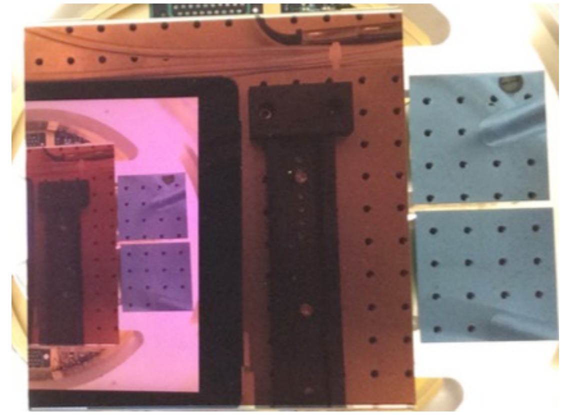


WASP
A new wafer scale imaging camera for the
Palomar Observatory 2018

E2V 6144x6160 CCD231-C6 Back Illuminated Science Detector

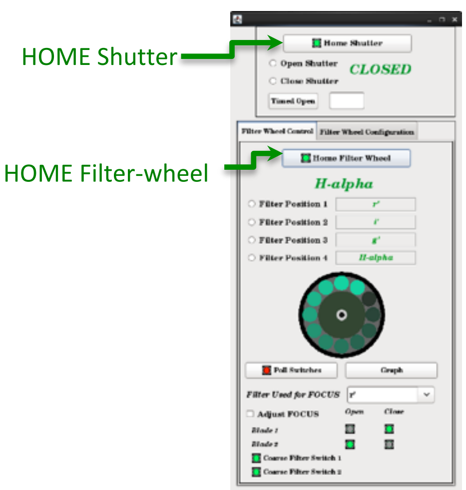
Two STA3600A 2064x2064 Guide and Focus Detectors

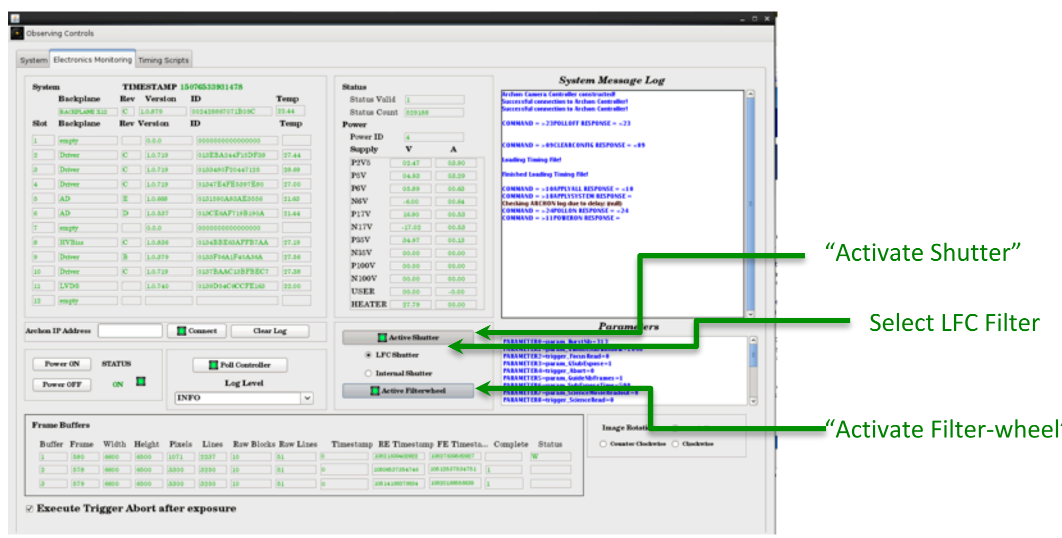
Jennifer W. Milburn February 7, 2018

Table of Contents

Quick Start Guide

- Open the following **vnc** desktop on the observer computer (***vncviewer 198.202.125.140:16***)
- Right mouse click on the desktop and select open terminal.
- Start the WASP instrument control software by typing “wasp”
- Open the ***“WASP Filter-wheel and Shutter Control”***
- “Home” the shutter first
- “Home” the filter-wheel
- Select filter you wish to focus in.
- Open the ***“Electronics Monitoring”*** tab and engage ***“Activate Shutter***” and “***Activate Filter-wheel***”
- Select ***“LFC Shutter”*** radiobutton.
- Return to the main panel and engage the ***“Display in DS9”*** button
- The WASP software is now ready to take images





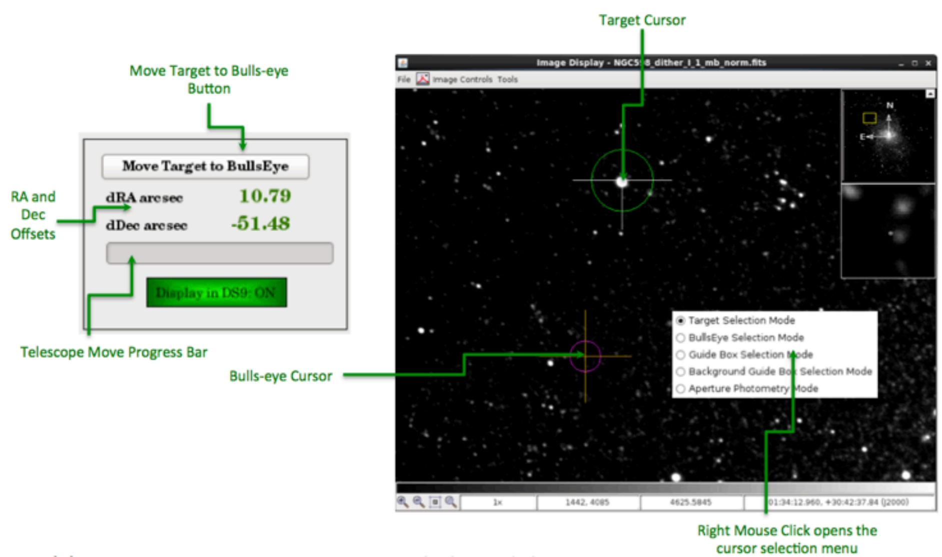
Quick Start Guide –continued
Taking calibration frames while the dome is dark in the afternoon

- Taking BIAS frames:
  - The easiest way to take bias frames is to set the exposure time to 0 seconds.
  - Deactivate the shutter so that it doesn't open ("Activate Shutter" icon should be red not green on the "Electronics Monitoring" tab).
  - Engage the "continuous" button so that it turns from grey to green (to the right of the "GO" button)
  - Press "GO" and then wait for the desired number of frames to be taken.
  - Disengage the "continuous" button so that the system stops taking frames after the desired number have been taken.
  - IMPORTANT: Remember to "Activate Shutter" after the finishing your bias frames

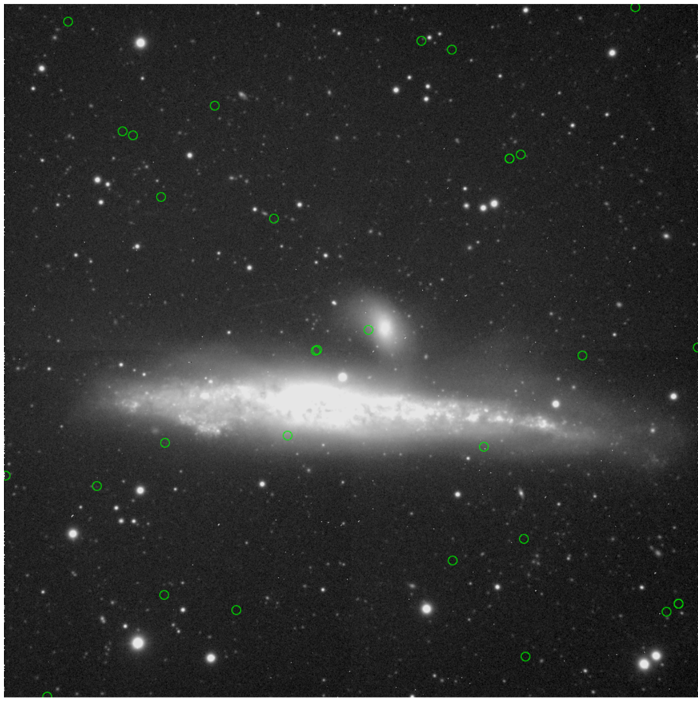
- Taking FLATS
  - The easiest way to take flats is to run a script "flats.txt" that will take 10 images in each of the 4 filter positions.
  - Open the "WASP Script Execution" control.
  - Select the "File" button and open the "flats.txt" script
  - Select the "Script Editor" panel
    - edit the filter names and the output BASENAME for each filter. Be careful with the filter names, they must exactly match the names in the filter GUI
    - Ask the support astronomers for the recommended exposure times and lamp settings for your filters. Edit the exposure time for each filter
  - Press the "Parse Script File" so that the commands table is updated
  - Press the "GO" button on the "WASP Script Execution" control
  - Go the dinner ☺
- Reducing the calibration frames
  - IRAF is installed on the WASP computer and is the typical tool for reducing WASP data.
  - Use imcombine with combine=median to create a master bias frame
  - Use imarith to subtract the master bias from each of the flat field images.
  - Use imcombine to combine the flat field images after the bias has been subtracted using combine=median, scale=mode
  - Run imstat on the combined image to calculate the mode
  - Normalize the combined flat field image by using imarith and divide the image by the mode.
  - Note: you can remove the prescan from a WASP image with ***imcopy $filename[51:6194,1:6160] $new_filename*** for images without overscan.

Quick Start Guide –continued
When your first On-Sky

- Establish telescope pointing
  - When you're first on-sky you need to set the telescope pointing so that a requested target star falls directly in the center of the science detector. This is important so that the preliminary WCS in the images is essentially correct.
  - Request that the telescope operator select a bright SAO star near zenith. The star simply needs to be bright enough so that you can easily identify the star in the image.
  - Take a short exposure time image (1 to 10 seconds) and examine where the star lies in the science detector field
  - Use the "Target to Bullseye" function to move the star to the center of the detector.
    - Right mouse click on the image and select the "Target" cursor. Place the target cursor on the SAO star.
    - Right mouse click on the image and select the "Bullseye" cursor. Place the bullseye cursor at the center of the science detector
    - Verify that the delta RA and delta Dec below the "Move Target to Bullseye" button are reasonable.
    - Press the "Move Target to Bullseye" button and then wait for the progress bar to indicate that the move is complete
  - Take a new image and verify that the SAO star is now at the center of the science detector
    - If the SAO star isn't in the exact center of the field then repeat the previous step with "Target to Bullseye"



Quick Start Guide –continued
When your first On-Sky – Calibrating the WCS



CRPIX1	3080	CRPIX2	3072
CRVAL1	190.5325	CRVAL2	32.5435555555555
CUNIT1	deg	CUNIT2	deg

- The image above displays the overlay of the UCAC3 catalog on the image. Note that the stars obviously don’t line up correctly.
- It’s relatively easy to visualize that the catalog is shifted to the North and West (up and to the right) relative to the image.

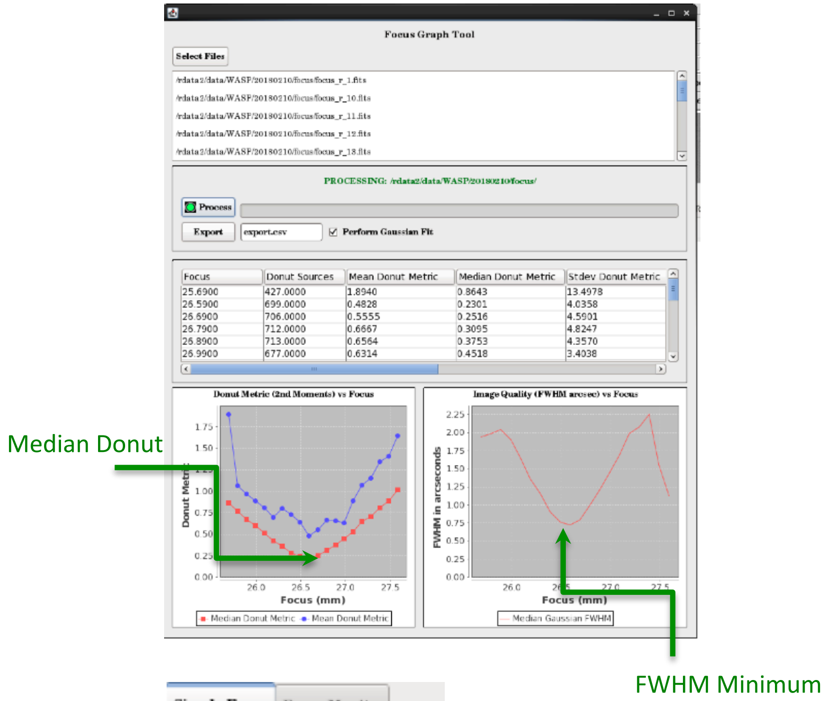
CRPIX1	2850	CRPIX2	2640
CRVAL1	190.5325	CRVAL2	32.5435555555555

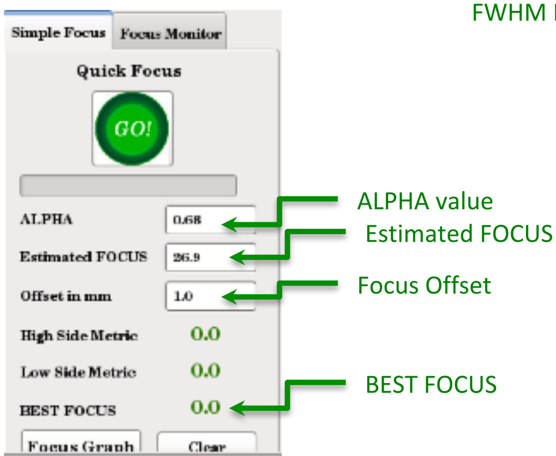
- Adjust the CRPIX1 and CRPIX2 keywords until the stars in the catalog obviously line up with the stars in the image.
- Since distortions are greatest near the lower right corner it’s best to line up stars in the middle of the field and to allow the distortion polynomials to take care of the correction.

Quick Start Guide –continued

Focusing the the telescope

- Focus the telescope
  - If the WASP instrument has just been installed you need to run a complete focus increment set of observations and then analyze the results
    - Open the “WASP Script Execution” control and then open the “focus2.txt” script. This script will take 20 images at focus increments of 0.1mm starting at a value below best focus. (ask the support astronomer if the script has been updated to take a smaller number of images)
    - Run the focus script to create the 20 images
    - Open the “Sextractor” control and press the “Focus Graph Analysis” button to open the control
    - Select the files created by the script by pressing the “Select File” button and browsing for the files.
    - Press “Process” and wait for the analysis to complete.
    - Determine the minimum focus position from the “Median” focus donut graph (left red curve), verify that it matches with the minimum of the FWHM graph (right).
    - Tell the telescope operator to set focus to the measure value.
  - If this isn’t the first night of a WASP install then you can use the “Quick Focus” tool to determine focus.
    - Ask the telescope operator what the focus was the last time the instrument was used and enter that value into the “Estimated FOCUS” field
    - Ask the support astronomer for the current best known value of ALPHA and enter it into appropriate field
    - Set the “Offset in mm”. The nominal value for this is 1mm but it can range from 0.7 to 1.5mm. As the support astronomer for their advice on what the best value is for the offset.
    - Set the exposure time (typically 10 to 30 seconds)
    - Press “GO” on the Quick Focus control. The system will then take two images, one at the estimated focus minus the offset and the other at estimated focus plus the offset. The system will then run Sextractor on both images and calculate the donut metric for each.
    - The estimated “BEST FOCUS” will be displayed.
    - Now enter the “BEST FOCUS” value into the “Estimated FOCUS” field and rerun the quick focus.
    - Check that the resulting donut metrics on the high and low side are close to identical.
    - Tell the telescope operator to set the focus to the “BEST FOCUS” value returned for the second run of the “Quick Focus”.
    - The instrument is now in focus.

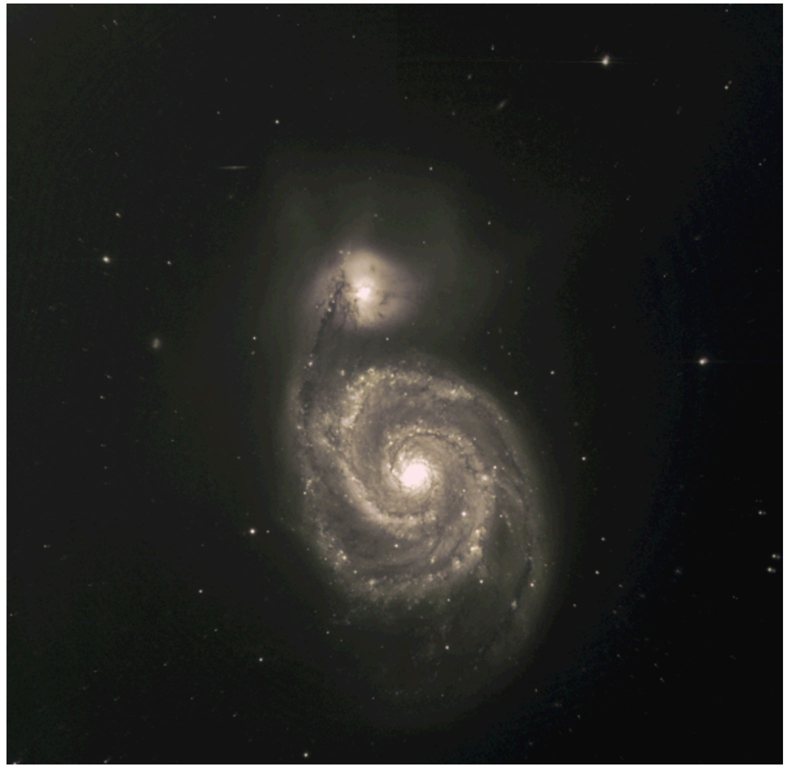




Quick Start Guide –continued

Congratulations! You are now ready to do science!

- Summary:
  - – Start the WASP software
  - – Home the Shutter
  - – Home the Filter Wheel
  - – Operations in the afternoon once the dome is dark
    - Collect calibration frames
      - – Collect BIAS frames and create a master BIAS frame
      - – Run the “flats.txt” script to collect flat field images.
  - – When you’re first on sky
    - Establish pointing with a bright SAO star
    - Focus the telescope
- You’re DONE! It’s time to do science



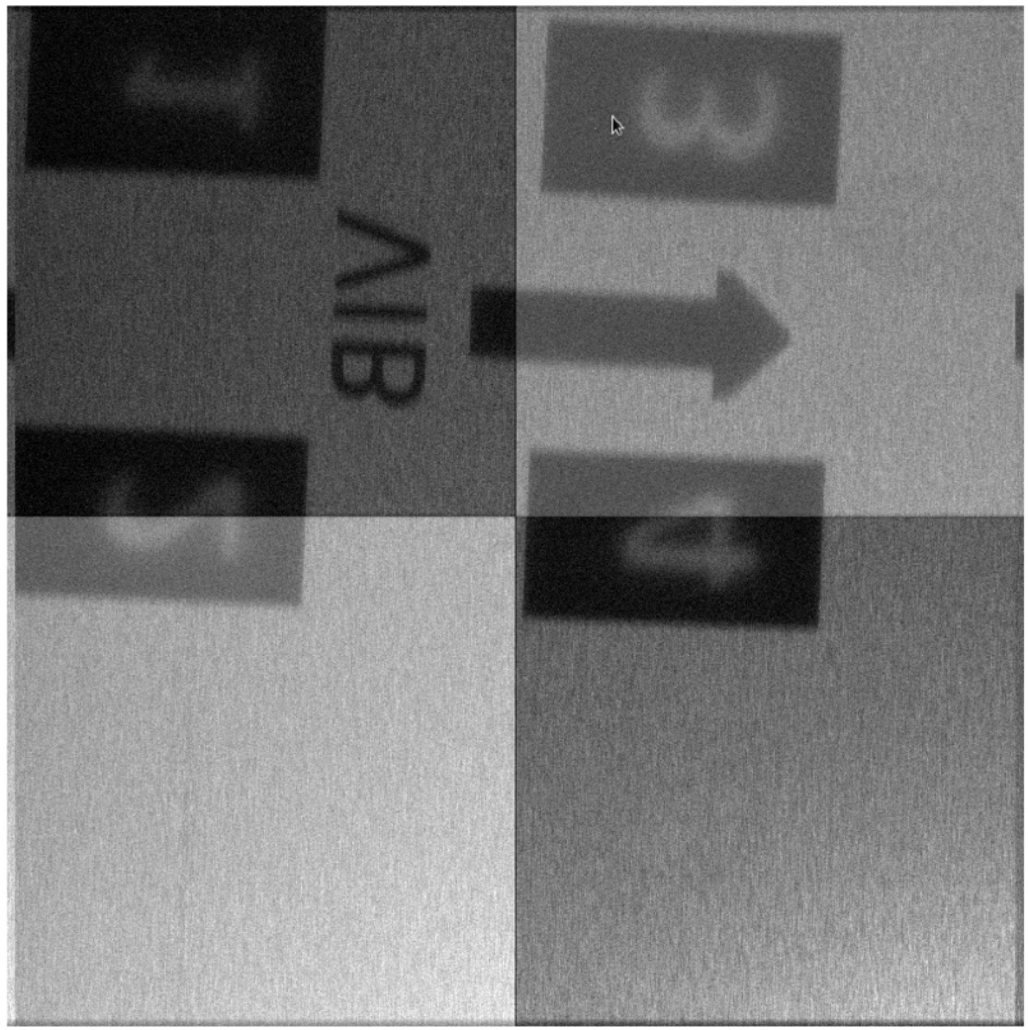
FIRST LIGHT IMAGES

WASP hardware components ready for assembly

WaSP "Laboratory First Light" Image

E2V 6144x6160 CCD231-C6 Back Illuminated Science Detector

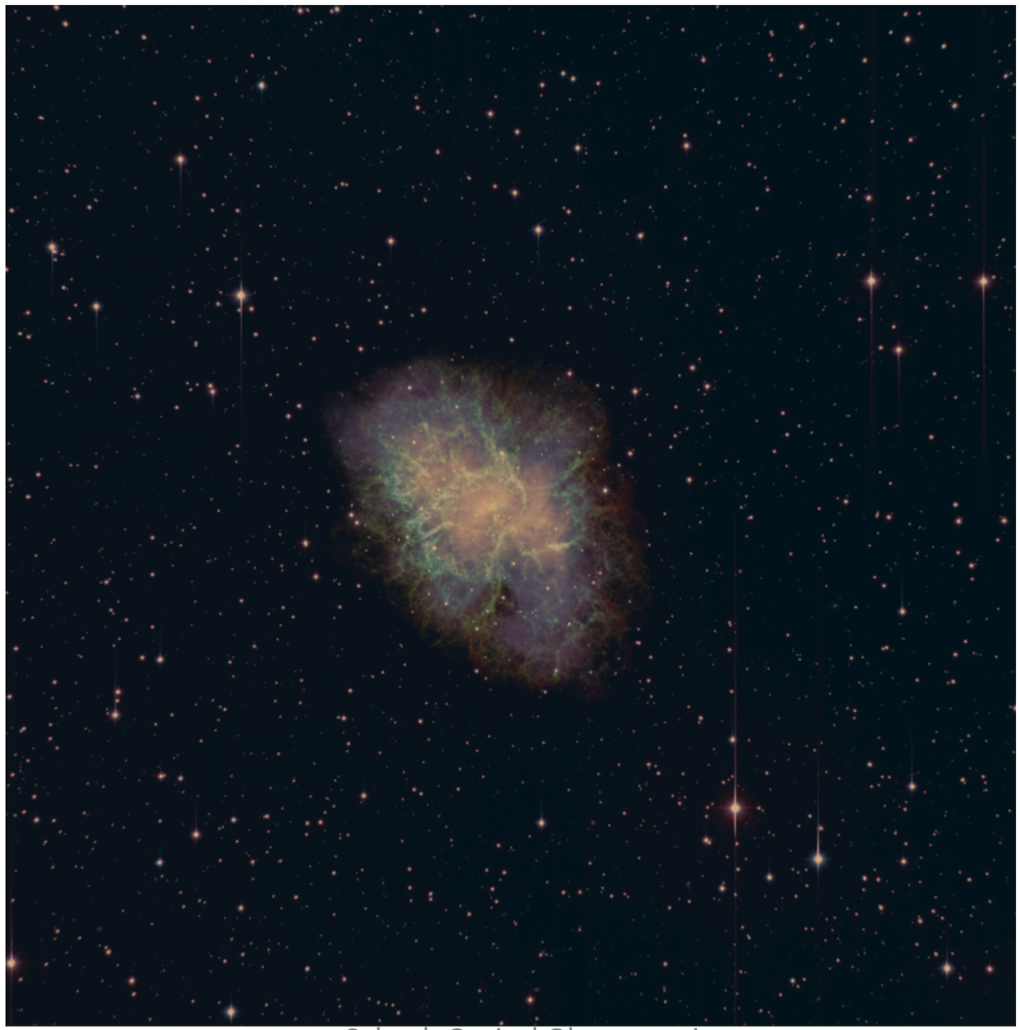
January 29, 2016



WASP First Light Images

February 29,2016
CRAB Nebula (M1)
G'=green, R'=red, I=blue

18.43 arc minutes



18.48 arc minutes

WASP First Light Images

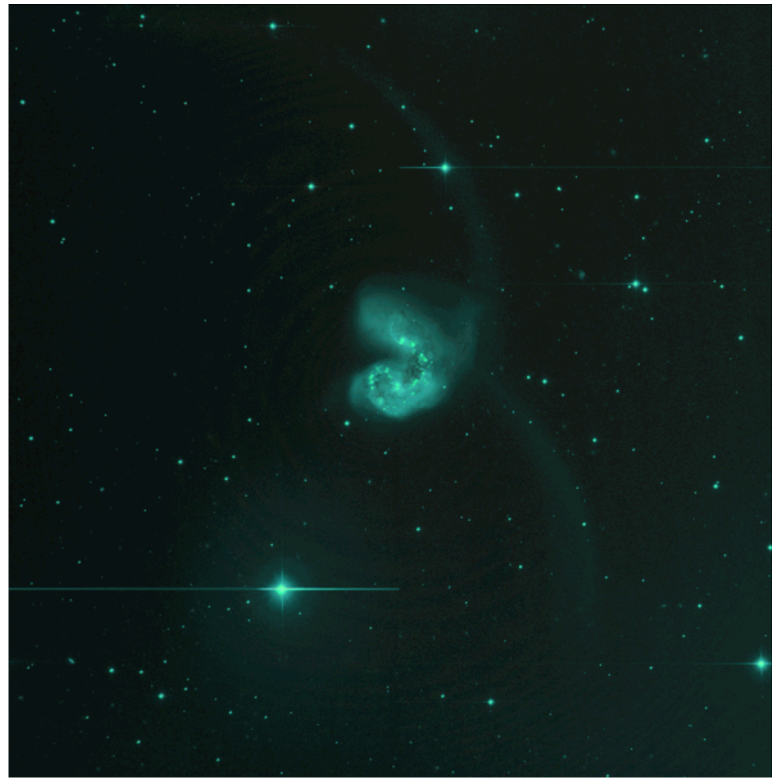
February 29,2016

M51 and M52, NGC4038 – The Antennae Galaxies

COLLIDING GALAXIES

M51 and M52

Taken March 2016 Palomar Observatory by Jennifer Milburn
Processed by Justin Belicki



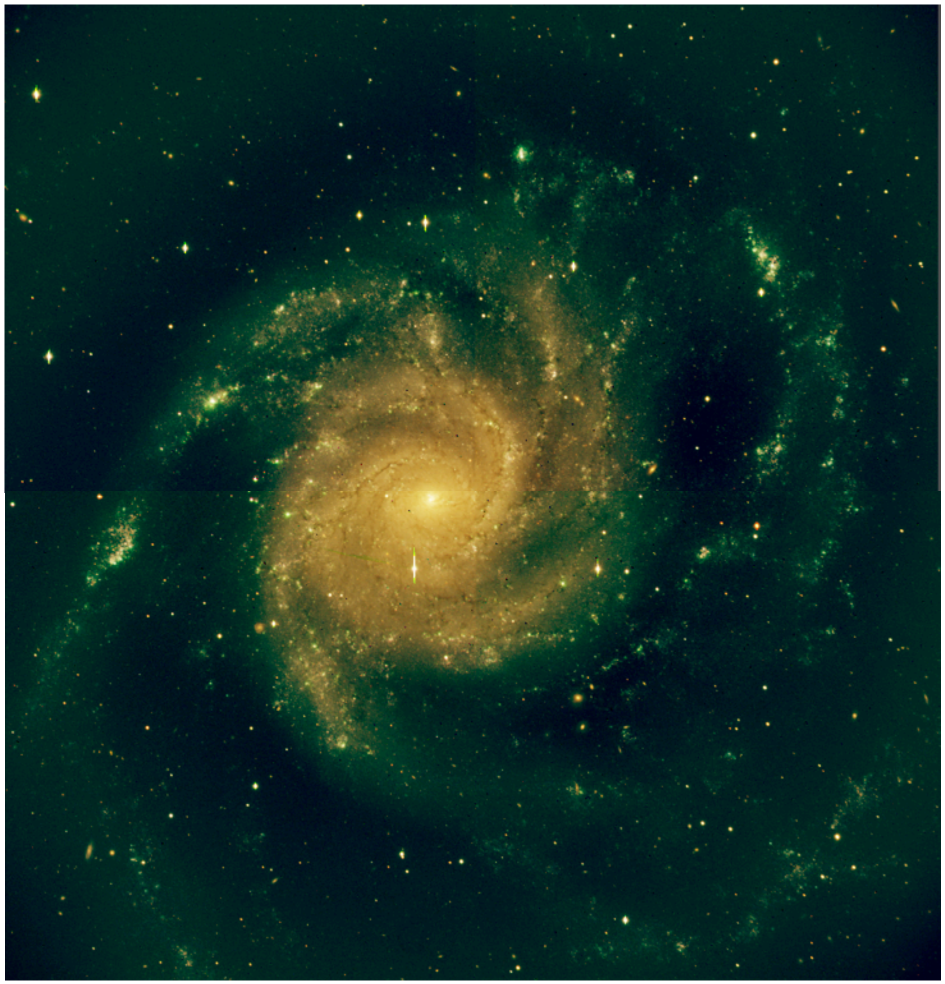
NGC 4038 The "Antennae Galaxies"

DS 9 Overlays G'=green, R'=red, I=blue

WASP First Light Images

December 31, 2017

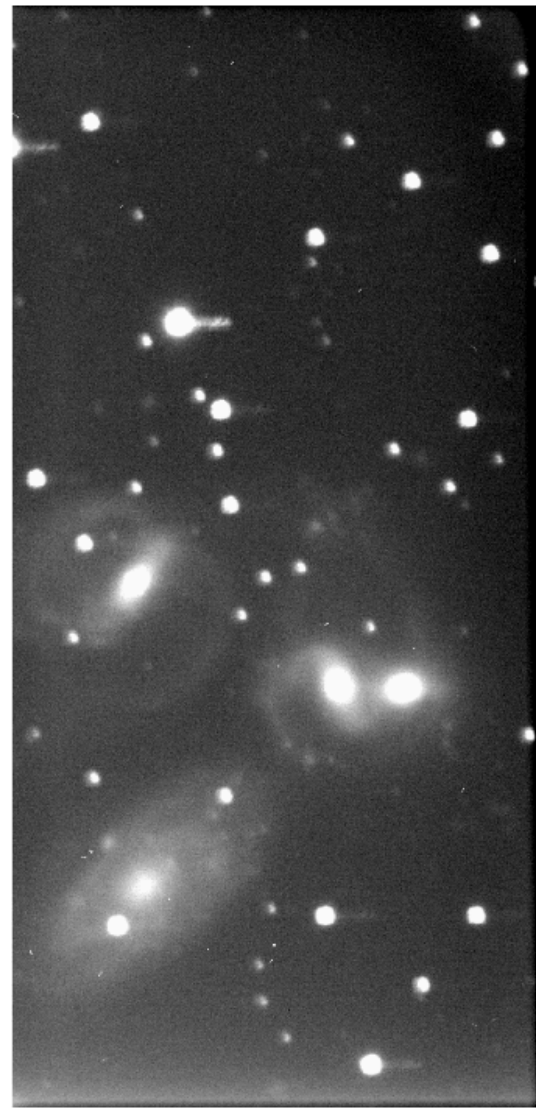
M101 – The Pinwheel Galaxy



WASP – Palomar P200 Telescope
First Light Delta-Doped STA3600A Detectors
September 13, 2016

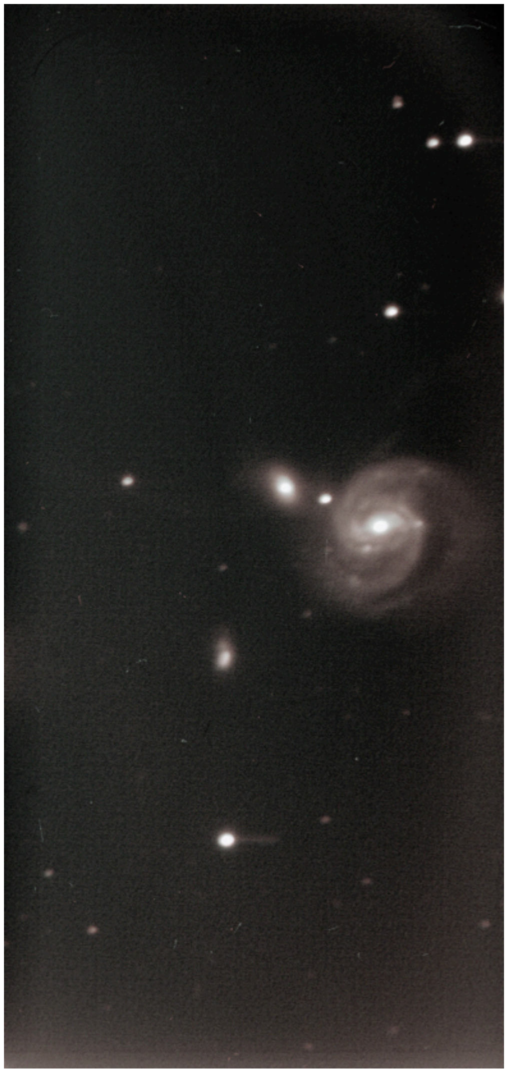
Colliding Galaxies – NGC 7674 G' Band and U' band

Colliding Galaxies – Stephen's Quintet R' Band
NGC 7318

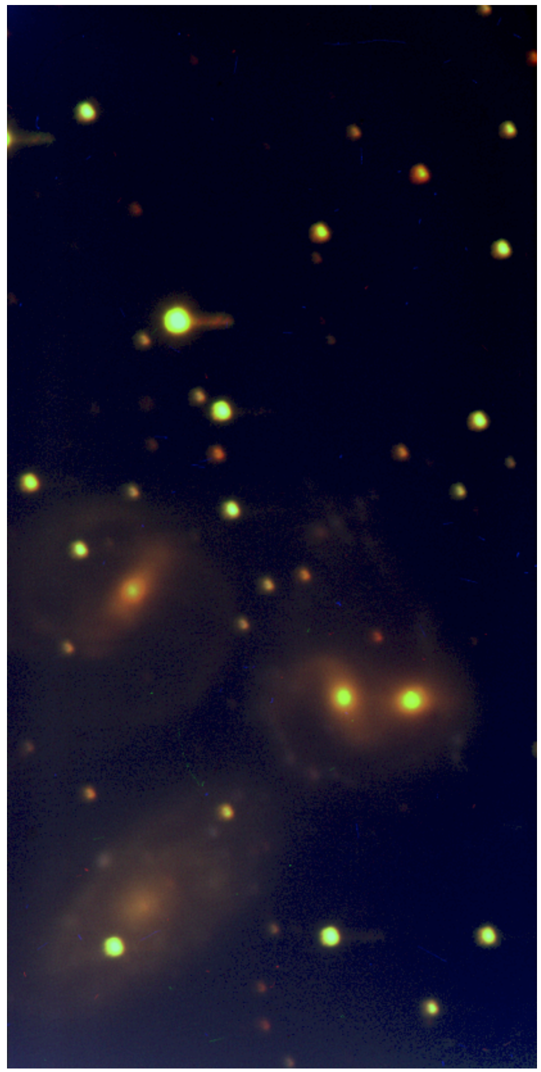


WASP – Palomar P200 Telescope
First Light Delta-Doped STA3600A Detectors
September 13, 2016
Exposure Time = 100seconds, U',G',R'

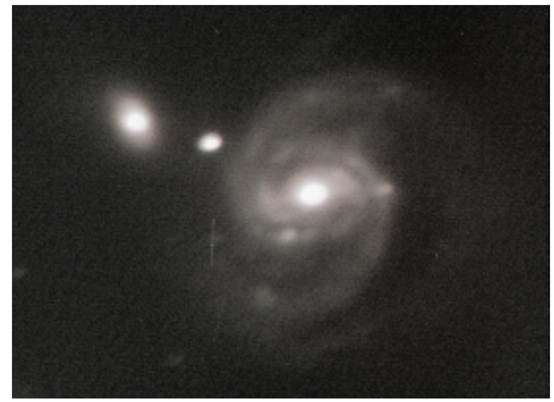
Colliding Galaxies – NGC 7674 G' ,R', and U'
G'=green, R'=red, U'=blue



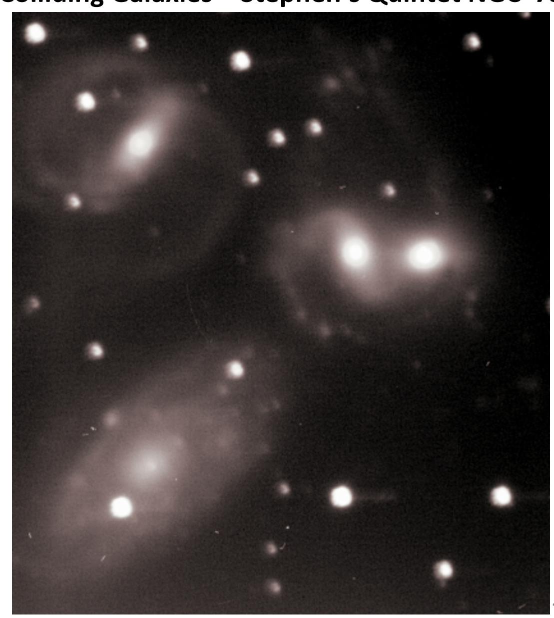
Colliding Galaxies – Stephen's Quintet
NGC 7318 G'=green, R'=red, U'=blue



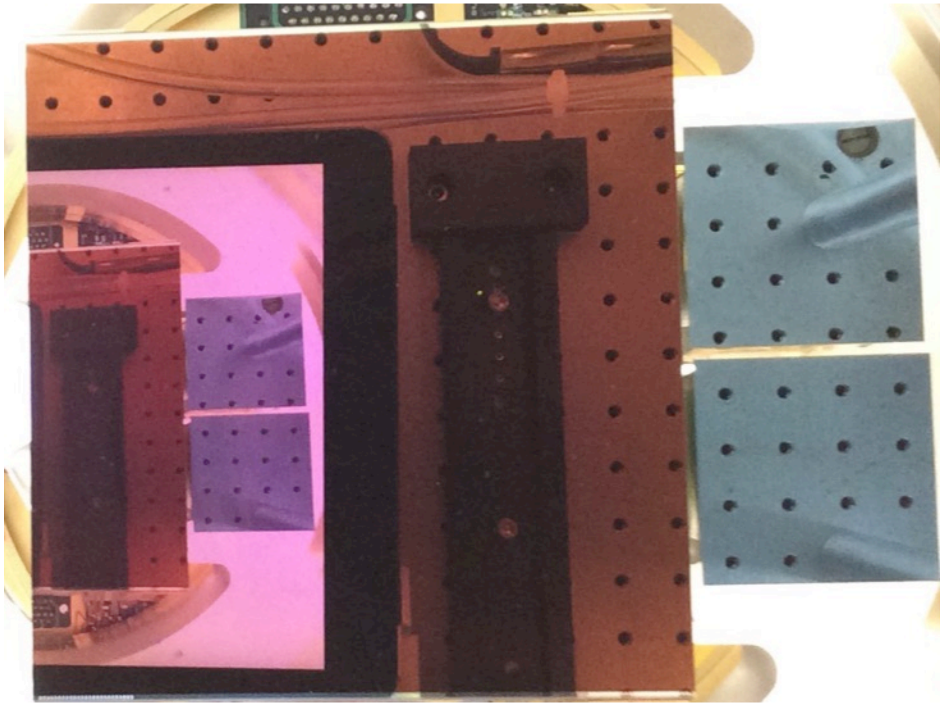
Colliding Galaxies – NGC 7674

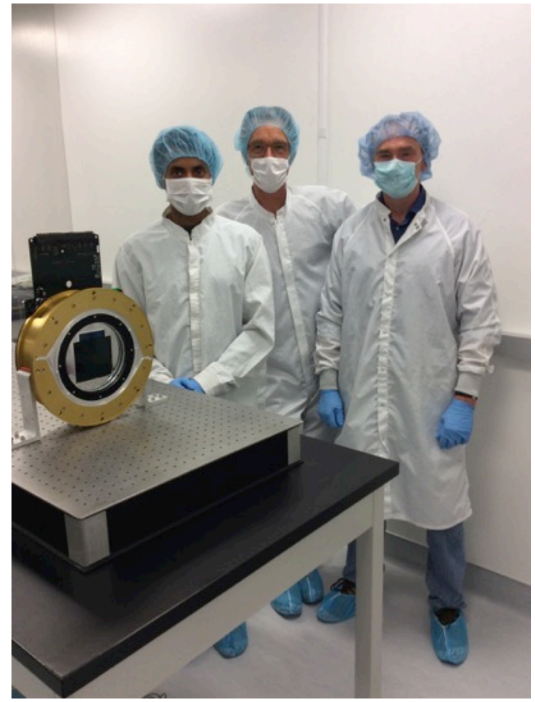


Colliding Galaxies – Stephen's Quintet NGC 7318



*Photoshop CC 2017 used to create color composites





Left to right: Pavan Bilgi, Roger Smith and Alex Delacroix during assembly of the WASP focal plane

DETECTOR CHARACTERISTICS

WASP Detector Characteristics Summary

- Summary of Detector Characteristics

	SCIENCE DETECTOR	GUIDE AND FOCUS DETECTORS
	E2V CCD231-C6 Back Illuminated	***STA 3600A delta-doped CCD***
number of pixels	6144 (H) x 6160 (V)	2064x2064
microns/pixel	15 um square	15um square
image area mm	92.2mm x 92.4mm	30.96mm x 30.96mm
Image area arcminutes	18.43 arcminutes x 18.48 arcminutes	6.192 arcminutes x 3.096 arcminutes
outputs	4	2
Readout Noise	5.0 e	2.0 e
full well capacity	350,000 e-	200,000 e-
dark current	3 e-/pixel/hour	2.0 e-/pixel/hour

Unique Features

19.2 arcminutes squared frame transfer enabled autoguider

Autofocus using a dedicated focus detector ("Donut" method)

Simple scripting language to allow complete control of complex imaging sequences

WASP Detector Characteristics
Summary from Data Sheet

SCIENCE DETECTOR
E2V CCD 231-C6 Back Illuminated, Deep Depletion Device

SUMMARY PERFORMANCE (Typical)

Number of pixels	6144(H) x 6160(V)
Pixel size	15 µm square
Image area	92.2 mm x 92.4 mm
Outputs	4
Package size	98.5 x 93.7 mm
Package format	Silicon carbide with two flexi connectors
Focal plane height, above base	20.0 mm
Height tolerance	±15 µm
Connectors	Two 37-way micro-D
Flatness	<40 µm (peak to valley)
Amplifier sensitivity	7.5 $\mu V/e^-$
Readout noise	$5\ e^-$ at 1 MHz $2\ e^-$ at 50 kHz
Maximum pixel data rate	3 MHz
Charge storage (pixel full well)	350,000 e^-
Dark signal	$3\ e^-$/pixel/hour (at –100 °C)

GUIDE AND FOCUS DETECTORS
STA 3600A delta-doped* CCD

FEATURES

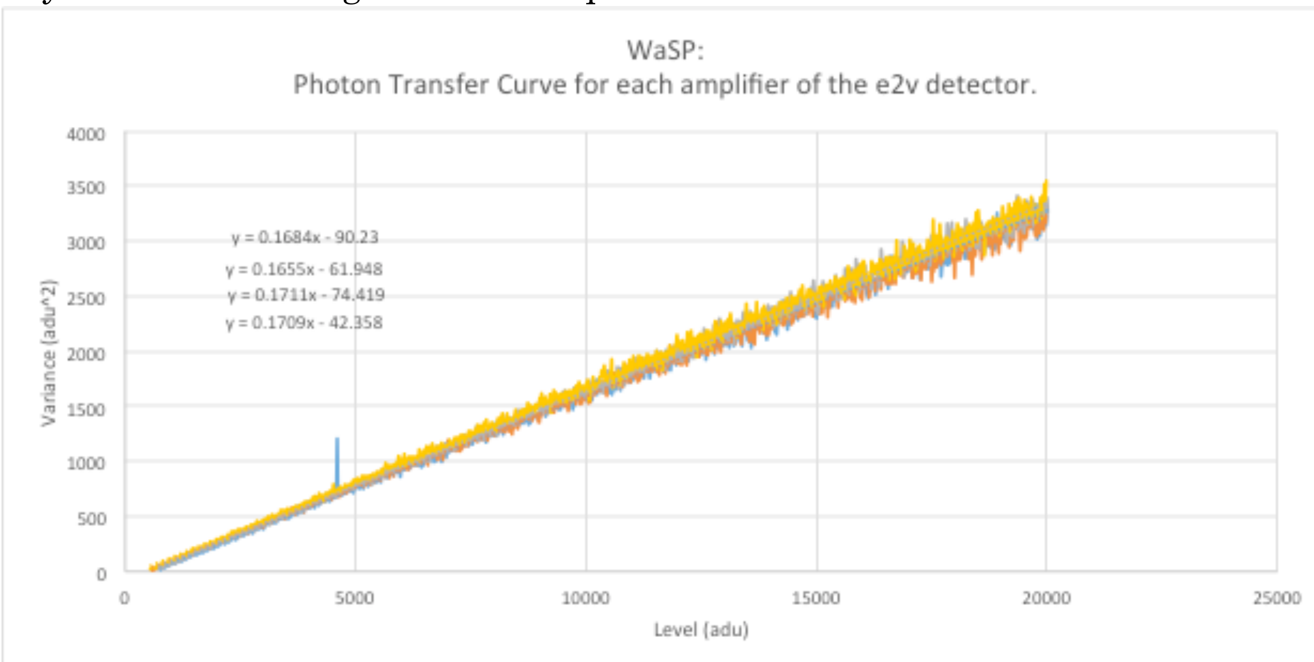
- 2064 x 2064 CCD Image Array
- 15 µm x 15 µm Pixel
- 30.96 mm x 30.96 mm Image Area
- Near 100% Fill Factor
- Readout Noise Less Than 3 Electrons at 100KHz
- 4 Single Stage 3MHz Outputs
- Three-Phase Buried Channel Image area
- Multi-pinned Phase (MPP)
- Three-Phase Buried Channel Readout Registers
- Selectable Video Output Channels
- Backside Illuminated

Operated as frame-transfer devices
With effective image area of 2064x10*32 pixels*

**** delta-doped to enhance UV performance***

WASP Detector Characteristics
E2V CCD 231-C6 Photon Transfer Curve

- The science detector is readout in quadrants with 4 separate amplifiers. The full well capacity and conversion gain for each quadrant are listed below.



Measured WASP Full well and Conversion Gain

Quadrant	*Full Well Capacity (e-)*	*Conversion Gain (e-/adu)*	*SATURATE (DN)*
AD5	326000	5.9382	54898.4
AD6	331000	6.0423	54780.5
AD7	330000	5.8445	56463.0
AD8	334000	5.8514	57080.6
Average	**330250**	**5.919**	**55806**

WASP Detector Characteristics E2V CCD 231-C6 Linearity Curve

- Detector Linearity: Within 1% up to 45,000 ADU

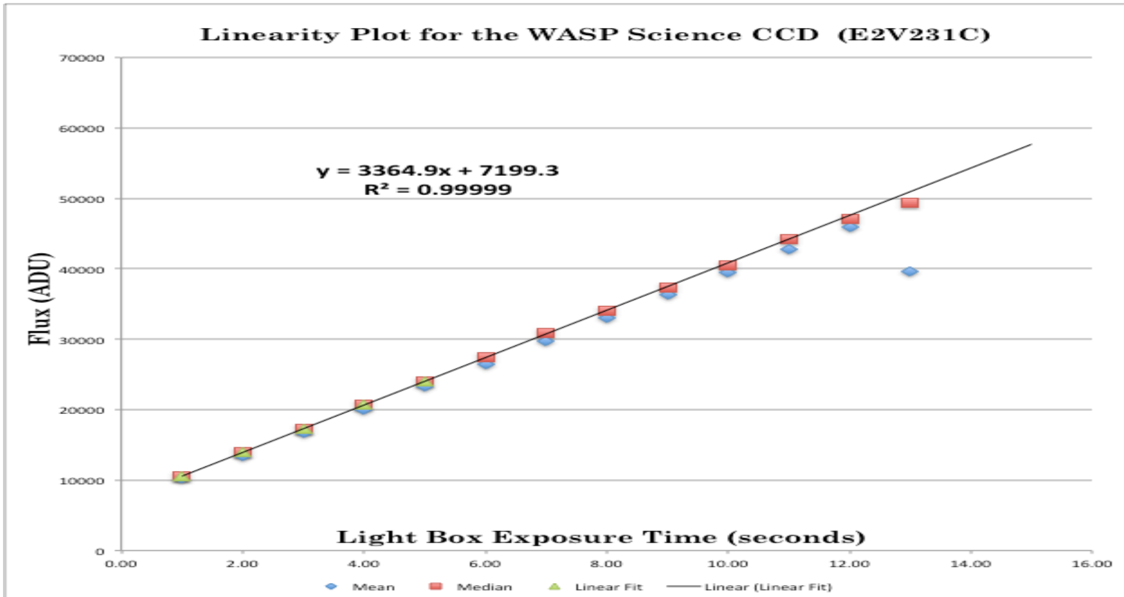
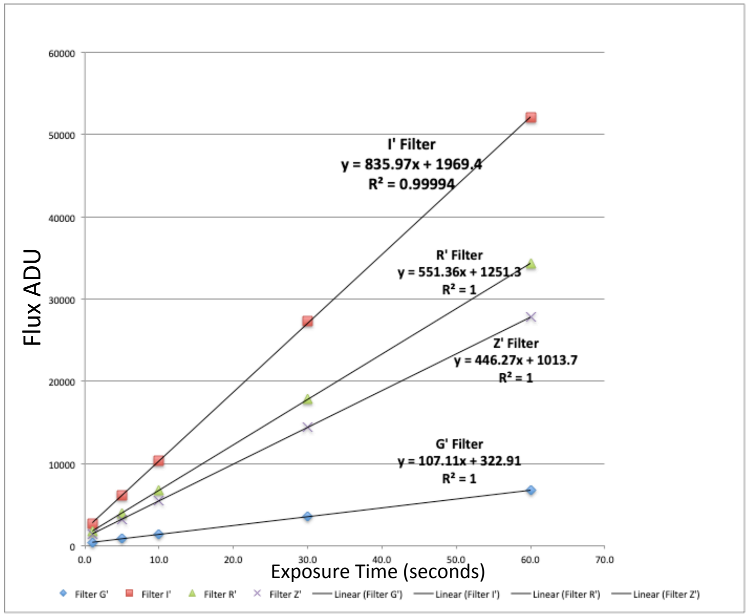


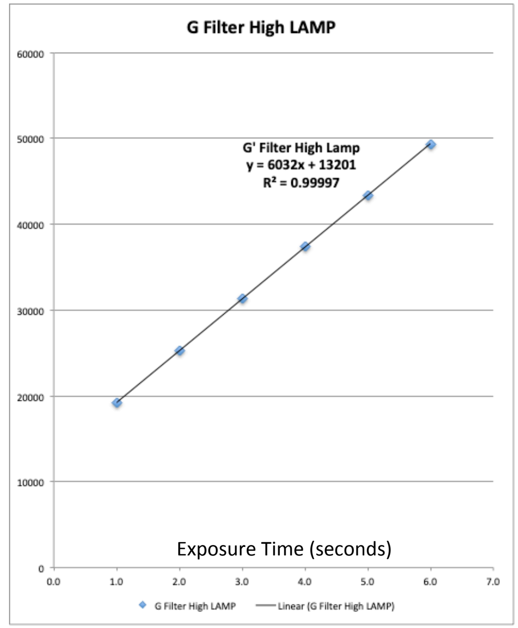
Table of Linearity Measurements

Exposure Time	Mean	Mode	Standard Deviation	Estimated Flux	Error ADU	Error %
1.00	10207	10567	1331	10564.2	-2.8	-0.03
2.00	13422	13908	1752	13929.1	21.1	0.15
3.00	16689	17311	2181	17294	-17.0	-0.10
4.00	19952	20677	2608	20658.9	-18.1	-0.09
5.00	23232	24007	3037	24023.8	16.8	0.07
6.00	26515	27404	3466	27388.7	-15.3	-0.06
7.00	29762	30868	3890	30753.6	-114.4	-0.37
8.00	33051	33974	4320	34118.5	144.5	0.42
9.00	36288	37281	4742	37483.4	202.4	0.54
10.00	39532	40540	5166	40848.3	308.3	0.75
11.00	42781	44204	5588	44213.2	9.2	0.02
12.00	45996	47101	6006	47578.1	477.1	1.00
13.00	39666	49423	17114	50943	1520.0	2.98

WASP Flat Field Calibration

Low and High Lamp flux in ADU/second





Recommended Exposure Time for Sloan Flats

Sloan Filter		
G'	***4.48***	**High Lamp (seconds)**
I'	***32.30***	**Low Lamp (seconds)**
R'	***48.97***	**Low Lamp (seconds)**
Z'	***60.50***	**Low Lamp (seconds)**

Optimal Flux for Flats: 60% full well

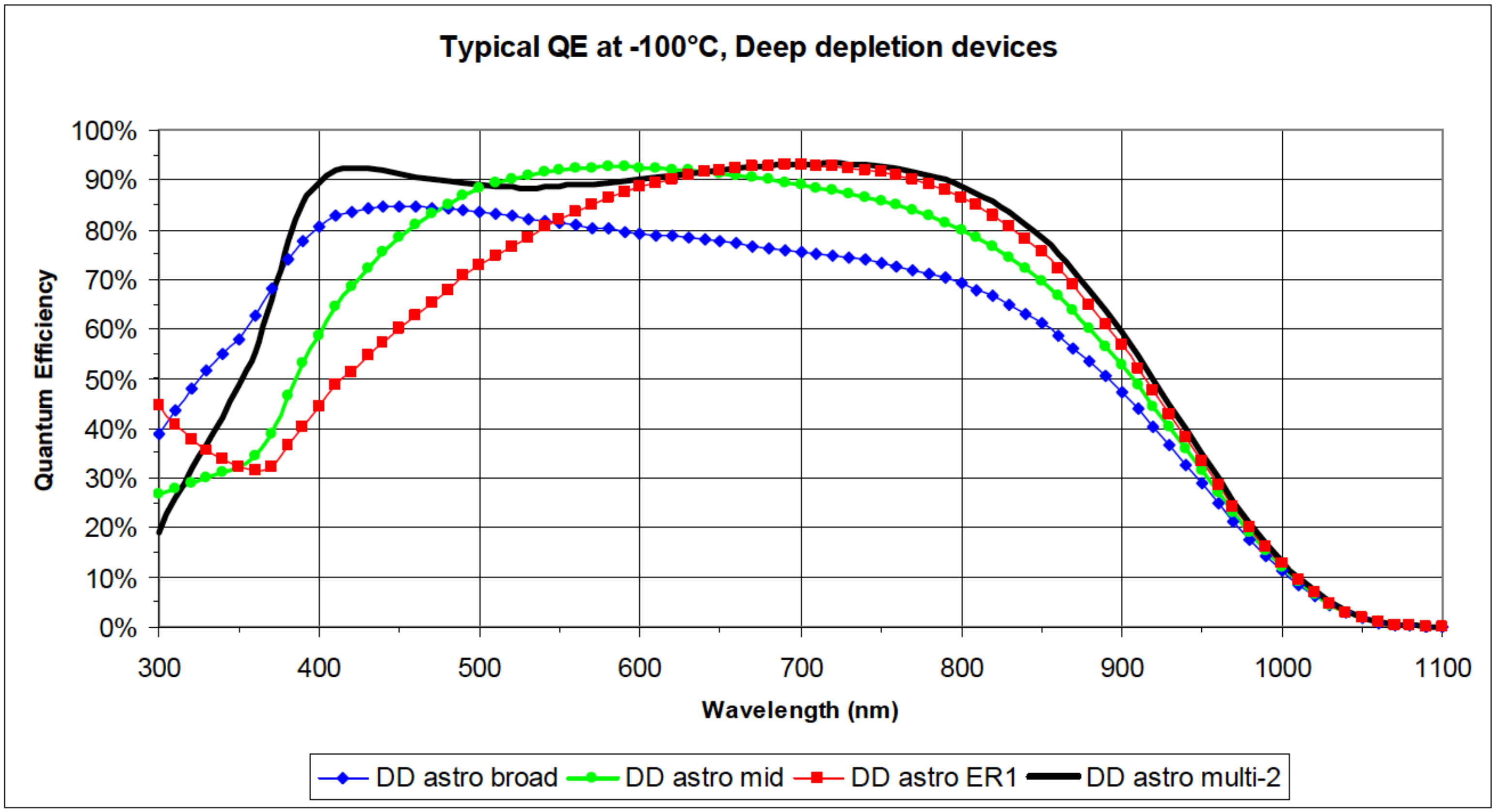
Full Well = 45000

			Time for flux in ADU					*(~27,000 ADU)*
Low Lamp Flux Summary		***1000***	***5000***	***10000***	***25000***	***50000***	**60% Full Well**	
G	**107.11** ***ADU/second***	9.34	46.68	93.36	233.40	466.81	***252.08***	***seconds***
I	**835.97** ***ADU/second***	1.20	5.98	11.96	29.91	59.81	***32.30***	***seconds***
R	**551.36** ***ADU/second***	1.81	9.07	18.14	45.34	90.68	***48.97***	***seconds***
Z	**446.27** ***ADU/second***	2.24	11.20	22.41	56.02	112.04	***60.50***	***seconds***
High Lamp Flux Summary								
G	**6032** ***ADU/second***	0.17	0.83	1.66	4.14	8.29	***4.48***	***seconds***

Note: R’,I’ and Z’ filters saturate in less than 1 second with the High Lamp

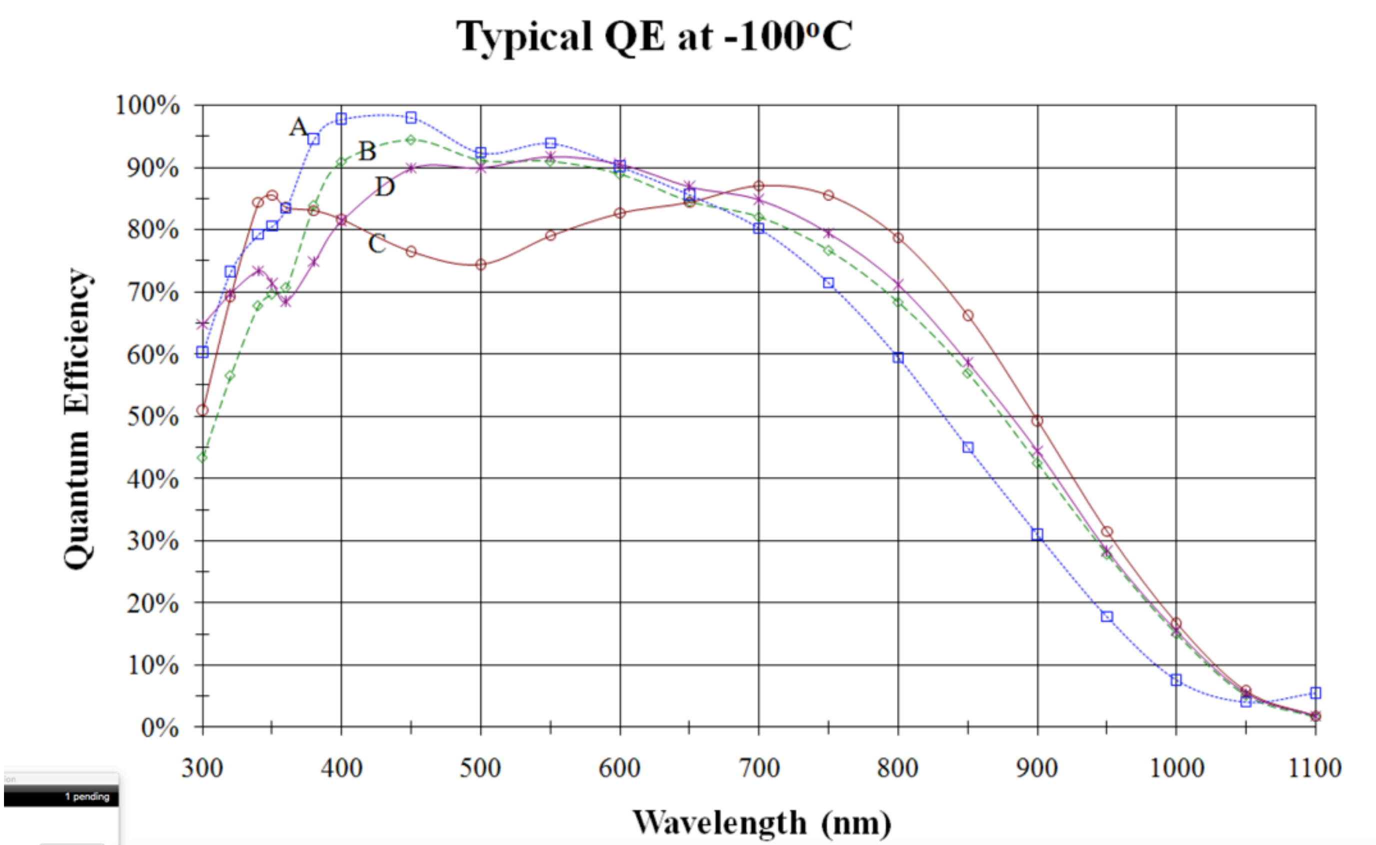
WASP Detector Characteristics
E2V CCD 231-C6
Quantum Efficiency Curves

- The quantum efficiency as a function of wavelength for the WASP science CCD (black curve)

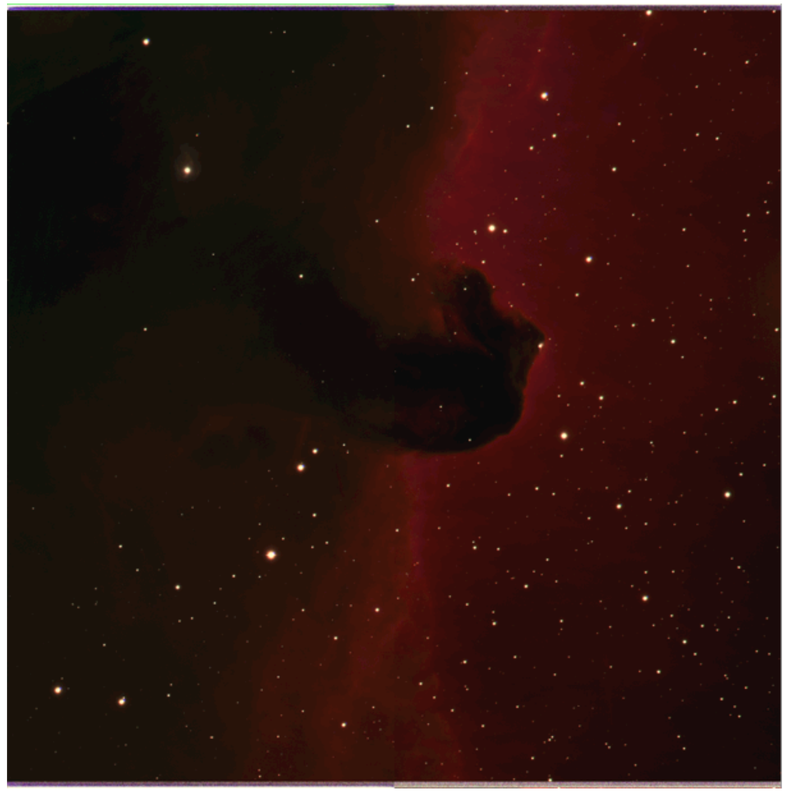


WASP Detector Characteristics
STA 3600 A 2064x2064 pixels CCD
Quantum Efficiency Curves

- The quantum efficiency as a function of wavelength for the WASP Guide and Focus CCD's (without the delta-doping)



DECEMBER 31, 2017 HORSEHEAD NEBULA



WASP FILTERS

WASP Filters
Transmission Curves for WASP filters

- WASP uses the same filter-wheel employed by LFC so the entire set of LFC filters is available.
- www.astro.caltech.edu/palomar/observer/200inchResources/lfcspecs.html

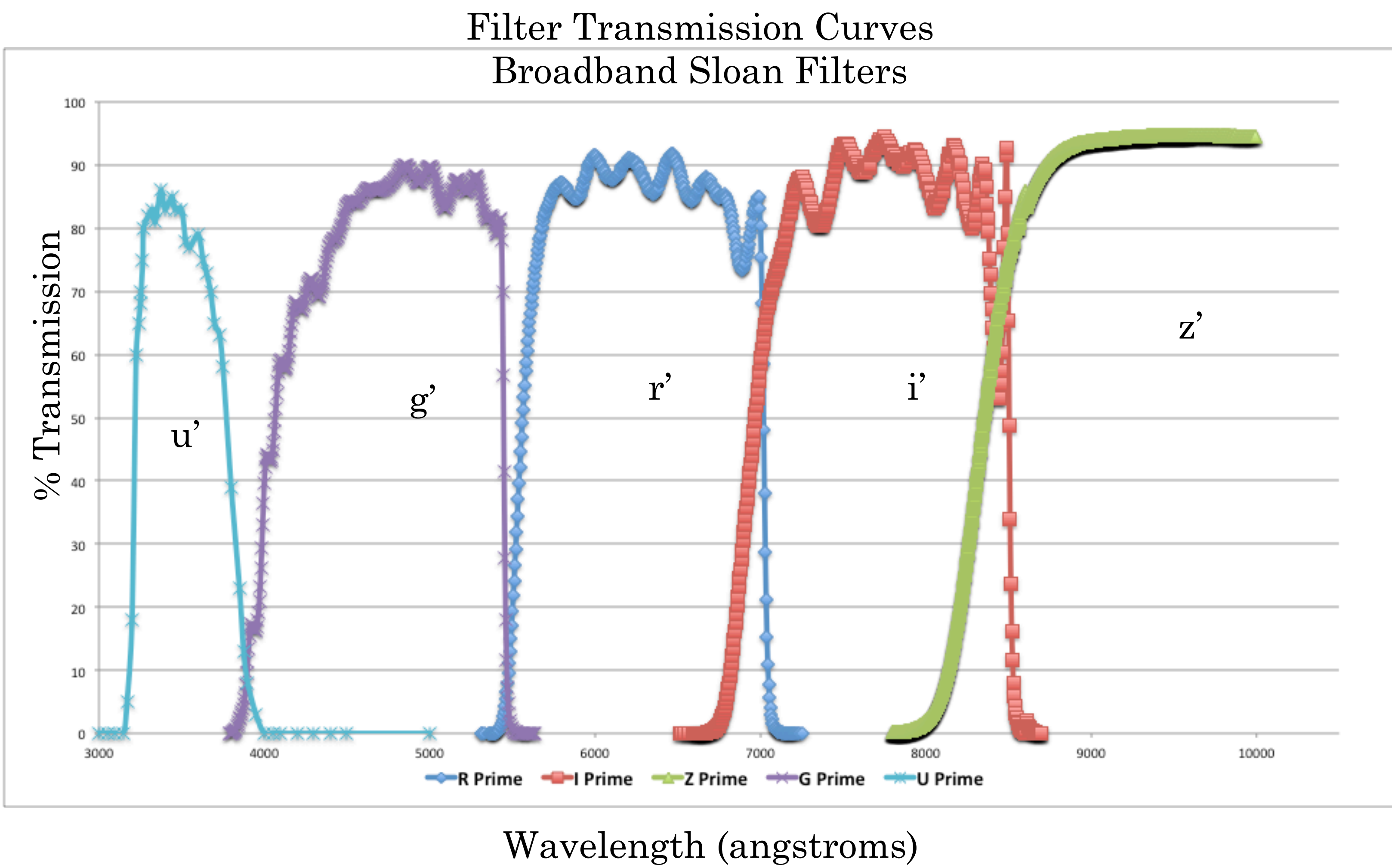
4. Filter Specs

Filter wheel has slots for 4 filters.

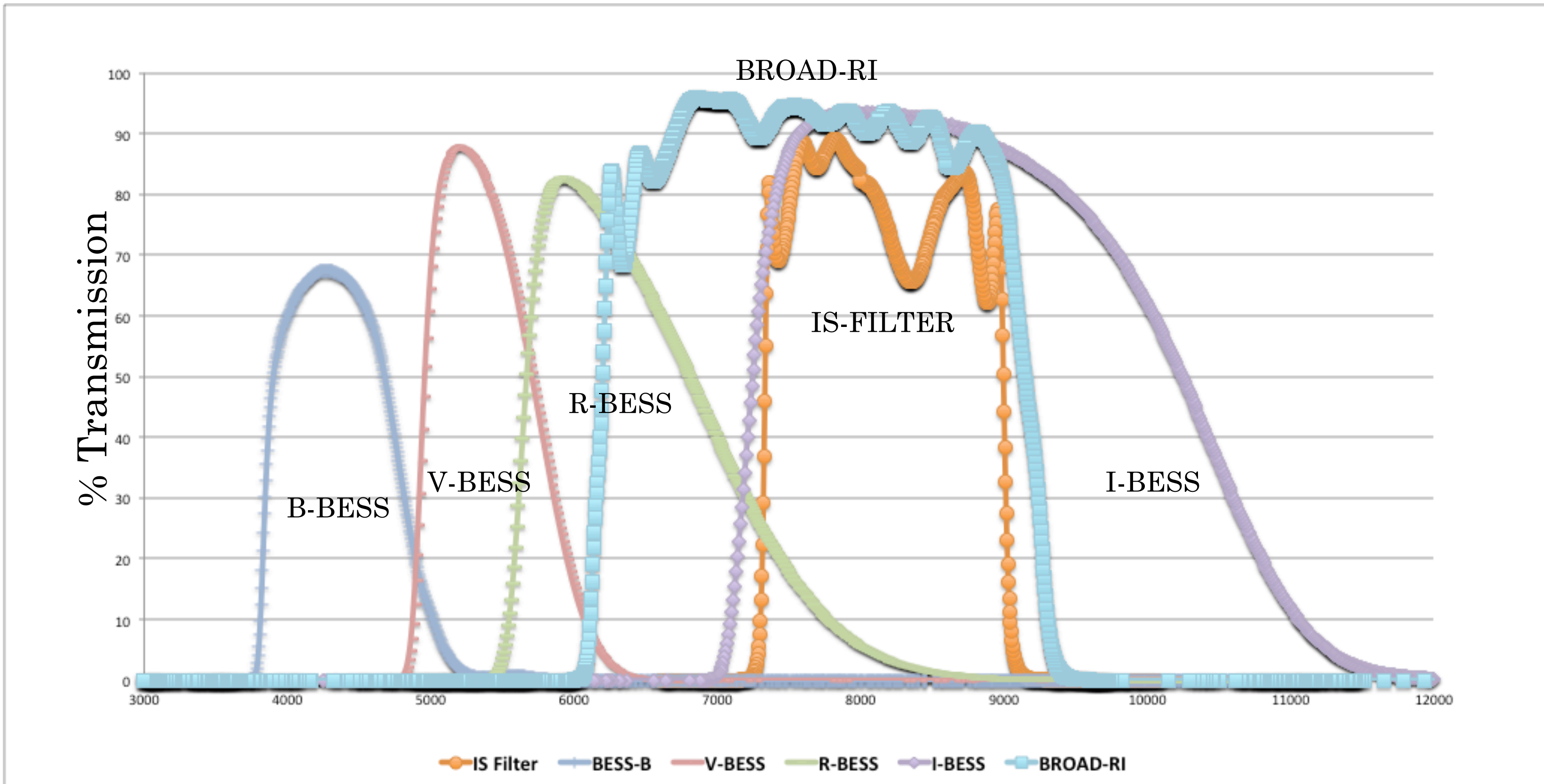
Filter	Central λ (Å)	Width (Å)	Thickness (mm)	Focus offset (mm from r')	Domeflats [b]	Dark sky [b] (raw chip 0)	Transmission
r'	6255	1470	3.05	–	5	1400	data, plot
i'	7680	1540	3.05	–	3	650	data, plot
z'	~9000	~1800 (w/qe)	3.05	–	5	750	data, plot
g'	4660	1400	8.02	+1.5	40		data, plot
u'	3540	590	8.38	+1.6	120 (highlamp)		data, plot
Rs	6930	1220	10.26	+2.0	8		data, plot
Is	8190	1670	10.26	+2.0	5		data, plot
B-bess	4400	1000	7.0	+1.3	2 (highlamp)		data, plot
V-bess	5500	900	7.0	+1.3	40		data, plot
R-bess	6300	1200	7.0	+1.3	10		data, plot
I-bess	9000	3000	7.0	+1.3			data, plot
Broad-RI	7670	2940	6.0				data, plot
Hα	6570	100	11.68	+2.8	120		plot
S-II	6730	90	11.68	+2.8	120		plot
6610/100	6610	100	7.06	+1.3	120		plot
6650/100	6650	100	7.06	+1.3	120		plot
6700/100	6700	100	6.93	+1.3	120		plot
5200/70	5200	70	4.90	?			not yet on record
5085/70	5085	70	5.13	?			not yet on record

[b] *Seconds to 10,000 DN (unbinned)*

WASP Filters
Transmission Curves for WASP filters
Broadband Sloan Filters



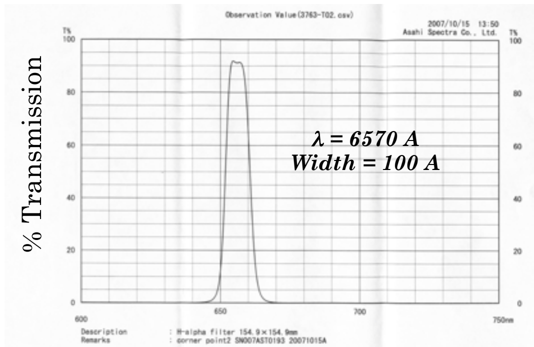
WASP Filters
Transmission Curves for WASP filters
Narrow Band and Special Filters



Wavelength (angstroms)

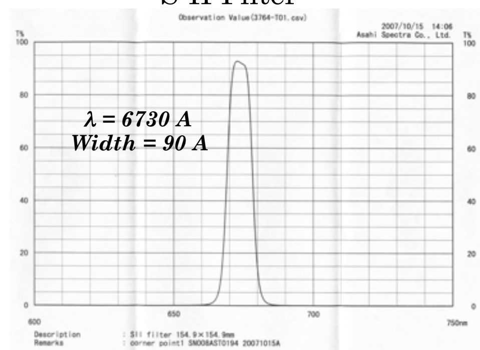
WASP Filters
Transmission Curves for WASP filters
Narrow Band Filters

H-Alpha Filter



Wavelength (angstroms)

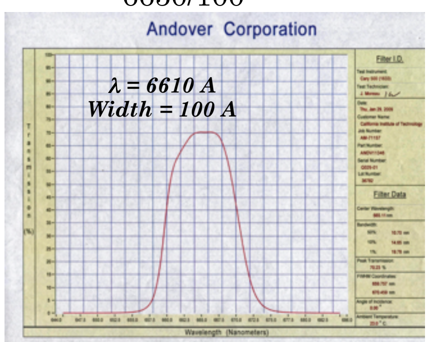
S-II Filter



Wavelength (angstroms)

6650/100

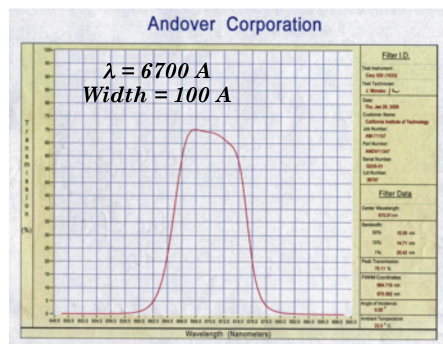
% Transmission



Wavelength (angstroms)

6700/100

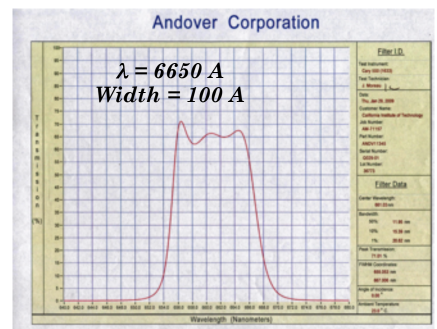
% Transmission



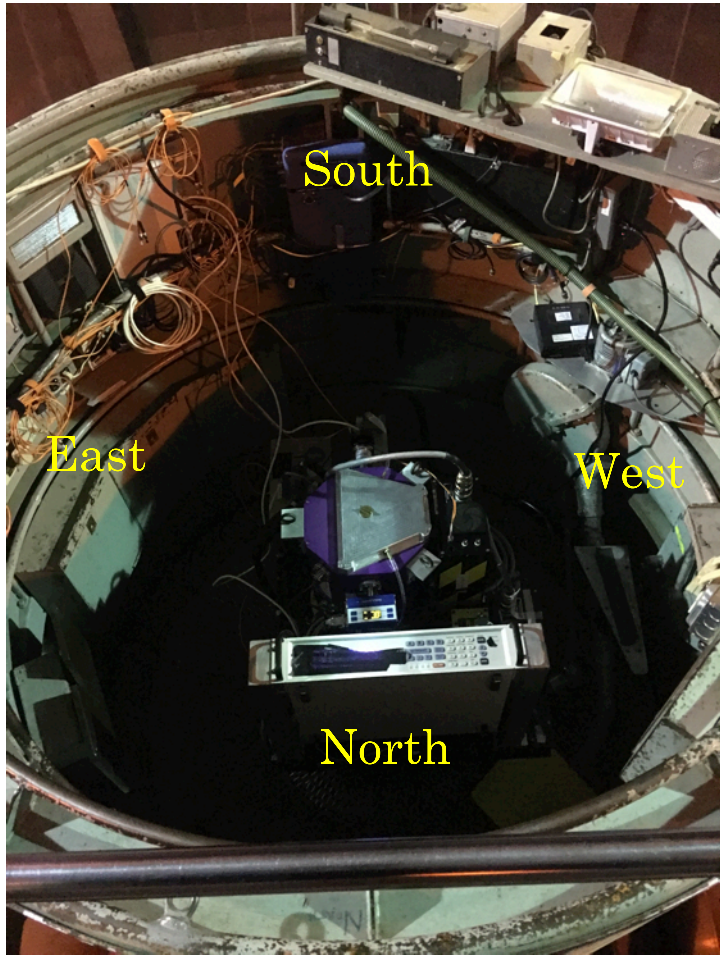
Wavelength (angstroms)

6610/100

% Transmission



Wavelength (angstroms)

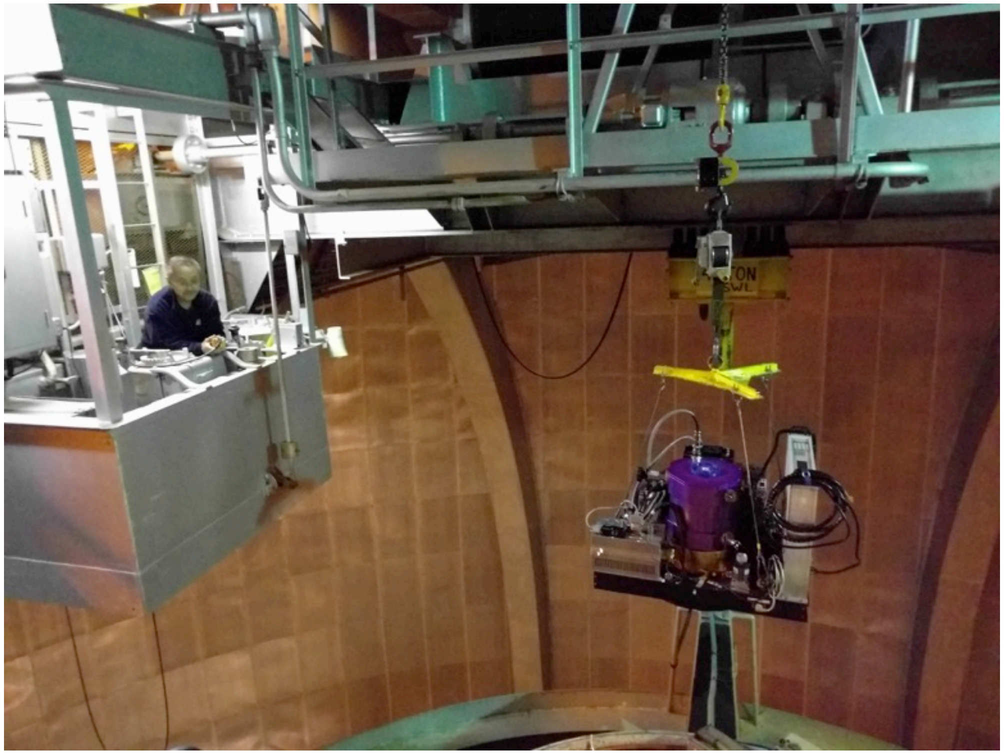


WASP INSTALLATION

WASP Installation at prime focus of the Hale 200" Telescope at Palomar Observatory

February 28, 2016

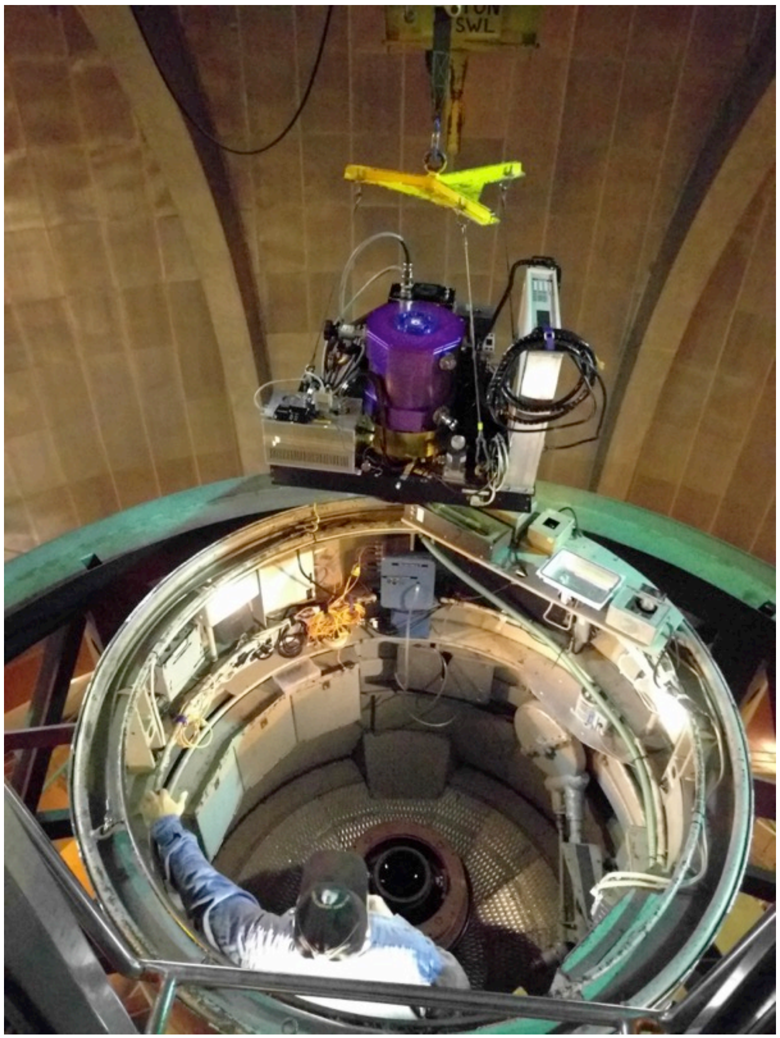
WASP assembled with shutter and filter wheel ready to be lifted to prime focus



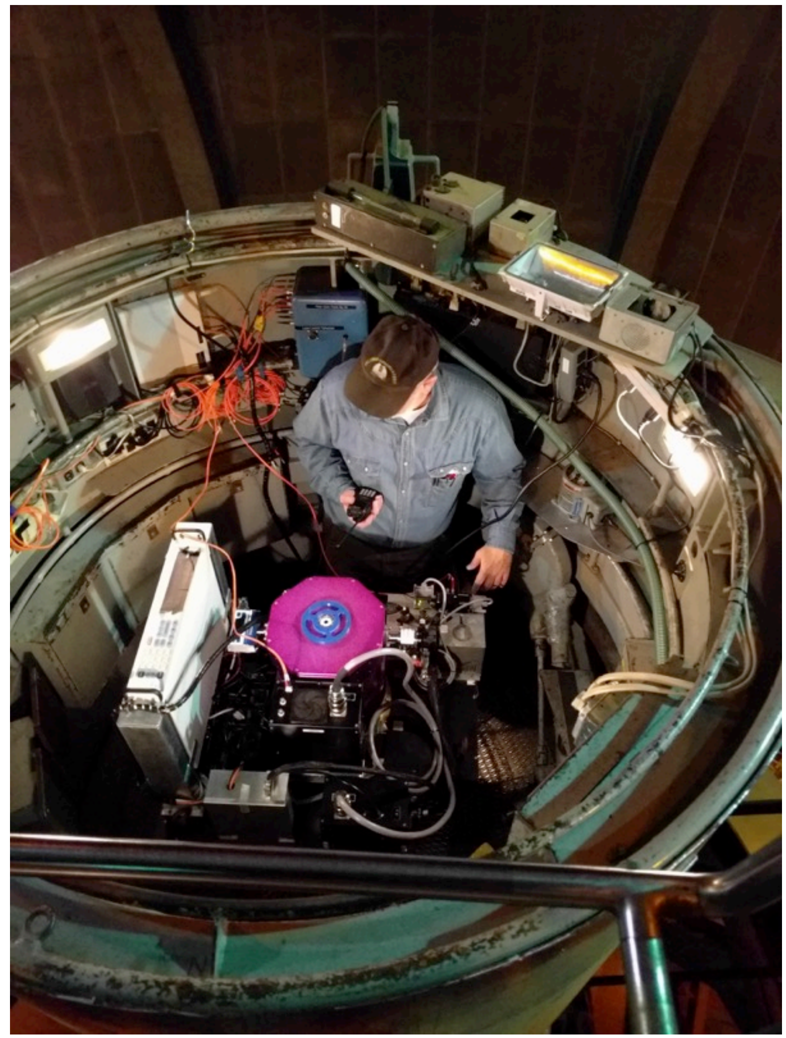
WASP being lifted by the crane to prime focus

WASP Installation at prime focus of the Hale 200” Telescope at Palomar Observatory

February 28, 2016



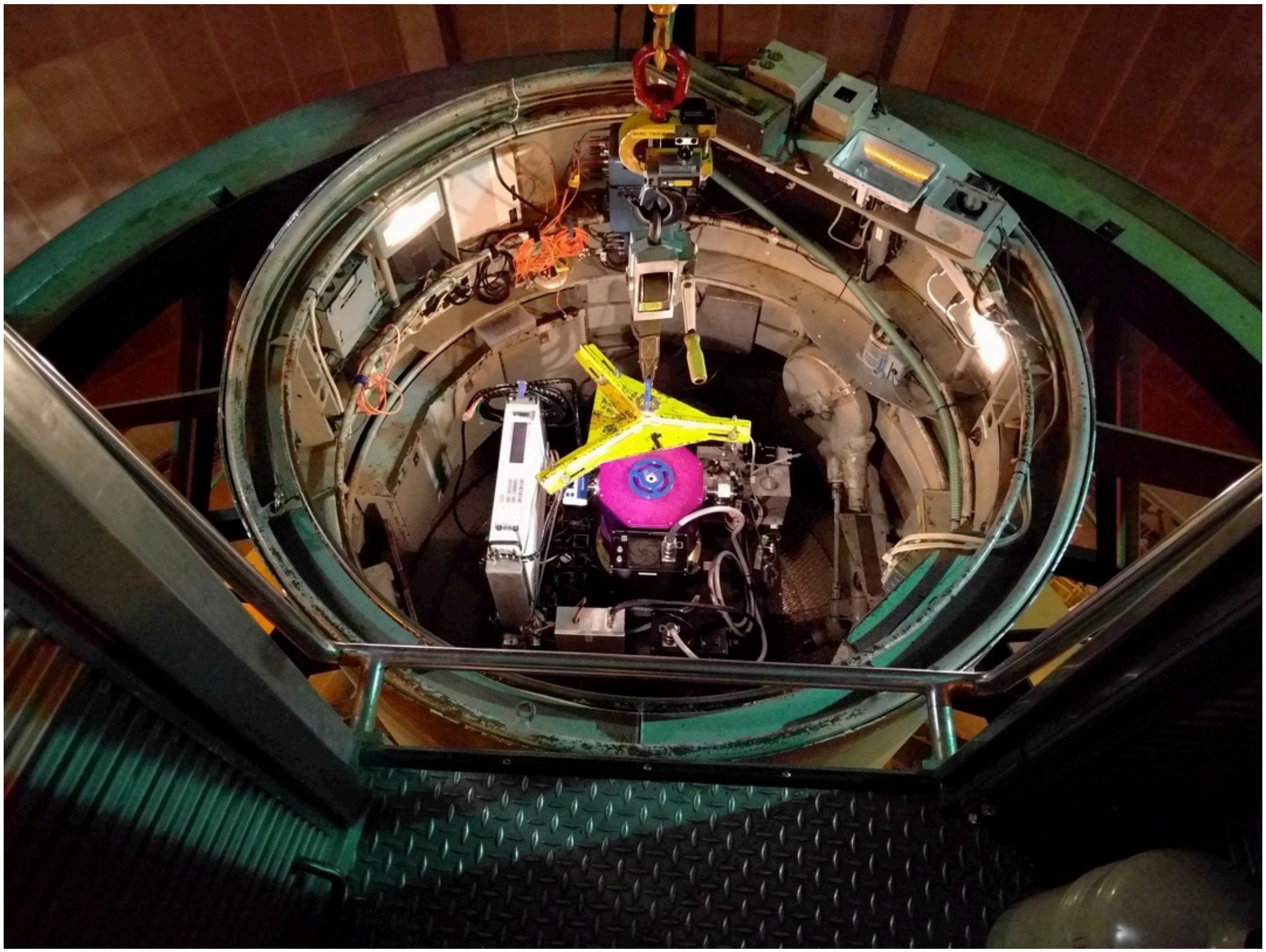
WASP being lowered into the prime focus cage



WASP installed and cabled – READY FOR OBSERVING!

WASP Installation at prime focus of the Hale 200” Telescope at Palomar Observatory

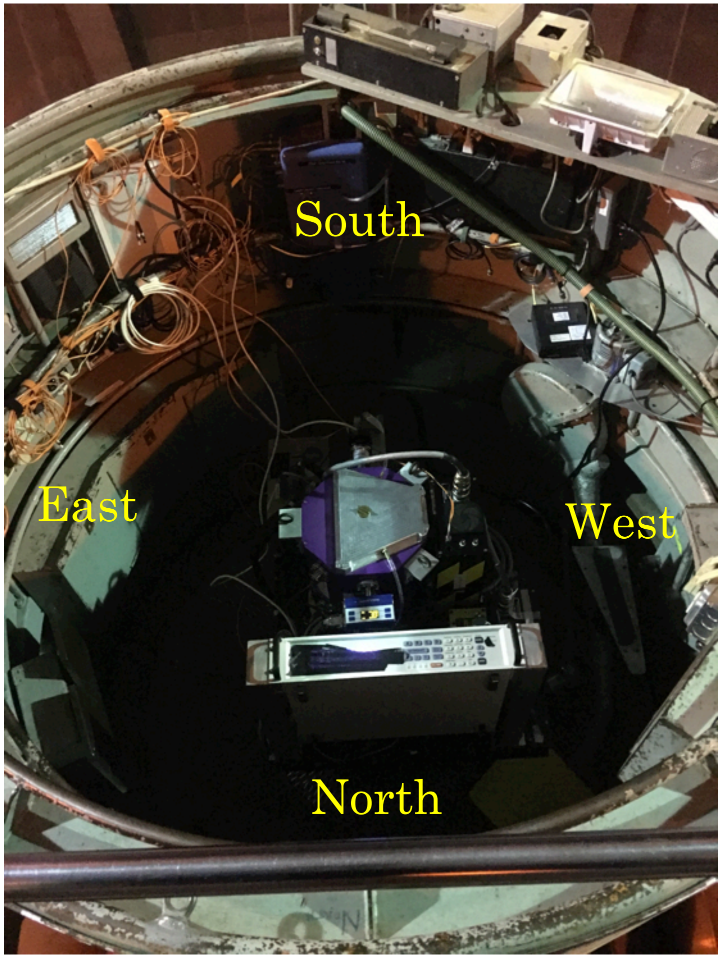
February 28, 2016



WASP installed and cabled – READY FOR OBSERVING!

WASP Installation Procedure

- WASP should only be installed in this orientation



The WASP Instrument
A Visual Tour

Network enabled power strip

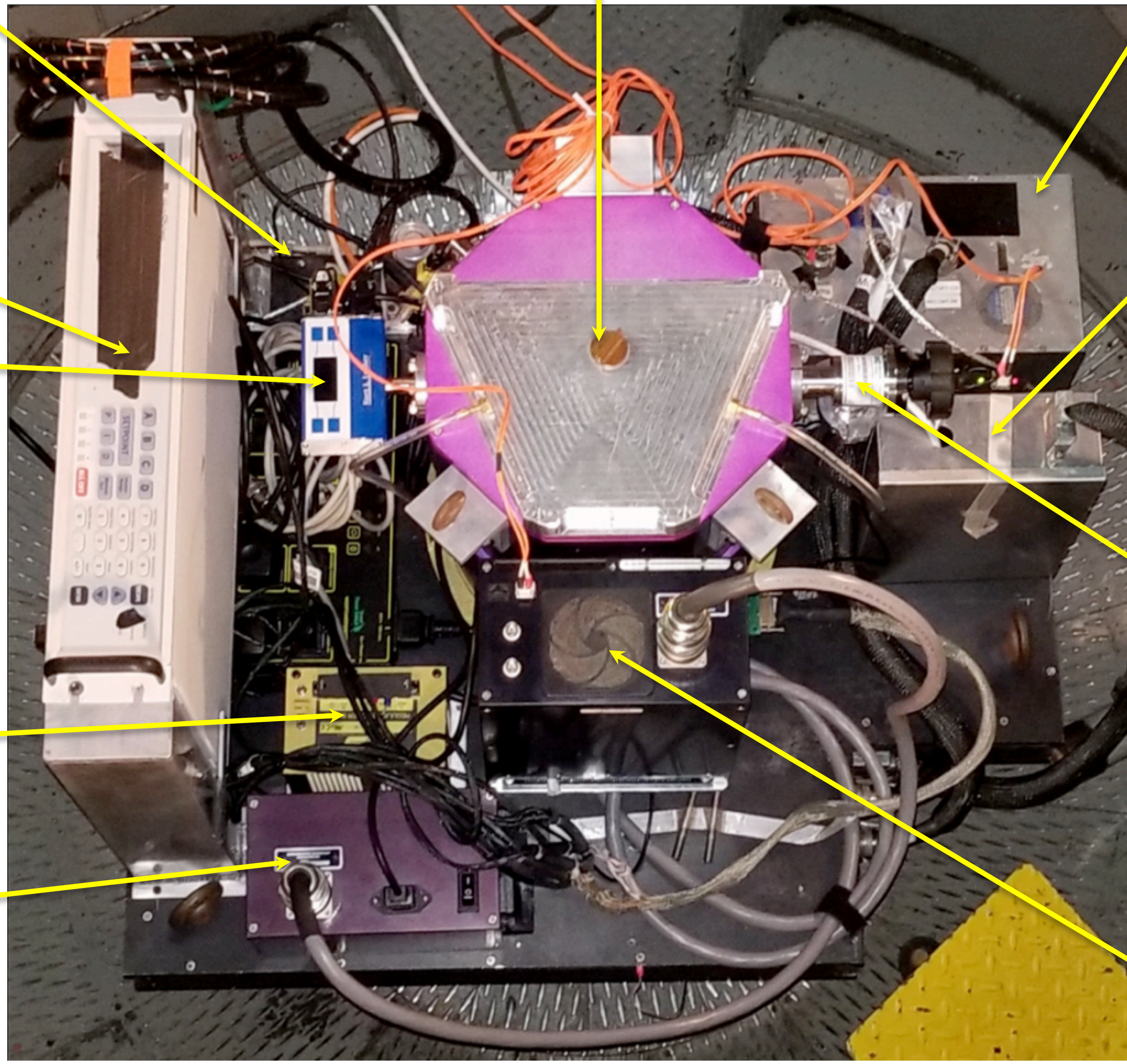
LN2 fill port

Motor Controller box for
the shutter and filter wheel

LAKESHORE 330
Temperature controller

LabJack enclosure –
reads the hall sensor states
for both shutter and filter
wheel

Lesker Pressure Monitor



Vacuum port

High voltage supply
For the STA detector
back side bias

ARCHON electronics
Power supply

ARCHON VIB electronics

The WASP Instrument
The computer connections

Computer Power Supplies

Ethernet Cable to public network

Eth1 Ethernet port
NOT USED AT PALOMAR -

Adnaco USB to fiber interface card
used for the USB to RS-232 port
employed by the shutter and filter wheel
(*note fiber not inserted in the absence of*
the shutter and filter wheel at Caltech)

Display port cable to monitor

Archon fiber interface card:

The WASP Instrument

How to tell that the shutter and filter-wheel are properly connected?

- First check that the USB 3.0 root hub shows up when you run “lsusb” in a terminal.
- 2nd check that the “Prolific Technology PL2303 Serial Port is present.
- As root, change the permissions on /dev/ttyUSB0 to rw (chmod a+rw ttyUSB0)
- If the USB 3.0 hub doesn’t show up; check that you have 2 green lights on the Adnaco (indicating correct fiber connection) then reboot the computer.

```
[developer@wasp2 ~]$ lsusb
Bus 001 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
Bus 002 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
Bus 001 Device 002: ID 8087:0024 Intel Corp. Integrated Rate Matching Hub
Bus 002 Device 002: ID 8087:0024 Intel Corp. Integrated Rate Matching Hub
Bus 001 Device 003: ID 062a:4101 Creative Labs Wireless Keyboard/Mouse
Bus 001 Device 004: ID 0557:2221 ATEN International Co., Ltd Winbond Hermon
Bus 003 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
Bus 004 Device 001: ID 1d6b:0003 Linux Foundation 3.0 root hub
Bus 003 Device 002: ID 067b:2303 Prolific Technology, Inc. PL2303 Serial Port
```

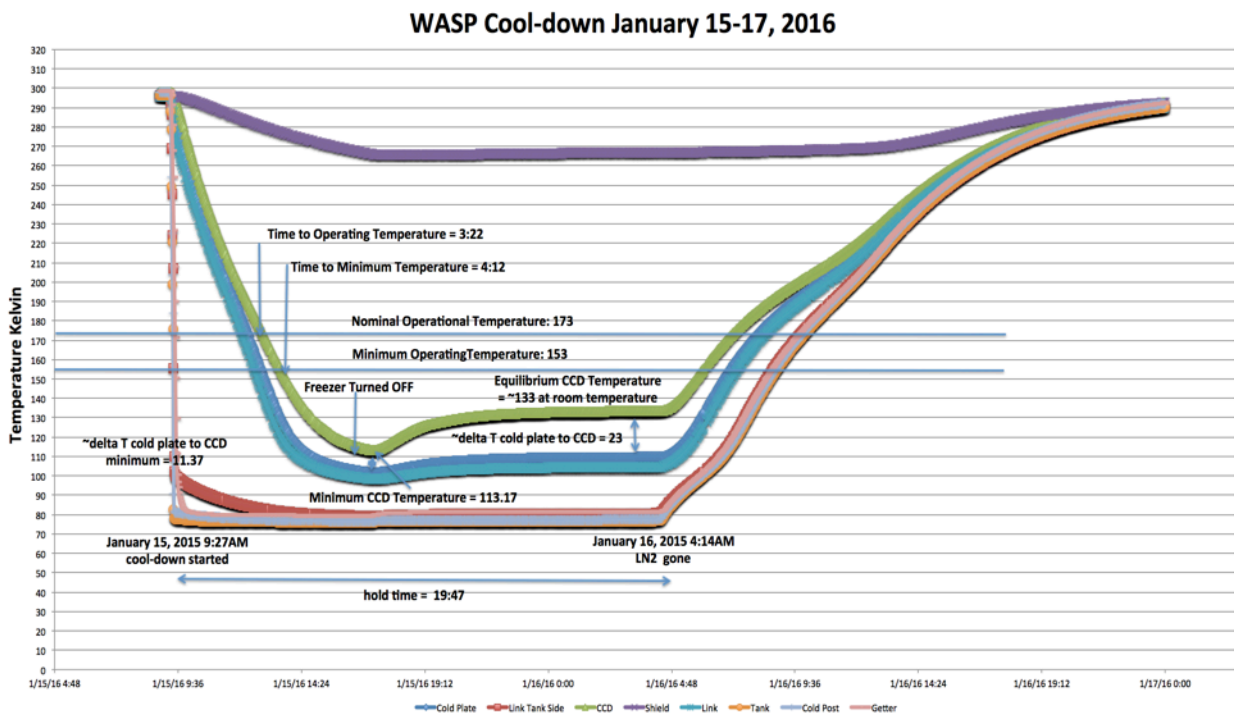
Adnaco USB to fiber interface card used for the USB to RS-232 port employed by the shutter and filter wheel (***note fiber not inserted in the absence of the shutter and filter wheel at Caltech)***

The WASP computer has no native USB 3.0 hub on the motherboard so the presence of a USB 3.0 hub indicates that the Adnaco is correctly connected.
The “Prolific Technology, Inc. PL2303 Serial Port” is the 25 pin serial to USB cable connected to the motor controllers for the shutter and filter-wheel.

WASP installation

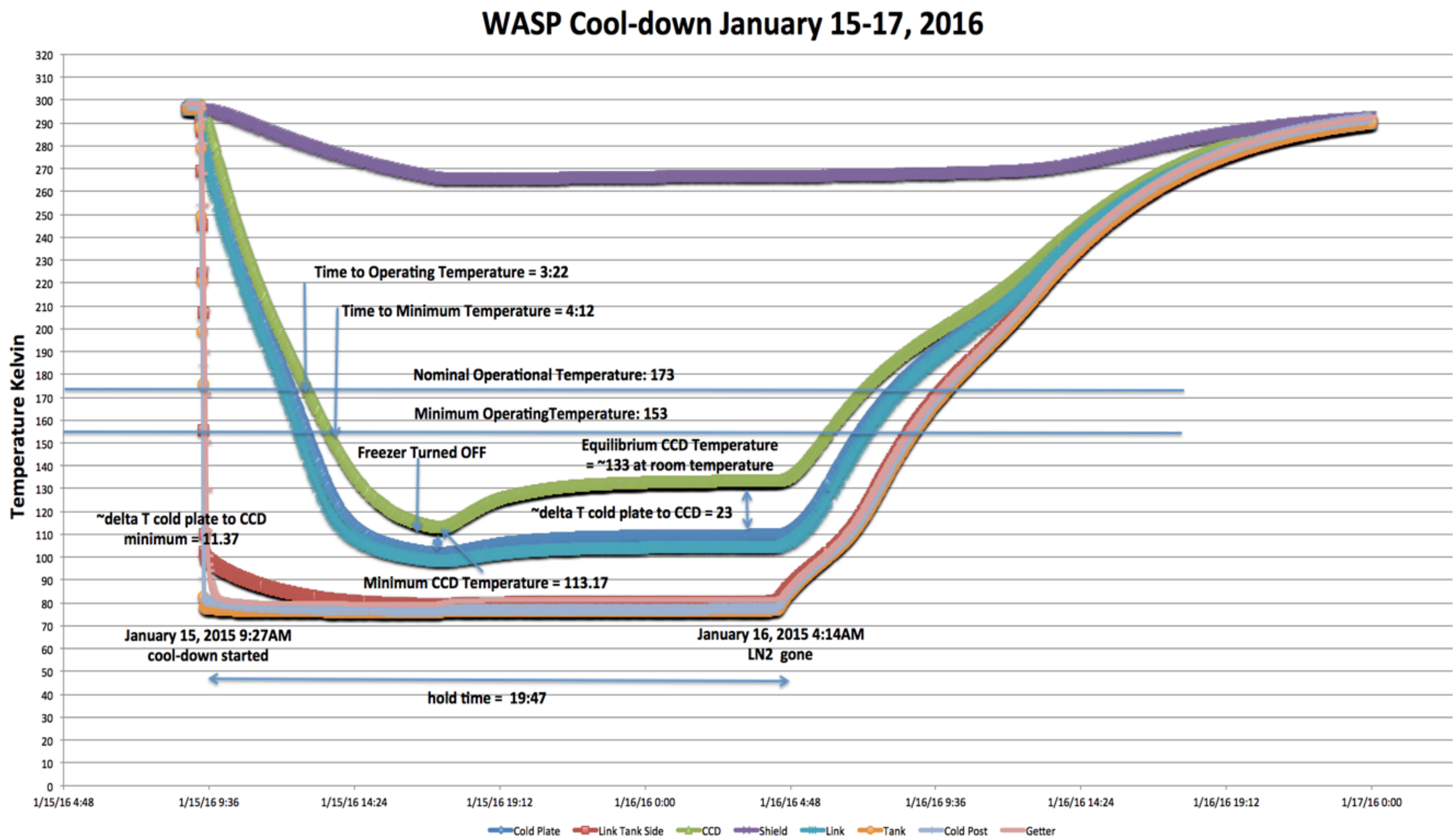
- PRIME FOCUS CAGE INSTALLATION
  - WASP connections to the Palomar prime focus cages - 2 pairs of fiber
    - Optical fiber connections
      - Archon controller
      - Adnaco USB to fiber
  - Ethernet connection - 3 Ethernet connections
    - Two possible configurations: With Ethernet switch and without
    - Without Ethernet switch: - each individual unit must be plugged into
      - Lakeshore 330 – used for monitoring temperatures PRIVATE NETWORK
      - LabJack Analog and Digital signal monitoring PUBLIC NETWORK
      - Network power switch PRIVATE NETWORK
    - With Ethernet switch
      - All of the Ethernet devices are first plugged into the Ethernet switch on the shutter and filter wheel base and then a single cable goes to the switch in the prime focus cage.
  - Power – 1 power connection
    - all electronic devices are plugged into the integrated network power switch. Only the main power cable for the network switch actually needs to be plugged in.

- COMPUTER INSTALLATION
  - Connect the optical fibers to the Adnaco card (upper fiber interface) and the Archon interface card
  - Plug in 2 power cables for the computer redundant power supplies
  - Plug in the Ethernet cable to Eth0 (upper network port if vertical, left-most port if the computer is horizontal)



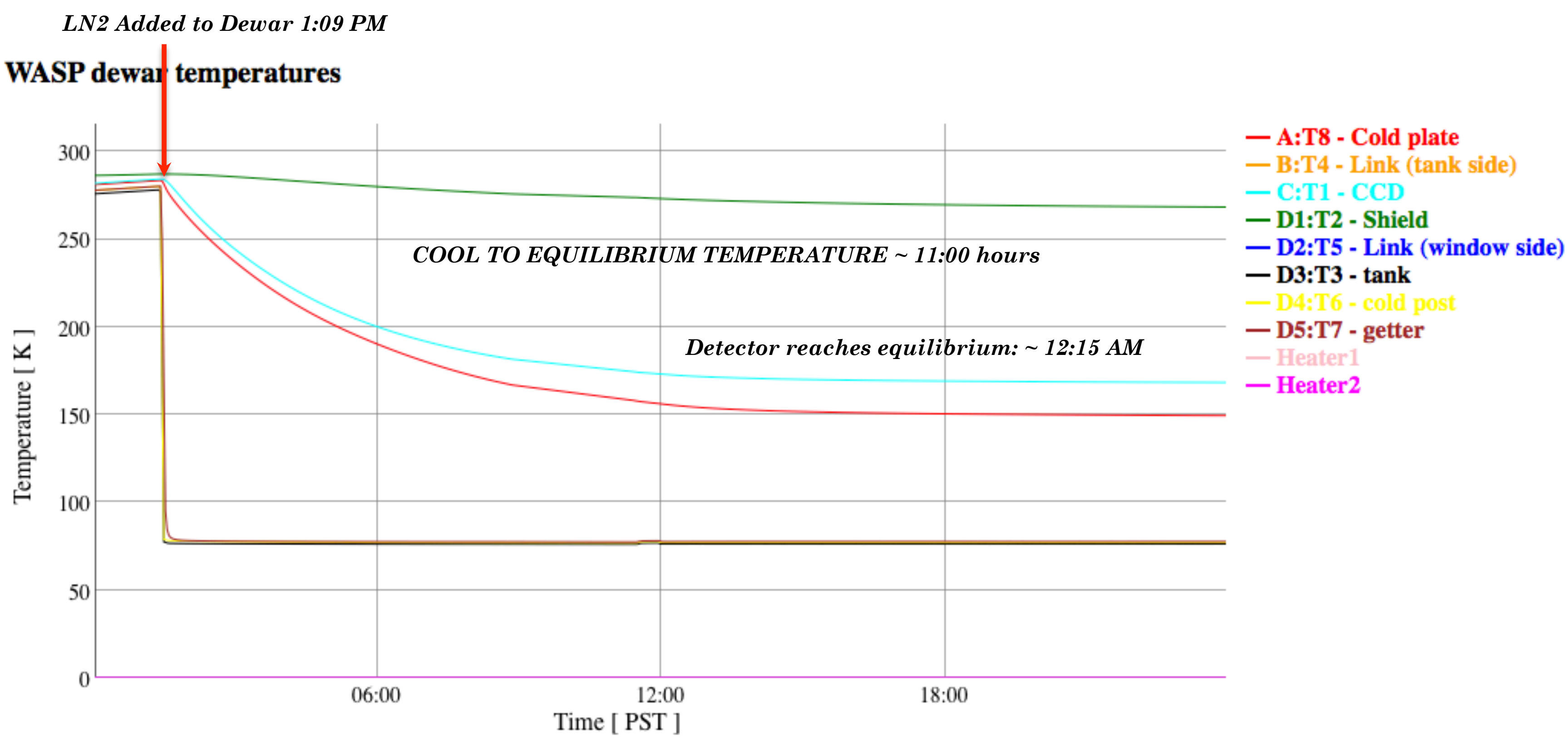
THERMAL MONITORING AND HOLD TIME

WASP First Cool-down

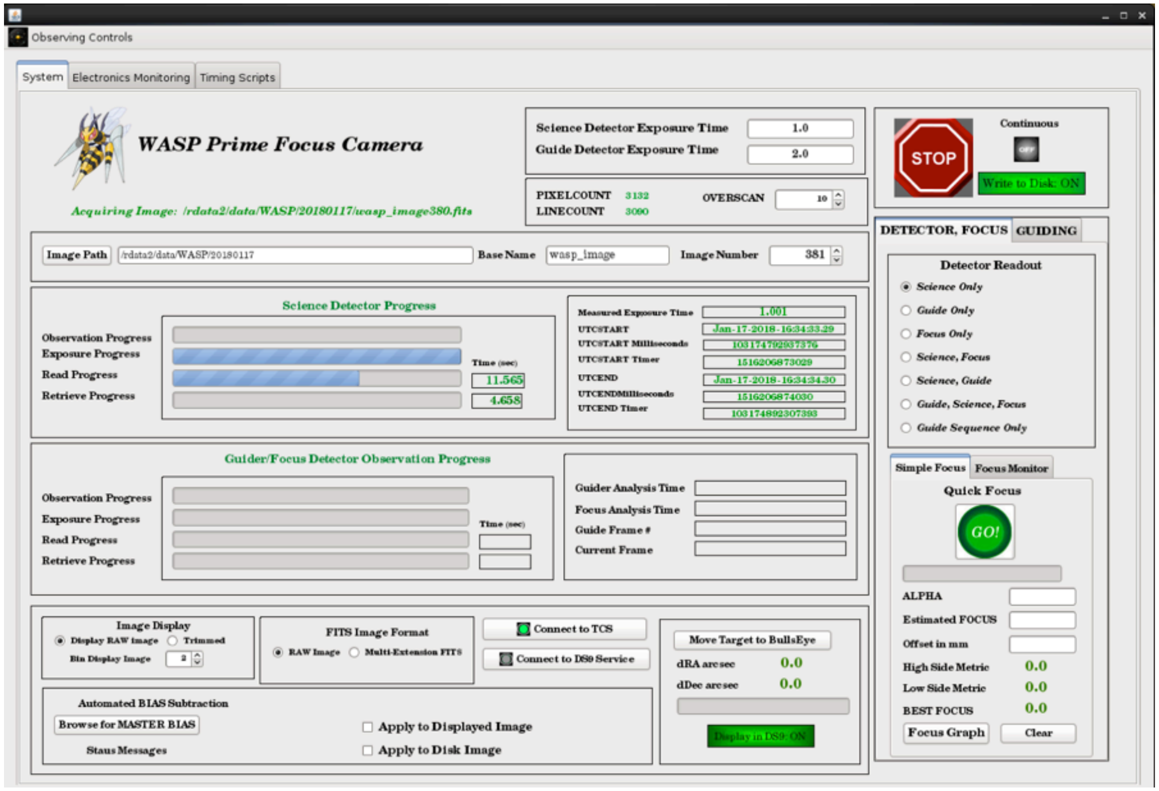


Liquid Nitrogen Hold-Time > 24 hours after optimization

How long does WASP take to cool to operational temperatures?



Liquid Nitrogen Hold-Time > 24 hours after optimization



BASIC OPERATION OF WASP

Basic Operations of WASP

Electronics Monitoring

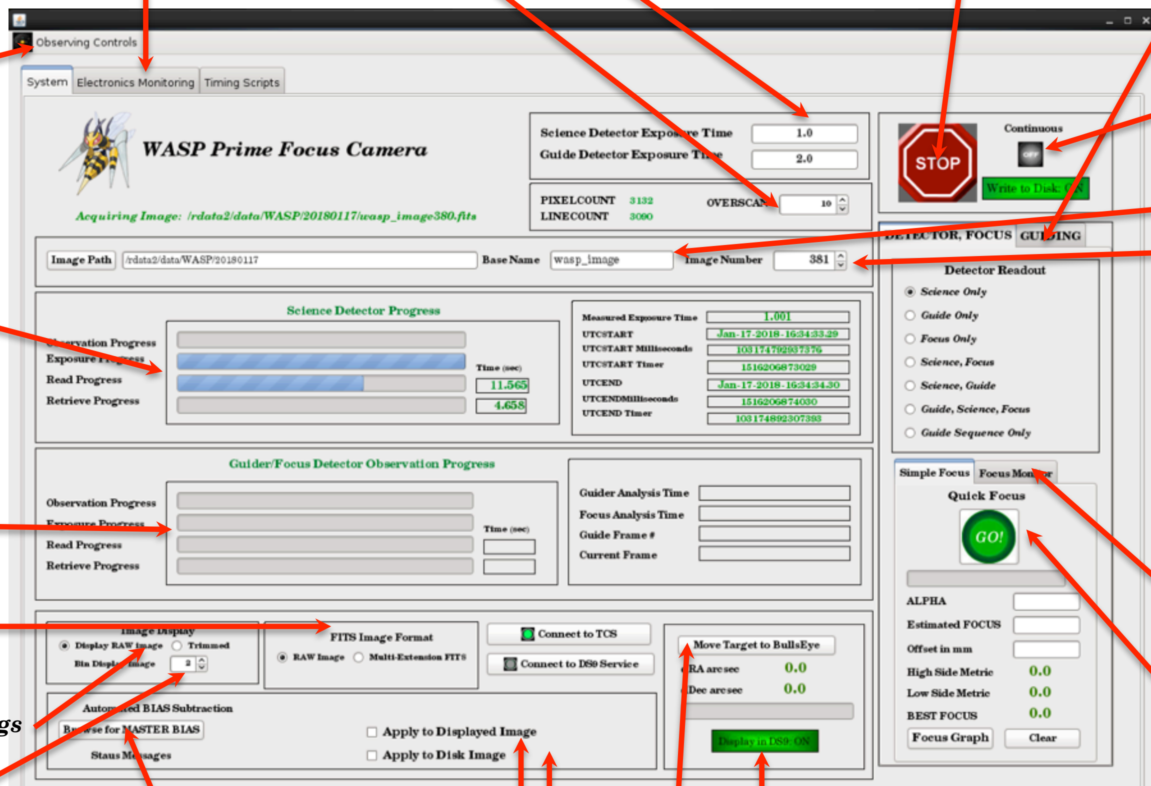
Enter Exposure Time

Press GO button!

GUIDING

Enter Overscan

Observing Controls
Dithering
Astrometry.net
Sextractor
Science Image Display
Guide/Focus Image Display
WASP Scripting



Continuous Button

Enter Image Basename

Enter Image Number

Science Detector
Exposure Progress
Read Progress
Retrieve Progress

Select Detector Readout Mode
Science ONLY
Guide ONLY
Focus ONLY

Science, Focus
Science, Guide
Science, Focus, Guide

Guide sequence

Guide / Focus Detector
Exposure Progress
Read Progress
Retrieve Progress

FOCUS Monitoring

Select FITS output format
Single Extension FITS
Multi-Extension FITS

Quick FOCUS

Select Image Display Settings
Trim prescan and overscan
Bin the Display Image

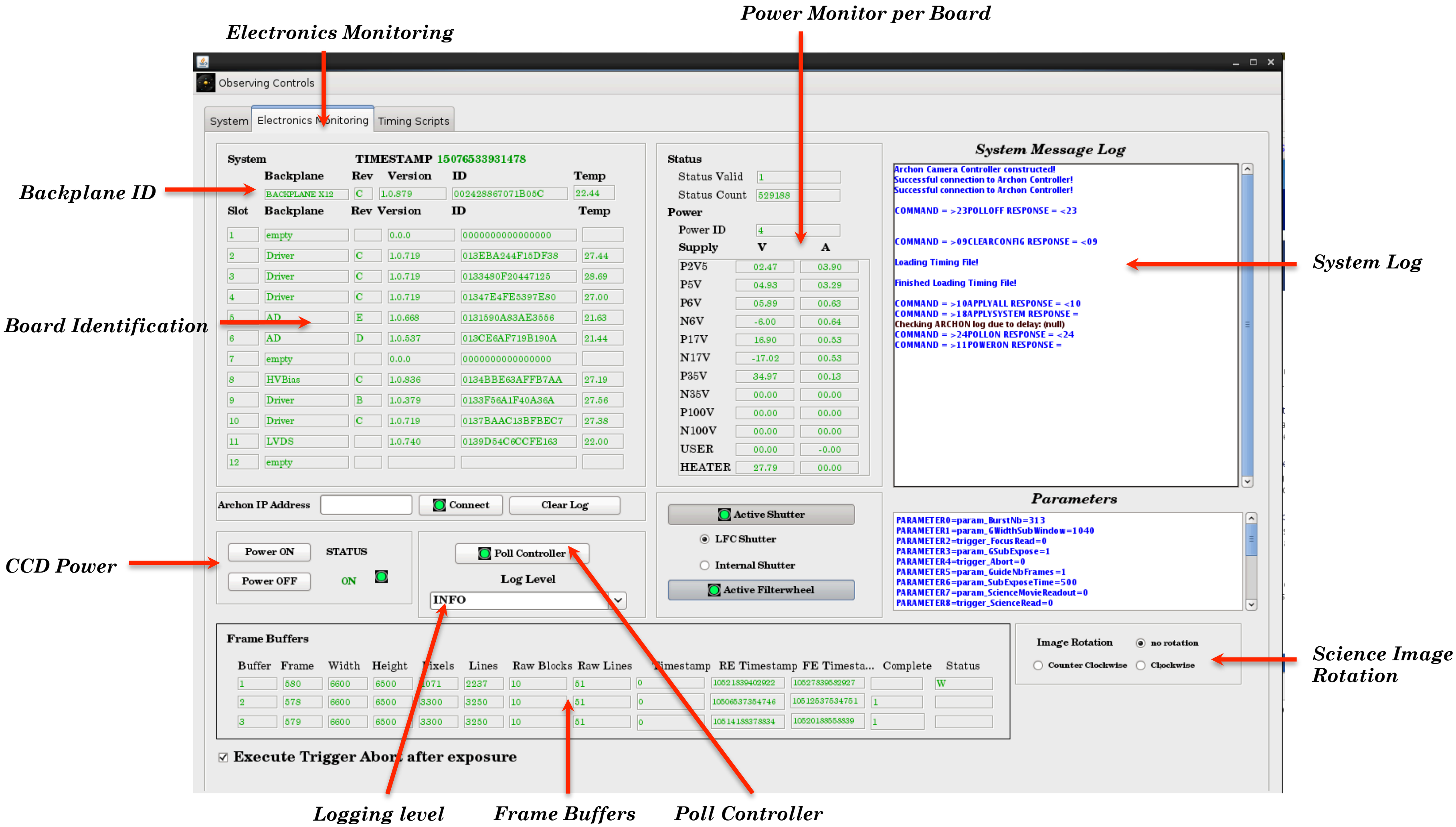
Subtract BIAS
Browse for MASTER BIAS image
Subtract BIAS from Display Image
Subtract BIAS from Disk Image

Display in DS9

Move Target to Bullseye

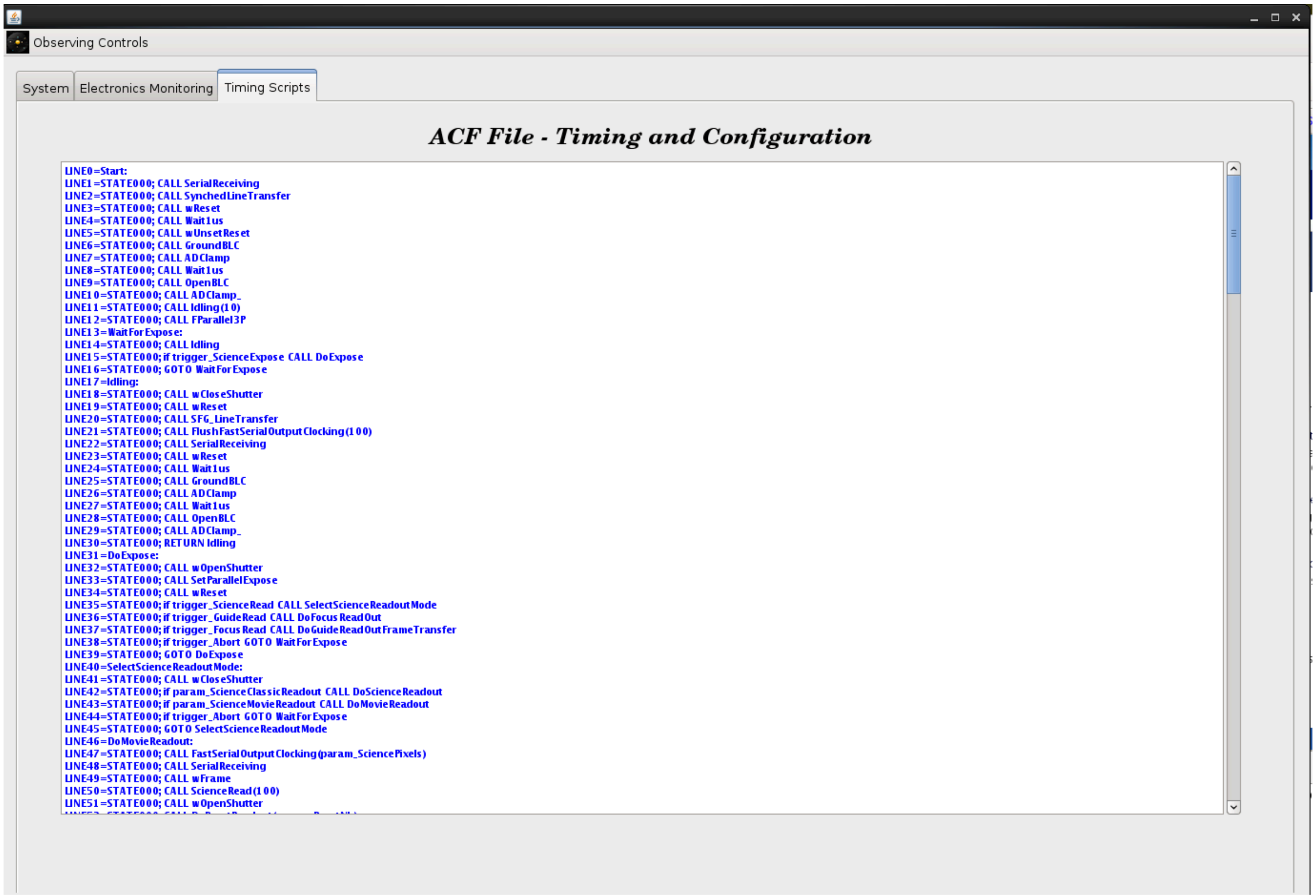
Basic Operations of WASP

Electronics Monitoring



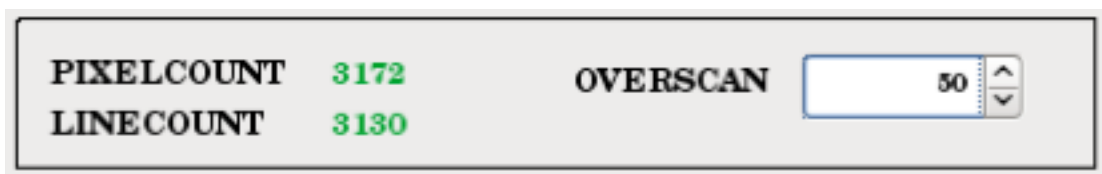
Basic Operations of WASP

Timing File



Basic Operations of WASP

- The first thing an observer needs to decide when using WASP is the format and naming of the FITS image files produced.
  - FITS images are stored within date stamped image directories that are automatically created whenever the software is started. The date stamped image directory is created under the DEFAULT_DATA_DIRECTORY specified in the Archon.ini configuration file. The currently configured output data directory is DEFAULT_DATA_DIRECTORY = /rdata2/data/WASP. This directory may be changed in the future dependent upon disk space requirements.
- FITS format: WASP science detector images are readout using 4 separate amplifier channels and the observer can choose to write the images as either multi-extension FITS images with each quadrant written to a different image extension (including the prescan and overscan) or as single image frames. The default is to use the “raw” format where a single image extension is included in the FITS file. If the primary analysis method will be using iraf’s ccdproc then the multi-extension format is preferred. For all other analysis methods the “raw” format is preferred.
- What overscan does the observer want in the image? The overscan size can be configured by setting the overscan size in the provided spinner control. Observers using ccdproc may want to set a specific overscan size. Observers who do not require the overscan for their data reduction process can simply set it to zero.



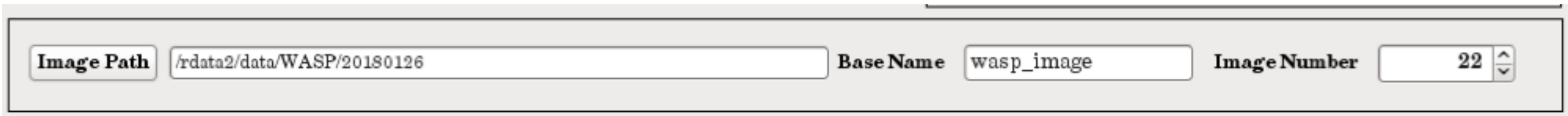
- Image naming convention:

  DEFAULT_DATA_DIRECTORY + $YYYYMMDD+$BASENAME+$IMAGENUMBER.FITS

  where DEFAULT_DATA_DIRECTORY = default data directory specified in the Archon.ini configuration file
  $YYYYMMDD = the date directory in year, month and day format
  $BASENAME = the image base name entered in the base name text field
  $IMAGENUMBER = the image number, this number automatically increments after each image is taken
  GUIDER IMAGES = DEFAULT_DATA_DIRECTORY + $YYYYMMDD+$BASENAME + ”_guide_”+$IMAGENUMBER.FITS
  FOCUS IMAGES = DEFAULT_DATA_DIRECTORY + $YYYYMMDD+$BASENAME + ”_focus_”+$IMAGENUMBER.FITS

Specifying how the FITS image is displayed and written to disk

- Specifying the image name: Set the BASENAME and the IMAGE NUMBER



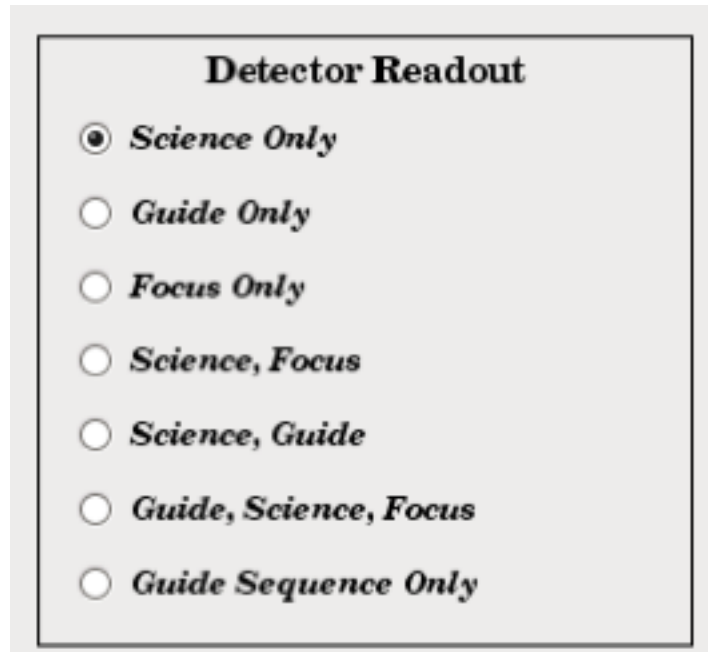
- Specifying the FITS format: Single or Multi-Extension FITS

- Determine how you want the image displayed: Trim prescan and overscan?
  - The size of the WASP images makes image display slow so the displayed image is binned 2x2 by default.
  - You can turn off binning by setting the “Bin Display Image” spinner control to 1x1 or increase the size of the binning.

- Do you have a bias frame that you’d like to subtract from the displayed image or the disk image?

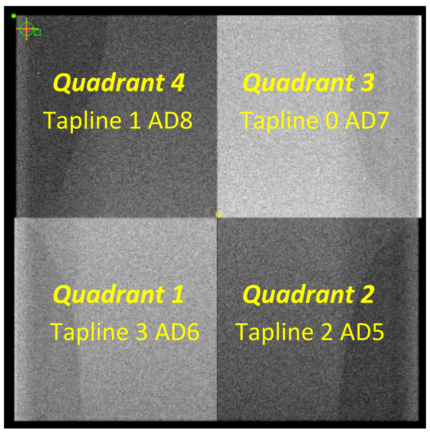
WASP Readout Modes

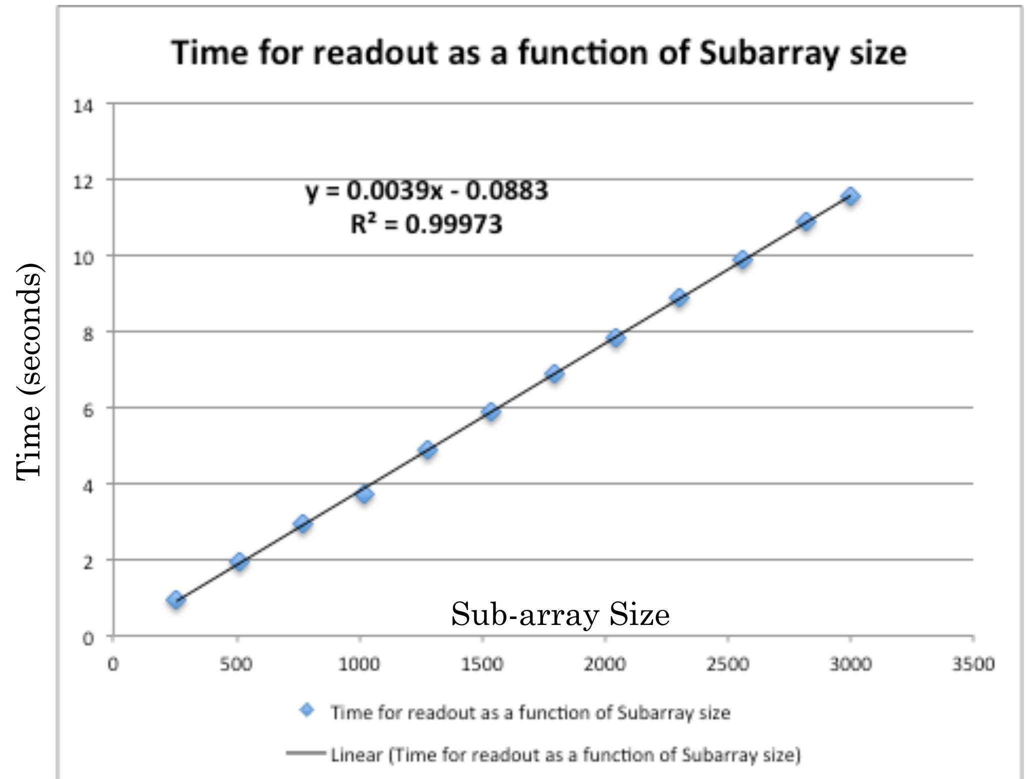
- Detector Readout Modes
  - **Science ONLY** – reads out only the science detector
  - **Guide ONLY** – reads out only the guide detector
  - **Focus ONLY** – reads out only the focus detector
  - **Science, Focus** – reads out both the science and focus detector after EXPTIME. Used for focus monitoring by automatically running Sextractor on each image.
  - **Science, Guide** – first exposes the guide detector for the selected guide exposure time, finds all stars in the image, automatically selects guide stars and configures the ROI for fast readout, guide during exposure, close shutter and readout the science detector.
  - **Guide, Science, Focus**– first exposes the guide detector for the selected guide exposure time, finds all stars in the image, automatically selects guide stars and configures the ROI for fast readout, guide during exposure, close shutter and readout the science detector then the focus detector.
  - **Guide sequence only**– first exposes the guide detector for the selected guide exposure time, finds all stars in the image, automatically selects guide stars and configures the ROI for fast readout, guide during exposure, close shutter. This is essentially a test mode for guiding and is not used in observing.



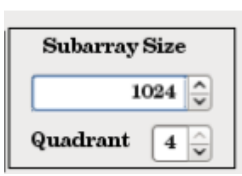
WASP Sub-array Mode

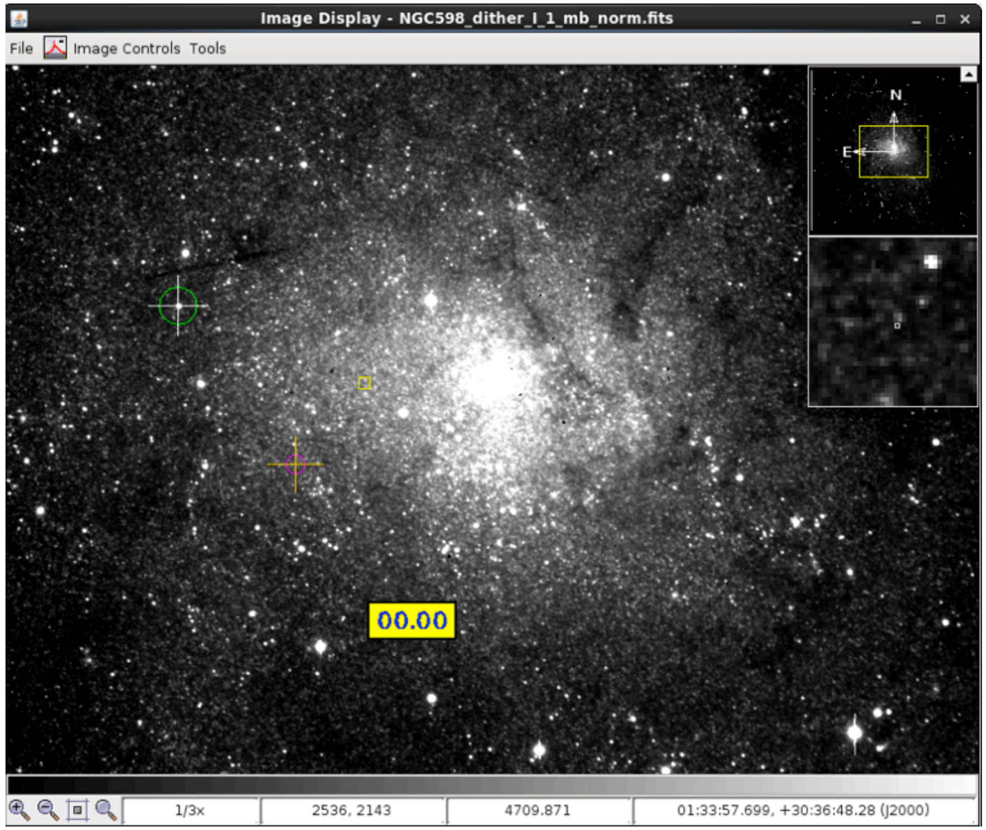
- Sub-arrays may be readout centered in any of the 4 quadrants
- Quadrants are numbered starting in the lower left quadrant and then numbered counter-clockwise.





Subarray Size	Readout Time (seconds)
256	0.961
512	1.927
768	2.929
1024	3.726
1280	4.883
1536	5.898
1792	6.857
2048	7.801
2304	8.883
2560	9.863
2816	10.874
3000	11.553



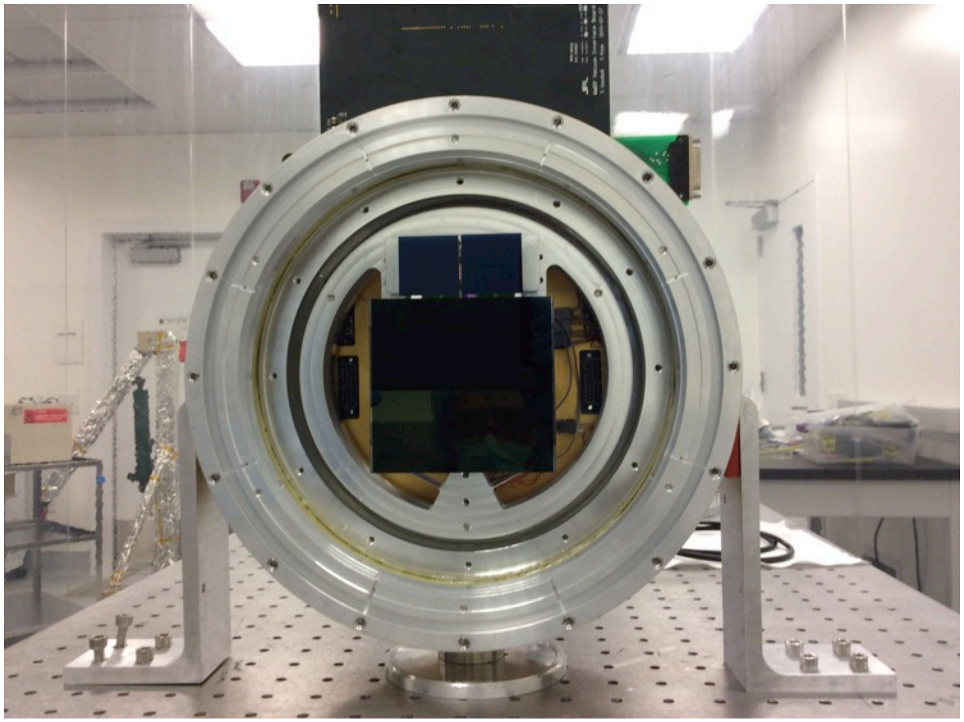


THE IMAGE DISPLAY SYSTEM

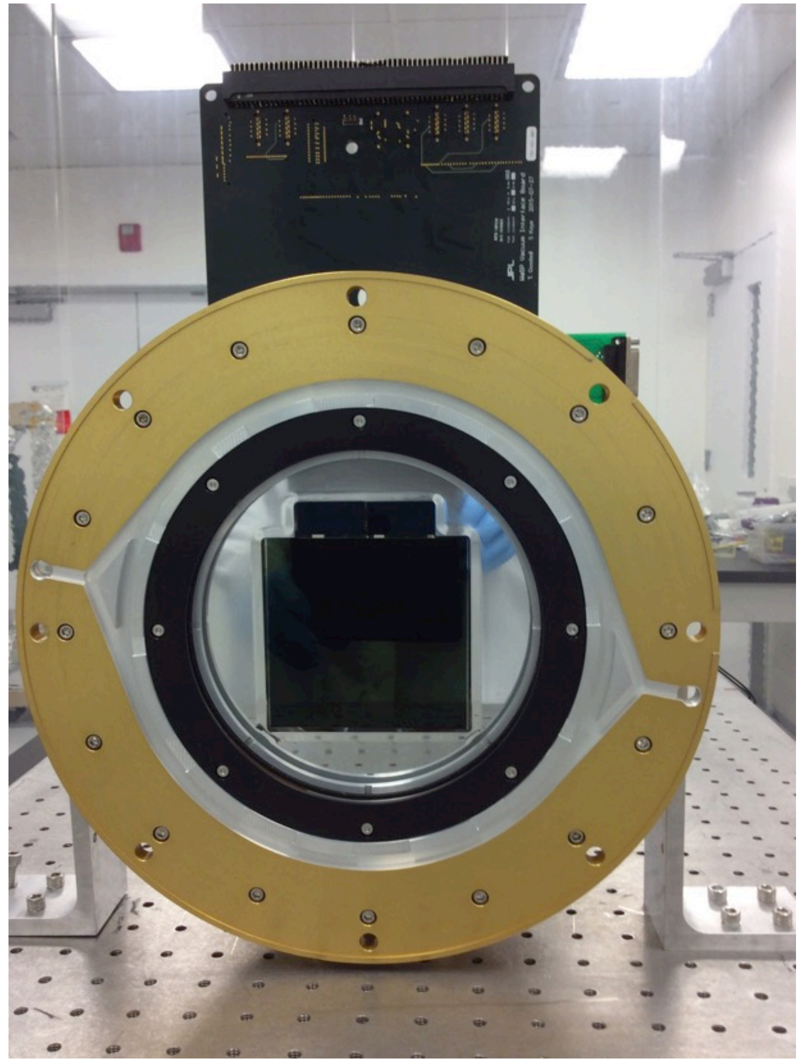
Science, Guide and Focus Detectors Installed in the WASP dewar

STA3600A 2064x2064
Guide Detector

STA3600A 2064x2064
Focus Detector



E2V 6144x6160 CCD231-C6
Back Illuminated Science Detector

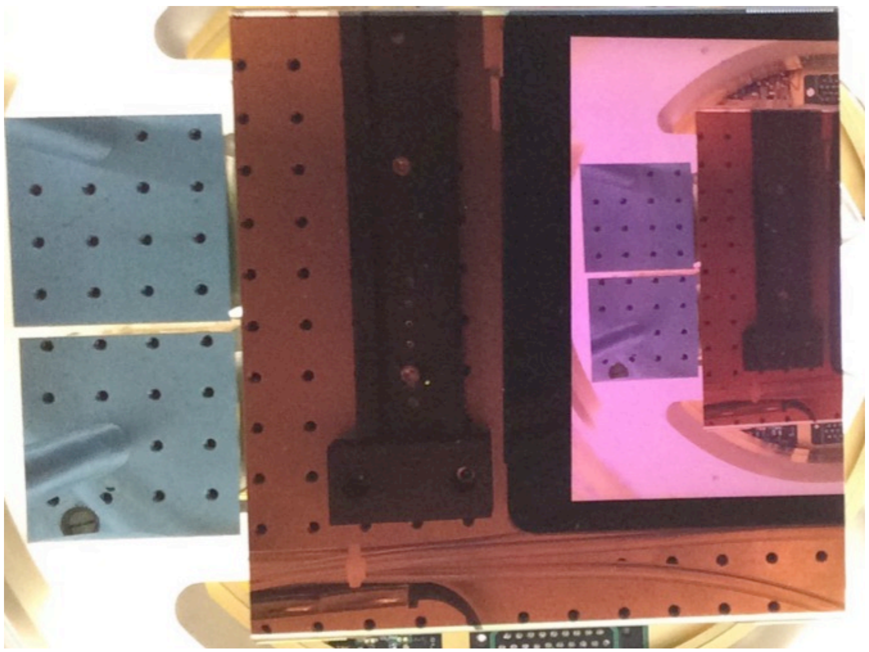


Lower half of the dewar with VIB attached fully assembled

WASP – Palomar P200 Telescope
On-Sky Orientation of Science, Guide and Focus CCDs
September 13, 2016

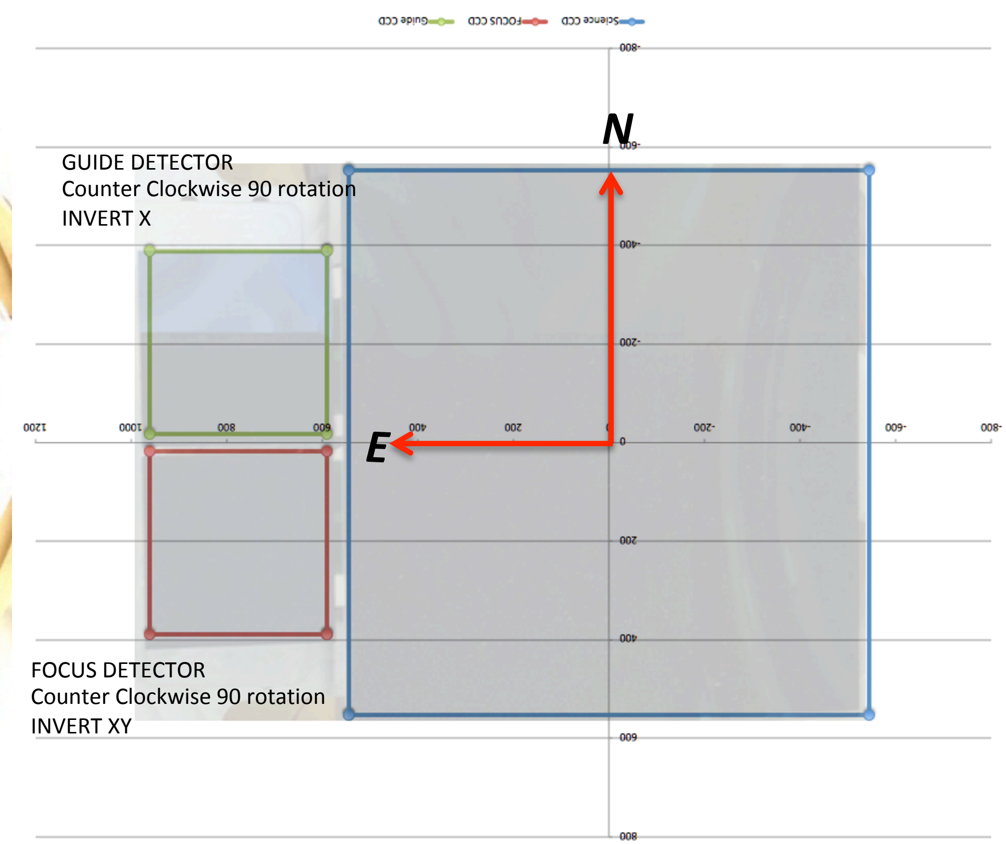
Science Detector Plate Scale = 0.18 arc-seconds/pixel

STA3600A 2064x2064
Guide Detector



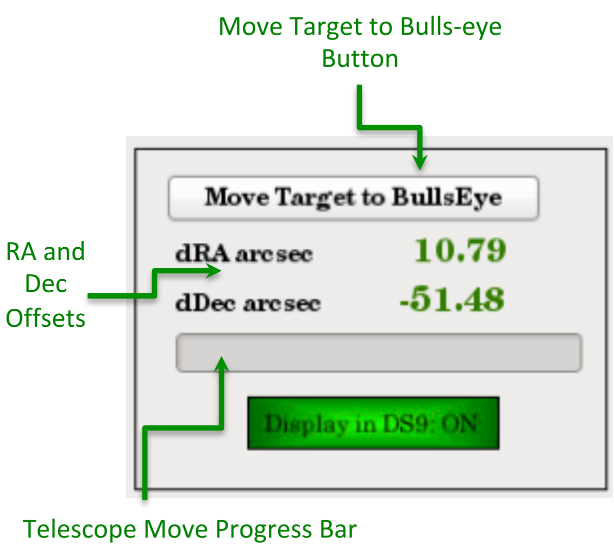
STA3600A 2064x2064
Focus Detector

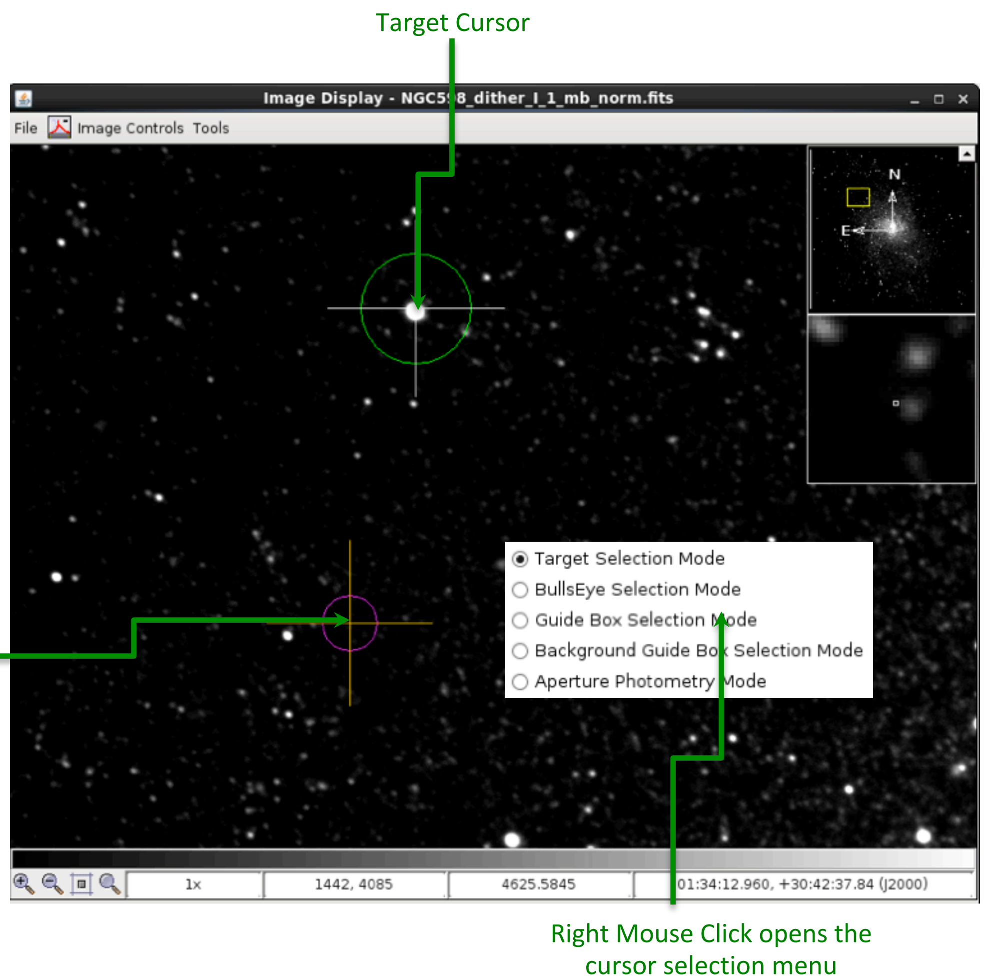
E2V 6144x6160 CCD231-C6
Back Illuminated Science Detector



Target Acquisition and Placement with WASP

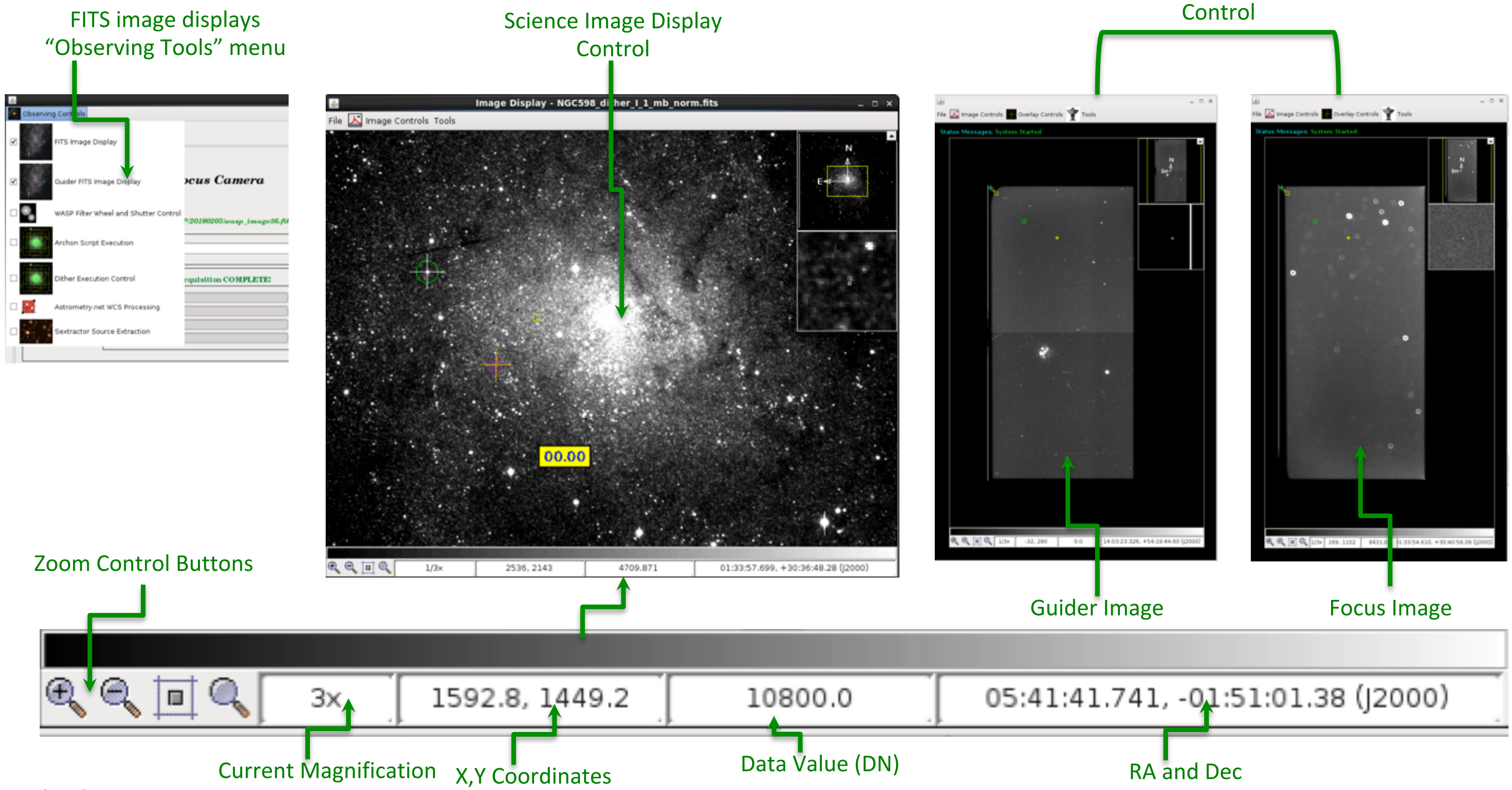
- **Where do you want your target to be placed on the WASP detector?**
- The WASP image display system integrates telescope control into the image display using the "Target to Bulls-eye" system.
- Place the "Target" cursor on the object that you wish to move and the "Bulls-eye" cursor where you want the object to be placed. The calculated offset required to move the target to the bulls-eye location is displayed on the main WASP controls panel.
- Press the "Move Target to Bulls-eye" button and the target is moved to the selected location.





WASP Image Display System

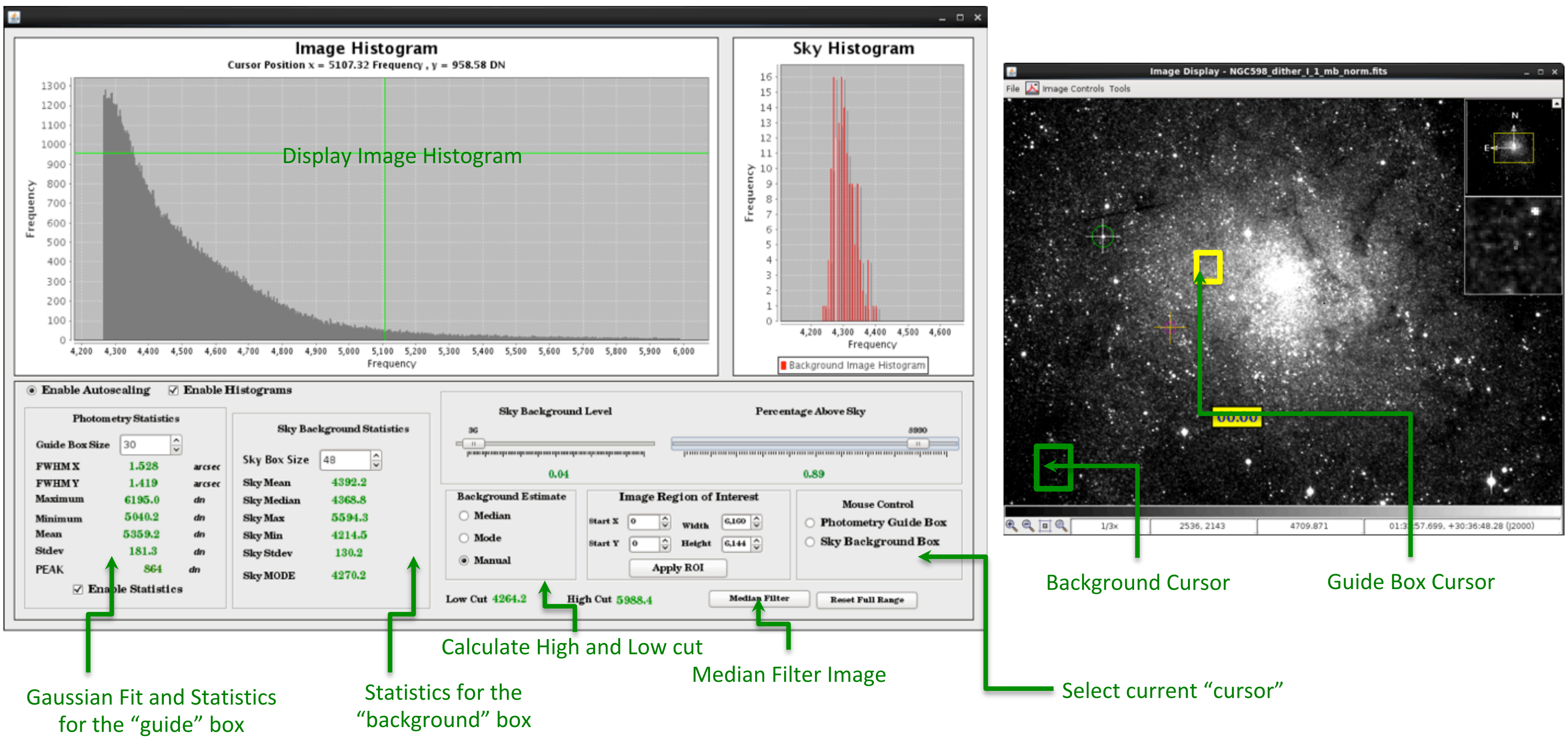
- The WASP instrument software uses two separate image displays for the science detector images and the guider/focus detector images.
- Access to the image displays is available from the “Observing Tools” menu on the main WASP controls panel.

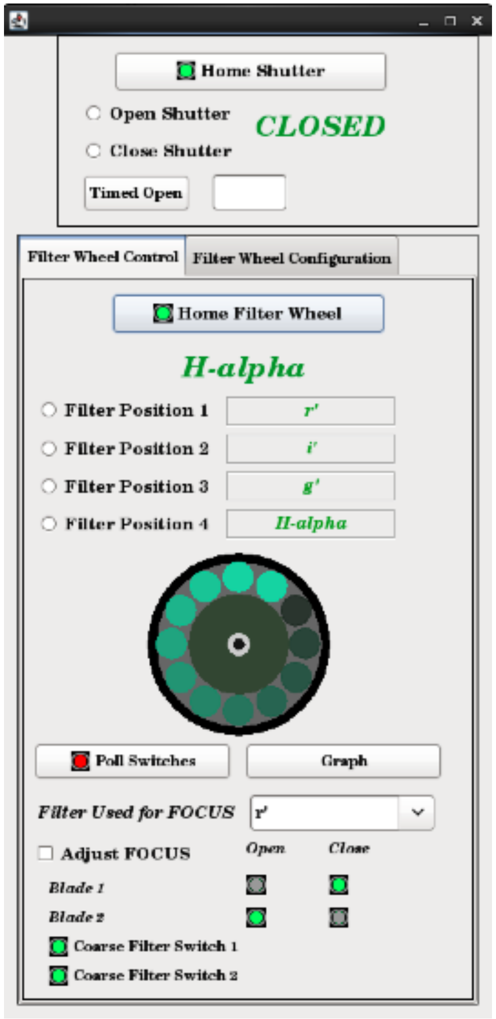


WASP Image Display System

Image Contrast Controls

- The science CCD image display has a sophisticated image contrast and brightness control that uses 2 mouse cursors to set the scaling limits for the image.
- First enable auto-scaling then place the “background” cursor on an area of the image to set the base of the image scale and the “guide” cursor on a star that sets the top of the image scale.



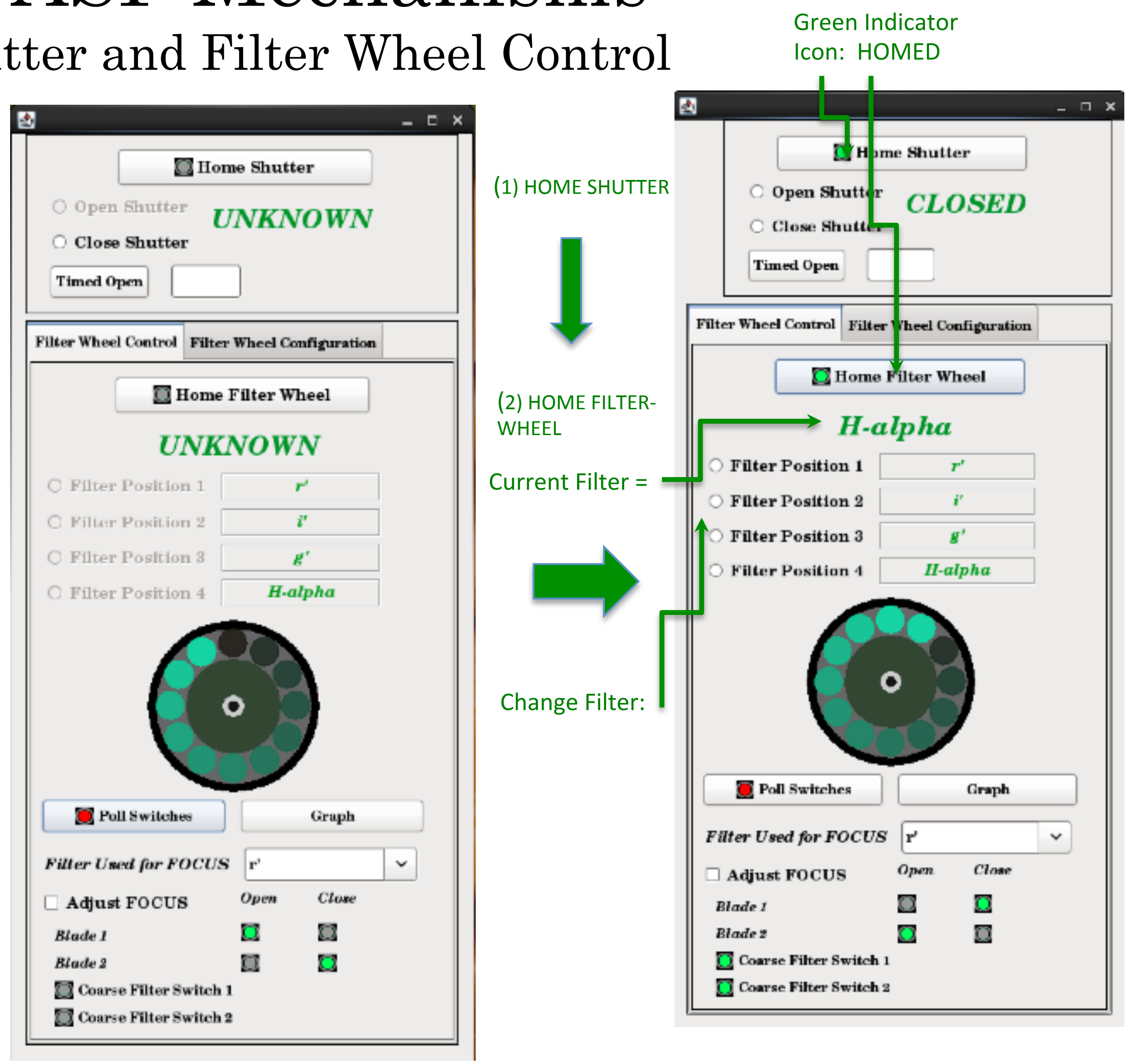


WASP MECHANISMS

WASP Mechanisms

Shutter and Filter Wheel Control

- The WASP camera uses the same shutter and filter-wheel originally created for LFC.
- Unlike LFC, the shutter and filter-wheel are controlled via a GUI accessed from the "Observing Tools" menu on the main panel
- It is necessary to "HOME" both mechanisms prior to use.
- IMPORTANT: FIRST HOME THE SHUTTER THEN THE FILTER-WHEEL
- EVEN MORE IMPORTANT: NEVER MOVE BOTH MECHANISMS AT THE SAME TIME!!! (*communication to both mechanisms is through a single serial port)*
- Shutter homing normal takes less than 60 seconds
- Filter wheel homing can take up to 5 minutes so please be patient.
- The filter wheel is SLOW due to the need to position the filter with high precision so that flats are reproducible.

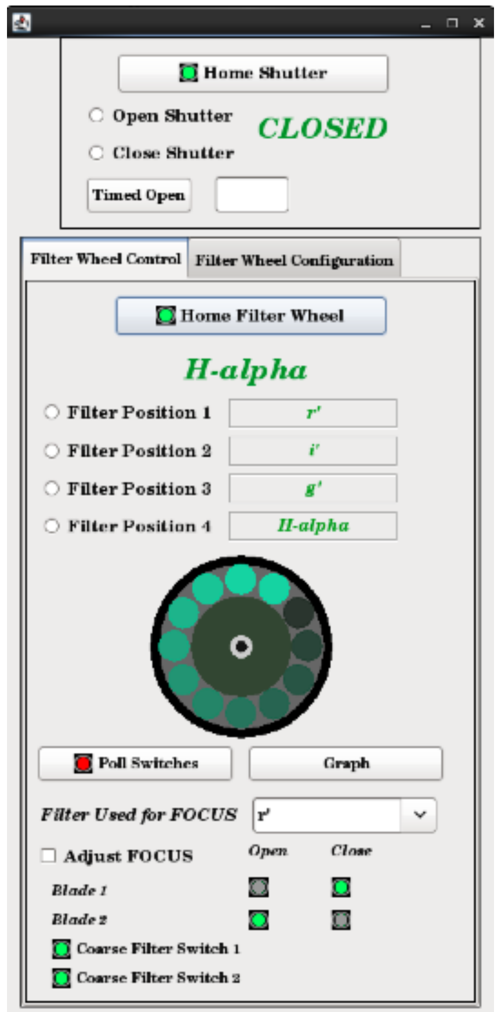


WASP Mechanisms

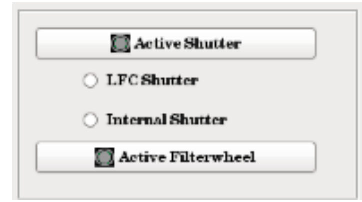
Shutter and Filter Wheel Control

- Palomar staff are responsible for loading the filters into the filter-wheel.
- Once the filters are placed in the filter-wheel the Palomar staff will select the correct filter for each position using the combo-box controls (Filter 1,2,3,4) and then save the configuration so that future software starts contain the correct filter name.

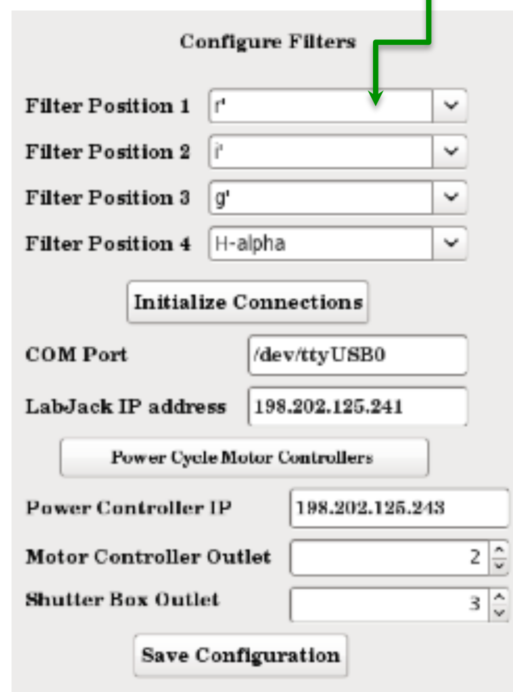
- Changing filters can effect the focus position by as much as 2.8mm so it's necessary that the software "knows" which filter was used to focus the instrument.
- If the "Adjust FOCUS" checkbox is checked then changing the filter also automatically changes the focus based upon the knowing which filter was used for focusing:
- Example: r' and i' filters focus at the same position but the g' filter focuses +1.5mm higher. If you focus in i' or r' and then change to g' the software automatically changes focus by 1.5mm



ACTIVATE SHUTTER and ACTIVATE FILTER-WHEEL



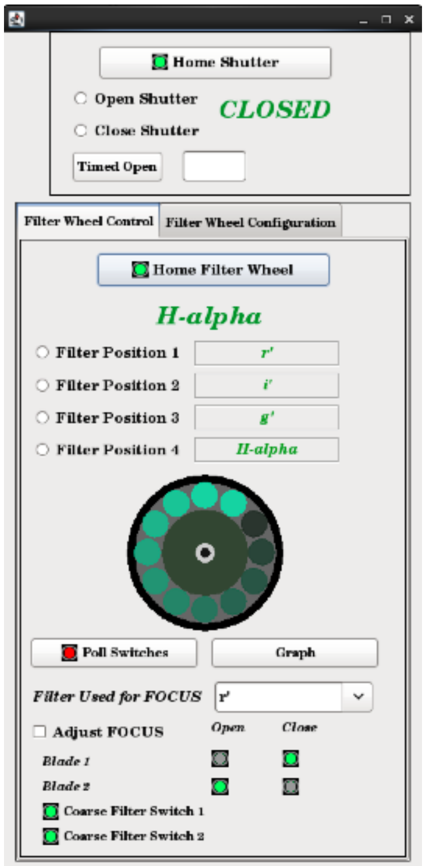
Select current filter in position: PALOMAR STAFF ONLY!!



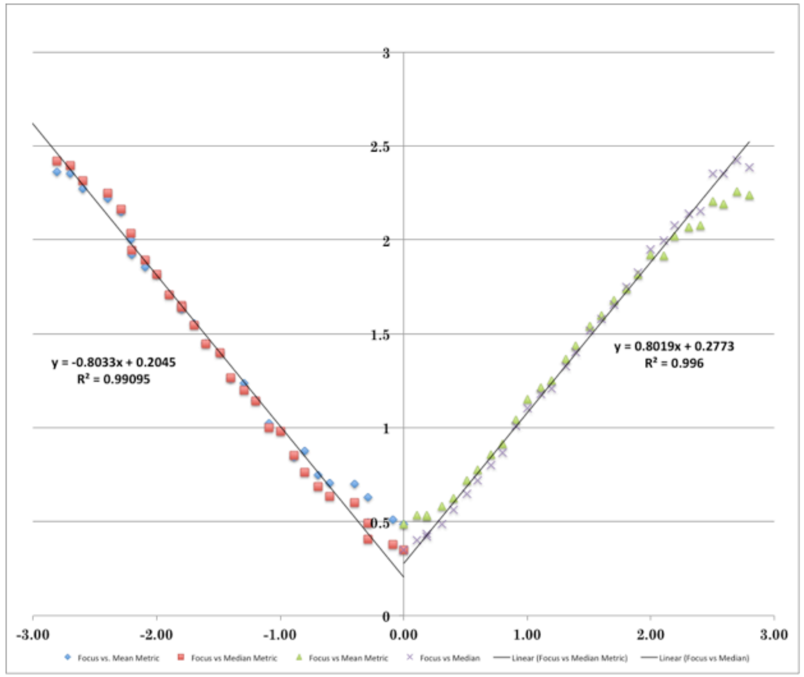
WASP Mechanisms

Filter wheel timing: How long does it take to move from one position to the next?

- The WASP filter-wheel takes approximately 18.68 +/- 1.1 seconds to move from one filter position to the next.



Filter Wheel Move	***Time (seconds)***
2 to 1	20.02
1 to 2	18.52
2 to 3	18.16
3 to 4	18.76
2 to 3	18.22
3 to 4	19.38
1 to 2	18.05
2 to 3	18.39
3 to 4	19.63
4 to 3	20.61
3 to 2	16.81
2 to 1	17.55
Mean	**18.68** ***seconds/position***
Standard Deviation	**1.07**

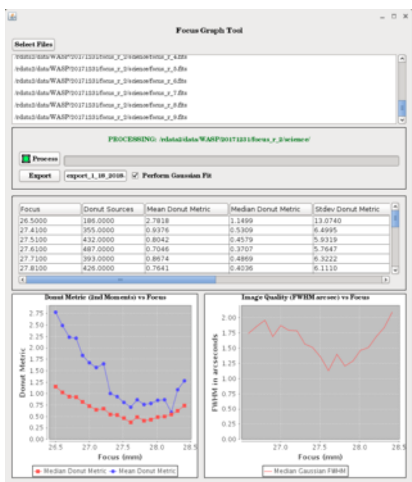


FOCUSING THE INSTRUMENT

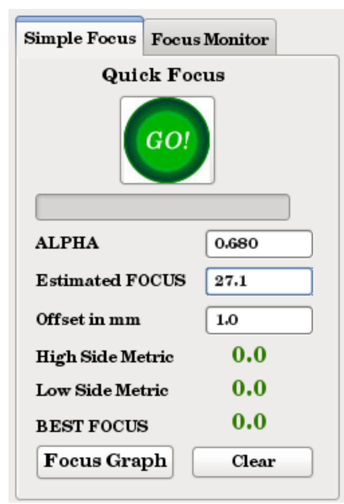
Focusing the WASP camera

- **There are 3 principle mechanisms for focusing the WASP camera**
  - (1**) Run a "focus script"** that acquires a set of images at different focus values and analyze the results using the provided focus graph tool. This should only be necessary when the instrument is first installed on the telescope and the best focus position is truly unknown.
  - (2) **Run the "Quick Focus" tool**. This is a quick method for determining focus by measuring the donut metric at two positions offset from and estimated best focus and calculating the best focus from the results.
  - (3) **Monitor best focus using the integrated focus detector.** The focus detector is offset from the science focal plane by 1.485 mm so the best focus can be calculated directly from a measurement of the donut metric on both the science and focus detectors.

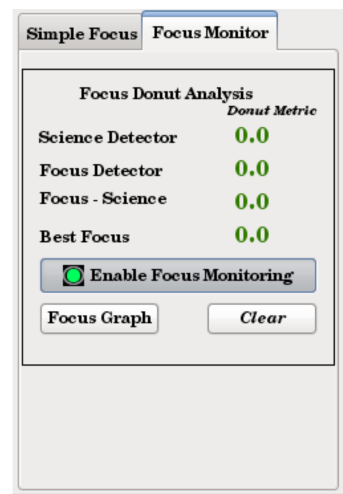
Focus Script Analysis



Quick Focus Tool

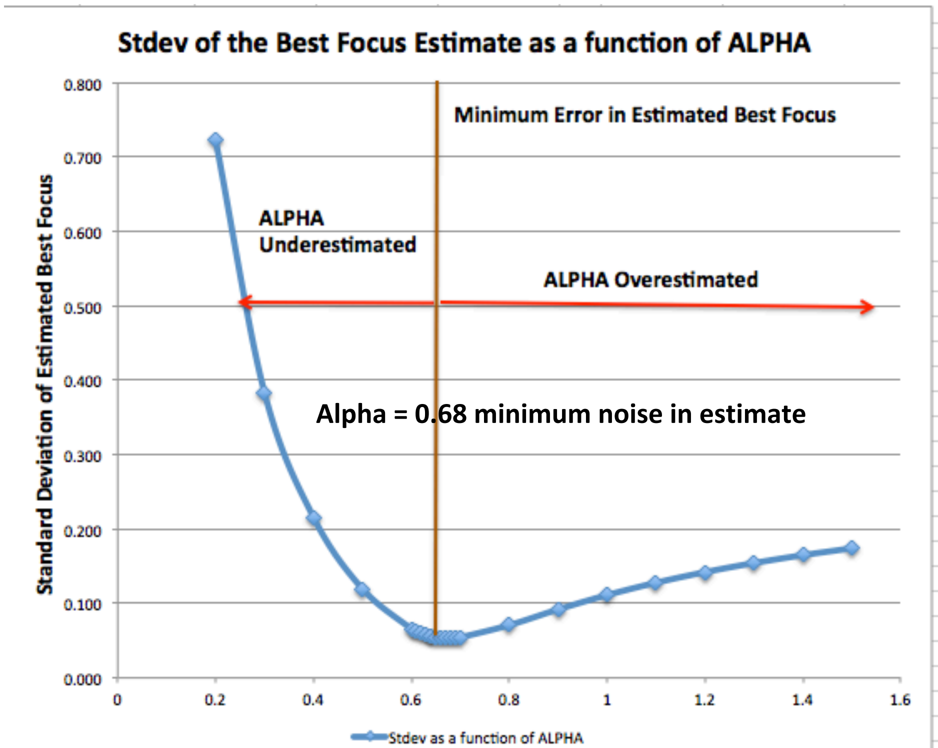


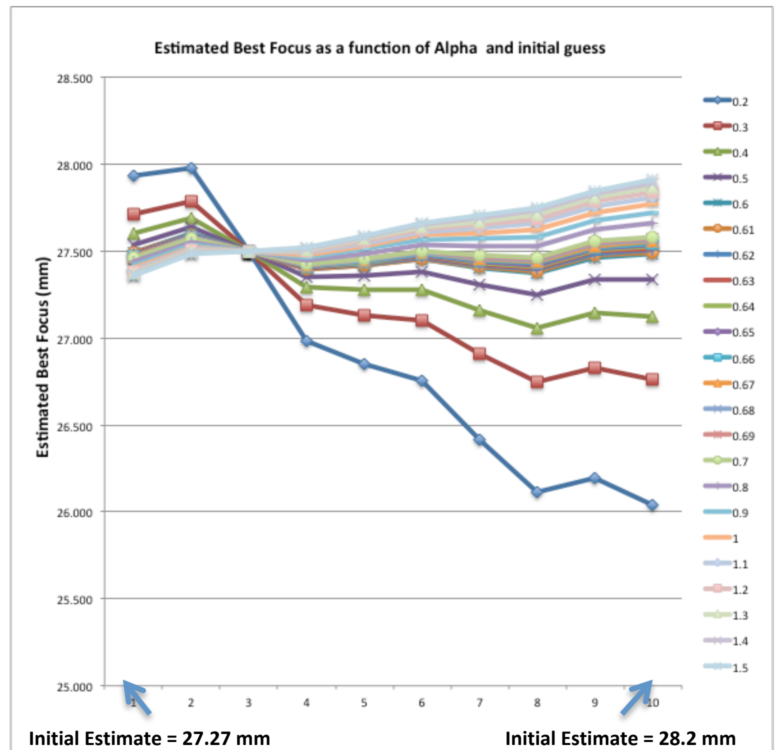
Focus Monitoring



Do we really know the value of Alpha?

Estimated best focus should be constant and not effected by initial estimate of focus.
For what value of Alpha is the standard deviation of the estimated best focus a minimum?

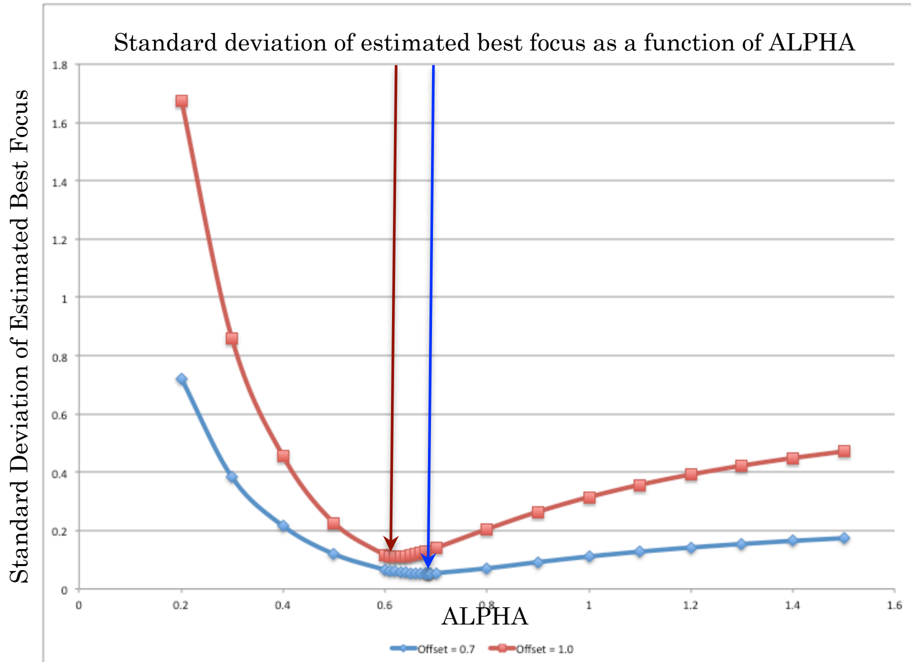


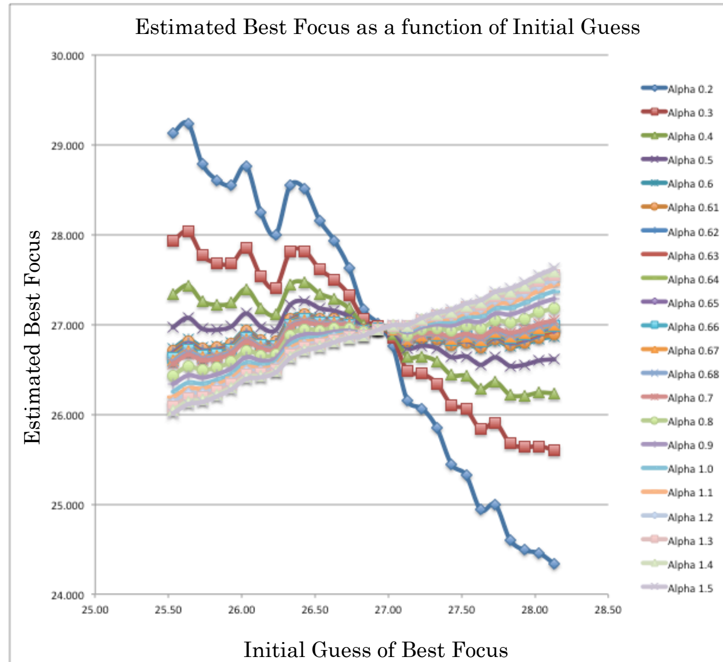


Value of Alpha for minimum noise in Estimated Best Focus = 0.68
Estimated error in Best Focus Estimate = 0.053 mm

Do we really know the value of Alpha? (continued)
Does the offset from the initial guess change the ALPHA value?

Estimated best focus should be constant and not effected by initial estimate of focus.
For what value of Alpha is the standard deviation of the estimated best focus a minimum?





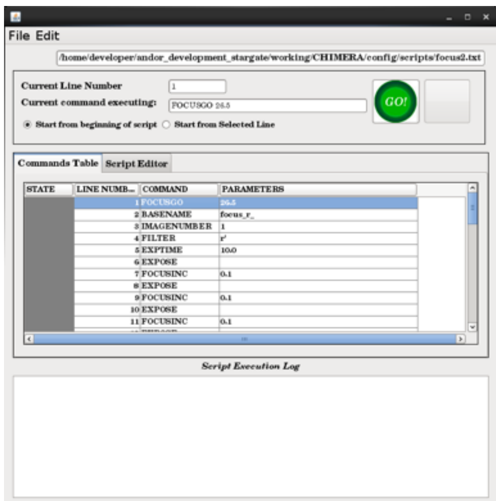
OFFSET = 1.0mm Value of Alpha for minimum noise in Estimated Best Focus = 0.63
Estimated error in Best Focus Estimate = 0.11mm

OFFSET = 0.7mm Value of Alpha for minimum noise in Estimated Best Focus = 0.68
Estimated error in Best Focus Estimate = 0.053 mm

Focusing the WASP camera

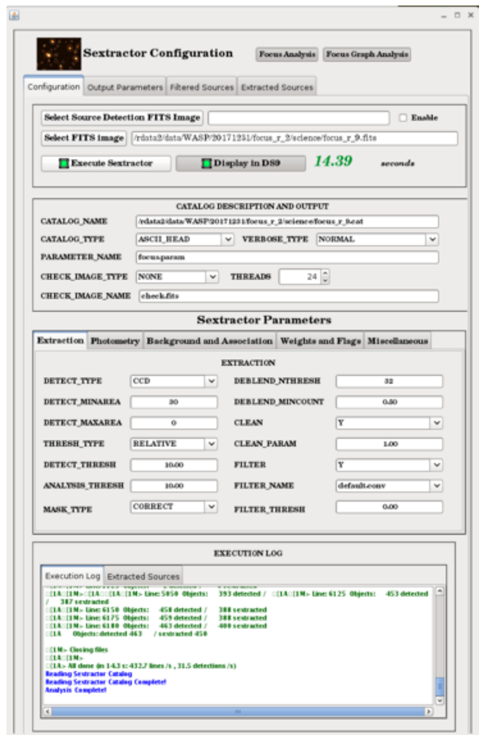
Running a complete focus curve analysis

Open and run the focus.txt script

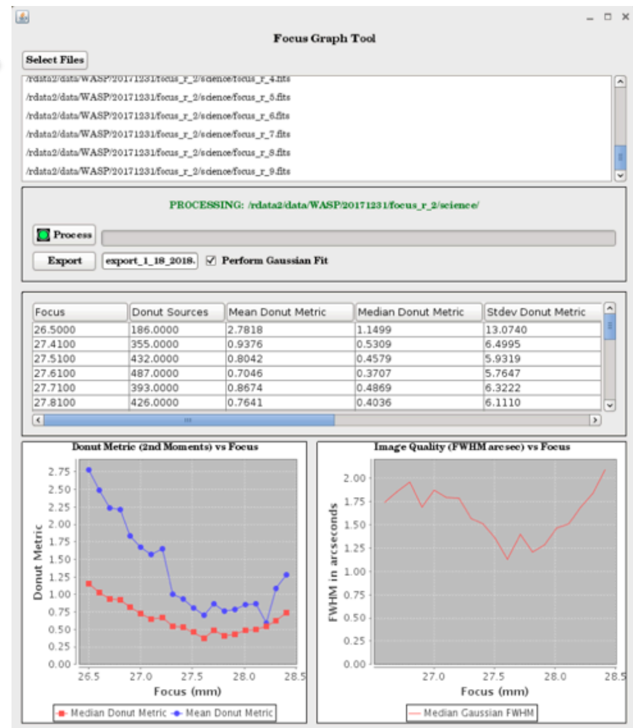


Specify the following parameters:
Initial focus
Focus increment
Exposure Time
Image BASENAME
Starting image number

Open the Sextractor controls panel and
Press the Focus Graph Tool button in the upper right corner of the control



Press “Select Files” and browse to locate the files produced by the Focus script and select and add them to the tool.



Press the “Process” button and wait while the tool analyzes the images and creates the plots

Read “Best Focus” from the graph minimum

Focusing the WASP camera

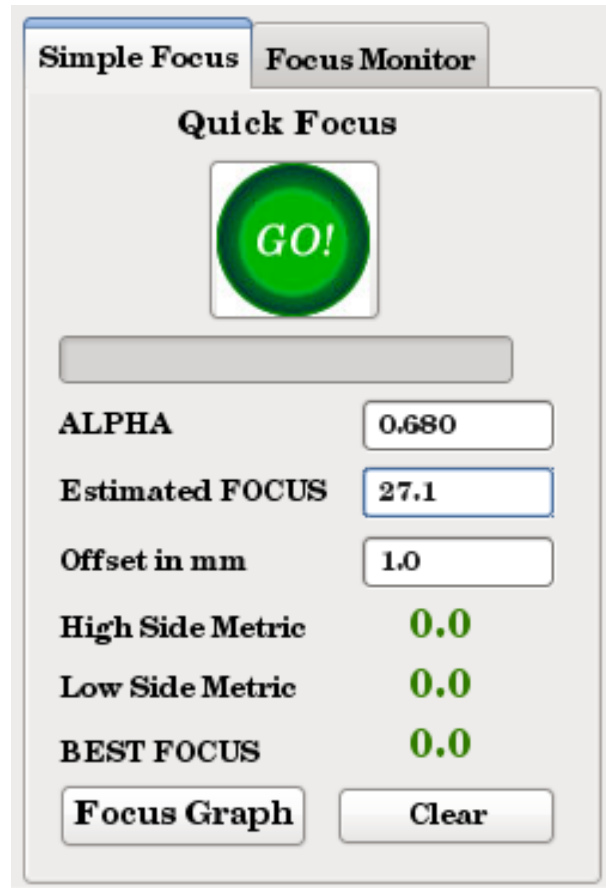
Running the Quick Focus Tool

Equation (1) $F_0 = (F^+ + F^-)/2 + (A_4^- - A_4^+)/(2\alpha).$

Quick Focus Tool

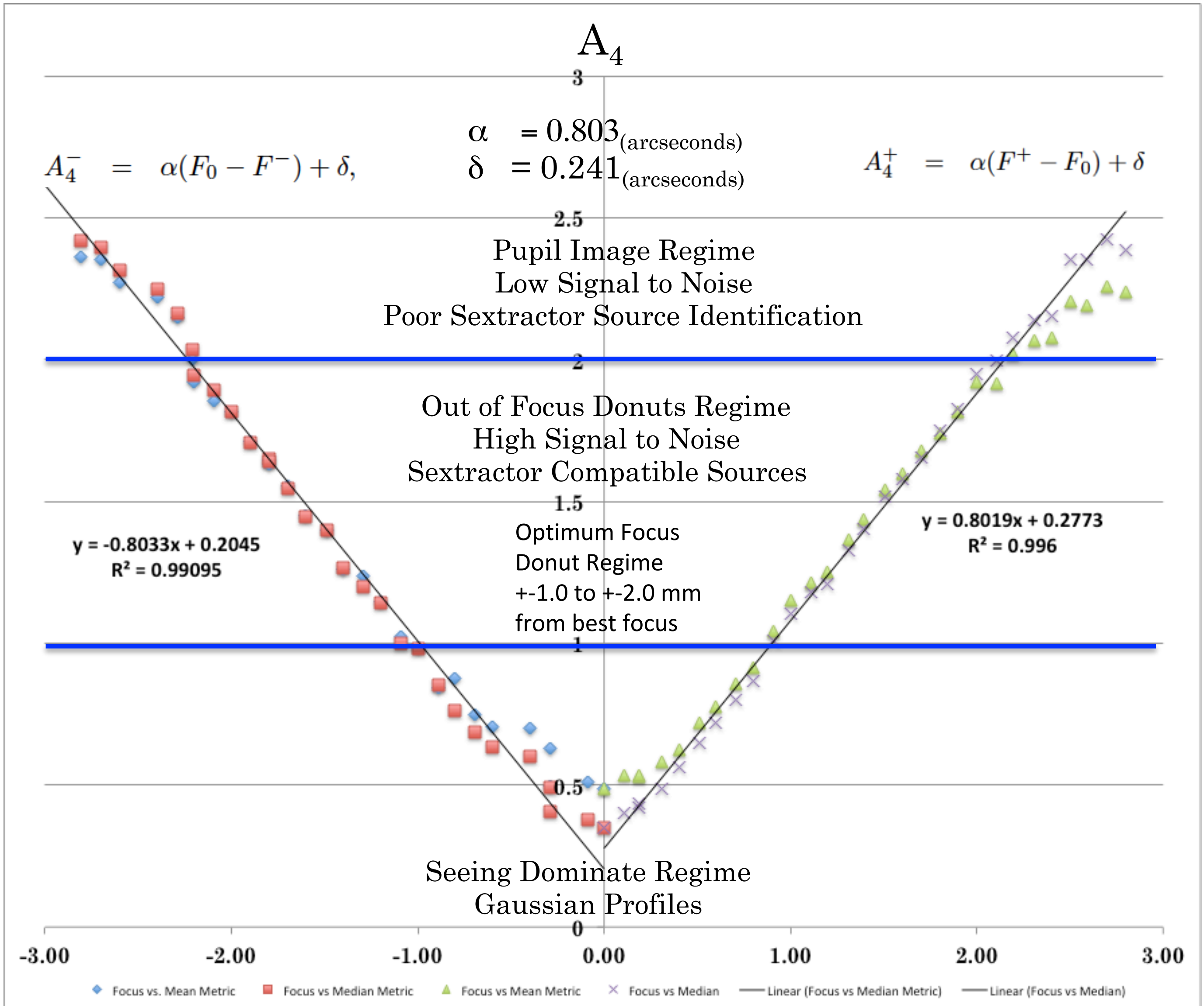
- The "Quick Focus" Tool is a the fast way to determine the best focus.
- Requirements:
  - Estimate the best focus
  - Set the offset in mm
- Process: The "Quick Focus" Tool first takes an image with the focus set to (ESTIMATED_FOCUS – OFFSET) followed by setting the focus to (ESTIMATED_FOCUS + OFFSET) and taking a second image. Each image is then analyzed using Sextractor to calculate the median donut metric in each image. Using the measured donut metric on both sides of focus and the known value of a, the best focus can be calculated from equation (1).
- How close does the estimated focus need to be? For Equation (1) to be valid each of the images must be taken of different sides of focus. Therefore, the estimate must be within +-OFFSET in mm from the true best focus.
- How can you tell that you're really at the "best" focus? If you set focus to the "best" focus estimate and then repeat the measurement (i.e. re-run the tool) the resulting high and low side donut metrics should be the same indicating that the measurements were taken symmetrically about the best focus position.
- ADVANTAGE: The measurement of the donut metric for images that are >= 0.5mm out of focus is not dependent upon the seeing and doesn't show the same noise

Quick Focus Tool



WASP – Palomar P200 Telescope Focus Analysis

Developing the "Donut" method for focus determination



Best Focus = 26.3mm

Donut: measuring optical aberrations from a single extra-focal image
T. Tokovinin and S. Heathcote, Cerro Tololo Inter-American Observatory, Cailla 603, La Serena, Chile

Focusing the WASP camera

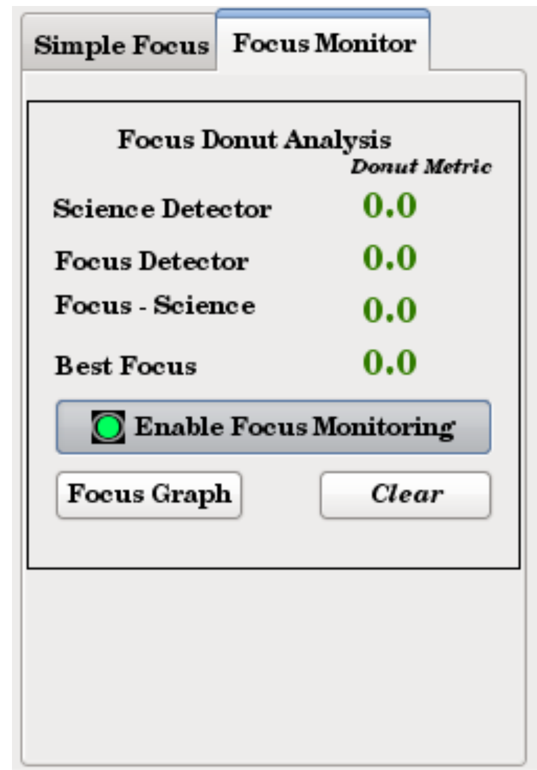
Turn on FOCUS Monitoring

Equation (1) $F_0 = (F^+ + F^-)/2 + (A_4^- - A_4^+)/(2\alpha).$

Focus Monitoring

- The focus monitoring system uses the integrated focus detector which is offset from the science detector by 1.485mm. By taking an image of both the science and focus detector simultaneously and measuring the donut metric on each the requirements of equation (1) can be satisfied.
- Substituting $F^- = F^+ - 1.485$mm into equation (1) allows a best focus estimate to be calculated from knowledge of the current focus, the measured donut metric on the two detectors and a known α.
- In order for the calculation to fulfill the requirements of equation (1) the science detector must be either at best focus or on the high side of focus. For this reason the focus monitoring tool is better used to monitor and make minor adjustments to focus rather than as the primary means of determining best focus.
- In order for the "Focus Monitoring" function to work both the science and focus detectors must be readout and analyzed. As a result the readout mode must be set to either Science, Focus or Guide, Science, Focus

Focus Monitoring

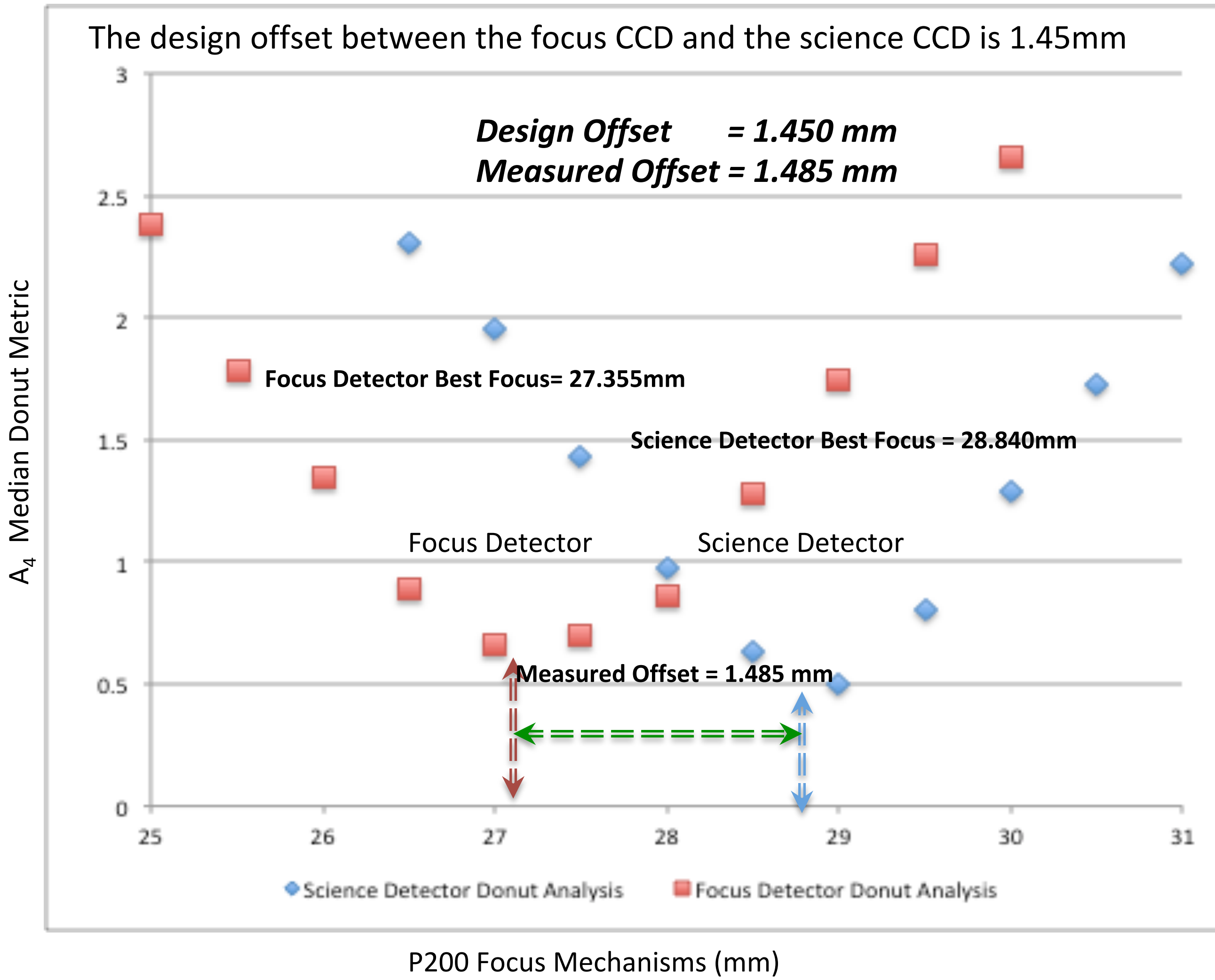


WASP – Palomar P200 Telescope Focus Analysis
September 13, 2016
Measuring the focus offset of the integrated STA focus detector

$$A_4 = p\sqrt{(M_x + M_y)/2}$$

$$M_x = I_0^{-1}\sum (x_{ij} - x_c)^2 I_{ij}$$

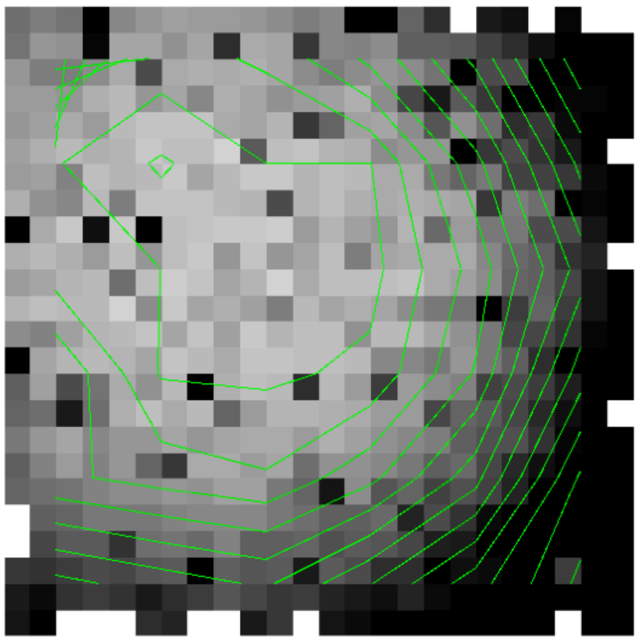
$$M_y = I_0^{-1}\sum (y_{ij} - y_c)^2 I_{ij}$$



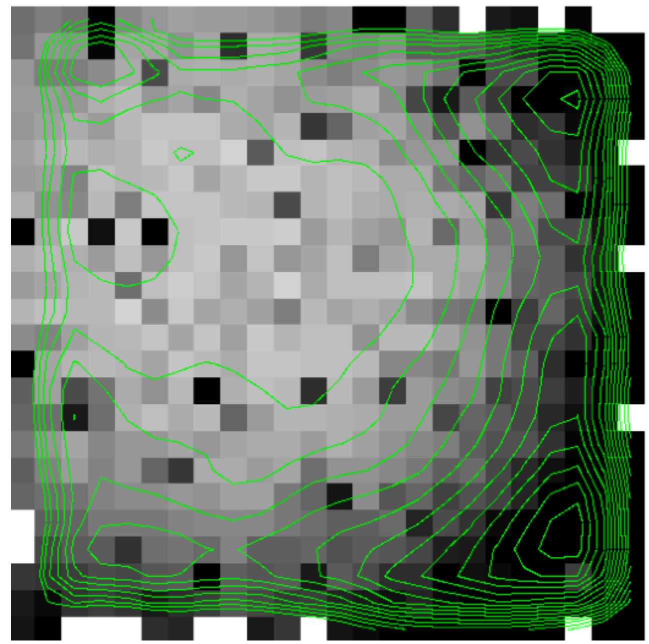
Focusing the WASP camera

The shape of the WASP best focus surface

FWHM Map of the WASP science detector



DS9 Contour METHOD = BLOCK



DS9 Contour METHOD = SMOOTH

CONTOURS

0.95
1
1.05
1.1
1.15
1.2
1.25
1.3
1.35
1.4
1.45
1.5
1.55
1.6
1.65
1.7
1.75
1.8
1.85
1.9
1.95
2

FWHM arcseconds

CONTOUR INTERVAL = 0.05 arcseconds per contour

Focusing the WASP camera

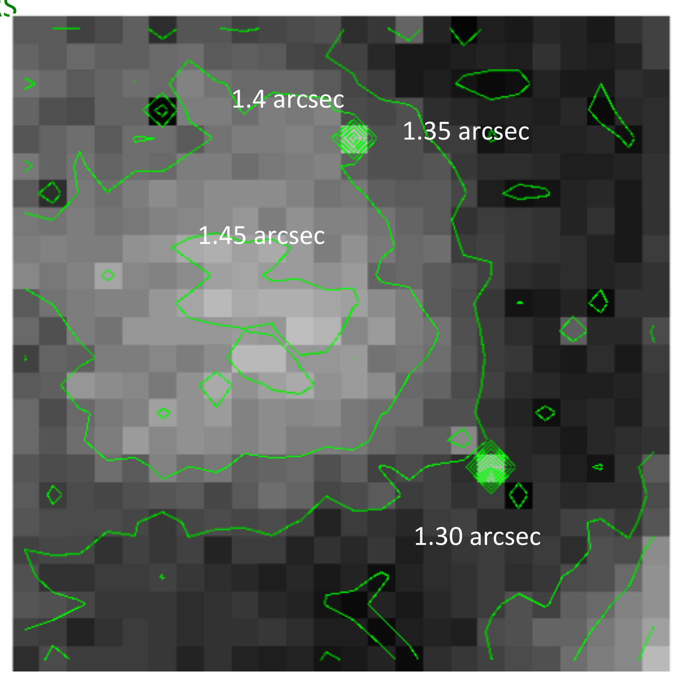
The shape of the WASP best focus surface December 2018

FWHM Map of the WASP science detector

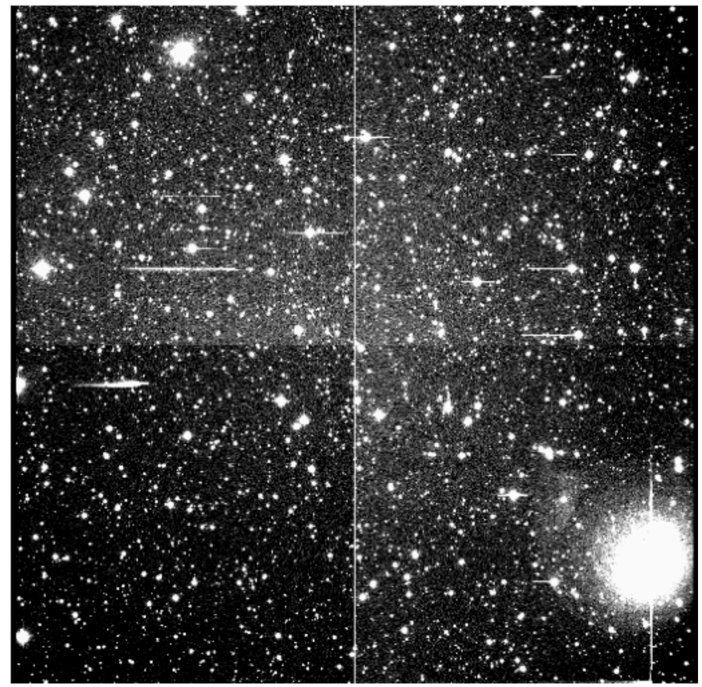
CONTOURS

0.95
1
1.05
1.1
1.15
1.2
1.25
1.3
1.35
1.4
1.45
1.5
1.55
1.6
1.65
1.7
1.75
1.8
1.85
1.9
1.95
2

FWHM arcseconds

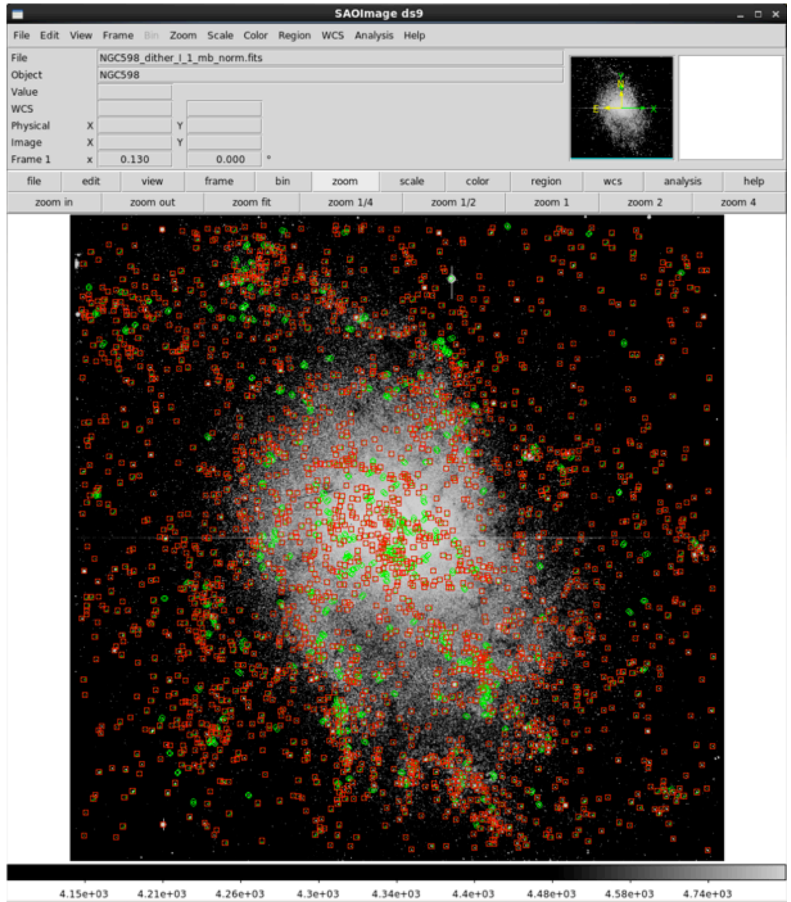


DS9 Contour METHOD = BLOCK



30 second "Best Focus" image used for generating the focus height map

CONTOUR INTERVAL = 0.05 arcseconds per contour

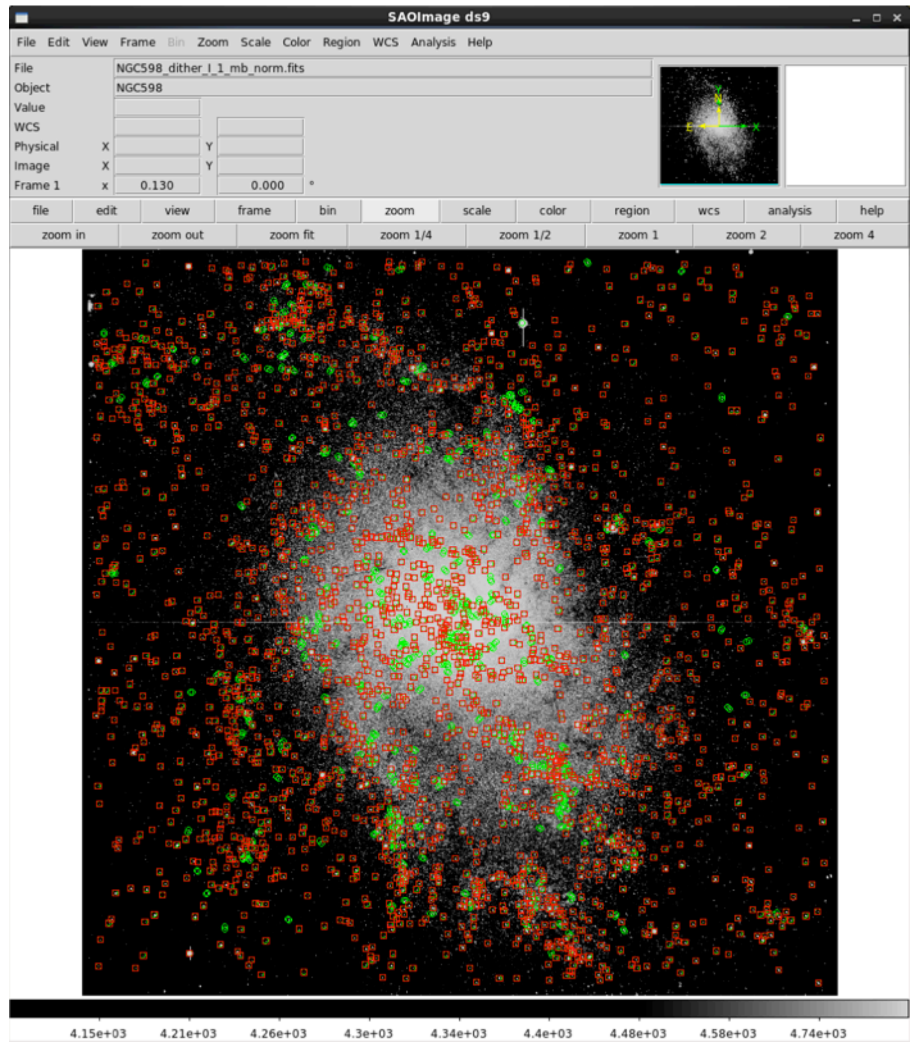


SEXTRACTOR INTEGRATION

WASP and Sextractor

GUI integration with DS9

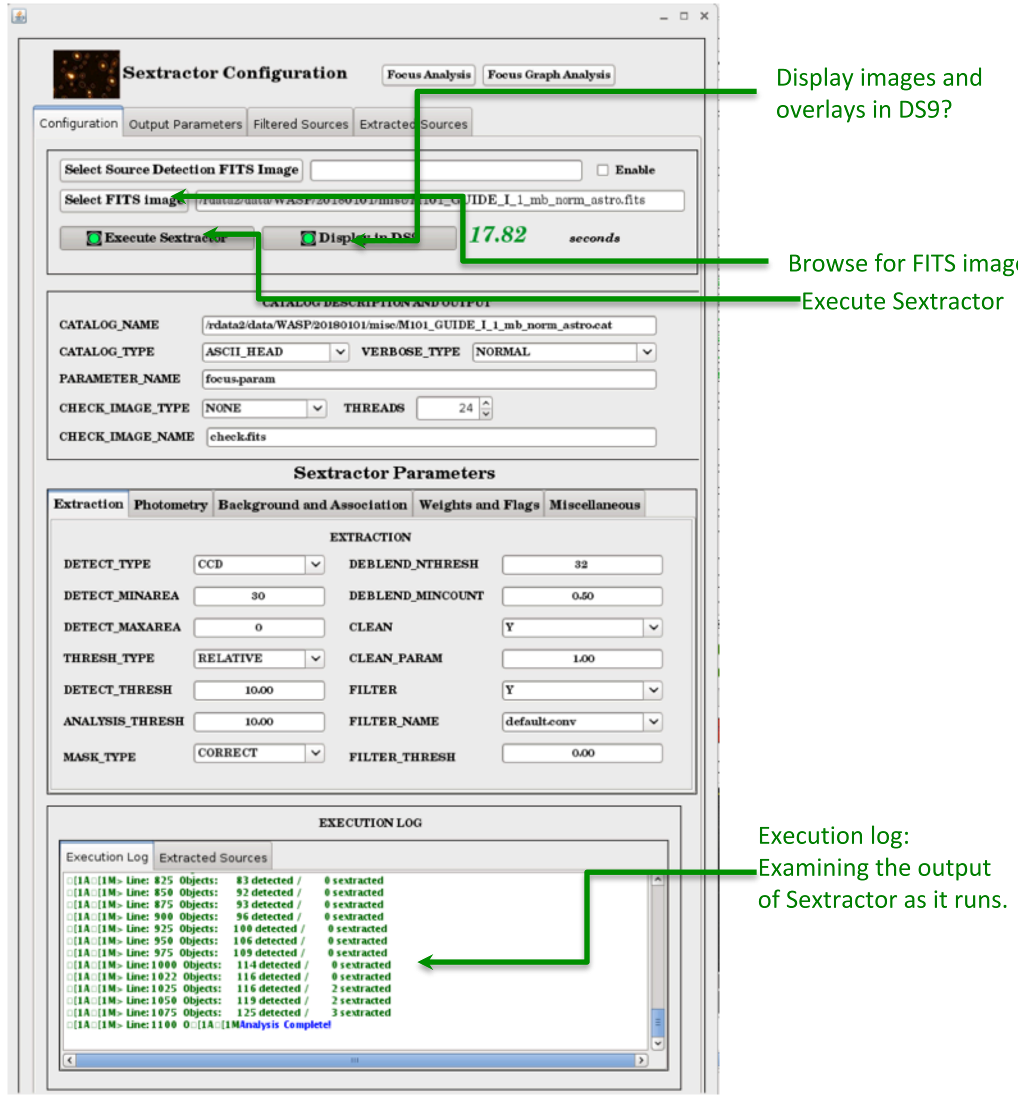
- When Sextractor is run inside WASP it automatically displays the selected image in DS9 (if Display in DS9 is ON)
- After analysis the Sextractor catalog file is read and output as DS9 region file.
- All of the green circles in the image below correspond to entries in the original, unfiltered Sextractor output catalog
- The red squares in the image correspond to the subset of star that pass the filtering for signal to noise, flux and distance from the nearest adjacent star.
- The goal of the filtering step is to identify, as far as possible, those stars that are not saturated at any point within their aperture, and that are separated sufficiently from adjacent stars.
- Filtering acts to remove outliers in the distribution and to select stars that might be appropriately used as guide stars.



WASP and Sextractor

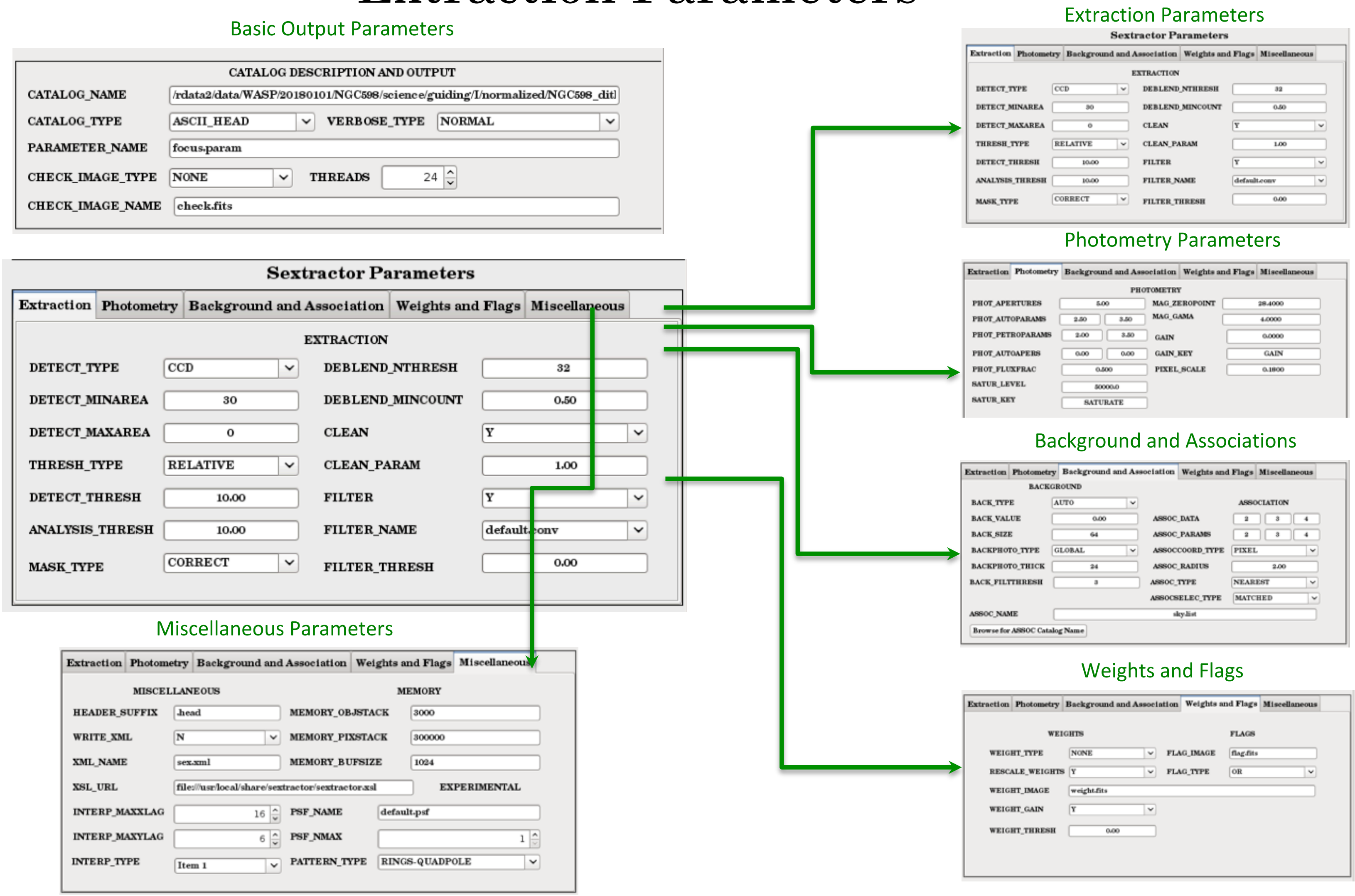
Overview – Basic Operations

- Sextractor is actually run as a separate command line program but the GUI allows the observer to easily modify extraction parameters and specify the output configuration from the GUI.
- The Sextractor configuration files are created on the fly containing the information in the GUI.
- Not all Sextractor options are available but most are.
- You do NOT need to know Sextractor to run WASP.
- All Sextractor configuration is done internally by the WASP software so observers do not need to edit any parameters for the system to work.
- This control is intimately integrated with DS9 and all identified sources are written into a "regions" file and displayed as an overlay.
- Sextractor catalogs and the associated DS9 region files are stored in the same image directory that contains the FITS image and named after the original image.



WASP and Sextractor

Extraction Parameters



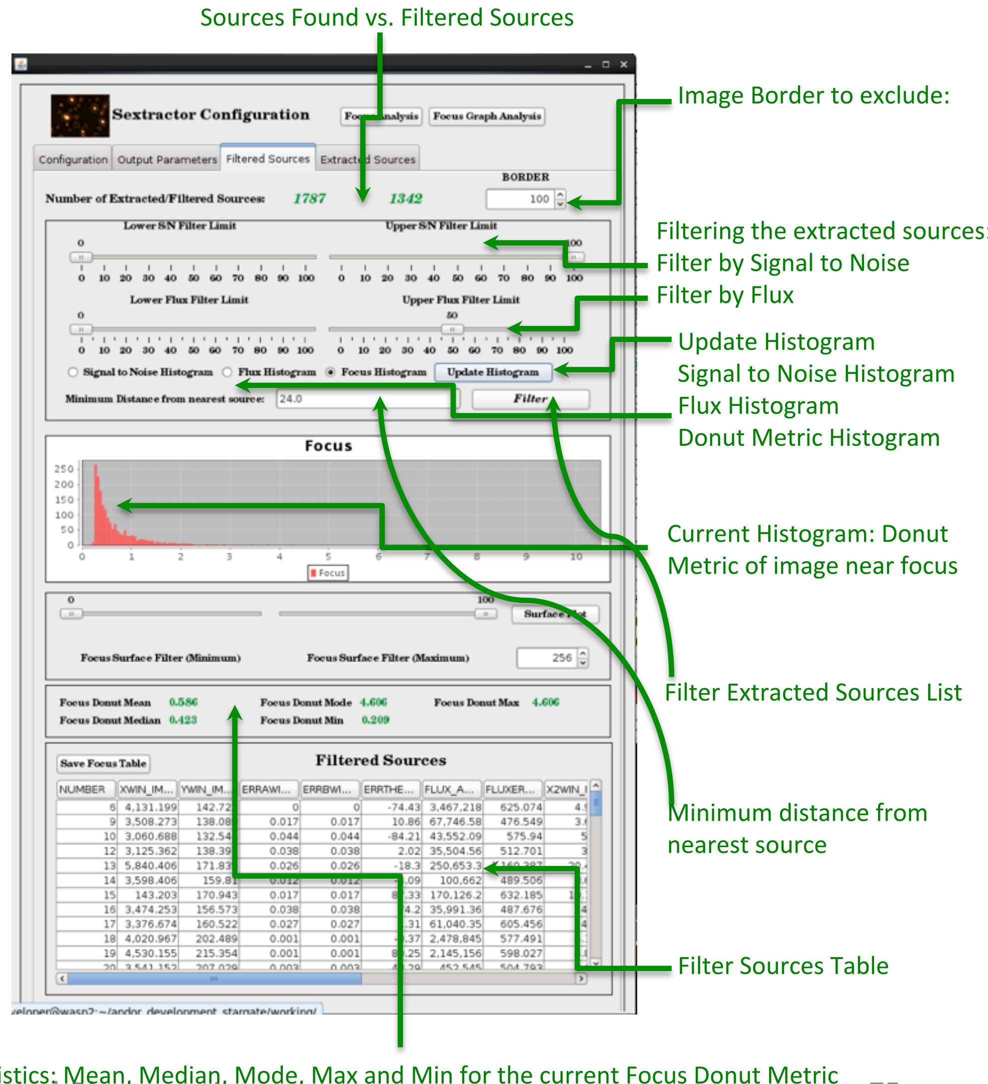
For a help understanding each of these parameters, please refer to the following primary source:

Bertin, E. & Arnouts, S. 1996: **SExtractor: Software for source extraction, Astronomy & Astrophysics Supplement 317, 393 [BibTeX entry].**

WASP and Sextractor

How does WASP actually use Sextractor?

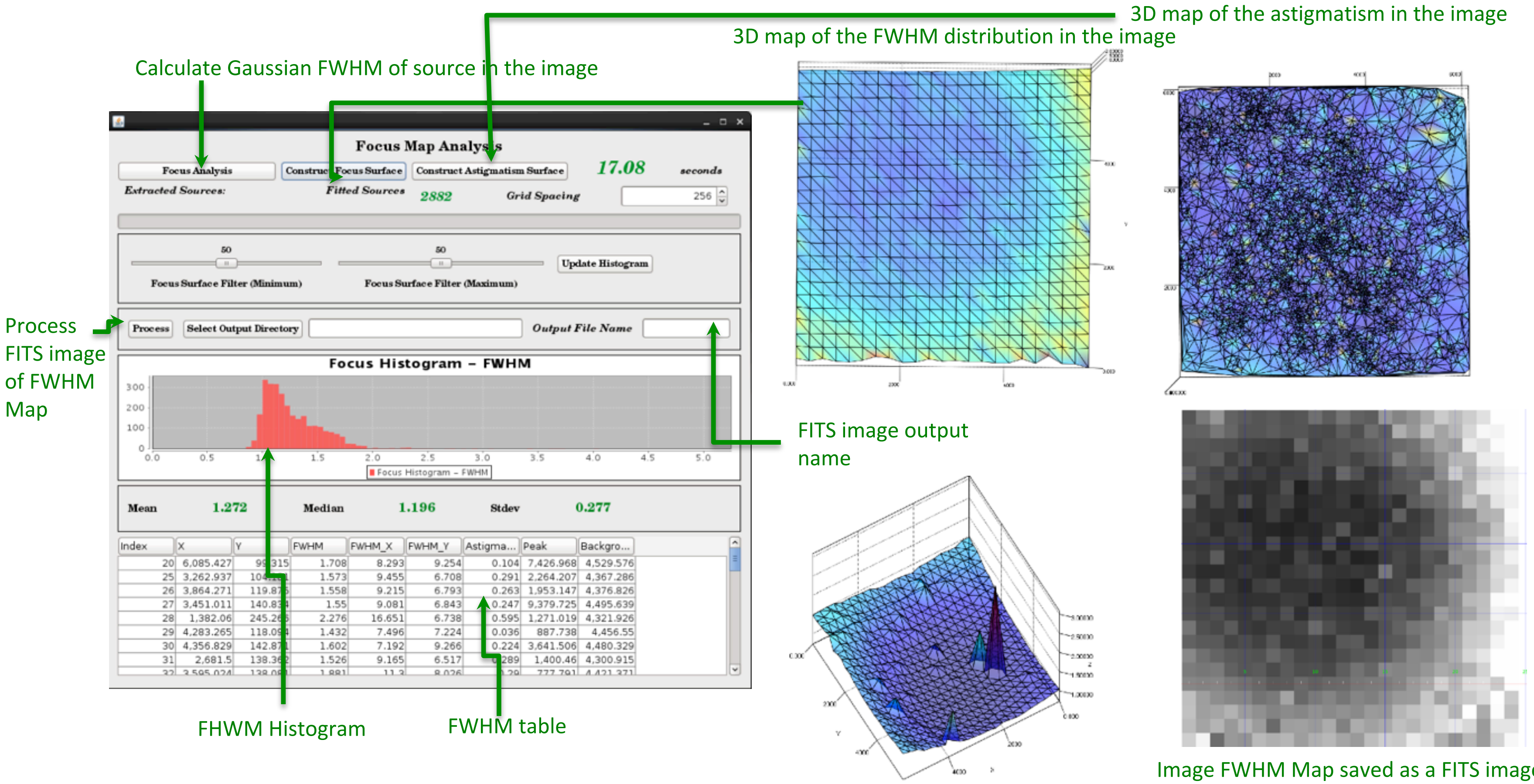
- WASP uses Sextractor internally in 2 fundamental ways
  - (1) extraction of source locations for guiding
  - (2) calculation of the “Donut” metric from Sextractor calculated 2nd moments
  - Source locations are also used as the starting point for complete 2D Gaussian fits to determine the FWHM as an image quality metric.
- In general, WASP doesn’t simply calculate the image quality metric (either FWHM or Donut metric) for a star but instead uses Sextractor to calculate the image quality of ALL extracted sources in an image and displays the distribution of values found across the entire field.
- Experience has shown that the median Donut metric and the median FWHM are much better measure of delivered image quality than the mean or any single measurement in the field.



WASP and Sextractor

2D Gaussian Analysis of stars in a WASP image

- After running Sextractor and identifying the sources, an observer can choose to fit 2D Gaussian to each of the identified sources using the Focus Analysis control.
- The primary output of this analysis is a histogram of the FWHM values measured in the image along with the mean, median and standard deviation of the distribution.

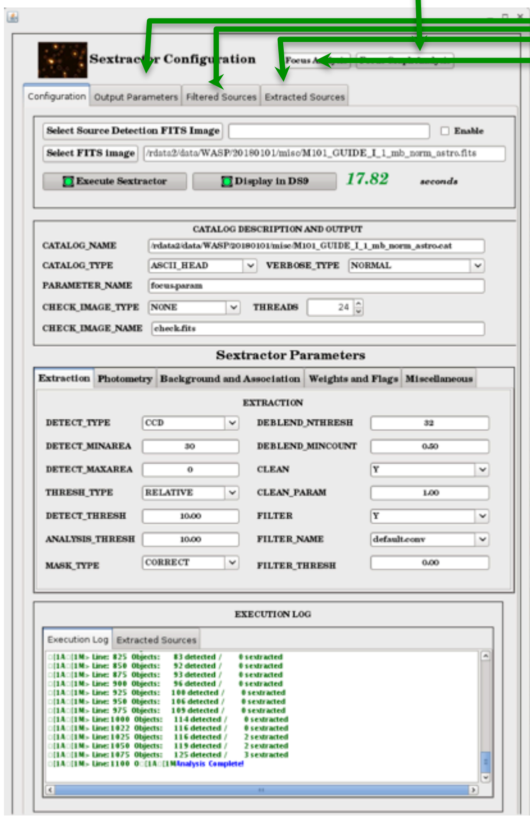


WASP and Sextractor

Overview

- The WASP instrument software makes extensive use of Sextractor for both focus and guiding.
- Sextractor is integrated into the WASP software through a GUI available in the “Observing Tools” menu.

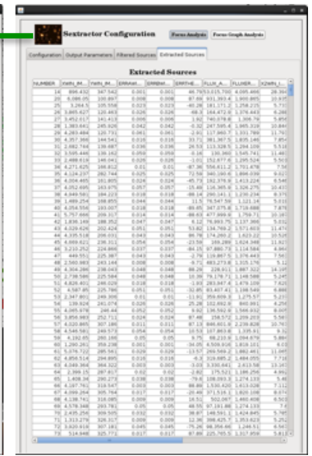
Main Sextractor GUI Panel



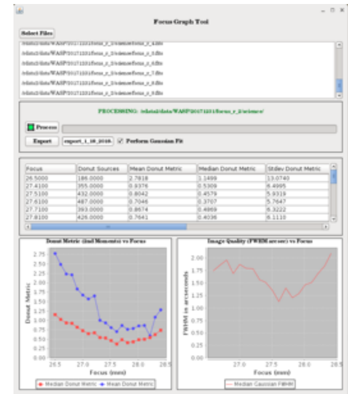
Output Parameters

Filtered Sources

Extracted Sources Table



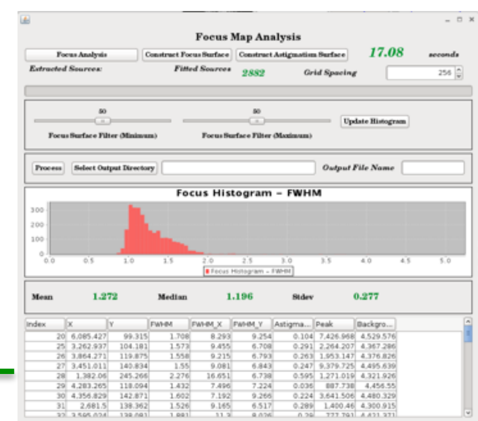
Focus Graph Analysis



Two of the output configuration
Choices are used extensively in WASP
“Coordinates Only” – used to identify source for guiding
“Out of Focus Donut” – used for focus measurement

Additionally useful output configurations:
SCAMP output configuration – needed for SCAMP and for determining distortion maps of the WASP field

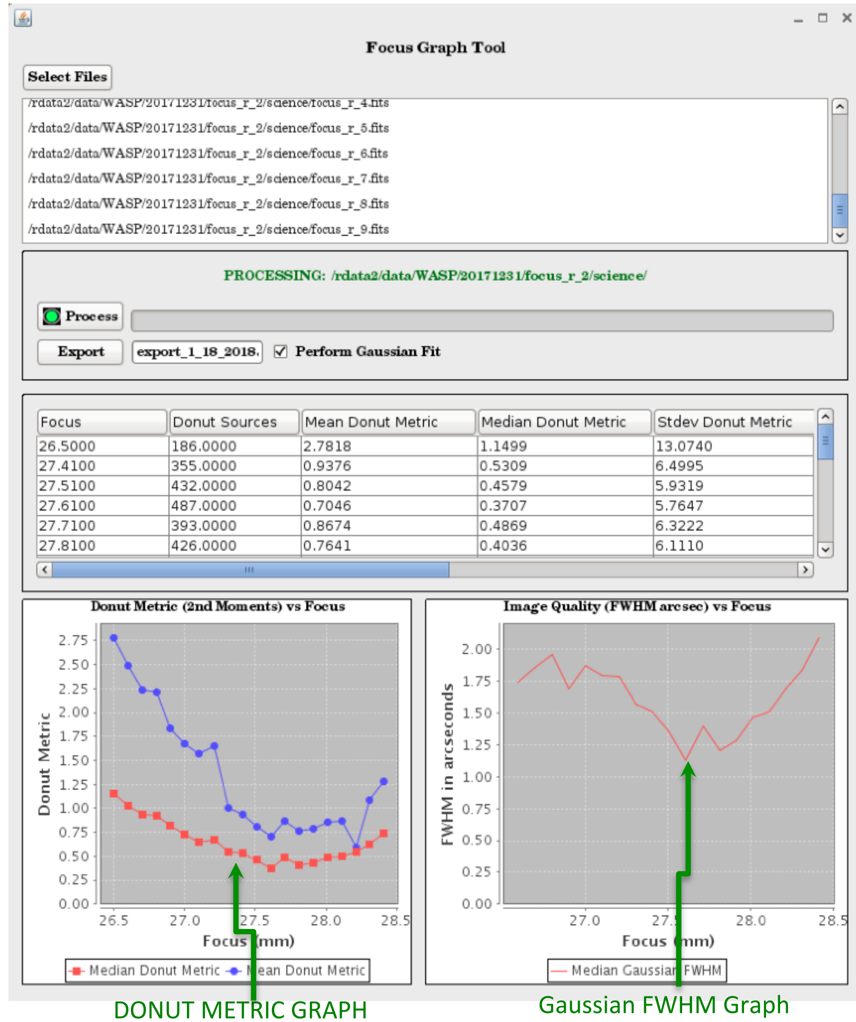
Gaussian Fit to extracted sources



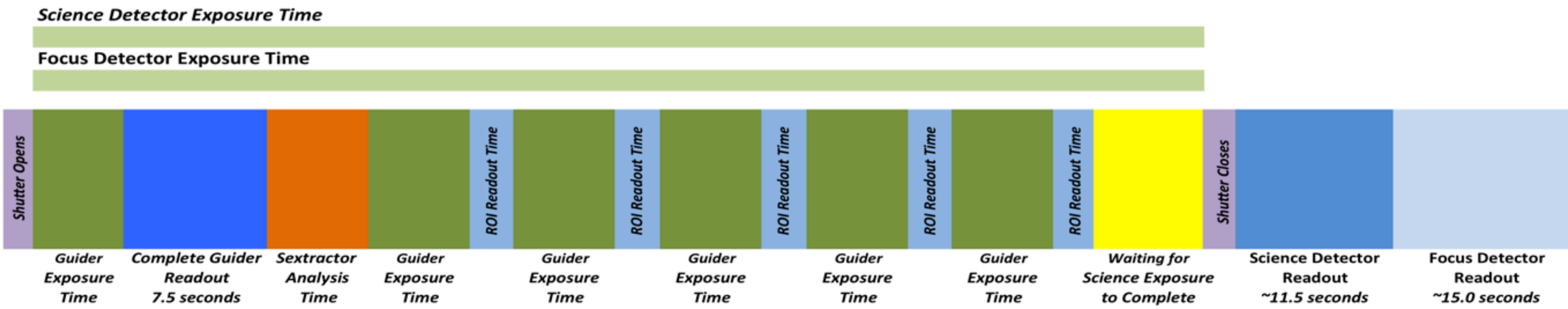
WASP and Sextractor

Creating Focus Curves with both the Donut metric and FWHM

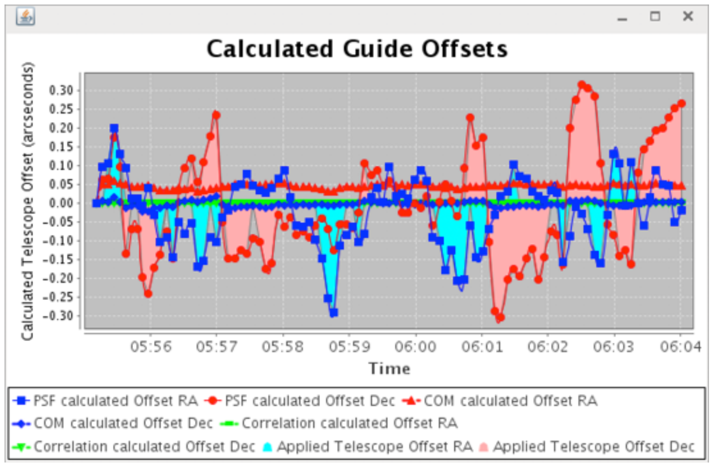
- If the user has observed a set of images at different focus values (see Focusing WASP) the simplest and most robust way to analyze the results is to use the “Focus Graph Tool”
- The “Focus Graph Tool” is available from the main Sextractor panel by pressing the “Focus Graph” button in the upper right hand corner of the display.
- Procedure:
  - Browse for FITS image files
  - Press the “Process” button.
- The donut metric graph (left) and the FWHM graph (right) are updated after each image is analyzed.
- After completion the table of values may be exported for further analysis.



Guide, Science, Focus Operational Mode Timeline



Note: ***After the Sextractor Analysis the system calculates how many guide frames can be observed before the science exposure is completed***



GUIDING

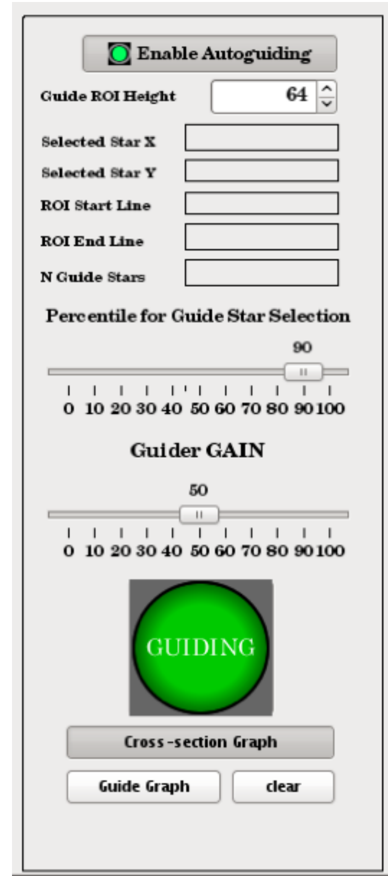
Guiding and the WASP camera

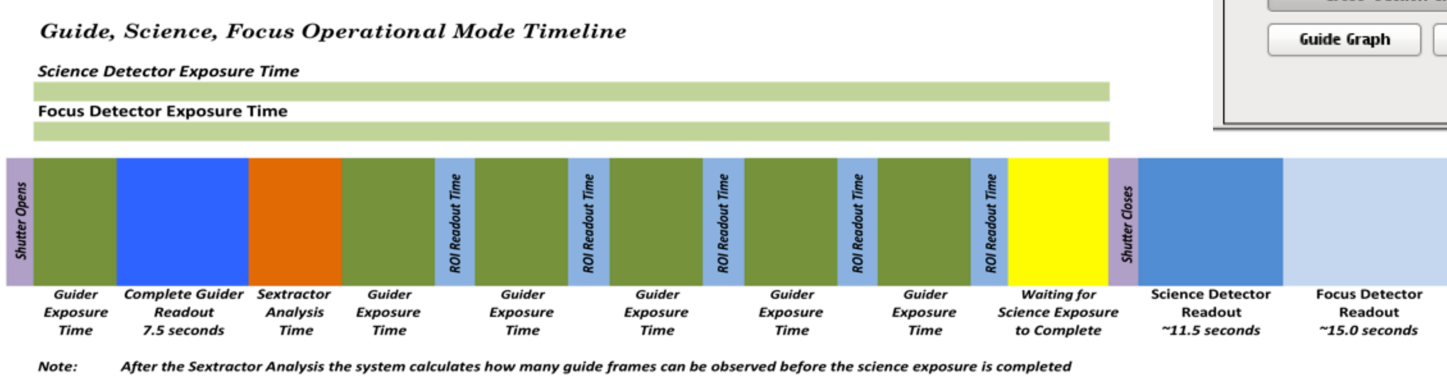
- The Hale telescope is a remarkably stable platform for observing with cumulative tracking error on the order of 1 arc-second every 15 minutes.
  - Tracking errors are typically larger in RA than in Dec.
  - Tracking errors in Dec increase with increasing distance from zenith but don't reach the same magnitude as the errors in RA.
- Guiding is typically not needed for exposures less than 300 seconds duration and has practically no effect for exposure times less than 150 seconds.
- Attempting to guide for exposure times less than 100 seconds may result in no actually guide frames being taken since the system calculates how many frames it can fit into the time remaining in the science exposure.
- Minimum possible science exposure with guiding:
- 2*(GUIDER_EXPOSURE_TIME + GUIDER_READOUT)+SEXTRACTOR_ANALYSIS_TIME
- Example: GUIDER_EXPOSURE_TIME = 5.0 seconds

  GUIDER_READOUT_TIME = 7.5 seconds

  SEXTRACTOR_ANALYSIS_TIME = 10.0 seconds – note: analysis may be much faster (1.0 second)

  Minimum Science exposure for 1 guide frame = 35 seconds



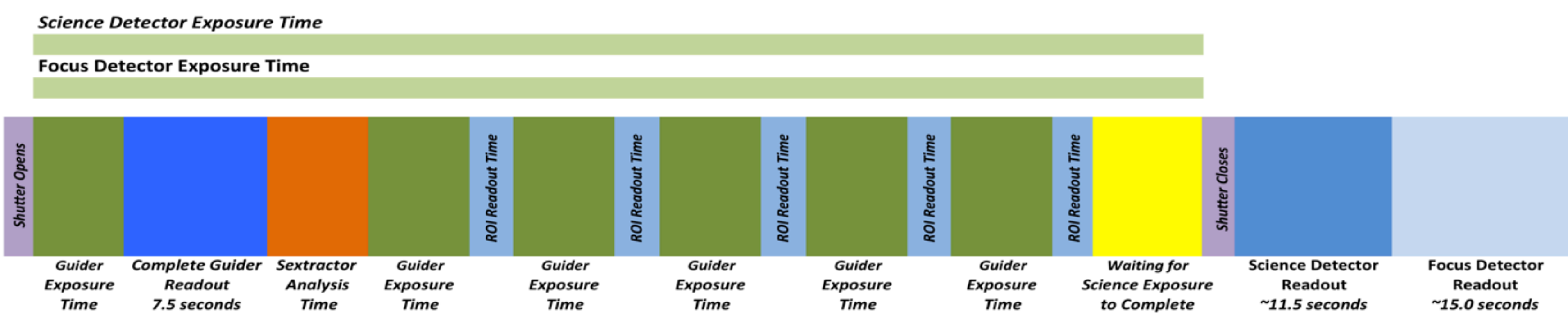


Guiding and the WASP camera

How does guiding actually work?

- WASP has only a single shutter and both the science and guide CCD's are located on the same focal plane. As a result, guiding with WASP requires that the shutter remain open while the science CCD is exposed and the guide detector must be read out while the CCD is still exposing.
- WASP attempts to completely automate the guiding process by internally finding all of the stars in the guider CCD field and then setting up the guide configuration as follows:
  - Run Sextractor to locate all stars in the image
  - Remove stars that are saturated on any pixel
  - Sort the resulting stars by total flux and select a single star at the 90th percentile (i.e. 90 percent of the stars in the image have less flux than the selected star) (note: the 90th percentile value is adjustable on the GUI)
  - Configure the region of interest (ROI) as a strip ROI_WIDTH wide (default = 64 pixels), centered on the selected star.
  - Identify any other stars that are wholly within the ROI.
  - Setup "guide boxes" on each star in the set identified in the previous step. (this step involve calculating where the stars will fall on the ROI based upon their coordinates in the original full frame guide image.
- With WASP the observer does not select the stars used for guiding; the system automatically picks the appropriate star.

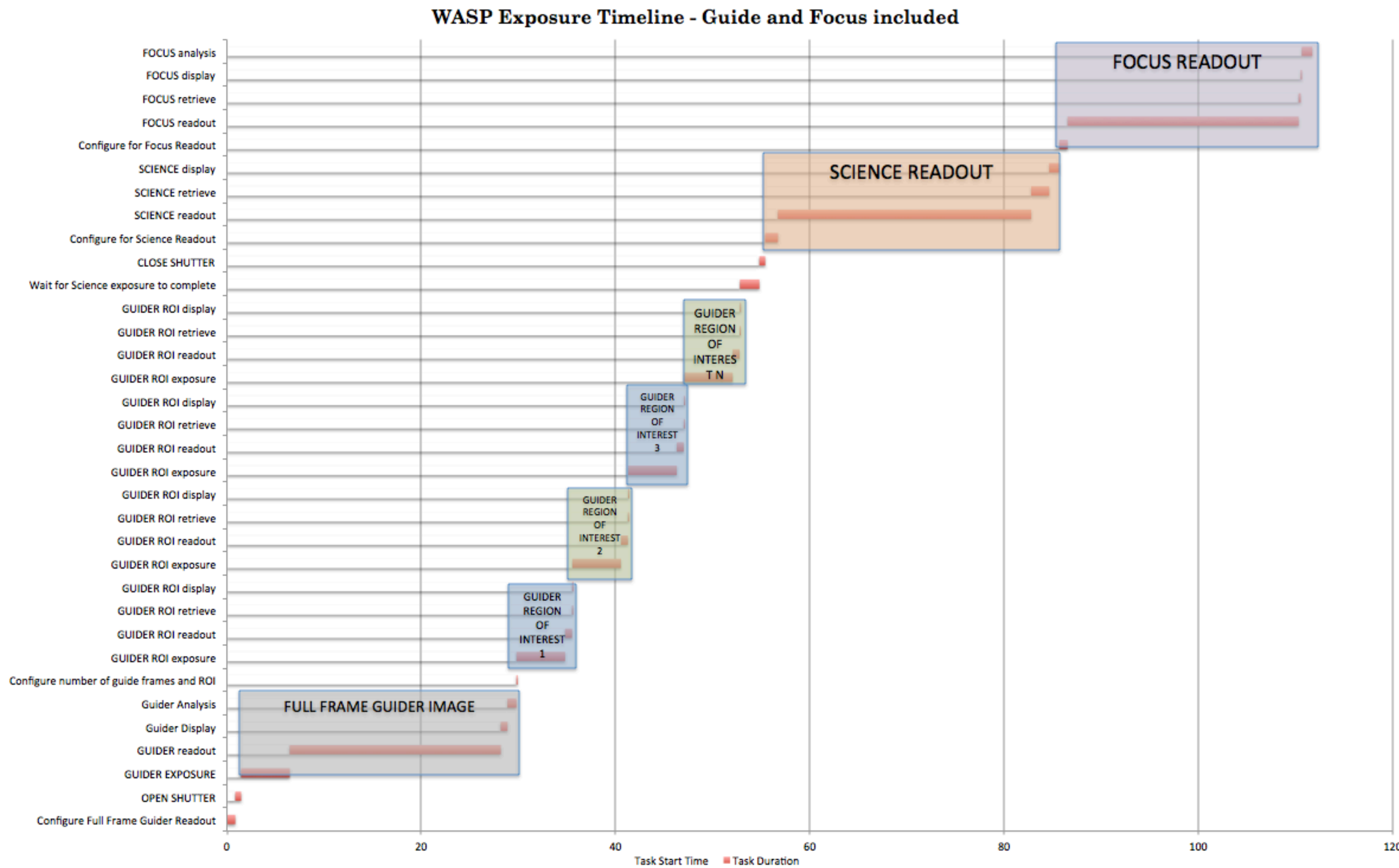
Guide, Science, Focus Operational Mode Timeline



Note: *After the Sextractor Analysis the system calculates how many guide frames can be observed before the science exposure is completed*

Guiding and the WASP camera

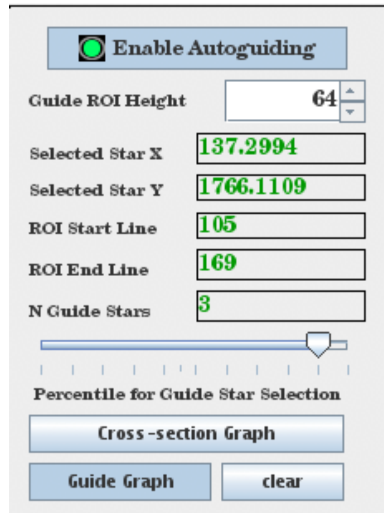
Example timeline for a GUIDE,SCIENCE,FOCUS mode image

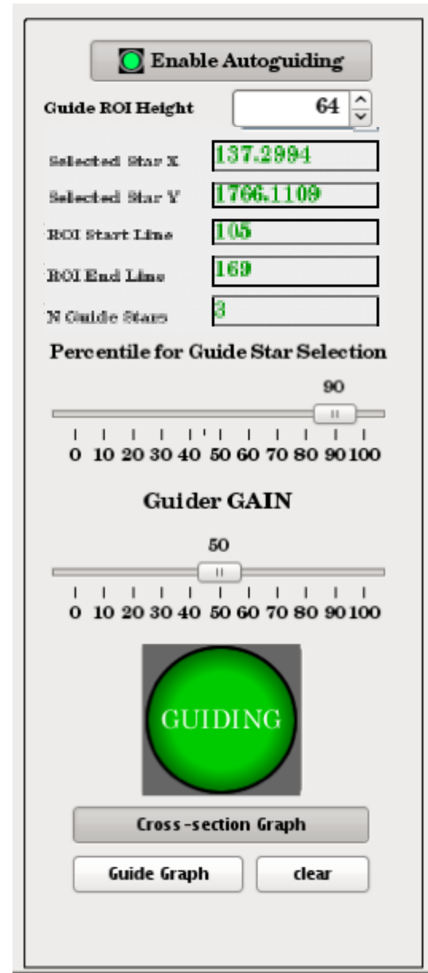


Guiding and the WASP camera

What guiding parameters are adjustable by the observer?

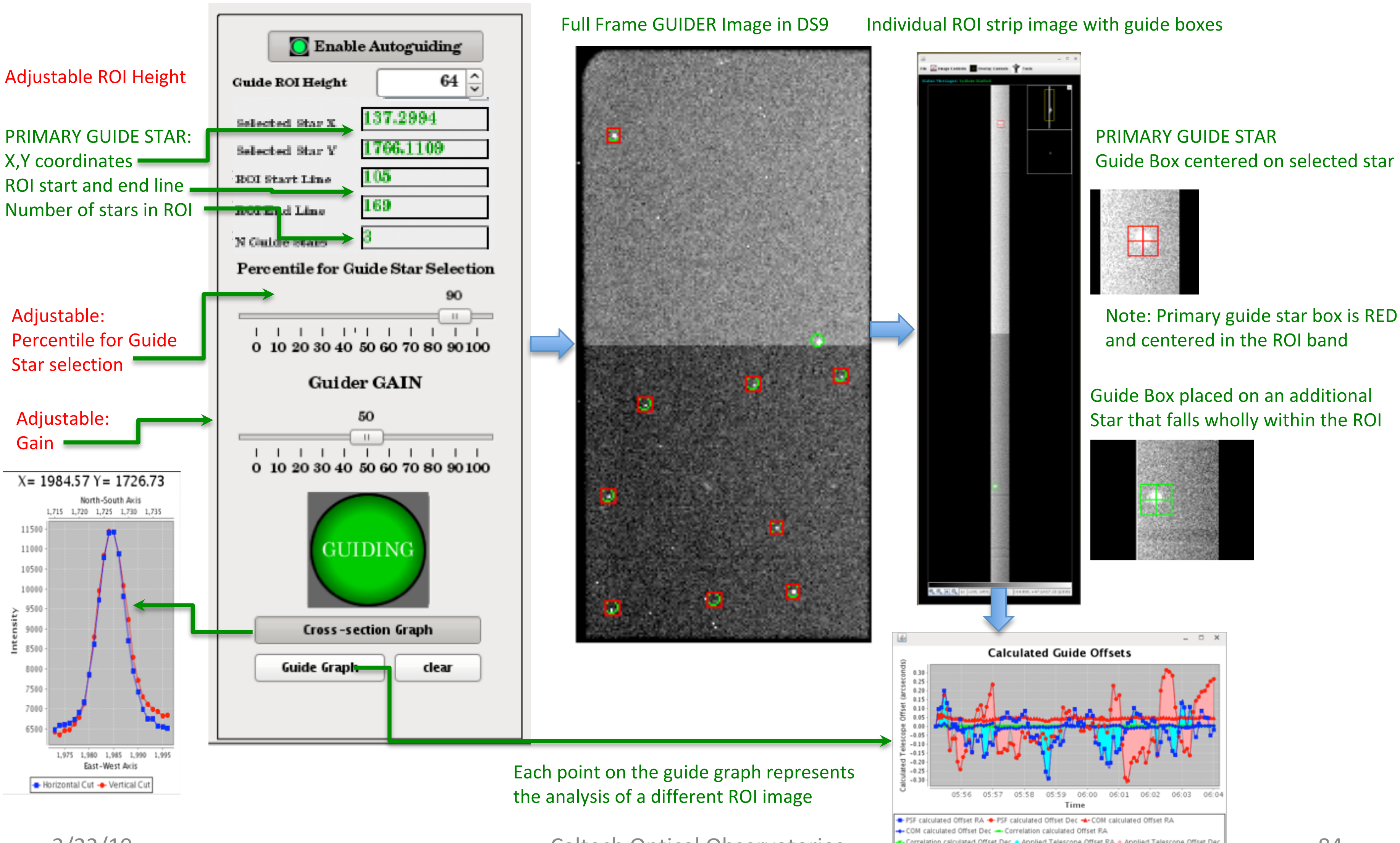
- So what guiding parameters are adjustable and how do they effect the guide performance?
  - Guide Exposure Time (Default = 2 seconds)
  - Guide Box Size (Default = 24 pixels)
  - ROI Height (Default = 64)
  - Guide Star selection percentile (Default = 90%)
  - PID loop gain
- **Guide Exposure Time** guidelines: guide exposure times between 1 and 10 seconds are appropriate. The selected guider exposure time depends upon how many and how bright the star in the guider CCD image are.
- The **ROI height** (i.e. the width of the ROI strip) effects only HOW MANY stars will be measured to calculate the guide signal. Increasing the ROI height increases the size of the ROI strip and more stars will be wholly contained within this strip. The example on the right shows that 3 guide stars are contained within the configured ROI strip.
- **Guide star selection percentile**. The slider control allows the observer to adjust the percentile used for selecting the primary guide star. If only one bright star is in the field along with a large number of faint stars you can force it's selection by setting the slider to 100%.
- **Guide Box Size.** The guide box size can be adjusted from 16 to 100 pixels with the default value at 24. Typical seeing at Palomar is on the order of 1 arc-second (FWHM = ~5 pixel) so most stars require a minimum guide box size of 16x16. Increasing the guide box size also increases the chance that other stars will contaminate the measurement and decreases the number of stars that fit wholly within the configured region of interest.
- **Gain.** The guiding loop is a simple proportional controller (only the P of the PID formalism is used) and the gain on the loop can be directly adjusted from the GUI.





Guiding and the WASP camera

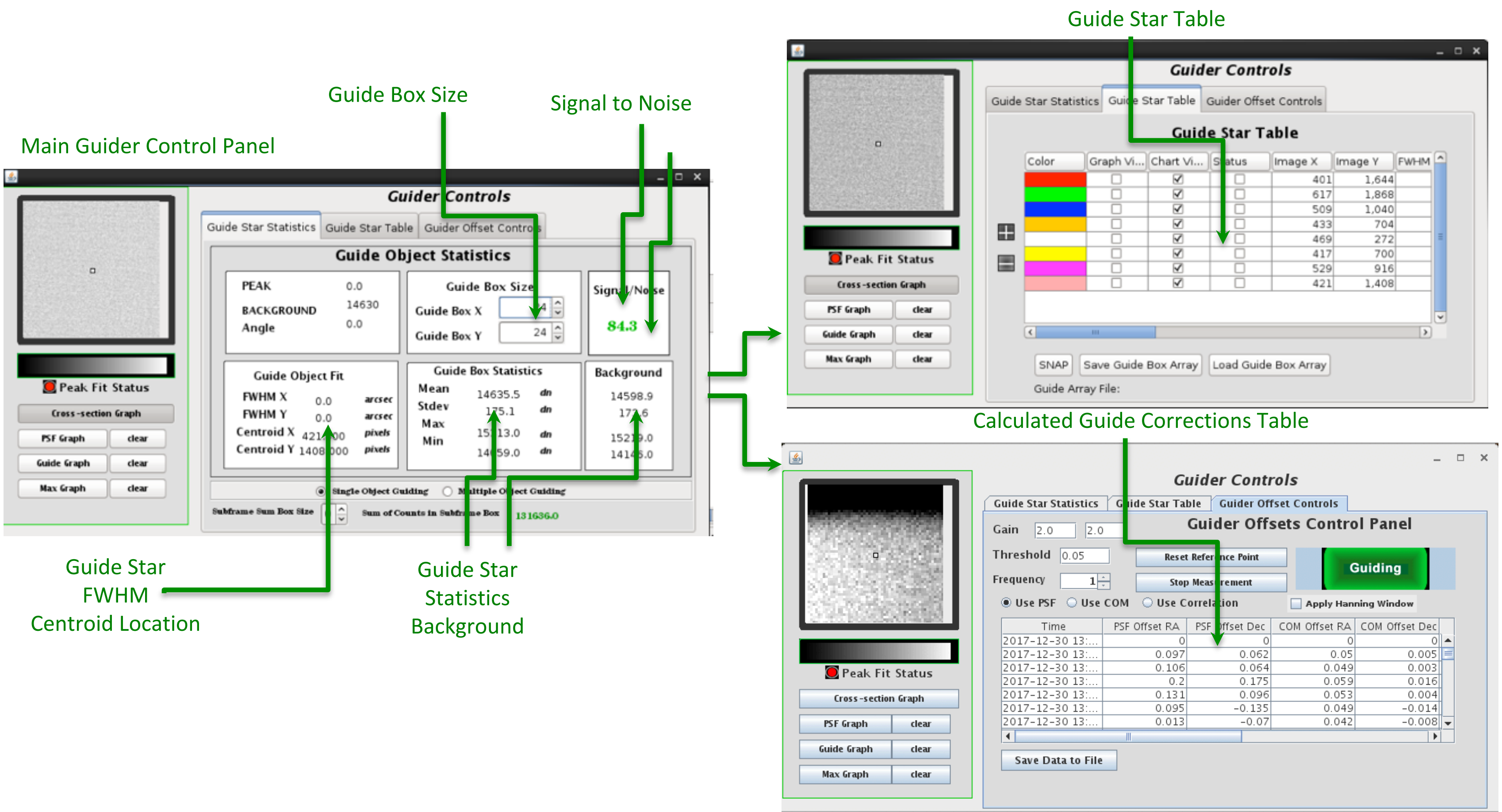
Guiding in action



Guiding and the WASP camera

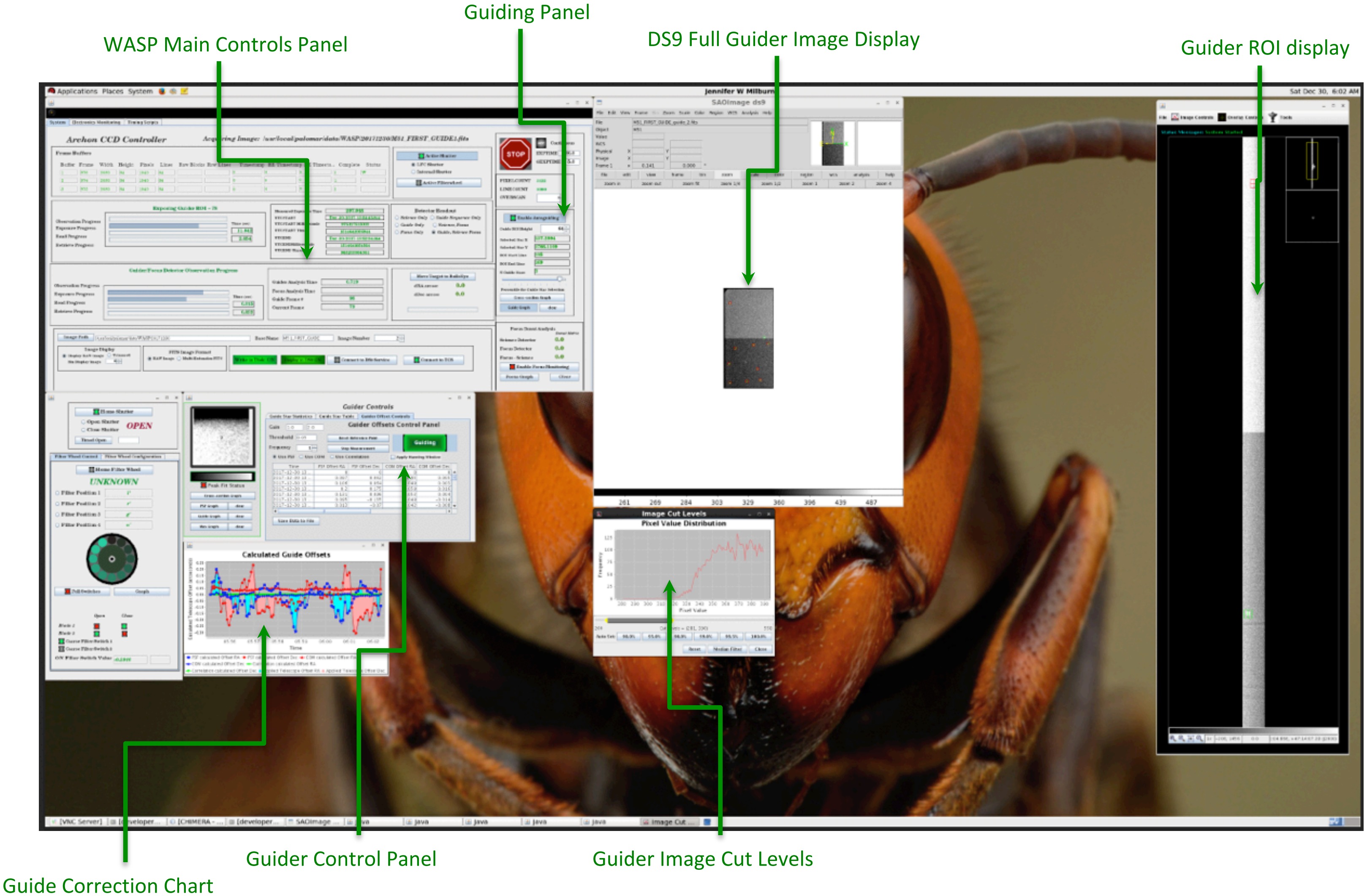
The Guider Control Panel

- The Guider Control Panel is integrated into the guider image display system and supports the operation of the guiding system. The Guider Control Panel is accessed from the guider image display panel under the “Tools” menu.
- The Guider Control Panel maintains the list of guide star locations and the record of calculated guide corrections.



Guiding and the WASP camera

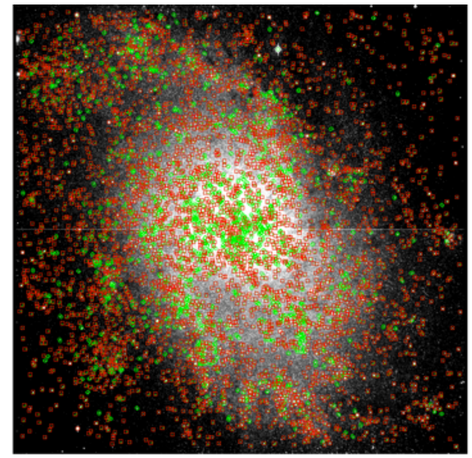
What do you need to monitor during guiding?



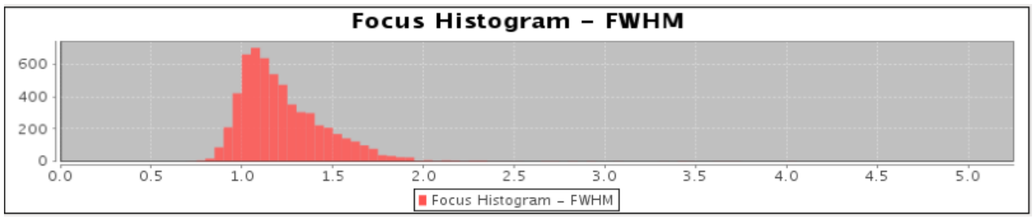
The results of Auto-Guiding NGC 598 R’ filter

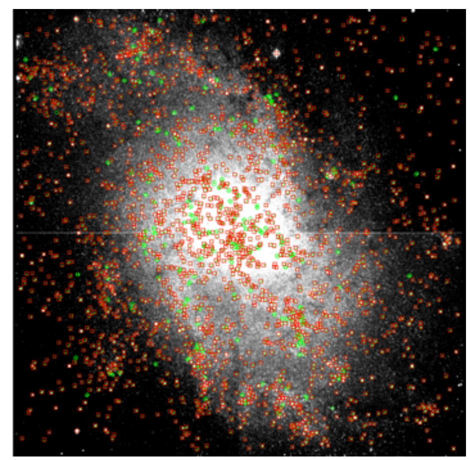
Image Quality Assessment

- Comparison between FWHM distribution with and without guiding.
- Two 300 second exposure images in the same (r’) filter taken consecutively with and without guiding

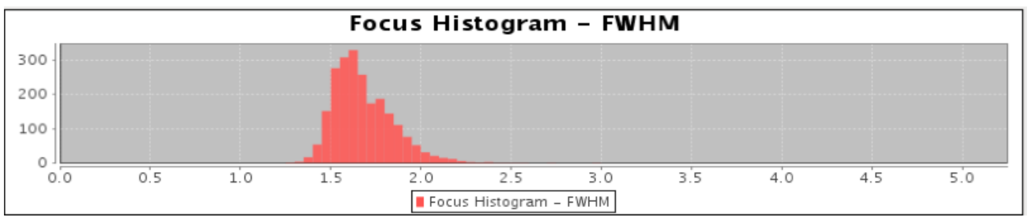


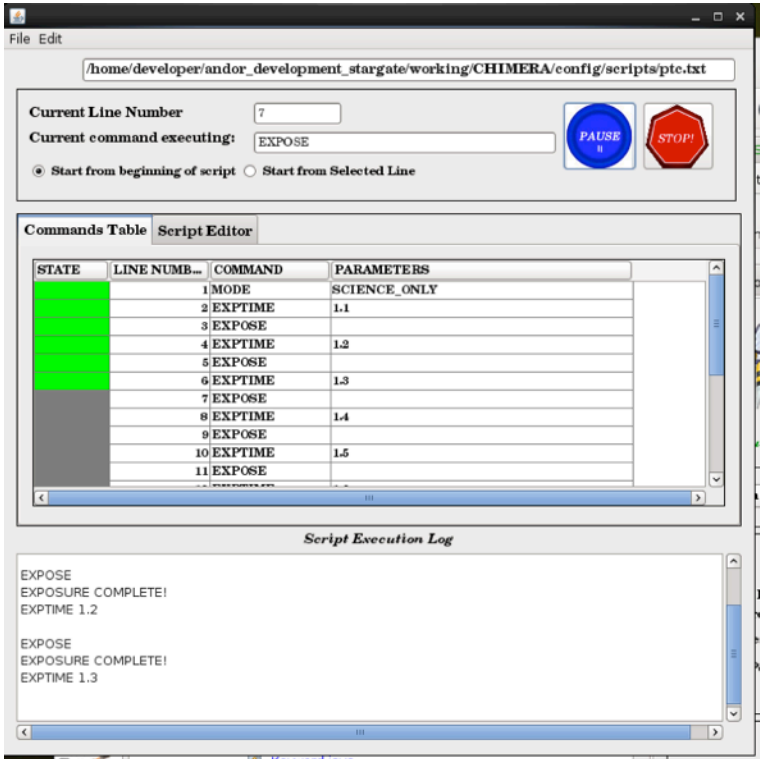
300 Second – Auto-guiding image





300 Second – no guiding image





WASP SCRIPTING LANGUAGE

WASP Scripting Language

- WASP supports a simple scripting language that executes sequential commands stored in simple text files. All commands consist of keywords followed by parameters (if necessary). If you find that additional commands would be desirable please request them.

WASP SCRIPTING LANGUAGE

Keywords	**Parameters**	**Description**
EXPTIME	double	*sets the exposure time for the science detector and focus detector if both are being readout*
BASENAME	string	*sets the basename for the FITS image file*
IMAGENUMBER	int	*set the image number for the FITS image file*
GEXPTIME	double	*set the guider exposure time*
MODE	string	*sets the operational mode of the camera (i.e. the detectors that will be readout)*
	SCIENCE_ONLY	
	FOCUS_ONLY	
	GUIDE_ONLY	
	SCIENCE_FOCUS	
	SCIENCE_GUIDE	
	SCIENCE_GUIDE_FOCUS	
EXPOSE		*starts the exposure of the camera given the current camera settings.*
FOCUSGO	double	*sets the telescope focus to the value specified in the command*
FOCUSINC	double	*increments the focus from the current value to the current value + offsset*
MOVE_TELESCOPE	double,double	*move the telescope by the specified offset in RA and Dec*
SET_DITHER_PATTERN	string	*name of a currently available dither pattern*
SET_DITHER_SCALE	double	*sets the scale factor for the dither pattern (scales pattern to the sky)*
RETRIEVE_DITHER_IMAGE		*retrieves a DSS image of the current telescope field*
FILTER	string	*selects the current filter, returns error if the specified filter is not installed.*

WASP Scripting

A simple example: FLATS in 4 filters

- One of the most useful simple scripts automatically takes a set of N images (N=5 in the example below) in each of the 4 filters installed in WASP.   Note that the script sets the focus for each filter using the FOCUSINC command.

Select which detector to readout → MODE SCIENCE_ONLY
Set the BASENAME of the images → BASENAME flat_r_prime_
Reset the image number → IMAGENUMBER 1
Change the filter → FILTER r'
Set the exposure time → EXPTIME 40.0
Execute an exposure → EXPOSE

```
MODE SCIENCE_ONLY
BASENAME flat_r_prime_
IMAGENUMBER 1
FILTER r'
EXPTIME 40.0
EXPOSE
EXPOSE
EXPOSE
EXPOSE
EXPOSE
```

```
BASENAME flat_g_prime_
IMAGENUMBER 1
FOCUSINC 1.5
FILTER g'
EXPTIME 60.0
EXPOSE
EXPOSE
EXPOSE
EXPOSE
EXPOSE
```

```
BASENAME flat_i_prime_
IMAGENUMBER 1
FILTER i'
EXPTIME 40.0
EXPOSE
EXPOSE
EXPOSE
EXPOSE
EXPOSE
```

```
BASENAME flat_u_prime_
IMAGENUMBER 1
FOCUSINC 0.1
FILTER u'
EXPTIME 60.0
EXPOSE
EXPOSE
EXPOSE
EXPOSE
EXPOSE
```

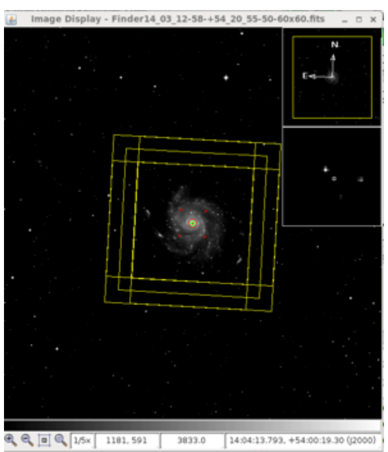
WASP Scripting

A more complex example: DITHERS in 3 filters

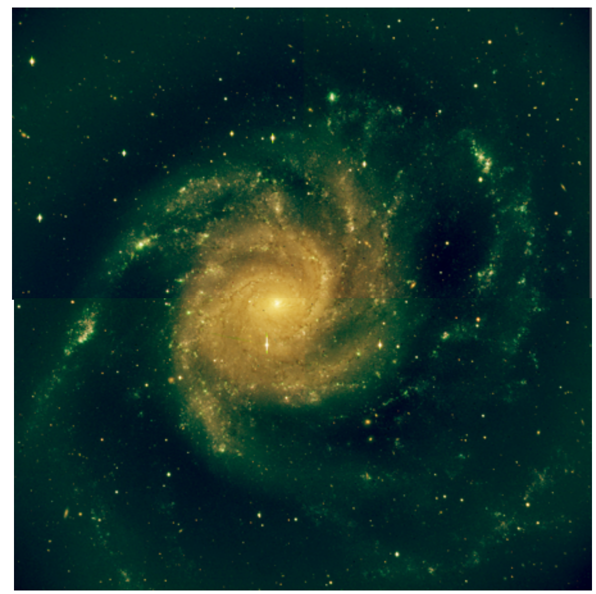
- The following script carries out a set of three, 5-point dither patterns in three filters (r’, i’, g’) of the object M101 with a 120 second exposure time at each position. A total of 15 fits images are produced by this script.

Retrieve a DSS image of the dither field → RETRIEVE_DITHER_IMAGE
Set the BASENAME of the image → BASENAME M101_DITHER_R_
Reset the image number → IMAGENUMBER 1
Change the filter → FILTER r'
Set the exposure time → EXPTIME 120.0
Select the dither pattern → SET_DITHER_PATTERN DITHER_5_SIMPLE
Set the dither scale factor → SET_DITHER_SCALE 100.0
Execute dither pattern → EXECUTE_DITHER

```
RETRIEVE_DITHER_IMAGE
BASENAME M101_DITHER_R_
IMAGENUMBER 1
FILTER r'
EXPTIME 120.0
SET_DITHER_PATTERN DITHER_5_SIMPLE
SET_DITHER_SCALE 100.0
EXECUTE_DITHER
BASENAME M101_DITHER_I_
IMAGENUMBER 1
FILTER i'
EXPTIME 120.0
SET_DITHER_PATTERN DITHER_5_SIMPLE
SET_DITHER_SCALE 100.0
EXECUTE_DITHER
BASENAME M101_DITHER_G_
IMAGENUMBER 1
FILTER g'
EXPTIME 120.0
SET_DITHER_PATTERN DITHER_5_SIMPLE
SET_DITHER_SCALE 100.0
EXECUTE_DITHER
```



Example output after data reduction



WASP Scripting Language

WASP Scripting Control

Selected Command Number

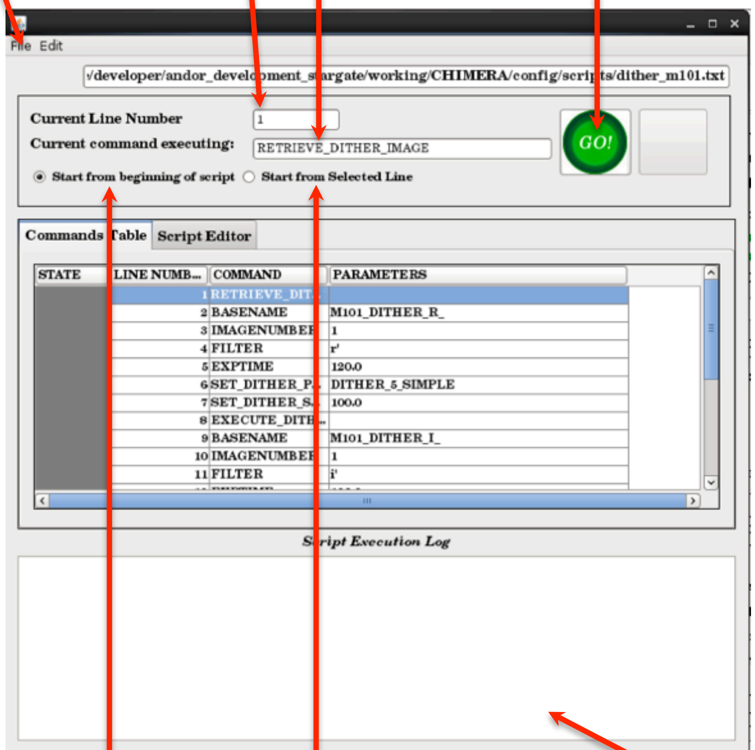
Current Selected Command

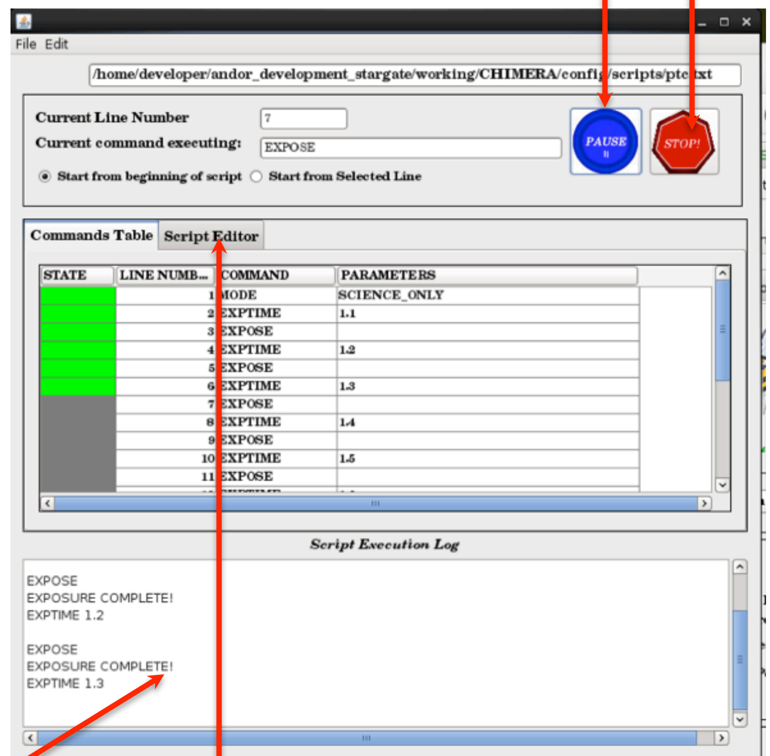
Select script file

Press GO button

Press PAUSE: Pauses execution after current command

Press STOP: Stops execution after current command



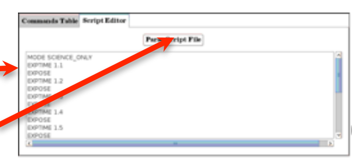


Start from the beginning of the script

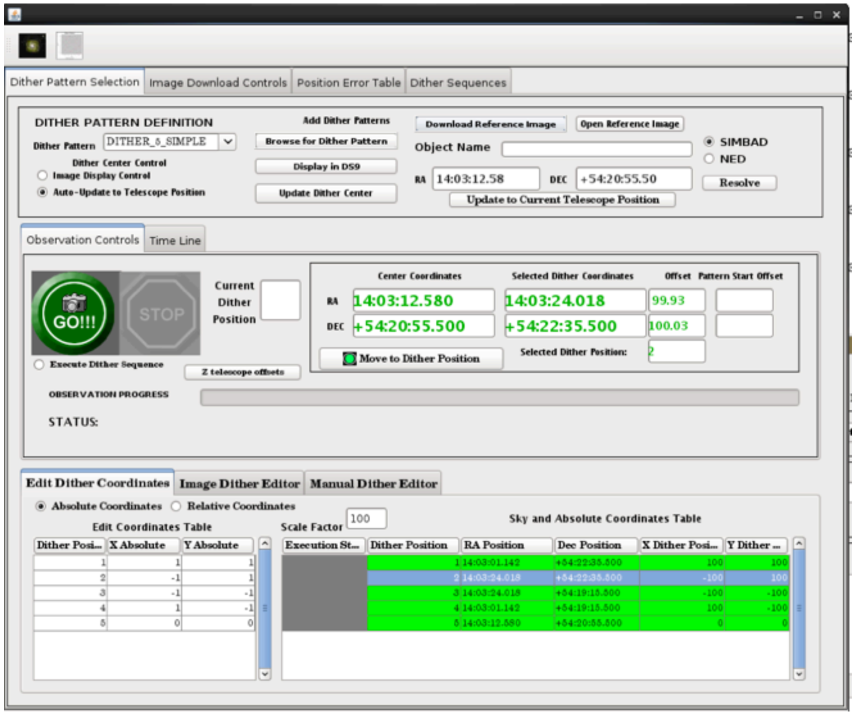
Start from the selected command number

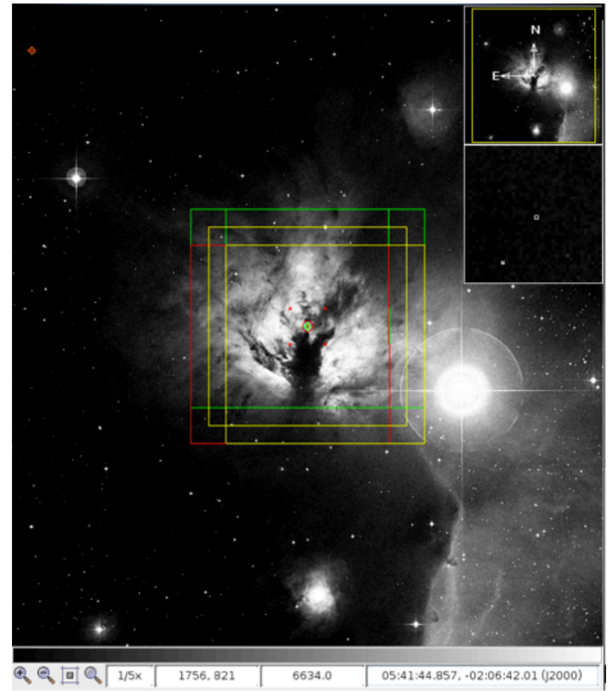
Script Execution Log

Script editor



Press Parse Script File after editing

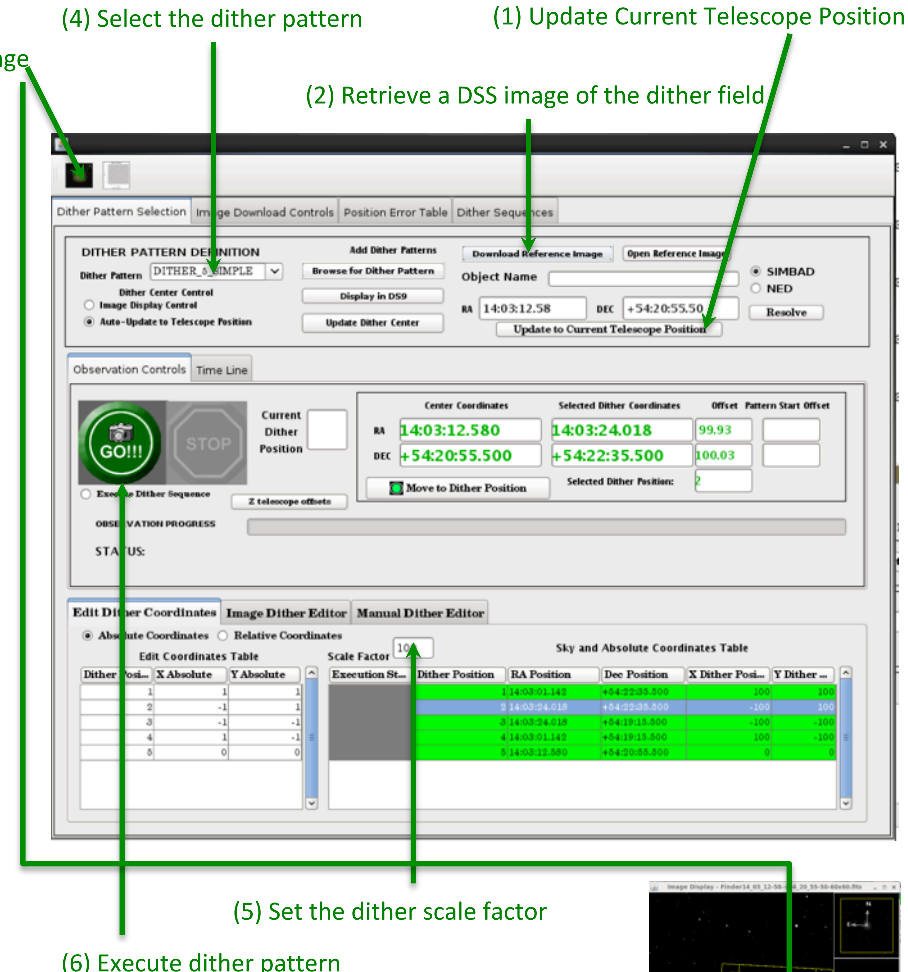


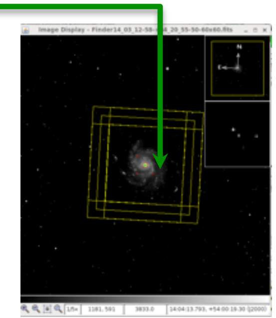


DITHER OPERATIONS

WASP Dither Pattern Control Introduction

- ***Executing a Dither sequence***
- (1) Update Current Telescope Position (this tells the control the current telescope pointing)
- (2) Download DSS reference image (based on the second Palomar Sky Survey)
- (3) Optional (open the DSS image display window)
- (4) Select the dither pattern to be executed.
- (5) Set the scale factor for the dither pattern's layout on the sky.
  - Typically dither patterns are specified with each position having an absolute x, y offset from the center between 0 and 1. The layout of the pattern on the sky is then determined by the scaling factor. The X and Y coordinates are multiplied by the scale factor to determine the offset in arcseconds from the pattern's center point. The RA and Dec coordinates of each dither position is calculated and displayed in the dither positions table.
- (6) Press the GO button
- Note: exposures are taken using whatever the current configuration (i.e. exposure time, overscan, image name, etc.) of the GUI is in effect

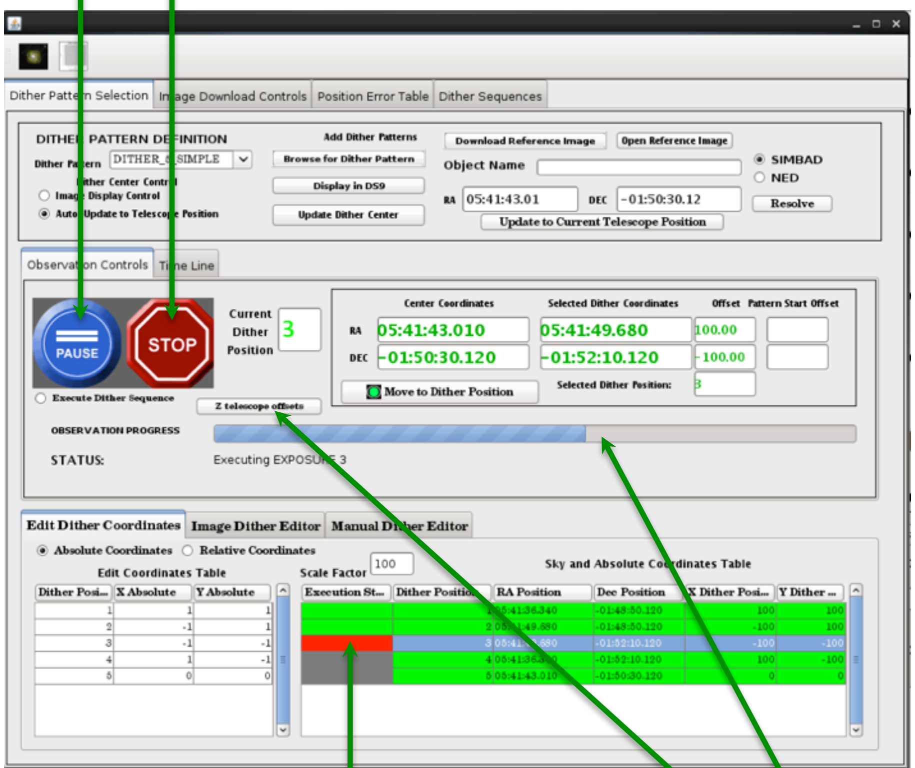


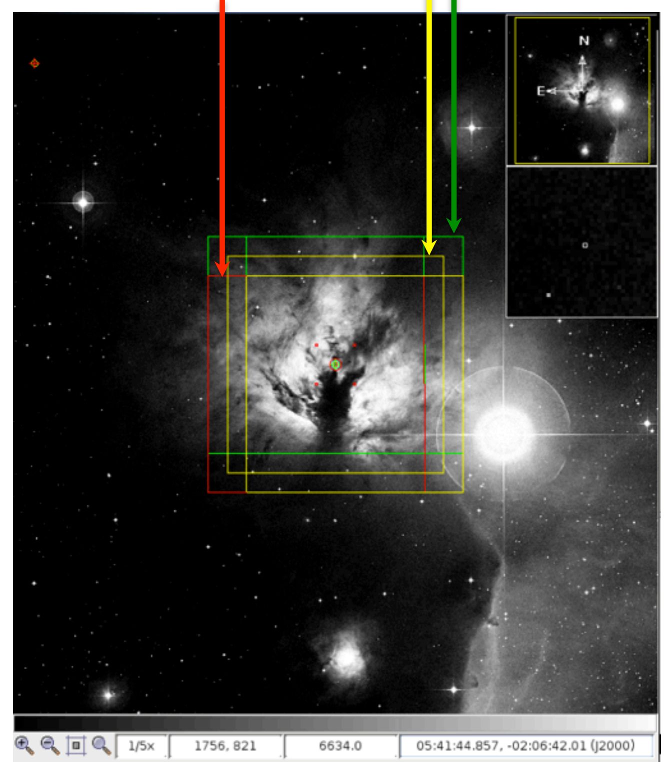


WASP Dither Pattern Control
The Dither Control in operation

While the Dither pattern is running you can either
PAUSE of STOP the pattern at any point. Note that the current
Observation step must finish before the control is reset to ready
(i.e. if you stop during an exposure that exposure must finish first)

During dither acquisition the dither position overlay changes
Color based upon the state of the observation:
GREEN   = COMPLETED
YELLOW = NOT COMPLETED
RED   = CURRENTLY OBSERVING





DITHER PATTERN TABLE:
GREEN = dither position completed
RED   = dither position currently being observed
GREY   = dither position not yet observed

Progress Bar indicates the percentage of the total pattern completed

If you Z the telescope offsets prior to starting the dither, then FACSUM and
the telescope status displays will display the real current offset from the dither center

WASP Dither Pattern Control
A tour of the Dither Pattern Control

Display DSS image with Dither overlay

Display dither position graph

Open a previously downloaded image

Retrieve a DSS image of the dither field

Optional: Enter Object Name

Optional: Resolve coordinates for the object using NED or SIMBAD

Select the dither pattern

RA and Dec coordinates for the center of the dither pattern

Offset from current position to the selected dither position.

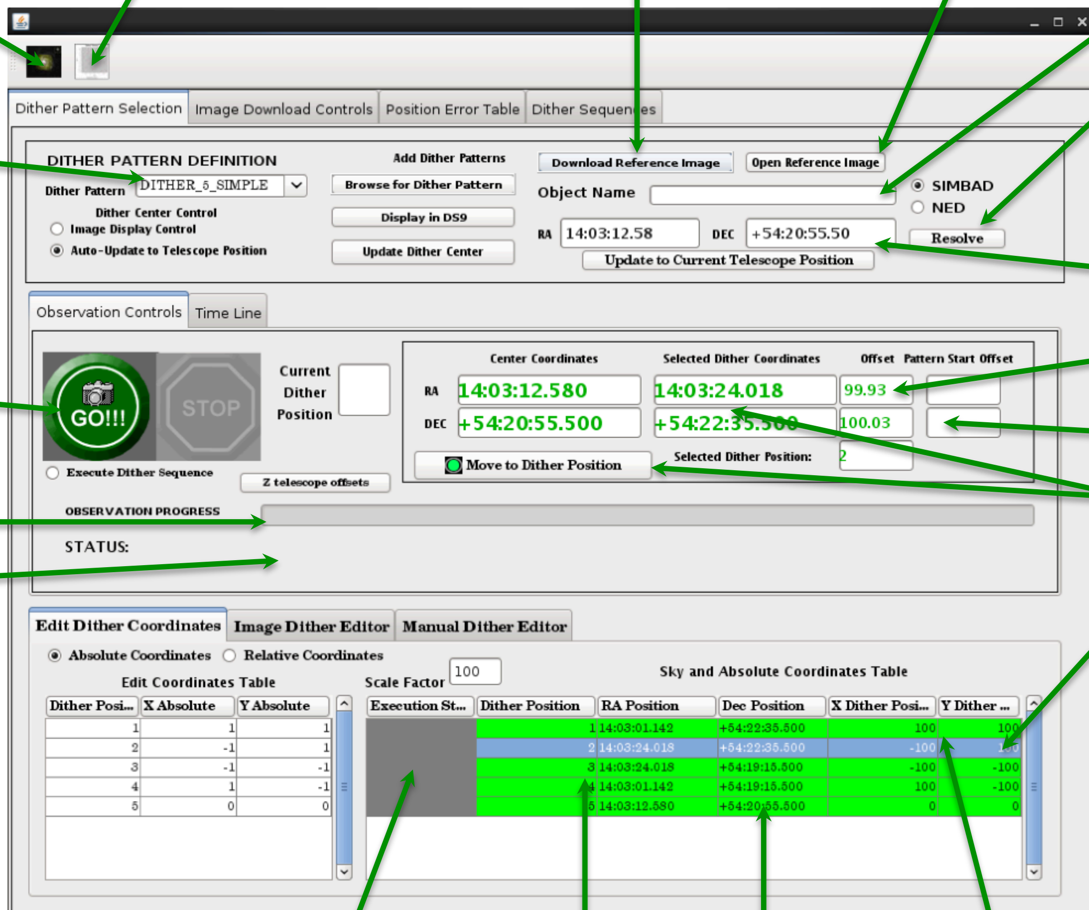
PRESS GO!! when ready

Offset from dither center to the selected dither position.

Selecting a row in table is linked to “Selected Dither Coordinates” and the Move to Dither Position Button

Observation Progress Bar

Status Messages



Execution State:
GREEN completed
RED observing
GREY not yet observed

Dither Sequence Number

RA and Dec of dither position

Dither Positions Table:

X,Y offset to position

WASP Dither Pattern Control

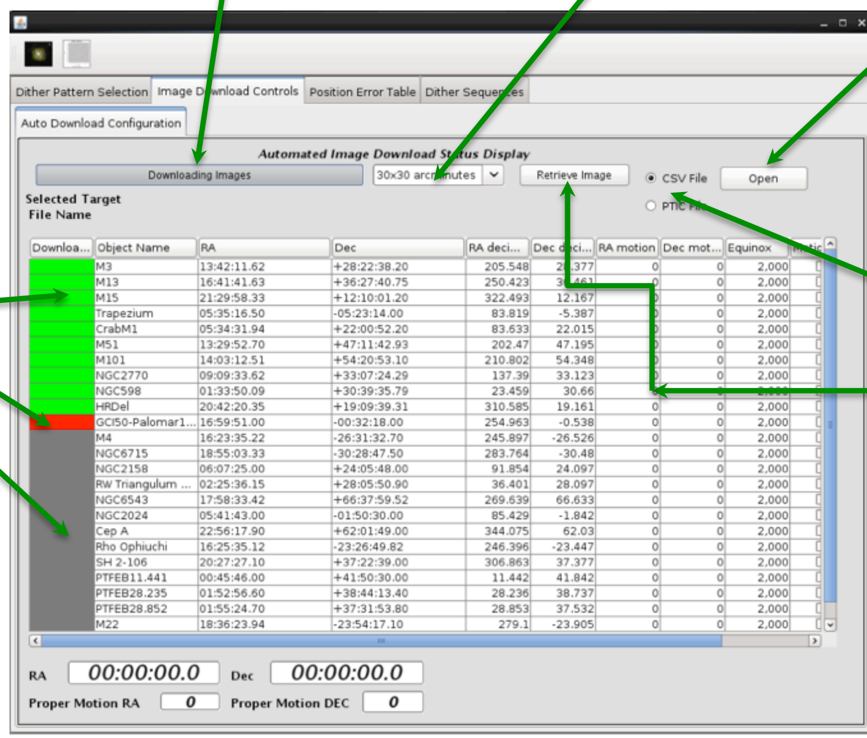
A tour of the Dither Pattern Control (continued)

- The image download control panel allows observers to load a target list (i.e. in the same format as used by FACSUM, either *.csv or *.ptic format) and then automatically download DSS images for each of the fields in the list.
- The primary use for this panel is to allow observers to download the DSS images in the afternoon for the coming nights run making operations slightly faster.

Automatically download the target list images

Specify the size of the image to download:
Recommend 30x30 arc-minutes so the entire WASP field is visible

Browse for target list:
Formats accepted = *.csv and *.ptic

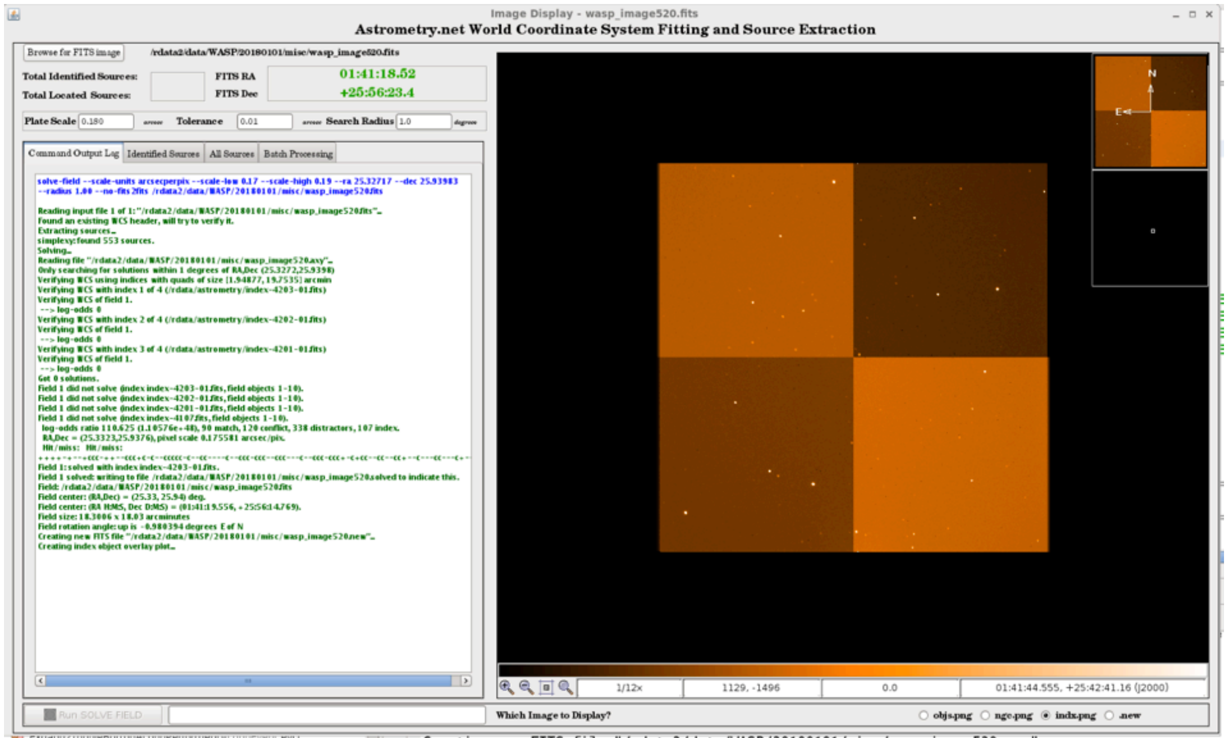


Specify the target list format

GREEN = downloaded
RED = currently downloading
GREY = not yet downloaded

Select row in the table and then press "Retrieve Image" to load the image into the control.

EXAMPLE CSV FORMAT: Ring Nebula,18:53:35.079,+33:01:45.03,2000 $NAME,RA,DEC,EQUINOX

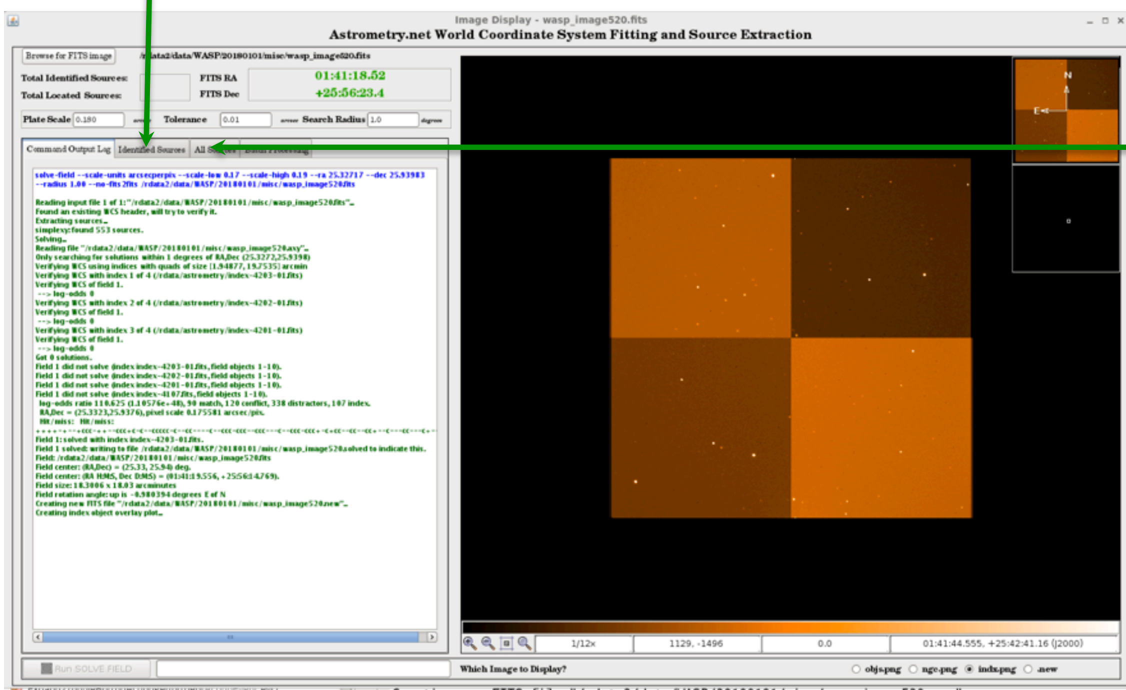


ASTROMETRY.NET INTEGRATION

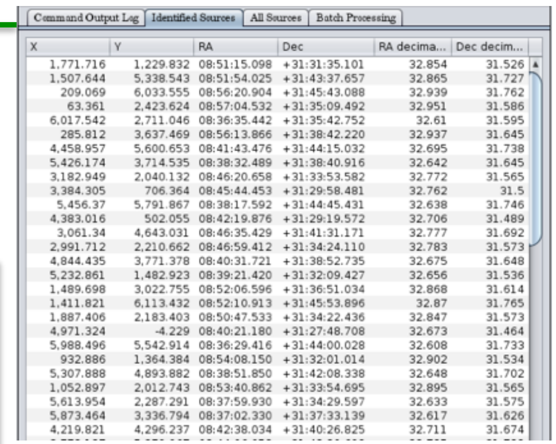
WASP and Astrometry.net

- The WASP computer contains a local distribution of the Astrometry.net program and it's associated set of database files.
- The main WASP GUI's "Observing Tools" menu allow the observer access to the built in Astrometry.net GUI

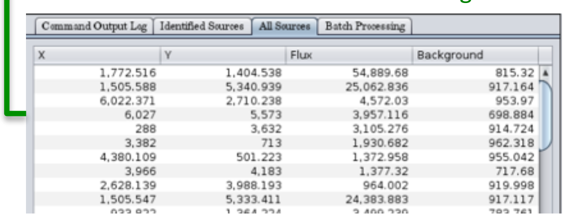
Browse for FITS image



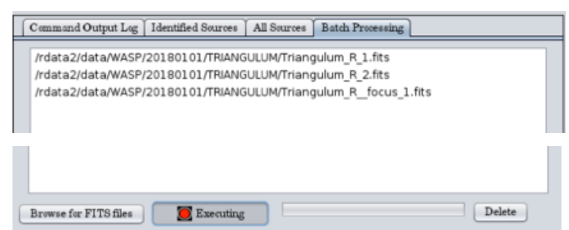
Identified SOURCES in the Image



All Sources found in the image



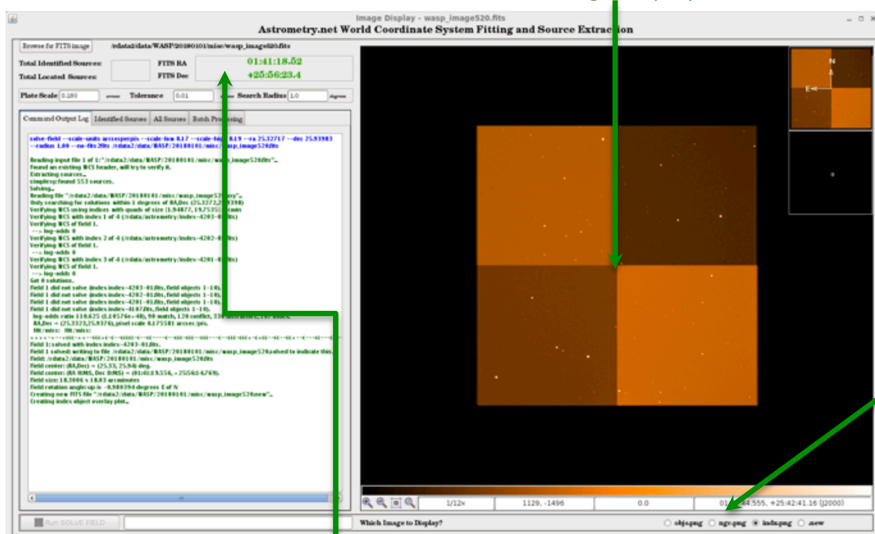
Batch process for running multiple files at once



WASP and Astrometry.net

- Astrometry.net is an excellent way to refine the WCS coordinates in WASP images.
- WASP has a large enough field of view that very few images fail to solve with Astrometry.net
- Supplying the plate scale (0.18 arc-seconds/pixel +- 0.01) and tolerance with a small search radius speeds up the solution substantially and most analyses complete in around 60 seconds.

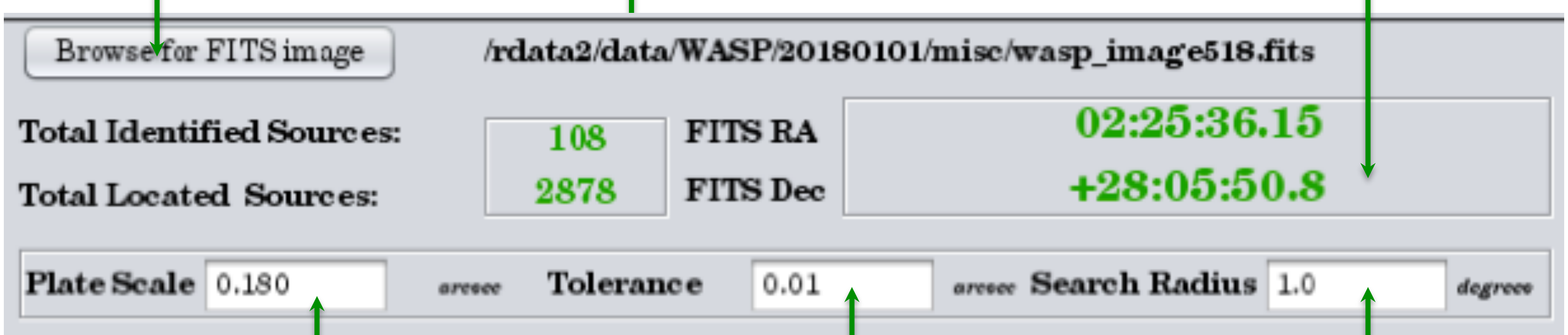
Image Display



Which image do you want to display after the solution is found?
-objs.png = png file annotated with sources
-ngc.png = png file with no annotation
-indx.png = displays “QUAD” used for solution
.new = FITS with updated WCS

Browse for FITS image

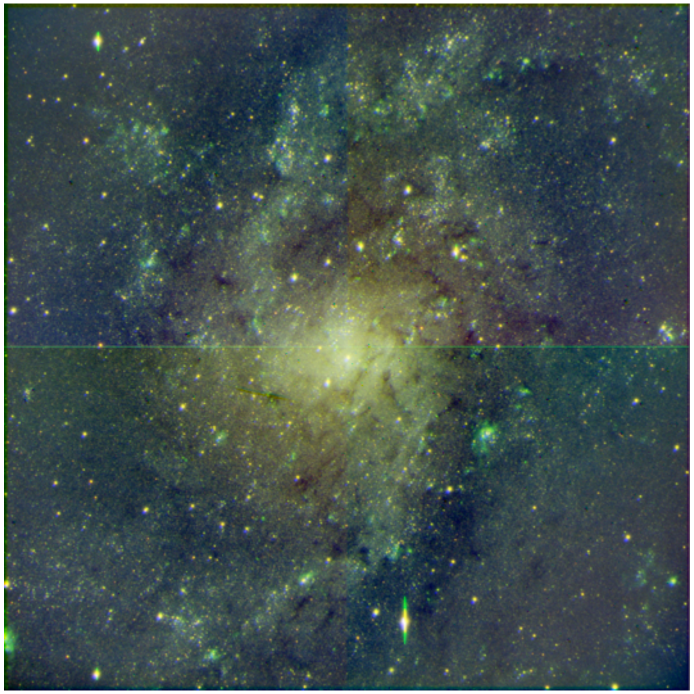
RA and Dec retrieved from FITS header

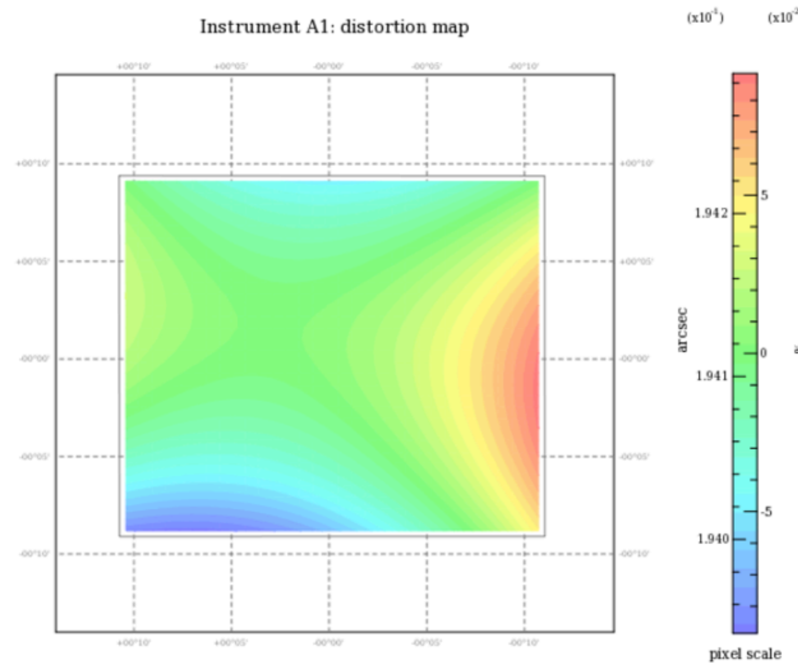


Input estimated Plate Scale: WASP 0.18 arc-seconds/pixel

Plate Scale Tolerance:

Search Radius about RA and Dec



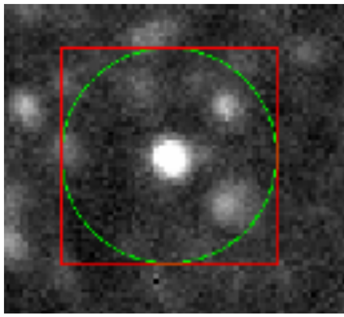


WASP OPTICAL DISTORTIONS

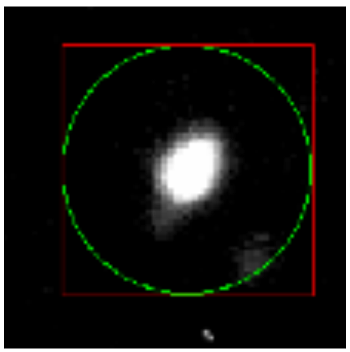
Optical Quality Assessment

Gaussian FWHM Map and
examples of coma at the periphery of the optical field

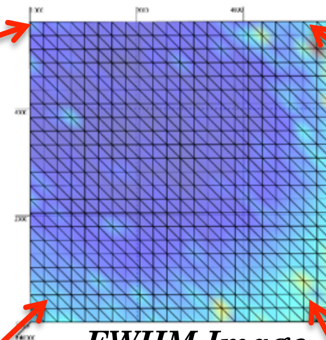
Coma NE quadrant



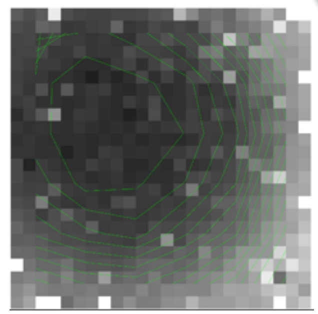
Coma SE quadrant



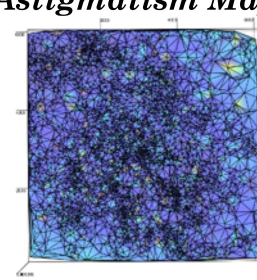
FWHM Map



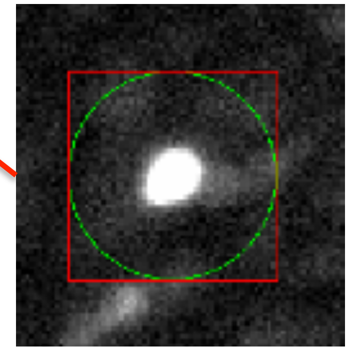
FWHM Image



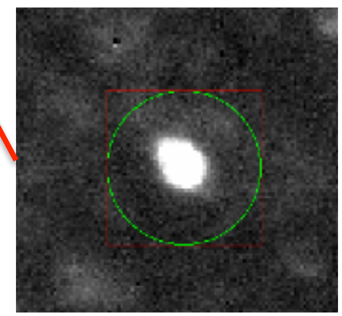
Astigmatism Map



Coma NW quadrant



Coma SW quadrant

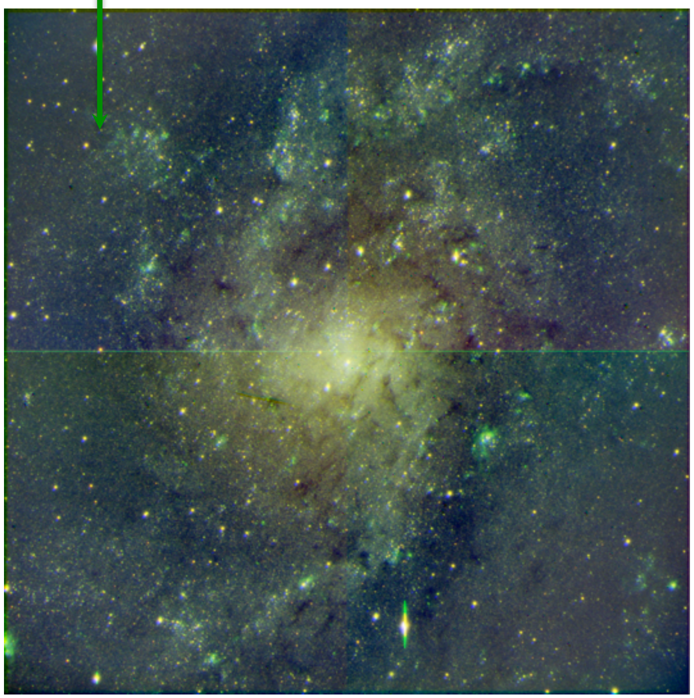


Optical Quality Assessment

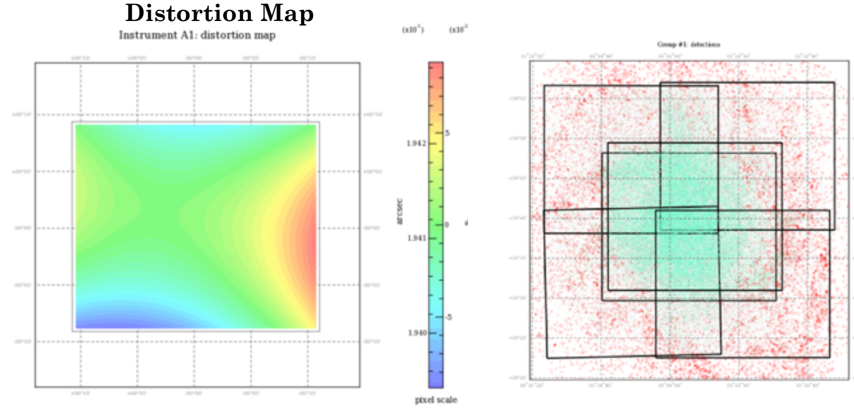
Example: SCAMP evaluation of astrometric distortions

The image of NGC 598 depicted below is a composite of 5 dither positions observed in 3 separate filters (r’, i’, g’)

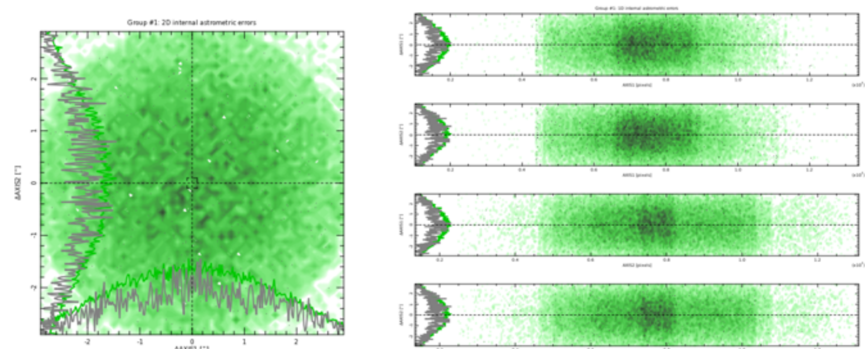
Example: NGC 598



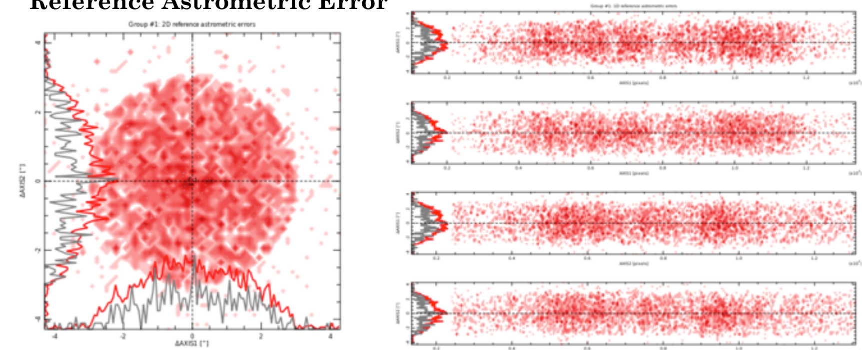
Distortion Map

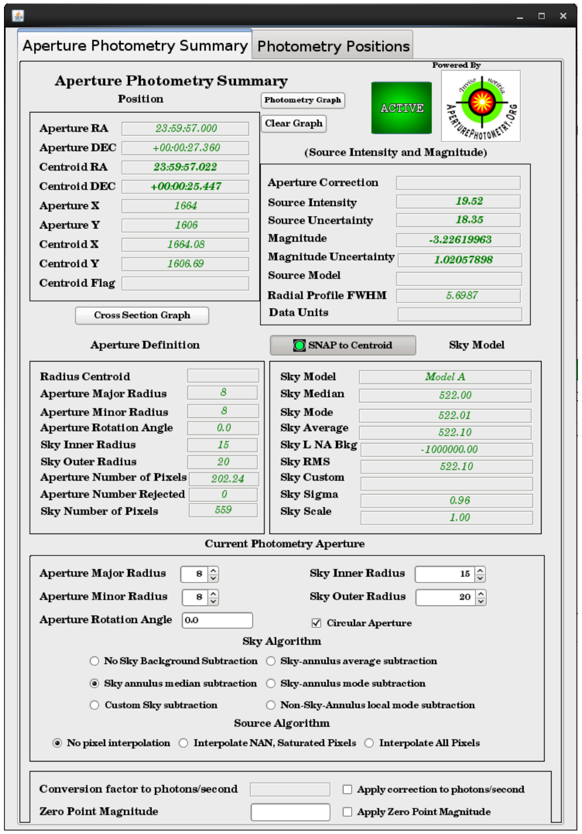


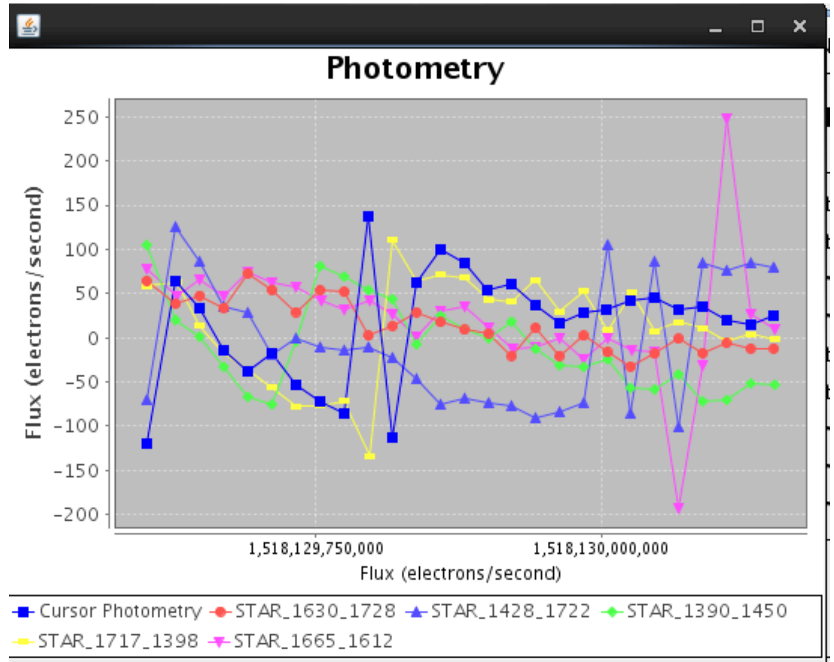
Internal Astrometric Error



Reference Astrometric Error



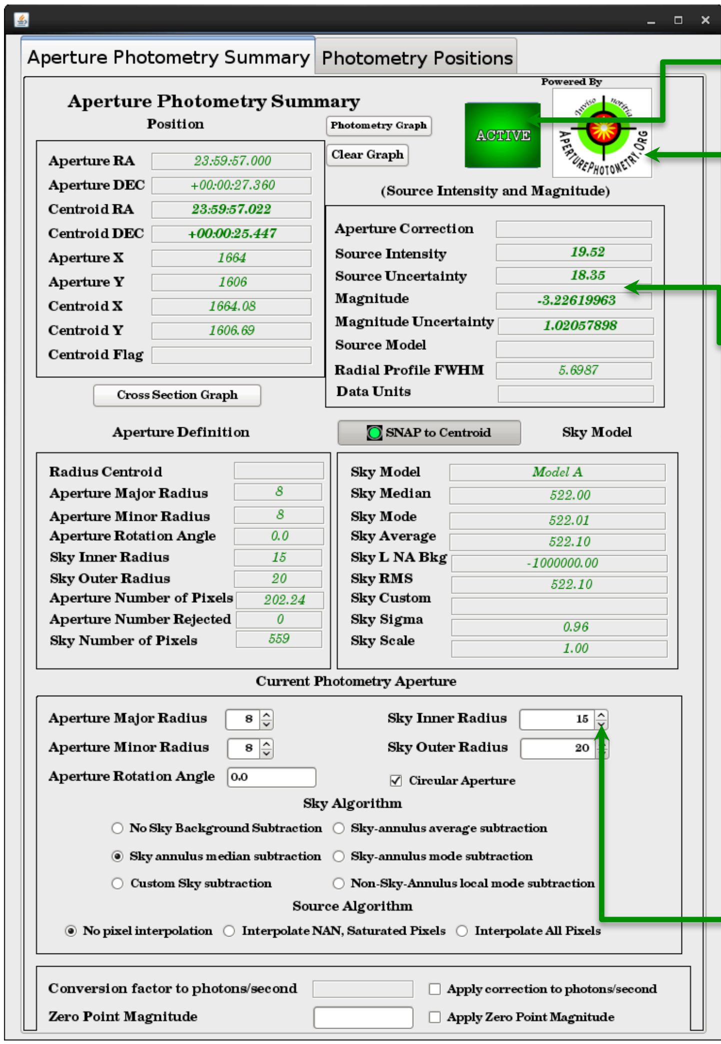




APERTURE PHOTOMETRY

Aperture Photometry

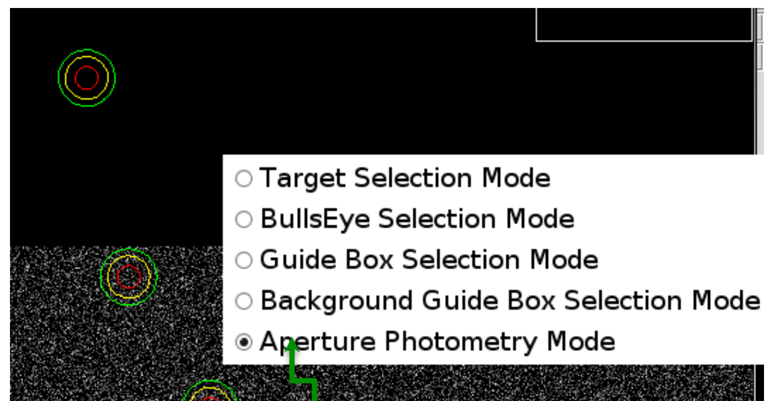
Aperture Photometry Tool Integration



First you need to "Activate" the Aperture Photometry Mode so that images are read into the correct structures for doing the aperture calculations. You need to "Activate" prior to taking the image.

Note: The code used for the aperture photometry calculations was written by Russ Laher of IPAC and incorporated into the WASP instrument. If there is a problem anywhere in the calculations it is solely my responsibility not Russ's.

Each time either the mouse is clicked on the image or a new image is taken the Aperture photometry parameters a updated in the GUI.



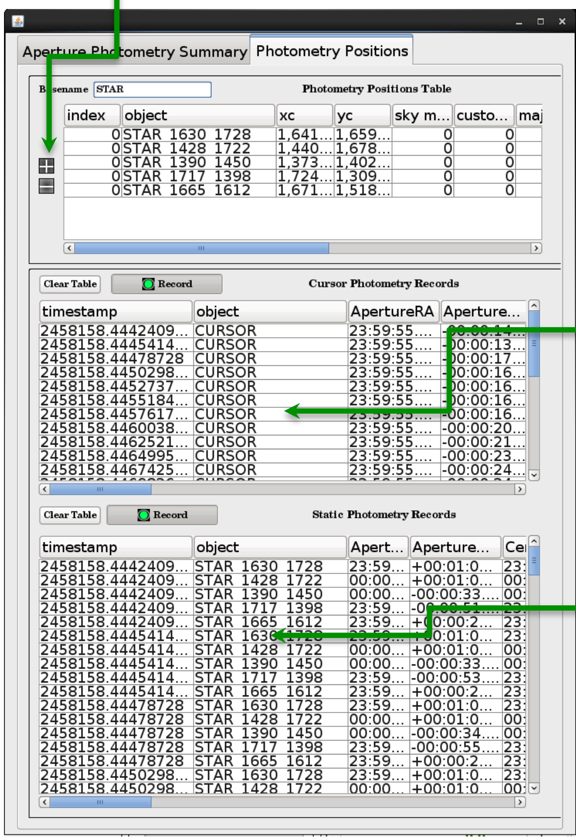
After an image has been taken you can right-mouse click on the image to display the cursor dialog and select "Aperture Photometry Mode".

Clicking on the image will then place a "Photometry" cursor on the image using a circular aperture with a Aperture Major Radius and a "Sky Inner Radius" and "Sky Outer Radius" controlled by the dialog spinners.

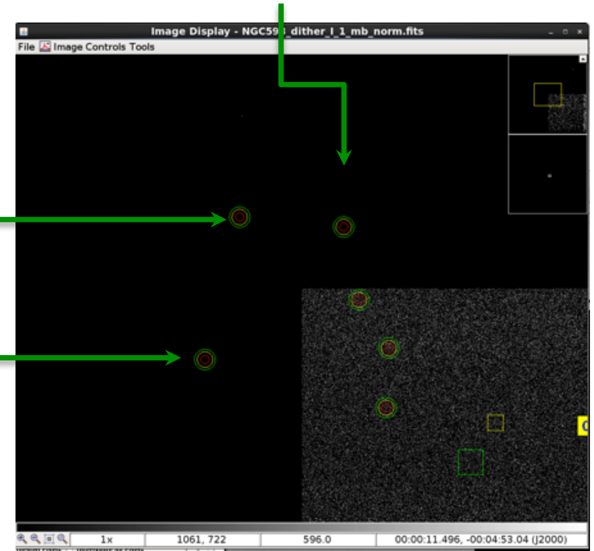
Aperture Photometry

Monitoring the photometry of multiple objects

If the + sign is engaged (i.e. icon turns green) each click on the image will add a new photometry cursor to the list of objects to monitor. Positions in this table are considered "static" photometry records.



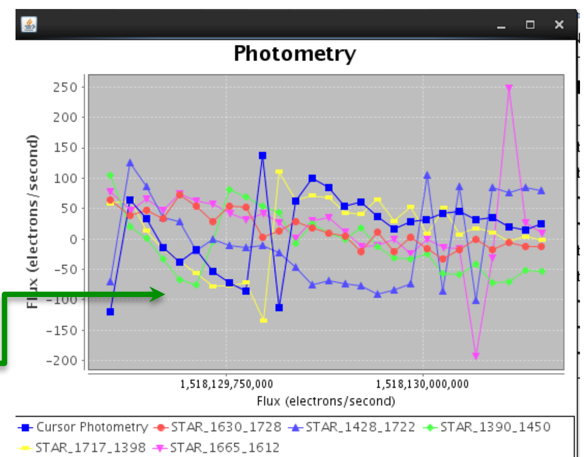
Science Image Display



Each time the image is clicked with the mouse a new record is added to the "Cursor Photometry Record" (note as long as the + button is not active)

Each new image will produce a new set of measurements in the "static photometry records" table for each photometry cursor.

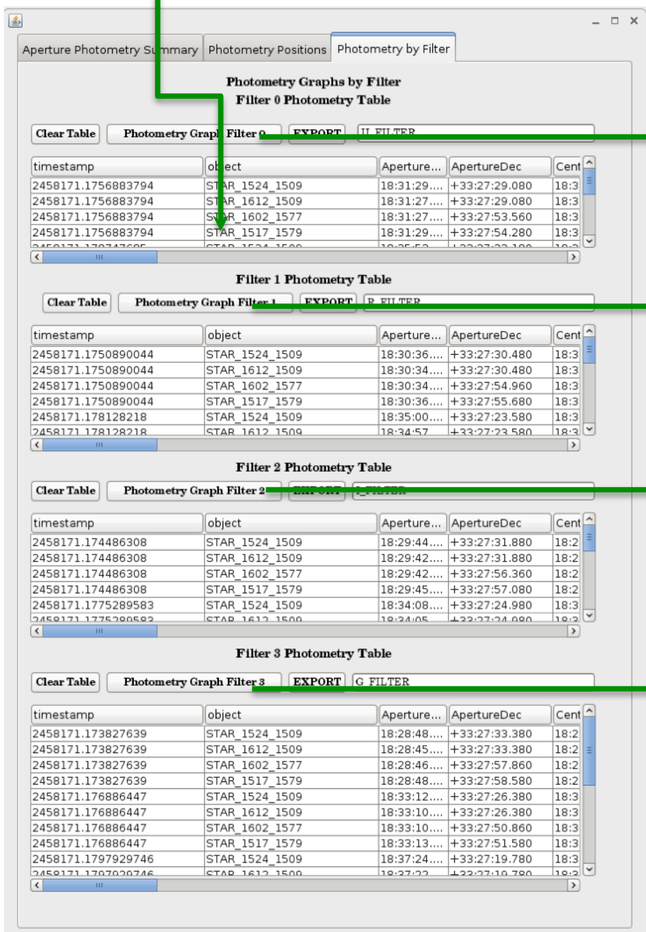
Photometry Graph: Each "static" photometry cursor appears as a separate "trace" in the photometry graph.



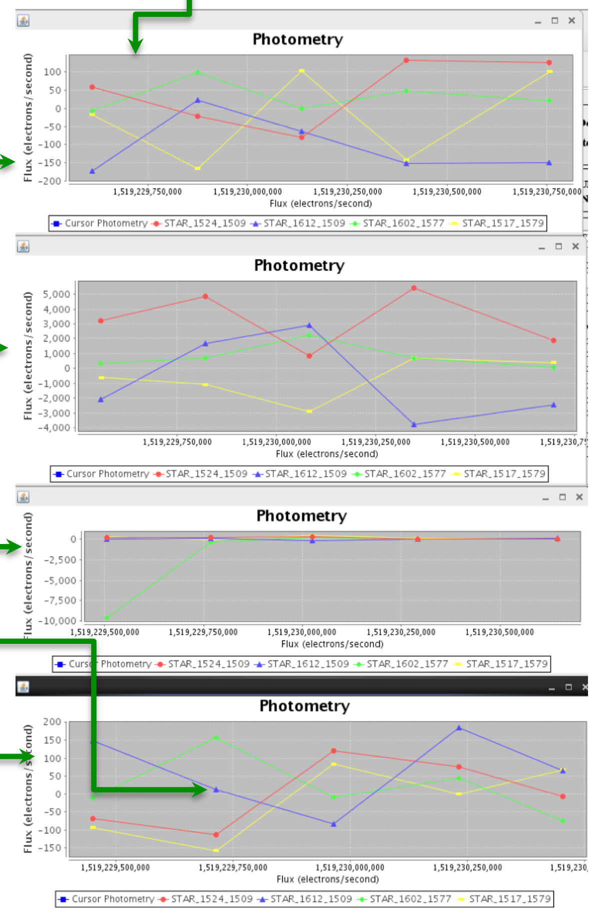
Aperture Photometry

Monitoring the photometry of multiple objects in multiple filters

Static Photometry cursors (4 in this case) are plotted separately for each filter to facilitate monitoring multi-filter observations.



Science Image Display
Observations in each filter are plotted on a separate graph

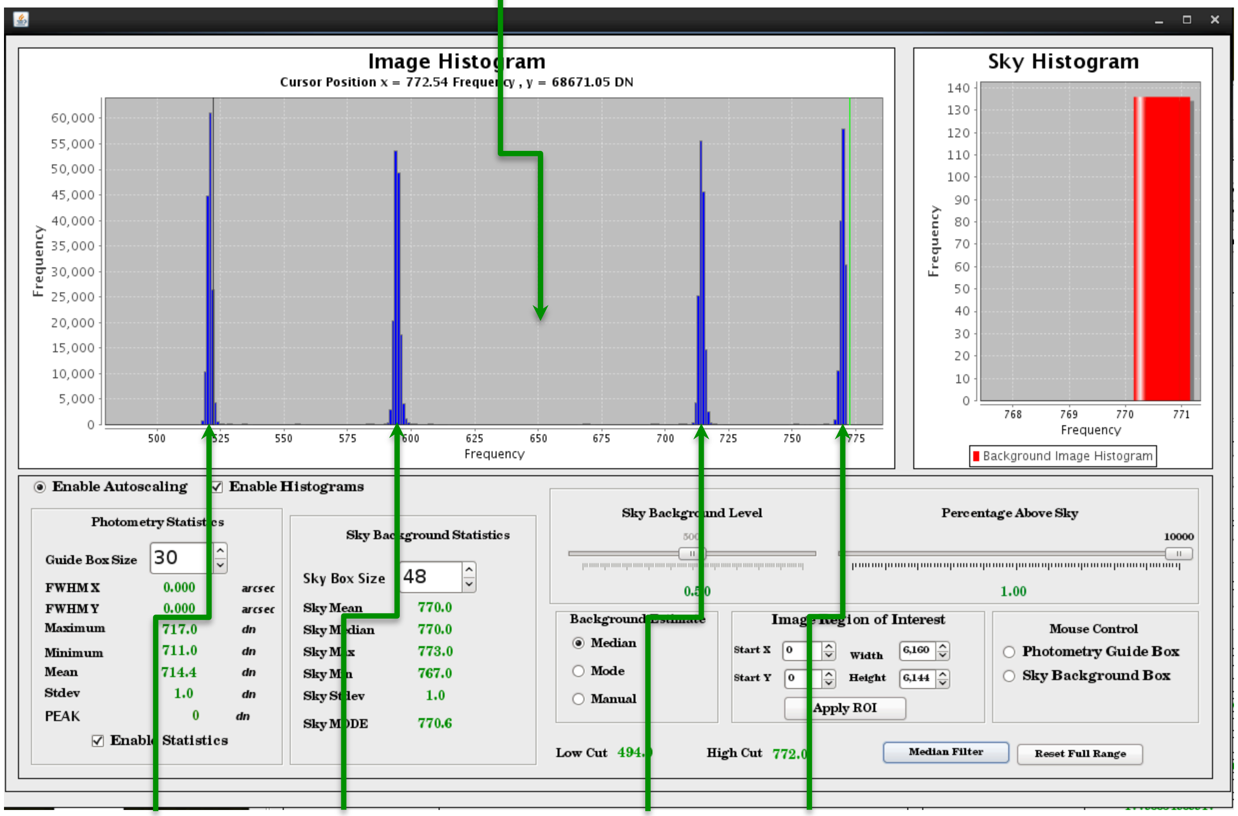


Photometry Graph: Each "static" photometry cursor appears as a separate "trace" in the photometry graph.

Aperture Photometry

Bias structure of a WASP image

HISTOGRAM OF A BIAS IMAGE



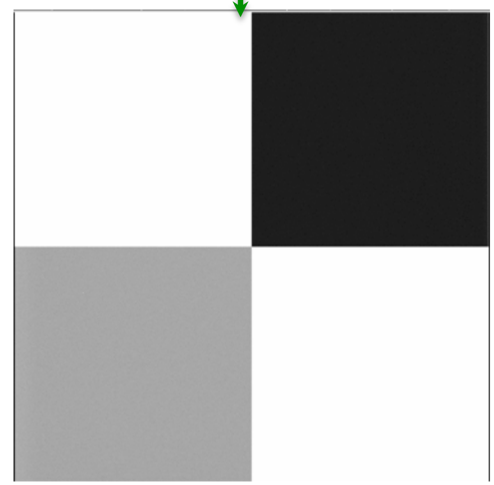
UPPER RIGHT QUADRANT

LOWER LEFT QUADRANT

UPPER LEFT QUADRANT

LOWER RIGHT QUADRANT

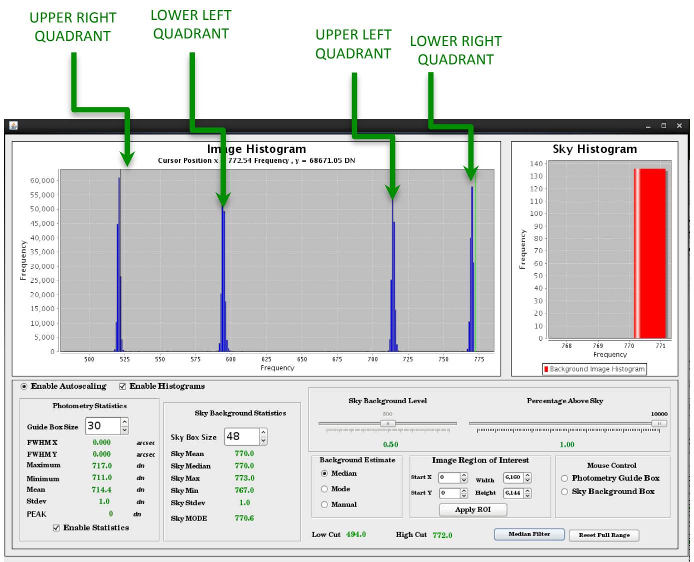
BIAS image of the WASP Science Detector



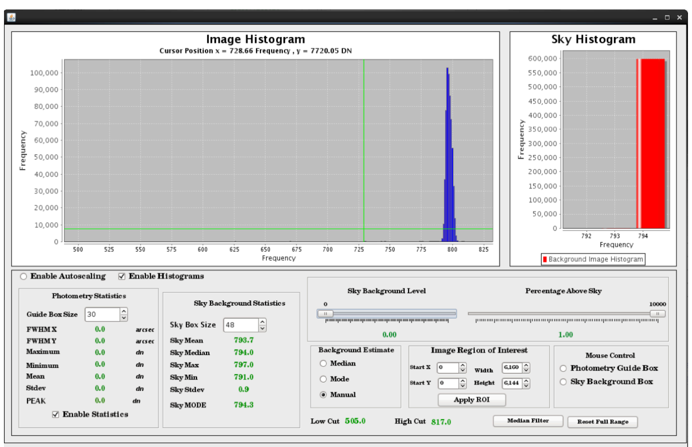
BIAS RANGE = 250 adu

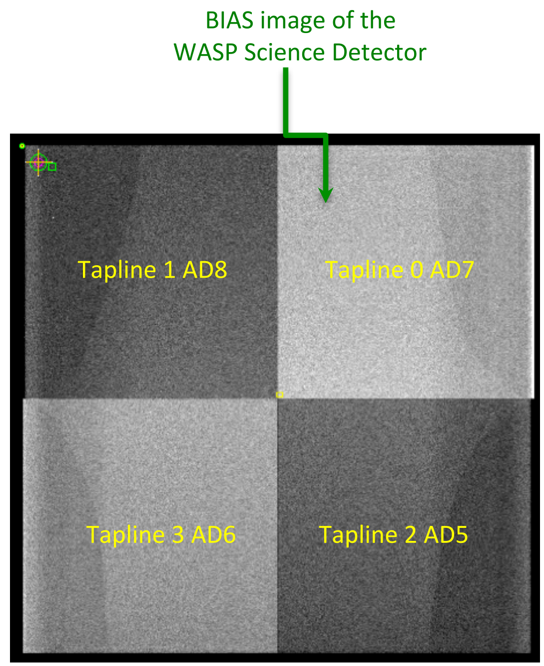
Aperture Photometry

Bias structure of a WASP image



HISTOGRAM OF A BIAS IMAGE AFTER OFFSET CORRECTION





ORIGINAL BIAS RANGE = 250 adu

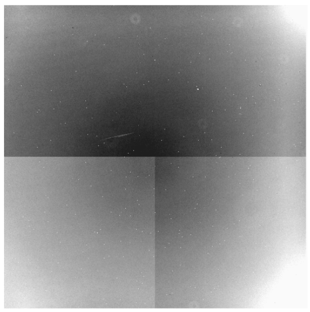
Offset Correction	*Median*	*Mean*	*Standard Deviation*	*Offset*	*Tapline*	
Quadrant 1	607	606.8	1	193	Tapline 3	AD6
Quadrant 2	794	793.6	1.1	6	Tapline 2	AD5
Quadrant 3	530	529.7	1.4	270	Tapline 0	AD7
Quadrant 4	738	737.6	1.1	62	Tapline 1	AD8

BIAS MEASUREMENTS IN EACH QUADRANT BEFORE OFFSET CORRECTION

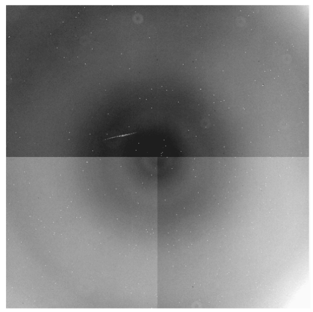
Aperture Photometry

Comparison between FLAT field images in different filters

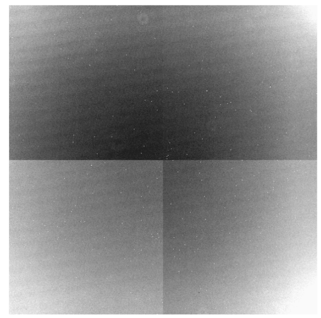
r' filter



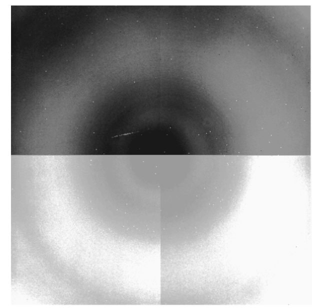
i' filter



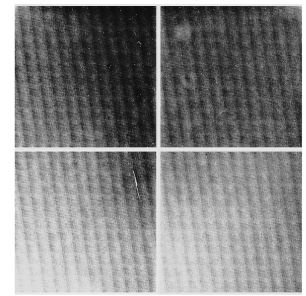
g' filter



z' filter

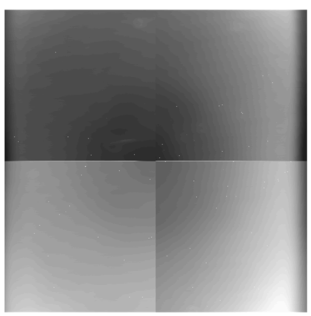


u' filter

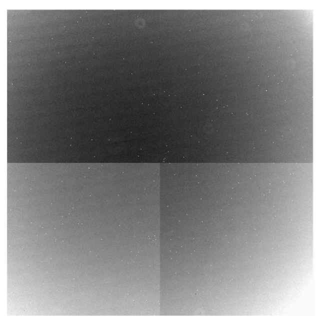


with 50 overscan

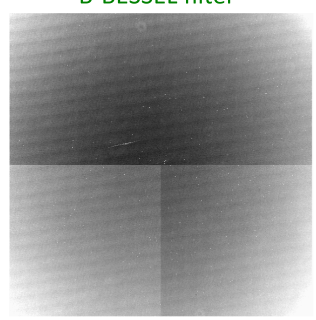
R-BESSEL filter



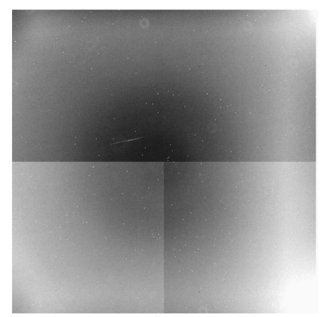
V-BESSEL filter



B-BESSEL filter



H-ALPHA filter



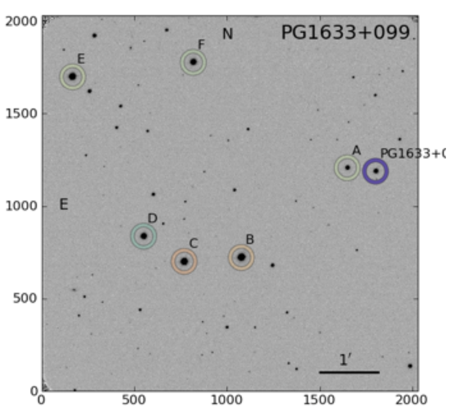
WASP Observing Run – August 3, 4 2017

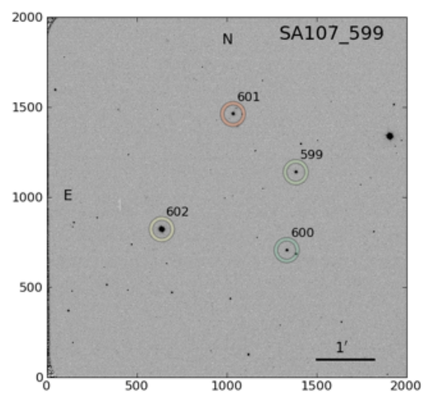
PHOTOMETRIC ANALYSIS – ZERO POINT MAGNITUDES

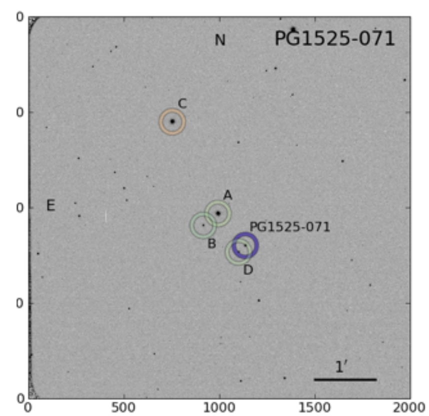
Photometric Standards
August 2017 – WAS

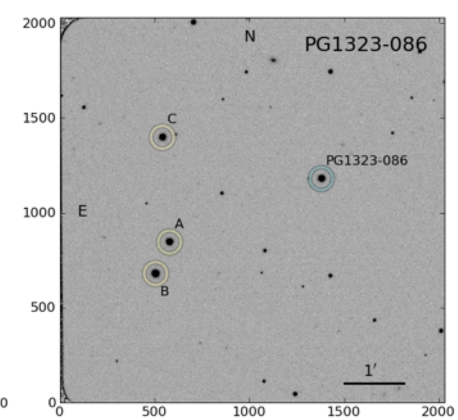
from: http://www.not.iac.es/instruments/stancam/photstd/

	V	B	U	R	I	B-V	U-B	V-R	V-I
PG1323-086									
PG1323-086	13.481	13.341	12.66	13.529	13.608	-0.14	-0.681	-0.048	-0.127
PG1323-086A	13.59	13.989	13.97	13.338	13.084	0.399	-0.019	0.252	0.506
PG1323-086B	13.406	14.167	14.432	12.98	12.573	0.761	0.265	0.426	0.833
PG1323-086C	14.003	14.71	14.955	13.608	13.244	0.707	0.245	0.395	0.759
PG1525-071									
PG1525-071	15.046	14.835	13.658	15.114	15.034	-0.211	-1.177	-0.068	0.012
PG1525-071A	13.506	14.279	14.561	13.069	13.085	0.773	0.282	0.437	0.421
PG1525-071B	16.392	17.121	17.262	15.942	16.005	0.729	0.141	0.45	0.387
PG1525-071C	13.519	14.635	15.708	12.926	13.01	1.116	1.073	0.593	0.509
PG1525-071D	16.3	16.693	16.917	15.895	15.957	0.393	0.224	0.405	0.343
PG1633+099									
PG1633+099	14.396	14.205	13.215	14.481	14.604	-0.191	-0.99	-0.085	-0.208
PG1633+099A	15.259	16.13	16.435	14.753	14.248	0.871	0.305	0.506	1.011
PG1633+099B	12.968	14.049	15.066	12.379	11.878	1.081	1.017	0.589	1.09
PG1633+099C	13.224	14.368	15.514	12.612	12.091	1.144	1.146	0.612	1.133
PG1633+099D	13.689	14.224	14.203	13.365	13.04	0.535	-0.021	0.324	0.649
PG1633+099E	13.113	13.954	14.291	12.629	12.16	0.841	0.337	0.484	0.953
PG1633+099F	13.768	14.646	14.9	13.245	12.733	0.878	0.254	0.523	1.035
SA 107 599									
SA 107 599	14.675	15.373	15.616	14.242	13.806	0.698	0.243	0.433	0.869
SA 107 600	14.884	15.387	15.436	14.545	14.184	0.503	0.049	0.339	0.7
SA 107 601	14.646	16.058	17.323	13.723	12.885	1.412	1.265	0.923	1.761
SA 107 602	12.116	13.107	13.692	11.571	11.042	0.991	0.585	0.545	1.074

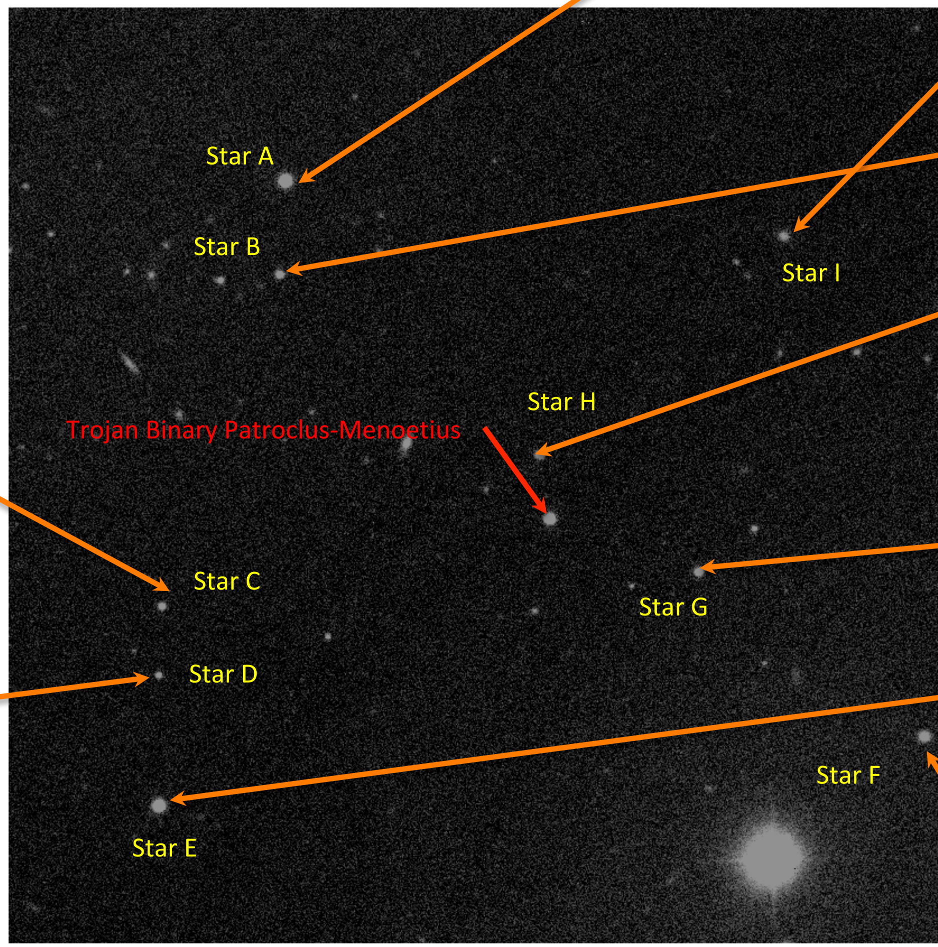








Patroclus-Menoetius Asteroids
April 9, 2018 WASP IMAGES



11:30:00.15 +26:49:13.6
G = 15.663
R = 15.3072
I = 15.1938
Z = 15.1637

11:29:45.89 +26:48:50.7
G = 20.35
R = 19.529
I = 19.008
Z = 18.851

11:30:00.27 +26:48:38.2
G = 17.9577
R = 17.5221
I = 17.3835
Z = 17.3499

11:29:52.94 +26:47:27.9
G = 17.985
R = 17.279
I = 17.011
Z = 16.899

11:30:03.95 +26:46:32.2
G = 19.678
R = 18.462
I = 17.65
Z = 17.294

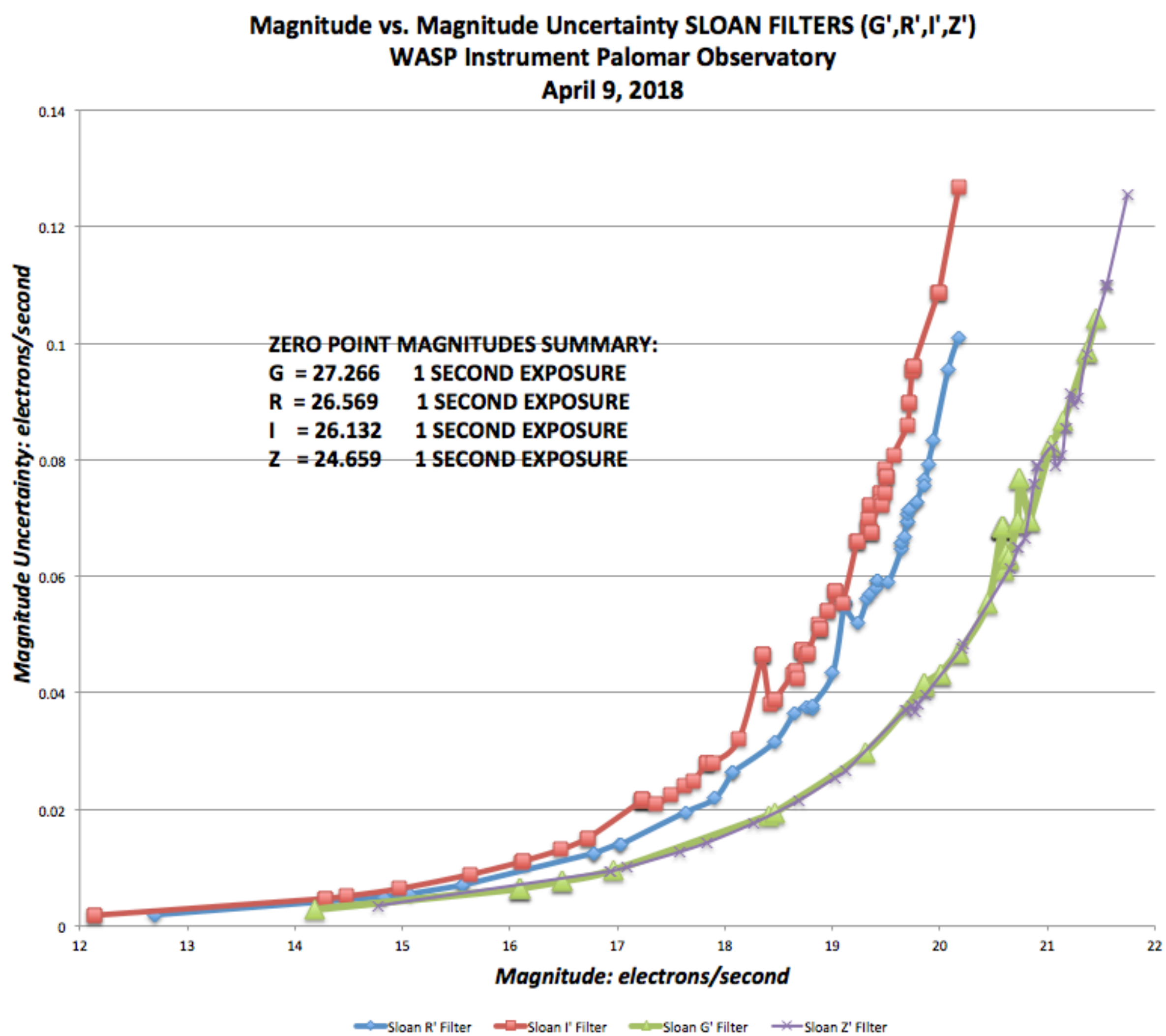
11:29:48.53 +26:46:41.5
G = 19.451
R = 18.213
I = 17.044
Z = 16.517

11:30:04.06 +26:46:05.4
G = 20.645
R = 19.413
I = 18.448
Z = 18.011

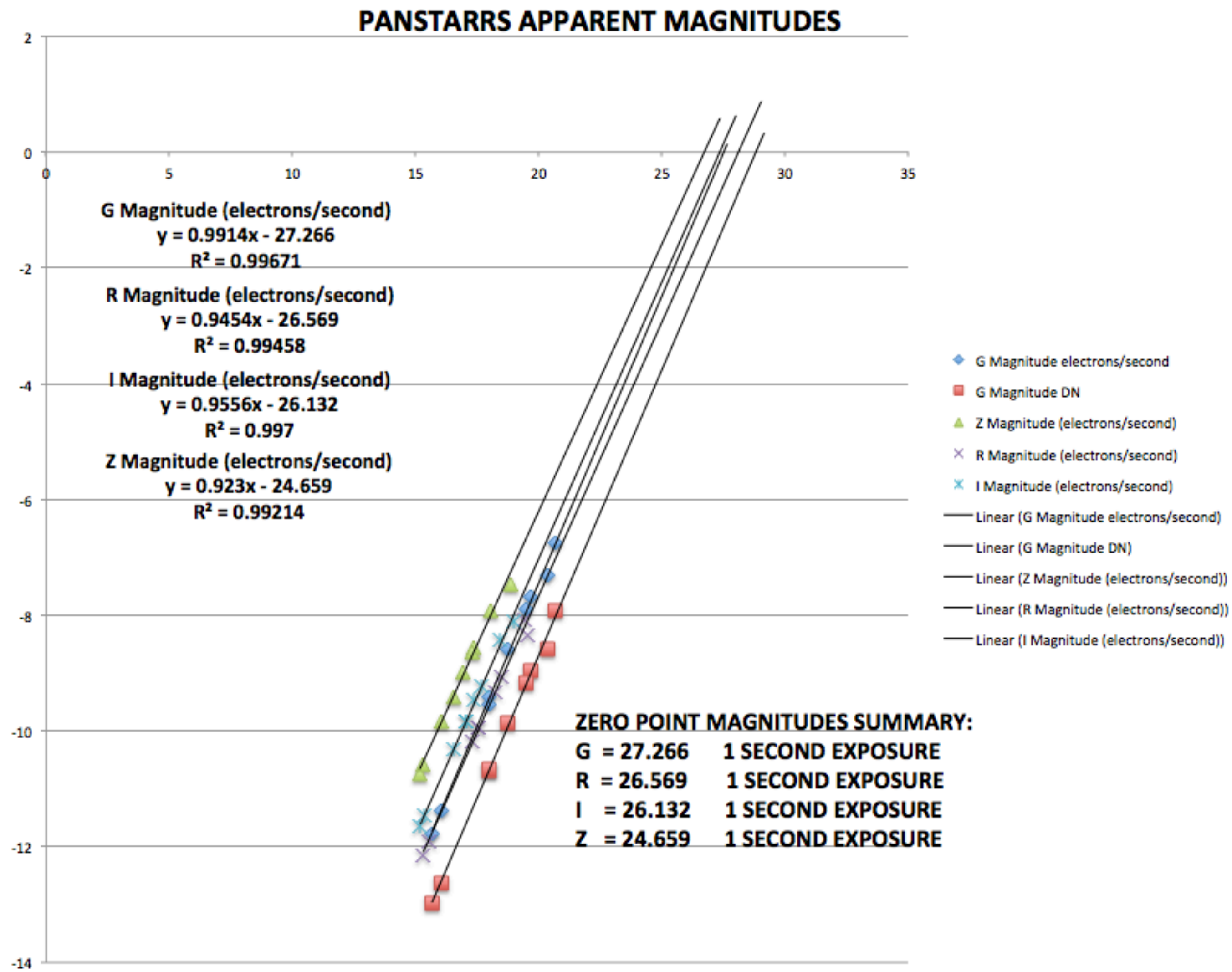
11:30:04.04 +26:45:15.3
G = 16.024
R = 15.56
I = 15.375
Z = 15.318

11:29:42.07 +26:45:38.1
G = 18.761
R = 17.548
I = 16.533
Z = 16.067

Magnitude vs. Magnitude Uncertainty WASP Instrument April 9, 2018

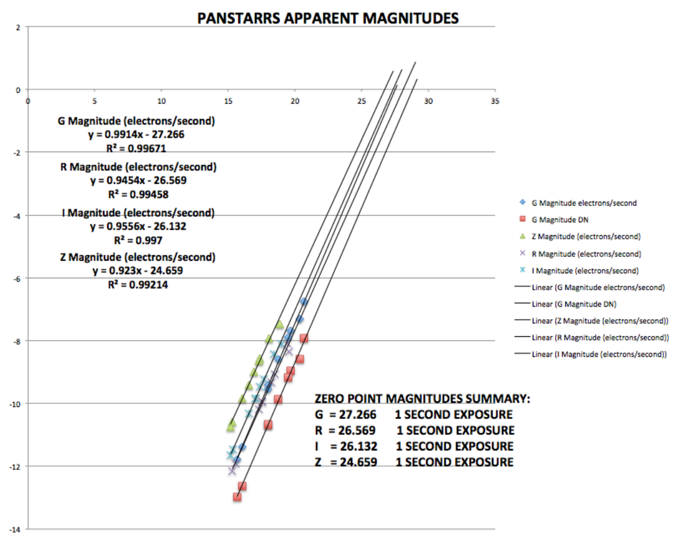


PANSTARRS Apparent Magnitudes vs. Instrumental Magnitudes
Calculation of Zero Point Magnitude for Sloan Filters
April 9, 2018



SUMMARY of Sensitivities
Calculation of Zero Point Magnitude for Sloan Filters
April 9, 2018

		Pixel (arcsec2)	P200 area (m2)	Gain (e-/DN)	u'	g'	r'	I'	z'	J	H	Ks
Detector	***WASP***		0.174	5.9	**50**	**90**	**92**	**93**	**60**			
Quantum	***LFC***	17.8	0.180	2	**12**	**24**	**45**	**47**	**19**			
Efficiency	***WIRC***	13	0.250	5.3								
	PHARO	16	0.025	1.9								
Zeropoint	***WASP***				**25.409**	**27.266**	**26.569**	**26.132**	**24.659**			
(1e/sec)	***LFC***				**24.900**	**27.300**	**27.400**	**27.100**	**26.100**			
	WIRC									**24.6**	**24.9**	**24.4**
	PHARO									**24.8**	**25.1**	**24.7**
Measured	***WASP***					**339.2**	**733.4**	**826.8**	**560.2**			
Sky Background	***LFC***					**247.0**	**741.0**	**1173.0**	**1420.0**			
(e/sec/arcsec2)	***WIRC***											
	PHARO											



R Band Zero-Point Magnitude

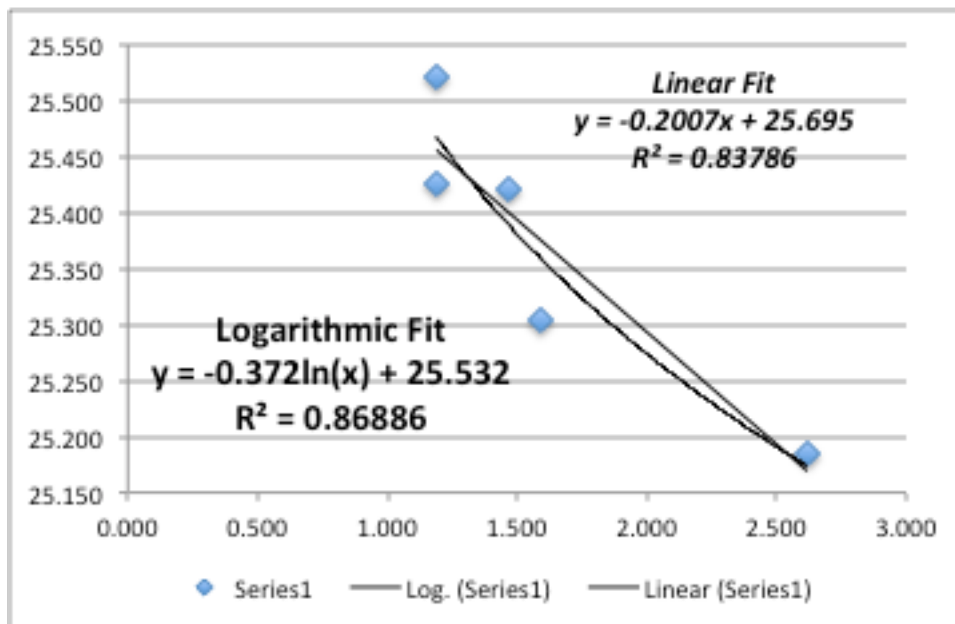
Normalized for 1 Second Exposure Time

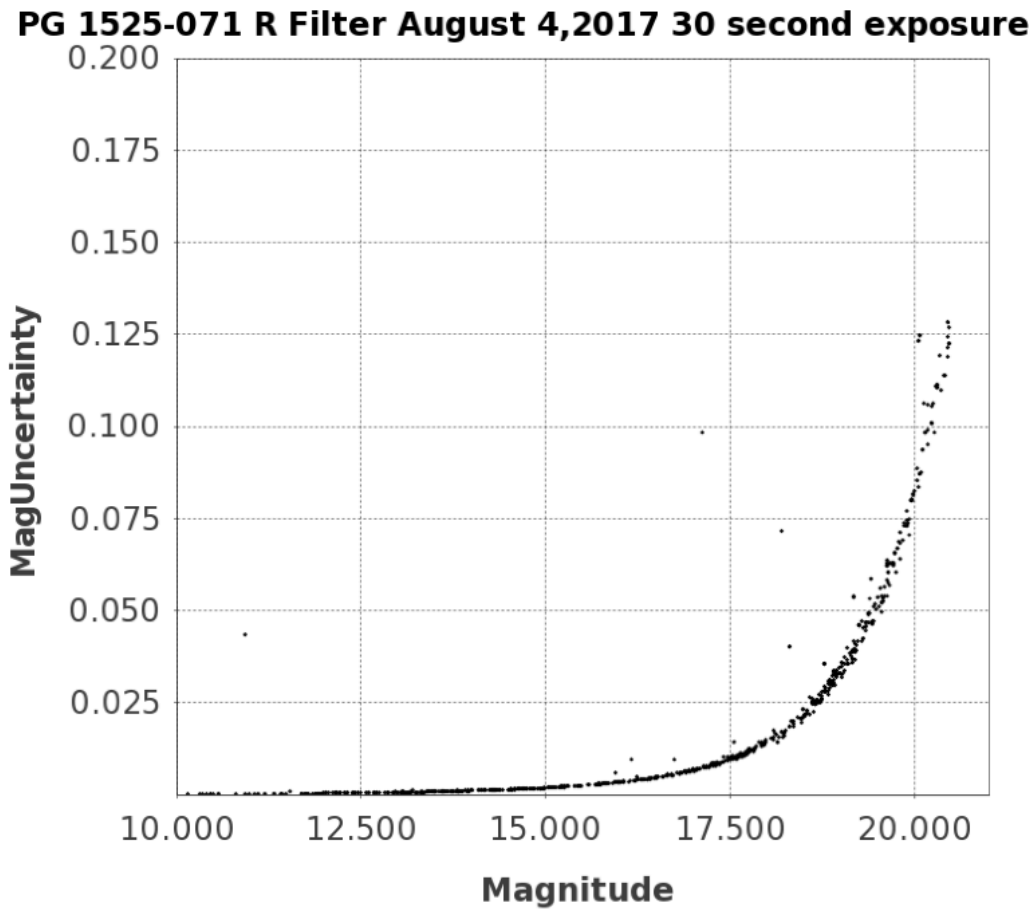
Aperture Photometry Tool - Determination of Zero Point Magnitude

R Band Filter

	Normalized by Exposure Time		*Not Normalized*			
	Zero Point	*Error*	*Zero Point*	*Error*	*Airmass*	
PG1323-086	25.185	0.022	28.878	0.022	2.618	
PG1525-071	25.305	0.016	28.997	0.016	1.593	
SA 107 599-602	25.422	0.052	27.922	0.525	1.465	
PG1633+099	25.425	0.023	28.678	0.023	1.188	***20 Second Exposure Time***
PG1633+099	25.521	0.024	28.021	0.024	1.188	***10 Second Exposure Time***
Mean	25.372					
Stdev	0.1294					

Extinction Coefficient	**-0.2007**
Zero Point at Airmass 1.00	**25.695**




PG 1525-071 R Filter August 4,2017 30 second exposure
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
MagUncertainty
10.000
12.500
15.000
17.500
20.000
Magnitude

I Band Zero-Point Magnitude

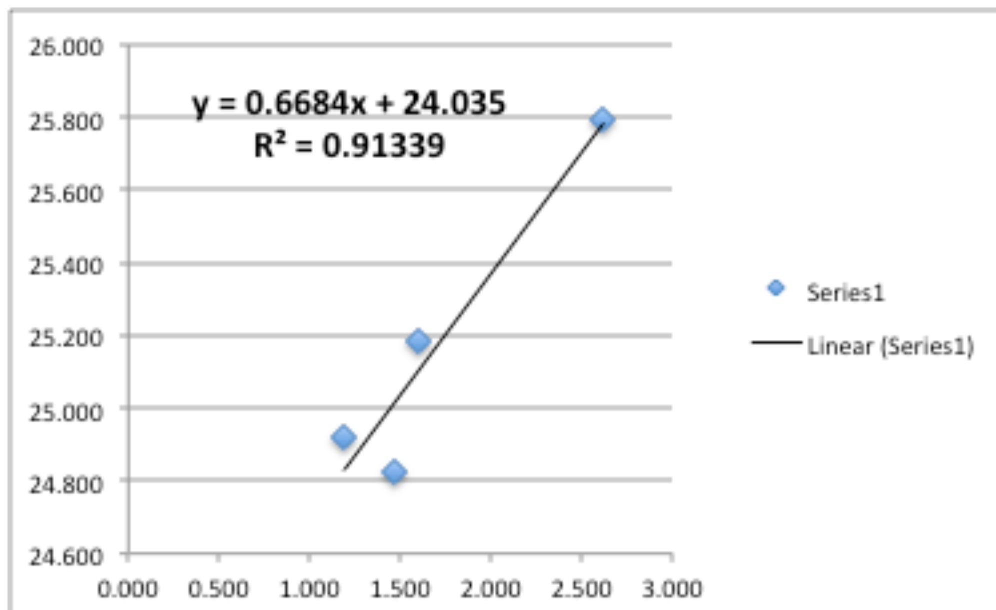
Normalized for 1 Second Exposure Time

Aperture Photometry Tool - Determination of Zero Point Magnitude

I Band Filter

	Normalized by Exposure Tin		*Not Normalized*		
	Zero Point	*Error*	*Zero Point*	*Error*	*Airmass*
PG1323-086	25.797	0.0439	28.297	0.044	2.618
PG1525-071	25.183	0.0467	28.860	0.047	1.593
SA 107 599-602	24.829	0.0464	27.329	0.046	1.465
PG1633+099	24.919	0.0526	27.419	0.052	1.188
Mean	25.182				
Stdev	0.4368				

Extinction Coefficient	**0.67**
Zero Point at Airmass 1.00	**24.703**



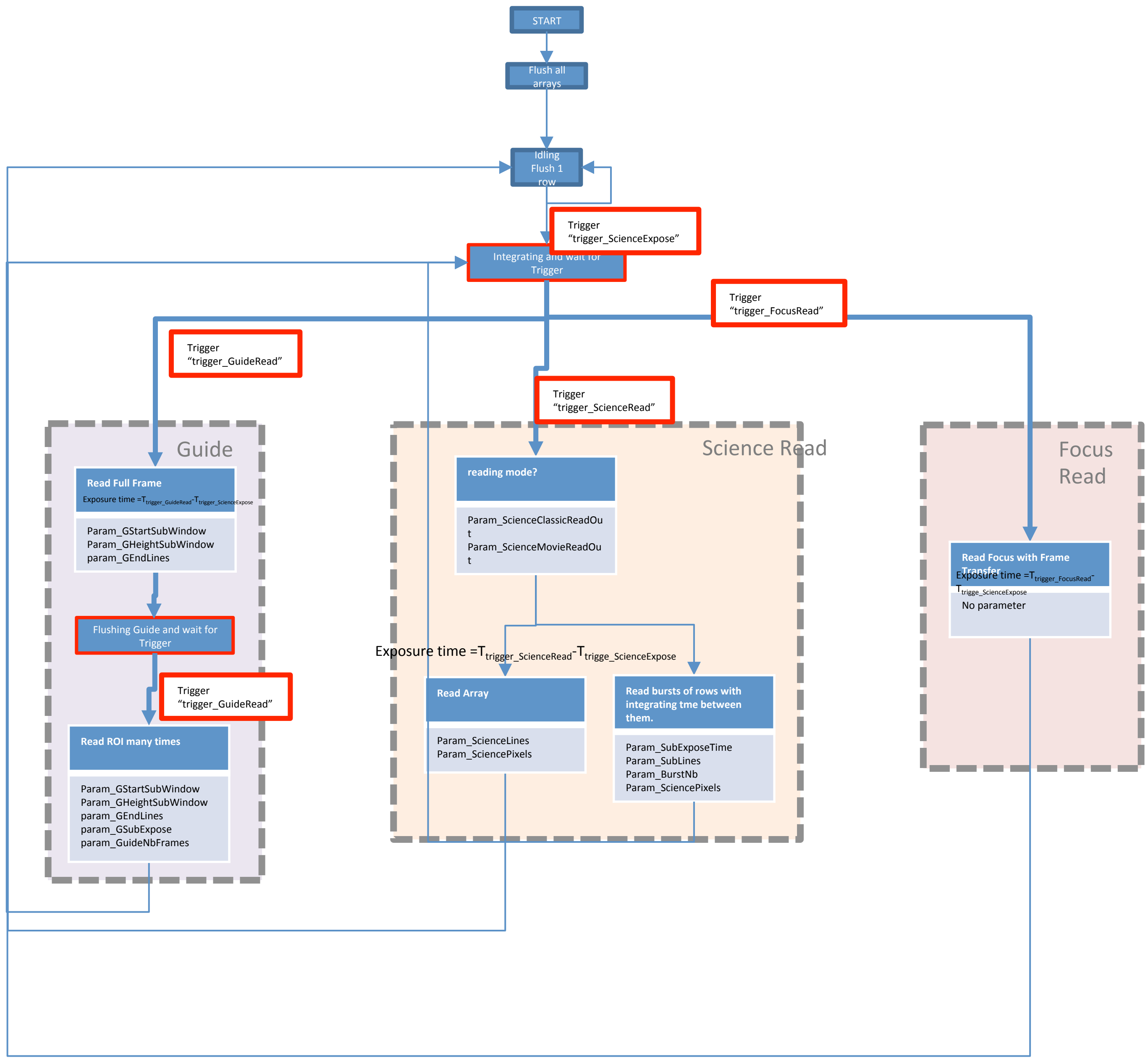
WHAT CAN GO WRONG?

What can go wrong?

- NEVER start 2 instances of the software at the same time.
  - Attempts to connect to the Archon controller when it is already connected to another process causes the controller to fault and requires power cycling to correct.
- Known Bug: If you guide while executing a dither pattern the guiding works correctly for the first and last image of the pattern but appears to not work for the intermediate frames.
- Remember to "Activate Shutter" and "Activate Filter-wheel" after homing the mechanisms. If you forget the shutter will not open when an exposure is taken and the filter-wheel will not move during script execution. (the default will be changed when the next version of the software is deployed.

Timothee Greffe, Caltech Optical Observatory Detector Engineer

APPENDIX A: ELECTRONICS STATE MACHINE AND TIMING


START
Flush all arrays
Idling Flush 1 row
Trigger "trigger_ScienceExpose"
Integrating and wait for Trigger
Trigger "trigger_FocusRead"
Trigger "trigger_GuideRead"
Trigger "trigger_ScienceRead"
Guide
Read Full Frame
Exposure time =T_trigger_GuideRead-T_trigger_ScienceExpose
Param_GStartSubWindow
Param_GHeightSubWindow
param_GEndLines
Flushing Guide and wait for Trigger
Trigger "trigger_GuideRead"
Read ROI many times
Param_GStartSubWindow
Param_GHeightSubWindow
param_GEndLines
param_GSubExpose
param_GuideNbFrames
Science Read
reading mode?
Param_ScienceClassicReadOut
Param_ScienceMovieReadOut
Exposure time =T_trigger_ScienceRead-T_trigge_ScienceExpose
Read Array
Param_ScienceLines
Param_SciencePixels
Read bursts of rows with integrating tme between them.
Param_SubExposeTime
Param_SubLines
Param_BurstNb
Param_SciencePixels
Focus Read
Read Focus with Frame Transfer
Exposure time =T_trigger_FocusRead-T_trigge_ScienceExpose
No parameter

List of external parameters

Triggers:

Name of Trigger	Comment
trigger_ScienceExpose	Trigger to start an exposure. No clocking is then sent to the sensor.
trigger_ScienceRead	Trigger to start a read of the Science detector
trigger_GuideRead	Trigger to start a read of the Guider detector
Trigger_FocusRead	Trigger to start a read of the Focus detector
Trigger_Abort	Trigger to stop current "waiting for trigger" state and goes back in idling mode.

Science detector parameters

Name of parameter	Comment
param_ScienceLines	Total number of lines per Tap.
param_SciencePixels	Total number of pixels per Tap
param_ScienceClassicReadOut	1 if Science Classic full frame ReadOut
param_ScienceMovieReadOut	1 if Movie ReadOut
param_ScienceSubLines	Number of lines in each burst
param_ScienceBurstNb	Number of Bursts. Has to be reset after each frame reading.
param_ScienceSubExposeTime	Exposure time between each burst

Science "Movie Mode" parameters

optional

Guide detector parameters

Name of parameter	Comment
param_GHeightSubWindow	Height of the selected sub-window
param_GStartSubWindow	First row of the sub-window
param_GEndLines	Remaining Lines to read to flush the array. = 1032-param_GStartSubWindow - param_GHeightSubWindow
param_GuideNbFrames	Number of frames to be read
param_GSubExpose	Exposure time between frames

Focus detector parameters

Name of parameter	Comment
param_FocusRead	Read the focus detector right after a read of Science detector

Parameters of the CDS digital processing unit must be updated before the start of a frame reading.

PIXELCOUNT to the total number of column per tap
LINECOUNT to the total number of lines per tap

Focus Chip
TAPLINE0=AD3L, 1,0
TAPLINE1=AD4L, 1,0
TAPLINE2=
TAPLINE3=

SHP1=330
SHP2=340
SHD1=700
SHD2=710

Guide Chip
TAPLINE0=AD1L, 1,0
TAPLINE1=AD2L, 1,0
TAPLINE2=
TAPLINE3=

SHP1=330
SHP2=340
SHD1=700
SHD2=710

Science Chip
TAPLINE0=AD5L, 1,0
TAPLINE1=AD6L, 1,0
TAPLINE2=AD7L, 1,0
TAPLINE3=AD8L, 1,0

SHP1=33
SHP2=43
SHD1=76
SHD2=86

Then APPLY using **02APPLYCDS**

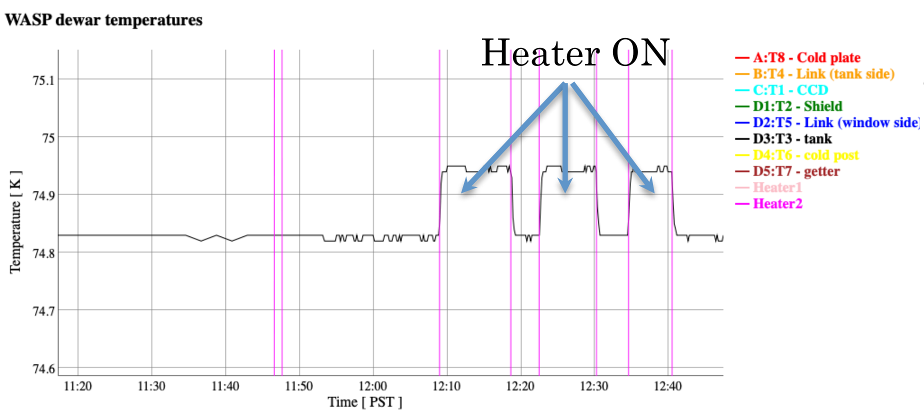
Requested Modifications

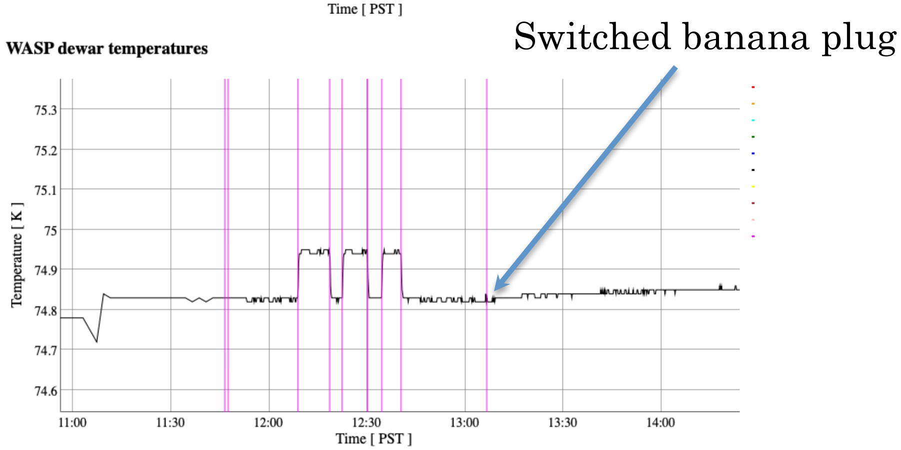
- **REQUESTED MODIFICATIONS TO THE WASP GUI**

- DONE Add an OBJECT keyword, and OBSERVER keywords with dialogs on the main panel
- DONE Add a number of repeats for the script
- DONE If possible add a number for exposures (i.e. set up so you can do N exposures)
- DONE add a PAUSE command in the Script Execution System
- DONE Check where and how the photometry records are saved to disk. May need to add an export command
- DONE Can you make separate tables and graphs for different filters for photometry?
- DONE The Sextractor control doesn't hide the control when closed but closes the program.
- DONE Create a new script location, set the location in the config file
- Make it impossible to move the shutter when the filter wheel is moving.
- Make it impossible to move the filter wheel when the shutter is moving
- Make it possible to display frames that are written to disk as multi-extension fits.

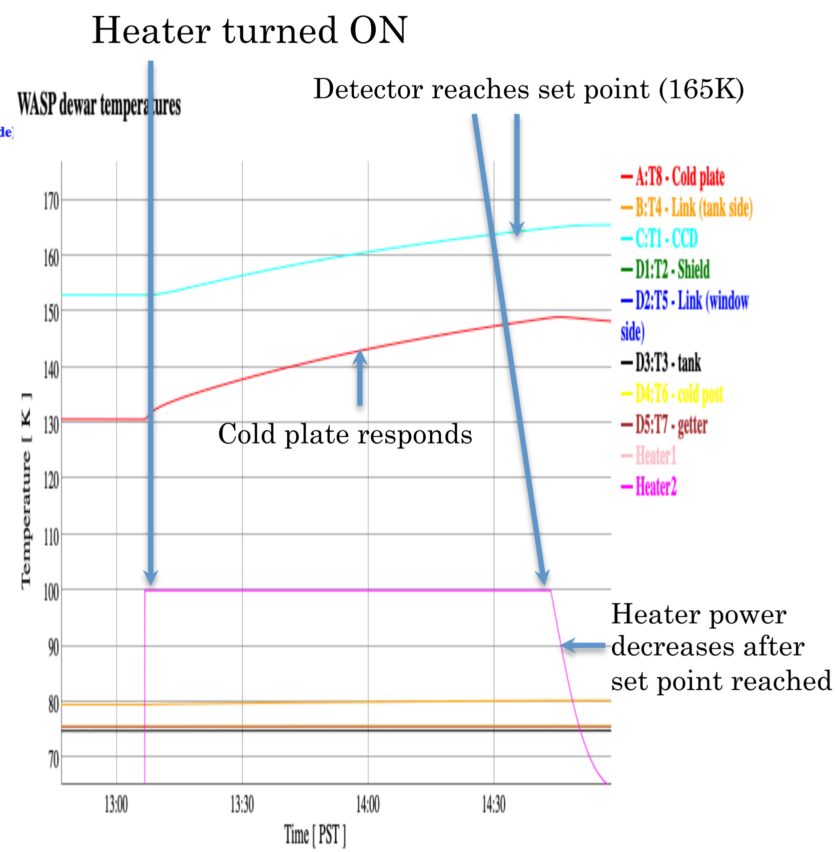
WASP Temperature Control Problem
Confirmation that the heater banana plugs were connected incorrectly.
December 13,2018

LN2 Tank response to Low Heater Power





New operating configuration:
after switching banana plugs



Experiment: Turn on heater in the original configuration and look at the LN2 tank temperature.
Does the temperature of the LN2 tank change? (YES) Does the cold-plate temperature change? (NO)
Switch the banana plugs and repeat the experiment. Does the cold-plate temperature change (YES)
Does the LN2 tank temperature change? (NO)