Deep Space Exploration Society (DSES) SuperSID station measures the Solar Eclipse!

The results closely match the prediction made by the DSES president Dr. Richard Russel in his paper, "*Ionospheric Reflection Variation During Sunrise and Sunset and Predictions for the 2017 Total Eclipse*" presented to the Society of Amateur Radio Astronomers (SARA) at the SARA Annual Conference in Green Bank, WV on July 25, 2017. Video is at time 1:27

https://www.youtube.com/watch?v=zOOuiirE1L4

Dr. Russel also presented a paper on the use of Monte-Carlos analysis: *"The Use of Monte-Carlo Analysis to Evaluate Radio Astronomy Source Detection"***.** The video is at time: 1:46:

https://www.youtube.com/watch?v=QQL1sarelQs

Background Science

The sudden ionospheric disturbance (SID) monitor measures the signal strength of a very low frequency (VLF) broadcast station after its signal is reflected off of the ionosphere. The characteristics of the signal strength is highly dependent on the local night and day.

The Sun's energy ionizes the Earth's atmosphere during the day. This produces different ionization layers defined as layers D, E, F. At night, there is only ionization from cosmic waves, and therefore there is only an F layer (1).

VLF radio waves reflect off the free electrons in the different ionosphere layers. The signal strength of this reflected signal can be detected by a SID small radio telescope. The normal use of the SID radio telescope is to detect solar flares which appear as short term signal strength increases during the daytime monitoring. The author will use the SID telescope's capability to measure and analyze the VLF signal strength variations and the effect of the solar eclipse on the ionosphere.

The total solar eclipse on August 21, 2017 in North America provided an opportunity to analyze the differences between the eclipse and normal daily ionospheric reflections.

The author has been using the SID radio telescope for over a year as an official observer for the American Association of Variable Star Observers (AAVSO). By chance, the eclipse umbra is passing between the VLF transmitter station and the author's SID radio telescope. This provides a unique opportunity to compare over a year's historic data with the eclipse data. In order to gain insight into the possible effects of the eclipse, the author developed two predictive models using historic data and eclipse times.

Dr. Russel developed a model for the effect of the eclipse on the SID signal and then measured the actual eclipse data on August 21, 2017.

SuperSID Monitor Measurements

The DSES SuperSID station is set up in Colorado Springs, CO.

Figure 1: Colorado Springs SuperSID Monitoring Station

Eclipse and VLF Signal Geometry

The solar eclipse forms when the Moon crosses between the Sun and the Earth. A total eclipse forms the umbra and a partial eclipse forms the penumbra. (figure 2)

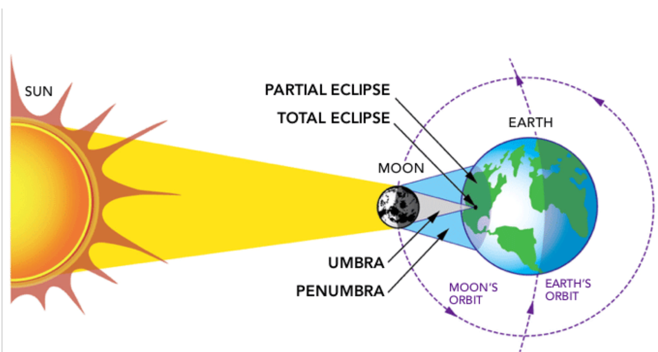

Figure 2: Eclipse Basics

NASA has plotted the umbra and penumbra for the August 21 path through North America. The umbra and penumbra happens to cross through the line between the LaMoore, North Dakota VLF station and the author's SID radio telescope in Colorado Springs, Colorado. (figure 3)

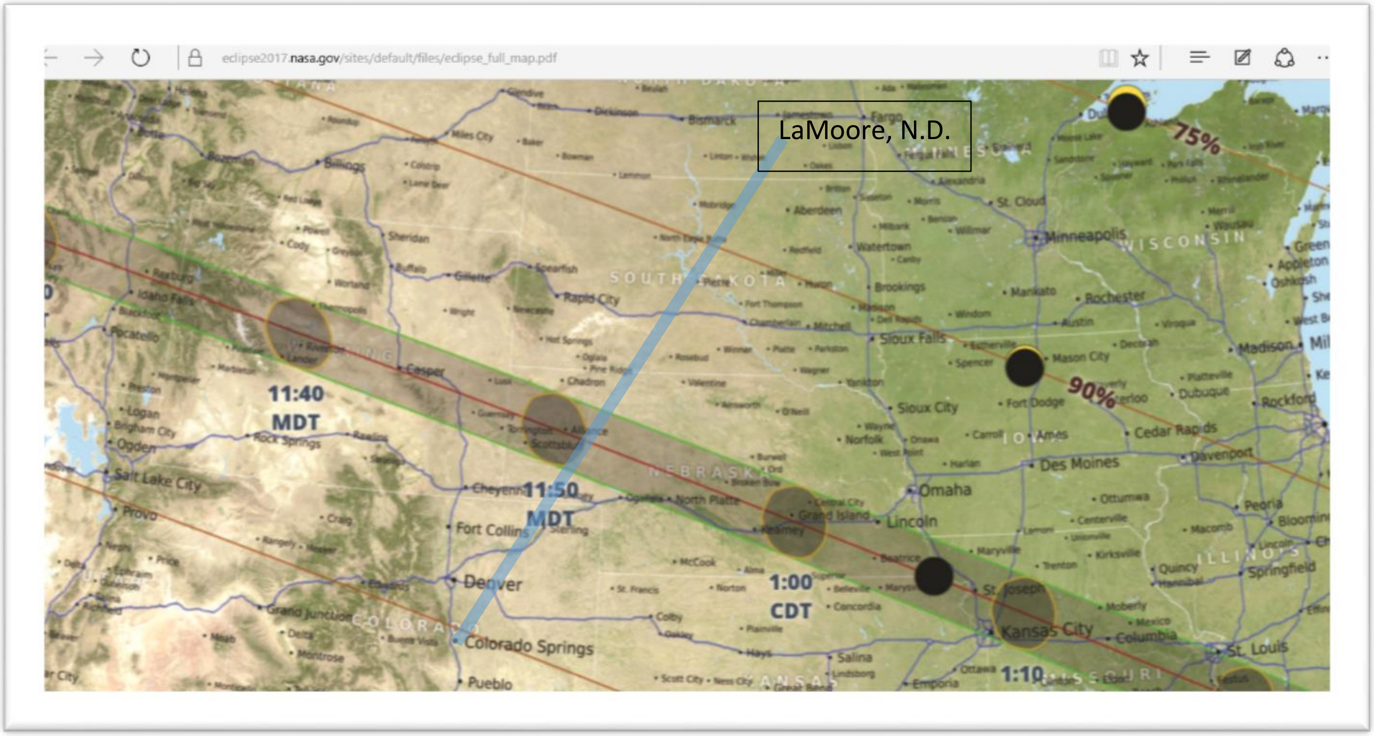

Figure 3: Eclipse Path

NASA also published the times for the eclipse for major cities along the path. (figure 4)

	Eclipse Begins	Totality Begins	Totality Ends	Eclipse Ends	
Madras, OR	09:06 a.m.	10:19 a.m.	10:21 a.m.	11:41 a.m.	PDT
Idaho Falls, ID	10:15 a.m.	11:33 a.m.	11:34 a.m.	12:58 p.m.	MDT
Casper, WY	10:22 a.m.	11:42 a.m.	11:45 a.m.	01:09 p.m.	MDT
Lincoln, NE	11:37 a.m.	01:02 p.m.	01:04 p.m.	02:29 p.m.	CDT

Figure 4: Eclipse Schedule

One of the key predictions will be to determine when the start, totality and end of the eclipse will appear for the SID radio telescope. The VLF path line crosses the full totality point at the 11:50 AM point. Using the Casper, WY schedule in figure 18, the rough estimate is that the times should be adjusted by + 8 minutes. Add 6 hours to convert from Mountain Daylight time gives:

Eclipse Begins: 1630 UTC
Totality Begins: 1750 UTC
Totality Ends: 1753 UTC
Eclipse Ends: 1917 UTC

Calculating the Eclipse Area over Time

As the Moon passes in front of the Sun, it subscribes an arc *abc*. The total area eclipsed is therefore areas (A1+A2). (figure 5).

Note: the full derivation is shown in the paper.

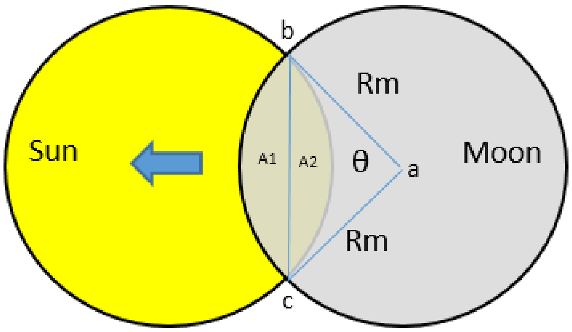

Figure 5: Sun and Moon Eclipse Geometry

$$Percent\ Sun\ Eclipsed = \frac{\theta}{180} - \frac{2}{\pi}\boldsymbol{cos}\left(\frac{\theta}{2}\right)\boldsymbol{sin}\left(\frac{\theta}{2}\right) \qquad (1)$$

Equation 1 allows for the calculation of the percentage of the Sun that is being eclipsed without knowing the apparent radius of either the Sun or the Moon. The eclipse area calculation is shown in figure 6.

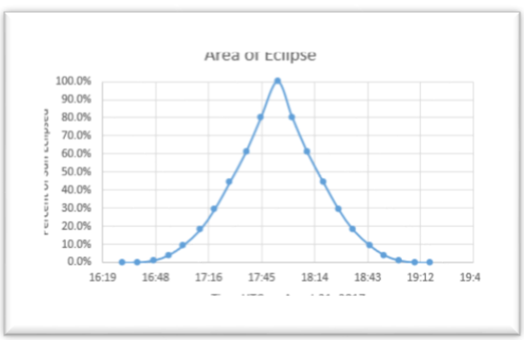

Figure 6: Calculations and Plot for % Sun Eclipsed over Time

The prediction for the effects of the eclipse on the SuperSID monitor is shown in figure 7.

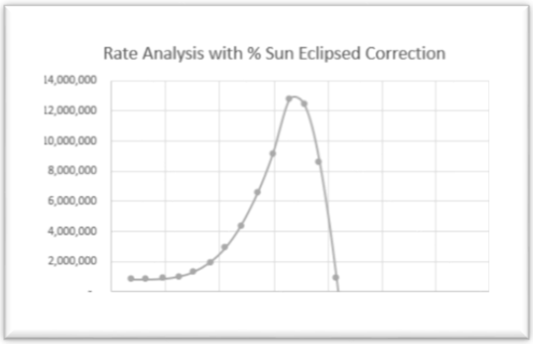

Figure 7: Prediction

Actual Eclipse Measurement

The data from the DSES SuperSID was analyzed using the SIDGRABBER software.

A significant signal was detected during the time of the eclipse! (figure 8).

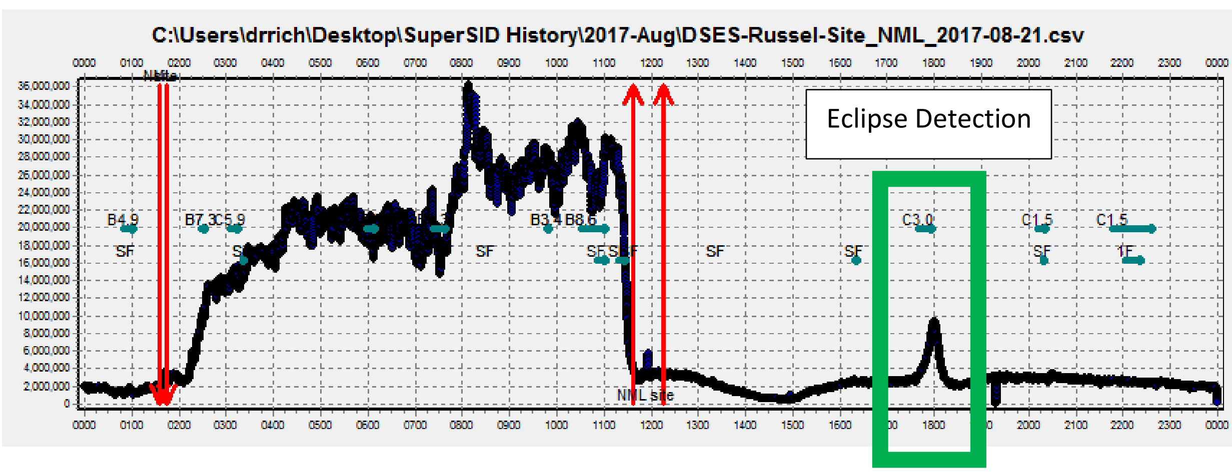

Figure8: August 21, 2017 Eclipse data

Zooming in on the eclipse time shows that the predicted and the actual eclipse signal is very close! Figure 9 shows the predicted and the actual side by side.

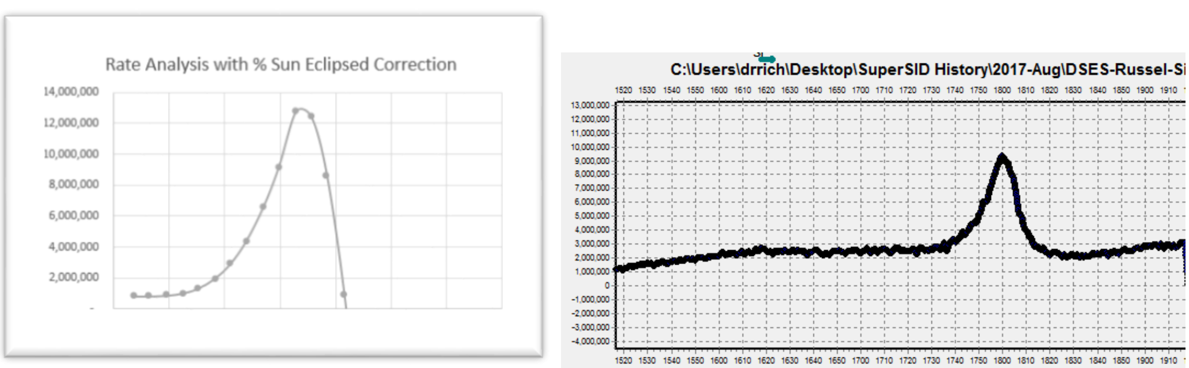

Figure 9: Dr. Russel's Prediction compared to actual measurement

Summary

Dr. Russel correctly predicted that the eclipse would produce a signal response on the SuperSID radio telescope. More analysis will be conducted to determine why there were differences between the model and the actual measurements.