NMSU 1m User's Manual

Jon Holtzman

November 2008

Contents

Chapter 1

Introduction

The NMSU 1m is an F/6 alt-az Ritchey-Chretien telescope located at the Apache Point Observatory. It was constructed by the AutoScope corporation, although the company went out of business before they really completed the project.

The 1m dome is the small dome located closest to the 3.5m dome. We currently have a rotating tertiary with instruments at the two Nasmyth ports: NA1 has a 2048x2048 LN2 cooled CCD camera on a instrument derotator, while NA2 has a single-object multi-color photometer that uses a combination of PMTs and APDs as detectors, along with a aperture-viewing camera; the photometer is not on a rotator.

The 1m is normally run in robotic or remote mode. This manual describes the interactive command set used for interactive observing, and provides some notes on scripts used for robotic observing.

1.1 Instruments

As of 2008, there is a rotating tertiary that can be directed on either of the Nasmyth ports.

1.1.1 NA1

There is an imaging camera on an instrument derotator at the NA1 port. This camera uses a E2V 2048x2048 CCD that is cooled in a LN2 dewar. The electronics were supplied by Bob Leach of Astronomical Research Cameras. The pixels are 13.5 microns on a side, giving a pixel scale of approximately 0.46 arcsec/pixel.

The camera is mounted behind a guider box and filter wheel. The filter wheel holds 10 2x2 inch filters; UBVRI, ugriz, Washington CM, DDO51, and some narrow band filters belonging to Rene Walterbos are available.

The guide box has a Finger Lakes Instrumentation CM2-1 camera with an E2V 1024x1024 CCD in it. The guide camera is located on a radial stage and is pointed at a diagonal pickoff mirror that is itself located on a stage on top of the radial stage to allow independent focussing of the guider.

1.1.2 NA2

At the NA2 port, a single-object, multi-channel (UBVRI) photometer has been built at NMSU. This uses photomultiplier tubes for UB and avalanche photodiodes for VRI. Light from the telescope hits a diagonal mirror with a small hole in it that allows light into the photometer. The rest of the field is imaged using an APOGEE 7P camera which has a 512x512 SITe CCD; the pixel scale is about 1.6 arcsec per pixel. There are no filters in front of this camera. It is used for object acquisition and subsequent guiding (on a field star).

1.2 Computers

In the 1m control room at APO, there is currently one computer: command1m, a Dell 3.2 Ghz Pentium D PC, which runs the Linux operating system. command1m is the main computer used for operating the 1m. A variety of software, including IRAF, xvista, TeX/LaTeX, etc. is available. On command1m, users should use the tcomm account; for the current password, check with Jon Holtzman. The normal mode of observing is that a VNC server is run on command1m , and all of the observing programs are run out of this server. See section 2.2 for instructions on how to start/kill the VNC server and how to connect to it.

Another computer, ccd1m, is located in the computer room in the main building. This computer controls the NA1 camera via a custom card and fiber optic connection, the guide camera via a USB port (through a fiber extender to the dome), and 3 remote video Webcams (through USB ports).

1.2.1 Dome computers

In the dome, there is a rack which holds the telescope control hardware. The left side of rack holds the main power switches for the telescope/dome, the telescope motor controllers, the guider/tertiary motor controllers, and the weather station. The right rack holds two PCs which control the telescope/guider and the APOGEE photometer acquisition camera. The two PCs are:

- toccl1m: PC which handles telescope, dome, and guider control, which is called the TOCC computer. This runs DOS.
- eyeball: PC for the photometer aperture-viewing CCD. This runs Linux. When the photometer is not being used, this can be powered down to minimize heat production in the rack.

There is a single monitor and keyboard in the rack that can be used with either computer, but the cables need to be plugged into the computer you want to look at.

1.3 Emergency telescope control

There are two emergency stop buttons in the dome: one on the pier across from the door, and another small which controls the power strip at the top of the left side of the power rack. **Please identify the locations of these buttons before using the telescope.** Hitting this button will kill power to the telescope and dome motors and should immediately stop the telescope and dome. This should be done if there is ever any question about whether the telescope is moving safely, or is about to run into something or someone. If the situation requires that you hit the emergency stop button, *you must contact Jon before restoring power and using the telescope*; after hitting the stop button, the telescope will be lost and not be aware of the fact that it is lost, which can be a very dangerous situation. Hopefully, you will never need to hit this button.

Emergency stop is also available through computer control using the power program which is automatically started when the telescope control suite (tcomm) is started.

If you kill the motor power with the dome open, the dome will automatically close (so long as there is site power). Note that the software will not be aware that the dome has closed if this happens.

1.4 WARNING about manual telescope motion

Although it is possible to move the telescope manually, this should **not** be done if it can be avoided. Always move the telescope using computer control, unless instructed otherwise. The reason for this is that it is possible with an alt-az telescope to have cable wrap-up problems, which can be avoided only if the software accurately can keep track of where the telescope is. If the telescope is moved manually, the software won't know about it, and it may then command moves which will cause trouble. This is especially true for the rotator, which has no limit switches at all, and consequently its state of wrap is monitored by software only.

Chapter 2

Starting up

You should get the telescope started and initialized well before it gets dark, to make sure everything is working well. Everything can be initialized without opening the dome.

2.1 Power to the telescope

All power to the telescope components is done using software control through several network controllable power strips. These devices allows network control of 24 outlets in the dome, into which various components are plugged in. Power switches in the dome should not be used except in the case of an emergency.

You can control the network power strips using the command line program *power1m on—off device*; *power1m* by itself gives the list of device names. You can also control the power using the graphical power program, just click on the item you want to power toggle, and it will ask for a confirmation. As mentioned below, don't power the telescope computer (tocc1m) off without quitting the software first if at all possible!

2.2 Starting up the software

Everything for the 1m can be done from inside the control room (or remotely). The telescope is run from the Linux PC, command1m. The normal mode of observing is that a VNC server is run on command1m , and all of the observing programs are run out of this server. If you should need to restart the server, e.g. after a computer reboot, enter *vncserver*; if you need to kill a running server, e.g. if the window manager fails, enter *vncserver -kill :1*.

Users on any machine with a VNC client can connect to the server on command1m, and thus control the telescope. On-site, simply enter: *vncserver command1m:1*. If you are off-site, you must channel the VNC viewer through an SSH channel to be able to access the VNC server: enter *ssh -L 5909:com-*

mand1m.apo.nmsu.edu:5901 tcomm@command1m.apo.nmsu.edu to open a channeled SSH session, then from another window, enter *vncviewer :9*.

Ideally, the set of telecope programs will already be running in the VNC window. Under some conditions, however, you may need to know how to restart them.

You can start the suite of telescope control programs by entering

tcomm

in an xterm window; usually, we use an xterm in the bottom left of the screen. You can create new xterms using the icon on the control bar at the bottom of the display. When you start the telescope control programs, a variety of windows will be opened.

The tcomm script will actually start several different programs:

- command : main command window from which ALL commands should be entered.
- telescope control (port) : lower right, used to communicate with TOCC computer. This progam emulates the TOCC computer display and you can directly type in this program with results which are the same as if you were typing in the dome. Can be started with *start_port* from home directory
- CCD control (lccd) : talks with the ccd1m computer to control the science CCD. Can be started with *start_lccd* from home directory
- FLI control (fccd) : talks with the ccd1m computer to control the guider CCD. Can be started with *start_fccd* from home directory
- APOGEE control (accd) : talks with the eyeball computer to control the guider CCD. Can be started with *start_accd* from home directoy
- status : upper right, reports telescope and CCD status information to user. Can be started with *start_status*
- power : upper panel of screen, shows power status and can be used to emergency stop the telescope, and toggle individual powers (which should not be necessary, as these can also be controlled through the command window). Can be started independently using command *power*
- rvideo : remote video, for use during telescope initialization to watch the telescope. Can be started with *start_rvideo*
- alive (runs in background): network aliveness program, sends a signal every 30 seconds from local computer to APO; if telescope control program doesn't see this signal for 5 consecutive minutes, the dome is closed and tracking turned off
- shutter35m: monitors status of 3.5m shutter, temperature in rack, etc.

In the future, the port, ccd, and spec programs may come up in an iconified state, as they are really only necessary for engineering work - you should not need to ever type anything in these windows.

When you start tcomm, the command program should automatically check to see whether various devices (telescope control program, telescope and dome motors, science CCD, and guider CCD) are powered up and responding. If they are, the program will proceed without requesting any input. If not, the program will ask if you wish to power various devices up.

Once the powers are checked, you will be prompted to initialize the telescope and dome if they have not already been initialized - see below for more details on this. After this, there will be question about which port you are observing on (NA1 or NA2), which sets the camera to which commands will be directed (this can be changed later during a command session as well). After the startup questions, you will get a Command: prompt and the program is ready to accept normal commands.

For reasons having to do with the automatic filling of the LN2 dewar for the NA1 camera, the command program should be left running at all times. For completeness, the command to gracefully quit the program is *QU*.

If there is a commanding problem, i.e. program lost or hung or in infinite waiting loop, you should be able to kill the programs by hitting a CTRL-
in the command window. If any of the other windows fail to disappear with this, they can be killed individually.

!To quit from the program, you enter the QU command. When this is entered, !the program will ask you if you wish to quit the telescope control program !running in the dome. In general, we leave the telescope control program !running. It is very important, however, that you do not kill the power to the !telescope control program in the dome without exiting it gracefully. !Note that the telescope control program which runs in the dome !needs to be exited gracefully !(i.e., commanded to exit) because the program writes out the current !rotator position which is essential to record to prevent cable wrapups. !Because of this, make sure NOT to turn off the computer power via the !network power switch without gracefully exiting the telescope control !software first!

2.3 Remote video cameras

There are three webcams in the 1m dome: one located along the “tube” of telescope, one looking at the NA1 port, and another mounted on the azimuth disk looking at the inside of the dome in the direction that the telescope is pointing: all three rotate along with the telescope.

All three cameras are controlled by a single program (rvideo, running on ccd1m) that can be started with the *start_rvideo* command. This opens a video window that shows the image from one camera. You can switch between cameras by clicking on the buttons in the lower right of the video window. Hitting ’s’ in the video window will take a snapshot, hitting ’u’ will toggle update mode (continuous shots) on and off. ’r’ redisplays the current image.

You can turn on lights in the dome using the graphical power program (Webcam lights) or on a command line with *power1m on lights*. Be aware that turning on the lights with the dome or louvers open can impact observations at the 3.5m and/or the 2.5m! The lights are automatically turned off once per hour.

2.4 Initializing the telescope

When the computers are powered up, the telescope and CCD programs go through some initialization commands. For the CCDs, no user input is required - you will see a series of commands come up automatically in the CCD control windows. For the telescope, some interaction is required which needs user input either from the command window or from the TOCC computer in the dome. During initialization it is important to watch the rotator to make sure that cables do not wrap - as a result, initialization should either be done in the dome, or, if operating remotely, using a video camera view of the rotator.

After the TOCC computer is booted up, you will see on the screen (both in the dome and in the telescope control window) the following question:

> Do you wish to initialize the telescope with a :
> I: normal init (uses stored coords to find home positions - will be very
> slow if stored coords are wrong)
> F: full init - finds home positions without any previous knowledge (but note, telescope must be CCW of azimuth limit, and rotator position must have been previously stored correctly!
> M: manual init - prompts for approximate current telescope position, then finds home position via full init. Use if reported rotator position does not match observed position
> Q: very quick init (stored coords - assumes telescope hasn't been moved!)
> S: skip initialization
> Enter your choice:

If the telescope has not been moved by hand, you should be able to do a normal init (I): this will use the saved positions to move to the home switches, and then reinitialize on the home switches. If the telescope has been moved manually, you will need to do a full init (F), which will move the telescope in azimuth clockwise until it hits a limit switch, and in altitude upward until it hits a limits switch, then uses these positions to go back and find the home switches. NOTE, however, that there is no limit switch for the rotator, so if the rotator is lost, doing a full init can lead to cable wrap and DAMAGE, so this must be done with extreme caution, and looking with the remote video at the rotator. If it appears that the cables leading to the rotator are wrapping, hit the emergency stop button (on upper part of left panel in dome), or, if running remotely, by clicking the mouse in the red Emergency Stop section of the power program at the top of the screen. If this happens, you should check with Jon before restarting anything.

You will not be able to move the telescope until it is initialized.

Next the program will ask:

Do you wish to initialize the dome (Y or N)?

Enter Y. The dome will spin around until it finds its home sensor. Very rarely, this fails; if it fails, the countdown on the screen will expire without the home position being found. If it fails, this is not a disaster as you can command a dome initialization from the command prompt later on with the DI command - you will need to remember to do this!

Next the program will ask:

Do you wish to slave the dome (Y or N)?

Enter Y. When the dome is slaved, it should automatically rotate so that the slit is oriented in front of wherever the telescope is pointed.

Finally, it will ask you which camera/Nasmyth port you will be using. This can be changed later with the LEACH/APOGEE and INST commands.

A list of available commands can be viewed at any time using the HP (Help) command.

2.5 Weather and telescope safety

You are fully responsible for the safety of the telescope in terms of its exposure to weather. You should **not** open the dome or the louvers if there is any chance that weather will damage any of the contents in the dome. It is important that you must consider not only clouds and the possibility of rain, but also the humidity and the dust conditions.

Our normal mode of operation is to automatically follow the judgement of the 3.5m telescope. The 3.5m broadcasts its dome status every minute or so. If the 1m receives a "3.5m is closed" message, or if it does not receive a "3.5m is open" message, the dome should automatically close and the telescope should stow. Clearly, it is good to confirm that this actually happens if possible!

It is possible, but **highly discouraged** to turn off the slaving to the 3.5m dome status; this might be done, for example, to allow the telescope to be moved during the day without continually stowing itself. Slaving is turned off using the *-35m* command, and can be turned back on using *+35m*. If you turn slaving off, you will need to enter *clear* to clear the shutdown flags before you will be able to move, etc.

You can monitor the APO 10-micron all sky image at:

http://irsc.apo.nmsu.edu/tonight

The main APO weather page is at:

http://weather.apo.nmsu.edu

2.6 Controlling the CCD temperature

2.6.1 NA2 (Leach) camera

The NA2 camera (Leach camera) has a E2V 2048x2048 CCD that is cooled using liquid nitrogen (LN2). Because the dewar has a vacuum to insulate it, it is important that all efforts be made to keep the camera cold continuously; thermally cycling the camera can lead to degradation of the vacuum and contamination on the chip.

The dewar for the science CCD needs to be filled with LN2 to keep the chip cold. We have a remotely operable filling system which can be commanded to fill the dewar. This can be done by simply typing FILL. If the telescope is initialized, The FILL command will move the telescope to the stow position, open the valve from the filling dewar, and then suspend things for the default fill time (currently 6 minutes); you can specify any desired fill time using *FILL t*, where t is the requested time in minutes. The fill system turns off by timing only; the power to the autofill system is turned off after the requested time. There is NO sensor that actually checks to see if the dewar has actually filled, so if there is some pressure problem, the possibility exists that the dewar will not have been filled. As a result, it is good to monitor the actual temperature.

Note that the valve for the fill system is controlled through the telescope control hardware, so motor power must be on, and the telescope computer running, for the FILL command to actually do anything!!

The current hold time for a full dewar is approximately 13 hours. It takes about 1.5 hours to cool the chip down completely if it starts out at room temperature. In general, it should be possible to fill the dewar just before starting observing and have it stay cold for the entire night.

The normal operating temperature is -125 C; this is controlled by a regulated heater inside the dewar. Sometimes the chip is kept at -130C during the day, just to conserve a bit of LN2.

Apart from manual fills, the CCD software will attempt to do autofills of the dewar when it detects that it has started to warm up. Autofills are triggered when the CCD reaches a temperature warmer than -110 C. If this occurs, the telescope will move to the stow position (if it has been initialized), and do a fill. If the motor power is off when the autofill is triggered (as it should be during the day), the software will automatically turn it on for the duration of the fill, then turn it off afterward; if the motor power is on at the trigger, it will remain on afterwards.

2.6.2 NA1 (Apogee) camera

The NA1 acquisition camera is an APOGEE AP7P with a 512x512 CCD. This is cooled thermoelectrically, and temperature cycling is not so much of an issue.

The thermoelectic cooler can cool the chip to about 50 degrees C below the ambient temperature in the dome. The dark current is a strong function of temperature, so it is desirable to operate as cold as possible. During the summer, you may not be able to get the CCD colder than -30 to -35 C, while during the winter, you might get to -50 or -55 C. If you will be doing dark current subtraction, you will want to get both science and dark frames at the same temperature. Unfortunately since the ambient temperature changes throughout the night, you may not be able to reach the coldest temperatures at the beginning of the night, and you will have to decide whether you want to change the temperature in the middle of your observing.

Chapter 3

Operating the telescope

3.1 The status window/display

The upper section of the status window gives information about the telescope/dome systems. The left column gives the current RA, DEC, hour angle of the telescope, coordinate epoch, and position angle. The next column gives the azimuth, altitude, rotator, focus positions for each of the three focus motors, and tertiary port. The rightmost column gives the current UT, local sidereal time, airmass, and the focus position in a coordinate system which gives mean focus, xtilt, and ytilt.

Other entries give the dome position and status (initialized/unitialized, slaved/not slaved, open/closed), and mirror cover status (open/closed).

If *any* of the items appear in reverse video, there is likely to be something configured such that you will have significant problems with your observations (e.g., the dome is closed!). Note that no mirror covers are currently installed, so the status of these can be ignored.

The telescope positions are not absolutely encoded, so the status only reports where the computer *thinks* the item is, which is not necessarily where it *really* is, although if things are working well, the computer should correctly know where things are. However, if something seems peculiar, it is important to check with the remote video cameras and/or by going out and looking at the telescope/dome!

If you hit a key in the status window, it will toggle into engineering mode, where some additional information is displayed, and where a graphical window will come up which shows a running plot of the current encoder positions relative to the desired positions. If you accidentally do this, you can minimize the plot window, and switch back to normal mode by hitting a key again in the status window.

3.2 The command window

All commands should be entered in the command window. For all commands, you will not get a command prompt until the previous command completes.

The software allows you to write simple scripts in an external file which can be read in by the program to issue a series of commands automatically. Input script files should have commands which are identical to what you would need to type in the command window. To execute a script, you use the command:

INPUT filename

where filename is the name of the file with the commands to execute. Our convention is to use .inp as the extension for script files. A script can call another script, up to 5 layers deep.

3.2.1 Restarting tcomm

If for some reason things appear to hang up (i.e., nothing returns for several minutes after you'd really expect it to, you can restart the tcomm programs after issuing a CTRL-\ in the command window. This should kill all of the windows, and then retyping tcomm should start everything up again. However, if this is necessary, please inform Jon of the circumstances - we would really like to get things working without ANY hangups.

3.3 Dome commands

OD

The OD command will open the upper dome slit. It will prompt for a confirmation before opening.

CD

The CD command will close the upper dome slit.

OLD

OLD will open the lower dome slit. **The upper dome slit must be opened first, since it has a lip over the lower dome slit**. Normally, we *do not open* the lower dome slit unless we are doing absolute (all-sky) photometry; the reason for this is that the lower dome slit is not on a hardware watchdog circuit, so in case of a failure, it will likely not get closed.

CLD

OLD will close the lower dome slit. **The lower dome slit must be closed before the upper dome slit is closed.**

ODS

ODS will open both upper and lower dome slits in conjunction. However, normally we *do not open* the lower dome slit unless we are doing absolute (all-sky) photometry; the reason for this is that the lower dome slit is not on a hardware watchdog circuit, so in case of a failure, it will likely not get closed.

CDS

CDS will open both upper and lower dome slits in conjunction.

DS (or DM)

DS toggles dome slaving on/off, i.e. the tracking of the dome position to the telescope azimuth position.

DA (or DOMEAZ or XDOME) azpos

DA will move the dome to the requested azimuth position (0 degrees is N, and az increases towards the east). DA will turn off dome slaving automatically (otherwise the dome would just rotate back to where the telescope is pointed!).

3.4 Telescope commands

3.4.1 Moving the telescope

The following commands can be used to move the telescope:

CO [*hh mm ss dd mm ss*]

The CO command will move the telescope to some user-specified coordinates. If you do not specify a position on the command line, the program will prompt for an RA and DEC, and then ask you to confirm the move. The coordinates will be interpreted using the current epoch, which defaults to 1950 (the default epoch can be changed using the NE command which will prompt you for a new epoch). Format is hh mm ss, separated by spaces (you can omit the mm or ss if they are zero).

SA

Move the telescope to an SAO star. The program will ask whether you want an SAO near near the current telescope position (T), near some other specified RA/DEC (O), or some specified ALT/AZ (A). If you choose one of the latter two options, you will be prompted for coordinates. You will then be prompted for an acceptable magnitude range for the SAO star (<CR> to allow any brightness). Note that the on-line SAO catalog only contains stars down to 7th magnitude and does not have fainter catalog members at this time. The program will find the nearest SAO star to your coordinates, and ask if you want to move there; enter Y to move.

SAFOC

Same as SA, but for a SAO catalog sample that contains only fainter stars with $V > 9$.

ALTAZ

Move the telescope to specified azimuth and altitude.

RF [*id*]

Move the telescope to the position of star *id* in an open user coordinate file (see section ??). If not specified on the command line, *id* will be prompted for.

PM

Recalls the last 5 previously commanded moves and allows you to select one to move back to.

QM [$\Delta\alpha\Delta\delta$]

Offset the coordinate by $\Delta\alpha$ arcseconds in right ascension and $\Delta\delta$ arcseconds in declination. If not specified on the command line, the offsets will be prompted for.

OFFSET [$\Delta x\Delta y$]

Offsets the telescope by Δx *pixels* along rows and Δy pixels along columns of the CCD. If not specified on the command line, the offsets will be prompted for. These allow "instrument plane" offsets, i.e., in the coordinate system of the CCD even if the instrument is rotated with N no longer oriented along columns. Unlike the 3.5m, the instrument plane offsets are specified in pixels, not arcseconds. The offset is for the *telescope*, so stars will move by $(-\Delta x, -\Delta y)$.

CENTER

Move the telescope such that a marked location on the CCD frame will be moved to the center of the CCD frame. This requires that an image has already been obtained. If you use this command, you will be prompted to mark the location of an object in the CCD frame; use C to centroid on the position of the cursor, or I to just take the integer pixel location of the cursor.

LOCATE

Move the telescope such that a marked location on the CCD frame will be moved to any another desired location. Again, this requires that an image has already been obtained. If you use this command, you will be prompted to mark the location of an object in the CCD frame, then prompted to mark a second position to which the object will be moved. Mark these positions using C to centroid at the location of the cursor, or I to use the integer pixel location of the cursor.

PA

Change the position angle to the specified PA. The position angle is measured from north to vertical on the chip when the image is displayed in sky orientation (for the PI CCD, this is (1,1) in the upper left).

INIT

Go through startup sequence that is run when starting tcomm, i.e. telescope initialization, dome initialization, and louver query.

3.4.2 User catalogs

Users can create catalogs of object positions which can be referenced by an ID number to maximize efficiency and minimize input error during the night. The format of the user catalogs is identical to that used by REMARK on the 3.5m. Each object should be put on a separate line with the following format:

> object name <TAB> RA (hh:mm:ss) <TAB> DEC (dd:mm:ss) <TAB> epoch <TAB> (proper motion in RA) <TAB>(proper motion in DEC)

The following commands can then be used with these files:

OF

Open a new input file. The file name will be prompted for.

RF [*id*]

Move to object *id*. If no *id* is given, it will be prompted for

3.4.3 Coordinate epoch and update commands

The default coordinate epoch on startup in 1950. The default epoch for coordinate entry can be changed using:

NE

Change the input epoch to a new value. The program will give the current epoch, and prompt for a new value. Note that the epoch on the display will not change until you move to an object using the new epoch.

UC

Update coordinates, i.e. set the current position of the telescope. With the command, the telescope will display a list of the last 5 commanded positions; you enter the index of the object that the telescope is currently pointed at, and the positions of the azimuth and altitude axes will be adjusted. The normal mode of operation is to slew to an SAO star (SA command), take an exposure (EXP or QCK), center star (CENTER), then update coordinates (UC).

3.4.4 Focus commands

The telescope can be focussed by moving the position of the secondary. The secondary position is controlled by three separate motors, so the mirror can be tilted as well as pistoned. Tilting the mirrors changes the collimation and thus is not a motion which should normally be done! All focus positions are negative: (0,0,0) is when the secondary is at the home position, farthest from the primary.

Note that the focus is a function of temperature, since the telescope structure expands/contracts as a function of temperature. As the temperature increases, the focus decreases, i.e. goes more negative.

The focus commands are:

FOCRUN

Take a series of exposures at different focus values. You will be prompted for a starting focus value, a delta focus (amount to change focus between each exposure), a number of exposures, and an exposure time. After entering these, the program will automatically take the requested number of exposures. The program will always approach a given focus value from the same direction, *assuming you specify a positive delta focus value.* When using FOCRUN, the CCD will automatically switch into a "fast" readout mode (which still isn't that fast!) which has increased readout noise; when done, the CCD will be switched back into the normal readout mode.

FO f

Move the focus to position f. This command will automatically approach the desired position from the same direction.

DF Δf

Moves the focus by a relative amount, Δf. If not specified on the command line, the amount to move will be prompted for

XTILT *tilt* (ENGINEERING)

YTILT *tilt* (ENGINEERING)

Tilt the secondary mirror to the specified angle.

SHO (ENGINEERING)

Move the secondary to the home position (i.e. farthest from primary).

3.5 Camera programs

All camera commands are normally entered in the command window, but these are passed to the appropriate camera control program, which are usually run from separate windows on the right part of the desktop.

After images are taken, they are normally written out to disk in FITS format. The images go into directory *images/yymmdd* under the tcomm home directory, where *yymmdd* refers to the current UT date. The default filenames are *yymmdd.index.fits* where *index* is a running index number: both the root filename and the index number can be changed, see below.

3.5.1 The image display window

The first time an image is taken, each camera program opens an Image Display window on the console; each subsequent image will be displayed in this window. Once an image has been displayed, some interactive commands are available in the display window, provided that a wait for input or any other I/O is not pending. To interact with the image, simply move the mouse onto the display window. The current pixel location of the cursor will be displayed in a frame at the base of the image display along with the pixel intensity. The arrow keys are used for fine control (one pixel at a time) of the cursor position. Note that, to maintain a small window, the image as originally displayed will likely only show every other, or even every 4th pixel (depending on the detector)

The following mouse buttons and keyboard keys are active while the mouse is located on the image display:

Mouse Buttons

Button	Function
LEFT	ZOOM IN, centered on the cursor
MIDDLE	ZOOM OUT, centered on the cursor
RIGHT	PAN, move the pixel under the cursor to the center

Keyboard Commands

Key	Function
R	RESTORE image to the original zoom/pan
+	BLINK Forwards through the last 4 images.
-	BLINK Backwards through the last 4 images.
P	Find the PEAK pixel near the cursor & jump the cursor there
V	Find the LOWEST pixel ("Valley") near the cursor & jump the cursor there
#	"Power Zoom" zoom at the cursor to the maximum zoom factor
H	Toggle between small and full-screen cross-hairs
]	Clear boxes and stuff off the image display

Color Bar Adjustment:

If you place the mouse on the color bar, these commands are available to adjust the contrast of the image:

LOW CONTRAST	Hold down the LEFT Mouse button, drag the left end of the color bar.
HIGH CONTRAST	Hold down the RIGHT Mouse button, drag the right end of the color bar.
ROLL COLOR MAP	Hold the MIDDLE Mouse button, "roll" the color bar left or right.

The position of the mouse cursor displays the range of intensities represented by that color.

Pressing the R key while the mouse is on the color bar restores the original color map (undoing any change of the contrast or "roll" changes made with the mouse buttons).

Note that you can also redisplay the current image with a different stretch using the SCALE command, see below.

3.5.2 Camera Commands

The following commands are available:

EXP [*time*]

Take an exposure of length *time* seconds.

QCK [*time*]

Same as EXP, but filename index exposure is **not** incremented, so next image will overwrite current one, i.e., exposure will not be permanently saved.

SETFILT [*name*]

Change the filter wheel to filter *name*. You must supply a name which matches that in the current filter table. For a list of available filters, use SETFILT without any arguments. SETFILT allows you to operate without knowing the details of which filter is located in which slot. SETFILT will also adjust the telescope focus for the relative focus difference between the filters (the filter specific offset is shown in parentheses in the status window).

FILTINIT

Initializes the filter wheel if it has gotten lost.

FILENAME [*name*]

Change the default root file name for output images to *name*.

NEWEXT [*ext*]

Change the extension for the next filename to be the number *ext*.

FITS

Set filetype for future image stores to be FITS.

-DISK/+DISK

Turn off/on autosaving of images.

+DISPLAY/-DISPLAY

Turn on/off autodisplay of images after they are taken.

SCALE *low high*

Redisplay the current image with greyscale scaling between *low* and *high*.

SKYSCALE

Sets mode for autoscaling to have black level somewhat below mean level in image, and white level above it. This is the default.

FULLSCALE

Sets mode for autoscaling of images to be from minimum pixel (black) to maximum pixel (white).

SAMESCALE

Sets mode for autoscaling of images to be identical to the current scale.

WINDOW [xs xe ys ye] or [FULL]

Sets CCD windowing. If 4 coordinates are given, CCD will be set to window to requested region. If FULL is specified, windowing will be set back to full chip mode. If nothing is specified, user will be prompted to mark two opposite corners on the current image display to define the window region. In all cases, the final requested window position will be displayed on the current image.

FLAT *ndesired nmax startexp fudge*

Takes a series of flat fields, adjusting exposures times to maintain good S/N, for use in taking twilight flats. A "good" flat is defined as one with a mean level (over bias) of somewhere between 5000 and 20000 DN, with a minimum exposure time of 1 second. The routine will start out by taking an exposure of length *startexp*. From this, it will compute a new exposure time which is required to obtain a mean of 10000, after multiplying by the fudge factor *fudge*, which accounts for the changing brightness of the twlight sky (*fudge* should be ~ 1.5 for evening twilight and arounge ~ 0.7 for morning twilight. In no case will the program let the exposure time be longer than 30 seconds, and any 30 second flat will be counted as a "good" flat to prevent a large number of unsuccessful flats being taken when it is too dark. The program will continue taking flats until it gets *ndesired* "good" flats or until it has taken "nmax" flats.

SETTEMP *temp* Set the desired CCD temperature (degrees C). See discussion in previous section.

3.5.3 Standard star observations

Several commands are available to increase your efficiency in observing standard stars. There is a full catalog of all of the Landolt standards, plus several others, in the top level observe directory, with filename standards.apo. To allow use of this catalog in conjuction with your own catalog of objects, there are separate commands to open and read from the standards file, so you can have both the standards file and a user file open simultaneously. The standards file also includes the UBVRI magnitudes of the stars, and the observing program knows about the throughput of the 1m telescope, so the program is also capable of choosing reasonable exposure times for you.

The relevant commands are:

OS

> Open the standards file (analagous to OF for user files). If you are running in a subdirectory under the top level observe login directory, you will enter: ../standards.apo

RS [*id*]

> Move to standard *id*. If no *id* is given, it will be prompted for.

STAN [*filtname*]

> Take an exposure of the current standard through filter *filtname*. You must have already moved to the star using the RS command. The program will move the filter automatically and will take an exposure based on the known magnitude of the star and the throughput of the system.

FUDGE [*fudge*]

> Sets a fudge factor for the automatic expossure time calculation of the STAN commands. All standard star exposure times will be multiplied by the fudge factor specified.

3.6 Guiding commands

The current guider CCD is a camera purchased from Finger Lakes Instrumentation; it uses a E2V 1024×1024 CCD with 13.5μ pixels.

In general, you can issue the same commands to the guider CCD as you can to the science CCD. To do so, use the same command names but preceeded by the letter "G", e.g., GEXP t will take a guider exposure of length t seconds.

Since our telescope is a three-axis telescope (alt-az-rot) and a single guide star only contains two positions (x-y), the absolute quality of the guiding depends on an accurate pointing model (although less so than if there were no guider at all!). We use the guider observations to update altitude and azimuth, and assume that the rotator angle is correct. Since the guider is located off axis, errors in the rotator angle will manifest themselves as small arcs of stars in the science camera, centered around the position of the guide camera (which is off of the chip).

To start guiding, first take a guider exposure to see if there is an acceptable guide star and to determine a good exposure time. Ideally, you will have a star which has good S/N with an exposure time of less than or approximately equal to 1 second. Once you have a picture taken with a good exposure time, you can start guiding by issuing the GUIDE command. This will take a picture with your exposure time, ask you to mark the guide star in the guide CCD image, and will then start autoguiding on this star.

If your original image was taken in full frame mode (WINDOW FULL), then all guiding images will be done with a small subframe around the guide star. If your original image was taken in windowed mode, then all guiding images will be taken with the same windowing.

Guiding will continue until you do a slew with the telescope or unless you issue a GUIDEOFF command.

Other commands relevant to guiding:

GUPDATE *n*

> Sets the number of guide exposures to average centroids from before sending a position update command to the telescope. Default is 5.

GSIZE *n*

> Sets the size of the box used for computing centroids. Default is 11 pixels.

NOSHUTTER

> Puts guider in NOSHUTTER mode where exposures are taken without using the shutter. You must remember to issue the OPEN command to open the shutter before starting to guide!

SHUTTER

> Puts guider into normal SHUTTER mode.

OPEN

> Opens the guider shutter.

CLOSE

> Closes the guider shutter.

WRITE

> Toggles mode where each individual guide exposure is saved to disk. Default is *not* to save each image. Currently, this command must be issued from the guider CCD control window (not the command window).

GUIDEFOC

GUIDEADJ

GUIDEMOVE

GUIDEINIT

> Initializes the guider stages by moving them to their home positions. Users should **not** issue this command without being instructed to do so!

Chapter 4

Shutting down

To close the telescope down, you need to move the telescope to its stow position, close the dome, and turn off motor power. In general, you should NOT quit the command program or the telescope control program!

The following commands are used:

ST

Stows the telescope in the default stow position.

CD

Closes the dome.

CL

Closes the louvers. Make sure that dome fans are off first (*power1m off domefan*)!

Appendix A

Command summary

- ALTAZ — Move the telescope to a specified alt/az position
- CD — **C**lose the **D**ome slit.
- CENTER — move the telescope to **CENTER** on an object in an image based on the current image display.
- CF — **C**lose the command **F**ile.
- CL — **C**lose the **L**ouvers - the large vents at the floor of the dome.
- CLOSE — **CLOSE**s the guide shutter.
- CO — move the telescope to the **CO**ordinates given as hh mm ss dd mm ss.
- DI — **D**ome **I**nitialization command.
- -DISK/+DISK — turn off/on autosaving of images to **DISK**.
- -DISPLAY/+DISPLAY — turn off/on auto **DISPLAY**ing of images.
- DF [Δf] — move focus position by **D**elta **F**ocus = Δf.
- DM — toggle **D**o**M**e tracking on/off.
- EXP [*time*] — take an **EXP**osure of length *time* seconds.
- FILENAME [*name*] — change the default root for image **FILENAME**s to *name*.
- FILL — **FILL** the dewar
- FLAT *ndesired nmax startexp fudge* — takes a series of **FLAT** field images; see text for more.
- FO [f] — move to **FO**cus position f.

- FOCRUN — **FO**cus **RUN**.
- FUDGE — setup for STAN command.
- FULLSCALE — set autoscaling of images to have greyscaling showing **FULLSCALE** of image.
- GCENTER — CENTER command for guider.
- GEXP — EXP command for guider.
- GFLAT — FLAT command for guider.
- GFOCRUN — **FO**cus **RUN** in the **G**uider.
- GFULLSCALE — FULLSCALE command for guider.
- GLOCATE — LOCATE command for guider.
- GOFFSET [Δx Δy] — **Offset** the telescope by a specified number of *pixels* in the guider
- GSAMESCALE — SAMESCALE command for guider.
- GSKYSCALE — SKYSCALE command for guider.
- GUIDE — turn on the **GUIDE** system.
- GUIDEOFF — turn the **GUIDE** system **OFF**; for long exposures, a warning will come up if guiding if off.
- GUPDATE [*n*] — **UPDATE** the number of **G**uide exposures to determine centroid.
- GSIZE [*n*] — set the **SIZE** of box used by **G**uide camera for computing star centroids.
- HP — **H**el**P** command.
- INIT — INITialize telescope.
- INPUT filenmae — execute a series of commands from the specified **INPUT** file
- INST — select a new default instrument for pointing (currently, either science CCD or guider CCD.
- LOCATE — move the telescope such that object in current image display is moved to some other specified **LOCATION** in the display.
- MEXP [*time number*] — take *number* of **M**ultiple **EXP**osures of length *time* seconds.

- NE — change to a **N**ew **E**poch for coordinates.
- NEWEXT [*ext*] — give a **NEW EXT**ension for the next image file.
- NOSHUTTER — set guide camera to use **NO SHUTTER** during guide exposures.
- OBJECT — specify **OBJECT** name for FITS header.
- OD — **O**pen the **D**ome slit.
- OF — **O**pen the command **F**ile created by user.
- OFFSET [Δx Δy] — **Offset** the telescope by a specified number of *pixels*.
- OL — **O**pen the **L**ouvers - the large vents at the floor of the dome.
- OPEN — **OPEN** the guide camera shutters.
- OS — **O**pen the **S**tandard star file.
- PA — change the **P**osition **A**ngle of the detector.
- PM — move the telescope to a position of one of the last five **P**revious **M**ove positions.
- QCK [*time*] — take a **Q**ui**CK** exposure of length *time* seconds, **but do not save it**.
- QM [Δ *RA* Δ *DEC*] — do a **Q**uick **M**ove with the offset in RA and DEC in arcsec.
- QU — **QU**it the telescope command program *gracefully*.
- RF [*id*] — **R**ead from command **F**ile created by user and move telescope to object *id*.
- RS — **R**ead from **S**tandard star file.
- SA — set the telescope to point at a **SA**o star.
- SAMESCALE — set autoscaling of images for future images to be the **SAMESCALE** as current image.
- SCALE *low high* — redisplay current image with new grey **SCALE** between *low* and *high*.
- SHUTTER — sets guide CCD camera into normal **SHUTTER** mode.
- SKYSCALE — set autoscaling of images to have grey**SCALE** levels around mean **SKY** level.
- SLEEP [*t*] — suspend operation (sleep) for specified number of seconds.

- STAN [n] — take an exposure through filter number n of a **STAN**dard star; program determines exp time.
- ST — **ST**ow the telescope to stow position to quit.
- TR — toggle **TR**acking on and off.
- UC – **U**pdate bf Coordinates for current telescope pointing.
- WRITE — toggles to mode where guide exposures are **WRITE**en to disk; default is not to save images.

Appendix B

Standard stars

For user convenience, a master coordinate/standards file with a large number of standard stars is available which can be used with the OS/RS and STAN commands. OS/RS allow ease of pointing to a desired standard, and the STAN command can be used to take an exposure, letting the software calculate a good exposure time based on the standard magnitude and the system throughput through a desired filter.

The master standards file is called standards.apo, and resides in the top level observe directory (/home/loki2/observe/standards.apo). The current version contains 918 entries. Entries 1-223 come from Landolt 1982, 224-250 are dummy entries, 251-280 are standards in M67 from Montgomery, 281-300 are dummy entries, 301-826 are from Landolt 1992 (some of which duplicate entries from Landolt 1982), 827-900 are dummy entries, 901-918 are southern spectrophotometric standards from Landolt 1992a.

Appendix C

Transferring files to NMSU

There is a simple script available to transfer image files from a given night down to a disk on ganymede at NMSU. Using this script, you can specify which images to transfer, and also, at what time the transfer will take place.

To run the transfer script, simply use:

dosftp *date time*

This will transfer all the images from the specified date at the specified time; if *now* is specified, the image transfer will start immediately.

For example, to transfer images from 981108 at 7am, use

dosftp 981108 7am

The images will be placed in /home/1m/*date*, viewable from all of the Linux machines at NMSU.

Appendix D

Robotic operation notes

D.1 Input file format

A separate file can be prepared for each night's observing. The file should have the name *yymmdd.inp* where yy, mm, and dd refer to the **UT** date of the observation (i.e. the date after midnight). The observing file is used to customize what sort of observations will be made, various observational parameters, set of filters to use, and will provide a list of potential targets and exposure times for each target.

A sample file can be viewed (in a separate browser window)

It is important to follow the correct file format. The first line is a header line that is ignored, but it should be used to label the values used in the second line. The second line has 9 numerical entries:

1. DTFOC: minimum time interval between refocussing, in hours (suggest 2 hours?)

2. DTEMPFOC: temperature difference that will trigger a refocussing attempt, even if DTFOC has not elapsed, in degrees C (suggest 2?)

3. PHOTOM: flag to trigger automatic observations of standard stars, set to 0 for no standards, 1 to do standards

4. DTLOW: if PHOTOM=1, sets time interval between observations of low airmass standards with airmass between 1 and 1.3 (a pair will be taken each time)

5. DTHIGH: if PHOTOM=1, sets time interval between observations of high airmass standards with airmass between 1.6 and 2.0 (a pair will be taken each time)

6. LDOME: flag to determine whether the lower dome slit will be opened (1 to open, 0 to leave closed). The lower dome will begin to occult the telescope at an airmass of about 2.0. The reason not to open the lower

dome shutter if you don't have to is because the lower dome shutter is less robust to both computer and mechanical failures than the upper dome, so there is a larger chance that it will not close if something goes wrong.

7. NPM: number of pointing models to run before starting observations

8. NFOCTEST: number of focus tests to run before starting observations (these are engineering tests, not normal focus runs, which are always done).

9. DAYTEST: flag to use a test mode where dome is not actually opened, allowing script to be run during daytime or bad weather for testing purposes only; 0 for normal operation, 1 for test operation

The third line is another header line, this time for filter information. The fourth line stars with a number that gives the total number of filters that will be used for the night; each entry for each object will have to specify exposure times for each of these filters (although one can certainly specify 0 length exposures to skip any desired filter for any desired object). After the number of filters, there should be nfilt entries giving the filter names, where the names are those as used by the control software for setting the filter (i.e., u, b, v, r, i, z, c); case is not important (although I prefer lowercase for consistency). For each of the specified filters, the program will attempt to get twilight flats, and also observations of standard stars if the PHOTOM flag is set; consequently, you don't want to include filters in this list that you won't need observations in.

The fifth line is a header line again, this time for the remaining object lines.

Starting with the sixth line, information is given for each desired object. The software works by observing the first object in the list that satisfies a set of requirements. The requirements are that the object has not already been observed the requested number of times, that sufficient time (as defined by the observer) has elapsed to observe the object again, and that the object falls into a desired window in airmass, UT, or hour angle. If all conditions are met, then the object will be observed for the amount of time in each filter specified on the object line.

IMPORTANT: the object lines are parsed by looking for white space between columns. As a result, you must not include any "extra" white space, e.g. in an object name or in the coordinates!

For each object, there needs to be $14 + nfilt$ entries on the line. The entries for the object lines are:

1. Object name. **No spaces are allowed!**

2. RA, in format hh:mm:ss (No spaces allowed)

3. DEC, in format +/-dd:mm:ss (No spaces allowed)

4. Epoch of coordinates

5. Minimum airmass to observe (at start of sequence)

6. Maximum airmass to observe (at start of sequence). To ignore airmass criterion, set minimum airmass to 0 and maximum airmass to 99.
7. Miminum UT to observe (at start of sequence)
8. Maximum UT to observe (at start of sequence). To ignore UT criterion, set minimum UT to 0 and maximum UT to 24
9. Minimum HA to observe (at start of sequence)
10. Maximum HA to observe (at start of sequence). To ignore HA criterion, set minimum HA to -12 and maximum HA to 12
11. Maximum number of visits, i.e. after this many sequences have been obtained, this object will be skipped. To request "infinite" repeats, set this to a very large number.
12. Minimum time between sequences, in hours. To request continuous coverage, set this to 0.
13. Guide flag, 1 to use guiding during exposures, 0 for no guiding (guiding recommended for sequences over 60s).
14. Exposure times in each of nfilt filters, in the order in which they are specified in the filter line (4th line of file).
15. Number of exposures to take in each filter during the sequence.

Appendix E

Telescope recovery notes