A Year of JOVE Solar Observations

James Brown B.S., M. Ed., A.E.T.
Hawks Nest Radio Astronomy Observatory
HNRAO@comcast.net

Introduction

Solar monitoring began 400 years ago with Galileo's invention of the telescope.

Most of the time, solar activity is of little concern in our everyday life. However, when the space environment is disturbed by eruptions from the Sun, technologies, that we depend on in our daily life, in orbit about the Earth as well as on the ground, can be affected. Some of the most dramatic effects occur in association with eruptions of material from the solar atmosphere into interplanetary space. The increasing number of radiation sensitive technological systems introduced over the last few decades and the increasing presence of complex systems in space combine to make society more vulnerable to solar disturbances. The large number of problems associated with the severe magnetic storms between 1989 and 1991 as the 11-year solar activity cycle peaked demonstrated this. (NOAA Spaceweather)

The Sun goes through cycles of high and low activity that repeat approximately every 11 years. The number of dark spots on the Sun (sunspots) marks this variation; as the number of sunspots increases, so does solar activity. Sunspots are sources of flares, the most violent events in the solar system. In a matter of minutes, a large flare releases a million times more energy than the largest earthquake. (NOAA About SEC)

Episodic solar activity has a number of effects that are of importance to us. A radiation dose from energetic particles is an occasional hazard for astronauts and for electronics on satellites. Geomagnetic field disturbances may damage power systems, disrupt communications, degrade high-tech navigation systems, or create the spectacular aurora (Northern and Southern lights). (NOAA About SEC)

The Space Environment Center (SEC), headquartered in Boulder, Colorado, is one of the 11 Environmental Research Laboratories of the National Oceanic and Atmospheric Administration (NOAA). SEC conducts research in solar-terrestrial physics, develops techniques for forecasting solar and geophysical disturbances, and provides real-time monitoring and forecasting of solar and geophysical events. SEC's research scientists, working toward a better under-standing of the Sun-Earth connection, study the Sun's electromagnetic, particle, and magnetic-field emissions and the processes by which they affect Earth's space environment. (NOAA About SEC)

Monitoring of solar activities can also be conducted in your own back yard. Using the inexpensive Project Radio JOVE receiver and antenna, it is possible for you to observe and record solar radio bursts.

What is JOVE?

Radio JOVE is an educational program sponsored by NASA Goddard Spaceflight Center and is a program where students and amateur scientists observe and analyze the natural radio emissions of the planet Jupiter and the Sun. This project is a joint effort of NASA's Space Science Data Operations Office, the University of Florida Astronomy Department, the Florida Space Grant Consortium, high school teachers, and volunteers. (JOVE) The program takes its name from the Roman word for Jupiter, Jove.

The project's goals are to:

- Educate people about planetary and solar radio astronomy space physics and the scientific method.
- Provide teachers and students with an astronomy exercise as a science curriculum support activity by building and using a simple radio telescope receiver/antenna kit.
- Create an on-line radio observatory that provides real-time data for those with Internet access.
- Allow interactions among participating schools by facilitating exchanges of ideas data and observing experiences.

Radio JOVE is intended for high school science classes, college science courses or laboratories and anyone else who would like to participate. (JOVE)

The Radio JOVE kit consists of a receiver designed to receive at 20.1 MHz and a set of phased dipole antennas. The cost of the Radio JOVE receiver and antenna kits is a modest $125 US (to recover materials expenditures) which includes receiver kit, antenna kit and JOVE chart software. The receiver is not difficult to construct since all the parts are included and should only take several hours to build and test. Likewise for the antennas.

A Year of JOVE Solar Observations

I began my Radio JOVE solar observations on October 5, 2000 and observed continuously for one year. Due to local power line noise interference, there are a number of months at the beginning of 2000 that I was unable to observe.

Observation runs were started each morning near sunrise and terminated each evening near sunset and left to run unattended. To verify my observations, each evening I would go to the NOAA website (NOAA Solar Indices) and compare their list of solar events as I played back the day's data run. . There were 90 solar radio events recorded during the course of the year. A complete listing of my data is available via my website. (Brown)

All observations were made from the same location with the same JOVE antenna. The standard JOVE antenna setup and alignment was used, which are antennas in phase, and aligned North and South. While the JOVE receiver was used for the vast majority of observations, I did experiment with several other receivers for comparison and the data from those are also included in this report.

Initially, data recording software was in the form of the Windows-based JOVE chart software to begin with, but I later switched to SkyPipe (Sky Publishing).

Types Of Solar Radio Emission Events

Solar radio bursts are associated with solar flares. There are typically three stages to a solar flare. First is the precursor stage, where the release of magnetic energy is triggered. Soft x-ray emission is detected in this stage. In the second or impulsive stage, protons and electrons are accelerated to energies exceeding 1 MeV. During the impulsive stage, radio waves, hard x-rays, and gamma rays are emitted. The duration of these stages can be as short as a few seconds or as long as an hour. (What Is A Solar Flare?)

Emission of the sun in radio wavelengths can occur in frequencies from centimeters to decameters under both quiet and disturbed conditions. Some patterns, known variously as noise storms, bursts, and sweeps, are identified as described below. (NOAA Glossary) The types of solar events that dominate the Radio JOVE data are referred to as “sweep-frequency radio burst” or RSP.

Briefly, solar radio emissions can be grouped into the following categories:

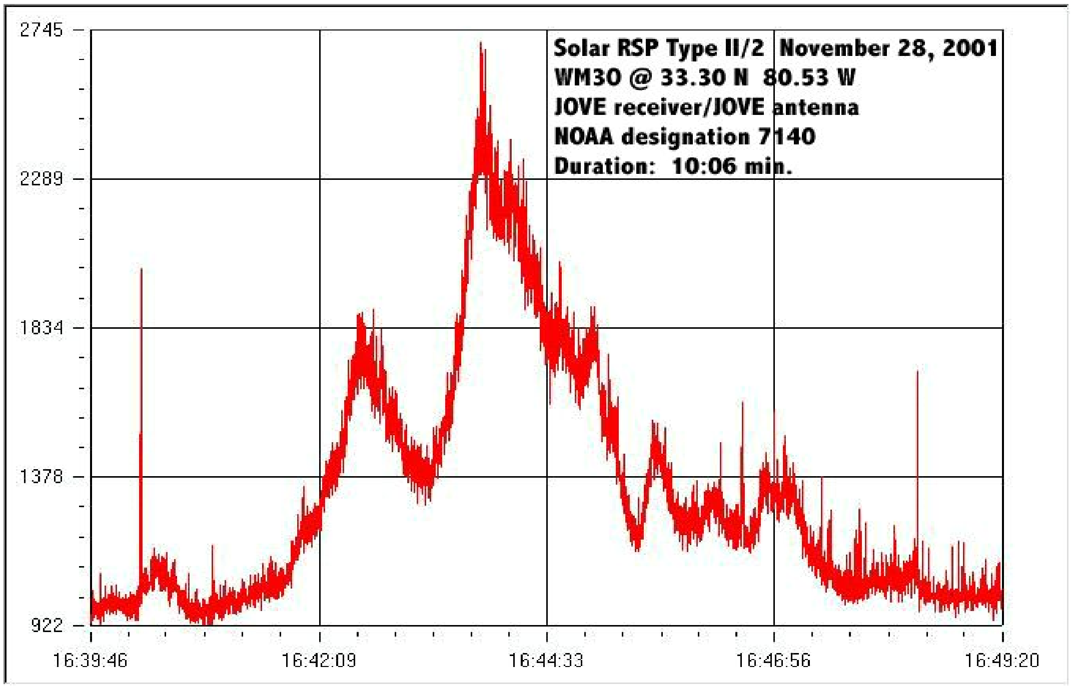
- Type I: Narrow-band burst
- Type II: Slow drift burst
- Type III: Fast drift burst
- Type IV: Broadband smooth continuum burst
- Type V: Brief continuum burst, generally associated with Type III bursts
- Type CTM: Broadband, long-lived, diametric continuum

These types of emission are subjectively rated on an importance scale of 1 to 3, 3 representing the most intense. It is possible to see a given event listed, for example, as Type III/1, III/2 or III/3 depending on its intensity.

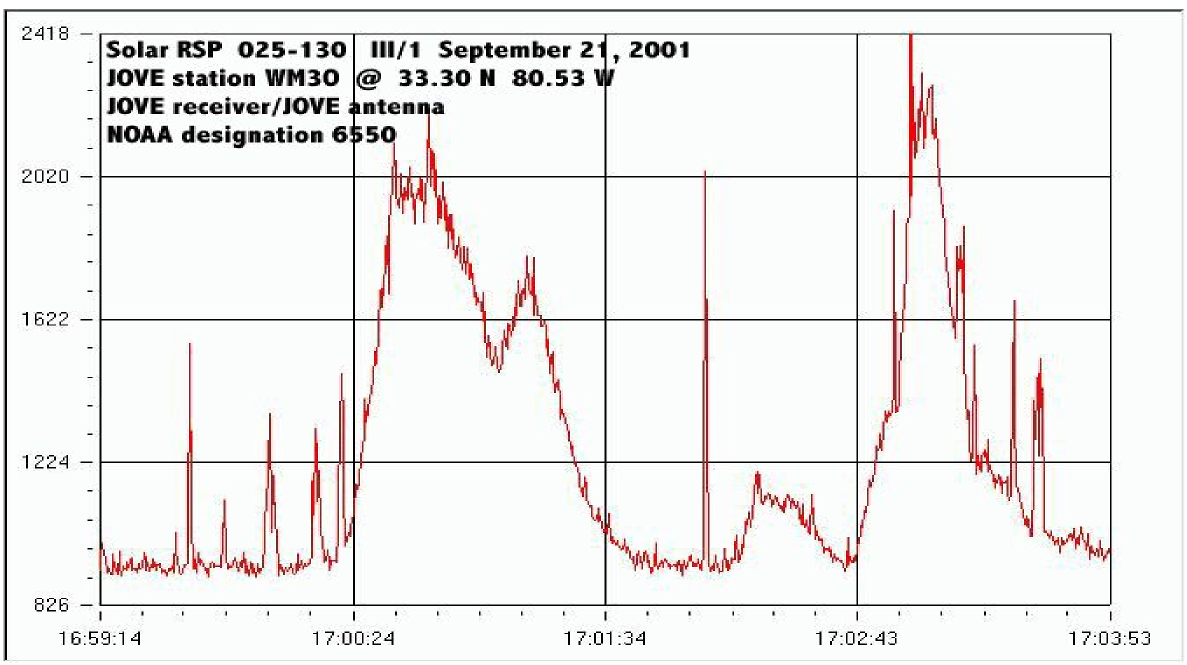
The following descriptions are taken from the NOAA website. (NOAA Glossary)

Type I events are a noise storm composed of many short, narrow-band bursts in the meter wavelength range (300-50 MHz), of extremely variable intensity. The storm may last from several hours to several days.

Type II events are narrow-band emissions (sweep) that begins in the meter range (300 MHz) and sweeps slowly (tens of minutes) toward decameter wavelengths (10 MHz). Type II emissions occur in loose association with major flares and are indicative of a shock wave moving through the solar atmosphere. These radio emissions are produced when a shock wave from the solar flare excites the Sun's hot but thin lower atmosphere, causing clouds of electrons to be ejected. Such Type II sweeps are often an indication of a mass being ejected from the flare.

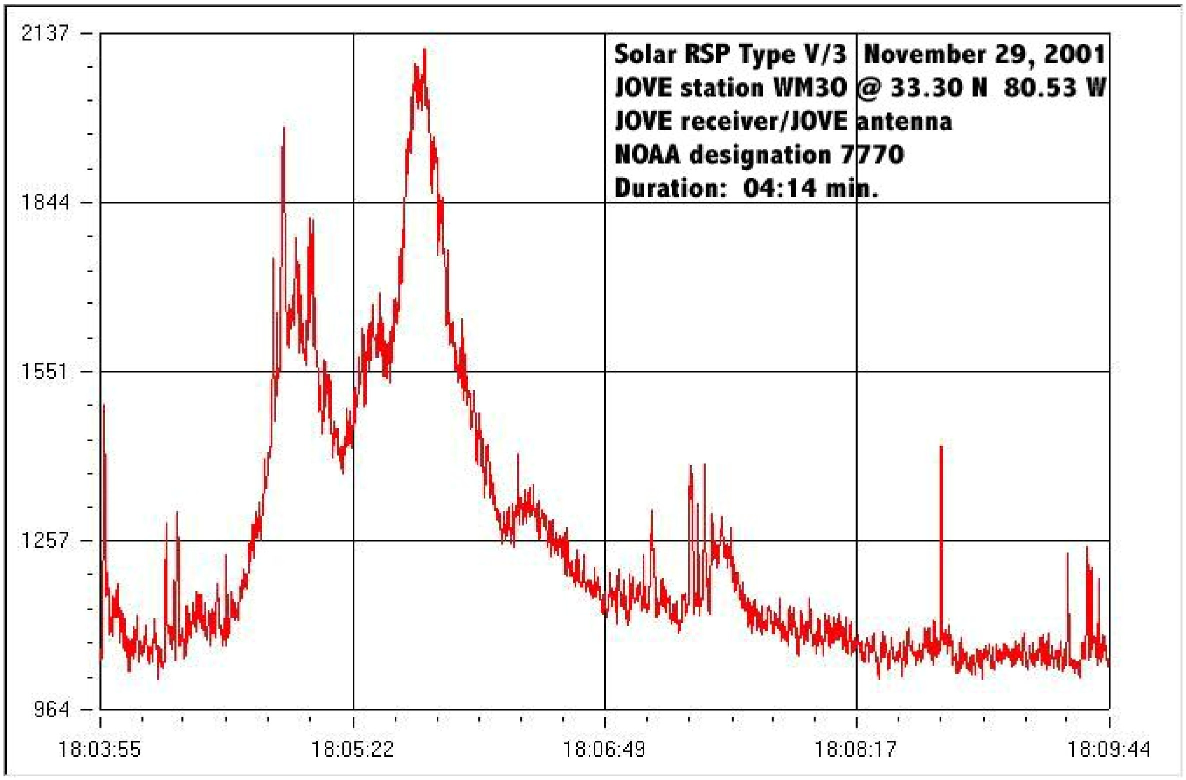


Type III events are narrow-band bursts that sweep rapidly (seconds) from decimeter to decameter wavelengths (500-0.5 MHz). They often occur in groups and are an occasional feature of complex solar active regions.

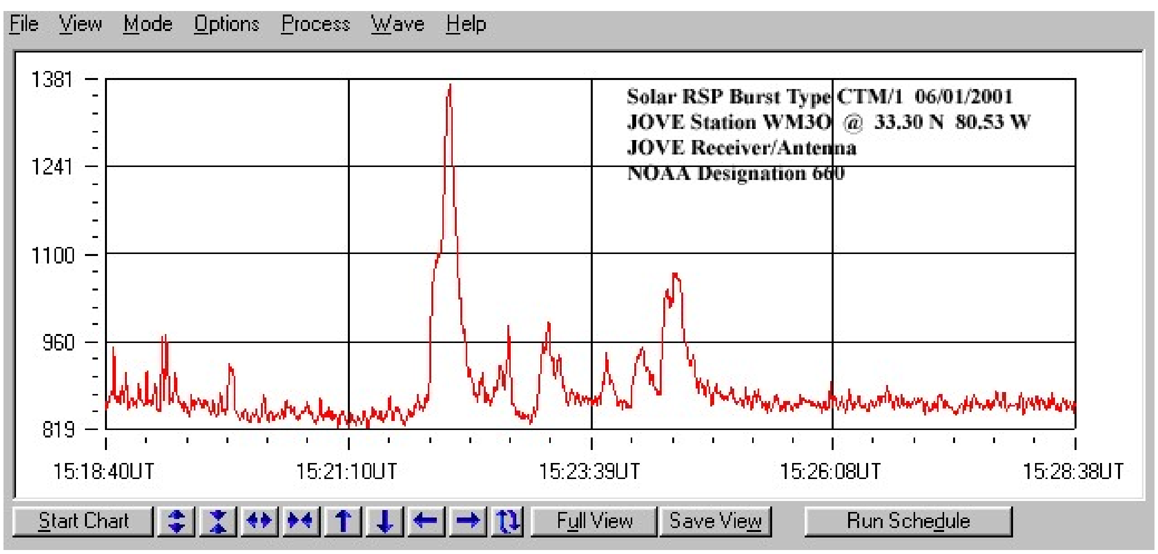


Type IV events are a smooth continuum of broadband bursts primarily in the meter range (300-30 MHz). These bursts occur with some major flare events; they begin 10 to 20 minutes after the flare maximum and can last for hours.

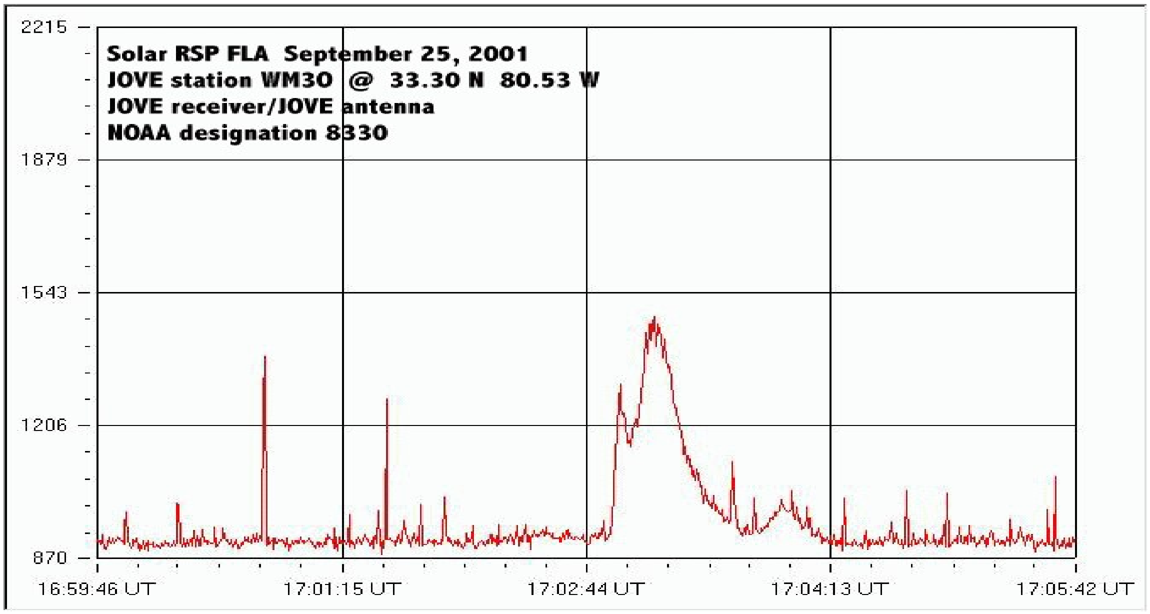
Type V events are short-duration (a few minutes) continuum noise in the decameter range usually associated with Type III bursts.



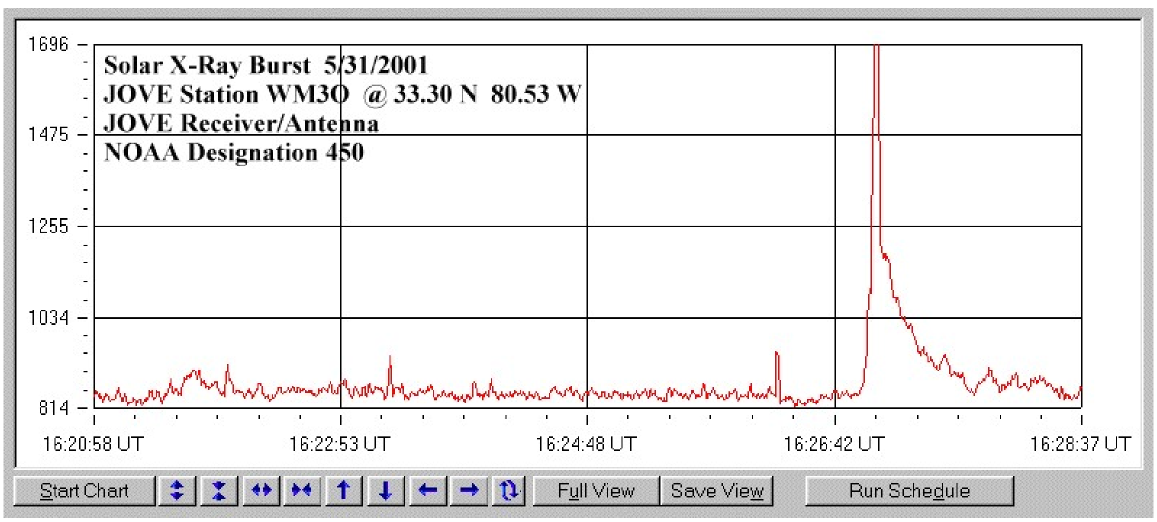
Type CTM events consist of broadband, long-lived, diametric continuum bursts.



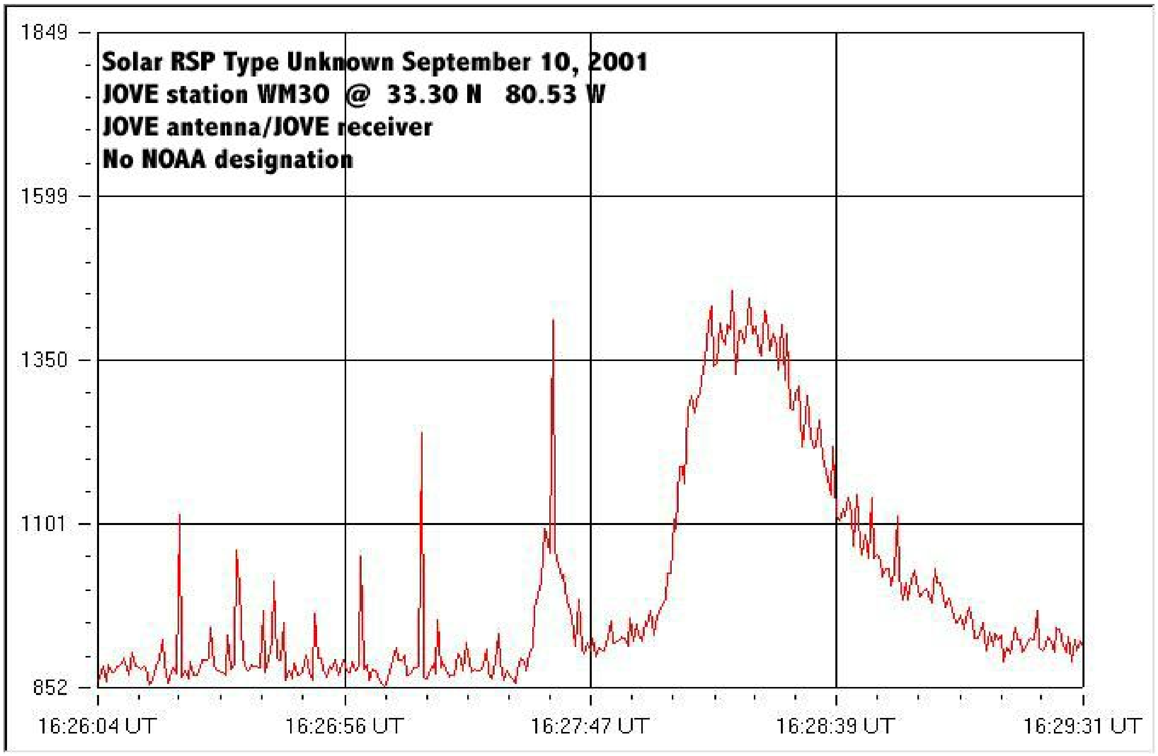
Flares were also observed.



As were x-ray bursts.



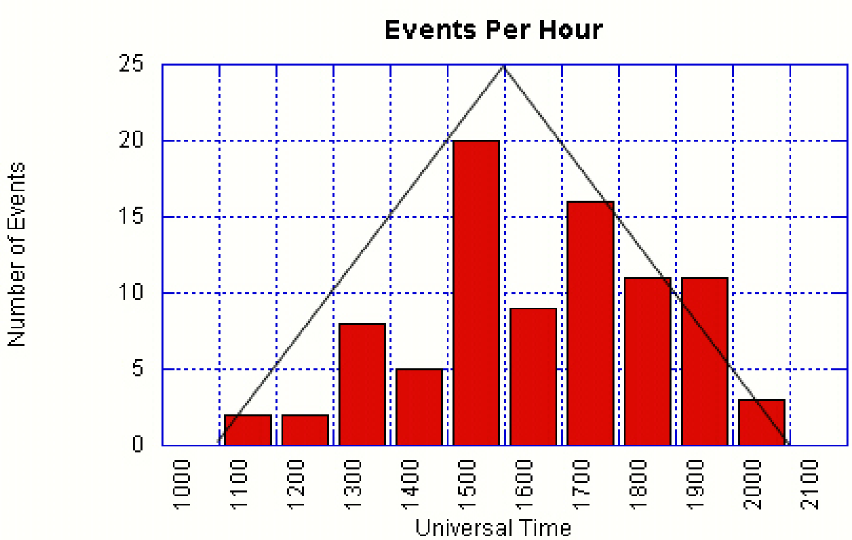
Nearly 18% (17.7%) of the observed events were unknowns. These are events NOAA does not recognize because they take place below the 25 MHz cutoff of NOAA and are not reported on their website.



When to Observe?

In viewing the data presented, keep in mind that all times are in Universal Time (UT).

For statistical purposes, I grouped the observations into hour time increments. The Radio JOVE antenna is a stationary double dipole. As such, the antenna's effectiveness diminishes from straight above it towards the horizon. It was my expectation to see a graph representing essentially the effective beam width of the Radio JOVE antenna. As you can see by the graph, this is exactly what was revealed.



Despite the power line interference and the subsequent lost data, the graph still shows that the vast majority of observations took place in the optimum beam width of the Radio JOVE antenna.

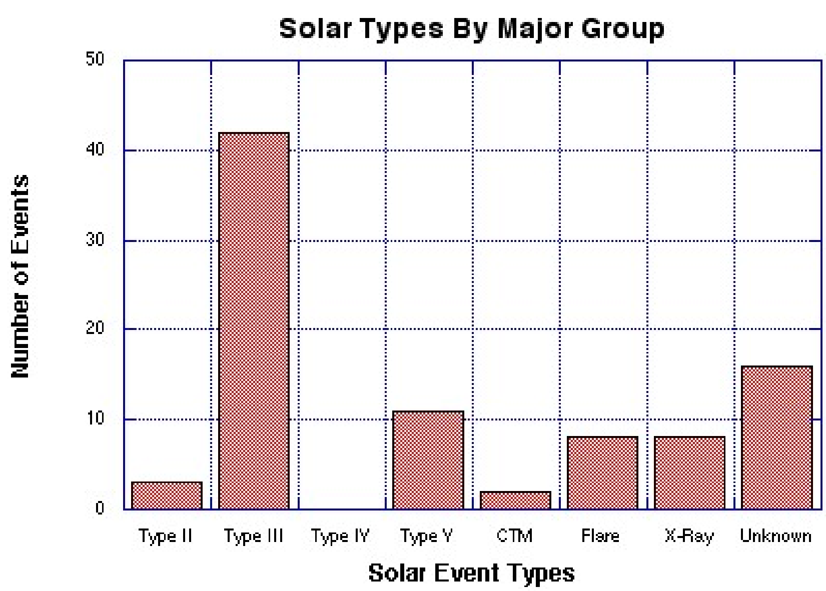
This information can be useful for teachers and other observers to show when to expect events when using the standard Radio JOVE antenna setup and alignment. Observers need not rush to begin observations in the morning, with peak observing between 1300 and 2000 UT (8 AM to 3 PM Eastern Standard), which is within the time frame of most public school hours. Observers in different time zones will have peak observing then between 8 AM and 3 PM local time.

Actual Solar Events Observed

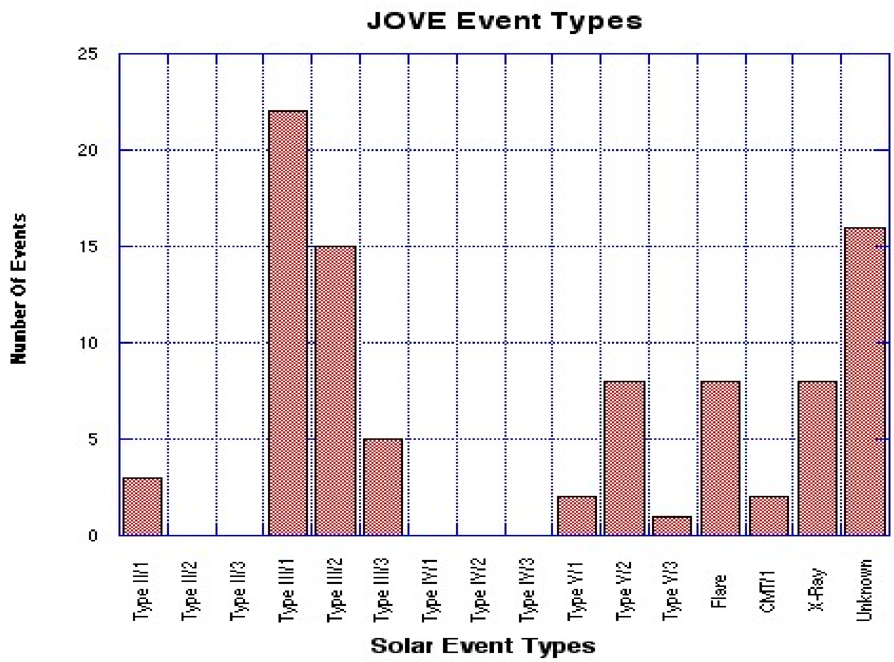
Of the solar event types listed above, the actual events I observed were Type II, Type III, Type V, CTM, Flares, X-Ray and a class listed as "Unknowns" because there was no NOAA designation, meaning that they were not listed as occurring by NOAA. NOAA does not collect data for any solar events below 25 MHz, and since the Radio JOVE receiver is designed for optimum reception at 20.1 MHz, the JOVE radio telescope can record data that NOAA does not.

While different types of events were recorded, the Radio JOVE telescope seems most sensitive to the fast drift and brief continuum burst type emissions.

It was observed that the majority of solar events occurred as single events; however, multiple events can occur simultaneously. Example: Type III, Type II and Type V together.



Further, it was observed that overall the low energy events (1's) were the most common at 39.2 %, mid energy events (2's) were the next most common at 31.1 % and high energy events (3's) were the least observed at 29.7 %. However, in the case of the Type V events, the most common were the mid-energy events. The next graph shows each event type broken down into its sub-groups.



Conclusions

While much of the data results were as expected, what was surprising to me was the number of events that went unrecorded by NOAA. Nearly 18% of the observations fell into this category, showing that NOAA is missing a substantial number of solar events in its monitoring program. It is possible that the Radio JOVE program could provide valuable information to NOAA by reporting solar events that take place below 25 MHz. Also, Radio JOVE collectively might simply be added to the list of US reporting stations since there are only two stations in the US reporting solar radio information to NOAA. (NOAA Contributing Stations)

The most difficult part of the observations for me was getting clear reception, free from local power line noise interference. If you have a number of sites where you can set up your Radio Jove equipment, select a site that is free from power line noise. In my case, the power line noise was strong enough to overwhelm all but the very strongest solar radio bursts. If you are limited in where you can set up your antennas and receiver as I was, then you will need to work with your local power company to eliminate this noise source.

Another source of unwanted noise is thunderstorms. A lightning discharge will produce radio noise and the Radio JOVE receiver is very sensitive to lightning discharges. The strength of the noise produced is proportional to the distance to the lightning discharge but even a distant thunderstorm can produce enough noise on your receiver to obscure even strong solar radio bursts.

You do not have to purchase the Radio JOVE kit to make observations. Virtually any short-wave receiver or amateur radio receiver with a wide enough bandwidth capable of receiving from 20 to 30 MHz can be utilized for observing provided that it has the ability to disable the automatic gain control (AGC). You can construct your own gain dipole antennas if you are so inclined. Purchasing the Radio JOVE kit, however, is the easiest way to get all the materials you need to start.

Radio JOVE is an excellent and inexpensive way for educators or anyone interested in radio astronomy to get started. During solar maximum periods, Radio JOVE provides nearly instant gratification when observing the sun since you are likely to observe a solar radio burst or multiple bursts on any given day. Combine solar and Jovian (Jupiter) observations and you can, at times, observe nearly around the clock.

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Data Sets

Event Types

Type I	0
Type II	3
Type III	42
Type V	11
Flare	8
X-Ray	8
CTM	2
Unknown	16

Event Types Subgroup

Type I/1	0
Type I/2	0
Type I/3	0
Type II/1	3
Type II/2	0
Type II/3	0
Type III/1	22
Type III/2	15
Type III/3	5
Type V/1	2
Type V/2	8
Type V/3	1

Events Per Hour

Time UT	Events
1000	0
1100	2
1200	2
1300	8
1400	5
1500	20
1600	9
1700	16
1800	11
1900	11
2000	3
2100	0