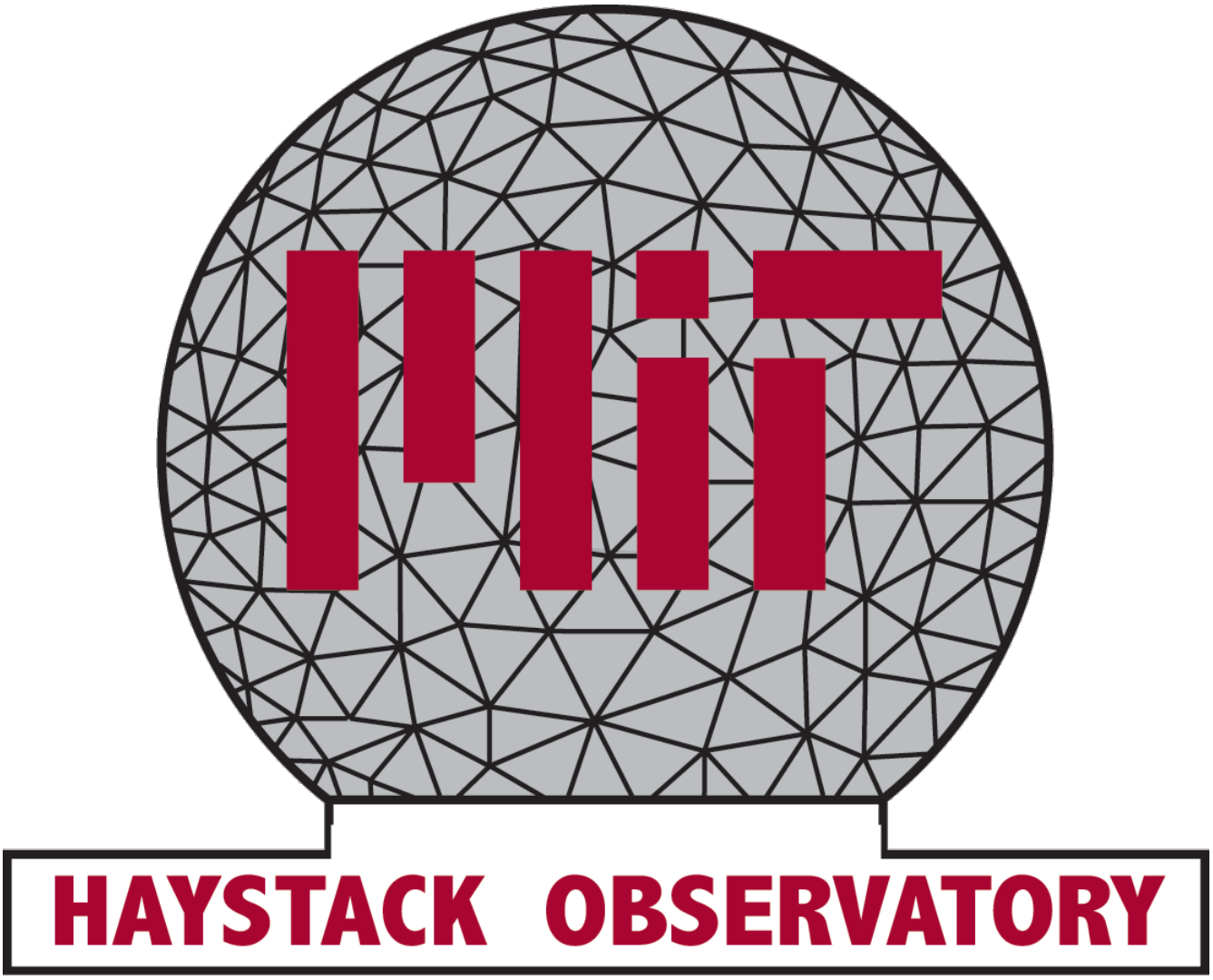
A New Software User Interface for the Upgraded Haystack 37-meter Radio Telescope



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Abstract

Recently the 37m Haystack antenna has undergone major hardware upgrades that have significantly enhanced its capabilities for radio astronomy observations. A new software user interface was developed to accommodate the new antenna and radiometer capabilities. The UI was designed for both real-time data acquisition and post-processing data pipelines. The software includes three applications that facilitate astronomical observation. The main application is a sky map of radio sources that displays important antenna status information. There is also a discrete source scan (DSS) plotting application, and an application to provide an astronomer with an idea of what is currently up in the sky. This report is intended to provide the user with a means to use this interface effectively when operating and collecting data from the 37m telescope.

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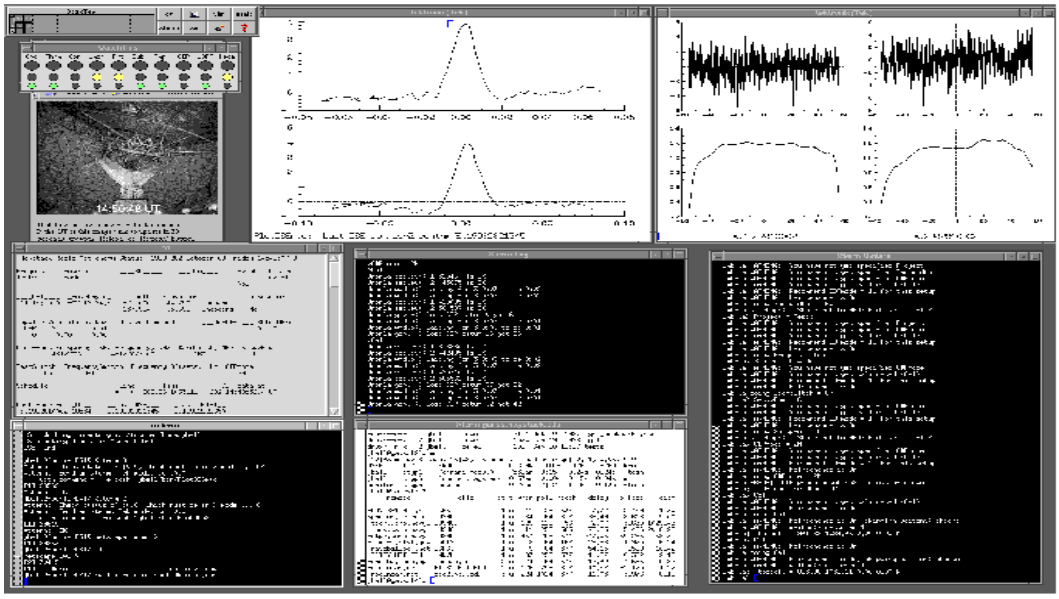
1. Introduction

1.1 Previous User Interface



(Figure-1, Previous UI)

Figure-1 is a screenshot of the previous user interface that was used to monitor and control Haystack's 37m radio telescope. The interface was very reliant on text to convey information to the user. For this reason, the user had to be very familiar with the system in order to use the interface effectively. The new interface is well organized and has a better aesthetic. It also has several visual aids to convey information quickly and hopefully reduce the learning curve associated with using new software.

1.2 Getting Started

The new 37m telescope UI is a Python-based program that was designed to be used on Linux systems. It was developed with Python v. 2.7.10 in the Spyder Interactive Development Environment provided by Anaconda 2.2.0 (64-bit) on an Ubuntu 14.04 LTS system.

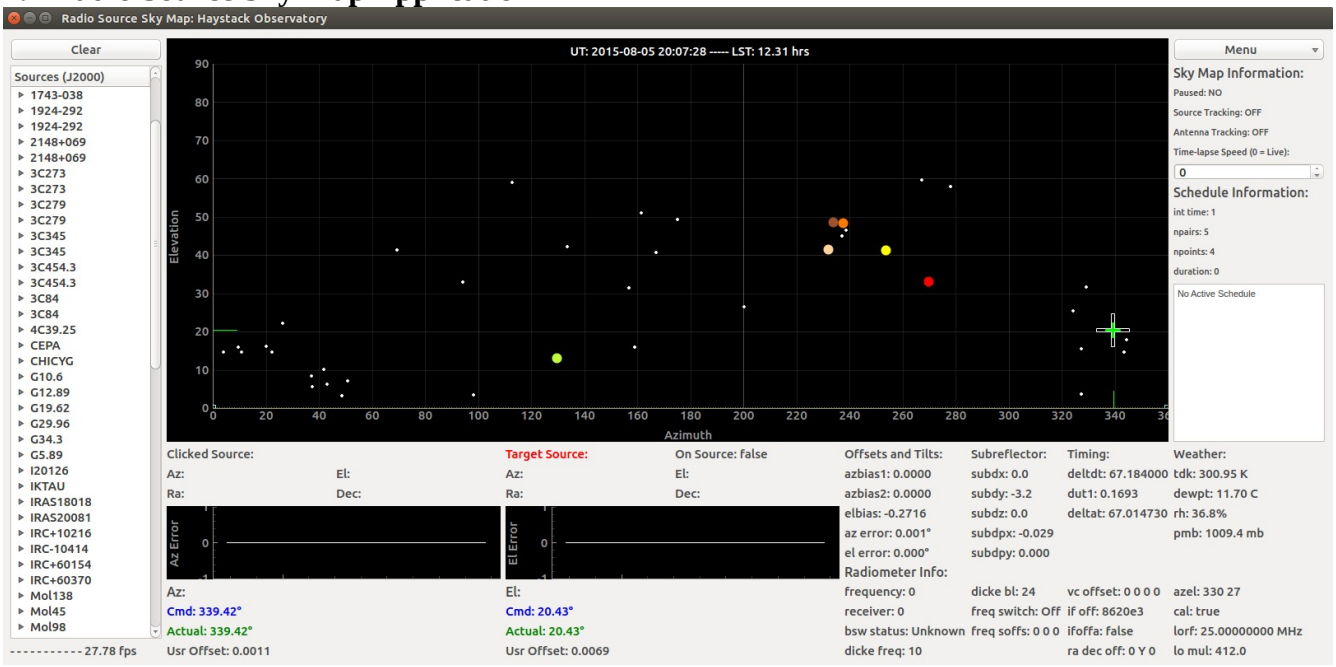
The python software consists of 6 .py files.

sourcemap.py	DSSqt.py	UpNow.py
GUI_Form.py	DSS_Form.py	
tail.py		

It is important to also install PyQtGraph as well as PyNOVAS on the machine running the UI software. PyQtGraph is a scientific graphics and GUI library for Python. It provides plotting utilities that are optimized for speed and necessary for the main application in this UI. PyNOVAS offers a collection of functions and applications for calculating the positions of the solar system bodies and other celestial objects. This package should be installed along with the DE405 ephermeris data set provided by JPL.

2. Software

2.1 Radio Source Sky Map Application



(Figure-2, Radio Source Sky Map)

The main component of the UI to the 37m radio telescope is a Python generated interactive window. The window consists of a radio source sky map, a sky map menu/information bar, a source list side bar, a source/pointing information section, an antenna information section, a schedule information side bar,, and a frame rate display. This section will describe each of these components in detail in order to allow the user to use them effectively.

2.1.1 Radio Source Sky Map

When the application is first launched, the user is prompted for a source list (must be a .lst file). The sources in the list must have the following format and be of the epoch J2000:

RTVIR 13 02 37.98 +05 11 08.38 2000 15.0

The first item is the name of the source, the next three items are the source's right ascension (hours, minutes, seconds), the following three items are the source's elevation (degrees, minutes, seconds), and the last two items are the epoch and line velocity respectively. Any information in the source list that is not in this format will be treated as other information and ignored.

The equatorial coordinates for each source are converted into horizontal coordinates for the current time and plotted on the sky map (white points). This map covers the entire sky in azimuth and elevation. The universal time and corresponding local sidereal time are displayed at the top of the map. The user may also use the mouse scroll wheel to zoom in and out in order to see the full range of elevation (-90 to +90 degrees). The yellow dashed line represents the horizon. The larger colored points displayed on the map are the solar system bodies' (sun, moon, planets) positions. The user can click on

any source and the source will be labeled and highlighted yellow with a white outline (solar system bodies are only labeled and retain their color). The current target source specified by the observer is highlighted red with a white outline.

The green cross-hairs represent the antenna's current pointing position on the sky and the white cross-hairs represent the antenna's commanded sky position. Both of these are accompanied by tick marks on the azimuth and elevation axes with the same respective colors. The green azimuth tick mark will turn yellow when the antenna leaves the main zone and enters a wrap zone (it will be labeled “CW” for clockwise or “CCW” for counterclockwise). If the antenna enters a wrap zone, the map will also display a red tick mark at the limiting azimuth position of the antenna. This alerts the user that soon he or she will not be able to keep moving the antenna in that direction.

2.1.2 Sky Map Menu / Information Side Bar

The menu at the top right of the application contains several functions that are useful when manipulating the sky map. When the user clicks on the menu button the following functions are displayed:

Change Source List – Clicking this option will prompt the user to choose a .lst file and restart the application using that file as the source list.

Paused / Unpause – Clicking this option will pause the sky map on the currently displayed time. Antenna position and status are still displayed in live time. Clicking the option again will unpause the sky map and return to plotting according to the current time-lapse settings.

Reset Axes – Clicking this option will return the axis ranges to their original states (0 to 360 degrees in azimuth, 0 to 90 degrees in elevation). This is useful after zooming in or out.

Toggle Ra-Dec Grid – Clicking this option will overlay a grid showing equatorial coordinates mapped on to the sky. The grid has 12 gray contours of constant right ascension (labeled from 0 to 22 hours), and 12 orange contours of constant declination (labeled from -90 to 75 degrees). The grid is intended to give the user a quick idea of how equatorial coordinates map on to the sky at the time displayed by the sky map. Clicking the option again will return the sky map to its original state.

Toggle Ephem – Clicking this option will remove the solar system bodies from the sky map and only plot the positions of the sources specified in the source list. If the current target source is a solar system body, this option will do nothing, to ensure that the target source is displayed. Clicking this option again will return the solar system bodies to the map.

Toggle Strip Charts – Clicking this option will begin plotting the antenna azimuth and elevation offsets on the strip charts in real time. Clicking this option again will clear the plots leaving them blank.

Toggle Click Track – Clicking this option will begin displaying the clicked source's trajectory as a yellow line as the source moves on the sky map. Clicking the option again will stop plotting the trajectory and leave the previous track displayed on the sky map. This function is useful in combination with increasing the time-lapse speed in order to follow a clicked source over longer periods of time.

Toggle Antenna Track - Clicking this option will begin displaying the antenna pointing trajectory as a green line. Clicking the option again will stop plotting the trajectory and leave the previous track

displayed on the sky map.

Clear Paths – Clicking this option will remove any yellow or green lines drawn on the map from when the “Toggle Click Track” or “Toggle Antenna Track” options were chosen.

Enter New UT – Clicking this option will open user input windows for entry of a desired UT (year, month, day, hour, minute, sec). After the user specifies these fields, the sky map will display all source positions for this UT. The state of the map becomes paused after changing the UT this way. Time-lapse and other map functions will work in the same way as before, and antenna position and status are still displayed in live time. Keep in mind that unpausing the map will begin changing time according to the time-lapse spin-box. This means that if the value in the spin-box is set to 0, the map will revert to current real time.

Add Object – Clicking this option will open user input windows for entry of a desired celestial object to be displayed. The information needed is name, right ascension (J2000 and in the form: RAhh RAmm RAss) , and declination (J2000 and in the form: DECdd DECmm DECss). The object will be highlighted green with a white outline and displayed at its current sky position and labeled.

Remove Objects – Clicking this option will remove all celestial objects from the sky map that were added via the “Add Object” option.

The sky map information sidebar contains valuable information regarding the current state of the map. The information is described below:

Paused: YES/NO – Displays whether or not the map is paused at the displayed UT. The text becomes red if the map is paused in order to alert the user. The default state is “NO”

Source Tracking: ON/OFF – Displays whether or not the clicked source trajectory is currently being tracked and plotted as a yellow line. The text becomes red if the map is tracking to alert the user. The default state is “OFF”.

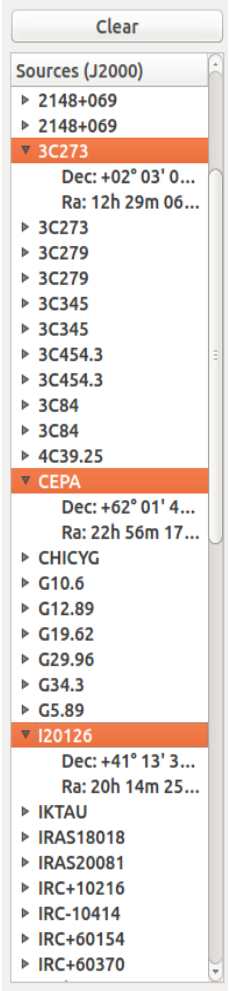
Antenna Tracking: ON/OFF – Displays whether or not the antenna pointing trajectory is currently being tracked and plotted as a green line. The text becomes red if the map is tracking to alert the user. The default state is “OFF”.

Time-lapse speed – When the value in the spin box is set to 0 and the map is not paused, the sky map is displaying the sources in live time. The value in the spin-box is a multiplier that determines how much time elapses between each successive frame (10s*multiplier). This can propagate the map forward and backward in time; however, antenna position and status are still displayed in live time. When live time is desired, simply change the value back to 0 and press enter.

2.1.2 Source List Side Bar

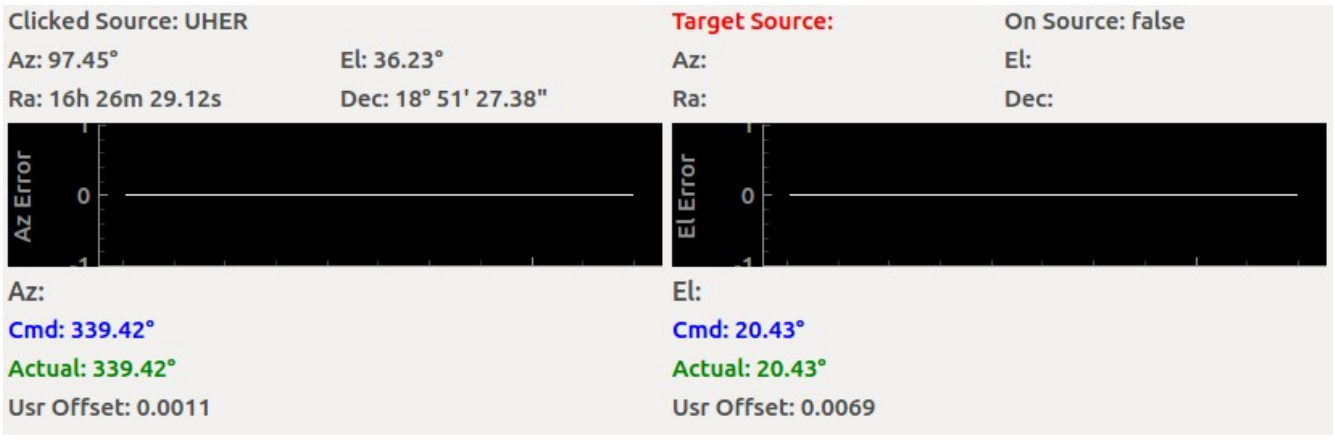
The left side of the sky map application is a sidebar that lists all of the specified sources in the selected source list. Clicking on the arrow next to a source name will display that source's equatorial coordinates (J2000) below its name. This can be done for multiple sources. The user can also click on any source name (highlighting the name in orange as in Figure-3) and the source will be highlighted blue with a white outline on the sky map. This can also be done for multiple sources. This is useful when the user has specific sources in mind, and wants to see where they are in the sky in real time or at a specific time.

Clear – Clicking this button will deselect any sources that are currently selected in the source list side bar.



(Figure-3, Source List Side Bar)

2.1.3 Source / Pointing Information section



(Figure-4, Source / Pointing Info)

On the bottom left side of the sky map application is a section that provides information regarding specific sources and antenna pointing status. This section contains the coordinates of both the clicked and target sources as shown at the top of Figure-4 (The target source is specified by the current schedule).

In the middle of Figure-4 are two strip charts for plotting the difference between the actual and commanded antenna positions. These plots can be activated and deactivated by clicking the “Toggle Strip Charts” option as described in section 2.1.1. When activated, the plots show the real time errors that are also displayed in text in the antenna information section. The plots show a history of the errors so that user can get a good idea of how the antenna is behaving.

Pertinent antenna pointing and status information is displayed below the strip charts. This data is currently read from an updating file and represents the real time state of the 37m antenna.

2.1.4 Antenna Information Section

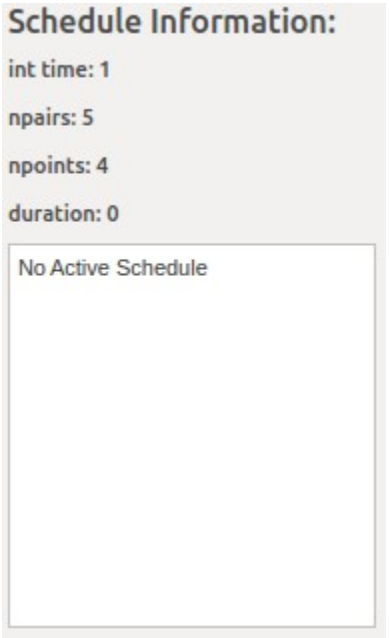
Offsets and Tilts:	Subreflector:	Timing:	Weather:
azbias1: 0.0000	subdx: 0.0	deltdt: 67.184000	tdk: 300.95 K
azbias2: 0.0000	subdy: -3.2	dut1: 0.1693	dewpt: 11.70 C
elbias: -0.2716	subdz: 0.0	deltat: 67.014730	rh: 36.8%
az error: 0.001°	subdpx: -0.029		pmb: 1009.4 mb
el error: 0.000°	subdpy: 0.000		
Radiometer Info:			
frequency: 0	dicke bl: 24	vc offset: 0 0 0 0	azel: 330 27
receiver: 0	freq switch: Off	if off: 8620e3	cal: true
bsw status: Unknown	freq soffs: 0 0 0	ifoffa: false	lorf: 25.00000000 MHz
dicke freq: 10		ra dec off: 0 Y 0	lo mul: 412.0

(Figure-5, Antenna Info)

On the bottom right side of the sky map application is a section that provides vital antenna information. These values are updated in real time from an updating status file. The five subsections are: offsets and tilts, subreflector, timing, weather, and radiometer info as shown in Figure-5.

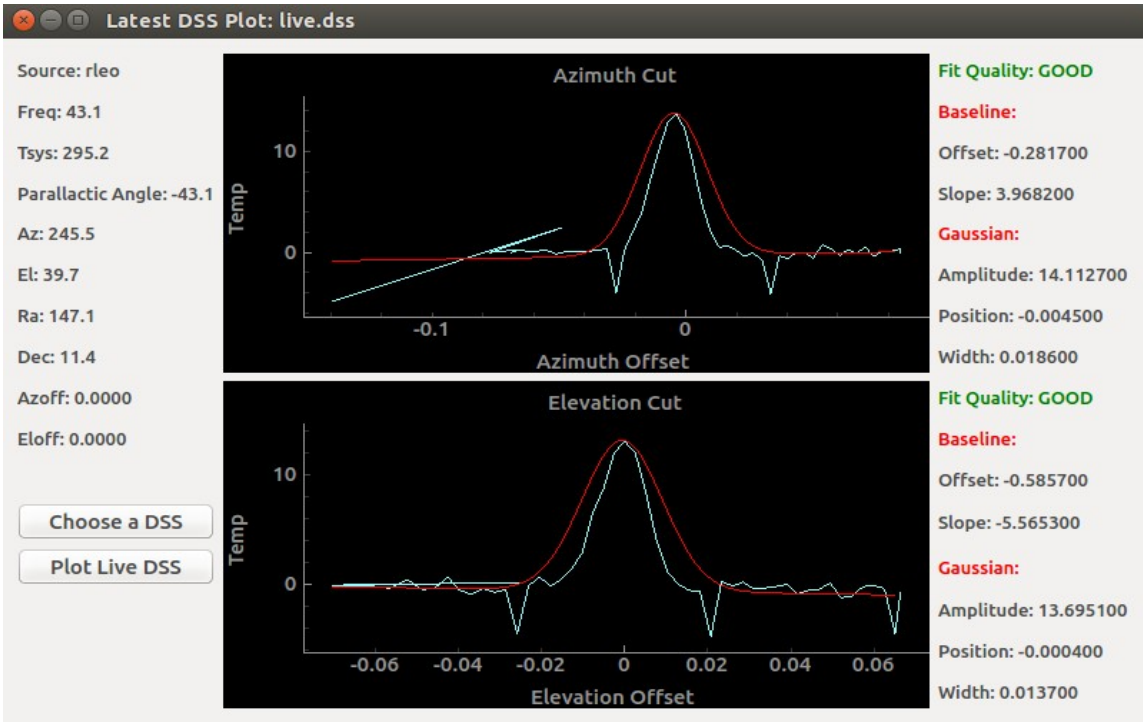
2.1.5 Schedule Information Side Bar

Below the sky map menu / information side bar on the right side of the application is a display of the current active Umbrella schedule along with other important schedule information. The path to this .skd file is specified from an updating file along with the antenna status information. This schedule tells the telescope when and how to perform various operations. The current operation being performed is highlighted red. If no schedule file is specified, the display will show “No Active Schedule”. (Note: This functionality is not fully implemented yet so the active schedule may not actually be displayed.)



(Figure-6, Schedule Info)

2.2 Discrete Source Scan Application



(Figure-7, DSS Application)

Another component of the UI to the 37m radio telescope is a Python generated window to display the results of discrete source scans (DSS). This application replaces the the plot window in the top-middle of the previous UI (Figure-1), and displays important information that was previously only provided in text. The new application consists of a source information side bar , two main DSS plots, and a fit information side bar.

Discrete source scans can be commanded in Umbrella and are useful for determining pointing offsets of the telescope before observing. In a DSS the antenna is first moved in a roughly 0.2 degree azimuth scan centered on the selected source. As the telescope scans across the source, the radiometer records the increase in temperature as the source passes through the telescope beam. When the scan is complete, Umbrella reports parameters that specify a Gaussian fit to the scan. This process is then repeated for a scan in elevation.

When launched, this application automatically plots the latest DSS. If the latest DSS is incomplete, then the application obtains the available information and plots the scan in real time. When the DSS completes, the Gaussian fit is plotted and the fit parameters are displayed.

2.2.1 DSS Plots

In the center of the application are two plots as shown in Figure-7. The top and bottom plots are the azimuth and elevation cuts respectively. The light blue curves represent the actual measured source temperature, and the red curves represent the Gaussian fits. If the plots are live, only the available temperature curves are shown, and the Gaussian fits are displayed when the scan is complete.

2.2.2 Source Information Side Bar

On the left side of the application there is a display of the important information regarding the target source and antenna status.

Source – The name of the target source

Freq – The current observing frequency in GHz

Parallactic Angle – The angle between the great circle through the source and the zenith, and the hour circle of the object.

Az – The azimuth of the target source in degrees

El – The elevation of the target source in degrees

Ra – The right ascension of the target source in degrees

Dec – The elevation of the target source in degrees

Azoff – The user commanded azimuth offset

Eloff – The user commanded elevation offset

(Figure-8, Source Information Side Bar)

This side bar also includes two buttons to control the DSS display:

Choose a DSS – Clicking this button will prompt the user to choose a completed DSS file. Once the user chooses a file, it is plotted and the source and fit information are displayed. Choosing an invalid file will clear the current contents of both plots, and change the title of the plot to alert the user to make a different selection.

Plot Live DSS – Clicking this button will cause the program to obtain the most recent DSS file and plot its contents whether it is complete or incomplete. This button can be essentially used as a refresh button. Once the current scan is completed, the application leaves its contents displayed until this button is pressed. Then it looks for a newer file to plot.

2.2.3 Fit Information Side Bar

On the right side of the application there is a display of the important parameters of the Gaussian fits for each scan. These parameters are only displayed for completed scans.

Fit Quality – Quality of the Gaussian fit. Can be “GOOD”, “SO-SO”, or “REJECT”

Baseline – The baseline that was added to the Gaussian fit

Offset – The vertical offset of the baseline

Slope – The slope of the baseline

Gaussian – The Gaussian fit (form: $y = a * \exp(-(x - p)^2 / w^2)$)

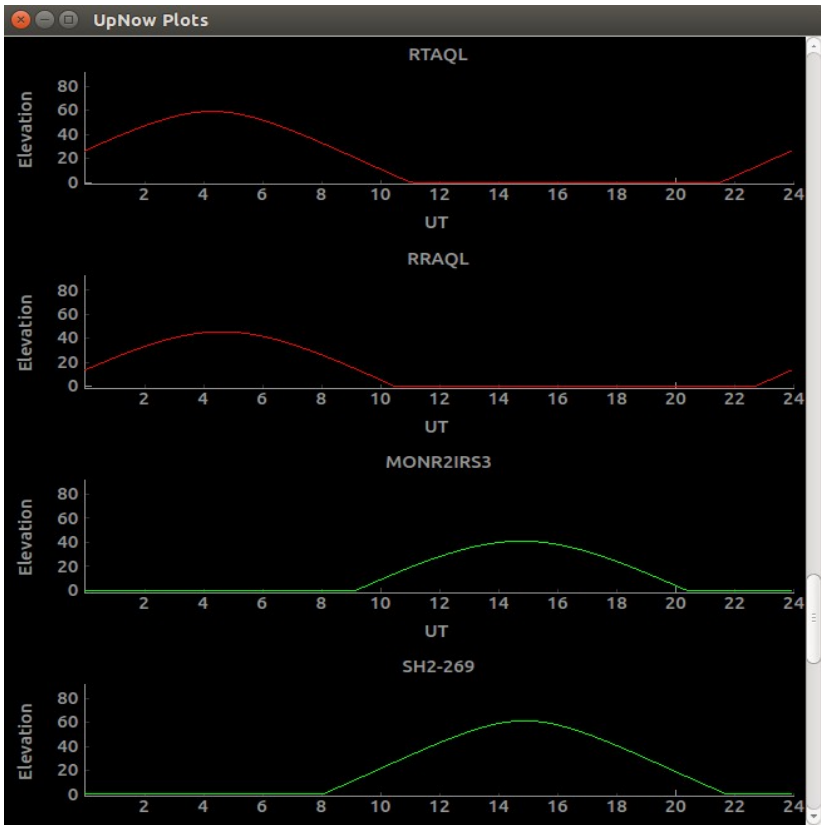
Amplitude – The amplitude of the fit (a)

Position – The position of the fit (p)

Width – The width of the fit (w)

(Figure-9, Fit Information Side Bar)

2.3 UpNow Application



(Figure-10, UpNow Application)

A small and useful component of the new UI to the 37m radio telescope is called the UpNow application. When the program is launched, it prompts the user for a source list (.lst) just like the sky map application. This application then generates a plot for every source in the list and formats each of them into a scrollable window. The plot represents the trajectory of the source in the sky over the course of the current day. When a source is below the horizon, the elevation is set to 0 so that the user can clearly see when the source will be up in the sky (the curved part of the trajectory). Sources that are currently up in the sky at the time of launching the application are indicated with green curves as shown in Figure-10. Sources below the horizon are indicated with red curves.

3. Conclusions and Future

The new user interface for the 37m radio telescope improves upon the previous interface and facilitates astronomical observation for both astronomers and engineers. The applications developed are user-friendly and provide several visual aids to help the user operate the antenna. The underlying python code is easy to modify and can be made to support better functionality in the future. For example, instead of processing a file, the code could be modified to process messages with antenna status information. It would also be useful to integrate Umbrella commands into the display and possibly allow the user to command a source simply by clicking on it. This new interface takes a step towards new functionalities like this, and allows the user to operate the telescope more efficiently.

4. Acknowledgments

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