HamSCI Plans for the Study of the 2023 & 2024 Solar Eclipse Impacts on Radio and the Ionosphere

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The University of Scranton

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.

The Ionosphere

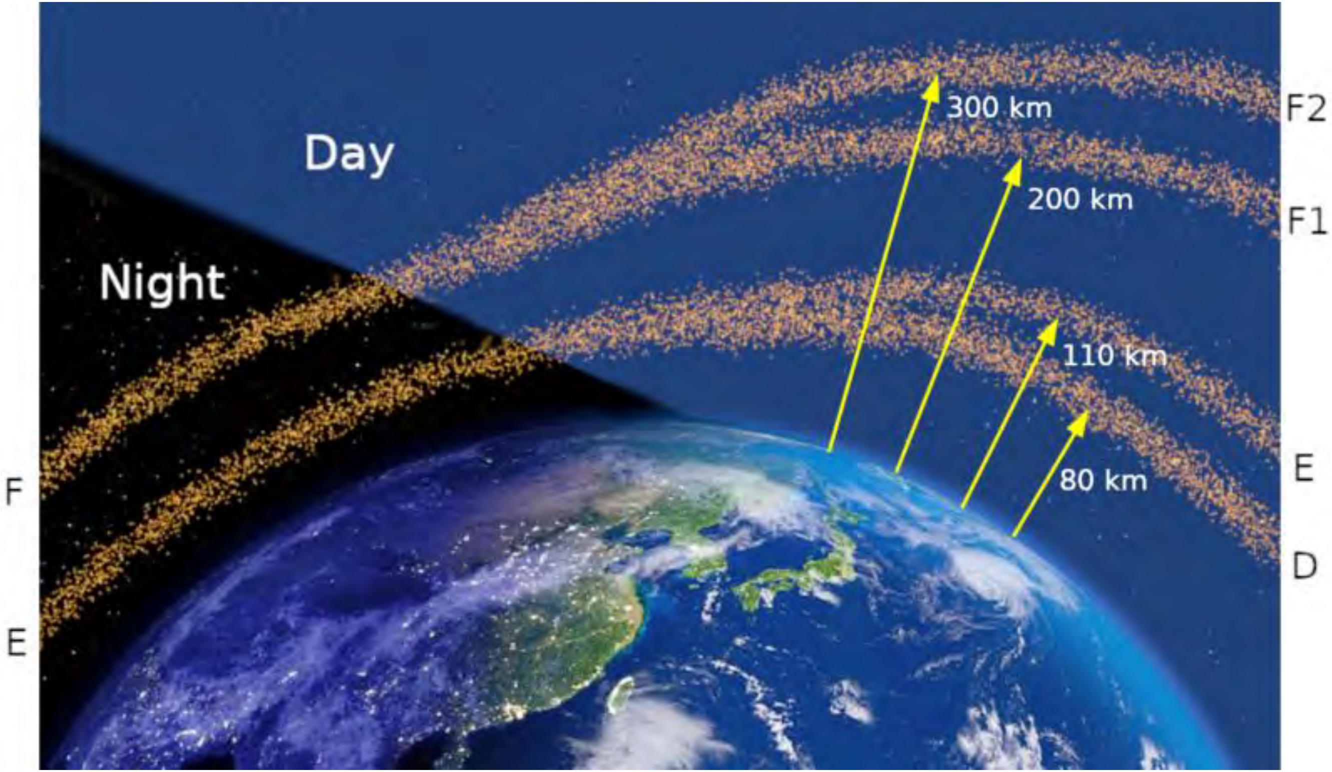

Figure by Carlos Molina (https://commons.wikimedia.org/wiki/File:Ionospheric_layers_from_night_to_day.png)

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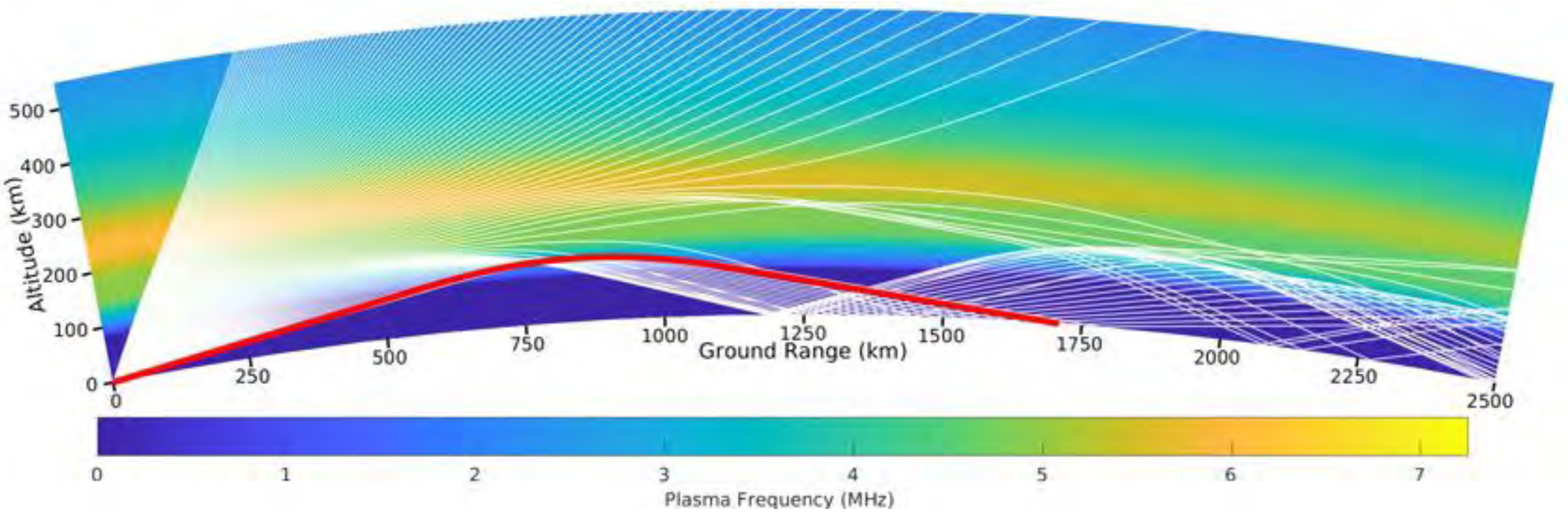
Refraction as a Function of Electron Density

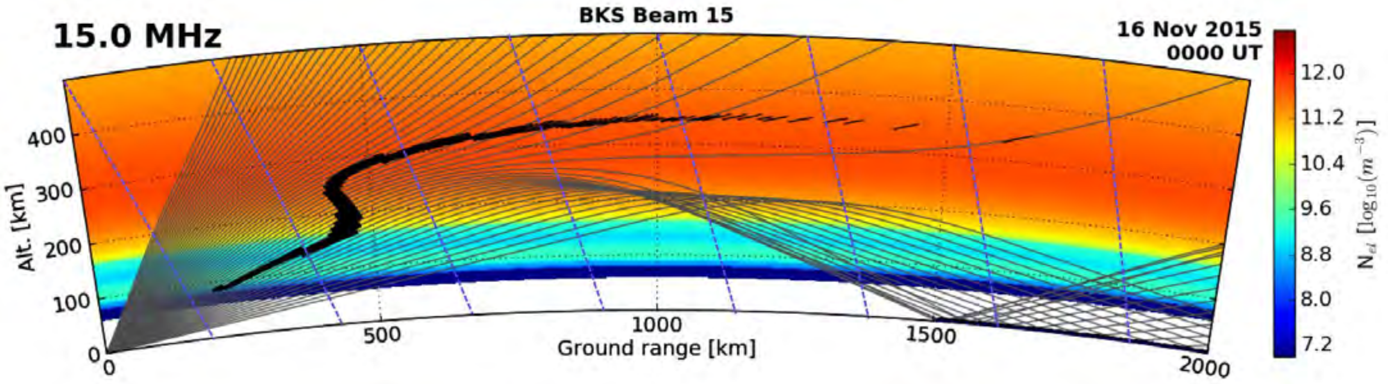
Eclipsed SAMI3 - PHaRLAP Raytrace

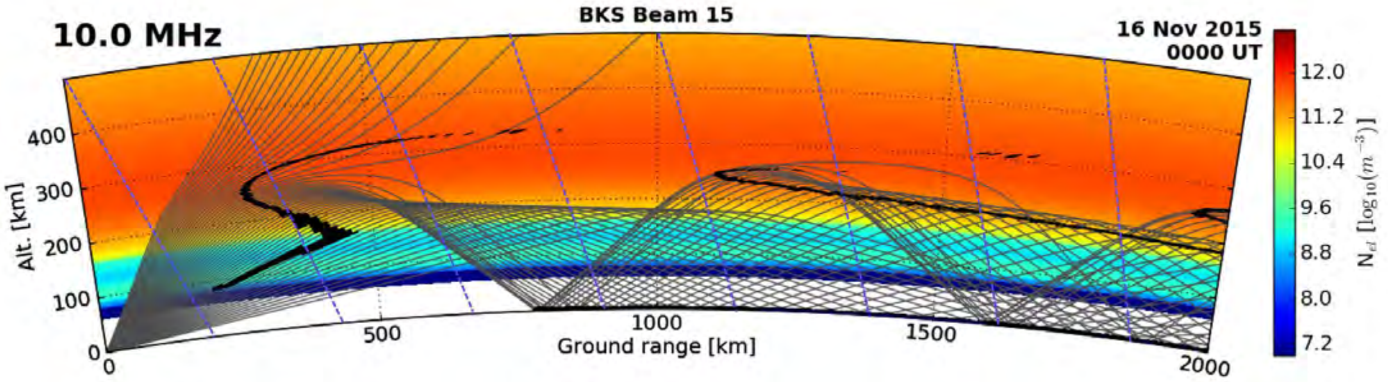
1600 UT 21 Aug 2017 • 14.03 MHz • TX: AA2MF (Florida) • RX: WE9V (Wisconsin)



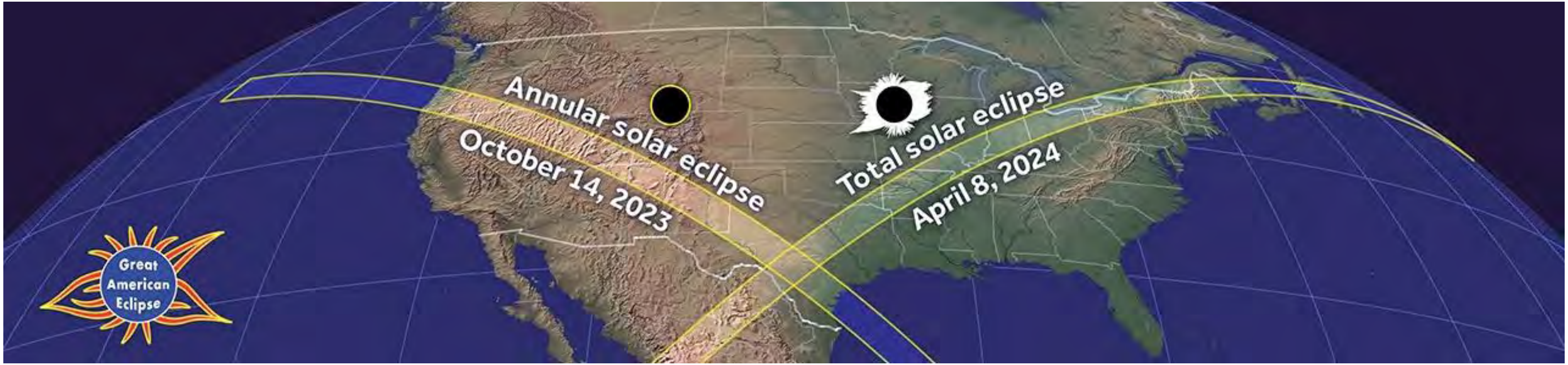
PHaRLAP: Cervera & Harris (2014), https://doi.org/10.1002/2013JA019247
SAMI3: Huba & Drob (2017), https://doi.org/10.1002/2017GL073549
Amateur Radio and the Eclipse: Frissell et al. (2018), https://doi.org/10.1029/2018GL077324

Refraction as a Function of Frequency





Eclipses 2023 and 2024

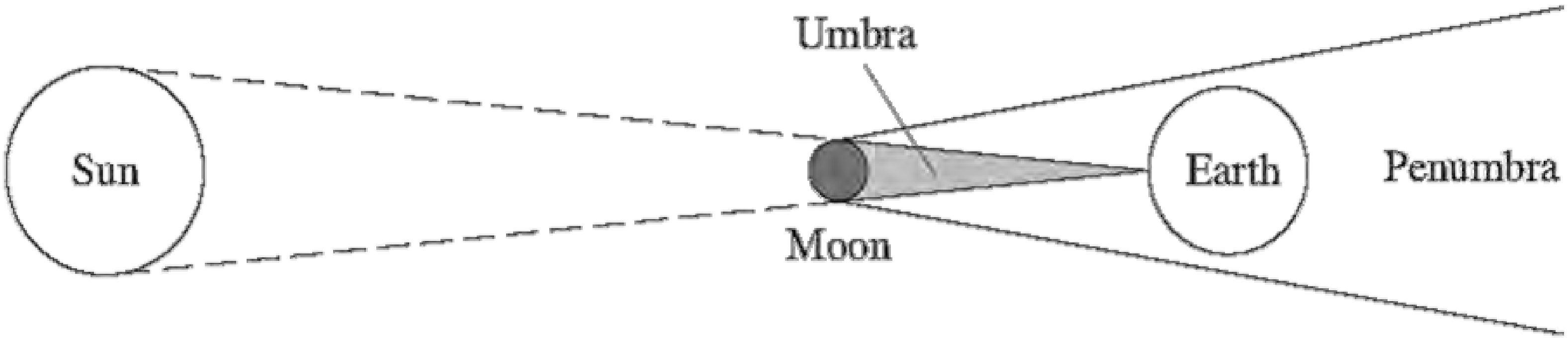


[https://www.greatamericaneclipse.com/]

Umbra and Penumbra

Moon's shadow has 2 parts:

- **Umbra:** innermost region of the shadow; Sun fully hidden & objects in total shadow.
- **Penumbra:** outermost region of the shadow; Sun partially hidden & objects still receive some sunlight.

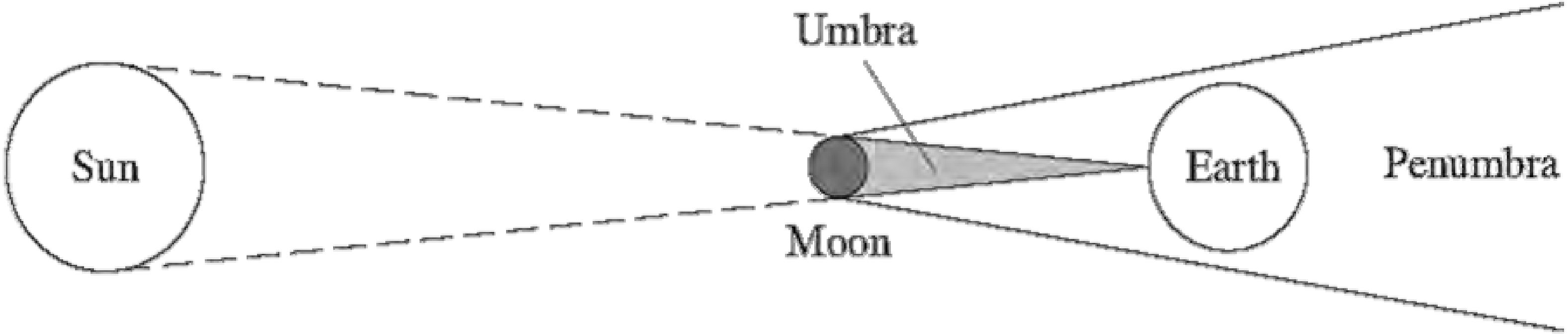


Ryden Fig 4.14: The geometry of a solar eclipse, showing the Earth's central shadow cone (umbra) and outer partial shadow (penumbra).

Total and Partial Eclipse

- **Total Eclipse:** Observer is located in the umbra.
- **Partial Eclipse:** Observer is located in the penumbra.

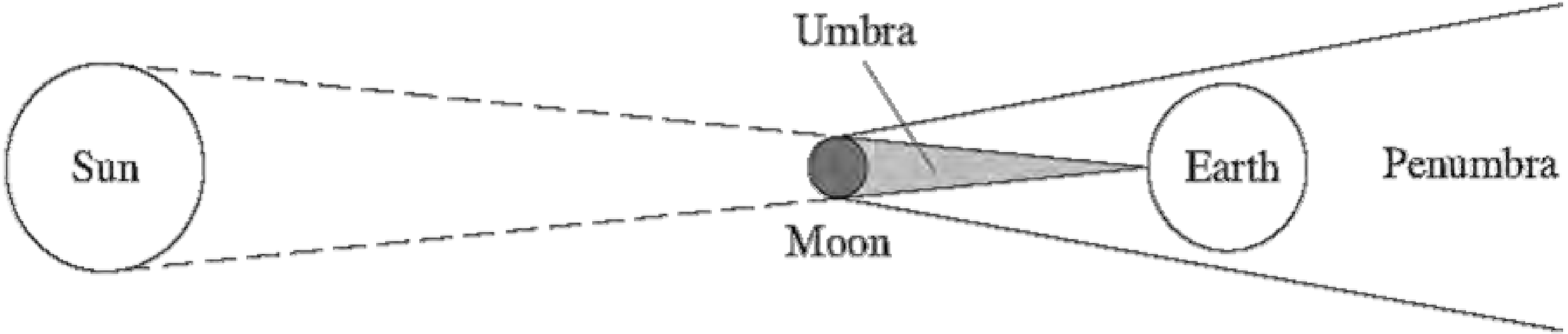
*A Total Solar Eclipse is **much** more dramatic than a partial solar eclipse. During a total solar eclipse, you can even see the Sun's Corona! If you have a chance to be in the path of totality during a solar eclipse, you should take the opportunity!*



Ryden Fig 4.14: The geometry of a solar eclipse, showing the Earth's central shadow cone (umbra) and outer partial shadow (penumbra).

Total and Annular Solar Eclipses

- The Moon appears larger in the sky at perigee compared to apogee.
- By coincidence, when the Moon is at or near perigee, it is sized to completely cover the solar disk during an eclipse. This results in a **Total Solar Eclipse.**
- At apogee when the Moon is farthest from the Earth, it will fit inside the Solar disk rather than totally obscure it. This creates an **Annular Solar Eclipse.**



Ryden Fig 4.14: The geometry of a solar eclipse, showing the Earth's central shadow cone (umbra) and outer partial shadow (penumbra).

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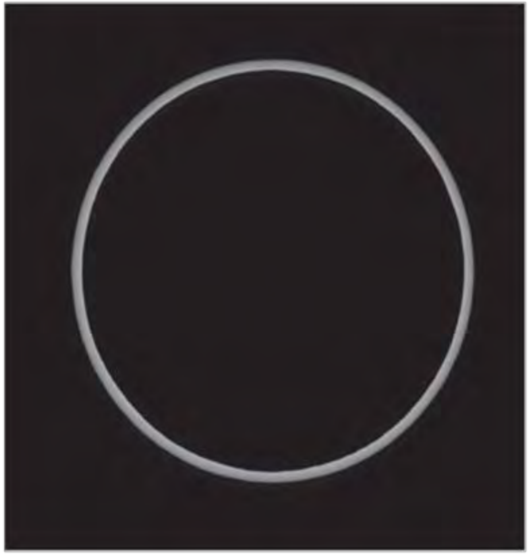
Total and Annular Solar Eclipses

Total

Ryden Fig 4.15

Partial

Annular



Eclipse Ionospheric Effects

- Because solar radiation is blocked from the atmosphere during an eclipse, we can expect the ionosphere to respond similarly to day and night.
- But, there are differences…

What are those differences?

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Differences Between Eclipses and Day-Night

- Eclipse is shorter duration.
- More localized.
- Travels at supersonic speeds.
- Travels in directions that are different from westward motion of dawn and dusk terminators.

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Eclipses as Controlled Experiments

- Aside from dusk, dawn, and the seasons, there are very few cases where we know a priori how much solar energy will be input into the upper atmosphere.
- Solar flares, geomagnetic storms, and others are random events we cannot predict.
- We can calculate eclipses with great accuracy ahead of time, and so can be considered a “controlled” ionospheric experiment.

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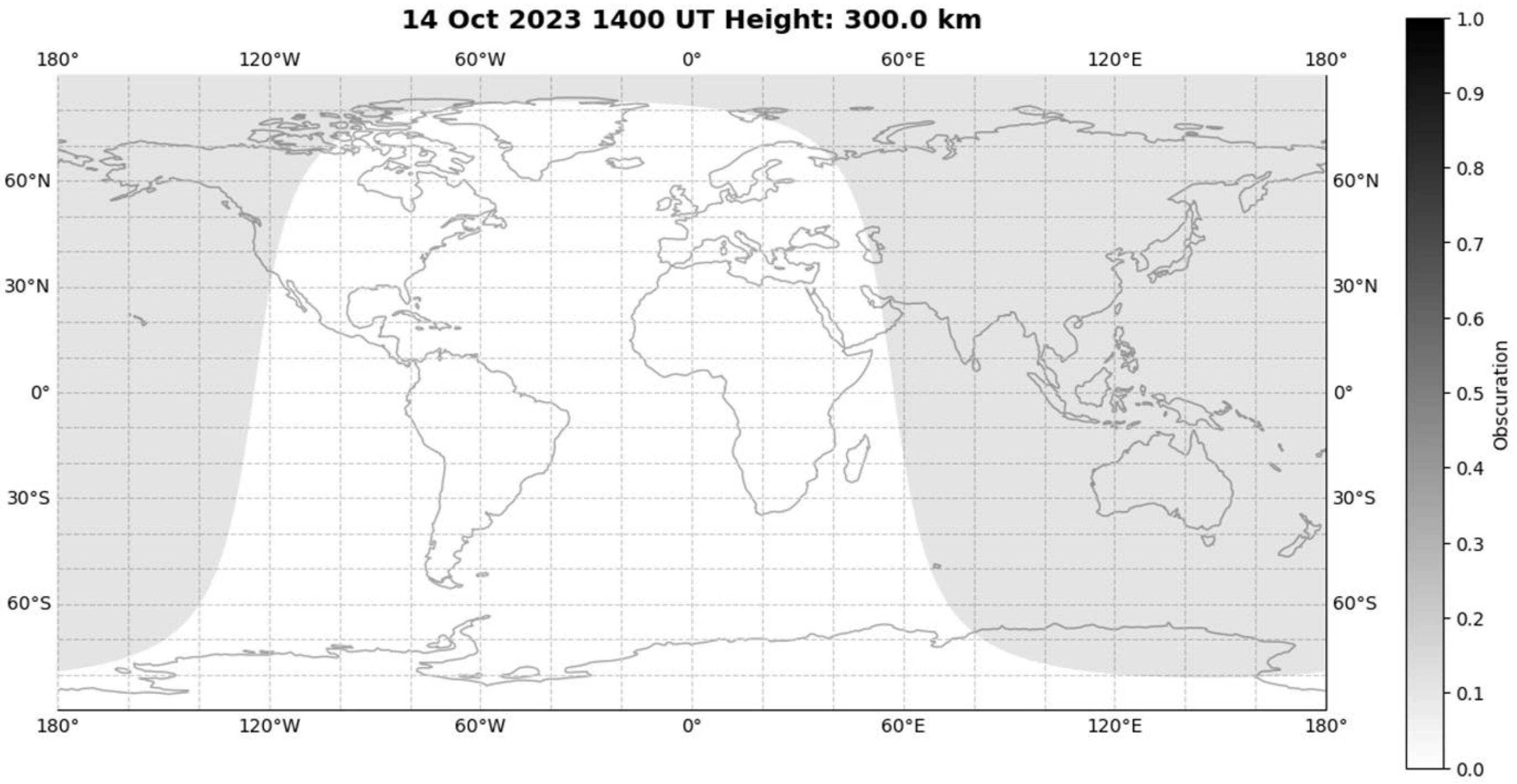
Annular Solar Eclipse: October 14, 2023



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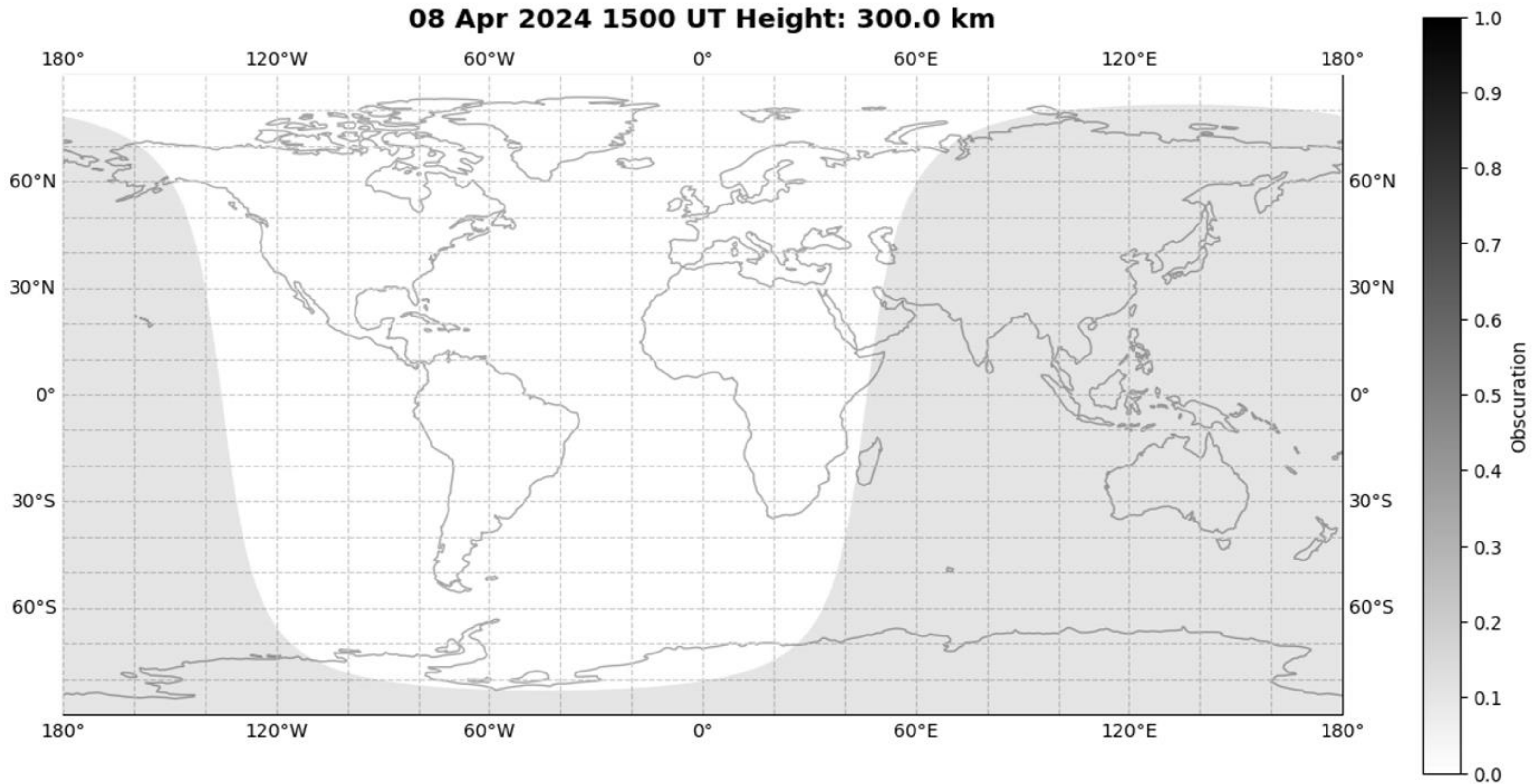
Total Solar Eclipse: April 8, 2024



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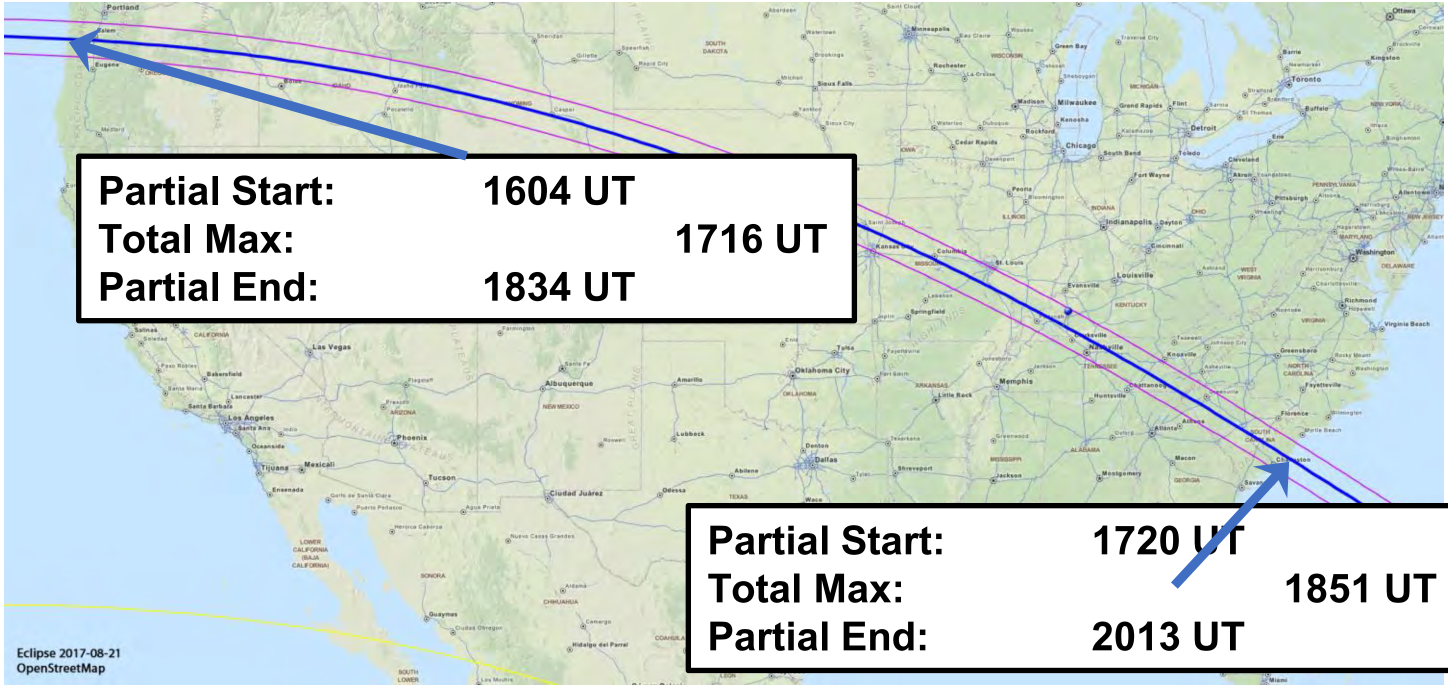
2017 Total Solar Eclipse

21 August 2017



Partial Start: 1604 UT
Total Max: 1716 UT
Partial End: 1834 UT

Partial Start: 1720 UT
Total Max: 1851 UT
Partial End: 2013 UT

Figure: W. Strickling, Wikipedia

HamSCI Eclipse Research Questions

- Can we use HF ham radio communications to observe eclipse effects on the ionosphere?
- Can we use data-model comparisons to:
  - Better understand the ham radio data?
  - Constrain or calibrate the model?

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Solar Eclipse QSO Party (SEQP)

- **August 21, 2017 from 1400 – 2200 UT**
- **Contest-like**
  - 2 Points CW or Digital
  - 1 Point for Phone
  - Multiply Score by # of Grids
- **Exchange**
  - RST + 6 Character Grid Square
- **Data sources**
  - Reverse Beacon Network
  - PSKReporter
  - WSPRNet
  - Participant-submitted logs

http://hamsci.org/seqp

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Solar Eclipse QSO Party

- 570 parsed logs
- 29,809 QSOs
- 4,929 unique callsigns
- 649 4-char grid squares
- 80 DX Entities

(from logs submitted to hamsci.org)

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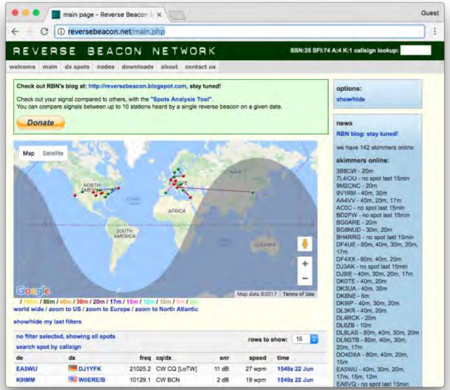
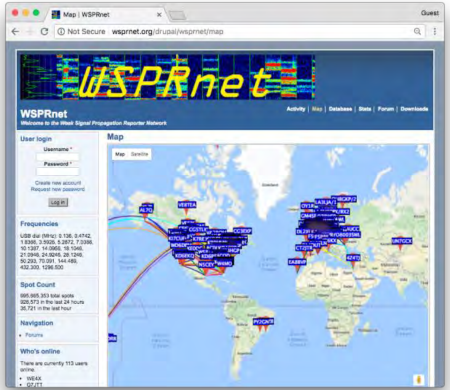
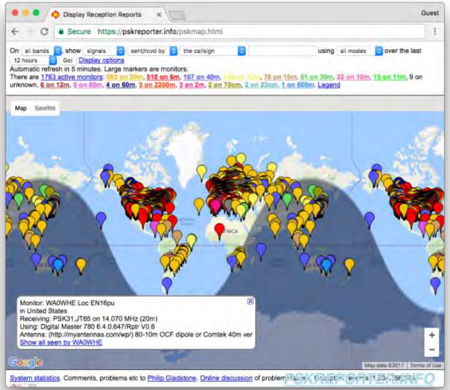
SEQP Observations



RBN
reversebeacon.net



WSPRNet
wsprnet.org



PSKReporter
pskreporter.info

Observations from 21 August 2017 1400 – 2200 UT

Network	# Spots / QSOs
RBN	618,623
WSPRNet	630,132
PSKReporter	1,287,962
Participant Logs	29,809

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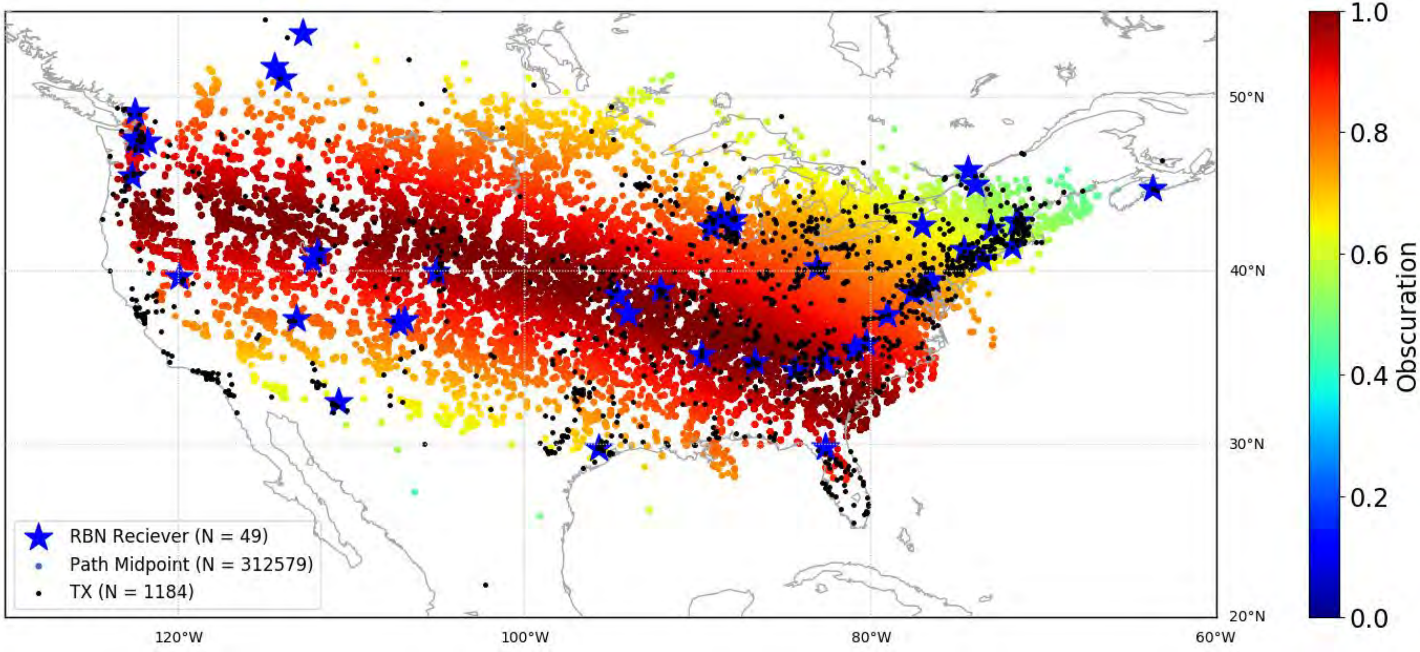
Solar Eclipse QSO Party RBN Observations



[Frissell et al., 2018]

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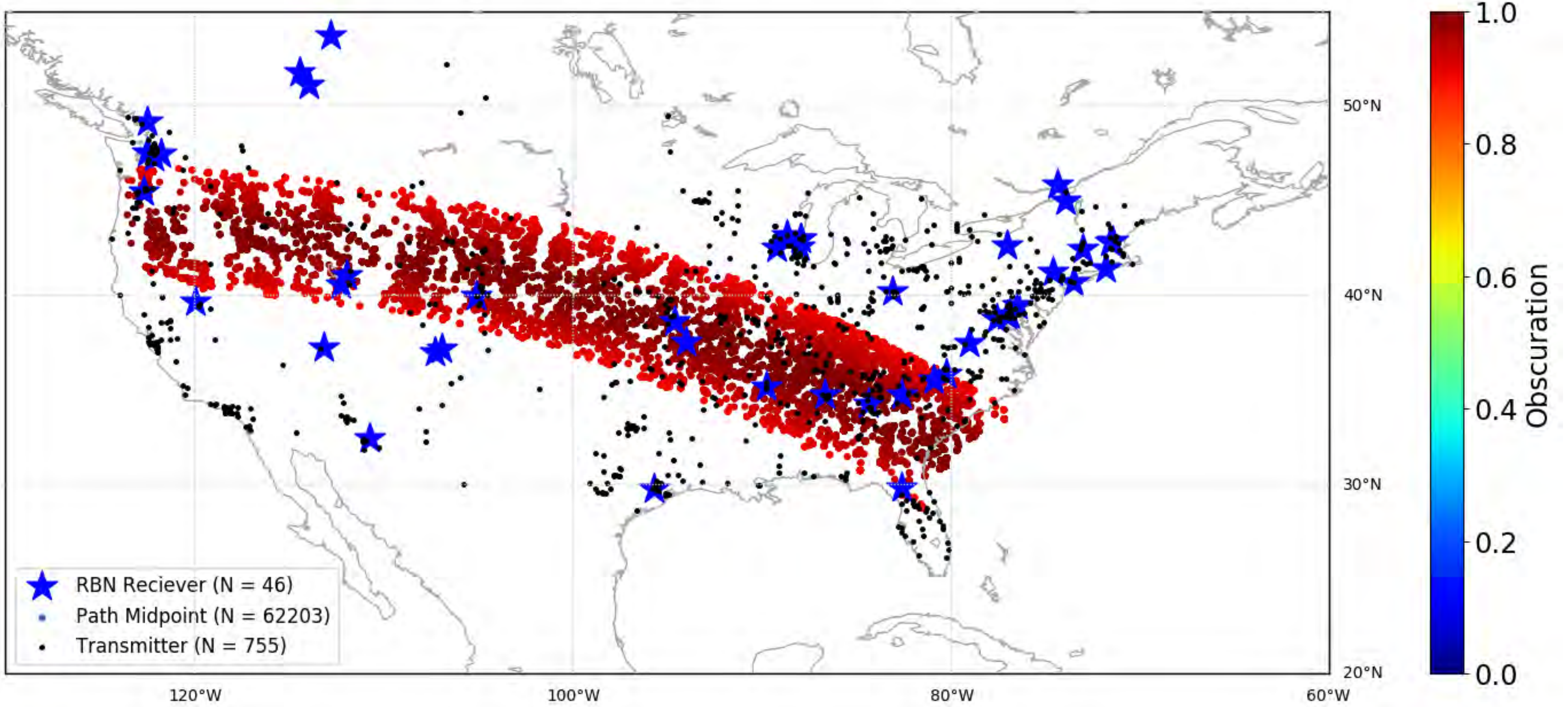
SEQP RBN ($O_{300} \geq 0.9$)



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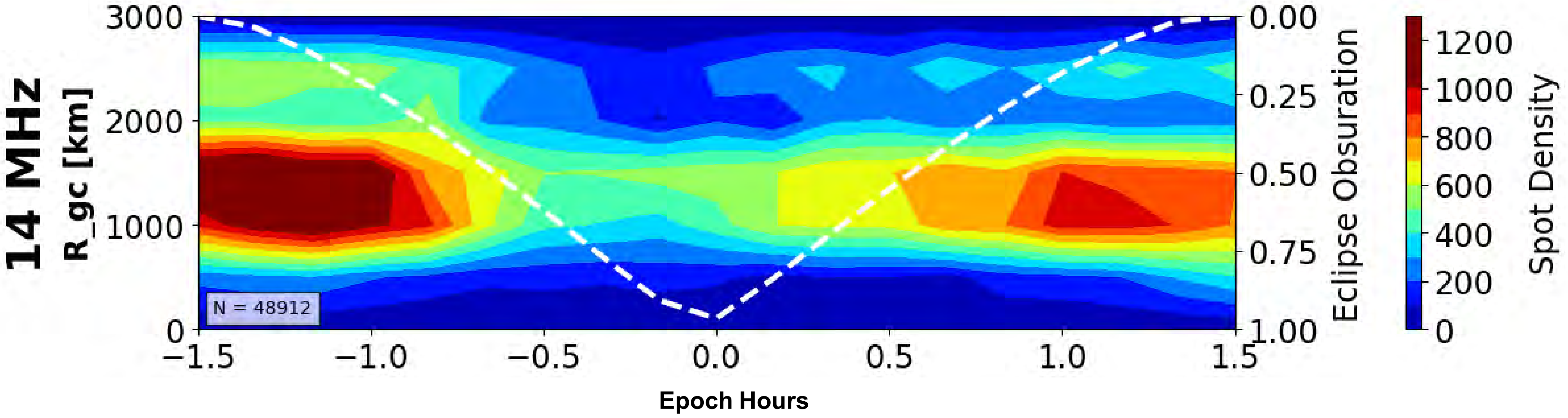
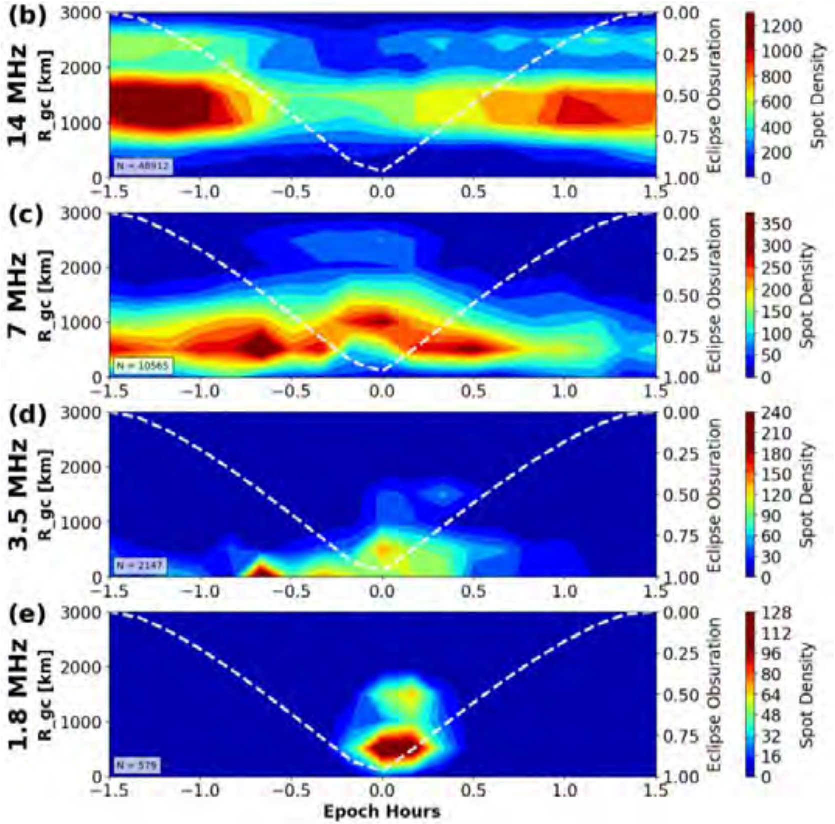
14 MHz 2017 SEQP RBN ($O_{300} \geq 0.9$)



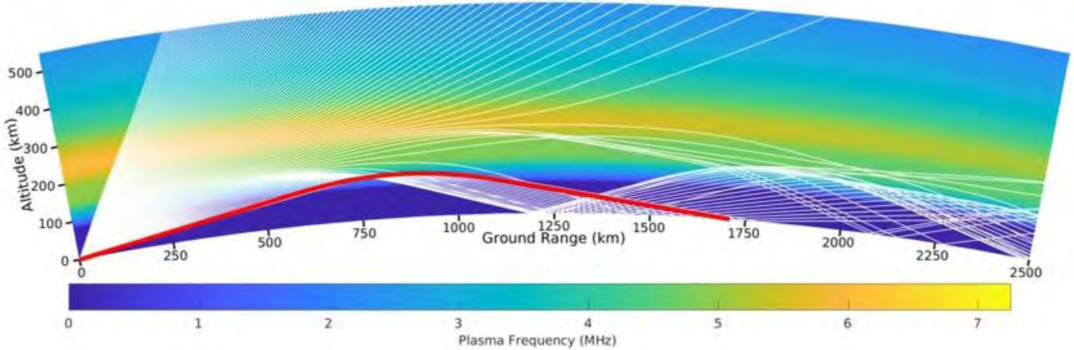
2017 SEQP RBN ($O_{300} \geq 0.9$)



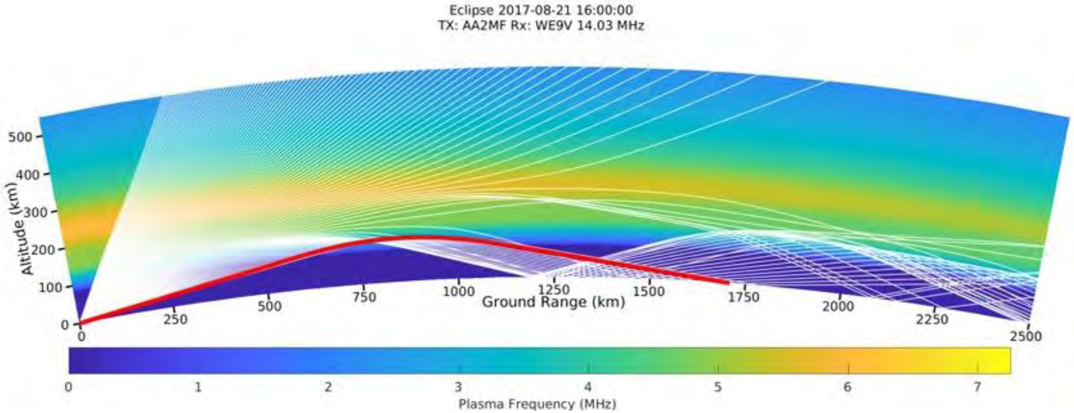
Modeling the Solar Eclipse QSO Party

SAMI3-PHaRLAP Raytrace
1600 – 2200 UT 14.03 MHz
TX: AA2MF (Florida)
RX: WE9V (Wisconsin)

Non-Eclipsed



Eclipsed



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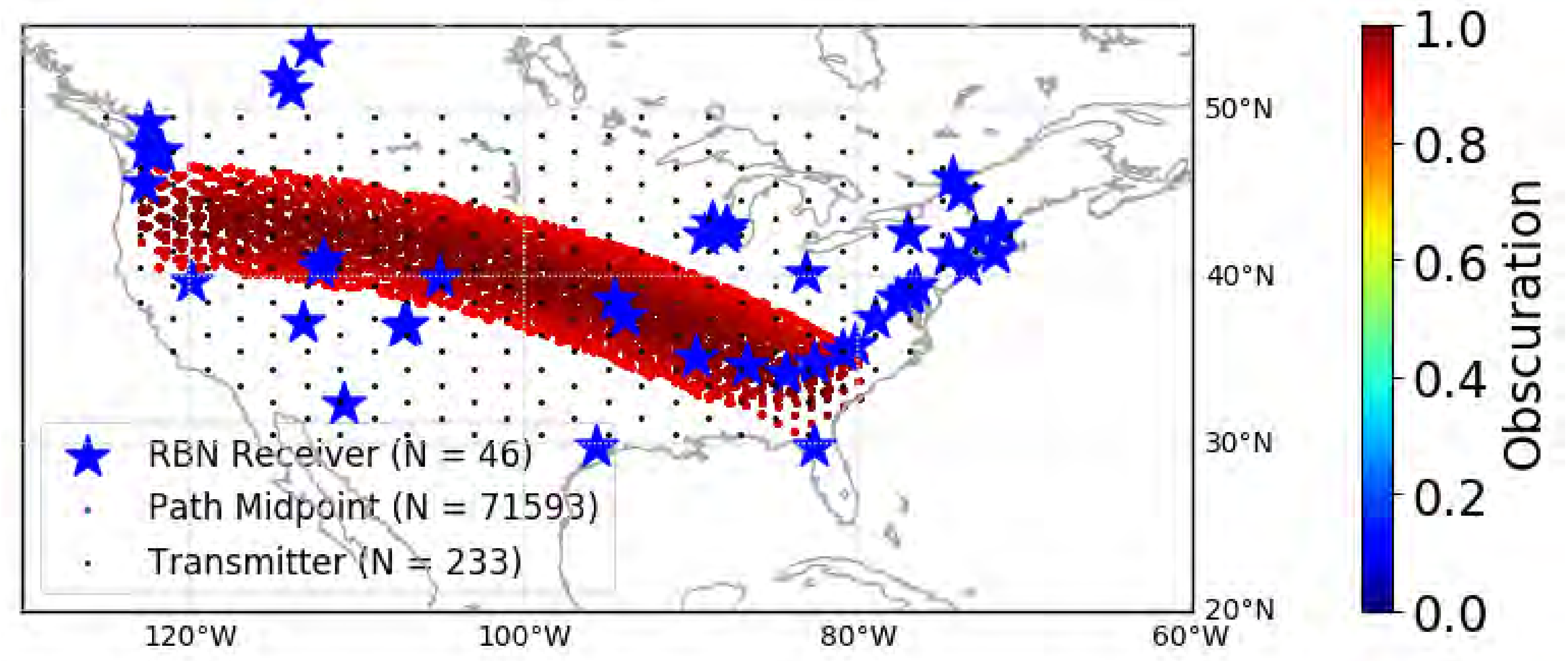
Modeling the Solar Eclipse QSO Party



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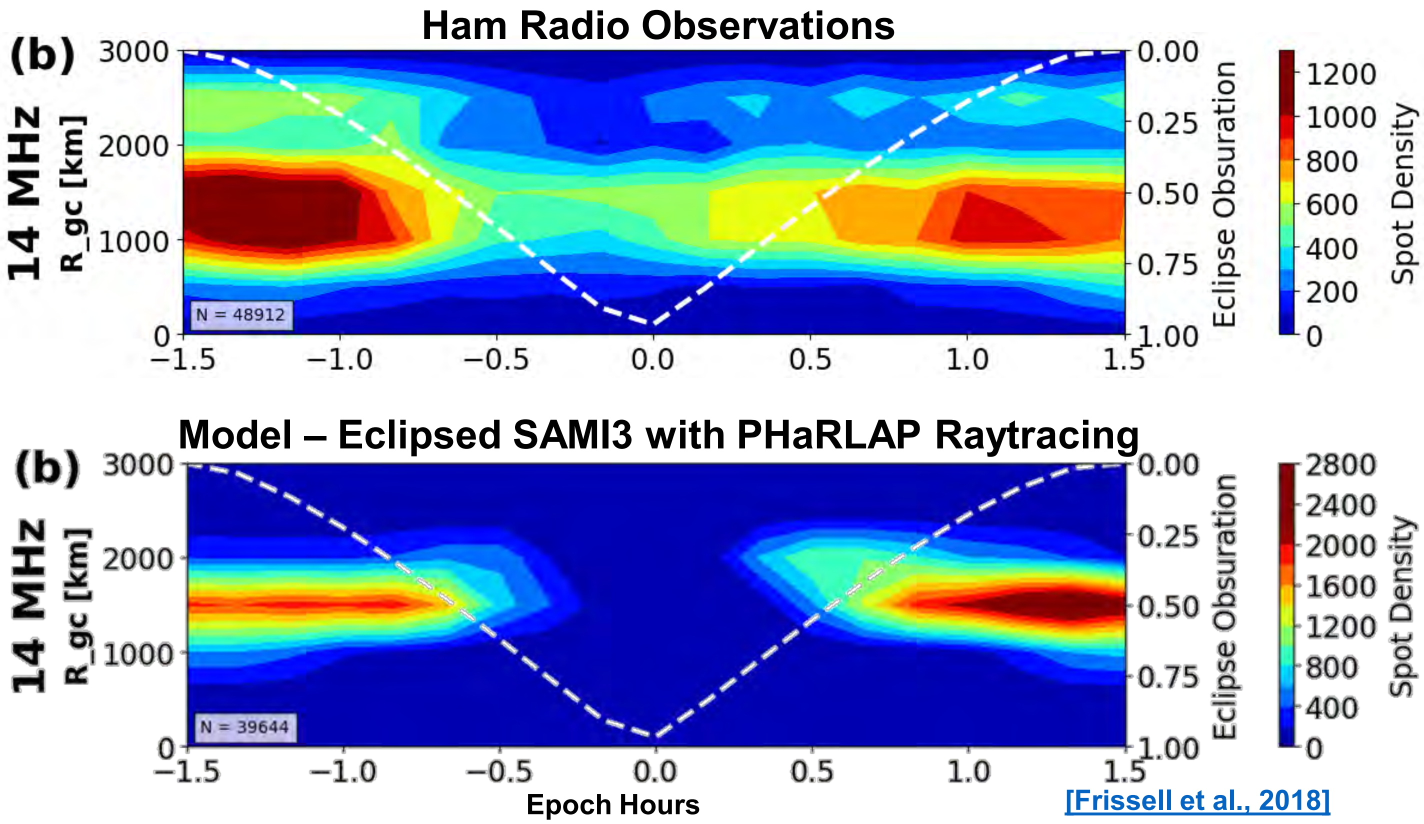
Observations and Model Results



[Frissell et al., 2018]

RBN Observations – SAMI3 Simulation

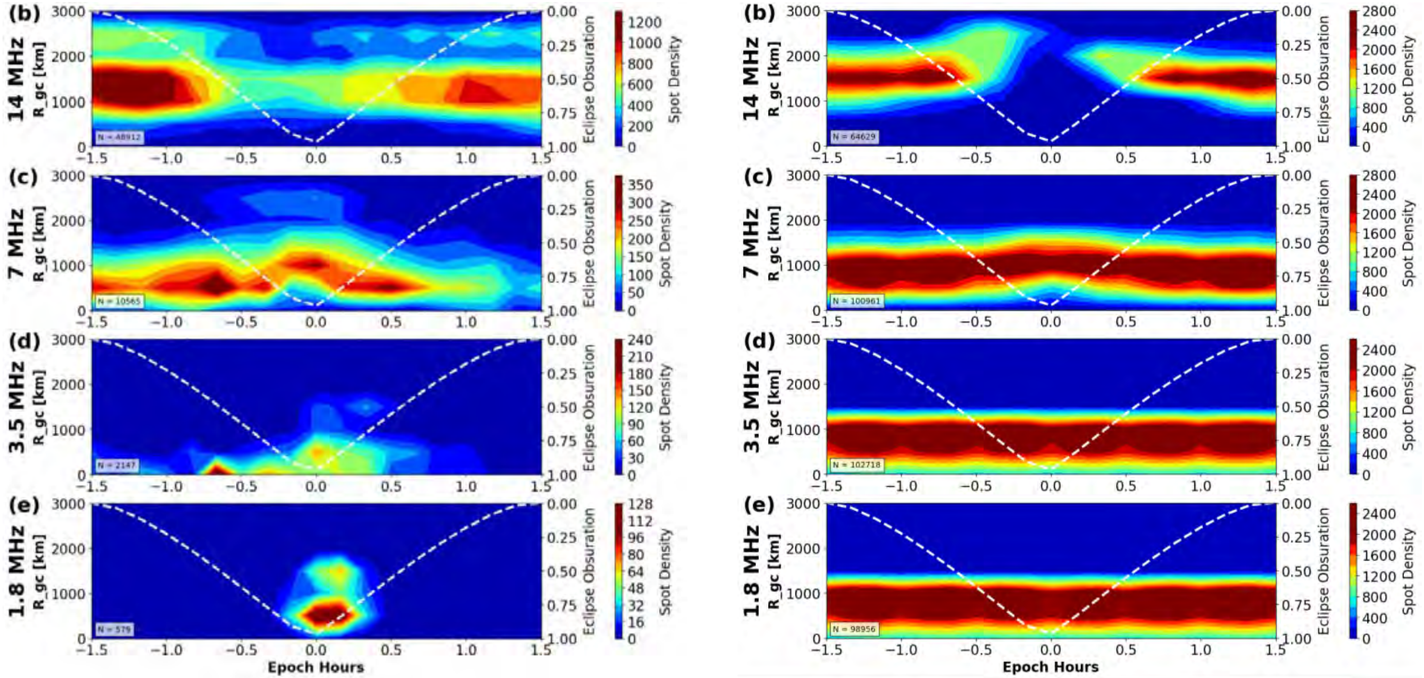
RBN Observations | **Eclipsed SAMI3 - PHaRLAP**

14 MHz

7 MHz

3.5 MHz

1.8 MHz



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SAMI3 < 125 km alt

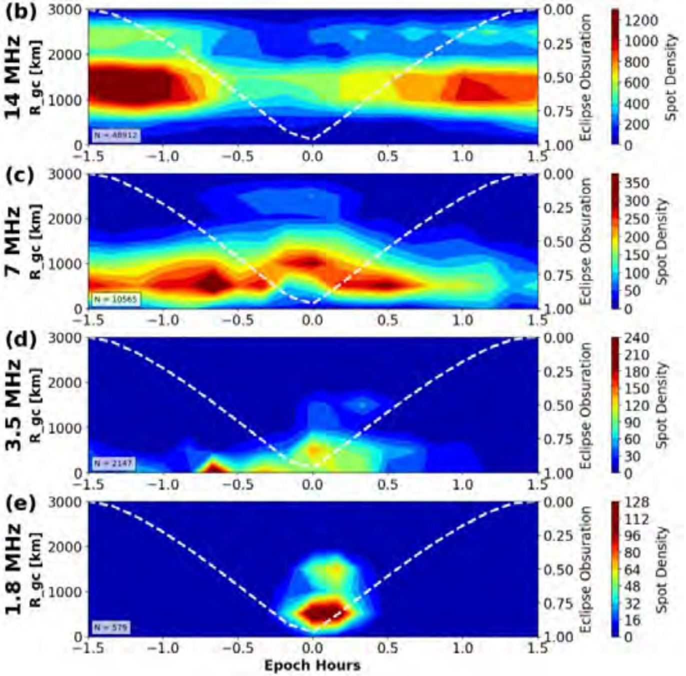
14 MHz

7 MHz

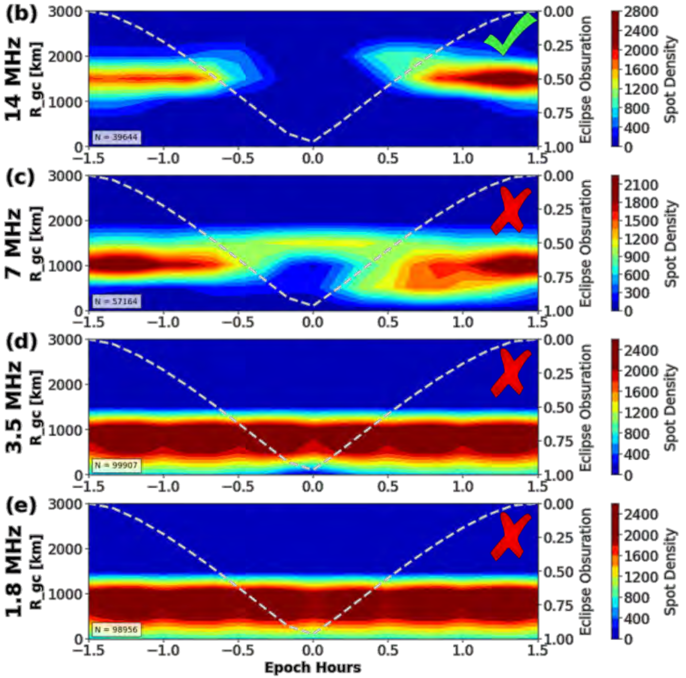
3.5 MHz

1.8 MHz

RBN Observations



SAMI3 < 125 km Altitude



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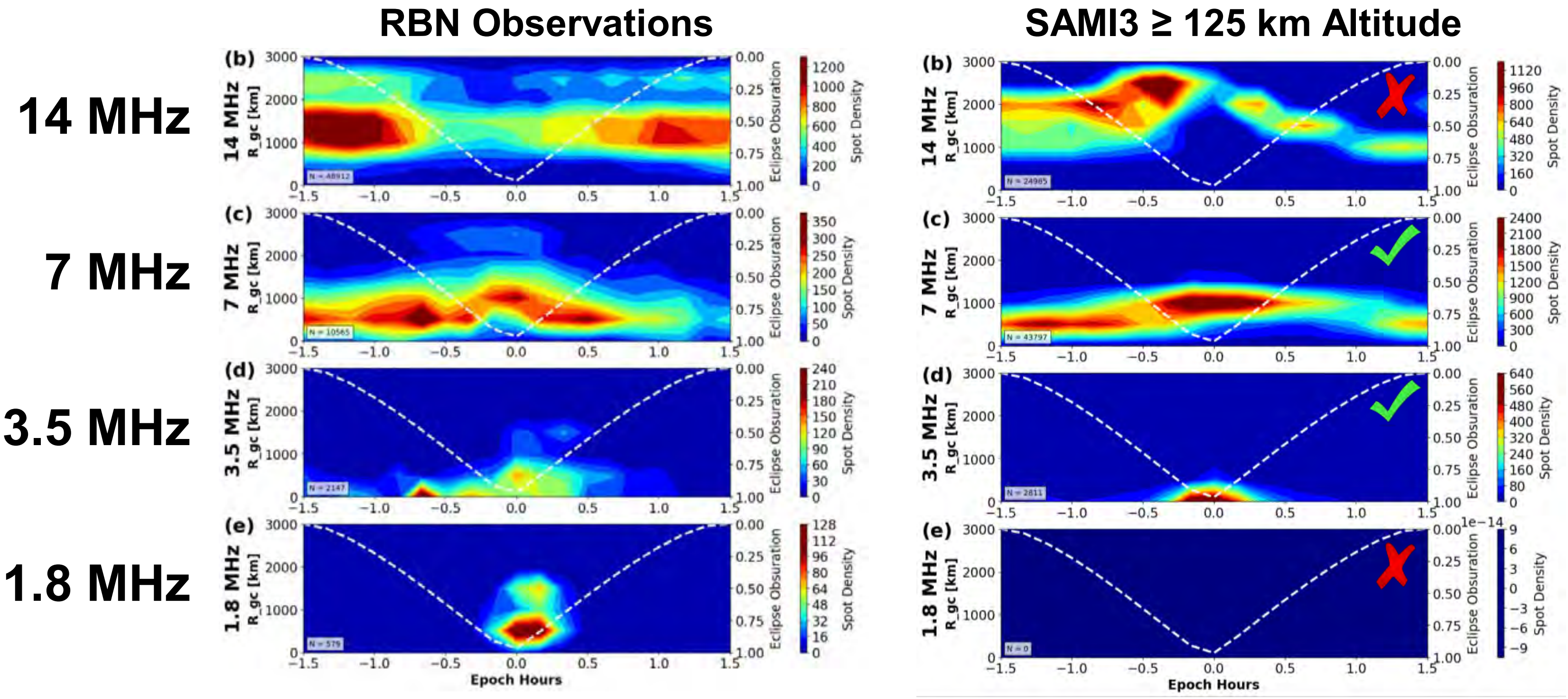
SAMI3 ≥ 125 km alt



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2017 Eclipse Conclusions

- SEQP generated over 2.5 million link soundings.

- Eclipse effects are observed:
  - ±0.3 hr on 1.8 MHz
  - ±0.75 hr on 3.5 and 7 MHz
  - ±1 hr on 14 MHz

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2017 Eclipse Conclusions: 14 MHz

Raytracing suggests 14 MHz refracted at h < 125 km

- This means E-layer ionosphere!
- Mean elevation angle was $< 10^\circ$
- Higher frequency meant D-layer absorption was not a problem, even at low elevation angles.
- Low-angle rays could be refracted by E-layer (secant law)
- Higher elevation angles penetrated both the E and F layers.

2017 Eclipse Conclusions: 1.8 - 7 MHz

Raytracing suggests 1.8 - 7 MHz refracted at h ≥ 125 km

- This means F-layer ionosphere!
- Elevation angle was > 60˚
- Low-angle rays were likely absorbed by the D-region and not observed.
- Higher elevation angles penetrated the E-layer but could be refracted by F-layer.

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SEQP for 2023/2024

- **Want to run SEQP again for 2023/2024.**
- **What would you change?**
- **What would you keep the same?**

- **Dates:**
  - Total: Monday, Aug 21, 2017
  - Annular: Saturday, Oct 14, 2023
  - Total: Monday, April 8, 2024

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2023/2024 Science Questions

- Can the annular eclipse be observed in HF communications?
- How large is the disturbance?
- How long before and after maximum eclipse are eclipse effects observed?
- Is an onset-recovery asymmetry observed?
- Will results again suggest E-layer propagation for 14 MHz and F-layer for 1.8 – 7 MHz?
- How similar are the eclipse effects to dawn and dusk (grayline)?

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HF Doppler Shift

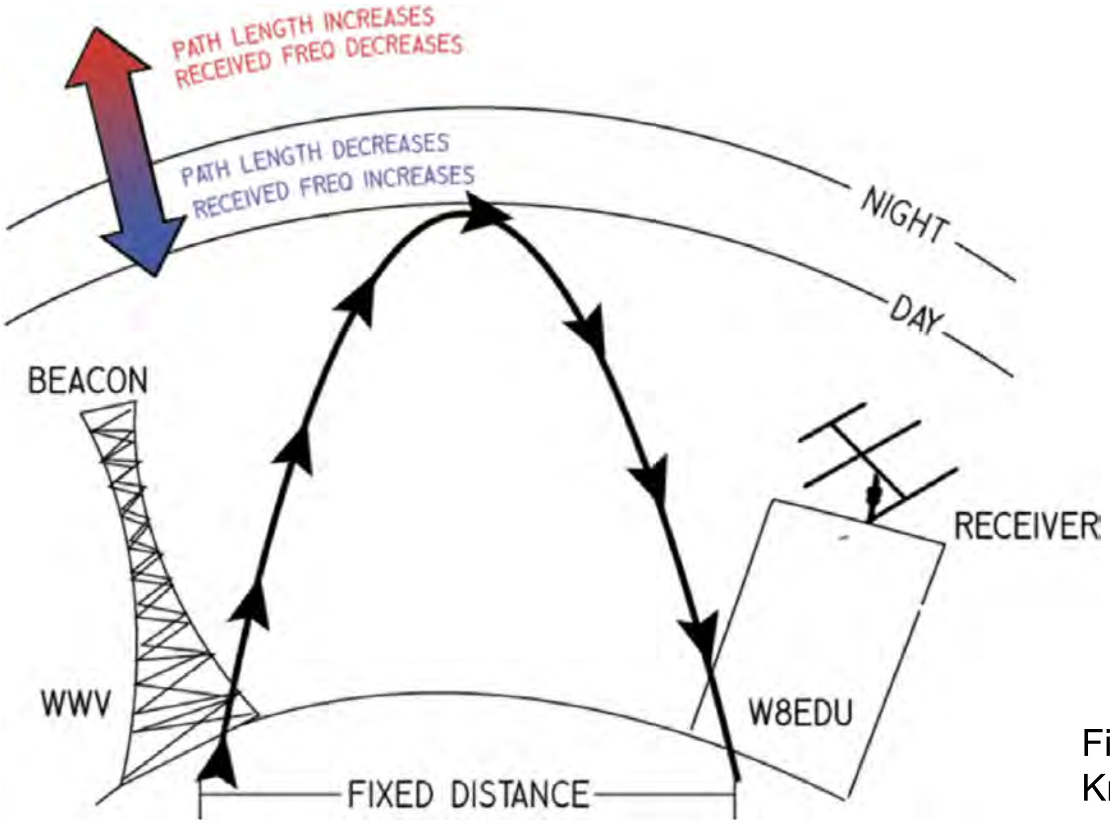


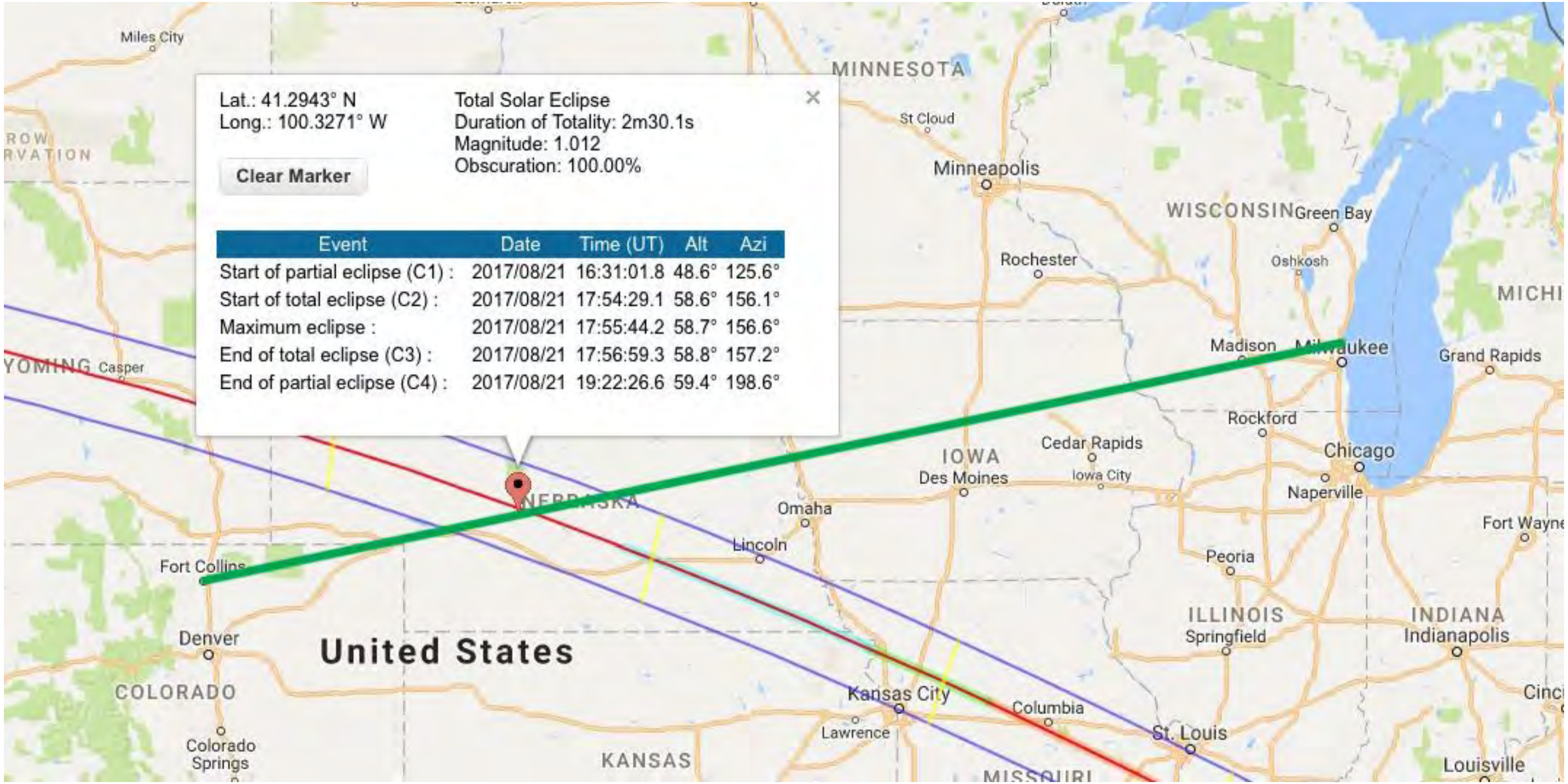
Figure by
Kristina Collins KD8OXT

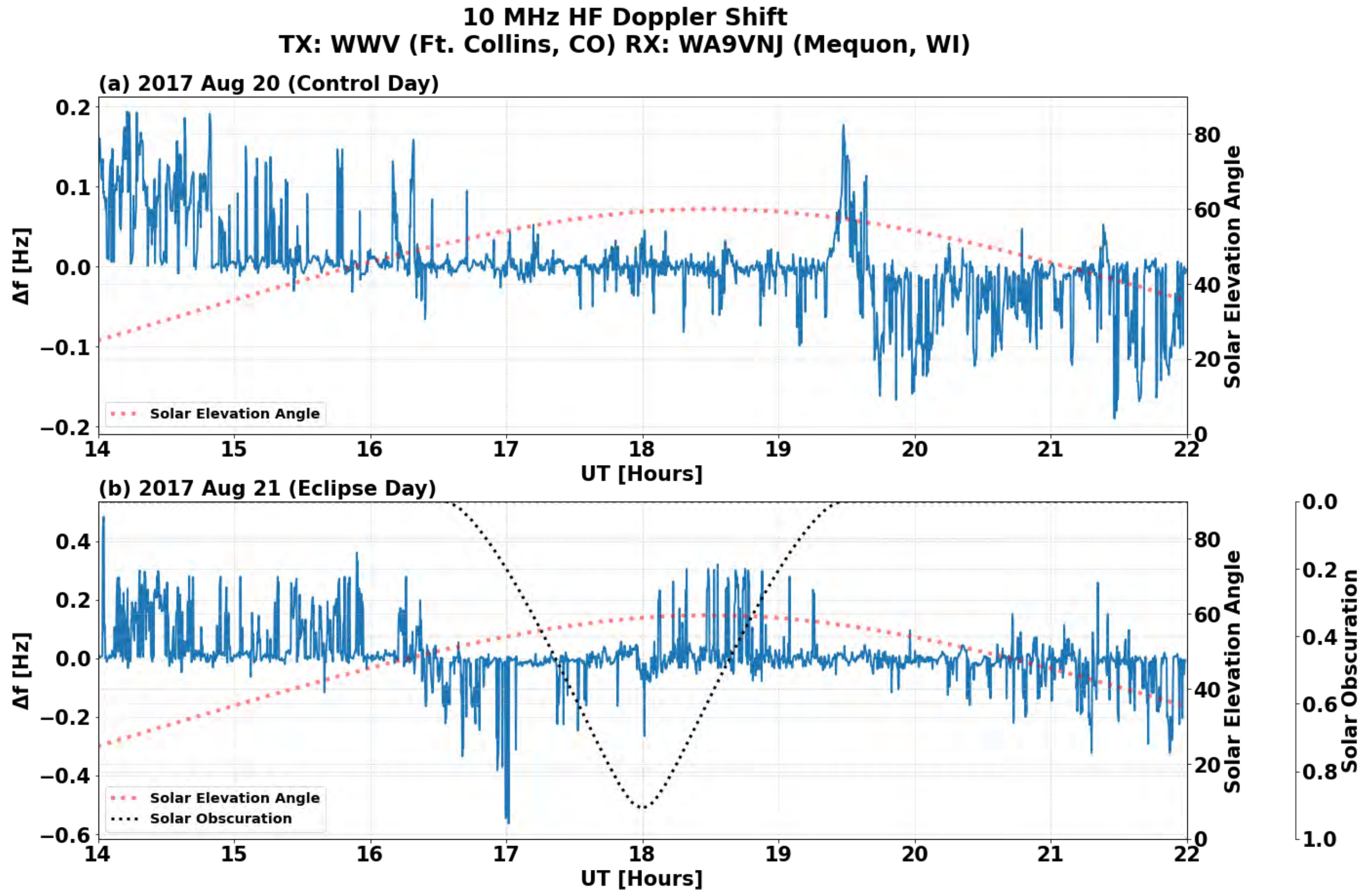
Steve Reyer, PhD, WA9VNJ (SK)

Steve Reyer
1950-2018

- Professor Emeritus of Electrical Engineering at the Milwaukee School of Engineering
- Teacher and Industry Consultant
  - digital signal processing
  - communications
  - microprocessors
  - circuits
  - Senior Design
- Active in FMT Community
- Very important for HamSCI Eclipse Frequency Measurement Experiment

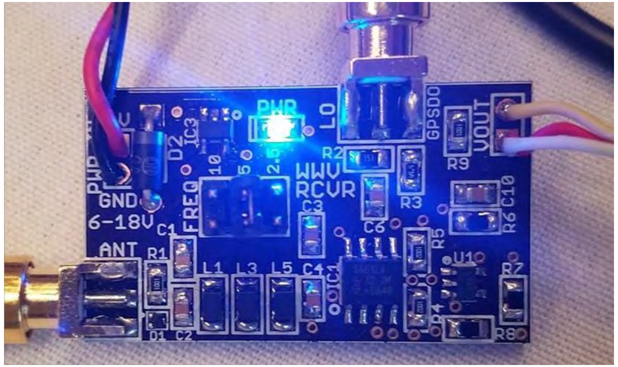
WA9VNJ 10 MHz WWV Observations




10 MHz HF Doppler Shift
TX: WWV (Ft. Collins, CO) RX: WA9VNJ (Mequon, WI)
(a) 2017 Aug 20 (Control Day)
Δf [Hz]
Solar Elevation Angle
UT [Hours]
(b) 2017 Aug 21 (Eclipse Day)
Solar Obscuration

Grape Low-Cost PSWS Status

- **Developed as the "Grape" Receiver by Case Western Reserve University and Case Amateur Radio Club W8EDU.**
- **Primary objective** is to measure Doppler Shift of HF standards stations such as WWV and CHU.
- **Cost of Grape v1 is ~$300 (not including antenna).**
- **Several stations** are currently deployed.
- Grape v1 build documentation is available at hamsci.org/grape1.
- Doppler shift data is collected via spectrographs and frequency estimation algorithms.
- Grape V2 will be capable of monitoring 3 HF channels simultaneously.



"Grape Receiver" Generation 1 by J. Gibbons N8OBJ

Raspberry Pi 4 with Switching Mode Power Supply for Grape Receiver and GNSS Disciplined Oscillator

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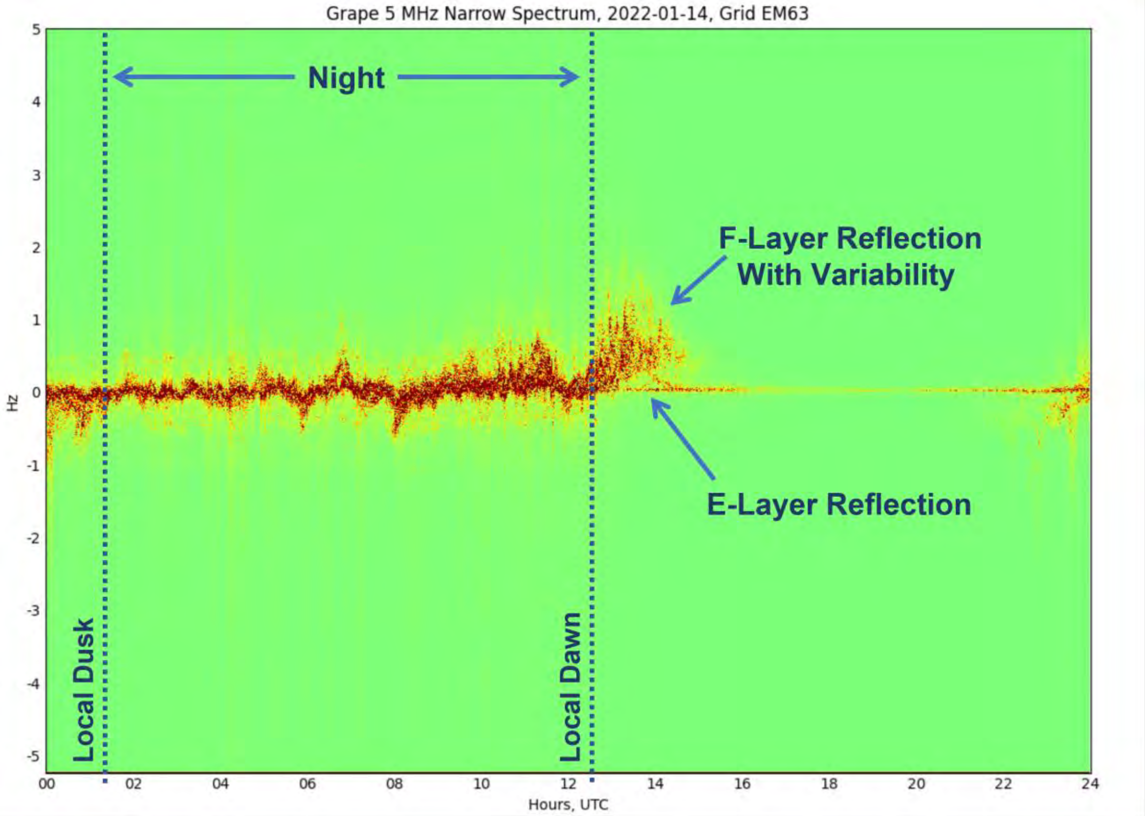
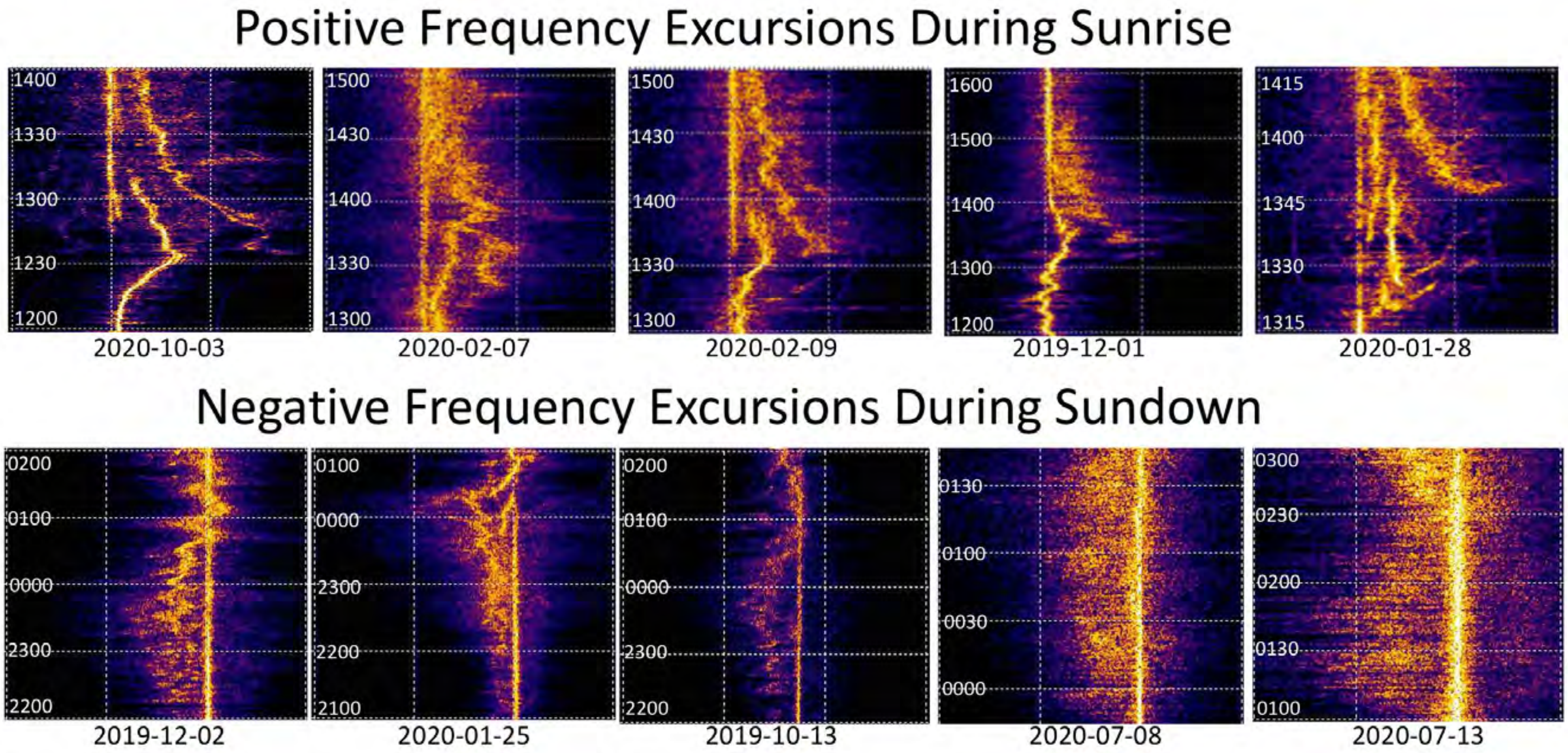
5 MHz WWV-AB4EJ Doppler Shifts



Data by
Bill Engelke AB4EJ

5 MHz WWV-WA5FRF Doppler Shifts



Data by Steve Cerwin WA5FRF

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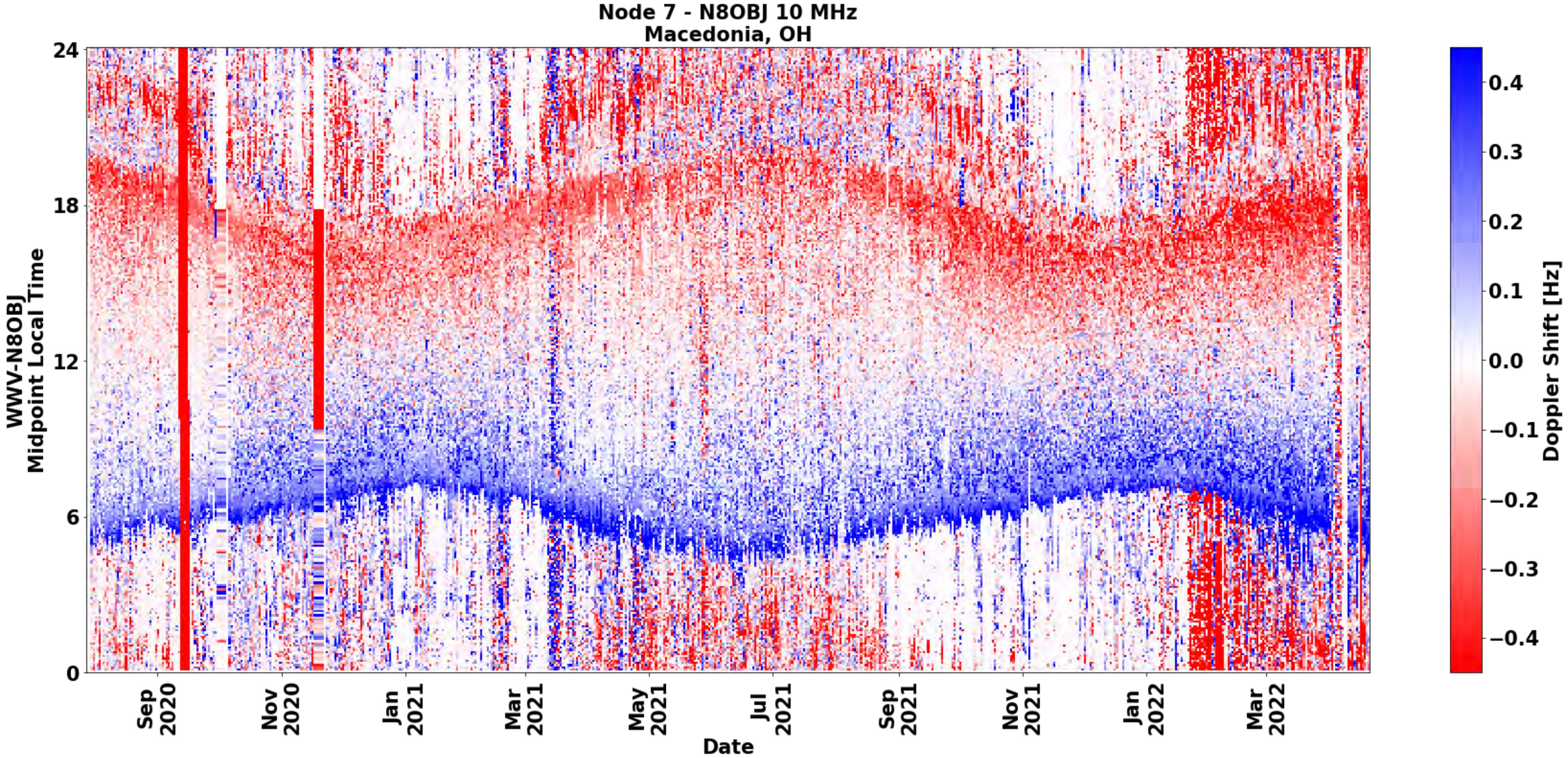
10 MHz WWV-N8OBJ (Cleveland, OH)



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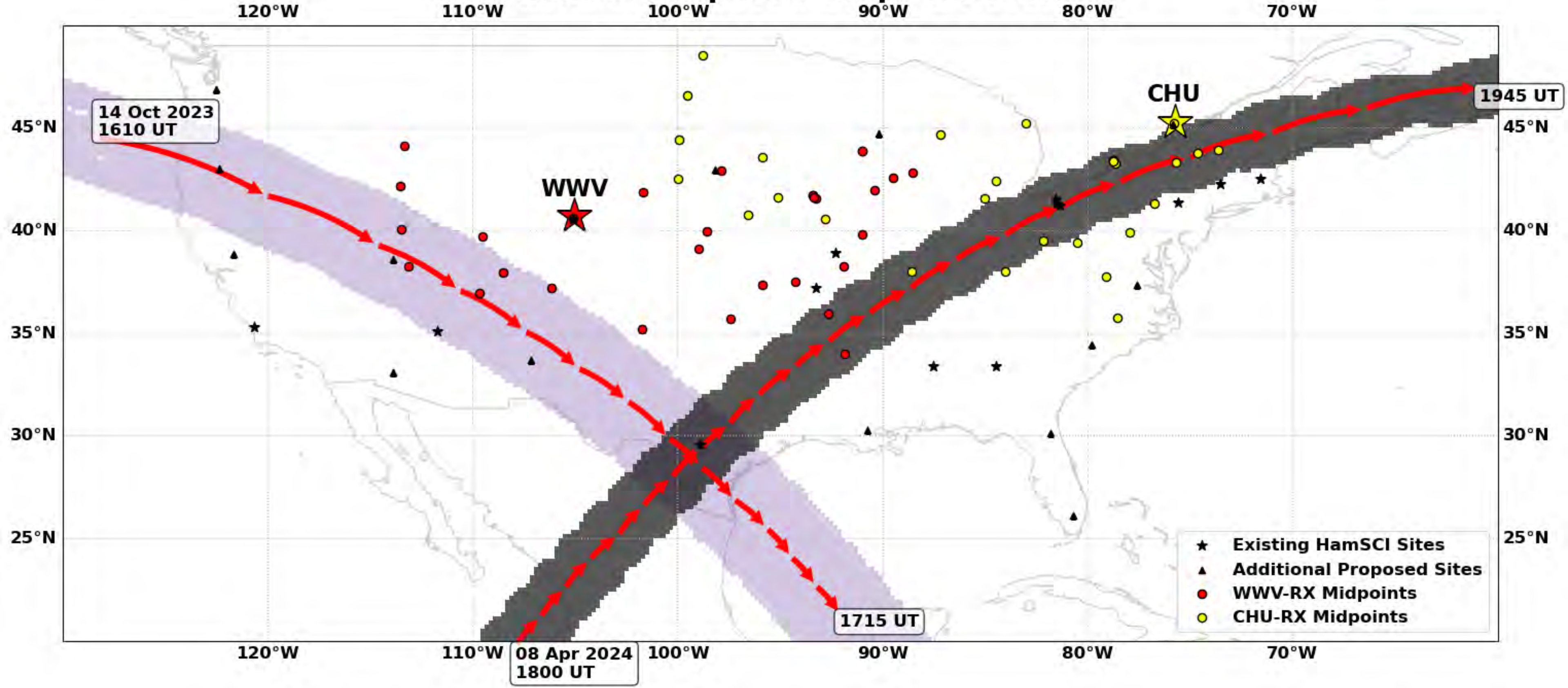
Locations of Proposed Grape 2 Receivers



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Solar Eclipse Grape Doppler Science Questions

1. How do dawn and dusk ionospheric variability as observed by HF Doppler shift measurements vary with local time, season, latitude, longitude, frequency, distance, and direction from the transmitter?
2. Is eclipse ionospheric response symmetric with regard to onset and recovery timing?
3. How similar is the eclipse to daily dawn and dusk terminator passage?
4. Do we observe multipath HF mode-splitting in the post-eclipse interval that is similar to dawn events?
5. How is the response different for the southward Annular eclipse in 2023 compared to the northward Total eclipse of 2024?

Solar Eclipse Grape Doppler Science Questions

- What are your thoughts?

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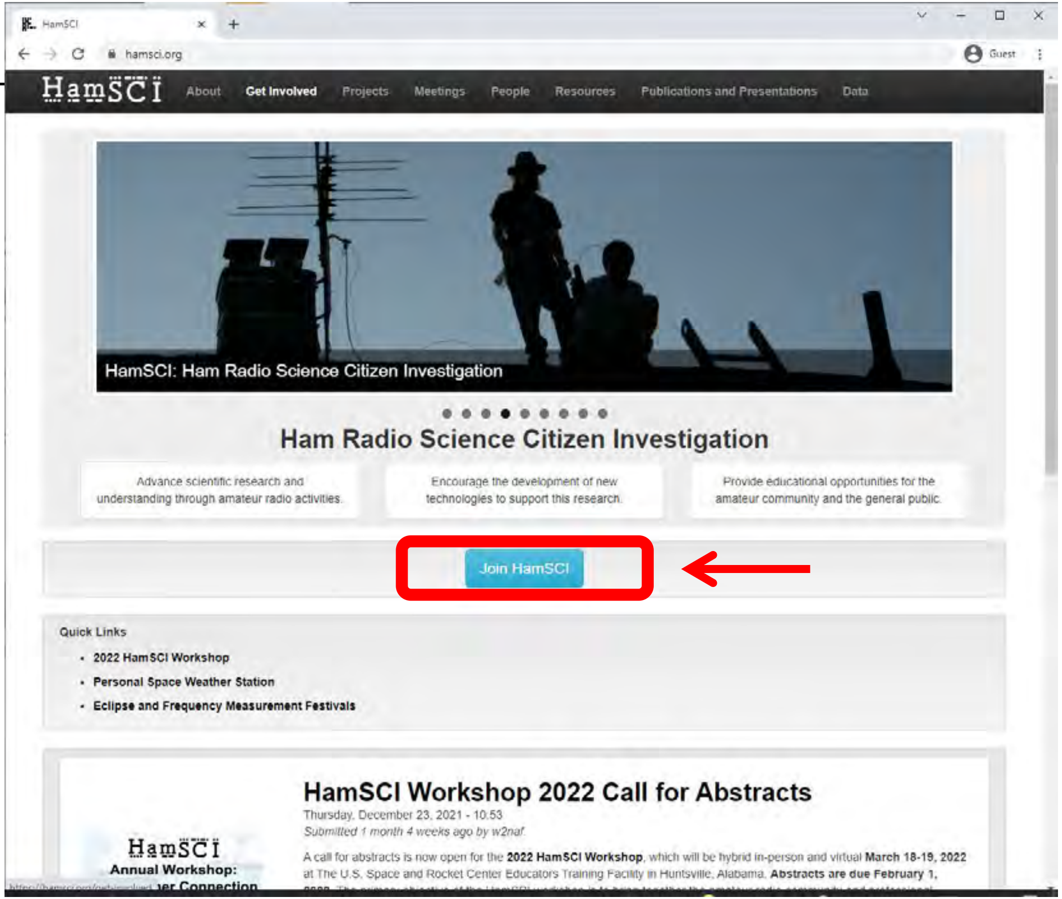
Getting Involved

- **HamSCI now has over 500 members!**
- Join by visiting **hamsci.org**
- Main Google group is open discussion for all things related to HamSCI.
- Many specialized email lists and telecons, too!
- Visit Booth 5008 (with TAPR)!



Visit us in Booth 5008 (with TAPR)!

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Visit us in Booth 5008 (with TAPR)!

- N8OBJ Grape v2 Booth Talk @ 1:00 PM
- HamSCI Forum 4 @ 2:50 PM

Thank you!

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References

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Acknowledgments

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