WIRC-Pol
Software Manual

Version 3.2
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Executive Summary

This document describes the WIRC-Pol Version 3.100 software. The software described in this manual is written in Java and is the primary user interface for the WIRC-Pol instrument. The software is accessed from the command line on the newton.palomar.caltech.edu computer. Starting the software is done by opening a terminal window on the newton computer and typing "wircpol3."

The software is dependent upon the ArcVIEW server that controls the WIRC camera. The ArcVIEW server is written in LabVIEW and is responsible for controlling the HgCdTe detector and writing FITS images. The ArcVIEW server may be run on any of the instrument computers (4-8) but requires the fiber and RS-232 connector to be switched to the correct computer.

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0.11 Getting started

Open a terminal window and type "wircpol3." The system is ready when the green "SYSTEM GOOD" icon displays on the "Main Controls" tab.

0.12 Infrared Exposure Parameters

The exposure controls are on the left side of the main instrument panel:

Exposure time (seconds)	Minimum exposure time is 0.92 seconds.
Number of Images (integer)	You will not see the images update until all are complete.
Coadds (integer)	default = 1
Fowler Samples (integer)	default = 1
SUR (Sampling-Up-the-Ramp)	Only used if the sampling mode is SUR.
Sampling Mode	Default is Fowler-N, where N is the number of samples.

Note: If you make a change while an exposure is running, the changes won't be applied until the next exposure is started.

Data can be retrieved from the following folder (UT date):
/remote/instrument6/WIRC/yyyymmdd

0.13 Setting the filters

The filter wheel controls are on the main panel. There are two filter wheels: FORE and AFT. Select the desired filter in the FORE combo-box then press the associated MOVE button. Wait until the move is complete (icon changes back to green from red) and the desired filter is displayed in green in the FORE text box. Follow the same steps for the AFT filter.

Notes:
The OPEN filter position is installed in the FORE filter wheel and most of the broadband filters (J, H, K, etc.) are installed in the AFT wheel.
When you have completed your observing run, it is good practice to set the FORE filter to BrGamma and the AFT wheel to J. This combination of filters blocks light from hitting the detector.

0.14 FITS headers

You can set the Object, Observer, and Object Type in the "COMMENT PARAMETERS" section of the Main Panel. You may also add a Comment to the header in the text field to the left of the image number, but you must add the comment before the image acquisition is started.

In order to show the FITS header of the currently displayed image, open the Image Display (Tools > Image Display Control) and select Image Display Controls > Image FITS Header.

0.15 Calibrations

Typically you will need bias, dark, and flat field images.

Biases can be taken after the dome is dark in the afternoon (typically 3:30 PM), and are taken with the minimum exposure time with the BrGamma and J filters. Observers tend to take 20 – 100 images.

Take dark frames using the same exposure times you intend to use (or did use) while on-sky to measure and account for dark current.

Flat field images are used to correct for non-uniform illumination, imperfections, or blemishes in the filter and/or optics. Flat field images must be taken using the specific filter combination that you used during observing (e.g., OPEN and J). You want approximately 30,000 ADU (60% of the full well capacity of the detector, which is around 50,000 ADU). Flats can be taken with the telescope pointed at zenith with the dome closed using lamps (low and high available). Some observers find that twilight flats can improve the flat field correction, but they can be a little hard to acquire as the sky is constantly changing. After selecting the filter and exposure time, you can manually take many of your calibration images by simply pressing the GO button or putting it into continuous mode operation with the CONTINUOUS button.

You can also write a script to run the calibration frames for you. Ask the support astronomers to point you to example scripts that you can modify.

0.16 Focusing

There are two ways you can obtain best focus. The first is to use the Tools > Image Display Control > Autofocus Control dialog to acquire a set of images starting at a specific focus value and incremented by an offset to produce a set of images at different focus values. The autofocus control is embedded into the image display and works using the guide box cursor. To focus the system, follow these steps:

(1) Take an image with reference subtraction on so you can see the stars in the image. (See section 0.17 below.)
(2) Select a star in the image that is not saturated and has sufficient signal. Right-mouse click on the image and select Guide Box cursor from the menu. Then left-mouse click on the star to place the guide box about the star.

(3) Open the Cross-section graph (Auto Guiding > Cross-Section Graph) and examine the cross-section. If the star is out of focus, the center of the profile will be depressed since you are looking at a donut.
(4) Set the following parameters: starting focus, focus increment, and number of steps.
(5) Press the Perform Autofocus button.
(6) The system will now move the focus to the starting focus and take an image. The FWHM in RA and Dec will be calculated for the star inside the guide box and plotted on the graph.
(7) For each of the specified focus steps, the system will change the focus, take an image, and then plot the FWHM until all images have been taken.
(8) The code fits a parabola to the focus vs. FWHM graph in both RA and Dec, calculating the point of inflection for each graph and determines the focus value halfway between the two inflection points. ***<u>Note</u>***: If the current focus is too far off the best focus, the system doesn't have the data required to fit a parabola and the resulting answer is nonsensical.

The second method is helpful for tuning up the focus during the night. Go to the Auto-Guiding panel and open the PSF graph. Follow these steps:
(1) Put the system in Continuous mode.
(2) Place a guide box cursor on the star you wish to use.
(3) Open the PSF graph and clear it.
(4) Go to the Main Panel > Telescope subpanel. If the system is connected to the TCS, there should be two green arrows pointing in opposite directions in the middle of the panel. Set the focus increment (between the arrow icons) to some value (e.g., 0.1 or 0.2 mm) and then press the left or right arrow.
(5) Each press of an arrow icon will move the focus up (right arrow) or down (left arrow). Observe the PSF graph at different focus values until you've reached minimum FWHM.

<u>Notes</u>:
The FWHM as a function of focus value or FHWM as a function of time graphs can be quite noisy. As a result, you may want to increase your exposure time to average out some of the variation. Keep in mind that the sky level may be changing very quickly; you may want to wait a little after changing focus for several images to be taken so you can properly assess the effect.

Once you have obtained best focus, you can run the Estimate Seeing button on the Auto-guiding. This is a better measure of the FWHM since it fits a Gaussian to every star in the image and reports the median.

0.17 Subtracting a reference image

The SNAP control is a fast way to get an image with sky background subtraction. Located at the bottom of the main panel, it will move the telescope by dRA, dDec, take an image, and then move back to the original position, take an image, and subtract thesecond image from the first.

You can also set the reference image by pressing the Set Reference Image button and then click the grey OFF button next to "SUBTRACT REF IMAGE." (It will change to green ON.) If you wish to subtract an image that is not currently displayed, choose the Browse for Reference button. You can also choose to subtract the median from the image by selecting the Subtract Median radio button.

Note that it is also possible to flat field correct the images as well as subtract a reference. Go to the Tools > Image Display Control > Tools > Image Compensation. The Image Compensation control allows you to browse for a flat field and to divide the displayed image by the flat field. You first need to specify a flat field file which activates the Apply Flat Field correction button and then turn it on.

0.18 Moving a star from one place to another on the array

To use the "Target to Bullseye" function to move a star from position A to position B:

(1) Right-mouse click on the image to bring up the cursor menu.
(2) Select the Target cursor.
(3) Left-mouse click on the star at Position A.
(4) Now right-mouse click again and change to the Bullseye cursor.
(5) Left-mouse click to place the Bullseye cursor on Position B.
(6) Go to the Main Panel > Telescope Controls panel. You will see the calculated offsets between the Target position and the Bullseye position as dRA and dDec values at the top of the panel.
(7) If the dRA and dDec look reasonable, you can press the Target to Bullseye button and the telescope will move the star from Position A to Position B.

<u>Note</u>: If you forget to click on the target, the coordinates for the target position may be left over from the last field you observed. The result is often (but not always) extremely large calculated dRA and dDec. This is why it's a good idea to check dRA and dDec before pressing the Target to Bullseye button.

0.19 Writing scripts

The WIRC-Pol instrument supports a very simple scripting language. (See section 5.4.) The scripts are simple ASCII files that contain commands followed by parameters. The best place to start when writing scripts is opening and modifying existing scripts that do something similar. For example, you can automate your calibrations (except for sky flats).

Another example is automating multi-band imaging. For a science program requiring J, H, and K images of multiple targets, you can write a script that will select the J filter and take an image, select the H filter and take an image, and finally select the K filter and take an image. You can write a script that will run a 27-point dither pattern in three different filters.

0.20 Observing a planetary transit

Creating a photometry curve with high precision requires taking one image after another using the same exposure parameters. The WIRC-Pol software supports this kind of scenario with a simple Continuous button that sets the system to take one image after another with a minimum of overhead. You could observe a planetary transit by simply placing the star somewhere in the image and taking one image after another for the duration of the experiment. Unfortunately, without active correction, the star will drift on the order of 1 arcsecond every 15 minutes. Most of the drift is in RA dimension but some declination drift is also observable. Writing a photometry reduction pipeline with a target that moves in the image is much more complicated than writing one that works with guided data.

The best way to observe a transit with WIRC-Pol is to guide. Take the following steps:

(1) Take an image and identify the target.
(2) Place the target where you want it for the observations. (See "Target to bullseye.")
(3) Take a sky reference image at a different position and set up the system to automatically subtract the reference image.
(4) Once you have a reference subtracted image on screen, go to the auto-guiding tab. You can choose the number of guide stars that you want and click the "Locate Guide Stars" button.
(5) Examine the image display and locate the selected guide stars. You want your guide stars to have good signal but not be saturated. You can delete guide stars by selecting them in the table and pressing the minus button to the left of the table.
(6) Go to the main panel and select the Continuous button.
(7) Press the GO button.
(8) Go back to the auto-guiding panel and press the Guide Graph button. The graph that pops up is continuously updated each time an image is available. The graph displays the calculated offsets from the original location of the star. I usually let a few images go by and observe the offsets before starting to guide. You should see the offsets change for each image, on the order of 1 arcsecond or less.
(9) Go back to the main panel and press the Guide button. The Guide button controls whether the guide corrections are sent to the TCS (Telescope Control System). Corrections will not take effect unless the GUIDE button is activated.
(10) The system will continue taking images and keeping the target star at its original location until it's told to stop. To stop the observation sequence, turn off the Guide button and then the Continuous button. Wait for the current image to be completed.

0.21 Dithering

The WIRC Dither Control is accessible from the Main Panel > Tools menu. We'll consider two cases: (1) using a canned pattern and (2) importing your favorite dither pattern.

The WIRC-Pol software includes a standard set of about 50 dither patterns that are always available. Follow these steps to run a canned pattern:

(1) Open the WIRC Dither Control.

(2) Press the Get DSS Sky Image button. This automatically downloads an image from DSS from the Palomar Sky Survey that is centered at the current telescope coordinates and is 15"x 15" arcminutes wide. (You can change the size if you need to.) This is an optional step.
(3) Press the View Dither Pattern button. This will bring up a control with an image display tab and a graph tab. The image displayed in the control is the image you just downloaded from DSS. The dither pattern will appear as an overlay on top of the image.
(4) The default dither pattern is called DITHER_5_SIMPLE. It's a pattern with one image in the center and 4 images at the corners of a square. The pattern can be scaled to whatever size you wish by changing the scale factor, which will be reflected in the dither overlay on the image.
(5) Once you are happy with the pattern press the GO button on the Dither Control. The pattern can be stopped at any time by pressing the STOP button that is active while the dither pattern is running. If the system is acquiring an image when the STOP button is pressed, it will ask if you wish to wait for the image to be completed or aborted. If a telescope move is in progress when the STOP button is pressed, the system will wait until the move has completed before returning to the ready state.

Running a dither pattern based on your own pattern specification is identical to the steps taken above. The only difference is you need to import your pattern and name it so you can select it in the combo-box. To run a dither using your own pattern follow these steps:
(1) A dither pattern file is simply an ASCII file containing two columns of numbers separated by a delimiter. The numbers can be interpreted as XY coordinates or as relative offsets.
(2) Press the Open button and browse for the file containing your pattern. The text of the file will be displayed in the Manual Dither Editor (left side text control). Specify whether the pattern should be interpreted as absolute coordinates or relative offsets. You also need to specify the delimiter. The most common is the comma and a 10,10 will be interpreted as a 10 arcsecond offset/coordinate in RA and 10 arcsecond in Dec.
(3) Once you have the text of the file displayed and you know the delimiter you can press the "Parse" button (i.e., below dither table). The Parse button reads the text and turns it into a series of entries in the dither pattern table, one row per file row.
(4) Verify the resulting table of offsets or coordinates. You can edit and parse the text as needed.
(5) Give the pattern a name and then press the Add to Active List button.
(6) Press the GO button on the Dither Control. The pattern can be stopped at any time by pressing the STOP button that is active while the dither pattern is running. If the system is acquiring an image when the STOP button is pressed, it will ask if you wish to wait for the image to be completed or aborted. If a telescope move is in progress when the STOP button is pressed, the system will wait until the move has completed before returning to the ready state.

Dither patterns use all of the specified infrared exposure parameters. You also can acquire a dither pattern using any of the filters or any of the mechanism positions. (See polarization mechanisms.) You can create very complex patterns or even maps of the sky to accomplish surveys of selected areas.

Introduction

The following document describes the operation of the WIRC-Pol instrument using version 3_100_00 (i.e., version 3.1) of the software. This manual describes a major update to the WIRC-Pol control code. This version is currently deployed on newton.palomar.caltech.edu and is started by typing “wircpol3” into a terminal window. The main goal of this software build is to simplify and streamline the interface with particular attention to the guiding and dithering components. Dithering has often been prone to reliability issues that cropped up when you attempted to stop the execution of a dither. Particular attention has been paid to increasing reliability and making starting and stopping execution seamless.

The main new feature of this build is the creation of a system to easily configure guiding. The new system automatically identifies appropriate guide stars in the active image and configures the system to guide on the median offset calculated from a set of guide stars. The number of guide stars to use in the calculation is an adjustable parameter.

The release of version 3.1 will be a major milestone in the development and improvement of the WIRC-Pol instrument.

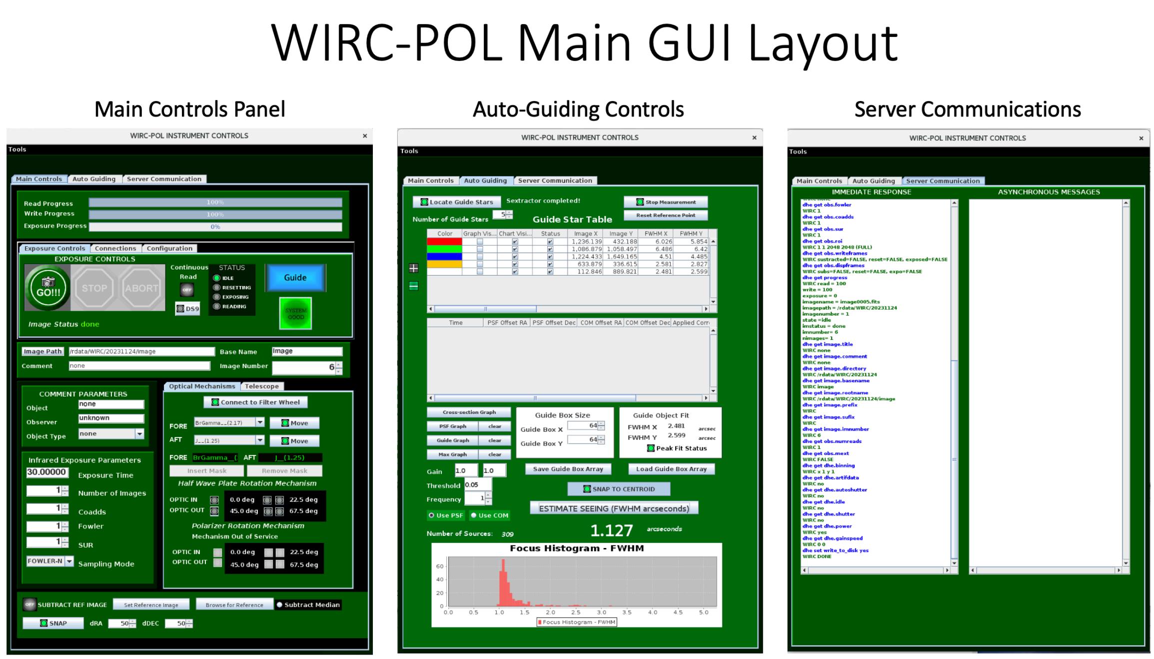


Figure 1 WIRC-POL Main GUI Layout

2.0 The Main Controls Panel

The main panel is the control that you will probably spend the most time working with. If you want to take an image, change exposure parameters, or move mechanisms, then you are working with the main panel. The main panel is divided into a set of subpanels, each dedicated to a different aspect of instrument control.

2.1 The Infrared Exposure Parameters Panel

The infrared exposure parameters panel is in the lower right corner of the main panel and contains the following controls: (1) exposure time, (2) number of images, (3) number of coadds, (4) number of Fowler samples, (5) number of Samples-Up-the-Ramp (SUR), and (6) the sampling mode. The controls in this panel determine how your image will be acquired. It is not necessary to hit a carriage return in the control to have the value take effect. The software waits until you press the GO button (to start an exposure) to read the parameter values and transmit them to the server.

There is a minimum exposure time of 0.92 seconds determined by the time it takes to read out the detector. The number of images to take is controlled by the "Number of Images" spinner. Be aware that when you use this control to take multiple images, you won't see each individual image as it's acquired but only the final image of the set. For this reason, I often use the "Continuous Read" button to assist with taking sets of images because it will display each individual image as it is acquired; however, you must keep track of how many images have been taken and turn off continuous read once you have the total number of images you wanted. The coadds spinner controls the number of images that are coadded in the electronics prior to writing the image to disk. The use of coadds is extremely important—particularly when imaging longer infrared wavelengths.

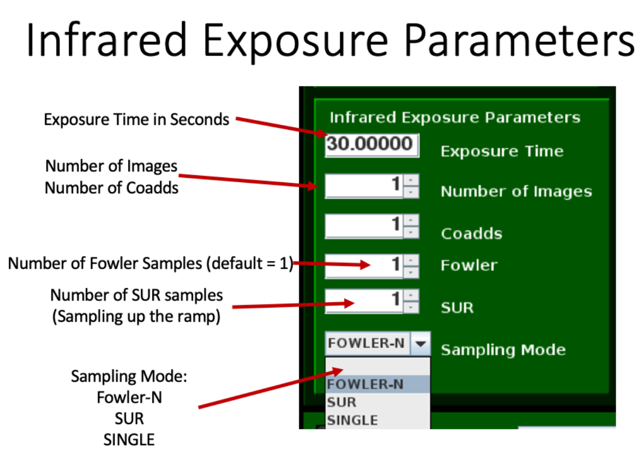


Figure 2 Infrared Exposure Parameter Controls

The Fowler sampling measures N non-destructive reads of the detector immediately after reset and another N reads at the end of the exposure and differences the values in the electronics to reduce read noise. Fowler samples greater than 1 are often used in infrared spectroscopy where reducing read noise is critical. With the WIRC instrument, however, it is rare to use multiple Fowler samples. (The TSPEC instrument uses a default of 4 Fowler samples since the instrument is a dedicated spectrograph.)

The SUR spinner controls the number of samples measured when the sampling mode is set to SUR (sample mode combo-box below the SUR spinner). The value of this control has no effect if the sampling mode is not SUR. For a more detailed discussion of SUR please see the IRS Instrument Handbook.

The sampling mode combo-box allows you to select from 3 different sampling modes: (1) Fowler (the default value and overwhelmingly used), (2) Sampling-Up-the-Ramp (SUR), and (3) Single Frame. When SUR mode is selected you need to select the number of samples you wish to acquire using the SUR spinner. For most imaging tasks, the default Fowler sampling mode is preferable.

2.2 Exposure Controls

The Exposure Controls panel is where you start or stop an exposure. When the system is started and connected to the WIRC server, the GO button is displayed as a large green button on the left side of the main panel slightly above the center line. The software is essentially a state machine that transitions from one state to another based on button presses. When you press the GO button, the software reads all of the control values in the GUI and updates the exposure parameters in the server and starts an exposure. While an exposure is in progress, you can either let the exposure complete or decide to STOP or ABORT the exposure. When you select STOP, the GUI waits for the current exposure to complete and write to disk before becoming ready again. If you select ABORT, on the other hand, an abort signal will be sent to the server and the system is immediately ready for the next exposure.

The Exposure Controls panel also contains some very useful additional controls. The Continuous Read button toggles the behavior when an exposure is complete. If the continuous read button is activated, the instrument will immediately begin a new exposure using the same exposure parameters when the current exposure is complete. The system MUST be in continuous read mode if you intend to guide on an object (e.g. during a planetary transit observation). When the continuous read button is turned off, the current exposure will complete and return to a ready state with the GO button visible. You can change the continuous read state at any point during an exposure or set of exposures. The DS9 button controls whether to send the image to a local instance of DS9 after it's written to disk. Viewing the image in DS9 can be useful because the image displayed in DS9 does not have any reference image subtraction or flat fielding applied to it; it is the raw image and should be inspected for saturation that may not be clear in a background subtracted image.

On the right side of the Exposure Control panel are status indicators that display what is going on in the server including: (1) idle, (2) resetting, (3) exposing, and (4) reading. These are status indicators only and not controls.

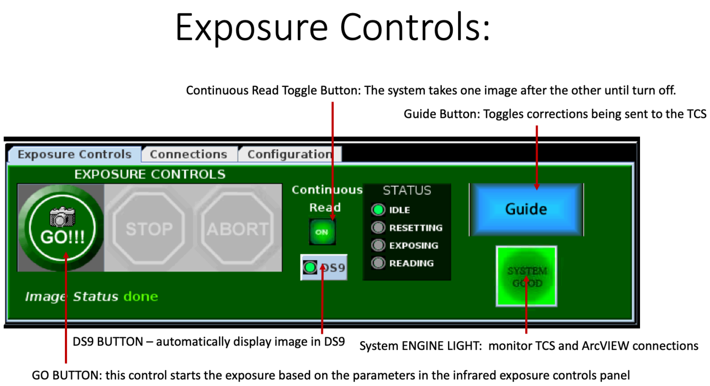


Figure 3 Exposure Controls

The final control in this panel is the Guide button. We will go into some detail on how to configure guiding later in this manual. The Guide button on the main panel controls whether the calculated guide corrections are actually sent to the telescope and that is all it does. You can configure guiding and be observing a continuous stream of images with the guide correction being calculated but the corrections are only sent to the telescope control system (TCS) when the Guide button is activated.

2.3 Connections

The WIRC-Pol software depends upon connections to the ArcVIEW server that communicates with the Hawaii II detector, and connections to the P200 telescope control system (TCS). These connections use a TCP/IP protocol and must be made successfully for the instrument to operate. The ArcVIEW server supports 3 different kinds of connections: (1) command (returns response immediately), (2) blocking (only returns when the command is complete), and (3) asynchronous messages. The command socket connection is the primary communication pathway and the asynchronous socket messages are monitored. Indicator lights for the connection status of each socket type are present on the connections panel. The Connect to Detector toggle button in the upper left corner of the panel controls whether the system is connected to the server. You can disconnect from the server by pressing this button and the indicator on the button will turn red. All of the socket indicator lights will also show disconnection. Pressing the button automatically connects all three sockets. The software automatically connects to the server when the software is started.

It's relatively rare that an observer needs to cycle the socket connections. However, if the server was restarted or closed after the GUI is started, you may need to assure that the connections are healthy.

Connections Panel

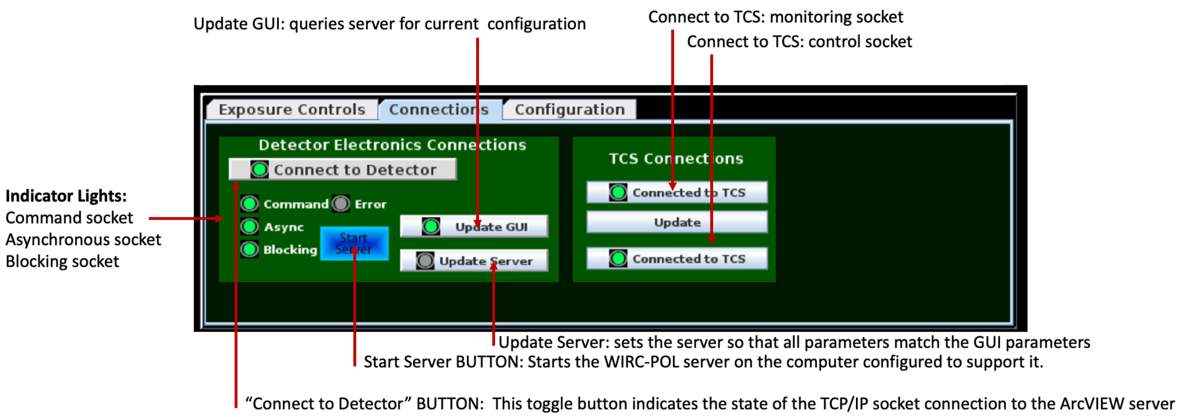


Figure 4 Connections Panel - TCS and ArcVIEW connections

If the server doesn't connect, it's possible (although unlikely) that the server hasn't been started or there's a problem with the startup. Typically, the WIRC-Pol server runs in the ArcVIEW account on instrument6.palomar.caltech.edu, but its location may be changed due to issues with the computer. Please ask the support astronomer if you're in doubt where the server is running. If the server is NOT currently running, you can use the "Start Server" button. The observatory has an application manager that is used to configure where each of the instrument software components is set up to run. This software maintains a configuration file that is accessible from any computer system on the instrument network. Pressing the "Start Server" button starts the ArcVIEW server in the location described in the application manager configuration file. If you need to change the location you should probably start the server using the application manager.

There are two additional buttons in the Detector Electronics Connections panel: (1) update GUI and (2) update server. When observatory personnel are troubleshooting an issue with the instrument, we frequently bypass the GUI entirely and send commands from a terminal window. This can create a situation where the GUI and the server are configured differently. Pressing the Update GUI button communicates with the server and updates the GUI with the current values in the server. (For example, if the server has an exposure time of 10 seconds, and the GUI shows 1.0 second, the server value will update the GUI so that it shows 10 seconds.) The Update Server button reads each control field on the main panel and sends the associated values to the server.

The TCS connections panel is used to monitor or cycle the TCP/IP connections to the TCS. The WIRC-Pol software uses 2 simultaneous connections to the TCS: one connection to monitor the telescope position and telemetry, and one connection to send motion commands (e.g., telescope offsets, changes to focus, etc.). Maintaining simultaneous connections allows us to monitor the position of the telescope while it's moving and tells us when actions such as focus changes are complete.

Occasionally the TCS needs to be rebooted during the middle of the night and the connections to the WIRC-Pol software fail. Although the software is designed to automatically reconnect in the event of connection failure, if the TCS has been down for more than a few minutes, the software eventually gives up trying to reconnect. In this case, the observer may need to reconnect these sockets by toggling the connection buttons.

Finally, the Update button controls whether the telescope telemetry thread is running and querying the TCS for its position. If the button is selected, the TCS will be polled at ~1 Hz. It may be necessary to toggle this button if the TCS has been rebooted.

2.4 Configuration

The configuration panel displays the location where the detector electronics server (ArcVIEW) is running, and the TCP/IP port numbers used for each of the TCP/IP sockets. The server location selected with the combo-box control determines where the software will attempt to connect to the ArcVIEW server. Be aware that this control only determines where the WIRC-Pol server will look for the ArcVIEW server. It does not determine where the "Start Server" button starts the server if that method is used. If the application manager has been used to move the server to a different computer, you may need to change where the software looks for the server. For example, if the application manager moves the server from instrument6 to instrument4, the "Server Location" combo-box should be set to instrument4.

The details displayed in this panel are stored in the /config/WIRC.ini configuration file associated with the active software build.

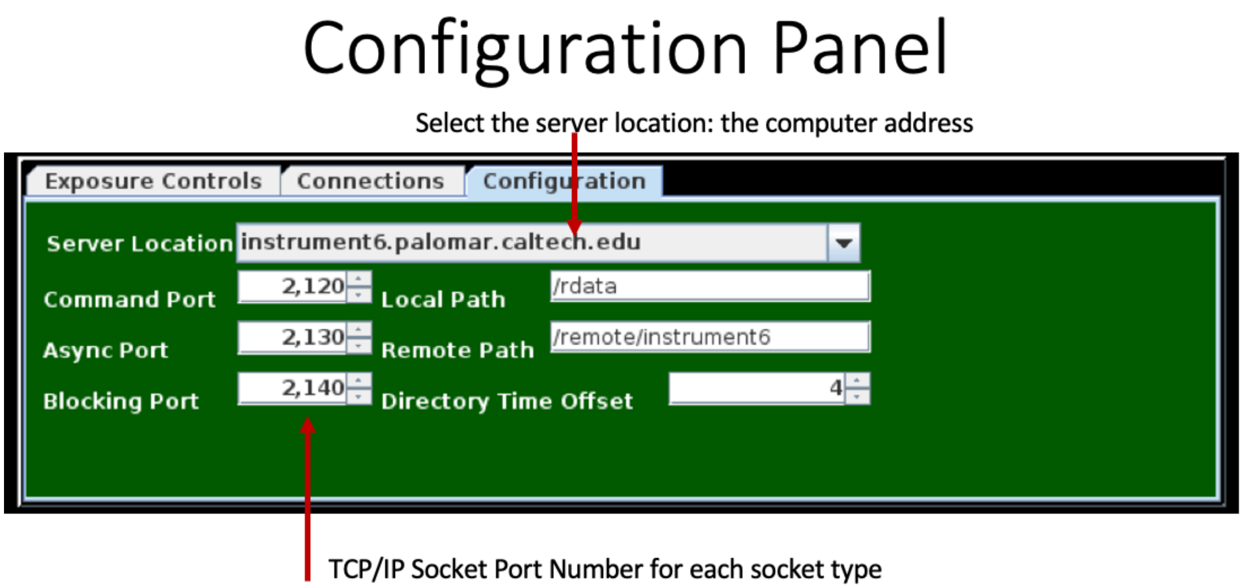


Figure 5 ArcVIEW Server Configuration Panel

The additional controls on the configuration panel are present purely for information purposes and should be modified. The "Local Path" and "Remote Path" fields are used by the code to transform the local name of an image supplied from the server into the actual path to the file on the remote mount so that it can be displayed. If you have moved the server you may need to change the "Remote Path" so that the new remote server path is used in the path transformation.

The "Directory Time Offset" is mainly used for setting up the current directory to store images. The directories are constructed when the server is started and are based on the UTC date. The change from one UTC date to another happens in early afternoon at Palomar and it's rather inconvenient to have to restart the WIRC-Pol server when the date changes so you have a directory with the current UTC date. Shifting the UTC time to 4 hours earlier when creating the directory name means that support astronomers that come in at noon can start up the software with the correct directory name for that night.

2.5 Exposure Progress Bars

The progress bar panel is located at the top of the main panel. The three progress bars display the percentage of the total read, write, and exposure times.

2.6 Comment Parameters Panel

This simple panel allows an observer to add an object name, observer name, and object type to be specified and written into the FITS header.

2.7 Image Path and Name Panel

The image path and name panel contain the following controls: (1) image path button, (2) image path text field, (3) base name text field, (4) image number spinner, and (5) comment. The image path button allows you to open a file browser to specify the directory where the images will be stored. In general, this control is not useful for the WIRC-Pol instrument since the server and GUI normally run on different systems. Using the "Image Path" button to change where the images are written assumes that both the server and the GUI are running on the same computer and can access the same file system. In most cases, this assumption is incorrect so this control should not be used unless you're running the system in an unusual way.

The image name is constructed by concatenating the base name and the image number and the image is written to the image path directory. For example, if the current date directory is /remote/instrument6/WIRC/20230828, the base name is "image," and the image number is 12, the image will be written to /remote/instrument6/WIRC/20230828/image12.fits.

The final control is the "Comment" text field. This control works similar to the controls in the comment parameters panel and simply adds the comment keyword to the header with the contents of the "Comment" text field.

2.8 Optical Mechanism Controls

The WIRC-Pol instrument contains a set of optomechanical components including two filter wheels, a mask, two slide mechanisms, and two optical rotation mechanisms. The filter wheels are internal to the WIRC instrument and are controlled individually. The mask, slide mechanisms, and rotators are integral parts of the polarization measurement system (i.e., part of the -POL instrument).

2.8.1 Filter Wheel Controls

The filter wheel controls on the main panel represent the essential subset of the controls necessary to select filters in each wheel. The filter wheel components are also represented by a more comprehensive control accessible from the “Tools” menu.

Each wheel is represented by a filter selection combo-box and a Move button. Simply select the appropriate filter in the combo-box then press the associated Move button. The indicator light on the Move button will turn red until the move is complete. The indicator light will return to green when the move is completed. Please only move one wheel at a time since the filter mechanism is controlled by RS232 communication with the motor controllers and only has single thread support. You should confirm that the selected filters are displayed in the FORE or AFT text fields (located below the controls and displayed in green text on a black background) after the move is complete.

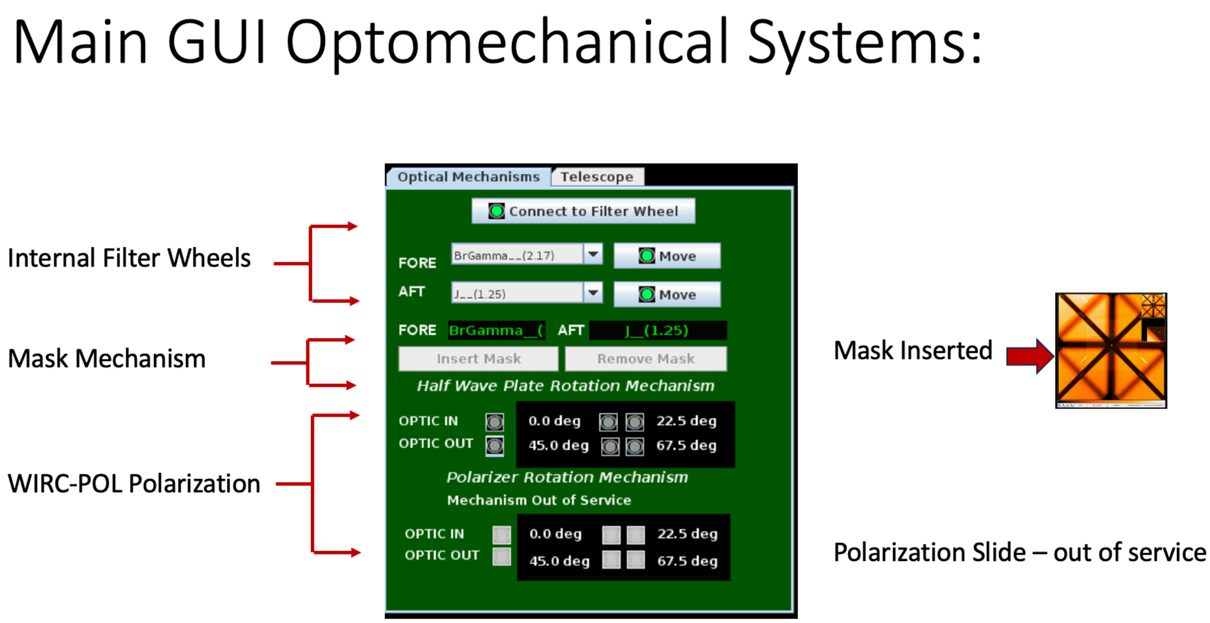


Figure 6 Optomechanical Systems - Main GUI

If you click the Move button and you don’t see the filter name in the FORE or AFT displays change to the selected filter, you might have a known issue. If the server has just been started, the filter wheel needs to be initialized. The lack of a known filter name in the FORE or AFT text fields or name like “unknown” is an indication that the filter wheel doesn’t know where it is and requires initialization. If the filter wheels require reinitialization please see the section of the manual on the filter wheel control in the Tools menu.

2.8.2 Mask Controls

The mask mechanism is used to insert a mask into the optical train for polarization measurement. The first step is to initialize the mechanism, if it isn’t already. The Initialize Mechanism button is only available on the Tools > WIRC-Pol Mask Mechanism Control dialog.

Once the mechanism is initialized, the Insert Mask and Remove Mask buttons will be activated. After clicking either the Insert Mask or Remove Mask button, the indicator light on the button will turn red and return to green once the move is complete.

2.8.3 Polarization Mechanisms

The WIRC-Pol instrument supports polarization measurements using a set of dedicated mechanisms connected to a Newport controller. Two slide mechanisms insert or remove optics from the optical train and 2 rotation mechanisms rotate optics mounted within the slide mechanisms.

One of the slide mechanisms inserts a polarizer into the field of view and the associated rotation mechanism controls its rotation angle. The polarizer was necessary during the calibration of the instrument's polarization measurement system; however, both mechanisms (i.e., slide and rotator) have been removed from service at this time. The slide mechanism supports moving the polarizer in and out of the field. The rotator has 4 preset angles that are the primary angles used during calibration: 0, 22.5, 45, and 67.5 degrees. Moving the rotator to an arbitrary angle is supported by the detail control on the Tools > WIRC-Pol Newport Controller menu.

The other slide mechanism inserts a half-wave plate into the optical train and the rotator controls its rotation angle. This combination of mechanisms is used for all polarization measurements. (These mechanisms turn WIRC into WIRC-Pol.) The rotator has 4 preset angles that are the primary angles used during observing: 0, 22.5, 45 and 67.5 degrees. Moving the rotator to an arbitrary angle is supported by the detail control on the Tools > WIRC-Pol Newport Controller menu.

The controls for the polarizer are intentionally locked since these controls are out of service. The controls for the half-wave plate are locked until each mechanism is initialized using the more complete dialog on the Tools > WIRC-Pol Newport Controller menu.

2.9 Telescope Controls

The telescope controls panel makes a few of the more commonly used actions available on the main panel. This panel contains controls for setting the focus and for moving the telescope with the image integrated target to bullseye and target to mask components.

2.9.1 Target to Bullseye

The “Target to Bullseye” control system integrates selecting coordinates on an image and automatically calculating the telescope move required to move the telescope from one coordinate (the Target) to another (the Bullseye). The image display is accessible on the Tools > Image Display Control menu.

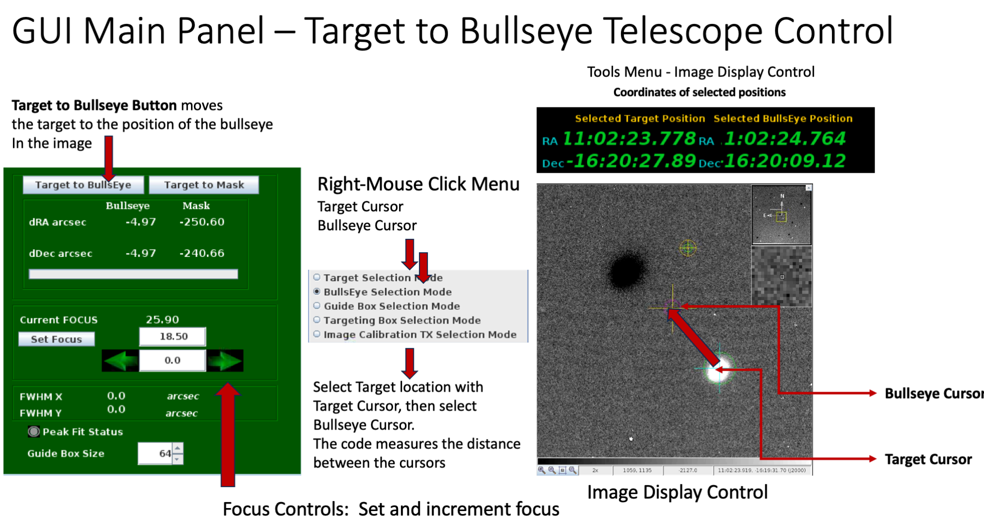


Figure 7 Target to Bullseye integrated TCS controls

The image display control supports a set of cursors that are selected by right clicking on the image to bring up the cursor menu. The two cursors that we are concerned with here are the "Target" and "Bullseye" cursors. Let's say you have a target that you want in the middle of the image and it's currently well away from the center. Select the "Target" cursor in the menu and then click on the image so that the cursor is directly on your target. This action reads the coordinates from the image using the rough WCS transform and stores it internally. Now switch to the "Bullseye" cursor and select where you want the target to appear in the image. This action also reads the coordinates from the image and once both the target and bullseye coordinates are known, the offset between the two coordinates is calculated.

To move the target to the bullseye position simply click the "Target to Bullseye" button and the offset move command is sent to the TCS. The calculated offset between the two coordinates in arcseconds is displayed in the GUI and labeled dRA, dDec. While the telescope is in motion the progress bar under the offsets displays the progress assuming that the telescope is moving at 45 arcseconds/second.

To make the "Target to Bullseye" motion work correctly, you must select the target and bullseye each time you execute a move. Sometimes the bullseye cursor is already located where you want the target to go but the coordinates of that position may be stale and reflect the last time the bullseye cursor was clicked on the image. The bullseye coordinate could be halfway across the sky if a long slew was carried out since the coordinates were updated. Examine the offset coordinates before you press the "Target to Bullseye" button and make sure that they look reasonable for the offset between the two positions.

2.9.2 Target to Mask

The "Target to Mask" function is like "Target to Bullseye" and is used primarily when making polarization measurements. The mask can be inserted into the optical train using the Tools > WIRC-Pol Mask Mechanism Control menu (Section 2.82) or with the controls on the Optical Mechanisms subpanel on the main panel. The "Target to Mask" button only requires selecting the Target cursor and selecting the target you wish to move to the mask position. The mask position is constant in image XY coordinates, so the code can easily calculate the offset between the known mask position and the selected target. The centerpoint of the mask is stored in one of the systems configuration files. Once you select the target with the Target cursor the offset between the selected target and the center of the mask is calculated and displayed in the telescope controls subpanel and labeled dRA, dDec. Simply press the “Target to Mask” button and the offset will be sent to the telescope control system. The progress bar will update during the move and then return to 0 when the move is complete.

2.9.3 Setting Focus

The telescope controls subpanel also contains controls to view, change and offset the focus of the P200 telescope. The current focus is displayed to the right of the “Current Focus” label and the units are in millimeters. If you wish to change focus to a particular value, enter the value in the text field to the right of the “Set Focus” button and then press the button. The telescope move progress bar will display the percent completed of the focus move. The focus may also be offset from the current value using the two controls with green arrows separated by a text field. Simply enter the offset (default is 0.0) you wish to make and then press the left or right arrow button. The left arrow offsets the focus downward and the right arrow offset the focus upward by the amount specified in the text field. The color of the arrows changes to red while the focus change is in progress and returns to green once completed.

2.9.4 FWHM for stars in the guide box

Just like the Target and Bullseye cursors, the Guide Box cursor can be selected by right clicking on the Tools > Image Display Control frame. The Guide Box cursor sets a square cursor around the selected position and attempts to fit a Gaussian to the image within the guide box. If the code can fit a Gaussian to the contents of the selected portion of the image, the “Peak Fit Status” icon will turn green. If the code can’t fit a Gaussian, the icon will turn red. The calculated full width at half maximum (FWHM) of the star in the guide box is displayed above the “Peak Fit Status” icon and labeled FWHM X and FWHM Y. The size of the guide box cutout is controlled by the spinner control labeled “Guide Box Size.” The default guide box size is 64 x 64 pixels.

Measuring FWHM of a star

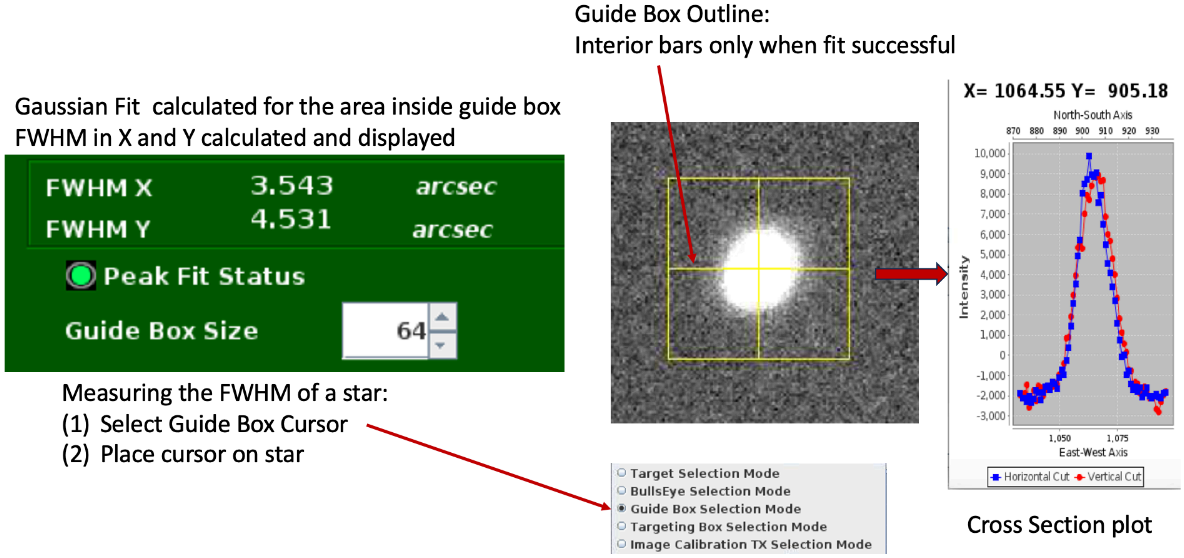


Figure 8 Measuring the FWHM of a star

2.10 Image compensation

The “Image Compensation” subpanel contains a subset of the controls available on the Tools > Image Display Control > Image Compensation menu. The more extensive “Image Compensation” controls can be used to flat field the images automatically as well as subtract darks or sky reference images. The most useful sky background subtraction controls are presented on the main panel in this subsection.

2.10.1 Subtracting reference images

Imaging in the infrared often requires subtracting a reference image to better see the stars in the image. This is particularly true for longer wavelengths (e.g. H and K filters). The raw FITS images (i.e., without any image subtraction) are always written to disk and are the primary data product. When displaying a subtracted image, the image is simply used for display and is written to a temporary file in a /temp directory.

The observer can choose to use the currently displayed image as the reference image by clicking the “Set Reference Image” button. Alternately, the observer can browse the file system to supply the reference image by pressing the “Browse for Reference” button. If you wish to see the full path and name of the file used for image subtraction, you can access this information on the Tools > Image Display Control > Image Compensation menu. The button on the left side of the image compensation subpanel controls whether the image subtraction is executed for the next image that will be displayed. The state of these controls determines the systems behavior for the next image taken and all subsequent images.

Main GUI – Image Compensation

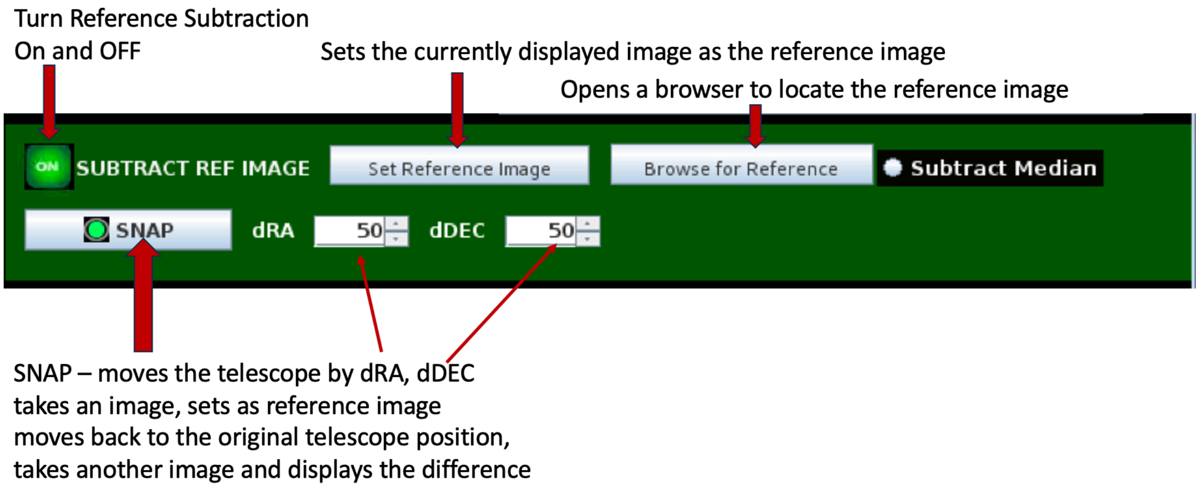


Figure 9 Main GUI - Image Compensation

2.10.2 SNAP

The SNAP button performs one of the most common operations used when acquiring infrared images: (1) offset the telescope by a small amount, (2) take an image and set it as the reference image, (3) move the telescope back to the original coordinates, (4) take an image of the target, and (5) display the current image after subtracting the reference image. The observer may configure how far the telescope offsets in RA and Dec using the dRA, dDEC spinner controls. The default offset is 50 arcseconds in both RA and Dec.

3.0 Auto-Guiding

The information in the "Auto-Guiding" panel is also available within the Tools > Image Display Control > Guider Control menu except for the "Locate Guide stars" button. The controls are largely duplicated to make them easier to access and to add some automation (e.g., locate guide stars) to the process.

3.1 Locate guide stars

The "Locate Guide Stars" button operates on whatever image is displayed in the Tools > Image Display Control window. The "Locate Guide Stars" button writes the currently displayed image (including any reference subtraction or flat field division) to disk and then runs Sextractor on the image to determine the set of stars in the image. The list is then sorted by the star's brightness and the brightest N stars are added to the Guide Star table. The number of guide stars selected is controlled by the "Number of Guide Stars" spinner located below the "Locate Guide Stars" button. The default number of stars is 5, with a minimum of 1 and maximum of 10.

Autoguiding: Setting up guiding

- The auto-guider always works on the displayed image in the Tools/Image Display window
- Press the Locate Guide Stars Button
- The system runs Sextractor and finds all the stars in the current image.
- The code selects N (see spinner control) guide stars and places guide box cursors on each one.
- Guide stars may be removed from the list using the minus button (select row then minus)
- Guide stars may be added by selecting the plus button and then selecting the star using the guide box cursor on the image display

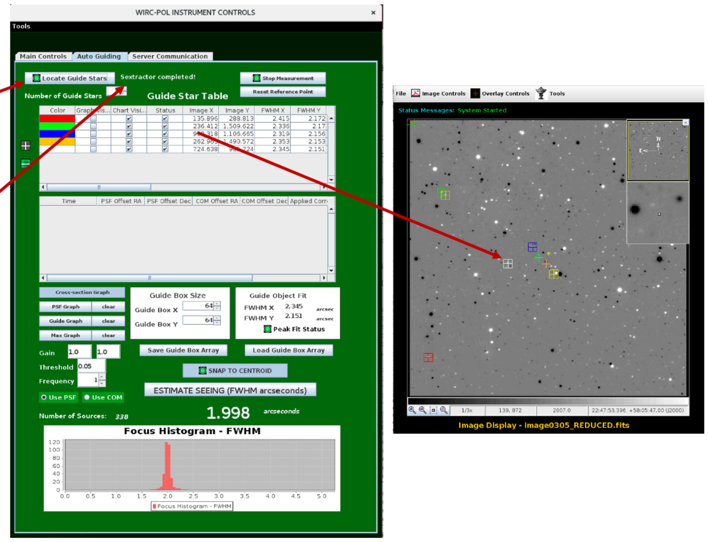


Figure 10 Setting up guiding

3.2 Guide star table

The guide star table displays the set of guide stars either produced by "Locate Guide Star" or by manually adding them to the image (see below). A Gaussian fit is calculated for each selected star and measurements derived from the fit are displayed in the table. Once the table is populated with guide stars, you may inspect the list of stars and remove any stars that aren't appropriate for guiding. There are several reasons that you might wish to reject a guide star. Sometimes the core of the star is saturated, and including the star will produce an unstable measurement of drift. Occasionally, the algorithm will select hot pixels or cosmic rays mistaking them for stars. To remove a star from the table, select the row of the table and then press the "-" (minus) button to the left of the table.

If you wish to manually add a star to the list: (1) select the guide box cursor on the image display (right mouse click to menu), (2) select the "+" (plus) icon on the auto-guiding panel, and (3) click on the star in the image display. Performing this sequence of steps will add a new star to the guide box table at the end of the list. Once you have added all of the stars you wish to add, turn off the "+" button. (If you take an image while the "+" button is activated, the system will automatically add a new star to the table at the location of the current guide cursor. If you do this when the system is in continuous imaging mode, it will add a new guide star for each image.)

The measured location of a star, by either the Gaussian fit (PSF) algorithm or the center of mass algorithm, is affected by mechanical drift of the telescope (which can be corrected) and the effect of scintillation on the star's location due to turbulence in the atmosphere (which cannot be corrected). The changes in the position of a star's centroid due to scintillation is essentially random and combining multiple measurements of different stars minimizes the effect of scintillation on the guide signal. It is true that the scintillation may be somewhat constant within an isoplanetic patch, but selecting guide stars over the entire image field tends to randomize the effect. If you want only one guide star, you can either set the number of guide stars to one before running "Locate Guide Stars" or just add one star manually.

There is no inherent reason you must use the "Locate Guide Stars" button to populate the table. If you know which stars you want to include in the table, you can use the "Plus" button to add stars individually. In general, I recommend examining the cross-sections for each of the selected stars to make sure that they aren't saturated and to determine if they have sufficient signal to noise. The second column in the guide star table is the "Graph Visibility" column and it controls the visibility of the cross-section graph for the associated star. You can easily go through the table and make the graph for each star visible. These graphs are automatically updated for each image.

3.2.1 Columns in the Guide Star Table

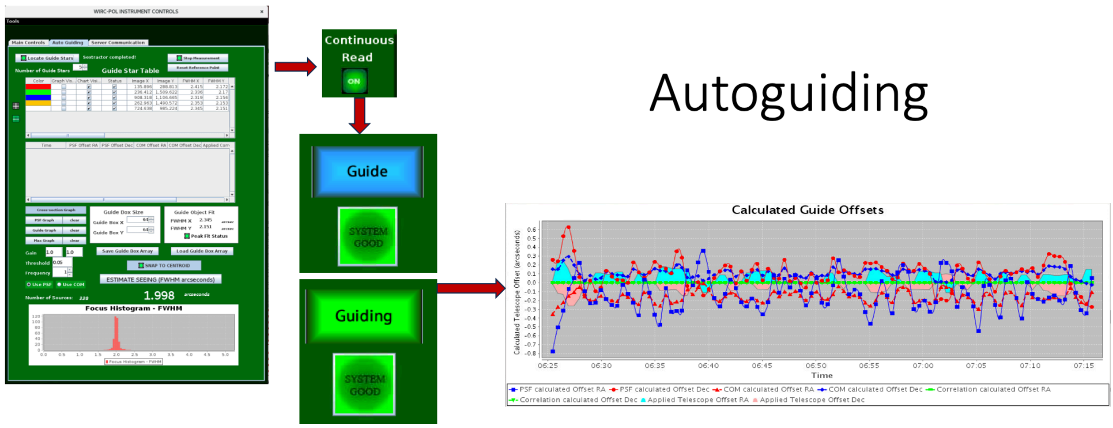
Column Name	Description
Color	Color of the guide box
Graph Visibility	Cross-Section graph visibility
Chart Visibility	deprecated, not editable
Status	Gaussian Fit status
Image X	X coordinate of fitted peak, PSF guide coordinate
Image Y	Y coordinate of fitted peak, PSF guide coordinate
FWHMX	FWHM in the X direction (RA) for this star
FWHMY	FWHM in the Y direction (Dec) for this star
Center of Mass X	X coordinate of the center of mass, COM guide coordinate
Center of Mass Y	Y coordinate of the center of mass, COM guide coordinate
Object Peak	Object peak intensity
Mean Background	Mean background
Angle	Angle of the fitted 3D Gaussian ellipse
Mean	Mean value within guide box
Minimum	Minimum value within guide box
Maximum	Maximum value within guide box
Standard Deviation	Standard deviation of the flux within guide box
Guide Box X	X coordinate of the upper left corner of the guide box
Guide Box Y	Y coordinate of the upper left corner of the guide box
Guide Box X size	Width of guide box when created
Guide Box Y size	Height of guide box when created

The guide star table consists of descriptions of stars including their position in the image and their magnitude. You can save the list of parameters to disk ("Save Guide Box Array" button) and retrieve from disk ("Load Guide Box Array" button). It is often advisable to save the list of guide stars and their reference locations to disk if you are planning on a long guiding sequence (e.g., a planetary transit observation). Sometimes the weather gets bad for a few minutes, and you must close the dome. Sometimes you'll run into a software glitch that requires you restart the GUI. If you wish to have your stars on the same pixels for the entire observation, you can save the guide star array and reload it when conditions improve. There may be some drift of the telescope while the system wasn't guiding, so you may need to assure that the stars are within the guide boxes. If the stars are within the guide boxes, the first correction should return them to the reference position.

3.3 Table of guide offsets

The table of guide offsets contains a single row for each image and displays the UTC time stamp, the offset in arcseconds from the initial reference position calculated for both the Gaussian fit algorithm (PSF) and the Center of Mass (COM) algorithm, and the correction that was sent to the telescope (including the effects of gain and thresholds). This table is the underlying data source for the guide graph. It does not contain any editable fields and is presented for information purposes only. The guide graph is initially hidden and is made visible by pressing the Guide Graph button below the table. The guide graph displays the offset from the reference position (Xref, Yref) calculated for each image using both the Gaussian fit (solid line) and the center of mass algorithms (dashed lines) as a function of time. The offset in both X (RA) and Y (Dec) are displayed for each measurement type for a total of 4 plots. The remaining two plots are the actual guide correction that is sent to the telescope based on which algorithm is selected (PSF vs COM), the applied gain (i.e., the gain applied to X and Y offsets), and any thresholding (i.e., eliminating corrections that are too small or too large).

The reference position of the star (i.e., image X, image Y, com X, com Y) is the X, Y coordinate of the star when the guide star record is created. When the system is actively guiding, the guide correction attempts to keep the star at the same X, Y position as the Xref, Yref. The calculated offsets are the difference between the reference location (created when the guide star was created) and the current location. Since the X, Y centroid calculated by the Gaussian fit and COM algorithms may be different, their reference positions are different. Sometimes it is useful to be able to reset the reference position, particularly after a pause in observing. For example, imagine starting a light curve observation and then having to close the dome after 5 minutes of observing. When the dome opens back up you may want to just restart but you're going to forget about that 5 minutes' worth of data.



The auto-guiding panel sets up guiding but it's only the setup. To start guiding follow these steps:

(1) Make sure the Start Measurements button is active (controls calculation of offsets)

(2) Turn on Continuous Read – this takes one image after the other when the GO button is pressed.

(3) Press the GO button.

(4) Each new image will generate a row in the guide offsets table and add a new set of points to the the Calculated Guide Offsets plot

(5) The GUIDE button on the main panel controls whether the offsets are sent to the telescope. If GUIDE is active (green icon) the offset corrections are sent to the telescope.

Figure 11 Autoguiding - turning guiding ON

3.4 Graph visibility buttons

There is a set of graphs that are automatically created and linked to buttons on the auto-guiding panel. Three of these buttons display graphs linked to the "guide box" cursor on the Tools > Image Display Control frame.

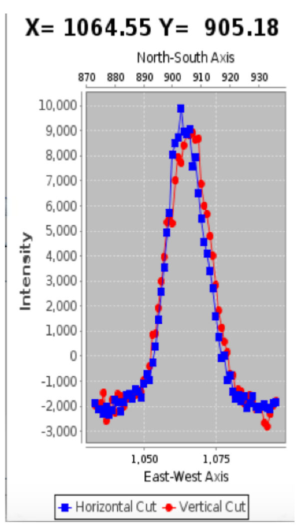


Figure 12 Cross-section of a star inside a guide box

3.4.1 Cross-section graph

A cross-section graph of the star within the guide box is displayed when the associated button is selected in both the X and Y directions. The cross-section graph is automatically updated with every mouse click on the image when the guide box cursor is active. The cross-section graph also updates whenever a new image is displayed. Whenever the graph is redrawn, the code attempts to fit a Gaussian to the guide box contents and indicates whether the fit was successful in the Auto Guiding > Guide Object Fit subpanel using the peak fit status indicator. The indicator light will be green if a Gaussian can be fit to the object in the guide box and turn red if the fit was unsuccessful. The FWHM in arcseconds in X and Y is displayed above the peak status indicator. Please note that the values displayed here are duplicated on the main GUI in the Telescope subpanel.

3.4.2 PSF graph

The PSF graph is similarly linked to the guide box cursor on the image display. As discussed in the previous paragraph, the FWHM in both X and Y is calculated whenever the guide box is moved and when a new image is displayed. The PSF graph plots the FHWM in X and Y versus time. If the system is running in continuous mode, you can use the PSF graph as a manual way to tune up the focus. If you open the PSF graph, place the guide box cursor on a star, and then systematically offset the focus using the focus arrows on the Main Panel > Telescope subpanel. This method is probably the best way to tune up the focus during the night. The contents of the graph can be cleared by pressing the associated clear button.

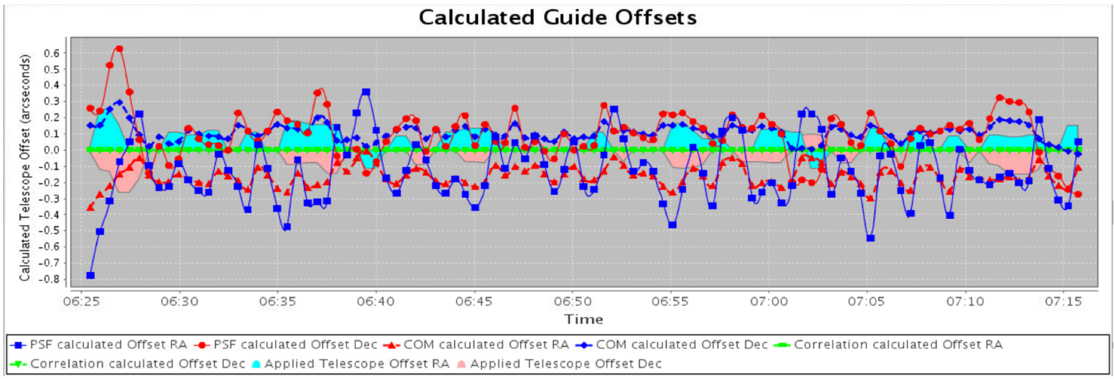
3.4.3 Maximum graph

The Max Graph displays the maximum within the guide box as a function of time. This graph behaves like the PSF graph and displays a new value each time the mouse is clicked on the image. This can easily be used to check the relative brightness of stars in the image. If the system is in continuous mode and the cursor is on a star, you can monitor changes in the atmosphere. The maximum in the guide box tends to reflect changes in the seeing/atmospheric turbulence.

3.4.4 Guide graph

The guide graph displays the contents of the table of offsets in an offset vs. time graph. The graph displays the offsets from the initial reference position measured using a Gaussian fit to the star (PSF) and by the center of mass (COM) algorithm. The graph displays the calculated offset in both the X (RA) and Y (DEC) directions. The observer can choose which algorithm to use when the offsets are sent to the telescope (TCS). When applying the offsets, the code first considers which algorithms to select for determining the offsets and then applies the thresholding and gain (See section) before sending the correction. The applied offsets are depicted as a graph in X (RA, light blue) and Y (Dec, light red) vs. time with the area under the graph filled in with color.

Guide Offsets Graph



- **The Calculated Guide Offsets graph displays the guide offsets calculated using a Gaussian fit to the stars position and the same metric calculated using the center of mass algorithm.**
- **The actual correction sent to the TCS is depicted as a solid area under the curve.**
- **Note: GUIDING must be ON for corrections to be sent to the TCS (solid graph)**

Figure 13 Guide offsets graph

Why does the software support two different algorithms? The Gaussian fit algorithm is vastly superior in measuring offsets from the reference position for tightly focused stars. Unfortunately, when the star is defocused to spread the center of the star over more pixels, the Gaussian fit may fail. In this circumstance the center of mass algorithm still works properly. It's important to remember, however, that the COM algorithm requires that the image have the sky background subtracted. The COM algorithm is particularly sensitive to gradients in the image and requires a flat background to measure offsets correctly.

3.5 Guiding controls

The guide signal is measured by calculating the offset from the reference position for each star in the guide list and then determining the median offset for a particular image. The control loop is a simple proportional controller with no derivative or integral term. As a result, the observer can influence the guiding by controlling the gain in RA and Dec. The gains are set by default to 1.0 and may be modified by changing the values in the Gain text fields. It is necessary to enter a carriage return when you change the value to propagate the value to the guide control loop.

Another way you can control the guiding behavior is to change the threshold applied to the calculated guide correction. Applying a guide offset takes time (at least 100 to 200 milliseconds, much longer if the correction is large) and it's wasteful to apply very small corrections. The threshold parameter is used as a high pass filter to eliminate sending corrections smaller than the specified value. The default is set to 0.05 arcseconds. The smallest offset that the telescope control system (TCS) considers "legal" is 0.007 arcseconds.

By default, the guide loop calculates and applies a guide correction for each image. Since the minimum exposure time for the WIRC array is 0.923 seconds, it's possible to provide a guide correction at between 1 and 2 Hz. The P200 is a very stable telescope and mechanical drift has consistently been measured at approximately 1 arcsecond every 15 minutes. Guiding at 1 Hz is not necessary and the observer may choose to only apply a correction for every other image, or even once every 10 images. The frequency of the applied guide correction is controlled by the frequency spinner control. Increasing the frequency decreases the correction cadence.

The choice of guide algorithm is determined by the selected "Use PSF" or "Use COM" radio buttons. By default, the system uses a Gaussian fit to determine the centroid location (i.e., PSF algorithm). The observer may choose to use the center of mass algorithm instead. Observers that have defocused the telescope to increase the number of pixels the light will fall on are cautioned that if the image is defocused too much the Gaussian fit may fail. The center of mass (COM) algorithm requires that the image be background subtracted, so be aware of changing background gradients that may push the COM algorithm to generate centroids at the edge of a guide box.

3.5.1 Guide box size

You can control the size of the guide box cursor on the image display control using the Guide Box X and Guide Box Y spinner controls. The default is 64 x 64 pixels. Observers are cautioned that making the guide box rectangular breaks the Gaussian fit algorithm, resulting in the FWHM and peak status not being calculated. You may, however, decrease the size of the guide box, and this may be necessary in highly crowded star fields.

3.5.1 FHWM and Peak Fit status

The information in the Guide Object Fit panel is identical to Section 2.9.4. Please see this section for a discussion of the determination of FWHM and Gaussian fit peak status.

3.5.2 Saving and loading the guide box array

The list of guide boxes in the Guide Star Table can be saved and then retrieved from a file. The information displayed in the Guide Start Table is stored as a comma-separated values (CSV) file in the ***/rdata/TEMP*** directory. The file is automatically created and is named CENTROID_YYYYMMDD_HH_MM.txt. When you click the "Load Guide Box Array" button it will allow you to browse the default directory and select the guide star list to load.

An example of when this feature may be useful is when observing a planetary transit on multiple days. On your first night, you select a set of guide stars and observe the transit with them. This particular set of guide stars will attempt to place the stars at their reference positions. At the end of the night, you saved the guide star list to a file. The next time you're on the telescope you realize that it would be nice to place the star in the same place as the last time you observed. Observing with the same pixels will increase the consistency of your data and may make your data reduction easier. Take an image of your field with appropriate background subtraction and then load the guide box array. You'll find that the stars probably aren't in the guide boxes. If you adjust the telescope position (probably by speaking to the telescope operator), you can place the guide stars inside the guide boxes. The stars don't need to be in the center of the guide box, they just need to be inside them. The first correction done when guiding is turned on will return the stars to their reference positions. As a result, the target will be placed on the same pixels as during the original observation.

In addition, software crashes are very infrequent, but saving the guide box array allows an observer to recover quickly and get their target back to its original position.

3.5.3 Snap to Centroid

The Snap to Centroid button controls how the guide box cursor functions on the image display. If the indicator icon is red, when the observer clicks on a star on the image, the location of the guide box is determined directly by mouse click coordinates. This location may or may not be centered on the star. In this mode, the star's profile will show up anywhere in the guide box (including near or at the edge) and the accuracy of placement is determined wholly by the observers' mouse clicks. If the indicator icon is green, the code fits a Gaussian to the guide box image, determines the centroid coordinates, and then centers the guide box around the star. If the Gaussian fit fails (e.g., it's a galaxy not a star, no star is in the guide box, etc.) then the guide location defaults to the other behavior (i.e., coordinates determined by the mouse click).

3.6 Estimating seeing

You can easily measure the FWHM of any star in a displayed image by placing the guide box cursor on the object and the FWHM in RA and Dec will be displayed. (See Section 2.9.4 and Section 3.5.1.) However, this just tells you the FWHM for a particular star. The "ESTIMATE SEEING" button can give you a good estimate of seeing in the entire image.

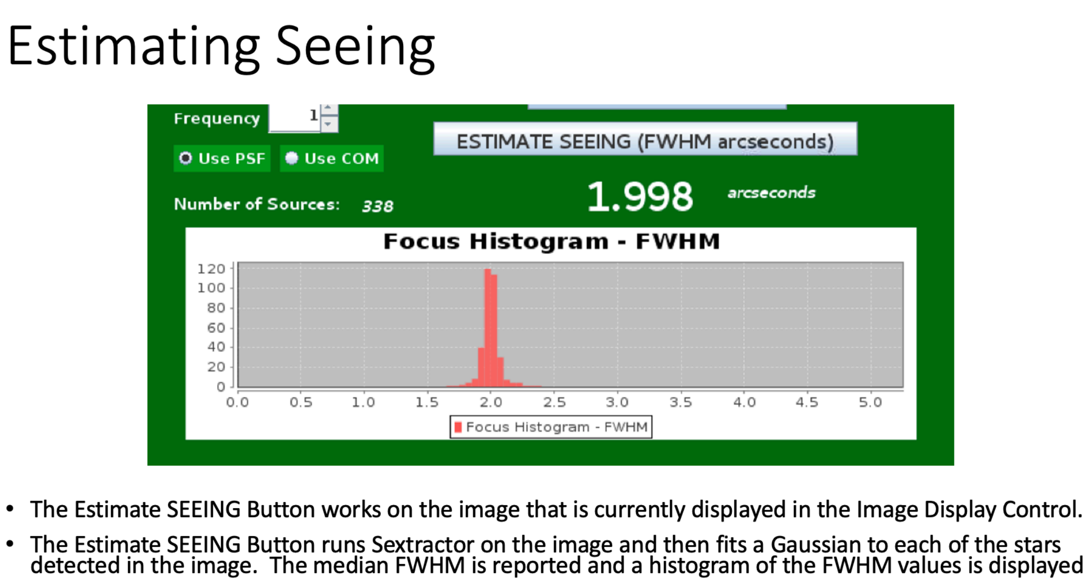


Figure 14 Estimating seeing

The "ESTIMATE SEEING" button performs the following sequence of operations on the currently displayed image:

(1) Writes the currently displayed image to disk.

(2) Runs Sextractor on the image and reads the list of located stars.
(3) For each identified star in the image, extracts a guide star postage stamp (i.e., bounded by the guide box) and fits a Gaussian to the star.
(4) If a Gaussian could be fit to the star in the guide box, adds the FWHM in RA and Dec to the array of solved stars.
(5) Once all of the stars have been processed, sorts the array and calculates the mean and median FWHM.
(6) Displays the median of all stars in the image as the seeing estimate.
(7) Displays a histogram of the FWHM distribution. (This may require pressing the button a second time.)

Examining the histogram can be very useful because it gives you an appreciation of the data that the seeing estimate is based on. Is the histogram sharp with almost all of the measurements close to one another? That's probably a pretty good estimate. If the histogram has a long tail, then the image probably has many galaxies or other non-stellar objects within it. Are there many objects with very small FWHM? This probably indicates that the Sextractor parameters are picking up hot pixels or cosmic rays rather than well-focused stars.

4.0 Server Communication

The final tab of the main display is dedicated to displaying the communication between the GUI and the server. Each command sent to the server is displayed in blue and the associated response is displayed in green. All communication is carried out primarily using the command socket to the server. The command socket does not block and returns immediately with either the result or and indicator that the command was received. The "conversation" that goes on between the GUI and the server is displayed in the editor pane on the left side of the "Server Communication" panel.

The right side of the "Server Communication" panel contains a record of the asynchronous messages that the server sends out periodically. For example, the asynchronous editor pane will indicate when an exposure is started and when it's completed by sending a message to the GUI. These messages are displayed primarily as a debugging aid in case the server runs into problems. Sometimes you can gain valuable insights into why the system is misbehaving by analyzing the conversation between the GUI and the server.

5.0 The Tools Menu

5.1 Image Display

The image display control is accessible from the Tools > Image Display Control menu option. The image display control is designed to display FITS images automatically when they are acquired. Most of the frame is taken up by the FITS image. You can change the size of the image display to whatever you wish by dragging the lower right corner or by grabbing any frame edge. The upper right corner of the image display contains both a zoom window (linked to the mouse position) and a pan window. In the upper right corner of the pan display is a button that will hide the pan and zoom displays if desired. If the entire image is not displayed due to the zoom level, a yellow rectangle will appear in the pan window, and you can move this rectangle around the pan window to select what portion of the image will be displayed.

The lower left corner of the frame contains the zoom level controls including: (1) zoom in, (2) zoom out, (3) zoom to frame, (4) normal zoom (1x). Directly to the right of these buttons is a text field displaying the current zoom level. This control displays the X, Y pixel coordinates of the mouse position and the flux value at that position in the bottom toolbar. If the header contains WCS keywords, the RA and Dec coordinates are displayed on the right of the toolbar.

5.1.1 Image Controls

The Tools > Image Display Control > Image Controls menu contains controls for modifying the way the image is displayed. The most used of these controls is the Image Cut Levels control.

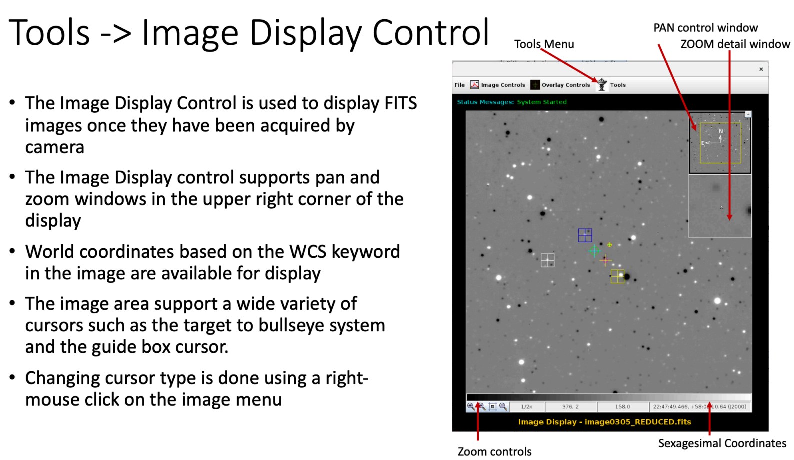


Figure 15 Image Display Control

5.1.1.1 Image cut levels

The image cut levels control displays a histogram of the flux values in the displayed image. Below the histogram is a bar (like a progress bar) that has triangular “handles” at each end and can be dragged left or right to change the upper or lower ends of the image stretch. The numerical values of the cut levels are displayed under the bar. There are a set of buttons that set the limits (upper and lower) at percentages of the measured range. (See Figure 16 below.) At the bottom right of this control there is a “Median Filter” button that is probably the best way to immediately produce a useful stretch of the image. The “Reset” button sets the limits to the measured range (minimum to maximum). The “Close” button simply closes the dialog.

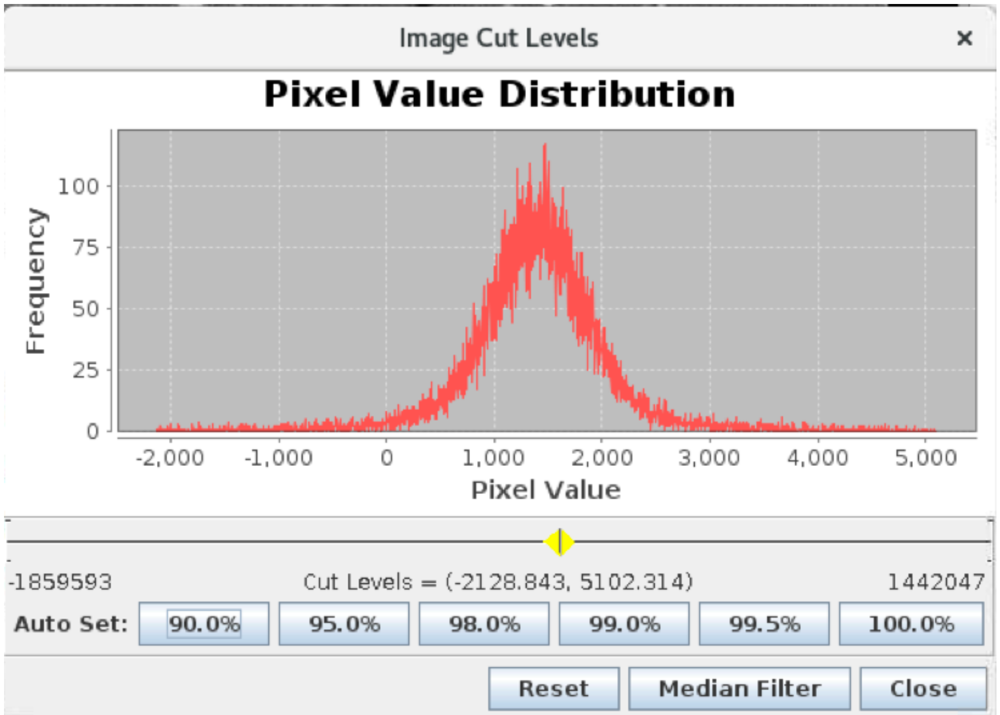


Figure 16 Image Cut Levels Control

5.1.1.2 Image color map

The Image color map control determines which color scale algorithm to use (Linear, Logarithmic, Square Root, and Histogram Equalization), with Colormap and Intensity options to choose from as seen in Figure 17 below.

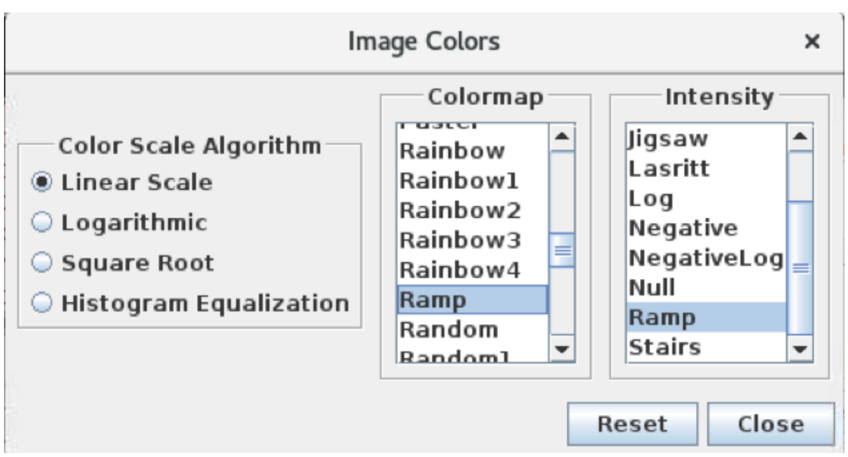


Figure 17 Image color maps and scaling

5.1.1.3 FITS header

The FITS header menu selection brings up a table of the FITS header keywords in the displayed image. The table contains columns for the keyword, the value, and the comment associated with the keyword.

5.2 Overlay Controls

The overlay controls menu contains checkbox menu items that determine whether cursors and markers on the image are visible. The following markers' visibility can be controlled using this menu:

(1) RA-DEC Grid
(2) Parallactic Angle
(3) Target Cursor
(4) Bullseye Cursor
(5) Telescope Boresight
(6) UCAC3 catalog

The RA-DEC grid and the parallactic angle are turned off by default and are turned on by checking the box. The Target and Bullseye cursor are used to move stars from one position in an image to another using the linked telescope controls. The telescope boresight is set at the center or the WIRC array.

5.3 Tools

The image display Tools menu provides a set of tools that are linked to the image or require image data to function. Many of these tools (e.g., guider controls, image compensation, telescope controls) support the backing data structures and functions that make controls on the main panel work (e.g., image compensation). These controls function in the same way as the ones on the main panel and may provide additional capabilities beyond those functions. For example, the image compensation controls on the main panel support background subtraction for the displayed image but not flat field division. The image compensation control supports flat field division in addition to background subtraction.

5.3.1 Exposure Controls

The Exposure control that is accessed from the Tools > Image Display Control> Tools > Exposure Control menu is a small frame containing only the most important controls into one small panel. This control includes an Expose button, a Guide button, and the controls for changing focus. The history of this control is that the telescope operators wanted a very simple control that would put only the most essential components on a small frame to declutter the desktop. The control is fully functional, and observers may use it for its original purpose if they wish.

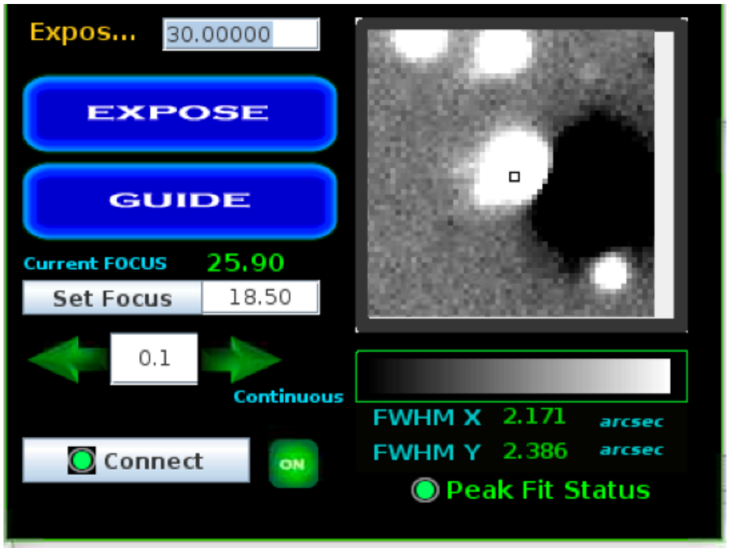


Figure 18 Exposure Control

5.3.2 Telescope Controls

The telescope controls panel is used to offset the telescope. This control is linked to the target and bullseye cursors and displays the RA and Dec coordinates of each, which are based on transforming X, Y pixel coordinates into RA and Dec coordinates using the WCS transform described by the WCS keywords in the image. The coordinates of the guide box cursor and the targeting box cursor are also displayed. Once the target and bullseye cursors are in the desired positions on the image, click "Move Target to Bullseye." The calculated telescope offset between the positions of the cursors is also displayed to the right of the arrows. There is also a "Move Target to Mask" button that operates in the same way. (See section 2.9.2.)

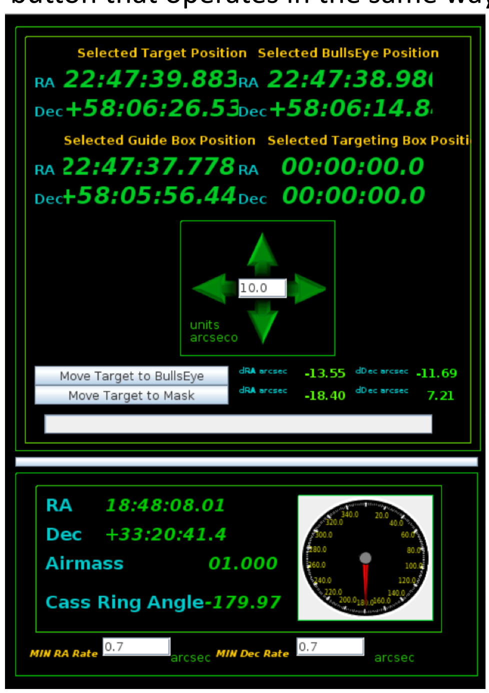


Figure 19 Telescope Control

If the software is connected to the P200 telescope, the 4 arrow controls turn green in color and are enabled. If the arrow controls are grey and not enabled, it means that the control socket to the TCS is not connected. The arrow controls offset the telescope to move the stars in the field the same direction as the arrow. The motion of the telescope is actually the opposite of the desired motion direction. For example, to move a star up (north), you need to move the telescope down (south). The arrow can be used to move the stars around the image by offsetting by the amount specified in the text field at the center of the arrows.

The bottom of the telescope control displays the current telescope right ascension (RA) and declination (Dec) as well as the airmass and the current Cassegrain ring angle.

5.3.3 Autofocus Control

The Autofocus control is accessible from the Tools > Image Display Control > Tools > Autofocus Controls menu item. When you open the control, you will see a graph dominating the left side of the frame and a table of focus vs. FWHM in both X and Y on the right side. At the bottom there is a Perform Autofocus button on the lower left and a progress bar directly below it.

The Autofocus control is linked to the guide box cursor in the Image Display control. The Autofocus control uses the location of the guide box cursor to extract a subarray for fitting a Gaussian to determine the FWHM. When the Perform Autofocus button is pressed, the telescope focus is first set to the Starting Focus value and an image is taken. Once the image has been acquired, the focus is offset by the specified Focus Increment and an image is taken again. This process continues until the number of images specified by the Steps spinner has been acquired. While the process is running, each time an image is acquired, the FWHM of the star in the guide box is determined and plotted in the graph in both X and Y as a function of focus position. When all of the images have been acquired, the code fits a parabola to the curve in X and Y and determines the inflection point for each curve (i.e., the minimum) and then calculates the best focus.

Autofocus Control

- The autofocus control sets up a sequence of images taken at different focus values.
- The observer specifies the starting focus value, the focus increment and the number of steps
- FWHM values are calculated using the star in the guide box on the image.
- Press the Perform Autofocus button to start the acquisition sequence.

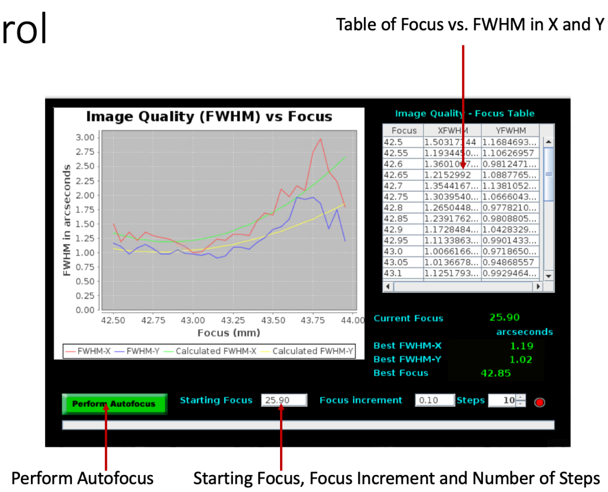


Figure 20 Autofocus Control

The graphs produced by the Autofocus control are obviously based on only one star but they can give a reasonable assessment of best focus. If the curve is very noisy you can use the files generated by the Autofocus control to run them through the Focus Graph tool (Tools > Sextractor > Focus Graph Analysis) that uses all of the stars in the image to determine best focus.

The telescope operator will have the focus set to the last best focus for the instrument. (If there is any question about this, you may ask the operator.) You typically want to produce a graph that starts below best focus and extends beyond best focus. If you think the telescope is near best focus you should use a 0.1 mm focus increment and set the starting focus as follows:
Starting Focus = Last Best Focus - ((Steps/2.0)*Focus Increment)
If the best focus position has not changed, this will produce a parabola centered at the last best focus position. Normally the focus will have changed at least slightly, and the center of the parabola will be shifted from the previous value.

5.3.4 Guider controls

The Guider controls are available on the Tools > Image Display Control > Tools > Guider Controls menu. The functionality of this control has been completely replaced by the controls now presented on the Auto Guiding tab of the main panel; however, this control still supports the data structures (i.e., array lists of selected guide stars) used by the newer controls on the Auto Guiding panel.

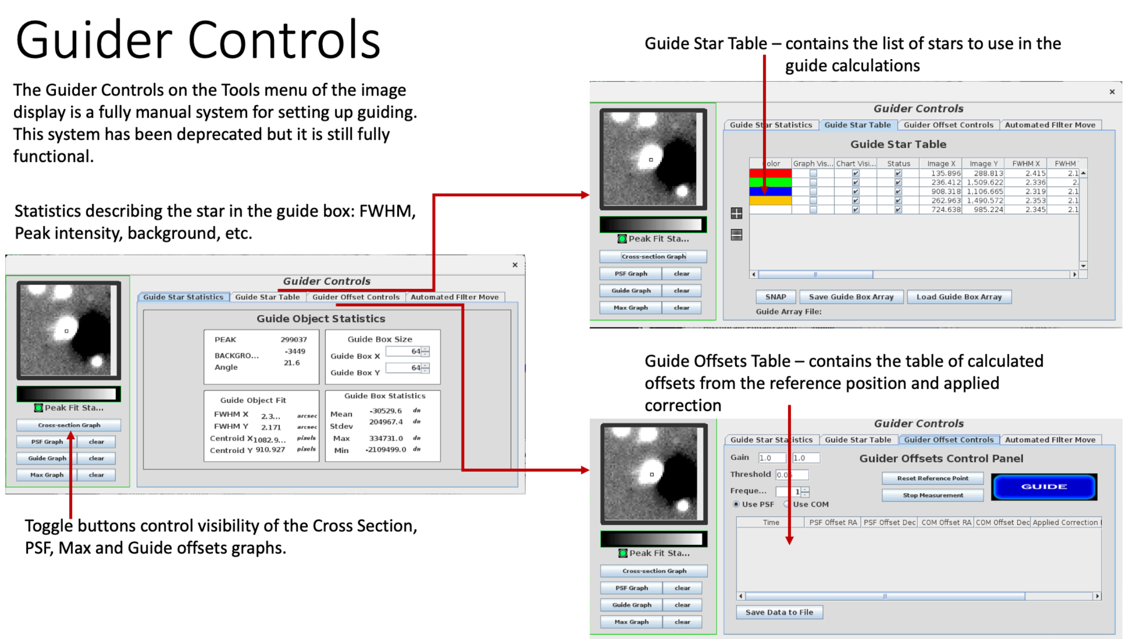


Figure 21 Manual Guider Controls

The Guide Star Statistics panel displays metrics calculated for the current position of the guide box cursor on the Image Display. You can control the size of the guide box using guide box X and Y spinner controls.

The Guide Star Table panel is used to maintain the currently active list of guide stars. To add guide stars to the table, click the plus sign so that it turns green, click on the star on the image display using the guide box cursor and the star will be added to the list. Click on each star you wish to add and when you're done remember to turn the plus sign back off. If you forget, you will get duplicates of the guide stars you just added when a new image is taken. If you wish to remove a guide star from the table, simply click on the row in the guide star table and then click the minus sign. Clicking the minus sign will remove the selected row from the table. Additionally, there are buttons at the bottom of this panel that can be used to save or retrieve the list of guide stars from disk.

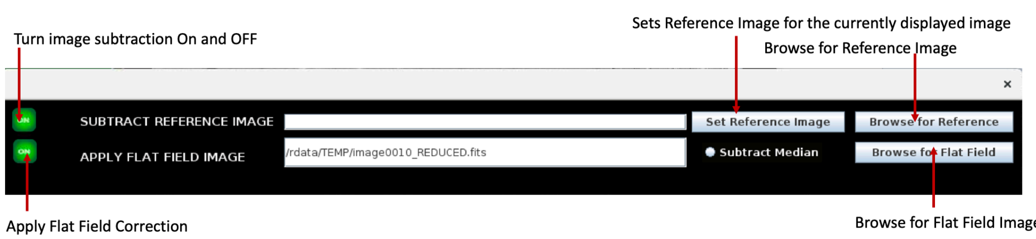
The Guider Offset Controls Panel contains a table of the calculated offset for each image. Each time an image is acquired, a new row is added to the table. The entries in the table are timestamped and record the offsets calculated by a Gaussian fit (PSF) to the stars' locations and offset produced by the center of mass algorithm. Guide parameters—including the gain in RA and Dec and the applied threshold and frequency—can be modified using the controls in the upper left corner of this panel. Whenever there are guide stars in the table, the offsets will automatically be calculated, and entries are made to the table; however, the offsets are not sent to the telescope unless the GUIDE button is activated. The GUIDE button only controls whether offsets are sent to the telescope. The Start Measurements/Stop Measurements button controls whether the calculations are carried out. By default, the system always calculates offsets but doesn't send them to the TCS unless requested.

The button of the left side of the display controls the visibility of the associated graphs. These graphs include the following:

(1) Cross-section graph
(2) PSF graph
(3) Guide offset graph
(4) Maximum graph

An image of the contents of the guide box cursor are displayed in an image control with an associated color bar in this panel, as well.

Image Compensation



- The Image Compensation control in the Image Display -> Tools menu is an active control and duplicates the image compensation controls on the Main GUI window.
- The application of Flat Field correction can only be done using this control.

Figure 22 Image Compensation - background subtraction and flat field correction

5.3.5 Image compensation

The Image Compensation control is used to configure whether the displayed image will have background subtraction and/or flat field correction applied before being displayed. The background subtraction can be configured from the WIRC-Pol main panel; those controls are essentially mirror those on this panel. The unique feature of the Image Compensation control is that it allows you to specify a flat field image and configure the system to divide the incoming frames by that image. To activate flat field division, you must provide the path to the flat field FITS image by pressing the Browse for Flat Field button and selecting the image. Once a flat field image is selected, the Apply Flat Field Image button is enabled and may be selected.

5.4 WIRC-Pol Script Controls

The WIRC-Pol instrument software supports a very simple scripting language. A script is a simple ASCII text file that contains one command per line terminated by a newline character (\n). Most commands are a simple keyword (e.g., EXPTIME) followed by a parameter and—in a few cases—more than one. The parameters are always separated from the keyword by a space and if more than one parameter is present, the different parameters are also separated by a space.

The File menu contains a submenu with Open, Save, and Save As options. The Open menu option brings up a file browser with the default directory as /observer/observer/scripts. The default directory is accessible from all the instrument computers and is the typical place to store scripts. When a file is opened, the entire file is displayed as text in the Script Editor panel and automatically parsed into commands and parameters to be displayed in the Commands Table panel. The Commands Table contains one row for each line in the ASCII file and it automatically assigns line numbers to the script. The table contains 4 columns: (1) state, (2) line number, (3) commands, and (4) parameters. While a script is running the “STATE” column becomes an indicator with a red color indicating that the command is currently executing. Once a command has been executed, the indicator column turns green.

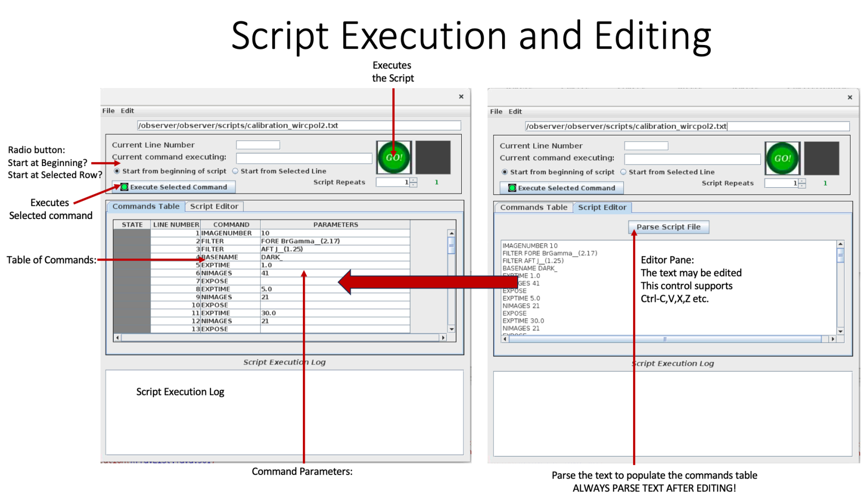


Figure 23 Scripting Language, Editing and Execution

You can use an external text editor to edit, save, and simply reload the file as needed. The best way, however, is to open the Script Editor panel and make any changes you wish. Once you have modified the text, you need to press the Parse Script File button to reparse the file and repopulate the Commands Table with the updated values. Once you have modified a script, you can save it to disk with the File > Save or Save As menu options.

Click the green GO button in the upper right corner of the WIRC-Pol Script Control panel to start running the script. The script will either start at the beginning of the file or on the selected line based on the selected radio button in the top panel. Once the script has started, the GO button changes to a PAUSE icon and an additional STOP button is activated. The observer is presented with a choice to either pause the execution of the script or to stop it completely. When you pause the execution, the script completes the current step and goes into a paused state, then changes the icon to "continue." If an exposure is currently in progress when you click PAUSE, the exposure is completed before the system transitions to the paused state. Similarly, if the telescope is currently moving, the system will wait for the move to be completed before entering the paused state. Stopping the execution also works in a similar way; the system will complete either an exposure or a telescope move before becoming ready again.

There are no "logic" functions in the scripting language. You can, however, repeat a script. There is a spinner control on the upper main panel of the scripting control that controls how many times the script is repeated before the execution is complete. Once the execution of the script is complete, the GO button will be reactivated, and the system is ready to run again.

Languages can always expand to make new words when the culture demands it. The command set available for controlling WIRC-Pol is extensive, but you still might find things you'd like to do in a script that aren't supported. If you find yourself in this position, please request the additional function. There is a good chance that on your next observing run using the instrument, the commands that you requested will be available.

Table of Script Commands

Options	Parameters
EXPOSURE PARAMETERS	
EXPTIME	exposure time in seconds (floating point)
COADDS	number of coadds (integer)
FOWLERS	number of fowler samples (integer)
NIMAGES	number of images (integer)
HEADER KEYWORDS	
OBSTYPE	observation type, which updates the header keyword (string)
OBJECT	this is the object name used to update the OBJECT header keyword
IMAGE NAME CONSTRUCTION	
BASENAME	the portion of the image name other than the image number

IMAGENUMBER		the image number appended to the end of the basename to create the image name
STATE COMMANDS		
EXPOSE		executes an exposure with the existing parameters
PAUSE		pause execution of the script
CONTINUE		continue the execution of the script
WAIT		wait for N milliseconds (integer)
TELESCOPE COMMANDS		
FOCUSGO		focus position in mm (floating point value)
FOCUSINC		offset the telescope focus by a given amount, (floating point number—positive or negative)
MOVE_TELESCOPE		offset the telescope by N arcseconds in RA, and M arcseconds in Dec (floating point numbers separated by a space)
DITHER COMMANDS		
SET_DITHER_PATTERN		sets the dither pattern name from the list in the dither.ini configuration file
SET_DITHER_SCALE		sets the scale factor used to multiply each coordinate in the pattern
RETRIEVE_DITHER_IMAGE		queries the DSS archive for an image centered at the current TCS coordinates
EXECUTE_DITHER		executes the currently select dither pattern
LAMP CONTROLS		
LOWLAMP	ON/OFF	turns the low lamp on or off
HIGHLAMP	ON/OFF	turns the high lamp on or off
ARCLAMP	ON/OFF	turns the arc lamp on or off
MECHANISMS		
FILTER	FORE/AFT	combined with a FORE or AFT specification, sets the current filter
POLARIZER	IN/OUT	inserts/removes the polarizer optic into/out of the optical path
WAVEPLATE	IN/OUT	inserts/removes the half-wave plate into/out of the optical path
POLARIZER_ANGLE		sets the rotation angle of the polarizer
WAVEPLATE_ANGLE		sets the rotation angle of the half-wave plate
MASK	IN/OUT	inserts/removes the mask into/out of the optical path

Most of the script commands are simple pairings of keywords and values (such as EXPTIME and COADDS), but some require multiple parameters (such as MOVE_TELESCOPE). Two of the polarizer mechanisms, POLARIZER and POLARIZER_ANGLE, are still supported in the code but the mechanisms are no longer functional and these commands should not be included in a script because the mechanisms cannot be initialized.

The only commands that may need further explanation are the dither commands. The dither control allows an observer to download a DSS (Digital Sky Survey) image of the telescope's current coordinates (RETRIEVE_DITHER_IMAGE). While it's not strictly necessary to download an image, the observer experience is significantly enhanced if you do. Downloading a reference image allows the observer to follow the execution of the dither by displaying an overlay on the image that depicts the current state of each requested image. In general, I recommend downloading a reference image, so the system works as intended. The SET_DITHER_PATTERN command accepts any of the names that are accessible from the pattern selection combo-box. One of the most frequent errors encountered is simply misspelling the name of the pattern and the code can't find a matching pattern to execute. If you have added your own dither pattern to the list, you can specify that pattern name as well. Most of the patterns are scaled with individual offsets between 0 and 1. You need to apply the SET_DITHER_SCALE command to transform the pattern to the actual offsets you wish you use. For example, the DITHER_5_SIMPLE pattern would offset the telescope by 1 arcsecond to form the pattern. If you set the dither scale to 10, the offsets will be 10 arcseconds, for 100 the offsets are 100 arcseconds, etc. The dither pattern is executed by including the EXECUTE_DITHER command in the script after the other commands have configured the system.

5.5 Dither Controls

The dither control contains a set of predefined dither patterns (e.g., 5-point, 9-point rectangular patterns) that are selected using the combo-box at the upper center of the main dither control. The patterns are typically defined by values between 0 and 1 and the executed pattern is then scaled by the scaling factor in the control directly below the combo-box. When you select a particular pattern and scale factor, the absolute X, Y coordinates of each dither position is presented in a table that dominates the right side of the control. The table of dither positions may be edited to modify the absolute coordinate of each dither position. When you edit a dither coordinate, there is no way to make this persistent. The modified value is active as long as the current pattern is selected but reverts to the default if the selected pattern is changed.

Dither Controls

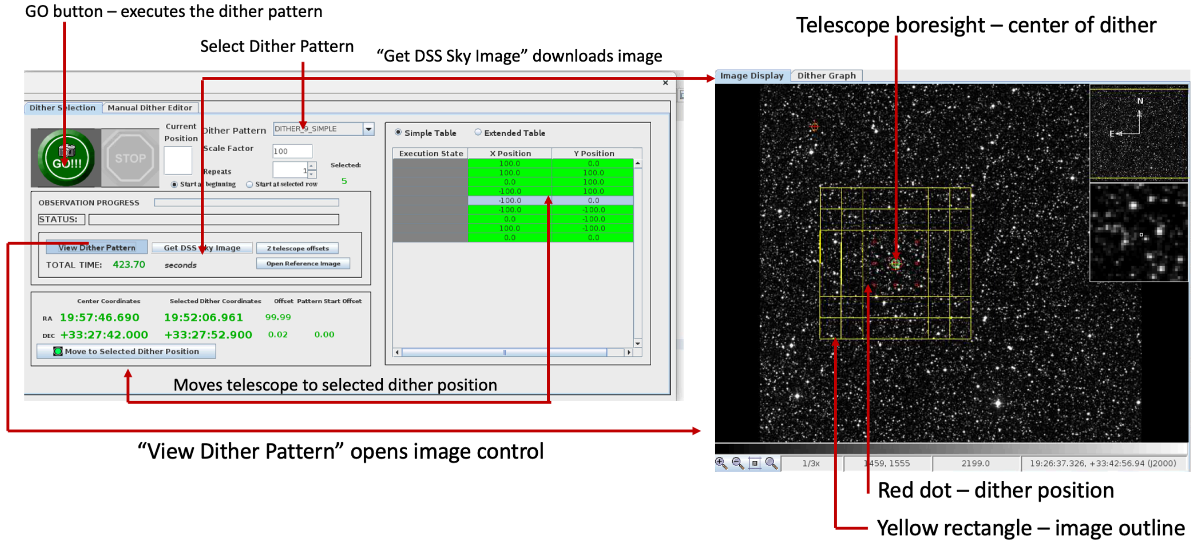


Figure 24 Dither Control - general overview

When you select a row in the table using the mouse, the RA and Dec coordinates of that position are displayed in the lower panel. The lower panel displays the current center of the dither pattern in RA and Dec, the coordinates of the selected dither position in RA and Dec, and the relative offset in arcseconds required to move to that position. The "Move to Selected Dither Position" button allows the observer to move the telescope to the selected dither position. Using this button, the observer can manually carry out the entire dither by moving to each position in turn and taking an image manually. The primary use for this function is to fill in patterns that had to be aborted due to weather issues. For example, if you completed 7 out of the 9 images in a pattern when the weather required the dome to close, you can use the "Move to Selected Dither Position" button to fill in positions 8 and 9 when you are able to resume observations.

The following are the recommended steps for carrying out a dither pattern.

(1) Optional: Download a DSS sky survey image. This is an optional step and takes about 30 seconds. When you download a DSS image, the system acquires a 30 x 30 arcminute image centered at the current telescope coordinates. The system uses this image as the background for displaying the dither pattern as it will be executed on-sky.
(2) Select the dither pattern you wish to use from the combo-box.
(3) Open the "View Dither Pattern" display. If you downloaded an image, the dither pattern will appear as an overlay on the image. If you didn't download an image, you can select the graph tab and a chart of the dither positions will be displayed.
(4) Adjust the scale factor. When you change the scale factor from 1 to some other number, the entire pattern is scaled by the entered scale factor. When you hit the enter key in the scale factor control, it forces the pattern to be recalculated and the graph and image overlay update simultaneously.

(5) Examine the image overlay. Is the pattern big enough to cover the observing area of interest? Is the pattern too large with too much of the field only covered by one or two images? You can adjust the size of the pattern by adjusting the scale factor.
(6) Is the telescope pointing exactly where you want it? You can move the telescope using the target to bullseye controls on the image display or you can simply ask the telescope operator to offset the telescope. You can watch the telescope move by watching the DSS image and the dither overlay. Once you're satisfied with the selected field, go on to the next step.
(7) An image will be acquired for each dither position using the parameters on the main WIRC-Pol GUI. You can even specify that multiple images be taken at each position using the Number of Images control. Set up the parameters (such as exposure time, coadds), the filters, and/or mechanism states prior to actually starting the dither execution. Once all of the parameters are specified, go to the next step.
(8) Optional: Z the telescope offsets. When you Z the telescope offsets before starting a dither, you can use the telescope display to determine the current offset from the start position. It is not necessary to do this, but it does allow you to monitor the motion during execution.
(9) Press the GO button to start the dither sequence. The GO button icon will change to PAUSE and the STOP button becomes active. The dither position in the table will have its execution state field turn from grey to red while the exposure is running. Once an exposure is complete, the execution state will change to green. Similarly, the dither overlay on the DSS image will have the outline of the current position change to red while it's being observed and then to green once it's completed.
(10) While the dither pattern is running, the progress bar will show the current percentage of the entire dither pattern that has been completed. The current dither position number will also be displayed to the right of the STOP button.
(11) While the dither is executing, the observer may PAUSE the execution of the pattern at any point. When the PAUSE button is pressed, the icon changes to CONTINUE. Note that the system will finish whatever step it is currently executing before truly becoming paused. If an exposure is executing, it will complete before the system enters the paused state. Similarly, if the telescope is moving, the move will be completed before the system becomes paused. Pressing the CONTINUE button when it is active will resume the pattern with the next step in the sequence (i.e., either exposure or telescope move). The STOP or PAUSE button activated during a telescope move always allows the move to complete before transitioning to the next state (i.e., either paused or stopped).
(12) The STOP button brings up a dialog box that asks if you wish to complete the current exposure or to abort it. When you press STOP during an exposure, you can choose to stop immediately and ABORT the current exposure or wait for the current image to be completed. If you choose to wait, the PAUSE and STOP buttons are disabled until the current exposure is complete. Once the system has stopped, the GO button is activated again and the colors of the execution state and dither overlays return to the defaults.

The default set of dither patterns is extensive (~ 38 in number) with the 5-point and 9-point rectangular patterns being the most used. There is a rather large set of 5-point and 9-point random dithers that can be selected, as well. In some cases, a random pattern eliminates some data reduction problems where the rectangular pattern imprints on the result. There are also three 27-point patterns that were randomly generated for the same reason. If you intend to use a particular pattern repeatedly and would like it added to the defaults, please inform the support astronomer and they can request that it be added to the defaults. What if none of the default patterns work for your observing? See the next section.

5.5.1 Editing a Dither Pattern

A dither pattern is essentially an ASCII text file containing two columns of numbers. The columns may be separated by any delimiter with the most common being the comma, space, and tab. Almost everyone has a particular dither pattern that they have used in the past that they like. There are hundreds of files in the /obs/obs/dither directory that describe different patterns. Observers are free to place dither definition files in folders they create. The Manual Dither Editor tab contains controls to read dither definition files and make them available during observing.

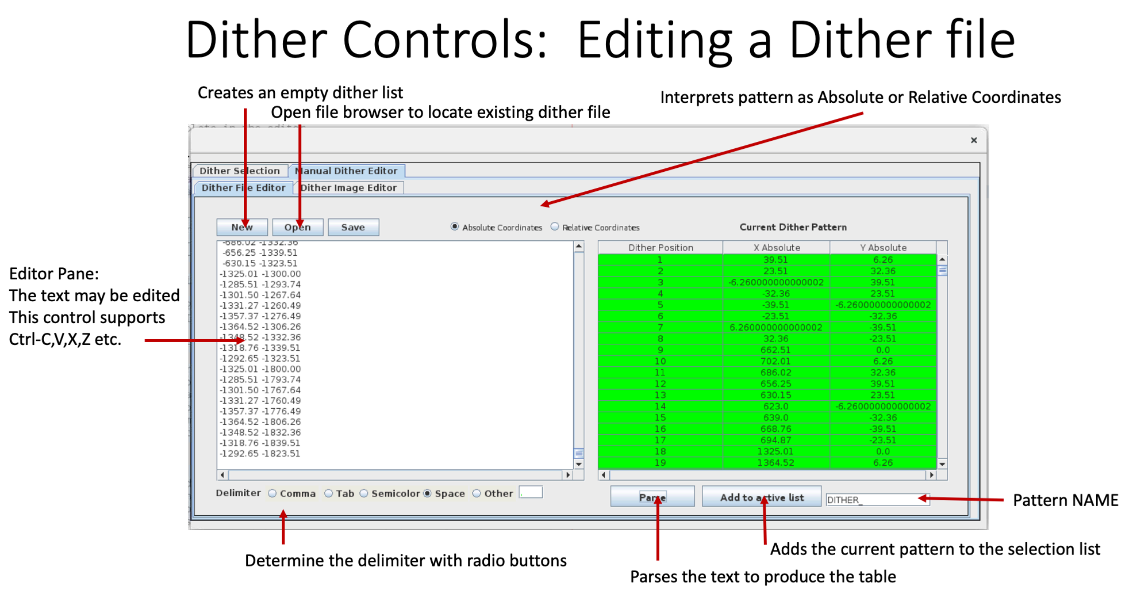


Figure 25 Dither Controls: Editing a Dither file

The Manual Dither Editor works with ASCII files that are stored in the /obs/obs/dither directory. Not all of the dither pattern files in this directory can be read, but most of them work if you select the correct delimiter. To edit an existing dither definition file, press the Open button and you can browse to the location of the file. Once the file has been opened, the file's contents will be displayed in the text area on the left side of the dialog. The format of the file should be quite simple: two columns of numbers separated by a character. You can specify what the delimiter is using the set of radio buttons below the text area. The default is a comma as the delimiter, but many files use either a space or a tab. Once you've selected the delimiter, click the Parse button to convert the text into a table of offsets or positions (relative vs. absolute coordinates).

All dither patterns are centered at the current telescope coordinates as the 0,0 position. If the pattern is interpreted in absolute terms, then each line represents the X,Y position of the dither position relative to the current telescope coordinates. If the pattern is interpreted in relative terms, then each line represents the offset to the next position in the pattern. The code can easily transform relative coordinates to absolute coordinates and vice versa.

The area containing the text to parse supports editing so you can make any changes to the file. You can use ctrl-X, ctrl-C, ctrl-V, etc. to copy, cut, and paste within the text area. You will need to re-parse the file after editing so the changes show up in the table.

Once you are happy with the way the system parsed your dither file, you need to add the dither to the list of available patterns. When you press the "Add to active list" button the system adds the dither pattern to the end of the list of selectable patterns and automatically selects it. Using the DSS image display visualizes the pattern and uses the scale control to modify the way the pattern appears on the sky. A dither pattern must have a name; the name is determined by the entry in the text field to the right of the "Apply to active list" button. If the pattern name you specify conflicts with an existing dither name, a dialog will pop up and request that you change the name to a unique, unused identifier.

5.5.2 Image Dither Editor

The "Dither Image Editor" is a unique way to specify a dither pattern. This control is linked to the DSS image display and allows you to create a pattern using the mouse. To use this control, you need to download an image of the current telescope position and open the image viewer. You can create a custom dither pattern using the following steps.

(1) Make sure the telescope is tracking.
(2) Download a DSS image of the field.
(3) Open the DSS image display.
(4) Open the "Dither Image Editor" tab
(5) Press the "Engage Editing Mode" button.
(6) Left-mouse click on the image. Each mouse click will add a row to the table.
(7) Once you have added all the dither positions, turn off the "Engage Editing Mode."
(8) Make the pattern available in the selection combo-box by pressing the "Add to Dither List" button. The name must be unique and not currently in the list of dither patterns. If the name is already in the list, a dialog will prompt the user to change the name.
(9) Optional: Save the dither to an external file on disk. Pressing the "Save" button opens a file browser dialog and you can specify a name for the file and where it should be stored.

Dither Control: Image Dither Editor

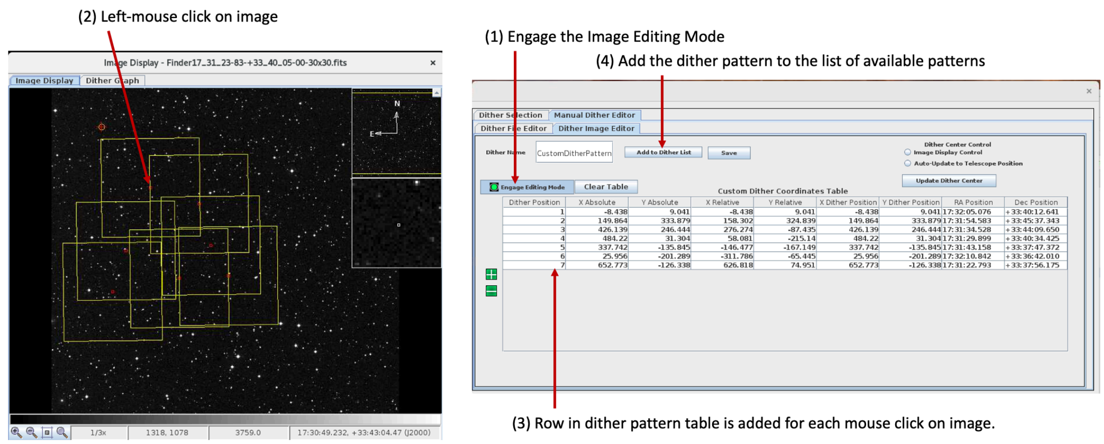


Figure 26 Dither Control: Image dither editing

If you created a position that you no longer wish to have in the table, select the row and then press the green "-" button to the left of the dither table. If you wish to start over, you can clear the table using the "Clear Table" button.

The dither control can be very simple to use; select a pattern, scale it, and press GO. You do not need to use the visualization tools to make the system work. However, the DSS image display provides more feedback to the observer during operation and can be extremely useful.

5.6 Filter Wheel Controls

Most of the time observers will use the filter selection controls on the main panel to change the filter; however, occasionally the mechanism needs to be reinitialized and the observer needs to access the dedicated filter control panel. The filter wheel control is accessible from the Tools > WIRC Filter Wheel Controls menu option.

At the top of the panel are two toggle buttons: (1) Connect to Filter Wheel and (2) Motor Init. The Connect to Filter Wheel button has an indicator light that will be green if the connection is successful. The system attempts to connect to the filter wheel module in the server and retrieve the list of installed filters. If the indicator is red on this button, it means that the connection to the filter wheel module was unsuccessful. In this event, ask the support astronomer to check the RS232 connection to the filter mechanism and to reinitialize the filter control module directly from the command line. Once the problem has been corrected, you can press the Connect to Filter Wheel button and it will connect, retrieve the list of filters in the fore and aft wheels, and display the filters currently in the optical path.

Filter Wheel Controls

- The Filter Wheel controls represent an expanded view of the filter control system compared to the simple controls on the main panel.
- These controls are particularly useful when debugging initialization issues or when you encounter problems.
- This control provides the same mechanism controls as the ones on the main panel but with additional status information available.

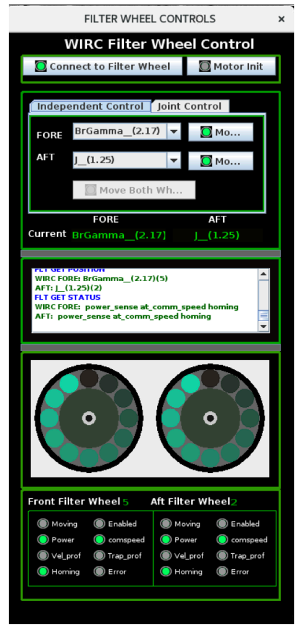


Figure 27 Filter Wheel Controls

If one or more of the current filters (see current filter fore and aft text boxes on the control) appear as "not named," then the filter wheel module needs to be initialized. In the upper right corner of the control there is a "Motor Init" button that becomes active once the connection to the filter wheels is established. Pressing the "Motor Init" button forces both wheels to go through a homing sequence and reestablishes the correct current filters, which may take a couple of minutes. You should see the filter names changing as the wheels are rotated.

The middle of the control panel has a small text field where the commands set to the ArcVIEW server are displayed in blue and the responses from the server are displayed in green. The wheel icons should rotate while the wheels are moving, and additional information is displayed in the set of indicators at the bottom of the control. The indicators are green if activated or grey if not. These indicators provide low-level information about what the mechanism is doing. For example, one or more of the indicators will be active whenever the mechanism is active, including the status of homing, motion, and power to name a few.

Directly under the "Connect to Filter Wheel" button there are controls for selecting a filter and moving that filter into the optical path. There are two tabs in the panel: (1) Independent Control and (2) Joint Control. Observers are cautioned that the wheels should be moved independently, and the Joint Controls should be avoided. The joint controls stopped working properly after the filter locations were modified to support polarization observations. The process for selecting a filter combination follows:

(1) Select the filter in the FORE combo-box.
(2) Press the associated MOVE button.
(3) The Move button indicator turns RED while the move is in progress.
(4) The Move button indicator turns back to GREEN once the move is complete.
(5) Repeat steps 1 through 4 for the AFT wheel.

In general, observers should not need to work with the WIRC Filter Wheel Controls panel since the software is started by the support astronomers. Observers will need to worry about the filter wheels only if the server needs to be restarted during the night. The “Connect to Filter Wheel” and “Motor Init” buttons are probably the only controls that the user needs to work with.

Changing the filters in one or both of the wheels is a major project, so you only have the filters that are installed to choose from. The filter wheels are inside the dewar and cannot be changed with opening the instrument. The following table shows the location and name of each filter in both the fore and aft wheels.

	Fore	**Aft**
1	PG	H2 (2.12)
2	Diffuser	K-cont (2.27)
3	H-cont (1.57)	H (1.64)
4	CO (2.29)	J (1.25)
5	Open	Ks (2.15)
6	GRISM	Open
7	BrGamma (2.17)	He

Table of installed filters as of 9-19-2023

5.7 Mask Mechanism Controls

The mask mechanism inserts a mask into the optical path that is essential for making polarization measurements. The mask control GUI is accessible from the Tools > WIRC-Pol Mask Mechanism Controls menu option. The GUI is very simple and can automatically connect to the mechanism controller when the software starts. There is a Connect button on the front panel with an indicator light that turns green when the connection is made. The mechanism is automatically initialized when the connection is established and places the mask out of the optical path. There is an animated GIF that simulates the mask being inserted or removed and this GIF should reflect the current state of the mechanism. Once the connection has been established, the “Insert Mask” button will be enabled. If the mask is inserted, the “Remove Mask” button is enabled and the “Insert Mask” button is disabled. Once the mask mechanism has been initialized, you can close the control and insert/remove the mask using the controls on the main panel.

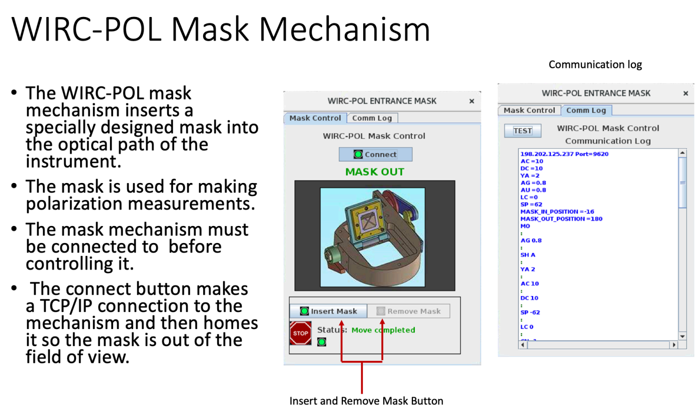


Figure 28 WIRC-POL Mask Mechanism

The Comm Log tab displays a log of the communication between the mechanism controller and the software. This display is useful particularly when you need to debug a problem. You can perform a mechanism test using the Test button on the panel. The mechanism "Test" first inserts the mask into the optical path and then removes it. In the process it sends commands to the controller that can be monitored in the communication log.

5.8 Polarization Mechanisms – Newport Controller

The presence of two slide mechanisms at the front of the instrument are what turns WIRC into WIRC-Pol. The slide mechanisms insert optics into the optical path that are mounted within rotation mechanisms that allow them to rotate. In total, there are 4 mechanisms (2 slides, 2 rotators) and they are all controlled by a Newport XPS-D ethernet-based mechanism controller. All four mechanisms are controlled via TCP/IP socket connections to the XPS-D controller.

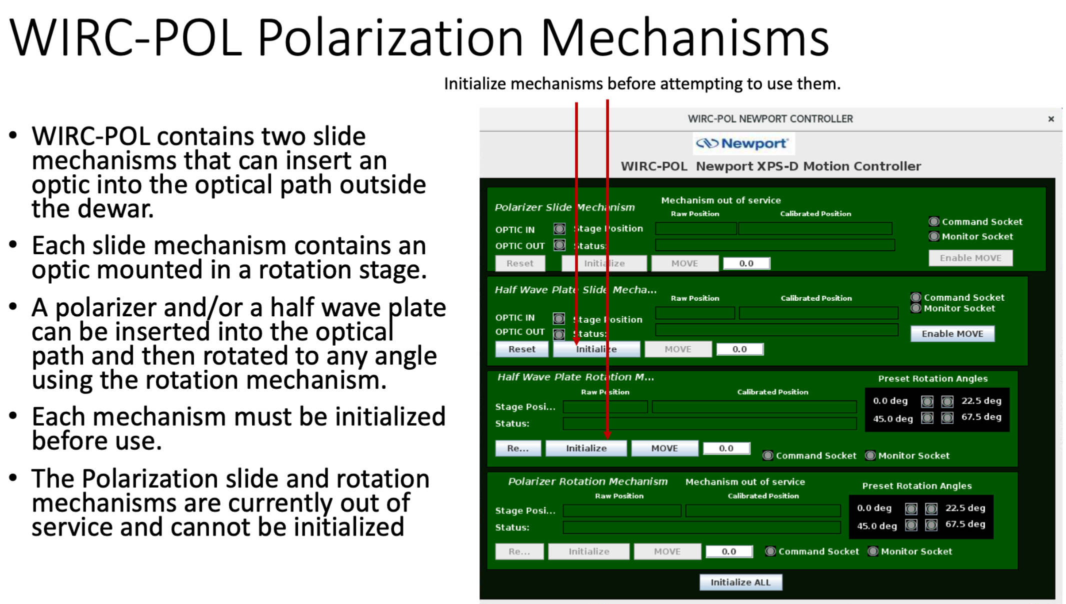


Figure 29 WIRC-POL Polarization Mechanisms

The Tools > WIRC-Pol Newport Controller menu item displays the detailed instrument controls for all four mechanisms. The most import of these controls is the "Initialize" button that establishes the socket connections and then homes the mechanisms and put them into the default state (i.e., optics out of the optical path, at default rotation angle). By default, these mechanisms are automatically initialized when the software is opened. All the other buttons and controls are disabled until initialization is complete.

The two slide mechanisms (i.e., polarization optic, half-wave plate optic) have equivalent control panels. When the mechanism is initialized, it displays the status of the command and monitoring sockets with a green indicator light if the connection is successful. The state of the slide mechanism is indicated by the OPTIC IN and OPTIC OUT indicator lights displayed on the buttons. The stage position and a status message are also displayed in text in the middle of each controller panel. By default, the observer can only insert or remove the optic. If you need to debug an issue that requires moving the mechanism to an intermediate position, you must first enable the move by selecting the "Enable Move" button. Selecting this button enables the Move button on the same panel. You can then move the mechanism to any intermediate motor position by entering the motor step position in the text field to the right of the Move button. Verification that the move is taking place is provided by the changing stage position and status messages.

The two rotation mechanisms have control panels that are designed to allow the optics to be rotated. If the initialization is successful, the command and monitoring socket indicator lights are turned green. The stage position and a status message are displayed in the panel and update visually when the mechanism is active. When the rotation mechanisms are used while making polarization measurements, it is typical to set the rotation to one of 4 preset positions: (1) 0 degrees, (2) 22.5 degrees, (3) 45 degrees and (4) 67.5 degrees. Each of the 4 preset position indicators is a button that turns red while the move is in progress and then green when the mechanism is at the desired rotation. The preset rotation angle controls are replicated on the WIRC-Pol main panel. If necessary, the Move button and the associated text field can be used to rotate the optic to an arbitrary angle.

At the time of this writing, the polarization slide mechanism and the associated rotator are out of service and the controls are intentionally disabled. Only the half-wave plate slide and its associated rotator are currently in service. The polarization mechanism was necessary when the system was being calibrated, but is not required when making polarization measurements. There are no plans to put the polarization slide and its rotation mechanism back into service. The Initialize button is disabled after initialization. If you need to reinitialize the mechanism for some reason, you can repeat the initialization by pressing the Reset button.

5.9 Sextractor source analysis

Sextractor is an analytical tool developed by Emanuel Bertin that is extremely useful for extracting star positions from an image. The intention in this section is not to teach an observer how to use Sextractor but to explain how it's integrated into the WIRC-Pol code. The Tools > Sextractor Source Analysis menu item pulls up a GUI that can be used to run Sextractor from within the WIRC-Pol software. When an image is produced by the WIRC-Pol software, the file's path is automatically added to the "Select Fits Image" text field.

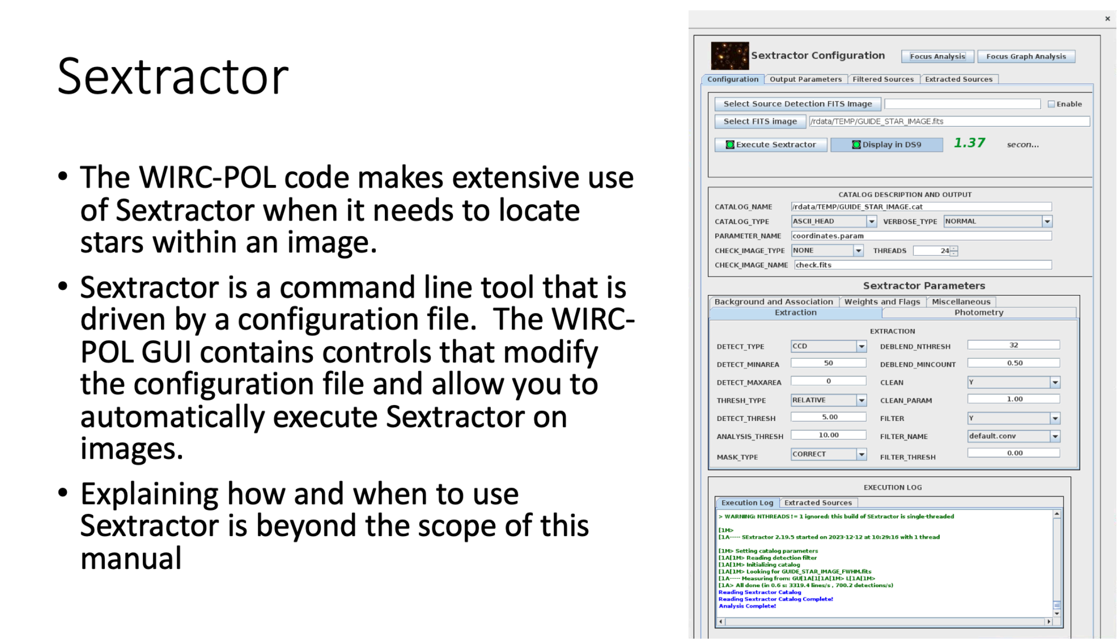


Figure 30 Sextractor

Sextractor works by running a command in a terminal and passing it a configuration file with the parameters to be used in the extraction along with the path to the file to be examined. The code constructs the required configuration file based on the entries in the GUI, and then constructs the command line to execute within the terminal. Once the analysis has been completed, the output of Sextractor is parsed and the sources are displayed in the "Extracted

Sources" panel. Sometimes the list of extracted sources needs to be filtered to remove overlapping stars, reject saturated stars, and cosmic rays that are mistaken for stars by the algorithm. The Filtered Sources tab contains controls for configuring the filtering such as setting the minimum distance between stars. You can plot a histogram of the signal-to-noise, flux, or focus (i.e., FWHM) based on the filtered list.

Sextractor can calculate a very large number of parameters. It determines which parameters to calculate based upon a file provided on the command line that lists the parameter names. The Output Parameters may be configured on the Output Parameters tab. The way this works is by having a set of configurations that have predefined lists of parameters for Sextractor to calculate. The following predefined parameter lists are available by default:

(1) Coordinates Only
(2) Pixel Coordinates Only
(3) World Coordinates Only
(4) Scamp Output Configuration
(5) Out-of-Focus Donut Configuration
(6) Custom output configuration

By default, the Out-of-Focus Donut Configuration is used because it constructs focus surfaces, using the donut method for determining best focus. The Scamp configuration is required if you intend to use Scamp to solve the astrometric solution for the image and produces catalogs in the required format.

The Sextractor control panel is not intended as a fully functional system for configuring and running Sextractor. The code is primarily intended to provide support for star selection for guiding and as a systematic way of determining the current seeing.

5.9.1 Focus Analysis

Once you have determined the location of all of the stars in an image by running Sextractor, you can easily evaluate the seeing in the image. The Tools > Sextractor > Focus Analysis button opens a display that operates on the current list of sources identified by Sextractor. Pressing the "Focus Analysis" button in the top left corner of the panel fits a Gaussian to each star in the list and constructs a histogram of the FWHM values. The mean, median, and standard deviation of the FWHM distribution is displayed under the histogram. The median is by the far the best measure of this distribution since a few galaxies can skew the mean to the high side and the hot pixels in the image can skew the value lower. If you are seeing cosmic rays and hot pixels being confused with stars, try increasing the DETECT_MINAREA parameter on the Sextractor main panel. Increasing this value effectively rejects cosmic rays and hot pixels from the FWHM histogram distribution.

The bottom half of the focus analysis display contains a table that presents the coordinates of each located star, the FWHM, astigmatism, peak intensity, and background intensity. Above the histogram is a panel that allows you to segment the image into a grid and calculate the mean value of the FWHM for each grid cell. The grid spacing is set by the Grid Spacing spinner control in the upper right corner of the "Focus Map Analysis" panel. The process button allows you to export the grid file as both a text file and a FITS image. This function can produce useful information—particularly if the image is of a densely populated portion of the galactic field where you have multiple stars in each grid unit. If you want to use this function, choose a field with lots of stars that are not overlapping (i.e., no closed clusters). You can also display the focus and astigmatism surfaces as mesh graphs by pressing the "Construct Focus Surface" or "Construct Astigmatism Surface."

5.9.2 Focus Graph Analysis

When you're focusing using the Tools >Image Display Control > Tools > Autofocus Controls, you are basing your estimate of focus using a single star. Why not take all the stars into account? You can do this with the Focus Graph Analysis panel.

Let's assume that you have already run the Autofocus and you created a set of files at different focus values. The "Focus Graph Tool" has a button in the upper left corner that will bring up a file browser and allow you to select the set of focus images. Once you select the images, they will appear as a list in the viewport below the button. Once the files have been selected, simply press the Process button. Each image will be processed by Sextractor, and if you check the "Perform Gaussian Fit" checkbox, a Gaussian fit will be done on each identified star.

A graph of the FWHM as a function of focus value is displayed in the lower right corner of the "Focus Graph Tool." A similar graph of the donut metric as a function of focus value is displayed in the lower left corner. The donut metric is essentially a measure of the area of the point spread function that can be used to evaluate focus when the images are too far out of focus to fit with Gaussians.

6.0 Using the Instrument

6.1 Calibrations

There are quite a few ways you can obtain calibrations, but the simplest is probably to write a script to carry out the observations automatically. There's a good chance that a script already exists to do what you need to do. Look through the scripts folder and find a script that's close to what you need to do. Make a copy of the script in the same folder and reopen it. Now you can modify the script to meet your needs.

To reduce the data later you need the following calibration images:

(1) Bias frames: Insert Br-gamma 2.25 in the FORE wheel and J_1.25 in the AFT wheel.)
(2) Dark frames: If you're doing exposures long enough to warrant them, you will need multiple frames at each exposure time you intend to use during observing.
(3) Flat Field Images: You will need a set of flat field images in each of the filters you're planning to use. The optimum signal level is ~ 60% of full well capacity. Make sure that the image is not saturated.

Everyone has a particular way they wish to reduce their data and therefore everyone needs slightly different calibration sets. It's simple to take bias frames by putting in the blocking filters, setting the exposure time to the minimum (0.923 seconds), putting the system in continuous mode, and pressing the GO button. The system will continuously take images until you disable the continuous button. But when you're taking darks or flat field images, you need to change the exposure time or filters, respectively. It's much easier to setup a script once (or modify one) and then just let the scripting system carry out your calibration observation. The one thing to be careful of is to really check that you've spelled the filter names correctly. The code isn't smart enough to guess what you meant when you used J as the filter name rather than J_(1.25). The code will detect the error but it will just print the warning to the execution log and you might not have noticed it.

When you're taking flat field images with the dome closed, you can specify which lamps to turn on/off for each filter. Check the exposure time and lamp you're using for each filter and take an image with those settings before starting your script. Palomar staff will open the mirror covers for you.

You can also take flat field images at dawn or dusk by letting the telescope drift (i.e., don't track) and taking enough images that any stars are removed when the images are median combined. The hardest thing about taking sky flats is that the sky is constantly changing (getting darker or lighter), and you may need to keep changing the exposure time to avoid saturation or to get enough signal. You want to measure the flat field structure with good signal-to-noise and you don't want to saturate the image. In general, sky flats can create better corrections, but they are more difficult to get right.

7.0 First Steps when On-Sky

8.0 Calibrate the image coordinates, Pointing

Verifying telescope pointing is a simple process where the telescope operator slews to a bright star in the SAO catalog. You may discover that the star will land exactly at the center (marked by the telescope boresight marker) of the image. Typically, the star will be close but not quite on the center pixel. You can use the "Move Target to Bullseye" function to place the star directly at the image center or offset into a quadrant. Once you've placed the star where you want it, ask the telescope operator to "X" to set the telescope pointing at this location.

When you first get on-sky after completing your calibrations, there are a couple of things you need to do. After verifying pointing, focusing is next. The telescope operator will have set the focus to the last best focus. Take an image, place the guide box cursor on a star and check the FWHM. Here are several ways to obtain best focus:

7.1 Focus: Manual Method

(1) Select a star in the image (not saturated but bright enough to measure easily) and place the guide box cursor on it.
(2) Open the PSF graph. Make sure that measurements are enabled and clear the graph.
(3) Engage the Continuous button.
(4) Press the GO button to start taking images.
(5) Watch the PSF graph begin plotting.
(6) On the main panel's "Telescope" tab, increment the focus in one direction using the focus offset arrows. Continue taking images and offsetting the focus value until you find the minimum FWHM.

(7) Optional: Once you're happy with the focus, take an image and then run it through Sextractor and the Focus Map control to record the best focus and report it to the telescope operator.

7.2 Focus: Autofocus Control

The easiest way to get best focus is to open the Autofocus control (Image Display Controls > Tools > Autofocus). Set the starting focus value to a value below the estimated best focus. Set the focus increment (0.2 for a coarse pass, 0.1 for a fine pass) and number of focus steps (default = 10) and press the "Perform Autofocus" button. The code will take an image, increment focus, and repeat until the total number of images has been fulfilled. Once the function completes, it will return the "Perform Autofocus" icon (icon changes to "Stop Autofocus" while it's running) and calculate the best focus based on fitting parabolas to the focus curve in both X and Y. The parabolic fit may not work very well if you haven't sampled both sides of the well correctly or if the signal is noisy. As a result, you may be better able to identify the parabolas' minima by eye. Verify that the telescope is at the best focus at the end of the process.

7.3 Focus: Scripting

One of the easiest scripts to write is a focus script. You can focus the instrument by running a script that follows this formula:

(1) Set the initial focus (FOCUSGO) to a value below best focus
(2) Take an image
(3) Increment the focus (FOCUSINC) by a small amount (0.05 to 0.2)
(4) Take another image
(5) Repeat steps 3 and 4 until you're well above focus (between 10 and 20 steps)

Once the script has completed, open the Tools > Sextractor > Focus Graph Analysis panel and add the image files you just created to the list. Press the Process button and the code will run Sextractor on each image and calculate and plot the median FWHM and the Donut metric (for very out-of-focus images) as a function of focus value. There should be a much stronger and less noisy signal of the seeing measurement since the plotted values are based on all of the stars in the field. This method will produce the best estimate of focus, but it does take a little more effort. If you want the best results, use a crowded galactic plane field with several thousand detectable stars in the image. Try to avoid closed clusters where it's difficult to separate one star from its neighbors.

9.0 Typical Observing Scenarios

Here are a few comments on a couple of the more common observing scenarios.

9.1 Transiting exoplanet light curves

WIRC-Pol has been used many times to measure light curves, particularly light curves for exoplanets transiting their stars. The guiding system was originally devised to improve the instrument's ability to measure light curves.

When you are measuring the flux of a star, you don't want the star moving during the observation because it increases the noise. Ideally, you want the star to fall on the same pixels throughout your observation sequence. If the star is very sharp and well-focused it will fall on a very small number of pixels and even small position shifts could generate large flux changes. To get around this, we would defocus the telescope slightly to increase the number of pixels the light falls on. When you defocus the telescope, you may not be able to use the Gaussian fit algorithm to monitor telescope offsets because the Gaussian algorithm simply won't fit an out-of-focus donut. The center of mass algorithm was developed to allow out-of-focus images to allow guiding in this circumstance. When we were first measuring light curves with WIRC this was the pattern: Defocus the telescope, then use center of mass for guiding, then apply background subtraction and flat fielding in real time.

The current filter list contains a diffuser in the FORE wheel that can be combined with any of the broadband filters in the AFT wheel. The diffuser spreads out the point spread function like defocusing the image does; however, the PSF with the diffuser in the optical path still produces point spread functions that can be accurately assessed by the Gaussian fit algorithm. Including the diffuser in the WIRC-Pol instrument simplifies measuring exoplanet light curves.

Here are the steps you should take when you're measuring a light curve:

(1) Identify the target star in the image and place the guide box cursor on it.
(2) Open the cross-section graph so you can assess the signal-to-noise for the given exposure time.
(3) Make sure that you have a good sky background to subtract and set it up to be automatically subtracted.
(4) Open the Autoguiding panel and press the Locate Guide Stars button. Examine the cross-section for each of the selected stars and reject those that are either saturated or with insufficient signal-to-noise.
(5) Once you're happy with the set of guide stars, save the list so it can be retrieved in case of emergency. You may have to increase the number of guide stars requested if you need to reject too many.
(6) Turn on continuous mode.
(7) Press GO button.
(8) While the observations are being carried out, monitor the guide graph, the cross-section of the target star and the maximum graph. These graphs will help you assess how the sky is changing during your observation.
(9) Often the sky background changes over the course of the night (i.e., moonlight, city lights, etc.) and you want to have a consistently good background image to be subtracted. If you need to take a background image, you can turn off continuous imaging, wait for the system to stop, offset to the background position, take an image, set the current image as the background, return to your original location, turn on continuous imaging, and press GO. If you have done this quickly enough (within a few minutes) the stars should still be in the guide boxes and the light curve measurement can continue. If they aren't, use the paddles to nudge them inside.

The WIRC-Pol guiding software should allow you to keep your target star within +/- 1-2 pixels over the course of an entire night's observing.

9.2 Dithering

Dithering in multiple filters is one of the more common observing scenarios. It's simple enough to implement manually: Open the dither control, run a dither pattern, then change the filter and rerun the dither pattern in the second filter. You can follow this pattern to write a simple script that will execute the pattern 3 times with different exposure times and different filters. The following is an example script that will acquire 3 dither patterns of 5 images each in three different filters (J,H, and K). This script can be easily extended to acquire complex sets of multi-band images with the WIRC-Pol instrument.

```
RETRIEVE_DITHER_IMAGE
SET_DITHER_PATTERN DITHER_5_SIMPLE
SET_DITHER_SCALE 100.0
IMAGENUMBER 10
FILTER FORE OPEN
FILTER AFT J_(1.25)
EXPTIME 120.0
EXECUTE_DITHER
IMAGENUMBER 20
FILTER AFT H_(1.64)
EXPTIME 60.0
EXECUTE_DITHER
IMAGENUMBER 30
FILTER AFT Ks_(2.15)
EXPTIME 30.0
EXECUTE_DITHER
```

10.0 In Conclusion

The software described in this manual represents an attempt to simplify and streamline the interface to the WIRC-Pol instrument. Particular attention has been put on improving the dither control system and implementing auto-selection of guide stars. The goal has been to simplify the interface and remove components that are rarely used. The auto=selection of guide stars is probably the biggest new feature added to this build. The dither control has been plagued by problems—particularly when attempting to stop a dither in the middle of execution. The focus has been on improving the reliability of the components—particularly during aborts or attempts to stop execution. The other concern was to create a small, simple control from the large and rather complex control that was available in WIRC-Pol-2

The build documented here is deployed as version 3_100_00 (i.e. 3.1) and it's currently deployed on the newton.palomar.caltech.edu computer for testing.

11.0 Programmer's Note: How the software works

The WIRC-Pol software is written in Java and any runtime Java installation should run it without problem. A Java program is typically packaged into a JAR file (*.jar) and the program runs by passing the Jar file to the Java runtime. The startup process works in the following sequence:

(1) Open a terminal window and type 'wircpol3' into the window and hit Enter.
(2) The operating system looks in all the $PATH environmental variable directories for a file or link named "wircpol3." A symbolic link exists in the /home/developer/bin2 directory named "wircpol3" that points to the location where the code is installed.
(3) The deployed code is located in the directory /rdata/software/instruments on the newton.palomar.caltech.edu computer. Each instrument has its own subdirectory and in this case the code is stored in the wirc3 subdirectory.
(4) When a completely new build is deployed, a new subdirectory is created that matches the version number of the code. For example, the current version of the code is stored in a directory named WIRC3_1_00_00. This indicates that this is the first major release of this code with no major or minor revision numbers. A major new release would be titled WIRC3_1_01_00 while a minor release would look like WIRC_1_00_01. Frankly, what's considered a major release vs. a minor release is a little vague. Any time a new library needs to be added to the library path requires a major release. Similarly, the presence of a new capability or support for a new mechanism or subsystem will be marked by a major release increment. On the other hand, minor releases are mostly bug fixes or minor variations that don't require major testing plans.
(5) When you investigate a particular release subdirectory, you will find a very predictable folder structure. The first we need to consider is the ~/bin directory. The bin directory contains the script file that starts the software.
(6) The script file is very simple. The first line changes directory to the folder containing the JAR file (/rdata/software/instruments/wirc3/WIRC3_1_00_00) and the second line starts the program: java -jar WIRC3.jar

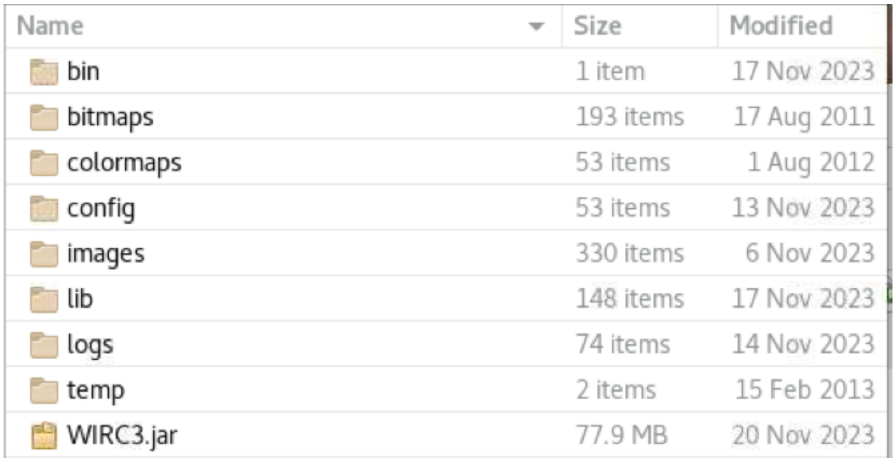
In summary, you type "wircpol3" in a terminal, the operating system finds wircpol3,and points to the executable script file in the bin directory of the release.

Upon startup, the software needs to know how to find resources such as images for icons, banners, etc. You can query the USERDIR from inside the program which tells you the directory where the process started. In general, the USERDIR is the directory that contains the JAR file. Because of this feature, when you deploy resources, you can place them relative to the USERDIR. If you look at the structure of a deployed version of the code, you will see a predictable directory structure.

Directory	Purpose
bin	contains executable scripts for starting the software
bitmaps	bitmaps used by the JAI and JSKY components
colormap	colormaps used by the JSKY FITS display components
config	contains configuration and initialization files
images	contains images, icons, banners, etc. used by the GUI
lib	library files that contain supporting JAR files

logs — location for some small logs (many stored in configured locations)

temp — location for writing temporary files, many of which are written in configured locations



Name	Size	Modified
bin	1 item	17 Nov 2023
bitmaps	193 items	17 Aug 2011
colormaps	53 items	1 Aug 2012
config	53 items	13 Nov 2023
images	330 items	6 Nov 2023
lib	148 items	17 Nov 2023
logs	74 items	14 Nov 2023
temp	2 items	15 Feb 2013
WIRC3.jar	77.9 MB	20 Nov 2023

Figure 31 Directory structure of a deployed code package

Java programs are organized into packages and in the case of WIRC-Pol, the code is encapsulated in the edu.caltech.palomar.instruments.wirc directory. The main class that starts the program is WIRCMain.java. The code is configured to make the WIRCMain class the main class in the JAR file. Within the WIRC package, there are subdirectories that encapsulate different components of the system. For example, there is a scripts subdirectory that contains all of the code supporting the scripting system for WIRC-Pol. Similarly, there is a package for the Newport stages that supports the polarization mechanisms. Another package supports the entrance mask used in polarization observations.

The system is also controlled by a set of configuration files (e.g., config directory) that influence many aspects of the systems operation. The TelescopeIniReader class is responsible for reading the "telecope.cfg" file in the config directory. Values in the configuration file are arranged in sections and each section includes multiple key, value pairs. The TelescopeIniReader reads the file and changes its internal variable to reflect the values in the file. In the case of the TCS, the file contains SERVERNAME and SERVERPORT fields that are read when the system starts. An instance of the TelescopeIniReader is passed to the P200Component. The P200Componet uses the values in the configuration file to set the IP address and socket number when connecting to the TCS.

Any time the code requires a default value or a path to a resource, there is probably an entry in a configuration file that determines the value. In general, the code is written to make it as portable as possible so it's easy to deploy it in a new context and on a new computer system. There are quite a few configuration files and many ways to use them. Configuration files are absolutely essential to the operation of the instrument.

There are two major components that are not part of the WIRCI-Pol package but are essential for operations: (1) DHEControl and (2) P200Component. The DHEControl encapsulates all interactions with the ArcVIEW server that controls the detector. WIRC-Pol uses the ArcVIEW server to control the detector and the DHEControl instantiates the TCP/IP sockets connections to the ArcVIEW server. When the program starts, an instance of the DHEControl is created that contains the TCP/IP management mechanisms for connecting to the control, blocking, and asynchronous ports. Most commands are sent on the control socket, and asynchronous messages from the server are also monitored. The WIRCDHEControl directly inherits from the DHEControl class and implements any interactions that are specific to WIRC-Pol.

The DHEControl contains all the code necessary to talk to the ArcVIEW server and maintains a class called DHEObject that represents the state of the server at any point in time. For example, when the system starts up, it connects to the ArcVIEW server and queries the server for every parameter that the server supports. The DHEControl parses the responses from the server and sets the values of the variables in the DHEObject representing the state of the server.

For example, I just started the GUI and the exposure time appears as 90.0 seconds. The DHEControl queries the ArcVIEW server over the command port for the current value of the exposure time. The response comes from the server and the DHEControl parses the response, turns the ASCII into a double value, and sets the exposure time variable in the DHEObject. To properly update the value of the exposure time in the GUI, the code that updates the value must be executed in the event dispatch thread. The way to do this is for the GUI to register as a listener for property change events propagated by the DHEObject. When the DHEControl calls a method in the DHEObject to set the exposure time, the method checks if the value of the exposure time has changed. If the value has changed and property change event is propagated to the GUI. The GUI (i.e., WIRC2_ExposureFrame) is registered as a listener for property change events on the DHEObject so that any time a value in the object changes, the GUI can process that event. This is an example of Model-View-Controller architecture. The model is the DHEObject that contains the state of ArcVIEW server. The view is the GUI (WIRC2_ExposureFrame) that presents the state of the system to the observer. The controller in this case is the code in the GUI that responds to changes in the DHEObject by changing the values on the view. Everything in the WIRC-POL code works this way using the model-view-controller paradigm.

The other example mentioned above is the P200Component. The P200Components encapsulates all interactions with the P200 telescope. The P200Component is the class that maintains the TCP/IP connections to the TCS and queries the telescope for telemetry information. The P200Component also support methods for offsetting the telescope, changing the focus, and monitoring the telescope's position. The code needs to be multi-threaded so that the system can continuously update the position during a move. The code supports a monitoring thread that updates the TCS coordinates at about 4Hz. When you attempt to offset the telescope, the P200Componets spawns a thread that executes the offset using a TCS command. Simultaneously, the monitoring thread is listening for changes in telescope position and updating the values of the TelescopeObject that maintains the state of the telescope. The GUI (several components) is registered as a listener to the TelescopeObject property change events. When the value of the TCS coordinates changes the TelescopeObject propagates the events to the GUI and the GU presents the new coordinates to the observer.

Model-View-Controller is the guiding paradigm for all the Java code. Every value you see on the GUI is backed by this system. In some cases, the component only has a few variables and it's not necessary to separate the object state from the component. In these cases, the component directly hosts the state variables and propagates the events directly to the GUI. A good example of this is the Newport stage control. The Newport XPS controller supports 4 mechanisms (2 slides and 2 rotation mechanisms), and each of these mechanisms is controlled by an instance of the XPSDNewportController class. The XPSDNewportController class is both a component that supports the communication with the Newport controller and the object that reflects the state. The GUI (NewportControllerFrame and/or the main panel) registers as a listener to each instance of the XPSDNewportController.

The Java code base make extensive use of several major development packages that should be mentioned. The image display system for FITS images is based on the JSky archive, an ESO project from the early 2000's. The ephemeris calculations are based on JSkyCalc written by John Thorstensen at Dartmouth. The JSkyCalc code is directly incorporated into the Palomar Java build tree as the edu.dartmouth.jskycalc package. In a similar way, the Aperture Photometry Tool written by Russ Laher at IPAC is incorporated into the build tree in the edu.caltech.ipac package. The WIRC-Pol software makes use of each of these packages for performing calculations to supply information for the FITS header and for producing graphs and telemetry plots.