

Observer's Guide for QUIRC

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1 System Overview

The University of Hawaii (UH) QUick Infrared Camera (QUIRC) utilizes a 1024×1024 pixel HgCdTe Astronomical Wide Area Infrared Imaging (HAWAII) array produced by Rockwell Science Center. This array is sensitive to radiation from 1 to $2.5 \mu\text{m}$. The reimaging optics provide a 1:1 scale, giving the pixel scales listed in Table 1 for the various telescopes and configurations.

Table 1. QUIRC pixel scales

Telescope	Optics	arcsec/pixel	FOV (arcsec)
UH 88-inch	$f/10$	0.1886	193x193
	$f/31$	0.06084	62x62
CFHT	$f/8$	0.150	154x154
0.61-m	$f/15$	0.43	440x440
QUIST 0.25m	$f/10$	1.5	1550x1550

The QUIRC system is comprised of four functional components: (1) the detector, optics, and dewar; (2) The detector readout electronics; (3) A DSP controller; and (4) the instrument control Sparcstation and fiber optic communications interface. The first three components are physically integrated and mounted on the telescope, while the fourth is typically located in the observing room and/or the computer room.

The QUIRC electronics are controlled from a Sparcstation by issuing commands and receiving data via fiber optic cables. The control program on the Sparcstation is called “qcdcom”. The qcdcom program is based on the ccdcom program by M. Metzger and was modified for use with QUIRC. The qcdcom program controls taking exposures and writing data in FITS format to disk, operates the moving parts of the instrument such as the shutter, filter wheel, and pupil mask, communicates with the telescope and guider to obtain information and perform mosaics, and provides a script capability for automatically performing simple observing tasks. qcdcom is a command line interface only and does not directly provide image display, but can be used with any popular display program that can read FITS files (e.g. saimage, Vista, IDL). A link has also been provided to the viewfits program to automatically display images (see below).

2 Near-Infrared Observing Techniques

Imaging in the near-infrared ($1\text{--}2.5 \mu\text{m}$) generally requires more effort than at optical wavelengths, because the background is so much higher. There are two general data reduction techniques in common use—both of these require frequent observation of sky fields.

The first data reduction philosophy is one in which the sky fields are used for subtraction, and the sky subtracted image is divided by normalized dome flats to remove the variations in quantum efficiency. The advantage of this technique is that the dome lights have similar color temperature to the typical sources being studied.

The second data reduction technique is one in which the sky exposures are also used as flats, so the image is sky subtracted, then divided by a normalized sky flat. This technique often will work better

in cases where the background has been changing rapidly. It may also give better results if the dome flat was not evenly illuminated (it is difficult to achieve even illumination at the 0.6m telescope). The dark should be subtracted from the sky before division. The disadvantages of this technique are that the sky flat shows the response of the detector to the OH airglow + thermal emission. In particular, fringing may be present in certain configurations (*e.g.* 2.2m f/10 1:1), and fringing is something which should be subtracted, not divided.

The number of bad pixels usually dictates a special technique for observing in which several exposures are made of the field being studied, with each exposure shifted slightly from the others (dithering). When the images are combined, the bad pixels in one image can be "filled in" with good pixels from a shifted image. This technique also improves flat-fielding relative to a single long exposure at the same position.

It is recommended that at the start and end of each night dome flats and darks be taken. The darks should ideally be exposures of the same length as the object exposures. Even if the darks are not directly used in the reduction, they will serve to show which pixels have high dark counts so that these pixels can be included in a bad pixel mask. Dome flats are generally taken as a lights on/lights off pair. Using this strategy results in a difference image (ON – OFF) which represents the detector's flat-field response to a source with color temperature of a few 1000 K, which is roughly the same temperature as some of the sources being studied.

The shutter is a leaf type shutter, meaning that the center part of the aperture is open slightly longer than the outside. Recent tests showed significant center-to-edge illumination differences for integration times less than 1 second. Therefore, short exposures should be avoided, particularly when exposing dome flats—it is far better to dim the lights with the domelight dimmer switch and use an exposure of a few seconds than to use the dome lights at full intensity and an exposure which is less than a second (this can introduce spurious radially varying structure into the flat-field). There is an uncertainty in the timing of the shutter of the order of 10 millisecc. Therefore, short standard star exposures should also be avoided—on the 2.2m, the Elias standards may need to be slightly defocused to allow reasonable exposure times in the broad filters.

At the 2.2m telescope there is a slight rotation in the nominal cassegrain rotator position (270). The rotation was measured in February 1996 to be 0.883 degrees CCW (*e.g.*, N is rotated 0.883 deg E of vertical when displayed in the normal way). One could attempt to adjust slightly for this by changing the rotator position, or adjust for it later during data reduction. If the precise rotation and scale is important to the observations, one must measure this carefully during the run since the exact rotation value is likely to change slightly between runs when the instrument is taken off the telescope and remounted.

2.1 Detector Linearity, Saturation, Read Noise, Dark Current

Hard saturation of the detector occurs at 50,000 ADU's. The total gain of the system results in a scale factor of 1.85 electrons/ADU. Recent tests (2/96) showed the device to be linear to better than 1% for values up to about 44,000 ADUs. However, the gain and illumination is variable across the array so care must be taken so that parts of the array are not saturating when the average ADU value is getting close to the non-linear region. The average value should be kept below 40,000 ADUs to ensure that one is not saturating areas of the array. The average detector dark current is ≤ 0.8 electrons/sec, and the read noise is ≤ 15 electrons rms.

2.2 Dewar Temperature

The dewar now has a temperature sensor and heater. For normal operation, the temperature controller should be used to set the detector temperature to 80.0K. If the controller is not used, drifts can occur as the telescope is moved, resulting in dark current instabilities in the array. The new array is not thought to be more sensitive to these effects than the previous detector, but some of the anomalies previously seen by observers with the original QUIRC detector may have been due to this effect.

2.3 Camera Sensitivity

The following sensitivity estimates are based on observations of 2 standard stars at the UH 2.2m telescope on 2/6/96. The Point SRC (source) and Mag/arcsec² values are for 1 minute of on-source integration time, 5 σ . The point source detection values below assume a PSF of 0.5 arcsec FWHM.

Table 2. QUIRC Sensitivity
UH 2.2m Telescope

Filter	Point SRC(Mag)	Mag/arcsec ²	Jy/ADU (1 sec)
J	18.6	17.9	1.052e-6
H	17.8	17.1	8.295e-7
K	16.2	15.5	9.622e-7
H+K	18.6	17.9	

2.3.1 QUIST sensitivity

The following numbers are based on observations of standard stars using QUIST at the UH 0.6m telescope on 2/9/97. The Point SRC (source) and Mag/asec² are for 1 minute of integration time, 5 sigma. The point source detection values below assume a PSF of 2.5 pixels FWHM.

Table 2. QUIRC Sensitivity on QUIST

Filter	Point SRC(Mag)	Mag/arcsec ²	Jy/ADU (1 sec)
K'	14.5	16.4	7.644e-5
Hs	14.7	16.6	2.291e-4
Hl	14.3	16.2	2.391e-4
2.12	12.0	15.0	4.563e-6
2.26	12.7	15.5	1.412e-5

3 Setup and Observing with QUIRC

The nominal orientation for QUIRC at the 88-inch telescope is for the black electronics box on the dewar (the utility box) to point North (toward the control room). Then the resulting FITS data files written by the program have N up and E to the left (i.e. the (0,0) pixel is in the SE corner).

3.1 Workstation setup

The program is run from a workstation in the control room, currently `io` (or `halley` on the 88"). There is one configuration file that `qcdcom` reads upon startup to determine the telescope, secondary, and other information. There are four preset configuration files currently used, located in the directory `/aux/inst/qconf`:

```
tel_config_06_quirc
tel_config_22_f10_quirc
tel_config_22_f31_quirc
tel_config_cfh_quirc
```

These files are for the 0.6m, the 88" at $f/10$, the 88" at $f/31$, and CFHT at $f/8$. To install the proper file, a symbolic link should be made in that directory called `tel_config` that points to the appropriate configuration. For example, to set up for the 88" at $f/10$,

```
% rm /aux/inst/qconf/tel_config
% ln -s tel_config_22_f31_quirc /aux/inst/qconf/tel_config
```

This step only needs to be done once when the telescope or secondary changes, and should already be set up properly for the current configuration. Be careful not to delete the configuration files themselves.

One `xterm` should be devoted to the camera program. The `qcdcom` program does not provide an integrated image display capability. A separate program should be used to display the data. One option is to use the `viewfits` program (`vf`). This is a display program developed by Tony Denault at the IRTF that displays images and has statistical and graphical analysis features. A link has been provided from `qcdcom` to this program that displays images automatically. The program can be run by typing the following in any window:

```
% vf &
```

To display images automatically, one must set the data directory to be the same as where `qcdcom` is storing the FITS files. This is done by clicking on the "File" button and entering the proper path. One must also issue the command `set vfout` in `qcdcom` to enable the link so that data are displayed automatically. See the section on `vf` below for more information.

The `saoimage` program can also be used to display the QUIRC images. The observer should open a `saoimage` window on the camera workstation. The command line usually must be edited to read in the fits file. This can be done by pressing the "n" key (for the "new" command) while in the `saoimage` window. For example,

```
-imtool -fits /scr/aug11/q940811.004
```

would read in file number 4. When in chop mode, `qcdcom` writes each chop position to a separate file, and the chop difference to a file ending in "chop" instead of the file number.

3.2 QCDCOM Setup and Operation

The `qcdcom` program should be run from the directory where you want your data to be written, though this can be changed from within `qcdcom` using the `cd` command. So execute the following commands:

```
% cd /scr/data (or wherever your data should go)
% qcdcom
```

When `qcdcom` is started, it initializes communications with the parallel interface, allocate memory into which to read IR array images, and read enough from the DSP memory to get an idea of the status of the DSP code. `qcdcom` also initializes itself for readout size and binning parameters from the numbers it reads from the DSP. Since `qcdcom` runs separately from the DSP computer and saves its own parameters, `qcdcom` can be terminated and then restarted without disturbing the DSP.

At startup `qcdcom` prints a short message identifying the program, and display the filters installed and the current filter and pupil position. It will also try establishing communication with the camera, and will give a warning if it fails. If the camera has not been initialized after powerup, or if for some other reason communications have failed, the DSP code will have to be downloaded to the camera. This is done with the `df` command. You should do this at the beginning of your observing run to make sure the correct code is running. The command to download the current standard DSP code is the following:

```
> df quirc
```

Occasionally the download will fail if the camera is in some undetermined state, and a reset will need to be done. The DSP reset is a red button on the white controller box mounted on the dewar. Usually pressing this once and waiting several seconds before retrying the download will work. Once the download has completed, the `sync` command can be used to see if the camera communications are OK. You can use the `sync` command at any time to verify that `qcdcom` and the DSP computer are talking. Once the main DSP program has been downloaded with the `df` command, the utility board program must be downloaded using the following command:

```
> du util
```

This loads the code that performs the filter wheel and pupil motions.

Next you should set the way files will be named on the disk. Files are named using a prefix with the frame number appended, thus you should set the prefix using the `fp` command and reset the running file number using the `fn` command (typically to 1 when you start up). For example, to have files named `qrc.001`, `qrc.002`, etc.:

```
> fp qrc.
> fn 1
```

Note you must specify a trailing dot in the file prefix if you want one.

You will also want to set the exposure parameters using `auto` at this time. Since you may inherit parameters from the previous observer, you should make sure they are set to the default values, which are correct for most observing. One easy way to do this is to use the `init` command described

below. This puts the program into a mode that will be appropriate for most observing, and will at least allow one to obtain “normal” images.

The description of the `auto` command below lists the parameters to be set. The proper defaults are # resets 1, shutter on, readout on, write on, idle on, double-correlated read on, number of samples 1, chop off, dummy read on, and dither subtract off. All of these parameters are saved each time they are changed, so if you have set these parameters previously, this initialization step may be skipped.

At the beginning of your run you will also want to re-initialize the filter wheel to make sure it is in the correct position. This can be done by issuing the command `filter home`. This can take a couple of minutes to complete. If there is any error in this procedure, try again; if the `filter home` command does not complete successfully the filter position will be wrong.

The pupil will most likely already be in the proper position; the current pupil position is displayed when `qcdcom` starts.

At this point the program is ready to start taking data. Since `qcdcom` saves almost all of the setup parameters whenever they are changed, when you quit `qcdcom` and re-start you can skip the initialization steps. If `qcdcom` should exit abnormally (i.e. crash) for any reason, the parameters it reads in may be old and you may need to set them again. Typically only resetting the file number is necessary.

3.3 Taking exposures

For each object you are observing you will typically use a sequence of the commands `filter`, `object`, and `go`. The following is a quick summary of basic observing commands, but you should read over the full set of command descriptions (given below) before you begin observing.

The `fi` command can be used to move the wheel to the proper filter. This command takes a numeric argument between 1 and 8. The complete list is given in a table below.

The `object` command is used to set the exposure time and object name. To set up a 180 second exposure of your favorite region, you might type “`object 180 My favorite region`”. The name “My favorite region” will be recorded in the header as the object name.

The `go` command can then be issued to take the exposure. `Qcdcom` will reset the array and read the reset level, open the shutter and take the exposure, read the array again, and write the difference between the first and second array reads to disk. You can then display this image using your favorite image display program.

When finished observing, the camera should be left in the IDLE mode. This mode has the DSP perform a reset every 5 seconds to prevent the array from saturating. This mode is executed automatically after an integration if the `auto idle` flag in the `qcdcom` program is true. Otherwise, it can be started using the `idle` command.

4 Writing Scripts and Taking Mosaics

Any sequence of qcdcom commands can be entered into a text file (using your favorite editor) and executed by qcdcom. The command to do this is `source file`, where `file` is the filename of the command list. This allows some routine types of observations to be performed automatically, for example taking a sequence of images in J, H, and K. By entering a sequence of filter move, exposure time, and go commands into a file, taking a JHK sequence can be done with one `source` command. Each command is printed along with its file name and line number before it is executed. If some command in the script fails, execution will stop and the line number where it stopped is printed. A script may be re-started at a particular line by adding the beginning line as the second argument to script. Thus "`source jhk3 5`" will begin execution at line 5 of the file `jhk3`.

Scripts can be most useful for taking mosaics, by using special commands to move the telescope and communicate with the guider. If you are taking a sequence of unguided exposures, such as for standard stars, the telescope may be moved directly; the command to do this is `tel aoffset RA Dec`, where RA and Dec are offsets from the base position (88") or current telescope position (CFHT, 0.6m). These commands can be interspersed with go commands, filter changes, etc. in a script to perform whatever pattern you wish.

You can also perform "guided" offsets, either directly (CFHT) or through communication with Atlas (88"). This is done via the `tel goffset RA Dec` command, which stops the guider, moves the telescope and guide probe, and turns the guider back on. On the 88" this communicates with Atlas and MiniOtto over the ethernet to perform the guider movements, and on CFHT commands are sent over a serial cable to the TCS.

As an example, a potentially useful script is one that takes data for a standard star. This might be a sequence of exposures in a dithered pattern (using alternating `tel aoffset` and `go` commands), followed by a filter change, followed by another dither pattern, and so forth. Several example scripts may be found in the home directory of obs/irgroup. Another useful script is one that takes a standard dithered pattern of a field (e.g. a 13-point diamond). This can be simply a sequence of alternating `tel goffset` and `go` commands, or a multiple-filter sequence.

If you prefer, it is also possible on the 88" to run mosaics from Atlas. To do this, turn pause and CCD modes off and QUIRC mode on on Atlas. After initiating the mosaic program on Atlas, the qcdcom `tel gnext` command tells Atlas to move to the first mosaic pattern position and waits for it to finish moving. The `go` command can then be issued, then another `tel gnext` causes Atlas to move to the next mosaic position. This can be repeated until the mosaic is complete, and any other qcdcom commands (except telescope motion, do not use `aoffset`!) can be interspersed. Note that if Atlas encounters an error, an alert box will pop up and Atlas will cease talking to qcdcom until the alert is cleared. This will most likely cause the script to fail, and the mosaic will need to be re-started from the middle.

5 Filters and Focusing

There are now two filter wheels in QUIRC with eight positions each. Because two OPEN positions (position 5 on both wheels) are required and one position (wheel 2 slot 8) holds a polarizer, thirteen

positions are available for filters. These will include the standard broadband filters J, H, K, K', and H+K. In addition there will usually be several narrowband and other special purpose filters installed. Below is a list of the current filters as of the date of this manual. These are subject to change; the most recent configuration can be obtained by using the `f.i` command in the `qcdcom` program, or by checking the QUIRC WWW homepage. The focus offsets for $f/10$ and $f/31$ are also given. The nominal focus positions are 4450 ($f/10$), 200 ($f/31$), and with HIPPO they are 5620 ($f/10$) and ~ 500 ($f/31$). These are to be used as starting points, the values will shift significantly with temperature, especially at $f/31$.

Table 2. QUIRC filters, thicknesses and focus offsets
(Focus setting correlates with λ)

Setting#	Wheel	Pos	Filter	2.2-m focus encoder offsets		
				thick (mm)	$f/10$	$f/31$
1	1	1	J	3.442	+60	+20
2	1	2	H	1.969	+10	+3
3	1	3	K	2.134	+10	+3
4	1	4	K'	1.080	0	0
5	1	6	H&K dual ($1.8\mu\text{m}$)	2.794	-20	-6
6	1	7	H2BP23 ($2.12\mu\text{m}$)	0.914	+2	+1
7	1	8	2260BP60 ($2.260\mu\text{m}$)	2.794	-20	-6
8	2	1	1560BP120 ($1.56\mu\text{m}$)			
9	2	2	1710BP120 ($1.71\mu\text{m}$)			
10	2	3	1.989BP50 ($1.989\mu\text{m}$)			
11	2	4	1.506/60 ($1.506\mu\text{m}$)			
12	2	6	1.107/50 ($1.107\mu\text{m}$)			
13	2	7	BrGamma ($2.166\mu\text{m}$)	0.965		
14	LOWFLUX ($0.000\mu\text{m}$)			
ATLAS Dichroic						
IN BEAM ($< 0.75\mu\text{m}$)				4	-75	-25

5.1 Focusing

The command `focus <n>` is an efficient way to focus QUIRC without taking many separate images. This routine opens the shutter n times between detector readouts to allow recording several focus images on the array. One can then directly compare the image quality at the different focus settings. The program pauses after each shutter open/close to allow the focus setting and position of the star to be changed. The telescope must be moved so that the images of the star do not overlap. See the `qcdcom` command section below for more details. There are two advantages to using this procedure. The first is that one can avoid the overheads with many different images and array readouts. The second advantage is that all the focus images are in the same image, which makes it easier to compare the different focus settings to choose the best one.

5.2 Taking Dark Frames

Since there is no blank position in the filter wheel and the shutter is warm, some extra care is required to obtain reasonable dark frames. With the installation of the second filter wheel, a "LOWFLUX" setting has been provided. This setting selects two filters simultaneously with incompatible bandpasses, e.g., the J filter and Br γ (2.16 μ m). This produces a reasonably low flux condition at the array, limited by the out-of-band blocking of the filters and leakage around the filter wheels.

Another way to get a dark frame is to move halfway between filters on the wheel to block most of the emission of the warm shutter. Special commands have been provided for doing darks, and a typical sequence might be as follows:

```
> filter 2
> filter DARK
> dark 180 Dark Frame
> go 5
> filter BACK
```

This takes 5 180-second dark frames. The `dark` command works exactly like the `object` command, except that the shutter will not open for the exposure. Note you must use the `object` command before your next data exposure, or change the default actions with `auto`, or the shutter will not open! Also note that you should always do only one `filter DARK` followed by exactly one `filter BACK`, always in pairs, otherwise the filter wheel will get lost and require a `filter home`. Be careful, there is no indication from the program when this has happened, as there is no encoder on the filter wheel. Moving the filter wheel between the J and H filters, as in the example, appears to minimize the thermal radiation from the warm shutter reaching the detector.

6 Cold Restart

If the power should fail or the DSP computer should need to be reset, the following sequence of commands should be issued:

```
> sy
> df quirc
> du util
```

If this happened during a filter wheel move or pupil mask motion, you will need to reset that with the `filter home` or `pupil home` commands, respectively. Note that the pupil mask re-initialization can take a long time (up to 30 minutes!) and is a bit tricky. Because of this, observers should never move the pupil mask unless you are sure it is absolutely necessary—it usually isn't.

7 Running VF to display data

The VF program is a tool for displaying FITS files, written by Tony Denault for the IRTF. See the VF manual for detailed information on the program and its capabilities. Its interaction with the `qcdcom`

program is described here.

7.1 Setting up

The setup file `.vf-init` has been installed in the home directory of the user `obs`. If running from a different user name, you must have this file in your home directory, as well as the `*.cm` files and `ps_proc`. The program can be run by typing the following in any window:

```
% vf &
```

To display images automatically, one must set the data directory to be the same as where `qcdcom` is storing the FITS files. This is done by clicking on the "File" button and entering the proper path. One must also issue the command `set vfout` in `qcdcom` to enable the link so that data are displayed automatically.

7.2 Image display options

The `qcdcom` program is set up to display the last file written. The images are displayed to the "Big Image" buffer, called E or B4 in the program. If the program is in chop or dither subtract mode, it displays the `.chop` image. If not, the last normal data file is displayed. The magnification of `.5x` will display the entire QUIRC image.

One useful feature is that if the data are not being saved and `vfout` is on, the data file is still written to the `.chop` image and displayed in `vf`. Therefore the observer can take focus frames, acquire and center the object, etc., without saving all the images as separate data files. This avoids filling the disk with useless files.

7.3 Quick VF tips

The VF manual has a complete listing of the capabilities of the program. Listed below are a few quick tips to get started:

After starting the program, click on the "E" button below the four canvases to display the big image canvas. The grayscale levels can be set to Auto or Fixed and the max and min set manually. The stretch can then be adjusted by pressing the right mouse button and moving it around the image, similar to `saoimage`.

The "Zoom on ObjBox" is a useful feature to zoom in on a source. After the image has been displayed, make a box around it by moving to the lower left corner and press & hold the middle mouse button, then move to the upper right corner and release. Then left click on the "Zoom on ObjBox" button and it will magnify it. Click on the `.5x` button to go back to full scale. When zoomed in, you can use the LineCut display mode to show the profile in the X and Y directions. Click on "Box" and turn AutoScale on to display the cuts through the box in the X and Y directions. You may need to adjust slightly the X and Y axis to go through the center of the source.

The TCS coordinate window (under Options) can be used to center a source or move it around the array at the 88-inch. The plate scale defaults to the f/10 scale (0.1886 arcsec/pix), for the f/31 scale it is 0.0608 arcsec/pix. First move to the source and press the "f" key, it will grab the pixel location as the "From" coordinates (you may need to click left with the mouse on the source before hitting the F key). Then move to the center or wherever and hit the "t" key to grab the "To" location. Alternatively, the from and to positions can be defined by holding the shift key and clicking and dragging the middle mouse button. Once the positions have been defined, click on "calculate offset" and then on "Offset TCS" to actually move the telescope (the 88-inch). You can also just read the offsets and move the telescope by hand.

8 QCDCOM commands

This is a description of the available QCDCOM commands. Any unique abbreviation will work, and qcdcom will prompt you if you enter an ambiguous command. When you first start qcdcom you should be aware of two self explanatory commands:

- > help `<>` Help help lists the currently recognized commands. Angle brackets indicate arguments, and square brackets indicate optional arguments.
- > quit `<>` Quit quit terminates qcdcom. Control-D will also do this.

8.1 DSP initialization commands

In general, you will need to initialize the DSP processor in the Leach electronics after power-up or after a DSP reset, because its cold-reset state is not appropriate for running the instrument. In order to do this you need to read a file of compiled DSP code, and then download it to the DSP. (Note that DSP assembler code in a .asm file is compiled by the a56 compiler into binary code in a .lod file. For example, a56 quircop1 will read quircop1.asm and write quircop1.lod.)

Note that while you may see several different versions of the code for QUIRC in the dsp directory, you can always find the current version of the code as quirc.lod. (It is maintained as a symbolic link to the working code.) Thus to download the current version of the code, after a power cycle or DSP computer reset, you can always use df quirc to load correct code. Remember that it is not necessary (and even undesirable) to download code when qcdcom is restarted. Quitting and re-starting qcdcom in itself has no effect on the on-board DSP computer, which runs independently.

- > df `<file>` Read and download DSP code

df is a combination of ll and dl, and is the normal command to use for sending code to the DSP. It will fill in a .lod extension if it is missing, and it will look in directories according to the environment variable LODPATH, which can be set to a list of directories separated by colons. Thus, the visitor account has been provided with:

```
setenv LODPATH ./aux/inst/dsp:./mydspcode
```

Example: df quirc

> ll *<file>* Read DSP code .lod file

ll reads a DSP code binary file into the Sparcstation memory.

> dl *<>* Download DSP code

dl sends the DSP code to the DSP electronics, and then causes the DSP to start executing this code. dl also asks the DSP to recalibrate its A/D converter, which takes about 2 seconds.

> du *<file>* Download Utility board code

du loads the utility board code. This command should be run after the DSP has been initialized with the dl or df commands above. The utility board code is necessary to perform filter wheel and pupil slide motions.

Example: du util

8.2 Commands for setting up and taking exposures

Qcdcom takes exposures and writes data files according to various parameters which you can set. The basic sequence that qcdcom follows is to

1. Reset the chip
2. Do dummy read to stabilize array
3. Perform first data read of double-correlation pair, store image in memory
4. Turn off output amplifiers
5. Open the shutter and wait for a predetermined exposure time
6. Close the shutter
7. Turn on output amplifiers
8. Do dummy read to stabilize array
9. Perform second data read, subtract the first from it, store in memory
10. Write the contents of memory into a FITS format data file
11. Put the controller into reset idle mode

These actions are performed by the fundamental command `go`, which is described below. First, the commands which tailor the sequence followed by `go` are given.

Not all of these steps may be taken, and the actual sequence followed depends on how the automatic actions are set, as described below. There are a number of ways to set the parameters which govern what qcdcom does. Several commands are available which can be used to set integration time, object name, object type (a FITS header item), and default automatic actions. None of these does anything more than setting parameters to be used later—only `go` takes an exposure.

> `object` \langle [time [name]] \rangle Setup for object

`object` prepares `qcdcom` to take an exposure of a general target. You can specify integration time as the first argument and an object name as the second. The `object` command sets the automatic actions: # of resets: 1, shutter on, readout on.

Example: `object 300 N3031` (set integration time to 300 sec and object name to N3031) Example: `object 0.18` (set integration time to 0.18 sec)

> `auto` \langle \rangle set automatic action

`auto` goes through the choices for the automatic actions, and allows you to set each. You should not normally need to use `auto` directly, since you can use the `object`, `dark`, `etc.` commands for most normal exposures. It is provided for those who need to do fancy things. The automatic actions are:

- #reset: n Number of times to reset the chip before starting the exposure. Should usually be set to 1.
- Shutter on/off Controls whether the shutter should be opened for the exposure. Usually set to ON, otherwise no flux from sky gets to detector.
- Readout on/off Controls whether the chip should be read out at the end of the exposure. Usually ON.
- Write on/off Controls whether a FITS file should be written after the chip is read out. Usually ON to save data. This can also be set using the command `set save`.
- idle on/off If on, at the end of a readout the chip is placed in a continuous reset, or idle, mode.
- double correlated read on/off Controls whether the device is read out before and after the shutter opening, or only after. If reading before and after, the difference between the two are taken, and this difference is written to the FITS file. Double correlated read ON is the normal operating mode.
- Number of samples n controls how many frames to co-add in the double correlated read. For each exposure, the chip will be reset and read n times before opening the shutter, and read n times after the shutter closes. Usually set to 1.
- chop on/off Controls whether a beamswitched pair of integrations is performed for each `go` command. If at the UH 88-inch, the beamswitch is done automatically. Use with caution. The on and off source frames are differenced and the result is stored in a file with the name constructed from the data file name plus "chop" added instead of the file number. This file is overwritten every time a new chop is done.
- dummy read on/off In order to get the array into a stable mode, a "dummy read" is done immediately before the read that is saved as data. This occurs both before and after the integration. This should be turned on for normal operation. The "dummy read" may not be necessary for broad-band imaging. Not using a dummy read causes the first three lines of each quadrant to be slightly unstable with respect to the rest of the array on the level of 5-10 ADU's. For narrow-band imaging, this may be a significant effect. The conservative approach is to use the dummy read. This will add 5 seconds overhead to each image.

- **dither subtract on/off** This option, when turned on, will subtract the previous image from the current one and store the result in a file with a “chop” added to the normal data file name instead of the file number. The name is the same as the chop mode described above. This is often useful when dithering on a faint source that cannot be seen without subtracting the sky/array background from the image.

For experienced users: note that if you want to use auto from a script, you can specify the complete set of parameters, in the order above, as numeric arguments. Be careful not to skip any, and use 1 for on and 0 for off.

> **clear** *{[num]}* Clear (reset) array

clear resets the detector *num* times, default 1. If you have CTRL-C'd out of an integration, you should do a **clear** to reset the device and **qcdcom**. If you do not use **clear** after CTRL-C, on typing the next **go qcdcom** will assume you want to continue the previous exposure.

> **comment** *{text}* Adds a comment to the obs.log file, and to the FITS header of the image file. This is added only to the next observation header, then it is cleared.

> **et** *{seconds}* Set exposure time

et sets the exposure time. Any floating point value is accepted; the accuracy of the exposure timing is somewhat better than 0.01 second, but it is ultimately limited by the mechanics of the shutter. **et** uses Unix to compute the exposure time, and an exposure which is based on Unix timing can be interrupted. Some care is taken to make sure that the unix timed exposures are correct, but the machine running **qcdcom** is heavily loaded it is possible for the shutter to stay open slightly longer. The exposure time recorded in the header, however, will reflect the true amount of time the shutter was open.

> **filter** *{num command}* Set filter

This command selects the filter setting. If no filter setting number is given, the list of installed filters and the current setting is given. To specify a filter setting, its number is given. If it is different than the current filter setting, the wheels are moved to the new position. Note that for a filter wheel setting, both wheel positions are specified and the movements are done simultaneously. See the **fw** command description below if other filter wheel motions are required. To reinitialize the filter wheels, the command **fi home** is used. One can use **fi home1** or **fi home2** to reinitialize only one particular wheel. To use the polarizer (wheel 2 position 8) with one of the filters in wheel 1, one adds the word “pol” after the number requested, e.g. **fi 1 pol** will select filter setting 1 and the polarizer instead of the OPEN position in wheel 2. Since the polarizer is in the second wheel, it can only be used with filters that are in wheel #1 (filter settings 1-7).

The command **fi DARK** will move the filter 1/2 filter step backward between filters to aid in taking a dark frame if necessary. Note that there is now a **LOWFLUX** filter setting which should give a reasonable dark frame. The command **fi BACK** inverts the **DARK** command and restores the wheel to its previous position. Be very careful to issue **BACK** when finished taking dark frames, otherwise the filter wheel position will be lost. If this happens, more than one **DARK** or **BACK** command in a row or not in pairs are issued, or the filter wheel motion fails for any reason, issue a **filter home** command to re-calibrate the filter wheel positions. It is well worth the extra time.

- > `fw` `<wheel# position>` Set filter wheel to position

Set the specified filter wheel (1 or 2) to a specific position (1 through 8). For example, one would give the command `fw 2 3` to move filter wheel 2 to position number 3. This command is normally not used, the `fi` command (see above) is used to set the standard filter positions. However, this command could be used to set some non-standard combination of filters, such as the K filter and a narrowband filter.

- > `fn` `<fileno>` Set running file number

Qcdcom writes files of the form `filename.xxx`, where `xxx` is a file number. `fn` allows you to specify the file number. Qcdcom uses the current file number as a prompt, and automatically increments the file number as each file is written.

- > `focus` `<[number]>` Do focus image

`focus` performs a focus integration, with the number parameter being the number of focus integrations in one detector readout. The shutter is open and closed “number” times, pausing between each integration for a focus change and movement of the object.

- > `fp` `<prefix>` Set file prefix

`fp` allows you to specify what the output file name will be. Qcdcom expects to write a file of the form `prefixNNN`, where `NNN` is the frame number. `fp` is how you specify `prefix`. Note that if you want a decimal point as a separator you must specify it. Qcdcom’s default for a file prefix is `qrc..`

Example: `fp q940811.`

- > `go` `<[num]>` Start exposure

`Go` is the command to take an exposure. As described above, according to the parameters which are set, `go` may reset the chip, open the shutter and close it a predetermined time later, read out the data into memory, write the data to disk, and set the controller into idle mode. An exposure which has been started with `go` and Unix timing (`et`) can be interrupted by control-C. This will close the shutter and return you to the `qcdcom` command level. You can then alter parameters while you are in the paused mode. For example, you can change the exposure time with `et`, or the eventual output file name with `fp` or `fn`. You can set or unset automatic flags to specify what `go` will do when it finishes. If you want to continue the exposure, you can reissue a `go` command. If you want to read out the device, you can issue an `rc` command. If you want to abort the exposure, use the `clear` command. You can take multiple identical exposures with the `<num>` argument.

- > `idle` `<>` Put camera in idle mode

`idle` starts an infinite loop of resetting the detector every 5 seconds. It is a good idea to leave the system in this state when not observing, so that the detector does not saturate. If the auto idle mode is set, the camera is put into idle mode after every exposure.

- > `init` Reset all “auto” parameters to defaults

This command initializes all the program parameters to a default state that is appropriate for most observing. One can use this as an easy way to reset the program when starting out after another observer has been using Quirc.

- > `name <objname>` Set object name

name is used to set the object name which will be written to the FITS header.

- > `pupil <num command>` Set pupil position

This command sets the pupil position. If no pupil number is given, a list of available pupils are given and the current pupil position is shown. If the pupil number is different from the current, the pupil slide is moved to the new position. Note that the positions are separated by 7500 steps of the motor, so it takes many minutes to move to a new position. The pupil can be moved to the reference position by typing `pu home`.

The command `pu switch` will report on the position of the pupil/filter wheel 2 switch. The same motor controller is used for these motors, and only one can be in operation at any time, selected by the switch on the utility (black) box on the QUIRC dewar. This command tells whether it is in the PUPIL or FILTER position.

For fine adjustment of the pupil position, the commands `pu FO` and `pu BA` will move the pupil 10 or -10 steps, respectively. This can be used to move the pupil by small amounts near its nominal position.

- > `rc <[Xnx Xny]>` read array

rc reads out the array, and if the auto-write flag is set, rc will write the resulting image to a disk file.

- > `set <param> [n]` Set parameter

Certain program parameters can be set or unset with this command. To set a parameter, for example "save", one issues the command `set save`. To unset, the command `set nosave` is used. Alternatively, one can type `set save 1` and `set save 0` to turn it on or off. Below are the available parameters:

- `clobber` – If on, existing files will be automatically overwritten. If off, the program will ask for confirmation from the user before overwriting files.
- `chop` – Turns chopping on or off. Also can be set via the `auto` command.
- `beep` – Causes the program to beep after each detector readout, and other operations. Can be annoying.
- `vfout` – Directs `qcdcom` to send commands to `vf` to display the most recent image.
- `save` – Turns auto save on or off. Also can be set via the `auto` command.
- `longshut` – Sets the long shutter mode. In this mode, the shutter is opened before the initial reset of the observation is done, and keeps it open until after the final read is completed. Because of the array read time, the minimum integration time is about 11 seconds. This mode can be used if one wants to avoid the background from the warm shutter when taking exposures of faint fields. Note that if any bright objects are in the field the detector will likely saturate on those sources.

- > `shutter <(open|close)>` Commands the specified shutter action.

- > `status <>` Show status

status shows the current parameters.

- > sound $\langle \rangle$ Toggle fancy sounds

Qcdcom will use distinctive sounds for various operations. If you don't want to listen to them you can turn them off with the sound command.

- > synch $\langle \rangle$ "Ping" the DSP by sending it data and asking it to send it back. This is useful to check to see whether the controller is alive and receiving commands properly from qcdcom, or if the electronics may need a hardware reset.
- > wf $\langle [\text{file}] \rangle$ Write FITS file

Qcdcom reads out the array into memory, and maintains the image there. The wf command puts together a FITS header for the image and writes it to a disk file. If the write fails (for example because the disk is full) wf will abort, but the program will keep the data in memory and you can save your data after rectifying the problem that prevented the write.

8.3 Diagnostic commands

These commands are for diagnostic purposes only, and should not be used for normal observing. They include commands to test the data link and provide direct access to the DSP computer.

- > hall $\langle \text{nloop} \rangle$ Read Hall sensors

read the Hall effect sensors nloop times. The filter wheel 1 sensor is displayed, and depending on the position of the switch, either the pupil or filter wheel 2 sensor. This is useful when adjusting the offset level of the amplifiers between warm and cold conditions to get the sensors within the range of the A/D's.

- > diag rm $\langle \text{M:addr}[-\text{addr}] \rangle$ Read DSP mem

rm reads the P:, X:, or Y: memory of the DSP chip. All in hex (alas?).

- > diag wm $\langle \text{M:Xaddr xval} \rangle$ Write DSP mem

rm writes values to the P:, X:, or Y: memory of the DSP chip. Also in hex (also alas?).

- > diag ii $\langle \rangle$ Re-init I/O

ii reinitializes the I/O with the parallel interface and fiber-optics parallel interface electronics.

- > diag ic $\langle \rangle$ Init camera

ic instructs the DSP cpu to reload its memory from ROM. This has the effect of destroying any downloaded code and replacing it with the basic monitor program which has code for a different detector.

- > diag oc $\langle \text{cmd} \rangle$ Issue a command to the DSP interpreter

oc sends a three letter mnemonic command to the DSP cpu. Most of the useful commands are sent by various qcdcom commands automatically, but some commands can only be sent via oc.

Examples:

- oc IDL put controller in idle mode
- oc RDC perform detector read

> diag 11 {cnt {r|c} data} 4MHz loopback test mode.

Test fiber optic interface in hardware loopback mode. Receiver is wired for operation at 4MHz, and a fiber is connected directly between the receiver and transmitter. This test runs cnt loops of 65536 words each, with values 0 through 0xFFFF. If the c option is specified, then data is a value (in hex) to be sent repeatedly. If the r option is specified, then data is used as a seed for a random number generator and 65536 words of random data are sent per loop.

> diag 13 {cnt [{r|c} data]} Timing board loopback test

Loopback test with timing board in place. Must have code downloaded or be in cold reset state. Similar to L1 in other respects.

> diag 14 {cnt} data read loop test

Test interface by repeatedly performing the RDC command and looking for data. If the proper number of data words are not received, an error message is generated and the program counts the errors.

> diag 15 {cnt [{r|c} data]} Timing board loopback test: high 16

Same as L3, but tests high 16 bits of data word. Must have code downloaded that supports the THI command (e.g. quircop1.asm)

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