Welcome to GoQat!

(Last updated: 28 November for version 1.0.2)

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Throughout this document, the following formatting conventions are applied:

The main body of the text appears like this.

- Items that may be incidental to the main flow of the text but which are worthy of attention appear like this.

Items that are important and require particular attention appear like this.

1. Disclaimer

Please read this document carefully and familiarise yourself with the terms of the GNU General Public License (GPL) before using GoQat. Remember that you use GoQat at your own risk. By using GoQat, you are accepting the terms of the GPL, in particular that this program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details.

For further information on compiling and installing GoQat, please see the README file that came as part of the GoQat package.

2. Introduction

Thank you for using GoQat! GoQat is expected to perform as follows:

- Run on Linux-based systems
- For imaging: drive any amateur astronomy CCD camera from Quantum Scientific Imaging, or any CCD camera from Starlight Xpress that uses the USB 2.0 interface. (Please note that this release does not support the add-on serial ports available via the 18-pin connector on some Starlight Xpress cameras).
- For autoguiding: drive any Starlight Xpress USB 2.0 camera (including the Lodestar and related devices), video-for-linux (V4L) video devices including webcams, any camera fully supported by the Unicap API (which includes webcams and the popular astronomy video cameras from The Imaging Source) and any of the low-light video cameras such as Watec or Mintron via the Imaging Source video-to-firewire converter.
- Record continuous or time-lapse video from any of the autoguider cameras supported via the Unicap library. Combining a Watec or Mintron device with a GPS video time inserter gives an excellent way to record asteroid occultations or monitor other transient events.
- Provide autofocus capability using Robofocus.
- Communicate with a telescope controller via Meade Instruments Autostar/LX200 protocol for basic telescope control. More advanced features from the Losmandy Gemini system are also supported, such as loading and saving pointing models and periodic error correction data.
- Send guide signals via the port on cameras such as the Lodestar or QSI cameras, via serial commands to a telescope controller or using TTL levels from a parallel port.

An up-to-date hardware compatibility list is maintained on the GoQat website.

3. Getting Started

For ease of use, you may wish to set up a shortcut using the GoQat icon that is provided as part of the distribution. Alternatively, start GoQat by typing 'GoQat' at the command prompt in a terminal window.

When GoQat starts, you will see the main window. The window consists of a menu bar and button bar at the top, with a number of tabbed pages in the centre. A scrollable and colour-coded message logging area is below that, with a status bar at the bottom. The window is re-sizable in the usual way. The CCD Camera, Autoguider and Focus tabs are greyed-out initially. The Gemini parameters tab is greyed-out unless you select to use Gemini commands.

GoQat communicates with you via the message log pane. Messages are colour coded:

Action messages (such as informing you that a CCD exposure is being made) are in blue

Warning messages are in orange

Error or urgent messages are in red

Information messages are in magenta

Text returned from scripts executed with the Exec task are in green

GoQat is quite talkative so please keep an eye on the message log!

4. Configuring Your CCD Camera

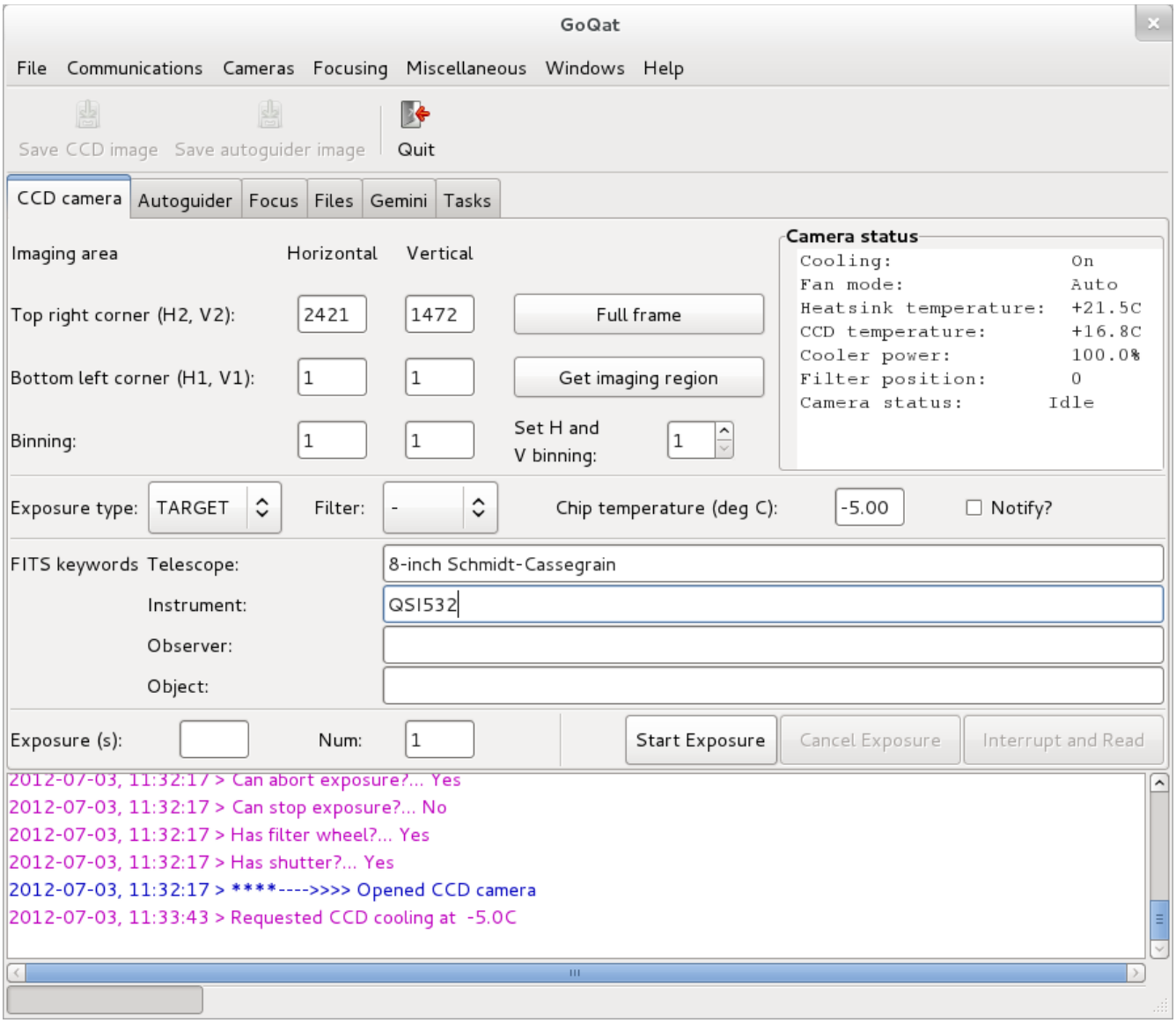
4.1 Connecting the camera

Follow the instructions that came with your QSI or Starlight Xpress camera to power up the camera and connect it to your computer. (For the rest of this documentation, SX will be used as an acronym for Starlight Xpress).

You do not have to load or configure any additional drivers. For QSI cameras you should have compiled and installed the QSI library already; Starlight Xpress cameras have the necessary driver code built into GoQat.

Choose the camera type (QSI or SX) from the 'Cameras | CCD Camera type' menu. The available camera types will depend on the libraries that were installed when you compiled GoQat If you have more than one QSI or SX camera connected to your computer, choose the 'Cameras | Select CCD camera...' option. The detected cameras will be presented as a numbered list in GoQat's message log. Select the number of the desired camera in the pop-up dialog box and click OK. Then click the 'Cameras | Connect to CCD camera' checkbox to open the camera. If you have only one camera connected to your computer, you can click this checkbox immediately; you do not have to select it via the 'Cameras | Select CCD camera...' option first.

GoQat should connect to your camera, and the CCD Camera tab should look something like the following screenshot. This screenshot is for a QSI camera; for an SX camera, there is a reduced number of items shown in the 'Camera status' panel.



The next thing to do is configure the settings for your camera.

4.2 Configuring a QSI camera

Select 'Configure CCD camera...' from the Cameras menu. The CCD camera configuration dialog box will open. This dialog box allows you to configure all your camera settings. Any changes to settings that you make in the configuration dialog box will be applied automatically next time GoQat connects to your camera. Settings are remembered on a per-camera basis, so if you have multiple cameras the appropriate settings will be applied depending on the one that you have connected to.

- Not all of the settings may apply to your model of camera. If you try to apply a setting that your camera does not support, you will receive an error message. In this case, you should set the '-' option.
- Please note that the configuration dialog box is a 'modal' dialog; you must close the dialog before you can interact with any other parts of GoQat.

Adjust any settings as follows:

4.2.1 Cooler Operations

- Check the 'Start cooler automatically' checkbox if you want the cooling to start as soon as GoQat connects to the camera.
- Enter a value for the desired target cooler temperature and click 'Set default'. This also alters the value in the 'Chip temperature' field on the CCD Camera tab, but you can change this independently of the default setting if you wish. The target temperature is the value that the chip will be cooled to when GoQat next connects to the camera, if you have chosen to start the cooler automatically.
- If you want to start or stop the cooler manually, click the 'Cooler on' or 'Cooler off' buttons. You must click the 'Set default' button before you start the cooling, if you have entered a new value for the default target temperature.

4.2.2 Fan Control

- Choose the desired fan state:
- 'High' runs the fans permanently at full speed.
- 'Auto' runs the fans at low speed by default but will change to high speed if the cooling requires it.
- 'Off' turns the fans permanently off.

The 'Off' state may be beneficial if you are using liquid cooling – in this case the fan motors may just be an additional heat source!

- Click the 'Set fan state' button to apply your chosen state.

4.2.3 Exposure Control

In this section of the dialog box you choose one of a number of settings for each item, and then click the corresponding 'Set' button to have it take immediate effect. Otherwise the setting won't be applied until you next connect to the camera. If you don't wish to change the default setting, or your camera doesn't support a given setting, then choose the option indicated by '-'. All of the settings are set to '-' initially. If you set an option that isn't supported by your camera you will see an error message in the message log when you click the 'Set' button.

The items are as follows:

Item	Option	Effect
Shutter priority	Mechanical	Shutter only opened for object and flat-field exposures, otherwise shutter is closed
	Electronic	Shutter only closed for dark frame and bias exposures, otherwise shutter is open (this allows for fastest back-to-back object exposures)
Shutter mode	Automatic	Shutter is under automatic control
	Manual	Shutter may be opened and closed independently of exposures
Manual shutter	Close	Close the shutter
	Open	Open the shutter
Pre-exposure flush	None	No pre-exposure flushing of dark current
	Modest	One flush cycle
	Normal	Two flush cycles
	Aggressive	Four flush cycles
	Very aggressive	Eight flush cycles
Fast exposure mode	Off	Do not allow the next exposure to begin while the current one is being downloaded
	On	Do allow the next exposure to begin while the current one is being downloaded (useful for fast sequences of exposures e.g. guiding applications)

NOTE:

- The shutter options apply only to those cameras with mechanical shutters
- The description of the pre-exposure flush cycles applies for cameras with Kodak (KAF) chips
- Fast exposure mode applies for interline cameras only

4.2.4 Miscellaneous

These settings are altered and applied in the same way as for the Exposure

Control options. The items are as follows:

Item	Option	Effect
Camera gain	High	Gives greatest sensitivity
	Low	Enables better capture of full dynamic range for binned image
Readout speed	Low	Gives least readout noise for high quality images
	High	Gives fastest readout speed (with higher noise) – good for focusing
Anti-blooming	Normal	Normal anti-blooming
	High	High anti-blooming

NOTE:

- The camera gain option applies only to those cameras that support it
- The readout speed option applies to 600-series cameras only
- The anti-blooming option applies only to those cameras that support it

4.2.5 Filters

If your camera has an in-built filter wheel, you need to specify which filters are in which positions in the wheel. If you have multiple filter wheels that you will exchange as required, you can enter the filters for more than one wheel.

- Select the wheel number (start with '1' if you have just one wheel)
- Select the filter for each position. If there is no filter in a particular position, pick 'NONE' from the list. If there is no corresponding filter position in your wheel then pick '-' from the list (e.g. if you have a filter wheel with five positions, then select filters for positions 0 to 4 and leave positions 5 to 7 set to '-').
- If you want to re-focus automatically after each filter change, enter a focus offset. (You also need a compatible electronic focuser).

Click the 'Save settings' button to save your settings.

The focus offset is a relative value (positive or negative) and gives the required focuser steps to bring the camera to focus for that filter. For example, since the camera initialises with the filter wheel at position zero, you could enter an offset of '0' for that filter. Suppose that you also enter an offset of 5 for position 1 and -3 for position 2. Now if you focus the telescope with the filter wheel at position

zero and then rotate to position 1, the focuser will move out 5 steps. If you then rotate to position 2, the focuser will move in 8 steps, since position 2 has an offset of three steps inwards relative to position zero. Because the offsets are relative, you could add or subtract the same value from all of them and the effect would still be the same – it isn't essential to define the offset as 0 for position zero.

If you want to rotate the filter wheel to a particular position, select the desired filter and click the 'Rotate' button (this is useful if you want to check for specks of dust on the filter for example). This option is not remembered when you re-connect to your camera; the filter wheel won't automatically be set to this position.

Of course, GoQat automatically sets the filter wheel for an actual CCD exposure using the filter that you select on the CCD camera tab – you don't need to rotate the wheel yourself.

4.2.6 Colour

If you have a colour camera with a Bayer filter (e.g. any of the QSI colour cameras with a Kodak KAF chip) you can specify the settings for your camera here.

- If you want GoQat to debayer the images, check the 'Debayer images?' checkbox. Otherwise, GoQat will give you the raw data and you will need to de-bayer it using other software.

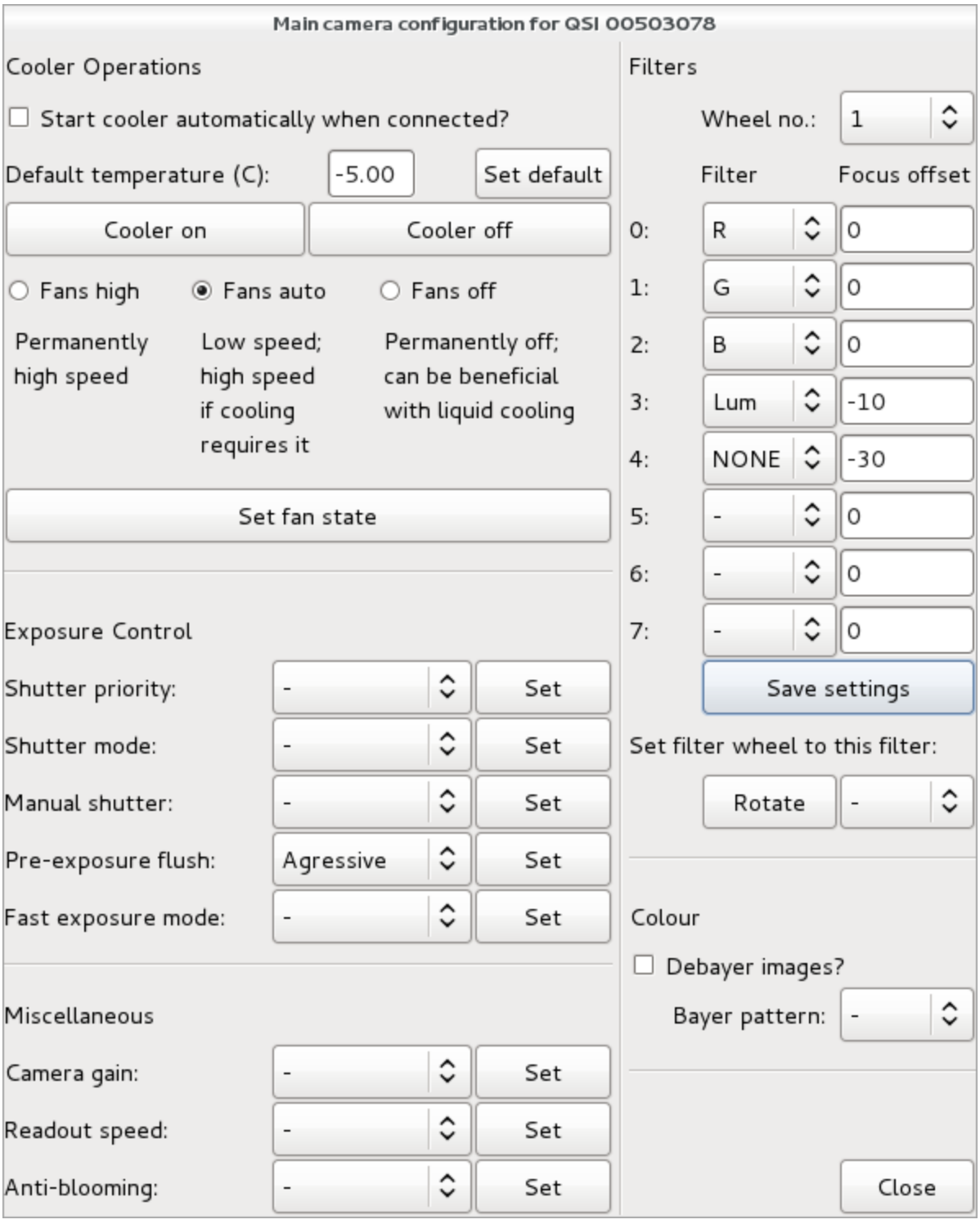
  Pick the appropriate Bayer pattern from the list. It is assumed that the first two pixels of the raw data for the full chip imaging area are one of 'RG', 'GR', 'GB' and 'BG', where R is red, G is green and B is blue. For any of the QSI colour cameras with a Kodak KAF chip, the correct setting is 'GR'. If you expose an image using only a subset of the full imaging area, GoQat will calculate the appropriate starting pattern.

  - If you leave the 'Debayer images?' checkbox un-checked, but still select a Bayer pattern, any image data from the camera is assumed to be raw colour data. Any un-binned images that you save will have the the starting Bayer pattern written to the FITS header.
  - If you select to de-bayer your images but have not entered a Bayer pattern (i.e. you have set the pattern option to '-'), GoQat will prompt you to enter a valid pattern before you close the configuration dialog box.

- After you close the CCD camera configuration dialog box, go to the Cameras menu and highlight the 'Debayer >' option. Choose the type of de-bayering that you want from the list. If a colour image is already being displayed, the raw data will be de-bayered using your chosen method and re-displayed each time you change the selection.

Note that it does not make sense to bin colour data before debayering; the colour information from the individual pixels is lost.

When you have finished configuring your camera, the dialog box should look something like this:



4.3 Configuring a Starlight Xpress camera

Select 'Configure CCD camera...' from the Cameras menu. The CCD camera configuration dialog box will open. This dialog box allows you to configure all your camera settings. Any changes to settings that you make in the configuration dialog box will be applied automatically next time GoQat connects to your camera. Settings are remembered on a per-camera basis, so if you have multiple cameras the appropriate settings will be applied depending on the one that you have connected to.

- Not all of the settings may apply to your model of camera. In this case, you should choose the '-' option.
- Please note that the configuration dialog box is a 'modal' dialog; you must close the dialog before you can interact with any other parts of GoQat.

Adjust any settings as follows:

4.3.1 Cooler Operations

- If your camera has cooler control, check the 'Can set CCD temperature' checkbox.

> Please DO NOT check this box if your camera does not support cooler control. If you do, you may hang GoQat or the camera. To escape from this situation, you may have to reset this option in GoQat's configuration file. To do that, find the GoQat folder in your home directory and edit GoQat.conf. Find the section called '[CCDConfig/SX/NAME_OF_YOUR_CAMERA]' and set the HasCooling key to zero. Save the file and restart GoQat. You may also need to power the camera off and on again.

- Check the 'Start cooler automatically' checkbox if you want the cooling to start as soon as GoQat connects to the camera.
- Enter a value for the desired target cooler temperature and click 'Set default'. This also alters the value in the 'Chip temperature' field on the CCD Camera tab, but you can change this independently of the default setting if you wish. The target temperature is the value that the chip will be cooled to when GoQat next connects to the camera, if you have chosen to start the cooler automatically.
- If you want to start or stop the cooler manually, click the 'Cooler on' or 'Cooler off' buttons. You must click the 'Set default' button before you start the cooling, if you have entered a new value for the default target temperature.

4.3.2 Miscellaneous

- Starlight Xpress cameras have a cylindrical profile with no obvious right or wrong way up. You may prefer a particular orientation because of the arrangement of your cabling for example. If you want the image to be the 'correct' way up, select or deselect the 'Invert image?' option as appropriate.

4.3.3 Colour

If you have a colour camera with a Bayer filter, you can specify the settings for your camera here.

- If you want GoQat to debayer the images, check the 'Debayer images?' checkbox. Otherwise, GoQat will give you the raw data and you will need to de-bayer it using other software.

  Pick the appropriate Bayer pattern from the list. It is assumed that the first two pixels of the raw data for the full chip imaging area are one of 'RG', 'GR', 'GB' and 'BG', where R is red, G is green and B is blue. If you expose an image using only a subset of the full imaging area, GoQat will calculate the appropriate starting pattern. You may need to experiment to determine the correct setting.

  - If you leave the 'Debayer images?' checkbox un-checked, but still select a Bayer pattern, any image data from the camera is assumed to be raw colour data. Any un-binned images that you save will have the the chosen Bayer pattern written to the FITS header.
  - If you select to de-bayer your images but have not entered a Bayer pattern (i.e. you have set the pattern option to '-'), GoQat will prompt you to enter a valid pattern before you close the configuration dialog box.

- After you close the CCD camera configuration dialog box, go to the Cameras menu and highlight the 'Debayer >' option. Choose the type of de-bayering that you want from the list. If a colour image is already being displayed, the raw data will be de-bayered using your chosen method and re-displayed each time you change the selection.

Note that it does not make sense to bin colour data before debayering; the colour information from the individual pixels is lost.

5. Capturing CCD Images

5.1 A full-frame exposure: quick-start guide

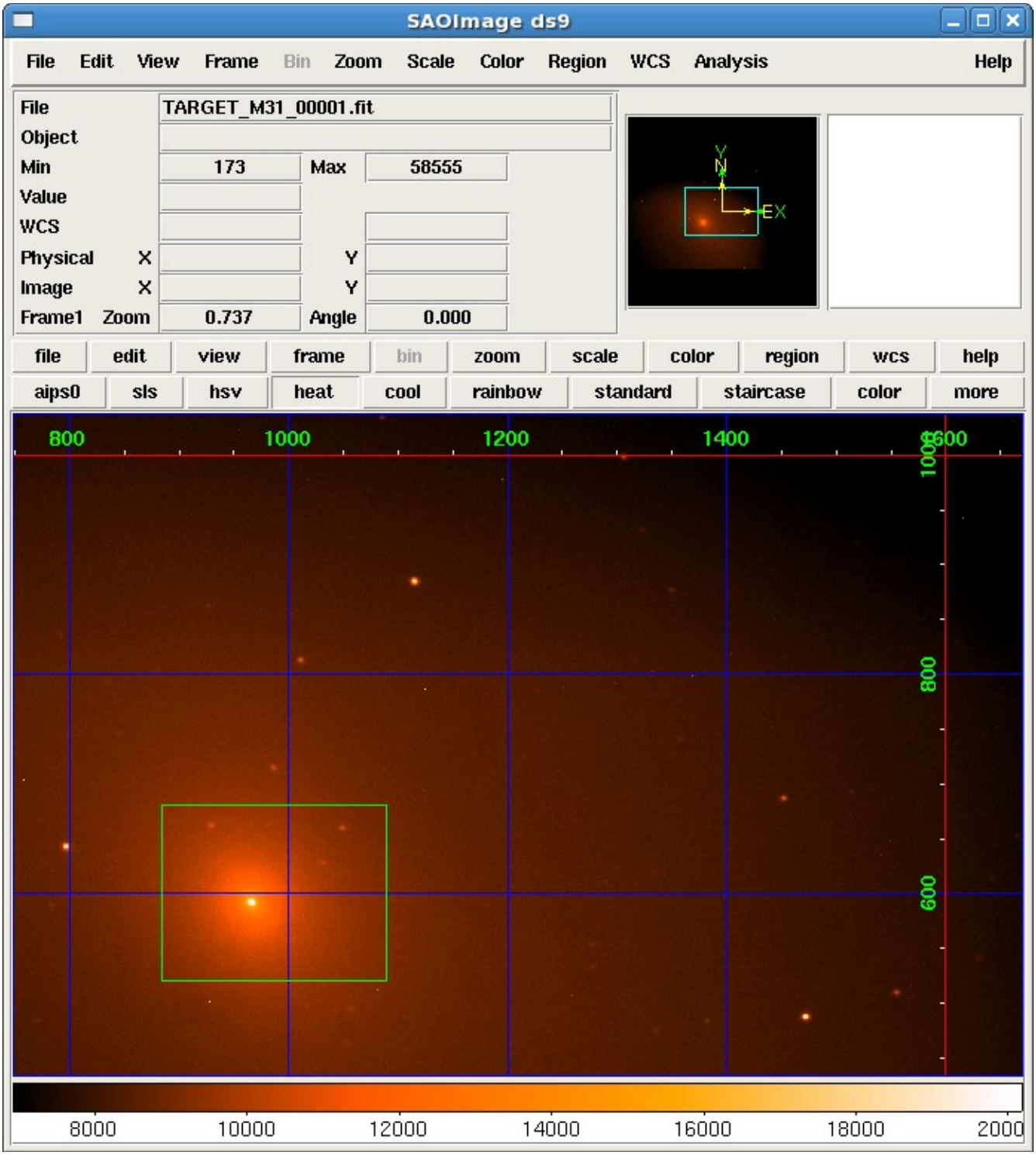
To capture a full frame exposure, go to the CCD camera tab and do this:

- Choose the type of exposure: use 'TARGET' for actual objects, 'FLAT' for flat-fields, 'DARK' for dark frames and 'BIAS' for bias frames. For QSI cameras, the exposure type governs whether or not the shutter will be opened for the duration of the exposure. If you choose 'BIAS' for QSI or SX cameras, the minimum possible exposure time will be entered automatically as the exposure length. The chosen exposure type forms part of the file name, should you choose to save the image.
- If your camera has a filter wheel, select the filter that you want to use. Otherwise, leave the filter choice set to '-'.
- Enter the chip temperature that you want for this exposure. By default, this value is set to the default target temperature specified in the camera configuration dialog, but you can enter any other value here. The chip temperature at the time of the exposure is written to the FITS header when the image is saved. This value is ignored for cameras with no cooling control.
- Optionally, enter any information for the FITS keywords describing the telescope, instrument, observer and object. These keywords and their associated values are written to the FITS header when the image is saved.
- Enter the exposure duration in seconds (or fractions of a second).
- Enter the number of exposures that you want to make.
- If you want a 'beep' to remind you that the exposure has finished, check the 'Notify?' box.
- Click the 'Start Exposure' button. GoQat will check that the chosen exposure length lies within the range allowed by the camera firmware. If the camera has cooling control and the cooling is not already running, GoQat will start the cooling and wait for the temperature to stabilise at the set value.

When the exposure has completed, GoQat will attempt to query the telescope controller for the current RA and Dec values for the FITS header (this requires the telescope controller to be in 'high precision' mode where applicable – see section 8.2.1). Then the image is displayed in DS9 (if installed). Please see section 5.6 for details of how to configure DS9 for use with GoQat, and some other useful hints and tips. See section 11 for how to save your CCD images.

> ⇨ A backup copy of CCD camera images is saved as ~/GoQat/ccd_display.fit before display (where '~' represents your home directory). So if DS9 dies for any reason before displaying the image, restart it and open the saved ccd_display.fit via DS9's File menu.

An image displayed in DS9 (in this case, the central region of M31 with grid overlaid) should look something like the following. A selected sub-frame area (see below) is shown as a green rectangle surrounding the galaxy's core:



5.2 Sub-frames and binning

5.2.1 Sub-frames

The imaging area is defined on the CCD camera tab by the coordinates of the bottom left (H1, V1) and top-right (H2, V2) corners in the horizontal and vertical directions on the chip. GoQat gets the full-frame values by querying the camera firmware. You may enter any other values that you wish if you want to take a sub-frame. If you want to revert to the full-frame values, click the 'Set to full frame' button.

You can also select an area in DS9 to be used for the sub-frame and import the chosen frame area into GoQat as follows (see also section 5.3):

- In DS9, go to the 'Region | Shape>' menu option and make sure that 'Box' is selected as the region shape.
- Drag a rectangle over the area that you want to select. Make sure that only one rectangle is on the display. To delete a rectangle, click anywhere within it and press the 'Delete' key on your keyboard. (If there is more than one rectangle, GoQat will use the first one that you defined).
- In GoQat, go to the Cameras menu and check 'Show full frame'. This makes the 'Get imaging region' button on the CCD camera tab available for use.
- Click the 'Get imaging region' button. This will load the coordinates of the selected region into GoQat.
- Then make the exposure as described above.

5.2.2 Binning

If you want to bin the data for your CCD exposure, enter the required binning in the horizontal and vertical directions on the CCD camera tab. If you want to set both to the same value, use the 'Set H and V binning' spin button to adjust both values together. GoQat will not allow you to set values that are not permitted by the camera firmware.

5.3 Sub-frames, binned images and the 'Show full frame' option

When you make a sub-frame or binned exposure, you naturally end up with fewer pixels in the resulting image. In the case of a binned exposure, the image appears to shrink, even though the angular coverage on the sky remains the same. You can have the *displayed* image remain the same size as a full frame image if you select the 'Show full frame' option from the Cameras menu. You need to set this option before making any sub-frame and/or binned exposures.

When this option is set, a sub-frame exposure is displayed embedded in an image the size of the full chip area, but any values outside the imaged area are set equal

to the minimum data value in the sub-frame. A binned image is expanded so that it covers the actual imaged area (i.e. an image that was binned 3x2 will have triplets of pixels in the horizontal direction set to the same value and pairs of pixels in the vertical direction set to the same value). If you have difficulty seeing the full-frame area in DS9, you may find the 'Staircase' colour option useful.

Note that embedding and expanding applies only to the displayed data; any images that you save via GoQat's File menu or 'Save CCD image' button will contain just the data as read from the camera.

> It is essential to select the 'Show full frame' option *before* making a sub-frame or binned exposure if you then want to select a sub-frame area in DS9 and import it into GoQat; GoQat needs to know where the selected area lies relative to the full frame area.

5.4 Cancelling and Interrupting an exposure

If the camera firmware permits you to abort an exposure, the 'Cancel Exposure' button on the CCD camera tab will be available. Click 'Cancel Exposure' to cancel any exposure currently in progress.

- Clicking 'Cancel Exposure' cancels only the current exposure. If you want to cancel a sequence of exposures, you must also stop the execution of the task list. See section 10.5.
- Clicking 'Cancel Exposure' does not switch the cooling off. You must also open the camera configuration dialog and click 'Cooler off' to switch the cooler off.

If the camera firmware permits you to stop an exposure, the 'Interrupt and Read' button on the CCD camera tab will be available. Click 'Interrupt and Read' to stop any exposure currently in progress and read the camera data. This is useful if you need to interrupt a long exposure due to deteriorating sky conditions, or the passage of a satellite across the target area, for example.

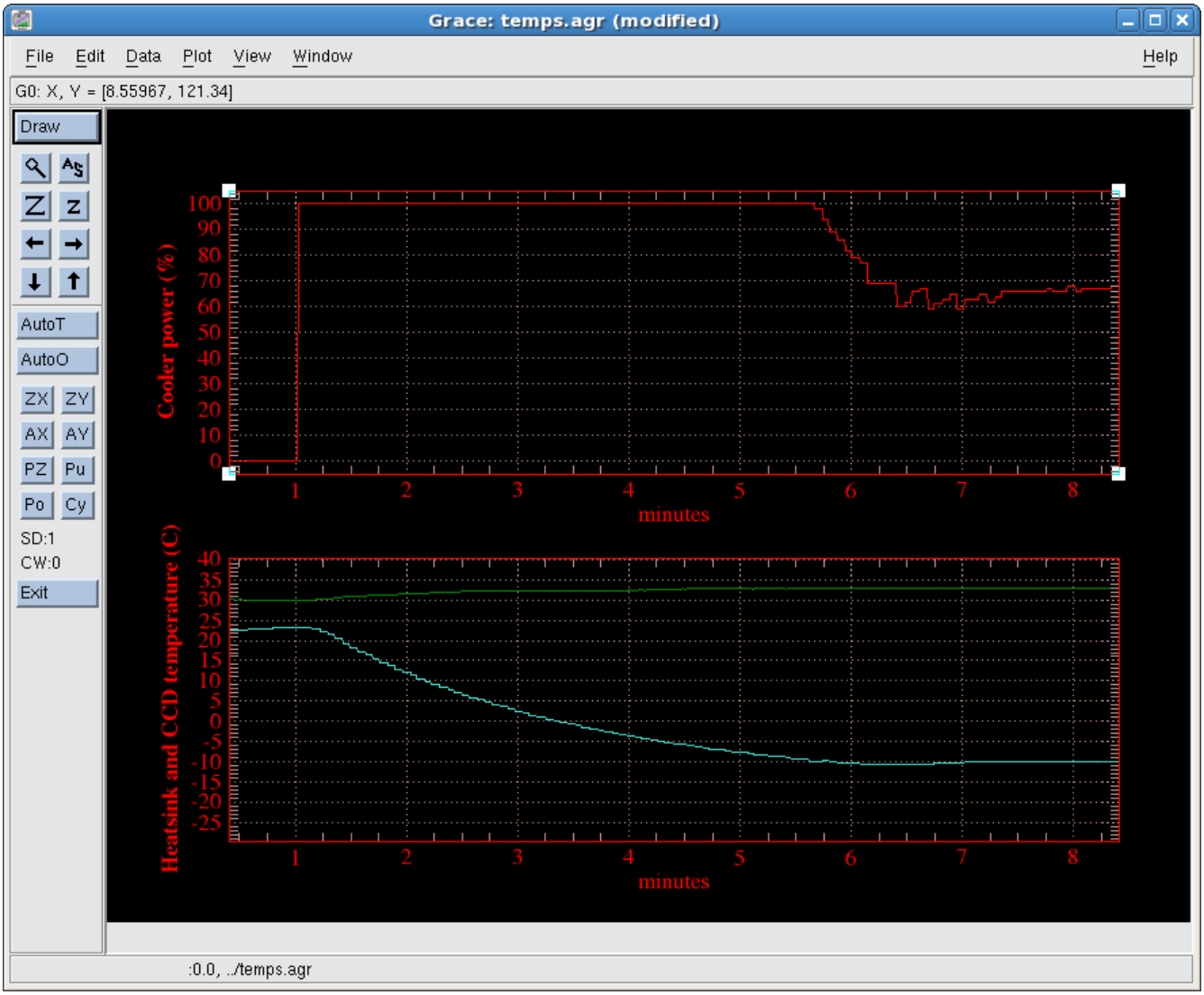
5.5 Camera cooling

For cameras with cooling control, the 'Chip temperature' field on the CCD camera tab defines the CCD temperature for the current exposure. If the CCD is not at the given temperature when the 'Start Exposure' button is clicked, the start of the exposure is delayed until the temperature has been reached. If the cooling is off when you attempt to start the exposure, it will be switched on to achieve the desired temperature.

The 'Camera status' panel on the CCD camera tab gives the current heatsink and chip temperatures for a QSI camera, or the current chip temperature for a SX camera. If you enter a temperature that is greater than the current heatsink temperature for a QSI camera, or a temperature that is greater than the current chip temperature for a SX camera, it will be ignored. In this case, the exposure will start without regard to the current chip temperature. This is useful if you want to take exposures (e.g. for framing an image or focusing) without waiting for

the camera to cool to its target temperature.

If you have installed the Grace plotting package, you can see a live scrolling display of cooler power and temperatures for a QSI camera, or just the chip temperature for a SX camera. Pick the 'CCD temperatures' option from the Windows menu to open the Grace plot. After eight minutes, the display scrolls to the left like a strip chart. Close the display by closing the Grace window. Note that you can use Grace's 'File' menu option to save the chart and its associated data if you wish. To re-start plotting, you need to de-select then re-select the 'CCD temperatures' menu option. For a QSI camera, your display should look something like this:



5.6 DS9 – Some hints and tips

GoQat optionally uses the SAOImage DS9 astronomical data visualization application for image display. DS9 is a very versatile image viewer for FITS files and offers much other functionality. It is well supported by the IRAF data reduction routines, and images displayed in DS9 can be examined directly by some IRAF tasks.

The user is encouraged to explore the functionality of DS9 by experimenting with the various menu options or reading the documentation available from the Help menu. To get the most from DS9 for displaying images from GoQat, the following hints and tips may be useful.

5.6.1 Configuring DS9 for use with GoQat

To make sure that DS9 works well with GoQat, configure the following two options. First of all, start DS9 (e.g. by typing “ds9” in a terminal window) and select 'Preferences...' on the Edit menu. Then:

For DS9 version 6 and lower:

- Select the File tab and click the 'Menu' button. Click 'Preserve During Load >' and choose 'Pan'. This will restore the pan settings whenever a new image is loaded. This is useful if you have zoomed and panned to a small area of your CCD image, e.g. for focusing.
- Select the Region tab and click the 'Menu' button. Click 'Shape >' and choose 'Box'. This makes a box the default region shape, so when you click and drag the mouse on an image, a box will be displayed. This is the required shape if you want to specify a subset of an image to be captured and displayed – see section 5.3.

For DS9 version 7 and higher, select the 'Menus and Buttons' option in the left-hand pane. Then:

- On the right-hand side, click the 'Menu' button under the 'File' option, slide the mouse down to 'Preserve During Load >' and choose 'Pan'. This will restore the pan settings whenever a new image is loaded. This is useful if you have zoomed and panned to a small area of your CCD image, e.g. for focusing.
- On the right-hand side, click the 'Menu' button under the 'Region' option, slide the mouse down to 'Shape >' and choose 'Box'. This makes a box the default region shape, so when you click and drag the mouse on an image, a box will be displayed. This is the required shape if you want to specify a subset of an image to be captured and displayed – see section 5.3.
- Click the 'Save' button at the bottom of the window to save your settings.

If DS9 is re-started during a GoQat session, GoQat will automatically restore the pan and zoom settings that you were previously using.

5.6.2 General hints and tips

- The menu items are replicated by two rows of buttons above the image display area; the first row corresponds to the main menu headings. Clicking one of the menu heading buttons brings up buttons corresponding to the items for that menu in the second row of buttons.
- Click 'Zoom' followed by 'to fit' to display the entire image.
- Click 'Scale' followed by 'square root' to display images with a faint background but with bright point sources (e.g. a star field or dark frame with hot pixels). Try this in combination with the 'zscale' option. If you want to set 'square root' as the default display option, follow the instructions in the previous section, but choose the Scale option to set the default scaling method.
- You can re-display saved images in DS9 using the File | Open... menu option. Pick the appropriate frame type from the Frame menu ('New Frame' for a greyscale image or 'New Frame RGB' for a colour image). If you are loading colour images, remember to select the appropriate image plane to be active in the 'RGB' window (see below) before loading the corresponding R, G or B file.

5.6.3 Colour images

When displaying colour images, GoQat loads separate R, G and B FITS files into R, G and B image planes in DS9. By default, DS9 will scale each of these images separately, resulting in an overall colour balance that is not correct. Try some of the following options to fix this:

- Make sure that the 'RGB' window is open (pick 'RGB...' from the Frame menu). Select the image that you want to adjust by using the appropriate 'Current' option button.
- Pick 'Scale Parameters...' from the Scale menu. This opens a pixel histogram with red and green vertical bars for the low and high extremes. Drag the bars to adjust the scale of the displayed image.
- To apply the same Scale menu options to each of the R, G and B planes simultaneously, first select the Lock menu of the 'RGB' window and check the 'Scaling' option.

  ⇨ GoQat should create Grey frames or RGB frames in DS9 according to the type of image being displayed. If communication between GoQat and DS9 appears to be muddled, just close DS9. Image display should then work correctly for subsequent images when GoQat re-opens DS9.

6. Autoguiding

GoQat can autoguide using the following imaging devices:

- Starlight Xpress cameras including the Lodestar
- Video-for-linux (V4L) devices including webcams
- Any device fully supported by the Unicap API. This includes the popular astronomy video cameras from the Imaging Source, and also any PAL or NTSC video camera connected to an Imaging Source DFG/1394 video-to-firewire converter

GoQat can send guiding commands via:

- A user-selectable serial port (this may be a real serial port, or a USB-to-serial converter) that is connected to a telescope controller or intermediate relay box
- A guide port built in to the CCD or autoguider camera that is connected to a telescope controller autoguider port
- TTL-level guiding signals from a parallel port, either a native port or an expansion card

The author has an older-style Gemini version 1 unit and sends serial commands to an Astro-Electronic relay box (http://www.astro-electronic.de/relbox.htm) connected between the computer and the telescope controller autoguider port. The Astro-Electronic relay box recognises Autostar-compatible guiding commands and is highly recommended if you need a relay box to interface to your telescope controller.

> IMPORTANT: The exact nature of the connections between your computer and the autoguiding device will depend on your hardware. It is your responsibility to consult your telescope controller's manual for further information and to avoid damage to your hardware.

6.1 Selecting a guide camera

To select your choice of guide camera, go to the Cameras menu and highlight the 'Autoguider camera type >' option. The available options will depend on the libraries that were installed when you compiled GoQat:

- Unicap: Any device supported by the Unicap API. This includes webcams, the Imaging Source astronomy cameras and the DFG/1394 video-to-firewire converter.
- V4L (/dev/video0 - /dev/video3): Video-for-linux support, typically for use with webcams.
- SX: A Starlight Xpress camera.
- SX guide head: A guide head connected directly to a Starlight Xpress camera.

6.1.1 Unicap options

If you choose the Unicap option, the 'Select Unicap device...' menu item becomes available. Select this option to pick your Unicap device. There may be a delay before the dialog box is fully displayed whilst attached devices are being searched for.

> You should pick the 'Grey' or 'Y800' option for the device format if available, but are free to choose whatever image size you like.

When you have opened the Unicap device, you can modify its properties via the 'Set Unicap properties...' menu item. If you are using a DFG/1394 video-to-firewire converter, you will need to use this option to specify the port on the firewire converter to which the video camera is connected.

6.1.2 General video-for-linux options

If you choose a V4L option, 'Greyscale conversion >' becomes available on the Cameras menu. Highlight this option and choose the colour-to-greyscale conversion method that you want to use. If you have a mono V4L device with no Bayer array (e.g. a modified webcam with mono chip), select the 'mono' option.

6.1.3 Starlight Xpress options

If you choose the SX option and have more than one SX camera connected to your computer (e.g. a main CCD camera and a guide camera), you should select the 'Cameras | Select SX camera...' menu option to specify which camera you want to use. The detected cameras will be presented as a numbered list in GoQat's message log. Select the number of the desired camera in the pop-up dialog box and click OK. If you have only one SX camera connected to your computer, that camera will be selected automatically.

6.2 Connecting to the autoguider device

You need to specify how the guide signals are to be sent to your telescope controller. Go to the Communications menu, highlight the 'Autoguider comms port >' option and select your choice from the list, as described below.

6.2.1 Serial/USB connections

GoQat presents four options for standard serial ports (/dev/ttyS0 to /dev/ttyS3). USB-serial converters appear as /dev/ttyUSBXXX where the 'XXX' is a number that depends on the order in which the USB adaptors were enumerated. The USB menu options appear and disappear as you plug in or unplug them. The list is refreshed each time you click the 'Communications' menu item. The name of the

port appears on the main Communications menu once you have selected it. If you previously selected a USB-serial converter that is not presently plugged in, then the port name does not appear on the main Communications menu until it is plugged in again.

If you have selected one of the serial or USB ports, check the 'Open autoguider comms' option on the Communications menu to open the link. The autoguider comms port options are greyed-out whilst the autoguider connection is open.

- Provided that the port you have selected actually exists, GoQat is likely to display a message stating that the port has been opened successfully. GoQat assumes that the autoguider is a dumb device and does not try to have a two-way conversation with it; therefore GoQat does not know whether any autoguiding device is actually attached to the port. You may need to experiment initially to find the correct port.
- It is possible to select the same link to your telescope controller's serial port for both autoguiding and telescope control commands. GoQat shares the port between autoguiding and telescope control commands and does not close the port until you close both the autoguider link and the telescope link.

If you close GoQat with the 'Open autoguider comms' option still selected, GoQat will automatically try to reconnect on the same port next time you start it. If you always use the same serial port for the autoguider connection, GoQat should be able to open the link automatically for you each time you start GoQat.

6.2.2 Connections via the guide camera or CCD camera head

If you are using an autoguider camera or a CCD camera with a built-in guide port, you can choose to send guide commands via that port to the autoguider, rather than directly from one of the serial or USB ports. Select the 'Use Guide camera' or 'Use CCD camera' option as required. You should ensure that you have opened the guide camera or CCD camera before you attempt to start autoguiding. The 'Open autoguider comms' checkbox is greyed-out if you pick either of these two options.

6.2.3 Connecting via the parallel port

Select the 'Parallel port' option to send guide signals via the parallel port. Then select 'Open parallel port' from the Communications menu. The 'Open autoguider comms' checkbox is greyed-out if you choose parallel port autoguiding.

Configuring the parallel port

The parallel port can be either a native port or an add-on port via an expansion card (including plug-in cards for laptop computers). For guiding, all pins are initially set low and a pin is set high to issue a guide signal; this is appropriate for

use with an intermediate relay box, for example.

To configure the port, select the 'Parallel port...' option from the Communications menu and enter the details for your port. If you have a native parallel port, the fixed address is likely to be one of 378, 278 or 3bc. If you have an expansion card, the address may be different from this and could change each time you plug the card in. Your system message log may give you the appropriate address.

If you are using the port for guiding, enter the pin numbers used for the RA+/- and Dec+/- control signals.

In all cases, the pin numbers to be entered are the actual physical pin numbers, not the data pin numbers (so physical pins 2 – 9 correspond to data pins 0 – 7).

When you have finished, close the window to save your settings. The settings are remembered by GoQat; if they don't change then you only need to enter them once.

Select 'Open parallel port' from the Communications menu to use the port.

> You must have root user privileges to access the parallel port, so you need to run GoQat as the root user to do this.

- GoQat is written using the Gtk toolkit, and for good reasons, Gtk does not permit applications to be run by a normal user with root permissions using the setuid capability. The easiest way round this is simply to run GoQat as the root user, but do be aware that this gives you access, via GoQat, to any part of the file system. This is unlikely to be a significant security hazard in practice.

6.3 Opening the autoguider camera

Go to the Autoguider tab and click the 'Use autoguider?' checkbox. The autoguider Image window will open and the autoguiding options on the Autoguider tab will become available.

- You may need to adjust the font used for text display on the Image window canvas. To do this, select the 'Set canvas font...' option from the Miscellaneous menu.

Autoguiding may depend on the telescope, autoguider and camera options on the Communications and Cameras menus, so be sure to set the desired options before opening the autoguider camera. Some options on these menus are greyed-out when the autoguider camera is open.

6.3.1 The autoguider image window

The Image window performs the following functions:

- It displays the image from the autoguider camera

- It provides some image display controls
- It enables you to set the exposure length for the autoguider camera
- It allows you to select the desired star for autoguiding
- It shows histogram and centroid plots of the camera data

These features are described in detail in this and the following sections.

The entire image is surrounded by a green selection rectangle. Click and drag the mouse to the lower right to select a smaller area within the rectangle. Note how the histogram and centroid plots change. Click the 'Z +' button to zoom in to the selected area and 'Z -' to zoom out again. Each click of the zoom buttons changes the degree of zoom by a factor of 2. Click 'Z 1:1' to restore the zoom level to actual size. Click 'Reset Area' to reset the selection rectangle to the full image area. You can use the scroll bars to move about the image if necessary.

The pixel with the highest value within the selected area is surrounded by a blue square. GoQat calculates the centroid of all the pixel values within that square and marks it with a small blue circle. Typically this will be close to the pixel with the highest value. The centroid 'dot' will be coloured red if the highest pixel value is at or above the saturation level – see section 6.4.1. If GoQat is unable to determine the centroid (perhaps because all the pixel values are very similar) then the dot disappears.

A set of cross-hairs marks the centre of the image. The red hair-line marks the default east-west direction and the yellow hair-line marks the default north-south direction. GoQat works out the actual orientation of your guide camera during autoguider calibration.

Some additional controls for adjusting the image display appear above and below the display area. These are described in detail in later sections.

The status bar at the bottom of the window shows the following information:

- Cursor coordinates.
- Minimum and maximum pixel values within the selection rectangle.
- Current pixel value at the cursor position.
- Image zoom ratio (1.00 is unzoomed).
- Number of north, south, east and west autoguider corrections for the current autoguiding session.
- Ratio (R) of autoguider images that resulted in a guide correction being made to the total number of autoguider images captured..

6.3.2 Setting the autoguider camera exposure length

Enter the exposure length for the guide camera in the 'Exposure length' field at

the top of the Image window. The default value is reset to 1 second each time you open the Image window.

You must enter a value here for any camera that you use, even if you set the exposure via the 'Unicap' options or directly in the camera hardware, because GoQat needs to know the exposure length when calibrating and autoguiding.

6.3.3 Adjusting the image display and dark subtraction

You can adjust the image display to give the best view of stars for autoguiding.

For V4L devices, the sliders at the bottom of the Image window can be used to adjust the brightness, contrast and gamma for the displayed image, as well as the camera gain. The settings of these controls affect the data that GoQat receives from the camera driver, as well as the displayed image.

For Unicap devices, you should adjust the brightness, contrast and any other available settings via 'Set Unicap properties...' on the Cameras menu. These settings affect the data that GoQat receives from the device driver, as well as the displayed image.

For SX cameras, you can adjust the gamma value to make guide stars more easily visible. However, this alters the image display only and does not affect the data that GoQat receives from the camera. Gamma values less than 1 slow down the rate at which images can be processed, so when you have found a guide star, you should set the gamma value back to 1. Very occasionally, you may see a completely white display when the camera opens. If this occurs, nudge the gamma slider and the display should appear normally. You can switch between 1x1 or 2x2 binning using the controls at the top of the Image window. Of course you must use the same setting for guiding as you do for calibrating the autoguider.

If it is necessary to 'remove' a noisy background sky, drag the 'Background level' slider (above the image display) to the right. Any pixels with values below this level are set to zero. However, this will rarely be necessary as GoQat does its own automatic sky subtraction in the region around any chosen guide star – see section 6.4.1.

Dark frames

If you want to subtract a dark frame, for example to remove hot pixels, you must first capture and average a number of exposures to make the dark frame:

- Cover the end of the telescope
- Enter the required number of frames to capture and average in the text entry field adjacent to the 'Capture dark exposures' button

- Click the 'Capture dark exposures' button

GoQat will average the number of consecutive exposures that you specify and then automatically subtract the resulting dark frame. You can choose to subtract it or not, by checking or un-checking the 'Subtract dark exposure' box. This applies even if you close and then re-start GoQat because GoQat saves a copy of the current dark frame. Clicking the 'Capture' button again overwrites the existing dark frame.

Finally, remember to uncover the end of the telescope!

6.3.4 Histogram and centroid plots

To the right of the image area, the Histogram window displays a histogram of the data within the selection rectangle. The plot is auto-scaled, and below the plot is given the data value at which the peak lies.

The Y-Centroid display gives the total number of counts in each row within the blue centroid square, and thus indicates where the 'centre-of-weight' must be in the Y-direction. Below the plot is shown the maximum number of counts in the brightest row. The X-Centroid display similarly shows the data for each column. GoQat derives the actual centroid of the data to sub-pixel accuracy. The RMS values give the root-mean-square deviations of the true centroid of the data in the X and Y directions. These values are reset when the selection rectangle is re-drawn, or when autoguiding starts.

6.4 Calibrating the autoguider

Autoguider calibration defines five things:

- The orientation of the north/south and east/west axes (i.e. the rotation angle of the guide camera)
- The direction along the north/south axis that the telescope moves when instructed to move north
- The number of pixels per second that a guide star moves north/south at the set guide speed
- The direction along the east/west axis that the telescope moves when instructed to move east
- The number of pixels per second that a guide star moves east/west at the set guide speed

The calibration process is completely automatic and requires just a single click of the 'Calibrate autoguider' button. All that is required is the ability to send guide commands using one of the options described in section 6.2.

It is possible for a single calibration to be used throughout the sky provided that

the autoguider camera orientation remains the same. To take advantage of this, the link to the telescope controller must be open so that GoQat can query the declination that the telescope is pointing to. (Note that this does not apply with German equatorial mounts after performing a meridian flip – the camera is then turned upside-down).

If you have a Losmandy Gemini telescope controller, it is also possible to use a different guide speed from the one used for calibration, as described below. In this case, you must check the 'Use Gemini commands' box on the Communications menu before opening the autoguider camera image window.

6.4.1 Choosing a guide star

You can choose any star for calibration and guiding, provided that it is clearly visible above the sky background. GoQat automatically selects the brightest pixel in the image (or the first one that it finds if two or more are the same). If you don't like GoQat's selection, drag the selection rectangle round the star of your choice. If you are going to calibrate the autoguider, remember to leave sufficient room for the star to move within the selected area – GoQat will ignore anything that lies outside. You must also ensure that a brighter star does not move into the selected area during calibration, or this may be mistaken for the original star.

GoQat marks the selected star with a blue square marker. This must be big enough to contain the star and some blank sky surrounding it. You can adjust the size of this in the 'Centroid size' field on the Autoguider tab.

GoQat performs automatic background subtraction when determining the centroid of the data within the square marker, but the effect of this subtraction is not shown on the displayed image. GoQat subtracts a constant level equivalent to a given number of standard-deviations (sigma) above the background. You can adjust this in the 'Guide star detection level' field on the Autoguider tab. When correctly adjusted, the centroid plots should show a distinct stellar profile above a zero background level (these plots include the effect of GoQat's automatic background subtraction). If required, you may also perform dark subtraction on the entire image, or adjust the background level for the entire image as described in section 6.3.3.

You should ensure that the central pixels of the chosen guide star are not saturated, or the location of the centroid will be determined inaccurately. The dot within the blue square marker shows the calculated position of the centroid and turns red if the highest pixel is saturated. The colour of the centroid dot is based on the raw data returned from the camera driver, so even if you perform dark subtraction or adjust the background level (thereby making the image seem darker on the display), the dot will still be red if the raw data is saturated. Make the necessary adjustments to the camera settings (e.g. by adjusting the brightness or altering the exposure length) to turn the centroid dot blue.

- Any adjustments that you make to the displayed data using the controls below the image display, or via the 'Set Unicap properties...' menu item, either alter the raw camera data in the camera driver, or affect actual camera settings. In both cases, GoQat sees this as a change to the raw data that it receives from the camera driver, so altering these settings will affect the colour of the centroid dot. But dark frame subtraction and adjustment of the background level are both applied by GoQat to the raw data, so applying these adjustments does not alter the saturation of the raw data, even though they affect the appearance of the displayed image.

You can specify a value for the saturation level in the 'Saturation level' field at the top of the Image window. Press the Enter key on the keyboard for this to take effect. By default, the saturation level is reset to 250 for 8-bit cameras and 65000 for 16-bit cameras each time the Image window is opened. You can enter other default values for each type of camera by specifying values for the appropriate keys in the configuration file. See section 14.2.

Adjustment of telescope position

For your convenience in selecting a guide star, it is possible to move the telescope using the arrow buttons at the top left of the Autoguider tab, if you have opened the autoguider link. GoQat sends separate commands to start and stop telescope motion when you press and release the buttons. Some devices do not support this because they only permit guide pulses of a specified duration (as of this writing, the QSI cameras fall into this category). So you must ensure that the chosen device can support separate start and stop commands. See section 6.8 for more details.

By default, the telescope moves at the currently set guide speed. If the telescope link is also open, you can check the 'Use centering speed?' checkbox to have the telescope move at the currently set centering speed instead. In this case, LX200-compatible serial commands are sent to the telescope controller to move the telescope.

If you have a Losmandy Gemini controller and have selected 'Use Gemini commands' from the Communications menu before opening the Image window, you can set the current guide speed in the 'Guide speed' field, and the centering speed in the 'Centering speed' field.

- To understand how the Gemini unit interprets the centering speeds, it is helpful to imagine that the earth is stationary, the celestial sphere is rotating overhead and the centering speed is applied to the celestial sphere. If you select a centering speed of one in the direction opposing the sidereal motion, this will cancel the existing sidereal motion and the star will appear to remain stationary. Likewise, a centering speed of one applied in the same direction as the sidereal motion will result in a star moving at twice the sidereal rate.

6.4.2 Performing calibration

To perform the calibration, GoQat moves the telescope west, east, south and north at the currently set guide speed (if you have a Losmandy Gemini controller, this can be set via the 'Guide speed' field. See the discussion above).

You should aim to reduce the backlash in the declination direction as far as possible before starting. Some controllers (e.g. Losmandy Gemini) can provide backlash compensation automatically. GoQat moves the telescope south before moving north, so you should at least take up any backlash in the southerly direction before calibration.

GoQat moves the telescope in the east/west and north/south directions for the length of time given in the 'E/W calibration time' and 'N/S calibration time' fields on the Autoguider tab. You may need to set these values to give a sufficiently large motion of the star – twenty or so pixels is ideal. This may not be achievable for high declination targets in the east/west direction, but guide corrections caused by periodic error are very small in such locations anyway.

- GoQat issues guide commands to perform the calibration. If you have chosen to use remotely timed guide corrections by checking the 'Remote timing?' checkbox, be aware that some devices have an upper limit on the maximum length of such corrections, and that GoQat may need to exceed this limit to move the telescope sufficiently.

Click the 'Calibrate autoguider' button to start calibration. Calibration needs no further user-intervention.

When calibration is done, GoQat will display some details in the log window and re-draw the cross-hairs to match the current rotation of the guide camera. You are now ready to start autoguiding.

6.4.3 Automatic correction for declination

If you are going to observe targets at various declinations, but without altering the orientation of the camera, it is not necessary to re-calibrate before each observation. GoQat can automatically calculate the east/west speed using the declination at which the calibration was done and the declination of the new object.

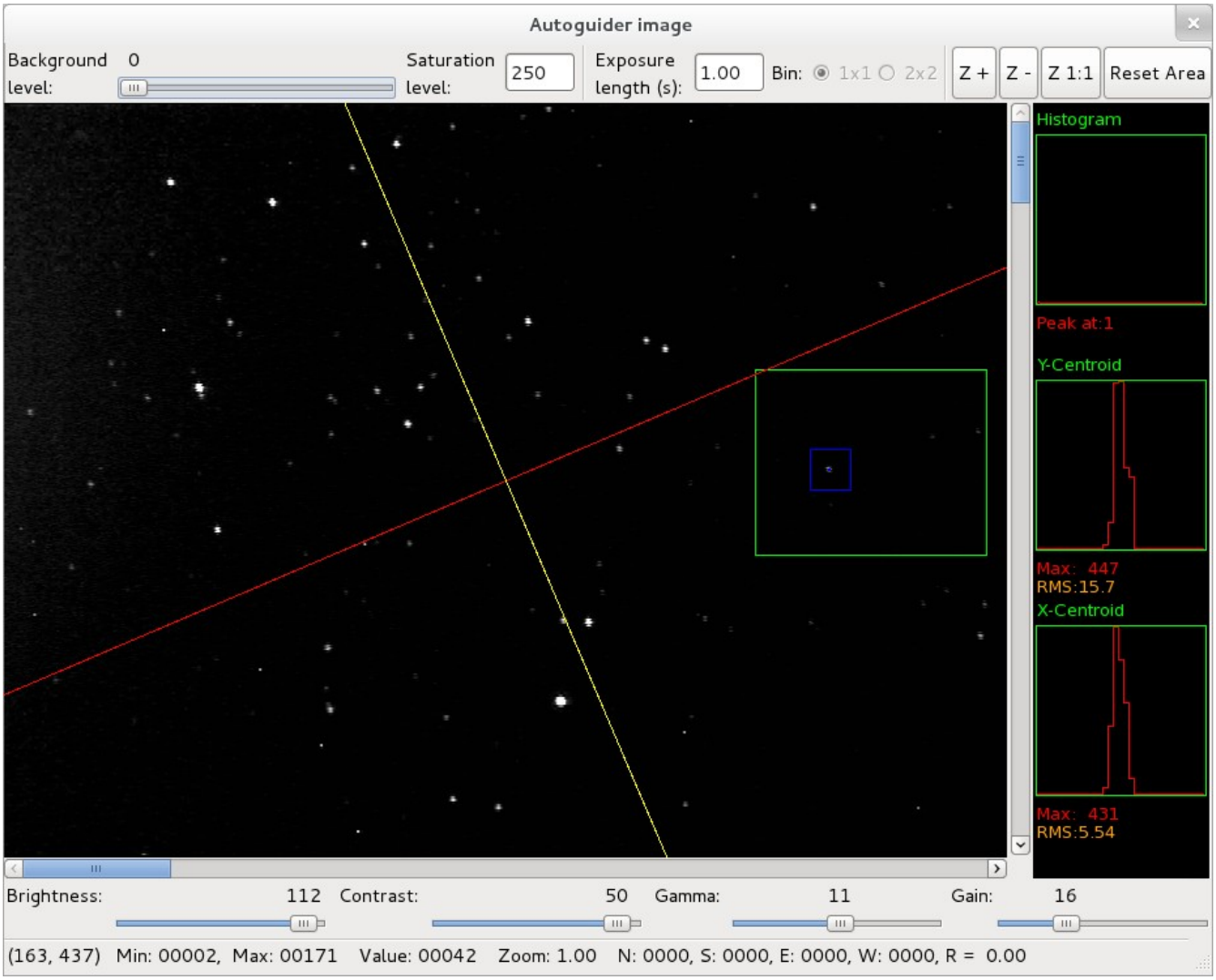
To make use of this, you must open the link to your telescope controller before starting calibration, so that GoQat can query the declination. You must also have the telescope link open for any new objects so GoQat can get the new declination.

If you want to use this feature, check the 'Apply dec. correction E/W' checkbox before starting calibration, and leave it checked afterwards.

- The value for the north/south speed is independent of declination; this will be the same no matter where on the sky you make the calibration.

The following figure shows the autoguider image window immediately after

performing calibration using the star within the green selection rectangle. The orientation of the camera has been calculated and the cross-hairs re-drawn accordingly.



6.5 Autoguiding parameters

The purpose of autoguiding is to correct errors in telescope tracking by making small adjustments to the telescope motion as required. GoQat distinguishes between two types of tracking error:

- Fast errors resulting in a shift of the guide star position
- Slow errors resulting in a drift of the guide star position

GoQat corrects for these two types of error independently. A shift occurs from one guide camera image to the next, whereas a drift occurs over multiple images. A shift is calculated as the difference between the guide star position in any one image and its original position, and a drift is calculated as the difference between the initial guide star position and its present position averaged over a number of images. Typically, shifts might be due to a rough worm gear surface, whereas drifts might be due to polar mis-alignment. On nights of poorer seeing where the star image may be dancing around, you might choose to take advantage of the averaging effect of the drift calculation on the star's position and make only drift corrections.

- ⇨ It is difficult to guide the worst mounts successfully, and the best mounts hardly need guiding at all, so it is hard to give definite advice on autoguiding. You will need to experiment to get the best results, depending on the behaviour of your particular mount.

Parameters

Autoguiding is governed by the following parameters on the Autoguider tab:

- Guide speed: If you are using Losmandy Gemini commands, this sets the guide speed at which the telescope will be moved to make guide corrections. Otherwise the telescope will move at the guide speed that is already set in your telescope controller.
- Correction factor: The proportion of the total guide correction that will be applied. Select values smaller than one to apply less than the full correction.
- Update: The minimum length of time between successive guide corrections. No guide correction will be made following a previous one until the update time has elapsed.
  - ⇨ The update time gives the autoguider and telescope system time to respond to the guide command and move the telescope, before calculating the next guide correction.
  - ⇨ GoQat applies the update time independently for corrections in the north/south and east/west directions. For example, a north/south correction can be made before the update time for an east/west correction has elapsed.
- Max. shift pixels: The maximum permissible shift of the guide star in pixels from its initial position before a shift correction is made.
- Max. drift pixels: The maximum permissible drift of the guide star in pixels from its initial position before a drift correction is made.
- Drift sample time: The number of seconds for which consecutive guide star positions should be averaged, when calculating the drift of the guide star from its initial position.
- Max. move: The maximum move that will be made for any single guide

correction (useful for preventing the autoguider from following sudden sharp spikes).

- Max. offset: The maximum permissible offset of the guide star from its initial position. If the star moves outside this range, no guide corrections will be made until it returns within range (useful for ignoring sudden gusts of wind for example).
- Directions for guide corrections: You can choose the directions in which guide corrections will be made by checking or un-checking the 'North', 'South', 'East' and 'West' checkboxes in the middle of the Autoguider tab. For example, for short exposures where there is not expected to be any declination motion (other than caused by atmospheric seeing), you may choose to disable guiding in the north and south directions.
- Simultaneous guiding N/S and E/W: If GoQat analyses an autoguider image and finds that corrections in both the north/south and east/west directions need to be made, both corrections will be issued simultaneously if this option is selected. If your autoguider device supports simultaneous corrections on both axes, check this box. If you are unsure, leave this option un-checked. In that case, GoQat will send the N/S correction immediately after the E/W correction. N/S corrections should be much less frequent than E/W corrections, so it is unlikely to matter which setting you choose.
- North/South drift correct only: You may choose to have only drift corrections and not shift corrections made in the north/south direction. Strictly, only drift corrections should be necessary to allow for slow changes in apparent north/south position due to atmospheric refraction or polar misalignment. North/south shift corrections are likely to arise as a result of trying to chase the seeing and you may wish to prevent that. Shift and drift corrections will still be made in the east/west direction.
- Remote timing: When calibrating the autoguider or issuing guide commands, setting the 'Remote timing' option means that GoQat sends a single command specifying the guide direction and duration and the guide pulse timing must be handled by the remote hardware; otherwise GoQat sends separate commands to start and stop the telescope motion and does the timing itself. You should check which of these options your hardware supports. If you set the 'Remote timing' option when sending guide signals via the port on a Starlight Xpress camera, GoQat emulates guide pulse timing in the camera driver. Setting this option for Starlight Xpress cameras guarantees that the timing of guide pulses cannot be disrupted by reading an image from the camera and neither will image downloads be affected by guide commands. However, it also means that guide commands in the north/south and east/west directions will always be treated sequentially irrespective of the 'Simultaneous guiding' setting. If you must have guide commands in the two separate directions processed simultaneously for some special reason, then leave the 'Remote timing' option

unchecked for SX cameras at the potential risk of having interference between guide timing and image downloads in some circumstances. Note that you cannot use remote timing if sending guide signals via the parallel port.

You must also enter the guide camera exposure length in the 'Exposure length' field at the top of the Image window. You need to do this for all guide cameras, even if you actually set the length elsewhere, since GoQat needs to know the duration of guide camera exposures.

6.6 Loading/saving autoguider settings

Most of the current autoguider settings are saved and re-loaded automatically when you close and re-open GoQat. If you have a number of different optical configurations that require different settings, you can save the settings for each configuration, and then pick from a list the settings that you want to load.

Go to the Cameras menu and pick the 'Autoguider settings...' option. This opens the 'Load/Save Settings' dialog. You can:

- Enter descriptions into the 'Telescope:' and 'Instrument:' fields and click 'Add existing settings to list' to add the current settings for this telescope and instrument. Note: the telescope and instrument fields here are independent of the ones on the CCD camera tab.
- Highlight one of the entries in the list and click 'Use selected settings' to adopt those settings as the current values.
- Highlight one of the entries in the list and click 'Delete selected settings' to delete the settings from the list.
- Click 'Save settings and close' to save all the settings in the list and close the dialog box.

6.7 Starting autoguiding

6.7.1 Guiding

When you have calibrated the autoguider, click 'Start autoguiding' on the Autoguider tab to begin guiding. To pause guiding, click 'Pause autoguiding'. Continue guiding by clicking 'Continue autoguiding' and stop autoguiding by clicking 'Stop autoguiding'.

If you have not opened the autoguider device as described in section 6.2, you will receive error messages when GoQat attempts to send guide signals. You will also receive error messages if you have selected the remote timing option and your autoguider device does not support it, or if your autoguider device only supports remote timing and you have not selected that option.

Autoguiding may be interrupted whilst images are being read from the CCD

camera (this is particularly likely if you are also sending guide signals via the CCD camera guide port). GoQat will automatically correct for any drift in the guide star's position during the camera read-out before starting the next exposure; the beginning of each exposure is delayed until the guide star has been returned to its initial position.

The number of guide corrections made in each direction is given on the status bar at the bottom of the Image window, along with the ratio (R) of the number of autoguider images that resulted in a guide correction being made compared to the the total number analysed. These numbers are summarised in the message log when you stop autoguiding.

If the guide star signal drops too low, or the star moves further than the distance specified by the 'Max. offset' parameter then autoguiding will stop; a message will be written to the message log and the selection rectangle will flash on and off. Guiding will continue if the guide star signal increases again or the star moves back within the 'Max. offset' range.

Selection rectangle colour

The colour and behaviour of the selection rectangle varies as follows:

- Green: No guide corrections being issued
- Red: Shift correction being issued
- Magenta: Drift correction being issued
- Orange: Waiting for 'Update' period to elapse following the most recent guide correction.
- Flashing: If the guide star signal level drops too low or the guide star moves outside the maximum offset limit, guiding is interrupted and the selection rectangle will flash on and off.

Viewing single autoguider images for further analysis

If for some reason you want to perform more image processing on a single autoguider image than is possible in GoQat (maybe you are using the autoguider camera for another purpose), click the 'Display single image in DS9' button to capture and display a single image in DS9.

Displaying autoguider messages

If you want to see in detail what the autoguider is doing, check the 'Write debug messages to log' option on the File menu. Be prepared for a lot of messages!

6.7.2 Saving guide star position and autoguiding data

Check the 'Write star position and guide data?' checkbox to save a log of the guide star positions. If you are autoguiding, the guiding data is saved too.

If you are using Losmandy Gemini commands and the serial link to the Gemini unit is open, the 'Write worm position?' checkbox will become available when you check the 'Write star position and guide data?' box. You can then choose to have the RA worm position saved with each guide star position, which is useful for periodic error analysis. Reading the worm position introduces a small delay each time the Gemini unit is queried so you probably won't want to do this whilst actually autoguiding.

Guide star position data

The guide star position data is saved in ~/GoQat/star_pos.csv, where '~' represents your home directory. New data is appended to the end of the file.

Two tab-separated header records like this are written initially:

```
52.306000 2013-04-12T14:14:06
     sec. WormPos   N/S (+/-) E/W (-/+) Guide     CCD exposure
```

where:

- the first item on the first row is the number of seconds that have elapsed since GoQat was started
- the second item is the corresponding date and time (UT)

The second row gives the column headers for the subsequent data:

- 'sec.' is the number of seconds that have elapsed since GoQat was started
- 'WormPos' is the worm position read from the Gemini unit (provided that you are using Gemini commands and the serial link to the Gemini unit is open)
- 'N/S (+/-)' is the north/south shift of the guide star centroid relative to its initial position (North is +, South is -). The shift is calculated relative to the star position when the selection rectangle was last re-drawn.
- 'E/W (-/+)' is the east/west shift of the guide star centroid relative to its initial position (East is -, West is +). The shift is calculated relative to the star position when the selection rectangle was last re-drawn.
- 'Guide' indicates (by writing an asterisk in this column) that autoguiding has

been turned on. Guiding actually starts at the row before the first asterisk occurs, so the star position in that previous row is the value that any autoguiding corrections will try to maintain. The N/S and E/W shifts for the guide star are reset to zero when guiding starts.

- 'CCD exposure' indicates (by writing the UT date and time in this column) that a CCD exposure is in progress. Note that the total exposure duration indicated by this method includes the time taken to download the data from the camera.

Autoguiding data

The autoguiding data is saved in ~/GoQat/guide_corr.csv, where '~' represents your home directory. New data is appended to the end of the file.

Two comma-separated header records like this are written initially:

```
150.651000,   2011-01-12T10:42:50
sec.,  E/W (-1/+1),  N/S (+1/-1),  length (ms)
```

where:

- the first item on the first row is the number of seconds that have elapsed since GoQat was started
- the second item is the corresponding date and time (UT)

The second row gives the column headers for the subsequent data:

- 'sec.' is the number of seconds that have elapsed since GoQat was started
- E/W (-1/+1) gives the east/west direction in which the telescope was moved by a guide correction; '-1' means east and '+1' means west
- N/S (+1/-1) gives the north/south direction in which the telescope was moved by a guide correction; '+1' means north and '-1' means south
- length (ms) is the length of the guide correction.

The guiding data is written to the file in such a way that a guide correction can be plotted as a square pulse in a spreadsheet. For example, a guide correction east of 337 milliseconds might appear like this, showing a square pulse beginning at 152.678s and ending at 153.015s:

```
150.651000,   2011-01-12T10:42:50
     sec.,  E/W (-1/+1),  N/S (+1/-1),  length (ms)
  152.678,            0,            0,          337
  152.678,           -1,            0,            0
  153.015,           -1,            0,            0
  153.015,            0,            0,            0
```

6.7.3 Plotting the guide star data

If you have installed Grace, GoQat will plot the guide star position via Grace. Select 'Autoguider trace' from the Windows menu to open the display.

The Grace window has two graphs that show the N/S and E/W positions simultaneously. Each graph has a time axis of eight minutes and scrolls smoothly to the left after that length of time.

Close the display by closing the Grace window. Note that Grace offers you the option of saving the chart and its associated data if you wish. To re-start plotting, you need to de-select then re-select the 'Autoguider trace' menu option.

6.8 A summary of telescope motion and guiding options

The various options currently supported for moving or guiding the telescope using GoQat are summarised in the following table.

Autoguider comms port (i.e. the location to which GoQat sends guide commands)	Moving telescope using arrow buttons	Calibrating autoguider or issuing guide corrections
Parallel port	Sets TTL-level signal high to start motion and low to stop it. The 'Remote timing' option is not applicable.	Sets TTL-level signal high to start motion and low to stop it. The 'Remote timing' option is not applicable.

Autoguider comms port (i.e. the location to which GoQat sends guide commands)	Moving telescope using arrow buttons	Calibrating autoguider or issuing guide corrections
Guide camera (with guide port on guide camera connected to guide port on telescope controller, possibly via a relay box)	SX cameras Sends separate commands to the camera, closing a guide port relay to start motion and opening the guide port relay to stop motion. The 'Remote timing' option is not applicable.	SX cameras The 'Remote timing' option should be selected (see note 1). GoQat then emulates a single 'guide pulse' command internally, although separate commands to close and open guide port relays are sent to the camera in practice.
CCD camera (with guide port on CCD camera connected to guide port on telescope controller, possibly via a relay box)	SX cameras Sends separate commands to the camera, closing a guide port relay to start motion and opening the guide port relay to stop motion. The 'Remote timing' option is not applicable. QSI cameras QSI camera firmware does not presently support separate 'relay close' and 'relay open' commands. The telescope motion cannot be controlled with the arrow buttons via a QSI camera guide port.	SX cameras The 'Remote timing' option should be selected (see note 1). GoQat then emulates a single 'guide pulse' command internally, although separate commands to close and open guide port relays are sent to the camera in practice. QSI cameras The 'Remote timing' option must be selected (see note 2). Sends a single 'guide pulse' command to the camera, specifying the duration for which the guide port relay must be closed.

Autoguider comms port (i.e. the location to which GoQat sends guide commands)	Moving telescope using arrow buttons	Calibrating autoguider or issuing guide corrections
Serial/USB-serial port (with serial/USB-serial port connected to serial port on telescope controller, or to a relay box that understands serial commands that is connected to the guide port on the telescope controller)	Sends separate serial commands to start and stop motion of the form ':Mx#' to move the telescope and ':Qx#' to stop it, where x is e, w, n, or s for east, west, north or south. These commands are LX200 and Losmandy Gemini compatible (see note 3) and are recognised by the Astro-Electronic relay box (see note 4). The 'Remote timing' option is not applicable.	If the 'Remote timing' option is selected, sends a single 'guide pulse' serial command of the form ':MgxDDDD#' where x is one of e, w, n or s and DDDD is the length of the guide pulse in milliseconds. These commands are Autostar, Losmandy Gemini and Astro-Electronic relay box compatible, but not LX200. If the 'Remote timing' option is not selected, commands are as for moving the telescope with the arrow buttons, with the timing done by GoQat (see note 5).

Notes:

1. When sending guiding commands via an SX camera, you should set the 'Remote timing' option because this guarantees no interference between guiding and downloading an image from the camera. In this case, GoQat considers the command to close a relay, wait the desired time and then open the relay as a single non-interruptible entity. If you do not set the 'Remote timing' option, a 'relay open' command might be ignored or delayed while the camera is downloading an image and the telescope could continue to move well beyond the intended point.
2. If you do not select 'Remote timing' when attempting to send guide commands via a QSI camera guide port, you will receive an error stating that separate 'guide start' and 'guide stop' commands are not supported by this camera.
3. If the serial commands are sent to a telescope controller serial port, the telescope will move at the currently selected motion rate. If the telescope link is also open, GoQat will send a LX200-compatible ':RG#' command to set the speed to guide rate initially. If the “Use centering speed?” checkbox is ticked, GoQat will send a ':RC#' command to set the telescope to centering speed. For Losmandy Gemini controllers, it is possible for GoQat to set the actual guide speed or centering speed at which the telescope moves.

4. If the serial commands are sent to an Astro-Electronic relay box that is connected to a telescope controller guide port, the relay box will close a relay for ':Mx#' commands and open the relay for ':Qx#' commands, thus moving the telescope at the guide speed.
5. If guiding commands are sent via a serial port with 'Remote timing' not selected, then GoQat sends the separate commands ':Mx#' and ':Qx#' (as described above) to start and stop telescope motion. To make sure that the telescope moves at the guide speed, GoQat will always attempt to set the telescope to the guide speed initially, sending the LX200-compatible ':RG#' command. GoQat cannot assume that the autoguider serial link goes to the telescope controller, so this command is only sent if the telescope link is open. So if you are guiding via serial commands to a telescope controller with 'Remote timing' not set, you should make sure that the autoguider and telescope links to the controller are both open.

7. Live View

If you are using a Unicap device as the autoguider camera, you may view the live data from the device via the Live View window. To do this, pick 'Live View' from the Windows menu. Remember to select the Unicap device from the Cameras menu before opening the Live View window. Of course, the Unicap device doesn't have to be used for autoguiding; asteroid occultation work or time-lapse recording of other phenomena is also a possibility. You can even view colour images from a webcam via the Live View window, although they will display as greyscale in the Image window.

- The autoguider Image window and the Live View window both display the data from the Unicap device and both windows can be open at the same time. The autoguider Image window display is slower because of the data analysis that takes place for each image. To view the data from the Unicap device at full frame rate (or as fast as your computer allows), make sure that only the Live View window is open.

7.1 Live View window

The Live View window displays the image from the Unicap device in the upper panel. The video stream can be recorded to disk using the options in the lower panel.

7.1.1 Recording video

To record the video stream from the camera, optionally enter a comment in the 'Comment:' text box and then choose where to save the file. By default, every frame is saved. If you want to save only every third frame for example, then enter '3' in the 'Save every... frames' text box. Click the 'Record' button to record. Recordings are named automatically according to the date and time of the start of the recording.

The 'Record' button changes to a 'Stop' button when recording; click the 'Stop' button to stop. Statistics from the recording process are summarised in the message log. You may need a fast computer with high-speed disk drive to save every frame.

- The recording process uses a double-buffering system so that 'n' frames are being written to a buffer in memory whilst 'n' frames from the other buffer are being written to disk. The default size of 'n' is 50 (i.e. every 2 seconds for 25 fps). You can tune this value for optimum performance by setting a value for the entry in the configuration file for 'Video/FrameBufSize'. You may need to create this entry in the file if it doesn't already exist – see section 14.2.
- The video stream is saved in a very simple uncompressed format. A header is written containing a file identifier, followed by the image dimensions and the comment. The

image data then follows as a continuous bit-stream, with each video frame preceded by a 100-byte header containing the time when the frame was captured from the video device.

7.2 Playback window

The Playback window is used to play back video data recorded via the Live View window. Pick 'Playback' from the Windows menu to open the Playback window.

7.2.1 Playing back video

To play back video, click the 'Open...' button to open the desired video file. The first frame in the file will be displayed, and the comment (if any) will be shown.

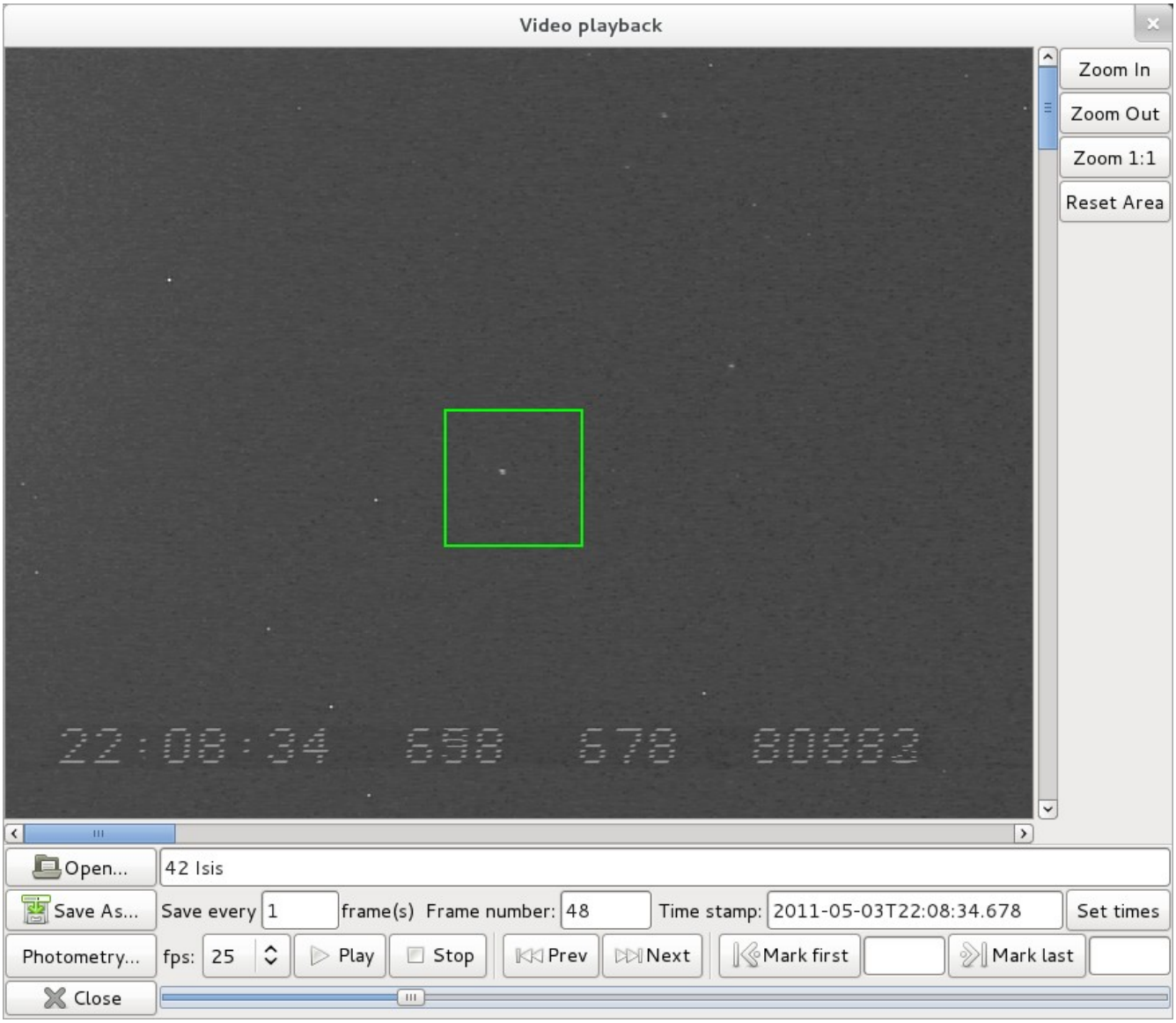
Other buttons have the following effect:

- 'fps': Pick the desired playback frame rate (can be altered whilst video is playing back)
- 'Play': Play the video file
- 'Stop': Halt playback at the current frame
- 'Prev': Display the frame previous to the current one (when playback is stopped)
- 'Next': Display the next frame following the current one (when playback is stopped)
- Drag the frame counter slider to set the current frame (when playback is stopped)

The current frame number is displayed in the 'Frame number:' box; you can jump to any desired frame by entering a valid frame number in this box and pressing the 'Enter' key on your keyboard.

The Playback window will look something like the following picture, showing a recording of a stellar occultation by the asteroid 42 Isis. The time-stamps have been set to match the GPS overlay (see the following section), and the area round the star has been selected for photometric analysis.

The default display size is 768x576. To display larger video frames, resize the window and/or use the scroll bars.



7.2.2 Setting video frame time-stamps

The time-stamp for the current frame is shown in the 'Time stamp' box. The time-stamp comes from the Unicap library and is the time that frame capture finished for that frame, according to your current computer time. If you are recording video with a timing overlay from a GPS time inserter, you are likely to see a difference between the time stamp and the video time. However, the difference between the two should stay reasonably constant.

You can adjust the time-stamps as follows:

- Find the first frame whose time-stamp you want to set, and click 'Mark first'.

Then enter the desired time-stamp in the 'Time stamp' box. You should use exactly the same format as the existing stamp. You must press the 'Enter' key after adjusting the time-stamp for your alteration to take effect.

- Click the 'Next' button to move to the next frame and set the time-stamp for that frame also, again remembering to press the 'Enter' key afterwards. This defines the elapsed time from one frame to the next.
- Find the last frame whose time-stamp you want to adjust and click 'Mark last'.
- Click the 'Set times' button to adjust the time-stamps for all the frames in the selected range. The stamps are set so that the increment from one frame to the next is the same as the increment between the first and second frames.

Setting time-stamps can take a while for very large video files, but you are unlikely to need to do this for more than about five minutes or so for a typical asteroid occultation measurement. You may stop setting the time-stamps by pressing and holding down the 'Esc' key until the process stops. Alternatively, keep clicking the 'Stop' button.

> ⇨ You must set the time-stamps for the first and second frames exactly as described above, even if they are already apparently correct. The original time-stamp is written to the frame header in a different format and at a higher numerical resolution, so the actual increment between the first and second frames may be different from that implied by the reduced precision of the displayed stamps. By following the procedure above, you cause the underlying time-stamp values to be truncated to match the displayed values exactly.

7.2.3 Saving video frames as FITS files

Individual frames can be saved in FITS format for later analysis. To do this:

- Decide whether you want to save all of each frame, or just a small part. If you want to save only a part of each frame, drag the selection rectangle over the desired area with the mouse (click to mark the top left corner of the rectangle, then drag the mouse to lower right). Drag again to change your selection, or right-click to revert to full frame.
- If you want to save every frame, leave the 'Save every... frames' text field set to 1. To save e.g. every third frame, enter 3 in the box etc.
- Find the starting point for the range of frames to be saved, either by playing and then stopping at the desired location, or by dragging the frame counter slider to the appropriate spot.
- Click 'Mark first' to set the starting frame number (or type the desired frame number into the corresponding text field).
- Find the finishing point for the range of frames to be saved in a similar way to setting the starting point (see above).

- Click 'Mark last' to set the finishing frame number (or type the desired frame number into the corresponding text field).
- Click 'Save As...' and pick 'Individual FITS files' as the format option in the pop-up dialog box. Then choose the desired file location and base file name to save the frames. Frames are saved as individual FITS files with the frame number appended to the base file name. The time-stamp of each frame is written to the FITS header.

You may stop saving frames by pressing and holding down the 'Esc' key until the process stops. Alternatively, keep clicking the 'Stop' button.

7.2.4 Saving video frames in GoQat video format

You can save a subset of a video recording as another video file in GoQat's native video format. Every frame in the selected range is saved in its entirety; you can not choose to skip frames or save a subset of each frame. To save in video format, do this:

- Mark the desired range of frames to save, as described in the previous section.
- Click 'Save As...' and pick 'GoQat video' as the format option. Then choose the desired file location and file name to save the frames.

Writing a new video file is a long process for very large video files. But typically you may only need to save a few minutes from a longer recording, if you want to keep just the disappearance and reappearance of a star from an observation of an asteroid occultation, for example. You may stop writing the new video file by pressing and holding down the 'Esc' key until the process stops. Alternatively, keep clicking the 'Stop' button.

7.3 Video photometry and astrometry with GoQat

You can perform photometry and astrometry on video frames, or selected parts of video frames. You can do this for individual frames or for ranges of frames. Once you have chosen the selected area of the video frame and identified the target objects, the photometry and astrometry is performed automatically using Emmanuel Bertin's SExtractor code.

> ☞ See the README file in the GoQat distribution for instructions on how to get SExtractor. You also need to have Perl installed because SExtractor is called via a Perl script, but it would be an unusual Linux distribution that comes without it! If you are familiar with SExtractor, you can find the supporting files in the data directory of the GoQat installation tree.

7.3.1 Setting initial parameters

To perform photometry/astrometry, load a video file (in GoQat's “*.vid” format)

into the Playback window and click the 'Photometry...' button. You may choose a subset of each frame to analyse by dragging a rectangle over the desired area if you wish.

The Photometry dialog box has the following parameters:

- Aperture diameter: The diameter of the aperture (in pixels) to use for the photometry measurement. You may enter non-integer values.
- Minimum area: The minimum contiguous area in pixels that an object must occupy before it is detected. Appropriate use of this value may make it possible to reject hot pixels, for example.
- Threshold: The number of standard-deviations above the background level that a pixel value must lie before it is detected.
- Max. shift: The maximum shift in the centroid of an object that is permissible from one frame to the next.

Note that it is not necessary to specify an area round each target object for the sky estimation: this is calculated automatically from an analysis of the background values across the selected area.

7.3.2 Performing measurements

To perform a measurement on the currently displayed frame, click the 'Measure single image' button. Circular apertures of the chosen diameter are drawn round the detected objects, and the results are summarised in the panel at the bottom of the dialog box. The displayed results are as follows:

- The x- and y-coordinates of the detected object.
- The number of sky-subtracted counts in the aperture for that object.
- The signal-to-noise ratio for that object.
- The sky background for that object.
- A flags value for the object. Try to set the detection parameters or selected area appropriately so that the flags value is zero. Non-zero values are warnings of varying severity (see the SExtractor documentation) that indicate potential problems with the measurement.

You can experiment with the aperture diameter to see how the signal-to-noise ratio varies, and to obtain an optimal diameter that includes the majority of the object's flux.

To perform measurements on a range of frames, you must first perform a measurement on a single frame from within that range. Usually this will be the first frame of the range. This initial single-frame measurement defines which objects will be detected in all subsequent frames. When you are satisfied with the

parameters for the single-frame measurement, enter the first and last frame numbers of the range in the 'Mark first' and 'Mark last' fields and click the 'Measure selected range' button.

If an object disappears in one or more frames (e.g. a star is occulted by an asteroid), the last frame containing the star is used as a template for the star's position. Photometry is made at that position until the star re-appears.

Moving objects are tracked (provided that the motion does not exceed the given limit in the 'Max. shift' field). Consequently, if a moving object is detected as object number 2 in the detection list (for example), it will still be reported as object number 2 even if it has moved across the frame.

If you change the selected area for photometry by redrawing the selection rectangle, you must perform photometry on a single frame with that new selected area, before performing photometry on a range of frames.

> If you see the 'Unable to read SExtractor output file' error message, then it is likely that the Perl script that GoQat uses has not been able to access the filesystem containing the video file. In this case, run GoQat from a terminal window and check the window for additional error messages from the Perl script.

7.3.3 Photometry and astrometry results

The results are presented in two files called VIDEO_FILE_NAME_photom_N.txt and VIDEO_FILE_NAME_astrom_N.txt, in the same directory as the video file. Each time you make a measurement, the value of the integer N is incremented by one, so that the results of new measurements never over-write old ones.

The 'photom' file contains one record for each frame as follows:

- The frame number
- The UT time in seconds since 00:00:00 UT, derived from the time-stamp for that frame. (If the UT date changes during the recording, then 86400s are added for each date change to subsequent time-stamps on later records, so that the UT time is a continuously increasing value for all frames).
- A pair of columns containing the flux measurement in the aperture, and the flux error estimate, for each measured object.
- In the last column, the average sky background measurement for all detected objects.

The 'astrom' file contains one record for each frame as follows:

- The frame number
- The UT time in seconds, exactly as for the 'photom' results.
- A pair of columns containing the x- and y- coordinates in the frame for each measured object. The first pair of coordinates in the 'astrom' file correspond to

the first object on each record of the 'photom' file etc.

See the Tutorials section of the website for an example.

8. Communicating with telescope controller

8.1 Connecting to the telescope controller

GoQat presents four options for standard serial ports (/dev/ttyS0 to /dev/ttyS3). USB-serial converters appear as /dev/ttyUSBXXX where the 'XXX' is a number that depends on the order in which the USB adaptors were enumerated. The USB menu options appear and disappear as you plug in or unplug them. The list is refreshed each time you click the 'Communications' menu item. The name of the port appears on the main Communications menu once you have selected it. If you previously selected a USB-serial converter that is not presently plugged in, then the port name does not appear on the main Communications menu until it is plugged in again.

To open telescope communications, go to the Communications menu and highlight the 'Telescope comms port >' option. Pick the appropriate port from the resulting list. Then check the 'Open telescope comms' option on the Communications menu to open the link. You may need to experiment initially to find the correct port. The telescope comms port options are greyed-out whilst the telescope connection is open.

> ☞ It is possible to select the link to the same serial port for both autoguiding and telescope control commands. GoQat shares the port between autoguiding and telescope control commands and does not close the port until you close both the autoguider link and the telescope link.

If you close GoQat with the 'Open telescope comms' option still selected, GoQat will automatically try to reconnect on the same port next time you start it (if this fails, the 'Open telescope comms' option will be deselected). If you always use the same serial port for the telescope connection, GoQat should be able to open the link automatically for you each time you start GoQat.

8.2 Generic Autostar/LX200 compatible controller

GoQat can communicate with any telescope controller that recognises the Meade Autostar/LX200 command set. This is useful for the following tasks:

- Obtaining the current right ascension and declination position of the telescope. This information can be written to the FITS header of any saved files. The declination information can also be used for autoguiding at a different location from the one at which the autoguider was calibrated.
- Instructing the telescope to move at the currently set 'move' speed, when using the arrow buttons on the autoguider tab.
- Issuing 'GoTo' commands to the telescope from the task list.

8.2.1 RA and Dec coordinates - setting high precision mode

If you intend to send or receive RA and Dec values from the telescope controller, you should ensure that it is in 'high precision' mode. This is because GoQat expects to send and receive RA and Dec coordinates using two digits for hours or degrees, two digits for minutes and two digits for seconds. You will receive an error message if GoQat does not find this format. Note that GoQat attempts to get the RA and Dec at the end of each CCD exposure (except when focusing) for writing to the FITS header.

8.3 Losmandy Gemini controller

GoQat can also use native commands from the Losmandy Gemini system In addition to using commands from the Meade Autostar/LX200 command set. This has been tested with Losmandy Gemini version 1, and is assumed to work with version 2.

Using Gemini native commands, you can set the telescope guiding and moving speeds, set the time in the Gemini controller, load and save pointing model and PEC data and other parameters.

To enable use of Gemini commands, check the 'Use Gemini commands' checkbox on the Communications menu. You need to do this before opening either the telescope communications link or the autoguider camera Image window.

Follow the steps in the previous section to open communications with the telescope controller. GoQat sends an 'ACK' request to the Gemini unit when it has opened the port; a message is displayed in the message log to tell you whether it has connected successfully.

GoQat can modify the centering speed and guide speed in the Gemini controller. To prevent any conflict with the original settings, GoQat saves the currently set values for these two speeds when it first connects to the Gemini controller, and then restores them when the communications link is closed.

Note that GoQat requires the Gemini controller to be in 'high precision' mode for sending and receiving RA and Dec coordinates. However, this is the default setting.

8.4 Gemini parameters

In addition to the Autostar/LX200 commands used elsewhere, some specific options for communicating with Gemini are available on the Gemini parameters tab.

8.4.1 Gemini pointing model

You can view, modify, save and load the currently used parameters for your

Gemini pointing model. In addition, you can edit the data by over-typing the values displayed in the text boxes:

- Click 'Read model from Gemini' to read and display the pointing model parameters (it make take a little while for the values to be retrieved). All of the values are in arc seconds. The azimuth misalignment value is equal to the true polar azimuth minus the current azimuth of the polar axis, and the elevation misalignment value is equal to the true polar elevation minus the current elevation of the polar axis. So a positive sign for the azimuth misalignment means that the north pole is east of where the telescope polar axis is currently pointing and a positive sign for the elevation misalignment means that the north pole is higher than where the telescope polar axis is currently pointing.
- Click 'Write model to Gemini' to write the values displayed in the text boxes to the Gemini unit.
- Click 'Load model from database' to load the model parameters stored in the configuration file into the text boxes.
- Click 'Save model to database' to save the values displayed in the text boxes into the configuration file.

8.4.2 Gemini Real Time Clock (RTC)

To set the date and time for the Gemini Real Time Clock from your computer time, click the 'Synchronise Gemini to PC time' button. GoQat sends your local timezone offset and civil time to Gemini so that Gemini can set the UTC value in the real time clock correctly.

8.4.3 Gemini status

Check the status of your Gemini unit by clicking the 'Show Gemini status' button. Gemini returns information such as whether modelling is in use or a GoTo operation is taking place. If you have just done a cold start, Gemini may not yet have any status information to return. The 'Gemini status' button also returns the current RA worm position if you have the appropriate version of the Gemini firmware to support this option.

8.4.4 Periodic Error Correction (PEC) data

GoQat can load PEC data into the Gemini unit, and save the currently active PEC data from Gemini.

- Click 'Load PEC from file...' to select a file containing the PEC data and load it into Gemini.
- Click 'Save PEC to file...' to select a file in which to write the current PEC data. Saving the current PEC data can be a lengthy process.

The PEC data file has a two-row header comprising:

- Number of PEC cells
- Guide speed to be used when PEC is active

Then follows as many guide correction records as required of the form:

- Guide direction; starting cell; number of consecutive cells with this correction

All records are of a fixed 13-character width followed by a line feed. All guide correction records have semi-colons at characters 2 and 8; the starting cell and number of consecutive cells values are right justified to positions 7 and 13.

A Scilab script (see www.scilab.org) for analysing the periodic error of the RA worm and creating the PEC data file is available from the GoQat website.

8.4.5 Default values

You can load any default values that you wish into the Gemini unit from a file – in fact you can set values for any of the items that Gemini lets you alter via its serial line command set (see the Gemini users' manual for more information). Typical values that you might want to load include your latitude and longitude and mount type. This can be useful after a Gemini CMOS reset, for example.

- Click 'Load defaults from file...' to select a file containing your default values and load it into the Gemini unit.

Each line of the Defaults data file must be padded with blanks to 40 characters followed by a line feed. LX200 command-set commands must begin with a colon in column 1 and end with a hash. Gemini native commands must have the command ID right-justified to column 5 followed by a semi-colon. The value to be set must follow immediately after the semi-colon. For those Gemini commands that don't take a value (e.g. the command to set the mount type), leave the character after the semi-colon blank. Lines beginning with a hash are ignored and may be used for comments. Lines beginning with a forward-slash are echoed to the log window.

A sample 'Defaults.dat' file is included in the GoQat package.

9. Focusing

GoQat presently supports Robofocus for focusing operations.

GoQat permits autofocusing, with calibration by the well-known 'V-curve' method published by Larry Weber and Steve Brady. You can also specify filter offsets if you want GoQat to refocus your telescope after each filter change, and you can define a thermal coefficient if you want to allow for the effects of temperature on focus position automatically.

9.1 Using Robofocus

Read the Robofocus manual carefully to set up your focuser and calibrate the range of travel. The configuration pane on GoQat's Focus tab lets you set values for the parameters described in the Robofocus documentation. Click the 'Get current settings' button to get the current settings. Note that some features are available only in Robofocus version 3 or higher.

9.2 Manual focusing

You can set the focus position manually using the buttons at top left of the Focus tab.

Enter the number of steps to move the focuser in or out, and click the 'IN' or 'OUT' buttons. To move to a particular position, enter a value and click the 'Move to:' button. You can stop a manual focus operation by clicking the 'STOP' button.

9.3 Calibrating autofocus

The calibration process measures the 'half-flux diameter' of a selected point source (star) over a range of positions of the focuser. The half-flux diameter is the diameter of the stellar image in pixels that contains half of the total flux. When these values are plotted against focuser position, a V-curve is produced, with a minimum at the point of focus. (In practice, the curve has straight sides away from the point of focus, but is curved at the bottom, near the point of focus). The actual point of focus is not important for the calibration process; only the slopes of the two sides are needed, along with the difference in the intercept of the the two sides on the focus position axis, when extrapolated to a half-flux diameter of zero pixels. Search for the papers by Larry Weber and Steve Brady to learn more about the theory behind the measurements.

Note that while this method works well for point sources against a dark background (and is very resilient to changes in atmospheric conditions), it probably won't help to focus a spectrograph, although it may just work for well resolved and widely spaced spectral lines.

It is worth taking time to produce a good-quality V-curve because you only need

to do it once for any given optical arrangement; you do not have to re-create a V-curve each time you use the telescope.

9.4 Creating the V-curve

Take a CCD exposure to check if you have any suitable stars in the field of view, and decide on an appropriate exposure length. You should choose an exposure that is sufficiently short that the star image is not saturated when the star is tightly focused. You may get more stable measurements of the half-flux diameter (HFD) if you choose longer exposures of faint stars (e.g. exposures of 2 seconds or so), rather than very brief exposures of bright stars. It may take some initial trial-and-error to get this right.

9.4.1 Selecting a star

If you want to select a particular star for the V-curve calibration, drag a box round the star in DS9. Make sure that the 'Show full frame' option is selected on GoQat's Cameras menu, then click 'Get imaging region' on the CCD camera tab to import the coordinates of the selected area. GoQat will use a box of these dimensions for all subsequent exposures during the calibration process, but will move the box to track the star position when it varies due to periodic drive error or polar misalignment. If you haven't defined a sub-frame area as described above, GoQat will automatically centre a box round the brightest pixel. However, this may be a hot pixel or cosmic ray hit, so you may wish to define the area yourself.

9.4.2 Running the calibration

When you have defined the desired area, select the Focus tab and click 'Configure autofocus...'; this opens the autofocus configuration dialog. Make sure the 'Set range' option is selected, then enter the desired start and end focuser positions. This range must enclose the point of focus. If you don't know where that is, set the beginning and end points to their minimum and maximum values respectively. Then enter the step size. For initial runs of the calibration process, you may want to choose a large value. This can be reduced as you subsequently shrink the focusing range. Next, specify how many times to repeat each measurement. Initially you may want to set this to 1, but as you refine the V-curve you can choose larger values. GoQat will take an average of all the measured HFD values for each focuser position. Finally, set the exposure length. If you are starting a new calibration run, click 'Clear old data' to clear out the previous results (if any) and then click the 'Measure HFD' button.

GoQat displays a plot of the measured HFD values against focuser position, as it moves the focuser through the defined range. The HFD value is very resilient to changes in atmospheric conditions, but if the star is lost completely (e.g. due to

temporary cloud) then GoQat will keep re-trying once per second until the star reappears. You may choose to stop the calibration process by clicking the 'Stop' button.

GoQat retains the previous results on the graph until you click the 'Clear old data' button, so if you had to stop a run prematurely, you can redefine the focusing range to be just the part that you didn't do initially and then click the 'Measure HFD' button again to finish creating the curve.

9.4.3 Calculating the results

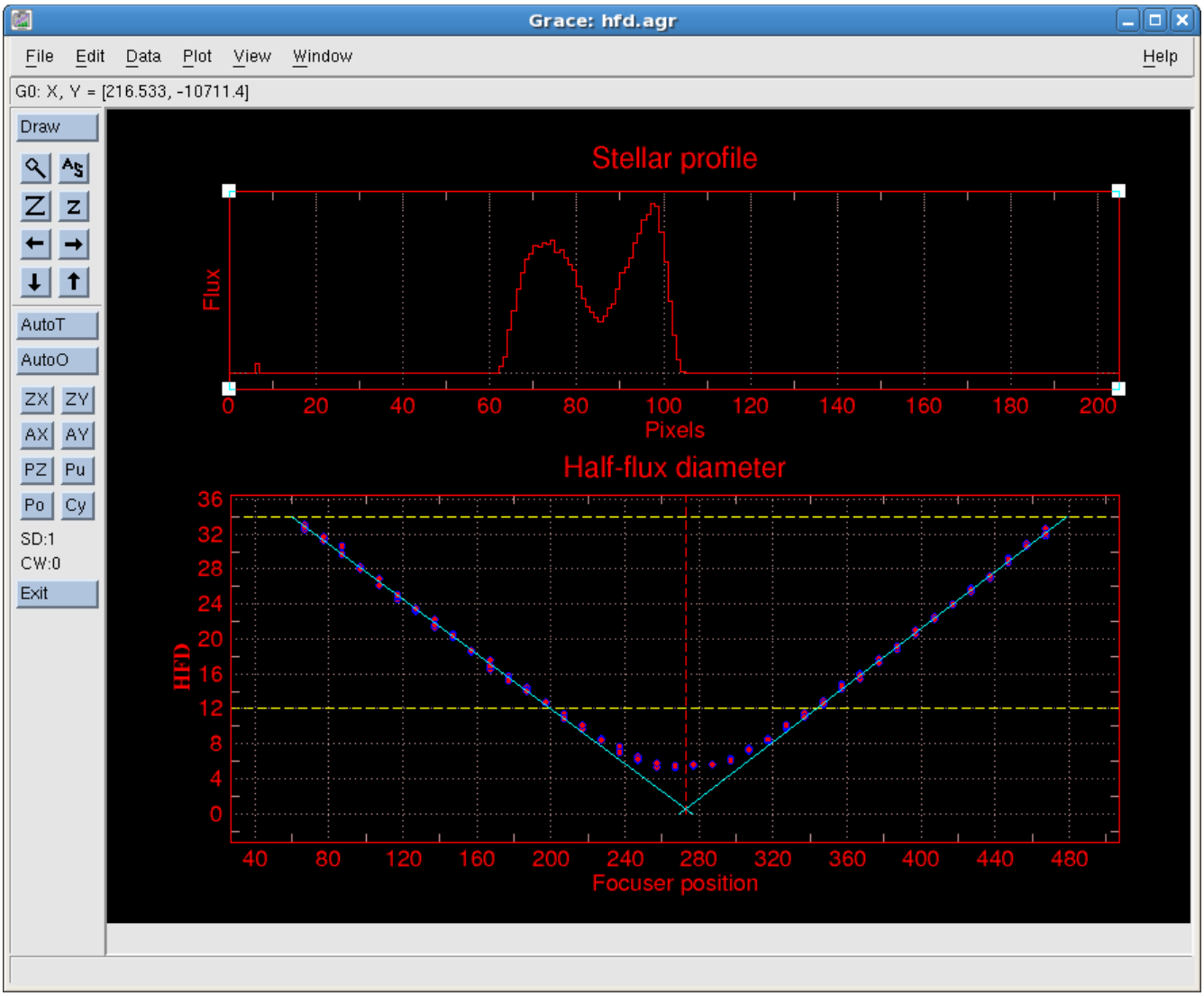
When you have finished the calibration run, choose the range of HFD values over which you want to fit the left and right hand slopes of the curve. You should make sure that you fit over the linear part of the V-curve, so choose a minimum HFD value that is above the curved bottom part. Click the 'Calculate' button to have GoQat determine the slopes of the two sides of the V-curve and the position intercept difference.

> ☞ GoQat actually calls a Perl script to do the calculation, so you need to have Perl installed. It would be a strange Linux distribution that came without it though!

The results are displayed in the bottom part of the autofocus configuration window and summarised in the message log. The left-most fields show the slope and position intercept for the left part of the V-curve, the right-most fields show these values for the right part of the curve, and the middle field at bottom gives the position intercept difference. The L/R ratio is the ratio of the left to right slopes and is for information only. If the two slopes are equivalent, the L/R ratio equals -1. The aim is to have a L/R ratio close to -1 and a position intercept difference that is very small (less than 10, say).

GoQat calculates the focuser position where the curve is at a minimum and enters this value in the 'Centre' field. You will need to have several attempts to get a good V-curve, and for your future attempts you can choose the 'Set centre' option and enter the number of steps each side of the centre position that you want to use. This will automatically result in a symmetrical V-curve for your subsequent attempts. Remember to clear the old data before starting the next calibration run.

You will know that you have a good V-curve when your results look something like the following graph. A 'Repeat' value of three was used, so there are three points per measurement obtained with exposures of two seconds through variable transparency haze. The slopes were fitted with a maximum HFD of 34 and a minimum of 12. The L/R ratio is -0.967 and the position intercept difference is 7.026. (The stellar profile was obtained from the final star measurement, when it was an out-of-focus donut).



When you are satisfied with your V-curve, click the 'Use these results' button to transfer them to the Focus tab.

9.5 Autofocusing

Autofocusing is very simple once you have calibrated your optical configuration with a V-curve, to give values for the left slope, right slope and position intercept difference (PID) on the Focus tab. Alternatively, if you know these values because you have already calibrated your system using equivalent V-curve software, you can just type the values in. You don't need to recalibrate in this case.

The V-curve slopes define the rate of change of HFD with focus position. This is used to autofocus the optical system. Autofocusing works by moving the focuser to a defined point to defocus a star, measuring the HFD, and then stepping to a

defined point close to focus. At that point, the HFD is measured five times to obtain a good average value, and the final position is calculated, using the slope and the position intercept difference.

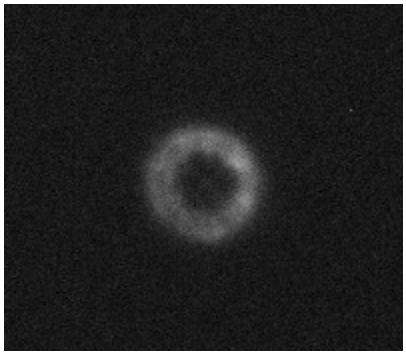
Enter the desired starting focus position in the 'Start at:' field on the Focus tab. This should be at a location on the straight part of the V-curve, away from the curved bottom. You can start well away from the point of focus; it is not necessary to be nearly focused initially. Then specify whether this start point is inside or outside the focus position (inside is at a lower value than the true focus position, outside is at a higher value).

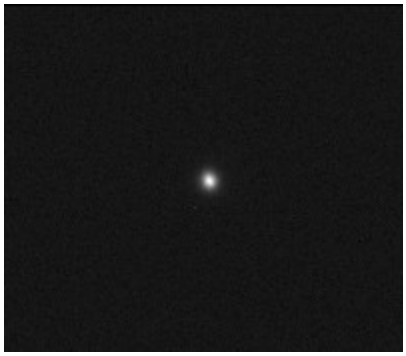
- ⇨ If the star's HFD at the start position is more than twice the near-focus value (see below), then GoQat will automatically detect if the focuser has moved the wrong way. But if the initial HFD is less than twice the near-focus value, you do need to specify correctly whether the initial position is inside or outside focus.

Then enter a value for the near-focus HFD. This is the half-flux diameter at which repeated measurements are made close to focus, in order to calculate the final focus position accurately. This HFD value should correspond to a focus position on the straight part of the V-curve. A good value of HFD to choose is the same value that you used for the lower HFD value when calculating the V-curve. Finally, enter the desired length for the focusing exposures. The same procedure applies for selecting a star as for the autofocus calibration - see section 9.4.1.

Click the 'Focus' button to focus the telescope. Click the 'Stop' button to interrupt autofocusing. The procedure may not stop immediately.

You should be able to start with a star image like the one on the left, and automatically bring it to focus, like the image on the right.





9.5.1 Setting the readout speed

If you have a 600-series QSI camera, you can choose to have it switched to fast readout speed during focusing operations. To do this, check the 'Use fast readout for focusing?' checkbox on the Focus tab. GoQat will reset the camera readout speed to its previous value when focusing is complete. The fast readout option applies to autofocus calibration as well as to focusing.

9.6 Automatic focus adjustments

GoQat can automatically adjust the focus when you change filters, and correct for changes in focus position with temperature.

9.6.1 Re-focusing after filter changes

Focus the telescope for each filter in turn, and note down the focuser position. You may want to re-focus a few times for each filter, and then take an average (although the autofocus works very well, it may not calculate exactly the same focus position each time). Try to avoid doing this if the temperature is changing rapidly; the focuser positions must not be affected by changing temperature. Then enter these values in the CCD camera configuration dialog box (see section 4.2.5). You can enter the actual focuser positions, or you can subtract the same value from each, perhaps to make the smallest value zero. It is only the relative differences between the focuser positions that is important, not the actual values themselves.

To have GoQat apply the offsets automatically after each filter change, check the 'Apply filter offsets?' checkbox on the Focus tab.

9.6.2 Correcting for changes in focus with temperature

GoQat uses a temperature coefficient to calculate how the focuser position should change with temperature in order to keep your system in focus. There is assumed to be a simple linear relationship between focuser position and temperature. You need to define the temperature coefficient for your optical arrangement as follows.

Try to pick a night where the temperature will change over the widest range that you are likely to encounter. Focus the telescope and note down the temperature given in the 'Current temperature' field. Do this a number of times as the temperature changes.

- If you are using Robofocus, note that the temperature is reported only to the nearest half a degree, so it is important to have well-spaced measurements for greatest accuracy. Also, the reported temperature is unlikely to be the actual ambient temperature because the sensor is in the Robofocus controller box – see the Robofocus manual for more information. But as long as the recorded temperature changes uniformly in step with the

ambient temperature, this procedure will still work. It is the change in temperature that is important, not its absolute value.

When you have a good set of measurements, plot a graph of focus position against temperature. Fit a straight line to the points and calculate the slope. You can use your favourite spreadsheet for this, or try using Grace. (Use the Data|Transformations|Regression... menu item, and pick the 'Linear' option). Enter the calculated slope in the 'Temperature coefficient' field in GoQat's Focus tab.

To apply automatic temperature compensation, check the 'Temperature compensation?' checkbox. If the temperature changes by more than the amount in the 'Delta T' field since you turned this option on, or since the most recent autofocus operation, then GoQat will apply automatic temperature compensation as required. Automatic temperature compensation is suspended during autofocus operations and during autofocus calibration.

10. Automatic Tasks

You can construct simple lists of tasks to control GoQat automatically, leaving GoQat to carry out your observations, park the telescope and shut down your computer unattended. Do this via the Tasks tab.

10.1 Creating the task list via the 'Edit tasks' window

Click the 'Edit tasks...' button to open the 'Edit tasks' window. To add a task to the list, enter the desired parameters (if any) for the chosen task and then click the corresponding button. The task then appears in the list on the Tasks tab.

The tasks are as follows:

Task: **BeginSequence** Parameters: None

- Resets the sequence counter that records the number of elapsed seconds on the Tasks tab to zero. A new sequence is automatically started when the first command in the list is executed, irrespective of whether or not a BeginSequence keyword is used explicitly.

Task: **Object** Parameters: 'Name'

- Sets the contents of the 'Object:' text box on the CCD camera tab to 'Name'.
- Sets the base file name for saving a CCD image on the Files tab to 'Name'.
- Sets the base file name for saving an autoguider image on the Files tab to 'Name'.

Task: **Expose** Parameters: 'Exposure type' 'Filter' 'No.' 'Seconds' 'H1' 'V1' 'H2' 'V2' 'Hbin' 'Vbin' 'deg.C'

- Starts a sequence of 'No.' CCD camera exposures of type 'Exposure type' through filter 'Filter'. Each exposure lasts 'Seconds' seconds and the chip is cooled to 'deg.C' degrees. The exposure uses a window on the chip defined by the horizontal and vertical coordinate at the bottom left of the window ('H1' and 'V1') and the horizontal and vertical coordinate at the top right of the window ('H2' and 'V2'). The exposure is binned by 'Hbin' in the horizontal direction and 'Vbin' in the vertical direction. If a CCD camera is connected to GoQat when you open the 'Edit tasks' window, the full-frame coordinates of the chip are automatically entered in the 'H1', 'V1', 'H2' and 'V2' fields, and selecting 'BIAS' as the exposure type automatically fills the 'Seconds' field with the shortest possible exposure time.

Be aware that if you start an exposure or sequence of exposures from the CCD camera tab, these exposures are controlled via the task list. When you click the 'Start Exposure' button on the CCD camera tab, any existing tasks in the list are deleted and the appropriate 'Expose' tasks are then added and automatically executed.

Task: **AugOn** Parameters: None

- Turns on the autoguider camera and opens the Image window.

Task: **AugOff** Parameters: None

- Turns off the autoguider camera and closes the Image window.

Task: **GuideStart** Parameters: None

- Starts autoguiding, including automatic calibration if the 'Calibrate when starting autoguiding' box is checked on the Autoguider tab. The autoguider camera must be on already (see AugOn above).

Task: **GuideStop** Parameters: None

- Stops autoguiding.

Task: **RecordStart** Parameters: None

- Starts video recording (with Unicap device only – the Live View window must already be open with the camera acquiring images).

Task: **RecordStop** Parameters: None

- Stops video recording.

Task: **GoTo** Parameters: 'RA' 'Dec'

- Performs a GoTo operation, moving the telescope to point to coordinates 'RA' and 'Dec'. Northerly declinations may optionally include the '+' sign. These coordinates can be equinox-of-date or J2000.0; you must tell the telescope controller (independently of GoQat) which coordinates you are sending. Note that GoQat expects two digits for each of the hours, degrees, minutes and seconds so you must ensure that your telescope controller is in 'high precision' mode.

- ⇨ GoQat queries the mount to see when the operation has ended if using Gemini commands. Otherwise, GoQat queries the RA and Dec every 5s and assumes that the mount has stopped moving if neither the RA nor Dec have changed by more than a certain amount over the last 5s period. The default value for this quantity is 15 arcsec, but you can change this by setting a value for the key Misc/GoToMotionLimit in the configuration file. If GoQat experiences an error reading the RA or Dec coordinates, it switches to a timed mode and assumes that the telescope has stopped moving after 60s.

Task: **Move** Parameters: 'RA' 'Dec'

- Moves the telescope by the specified amount in arc minutes. A positive value for RA moves in the direction of increasing RA, a negative value moves in the direction of decreasing RA; similarly for declination.
  - ⇨ Note that the RA value is not minutes of time – it is minutes of arc, which is more intuitive. Typically, you will know the field of view of your CCD chip in arc minutes and will tend to think of any required telescope motion in terms of arc minutes, wherever in the sky the telescope is pointing. The field of view stays fixed but lines of right ascension converge at the poles, so GoQat calculates the appropriate motion in right ascension depending on the declination that the telescope is pointing to.
  - ⇨ GoQat executes the Move task via a GoTo command; see the description of the GoTo task for more information.

Task: **WaitUntil** Parameters: 'seconds'

- Waits until the sequence counter reaches 'seconds' seconds, before executing the next task in the list.

Task: **PauseFor** Parameters: 'seconds'

- Pauses for 'seconds' seconds before executing the next task in the list.

Task: **At** Parameters: 'hh:mm:ss'

- Executes the next task starting at 'hh:mm:ss', with hh:mm:ss in 24-hour format. If the 'Use UTC' menu option is active, the time is interpreted as a UTC time; otherwise it is interpreted as your local (computer) time.

  Suppose the time at which the 'At' task is executed is 'now':

  If 'now' >= 12:00:00, then values of 'hh:mm:ss' less than 'now' are interpreted as occurring at the beginning of the following day.

  If 'now' < 12:00:00 then all values of 'hh:mm:ss' are interpreted as occurring

during the current day.

Examples:

'now' = 23:15:00, 'hh:mm:ss' = 02:45:00 – the task queue waits 3.5 hours until 02:45:00 before executing the next task.

'now' = 23:15:00, 'hh:mm:ss' = 23:50:00 – the task queue waits 35 minutes until 23:50:00 before executing the next task.

'now' = 23:15:00, 'hh:mm:ss' = 22:30:00 – this time is interpreted as having already happened and the task queue continues immediately with the next task.

'now' = 10:45:00, 'hh:mm:ss' has any value greater than 'now' – the task queue waits until hh:mm:ss before executing the next task.

'now' = 10:45:00, 'hh:mm:ss' has any value less than 'now' – this time is interpreted as having already happened and the task queue continues immediately with the next task.

Task: **BeginLoop** Parameters: 'Repeat'

- Marks the beginning of a sequence of tasks that is to be repeated 'Repeat' number of times. Loops may be nested up to ten deep; i.e. there may be up to ten BeginLoop statements before an EndLoop statement.

Task: **EndLoop** Parameters: None

- The EndLoop statement marks the end of a repeating sequence of tasks that was started with a BeginLoop statement.

Task: **FocusTo** Parameters: 'Position'

- Moves the focuser to position 'Position'.

Task: **FocusMove** Parameters: 'Steps'

- Moves the focuser by the given number of steps, either positive or negative, depending on the required direction.

Task: **IfTrue/IfFalse** Parameters: 'Val'

- If 'IfTrue' is selected, executes the following tasks provided that 'Val' is true. If 'IfFalse' is selected, executes the following tasks provided that 'Val' is false. 'Val' must be an integer, or must be a parameter that evaluates to an integer.

A value of zero is false; any other value is true.

Task: **EndIf** Parameters: None

- Ends an IfTrue/IfFalse block.

Task: **While** Parameters: 'Val'

- Repeatedly executes the following tasks while 'Val' is true. If 'Val' is false initially, the While loop will not be executed at all. 'Val' must be an integer, or must be a parameter that evaluates to an integer. A value of zero is false; any other value is true.

Task: **EndWhile** Parameters: None

- Ends a While loop.

Task: **Exec/ExecAsync** Parameters: 'Script'

- Executes a script externally to GoQat, either synchronously or asynchronously. If executed via the Exec command, GoQat waits until the script has finished and then reads any results from the script. If executed via the ExecAsync command, GoQat continues with the following task immediately and does not read any results from the script. The script can be written in any language of the user's choice (e.g. a shell script, or using Perl) and can perform any actions.

Task: **SetParam** Parameters: '%' 'Value'

- Sets parameter number '%' to value 'Value'. Presently, there are 10 permitted parameters, so '%' may take any value from 0 to 9. 'Value' can take any value (character string or numeric). The SetParam task is typically used to initialise parameter values before passing them to a script via Exec or ExecAsync, or to set the 'Val' parameter of a While loop to a 'true' value, to ensure that the loop is executed at least once.

Task: **ParkMount** Parameters: None

- Parks the telescope at the pre-defined home position. You must define the home position independently of GoQat. If the link to the telescope controller is open and you are using Gemini commands, the RA worm position after parking is written to the configuration file (at the key PEC/WormPos) and is reported to

the message log.

➾ For Gemini-controlled German Equatorial mounts, the home position is not necessarily the conterweight-down position, unless you have defined it to be so.

Task: **Shutdown** Parameters: None

- Exits GoQat and schedules a system shutdown to occur one minute later. This will shutdown your computer.

The Shutdown command is executed via 'sudo'. Depending on your Linux distribution, this may require an entry of the form:

username my_computer_name=NOPASSWD: /sbin/shutdown

in the /etc/sudoers file (or similar), where username is the user name of the account from which you are running GoQat and my_computer_name is the name you have given your computer, as listed in /etc/hosts (not localhost!). You may need to comment out a line in the sudoers file that says "Defaults requiretty".

You will probably need to run 'visudo' as the root user to edit the sudoers file successfully.

Task: **WarmRestart** Parameters: None

- Executes a warm restart in the Gemini controller if you are using Gemini commands. Note that this can only be done immediately after the Gemini unit has been turned on.

Task: **Exit** Parameters: None

- Exits the task list immediately. This can be useful in conjunction with the IfTrue and IfFalse tasks.

If you want to save the task list, click the 'Save tasks to file...' button to write the tasks to a file of your choice, where you can edit them if you wish (see the following section). To load a file of tasks, click the 'Load tasks from file...' button and choose the appropriate file.

10.2 Creating the task list with a text editor

You can create or modify the task list with your favourite text editor, using any of the commands exactly as listed in the previous section.

The file may contain blank lines. Lines whose first non-blank character is a “#” symbol are treated as comments. Lines may be indented with white space to aid

readability. Task names and their corresponding parameters must appear on the same line, but they may be surrounded by any amount of white space. White space comprises tab characters or spaces.

You can also edit the task list 'in-situ' by right-clicking on the task list. This opens the list in the GNOME editor 'gedit' by default. Manipulate the task list as desired, then save it and exit the editor. The task list is re-loaded into GoQat automatically. You will be warned of any grammatical errors in the list, and re-loading halts when the first error is encountered. If this happens, clear the incomplete list using the 'Clear tasks' button, then right-click on the blank task list. This will re-load your last version of the entire list, including errors, into the external editor.

> ⇨ To change the choice of external editor, set the value of the Misc/Editor key in the configuration file (see section 14.2) to the command that you would type at the command line to invoke the editor.

10.3 Manipulating the task list

The contents of the task list are displayed on the Tasks tab. You can manipulate the contents of the list as follows:

- To move a task up the list, select the task by clicking on it in the list and then click the 'Up' button.
- To move a task down the list, select the task by clicking on it in the list and then click the 'Down' button.
- To delete a task, select the task by clicking on it in the list and then click the 'Delete task' button.
- To clear all the tasks from the list, click the 'Clear tasks' button.

New tasks are added to the list below the currently selected task. Therefore you can insert tasks into the list as well as appending them to the end.

10.4 External scripts and parameters

10.4.1 Scripts

You can execute external scripts using the Exec and ExecAsync tasks. These scripts can be written in any language of your choice, and can perform any actions that are possible from a script (for example, performing data processing; e-mailing image files or uploading them via ftp; converting FITS files to jpg or tiff format etc).

GoQat invokes the script with the following items as input parameters in the order shown below:

(1) '1' if the script is to be executed synchronously, or '0' if asynchronously.

(2) The name of the file that the script must write any results to, for passing back to GoQat.

(3) The name of the file that the script must create, to indicate to GoQat that it has finished.

(4) The number of task parameters to be passed to the script (at present there are ten such parameters; their values can be set using the SetParam task).

(5) – (14) Each of the (ten) task parameters.

(15) The name of the most recently saved CCD image file.

(16) The exposure type of the most recently saved CCD image (Target / Flat / Dark / Bias).

(17) The filter used for the CCD image.

(18) The Exposure length (seconds).

(19) The H1 (bottom left horizontal coordinate) of the image.

(20) The V1 (bottom left vertical coordinate) of the image.

(21) The H2 (top right horizontal coordinate) of the image.

(22) The V2 (top right vertical coordinate) of the image.

(23) The binning in the horizontal direction.

(24) The binning in the vertical direction.

(25) The chip temperature.

(26) The current right-ascension to which the telescope is pointing.

(27) The current declination to which the telescope is pointing.

(28) The focuser maximum range of travel.

(29) The current focuser position.

(30) The current focuser temperature.

If the script needs to pass values back to GoQat, it can return a value for any of the task parameters. To do this, the script must write a separate line for each parameter to the file given as the second item above. For example:

```
%0 23.45
%1 12:34:56
```

```
%2 A large bright nebula
```

sets parameter 0 to “23.45”, parameter 1 to “12:34:56” and parameter 2 to “A large bright nebula”.

The script can also return comments to appear in GoQat's log window. To do this, the script should begin any comment lines in the results file with a hash:

```
#The script has finished!
```

This example will result in the text “The script has finished!” appearing in green in the log window.

If the script is running synchronously, the script must finally create an empty file (with a name given by the third item above) to indicate to GoQat that it has finished. GoQat will wait indefinitely until this occurs. When the script has finished, GoQat reads the results file, sets any parameter values that have been passed back, and displays any messages in the log window.

There is an example task list with accompanying shell script and Perl script installed in the .../GoQat/data/ directory of the installation tree. Please see the Tutorials section of the website for further information and examples.

10.4.2 Parameters

Parameter values that are passed back to GoQat from a script can be used in any of the tasks, where there is a text-entry field in the “Edit tasks” window. (Of course you can also specify these parameters in those corresponding places if you create a task list by hand and load it from a file).

For example, a script might perform astrometry on a CCD image, calculate the offset between the centre of the image and the desired location, and then calculate how much the telescope should be moved to point to that location. If the desired right-ascension and declination motions are returned from the script in parameters %0 and %1, then the next task in the task list could be:

```
Move %0 %1
```

and the telescope will move accordingly.

Another important use of parameters is as arguments to the IfTrue/IfFalse and While tasks. This permits the execution of tasks to be decided depending on the results returned from the script.

GoQat remembers the values of the task parameters until you overwrite them with a different value. So if a parameter is not being used in the task list, you can use it to store a script's private values from one invocation to the next, or even to pass values between scripts.

10.5 Executing the task list

- Click the 'Start' button to start executing tasks from the top of the list. The task list is checked before execution, and errors are reported to the message log. In addition to checking that any values are within their permitted bounds, GoQat also checks to make sure that the system is in an appropriate initial state. For example, if there is an Expose task in the list, GoQat will flag an error if the CCD camera is not already connected. Any errors must be corrected before the task list can be executed.
- Click the 'Pause' button to pause task execution at the end of the currently active task.
- Click the 'Stop' button to stop task execution at the end of the currently active task.

> If you want to stop a sequence of CCD exposures, you must stop execution of the task list AND cancel the current exposure. Clicking the 'Cancel Exposure' button on the CCD camera tab cancels only the current exposure, not the entire sequence.

Tasks are executed sequentially and the next task in the list is not started until the current one has finished. Consequently, if a task does not finish for some reason, then no further tasks will be executed. You may need to stop the task list execution manually by clicking the 'Stop' button if this situation arises.

Messages appearing in the log window are automatically written to the log file (see section 11.3.1) when the task list is running, so you have a complete record of everything that GoQat did whilst you were asleep!

11. Files

11.1 CCD camera and autoguider image files

File handling for CCD camera and autoguider camera image files is managed via the Files tab.

11.1.1 Saving CCD images

Before you can save any CCD camera images, you must choose the location to save the files and the base file name. By default, the full file name is constructed as follows:

EXPOSURETYPE_BASEFILENAME_NUMBER_FILTER.fit

where:

- EXPOSURETYPE is one of the exposure type options from the CCD camera tab.
- BASEFILENAME is the base file name that you have set on the Files tab.
- NUMBER is a sequential file number. The file number starts at 1 by default, but you can set any other value on the Files tab.
- FILTER is the filter name selected on the CCD camera tab. If you set the Filter option to '-' on the CCD camera tab, then the final '_FILTER' part of the file name is omitted.

In addition, you may also choose to have the CCD chip temperature and the exposure length appended to the file name, so that the full file name becomes:

EXPOSURETYPE_BASEFILENAME_NUMBER_FILTER_CCDTEMP_EXPLENGTH.fit

To choose this option, check the 'Use long file names?' option on the Files tab. Note that if the CCD camera does not support setting the chip temperature, this value will appear as zero in the above file name.

If you are running an automated sequence of exposures via the task list, the full file name is constructed in the same way from the parameters of the 'Expose' task. Note that you will either need to set the base file name before executing the task list, or use an 'Object' task to set the base file name automatically.

To save individual images, click the 'Save CCD image' toolbar button, or click the 'Save CCD image' option from the File menu.

To save each image automatically, check the 'Autosave each image?' option on the Files tab. If the Autosave option is selected, any existing files with the same name will be overwritten.

GoQat will attempt to retrieve the current right ascension and declination from the telescope controller for the FITS header, before saving each file. The message log will display a warning if this is not possible.

11.1.2 Saving autoguider images

Before you can save any autoguider camera images, you must choose the location to save the files and the base file name. The full file name is constructed as follows:

BASEFILENAME_NUMBER.fit

where:

- BASEFILENAME is the base file name that you have set on the Files tab.
- NUMBER is a sequential file number. The file number starts at 1 by default, but you can set any other value on the Files tab.

To save individual images, click the 'Save autoguider image' toolbar button, or click the 'Save auoguider image' option from the File menu.

To save each image automatically, check the 'Autosave each image?' option on the Files tab. If the Autosave option is selected, any existing files with the same name will be overwritten.

> Note that this will not save a stream of FITS files at the full frame rate of a video camera – to attempt that, you need to record the video stream via the Live View window, and then use the Playback window to break the video stream into FITS files.

If you want to save an autoguider image periodically, enter a time interval in seconds and check the 'Save images every (seconds):' checkbox.

GoQat will attempt to retrieve the current right ascension and declination from the telescope controller for the FITS header, before saving each file. The message log will display a warning if this is not possible.

11.2 Watching a file for incoming tasks

GoQat can watch a file for incoming tasks and act on those tasks as they are received. To specify a task file to watch, specify the folder and file name on the File tab. Check the 'Activate watch?' checkbox to start watching. These settings

are saved when you quit GoQat, so it is ready to start watching the specified file as soon as you restart it.

Any existing tasks in the watch file are ignored when the watch is activated; only new tasks are processed. The watch file must not be updated more than once per second or some tasks may be lost.

To send a single task, do this:

```
echo “AugOn” > /home/my_watch_file
```

This will send the task “AugOn” to the file /home/my_watch_file and GoQat will turn the autoguider camera on.

To send multiple tasks, do this:

```
echo -e "AugOn \n PauseFor 5 \n AugOff" > /home/my_watch_file
```

Note the use of “echo -e” to have the echo command process the new line characters (“\n”) correctly.

To send many commands, you can also copy an entire task list to the watch file in one go:

```
cp task_list /home/my_watch_file
```

11.3 Miscellaneous other files

11.3.1 Message log file

If you click the 'Write log to file' option from the File menu, the entire contents of the message log will be appended to ~/GoQat/log.txt, where '~' represents your home directory.

The message log is written to this file automatically for tasks that are executed via the task list. You do not need to select the 'Write log to file' option in this case.

11.3.2 Autoguider star position and guide correction files

The guide star position data is saved in ~/GoQat/star_pos.csv, where '~' represents your home directory.

The autoguiding data is saved in ~/GoQat/guide_corr.csv, where '~' represents your home directory.

11.3.3 Dark frames and image display files

The most recent dark frame created via the Autoguider tab is saved in ~/GoQat/dark_frame.

A copy of any image is saved before display in DS9. Autoguider camera images are saved in ~/GoQat/aug_display.fit and CCD camera images are saved in ~/GoQat/ccd_display.fit.

12. Menu Items

This section describes the purpose of all the menu items. Note that some of these may be absent if you have not compiled GoQat with the libraries that the menu options require.

The menu items have the following functions:

12.1 File

- 'Save CCD image' saves the current CCD image.
- 'Save autoguider image' saves the current autoguider image.

- 'Write debug messages to log' writes debug messages to the log window.
- 'Write log to file' appends the contents of the message log to the log file.
- 'Clear log window' clears the contents of the message log window.

- 'Quit' quits GoQat.

12.2 Communications

- 'Telescope comms port >' sets the desired port for communications with the telescope controller.
- 'Open telescope comms' enables/disables communications with the telescope controller on the selected port.
- 'Use Gemini commands' enables the options that take advantage of native commands for the Losmandy Gemini controller.

- 'Autoguider comms port >' sets the desired port for communications with the autoguider.
- 'Open autoguider comms' enables/disables communications with the autoguider on the selected port.

- 'Focuser comms port >' sets the desired port for communications with the focuser.
- 'Open focuser comms' enables/disables communications with the focuser on the selected port.
- 'Parallel port...' permits the parallel port to be configured for autoguiding.

- 'Open parallel port' opens the parallel port.

12.3 Cameras

- 'CCD camera type >' selects the make of CCD camera.
- 'Select CCD camera...' selects the active CCD camera when more than one is connected to the computer.
- 'Connect to CCD camera' enables/disables communications with the CCD camera.
- 'Configure CCD camera...' sets the various CCD camera configuration options.
- 'Show full frame' enables/disables displaying a subset of a CCD image embedded in the full frame image area, if the exposure was windowed or binned.
- 'Debayer >' sets the active debayering algorithm for colour cameras.

- 'Autoguider camera type >' sets the type of autoguider camera.
- 'Select Unicap device...' selects the active Unicap device out of those connected to the computer.
- 'Set Unicap properties...' sets the properties of the active Unicap device.
- 'Select SX camera...' selects the active autoguider camera when more than one is connected to the computer.
- 'Configure SX camera...' sets the various autoguider camera configuration options.
- 'Greyscale conversion >' sets the active method for converting from three-colour format to greyscale for those V4L autoguider camera images that are initially in colour. If you have a mono device (e.g. a modified webcam with no Bayer array), choose the 'mono' option. This will also display just the Y-plane for YUV devices.
- 'Autoguider settings...' selects, loads and saves autoguider configuration data for different optical configurations.

12.4 Focusing

- 'Focuser type >' sets the type of focuser.

12.5 Miscellaneous

- 'Periodic Error Correction' enables/disables periodic error correction in the Gemini controller, if available.

- 'Precess coords to J2000.0' enables/disables precessing of coordinates from the telescope controller to epoch J2000.0 from the current epoch. This is useful if the telescope controller returns coordinates that are for the current epoch and you want to precess them to J2000.0 before writing to the FITS header of a CCD image file. This option does not have any effect on coordinates sent to the controller.
- 'Use UTC' toggles between UTC and your local (computer) time for writing time stamps to the message log and the autoguider star positions and guide corrections files. It also governs whether the time parameter for 'At' tasks is interpreted as UTC or local time. Note that times written to FITS file headers are unaffected by this option; they are always written as UTC.

- 'Set canvas font...' sets the font for the text in the plot and image areas in the Image window.

12.6 Windows

- 'Live View' opens/closes the Live View window, if a Unicap device is the active autoguider camera.
- 'Playback' opens/closes the Playback window for replaying videos made via the Live View window.

- 'CCD temperatures' enables/disables plotting of cooler power and CCD temperatures if a camera is connected.
- 'Autoguider trace' enables/disables plotting of autoguider star positions.

- 'Show toolbar' enables/disables the display of the main application toolbar.

12.7 Help

- 'About' displays the About dialog box.

13. Keyboard Shortcuts

The following keyboard shortcut keys are available (provided that they have not been grabbed by your window manager!):

- 'Esc' swaps between the main GoQat window and the Image window.
- 'F1' toggles the autoguider camera on/off.
- 'F2' captures and subtracts a sequence of autoguider dark frames.
- 'F3' starts/stops autoguiding.
- 'F4' pauses/continues autoguiding.
- 'F12' cancels the current CCD exposure.

You can also navigate between different elements of the user interface with the arrow keys and tab keys, and activate/deactivate the currently selected element with the space bar/Enter key in the usual way.

14. Configuration File

Many of the user-selectable options in GoQat are saved in GoQat's configuration file. This means that your chosen options remain selected from one invocation of GoQat to the next.

GoQat has a few 'hidden' options that can be set only by editing the configuration file directly. If the corresponding entry in the file does not already exist, you will need to create it.

The configuration file is called 'GoQat.conf' and you can find it in the 'GoQat' folder in your home directory.

14.1 Creating a configuration file entry

GoQat's configuration file consists of groups of entries, each of which begins with a group name in square brackets. Any entries on separate lines below that group name that are of the form 'KEY=VALUE' are considered to be part of that group, and each such entry defines a value for the given key. So part of the configuration file might look like this:

[GroupName]

Key1=Value1

Key2=Value2

A shorthand way of referring to 'Key2' in group 'GroupName' is as follows: 'GroupName/Key2'. If a key is referred to as 'My/Group/Name/Key1', then the group name is 'My/Group/Name' and the key name is 'Key1'. So in this case, there would be an entry like this:

[My/Group/Name]

Key1=Value

To create an entry in the configuration file, do this:

- Suppose you want to create an entry called Video/FrameBufSize.
- Open the configuration file with your favourite editor and look for a section beginning with '[Video]'. If there isn't one, start a new line at the end of the file and type it in.
- On a new line immediately below the '[Video]' heading, enter

'FrameBufSize=NNN', where 'NNN' is the size of framebuffer that you want.

- You can modify an existing key by overtyping the present value, and you can delete a key by deleting the line on which that key occurs. GoQat will use its internal default values for any key that doesn't exist, and it will save that value to the configuration file when it exits.
- If your configuration file gets muddled in some way, just delete it and GoQat will create a new one for you.

> GoQat does not necessarily perform any checks on the values that you create or modify by hand in the configuration database. You must make sure that you have entered sensible values. Be particularly careful when setting a value for the Video/FrameBufSize entry.

14.2 GoQat 'hidden' configuration entries

The following 'hidden' entries can be set only by editing the configuration file directly:

- Video/FrameBufSize – sets the number of video frames to be buffered in memory before writing to disk, when recording via the Live View window. The default size (which applies if there is no configuration database entry) is 50 frames – equivalent to a disk-write every two seconds with a 25 fps frame rate.
- Misc/Editor – sets the command to be used to invoke an external editor for editing task lists. It is assumed that a command of the form 'edit filename' will correctly invoke an editor called 'edit' and load a file called 'filename'. The default command is: gedit.
- Misc/GoToMotionLimit – if the telescope moves less than this amount in arc seconds in both RA and Dec over a 10 second period, then a GoTo command is assumed to have finished (this applies to non-Gemini mounts only – for Gemini mounts, GoQat queries the status directly). The default is 15 arcsec.
- Focus/Config/AFBox – sets the edge length of the box (in pixels) containing the star for autofocus calibration, if the user has not already defined such a region. The default value is 40 pixels.
- AugImage/Unicap/SatLimit – sets the default saturation level at which the centroid dot turns red in the autoguider image window for unicap devices.
- AugImage/V4L/SatLimit – sets the default saturation level at which the centroid dot turns red in the autoguider image window for video-for-linux devices.
- AugImage/SX/SatLimit – sets the default saturation level at which the centroid dot turns red in the autoguider image window for SX cameras.
- AugImage/SX_GH/SatLimit – sets the default saturation level at which the centroid dot turns red in the autoguider image window for SX guide heads (i.e. devices that plug directly in to a SX camera).

15. Modifying Grace plots

If you have installed Grace, you can plot scrolling strip-charts of autoguider star positions or CCD temperatures using Grace. You can alter the appearance of the charts whilst they are being plotted, and save the charts with their data.

You may wish to alter the appearance of the template files that Grace uses (for example to change the size of the graphs, or the font styles or plot colours). However, please note that GoQat assumes that the time axis on each plot is eight minutes, and you are invited not to alter this aspect of the templates; doing so may give unpredictable results.

15.1 Grace plot hints and tips

To modify a template file, try some of these options:

- Open the desired template. The templates are installed in /usr/local/share/GoQat/data by default. The autoguider template is trace.agr and the CCD temperatures template is temps.agr.
- To modify the graph page size, use the View|Page setup... menu option.
- To modify the background colour, use the Plot|Plot appearance... menu option.
- To modify the size of a graph, select the desired graph by clicking within the graph boundaries, activate the Plot|Graph appearance... menu option and adjust the viewport size.
- To modify the line colour used for a plot, select the desired graph by clicking within the graph boundaries and use the Plot|Set appearance... menu option. Select the desired set (the temperatures graph in temps.agr has two sets; all other graphs have only one) and adjust the line properties as desired.
- To modify the axis properties, including ticks and labelling, select the desired graph by clicking within the graph boundaries and use the Plot|Axis properties... menu option.

You will need root user permission to save the modified template back to /usr/local/share/GoQat/data.

You cannot alter the initial size of the Grace window; this is set by GoQat.