LWA TV on the Raspberry Pi

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Abbreviations
DHCP: Dynamic Host Configuration Protocol
DVI: Digital Visual Interface
GUI: Graphical User Interface
HDMI: High Definition Media Interface
IP: Internet Protocol
LAN: Local Area Network
LWA: Long Wavelength Array
RPi: Raspberry Pi
UNM: University of New Mexico
VGA: Video Graphics Array

1. Introduction

This article describes how to use the tiny and inexpensive Raspberry Pi computer with the Long Wavelength Array (figure 1) in New Mexico to observe celestial radio sources in near-real-time. The application was developed by the University of New Mexico (UNM) as part of LWA Education and Public Outreach. It is a good way to become familiar with the LWA, LWA TV and the Raspberry Pi, all at the same time. The LWA TV program does not allow user control, only observation, and it runs "out of the box" with no user programming whatsoever.

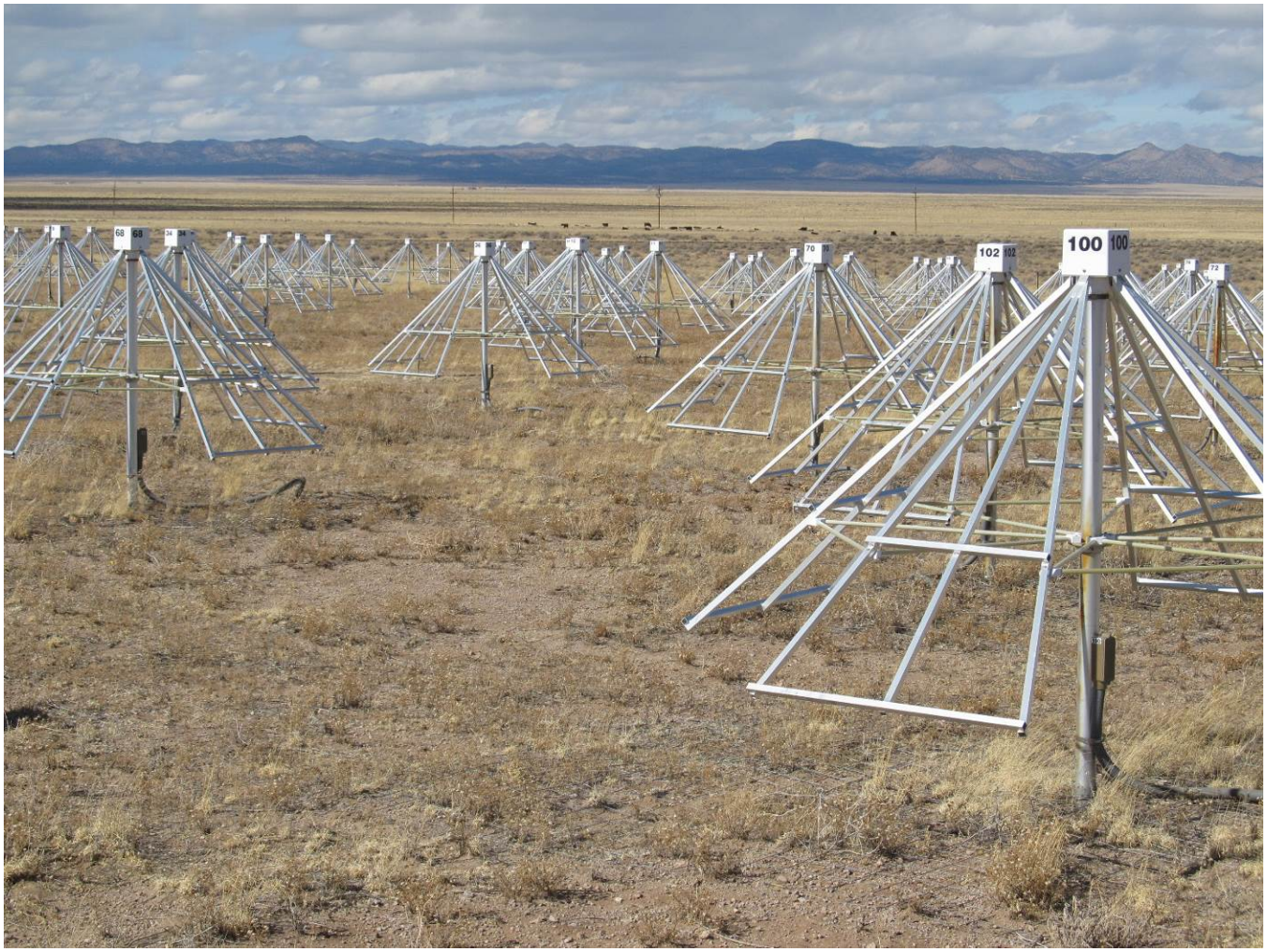


Figure 1 ~ The first Long Wavelength Array station in New Mexico consists of a forest of 257 crossed-dipole, tied-fork antennas. Beams are formed through signal processing to observe specific celestial radio sources or areas of the sky. (Image © 2014 W. Reeve)

One of the advantages of the approach described here is that no hardware construction or software programming is required – off-the-shelf hardware and software is all that is needed. Another advantage is that

the software for the LWA TV graphical user interface (GUI) is prepackaged by UNM and available for free. When I started working on this project (August 2014) UNM's software worked only with the Raspberry model B. I contacted Jayce Dowell at UNM and he updated the software to run on both the model B and B+ (the B+ is the latest Raspberry Pi hardware version). Although the LWA TV software is plug-and-play, there is room for some customization, which I describe in **section 5**.

I started writing this article to answer most of the questions that might arise while setting up the LWA TV application and ended up writing a reference manual. The first half provides general descriptive information and the second half contains setup details. This article was updated in August 2016.

2. Long Wavelength Array

Note: Internet links in braces { } and references in brackets [ ] are provided in **section 6**.

The LWA is used to study celestial objects or areas of the radio sky in the frequency range 10 to 90 MHz {LWA}. Its primary purpose is scientific but education and public outreach are important parts of its government-funded mission. One of the features of the LWA website is LWA TV {LWA TV} – a near real-time visual representation of the data produced by the array (figure 2).

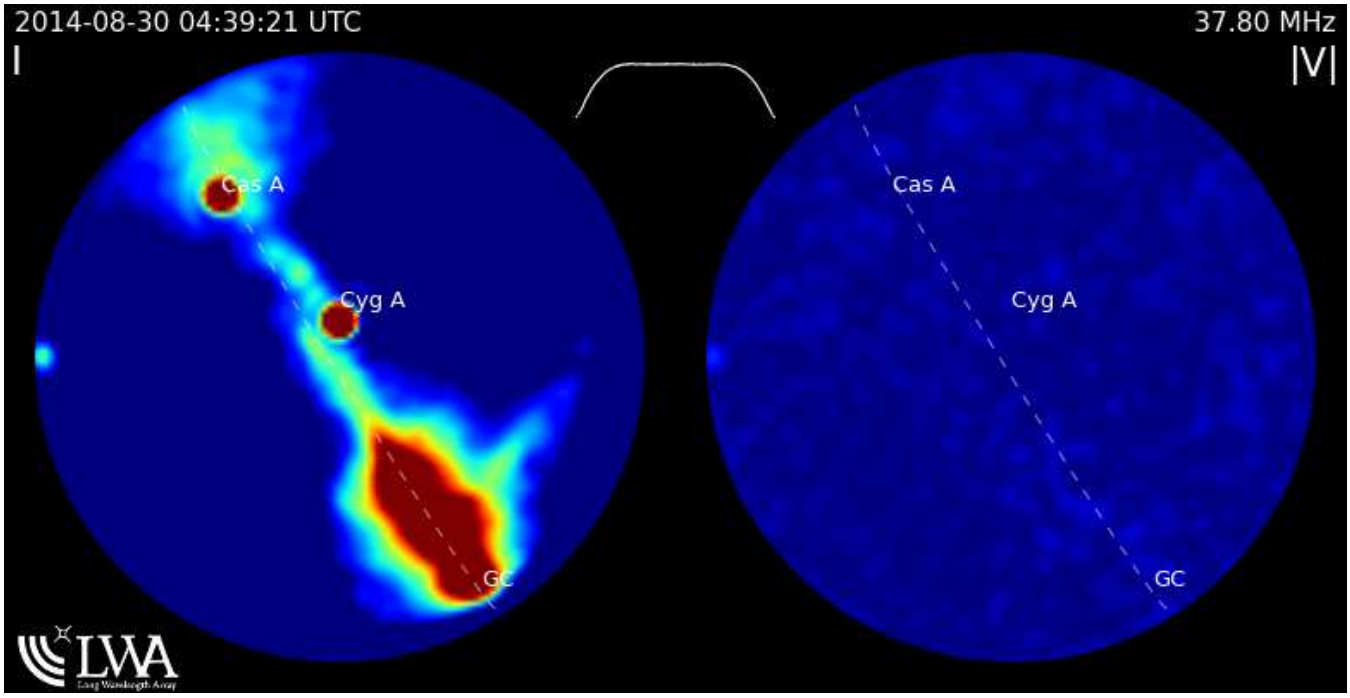


Figure 2 ~ Image from LWA TV as seen on the internet. The two circles represent the sky seen by the LWA at radio frequencies, in this case, 37.80 MHz. The horizon is along the circle edges and the zenith (straight up) is in the middle of each image. Dark blue is the background and brighter areas (in order of increasing radio intensity – blue, green, yellow, red) are the Milky Way galaxy and spots are radio sources. The locations of some of the brighter celestial radio sources are labeled. The images show total intensity (left) and intensity of circularly polarized radio waves (right). (Image source: http://www.phys.unm.edu/~lwa/lwatv.html)

Although LWA TV can be watched in near real-time on any PC with internet access, observers may want to setup a dedicated monitor for LWA TV and then use the PC for another purpose such as their own radio telescope. For example, one could observe Jupiter or the Sun with their own radio telescope using Radio-SkyPipe (RSP) or Radio-Sky Spectrograph (RSS) while watching for activity on LWA TV. This allows confirmation or correlation of observations. Of course, the radio sources would need to be in common view of the LWA and the observer's radio telescope. Another application is radio astronomy club outreach. The setup could be used at meetings, conventions and conferences. It should be noted that LWA TV itself does not allow real-time access to the actual data nor does it store any of the individual real-time images; however, LWA TV does save movies of the last seven days on the Raspberry Pi and the movie archives also are easy to download from the LWA TV website.

3. Raspberry Pi

The Raspberry Pi (abbreviated RPi throughout this article) is a small computer platform designed for educational purposes by the Raspberry Pi Foundation {RPi}. The RPi is low cost, about 35 USD (40 USD with memory card), and has HDMI video, Ethernet LAN and USB interfaces (figure 3). It is euphemistically advertised as "credit-card size" but actually is much larger. It can be plugged into an ordinary computer monitor or TV and can use a WiFi wireless access device for LAN and internet access and wireless or wired USB keyboard and mouse.

Figure 3 ~ Raspberry Pi model B and B+ hardware. The model B+ is shown in the middle with an optional clear plastic enclosure. The model B on the left is in an optional milled aluminum enclosure and is shown with a Bluetooth USB dongle. The model B on the right is in a molded clear plastic enclosure and rotated to show the opposite end. The interfaces vary slightly between the model B and B+. Enclosure dimensions are approximately 100 x 65 x 25 mm. (Image © 2014 W. Reeve)

The RPi hardware usually runs an operating system derived from Linux and (as of this writing) has become available in many versions – original model A, model B and model B+ model 2 and model 3. The model B and B+ are compared (table 1). For a dedicated LWA TV application, there is no advantage of one over the other model.

I have not tried the RPi model A, and I initially could not get the LWA TV software image provided by UNM to work on the RPi B+. I was successful only with the RPi B. All the information available from the Raspberry Pi Foundation for the model B+ insists that it is software compatible with the model B but I found there were problems that affected the LWA TV GUI. These were resolved in September 2014 and the software image now available from UNM works fine on both the B and B+ including the model 2 and model 3.

Table 1 ~ Comparison of Raspberry Pi Model B and B+ Hardware

Description	**RPi B**	**RPi B+**
RAM	512 MB	512 MB
Memory card	SD	micro-SD
Processor system	BCM2835 SOC	BCM2835 SOC
Video 1 connector	Standard HDMI	Standard HDMI
Video 2 connector	RCA Composite	3.5 mm audio + Composite
Audio connector	3.5 mm	see Video 2
USB connector	2	4
Power connector	micro-USB	micro-USB
GPIO connector	26 pin	40 pin
Network connector	10/100 Ethernet	10/100 Ethernet
Power	5 V, ~5 W	5 V, ~3 W
Dimensions	85 x 56 x 21 mm	85 x 56 x 21 mm
Mounting	2 holes	4 holes
Cost	35 USD	35 USD

Hardware: The Raspberry Pi can be purchased from any number of suppliers worldwide. It is necessary to add a Secure Digital (SD) memory card to the model B or micro-SD memory card to the model B+ and later for the LWA TV software image. Sometimes the vendor supplies a card with the RPi purchase. A card with 8 GB minimum capacity is recommended but 4 GB is sufficient. Also, an HDMI monitor is needed. A VGA monitor may be used if an HDMI-to-VGA converter (figure 4) is connected between RPi and the monitor. A keyboard with or without a mouse might be handy but is not necessary. No changes are required to the RPi platform but it should be installed in an enclosure (preferably a metal enclosure). A Secure SHell (SSH) terminal generally is used to communicate and manage RPi from another computer on the same network. This is described in more detail in **section 5**.

Figure 4 ~ HDMI-to-VGA converter allows the RPi to be used with most computer monitors. The converters seen here cost about 10 USD. The RPi requires a full-size HDMI connector seen on the left converter. An adapter will be needed If the converter has a mini-HDMI connector as seen on the right converter. (Image © 2014 W. Reeve)

The power requirements of the RPi are modest, about 5 W for the model B and 3 W for the B+ assuming no current is being drawn from the USB ports. Because these powers are more than supplied by a standard USB port on a PC it is necessary to use an external power supply or power adapter. If no USB peripherals are used,

the RPi can be powered by a well-regulated, low ripple, electrically quiet power source rated ≥ 1.0 A at 5.0 Vdc (≥ 5 W). If the RPi USB ports are to supply power to peripherals, then a 10 W or higher power source should be used. Using a poor quality power supply will lead to unreliable operation so be sure it meets these requirements. One of the most common problems users have with the RPi is inadequate power supply current. To minimize electrical noise, it is recommended that ferrite beads be installed on the power cable (figure 5).

Figure 5 ~ AC wall power adapter with 5 V, 2.4 A (12 W) output purchased at BestBuy. One or more clamshell ferrite beads on the dc power lead help reduce radio frequency interference from the switch-mode power supply. This image shows one bead on the right with three windings of the power lead. The Raspberry Pi uses a micro-USB connector for power. (Image © 2014 W. Reeve)

Software: The RPi uses a software image that includes the operating system and applications. The RPi image developed by UNM for the LWA TV GUI is based on a Raspbian distribution. The software must be user-installed on a memory card. Installation is not difficult but it is done in a way that is not obvious to most Windows PC users. UNM provides links to web pages with the necessary procedures (see {LWA EPO}). These procedures also are briefly listed in the Software installation part of **section 5**. To make this process a little simpler, I can provide a preprogrammed micro-SD card in an SD card carrier to interested readers. See **Contact information** at the end of this article. With this memory card, the system truly is plug-and-play.

When running the LWA TV GUI software, the RPi can be used only for that purpose. However, the software is written in Python and may be modified by users if they feel "adventurous". Python is an interpreted language and, therefore, is not compiled so nothing more than a text editor is needed to write or modify an application. Notepad++ is perfect for this purpose and is free {Notepad++}, but Windows Notepad will also work. The advantage of Notepad++ is that it automatically formats and indents the code to make it easier to read and work with.

The main piece of software in the LWA RV GUI is *lwaTV3rpi.py*, about 16.5 kB of text. Examining the code shows that it includes four command line switches, or options, which may be used to customize the GUI. The program operates normally with its default settings, and there is no compelling reason to change them except for experimental purposes. Using these options requires knowledge of the operating system and I will not discuss them further.

4. LWA TV on Raspberry Pi

The setup for LWA TV is very simple (figure 6). By default the LWA TV GUI uses the wired network interface (Ethernet) built into the RPi and acquires a network (IP) address automatically using dynamic host configuration protocol (DHCP). You can change this to a static IP address and add a WiFi interface. However, to eliminate many

potential problems, I recommend first running the LWA TV GUI in its default configuration to become familiar with it before making any changes. See **section 5** for some changes that you might find useful.

With the programmed memory card installed, make all connections before applying power to the RPi: (1) HDMI connection to your monitor or television set (be sure it is turned on); (2) Ethernet connection to your internet router; and (3) micro-USB connection to an ac power adapter. When power is applied, the RPi system automatically starts and the display will show lines of text that scroll by rather quickly. Upon completion of the boot up process, the display will momentarily blank and then the LWA TV GUI will appear. The LWA TV GUI shows the real-time images plus archived movies (figure 7). If the program is running but does not have a proper network connection, you will see "Error Downloading Image" and "Network Connection Error" on the display (figure 8). An archived movie may be running but the live portion of the display will be gray. The LWA TV GUI connects within a second or two after the network connection is established. I did not have to make any changes in my internet router for LWA TV, but if you have network connection problems your router and its firewall are the first place to start troubleshooting (after checking that the cable is plugged in).

If everything seems to be working okay it is a good idea to update both the software and the archived movies upon first use. Log into the RPi console as discussed in the RPi console part of **section 5** and execute the commands given in the Update part.

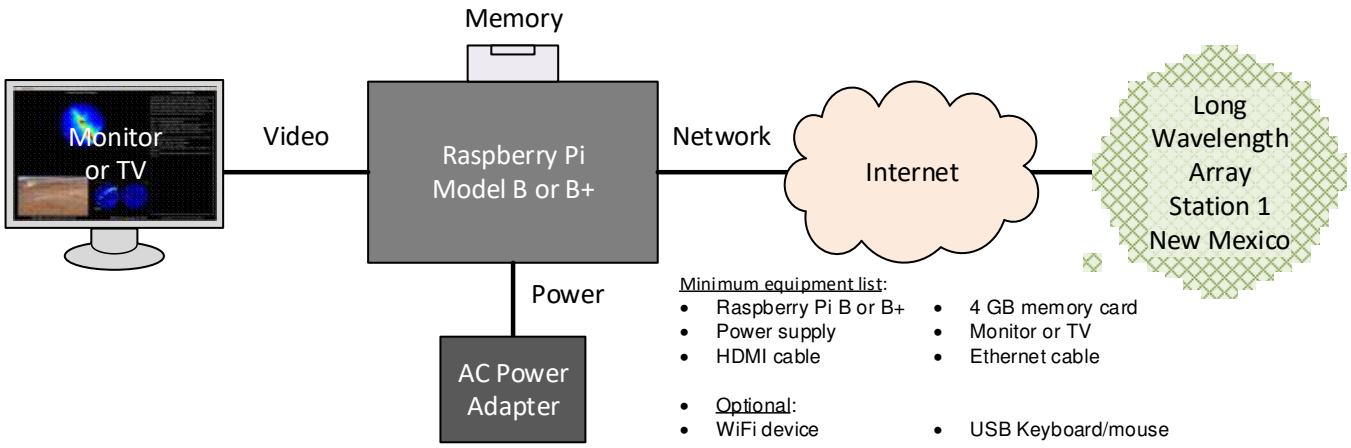


Figure 6 ~ Block diagram and equipment list for the RPi when setup for LWA TV. See text for description of each item. Before applying power to the RPi make all connections and turn on power to the monitor or television set. (Image © 2014 W. Reeve)

When connected, LWA TV downloads a daily average of approximately 25 kB/s, 91 MB/h or 2.2 GB/d. The internet traffic is split between the real-time images and archived movies. The LWA station processes the data and prepares images in near real-time. The LWA TV GUI checks for and downloads a new image every 5 s. Each image includes the total radio energy received during the 5 s interval, so transient emissions lasting less than 5 s are recorded. The images are about 120 kB each so the average network traffic load is about 25 kB/s. The archived movies normally are downloaded in the evening and are usually around 100 MB each. Downloading uses whatever internet bandwidth is available.

If your internet service has download limits and imposes penalties when exceeded, it would be wise to monitor your usage closely. If you want to reduce the internet usage overnight or other times, you can setup the software to suspend the program during predetermined hours as described later. Alternately, simply unplug the Ethernet cable rather than shutting down the RPi or, if you use a wireless network connection, you will need to use a software method to stop network usage.

The LWA TV application updates the movie archive cache at 1830 in the time zone used by the RPi. By default, the LWA TV software uses mountain daylight time (MDT) but both the time zone and movie cache update time can be changed. See Date, time and time zone in **section 5** for these and a method to suspend the software at night or outside normal observation times to reduce network usage.

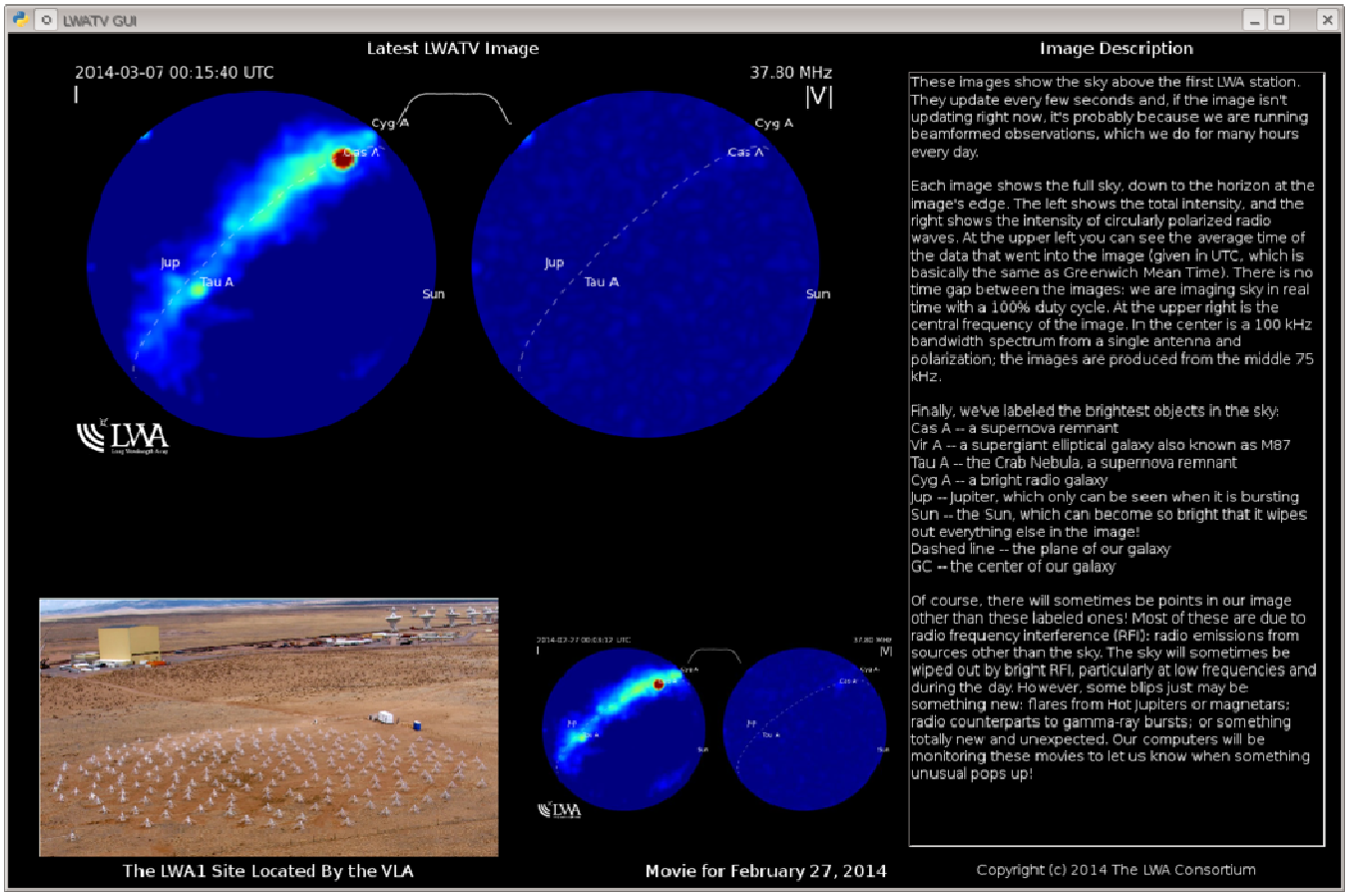


Figure 7 ~ LWA TV screen. The live image at top-left shows one or two circles depending on the current LWA operating mode. When LWA is setup for beam pointing, only one circle may appear as shown here; otherwise, two appear. The two circles at bottom-middle are archive movies from the previous several days. The movies cover a full day, often with gaps, and each requires about 12 minutes to run. Sometimes radio frequency interference is seen along the edges of the circles. The aerial image of the LWA at lower-left is fixed and text on right changes depending on normal or beam-pointing view of the live image. (Image source: http://fornax.phys.unm.edu/lwa/trac/wiki/EPO)

5. Installation and Operation Notes

This section provides information that will help first-time users. It is focused on the LWA TV application.

Software installation: The brief instructions here assume the reader is using a Windows PC to install the LWA TV GUI software on the memory card: (1) Install 7-Zip {7-Zip}, SD Formatter {SDFmt} and Win32 Disk Imager {WDImg} on the Windows PC (or HDD Raw Copy Tool, {HDDRaw}). When running the latter two programs, run them as Administrator; (2) Put the memory card in a card reader (see Note below) connected to the PC and use SD Formatter to format the card. In SD Formatter set the Options to Format Type = Full Erase and Format Size Adjustment = On; (3) Download the LWA TV GUI software image for the RPi from {LWASoft}. The file is compressed so decompress it with 7-Zip to a raw image file (*.img). This will take a few minutes; (4) Write the software image to the memory card with Win32 Disk Imager using its default settings (or use the HDD Raw Copy Tool). This will take a few minutes. After the Write operation is finished, the memory card is ready to use in the RPi. Be sure RPi power is OFF and insert the card. Note: Some micro-SD cards and card readers are incompatible, so it is best to install the micro-SD card in a full-size SD card carrier, insert the carrier into the reader and then format the card and load the software image.

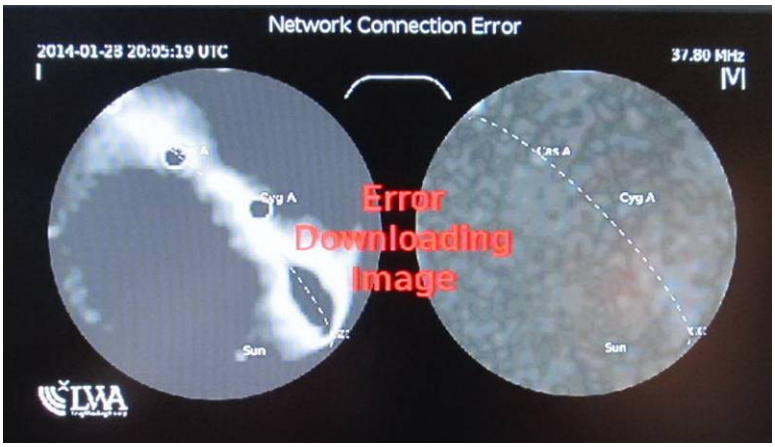


Figure 8 ~ If there is a network connection problem, the live globes are gray and warnings appear. During normal operation, the Error Downloading Image message may momentarily appear but it is nothing to worry about if it happens only occasionally. (Image © 2014 W. Reeve)

The RPi model B and B+ model 3 use an ordinary push-to-insert/pull-to-release slot connector whereas the model B+ uses a push-to-insert/push-to-release slot connector. When the RPi is powered ON, the software will load and run automatically.

RPi console: In order to make changes to the RPi setup (described later in this section), it is necessary to log into the RPi console (command line interface). This may be done from a Windows PC that is on the same network as the RPi or through a wireless or wired keyboard. The RPi uses secure shell (SSH) for console communications so it is necessary to install an SSH client application such as {PuTTY} or {TeraTerm} on your PC if using the network connection.

To use SSH, first determine the IP address assigned to the RPi by your internet router. Procedures vary widely and it is best to read your router user manual or search for online help. The RPi host name is “lwatvgui” (without quotes) and will be identified as such in your router’s local network status screen. An alternate, and perhaps quicker, method is to download and install on a Windows PC a network scan program as described in {RPiSetup}.

For PuTTY place the RPi IP address into the Host Name or IP address field and click Open (figure 9). After authentication you will see the RPi login prompt. The default username is“pi” (without quotes). After you enter

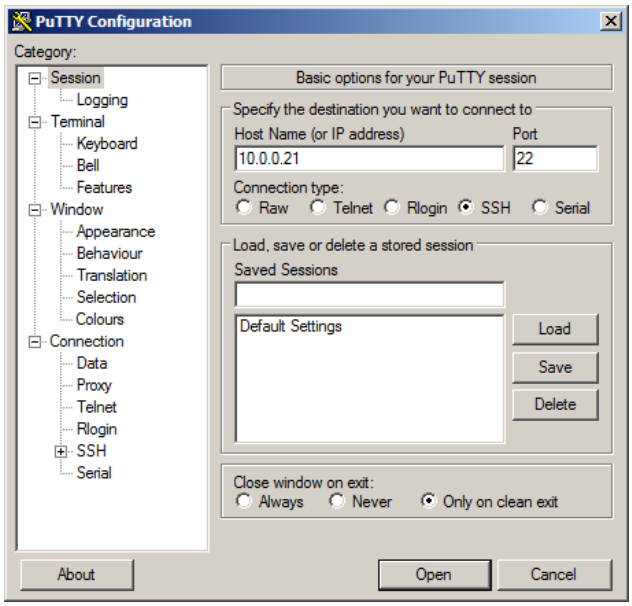
the username, RPi will ask for the password. For obvious reasons I will not publish the password here, but it can be obtained by emailing the address given at the very bottom of {LWA EPO}.

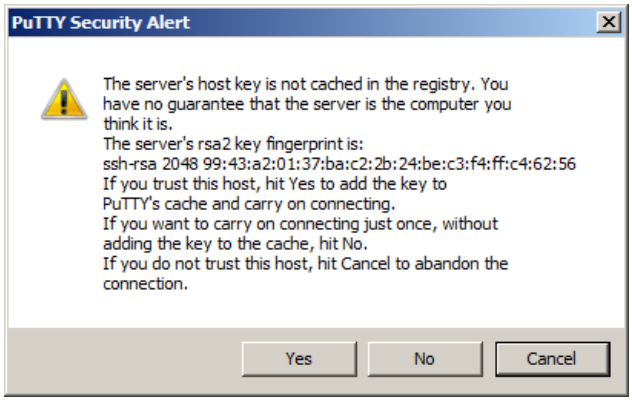
Updates: To update the LWA TV software and archived movie cache, enter the following commands one at a time using the SSH terminal described above. Wait for each process to complete before entering the next command. It is necessary to send these commands only upon first use of the LWA TV (the updateMovies command is run automatically each day and the LWATV software is updated weekly):

```
cd ~/LWATV/
svn update
./updateMovies.py -v
sudo rpi-update
sudo reboot
```

It is a good idea to routinely update the Raspbian software distribution as well. Enter the following commands with an SSH terminal to update the non-LWA TV software (these updates and upgrades can require tens of minutes if new distributions have become available after the last update):

```
sudo apt-get update
sudo apt-get upgrade
```





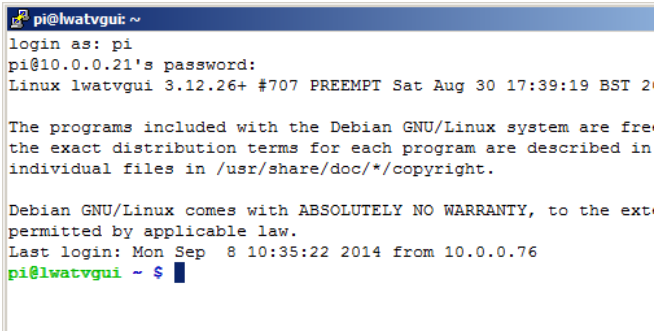


Figure 9 ~ Upper-left: Screenshot of PuTTY configuration window with the IP address for one of my setups. Upper-right: Upon first connection, PuTTY asks for authentication. Lower-left: When PuTTY is connected, the window changes to a simple command line interface. After login, you can make changes to the RPi. (Images © 2014 W. Reeve)

Documentation: Online documentation for the Raspberry Pi including troubleshooting information is available at {RPiDoc} and {RPiHub}. There also are numerous forums that have information related to RPi. The only documentation that exists for the LWA TV application is this article and information at {LWA EPO}.

Keyboard-mouse: The LWA TV GUI has built-in drivers for a USB keyboard and mouse but they are not required for normal operation. However, a keyboard is nice to have if you need to directly access the RPi or cannot access it indirectly using SSH as described above. Small wired or wireless keyboards, with or without a mouse (figure 10), are available from {Adafruit}.

Figure 10 ~.Wireless keyboard and mouse uses a Bluetooth connection. The keyboard is about 285 mm long. A Bluetooth dongle is included and requires one USB port as seen on the left of the RPi model B in the image. (Image © 2014 W. Reeve)

Heat: The RPi processor normally runs warm but not hot. While using LWA TV I measured about 30 °C using an infrared non-contact thermometer pointed at the processor chip.

Enclosure: Many different types of enclosures are available for the model B and B+ RPi including the model 2 and 3, but the enclosures for one model do not necessarily fit another. Most enclosures are plastic and provide no shielding whatsoever. This might be of concern where the RPi is used near a radio telescope antenna or receiver. Relatively expensive aluminum enclosures are available for the model B and B+, but they provide much better shielding than any plastic or non-metallic enclosure.

Radio frequency interference: I took some measurements with a spectrum analyzer and a shielded magnetic loop probe and electric field probe and found several spectral spikes in the high MF and low HF ranges, about 1.5 to 8 MHz or so. These were apparent only when the probes were held against the clear plastic enclosure of the model B+. I checked up to several hundred MHz but found no other indications. I did not make any measurements with the aluminum enclosure on the model B. It should be noted that conducted interference in connecting cables often is radiated because the cables act like antennas, so each installation will have different RFI characteristics and it may be necessary to install ferrite beads on all connecting cables.

Video monitor: The RPi uses a standard HDMi connector for video. It may be used with a monitor or TV with an HDMI input. It also may be used with a VGA monitor by using an HDMI-to-VGA converter or with a DVI monitor or TV with an HDMI-to-DVI converter. I experimented with the HDMI and VGA interfaces on monitors and televisions but did not attempt to use DVI. For portable use, say at a convention, a small screen monitor would

be handy. Many compatible types are available; for example, search “monitor” at {Adafruit} to see a variety of 5.6, 7 and 10.1 in monitors with HDMI inputs. I have not tried any monitors/TVs except those discussed below.

I initially connected the RPi to the HDMI port on a Hannspree HF-199 monitor. The HF-199 has HDMI and VGA input connectors, and its maximum resolution is WXGA+ (1440x900 pixels, 16:10 aspect ratio). I found that the displayed image was slightly elongated horizontally when using the LWA TV GUI default settings.

To change the video settings, it is necessary to edit the config.txt file in the /boot/ folder of the RPi. It is best to do a little research on the internet before making any changes. Use *nano* to edit the file (nano is a simple text editor built-into the software image):

```
sudo nano /boot/config.txt
```

After making the desired changes and saving the file, reboot the RPi:

```
sudo reboot
```

I tried changing the RPi video settings to different screen resolutions and eventually found that only one HDMI mode provided a better display and that was at the monitor’s maximum resolution 1440x900 (hdmi_group=2, hdmi_mode=47). However, at this high resolution, the real-time display and archive movies sometimes would momentarily stall or skip.

I then tried an HDMI-to-VGA converter on the monitor’s VGA input and could not obtain a good display. With many settings I had no display at all. I spent about one full day trying different port settings on the monitor and RPi. I finally gave up and settled on using only the monitor’s HDMI port. This monitor works very well at 1440x900 pixel resolution with the VGA interface on the lab PC.

I also tried our Philips 47 in LCD television set. This TV has three HDMI ports and supports several resolutions, 480p, 720p, 1080p and 1080i. I found I could obtain a nice picture using RPi settings for 720p (hdmi_group=1, hdmi_mode=4) and overscan (overscan_right=40, overscan_left=40, overscan_top=16, overscan_bottom=16) (figure 11). Although this TV supports 1080p and 1080i, I could not find any RPi overscan settings that provided a properly positioned horizontal display. Based on my experience so far, I think the video interface implementation is the RPi’s biggest shortcoming (the video implementation is separate from the LWA TV GUI). Perhaps with enough time and experimentation, I could make it work better at different resolutions, or later versions of the RPi firmware may correct the deficiency.

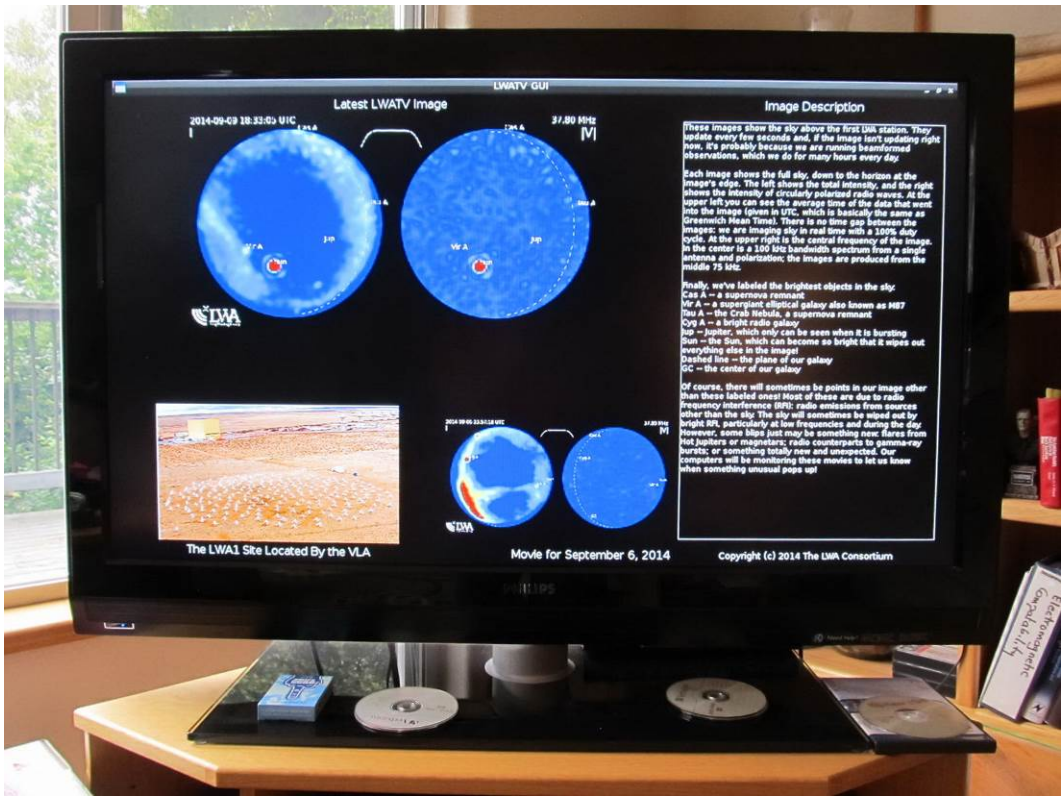


Figure 11 ~ Philips 47 in LCD television set connected through one of its HDMI ports to the RPi. The RPi HDMI port was set for 720p resolution (see text). (Image © 2014 W. Reeve)

As a final video test, I connected a Dynex 19 in LED-LCD TV that I use in the lab. This is a small set designed as a kitchen counter TV with a wide range of video inputs. After using the TV menu to select the HDMI port, the screen immediately showed the correct display. I made no changes in the RPi video settings (720p) used with the 47 in TV previously described.

Date, time and time zone: By default, the Raspbian distribution uses Network Time Protocol (NTP) to automatically set the RPi time when it is connected to the internet. The RPi does not have a real-time clock or battery backup, so it must be running and connected to the internet to correctly set and maintain the time and date. To confirm the date, time and time zone, enter the following at the RPi prompt on the SSH terminal:

```
date
```

To change the time zone, enter the following. The displayed instructions will lead you through the reconfiguration:

```
sudo dpkg-reconfigure tzdata
```

To confirm the scheduled download time for the daily LWA TV movie archive update, enter the following to see what is in the cron table (*cron* is a utility that runs automatically in the background at specified times):

```
crontab -l
```

The cron table (or crontab) has entries to update the LWA TV movies daily and update the software and reboot the RPi weekly (early versions of LWA TV may not have all the entries):

```
## Update the movies daily at 1630 UTC
```

```
30 16 * * * python ~/LWATV/updateMovies.py
## Update the software weekly on Saturday at 0630 UTC
30 06 * * 6 svn update ~/LWATV/
## Reboot weekly on Saturday at 1530 UTC
30 15 * * 6 sudo /sbin/shutdown –r +5
```

The times in crontab are in the system time zone, which may be UTC (see above), and times are shown with minutes before the hour. As seen above the scheduled event with a time of 1630 updates the movies. To change the scheduled time, enter the following to edit the cron table. This will invoke the default editor:

```
crontab –e
```

Do not change anything on the lines except the minutes and hour. You also may need to change the update and reboot times so they are coordinated with your observation activities.

The crontab function also can be setup to with a suspension feature, which temporarily stops and then restarts the LWA TV application software at regular intervals to reduce network usage. For example, you could use a stop process at a specified time in the evening, and then a start process the next morning. The stop and start times can be set as required and are easy to change depending on observation activities. Each hour the software is suspended will reduce network usage by about 91 MB.

It will be necessary to coordinate the start and stop times with the other times in crontab discussed above, and they must correspond to the time zone used in the RPi. For example, if the RPi is setup to use UTC, the start and stop times must be UTC times. If the RPi uses a local time zone, the times must be local times.

To use the suspension feature, add the following lines to the cron table using the crontab editor (crontab –e). The lines shown here will start the program at 1600 and stop it at 0600 (times in this example are UTC in North America):

```
## Suspend LWA TV during night and restart in morning
DISPLAY=":0"
00 16 * * * python ~/LWATV/lwaTV3.rpi.py
00 06 * * * pkill –f lwaTV3.rpi.py
```

When using this feature, the RPi must be running and connected to the network. When the suspension is invoked, the RPi screen will blank. If you later change your mind about using the suspension feature, simply delete the above lines or comment them out with the # character.

When finished with the edits in crontab, type CTRL-X, Y and Enter. Changes to crontab take immediate effect and it is not necessary to reboot.

Display text customization: The text in the right frame of the LWA TV display is stored in the directory /home/pi/LWATV/info in text files: beams.txt, lwatv.txt and lwa2tv.txt files. One of these files is used depending on what the main display shows. This text may be modified to suit local purposes; however, it is a good idea to backup the original files or copy them to a safe location before making any changes just in case they are needed later.

The following uses WinSCP to edit the text files; see {RPiSetup} to install WinSCP if not already on your PC. The nano editor also may be used. For WinSCP navigate to the directory /home/pi/LWATV/info and double-click (or right-click and select **Edit**) the file to be edited (beams.txt, lwa1.txt or lwasv.txt). It will open in an editor (figure 12) and you can make the desired changes. When finished click the Save icon at the left end of the Editor Menu bar. If desired, repeat the edit operation for each of the three text files. The changes will take effect when the RPi is rebooted:

```
sudo reboot
```

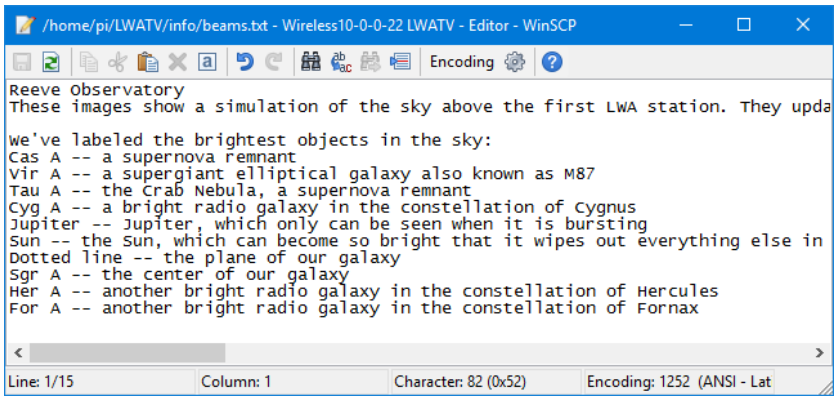


Figure 12 ~ Screenshot of the WinSCP editor with the lwa1.txt file loaded.

Displaying LWA2 (LWA-Sevilletta, LWA-SV): By default, LWA TV displays the first LWA station (LWA1) west of Socorro, New Mexico. Another station located in the Sevilleta National Wildlife Refuge, called LWA-Sevilleta or LWA-SV or LWA2), south of Albuquerque, New Mexico also can be viewed. One LWA station can be viewed at a time. Only a couple changes are needed to the LWATV software to view LWA-SV. The following information was provided by Jayce Dowell at UNM (see **Acknowledgement**).

The RPi uses a version of the Linux operating system, and in Linux the $DISPLAY environment variable controls which display the LWA TV graphical user interface (GUI) uses. When using the console to change to LWA2, it is not possible to start the GUI without first setting $DISPLAY. There are two ways to do this; one is temporary (until next reboot) and the other is permanent (persistent through reboot).

Before making any changes to your existing LWA TV installation, it is a good idea to backup your existing RPi software image. Procedures are given in {RPIBackup}. Also, be sure the latest LWATV software is installed by entering the following in the RPi command line:

```
cd ~/LWATV/
svn update
```

Temporary: This method requires only a couple changes. First, manually set the $DISPLAY variable in the console and then set the LWATV2 mode. This method does not download LWA2 movies. At the RPi command line enter the two lines below, following each by Enter:

```
export DISPLAY=:0
./lwaTV3.rpi.py -2
```

The second line above runs the LWA TV Python program with the -2 option, which downloads the LWA2 images. Do not reboot the RPi after entering these changes.

Permanent: This method is slightly more complicated but requires only a couple minutes. First, set the LWATV2 mode as the boot time default by editing the /etc/xdg/lxsession/LXDE/autostart file and adding the -2 option at the end of the line that calls lwaTV3.rpi.py. Since autostart is a system file it needs to be edited with sudo privileges, as in

```
sudo nano /etc/xdg/lxsession/LXDE/autostart
```

Several lines will be seen in the editor, most of them commented out with the hash "#" character. Look for the line that specifies the lwaTV3.rpi.py file, probably the last line (figure 13).

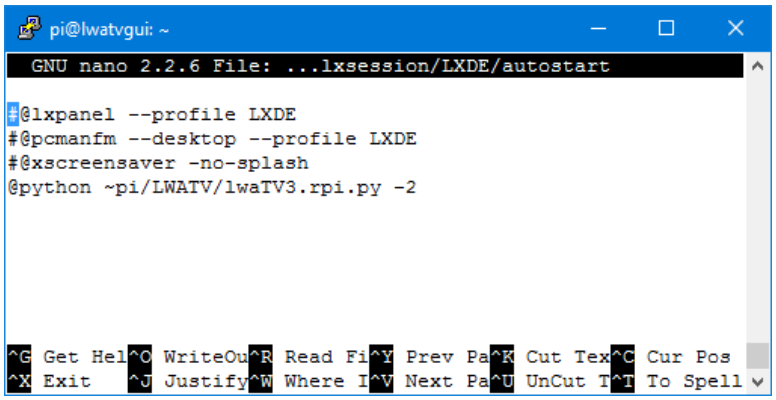


Figure 13 ~ Screenshot of the nano editor with autostart file loaded. The -2 at the end of the first line specifies LWA2 (LWA-SV).

Add the -2 option at the end of that line

```
@python ~pi/LWATV/lwaTV3.rpi.py -2
```

Make no other changes and, when finished, type CTRL-X, Y and Enter.

It also is necessary to modify the cron table (crontab) so that the LWA2 movies are downloaded. To invoke the crontab editor enter at the command line

```
crontab -e
```

Look for the lines about the movie update. It may be necessary to scroll down using the cursor keys:

```
## Update the movies daily
30 18 * * * python ~pi/LWATV/updateMovies.py
```

Change the line that calls updateMovies.py to include the -2 option; do not make any other changes to this line unless you also want to change the download time:

```
30 18 * * * python ~pi/LWATV/updateMovies.py -2
```

If the suspension feature is used as described in {ReeveLWATV}, it also is necessary to put the -2 option at the end of the line that starts lwatv3.rpi.py.

When finished, save the changes by typing CTRL-X, Y and Enter. The changes in crontab take effect immediately, but the changes to autostart require reboot:

```
sudo reboot
```

When the RPi reboots it should be in the LWA2 mode.

To go back to the LWA1 mode, simply reverse the changes made above; that is, remove the -2 option from the appropriate lines in autostart and crontab. Be sure to reboot to load the revised autostart file.

LWA TV screenshots: If screenshots of LWA TV are needed, a screen capture tool such as scrot (SCReenshOT) must be installed on the RPi. From the RPi command line type

```
sudo apt-get install scrot
```

After installation completes, capture a screen by typing in the command line

```
DISPLAY=:0 scrot screenshot.png
```

The above command captures the currently displayed screen and places the PNG image in the /home/pi/ directory. To avoid having to type the DISPLAY=:0 portion of the command each time, it can be assigned persistently (until the next reboot) by using the following sequence:

```
export DISPLAY=:0
scrot screenshot1.png
scrot screenshot2.png
.....
```

When capturing a sequence of screens, be sure to use different filenames. The PNG image files may be copied or moved from the RPi to a Windows folder or desktop with WinSCP. The screen capture operation can be delayed and image directory can be assigned. To learn how to use these and other scrot features use online resources or view the scrot manual by typing

```
man scrot
```

The captured image's pixel dimensions are identical to the display (less any overscan specified in the RPi configuration file). I tried to use LWA TV on the 7 in touchscreen LCD endorsed by the Raspberry Pi project. It has 800 x 480 pixel resolution. As expected, the Image Description text in the right frame is too small to be readable. After several hours of experimentation I was unable to find any video settings that properly center the display. Screenshots also are off-center (figure 14). This apparently is due to a problem in the RPi display driver or display adapter board because a different 7 in LCD with 1024 x 600 resolution (no touchscreen) worked fine (figure 15).

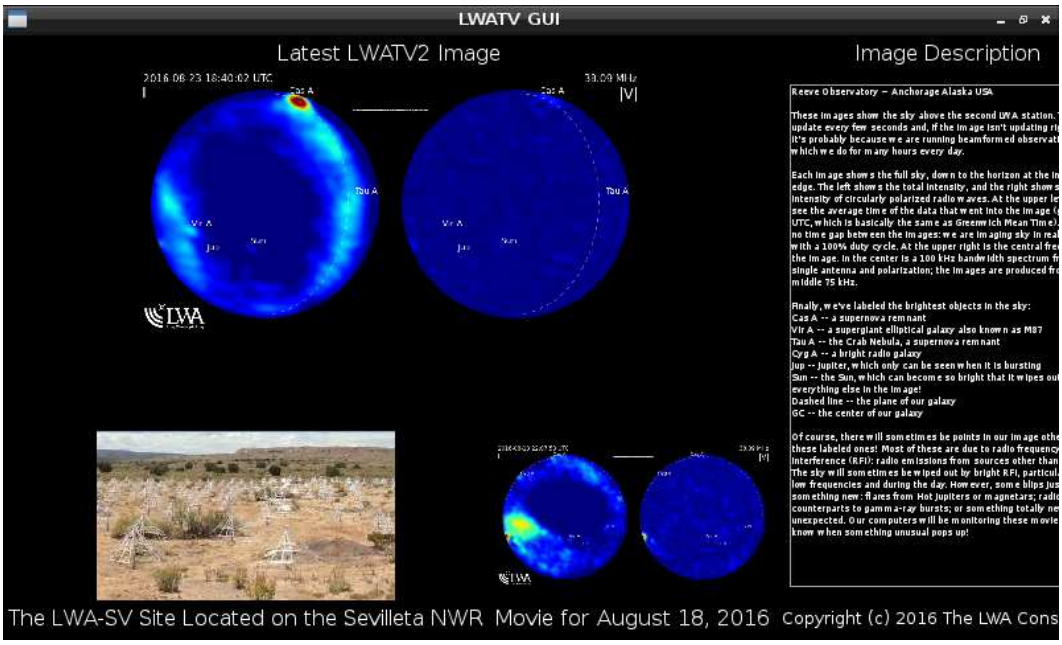


Figure 14 ~ Screenshot image with the RPi connected to a small 800 x 480 pixel touchscreen LCD monitor using the RPi's Display Serial Interface (DSI). The touchscreen function is not used. The actual image size is 784 x 472 pixels. Note that some text is oversized and that the display is not properly centered (it runs off to the right). I was unable to correct this in the RPi configuration file.

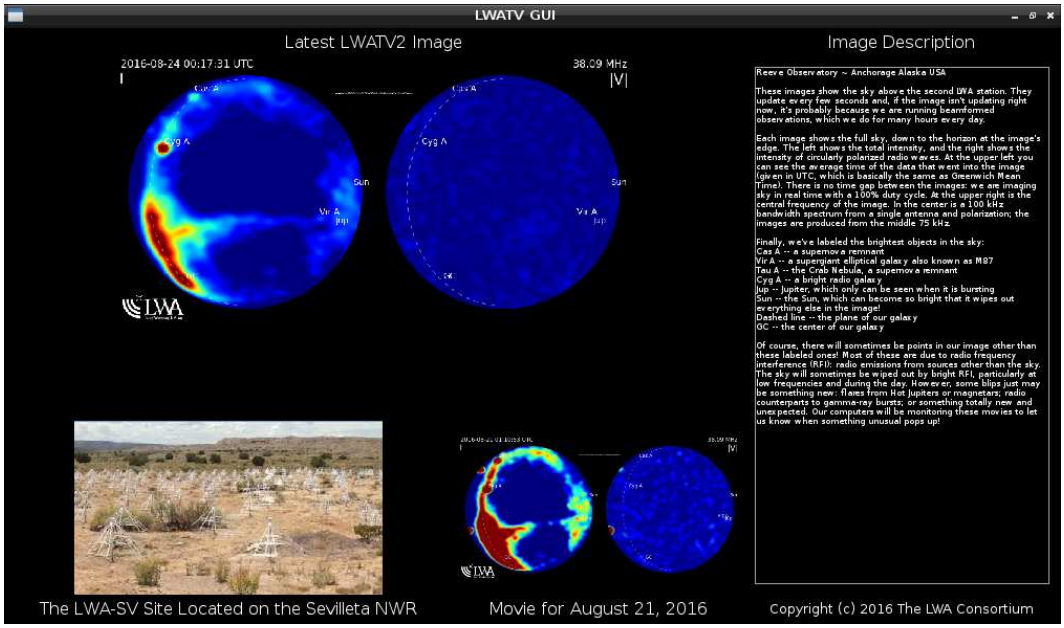


Figure 15 ~ Screenshot image with the RPi HDMI output connected to a Tontec 7 in 1024 x 600 pixel TFT-LCD monitor. The RPi is very easy to configure for this display. The actual image size is 1008 x 592 pixels. Compare the text to the previous screenshot.

Static IP and WiFi: To setup a static IP address, see: {RPiWLAN) and {RPiStatic}. The RPi 3 model B has a built-in WiFi transceiver and antenna. However, if the RPi 3 is installed in a metal enclosure, it probably will not work or will have very limited range. In this case, an external WiFi dongle will be needed.

The RPi works fine with both the Ethernet and WiFi connections enabled and it is not necessary to unplug one when using the other. You will need a WiFi dongle (figure 16). I purchased one from {Adafruit}. It should be remembered that a wireless dongle derives power from the RPi USB port and this power is in addition to that required by the RPi itself. The dongle should be plugged into the USB port before power is applied to the RPi; otherwise, the RPi may reboot because of the momentary voltage drop on its power bus. This is a design deficiency in the early RPi.

Figure 16 ~.WiFi dongle provides wireless access and uses one USB port. I found the distance from the RPI to the wireless access point to be surprisingly good (> 3 m) in spite of its very small antenna. (Image source unknown)

The following commands can be used to check the quality of the wireless connection after it has been setup:

```
sudo iwlist wlan0 scan
```

or

```
sudo iwconfig
```

Downtime: Sometimes the LWA TV does not seem to be working or the display does not properly render the archive movies or live presentation. You may see “Error Downloading Image” and “Network Connection Error” on the display for brief periods. This does not appear to be a fault with the RPi but possibly with the network connection or the UNM server and related maintenance activities. It also may occur during the transition from normal view to beam pointing view at LWA1. The outages do not last long, maybe tens of minutes at most, and always self-corrected (in other words, I just let the RPi run and never rebooted it). If you suspect your WiFi connection, confirm connectivity as described in the previous item.

Backup: You will want to backup your memory card before and after any major changes. You will need this backup if you corrupt the program so badly that it will not boot. There are several ways to run a backup. If you are a Windows user, you can use Win32DiskImager, the same program used to *Write* the image to the memory card in the first place. However, to backup, you will *Read* the image. Another good program for reading and writing the memory card is HDD Raw Copy tool {HDDRaw}.

This method requires removing the SD card from the RPi and then inserting it in a card reader connected to the Windows PC. Be sure to shutdown the RPi before removing the memory card (see next item). For more detailed procedures, see {RPiBackup}.

Shutdown the RPi: To avoid corrupting the RPi software, the system must be properly shutdown before removing power (just like a Windows PC). This may be done from a keyboard connected to the RPi by pressing CTRL-ALT-F1 to invoke the console directly on the display, or by using an SSH client on a PC. Log into RPi at the prompts and then enter;

```
sudo shutdown –h now
```

or

```
sudo halt
```

The display will indicate the shutdown process. All LED indicators except the red power LED on the RPi board will extinguish when the shutdown is complete. Power may then be removed. If you are at the console and change your mind before entering the shutdown commands, press CTRL-ALT-F7 to return to LWA TV.

6. References and Web Links

{7-Zip}	http://www.7-zip.org/
{Adafruit}	http://www.adafruit.com/
{HDDRaw}	http://hddguru.com/software/HDD-Raw-Copy-Tool/
{LWA}	http://www.phys.unm.edu/~lwa/index.html
{LWA TV}	http://www.phys.unm.edu/~lwa/lwatv.html
{LWA EPO}	http://fornax.phys.unm.edu/lwa/trac/wiki/EPO
{LWASoft}	http://fornax.phys.unm.edu/lwa/trac/downloads/
{Notepad++}	http://notepad-plus-plus.org/
{PuTTY}	http://www.putty.org/
{RPi}	http://www.raspberrypi.org/
{RPIBackup}	http://www.reeve.com/Documents/Articles%20Papers/Reeve_RPi_BackupRestore.pdf
{RPiDoc}	http://www.raspberrypi.org/documentation/
{RPiHub}	http://elinux.org/RPi_Hub
{RPiStatic}	http://www.reeve.com/Documents/Articles%20Papers/Reeve_RPi_StaticIP.pdf
{RPiSetup}	http://www.reeve.com/Documents/Articles%20Papers/Reeve_RPi_BasicSetup.pdf
{RPiWLAN)	http://www.reeve.com/Documents/Articles%20Papers/Reeve_RPi_WLANSetup.pdf
{SDFmt}	https://www.sdcard.org/downloads/formatter_4/
{TeraTerm}	http://ttssh2.sourceforge.jp/index.html.en
{WDImg}	http://sourceforge.net/projects/win32diskimager/

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Jayce Dowell at UNM helped me immensely with this project, and I hereby extend my thanks and appreciation.

Contact Information for Preprogrammed Memory Card

A preprogrammed micro-SD memory card may be ordered by emailing: OrderInfo@reeve.com
The micro-SD card includes an SD carrier and will work in the Raspberry Pi model B or B+, model 2 and model 3. The cost is 15 USD including postage to any US destination. The postage to countries other than the US will be quoted separately.

Document information

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1.2 (Added Appx A and B, 05 Feb 2015)
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