

Welcome to GoQat!

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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 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.

2. About this document

Operation of GoQat should be fairly intuitive. This document exists to help you in cases where it is not. In particular, if you are planning to use GoQat for autoguiding, please do read all of the relevant chapter before you start. Large quantities of documentation can be off-putting and you probably won't need to read all of it, but if something doesn't seem quite right, have a look in this manual! GoQat is a very capable application and if you want to do something a bit unusual with it, you probably can. The documentation is here to help you.

3. A Note on the Ceaseless March of Progress

Throughout this document and its associated web pages and in GoQat's code and graphical user interface, the acronym 'CCD' or 'ccd' is used several thousand times. The first digital image capture devices available to amateurs were based on charge-coupled device technology so CCD became a convenient short-hand way to refer to the camera itself. In fact it avoids being specific about the camera's use and is more convenient than saying "main/imaging/science camera". Nowadays, CMOS devices are becoming more prevalent, but 'CCD' still seems like a convenient handle. However, you will sometimes find the term 'main camera' used. Be assured that wherever you see 'CCD', your CMOS camera will work fine. Just assume in those cases that 'CCD' stands for 'Compact CMOS Device'!

4. Introduction

Thank you for using GoQat!

This release of GoQat offers three ways of interacting with hardware:

- Direct control of INDI devices using the features provided by GoQat's own user

interface tabs, such as the CCD Camera tab and the Telescope tab.

- User control of INDI devices via the INDI client interface. These tabs are named after the devices themselves and are built dynamically to reflect the features offered by the INDI drivers. More features may be exposed in the client interface than are accessible via GoQat's own UI tabs, but control cannot be automated to the same extent.
- Native control of certain devices using GoQat's own built-in support, not via INDI. These include QSI and Starlight Xpress cameras, Robofocus and Losmandy Gemini mount controllers.

5. Getting Started

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

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 below that.

GoQat has seven 'native' tabs that are always present: CCD Camera, Filter, Focus, Autoguider, Telescope, Files and Tasks. Other tabs may appear if GoQat is connected to an INDI server. These are INDI Client tabs.

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.

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

Action messages (such as informing you that a camera 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!

5.1 Command-line options

You can start GoQat with various command-line options. Type 'GoQat --help' in a terminal window to see the full list. The options are explained where appropriate later in the manual. You can use more than one command-line option at once. See also examples on the website Tutorial pages.

6. Using the INDI Client

GoQat builds a tabbed client interface for each INDI device that it finds. The interface is built according to the properties that an INDI driver reports for a device. The functionality that is available via the client interface is entirely dependent on the INDI driver. To use the INDI client, you must first have an INDI server running.

6.1 Starting the INDI server

You should read the INDI documentation to familiarise yourself with INDI and the various ways that you can run the INDI server to talk to devices on a local or remote computer. The simplest way is to open a terminal window and issue a command like this:

```
indiserver indi_driver_1 indi_driver_2 indi_driver_3 ...
```

where 'indiserver' starts the server and loads the chosen drivers.

If you always want to start the INDI server in this fashion when you start GoQat, then do this:

- On the INDI menu, pick 'Configure INDI server...'
- Enter the hostname for the location of the server that you want to connect to. To run a server and load drivers on your local machine, enter "localhost".
- Enter the port on which you wish to connect to the server – the INDI default port is 7624.
- Enter the command for starting the server and associated drivers as given above in this example.
- Close the INDI configuration window.
- Click on the 'Start server when GoQat starts' option on the INDI menu.

Now close GoQat. When you re-open it, it will attempt to start the INDI server with these parameters, provided that the server is not already running.

If you have set GoQat to start the INDI server automatically, you should ensure that all your INDI devices are physically connected to the computer running the server and powered on before starting GoQat or INDI may not find them.

6.2 Starting the INDI client

To connect to your INDI devices when an INDI server is running, click the 'Connect to server' option on the INDI menu. If you want to connect to your devices automatically each time GoQat starts, leave this option checked when you close GoQat. If you have also selected to start the server automatically, then GoQat will start the server and connect to your devices whenever you start GoQat.

GoQat attempts to connect to the server once per second for up to five seconds after you click the 'Connect to server' option. If the server is not running or cannot be found, GoQat will issue an error message and un-check the 'Connect to server' menu option.

When GoQat connects to the server, it adds a new tab to the main window for each device that it finds. If you un-check the 'Connect to server' option after you have finished using your devices, the tabs will be removed.

6.3 Using the INDI client

GoQat adds a new tab to the main window for each INDI device that it finds. If there are too many tabs for the width of the window, you can:

- Drag the window edge to increase the window width
- Use the scroll arrows that appear at the left and right of the window to scroll through the tabs
- Right-click on a tab name and then choose another tab from the pop-up list

To use an INDI device, select the desired device tab. Make sure that the 'Main Control' tab is selected on the device tab and click 'Connect'. Further tabs will appear down the left hand side of the device tab according to the functions of the device. Device properties of a similar nature are grouped together on these various additional tabs. Some properties appear and disappear depending on the options you select. For example, if your device has a 'Debug' option, further properties will appear if you enable debugging and will disappear when you disable debugging. When you disconnect from the device on the 'Main Control' tab, all but the most basic properties will disappear, but any tabs at the left hand side of the device tab will remain in place. Figure 1 shows GoQat's INDI client connected to a ZWO camera.

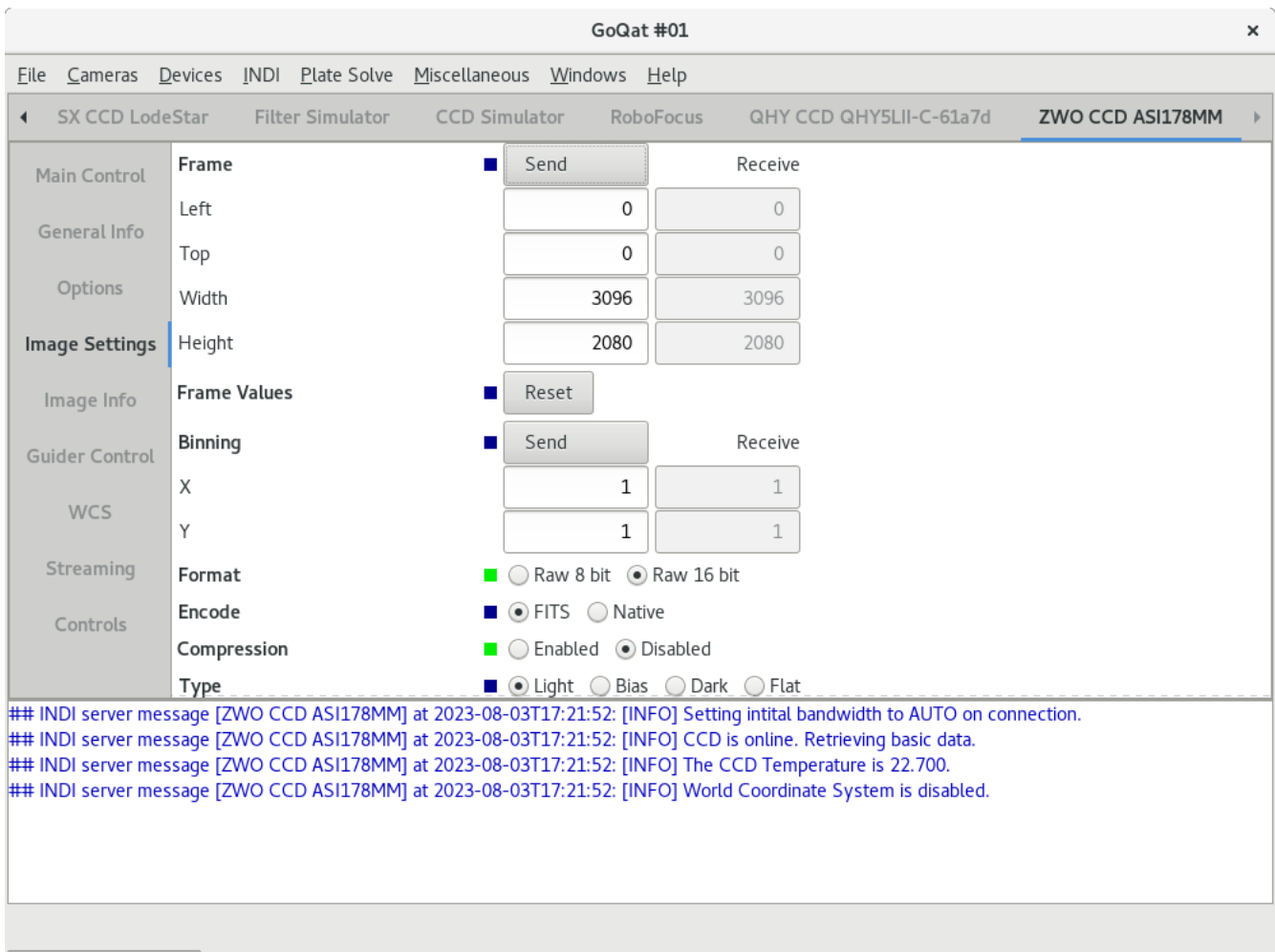


Figure 1: GoQat's INDI client connected to a ZWO camera

6.3.1 INDI client controls

There are four different types of controls used on the device tabs. These are: data entry fields, push buttons, option (radio) buttons and check boxes. When you send data to your device, typically you will enter data in a data entry field and click the 'Send' button immediately above the field. Often data entry fields are grouped together and clicking the 'Send' button above a group of fields sends the data in all the fields to the device. The INDI server responds by echoing back the data you have sent, so for each data entry field in which you can type data, there is a corresponding 'Receive' field showing what has been received from the server. Often you will interact with your device by setting switches or choosing options: the option buttons let you select at most one of a number of possible options and check boxes let you pick one or more of a number of

possible options. You will also find push buttons that permit sending a particular state to the server (e.g. to start or stop telescope motion).

Because the INDI server broadcasts changes that have occurred, two or more instances of GoQat that are connected to the INDI server will both show the current state of the device. So two such instances of GoQat will remain completely synchronised; if you click a check box in one copy of GoQat for a device, this will be clicked automatically in the other copy.

6.3.2 INDI status settings

GoQat uses coloured lights by each set of controls to indicate the status of INDI's most recent response to that control. There are four possibilities:

- Idle – dark blue
- OK – green
- Busy – orange
- Alert - Red

If you want to change these default colours, you can create a new entry in the configuration file by hand exactly as follows (see also section 26):

```
[INDIStateColours]
Idle=rgb(rrr,ggg,bbb)
OK=rgb(rrr,ggg,bbb)
Busy=rgb(rrr,ggg,bbb)
Alert=rgb(rrr,ggg,bbb)
```

In each case, 'rrr', 'ggg', and 'bbb' represent the value you want for the red, green and blue components of the colour on a scale from 0 to 255. You need to specify an entry only for those colours that you wish to change.

If an alert state exists for a control on a given tab, the name of that tab is prepended with '[*]', as is the name of the device on the INDI client tab. These markers are removed when alerts are cleared, or when you close the device.

6.4 Example use of the INDI client: capturing an image

Make sure that you have started the INDI server with the appropriate driver for your camera and that you have connected to the server as described above.

Now do this:

- Click on the tab for your camera
- On the 'Main Control' tab for your camera, click the 'Connect' button
- Additional tabs will appear at the left of the main device tab, offering you further options to configure your device
- On the 'Main Control' tab, enter an exposure duration
- Click the 'Send' button above the exposure duration entry field. Alternatively, press the Return key while the exposure duration field has the keyboard focus.
- You will see the exposure duration count down to zero from the chosen value in the 'Receive' field next to the exposure duration field
- When the image has been downloaded, GoQat opens an instance of DS9 to display it. This can be zoomed and panned in the usual way; GoQat remembers these settings so that even if you close DS9, the next image will still be displayed with the same zoom and pan after DS9 is re-opened.

6.5 Displaying and saving images from INDI

GoQat opens a new DS9 window for each different camera so you can capture and display images from multiple cameras simultaneously. You can find some general hints and tips on using DS9 in section 9.8.2.

To save each image automatically, do this:

- Select the 'Options' tab to the left of the main device tab for your camera
- For the 'Upload' option, pick 'Both'. This means that the image is sent to the client for display and saved to the specified location. (Picking 'Client' displays the image without saving it and picking 'Local' saves the image without displaying it).
- Specify the location for saving the image by entering the desired directory in the 'Dir' field of 'Upload Settings' on the 'Options' tab and enter the desired file name prefix in the 'Prefix' field. Remember to click the 'Send' button above these two fields to send this information to the server. If you specify IMAGE_XX as the file

prefix, the first image will be saved as IMAGE_01.fits and others will be given the next sequential number.

By default, GoQat displays all images that it receives from the INDI server. This includes images from cameras that have been opened by any other instance of GoQat, or indeed by any other INDI client at all. If you are running two or more instances of GoQat on the same machine this behaviour can lead to conflicts, so you probably want each instance of GoQat to display only those images from cameras opened by that instance. To do this, deselect the 'Display all INDI images' option on the INDI menu.

You can choose GoQat not to display images from a given camera at all by deselecting the 'Auto display camera image' check box on the Image Info tab for that camera. This option is always set on initially by default.

7. Some General Remarks about Using INDI Devices Directly with GoQat

To control an INDI device directly by GoQat's own functions rather than via the client interface, choose the desired device from the appropriate menu. For cameras, use the Cameras menu and for all other devices use the Devices menu. The INDI device is opened by going to the relevant native tab and clicking the check box to open the device (e.g. go to the Focus tab to open the chosen INDI focuser).

- GoQat lists all available INDI devices on every menu; it doesn't know what a particular device is until it has been opened, so choose carefully.

It is also possible to open the device from the client interface first. Sometimes this is useful if the client interface presents options for adjusting device settings that are not available via GoQat's native tabs. Examples might be settings for video streaming devices, or gain settings for CMOS cameras.

It is still necessary to 'open' the device via GoQat's appropriate native tab even if it is already open in the client interface. This is so GoQat can make a 'logical' connection to that particular device. You can still adjust settings in the client interface for the chosen device after making the logical connection but some changes might interfere with GoQat's control of the device and some settings changes might be ignored by GoQat after it has opened the device, so do this with caution.

Closing an INDI device via GoQat's own native tab also closes the device on the client interface tab by default. If you just want to break the logical connection to the device without actually closing the device itself, go to the INDI menu and deselect the 'GoQat closes INDI devices' option.

8. Opening and Configuring Cameras Directly with GoQat

You can control INDI cameras directly via GoQat's own CCD Camera tab. In addition, GoQat provides native support for Starlight Xpress and QSI cameras. Follow the instructions in the rest of this chapter to make images with one of these cameras via the CCD Camera tab.

8.1 Connecting the camera

The documentation that came with your camera should tell you how to power up the camera and connect it to your computer. To control QSI cameras natively with GoQat you must install the QSI library before compiling GoQat. You can either compile the library yourself or use the pre-compiled version that ships with INDI. Starlight Xpress (henceforth referred to as 'SX') cameras have the necessary driver code built into GoQat.

Choose the camera type from the 'Cameras | CCD Camera type' menu. The available camera types will depend on the libraries that were already installed when you compiled GoQat. Pick 'QSI' or 'SX' for QSI or SX cameras, or slide the mouse down to 'INDI >' and pick the desired camera from the pop-out list. This list is populated according to the drivers that were loaded when the indiserver started.

- If you have more than one QSI or SX camera connected to your computer, choose the 'Cameras | Select CCD camera...' option. Select the desired camera in the pop-up dialog box and click OK. GoQat will remember your last selected choice and open that camera automatically if it is available.

Then go to the main CCD Camera tab and click the 'Open camera' check box to open the camera. The name of the camera you have selected is shown next to the check box.

When GoQat connects to your camera, the CCD Camera tab should look something like Figure 2 on the next page. This screenshot is for a natively-supported QSI camera; for an SX or INDI camera there is a reduced number of items shown in the 'Camera status' panel.

If GoQat cannot find your SX camera, you may need to tell GoQat more about it. Please see section 23.3.

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

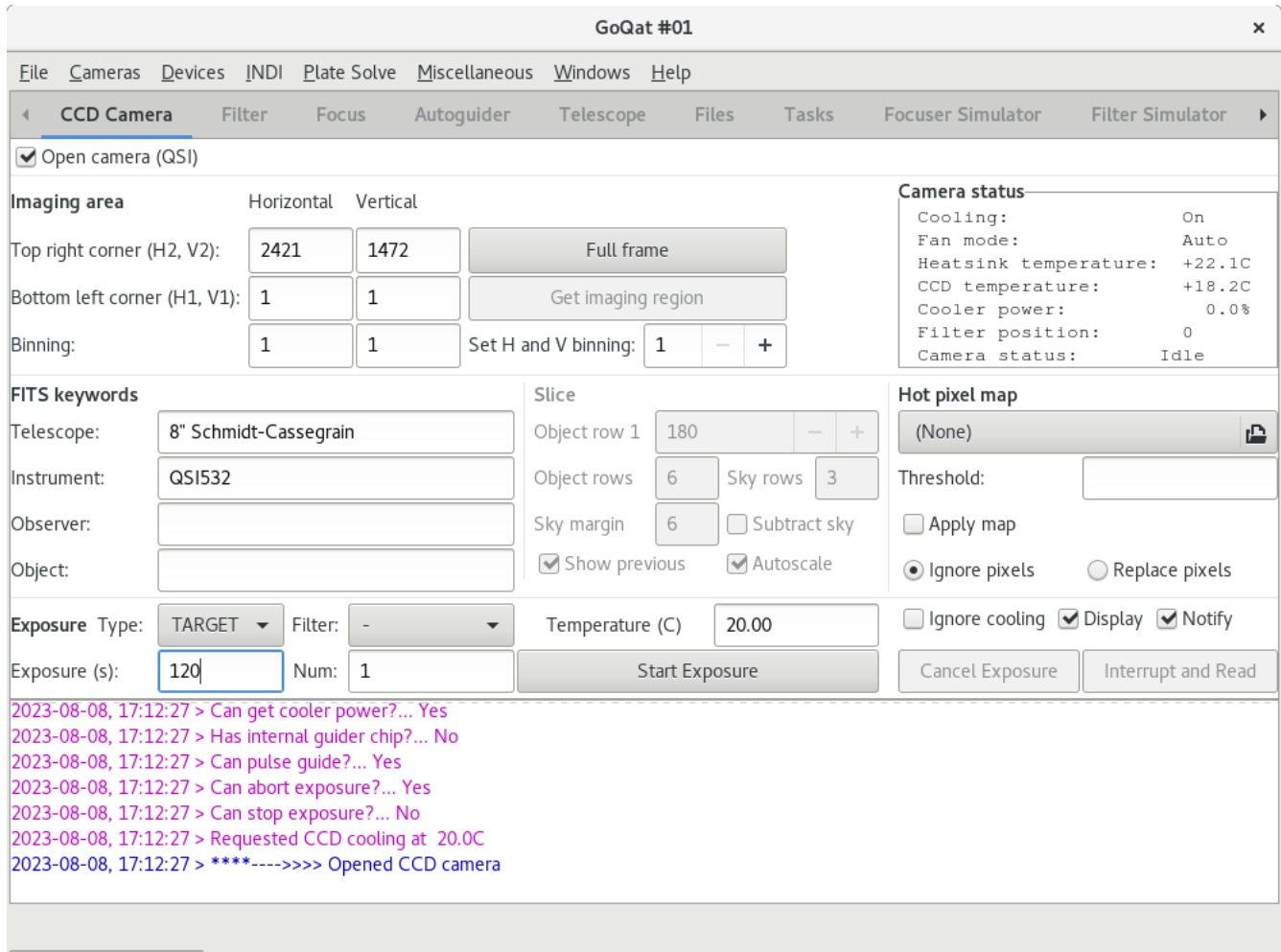


Figure 2: GoQat's main window when connected to a QSI camera

8.2 Configuring an INDI camera

Select 'Configure CCD camera...' from the Cameras menu after you have opened the camera. The CCD camera configuration dialog box will open. This is a 'modal' dialog; you must close it before you can interact with other parts of GoQat.

- GoQat remembers settings on a per-camera basis, so any changes you make will also be applied automatically next time you open the same camera.

Adjust any settings as follows:

8.2.1 Cooler Operations

If your camera has cooler control, the Cooler options will be available.

- Enter a default cooler temperature and click 'Set'. This also alters the value in the 'Temperature' field on the CCD Camera tab, but you can change this independently if you wish.
- Enter a value in the 'Temperature tolerance' field and click 'Set'. GoQat considers the camera to be at its target temperature if it lies within this tolerance of the target value. By default, GoQat will not make an exposure until the target temperature is met, but you can switch off this behaviour by clicking 'Ignore cooling' on the CCD Camera tab.
- If you want to start or stop the cooler manually and your camera supports this, click the 'Cooler on' or 'Cooler off' buttons. If you have entered a new value for the default target temperature you must click the corresponding 'Set' button before you start the cooling.

8.2.2 Image orientation and binning

- You may choose to flip the image orientation vertically or horizontally, or both, by selecting the appropriate check box. For performance reasons, this applies only to non-streamed images. The INDI client tab for the camera may offer this for streamed images instead.
- GoQat needs to know whether your camera allows asymmetric binning, e.g. 1x2 or 3x2. Check the asymmetric binning check box if it does allow this.
- If your camera allows odd-number binning, e.g. 2x3 or 3x3, check the odd number binning check box.

8.2.3 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' check box. 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. You may need to experiment to determine the correct setting. If you expose an image using only a subset of the full

imaging area, GoQat will calculate the appropriate starting pattern from this full-frame setting.

- If you leave the 'Debayer images' check box 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 de-bayered image is already being displayed, the raw data will be de-bayered again 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.

8.2.4 INDI configuration

You can save a camera configuration from the INDI client tab. This configuration comprises the current INDI client settings for that camera. If you want GoQat to re-load these settings for you when the camera is opened, check the 'Load INDI config when opening camera' option.

8.3 Configuring a QSI camera

Select 'Configure CCD camera...' from the Cameras menu after you have opened the camera. The CCD camera configuration dialog box will open. 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:

8.3.1 Cooler Operations

- Check the 'Start cooler automatically' check box if you want the cooling to start as soon as GoQat connects to the camera.

- Enter a value for the default cooler temperature and click 'Set default'. This also alters the value in the 'Temperature' field on the CCD Camera tab, but you can change this independently if you wish. The default 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.

8.3.2 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.

8.3.3 Exposure Control

Here 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 described in the table on the following page.

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)
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

	Low/High	Switches to high speed from low speed for autofocus calibration and focusing
Anti-blooming	Normal	Normal anti-blooming
	High	High anti-blooming

NOTE:

- The shutter options apply only to those cameras with mechanical shutters
- Fast exposure mode applies for interline cameras only
- 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

8.3.4 Image

You may choose to flip the image orientation vertically or horizontally, or both, by selecting the appropriate check box at the bottom left of the Configuration dialog.

8.3.5 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' check box. 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. You may need to experiment to determine the correct setting. If you expose an image using only a subset of the full imaging area, GoQat will calculate the appropriate starting pattern from this full-frame setting.
- If you leave the 'Debayer images' check box 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 de-bayered image is already being displayed, the raw data will be de-bayered again 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 Figure 3 below.

Main camera #01 configuration for QSI 00503078

<p>Cooler Operations</p> <p><input checked="" type="checkbox"/> Start cooler automatically when connected</p> <p>Default temperature (C): <input style="width: 50px;" type="text" value="-5.0"/> <input type="button" value="Set default"/></p> <p><input type="button" value="Cooler on"/> <input type="button" value="Cooler off"/></p> <p> <input type="radio"/> Fans high Permanently high speed </p> <p> <input checked="" type="radio"/> Fans auto Low speed; high speed if cooling requires it </p> <p> <input type="radio"/> Fans off Permanently off; can be beneficial with liquid cooling </p> <p><input type="button" value="Set fan state"/></p>	<p>Exposure Control</p> <p>Shutter priority: <input style="width: 50px;" type="text" value="-"/> <input type="button" value="Set"/></p> <p>Shutter mode: <input style="width: 50px;" type="text" value="-"/> <input type="button" value="Set"/></p> <p>Manual shutter: <input style="width: 50px;" type="text" value="-"/> <input type="button" value="Set"/></p> <p>Pre-exposure flush: <input style="width: 50px;" type="text" value="Agressive"/> <input type="button" value="Set"/></p> <p>Fast exposure mode: <input style="width: 50px;" type="text" value="-"/> <input type="button" value="Set"/></p> <p>Camera gain: <input style="width: 50px;" type="text" value="-"/> <input type="button" value="Set"/></p> <p>Readout speed: <input style="width: 50px;" type="text" value="-"/> <input type="button" value="Set"/></p> <p>Anti-blooming: <input style="width: 50px;" type="text" value="-"/> <input type="button" value="Set"/></p>
--	---

Image

Flip image up/down Flip image left/right

Colour

Debayer images

Bayer pattern:

Figure 3: Camera configuration dialog box for QSI camera

8.4 Configuring a Starlight Xpress camera

Select 'Configure CCD camera...' from the Cameras menu after you have opened the camera. The CCD camera configuration dialog box will open. Any changes to configuration settings will also 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.

► 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:

8.4.1 Cooler Operations

If your camera has cooler control, the Cooler options will be available.

- Check the 'Start cooler automatically' check box if you want the cooling to start as soon as GoQat connects to the camera.
- Enter a default value for the desired cooler temperature and click 'Set'. This also alters the value in the 'Temperature' field on the CCD Camera tab, but you can change this independently if you wish. The default 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.
- Enter a value in the 'Temperature tolerance' field and click 'Set'. GoQat considers the camera to be at its target temperature if it lies within this tolerance of the target value. By default, GoQat will not make an exposure until the target temperature is met, but you can switch off this behaviour by clicking 'Ignore cooling' on the CCD Camera tab.
- If you want to start or stop the cooler manually, click the 'Cooler on' or 'Cooler off' buttons. If you have entered a new value for the default target temperature you must click the corresponding 'Set' button before you start the cooling.

8.4.2 Image

- You may choose to flip the image orientation vertically or horizontally, or both, by selecting the appropriate check box.

8.4.3 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' check box. 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. You may need to experiment to determine the correct setting. If you expose an image using only a subset of the full imaging area, GoQat will calculate the appropriate starting pattern from this full-frame setting.
 - If you leave the 'Debayer images' check box 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 de-bayered image is already being displayed, the raw data will be de-bayered again 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.

8.4.4 A remark about exposure length with interlaced cameras

Interlaced SX cameras such as the Lodestar have the image read in two interlaced halves. These two half images are normally read sequentially, so for very short exposures the difference in exposure time between the two halves would be significant because of the read time of the first half. Consequently, very short exposures of less than 0.1s have the two halves of the image exposed and read sequentially so that they are both the same length. (The read time is about 0.1s for one half of a Lodestar image; for other interlaced cameras it may be longer). Longer exposures have the two halves exposed simultaneously and the exposure length reported to the FITS header is the requested exposure time plus the read time of the first half – so it's a (sort of) average exposure length for the two halves.

For short exposures a stepped appearance can be seen down the image as the brightness differs from one line to the next. GoQat attempts to minimise this by scaling the shorter half such that its median value is the same as for the longer half. Note that this scaling is not perfect – GoQat scales ‘data + bias’ of the shorter exposure, rather than subtracting off the bias, then scaling the data values and adding the bias back on. This makes a cosmetic improvement but you should be wary of using an interlaced camera for high precision photometric work with short exposures.

9. Capturing Camera Images Directly with GoQat

This chapter applies to cameras controlled by GoQat's CCD Camera tab, rather than via the INDI client interface. This includes natively supported QSI and Starlight Xpress cameras and any other camera for which there is an INDI driver.

9.1 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. The chosen exposure type forms part of the file name, should you choose to save the image.
- If your camera has a filter wheel, or you are using an external wheel that you have already connected to, 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.
- By default, GoQat waits until the camera is within the specified tolerance of the target temperature before making an exposure (this tolerance is set in the camera configuration dialog for SX and INDI cameras; for QSI cameras it is hard-wired to 0.1K and the user does not have the option to change it). If you want to ignore the temperature setting, check the 'Ignore cooling' box.
 - If you specify a chip temperature higher than the current ambient temperature then GoQat may wait indefinitely for it to be reached.
- By default, the acquired image is displayed in DS9. If you don't want to display the image, or perhaps you have a different image viewer, un-check the 'Display' box. This can be useful if you are running GoQat in the background and don't wish to be disturbed. But please remember to save your images! (Un-checking the 'Display' box also removes the warning message about DS9 being unavailable if you have chosen to compile GoQat without support for it).
- If you want a 'beep' to remind you that the exposure has finished, check the 'Notify' box.

- 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 (and fractions of a second).
- Enter the number of exposures that you want to make.
- Click the 'Start Exposure' button. GoQat will rotate any filter wheel to the correct position and 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 unless you have checked the 'Ignore cooling' option.

When the exposure has completed, GoQat will attempt to query the telescope controller for the current RA and Dec values to write them to the FITS header (this may require the telescope controller to be in 'high precision' mode where applicable). Then the image is displayed in DS9 (if installed). Please see section 9.8 for details of how to configure DS9 for use with GoQat, and some other useful hints and tips. See section 23 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, M57 in false colour) should look something like Figure 4 on the following page.

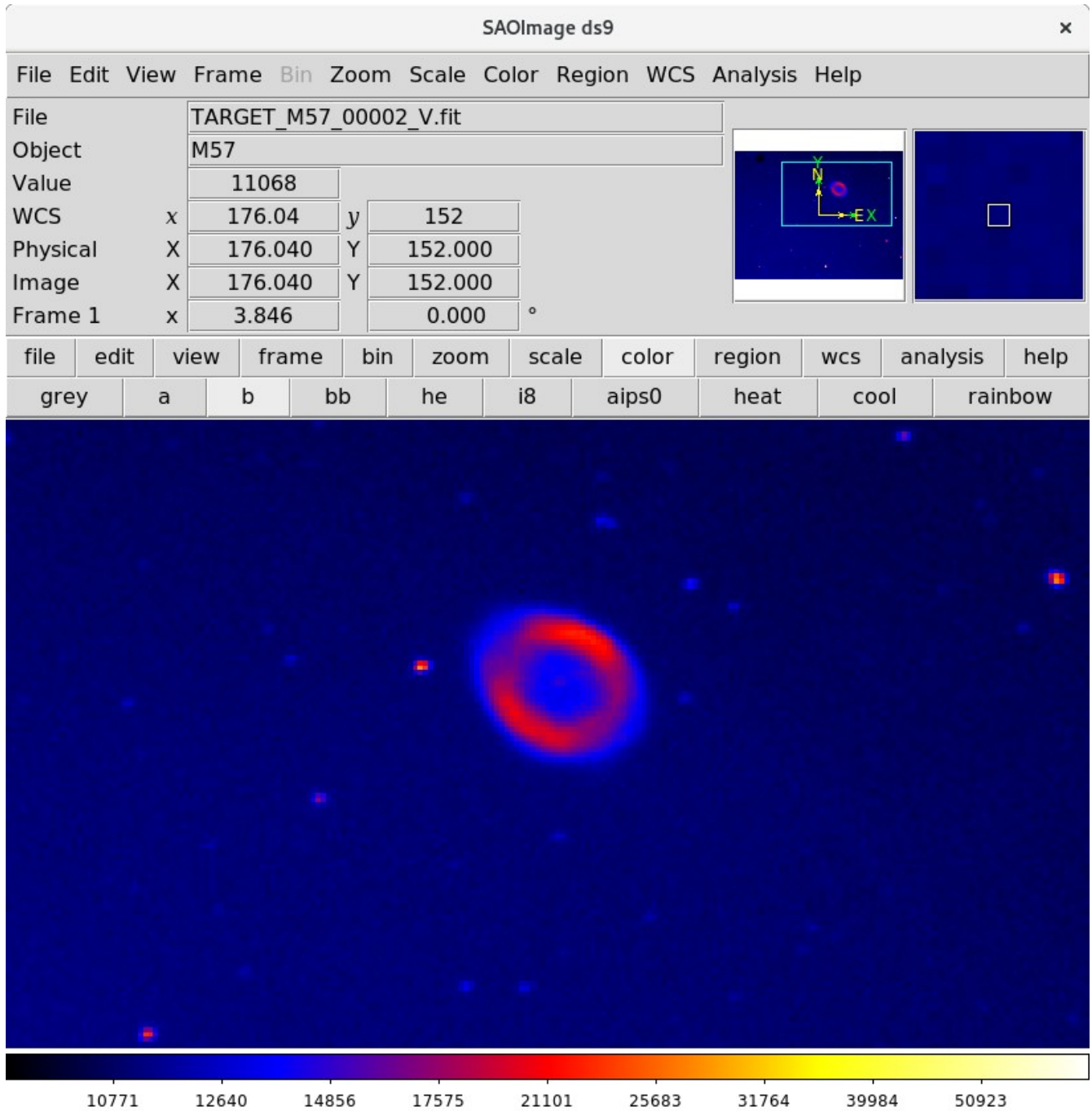


Figure 4: Image display in DS9

9.2 Sub-frames and binning

9.2.1 Sub-frames

The imaging area is defined on the CCD Camera tab by the horizontal and vertical coordinates of the bottom left (H1, V1) and top-right (H2, V2) corners 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 '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 9.3). Please read section 9.8 to ensure that DS9 is set up correctly first.

- Either click the 'Full frame' button and set binning to 1x1, or set the 'Embed in full frame' option on the Cameras menu (this is the default choice). Then make a camera exposure. The 'Get imaging region' button on the CCD Camera tab now becomes available.
- Click and drag a rectangle over the area in DS9 that you want to select. If there is more than one rectangle, GoQat will use the first one that you defined. To delete a rectangle, click anywhere within it and press the 'Delete' key on your keyboard.
- Click the 'Get imaging region' button on the CCD Camera tab. This will load the coordinates of the selected region into GoQat.
- Then make the sub-frame exposure (this can be at any permissible binning value).

9.2.2 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, you can use the 'Set H and V binning' spin button to adjust both values together. Be careful to choose only those values that are allowed by the camera firmware. GoQat will not permit you to use values that are prohibited by settings in the camera configuration dialog.

9.2.3 Image sizes for sub-frames and binning

GoQat applies the following rules for sub-frames, so the actual size and location of the sub-frame may differ slightly from the one that you choose.

- The height and width of the sub-frame are trimmed to a multiple of the binning value in the two respective directions.
- The coordinate of the first image corner is set to a multiple of the binning size in each respective direction.
- For sub-frames that are not binned vertically, the height of the image and the vertical coordinate of the first image corner are set to an even value in case the camera has an interlaced chip.

9.3 Sub-frames, binned images and the 'Embed in 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 of a binned exposure remain the same size as the un-binned exposure if you select the 'Embed in full frame' option on the Cameras menu. When this has been selected, subsequent binned images are expanded for display (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) so that the image occupies the same area on the display as an un-binned image would do.

When this option is set, sub-frame exposures are displayed embedded in an image the size of the full chip area, but any values outside the sub-frame area are set equal to the minimum data value in the sub-frame.

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.

9.4 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 queue. See section 18.5.

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 for the passage of a satellite across the target area, for example.

9.5 Camera cooling

For cameras with cooling control, the '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, GoQat waits until the camera is within the specified tolerance of the target temperature before making an exposure (this tolerance is set in the camera configuration dialog for SX and INDI cameras; for QSI cameras it is hard-wired to 0.1K and the user does not have the option to change it). If the cooling is off when you attempt to start the exposure, it will be switched on to achieve the desired temperature. You can override this behaviour by checking the 'Ignore cooling' option on the CCD Camera tab.

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 SX and INDI cameras if they report one. If you enter a temperature that is greater than the current heatsink temperature for a QSI camera, it will be ignored. In this case, the exposure will start immediately without regard to the current chip temperature. For SX and INDI cameras, GoQat may wait indefinitely for this new higher temperature to be reached.

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 SX and INDI cameras. 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. You may also pause plotting by de-selecting the 'CCD temperatures' menu item.

For a QSI camera, your display should look something like Figure 5.

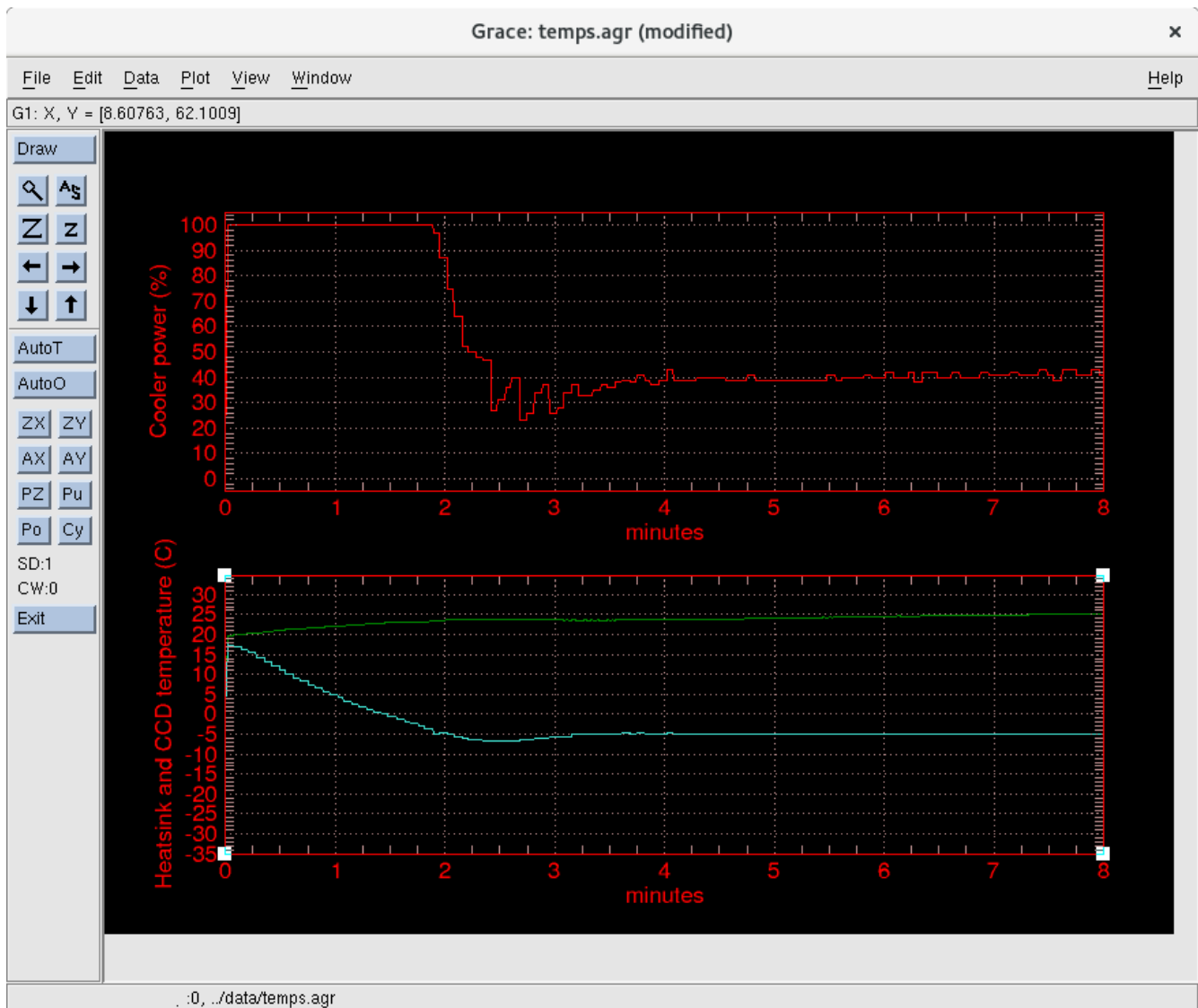


Figure 5: Plot of cooler power, heatsink and CCD temperatures for a QSI camera in Grace

9.6 Image slice

GoQat can display a horizontal slice (along the row direction) of an image. This can be useful for checking star profiles for focusing purposes, for examining regions of the image to check that it is well exposed, or for displaying a 'quick look' at a spectrum.

To activate the display, select the 'CCD image slice' menu option from the Windows menu. If you have already made a camera image, GoQat will display the slice of the chosen region. GoQat will display and update the image slice for each new image.

Object regions and sky regions

To specify the object region, enter the first row number containing the region of interest as 'Object row 1'. The row number is given on the DS9 display as the Image Y-coordinate. Then enter the number of contiguous rows to include in the object region. (Entering '1' for 'Object rows' includes just the row specified for object row 1, entering '2' also includes the row immediately above it etc).

Enter the number of sky rows to use if you want to do sky subtraction. The number of rows that you enter defines two sky regions, each of that number of rows, spaced symmetrically above and below the object region.

The sky margin is the number of rows above and below the object region by which the sky regions are separated from it.

GoQat will subtract the sky region from the object region if you select the 'Subtract sky' check box. The sky region is scaled to the same number of rows as the object region.

If you are displaying a binned image with the 'Embed in full frame' option active, GoQat expands the binned image to the unbinned chip size for display. In this case, the placement of the object and sky regions is constrained to bin boundaries. The image slice graph still displays the true binned image values correctly.

You can step the entire object and sky region in lockstep up and down the image by pressing the '+' and '-' buttons on the 'Object row 1' spin button. Figure 6 shows how the various regions are defined.

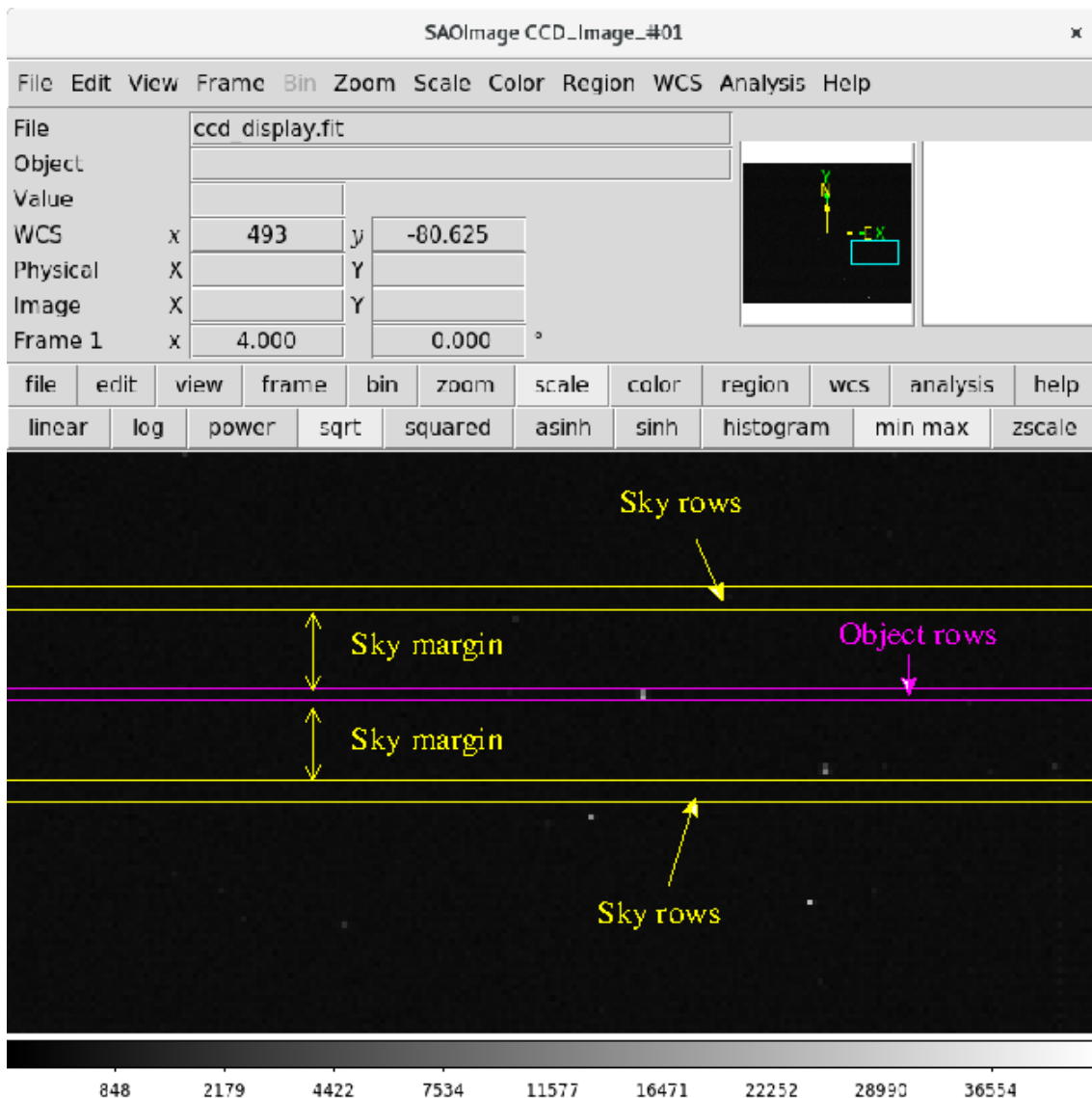


Figure 6: Object and sky regions for the image slice

Re-drawing and scaling the image slice

GoQat redraws the image slice each time you alter any of the entry fields defining the object and sky regions or the margin. Press the Enter key after making any changes.

If you select the 'Show previous' option, GoQat will show the previous image slice in blue each time a new image slice is drawn. This way it is easy to compare the current image

slice with the previous one. This is useful (for example) if you want to see whether a change of focus has improved the image or not.

GoQat autoscales the graph if you check the 'Autoscale' check box. You can also use the controls provided in the Grace graph window.

Closing the image slice window

You may close the Grace graph window by clicking the 'x' in the top right corner when you have finished with it. This will automatically turn off the 'CCD image slice' menu option. Deselecting the 'CCD image slice' menu option prevents further graph updates but does not close the graph window.

Your chosen image slice settings are saved on a per-camera basis and restored when you re-open the camera.

9.7 Hot pixel map

You can create a hot pixel map for use with GoQat. Hot pixel maps apply to monochrome images only.

To create the map, cover the camera and take an exposure of sufficient length to activate those pixels that you want to ignore. Then save the image. The hot pixel map should be a full-frame image in the same orientation and binned the same way as the images to which it will be applied. You can apply a full-frame hot pixel map to a sub-framed image.

To use the hot pixel map, choose the desired image file in the 'Hot pixel map' part of the CCD Camera tab. Enter the desired value for the hot pixel threshold. Any pixels whose values are greater than this in the hot pixel map are considered to be hot pixels in any image to which the map is applied.

Click 'Apply map' to apply the map to subsequent images. You must do this before starting the exposure to which the map is applied.

There are two possible ways of applying the map:

- 'Ignore pixels' instructs GoQat to ignore the hot pixels when calculating some of the image statistics. In particular, the maximum value will not include the values of any hot pixels. This is useful when you want GoQat to ignore hot pixels, for example during focusing routines, but you would still like to see where such pixels are. The maximum value written to the FITS header of a saved image file will also exclude hot pixels in this case.

- 'Replace pixels' has the same effect as above but in addition hot pixels are replaced with the modal (most likely) value in the image . This will be a good estimate of the sky background for nighttime sky images, thus making the hot pixels 'disappear'. This option can have the effect of enhancing hot pixels in daytime images so isn't really suitable in that case.

9.8 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.

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

9.8.1 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 9.3.

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 'Edit' option and slide the mouse down to 'Region'. This ensures that a region of interest box will be displayed when you click on an image.
- 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 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 9.3.
- 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.

9.8.2 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 some of the items for that menu in the second row of buttons.
- 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 before loading the corresponding R, G or B file (see below).
- 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.

9.8.3 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 may not be 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 in the pop-up 'RGB' window.
- 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.

10. Autoguiding

GoQat can autoguide using the following imaging devices:

- Any INDI camera, including image-streaming devices
- Natively-supported Starlight Xpress cameras including the Lodestar
- Natively-supported QSI cameras
- Natively-supported Video-for-linux (V4L) and Unicap devices including webcams and frame-grabbers

GoQat can send guiding commands via:

- A guide port built in to the CCD or autoguider camera that is connected to a telescope controller autoguider port.
- 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
- TTL-level guiding signals from a parallel port, either a native port or an expansion card
- Any INDI device capable of sending guide signals (including sending guide signals directly to an INDI telescope device driver rather than via an autoguider port)

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

10.1 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:

- V4L (/dev/video0 to /dev/video3): Native video-for-linux support, typically for use with webcams or frame-grabbers.
- Unicap: Natively-supported Unicap devices including image-streaming cameras and frame grabbers.
- SX: A natively-supported Starlight Xpress camera.

- SX guide head: A guide head connected directly to a natively-supported Starlight Xpress camera.
- QSI: a natively-supported QSI camera
- INDI: An INDI camera (which may be a guide chip internal to the main CCD camera)

10.1.1 Video-for-linux options

GoQat displays autoguider images in monochrome and automatically selects an appropriate method of image decoding. For devices returning colour images you can choose the colour-to-greyscale conversion method that you want to use from the 'Greyscale conversion >' item on the Cameras menu. You may also choose 'mono' if you want to force GoQat to decode the image as 8 bit greyscale.

10.1.2 Unicap, Starlight Xpress and QSI options

If you choose the Unicap, SX or QSI option and have more than one Unicap device, SX or QSI camera connected to your computer, you should select the 'Cameras | Select camera...' menu option to specify which camera you want to use. Choose the desired camera in the pop-up dialog box and click OK. GoQat remembers your selection and will open that camera automatically in future if it is available, but you can change the selection at any time. If you have only one camera connected to your computer, that camera will be selected automatically. You can choose the colour-to-greyscale conversion method for colour images from Unicap devices as for video-for-linux devices above.

10.1.3 INDI cameras

Choose any of the INDI cameras available from the pop-out menu. If you wish to use a guide chip internal to the main camera, choose the main camera here and check the 'Use main camera guide chip' check box on the Autoguider tab before opening the camera.

10.2 Selecting a guide signals device

You need to specify how the guide signals are sent to your telescope controller. Go to the Devices menu, highlight the 'Guide commands >' option and select your choice from the list, as described below.

10.2.1 Via the guide camera or CCD camera

If you are using an autoguider camera or a CCD camera with a built-in guide port, you can choose to send guide commands to your telescope controller via that port. Select the 'Via autoguider camera' or 'Via CCD camera' option as required. You should ensure that you have opened the guide camera or CCD camera before you attempt to start autoguiding if you have selected one of these options.

10.2.2 Serial/USB connections

GoQat lists serial ports `/dev/ttyS0` to `/dev/ttyS9` by default in the pop-out menu. USB-serial converters appear as `/dev/ttyUSBXXX` where the 'XXX' is a number that depends on the order in which the USB converters are enumerated. The USB menu options appear and disappear as you plug in or unplug the converter.

10.2.3 Via the parallel port

Select the 'Via Parallel port' option to send guide signals via the parallel port.

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 'Configure parallel port...' option from the Devices 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. These settings are remembered by GoQat.

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.

10.2.4 Via an INDI device

GoQat supports any INDI device capable of sending guide signals to a telescope controller. Choose the required device from the pop-out menu. If you want to send guide signals via the autoguider or CCD camera you may choose the 'Via autoguider camera' or 'Via CCD camera' options described above, or pick the same INDI device as the autoguider or CCD camera from the pop-out list.

10.3 Opening the autoguider camera and the guide signals device

Camera

Go to the Autoguider tab and click the 'Open camera' check box. If you are using an INDI device that only streams images (e.g. a webcam), check the 'Stream video' option before opening the camera. Some INDI cameras allow you to choose between streaming and non-streaming mode. Check the 'Stream video' option if you want to open such a camera in streaming mode.

- For ZWO cameras it may not be possible to stream images to GoQat in 16-bit mode. This may be a bug in the INDI driver. In this case, you should connect to the camera on the INDI client tab and set the camera to 8-bit mode before opening the camera on the Autoguider tab.
- To use the INDI 'V4L2 CCD' driver with GoQat, you should set mono format, native encoding and disable compression on the client tab. Planar YUV 4:2:0 is a good capture format if present.

The autoguider Image window will open when the camera is opened and the autoguiding options on the Autoguider tab will become available.

- You may wish 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.

Images from the autoguider camera are captured and displayed as soon as the Image window is open. You can pause capturing autoguider images for most cameras by clicking the 'Pause' button at top left of the Image window. The main reason for doing this is discussed in section 11.

Guide signals device

To open the guide signals device, click the 'Open guide port' check box on the Autoguider tab.

- If you have selected the same INDI telescope driver for both the telescope controller and the guide signals device, the guide port will be opened and closed automatically when you open and close the telescope controller on the Telescope tab.
- You can still uncheck the 'Open guide port' check box after the telescope controller has been opened and then open a different guide signals device if desired. It is not necessary to close the telescope controller first.

- If you have selected one of the serial or USB ports, GoQat is likely to display a message stating that the port has been opened successfully. GoQat assumes that the device it is talking to is a dumb device and does not try to have a two-way conversation with it; therefore GoQat does not know whether any 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 serial port for both guiding and telescope control commands. GoQat can share the same serial/USB port between guiding and telescope control commands and does not close the port until you close both the guide port and the telescope port.

10.3.1 Autoguider camera settings

When the camera has been opened, it is possible to adjust certain settings:

Native V4L cameras

The 'Set V4L properties...' menu item becomes available on the Cameras menu. You can set frame size, frame rate, the video standard for any cameras connected to a frame-grabber (e.g. PAL, NTSC or SECAM) and the port on the grabber to which such cameras are connected. Some of the above options may not be supported by some devices. Permitted image sizes and frame rates are listed in the log window when the camera is opened.

Native Unicap cameras

The 'Set Unicap properties...' menu item becomes available on the Cameras menu. You can adjust any properties supported by the Unicap library for the connected device. This typically includes signal sources, image formats and brightness/contrast settings. Some settings (e.g. brightness and contrast) can be adjusted directly. Others, such as those requesting a change of image format, require the camera to be re-opened. To do this, click the 'Apply settings' button.

Native QSI and SX cameras

The 'Configure autoguider camera...' menu item becomes available on the Cameras menu. See sections 8.3 and 8.4.

You can set the desired image size and binning in the camera configuration window. The image size is specified as a percentage of the width and height of the full frame image size, centered on the middle of the camera sensor. So an image size of 60% returns an image that covers 60% of the width and 60% of the height of the sensor, beginning and ending 20% of the way in from each edge. After modifying the image size or binning you must click the 'Restart autoguider camera' button to have the changes take effect. The image will be zoomed to fit the display as far as possible.

GoQat does not presently debayer autoguider camera images but this is only of consequence for unbinned images.

INDI cameras

The 'Configure autoguider camera...' menu item becomes available on the Cameras menu. See section 8.2.

You can set the desired image size and binning in the camera configuration window for cameras that permit it. The image size is specified as a percentage of the width and height of the full frame image size, centered on the middle of the camera sensor. So an image size of 60% returns an image that covers 60% of the width and 60% of the height of the sensor, beginning and ending 20% of the way in from each edge. After modifying the image size or binning you must click the 'Restart autoguider camera' button to have the changes take effect. The image will be zoomed to fit the display as far as possible.

GoQat does not presently debayer autoguider camera images but this is only of consequence for unbinned images.

In addition, you may still set any device-specific configuration options on the corresponding INDI client tab (see section 6.3), but GoQat will manipulate some of the standard options when it takes control of the camera.

For image-streaming devices in particular, you may find it useful to open the device via the INDI client tab first and set desired parameters before opening the camera on the Autoguider tab. In particular GoQat does not support native image flipping for streaming INDI devices for performance reasons but this option may be available on the corresponding INDI client tab.

- You do still need to 'open' the camera on the Autoguider tab after opening it in the INDI client interface to make the 'logical' connection with GoQat.

10.3.2 The autoguider image window

The Image window performs the following functions, which are described in detail in this and the following sections:

- 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

By default, images are zoomed to fit the display as far as possible when the camera is opened.

Region of Interest (ROI)

The entire image is surrounded by a green rectangle that defines the region of interest. The guide star must lie within this region. You can interact with the ROI rectangle as follows:

- Hold down the Ctrl key and click and drag to expand or shrink the rectangle, subject to it being at least as large as the centroid box (see below). You cannot drag the rectangle outside the image area.
- If the rectangle is smaller than the image window, hold down the shift key and then make a single mouse click to centre the rectangle over the desired point.

Cross-hairs

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 and adjusts the rotation of the cross-hairs accordingly.

Zooming and scrolling

Click the '+' button at top right to zoom in and '-' to zoom out again. Each click of the zoom buttons changes the displayed image area by a factor of 2. Click '1' to restore the

zoom level to actual size. Click the rightmost button to zoom the image to fit the display as far as possible – this also resets the ROI rectangle to the full image area. You can use the scroll bars to move about the image if necessary.

Status bar

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

- Cursor coordinates.
- Minimum, maximum and median pixel values within the ROI 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.
- Temperature of autoguider camera chip (T) where this is available; otherwise 0.0 is shown.

Histogram plot

To the right of the image area, the Histogram plot displays a histogram of the data within the ROI rectangle, after any manual background level adjustment and dark subtraction (see section 10.3.3). The plot is auto-scaled, and below the plot is given the data value at which the peak lies.

Centroid plots

The centroid plots include the effects of manual background level adjustment and dark subtraction and automatic sky background subtraction (see below). The plots are autoscaled and the maximum value is given below each plot. The Y-Centroid display gives the total number of counts in each row within the blue centroid box (see below) and thus indicates where the 'centre-of-weight' must be in the Y-direction (in the Image window, the y-coordinate increases downwards). The X-Centroid display similarly shows the data for each column. GoQat derives the actual centroid of the data to sub-pixel accuracy and adopts this as the location of the guide star. The RMS values give the root-mean-square deviation of the centroid in the X and Y directions from its initial position. The initial position is determined whenever the ROI rectangle is re-drawn, or when autoguiding starts, at which point the RMS values are re-set to zero.

GoQat automatically estimates the sky background from the histogram data when calculating the centroid of the guide star position and subtracts a constant value equal to a given number of standard-deviations (σ) above this background level. You can adjust this σ value in the 'Guide star detection level' field on the Autoguider tab. When correctly set, the centroid plots should show a distinct stellar profile above a zero background.

Centroid box

By default, the pixel with the highest value in the ROI rectangle is centered within a blue centroid box. GoQat uses the data shown in the centroid plots to calculate the centroid of all the pixel values within that box and marks it with a small blue circle (the centroid 'dot'). The dot will be coloured red if the highest pixel value is at or above the saturation level. If GoQat is unable to determine the centroid (perhaps because there are no pixel values above the estimated sky background level) then the dot disappears. GoQat assumes that the position of the centroid dot marks the photocentre of the guide star and uses this when calculating guide corrections.

You can choose to place the centroid box somewhere other than the brightest pixel by clicking on a different location (this is mostly useful for autoguider calibration – see below). If GoQat cannot determine the centroid of that location it will return to the brightest pixel. You can only choose a location within the ROI rectangle; the rectangle will flash as a warning if you click outside. The centroid box also returns to the brightest pixel whenever the ROI rectangle is redrawn.

The size of the centroid box is adjustable. Set the width and height of the box in pixels in the 'Centroid size' field on the Autoguider tab. A width of around 15 pixels is a good starting point to include sufficient sky round the chosen star. You may want to change this if you alter the binning used by the autoguider camera. You can also turn the box on and off using the 'Show centroid box' check box.

10.3.3 [Adjusting the image display](#)

Brightness, Contrast, Gamma, Gain

For V4L devices (either natively-supported or via INDI), the sliders at the bottom of the Image window can be used to adjust the brightness, contrast, gamma and camera gain (not all V4L devices may support gain adjustment). These settings affect the data that GoQat receives from the V4L camera driver, so you may be able to improve guiding performance by making any such adjustments. For INDI image-streaming devices you may be able to adjust other settings using the INDI client interface.

For non-streaming devices such as CCD/CMOS cameras, you can adjust the gamma value to make guide stars more easily visible. This is a convenience for the user only and does not affect the raw data that GoQat receives from the camera, nor does it affect guiding performance. Gamma values less than 1 slow down the rate at which images can be processed, so when you have selected a guide star, you may wish to 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.

Background level

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.

Dark subtraction

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 in the text entry field adjacent to the 'Capture dark exposures' button on the Autoguider tab
- 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. Clicking the 'Capture' button again overwrites the existing dark frame.

You can re-use your most recent dark frame even if you close and then re-start GoQat or if you change cameras because GoQat saves a camera-specific copy of the current dark frame. If you change the binning value (and thus the image size) you will need to capture a new dark frame.

Finally, after making your dark exposures, remember to uncover the end of the telescope!

Saturation

The 'Saturation' field at the top of the Image window defines a value above which pixels

are considered to be saturated. This value governs the level at which the dot at the centre of the centroid box turns from blue to red. You can also choose to have all pixels above the saturation level displayed in a particular colour. This allows you easily to see if any parts of the image are saturated and therefore unlikely to be useful for autoguiding. Press the Enter key on the keyboard for changes to this value to take effect. By default, the saturation level is 250 for 8-bit cameras and 65000 for 16-bit cameras, but the value you choose is remembered on a per-camera basis and restored each time the camera is opened.

To enable the display of saturated pixels, click the 'Advanced...' button on the Autoguider tab and check the 'Highlight saturated pixels' box. By default, saturated parts of the image are displayed in red but you can set some other colour by entering values for R, G and B. Click the 'Set' button to have them take effect.

GoQat determines saturation from the raw camera data, so background level subtraction or dark subtraction does not affect this even though they may make the image darker on the display. You should ensure that your chosen calibration and guide stars are not saturated or the centroid position will not be calculated accurately.

10.4 Calibrating the autoguider

10.4.1 Locating a guide star

You can use any star for calibration and guiding provided that it is clearly visible above the sky background. By default, GoQat chooses the brightest star within the ROI rectangle and moves the centroid box to that position. Make sure that the chosen star is not saturated (see section 10.3.3) - you should set the exposure length accordingly (see below). For your convenience you can adjust the direction of telescope pointing using the arrow buttons on the Autoguider tab (see section 14.3.6).

10.4.2 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 and press the Enter key to have it take effect. This also applies for streamed images from INDI devices that support it. The default is 1 second but your chosen value is remembered on a per-camera basis and restored each time you open the camera. The exposure is automatically restarted whenever you press the Enter key so you do not have to wait for a long exposure to finish before beginning a shorter one.

Attempting to set the exposure length via the 'Exposure length' field may not work for some streaming devices (e.g. webcams or frame-grabbers). In this case, you may be able to set the required exposure length (or frame rate) via the appropriate camera configuration menu option or via the INDI client tab for INDI devices. But you should still tell GoQat the chosen exposure length in the 'Exposure length' field because this value governs the cadence with which images are processed for autoguiding corrections. For example, if you give an exposure length of 0.5s for a 30 fps webcam, GoQat uses at most two of the thirty individual frames per second for autoguiding.

10.4.3 Performing calibration

GoQat has two calibration modes:

(a) Automatic guide star selection

In the default automatic mode, GoQat picks the brightest pixel within the ROI rectangle (which may be a hot pixel if you have not done any dark subtraction). You can adjust the ROI to contain the star that you want and exclude others. A disadvantage with this mode is that calibration will fail if a star that is brighter than the chosen star moves into the ROI during the calibration process.

(b) Manual guide star selection

In manual mode, you tell GoQat where the calibration star is by clicking on it at each stage of the process. Whenever GoQat wants you to do this, a message is printed in the log window, the centroid box turns cyan rather than dark blue and an 'OK' button appears in the Image window to the left of the zoom buttons. When requested, click on the calibration star to set the centroid box to that position and then click the 'OK' button.

Calibration

Click the 'Calibrate autoguider' button to start calibration.

To perform the calibration, GoQat moves the telescope at the currently set guide speed. If you have a Losmandy Gemini controller, this can be set via the 'Guide speed' field on the Autoguider tab.

GoQat moves the telescope in each direction for the length of time given in the 'E/W calibration time' and 'N/S calibration time' fields. You may need to set these values to give a sufficiently large motion of the star. The duration of movement is subdivided into one-second intervals with a half second pause between them to mimic a typical guide correction.

GoQat instructs the telescope to move west and then back east initially. Then it instructs to move north and back south, to take up any backlash in the southerly direction. Finally it requests a motion south to measure the true north/south rate of motion, followed by north to estimate the degree of backlash.

The actual directions corresponding to north, south, east and west as well as the rate of motion in those directions is determined by the calibration procedure. GoQat also calculates the length of correction needed before any telescope motion occurs when changing declination direction.

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 begin autoguiding.

GoQat remembers the most recent autoguider calibration even if you close and then re-open the camera. You can reset the calibration by clicking the 'Reset calibration' button.

Declination backlash

You should aim to reduce the backlash in the declination direction as far as possible before starting calibration or guiding. Some controllers (e.g. Losmandy Gemini) can provide backlash compensation automatically.

GoQat tries to estimate the amount of remaining backlash during the calibration procedure. This value is displayed in the Autoguider Advanced Configuration window as the 'Apply declination backlash' time. This is the time required for the telescope to reverse direction at the calibration guide speed. You can change this value manually if desired and choose whether or not to use it.

When guiding starts, GoQat assumes that the last direction for declination motion was north, so if you move the telescope south after autoguider calibration and you intend to use the backlash correction you should make sure that you nudge the telescope north again to take up any backlash.

Automatic correction for declination position

A single calibration can be used throughout the sky provided that the autoguider camera orientation remains the same. (Note that this does not apply with German equatorial mounts after performing a meridian flip – the camera is then turned upside-down). 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 when performing the calibration and when autoguiding.

If you want to use this feature, click the 'Advanced...' button on the Autoguider tab to open the advanced configuration options and check the 'Apply dec. correction' check box before starting calibration. Leave it checked afterwards.

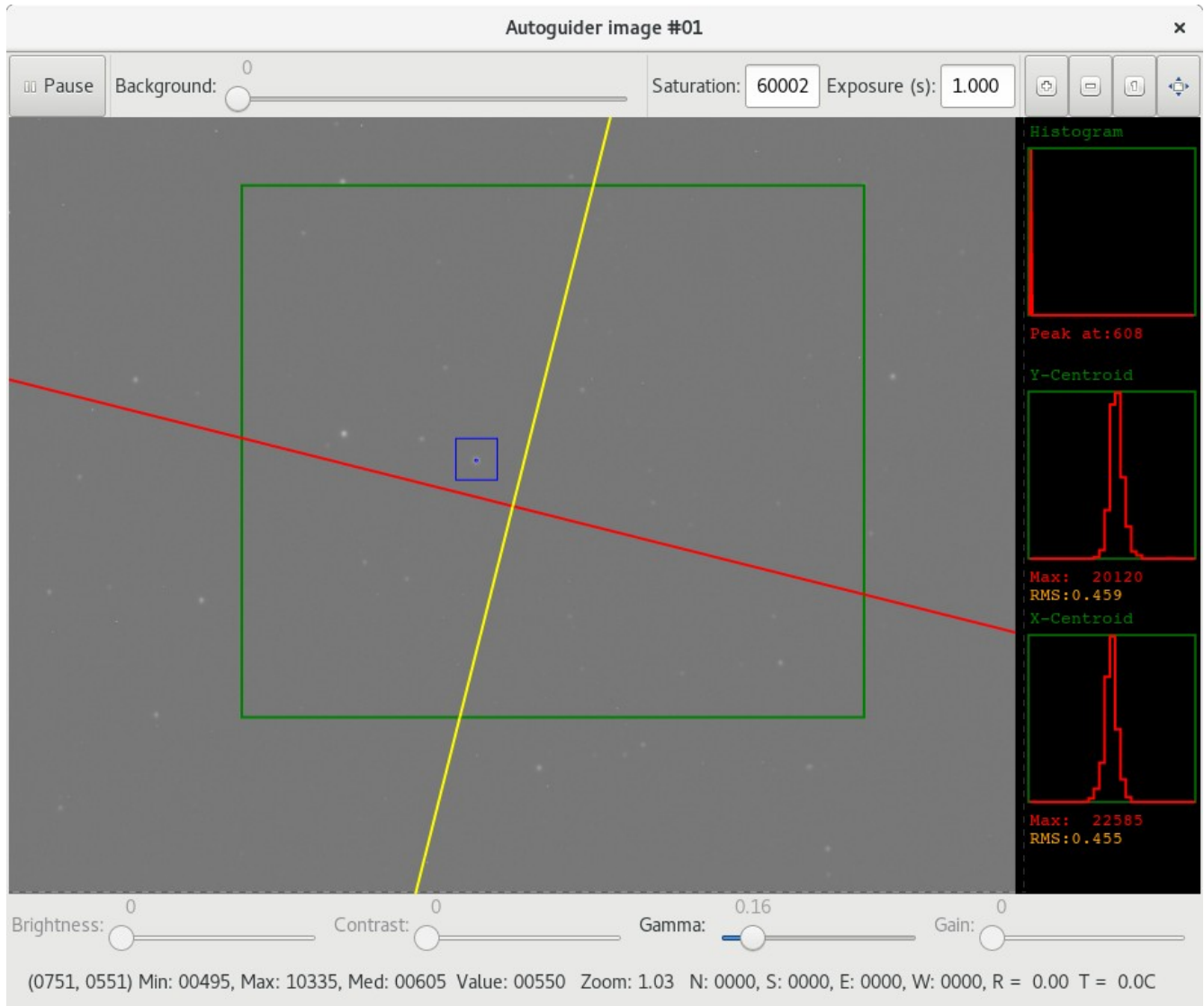


Figure 7: Autoguider image window after calibration

Figure 7 shows the autoguider image window immediately after performing calibration using the star within the green ROI rectangle. The orientation of the camera has been calculated and the cross-hairs re-drawn accordingly.

10.5 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 misalignment.

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.

For heavy setups with a large moment of inertia it can be a good strategy to select a small threshold value and a correction factor rather less than 1. These items are described below.

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. You can use a different speed from the one used for calibration. For non-Losmandy controllers, 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. This is useful if your telescope tends to overshoot the desired position or has a large moment of inertia.
- **Threshold (pixels):** The maximum permissible movement of the guide star in pixels from its initial position before a guide correction is made. This applies to shift corrections (see below).

- **Max. offset (pixels):** The maximum permissible movement of the guide star from its initial position, beyond which no corrections will be made. 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' check boxes at the bottom 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.

The following advanced configuration options are available by clicking the 'Advanced...' button on the Autoguider tab:

Guider calibration

- **Interactive:** Check this setting to perform interactive autoguider calibration, where you click on the chosen calibration star at each stage of the process. (If not selected, GoQat chooses the brightest pixel within the ROI).
- **Calibrate when starting guiding:** Check this setting to have GoQat start the calibration procedure when you click the 'Calibrate autoguider' button on the Autoguider tab.
- **Apply dec. correction:** Select this if you want to perform a single autoguider calibration and then re-use that when pointing elsewhere. The link to the telescope controller must be open so GoQat can determine where it is pointing for calibrating and guiding.

Guiding

- **Shift corrections/Drift corrections/Both:** If you select 'Shift corrections', GoQat corrects for shifts in the measured guide star position, where a shift is the difference between the initial position and the position in any single autoguider camera exposure. If you select 'Drift corrections', GoQat corrects for drifts in the measured guide star position relative to its initial position. A drift is the rolling average of the guide star position over a number of successive autoguider camera exposures. If you select 'Both', GoQat corrects for shift and drift corrections simultaneously, but independently.

- Drift threshold (pixels): The maximum permissible drift of the guide star in pixels from its initial position before a drift correction is made.
- Number of drift samples: The number of successive autoguider camera exposures over which the rolling average of the guide star position is calculated for making drift corrections.
- 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 is handled by the remote hardware; otherwise GoQat sends separate commands to start and stop the telescope motion and does the timing itself. Generally you should leave this box ticked unless GoQat is operating the telescope controller's guide relays directly e.g. via a parallel port.
- If you set the 'Remote timing' option when sending guide signals via the port on a natively-supported 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.
- Use separate E/W rates: The east and west motions are averaged by default when calibrating the autoguider because these are in principle the same (i.e. the telescope moves west and then back east again for the same duration). Averaging may reduce any effects of periodic error. However, a change in guide rate as happens when calibrating implies an acceleration (no matter how small) and hence not an instantaneous change of speed. For unbalanced mounts with a large moment of inertia or with significant wind-up in the gear train the rate of motion can be different for short guide corrections in the east and west directions. Select this to use the different east and west rates obtained from the calibration rather than an average value.
- Simultaneous guiding N/S and E/W: If this is selected, GoQat will attempt to issue guide corrections in north-south and east-west directions simultaneously, if a given correction requires it. Some hardware may not support this option. Otherwise, GoQat sends the two commands sequentially.
- Apply declination backlash (ms): Select this to apply the given correction in milliseconds in addition to any guide correction when the direction of declination

guiding reverses. This is calculated as part of the autoguider calibration, but you may enter any value as desired.

- Guide camera exposure interval (s): In normal operation, one guide camera exposure immediately follows another (or follows after a guide correction has been made). If you want to decrease the rate at which GoQat makes guide camera exposures, select this option and then choose the interval between the end of one exposure and the start of the next. You must deselect this option before changing the interval. This setting does not apply to image-streaming devices where GoQat has no control over the start of the exposures.
- You do not have to use the guide camera specifically for autoguiding. It is possible to save images from the guide camera as .SER video files, even for non-streaming devices, so you could use this option to create a video of the passage of the night sky overhead, recorded at 1-minute intervals, for example.
- Minimum guide corrections interval (s): If you do not want to make guide corrections too frequently, enter the minimum time in seconds that must elapse between successive guide corrections.
- Wait for autoguider before each main camera exposure: If you select this option, a pending exposure for the main imaging camera will be delayed if necessary until any guide corrections that are currently in progress have finished.

Dithering

- Dither: Select this to have the telescope pointing dithered between exposures (see section 10.7).
 - 1) Automatic: choose this to have dither steps made in random size and direction, constrained by the specified smallest and largest step size.
 - 2) Manual: choose this to specify size and direction of dither steps manually.

Spectroscopy

- Show slit: Select this option to display the location of a spectrograph slit. Enter the coordinates of the centre of the slit, its width and height, in pixels appropriate to the binning that you are using. Click 'Set' to have changes to these values take effect. If you change the camera binning or image orientation after clicking 'Set', you will need to adjust the coordinates, width and height, accordingly.
- GoQat does not rotate the orientation of the slit after autoguider calibration if the guide camera is not aligned with the RA/Dec axes. You should ensure that the camera is correctly aligned if you want to use this feature.

Image display

- **Highlight saturated pixels:** Select this to have pixel values above the saturation level in the autoguider image window displayed in the colour of your choice. Enter the desired R, G and B values and click 'Set' to set the colour.
- **Show every 'n' images:** If you want the autoguider image display to be updated only every 'n' images, enter the value here and click 'Set'. Every autoguider image is processed by GoQat, but only every 'n' images is actually displayed. This can be useful if you are autoguiding via an image-streaming device connected to a computer local to the telescope but are forwarding the X server connection via SSH from the local computer to another machine elsewhere, possibly over a slow WiFi link.

Miscellaneous

- **Write star position and guide data:** Choose this to have GoQat write out star position and guiding data to a file. See section 10.8.
- **Write worm position:** Select this option to write the telescope's RA worm position to the guide star position file for Losmandy Gemini controllers. See section 10.8. This can be useful for periodic error correction analysis.
- **Autoguider trace vertical axis scale (pixels):** If you have the autoguider trace window open (via the Windows menu), you can adjust the vertical scale of each graph in pixels. Enter the desired value and click the 'Set' button.
- **Show single image in DS9:** Click this button to display the current autoguider camera image in DS9. You may wish to do this if you want to perform more detailed image processing on an autoguider camera image for some reason. This has no effect on autoguiding with GoQat.
- **Close:** Click the Close button to close the window.

10.6 Starting autoguiding

10.6.1 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 guide signals device as described in section 10.2, 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 guide signals device does not support it, or if your guide signals 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).

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 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 centroid box containing the guide star 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.

The colour and behaviour of the centroid box containing the guide star varies as follows:

- Blue: No guide corrections required – autoguider is idle
- Orange: Either the autoguider is dithering to a new position, or the guide star is being moved to the centre of the locked cross-hairs from anywhere within the centroid box before starting guiding
- Magenta: A guide correction has been issued
- Red: A guiding error has occurred
- 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 box will flash on and off.

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!

10.6.2 Updating guiding parameters

The guiding parameters may be updated while autoguiding is in progress. This is very useful to see the immediate effect of any changes on the quality of the guiding. Change any of the desired parameters on the main Autoguider tab or in the Autoguider Advanced Configuration window and click the 'Apply new settings' button on the main Autoguider tab. The new settings will take effect at the end of any guide correction that is currently in progress.

10.6.3 Locking the guide star position

You can force GoQat to guide with the star at a particular location on the Image display. Enter the desired coordinates in the 'Guide star position' panel and click the 'Lock' button. The centroid box and cross-hairs are moved to the locked position and a pale grey circle appears centred on that location. Click 'Unlock' to unlock again. Alternatively, click on the image display with the right mouse button while pressing the Ctrl key to lock the cross-hairs at the clicked location.

To guide on a locked position you should first lock the desired location and then move the telescope to put the guide star within the centroid box. Then start guiding. The centroid box will turn orange and the autoguider will move the star to the intersection of the cross-hairs before guiding commences.

Each time you start guiding without locking the position, the initial coordinates of the centroid of the guide star are written to the fields in the 'Guide star position' panel and they are saved when GoQat exits, so the last-used guiding location is always stored for re-use.

10.6.4 Slit guiding

If you wish to guide on a star whose image is bisected by a spectrograph slit, press the Ctrl key and right-click on the centre of the slit to lock the guider to that position. Then move the star within the centroid box, from where the guider will move it to the locked position when guiding starts. You may wish to set the correction factor to a value smaller than 1 if the guider oscillates too much between the two sides of the slit.

10.7 Dithering

Once autoguiding is in progress, it is possible to dither the pointing of the telescope between successive exposures of the main camera. GoQat does this by 'pretending' that the position of the guide star has changed relative to its initial position when guiding

first started. This forces the autoguider to guide the star to its new position, thereby effecting the desired dither. In this way it is possible to dither the telescope pointing by defined small amounts as precisely as your telescope mount will allow. The centroid box on the autoguider image display turns orange while a dither motion is being made.

To start dithering, click the 'Advanced...' button on the Autoguider tab and activate the 'Dither' check box in the Dithering section of the Autoguider Advanced Configuration window. There are two choices for the type of dither, either automatic or manual, described below. In either case, it is advisable to keep the dithered position within the bounds of the centroid box.

10.7.1 Automatic dither

Enter the smallest step and the largest step (in autoguider camera pixels) that you would like GoQat to make and press 'Set' to use these values. After each main camera exposure, GoQat will move the telescope by a random amount in a random direction, with the size of the dither always lying between the smallest and largest step size. In general, the telescope will move in a 'diagonal' direction, rather than parallel to the rows and columns of the autoguider camera image.

In automatic mode, GoQat will execute a random walk with each subsequent dither step. The average pointing position should thus remain the same as the initial position over sufficiently many steps, but it could also wander some distance away from the starting position.

10.7.2 Manual dither

Click the 'Define steps...' button to set the steps you would like to use. A step is defined as a distance in autoguider camera pixels followed by the desired direction, using 'N' or 'n' for north, 'E' or 'e' for east, 'S' or 's' for south and 'W' or 'w' for west, e.g.:

2.4 N

3.5 e

4.6 W

You may use ',' as the decimal point if that is the default for your locale. Manual dither steps are always parallel to the cardinal directions, with any rotation of the autoguider camera taken into account.

The existing dither steps (if any) are displayed in the 'List of items' combo box. To enter a dither step in the list, select the item before or after which you want it to appear in the combo box. Enter the desired step in the text entry field and click 'Insert before' or 'Insert after'. Pressing the enter key while typing in the text entry field has the same effect as clicking the 'Insert after' button. To remove an item, select it in the combo box and click 'Remove'. To clear the list, click 'Clear list'. Your changes are saved when you click the 'Close' button.

GoQat starts at the beginning of the list and moves down by one item each time. If the end of the list is reached, GoQat starts again from the beginning. If the list contains only one item, this same step size and direction will be repeated after each main camera exposure. This can be useful if, for example, you are performing spectroscopy of an extended object and want to move the spectrograph slit across the object by a defined amount after each exposure.

You can force GoQat to restart at the beginning of the list by toggling dithering off and on again.

10.7.3 Autoguider settings for dithering

When making dither steps, the correction factor on the Autoguider tab is ignored; a value of 1.0 is always used. The maximum offset value is also ignored; in principle GoQat will make a dither step of any size. But the threshold value still applies: once the guide star is within the threshold value of its new position, the dither step is considered to be complete. So the threshold value effectively defines the smallest dither step that GoQat will make.

10.8 Logging guide star position and autoguiding data

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 2023-04-12T14:14:06
    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 -).
- 'E/W (-/+)' is the east/west shift of the guide star centroid relative to its initial position (East is -, West is +).
- '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 main camera 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,    2022-01-12T10:42:50
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
```

10.8.1 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. The vertical axes of the plots may be adjusted from the Autoguider Advanced Configuration window.

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. You may also pause plotting by de-selecting the 'Autoguider trace' menu option, but this does not close the window.

10.9 A summary of telescope motion and guiding options

The various options for moving or guiding the telescope from the Autoguider tab are summarised in the following table.

In some situations in the table you can select 'Move for defined duration at guide speed' on the Autoguider tab. In this case, you must also enter the desired duration. By default, this is a value in seconds (or parts thereof). If the autoguider has been calibrated, you can also choose to enter a value in pixels or arcsec. GoQat will make the necessary conversion to turn this into a value in seconds. So GoQat always sends a command to the chosen guide port to move for a specified number of seconds.

In practice you should find that guiding works straightforwardly without having to be concerned with the details given in the table. The table information is intended to be helpful for those with an unusual guiding arrangement.

Guide port (i.e. the location to which GoQat sends guide commands)	Moving telescope using arrow buttons	Calibrating autoguider or issuing guide corrections
<p>Via Autoguider camera (with guide port on guide camera connected to guide port on telescope controller, possibly via a relay box)</p> <p>or...</p> <p>Via CCD camera (with guide port on CCD camera connected to guide port on telescope controller, possibly via a relay box)</p>	<p><u>Native SX cameras</u> Sends separate commands to the camera, closing a guide port relay to start motion and opening the guide port relay to stop motion. Works with or without 'Move for defined duration at guide speed'. The 'Remote timing' option is irrelevant.</p> <p><u>Native QSI cameras</u> Select 'Move for defined duration at guide speed' and enter the desired duration. Also select the 'Remote timing' option.</p> <p><u>INDI cameras</u> Select 'Move for defined duration at guide speed' and the 'Remote timing' option as above.</p>	<p><u>Native SX cameras</u> 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.</p> <p><u>Native QSI cameras</u> The 'Remote timing' option must be selected. Sends the required guide pulse length to the camera.</p> <p><u>INDI cameras</u> The 'Remote timing' option must be selected. Sends the required guide pulse length to the camera driver.</p>
<p>Parallel port, connected probably via a relay box to the guide port on the telescope controller</p>	<p>Sets TTL-level signal high to start motion and sets TTL-level signal low to stop motion. Works with or without the 'Move for defined duration at guide speed' option. The 'Remote timing' option must be deselected.</p>	<p>Sets TTL-level signal high to start motion and low to stop it. GoQat does the guide pulse timing internally. The 'Remote timing' option must be deselected.</p>

Guide port (i.e. the location to which GoQat sends guide commands)	Moving telescope using arrow buttons	Calibrating autoguider or issuing guide corrections
<p>Serial/USB port (with serial/USB port connected to serial port on telescope controller, or to a relay box that understands serial commands with the relay box connected to the guide port on the telescope controller)</p>	<p>Without the 'Move for defined duration at guide speed' option:</p> <p>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 2). The 'Remote timing' option is not applicable.</p> <p>With the 'Move for defined duration at guide speed' option:</p> <p>As above if 'Remote timing' is not selected. If 'Remote timing' 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 and Losmandy Gemini compatible, but not LX200.</p>	<p>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 and Losmandy Gemini compatible, but not LX200.</p> <p>If the 'Remote timing' option is not selected, commands are as for moving the telescope with the arrow buttons without the 'Defined duration' option and with the timing done by GoQat (see note 3).</p>

Guide port (i.e. the location to which GoQat sends guide commands)	Moving telescope using arrow buttons	Calibrating autoguider or issuing guide corrections
INDI driver sending signals to the guide port on the telescope controller via some intermediate hardware (i.e. cameras with built-in guide ports or standalone guide-signals devices)	Select the 'Move for defined duration at guide speed' option and the 'Remote timing' option.	Sends the required guide pulse length to the INDI driver. The 'Remote timing' option must be selected.
INDI telescope driver sending guide signals directly to the telescope controller's comms port, not via the guide port	<p>Without the 'Move for defined duration at guide speed' option:</p> <p>Sends a 'move' command to the INDI driver to start motion and a 'stop' command to stop it (see note 4).</p> <p>With the 'Move for defined duration at guide speed' option:</p> <p>As above if 'Remote timing' is not selected. If 'Remote timing' is selected, sends a single 'timed guide' command of the required pulse length to the INDI driver.</p>	Sends the required guide pulse length to the INDI driver. The 'Remote timing' option must be selected.

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 serial moving commands are sent then 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 'Move at centering speed' check box is ticked, GoQat will instead 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.

➤ GoQat requires the telescope link to be open and connected to the telescope controller's serial port to send the ':RG#' and ':RC#' commands because the serial motion commands could actually be sent to an intermediate relay box rather than directly to the telescope controller's serial port. The relay box might understand the ':Mx#' and ':Qx#' commands but would not be able to pass on the ':RG#' and ':RC#' commands if the relay box output is connected to the telescope controller's guide port.

3. If serial guiding commands are sent 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 (it might go to an intervening relay box), so this command is sent only 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.

4. If an INDI telescope device is selected and the link to the telescope is open, you can check the 'Move at centering speed' check box to have the telescope move at whatever is the currently set centering speed when the arrow buttons are pressed.

11. Using the same camera for imaging and autoguiding

GoQat permits you to open the same camera for both the main camera and the autoguider camera.

To use this feature, select the 'CCD Camera type >' submenu from the Cameras menu and pick your chosen camera. Do this also for the 'Autoguider camera type >' submenu and pick the same camera. Then open the camera on both the CCD Camera and Autoguider tabs respectively.

When the camera is open on both tabs, you may adjust the camera configuration in the usual way from the Cameras menu, but you cannot open the autoguider camera configuration window and the CCD camera configuration window simultaneously.

11.1 Pausing and re-starting autoguider exposures

The autoguider camera will immediately start to capture and display images in the Image window when opened. To capture an image from the CCD Camera tab, first pause the autoguider camera using the 'Pause' button at top left on the Image window. Then wait for the current autoguider camera exposure to finish before making a main camera exposure. To continue autoguiding, click the 'Pause' button again (re-labelled 'Play' when paused) after the main camera exposure has finished. Issuing guide corrections is automatically paused while the camera is not in autoguider mode.

11.2 Taking exposures with the main camera

When autoguider exposures are paused, you may take exposures from the CCD Camera tab. You can use different sub-framing and binning from those used for the autoguider exposures. GoQat will reset the autoguider exposure parameters when autoguider exposures are restarted. For those INDI cameras that support it, you can even use the camera in streaming mode for autoguider exposures and still mode for main camera exposures.

11.3 Example 1: Autofocusing a spectrograph

Suppose you have a spectrograph whose guide camera shows a view of the star field and the slit and this is parfocal with the camera recording the spectrum.

Run an instance of GoQat with the autoguider camera opened as both the main camera and the autoguider camera. With autoguider exposures paused, make a main camera

exposure and select a region round an appropriate star in DS9 to run an autofocus calibration sequence (see section 13.4 and the following sections). Because the main camera remains open, GoQat remembers this sub-frame area on the CCD Camera tab, so now it is a simple matter to autofocus the spectrograph. Just pause autoguider exposures and click the 'FOCUS' button on the Focus tab to refocus the camera using the same star for which you performed the autofocus calibration routine. Then continue autoguider exposures by clicking the 'Play' button at top left on the Image window.

11.4 Example 2: Autoguiding with the main imaging camera

If you have a top-end mount that permits long exposures between guide corrections, or you are using a short focal length telescope with short exposures, then it is straightforward to use the main imaging camera as the autoguider camera.

Start by opening the camera as the autoguider camera and calibrate the autoguider. Then begin autoguiding and pause the autoguider exposures with the 'Pause' button on the Image window.

Now open the camera on the CCD Camera tab and make an exposure in the usual way. After each exposure, restart the autoguider exposures and allow any guide corrections to be made before pausing autoguider exposures again and making another main camera exposure.

12. Filter wheels

GoQat has direct support for INDI filter wheels and also native support for filter wheels in QSI cameras and for the stand-alone Starlight Xpress USB filter wheels. The INDI filter wheel may be internal to a camera with an INDI driver, or may be a stand-alone device. You can also interact with INDI filter wheels directly via the INDI client interface.

12.1 Selecting a filter wheel

12.1.1 Selecting an INDI filter wheel

Select 'Filter wheel >' from the Devices menu, slide the mouse down to 'INDI >' and pick the desired filter wheel from the pop-out list. If you want to use an internal wheel in an INDI camera, pick the camera name from the list.

12.1.2 Selecting a QSI internal filter wheel

Select 'Filter wheel >' from the Devices menu and pick 'QSI Internal'. (You are not obliged to use the camera's internal wheel; you may select any other available option).

12.1.3 Selecting a SX filter wheel

Select 'Filter wheel >' from the Devices menu and pick 'SX'. If you have more than one Starlight Xpress filter wheel attached to the computer, click the 'Select filter wheel...' menu option and choose the one that you want from the pop-up dialog box.

12.2 Opening the filter wheel

Select the Filter tab and click the 'Open wheel' check box. If you have chosen to use a filter wheel internal to the CCD camera, the 'Open wheel' box will be checked automatically when the camera is opened and unchecked when the camera is closed.

If you are opening a natively-supported SX filter wheel and more than one is detected, you will be prompted to specify the one you want via the 'Select filter wheel...' option.

You can close the wheel at any time (even if it is internal to an opened CCD camera) and select another one if desired.

12.3 Configuring filters

The filter wheel settings can be configured on the Filter tab when the wheel has been

opened. If your chosen device has interchangeable wheels, you can enter the filters for more than one wheel.

GoQat will display up to 18 filter positions on the Filter tab in two columns. The second column is shown only if needed. Filter positions start at one except for QSI internal filter wheels which start from zero.

GoQat comes with a default list of filter names that you can edit by picking 'Set filter names...' from the Miscellaneous menu. The existing filter names are displayed in the combo box list. To enter a filter name in the list, select the item before or after which you want it to appear in the combo box. Enter the desired filter name (without spaces) in the text entry field and click 'Insert before' or 'Insert after'. Pressing the enter key while typing in the text entry field has the same effect as clicking the 'Insert after' button. To remove an item, select it in the combo box and click 'Remove'. To clear the list, click 'Clear list'. Your changes are saved when you click the 'Close' button. You will need to restart GoQat for your changes to take effect.

To set up your wheel(s):

- 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 GoQat displays eight filter positions but you have a filter wheel with five positions, then select filters for positions 1 to 5 and leave positions 6, 7 and 8 set to '-'). Note that for QSI internal filter wheels, the filter position numbering starts from zero, not one.
- If you want to re-focus automatically after each filter change, enter a focus offset – see below. (You also need a compatible electronic focuser).

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

If you want to rotate the filter wheel to a particular position, select the desired filter ('Set to this filter') and click the 'Rotate' button (this is useful if you want to check for specks of dust on the filter for example). 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.

Focus offset

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, if the camera initialises with the filter wheel at position one, you could enter offsets like this:

Position	Focus offset
1	0
2	5
3	-8

If you rotate to position 2, the focuser will move out 5 steps, since position 2 has an offset of five steps outwards relative to position one. If you then rotate to position 3, the focuser will move in 13 steps because position 3 has an inward offset of eight steps relative to position one, but had already moved out five steps.

Since 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 one.

13. Focusing

GoQat supports INDI focusers and Robofocus natively for focusing operations.

GoQat permits autofocusing with calibration by the well-known 'V-curve' method published by Larry Weber and Steve Brady.

You can specify filter offsets if you want GoQat to refocus your telescope after each filter change (see section 12.3), and you can define a thermal coefficient if you want to allow for the effects of temperature on focus position automatically.

13.1 Selecting a focuser

13.1.1 Selecting an INDI focuser

Select 'Focuser >' from the Devices menu, slide the mouse down to 'INDI >' and pick the desired focuser from the pop-out list.

13.1.2 Selecting native Robofocus

Select 'Focuser >' from the Devices menu, slide the mouse down to 'Robofocus >' and pick the desired serial/USB port from the pop-out list. USB-serial converter ports appear and disappear from the list as you plug them in or unplug them.

13.2 Opening the focuser

Go to the Focus tab and click the 'Open focuser' check box.

13.2.1 INDI focusers

For INDI focusers, the available features will depend on the particular device. You may need to calibrate the focuser for a particular range of travel. Read any documentation that came with your focuser to be sure how to use it.

13.2.2 Native 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.

13.3 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.

13.4 Calibrating autofocus

The calibration process measures the 'half-flux diameter' of a selected 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 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.

The calibration process uses the main imaging camera, not the autoguider camera, but you can set the autoguider camera to be the same as the main camera if you want to autofocus the autoguider (see section 11).

13.5 Creating the V-curve

Take an 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. This might require trial and error because the star is probably not focused to start with! You may get more stable measurements of the half-flux diameter (HFD) if you choose longer exposures of fainter stars (e.g. exposures of 2 seconds or so), rather than very brief exposures of bright stars. Tube currents can cause havoc for out of focus images where parts of the 'donut' can briefly flare up giving erroneously large HFD measurements.

Your final exposure before beginning the V-curve creation process should either be a full frame exposure, or you should set the 'Embed in full frame' option on the Cameras menu, so that GoQat can determine the location of the star on the chip correctly.

13.5.1 Selecting a star

If you want to select a particular star for the V-curve calibration, drag a box round the star in DS9. GoQat will get the coordinates from DS9 automatically. Otherwise, GoQat will centre a 100-pixel square box round the brightest point in the image. This might be too small for a heavily de-focused star but you can change this default size by setting a value for the Focus/Config/AFBox configuration key – see section 26.3.

13.5.2 Running the calibration

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. You probably don't know where that is to begin with, so you could set the beginning and end points to their minimum and maximum values respectively. Even when you refine the range in subsequent steps, it is still important to choose a range that's big enough. Otherwise the success of the process can seem rather underwhelming.

Next, enter the step size. A step of about a tenth or twentieth of the chosen range is usually appropriate initially. Then 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. This is a good idea in case you have a bad measurement at one position because GoQat will reject outliers.

Finally, set the exposure length. This is automatically copied from the CCD Camera tab but you can adjust it as desired.

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 in a Grace window, as it moves the focuser through the defined range. The HFD value is quite 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 interrupt 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.

Setting the camera readout speed for focusing

If you have a 600-series QSI camera, you can choose to have it switched from low readout speed to high readout speed during focusing operations. To do this, open the camera configuration dialog from the Cameras menu and set the readout speed option to Low/High.

13.5.3 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!

GoQat will reject any points that differ by more than a specified amount from the fitted value. Rejected points are excluded from the final fit. By default the maximum allowed deviation for a point from a line is 20%, but you can alter this by setting a value for the Focus/MaxFitPercError configuration key – see section 26.3.

The results are summarised in the message log and displayed in the bottom part of the autofocus configuration window. 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 the bottom of the configuration window 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 as small as possible.

GoQat calculates the focuser position where the curve is at a minimum and enters this value in the 'Centre' field at the top of the autofocus configuration window. 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.

A typical V-curve looks something like Figure 8 on the following page. A 'Repeat' value of three was used, so there are three points per measurement. The slopes were fitted

with a maximum HFD of 11 and a minimum of 3. The L/R ratio is -0.944 and the position intercept difference is 8.92. (The stellar profile was obtained from the final star measurement, when it was an out-of-focus donut). You can see some rogue measurements caused by tube currents and occasional unsteady seeing, but the fitting process has coped well by rejecting them.

In practice it's worth spending an evening experimenting to find the optimum values to use for your set-up.

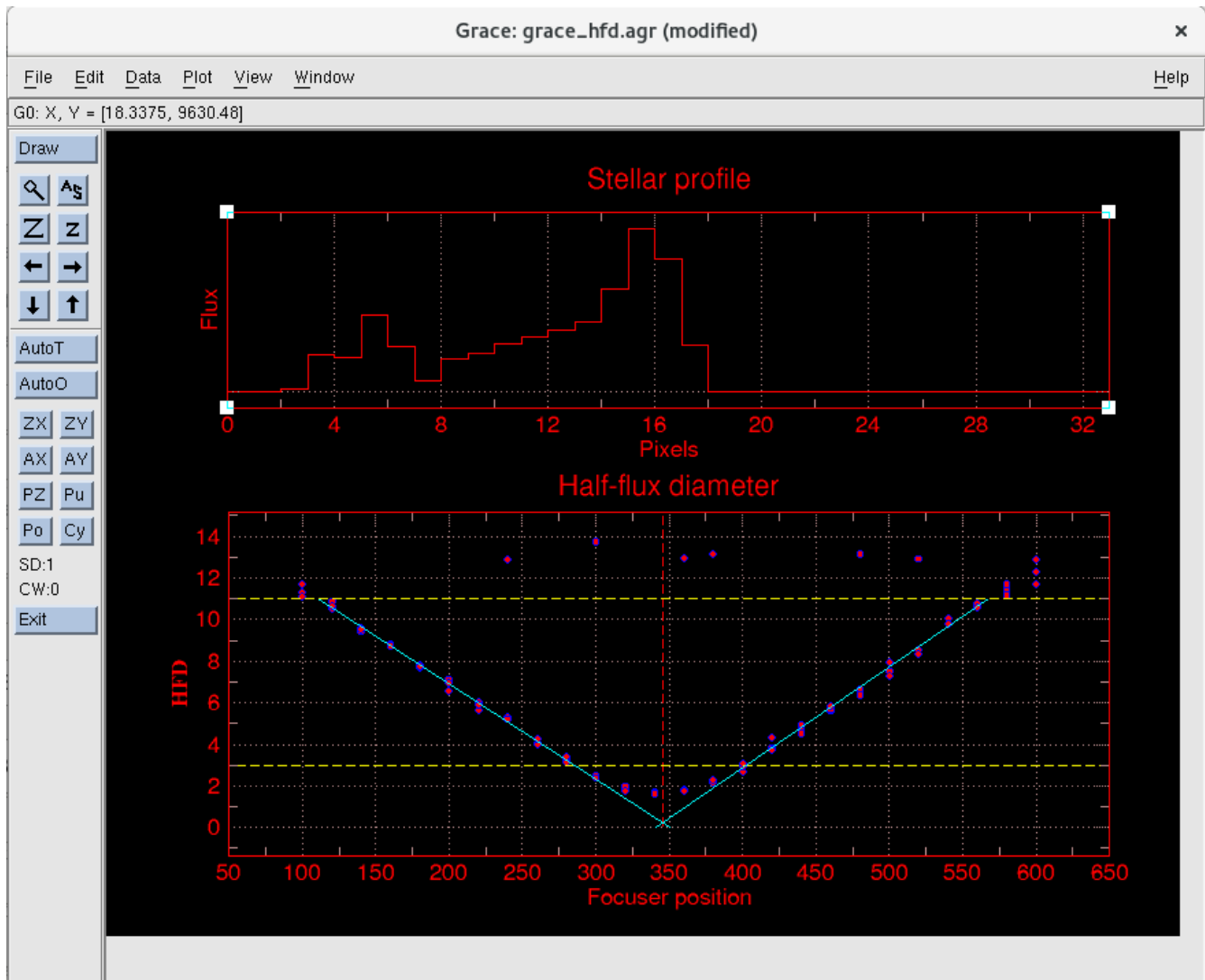


Figure 8: Autofocus calibration V-curve in Grace

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

GoQat remembers your latest V-curve results when you restart it, but if you have various optical configurations you might want to store the values for each. You can do this via the configuration settings dialog – see section 17.

13.6 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.

Follow the same procedure for selecting a star as for the autofocus calibration - see section 13.5.1.

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 but ideally within the range over which you fitted the calibration curve. 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), 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.

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

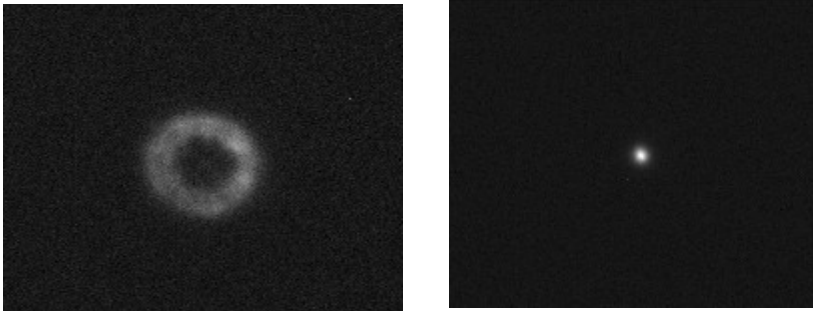


Figure 9: Star image before and after autofocus using the V-curve calibration of Figure 8.

You should be able to start with a star image like the one on the left in Figure 9, and automatically bring it to focus, like the image on the right. These are actual star images obtained before and after running the autofocus procedure.

While the autofocus routine does work spectacularly well, you may find that you have to recreate the V-curve if you disassemble and then reassemble the imaging train. Another reason why a curve constructed on one night may not work another night is because of changes in temperature. This can be allowed for if your focuser supports temperature compensation (see below).

Setting the camera readout speed for focusing

If you have a 600-series QSI camera, you can choose to have it switched from low readout speed to high readout speed during focusing operations. To do this, open the camera configuration dialog from the Cameras menu and set the readout speed option to Low/High.

13.7 Automatic focus adjustments

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

13.7.1 Refocusing after filter changes

The position of best focus may depend on the filters that you are using. GoQat can adjust for this automatically.

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 on the Filter tab for the corresponding filters. 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' check box on the Focus tab.

13.7.2 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'

check box. 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.

14. Telescope controllers

This release of GoQat supports direct control of telescopes with an INDI driver, native support for Autostar/LX200 commands and Losmandy Gemini controllers via a serial/USB port. You can also control an INDI telescope via GoQat's INDI client interface. In the following sections it is assumed that the telescope mount is polar-aligned and a pointing model has been built. Your mount manual should tell you how to do this.

14.1 Connecting to the telescope controller

14.1.1 Selecting an INDI telescope controller

Select 'Telescope >' from the Devices menu, slide the mouse down to 'INDI >' and pick the desired controller from the pop-out list.

14.1.2 Selecting native support for Autostar/LX200/Losmandy Gemini

Select 'Telescope >' from the Devices menu, slide the mouse down to 'Serial/USB >' and pick the desired port from the pop-out list. USB-serial converter ports appear and disappear as the adaptor is plugged in or unplugged. Natively-supported serial ports `/dev/ttyS0` to `/dev/ttyS9` are shown by default. USB-serial converters appear as `/dev/ttyUSBXXX` where the 'XXX' is a number that depends on the order in which the USB adaptors are enumerated.

14.2 Opening the telescope controller

To open telescope communications, go to the Telescope tab and click 'Open telescope'.

14.2.1 INDI devices

To sent guide signals directly to your telescope controller (rather than via a guide port on a camera head or some other stand-alone guide signals device), select the same INDI driver for the telescope controller and the guide signals device. In this case, the guide port on the Autoguider tab will be opened and closed automatically when you open and close the telescope controller.

14.2.2 Losmandy Gemini controllers

To connect to a Losmandy Gemini controller via a native serial/USB connection, click on

the 'Use Gemini commands' check box on the Telescope tab before opening the telescope link. This option is available only if you select a serial or USB port from the Devices menu.

It is possible to select the same serial port for guide signals and telescope control commands. In this case, GoQat shares the port between guide signals and telescope control commands and does not close the port until you close both the guide signals link and the telescope link.

14.3 Controlling the telescope

When the telescope controller has been opened, the following options become available on the Telescope tab:

14.3.1 GoTo

Enter the coordinates of the desired target. For INDI telescope drivers, these coordinates must be equinox-of-date; in all other cases you may use J2000.0 if your telescope controller will accept them but you must tell the telescope controller (independently of GoQat) which coordinates you are sending.

You may use abbreviated coordinates for speed of entry. For example, a declination of -00:00:30 may be entered as -::30. The '+' sign is optional for positive declinations. Click the GoTo button to slew the telescope to the given coordinates. You should ensure that your telescope controller is in high precision mode (i.e. it expects coordinates in the form 'nn:nn:nn') before sending or receiving coordinates.

You can also create a file containing three columns of object names and coordinates, e.g.:

```
Procyon    07:39:17  05:13:09
Sirius     06:45:08 -16:43:23
Betelgeuse 05:55:10  07:24:26
Aldebaran 04:35:55  16:30:30
```

To load the file, click on the drop-down list to the right of the GoTo button, then click again on the '...' option. Select the desired file from the 'Open File' dialog. GoQat will read the contents of the file and set the drop-down list to the first item. Choose the

desired object from the list and click the GoTo button to move the telescope to that object. The name of the object is copied to the 'Object' FITS keyword on the CCD Camera tab. You may select '..' again to open a different coordinates file.

Check the 'Show position' check box to have GoQat read and display the coordinates from the telescope controller. For INDI telescope drivers and natively-supported Gemini controllers, GoQat requests coordinates according to equinox-of-date. In all other cases they will be governed by settings in your telescope controller independently of GoQat. By default the coordinates are queried every ten seconds; you can change this by creating a Telescope/CoordsInterval key in the configuration file and setting it to the desired value. See section 26 for more information. Querying coordinates may interfere with sending guide signals if the same serial/USB port is being used for both.

Irrespective of the 'Show position' check box, GoQat requests the telescope coordinates automatically after each CCD exposure (except during autofocus routines) to write them to the FITS header if the image is saved. A warning is displayed if the telescope link is closed.

Determining when a telescope slew has ended

GoQat queries the telescope controller to see when the GoTo 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 Telescope/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.

14.3.2 Move

To move the telescope by a defined angle, enter the number of minutes of right ascension (RA) and arcminutes of declination (Dec) and click the Move button. You may enter positive and negative values and non-integer amounts.

14.3.3 Abort

Click the Abort button to stop any telescope motion while it is in progress.

14.3.4 Park

Click the Park button to park the telescope. Some telescope controllers offer more than one parking position and you should set which one you wish to use in your telescope controller before using this option.

14.3.5 UnPark

Click UnPark to wake the telescope from its parked position. If you have selected to use Gemini commands, you can choose whether unparking should initiate a Warm Start or a Warm Restart. See your Gemini manual for an explanation of these two options. For INDI telescope drivers, GoQat sends an 'Unpark' command. For any other controller opened via a direct serial/USB link, GoQat sends an Autostar II command to wake the telescope.

14.3.6 Adjusting the telescope position from the Autoguider tab

When an autoguider camera is open, you can move the telescope using the arrow buttons in the 'Guide star position' panel at the top left of the Autoguider tab. There are two options:

1. Press and hold down the desired arrow button for the chosen length of time:
 - (a) By default the telescope is moved at the guide speed that is currently set in the telescope controller. Commands to move the telescope are sent via the guide signals device which must support separate 'start moving' and 'stop moving' commands. These are issued when you press and release the arrow buttons.
 - (b) You can choose to move the telescope at the currently set centering speed by clicking the 'Move at centering speed' check box. Commands to move the telescope are sent via the telescope controller which must support separate 'start moving' and 'stop moving' commands. If you have a Losmandy Gemini telescope controller you can specify the centering speed that you would like to use.
2. Rather than moving the telescope by 'holding down' one of the arrow buttons, you can choose to have the telescope moved at the currently set guide speed for a defined duration by checking the 'Move for defined duration at guide speed' check box on the Autoguider tab. Then, just click and immediately release the desired motion button. Commands to move the telescope are sent via the guide signals device which must support guide pulse timing. Almost all devices do this.

- For best results, make sure the 'Remote timing' option is selected in the Advanced Autoguider Configuration window.
- The 'Move for defined duration at guide speed' check box is mutually exclusive with the 'Move at centering speed' option.

Choose whether you want the motion to be for seconds of time, pixels on the autoguider camera display or arcseconds, and enter the desired duration. The autoguider must be calibrated to use the 'pixels' or 'arcsec' options. For the 'arcsec' option, GoQat needs to know what guide speed was used when calibrating. If you are using a Losmandy Gemini controller GoQat will have remembered this value for you. If not, a spin button entry field appears when you select this option and you must select the calibration guide speed as a fraction of the sidereal rate. The 'pixels' and 'arcsec' options will be accurate only if the telescope has not been moved from the pointing location in which the guider was calibrated.

You can swap the direction of telescope motion by checking the 'Swap N/S' and 'Swap E/W' check boxes. These choices apply only when moving the telescope with the arrow buttons. They have no other effect.

14.4 Losmandy Gemini controller

GoQat offers native support of a Losmandy Gemini controller via a direct serial/USB link. To enable use of Gemini commands, check the 'Use Gemini commands' check box on the Telescope tab. You need to do this before opening the telescope communications link. You must also do this before opening the autoguider camera if you intend to autoguide because the guiding process needs to know whether it can use Gemini commands. When the Gemini commands option is selected, additional data entry fields and command buttons become available on the Telescope tab.

When the telescope link is opened, GoQat sends an 'ACK' request to the Gemini unit; a message is displayed in the message log to tell you whether it has connected successfully.

GoQat may wish to modify the centering speed and guide speed in the Gemini controller. 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.

14.5 Gemini parameters

14.5.1 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. Gemini level 5 and above allows two models to be built and stored in the controller. You can simulate this behaviour for earlier versions of the Gemini firmware with GoQat because GoQat allows you to save two different models to the configuration file and load them into the controller as required.

- For any version of the Gemini firmware, select Gemini model 0 or 1. For level 5 and above only, then click 'Set model' to tell the controller which model you want to use.
- Click 'Read from Gemini' to read and display the pointing model parameters (it may 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 to Gemini' to write the values displayed in the text boxes to the Gemini unit.
- Click 'Load from config' to display the model parameters stored in the configuration file for the selected model number (0 or 1).
- Click 'Save to config' to save the values displayed in the text boxes into the configuration file as the selected model number.

14.5.2 Model building and synchronising

GoQat offers some options to aid building of pointing models and synchronising the model with the sky. This can make model building very quick if used in conjunction with a list of target stars for the GoTo function.

- To start building a model, go to the first star and click the 'Initial' button when the star has been centered. This option applies to firmware level 5 and above only.

- To add more stars to the model, go to the next star and when centred, click the 'Additional' button.
- To correct a mistake with the most recent additional alignment, click the 'Undo last' button. This option applies to firmware level 5 and above only.
- To synchronise the pointing model with the telescope's position on the sky, click the 'Synchronise' button.

14.5.3 Gemini Real Time Clock (RTC)

To set the date and time for the Gemini Real Time Clock from your computer time, click the 'Set Gemini 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.

14.5.4 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.

14.5.5 Periodic Error Correction (PEC)

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. This can take a while.
- 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.
- Click the 'Run PEC' check box to turn periodic error correction on, if it is available.

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

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.

14.5.6 Default values

You can load any default values that you wish into the Gemini unit from a file. 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.

LX200-style commands must begin with a colon and end with a hash. Gemini native commands must have the command ID followed by a colon and then the value. There are no spaces within the commands. For those Gemini commands that don't take a value (e.g. the command to set the mount type), the colon is not required. 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 'Gemini_defaults.dat' file is included in the 'examples' folder of the GoQat package.

15. Plate Solving

Plate solving is a process that automatically determines the coordinate system for an image. GoQat plate solves using the astrometry.net offline solver called 'solve-field'. You will need to install the appropriate astrometry.net package for your Linux distribution and then download the required index files, depending on the field of view. Please see the astrometry.net website for further details. You can install astrometry.net at any time; it does not have to be present when you compile GoQat.

15.1 Overview

15.1.1 Plate solve methods

GoQat offers three different ways to plate solve using whichever cameras you choose. The three options offered on the Plate Solve menu are:

GoToPS

1. The telescope is instructed to slew to the coordinates entered on the Telescope tab.
2. An image is taken and plate solved.
3. GoQat instructs the telescope to make a corrective motion to reduce the error between the instructed location and the plate solved location.
4. Another image is taken and plate solved to determine the adjusted pointing location.

Steps 3 and 4 can be iterated a user-specified number of times to reduce the pointing error further.

RefinePS

This is as for GoToPS, but starting at step 2 above. It is useful if the pointing location is already approximately correct. If the pointing model in the telescope controller is poor, choosing this option avoids an initial slew to a possibly incorrect location.

Plate solve any image

This does not move the telescope at all; it just plate solves a user-selected image.

15.1.2 Plate solve cameras

You can use images from the main imaging camera, the autoguider camera, or a third camera (e.g. mounted on a finderscope) by selecting the desired camera from the Plate Solve menu.

For example, you could slew to a given location using GoToPS, capturing an image with a camera on a wide-field guide scope and iterating the 'move and plate solve' process a couple of times. Next, you could switch to a narrow-field image through the main camera or autoguider camera and use RefinePS to make the pointing as accurate as required. An advantage of doing this is that the wide-field solution is usually quite quick and reliable, requiring fewer slow narrow-field solutions afterwards. The precision with which the pointing can be refined will depend to some extent on the quality of the telescope mount.

15.2 Configuring the plate solver for GoToPS and RefinePS

15.2.1 Choosing a camera

To use the GoToPS or RefinePS options, you must choose the desired camera. Select the Plate Solve menu on the main menu bar and choose 'Plate solve camera >'. To use the main imaging camera for plate solving, pick 'CCD Camera'. To use the autoguider camera, pick 'Autoguider camera' and to use a standalone camera that is neither of these, choose the desired camera from the 'INDI >' submenu.

GoQat can use cameras that provide either individual exposures or an image stream when selected as the autoguider camera. Cameras must be in non-streaming mode when used as the main camera or as a standalone INDI camera.

15.2.2 Configuring the plate solve settings

The field of view for any image to be solved depends on both the camera sensor size and the optical train. When you choose a camera for plate solving, it is implied that this camera is associated with a particular optical configuration, which will typically be the case.

If you have a number of different camera/optical arrangements you might find it convenient to run a dedicated instance of GoQat for each one. Each different instance of GoQat remembers its own plate solve settings.

Pick 'Configure plate solve...' from the Plate Solve menu to open the configuration dialog. The various data entry fields are:

- Path to executable: The default value for this is 'solve-field'. If GoQat cannot find the executable file, you should enter the correct full file path here (e.g. '/usr/local/astrometry/bin/solve-field').
- Use guide chip in main camera: If you have selected an INDI camera other than the main or autoguider cameras, this option becomes available. Check the box if the camera has an internal guide chip and you want to use it for plate solving.
- Minimum field width (degrees): Enter the minimum field width in degrees (or fractions of a degree) for the solver to try.
- Maximum field width (degrees): Enter the maximum field width in degrees (or fractions of a degree) for the solver to try.
- Search radius (degrees): This is the search radius that the plate solver will use, taking the coordinates entered on the Telescope tab as the centre of the search circle. This value need not be too much larger than the maximum telescope pointing error. If too small, the plate solution may not be found.
- RA and Dec tolerance (degrees): When iterating the 'move telescope and plate solve' operation, the requested position and plate solved position are considered to match when both the RA and Dec pointing errors are less than this value. Iteration will stop when this condition is met, or when the maximum number of iterations is reached.
- Time limit (seconds): This is the maximum elapsed time for which the plate solver will run before giving up. This prevents the solver from running for a very long time if it is failing to find a solution. Note this is clock time and not processor time.
- Maximum iterations: GoQat can repeat the 'move the telescope and plate solve' operation more than once to reduce the error between the requested pointing location and the plate solved position. Enter the number of iterations that you want to use. To refine the pointing, this value must be at least 2.
- Exposure length (s): Enter the exposure length in seconds for the plate solve image. If you have specified the autoguider camera as the plate solve camera and it is in a streaming mode that does not permit the exposure length to be set directly (e.g.

webcams), GoQat will grab one of the exposures from the image stream at whatever exposure length or frame rate is currently used.

- Additional options for solve-field: You can enter any additional options for the plate solver here, separated by spaces, or leave this field blank. A very useful option is '-z 2' (that's a lower case 'z'), which downsamples the image by a factor of two before plate solving. This can result in a spectacular increase in solution speed. Of course you can try more aggressive downsampling if you wish, but extreme values risk obliterating stars altogether.

The default command string for the plate solver is:

```
solve-field --fits-image -O -D working_directory -L lower_width -H  
upper_width -u dw --ra RA --dec Dec --radius search_radius options -S  
done_file -C stop_file plate_solve_image
```

where:

`working_directory` is the directory for the plate solver files. This is '`~/GoQat/PlateSolve`' for instance number 1 of GoQat and '`~/GoQat/PlateSolve_nn`' for any other instance '`nn`' of GoQat, where '`~`' is your home directory.

`lower_width` is the minimum field width.

`upper_width` is the maximum field width.

`RA` is the right ascension value entered on the Telescope tab.

`Dec` is the declination value entered on the Telescope tab.

`search_radius` is the value entered for the search radius.

`options` is a string containing all the options (if any) that you enter as additional options. Run `solve-field` at a command prompt with no arguments to see a list of all the possibilities.

`done_file` is the name of a file created by `solve-field` to indicate that it has found a solution. This is created in the working directory and is called '`plate_solve_done`'. Any existing file of this name is deleted before the solver starts.

`stop_file` is the name of a file created by GoQat to tell the solver that it should stop. This is created in the working directory and is called 'plate_solve_stop'. Any existing file of this name is deleted before the solver starts.

`plate_solve_image` is the name of the image to be solved. This is always found in the working directory and is called 'plate_solve.fit'.

15.3 Running the plate solve process for GoToPS and RefinePS

Select your plate solve camera and configure the settings from the Plate Solve menu, then open the camera either on the CCD Camera tab, the Autoguider tab or the relevant INDI client tab depending on your selection. Open the telescope controller on the Telescope tab and enter the desired coordinates. Then choose GoToPS or RefinePS from the Plate Solve menu, or click GoToPS on the telescope tab. Telescope movement, image capture, plate solving and (optionally) pointing refinement will commence as described in section 15.1.1 above.

15.3.1 Stopping the solver

To stop the solver, select 'Abort' from the Plate Solve menu. This cancels the solver if it is running and stops any iterative 'plate solve and move' process.

15.4 Configuring and running the plate solver for any image

Pick 'Plate solve any image...' from the Plate Solve menu to open the plate solver window. Enter the minimum and maximum field width to try, the search radius and any additional solver options – see section 15.2.2. You must also provide approximate RA and Dec coordinates for the centre of the image. Then choose the image file and click 'Execute' to run the solver. You can stop the solver at any time by clicking 'Abort'. If a solution is found, you can click 'Apply plate solution to image file' to add the WCS information to your image.

15.5 Viewing output from the solver

To view solver output, check 'Write solver output to log window' on the Plate Solve menu. Solver output appears in black text and is not written to the log file. Any error messages from the solver appear in red text and are written to the log file (provided that 'Write messages to log and file' is checked on the File menu).

The field size and coordinates of the image centre are always written to the log window irrespective of this setting.

15.6 Using the plate solved coordinates

You can use the plate solved coordinates for the RA and DEC keywords in the FITS header of any images from cameras that are controlled via GoQat's CCD Camera or Autoguider camera tabs.

► The coordinates are not written to the FITS header for images that you capture and save via the INDI client tab.

There are two mutually exclusive options; GoQat stores the plate solved coordinates for both of them:

- After using GoToPS or RefinePS, check the 'Use plate solve coords for FITS header' check box on the Plate Solve menu.
- After plate solving any image, check the 'Use these coords for FITS header' check box on the Plate Solve menu.

Provided that GoQat considers the solved coordinates to be valid, they will be written to the FITS header rather than any coordinates read from the telescope controller. The coordinates will also be made available to any other instance of GoQat that uses the current instance as the data source for telescope coordinates (see section 21.1). Plate solved coordinates are by default invalid until a solution is found.

For the GoToPS and RefinePS options, the plate solved coordinates become valid if the iterative process concludes successfully and the solver finds a solution within the allotted time. The coordinates remain valid if you adjust the telescope position via the arrow buttons on the Autoguider tab (the assumption being that this is very fine tuning). The coordinates become invalid at the start of any GoTo, GoToPS or RefinePS operation.

For plate solving any image, the coordinates become valid if a solution is found. They remain valid until the next solution starts.

In either case, GoQat does not check if the telescope position has changed by external means since the last valid solution was found. So if you move the telescope with the controller keypad (for example) this will not invalidate the previous solved coordinates.

15.7 Controlling plate solving remotely with commands

If you are operating GoQat remotely by sending commands you can easily select the desired camera and start solving as in the following example. Each command below should be written in turn to the file that GoQat is watching for incoming commands. See section 19 for more information.

Suppose you want to use a standalone INDI camera (e.g. connected to a finderscope) for the initial solution, rather than the main camera or autoguider camera. To set an ASI 178MM camera controlled via an INDI driver to be the active plate solve camera and open the camera on the corresponding INDI client tab, send these commands:

```
p_indi_ZWO CCD ASI178MM 1
```

```
opts_ZWO CCD ASI178MM!CONNECTION!CONNECT! 1
```

Open the telescope link on the Telescope tab and set the desired RA and Dec coordinates:

```
chkTelescopeOpen 1
```

```
txtTelescopeGoToRA 1:24:35
```

```
txtTelescopeGoToDec 04:30:59
```

Issue a GoToPS command:

```
goto_ps
```

Now set the currently selected main camera to be the plate solve camera and open it on the CCD Camera tab:

```
p_CCDCam 1
```

```
chkCCDOpen 1
```

Issue a RefinePS command:

```
refine_ps
```

You can check to see if a plate solution has been found by inspecting the contents of the relevant PlateSolve directory (see above). If a solution has been found, there will be a file called 'plate_solve_done'. If a solution has not been found in the allotted time, there will be a file called 'plate_solve_stop'. If neither of these files exists after starting plate solving then the solver has either not yet found a solution or has not yet exceeded its time limit.

16. Video Recording and Playback

GoQat can record the images from an autoguider camera to disk as an .SER format video file. This can be useful for asteroid occultation work if a video-for-linux frame grabber is being used with a low-light video camera, or for time-lapse recording of other phenomena.

To do this, open the autoguider camera in the usual way and then pick 'Live View' from the Windows menu. This turns off the overlay on the Image window to give an unobstructed live view of the video stream.

16.1 Live View window

GoQat displays a Live View dialog when in Live View mode. This contains text entry fields for descriptive data and enables you to start and stop the recording.

16.1.1 Recording video

To record the video stream from the camera, optionally enter descriptions in the 'Telescope', 'Instrument' and 'Observer' fields. By default, every frame is saved. If you want to save only every third frame for example, enter '3' in the 'Save every... frames' text box. Select a location to save the video file. The file is named automatically according to the date and time of the recording. Click the 'Record' button to record.

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, depending on the frame size and frame rate. However, if GoQat has to drop any frames because disk-writes are too slow, the frame number of any such frame since the start of the recording is listed in the message window. If no such frames are listed, you can be confident that all the frames have been written to disk.

- The recording process uses a double-buffering system so that new frames are being written to one half of a memory buffer whilst earlier frames from the other half of the buffer are being written to disk. You can tune the size of the memory buffer for optimum performance by setting a value for 'Video/FrameBufSize' in the configuration file. You may need to create this entry in the file if it doesn't already exist – see section 26.3. The default buffer size is 50 megabytes.

16.2 Playback window

The Playback window is used to play back video data recorded via the Live View window,

or any greyscale .SER format file from another source. Pick 'Playback' from the Windows menu to open the Playback window.

16.2.1 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, zoomed to fit the display as far as possible. The telescope, instrument and observer data (if any) will be shown in the field below the image.

Other buttons have the following effect:

- 'fps': Pick the desired playback frame rate in frames per second (can be altered whilst video is playing back)
- 'Play': Play the video file
- 'Stop': Halt playback at the current frame
- 'Previous': 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), or enter the frame number in the 'Frame number' field and press the Enter key

The image may be zoomed using the buttons at the top right of the window. The '+' button zooms in, '-' zooms out, '1' zooms to a 1:1 display and the final button zooms to fit the display.

GoQat comes with a default list of playback frame rates that you can edit by picking 'Set playback frame rates...' from the Miscellaneous menu. The existing frame rates are displayed in the combo box list. To enter a frame rate in the list, select the item before or after which you want it to appear in the combo box. Enter the desired frame rate (integer or floating point) in the text entry field and click 'Insert before' or 'Insert after'. Pressing the enter key while typing in the text entry field has the same effect as clicking the 'Insert after' button. To remove an item, select it in the combo box and click 'Remove'. To clear the list, click 'Clear list'. Your changes are saved when you click the 'Close' button. You will need to reopen the Playback window for your changes to take effect.

16.2.2 De-interlacing video frames

You can display de-interlaced video frames if you wish. This is perhaps most useful for rapidly changing events captured via a frame grabber from an interlaced video camera

running at the full (non-integrating) frame rate of 25 or 30 fps.

Click the 'De-interlace' check box to display the frame as two separate de-interlaced video fields. (GoQat does not know whether the frame was actually captured in interlaced mode so this will appear to work even for non-interlaced video). For video captured at the full frame rate with a GPS time stamp overlay, you will see different time stamps on the two fields.

You can save the de-interlaced video as a new video file (see below). The new file contains each video field as a new frame. You should make sure that the fields are saved in the correct order. If there is a GPS time stamp overlay, you can easily tell which is which. The earlier field in de-interlaced mode must be at the top and the later one at the bottom of the display. Click the 'Swap field order' check box if necessary to make this so. Then save the selected range of frames as a new video file.

You cannot save video as FITS files or perform photometry in de-interlaced mode. You should first create a new de-interlaced video and then operate on that.

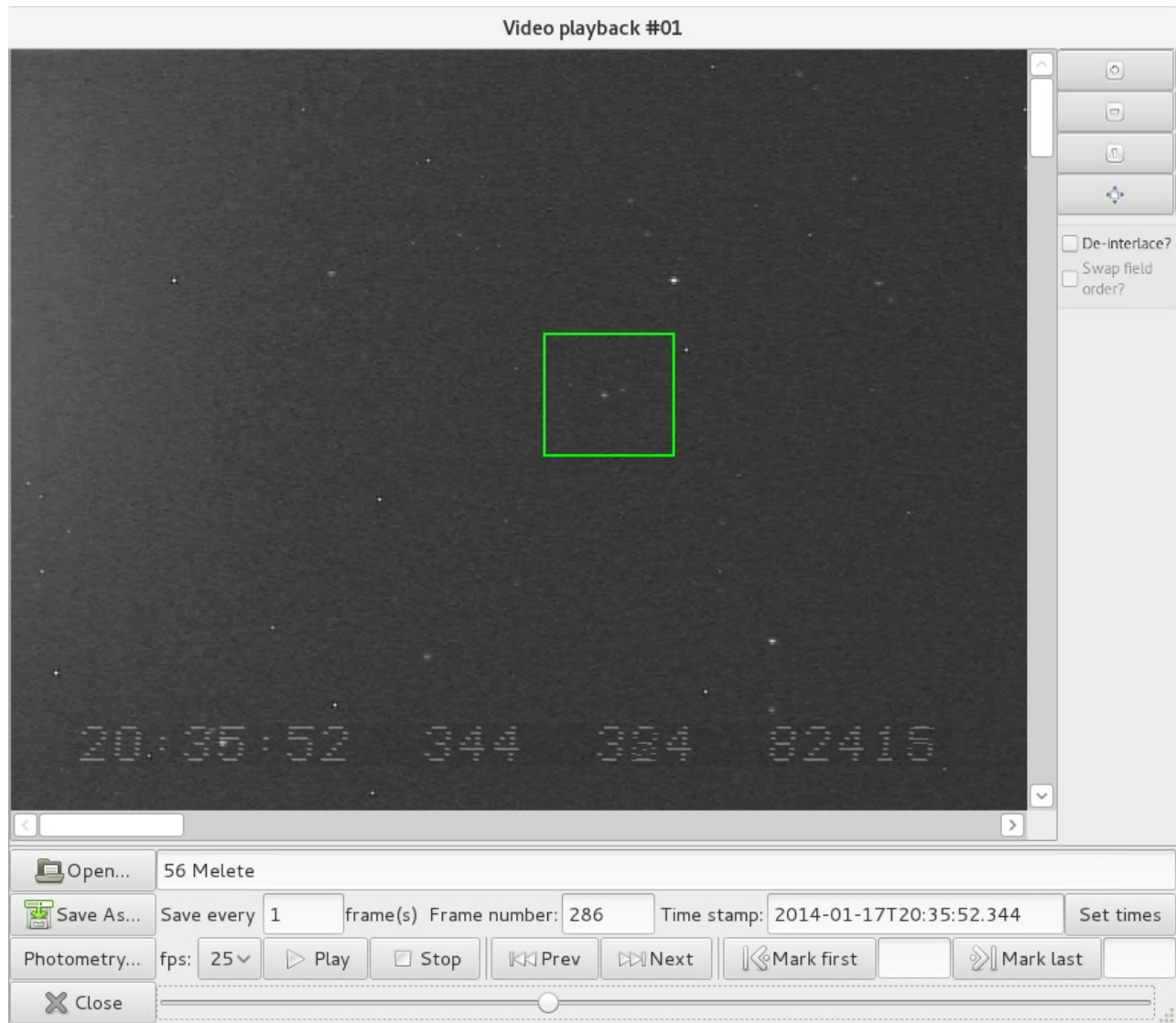


Figure 10: Playback window showing asteroid occultation recording

The Playback window will look something like Figure 10, showing a recording of a stellar occultation by the asteroid 56 Melete. 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.

16.2.3 Setting video frame time-stamps

The time-stamp for the current frame is shown in the 'Time stamp' box. 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 box and the GPS time. However, the difference between the two should stay reasonably constant.

The value in the time stamp box is written to the results files if you perform astrometry or photometry on video frames, so you may wish to make it match the time given by any GPS overlay.

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.
- 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 file 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.

16.2.4 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, hold down the Ctrl key and click and drag the ROI rectangle over the desired area with the mouse. Hold down the Shift key and click on the image to centre the ROI rectangle at that location. Drag again to change your selection, or click the 'Reset Area' button to reset the ROI rectangle to the full image

area.

- 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, by dragging the frame counter slider to the appropriate spot, or by entering the desired frame number in the 'Frame number' field and pressing the Enter key.
- 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 along with any telescope, instrument and observer data.

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

16.2.5 Saving video frames in .SER format

You can save a subset of a video recording as another .SER video file. Every frame in the selected range is saved in its entirety; you cannot save a subset of each frame. To save in video format, do this:

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

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.

16.3 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. If you want to perform photometry on individual fields of an interlaced video recording, you should first create a de-interlaced version as described in the previous section.

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.

16.3.1 Setting initial parameters

To perform photometry/astrometry, load a video file 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.
- Path to executable: The file path to the source extractor binary executable. If it has been installed somewhere in the usual file path, you may enter just the name of the executable file. Otherwise you will need to give the full file path. The executable file is likely to be called either 'sex' or 'source-extractor' depending on the distribution.

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.

16.3.2 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 of the playback window 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 ROI 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.

16.3.3 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. VIDEO_FILE_NAME is the base name of your saved video file.

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.

17. Saving and loading parameters for different optical configurations

If you use GoQat with more than one optical configuration, you may find that you need different autoguiding and autofocus parameters. You can save and load these using the configuration settings dialog available from the Miscellaneous menu. Click 'Configuration settings...' on the Miscellaneous menu to open the dialog.

The settings are saved to a list and are referenced by the currently used values for the Telescope and Instrument FITS keywords from the CCD Camera tab, plus any comment that you choose to add in the configuration settings dialog. For your convenience, the current values for the Telescope and Instrument FITS keywords appear in the corresponding fields in the dialog when it opens. You may alter these if you wish and it is advisable to enter a unique comment in the Comment field.

Click 'Add existing settings to list' to store the displayed values for Telescope and Instrument FITS keywords from this dialog, the autoguider and autofocus settings and the current region-of-interest settings for the camera from the CCD Camera tab.

You may delete unwanted settings from the list by selecting an entry in the list and clicking 'Delete selected settings'.

To apply settings from the list, select the required entry in the list and then choose which settings you wish to restore by checking one or more of the items next to the 'Apply selected settings' button. Then click 'Apply selected settings' to restore the given items.

18. Communicating with GoQat - 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.

18.1 Creating the task queue via the 'Edit tasks' window

Click the 'Edit tasks...' button to open the 'Edit tasks' window. To add a task to the queue, 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 queue 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' 'Seconds'

'H1' 'V1' 'H2' 'V2' 'Hbin' 'Vbin' 'deg.C'

- Starts a CCD camera exposure 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

camera is open on the CCD Camera tab 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 queue. When you click the 'Start Exposure' button on the CCD Camera tab, any existing tasks in the queue 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. The Live View dialog must already be open with the autoguider 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. For INDI telescope drivers, these coordinates must be equinox-of-date; in all other cases you may use J2000.0 if your telescope controller will accept them but you must tell the telescope controller (independently of GoQat) which coordinates you are sending.

Task: **GoToNext**

- Performs a GoTo operation, pointing the telescope to the currently selected coordinates in the GoTo drop-down list on the Telescope tab. The list is adjusted to display the coordinates of the next target, or reverts to the top of the list if there are no more entries. The 'Object:' field on the CCD Camera tab is filled with the name of the target. See the Tutorials section of the website for examples.

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

- Moves the telescope by the specified angle in minutes of RA and arcminutes of Dec. 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. You may enter non-integer amounts.

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

- Waits until the sequence counter reaches 'seconds' seconds, before executing the next task in the queue. The counter can be reset with the BeginSequence task.

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

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

Task: **SyncWait** Parameters: 'Instance'

- Pauses the task queue until synchronised with instance number 'Instance' of GoQat. The instance with which GoQat is being synchronised must have a corresponding SyncWait task. See the Tutorials section of the website for examples.

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 or Python) and can perform any actions. See the Tutorials section of the website for examples.

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.

Task: **UnPark** Parameters: None

Task: **WarmRestart** Parameters: None

- Wakes the telescope from its parked position. Use the task name 'UnPark' for all telescope controllers except natively-supported Gemini units. For these, use the task name 'WarmRestart'. This results in a warm restart for the Gemini controller, but can only be done immediately after the Gemini unit has booted.

Task: **Exit** Parameters: None

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

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.

18.1.1 Saving and loading tasks

If you want to save the task queue, 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.

18.2 Creating the task queue with a text editor

You can create or modify the task queue 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 queue 'in-situ' by right-clicking on the list of tasks. This opens the list in the editor 'gedit' by default. Manipulate the task queue as desired, then save it and exit the editor. The task queue is re-loaded into GoQat automatically. You will be warned of any grammatical errors in the queue. Re-loading the task queue may not work if you already have another instance of the editor open elsewhere.

- To change the choice of external editor, set the value of the Misc/Editor key in the configuration file (see section 26.3) to the command that you would type at the command line to invoke the editor.

18.3 Manipulating the task queue

The contents of the task queue are displayed on the Tasks tab. You can manipulate the

contents of the queue as follows:

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

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

18.4 External scripts and parameters

18.4.1 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).

A script will assume that the working directory is the same as that in which the script resides. If this is not the case, you should change to the working directory explicitly in the script (e.g. with the 'cd' command if a bash script).

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

- '1' if the script is to be executed synchronously, or '0' if asynchronously.
- The name of the file that the script must write any results to, for passing back to GoQat. (GoQat will read script results from this file after the script has finished executing if the script is invoked synchronously with the Exec task).
- The name of the file that the script must create to indicate to GoQat that it has finished.
- The number of task parameters to be passed to the script (at present there

is a maximum of ten such parameters; their values can be set using the SetParam task).

- Each of the ten task parameters of maximum length 127 characters. (Unused parameters will be blank).
- The name of the most recently saved CCD camera FITS file.
- The exposure type of the most recently saved CCD image (Target / Flat / Dark / Bias).
- The filter used for the CCD image.
- The Exposure length (seconds).
- The H1 (bottom left horizontal coordinate) of the image.
- The V1 (bottom left vertical coordinate) of the image.
- The H2 (top right horizontal coordinate) of the image.
- The V2 (top right vertical coordinate) of the image.
- The binning in the horizontal direction.
- The binning in the vertical direction.
- The chip temperature.
- The minimum pixel value in the most recent CCD exposure (if monochrome)
- The maximum pixel value in the most recent CCD exposure (if monochrome)
- The mean pixel value in the most recent CCD exposure (if monochrome)
- The modal pixel value in the most recent CCD exposure (if monochrome)
- The current right-ascension to which the telescope is pointing (either a plate-solved coordinate or the coordinate read from the telescope controller, depending on the choices on the Plate Solve menu).
- The current declination to which the telescope is pointing (either a plate-solved coordinate or the coordinate read from the telescope controller, depending on the choices on the Plate Solve menu).
- The focuser maximum range of travel.
- The current focuser position.
- The current focuser temperature.

- The workspace string (a character string of up to 127 characters).

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 script's results file (with a name given by the second item above), sets any parameter values that have been passed back, and displays any messages in the log window. These files are created in the script's working directory.

Any output from the script is captured in a file called XXXXXscript_output_nn, where XXXXX is the process id of the instance of GoQat invoking the script and nn is GoQat's instance number. This can be useful for debugging scripts. This script is created in the working directory.

There are example bash, perl and python scripts in the 'examples' folder of the GoQat package. If you want to write a script in a different language, the script should accept all the parameters described above.

Please see the Tutorials section of the website for further information and examples.

Passing values from the script back to GoQat

1. Parameters

The script 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 results file whose name is given as the second item above.

For example, writing the following strings to the results file...

```
%0 23.45
%1 12:34:56
%2 A large bright nebula
```

...causes GoQat to set parameter 0 to "23.45", parameter 1 to "12:34:56" and parameter 2 to "A large bright nebula".

Parameter values are initialised to a single blank character when the task queue is started.

2. Workspace variables

The script can return working variables to GoQat that will be passed back to the script

on its next invocation. This is useful if the script is being called in a loop and it needs to remember values from when it was last called. Working variables are returned by writing a string such as in the following example to the results file (note the initial '@' which defines that this is to be interpreted as the workspace string):

```
@ $value1 $value2 hello goodbye
```

If the variables \$value1 and \$value2 contain '23.456' and 'M42' then GoQat will store a string containing '23.456 M42 hello goodbye'. This string is passed back to the script next time it is called and it is up to the script to extract the values from it in the desired fashion. GoQat clears the workspace string to blanks whenever task execution is started, so any script using the workspace variable must anticipate that it will be blank at its first invocation. The maximum length of 127 characters includes everything after the initial '@' when writing to the results file.

3. Comments

The script can 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.

18.4.2 Using parameters in GoQat

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.

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 queue 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.

18.5 Executing the task queue

- Click the 'Play' button to start executing tasks from the top of the queue. The task queue 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 queue, GoQat will flag an error if the CCD camera is not already open. Any errors must be corrected before the task queue 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 queue AND cancel the current exposure. Clicking the 'Cancel Exposure' button on the CCD Camera tab cancels only the current exposure, not the entire sequence.

Set the Tasks/EmergencyStop configuration key to 1 to force any active CCD camera exposures or telescope slews to be stopped when you stop the task queue. See section 26.3.

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

18.6 Submitting tasks to GoQat from another program

GoQat can watch a file for incoming tasks and act on those tasks as they are received. To specify a task file to watch, choose the folder and file name for incoming tasks on the Files tab. Check the 'Activate' check box 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.

If the file does not already exist, GoQat will attempt to create an empty file. This will fail if GoQat's access to the file system is read-only. In this case, you should ensure that the selected file already exists before telling GoQat to watch it. Any existing tasks in the watch file are ignored when the watch is activated; only new tasks are processed.

You can submit tasks yourself from a terminal window or you may use another program or script to write any desired tasks to the task file, thus permitting GoQat to be controlled by another application.

18.6.1 Individual tasks

To send a single task from a command prompt, do this for example:

```
echo 'AugOn' > /home/my-files/my_task_file
```

This will send the task 'AugOn' to the file /home/my-files/my_task_file and GoQat will turn the autoguider camera on if watching this file.

18.6.2 Multiple tasks

GoQat checks for new tasks many times per second (the exact rate depends on how busy GoQat is with other activities), but if you send new tasks at a faster rate than this, some tasks may be lost. To avoid this, you can send many tasks at once by copying an entire task queue to the watch file in one go:

```
cat task_queue > /home/my-files/my_task_file
```

The 'task_queue' file may also contain blank lines and comment lines beginning with '#'.

18.7 Telling GoQat which task file to watch when it starts

You can give GoQat a file name and activate watching it for incoming tasks when you start GoQat like this:

```
GoQat --taskfile /watch/this/task_file
```

or

```
GoQat -t /watch/this/task_file
```

GoQat will watch 'task_file' in the '/watch/this' folder and create it if it doesn't exist.

19. Communicating with GoQat – Using commands

Every graphical user interface element (e.g. push button, menu item - also known as a 'widget') can be interacted with from outside GoQat by writing the widget name and its desired state to a file that is monitored by GoQat. The widget name and state together comprise a GoQat command.

19.1 Widget names and states

To see the name and current state of any of GoQat's widgets, select 'Show widget commands' from the File menu. Then middle-click on any widget. The widget name and its current state will be displayed in black text in the log window. Note that the widget must be visible (i.e. in an open window or an a visible tab) and sensitive (i.e. not 'greyed-out').

To save the widget name and state to a file, check the 'Write commands to log and file' menu item on the File menu. Commands will then be written to a file called `commands.txt` in your `~/GoQat` folder, where `'~'` represents your home directory. Commands are not written to the general log file.

19.2 Watching a file for incoming commands

To specify a command file to watch, specify the folder and file name on the Files tab. Check the 'Activate' check box 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.

If the file does not already exist, GoQat will attempt to create an empty file. This will fail if GoQat's access to the file system is read-only. In this case, you should ensure that the selected file already exists before telling GoQat to watch it. Any existing commands in the watch file are ignored when the watch is activated; only new commands are processed.

19.3 Submitting commands to GoQat

19.3.1 Individual commands

To send a single command from a shell prompt, do this for example:

```
echo 'chkAutogSubDark 1' > /home/my-files/my_command_file
```

This will write the command 'chkAutogSubDark 1' to the file /home/my-files/my_command_file to check the 'Subtract dark exposure' check box on the Autoguider tab if GoQat is watching this file.

19.3.2 Multiple commands

GoQat checks for new commands many times per second (the exact rate depends on how busy GoQat is with other activities), but if you send new commands at a faster rate than this, some commands may be lost. To avoid this, you can send many commands at once by copying an entire command list to the watch file in one go:

```
cat command_list > /home/my-files/my_command_file
```

The 'command_list' file may contain blank lines and comment lines beginning with '#'.

19.4 Telling GoQat which commands file to watch when it starts

You can give GoQat a file name and activate watching it for incoming commands when you start GoQat like this:

```
GoQat --commandfile /watch/this/command_file
```

or

```
GoQat -c /watch/this/command_file
```

GoQat will watch 'command_file' in the '/watch/this' folder and create it if it doesn't exist.

19.5 Viewing GoQat's response to commands in the terminal window

If you are sending commands to GoQat from a terminal session, you might want to see any response that GoQat makes in your terminal window. You can start GoQat like this:

```
GoQat --logtoterms
```

or

```
GoQat -l
```

Either of these options tells GoQat to direct log messages to the terminal session.

19.6 Command summary

The following table lists possible states for any type of widget.

Widget type	Initial letters of widget name	Permissible states
Push button	btn	Most have no state; they can be 'clicked' simply by specifying the widget name. There are two exceptions: (a) Those few cases where clicking a button causes a file-chooser dialog to open. In this case, the state is the path plus file name of the desired file. (b) The telescope motion buttons on the Autoguider tab, where specifying a state of '1' causes the button to be pressed and specifying a state of '0' causes it to be released again.
Check box	chk	'1' if it is checked, '0' if not.
Toggle button	tgl	'1' if pushed in, '0' if released.
Option (or radio) button	opt	'1' if the item is selected, otherwise no state. (If one option of a set of options is selected, it isn't possible to deselect it by setting its state to '0'; this can happen only by selecting

Widget type	Initial letters of widget name	Permissible states
		another option by setting the other option's state to '1').
Combo box	cmb	<p>The desired option from the list of values.</p> <p>There is one addition to this rule:</p> <p>(a) The combo box adjacent to the 'GoTo' button on the Telescope tab may have its state set to a file path plus name, in which case this file of GoTo positions will be read and loaded.</p>
Spin button	spb	The desired numerical value.
Data entry field	txt	The desired field content. No state (a blank value) erases the content of the field.
File chooser	flc, flf	<p>There are two options:</p> <p>(a) Widgets beginning 'flc' - set the desired file path.</p> <p>(b) Widgets beginning 'flf' - set the desired file path plus name.</p>
Slider	hsc	The desired numerical value.
Main tabbed notebook	ntb	The name of the desired notebook tab.
Scrolling list	trv	This applies only to the list of configuration settings accessible via 'Miscellaneous Configuration settings...'. Set the state to the contents of the Comment field for the desired setting. To enable a given setting to be selected, each setting should have a different, non-blank comment.

Widget type	Initial letters of widget name	Permissible states
Autoguided image display	cvi	The state consists of four separate items: the coordinates of the midpoint of the green ROI rectangle, its width and height.
Check box menu item		'1' if it is checked, '0' if not.
Option (or radio) menu item		'1' if the item is selected, otherwise no state. (If one option of a set of options is selected, it isn't possible to deselect it by setting its state to '0'; this can happen only by selecting another option by setting the other option's state to '1').
All other menu items		No state; they can be 'clicked' simply by specifying the widget name.

Examples commands for each type of widget are given in the table below.

Widget type	Example command
Push button	<p>Start a CCD exposure on the CCD Camera tab:</p> <pre><i>btnCCDStart</i></pre> <p>Start a CCD exposure using the INDI driver for the Starlight Xpress LodeStar via the INDI client tab (note the space between 'SX' and 'CCD' and 'LodeStar'):</p> <pre><i>btns_SX CCD LodeStar!CCD_EXPOSURE!</i></pre> <p>Load the file /home/my-files/movie.ser into the video playback viewer:</p> <pre><i>btnPBOpenFile /home/my-files/movie.ser</i></pre> <p>Press and then release one of the telescope motion buttons on the Autoguider tab:</p> <pre><i>btnAutogWest 1</i> <i>bntAutogWest 0</i></pre>
Check box	<p>Open the filter wheel on the Filter tab:</p> <pre><i>ChkFilterOpen 1</i></pre> <p>Close the filter wheel:</p> <pre><i>ChkFilterOpen 0</i></pre>
Toggle button	<p>Start autoguiding on the Autoguider tab:</p> <pre><i>tglAutogStart 1</i></pre>

Widget type	Example command
	Stop autoguiding: <i>tglAutogStart 0</i>
Option button	Select the autoguider to make just drift corrections in the Autoguider Advanced Configuration dialog: <i>optA_AutogDrift 1</i> Connect to the Starlight Xpress LodeStar via the INDI client tab: <i>opts_SX CCD LodeStar!CONNECTION!CONNECT! 1</i>
Combo box	Set the filter for the CCD exposure on the CCD Camera tab to 'R' (assuming that 'R' is one of the options in the list): <i>cmbCCDFilType R</i> Load a file of GoTo positions on the Telescope tab: <i>cmbTelescopeGoTo /home/my-files/goto.txt</i>
Spin button	Set the binning to 2x2 on the CCD Camera tab: <i>spbCCDBin 2</i>
Data entry field	Set the horizontal binning to 2 for the Starlight Xpress LodeStar via the INDI client tab: <i>txts_SX CCD LodeStar!CCD_BINNING!HOR_BIN! 2</i> Set the 'Observer' FITS keyword to blank by omitting a value on the CCD Camera tab: <i>txtCCDObserver</i>
File chooser	Set the folder containing the file to watch for tasks being sent to GoQat:

Widget type	Example command
	<p><i>flcWatchTaskFolder /home/my-files</i></p> <p>Set the script file to be executed in the 'Edit tasks' dialog:</p> <p><i>flfTScriptFile /home/my-files/my_script.py</i></p>
Slider	<p>Set the background level on the Autoguider image window display to 2000:</p> <p><i>hscBackground 2000</i></p>
Main tabbed notebook	<p>Set the notebook tab to 'Telescope':</p> <p><i>ntbMainNotebook Telescope</i></p> <p>Set the notebook tab to the INDI client tab for the Starlight Xpress Lodestar (note the spaces):</p> <p><i>ntbMainNotebook SX CCD LodeStar</i></p>
Scrolling list	<p>Select the entry in the list of saved configurations that has 'Telescope config 1' for the comment field in the Configuration settings dialog:</p> <p><i>trvSetting Telescope config 1</i></p>
Autoguider image display	<p>Set the location and size of the ROI rectangle:</p> <p><i>cviRect 300 200 50 50</i></p>
Check box menu item	<p>Use UTC time (Miscellaneous Use UTC):</p> <p><i>use_utc 1</i></p> <p>Stop using UTC time:</p> <p><i>use_utc 0</i></p>
Option menu item	<p>Set the port for telescope controller communications to /dev/ttyS4</p>

Widget type	Example command
	(Devices Telescope > Serial/USB /dev/ttyS4): <i>t_ttyS4 1</i> Other prefixes are as follows: ccd (main) camera: <i>'ccd_'</i> autoguider camera: <i>'aug_'</i> telescope mount: <i>'t_'</i> guide commands device: <i>'a_'</i> filter wheel: <i>'w_'</i> focuser: <i>'f_'</i> plate solve camera: <i>'p_'</i> INDI devices have <i>'indi_'</i> appended to the prefix, e.g.: <i>'t_indi_'</i>
All other menu items	Save the CCD camera image (File Save CCD image): <i>save_ccd_image</i>

Note that the widget must exist before you can change its state (so if the widget appears in a dialog box, that dialog box must actually be open) and it must also be sensitive (i.e. not 'greyed-out'). So you have to interact with GoQat when sending commands in just the same way as if you were doing so with the mouse. There is one exception to the above rule; when interacting with GoQat's menus, you can set the state of a menu item directly, rather than having to navigate through the levels of the menus. An example of this is given in the table above for an option menu item; see the Tutorials section of the website for more examples.

GoQat can be set to emulate the effect of pressing the Enter key after entering data into a data entry field (see section 26.3). So for example, a CCD camera exposure can be started just by writing the exposure length to the command file:

```
txtCCDExposure 120
```

This would start a 120 second exposure without needing to send the additional command:

btnCCDStart

This behaviour is disabled by default.

20. Multiple Instances of GoQat

You can run multiple instances of GoQat independently of each other, each with its own associated settings and files.

The instance number starts at '01' and is displayed in the window and dialog title-bars. The instance number is generally incremented for each new instance that you start, but GoQat does fill in missing instance numbers, so if you opened instances 1, 2 and 3 and then closed instance 2, the next instance to be opened would be 2 again and not 4.

You can start a particular instance of GoQat like this:

```
GoQat --instance 3
```

or

```
GoQat -i 3
```

Either of these commands will start instance number 3 without having to start instances 1 and 2 first.

The instances don't have to be independent: you can synchronise tasks between instances of GoQat which is very useful for controlling multiple cameras on the same telescope mount for example. Please see the Tutorials section of the website for a detailed discussion.

20.1 Instance numbering and synchronisation

Instance numbering and synchronisation between instances of GoQat is performed via a 'Sync' directory that is in your home GoQat folder by default. GoQat creates a new Sync directory if it doesn't exist.

20.1.1 Instance numbering

Each instance of GoQat creates a file in the synchronisation directory with the same name as its instance, e.g. '01', '02', etc. GoQat writes a time stamp to this file every five seconds to indicate that it is running. When GoQat starts, it scans the synchronisation

directory for any existing files and sets its instance number according to the following rules:

(a) Find the lowest numbered file for which the timestamp is older than ten seconds. Assume that this belonged to an instance of GoQat that terminated abnormally and hence this instance number is now available.

(b) Find the lowest available instance number for which there is no file.

The instance number for this new instance of GoQat is the lowest of (a) and (b).

GoQat does not permit two or more instances with the same instance number to share the same synchronisation directory. So if you force GoQat to start with a particular instance number but that instance terminates abnormally, you will need to wait at least ten seconds to restart it.

20.1.2 Synchronisation

You can synchronise multiple GoQats across different machines by setting the location of the Sync directory to a common location that all instances of GoQat can see. For example, start each instance of GoQat like this:

```
GoQat --syncdir /common/location
```

or

```
GoQat -y /common/location
```

GoQat will make a folder called Sync in /common/location if it doesn't already exist. You then synchronise instances of GoQat using the SyncWait task (please see section 18 and the Tutorials section of the website for some examples).

20.2 Message logging

By default each instance of GoQat writes its message log to your home GoQat folder. You might want to change this location if you have multiple instances of GoQat on different machines. Perhaps you want them all to write their logs to one central location. You can start GoQat like this:

```
GoQat --logdir /central/location
```

or

```
GoQat -g /central/location
```

Each instance of GoQat started in this fashion will write its log to /central/location.

You should do this only if all such instances of GoQat have different instance numbers, otherwise they will attempt to overwrite each other's log files. (Log files have the instance number appended to the file name, except for instance 1 which has just 'log.txt').

21. Monitoring the status of devices

GoQat writes the status of various devices to files in a directory structure in your home GoQat folder. This can be useful if GoQat is being controlled by an external program that needs to know when certain processes such as a camera exposure or telescope slew has finished.

By default the top-level directory is `~/GoQat/Status`, where `'~'` represents your home directory. Instances of GoQat higher than 1 append their instance number to the directory name, e.g. `'Status_02'` for instance number 2.

The status directory can be written elsewhere if you start GoQat like this:

```
GoQat --statusdir /written/elsewhere
```

or

```
GoQat -u /written/elsewhere
```

This causes GoQat to create the Status directory in `/written/elsewhere`.

If you have instances of GoQat on different machines writing their status directories to the same location, you must make sure that they have different instance numbers. Otherwise they will attempt to overwrite each other's directories.

The reported device statuses are as follows, where e.g. `'Autoguider/Camera/Open'` means the file called `'Open'` in the folder `'Camera'` of the `'Autoguider'` subdirectory of `'Status'` contains the given value:

- `Autoguider/Camera/Open` - 1 if open, 0 if closed
- `Autoguider/Guide_Device/Open` - 1 if open, 0 if closed
- `Autoguider/Guide_Device/Guiding` - 1 if guiding, 0 if not
- `CCD_Camera/Open` - 1 if open, 0 if closed
- `CCD_Camera/Exposing` - 1 if exposing, 0 if not
- `CCD_Camera/FileName` - the name of the most recently saved image file

- CCD_Camera/ObjectName – the name of the object, if set
- Filter/Open - 1 if filter wheel open, 0 if closed
- Filter/Position – current position of filter wheel
- Filter/Name – name of filter in current position
- Focus/Open - 1 if focuser open, 0 if closed
- Focus/Position – current focuser position
- Telescope/Open – 1 if telescope controller link is open, 0 if closed
- Telescope/RA – current right ascension
- Telescope/Dec – current declination
- Tasks/Executing – 1 if task queue is executing, 0 if not
- Tasks/Paused – 1 if task queue is paused, 0 if not

21.1 Using the status directory with GoQat

GoQat can read the status directory of another instance of GoQat. Suppose instance 1 is controlling a camera and telescope mount and instance 2 is controlling another camera on the same mount. The camera controlled by instance 2 can get the object name and telescope pointing coordinates from instance 1 to write to the FITS header for images saved by instance 2.

To do this for instance 2, go to the Files tab and set the data source folder to be `/my/folders/Status`, where `/my/folders/Status` represents the status directory for instance 1. Then check the 'Use for object name' and 'Use for telescope coordinates' check boxes to have instance 2 read the object name and telescope coordinates from the directory structure described above.

Please see the website Tutorials pages for a more detailed example.

22. Running GoQat on a device with no display or keyboard

If you are running GoQat on a machine with no display or keyboard, or you wish to hide the GUI, you can install the Xvfb virtual framebuffer X server and then run GoQat as follows.

Start Xvfb in the background to listen for connections as server number 1 (in some situations you may wish to use a different server number):

```
Xvfb :1 &
```

Then start GoQat, telling it to use the sever number you chose when starting Xvfb (in this example it is server number 1):

```
GoQat --display=:1
```

If you are doing this, you may well be sending commands to a file that GoQat is watching and you might want to see GoQat's responses written to the terminal session, so you could start GoQat like this:

```
GoQat --display=:1 -c /my/directory/commands_file --logto term
```

23. Files

23.1 CCD camera and autoguider image files

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

23.1.1 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. These settings are saved when you exit GoQat.

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 queue, 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 queue, 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 writing to the FITS header, before saving each file. The message log will display a warning if this is not possible.

23.1.2 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. These settings are saved when you exit GoQat.

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 streaming 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):' check box.

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.

23.2 Miscellaneous other files

The following files are unique to each instance of GoQat. For instances greater than 1, the instance number is appended to the file name; so for instance 2, log.txt becomes log_02.txt and GoQat-2.conf becomes GoQat-2_02.conf etc.

In the following sections, '~' represents your home directory.

23.2.1 Message log file – log.txt

The message log file ~/GoQat/log.txt contains the content of the message log pane if you select 'Write messages to log and file' from the File menu.

If you click the 'Flush log to file' option from the File menu, the entire current contents of the message log will be appended to the log file.

23.2.2 Image display files – ccd_display.fit and aug_display.fit

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

23.2.3 Autoguider star position and guide correction files – star_pos.csv and guide_corr.csv

The guide star position data is saved in ~/GoQat/star_pos.csv.

The autoguiding data is saved in ~/GoQat/guide_corr.csv.

This is activated from the autoguider advanced configuration dialog.

23.2.4 Autoguider dark frame - dark_frame

The most recent dark frame created via the Autoguider tab is saved in `~/GoQat/dark_frame_camera`, where 'camera' is a string representing the camera used.

23.2.5 Widget commands – commands.txt

Widget commands are written to `~/GoQat/commands.txt` if 'Show widget commands' and 'Write commands to log and file' are activated on the File menu.

23.3 Starlight Xpress camera PIDs and names – sx_cams.txt

Starlight Xpress PIDs and camera names are stored in `~/GoQat/sx_cams.txt`. This file is shared by all instances of GoQat.

The file is read by GoQat for natively-supported SX cameras (it has no effect for SX cameras controlled via INDI). If your camera is not in this list, GoQat will not be able to find it for native support, but you can add it yourself.

The PID (product ID) is unique to each device. You may be able to obtain it from the Starlight Xpress website or maybe from your camera documentation. Otherwise if `/proc/bus/usb/devices` exists on your system, find the group of entries for the Starlight Xpress device and look for the line beginning "P: Vendor=1278". The "ProdID" field gives you the product ID that you require. Alternatively, run `lsusb` (available in the `usbutils` package) and find the relevant entry containing ID 1278. The product ID is the four numbers following the colon in that entry.

To add a new camera to the list, edit `sx_cams.txt` and type in the product ID. Then give a name for the device; this can be up to 18 characters long.

24. 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:

24.1 File

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

- 'Show normal debug messages' writes normal debug messages to the log window.
- 'Show INDI debug messages' writes INDI debug messages to the log window.
- 'Show INDI server messages' writes INDI server messages to the log window.

- 'Write messages to log and file' appends each new message to the log file as well as writing messages to the log window.
- 'Flush log to file' flushes the current contents of the message log to the log file.
- 'Clear log window' clears the contents of the message log window.

- 'Show widget commands' displays the widget command associated with any widget in the GUI on which you middle-click.
- 'Write commands to log and file' writes the widget commands to the commands.txt file as well as writing them to the log window.

- 'Quit' quits GoQat.

24.2 Cameras

- 'CCD camera type >' selects the camera to be controlled from the CCD Camera tab.
- 'Select CCD camera...' selects the active CCD camera when more than one natively-

supported QSI or SX camera is connected to the computer.

- 'Configure CCD camera...' sets the various CCD camera configuration options.
- 'Embed in full frame' enables/disables displaying a subset of a CCD image embedded in the full frame image area, if the exposure was a sub-area or binned.
- 'Debayer >' sets the active debayering algorithm for colour cameras.

- 'Autoguider camera type >' sets the type of autoguider camera to be controlled from the Autoguider tab.
- 'Select camera...' selects the active autoguider camera when more than one natively-supported Unicap, QSI or SX camera is connected to the computer.
- 'Set V4L properties...' sets some properties of the natively-supported active V4L device.
- 'Set Unicap properties...' sets some properties of the active Unicap device.
- 'Configure autoguider camera...' sets the various autoguider camera configuration options for non-streaming devices (i.e. for typical CCD/CMOS cameras).
- 'Greyscale conversion >' sets the active method for converting from three-colour format to greyscale for natively-supported V4L and Unicap autoguider camera images that are decoded as RGB. The mono option forces images to be decoded as if they were 8 bit greyscale.

24.3 Devices

- 'Telescope >' sets the desired port for native communications with the telescope controller, or selects the desired INDI device.

- 'Guide commands >' sets the desired route for communications with the guiding hardware.
- 'Configure parallel port...' permits the parallel port to be configured for autoguiding.

- 'Filter wheel >' sets the desired filter wheel type.
- 'Select filter wheel...' permits choosing the active filter wheel if more than one SX filter wheel is connected to the computer.

- 'Focuser >' sets the desired focuser.

24.4 INDI

- 'Configure INDI server...' configures the commands to start and connect to the INDI server.
- 'Start server when GoQat starts' starts the INDI server when GoQat starts, provided it is not already running.
- 'Connect to server' connects GoQat to the INDI server.
- 'GoQat disconnects INDI devices': For an INDI device that is being controlled directly by GoQat (rather than via the corresponding client interface tab), closing the device on one of GoQat's native tabs also causes GoQat to disconnect the INDI device on the client tab. Deselect this option if you want the INDI device to remain connected.
- 'Display all INDI images' tells GoQat to display all images it receives from the INDI server, even from cameras not opened by this instance of GoQat. To display images from cameras opened by this instance only, deselect this option.

24.5 Plate Solve

- 'Plate solve camera >' sets the camera whose images will be used for plate solving.
- 'Configure plate solve...' opens the plate solver configuration window.
- 'GoToPS' instructs the telescope to move to the coordinates entered on the Telescope tab, make an exposure with the selected camera and plate solve it. The pointing can be refined by iterating a given number of times.
- 'RefinePS' is as for GoToPS except that the initial telescope slew is not made. The pointing location can be refined by iterating 'move and plate solve' operations.
- 'Use plate solve coords for FITS header': check this to have the plate solved coordinates from a GoToPS or RefinePS operation used for the FITS header, rather than coordinates read from the telescope controller. This is mutually exclusive with 'Use these coords for FITS header'.

- 'Plate solve any image...' opens the plate solve window to permit solving any desired image. No telescope movements are made.
- 'Use these coords for FITS header': check this to have plate solved coordinates from a solution of any image used for the FITS header, rather than coordinates read from the telescope controller. This is mutually exclusive with 'Use plate solve coords for FITS header'.
- 'Abort' aborts plate solving (including any 'go to' iterations).
- 'Write solver output to log window': check this to have output from the plate solver written to the log window.

24.6 Miscellaneous

- 'Configuration settings...' opens the configuration window for saving and loading autoguider and autofocus settings and FITS keywords.
- 'Set filter names...' opens the configuration window for editing the list of filter names.
- 'Set playback frame rates...' opens the configuration window for editing the list of frame rates.
- 'Precess to J2000.0 for FITS' 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 equinox-of-date and you want to precess them to J2000.0 before writing to the FITS header of an image file. GoQat requests equinox-of-date coordinates for INDI telescope drivers and natively-supported Gemini controllers. In all other cases the received coordinates will be as set in the telescope controller independently of GoQat. This option does not have any effect on coordinates sent to the controller or the received coordinates displayed on the Telescope tab.
- '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 autoguider Image window.

24.7 Windows

- 'Live View' sets the autoguider image window into Live View mode and opens the Live View dialog.
- '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 compatible camera is connected.
- 'CCD image slice' enables/disables plotting of a selected slice through an image from the CCD camera.
- 'Autoguider trace' enables/disables plotting of autoguider star positions.
- 'Show toolbar' enables/disables the display of the main application toolbar.

24.8 Help

- 'About' displays the About dialog box.

25. Keyboard Shortcuts

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

- '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.

26. 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-2.conf' and you can find it in the 'GoQat' folder in your home directory.

Instances of GoQat greater than 1 have their own configuration file. Initially this is a copy of GoQat-2.conf, but is saved as GoQat-2_nn.conf where 'nn' is the instance number. Each instance of GoQat thus has its own private settings.

26.1 Configuration file format

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=Value1
```

26.2 Creating a configuration file entry by hand

By way of an example, suppose you want to create an entry called Video/FrameBufSize. Then do this:

- 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 default one for you. This will of course lose all your existing settings.

GoQat does not necessarily perform any checks on the values that you create or modify by hand in the configuration file. You must make sure that you have entered sensible values.

26.3 GoQat 'hidden' configuration entries

The following 'hidden' entries can be set only by editing the configuration file directly. If they don't already exist, you will need to create them. GoQat uses its own internal default values when a key/value pair does not exist.

- CCD/BlockCCDCommands – GoQat can prevent commands being sent to the main imaging camera shortly before an exposure ends. Examples might be guiding commands or camera status requests. Some cameras may hang or do other unexpected things if such commands are being processed when an exposure finishes. To block all such commands 'n' milliseconds before the exposure ends, set CCD/BlockCCDCommands to the desired value of 'n'.
- Video/FrameBufSize – sets the size of memory in megabytes for buffering video frames, when recording via the Live View window. The default size (which applies if there is no configuration file entry) is 50 megabytes.
- Misc/Editor – sets the command to be used to invoke an external editor for editing the task queue. (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 value is: gedit.

- Misc/CommandsPressEnter – set this value to 1 to have GoQat emulate the effect of pressing the Enter key after modifying a data entry field, if the value of that field is set via a command sent to a commands watch file. The default value is 0.
- Telescope/GoToMotionLimit – sets the maximum amount that the telescope can move in arc seconds in both RA and Dec over a 5 second period before a GoTo command is assumed to have finished (this applies to non-Gemini mounts only – for natively-supported Gemini mounts, GoQat queries the status directly). The default is 15 arcsec.
- Telescope/CoordsInterval – sets the interval in seconds between successive queries of the telescope position if the ‘Show position’ check box on the Telescope tab is selected. The default is ten seconds.
- 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 100 (pixels).
- Focus/MaxFitPercError – for autofocus calibration curve fitting, if the HFD value of a measured point lies more than this amount from the fitted HFD value at that focus position, the point will be rejected. Rejected points are excluded from the final fit. The default value is 20 (percent).
- Tasks/EmergencyStop – if set to 1, stopping the task queue will also stop any telescope slews or CCD camera exposures that may be taking place. The default value is 0.
- DS9/WaitToOpen – sets the number of seconds that GoQat should wait for DS9 to open when first displaying a camera image. The default value is 30s.

27. Modifying Grace plots

If you have installed Grace, you can plot scrolling strip-charts of autoguider star positions or CCD camera temperatures and image slices. You can alter the appearance of the charts whilst they are being plotted, and save the charts with their data. You can display only one type of plot at once.

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 the autoguider and camera temperature plots is eight minutes, and you are invited not to alter this aspect of the templates; doing so may give unpredictable results.

27.1 Modifying a template file

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

- Open the desired template in Grace. 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 permission to save the modified template.

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

27.2 Grace plot hints and tips

You can use the buttons at top left of the Grace window to control your view of the plot:

- Click the magnifying glass button and drag a rectangle over the area of interest to zoom the view.
- Use the arrow buttons to navigate a zoomed view.
- Save a zoomed view to the stack by clicking 'PZ' and then selecting an area to zoom. Use the 'Cy' button to cycle between your zoomed views. You can also push and pop views on and off the stack with the 'Pu' and 'Po' buttons.
- Click 'AS' to autoscale both axes, or use the 'AX' and 'AY' buttons to autoscale the x and y axes respectively.

28. Changing GoQat's appearance

GoQat is built using the gtk library. This permits you to alter the visual appearance of selected elements of the interface using a syntax similar to web-page style sheets.

You must create a file called 'gtk.css' in the GoQat folder of your home directory and add the required commands to that. You may find other gtk.css files on your computer corresponding to your installed gtk themes. Have a look at these for ideas on how to modify GoQat's appearance.

Remember that you can alter the overall colour of GoQat by selecting or installing an entire gtk theme, for example to make it more dark-adaption friendly if using GoQat outside at night.

28.1 Changing the size of GoQat's windows

One very simple change that you might want to make is to alter the size of GoQat's windows. This could be useful if you have a laptop with a small but high resolution screen and would like to tile some of GoQat's windows and dialogs rather than having them overlap.

An easy way to do this is to change the font size throughout the application. An example called gtk-sample.css is installed in /usr/local/share/GoQat/data by default. You can copy this to your home GoQat folder and rename it to gtk.css.

This is what it looks like:

```
*:not(separator) {  
    font: 8px;  
    min-height: 10px;  
    min-width: 10px;  
}
```

This instructs gtk to use a font size of 8px and set a minimum height and width of 10px for every component except the separators. (Separators are the narrow vertical or horizontal lines used to delineate different areas of dialogs and tabs). Try it and see what happens - you will need to restart GoQat if it is already running. Of course you can set a different font size to suit your screen and eyesight!