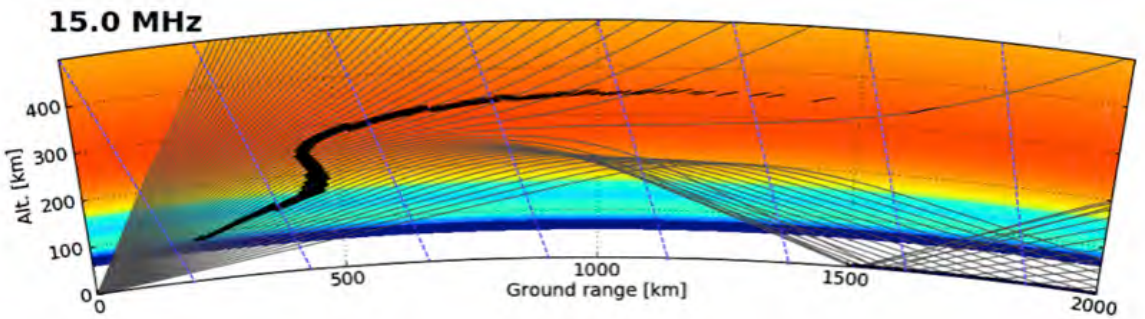
HamSCI - Ham Radio Science Citizen Investigation - Connecting Communities

Gwyn Griffiths G3ZIL



RSGB

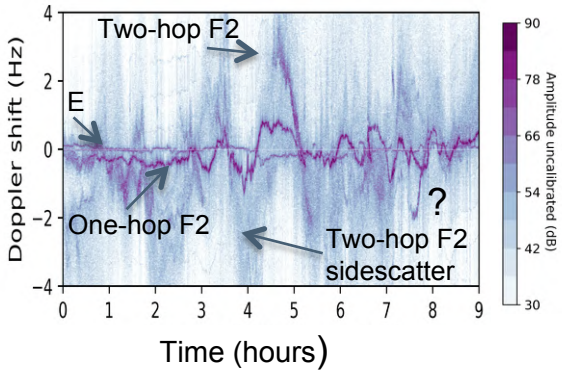
RSGB 2024 Convention

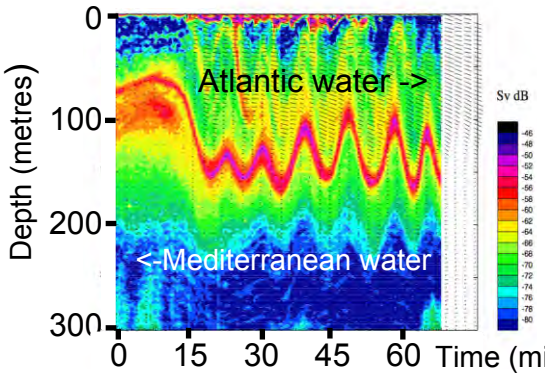
My Background: Oceanography

Aurora from the ISS at 400 km.

Ocean Internal Waves - ISS view

Travelling Ionospheric Disturbance. 10 MHz WWV-N8GA.





Amplitude and Doppler from 38 kHz sonar. Gwyn Griffiths,1998.

HamSCI

HamSCI Booth at Dayton Hamvention

A collective that allows university researchers to collaborate with the amateur radio community in scientific investigations.

Objectives:

1. **Advance** scientific research and understanding through amateur radio activities.
2. **Encourage** the development of new technologies to support this research.
3. **Provide** educational opportunities for the amateur radio community and the general public.

Founder/Lead HamSCI Organizer: Dr. Nathaniel A. Frissell, W2NAF The University of Scranton

Citizen Science

"*Scientific work, for example collecting information, that is done by ordinary people without special qualifications, in order to help the work of scientists.*"

Some of 30 NASA-supported projects involving Citizen Scientists:

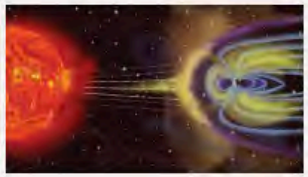
science.nasa.gov/citizen-science/

Dr Frissell W2NAF NASA
Grant $481,260 in 2021 etc.

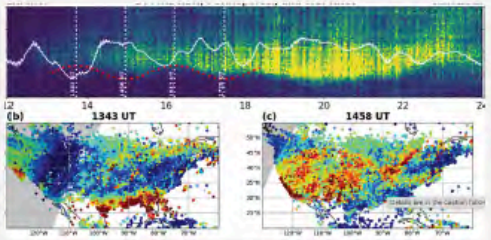
HamSCI's Citizen Science Focus

Recent projects sponsored by HamSCI

Investigating Solar Eclipse Effects on the Ionosphere



Designing and building Personal Space Weather Stations (PSWS)

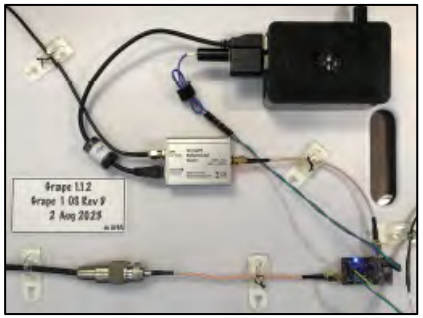


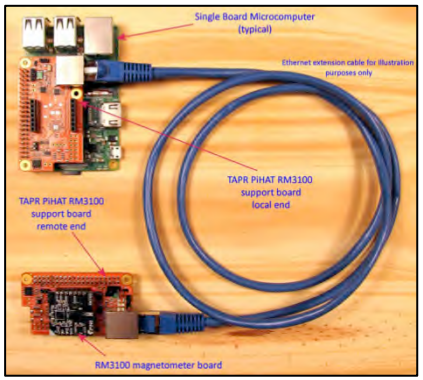
Searching for Traveling Ionospheric Disturbances using PSKReporter and WSPRNet data

THE UNIVERSITY OF SCRANTON A JESUIT UNIVERSITY · CASE WESTERN RESERVE UNIVERSITY · NJIT New Jersey Institute of Technology · MIT HAYSTACK OBSERVATORY · TAPR · NSF · ARDC · NASA Partner

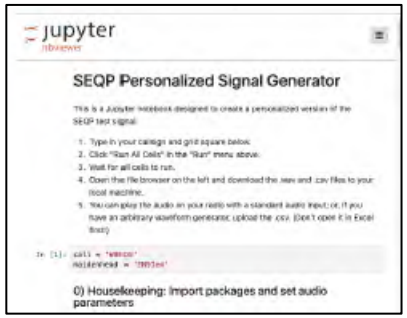
Amateurs and Scientists Together

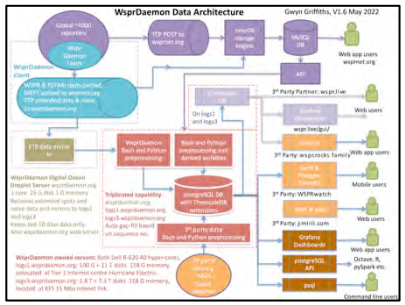
Building…





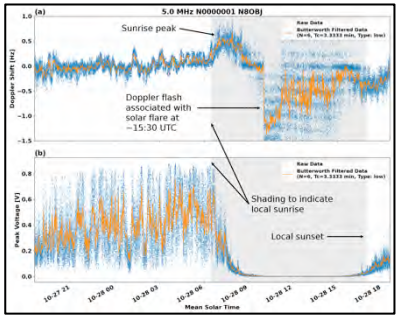
Coding…

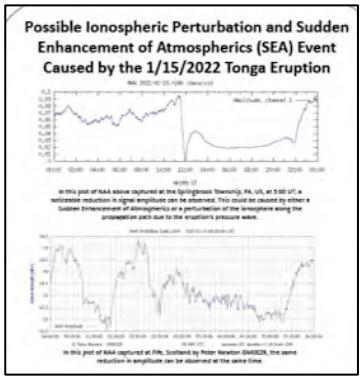




Operating…

Analysing…





Credits: HamSCI collectively and Nathaniel Frissell W2NAF, Gary Mikitin AF8A, Gary Crum KK7DV, Tom Bunch WO7I, Rob Robinett AI6VN, the Grape team, TAPR and the Magnetometer team, Kristina Collins KD8OXT and colleagues, Jonathan Rizzo KC3EEY.

Building: GRAPE Receivers

GRAPE = Great Radio Amateur Propagation Experiment

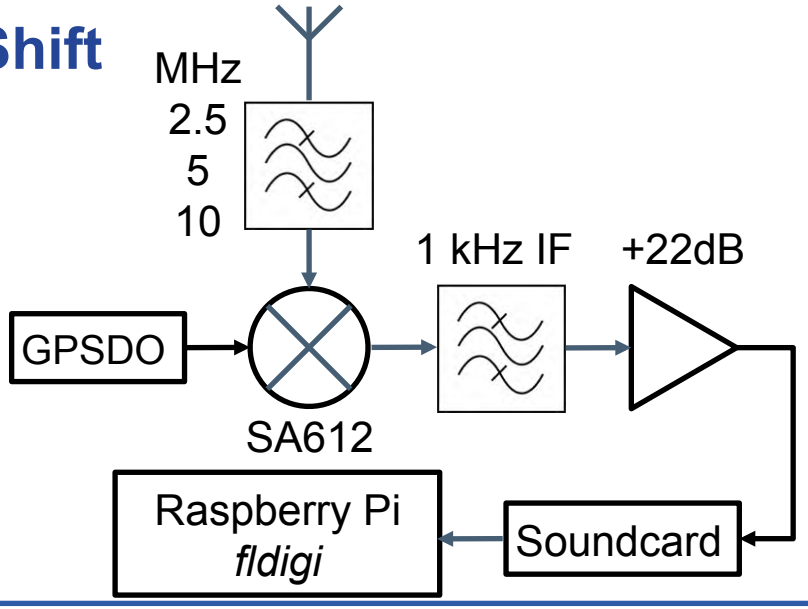
Original GRAPE Receivers led by John Gibbons N8OBJ,
Case Western Reserve University / Case Amateur Radio Club W8EDU.

Primary objective: Measure Doppler Shift of HF standards stations e.g. WWV.

GRAPE v1

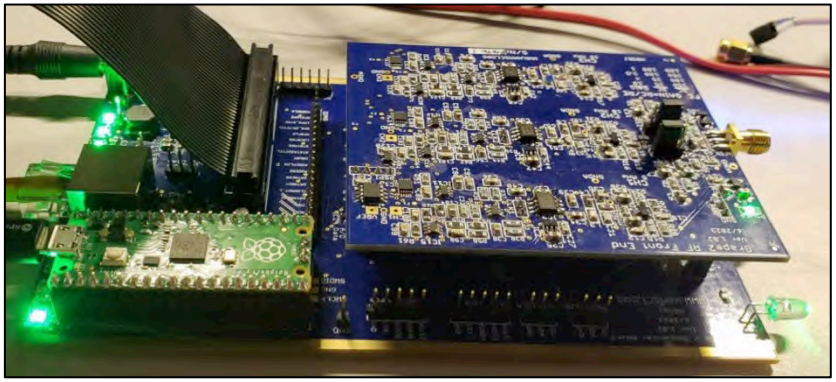
- Single Frequency
- Build it yourself
- hamsci.org/grape1

Image courtesy John Gibbons N8OBJ and HamSCI



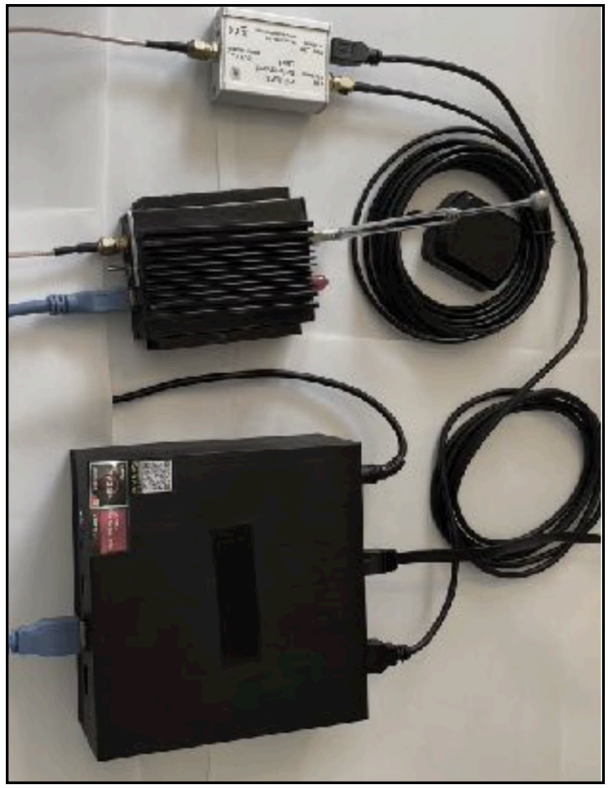
GRAPE v2 Receiver

- Three Simultaneous Frequency Bands, triplicated analogue RF as GRAPE v1
- Preassembled
- 30 deployed to volunteers for April 2024 Total Eclipse



Images courtesy John Gibbons N8OBJ and HamSCI

WsprDaemon GRAPE

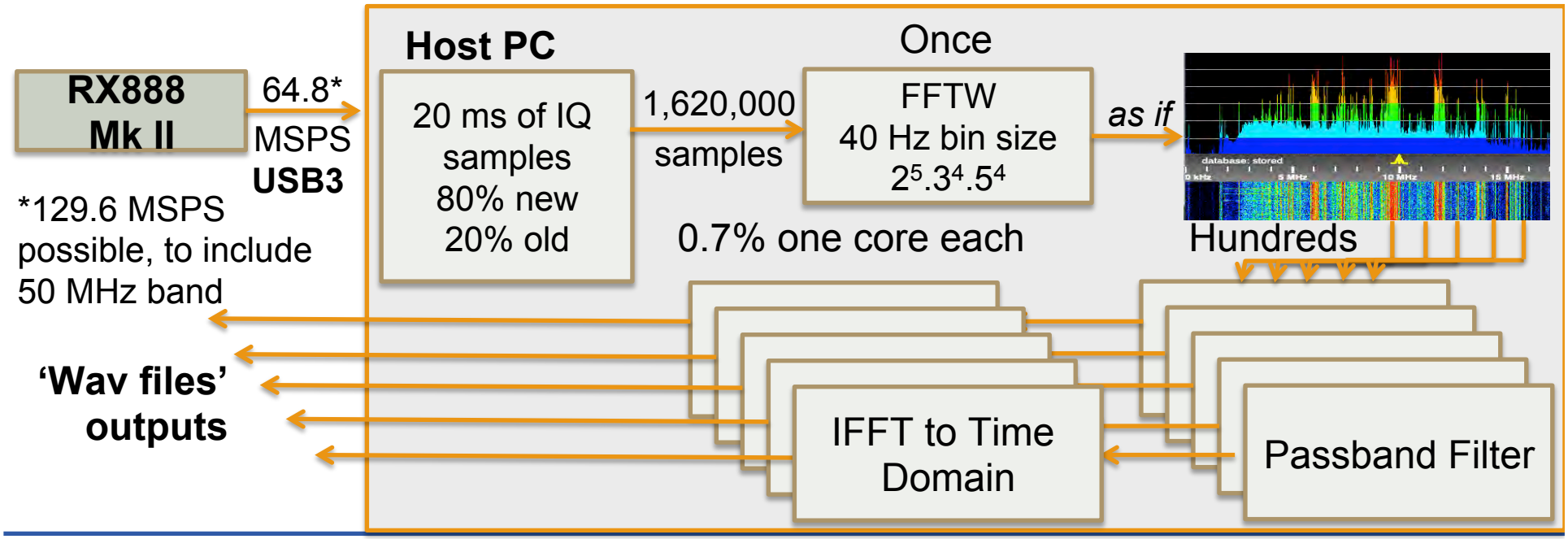


An initiative of HamSCI member Rob Robinett AI6VN using commercially available hardware.

- GPS Disciplined Oscillator, here Leo Bodnar Mini, output at 27 MHz
- The RX888 Mk II SDR. **No FPGA**
  1 kHz – 30 MHz spectrum 64.8 MSPS
  16 bit IQ output over USB3 to host PC.
- Suitable miniPC: Beelink AMD Ryzen 5, 5560U 16 GB six core 2.3 – 4.0 GHz

Coding: ka9q-radio

"General purpose open source software, using fast convolution and IP multicast to digitally down convert, demodulate and distribute 100s of simultaneous channels." Phil Karn https://github.com/ka9q/ka9q-radio/



Coding: WsprDaemon

Rob Robinett
AI6VN
github.com/
rrobinett/
wsprdaemon

Wav files input

All WSPR bands

All FT4/FT8 bands

All time station bands

wsprd* & jt9* decoders

FT4*/FT8* decoders

wav2grape** digital_RF coder

Same host PC

**Franco K4VZ & Rob AI6VN & MIT Haystack

wsprnet.org
wsprdaemon.org

pskreporter.info

pswsnetwork.caps.ua.edu

Outputs to databases

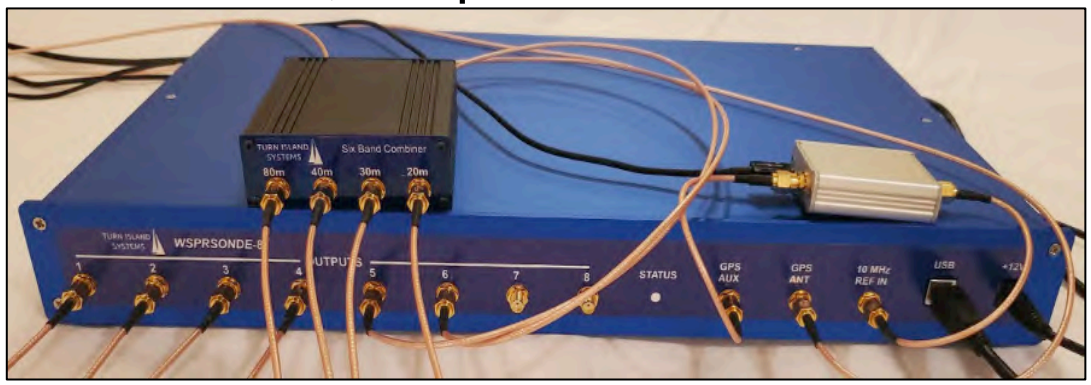
* Decoders from WSJT-X under GNU GPLv3

Building: WsprSonde TX

Design and build by HamSCI member Paul Elliott WB6CXC

Goal: Transmit stable, accurate multiband WSPR & FST4W

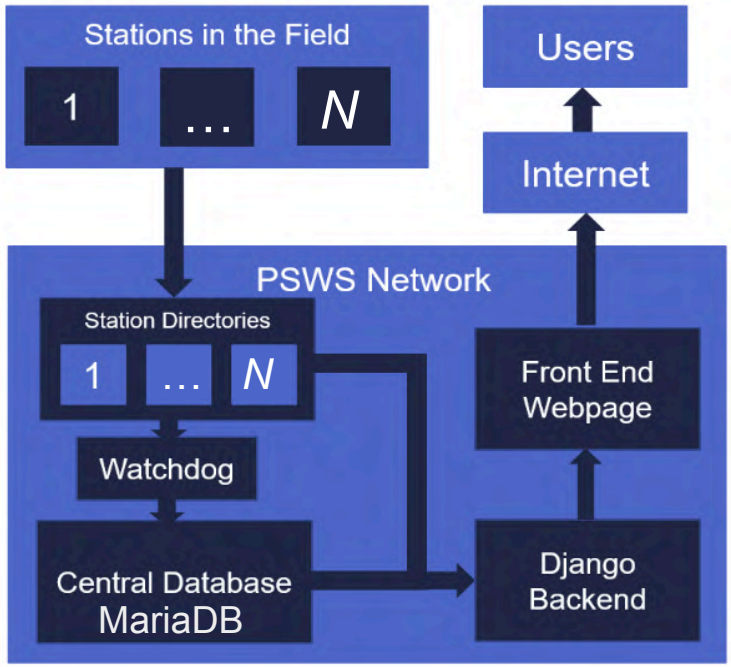
- ❑ CW ID each frame: *WSPRSONDE WB6CXC*
- ❑ Up to 8-band simultaneous 1 W outputs
- ❑ Combiners to one multiband tx antenna, or split
- ❑ One 10 MHz GPSDO
- ❑ One 12 V power supply
- ❑ No Internet connection required, but useful
- ❑ Eight WsprSondes in use



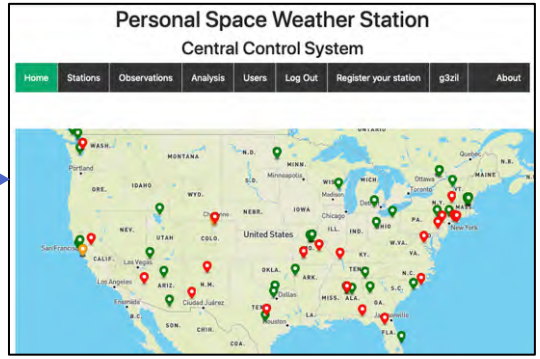
More information at turnislandsystems.com/

Coding: pswsnetwork.caps.ua.edu

Database for GRAPE receivers

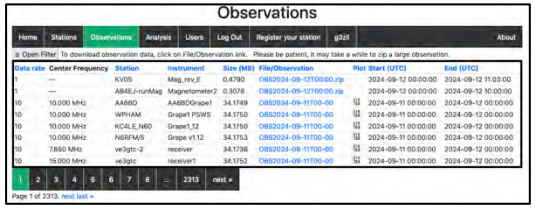


From Liddle, Muscolino, Engelke and Atkison, University of Alabama

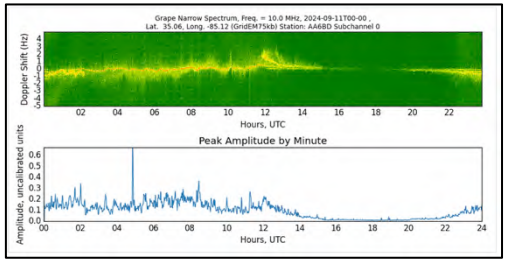


Web page

Station Map

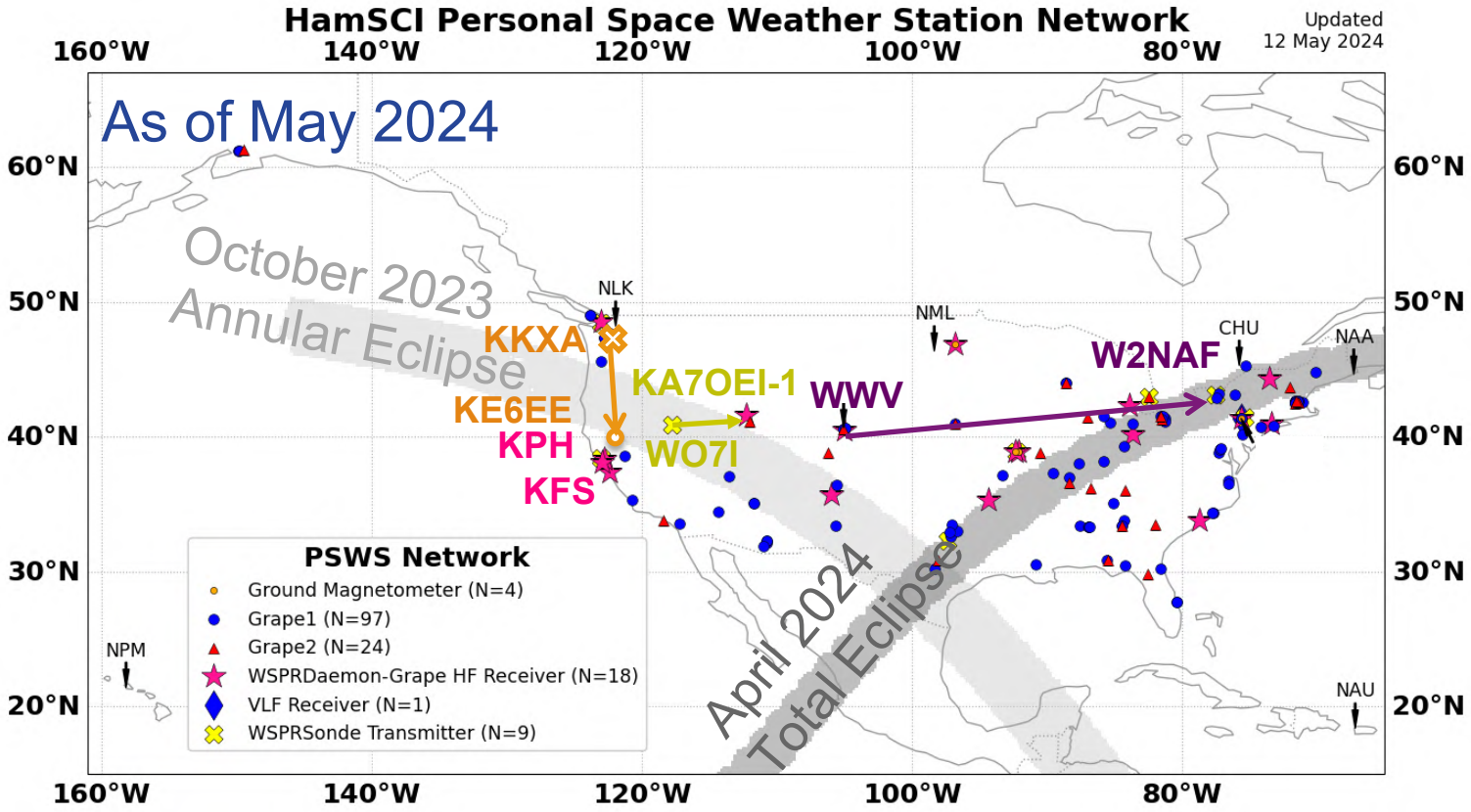


Searchable list of stations and data



Quick-look plots

HamSCI PSWS Network



Examples today

Medium Wave
KKXA to KE6EE

Noise
KPH and KFS

WSJT-X FST4W
WO7I to KA7OEI

Freq standard
WWV to W2NAF

Operating: '23 and '24 Eclipses

HamSCI sponsored two different community operating events during 2023 and 2024 eclipses.

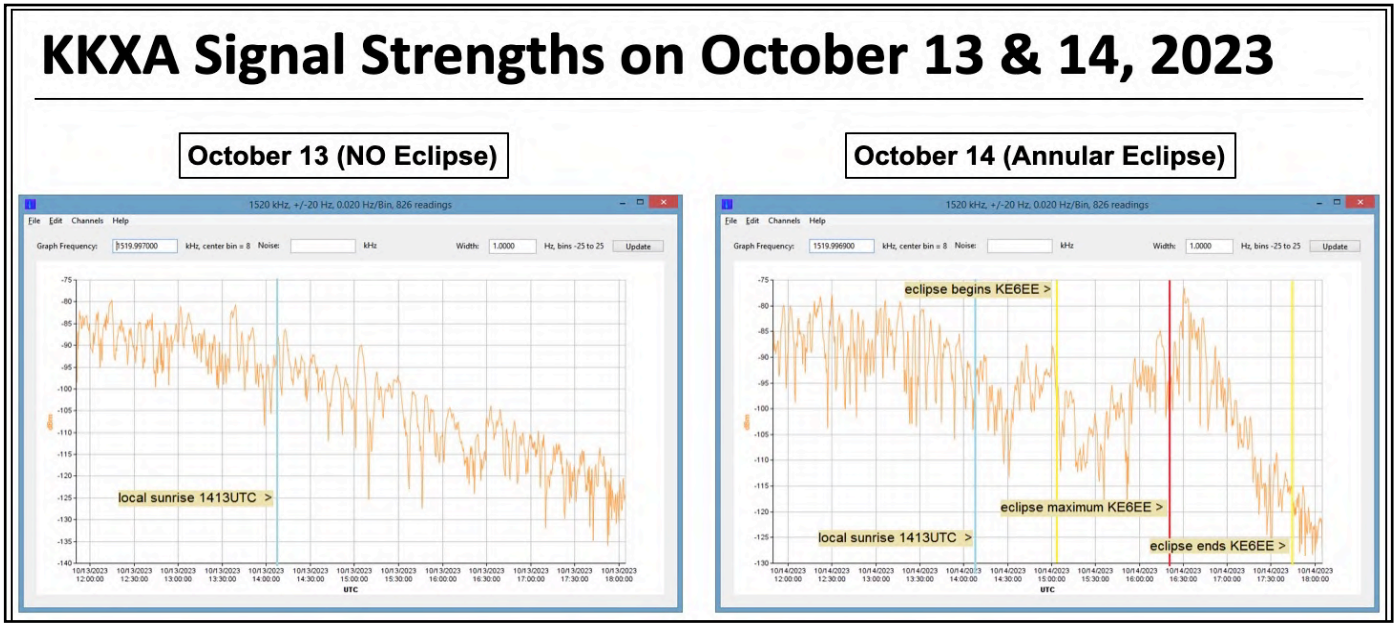
Solar Eclipse QSO Party: A fairly typical low band contest, for CW, SSB and FT8.

Gladstone Signal Spotting Challenge: A unique event, a contest of sorts, but for one-way transmissions (using digital modes WSPR and FST4W from the WSJT-X software package).

Combined, those events created over 760,000 data points (October 2023 eclipse), and over 1.1 million data points (April 2024 eclipse).

Operating: MW Eclipse Reception

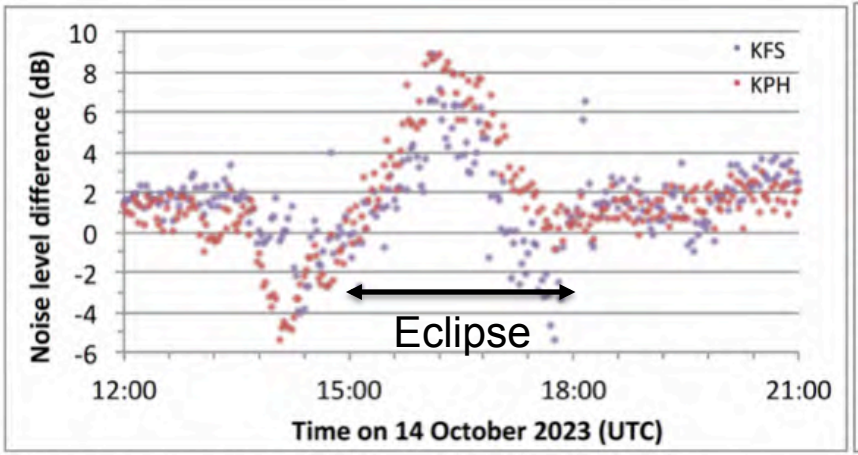
These graphs demonstrate the value of control data: Signals received one day prior to the eclipse *vs*. enhancement at 1520 kHz during eclipse on1024 km path Washington State to KE6EE California.



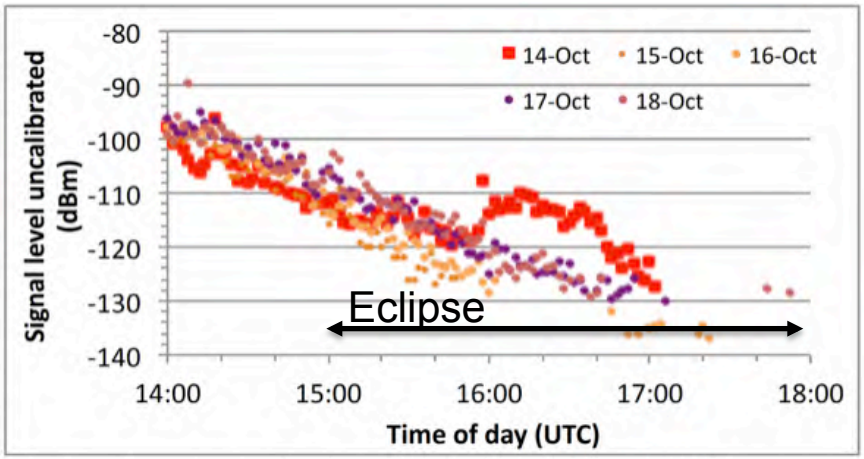
Courtesy Nick Hall-Patch VE7DXR Coordinator of HamSCI MW listener eclipse observations.

Analysis: Noise and Signal Level

Careful graphing of FST4W mode received signals show noise levels peaking (left) and signal levels peaking (right) during the October eclipse. Data from WsprDaemon database.



7.040 MHz noise anomaly, the difference between noise on 14 October and the average at the same time over the previous five days for KFS and KPH

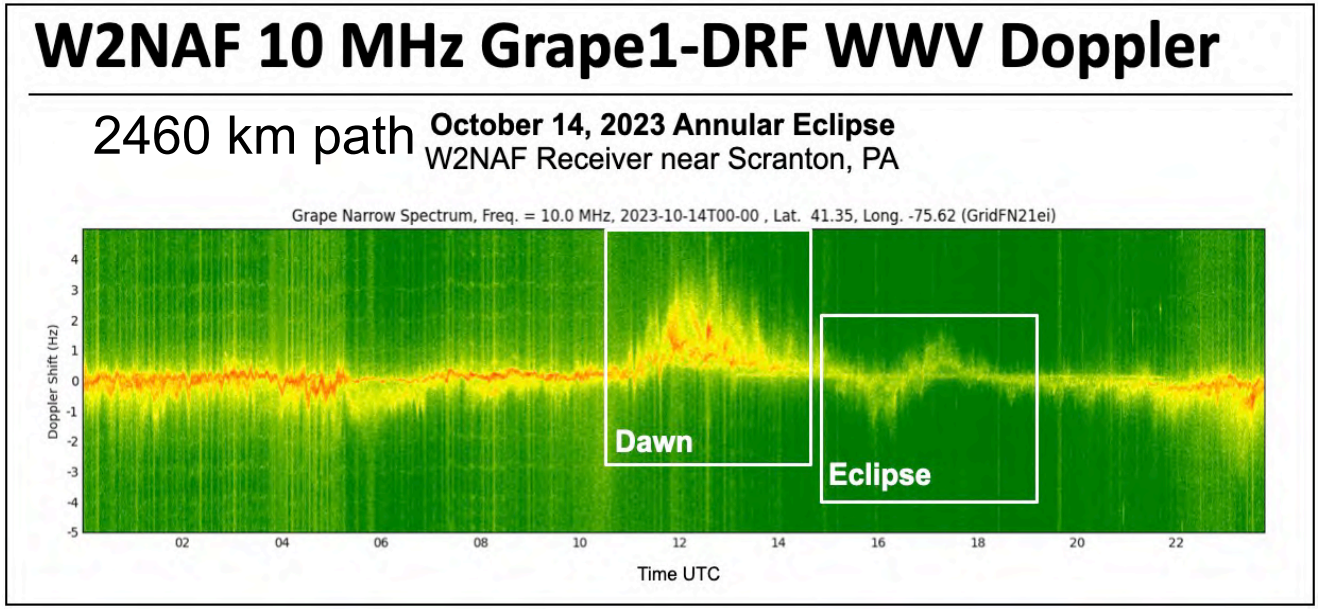


Signal levels on 14-18 October 2023 at KA7OEI-1 for FST4W transmissions from WO7I on 3.57 MHz.

Plots generated by Gwyn Griffiths, G3ZIL

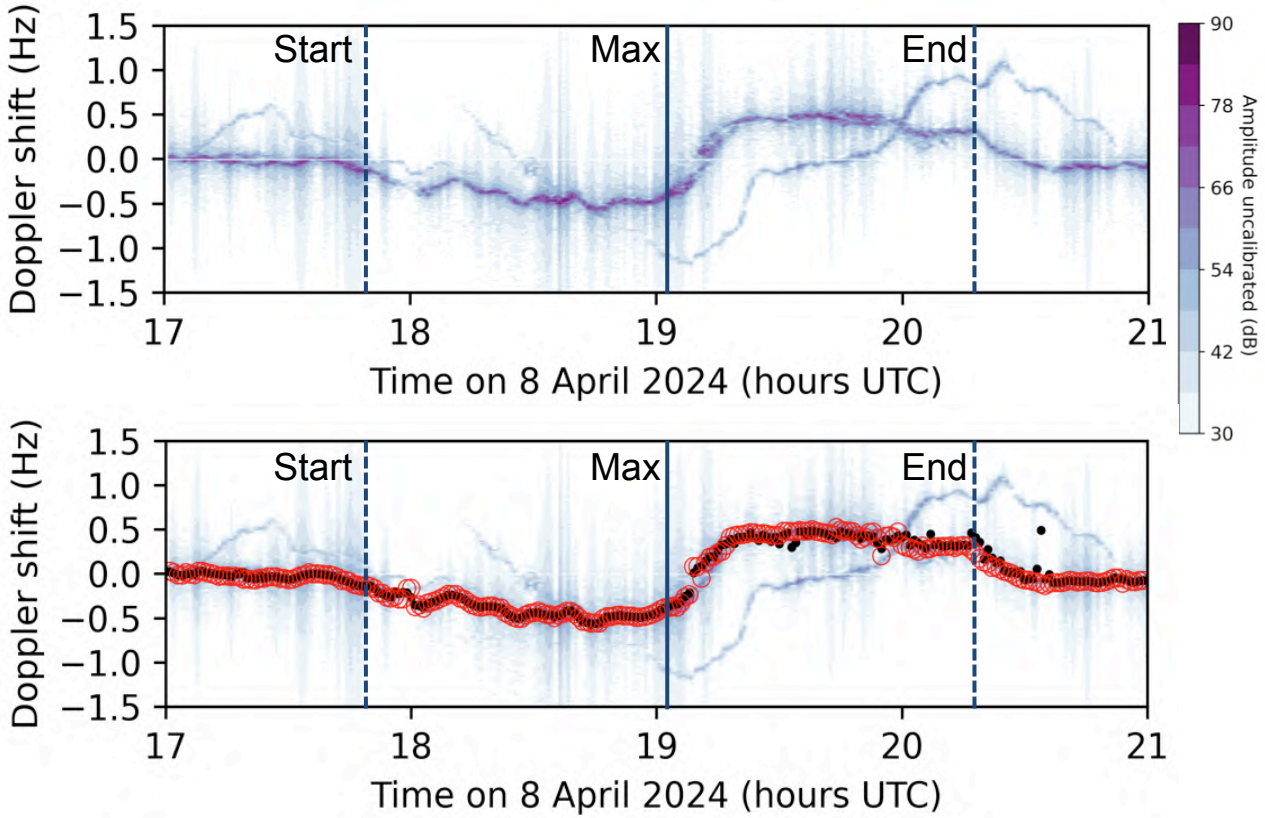
Operating: Quick-Look Doppler

Here is evidence that the ionosphere's eclipse reaction is similar to its dusk and dawn reaction - important for validating the receive system.



Spectrograms automatically available on HamSCI Personal Space Weather Station website: pswsnetwork.caps.ua.edu next day.

Analysis: Beyond Quick-Look



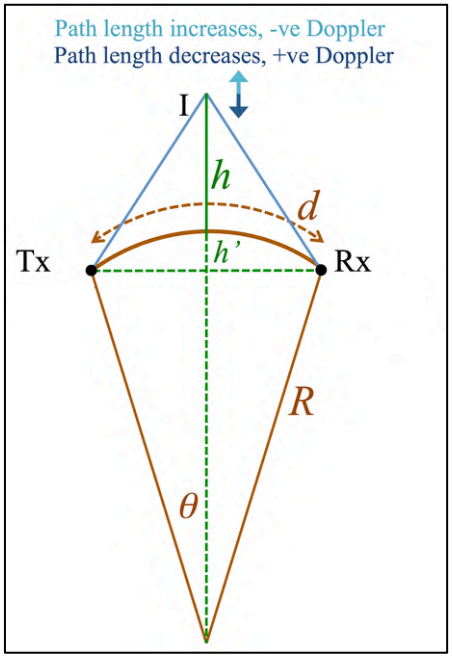
20 MHz WWV to W2NAF
8 April 2024 eclipse

Spectrogram from downloaded digital_RF

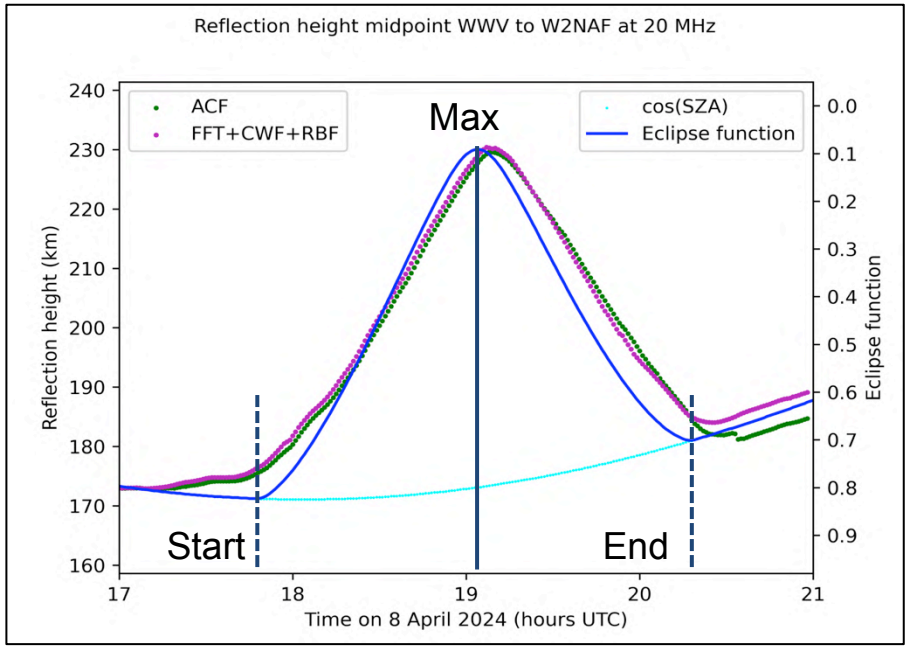
But we need values for Doppler peaks. Results from two algorithms:

- Autocorrelation at one lag
- Continuous Wavelet Transform of FFT spectra

Analysis: Doppler to Height



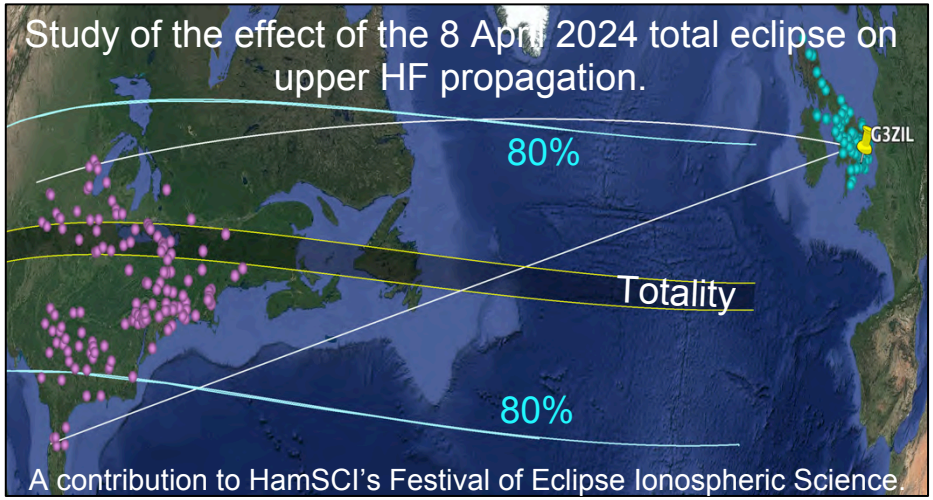
- Find height *h* once from ray trace or ionosonde.
- Calculate initial path length Tx > I > Rx as P_0
- From Doppler obtain *rate of change* of path length Tx > I > Rx i.e. $\Delta P/\Delta t$
- Multiply $\Delta P/\Delta t$ by time interval Δt to get path length increment ΔP
- Calculate new path length $P_1 = P_0 + \Delta P$
- Use geometry to calculate new height *h*
- Repeat every minute

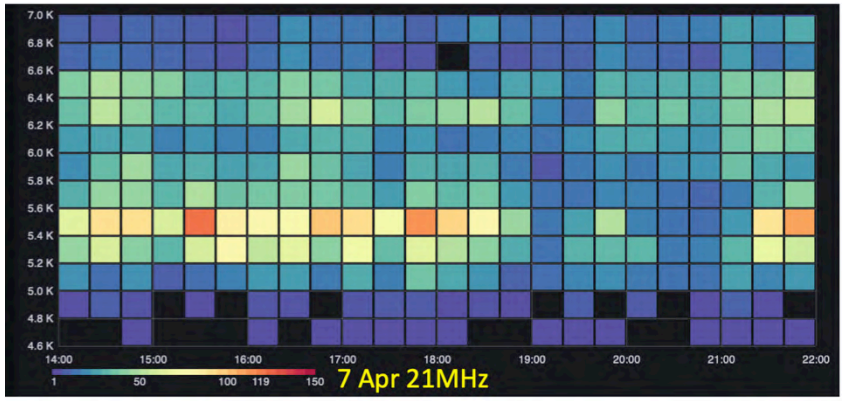


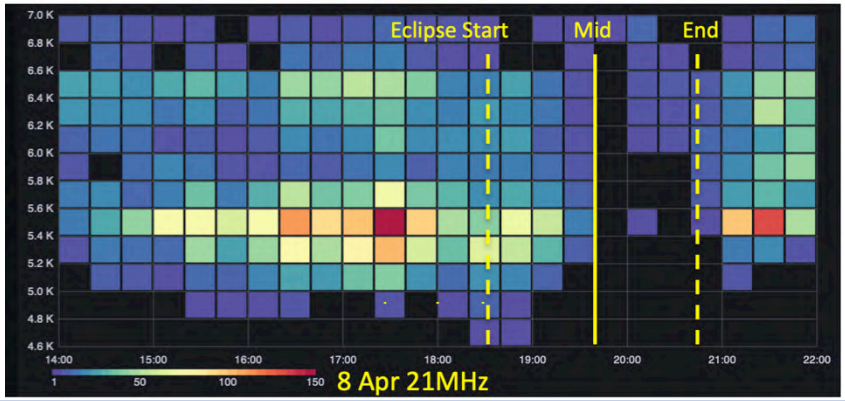
Eclipse function minimum at 19:04 UTC
Maximum height at 19:09 UTC

More details in my article: Measuring height of reflection at HF. *RSGB RadCom,* 100(8): 42-44.

Operating: Crowd-sourced Data

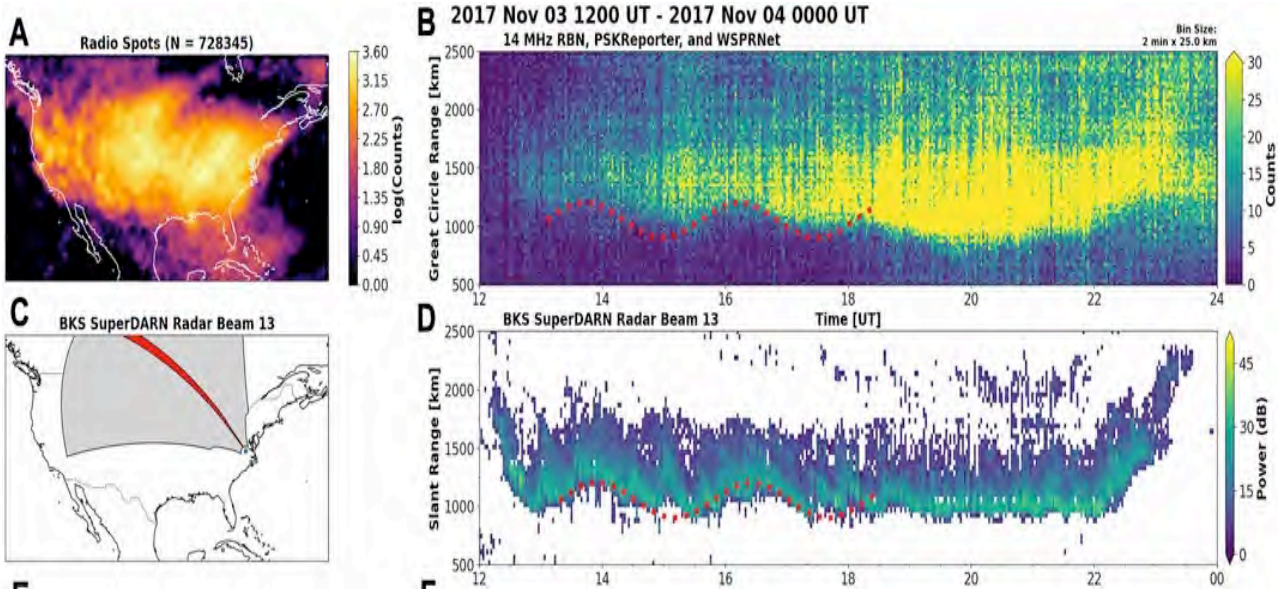






Some 49 UK WSPR tx active on 21 MHz. Heat-maps of spot counts with time and range bins to 149 receivers in N. America. The one spot during 19:40–19:59 was GW4SYI received at N5TNL, Arizona.

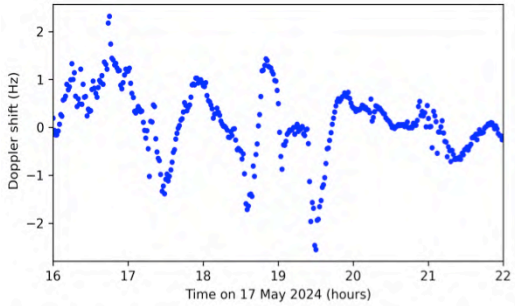
Operating: Crowd-sourced LSTID

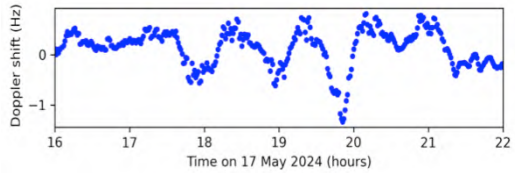


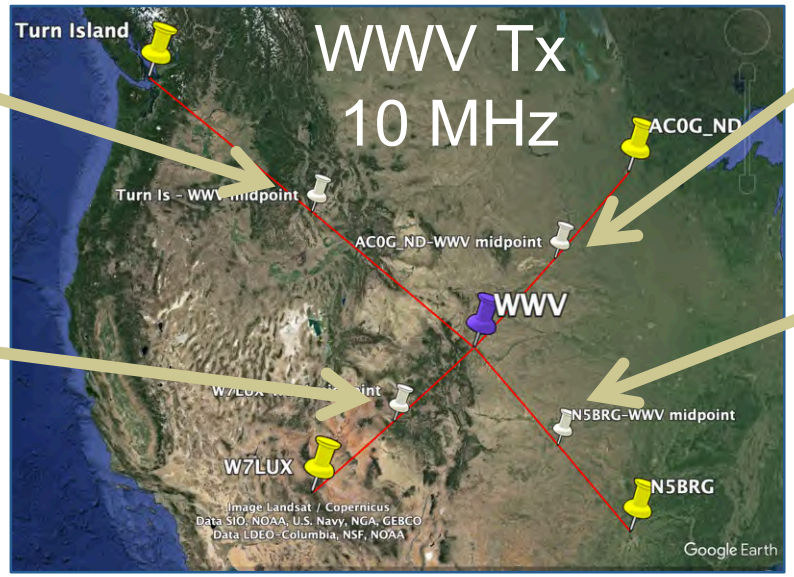
(W2NAF) Frissell, N. A. et al. (2022). First observations of **L**arge **S**cale **T**raveling **I**onospheric **D**isturbances using automated amateur radio receiving networks. Geophys. Res. Lett. 49, e2022GL097879.
23 citations to date

Analysis: LSTID Measurements

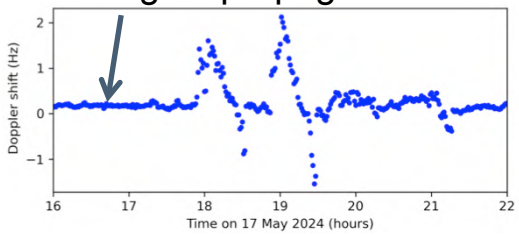
A **L**arge **S**cale **T**ravelling **I**onospheric **D**isturbance on 17 May 2024 modulated the F2 propagation-path length, inducing Doppler shifts on paths across the continental USA. **Period:** 58 minutes. **Wavelength:** 3160 km

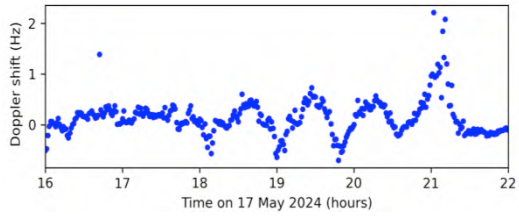




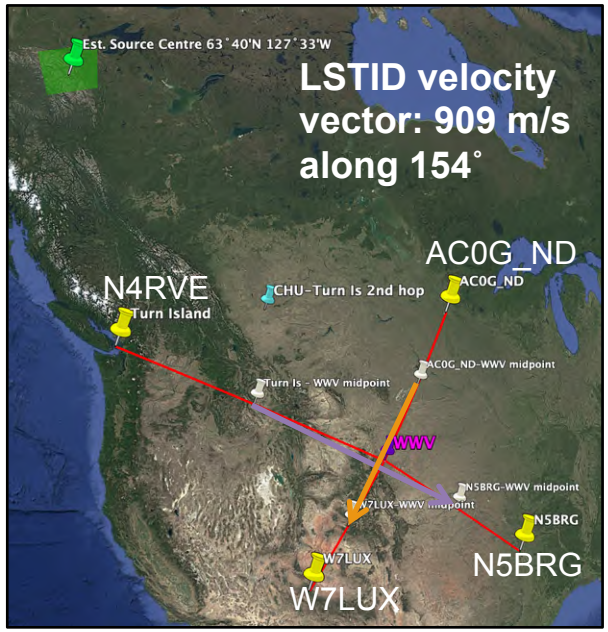


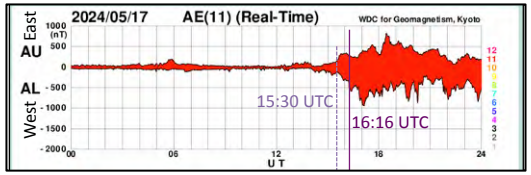
E region propagation



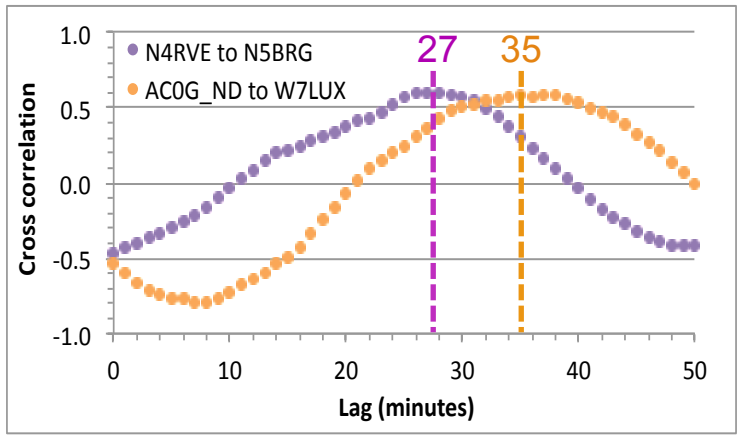


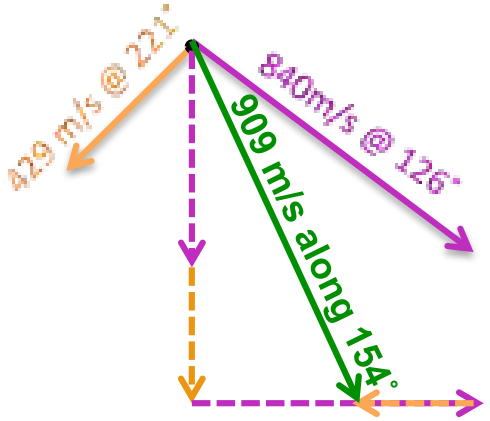
Analysis: LSTID Trace to Source





Cross-correlate pairs: Slide Doppler shift of earlier arrival forward in time. Time max correlation reached is LSTID travel time between the midpoints.





Resolve to East and North components then add: 909 m/s along 154˚

HamSCI: Next Generation

Communities that look to the future are Effective Communities

Rachel AC8XY
Analysing Grape eclipse data

Erin KQ4IES
Experiences at the National Radio Astronomy Observatory

Mia KQ4MGZ
Students operating Greenbank Radio Telescope

Kukkai
Using ray tracing to reproduce WSPR variations

Veronica KD2UHN
Medium-scale Travelling Ionospheric Disturbances

Shae and Walter
Cat-Sat: a student Cube-Sat with amateur radio

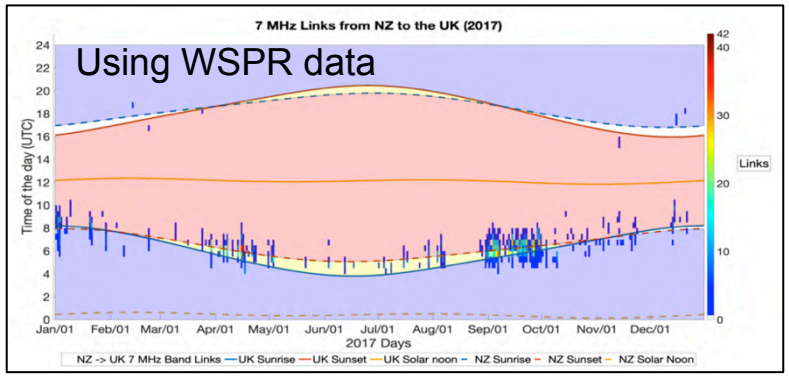
Nathaniel KB1QHX
Collegiate Amateur Radio

and others…

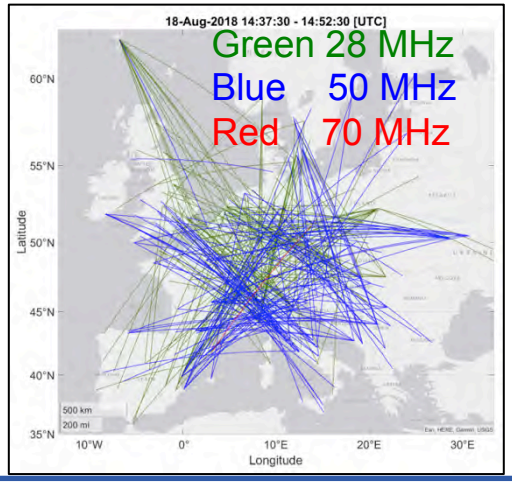
Research: UK Doctoral Theses

Supervised by Prof. Cathryn Mitchell M0IBG, Professor of Radio Science, Bath University. *Cathryn convened a HamSCI UK workshop alongside the 2017 RSGB Convention*.

Sam Lo PhD et al. *A Systematic Study of 7 MHz Greyline Propagation Using Amateur Radio Beacon Signals*, 2022. Atmosphere **13**: 1340.



Chris Deacon G4IFX PhD et al. *Consolidated Amateur Radio Signal Reports as Indicators of Intense Sporadic E Layers*, 2022. Atmosphere **13**: 906.



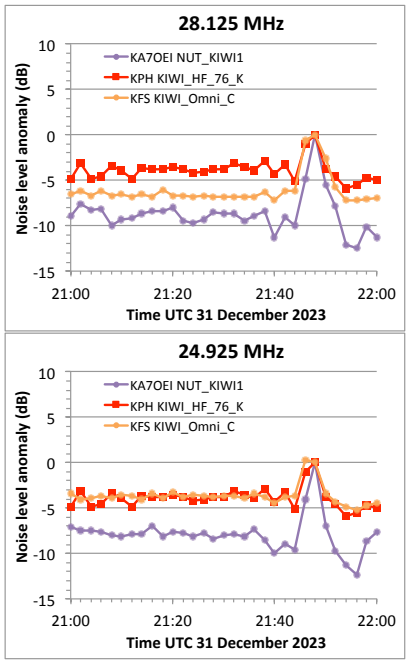
Two of Chris' talks: HamSCI 2024, Cleveland, Ohio. *Why is sporadic-E propagation so weird?* RSGB Convention 2024, Milton Keynes.

Analysis: Professional Guidance

From Dr Phil Erickson W1PJE,
Director MIT Haystack Observatory

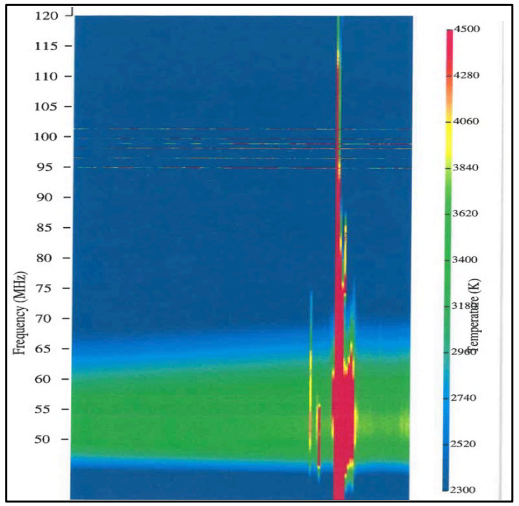
Hi Gwyn…,

You mentioned: "what may be a solar noise burst." *My distinguished colleague Dr. Alan EE Rogers … operates the precisely calibrated EDGES system … So I asked Alan and sure enough, on 31 December 2023, the system caught a spectacular radio burst signature associated with the X5 solar flare.*

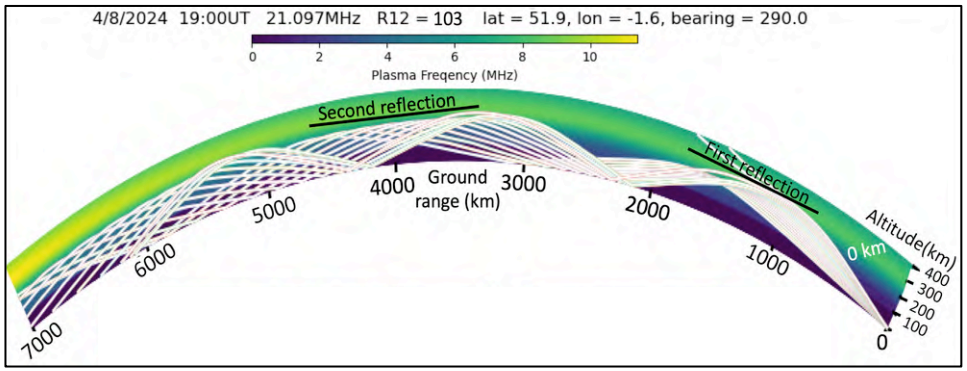


Noise level anomalies from uncalibrated KiwiSDRs with 21:48 UTC at 0dB.

Noise Temperature Spectrum 40-120MHz from EDGES system courtesy Dr Alan Rogers, MIT

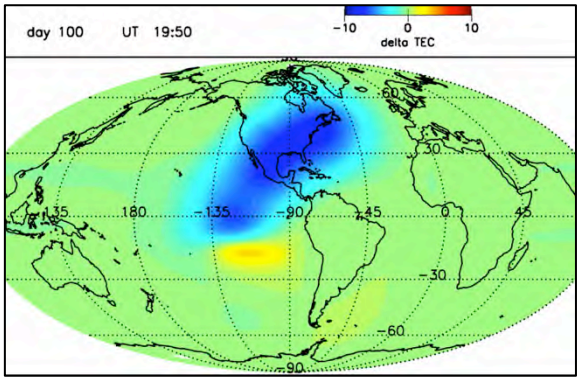


Toolkit: Ray Trace and Modelling



PyLap is a ray trace toolbox, a wrapper for PHaRLAP. HamSCI member Bill Liles NQ6Z began PyLap, completed as a Masters thesis at Scranton by Devin Diehl. /github.com/hamsci/pylap

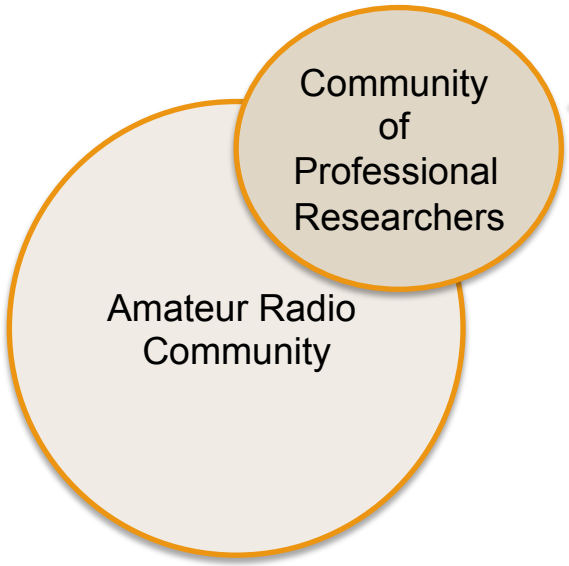
Devin added data import from a physics-based ionosphere model - SAMI3 from Dr. Joe Huba to PyLap.



Supported by grants to Dr Frissell W2NAF at Scranton:
NSF AGS-2230345, AGS-2230346, AGS-2045755, NASA 80NSSC23K1322

Influence: Setting Challenges

Connected Communities are Effective Communities



Two 'White Papers' to US National Academy of Sciences Decadal Survey on Heliophysics 2022

Distilled into a peer reviewed paper in a special issue of Frontiers in Astronomy and Space Sciences 2023

frontiers | Frontiers in Astronomy and Space Sciences

Heliophysics and amateur radio: citizen science collaborations for atmospheric, ionospheric, and space physics research and operations

Nathaniel A. Frissell, John R. Ackermann, Jesse N. Alexander, Robert L. Benedict, William C. Blackwell Jr., Rachel K. Boedicker, Stephen A. Cerwin, Kristina V. Collins, Scott H. Cowling, Chris Deacon, Devin M. Diehl, Francesca Di Mare, Timothy J. Duffy, Laura Brandt Edson, William D. Engelke, James O. Farmer, Rachel M. Frissell, Robert B. Gerzoff, John Gibbons, Gwyn Griffiths, Sverre Holm, Frank M. Howell, Stephen R. Kaeppler, George Kavanagh, David Kazdan, Hyomin Kim, David R. Larsen, Vincent E. Ledvina, William Liles, Sam Lo, Michael A. Lombardi, Elizabeth A. MacDonald, Julius Madey, Thomas C. McDermott, David G. McGaw, Robert W. McGwier Jr., Gary A. Mikitin, Ethan S. Miller, Cathryn Mitchell, Aidan Montare, Cuong D. Nguyen, Peter N. Nordberg Sr., Gareth W. Perry, Gerard N. Piccini, Stanley W. Pozerski Jr., Robert H. Reif, Jonathan D. Rizzo, Robert S. Robinett, Veronica I. Romanek, Simal Sami, Diego F. Sanchez, Muhammad Shaaf Sarwar, Jay A. Schwartz, H. Lawrence Serra, H. Ward Silver, Tamitha Mulligan Skov, David A. Swartz, David R. Themens, Francis H. Tholley, Mary Lou West, Ronald C. Wilcox, David Witten, Ben A. Witvliet and Nisha Yadav

https://hamsci.org/article/white-papers-submitted-national-academy-sciences-decadal-survey

https://www.frontiersin.org/journals/astronomy-and-space-sciences/articles/10.3389/fspas.2023.1184171/full

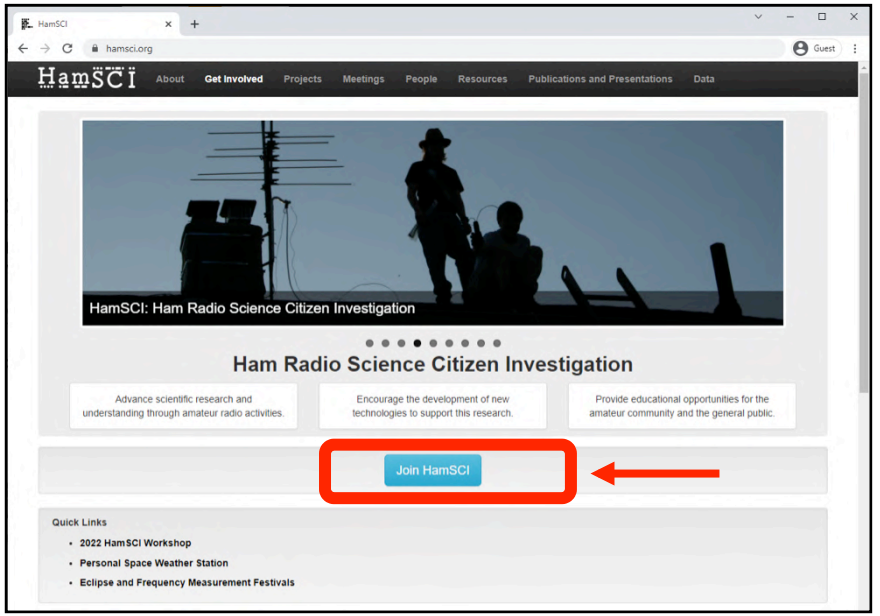
Getting Involved

HamSCI now has over 1200 members!

Join by visiting hamsci.org

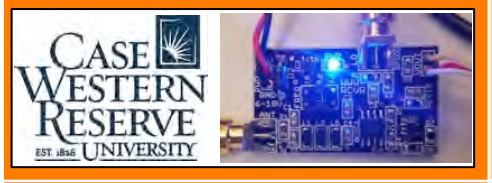
Our main **Google Group** is open discussion for all things related to HamSCI.

Plus, many specialized email lists!



For HamSCI publications: Visit scholar.google.com search 'hamsci'
Also a bibliography at hamsci.org/publications

HamSCI Zoom Telecons - Join Us

TAPR/Tech Telecon	**Engineering telecon to support the development of high performance sensing systems, such as the WSPR Daemon/ GRAPE RX-888**	**Mondays 9 PM Eastern (Tuesdays 0100 UTC)**
GRAPE Telecon 	**Telecon to support engineering and science related to the GRAPE (low-cost) Personal Space Weather Station.**	**Thursdays 10 AM Eastern (1400 UTC during DST)**
HamSCIENCE Telecon	**Telecon to discuss science questions, observations and findings releated to HamSCI's research interests.**	**Thursdays at 4 PM Eastern (2000 UTC during DST)**

hamsci.org/get-involved

theRSGB @theRSGB YouTube

RSGB 2024 Convention

Acknowledgments
Connecting Communities in Action

HamSCI is especially grateful for the:

- Support of US National Science Foundation Grants AGS-2002278, AGS-1932997, AGS-1932972, AGS-2045755, AGS-2230345, and AGS-2230346.
- Support of the NASA SWO2R Grant 80NSSC21K1772.
- Support of Amateur Radio Digital Communication (ARDC).
- Amateur radio community volunteers directly contributing to HamSCI projects.
- Amateur radio community who produced and provided the observations mentioned here, and the operators of qrz.com, RBN (reversebeacon.net), WSPR (wsprnet.org), and PSKReporter (pskreporter.info)
- Use of Open Source Software used in HamSCI analysis: Ubuntu Linux, Python (van Rossum, 1995), matplotlib (Hunter, 2007), NumPy (Oliphant, 2007), SciPy (Jones et al., 2001), pandas (McKinney, 2010), xarray (Hoyer & Hamman, 2017), iPython (Pérez & Granger, 2007), and others (e.g., Millman & Aivazis, 2011).

In addition, Gwyn Griffiths is grateful to Rob Robinett AI6VN for WsprDaemon, the late Craig McCartney, W6DRZ, KFS Radio Club, and Globe Wireless Radio Services for KFS, and the Maritime Radio Historical Society for KPH. PyLap uses the HF propagation toolbox, PHaRLAP, created by Dr. Manuel Cervera, Defence Science and Technology Group, Australia, available by request.

Find out more…

https://hamsci.org/

https://www.youtube.com/@hamsci

http://wsprdaemon.org

www.rsgb.org