Amateur Radio: An Integral Tool in Magnetospheric and ITM Physics Research

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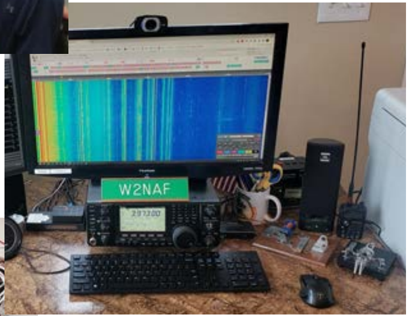
What is Amateur (Ham) Radio?

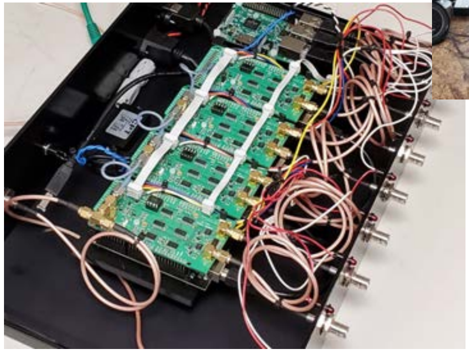
- **Hobby for Radio Enthusiasts**
  - Communicators
  - Builders
  - Experimenters
- **Wide-reaching Demographic**
  - All ages & walks of life
  - Over 760,000 US amateurs; ~3 million Worldwide
    (http://www.arrl.org/arrl-fact-sheet)
- **Licensed by the Federal Government**
  - Basic RF electrical engineering knowledge
  - Licensing provides a path to learning and ensures a basic interest and knowledge level from each participant
  - Each amateur radio station has a government-issued “call sign”
- **Ideal Community for Citizen Science**

Note: A license is not required to operate a PSWS because it is receive only!

University of Scranton Students at W3USR



W2NAF Home Station



N8UR multi-TICC: Precision Time Interval Counter

HamSCI Ham radio Science Citizen Investigation

hamsci.org/dayton2017

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

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

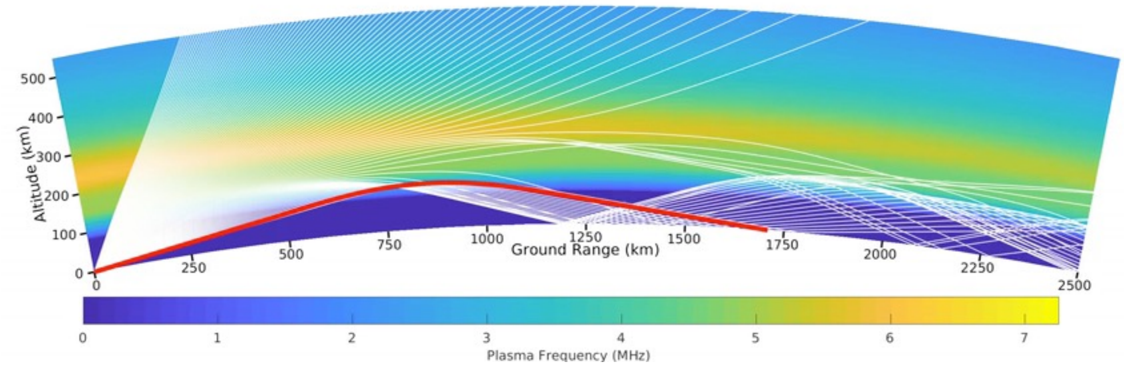
Objectives:

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.

Amateur Radio Frequencies and Modes

Eclipsed SAMI3 - PHaRLAP Raytrace

1600 UT 21 Aug 2017 • 14.03 MHz • TX: AA2MF (Florida) • RX: WE9V (Wisconsin)



PHaRLAP: Cervera & Harris (2014), https://doi.org/10.1002/2013JA019247
SAMI3: Huba & Drob (2017), https://doi.org/10.1002/2017GL073549
Amateur Radio and the Eclipse: Frissell et al. (2018), https://doi.org/10.1029/2018GL077324

- **Amateurs routinely use HF-VHF transionospheric links.**
- **Often ~100 W into dipole, vertical, or small beam antennas.**
- **Common HF Modes**
  - Data: FT8, PSK31, WSPR, RTTY
  - Morse Code / Continuous Wave (CW)
  - Voice: Single Sideband (SSB)

	Frequency	Wavelength
LF	135 kHz	2,200 m
MF	473 kHz	630 m
	1.8 MHz	160 m
HF	3.5 MHz	80 m
	7 MHz	40 m
	10 MHz	30 m
	14 MHz	20 m
	18 MHz	17 m
	21 MHz	15 m
	24 MHz	12 m
	28 MHz	10 m
VHF+	50 MHz	6 m
	And more…	

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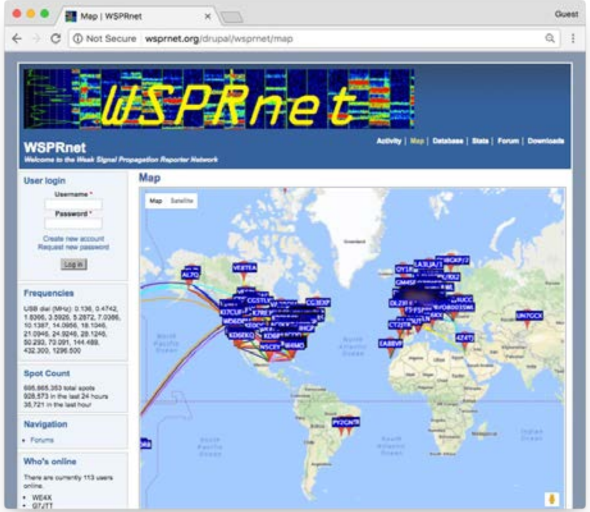
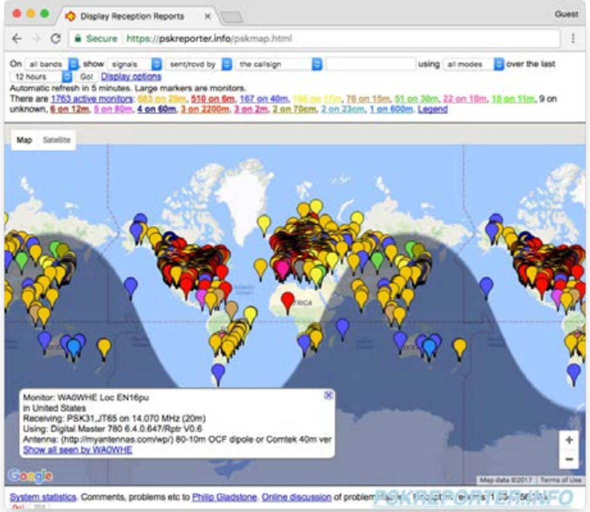
Amateur Radio Observation Networks

Reverse Beacon Network (RBN)
reversebeacon.net



WSPRNet
wsprnet.org



PSKReporter
pskreporter.info

- Quasi-Global
- Organic/Community Run
- Unique & Quasi-random geospatial sampling

- Data back to 2008 (A whole solar cycle!)
- Available in real-time!

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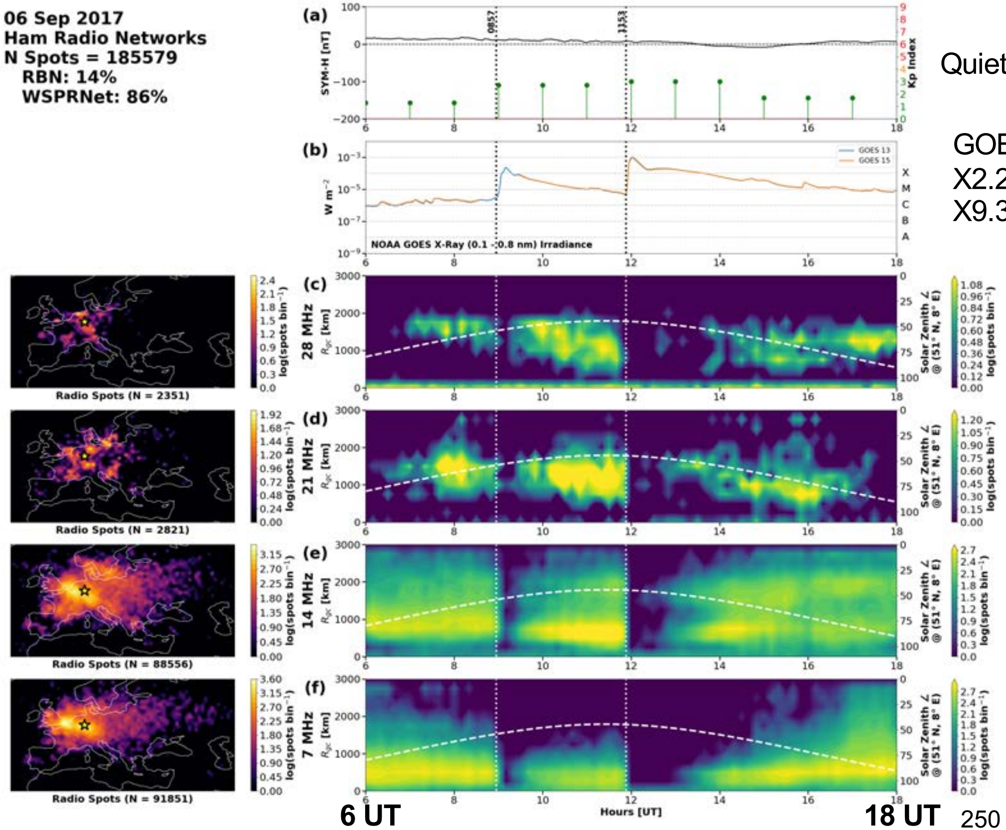
EU Response to Solar Flares

- Europe in daylight.
- Both flares cause deep blackouts.



Quiet Kp/Sym-H

GOES Flares
X2.2: 0857 UT
X9.3: 1153 UT

28 MHz

21 MHz

14 MHz

7 MHz

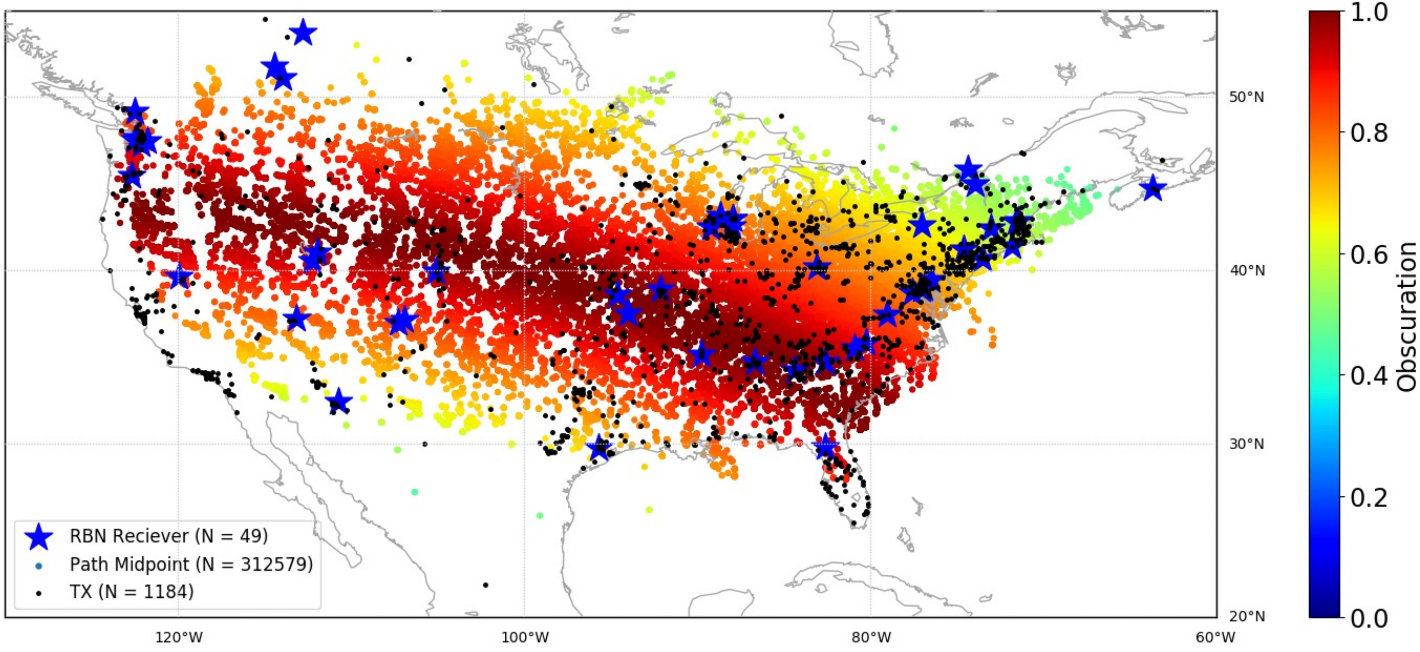
6 UT

18 UT

250 km × 10 min bins

[Frissell et al., 2019]

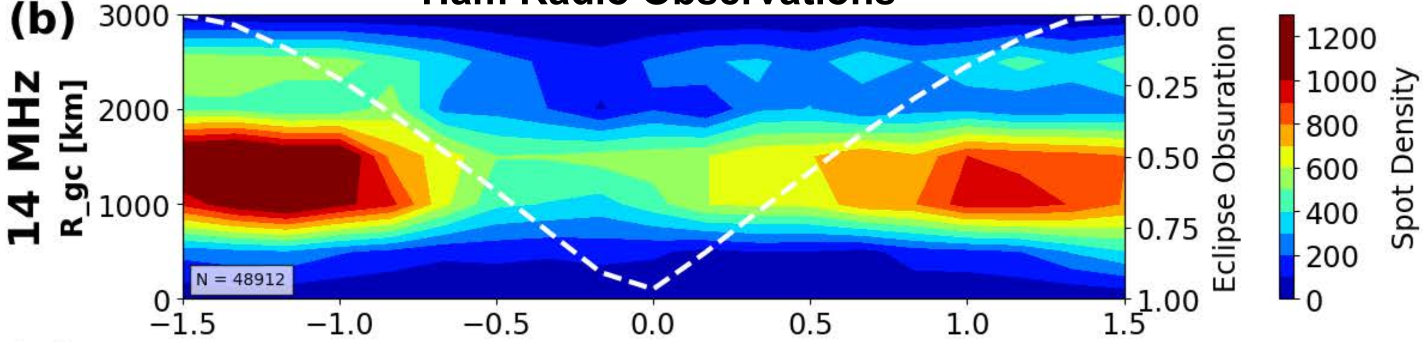
Solar Eclipse QSO Party RBN Observations



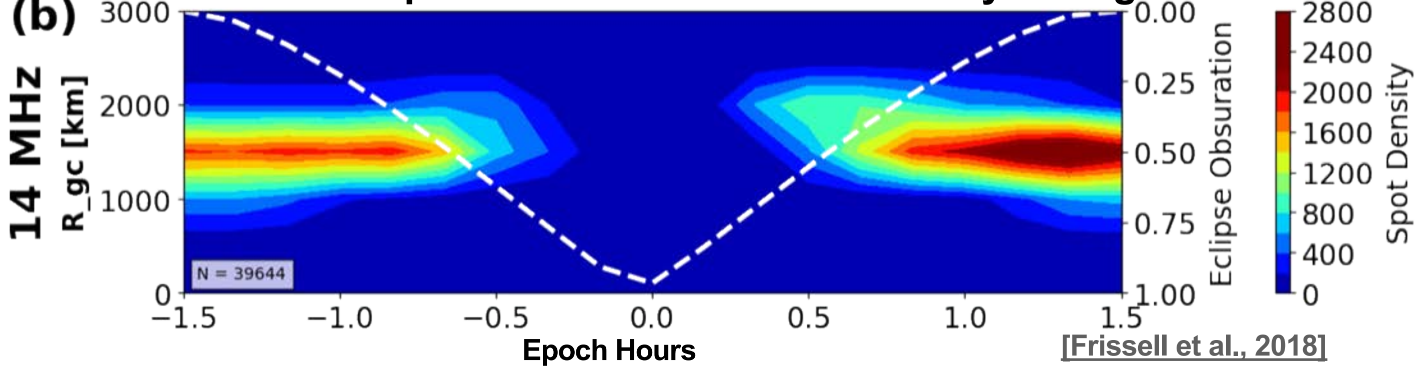
[Frissell et al., 2018]

Linking Radio Observations to Physics with Modeling

Ham Radio Observations



Model – Eclipsed SAMI3 with PHaRLAP Raytracing



[Frissell et al., 2018]

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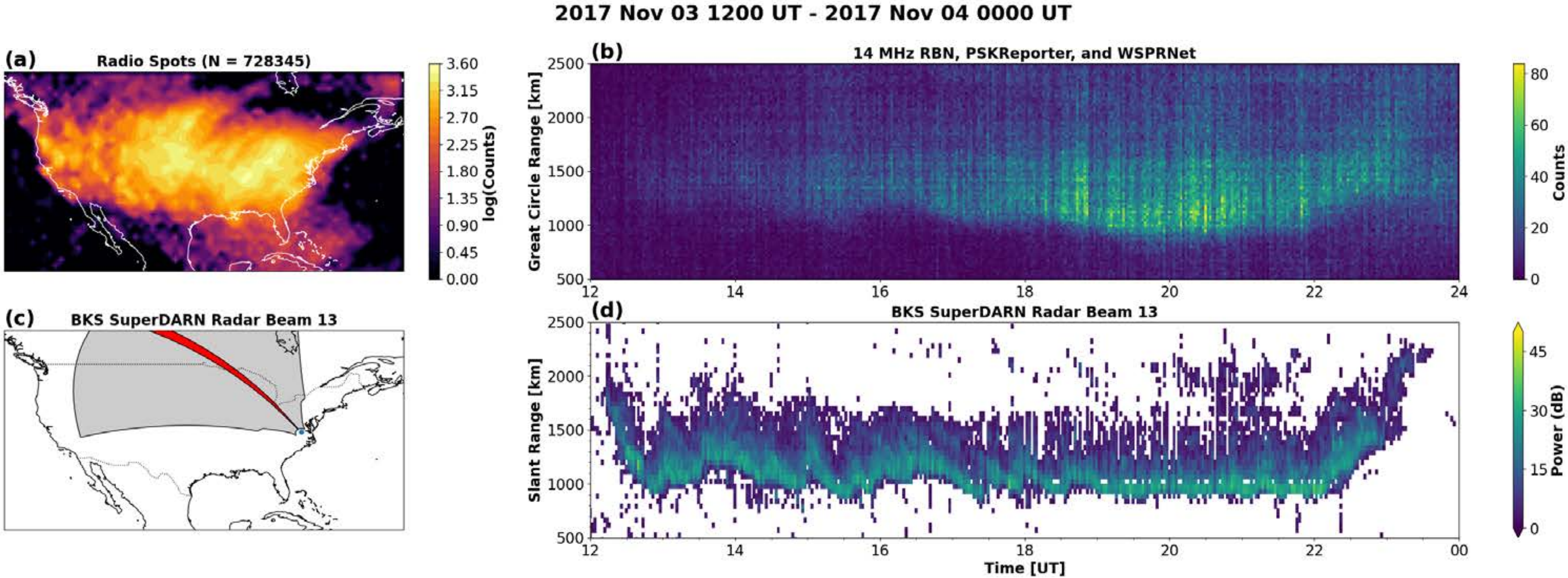
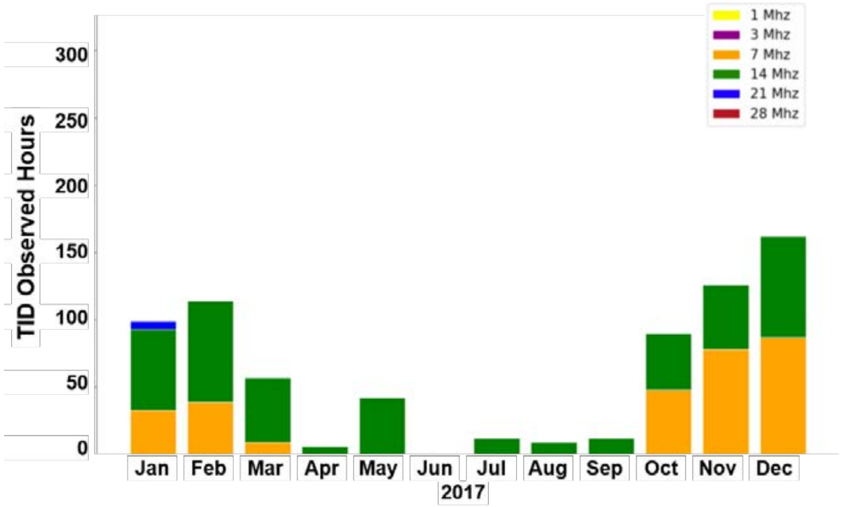
November 3, 2017



(Frissell et al., 2022, https://doi.org/10.1029/2022GL097879)

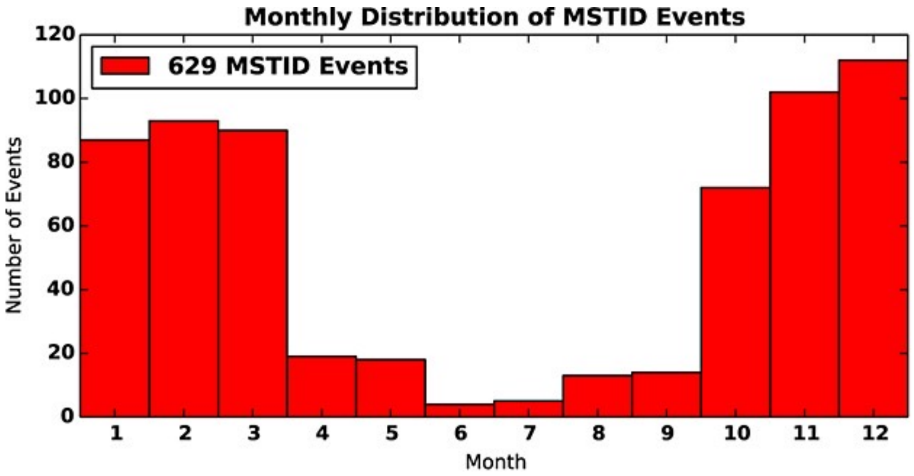
Comparison with SuperDARN MSTID Statistics

Amateur Radio TID Statistics
2017



RBN/WSPR statistical study by Diego Sanchez et al. (2021)

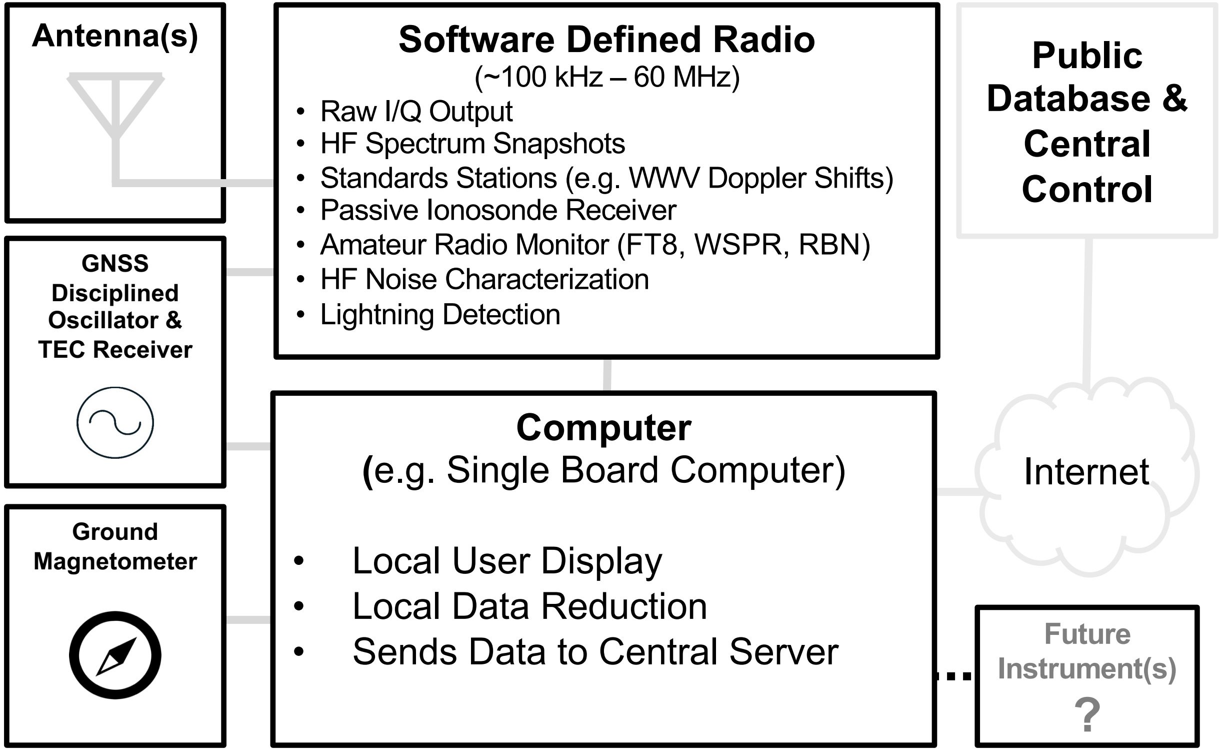
Blackstone, VA SuperDARN MSTID Statistics
2010



[*Frissell et al.*, 2014]

HamSCI Personal Space Weather Station

- **The PSWS is a multi-instrument, ground-based device designed to observe space weather effects** both as a single-point measurement and as part of a larger, distributed network.
- It is "Personal" because it is being designed such that an individual should be able to purchase one and operate it in their own backyard.
- The PSWS design also works to take into account the needs of both amateur radio operators and professional researchers.



For more information, visit http://hamsci.org/psws

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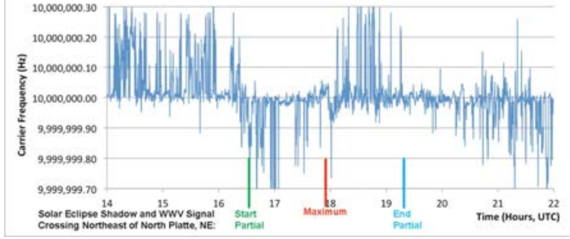
Low-Cost “Grape” PSWS

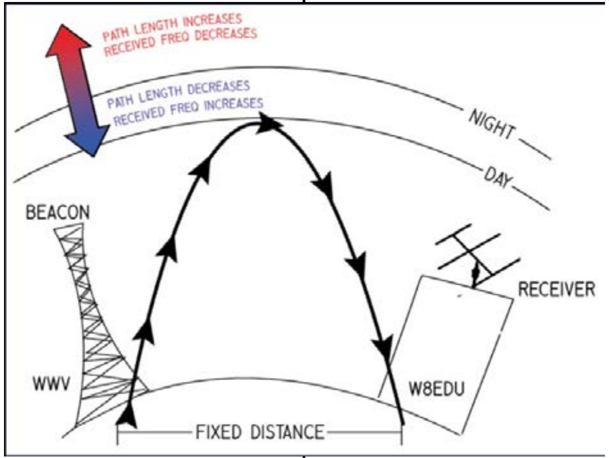
- HF “Doppler Shift” Monitoring
- Main components: Raspberry PI, GPSDO, Custom Direct-conversion receiver board
- Cost: ~$100 to $200
- Developed by Case Western

SDR-Based “Tangerine”

- HF FPGA-based Software Defined Radio
- Precision timing and frequency measurement
- 2 to 4 coherent, phase-locked receive channels
- Cost ~$500 to $1000
- Developed by Amateur Radio Group TAPR

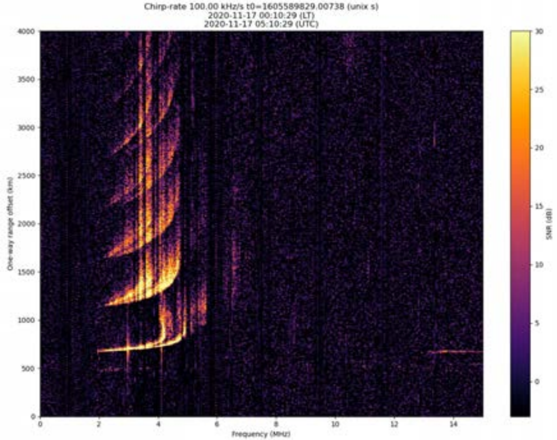
10 MHz Doppler During 2017 Eclipse
TX: WWV RX: WA9VNJ (Milwaukee)





[Collins et al., 2021]

Oblique Ionograms
(Currently on Ettus N200 but will be ported to Tangerine)



Movie by Dev Joshi
GNUChirpsounder2 by Juha Vierinen

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Summary

- **Amateur radio networks provide** an important set of global-scale measurements that can not only operate on their own but also jointly work alongside existing professional networks to greatly improve the geospatial and temporal observational coverage of the currently under sampled global ionosphere.
- **When added to information provided by** incoherent scatter radars (ISRs), SuperDARN, GNSS TEC networks, and ionosondes, amateur radio instrumentation will play an integral role in advancing magnetospheric and ITM science.

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Thank You!

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- amateur radio community who voluntarily produced and provided the HF radio observations used in this paper, especially the operators of the Reverse Beacon Network (RBN, reversebeacon.net), the Weak Signal Propagation Reporting Network (WSPRNet, wsprnet.org), PSKReporter (pskreporter.info) qrz.com, and hamcall.net.
- use of the Free Open Source Software projects used in this 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).

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