Citizen Science Training Modules

The Radio JOVE Project

radiojove.gsfc.nasa.gov

A Partnership Between

SUNRISE GROUND RADIO LAB | NASA Partner | UNIVERSITY OF MICHIGAN

Welcome to The Radio JOVE Project Citizen Science Training Modules. I am Professor Chuck Higgins from Middle Tennessee State University and one of the leaders of The Radio JOVE Project.

These training modules are a partnership between the SunRISE mission team and The Radio JOVE Project. We acknowledge contributors to these modules as well as our funding sources of support.

This is Training Module 1.4 – Jupiter Radio Emissions

Prerequisites for Training Modules

1. High School Reading Comprehension and General Science
2. Scientific Notation
3. Electromagnetic Spectrum
4. Speed, Wavelength, and Frequency of Waves
5. Graphical Interpretation of Data
6. Training Modules 1.0, 1.1, 1.2, and 1.3

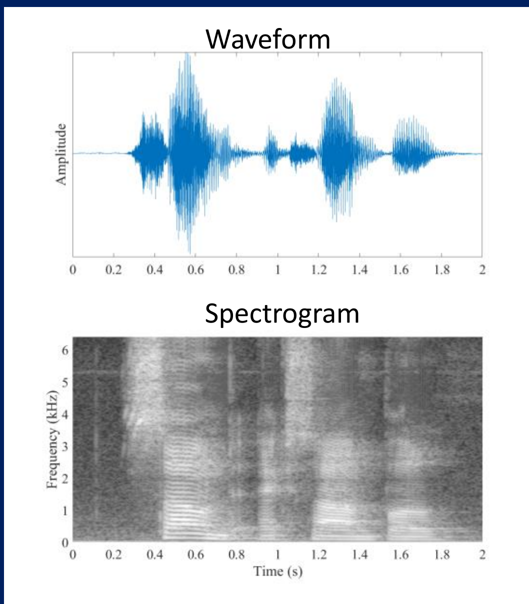
This is a list of prerequisites needed to be able to understand the material in this module.

Learning Objectives

1. Understand the radio spectrogram
2. Discovery of Jupiter radio emissions
3. Jupiter’s magnetosphere and Io’s plasma torus
4. Source locations of Jupiter decameter radio waves
5. Examples of Jovian radio emission sources

This is a list of the learning objectives for this presentation. We first define and overview a radio spectrogram to help you understand how to interpret them. Then we give a brief history of the discovery of Jupiter radio emission, followed by an overview of Jupiter’s magnetic field and Io plasma torus. Finally, we discuss the source locations of the decameter radio emissions and give examples to help you identify them.

What is a Spectrogram?



Waveform – An amplitude vs time graph showing the waveform of 2 seconds of the spoken words “sound example”.

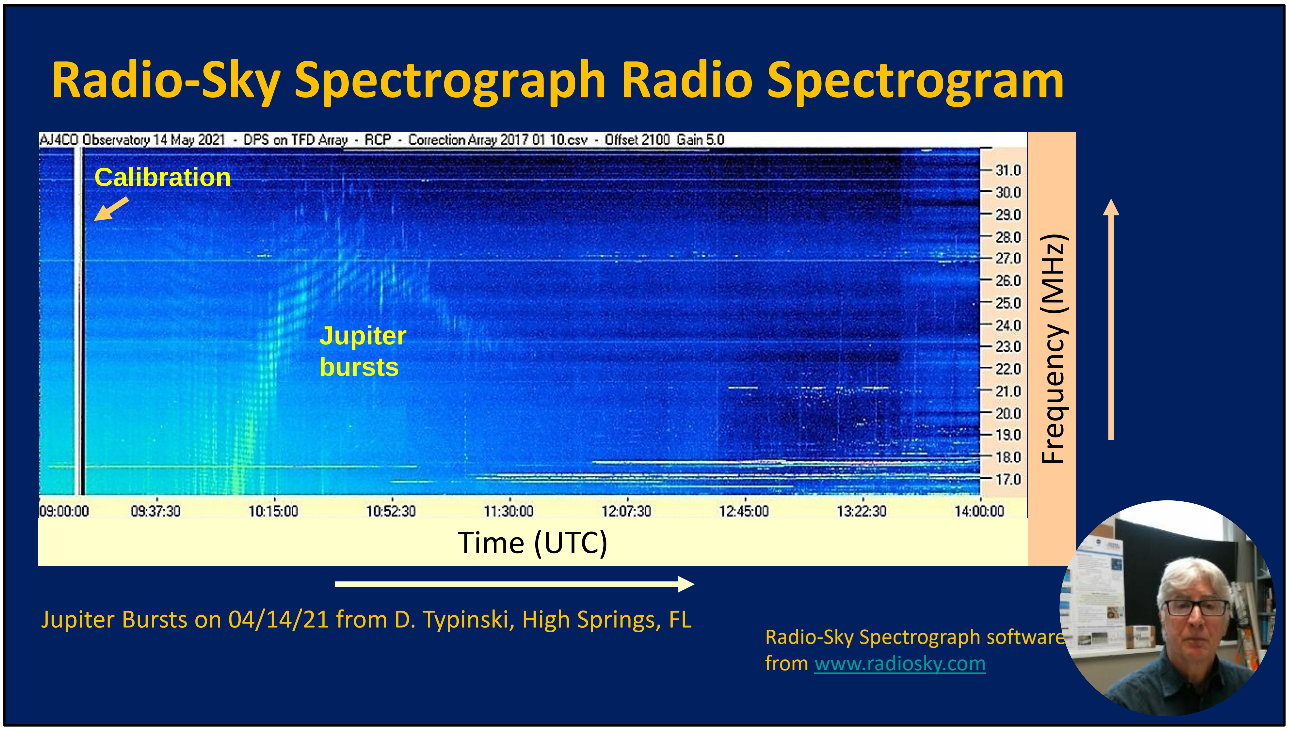
Spectrogram – A frequency vs time vs intensity graph, a spectrogram, of the same sounds. The amplitude of the sounds are given in grayscale. The louder sounds are depicted as white, quieter sounds in black.

https://wiki.aalto.fi/display/ITSP/Spectrogram+and+the+STFT

A waveform is an amplitude vs time graph of data, most often sound information; the top graph shows the waveform of 2 seconds of the spoken words “sound example”.

A spectrogram is a visual way of representing the signal strength, or “loudness”, of a signal over time at various frequencies present in a particular waveform. One can see where there is higher or lower energy at a particular frequency, and one also sees how energy levels vary over time. Spectrograms are commonly used to display frequency-time data.

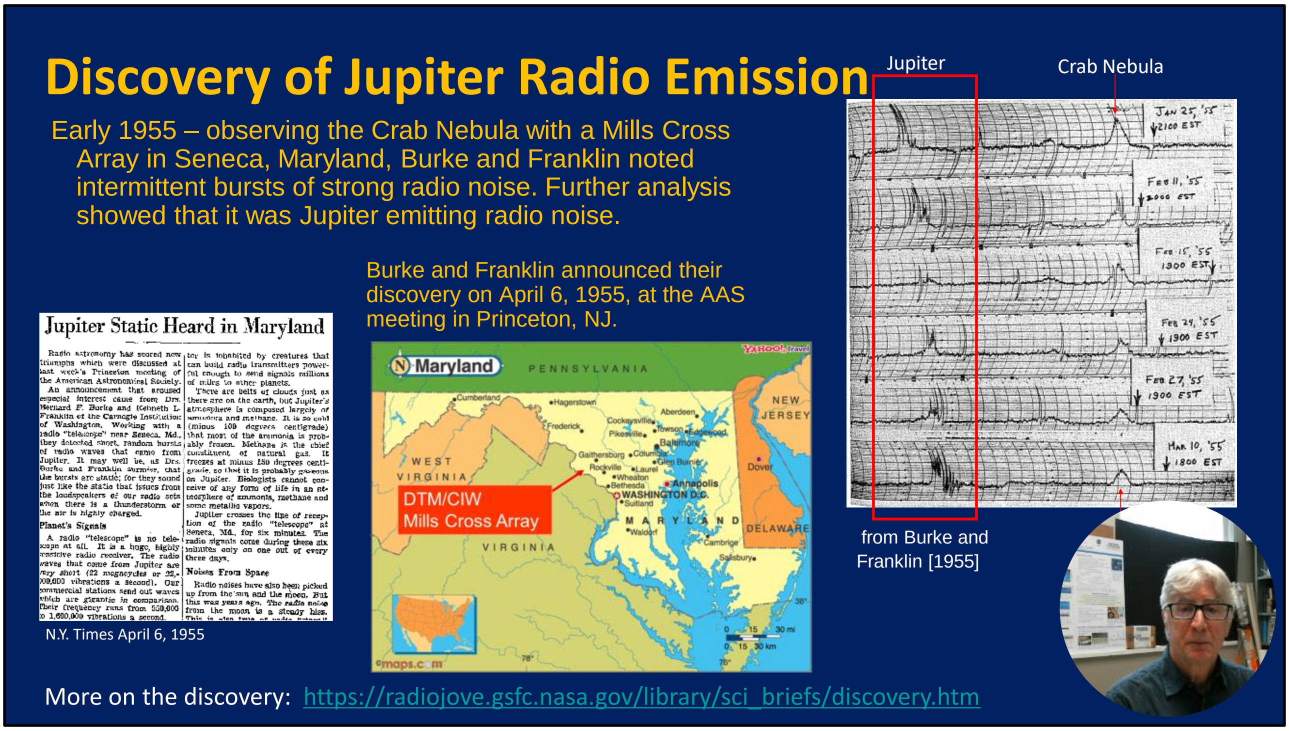
In the example, a frequency vs time vs intensity graph of the spoken words “sound example” is given in the lower graph. The amplitude of the sounds are given in grayscale, and the louder sounds are depicted as white and quieter sounds in black.



A radio spectrogram is typically three-dimensional graph of time, frequency, and intensity, where intensity is represented by a color scale. Shown here is a radio spectrogram of 5 hours of data (09:00:00 to 14:00:00 UTC) over a bandwidth of 16-32 MHz. Time increases from left to right, frequency increases from bottom to top, and the intensity is represented by a rainbow color scale where black is zero and white is the maximum signal.

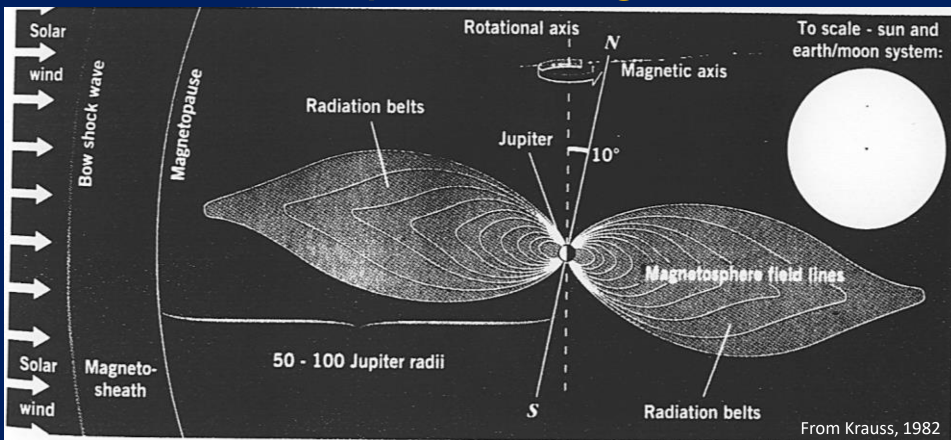
The arc-shaped feature are Jupiter radio bursts. This is typical of an Io-B related emission source to be discussed shortly. The curved lines of alternating high and low intensity emission is caused by radio propagation through Earth's ionosphere.

The Radio-Sky Spectrogram program used by Radio JOVE is freeware from Radio-Sky Publishing (www.radiosky.com). There are many excellent features to this software, and a help guide is found on radiosky.com.



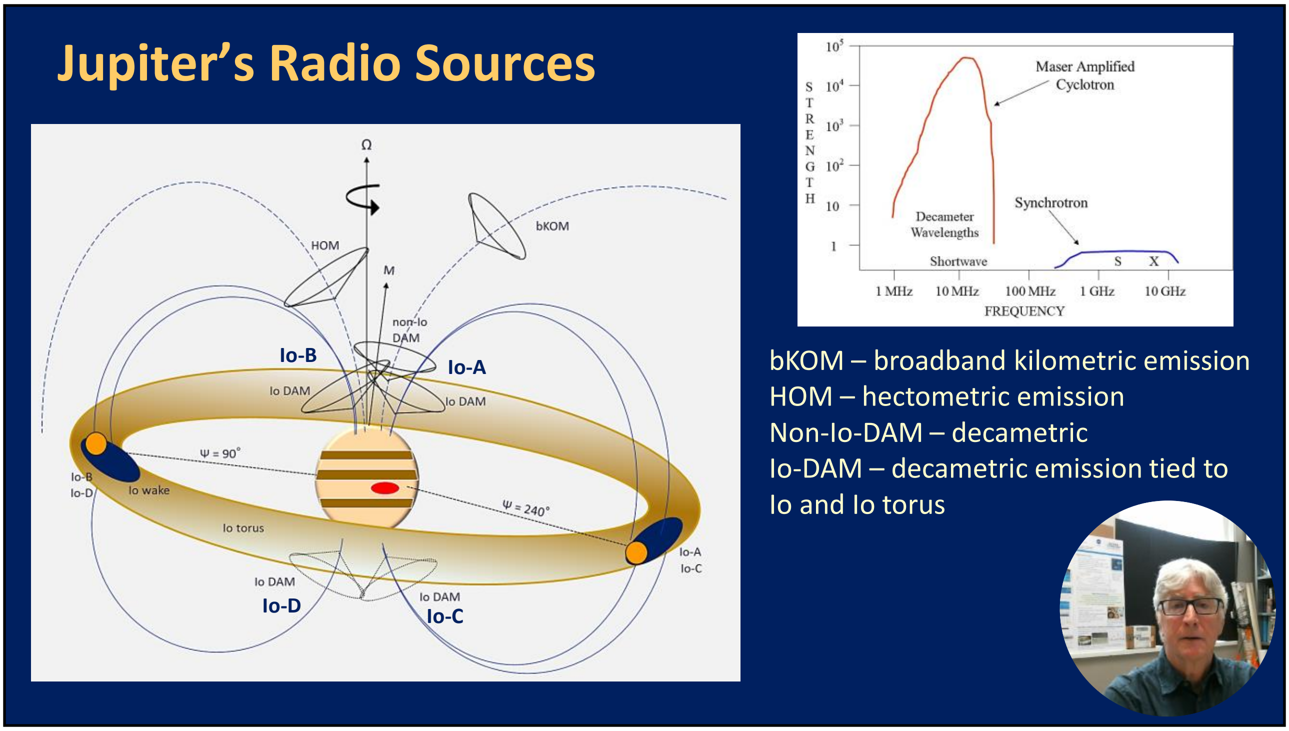
Early in 1955 while observing the Crab Nebula with a Mills Cross Array in Seneca, Maryland, Bernard Burke and Kenneth Franklin noted intermittent bursts of strong radio noise. The timing of the bursts changed at a sidereal rate, one associated with sky motions (i.e., not terrestrial), and further analysis verified it was Jupiter causing the radio emissions. Burke and Franklin announced their discovery on April 6, 1955, at the American Astronomical Society (AAS) meeting in Princeton, NJ.

Jupiter's Magnetic Field



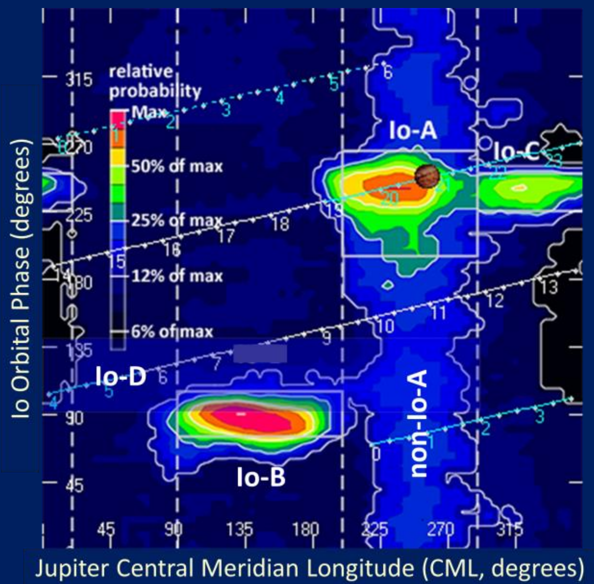
- Jovian radio emission discovered by Burke and Franklin in 1955
- Radiation belts discovered in 1959
- In 1964, Jupiter's moon Io strongly influences the radio emission source
- 1998 – 2008 Callisto, Ganymede and Europa shown to influence Jupiter radio emissions

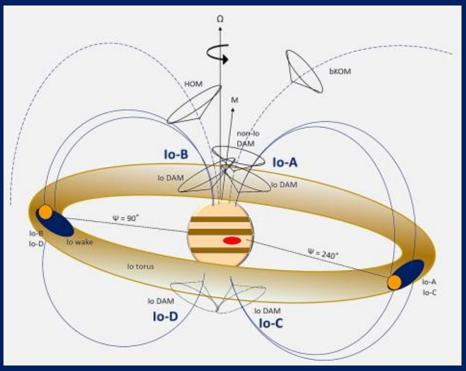
A scale drawing showing the size of Jupiter's magnetosphere relative to the Sun and the Earth-Moon system. Note that Jupiter's magnetic axis is tilted about 10 degrees relative to its rotation axis. Jovian radio emission discovered by Burke and Franklin in 1955, and the radiation belts were discovered in 1959. In 1964, it was found that Jupiter's moon Io strongly influences the radio emission source. From 1998 – 2008 Callisto, Ganymede and Europa were shown to have a minor influence on Jupiter radio emissions.



An overview of Jupiter’s low frequency radio emission structure. These radio emissions are strongly circularly polarized and influenced by Jupiter’s magnetic field and rotation, the solar wind, and the Io plasma torus. Emissions are: bKOM – broadband kilometric; HOM – hectometric and Non-Io-DAM – decametric are related to auroral emissions; Io-DAM – decametric emission tied to Io flux tube and Io torus. The Io-related radio emission are labeled Io-A, Io-B, and Io-C, Io-D located in the northern and southern hemispheres, respectively. The Io plasma torus supplies much of the plasma for the Io-related radio emission. The DAM emission is a cyclotron maser mechanism where electrons are accelerated by strong electric and magnetic fields and generate radio waves emitted in a cone-like pattern. Jupiter’s magnetic field magnitude limits the emissions to below 39.5 MHz. Different radio sources, those in Jupiter’s radiation belts closer to the planet, are responsible for the synchrotron emission at higher frequencies.

Jupiter Longitude and Io Phase

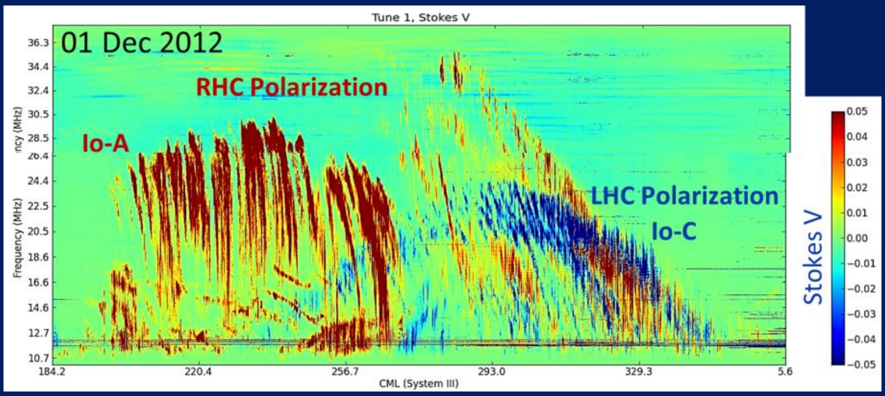




Radio Jupiter Pro software
from www.radiosky.com/

This a map of the probability of receiving Jupiter's radio emissions near 20 MHz adapted from Radio Jupiter Pro software from radiosky.com. Maps like this have been produced since the late 1950s where the y-axis is the Io orbital position, and the x-axis is the Jupiter longitude. The software allows one to predict the times when Jupiter is more favorable for Earth-based reception of radio emissions. High probability regions are shown in red and yellow; they are labeled Io-A, Io-B, and Io-C. Lower probability regions are non-Io-A and Io-D emissions. The UT times are marked along the diagonal lines on the map and the Jupiter icon gives the current longitude/phase of Jupiter/Io.

Example Io-A and Io-C emissions

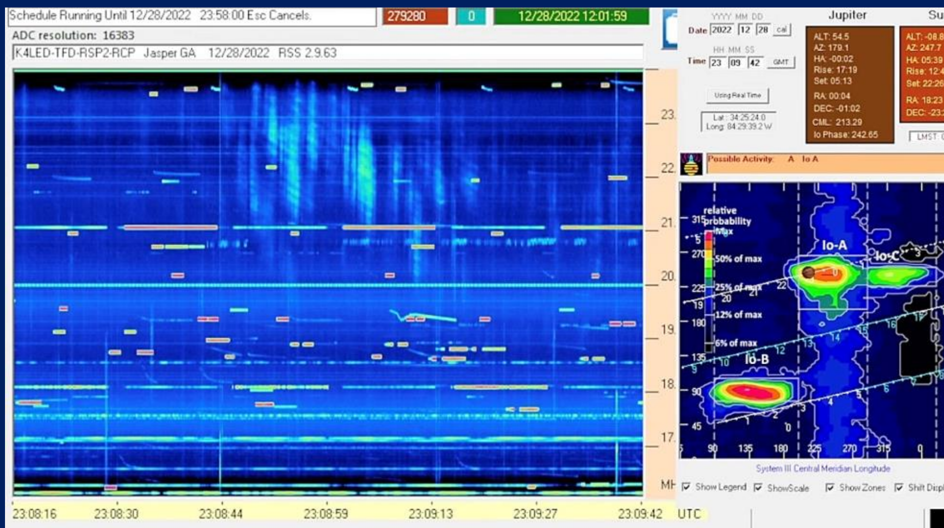


Io-A and Io-C emissions observed with the professional radio telescope LWA1, Socorro, NM.

These are example Io-A and Io-C emissions observed with the professional radio telescope LWA1, in Socorro, NM.

This Io-A/Io-C event is shown over a frequency range 10 – 38 MHz with RH circular polarization shown in red and LH circular polarization shown in blue. The Io-A comes from Jupiter's northern hemisphere while the Io-C is from the southern hemisphere. Notice the arc-like structures of the Io-A and Io-C sources and the similar structure seen in different events.

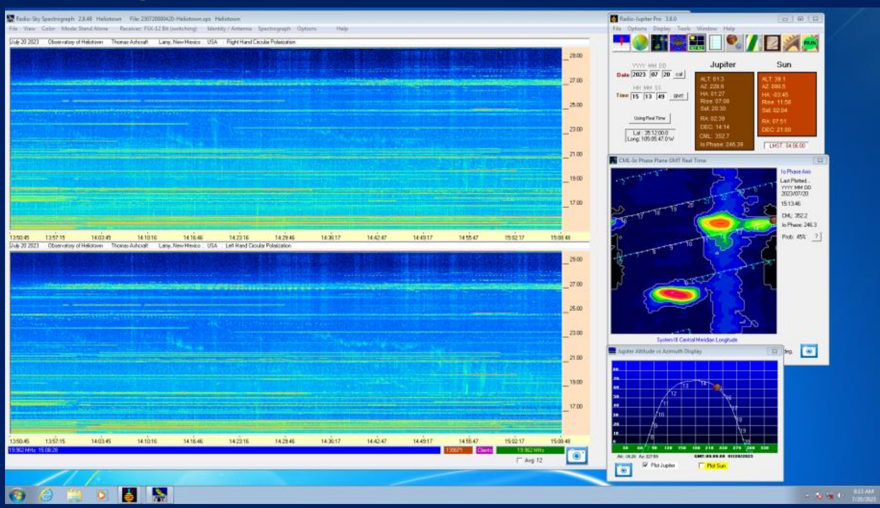
Example Io-A



Jupiter Io-A emissions on Dec 28, 2022, from L. Dodd, Jasper, GA

Jupiter Io-A emissions on Dec 28, 2022, from L. Dodd, Jasper, GA. Notice that you can detect the Jupiter emissions among the interference if you know what you are looking for. Also notice the Radio Jupiter Pro prediction in the right of the image. The Jupiter icon is over the high probability Io-A source.

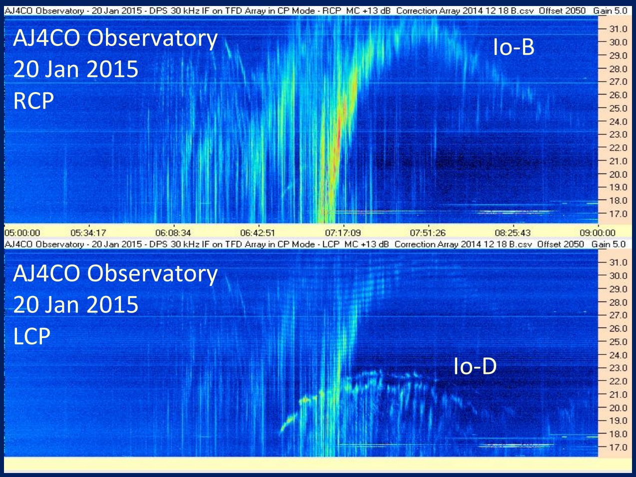
Example Io-C



Jupiter Io-C emissions on July 20, 2023, from T. Ashcraft, Lamy, NM

Jupiter Io-C emissions on July 20, 2023, from T. Ashcraft, Lamy, NM. Notice the Radio Jupiter Pro prediction in the right of the image. The Jupiter icon is over the high probability Io-C source.

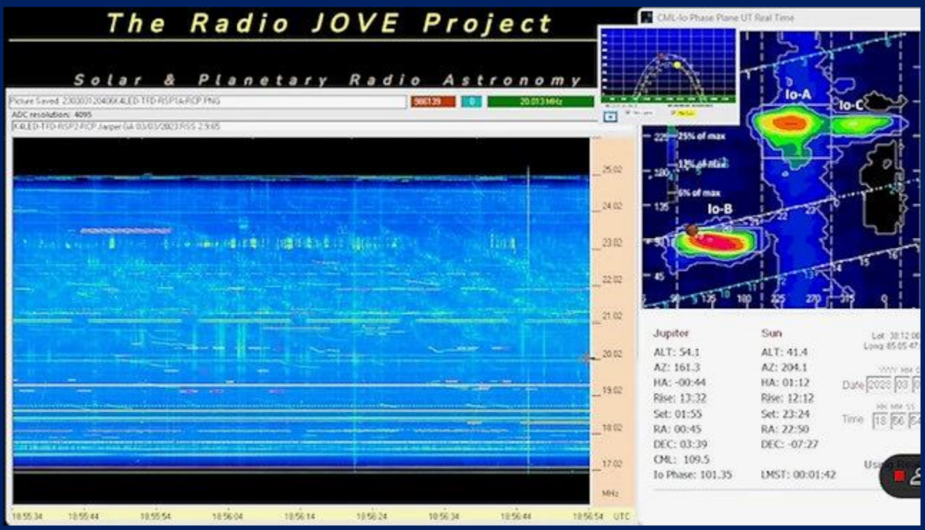
Io-B and Io-D Observations



Radio polarimeter observations on 20 Jan 2015 from D. Typinski, AJ4CO Radio Observatory, Florida.

Jupiter observations from D. Typinski, AJ4CO Radio Observatory, Florida. The Io-B and Io-D events are shown here with RH circular polarization on the top graph and LH circular polarization shown on the bottom graph. Again, notice the overall arc shape and the individual broadband structures of the emissions.

Example Io-B



Jupiter Io-B emissions on March 3, 2023, from L. Dodd, Jasper, GA

Jupiter Io-B emissions on March 3, 2023, from L. Dodd, Jasper, GA. These are weak Jupiter emissions. Note the Radio Jupiter Pro prediction in the right of the image. The Jupiter icon is close to the high probability Io-B source.

Sometimes the best way to confirm a Jupiter radio observations is to compare with another observer. The Radio JOVE groups.io listserv is an excellent resource for this.

Resources

Summary of Jupiter Radio Emission
https://radiojove.gsfc.nasa.gov/library/sci_briefs/decametric.htm
https://www.radiosky.com/rjcentral.html

A PROJECT TO DETECT RADIO EMISSIONS FROM JUPITER
https://www.spaceacademy.net.au/spacelab/projects/jovrad/jovrad.htm

Radio Jupiter Pro Software
https://radiosky.com/rjpro3ishere.html

Radio Observations of Jupiter
https://www.atnf.csiro.au/research/solarsys/jupiter/index.html

Nançay Radio Observatory
https://www.obs-nancay.fr/

This is a short list of good resources on Jupiter radio astronomy.

Thanks for watching

Next up is a training module on Galactic radio emissions …

Thanks for watching. Next up is a training module on Galactic radio emissions …