Constructing a Radio Telescope for Detecting Jovian Aurora Emissions

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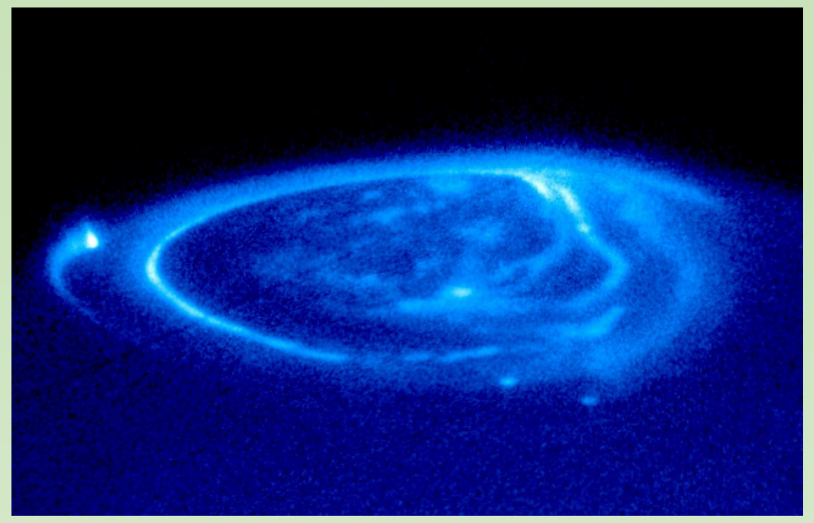
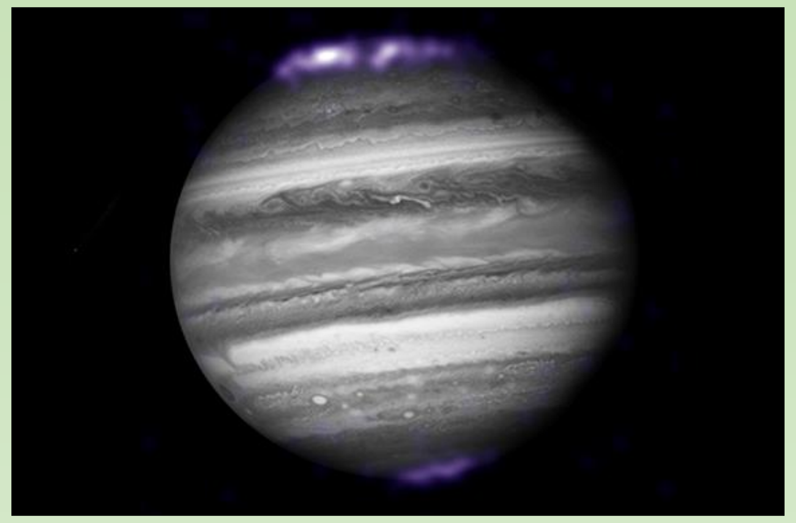
Abstract

The purpose of this experiment is to detect Jovian emissions with a 20.1 MHz radio telescope in order to better understand the Jovian aurora, its emissions, Jupiter's magnetic field, and how Jupiter interacts with its moon Io to enhance the emission of decametric radio waves. This radio telescope is constructed using blueprints from NASA's Radio JOVE Project, a project designed to provide radio astronomy resources to amateur and professional scientists alike. With this radio telescope, Jovian radio emission data has been gathered over three months, and the results have been compared with Jupiter noise storm predictions to depict the likelihood of storm detection and its correlation with the planetary configuration of Jupiter, Io, and the Earth.



A Close-Up of Aurora on Jupiter



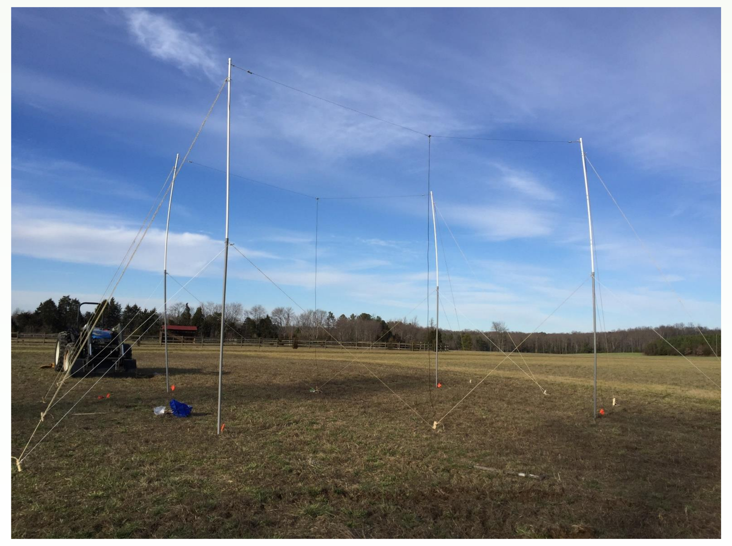
Jovian Aurora X-Ray Image Overlaid on Image of Jupiter

Background

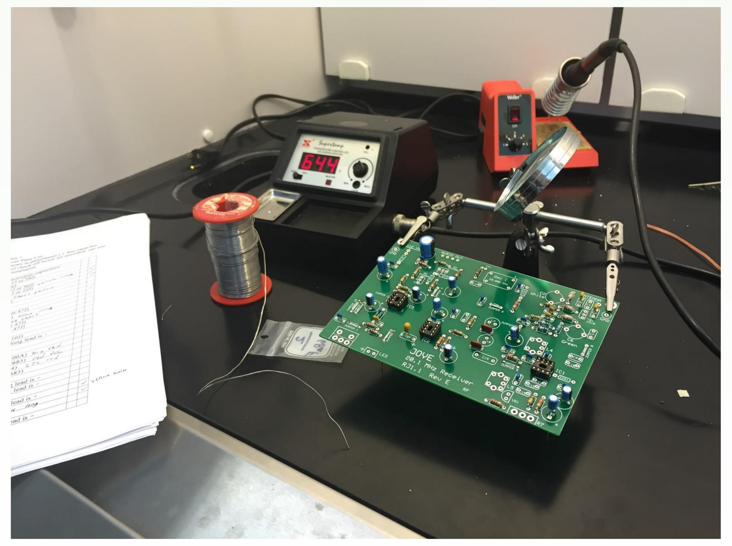
The Jovian aurora is a powerful source of energy, producing 1,000 times more power than the Earth's aurora. Jupiter's aurora is permanent and thought to come from the sulfur and oxygen ions produced by volcanoes on the moon Io. These charged particles accelerate through Jupiter's magnetosphere along the magnetic field lines towards the northern and southern magnetic poles, where they excite. When the atmospheric particles return to their normal state, they release light particles known as photons, which create a visible aurora. The streams of particles responsible for these aurorae also release radio emissions in the range of 3-40 MHz known as decametric radiation (DAM). These converted radio emissions present themselves in two ways: L-burst sounds and S-burst sounds, standing for "long" and "short" bursts, respectively. The former is caused as DAM is propagated through space, and the latter is theoretically caused by heightened storm activity on Jupiter's moon Io as it passes around Jupiter.

Methods

- 20' dual-dipole antenna array receives DAM from Jovian emissions, which are driven to the Radio JOVE 20.1 MHz receiver where out-of-band frequencies are filtered, desired frequencies are amplified, the radio signals are converted to audio signals, which is driven via auxiliary cable to a computer running the charting software Radio SkyPipe II.
- Radio SkyPipe II is a licensed software designed for use with the Radio JOVE to collect, store, retrieve, and edit data. The program records and graphs the audio signal on a strip-chart in real-time while simultaneously recording the audio signal as a wave file. The incoming data is charted as audio signal strength over time.
- Radio-Jupiter Pro III (RJP) is a Jupiter noise storm program that offers customizable storm predictions based on the location of the antenna array.



20' Dual Dipole Array



Radio JOVE Circuit Board

Data

Galactic Background Noise

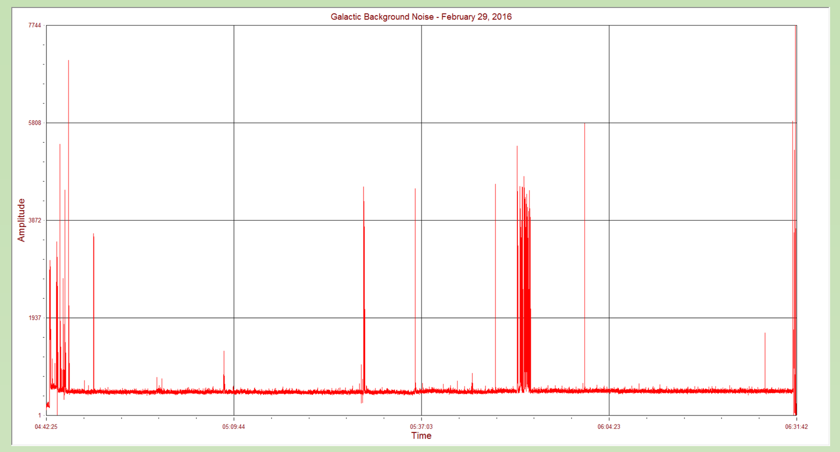


Figure A: Galactic Background Noise – 4:42 – 6:31 am

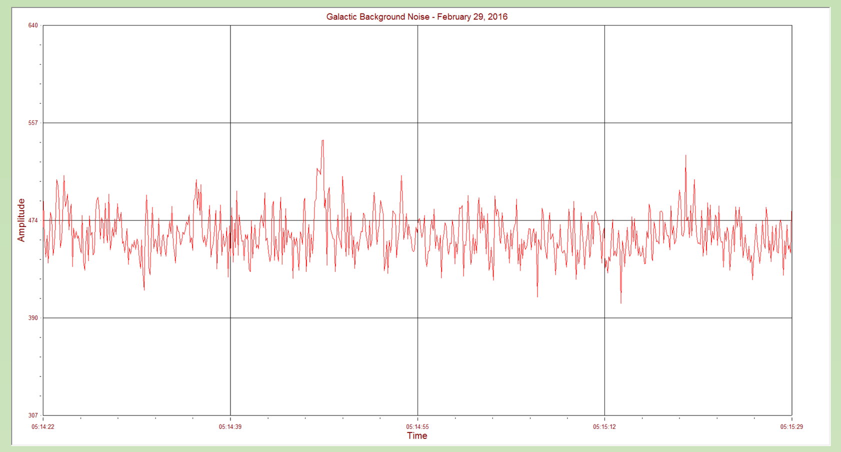


Figure B: Galactic Background Noise – 5:14 – 5:15 am

Galactic radio noise is random noise originating outside of the Earth's atmosphere that is detectable on certain radio receivers. Sources of this noise can include: celestial objects like Quasars, relativistic electrons spiraling in the galactic magnetic field, and meteorites falling and ionizing gases as they burn up in the atmosphere. Galactic background noise peaks in the direction of the center of the Milky Way galaxy, and it is represented on the strip chart as a steady signal devoid of any bursts or sudden change in amplitude with an average range of 432 – 504.

Sun Radio Emissions

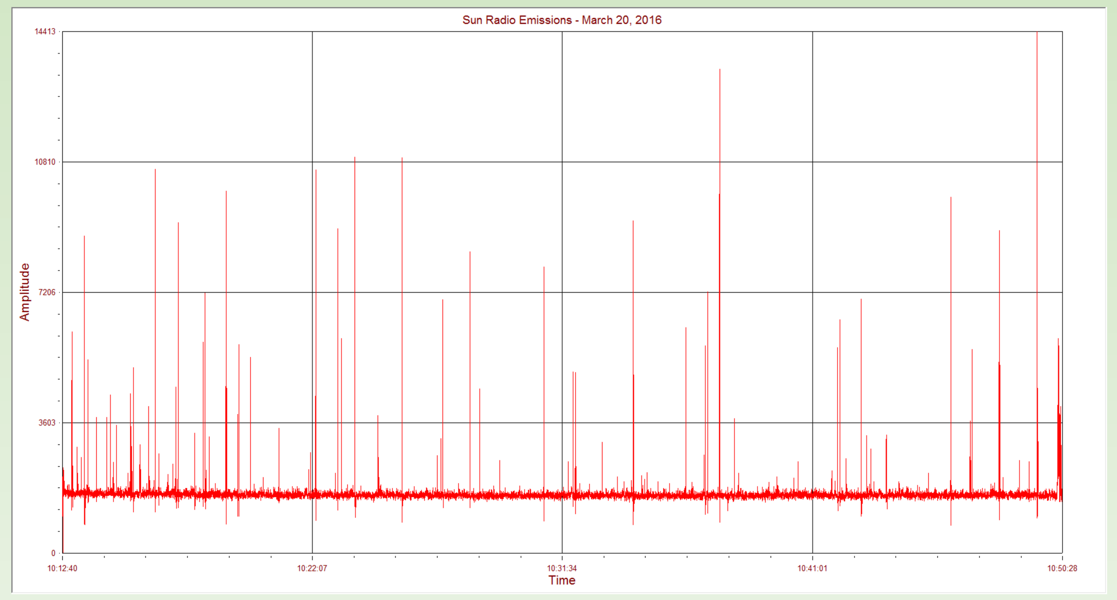


Figure C: Sun Radio Emissions – 10:12 – 10:50 am

While the radio telescope is configured for receiving Jupiter's emissions, it also has the capability of receiving the Sun's radio emissions. The Sun is much closer and much bigger than Jupiter, and therefore the Sun's signal is much stronger than Jupiter's, as shown by the amplitude in the figure above, which shows a signal strength range of 1500 – 15080.

A and C Jovian Emissions

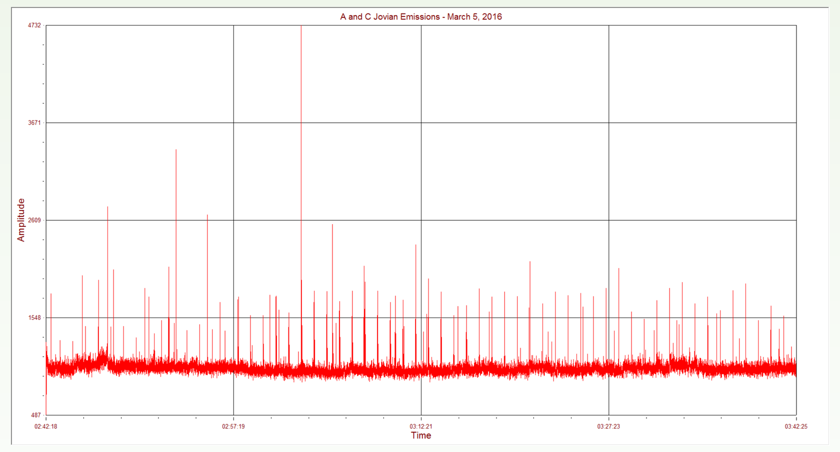


Figure D: A and C Jovian Emissions – 2:42 – 3:42 am

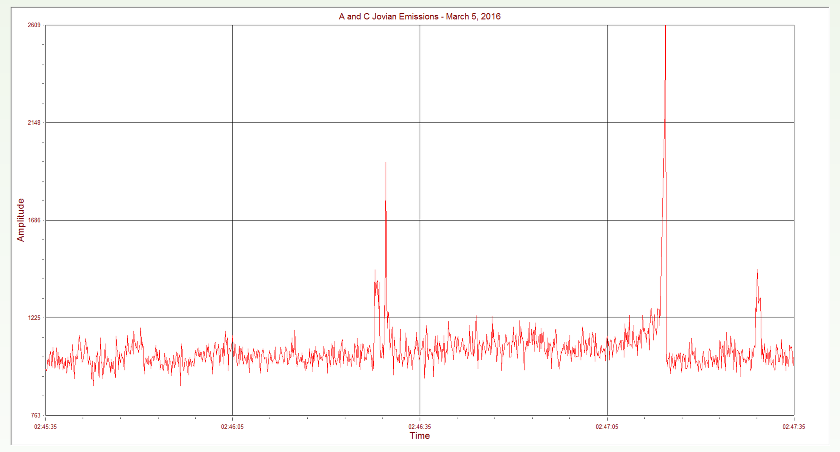
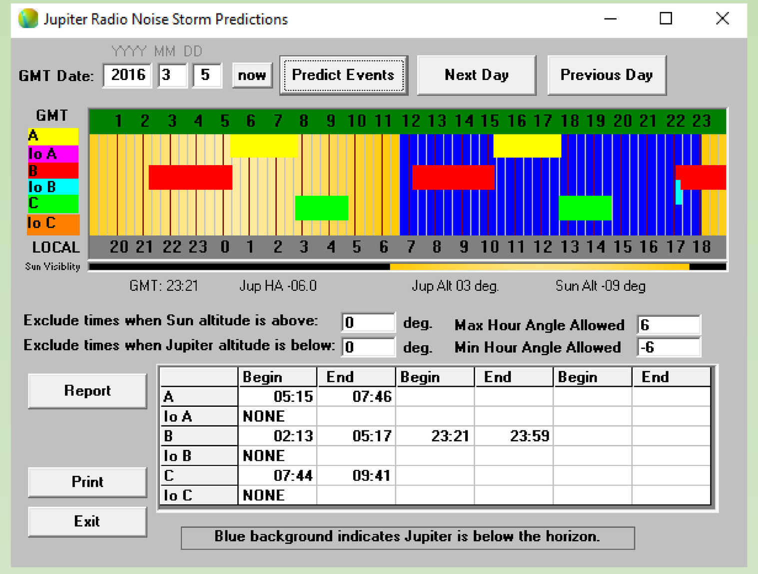


Figure E: A and C Event Detail – 2:45 -2:47 am

Figure D shows Jovian emission data acquired March 5, 2016 at 2:42 – 3:42 am. This graph shows a low range of periodic signal strengths with few anomalous peaks above the average range of 900 – 2185, with a declining trend in peak signal strength as time progresses. There was an event around 2:46 am, however apparently slight on the full graph, Figure E shows a closer view of this event over the range of two minutes.

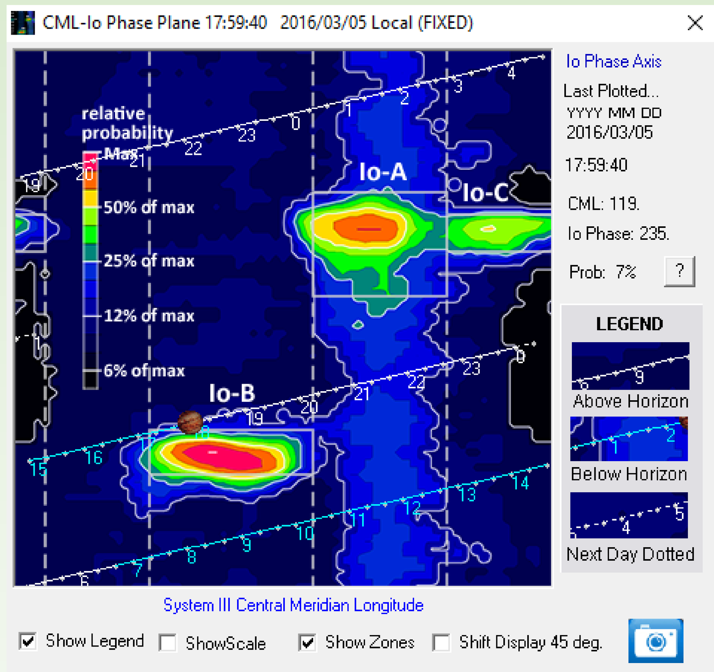
Results

The event shown in Figure E is corroborated by Radio-Jupiter Pro's Noise Storm Prediction, shown below. Longitudinal regions of Jupiter are labeled A, B, and C, with Io interactions labeled Io A, Io B, and Io C. On March 5, 2016 at 2:44 am EST, Jupiter rotated out of region A to region C, with a brief period of overlapping emissions.



Noise Storm Predictions for March 5, 2016

The availability of detectable Io A, Io B, and Io C S-burst emissions is incredibly limited. Due to the rapid nature of Io moving through regions of Jupiter, Io interactions with a longitudinal region which is directed towards Earth are limited, and it is even more limited that that interaction will occur when Jupiter is overhead and in the beam pattern of the antenna. To complicate things even further still, these are indeed predictions and there is a varying probability of detecting radio storms, depicted by CML-Io plots.



CML-Io Probability Plot for March 5, 2016

Conclusions

Due to the sparsity of Io interactions, no S-burst data was collected. However, ample L-burst emission data was collected from Jupiter's persistent aurora. Figure A and C show the distinction between two different sources of decametric radio emissions – galactic background noise and the Sun, respectively – and how they differ from Jupiter's radio emissions in the average amplitude of signal strength, height of spike activity, periodicity of spikes in signal strength, and general trends towards non-sudden fluctuations of signal strength. Furthermore, the collected Jupiter data can be compared to NASA's Radio JOVE data archive, which contains data uploaded by amateur and professional scientists from around the world.

Acknowledgements and Resources

NASA's Radio JOVE Project
Radio JOVE Data Archive
Radio-SkyPipe II

Radio-Jupiter Pro III
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Raymond Duncan