

# Cosmic Web Imager User's Guide

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# 1. INTRODUCTION

The Cosmic Web Imager (CWI) is a UV-visible integral field spectrograph for the Cassegrain focus of the Hale 200" telescope at the Palomar Observatory with a field of view of 60"x40". The instrument spatial resolution is seeing-limited ( $\sim 1''$ ) along the slices in the short direction and slit limited ( $\sim 2.5''$ ) in the long direction. The instrument is bolted to the Cassegrain rotator and the field of view can be rotated on the sky.

CWI has an anticipated wavelength coverage from 380 nm to 800 nm (limited by CCD fringing) with resolving power  $R \sim 5000$ . As of August 2014 CWI four gratings are available for use with CWI. There are three  $R \sim 5000$  volume-phase-holographic transmissive gratings. The **BLUE** Grating covers 460 to 550 nm, **YELLOW** from 555 to 690 nm, and **RED** from 640 to 770 nm. A sub-range of these is available at any single setting (approximately 45 nm for the blue, 50 nm for the YELLOW, and 55 nm for the RED in full CCD mode, and 1/3 of that in nod-and-shuffle). Additionally, there is an  $R \sim 2000$  surface-relief reflective grating that can access 380 to 600 nm, with instantaneous coverage of about 100 nm, 1/3 of which would be visible with the nod-and-shuffle mask in place. This **MEDREZ** grating is not yet well characterized; it is slightly smaller format and thus, likely, lower efficiency than the full VPH gratings. Key CWI parameters are listed in Table 1.

The nod-and-shuffle mask is retractable; the interchange requires a person familiar with the instrument and takes, roughly, 30 minutes.

The instrument is commanded through a `tc1` shell interface. This is used to set exposure times, initiate calibration exposures, configure the instrument, command the guider, start on-sky exposures, etc. For reasons that are beyond the scope of this document, much of the instrument configuration is not recorded in image headers but in separate ".info" files. These files are only generated when exposures are commanded through the CWI `tc1` interface.

A data reduction pipeline is being developed for the KCWI instrument that is applicable to the CWI data cubes. The pipeline can be obtained by contacting Don Neill ([neill@srl.caltech.edu](mailto:neill@srl.caltech.edu)).

Nota Bene:

- It is always good to have a flashlight handy whenever in cage and dome
- CWI is sensitive enough to pick up ambient light within the dome, especially during long exposures. For observations of very faint targets it is a good idea to check for any remaining light inside dome before opening the dome after adapting eyes to the dark.

**THE FOLLOWING IS IMPORTANT. ALL MOTOR STAGES SHOULD BE RETURNED TO THEIR ZERO POSITION BEFORE TURNING OFF THE MOTOR CONTROLLER. THIS IS DETAILED BELOW. FAILURE TO DO SO RESULTS IN A RE-ZEROING OF THE MOTOR/S IN A NON-ZERO LOCATION WHEN THE CONTROLLER IS POWERED ON AGAIN. THIS MEANS LOSS OF CALIBRATION.**

Table 1. CWI Parameters

Parameter	Value	Notes
Field-of-view	60 x 40"	
Field-of-view format	24 2.5" x 40" slits	
Spatial resolution	2.5" x Seeing (~1")	
Accessible spectral range (blue)	4600 Å to 5500 Å	G' filter, a bit further red with the r' filter installed.
Single setting spectral range (blue)	450 Å 120 Å	Full CCD Nod-and-Shuffle
Accessible spectral range (yellow)	5560 Å to 6900 Å	r' filter
Single setting spectral range (yellow)	500 Å 140 Å	Full CCD Nod-and-Shuffle
Accessible spectral range (red)	6460 Å to 6900 Å 6900 Å to 7700 Å	r' filter i' filter
Single setting spectral range (red)	570 Å 170 Å	Full CCD Nod-and-Shuffle
Spectral resolution	5000	$\lambda/\Delta\lambda$
Guider field-of-view	3' x 2'	Palomar autoguider
Guider sensitivity	V~17	Palomar autoguider
Read noise	< 3e	2.5 e (typical)
Detector gain	0.145	e/DN
Read-out-time	100 s	Single amplifier
Throughput (blue)	10%	Including sky+telescope
Throughput (yellow)	10%	Estimate, incl. sky+telescope
Throughput (red)	10%	Including sky+telescope

## 2.

### *2.1.1. COMMAND LINE VS. GUI*

The CWI instrument, including the detector, should be commanded from the CWI TCL shell. While it is possible to use the detector GUI to take images, that approach does not lead to all the data needed for the data reduction pipeline (DRP) being stored.

### *2.1.2. LATERAL IMAGE ALIGNMENT*

Whenever the detector dewar is serviced outside the instrument, or gratings are exchanged, the spectra might shift slightly in the spatial direction. A tilt of Fold Mirror 4 (FM4) will correct for resulting misalignment.

Appropriate FM4 settings for the blue and red gratings have been determined and can be set by invoking “CWI> RedSettings”, “CWI> BlueSettings”, “CWI> YellowSettings”, “CWI> RichSettings” from the CWI `tcl` prompt. It should be noted that this also adjusts the FM2 position (i.e., focus).

A rotation by +200 RP motor steps shifts the spectrum by ~64 unbinned CCD pixels to the right.

### *2.1.3. SPECTROGRAPH INTERNAL FOCUS*

The spectrograph must reimagine the image slicer onto the detector. This image must be in focus. The focus adjustment is done by translating one of the folding flats in the instrument, FM2, along the optical path. This alters the path length from the slicer to the collimator mirror, while keeping the collimator mirror to the camera lens distance fixed.

The best spectral focus positions have been determined for the blue, red, yellow, and Richardson (MedRez) gratings. The CWI `tcl` shell commands “CWI> RedSettings”, “CWI> BlueSettings”, “CWI> YellowSettings”, and “CWI> RichSettings” move FM2 to those values. It should be noted that these also command FM4 to a position that centers the spectra laterally on the detector.

The optical design has slight astigmatism, and the best spectral focus is at a different FM2 location than the best spatial focus. At the time of this writing (July 2012), the best instrument spectral focus has been found at RP encoder reading for FM2 of +140,000.

- A `tcl` procedure `fm2_focus.tcl` has been written to take a set of arc lamp images at various FM2 locations; this procedure should not be ran very often, in fact, it probably doesn't need to be ran at all anymore, unless something odd happens.

The procedure steps through possible FM2 positions in coarse steps and takes arc lamp images. These can then be inspected (manually, or automatically) to find the best focus location.

The data set consists of roughly 10 images, and the length of time required will depend on the read out mode. The slowest CWI read out mode will require about 30 minutes. The script generates an output log file `fm2_focus.dat`, which contains the image numbers and corresponding stage positions.

#### 2.1.4. GRATING AND CAMERA SETTINGS

The grating and camera positions must be set to select the desired wavelength range and to maximize the instrument efficiency. The encoder readings in this section are contingent on proper handling of the CWI motor controllers and stages, i.e., parking them between uses and ensuring that positions are properly recovered after any power outages.

When using a tabulated configuration, it is recommended that the setting be verified. When using an interpolated value, it is a good idea to both verify the setting and to ensure that the grating efficiency is peaked and no ghosts lie on important parts of the spectrum.

The articulation stage travel limits are +290,000 and -1,700,000. Note that the settings below should be verified every time a grating change is made. Some care should be taken when coming close to either limit.

A method for configuring new settings is described in detail in Section 7 on page 40.

##### 2.1.4.1. Blue Grating Configuration

Table 2 shows the preconfigured settings, while the equations that follow allow the user to compute grating and camera positions for other wavelengths of interest. The accessible wavelength range is limited by the minimum angle of incidence that the articulation stage can be commanded to on the blue side (4500 Å), and by the filter cut-off wavelength on the red side (5400 Å, 5600 Å without filter). The articulation stage travel limits are +250,000<sup>1</sup> and -1,700,000. Note that the settings below should be verified every time a grating change is made.

**Table 2. Blue Grating Configuration Settings**

Central Wavelength	Grating Setting	Camera Setting	Date Verified	Notes
4680 Å	8,000	180,000	12/05/2012	
4862 Å	4,600	-115,000	12/05/2012	
4935Å	2,450	-235,000	12/05/2012	
4984Å	600	-315,000	12/05/2012	
5005 Å	0	-350,000	?	
5207 Å	-6000	-700,000	?	
5527Å	-14500	-1,300,000	?	

<sup>1</sup> 140526 – The actual limit is +290,000, but that is very close to a hard stop. Best to avoid going that far, but can if necessary. Central wavelength for this value is ~4605Å

A simple quadratic was fit to the above points:

$$\begin{aligned} \text{GRATING} &= 1985.42 \lambda_{1000}^2 - 48421.28 \lambda_{1000} + 192442.81, \\ \text{CAMERA} &= -264292.78 \lambda_{1000}^2 + 963054.31 \lambda_{1000} + 1450808.62, \end{aligned}$$

where  $\lambda_{1000}$  is the wavelength, in angstroms, divided by 1000.

An IDL procedure, `cwi_settings.pro`, returns the grating and camera settings when it is given a list of central wavelengths. Note, as of 140526 the solutions above appear about +10Å off from the actual central wavelength. It is possible that in the past we were not as sensitive to misalignments of this scale and did not notice them.

#### 2.1.4.2. Red Grating Configuration

Table 3 shows the preconfigured settings, while the equations that follow allow the user to compute grating and camera positions for other wavelengths of interest. The accessible wavelength range is limited by the minimum angle of incidence that the articulation stage can be commanded to on the blue side (6400 Å), and by the filter cut-off wavelength on the red side (7000 Å, 7700 Å without a filter).

**Table 3. Red Grating Configuration Settings**

Central Wavelength	Grating Setting	Camera Setting	Date Checked	Note
6500 Å	8,000	+250,000	20/07/2012	
H $\alpha$ (6562Å)	5,500	180,000	11/05/2012	Centered on H $\alpha$
6640 Å	4,400	116,000	11/05/2012	Lines fit in N+S config, H $\alpha$ (6562Å), SII(6716Å), NII (6583 Å)
6740 Å	3,000	0	20/07/2012	
6895 Å	0	-180,000	20/07/2012	
7045 Å	-3,000	-350,000	20/07/2012	Filter cut-off around 7000 Å

A simple quadratic was fit to the above points:

$$\begin{aligned} \text{GRATING} &= 2842.68 \lambda_{1000}^2 - 57413.39 \lambda_{1000} + 260526.19, \\ \text{CAMERA} &= -21108.91 \lambda_{1000}^2 + 1754184.88 \lambda_{1000} - 2237841.50, \end{aligned}$$

where  $\lambda_{1000}$  is the wavelength, in angstroms, divided by 1000.

- An IDL procedure, `cwi_settings.pro`, returns the grating and camera settings when it is given a list of central wavelengths.

### 2.1.4.3. Yellow Grating Settings

As of August 2014, CWI is equipped with a “yellow” grating designed to work in the gap wavelengths between the blue and the green (5560 to ~6800 Å). As of late August 2014 the reddest part of the wavelength range (out to camera setting of -1,700,000) has not been explored. The full CCD will contain about 550Å, and 1/3 of that will be available in N+S.

**Table 4. Yellow Grating Configuration Settings**

Central Wavelength	Grating Setting	Camera Setting	Date Verified	Notes
5590 Å	6,200	250,000	23/08/2014	
5785 Å	2,000	0	23/08/2014	
5968 Å	-2,500	-250,000	23/08/2014	
6150 Å	-7,000	-500,000	23/08/2014	
6320 Å	-10,000	-750,000	23/08/2014	
6481 Å	-15,000	-1,000,000	23/08/2014	

### 2.1.4.4. MEDREZ Grating Settings

Note that this data is VERY PRELIMINARY. We don't have a good idea of the throughput here, though it seems OK, or if the grating angles are optimized. Here are some settings, non-the-less! In full-ccd mode, we can fit about 900Å at once, 1/3 of that in N+S mode. The central wavelength values for this grating are quite approximate.

Central Wavelength	Grating Setting	Camera Setting	Date Verified	Notes
4300 Å	-237,500	-1,710,600	25/08/2014	Serious efficiency loss below 3900 Å and no cont-lamp flux
4950 Å	-242,500	-1,710,600	25/08/2014	
5400 Å	-246,500	-1,710,600	25/08/2014	
5900 Å	-250,500	-1,710,600	25/08/2014	
6300 Å	-254,500	-1,710,600	25/08/2014	Dubious efficiency.

### 2.1.4.5. Wavelength Verification

Wavelength verification is currently performed manually. This is, obviously, not ideal.

- An IDL program has been written (`cwi_compare_arc`) which takes the image number of an arc exposure, the name of the grating, (`/red` or `/blue` or `/yellow` or `/medrez`), and whether nod-and-shuffle mask was in (`/ns`). This can be ran from **beach**, or your personal unix-like idl-enabled computer.
- e.g., `cwi_compare_arc, 7481, /ns, /red, /remote`
- A sample output of the procedure is shown in Figure 1.

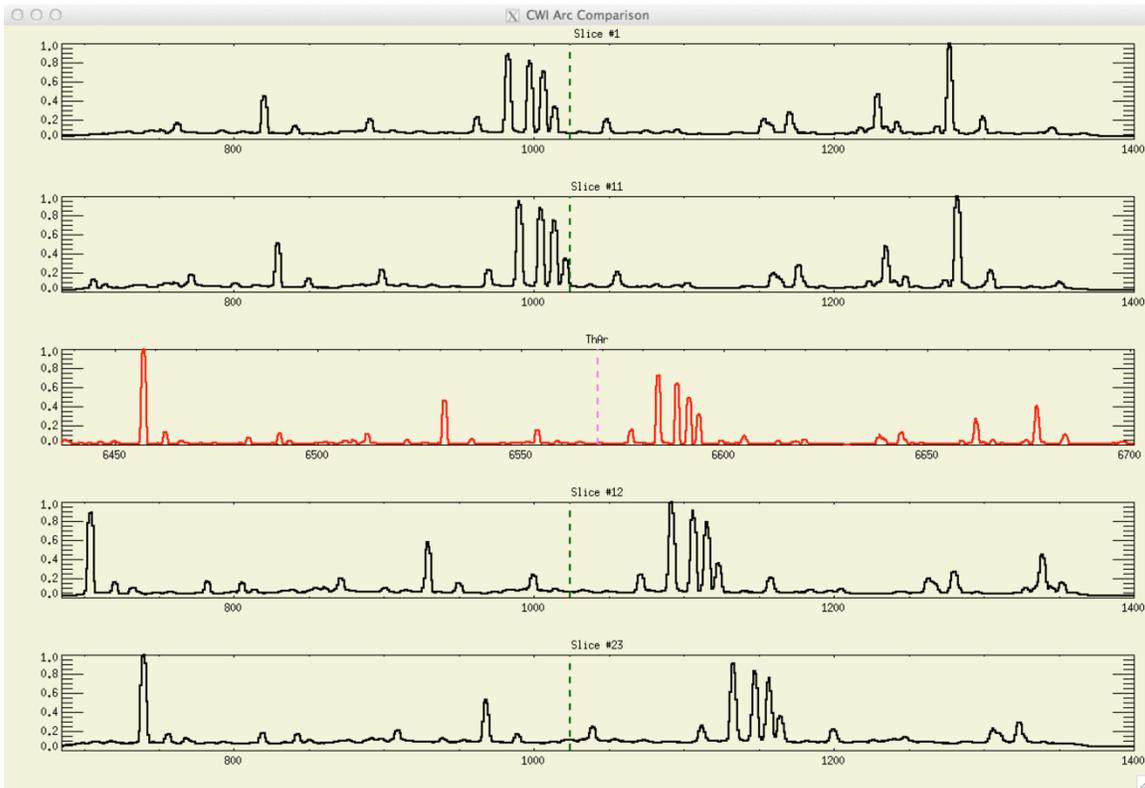


Figure 1. Output of cw\_i\_compare\_arc.

The top and bottom two panels show acquired spectra, while the central panel is a reference spectrum

#### 2.1.4.6. Grating Efficiency Peaking (Engineering Task)

While the camera articulation stage location determines (to first order) the central wavelength and wavelength range for the VPH gratings, the grating angle sweeps the efficiency curve across the bandwidth. Once the grating and camera values for a desired wavelength have been selected using data in sections above and the central wavelength has been verified as explained in section the grating ought to be peaked. This is done by taking 7 arc lamp exposures at grating position offsets of -3000,-2000, -1000, 0, +1000, +2000, +3000 from the estimated position.

It is important that the arc lamp has had time to warm up, at least 5 minutes, before the first exposure in the sequence is taken.

- IDL routine `peak_grating.pro`, which takes the path and set of image numbers as input, produces graphical output that allows the user to decide which image in the sequence peaks efficiency at the center of the band.

The determination is performed by looking at a spectral peak near the center of the spectral bandpass, recording how the peaks grow and diminish for slices 11 and 12 (starting at 1). Figure 2 shows the output of this program. The center of the CCD is shown with a yellow dashed line. The legend shows the relation between image numbers and curve colors. Arc exposure 5899 corresponds to the highest efficiency.

Note that the behavior is different for the surface relief grating **MEDREZ**.

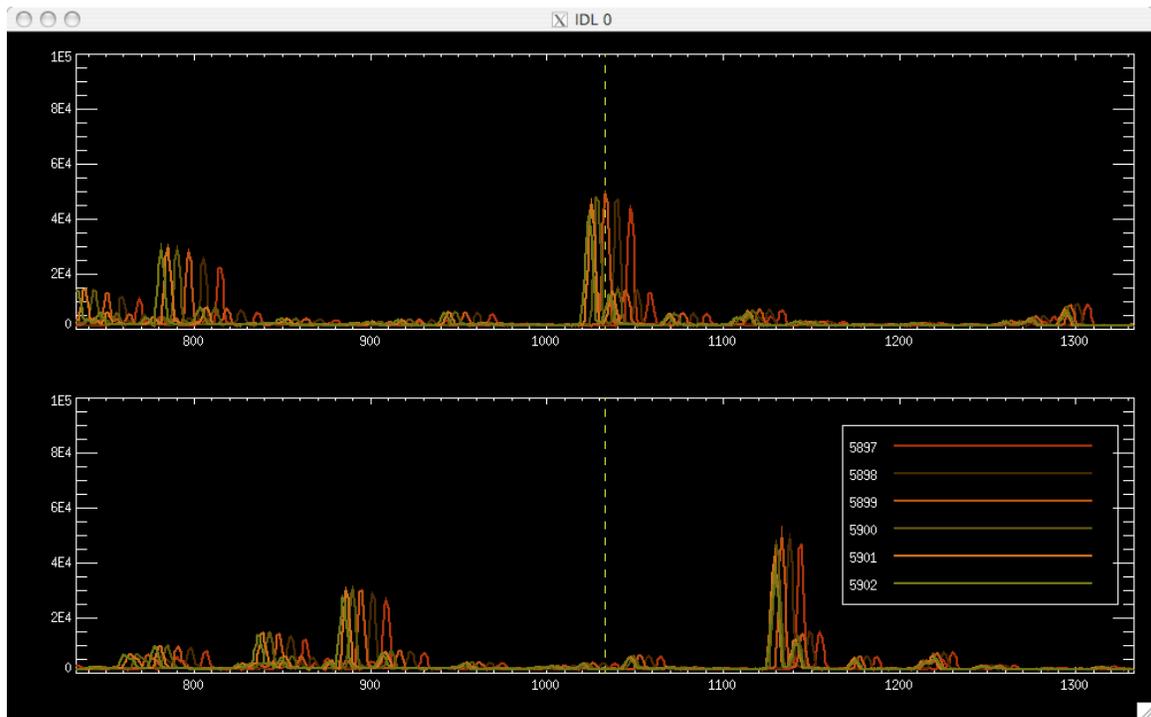


Figure 2. Output of IDL routine `peak_grating.pro`

#### 2.1.4.7. Ghost Location

[CHECK THE 8Å NUMBER]

Grating Littrow ghosts may fall on a critically important part of the spectrum. Slight grating rotations, up to 800 RP counts or so, will move the ghosts without sacrificing instrument efficiency. A change in grating position of +200 counts moves the ghosts  $-8\text{\AA}$  (60 unbinned pixels) at the  $4935\text{\AA}$  setting; thus a move of  $Z\text{\AA}$  in waveband centered on  $\lambda$  requires a grating rotation of:

$$\text{ROT} = -200 Z / (8\text{\AA}) * (\lambda / 4935\text{\AA}) \text{ (RP counts)}$$

## 2.2. OBSERVING

### 2.2.1. OBSERVING LOG

#### 2.2.1.1. What to Record and How

As much information as possible should find its way into the nightly log. The primary nightly text log is contained in an Excel spreadsheet and should be as detailed as possible. Information such as instrument set-up, observers, entry into dome, absolutely anything that tells a future data reduction analyst may find useful information should be recorded here. You can use your own log format, if you prefer, but keep in mind the data elements we like to record for the instrument.

A log template is available on porgy and beach.

At the end of each night, prior to data transfer, the log must be placed in the night's data directory in three formats: xlsx, csv, txt.

Motor position information is generated automatically by the CWI scripts and is kept in the following file:

`/home/cwi/oldporgy/palomar_guider/log.txt`

#### 2.2.1.2. Log Example

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Time	Notes	Number	Type	Exposure	Set Target	RA	Dec	Mag Target	Mag Pointing	Script	CCD Temp	CCD CP Temp	CCD Pressure	RP (Steps)	TF (Encoder)	
2		created today's directory and started log															
3																	
4	9:30	John the red grating is in, the red and shuffle mask is out.	7402	bin	0							-100.4	-195.8		0, 0, 0, 0, 0, 0, 0	8, 0, 0, 0, 0, 0, 1, 0	
5																	
6																	
7	9:25	beats.	7403	bin	0												
8			7404	bin	0												
9			7405	bin	0												
10			7406	bin	0												
11			7407	bin	0												
12			7408	bin	0												
13			7409	bin	0												
14			7410	bin	0												
15			7411	bin	0												
16			7412	bin	0												
17	9:36	Callister	7413	arc/flat	25							99.83	-195.05		0, 0, 0, 0, 0, 0, 160000, 0	8, 0, 0, 0, 0, 0, 5, 64000, 0	
18			7414	arc/lines	10												
19			7415	comp/lines	10												
20			7416	comp/flat	10												
21	9:25	RedSettings (best internal focus = f44 pos)															
22	9:35	Started the fit															
23	9:40	Finished the fit - liquid dripping from vent hole										99.7	-188.5				
24		will have stuff after dinner										99.8	-196.17				
25	7:40	back from a delicious dinner. Chris, Patrick, and Heather definitely missed out.															
26	8:30	Topping off the dewar															
27	8:30	dewar is refusing to fill - no liquid. The tank will have to be replaced.															
28	8:40	moving stages to art_half															
29		John looks good	7417	bin	0												
30	8:49		7418	star	3	SAO_065192	16 50 33.05	33 47 47.7				-101.7	-196.5	260000, 160000, 0, 550, 4400, 116000, 110000, 0	103995, 63996, 0, 215, 1750, 46393, 43998, 0		
31	8:54	slightly l	7419	comp/flat	10							-101.859	-196.546	260000, 160000, 0, 550, 4400, 116000, 110000, 0	103995, 63996, 0, 215, 1750, 46393, 43998, 0		
32	9:00	moved 2 arcs W to 7420, v red	7420	comp/flat	10												
33	9:08	continued on this star	7421	star	3												
34	9:11	adjusting seeing coordinates due to type	7422	object	300	MS12H	13 29 00.00	47 12 48.5									
35	9:20	adjusting seeing coordinates due to type	7423	object	300	MS12H	13 29 00.00	47 12 48.5				-102.232	-196.693				
36			7424	object	300	MS12J	13 29 58.60	47 12 48.9									
37	9:33	nice set, much h-alpha and sulfur, Dan's seeing is great	7425	object	300	MS12J	13 29 58.36	47 12 40.0									
38	9:42		7426	object	300	MS12K	13 29 58.16	47 13 35.0									
39	9:47		7427	object	300	MS12L	13 29 58.16	47 34 29.6									
40	10:01		7428	object	300	MS12M	13 29 49.73	47 33 34.6									
41	10:09		7429	object	300	MS12N	13 29 49.73	47 32 39.9									
42	10:07		7430	object	300	MS12O	13 29 49.73	47 31 44.4									
43	10:14	check ra and to and temps										-102.272	-196.655	260000, 160000, 0, 550, 4400, 116000, 110000, 0	103996, 63996, 0, 215, 1750, 46393, 43998, 0		
44	10:15		7431	object	300	MS12P	13 29 46.33	47 11 44.4									
45	10:22		7432	object	300	MS12Q	13 29 46.33	47 12 39.5									
46	10:32		7433	object	300	MS12R	13 29 46.33	47 13 34.5									
47	10:36		7434	object	300	MS12S	13 29 42.88	47 13 34.5									
48	10:37	calibration sequence using "Callister" "arc looks beautiful" - Matt - "if only the arc's were dirtier..."	7435	arc/flat	25							-102.128	-196.644	0, 160000, 0, 550, 4400, 116000, 165000, 0	12, 63996, 0, 215, 1750, 46393, 63996, 0		
49			7436	arc/lines	10												
50			7437	comp/lines	10												
51	10:46	calibration image slightly out of focus to Grating and camera configuration: set: apply240 - 02	7438	comp/flat	10												
52	10:46	calibration image slightly out of focus to Grating and camera configuration: set: apply240 - 02	7439	object	30	BD +26 2606											
53																	
54	10:58	1 arc exposure at Dan's request	7440	arc/flat	25												
55	11:00	done with arc off - if source visible during	7441	arc/flat	25												

Figure 3. Example Log Screenshot

Figure 3 is a screen capture of the new CWI log in Excel format. The columns are briefly described here:

A. *Time*. The wall clock time the entry is made

B. *Notes*. Self-explanatory. Key entries (grating/filter changes, etc.) to be made in **RED**

C. *Number*. The image number.

D. *Type*. The type of image being acquired. Possible types:

- Bias
- Arc/flat
- Arc/bars
- Cont/flat
- Cont/bars
- Star (Standard?)
- Object
- Background
- NS image
- Dome flat
- Dark
- Test
- Other (users may enter any ascii string)

E. *Exposure*. Exposure time in seconds

F. *Sci Target*. Name of the target being observed

G. & H. *Sci Pointing*. The (RA, Dec) of the target

I. *Bkg Target*. Name of the background target being observed

J. & K. *Bkg Pointing*. The (RA, Dec) of the background field

L. *Script*. The name of the script ran to take exposures

M. & N. *Temperatures*. The CCD and Cold plate temperatures. The values can be obtained by executing "CWI> getTemps" from the CWI TCL command prompt.

O. *Pressure*. The pressure registered at the Pirani gauge. This can only be recorded when the Pirani gauge is plugged in. This happens typically before the run or, sometimes, in the afternoon.

P. & Q. *Stage information*. The positions of the CWI stages. This information can be issuing "CWI> rp" and "CWI> tp" commands at the CWI TCL prompt

## 2.2.2. PREPARING FOR OBSERVATIONS

### 2.2.2.1. General Approach

Preparing for astronomy with CWI requires a number of set-up, calibration and alignment steps. The following is an outline of these steps and actions grouped roughly in chronological order

### 2.2.2.2. Target and Instrument Settings List

It is the Observer's responsibility to have a list of targets (including coordinates) and instrument settings ready. The latter should be discussed with the CWI team or observatory staff prior to the observing date.

#### 2.2.2.2.1. Standard Observations

For standard observations only the field coordinates are necessary (target or background). The observer should have an idea of the exposure times required. Often an initial 60 s exposure is useful for deciding on exposure time.

#### 2.2.2.2.2. Nod and Shuffle Observations

For nod and shuffle pointings, the observer must prepare the following information:

- target field coordinates
- background field offset in ARC SECONDS from the target field. The throw should not exceed 10 arc minutes
- Total exposure time on the target field in seconds
- Number of sub-exposures to divide the main observation into. The subexposures ought to be 120s or longer; shorter exposures are allowed, though they lead to less efficient observing

### 2.2.2.3. Calibration Strategies

The following calibration sets should be obtained, starting with the least frequent:

#### 2.2.2.3.1. Photon transfer data (once per run)

The photon transfer data is invoked by command:

```
CWI> photon_transfer exposure_time (NOT YET IMPLEMENTED)
```

Where exposure\_time is the exposure time (in seconds) needed for a continuum flat to nearly saturate the ADC (peak around 50kcounts). It is better if the dome is dark, but normal morning/afternoon situation is OK provided the illumination conditions do not change significantly and the Cass cage lights are off.

#### 2.2.2.3.2. Biases (each afternoon, morning, and a few throughout the night)

Collect 10 in the afternoon, as many as you are willing to sit through in the morning.

These are obtained by commanding:

```
CWI> bias N
```

Where N is the number to take

2.2.2.3.3. *Long calibration sequences (for each instrument setting, each afternoon)*

This collects an arc flat, arc bars, cont bars, and 9 cont flats, strategically offset from one another. The whole set takes about 30 minutes. The user should first establish the correct exposure time for the arc and for the continuum flat image. Neither should be saturated (Except for the occasional cosmic ray). Ideal peak is 45 to 50 kcounts. The dome needs to be dark and the instrument should be buttoned up.

The script is invoked via:

```
CWI> dayCalib
```

The exposure times are set automatically, provided the setting was configured using the new (Sep 2014) `cwiset` command.

There is also a:

```
CWI> dayCalibShort
```

which takes fewer continuum flats. Exposure times are set automatically, provided the setting was configured the new (Sep 2014) `cwiset` command.

2.2.2.3.4. *Dome flats (for each instrument setting, each afternoon)*

3 to 5 of these should be collected for each afternoon/evening/following morning for every relevant spectrograph configuration. The dome should be dark (with the exception of the high-lamp). The instrument should be buttoned-up and in astronomy mode. The exposure time should be such that the signal from the dome lamp peaks at 45-50kcounts. Dome flats can be collected in two ways:

```
CWI> exptime exposure_time
```

```
CWI> nexpose number
```

where the `exposure_time` is in seconds and the number of dome flats to be taken

Or:

```
CWI> domeflat number
```

where the exposure time is set automatically, provided the setting was configured using the new (Sep 2014) `cwiset` command.

2.2.2.3.5. *Short calibration sequences (for each instrument setting, during the night, as needed)*

There is flexure in the system and it is important to take at least one calibration set with the data during the night. How often these are needed for a single setting depends on the data being acquired. Long exposures, where sky lines are well defined, are more easily correctable for flexure effects. Brighter objects, where the sky lines are generally very faint, could possibly benefit from more frequent calibration sets. The short calibration consist of one arc flat and one cont bars. The sequence takes about 6 minutes and is invoked via:

```
CWI> Calib
```

where the exposure time is set automatically, provided the setting was configured using the new (Sep 2014) `cwiset` command.

#### 2.2.2.3.6. Spectrophotometric standards

The observer should take spectrophotometric standards as with any other spectroscopic observation. The more signal, the better, obviously. It is probably better to dither a slice or two between exposures to have the star sample different parts of the IFU.

#### 2.2.2.3.7. Detector darks (Optional each afternoon)

Detector darks are generally not used in N+S, but might be needed for standard observations where the sky is scaled. Usual techniques apply.

### Guider Calibration

*This is a task performed by the Night Assistant.*

As CWI is not fitted with a permanent guider, the configuration changes slightly every time the guider is installed. On the Palomar autoguider screen set trial move rate to 3 seconds. Set trial move distance at 45 arc seconds (field is 2 x 3 arc minutes).

Guider must be calibrated every time the Cass ring angle is changed.

#### 2.2.2.4. Centering Telescope on CWI IFU and Guider-IFU Offset.

*This is a task performed by the observer with the Night Assistant (NA).*

This procedure should be performed at the start of each night on an overhead star and near targets that are far from zenith. It serves a dual purpose, first of all it configures the telescope pointing such that the target is at the center of the IFU, secondly it refines the offset between the center of the CWI IFU and the Guider.

1. Ask the NA to select a 7 to 9<sup>th</sup> magnitude SAO star near the target and begin the move.
2. Once the move is complete, ask the NA to transfer the star to the guider. The NA may have the needed offset, although for non-standard Cass ring angles we will need to provide it. This is done by running the IDL procedure `CWI_GUIDER_OFFSET` in a **beach** IDL terminal (see Section 8.4)
3. While the NA is moving the star to the guider, issue, in the **porgy** TCL window:
 

```
CWI> startguider (if necessary)
CWI> centerBox
CWI> contbars <exptime>
```

 where <exptime> is the exposure time for continuum flat. Make a note of the image number (we will call it BARNO here)
4. Ask the NA to steer the star into the box (if necessary) and turn on guiding in GUIDE mode (NOT DRIFT).
5. Once the star is at the center of the box, ask the NA to:
  - a. turn off the guiding
  - b. "Z" the offsets
  - c. send reverse offsets (to step 2) to put the star on the IFU.  
Note that we do **not** want to simply issue "return".

6. When the reverse motion is complete, take a short exposure on the star:  
 CWI> exptime <exptime>  
 CWI> expose  
 Where the exposure time is typically 3-10 seconds, depending on the magnitude of the star. Make a note of the exposure (we will call it STARNOA here)
7. Inspect the image after read-out. If the star is not visible on the IFU, we have a problem:
  - a. first make sure the offset issues were in the correct direction
  - b. if they were, ask the operator to repoint to another nearby star and repeat
  - c. if that fails, call for help
8. If the star is on the IFU (most of the time!), run in the *beach* terminal IDL window:  
 IDL> cwi\_center\_star, /remote, barno=BARNO, starno=STARNOA  
 (see Section 8.2)  
 This will produce graphical and text output telling you how much the telescope needs to be nudged to center the star at the IFU, as well as a coarse measurement of the stellar FWHM. Ask the NA to make the nudge. Take another stellar exposure, make note of the image number, STARNOB. Rerun IDL> cwi\_center\_star with this number to confirm the correction. Repeat if necessary.
9. If the offset is acceptable (generally < 1" is good), then:
  - a. Make a note of the -dRA and -dDec needed to move from the guider to the IFU, as displayed on the TCS monitor. Note that it is the negatives that are needed to move an object from the IFU to the Guider, and it is the negatives are what we want to record. Ask the NA to record these also.
  - b. Ask the NA to "TX" the telescope (unless this is the first procedure of this sort being performed during the run, in which case ask them to "X").

#### 2.2.2.5. *Focusing the Telescope*

*This task is performed by the observer with the Night Assistant.*

The telescope must be focused so that the images it creates at the CWI slicer are as close to seeing-limited as is achievable/necessary. The Xyblon guider, if it has been installed following the instructions above, is close to being a proxy for the telescope-slicer focus. In late 2013 and 2014 it seems that the instrument is better focused when the secondary is moved -0.5 mm from the best guider focus.

Typically, good CWI focus is a stellar FWHM on the order of 3-5 unbinned (2-3 binned) CCD pixels. If stars imaged with the spectrograph appear blurrier, a focus sequence will need to be performed. This is done by taking images from -0.1 mm to +1 mm of the best guider focus location in 0.25 mm increments, and looking at looking at the resultant images in sequence using ds9, or another image viewer. Alternatively, the images could be inspected via `cwi_center_star` to get a quantitative idea of the focus curve. The offset between the guider and instrument best focus should be recorded and used throughout the run.

#### 2.2.3. *NIGHT-TIME OBSERVATION*

### 2.2.3.1. Logs

The observer is responsible for the nightly logs. These are discussed in Section 2.2.1

### 2.2.3.2. Science Target Acquisition after Slewing

There appears to be flexure or pointing error within the Hale—CWI system on the order of a few tens of arc-seconds. This is commensurate with the CWI field of view, but smaller than the guider field-of-view. Consequently, it is often necessary to recalibrate the pointing each time a new target is slewed to. This procedure assumes that the guider—CWI IFU offset has been determined (Section **Error! Reference source not found.**). This procedure should take no more than 5 minutes

1. Slew to a 7<sup>th</sup> to 9<sup>th</sup> magnitude SAO star near the desired science target
2. Take a contbars exposure. Continue with this procedure while that is exposing/reading out
3. Offset the star to the guider field of view by ordering a  $g_{RA}$   $g_{Dec}$  offset determined in Section 2.2.2.4.
4. Center the guide box on the guider screen by issuing the TCL command:  
"CWI> centerBox"  
GUIDING should be OFF.
5. Move the telescope until the star is within the box either via paddle or manual commands
6. Set the guider mode to "GUIDE" (not DRIFT)
7. Turn GUIDING ON.
8. Once the star is centered within the box, turn off guiding.
9. Order an opposite offset to the one ordered before :  $-g_{RA}$   $-g_{Dec}$ .
10. Take a 2-5 second exposure to verify the star is now centered within the IFU. If it is, TX the telescope (this step is optional, though recommended if the move on the sky was very large [QUANTIFY!]). Use `cwi_center_star`
11. If the star is not centered at the IFU, adjust the position so that it is. You may need to take additional diagnostic exposures. TX once it is.
12. Command telescope move to the desired science target. Have the telescope operator select a star from the guider field of view to guide on. The guider should be set to DRIFT mode and GUIDING ENABLED. This will move the guiding box onto the star, without moving the telescope boresight. The instrument is now ready to take science exposures.

### 2.2.3.3. Science Target Acquisition after Long or nearby Exposure

CWI may be used to tile objects larger than the field of view or to look for signal in nearby fields that require long exposure times. In either case, flexure or pointing error may accumulate. It is recommended that the telescope be TX-ed after long exposures that used the guider before the guiding is turned off. Not doing so may introduce a few arc seconds of offset between desired and commanded positions to nearby slews.

### 2.2.4. *STANDARD OBSERVATIONS*

Standard observations are performed in the same way as any other instrument

1. (Optional) Slew to SAO star near target. Confirm pointing.
2. Slew to target, acquire target
3. Select guide star and have the TO DRIFT the guide box onto the star, then GUIDE
4. Set exposure time at the CWI TCL prompt (CWI> exptime T), where T is the exposure time in seconds
5. Start the exposure at the CWI TCL prompt (CWI> expose)
6. After the exposure, provided the instrument was guiding and especially if it was a long image, ask the operator to TX the telescope

## 2.2.5. NOD-AND-SHUFFLE OBSERVATIONS

As of January 2015 there is a new method for setting up nod-and-shuffle observations. We first describe the new (streamlined) method and then the old (manual) method.

Nod-and-shuffle observations require a little more preparation than a standard observation. The first image the N+S script takes is a bias exposure to clear the array.

### 2.2.5.1. Streamlined method

The streamlined method involves running a setup script that asks for user's input and for interaction with the telescope operator. You should have the offset vector from the source field to the background field in arc seconds North and arc seconds East available.

#### 2.2.5.1.1. Streamlined method setup

The steps for the setup are outlined below.

1. Ask the telescope operator to command the telescope to the target field
2. On *porgy*, command `CWI> nssetup ns_identifier`  
where identifier is the *identifier* (essentially filename, so avoid funny characters) that is unique to the observation
3. Follow the prompts on the screen. The script will tell you when it is done.

If you make a mistake, you can find the script on *porgy* in:

```
~/oldporgy/palomar_guider/ns/ns_identifier.ns
```

You can either edit it with your favorite editor (*vi/vim/emacs*) if you know what you are doing or delete it and start over with `nssetup`.

Experienced users may copy an existing script to a new filename and edit some of the parameters to generate a derived script that adds dithers or shifts, etc.

#### 2.2.5.1.2. Streamlined method invocation

The steps to invoke the streamlined method are discussed below

1. Make sure the telescope is pointed at the target field and it is guiding
2. On *porgy*, command `CWI> nsrun ns_identifier`
3. Pay attention to the guider moves for the first 2 steps to make sure there are no delay issues. If there are, the script may need to be stopped and the wait time (`twait`) parameter may need to be adjusted in the script. (if you do break out of the script, see description of `ns_recover` in Section 2.2.5.3 on page 25)

#### 2.2.5.1.3. Streamlined method discussion

The data entered by the user and collected by the `nssetup` command is saved to a `ns_identifier.ns` file. The file is basically a piece of tcl source code that is sourced by a script called `ns_wrapper.tcl` when `nsrun` is called. An example \*.ns file is shown below with additional explanations in **blue on yellow background**.

## Listing of ns\_ngcXXX.ns

```
# Nod-and-shuffle script parameter file
# Generated by NSSETUP
# Sunday, 18 January 2015, 12:56:09 PST
# Guider rose: GUIDGEOM 0.267857 0.321429 -1 1.53535 0.999372 0.0354387
# P200 focus: 14.88
# Cass angle: -179.97
# Total source exposure time: 1200 seconds
# Total bakgnd exposure time: 1200 seconds
# 10 iterations.
# Wall clock duration will be ~48 minutes.
# Number of subexposures per field
set n 10

# Exposure times on source and background in ms.
set expts 120000
set exptb 120000

# Source field guider information (same as output of CWI> getTarget)
set plx 329
set ply 124
set pls 30
set plm 5
set intens1 0
set ccd x4
set grabmode1 frame
set grabexp1 1
set grabstack1 11

# Vector from source to background (Note that these need to be integers)
set mvN1 110 (moves under 300 arc seconds in each axis are preferred)
set mvE1 -54

# Background field guider information (same as output of CWI> getBackground)
set p2x 329
set p2y 124
set p2s 30
set p2m 5
set intens2 0
set grabmode2 frame
set grabexp2 1
set grabstack2 11

# Delay times (in milliseconds)
# Change twait for long throws
set twait 8000 (Increase this if your subexposures start before moves complete)
set gwait 3000

# NS Version:
set nsversion ns_ngcXXXX
```

### 2.2.5.2. Manual Method – *EXPERT USE ONLY*

The manual method involves more interactions with the telescope operator and cutting-and-pasting command outputs into a nod-and-shuffle script.

#### 2.2.5.2.1. Quick Version

1. Copy template script to new filename for use for this N&S
2. Turn guiding off
3. Go to target
4. Drift onto guide star, enable, then guide
5. getTarget
6. paste position data into script
7. stop guiding (guider set guiding 0)
8. move to bg field (e.g., guider set move 86 -136 30)
9. drift, enable, guide
10. getBackground
11. paste position data into script
12. stop guiding (guider set guiding 0)
13. move back to fg field (e.g., guider set move -86 136 30)
14. make sure the correct target to background offset is in the script
15. start script

#### 2.2.5.2.2. Long Version

1. Make sure you have the following information from the observer:
  - a. Target coordinates
  - b. Background coordinates
  - c. Offset from target to background in arc seconds (dNorth, dEast)  
(yes, you could compute it from the values in a and b, in principle)
2. In the ~/oldporgy/palomar\_guider directory copy ns\_template\_150118.tcl to pickaname.tcl. Alternatively, you could copy scripjustused.tcl to pickaname.tcl. You will need to edit the script to adjust guiding information and tune exposure times. The start of a script is reproduced below with the parts that you may need to adjust highlighted and explanations in red.

```
# NOD AND SHUFFLE SCRIPT
# TAKES 1/2 EXPOSURE OF SKY, LOOPS THROUGH TARGET
# AND SKY AND ENDS WITH 1/2 EXPOSURE OF SKY

# version of this NS script

set nsversion [info script]

# tracker flag, decides whether we try to access the palomar guider or
not.
set tracker 1

if {$tracker} {
```

```

    puts "load guider package"
    load /usr/lib/libautoguider.so
    puts "connect to guider"
    guider host 198.202.125.194
}; #stracker

#total number of cycles
set n 10 ← Number of on-target exposures

# total number of subexposures:
set nsteps [expr {2*$n+1}]

#exposure time at source (ms)
set expts 120000 ← Exposure time on source per cycle (in ms)

#exposure time at background (ms)
set exptb 120000 ← Exposure time on background per cycle (in ms)

#exposure time for half-fields
set exptb2 [expr {$exptb/2}]

# write the exposure time to file
set nsfile [open "ns.exptime" w]
puts $nsfile $expts
close $nsfile

### GUIDER SETTING BEGIN -----
#time to wait (ms)
set twait 8000 ;# settling time after a move
set gwait 5000 ;# waiting time after a "stop guiding" command is issued
#guider gain setting
set ccd x4 ; # CCD gain

#source guide star coordinates and intensity data
# the 'getTarget' command in the stage.tcl program
# will return all these values
#
# Go to science field
# Drift guider box onto guide star
# run getTarget: prints out required settings for target field
#
# next, move to background field
# Drift guider box onto guide star
# run getBackground: prints out required settings for background field
#
# source field will move 4 steps, then back
# background field will move up to F
#
# script always starts and ends on source position (even though first and
# last exposures are on background)
#
# getTarget
# x,y are guider coordinates for science field
# s is size of box
# m is box margin size (delta from inside box to outside box)

```

```

set plx 436 ← These entries are cut-and-pasted from the output of getTarget
set ply 151
set pls 27
set plm 5
set intens1 95
set ccd x4
set grabmode1 frame
set grabexp1 2
set grabstack1 8

# the 'getBackground' command in the stage.tcl program
# will return all these values
set p2x 461 ← These entries are cut-and-pasted from the output of getBackground
set p2y 360
set p2s 27
set p2m 5
set intens2 93
set grabmode2 frame
set grabexp2 2
set grabstack2 8

#source to background move
set mvN1 -107 ← These values to be supplied by the observer (dNorth, dEast)
set mvE1 -110

```

3. [Optional, but strongly recommended] Slew to an SAO star near the main target to confirm pointing
4. Ask the telescope operator to slew to target
  - a. Ask the telescope operator to adjust the guider settings to their satisfaction and to DRIFT the guide box onto an acceptable star. Then switch to GUIDE mode. Note that stars near the center of the guider field are preferred if you intend to do macroscopic dithers.
  - b. Issue "CWI> getTarget"
 

This prints out the guider information for the target field that will need to be cut-and-pasted into the nod-and-shuffle script. Example:

```

CWI> getTarget
set plx 548
set ply 165
set pls 24
set plm 4
set intens1 0
set ccd x4
set grabmode1 frame
set grabexp1 3
set grabstack1 17

```
  - c. Stop guiding "CWI> guider set guiding 0"
5. Ask the telescope operator to slew to the background field

- a. Ask the telescope operator to adjust the guider settings to their satisfaction and to DRIFT the guide box onto an acceptable star. Then switch to GUIDE mode
  - b. Issue "CWI> getBackground"  
This prints out the guider information for the target field that will need to be cut-and-pasted into the nod-and-shuffle script.
  - c. Stop guiding "CWI> guider set guiding 0"
6. Verify that the offset move is correct.
- a. While still on the background field issue:  
"CWI> guider set move -dNorth -dEast 30"  
This will return the telescope pointing to the source field.
  - b. Once the move is completed, move the guider box via  
"CWI> guider set target 1 valp1x valp1y palp1s valp1m"  
where valp1? are the numerical values obtained in 4b above.
7. You should now be guiding on target. Save the N+S script and execute it:
- a. "CWI> source pickaname.tcl"
  - b. Sit back and take a nap. You may want to make sure that there wasn't an extra 0 in the exposure time length and you didn't just ask for a day-long exposure

### 2.2.5.3. *Aborting an exposure and resetting the system*

Aborting a nod-and-shuffle exposure can be problematic. But it must be done sometimes (clouds, fog, wrong parameters or target).

1. Break the Nod-and-Shuffle script via CTRL+C.  
This is best done during a telescope move during the execution
2. Restart the CWI tclsh with 'sudo -E tclsh' at the *porgy* shell prompt
3. "CWI > source ns\_recover.tcl"

Note that this procedure may need to wait a few minutes for a previously commanded sub-exposure to finish.

### 3. END OF NIGHT (THINGS TO DO AT THE END OF EACH NIGHT)

#### 3.1. PARK TELESCOPE

Ask the telescope operator to park the telescope, close the dome shutters, and the mirror cover.

#### 3.2. COPY MISCELLANEOUS FILES

Copy the logfile (in xlsx, txt, and csv formats) to the nightly data directory on **porgy**

Copy and scripts used to the nightly data directory on **porgy**

#### 3.3. TRANSFER DATA TO *BEACH*

Transfer files from **porgy** to **beach** by issuing “porgy2beach” from **beach** command prompt.

As of 150414 this may be automated. Ask your support person.

#### 3.4. TRANSFER DATA TO *SRL.CALTECH* AND GUEST OBSERVER’S REPOSITORY, IF APPLICABLE

#### 3.5. PLUG IN THE GRATING ROTATOR ENCODER IF IT WAS UNPLUGGED

Reattach the grating encoder if it was detached for observations.

#### 3.6. PARK ALL MOTORS (**IMPORTANT!**)

Park stages by issuing the “CWI> park” command from the CWI TCL shell on **porgy**. Telescope must be parked for this.

#### 3.7. CHECK/TURN OFF CALIBRATION LAMPS

### 4. END OF INSTRUMENT RUN (THINGS TO DO AT THE END OF THE LAST NIGHT)

#### 4.1. GO THROUGH “END OF NIGHT” ACTIONS

#### 4.2. TRANSFER SCRIPT DIRECTORY

Tarball the palomar\_guider directory on **porgy**. Name it palomar\_guider\_YYMMDD.tar.gz

Transfer the tarball to **beach** and to the campus repository

#### 4.3. POWER DOWN THE INSTRUMENT (OBSERVATORY STAFF)

- “dhe close” to power down the CCD
  - Issue “dhe close” at command prompt on **porgy** to switch off power to the detector.
- Power down shutter control

- Close the GUI
- Power down gray CCD power supply
- Power down Lakeshore unit
- Power down calibration unit power supplies
- Turn off motor power supplies
- Power down **porgy**
  - Issue “sudo shutdown –h now” at **porgy** command prompt
- Unplug bench from rack
- Unplug rack from Cassegrain cage
- Turn off the offset guider
- Power down beach and stow
- Coil cables inside enclosure
- Button up enclosure
- Install dust covers on top of instrument

## 5. APPENDIX I – OBSERVER’S REFERENCE

### 5.1. GENERAL COMMENTS

The observer is responsible for designating the grating, filter, and nod-and-shuffle mask configuration for each night sufficiently early for the instrument staff to implement any necessary changes. Multiple instrument configurations for a single night require the presence of qualified personnel during the observing night and will only be considered under special circumstances upon request.

The lists below do not explain the individual tasks. That is addressed in other sections and referenced here.

### 5.2. AFTERNOON

#### *5.2.1. BEFORE DOME IS DARK*

- 1) Confirm with observatory staff that the desired grating, filter, and nod-and-shuffle mask position are configured for your desired wavelengths.
- 2) Start a daily log. This is mostly for you, but relevant instrument comments are vital in case something goes wrong and/or to help with data reduction.
- 3) Confirm with the staff that the instrument focus (FM2), and lateral position (FM4) stages have been configured for the installed grating
- 4) Make sure the data directory is set correctly and take a test bias image
- 5) **[MAKE SURE THE CAMERA IS FREE TO MOVE—ASK]** For each setting:
  - a. Confirm wavelength range for each setting
  - b. Establish exposure times for calibration and dome flat images

#### *5.2.2. AFTER DOME IS DARK*

- 1) Complete “Afternoon” tasks
- 2) Take a set of 10 biases [20 minutes]
- 3) **[MAKE SURE THE CAMERA IS FREE TO MOVE]** For each setting:
  - a. Take a full internal calibration set [~30 minutes]
  - b. Take 3 to 5 dome flats [7 to 10 minutes]

### 5.3. EVENING TWILIGHT

- 1) Complete “After Dome is Dark” items
- 2) Send camera to 0 position and ask Palomar staff to top off the dewar and **WAIT FOR FILL TO BE COMPLETED AND DEWAR DISCONNECTED**  
Note: Some non-zero positions are OK for fill (notably, any positive articulation stage positions, for instance).
- 3) Open the dome when ready
- 4) Put camera/grating in first required setting **after fill is complete and dewar disconnected**

- 5) Rotate the instrument to the desired Cass ring angle
- 6) Calibrate the guider if the Cass angle is different than previous observation
- 7) Start tracking and focus the guider
- 8) Establish/Confirm the guider—IFU offset for Zenith
- 9) Focus the instrument
- 10) Go to first target
  - a. refine guider—IFU offset, if needed
  - b. refocus, if needed
  - c. set up N+S script, as needed
- 11) Take twilight flats/standard stars/etc., as desired

#### 5.4. NIGHT

- 1) Complete the major “Twilight” tasks, if necessary (hopefully, you’re done)
- 2) Line up on target
- 3) Observe
- 4) Take at least one calibration set for each setting during the night (7 minutes)
- 5) Periodically transfer data to **beach** (*automatic since 150414*)
- 6) Periodically issue a getTemps command (few seconds)

#### 5.5. MORNING TWILIGHT

- 1) Perform any observations that are OK in twilight
- 2) Complete any relevant “Evening Twilight” tasks
- 3) Complete any relevant “Afternoon” tasks
- 4) Start any “Morning” tasks

#### 5.6. MORNING

- 1) Park telescope
- 2) Complete any relevant and outstanding “Morning Twilight” tasks
- 3) Park instrument stages (**plug in grating encoder, if unplugged; telescope must be parked**)
- 4) Turn off all lamps
- 5) Copy your logfile to the **porgy** data directory
- 6) Copy any observing scripts used to the **porgy** data directory
- 7) Take a stack of 10 biases (especially if you didn’t in the aft/eve) (20 minutes)
- 8) Transfer data to **beach** and tarball
- 9) Transfer data to campus and your repositories

## 6. APPENDIX II – COMMAND GLOSSARY

This is an abbreviated command summary, functionally ordered. “CWI>” is simply the CWI `tc1sh` prompt.

### 6.1. CONFIGURATION COMMANDS

#### **CWI> cwiSet configuration\_name**

Added September 14, 2014. Intended as a replacement for the `art_XXXX` commands.

This command loads a `cwi` setting that has been previously determined. The settings are stored in the `./settings/` subdirectory of the `palomar_guider` directory. Setting information includes the expected grating, central wavelength, camera articulation setting, grating stage setting, exposure time for arc lamp and continuum lamp calibrations and dome flat exposure time. The `configuration_name` is typically of the form `B_4861` or `R_alpha`, where the first character implies the grating and the remainder identifies the setting.

#### **CWI> ConfigureDetector [ONCE PER RUN]**

Send the `SRS`, `SOS`, and `readmode` commands to set up the detector for slow lower-left amp readout

#### **CWI> YellowSettings**

Move FM2 for the blue grating focus position and adjust FM4 to center the spectra

#### **CWI> RichSettings**

Move FM2 for the blue grating focus position and adjust FM4 to center the spectra

#### **CWI> BlueSettings**

Move FM2 for the blue grating focus position and adjust FM4 to center the spectra

#### **CWI> art\_hbeta [DEPRECATED]**

Set the CWI grating and camera positions to place H-beta near the center of the CCD, assuming the BLUE grating and filter are in.

#### **CWI> RedSettings**

Move FM2 for the red grating focus position and adjust FM4 to center the spectra

#### **CWI> art\_alpha [DEPRECATED]**

Set the CWI grating and camera positions to place H-alpha near the center of the CCD, assuming the RED grating and filter are in.

**CWI> art\_has2 [DEPRECATED]**

Set the CWI grating and camera positions to have H-alpha and SII (6716) within the nod-and-shuffle mask, assuming the RED grating and filter are in. You only get the shorter of the two SII lines and the config is a little iffy.

**CWI> rp**

Print out the stage positions (motor counts).

Order: FM1, FM2, FM3, FM4, Grating, Camera, CalX, CalY

**CWI> tp**

Print out stage positions (encoder counts)

Order the same as "rp" above

**CWI> st**

Stops stage motion

**CWI> grating\_pa N**

Set the grating position to the specified value

**CWI> camera\_pa N**

Set the camera articulation stage position to the specified value

**CWI> lockGrating**

Creates a lock file that prevents grating move commands from being executed

**CWI> unlockGrating**

Removes the lock file that prevents grating move commands from being executed

**CWI> TelFocus mm.m**

Change the telescope focus to position mm.m (secondary setting). Will not perform the move if mm.m < 10.0 or > 20.0. This is a CWI code limitation, not a Palomar constraint.

**CWI> park**

Park all mechanisms. **NOTE:** Telescope must be parked before issuing this command.

## 6.2.MODE COMMANDS

### **CWI> fm1\_astro [ENGINEERING]**

Move the periscope into astronomy position

### **CWI> fm1\_calib [ENGINEERING]**

Move the periscope into calibration position

### **CWI> sel\_flat [ENGINEERING]**

Selects the flat calibration object

### **CWI> sel\_dark [ENGINEERING]**

Selects the dark calibration object (a cover, of sorts)

### **CWI> sel\_horizontal [ENGINEERING]**

Selects the vertical bars (despite the name – historical)

## 6.3.CALIBRATION COMMANDS

### **CWI> CalibRed [DEPRECATED]**

Takes the following calibration sequence:

- 20 second arc flat
- 10 second continuum bars
- 10 second continuum flat

Returns the instrument to astronomy mode, turns off lamps, selects “dark” target

### **CWI> CalibBlue [DEPRECATED]**

Takes the following calibration sequence:

- 20 second arc flat
- 30 second arc bars
- 60 second continuum bars
- 40 second continuum flat

Returns the instrument to astronomy mode, turns off lamps, selects “dark” target

**CWI> CalibBlueDim [DEPRECATED]**

Takes the following calibration sequence:

- 60 second arc flat
- 60 second arc bars
- 90 second continuum bars
- 60 second continuum flat

Returns the instrument to astronomy mode, turns off lamps, selects “dark” target

**CWI> contbars T**

Takes a continuum bars exposure of specified exposure length T. T defaults to 25 seconds if not specified. Returns all stages to astro mode. Writes out \*.info file.

**CWI> arcflat T**

Takes an arc flat exposure of specified exposure length T. T defaults to 15 seconds if not specified. Returns all stages to astro mode. Writes out \*.info file.

**CWI> contflat T**

Takes a continuum flat. Returns all stages to astro mode. Writes out \*.info file

**CWI> calibrate a b c d e f g h [DEPRECATED]**

Should not need to invoke this command. Takes the following exposures:

- arcflat: a exposures of exposure time b
- arcbars: c exposures of exposure time d
- contbars: e exposures of exposure time f
- contflat: g exposures of exposure time h

Exposure times are in seconds, number of exposures must be 1 or greater. Returns the instrument to astro mode after. Writes out \*.info file.

**CWI> calibshort a b c d e f [DEPRECATED]**

Should not need to invoke this command. Takes the following exposures:

- arcflat: a exposures of exposure time b
- contbars: c exposures of exposure time d
- contflat: e exposures of exposure time f

Exposure times are in seconds, number of exposures must be 1 or greater. Returns the instrument to astro mode after. Writes out \*.info file

**CWI> domeflat N**

Takes N dome flat exposures. The high lamp needs to be on and the mirror cover must be open. The exposure time defaults to that loaded when `cwi.Set` is invoked.

**CWI> arc\_on [ENGINEERING]**

Commands the arc lamp on

**CWI> arc\_off [ENGINEERING]**

Commands the arc lamp off

**CWI> cont\_on [ENGINEERING]**

Commands the continuum lamp on

**CWI> cont\_off [ENGINEERING]**

Commands the continuum lamp off

**CWI> all\_off**

Commands all lamps off.

#### 6.4. EXPOSURE COMMANDS

**CWI> exptime T**

Set the CWI exposure time in SECONDS. T defaults to 1 second.

**CWI> expose**

Start a CWI exposure. Writes out a \*.info file along with the image.

**CWI> nexpose N**

Takes N CWI exposures. Writes out a \*.info file for each image.

**CWI> bias N**

Takes N bias exposures. N defaults to 1.

**CWI> ndark N**

Takes N dark exposures. N defaults to 1. Set exposure time with **exptime** first

**CWI> domeflat N**

Takes N dome flat exposures. The high lamp needs to be on and the mirror cover must be open. The exposure time defaults to that loaded when **cwiSet** is invoked.

## 6.5.GUIDER COMMANDS

### **CWI> startguider**

Initializes the connection to the Shepherd Palomar autoguider. There is separate documentation for this code.

### **CWI> centerBox**

Centers the tracking box on the guider field of view

### **CWI> getRose**

Prints the guider plate scale and orientation information.  
Wrapper for "guider get geom a b c d e f"

### **CWI> getTarget**

Prints the information for the target currently being guided on. Prints the data out in a format to be used in nod-and-shuffle scripts for the target field  
(wrapper for guider get target a b c d e)

### **CWI> getBackground**

Prints the information for the object currently being guided on. Prints the data out in a format to be used in nod-and-shuffle scripts for the background field

### **CWI> guider set move North East Rate**

Moves the telescope the specified amount (in arc seconds) at the specified rate (in arc seconds/second). Rate should be < 35. There are problems if it is above 35.

### **CWI> guider set target 1 X Y S M**

Moves the guider box to guider pixel (X,Y). Box is of size S with margin M. Note the '1' as the first parameter, this is mandatory.

### **CWI> guider set guiding 1/0**

Turn the guiding on or off. Always be careful as to whether the guider is set to "GUIDE" or "DRIFT" mode

## 6.6. INFORMATIONAL COMMANDS

**CWI> getTemps N**

Prints the last N CCD temperature readings to the screen. N defaults to 3.

**CWI> reqpos**

Get some information from the telescope and print it to the screen

**CWI> reqstat**

Get some other information from the telescope and print it to the screen

## 6.7. DRAGSTAR.TCL [NOT TESTED RECENTLY]

This is a tcl procedure that starts with a star at the center of the slicer it then scans the star across the slicer (over all 24 slicer mirrors). The program is not very sophisticated – the current exposure time is ~ 2.5 seconds per slice.

**CWI> source dragstar.tcl**

## 6.8. APPENDIX III – ALPHABETIZED COMMAND LIST

Observer accessible commands are in GREEN

**CWI> all\_off**

**CWI> arc\_on [ENGINEERING]**

**CWI> arc\_off [ENGINEERING]**

**CWI> arcflat T**

**CWI> bias N**

**CWI> BlueSettings [ENGINEERING]**

**CWI> Calib**

**CWI> CalibBlue [DEPRECATED]**

**CWI> CalibBlueDim [DEPRECATED]**

**CWI> calibrate a b c d e f g h [DEPRECATED]**

**CWI> CalibRed [DEPRECATED]**

**CWI> calibshort a b c d e f [DEPRECATED]**

**CWI> camera\_pa N [ENGINEERING]**

**CWI> centerBox**

**CWI> ConfigureDetector [ENGINEERING]**

**CWI> contbars T**

**CWI> contflat T**

**CWI> cont\_on [ENGINEERING]**

**CWI> cont\_off [ENGINEERING]**

**CWI> dayCalib**

**CWI> dayCalibShort**

**CWI> domeflats**

**CWI> expose**

**CWI> exptime T**

**CWI> fm1\_astro [ENGINEERING]**

**CWI> fm1\_calib [ENGINEERING]**

CWI> getBackground

CWI> getRose

CWI> getTarget

CWI> getTemps N

CWI> grating\_pa N [ENGINEERING]

CWI> guider set guiding 1/0

CWI> guider set move North East Rate

CWI> guider set target 1 X Y S M

CWI> lockGrating [ENGINEERING]

CWI> ndark N

CWI> nexpose N

CWI> park **NOTE: Telescope must be parked before issuing this command.**

CWI> RedSettings [ENGINEERING]

CWI> reqpos

CWI> reqstat

CWI> RichSettings [ENGINEERING]

CWI> rp

CWI> sel\_dark [ENGINEERING]

CWI> sel\_flat [ENGINEERING]

CWI> sel\_horizontal [ENGINEERING]

CWI> st

CWI> startguider

CWI> TelFocus mm.m [ENGINEERING]

CWI> tp

CWI> unlockGrating [ENGINEERING]

CWI> YellowSettings [ENGINEERING]

## 7. DETERMINING CONFIGURATIONS AND MAKING CONFIG FILES

This is intended as a quick-look reference for generating configuration files

1. Make sure you have the desired central wavelength from the observer in Angstroms
2. Make sure the correct grating is installed
3. on *beach*, run `IDL> CWI_SETTING, wavelength`  
(where wavelength is in angstroms)  
Make a note of the required camera and grating readings for the **installed grating**
4. on *porgy* in `~/oldporgy/palomar_guider/settings/`  
`cp X_Template.cwi G_WVLG.cwi`  
where: G is the grating code (B/R/Y/M) and WVLG is the 4 digit wavelength in Angstrom,  
e.g.: `B_5005.cwi` (blue grating, 5005A)
5. edit `G_WVLG.cwi` in your favorite text editor (choose: vi? emacs?), change the comments, the grating name (if necessary) and set `grating_pos` and `camera_pos` to the values found in 3. Verify the signs, they are important. Leave the arc (10s), cont (10s), and dome (25s) exposure times at the values in the template file for now.
6. **Make sure the dewar is not filling and the camera is free to move**  
on *porgy*, run `CWI> cwiSet G_WVLG`  
Wait for the camera and grating stages to finish moving
7. take a 10 second arc flat: `CWI> arcflat 10` ; Check the flux, compute an exposure time that would put the peak value around 50,000 counts. Edit the `G_WVLG.cwi` file to reflect this value. Make a note of the arc lamp file number ARCNO
8. on *beach*, Run `IDL> cwi_compare_arc, /GRATING, ARCNO`  
where `/GRATING` is the grating, i.e., `/BLUE, /RED`, etc.  
Add a `/NS` switch if the nod-and-shuffle mask is installed  
Inspect the IDL graphics window to confirm the setting
9. Take a 10 second continuum flat: `CWI> contflat 10` ; Check the flux, compute an exposure time that would put the peak value around 50,000 counts. Edit the `G_WVLG.cwi` file to reflect this value.
10. run `CWI> cwiSet G_WVLG` to load the new arcflat and contflat exposure times
11. Run a short calibration script: `CWI> Calib` ; Inspect the three resultant images for flux level.
12. Once the dome is dark and CWI rear panel installed, take a 25 s dome flat:  
`CWI> domeflat`  
inspect the dome flat image and adjust the exposure time to peak around 50,000 counts.  
Edit the `G_WVLG.cwi` file to reflect this exposure time value.
13. Run `CWI> cwiSet G_WVLG` again to load in the new values. You are done.

## 8 . APPENDIX III – AUXILLIARY PROGRAMS

There are a number of IDL auxiliary procedures that have been written. This section is a quick (and incomplete) list of the programs that might be useful.

### 8.1.CWI\_SETTING.PRO

Prints the CWI settings needed to center a particular wavelength on the CWI detector. Note that CWI settings might actually differ somewhat from the values reported by the program as they are then optimized for ghost position, etc. Note that more than one grating may be able to access a particular wavelength – make sure you use the correct grating values when generating a settings file.

*Calling sequence:*

```
IDL> CWI_SETTING,Wavelength
```

*Example:*

```
IDL> cwi_setting,6563
```

```
% CWI_SETTING: CWI Grating Settings Calculator
```

```
% CWI_SETTING: *****
```

```
% CWI_SETTING: BLUE GRATING
```

```
% CWI_SETTING: *****
```

```
% CWI_SETTING: 6563.0A is outside the BLUE grating range.
```

```
% CWI_SETTING: *****
```

```
% CWI_SETTING: Yellow GRATING
```

```
% CWI_SETTING: *****
```

```
% CWI_SETTING: YELLOW grating setting for          6563.0A:
```

```
% CWI_SETTING: Articulation/Camera stage  RP = -1128221
```

```
% CWI_SETTING: Grating stage                RP =   -16749
```

```
% CWI_SETTING: *****
```

```
% CWI_SETTING: RED GRATING
```

```
% CWI_SETTING: *****
```

```
% CWI_SETTING: RED grating setting for          6563.0A:
```

```
% CWI_SETTING: Articulation/Camera stage  RP =   186093
```

```
% CWI_SETTING: Grating stage                RP =     6164
```

## 8.2. CWI\_CENTER\_STAR.PRO

One of the tasks we have had a lot of “fun” with is centering reference stars on the CWI IFU. Usually this is done manually by holding a pencil up to the monitor or blinking two images. This program is an attempt to automate the procedure and make it more repeatable. It requires a few things:

1. IDL window open on **observer2**
2. A continuum bars image taken at current telescope orientation to ensure flexure does not affect the alignment. Best way to acquire this is to go to the SAO star that will be used for preliminary alignment near the target and to issue the “CWI> contbars” command which will acquire a continuum bars image
3. A good quality CWI spectrum of the star being used for alignment

### *Calling sequence*

```
IDL> CWI_CENTER_STAR, /REMOTE, BARNO=barno, STARNO=starno
```

The /REMOTE switch tells the program to look for the files on porgy rather than on the local machine

**barno** is the number of the continuum bars

**starno** is the number of the star

### *Example:*

```
IDL> cwi_center_star, /REMOTE, barno=7644, starno=7642
```

*<some diagnostic numbers show up here>*

```
To center the star from image: 7642
```

```
on bars from image:           7644
```

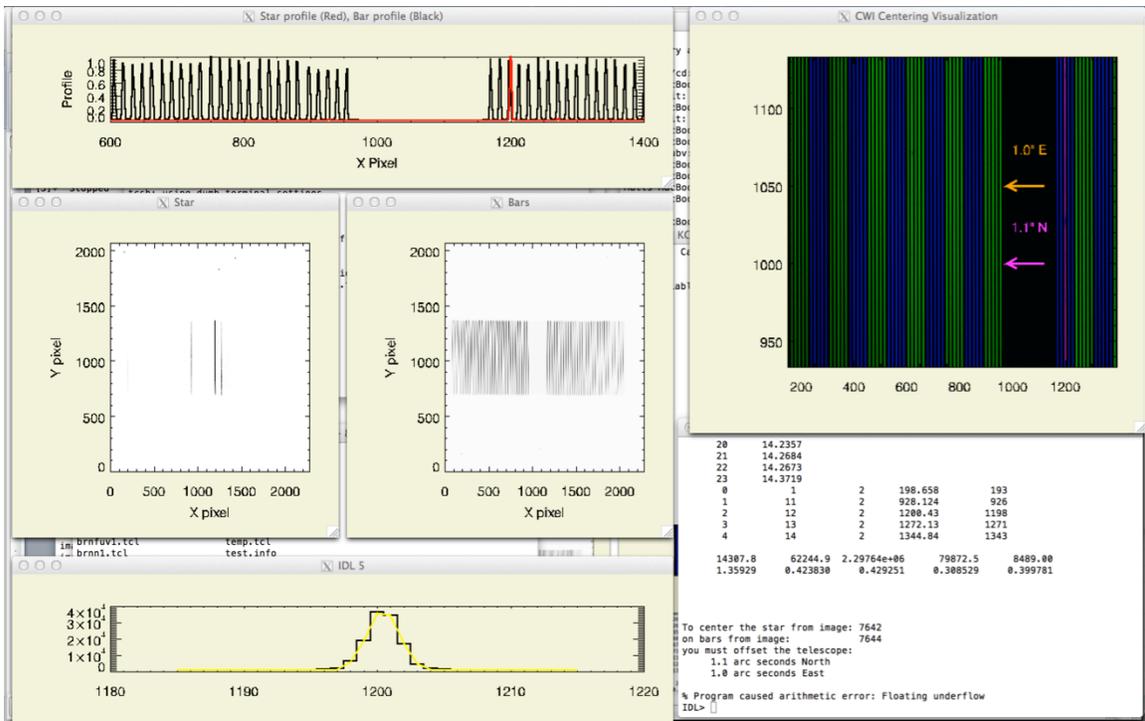
```
you must offset the telescope:
```

```
    1.1 arc seconds North
```

```
    1.0 arc seconds East
```

### *Discussion:*

The program centers the star by straddling it between the two center slices and matching the centroid within the slice. It corrects for relative flux differences between slices. While the program works OK, it has not been extensively tested for robustness. A screencap is given below. The code now takes into account the rotation of the Cass ring. It also attempts to compute the stellar FWHM.



### 8.3.CWI\_COMPARE\_ARC.PRO

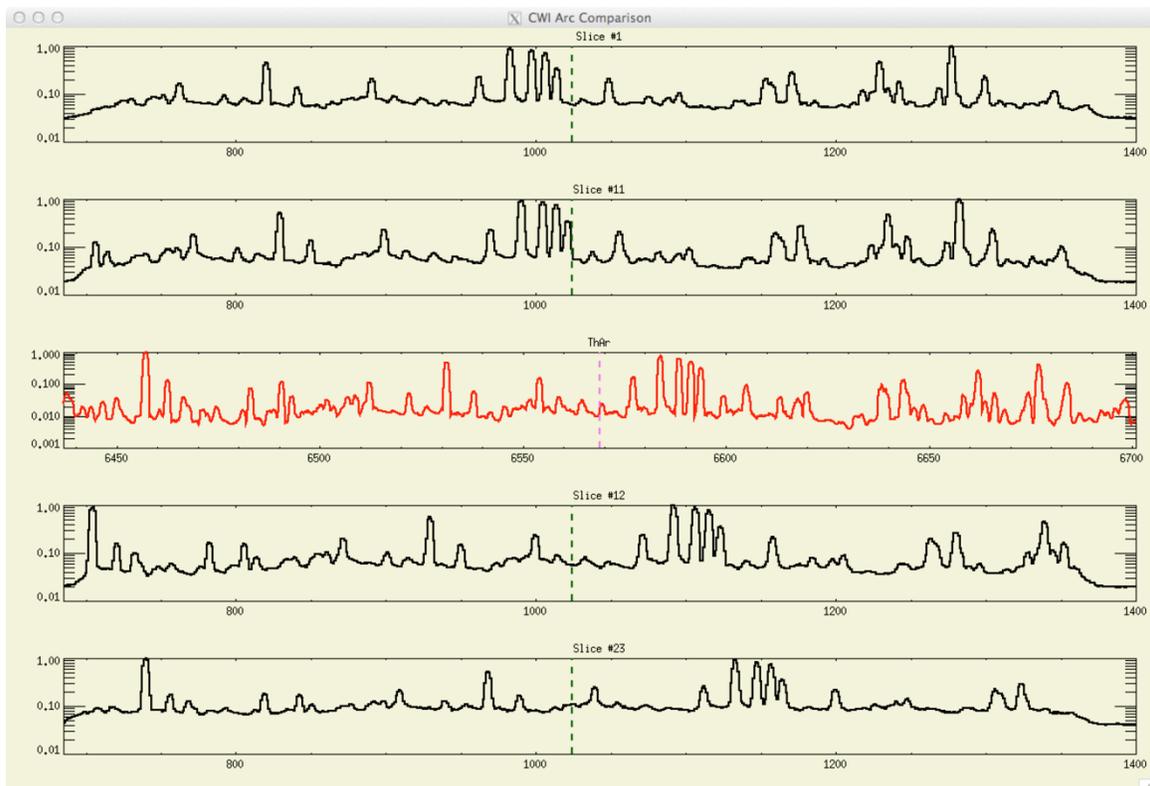
It's generally a good idea to make sure that the spectrograph has been configured to the correct wavelength range. The program reads the .info file associated with the specified arc to determine the stage settings. It then plots cuts through four slices and a reference spectrum. User needs to specify which grating is in, and whether the nod-and-shuffle mask is inserted

#### Calling Sequence:

```
IDL> CWI_COMPARE_ARC, arcno, /NS, [/grating_name]
      /NS : set if N+S mask is in
      /RED: if the red grating is in
      /BLUE: if the blue grating is in
      /YELLOW: if the yellow grating is in
      /MEDREZ: if the medium resolution grating is in
      arcno : the number of the arc to plot
```

#### Example:

```
IDL> cwi_compare_arc, 7481, /ns, /red
```



The color of the reference spectrum indicates which grating this is for. The dashed lines show the center row for the slice cuts and the nominal tuning wavelength for the reference.

## 8.4. CWI\_GUIDER\_OFFSET

Computes the approximate guider offset from the CWI IFU to the guider field center.

The angle is given in degrees.

Remember that the offset is approximate and will have to be corrected using an IFU-centering procedure.

```
% Compiled module: CWI_GUIDER_OFFSET.  
% CWI_GUIDER_OFFSET: TCS Cass angle in Degrees  
% CWI_GUIDER_OFFSET: The values are approximate!  
% CWI_GUIDER_OFFSET:  
% CWI_GUIDER_OFFSET: IFU --> Guider: 489.6" S, 396.5" W
```

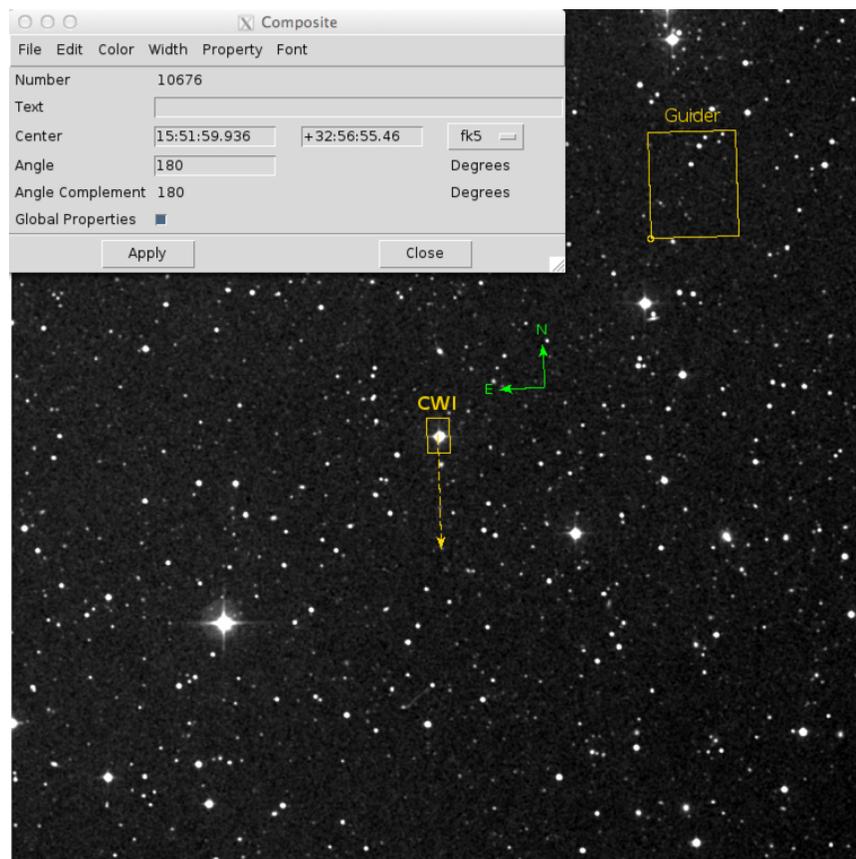
## 8.5. CWI DS9 REGION TEMPLATE FILE

A ds9 region template file is available. The template includes both the CWI instrument and guider fields-of-view. Figure 4 is a screenshot of a ds9 window along with a configuration dialog that allows the user to set the Cass ring angle (Angle). The field is a DSS image downloaded using ds9. The small circle in the bottom-left corner of the guider field corresponds to the top-right corner of the guider screen (0,0) coordinate.

Figure 5 shows a zoomed in screen-shot of the guider field in the ds9 window and a photograph of the guider screen.

The Palomar Autoguider, in the CWI configuration, seems to guide OK down to V~17<sup>th</sup> in reasonable seeing conditions.

The region `cwi_fov.tpl` source code is reproduced below and can be obtained by contacting Matt ([matmat@caltech.edu](mailto:matmat@caltech.edu)), or you could just cut-and-paste from below. The file is loaded via 'Region -> Template -> Load...' in the top menu bar.



**Figure 4. CWI ds9 template superimposed on a target field. IFU FOV is labeled "CWI." Guider FOV is labeled "Guider." The "Angle" field in the ds9 dialog window corresponds to the Cassegrain rotator setting.**

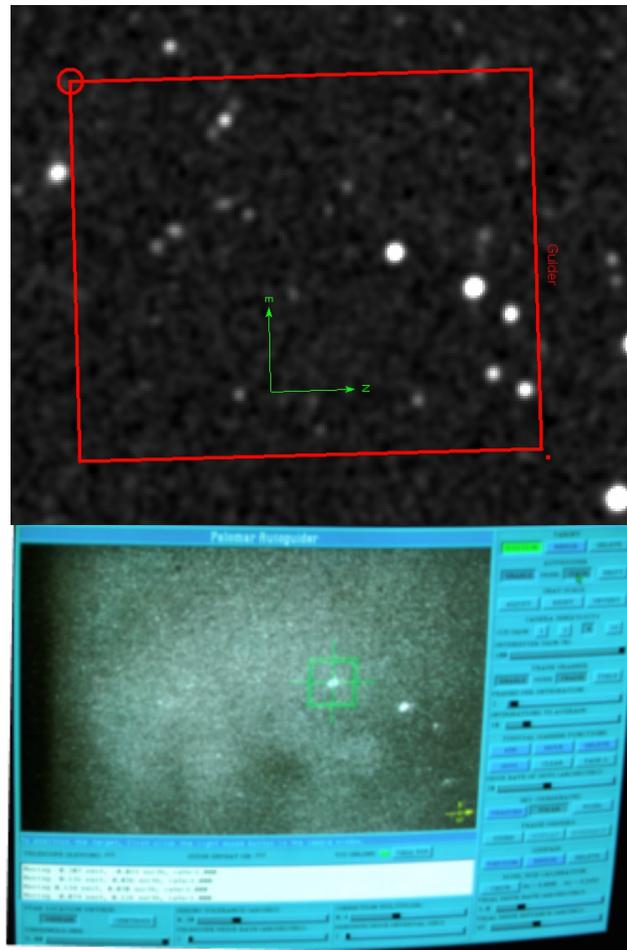


Figure 5. CWI Predicted field and corresponding guider photo

```
# Region file format: DS9 version 4.1
# Matuszewski 140421
# Guider field position and size are good to about +/-5 arc seconds
# The limiting star magnitude for the guider is (at present) unclear.
# CWI has guided on Vmag-15 stars and, ought to be able to go down to Vmag-17.

# These values will be updated over the next couple of CWI runs.
global color=gold dashlist=8 3 width=1 font="helvetica 10 bold roman" select=1 highlite=1 dash=0
fixed=0 edit=1 move=1 delete=1 include=1 source=1
wcs0;fk5
# composite(0,0,180.00) || composite=1 color=gold font="helvetica 12 bold roman"
box(0,0,40",60",0) || # color=gold font="helvetica 12 bold roman" text={CWI}
# vector(0,0,200.0",-90) || vector=1 color=gold font="helvetica 12 bold roman" dash=1
box(-0.12733239,0.11851218,153",185",0) || # color=gold font="helvetica 12 normal roman" text={Guider}
```