An Overview of the Radio JOVE Project

Chuck Higgins, Middle Tennessee State University

Abstract

Radio JOVE is an education and outreach project intended to give students and other interested individuals a hands-on experience in learning radio astronomy. After selling its first kit in 1999, Radio Jove has now sold over 1900 radio telescopes in more than 70 countries around the world. Hardware and software has evolved in this time, and the Radio Jove Team will give a complete update and overview of the status of the program as of 2014. Specifically, we will summarize the latest hardware and software for Radio Jove, include some recent Jupiter and solar observations highlighting the data archive, and discuss some research projects for students. Finally, we will discuss some upcoming projects for Radio Jove and highlight some advanced equipment, software, and results.

I. Overview of Radio JOVE

a. Brief JOVE History

Radio Jove is a hands-on educational activity that brings the radio sounds of the Sun, Jupiter, the Milky Way Galaxy, and terrestrial radio noise to students, teachers, and the general public. Radio Jove is a non-profit group specifically founded to educate the general public about radio astronomy. Participants may build a simple radio telescope kit, make scientific observations, and interact with professional radio observatories in real-time over the Internet. Our website (http://radiojove.gsfc.nasa.gov) includes science information, construction manuals, observing guides, and education resources for teachers and students. The goals of Radio Jove are:

1. Educate people about planetary and solar radio astronomy, space physics, and the scientific method
2. Make available a complete and inexpensive radio telescope for construction and use for observations
3. Provide teachers and students with hands-on radio astronomy exercises as science curriculum support and special projects for clubs or individuals
4. Enable access to on-line observatories providing real-time data via the Internet
5. Facilitate the exchange of ideas, data, and observing experiences among participants

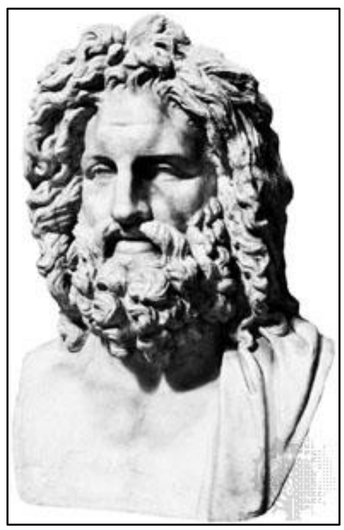

Figure 1. Jupiter sculpture in the Vatican Museum (Credit: Alinari/Art Resource, New York)

The Radio Jove Project, named after Jove, or Jupiter, from Roman mythology (Figure 1), is sometimes written as The Radio JOVE Project where JOVE represents the four letters of the call sign of a radio station. Radio Jove is a project that is geared toward high school level students, and it provides a hands-on and interactive experiment to develop and encourage students to become interested in science. It is easily adapted to accommodate college science classes and even can be used by middle school students and teachers. Our history has shown, however, that the most resourceful and dedicated participants have come from interested individuals and radio enthusiasts.

Participation can primarily come in 3-4 different ways: (1) buy and build your own Radio Jove receiver and antenna to collect your own Jupiter or solar radio data; (2) use available software, called Radio-Skypipe, to monitor, record, and analyze radio data remotely from another Radio Jove user; (3) download data from the Radio Jove Archive (http://radiojove.org/archive.html); and (4) modify or purchase your own radio equipment to make observations and contribute to the community. Option 2 is particularly useful for schools or people that may not have the space or funding to set up their own telescope. Telecons are scheduled periodically to help answer questions and foster interactions and data collections during times of predicted Jupiter or solar activity.

The Radio Jove standard kit presently costs $210 + shipping. Kit ordering and payment can be made from the project website (http://radiojove.gsfc.nasa.gov). Other options for ordering kits are available on the website ordering page. The website also includes a wealth of information about Jupiter and solar science and education lesson plans. The project was conceived and tested from 1997-1999 and sold its first kit in 1999. A complete history of the beginnings of the Radio Jove project can be found in the article by Jim Thieman in the SARA conference Proceedings from 2010.

b. Program Status and Statistics

Radio Jove will celebrate 15 years of existence in July 2014 and it is still going. In total Radio Jove has sold over 1900 radio telescope kits in more 70 countries around the world. Figure 2 shows an updated map with countries having participants.

Figure 2. This is a world map showing countries with Jove observers. Note that the map shows one dot per country regardless of the number of observers.

II. Jove Hardware

a. Receiver

The Radio Jove receiver (Figure 3) operates over a narrow frequency range centered on 20.1 MHz. The frequency and bandwidth were chosen to be within the Jupiter decameter emission band, above the ionosphere cutoff, and near the WWV terrestrial radio signal at 20.0 MHz to be used for a system check. The receiver has a low noise figure compared to the galactic background which serves as a baseline and reference for observations providing your observing site is free from a large amount of terrestrial interference. The receiver layout and components were selected to be easy to read and assemble by a novice with only a little bit of training.

Figure 3. The Radio Jove Receiver

b. Antenna

The antenna for Radio Jove was also designed to be relatively inexpensive and easy to construct, assemble, and deploy. A dual dipole antenna system cut for 20.1 MHz was chosen for Radio Jove to achieve enough gain to receive many of the strong and moderate Jupiter emissions (Figure 4). However, a single dipole antenna is good for solar observing. More detailed information regarding the antenna, or the receiver, can be found in the assembly manuals on the Radio Jove website.

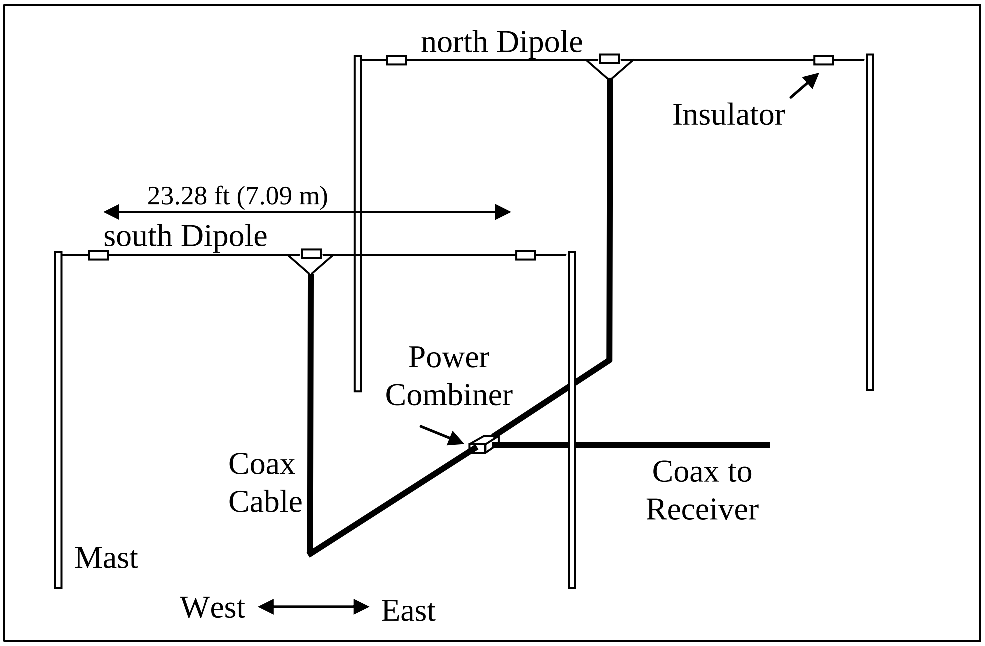

Figure 4. The Jove dual dipole antenna is shown with equal lengths of transmission line connecting each dipole to the power combiner. (Credit: Radio Jove)

c. Advanced Equipment

i. Calibration

Since inception, the Radio Jove team has always encouraged observers to make their observations as scientific as possible. In order to facilitate this, Radio Jove began selling a one-step noise calibrator in 2010 as an option for participants. Using the known calibrator noise temperature of 25,000 K in combination with the known linear response of the receiver, observers can get a calibrated scale for their observations. The Radio-Skypipe software (see Section III) is used to convert the receiver output into the scientifically useful scale of antenna temperature. An example of a strip chart without calibration is given in Figure 5 while Figure 6 shows the y-axis calibrated and already converted to antenna temperature.

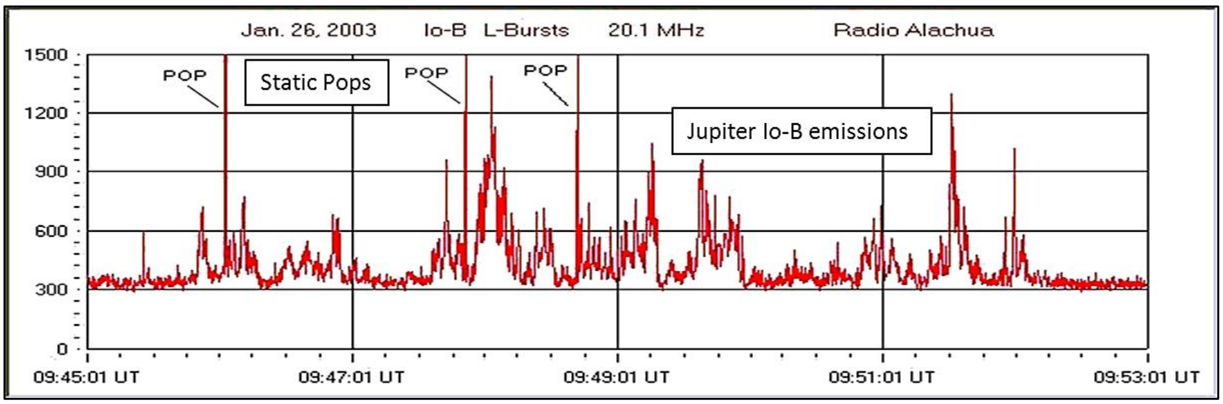

Figure 5. A stripchart of Jupiter Io-B bursts without calibration. In this example the units for the y-axis are arbitrary digital values from the computer. For this event a calibration was done later with a separate calibrator. (Credit: Wes Greenman).

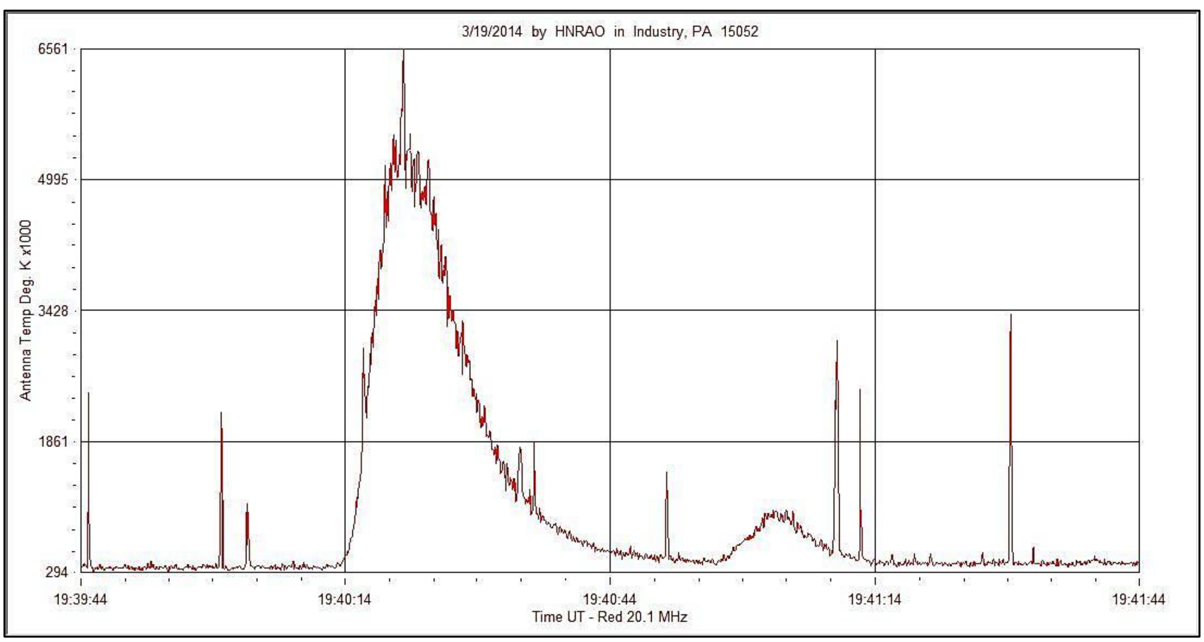

Figure 6. A Radio-Skypipe recording of solar bursts on 19-March 2014 with the y-axis calibrated to antenna temperature (Credit: Jim Brown).

ii. Spectrographs

Recently, many observers have taken a big step towards a professional capability for Jupiter and solar radio observations. Because the Radio Jove receiver is limited to basically single frequency measurements, it is difficult to understand the spectral nature of the emissions. An instrument that can make measurements over a large bandwidth by separating incoming waves into a spectrum is called a spectrograph. The spectrograph is sensitive to radio frequencies for our purposes, and although fairly expensive, is becoming easier to obtain and use. The primary benefit of these systems is that observers can learn more about the radio physics of the source emissions and the nature of the waves and their propagation. Imagine viewing the world with your eyes in monochrome and you can appreciate the use of a spectrograph.

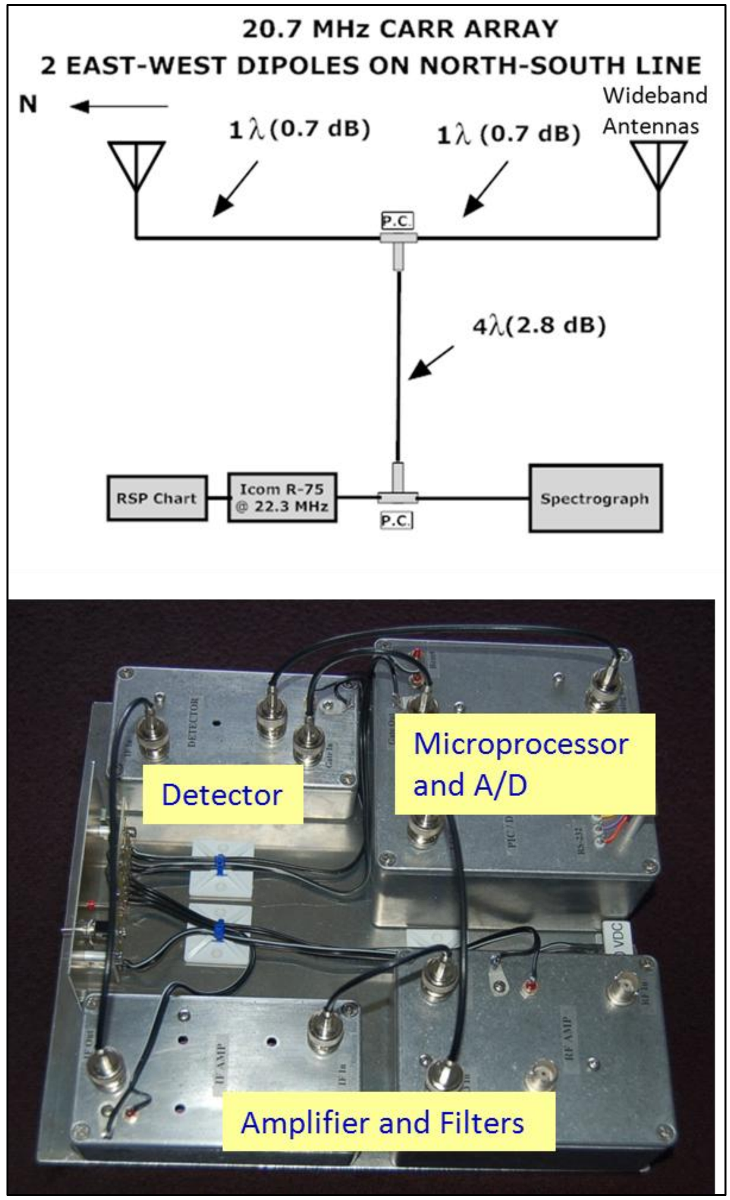

Figure 7. Top: Schematic for a spectrograph antenna system (Credit: Wes Greenman). Bottom: Hardware for FSX-5 spectrograph (Credit: Richard Flagg)

An example spectrograph system schematic and spectrograph system hardware are shown in Figure 7. Not only is a wideband receiver needed, but it must be driven by wideband antennas, that is, antennas capable to receive signals over a large bandwidth. The system shown in Figure 7 has a bandwidth of about 4 MHz, but other systems can have bandwidths as wide as 16 MHz. In either case these systems allow one to detect many spectral features in both Jupiter and solar emissions.

The output of a 16 MHz bandwidth spectrograph is shown in Figure 8 as a two hour frequency-time spectrogram. This specialized antenna system shows the wispy nature and arc-like structure of Jupiter's Io-A radio emission. Not only do spectrograph antenna systems show more detail in the Jupiter or solar emissions, but it can also be helpful in detecting terrestrial interference. The horizontal lines on the spectrogram are individual radio stations.

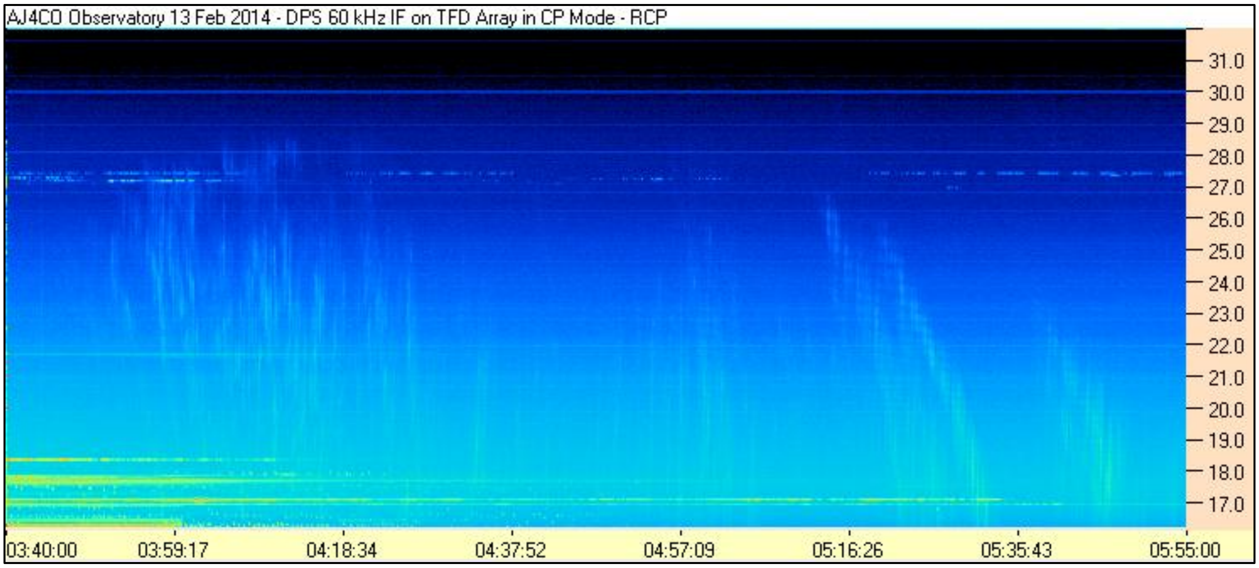

Figure 8. This is a spectrograph of Io-A emissions on 13-Feb 2014. The y-axis shows the spectral range from about 16 – 32 MHz (Credit: Dave Typinski)

III. JOVE Software

a. Radio Skypipe

The Radio Jove Project has had the great fortune of being associated with Jim Sky of Radio-Sky Publishing. Jim has contributed so much to Radio Jove and one of the best examples is the useful Radio-SkyPipe software program. This software is included with the purchase of a receiver from The Radio Jove Project. Radio-Skypipe is software that uses the sound card of a computer to digitize analog signals from a radio receiver and display them on a nice intensity versus time graph. Figures 5 and 6 are excellent examples of these records. The software records and saves the data and allows users to easily share data with others. Just as Radio Jove has evolved and improved so has Radio-Skypipe. It has a software wizard for easy calibration of your radio telescope, fancy data recording features (WAV sound file recording/playback, atomic clock synchronization, multiple file writing capabilities, etc.), and many data analysis tools. You can freely try the latest version 2.6.5 by downloading it from the website (www.radiosky.com).

b. Radio Jupiter Pro

Another useful software program from Radio-Sky Publishing is Radio Jupiter Pro (Figure 9). This software uses ephemeris routines to allow anyone to easily plan Jupiter or solar radio observations. Because Jupiter radio emissions are tied to its rotation and the position of the moon Io, this program can help tell you when the best opportunity for receiving Jupiter emissions. Figure 9 also shows maps and guides that allow you to model your antenna setup and find out when objects are within your antenna beam. In the lower part of Figure 9 the paths of Jupiter and the Sun are shown relative to the zenith (center of blue circle) and your antenna pattern (red oval).

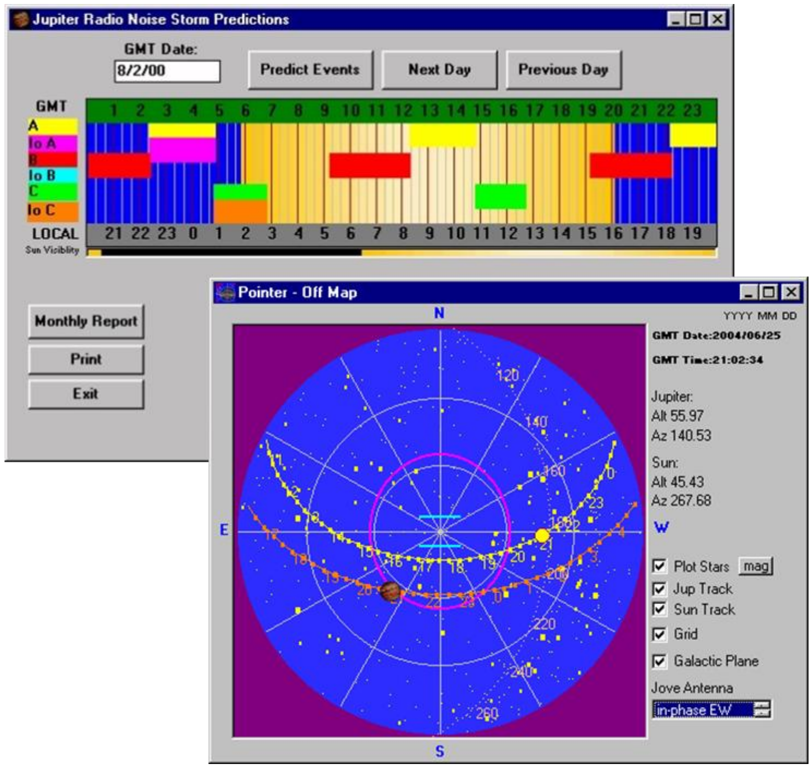

Figure 9. A screenshot of the Radio Jupiter Pro software program for planning Jupiter and solar observations (Credit: Jim Sky).

c. Spectrograph Software

As mentioned previously, the improvement of electronics and other receiver/antenna hardware equipment has made it easier for amateurs to purchase and use high quality spectrograph radio telescopes. Software to display the frequency-time spectrograms has been developed by Jim Sky and is available on the Radiosky website (www.radiosky.com). Figure 10 is an example display of a spectrogram showing several solar bursts. This software is very useful because not only can you display your own data, but like Radio-Skypipe, you can monitor data from other observers in real time via the Internet. This practice is a great way for beginners to learn to identify radio sources.

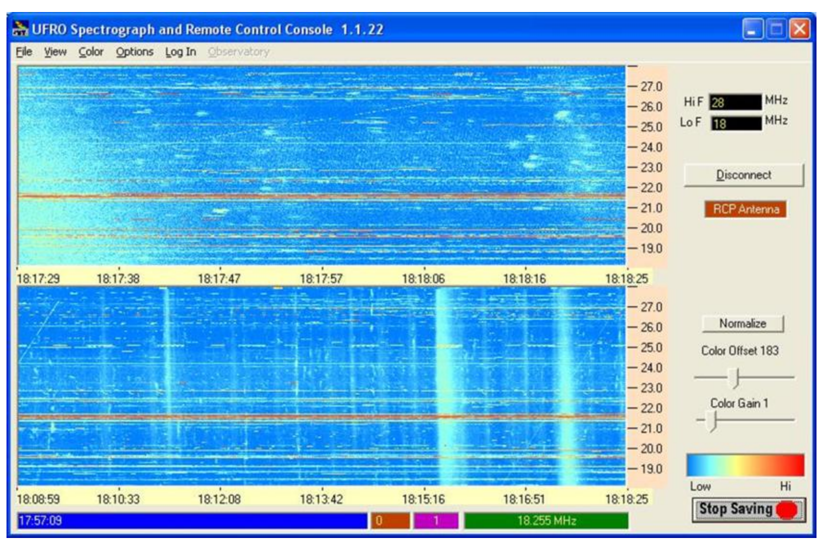

Figure 10. This is an example display of some solar bursts using the Spectrograph software. The upper panel is a 1-minute widow and the lower panel is a 10-minute window (Credit: Jim Sky).

IV. Radio JOVE Archive

a. Example Data

In the fifteen years of the Radio Jove Project, thousands of records have been submitted to our data archive by dozens of observers. The archive website may be found at radiojove.org/archive.html. Figure 11 shows an example calendar view for the month of March 2014 and the list of data records for Jupiter on 4-March 2014. Data records may include reception logs, text files, audio samples, Radio-SkyPipe images and files, and spectrograph images and files. Radio Jove welcomes low frequency radio observations of Jupiter, the Sun, and/or the Milky Way galaxy, and any interesting terrestrial interference as well.

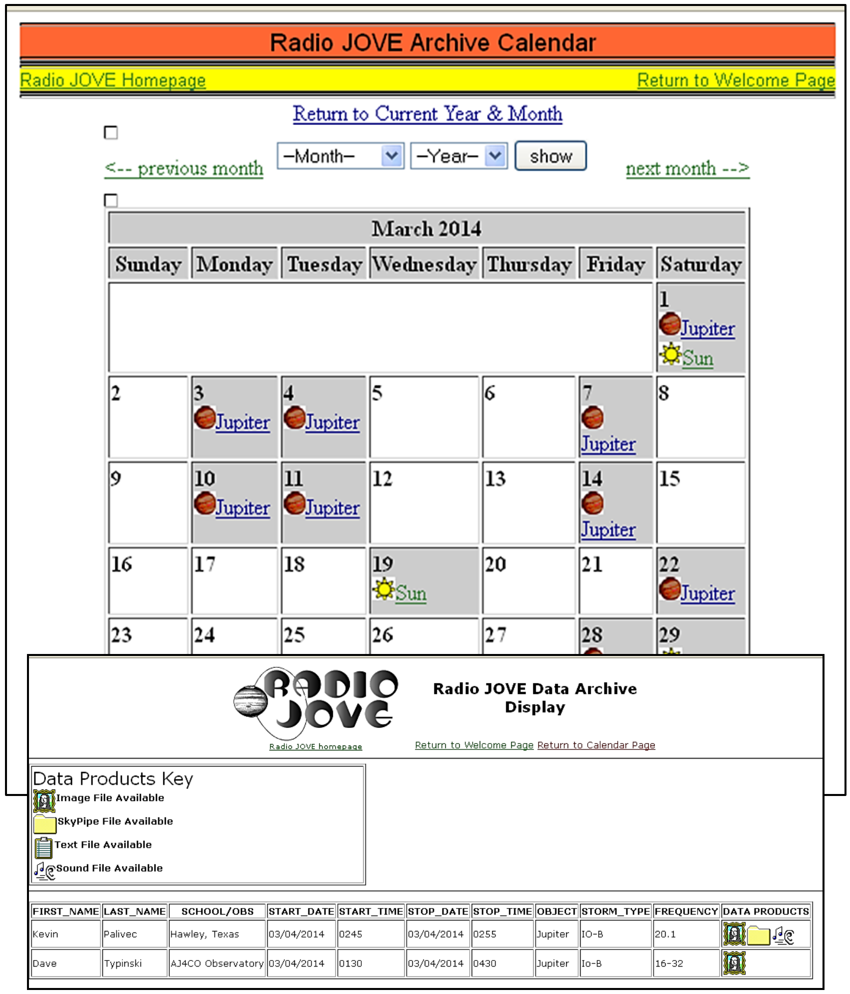

Figure 11. The Radio Jove data archive is shown with the Jupiter and solar data entries for March 2014 (Credit: Radio Jove).

Observers can use the archive data to help confirm (or reject) the source of their own observations, as well as to learn about radio emissions by seeing and hearing example radio data. As the number and quality of the data entries increases the archive will become more scientifically useful. As of May 2014, the Radio Jove archive has these holdings:

Radio Jove Archive – May 2014

Types of Files	Number	Targets of Observation	Number
Images (jpg, etc.)	5890	Sun:	4970
Radio-SkyPipe (.spd) files	3736	Jupiter:	1464
WAV format sound files	897	Galaxy:	33
Text files	906	Interference:	28

b. Coordination with Virtual Observatories

Recently the Radio Jove Project has been coordinating with professional radio observers in hopes that the Radio Jove archive can be linked with other low frequency radio archives and be used for scientific purposes. We are in the initial stages of working with French radio scientists at Nancay Radio Observatory in creating this virtual database. As an example of such "virtual observatories", Figure 12 shows a website called the Virtual Wave Observatory for solar radio and solar physics wave data. A similar type of website is planned for both amateur and professional Jupiter radio data.

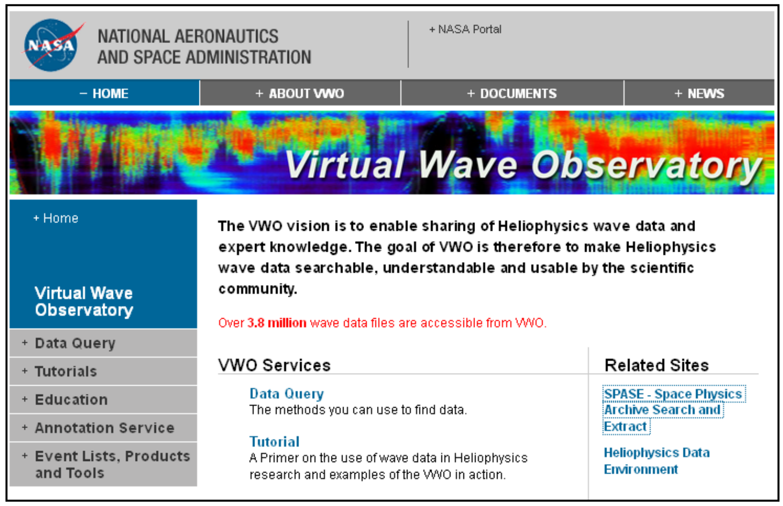

Figure 12. This is an image of the Virtual Wave Observatory website for heliophysics wave data. (Credit: NASA)

c. Research Projects

Radio Jove participants are now making good enough observations to be scientifically interesting. One useful display of Jupiter observations is a graph of data plotted as functions of the orbital position of the satellite Io and Jupiter's longitude called the Central Meridian Longitude (CML). The most recent season of Jupiter observations is shown in Figure 13. These data were taken by Dave Typinski at his AJ4CO Observatory in High Springs, Florida. The vertical axis is the Io orbital position angle and the horizontal axis is Jupiter's longitude. The slanted green, blue, and red lines are the times when Jupiter's radio emissions were detected, and the color represents different

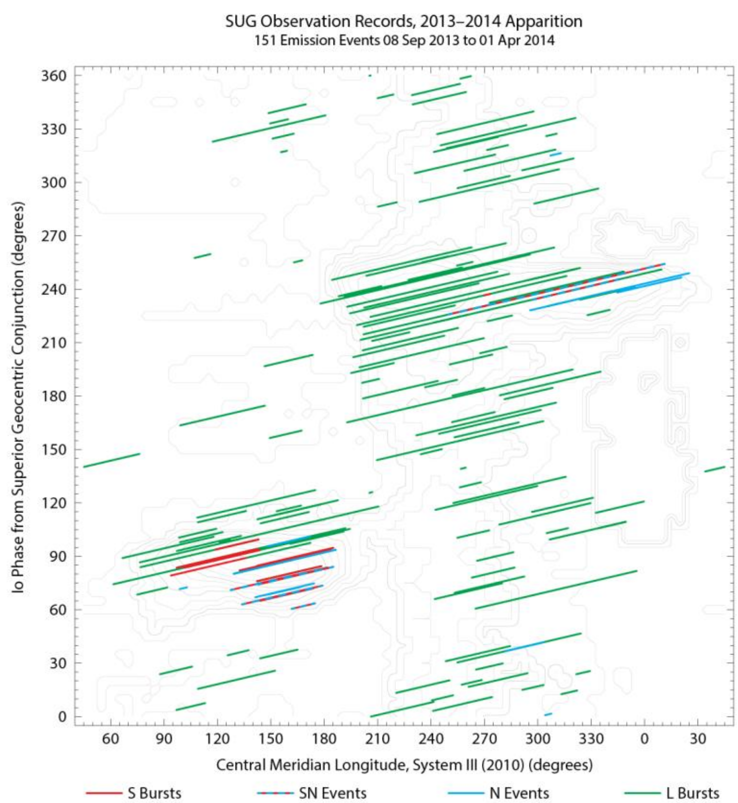

Figure 13. Colored diagonal lines showing Jupiter emission for the 2013-2014 observing season are graphed on an Io-phase vs. Jupiter longitude plane (Credit: Dave Typinski)

spectral features seen in the emission. Note how the emission detections are grouped according to both Io's position and to Jupiter's longitude. This has been known since the 1950s, but seasonal data like this can be added to previous data and used to investigate long term changes in Jupiter's radio sources.

Another useful set of data from Radio Jove observations is shown in Figure 14. The yellow line shows the monthly-averaged sunspot number from March 2005 – February 2012, while the blue line shows the 20 MHz solar burst counts over the same time period. These data show that the number of solar radio bursts correlate very well with the sunspot numbers. More data will be added to update this graph through the current solar cycle.

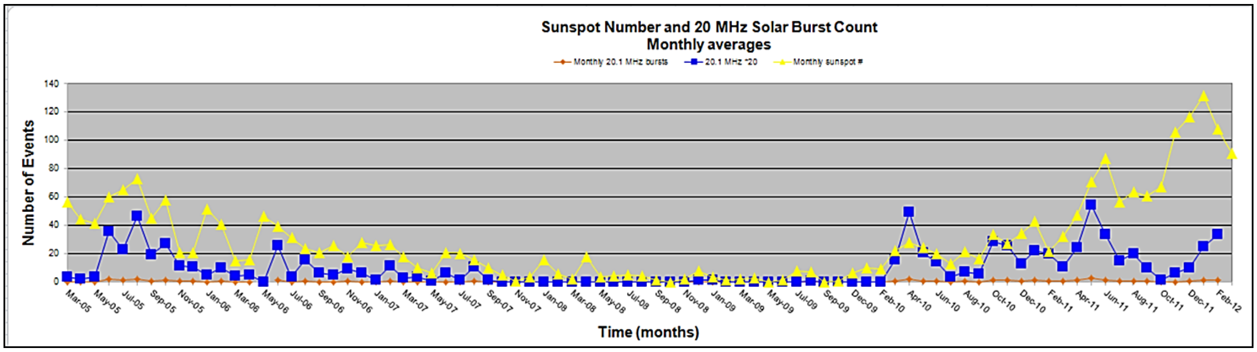

Figure 14. Monthly averaged sunspot numbers (yellow) and 20 MHz solar burst counts (blue) are graphed over seven years from 2005-2012. (Credit: Joe Kimball, MTSU Undergraduate)

V. Outlook to the Future – Juno Mission in 2016

The Juno Mission will arrive at Jupiter in 2016 with a vast array of instrument to observe Jupiter's aurora, radio emissions, magnetic field, charged particles, and gravity field. A unique polar orbit will give unprecedented information regarding Jupiter's high latitude and polar radio sources. We are planning for the Radio Jove community to make observations to coincide with the NASA Juno mission. With the improved data archive and connection with professional observatories, amateur radio astronomers should have every opportunity to make real contributions to Jupiter science.