The Care and Feeding of Mt. Stony Brook Observatory

Nancy R. Adams, James G. Petreshock, and Scott J. Wolk

Astronomy Program, University at Stony Brook, Stony Brook, NY 11794-2100

1 Introduction

This document is a manual, of sorts, for the equipment and software at SUNY at Stony Brook. The telescope is a nasty beast to care for and experience has shown that it needs to be treated properly. The material presented here is a collection of what has worked in the past for keeping the mighty beast happily collecting quality data. There are formal manuals for the commercial equipment available, and these should be reviewed in conjunction with this paper.

2 The Telescope and Dome

For several years, the observatory at SUNY Stony Brook was used solely for undergraduate classes. Built in 1968, the observatory is located at the western end of the academic mall, atop the Earth and Space Sciences building. The campus is approximately 40 miles from New York City. The location of the observatory makes it a very light polluted site. This, along with the fact that the telescope drive motor is misgeared, made it difficult for the telescope to collect research data. The telescope now runs as an effective research facility. The changes are detailed below as the telescope was transformed from an old dinosaur to a more useful one.

The dome houses a 14" Celestron Schmidt-Cassegrain telescope that was installed in 1981. This telescope has some problems which make data collection arduous. The corrector plate is slightly skewed, the drive is misgeared, and the finding scope is difficult to use in the winter. The finding scope is a 30mm refractor that tends to become misaligned with the

14" when exposed to cold weather due to shrinkage of the adjusting screws. To correct for this, a 3" refractor was added to this to the 14". This addition gives a deeper finding field and has a more stable alignment. The drive motor for the telescope cannot track objects for longer than fifteen seconds before the guiding error is greater than the seeing disk size.

In 1993, a hole was drilled through the roof to a laboratory on the fourth floor. Several cables were run from a warm room to the telescope. The operator of the telescope can observe from the fourth floor, only exposing himself to the cold when finding a new target.

The operation of dome and the telescope will be discussed in later sections.

3 The Computer Hardware and Relevant Equipment

Currently a 50MHz 486DX PCBrand personal computer, located on the fourth floor in the warm room in lab number 443C, is used to control the charge coupled devices (CCDs). The PC has 8 megabytes of RAM and a 25 megabyte hard drive which is useful for temporarily storing images taken with the CCD cameras. The PC also has 4 communications ports and 2 printer ports. The Colorado tape drive next to the PC is useful for backing the hard drives and storing data, but these tapes are not compatible with the network tape drives. The PC runs on DOS 6.0 and uses version 3.1 of WINDOWS. The Lynxx should not be run through WINDOWS because the BIOS chip is not compatible with the Lynxx software and the exposure times become distorted. For a listing of the exposure times for the Lynxx, see Appendix I. The more applications that are run on WINDOWS, the slower the clock runs, thus the exposure time becomes dependent on how many applications you are running. The ST-6 and ST-4 also should not run through WINDOWS as data transfer time is slowed. Within WINDOWS, the communication rate is set at 19.2 kbps, otherwise the communication rate can be 115 kbps.

The PC is connected via a switch box to a VGA monitor and keyboard in the warm room and in the dome itself. The active keyboard and monitor pair is selectable via the switch box in the warm room. The cabling for the Lynxx, ST-6, ST-4, monitor, keyboard and the FW-1 filter wheel are run from the warm room, along the wall, and through the hole that is directly under the steps in the dome. The software for ST-4 and ST-6 is set so that the communication line for either camera is through communication port 1. Because they are operated through the same communication port the two cameras cannot currently be operated simultaneously. The Lynxx software runs from a card in one of the expansion slots, and the cabling is connected directly to a port on the card. Another cable running into the warm room is used to connect the PC via Kermit to the astronomy server. This connection can be used to upload data to any machine in the cluster at 19.2 kbps.

An intercom system is facilitates communication between the dome and the warm room. Usually one of the intercoms in the dome is locked on channel b, so the observer in the warm room can hear what is happening in the dome. The second intercom in the dome is used for two way communication between the dome and the warm room.

4 CCD Systems and Their Hardware

Currently, there are three CCD systems available at Mt. Stony Brook. The Santa Barbara Instrument Group (SBIG) ST-4 is an 8-bit camera used primarily for tracking. SpectraSource's Lynxx camera uses a 12-bit format, and the SBIG ST-6 follows a 16-bit format; both are used for imaging. Each camera is utilized in different areas of data collection. Table 1 contains specifications of the cameras. When working with the PC, all software packages are to be executed outside of the WINDOWS operating system for the reasons explained above.

	Lynxx	ST-4	ST-6
Pixel array	192×165	192×165	375×242
Pixel Size	13.75×16.00μm	13.75×16.00μm	23×27μm
Active Area	2.5×2.5 mm	2.5×2.5 mm	8.63×6.53 mm
Dark Current (in e^-/sec/pixel)	100	160	30
Full Well	95,000 e^-	95,000 e^-	400,000 e^-
Field of View (in 14 inch)	2×2 arcmin	7×7 arcmin [a]	8×8 arcmin
Field of View (with a focal reducer)	4×4 arcmin	N/A [b]	16×16 arcmin
Limiting Magnitude (1 min exposure)visible	15	9 [c]	18
Photometric Accuracy			
Gain Available			

Table 1: Technical Specifications Of The CCD Cameras.

[a] This is the field of view through the 3".

[b] The focal reducer cannot be used with the ST-4.

[c] In the 3" with a 3 second integration time, no filter.

4.1 The Lynxx

SpectraSource's Lynxx camera contains a Texas Instrument TI241 chip and is an array of 165 x 192 pixels, each pixel is approximately 13.75μm by 16μm. The chip is housed within the camera head which is cooled by a thermoelectric cooler (TEC) to approximately 30^o Celsius below the ambient temperature. The pixel size of the Lynxx's chip gives it the capability of very high angular resolution. The atmospheric seeing at Stony Brook does not allow it to be used to its full capability. The oversampling can be useful in some fourier transform analysis. The Lynxx has a physical shutter creating a uniformly exposed picture. It has a fast image readout time: 1 sec for 12 bit, .3 sec for 8 bit and real time display. Therefore Lynxx is better capable of observing asteroids, planets and occultations. Another useful aspect of the is the Optec retrofit for the Lynxx. The retrofit package includes a flip mirror and filter box. This allows the observer to see the targets and take an image just by flipping the mirror. A set of Optec Johnson BVRI filters are used with the Lynxx, and a clear filter is used to maintain focus on the chip when the BVRI filters are not being used. The filter response curves are given in Appendix III. Undergraduates have used the Lynxx camera for research projects such as; asteroid light curves, periodicity of eclipsing binary stars (β Persei) and variable stars (W UMa). High school students also have used the camera as part of Westinghouse Research projects. These projects have included observations of weather patterns on Saturn, particle size distribution in the early Solar nebula by observing Lunar crater size and density and BVRI photometry of χ Persei.

4.2 The ST-4

The SBIG ST-4 uses the same CCD chip that is used by the Lynxx. The ST-4 uses a CPU box as opposed to a card that must be installed in the computer. This makes the ST-4 more portable than the Lynxx, since it can be run by a laptop computer for imaging, or with just the CPU box for guiding. Here the ST-4 is used with the CPU box in the dome. The black CPU box is placed in the dome and can be connected to the computer currently through the 9pin serial cable labeled ST-6. The chip is cooled by a TEC similar to the one in the Lynxx. This cooler lowers the temperature of the chip to approximately 20^o Celsius below ambient temperature.

The ST-4 is also capable of moving the telescope. To do this, a relay box was built locally (for schematic diagram see figure 1). Its purpose is to allow the CCD computer to communicate with the telescope's drive. The relay box has three connecting cables. The standard grounded plug is connected to the power supply, the gray 15 pin female cable connects to the CPU box, and the gray 6 pin male polarized cable connects to the telescope's drive.[1] The telescope's drive has two speeds. The current relay box has been designed to work with the faster speed of the drive. To adapt the ST-4 to a different telescope, a new relay box would have to be designed.

Software is available to allow the ST-4 to track using an interactive image on a computer. The difficulty with this method is the computer can only operate one CCD at a time. If the ST-4 and the Lynxx are to be run at the same time, the computer will interactively run the Lynxx, and the ST-4 will operate through the CPU box. The CPU box contains built in tracking software.

At the Mt. Stony Brook Observatory, the ST-4 is used solely as a tracking device. The camera head is attached to the 3" telescope. A 36mm plössl eyepiece has approximately the same focus as the ST-4 in the 3" telescope and can be used to center a star for the ST-4 to track. In the track mode, the ST-4 will chose a star to track and move the telescope via the relay box to keep the star in its field of view at approximately the same position on the chip.

[1] It is still possible to plug the cord to the drive in upside down. The operator should take care in placing this plug.

This makes it possible to take exposures longer than 15 seconds with the Lynxx camera. As mentioned earlier, the drive motor is fails to track accurately after 15 seconds. With the ST-4 guiding the telescope, images of ten minutes and longer have been recorded. In many of the projects utilizing the Lynxx, the ST-4 is used to guide the telescope.

4.3 THE ST-6

One SBIG upgrade from the ST-4 is the ST-6. The ST-6 utilizes a Texas Instrument TC241 chip. This is an array of 375 by 242 pixels each 23μm by 27μm. The components of the ST-6 system are similar to the ST-4. There is a CPU box, camera head, and the same relay box. This system also uses a motorized filter wheel made by Compuscope. The filter wheel contains BVRI Bessel filters and a clear filter. (See Appendix III for the response curves of the filters.) The TEC for this camera head is similar in operation to that of the Lynxx, however the ST-6 allows the temperature to be set. The ST-6 is usually set at -25^o Celsius at Mt. Stony Brook Observatory.

The ST-6 is capable of simultaneous data aquisition and guiding. Used in conjunction with the ST-4, longer uninterrupted exposures are possible. The uninterrupted exposures will reduce readnoise since only one read-down occurs. This makes simultaneous use the preferred method of operation, however it is too cumbersome for regular use. A function in the software allows the operator to combine several short exposures to create a composite image. The basic idea of the *track and accumulate* function is to take a short image, and then chose a star for the telescope to track on. The software will take short exposures and move the telescope to keep the star in the same region of the chip. Another image is taken, and the two images are aligned. This is the main data collection method. The track and accumulate function allows very deep exposures to be made. A 60 second exposure of a star forming region in Aurigae contained a 18th magnitude object in the infrared. The maximum magnitude that was detected by the Lynxx was 16th magnitude in 600 seconds. The ST-6 does not have a physical shutter. Instead of a physical shutter, an electronic shutter is used in conjunction with a vane. This can lead to short images not being exposed uniformly.

5 Data Acquisition

In this section the methods of data acquisition will be discussed. The means of finding targets are important part to any observing program, and are included here. The operations of each camera is also covered, including some suggested settings that can be useful for the inexperienced user.

5.1 Target Finding

The main method of finding targets is a modified version of the classical star hopping method. Lock onto a bright star, no fainter than third magnitude, that has a similar declination or right ascension as the target star and therefore it is necessary to slew in only one direction. The 30mm guide telescope is used to acquire the bright starting star. The slew can be followed by observing in the 30mm. We would prepare finder charts that would include; a wide constellation field, the 30mm field, the 3" field and the of the 14" field. The charts were made using the Space Telescope Science Institute Guide Star Catalogue, and Tirion 2000. The 30mm has a field of view of 2.5 arcminutes, the 3" has a 40 arcsecond field of view, and each camera's field of view is specified in Table 1. Once the target star has been found in the 3", data acquisition can now begin.

5.2 Data Aquisition with the Lynxx

The Lynxx software is under the D:\CCDS\LYNXX directory and the software package can be executed by entering CCD.

Once in the Lynxx Menu the first thing that must be done is the TEC must be turned on, the command to activate it is under *initialize*. The chip needs approximately fifteen minutes to cool sufficiently. The filepath for images to be stored will always be set to the default. This should be reset to F: each time the software is restarted. See Table 3 for the capacity of Lynxx images that can be held on various drives.

There are two methods to obtain an image using the Lynxx. Using the *expose* command will take an 12 bit image that has a readout time of .5 second. The second method is the *full-frame focus* command which utilizes the camera ability to readout 8 bit images. This has the benefit of having a shorter readout time, which is about one third of a second. Sub-frame images can be readout in .3 seconds and are 96 pixels high by 82 pixels wide as compared to 192x165 for the full frames.

When observing time dependent phenomena it is useful to use the "green monitor" to video tape the observations. It is possible to tape images on the monitor, using the video port on a VCR. Simultaneously a connection with the radio broadcast of "WWV" (the time counter) using the audio port can be made. This setup will give an extremely accurate time-image correlation for observations.

All corrections made to an image are permanent, therefore it is not to advised to use *stretch* or *log scale* until the image is saved or copied. *False color* is useful to enhance contrast in nebulous structure and between faint objects in a image while not affecting the actual image. The image can be saved using the *imagesave* command under *save/load*. The *image filepath* should be check to ensure the correct filepath. The format for saving images form the Lynxx is *******.ccd.

Certain calibration frames, such as thermal frames, bias frames and flat field frames, should be taken because they play a key role in data reduction. Bias and thermal frames can be acquired by using the commands under the *initialize* menu. The thermal frames are always placed in the fourth frame and the bias frames are always placed in the fifth frame.

The flat field frames are stored in the sixth frame. It best to take five twilight flats in each filter using the *expose* command. An alternative means of finding flats can be used at Stony Brook:sky flats. Sky flats are medianed images of a relatively starless field. The *get flat field* command is not recommended because the normalization process the Lynxx uses creates extra noise.

5.3 The ST-4

Since there are superior cameras and software packages for imaging at Stony Brook, the imaging software for the ST-4 will not be discussed. The tracking software is extremely important to data collection, and will be presented here. The tracking software is run from the CPU box. There are several controls including a menu which allows the operator to change parameters necessary for the tracking process. Table 2 includes a rough guide of settings for the ST-4. The *exposure adjust* will set the exposure time. *Calibration adjust* controls the period of time that the ST-4 moves each of the four relays during the calibration process. Each axis can be given its own time. The *scintillation adjust* allows for atmospheric turbulence. If the sky is turbulent when observing, this should be set at a fairly high number to track on a 'twinkling' star. The *brightness adjust* has two settings, average and faint. In the faint mode, the chip will take an average of a 3 by 3 pixel square and place the average in the center pixel. This helps find fainter stars, but will also increase the background. The *hysteresis* parameters can correct for backlash in the telescope's drive motor. The times are set in tenths of seconds and the ST-4 will use this time to set the motor in the correct direction before making a move. The last parameter is the *gain boost.* This increases the gain of the chip, but it is important to remember the background noise increases with the gain.

Once these parameters are set, a star can be found for tracking. As stated before, a 36mm plössl eyepiece has the same focus as the ST-4. This can be used to find a star in the

Command		Value
EA	Exposure Adjust	3
b	Gain Boost	3
bA	Brightness Adjust	A
SA	Scintillation Adjust	2
FL	Focal Length	S
C1	Calibration Time, X Axis	1
C2	Calibration Time, Y Axis	3
H1	Hysteresis, X AXIS(.1 sec)	2
H2	Hysteresis, Y AXIS(.1 sec)	1
AA	Averaging Adjust	3
AL	Cycles Before Alarm	4

Table 2: Sample settings for the ST-4 guiding on a 7 mag star.

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region of interest to guide on. If the star is slightly out of center relative to the 14", there are two sets of adjustment screws which can be moved to center the 3" telescope on the star while not moving the 14". The camera can be replaced and the find and focus can start.

Find and focus will read down the brightness of the star on a scale where 99 is over-exposed, along with the coordinates on the chip. The star can be found by using the four arrow keys to move the drive motor slightly. Once the display shows high counts, the focus of the three inch can be changed until the counts reach a maximum. Before tracking with the camera, the CPU and the drive have to be calibrated. It is best to place the guide star near the position X=20, Y=80. When the calibration button is depressed, the telescope will be moved in all four directions. The CPU will determine how much time is necessary to move the telescope a certain number of pixels. Then when the star moves away from the centered position, the CPU will know how long to move the drive to get the star back in place.

After the drive is calibrated, the track button will set the ST-4 in a mode where it will track the star until it either loses track or the operator stops the track. The CPU box also contains a button to take a dark frame. If the dark frame is taken, a cover must be placed over the telescope. The ST-4 has neither a shutter, nor a vane which will block out the light.

5.4 ST-6 Data Collection

Like the Lynxx and the ST-4, this camera has a preferred orientation with the telescope (see figure 4). The software is located in the directory D:\CCDS\ST-6. The filter wheel can be started here with the command FW. Once the camera is attached to the telescope, and the several cables are set, the ST-6 software is started with the executable ST6OPS. The link between the computer and the camera will be established. The cooler can be set to a specific temperature. This is done by going to the *camera* menu, and selecting *setup*. The temperature control is contained in this menu. Mt. Stony Brook operates at a camera temperature of -25.00^o Celsius.

Before taking images, the camera and the telescope have to be calibrated. This process is similar in operation to the calibration with the ST-4. A star is placed near the center of the field, and the camera moves the drive to determine the times for each relay. These times tend to change depending on the region of the sky that is being observed. After moving to a new target, the calibration should be done again. The commands for calibration are under the *track* menu.

Now the telescope is ready for imaging. The *focus* command allows the operator to find the target and then move the telescope to center the object. The focus mode is preferable to find a target since there is an option for a low resolution readout. This produces poor quality images, but they are readout faster than a normal image. Another advantage to the focus command is the ability to move the telescope. The a,s,w,and z keys will move the telescope in the -X, +X, -Y, and +Y directions respectively. This feature will only work in the focus mode.

There are two ways to collect images with the ST-6. The first is using the *grab* command. This will take an image for the requested time period, and then download the image. This is the normal CCD camera image mode. The second method is the *track and accumulate* mode. In this mode, the camera takes several short images, and then add them together to give an image that is comparable to the same total time image as taken by the grab function. The advantage of the second method is clear when using a telescope that cannot track well. At Mt. Stony Brook, a 60 second image under grab would have star trails throughout it due to the periodic guiding error (see figure 3). A 60 second track and accumulate image contains fairly round stars. The camera calculates how far the star has moved from the first image and will move the telescope to compensate for the movement that occurred in between exposures. This is the nominal data collection method for the equipment at Mt. Stony Brook.

Another feature about the ST-6 is the dark frames can be removed from the image as the data is collected. Unlike the Lynxx, which creates a dark frame by taking an exposure of the shutter and then removing the bias level, the darks from the ST-6 include the bias level. In lieu of a shutter, the ST-6 has a vane which falls into place to collect a dark frame. When an image is taken, the electronics act as a shutter.

To save images under the ST-6 software, the *file* menu is utilized. The default *filepath* is usually D:\CCDS\ST-6. This should be changed to F:\. The filename can be eight characters long, and the operator has a choice of formats. The formats will be discussed in a later section. One important point: **save the tracklist.** After each track and accumulate image is taken, a tracklist is created. This records how far the telescope was moved each frame of the image. This must be saved to calculate the offsets that are needed for the flat corrections. The save tracklist option also allows eight characters, so the image and tracklist can have the same filename until the extension.

6 Data Storage

All of the data are stored initially in the F:\ drive of the PC. About 25 ST-6 images or 172 Lynxx images can be saved here. After all of the data for the night are collected, the data are transferred from the PC to the VAX mainframe in the department. The file transfer protocol used is kermit. The data are saved in various formats depending on the software used. Appendix I contains the procedure for transferring data to the VAX.

6.1 Data Formats

There are several different ways for CCD images to be stored. Each software package has its own format for saving the data. The ST-4 can save data when used as an imaging camera. The format of the saved files is not discussed in the ST-4 manual.

The Lynxx saves data in a format that best uses its memory allocation. Since the Lynxx data is stored in 12 bits, the format rearranges the data to send 2 pixels of information in 3 bytes. This is really just a redistribution of data, so that it is sent faster and stored more efficiently. Two pixels can be represented as 3 bytes of information. The first byte contains the 8 least significant bits of pixel 1. The second byte carries two nibbles. The first nibble has the 4 most significant bits of pixel 1, and the second contains the 4 most significant bits of pixel 2. Finally the last byte contains the 8 lest significant bits of pixel 2. The Lynxx manual suggests that data stored in this format be saved with a ccd extension.

The ST-6 offers its own format in compressed and uncompressed versions, along with FITS (Flexible Image Transport System) and TIFF (Tagged Interchange File Format) formats. The ST-6 format saves data in 16 bit words for each pixel value. In the uncompressed version, the data is read down with each pixel being described by a 16 bit word. The compressed version saves the data in a slightly different manner. The first pixel in a row is described by a 16 bit word. The rest of the pixels are described by an 8 bit word, provided that the value varies from the first pixel by ± 127 counts. If the difference is more than ± 127 counts, that pixel's value will be described by a 16 bit word. It is obvious that the compressed format will save the data in less space than the uncompressed format.

The other formats are FITS, a common astronomical format, and TIFF, a publication format. Under the FITS format, the user has the option of saving data in either a 16 bit or 8 bit mode. To save the original image, the data should be saved with 16 bits per pixel. When 8 bit is selected, the 16 bit image data will be reduced to 8 bits and will be photometrically useless. The ST-6 also allows the observer to record information about the image collection and comments about the collection. A word of caution for those using the FITS format. The ST-6 software will record the time of the FITS creation, not the time of the file creation. This information can be found in the comments.

The TIFF format under the ST-6 can only write in 8 bits while the ST-6 images are in a 16 bits format. This can be a disadvantage since this compresses the data and slightly alters it. This format is not suggested for images with astronomical data. This program also allows the observer to record collection conditions.

6.2 Other Methods of Storage

There several backup systems to record the data if the vax connection has failed or a disk on the VAX has failed. The first backup system is the use of floppy disks with the PC. Since all of the data are stored on the PC, the data can be sent directly from the F: drive to a floppy disk. The PC can read both $5\frac{1}{4}$" and $3\frac{1}{2}$" disks. Table 3 shows the disk capacity for each system. The data can then be stored on floppy disk until they can be sent to the

Camera	$5\frac{1}{4}$" HD	$5\frac{1}{4}$" DD	$3\frac{1}{2}$" HD	$3\frac{1}{2}$" DD	QIC-80
Lynxx	28 images	7 images	35 images	14 images	5000 images
ST-6 images	4 images	1 images	5 images	2 images	600 images

Table 3: Storage Capacity For Lynxx and ST-6 Images.

VAX.

A second form of backup for the PC is a tape drive. The Colorado Memory Systems tape drive stores data on QIC-80 tapes. The QIC-80 tapes can store 250 megabytes of compressed data. From here several nights worth of data can be transferred to a single tape. This is a stronger system than the disks because the tape can hold 600 ST-6 images. The entire contents of the PC is backed using this system occasionally.

The data are also backedup on the VAX with an 8mm or 4mm tape. A tape backup should occur once every month. This backup becomes important if the disk fails. A month's worth of data was lost when one of the VAX data disks failed. The disk in question had stored data from a year before the failure date, but they were stored on tape and recovered. The VAX has a routine that allows TAR procedures to run within VMS.

7 Data Processing

Once the data are collected and stored, the next logical step is to process the images. If photometry is desired, there are several tools available to make measurements from the images.

7.1 Quick Look Tools

Each program allows the operator to get a quick look at the data and do some processing. The ST-4 and ST-6 have the same basic tools, so only the ST-6 tools will be described here. Most of the tools are under the *display* menu. When an image is displayed in analysis mode, data can be roughly analyzed. Any process done under display will only alter the display and not the image itself.

The operator can use the *X-Hairs* to find the pixel coordinates and value. The average value of all pixels in a square area can be determined with the smooth command. This program will also give a relative magnitude of the star. An accurate magnitude can be determined if the telescope parameters are modified. If the object is a diffuse object such as a nebula, the diffuse magnitude is expressed in units of mag/square arcsecond. The separation in arcseconds and degrees can be determined between two stars.

Other operations include flipping the image horizontally and vertically, and a zoom which enlarges a section of the image by a factor of four. The image can also be cropped. If the image is not at a contrast that is desirable, the contrast can be manipulated by the operator. The image can be smoothed. This is a process that removes the effects of rapidly varying pixels values. This is accomplished by replacing each pixel by the weighted average of a 3 by 3 square centered on the pixel. This can blur the details of an image, but can help bring out faint objects. A histogram can be displayed in either a text or graphical format for the ST-6. The ST-4 can only display a graphical histogram.

The ST-6 has an utilities menu which alters the image. The image should be saved before any processing is done to it. Several functions can be done here including *dark subtracting, co-adding frames, smoothing, sharpening,* and *flat fielding.* The *dark subtract* will remove the dark current and bias from the image. This removes background noise that is intrinsic to the chip. The *co-add* command allows two images to be added. This produces a third image with a better signal to noise ratio. *Smoothing* the image will have the same effect that it did before except now the image is permanently altered. Another form of filtering is the *sharpening*. This is a process called unsharp masking which brings out the details of the image. *Flat fielding* will remove the flat field from the image. This corrects for differences in gain from pixel to pixel and variations from the telescope. The tracklists must have been saved earlier if this tool is to be used in a track and accumulate image. Also under the *utilities* menu, the image can be rescaled. Cool and warm pixels can be removed.

The ST-4 allows some of these processes, but not all. Before using these commands, consult the manuals for these cameras.

7.2 The Lynxx Tools

The Lynxx software has its own quick analysis tools. Some of the processes are similar to the ST-6 tools. As previously discussed, the images can be rescaled, but if intensities are to be measured, the images should not be rescaled. The rescaling process destroys the raw data and makes intensity measurements inaccurate.

The processes for analysis are under the *analyze* menu. A histogram of the image can help determine if any part of the chip was over exposed. Changing the falsecolor of the image can also help in determining if a pixel is overexposed. The falsecolors display the image in a strongly varying colorbar that makes it easier to determine the counts in the pixel on examination. X and Y line scans can determine the focus of the image. When focusing the telescope, the lines scans can be a benefit to the focusing process. These procedures display the intensity along a chosen line. A zoom window is also available.

Before starting any analysis on an image, the calibration frames must be removed from the image. While these are generally carried out on the VAX using IRAF or IDL, the quick reduction methods included in the software is detailed here. The *process* menu contains the tools to remove the calibration frames. The *flat adjust* removes the bias which is stored in frame 5 (see figure 1 for frame positions). The flat stored in frame 6 is used to correct the image. The *therm adjust* process removes the dark current. This will correct for the dark in frame 4 in addition to the bias and the flat. When executing either of these procedures, the operator should place the correct flat frame and correct dark frame in the buffers.

The remainder of the commands can be used for determining the intensity of the objects in the frame. *Meas intensity* is the command that will measure the intensity of the object in a square region around a star. The size of the square region can be changed with the command square size. A suggested size for the aperture is one that encloses all of the star and has a small section of sky around the star. After the star is measured, the background should also be removed. To do this, a square of the same size should be placed on a region that represents the background around the star. The difference between the two values is a more accurate representation of the relative intensity. An appendix to the Lynxx manual describes photometry with the Lynxx software.

A separate software package is The Personal Observatory. This is a package which allows the ST-6 and the filterwheel to be run simultaneously. Unfortunately, the track and accumulate mode will not work if the ST-6 is run by Personal Observatory. It is advised to use the SBIG software.

Even though the camera cannot be operated by the Personal Observatory, it can be used for data reduction. Again, there are better processes in IRAF and IDL. This is a description for a quick look at the data. There are procedures for tricoloring images by using three images in different bands,and some photometry can be done in this software. The Adobe Photoshop can be utilized for color images also.

7.3 IDL

There are several IDL programs on file at Stony Brook. Several of these programs have been written locally to reduce the data collected. The programs cover a large range of functions, but all can be useful in the reduction of data. The help screens of all of these programs are listed in Appendix II. IDL can run from either the astronomy mainframe, or from the PC. On the PC, IDL is located on the C: drive.

If the images being used were taken using the Lynxx the observer can use either IRAF or IDL to reduce the data. If IRAF is preferred there is an IDL routine CCD2FIT formatted image into a FITS format which is readable by IRAF. The *auto2fit* program is currently limited to approximately twenty seven images, although it is being corrected.

If IDL is preferred the CCD12BIT routine will reformat the .ccd images into an image that IDL can read as an array. The AUTOCCD routine will reformat a given list of .ccd images and convert it into an image cube that IDL can read. The CCD12BIT routine requires an image as the input, the directory where the image is located and a name for the output. This routine only works for one image. The AUTOCCD routine requires an image list as the input, the directory where the images are held and the name of the resulting image cube as the output, in order to be work when executed. Now that the images have been reformatted for use by IDL they can be displayed. IDL has several commands to view images; TV, TVSCL and BYTSCL. The TV command writes the image array to the display without scaling it. The TVSCL command scales the image by a specified factor and displays it the scaled version. The BYTSCL command allows one to scale the individual pixels using minimum and maximum operators for improved color contrast.

Before reduction of data can take place the calibration images must be dealt with properly. There is a routine available that helps with this process, MEDIAN. The MEDIAN routine takes the inputted image cube and finds the median value for each pixel position throughout the image cube. This new image with every pixel value a median of all of the inputted frames is the output. The main purpose for using this process of the removal of spurious high and low points which effectively reduces noise and therefore, the uncertainty.

Both biases and dark frames can be medianed easily using this routine. Flat fields are slightly more complicated. The flat field frames for9r a specific filter should be medianed together after which the medianed bias and dark frames should be removed. Flat fields must also be normalized. This is accomplished by weighing the medianed frames to the average value. To do this, set the scale to 1 when running the procedure. When this has been done for all filters, the reduction is almost complete.

The data frames must be reduced now. This involves subtracting the medianed bias and dark frames. They are subtracted because the CCD chip accumulates a thermally induced time dependent charge and operates with some background level of charge. The dark frame must be of the same time as the image since it is time dependent. The data frames should then be divided by the normalized flat field. This step smooths brightness gradients in the image caused by variations in the chip.

If the images being used are from the Lynxx and the user wishes to use IRAF for reduction, the images can be rewritten into FITS format by the CCD2FITS procedure. Data reduction can be done in either IDL or IRAF.

There is an automatic reduction procedure called AUTORED2. This is currently programmed for Lynxx images. The program requires the operator to arrange the images in a certain order. Then the number of each type of image is inputted following the prompts from the computer, and the program removes the bias, darks and flats from the image cube. The flats used are premade, meaning that they were already medianed and weighted. The output is an image cube containing the corrected images.

There are two aperture photometry procedures. One is named APPHO, and the other is APPHOT. APPHO calculates the flux within a circle of a radius that is determined by the user. The error associated with the flux is also in the output. This is not really the flux from the star, but the counts in that area. To find the background, the cursor should be placed over a background position on the image. The two values can be subtracted to give the counts in the circle that belong to the star. This still is not the flux, but it gives an accurate measure of the counts from the star. To increase the accuracy of this process, it is advisable to take several measurements from the background and the star, and subtract the averages.

APPHOT is similar to APPHO, but has a minor adjustment which makes it easier to use. This program uses a centroid to center on the star, and calculates the flux in a circle around the star. In addition, a second circle of 1.5 times the stellar aperture is drawn. This measures the background around the star and subtracts it from the inner aperture. Th output is the counts from the star with the background already subtracted and the associated error. Future versions of this code will allow the operator to decide the size of the second aperture.

If the subject that is being studied is a periodic phenomenon, there are a few period finding programs. One of the programs, SHORTSTRING, works by taking an intial guess of the period, then the program determines periods which fit the points. From these periods, the one with the shortest path connecting all of the data points is the period that is returned. The operator may wish to plot the period array against the path array to help determine the true period since this procedure will always return a shortest path. A second period finding program also exists. This program, PERIODOGRAM, uses Fourier analysis to search for a period. The data points are fit to different sine curves. The probability of each curve being the best fit to the data points is then calculated. This program is based on Horne and Baliunas(1986).

To gain a better signal to noise ratio (S/N), two frames can be added. There is a program called SA, short for shift and add. This program takes two input images and asks for a star to center on in the first image. It then asks for the same star in the second image. The offset between the two images is calculated and the images are shifted. The pixel values for the two overlaid images are added for the output image. This procedure is important when working with faint sources. There are several variations of this program.

If a true color image is desired from series of blue, green, and red images, the procedure MAKE_GIF can overlay the images and create a color bar so that the resultant image appears to have the true colors. This program does not shift the images so they are properly aligned. The operator must determine the offsets and include this information in the input to the procedure.

Another IDL procedure which can be useful, is the MULTICHART program. This program will read the guidestar catalogue and plot out a field based on the input parameters of coordinates and field size. This is very helpful when searching for faint targets. Charts are created for the corresponding field of view and limiting magnitude for each telescope.

7.4 IRAF

The image reduction and analysis facilty (IRAF) is a powerful tool for the reduction of images. This package is available on the VAX and UNIX machines in the astronomy cluster. Images start as FITS images and are converted to a format that IRAF can read. The images can then be calibrated and reduced. IRAF can make photometric measurements as well. This package is a major part of data reduction at Mt. Stony Brook. The details of IRAF's procedures are too lengthy to describe here. Figure 5 contains a flowchart to show the usual reduction procedure. There are many more tasks that can be completed by IRAF, and the manuals available in the department should be consulted.

8 A Night At The Telescope

A night at the Mt. Stony Brook Observatory begins not in the dome, but in the warm room. Here the computer that collects the data resides. The computer is set up so that the software for whatever camera is running and the switch box set to channel B. This allows the monitor and keyboard upstairs to operate the computer.

Now the telescope can be set up. The dome is fairly simple to operate. In the North west of the dome, there is a motor that turns the dome. The dome opens with a motor that pulls the slit back. The switch for the slit motor is near the light switches. The slit motor must be plugged in before it is moved. The plug is an eight prong polarized plug that must be unplugged as soon as the slit is open. The power cord is attached to the dome itself. A nice feature to the slit is a horizon shield which can be disconnected from the slit to block the lights from the campus. This also allows the telescope to view at zenith.

The next step is to mount the camera on the telescope. Each camera had a specific alignment with the telescope. This insures that the flat fields are in the same alignment as the images, and that images from night to night do not vary in orientation. The exact alignments are shown in figure 4, but it is important that a consistent alignment was used is.

Once the camera is attached and aligned, the cooler is started. This has been described in an earlier section for each camera. The observer usually has to wait for a fifteen minute period for the Lynxx to cool to temperature. The ST-4 and ST-6 cameras only take about 5 minutes to cool. When starting, the observer should check to make sure that the telescopes are in alignment with each other. Many hours of observing time has been lost by misaligned telescopes. The object of choice is the University Hospital. The lights on the roof provide a nice target to center in all three telescopes.

The first part of data collection is to take the flat fields. Twilight flats are usually taken. The campus has a fairly turbulent atmosphere, so morning flats are not superior to these. The dome is placed in the east, and the telescope's drive is turned off. Three images in each filter are taken so that the chip is a quarter saturated. This is done approximately a half hour before sunset.

Once the target has risen, the observer can star hop to the target. This is described in an earlier section. Usually a focus frame is taken of a star to determine if the telescopes are aligned. Once at the target, the observer can go to the warmroom and run the cameras in a warm environment. With the ST-6, the filter wheel is entirely controllable from the warmroom. The Lynxx camera requires manual changing of the filters. The observer can be in contact with another observer via a set of intercoms. The intercoms allow the warmroom to monitor the dome. The ST-6 and ST-4 cameras can control the drive. If there is a malfunction, the person in the warmroom will hear the drive motor slewing the telescope, and he can stop the camera immediately before the telescope crashes into anything.

8.1 The End Of The Night

After all of the targets are found and recorded, the observer can begin the shut down. The drive is turned off and unplugged. All of the electronics are turned off and the items that belong in the warm room return there. Cables that remain in the dome are wrapped around the pedestal to prevent tripping. The telescope is stowed so the declination is reading 90 degrees. The 3" telescope should be on the east side of the 14" when properly stowed. This position serves two purposes. The first is to place even weight on the motors. The second is to allow the observer 12 hours to remember to turn off the drive. The motor will carry a balanced weight if the 3" is on the west side or the east side. By putting the telescope on the east side, the telescope's drive can be left on accidently for approximately 12 hours longer before it crashes into the pier.

9 Maintenance

As with any system, there must be maintenance preformed occasionally. The main points of maintenance at Mt. Stony Brook include the dome motors, and the cameras. The slit motor was replaced in 1993. The rotation motor is currently the original motor. The motor has shown considerable amounts of hysteresis, and to move the dome to west, one must first let it move to the east, the try to move it west. The track for the dome rotation must also be oiled occasionally. Once an observing season is recommended.

The cameras need to be maintained as well as the dome. The filters need to be cleaned once a week, as they are wonderful lint collectors. The window above the chip should also be cleaned once a week. Dust on the filters or window will be extremely apparent when examining flat field exposures.

The telescope must not be forgotten either. The declination lock wears itself loose over a few weeks. This should be checked as often as possible. The lock is easily tightened. An important note for the serious observer is moisture. The telescope is not sealed so water can condense on the corrector plate. If this happens in winter, the water will freeze. A hairdryer is stored in the warmroom for just this problem. In 30 minutes or less, the ice can be melted and the water evaporated.

These are the major problems with maintenance have occurred in the past. As with any experiment, one has to periodically check for problems.

10 Improvements

The system is not yet perfect. Some improvements for the future are listed in this section. The filter wheel can be attached to the Lynxx camera. This has not been done yet, but may be a consideration for the future. The filter wheel also has three empty positions.

Additional filters would be useful. Suggestions for Hα and OIII have been made. A second PC would be useful, since the observer could use the ST-4 to see the guide star as he is imaging with the Lynxx or ST-6. This would prevent lost hours from trying to find the star that the ST-4 was tracking on. A second PC would also allow the filter wheel to be run in a different mode. Presently, the filter wheel is run in a pop-up window mode. This doesn't tell the operator which filter is in position. The other program with the filter wheel would show that information.

Better reduction and camera software would be an improvement to the current system. More programs that are user friendly would be helpful to the current library. An upgrade for the WINDOWS software would also be helpful. WINDOWS 4.0 will be capable to transfer data at much faster rates than currently available under WINDOWS. Another computer improvement would be an Ethernet card,which would allow a faster data transfer from the PC to the astronomy mainframe.

A final considersation would be electronic setting circles. With these circles, observered could simply align the telescopess, calibrate the circles, and then type in the numbers for the target. This system would make observering a much shorter routine, but the thrill of finding a target is gone.

Several other improvements have been sugested, but only those which are feasible in the near future.

Refernces

Horne,J. H., and Baliunas,S. L.. 1986. ApJ.**302**p757.

Appendix I: Help Sheets For The Operation Of The PC

Lynxx Time Sheet

When using the PC out of the WINDOWS mode, use this conversion sheet to run the Lynxx camera.

Time	Type	Time	Type	Time	Type
1 sec	3 sec	15 sec	57.0 sec	6 min	1368 sec
2 sec	7 sec	20 sec	76.0 sec	7 min	1596 sec
3 sec	11.5 s	25 sec	94.5 sec	8 min	1824 sec
4 sec	15.0 s	30 sec	114 sec	9 min	2052 sec
5 sec	19.0 s	45 sec	171 sec	10 min	2280 sec
6 sec	22.5 s	60 sec	228 sec		
7 sec	26.5 s	2 min	456 sec		
8 sec	30.5 s	3 min	684 sec		
9 sec	34.5 s	4 min	912 sec		
10 sec	37.5 s	5 min	1140 sec		

To get any time that is not printed here, you can add, subtract, multiply and divided at will to get the desired time. ie) 2.5 min=2 min+30 sec= 456+114=570 so you would type in 570 for a 2.5 min exposure. You must be out of windows for these times to work.

PC To VAX Kermit Commands

At the end of each night, send the data you have collected over to the VAX cluster. Here's how to do it:

1. Turn off the sleeper by going into the Norton Desktop menu and click twice on sleeper. Then just close the sleeper. It will ask you if you really want to close it. You do. Close it and then close Norton Desktop.

2. Before you transfer data over, you must create a dir.out file. <u>This contains the most important information of the night. Without this, the pictures you took are useless.</u> To create a dir.out file, click MS-DOS and type F:. This should put you in the F: disk. Once in F: you can make the dir.out file. Type DIR > DIR.OUT. This should make the file. Type DIR to see if it was created. Type EXIT, and click on the Applications menu. Click on the Kermit icon. Use the Kermit on PC sheet to login.

3. Login to the OBSERVER account. Once there, type MTSB. This will put you into our data directory.

4. Type SWING and create a new directory under mtsb named for the month and the date after midnight. (ie. for the night of November 2 to the morning of the 3, use NOV_3. Just type C to create.) Once the directory is created, move the cursor over to the new directory.

5. Type Q to quit the swing. Check to make sure you are in the right directory by typing SD. SBAST9$USER:[OBSERVER.MTSB.NOV_3] is what you would see if you used the example from above. If you are not, use the CD command to change the directory.

6. Now you can transfer data. Type CKERMIT. At [OBSERVER.MTSB.NOV_3]CKERMIT>, type SET FILE TYPE BINARY. The next line is SERVER.

7. When you type SERVER, you lose the prompt. Type] while hitting the control key. This should give you a black bar at the bottom of the screen. Type C.

8. Now the line SET FILE TYPE BINARY must be typed into the PC kermit. BOTH must be told that the data is binary.

9. Now type SEND F:*.* (this will send everything from the F:\ drive to the directory you were in when you typed ckermit).

10. Turn off the screen.

    If the files have finished the transfer (this would be in the morning), you can finish the process. To do this:

11. Type FINISH at the cursor. Click back into Kermit and hit the return key. This will give you the CKermit>. Type EXIT. Then type EXIT again. Finally, logout of the OBSERVER account.

14" Telescope Shut Down Check Sheet

This is a check list for how to leave the telescope at the end of the night. Please make sure you have completed all of the following steps.

1. Turn off the drive to the telescope and unplug.
2. Unplug all electronics, including the Lynxx, the autoguider and its many components, and any other pieces of equipment you may have used. Replace any filters etc. to their boxes.
3. Remove any eyepieces and cover the eyepiece openings (there should be some film containers to use for this purpose). Also, the telescope should be covered now.
4. Return the telescope to the stowed position. (With the 3 inch on the EAST side of the 14 inch)
5. Rotate the dome so that the slit is above the door. Close the slit and unplug the motor to the slit.
6. Turn off the monitor, the lights and lock the dome.
7. Replace all equipment and the keys to the warm room.
8. Rotate the dome so that the slit is above the door. Close the slit and unplug the motor to the slit.
9. Turn off the monitor, the lights and lock the dome.
10. Replace all equipment and the keys to the warm room.
11. Reset the computer to warm room control.

Appendix II: IDL Program Help Pages

CCD2FITS: CONVERSION OF CCD FILES TO FITS FORMAT

CCD2FITS,file,ofile

FILE: File to be read

OFILE:Name of output file

Procedure to convert three 8 bit words to two 12 bit words

Writes out in FITS

AUTO2FITS: AUTOMATIC CCD TO FITS CONVERTER

AUTO2FITS,ccdfiles,fitsfiles

CCDFILES: file containing list of files to be read

FITSFILES: file containing list of files to be written

Converts several CCD format files to FITS

CCD12BIT: LYNXX IMAGE READER

CCD12BIT,file,pix2

FILE:file to be read

PIX2:output filename

Procedure to convert three 8 bit words to two 12 bit words

AUTOCCD: MULTIPLE CCD FILE READER

AUTOCCD,filenames,dir,imagecube

FILENAMES: file containing list of files to be read

DIR: string containing location of source directory

IMAGECUBE: name of output image vector

MEDIAN: IMAGE MEDIANS

MEDIAN,imagecube,m,scale

IMAGECUBE: images to find median of

M: name of output image

SCALE: =1 for normalized images, =0 for non-normailized

AUTORED2: LYNXX AUTOMATIC REDUCTION

The operator is queried for all inputs

The image cube must be filled so that the bias images

are first, then the dark15,dark30 and dark60 images.

Then the colors are filled with red, infrared,visible

and blue. Each color should have the 15,30 and 60 second

images in that order.

APPHO:APERTURE PHOTOMETRY

APPHO,image,rad,cts,nbins,x,y or

APPHO,image,rad,counts,xvec,yvec,col=col,resize=resize

RAD: radius of square in pixels; def=3

X,Y: center for remote call

KEYWORDS:

COL: color for circle

RESIZE: expand the image by a factor

APPHOT:APERTURE PHOTOMETRY AND BACKGROUND SUBTRACTION

APPHOT,image,rad,cts,nbins,x,y

APPHOT,image,rad,counts,xvec,yvec,col=col,resize=resize

RAD: radius of square in pixels; def=3

X,Y: center for remote call

KEYWORDS:

COL: color for circle

RESIZE: expand the image by a factor

PERIODOGRAM:PERIOD FINDING PROGRAM

PERIODOGRAM,t,v,p1,p2,np,title

T: observation times

V: observed values

P1,P2: first and last periods to be tested

NP: number of points to be tested

TITLE: optional plot title

OUTPUTS:

pdgm: power(p1 or p2)

p1: frequency

p2: period

finds periods in timed magnitude data

SA: SHIFT AND ADD IMAGES

SA,image1,image2,image3,dispmin,dispmax

IMAGE1,IMAGE2: images to be added

IMAGE3: output image

DISPMIN,DISPMAX: limits to the byte scale of the images

shifts and adds two images together

MAKE_GIF: SHIFT AND ADD THREE BAND IMAGES TO PRODUCE TRUE COLOR IMAGE. WRITTEN INTO A GIF FILE

MAKE_GIF,ri,gi,bi,fileout,warp=warp

RI: red image

GI: green image

BI: blue image

FILEOUT: name of output image without .gif

WARP: If set will poly warp the fields, only needed for SQIID data

MULTICHART: AUTOMATICALLY READ GSC AND PRINTS FINDER CHARTS

MULTICHART,filename,hard=hard

FILENAME: file containing star name,RA in h,m,s DEC in d,m,s

HARD: if set will produce a hard copy of the charts

SHORTSTRING: FIND THE PERIOD FOR A DATA SET

SHORTSTRING,time,deltamag,guess

TIME: the time array to be plotted folded over the period

DELTAMAG: the magnitude array to be plotted

GUESS: intial guess at period

Appendix III: Response Curves Of The Filters