SWIFT GUIDER MANUAL

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CHANGE HISTORY

Version	Date	Author	Change
1.0	May 2012	FJC	First release. Based on laptop solution
1.1	October 2012	FJC	Updated to work with swiftic
2.0	January 2013	FJC	Full document
2.1	January 2013	FJC	Small fixes. Added information on shared disc on swiftws and differential flexure. Fixed small offset relationship
2.2	June 2013	FJC	Small updates following feedback from observers. Added section explaining how to use guide region template in DS9
2.3	October 2016	FJC	Moved into word format. Some updates to the format.

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LIST OF TABLES

NO TABLE OF FIGURES ENTRIES FOUND.

LIST OF ACRONYMS AND ABBREVIATIONS

AO	Adaptive Optics
CCD	Charge Coupled Device
DCS	Detector Control System
DM	Deformable Mirror
FM3	Fold Mirror ‘3’ (actually the first mirror inside SWIFT)
GUI	Graphical User Interface
HODM	High Order Deformable Mirror
ICS	Instrument Control System
IFU	Integral Field Unit
IFS	Integral Field Spectrograph
LODM	Low Order Deformable Mirror
P3K	See PALM3K
PA	Position Angle (angle of minor axis of field North through East)
PALM3K	Palomar Adaptive Optics System (post-2011)
PALAO	Palomar Adaptive Optics System (pre-2011)
RTD	Real Time Display
SDSU	San Diego State University
Spaxel	SPAtial PIXel, referring to a single spatial pixel in the reconstructed data cube, to differentiate it from a single pixel on the CCD detector
SSM	Star Select Mirror
TBD	To be decided
TCS	Telescope Control System
TO	Telescope Operator
TTM	Tip-Tilt Mirror

1 APPLICABLE AND REFERENCE DOCUMENTS

1.1 Applicable Documents

The following documents at their indicated revision form part of this document to the extent specified herein.

AD1. None

1.2 Reference Documents

The following documents provide useful reference information associated with this document. These documents are to be used for information only. Changes to the date and/or revision number do not make this document out of date

RD1. None

2 GUIDER OVERVIEW

The SWIFT guider is a CCD camera mounted on-top of the PALM3K optical bench (Figure 1), which sees a small (~1x1 arcminute) field off-axis from the SWIFT field. It is used to provide guiding during SWIFT non-AO operations. The guider is capable of working with stars down to R=20.5, depending on sky brightness and seeing. Typical guide star magnitudes of R<17 are more comfortable. In typical conditions, the guider stabilises the image on SWIFT to <0.4" on timescales of 30-60minutes, but can drift (due to flexure) by ~0.5-1.0"/hr as the telescope tracks.

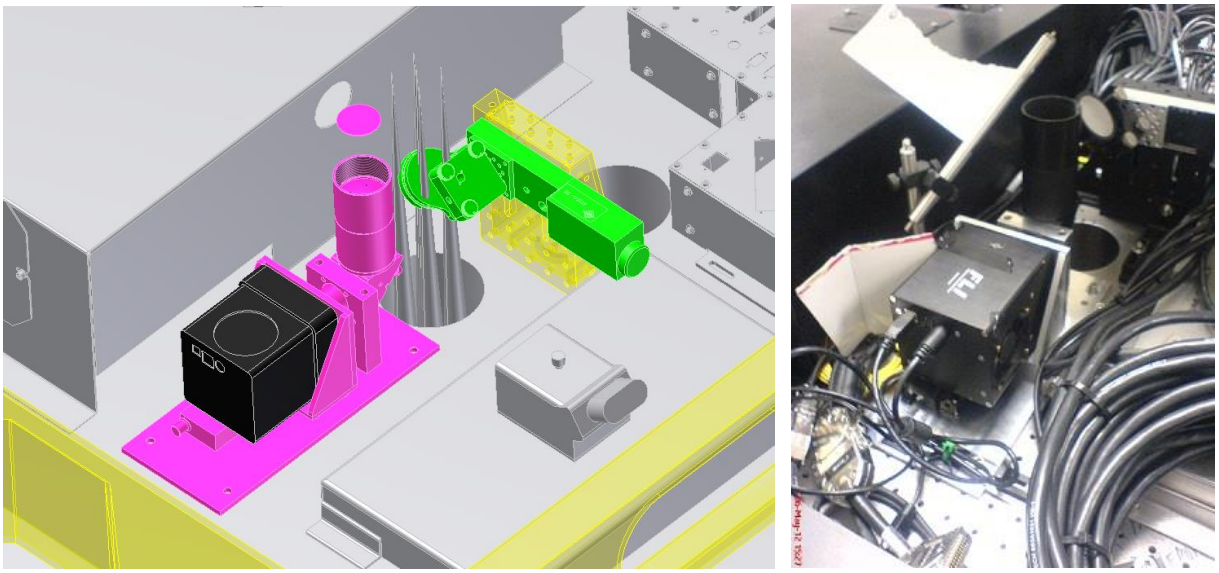

Figure 1 : CAD rendering (purple and black) and image of the guider installed on-top of the PALM3K bench.

The guider is controlled via the commercial/amateur CCD control software "MaximDL", which runs on a windows machine physically mounted on SWIFT. The ***guider is not directly linked to the SWIFT control software***, so starting/stopping the guider must be done manually. The observer can log into the windows machine via remote desktop from the SWIFT workstation.

Acquisition images from the guider can be saved (manually) and transferred to the SWIFT workstation. These can provide additional reference information for aligning science images post-facto.

The guider rotates with the SWIFT field, and can patrol a ~180 degree arc to pick-up guide stars. Figure 2 shows the patrol area, guider field, and SWIFT field relative to each other.

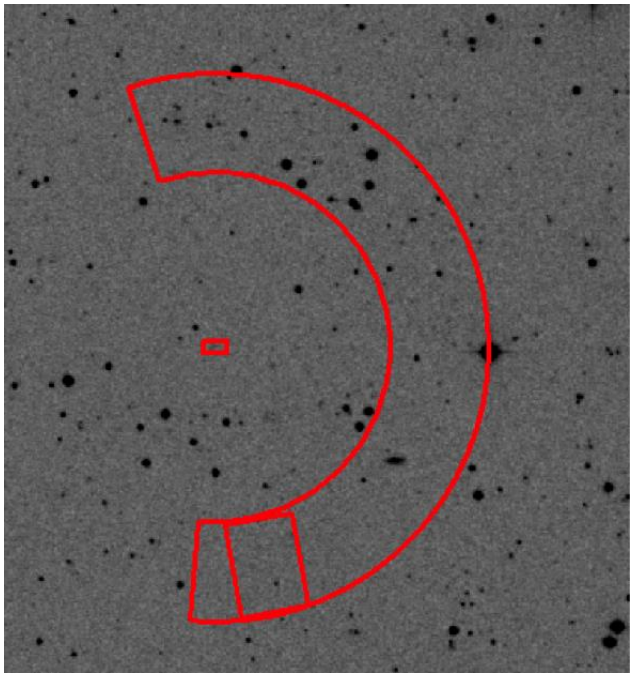

Figure 2 : Guider patrol field relative to SWIFT field

3 QUICK START GUIDE

This section provides a quick start guide to the guider. It is only intended as a reminder for experienced observers. Details on each step are provided later in the manual.

3.1 Before the run

- Identify potential guide stars using DSS images and the guider template. Check position angles required to get a guide star.

3.2 Each run / Daily

- Set detector cooling to -20C (should start automatically, but check)
- Take and process calibration files for
    - Darks
    - Biases
    - Flats (preferably at the position angle which will be used, if feasible)
- Run the astrometric calibration to determine the relationship between X/Y and RA/DEC

3.3 Each observation

- Take an acquisition image (5-20s)
- Click on guide star, or enter coordinates manually
- Start guiding
- Wait a few cycles (if feasible depending on exposure time)
- Stop guding at the end of the science exposure
- Offset telescope
- Reacquire guide star & start guiding

3.4 Morning shutdown

- Shutdown the cooling on the detector at the end of the run

4 GUIDER SETUP

4.1 Hardware setup

The guider hardware is an FLI ML8300 camera mounted on a focus stage. The camera is fed by a pair of doublet lenses, which image a ~90x60" field of view onto the camera. The whole assembly is mounted on a baseplate, which mounts to the top (telescope side) of the AO bench. Currently (Jan 2013) this is left permanently attached, so the only hardware set-up is to connect the power and signal cables to the swiftic computer mounted on SWIFT (small black computer mounted on the aluminium bridge).

4.1.1 Cabling

The cabling procedure during SWIFT installation is;

- Plug in the 4-way socket on top of AO to power the camera and focus stage
- Uncoil the USB (camera) and RS232 (focus stage) cables from the AO frame
- Plug the USB cable into the swiftic computer on SWIFT
- Connect the RS232 cable into the RS232 flying lead coming from swiftic

Reverse this for removing SWIFT.

4.2 Software setup

The guider is currently run from a windows machine mounted on SWIFT. This machine is called "swiftic" and has the IP address 198.202.125.175. To log into the machine from swiftlcu or swiftws, use the Remote Desktop programme as described below. Once on swiftic, the guider is controlled with MaximDL software package.

4.2.1 Remote Desktop

The remote desktop connection tool is available for Windows, Mac and Linux. On linux (e.g. swiftlcu and swiftws), it is accessed via a command line prompt "rdesktop". There are lots of configuration options, but a generic command line which should work well is;

```
rdesktop 198.202.125.175 –u swift –d swiftic –g1600x1024 –r
sound:local:oss &
```

This should bring up a new window with a login prompt. Password is the same as usual. You're then logged into swiftic, which is running Windows 7. On swiftws, the above command is wrapped up into a shell script;

```
goswiftic.sh
```

4.2.2 MaximDL

MaximDL is an amateur astronomy programme which provides good guiding facilities. We have developed a driver which allows the programme to talk to the P200 telescope control system, and therefore send guiding commands to the telescope.

4.2.2.1 Connecting the camera

- Open the “Camera Control” window (in the View menu)
- The camera should be set-up by default, so click “connect”. If the camera doesn’t connect, check that “FLI Camera” is listed under “Devices and Printers” on the start menu. If it is not, it probably isn’t powered on, or the USB isn’t properly connected. Check the connections. You may need to restart MaximDL to get it to pick up again.
- Turn on the coolers, which sets the cooling on the chip to -20C to reduce the dark current

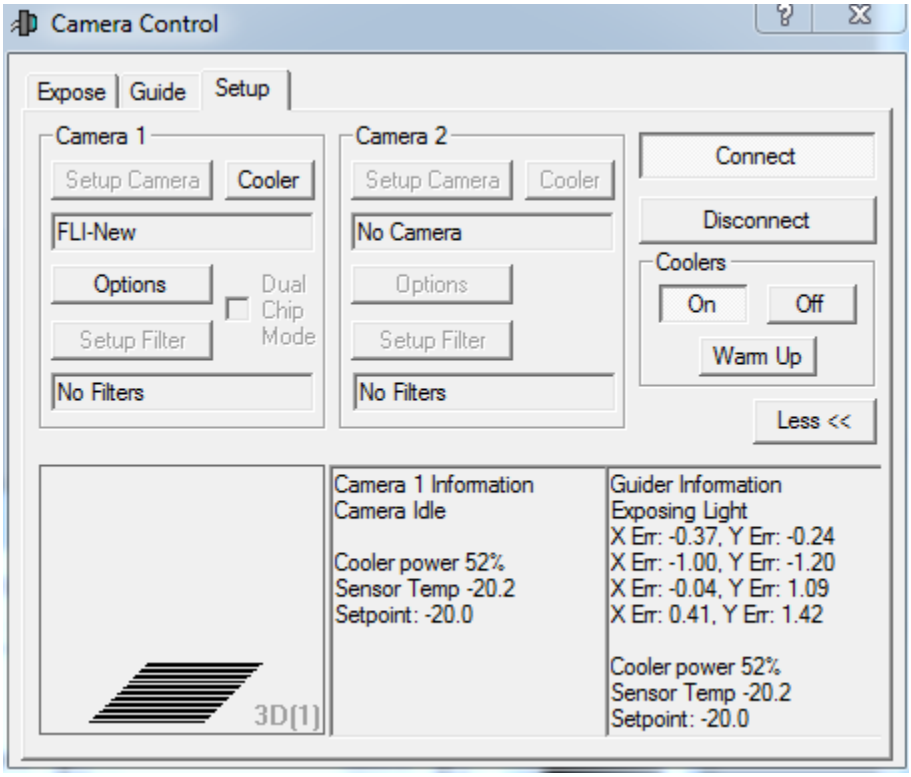

Figure 3: Camera Control setup window. Click "connect" should connect to the FLI CCD. Click "Coolers - On" to turn on cooling at the start of the night.

4.2.2.2 Connecting the telescope

- Open the “Observatory Control” window (in View menu)
- Go to the “Setup” tab, and click “connect” on the telescope box in the top-left. It should already be displaying “Palomar 200-inch TCS” as the Telescope (see Figure 4).
- This should open up another window, which is used for guider status commands from the driver. The TCS information (i.e. pointing) should now be displayed in the “Telescope” tab.

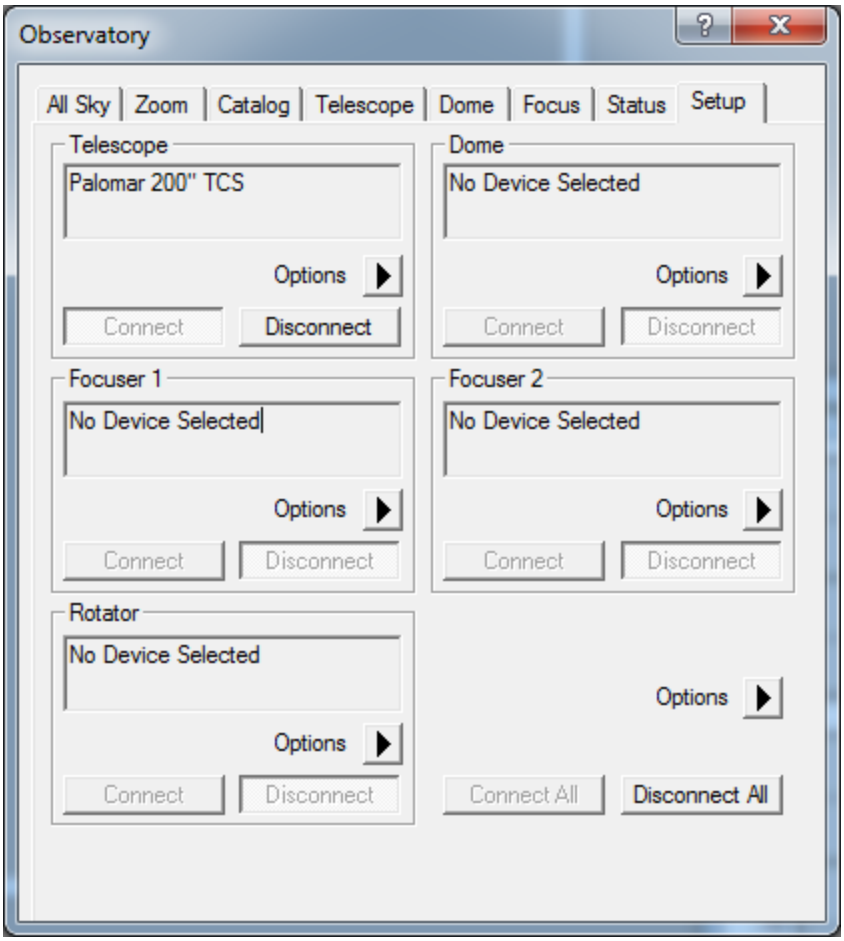

Figure 4: Observatory Control Window setup box. Click connect on Telescope with Palomar 200-inch TCS.

4.3 Calibration and Configuration

The guider requires some calibration (bias/dark/flat) and configuration (astrometric "calibration" to set the X/Y vs RA/DEC relationship). These should be done at least at the start of every run, and ideally more regularly.

4.3.1 Astrometric Calibration

The guider needs to be calibrated so that it can convert measured x-y pixel shifts of the star into ra-dec offset requests to the TCS. This should to be done at least ***once per run***, and ideally every time the position angle of the instrument is changed (though see below for a quick workaround). It's best to do this on a bright guide star which only needs 2—5s exposures. The star should be away (>40 pixels) from the edge of the chip.

- Pick a bright guide star and take an exposure in the guide tab
- Click on the star
- Select "calibrate" and click start

The software will now move the telescope in ra and dec, and measure how much the star moves. If all runs successfully, it will draw a small red right-angle on the guider window (Figure 5). After five exposures, the guider is calibrated.

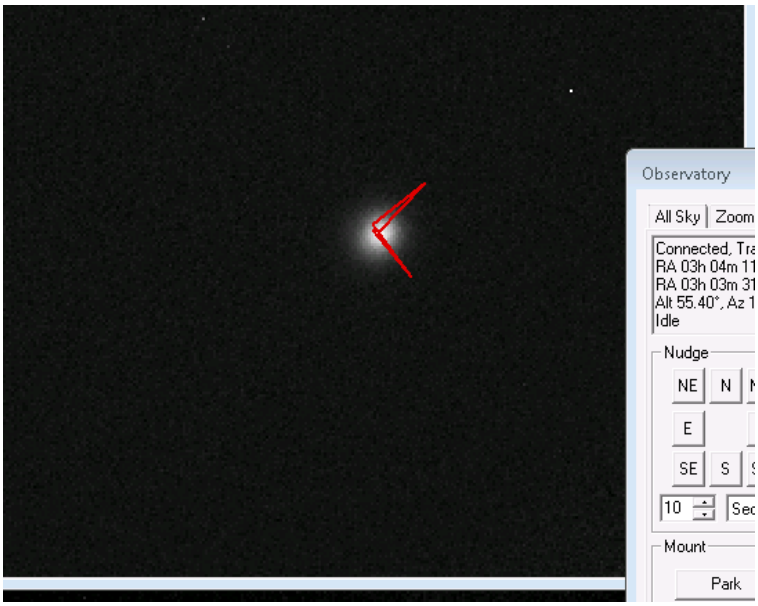

Figure 5: Red rectangle drawn on image by a successful astometric calibration of the guider. The angle of the rectangle depends on the cass ring angle.

4.3.2 Image calibration exposures

Confusingly named… nothing to do with the 'astrometric' calibration above. The guider has a set of stored calibration files (biases, darks and flats) which it automatically applies to the guider image. These calibrations probably need to be redone once per run at most.

4.3.2.1 Taking calibrations

There are several scripts to take calibration images;

```
C:\Data\darks_8x8.seq
C:\Data\darks_16x16.seq
C:\Data\twilight_flats.seq
```

These can be loaded by clicking on "Autosave" on the expose tab of the camera control window (Figure 6), which brings up the autosave sequence window. To load a predefined sequence, click on the arrow next to "options", and select "load sequence" (Figure 7). Once loaded, click "OK" and then "Start" on the camera control window. This will execute the sequence and automatically save the files. The dark sequences include biases exposures.

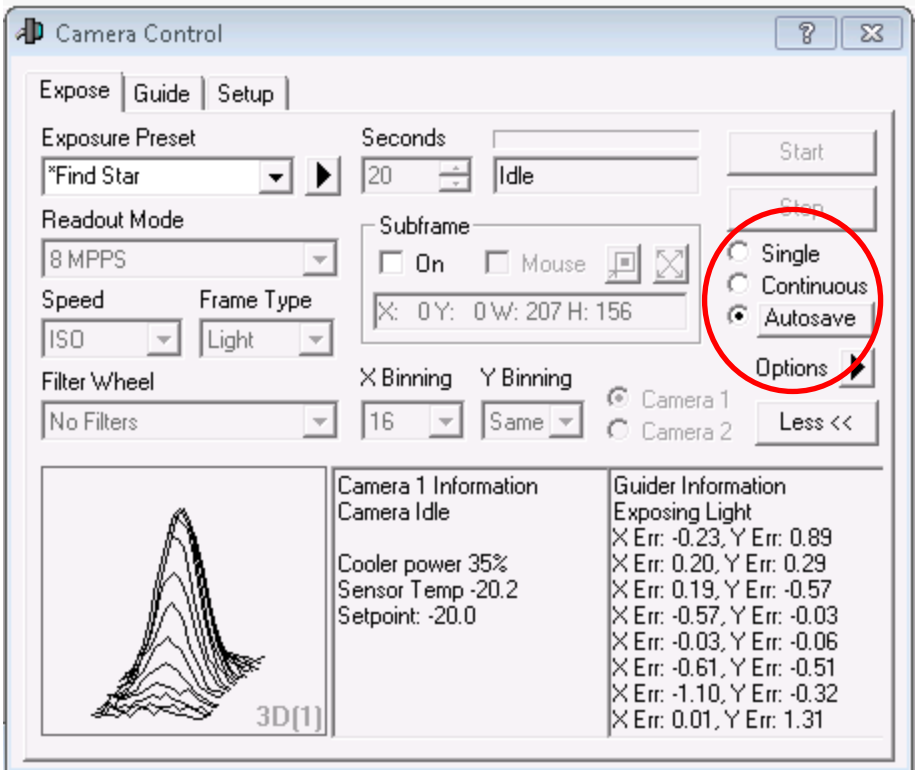

Figure 6: Expose tab of the camera control window. Click on "autosave" to load the autosave sequence menu. Remember to click back onto "single" when you want to take a normal single exposure.

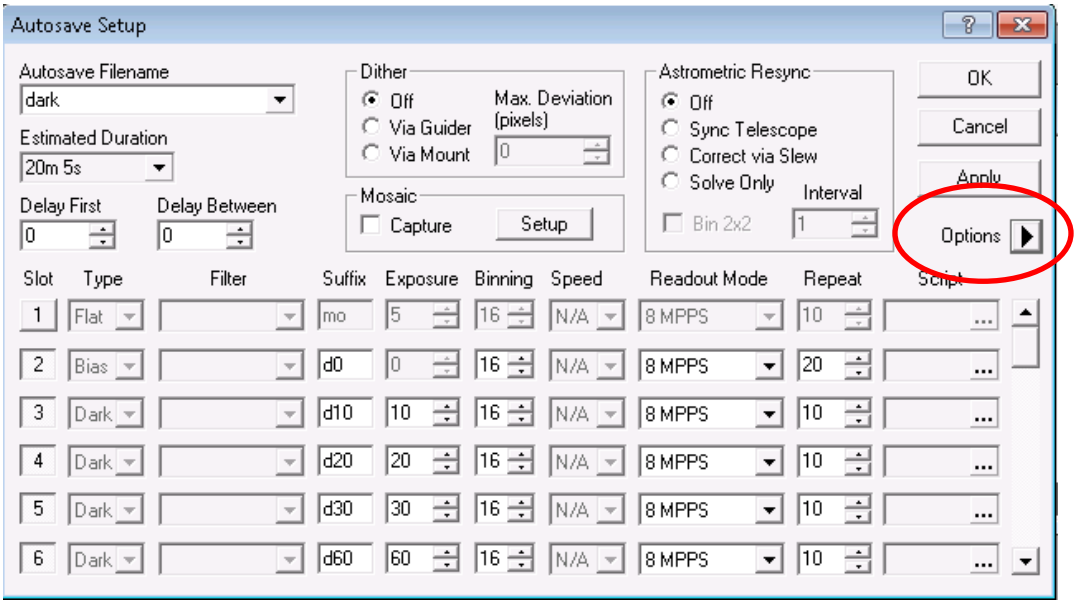

Figure 7: Autosave setup menu. To load a predefined sequence, click on the arrow next to "options" and select "load sequence" from the drop down list. Click "OK" to close the window.

4.3.2.1.1 Darks and Biases

The dark/bias sequences take about 20 minutes to run.

4.3.2.1.2 Twilight flats

The twilight flat sequence should be run when the twilight flat produces a background of ~40,000 counts in a 2 second exposure in 8x8 binning. You can use the “single exposure” mode to test for this. It seems that is usually around 6 degree twilight.

The `twilight_flats.seq` file will then take flats in 8x8 and 16x16 binning.

Note that the flats are only valid for the cass ring angle they were taken at. However, the major flat field contribution is the vignetting, which is rotationally symmetric. In most cases, the default flats will work well enough at all ring angles. You may need better flats (i.e. specifically for the ring angle used) if you’re observing in bright time.

4.3.3 Processing calibrations

Once you have taken calibration images, they need to be loaded into the default calibration database. To access this, go to “Process->Set Calibration”, which will show the currently active calibration images (Figure 8). To add new images, click “Add Group”, but first selecting the type of group (Bias/Dark/Flat). Then click “Add” and add the relevant files to the group. Once you’ve added all groups, click “Replace with masters”. This should combine the individual files to make master calibration images.

You can clean up old calibrations by either “Remove group”, or by deselecting them in the list.

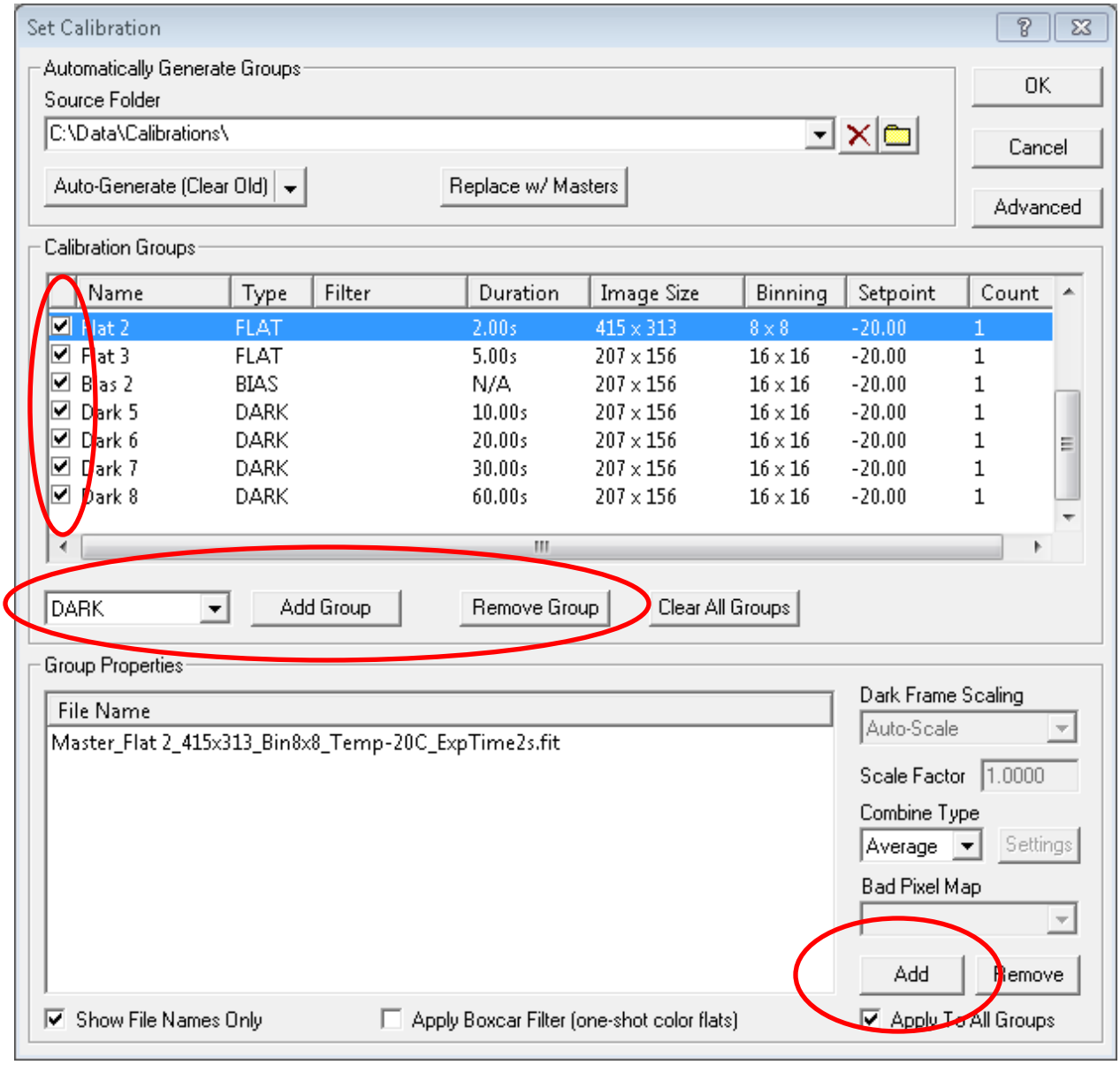

Figure 8: Automatic calibration file database. Files in use are selected with a tick on the left.

The guider should now be ready for use.

5 OBSERVING WITH THE GUIDER

5.1 Finding guide stars (pre-run)

The guider has a relatively small field of view, so it is best to confirm before the run that guide stars are available for your targets beforehand. The easiest way to do this is via ds9[1] and the associated guider field of view template ("`SWIFTGuiderRegion.tpl`");

```
# Region file format: DS9 version 4.1
# composite(0,0,359.84039) || composite=1 color=red width=3
box(0.0045014971,0.019493888,22",11",359.84039) ||
panda(0.0045014971,0.019493888,265.84039,469.84039,1,168.00005",2
64.00037",1) || # color=red width=3
box(359.991,-0.038987771,90",65",280) # color=blue width=3
```

To place find guide stars for a given target with ds9, use the following steps;

1. In ds9, go to `Analysis->Image Servers->SAO-DSS`. (or another DSS server if you prefer)
2. Enter the coordinates of your object, and select a width/height of 10 arcminutes
3. Click Retrieve. This will download a DSS image to the screen, hopefully with your object in the middle!
4. In the main ds9 window, go to `Region->Template->Load`. Select `SWIFTGuideRegion.tpl` from the file selector. This will load up a red shape overlay on the image, showing the SWIFT field of view, the guider field of view, and the patrol field (Figure 9).
5. Rotate the field of view until a guide star is available within the guider field of view;
    a. Double click on the red shape to open its properties window
    b. Edit the Angle field to set the position angle of the SWIFT field, which will also move the guide box within the 'C' shape patrol field
    c. Move the whole shape back to be centred on the science target (click and drag on the red shape). Unfortunately changing the angle moves the whole shape!!
    d. Iterate until you have a suitable guide star within the guider box. Note the angle, you will need to set this is as the *position angle* of the instrument. Remember that *Position Angle = Cassegrain ring angle – 100.9*
    e. Be cautious of objects near the edge of the guider field, as the exact alignment between the guider and the science field may change from run-to-run.
6. The guider can generally guide on any object visible in the DSS images (R~20.5), though it may need brighter targets during bright time (R<18.0).

[1] http://hea-www.harvard.edu/RD/ds9/site/Home.html

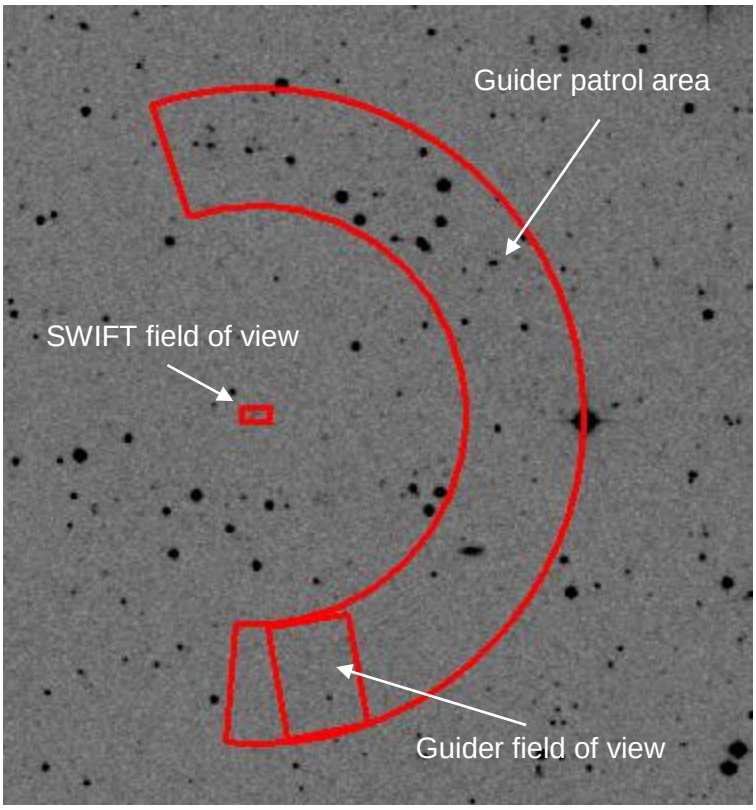

Figure 9: SWIFTGuiderTemplate.tpl for ds9 plotted on a faint target. The SWIFT field of view (235mas scale) is shown by the small rectangle in the centre. The 'C' region is the total area available to the guider. The larger rectangle is the guider field of view and location at the default position angle.

5.2 Guiding

This section assumes you have set-up and connected the guide camera as per Software Setup section above.

Open the camera control window in MaximDL via View->Camera Control Window, which opens the window shown in Figure 10

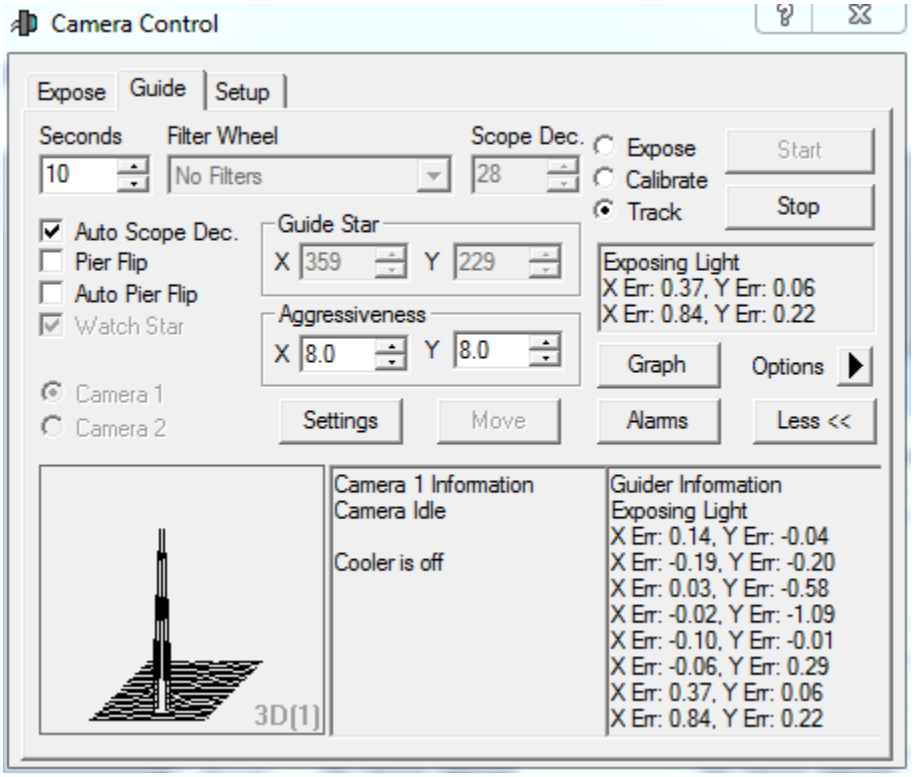

Figure 10: Guider control tab in the camera control window.

Go to the “Guide” tab in the camera control window (Figure 10). Assuming the guider is calibrated;

- Click the “expose” radio button and chose an exposure time (5 or 10s is a good starting point).
- Take an exposure (click ‘start’) and look for any guide stars. Increase the exposure time up to 60s if you need. At 60s, in OK seeing and not too close to the moon, you should be able to see R=20.5 galaxies and guide on them.
- Click on the core of a suitable guide star, which should change the values in the Guide Star X and Y boxes (you can set these boxes manually, if you wish to return the guider, and hence instrument, to an exact location).
- Click on the ‘track’ radio button, and click Start.
- Click on the “graph” button to display a graph of the x-y guiding errors (Figure 11). The Y and X scale of the plot can be adjusted as appropriate.

Remember to stop guiding when you want to move the telescope!

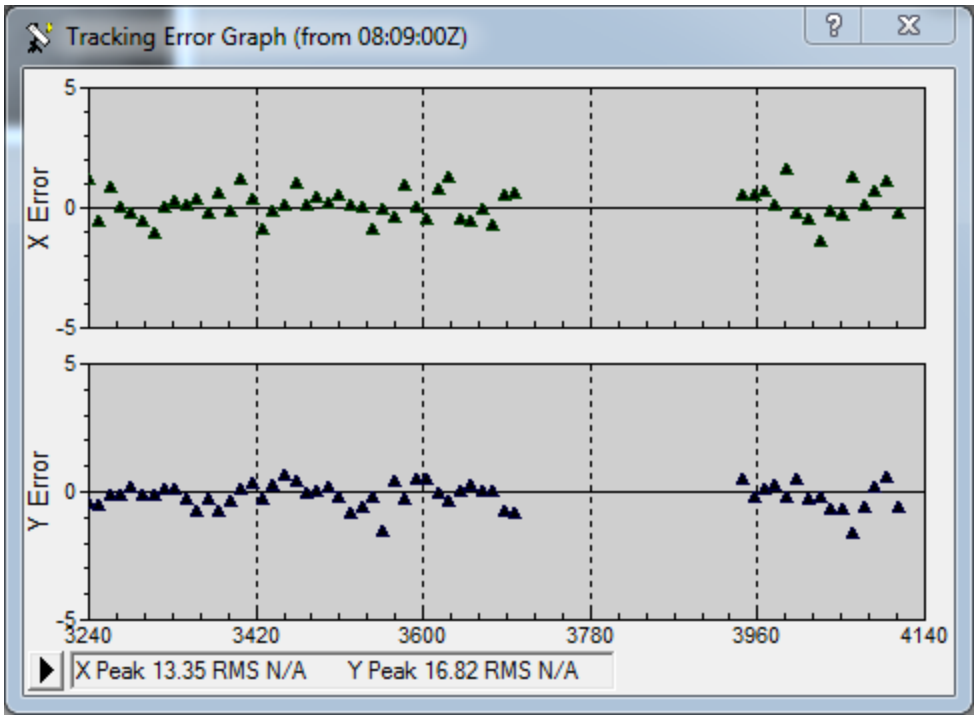

Figure 11: A tracking graph. The gap between the two sequences was for an offset between frames

5.3 Hints and tips

Below are some hints and tips for using the guider during science observations. We assume the guider is properly calibrated (both image calibration and astrometric calibration) as described above.

This procedure seems to work well for general use.

- Acquire target and guide star
  - Slew to the target and acquire roughly in the AO/SWIFT
  - When you are happy with the location of the object in SWIFT, take a 5—10s exposure with the guider to identify guide stars.
  - If there aren't stars, expose longer (20,30 or 60s)
- Start tracking
  - Click on a star; make sure the click is as close to the centre of the star as possible (alternatively, enter previous guider X and Y coordinates manually)
  - Click on "track" and "start"
  - Note down the guider X and Y coordinates for future reference
  - If exposure time is short enough (<20s), wait for a few cycles for the guider to stabilise
  - Start exposing on SWIFT
- At the end of the exposure
  - Stop the tracking once SWIFT is reading out (remember that you must ***stop the tracking before offsetting the telescope***!)

    - Confirm pointing
        - Take a long 'pointing' exposure with the guider (typically 60s, unless there are very bright stars in the field)
    - Save the pointing file with some reference to what the science exposure is. These deep images can be used later to make sure the science frames are properly aligned.
- Offsetting
    - If a small offset (<2") is needed, modify the guide X and Y positions by hand and restart tracking.
    - If a larger offset (>2") is needed, it is best to ask the TO to move the telescope and repeat the acquisition image with the guider.

5.3.1 Small Offsets

You can make small, precise offsets with the guider by manually moving the centre of the guide box. To do this;

- Stop guiding
- Edit the guider X and Y coordinates;
    - Increasing X by one pixel moves the *telescope* ~0.22" North (at default PA). This corresponds to moving the *object* across the image slicer (to higher Y values on the RTD images)
    - Increasing Y by one pixel moves the *telescope* ~0.22" East (at default PA). This corresponds to moving the *object* along the image slicer (to lower X values on the RTD images)
- Restart guiding

5.3.2 Changing the position angle

The x/y->ra/dec calibration of the guider depends on the position angle of the cassegrain rotator. Ideally one would recalibrate the guider (see section 4.3.1 above) when the position angle is changed to make sure it is correct. The software does however include a function to change the angle of the guide calibration manually, and this can be used to save time. Figure 12 and Figure 13 show how to change this parameter.

Note the guider angle *does not equal the cass ring angle* (it should be ~180 lower than the cass ring angle). Note also that the screen grabs are not from the SWIFT set-up, so other parameters are different from the ones you will see.

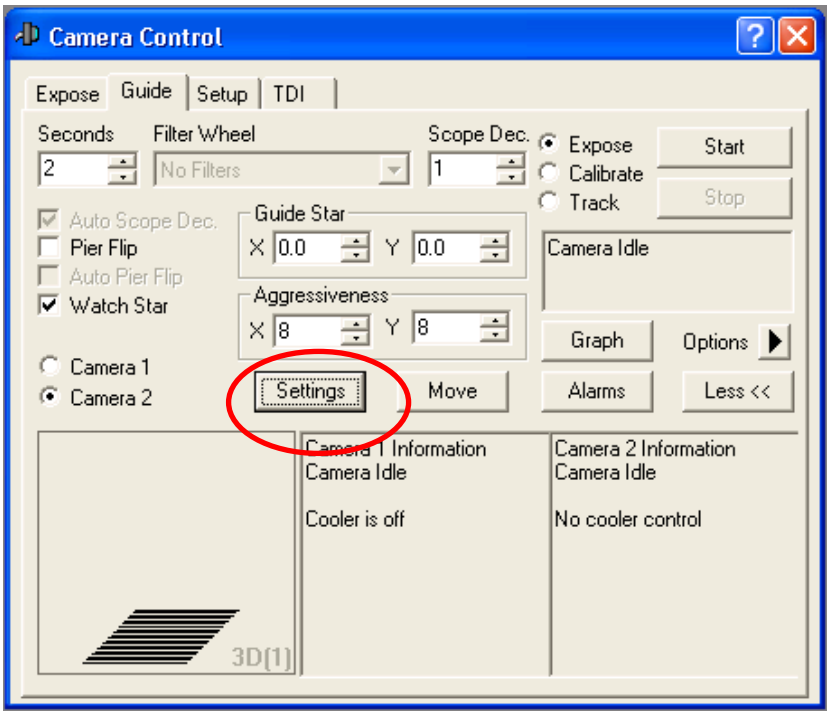

Figure 12: Guider set-up tab in Maxim camera control window. Click on "settings" to access advanced set-up features for the guider.

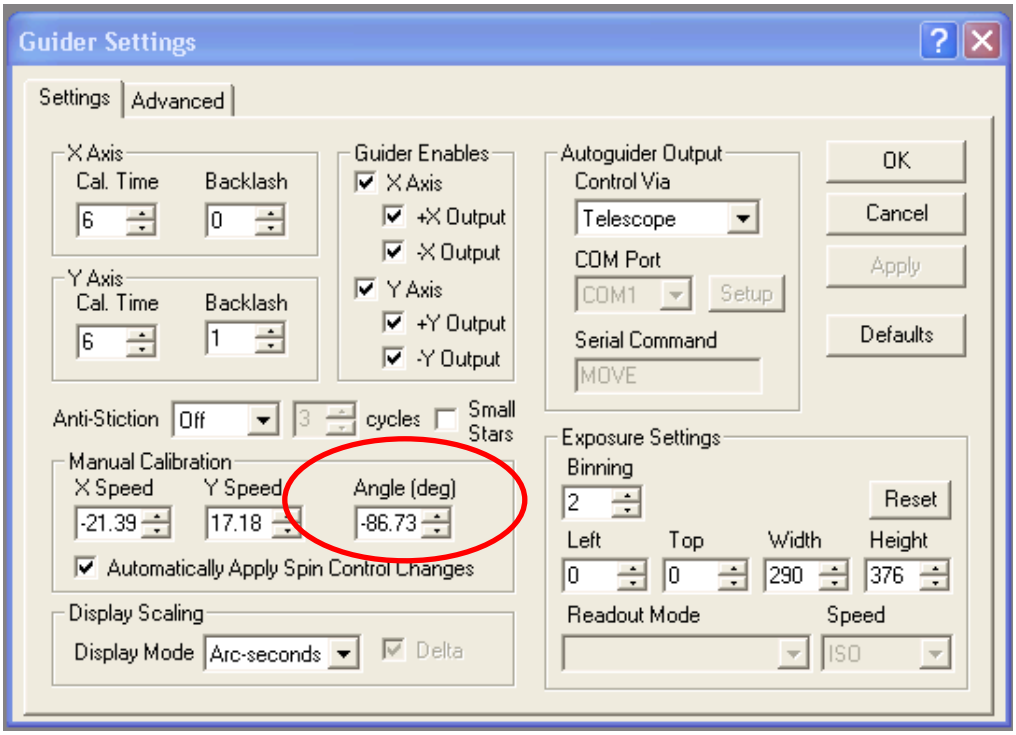

Figure 13: Guider settings tab. To change the guider calibration for a new cass rotator angle, change the value in "Angle (deg)" box by the amount of change in the cass rotator angle.

5.3.3 Coming back to the same place

The guider provides a useful reference to make sure you come back to the same place (within the limits of differential flexure, which seems to be on the order of 1”/hour). Before you move away, note down the X and Y position of the guide star. Then, when the telescope is back roughly in position, manual enter the previous X and Y positions in the guide X and Y boxes, and start tracking. If the star is within ~25 pixels (5 arcseconds) of the position, it will pull the star, and hence the telescope, back to the previous location. It usually takes 5-10 iterations to settle, depending on the size of the correction. Check the guide graph to see when the residuals approach zero.

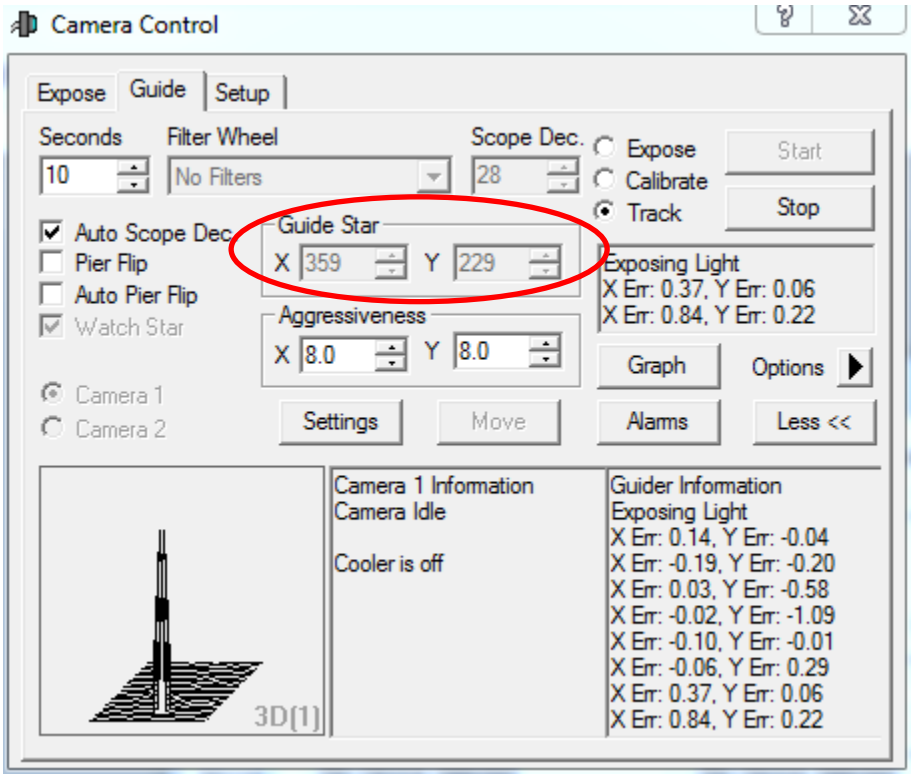

Figure 14: Guide Star X and Y position can be manually entered (when not tracking) to ensure the guider (and hopefully SWIFT!) come back to the same place after an offset.

5.3.4 Astrometric reference images

The guider can provide useful information for post-combining observations of faint targets, or building mosaics of large fields. Stop guiding, and take a 60 second exposure whilst the main camera is reading out. You will have to save these images manually and copy them off the swiftic. By default they will be saved in;

```
C:\Data\YYYY-MM-DD\
```

You must save each image manually though!

If you started up the connection to swiftic from the icon on the swiftws desktop, you should see a “Data on swiftws” directory under “Computer” in windows explorer. This directory is mapped to /home/swift/data/GuiderImages/ on swiftws, so you can easily copy over astrometric reference images to swiftws.

5.3.5 Bad seeing

In poor seeing (>2”), it is worth increasing the guider binning to 16x16 to increase the sensitivity. To do this, go to “Settings” in the guider tab, and change the binning in the “exposure settings” section (Figure 15).

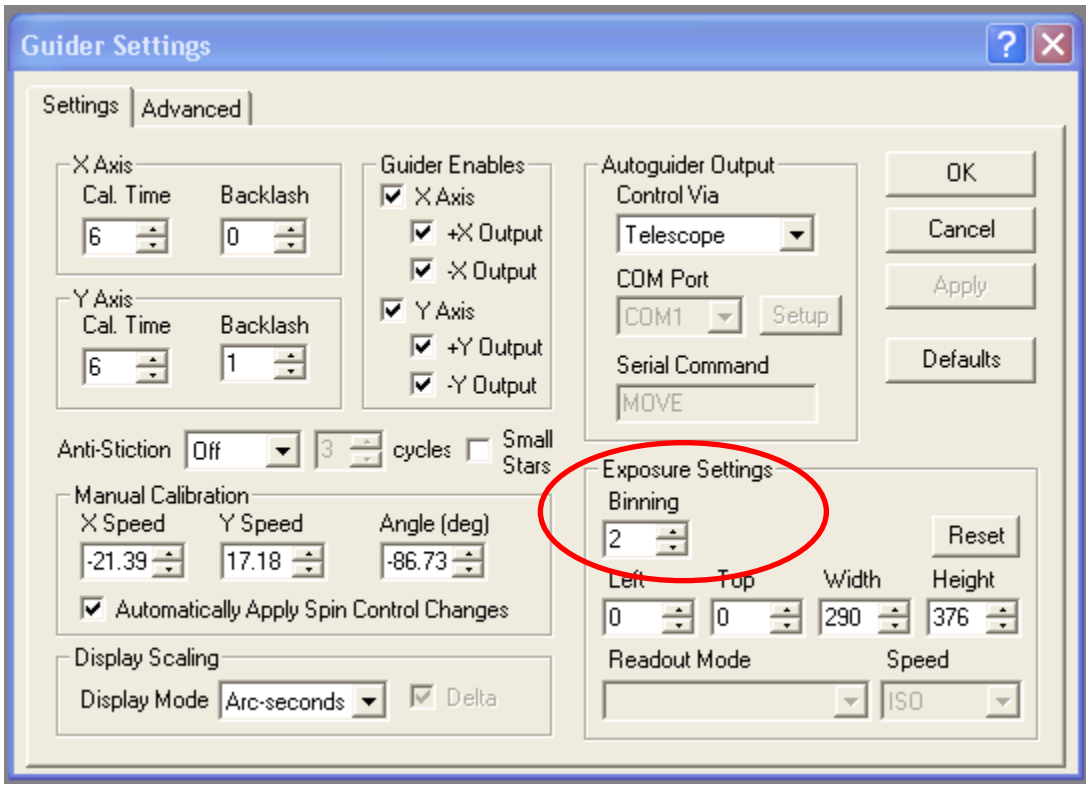

Figure 15: Changing the binning on the guider can help in poor seeing conditions. Choose 8x8 (default for good seeing) or 16x16 (>2" seeing). Note, this screen grab is not from the SWIFT guider, so values here are different.

6 SPECIFICATIONS OF GUIDER

As measured on sky, very roughly.

6.1 Field of view

The guider field of view is ~88 x 66 arcseconds, rotated at an angle of 10 degrees north thru east (at the default position angle of SWIFT; cass_ring=100.9 degrees). The fully illuminated field of view is a circle around the detector centre with diameter of ~70 arcseconds. Outside of this, flux drops off quickly as does the image quality.

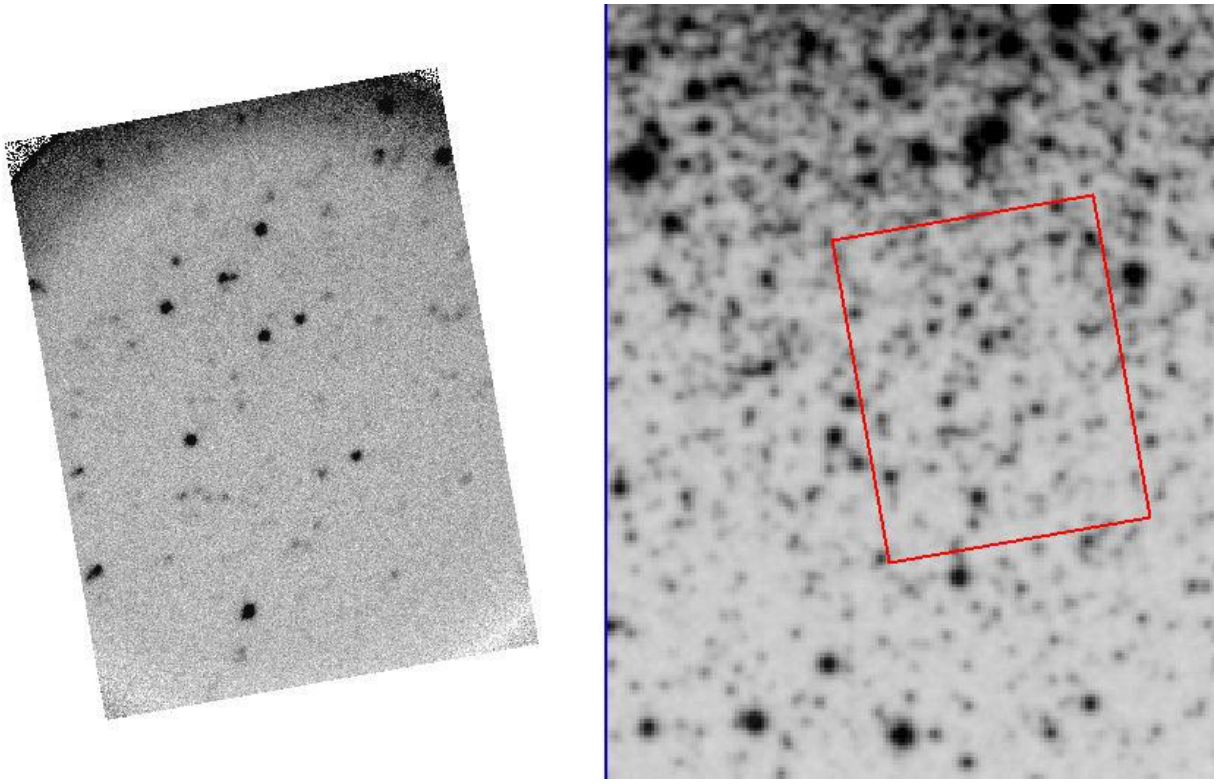

Figure 16: SWIFT guider FoV in the outskirts of M92. Guider image (left) compared with a DSS image. Astigmatism towards the edge of the guider field is obvious, and is an artefact of the simple optical design of the guider. This shows the orientation at the default position angle of the guider (cass ring at 100)

The guider is located ~3.5 arcminutes south-west of the SWIFT field of view (centre ~210" S and 40" W), at the default position angle. Increasing the position angle on SWIFT (increasing the cass_ring angle) swings the guider to the North-West of the central field. The total range of the cass_ring for SWIFT is 90 degrees to 290 degrees, with the default position angle (N up, E left) at 100 degrees ring angle. There is a ds9 template file ("SWIFTGuideTemplate.tpl") available to overlay on DSS images, which helps identify guide stars;

```
# Region file format: DS9 version 4.1
# composite(0,0,359.84039) || composite=1 color=red width=3
box(0.0045014971,0.019493888,22",11",359.84039) ||
panda(0.0045014971,0.019493888,265.84039,469.84039,1,168.00005",2
64.00037",1) || # color=red width=3
box(359.991,-0.038987771,90",65",280) # color=blue width=3
```

In the display on MaximDL, the field is displayed pixel (0,0) in the top-left corner. At the default position angle, North/South runs ~left/right on the display, and East/West runs up/down.

6.2 Plate scale

The pixel scale in the default 8x8 binning mode is about 0.22” per pixel.

6.3 Sensitivity

Using a 60s exposure, we’ve been able to guide on 20th magnitude galaxies in dark time. 16th mag or brighter is a much more comfortable guide magnitude!

6.4 Typical stability

In most locations on the sky, for most guide stars, the guide trace should be stable to ~+/-1 pixel (~0.4 arcseconds). Faint stars or large hour angles can be worse.

7 TROUBLESHOOTING

7.1 MaximDL hangs up completely

This is usually caused by a communications problem with the camera. Disconnect the camera from the USB redirector client, and Maxim should come back to life. Reconnecting the camera then seems to work fine. You will have to “disconnect/reconnect” the camera in Maxim too.

[NOTE – This really shouldn’t happen anymore!]

7.2 Can’t connect to camera in Maxim

Check the USB connection to the camera. You may need to restart Maxim as well.

7.3 Maxim asks for admin password

It’s trying to update something in the registry… You should be able to give it the usual admin password.

[NOTE – This really shouldn’t happen anymore!]

7.4 Guider doesn’t stabilise/converge

Check that the guider calibration is correct for the rotation angle of cass. Also check that the TCS is receiving guider offset commands.

7.5 Guider image looks cruddy

The calibration images are possibly out of date, or you are using a binning other than 8x8 or 16x16. Change to default pixel scales and/or regenerate the calibration images.

7.6 'one or more of the master frames is corrupt’

This is a rare error which seems to be generated if one of the calibration frames is corrupted for whatever reason. Solution just seems to be to retake the calibration (dark/flat) frames and reprocess them.

7.7 Object did not come back to the same place the next night

The guider is just a guider, not a proper acquisition camera. There is differential flexure at the level of ~1”/hour. The guider should not be used to accurately acquire objects on the IFU field of view, particularly if observing at different hour angles.