THE RADIO JOVE PROJECT 2.0

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Abstract

Radio JOVE (radiojove.gsfc.nasa.gov) is a well–known public outreach, education, and citizen science project using radio astronomy and a hands–on radio telescope for science inquiry and education. Radio JOVE 2.0 is a new direction using radio spectrographs to provide a path for radio enthusiasts to grow into citizen scientists capable of operating their own radio observatory and providing science–quality data to an archive. Radio JOVE 2.0 uses more capable software defined radios (SDRs) and spectrograph recording software as a low cost ($350) radio spectrograph that can address more science questions related to heliophysics, planetary and space weather science, and radio wave propagation. Our goals: (1) Increase participant access and expand an existing radio spectrograph network (2) Test and develop radio spectrograph hardware and software (3) Upgrade the science capability of the data archive (4) Develop training modules to help people become citizen scientists

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1 Introduction

Radio JOVE 2.0 (radiojove.gsfc.nasa.gov) is a NASA Partner citizen science project using a multi–frequency (16–24 MHz) radio telescope to observe Jupiter, the Sun, the Milky Way Galaxy, and Earth–based radio emissions. We help people learn and do science, and help scientists study the solar system and the Galaxy using radio telescopes. Participants assemble and operate a multi–frequency radio astronomy telescope to gather and contribute quality data to support scientific studies. For reviews of the science and history of solar radio emission, see Bastian et al. (1998) and Kellerman & Bouton (2023), and for planetary radio emissions, see Zarka (2004). To illustrate the improvements in the Radio JOVE system, Figure 1 shows a strong solar burst using the original 20.1 MHz Radio JOVE receiver and the same solar burst using the new 16–24 MHz radio spectrograph.

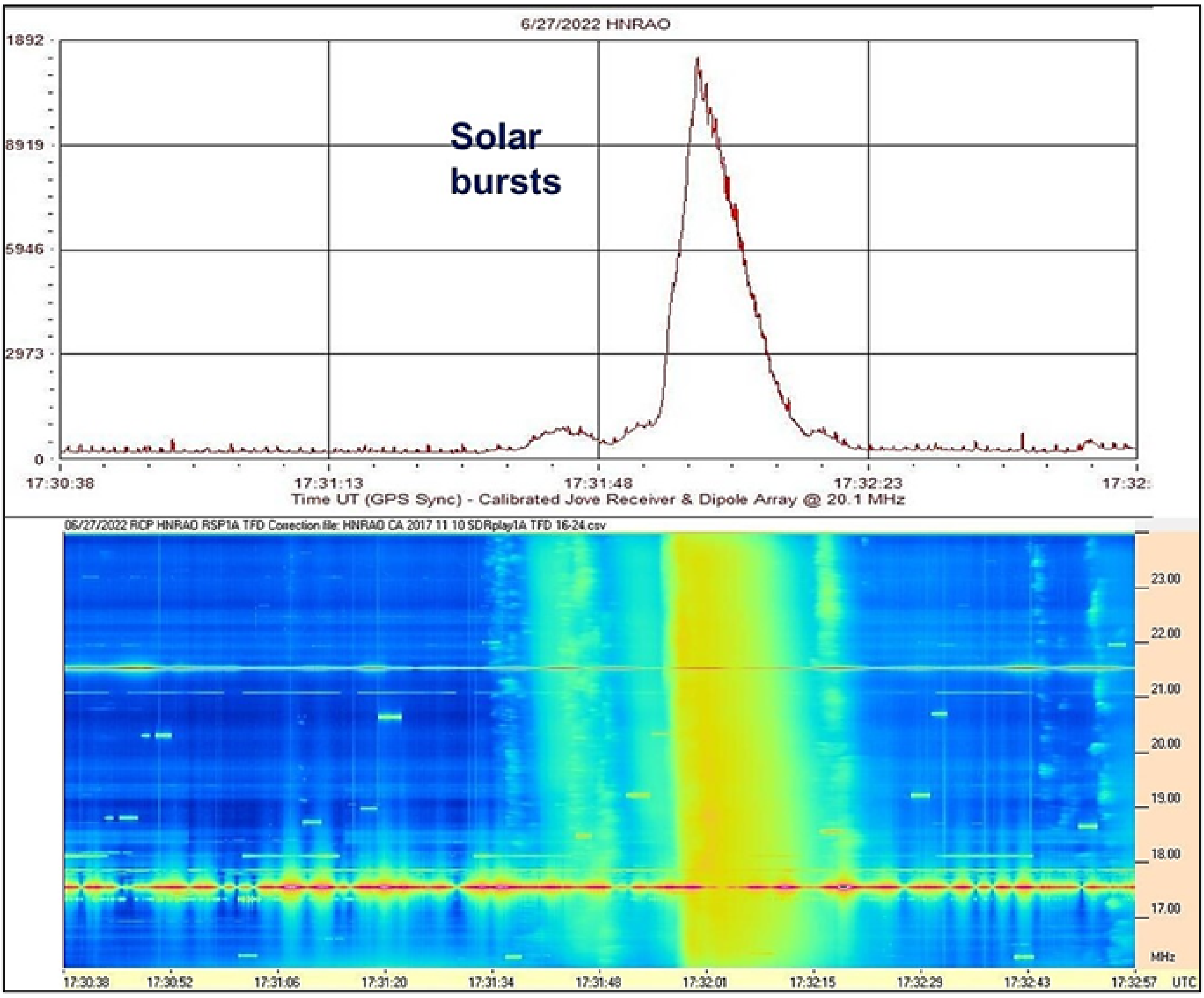

Figure 1: *(top) Solar bursts from J. Brown, Industry, PA on 27 June 2022 on a calibrated 20 MHz antenna temperature versus time chart; (bottom) Solar bursts are seen as near vertical bands of enhancement on a 16–24 MHz frequency–time spectrogram using the SDRplay RSP1A receiver. Horizontal bands are distant and local stations and interference.*

Radio JOVE participants include radio enthusiasts, the public, high schools, and colleges and universities, and they can interact with other radio observatories in real–time over the Internet. We continue to introduce new observers to scientific methods and help them experience the thrill of receiving cosmic radio signals. Through a developing series of educational training modules and observing and analysis projects we hope to guide new observers to levels where they can contribute to citizen science projects.

Radio JOVE started as a NASA sponsored educational outreach project in 1999. We developed a radio telescope kit suitable for receiving signals from Jupiter, the Sun, the Galaxy, and Earth–based radio emissions. The kit comprised a RJ1.1 20 MHz radio receiver, a dual dipole antenna, Radio–SkyPipe data recording and analysis software, and an optional calibrator.

2 Discussion

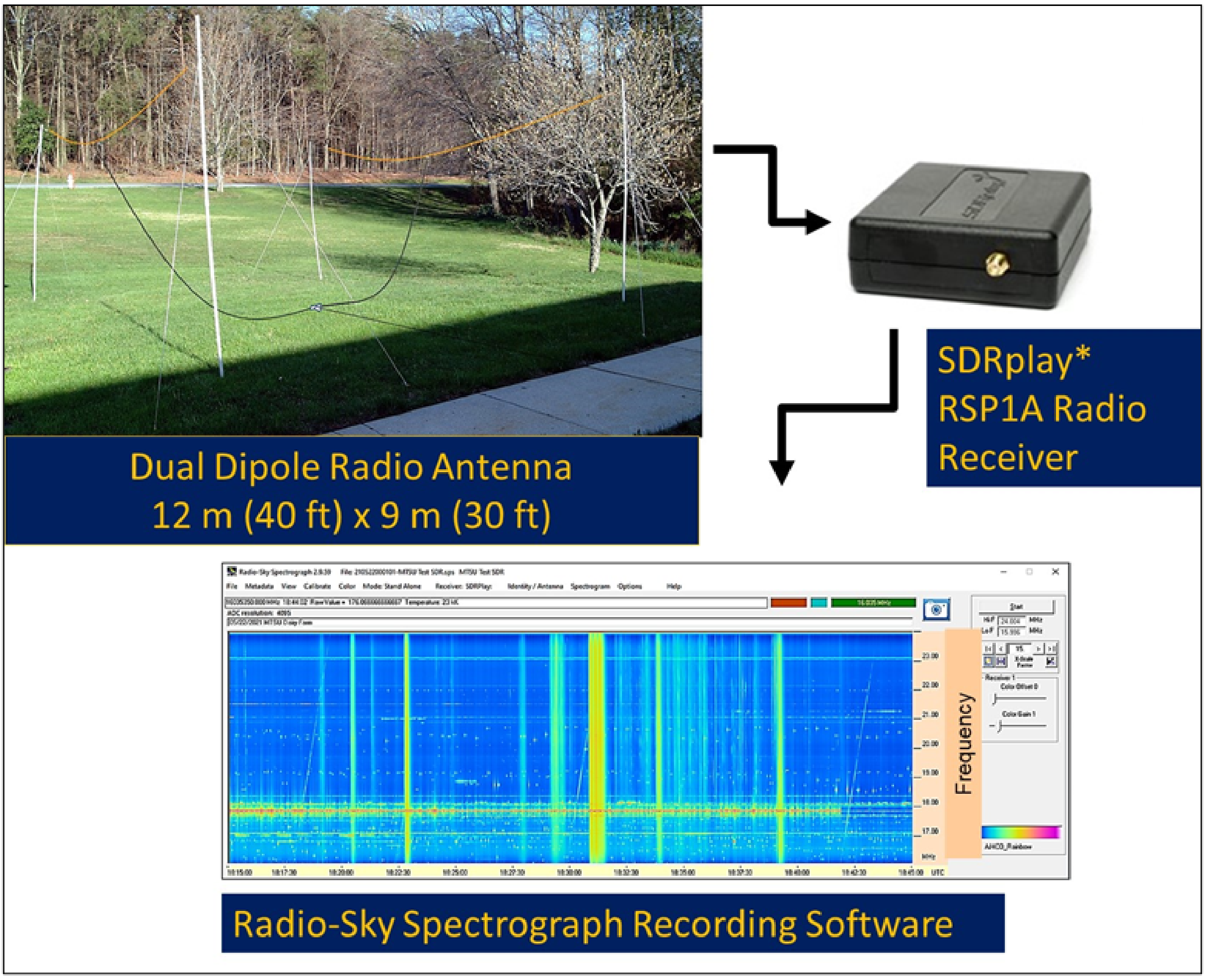

Figure 2: *Radio JOVE 2.0 kit showing the dual dipole antenna, SDRplay RSP1A receiver. SDRplay at* `www.sdrplay.com` *is a UK–based company that manufactures Software Defined Radio radios, and Radio–Sky Spectrograph (RSS) software with the SDRPlay2RSS program is provided by Radio–Sky Publishing at* `www.radiosky.com`*. The 22 May 2021 spectrograph display from C. Higgins shows many solar radio bursts (vertical bands) from 16 to 24 MHz. Horizontal bands are distant and local stations and interference, and the diagonal lines are radar sweepers (Higgins, 2022).*

Radio JOVE 2.0 is a big step forward because new software defined radios (SDRs) can generate spectrograms that depict radio activity as a function of frequency and time as seen in Figure 1 of Garcia (2022). Such displays offer new insights into our studies of the Sun, Jupiter, the Galaxy, and both natural and artificial Earth–based radio emissions. The Radio–Sky Spectrograph (RSS) software (`www.radiosky.com`) developed by Jim Sky, and the associated SDRPlay2RSS program developed by Nathan Towne, provides control of the radio as well as data display, recording, and analysis. Figure 2 shows a diagram of the Radio JOVE 2.0 kit.

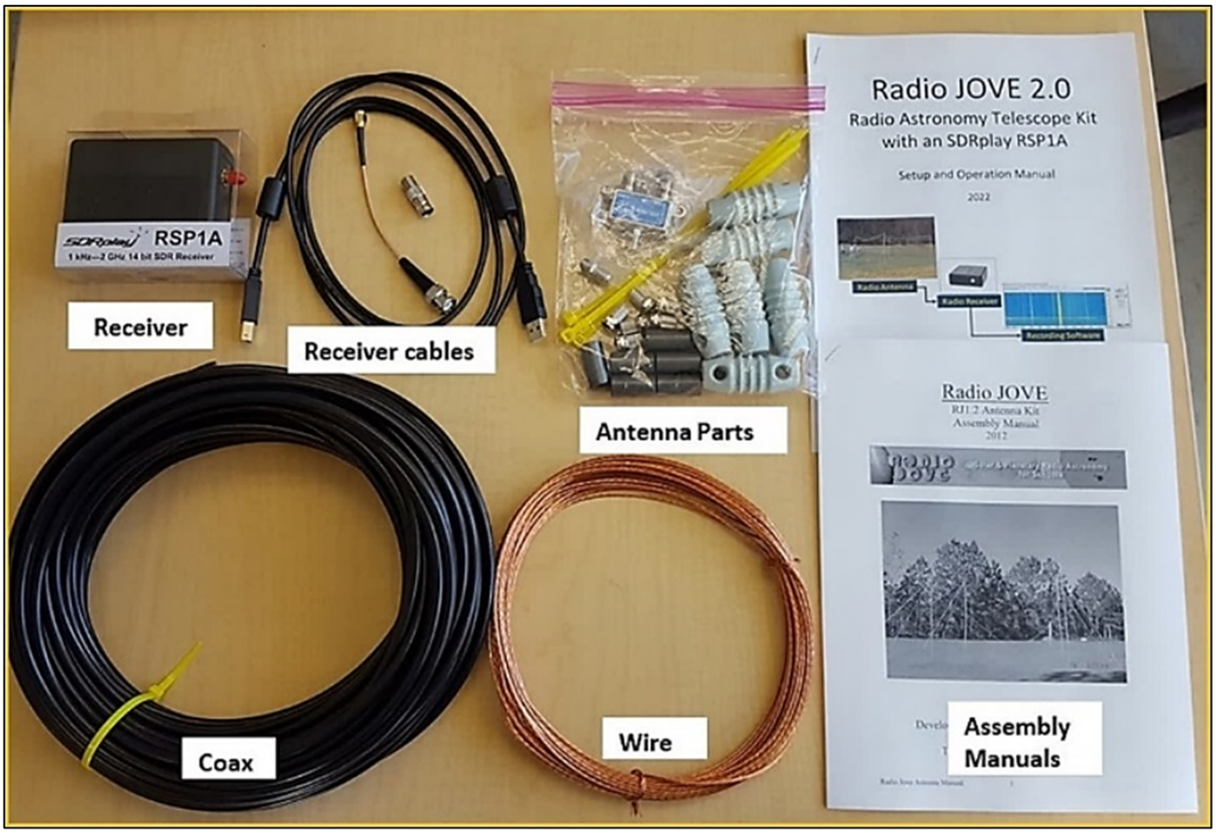

Figure 3: *Radio JOVE 2.0 Kit: SDRplay RSP1A, cables, Antenna Kit, assembly manuals, and Radio–Sky Spectrograph (RSS) software.*

Radio JOVE kits are currently available as a complete kit which can be ordered unbuilt or prebuilt, with options to buy a receiver or antenna separately (Figure 3). Current costs for the Radio JOVE 2.0 kit are: (1) Complete kit (receiver, software, unbuilt antenna): \$220.00 + shipping; (2) Prebuilt Complete kit (receiver, software, professionally built antenna): \$384.00 + shipping. Not included with the kit are antenna support materials that could be \$150.00 extra. More details and more options for kit purchases are found on order page: `https://radiojove.net/kit/order_form.html`.

For participants interested in advanced measurements and more scientifically useful data for citizen science, the original Radio JOVE RJ1.1 receiver and RF2080 Calibrator/Filter are great options. However, these items are no longer being produced. In general, equipment for advanced spectral measurements and calibration are expensive, costing many hundreds of dollars. These include wide band antennas and arrays, polarized antennas,

Figure 4: *Automatic multistep calibrator and the RSS software calibrator control panel showing the response of an SDRplay RSP1A receiver.*

GPS timing, and multi–step calibration (Figure 4). The Radio JOVE team is researching and testing more inexpensive ways to build polarimeters and to calibrate the SDR receivers to provide science–quality measurements.

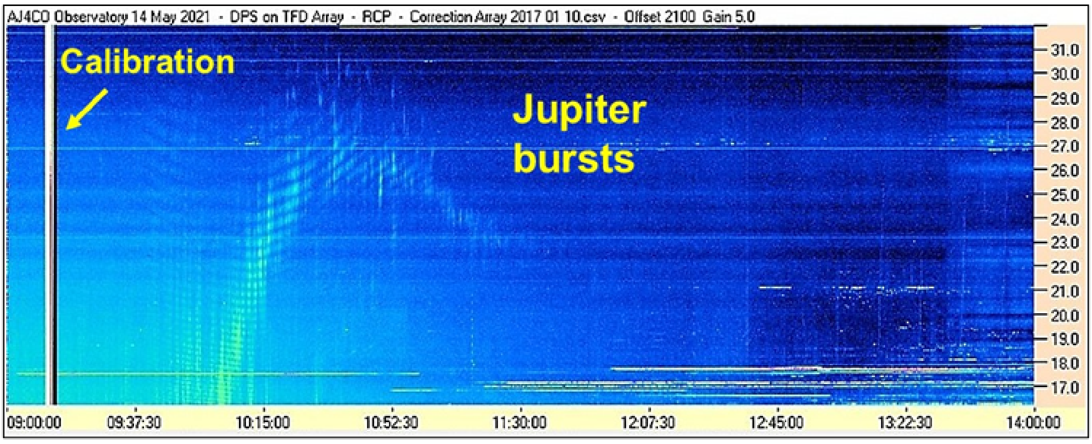

Figure 5: *Jupiter Io–B event from D. Typinski in High Springs, FL on 14 May 2021 recorded with an advanced 16–32 MHz radio spectrograph and a right–hand circularly polarized (RCP) antenna. The curved bands in the data are due to Faraday rotation through the Earth's ionosphere.*

Figures 5–7 show examples of observations of solar, Jupiter, and terrestrial radio emissions demonstrating the capabilities of citizen scientists using advanced receivers and antennas. Figure 5 is an excellent observation of a Jupiter Io–B radio event from custom–built radio spectrograph and a wideband antenna. We recommend that participants start simple and then expand their capabilities as their knowledge and experience increases. It is our plan to use the best citizen science data for scientific presentations and publications where the observer gets credit and potentially a co–authorship in published work.

The Radio JOVE website (`https://radiojove.gsfc.nasa.gov/`) provides a wealth of information describing observation methods and various materials intended to teach radio astronomy techniques and scientific methods. We are developing training modules to help a novice radio astronomer become more advanced and capable of doing science–quality observations and analyses. We also produce biannual newsletters and host many telephone and video help sessions each year and have an active community on the Radio JOVE

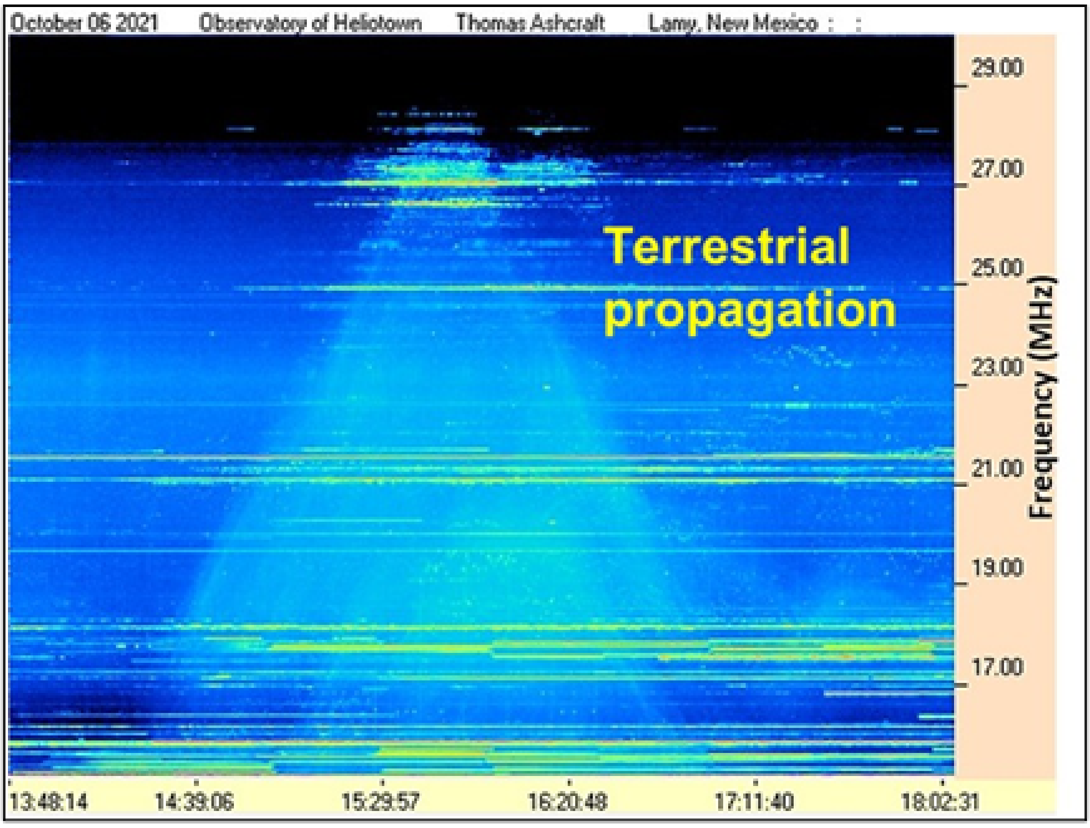

Figure 6: *An advanced radio spectrograph set to 15–30 MHz from T. Ashcraft in Lamy, NM shows terrestrial 'TP–shaped' propagation on 06 October 2021 from radio signals coming from distant lightning that are reflected and refracted in the ionosphere.*

listserv on Groups.io: `https://groups.io/g/radio-jove`.

The data archive contains thousands of Jupiter and solar observations (data files, images, sound files), and is a great resource for comparing data between radio observatories. For our citizen scientists contributing high quality data, Radio JOVE partners with the NASA Space Physics Data Facility (`https://spdf.gsfc.nasa.gov`) and the Planetary Data System Planetary Plasma Interaction Node (`https://pds-ppi.igpp.ucla.edu`) for archiving data. We encourage our observers to archive their data to help them learn data analyses and archiving methods, and to participate more fully in the scientific process. To facilitate this Radio JOVE will provide training modules to educate citizen scientists about data collection techniques and data archiving. This includes source identification (i.e., solar Type III, Jupiter Io–A), calibration, timing, and meta–data for files submitted. High quality data that has been vetted by the Radio JOVE team is then converted to Common Data Format (CDF) for potential use by the science community.

The Radio JOVE Project continues to have research interests in solar system radio astronomy, ionosphere radio wave propagation, space weather, and the Milky Way galaxy. Using archived data and new observations we have several citizen science projects ongoing and welcome new participants to help do more science. For example, a list of citizen science projects include: (1) Coordinated observing campaigns for solar eclipses and/or Jupiter events, (2) Create a galactic background Quiet Day Curve (QDC), (3) data analysis of

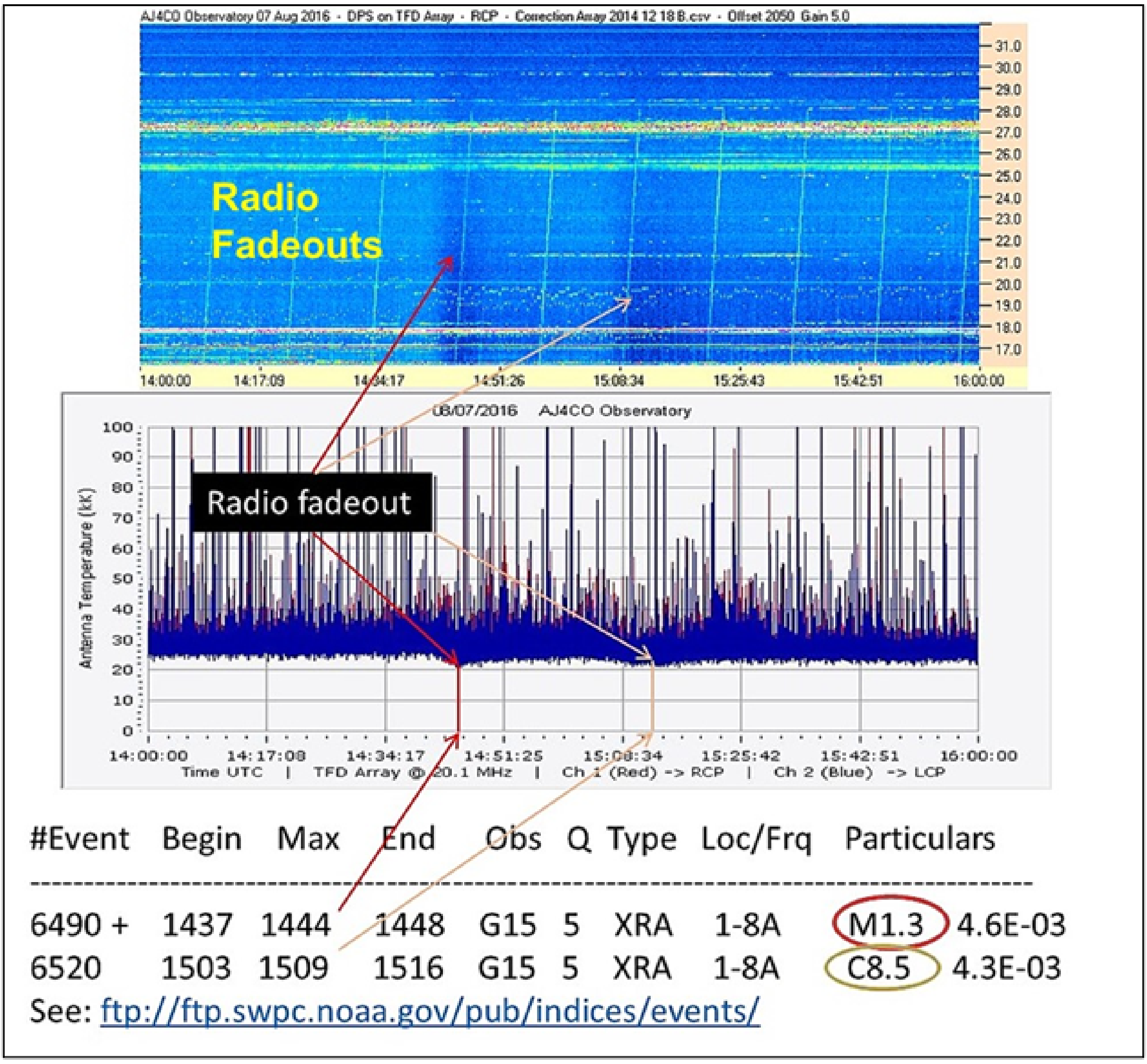

Figure 7: *Radio fadeout ionosphere disturbances associated with M– and C–class solar flares on 07 August 2016 from D. Typinski in High Springs, FL using an advanced 16–32 MHz spectrograph.*

ionosphere radio wave propagation and space weather, and (4) extend a monthly solar radio burst count graph (Figure 8).

3 Conclusions and perspectives

Radio JOVE has continued goals to introduce new observers to radio astronomy, scientific methods, and to help them experience the thrill of receiving cosmic radio signals from their own radio telescope. Through a series of training modules and observing and analysis projects we hope to guide new observers to levels where they can contribute to citizen science projects. We welcome both new and experienced observers to the Radio JOVE program as we share the excitement of receiving, studying, and understanding radio signals from our corner of the Galaxy.

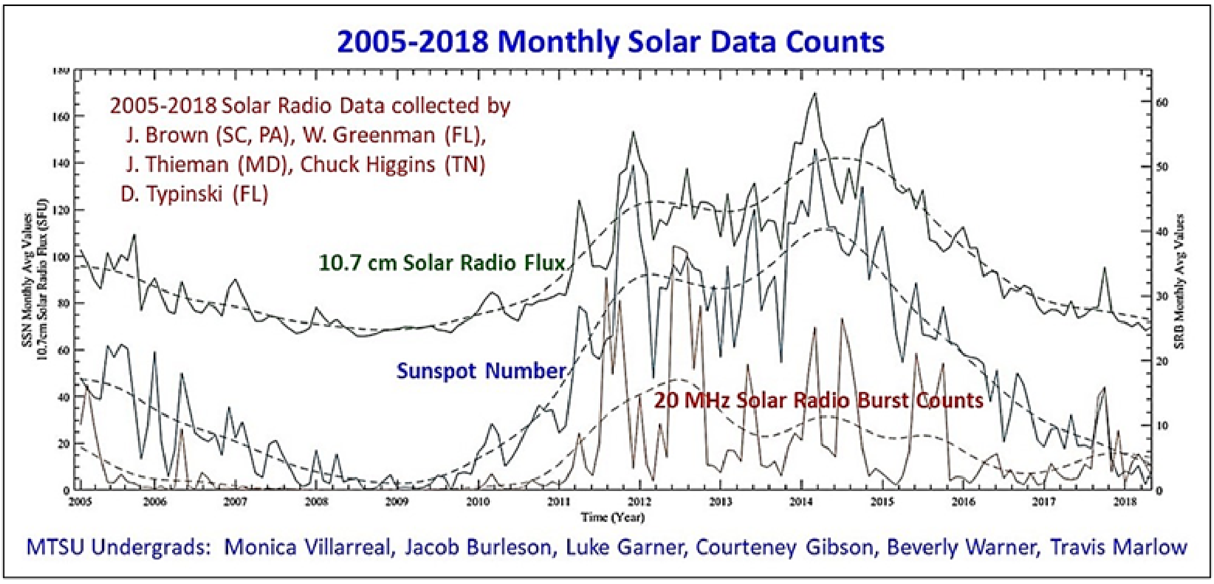

Figure 8: *The 2005–2018 Monthly Average Solar Radio Burst Counts (SRB) at 20 MHz correlate well with the visible Sunspot Number (SSN) and the 10.7 cm (2800 MHz) Radio Flux data (Higgins et al., 2018).*

We plan to expand our existing network of radio telescopes and provide a hands–on experience in radio astronomy. We also enable access to online observatories and data as well as facilitate the exchange of data and ideas among participants. The simplest way to join is to visit our website (`radiojove.gsfc.nasa.gov`) and/or contact our listserv on Groups.io (`groups.io/g/radio-jove`). Join us and become a citizen scientist and do science.

References

Bastian T. S., Benz A. O., Gary D. E., 1998, Radio Emission from Solar Flares, *Annu. Rev. Astron. Astrophys.*, *36, A30*

Garcia L., 2022, Welcome to the Radio JOVE Project 2.0, *Radio JOVE Bulletin March 2022*, *Special Issue*

Higgins C., 2022, The Radio JOVE Brochure, *The Radio JOVE Project Website*, *2022*

Higgins C., Fung S., Thieman J., Garcia L., 2018, Radio JOVE Citizen Science Partnerships, *Presentation at the Magnetospheres of the Outer Planets Conference*, *2018*

Kellerman K. I., Bouton E. N., 2023, Radio Emission from the Sun and Stars, *in Star Noise: Discovering the Radio Universe, Cambridge University Press, 2023*, pp 41–70, doi:10.1017/9781009023443.005

Zarka P., 2004, Radio and plasma waves at the outer planets, *Adv. Space Res.*, *33, 2045*