used in this study. All the samples from multiple nights were converted to an integrated frequency spectrum and added to represent the signal power distribution across the full measured spectrum. A total of 40,470 samples were collected over 10 days, from April 14th, 2024, to April 29th, 2024, at a center frequency of 1420.405 MHz. The telescope elevation was adjusted from 90° by 10° in each subsequent scan. The azimuth was 180° throughout the study period and the telescope remained stationary. Reference samples were also collected at a frequency of 1423.405 to counter interference at the local site.

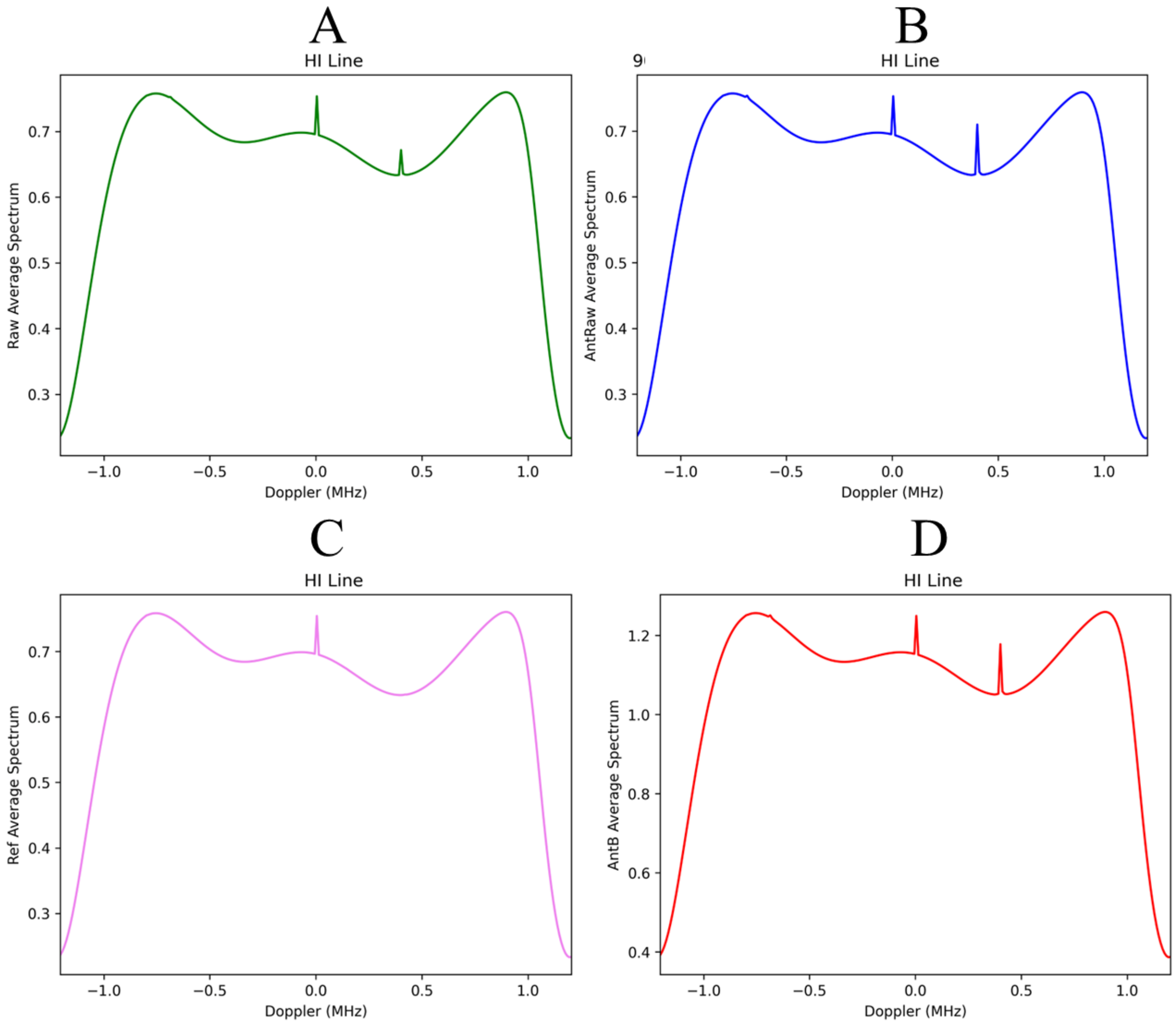

Figure 4 - Raw Average Spectrum Graphs of Collected Samples

Note: Panel A-Raw average spectrum includes all samples collected (Antenna and Reference samples). Panel B-AntBRaw shows the average spectrum of antenna samples after reference samples are filtered out. Panel C-Ref Average shows the average spectrum of reference samples collected, centered at 1422.405 MHz (range of 1422.405 to 1424.605 MHz). Panel D-AntB average shows the AntB spectrum, where background samples (upper and lower 60 frequency bins) have been filtered out. ezRA auto scales both axes for all graphs.

3.2 Raw Data

Figure 4 shows the average spectrum (signal strength) across different frequencies observed during the drift scans created from the integrated frequency spectrum. The lower x-axis shows the frequency, centered at 1420.405 MHz (1423.405 MHz for panel C and shown as 0.0 on all panels) with the surrounding range ±1 MHz, and the vertical axis corresponds to the amplitude (amount of signal detected) measured in dB. The sharp peaks on the graph indicate an excessive signal received at that certain frequency. The two rounded peaks close to ±1 MHz are created by the SDR module. Panel A shows the average spectrum of all samples collected (including Antenna samples and Reference samples). Panel B shows the average spectrum of all antenna samples after reference samples are filtered out. Panel C shows the average spectrum of all reference samples collected, centered at 1423.405 MHz (range of 1422.405 to 1424.235 MHz). Panel D shows the AntB spectrum, where background samples have been filtered out, excluding the highest and lowest 60 frequency bins.

For all average spectrum graphs, the peak at the center signifies a greater signal detected, indicating the signals the telescope collected were likely HI. Other peaks around 0.5 MHz could indicate strong outside sources of interference since these frequencies are not expected to be as strong as the central peak. Panel D shows the AntB values in which the most background noise and reference frequencies have been filtered out, leaving a stronger signal likely from HI. The peak of this graph is above 1.2 dB while Panels A, B, and C show maximum signal strengths near 0.7. For these reasons, the AntB Average spectrum shown in Panel D was used in the final right ascension-declination plot.

3.3 Right Ascension & Declination Plots

To create the final map of the Milky Way, the data showing the signal strength of the HI is taken and plotted based on the right ascension and declination (converted from elevation) from where it was recorded in the study. Figures 5 and 6 show the resulting map, with right ascension measured in hours present on the horizontal axis and the corresponding declination on the vertical axis in degrees, using the calculated AntB values. The observed signal strength is plotted against the average, shown in red points for Figure 5.

In Figure 5, the HI signal strength is fairly constant throughout all scans with relatively small increases in signal strength, notably around 18-20 hours and 4-6 hours, likely indicating only a weak signal was detected. Due to this weak signal, there are no clear significant spikes in concentrations across the image, making the map vague as the features such as the galactic curve are not easily seen. Additionally, some inconsistencies are present on the right side of the graph from a declination of -45° and 2-6 hours, where the measured signal appears to jump between low and high values or overlaps. From hours 7-18, there are conflicting signal strength values as some declinations show a strength above the average while others show a signal below the average.

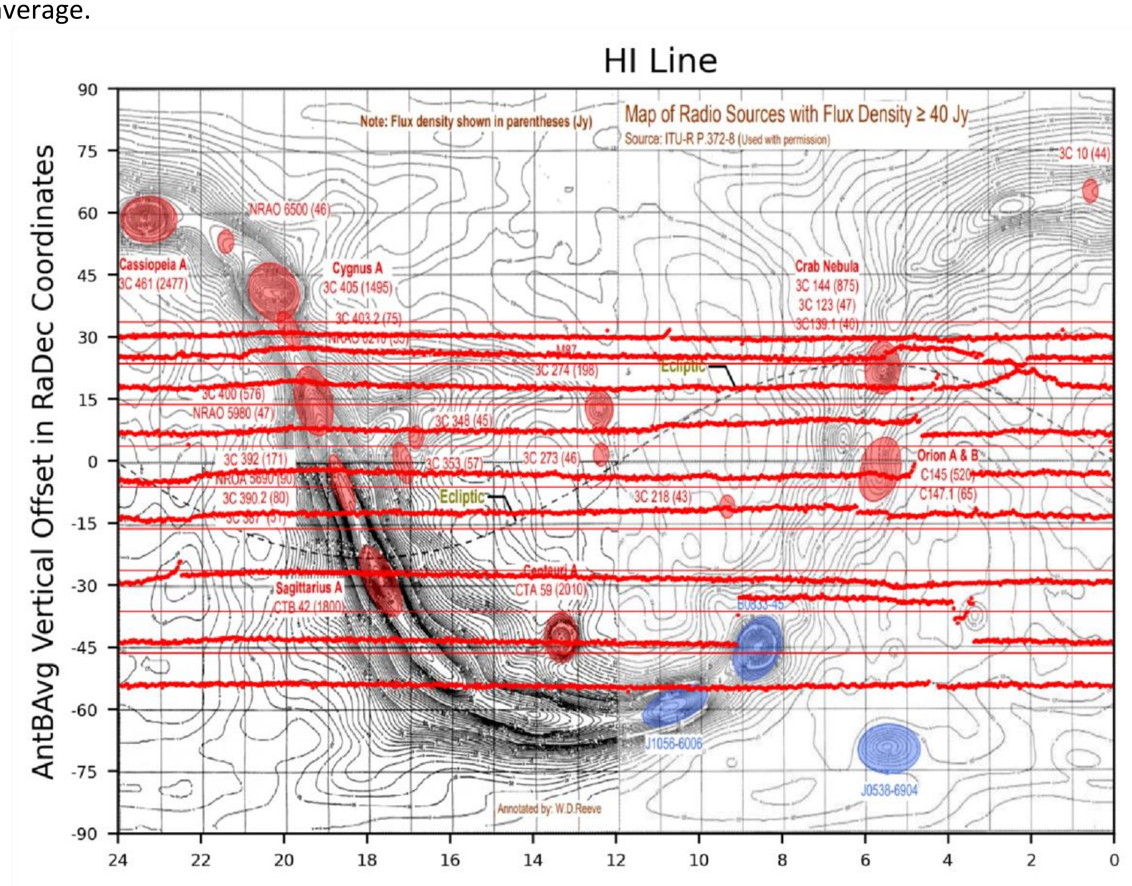

Figure 5 - Right Ascension - Declination Map of the Galaxy

Note: The larger red points and lines represent data collected in this study as an offset of the average, and the thin red lines represent the signal average at the corresponding declination. The larger red and blue circles and the shaded curve represent parts of the galaxy and are part of the background image generated with the figure.

Figure 6 details a similar plot, with the major curve of the Milky Way shown in red and green dots plotted at the maximum signal value observed. Each green dot represents a greater amount of HI observed in a region, potentially indicating the location of the galaxy. A small number of these green points align with the red curve, showing a high amount of HI detected at the galactic center signal concentrations at a declination of 30° to -15° appear to align with the galactic curve between the hours of 19-20 (left side) and at a declination of -15° to -45° between the hours of 7-9 (right side). There are also green points on the left and right of the curve (non-red areas) that appear to be in areas of low observed HI concentration (compared to the image background) yet observed a strong amount of HI. Notably, the points between declinations 30° to 45° and 10-13 hours along with the point at a declination of -15° between hours 12-13 show signal maximums at large areas where a weak HI signal is expected. Since some of the points align with the curve, the signal collected likely originated from HI in the galaxy, however, interference is present within the data and diminishes the clarity and analysis of the map.

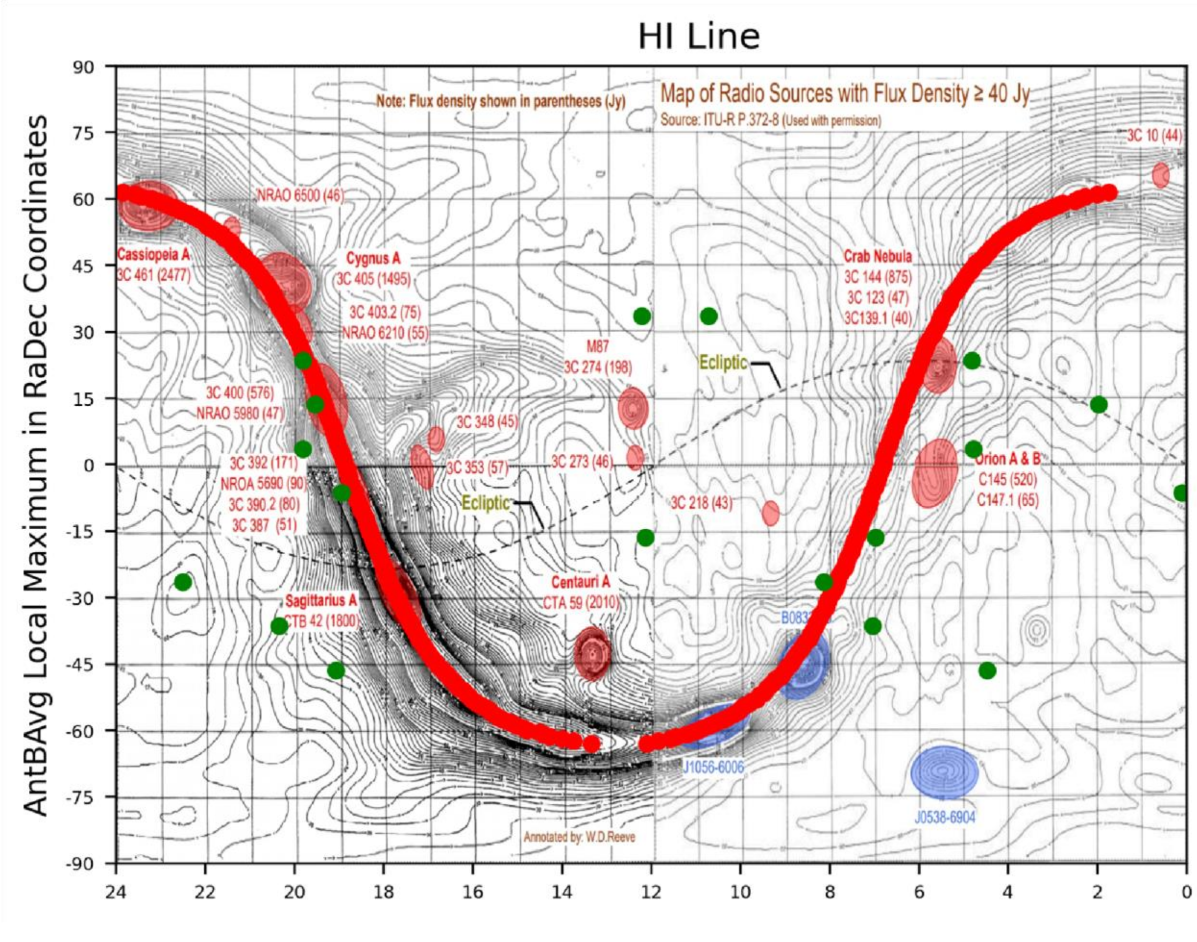

Figure 6 - Right Ascension - Declination Map of the Galaxy

Note: Each green dot represents the maximum signal strength observed at the corresponding location. The red line represents the galaxy's curve, an area of high hydrogen concentration. The larger red and blue circles and the shaded curve represent parts of the galaxy and are part of the background image generated with the figure.

IV. Discussion

In this study, the goal of this study was to generate a map of the Milky Way galaxy through 24-hour drift scans over multiple elevations and the utilization of ezRA software. It generated a right ascension-declination map of the galaxy, aiming for a more precise approach. The data collected is still more precise compared to the previous work. The findings from the right ascension-declination map generated only partially show the galaxy and its associated curve, indicating that the telescope system was likely detecting HI in the galaxy, but may also be detecting other sources of interference. A total of 68,415 samples were collected, which is more than Russel's (2019b) work, indicating that the telescope's design can detect more HI spectra and is more advanced when compared to other low-cost radio telescope designs.

4.1 Analysis

To assess the precision of the Right Ascension (Ra) versus Declination (Dec) plots and the effectiveness of changes to the telescope system, a comparative analysis of the plots generated was necessary. Figures 5 and 6 are considered.

The plot created by Russel (2019b) used a similar methodology of conducting drift scans at various elevations to record hydrogen gas concentrations at those points in the sky. The telescope used was a 9ft circular dish and two low noise amplifiers, covering dec of 80°to -40°. It was generated from limited equipment and software, causing the plot to have a lower resolution and be less precise with only 24 data points collected per scan. The plot from Radio Eyes (Sky, 2024), is a visualization program that shows the entire radio sky, including the Milky Way and other celestial sources. The data used in Radio Eyes is more precise and compiled from catalogs of radio sources, collected with more advanced telescopes, resulting in a clear map. Individual radio sources and a detailed galactic curve are present on this map with real-time data.

Regarding trends, the plot created in this study (Figure 5) does show an increase in concentration at a similar location compared to Russel's research and Radio Eyes at 18-24 hours. However, this increase is not prominent, indicating the signal is likely not as strong as the previous research. Russel's and Radio Eyes show strong concentrations at these points, through a high color contrast displayed in a similar curve. Between 8-17 hours, there was limited to no concentration observed in the plot created from this study and previous literature. From 0-6 hours, the data in this study had some conflicting results, where the signal appears to increase to the maximum values (Figure 6) between 2-5 hours, with no apparent shape. Russel's research displays prominent HI concentrations in this region, with a strength comparable to the curve observed at 18-24 hours. Conversely, Radio Eyes displays weaker signals in this region, with most of the observed HI occurring around 17 hours.

The plot created in this study appears to align the most with Russel's research, as both observed an equal amount of HI signals on both sides of the plot, compared to Radio Eyes which only displays a prominent signal on one. Overall, the data collected in this study exhibited irregularities and inconsistencies, particularly in regions of high signal strength, suggesting potential issues with data collection or processing at certain points during the drift scan. Further investigation is needed to identify and address the sources of these discrepancies, ensuring the accuracy of the data for the full 24 hours. While unable to surpass the quality of previous literature, it is hypothesized that more data collection could clarify findings and lead to more accuracy in future research.

4.2 Filling a Gap in the Field

There has been abundant research regarding large surveys with professional equipment, techniques, and software in our galaxy, and high-resolution surveys and images. Due to the large scale of the Milky Way, however, these efforts are time-consuming and costly. As a result of technological advances, small radio telescopes can be easily constructed and collect accurate data at a fraction of the cost. Their increased accessibility and adaptability allow more scientists to contribute to the current data and observations of the Milky Way galaxy. This research aims to design a more accurate radio telescope system to collect HI data from the Milky Way and use this information to create a more precise map of the galaxy. Other papers have also tested low-cost telescope designs, but this study is the first to test these specific components used together in this telescope design and the first to test the system's effectiveness in creating a right ascension-declination plot from the collected data. While the findings were mixed, the data still fills a gap in the research since it adds to the growing research regarding the use of small radio telescopes and the overall understanding of the Milky Way galaxy. The discrepancies found in the data were likely due to outside interference where the telescope collected signals that were not emitted from HI sources.

Furthermore, ezRA software provided a more sophisticated and precise approach to analyzing and visualizing the data. This software allows for detailed examination of celestial objects and structures. Using it in this study contributes to the field through comprehensive visualization capabilities that enable astronomers to explore complex data more easily and efficiently.

4.2 Real-World Implications

This research can benefit researchers and astronomers by contributing to the wider knowledge and data available today on the Milky Way galaxy. Even though data signals collected in this study were relatively weak, there were still notable signal increases at relevant points, indicating that the telescope was detecting HI, and it collected numerous samples. This study can serve as an initial reference point, as the data collected can still be further analyzed and added to larger data sets about the Milky Way, contributing to the wider field. Additionally, noise reduction and signal filtering techniques can be applied to refine the HI signals collected, which may reveal new findings.

Another implication of this research is its application to schools and other educational institutions for science experiments and generating interest in STEM-related fields (Reckziegel et al., 2022). This study focuses on researching an accurate low-cost telescope design, which is important to institutions that aim to find an effective design for their needs. The telescope design from this study could be used as a template for new designs in the future and the methodology could be replicated to create a comprehensive map of the galaxy.

4.3 Limitations

The location, limited sky coverage, and outside sources of interference may have negatively impacted this study. The telescope location was imperfect, as nearby structures such as buildings and trees obstructed the telescope's clear view of the sky at lower elevation. The data collected at these locations may be less accurate overall and contributed to the inconclusive findings, since it likely obstructed any HI signals, leading to weaker detection and analysis. Another limitation of this study was the limited portion of the sky surveyed. In total, the telescope covered 0-90° elevation while facing directly south. Due to time constraints, the other half of the sky was not surveyed and therefore the data in the resulting map (Figures 5 and 6) only covers the middle portion of the sky (dec. of 33.7° to -56.3°). As a result, only a partial map was created with limited elevations.

Interference from surrounding radio sources most likely greatly affected the data. Radio frequencies are very vulnerable to interference, which can come from both Earth and space. From Earth, the most interference will come from communication devices, wireless networks, and local weather. From space, the interference in the data will come from HI located outside the galaxy in the Interstellar Medium. Interference in this study was likely due to local wireless networks and cell towers in the area because the observation location was residential. While 1420 MHz is a protected frequency, some of these signals likely were detected and caused extra signal strength spikes present in Figure 4. Due to the limited software and computational ability, only some signal filtering for interference was applied to the data. Given the complexity and number of samples collected, only a basic level of signal filtering, already included in ezRA, could be implemented, limiting the extent to which interference could be effectively accounted for. This resulted in levels of interference still present in the data and affecting the outcomes.

4.4 Future Directions

To gather more precise findings, this study could be repeated with notable changes such as a new location and more attention to filtering interference from outside sources. The changes will allow clearer HI signals to be detected, and result in more distinct figures and conclusions. If this study were to be repeated a new location would be chosen with a full, clear view of the sky and special consideration would be taken to collecting data at lower elevations.

This study focused on creating a map of the galaxy using drift scans and plotting them with right ascension declination. However, many other plots and representations could be made with the data collected in this study. By calculating the velocity of HI emissions along the line of sight using data from this study, researchers can infer the spatial distribution of gas concentrations and map out the three-dimensional structure of the Milky Way. Plotting these velocity measurements against galactic coordinates would create another representation of the galaxy, showing the overall shape of the galaxy and features such as spiral arms.

Another study could analyze the interference captured in this data and find ways to mitigate or remove it from the data set. This would increase the accuracy of the data and benefit future astronomers since most data collected will almost always detect signals from other sources. To mitigate this interference in future trials, a remote location could be selected, or more advanced signal filtering techniques could be applied, notably adding specialized components to the receiver chain leading to new designs based on this research.

ezRA is a relatively new set of Python programs used for radio astronomy. Future research could be conducted into how effective and accurate it is compared to other more prominent software such as GNU Radio and Digital Signal Processing in Radio Astronomy (Testori et al., 2001; Langevelde, 2007). The most notable research into software used in radio astronomy surveys is Common Astronomy Software Applications (CASA), which includes open-source software for processing radio astronomy and interferometric data, using Python programs (Bean et al., 2022). Collecting data or utilizing data from this study and analyzing how well each program can visualize would also benefit research into and support low-cost telescope systems.

4.5 Conclusions

In conclusion, this study created the right ascension-declination map of the Milky Way galaxy with a low-cost radio telescope through 24-hour drift scans, employing ezRA software for data processing. Despite efforts to refine the mapping process and enhance accuracy, discrepancies emerged when comparing the results with existing literature and maps, indicating inconsistent findings. However, the research fills a crucial gap in the field by exploring the potential of small radio telescopes and providing insights into the challenges and opportunities associated with such endeavors. The data collected is still valuable to the wider field of astronomy as it adds to the growing body of knowledge on the Milky Way galaxy. Using a low-cost telescope also promotes greater accessibility for educational purposes such as schools. Some limitations of this research include limited sky coverage location and interference which likely resulted in this study’s inconclusive results. Future research could create a map of the galaxy with galactic coordinates, analyze the interference in this study’s data, and compare different software for radio astronomy.

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Test and Rework of EBay Noise Source for Jove Calibration

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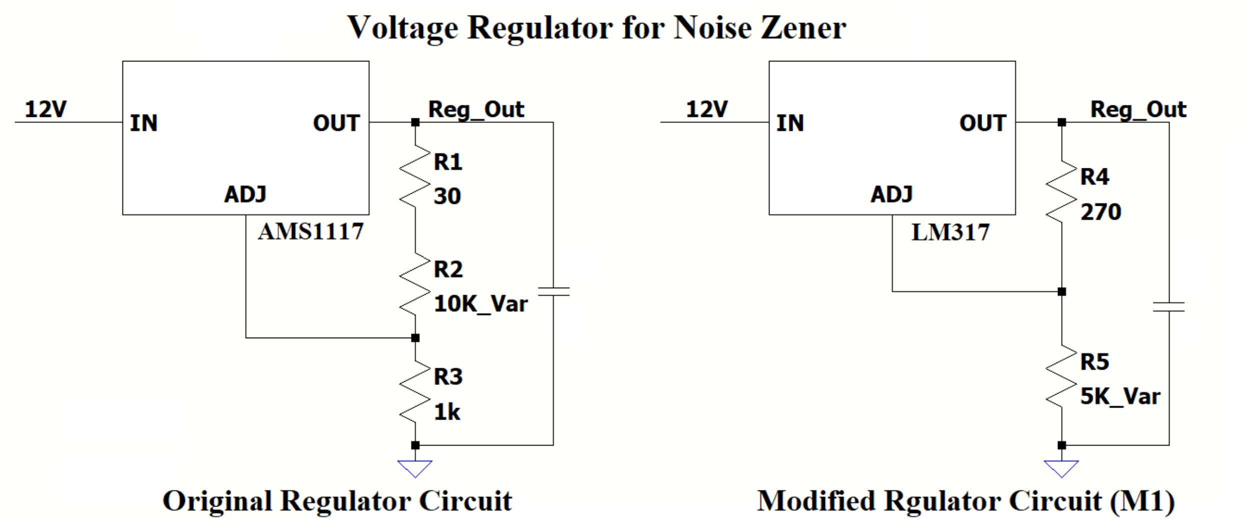
As I started working on a calibrator for Radio Jove, [1] I purchased from EBay the noise source that seemed to be the one needed. A few quick lab measurements showed problems related to poor design. The output varied about 30dB from 11 V to 13 V power input. Jim Sky did call for a well-regulated 12 V power supply for the noise source. [1]

A quick look at a few voltages in the unit revealed that the AMS1117 voltage regulator for the noise Zener diode was shorted from input to output. I replaced it with an LM317 regulator in the same package. The trim pot to adjust the voltage was very touchy and erratic to set. The trim pot circuit was changed to the arrangement recommended by both regulator manufacturers. The noise output peaked at 6.7 V out of the regulator, so it was set there.



The regulator fix improved the power supply sensitivity somewhat, but it was still not acceptable. The voltages around the MMIC (Monolithic Microwave IC) amplifiers were looked at next. The MMIC's were marked "N10" which is an HP INA10386 part. The DC voltage on the output pin was expected to be about 6 V. It was found to be about 3.3 V and a current of 35 mA, based on the 250 ohms of load resistance from 12 V. Looking at the data sheet showed a large sensitivity of gain vs operating current. See figures 2 and 3 from the data sheet. The input terminal on the MMIC's showed about 0.7 V, which implies a single transistor is in the part. More modern MMICs from Mini-Circuits™[2] have Darlington transistors which allow better control of DC parameters while still not interfering with the RF feedback. A decision was made to replace the MMICs with Mini-Circuits™ parts. U2 and U3 are MAR1's and U4 is a RAM-3 (A MAR-3 in a ceramic package). The load resistors were not changed, leaving the current slightly high in U2 and U3, and slightly low in U4. MMIC selection was based on my spare parts box.

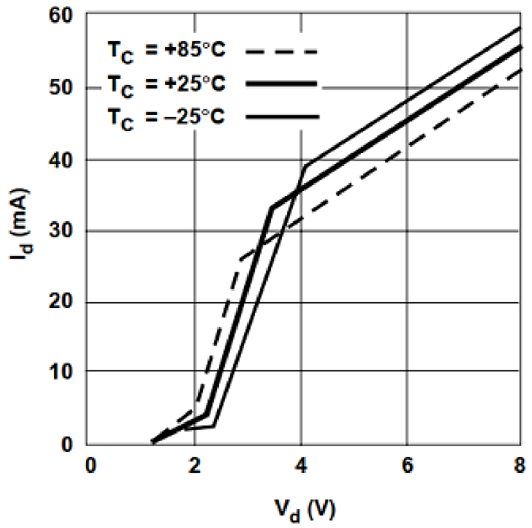


Figure 2. Device Current vs. Voltage.

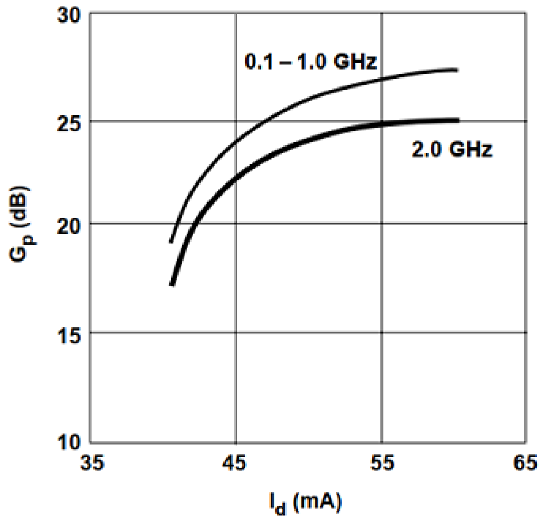
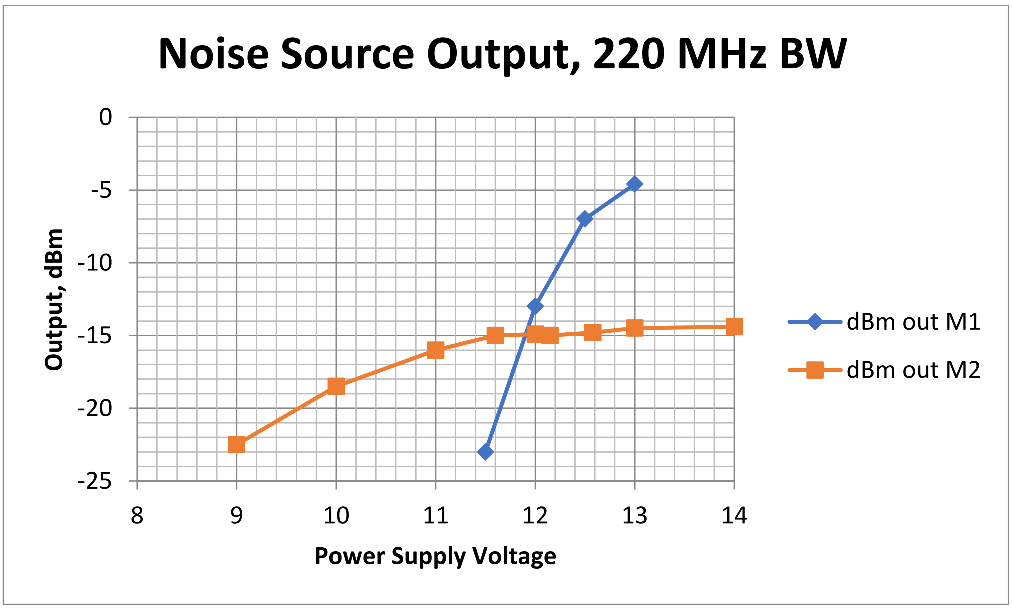


Figure 3. Power Gain vs. Current.

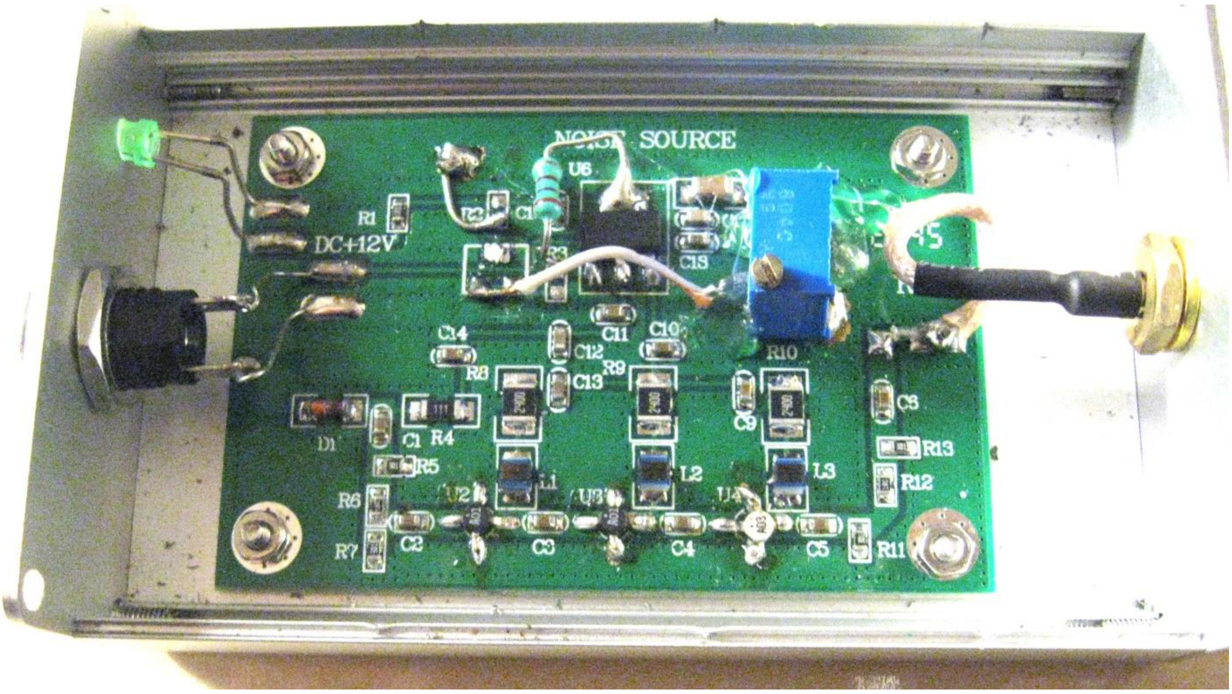
The sensitivity to power supply voltage was significantly improved. The M1 curve has the regulator fixed. The M2 curve has the MMICs changed out as well.



The new MMIC's do not have the bandwidth of the originals. The output is flat to 200 MHz. I believe that is a realistic claim unlike the original 2000 MHz claim which should have been about 1000 MHz.

Another possible approach to fix poor power supply voltage effects would be to use lower value load resistors on the 3 existing MMICs. 120 ohms ½ W for each load resistor should be about right.

Below is a picture of the modified circuit board. Note the hack job needed to make the voltage regulator work properly. Also Note the changed MMICs, U2, U3 and U4.



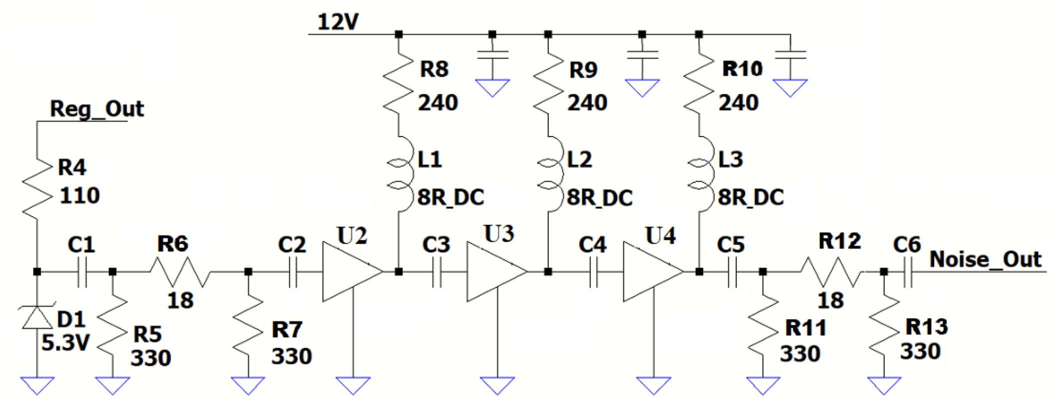
Because there is no part number, serial number or other control on these EBay specials, other units that look the same on the outside might have different MMICs or other parts. Any unit should be tested to see what it actually does, ignoring any performance claims.

I identify items like this by the supplier and date purchased. Note on this unit there is an ENR (Excess Noise Ratio) value label on it. Because ENR has a per Hz term in it, this was tested with a filter of 222 MHz noise bandwidth. Establishing noise bandwidth is another paper. It is not the same as the 3dB bandwidth. It is normally slightly wider for a low pass filter.

ENR Calculation: Using an Excel™ spreadsheet.

Test 20230803 at 10:30 EDT		**Using HP432 power meter**
Power at 12.0 V		
	-14.7	**dBm with filter at 215MHz**
	-11.6	**dBm with NO filter**
	-8.6	**dBm estimate at last MMIC in chain**
	9	**dBm est. 1dB compression at 25mA bias**
This is almost 18 dB head room which is OK for noise.		
Estimate of ENR and temperature in K, with filter		
Power	**0.0339**	**mW**
Power	**3.39E-05**	**Watts**
Bandwidth	**2.22E+08**	**Hz, Est noise bandwidth**
Watts/Hz	**1.53E-13**	
Boltz Const	**1.38E-23**	**in WattSeconds / Kelvin**
Temp.	**1.11E+10**	**= power/Hz / Boltz in Kelvin**
ENR = 10 log ((Th-290)/290)		
ENR =	**75.81**	**dB ENR**

Partial schematic of this noise source:



Other noise sources are available from EBay and Amazon. Many of them have questionable backgrounds. It is advisable to test them for sensitivity to power supply voltage and temperature. A blast of hot air from a hair dryer will find temperature sensitivity. If a significant change in output occurs or it quits working altogether, it is NOT something to use as part of a radio telescope.

References:

[1] https://radiosky.com/jovecal/JOVE_Cal1_Manual_V2.pdf

[2] https://www.minicircuits.com/

Observation of Water Masers in W49 with the Stockert 10-m dish

Wolfgang Herrmann

1. Introduction

W49 is a star forming region in the Milky Way at a distance of 11.11 kpc [1]. Under the conditions found in such star forming regions, very bright water masers can occur. These water masers are highly variable and therefore are an interesting subject for repeated and longer-term observations, see for example [2].
In this article first results from observations performed with the 10-m dish of the Stockert telescope are presented.

2. The Stockert 10-m telescope

The 10-m dish at the Stockert Radio Observatory was built in the year 1965 primarily for solar observations (fig. 1). It is an equatorial mount design where the hour angle is driven by a synchronous motor following the motion of the sun. Since the solar motion deviates only ~4 minutes per day compared to the star background, it can be used for tracking celestial objects as long as integration times are reasonably short. The declination is set by a DC Motor which is operated manually. Both the hour angle and the declination axes are equipped with high resolution encoders to allow precise pointing. The dish is equipped with Cassegrain "optics" using a hyperbolic secondary reflector and a cylindrical feed horn which ends in a waveguide for connection to the receiver.

Figure 1: The Stockert 10—m dish

3. 22 GHz receiver

The receiver is a modified commercial LNB supporting both Ku- and Ka-Band [3]. The modification refers to the local oscillator signal. The original local oscillator for Ka-band is based on a dielectric resonator with a frequency of 10.125 GHz which is frequency-doubled. Both the accuracy and stability of such a design is not well suited for radio astronomy observations. Therefore, a PLL oscillator with a frequency of 3.375 GHz was built which is locked to an external reference signal of 25 MHz. The output of this oscillator is frequency-tripled to deliver the required 10.125 GHz signal. This additional hardware is placed in an aluminum box attached to the LNB as shown in fig. 2 below.

Figure 2: Ku- Ka band LNA with modification

In order to account for the cable losses between the telescope and the indoor backend an additional line amplifier is added to each output. The receiving range of the LNB is from 21.3 GHz to 22.7 GHz, corresponding to an intermediate frequency (IF) between 1050 and 2045 MHz.

The LNB is controlled via DiSEqC signals, control tones and the supply voltage. This functionality is implemented in a controller which was built based on an Arduino. This unit is depicted in fig. 3.

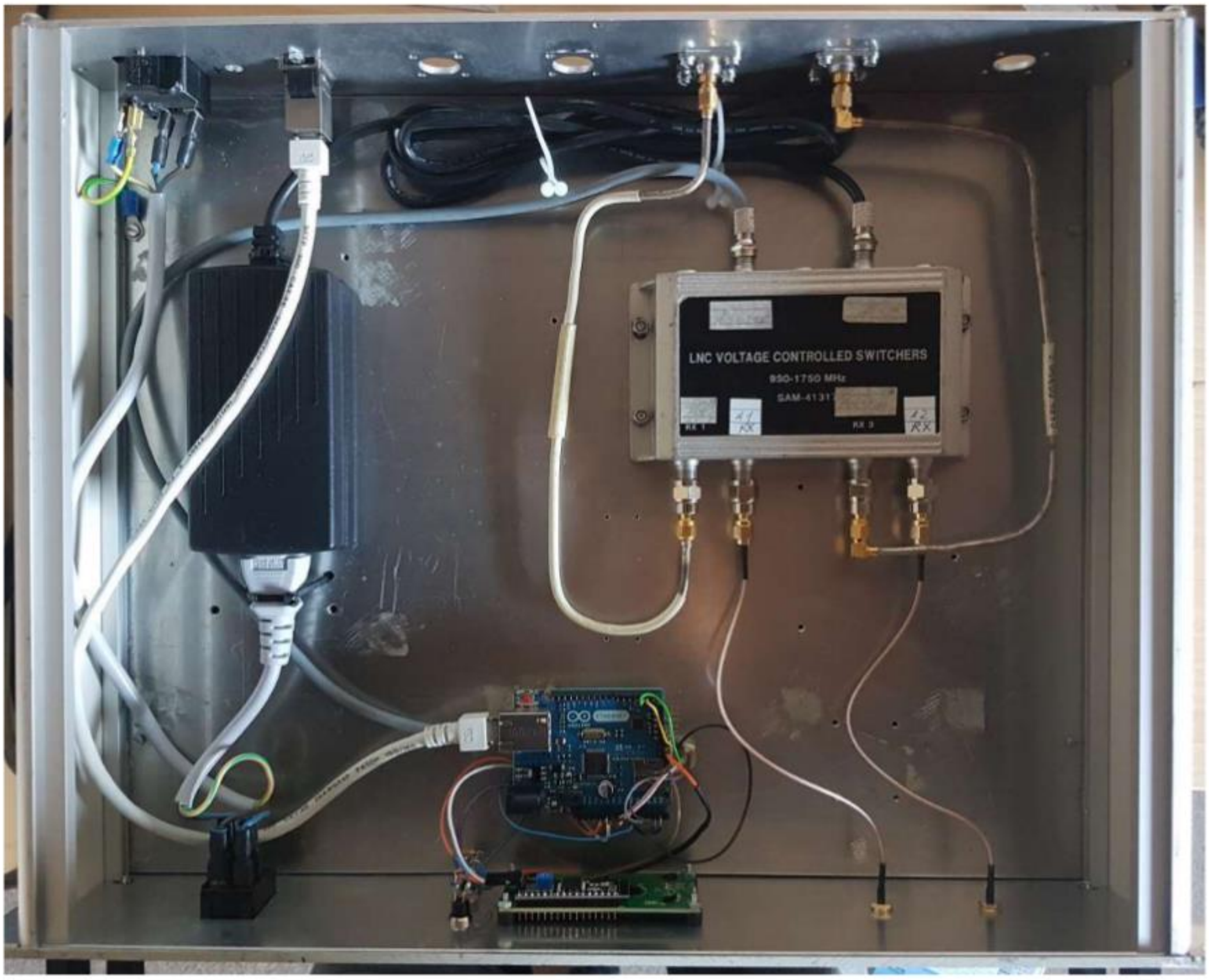


Figure 3: Control unit for LNB

4. Backend and Software

An Ettus Research B210 software defined radio [4] was used to record the IF signal from the LNB with a bandwidth of 16 MHz. Our "observatory standard software" for spectral observations using software defined radios is called "Spectrometer_II". It provides the functionality to perform the FFT, integrate over time and write FITS files containing the resulting spectra. This software also communicates with the telescope control and provides the necessary corrections for the local standard of rest. The evaluation of the spectra was performed with CLASS from the GILDAS suite [5].

5. Observations and Results

Several test observations were performed in order to optimize the pointing and to verify the setup. Pointing is quite critical as the beam width is only about 0.13° full width half maximum. Since the masers are very bright, only very short integration times of a few seconds were needed for testing.

After the test had been completed, spectra were recorded with 5 minutes integration time. In order to determine the baseline, another "off target" recording was done. This data was used to correct for gain variations across the spectrum. The resolution bandwidth was 3.9 kHz corresponding to a velocity resolution of about 0.05 km/s. All velocities are related to the Local Standard of Rest. At this time, we do not have a proper calibration of the intensity, so all intensities are given in arbitrary units of flux density.

The spectrum taken on November 24th, 2024, is shown below in fig. 4.

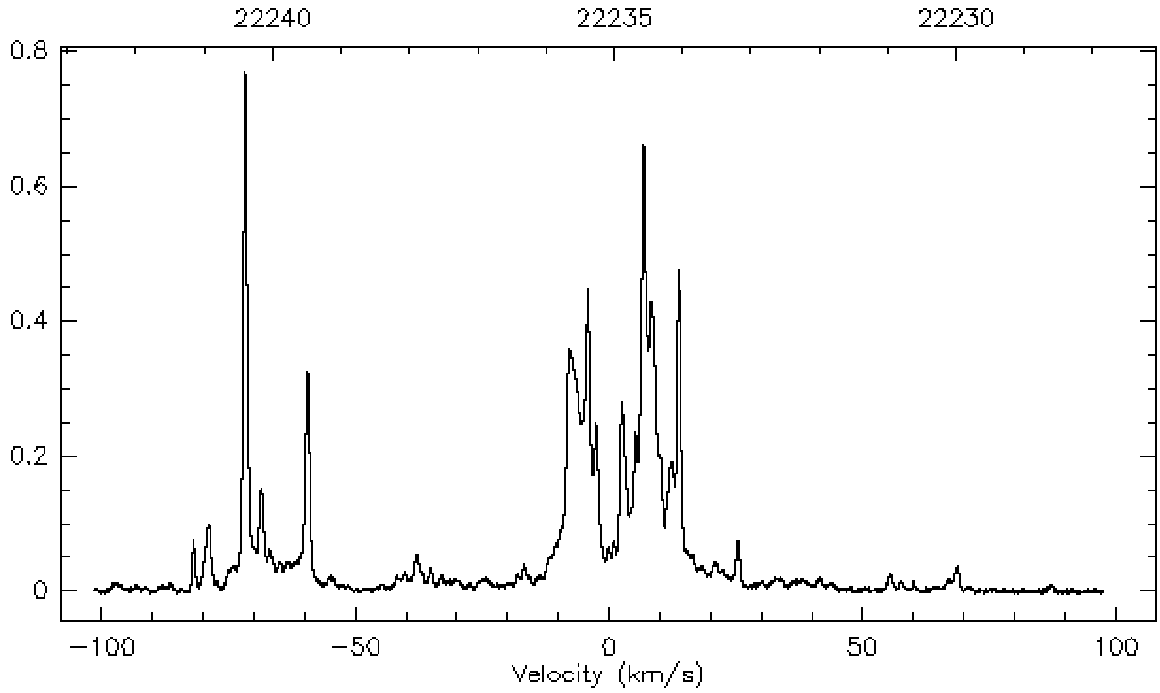


Figure 4: Spectrum of the Water Maser in W49, November 24th, 2024

At the time of the observation, there were two stronger emission features covering the velocity ranges of -20 to +30 km/s and -90 to -50 km/s. Besides that, there are weaker emissions almost all across the spectrum. Only the range > 70 km/s seems to be almost free of emission.

The complex nature of the spectrum and the great variations in velocities can be attributed to the fact that there is not just one emission region, but there are numerous emission regions within W49. Even though the beam width of our instrument is fairly small, it is not sufficient to provide any spatial resolution of W49. Interferometry would be required to resolve the different maser locations.

Water masers are known to have great variations on fairly short time scales. Therefore, it will be interesting to see how the spectrum will change over time. A first follow up observation was done on December 1st, 2024. The result is shown below in fig. 5.

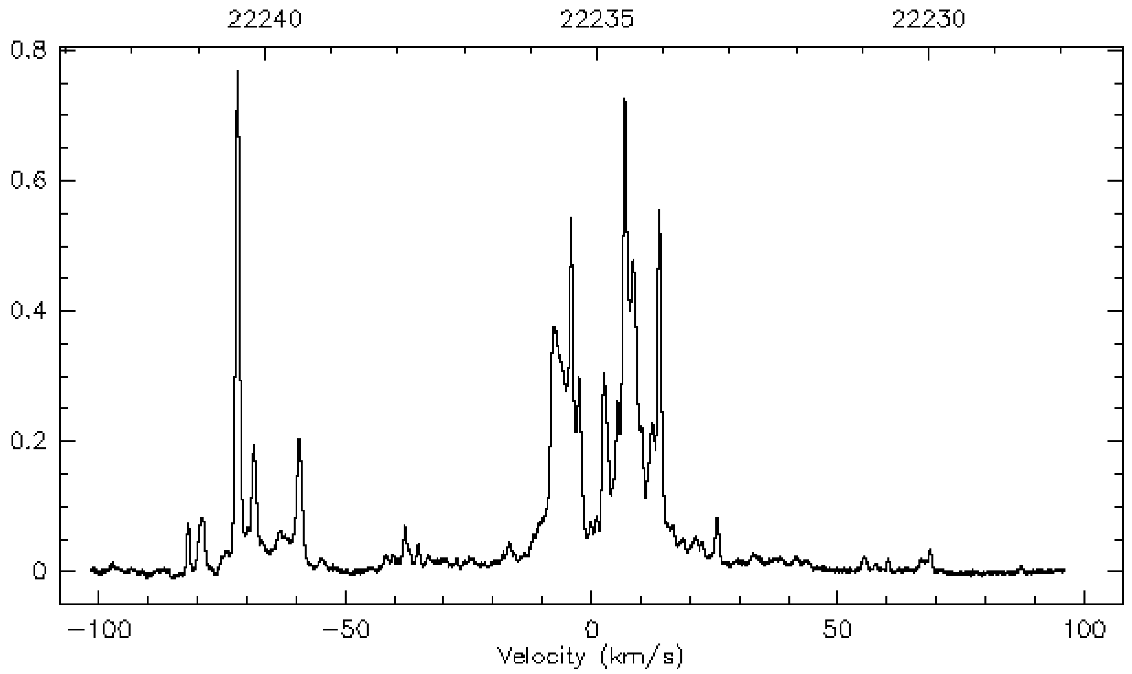


Figure 5: Spectrum of the Water Maser in W49, December 1st, 2024

At a first glance, the spectra seem to be identical. However, in a one to one comparison it turns out that the emission in the -90 to -50 km range has changed slightly (fig. 6):

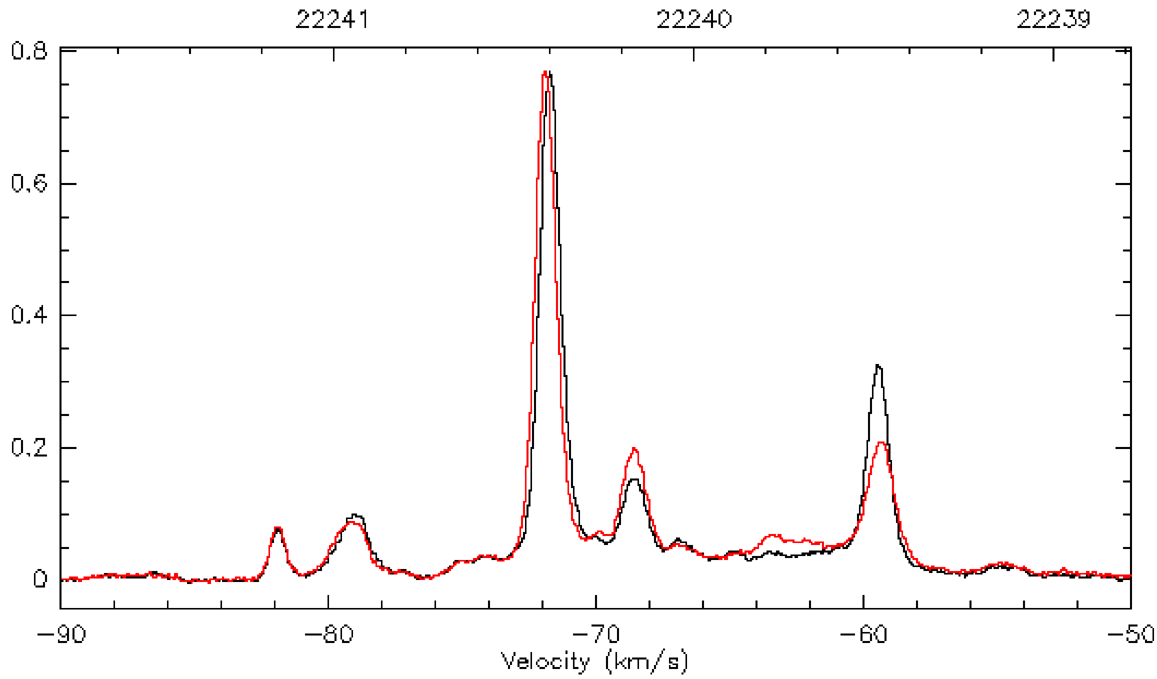


Figure 6: Comparison of the spectrum of Nov. 24th (black) and Dec. 1st (red) in the range -90 to -50 km/s

In contrast to this, the spectrum in the range -20 to 30 km/s is essentially unchanged (fig. 7):

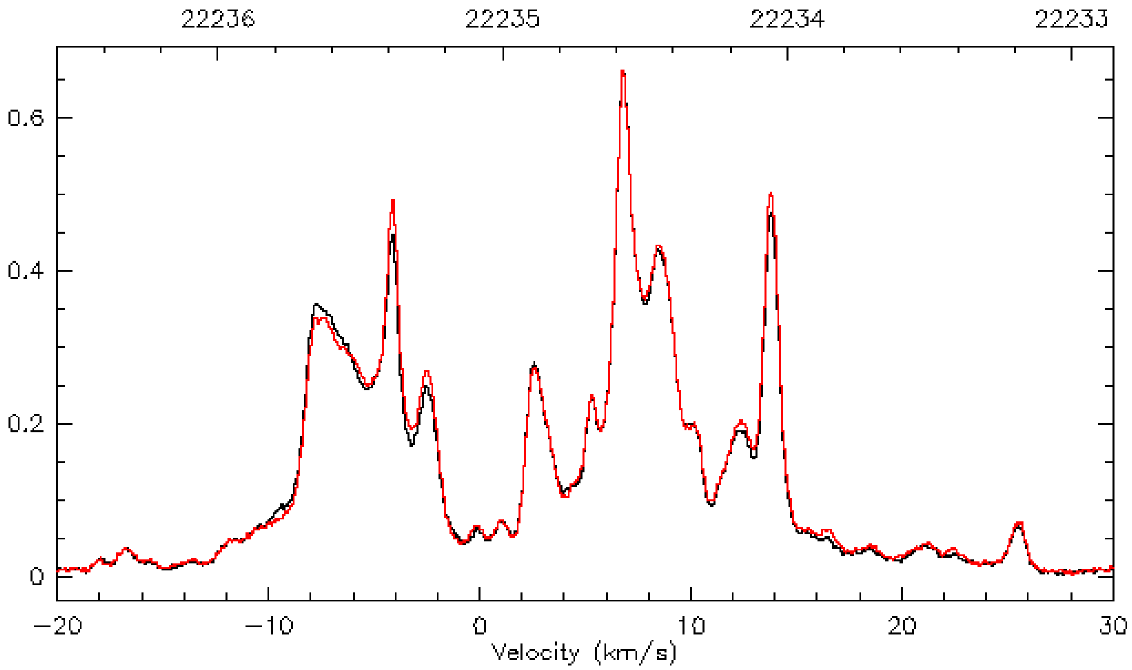


Figure 7: Comparison of the spectrum of Nov. 24th (black) and Dec. 1st (red) in the range -20 to 30 km/s

The small changes observed within just a few days underline the known fact that water masers are highly variable. Therefore, it will be interesting to continue the observations over a longer time period and also to extend the observation to other sources.

Literature and links:

[1] Zhang B, Reid M J, Menten K M, Zheng X W, Brunthaler A, Dame T M and Xu Y 2013 Astrophys. J. 775 79
[2] L.Z. Little, G.J. White and P.W. Riley; Mon.Not.R.astr.Soc. (1977) 180 639-656
[3] www.inverto.tv/lnb/208/kaku-co-locate-linear-23mm-lnb-with-one-kaku-switchable-output-and-one-ka-output
[4] www.ettus.com/all-products/ub210-kit/
[5] www.iram.fr/IRAMFR/GILDAS/doc/html/class-html/class.html

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He received his PhD in Physics from the University of Bonn. He has spent most of his professional career in the telecommunication industry. At retirement age, he now enjoys learning as much as possible about radio astronomy, doing observations and improving the instruments at Astropeiler.
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Velocity Plotting
By
Paul Gochin (KB3PUW)

Being rather new to radio astronomy (only a few months since I started) I have been trying to understand the range of topics of interest. I started with the basics, collecting data with something close to the “scope in a box” setup and using ezRA to collect 5 days of 24 hour sweep data at varying angles of inclination of the antenna (30, 40, 50, 60, 70 degrees) with the direction of the antenna fixed pointing southeast from my location. This is my resulting plot:

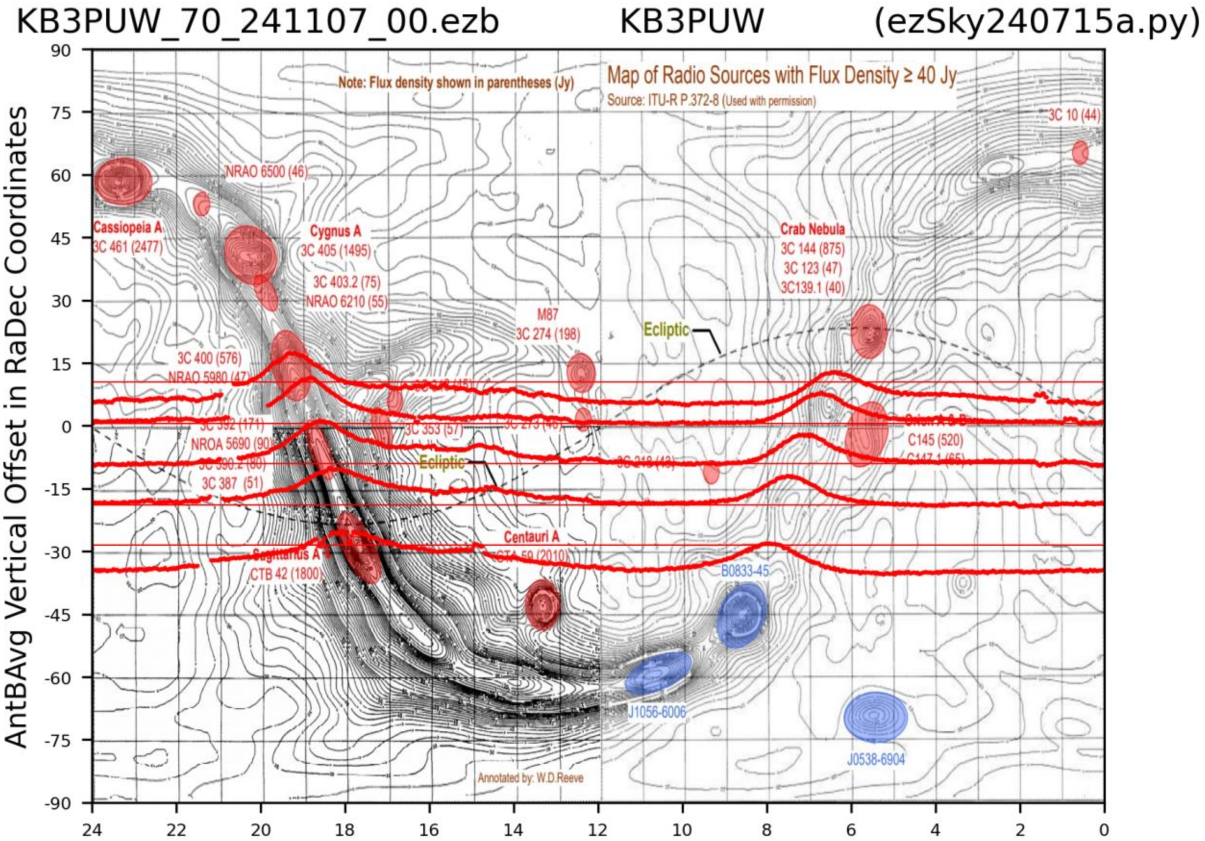


Figure 1

As I understand the results shown in this plot, each curve is a plot of the total power over a limited spectrum centered around about 1.4 GHz at numerous time points over a 24 hour period. There are 5 curves covering the various inclinations.

Below is a sample of one day's worth of scan data. As expected, the doppler shift of the signal varies (the peak is not at a constant frequency). My understanding is that the frequency variation is due to the relative velocity of the signal sources, and that the variation in velocity is a function of a combination of the rotation of the Earth, movement of the Earth around the Sun and variations in velocity of the hydrogen sources relative to the Sun.

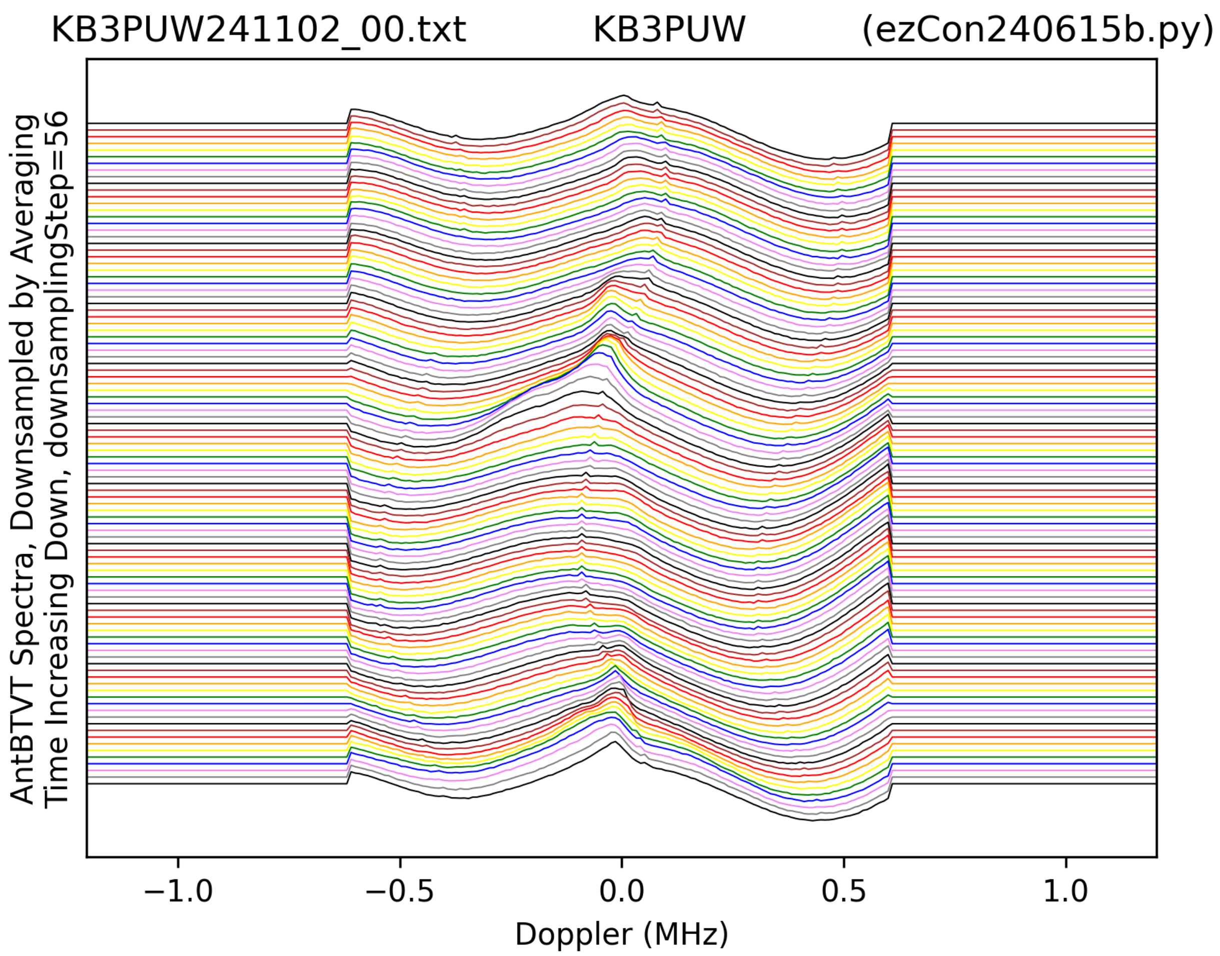


Figure 2

As best I could tell, looking through the various plots available in ezRA, there was no representation capturing both the velocity characteristics and the 2 dimensional location of the signal source in one plot.

I attempted to address this problem by writing some software on my own. Below is the resulting plot:

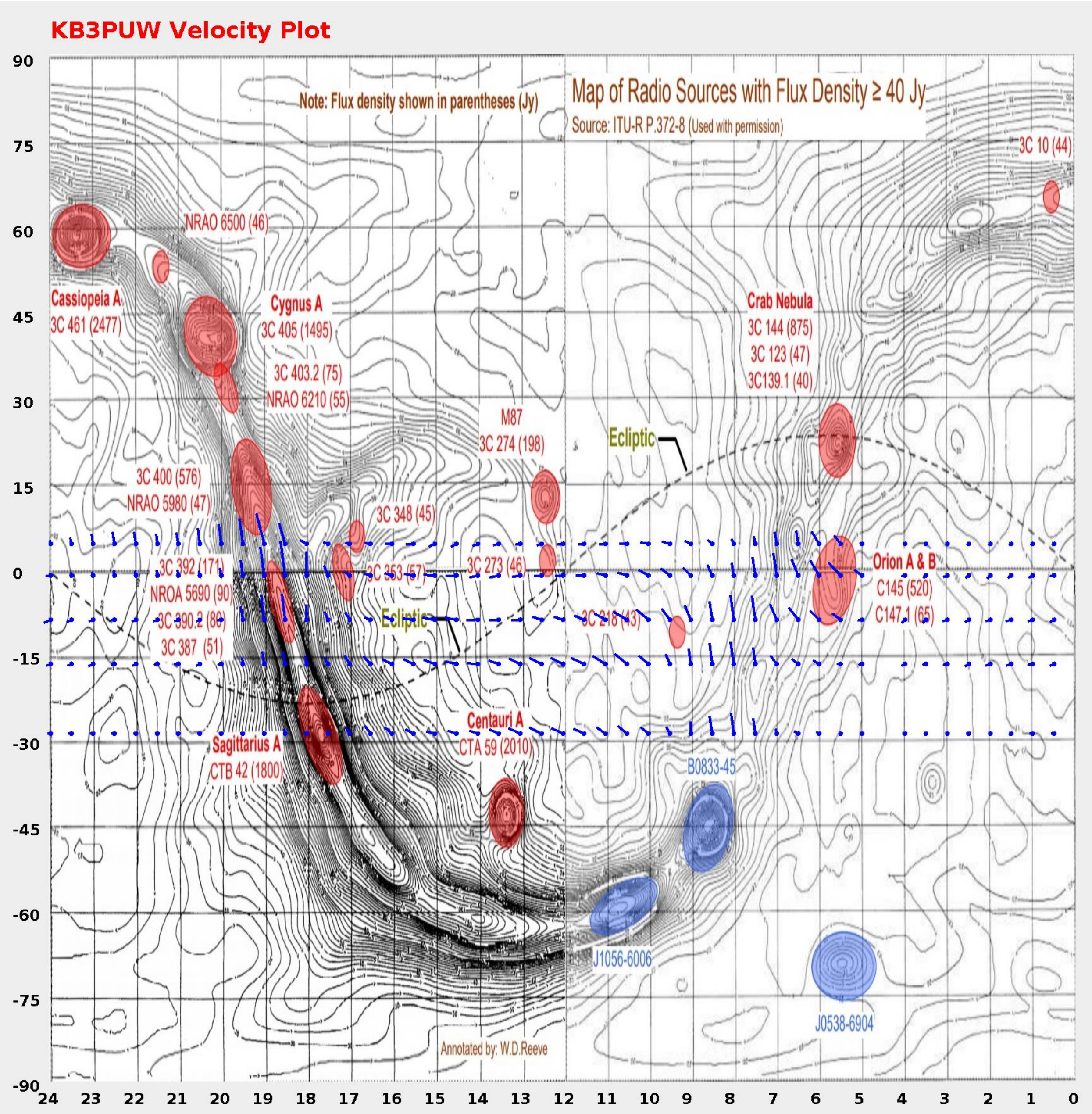


Figure 3

In this plot, each “arrow” is a vector whose length is proportional to the amplitude of the peak at each measured time point, and the direction is related to the direction of the doppler shift of those peaks.

The data for the plots was from ezCol. I wrote code to average over a configurable time period (in this case ½ hour). I attempted to flatten the raw data by computing a high pass filter of the data (low pass using a simple box car algorithm subtracted from the original). I further straightened out the baseline by doing a linear regression and subtracting it from the filtered data. I then applied a simple peak finding algorithm and produced a complex number representing the amplitude of the peak and the doppler shift for each of the half hour average spectrum data sets. I plotted the data against the same background used in ezSky (stretched a bit vertically). I rotated the data so that it would line up with the 24 hour marks. I also manually adjusted the vertical offset and gain for the base dots of each arrow because I did not know the formula for converting from the ezDefault values to RaDec coordinates.

This was a crude first attempt on my part to understand this data. The arrow vectors are not calibrated in either amplitude or direction. I would be quite interested in feedback as to whether my efforts are on the right track.

Observations of methanol masers 6.7 GHz in W51 star forming nebula

by Dimitry Fedorov UA3AVR

W51 is a star forming region, one of the largest in the Galaxy. This report is about observations of methanol masers 6.7 GHz in W51 molecular clouds in October-November 2024 with small single dish radio telescope 2.4 m. Detected line corresponds to the molecular transition $5_1 \rightarrow 6_0$, A^+ methanol molecule type, accurate frequency 6668.5192 MHz [1]. This maser belongs to class II, i.e. it is pumped to the inverse state by the infrared radiation from nearby objects and can work as a molecular tracer in star forming regions. W51 is characterized by high infrared luminosity; its colored infrared image is shown on Figure 1. Coordinates of W51 by the methanol radiation are G049.490-0.388, RA 19:23:43.95, DEC +14:30:34.44 (J2000).

Figure 1. Spitzer Image of Star Factory W51 https://www.spitzer.caltech.edu/image/ssc2020-14a-w51, observations 2012. Colors: blue – 3.6 μm, blue-green – 4.5 μm, green – 8 μm, red – 24 μm.

More info about W51 and its methanol radiation

Some common info about W51 [2]: distance to is about 5.4 kpc, total mass ~ 10^6 $M_\odot$, total infrared luminosity 9.31×10^6 (Distance / 5.4 kpc)^2 $L_\odot$. W51 contains infrared regions IRS1 and iRS2 (for details see the molecular map below), 20 spectral class OB stars and 20 independent HII regions. Its part W51A – is the most luminous with velocities about 55-65 km/s, see the W51 infrared map in Figure 2; this part gives the strongest spectral peak of methanol maser tracers. Other remarkable part is a supernova remnant W51C; see detailed image in different wavelengths in Figure 3.

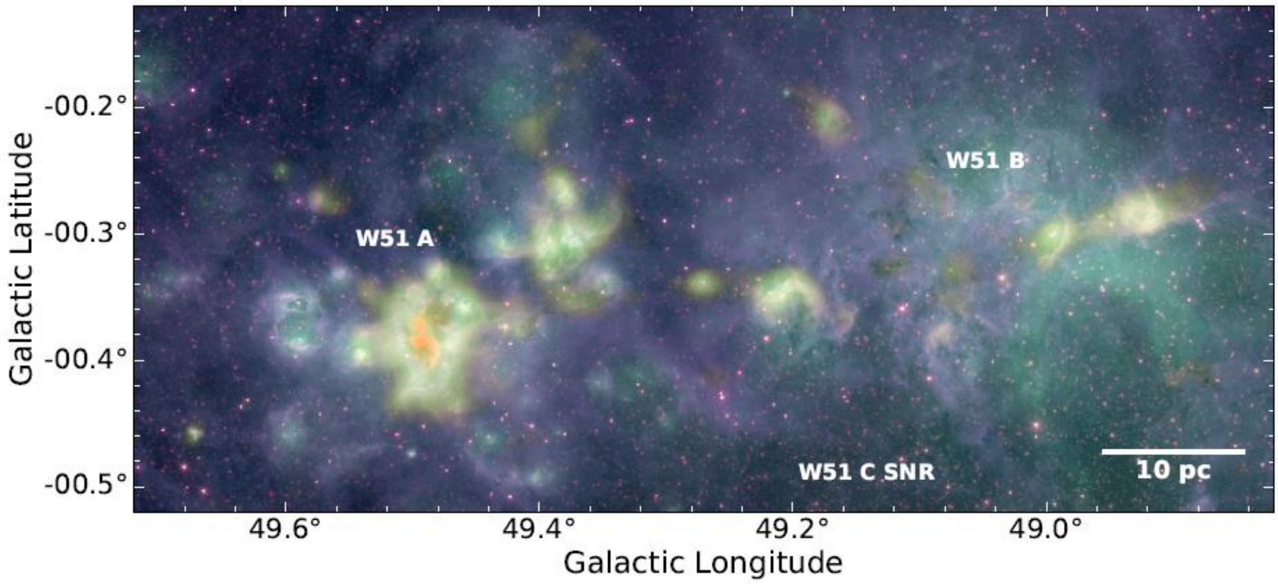


Figure 2. Detailed infrared map of W51 [2]. Colors are WISE's blue – 3.4 μm, green – 12 μm, red – 22 μm, yellow-orange – Bolocam 1.1 mm.

More far infrared spots in W51 location by database [3] are shown on Figure 4.

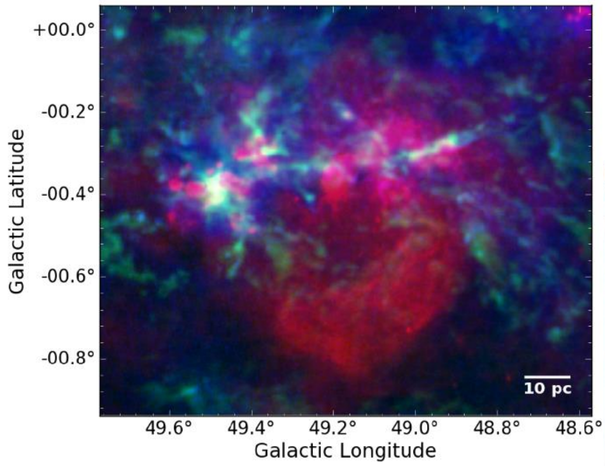


Figure 3. Supernova remnant in W51, an image in different wavelengths [2]. Colors are red – 90 cm VLA image (2013), blue – ATLASGAL 870 μm, green – ^{13}CO emission (Galactic Ring Survey, 2006).

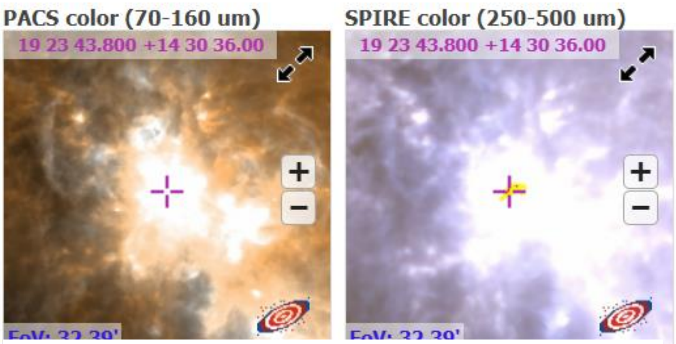


Figure 4. Far infrared spots from W51 location, database [3].

A typical methanol 6.7 GHz spectrum of W51 is shown on Figure 5 (left), and the features distinguished by Ibaraki iMet [4] on Figure 5 (right). The database [4] contains two very close objects with similar spectrums; Figure 5 shows spectrum and features form first of them in [4]. The distance between their locations may be less then estimated spatial resolution of the Ibaraki instruments (HPBW about 0.1°, single dishes 32 m).

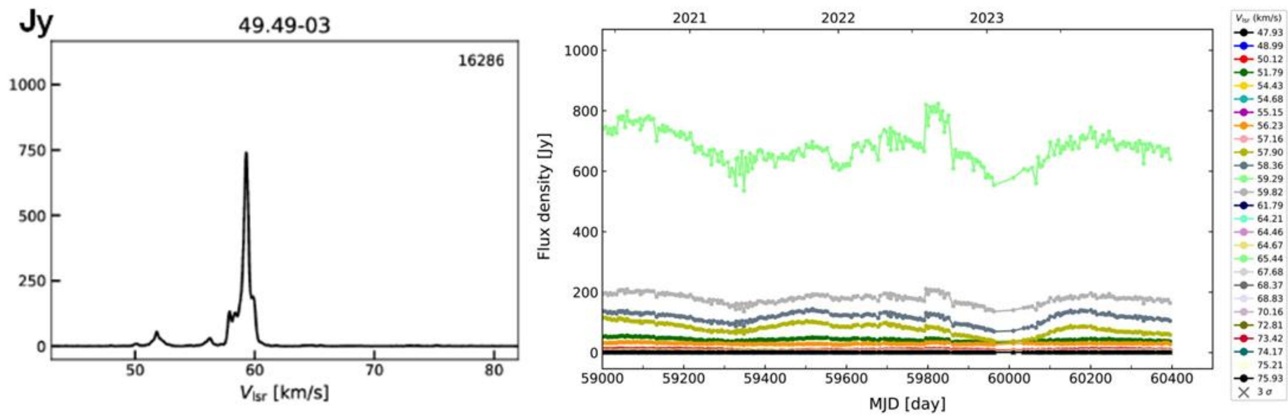
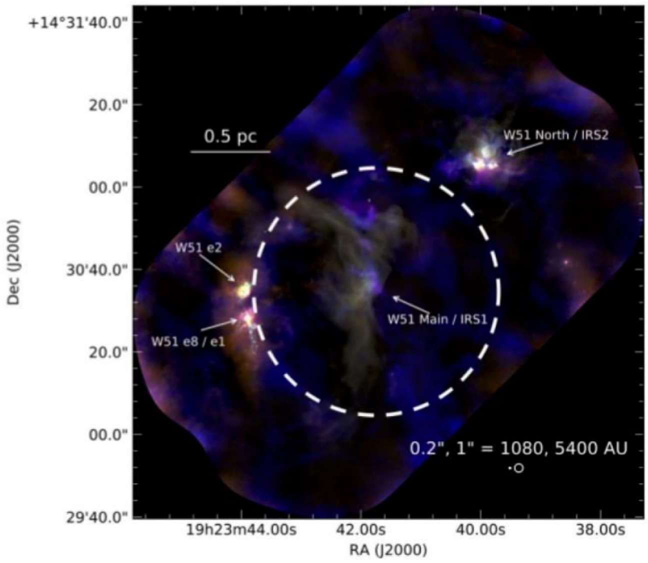


Figure 5. Ibaraki iMet data for W51 [4]: left – a typical spectrum, right – peak flux densities for lines (features) of the 6.7 GHz maser.



Typical spectrum contains a primary line 59.3 km/s >600 Jy; also iMet distinguishes several features up to 200 Jy what are forming a pedestal to the primary line. Maser seems relatively stable with primary line variations about 200 Jy.

Molecular map of W51 [5] with marked infrared regions, IRS1 and IRS2, is shown on Figure 6; the map shows also star forming cores e2, e8/e1 with molecular clouds, and spots of other molecular species besides the methanol.

Figure 6. W51 molecular map [5] with exciting infrared regions IRS1 and IRS2. Colors are blue – Carbon oxide CO, orange – Methanol CH_3OH, purple - Cyanoacetylene HC_3N (Arecibo), white – radio continuum 1.3 mm (ALMA), green – radio continuum 2.1 cm (JVLA).

Instrumentation

Observations at 6.7 GHz were made using 2.4 m small single dish telescope, see Figure 7.

Dish size: **D** = 2.4 m. The dish does not allow to distinct different W51 maser spots, and receives the methanol radiation from the whole of W51 region; its Half Power Beam Width δ_{HPBW} = 1.3°.

Telescope characteristics:

η_A = 0.65 – Aperture Efficiency obtained by solar measurements [6] and Learmonth solar observatory data [7] interpolated to 6.7 GHz. Antenna Half Power Beam width δ_{HPBW} = 1.3° is comparable with the Sun angular size δ_{sun}=0.53°; hence, the Beam filling factor $=1-2^{\left(\frac{\delta_{sun}}{\delta_{HPBW}}\right)^2}$ was included in calculations (ch. 8.2.3 in [8] and [9]), dish sensitivity (forward gain) Γ = 0.001 K/Jy;

T_{sys} = 110 K – from Y-factor Moon measurements [10], T_{sys} = 120 K, obtained from known receiver NF and estimated spillover;

SEFD = T_{sys}/Γ = 112690 Jy (with worst value T_{sys} = 120 K);

Minimal detectable peak flux density ≈ 80 Jy (RBW≈5 kHz, 1 hour of integration).

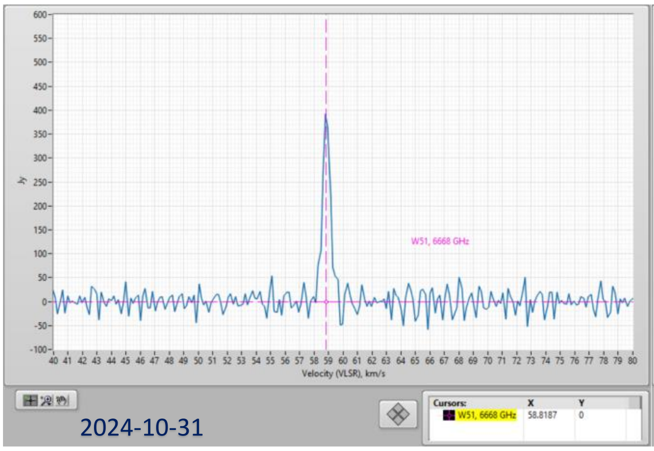
Figure 7. 2.4 m dish mounted on the roof of apartment building (55°46'00.5"N 37°49'25.8"E) with 6.7 GHz RX downconverter at the focus. The dish was designed by Sergei Zhutyaev RW3BP for mm-waves initially.

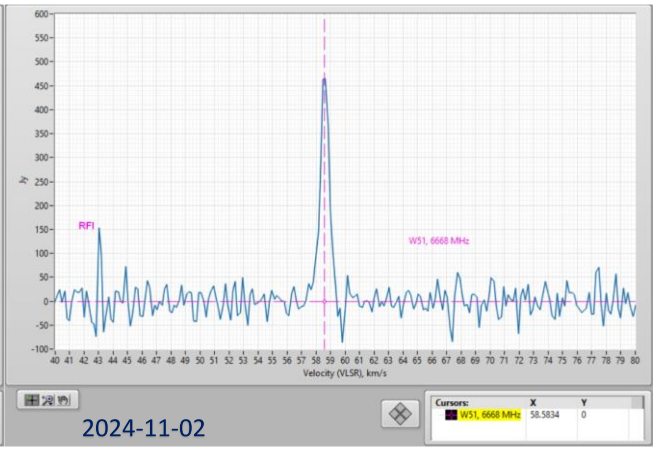
Linear polarization. Source automatic tracking during all the integration time (with F1EHN software).

Outdoor downconverter: Terrasat 6.4-7.1 GHz RX module (LO 5.7 GHz) + LNA (NF=1.2 dB). Indoor IF receiver: USRP B200mini, receiver resolution – 5 kHz by noise bandwidth (about 0.2 km/s in velocity units), total receiver bandwidth – 1.5 MHz. The indoor IF receiver USRP B200mini is controlled using LabVIEW software with on-fly averaging of spectra (no intermediate data are stored), see more details about IF receiver and post-processing procedures in papers [11].

Results and discussion

Observed spectrum of the maser is shown at Figure 8. Integration time was 1 hour. The levels can be underestimated in comparison to Ibaraki iMet data, see Figure 5 or [4], presumably due to polarization effects.





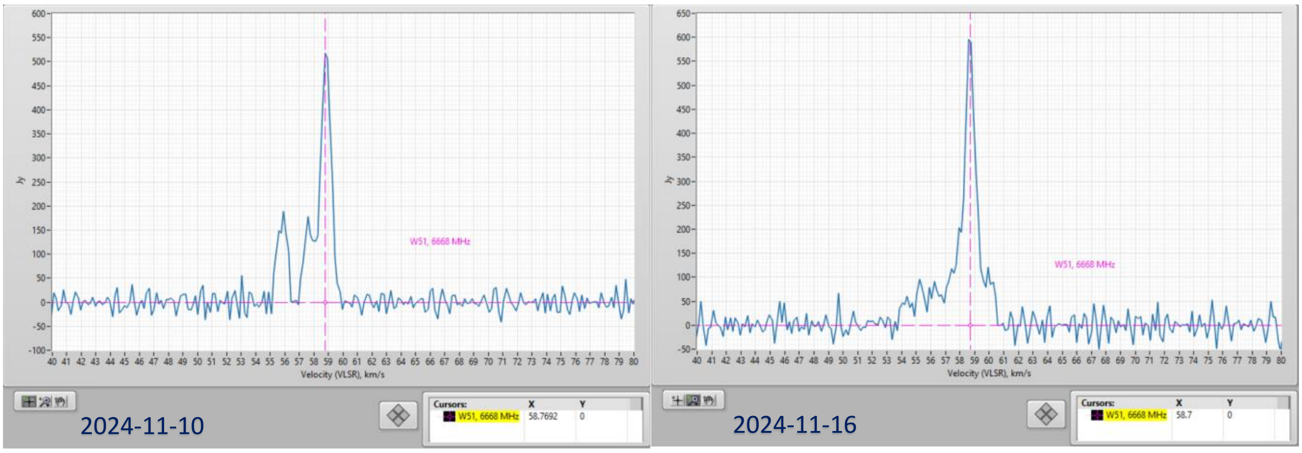


Figure 8. Observed W51 methanol spectrums 6.7 GHz from 2024-10-31 to 2024-11-16, integrations 1 hour.

The primary line about 59 km/s from most luminous W51A part (see Figure 2) is well detected and seen on all spectra. The spectrum from 2024-11-10 contains noticeable and rather wide line about 56 km/s. Such line can appear form possible flare in W51; similar lines in water H_2O masers 22 GHz already observed recently (see [12] including good explanatory work by Eduard Mol about H_2O flares in W51 and references therein). Unfortunately, this line did not appear again a bit later 2024-11-16, and has considered as a receiver artifact.

Acknowledgments

A lot of thanks to Sergei Zhutyaev RW3BP for access to his 2.4 m dish, Figure 7, neat work with its tracking system, and valuable help in observations.

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About the author

Dimitry Fedorov was first licensed as radio amateur since 1982, as UA3AVR since 1983. In 1990 graduated as MS in electronics in Moscow Power Engineering University. Now works as research and development engineer in wireless industry, LTE/5G NR, RF and microwave modules development. Previous scientific experience in nuclear and particle physics, worked in Moscow State University, Institute of Nuclear Physics and Universität Tübingen, Institut für Theoretische Physik, see profile blog at https://www.researchgate.net/profile/Dimitry-Fedorov-2. Radio Astronomy hobby since 2012, mainly in applications for weak signals reception. You can contact the author at ua3avr@yandex.ru.

ezRA Now Supports RINEARN 3D and 4D Plots

by Ted Cline N0RQV

The ezRA Easy Radio Astronomy set of programs are free PC tools to help explore Radio Astronomy,

ezRA - Easy Radio Astronomy
Free 1420 MHz Galactic hydrogen data collection and analysis
Open source
Windows and Linux
https://github.com/tedcline/ezRA

ezRA creates many plots. Five of the ezRA plots,

ezCon087	3D plot
ezSky400	3D plot
ezSky500	3D plot
ezSky520	3D plot
ezGLon580	4D plot

can now provide their data in a CSV (Comma Separated Value) file to drive RINEARN Graph plots,

RINEARN Graph 3D
https://www.rinearn.com/en-us/graph3d/

RINEARN Graph 3D is an install-free, 3-dimensional and 4-dimensional graph plotting software that allows you to easily visualize data from numerical files or spreadsheet applications.

These instructions require recent ezRA program versions,

ezCon241024a.py
ezSky241201a.py
ezGLon241118a.py

Instructions for Linux

The Linux Ubuntu 22.04.5 LTS instructions are the same as the Windows instructions which follow, except for these small differences,

Windows uses
    py
and
    \
whereas Linux uses
    python3
and
    /

So, small spelling changes in the ezCon command (all on one line),

```
python3  ../ezRA/ezCon.py  data/2020_123_00.rad.txt  data/2020_124_00.rad.txt
    -ezConAntXTFreqBinsFracL 0 1  -ezConUseVlsr 0  -ezConAntXTVTFreqBinsFracL 0 1
    -ezConPlotRangeL 87 87  -ezCon087Csv 1
```

I invoked the installed RINEARN Graph 3D software each time with a CSV file parameter, like this,

```
ring3d  ezCon087antRBTVT.csv
```

which was simpler than using the Windows
    File menu - Open File
method.

Small spelling changes in the ezSky command (all on one line),

```
python3  ../ezRA/ezSky.py  .  -ezSkyInput 14
    -ezSkyMaskIn  ../ezRA/ezSkyMaskLtoNot_46.5_-49.7.npz
    -ezSkyPlotRangeL  400  520    -ezSky400Csv 1    -ezSky500Csv 1    -ezSky520Csv 1
```

Small spelling changes in the ezGLon command (all on one line),

```
python3  ../ezRA/ezGLon.py  .
    -ezGlonGalCrossingGLonNear 2  -ezGLonPlotRangeL 580 580
    -ezGLon580CsvFrac  0.15
    -ezGLonGalCrossingGLonCenter 70
```

I combined all the 16   ezGLon580*.csv   files into one long file, with this command,

```
cat  ezGLon580g*.csv  >  ezGLonAll580.csv
```

(wc ezGLonAll580.csv
says the   ezGLonAll580.csv   file has 90,395 lines)

Instructions for Windows

After installing RINEARN Graph 3D on Windows,

https://www.rinearn.com/en-us/graph3d/guide/launch

I now had a

rinearn_graph_3d_5_6_36b_en\rinearn_graph_3d_5_6_36b_en\RinearnGraph3D_5.6.36.bat

batch file to run to invoke RINEARN Graph 3D.

In a command prompt window, I changed to my directory, perhaps with this command prompt window command,

```
cd  ezRABase\N0RQV-8
```

The ezCon command (all on one line),

```
py  ..\ezRA\ezCon.py  data\2020_123_00.rad.txt  data\2020_124_00.rad.txt
   -ezConAntXTFreqBinsFracL 0 1  -ezConUseVlsr 0  -ezConAntXTVTFreqBinsFracL 0 1
   -ezConPlotRangeL 87 87  -ezCon087Csv 1
```

created an

ezCon087antRBTVT.csv

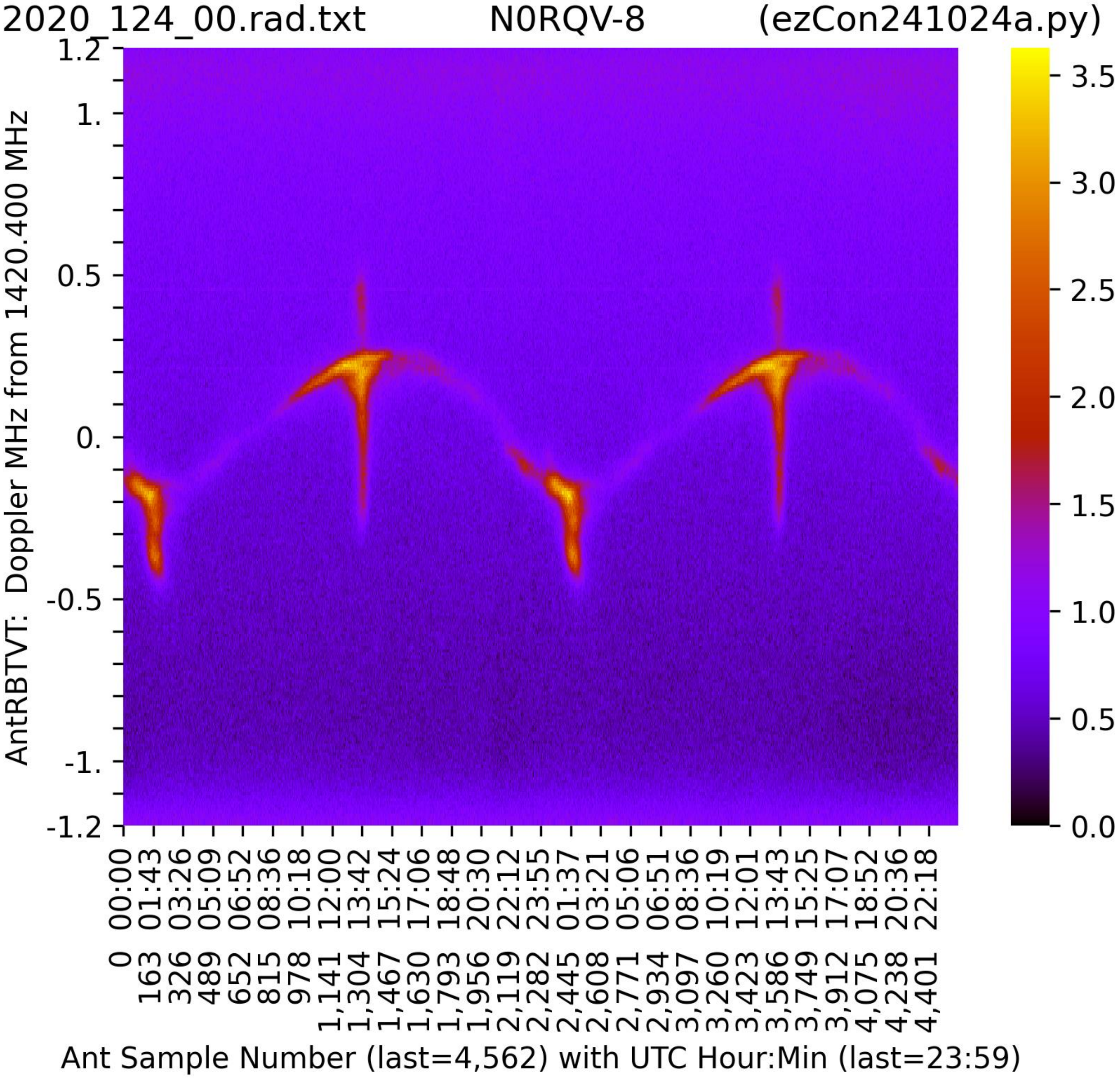
file (which may be big, mine was over 85 MB).

That long ezCon command line included

data\2020_123_00.rad.txt	= the first .txt data file
data\2020_124_00.rad.txt	= the second .txt data file
-ezConAntXTFreqBinsFracL 0 1	= disable the first post-processing frequency filter
-ezConUseVlsr 0	= disable the VLSR math, to show the Galactic snake
-ezConAntXTVTFreqBinsFracL 0 1	= disable the second post-processing frequency filter
-ezConPlotRangeL 87 87	= plot only ezCon087, to save time
-ezCon087Csv 1	= enable output of CSV file for the ezCon087 plot

ezCon087 3D Plot

That command also created this ezCon087 plot, with a curvy Galactic hydrogen snake,
with 4 Galactic plane crossing hotspots over the 2 days,



I now ran that

rinearn_graph_3d_5_6_36b_en\rinearn_graph_3d_5_6_36b_en\RinearnGraph3D_5.6.36.bat

batch file to run to start the RINEARN Graph 3D software.

I maximized the new window, by left-clicking the small square in the very top right.

I clicked

File menu - Open File

and an Open File window popped up.

I clicked the big OPEN button and eventually found and chose that new CSV file,

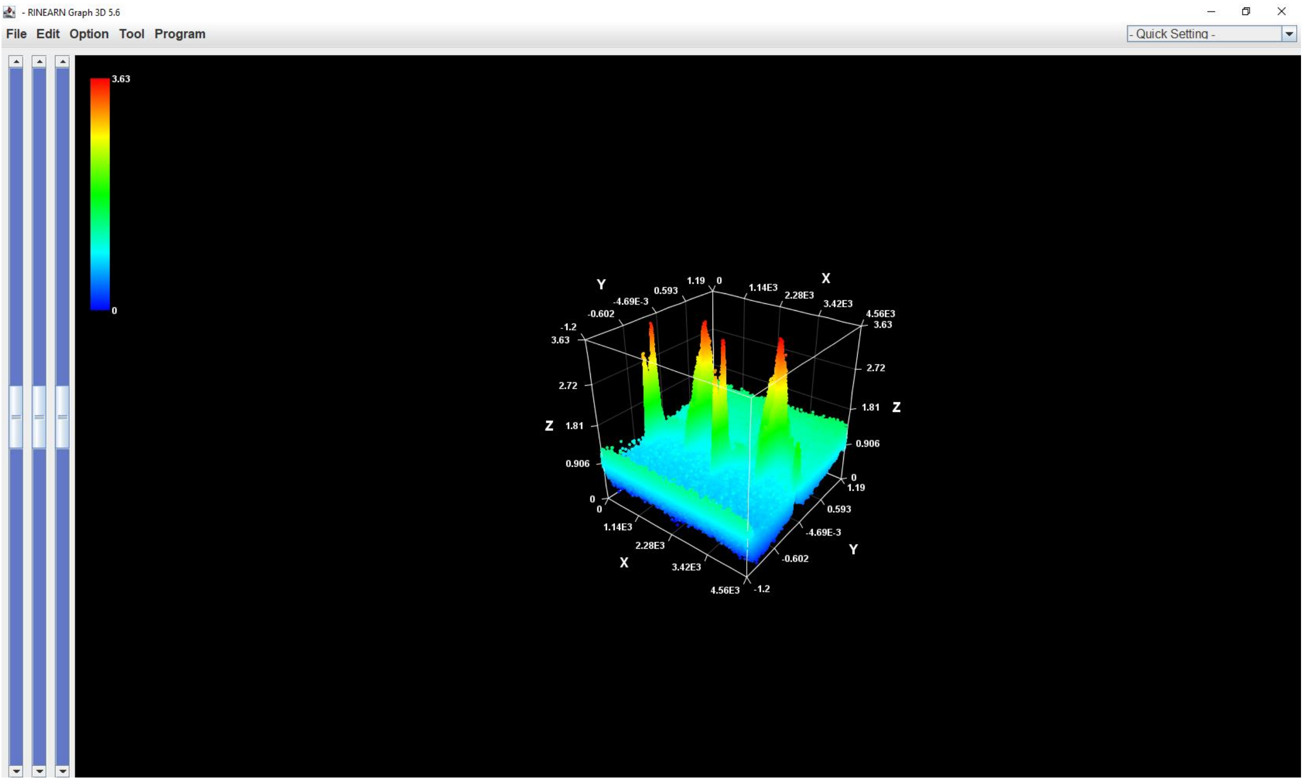
ezCon087antRBTVT.csv

I clicked the big PLOT button and waited almost 29 seconds before a new plotting appeared.

RINEARN Graph 3D had to render all those 4,563 samples.

This example had 4,563 * 256 = 1,168,128 dots to display.

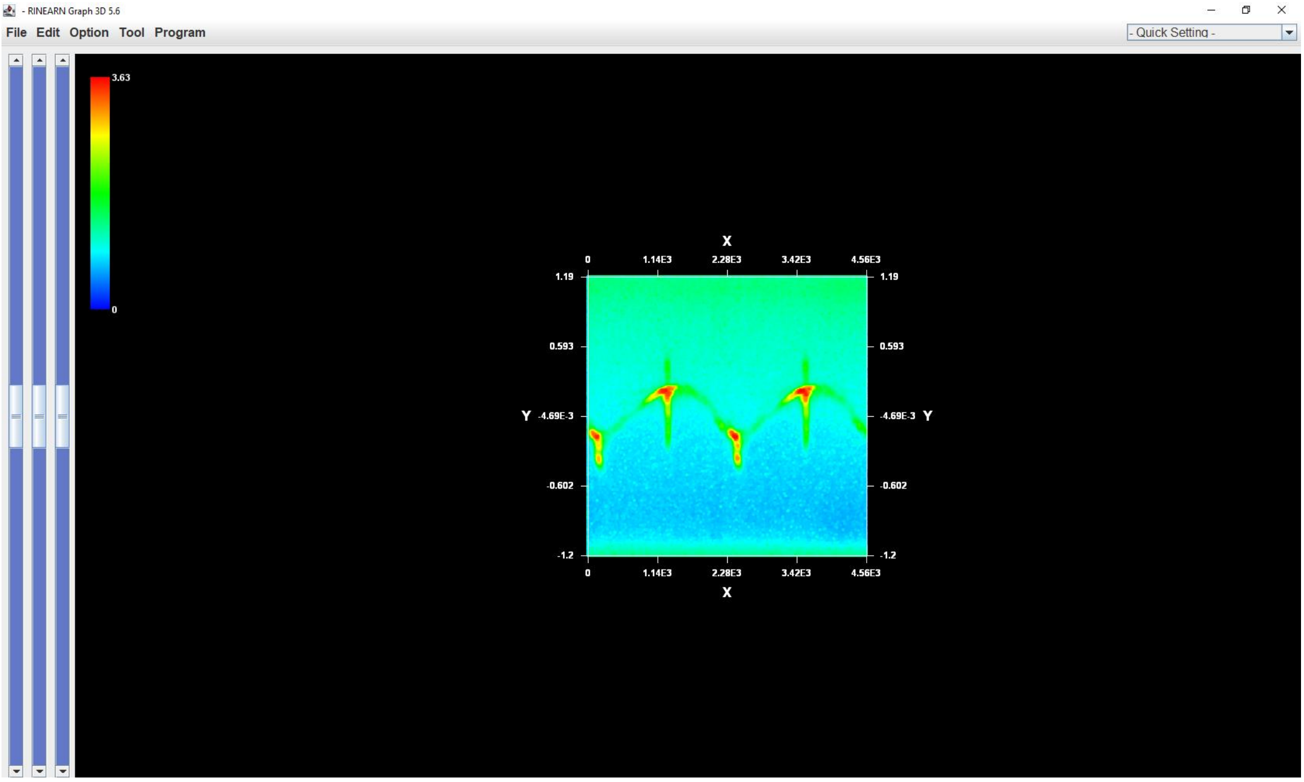
After closing the Open File window, I saw this,



I clicked

Option menu - Flat on (checked)

After closing the Flat window, I saw this,



This view from above (Zenith) should look like the ezCon087 plot above (perhaps with different colors).

Good.

I clicked

Option menu - Flat off (unchecked)

You may try mouse-dragging the 3D plot to see it from different angles, but I found it delicate (because this big plot renders slowly).

Maybe move the Camera instead:

Edit menu - Set Camera (again, slow to render to the defaults)

My default

Horizontal Angle

Vertical Angle (Z Axis)

was 0.65, 1.04 (in radians, not degrees).

The Vertical Angle (Z Axis) is from the Zenith overhead.

I changed that to 0.3, 0.6

and then clicked the big SET button.

My default

Camera Distance

Magnification

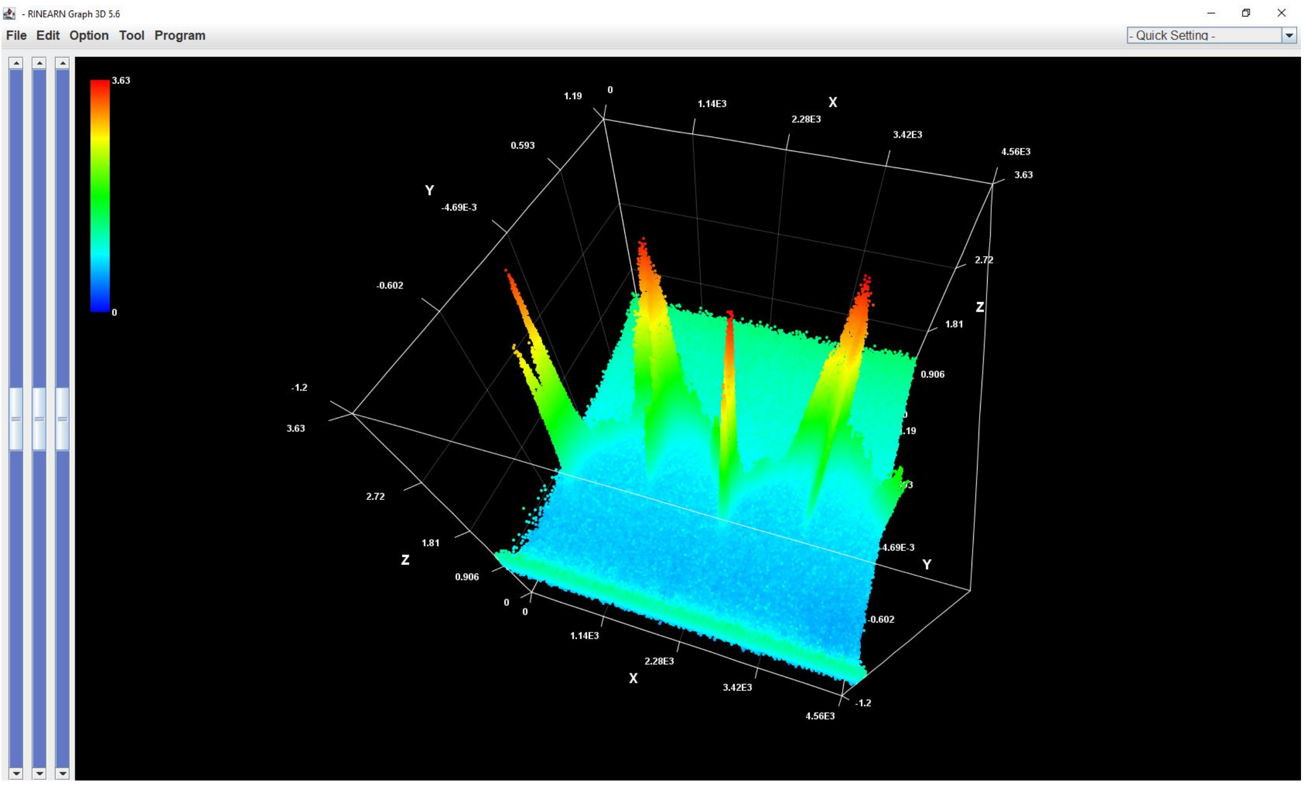
was 6.0, 700.0

I changed that to 3.0, 700.0

and clicked the big SET button,

and closed the Set Camera window.

I saw this,



I made other changes,

Option menu - Frame off (unchecked)

Option menu - With Lines on (checked)

Line Width = 1.0

Option menu - With Points off (unchecked)

Edit menu - Set Range

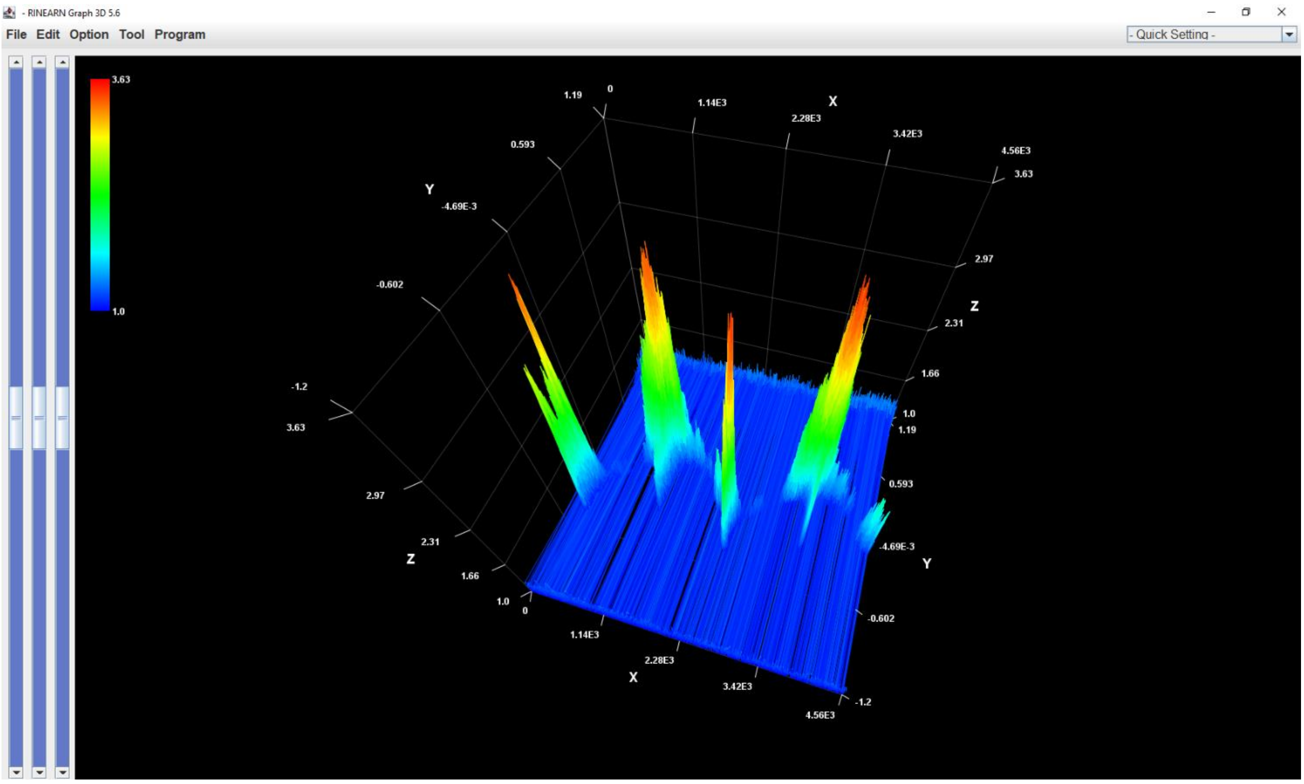
Z Axis Auto Ranging off (unchecked)

Z Axis Z-min to 1.0

and then click the big SET button,

and close the Set Range window.

I saw this, showing the curvy Galactic hydrogen snake from high above,



I clicked

File menu - Save Image

to the default

graph3d.png

filename by clicking the big SAVE button,
and closed the Save Image window.

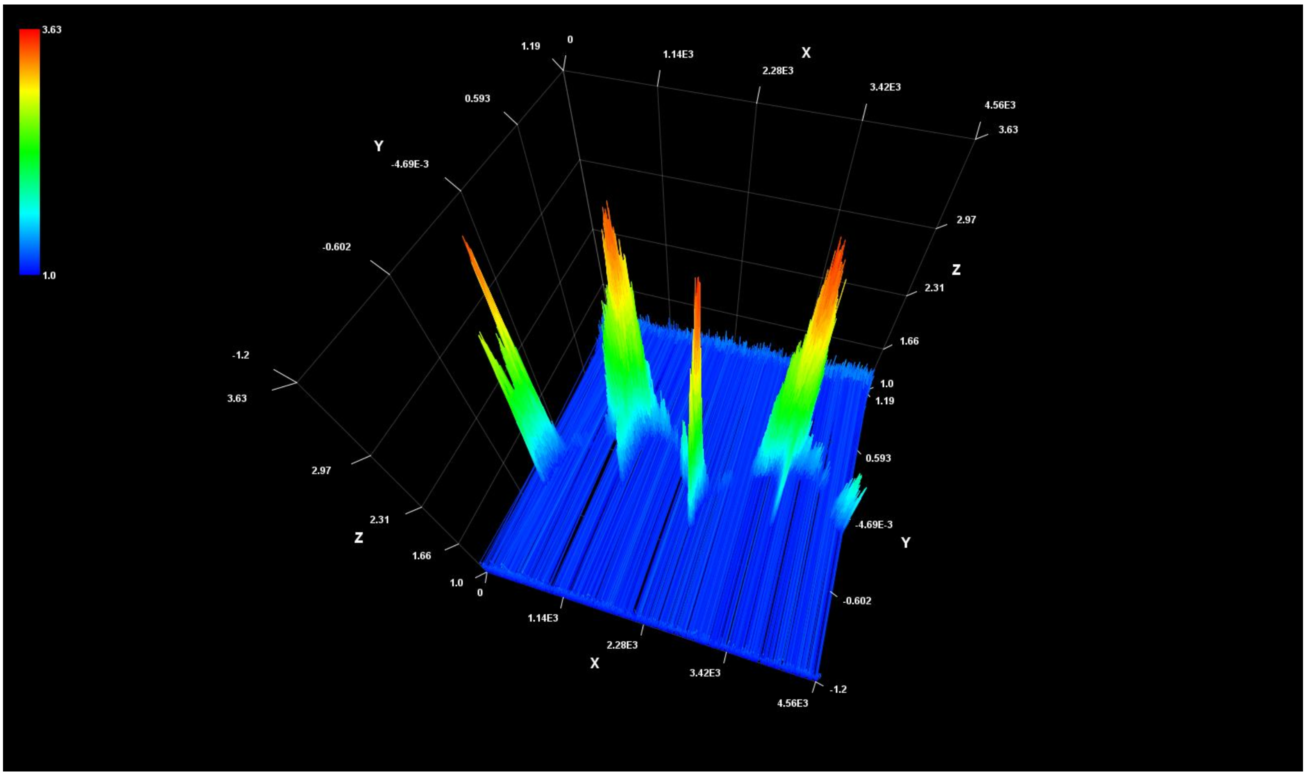
Then I renamed that

graph3d.png

plot file to

ezCon087antRBTVTCsv.png

which looked like this,



3 ezSky 3D Plots

For the 3 ezSky 3D plots (ezSky400, ezSky500, and ezSky520), the process is similar to above,
but also do

Option menu - Reverse X

because the

Right Ascension X axis
Galactic Longitude X axis

increase to the left.

Better ezSky plots are possible if I use the big MIT Haystack data collection of the LTO16 antenna.

In a command prompt window, I changed to my directory, perhaps with this command prompt window command,

```
cd  ezRABase\lto16h
```

The ezSky command (all on one line),

```
py  ..\ezRA\ezSky.py  .  -ezSkyInput 14
    -ezSkyMaskIn  ..\ezRA\ezSkyMaskLtoNot_46.5_-49.7.npz
    -ezSkyPlotRangeL  400  520    -ezSky400Csv 1    -ezSky500Csv 1    -ezSky520Csv 1
```

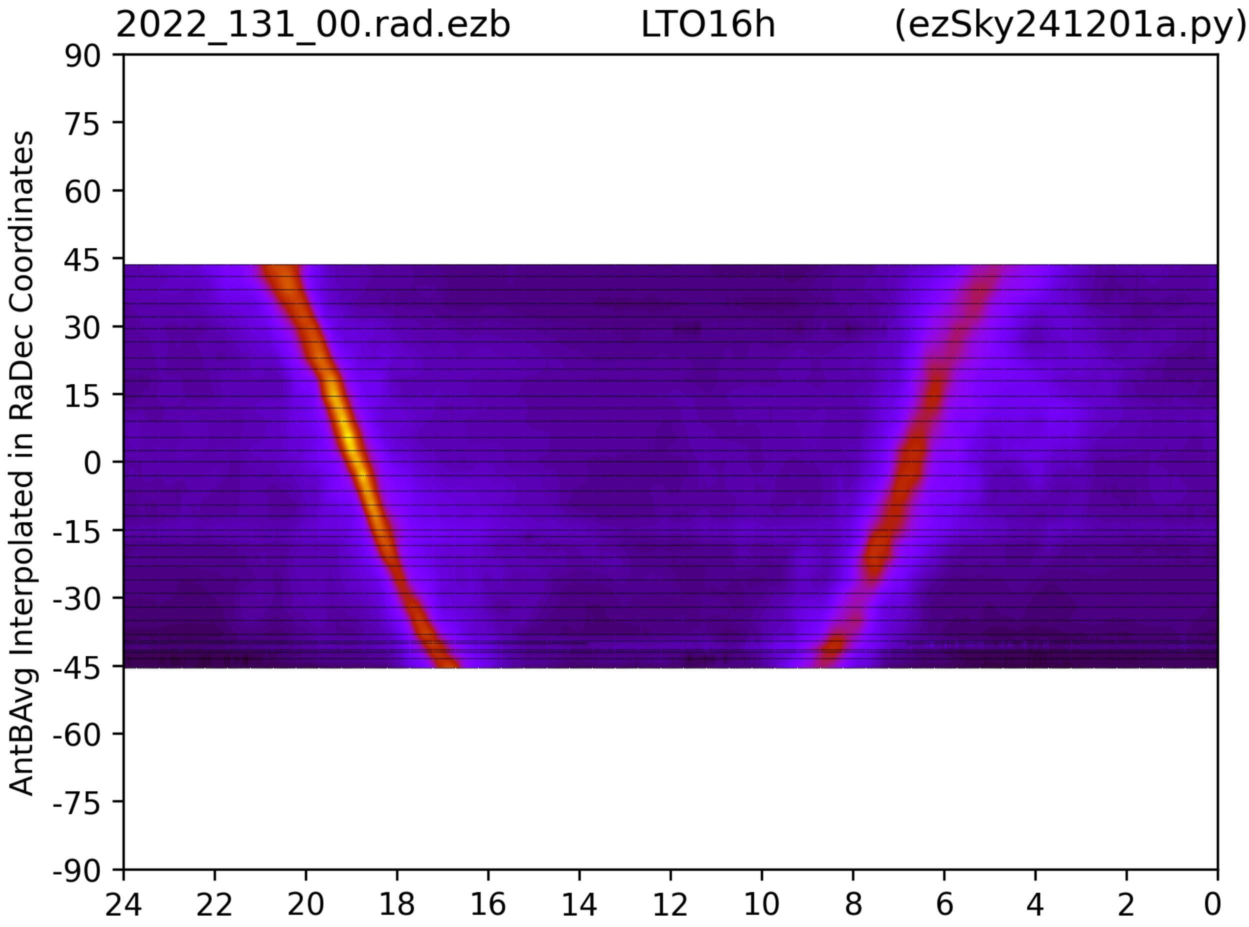
created 3 .csv files,

ezSky400RI_14AntBAvg.csv
ezSky500GMI_14AntBAvg.csv
ezSky520GOI_14AntBAvg.csv

(which may be big, mine were about 18 MB).
That long ezSky command line included

```
.  (period)                          = process all the  .ezb  files in the current directory
-ezSkyInput 14                       = use the AntB signal (  .ezb  data files' column 14)
-ezSkyMaskIn  ..\ezRA\ezSkyMaskLtoNot_46.5_-49.7.npz
                                     = mask data above 46.5 and below -49.7 declination
-ezSkyPlotRangeL  400  520           = plot only ezSky400 through ezSky520, to save time
-ezSky400Csv  1                      = enable output of CSV file for the ezSky400 plot
-ezSky500Csv  1                      = enable output of CSV file for the ezSky500 plot
-ezSky520Csv  1                      = enable output of CSV file for the ezSky520 plot
```

ezSky400 3D Plot



For the

ezSky400RI_14AntBAvg.csv

file,

Edit menu - Set Camera

Horizontal Angle

Vertical Angle (Z Axis)

to 0.5, 0.6

Camera Distance

Magnification

to 3.0, 700.0

Option menu - With Lines on (checked)

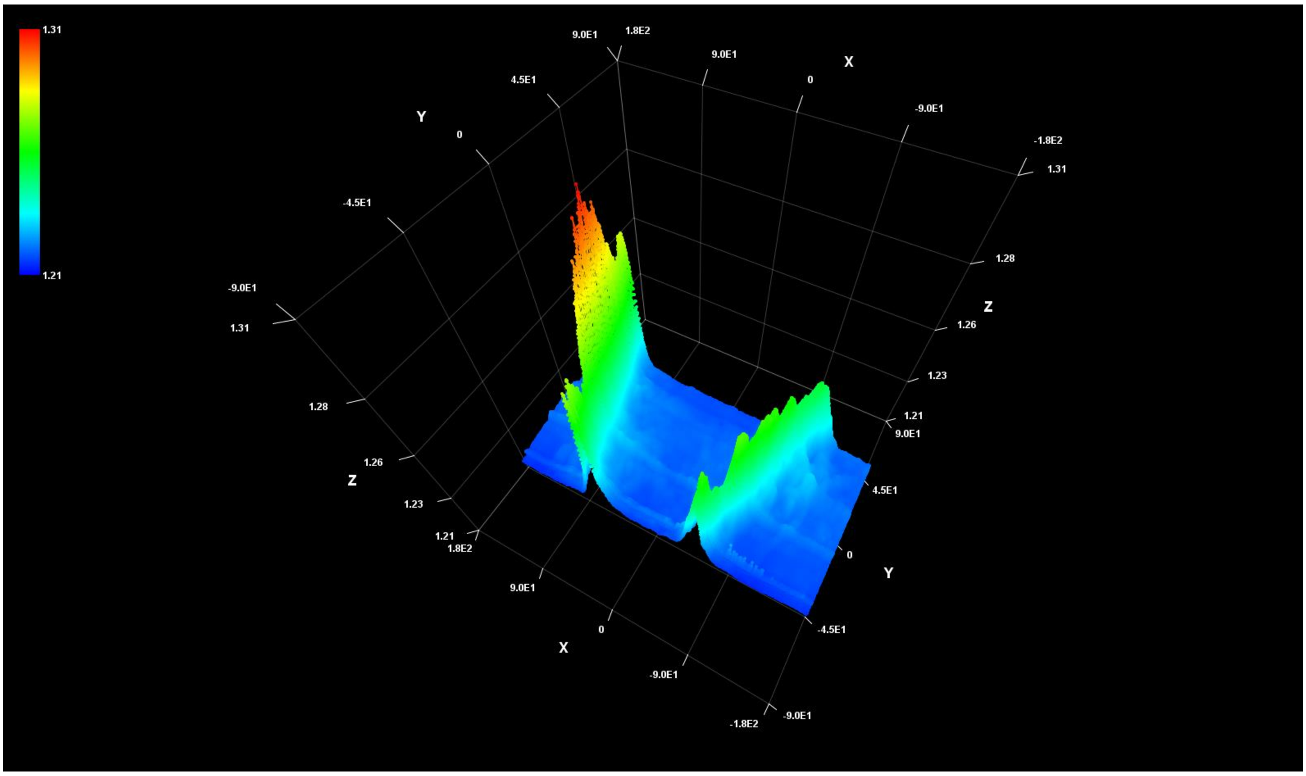
Line Width = 1.0

Option menu - With Points on (checked)

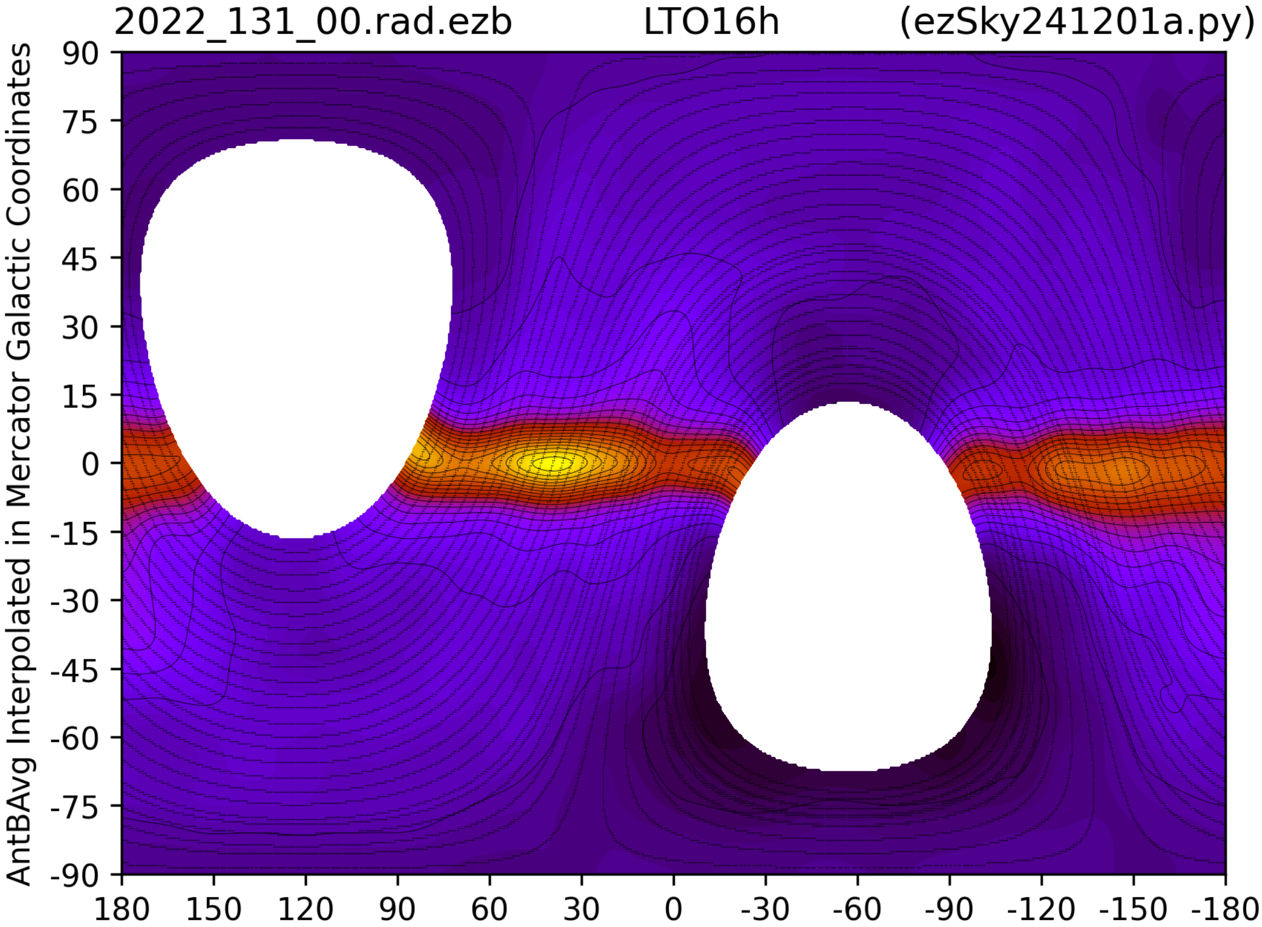
Option menu - Reverse X on (checked)

Option menu - Frame off (unchecked)

I renamed that saved graph3d.png to ezSky400RI_14AntBAvgCsv.png
showing Galactic hydrogen power across the radio sky, in RaDec coordinates,



ezSky500 3D Plot



For the

ezSky500GMI_14AntBAvg.csv

file,

Edit menu - Set Camera

Horizontal Angle

Vertical Angle (Z Axis)

to 0.9, 0.5

Camera Distance

Magnification

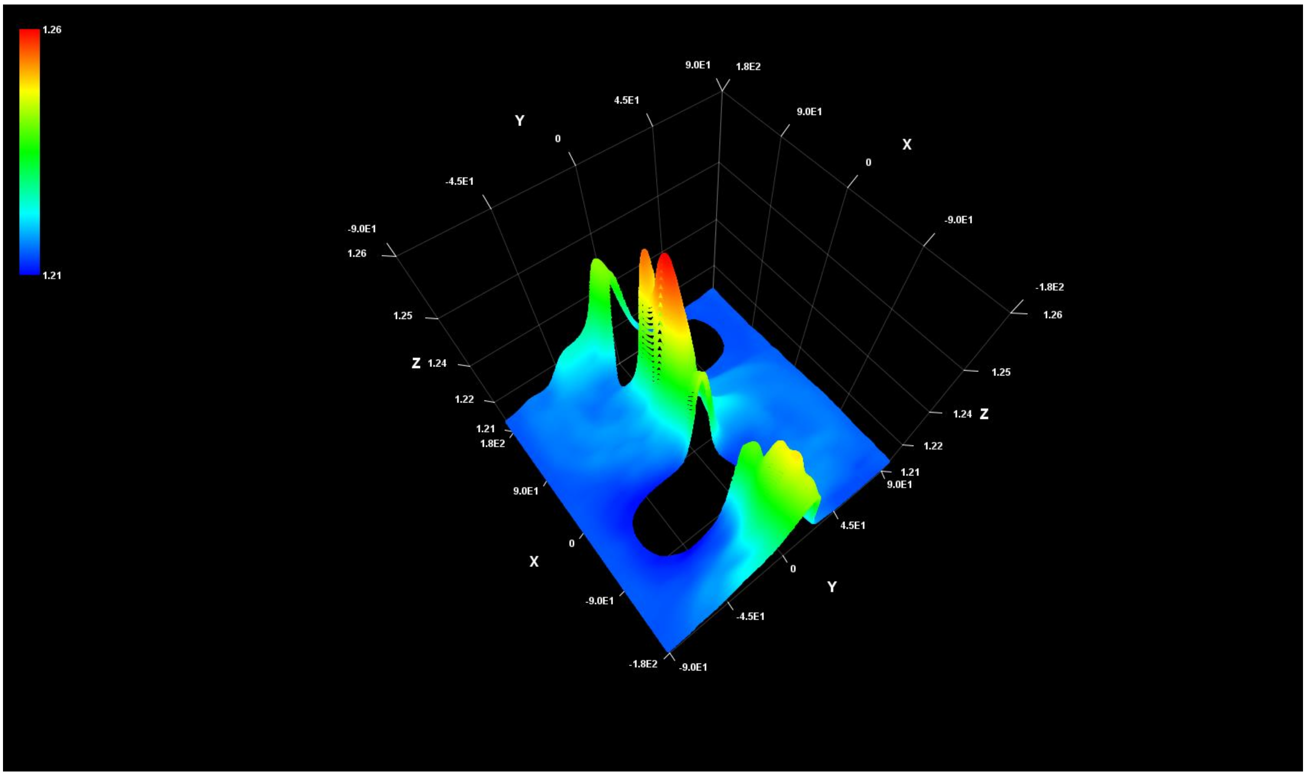
to 3.5, 700.0

Option menu - With Points on (checked)

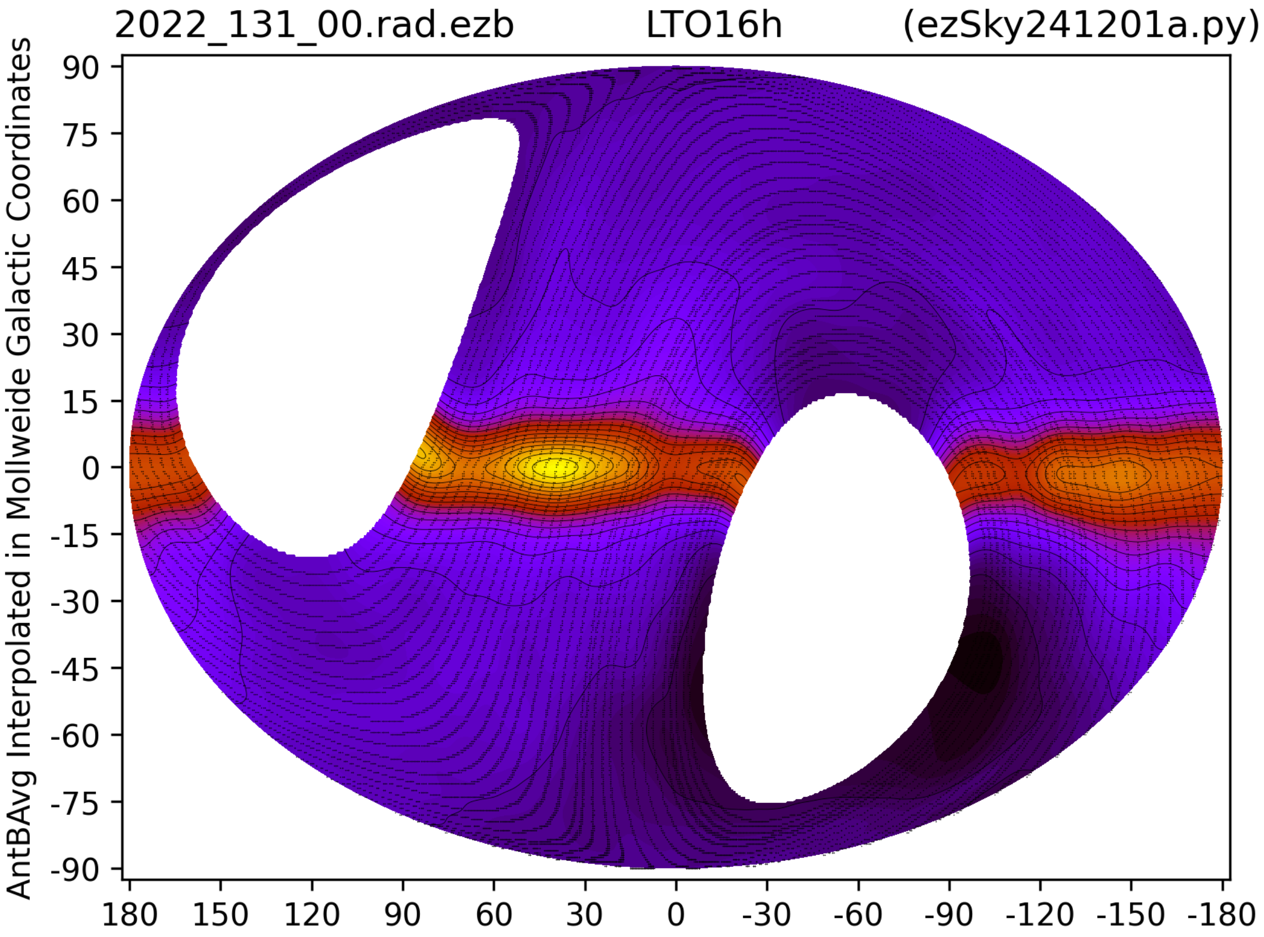
Option menu - Reverse X on (checked)

Option menu - Frame off (unchecked)

I renamed that saved   graph3d.png   to   ezSky500GMI_14AntBAvgCsv.png
showing Galactic hydrogen power across the radio sky, in Galactic coordinates,



ezSky520 3D Plot



For the

ezSky520GOI_14AntBAvg.csv

file,

Edit menu - Set Camera

Horizontal Angle

Vertical Angle (Z Axis)

to 0.7, 0.3

Camera Distance

Magnification

to 3.5, 700.0

Option menu - With Lines on (checked)

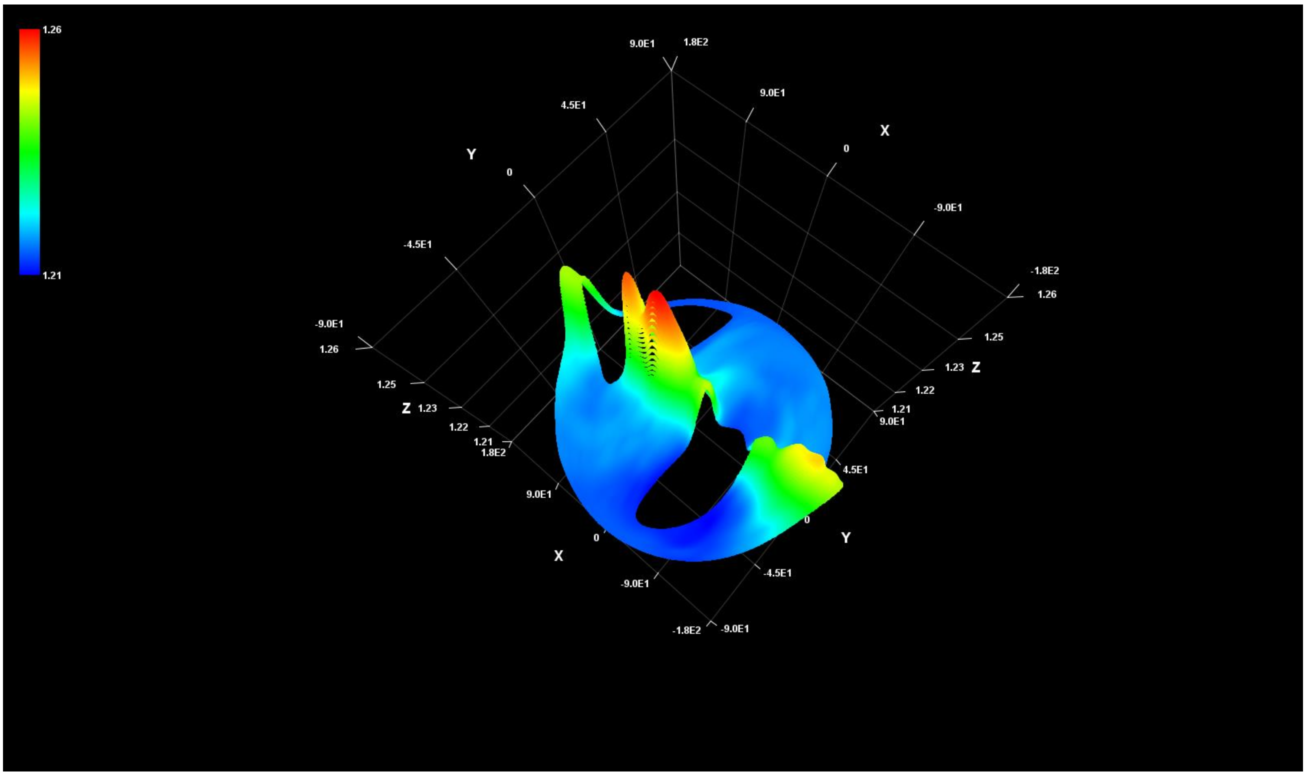
Line Width = 1.0

Option menu - With Points on (checked)

Option menu - Reverse X on (checked)

Option menu - Frame off (unchecked)

I renamed that saved   graph3d.png   to   ezSky520GOI_14AntBAvgCsv.png
showing Galactic hydrogen power across the radio sky, in a Mollweide projection with Galactic coordinates,



Galactic Arms 4D Plot

First, a review of Galactic Latitude and Galactic Longitude coordinates,
https://en.wikipedia.org/wiki/Galactic_coordinate_system
Galactic Longitude angle increases to the east (left) from the Galactic center.
Galactic Latitude angle increases to the north (up) from the Galactic plane.

After collecting a lot of data samples, I can gather data spectra subsets, either
parallel to the Galactic plane
(all with the same Galactic Latitude)
and also
in a cross section perpendicular to the Galactic plane
(all with the same Galactic Longitude).

To plot the Galactic arms,
I want only the data spectra subset from near the Galactic plane, near Galactic Latitude 0.
I might use the ezCon program's defaults,
ezConGalCrossingGLatNear = 5.
ezConGalCrossingGLatCenterL = 0.
to gather only the spectra parallel to the Galactic plane
(all with the same Galactic Latitude)
within -5 degrees and +5 degrees,
near Galactic Latitude 0, the Galactic plane.

The ezCon program would write the spectra into
*Gal.npz
files, like
2023_215_04.radP00.0Gal.npz
(with "P00.0" for +00.0 Galactic Latitude degrees).

But I want to plot cross sections perpendicular to the Galactic plane.
I might want only the data spectra subset from Galactic Latitudes 0, 10, 20, ... and 90.
Everytime I run ezCon, I might specify
-ezConGalCrossingGLonNear 0.5 -ezConGalCrossingGLonCenterL 0 90 10
to gather only the spectra in a cross section perpendicular to the Galactic plane
(all with the same Galactic Longitude)
within -0.5 degrees and +0.5 degrees,
of the 10 Galactic Longitudes 0, 10, 20, ... and 90 degrees.

The ezCon program would write the spectra into
*GLon.npz
files, like
2023_215_04.radP070.0GLon.npz
(with "P70.0" for +70.0 Galactic Longitude degrees).

After all that, I have 18   *GLon.npz   files (mostly about 21 KB), from different collection days in 2023, here sorted by increasing Galactic Longitude,

2023_279_00.radP010.0GLon.npz
2023_260_00.radP020.0GLon.npz
2023_255_00.radP030.0GLon.npz
2023_253_01.radP040.0GLon.npz
2023_220_01.radP060.0GLon.npz
2023_231_00.radP065.0GLon.npz
2023_221_02.radP050.0GLon.npz
2023_269_01.radP055.0GLon.npz
2023_215_04.radP070.0GLon.npz
2023_222_01.radP075.0GLon.npz
2023_236_00.radP078.0GLon.npz
2023_216_02.radP080.0GLon.npz
2023_276_22.radP082.0GLon.npz
2023_223_03.radP085.0GLon.npz
2023_264_00.radP087.0GLon.npz
2023_218_04.radP090a.0GLon.npz
2023_218_04.radP090b.0GLon.npz
2023_218_04.radP090c.0GLon.npz

(The GLon 90   .txt   data file was split to remove bad RFI samples)
Each Galactic Longitude required about 6 hours with the automated motored LTO15 dish.

To create the Galactic plane cross section for Galactic Longitude +70,
I ran this ezGLon command (all on one line) to use those 18   *GLon.npz   files,

```
  py  ..\ezRA\ezGLon.py  .
        -ezGlonGalCrossingGLonNear 2  -ezGLonPlotRangeL 580 580
        -ezGLon580CsvFrac  0.15
        -ezGLonGalCrossingGLonCenter 70
```

which created an

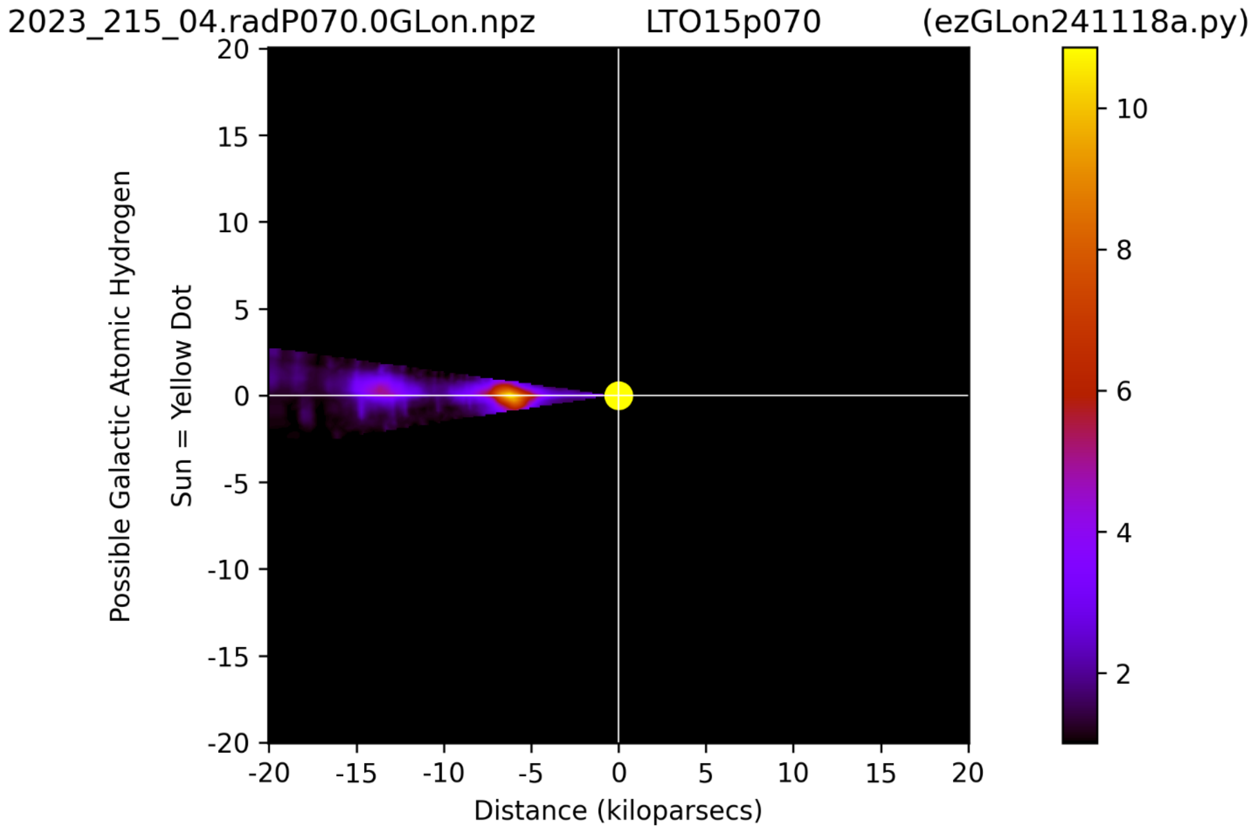
ezGLon580galArmsSunIP070.0P002.0.csv

file (about 600 KB).
That long ezGLon command line included

```
        .   (period)                               = process all the   *GLon.npz   files in the directory
        -ezGlonGalCrossingGLonNear 2  = use only samples -2 to +2 degrees from center GLon
        -ezGLonPlotRangeL 580 580              = plot only ezGLon580, to save time
        -ezGLon580CsvFrac  0.15                = enable output of CSV file for the ezGLon580 plot,
                                                          with a minimum power value of 0.15
        -ezGLonGalCrossingGLonCenter 70   = cross section center of Galactic Longitude +70
```

I determined my ezGLon580CsvFrac value of 0.15 by repeated experiments, for my best 4D plot appearance.

That command also created this   ezGLon580galArmsSunIP070.0P002.0.png   plot, showing the cross section at Galactic Longitude 70, with the yellow Sun in the center, and a thin horizontal white line indicating the Galactic plane, with 2 sliced Galactic arms in red on the left,



I wanted a CSV file with the X, Y, Z location and Power for each value shown above which was above the chosen ezGLon580CsvFrac power value of 0.15 .

After a similar   ezGLon   command on each available Galactic Longitude, I had 16 ezGLon580*.csv files (each about 600 KB),

ezGLon580galArmsSunIP010.0P002.0.csv
ezGLon580galArmsSunIP020.0P002.0.csv
ezGLon580galArmsSunIP030.0P002.0.csv
ezGLon580galArmsSunIP040.0P002.0.csv
ezGLon580galArmsSunIP050.0P002.0.csv
ezGLon580galArmsSunIP055.0P002.0.csv
ezGLon580galArmsSunIP060.0P002.0.csv
ezGLon580galArmsSunIP065.0P002.0.csv
ezGLon580galArmsSunIP070.0P002.0.csv
ezGLon580galArmsSunIP075.0P002.0.csv
ezGLon580galArmsSunIP078.0P002.0.csv
ezGLon580galArmsSunIP080.0P002.0.csv
ezGLon580galArmsSunIP082.0P002.0.csv
ezGLon580galArmsSunIP085.0P002.0.csv
ezGLon580galArmsSunIP087.0P002.0.csv
ezGLon580galArmsSunIP090.0P002.0.csv

Each file line had 4 comma-separated-value columns: X, Y, Z, Power.
Each file's first 2 lines (with minimum power) control the plot's X, Y, Z auto scaling.

I combined all the 16   ezGLon580*.csv   files into one long file, with this command,

TYPE ezGLon580*.csv > ezGLonAll580.csv

Like with the   ezCon087   3D plot above, I now ran that

rinearn_graph_3d_5_6_36b_en\rinearn_graph_3d_5_6_36b_en\RinearnGraph3D_5.6.36.bat

batch file to run to start the RINEARN Graph 3D.

I maximized the new window, by left-clicking the small square in the very top right.

I clicked

File menu - Open File

and an   Open File   window popped up.
I clicked the big   OPEN   button and eventually found and chose that new combined file,

ezGLonAll580.csv

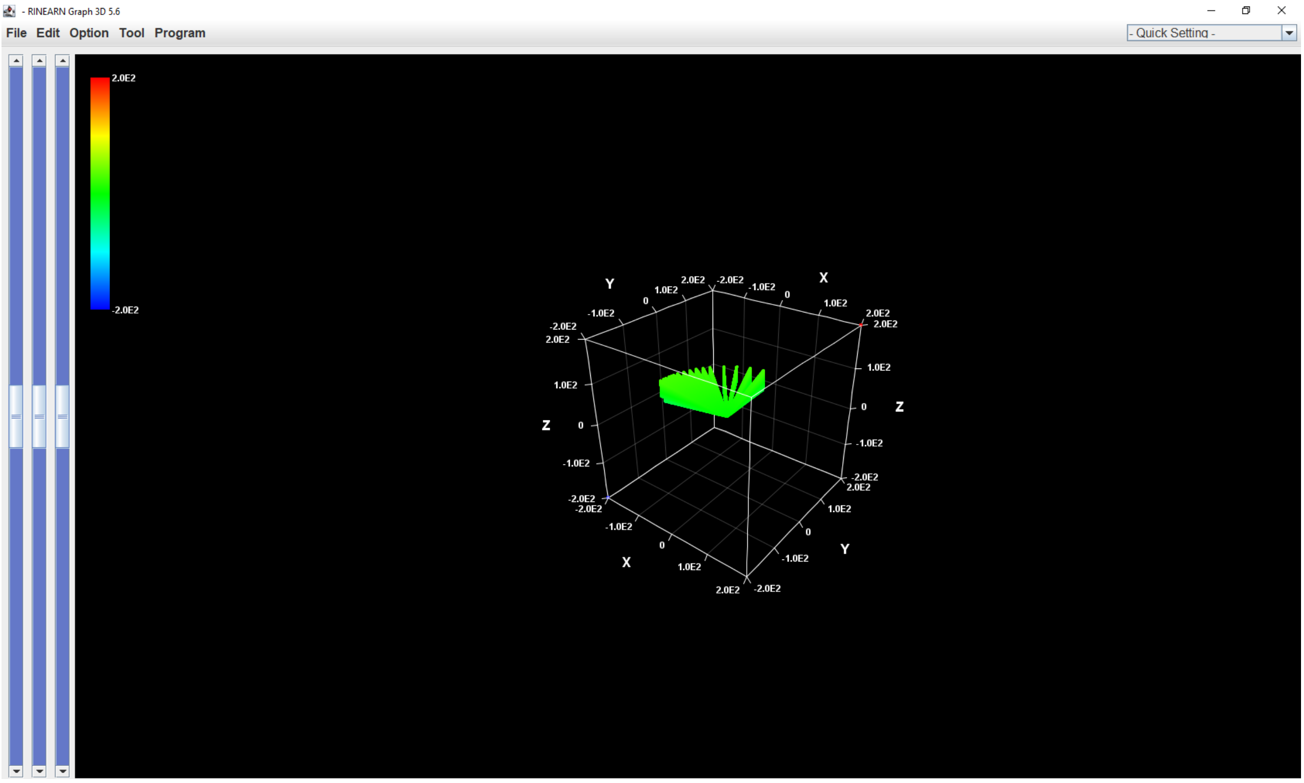
I clicked the big   PLOT   button and approved the

4-COLUMNS

file format, and a new plotting quickly appeared.
Here, RINEARN Graph 3D had to render 90,395 dots.

(TYPE ezGLonAll580.csv | FIND /C /V ""
says the combined   ezGLonAll580.csv   file has 90,395 lines)

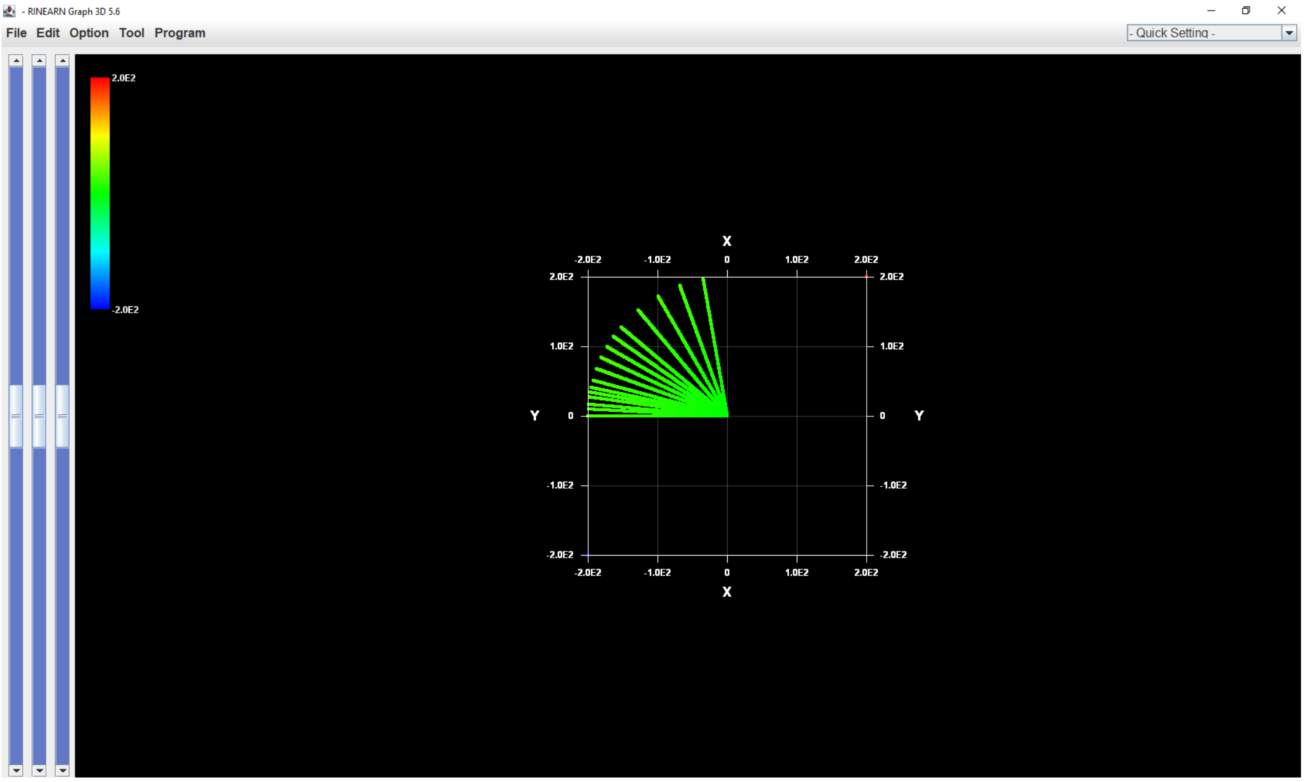
After closing the Open File window, I saw this,



I clicked

Option menu - Flat on (checked)

After closing the Flat window, I saw this, showing the 16 green Galactic Longitude cross sections from far above the Galactic plane, radiating from the Sun at the center,



But I wanted color, showing the Power.

I clicked

Option menu – Gradation off (unchecked)

The green radials turned red.

Again, I clicked

Option menu – Gradation on (checked)

I changed the AXIS from

Z

to

COLUMN-4

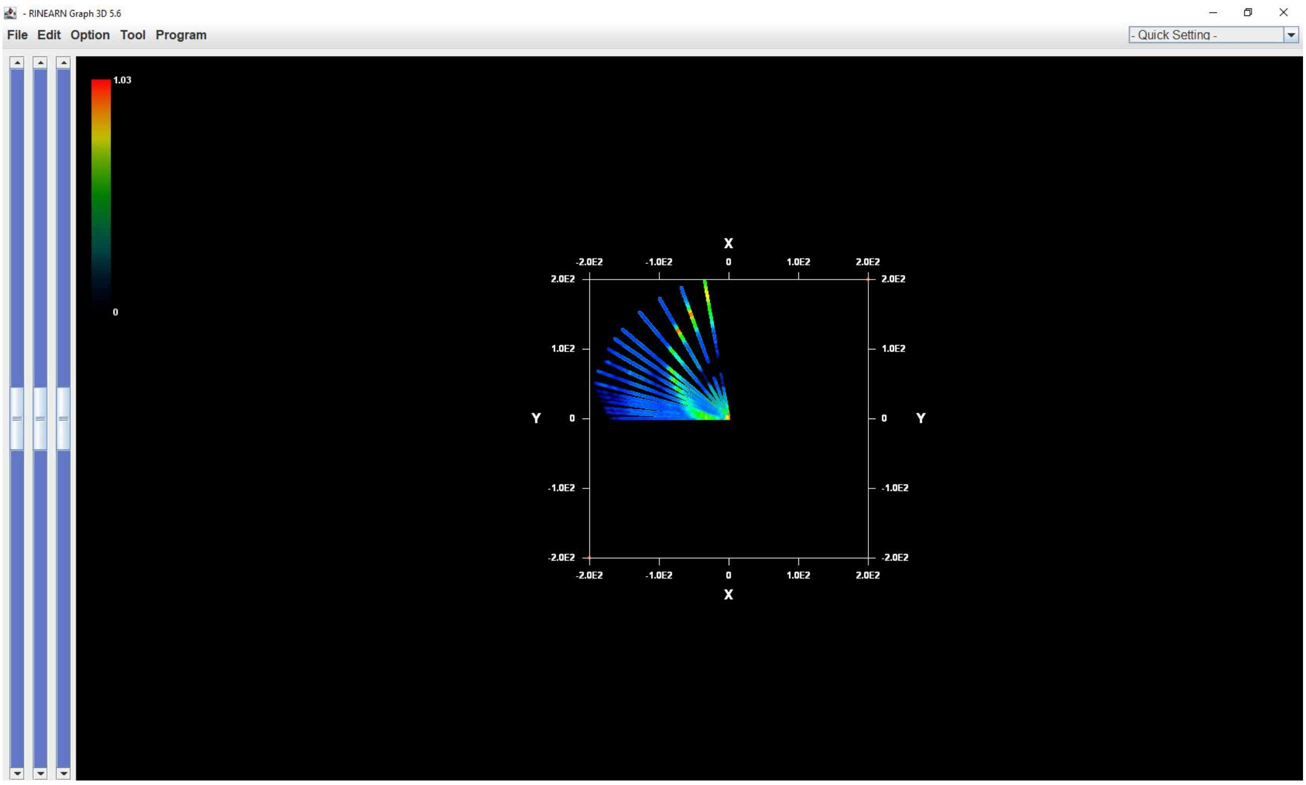
I clicked

Fade In on (checked)

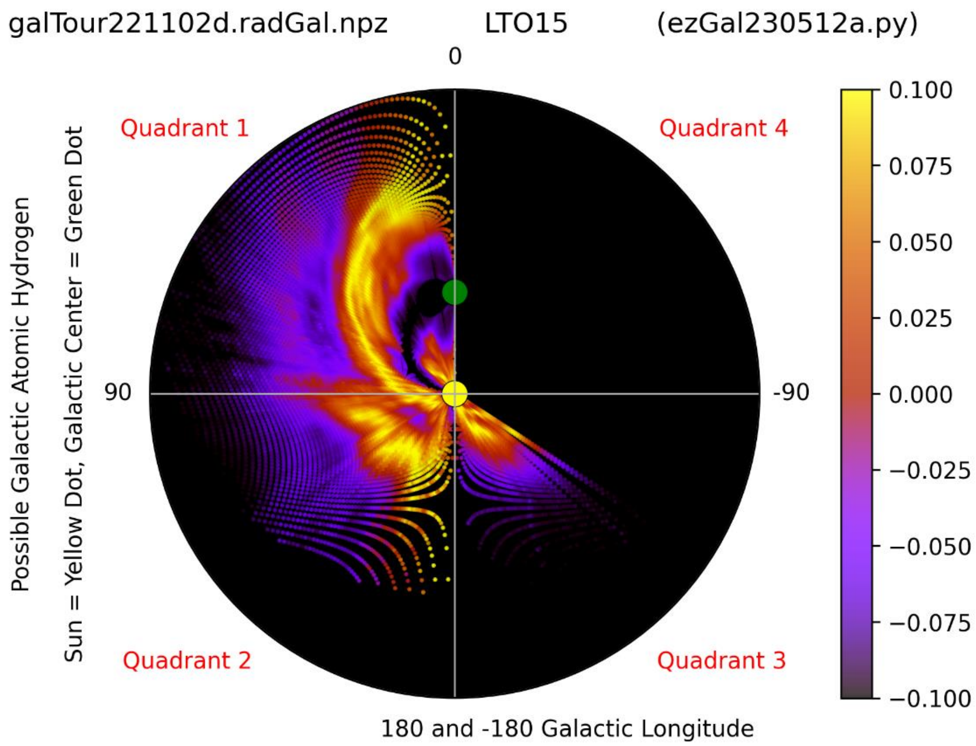
and then clicked the big SET button,

and closed the Gradation window.

I saw this, with the Power values expressed in color,



This flat view above should look like the upper left part of an ezGal570 plot, with spiral Galactic arms (perhaps with different colors),

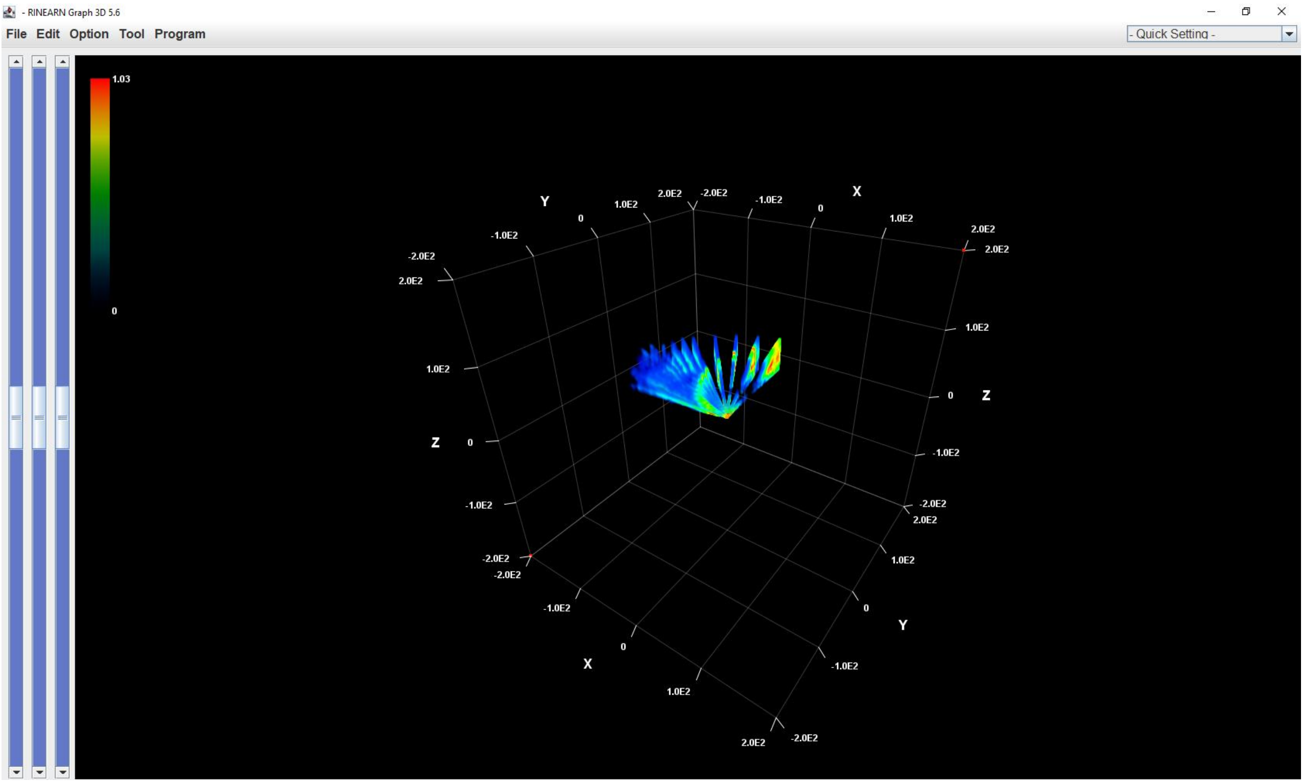


Good.

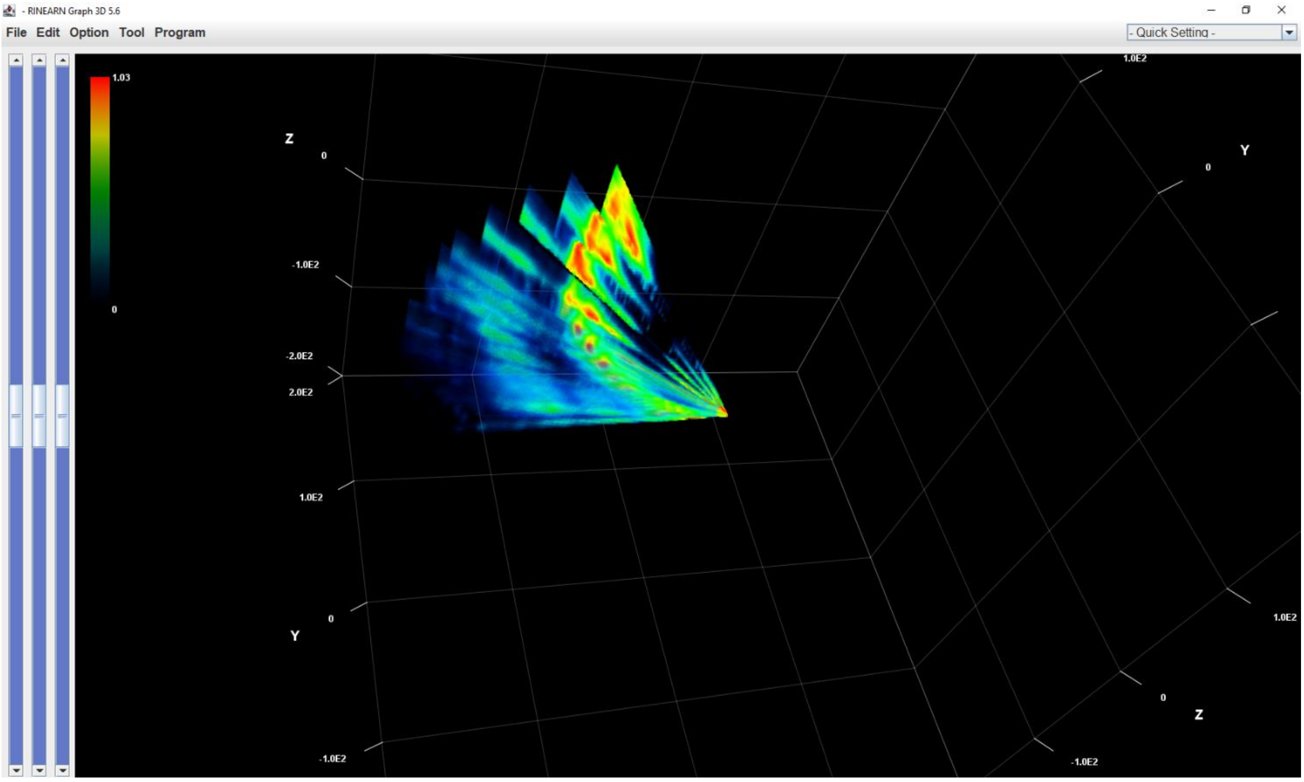
I clicked

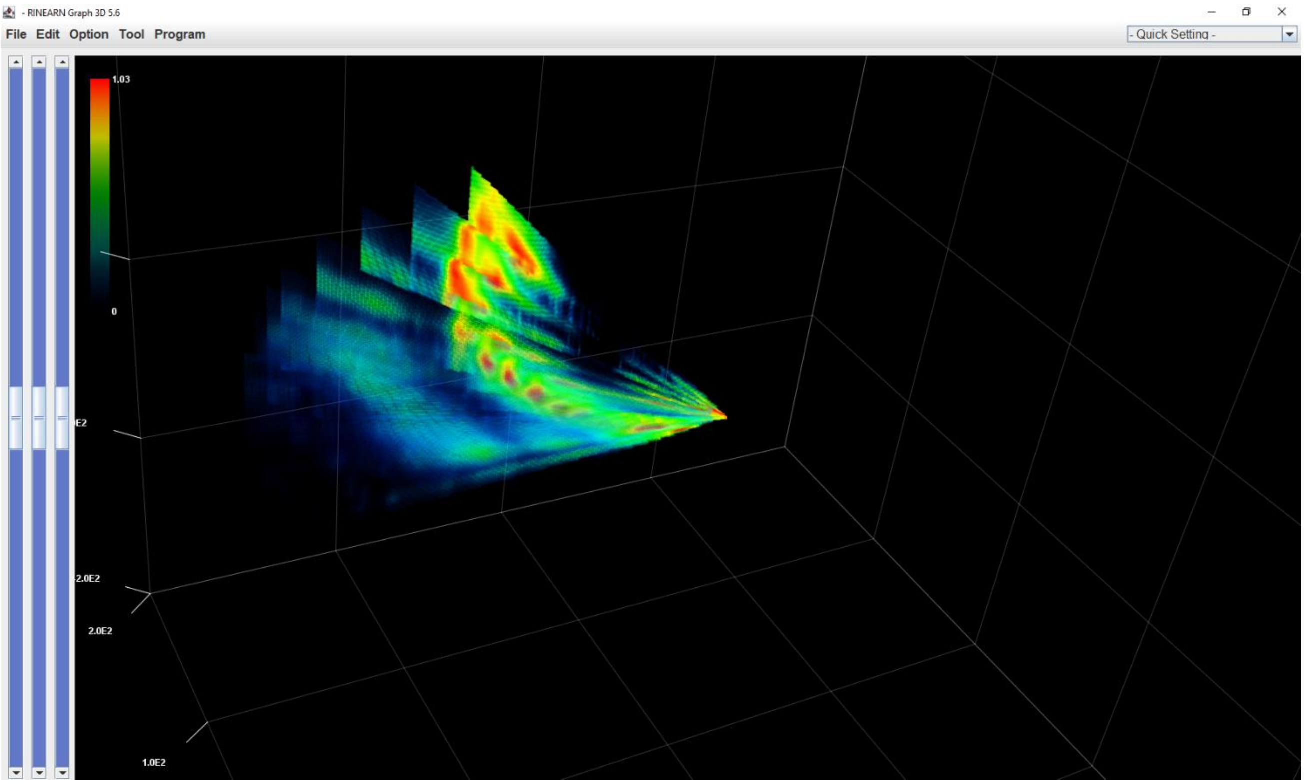
Option menu - Flat off (unchecked)
Option menu - Frame off (unchecked)
Option menu – Grid Line on (checked)
Edit menu - Set Camera
Horizontal Angle
Vertical Angle (Z Axis)
to 0.6, 1.0
Camera Distance
Magnification
to 3.5, 700.0

Closing the Set Camera window, I see this,



Try mouse-dragging the 3D plot to see it from different angles, and mouseWheel up to zoom in.
I see 16 cross sections of 2 Galactic arms floating in 4D space,





Galactic Arms Rotation Animation

After deciding upon a good camera configuration, I saved its many parameters with

Option menu – Grid Line off (unchecked)
Option menu – Frame off (unchecked)
Option menu – Scale off (unchecked)
Option menu – Label off (unchecked)
File menu – Save Setting
  All Settings on (checked)
  Save at: Data-File Directory
  File Name: RinearnGraph3DSetting.ini

which created a RinearnGraph3DSetting.ini text file in my local directory, which included this line,

```
CAMERA_HORIZONTAL_ANGLE=0.0
```

On Linux, I wrote and ran this galRotate241205a.sh script file, to partly automate my image-saving process, for CAMERA_HORIZONTAL_ANGLE values 6.292 through 0.0 (in radians),

```
#!/bin/bash
# galRotate241205a.sh
process() {
    # Print the first argument to the screen
    echo $1
    cat RinearnGraph3DSetting.ini > rot.ini
    echo >> rot.ini
    echo CAMERA_HORIZONTAL_ANGLE=${1} >> rot.ini
    ring3d --config rot.ini --overwrite --saveimg rot${1}.png --quit ezGLonAll580.csv
}
process 6.292
process 6.2
process 6.1
process 6.0
    …
    (many similar lines)
process 0.2
process 0.1
process 0.0
```

which created 64 image files (rot6.292.png through rot0.0.png), which I combined with Clipchamp into this 20 kiloparsec radius circle flight, centered on and just above the Sun,

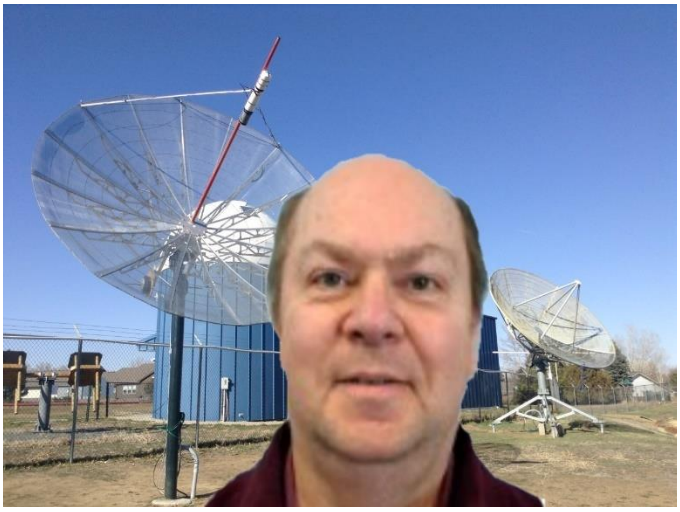
galRotate241204a.mp4
https://drive.google.com/file/d/1NY_-PGukPPVzHbileVw-CqPMNaQwGjBV/view?usp=sharing
https://youtu.be/8qk0QFxbPO8

This Linux command,

```
ring3d --help
```

displayed more options to control the RINEARN Graph 3D software.

Automating my image-saving process with a Windows batch file was slightly more complicated, but successful.
About the author



Ted Cline is an active volunteer at the Little Thompson Observatory in Berthoud Colorado USA,
http://www.starkids.org

He received his Master of Engineering from Cornell University in 1981.

He enjoyed work at IBM and 22 years at Hewlett-Packard in computer product research and development, and later, online technical support.

He now encourages others to explore the entry into radio astronomy.

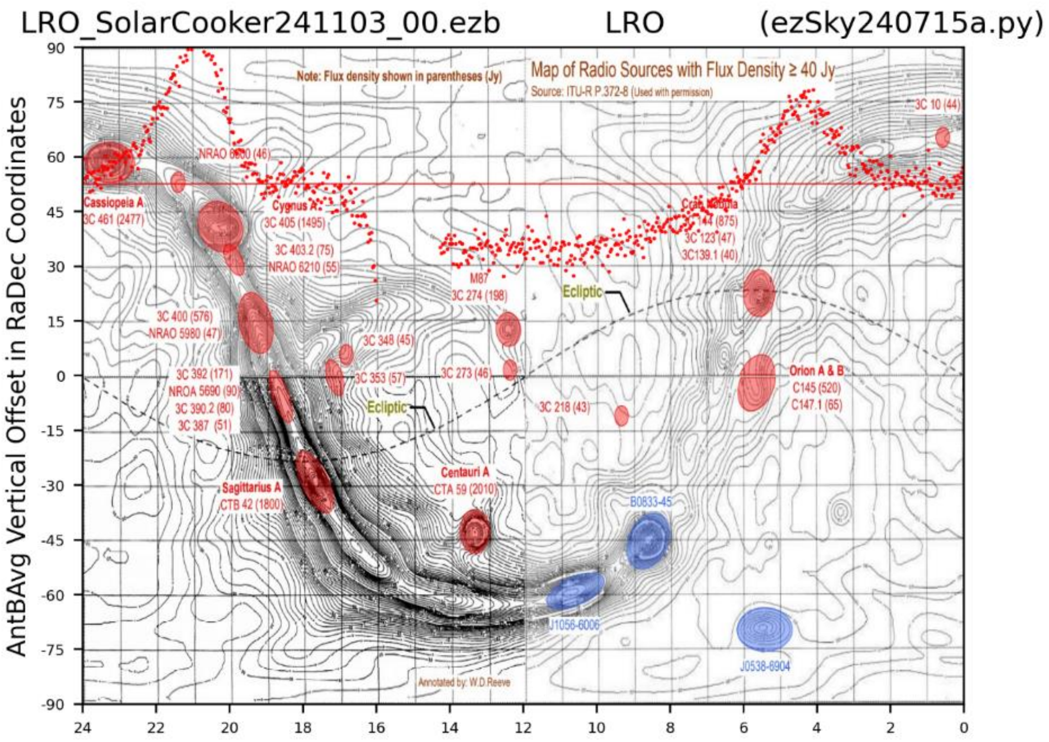
Review of WTMicrowave* WT-A9940-Q08 *Chinese Hydrogen Cavity Filter covering hydrogen band.
Dr Andrew Thornett, M6THO, Lichfield Radio Observatory, Lichfield, UK *www.astronomy.me.uk*

Filtering hydrogen signal.
The availability of cheap and effective antennae/dishes and software defined radios (SDRs) has made it much more practical to create and run an effective (and oftentimes quite large) Milky Way mapping radio experiment in any station with a moderate backyard and access to an external power socket. SARA has created a well put together and described project called "Scope in the Box" to encourage first year undergraduates and other people with an interest in astronomy and physics but not necessarily a higher-level qualification in the area to conduct such mapping for themselves, demonstrate the arms of the Milky Way, measure its mass, and explore the role of dark matter in affecting velocity in different regions of the galaxy. The Milky Way is composed mostly of hydrogen and, therefore, the mapping is best done using the frequency for hydrogen (1420.405MHz). Unfortunately, this area of the electromagnetic spectrum is subject to quite a lot of radio interference in many of the areas in which we live, a situation made worse as more houses are built and more people living in built up areas become interested in taking up radio astronomy as a hobby. It is therefore important to explore methods that effectively filter the signal to isolate this frequency and a small range around it to incorporate Doppler shifted signal.

Many amateur radio astronomers use the Nooelec SAWBird H1 low noise amplifier (LNA) to achieve this filtering (https://www.nooelec.com/store/sdr/sdr-addons/sawbird.html), available for $44.95 at the time of writing of this article on amazon.com (https://www.amazon.com/Nooelec-SAWbird-H1-Applications-Frequency/dp/B07XPV9RX2). The SAW filter in this device provides significant attenuation at +/- 30 MHz either side of 1420 MHz This current paper looks at an alternative filter using a different design that provides an attenuation over a narrower frequency range, promising to improve signal to noise ratio and give clearer hydrogen signals and improved detail in the maps produced in systems using it.

SAWBird H1 LNA Dongle (below).

Data collection on a hydrogen-line radio telescope (1420MHz – Easy Radio Astronomy) (below).



A Chinese Cavity Filter for Hydrogen.

A Cavity Filter is a type of radio frequency (RF) filter used in communication systems to filter out noise and select signals at specific frequencies. They are typically composed of one or more hollow metal cavities containing conductor structures (www.temwell.com/en/pages/what-is-cavity-filter).

Cavity Filters operate using resonance. They contain a resonator with a tuning screw (to fine-tune the frequency) inside a conducting box. An RF or microwave resonator is a closed metallic structure (i.e., waveguides with both ends terminated in a short circuit). The resonator oscillates with higher amplitude at a specific set of frequencies, called resonant frequencies. When an RF signal passes through the cavity filter, a resonator acts as a band-pass filter and passes RF signals at specific resonant frequencies while blocking other nearby non-resonant frequencies. The resonant frequency of the cavity resonator depends on its dimension (length, width, height), mode number, dielectric constant (εr), and magnetic permeability (μr) of the material of construction. In a cavity filter, the resonator is fitted with a screw to tune the frequency range which allows to modify the physical length (inner space length) of the resonator as well as its capacitance to the ground, hence tuning the resonant frequency. Cavity filters are used in the MHz/GHz frequency range. They provide high Q-factor (i.e., high-selectivity/sharply attenuates the unwanted signals), low insertion loss, and robust temperature stability when compared to other forms of filters commonly used in amateur radio astronomy. These advantages make cavity filters ideal for use in microwave and millimetre-wave systems, particularly in professional systems, which need filters with high-Q factor, lower insertion loss, and temperature stability. Advantages of cavity filters: (1) High Q-factor (up to the order of 106), low insertion loss, and robust temperature stability. (2) Superior selectivity and good frequency stability. (3) Reduces the transmitter sideband noise and protects receivers against desensitization. (4) Better performance in microwave range (including 1420MHz that we use for hydrogen detection) when compared to other common forms of filter (https://www.everythingrf.com/community/what-are-cavity-filters).

Traditionally, amateur radio astronomers have had to make their own cavity filters if they wished to use one, a labour-intensive exercise requiring some skill and a lot of fiddling and ideally additional expensive equipment to tune the filter accurately. Commercial versions have been very expensive, limiting their use to professional observatories. However, like most areas of technology, new ranges of these devices have become available from China at much more competitive prices, and these new models provide an opportunity to consider these filters for amateur applications.

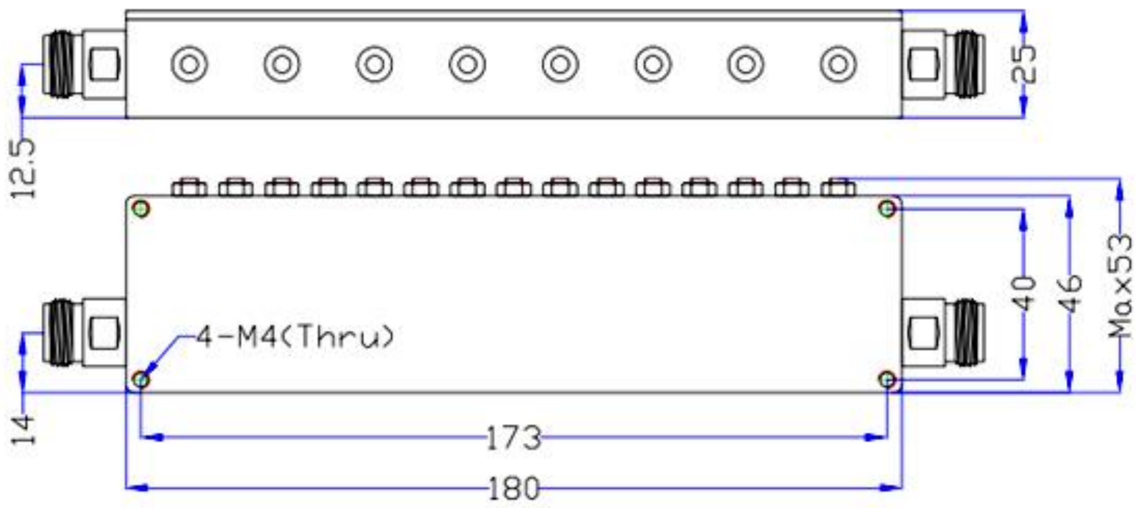
I obtained an example of the WT-A9940-Q08 cavity filter from WTMicrowave (www.wtmicrowave.com), which is designed to cover 1400-1427 MHz, and gives up to 69 dB attenuation either side of this. This gives a range of -20 MHz to +7 MHz from 1420 MHz, an improvement over the +/-30 MHz of the Nooelec SAWBird H1 LNA.
WTMicrowave WT-A9940-Q08 cavity filter 1400-1427 MHz (below).

This cavity filter has N-type connectors at either end, so adapters are required to use with cables terminated with SMA connectors commonly used in amateur radio astronomy stations where software-defined radios are usually used, or the connector needs to be changed on the cable. Those users who control their systems with an amateur radio transceiver should be able to directly connect to the filter.

Specifications of the WT-A9940-Q08 cavity filter (below):

S/N	Item	Parameters	
1	Center Frequency(F0)	1413.5MHz	
2	Pass Band Frequency	1400 ~ 1427MHz **	
3	Pass Band Insertion Loss	≤1.5dB	
4	Pass Band Ripple	≤0.6dB	
5	Pass Band Return Loss	≥23dB	
6	Stop Band Rejection	≥50dB @ DC ~ 1375MHz	≥50dB @ 1452 ~ 3500MHz
7	Impedance	50 Ohms	
8	Power Handling	200W Max.	
9	Connectors	N-Female	
10	Surface Finish	Painted Black	
11	Temperature Range	-30℃ ~ +70℃	
12	Material	Housing: 6061 Aluminum alloy Cover: LY12 Aluminum alloy Tuning screw: H62 Copper alloy	Resonant column: H59 Copper alloy Connectors: H59 Copper, Plated ternary alloy Other screw: Stainless Steel
13	Dimensions	180*46*25mm	
14	Net weight	0.374 KG	

Outline Drawing of the WT-A9940-Q08 Cavity Filter (below, dimensions units: mm, dimension tolerance +/-0.5mm):

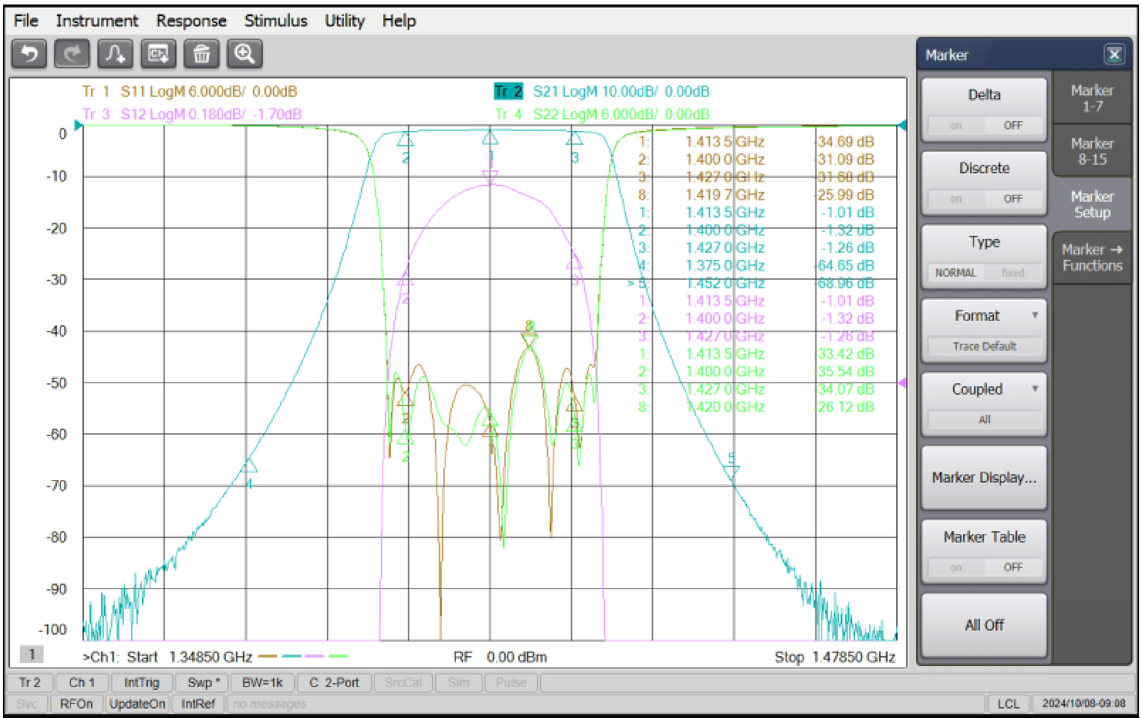


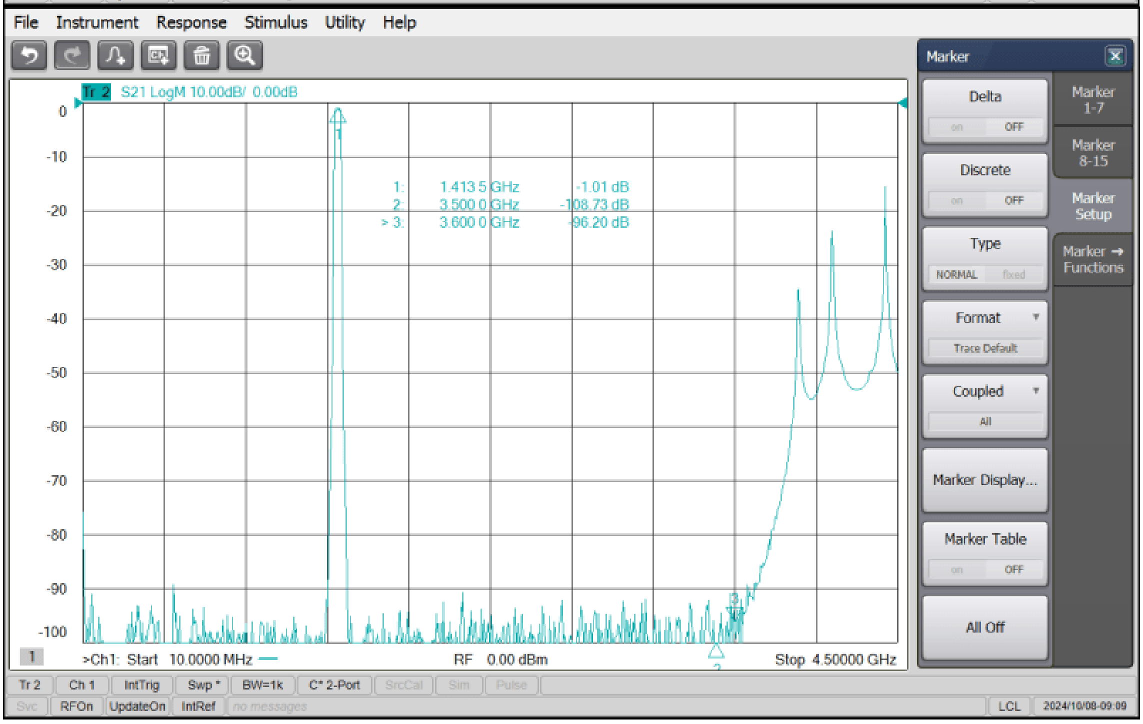
"The actual design bandwidth will be greater than the Pass Band Frequency, and there is no bandwidth limit.

The plots below show test report and curves for an example of these filters that I have been sent by the company (below).

Product Inspection Records

Model	WT-A9940-Q08		Item	Cavity Band Pass Filter		Quantity	3pcs
Test Data							
Appearance	Major Parameter					Other Parameter	
	Pass Band 1400 ~ 1427MHz F0=1413.5MHz			Stop Band		Connectors	Surface Finish
Reference value / S/N	Insertion Loss	Ripple	Return Loss	DC ~ 1375MHz	1452 ~ 3500MHz	N-Female	Painted Black
	⩽1.5dB	⩽0.6dB	⩾23dB	⩾50dB	⩾50dB		
1	1.32	0.31	25.9	64	69	N-Female	Painted Black
2	1.29	0.27	27.2	63	69		
3	1.33	0.31	27.1	66	71		
Verdict:	Inspection way: Full inspection					Data recording mode: Full record	
Test Equipment: N5227B	Date: 2024-10-08		Tester: Liqiong Yong			Check: Xiaotao Yang	





Report on initial tests with the cavity filter.

I have installed the cavity filter in line before the SAWBird H1 on both of my hydrogen line radio telescopes (LRO-H1 and LRO-H2) at Lichfield Radio Observatory, UK (www.astronomy.me.uk). Effective detection of hydrogen is evident. As yet, I have not had an opportunity to test the systems with and without the filter, and will present this information in a future report.

Further information.

Further information about this project is available on the www.astronomy.me.uk website or by contacting me using the “contact us” page on that website.

Creating a 2,500-hour map of the Milky Way using hydrogen line (1420MHz) using Lichfield Radio Observatory's LRO H1 radio telescope

Andrew Thornett, M6THO, Lichfield Radio Observatory, Lichfield, UK www.astronomy.me.uk

Article for SARA Journal Dec 2024.

The Lichfield LRO H1 Radio Telescope

Lichfield Radio Observatory (LRO) is located at latitude 52.6815 north, longitude -1.8255 (1.8255 west). Lichfield is a cathedral city and civil parish in Staffordshire, England. One of eight civil parishes with city status in England, Lichfield is situated roughly 16 mi (26 km) north of Birmingham. The LRO H1 Radio Telescope is composed of a Ptarmigan Triffid ex-military 4x4 dipole array. Filtering is two-stage using a 1400-1427MHz cavity filter, followed by a Nooelec SAWBird H1 LNA/filter. The system uses an RTL-SDR Blog V3 Software Defined Radio and data for this paper was recorded using Easy Radio Astronomy Software Suite (ezRA; Ted Cline; https://github.com/tedcline/ezRA).

The telescope is mounted on a simple wooden mount that allows variation in elevation. It points at the same azimuth constantly – data is collected using 24-hour drift scans which allow individual azimuth points to be calculated by the software during the sidereal day.

Ptarmigan Triffid Band 3 Ex-Military Dipole Array (below):

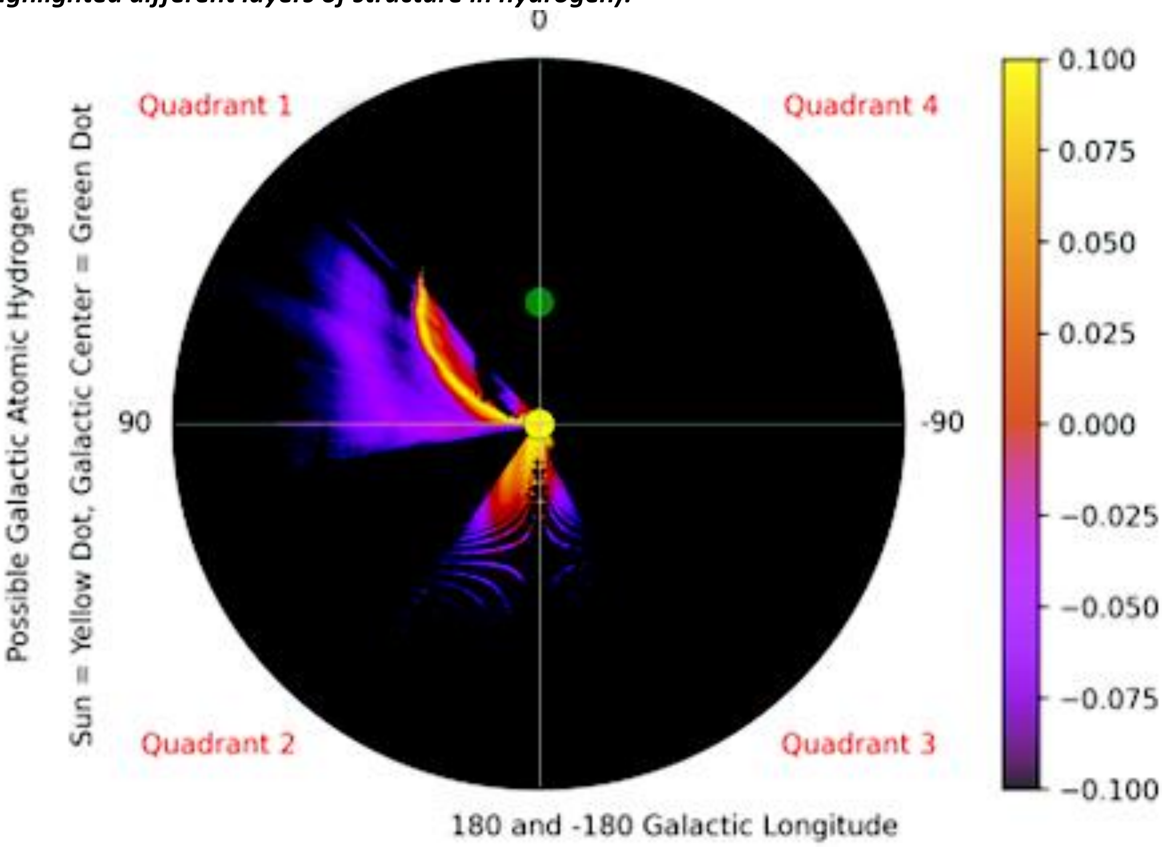
Simple wooden mount for telescope (below):

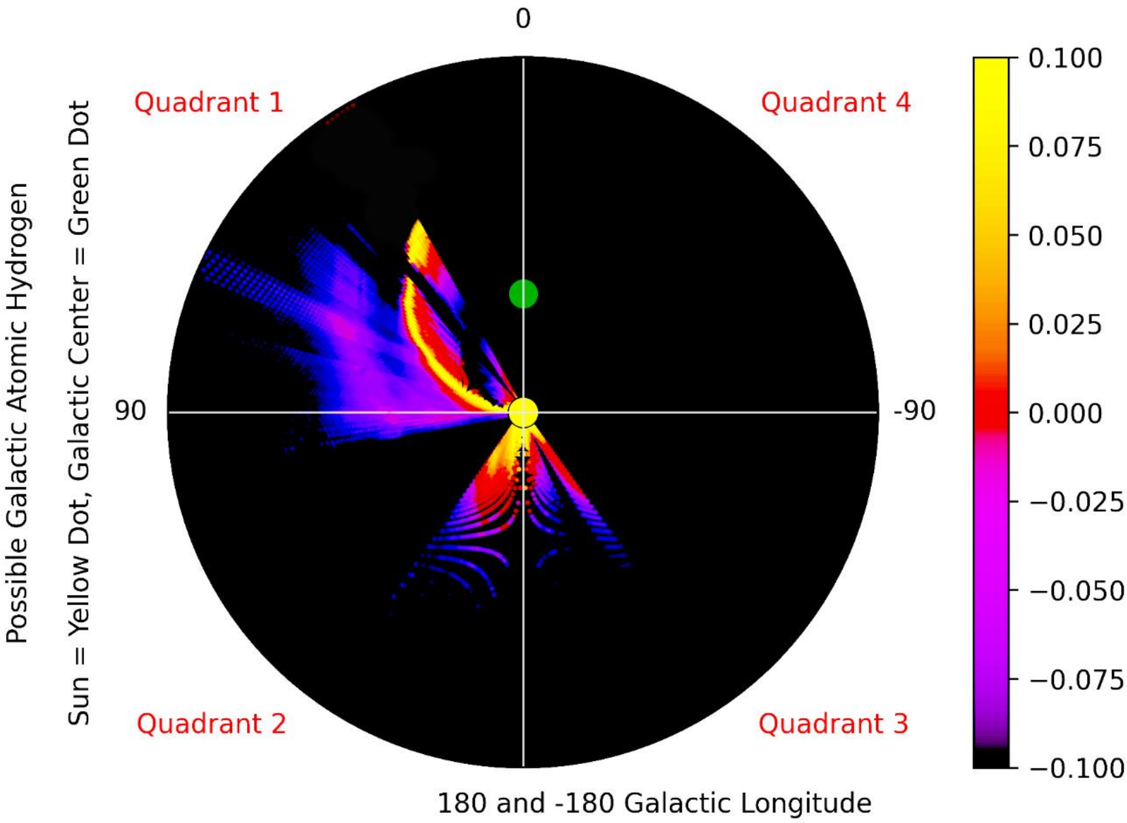
Ptarmigan array on mount below. Each measurement indicated on the photograph is 86cm (so array is 86cm x 86cm in size):

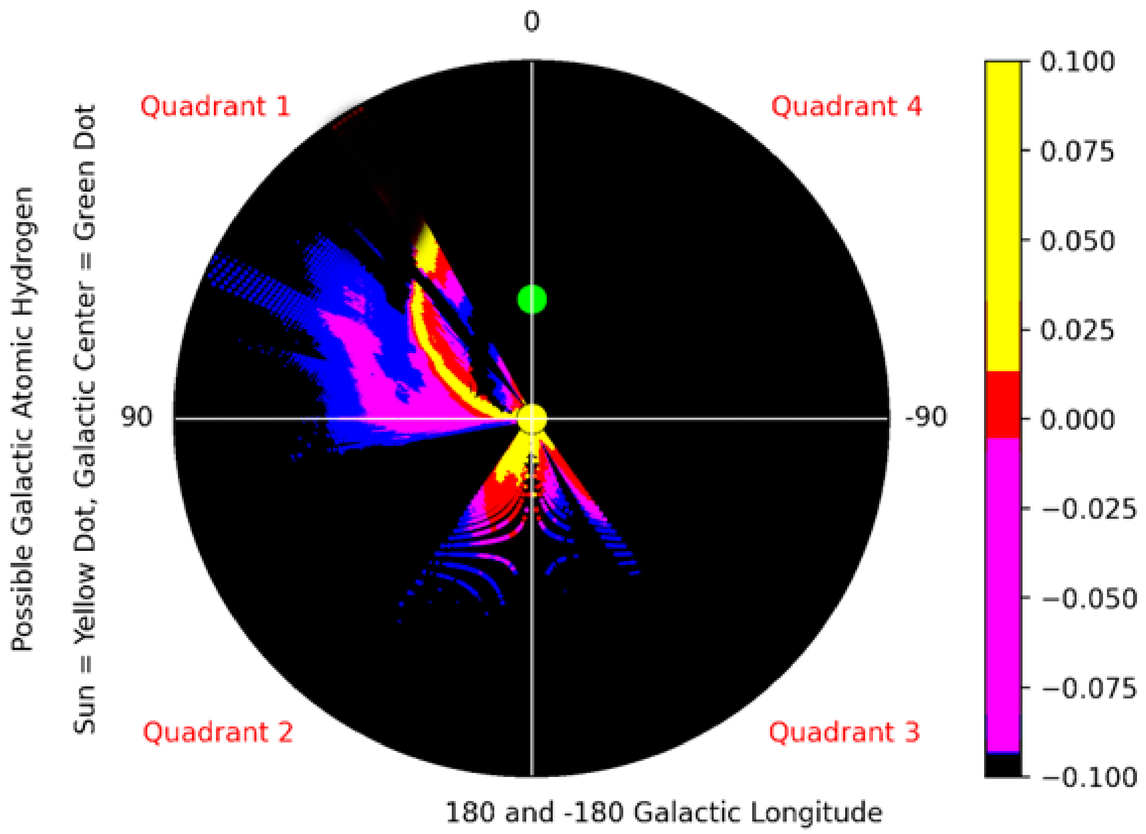
Data collected for this paper

Data was collected for this paper between 6th January 2024 and 16th November 2024. It is composed of 582,492 samples (approx. 2,500 hours of data). Most of the data is within Milky Way galactic longitudes 0-90 degrees. It demonstrates several galactic arm features.

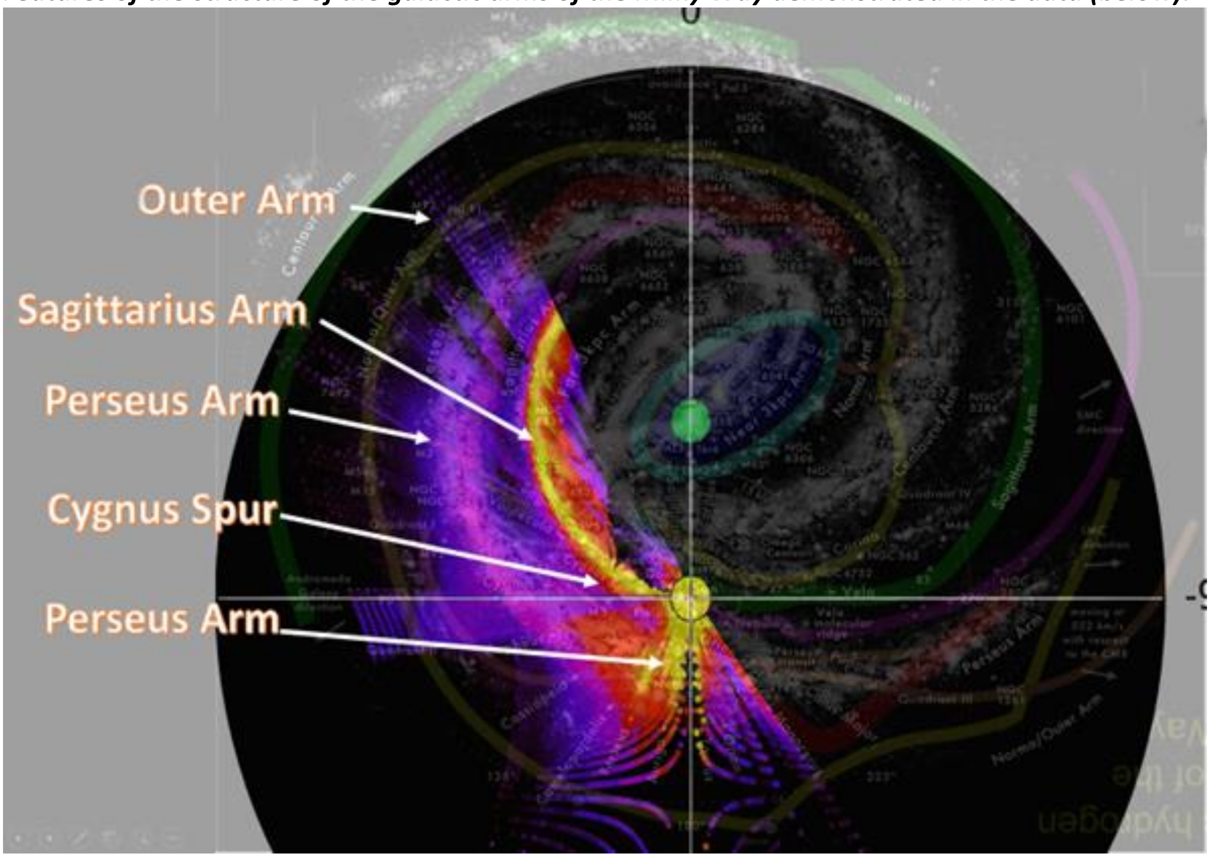
Latest map of Milky Way from LRO using 582,492 samples (in the three versions of this map, I have highlighted different layers of structure in hydrogen):





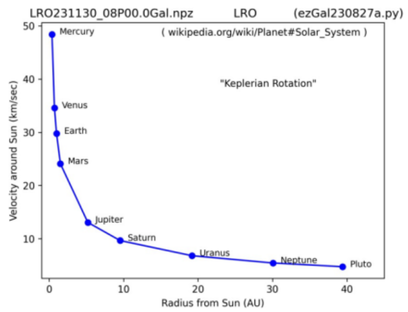


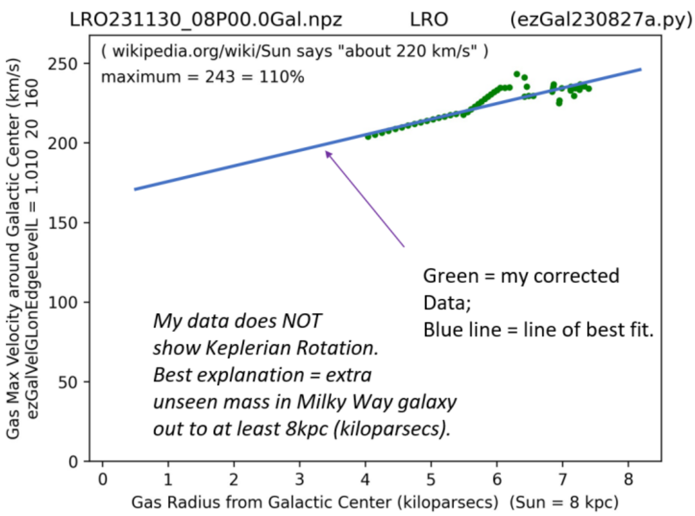
Features of the structure of the galactic arms of the Milky Way demonstrated in the data (below):



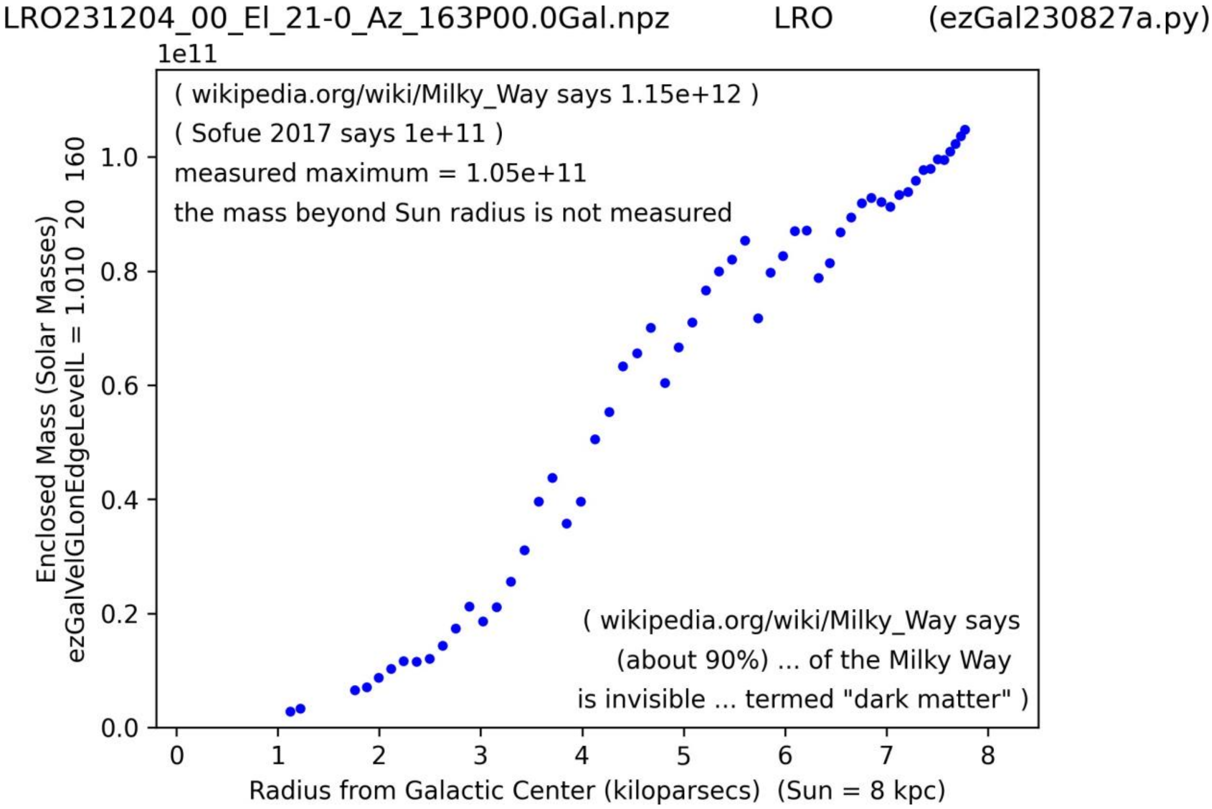
Demonstrating “smoking gun” for dark matter – rotation curve does not follow Keplerian predictions in my data (below):

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





Weighing the Milky Way with LRO data (below) – the Sun is at 8kpc so this is limit of what can be seen in this data below and above:



Further information.

Further information about this project is available on the www.astronomy.me.uk website or by contacting me using the “contact us” page on that website.

Creating a hydrogen line (1420MHz) radio telescope from a 1.5m Solar Cooker Dish sold on eBay
Andrew Thornett, M6THO, Lichfield Radio Observatory, Lichfield, UK [*www.astronomy.me.uk*](http://www.astronomy.me.uk)

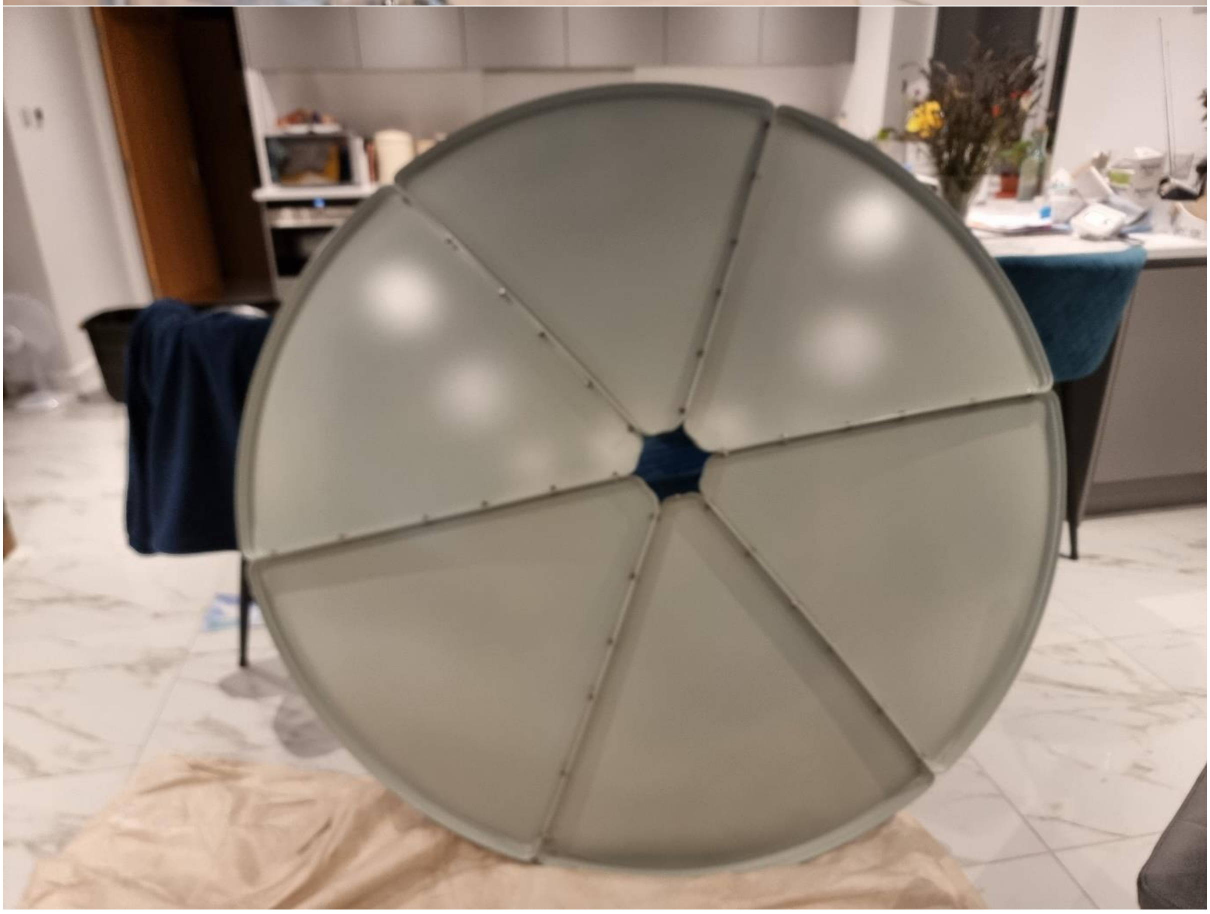
The Parabolic Solar Cooker.
Many of us at some time or other have desired a large dish to use for radio astronomy – not only will such a dish improve the sensitivity of our systems but it also appears similar in appearance to that expected by most people of a radio telescope.

Unfortunately, large dishes are expensive, unwieldy, and often difficult to source and mount.
Recently, a new breed of parabolic reflector dish has started to be sold in the USA on ebay.com as a form of solar cooker where users place a kettle or similar object at prime focus and the focused rays of the sun heat the water within it. These reflectors are 1.5m in total size, composed of 6-8 segments, relatively light-weight, and surprisingly cheap – at around 50 US dollars plus postage.

Unlike visual parabolic mirrors where the mirror surface needs to be accurate to a very precise level measured in nanometres, this level of precision is less important for radio hydrogen detection. The hydrogen frequency of 1420.405MHz equates to 21cm (0.21m) wavelength. If the parabolic surface is accurate to 1/10th lambda (1/10th of a wavelength) then this means a variation of 2cm (nearly 1 inch) can be tolerated across the parabolic surface.

These solar cooker parabolic reflectors are not sold on ebay.co.uk (I am based in the UK), but I was fortunate enough to find someone selling one second-hand from a house clearance.
So, with my new 1.5m parabolic dish, I was ready to turn it into a radio telescope.

Assembling the parabolic dish.
The dish is designed to be transported as smaller segments which are then assembled by the user.



Software for Detecting Hydrogen.
There are a variety of software options available for detecting and processing hydrogen data. My personal preference is Easy Radio Astronomy Suite (https://github.com/tedcline/ezRA). This software suite includes a group of Python scripts and will run on Windows or Linux. It is free of charge (like nearly all amateur radio astronomy software). It contains its own data collection program (ezCol) but also works well with data collected using SDR Sharp software (https://airspy.com/download/ or https://www.rtl-sdr.com/rtl-sdr-quick-start-guide/sdrsharpdownload/).

In both cases, data is collected using drift scans of the sky. Drift scan imaging, also known as transit imaging, is a method used in astronomy to capture images of celestial objects (in this case the Milky Way itself) as they move across the sky. In this technique, a telescope is fixed in position while the Earth's rotation causes the Milky Way to drift through the field of view. In professional observatories, this method can provide higher resolution images over large fields compared to traditional tracking techniques, and drift scan imaging is widely used in surveys that require continuous, wide-area coverage, making it an essential tool in modern astronomical research (https://www.vaia.com/en-us/explanations/physics/astrophysics/drift-scan-imaging/#:~:text=Drift%20scan%20imaging%2C%20also%20known%20as%20transit%20imaging%2C,objects%20to%20drift%20through%20the%20field%20of%20view).

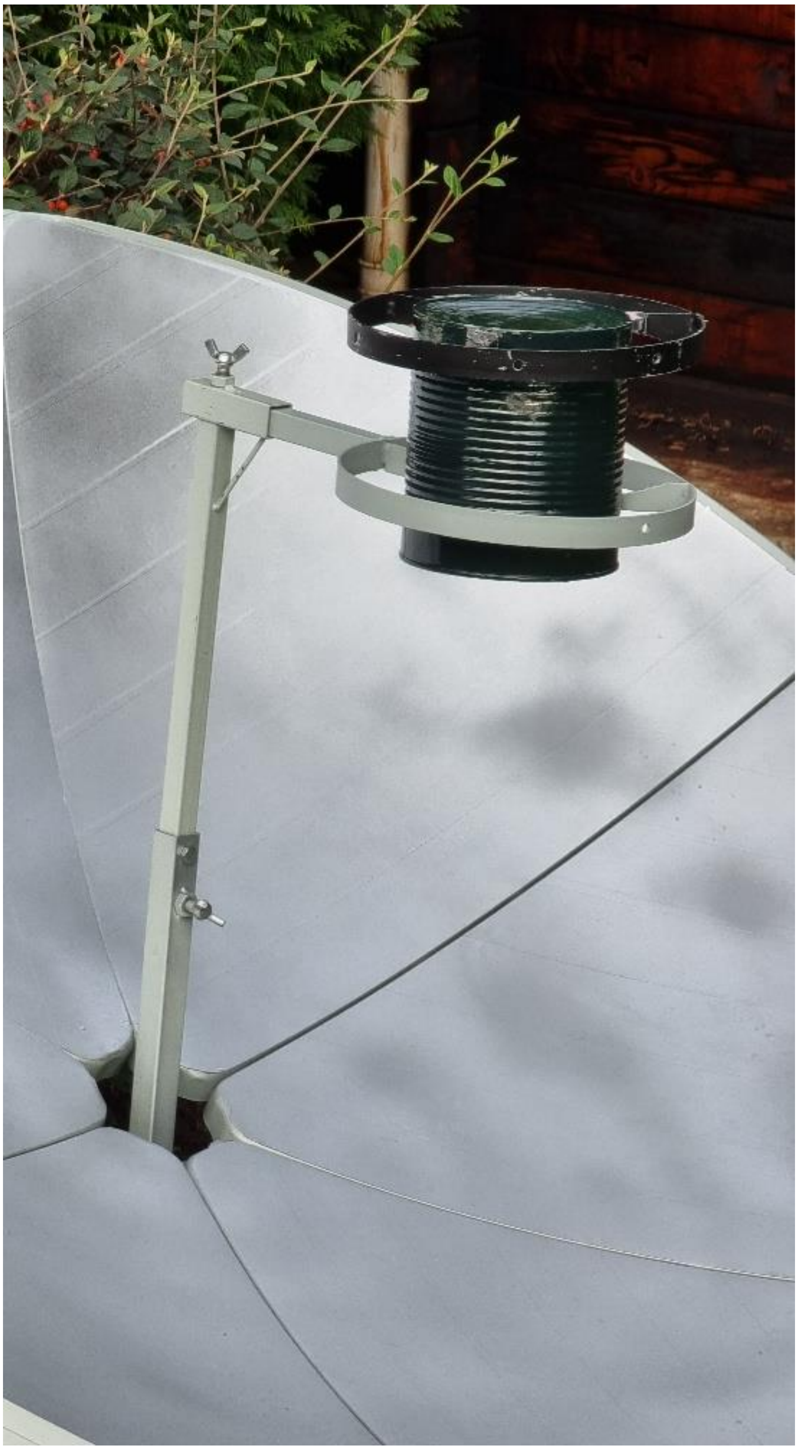
In amateur observatories, the use of drift scans means that the mount can be set to point in one azimuth direction only without needing to be moved. The scanning process allows data to be collected over the whole 360-degree azimuth circle as the Earth rotates about its axis during the day.

Drift scans are collected for at least 24 hours, although longer times allow a better signal to noise ratio. Then the altitude of the telescope is adjusted before a further drift scan is collected. The process is repeated until the sky is covered to the maximum extent allowed by the observer's latitude and other obstructions such as trees and houses.

Making a waveguide for the telescope.
In a previous project, I built a cantenna using an old coffee tin and straightened paperclip. This now served to act as my waveguide, replacing the original mechanism for heating kettles and pots. I then purchase some pre-twisted pieces of metal from my local hardware store and: Voila! A new waveguide was in place! The original hole in the centre of the dish for the pole to hold the kettle at prime focus now serves as a drainage hole for water when the dish points upwards.

The reflective mylar surface of the dish easily burnt a hole in a cardboard box on a moderately sunny day – I removed that with several tins of aluminium and zinc spray paint, which also serves to give the structure some rust protection (zinc is a sacrificial metal).

In the two photos below, the cantenna is mounted on the original pole designed to hold the kettle and the dish as a whole is mounted on the original mount that came with it. This mount is rather unstable and needed replacing.

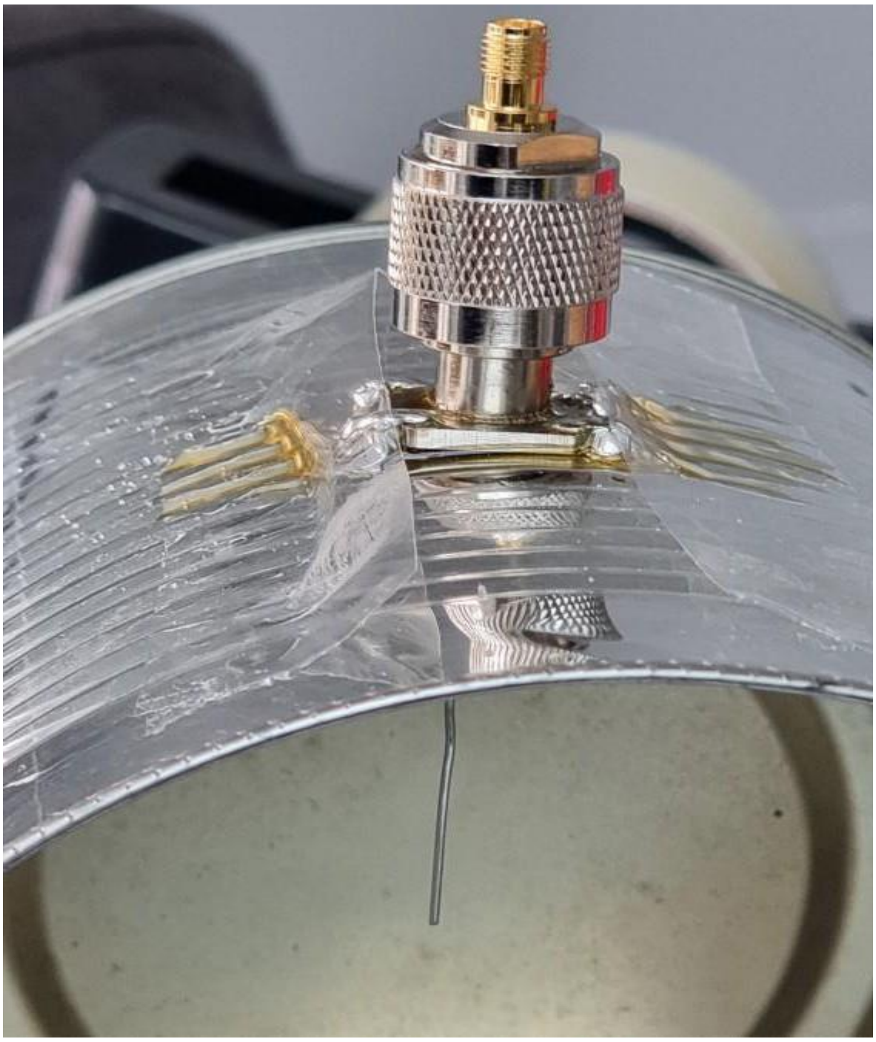


The photograph below shows the cantenna mounted in the new arrangement that is now used in the finished telescope.

Mounting the reflector.
This is a large dish and requires a solid mount. In addition, the large dish acts like a sail in strong wind, risking damage to the dish if it is blown over.

I designed a wooden mount based on a simple table design that points the dish roughly south (the software can compensate for exact direction). Altitude is varied by the use of wooden strips on either side with several holes in each of them – varying which hole is used changes the altitude. Several guy ropes and pegs improve the stability of the structure and give it protection against wind.

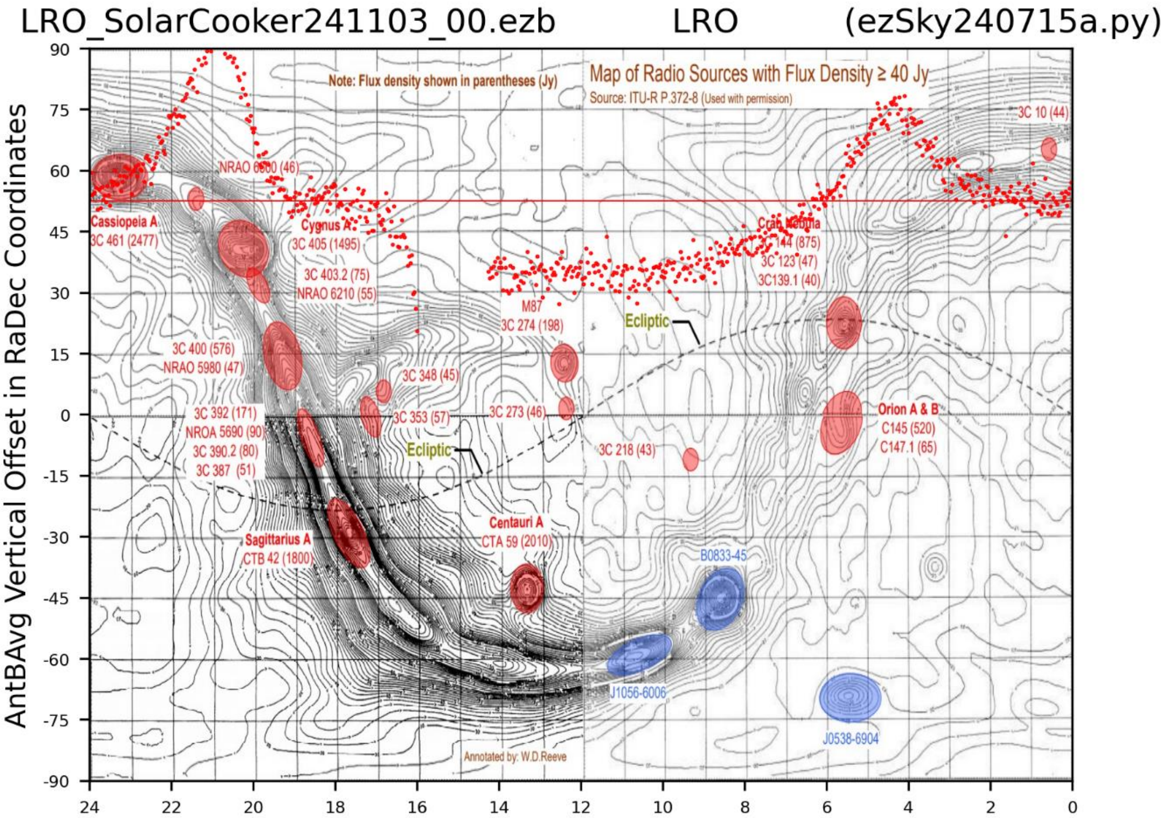

The cantenna I build showing the monopole inside made from a paper clip (below).



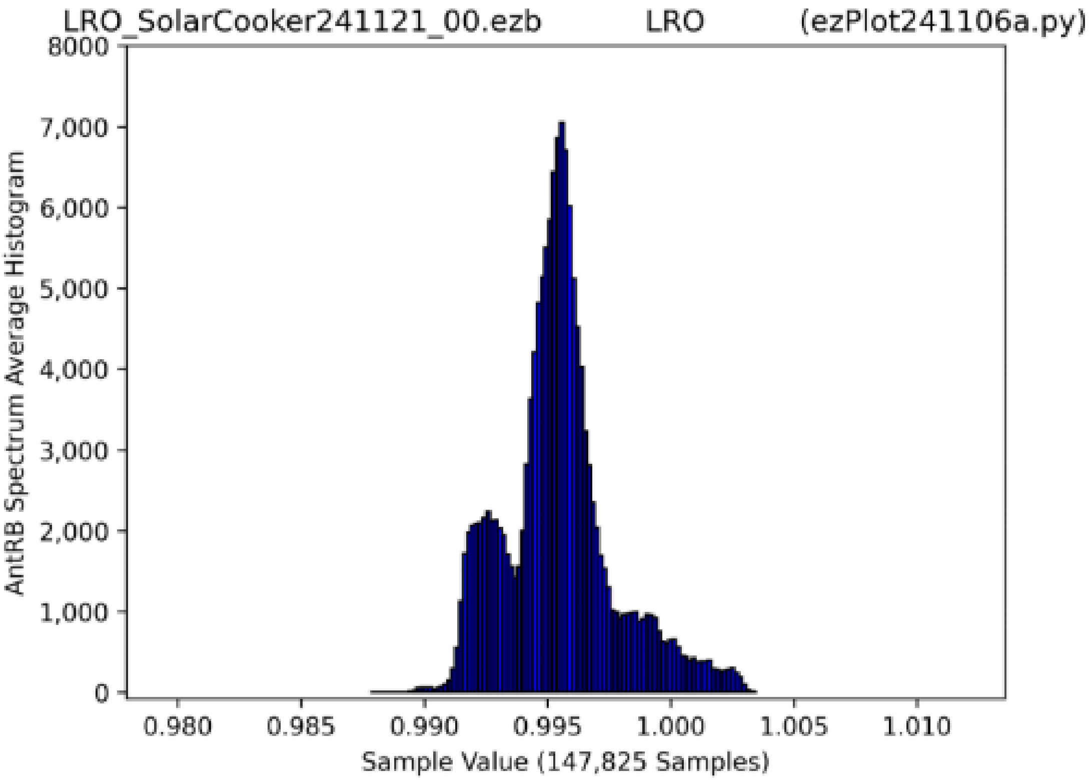
Other hardware requirements.
Apart from the dish and mount, this telescope requires a computer (requirements not particularly strenuous – most old computers or laptops will serve), a software defined radio (I use RTL-SDR Blog V3 but there are alternatives), and a SAWBird H1 low noise amplifier and hydrogen filter. I keep these in a black box behind the telescope, but this is an arrangement that might change as I improve the telescope in the future.

SAWBird H1 LNA Dongle (below).

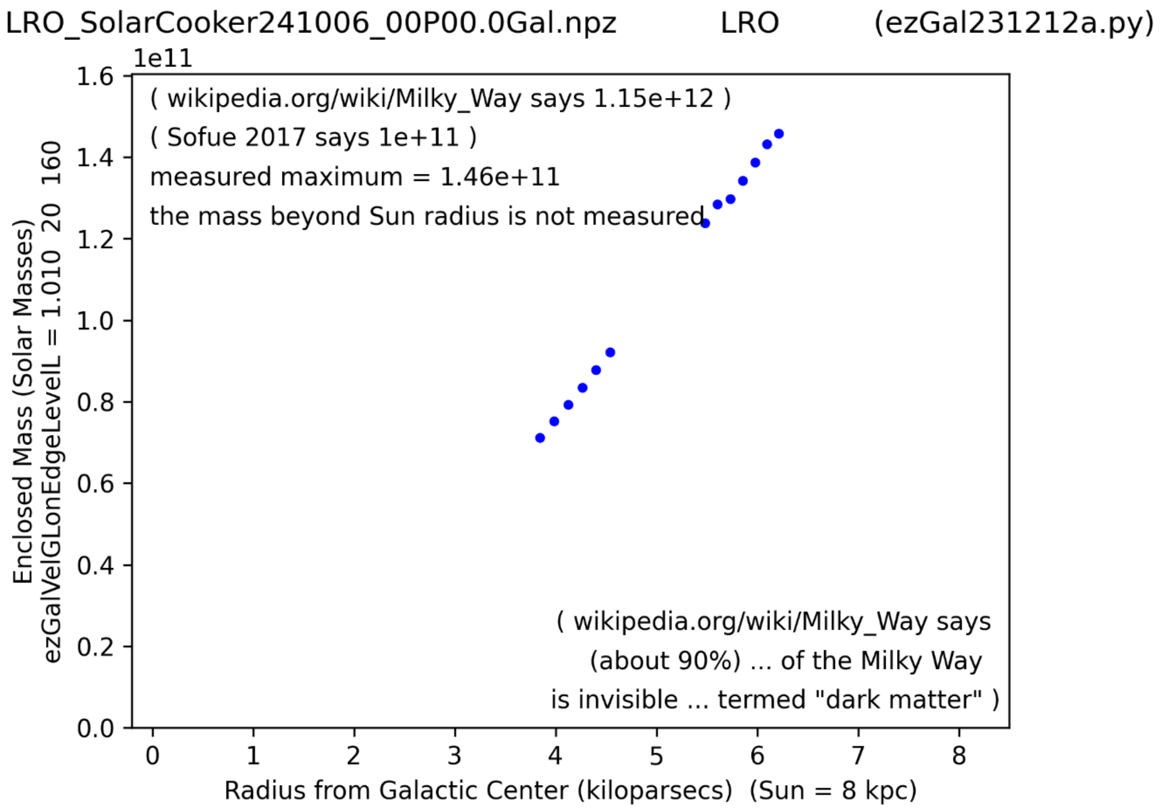
First light data collection.
It is early days, but the scope is successfully detecting hydrogen (below).



Distribution of data (below).



Even on just two elevation points from this solar cooker dish data so far, allows some measurement of mass of Milky Way (below).



Naming the telescope.

After a bit of a competition on the SARA mailing list and mailing list of my local astronomy group in the UK, the radio telescope has been named "Dishy McDishFace" or the LRO-H2 telescope.

Further information.

Further information about this project is available on the www.astronomy.me.uk website or by contacting me using the "contact us" page on that website.

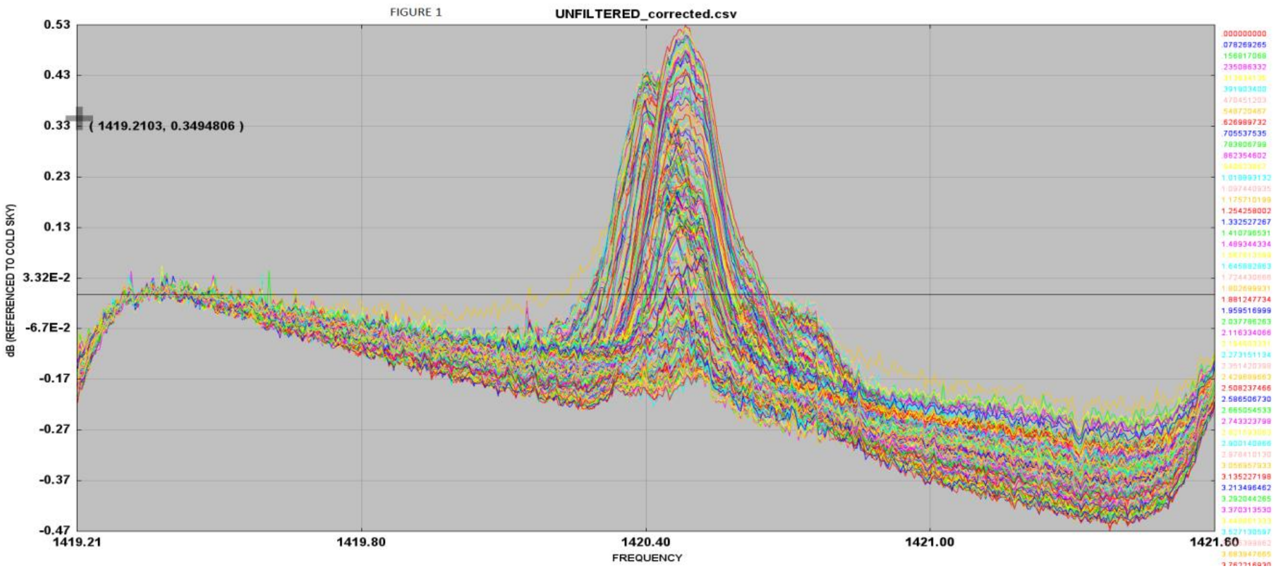
Mitigating RFI and Signal Drift in Hydrogen Line Observations: A Beginners Technical Guide

Jerry Taylor

I am still a "newbie" in Amateur Radio Astronomy and have been involved for less than two years. I have mentioned on a couple of the RTOPs (Radio Telescoped Observation Party) that I live in the world's worst location for doing radio astronomy. I live on a residential sized lot, in a city, neighboring houses less than 50 feet away, surrounded by large deciduous trees. The only clear sky I have is about a 30 degree window to the West, but I have to do my observations over my neighbor's rooftop. So, I am well aware of the gremlins of RFI, frequency and temperature drift that can interfere with an observation. I briefly considered abandoning radio astronomy after a frustrating start, but after packing my gear and going to a quieter area and having a relatively noise free observation I decided there must be a way to minimize the noise and drifting plots without having to pack up and move for observations, so I have spent the last few months trying to accomplish this. I should point out that the typical methods of RFI mitigation, shielding, removal of potential RFI sources, bandwidth limiting and changing observation locations provided minimal results.

(NOTE: My basic system consists of a plate yagi designed by Alex Pettit placed outside a second story window, Nooelec H1 LNA, 20' of KMR 240 coax, RTL-SDR V3 receiver, laptop running SDR# with the IF Average plugin)

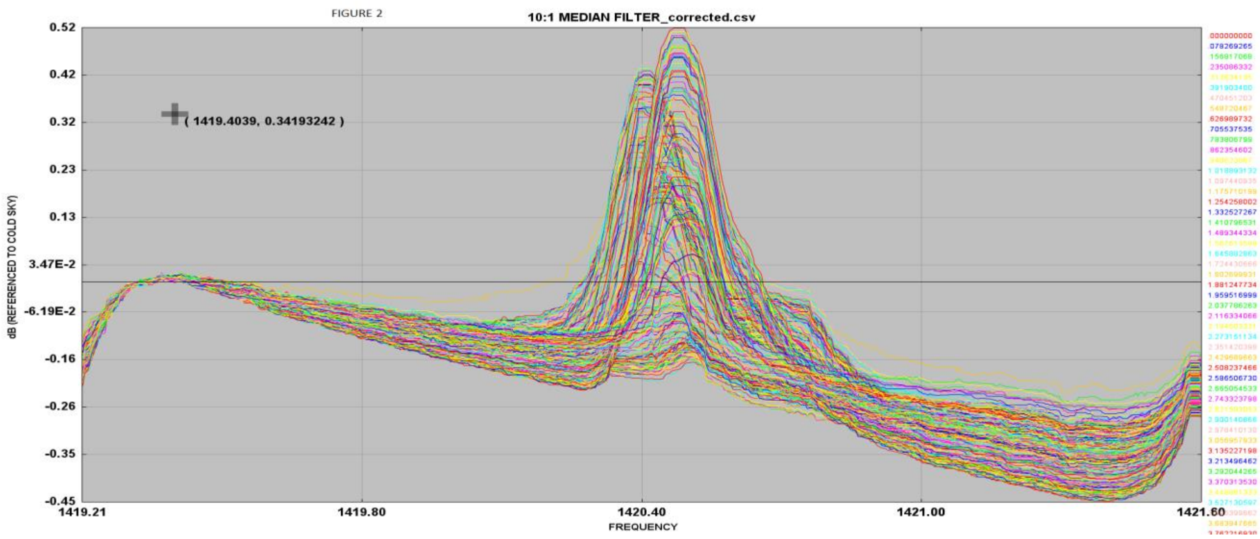
(See Figure 1 below-24 hr. drift scan on October 27, 2024, at declination +40°, data as processed with HLine3D



and single point correction, no filtering)

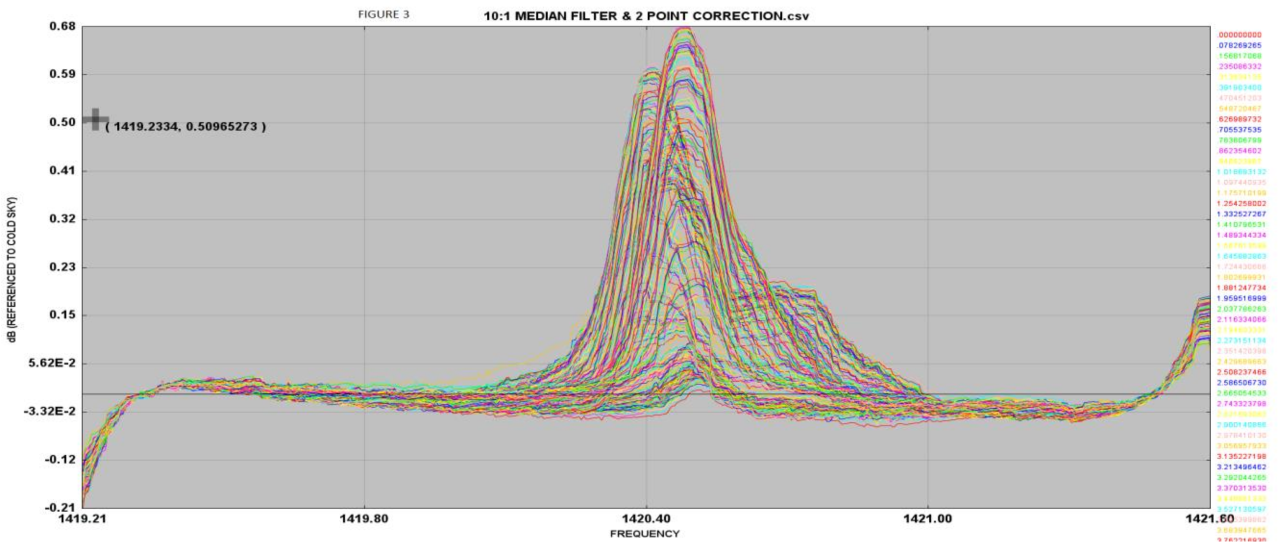
Since the typical methods of RFI/drift mitigation were minimally helpful, I decided to try a software approach in the post-processing of my scan data. I have very limited experience with writing code. My last attempts were writing Basic programs in a college class 40+ years ago. So, I thought that AI, ChatGPT in particular, might be an answer. Based on a recommendation from Marcus Leech, I began experimenting with median filters. From Wikipedia here is a good explanation of Median Filtering. "*The main idea of the median filter is to run through the signal entry by entry, replacing each entry with the median of the entry and its neighboring entries. The idea is very similar to a moving average filter, which replaces each entry with the arithmetic mean of the entry and its neighbors. The pattern of neighbors is called the "window", which slides, entry by entry, over the entire signal.*" After iterating several times and providing ChatGPT with detailed explanations, it generated a simple yet effective Python script. I appreciated the comments that were included within the script as they explained what each section of the script was going to perform. I should point out that there is no graphical user interface for this script. It is bare bones. However, the median filter window size can be easily edited, and the only other edit is to change the directory location where your data is stored. *(It is beyond the scope of this article to include step by step instructions for this process but if anyone is interested in further instructions, they can contact me at gfajerry@gmail.com)*

(See Figure 2 below-Same data as Fig. 1 after processing with a 10:1 window Median filter.)



And finally, thanks to the recent efforts of Alex Pettit the drift of the data can be corrected with the Java script IFAvgtoCSV_mxb.jar that he recently uploaded to the HLine3D Github.

(See Fig. 3 below and note the slight increase in dB due to the 2 point correction)



In summary, when hardware or environmental solutions prove insufficient for mitigating RFI or drifting scans, software-based post-processing can be a highly effective alternative. I found that with a little patience and research that ChatGPT was able to generate a basic Python script that I was able to tweak to my needs to minimize the RFI effects and the new HLine3D package was able to minimize the drifting.

SIDs as seen by Stokes parameters of VLF transmitter signals
Nathan Towne
11/28/2024

SuperSID [1], sidmon2 and sidmon3 [2] are instruments sensitive to the impact of lightning, solar x-ray bursts, and artificially-induced disturbances on the ionosphere. The ionization transients due to these electromagnetic sources, termed SIDs, or sudden ionospheric disturbances, affect the propagation of waves within the Earth-ionosphere waveguide from VLF transmitters used for communication with submarines. So SIDs can cause transients in the intensities of received waves. These and other tools can detect these changes in intensity.

sidmon3 is different in that it uses two upright loop antennae sensing the two horizontal H-field polarizations. The intensities of the two polarizations are used to infer a direction from which the waves travel. SIDs often affect x and y polarizations differently, so that there are (in fact detectable) transients in the inferred directions.

But more can be done with a dual-polarization receiver. With simultaneously-sampled signals from two orthogonal antennae there is the opportunity to compute the Stokes parameters [3], which fully characterize polarization -- linear, circular, and in between. I developed sidmon5 to do this. Figure 2 is an example showing an intense SID at 21h evident in all the Stokes parameters.

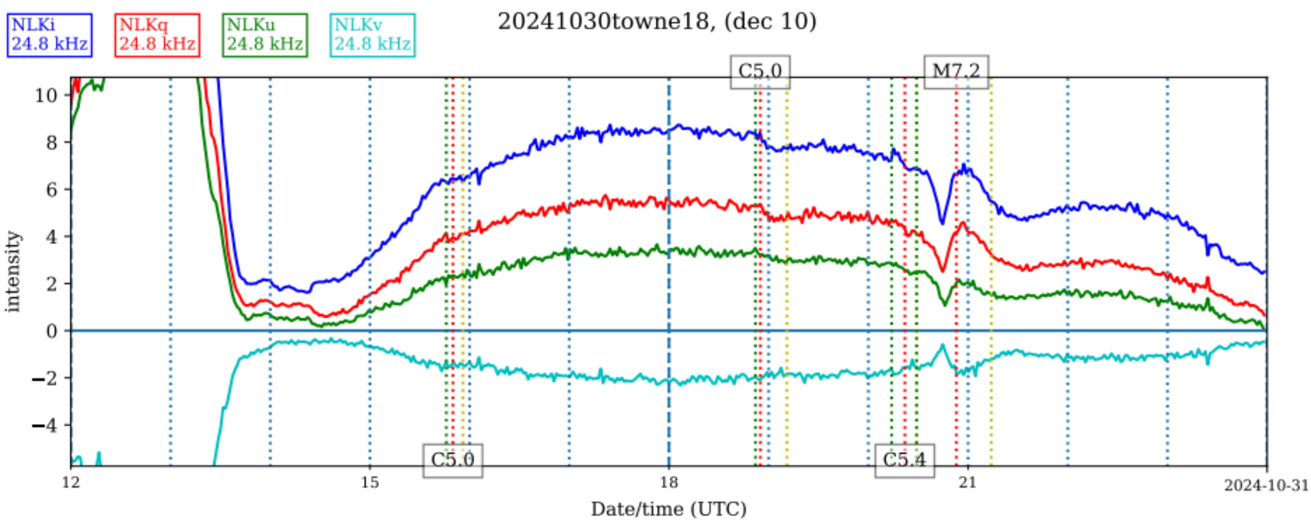


Figure 1: Stokes parameters of the signal from NLK in Washington state showing a prominent SID at 21h UT from an M7.2 x-ray burst. Stokes I, Q, U, and V are reflected in the lower-case suffixes of the legend in the upper left. The figure shows mostly daytime hours at the receiver in New Mexico. The date of the observation is embedded in the filename at the top of the figure. The labeled triplets of vertical lines represent x-ray bursts as reported by NOAA's Space Weather Prediction Center [4].

In this figure, linear polarization dominates in Stokes Q and U, while Stokes V, indicating circular polarization, is weaker. A first look at the variation of intensities suggests that the Stokes parameters are all proportional to each other during the daytime hours and during the transient from the x-ray burst. Such a proportionality does not suggest an ionospheric transient, but simply a variation of total power transmission to the receiver. To more sensitively detect an ionospheric change beyond intensity, one can normalize Q, U, and V to the total polarized power and look for change, again during daytime hours (Fig. 2) since all bets are off during the nighttime hours when the ionosphere is turbulent. Note that the normalized Stokes Q, U, and V are approximately constant during the daytime hours, except where there are bumps during and after the x-ray burst. This is a disproportionality that suggests that something else changed in the ionosphere during and after the burst.

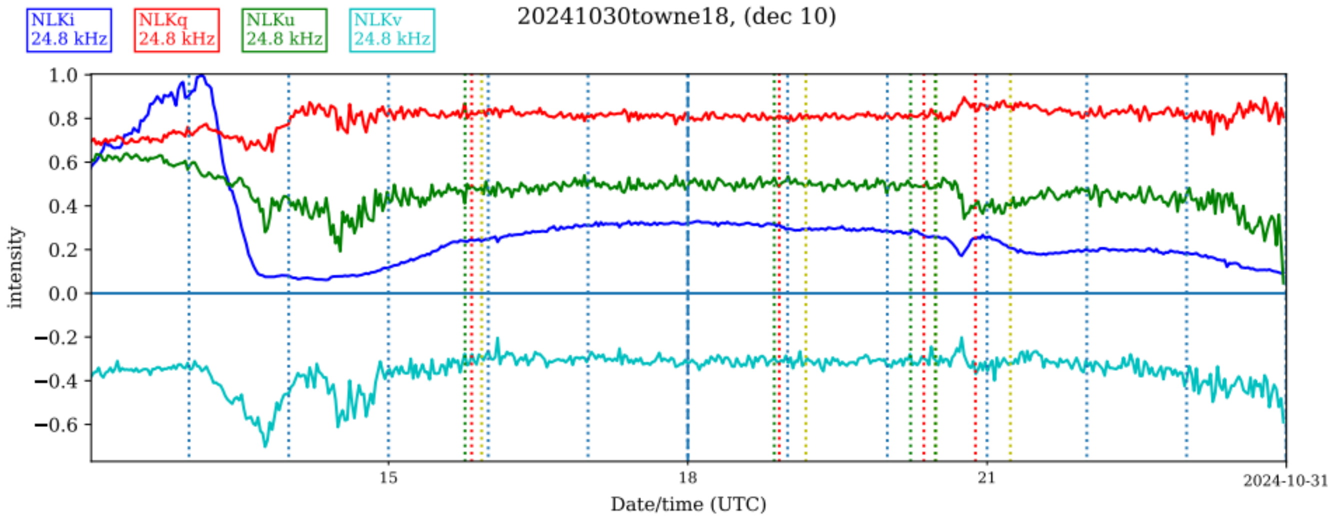


Figure 2: Normalized Stokes parameters. Stokes I in blue is scaled to a maximum of 1.0, while Stokes Q, U, and V are divided by Stokes I. Note that Stokes I is very close to the total polarization (Q, U, and V added in quadrature) due to the line-intensity measurement algorithm employed by the instrument.

We can also compute the x-y relative phase (usually computed with the x and y scalar amplitudes) from the Stokes parameters and look for a phase transient. This is what is done in Fig. 3 showing a jump in the phase of one polarization relative to the other.

Alternatively, one can plot the polarization-ellipse parameters, i.e., the major and minor axes, and the major-axis orientation with respect to the linear polarization axes. If the minor axis is zero, then the polarization is again entirely linear with its orientation measured by the orientation parameter just mentioned. With a non-zero minor axis, there is a degree of circular polarization (see Fig. 4). Although the direction computed from intensities and the major-axis orientation are computed differently, they are practically identical.

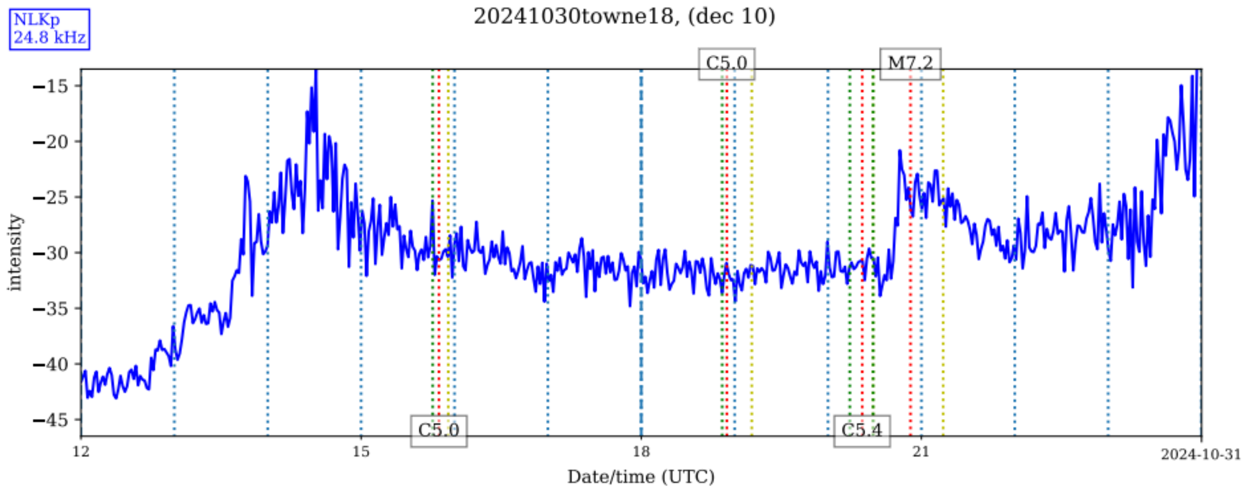


Figure 3: Relative phase of the x and y waves of Fig. 1. The unit is degree in spite of the vertical axis label.

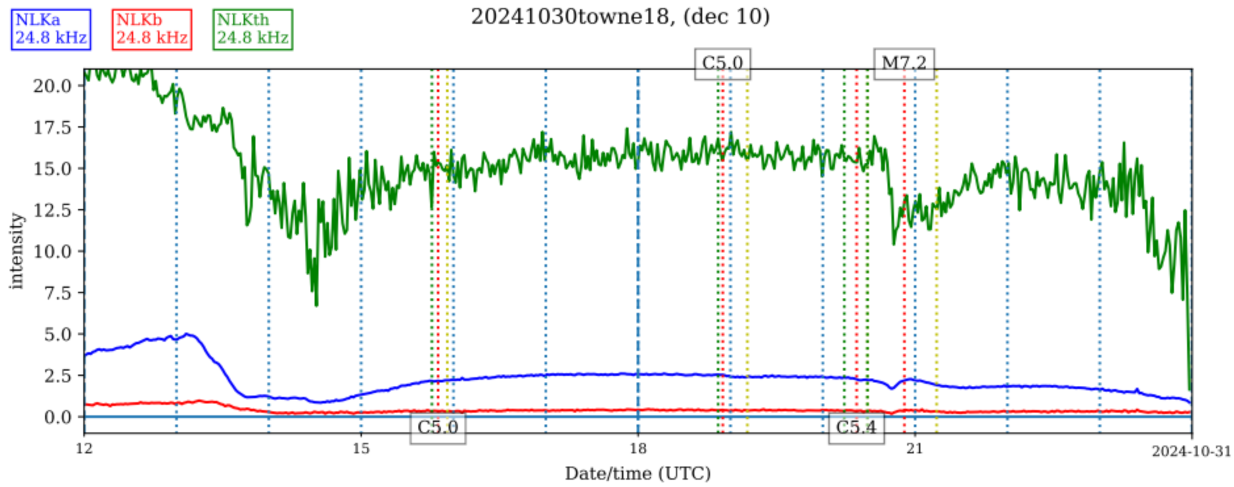


Figure 4: Polarization ellipse parameters of Fig. 1. The red and green traces are the major and minor axes, while the green trace is the major axis orientation with respect to the polarization axes. In the last case, the unit is degree.

The information contained in these parameters is redundant to a degree. Particularly, the directions inferred from the x and y intensities and the orientations of the polarization-ellipse major axis are almost indistinguishable. Similarly, the major-axis and x and y magnitudes look similar. Finally, x-y relative phase, Stokes V, and polarization-ellipse minor axis may as a third group contain similar information among them, but distinct from the other groups. The literature surely has more information on the relationships among these parameters.

It may be possible to measure parameters of what is called the `scattered wave' caused by a SID, i.e., the total wave minus the unscattered wave, the latter measured from the Stokes parameters before and/or after the SID transient [5]. The scattered wave is characterized by four parameters at a given time, the x and y scalar amplitudes, and the x and y phases relative to the unscattered wave. Unfortunately, I have not been able to repeat this calculation.

In any case there is more in SIDs to be explored using measurements of Stokes parameters.

References

[1] https://www.radio-astronomy.org/node/210
[2] https:https://sourceforge.net/p/sidmon3/
[3] http://en.wikipedia.org/wiki/Stokes_parameters#Representations_in_fixed_bases
[4] ftp://ftp.swpc.noaa.gov/pub/indices/events
[5] Burch and Moore, "Scattered Field Polarization for VLF Remote Sensing of Transient Events", URSI GASS 2023.

Observation Report
Taurus A and CTA 38: Analysis and Findings

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Royal Astronomical Society (RAS)

Location:
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Abstract

Purpose
For amateur radio astronomers, the analysis of Taurus A (the Crab Nebula) provides an opportunity to engage with real astrophysical phenomena while contributing to the broader community's understanding of supernova remnants. Amateurs often focus on detecting and monitoring the flux variations and spectral characteristics of Taurus A to study its structure and dynamic emissions.

Key Results

1. **Detection and Monitoring:** Amateur radio astronomers successfully detected radio emissions from Taurus A, adding valuable data to its long-term monitoring efforts.
2. **Educational Value:** These observations enhance amateurs' understanding of radio astronomy techniques and the physical processes governing celestial objects.

While these efforts are more limited in scope compared to professional studies, they offer significant educational and scientific value, enhancing the capabilities of amateur astronomers and occasionally contributing valuable data to the field

Introduction to Radio Astronomy Observation of Taurus A

Observation Target
Taurus A, or the Crab Nebula, is a supernova remnant in the constellation Taurus, formed from a supernova explosion observed in 1054 AD. Approximately 6,500 light-years from Earth, it features the dynamic Crab Pulsar, PSR B0531+21, a neutron star emitting pulsating radio waves and energetic particles driving the nebula's expansion and illumination.
Scientific Relevance

Observing Taurus A in radio astronomy enhances understanding of:

- **Supernova Remnant Physics:** Insights into the dynamics of shock waves and post-supernova evolution.
- **Pulsar Mechanics:** Understanding pulsar winds and their interaction with the nebular material.
- **Magnetic Field Structures:** Exploring the role of magnetic fields in astrophysical plasma dynamics.

These attributes make Taurus A an essential target for radio astronomers, aiding in the study of stellar evolution and neutron star behavior.

Results Section

Overview

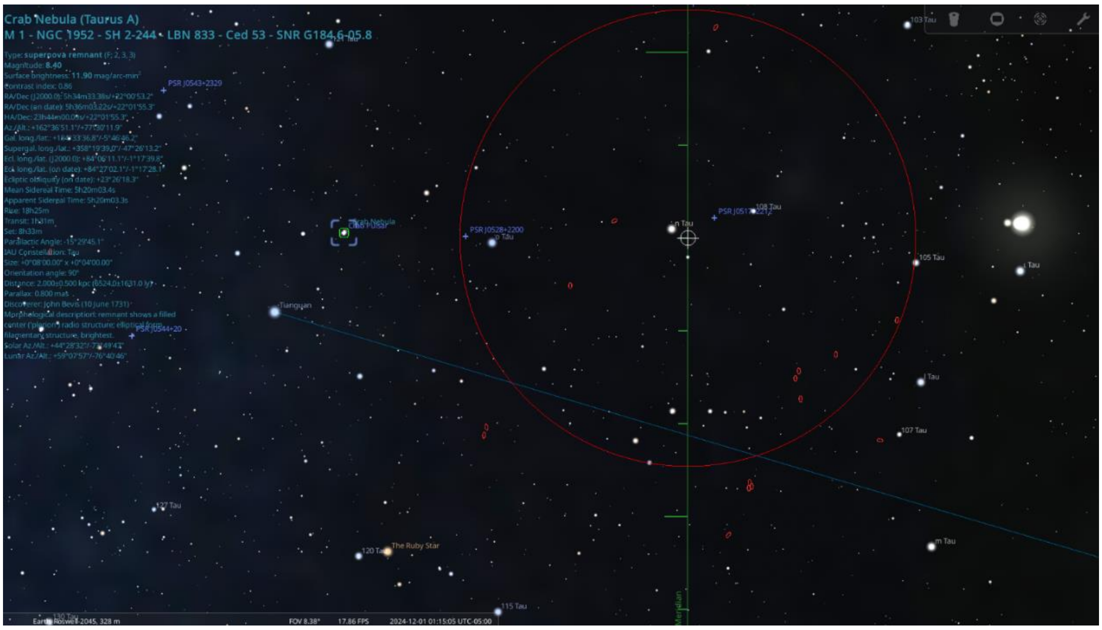
This section summarizes observations of Taurus A December 01, 2024, with images illustrating power, sinusoidal patterns, and fringe washout effects.

Taurus A Observations:

Approach to FOV:

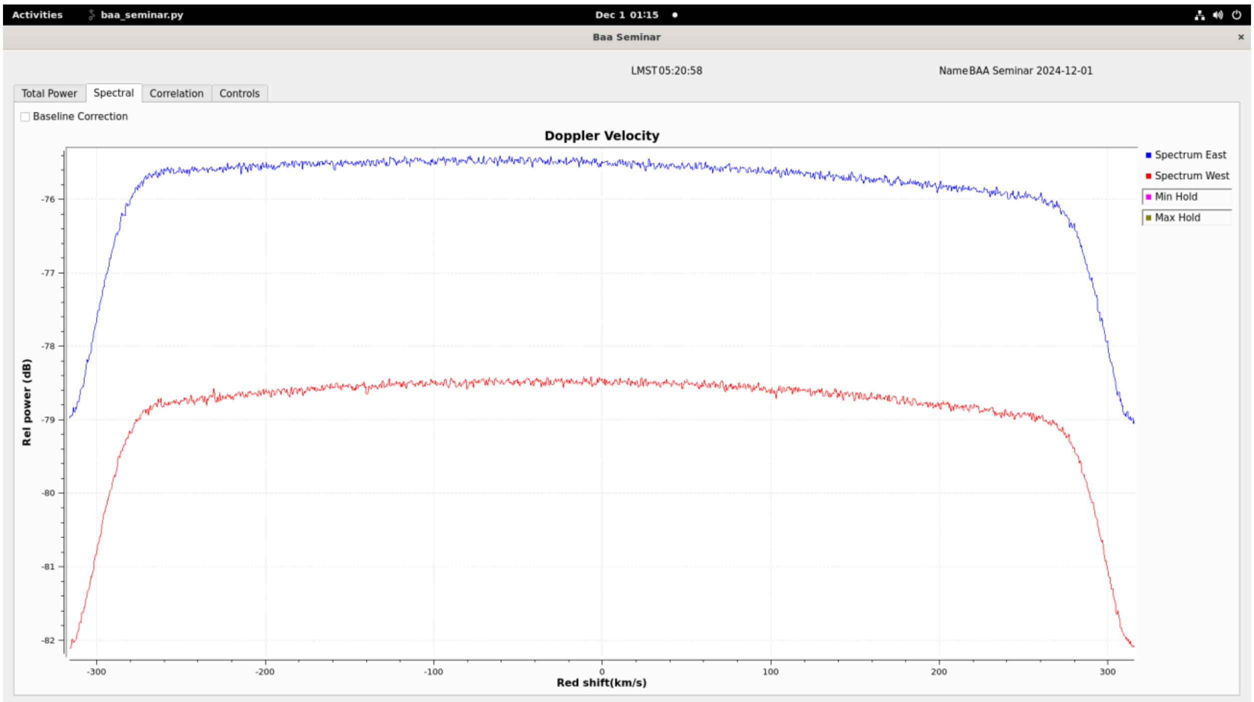
Image FOV_4.923_9.png (Stellarium): Taurus A approaches the combined field of view (FOV) of the two 3-meter dishes, which have a beamwidth of approximately 4.923°.

Image FOV_4.923_9.png



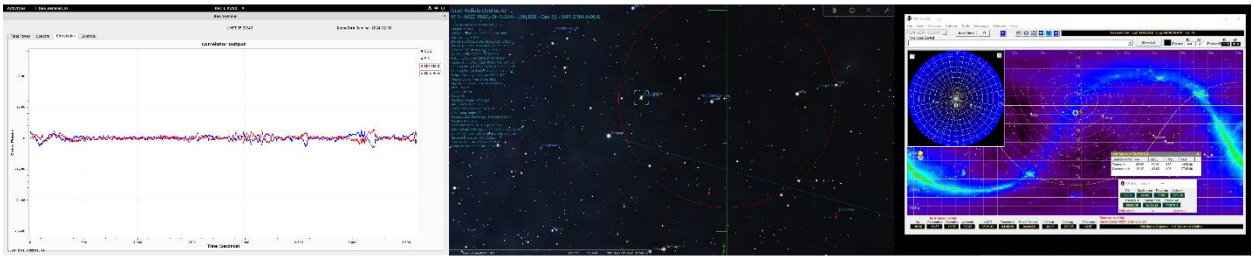
Background Spectral Power:

Image FOV_4.923_12.png: Displays the background spectral power in dB, with minimal redshift observed due to the short observation timescale. The data suggests minimal noise interference in the absence of Taurus A.



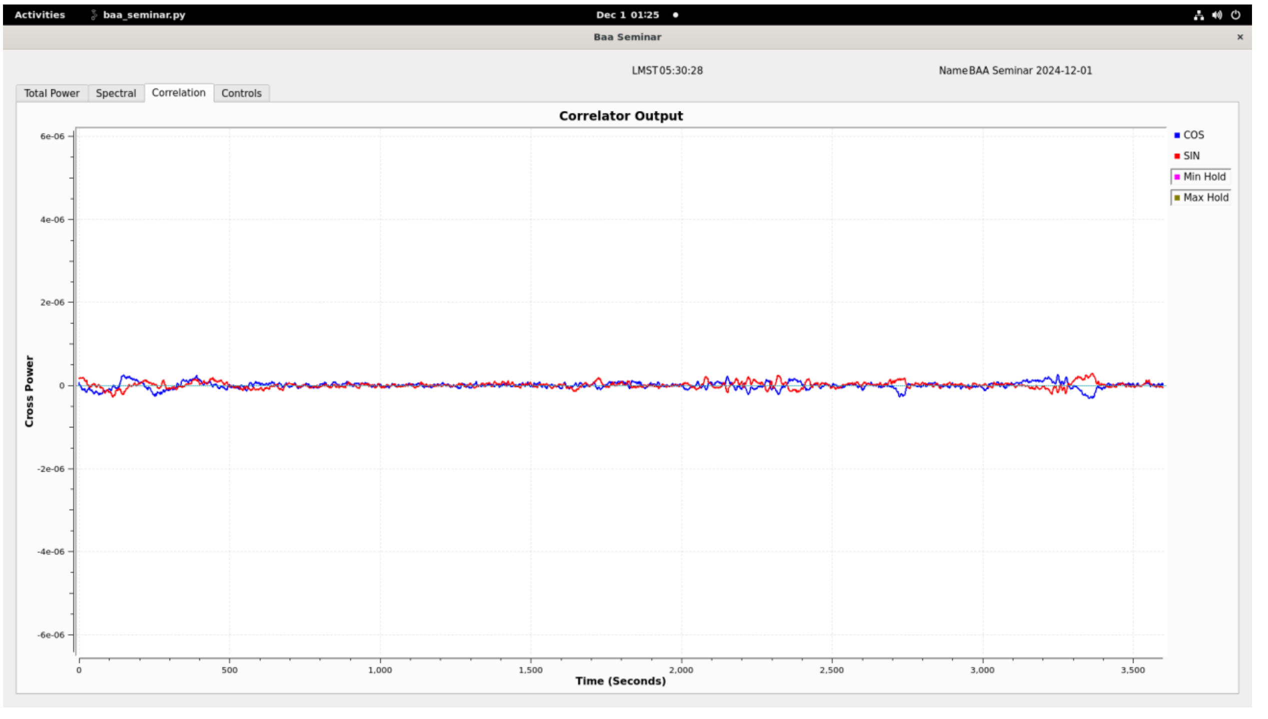
Entry into FOV:

screen_1733034161.1.png: Taurus A enters the FOV, with initial signs of signal amplification becoming evident



Sinusoidal Fringe Patterns:

Image FOV_4.923_16.png: Correlation data reveals the emergence of sinusoidal fringe patterns, indicating the detection of coherent signals.



Transit Through Narrow Beamwidth:

Image Tau_A_Transit_1.png: With the beamwidth adjusted to 0.86°, Taurus A is captured at its peak transit through the interferometer's FOV.

Sinusoidal Fringe Patterns after Transit:

Image screen_1733035289.74.png and image Tau_A_Transit_13: Display strong sinusoidal fringe patterns, confirming the system's sensitivity and coherence detection.

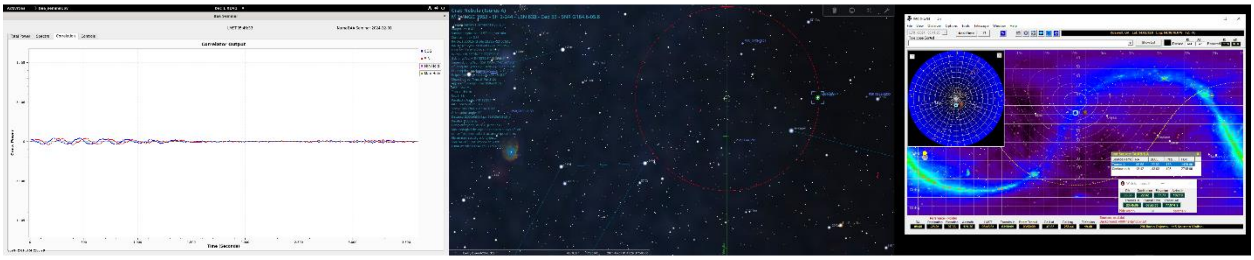
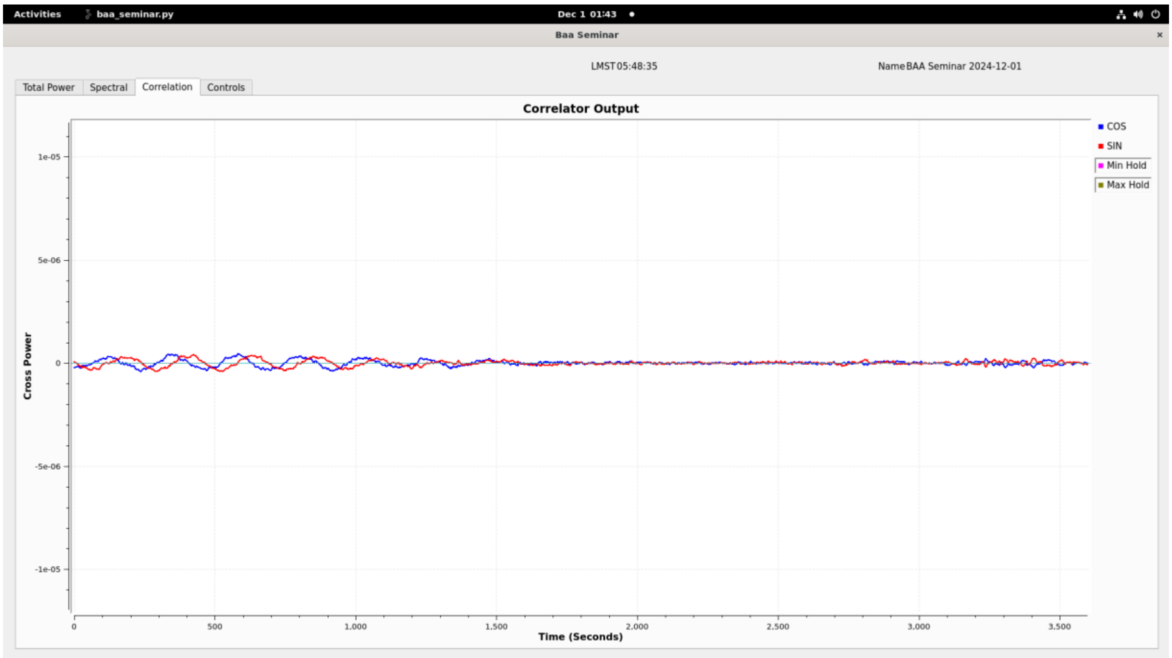


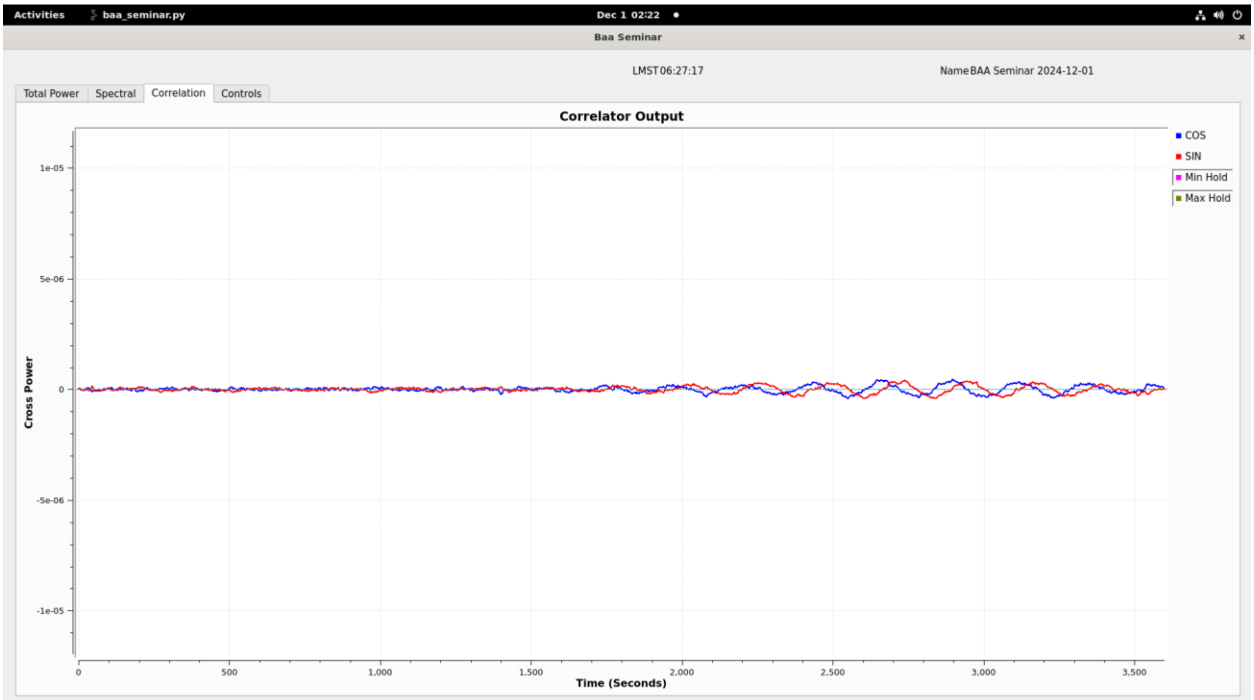
Image Tau_A_Transit_13



Fringe Washout During Exit:

Image Tau_A_Washout9.png **and** ***Image Tau_A_Washout26:*** Illustrate the gradual decline of sinusoidal fringe patterns as Taurus A moves out of the FOV of the two 3-meter satellite dishes.

Image Tau_A_Washout26



Post-FOV Exit:

Image Tau_A_Washout37.png and Image Tau_A_Washout41: Depict the complete diminishment of sinusoidal interferometric patterns as Taurus A fully exits the FOV.

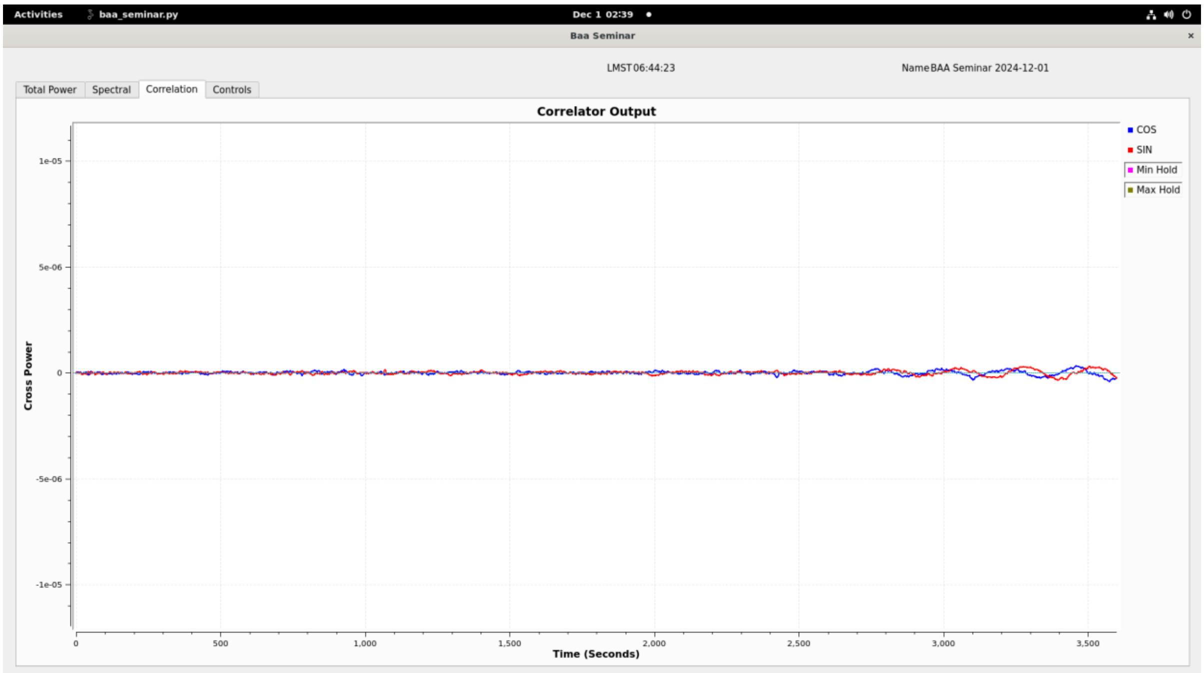


Image Tau_A_Washout41

CTA 38 Misidentification

CTA 38 Misidentification

CTA 38, also classified as DGVW 27, is a supernova remnant with a reported flux density of 1.3 Jansky at 1420 MHz, as outlined in Galt and Kennedy's 1968 study. Its faint and resolved nature make’s detection unlikely with the current radio interferometer system. Observed fringes during the CTA 38 observation on December 07, 2024, were identified as sidelobe interference from Taurus A (~22000 Jy). This conclusion is supported by Stellarium visualizations and correlation data from BAA Seminar.

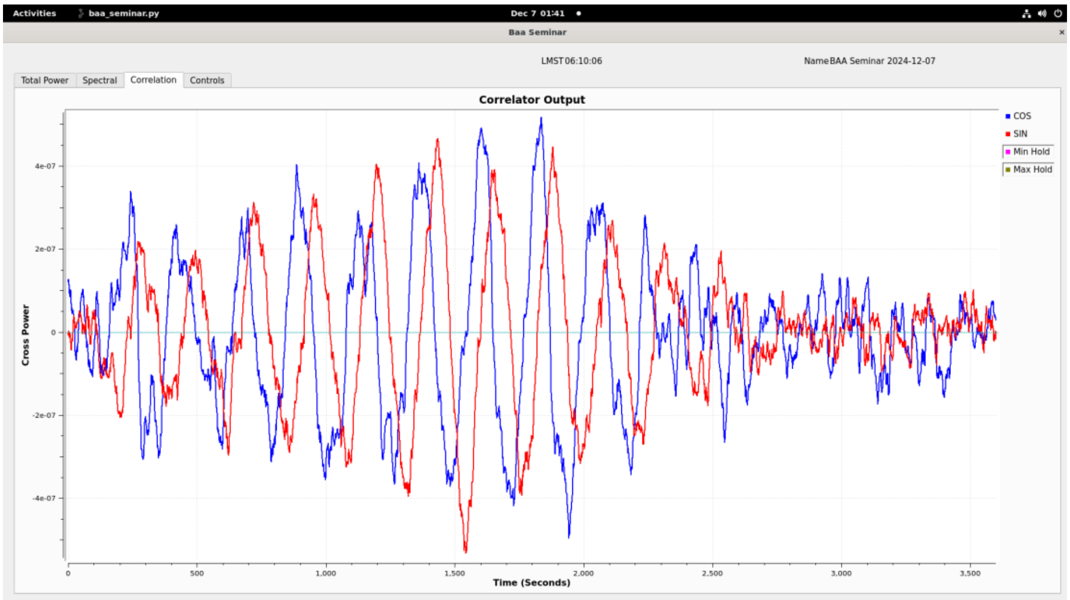
Expanded Discussion: CTA 38 Misidentification

Stellarium View:

- The panel image *screen_2024-12-07_01-56-18.png* from BAA Seminar, Stellarium, and Radio Eyes confirms that CTA 38 (circled in the upper right) had exited the FOV of the radio interferometer. Meanwhile, Taurus A (in the bottom right) remained within the interferometer's broader field, contributing significantly to sidelobe interference.

Correlation Tab Evidence:

- Sinusoidal fringes observed in *Image Fringe6.png* align with Taurus A's high flux density, far exceeding the weak signal expected from CTA 38.



BAA Seminar Total Power Analysis:

Image Fringe10.png captures the Total Power field data recorded during the CTA 38 observation attempt.

The data is represented across multiple channels:

- **Detector (Sum):** Displays the combined power detected from both 3-meter dishes. The stable curve indicates consistent total power measurements.
- **Detector (Difference):** Reflects the power difference between the two dishes. The near-baseline curve confirms accurate alignment and balanced sensitivity of the dishes during the observation.

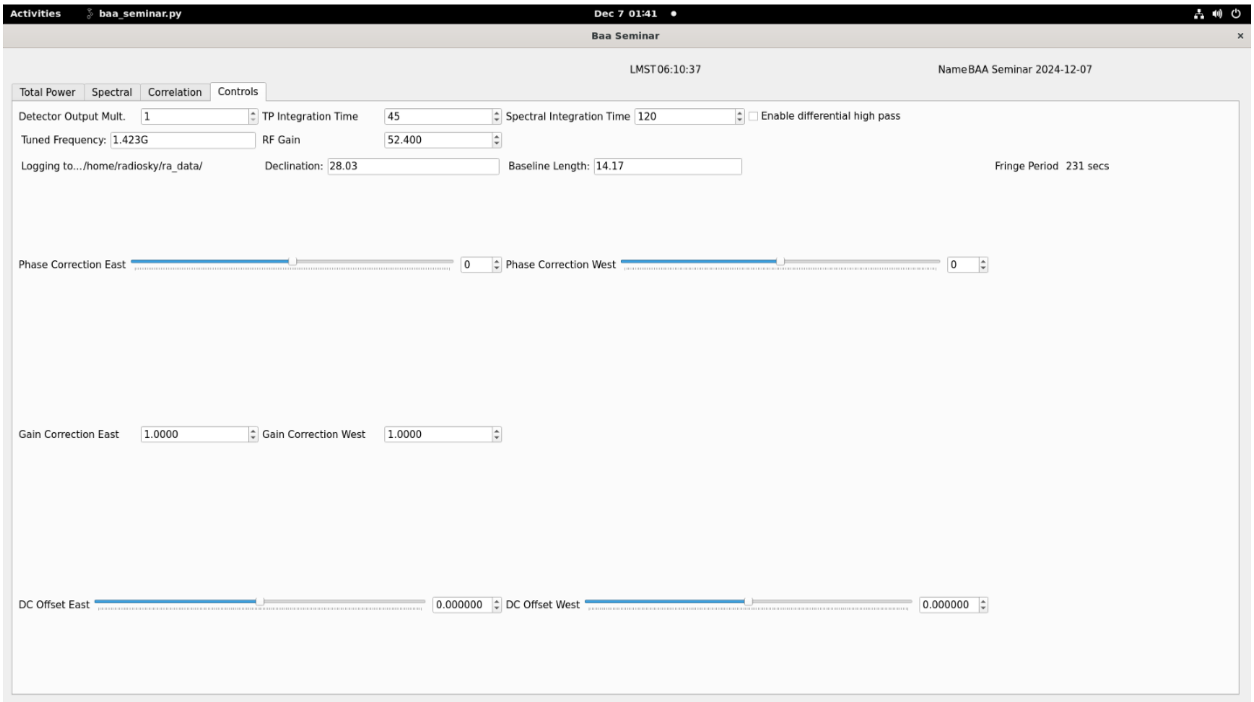
- **Detector (East) and Detector (West):** Show individual power contributions from the eastern and western dishes, respectively. Both detectors exhibit comparable power levels, demonstrating equal sensitivity and alignment.
- **Observation Duration:** Despite the limited observation time represented on the X-axis, the flatness across all curves suggests stable system performance and minimal environmental interference.

BAA Seminar Total Power Feature Description:

1. **Axes Description**:
    - **Y-Axis (Detector Power):**
        - Represents relative power measurements (in arbitrary units or normalized values). The scale highlights power contributions from various detectors, distinguishing between summed power, differences, and individual dish outputs.
    - **X-Axis (Time in Seconds):**
        - Reflects the observation duration in seconds. Due to the short observation period, the temporal dynamics in the recorded data are limited.
2. **Data Interpretation**:
    - **Detector (Sum)** (*Blue Curve*):
        - Represents the combined power detected from both dishes.
    - **Detector (Difference)** (*Red Curve*):
        - Captures the difference in power between the two dishes. This curve stays near baseline (zero), indicating minimal power imbalance or misalignment.
    - **Detector (East)** (*Green Curve*):
        - Reflects power levels recorded by the eastern dish, consistent with expected performance.
    - **Detector (West)** (*Magenta Curve*):
        - Displays power levels from the western dish. Its amplitude closely matches the eastern dish, suggesting similar system sensitivity and alignment accuracy.

3. **Observation Insights**:
    - **Detector Stability:**
        - The stability of both individual detectors (East and West) and the summative data (Sum) indicates a well-calibrated system with minimal noise interference.
    - **Detector Difference Insights:**
        - The near-zero Detector Difference highlights that both dishes were well-aligned and equally sensitive during the observation.

BAA Seminar Control Settings:
The image *Fringe8.png* illustrates the BAA Seminar control interface during the observation attempt. Key parameters included:



- **Tuned Frequency:** 1.423 GHz, aligned with the spectral region of the target source.
- **Baseline Length:** 14.17 meters, the physical separation between the two dishes.
- **RF Gain:** 52.4 dB, optimized for detecting faint source.
- **Integration Times:** Total Power (45 seconds) and Spectral (120 seconds), chosen to balance noise reduction with temporal resolution.
- **Fringe Period:** 231 seconds, calculated based on the target's declination and baseline length.

Technical Expertise:

1. **Marcus Leech (Canadian Centre for Experimental Radio Astronomy):**
   Marcus Leech, Director of the Canadian Centre for Experimental Radio Astronomy (CCERA), has an extensive background in technology development, encompassing both software and hardware since 1979. He was the first to suggest that the observed detection of CTA 38 might, in fact, have been Taurus A, located at the edge of the radio interferometer's FOV.

2. **Dr. Herman Wolfgang** (Astropeiler Stockert e.V.):
   Dr. Herrmann Wolfgang, President of Astropeiler Stockert e.V., oversees operations of the 25-meter Astropeiler Stockert Radio Telescope. With a Ph.D. in laser spectroscopy from the

University of Bonn, he focuses on advancing amateur radio astronomy through the Astropeiler initiative. Dr. Wolfgang confirmed that the flux density of CTA 38 was too faint to produce detectable fringes with the current configuration, concluding that the observed fringes likely originated from Taurus A.

3. **Dr. Leonid Y. Petrov (NASA, Goddard Space Flight Center):**
   Dr. Petrov, a leading expert in astrometry, geodesy, and Very Long Baseline Interferometry (VLBI), noted that CTA 38 might be associated with S147, a highly resolved supernova remnant. He emphasized that sources like S147, with their extended structures, are typically resolved out unless observed with larger interferometers possessing significantly higher resolution.

Conclusion:

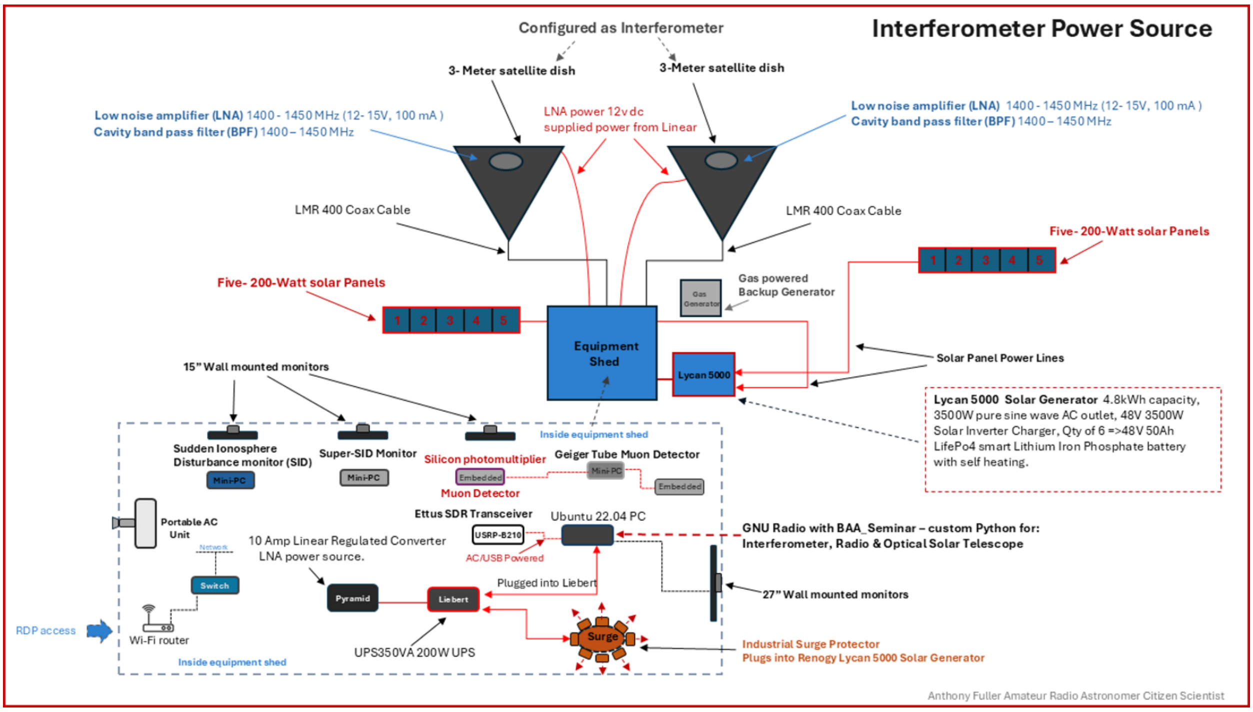
- The system's angular resolution (~0.86°), individual dish beamwidth (~4.9°), and 14.17-meter interferometer baseline are insufficient to detect or isolate the faint emissions of CTA 38 from the significantly stronger signals of Taurus A.

Lessons Learned and Future Directions

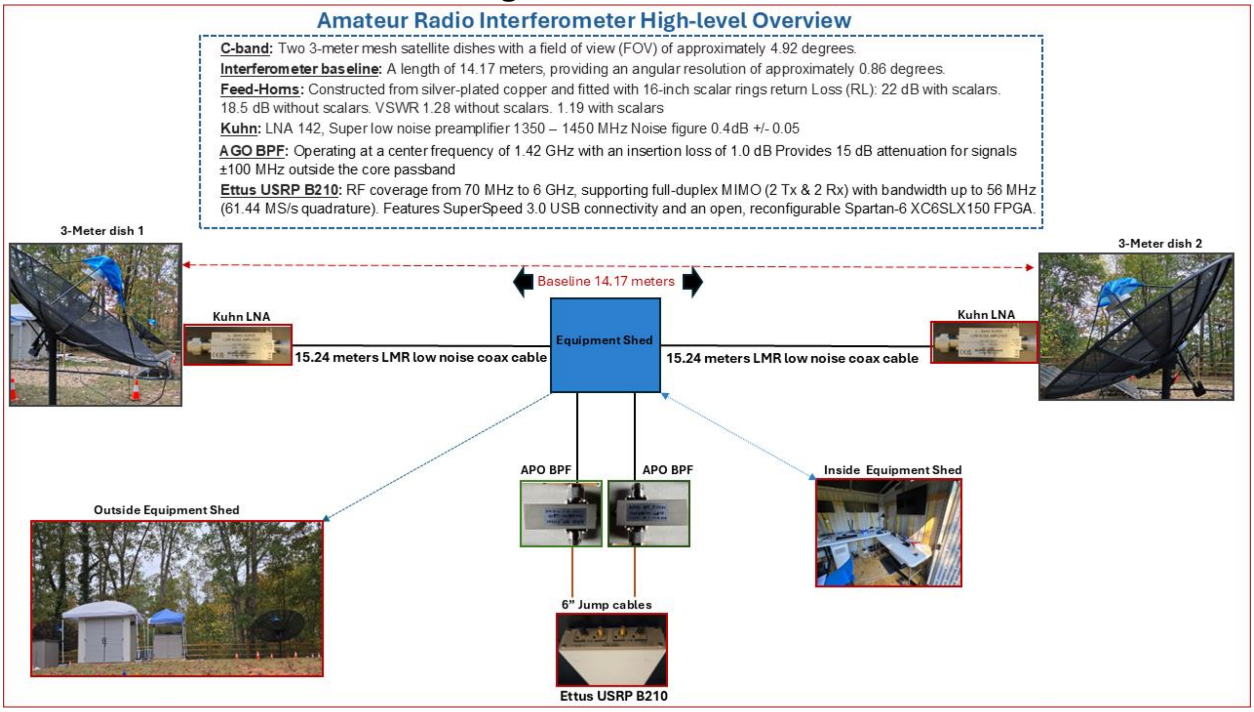
1. **Observational Adjustments:**
   - Pre-calibrate the system using strong sources, such as Cassiopeia A and Cygnus A, to optimize alignment and sensitivity.
   - Cross-reference Radio Eyes flux density data with other reliable online resources for verification.
2. **Environmental Improvements:**
   - Mitigate tree obstructions near the observation site to enhance clarity and reduce noise interference.

Amateur Radio Interferometer

Amateur Radio Interferometer Architecture



Amateur Radio Interferometer High-Level Overview



Acknowledgments

1. Marcus Leech for the early identification of Taurus A's contribution to the CTA 38 observation.
2. Jan Lustrup for highlighting sidelobe interference in the CTA 38 observation.
3. Dr. Herrmann Wolfgang and Dr. Leonid Y. Petrov for providing valuable scientific insights on CTA 38.
4. Members of the Society of Amateur Radio Astronomers for their guidance and feedback.

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Castelli U Burst or Just Interference Due to a Noise Storm Close to the Horizon?

Christian Monstein and Whitham D. Reeve

1. Introduction

An x-ray-flare on May 8, 2024, was accompanied by bright radio bursts of different types including Type II, Type III, Type IV and, according to NOAA, also a Castelli U burst, usually denoted as Type U (table 1). Actually, one of us (Monstein) was not able to detect any U-like structure at L-band (figure 1) from the Callisto station at Svalbard Norway (Ny-Ålesund) or in the HF-band (figure 2) from a Callisto station at Alaska USA (Cohoe). Both stations participate in the e-CALLISTO solar radio spectrometer network (https://e-callisto.org/). Compare the bright structure around 21:41 and 22:07 UT in both images. This led to discussions among solar physicists.

One physicist was convinced that the structure observed at Svalbard shown in figure 1 is nothing more than man-made radio interference (RFI) or, in correct gender-neutral way, anthropogenic background. But, observations from other stations, such as in Alaska, proved that the burst shown in figure 2 really was from the Sun. As a result of this discrepancy, one of us (Monstein) investigated and concluded that the Ny-Ålesund spectra was influenced by some kind of propagation interference. He was reminded of some experiments in the 1970s with a so-called sea-interferometer where similar patterns were generated due the reflection of the solar radiation from a flat surface such water, ice or wet ground when the Sun was at low elevations. Low elevations usually mean roughly less than FWHM beamwidth of the antenna.

Table 1 ~ NOAA Event list (partial) for 8 May 2024 (source: ftp://ftp.swpc.noaa.gov/pub/indices/events/20240508events.txt)

Event	Begin	Max	End	Obs	Q	Type	Loc/Frq	Particulars		Reg#
620	2108	2140	0307	G16	5	XRA	1-8A	X1.0	2.0E-01	3664
600	2114	2114	2114	PAL	G	RBR	410	1200		
600	2114	2114	2114	PAL	G	RBR	610	500		
890	2114	2114	2114	PAL	G	RBR	1415	140		
600	2128	2208	2301	PAL	G	RBR	4995	3200	CastelliU	
600 +	2128	2207	2254	PAL	G	RBR	1415	2800	CastelliU	
600	2134	2209	2309	PAL	G	RBR	2695	1000	CastelliU	

As the Callisto can only observe in its native frequency band 45 – 870 MHz, a heterodyne down-converter with a 1 GHz local oscillator was used at Ny-Ålesund between the antenna and Callisto spectrometer to shift the L-band solar radiation into the Callisto band. Similarly, a heterodyne up-converter with a 200 MHz local oscillator was used at Cohoe to shift the HF-band radiation into the Callisto band.

2. Analysis

One of us (Monstein) decided to prove that the periodic pattern in figure 1 is neither a U-burst nor RFI but is from a simple interferometer formed by the reflection of the solar radio waves from the frozen ground at Ny-Ålesund during the specific time and date.

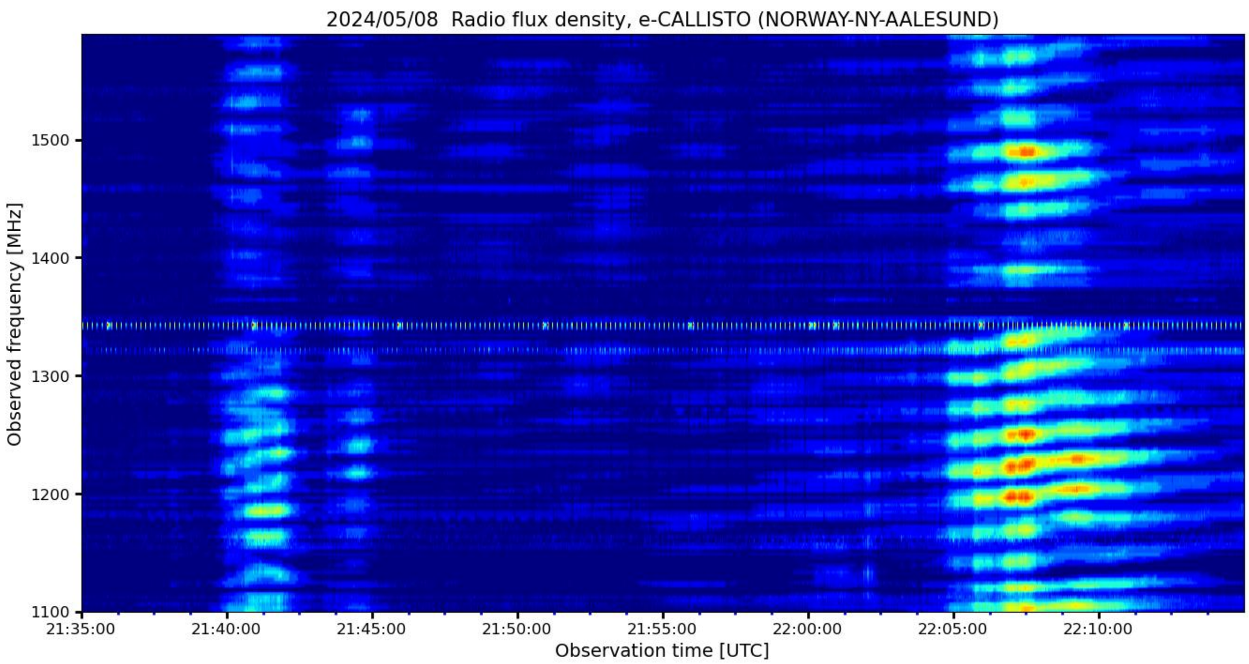


Figure 1 ~ Dynamic spectrum for May 8 from Ny-Ålesund, Svalbard Norway with reflection of Sun's radiation from the frozen ground. Data from FHNW Brugg/Windisch and IRSOL Locarno, Switzerland.

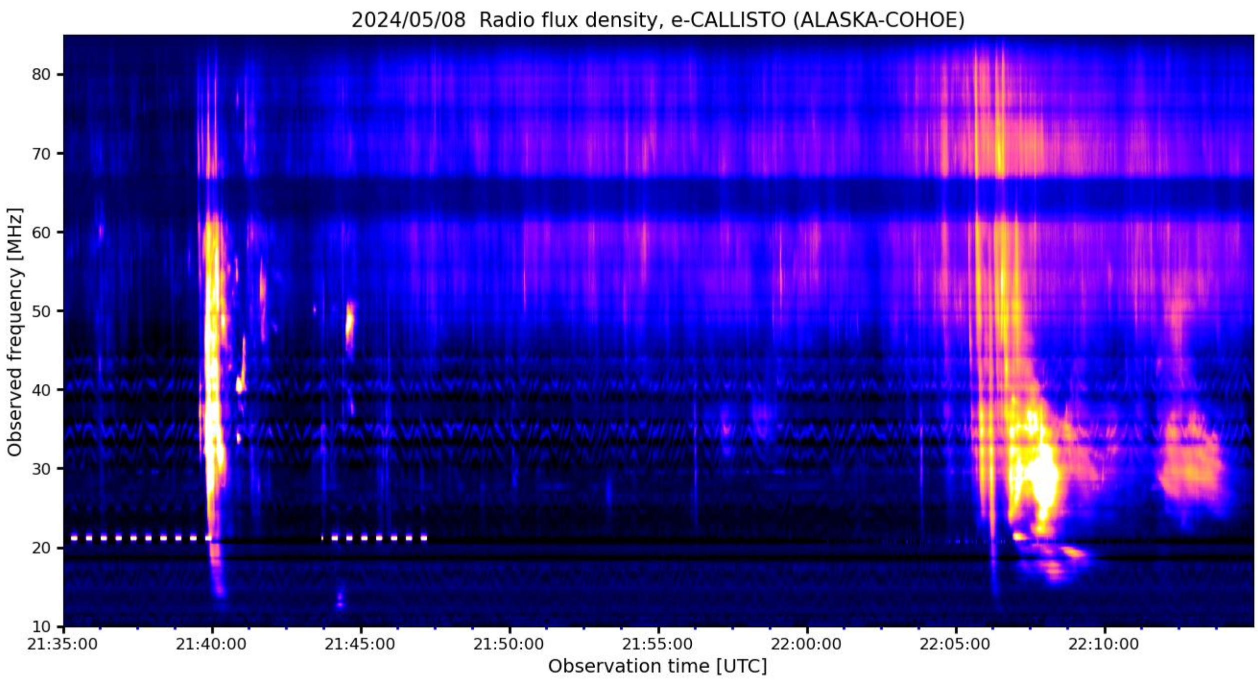


Figure 2 ~ Dynamic low frequency spectrum from May 8 from Cohoe, Alaska with the sun at higher elevation; thus, no ground reflection interference can be generated. Data from FHNW Brugg/Windisch and IRSOL Locarno, Switzerland.

At the maximum time of the burst, 22:07:24 UT, the Sun was at 6.81° elevation and 345.13° azimuth as calculated by a simple python script with local longitude and latitude of the Ny-Ålesund station as inputs. Due to the Sun's low elevation, the direct radiation as well as reflected radiation are well within the main beam of the station's Log Periodic Dipole Array (LPDA) antenna. The median received wavelength was 24 cm and an estimate from Google Earth of the altitude of the antenna, denoted h, with respect to the frozen reflection point to the north-northwest is approximately 48.5 ± 2 m.

An internet search yielded an interesting paper by J. G. Bolton and O. B. Slee, The Sea Interferometer, 1953 at https://adsabs.harvard.edu/full/1953AuJPh...6..420B . They described the received power at an antenna terminal with height h above reflective ground with a source elevation ε and wavelength λ as

$$P = 2 \cdot P_0 \cdot \{1 - cos[4 \cdot \pi \cdot h \cdot sin(\varepsilon)/\lambda]\}$$

Another Python script was written to solve this equation. Since we are interested in the period of the interferogram and not the power, the first two terms were set to 1. A plot of the resulting trigonometric function with the values mentioned above for h, ε, and λ is shown in figure 3.

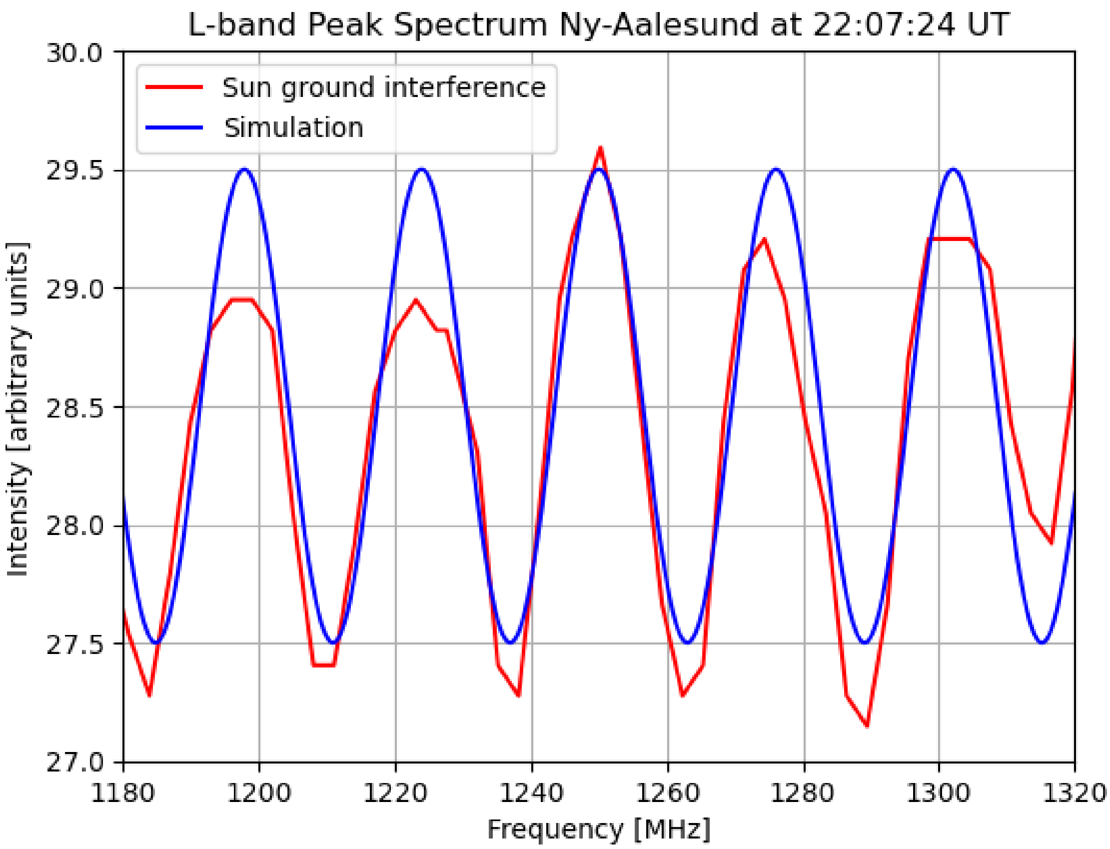


Figure 3 ~ Red observed spectrum at 22:07:24 and blue simulated spectrum according to the above equation. To fit the observation and simulation, the simulation had to be phase-shifted 195°, corresponding to ~12 MHz shift in frequency space.

Because the observed pattern nicely fits with the cosine-function in the simulation, we can be sure that the previous assumption is true, namely, that the interference between direct radiation from the Sun and the reflected radiation from the ground produces such an interferogram. Additionally, we can see that the phase of the pattern shifts slightly in time, due to the Sun's elevation slowly decreasing as it moves closer to the horizon. Thus, this radio phenomena have nothing to do with man-made interference nor is it a U-burst as reported by NOAA.

3. Conclusion

Decisions or conclusions, based on only one observation from one station, is not constructive. One should always consider as many observations as possible to be on the safe side such as in this analysis of the spectrograms from Alaska and Ny-Ålesund.

Radar Observations of Meteor Events Summary:

James Van Prooyen

These are observation from a HF Bi-Static radar which operates along the 43 parallel between Lake Michigan and the Atlantic coast of New York State. The source transmitter is located near London Ontario. The system is used for several areas of research, looking for unknown meteor showers, counting Fireball meteors.

The system is called the Michigan Space Fence (MSF) because its beam pattern is more like a fence then a VHF system. The range at which it will detect events has turned out to be much more than planned.

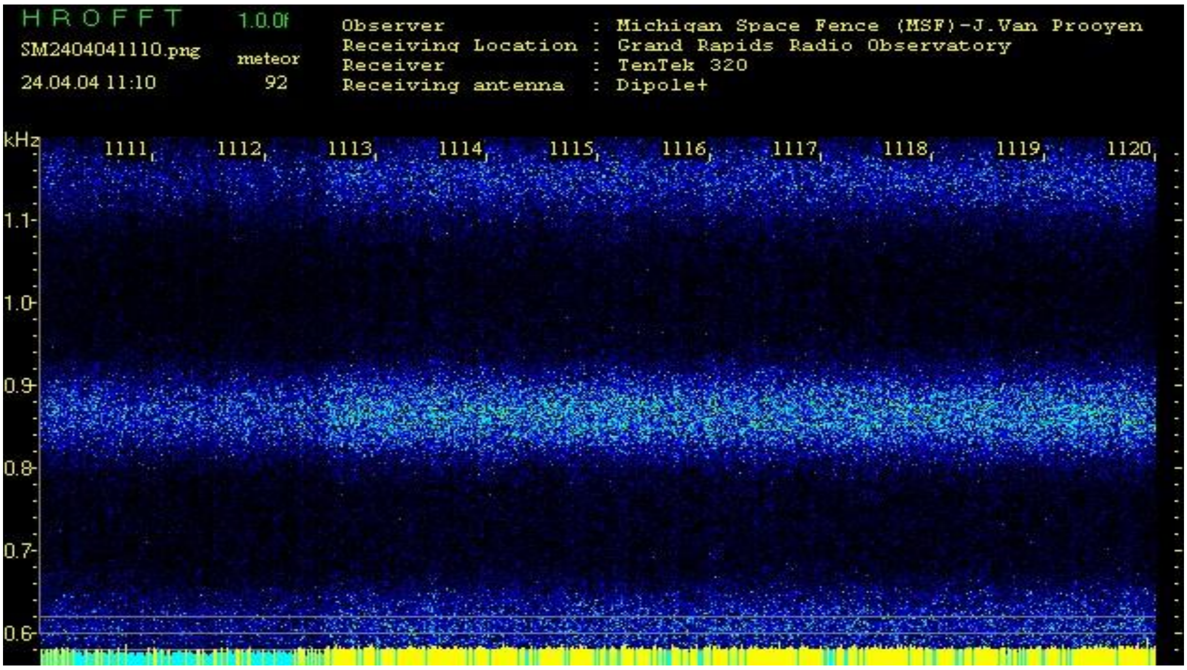
Hardware/Software Used:

The software used is "HROFFT" which can be found here:
http://radio.meteor.free.fr/hrofft2rmob/

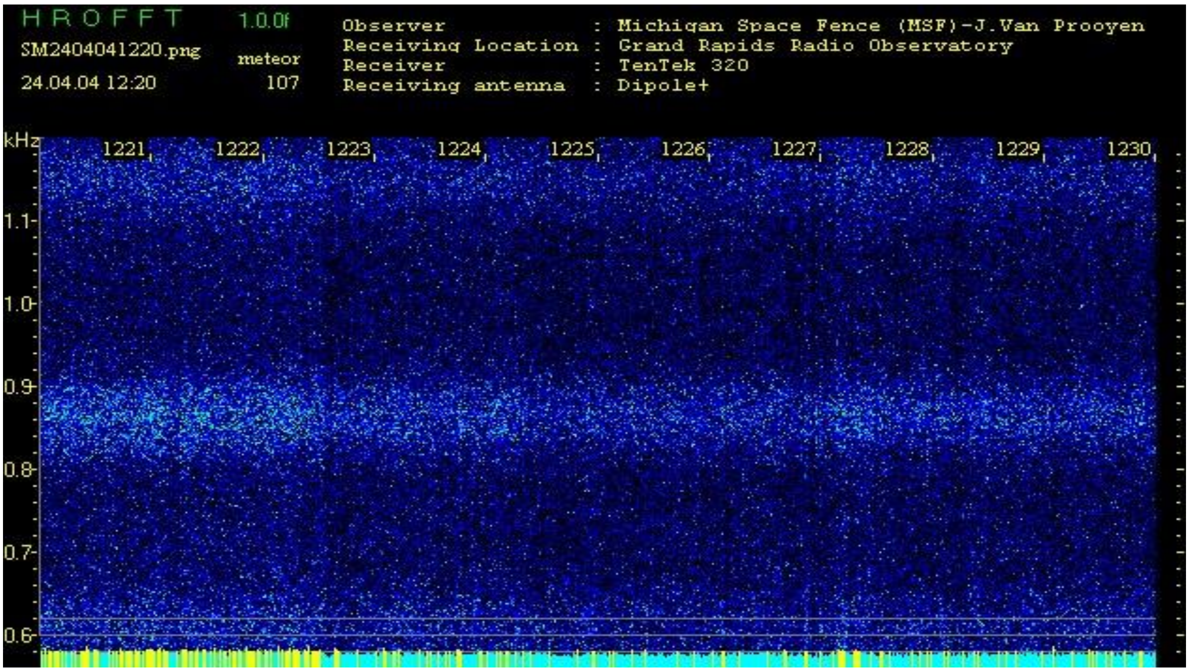
The Radio can be any HF receiver with audio output that can be connected to a PC. I use old PC's running older version of Windows.

Unknown Meteor Shower:

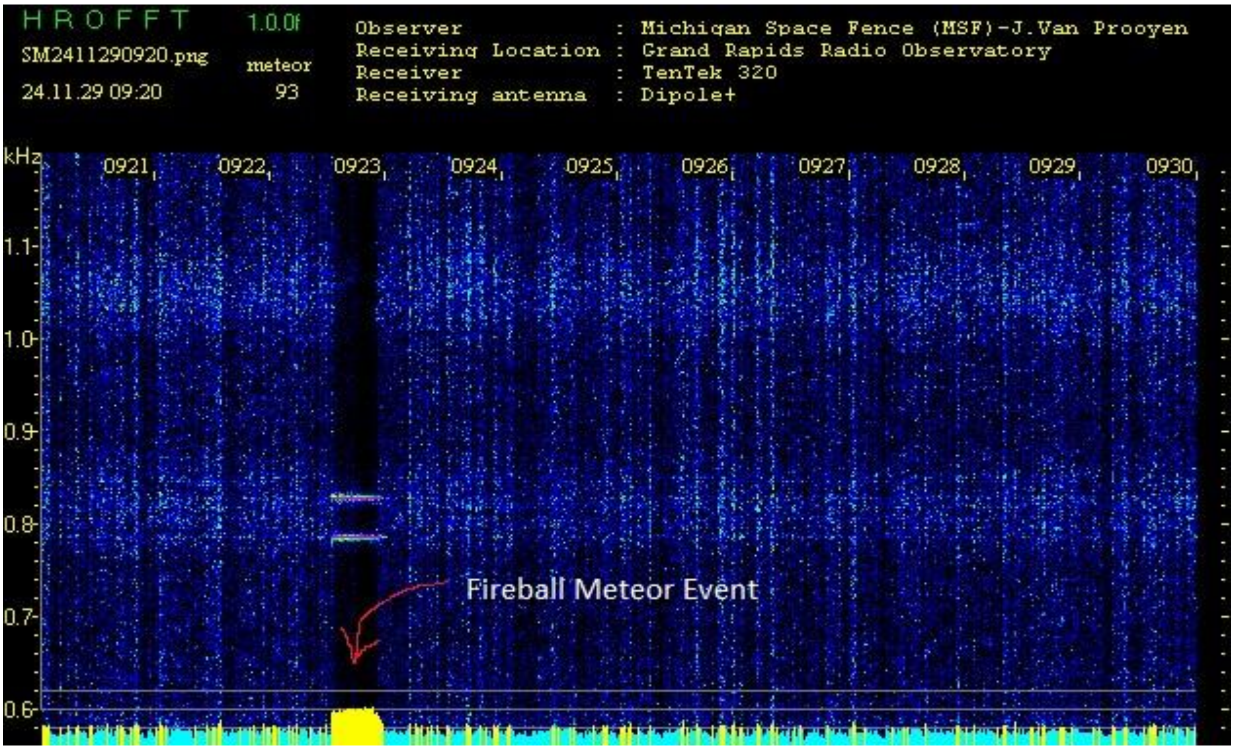
Here is a plot showing the start of an unknown meteor shower that occurred on April 4 2024. I could not find any know meteor showers that fit this event.



The plot below is what appears to be the end of the meteor shower, ~1 hour and 10 minutes later.

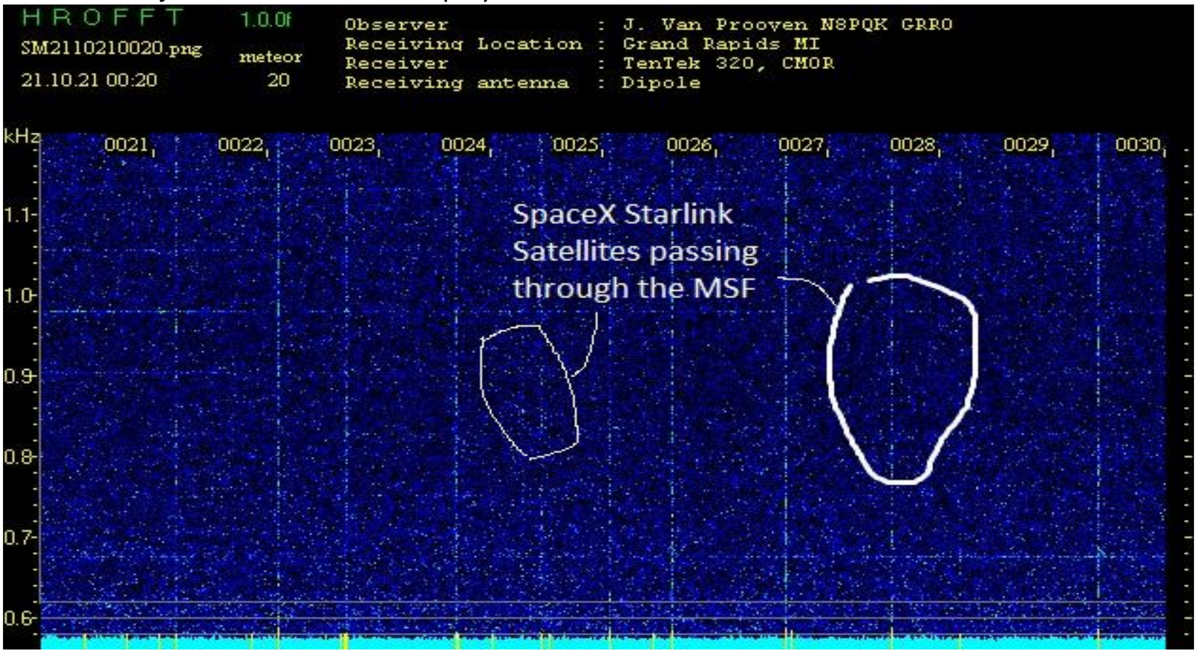


Fire Balls:
These are the primary focus of the research, in this case how many meteor Fire Balls events are not seen, I am still collection data, but it appears that the ratio is somewhere around 100 to 1, i.e. for every fireball seen 100 others are not seen (and reported).



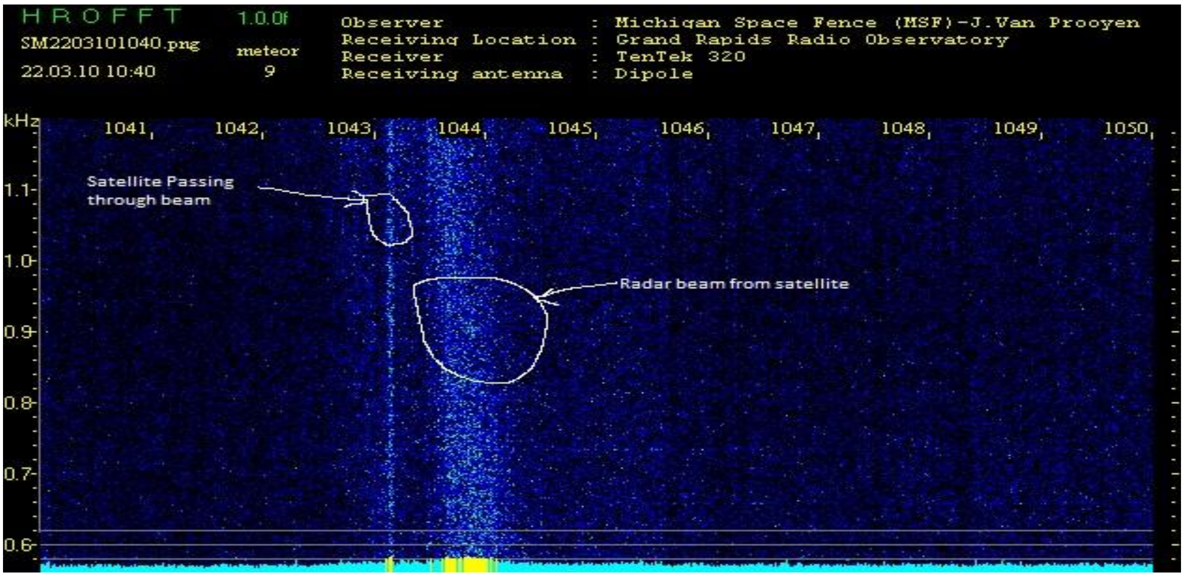
I have some rules that I use:
-The plot must be rounded.
-The event should be less than ~1 minute in length.
Other types of Events:

Satellites:
From time-to-time I see some satellites in low earth orbit, the example show below appear to be SpaceX Starlink Satellites just after launch and deployment.

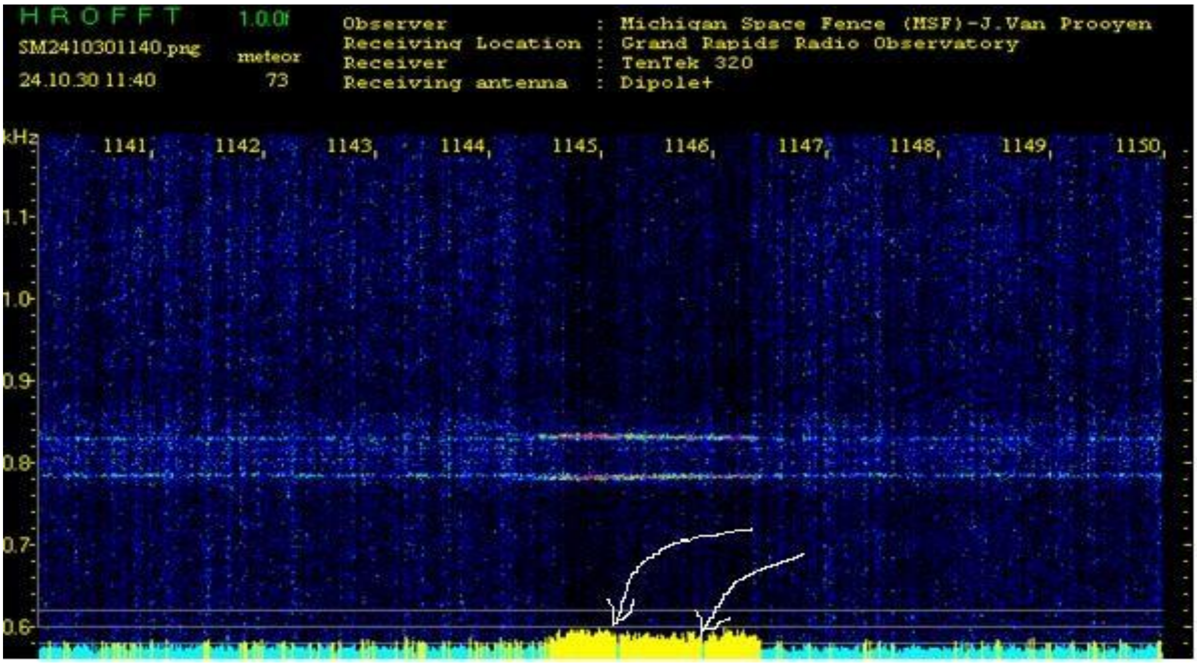


When the Starlink satellites reach their intended orbit they are no longer visible to the MSF.

Strange Events – Earth Radar Satellite in operation:
This event was kind of strange; it turned out to be an earth resource radar satellite operating its radar, while passing through the MSF. Note the Doppler shift of the radar beam!



Space Junk!
Each month we see what appears to be "space junk", note the notches in the plot. Based on the notches we may be able to identify each debris cloud, still working on this.



An online example of this can be seen at the following web page:

Live Meteors.com
https://www.livemeteors.com/

If the is of interest, I will do some more formal reporting of this system.

James Van Prooyen N8PQK grro@sbcglobal.net

Type V Solar Radio Burst Observed 15 November 2024

Whitham D. Reeve and Christian Monstein

Type V solar radio bursts consist of Type III fast radio sweeps combined with continuum emissions, both originating in the Sun’s corona. The Type V shown in the annotated spectrogram below, which was observed at HAARP Radio Observatory near Gakona, Alaska, covers the frequency range of approximately 26 to 82 MHz. The observed lower frequency is limited by Earth’s ionosphere and the upper frequency by the lowpass filter in the spectrometer’s up-converter. HAARP Radio Observatory participates the e-CALLISTO solar radio spectrometer network (http://e-callisto.org/).

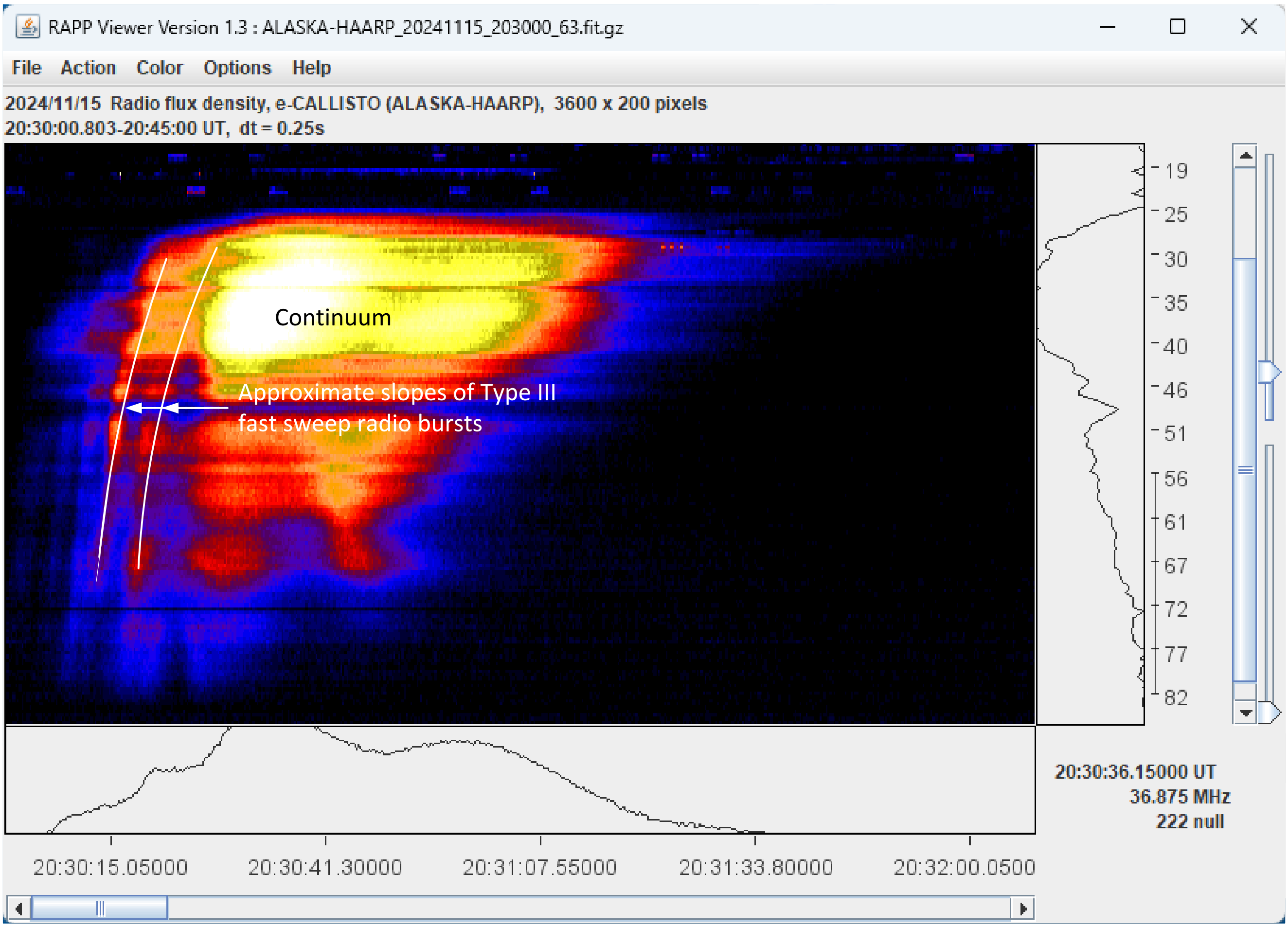


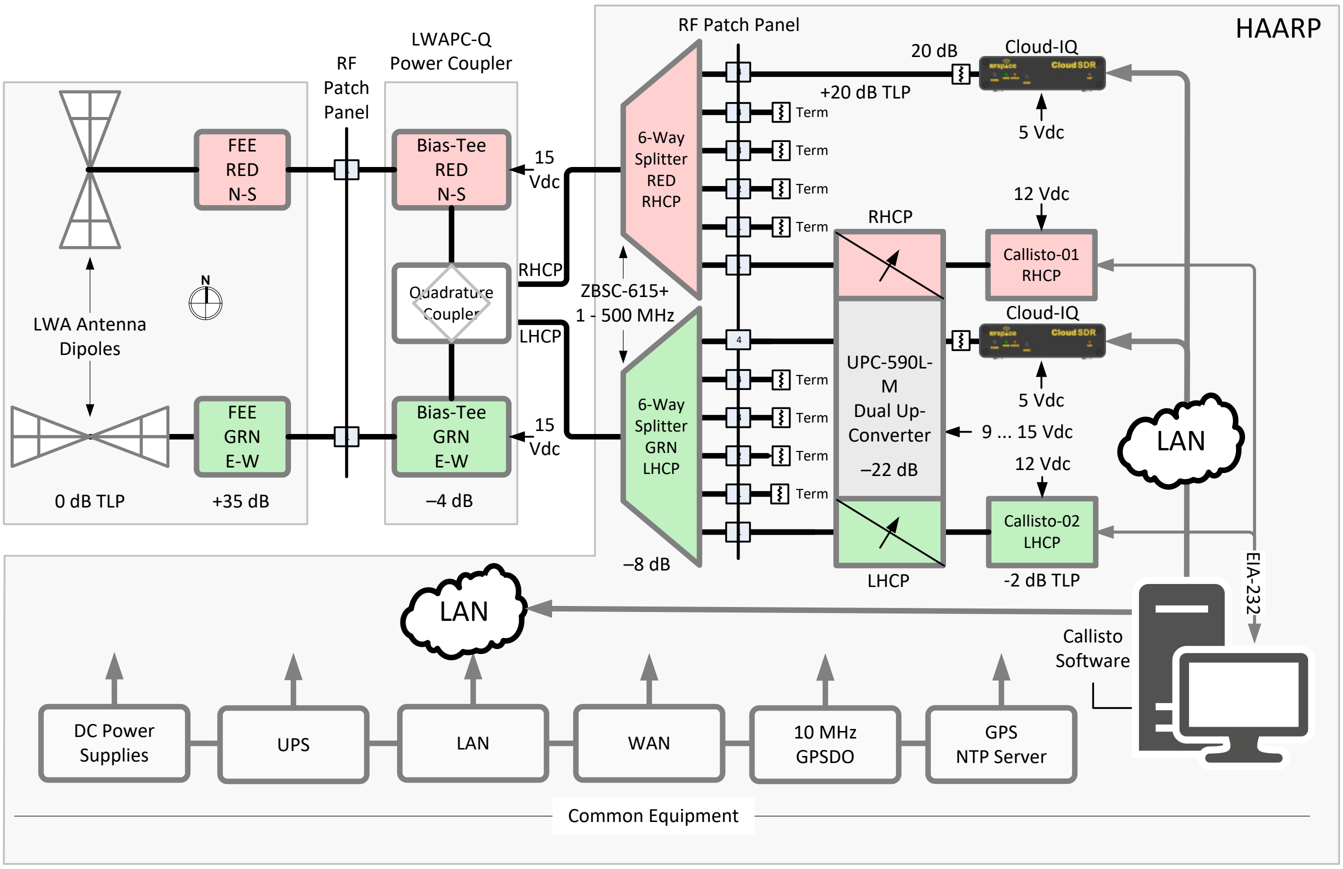
Image data source: FHNW Brugg/Windisch and IRSOL Locarno, Switzerland

The sweep (or drift) rates of Type III bursts in the high frequency band are observed to decrease with decreasing frequency. The white lines in the above spectrogram have been added to two of the Type III bursts. After noting the frequency scale on the right-side of the plot is inverted, the line slopes are approximately –2.6 MHz s^{-1} around 26 MHz (upper-left) and about –7.3 MHz s^{-1} around 82 MHz (lower-left). Both rates were determined graphically. The observed drift rates depend on how close the source, which produced the bursts, is to the central meridian. The closer it is, the higher the observed drift rate. However, the drift rates of many Type III bursts measured over time show significant variability. The source and position of the bursts observed here are not known.

Type III bursts are thought to be caused by the reconfiguration of unstable coronal magnetic fields. This results in the conversion of free magnetic energy to kinetic energy and acceleration of a large group of electrons to near light speed (about 1/3 the speed of light). The electrons are trapped by the Sun's magnetic field to form a beam. As this beam moves through the plasma in the solar corona it produces radio waves at the local plasma frequency, which decrease as the beam propagates away from the Sun through decreasing electron densities.

The continuum associated with a Type V burst is relatively rare compared to Type III bursts by themselves. It can be weakly polarized and never occurs in isolation. It is thought to be caused by the same mechanisms as the Type III bursts, but the source region of the continuum is often displaced by a few tenths of a solar radius from the associated Type III. The continuum is short-lived, usually lasting less than a couple minutes. For additional information about Type V and other solar radio emissions, see
https://www.reeve.com/Solar/Solar.htm .

The instrumentation used for this observation consisted of a crossed-dipole LWA Antenna and associated LWA Power Coupler, a dual UPC-590L-M Up-Converter and two Callisto radio spectrometers as well as power supplies and other infrastructure shown in the block diagram below. The Callistos are programmed to observe every day during daylight hours. The installation includes a quadrature coupler in the power coupler, which allows detection of circular polarizations from the linear polarized dipoles. This diagram also shows the Transmission Level Points (TLP) at each location in the RF signal chain starting with the radio sky reference at 0 TLP and progressing through each gain and loss block to the spectrometer inputs. Note: The Cloud-IQ software defined radio receivers shown here were not used in the observations.



Observation report: A wide spectrum of the water masers in W49

Eduard Mol

Introduction and background

Westerhout 49 is a massive star forming region in our galaxy, located at a distance of about 11.4 kiloparsec (37000 lightyears) [1]. It displays bright and highly variable water maser emission, which can regularly reach peak flux densities exceeding 10,000 Jansky [2], making it an interesting target for long-term observation with small amateur radio telescopes.

The "mini maser telescope" is a small 1 metre radio telescope built for observing the brightest methanol masers at 12.2 GHz and water masers at 22.2 GHz. The 22 GHz setup is described in more detail in the August 2022 SARA journal [3]. Briefly, the setup consists of a 1 metre off-axis satellite dish which can be mounted on a HEQ5 equatorial mount for accurate pointing and tracking. The feed can be swapped out between a bullseye Ku band LNBF for observations in the 10.5- 12.5 GHz band, and a norsat 9000LD Ka band LNB for 22.2 GHz. Because the local oscillator of the Ka band LNB is prone to frequency drifting a weak reference signal generated with a Leo Bodnar GPSDO is used for post-facto frequency correction. An airspy mini SDR is used as a receiver. Spectra are averaged and saved every 60 seconds using the SDR# IF average plugin.

In recent years the telescope has mainly been used for observing the brighter water masers, including regular (every 4- 8 weeks) observations of the strong water maser sources W49 and W51 to look for changes in their spectrum (see also the earlier SARA journal observation reports on this subject [3, 4, 5]). The spectrum of W49 is particularly complex and variable, displaying a cluster of strong and long-lived features centered around 10 km/s, as well as several more intermittent peaks at greater red- and blueshifts up to ±280 km/s [2]. Due to the limited 6 MHz bandwidth of the airspy SDR receiver my spectra usually only cover the strong emission at lower red- and blueshifts between -30 km/s and 30 km/s. Recently, Wolfgang Herrmann reported strong water maser emission in W49 around -70 km/s observed with the 10 metre dish at Astropeiler (personal communications). This observation motivated me to make a wider spectrum of W49 with the 1 metre dish.

Observations and results

In order to cover a wider velocity range four spectra were recorded with center frequencies 4 MHz apart. Despite the SDR bandwidth being 6 MHz, it only provides approximately 5 MHz of useful bandwidth due to gain roll- off and strong artifacts at the lower and upper edges of the spectrum. By maintaining a 4 MHz difference between the spectra there is still some overlap, even if the first and last 500 KHz of each spectrum cannot be used due to gain artifacts. For each spectrum, recordings were first made with the dish pointed at W49 for 15 minutes, and subsequently with the dish pointed a few degrees away from the source for the same amount of time. The on-target spectra were then divided by the off-target spectra to remove the SDR bandpass response. Residual slope or curvature in the background was removed by fitting and subtracting a third-order polynomial through the background. The frequency axis was converted to velocity with respect to the Local Standard of Rest (Vlsr), using the Astropy-based LSR calculator developed by T. J. Dijkema to derive the LSR correction [6].

Figure 1 shows the four spectra plotted together, covering a velocity range from -120 to +80 km/s. Besides the main emission features around 0 km/s which have been extensively observed in the past, there is an even stronger peak at -72 km/s in the blueshifted part of the spectrum. The redshifted wing above +20 km/s has no discernible features above the noise floor.

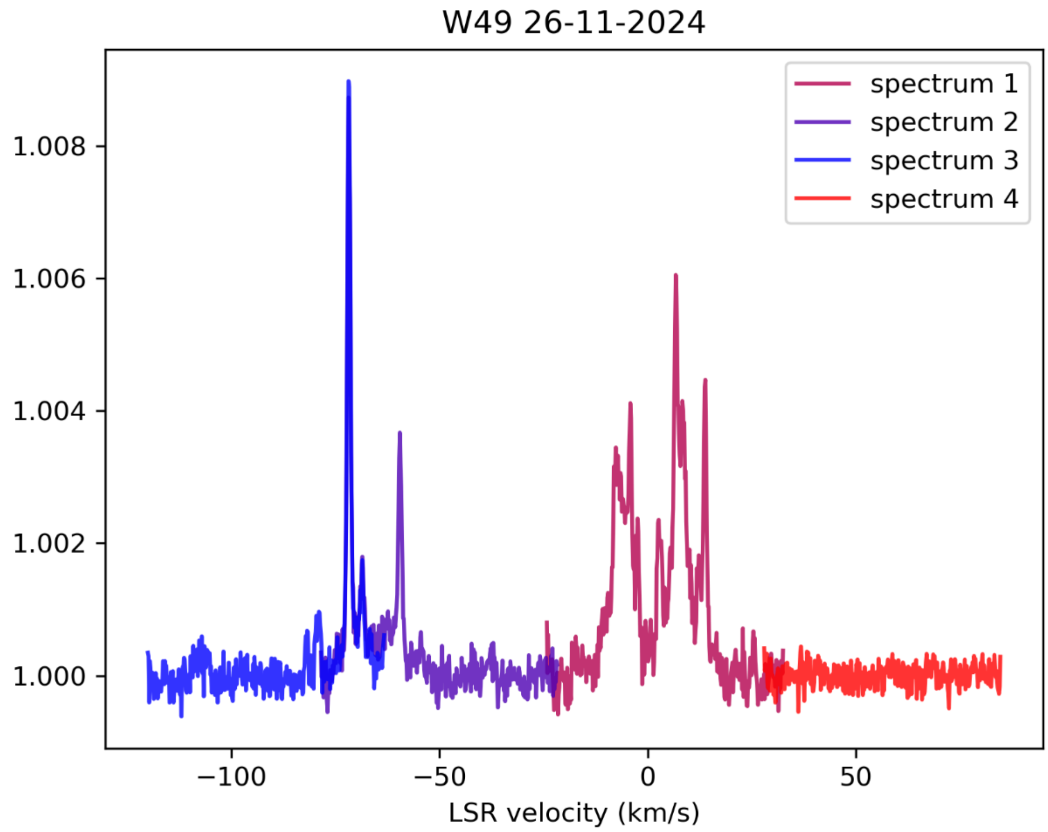


Figure 9: wide composite spectrum of W49 recorded on November 26, 2024.

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6) https://gitlab.camras.nl/dijkema/HPIB/blob/185d241ad9bd7507ed90c9fa91fe0a63009d3eee/vlsr.py

Observing Messier 87 Using Green Bank's Forty-Foot Antenna

Marcus Fisher (Marcus.S.Fisher@gmail.com)

Figure 1: Messier 87 (M87)

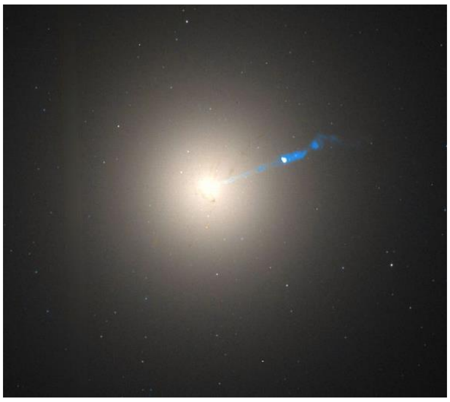

Figure 2: M87's blackhole emitting particles

During 2024 Society of Amateur Radio Astronomers (SARA) Eastern Conference, a group of attendees used Green Bank's forty-foot telescope to observe Messier 87 (M87) on Sunday August 4, 2024.

Virgo A, also known as Messier 87 (M87) or NGC 4486, is a supergiant elliptical galaxy in the constellation Virgo. M87 galaxy, in Figure 1, has an apparent magnitude of 9.59 and lies 53.5 million light years from Earth. It's one of the largest and most massive galaxies in the local universe, containing several trillion stars and roughly 15,000 globular star clusters. M87 is also home to a supermassive black hole that's six and a half billion times the mass of the Sun and 24 billion miles across. M87 is famous for the jet of material that extends from its supermassive black hole, see figures 2, 3, and 4. M87 is also one of the brightest radio sources in the sky and a strong source of X-rays. It occupies an area 7.2 by 6.8 arc minutes of apparent sky, which corresponds to a linear diameter of 120,000 light years, roughly the same size as the Milky Way. It is the second brightest galaxy in the northern part of the Virgo Cluster, second only to Messier 49 [1].

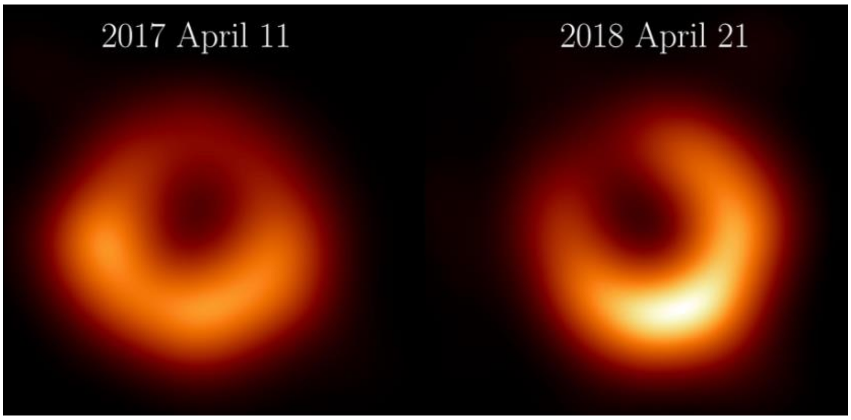

Figure 3: The Event Horizon Telescope Collaboration has released new images of M87 from observations taken in April 2018, one year after the first observations in April 2017. The new observations in 2018, which feature the first participation of the Greenland Telescope, reveal a familiar, bright ring of emission of the same size as was found in 2017. This bright ring surrounds a dark central shadow, and the brightest part of the ring in 2018 has shifted by about 30º relative from 2017 to now lie in the 5 o'clock position [2]

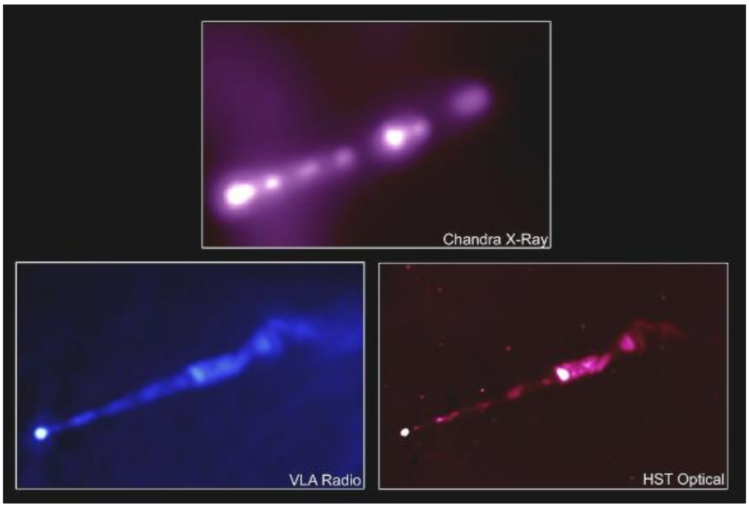

Figure 4: The energy jet of M87. The glow is caused by synchrotron radiation, high-energy electrons moving along a spiral track along the magnetic field [1].

Observation

The forty-foot telescope at Green Bank Observatory was used to observe M87. The telescope is a 40-foot diameter parabolic reflector that was constructed in 1962 [3]. The electromagnetic radiation sensed by its dipole antenna is converted into a corresponding intensity level, based on the radio source, that is then displayed on a strip chart recorder (see figure 5). The effective beamwidth for the telescope is approximated to be 1.0 degree of arc.

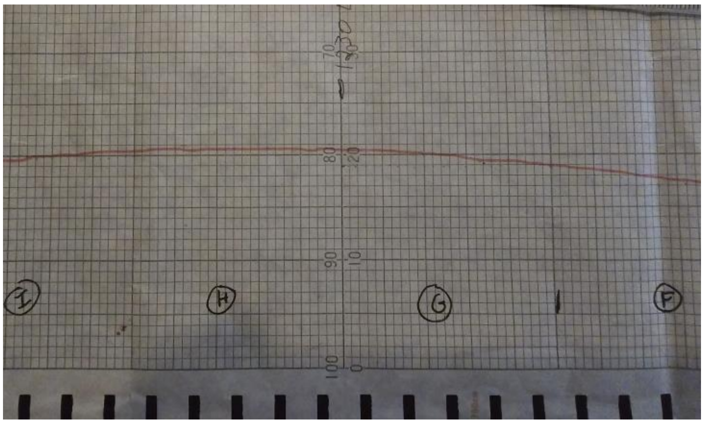

Figure 5: Strip chart recording of M87 as it crossed our meridian.

The radio telescope is a transit telescope, which means it only moves along the celestial meridian (north-south direction). It can point to almost any declination and utilizes the Earth's rotation to change what it is looking at in right ascension. As a result, the astronomer must know when the object is going to cross the celestial meridian. When that is known, the observer sets the declination of the telescope to the object's declination and waits for the observer's local sidereal time to equal that of the object's right ascension.

The object will cross the Celestial meridian when the local sidereal time matches the object's right ascension. Appendix VI from the 40-Foot Radio Telescope Operator's Manual [3] provides a table of observable objects along with their right ascensions and declinations. For this exercise, the group chose M87, Virgo A, which has a right ascension of 12 hours 28 minutes and 18 seconds and a declination of 12 degrees 40 minutes and 02 seconds.

Using a transit telescope, the astronomer uses the Earth's rotation to move the object through the telescope's beamwidth. The amount of time that an object remains in the telescope's beam depends on the object's declination. If the telescope was pointing at Polaris, then it would observe Polaris constantly since the declination would be +90 degrees (e.g., the telescope's beamwidth is parallel to the Earth's axis of rotation). The Earth makes an angular movement of 1 degree in 4 minutes, for an object on the celestial equator, the relationship between time and angular distance is such that one hour is equivalent to 15 degrees [3]. According to our data we observed Virgo A for around 7 minutes.

Our observation approach was a simple drift scan in which we positioned the telescope to Virgo A's declination, 12 degrees 40 minutes 02 seconds, prior to 12 hours 28 minutes local sidereal time, park the telescope in that position and let the Earth rotate and Virgo A move through the telescope's beam. Prior to making the observation, we also fired and recorded a calibration signal before M87 transited but we did not fire and record a calibration signal afterwards.

<u>Data Analysis</u>

There were a few assumptions and notes that need to be documented after the observation:

1) According to the Operator's Manual, the strip chart can be set to move at 60 centimeters (cm) per hour, 12 cm per hour, or 60 millimeters per minute. The rate that the strip chart was set for this observation was not documented and as such must be calculated based on the local sidereal time that was written down on the strip chart.
    a. As an example, on the strip chart we recorded a time of 12:30 local sidereal time, another time marked on the strip chart was 12:32. The distance between these two marks was 12 cm, which means the strip chart recorder was moving at 6 cm per minute.
2) Only one calibration signal was recorded which is not enough but was still used in the analysis
3) The frequency at which we were recording was not documented on the strip chart.
4) Converting strip chart data over to electronic format could have introduced error in the data that would need to be considered. In the future, when using a strip chart we should use the application identified by Mr. Mike Otte to convert the physical plot to digital data [6]

The strip chart was converted into electronic format by counting the number of blocks under the line for each vertical line on the graph. See a closeup in Figures 5 and 6.

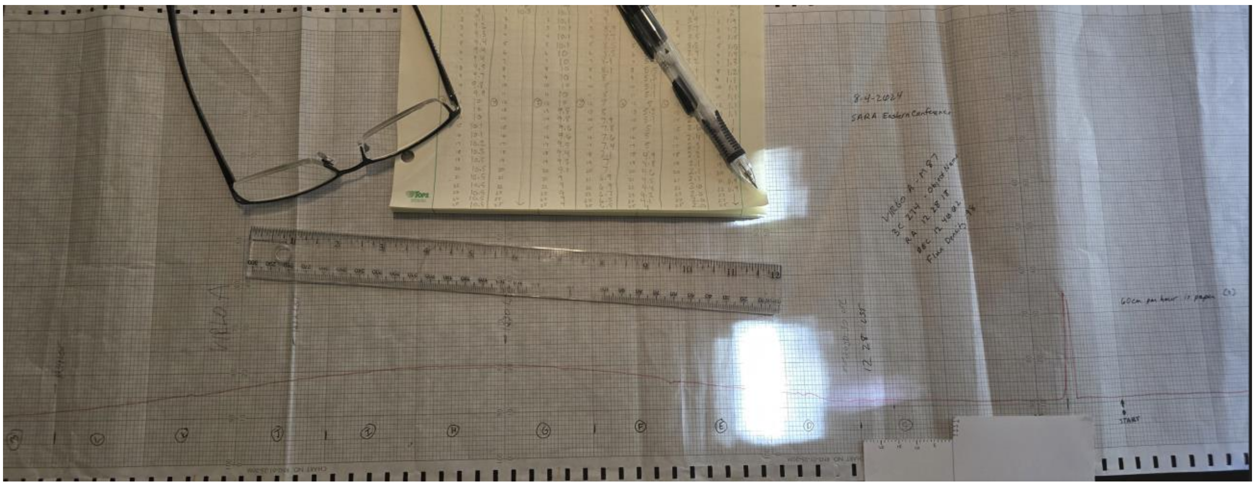

Figure 6: Strip chart was converted into electronic format by counting the number of blocks under the line for each vertical graph line.

After the strip chart was converted into electronic format, the data was then graphed. First the raw data was graphed as you can see in Figure 7. Secondly, the data was graphed after using the calibration signal to normalize the data as you can see in Figure 8.

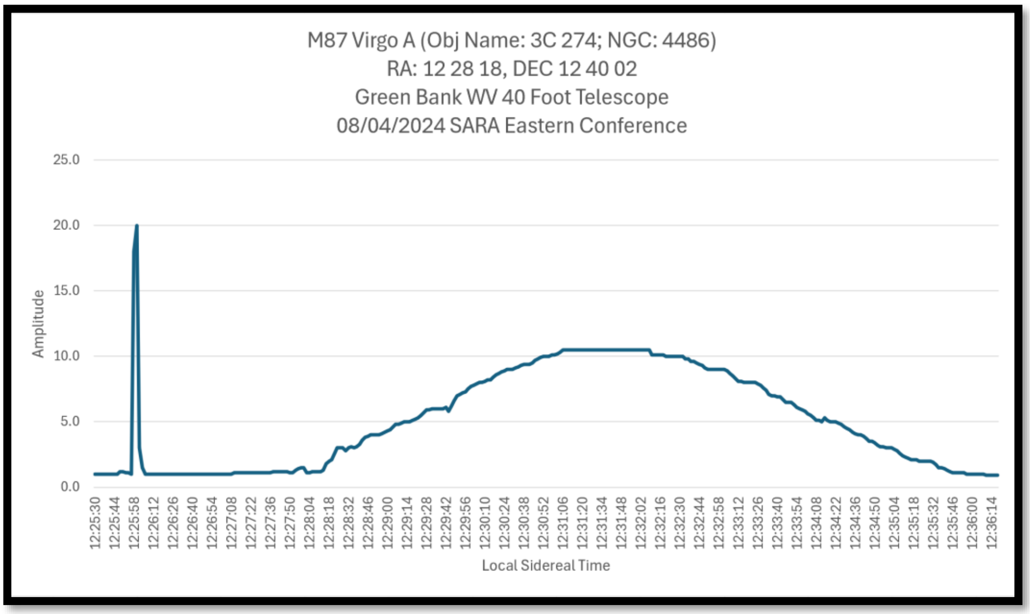

Figure 7: Observational data of M87 showing amplitude of signal versus local sidereal time. The extreme signal early on in the recording is the calibration signal.

Simply graphing the raw values is the chart in figure 7. As you can see in figure 7, Virgo A appears at 12:28 on the graph as expected and steadily climbs until it peaks at about 12:31 and then linearly declines until about 12:35.

The calibration signal, which averaged at 19 on the strip chart was applied by taking each raw count and dividing by the calibration signal to yield relative amplitude values. Figure 8 is the graph of the data after incorporating the calibration data.

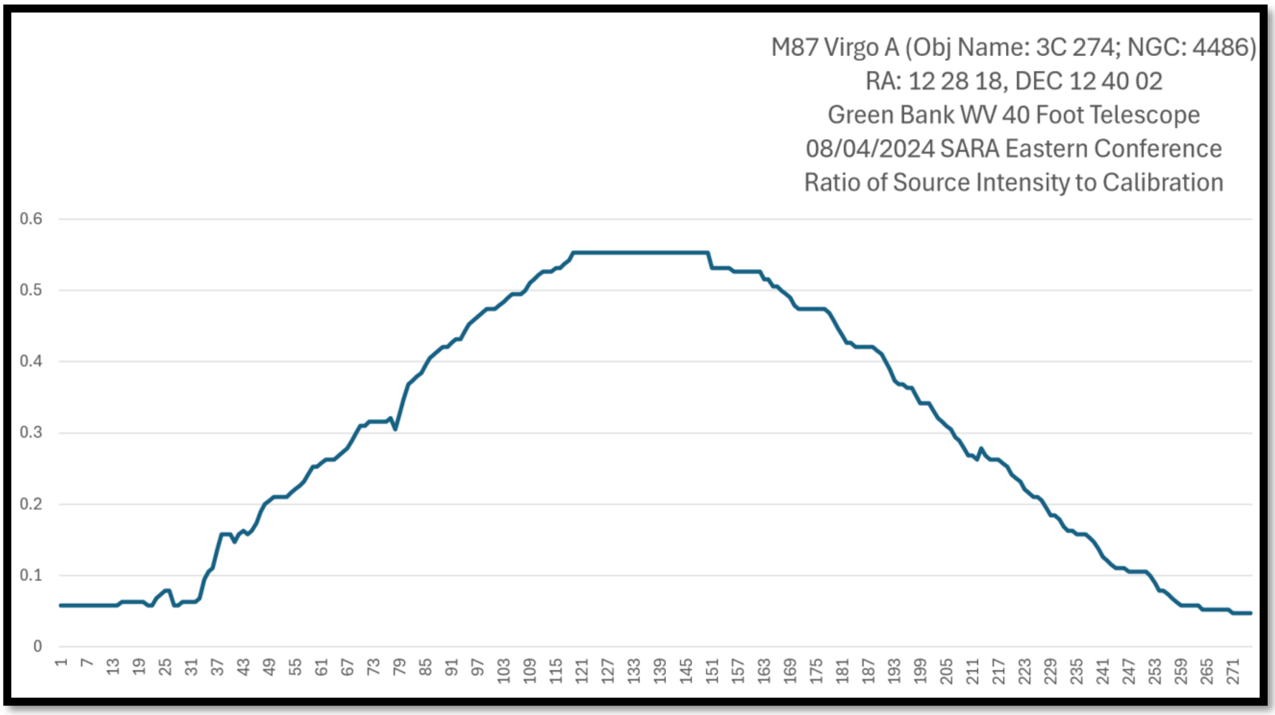

Figure 8: Ratio of Source Intensity to Calibration Intensity of Virgo A

Discussion

Two points of interest in looking at the data

1) The slope of the signal's amplitude is steeper early on and does not dissipate as quickly as when the signal was first detected, see Figure 9. Basically, the antenna is picking up signal intensity much faster as the galaxy comes within the beamwidth. Over time, it seems the galaxy "slows" down and the intensity of the signal does not drop off as quickly as it came in.
    a. Mr. Nathan Butts commented that "On H1 measurements, usually the slope corresponds to relative velocity of the incoming H1 signals to the observer's position, but without knowing the units of the values it's hard to say if this is actual doppler shift or something else."
    b. Mr. Marcus Leech commented "If you look at the Bonn/Astropeiler sky maps, available on NASA Sky View, you can see, in the logarithmic scaling, a slight sky temperature difference in the average background "across" M87. That's probably where your asymmetry is coming from. A single-dish radiometer cannot distinguish the background from the object you're looking at."

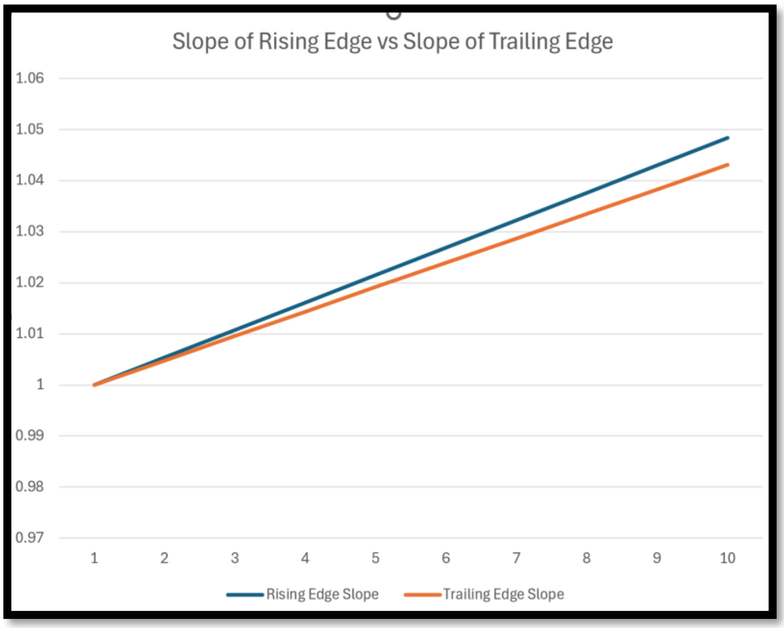

Figure 9: Slopes of the rising edge of the data (left side of the graph in Figure 8) versus the slope of the trailing edge of the curve (right side of the graph in Figure 8).

Data from NASA's High Energy Astrophysics Science Archive Research Center (HEASARC) [5] was used to understand the temperature gradient across M87 as well as to determine if that temperature gradient could cause the varying slopes seen during this observation, as Mr. Marcus Leech commented.

In looking at the data from HEASARC, Figure 10, you can see that there does appear to be a temperature gradient across the face of the image.

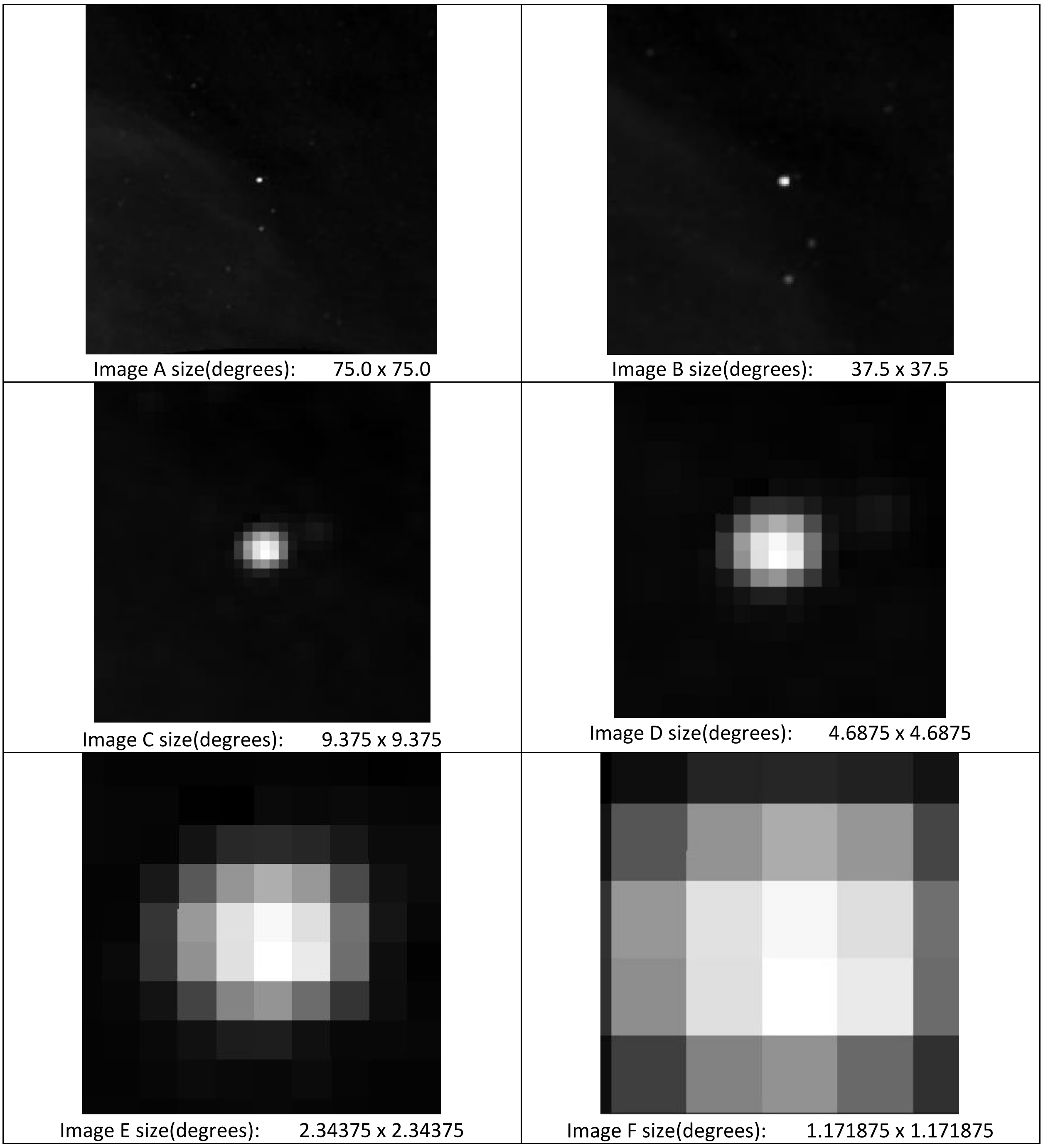

Figure 10: Images A – F are images taken from the 1420 MHz (Bonn) all sky survey of M87 zoomed in at different ratios [4]

Data in Figure 10 Image A was taken with the Bonn Stockert 25m telescope, see Figure 11. It was distributed on the NRAO Images from the Radio Sky CD-ROM. This image was delivered as a four-map mosaic but was combined into a single map before being included in SkyView [4].

Image color table:	
Image scaling:	Log, values range from 0.0 to 14239.2001953125
Image size(degrees):	75.0 x 75.0
Image size(pixels):	300 x 300
Requested Center:	m 87
Requested Center:	187.705931, 12.391123
Coordinate System:	J2000.0
Map projection:	Tan
Sampler:	NNSampler
Provenance:	Max Planck Institute for Radio Astronomy, generated by P. Reich and W. Reich
Copyright:	Max-Planck-Institut fur Radioastronomie (permission for educational and private non-commercial use granted without further request)

Figure 11: 1420MHz (Bonn): Bonn 1420 MHz Survey Taken from NASA GSFC Sky View [4]

2) There are a few interesting “blips” in the data (see figure 12). Items A – D in Figure 10 show discontinuous signal intensities with more occurring as the galaxy came into view versus as the galaxy was leaving the telescope beam.
    a. Mr. Marcus D. Leech commented, “Small-scale bumps and blips are normal. The electronics on the 40ft are pretty old at this point (unless they've been recently upgraded), PLUS, the RFI situation, world-wide, has been getting worse”
    b. Mike Otte also commented that “Wiggles are good”

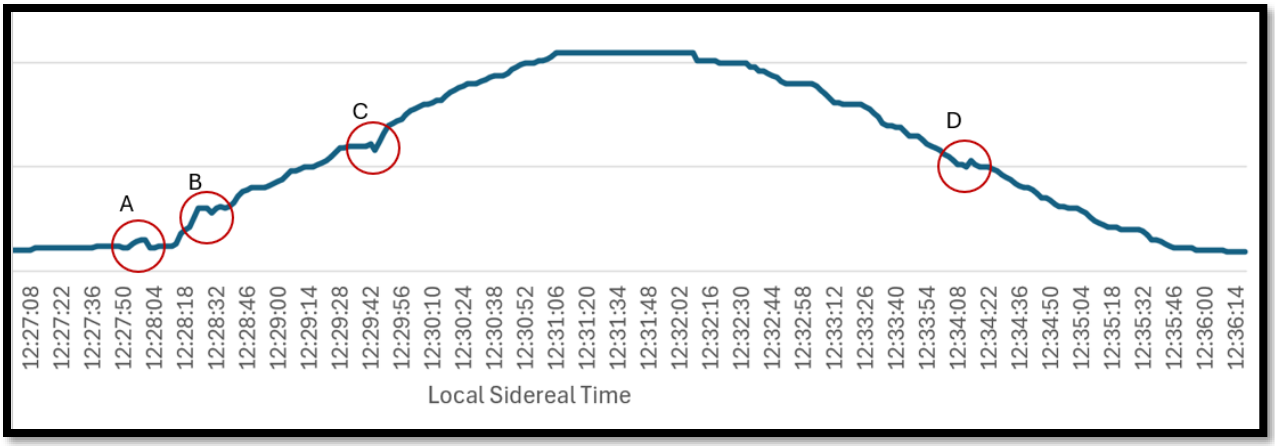

Figure 12: Areas in the data that seem interesting given that the signals are discontinuous, with more occurring early on when the galaxy first came into the telescope’s beam versus when the galaxy was leaving the telescope’s beam.

Open Questions and Future Work

This observation and subsequent data analysis was the author’s first radio astronomy exercise. As such, numerous things were learned and new questions and challenges surfaced. As a result of this observation and data analysis there were a few things that the author needs to gain a better understanding of:

- Need to understand how right ascension and local sidereal time is calculated in order to calculate an observation list for transit telescopes
- Regarding the 40-foot telescope and possibly others (e.g., 20 meter), when analyzing the data are we simply looking at the changes in amplitude or what else we can we tell from the data? The author is assuming a “reference voltage” is needed like in embedded systems, if that is true then the author needs to understand how to obtain the “reference voltage”?

- As with anything, one must thoroughly understand the tools they use when doing precision work. And this goes without saying in using the 40-foot telescope, the author needs a better understanding of the telescope (e.g., understanding all the steps, getting data in electronic format, understand rate at which recorder moves, understand calibration, understand sources of noise, etc.)
- The author needs to gain a better understanding in doing data analysis of the observations
- The author would like to take readings of Virgo A using 20 meter and compare and contrast the two observations
- Ideally, the author would have liked to understood the timing of the data collection so that better analysis on the rate at which the galaxy moved in front of the antenna.
- Multiple observations to be able to better conclude if the slopes of the curve are correlated with the temperature gradient across M87
- The author needs to and would like to study the HEASARC better to determine if there are correlations between the temperature gradient across the surface of M87 and the data obtained from the forty foot telescope in Green Bank.

Conclusion

Observations of Messier 87 were performed using Green Bank's forty-foot radio telescope during the 2024 SARA Eastern Conference. On August 4, 2024 observations were taken of the elliptical galaxy and the data was converted into electronic format and analyzed. Presented in this paper is that observational procedure and observational data. Although nothing of great significance can be reported as to what the data revealed, one item of significance to the author was that I was able to confirm a prediction for when a galaxy was to appear in front of the telescope versus actually seeing the galaxy as it moved across the telescope's beamwidth. This particular observation was the author's first attempt at observing the radio sky and it left the author with more questions than answers, as I am sure every veteran of radio astronomy probably agrees.

References:

[1] https://www.messier-objects.com/messier-87-virgo-a/
[2] https://eventhorizontelescope.org/M87-one-year-later-proof-of-a-persistent-black-hole-shadow
[3] Bradley, Richard F., Benjamin Malphrus, Sue Ann Heatherly, Green Bank Observatory 40-Foot Radio Telescope Operator's Manual, 02/13/2017
[4] Reich, W., "A radio continuum survey of the northen sky at 1420 MHz - Part I", Astronomy and Astrophysics, Suppl. Ser., Vol. 48, p. 219-297 (1982)
[5] https://skyview.gsfc.nasa.gov/current/cgi/titlepage.pl
[6] https://plotdigitizer.com/app Web Application provided by Mike Otte to convert raw chart plots into electronic format

Journal Archives and Other Promotions

The rich and diverse legacy of member contributed content is available in the SARA Journal Archives. Table of contents for journals is available online at: SARA-Journal-Master-Index.xlsx (live.com)

The entire set of The Journal of The Society of Amateur Radio Astronomers is available by online download. It goes from the beginning of 1981 to the present (over 6000 pages of SARA history!)

All SARA journals and conference proceedings are available through the previous calendar year.

SARA Store (radio-astronomy.org/store.)

SARA Online Discussion Group

SARA members participate in the online forum at http://groups.google.com/group/sara-list. This is an invaluable resource for any amateur radio astronomer.

SARA Conferences

SARA organizes multiple conferences each year. Participants give talks, share ideas, attend seminars, and get hands-on experience. For more information, visit http://www.radio-astronomy.org/meetings.

What is Radio Astronomy?

Radio Astronomy is just what the name implies…. Astronomy observed at radio wavelengths instead of optical. But why do radio astronomy? Radio astronomy has expanded the knowledge of the universe about as much since its discovery in 1932 as optical has since humans first looked up at the sky. (The sky in the different frequencies or colors of radio are as different and varied as all of the flowers on Earth. Each frequency has its own information about what is happening in the universe.) This knowledge has been gained by both professional astronomers as well as amateurs, with amateurs contributing to this day.

Do I need a big dish and expensive equipment?

No. Complete beginner projects are available at the SARA store at very reasonable prices. You can monitor the Sun's effects upon our planet with SuperSID. This information is gathered for Stanford for research into our ionosphere and radio signal propagation. Another project is the detection the hydrogen line just like Dr. Ewen had done in 1951 for a fraction of the cost using the Scope in a Box kit.

That said, radio astronomy is like optical astronomy in that you can spend as much as you want to. Many amateurs push the lower boundaries of cost by using very low-cost receivers and low-noise low-cost amplifiers that were not available even a few years ago. (See the Scope in a Box kit in the store for examples of both.)

Is everything 'plug and play' and boring?

The kits mentioned above are a starting point which are mostly plug-and-play… that gets you started. After you have mastered the basics, where you go from there depends upon your interests. Monitoring pulsars is done by amateurs. (One even noticed a pulsar glitch before the professionals!) These amateurs are pushing the boundaries of what can be done. Papers are being published and discussions had about pulsar detection as well detection of a MASER with a 50-inch dish. Techniques on new detection methods are posted in the SARA forum and elsewhere. You are free to build your own equipment to receive the signals as well as software to collect and analyze the data.

What is SETI?

SETI is the Search for Extra-Terrestrial Intelligence. Some amateurs scan the sky and search for signals that might be from aliens. To date no one has received a definitive alien signal (professional or amateur), but the search continues. The search has resulted not just in better receiving equipment but also wide and lively discussions about how aliens might communicate and how they might be trying to contact us. Some of these techniques have interesting ideas for our own communication techniques here on Earth!

What should I do to get started?

You should start with reading our Introduction to Radio Astronomy and joining our online SARA Forum. Look at the SARA store to get a project to get your feet wet without much expense and minimal risk. We will work with you so you can succeed.

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The Society of Amateur Radio Astronomers is an all-volunteer organization. The best way to reach people on this page is by email with SARA in the subject line SARA Officers.

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Resources

Great Projects to Get Started in Radio Astronomy

Radio Observing Program

The Astronomical League (AL) is starting a radio astronomy observing program. If you observe one category, you get a Bronze certificate. Silver pin is two categories with one being personally built. Gold pin level is at least four categories. (Silver and Gold level require AL membership which many clubs have membership. For the bronze level, you need not be a member of AL.)

Categories include.
1) SID
2) Sun (aka IBT)
3) Jupiter (aka Radio Jove)
4) Meteor back-scatter
5) Galactic radio sources

This program is a collaboration between NRAO and AL. Steve Boerner is the Lead Coordinator and a SARA member.

For more information:
Steve Boerner
2017 Lake Clay Drive
Chesterfield, MO 63017
Email: sboerner@charter.net
Phone: 636-537-2495
http://www.astroleague.org/programs/radio-astronomy-observing-program

Radio Jove

The Radio Jove Project monitors the storms of Jupiter, solar activity and the galactic background. The radio telescope can be purchased as a kit, or you can order it assembled. They have a terrific user group you can join. http://radiojove.gsfc.nasa.gov/

INSPIRE Program

The INSPIRE program uses build-it-yourself radio telescope kits to measure and record VLF emissions such as tweeks, whistlers, sferics, and chorus along with man-made emissions. This is a very portable unit that can be easily transported to remote sites for observations.
http://theinspireproject.org/default.asp?contentID=27

SARA/Stanford SuperSID

Stanford Solar Center and the Society of Amateur Radio Astronomers have teamed up to produce and distribute the SuperSID (Sudden Ionospheric Disturbance) monitor. The monitor utilizes a simple pre-amp to magnify the VLF radio signals which are then fed into a high-definition sound card. This design allows the user to monitor and record multiple frequencies simultaneously. The unit uses a compact 1-meter loop antenna that can be used indoors or outside. This is an ideal project for the radio astronomer that has limited space. To request a unit, send an e-mail to supersid@radio-astronomy.org

Radio Astronomy Online Resources

SARA YouTube Videos: https://www.youtube.com/@radio-astronomy	Pisgah Astronomical Research Institute: www.pari.edu
AJ4CO Observatory – Radio Astronomy Website: http://www.aj4co.org/	A New Radio Telescope for Mexico - ORION 2021 01 20. Dr. Stan Kurtz https://www.youtube.com/watch?v=Q9aBWr1aBVc
Radio Astronomy calculators https://www.aj4co.org/Calculators/Calculators.html	National Radio Astronomy Observatory http://www.nrao.edu
Introduction to Amateur Radio Astronomy (presentation) http://www.aj4co.org/Publications/Intro%20to%20Amateur%20Radio%20Astronomy,%20Typinski%20(AAC,%202016)%20v2.pdf	NRAO Essential Radio Astronomy Course http://www.cv.nrao.edu/course/astr534/ERA.shtml
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RFSpace, Inc. http://www.rfspace.com	The Radio JOVE Project & NASA Citizen Science – ORION 2020.6.17. Dr. Chuck Higgins https://www.youtube.com/watch?v=s6eWAxJywp8&t=5s
CALLISTO Receiver & e-CALLISTO http://www.reeve.com/Solar/e-CALLISTO/e-callisto.htm	UK Radio Astronomy Association http://www.ukraa.com/
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Deep Space Object Astrophotography Part 1 -- ORION 2021 02 17. George Sradnov https://www.youtube.com/watch?v=Pm_Rs17KIyQ	Radio Jove Spectrograph Users Group http://www.radiojove.net/SUG/
European Radio Astronomy Club http://www.eracnet.org	Radio Sky Publishing http://radiosky.com
British Astronomical Association – Radio Astronomy Group http://www.britastro.org/baa/	The Arecibo Radio Telescope; It's History, Collapse, and Future - ORION 2020.12.16. Dr. Stan Kurtz, Dr. David Fields https://www.youtube.com/watch?v=rBZlPOLNX9E
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SETI League http://www.setileague.org	SARA Web Site http://radio-astronomy.org
NRAO Essential Radio Astronomy Course http://www.cv.nrao.edu/course/astr534/ERA.shtml	Simple Aurora Monitor: Magnetometer http://www.reeve.com/SAMDescription.htm
NASA Radio JOVE Project http://radiojove.gsfc.nasa.gov Archive: http://radiojove.net/archive.html https://groups.io/g/radio-jove	Stanford Solar Center http://solar-center.stanford.edu/SID/
Green Bank Observatory https://greenbankobservatory.org/ .	https://www.csiro.au/ There's a wealth of info on this site of the Australian National Science Agency. It's much more than just radio astronomy. Looking under "Research" opens a real family tree of interesting pages of things they are involved with.

Found an interesting Grote Reber link: https://www.utas.edu.au/groterebermuseum Their gallery is interesting, but sure wish they had some captions to indicate who and what some of it is about. I can guess, knowing some of Grote's stories, but others might need more info. Several pictures show the University of Tasmania 26m dish that was once one of the NASA worldwide Satellite Tracking and Data Network (STDN) dishes like the ones at the Pisgah Astronomical Research Institute (www.pari.edu). PARI's dishes were the first qualification units for that network.

For Sale, Trade and Wanted

At the SARA online store: radio-astronomy.org/store.

New on-demand store for SARA SWAG! https://saragifts.org/

Scope in a Box

radio-astronomy.org/store.

Kit of parts and software to build a working Radio Telescope to detect Hydrogen Line emissions. Available to USA addresses only at this time.

SuperSID Complete Kit

radio-astronomy.org/store.

SARA Publication, Journals and Conference Proceedings (various prices)

radio-astronomy.org/store.

SARA Journal Online Download

radio-astronomy.org/store.

The Journal archive covers the society journal "Radio Astronomy" from the founding of the organization in 1981 through the present. Articles cover a wide range of topics including cosmic radiation, pulsars, quasars, meteor detection, solar observing, Jupiter, Radio Jove, gamma ray bursts, the Itty Bitty Telescope (IBT), dark matter, black holes, the Jansky antenna, methanol masers, mapping at 408 MHz and more.

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These are the current items – more to come in the future!

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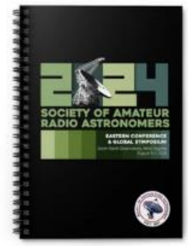

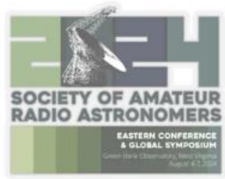


SOCIETY OF AMATEUR RADIO ASTRONOMERS
EST. 1981

SARA Brochure

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For further information, see our website at:
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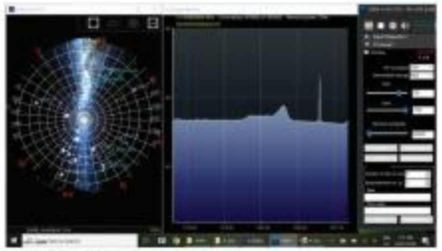
How to get started?

SARA has a made a kit of software and parts to detect the Hydrogen line signal from space. This is an excellent method to get started in radio astronomy. It teaches the principles of antenna design, signal detection, and signal processing. Read more about this and other projects on our web site.



Society of Amateur Radio Astronomers, Inc.

Founded 1981

Membership supported, nonprofit [501(c) (3)]
Educational and Radio Astronomy Organization

Knowledge through Common Research, Education and Mentoring

SARA members have been privileged to use this forty foot diameter drift-scan hydrogen line radio telescope every year at their annual meeting in Green Bank.

http://radio-astronomy.org

Why Radio Astronomy?

Because about sixty five percent of our current knowledge of the universe has stemmed from radio astronomy alone. The discovery of quasars, pulsars, black holes, the 3K background from the "Big Bang" and the discovery of biochemical hydrogen/carbon molecules are all the result of professional radio astronomy.

The Society of Amateur Radio Astronomers

SARA was founded in 1981, with the purpose of educating those interested in pursuing amateur radio astronomy.

The society is open to all, wishing to participate with others, worldwide.

SARA members have many interests, some are as follows:

SARA Areas of Study and Research:

- Solar Radio Astronomy
- Galactic Radio Astronomy
- Meteor Detection
- Jupiter
- SETI
- Gamma Ray/High Energy Pulse
- Detection
- Antennas
- Design of Hardware / Software

The members of the society offer a friendly mentor atmosphere. All questions and inquiries are answered in a constructive manner. No question is silly!

SARA offers its members an electronic bi-monthly journal entitled Radio Astronomy. Within the journal, members report on their research and observations. In addition, members receive updates on the professional radio astronomy community and, society news.

Once a year SARA meets for a three-day conference at the Green Bank Observatory in Green Bank West Va.

There is also a spring conference held at various cities in the Western USA. Previous meeting have been at the VLA in Socorro, NM and at Stanford University.

How do I get started?

Just as a long journey begins with the first step, the project you elect must start with a clear idea of your objectives. Do you wish to study the sun? Jupiter? Make meteor counts? Do you wish to engage in imaging radio astronomy? What you decide will not only determine the type of equipment you will need, but also the local radio spectrum.

How do amateurs do radio astronomy?

Radio astronomy by amateurs is conducted using antennas of various shapes and sizes, from smaller parabolic dishes to simple wire antennas. These antennas are connected to receivers and most of these receivers are software defined radios these days. Data from the receivers are collected by computers, and the received signals will be displayed as charts, graphs or maybe even sky maps. As diverse as the observed objects, so is are the instruments and tools used. SARA members will always be supportive to find good solutions for what one wishes to observe.

Is amateur radio astronomy instrumentation expensive?

Technical information freely circulated in our monthly journal helps amateurs to obtain good low noise equipment from off the shelf assemblies, or to build their own units. The actual cash investment in radio astronomy equipment need not exceed that of any other hobby.

What are amateurs actually looking for in the received data?

The aim of the radio amateur is to find something new and unusual. Just as an amateur optical observer hopes to notice a supernova or a new comet, so does an amateur radio observer hope to notice a new radio source, or one whose radiation has changed appreciably.

The Reber Telescope at NRAO. Constructed by Grote Reber in 1937 in his back yard in Wheaton, Illinois

SARA Members discussing the IBT (Itty Bitty Telescope)