LOIS (VERSION 4) MANUAL FOR MAGIC

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Last revised: September 6, 2006 (S. D. Kern)

PLEASE NOTE THAT THE SCREEN SHOTS OF THE GUIs ARE OLD AND NEED TO BE UPDATED. SOME OF THE BUTTONS MENTIONED IN THE TEXT DO NOT SHOW IN THE FIGURES.

1. INTRODUCTION TO MAGIC

The Raymond and Beverly Sackler Magellan Instant Camera (MagIC) hosts a 2k x 2k SITe CCD which at the f/11 focus of Magellan has a plate scale of 0.069 arcseconds/pixel (2.36 arcminutes square). It is constantly cooled by a CryoTiger to hold a detector temperature of -120C. The camera is run using the Lowell Observatory Instrument System (LOIS) which was developed through collaboration between MIT and Lowell Observatory. The dewar is mounted to a dual filter wheel which contains 18 positions for 16 4-inch square filters which can be mounted at one time. The standard mounted filters are the Harris B, V, R, I and Sloan u',g',r',i',z' as well as a custom VR (Table 1). The full array read out in quad amp mode takes ~23 seconds. The readnoise in the four quadrants varies from about 4.5-6.2 electrons with a gain of 1.9-2.04 e-/ADU. Quad amplifier images binned 2x2 read out in ~8 seconds. Unbinned images read out of a single amplifier take ~73 seconds and binned 2x2 take ~24 seconds.

Table 1: Filters

Filter	Central λ (Å)	Passband FWHM (Å)	Throughput[a]	
			Mag for 1 e-/sec	Extinction coefficient
Harris B	4303	1045	27.13	0.21
Harris V	5430	971	27.17	0.12
Harris R	6393	1524	27.42	0.10
Harris I	8372	2102	26.79	0.04
VR[b]	6100	836		
Sloan u'	3522[c]	634[c]	25.09	0.49
Sloan g'	4803[c]	1409[c]	27.51	0.09
Sloan r'	6254[c]	1388[c]	27.44	0.16
Sloan i'	7668[c]	1535[c]	27.17	0.04
Sloan z'	9114[c]	1409[c]	26.21	0.04

[a] measurements based on engineering observations taken on 08 March 2004 are tabulated as zero point magnitudes

[b] custom filter for KBO observations, see Jewitt, D., Luu J., & Chen J. 1996 Astron. J., 112, 1225.

[c] Fukugita, M., Ichikawa, T., Gunn, J. E., Doi, M., Shimasaku, K., & Schneider, D. P. 1996, AJ, 111, 1748

2. LOIS OVERVIEW

Data acquisition for MagIC is carried out using version 4 of LOIS. LOIS-4 runs on a Sun computer, `MAGIC2`, in the equipment room. The observer logs into `MAGIC2` via telenet from one of the two observer workstations in the Clay control room – `ZORRO` or `GUANACO` – and starts LOIS. LOIS then displays a master GUI called the LOIS system console. This in turn launches subsidiary "modules" that control various aspects of the system: a telescope interface, a camera interface, an instrument interface, a display interface and a storage interface. This last GUI stores data on `MAGIC2`. There is a task that is launched from the console window that copies the data to the observer workstation, which will typically be running a data reduction and

analysis program (e.g. IRAF, IDL). Data is written to transportable media from the observer workstation for which an account is provided upon arrival.

2.1 Startup

2.1.1 Connect to MAGIC2

After logging into the observer workstation telnet to magic2.lco.cl under the observer account:

`observerworkstation%` *xhost +magic*2
`observerworkstation%` *telnet magic*2 (password will be provided by the instrument specialist)

There is disk intended only for data on `MAGIC2`, mounted as /DATA. Create a data directory on this disk with your name or that of your institution. `cd` into this directory and make a subdirectory for the night. This is temporary data storage and will be erased at the end of each night or at most at the end of the run. Data can (and should) also be written directly to the observer workstation, where they can be stored during your run. DVD drives are available on these machines to copy your data for transport home.

2.1.2 Start LOIS

First, be sure that the CCD electronics have been powered ON (the power supply is the grey box to the upper left of the camera when the system is in the standard horizontal position). The power is usually left ON. In the window from which you telneted to `MAGIC2`, type:

`observer@magic2%` *startlois.machine*

substituting the name of the observer workstation, either `ZORRO` or `GUANACO`, as appropriate. There may be some diagnostic messages indicating that old files have been cleaned up. The start script will configure the required environment variables and path names, start the default display tool (`ds9`), and start the main LOIS program.

The display tool window will appear on the screen (`ds9`) first, followed by the "`LOIS system console`" (Figure 1). The LOIS system console has two windows – a command window and a log window.

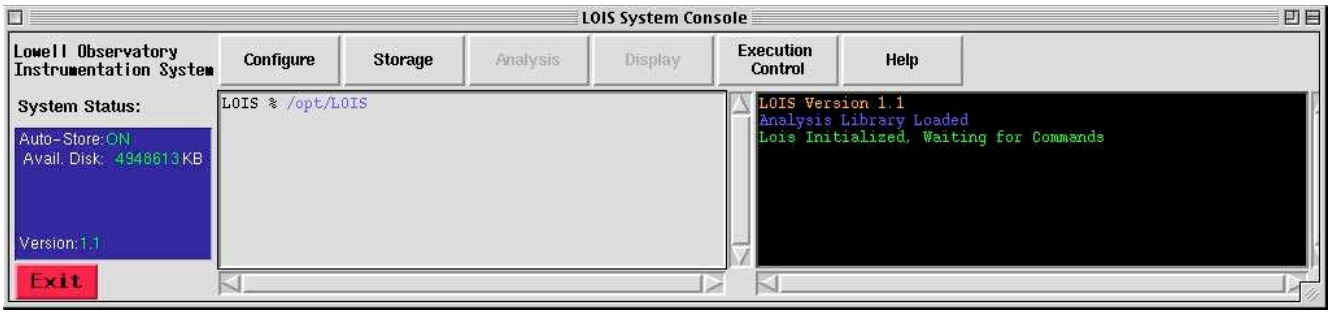


Figure 1. LOIS System Console startup screen.

2.1.3 Open subsidiary GUIs

On the "`LOIS system console`" click on the "`Configure`" button. The configuration window found in Figure 2 should be displayed.

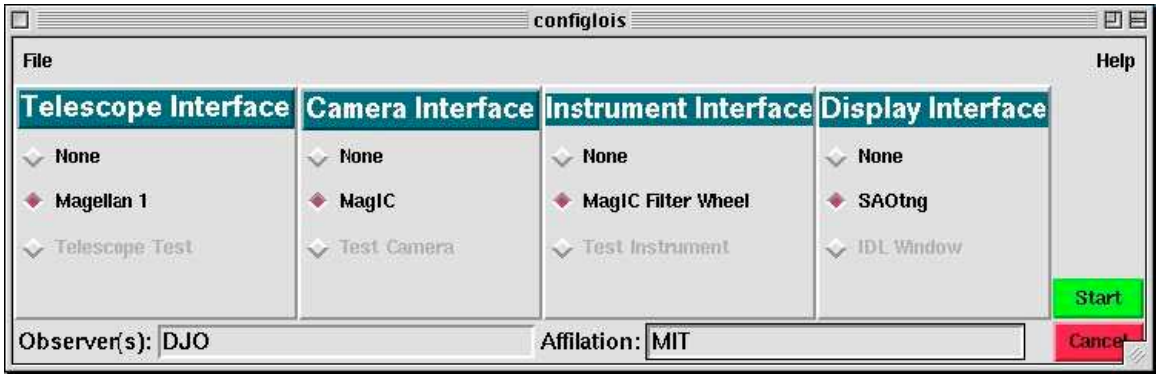


Figure 2. LOIS configuration window. Set telescope, camera, instrument and display interfaces here as well as observer information (names and affiliations).

The default configuration is for the *`Magellan 1`* telescope module, the *`MagIC`* camera module, the *`MagIC Filter Wheel`* instrument module and the *`ds9 (SAOTng)`* display interface. You have the option to disable any of these modules. After choosing your configuration, fill in the fields for `Observer` and `Affiliation` and click on "`Start`."

The camera, instrument, and telescope modules will be loaded and initialized. This process can take a few minutes, mostly for the initialization of the filter wheels. Three new GUI elements should appear; a "`Camera Control Module`", an "`Instrument Module`", and a "`Telescope Control Module`". These modules are described in the following sections. Information regarding what is being loaded and what else is occurring can be found in the LOIS Console window log screen (Figure 3)

Figure 3. LOIS System Console. The log screen on the right-hand side tells the user what the instrument is doing.

2.1.4 Set up storage on `MAGIC2`

In the "`LOIS System Console`," click the "`Storage`" button. The Storage window will display as found in Figure 4. In this window, set the pathname and file structure for the data and click on "`Apply`". Store your data on magic2.lco.cl in "`/DATA/whatever_directory_you_created`". To be sure that the storage path exists, select the path via the GUI rather than typing a pathname. If you type a path that does not exist then the storage will not properly activate. The storage path is actually written to a configuration file in the observer account on `magic2.lco.cl` at `/home/observer/.lois/storage/fits.cfg` and it is this file that will need to be edited if an incorrect path is set since the storage GUI in LOIS will not properly load with a bad default path.

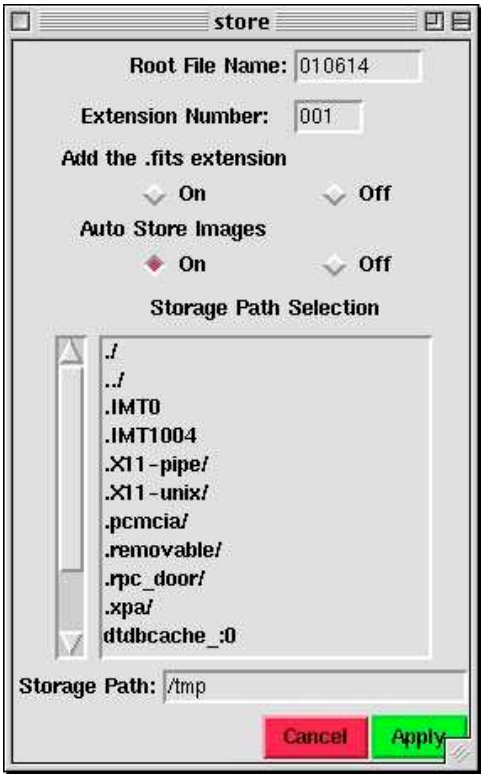


Figure 4. Storage window in LOIS. Put information here to describe the `root file name` for images, the `extension number` you want to start at, if you want to have "`.fits`" extensions on your image filenames, if you want to auto store the images and where you want to store the images to. It is important that the path where you want to store the images exists before you define it in the LOIS storage window.

2.1.5 Remote data storage

The automatic copying of data from `MAGIC2` to the observer workstation is accomplished by starting a daemon on the observer workstation that permits copying of the data and a process on `MAGIC2` that actually copies it. First, on the observer workstation (`ZORRO` or `GUANACO`), create the directory into which data will copied. Then type:

`observerworkstation%` */home/obsmag2x/magic_store.csh full_director_path_name*

where `x` will be either "`a`" or "`b`" depending upon which user account name you have been given. Then go to the `command window` within the LOIS system console and type:

LOIS% *machinename_xfer*

again substituting `ZORRO` or `GUANACO` as appropriate.

If you create new data directories on ZORRO or GUANACO for each night of your run, you must restart both magic_store from the observer workstation and the xfer process from the LOIS system console command window.

Once the proper data paths are set up, the instrument is ready for operations. All further operational details can be found in the detailed module descriptions in the following sections of this manual.

2.2 Trouble

Under ideal circumstances the system will have be started and tested ahead of your observing run by the instrument specialist and will remain ready to be powered for your run. When properly set up, the operation of MagIC under LOIS has proven quite robust.

In the case that odd error messages occur during the startup, simply exit the current LOIS session and run the start script again.

If problems persist, exit LOIS and cycle power on the CCD control electronics (a standard, off-on switch on the gray box next to the CCD control electronics) and the filter wheel (push in the large, red button on the power box to power down, then twist and pull it out to power up), then restart LOIS with the start script.

If the system is completely hung (not a likely occurrence), reboot the instrument host computer magic2.lco.cl, located downstairs (use boot -r), recycle the power on the electronics (grey power supply box) and the filter wheel (red button) and start over.

2.3 Shutdown

To shutdown the system at the end of a night, **first home the filter wheel**. Then simply hit the "Exit" button on the "LOIS Console Window". A dialog box (Figure 5) will be displayed to verify your request.

Figure 5. Dialog box confirming desire to exit LOIS.

After you exit the LOIS session, you should turn off the power to the CCD electronics (the grey box). Also, remember to remove your local copy of data from the host computer magic2.lco.cl prior to the end of your observing run. The data copy on magic2.lco.cl is intended as a temporary backup, not the primary data storage, which should be located on the observer workstation.

2.3.1 Detailed description of LOIS modules

2.4 Display Tool

`SAOimage ds9` (Figure 6) is a standard image analysis tool that is fully documented with its own help files. It is also fully integrated with the IRAF display tools installed on both of the instrument computers. All images are automatically displayed to the ds9 window. For modifying the display (for future images) the following command may be entered into the LOIS System Console command window:

`LOIS%` *: disp_set state=on min=XXX max=XXX scale=<log|linear|raw|auto>*

Images can also be displayed in `SAOimage ds9` using standard `IRAF` commands. See the weblink for "Reducing MagIC Images with IRAF" for more details.

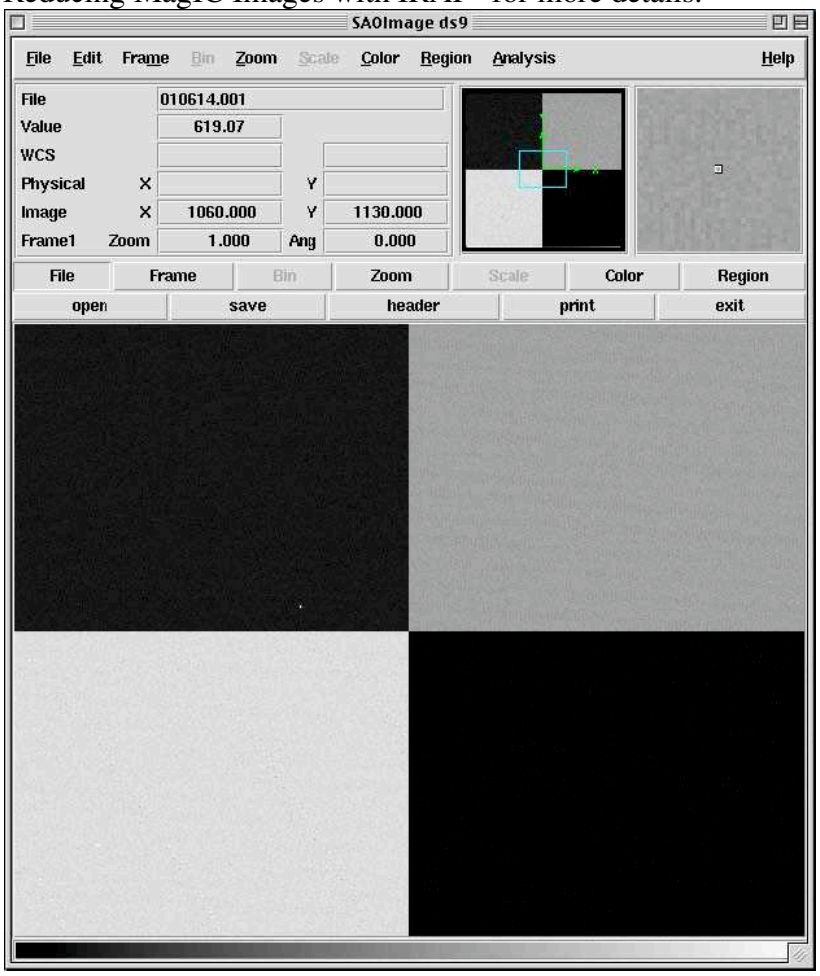


Figure 6. Sample of `SAOimage ds9` display tool for `LOIS`.

2.5 Camera Module

The Camera is controlled through the "`MagIC CCD Camera Control`" module displayed in Figure 7. This module is where the observer controls the execution of exposures using either the "`test`" or "`go`" buttons. Table 2 describes each of the inputs for this module.

Figure 7. MagIC CCD Camera Control module. This module is where the observer defines the requirements for the observations: number of exposures, exposure times, object title, type of image (object, dark, bias), binning, detector mode and comments. It is also the module from which the observer starts the camera collecting data by selecting either the "`test`" or "`go`" buttons.

Table 2: MagIC CCD Camera Control Module Inputs

Input	Description
Detector Mode	Quad-, double-, and single amp readouts with gains of 1 (approx 2e/ADU) are available.
Binning	1x1, 2x2, and 4x4.
Number of Exp	Enter the number of exposures in a sequence.
Exp Time	Enter the required exposure time in seconds.
Object Title	Enter the object title. This will be entered into the FITS header as Object.
FITS Comments	Provides two comment lines for the FITS header.
Frame Type	Selection for frame type in the FITS header - Object opens the shutter, Dark and Bias do NOT open shutter.
Test	Takes the current exposure and writes to the temporary file "test.fits". This file will be overwritten by subsequent test images (or it can be renamed and saved).
Go	Takes the current exposure (sequence) and writes the data to the configured data directory. These files will not be overwritten on the host machine even if you use the same filename.
Abort	Abort the current exposure or the current series of exposures. This does not handle aborting scripts, which must be done from the LOIS system console.

All information entered into the input fields will be mirrored to the Status window and recorded in the FITS header. After you choose either `Test` or `Go`, a "`process bar`" keeps you apprised of what the camera is doing, Figure 8. The `process bar` is blue while the camera is exposing or reading out the chip. During exposures a timer counts down the remaining exposure time and tells the user what number exposure is being collected if more than one are required.

Figure 8. MagIC CCD Camera Control status of exposure progress.

Once an exposure is complete the `process bar` says "`Reading`" (Figure 9) until the file is read out and the system is ready for the next action, at which point the bar turns green and says "`camera ready`" for the next exposure.

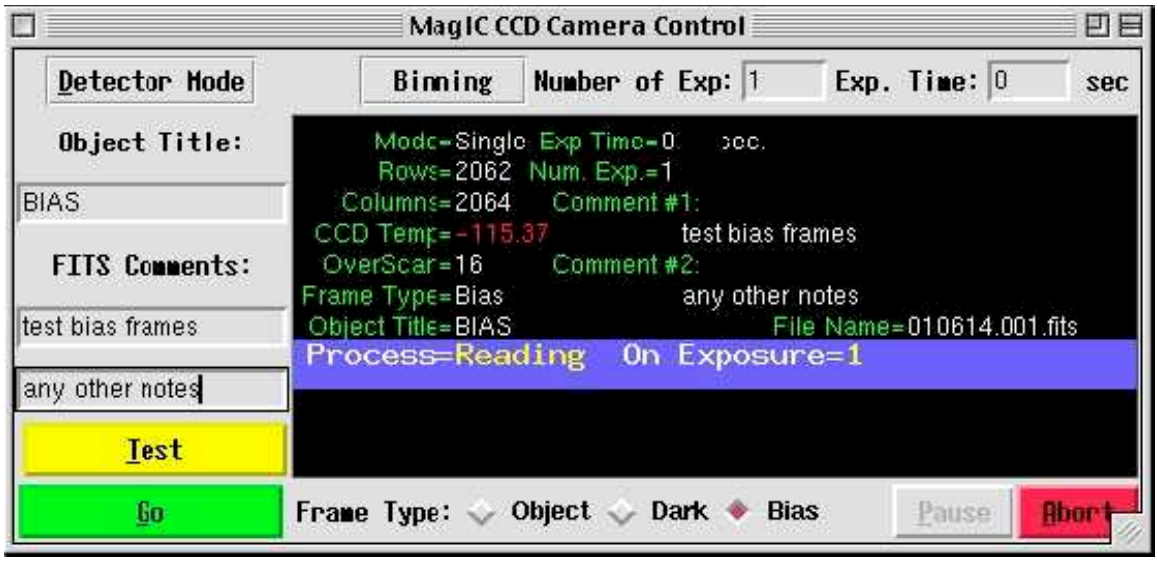


Figure 9. MagIC CCD Camera Control status of readout progress.

2.6 Instrument Module

The filter wheel is controlled through the "`MagIC Filter Wheel Control`" window. At startup, the GUI pops up, but without specifying filter names – the wheels must first be initialized. This is part of the opening procedure. Once initialization is complete the wheel positions should all have the correct filter identified or be marked as XXnone (Figure 10).

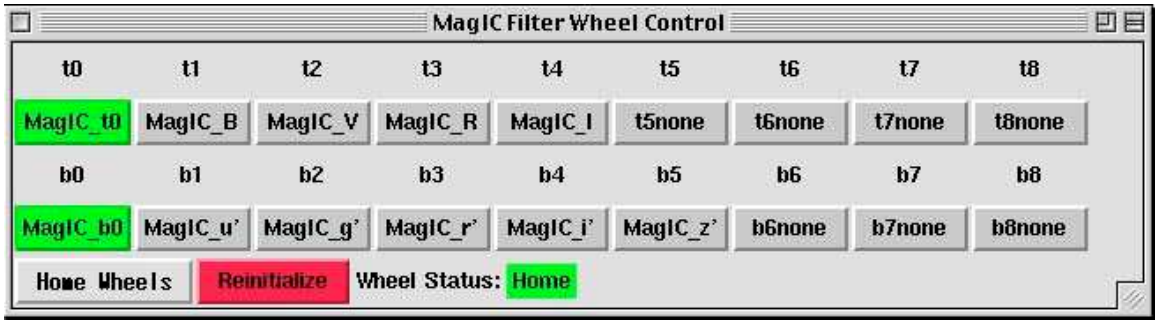


Figure 10. MagIC Filter Wheel Control, status after initialization.

To move the filter wheels, click on the desired filter name buttons. The current filter on the wheels will be lit green. If moving to another filter position, the previous filter on the wheels will be lit yellow and the chosen filter on the wheels will be lit red (Figure 11).

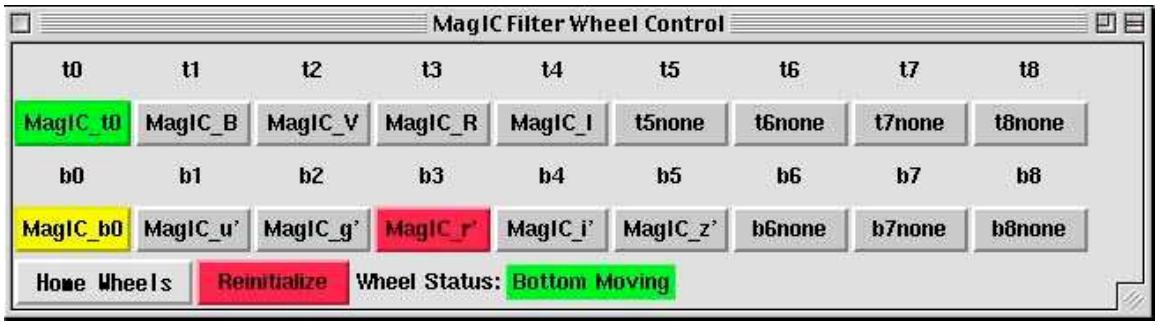


Figure 11. MagIC Filter Wheel Control, status during selection of new filter and motion of filter wheel. Yellow indicates the filter that the wheel is moving from, the red filter name indicates that is the filter the wheel is moving to.

When the filter is in position it will be lit green (Figure 12): only 2 filters should be lit green at any one time and one of those filters should be in the OPEN (`MagIC_t0` or `MagIC_b0`) position (on the LEFT side of the display). BE SURE THAT THE WHEEL NOT CONTAINING THE DESIRED FILTER IS IN THE OPEN POSITION. To home the filter wheels, click on the "`Home Wheels`" button. When the filter wheels are done moving, the home filter positions will be lit green. **Please home the filter wheels at the end of the night**.

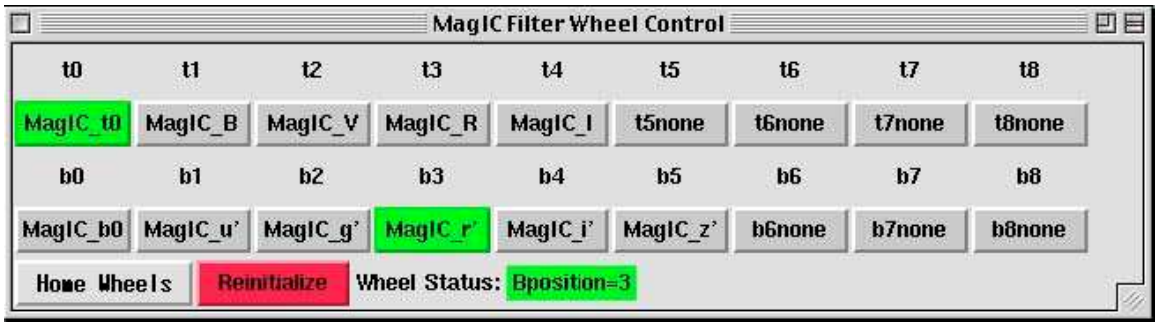


Figure 12. MagIC Filter Wheel Control, status after selection of new filter. The green filter name indicates that is the filter the wheel is on. Be sure that the wheel not containing the desired filter is in the OPEN (`MagIC_t0` or `MagIC_b0`) position.

2.7 Telescope Control System Module

The "`Magellan II Telescope Control Module`" provides a communication link to the Magellan II TCS. The "`coord move`" button opens a pop up window which is used to execute a "`coordinated offset`" – moving the telescope and moving the guiders so as to keep the guiders tracking the guide- and wavefront stars. The "`rel move`" button offsets the telescope without moving the guiders. Make sure the telescope is not guiding before using this button.

The information in the window is NOT a real time display of the TCS information. To get current information, click on the "Update" button. Whenever you take an exposure (either via `Test` or `Go`), the TCS module will automatically be updated at the beginning of the exposure and information in Table 3 will be included in the FITS header.

Table 3: FITS header information from TCS

TCS Information	Header Keyword
RA	RA
Dec	DEC
Epoch	EQUINOX
Airmass	AIRMASS
Focus	TELFOCUS
Rotator Angle	ROTANGLE

WARNING: Do not update the telescope module during an exposure or else the most recent update information will be written to the header instead of the original exposure information.

2.8 Scripts

Scripts written in Tcl can be written to take a series of exposures, changing filters and moving the telescope as needed. Scripts should be stored in the top level startup directory on `MAGIC2`,

`/home/observer.`

Scripts must first be loaded and then run, both from the LOIS system console command window. To load a procedure, in the command window type:

`LOIS%` *source script_file_name*

To run a script, in the command window type:

`LOIS%` *procedure_name*

Scripts can be aborted using the ugly red "`Abort current script`" button on the LOIS system console. Table 4 describes the command line information necessary in scripts. If a value is not specified is assumed to be zero in the case of a floating point input. For example, Using `delta_rot=0` means that the rotation does not change from whatever it was defined as, but it is not necessary to specify this in order to keep the same orientation.

Table 4: Commands for LOIS Scripts

Command	Options	DEFINITION/NOTES
`filter wheel`	`0 or 1`	Top or bottom filter wheel
`pos`	`0 - 8`	Filter position on the wheel
`go`	—	Command, starts an exposure, followed by `frame=`
`frame`	`bias, dark, object`	Type of frame
`nexp`	`float`	Number of exposures
`time`	`float`	Exposure duration (seconds)
`set_amplifier`	—	Command to set amplifiers to use, followed by `amp=`

Command	Options	DEFINITION/NOTES
amp	A,B,C,D,AB,CD,ALL	Amplifiers to use, case sensitive
offset	—	Command to set telescope offset, followed by delta_ra=<float> delta_dec=<float> ...delta_rot=<float>
delta_ra	float	Offset in ra, arcseconds
delta_dec	float	Offset in dec, arcseconds
delta_az	float	Offset in altitude
delta_el	float	Offset in elevation
delta_rot	float	Offset in rotation
delta_rot	float	Offset in rotation
timeout	int	Integer, default timeout is 90s
-noguide	-noguide	Used for a relative move [a]
epoch	float	The epoch of the coordinates that you are offsetting from and is require for an offset w/o guiders. [a]

[a] Note the -noguide and epoch are used in a relative move that is not coordinated with the guiders.

How you use the keywords defines the type of offset you want . For a coordinated RA and DEC offset with the guiders:

```
offset delta_ra=<value> delta_dec=<value>
```

With the instrument rotator:

```
offset delta_ra=<value> delta_dec=<value> delta_rot=<value>
```

Offset move in RA and DEC without the guiders:

```
offset delta_ra=<value> delta_dec=<value> epoch=<value> -noguide
```

Add the delta_rot value for to include the instrument rotator.

Offset move in azimuth and elevation:

```
offset delta_az=<value> delta_el=<value> delta_rot=<value>
```

2.8.1 Example #1: stdstar

The following script takes a set of exposures through a series of filters and exposure times. The script is defined in detail in Table 5.

```
proc stdstar {}  {
filter wheel=0 pos=0
filter wheel=1 pos=1
go frame=object nexp=2 time=5
log_3 {u filter has finished}
```

```
filter wheel=1 pos=2
go frame=object nexp=2 time=5
log_3 {g filter has finished}
filter wheel=1 pos=3
go frame=object nexp=2 time=5
log_3 {r filter has finished}
filter wheel=1 pos=4
go frame=object nexp=2 time=5
log_3 {i filter has finished}
filter wheel=1 pos=5
go frame=object nexp=2 time=5
log_3 {z filter has finished}
filter wheel=1 pos=0
filter wheel=0 pos=2
go frame=object nexp=2 time=5
log_3 {V filter has finished}
filter wheel=0 pos=3
go frame=object nexp=2 time=5
log_3 {R filter has finished}
log_3 {stdstar has finished}
}
```

Table 5: Detailed description of LOIS "stdstar" Script

Script line	Explanation of command
`proc stdstar {}  {`	Define procedure name, open script
`filter wheel=0 pos=0`	Move top filter wheel to OPEN position
`filter wheel=1 pos=1`	Move bottom filter wheel to Sloan u' filter position
`go frame=object nexp=2 time=25`	Execute an object frame: 2 exposures, 25 seconds each
`log_3 {u filter has finished}`	Write to LOIS log screen: u filter set has finished
`filter wheel=1 pos=2`	Move bottom filter wheel to Sloan g' filter position
`go frame=object nexp=2 time=10`	Execute an object frame: 2 exposures, 10 seconds each
`log_3 {g filter has finished}`	Write to the LOIS log screen: g filter set has finished
`filter wheel=1 pos=3`	Move bottom filter wheel to Sloan r' filter position
`go frame=object nexp=2 time=5`	Execute an object frame: 2 exposures, 5 seconds each
`log_3 {r filter has finished}`	Write to the LOIS log screen: r filter set has finished
`filter wheel=1 pos=4`	Move bottom filter wheel to Sloan i' filter position
`go frame=object nexp=2 time=5`	an object frame: 2 exposures, 5 seconds each
`log_3 {i filter has finished}`	Write to the LOIS log screen: i filter set has finished
`filter wheel=1 pos=5`	Move bottom filter wheel to Sloan z' filter position
`go frame=object nexp=2 time=5`	an object frame: 2 exposures, 5 seconds each
`log_3 {z filter has finished}`	Write to the LOIS log screen: z filter set has finished
`filter wheel=1 pos=0`	Move bottom filter wheel to OPEN position
`filter wheel=0 pos=2`	Move top filter wheel to V filter position
`go frame=object nexp=2 time=5`	an object frame: 2 exposures, 5 seconds each
`log_3 {V filter has finished}`	Write to the LOIS log screen: the V filter set has finished
`filter wheel=0 pos=3`	Move top filter wheel to R filter position
`go frame=object nexp=2 time=5`	an object frame: 2 exposures, 5 seconds each
`log_3 {R filter has finished}`	Write to the LOIS log screen: the R filter set has finished
`log_3 {stdstar has finished}`	Write to the LOIS log screen: the stdstar script has finished

Script line	Explanation of command
}	Close script

2.8.2 Example #2: dither

The following script sets the filter wheel, takes an exposure, executes a coordinated offset and takes another exposure.

```
proc dither {}  {
filter wheel=0 pos=0
filter wheel=1 pos=3
go frame=object nexp=1 time=60
log_3 {r filter position 1 has finished}
offset  delta_ra=-10 delta_dec=0 delta_rot=0
go frame=object nexp=1 time=60
log_3 {r filter position 2 has finished}
offset  delta_ra=0 delta_dec=-10 delta_rot=0
go frame=object nexp=1 time=60
log_3 {r filter position 3 has finished}
offset  delta_ra=10 delta_dec=0 delta_rot=0
go frame=object nexp=1 time=60
log_3 {r filter position 4 has finished}
log_3 {dither has finished}
}
```

2.8.3 Example #3: dither2filter

The following script sets the amplifier to single readout mode then sets the filter wheel, takes an exposure, executes a coordinated offset and takes another exposure, changes the filter, takes an exposure, executes a coordinated offset (back to the original position) and repeats the process 3 times.

```
proc dither2filter {{nexp 3}}  {
set_amplifier amp=D
log_3 {set amplifier to single amp D}

for {set i 0} {$i < $nexp} {incr i} {
   filter wheel=0 pos=0
   filter wheel=1 pos=3
   go frame=object nexp=1 time=60
   log_3 {r filter position 1 has finished}
   offset  delta_ra=-10 delta_dec=-10 delta_rot=0
   go frame=object nexp=1 time=60
   log_3 {r filter position 2 has finished}
   filter wheel=1 pos=4
   go frame=object nexp=1 time=60
   log_3 {i filter position 2 has finished}
   offset  delta_ra=10 delta_dec=10 delta_rot=0
```

```
   go frame=object nexp=1 time=60
   log_3 {i filter position 1 has finished}
   log_3 {dither2filter has finished}
   }
}
```

3. OPERATIONAL ISSUES

3.1 Catalog Files

At the folded port on the CLAY telescope, the rotator angle offsets (to be included in the .CAT files) for target positions are different that those adopted at the Nasmyth ports. Most observers will chose EQU mode with argument of 30 degrees. An alternative is to choose OFF mode with arguments 30 degrees south of the zenith and 210 degrees north of the zenith. Both of these align the CCD with the cardinal directions.

4. KNOWN PROBLEMS AND SHORTCOMINGS

4.1 Aborting scripts

This can be done only when neither the telescope nor the filter wheel is moving. It is safe to abort a script when the process bar on the camera module is blue, indicating that the camera is either exposing or reading out.

4.2 Phantom pixels at row 1991

When reading out in single amp mode the software inserts two bogus pixels at row 1991. The sky data is seen shifted. This can in principle be corrected in software, but in practice it lies so close to the edge of the field (4 arcseconds) that one may not want to go through the effort.

APPENDIX A – AMPLIFIER DEFINITIONS

LOIS/MagIC Information Document **Number: 001**
Title: Amplifier Definitions

Author: Brian W. Taylor
Started: 11/04/05 Last Revised: 08/31/06

Introduction

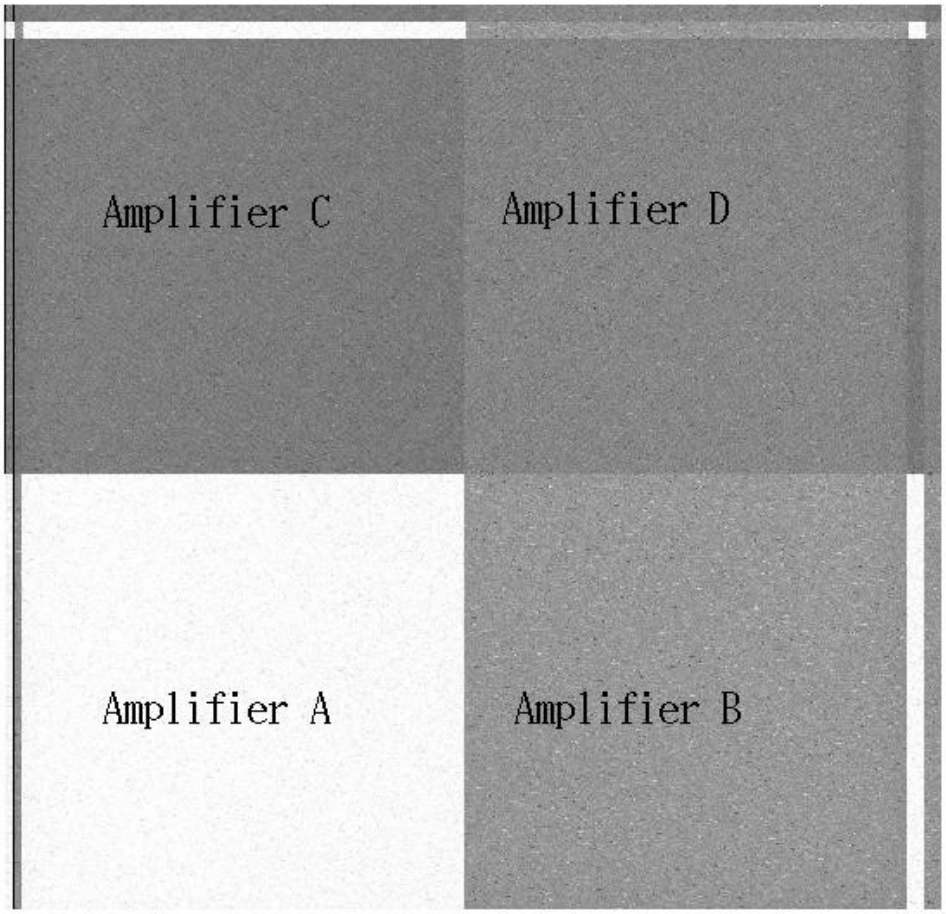
The MagIC SITe 424a CCD has four amplifiers and an image area of 2048 columns and 2049 rows. Each amplifier when used will generate 20 prescan pixels. With MagIC along with these prescan pixels there are 40 overscan columns per amplifier and 20 parallel over clocked rows in each frame.

Quad-Amplifier Frame Organization

Frame organization for the quad amp as shown in the above image demonstrates the location of each amplifier in the final deinterlace of the image and are defined as follows using the IRAF inclusive image block

[x1:x2, y1:y2] or [column 1:column 2, row 1:row2]

Prescan Amplifier A:	[1:20,1:1025]
Prescan Amplifier B:	[21:40,1:1025]
Prescan Amplifier C:	[1:20,1026:2049]
Prescan Amplifier D:	[21:40,1:2049]
Image Amplifier A:	[41:1064,1:1025]
Image Amplifier B:	[1065:2088,1:2025]
Image Amplifier C:	[41:1064,1026:2049]
Image Amplifier D:	[1065:2088,1026:2049]
Overscan Amplifier A:	[2089:2128,1:1025]
Overscan Amplifier B:	[2129:2168,1:1025]
Overscan Amplifier C:	[2089:2128,1026:2049]
Overscan Amplifier D:	[2129:2168,1026:2049]
OverClock Amplifier A:	[42:1065,2050:2088]
OverClock Amplifier B:	[1066:2089,2050:2088]
OverClock Amplifier C:	[42:1064,2090:2128]
OverClock Amplifier D:	[1065:2089,2050:2088]



Dual Amplifier Frame Organization

This reference is for the dual amp readout for Amps C and D. If switching to dual amp readout for Amps A and B, the values are the same using A for C and B for D.

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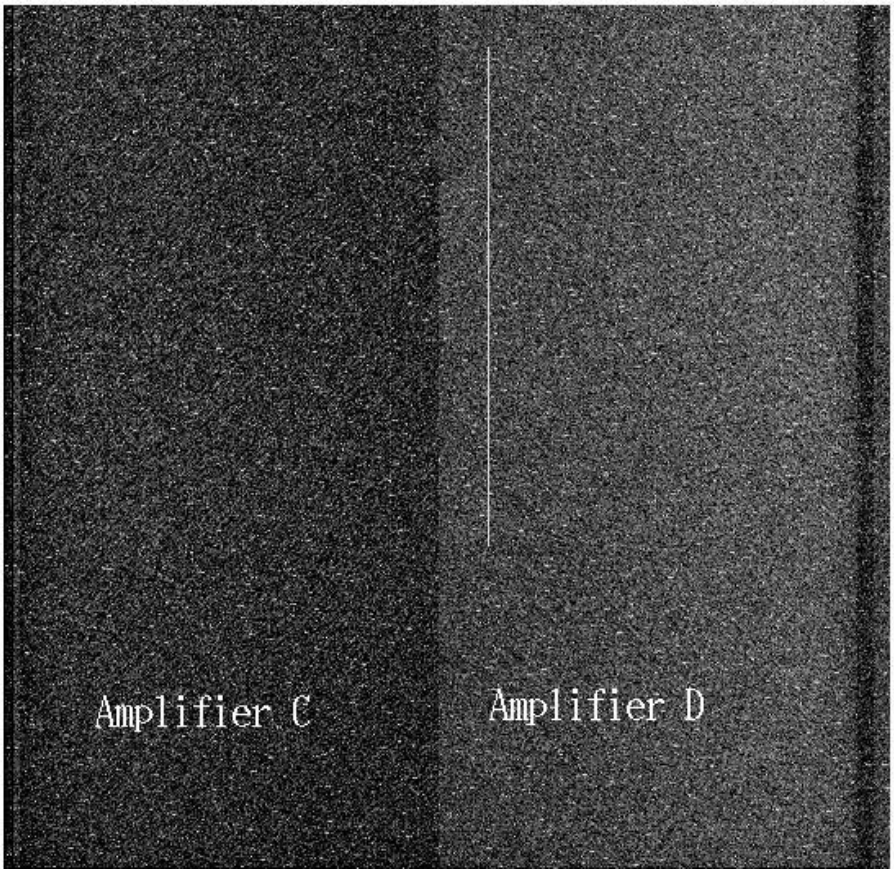
Prescan Amplifier C:       [1:21,1:2049]
Prescan Amplifier D:       [21:40,1:2049]

Image Amplifier C:         [41:1064,1:2049]
Image Amplifier D:         [1065:2088,1:2049]

Overscan Amplifier C:      [2089:2128,1026:2049]
Overscan Amplifier D:      [2129:2168,1026:2049]

OverClock Amplifier C:     [42:1064,2050:2068]
OverClock Amplifier D:     [1065:2089,2050:2068]
```


Amplifier C
Amplifier D