



**WASP (Wafer-Scale camera for Prime)  
Wide Field Prime Focus Camera for Palomar Observatory  
Instrument Manual  
JWM & AFB  
vFeb2018**

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# Introduction

**WASP** (Wafer-Scale camera for Prime) is a wide-field imaging camera equipped with an **E2V 231C 6144x6160** pixel science detector operated at LN2 temperature (~165K) with low noise (5 e) and dark current of (3 e/pixel/hour). The **WASP** camera offers an 18.4 x 18.5 arc minute field of view with a plate scale of 0.18 arc seconds per pixel. Unique features of the instrument include automatic guiding for long exposure (> 100 seconds) using an integrated 2064x2064 pixel **STA 3600A** delta-doped CCD operated as a frame-transfer device (imaging area 2064x1032 pixels) located on the instrument focal plane. The instrument also employs a dedicated focus detector (same sensor as the guider) that is offset from the focal plane by 1.485mm to facilitate focus determination using the “Donut” method (**A. Tokovinin and S. Heathcote 2006**). The **WASP** instrument also comes equipped with a very simple but versatile scripting language to allow automation of most calibration tasks and can be used to carry out complex observing scenarios such as multi-filter imaging of extended sources with ease. The instrument has been designed as a GUI driven, simple to operate, “point and shoot” camera with an exceptionally large field of view.

## Camera Parameters

The WASP camera contains an E2V 6144x6160 science detector and two delta-doped versions of the STA 3600A 2064x2064 CCD configured as frame transfer devices for guide and focus. The following table summarizes the detector characteristics.

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

**Unique Feature:**

19.2 arcminute squared, frame transfer enabled auto-guider

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

Simple scripting language to allow complete control of complex imaging sequences

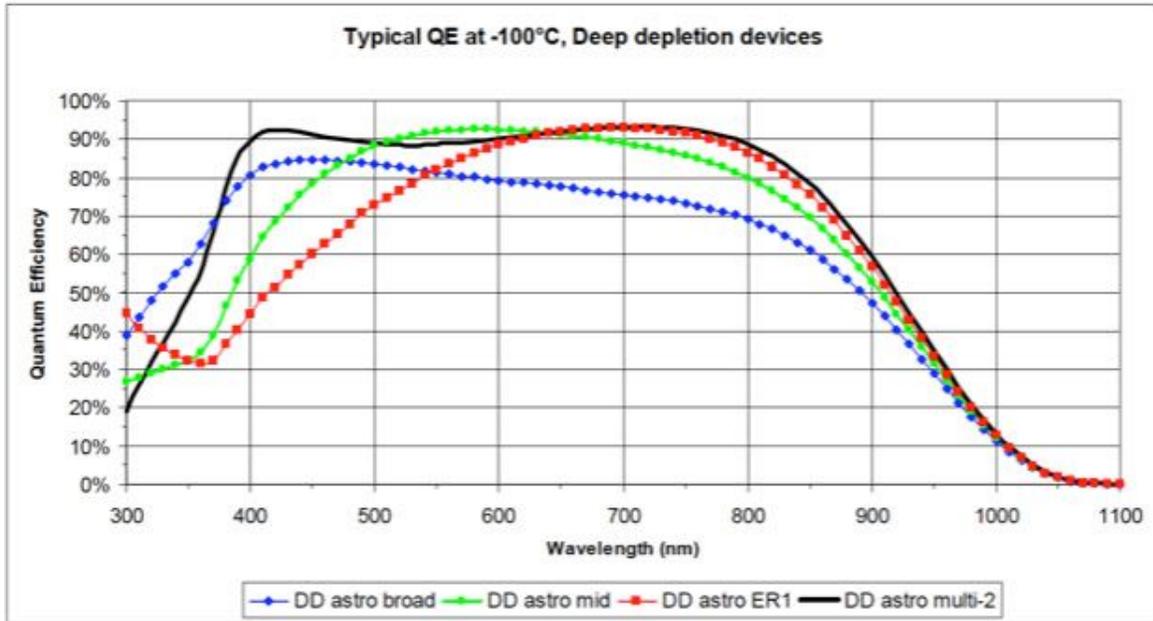


Figure 1: Quantum efficiency of the E2V CCD231-C6 deep depletion CCD

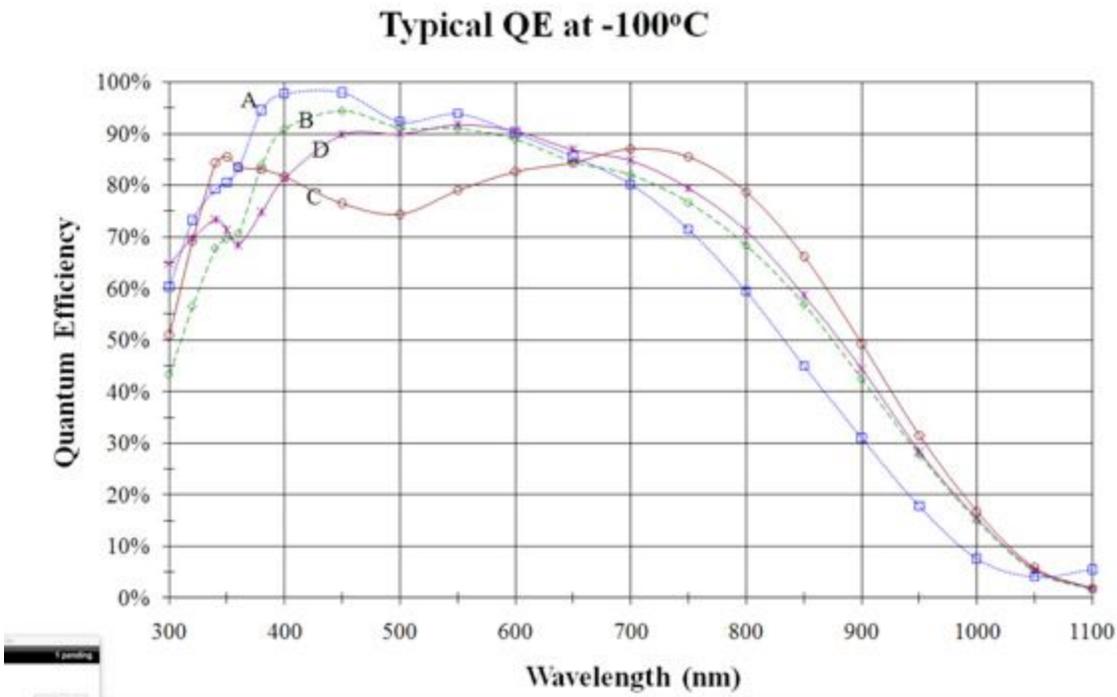


Figure 2: Quantum efficiency of the STA 3600A guide and focus CCDs

### Field Diagram and Chip Orientation

All WASP images are oriented with north (N) at the top and east (E) to the left. The guide and focus CCD's are situated east of the science detector with the guide CCD to the north of the focus detector. The science and guide/focus CCD pixels are the same size (15umx15um) and the plate scale is fixed at 0.18 arcseconds per pixel.

Science Detector Plate Scale = 0.18 arc-seconds/pixel

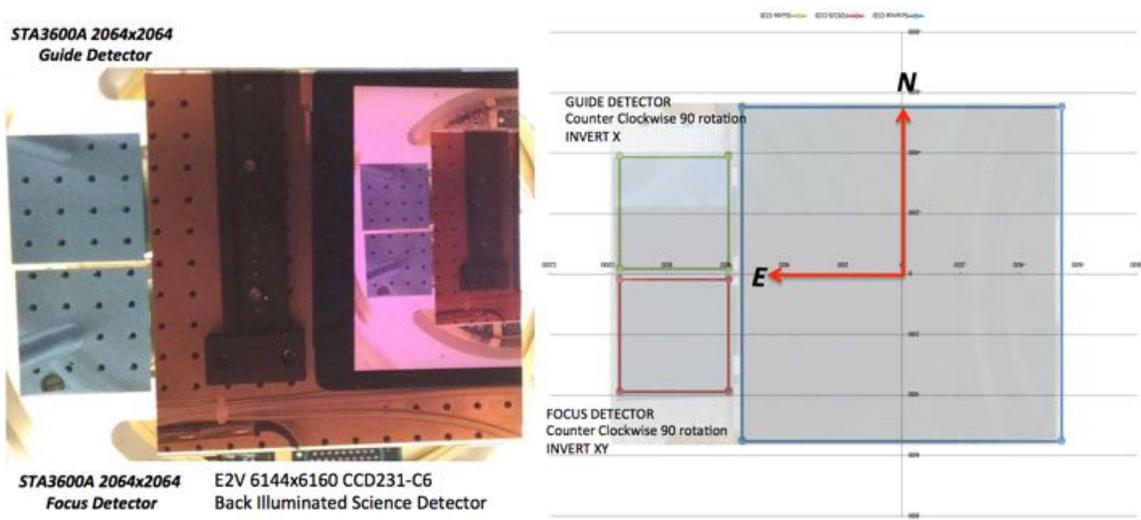


Figure 3: On-sky orientation of the science, guide and focus CCDs

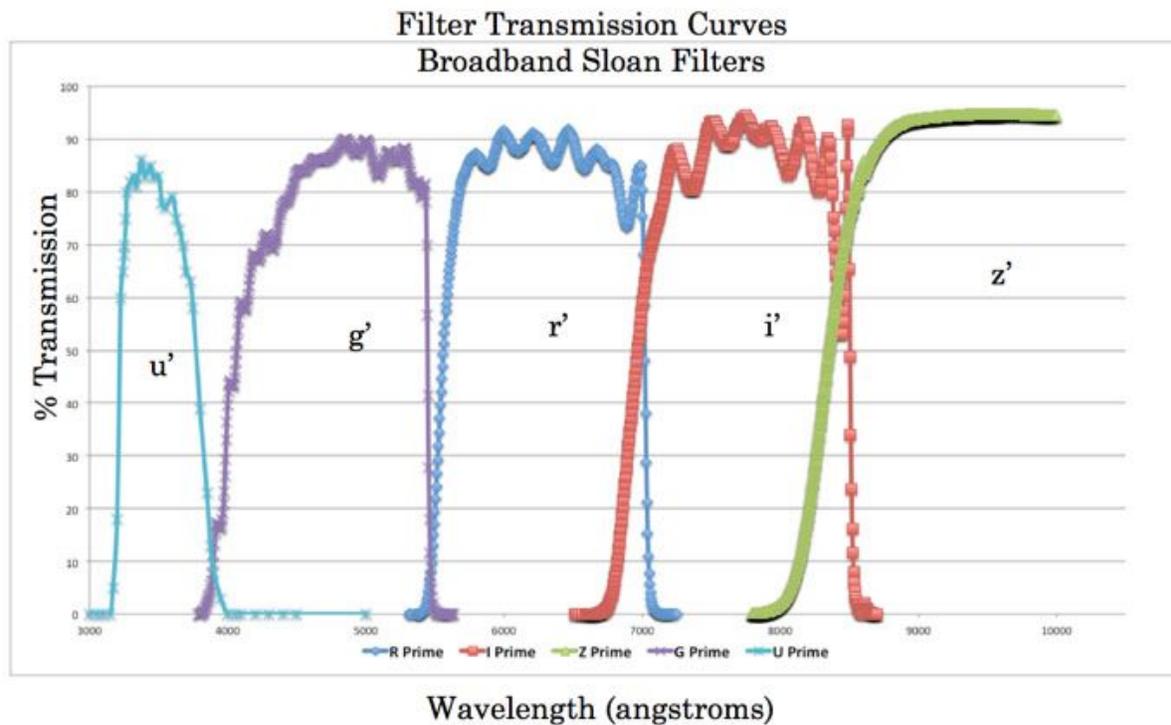
## Filter Specs

Filter wheel has slots for 4 filters.

Filter	Central $\lambda$ (Å)	Width (Å)	Thickne ss (mm)	Focus offset (mm from r')	Domeflats [b]	Dark sky [b] (raw chip 0)	Transmission
r'	6255	1470	3.05	-	5	1400	<a href="#">data</a> , <a href="#">plot</a>
i'	7680	1540	3.05	-	3	650	<a href="#">data</a> , <a href="#">plot</a>
z'	~9000	~1800 (w/qe)	3.05	-	5	750	<a href="#">data</a> , <a href="#">plot</a>
g'	4660	1400	8.02	+1.5	40		<a href="#">data</a> , <a href="#">plot</a>
u'	3540	590	8.38	+1.6	120 (highlamp)		<a href="#">data</a> , <a href="#">plot</a>
Rs	6930	1220	10.26	+2.0	8		<a href="#">data</a> , <a href="#">plot</a>
Is	8190	1670	10.26	+2.0	5		<a href="#">data</a> , <a href="#">plot</a>
B-bess	4400	1000	7.0	+1.3	2 (highlamp)		<a href="#">data</a> , <a href="#">plot</a>

V-bess	5500	900	7.0	+1.3	40	<a href="#">data</a> , <a href="#">plot</a>
R-bess	6300	1200	7.0	+1.3	10	<a href="#">data</a> , <a href="#">plot</a>
I-bess	9000	3000	7.0	+1.3		<a href="#">data</a> , <a href="#">plot</a>
Broad-RI	7670	2940	6.0			<a href="#">data</a> , <a href="#">plot</a>
H $\alpha$	6570	100	11.68	+2.8	120	<a href="#">plot</a>
S-II	6730	90	11.68	+2.8	120	<a href="#">plot</a>
6610/100	6610	100	7.06	+1.3	120	<a href="#">plot</a>
6650/100	6650	100	7.06	+1.3	120	<a href="#">plot</a>
6700/100	6700	100	6.93	+1.3	120	<a href="#">plot</a>
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)



**Figure 4: Transmission curves for Sloan broad-band filters**

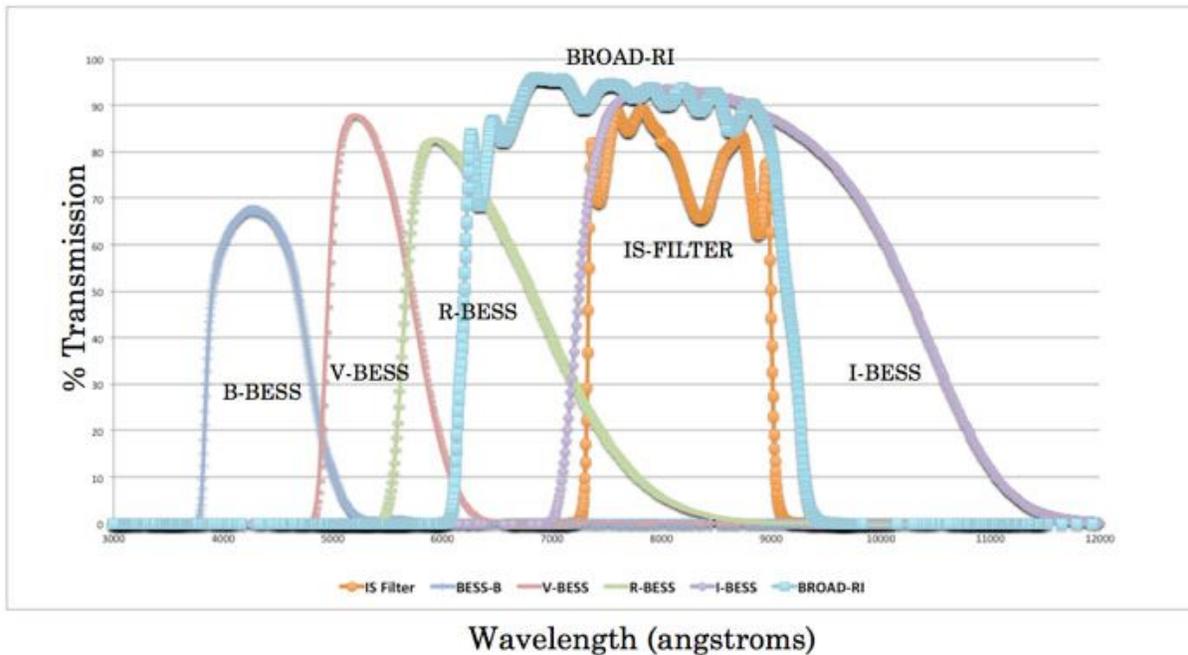


Figure 5: Transmission curves for Bessel filters and specialize variants

## Quick Start Guide

### Starting the WASP software

Open the following vnc desktop on the observer computer (*vncviewer 198.202.125.140:16* or *wasp.palomar.caltech.edu: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



Figure 6: WASP mechanism controls, homing and activating the mechanisms

## Basic Operations of WASP

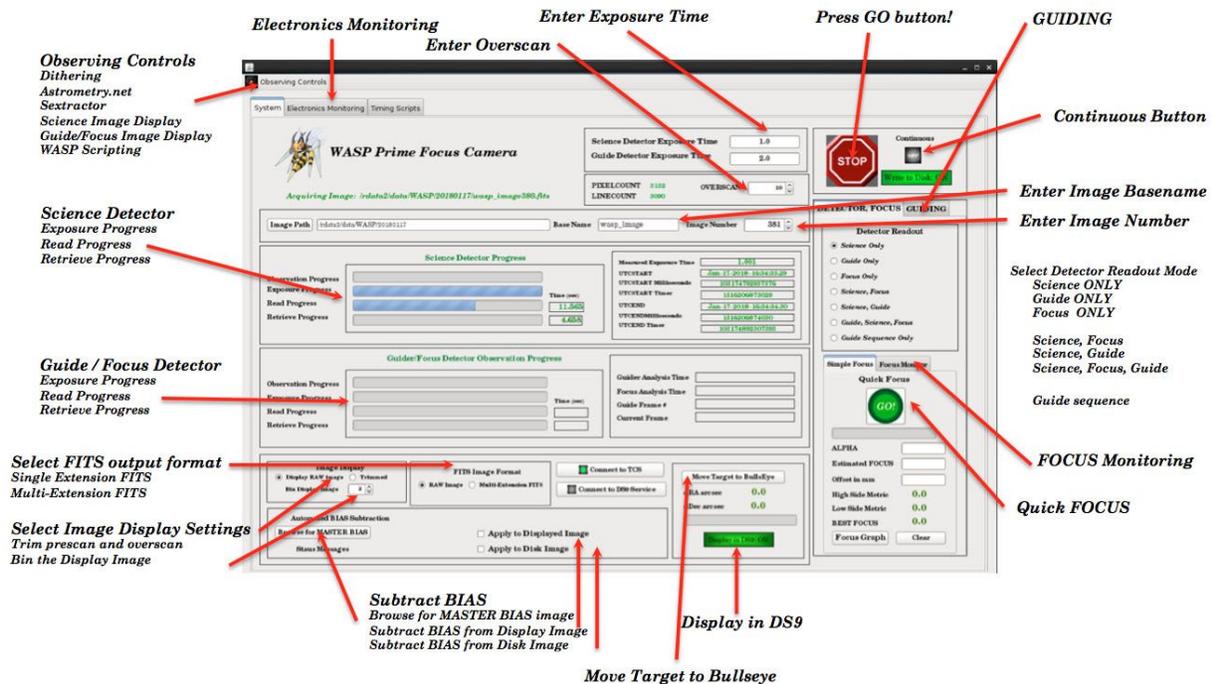


Figure 7: Basic operation of the WASP instrument

# Electronics Monitoring

*Power Monitor per Board*

**Electronics Monitoring**

Observing Controls

System | Electronics Monitoring | Timing Scripts

System

TIMESTAMP 15976533981478

Backplane	Rev	Verston	ID	Temp
BACKPLANE 212	C	1.0.879	002428887071B05C	22.44

Slot

Slot	Backplane	Rev	Verston	ID	Temp
1	empty		0.0.0	0000000000000000	
2	Driver	C	1.0.719	012EBA44F1DF39	27.44
3	Driver	C	1.0.719	0133480F20447133	28.69
4	Driver	C	1.0.719	01247E4F5E97E90	27.00
5	AD	E	1.0.668	0131990A83AE3556	21.60
6	AD	D	1.0.837	019C6AF719B190A	21.44
7	empty		0.0.0	0000000000000000	
8	HV Bias	C	1.0.830	0134BBE63AFFE7AA	27.19
9	Driver	B	1.0.379	0133F6A1F40A36A	27.86
10	Driver	C	1.0.719	0187BAAC13BFEEC7	27.39
11	LVDS		1.0.740	0139D44C4CCFE163	23.00
12	empty				

Archon IP Address:  Connect Clear Log

Power ON STATUS Power OFF ON

Active Shutter LFC Shutter Internal Shutter Active Filterwheel

Log Level INFO

Buffer	Frame	Width	Height	Pixels	Lines	Raw Blocks	Raw Lines	Timestamp	RE Timestamp	FE Time	Complete	Status
1	580	4800	6500	3171	3237	10	51	0	1002100040000	1002100040000		
2	579	4800	6500	3300	3350	10	51	0	1000607204744	10012037034701	1	W
3	579	4800	6500	3300	3350	10	51	0	10014100378004	10020100358009	1	

Execute Trigger Abort after exposure

Image Rotation no rotation Comaster Checkboxes Checkboxes

System Message Log

Archon Camera Controller constructed  
Successful connection to Archon Controller  
Successful connection to Archon Controller  
COMMAND = +23PULLOFF RESPONSE = +23  
COMMAND = +93CLEARCONFIG RESPONSE = +93  
Loading Timing File  
Finished Loading Timing File  
COMMAND = +18APPLYALL RESPONSE = +18  
COMMAND = +18APPLYSYSTEM RESPONSE =  
Checking ARCHON log due to delay: null  
COMMAND = +24PULLON RESPONSE = +24  
COMMAND = +11POWERON RESPONSE =

Parameters

PARAMETER-param, SciTab=113  
PARAMETER1-param, ScienceRead=1848  
PARAMETER2-trigger, ScienceRead=0  
PARAMETER3-param, SciTabExpos=1  
PARAMETER4-trigger, Abort=0  
PARAMETER5-param, GuideNoFrames=1  
PARAMETER6-param, SubExposureTime=500  
PARAMETER7-param, ScienceMessageRead=0  
PARAMETER8-trigger, ScienceRead=0

Logging level Frame Buffers Poll Controller

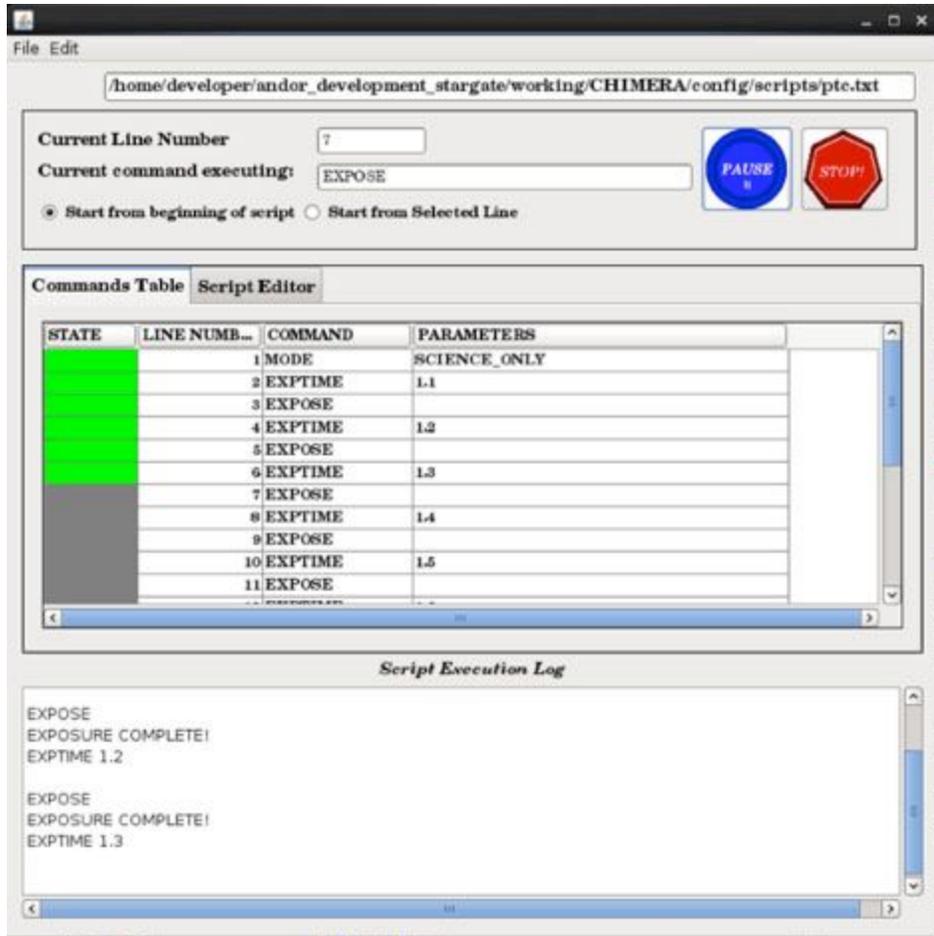
Figure 8: Basic operation of the WASP instrument, electronics monitoring

## 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.



**Figure 9: WASP script execution control. Automating the taking of FLAT calibration images**

- 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 J
- 
- **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.

## When you're 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"
- 

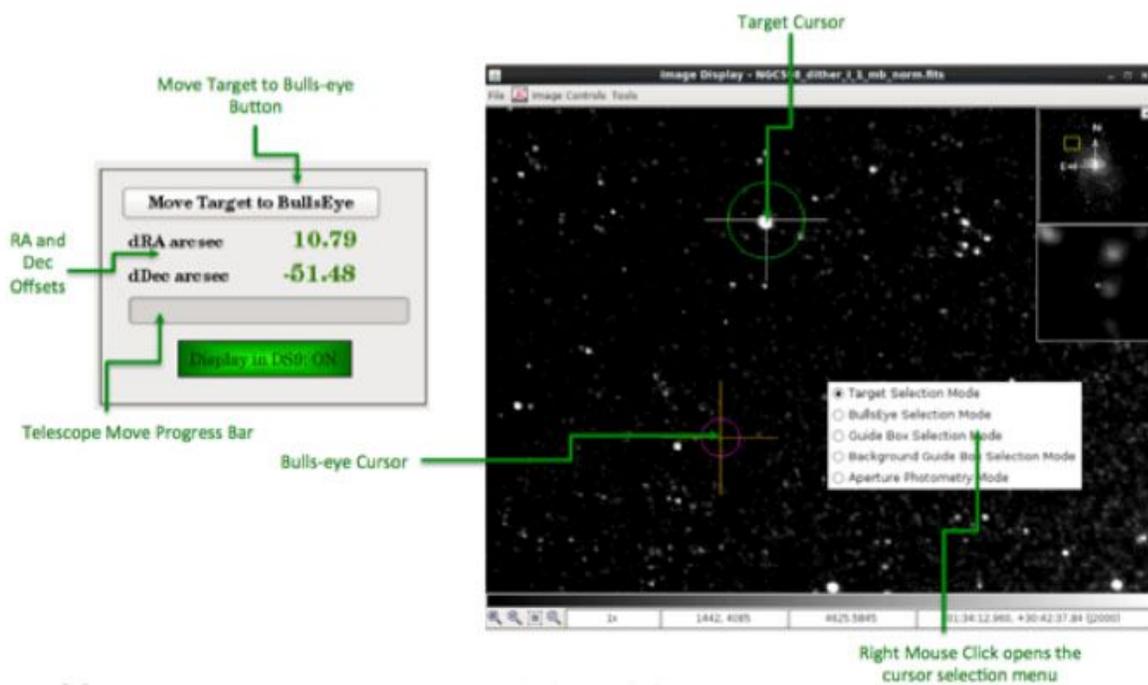


Figure 10: Using the "Target to Bullseye" control to position your target

Focus the telescope

### Developing the “Donut” method for focus determination

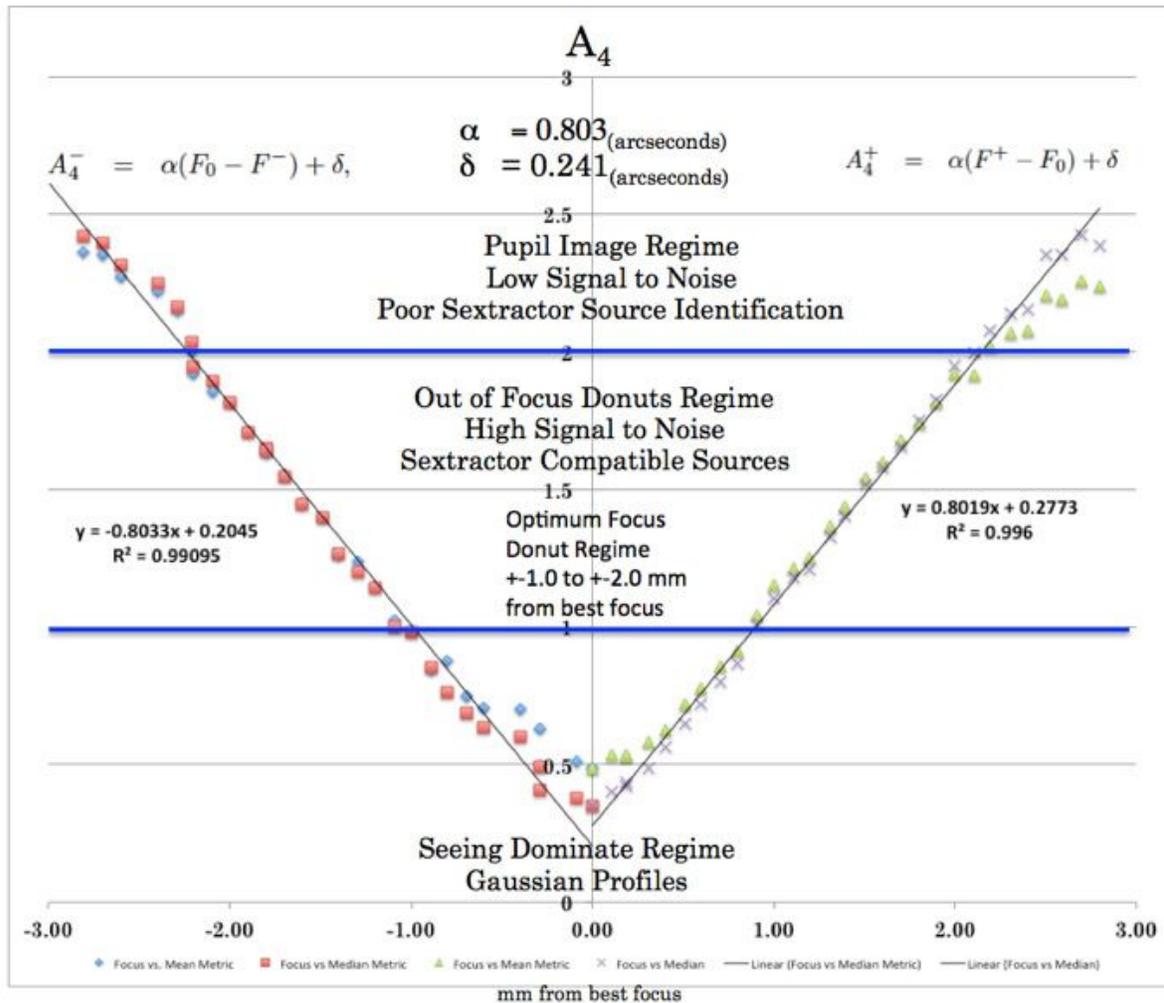


Figure 11: The “Donut” method of determining focus. Based on (A. Tokovinin and S. Heathcote 2006)

– 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.



**Figure 12: Analysis of a classical “focus run” but using the donut metric based on the 2nd moments of out of focus donuts**

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.

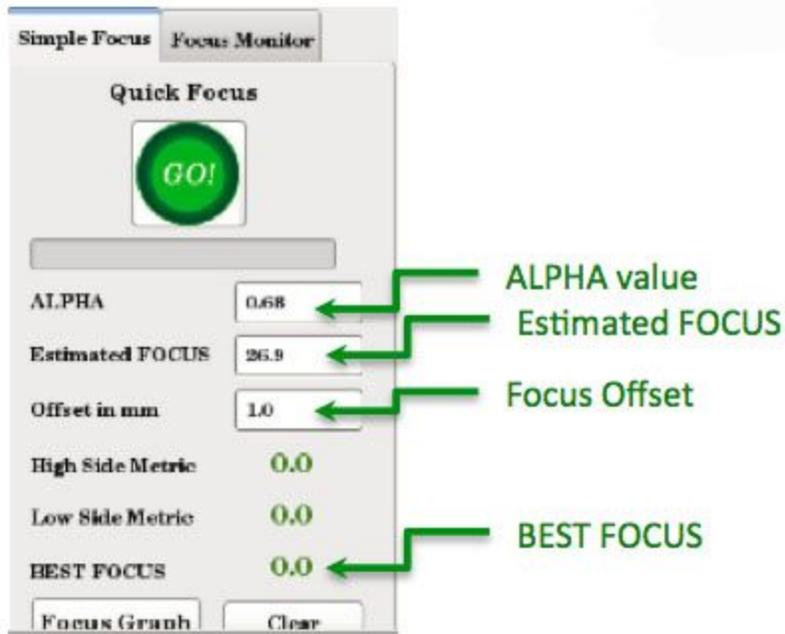


Figure 13: Using the “Quick Focus” tool

## 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